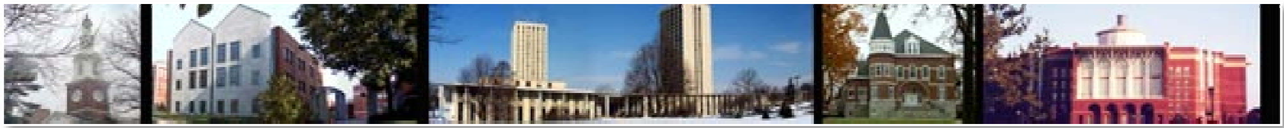

POST-CONSTRUCTION STRUCTURAL BMP OPERATION & MAINTENANCE PLANS

FEBRUARY 2012

UNIVERSITY OF KENTUCKY

LEXINGTON, KENTUCKY

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1.0 INTRODUCTION

The University of Kentucky (UK) is located within Lexington in Fayette County, Kentucky. UK is permitted by the Kentucky Division of Water (KDOW) as a municipal separate storm sewer system (MS4). The UK MS4 is classified as a Phase II or small MS4 for permitting purposes. As part of the state's small MS4 permit, UK must address post construction stormwater quality management for new development and redevelopment that disturbs an acre or more. Structural best management practices (BMPs) will be used where appropriate to satisfy post construction stormwater quality management permitting requirements. As required in the MS4 permit, post construction stormwater quality management measures must be perpetually maintained. To this end, operation and maintenance (O&M) plans are needed for each type of structural practice to describe the operational and maintenance needs for the structural controls.

The UK personnel from Environmental Management, Grounds, and Capital Project Management Division (CPMD) involved in the design or long-term operation of stormwater management BMPs evaluated the BMPs included in LFUCG's manual for potential use on UK's campus. Based upon this evaluation, the following BMPs were identified as standard stormwater quality management measures for use on UK's campus.

Figure 1. Post-Construction Stormwater Quality BMPs Use on UK's Campus.

Detention Ponds:
- Dry Detention Ponds
- Extended Dry Detention Ponds
- Wet Detention Ponds

Constructed Wetlands

Vegetated Swales

Filter practices:
- Filter Strips
- Bioretention Areas
- Rain gardens

Sand filters:
- Underground
- Perimeter

Prefabricated devices

Pavement/pavers:
- Modular pavement
- Pervious concrete

Green roofs

Cisterns

The design of these controls can be found in CPMD's Design Standards. This document contains the O&M plans for the structural BMPs identified above. Where applicable, the O&M plans are based upon BMP information from Lexington-Fayette Urban County Government's (LFUCG) Stormwater Manual (LFUCG, 2009). For BMP information not included in LFUCG's Stormwater Manual, O&M information was obtained from other references. The BMP O&M plans were also modified where applicable to adjust to UK's MS4 area and program.

2.0 DETENTION PONDS

Detention ponds can be dry or have a permanent pool. Detention ponds are traditional stormwater quantity control devices that are designed for peak discharge control and provide some stormwater quality benefit. The following three detention pond types are discussed in this section: dry ponds, dry extended detention ponds and wet ponds.

Dry Detention Ponds

Dry detention ponds are designed to drain completely, and are typically designed to control peak discharges from specified storm events. Dry detention ponds must be combined with other structural controls as a part of a treatment train to address stormwater quality treatment. Figure 2 shows a schematic of a dry detention pond measure.

Dry Extended Detention Ponds

An extended detention pond is a dry detention pond equipped with an outlet structure that provides extended detention time (typically 24 hours or more) for a specific stormwater quality treatment volume. A dry extended detention pond detains runoff from small, frequent storms and the "first flush" from larger storms in a lower second stage, with a normally dry upper stage for detention of larger storms for flood control. Extended detention ponds can be used for both stormwater quality treatment and stormwater quantity management. For extended detention, a dry detention system has a discharge structure that is modified to extend the detention time of runoff, typically up to 24 to 48 hours. The modified discharge may also include some type of filtering device (i.e., gravel or sand envelope) to improve the removal of particulate pollutants.

Dry extended detention ponds may also be modified to improve stormwater quality benefits. The pond may be modified to include a second stage that is a shallow marsh. In locations with continuous dry weather flow, an extended detention pond will tend to be continuously wet.

Pollutant removal in dry extended detention ponds includes up to three mechanisms. The first mechanism is settling or sedimentation. For two-stage systems that include shallow marsh, pollutants may be removed by plant uptake and bacterial activity. Finally, some systems include limited infiltration.

There are multiple configurations and variations for dry extended detention ponds. A plan view schematic of a dry extended detention pond is shown in Figure 3. Figures 4 and 5 show two different dry extended detention pond outlet configurations.

Figure 2. Dry Detention Pond (from LFUCG, 2009).

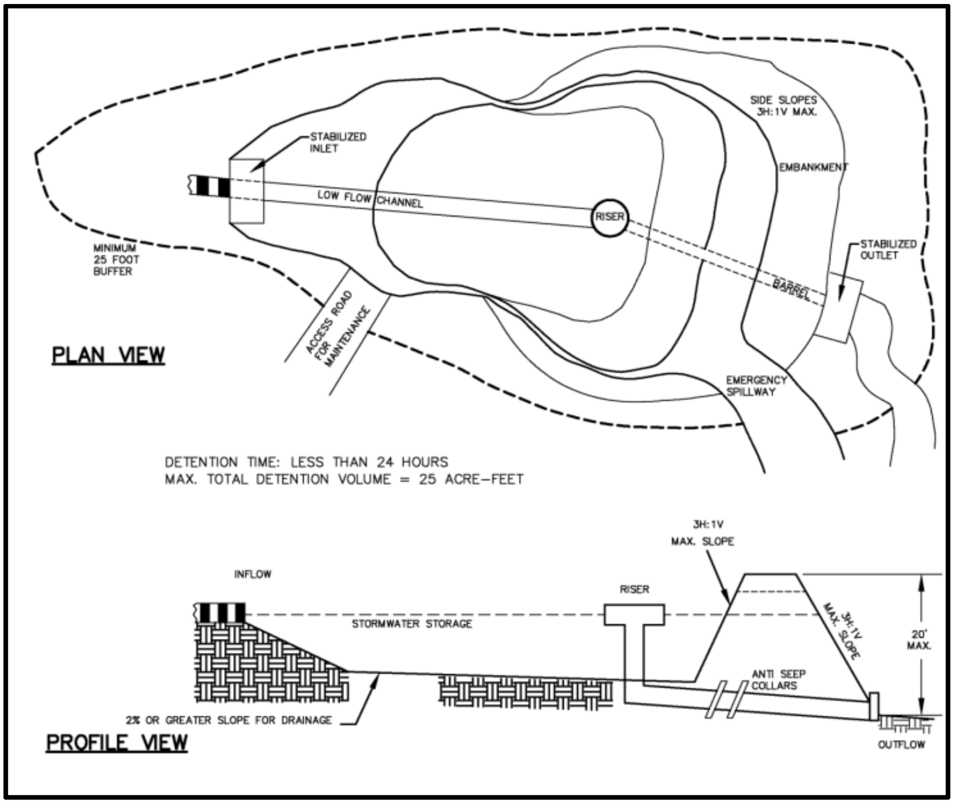


Figure 3. Dry Extended Detention Pond (from LFUCG, 2009).

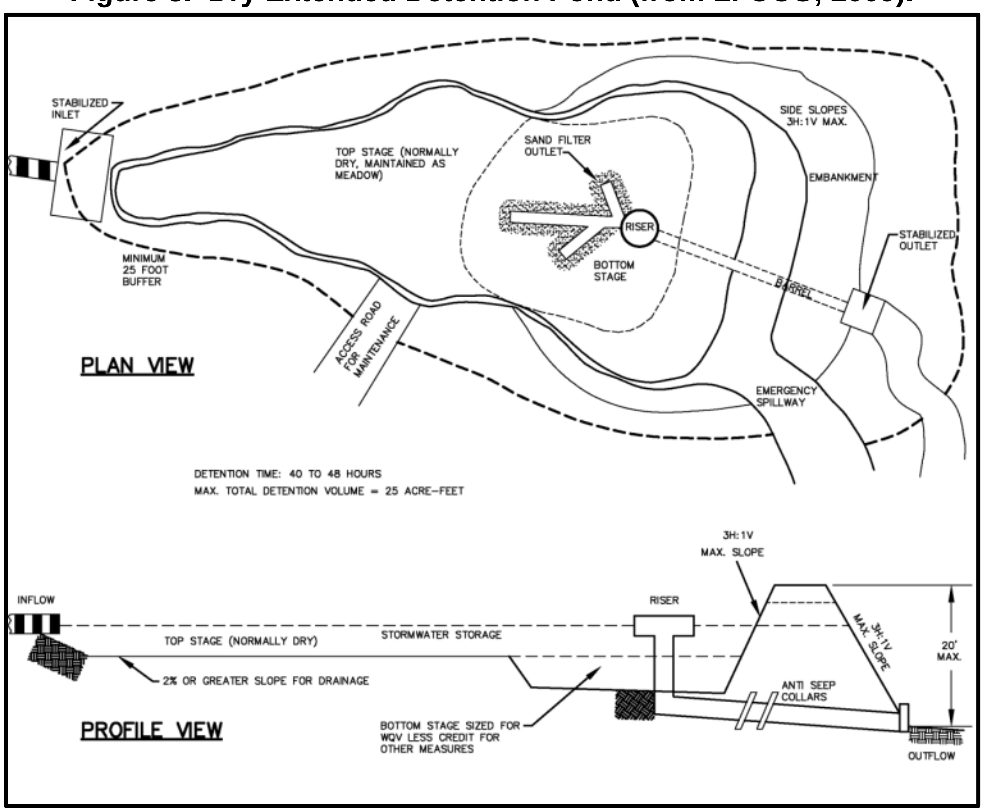


Figure 4. Dry Extended Detention Pond Outlet (from LFUCG, 2009).

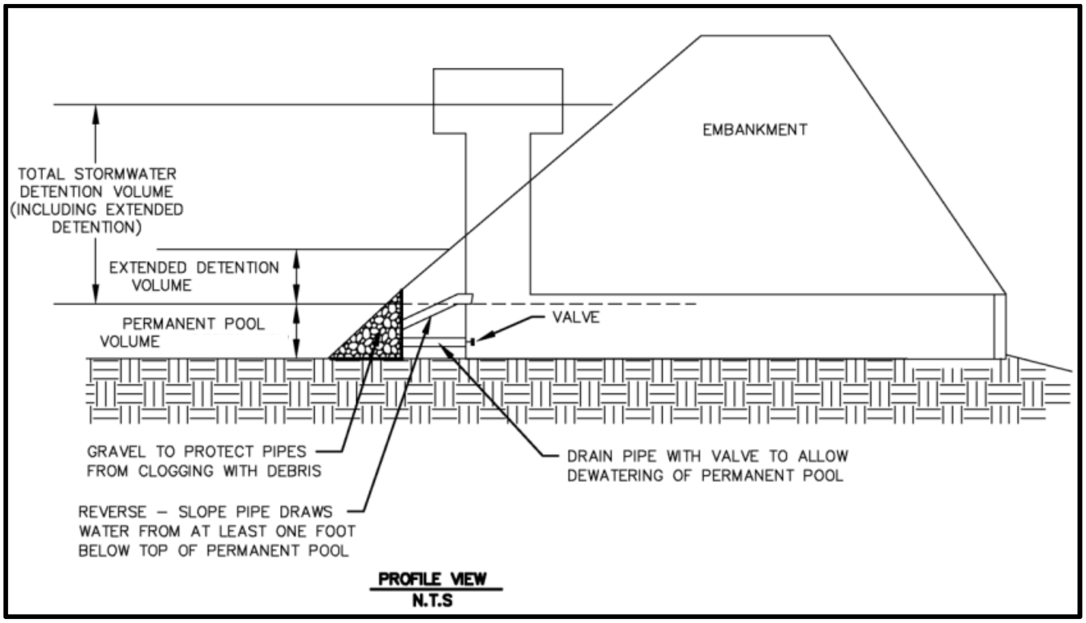
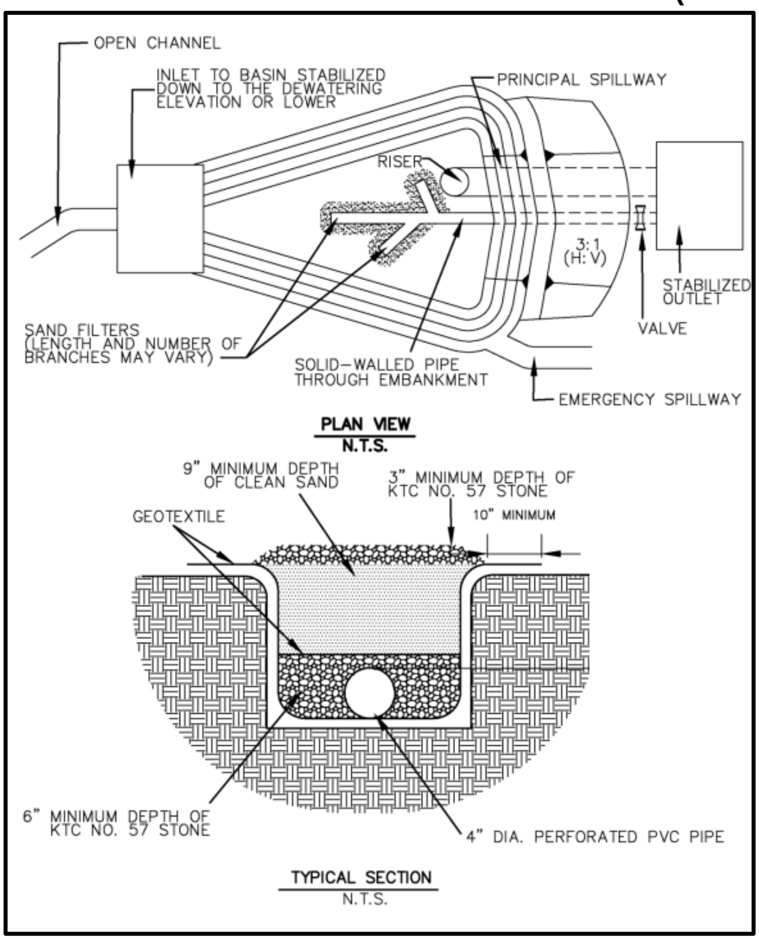


Figure 5. Dry Extended Detention Pond Outlet and Sand Filter (from LFUCG, 2009).

