Technical
Storm Water Manual

Henderson Water Utility
Henderson, Kentucky

April 27, 2004
CHAPTER 1
PURPOSE AND OVERVIEW
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PURPOSE AND OVERVIEW

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1.1 INTRODUCTION

This chapter consists of general criteria required for the management of storm water in new development. Many of the criteria presented in Chapter 1 are discussed in more detail in later chapters.

The requirements contained herein are applicable to all storm water infrastructure owned or regulated by Henderson Water Utility (HWU).
1.2 PURPOSE

The purpose of these regulations is to provide standards to assure quality in the design and construction of storm water infrastructure that becomes a part of that owned or regulated by the HWU by providing standard design criteria to the engineers who design the infrastructure, and to establishes uniformity in design assumptions and general methods of design. These regulations also set policy regarding design standards and specifications and provides for uniform interpretation of the specifications. Finally, these regulations outline the required calculations and design details applicable to all storm water infrastructure as well as to address the quality of storm water that is allowed to enter the HWU storm water system.

These regulations draw heavily on technical information and design criteria used in numerous city and state manuals and are thus similar in many instances to those manuals. However, these regulations have been tailored to fit the City of Henderson and its surrounding developing areas and contain important provisions that are unique to this area.
1.3 GENERAL CRITERIA FOR NEW DEVELOPMENT

1.3.1 Regional Storm Water Management

The HWU shall require regional storm water management facilities when practicable. Where HWU has a drainage master plan or has completed a regional storm water study for a particular watershed, it may exempt on-site requirements for storm water detention or quality practices and establish and collect a fee-in-lieu of storm water management as defined later in this chapter.

1.3.2 Mitigation

It is the intent of the HWU to ensure that impacts to streams and wetlands are mitigated. Some impacts are regulated by the U.S. Army Corps of Engineers (COE) and the Kentucky Division of Water (DOW) and require mitigation plans to be approved by those agencies. In those cases, the mitigation plans approved by the COE and the DOW will satisfy the requirements of this section if the mitigation takes place in Henderson County.

In cases where neither the COE nor the DOW regulates a stream or wetland impact, the following mitigation guidelines shall be followed:

Fills Along a Stream > 200 Feet
Fill for road crossings and embankments shall be mitigated by establishing a riparian buffer zone on each side of the stream for a length equal to the width of the post-development floodplain.

Stream Relocations > 200 Feet
The relocated stream shall be designed to:
- restore the geomorphic function, including the meandering pattern
- include measures to enhance aquatic habitat
- use natural or bioengineering techniques to stabilize banks
- include a minimum 25 foot vegetative buffer strip on each side

1.3.3 Maintenance of Storm Water Facilities

Commercial and Industrial Property
The property owner shall be responsible for all maintenance. The perpetuation of maintenance shall be established as a clause on the face of the final recorded plat in accordance with the regulations and standard practices of the Planning Commission.

Residential Areas

Property Owner
The adjacent property owner(s) shall be responsible for the following:
- mowing (including the dam in detention ponds)
- removing all debris that accumulates in BMPs, including litter and tree limbs
• sodding or seeding bare areas, including areas on earthen berms or dams
• maintaining landscaped areas such as trees and shrubs

The property owner shall not plant trees on an earthen berm or dam because it may make the dam unstable. Trees may be planted in other areas of dry detention ponds. Since water may sometimes cover an entire dry detention pond, no structures shall be placed in the pond that could float and obstruct the outlet pipes. No fences, gazebos, swimming pools, trampolines, or buildings shall be placed in dry detention ponds. Questions about what may be allowed in ponds should be directed to the HWU.

The property owner shall ensure that a dry detention pond retains its original size (area and volume) and shape. Fill dirt shall not be placed in the pond unless approved in advance by the HWU.

In the event of responsibilities falling to more than one property owner, the perpetuation of maintenance shall be established as a clause on the face of the final recorded plat in accordance with the regulations and standard practices of the Planning Commission.

Henderson Water Utility
The HWU shall maintain the dam and structural items in dry detention ponds and other BMPs. This includes repairing concrete, pipe, gabions, stone, spillways, and headwalls. It also includes repairing eroded areas on dams that threaten the stability of embankments. The HWU shall repair paved ditches and inlet structures and remove large debris that obstructs the outlet pipes or spillways. HWU shall repair damage to any to grass or landscaping resulting from its maintenance activities. HWU will not be responsible to repair or replace any landscaping placed by a property owner damaged by natural causes or their effects on the BMP, including erosion or sedimentation near roots or structural foundations.

1.3.4 Lot Drainage in Residential Development

Constructed channels shall be provided for drainage areas greater than 1 acre in residential developments. The channel shall be designed to carry the 100-year storm to the receiving stream. The drainage easement along the channel shall be 20 feet wide, or the width of the 100-year flow plus 5 feet on each side, whichever is wider. The Engineer shall design these channels as part of the Improvement Plans.

1.3.5 Maintenance of Drainage Easements

The HWU shall be responsible for maintaining the major structural items in the public drainage system easement. These items include pipes, paved channels, and headwalls. In residential areas, minor maintenance like mowing shall be the responsibility of the property owner. For commercial and industrial areas, the property owner shall be responsible for all maintenance.

Property owners shall not construct anything in the public drainage system, including open ditches and swales adjoining their property that will impede the flow of water.
1.3.6 Class C Impoundments

Construction of Class C Impoundments as defined by the Kentucky Division of Water shall be prohibited. Proposed new impoundments shall be evaluated to determine the hazard classification. The evaluation shall be based on fully developed conditions downstream of the structure in accordance with the Comprehensive Plan.

1.3.7 Development Downstream of Existing Impoundments

The Developer shall be responsible for obtaining all permits and making improvements to upstream structures, in accordance with the Kentucky Division of Water criteria, if the proposed development would cause an impoundment to be reclassified as a Class B or Class C impoundment. Copies of all permits and any appropriate agreements between the Developer and the owner of the impoundment shall be submitted to the HWU. Rather than improve the upstream structure, the Developer may choose to establish an easement to ensure that the impact area downstream of a failed impoundment is not developed.

1.3.8 Offsite Drainage Problems

Where offsite storm water problems are known to exist, development projects shall consider these problems and integrate solutions determined through the Regional Storm Water Management Plan discussed above. Development projects shall help mitigate these existing problems.
1.4 WATER QUANTITY CRITERIA FOR NEW DEVELOPMENT

1.4.1 Exemptions from Quantity Controls

Development sites that are part of a regional storm water quantity master plan are exempted from quantity controls. Other sites are exempted as described below.

1. In general, runoff controls shall not be required if it can be shown by a watershed study that any of the following exists:

   • The construction of detention ponds would have insignificant effects on reducing downstream flood levels, or
   • Detention ponds are not needed to protect downstream property and the downstream drainage system has sufficient capacity to receive any increase in runoff for the 100-year storm, or
   • Detention ponds are not necessary to control runoff at the exit of a proposed development and constructing such detention ponds would increase flood levels at some point downstream, or
   • HWU determines that detention ponds are not needed to control runoff and installing such facilities would not be in the best interest of the HWU.

Therefore, detention shall not be required for a site if the effect of uncontrolled runoff for the 25-year 6-hour and 100-year 24-hour storms can be shown to have an insignificant effect on water levels on downstream properties.

Small “bathtub” detention ponds for small drainage areas are generally ineffective at reducing peak flows because they clog easily. Therefore, small drainage areas shall not be required to have detention ponds to control peak flows if the drainage area is less than 1 acre in size and the pipe/open channel drainage system from the site to the blue line stream has sufficient capacity, as defined above, to carry the 100-year storm.

1.4.2 Peak Flow Design Criteria

Storm water BMPs shall be designed and constructed to reduce peak flows from development projects to 30% below pristine conditions. The design storms used for this analysis are contained in Chapter 5. BMPs for controlling peak flows are contained in Chapter 10. The BMPs that can be used for residential and commercial/industrial development are shown in Table 1-1.
### TABLE 1-1
OPTIONS FOR STORMWATER MANAGEMENT

<table>
<thead>
<tr>
<th>Best Management Practice</th>
<th>Residential Development</th>
<th>Commercial and Industrial Development</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Quantity</td>
<td>Quality</td>
</tr>
<tr>
<td>Bioretention Systems</td>
<td></td>
<td></td>
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<tr>
<td>Infiltration Systems</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Downspouts to Grass</td>
<td>•</td>
<td></td>
</tr>
<tr>
<td>Modular Pavement</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Swales</td>
<td>•</td>
<td></td>
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<tr>
<td>Bermed Swales</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biofiltration Swales</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Terraforming</td>
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<td></td>
</tr>
<tr>
<td>Infiltration Basins</td>
<td>•</td>
<td></td>
</tr>
<tr>
<td>Vegetated Filter Strips</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Riparian Buffers</td>
<td>•</td>
<td></td>
</tr>
<tr>
<td>Sand/Organic Filters</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prefabricated Treatment Devices</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Detention Ponds</td>
<td>•</td>
<td></td>
</tr>
<tr>
<td>Extended Detention Ponds</td>
<td>•</td>
<td></td>
</tr>
<tr>
<td>Wet Ponds</td>
<td>•</td>
<td></td>
</tr>
<tr>
<td>Constructed Wetlands</td>
<td>•</td>
<td></td>
</tr>
</tbody>
</table>
1.4.3 Downstream Study Limits

Storm water facilities for future development shall be designed so that the capacity of the existing and proposed pipes, culverts, channels, and other components of the drainage system are not exceeded. The study limits for a proposed development site shall extend downstream to the point of outfall to a named ditch, creek or river or to a point where the drainage area is 10 times the area of the proposed development as determined by the latest version of the USGS 7.5 degree quadrangle maps, whichever occurs first. Use of the latest version of the USGS 7.5 degree quadrangle maps to define major subwatersheds will be considered sufficient for the downstream study. Table 1-2 lists the flow criteria for drainage system components.

1.4.4 Capacity of the Proposed Drainage System

Storm sewers, inlets, culverts, and constructed channels shall be designed to meet the design criteria in Table 1-2.

<table>
<thead>
<tr>
<th>Storm water Appurtenance</th>
<th>Criteria</th>
<th>Manual Reference Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road Inlets</td>
<td>Top of Curb: 10-year Back of Sidewalk: 100-year</td>
<td>Chapter 6</td>
</tr>
<tr>
<td>Storm Sewers</td>
<td>10-year and 100-year</td>
<td>Chapter 6</td>
</tr>
<tr>
<td>Culverts</td>
<td>100-year</td>
<td>Chapter 7</td>
</tr>
<tr>
<td>Constructed Channels</td>
<td>100-year</td>
<td>Local Standards</td>
</tr>
</tbody>
</table>

1.4.5 Construction within Floodplain

Developments shall be designed so that the wall and foundations of any principal or accessory structure can be located entirely outside of the 100-year 24-hour post-development floodplain.
1.5 WATER QUALITY CRITERIA FOR NEW DEVELOPMENT

1.5.1 Exemptions from Quality Controls

Development sites that are part of a regional storm water quality master plan are exempted from on site quality controls upon payment of the fee-in-lieu established by HWU.

