Detention Ponds and Basins

Practice Description

A dam designed to hold stormwater runoff and release the water slowly to prevent downstream flooding and stream erosion. Detention ponds and basins are an extremely effective water quality control measure and significantly reduce the frequency of erosive floods downstream. Ideally, a detention pond will store at least the first 1/2 inch of runoff from the design storm and release the remainder at the predevelopment rate. Their usage is best suited to larger, more intensively developed sites of over 20 acres.

Regular detention ponds have less storage and different outlet conduits than extended detention ponds. Both can have permanent pools of water or be designed as dry basins. Both can be designed to hold sediment.

C. Rahm, NRCS. Platte Co.

Detention ponds are designed to hold excess stormwater runoff and release it slowly to avoid flooding downstream areas.

Recommended Minimum Requirements

Prior to start of construction, detention ponds should be designed by a registered design professional. Plans and specifications should be referred to by field personnel throughout the construction process. The detention pond should be built according to the planned grades and dimensions.

- **Drainage Area:** 20 to 50 acres
- **Structure Life:** 10 years or more
- **Detention:** 24 to 48 hour detention of runoff from the design storm
- **Trap efficiency:** The length to width ratio of the basin should be 2:1 or greater; 5:1 is optimal to capture fine sediments.
  Inlet: Locate as far upstream as possible from the outlet.
  Collector Channels: Leading to the detention pond should be constructed of riprap, concrete or paved material to route water to the detention pond.
- **Anti-seep Devices:** Either of the following is recommended:
  - At least two watertight anti-seep collars should be used around the outlet conduit; collars should project 1 to 3 feet from the pipe, or
  - a sand diaphragm (see *Glossary*)
- **Embankment Slopes:** 2.5:1 or flatter; 3:1 where maintained by tractor or other equipment.
- **Basin Slopes:** No steeper than 3:1 and no flatter than 20:1
- **Vegetative Buffer:** A minimum width of 25 feet around the pond (see *Filter Strips*)
- **Settlement:** Allow for at least 10% of extra fill
- **Site Access:** Reserved for bringing in heavy maintenance equipment and to remove and dispose of sediments

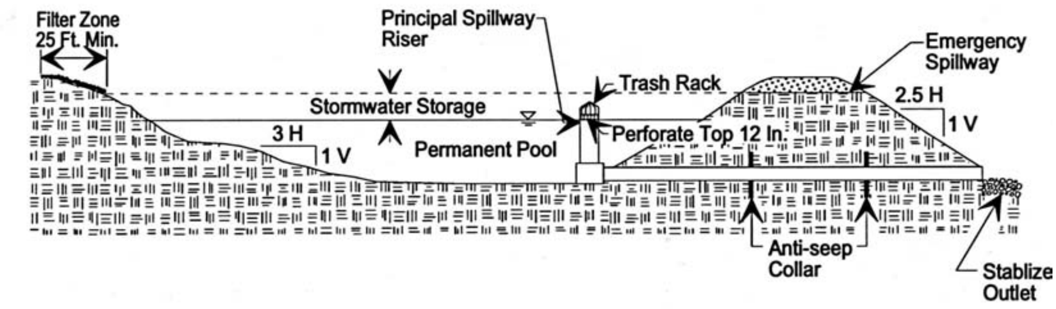

Figure 5.43 Typical Detention Pond

Construction

Site Preparation

Locate the detention pond as close to the stormwater collection system as possible, considering pool area, dam length and spillway conditions. Locate all underground utilities. Clear, strip and grub the dam location, removing all woody vegetation, rocks and other objectionable material.

Follow all federal, state and local requirements on impoundment sites.

Dispose of trees, limbs, logs and other debris in designated disposal areas.

Excavate the embankment foundation (outlet apron first), stockpiling any surface soil having high amounts of organic matter for later use.

Principal Spillway

Clear the sediment pool to facilitate sediment clean out.

Situate the spillway pipe and riser on a firm, even foundation. Prepare the pipe bedding.

Place around the barrel 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.)

Perforate the top 12 inches of the riser with $1/2$-inch diameter holes spaced 3 inches apart. Set the top elevation of the riser to allow the detention pond to store the first $1/2$ inch of basin runoff in this 12-inch perforated zone, or according to the design plan.

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.

Buoyant Force = Volume of Riser x 62.4 lbs/ft^3

Surround the base of the riser with 2 feet of clean uniformly graded stone.

Place a trash rack around the riser inlet. The trash rack should have 4- to 6-inch square openings.

At the pipe outlet, install a riprap or concrete apron at least 5 feet wide and 10 feet long to a stable grade.

Optional: A slotted or V-notch weir, constructed within an open channel spillway, can be used in place of a riser and conduit as a principal spillway.

Embankment

Scarify the embankment foundation before placing fill.

Use fill from predetermined borrow areas. It should be clean, stable, mineral soil free of organic material, 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 layers over the length of the dam. (One way is by routing construction equipment over the dam so that each layer is traversed by at least one wheel of the equipment). Tracked construction equipment does not provide adequate compaction.

Protect the spillway barrel with 2 feet of hand tamped, compacted fill before traversing over the pipe with equipment.

Place a stake at the height sediment must be cleaned out of the basin (50% of design elevation).

Emergency Spillway

Construct the spillway in undisturbed soil around one end of the embankment and locate it so that all excess flow will return to the receiving channel without damaging the embankment.

Erosion Control

Stabilize the spillway with vegetation as soon as grading is complete; or install paving material to finished grade if the spillway is not to be vegetated.

Minimize the size of all disturbed areas. At the completion of each phase of construction, vegetate the disturbed areas to minimize erosion.

Use temporary diversions to prevent surface water from running onto disturbed areas.

Divert sediment-laden water to the upper end of the sediment pool to improve trap effectiveness.

Direct all runoff into the pond at low velocity.

Stabilize all disturbed areas (except the lower one-half of the sediment basin) immediately after construction.

Safety

Because detention ponds that impound water are hazardous, the following precautions should be taken:

- Avoid steep slopes; cut and fill slopes should be 2.5:1 or flatter; 3:1 where maintained by tractor or other equipment.

- Fence area and post with warning signs if trespassing is likely.

- Provide a means of dewatering 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.

Troubleshooting

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

- Seepage is encountered during construction; it may be necessary to install drains.
- Variations in topography on site indicate detention pond 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.

Maintenance

Inspect the detention pond after each storm event.

Remove and properly dispose of sediment when it accumulates to one-half the design volume.

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.

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 nuisance vegetation on embankment.

Remove rodents that burrow into the dam.

Common Problems

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 and/or vegetation.

Slumping and/or settling of embankment; caused by inadequate compaction and/or use of unsuitable soil—excavate failed material and replace with properly compacted suitable soil.

Slumping failure; caused by steep slopes—excavate failed 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.

Sediment not properly removed; results in inadequate storage capacity—remove sediment at regular frequent intervals and after major storms.

Lack of anti-flotation; results in riser damage from uplift—install anti-flotation structure.

Lack of trash guard; results in the riser and barrel being blocked with debris—remove blockage and install properly designed trash guard.