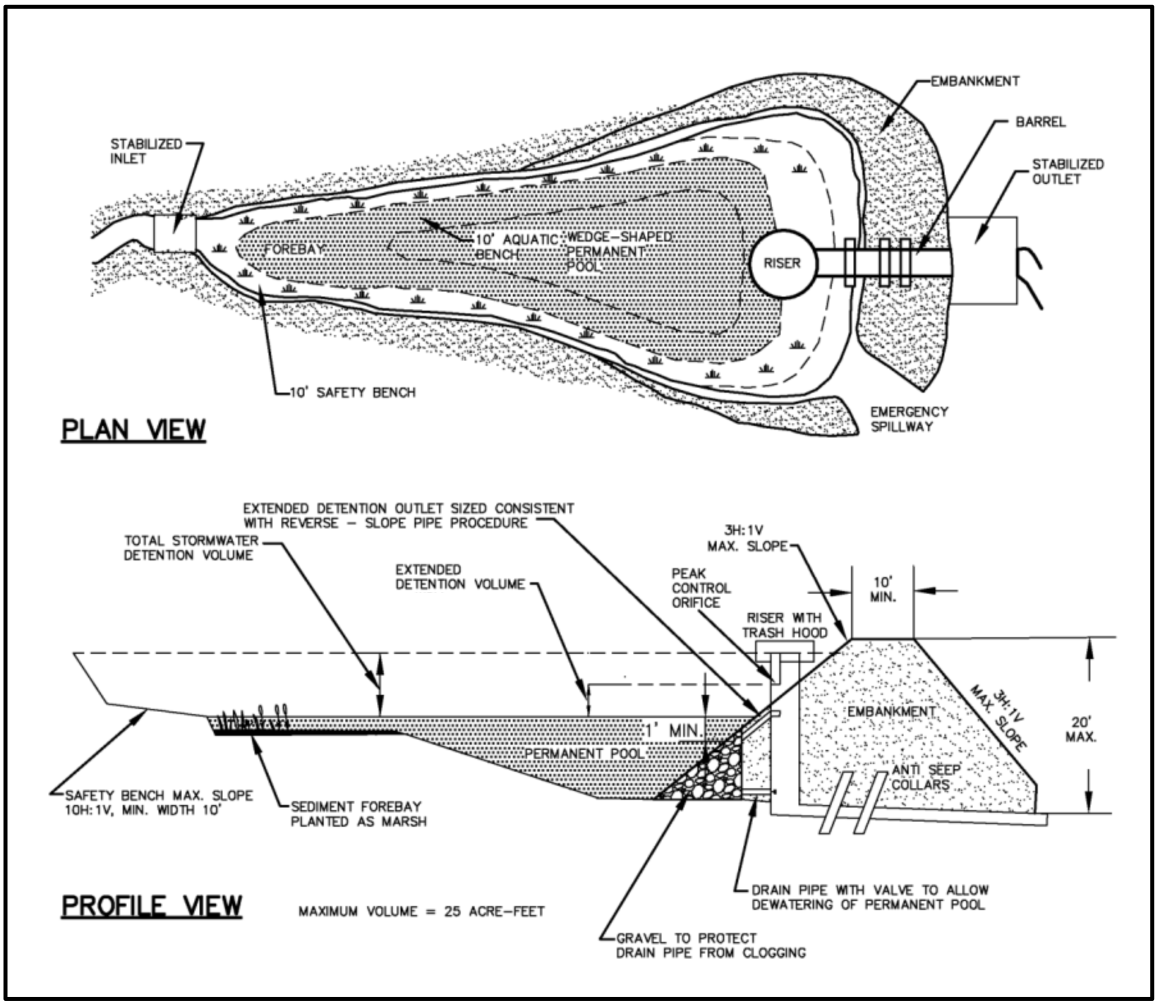


Wet Ponds

A wet pond is designed for both stormwater quality and stormwater quantity management, and has a permanent pool. The permanent pool is completely or partially displaced by incoming stormwater from the contributing drainage area. Water is temporarily stored before it is slowly released. A wet detention system is essentially a small lake with rooted wetland vegetation in the littoral zone.

Multiple pollutant removal mechanisms are present in wet pond systems. The pollutant removal occurs mainly during the relatively long inactive period between storms. One mechanism is settling or sedimentation. Chemical flocculation also occurs when heavier sediment particles overtake and coalesce with smaller, lighter particles to form a still larger particle. Dissolved pollutants may also be reduced by biological processes such as filtering, adsorption onto bottom sediments, uptake by aquatic plants including algae, and metabolism by microorganisms inhabiting bottom sediments and aquatic plants.

Figure 6. Wet Detention Pond (from LFUCG, 2009).



2.1. Operation

Successful detention pond operation depends on the following items:

- Maintaining the storage volume – Sediment and debris can reduce the storage volume available for treatment.
- Maintaining the discharge rate – Decreased storage or a modification to the outlet structure can impact the discharge rate. Where the pond is designed for stormwater quantity control, flooding or downstream erosion can occur.
- Maintaining the system's infiltration capability – When the infiltration rate is decreased from clogging or other obstruction, the pond storage volume may be overwhelmed by the additional stored water, causing the pond to poorly manage quantity or quality.
- Maintaining the discharge structure – The discharge structure is one of the most important components of the pond, as it controls discharge. Small outlet pipes easily clog with debris and sediment.
- Littoral zone vegetation maintenance (wet detention ponds only) – The shoreline around the pond should be protected from erosion with plants that can withstand short term inundation when the pond is full.

2.2. Maintenance

Each detention pond type includes maintenance activities that need to be performed as needed. Table 1 contains a matrix of maintenance activities for each detention pond type - dry detention (Dry), dry extended detention (Dry ED) and wet detention (Wet). The matrix is based on the LFUCG Stormwater Manual (LFUCG, 2009).

Table 1. Detention Pond Maintenance Activity Summary.

Maintenance Activity	Detention Pond Type		
	Dry	**Dry ED**	**Wet**
Removal of trees, brush and animal burrows from the embankment	X	X	X
Vegetative stabilization of eroding sides and embankment	X	X	X
Structural repairs (inlets, outlets and emergency spillway)	X	X	X
Dam, embankment or slope repairs to prevent erosion or piping	X	X	X
Frequent removal of accumulated solids, debris, and litter from the detention area, especially from the low flow channel	X	X	
Sediment removal when sediments are dry and have cracked, separating from the bottom and vegetation	X	X	
Debris removal from vegetated areas	X	X	X
Debris removal from the pond bottom to reduce clogging for outlet structures, trash racks, and other mechanical components	X	X	
Mowing	X	X	
Vegetative stabilization of pond bottom	X	X	
Remove debris from extended detention outlet (typically small orifice)		X	
Aquatic plant management (if pond includes a constructed wetland)		X	
Grass mowing and removal from side slopes and the embankment			X
Trash and debris removal and disposal for wet pond area			X
Monitoring and periodic removal of nuisance species in the littoral zone			X
Thinning and transplanting of thriving littoral zone plants as needed to maintain good growth throughout the littoral zone			X
Monitoring for mosquitoes and introducing natural predators as needed			X
Sediment accumulation monitoring in forebays or in the pond bottom			X
Channel erosion monitoring in downstream conveyances			X
Dewatering the pond dewatering and sediment removal			X
Repairs to fences, if applicable			X

For wet pond sediment removal activities, the frequency of removal will depend on multiple factors including use of pretreatment BMPs or forebays, land cover and land use for the contributing drainage area, sediment loading, etc. A good rule of thumb is to remove sediment when 10 to 20% of the system's storage volume has been lost.

2.3. Inspection

Inspections should be performed on all detention practices at least once per 5 years. However, more frequent "informal" inspections should occur to monitor vegetation, sediment deposition and drainage. During inspection of all detention pond types, watch for proper drainage through the outlet structure, outlet structure clogging, healthy vegetative growth, and sediment and debris accumulation. Inspections should consider the following factors:

- Debris or trash obstructions at the inlet or outlet devices;
- Excessive erosion or sedimentation;
- Dam cracking or settling;

- Low spots in the bottom of an extended detention facility;
- Pipe deterioration;
- Emergency spillway condition;
- Stability of the side-slopes;
- Sparse or missing vegetative growth in littoral zone (for wet ponds);
- Up and downstream channel conditions; and
- Signs of vandalism.

All detention facilities must be formally inspected at least once per 5 years. The inspections should be documented in writing on the inspection report found in Section 2.4. Required maintenance items or activities should be clearly documented on the inspection report and completed as soon as possible after the inspection where the need was noted. Routine screening inspections should also be conducted by Grounds staff while performing day to day operations. The routine screening should determine mowing and vegetation management needs.

Each detention pond type requires sediment removal to maintain proper pond function. For dry detention ponds, the anticipated frequency for removing deposited sediment is about once every five years. Dry extended detention ponds have an anticipated frequency for removing deposited sediment of about once every two to five years. The anticipated frequency for removing deposited sediment from wet ponds will depend on multiple factors including use of pretreatment BMPs or forebays, land cover and land use for the contributing drainage area, sediment loading, etc. A good rule of thumb is to remove sediment from wet ponds when 10 to 20% of the system's storage volume has been lost.

2.4. Inspection Checklist

The inspection report checklist is patterned after the LFUCG Stormwater Manual checklist (LFUCG, 2009).

University of Kentucky

Operation and Maintenance Inspection Report for Detention Ponds

Circle Pond Type Dry Dry Extended Detention Wet	
Circle Inspection Type 5 year Routine After Major Storm	
Inspection Date:	Inspector Name:
Inspection Location:	

Inspection Item	Item Checked? Yes	No	Maintenance Needed? Yes	No	Remarks
A. Embankment and emergency spillway					
1. Vegetation and ground cover adequate					
2. Embankment erosion					
3. Animal burrows					
4. Unauthorized plantings					
5. Dam cracking, bulging, or sliding a Upstream face					
b Downstream face					
c At or beyond toe (upstream)					
d At or beyond toe (downstream)					
e Emergency spillway					
6. Pond, toe & chimney drains clear and functioning					
7. Downstream face seeps/leaks					
8. Slope protection or riprap failures					
9. Vertical and horizontal alignment of top of dam as per “As-Built” plans					
10. Emergency spillway clear of obstructions and debris					
11. Other (specify)					
B. Riser and principal spillway					
Circle Type: Reinforced concrete Corrugated pipe Masonry 1. Low flow orifice obstructed					
2. Low flow trash rack a Debris removal necessary					
b Corrosion control					
3. Weir trash rack maintenance					
a Debris removal necessary					
b Corrosion control					
4. Excessive sediment accumulation inside riser					

Inspection Item	Item Checked? Yes	No	Maintenance Needed? Yes	No	Remarks
5. Concrete/masonry condition riser and barrels a Cracks or displacement					
b Minor spalling (< 1")					
c Major spalling (rebars exposed)					
d Joint failures					
e Water tightness					
6. Metal pipe condition					
7. Control valve a Operational/exercised					
b Chained and locked					
8. Pond drain valve a Operational/exercised					
b Chained and locked					
9. Outfall channels functioning					
10. Other (specify)					
C. Permanent pool (wet pond only)					
1. Undesirable vegetative growth					
2. Floating or floatable debris removal required					
3. Visible pollution					
4. Shoreline problems					
5. Other (specify)					
D. Sediment forebays					
1. Sedimentation noted					
2. Sediment cleanout when depth < 50% design depth					
E. Dry pond areas					
1. Vegetation adequate					
2. Undesirable vegetative growth					
3. Undesirable woody vegetation					
4. Low flow channels clear of obstructions					
5. Standing water or wet spots					
6. Sediment and/or trash accumulation					
7. Other (specify)					
F. Condition of outfalls into pond					
1. Riprap failures					
2. Slope erosion					
3. Storm drain pipes					
4. Endwalls/headwalls					
5. Other (specify)					
G. Sediment accumulations for wet ponds					
1. Record sediment accumulation level. Estimate sediment accumulation volume. Remove sediment when pond's storage volume is reduced by 10%-20%.					
H. Other					
1. Encroachments on pond or easement area					

3.0 CONSTRUCTED WETLANDS

A constructed wetland is a constructed device to treat and control stormwater that also incorporates some of the properties of natural wetlands such as shallow, sheet flow through dense, diverse assemblage of wetland plants that also serve as habitat for microorganisms. Constructed wetlands can provide both water quality and water quantity management or water quality management only. Constructed wetlands can provide a very effective management measure for runoff pollution mitigation because they have the ability to assimilate large quantities of suspended and dissolved materials from inflow. The term “constructed wetland” can apply to a wetland constructed to mitigate impacts to a natural wetland (per a Corps of Engineers permit), or a wetland which is constructed as part of a wastewater treatment system. Natural wetlands cannot be used as constructed wetlands. For management of water quantity, a wetland would be constructed much like a wet pond with a 6-12 inch deep permanent pool and varying water levels in other areas of the wetland. The key factor for determining whether a location is suitable for a constructed wetland is the existence of the required base flow to supply the permanent pool.

Constructed wetlands can incorporate multiple pollutant removal mechanisms. One mechanism is settling or sedimentation. A second method is through pollutant adsorption to sediment, vegetation or detritus. Plants and/or algae may also provide filtration and uptake benefits. In addition, wetland microbes can remove stormwater pollutants through uptake and/or transformations. The extended detention in a constructed wetland allows pollutant removal during the relatively long inactive period between storms.

Figures 7 – 14 show multiple schematics for different variations of constructed wetland systems from the Georgia Stormwater Management Manual (Atlanta Regional Commission, 2001). Figures 7-8 show a shallow wetland configuration. Figures 9-10 depict a shallow extended detention wetland that has similar function and characteristics to the dry extended detention pond. Figure 11-12 combine a wet detention pond with a constructed wetland. The pocket wetland shown in Figures 13-14 is a configuration used for small areas where a typical constructed wetland will not fit due to space constraints.

Figure 7. Shallow Wetland Plan View (Atlanta Regional Commission, 2001).

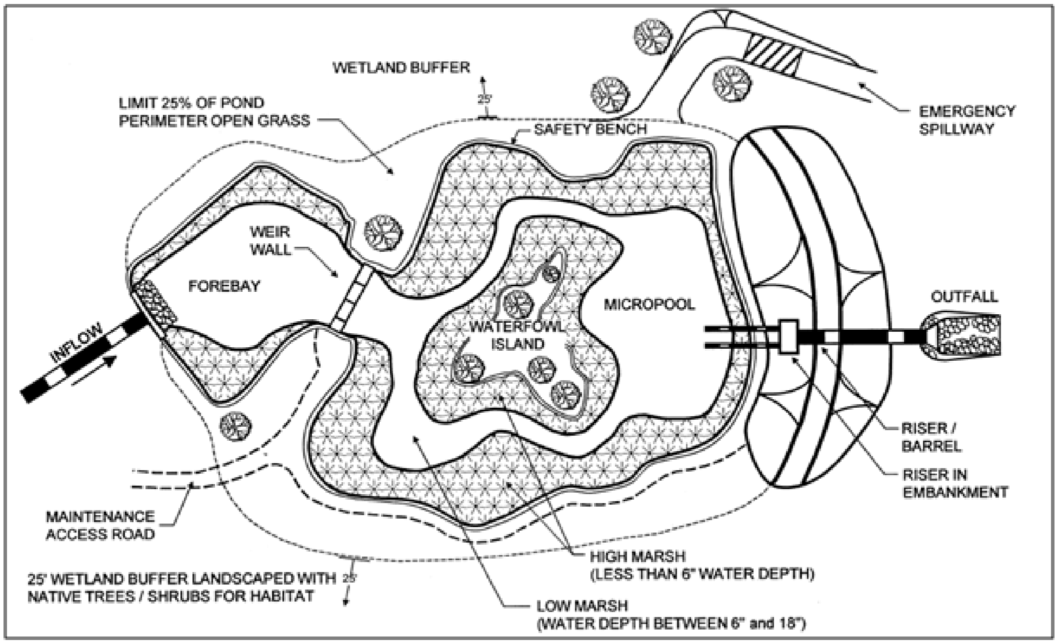


Figure 8. Shallow Wetland Profile View (Atlanta Regional Commission, 2001).

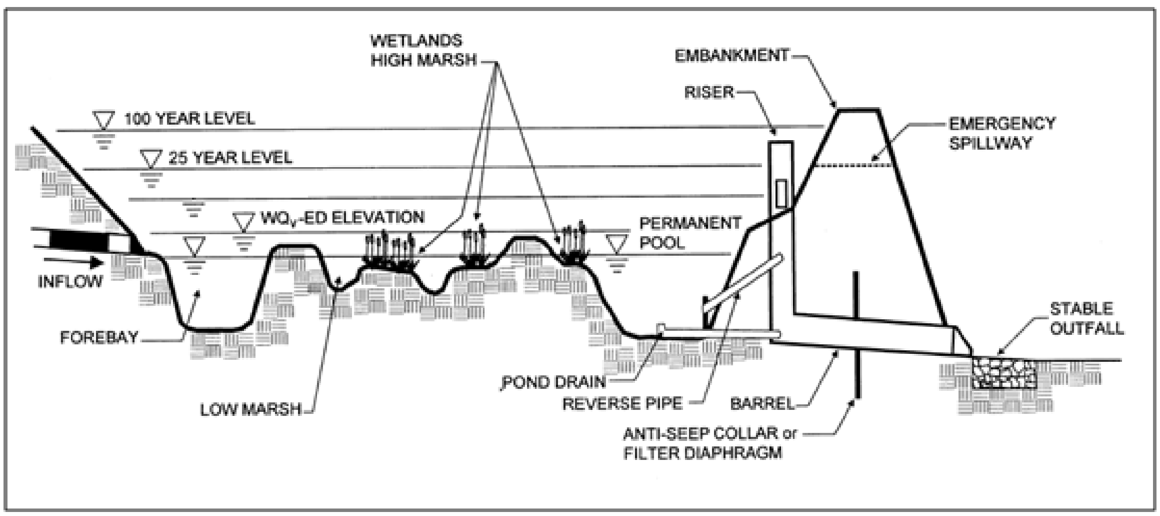


Figure 9. Shallow Extended Detention Wetland Plan View (Atlanta Regional Commission, 2001).