1.5.2 Water Quality Criteria

The impact of the increase in the volume of water that becomes runoff rather than infiltration from a development site shall be mitigated through the capture, storage, and release of a volume of water proportional to the amount of impervious area. Storm water from development projects shall be treated using one or more of the BMPs shown in Table 1-1 and described in Chapter 10.

The owner/developer or his engineer shall meet with the HWU’s Chief Engineer to establish a minimum level of storm water quality treatment for each development project. For single-family residential developments, the percentage of impervious area, undisturbed floodplain area, erosivity of soils, and mean sediment particle size will be the primary criteria for evaluation. Criteria to be considered in the establishment of the minimum level of treatment for multi-family, commercial and industrial development projects will include:

- Percentage of impervious area
- Undisturbed floodplain area
- Erosivity of soils and mean sediment particle size
- Projected traffic count
- Anticipated on-site activities
- Anticipated materials to be used or stored on site

For commercial and industrial areas, at least 50% of the site shall be treated using bioretention or infiltration unless otherwise approved in writing by HWU. All runoff from rooftops and parking lots shall pass through a bioretention or infiltration system, sand filter, or prefabricated treatment device before discharging to a pond or surface water.

1.5.3 Culvert Outlet Velocity Criteria

The design velocity at culvert outlets shall be reduced to match the natural stream velocity in accordance with the design procedures in Chapter 7.
1.6 FEE-IN-LIEU FOR NEW DEVELOPMENT

At its discretion, the HWU may charge a fee instead of requiring a development to provide water quality and water quantity practices listed above. This is called a fee-in-lieu program and may be used when

- the HWU has constructed or plans to construct facilities providing an equivalent degree of protection or treatment
- situations exist in new development that have small drainage areas for which there are no applicable BMPs
1.7 Water Quantity and Water Quality Criteria for Redevelopment Projects

1.7.1 – Background

Providing storm water controls on redevelopment sites is typically more difficult and more expensive than on new development sites, and could create a disincentive for redevelopment. To prevent this, the water quantity and water quality requirements for redevelopment will be different than those for new development. In essence, the requirements for redevelopment will be approximately 20% of the requirements for new development. For the purposes of this requirement, “redevelopment” shall mean, “…alterations of a property that change the ‘footprint’ of a site or building in such a way that results in the disturbance of equal to or greater than 1 acre of land” (40 CFR Parts 9, 122, 123 and 124, II.H.3.b.v. Federal Register, December 8, 1999, www.epa.gov/npdes/regulations/phase2.pdf)

1.7.2 – Exemptions

Redevelopment projects shall be exempt from water quantity and water quality control requirements if the imperviousness of the original site is reduced by at least 20%.

1.7.3 – Water Quantity Criteria

Storm water BMPs shall be designed and constructed to reduce peak flows, after redevelopment, to 80% of the peak flows before redevelopment. The design storms are contained in Chapter 5.

1.7.4 – Water Quality Criteria

Storm water BMPs shall be designed and constructed to treat 20% of the original impervious acreage plus 100% of any increase in impervious acreage.

1.7.5 – Fee-In-Lieu

At the discretion of the Commissioner of Public Works, a fee may be charged instead of constructing on-site BMPs.
CHAPTER 2

(RESERVED)
CHAPTER 3

(RESERVED)
CHAPTER 4

(RESERVED)
CHAPTER 5
HYDROLOGY

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5.1 INTRODUCTION

5.1.1 Purpose

The purpose of this chapter is to describe approved methods of hydrological analysis for watershed studies and for the design of sediment ponds, stormwater best management practices, inlets, storm sewers, culverts, and channels.
5.2 APPROVED METHODS

5.2.1 HEC-1 and HEC-HMS Programs

The HEC-1 or HEC-HMS computer program from the U.S. Army Corps of Engineers shall be used for hydrologic analysis. More information is given later on these models.

Other computer programs may be used for designing storm sewers, open channels, culverts, inlets, and detention ponds if they use the methods in this chapter for determining runoff hydrographs and peak flows. Examples of these include computer programs from Haestad Methods.

5.2.2 Rational Method

The Rational Method may be used to compute peak flows for drainage areas less than or equal to 200 acres when designing inlets, storm sewers, culverts, and channels.
5.3 DESIGN STORMS

5.3.1 Design Storms

Stormwater facilities shall be designed using the design storms in Table 5-1. The design storm distributions are contained in Appendix 5A.

**TABLE 5-1**
APPLICATION OF DESIGN STORMS

<table>
<thead>
<tr>
<th>Design Storm</th>
<th>Floodplains</th>
<th>Ponds (1)</th>
<th>Inlets</th>
<th>Storm Sewers</th>
<th>Culverts</th>
<th>Constructed Channels</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 year - 1 hour</td>
<td></td>
<td></td>
<td>•</td>
<td>•</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25 year - 6 hour</td>
<td></td>
<td>•</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100 year - 1 hour</td>
<td></td>
<td>•</td>
<td>•</td>
<td></td>
<td>•</td>
<td></td>
</tr>
<tr>
<td>100 year – 24 hour</td>
<td>•</td>
<td>•</td>
<td></td>
<td></td>
<td>•</td>
<td></td>
</tr>
</tbody>
</table>

1. Ponds shall be designed to reduce post-development peak flows to 30% below pristine conditions for the 25-year 6-hour storm and the 100-year 24-hour storm. The emergency spillway shall be designed to pass the 100-year 24-hour storm.

2. Constructed channels in back yards and side yards of residential areas shall be designed for the 100-year 1-hour storm, including any necessary erosion protection.

3. The storm producing the largest peak flow shall be used to design culverts.
5.4 HEC-1 MODEL

5.4.1 Input Parameters

Runoff Volume
- The Curve Number method shall be used to determine the runoff volume.
- Curve Numbers are based on the type of land use. Typical values are given in Table 5-2.

Unit Hydrograph
- The SCS Unit Hydrograph Method shall be used. The time of concentration shall be determined using the method described in Technical Release No. 55 published by the U.S. Department of Agriculture, Soil Conservation Service.

Storage Routing
- Use the stage-discharge-volume relationship for the structure.

Computation Interval
- 5 minutes

Watershed Delineation
- Watersheds shall be subdivided into areas with homogenous land use. The subwatersheds shall have an average size of 10-25 acres, and a maximum size of 50 acres.
### TABLE 5-2
**CURVE NUMBERS**

<table>
<thead>
<tr>
<th>Land Use</th>
<th>Percent Impervious</th>
<th>Hydrologic Soil Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>A</td>
</tr>
<tr>
<td>5.5 <strong>Urban Areas</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parking Lots, Roofs, Driveways, and Streets</td>
<td>100</td>
<td>98</td>
</tr>
<tr>
<td>Commercial Development</td>
<td>85</td>
<td>89</td>
</tr>
<tr>
<td>Industrial Development</td>
<td>72</td>
<td>81</td>
</tr>
<tr>
<td>Residential Development:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1/8 acre lots or less</td>
<td>65</td>
<td>77</td>
</tr>
<tr>
<td>1/4 acre lots</td>
<td>38</td>
<td>61</td>
</tr>
<tr>
<td>1/3 acre lots</td>
<td>30</td>
<td>57</td>
</tr>
<tr>
<td>1/2 acre lots</td>
<td>25</td>
<td>54</td>
</tr>
<tr>
<td>1 acre lots</td>
<td>20</td>
<td>51</td>
</tr>
<tr>
<td><strong>Pervious Areas</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lawns, Parks, Golf Courses, Cemeteries, etc.</td>
<td>-</td>
<td>39</td>
</tr>
<tr>
<td>Pasture for Grazing (not mowed)</td>
<td>-</td>
<td>39</td>
</tr>
<tr>
<td>Meadows (mowed for hay)</td>
<td>-</td>
<td>30</td>
</tr>
<tr>
<td>Brushy Areas</td>
<td>-</td>
<td>30</td>
</tr>
<tr>
<td>Woods</td>
<td>-</td>
<td>30</td>
</tr>
</tbody>
</table>

1. For urban areas that have a different percent impervious than those shown above, calculate a composite Curve Number using a Curve Number of 98 for impervious areas and the associated Curve Number for the pervious area from the table above.

2. For areas where there is no detailed SCS Soil Survey, assume the subwatershed is 50% Group B soils and 50% Group C soils.
5.6  RATIONAL METHOD

The following equation may be used to calculate peak flows for drainage areas less than or equal to 200 acres, and it shall be used to calculate peak flows for drainage areas less than or equal to 10 acres.

\[ Q = CIA \]

where:

- \( Q \) = peak flow in cubic feet per second
- \( C \) = 0.95 for impervious areas
  - 0.20 for pervious areas
- \( A \) = drainage area
- \( I \) = rainfall intensity

The rainfall intensity shall be determined based on Table 5-3:

\begin{center}
\begin{tabular}{|c|cccc|}
\hline 
Time of Concentration (minutes) & 1 yr. & 10 yr. & 25 yr. & 100 yr. \\
\hline
10 & 3.5 & 5.4 & 5.9 & 7.1 \\
15 & 3.0 & 4.5 & 5.0 & 6.2 \\
30 & 2.0 & 3.2 & 3.6 & 4.6 \\
60 & 1.3 & 1.8 & 2.1 & 2.7 \\
120 & 0.8 & 1.2 & 1.4 & 1.8 \\
\hline
\end{tabular}
\end{center}

The time of concentration shall be determined using the method described in Technical Release No. 55 published by the U.S. Department of Agriculture, Soil Conservation Service. The minimum time of concentration shall be 10 minutes.
APPENDIX 5A
DESIGN STORM DISTRIBUTIONS
## 1-HOUR RAINFALL DISTRIBUTIONS

<table>
<thead>
<tr>
<th>Minutes</th>
<th>Cumulative Rainfall (Inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 year</td>
</tr>
<tr>
<td>0</td>
<td>0.00</td>
</tr>
<tr>
<td>3</td>
<td>0.23</td>
</tr>
<tr>
<td>6</td>
<td>0.48</td>
</tr>
<tr>
<td>9</td>
<td>0.63</td>
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<tr>
<td>12</td>
<td>0.76</td>
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<td>15</td>
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<td>18</td>
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<td>21</td>
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<td>24</td>
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<td>60</td>
<td>1.46</td>
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25-YEAR 6-HOUR RAINFALL DISTRIBUTION

<table>
<thead>
<tr>
<th>Minutes</th>
<th>Cumulative Rainfall (Inches)</th>
</tr>
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<tbody>
<tr>
<td>0</td>
<td>0.00</td>
</tr>
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CHAPTER 6
INLETS / PIPES / MANHOLES
CHAPTER 6
INLETS / PIPES / MANHOLES

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APPENDICES

APPENDIX 6A – CONSTRUCTION SPECIFICATIONS
6.1 DESIGN CRITERIA

6.1.1 General

The primary objective of street drainage design is to limit the amount of water flowing along the gutters or ponding at the low points to quantities that will not interfere with the passage of traffic for the design frequency. This is accomplished by placing inlets at such points and at such intervals to intercept flows and control spread.