Principal and emergency spillway elevations too high relative to top of dam; results in overtopping—lower principal and emergency spillway elevations to decrease overtopping potential.

Sediment disposal area not designated on design plans; results in improper disposal of accumulated sediment—locate acceptable disposal area and indicate location on plans.

Safety and/or health hazard from pond water; caused by gravel clogging the drainage system—clean out clogged drainage system on regular basis.

Principal spillway too small; results in frequent operation of emergency spillway and increased erosion potential—consider increasing capacity of principal spillway, install supplemental spillway or install suitable erosion protection in emergency spillway.

Stormwater released from pond or basin too rapidly; caused by spillway pipe sized too large—consider resizing spillway pipe.

Extended Detention Ponds and Basins

Practice Description

A dam designed to hold stormwater runoff for a prolonged time and release the water slowly to prevent downstream flooding, stream erosion and pollution. Extended detention ponds and basins improve the quality of runoff by retaining chemical-laden sediment. They also significantly reduce the peak flow rate from flood events, thus reducing the frequency of erosive floods downstream. Ideally, an extended detention pond will store the first 1 inch of runoff and release the remainder at the predevelopment rate. Their usage is best suited to large, intensively developed sites of over 20 acres.

Extended detention ponds differ from regular detention ponds by having additional storage. Both can have permanent pools of water (retention basin) or be designed as dry basins. Both can be designed to hold sediment.

Extended detention ponds are designed to hold excess runoff. They reduce the impact of increasing impervious surfaces in the watershed.

R. Braun, NRCS. St. Charles Co.

Recommended Minimum Requirements

Prior to start of construction, extended detention ponds should be designed by a registered design professional. Plans and specifications should be referred to by field personnel throughout the construction process. The extended detention basin should be built according to planned grades and dimensions.

- **Drainage Area:** 20 to 100 acres
- **Structure life:** 10 years or more
- **Detention:** 24 to 72 hour detention of runoff from the design storm
- **Extended Detention Control Device:** Usually consists of a small drawdown pipe or a subsurface drain
- **Collector Channels:** Constructed of riprap, concrete or paved material to route water to the detention pond. Locate collector channels as far upstream as possible from the detention pond outlet.
- **Anti-seep Devices:** Either of the following is recommended:
  - At least two watertight anti-seep collars should be used around the outlet conduit; collars should project 1 to 3 feet from the pipe, or
  - a sand diaphragm (see *Glossary*)
- **Embankment Slopes:** 2.5:1 or flatter; 3:1 where maintained by tractor or other equipment
- **Basin Slopes:** No steeper than 3:1 and no flatter than 20:1
- **Vegetative Buffer:** A minimum width of 25 feet around the pond (see *Filter Strips*)
- **Settlement:** Allow at least 10% of extra fill
- **Site Access:** Reserved for the passage of heavy equipment and to remove and dispose of sediments
- **Location:** As close to the stormwater collection system as possible, considering pool area and spillway conditions

Construction

Site Preparation

Locate all underground utilities.

Follow all federal, state and local requirements.

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 principal spillway area (outlet apron first), stockpiling any surface soil having high amounts of organic matter for later use.

Clear the sediment pool to facilitate sediment clean out.

Principal Spillway

Situate the spillway pipe and riser on a firm, even foundation. Prepare the bedding for the pipe.

Place around the barrel 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.)

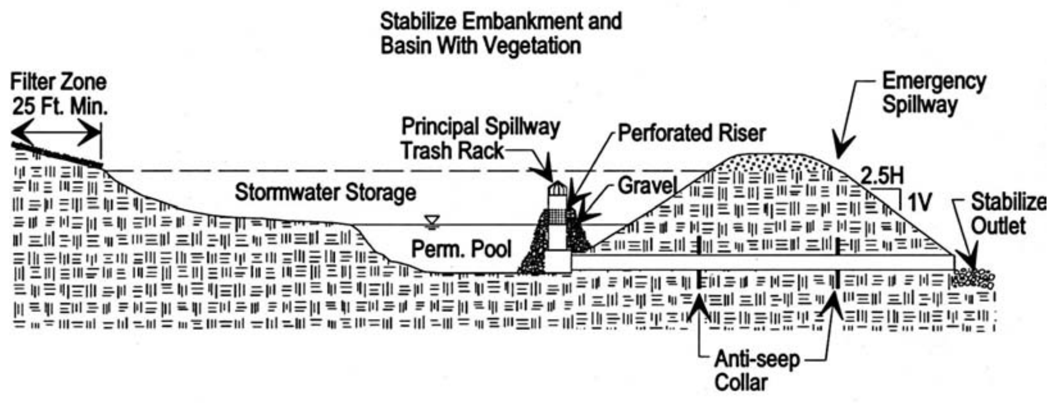

Figure 5.44 Typical Extended Detention Pond

Construct an orifice hole in the riser at normal pool or connect a 6-inch diameter low level drawdown pipe to the riser with the pipe inlet at the normal pool elevation. Set the normal pool elevation to allow enough storage between the pipe and the top of the riser for the first inch of runoff, or according to the design plan.

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.

$$\text{Buoyant Force} = \text{Volume of Riser} \times 62.4\ \text{lbs/ft}^3$$

Place a trash rack around the riser inlet. The trash rack should have 4- to 6- inch square openings.

At the pipe outlet, install a riprap or concrete apron at least 5 feet wide and 10 feet long to a stable grade.

Optional: A slotted or V-notch weir, constructed within an open channel spillway, can be used in place of a riser and conduit as a principal spillway.

Embankment

Scarify the embankment foundation before placing fill.

Use fill from predetermined borrow areas. It should be clean, stable soil free of organic material, 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 layers over the length of the dam. (One way is by routing construction equipment over the dam so that each layer is traversed by at least one wheel of the equipment). Tracked construction equipment does not provide adequate compaction.

Protect the spillway barrel with 2 feet of compacted hand-tamped fill before traversing over the pipe with equipment.

Place a stake at the height sediment must be cleaned out of the basin (50% of design elevation).

Emergency Spillway

Construct the spillway in undisturbed soil around one end of the embankment and locate it so that all excess flow will return to the receiving channel without damaging the embankment.

Stabilize the spillway with vegetation as soon as grading is complete; or install paving material to finished grade if the spillway is not to be vegetated.

Erosion Control

Minimize the size of disturbed areas. At the completion of each phase of construction, vegetate the disturbed areas to minimize erosion.

Use temporary diversions to prevent surface water from running onto disturbed areas.

Divert sediment-laden water to the upper end of the sediment pool to improve trap effectiveness.

Direct all runoff into the pond at low velocity.

Stabilize all disturbed areas (except the lower one-half of the sediment basin) immediately after construction.

Safety

Because extended detention ponds that impound water are hazardous, the following precautions should be taken:

- Avoid steep slopes; slopes around the extended detention pond should be 2.5:1 or flatter; 3:1 where maintained by tractor or other equipment.
- Fence area and post with warning signs if trespassing is likely.
- Drain the basin to normal pool elevation between storm events.
- Determine effect on life and property in case of dam failure. Alter design to incorporate necessary safety.