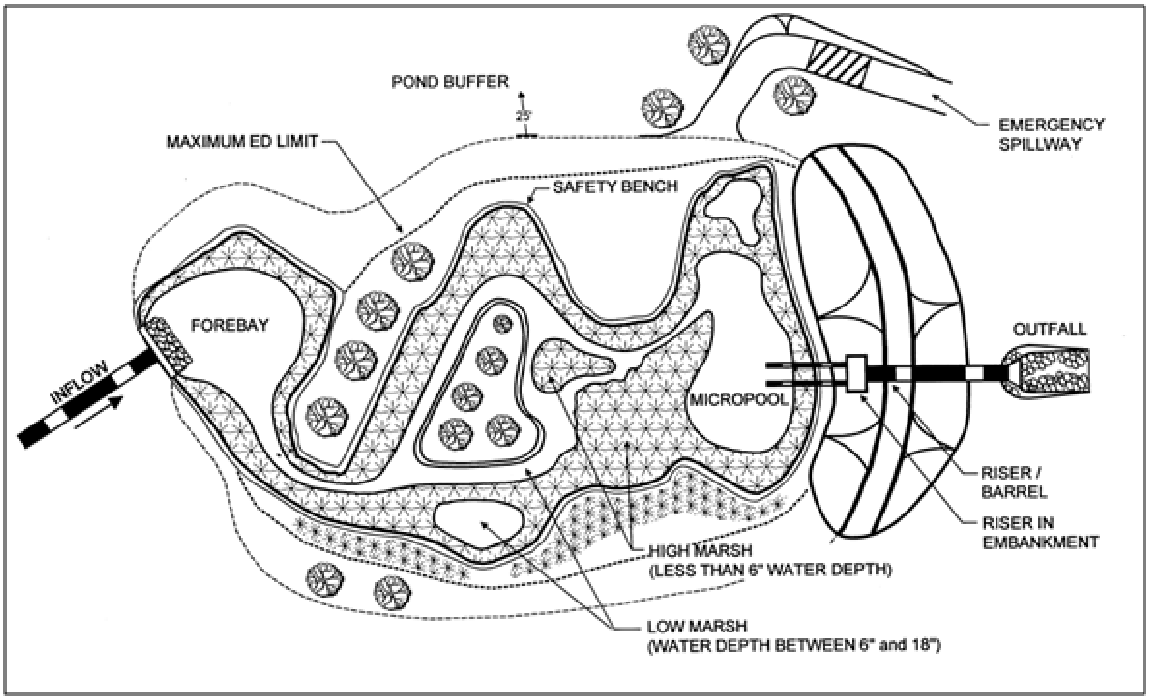


Figure 10. Shallow Extended Detention Wetland Profile View (Atlanta Regional Commission, 2001).

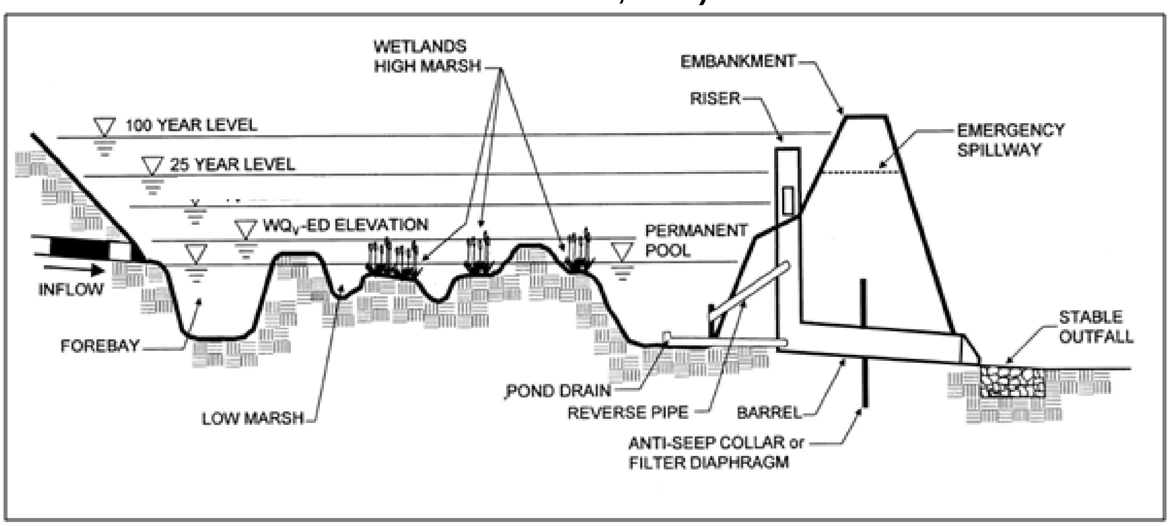


Figure 11. Pond and Wetland System Plan View (Atlanta Regional Commission, 2001).

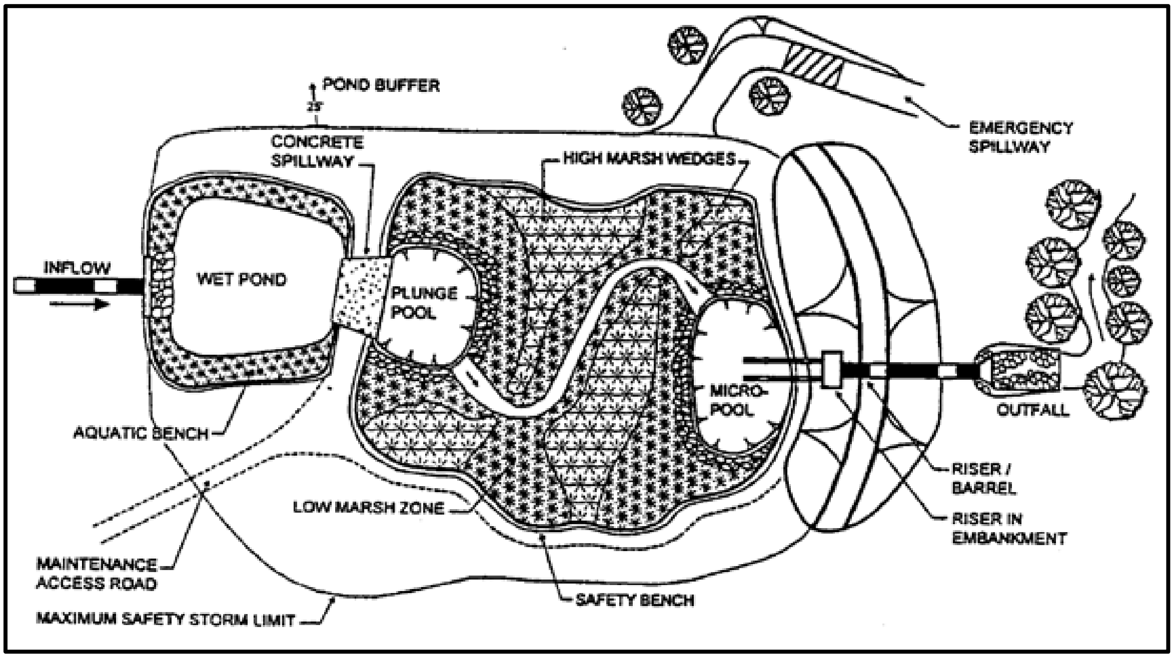


Figure 12. Pond and Wetland System Profile View (Atlanta Regional Commission, 2001).

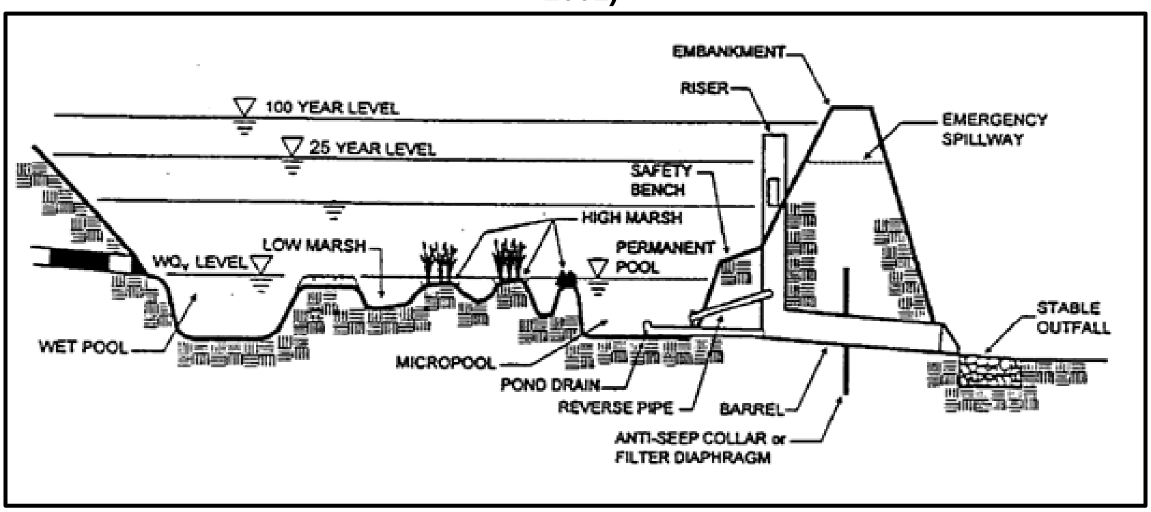


Figure 13. Pocket Wetland Plan View (Atlanta Regional Commission, 2001).

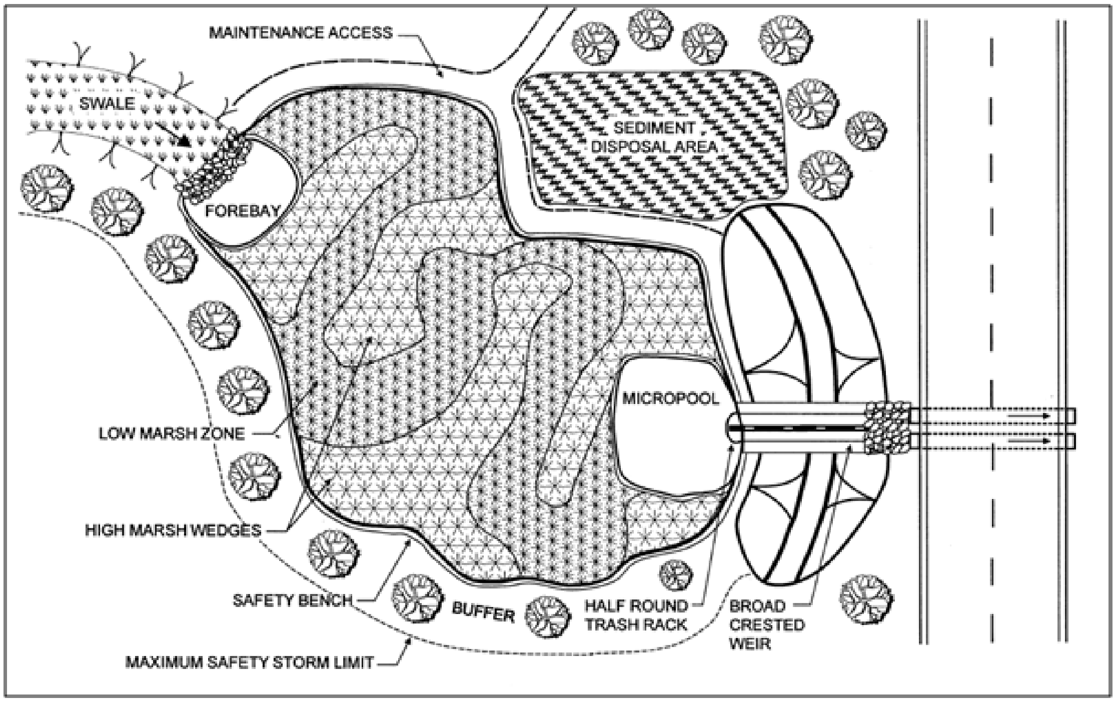
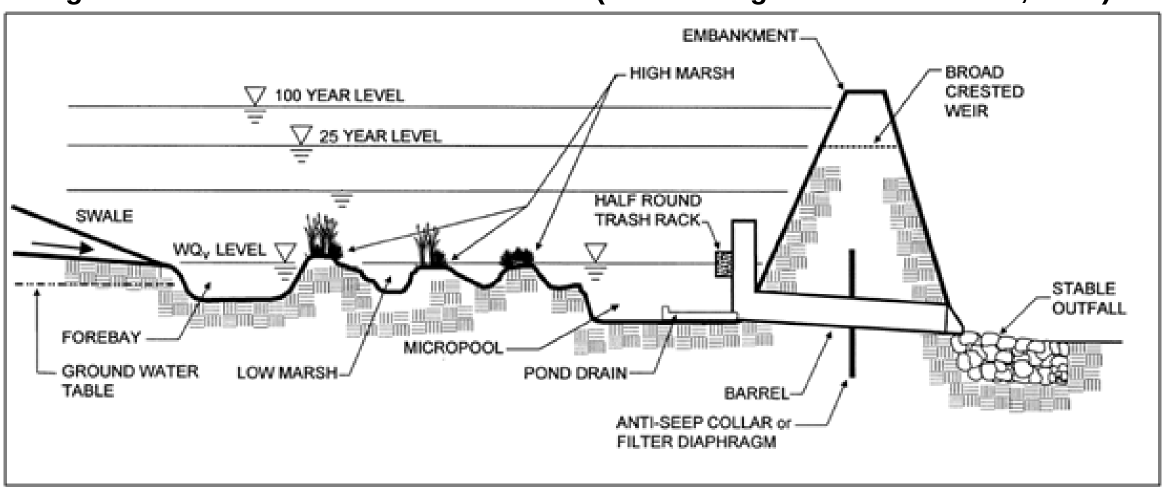


Figure 14. Pocket Wetland Profile View (Atlanta Regional Commission, 2001).



3.1. Operation

Successful operation depends on the following key factors:

- Good design – If a wetland isn't designed correctly, it may become more of a nuisance with stagnant water or more like a wet pond.
- Good construction – All design components must be translated into the field. If the construction doesn't follow the design, the vegetation may not live or the wetland may not hold the base flow necessary to support the vegetation.

- Good maintenance, especially for the discharge structure and littoral zone vegetation – Often, wetlands will have a small opening in the discharge structure that can get blocked by debris. In addition, heavy sediment loads can overwhelm the vegetation or change the water depths in different areas of the wetland.

3.2. Maintenance

Constructed wetland maintenance activities required to maintain its long term functioning include the following:

- Grass mowing and removal from side slopes and the embankment;
- Removal of trees, brush, and animal burrows from the embankment;
- Vegetative stabilization to prevent side slope and embankment erosion;
- Trash and debris removal and disposal, especially at inlet or outlet structures;
- Monitoring and periodic removal of nuisance plant and animal species, including monocultures;
- Thinning and transplanting of thriving wetland plants as needed to maintain good growth throughout the wetland;
- Monitoring for mosquitoes; and
- Sediment accumulation monitoring and removal in forebays or within the constructed wetland.

3.3. Inspection

Inspections must be performed on all constructed wetlands at least once every 5 years. Routine informal inspection screening should be conducted annually. Inspections should consider the following factors:

- Water levels noted in the plans should be generally maintained in the treatment area.
- Monitor accumulations of trash and debris, as well as sediment. Sediment should be removed when 25% of the storage volume of the forebay has been lost.
- Mow grassed areas to maintain a good cover. Remove invasive species to avoid having a monoculture. Remove cut vegetation from the wetland to prevent clogging the spillway.
- Determine health of wetland vegetation. Replant or replace when necessary.
- Monitor the wetland plants both during the growing season and during the dry season to watch for healthy growth of desired plants.
- Remove exotic or nuisance species as soon as they appear.
- Thin or transplant plants from dense growth areas and use these plants to further establishment or growth in areas with less vigorous plant growth.

Inspections performed once every 5 years must be documented in writing using the report in Section 3.4. Required maintenance needs should be clearly documented on the inspection report and completed as soon as possible after the inspection where the need was noted. The anticipated frequency for removing deposited sediment will depend on multiple factors including use of pretreatment BMPs or forebays, land cover and land use for the contributing drainage area, sediment loading, etc. A good rule of thumb is to remove sediment when 25% of the system's storage volume has been lost. Routine screening inspections should also be conducted by Grounds staff while performing day to day operations. The routine screening should determine mowing and vegetation management needs.