6.1.2 Curb Inlets

Curb inlets shall be used for street drainage except where curb cuts are used per Chapter 10 and shall be designed as follows:

- Space inlets on grade to limit the spread of water as follows, using an intensity if 4 inches per hour:
  - local streets – ¾ of the driving lane
  - collector streets – ½ of the driving lane
  - arterial streets – 4 feet in the driving lane
- At low points (sags), limit the depth of water to the top of the curb using an intensity of 4 inches per hour, and to the back of the sidewalk using an intensity of 10.2 inches per hour (100-year storm with a 10 minute time of concentration).
- Space inlets to prevent concentrated water from flowing across the road.
- Place inlets on the upstream side of intersection radii.
- Design the inlet assuming flow only through the curb opening, if a grate is present.
- Provide an overflow channel assuming that inlets in low points are 50% obstructed. The channel shall be designed to carry the portion of the 100-year storm that does not enter the inlets.

6.1.3 Surface Inlets

Surface inlets in grassed areas, parking lots, and roadside channels shall be designed as follows:

- Inlets in grass areas shall be constructed in a sump condition so that the top elevation of the berm around the inlet is at least 1 foot above the 100-year storm elevation.
- Limit the depth of water for the 100-year storm to at least 2 feet below the elevation of the lowest opening of adjacent structures.
- Provide a clear path for water to flow overland to a channel or the street assuming that inlets in low points are obstructed.
- For roadside channels, limit the depth of water to the edge of pavement or sidewalk, whichever applies, for the 100-year storm.

Surface inlets shall not be used within a roadway for street drainage.
6.1.4 Pipes

Stormwater pipes shall be designed as follows:

- Size the pipes to flow under gravity (not under pressure) for the 10-year storm.
- Size the pipes so that inlets and manholes do not overflow for the 100-year storm.
- Use a minimum pipe size of 15 inches.
- Use open channels for flows greater than 100 cfs for the 100-year storm.
- Limit the cumulative discharge from pipes in a 200 feet section of channel to less than 100 cfs, calculated for the 100-year storm.
- Provide a minimum velocity of 3 feet per second at full flow.
- Provide a minimum cover of 18 inches, unless otherwise approved in writing.
- Construct pipes of reinforced concrete pipe, ductile iron pipe (cement lined), PVC pipe (solid wall or Vylon, by Lamson), or HDPE corrugated (smooth interior wall).

Outfalls shall be extended to the rear property line in residential developments where possible.

Streams that are part of the waters of Henderson County shall not be routed to flow through pipes.

Pipes shall not be used to channel flows from areas upstream of a development unless the 100-year peak flow is less than 100 cfs.

6.1.5 Manholes

- Place manholes at the following locations:
  - Where 2 pipes intersect
  - At changes in pipe size
  - Where the slope changes
  - Where horizontal alignment changes
- Space manholes no more than 500 feet apart. Greater spacing may be allowed for large storm sewers on a case by case basis.
- Match the crown line of the upstream pipe to the crown line of the downstream pipe.

6.1.6 Passthrough Drainage

Runoff from off-site areas shall be evaluated based on future land use as shown in the Comprehensive Plan. Pass through systems shall be designed for the 100-year storm. The upstream area shall be assumed to have detention unless it is exempted as described in Chapter 1.
6.2 INLET DESIGN PROCEDURES

6.2.1 Curb Inlets on Grade

The following programs are acceptable for computing the spread of water and the interception efficiency of curb inlets on a grade.

Other similar programs may be acceptable for use subject to HWU approval.

- CURBIN – Kentucky Transportation Cabinet
- QuickHEC12 – Haestad Methods

6.2.2 Curb Inlets in Low Points

Use the weir flow equation for depths less than or equal to the curb opening.

\[ Q = C_w L d^{1.5} \]

where:

- \( Q \) = flow in cfs
- \( C_w = 2.3 \)
- \( L \) = curb opening length (ft)
- \( d \) = depth of water at curb measured from the normal cross slope gutter flow line (ft)

Use the orifice equation for depths greater than the curb opening.

\[ Q = C_o A \left[ 2g(d_i - h/2) \right]^{0.5} \]

where:

- \( Q \) = flow (cfs)
- \( C_o = 0.67 \)
- \( h \) = height of curb opening (ft)
- \( A \) = clear area of opening (ft²)
- \( d_i \) = depth at lip of curb opening (ft)
- \( g = 32.2 \) (ft/sec)
6.2.3 Surface Inlets

Use the weir flow and orifice flow equation to compute flow through the grate:

For $d \leq 0.4\text{', use the weir flow equation:}$

$$Q = C P d^{1.5}$$

where:
- $Q =$ flow in cfs
- $C = 3.0$
- $d =$ depth of water in feet
- $P =$ perimeter of the grate in feet

For $d \geq 1.0\text{'}, use the orifice flow equation:

$$Q = CA \sqrt{2gd}$$

where:
- $C = 0.67$
- $A =$ clear opening area of the grate ($\text{ft}^2$)
- $g = 32.2 \text{ ft/sec}$
- $d =$ depth of water in feet

For $0.4' < d < 1.0'$, compute the flow using both the weir flow and orifice flow equations. Use the smallest flow for a given depth.
TRENCH SECTION METHOD "A" OPEN TERRAIN REINFORCED CONCRETE PIPE STORM SEWER OPEN CUT INSTALLATION

NOTE:

HAND PLACE AND TAMPER BEDDING SO AS NOT TO DISTURB OR DAMAGE PIPE.

UPPER PORTION OF TRENCH USE EXCAVATED MATERIAL FREE FROM OBJECTS HAVING A VOLUME EXCEEDING EIGHT CUBIC INCHES.

PLACE BURIED METALLIC LOCATOR TAPE 18"–24" ABOVE TOP OF PIPE AS SHOWN. TAPE MUST CONTINUOUSLY READ: "CAUTION: BURIED STORM SEWER LINE BELOW".

HOLES IN BEDDING FOR PIPE BELLS MUST BE PROVIDED AT EACH JOINT.
TRENCH SECTION METHOD "B" SIDEWALKS & UNPAVED DRIVEWAYS
REINFORCED CONCRETE PIPE STORM SEWER
OPEN CUT INSTALLATION

NOTE:

BACKFILL TRENCH FROM BEDDING TO FINISH GRADE WITH #9 CRUSHED STONE. HAND PLACE AND TAMP BEDDING TO 6" ABOVE TOP OF PIPE SO AS NOT TO DISTURB OR DAMAGE PIPE.

PLACE BURIED METALLIC LOCATOR TAPE 18" - 24" ABOVE TOP OF PIPE AS SHOWN. TAPE MUST CONTINUOUSLY READ: "CAUTION: BURIED STORM SEWER LINE BELOW".

HOLES IN BEDDING FOR PIPE BELLS MUST BE PROVIDED AT EACH JOINT.
TRENCH SECTION METHOD "C"
STREETS, ROADS, & PAVED DRIVEWAYS
REINFORCED CONCRETE PIPE STORM SEWER
OPEN CUT INSTALLATION

NOTE:

HAND PLACE AND TAMPO BEDDING MATERIAL TO 6" ABOVE THE TOP OF PIPE SO AS NOT TO DISTURB OR DAMAGE PIPE.
LOWER PORTION OF TRENCH FROM BEDDING TO SIX INCHES BELOW BASE OF PAVEMENT USE #9 CRUSHED STONE.
UPPER PORTION OF TRENCH FROM #9 STONE TO BASE OF PAVEMENT USE A BASE COURSE OF DENSE GRADED AGGREGATE.
PLACE BURIED METALLIC LOCATOR TAPE 18"–24" ABOVE TOP OF PIPE AS SHOWN. TAPE MUST CONTINUOUSLY READ:
"CAUTION: BURIED STORM SEWER LINE BELOW".
HOLES IN BEDDING FOR PIPE BELLS MUST BE PROVIDED AT EACH JOINT.
NOTES:
CONCRETE TO CONFORM TO ASTM C-478 STANDARDS
2" MIN. CONCRETE COVER
RESILIENT CONNECTORS MEET ASTM C-923
MEETS OR EXCEEDS ASTM C-478

NOTES:
WEIGHT: BASE - 4,350 LBS. (30" HT.)
RISER - 850 LBS./VERT. FT.
CONICAL - VARIES
LEVEL AND TAMP BEDDING MATERIAL PRIOR TO PLACING MANHOLE SECTION
CONCENTRIC TOP SECTION TO BE USED UNLESS SPECIFICALLY APPROVED OTHERWISE ON A CASE-BY-CASE BASIS

EAST JORDAN IRON WORKS PART NO. 41366543 OR NEENAH FOUNDRY PART NO. 1015741
TOP OF CASTING TO BE 1" ABOVE GROUND LINE

1/4" WIDE STRIP OF JOINT SEAL BITUMINOUS
Mastic Strip with non-Shrinking Grout Applied to INSIDE SEAM

48" MINIMUM
2'-0" DIA.

CONCRETE BENCH

WATER STOPS, RUBBER DIAPHRAGM, OR BOOT, FOR EVERY PIPE ENTERING THE MANHOLE MEETING ASTM C-923, LATEST EDITION.

1/4" WIDE STRIP OF JOINT SEAL BITUMINOUS
Mastic Strip with non-Shrinking Grout Applied to INSIDE SEAM

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Mastic Strip with non-Shrinking Grout Applied to INSIDE SEAM

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2'-0" DIA.

CONCRETE BENCH

WATER STOPS, RUBBER DIAPHRAGM, OR BOOT, FOR EVERY PIPE ENTERING THE MANHOLE MEETING ASTM C-923, LATEST EDITION.
FIGURE 6–6

TOP VIEW

2" DIA. HOLES FOR DOWEL RODS

SECTION A–A

3'–4" DIA

4"

2'–8" DIA

4"

2'–0" DIA

2", 3", 4", 6"

NOTES:
CONCRETE TO CONFORM TO ASTM C–478 STANDARDS
MEETS OR EXCEEDS ASTM–C478

WEIGHT: 2" – 140lbs.
3" – 210lbs.
4" – 279lbs.
6" – 420lbs.

HENDERSON WATER UTILITY
111 FIFTH STREET
HENDERSON, KENTUCKY
PLACe CONC. TO SUPPORT FRAME BACK, SET LUGS FOR ATTACHMENT AS NECESSARY
FACE OF CURB
1/2" NON-EXTRUDED PREFORMED EXPANSION JOINT MATERIAL 3 SIDES
EAST JORDAN 7030 OR NEENAH CASTING R-3067 OR APPROVED EQUAL

2" CL. (TYP.)
#5 BARS @ 12" E.W.