Construction Verification

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

Troubleshooting

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

- Seepage is encountered during construction; it may be necessary to install drains.
- Variations in topography on site indicate detention pond 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.

Maintenance

Inspect the extended detention pond after each storm event.

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.

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 rodents that burrow into dam.

Common Problems

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 and/or vegetation.

Slumping and/or settling of embankment; caused by inadequate compaction and/or use of unsuitable soil—excavate failed material and replace with properly compacted suitable soil.

Slumping failure; caused by steep slopes—excavate failed material and replace with properly compacted 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.

Sediment not properly removed; results in inadequate storage capacity—remove sediment at regular frequent intervals and after major storms.

Lack of anti-flotation; results in riser damage from uplift—install anti-flotation structure.

Lack of trash guard; results in the riser and barrel being blocked with debris—remove blockage and install properly designed trash guard.

Principal and emergency spillway elevations too high relative to top of dam; results in overtopping—repair erosion damage and reevaluate spillway design.

Sediment disposal area not designated on design plans; results in improper disposal of accumulated sediment—locate acceptable disposal area and indicate location on plans.

Safety and/or health hazard from pond water; caused by gravel clogging the drainage system—clean out clogged drainage system on regular basis.

Principal spillway too small; results in frequent operation of emergency spillway and increased erosion potential—consider increasing capacity of principal spillway, install supplemental principal spillway or install suitable erosion protection in emergency spillway.

Stormwater released from pond or basin too rapidly; caused by spillway pipe sized too large—consider resizing spillway pipe.

Infiltration Basin

Practice Description

A dam designed to detain stormwater allowing it to slowly filter through the soil. Infiltration basins can be constructed to reduce the peak flow rate from the design storm, recharge groundwater in the vicinity of the basin, filter contaminants and increase flows during low stream flow conditions. The basins are effective in removing pollutants from stormwater runoff in urban settings. Their usage is best suited to larger, more intensively developed sites.

Infiltration basins should be considered at sites where the soil is permeable and the groundwater elevation is well below the soil surface. Disadvantages of infiltration basins include standing water, mosquitoes in summer, frequent maintenance, unsuitable soils and the possibility of transporting soluble pollutants to the groundwater.

Recommended Minimum Requirements

Infiltration basins should be designed by a registered design professional. Plans and specifications should be referred to by field personnel throughout the construction process. A detailed soils investigation is required to determine the minimum infiltration rate and soil suitability for this practice. The basin should be built according to planned grades and cross sections.

- **Drainage Area:** Up to 15 acres
- **Detention:** 24 to 72 hours
- **Soils in the Basin:** A permeability between 0.5 and 2.4 inches per hour to ensure proper infiltration and adequate treatment of runoff; less than 30% clay content; less than 40% silt content
- **Principal and Emergency Spillways:** Necessary to pass the design storm
- **Basin Floor:** The basin floor should be as level as possible to spread inflow evenly over floor of basin.
- **Vegetation:** A good stand must be established on the floor of the normally dry basin.

- **Collector Channels:** Channels leading to the basin should be capable of settling out as much coarse grained sediment as possible to keep the floor of the basin from becoming clogged.

- **Sediment Collection:** Inflow into the basin should be diverted through a riprap apron or other sediment collection structure to settle out coarse grained sediment.

- **Anti-seep Devices:** Either of the following is recommended:

  - At least two watertight anti-seep collars should be used around the outlet conduit; collars should project 1 to 3 feet from the pipe, or

  - A sand diaphragm (see *Glossary*)

- **Embankment Slopes:** 2.5:1 or flatter; 3:1 where maintained by tractor or other equipment.

- **Basin Slopes:** No steeper than 3:1

- **Filter Strip:** A minimum width of 25 feet placed around the basin (see *Filter Strips*)

- **Settlement:** At least 10% of extra fill

- **Site Access:** Reserved for the passage of heavy equipment, and to remove and dispose of sediments

- **Location:** In an area of mild topography in soils with good permeability; at least 25 feet from drain fields, septic tanks and drinking water supplies.

Construction

Site Preparation

Locate all utilities at the site.

Follow all federal, state and local requirements on impoundment sites.

Clear, strip and grub 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 of the embankment (outlet apron first), stockpiling any surface soil having high amounts of organic matter for later use.

Clear the infiltration basin, and grade to allow surface drainage and to encourage establishment of a good cover of vegetation. Use tracked equipment to avoid compaction.

Principal Spillway

Situate the spillway pipe and riser on a firm, even foundation. Prepare the bedding for the pipe.

Place around the barrel 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.)

Embed the base of 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.

Buoyant Force = Volume of Riser x 62.4 lbs/ft^3

Place a trashrack around the riser inlet. Trashracks can be constructed by welding reinforcing steel (#4 rebar) in a grid with 4- to 6-inch openings.

Construct anti-seep devices.

At the pipe outlet, install a riprap or concrete apron at least 5 feet wide and 10 feet long to a stable grade.

Optional: A slotted or V-notch weir, constructed within an open channel spillway, can be used in place of a riser and conduit as a principal spillway.

Embankment

Scarify the foundation for the embankment before placing fill.

Use fill from predetermined borrow areas. It should be clean, stable clayey soil free of organic material, 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 clayey soil in the center portion of the dam.

Compact the fill material in 6- to 8-inch lifts over the length of the dam. (One way is by routing construction equipment over the dam so that each layer is traversed by at least one wheel of the equipment.)

Protect the principal spillway pipe with 2 feet of hand-compacted fill before traversing over the pipe with equipment.

Construct and compact the dam to 10% above the design height to allow for settling.

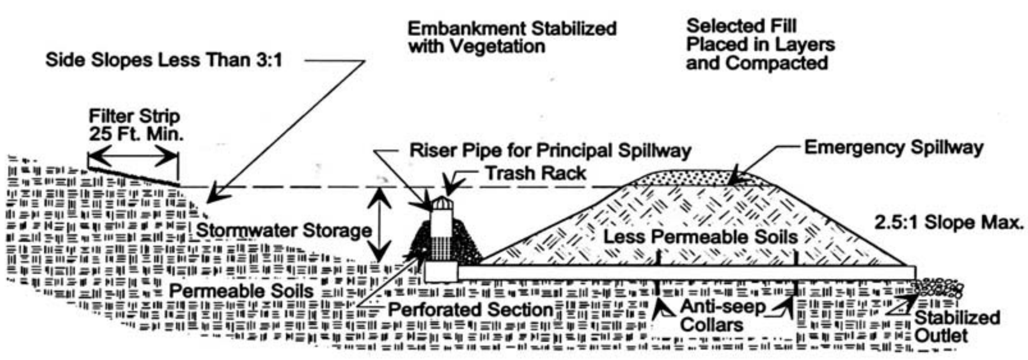

Figure 5.45 Typical Infiltration Basin

Emergency Spillway

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; or install paving material to finished grade if the spillway is not to be vegetated.

Sediment Collection System Construct a riprap apron or other sediment collection structure at the upper end of the basin at all locations where sediment-laden flows enter the basin.

Erosion Control Minimize the size of all disturbed areas and establish vegetation as soon as each phase of construction is complete.