3.4. Inspection Checklist

This checklist is patterned after the City of Bowling Green, Kentucky's post-construction stormwater BMP manual (City of Bowling Green, 2011).

University of Kentucky

Operation and Maintenance Inspection Report for Constructed Wetlands

Circle Inspection Type: 5 yr Inspection Routine After Major Storm	
Inspection Date:	Inspector Name:
Inspection Location:	

Inspection Item	Item Checked? Yes	Item Checked? No	Maintenance Needed? Yes	Maintenance Needed? No	Remarks
A. Vegetation Inspection					
Check that at least 50% of wetland plants survive.					
Check for invasive wetland plants.					
B. Wetland Inspection					
Inspect low flow orifices and other pipes for clogging.					
Check the permanent pool area for floating debris, undesirable vegetation.					
Investigate the shoreline erosion.					
Monitor wetland plant composition and health.					
Look for broken signs, locks and other dangerous items.					
C. Vegetation					
Monitor wetland plant composition and health.					
Identify invasive plants.					
Assure mechanical components are functional.					
D. Drainage/Spillways					
Inspect riser, barrel, and embankment for damage.					
Inspect all pipes.					
Monitor sediment deposition in facility and forebay.					

4.0 VEGETATED SWALES

Swales are vegetated parabolic or trapezoidal channels with a large width to depth ratio that are used for conveying stormwater runoff. Vegetated swales tend to slow runoff rates and to allow for particle settling and stormwater infiltration. A biofiltration swale is a variation of a bioretention area without an underdrain system. Swales may be used with curb cuts for roadside drainage that replaces a traditional curb inlet/storm sewer system. Bermed swales use berms installed across the swale to impound shallow water for added particle settling and stormwater infiltration. Pollutant removal by vegetated swales can involve multiple mechanisms, including settling, infiltration, ion exchange, adsorption, microbial action, and vegetative filtration and uptake. Figures 15 and 16 show a biofiltration swale and a combination of curb cuts and vegetated swales, respectively.

4.1. Operation

Successful operation depends on the following key factors:

- Good design, especially hydraulic residence time and infiltration rates (which typically translate to a gentle or mostly flat slope);
- Good construction and stabilization with grass; and
- Regular maintenance.

Figure 15. Biofiltration Swale (from LFUCG Manual).

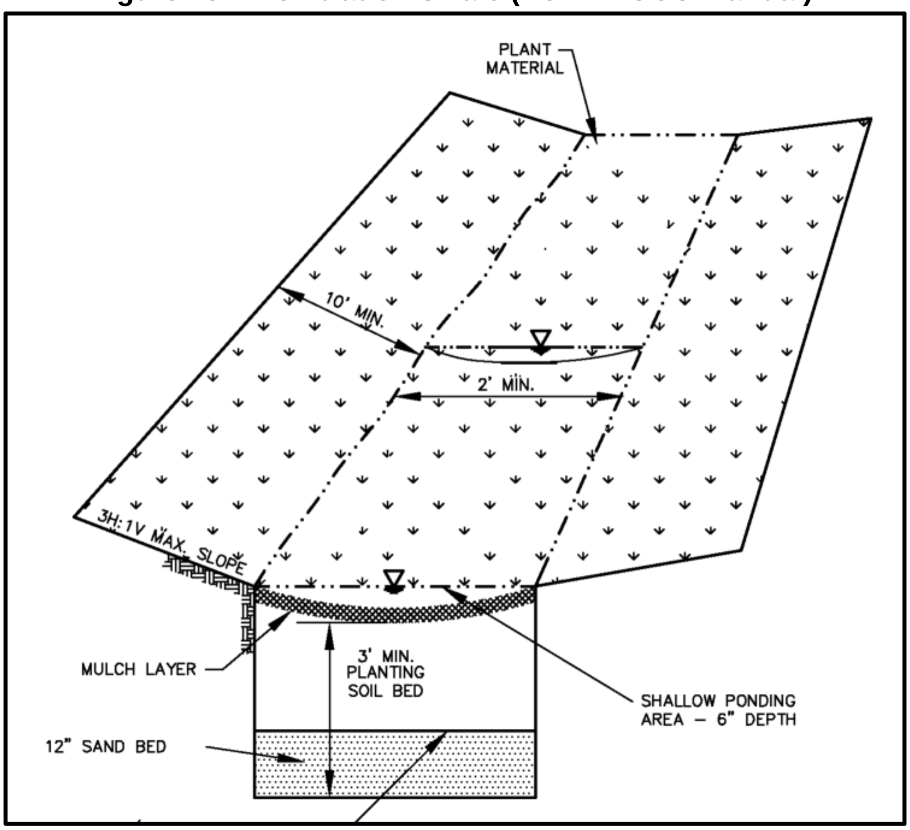
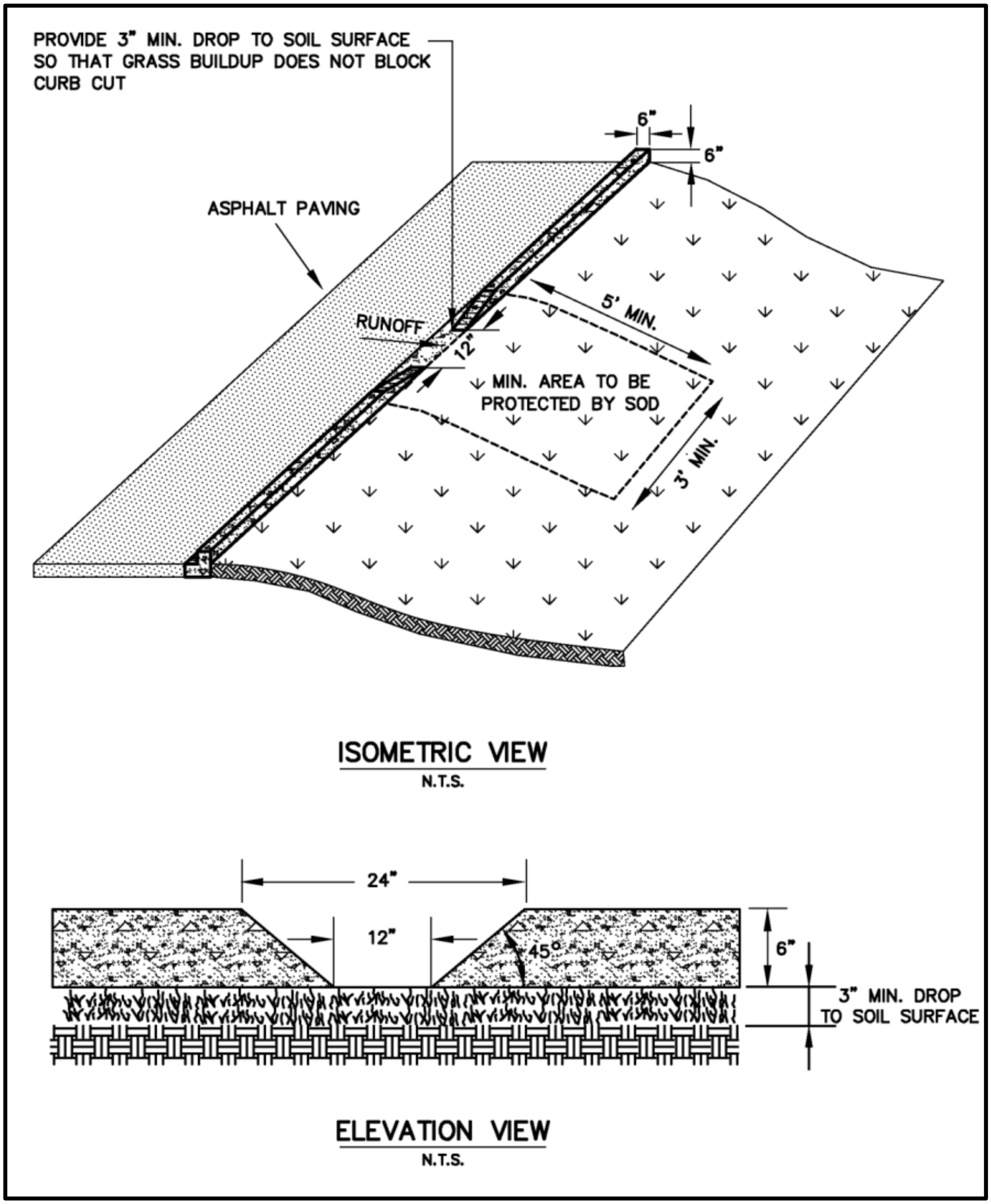


Figure 16. Curb Cut to Vegetated Swale (from LFUCG Manual).



4.2. Maintenance

Vegetated swales require the following maintenance activities for maintaining long-term function:

- Vegetation must be mowed to maintain adequate hydraulic functioning. Turf grass height should be between two to six inches. Excessively long grass can flatten when water flows over it, preventing filtration and sedimentation. Remove mowed grass so that decaying vegetation cannot release captured nutrients and other pollutants.
- Remove visible deposits of sediment, debris, and litter.
- Stabilize areas of the swale that are eroding.
- Fertilizer use should be minimized.
- If swale berms/blocks are used to promote infiltration or sedimentation, these blocks must be considered when performing maintenance. Sediments need to be carefully removed without damaging the swale block or its associated vegetation.
- If curb cuts are used as inflow diversions to a vegetated swale, sediments and vegetation should be removed from the curb cut when these items begin to interfere with the inflow to the swale.

4.3. Inspection

Inspect vegetated swale at least once every 5 years. Routine inspections should after large storm events. All inspections should consider the following:

- Ensure positive drainage. Ponding water can kill vegetation.
- Inspect all components of the swale for evidence of erosion and stabilize these areas.
- Watch for sediment deposits. Sediment and debris should be removed from the swale once identified.
- Inspect for evidence of dead or dying vegetation on berms, side slopes or bottom.

Inspect all swales at least once every 5 years and document the inspection using the form in Section 4.4. Required maintenance items or activities should be clearly documented on the inspection report. Any required maintenance activities should be completed after they have been identified. Routine screening inspections should also be conducted by Grounds staff while performing day to day operations. The routine screening should determine mowing and vegetation management needs.

4.4. Inspection Checklist

The inspection report checklist is patterned after the LFUCG Stormwater Manual checklist (LFUCG, 2009).

University of Kentucky

Operation and Maintenance Inspection Report for Vegetated Swales

Circle Filter Practice Type: Vegetated Swale	
Circle Inspection Type: 5 year Routine After Major Storm Event	
Inspection Date:	Inspector Name:
Inspection Location:	

Inspection Item	Item Checked? Yes	Item Checked? No	Item Satisfactory? Yes	Item Satisfactory? No	Remarks
A. Debris cleanout					
Swales and contributing areas clean of debris					
B. Vegetation					
Mowing done when needed					
Fertilized per specifications					
No evidence of erosion					
Minimum mowing depth not exceeded					
C. Dewatering					
Swale dewaters between storms					
D. Check dams or energy dissipators					
No evidence of flow going around structures					
No evidence of erosion at downstream toe					
E. Sediment deposition					
Swale clean of sediments					
F. Outlets/overflow spillway					
Good condition, no need for repair					
No evidence of erosion					

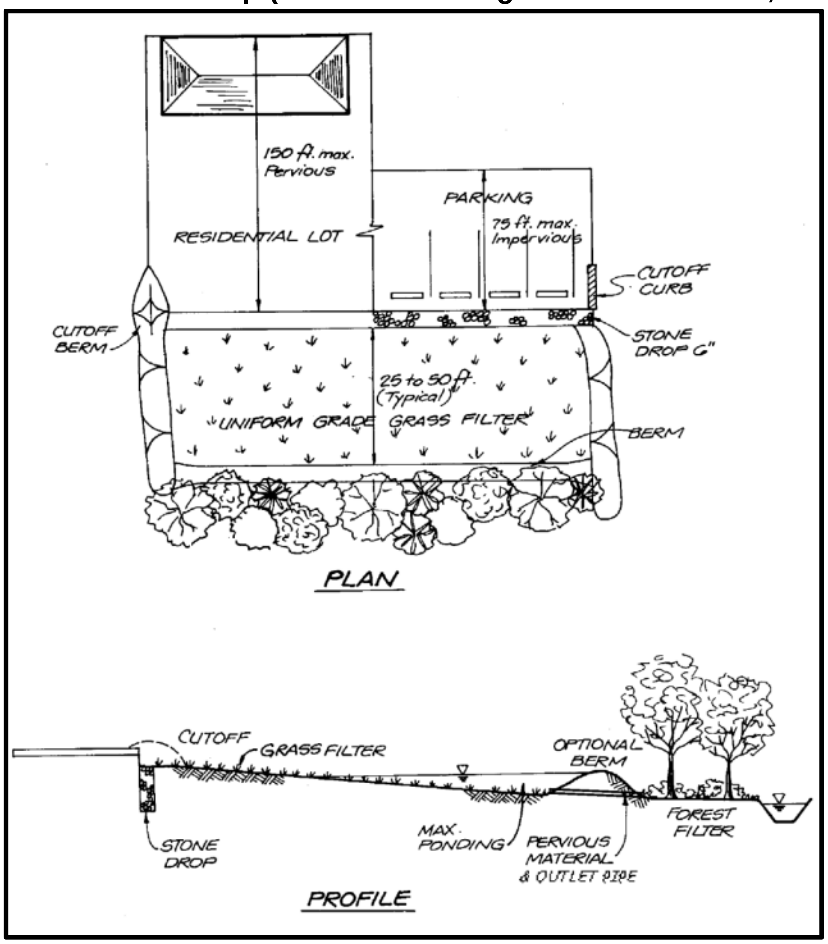
5.0 FILTER PRACTICES

Filter practices include multiple measures that use infiltration as a primary mechanism for addressing water quality. Examples of filter practices include the following practices: filter strips, bioretention areas and rain gardens. Each type of filter practice provides pollutant removal using the following mechanisms: settling, infiltration, ion exchange, adsorption, microbial action and vegetative filtration and uptake.

Filter Strips

A vegetated filter strip relies on sheet flow through vegetation to filter out sediment and other pollutants from stormwater. These filters also provide an opportunity for stormwater infiltration. Vegetated filters are typically used for small subareas of a larger development. For example, filter strips may be used at the edge of a parking lot or other paved surface. To work property, a filter strip should have sheet flow across the entire width of the vegetated area. The vegetation is typically grass or other ground covers that provide dense vegetation. Figure 17 shows a filter strip schematic.