EAST JORDAN 7030 OR NEENAH CASTING R-3067 OR APPROVED EQUAL

PLAN VIEW
SECTION A–A
SECTION B–B
CURB INLET

NOTES:
CAST–IN–PLACE BOX WALLS TO BE 8" THICK w/3" CLEAR OVER REINF. STEEL.
CURB BOX TO BE INSTALLED FLUSH WITH TOP AND FACE OF CURB.
CURB BOX TO BE MONOGRAMMED TO SAY "DUMP NO WASTE DRAINS TO RIVER".
CONCRETE TO BE MIN. 4,000 PSI @ 28 DAYS, ASTM C–478.
LIFTING DEVICES TO BE GROUTED IN AFTER INSTALLATION. (FOR PRECAST HEADWALLS)

<table>
<thead>
<tr>
<th>PIPE DIA.</th>
<th>H</th>
<th>L</th>
<th>W-1</th>
<th>W-2</th>
<th>WEIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td>12&quot;</td>
<td>2' 5&quot;</td>
<td>3' 6&quot;</td>
<td>4' 0&quot;</td>
<td>2' 6&quot;</td>
<td>2,349 lbs.</td>
</tr>
<tr>
<td>15&quot;</td>
<td>2' 8&quot;</td>
<td>4' 0&quot;</td>
<td>4' 9&quot;</td>
<td>2' 9&quot;</td>
<td>3,037 lbs.</td>
</tr>
<tr>
<td>18&quot;</td>
<td>2' 11&quot;</td>
<td>4' 6&quot;</td>
<td>5' 3&quot;</td>
<td>3' 0&quot;</td>
<td>3,766 lbs.</td>
</tr>
<tr>
<td>21&quot;</td>
<td>3' 2&quot;</td>
<td>5' 0&quot;</td>
<td>6' 0&quot;</td>
<td>3' 3&quot;</td>
<td>4,617 lbs.</td>
</tr>
<tr>
<td>24&quot;</td>
<td>3' 5&quot;</td>
<td>5' 6&quot;</td>
<td>6' 6&quot;</td>
<td>3' 6&quot;</td>
<td>5,467 lbs.</td>
</tr>
<tr>
<td>27&quot;</td>
<td>3' 8&quot;</td>
<td>6' 0&quot;</td>
<td>7' 0&quot;</td>
<td>3' 9&quot;</td>
<td>6,358 lbs.</td>
</tr>
</tbody>
</table>

NOTES:
USE CLASS A CONCRETE
2" MIN. CONCRETE COVER
OPENINGS FOR PIPE AS REQD.
REINF.-#5 REBAR Ø 12" C.C. EA. WAY
8" THICK BASE SLAB
WEIGHT: BASE - 3,600 lbs. max
RISER - 900 lbs./vert.ft.
WINGWALLS ARE FLARED 15°
LIFTING DEVICE TO BE GROUTED IN AFTER INSTALLATION FOR PRECAST.

**DIMENSIONS**

<table>
<thead>
<tr>
<th>PIPE DIA.</th>
<th>H-1</th>
<th>H-2</th>
<th>L</th>
<th>W-1</th>
<th>W-2</th>
<th>WEIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td>30&quot;</td>
<td>4'-5&quot;</td>
<td>1'-3&quot;</td>
<td>4'-5&quot;</td>
<td>7'-6&quot;</td>
<td>3'-1&quot;</td>
<td>6,800lbs.</td>
</tr>
<tr>
<td>36&quot;</td>
<td>5'-0&quot;</td>
<td>1'-6&quot;</td>
<td>5'-0&quot;</td>
<td>8'-8&quot;</td>
<td>3'-8&quot;</td>
<td>8,700lbs.</td>
</tr>
<tr>
<td>42&quot;</td>
<td>5'-7</td>
<td>1'-9&quot;</td>
<td>5'-7&quot;</td>
<td>10'-0&quot;</td>
<td>4'-3&quot;</td>
<td>10,800lbs.</td>
</tr>
<tr>
<td>48&quot;</td>
<td>6'-2&quot;</td>
<td>2'-0&quot;</td>
<td>6'-2&quot;</td>
<td>11'-2&quot;</td>
<td>4'-10&quot;</td>
<td>13,200lbs.</td>
</tr>
<tr>
<td>54&quot;</td>
<td>6'-9</td>
<td>2'-3&quot;</td>
<td>6'-9&quot;</td>
<td>12'-6&quot;</td>
<td>5'-5&quot;</td>
<td>15,800lbs.</td>
</tr>
<tr>
<td>60&quot;</td>
<td>7'-4&quot;</td>
<td>2'-6&quot;</td>
<td>7'-4&quot;</td>
<td>13'-8&quot;</td>
<td>6'-0&quot;</td>
<td>18,600lbs.</td>
</tr>
</tbody>
</table>

**NOTES:**

USE CLASS A CONCRETE
2" MIN. CONCRETE COVER
HOLE SIZE <= PIPE O.D. + 3"
REINF.-#5 REBAR @ 12" C.C. EA. WAY
8" WALLS UNLESS OTHERWISE NOTED
3/4" CHAMFER ON ALL EXPOSED EDGES
8" THICK BOTTOM SLAB
WINGWALLS ARE FLARED 30°
FIGURE 6-10

LIFTING DEVICE TO BE GROUTED IN AFTER INSTALLATION

DIMENSIONS

<table>
<thead>
<tr>
<th>BOX SIZE (SPAN x RISE)</th>
<th>H-1</th>
<th>H-2</th>
<th>L</th>
<th>W-1</th>
<th>W-2</th>
<th>WEIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td>3'X2'</td>
<td>4'-0&quot;</td>
<td>1'-0&quot;</td>
<td>4'-0&quot;</td>
<td>7'-6&quot;</td>
<td>3'-8&quot;</td>
<td>6,419lbs.</td>
</tr>
<tr>
<td>3'X3'</td>
<td>5'-0&quot;</td>
<td>1'-6&quot;</td>
<td>5'-0&quot;</td>
<td>8'-6&quot;</td>
<td></td>
<td>8,889lbs.</td>
</tr>
<tr>
<td>4'X2'</td>
<td>4'-2&quot;</td>
<td>1'-0&quot;</td>
<td>4'-2&quot;</td>
<td>8'-10&quot;</td>
<td></td>
<td>7,573lbs.</td>
</tr>
<tr>
<td>4'X3'</td>
<td>5'-2&quot;</td>
<td>1'-6&quot;</td>
<td>5'-2&quot;</td>
<td>10'-0&quot;</td>
<td></td>
<td>10,246lbs.</td>
</tr>
<tr>
<td>4'X4'</td>
<td>6'-2&quot;</td>
<td>2'-0&quot;</td>
<td>6'-2&quot;</td>
<td>11'-2&quot;</td>
<td></td>
<td>13,365lbs.</td>
</tr>
<tr>
<td>5'X3'</td>
<td>5'-4&quot;</td>
<td>1'-6&quot;</td>
<td>5'-4&quot;</td>
<td>11'-5&quot;</td>
<td>6'-0&quot;</td>
<td>11,664lbs.</td>
</tr>
<tr>
<td>5'X4'</td>
<td>6'-4&quot;</td>
<td>2'-0&quot;</td>
<td>6'-4&quot;</td>
<td>12'-7&quot;</td>
<td></td>
<td>14,964lbs.</td>
</tr>
<tr>
<td>5'X5'</td>
<td>7'-4&quot;</td>
<td>2'-6&quot;</td>
<td>7'-4&quot;</td>
<td>13'-8&quot;</td>
<td></td>
<td>18,711lbs.</td>
</tr>
<tr>
<td>6'X3'</td>
<td>5'-6&quot;</td>
<td>1'-6&quot;</td>
<td>5'-6&quot;</td>
<td>12'-9&quot;</td>
<td>7'-2&quot;</td>
<td>13,182lbs.</td>
</tr>
<tr>
<td>6'X4'</td>
<td>6'-6&quot;</td>
<td>2'-0&quot;</td>
<td>6'-6&quot;</td>
<td>13'-11&quot;</td>
<td></td>
<td>16,645lbs.</td>
</tr>
<tr>
<td>6'X5'</td>
<td>7'-6&quot;</td>
<td>2'-6&quot;</td>
<td>7'-6&quot;</td>
<td>15'-1&quot;</td>
<td></td>
<td>20,574lbs.</td>
</tr>
</tbody>
</table>

NOTES:
USE CLASS A CONCRETE
2"MIN. CONCRETE COVER
HOLE SIZE <=PIPE O.D. + 3"
REINF.-#5 REBAR @ 12" C.C. EA. WAY
8" WALLS UNLESS OTHERWISE NOTED
3/4" CHAMFER ON ALL EXPOSED EDGES

HENDERSON
WATER
UTILITY

111 FIFTH STREET
HENDERSON, KENTUCKY

<table>
<thead>
<tr>
<th>Sheet</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
CONSTRUCTION SPECIFICATIONS

PART 1 - GENERAL

Scope

The work to be accomplished under this section of the Specifications consists of the furnishing of all labor, materials, equipment, and services necessary for the construction of storm sewer and appurtenances as shown on the Drawings and more fully described within the contract specifications and herein.

The purpose of this document is to provide information and guidance to developers, contractors, and design engineers in the construction of storm sewer facilities that shall be owned or connected to Henderson Water Utility (HWU). This document shall be adhered to in its entirety.

Designation of Parties

The City of Henderson, Henderson Water Utility is the utility having jurisdiction and supplying stormwater service and is referred to herein as Henderson Water Utility and abbreviated as HWU.

Contractor shall refer to the party or parties who have been retained by either HWU or others to perform the construction work.

Engineer refers collectively to the HWU General Manager, an Engineer in responsible charge working under contract to HWU or in the employ of HWU, or an Engineer in responsible charge working in the employ of a developer working under an Infrastructure Construction Agreement.

Owner refers collectively to HWU or to a developer working under an Infrastructure Construction Agreement.

Safety

All work shall be carried out in strict accordance with all applicable rules and regulations of the Kentucky Labor Cabinet, Division of Occupational Safety and Health, and the document titled HWU Safety Policies, which is a part of these specifications.

Product Delivery, Storage, and Handling

Care shall be exercised in transporting and handling to avoid damage to pipe and fittings, and all appurtenances.

Materials shall be stored in an enclosure or under protective coverings if required by the engineer to prevent damage.

Materials shall not be stored directly on the ground.
The inside of pipes and fittings shall be kept free of dirt and debris.

Contractor shall be responsible for all materials furnished and shall replace at his own expense all materials found defective in handling after delivery. Contractor shall report to the Engineer immediately upon finding any material defective in manufacture. Contractor shall furnish all materials and labor required for replacement of installed materials discovered defective or damaged.

HWU reserves the right to reject any materials that do not comply with these standards.

**Cooperation**

Cooperation with the Owner concerning construction activities is required.

**Notification**

The Contractor shall give the Owner or Owner’s representative a minimum of 48 hours notice before starting construction.

**Inspection**

The Owner’s Engineer shall make sufficient periodic observations during construction to certify that the improvements were installed in conformance with HWU’s standards and the approved construction drawings as per the requirements of HWU’s Infrastructure Construction Agreement. Access to the construction site and construction records shall be provided at all times to HWU staff.