Use temporary diversions to prevent surface water from running onto disturbed areas.

Direct all runoff into the basin at low velocity. Establish the principal spillway outlet elevation to prevent prolonged ponding of water (greater than 72 hours).

Stabilize all disturbed areas (except the lower one-half of the infiltration basin) immediately after construction.

Safety Because infiltration basins can impound water for short periods of time, they can be hazardous:

- Avoid steep slopes; slopes around the infiltration pond should be kept as mild as possible (2.5:1 or flatter; 3:1 where maintained by tractor or other equipment).
- Fence area and post warning signs if trespassing is likely.
- Dewater the basin between storm events.

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

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

- Variations in topography on site indicate that the basin will not function as designed.

- Design specifications for fill, riprap, seed or pipe cannot be met; substitutions may be required. Unapproved substitutions could lead to failure of the basin.

Maintenance

Inspect the infiltration basin after each storm event. If the basin starts to pond water for extended periods of time, it may be clogged and need to be cleaned out.

Remove and properly dispose of any sediment that is collected at the upstream end of the basin.

Periodically check the embankment, emergency spillway and outlet for erosion damage, piping, settling, seepage or slumping along the toe or around the pipe; 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.

Common Problems

Piping failure along conduit; caused by improper compaction, omission of anti-seep collar, leaking pipe joints or use of unsuitable soil—repair erosion damage and install preventative measures to prevent reoccurrence of the problem.

Erosion of spillway or embankment slopes; caused by inadequate vegetation or improper grading and sloping—repair erosion damage and reevaluate erosion protection measures.

Slumping and/or settling of embankment; caused by inadequate compaction and/or use of unsuitable soil—return embankment to original configuration using properly compacted soil as specified in the original plans.

Slumping failure; caused by steep slope—remove slide debris and replace with properly compacted soil.

Erosion and caving below principal spillway; caused by inadequate outlet protection—repair erosion damage and provide adequate erosion protection.

Basin not located properly for access; results in difficult and costly maintenance—consult registered design professional about relocating sediment basin access.

Lack of anti-flotation; results in riser damage from uplift—repair damage to riser and retrofit anti-flotation device to riser.

Lack of trashrack; results in the riser and pipe being blocked with debris—remove debris and install properly designed trashrack.

Principal and emergency spillway elevations too high relative to top of dam; results in overtopping—repair erosion damage and reevaluate spillway design.

Principal spillway too small; results in frequent operation of emergency spillway and increased erosion potential—reevaluate sizing of principal spillway.

Inadequate soils investigation; water does not infiltrate or filter effectively—consult registered design professional to reevaluate the appropriateness of the design.

Improper construction techniques; soil is compacted; prolonged ponding occurs—reconstruct the basin in accordance with the design specifications.

Infiltration Trench

Practice Description

A shallow excavated trench that has been backfilled with stone designed to filter pollutants from stormwater runoff and allow runoff to infiltrate back into the groundwater. Infiltration trenches are effective in removing pollutants from stormwater runoff in urban settings. Sediments must be screened before runoff enters the trench to prevent the trench from becoming clogged. Infiltration trenches provide a good source of groundwater recharge in areas with permeable soils and bedrock well below the bottom of the trench. They require careful construction and regular maintenance. Infiltration trenches cut off the flow of subsurface drainage and work well in areas where there is not sufficient land available for infiltration basins.

Infiltration trenches are normally constructed 3 to 8 feet deep, lined with filter fabric or a sand filter, and backfilled with clean stone or gravel. Grass filter strips (see *Filter Strips*) or inlets can be designed to filter sediments before entering the trench.

Recommended Minimum Requirements

Prior to start of construction, infiltration trenches should be designed by a registered design professional. Plans and specifications should be referred to by field personnel throughout the construction process. The infiltration trench should be built according to planned grades and dimensions.

- **Detention:** 24 to 72 hours
- **Size:** To store either 1/2 inch of runoff per impervious acre, or the volume of runoff produced by a 1-inch storm over the contributing watershed
- **Contributing Slopes:** 5% or flatter
- **Soils:** Permeable soils with combined silt/clay contents of 40% or less in NRCS hydrologic groups A, B or C (see *Glossary*)
- **Water Table:** Minimum of 2 to 4 feet of clearance from the seasonal high water table to the bottom of the trench

- **Drainage Area:** Less than 5 acres
- **Collector Channels:** Capable of settling out as much coarse-grained sediment as possible to keep the trench from becoming clogged.

Construction

Locate the infiltration trench in a gentle sloping area where the bottom of the trench will be level. Before any development occurs, rope off the infiltration trench area to prevent construction equipment from compacting the underlying soils.

Site Preparation

Follow erosion control plans to ensure that sediment and runoff are kept from the trench area during construction. All development should be complete before the trench is excavated.

Locate all utilities at the site.

Clear, strip and grub the trench area removing all woody vegetation, rocks and other objectionable material.

Dispose of trees, limbs, logs and other debris in designated disposal areas.

Swale Trench

Excavate the trench to dimensions specified in the design plan with a backhoe or trencher equipped with tracks to avoid compacting the trench area. The bottom of the trench should be level.

Slope trench sides or provide shoring according to safety regulations.

Line the bottom and sides of the trench with geotextile fabric. The fabric should be permeable enough to allow the trench to drain within 72 hours, yet fine enough to filter out the soil on the sides of the trench. Refer to design plan for a description of the filter fabric.

Backfill the trench with uniformly graded sand or gravel. Do not use crushed limestone, shale or any crushed rock that will become cemented over time.

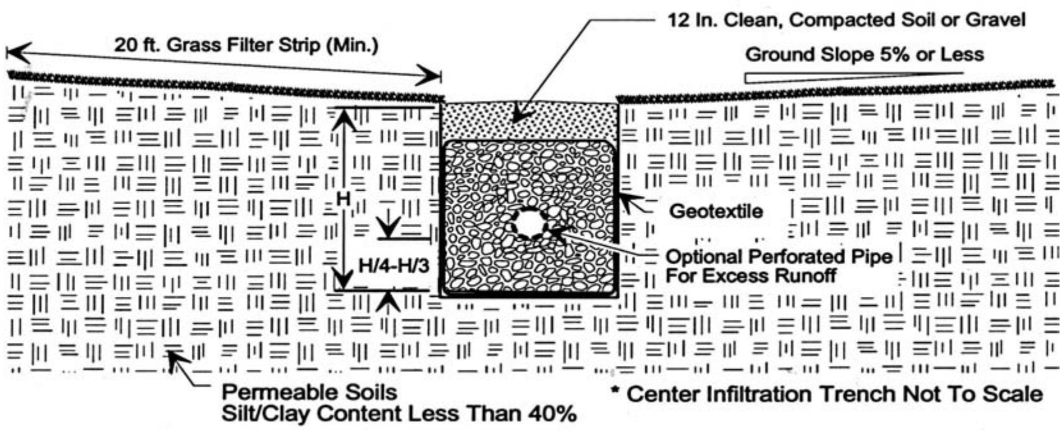

Figure 5.46 Typical Infiltration Trench

The installation of a perforated pipe to collect and transport excess runoff is optional. The trench should be designed to filter all runoff within 72 hours.