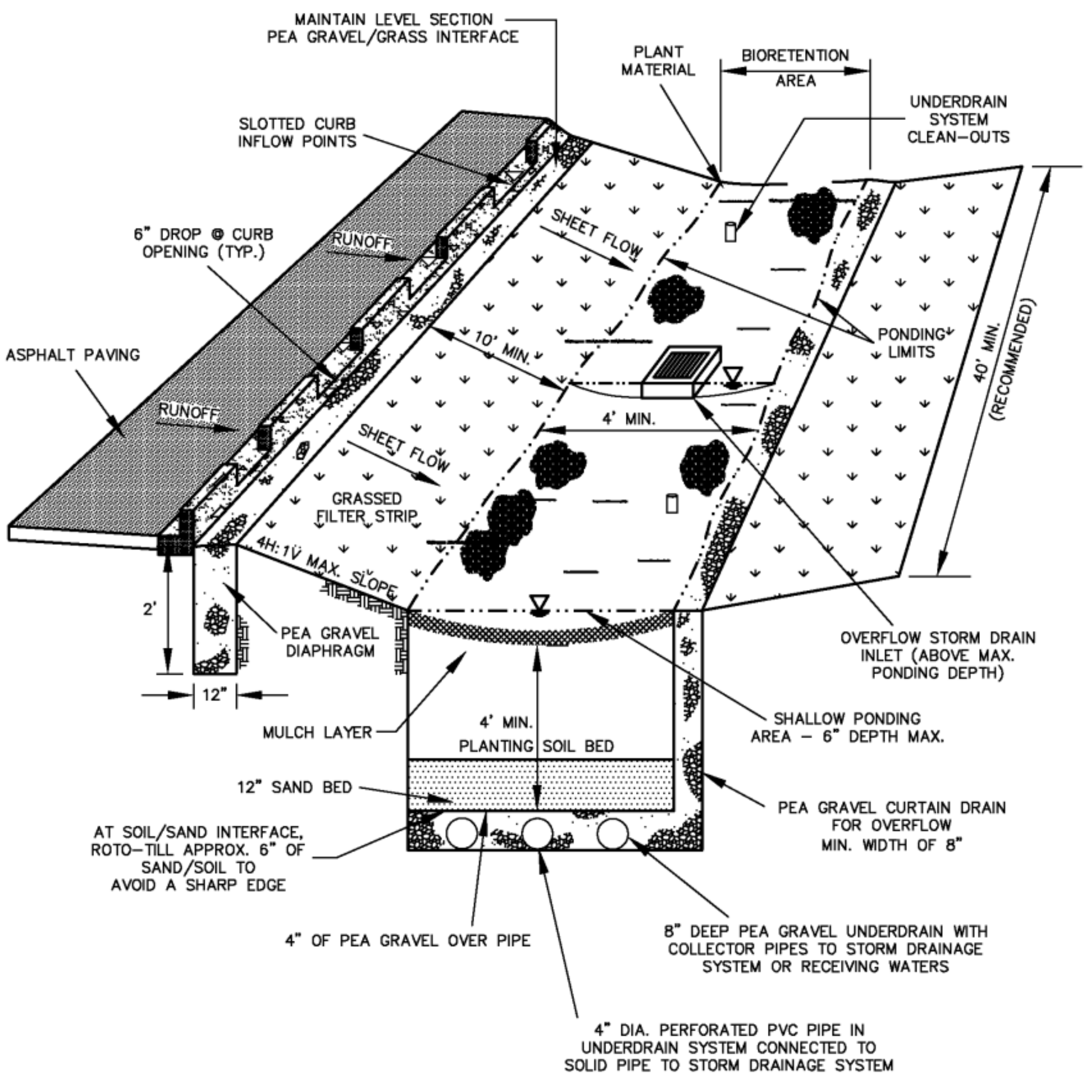
Figure 17. Filter Strip (from Atlanta Regional Commission, 2001).



<u>Bioretention Areas</u>

Bioretention areas treat stormwater runoff using a conditioned planting soil bed and planting materials to filter runoff stored within a shallow depression. The practice combines physical filtering, adsorption and biological processes to remove pollutants. The system consists of a structure to spread flow, a pretreatment filter strip or grass channel, a sand bed, pea gravel overflow curtain drain, a shallow ponding area, a surface organic layer of mulch, a planting soil bed, plant material, a gravel underdrain system, and an overflow system. Bioretention systems are particularly well suited for use in parking lot islands, roadside swales, and median strips. Figure 18 contains a schematic for a bioretention area.

Figure 18. Bioretention Area (from LFUCG Manual).



Rain Gardens

Rain gardens are depressed planting areas designed with shallow, level bottoms to help capture runoff before it reaches the drainage system (LJCMSD, 2009; LJCMSD, 2008). Rain gardens are often used to collect stormwater diverted from disconnected roof downspouts or from driveways or similar areas. The plants are typically native, drought tolerant and non-invasive. Rain gardens should not have standing water for more than 24 hours. Rain gardens use multiple mechanisms for removing pollutants, including settling, infiltration, ion exchange, adsorption, microbial action, and vegetative filtration and uptake. Figures 19-21 depicts three typical rain garden layouts with differing underdrain systems.

Figure 19. Rain Garden Without Underdrain System (LJCMSD, 2009).

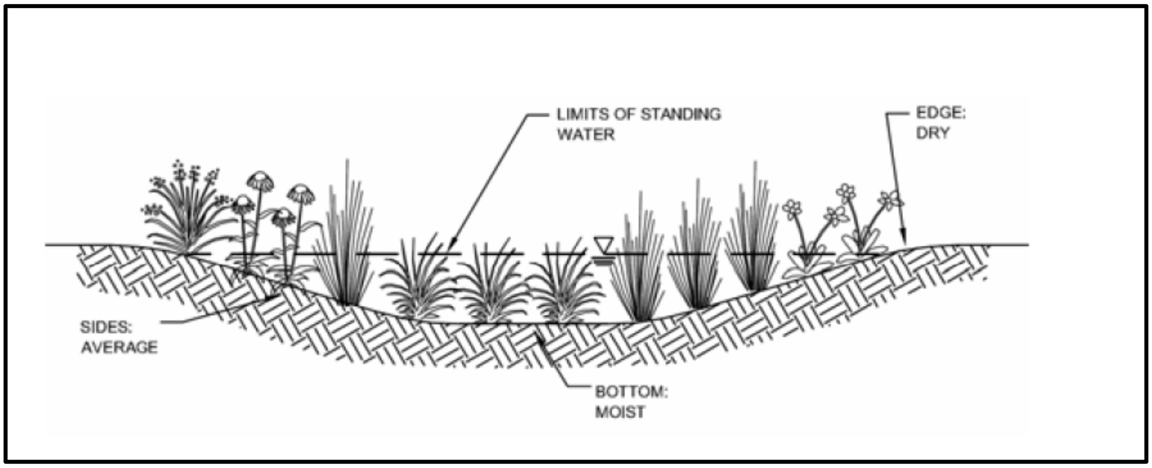


Figure 20. Rain Garden With Stone Filter Underdrain System (LJCMSD, 2009).

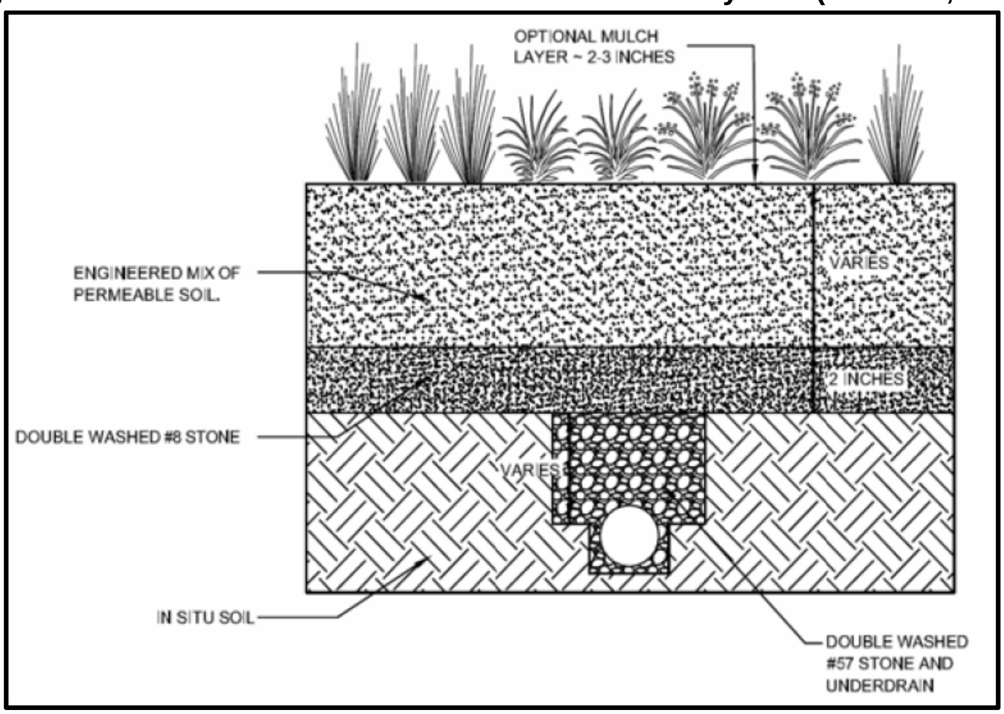
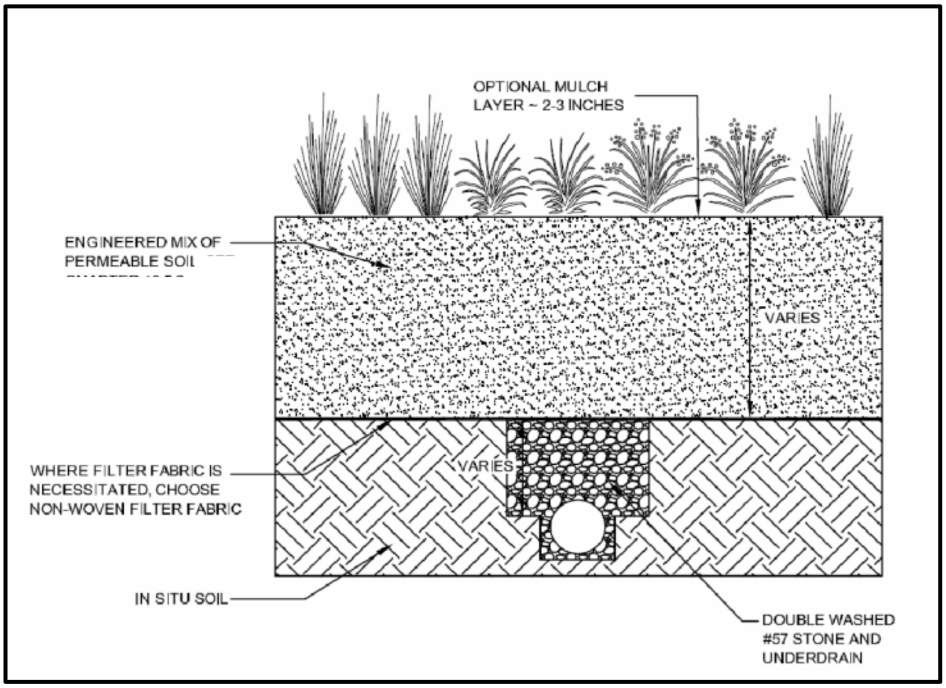


Figure 21. Rain Garden With Filter Fabric and Underdrain System (LJCMSD, 2009).



5.1. Operation

Filtration practices depend on the following key factors for successful operation:

- Good design, especially hydraulic residence times and infiltration rates. The design should emphasize ponding for no more than 24 hours in the treatment area and sheet flow.
- Good construction. A critical item in filter practices is the ability to maintain the infiltration rates through the engineered soils or underdrain. Failure of these components typically means ponding in the treatment area and will kill vegetation.
- Reducing or avoiding erosion is a necessity in the treatment area or across the filter strip. Level spreaders, dissipators and other practices should be incorporated into the design and installed in the field to prevent erosion.
- Regular maintenance is necessary to maintain the vegetation, replace the mulch and/or replace dying or overgrown vegetation.

5.2. Maintenance

Some maintenance activities are common for all filter practices while other maintenance activities are specific to the filter practice type. Filter practices require the following general maintenance activities to sustain successful long-term function:

- Vegetation must be maintained and/or removed as necessary to preserve adequate hydraulic functioning. Filter strip turf grass height should be 2-6 inches.
- Any mowed grass clippings or removed vegetation should be removed from the practice to avoid releasing nutrients and pollutants.
- Frequently remove accumulated solids, debris, and litter as necessary. Sediment should be removed when a visible deposit is noticed. Maintenance workers should give special attention to sediment accumulation in the upper portion of the practices after major storm events. Sediment and debris should be removed from the practices when necessary.
- Use vegetation to stabilize eroding areas within these practices or upslope areas draining to the practices. Sediment will clog filter practices, causing failure of the filtering mechanism.
- Fertilizer use should be minimized.

Rain gardens also require the following maintenance activities for long-term function:

- Mulch is a vital component of the rain garden. Replace the mulch when it degrades or erodes.
- Remove weeds and invasive vegetation.
- Water the rain garden during the first year after planting to establish vegetation.
- Replace dead or diseased vegetation and replace.

5.3. Inspection

Inspect filter practices once every 5 years and routinely during daily operations. The following items need to be inspected for all types of filter practices:

- Ensure the filtering practice drains correctly. Evidence that it is not correctly draining includes standing water, dead vegetation, or wetland vegetation.
- Inspect for sediment and debris buildup at inlets and outlets, which can cause scour and internal erosion.
- Check for signs of erosion occurring in the filter practice. Repair and revegetate eroding areas as soon as possible. Install level spreaders or dissipators to recreate sheet flow, where possible.
- Inspect the filter practice vegetation for sparse or missing vegetation.

Formal inspections must be conducted at least once every 5 years and documented in writing using the inspection report in Section 5.4. Required maintenance items or activities should be clearly documented on the report. Any required maintenance activities should be completed as soon as possible after the inspection. Routine screening inspections should also be conducted by Grounds staff while performing day to day operations. The routine screening should determine mowing and vegetation management needs.

Filter Strips

Filter strips should also be inspected for erosion, which may indicate that flow is concentrating along the filter strip and may need further attention.

Bioretention Areas

In addition to the general inspection items listed above, bioretention areas should be checked to make sure that the treatment area drains within the designed drain time following rain event (i.e., no problems with the underdrain system).

Rain Gardens

Rain gardens should be inspected to confirm that it dewater within 24 hours and that the vegetation is healthy.

5.4. Inspection Checklist

The inspection report checklist is similar in format to other checklists from the LFUCG Stormwater Manual checklist (LFUCG, 2009). The checklist items were developed from the maintenance items.

University of Kentucky
Operation and Maintenance Inspection Report for Filter Practices

Circle Filter Practice Type: Filter Strip Bioretention Area Rain Garden					
Circle Inspection Type: 5 year Routine After Major Storm Event					
Inspection Date:			Inspector Name:		
Inspection Location:					
Inspection Item	**Item Checked? Yes**	**Item Checked? No**	**Item Satisfactory? Yes**	**Item Satisfactory? No**	**Remarks**
A. Debris cleanout					
Filter practice and inlets/outlets clear of debris and trash					
Visible sediment or debris deposits. Be sure to check the upper portions of the practice.					
B. Vegetation Inspection and Management					
No signs of excessive erosion or sedimentation					
No sparse or missing vegetation growth at any locations on the filter practice					
For filter strips, the grass height is between two and six inches					
No need to remove undesirable or dying vegetation or weeds					
For rain gardens, mulch is in place and in good condition to discourage weed growth					
Any removed vegetation (mowing clippings, dead vegetation, etc.) have been removed from BMP					
C. Flow and Drainage Systems					
For bioretention areas and rain gardens, the filter practice drains within the required time after a rain event. Bioretention area drain time should be based on the design drain time. Rain gardens should drain within 24 hours.					
For filter strips, there are no indications of concentrated flow along the filter strip (e.g., erosion)					

6.0 SAND FILTERS

The following two types of sand filters are approved for post construction stormwater quality use on campus: underground sand filters and perimeter sand filters. Both filter types are suitable for locations where there are space constraints and the drainage area is mostly impervious (paved).