**Permits, Easements, and Rights-Of-Way**

The Contractor shall make application in the Owner’s name, obtain and pay fees for all licenses, permits, easements, and rights-of-way, including railroad permits (where applicable). The Contractor shall be required to comply with all State and municipal ordinances, laws, and/or codes, which may apply to same.

**Contractor’s Certification**

The Contractor shall certify, upon completion of project construction, that all work was completed in accordance with drawings and specification, bearing Owner’s approval. The certification must be signed, and dated by the contractor.

**PART 2 – PRODUCTS**

**Pipe and Joints**
Pipe for storm sewers shall be reinforced concrete pipe (RCP), ductile iron pipe (cement lined), PVC pipe (solid wall or Vylon, by Lamson), or HDPE corrugated (smooth interior wall).

Reinforced Concrete Pipe:
Circular Reinforced Concrete Pipe shall meet the requirements of ASTM C 76, Standard Specification for Reinforced Concrete Culvert, Storm Drain and Storm Pipe. Elliptical reinforced concrete pipe shall meet the requirements of ASTM C 507, Standard Specification for Reinforced Concrete Elliptical Culvert, Storm Drain and Sewer Pipe. Unless shown otherwise on the approved plans, Class III pipe shall be used.

Rubber and plastic joints shall meet the requirements of AASHTO M 198, Standard Specification for Joints for Circular Concrete Sewer and Culvert Pipe Using Flexible Watertight Gaskets, for Type A (Rubber Gaskets) and Type B (Flexible Plastic Gaskets) gaskets. Bituminous mastic joint sealing material shall not be allowed in the construction of reinforced concrete pipe systems.

Ductile Iron Pipe:
Ductile Iron Pipe shall be designed in accordance with the latest revision of ANSI/AWWA C150/A21.50 pressure class 150 (or project requirements, whichever is greater). Ductile iron pipe shall be manufactured in the U.S.A. in accordance with the latest revision of ANSI/AWWA C151/A21.51. Each pipe shall be subjected to a hydrostatic pressure test of at least 500 psi at the point of manufacture.

Pipe shall have standard asphaltic coating on the exterior. The class or nominal thickness, net weight without lining, and casting period shall be clearly marked on each length of pipe. Additionally, the manufacturer’s mark, country where cast, year in which the pipe was produced, and the letters “DI” or “DUCTILE” shall be cast or stamped on the pipe.

All pipe shall be furnished with Push-on Type Joints, such as Tyton® or Fastite®. Joints shall be in accordance with ANSI/AWWA C111/A21.11, of latest revision, and be furnished complete with all necessary accessories.

PVC Pipe
PVC Pipe shall be solid wall SDR 35 or greater wall thickness and conform to ASTM D-3034 and ASTM F-679. Nominal laying lengths shall be 13’-0”. Pipe joints are to be made by the use of an integral bell with elastometric gasket and according to manufacturer’s recommendations.

HDPE Pipe
HDPE pipe shall be corrugated with an integrally formed smooth interior wall. The pipe shall have a full circular cross-section. All sizes shall conform to AASHTO classification “Type S” for smooth waterway.

The pipe shall comply with the requirements for test methods, dimensions and markings found in AASHTO Specification M252 and M294. Pipe joints and fittings shall be of the same pipe stiffness as the pipe. Gaskets shall be manufactured in accordance with ASTM F477.
Pipe Bedding

See Figures 6-1 through 6-3, “RCP Bedding Detail.”

Manholes

Manholes of the form and dimensions shown on the plans and in Figures 6-4 through 6-9 shall be built as directed. At the option of the Contractor, the manhole may be constructed of precast concrete rings. They shall be constructed on 3000-psi concrete foundations.

Standard Manholes

The standard manhole shall be six feet or greater in depth, measured from the top of the cover frame to the lowest pipe invert and shall be of the concentric cone type top construction as shown on the plans. Manholes shall be sufficiently large to accommodate all pipes entering such manhole with a minimum of one-foot separations in all directions.

Shallow Manholes

The shallow manholes shall be less than 6 feet in depth, measured from the top of the cover frame to the lowest pipe invert and shall be of flat top construction as shown on the plans.

Special Manholes

Nonstandard or oversized manholes may be precast or cast in place concrete.

Precast Concrete Rings

Precast concrete rings for manholes shall conform to ASTM C-478. See Figure 6-10.

Precast Concrete Cones

Precast concrete cones shall be of the size and shape shown on the plans and shall conform to the ASTM C-478. See Figure 6-4.

Manhole Frames and Covers

Manhole casting shall consist of cast iron frames and 22-3/4 inch diameter covers, weighing not less than 300 pounds per frame and cover, dimensioned as shown on the plans. Manhole covers must sit neatly in the frames, with contact edges machined for even bearing and tops flush with frame edge. They shall have sufficient corrugations to prevent slipperiness. The lids shall have two pick holes about 1-1/4 inches wide and 1/2 inch deep with 3/8 inch undercut all around. The words “storm sewer” shall be cast in each manhole cover. Heavy-duty manhole lids shall be used under traffic conditions.
Curb Inlets, Grate Inlets, and Headwalls

Curb Inlets, Grate Inlets, and Headwalls shall be constructed to forms and dimensions shown on Figure 6-11. Headwalls shall be required on all storm drains that terminate in an existing or proposed opened waterway. See Figures 6-12 through 6-14. All concrete for reinforced walls and slabs shall be Class “A” concrete. Reinforcing steel shall be ASTM A-615, Grade 60 and the size and layout approved by the Engineer. At the option of the Contractor, precast or cast in place curb inlet boxes and headwalls may be used.

Water Stops

All pipes shall have water stops when tied to precast inlet, manhole or other precast structures. Non-shrink grout may be used for RCP through structure walls where water stops cannot be installed, except that any storm sewer pipe material may be used for concrete headwalls and flared end sections.

PART 3 - EXECUTION

Trench Excavation

Trenching shall be accomplished as described hereinafter. All excavation on this project is “unclassified” and no additional payment will be made for rock excavation.

Unless otherwise directed by the Engineer, trenches in which pipes are to be laid shall be excavated in open cut to the depths shown on the plans, or as specified by the Engineer. Excavation in earth shall undercut the pipe to a depth below the required invert elevation that will permit laying the pipe in a bed of granular material to provide continuous support for the bottom quadrant of the pipe. The bedding shall be as set out hereinafter.

Trenches shall be of sufficient width to provide free working space on each side of the pipe and to permit backfilling around the pipe; but, unless specifically authorized by the Engineer, trenches shall in no case be excavated or permitted to become wider than 2 feet 6 inches plus the nominal diameter of the pipe at the level of or below the top of the pipe. If the trench does become wider than 2 feet 6 inches at the level of or below the top of the pipe, special precautions may be necessary, such as providing compacted, granular fill up to top of the pipe or providing the pipe with additional crushing strength as determined by the Engineer after taking into account the actual trench loads that may result and the strength of the pipe being used. The Contractor shall bear the cost of such special precautions as are necessary.

All excavated materials shall be placed a minimum of 2 feet back from the edge of the trench.

Before laying the pipe, the trench shall be opened far enough ahead to reveal obstructions that may necessitate changing the line or grade of the pipeline.

Watchman or barricades, lanterns and other such signs and signals as may be necessary to warn the public of the dangers in connection with open trenches, excavation and other obstructions,
shall be provided by and at the expense of the Contractor. Conformance to all state highway requirements shall be the responsibility of the Contractor when encroachment on highway right-of-way is necessary.

When so required or when directed by the Engineer, only one-half of street crossings and road crossing shall be excavated before placing temporary bridges over the side excavated for the convenience of the traveling public. All backfilled ditches shall be maintained in such a manner that they will offer no hazard to the passage of traffic. The convenience of the traveling public and property owners abutting shall be taken into consideration. All public or private drives shall be taken into consideration and shall be promptly backfilled or bridged at the direction of the Engineer. Disposal of excavated materials shall cause as little interference with the work as possible, and in every case the disposition of materials shall be satisfactory to the Engineer. Trenches in which pipes are to be laid shall be excavated in open cut to the depths shown on the approved plans, cut sheets or as specified by the Engineer.

Where conditions exist that may be conductive to slides or cave-ins, proper and adequate sheeting, shoring and bracing shall be installed to provide safe working conditions and to prevent damage to work. Trenches shall be kept free of water during the laying of the pipe and until the pipeline has been backfilled. All excavation shall be in accordance with OSHA and/or KOSHA regulations.

Dewatering of trenches shall be considered a part of trenching, at no extra cost to the owner. Dewatering of trenches shall include ground water and storm or sanitary sewage. Suitable pumping and other dewatering equipment are to be provided by the CONTRACTOR, to insure the installation of the pipeline structure in a dewatered trench and under the proper conditions. Dewatering shall include all practical means available for prevention of surface runoff into trenches and scouring against newly laid pipe.

Wherever pipelines are in, or cross, driveways and streets, the Contractor shall be responsible for any trench settlement which occurs within these right-of-ways within one (1) year from the time of final acceptance of the work. If paving shall require replacement because of trench settlement within this time, it shall be removed and/or replaced by the Contractor at no extra cost to the Owner. Repair of settlement damage shall meet the approval of the Engineer and the agency having jurisdiction over the roadway.

**Laying of Pipe**

**Laying Requirements**

All pipe shall be laid to lines, cover or grades shown on the Drawings.

All pipe shall be visually inspected for cleanliness and proper jointing.

The points insisted upon in the laying of pipe will be: Proper alignment, evenness of width and depth of joints, perfection in jointing, and care of the pipe in handling.
Precautions must be taken to prevent flotation of the pipe should water enter the trench prior to putting the pipeline into operation.

In wet, yielding and mucky locations where pipe is in danger of sinking below grade or floating out of grade or alignment, or where the backfill materials are of such a fluid nature that such movements of the pipe might take place during the placing of the backfill, the pipe must be weighted or secured permanently in place by such means as will prove effective. If additional crushed rock fill beneath the pipe is necessary for stability, it will be paid for at the unit price bid per ton of such material in place except in cases where instability is caused by neglect of the CONTRACTOR.

A manhole will be required at the termination of any line installation, except for those that terminate at inlets.

No pipe shall be laid resting on solid rock, blocking or other unyielding objects. Jointing before placing in the trench and subsequent lowering of more than one section jointed together will not be allowed.

When locating near water lines, the horizontal separation between water and stormwater pipes should be at least 10 feet measured from the inside edge to inside edge of the two pipes. Should location conditions prevent a horizontal separation of 10 feet, HWU may allow a deviation on a case by case basis, if supported by data from the engineer. Such deviation may be allowed if the stormwater pipe is laid in a separate trench or if it is laid in the same trench with the water line located at one side on a bench of undisturbed earth. In either case, the elevation of the top crown of the stormwater pipe shall be at least 18 inches below the bottom of the water line.