A perforated pipe may be placed in the upper part of the trench to quickly drain the top of the trench after each runoff event; however, this may allow pollutants to be transported off site with the surface water runoff.

Place at least one observation well in each infiltration trench to monitor the performance of the trench. Perforated polyvinyl chloride (PVC) pipe or high density polyethylene pipe is recommended. The bottom of the pipe should extend to within 1 inch of the filter fabric in the bottom of the trench.

Overlap the geotextile fabric on the top of the gravel, approximately 6 inches below the top of the trench. Follow manufacturer's recommendations regarding the amount of overlap, but in no case should the overlap be less than 12 inches. Backfill the top of the trench with gravel.

Underground Trench

Underground trenches can be applied to a variety of situations and are aesthetically pleasing but more difficult to maintain.

Excavate the trench to dimensions specified in the design plan, line with filter fabric and backfill the bottom of the trench as recommended for swale trenches. Place a perforated pipe on top of the gravel approximately 1/4 to 1/3 of the distance to the top of the trench. The pipe should be placed with zero grade. The size of the pipe will vary; a larger pipe can be placed in the trench, but the width of the trench will have to be increased. The trench width should be a minimum of twice the diameter of the pipe.

Connect the perforated pipe to the collection pipe. The collection pipe may be connected to an inlet structure used to trap sediment.

Backfill clean gravel over the pipe to within 12 inches of the top of the trench.

The installation of a perforated pipe to collect and transport excess runoff is optional. The trench should be designed to filter all runoff within 72 hours. A perforated pipe may be placed in the upper part of the trench to quickly drain the top of the trench after each runoff event.

Overlap the geotextile according to manufacturer's recommendations, but in no case should the amount of overlap be less than 12 inches.

Backfill over the filter fabric with at least 12 inches of clean, compacted soil.

Erosion Control

During development, use temporary diversions to prevent surface water from running onto disturbed areas.

Minimize the size of all disturbed areas and vegetate all buffer strips as soon as the trench is constructed.

Divert sediment-laden water to shallow vegetated basins or a sediment collection system capable of removing sediment to prevent the infiltration trench from becoming clogged.

Direct all runoff into swale trenches at low velocity. Establish the slope of the top of the swale to prevent prolonged ponding of water (greater than 12 hours).

Safety

Because swale infiltration trenches can impound water for short periods of time, they can be hazardous:

- Avoid steep slopes; slopes around the swale infiltration trench should be kept as flat as possible (20:1 or flatter).
- Fence area and post warning signs if trespassing is likely.
- Drain the trench between storm events.
- Slope sides of trench or provide shoring.

Construction Verification

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

Troubleshooting

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

- Variations in topography on site indicate infiltration trench will not function as intended.
- Design specifications for fill, pipe, gravel or filter fabric cannot be met; substitutions may be required. Unapproved substitutions could lead to failure.

Maintenance

Inspect the infiltration trench after each storm event during the first few months of operation and annually thereafter. Water levels in the observation wells should be recorded over several days to check trench drainage.

Annually inspect the condition of the grass buffer strips in swale trenches. Growth should be vigorous and dense. Bare spots, eroded areas or "burned out" areas should be reseeded or resodded.

Mow grass filter strips at least twice a year to prevent woody growth.

Sediment removal inlets should be cleaned out when sediment fills 25% of the available capacity.

Prune tree limbs overhanging the swale trench to prevent leaves from falling onto the trench.

Common Problems

No filter installed or filter fabric not appropriate for site soils; resulting in piping of soil into the underground infiltration trench, clogging and reduction of capacity—reinstall gravel using proper filter fabric.

Inadequate vegetation or improper grading and sloping; resulting in erosion of slopes leading to the trench—improve vegetation or regrade to establish slopes.

Inadequate sediment collection system; resulting in clogging of swale trench with sediment—improve sediment collection system.

Trench not located properly for drainage; resulting in difficult and costly maintenance and rehabilitation—relocate trench or improve drainage.

Sediment not properly removed from sediment collection system; resulting in trench becoming clogged—clean out clogged section of trench; remove sediment from collectors regularly and after major storms.

Sediment disposal area not designated on design plans; resulting in improper disposal of accumulated sediment—designate appropriate disposal area on design.

Drainage system clogged by sediment; resulting in safety and/or health hazard from pond water—clean out drainage system regularly and after major storms.

Porous Pavement

Practice Description

A permeable asphalt or concrete layer underlain by a stone reservoir, designed to intercept storm runoff and allow it to gradually infiltrate into the subsoil. Porous pavement allows surface runoff to infiltrate the pores of a 2- to 4-inch asphalt layer or a 4- to 6-inch concrete layer into the voids of an underground stone reservoir. Under normal conditions, the porous pavement acts as a rapid conduit for runoff to reach a stone reservoir which also serves as the base course for the pavement. Porous pavement falls into three different categories: a full exfiltration system, a partial exfiltration system and a water quality exfiltration system. These categories are based on the storage provided by the stone reservoir.

Concrete grids and modular pavement are made out of precast concrete, poured-in-place concrete, brick or granite. They have some of the same limitations as porous pavement, being limited to low traffic areas and suitable soils.

Porous pavement provides groundwater recharge, low flow in streams during dry periods and reduced downstream flooding. It requires a high level of maintenance to insure that the pavement does not become clogged.

Recommended Minimum Requirements

Prior to start of construction, porous pavement structures should be designed by a registered design professional. Plans and specifications should be referred to by field personnel throughout the construction process. The porous pavement should be built according to planned grades and dimensions.

- **Drainage Area:** 1/4 to 10 acres
- **Side Slopes:** 20:1 (5%) or flatter
- **Pavement Thickness:** Asphalt should be 2 to 4 inches; concrete pavement thickness should be 4 to 6 inches.
- **Water Table:** Should be relatively deep

- **Soils:** Permeable soils with combined silt/clay contents of less than 40% in NRCS hydrologic groups A, B or C. (See *Glossary.*)
- **Stone Reservoir:** Should be able to drain within 72 hours
- **Depth:** A minimum of 2 feet (preferably 4 feet) of clearance between the bottom of the stone reservoir and the bedrock

Construction

Locate the porous pavement in areas of relatively gentle slopes and permeable soils. Porous pavement is generally used only for parking lots and lightly-used access roads.

Site Preparation

Before the site is graded, rope off the porous pavement area to prevent heavy equipment from compacting the underlying soils. Determine the exact location of all underground utilities.

Follow all federal, state and local requirements, and obtain required land disturbance permits for stormwater.

Place diversion berms around the perimeter of the porous pavement area to keep runoff and sediment completely away from the site both before and during construction.

Use earthmoving equipment with tracks or oversized tires to clear, grub and grade the subgrade. Avoid normal rubber tires because they compact the subsoil and reduce its infiltration capabilities. Grading in wet conditions should be avoided.

Full Exfiltration System

With a full exfiltration system, the only way runoff can exit the stone reservoir is to exfiltrate through the underlying subsoil. There are no pipe outlets draining the stone reservoir in a full exfiltration system.