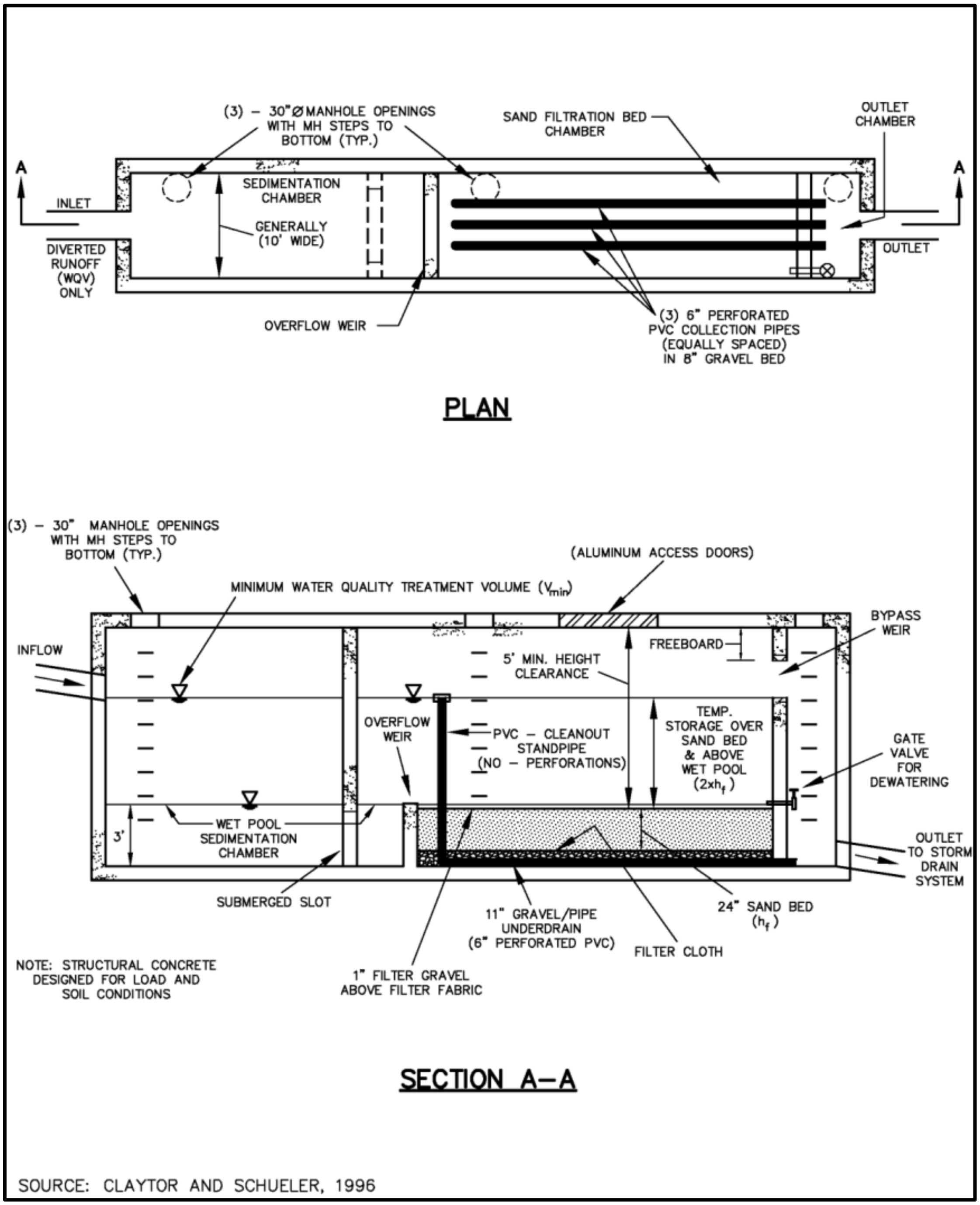
Underground Sand Filters

Underground sand filters are suitable for intensely developed urban areas where space is at a premium. Underground sand filters may be used for water quality treatment, but are not designed for water quantity control. These systems are also suitable in locations that are easily accessible to the public.

The underground sand filter is a two or three chamber vault accessible by manholes or grate openings. The first chamber is a sediment chamber used for pretreatment. It is connected to the second chamber (the sand filter bed) by an inverted elbow or submerged slot, which keeps the filter surface free from trash and oil. The filter bed is 18 to 24 inches in depth and has a protective screen of gravel over filter fabric to act as a pre-planned failure plane that can easily be replaced when the filter surface becomes clogged. During a storm, the water quality volume is temporarily stored in both the first and second chambers. Flows in excess of the filter's capacity are diverted through an overflow weir, into a third chamber or directly into the storm drain system.

Underground sand filters have two primary mechanisms to remove pollutants. The first mechanism is through settling or sedimentation. Pollutants are also removed through filtration by the sand. Figure 22 shows a schematic for an underground sand filter system.

Figure 22. Underground Sand Filter Plan and Cross-Section View (LFUCG, 2009).

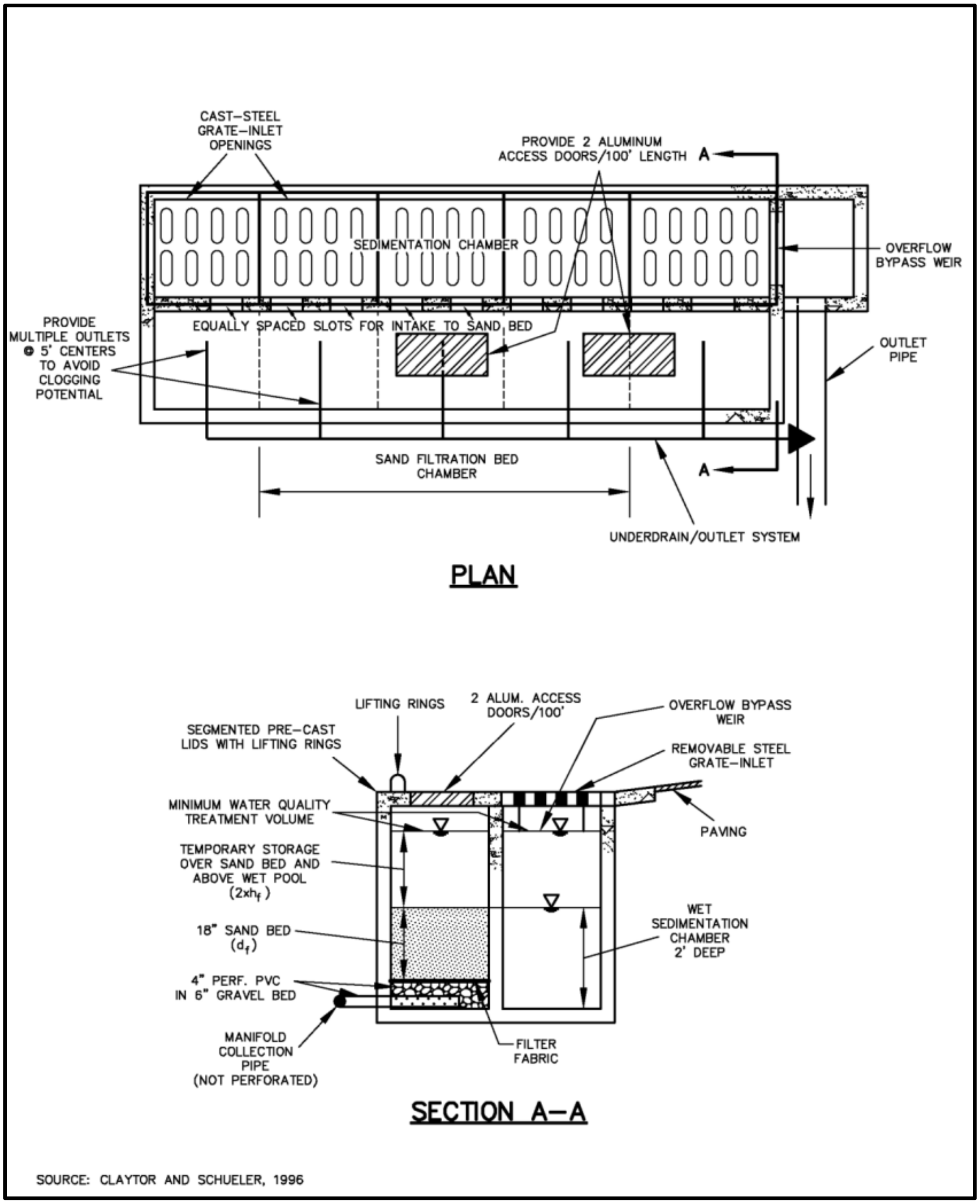


Perimeter Sand Filters

The perimeter sand filter consists of two parallel trench-like chambers that are typically installed along the perimeter of a parking lot. Parking lot runoff enters the first chamber which is a sedimentation chamber. The first chamber provides pretreatment before the runoff spills into the second chamber, which consists of an 18-inch deep sand layer over a gravel/perforated pipe underdrain system. During a storm event, runoff is temporarily ponded above the normal pool and sand layer, respectively. When both chambers fill up to capacity, excess parking lot runoff is routed to bypass the treatment system and into the storm drain system. Perimeter filters can be used for water quality treatment, but are not appropriate for peak flow (quantity) control.

Perimeter sand filters have two primary mechanisms to remove pollutants. The first mechanism is through settling or sedimentation. Pollutants are also removed through filtration by the sand. Figure 23 depicts a perimeter sand filter system.

Figure 23. Perimeter Sand Filter Plan and Cross-Section View (LFUCG, 2009).



6.1. Operation

Successful sand filter operation depends on the following key factors:

- Good design. The chambers must be sized based upon the contributing drainage area. The design must include a bypass for large storm events.
- Good construction. The measure must be installed as design to work properly, including the sand filter and chamber weir overflow elevations
- Regular maintenance, especially to prevent filter media clogging. The sand filter may crust over time and need debris and oil removed. Cleaning may not be enough, and the sand filter may need to be replaced. Sediment must also be cleaned out of the sedimentation chamber to allow for additional sediment trapping over time.

6.2. Maintenance

Both underground and perimeter sand filters require the following maintenance activities for maintaining long-term function:

- All upslope areas above the filter must be stabilized to prevent sediment from clogging the filter.
- Trash and debris in the sedimentation chamber and on the filter must be removed.
- Periodic scraping and aeration of the filter media is necessary to break the crust that will form on the filter. Depending on the loading to the filter, the upper 2-4 inches of sand may need to be removed and replaced.

6.3. Inspection

Inspect sand filters at least once every 5 years and document the inspection. Routine inspections should also occur during day to day operations. Watch for the following issues:

- Ensure the filer practice is draining as designed.
- Monitor sediment and debris accumulations in the sedimentation chamber and on the filter.
- Check that upslope areas are well vegetated.
- Inspect the chambers for nuisance issues such as odors, which may mean the chambers are not draining properly.

Inspections should be performed at least once every 5 years and documented in writing using the inspection report in Section 6.4. Sediment should be removed from the sediment chamber when 50% of the storage volume has been lost. Required maintenance items or activities should be clearly documented on the inspection report.

Any required maintenance activities should be completed as soon as possible following the inspection where the need was noted. Routine screening inspections should also be conducted by Grounds staff while performing day to day operations. The routine screening should determine mowing and vegetation management needs.

6.4. Inspection Checklist

The inspection report checklist is patterned after the LFUCG Stormwater Manual checklist (LFUCG, 2009).

University of Kentucky

Operation and Maintenance Inspection Report for Sand Filters (Underground or Perimeter)

Circle Filter Practice Type: Underground Sand Filter Perimeter Sand Filter	
Circle Inspection Type: 5 year Routine After Major Storm Event	
Inspection Date:	Inspector Name:
Inspection Location:	

Inspection Item	Item Checked? Yes	No	Item Satisfactory? Yes	No	Remarks
A. Debris cleanout					
Contributing areas clean of debris					
Filtration facility clean of debris					
Inlets and outlets clear of debris					
B. Vegetation					
Contributing drainage area stabilized					
Clippings removed from contributing area mowing					
No evidence of erosion					
C. Oil and grease					
No evidence of filter surface clogging					
Activities in drainage area minimize oil & grease entry					
D. Water retention where required					
Water holding chambers at normal pool					
No evidence of leakage					
E. Sediment deposition					
Filtration chamber clean of sediments					
Water chambers not more than ½ full of sediments					
F. Structural components					
No evidence of structural deterioration					
Any grates are in good condition					
No evidence of spalling or cracking of structural parts					
G. Outlets/overflow spillway					
Good condition, no need for repair					
No evidence of erosion (if discharging to an erodible area)					
H. Overall function of facility					
No evidence of flow bypassing facility					
No noticeable odors outside of facility					

7.0 PREFABRICATED DEVICES

Prefabricated devices include those installed to manage stormwater quantity or treat stormwater quality. Most prefabricated devices designed to manage stormwater quantity are installed underground and can include different treatment mechanics, including storage only, storage and infiltration, or storage and settling. For stormwater quality treatment, several manufacturers produce devices that are effective in removing suspended solids and oils from stormwater runoff. These devices are typically well-suited to sites that are relatively small and have a high percentage of impervious cover. These devices are not as effective in applications where a majority of the ground cover is pervious and a high percentage of the suspended solids are eroded fine soil particles. These devices typically consist of flow-through concrete structures with a settling or separation unit or filtering mechanism.

For prefabricated stormwater quality treatment devices in general, pollutant removal occurs mainly by swirl action, indirect filtration, or direct filtering. The treatment devices shall be capable of demonstrating 80% capture of particles in a size range of 2 mm (very coarse sand) to 0.125 mm (very fine sand). The design storm shall have an intensity of 2.1 inches/hour (3-month frequency storm) with a time of concentration of 10 minutes. Underground detention structures designed only for stormwater quantity management cannot be included in the stormwater quality treatment design.

Prefabricated devices may vary considerably in configuration and function. The designer must provide a schematic or drawing for any prefabricated device installed on UK's campus and will be required to submit an operations and maintenance plan.

7.1. Operation

Successful operation depends on the following key factors:

- Good design. The device must be designed to handle the runoff from the contributing drainage area, with a bypass mechanism for storms larger than the design storm.
- Good construction. All components noted in the design (elevations, diameters, media/material, etc.) must be constructed as shown in the design.
- Regular cleaning and maintenance. High sediment loads can cause failure of filtering devices. Regular removal of sediment and debris is necessary to ensure proper functioning of any manufactured device.

7.2. Maintenance

Prefabricated devices should be operated and maintained per the manufacturer's directions. In general, prefabricated devices will require the following maintenance activities for maintaining long-term function:

- All upslope areas above the device must be stabilized to prevent erosion and clogging at the filter.
- Routinely remove and dispose of trash and debris, especially from inlet or outlet structures.
- Remove sediments and other materials that accumulate in the device or pretreatment practices.

7.3. Inspection

Prefabricated devices should be inspected at least once every 5 years and as suggested by the manufacturer. Inspection criteria will be outlined in the operations and maintenance plan provided by the designer.

Inspections must be performed at least once every 5 years and documented in writing using an inspection report provided by the designer or by the device's manufacturer. Required maintenance items or activities should be clearly documented on the inspection report. Any required maintenance activities should be completed as soon as possible after the inspection where the need was noted.

7.4. Inspection Checklist

The designer will provide an inspection checklist along with operation and maintenance guidance for the prefabricated device. These items may include operation and maintenance guidance from the manufacturer.

8.0 PAVEMENT/PAVERS

Two types of pervious pavement/pavers are approved for use at the University of Kentucky. These measures are modular pavement and pervious concrete.

Modular Pavement

Modular pavement consists of strong structural materials, typically concrete, having regularly interspersed void spaces that are filled with pervious materials such as sand, gravel, or sod. These pavements can be used as driveways or as overflow parking in areas that are used less frequently than the main parking areas. Modular pavement is an infiltration practice that reduces the adverse impacts on the receiving waters that result from increasing the impervious area. This practice will likely not function as the sole water quality infiltration and treatment device, but will provide significant reduction of the amount of runoff that must be detained and treated.

Modular pavement uses two main methods for pollutant removal. The first is percolation of rainfall and runoff through the voids into the underlying permeable base and then into the soil. The second is filtration of rainfall and runoff by the vegetation that can grow in the voids. Figures 24-25 shows schematics for two modular pavement systems – one without an underdrain system and one with an underdrain system.

Figure 24. Modular Pavement Without Underdrain System (from LJCMSD, 2009).