Whenever stormwater pipes must pass below water lines, the stormwater pipes shall be laid at an elevation such that the top crown of the stormwater pipe is at least 18 inches below the bottom crown of the water line. Should location conditions prevent the stormwater line from being buried to meet the above requirements, HWU may allow a deviation on a case by case basis, if supported by data from the engineer. Such deviation may be allowed if the stormwater pipe is constructed with reinforced concrete pipe or cement coated ductile iron pipe for a distance of 10 feet on each side of the water main. At all crossings, one full length of the water main pipe shall be located so both joints will be as far from the storm sewer as possible. Special structural support for the water and sewer pipes may be required.

**Pipe Bedding**

Standard Bedding – Sewer pipe shall, as a standard practice, be laid using bedding of No. 9 crushed limestone that shall be placed a minimum depth of 4 inches below the bottom of the pipe barrel.

In no case shall the pipe be supported directly on solid rock. When rock is encountered in the trench bottom, bedding shall consist of size #9 crushed limestone only.
**Special Pipe Bedding**

**Unstable Soils**

Unstable soils shall be stabilized by over excavating to allow a layer of #3 crushed stone below the 4 inches of #9 crushed stone bedding.

All bore pits and any over digging related to such will be stabilized with #3 stone and backfilled with #9 stone to sub-grade.

**Installation and Jointing**

Jointing of push on type reinforced concrete pipe, ductile iron pipe, or PVC pipe rubber gasket couplings shall be accomplished in accordance with the manufacturer’s specifications.

Pipe shall not be laid in water or upon frozen sub grade at any time or condition when, in the opinion of the Engineer or HWU, or conditions are unsuitable.

**Backfilling**

Backfilling of pipeline trenches shall be accomplished in accordance with the details set forth hereinafter.

In all cases walking or working on the completed pipelines, except as may be necessary in tamping or backfilling, will not be permitted until the trench has been backfilled to a point one foot (1’) above the top of the pipe. The filling of the trench and the tamping of the backfill shall be carried on simultaneously on both sides of the pipe in such a manner that the completed pipeline will not be disturbed and injurious side pressures do not occur. The methods of backfilling shall be as follows:

**Method “A” - Backfilling in Open Terrain:**

The lower portion of the trench, from the top of the pipe bedding material to a point one (1) nominal pipe diameter above the top outside surface of the pipe, shall be backfilled with #9 stone.

The upper portion of the trench above the #9 stone shall be backfilled with material, which is free from large rock. Incorporation of rock with any individual piece having a volume exceeding eight (8) cubic inches is prohibited. Backfilling this portion of the trench may be accomplished by any means approved by the Engineer. The trench backfill shall be heaped over the top of the trench or leveled as directed by the Engineer. Material for backfilling the upper portion of the trench is not a separate pay item.

**Method “B” - Backfilling Under Sidewalks and Unpaved Driveways:**

The entire trench shall be backfilled with No. 9 crushed stone.
**Method “C” - Backfilling Under Streets, Roads and Paved Driveways:**

The lower portion of the trench, from the top of the pipe bedding to a point six inches (6”) below the base of the pavement or concrete sub-slab, shall be backfilled with No. 9 crushed stone or fine gravel. Backfill for the lower portion of the trench is not a separate pay item.

The upper portion of the trench, from the top of the #9 stone to the base of the pavement or concrete sub-slab, shall be backfilled with a base course of dense graded aggregate. At such time that pavement replacement is accomplished, the excess base course shall be removed as required.

Material for backfilling the upper portion of the trench is not a separate pay item.

Before final acceptance, the Contractor will be required to level off all trenches or to bring the trench up to grade. The Contractor shall, at his expense, also remove and dispose of all excess earth or other materials resulting from construction from roadways, right-of-ways, and/or private property.

In the event that pavement is not placed immediately following trench backfilling in streets and highways, the Contractor shall be responsible for maintaining the trench surface in a level condition at proper pavement grade at all times. The Contractor shall be liable for any damage to persons or property resulting from the Contractor’s failure to maintain the trench surface.

**Concrete Cradle Anchors, Thrust Blocks, or Encasements**

Concrete cradle, anchors, or encasement of stormwater pipes and/or fitting shall be placed where shown on the plans, required by the specifications, or as directed by the Engineer. Concrete shall be Class “B” and shall be mixed sufficiently wet to permit it to flow under the pipe to form a continuous bed. In tamping concrete, care shall be taken not to disturb the grade or line of the pipe or injure the joints.

Concrete cradles and/or encasement shall not be allowed except with written permission by HWU. If concrete trench stabilization is necessary, excavate the trench and place the concrete to allow a minimum of 4 inches of granular material between the concrete and the installed pipe or structure. If concrete protection is required over the top of the pipe, place a minimum of 4 inches of granular material between the pipe and the concrete. If flowable fill concrete is used to backfill the trench, bed the pipe as indicated on the drawings to a point at least 12 inches above the top of the pipe prior to the placement of the flowable fill concrete.

**Connections to Existing Lines**

Connections to existing stormwater pipes shall be made with new or existing manholes as indicated on plans.

Connections of new stormwater pipes to existing stormwater pipes by tapping into the side of an existing stormwater pipe shall not be permitted unless specifically approved in writing by HWU.
Field Quality Control

After the completion of the stormwater system and prior to final inspection, the Contractor will be required to clean all dirt, debris and trash from lines and manholes.

During the final inspection, the Engineer will inspect each individual line, from manhole to manhole, either by use of lights or other means at his/her disposal to determine whether the completed lines are true to line and grade as laid out or as shown on the plans.

Flexible pipe (PVC and HDPE) shall be lamp tested not less than 30 days after completion of installation and shall not be allowed to show more than 5% deflection.
CHAPTER 7

CULVERTS AND BRIDGES
7.1 INTRODUCTION

As used in this manual, bridges are defined as structures 20’ wide or greater (support to support) that transport vehicles over streams or constructed channels. Culverts are structures narrower than 20’ wide that transport vehicles over streams or constructed channels.
7.2 CULVERT DESIGN CRITERIA

7.2.1 General

Culverts shall be located and designed to present a minimum hazard to traffic and people.

7.2.2 Alignment and Slope

The culvert shall be designed to approximate the existing alignment and slope of the stream.

A culvert shall not be placed within 50 feet of a bend in a stream or channel greater than 20 degrees.

7.2.3 Allowable Headwater

The culvert shall be designed so that:

- HW/D (headwater/barrel height) is no greater than 1.2 for the 100-year storm for drainage areas less than or equal to one square mile,
- HW/D is no greater than 1.0 for the 100-year storm for drainage areas greater than one square mile.
- The headwater is at least 12 inches below the edge of pavement for the 100-year storm, and
- The headwater is at least 24 inches below the lowest opening of upstream structures for the 100-year storm.

7.2.4 Culvert Size and Shape

A minimum culvert diameter of 15 inches shall be used to avoid maintenance problems and clogging.

7.2.5 Multiple Barrels and Stages Culverts

Culverts with a drainage area of greater than 1.0 square miles and smaller areas where the floodway flow path broadens out from the main channel shall be designed so that the distribution of outlet flow approximates that prior to construction. Possible considerations may include:

- Staged-discharge through multiple culverts with the main culvert accommodating bank full flow and other culverts handling events greater than bank full flow.
- Disbursement of flows at the culvert outfall in conjunction with other velocity reduction and erosion control measures.
7.2.6  Culvert Skew

A culvert shall be designed with a maximum skew of 45 degrees as measured from a line perpendicular to the roadway centerline.

7.2.7  End Treatments

All culverts shall be designed with inlet and outlet concrete sloped box end sections conforming to KYTC Standard Drawings or headwalls conforming to HWU standard drawings in Chapter 6. The parapet wall of each headwall shall be parallel to the road.

7.2.8  Outlet Protection

The outlet of culverts shall be protected with gabion mattresses or impact stilling basins. Gabion mattresses shall be used at the outlets of all culverts and storm drains with an exit velocity greater than 5 feet per second when flowing full, except where there are paved ditches. Impact stilling basins shall be used at the outlet of culverts and pipes with calculated exit velocities greater than 15 feet per second when flowing full.
7.3 CULVERT DESIGN PROCEDURES

7.3.1 Approved Methods

Culverts shall be designed in accordance with methods described in “Hydraulic Design of Highway Culverts” (Hydraulic Design Series (HDS) No. 5) of the Federal Highway Administration (FHWA). HDS No. 5 is based on the concept of analyzing a culvert for both inlet and outlet control and designing for the control that produces the minimum performance. Design computations may be performed using the following computer programs based upon HDS No. 5. Other programs may be accepted for use subject to HWU approval.

- CulvertMaster – Haestad Methods
- HYDRAIN – GKY and Associates
- HYPACK – Kentucky Transportation Cabinet

7.3.2 Inlet Control

Inlet control occurs when the culvert barrel is capable of conveying more flow than the inlet will accept. For inlet control, the control section is at the upstream end of the barrel (the inlet). The flow passes through critical depth near the inlet and becomes shallow, high velocity (supercritical) flow in the culvert barrel. Depending on the tailwater, a hydraulic jump may occur downstream of the inlet.

Factors that affect the flowrate for a given headwater depth during inlet control are inlet area, inlet edge configuration and inlet shape. The following definitions are important for inlet control:

- The control section is the location where there is a unique relationship between the flow rate and the upstream water surface elevation.
- Headwater depth is measured from the inlet invert of the inlet control section to the surface of the upstream pool.
- Inlet area is the cross-sectional area of the face of the culvert. Generally, the inlet face area is the same as the barrel area.
- Inlet edge configuration describes the entrance type. Some typical inlet edge configurations are thin edge projecting, mitered, square edges in a headwall, and beveled edge.
- Inlet shape is usually the same as the shape of the culvert barrel. Typical shapes are rectangular, circular, elliptical, and arch.

7.3.3 Outlet Control

Outlet control occurs when the culvert barrel is not capable of conveying as much flow as the inlet opening will accept, and the downstream end of the culvert controls the flow. Outlet control has depth and velocity that are subcritical. The tailwater depth is either assumed to be critical depth near the culvert outlet or the downstream channel depth,
whichever is higher. In addition to the inlet control factors, the following factors also affect outlet control flow:

**Barrel Roughness**
Barrel roughness is a function of the material used to fabricate the barrel. The roughness is represented by a hydraulic resistance coefficient such as the Manning n value.

**Barrel Area and Shape**
Barrel area is measured perpendicular to the flow. Barrel shape impacts the friction loss through the barrel.

**Barrel Length**
Barrel length is the total culvert length from the entrance to the exit of the culvert. Because the design height of the barrel and the slope influence the actual length, an approximation of barrel length is usually necessary to begin the design process.

**Barrel Slope**
Barrel slope is the actual slope of the culvert barrel, and is often the same as the natural stream slope. However, when the culvert inlet or outlet is raised or lowered, the barrel slope is different from the stream slope.