The stone reservoir must be large enough to accommodate the entire runoff volume from the design storm.

Construct an emergency overflow channel above ground (such as a raised curb or swale) to handle the excess runoff from storms greater than the design storm.

Partial Exfiltration System

A partial exfiltration system contains an underground drainage system. The system should include regularly spaced, perforated pipes located in shallow depressions. The pipes collect the runoff and direct it to an infiltration basin or a central outlet.

The size and spacing of the underdrain network should allow passage of the 2-year storm event or the design storm.

Set the underdrain pipes near the top of the stone reservoir to allow the reservoir to totally fill before any water is discharged from the underdrain.

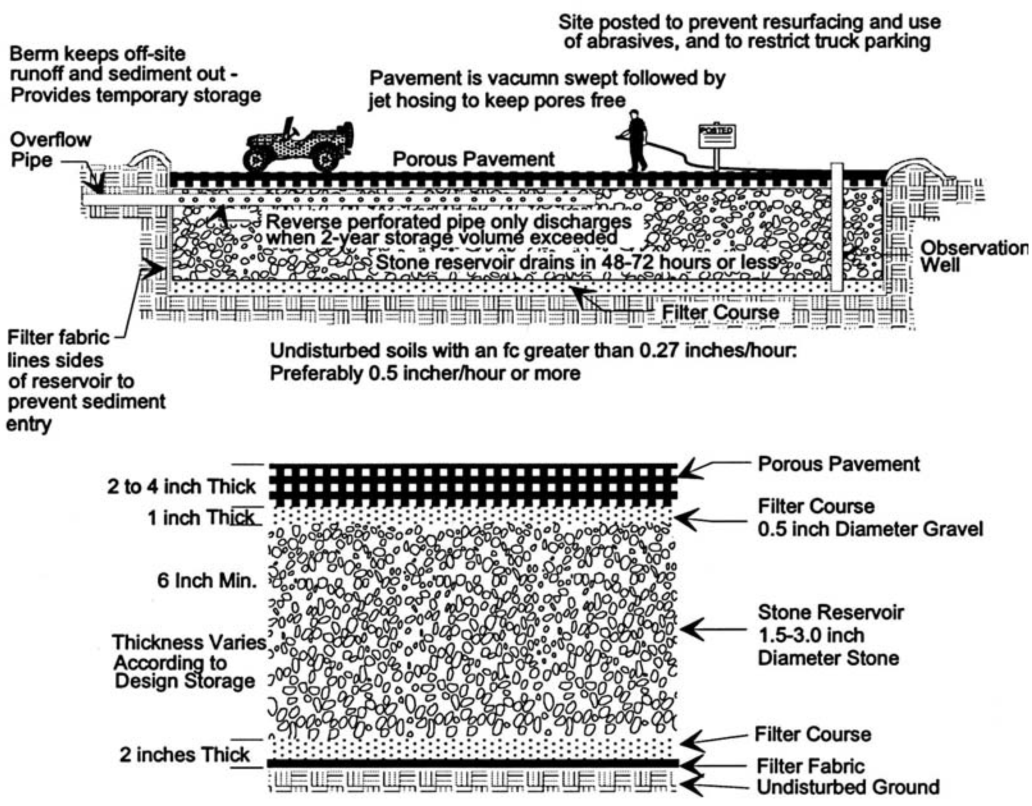

Figure 5.47 Typical Porous Pavement Design

Water Quality Exfiltration

With the water quality exfiltration system, the stone reservoir capacity is set to store the first flush of runoff volume during a storm. The first flush should be the volume of runoff produced by a 1-inch storm event or the design storm.

Runoff volumes in excess of the first flush are not treated by the system, but are conveyed to a conventional stormwater management facility.

Slot or drop inlets through conventional pavements can be used to transmit runoff to the stone reservoir.

The thickness of the stone reservoir should be a minimum of 6 inches.

After the excavated area is graded, line the bottom and sides of the stone reservoir with filter fabric to prevent upward piping of underlying soils. The fabric should be placed flush with 12 inches of overlap between rolls.

Clean, washed 1- to 2-inch stone aggregate should be placed in the excavated reservoir in lifts and lightly compacted with plate compactors to form the base course. Only river or creek run gravel should be used. Unwashed stone and crushed rock such as limestone should not be used; it has enough fine material to pose a clear risk of clogging the soil-filter-cloth interface.

A 1-inch deep layer of 3/8- to 5/8-inch stone should be placed over the base course and manually graded to plan specifications.

Any perforated underdrains should be installed to grade in the base course. Pipe should be laid with the perforations down.

The porous asphalt layer should be placed over the base course when the air temperature is above 50^{o}F and the laying temperature is between 230 and 260^{o}F. Failure to follow these guidelines can lead to premature hardening of the asphalt and subsequent loss of infiltration capacity.

Rolling of the asphalt can begin when the material is cool enough to

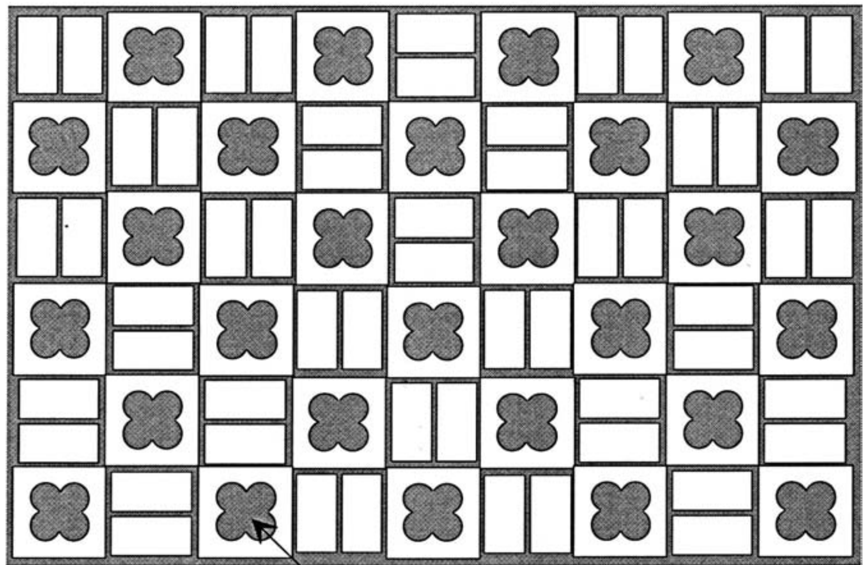

Figure 5.48 Typical Concrete Grid

withstand a 10-ton roller. Normally only one or two passes of the roller are necessary. More frequent rolling can reduce the infiltration capabilities of the asphalt.

Concrete Grids and Modular Pavements

Concrete grids and modular pavements have open spaces within the pavement that stormwater can pass through and infiltrate into the ground. The open spaces are typically filled with gravel, sand or have vegetation growing out of them. Construct or install according to design plan and manufacturer's recommendations.

Sediment Control

After rolling is complete, all traffic should be kept out of the porous pavement area for a minimum of one day to allow proper hardening.

An observation well, consisting of a well-anchored, vertical, perforated PVC pipe with a locking above-ground cap, should be installed on the down slope end of the porous pavement area to monitor runoff infiltration rates.