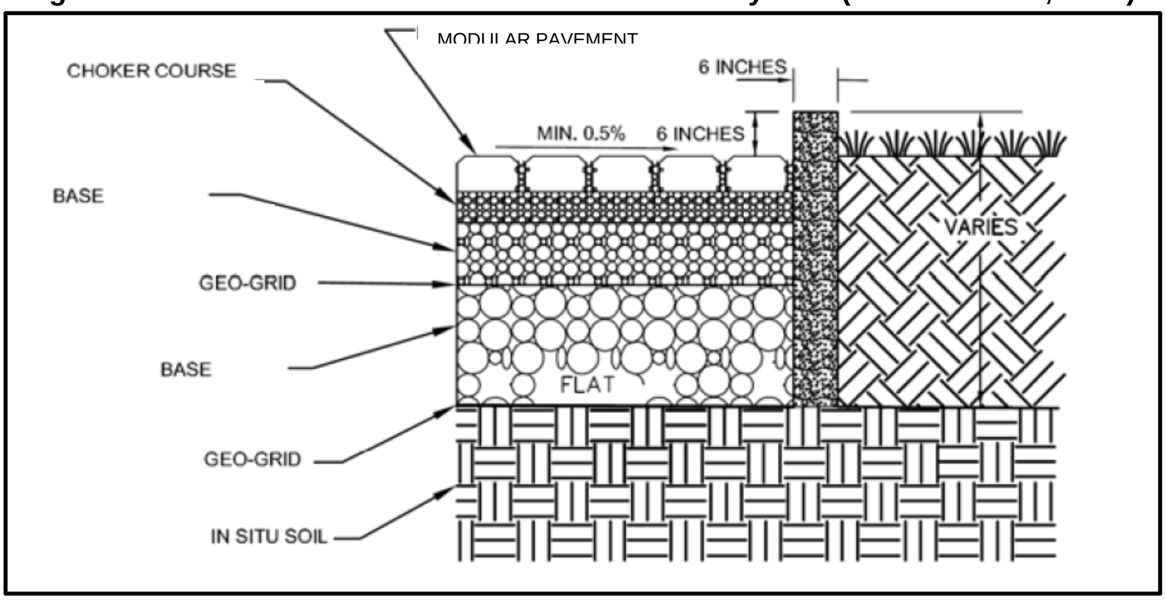
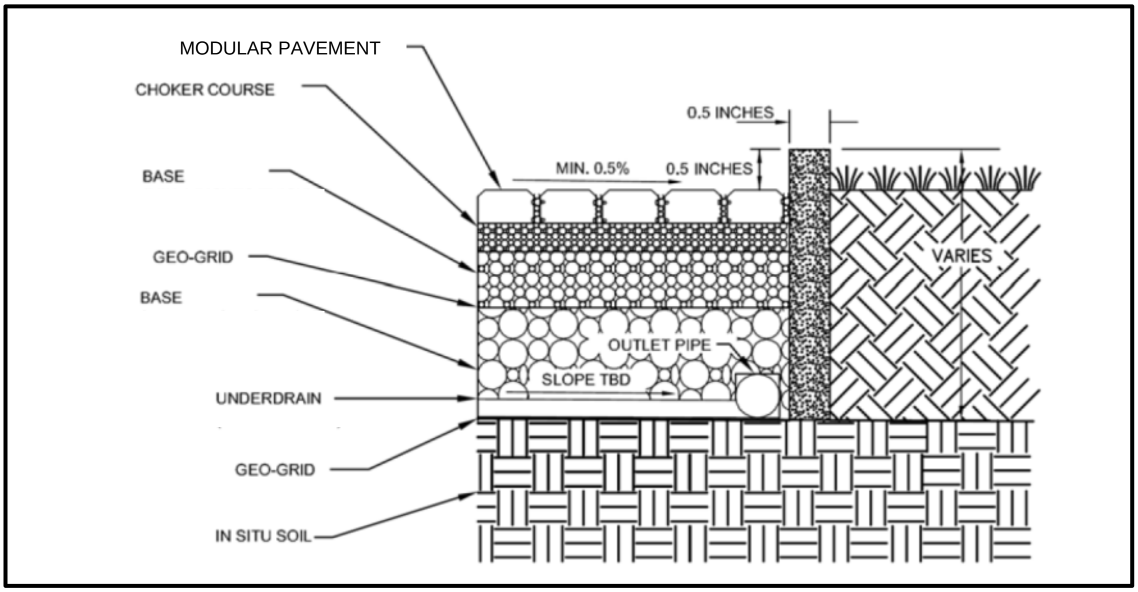


Figure 25. Modular Pavement With Underdrain System (from LJCMSD, 2009).



Pervious Concrete

Pervious concrete is another example of a porous pavement system for increasing infiltration and decreasing surface runoff volume. This application requires using a concrete with a higher void ratio that is designed to allow stormwater to infiltrate through the pavement. Pervious concrete is effective for reducing runoff volume by allowing stormwater to infiltrate through a porous upper layer and into a stone aggregate reservoir below. Runoff eventually infiltrates into the ground or may be collected by an underdrain collection system. One key consideration in the design is the infiltration rate of the underlying soils. Pervious concrete should be limited to light traffic conditions without heavy truck use, such as overflow parking lots. Pervious concrete may have multiple configurations depending on whether an underdrain system is used. Figures 26-28 show three configurations for pervious concrete systems.

Figure 26. Pervious Concrete Without Underdrain System (from LJCMSD, 2009).

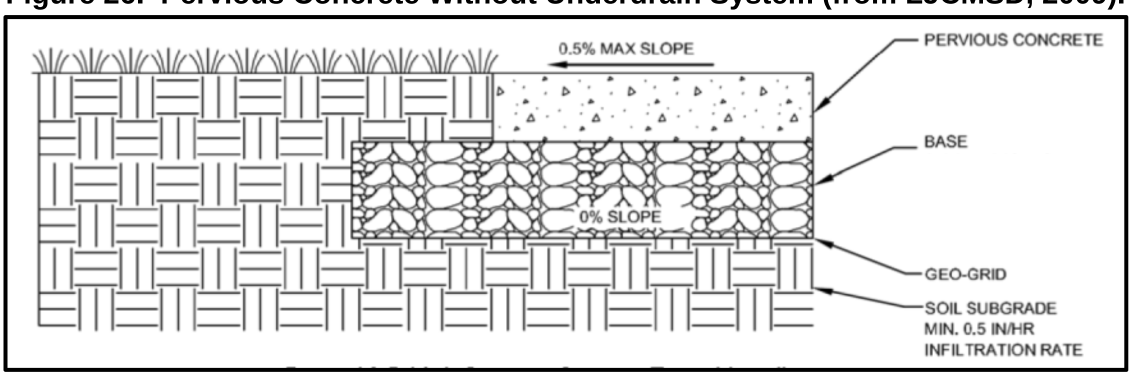


Figure 27. Pervious Concrete With Underdrain System (from LJCMSD, 2009).

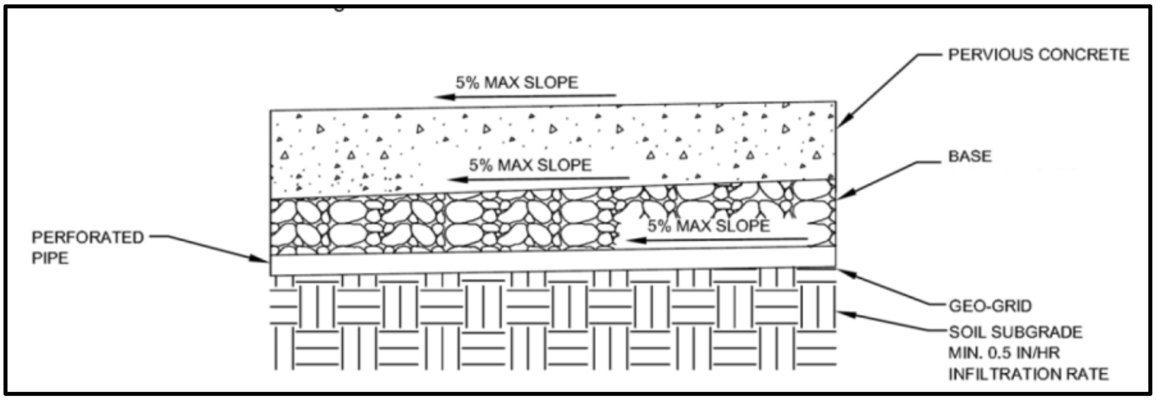
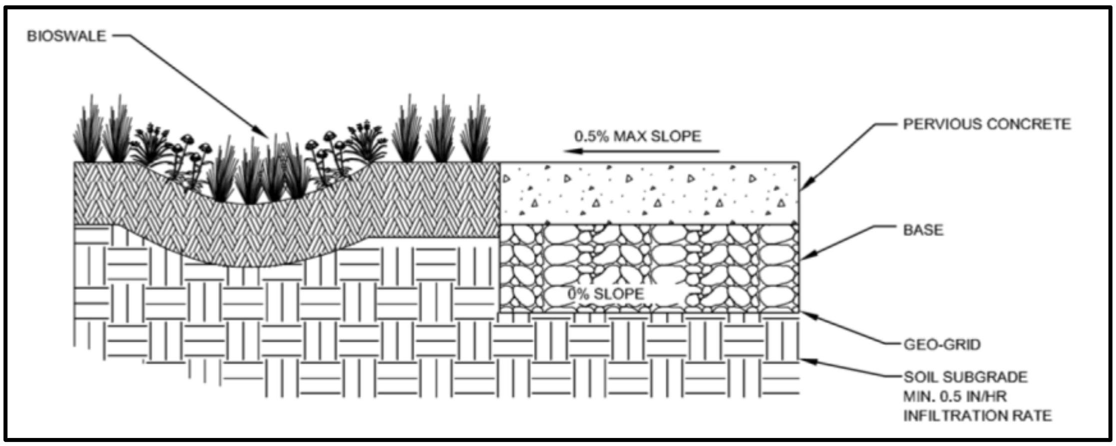


Figure 28. Pervious Concrete With Underdrain System and Bioretention Area Outlet (from LJCMSD, 2009).



8.1. Operation

Successful operation of both types of pavement/pavers depends on the following factors:

- Maintaining the infiltration rate of the void spaces in the paver/pavement and the underlying base and soils.
- Accurate estimation of the underlying soil's percolation rate.
- Proper construction technique. Pervious concrete requires specialized construction knowledge and techniques.
- Regular maintenance.

8.2. Maintenance

Both modular pavement and pervious concrete require the following maintenance activities for sustaining long-term performance:

- Using “good housekeeping” practices to minimize the production and transport of sediment onto the modular pavement. Areas draining onto pervious pavers or pavement should be stabilized. The void spaces within the pavers or pavement can easily be filled with soil, greatly reducing the infiltration capacity of the practice.
- Replace base and underlying soils if there is clogging and persistent water ponding. This type of maintenance is expensive and may cause the area to be unusable for parking during rehabilitation. To avoid this issue, the as-built inspection must verify the drainage features for the pavers/pavement have been installed as designed.
- Remove debris and sediment at least annually from pervious pavement using vacuum sweeping to avoid loss of infiltration capacity. Over time, some loss of infiltration is expected and built into the design. Annual vacuuming removes debris and typically re-establishes surface material infiltration capacities.
- For installations with turf, normal turf maintenance is required. However, mowing is seldom required in areas of frequent traffic, and fertilizers and pesticides should be used sparingly since these materials may adversely affect concrete products and groundwater.

8.3. Inspection

The inspection frequencies for both modular pavement and pervious concrete should include more frequent inspections during the first few months following installation to check for proper operation. These initial inspections should be conducted after storms to check for long duration surface ponding that may indicate local or widespread clogging or presence of a spring. After the initial few months of checking for proper installation and operation, the inspection frequency can be decreased to annual inspections for the system’s components. Inspections for both BMP types should consider the following items:

- Watch for proper drainage.
- Monitor sediment and debris accumulation.
- Excessive ponding time above the modular or pervious pavement may indicate clogging.
- Monitor the contributing drainage areas for erosion and stabilize these areas to prevent clogging the pervious pavers or pavement.

All inspections should be documented in writing using the inspection report in Section 8.4. Initial inspections should be conducted monthly, progressing to annual inspections and then once per five years, as a minimum. Required maintenance items or activities should be clearly documented on the inspection report. Any required maintenance activities should be completed as soon as possible following the inspection where the need was noted.

8.4. Inspection Checklist

The inspection report checklist is patterned after the LFUCG Stormwater Manual checklist (LFUCG, 2009).

University of Kentucky

Operation and Maintenance Inspection Report for Pavement/Pavers

Circle Filter Practice Type: Pervious Paver Pervious Pavement	
Circle Inspection Type: Initial Annual 5 year	
Inspection Date:	Inspector Name:
Inspection Location:	

Inspection Item	Item Checked? Yes	No	Item Satisfactory? Yes	No	Remarks
A. Debris on infiltration paving parking area					
Paving area clean of debris					
B. Vegetation					
Mowing done when needed					
Fertilized per specifications					
No evidence of erosion					
C. Dewatering					
Infiltration paving dewaters between storms					
D. Sediments					
Area clean of sediments					
Area vacuum swept on a periodic basis					
E. Structural condition					
Swale clean of sediments					
F. Outlets/overflow spillway					
No evidence of surface deterioration					
No evidence of rutting or spalling					

9.0 GREEN ROOFS

Green roofs are roofs of buildings that are planted over a waterproof membrane with vegetation including plants, shrubs or trees (LJCMSD, 2009, VDCR, 2011). This practice is typically used in urban areas to capture and absorb rainwater, resulting in decreased stormwater runoff. All buildings must have the structural capacity to hold a green roof. In general, green roofs include the following basic layers: a deck layer (roof support), a waterproofing layer, an insulation layer, a root barrier, a drainage system and drainage layer, a growing media layer and a plant cover layer. Green roofs use multiple mechanisms for removing pollutants, including vegetative filtration and uptake; infiltration; ion exchange; adsorption; and microbial action.

There are two major types of green roofs – extensive and intensive. An extensive green roof has a shallow growing media depth (two to six inches). Extensive green roof vegetation must be carefully selected to be both drought tolerant and have a suitable rooting depth for the growth media. An intensive green roof has a much thicker growing media depth (six inches to four feet) and can support a wider variety of plants including trees. Intensive green roof vegetation must also be carefully selected considering factors such as rooting depth, maintenance and drought tolerance. Extensive green roofs are lighter than intensive green roofs, but intensive green roofs can provide additional stormwater runoff treatment. Figure 29 shows a cross-sectional view of an extensive green roof. Figure 30 shows a similar view for an intensive green roof.

Figure 29. Extensive Green Roof (LJCMSD, 2009).

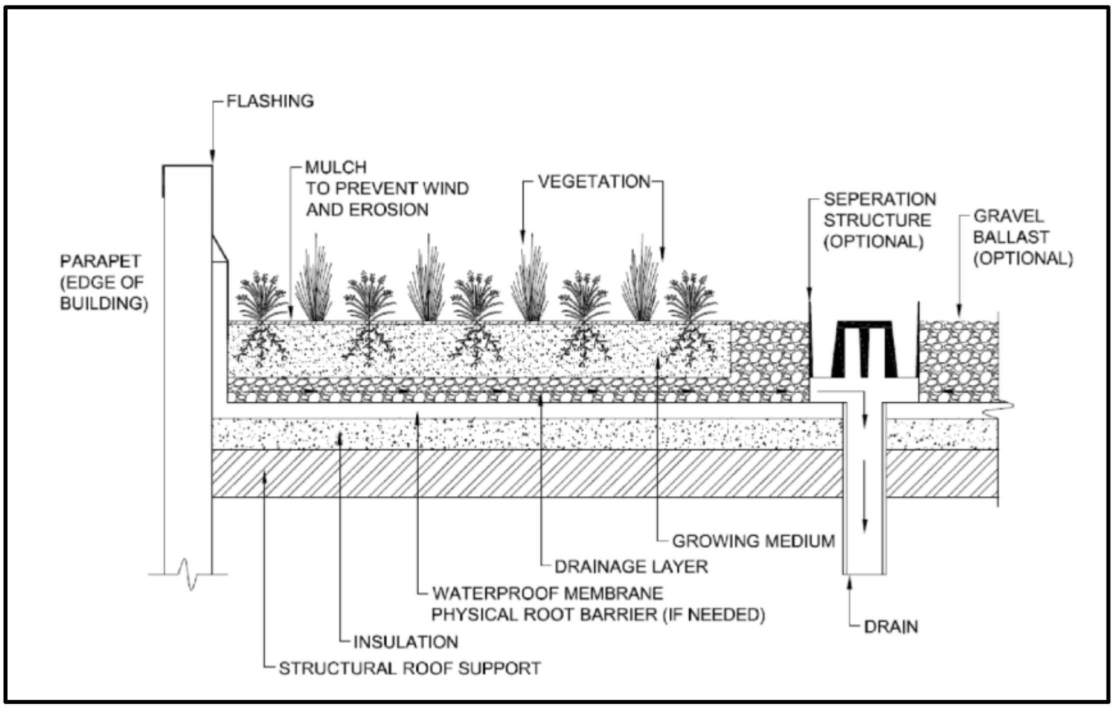
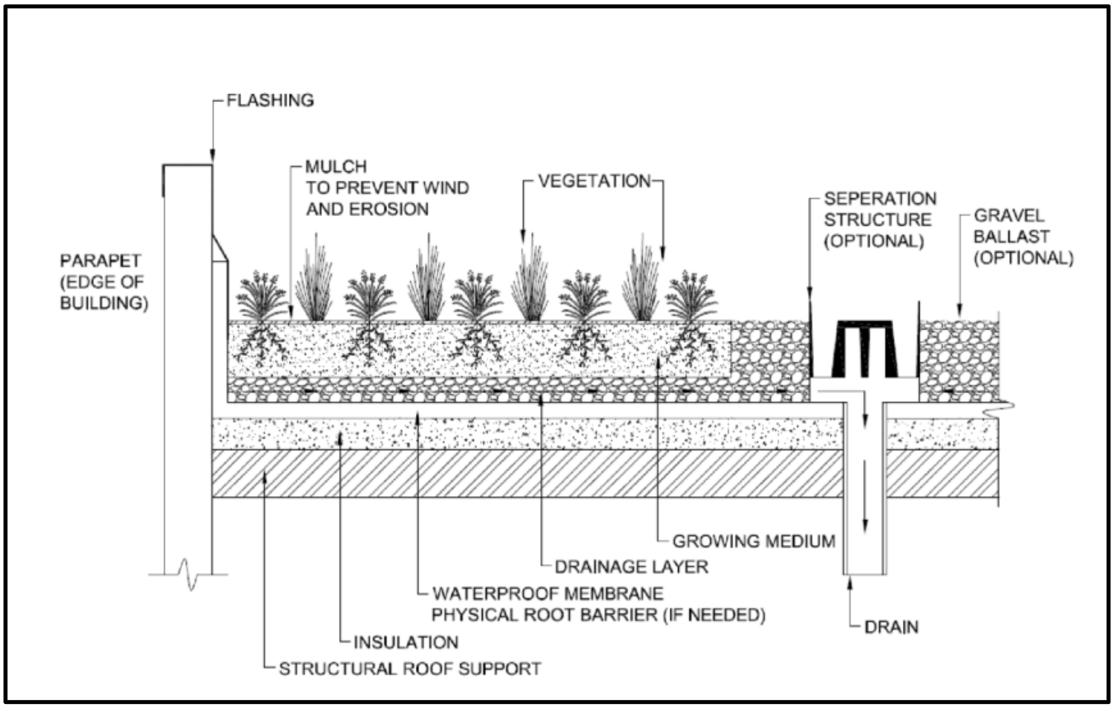


Figure 30. Intensive Green Roof (LJCMSD, 2009).