**Tailwater Elevation**
Tailwater is based on the downstream water surface elevation. Backwater calculations from a downstream control, a normal depth approximation, or field observations are used to define the tailwater elevation.
7.4 BRIDGE DESIGN CRITERIA

7.4.1 General

Bridges shall be designed to:

- pass the 100-year flow with one foot of freeboard below the bottom of the bridge structure,
- not damage the road or increase damages to adjacent property because of high velocities,
- maintain existing flow distribution in the floodplain to the extent practicable,
- minimize flow disruption and potential scour from pier spacing, pier orientation, and abutment,
- avoid failure by scour,
- pass anticipated debris,
- provide measures to counteract the sometimes unstable or unpredictable nature of alluvial streambeds or demonstrate that the risk of damage is low,
- produce minimal disruption of ecosystems and values unique to the floodplain and stream, and
- accommodate pedestrian access.

7.4.2 Backwater Increases

Bridges shall be designed so that flooding to upstream properties is not increased over existing levels. Verify this by conducting a flow profile analysis for the waterway, using the 100-yr storm flow, for conditions prior to and following construction of the bridge. Limit the allowable increase in backwater at the bridge to 1 foot during passage of the 100-yr flow.
7.5 BRIDGE DESIGN PROCEDURES

Use HEC-RAS to evaluate the effects of the bridge.
7.6 CONSTRUCTION SPECIFICATIONS

7.6.1 Culvert Pipe

Culvert pipe shall be reinforced concrete pipe and shall be installed in accordance with the Kentucky Department of Highway Standard Drawings, latest edition.

7.6.2 Box Culverts

Box culverts shall be constructed in accordance with the Kentucky Department of Highway Standard Drawings, latest edition.
CHAPTER 9

(RETERVED)
CHAPTER 10

STORMWATER BEST MANAGEMENT PRACTICES
FOR
WATER QUANTITY AND WATER QUALITY CONTROL
CHAPTER 10
STORMWATER BEST MANAGEMENT PRACTICES
FOR
WATER QUANTITY AND WATER QUALITY CONTROL

10.1 GENERAL DESIGN CRITERIA

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10.2.2 Design Criteria

10.2.3 Design Procedures

10.2.4 Specifications

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10.3.2 Modular Pavement

10.3.3 Swales

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10.3.5 Biofiltration Swales

10.3.6 Terraforming

10.3.7 Infiltration Basins

10.3.8 Vegetated Filter Strips

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10.4 SAND AND ORGANIC FILTERS

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10.4.4 Underground Sand Filter

10.4.5 Perimeter Sand Filter

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10.5 PREFABRICATED TREATMENT DEVICES

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10.6 DETENTION PONDS

10.6.1 Applicability

10.6.2 Design Criteria

10.6.3 Design Procedures

10.6.4 Material Specifications

10.6.5 Construction Specifications
10.1 GENERAL DESIGN CRITERIA

Stormwater management shall include management for quality and quantity. This section provides the general design criteria for both.

10.1.1 Water Quantity Control

Water quantity controls shall be implemented so that post-development peak discharges for two design storms, the 25-year 6-hour and 25-year 24-hour storms, are reduced to 30% below pristine conditions (natural condition prior to any human impact) for each storm.

10.1.2 Water Quality Control

In addition to carrying pollutants, stormwater runoff from developed areas increases the frequency and duration of bankfull flows in the receiving streams, causing increased erosion of the stream banks and further degradation of in-stream water quality. On-site infiltration, designed for the increased runoff due to development, is the preferred solution to this impact.
10.2 BIORETENTION SYSTEMS

Bioretention is a practice to treat stormwater runoff using a conditioned planting soil bed and planting materials to filter runoff stored within a shallow depression. The method combines physical filtering and adsorption with biological processes. 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. Figure 10-1 shows a diagram of a bioretention system designed to receive runoff from a paved area.

10.2.1 Applicability

Bioretention systems are very effective for water quality treatment. Bioretention systems are particularly well suited for use in parking lot islands, roadside swales, and median strips.

10.2.2 Design Criteria

Size the area of the filter bed in accordance with the design treatment volume corresponding to the area draining to it. (See the next section for procedure).

Design the bioretention system to be on-line with an overflow catch basin, as shown in Figure 10-1, to handle volumes exceeding the design treatment volume.

Design the bioretention system to have a longitudinal slope of 0 to 1 percent.

Provide a pretreatment system composed of a pea gravel diaphragm and a grassed filter strip. The pea gravel diaphragm also serves as a flow spreader. Dimensions of the gravel diaphragm and grass filter strip shown in Figure 10-1 are minimums. When flow into a bioretention system is parallel to its long dimension (i.e., from a drainage swale), omit the gravel diaphragm shown in Figure 10-1 and provide a berm across the downstream end of the system to impede the flow. The top of the berm shall be level across the base of the bioretention system and be 12 to 18 inches high in the center.

Provide a planting soil bed with a minimum width of 4 feet and a minimum depth of 4 feet (including a 12 inch sand bed). The planting soil bed can be as wide as 15 feet. The area of the system is determined by the required area of the filter bed. The minimum length is 15 feet.

For widths greater than 10 feet, maintain at least a 2:1 length to width ratio.

Provide a pea gravel curtain drain, as shown in Figure 10-1. The minimum width of the curtain drain is 8 inches.

Provide a 2 to 3 inch thick mulch layer above the planting soil bed.
Grade the top of the planting soil bed to provide a shallow ponding area with a maximum depth of 6 inches.

Provide an underdrain system of gravel and perforated pipe. Design the gravel bed to be at least 8 inches deep. Connect the underdrain to the storm drainage system or design it to daylight to a suitable non-erosive outfall.

10.2.3 Design Procedures

Size the filter bed using the following equation:

\[ A_f = \frac{V*d_f}{[k*(h_f + d_f)(t_f)]} \]

where:
- \( A_f \) = surface area of the sand filter bed (ft\(^2\))
- \( V \) = treatment or infiltration volume (ft\(^3\))
- \( d_f \) = planting bed depth (ft)
- \( k \) = coefficient of permeability for planting bed (ft/day)
- \( h_f \) = average height of water above the planting bed (ft); \( h_f = 0.5 * h_{\text{max}} \)
- \( t_f \) = time required for \( V \) to filter through the planting bed (days).

Note:
- \( d_f = 4 \) feet (including sand filter) unless it is increased by designer
- \( k = 0.5 \) feet/day (median value of a silt loam)
- \( h_f = 0.5 * h_{\text{max}} = 3 \) inches = 0.25 feet
- \( t_f = 3 \) days.

Design the bioretention system to provide the minimum filter area required and to meet the design criteria.

10.2.4 Specifications

Provide planting soil with the following characteristics:

- pH of 5.2 to 7.0,
- organic content of 1.5 to 4 percent,
- magnesium of 35 pounds per acre minimum,
- phosphorus (as \( P_2O_5 \)) of 75 pounds per acre minimum,
- potassium (as \( K_2O \)) at 85 pounds per acre minimum,
- soluble salts less than 500 ppm,
- clay content of 10 to 25 percent by volume,
- silt content of 30 to 55 percent by volume,
- sand content of 35 to 60 percent by volume,
- free of stones, stumps, roots, or other woody material greater than 1 inch in diameter.

Place planting soil in lifts of 12 to 18 inches and loosely compact or tamp lightly with backhoe bucket.
Provide shredded hardwood mulch aged at least 2 months. Place mulch layer 2 to 3 inches deep.

Provide clean river pea gravel for the curtain drain and diaphragm sized to meet ASTM D-448 size no. 6 with diameter ranging from 1/8 to ¼ inch.

Provide gravel for the underdrain sized to meet AASHTO M-43 with size range of ½ to 2 inches in diameter.

Provide PVC piping for the underdrain satisfying AASHTO M-278 standard for rigid schedule 40 pipe. Provide 3/8 inch diameter perforations on 6 inch centers with 4 holes per row.

Plant base of bioretention system (planting soil bed) in herbaceous ground cover and shrubs. Plant side slopes of bioretention system in herbaceous ground covers, vines, and shrubs. Trees may also be used in the bioretention system. Use direct seeding for herbaceous varieties and nursery stock for vines, shrubs, and trees.

Areas to be seeded with herbaceous varieties shall be roughened with a rake or similar tool. Seeding rates shall be minimum of 10 pounds of seed mix per 1000 square feet of area.

Bare root or containerized stock shall be planted at the same depth as planted in the nursery. The stock should be planted in a hole large enough to accommodate the root system when well spread. Shrubs and vines shall be planted at a minimum density of 1,700 stems per acre (one stem per 25 square feet at 5 feet on center).

Select herbaceous species for the planting soil bed from the following list. Use a minimum of two species.

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Scientific Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barnyard grass</td>
<td>Echinochloa crusgalli</td>
</tr>
<tr>
<td>Switch Grass</td>
<td>Panicum virgatum</td>
</tr>
<tr>
<td>Swamp Milkweed</td>
<td>Asclepias incarnate</td>
</tr>
<tr>
<td>Giant Cane</td>
<td>Arundinaria gigantean</td>
</tr>
<tr>
<td>Jewelweed</td>
<td>Impatiens capensis</td>
</tr>
<tr>
<td>River oats</td>
<td>Chasmanthium latifolia</td>
</tr>
<tr>
<td>Deertongue</td>
<td>Panicum clandestinum</td>
</tr>
<tr>
<td>Boneset</td>
<td>Eupatorium perfoliatum</td>
</tr>
</tbody>
</table>

Select herbaceous species for the side slopes from Table 10-1. Also, select vines, shrubs, and trees from Table 10-1.
### TABLE 10-1
NATIVE PLANT SPECIES SUITABLE FOR STREAMBANKS AND RIPARIAN BUFFERS IN WESTERN KENTUCKY

#### Herbaceous Ground Covers:

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Scientific Name</th>
<th>Shade/Sun</th>
</tr>
</thead>
<tbody>
<tr>
<td>River Oats</td>
<td>Chasmanthium latifolia</td>
<td>shade</td>
</tr>
<tr>
<td>Indian Grass</td>
<td>Sorgastum nutans</td>
<td>sun</td>
</tr>
<tr>
<td>Switch Grass</td>
<td>Panicum virgatum</td>
<td>sun</td>
</tr>
<tr>
<td>Redtop</td>
<td>Agrostis alba</td>
<td>sun</td>
</tr>
<tr>
<td>Deer tongue</td>
<td>Panicum clandestinum</td>
<td>shade</td>
</tr>
<tr>
<td>Broomsedge</td>
<td>Andropogon virginicus</td>
<td>sun</td>
</tr>
<tr>
<td>Big Blue Stem</td>
<td>Andropogon gerardii</td>
<td>sun</td>
</tr>
<tr>
<td>Frank's Sedge</td>
<td>Carex frankii</td>
<td>sun</td>
</tr>
<tr>
<td>Gray's Sedge</td>
<td>Carex grayii</td>
<td>shade</td>
</tr>
<tr>
<td>Soft Rush</td>
<td>Juncus effusus</td>
<td>sun</td>
</tr>
<tr>
<td>Flat Sedge</td>
<td>Cyperus strigosus</td>
<td>sun</td>
</tr>
<tr>
<td>Lady Fern</td>
<td>Athyrium felix-femina</td>
<td>shade</td>
</tr>
<tr>
<td>Sensitive Fern</td>
<td>Osmunda cinnamomea</td>
<td>shade</td>
</tr>
<tr>
<td>Cinnamon Fern</td>
<td>Osmunda cinnamomea</td>
<td>shade</td>
</tr>
<tr>
<td>Common Boneset</td>
<td>Eupatorium perfoliatum</td>
<td>sun</td>
</tr>
<tr>
<td>Golden Ragwort</td>
<td>Senecio aureus</td>
<td>shade</td>
</tr>
<tr>
<td>Wrinkled Goldenrod</td>
<td>Solidago rugosa</td>
<td>sun</td>
</tr>
<tr>
<td>Tall Goldenrod</td>
<td>Solidago gigantea</td>
<td>sun</td>
</tr>
<tr>
<td>Beard Tongue</td>
<td>Penstemon hirsutus</td>
<td>shade</td>
</tr>
<tr>
<td>Monkey Flower</td>
<td>Mimmulus ringens</td>
<td>shade</td>
</tr>
<tr>
<td>Cardinal Flower</td>
<td>Lobelia cardinalis</td>
<td>shade</td>
</tr>
<tr>
<td>Great Blue Lobelia</td>
<td>Lobelia siphilitica</td>
<td>shade</td>
</tr>
</tbody>
</table>