Post construction sediment control is critical. Vegetated filter strips should be placed around the porous pavement, concrete grids and modular pavements.

Reinforced silt fences should be placed around porous pavement, concrete grids and modular pavements while vegetation is being established.

Signs should be posted and construction personnel advised not to enter the parking lot or access area with muddy tires.

- Store all construction materials and waste material well away from the porous pavement site.
- If new utility lines are buried beneath the porous pavement site, do not construct the stone reservoir until all trench settlement has taken place.
- Provide temporary fencing and post warning signs around the porous pavement until vegetation in the filter strip is established.
- Provide an uncontrolled means of draining the construction site.

Construction Verification

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

Troubleshooting

Consult with design professional if any of the following occur:

- Variations in topography or site geology indicate porous pavement will not function as intended.
- Design specifications for fill, pipe, gravel, filter fabric and asphalt paving material cannot be met; substitutions may be required. Unapproved substitutions could lead to failure.

Maintenance

Inspect the porous pavement after each storm event. Inspectors should check for ponding on the asphalt surface which might indicate local or widespread clogging.

The condition of the vegetative filter strip should be inspected.

The observation well should be checked several times in the first few months after construction. Water depth in the well should be measured at 0-, 24-, and 48-hour intervals after a storm.

The porous pavement site should be posted with signs indicating the nature of the surface, and warning against resurfacing the site with conventional pavement or the use of abrasives such as sand or ash for snow removal.

Sediment must be kept completely away from a porous pavement site after construction.

The porous pavement should be vacuum swept at least four times per year, followed by high-pressure jet hosing to keep the asphalt pores open.

Potholes and cracks can be repaired using conventional, nonporous patching mixes as long as the cumulative area repaired does not exceed 10% of the parking lot area.

Spot clogging of the porous pavement layer can be relieved by drilling 1/2-inch holes through the porous asphalt layer every few feet. In cases where clogging occurs in a low spot in the parking lot, it may be advisable to install a drop inlet to route water into the stone reservoir.

Follow guidelines for porous pavement maintenance to maintain concrete grids and modular pavements. Where vegetation is planted in the grids, mowing, fertilizing and irrigation may be needed.

Common Problems

Inadequate vegetation, too great a length of overland flow, too great a slope or high flow rates; resulting in erosion of filter strip—reduce flow rates, length of flow or slope by regrading or diversion of runoff. Establish adequate vegetation in filter strip.

Capacity of the stone reservoir exceeded; resulting in ponding on the porous pavement—reduce runoff into reservoir or enlarge reservoir.

Porous pavement becomes clogged; resulting in ponding on pavement—vacuum pavement regularly and after major storms.

Interface between the stone reservoir and the subgrade soil becomes clogged; resulting in maximum draining time exceeding 72 hours—reduce runoff into reservoir or replace filter between stone and subsoil.

Constructed Wetland

Practice Description

A pool that creates conditions suitable for the growth of marsh plants. Stormwater wetlands, wet ponds and retention ponds are effective in reducing the quantity of stormwater runoff and improving water quality by pollution removal through sedimentation and nutrient uptake. Urban runoff pollutants which can be treated include sediment, trace metals, nutrients, hydrocarbons, oxygen demanding substances and harmful bacteria. Wetlands and wet ponds can be created by constructing an embankment across a valley, constructing a perimeter berm or by excavating a shallow basin in natural soil. Stormwater wetlands differ from artificial or created wetlands because they lack the ecological functions of natural wetlands.

Stormwater wetlands require more management during the first three years to establish marsh conditions. Thereafter, maintenance requirements are similar to wet ponds.

Constructed wetlands can be used effectively to control stormwater runoff quantities, improve water quality and provide urban habitat for wildlife.

NRCS. Maine.

Recommended Minimum Requirements

Prior to construction, constructed wetlands should be designed by a registered design professional. Plans and specifications should be referred to by field personnel throughout the construction process. The wetlands should be built according to planned alignment, grade and cross sections.

- **Contributing Drainage Area:** At least 10 acres: 6 acres is needed for each surface acre of wetland; 10 acres is recommended to maintain a permanent pool

- **Detention:** Up to 72 hours for the entire range of design storms. The initial 1/2 inch of runoff should be detained for a minimum of 6 hours. This is the "first flush" of runoff which contains the largest concentration of pollutants.

- **Anti-seep Devices:** Either of the following is recommended:
  - At least 2 watertight anti-seep collars used around the outlet conduit; collars should project 1 to 3 feet from the pipe, or
  - a sand diaphragm (see *Glossary*)

- **Embankment Slopes:** 2.5:1 or flatter; 3:1 when maintained by tractor or other equipment

- **Contributing Slopes:** 3:1 or flatter

- **Soils:** Moderate to low permeability in NRCS hydrologic groups C or D (see *Glossary*)

- **Collector Channels (leading to the wetland):** Capable of settling out as much sediment as possible. Leave natural meandering channels with good streambank vegetation (100 feet wide), if possible. Constructed channels should be as long as possible.

- **Sediment Basin:** Constructed at the entrance to the wetland with 20 to 40 years of sediment storage available

- **Principal and Emergency Spillways:** Designed to pass the runoff from the design storm. The principal spillway should include a water control structure to draw down the permanent pool to manage wetland vegetation, clean sediment out of the basin and other maintenance.

- **Filter Strip:** 50-foot wide grass or natural vegetative buffer around wetland area and wet ponds; greater width may be necessary for steeper slopes and some landforms (see *Filter Strips*)

- **Embankments:** At least 10% of extra fill to allow for settlement; should not constrict the floodplain

Construction

Site Preparation

Locate the stormwater wetland away from natural wetlands (See *Glossary*) that may be subject to national, state and local laws and regulations. The stormwater wetland should be in an area of mild topography in NRCS hydrologic group C or D soils. A clay liner may be needed for wetlands located in NRCS hydrologic group A or B soils.

Determine the exact location of all underground utilities.

Follow all federal, state and local requirements on impoundment sites.

Clear, strip and grub the stormwater wetland or wet pond area. Remove all woody vegetation, rocks and other objectionable material. Depending on the type, some trees may be left in the wetland or wet pond area.

Dispose of trees, limbs, logs and other debris in designated disposal areas.

Grade the stormwater wetland area to allow surface drainage and the establishment of a good cover of vegetation.

Stormwater Wetland

Excavate a sediment basin where concentrated surface drainage enters the wetland. The sediment basin should be separated from the wetland by a berm or baffle which will be approximately 1 foot beneath the permanent pool elevation. Pipes may become clogged with sediment and are not recommended for transporting flow from the sediment basin to the wetland.

Excavate the wetland pool to a depth of 3 to 6 feet or according to the design plan.

Construct an embankment and a principal spillway to maintain a permanent pool in the wetland. Depending on the size of the watershed, an emergency spillway may be necessary.

Grade a gently sloping aquatic bench around the perimeter of the stormwater wetland. The bench should be approximately 10 to 25 feet wide and will provide a transition from the filter strip to the wetland.