9.1. Operation

Successful operation depends on the following key factors:

- Good design, especially consideration of the building's structural capacity, roof waterproofing, drainage and planting media;
- Good construction; and
- Regular maintenance.

9.2. Maintenance

Green roofs need the following maintenance activities to sustain long-term function:

- Vegetation must be maintained and, if necessary, mowed, trimmed, pruned or removed.
- Remove debris from discharge points and drains.
- Routinely inspect the structural integrity of green roof, including inspection of the waterproof membrane system for leaks.
- Check that the roof drains within 24 hours without excessive ponding.
- Replace filter media (if needed).
- Irrigate and weed as required.
- Annual mow, trim or prune to prevent woody species growth (as necessary).

- Remove invasive species.

Green roofs also require long-term maintenance to remove and replace woody vegetation such as trees or shrubs with smaller plants. This replacement prevents woody vegetation from exceeding the building's structural capacity and also prevents leaks in the waterproof membrane by root growth. The anticipated timeframe for replacing woody vegetation is between 10-25 years.

9.3. Inspection

Green roofs should be inspected at minimum once every 5 years. However, additional more frequent inspections are needed during vegetation establishment and after major rain events. Inspections should consider the following items:

- Watch for excessive ponding and improper drainage, including leak detection.
- Check for debris and trash accumulation, especially where vegetation growth or drainage may be affected.
- Manage vegetation. Replace dead or diseased vegetation. Remove overgrown vegetation.

All inspections should be documented in writing using the inspection report in Section 9.4. Required maintenance items or activities should be clearly documented on the inspection report. Any required maintenance activities should be completed as soon as possible following the inspection where the need was noted.

9.4. Inspection Report

The inspection report checklist is similar in format to other checklists from the LFUCG Stormwater Manual checklist (LFUCG, 2009). The checklist items were developed from the maintenance items discussed in Section 9.3 (LJCMSD, 2009; VDCR, 2011).

University of Kentucky

Operation and Maintenance Inspection Report for Green Roofs

Green Roof					
Circle Inspection Type: Vegetation Establishment 5 year After Major Storm Event Other					
Inspection Date:			Inspector Name:		
Inspection Location:					
Inspection Item	**Item Checked? Yes**	**No**	**Item Satisfactory? Yes**	**No**	**Remarks**
A. Vegetation					
Plants are not stressed and no irrigation or watering is required					
No sparse or missing vegetation growth at any locations on the roof					
No need to remove and replace dead or dying vegetation					
No need to remove undesirable vegetation or weeds					
Roof is annually fertilized during first five years of vegetation establishment					
No signs of excessive erosion or sedimentation					
If required or desirable, vegetation is trimmed to maintain					
B. Waterproofing					
Waterproof membrane does not have signs of leaks or cracks					
C. Drainage System					
Sediment, debris or trash does not obstruct roof drains, gutters, or other drainage system features					
Drainage system features are not obstructed by vegetation growth					
There are no signs of ponded water or other undesirable drainage patterns					
The roof system properly drains within 24 hours					
D. Roof System					
The roof layers underneath the vegetation, drainage system and waterproofing do not show signs of leakage or damage					

10.0 CISTERNS

Cisterns are permanent structures typically having volumes over 100 gallons that are used for rainwater harvesting, or collecting and temporarily storing rainwater (LJCMSD, 2009). Typically, cisterns are limited to rainwater runoff from roofs with the intent for the captured roof runoff to be used following the rain event. The harvested rainwater may be used for watering nearby landscaping, washing vehicles or for HVAC or boiler make-up water. Rainwater harvesting reduces stormwater runoff volumes and the associated pollutants through collection and beneficial reuse of the collected water. The harvested rainwater needs to be used prior to the next rain event to allow for continued harvesting.

Cisterns may be installed either above ground or below ground. The cistern system will need to be equipped with an overflow port or mechanism to allow excess rainfall from larger storm events to be diverted to another stabilized location. The cistern system should also include mechanisms for moving water from the cistern to the reuse location. If the cistern is below ground, a pump will be required to move the water from the cistern to the reuse location. Figure 31 shows a schematic for an example cistern system. Figures 32-33 show example diverters that direct overflow away from the cistern.

Figure 31. Cistern System (TWDB, 2005).

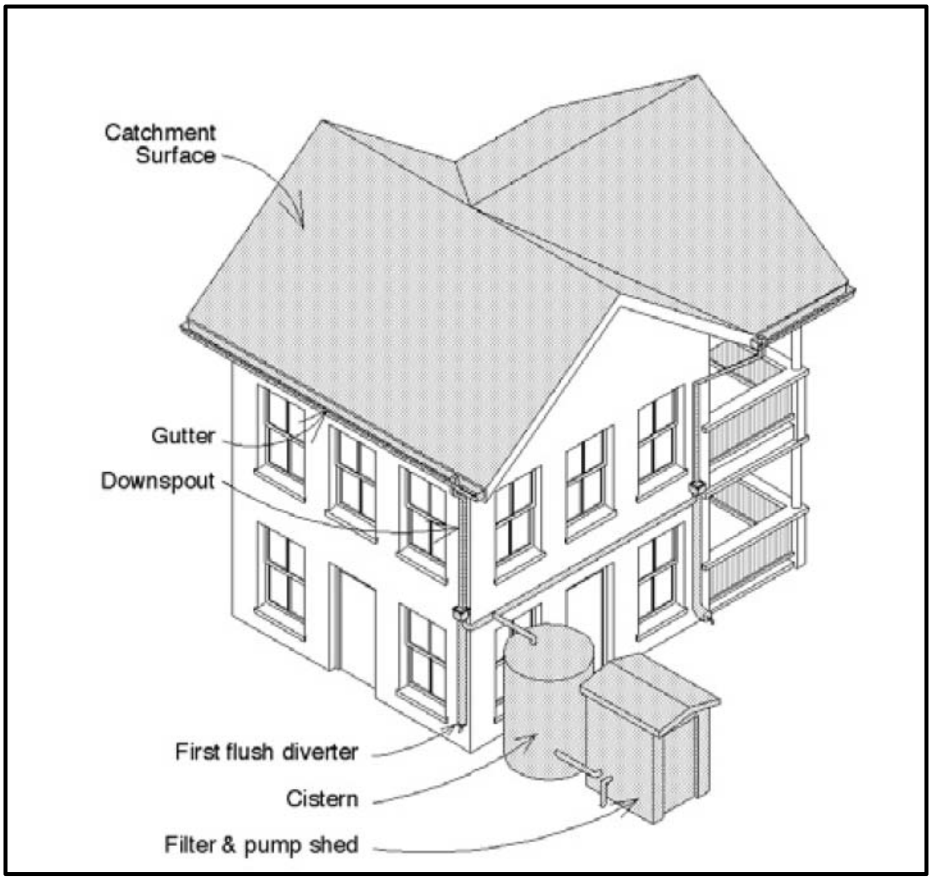


Figure 32. Standpipe Diverter for Cistern System (TWDB, 2005).

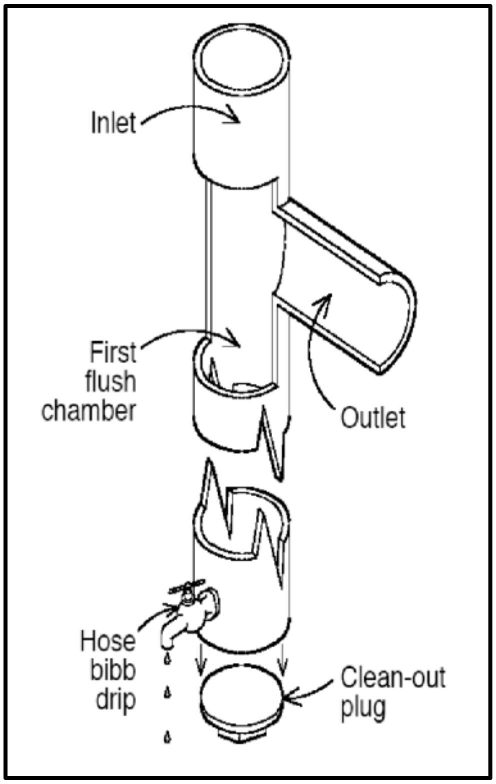
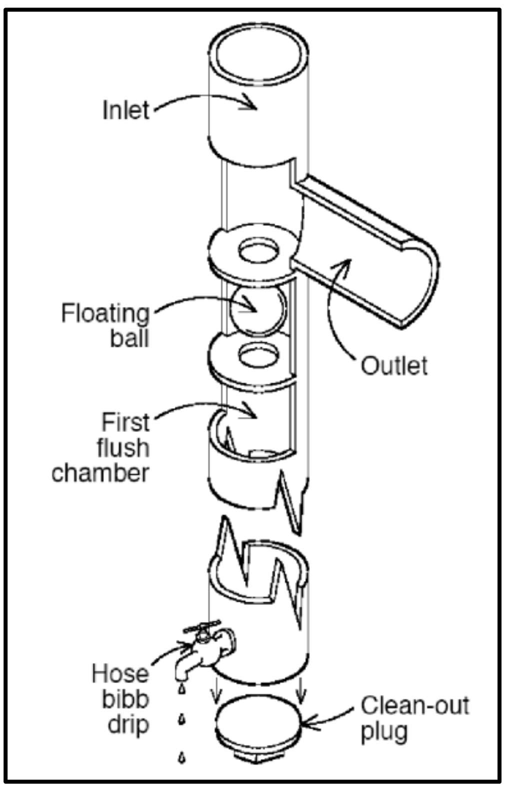


Figure 33. Standpipe with Ball Valve Diverter for Cistern System (TWDB, 2005).



10.1. Operation

Successful operation for cisterns depends on the following key factors:

- Appropriate cistern sizing and water reuse planning.
- Proper location. The cistern should be located close to the reuse area.
- Regular maintenance. See below.

10.2. Maintenance

Rainwater harvesting cisterns will require routine maintenance in the spring and fall, including the following activities:

- In late fall, roof downspouts should be disconnected and the cistern should be drained before the first significant freeze.
- Disconnected downspout drainage (fall and winter) should go to a stabilized, pervious area;
- In the early spring, the roof downspouts should be reconnected to the cistern;
- Cisterns should be drained and removed or kept at half capacity with the spigot open during the winter months to prevent ice damage;
- System replacements and repairs should be conducted as needed;
- Twice annually, flush piping as necessary and consult the owner's manual or a professional for further troubleshooting;
- Gutters and downspouts should be kept clean and free of leaks;
- Annually check sediment accumulations, and remove accumulated sediment when it is more than 5% of the cistern's volume; and
- Vegetation receiving the rainwater should be inspected for health and signs of stress and replaced if necessary.

10.3. Inspection

Cistern systems should be inspected in the spring and fall, and the inspection should evaluate the following items:

- In spring, check that the cistern is properly connected to the downspouts and that there are no signs of leakage;
- In fall, check that the downspouts are properly disconnected from the cistern and that the downspout drainage is routed to a stabilized, pervious area;
- In fall, check that the cistern has either been fully drained or is at half capacity with the spigot open during the winter months to prevent ice damage;
- Check that the rainwater is draining properly from the cistern to the reuse location;
- Check for algae growth in the cistern, and treat water and cistern if algae is found;

- Look for debris or trash that may cause obstructions;
- Annually check sediment accumulations, and remove accumulated sediment when it is more than 5% of the cistern's volume; and
- Vegetation receiving the water should be inspected for health and signs of stress and replaced if necessary.

All inspections should be documented in writing using the inspection report in Section 10.4. Required maintenance items or activities should be clearly documented on the inspection report. Any required maintenance activities should be completed as soon as possible following the inspection where the need was noted.

10.4. Inspection Report

The inspection report checklist is similar in format to other checklists from the LFUCG Stormwater Manual checklist (LFUCG, 2009). The checklist items were developed from the maintenance items discussed in Section 10.3 (LJCMSD, 2009).

University of Kentucky
Operation and Maintenance Inspection Report for Cisterns

Cistern Type:	Above Ground	Below Ground	
Circle Inspection Type:	Spring	Fall	Other
Inspection Date:		Inspector Name:	
Inspection Location:			

Inspection Item	Item Checked? Yes	Item Checked? No	Item Satisfactory? Yes	Item Satisfactory? No	Remarks
A. Cistern System –Spring inspection (inspect once in spring).					
Cistern is properly connected to downspouts					
B. Cistern System –Fall inspection (inspect once in fall before the first significant freeze).					
The cistern has been disconnected from the downspouts for winter months					
The downspouts have been routed to stabilized, pervious area					
The cistern is drained or halfway drained with outlet open for winter freezing conditions					
Check for sediment accumulations and remove as necessary (>5% of cistern's volume)					
C. Cistern System –Inspection semiannually (Spring and Fall).					
Cistern, gutters and downspouts are free of leaks					
Cistern and system are not otherwise damaged					
Trash and debris obstructing flow in or from the system removed					
If applicable, cistern anchoring to building is not damaged.					
Flush the piping as necessary (use manufacturer guidance)					
Vegetation receiving the water is in good condition and not stressed					
Rainwater is properly draining from cistern to reuse location					
Check for algae growth in cistern					

11.0 REFERENCES

Atlanta Regional Commission, 2001. *Georgia Stormwater Management Manual*. Volume 2: Technical Handbook. First Edition.

City of Bowling Green, 2011. *Best Management Practices Manual*. Post-Construction Best Management Practices Chapter (revised 2011).

Lexington-Fayette Urban County Government (LFUCG), 2009. *Lexington-Fayette Urban County Government Stormwater Manual*.

Louisville and Jefferson County Metropolitan Sewer District (LJCMSD), 2009. *Green Infrastructure Design Manual.*

LJCMSD, 2008. *A How-to Guide for Building Your Own Rain Garden*. 2nd Edition.

Texas Water Development Board (TWDB), 2005. *The Texas Manual on Rainwater Harvesting*. 3rd Edition.

Virginia Department of Conservation and Recreation (VDCR), 2011. "Virginia DCR Stormwater Design Specification No. 5: Vegetated Roof." Version 2.3. March 1, 2011.

4/2026 - This document has been reformatted to meet current ADA digital accessibility requirements. No changes have been made to the technical content from the previously posted version.