Grade a filter strip around the stormwater wetland. The filter strip slope should be no steeper than 5:1 and no flatter than 20:1.

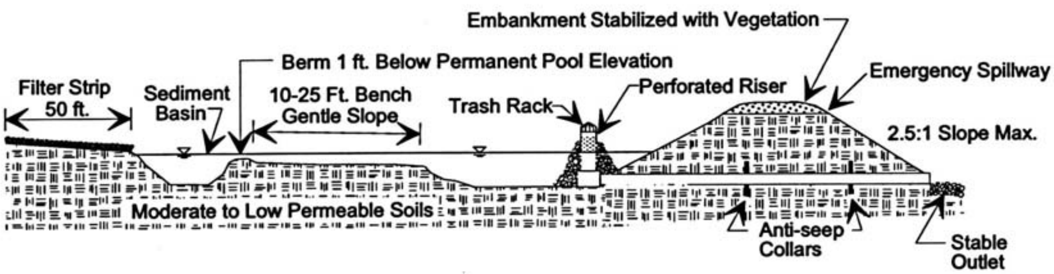

Figure 5.49 Constructed Wetland

Construct a maintenance right-of-way to the sediment basin for removing sediment. The right-of-way should include base material to support vehicle traffic but should also be capable of supporting vegetation. Concrete armor blocks and geotextile mats support the growth of vegetation and work well when constructed on good base material.

Excavate the foundation of the embankment (outlet apron first), stockpiling topsoil for later use.

Place the spillway pipe and riser on a firm, even foundation. Prepare the bedding for the pipe.

Principal Spillway

Place a 4-inch layer of moist, clayey, workable soil (not pervious material such as sand, gravel or silt) around the pipe and compact it with hand tampers to at least the density of the foundation soil. Don't raise the pipe from the foundation when compacting under the bottom of the pipe.

Construct the riser within the embankment. If the riser must be constructed in the pond, embed the base of 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.

$$\text{Buoyant Force} = \text{Volume of Riser} \times 62.4 \text{ lbs/ft}^3$$

Connect a minimum 6-inch diameter pipe and valve to the riser at the drawdown elevation. The valve stem should be accessible for opening and closing the valve.

Perforate the top 12 inches of the riser with 1/2-inch diameter holes spaced 3 inches apart (or use a manufactured perforated riser). The perforations will allow stormwater detention of the first flush of runoff into the wetland.

For risers extending into the wetland, surround the riser with 2 feet of clean, uniformly graded stone. The top of the riser should be set at the permanent pool elevation of the wetland.

Place a trashrack around the riser inlet. Trashracks can be constructed by welding reinforcing steel (#4 rebar) in a grid with 4- to 6-inch openings.

Construct anti-seep devices.

At the pipe outlet, install a riprap or concrete apron at least 5 feet wide and 10 feet long to a stable grade.

Optional: A slotted or V-notch weir, constructed within an open channel spillway, can be used in place of a riser and conduit as a principal spillway.

Embankment

Scarify the foundation for the embankment before placing fill.

Use fill from predetermined borrow areas. It should be clean, stable mineral 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 lifts over the length of the dam. (One way is by routing construction equipment over the dam so that each layer is traversed by at least one wheel of the equipment.)

Protect the spillway pipe with 2 feet of hand-tamped fill before traversing over the pipe with equipment.

Construct and compact the wetland embankment to 10% above the design height to allow for settling.

Place a reference stake at the sediment clean out elevation in the sediment basin at the upstream end of the wetland (50% of design elevation).

Emergency Spillway

Construct the spillway in undisturbed soil around one end of the embankment. Locate it so that any flow will return to the receiving channel without damaging the embankment.

Erosion Control

Stabilize the spillway as soon as grading is complete; or install paving material to finished grade if the spillway will not be vegetated.

Minimize the size of all disturbed areas and vegetate as soon as each phase of construction is complete. Consult the Missouri Department of Conservation, Kansas Wildlife and Parks, NRCS or University Extension for wetland vegetation specifications and plant materials.

Use temporary diversions to prevent surface water from running onto disturbed areas.

Direct all runoff into the stormwater wetland or wet pond at low velocity. Establish the principal spillway outlet elevation to allow the stormwater wetland or wet pond to return to normal pool elevation within 72 hours.

Safety

Because stormwater wetlands and wet ponds permanently impound water, they can be hazardous:

- Avoid steep slopes; slopes around the stormwater wetland or wet pond should be kept as mild as possible (2.5:1 or flatter; 3:1 when maintained by tractor or other equipment).

- Fence area and post with warning signs if trespassing is likely.

Construction Verification

Check finished grade and cross sections of the constructed wetland. Verify dimensions of embankments, spillways and diversion waterways.

Troubleshooting

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

- Variations in topography on site indicate wetland will not function as designed; changes in plan may be needed.

- Design specifications for spillway pipes, trashracks and rock cannot be met; substitution may be required. Unapproved substitutions could result in the wetlands not operating as designed.

Maintenance

Initially, inspect the stormwater wetland or wet pond after each storm event. Once the operation of the structure has been established, inspect annually. Pay close attention to the amount of sediment in the sediment basin.

Remove and properly dispose of sediment collected in the sediment basin.

Intensive management of the water levels will be necessary during the first year to establish wetland plants.

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.

Remove trash and other debris from the riser, emergency spillway and pool area.

Common Problems

Piping failure along conduit; caused by improper compaction, omission of anti-seep collar, leaking pipe joints or use of unsuitable soil—repair piping damage and install preventative measures to prevent reoccurrence of problem.

Erosion of spillway or embankment slopes; caused by inadequate vegetation or improper grading and sloping—repair erosion damage and reevaluate erosion protection measures.

Slumping and/or settling of embankment; caused by inadequate compaction and/or use of unsuitable soil—return embankment to original configuration using properly compacted soil as specified in the original plans.

Slumping failure; caused by steep slopes—remove slide debris and replace with properly compacted soil.

Erosion and caving below principal spillway; caused by inadequate outlet protection—repair erosion damage and provide adequate erosion protection.

Difficult and costly sediment removal; caused by inadequate sediment basin access—consult registered design professional about relocating sediment basin access.

Inadequate sediment storage capacity; caused by basin constructed too small or sediment not properly removed—review sediment removal program and, if necessary, resize sediment basin.

Uplift damage to riser; caused by lack of anti-flotation device—repair damage to riser and retrofit anti-flotation device to riser.

Riser and pipe blockage; caused by lack of trash guard—remove blockage and install properly designed trashrack.

Overtopping of embankment; caused by principal and emergency spillway elevations too high relative to top of dam—repair erosion damage and reevaluate spillway design.

Improper disposal of accumulated sediment; caused by sediment disposal area not designated on design plans—remove improperly placed sediment and clearly define disposal area.

Frequent operation of emergency spillway; due to principal spillway being too small—reevaluate sizing of principal spillway.

Vegetation not established; due to improper management of water regimes, or failure to follow seeding or planting specifications—reseed or replant in accordance with design specifications.

Evidence of pollution exists; caused by pollutants such as trace metals accumulating in the bottom sediments—consult with registered design professional about testing or restricting access for people and wildlife.