#### Vines and Shrubs:

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Scientific Name</th>
<th>Shade/Sun</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cross Vine</td>
<td>Bigonia capreolata</td>
<td>shade</td>
</tr>
<tr>
<td>Trumpet Creeper</td>
<td>Campsis radicans</td>
<td>sun</td>
</tr>
<tr>
<td>Climbing Hydrangea</td>
<td>Decumaria barbara</td>
<td>shade</td>
</tr>
<tr>
<td>Giant Cane</td>
<td>Arundinaria gigantea</td>
<td>sun</td>
</tr>
<tr>
<td>Buttonbush</td>
<td>Cephalanthus occidentalis</td>
<td>sun</td>
</tr>
<tr>
<td>Meadowweet</td>
<td>Spirea alba</td>
<td>sun</td>
</tr>
<tr>
<td>Sweetspire</td>
<td>Itea virginica</td>
<td>shade</td>
</tr>
<tr>
<td>Spicebush</td>
<td>Lindera benzoin</td>
<td>shade</td>
</tr>
<tr>
<td>Paw-paw</td>
<td>Asimina triloba</td>
<td>shade</td>
</tr>
<tr>
<td>Arrowwood</td>
<td>Viburnum dentatum</td>
<td>shade</td>
</tr>
<tr>
<td>Nannyberry</td>
<td>Viburnum lentago</td>
<td>sun</td>
</tr>
<tr>
<td>Swamp Haw</td>
<td>Viburnum nudum</td>
<td>shade</td>
</tr>
<tr>
<td>Ninebark</td>
<td>Physocarpus opolifolius</td>
<td>sun</td>
</tr>
<tr>
<td>Hazelnut</td>
<td>Corylus americana</td>
<td>sun</td>
</tr>
<tr>
<td>Possum Haw</td>
<td>Ilex decidua</td>
<td>sun</td>
</tr>
<tr>
<td>Winterberry</td>
<td>Ilex verticillata</td>
<td>shade</td>
</tr>
<tr>
<td>Chokeberry</td>
<td>Aronia arbutifolia</td>
<td>sun</td>
</tr>
<tr>
<td>Elderberry</td>
<td>Sambucus candensis</td>
<td>sun</td>
</tr>
<tr>
<td>Juneberry</td>
<td>Amelanchier arborea</td>
<td>shade</td>
</tr>
<tr>
<td>Mountain Camelia</td>
<td>Stewartia ovata</td>
<td>shade</td>
</tr>
<tr>
<td>Sweetbells</td>
<td>Leucothe racemosa</td>
<td>shade</td>
</tr>
<tr>
<td>Smooth Azalea</td>
<td>Rhododendron arborens</td>
<td>shade</td>
</tr>
<tr>
<td>Silky Dogwood</td>
<td>Cornus amomum</td>
<td>sun</td>
</tr>
<tr>
<td>Redosier Dogwood</td>
<td>Cornus stolonifera</td>
<td>shade</td>
</tr>
</tbody>
</table>
TABLE 10-1
NATIVE PLANT SPECIES SUITABLE FOR STREAMBANKS
AND RIPARIAN BUFFERS IN WESTERN KENTUCKY
(continued)

<table>
<thead>
<tr>
<th>Vines and Shrubs (continued):</th>
<th>Scientific Name</th>
<th>Shade/Sun</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rough-leaf Dogwood</td>
<td>Cornus drummondii</td>
<td>shade</td>
</tr>
<tr>
<td>Pagoda Dogwood</td>
<td>Cornus alternifolia</td>
<td>shade</td>
</tr>
<tr>
<td>Smooth Alder</td>
<td>Alnus serrulata</td>
<td>sun</td>
</tr>
<tr>
<td>Sandbar Willow</td>
<td>Salix interior</td>
<td>sun</td>
</tr>
<tr>
<td>Silky Willow</td>
<td>Salix sericea</td>
<td>sun</td>
</tr>
<tr>
<td>Dwarf Willow</td>
<td>Salix humilis var. macrophylla</td>
<td>sun</td>
</tr>
<tr>
<td>Pussy Willow</td>
<td>Salix discolor</td>
<td>sun</td>
</tr>
<tr>
<td>Streamco Willow</td>
<td>Salix purpurea</td>
<td>sun</td>
</tr>
<tr>
<td>Bankers Willow</td>
<td>Salix x cotteli</td>
<td>sun</td>
</tr>
<tr>
<td>Heart-leaf Willow</td>
<td>Salix rigida</td>
<td>sun</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Trees:</th>
<th>Scientific Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black Willow</td>
<td>Salix nigra</td>
</tr>
<tr>
<td>Boxelder</td>
<td>Acer negundo</td>
</tr>
<tr>
<td>Red Maple</td>
<td>Acer rubrum</td>
</tr>
<tr>
<td>Silver Maple</td>
<td>Acer saccharinum</td>
</tr>
<tr>
<td>Green Ash</td>
<td>Fraxinus pennsylvanica</td>
</tr>
<tr>
<td>White Ash</td>
<td>Fraxinus americana</td>
</tr>
<tr>
<td>Red Elm</td>
<td>Ulmus rubra</td>
</tr>
<tr>
<td>Silverbell</td>
<td>Halesia carolina</td>
</tr>
<tr>
<td>Persimmon</td>
<td>Diospyros virginiana</td>
</tr>
<tr>
<td>River Birch</td>
<td>Betula nigra</td>
</tr>
<tr>
<td>Black Gum</td>
<td>Nyssa sylvatica</td>
</tr>
<tr>
<td>Hackberry</td>
<td>Celtis occidentalis</td>
</tr>
<tr>
<td>Cottonwood</td>
<td>Populus deltoides</td>
</tr>
<tr>
<td>Sweet Gum</td>
<td>Liquidambar styraciflua</td>
</tr>
<tr>
<td>Tulip Polar</td>
<td>Liriodendron tulipifera</td>
</tr>
<tr>
<td>Sycamore</td>
<td>Platanus occidentalis</td>
</tr>
<tr>
<td>American Beech</td>
<td>Fagus grandiflora</td>
</tr>
<tr>
<td>Ironwood</td>
<td>Carpinus caroliniana</td>
</tr>
<tr>
<td>Yellow Buckeye</td>
<td>Aesculus octandra</td>
</tr>
<tr>
<td>Shellbark Hickory</td>
<td>Carya lacinosa</td>
</tr>
<tr>
<td>Shagbark Hickory</td>
<td>Carya ovata</td>
</tr>
<tr>
<td>Pecan</td>
<td>Carya illinoensis</td>
</tr>
<tr>
<td>Black Walnut</td>
<td>Juglans nigra</td>
</tr>
<tr>
<td>Bur Oak</td>
<td>Quercus macrocarpa</td>
</tr>
<tr>
<td>Pin Oak</td>
<td>Quercus palustris</td>
</tr>
<tr>
<td>Swamp Oak</td>
<td>Quercus bicolor</td>
</tr>
<tr>
<td>Swamp Chestnut Oak</td>
<td>Quercus michauxii</td>
</tr>
</tbody>
</table>
10.3 INFILTRATION SYSTEMS

Infiltration practices and/or bioretention systems reduce the adverse impacts on the receiving waters that result from increasing the impervious area. This chapter describes several infiltration practices that can be used in many different situations. Many of the practices cannot function as the sole water quality infiltration and treatment device, but are intended to be used with other BMPs to achieve the desired storm water quality.

10.3.1 Downspouts to Grass

Discharging downspouts from roofs onto grassed yards encourages infiltration and reduces direct discharge to impervious areas such as driveways.

Design Criteria
The lot must be graded so that the downspout discharge travels at least 30 feet over grass before reaching a driveway, roadway, paved ditch, or any other impervious conveyance.

10.3.2 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 for civic, commercial, and industrial facilities. Modular pavement can be used for any portion of parking up to that amount allowed by the Planning Commission. Any area that is paved using modular pavement can be treated as pervious for purposes of determining the level of storm water quality treatment and calculating post-development peak runoff, as long as appropriate design criteria and construction specifications are satisfied.

Design Criteria
Large void spaces in modular pavement shall represent at least 30 percent of the total surface area of the pavement.

Voids shall be filled with silty soil and vegetated with permanent grass. If vegetation is inappropriate, voids may be filled with sand or gravel, but the material shall be clean and uniform (poorly graded) to ensure high permeability.

Construction Specifications
Install all modular pavements following manufacturer’s specifications.

To prevent premature clogging and/or failure, modular pavements shall not be placed into service until the entire contributing surface drainage area has been completely stabilized.

Clearly mark the planned area for modular pavement to prevent heavy equipment from compacting the underlying soils.
Excavate the subgrade soil using equipment with tracks or oversized tires to minimize compaction.

### 10.3.3 Swales

Swales are typically vegetated parabolic or trapezoidal channels with a large width to depth ratio that are used for conveying stormwater runoff. Swales can act both as vegetated filters and infiltration practices because they tend to slow runoff rates and allow for both particle settling and stormwater infiltration. Swales are encouraged wherever they can be used as an alternative to narrower, deeper channels that tend to convey flow at higher velocities. Swales are especially effective in reducing water quality impacts when used for roadside drainage instead of the traditional curb inlet/storm sewer system. In this application curb cuts are used instead of drop inlets in the gutter. See Figure 10-2.

Swales can be even more effective when constructed using berms or infiltration beds to encourage additional ponding and infiltration. These cases are discussed in subsequent sections.

The area draining to the swale must be at least three times the area of the swale considering that the swale itself is part of the drainage area.

To calculate area of the swale, the width will be the average water surface width corresponding to the flowrate associated with the 100-year storm.

**Design Criteria**

To be considered a swale, a channel must have a width to depth ratio of at least 6:1, have a bed slope of not greater than 4 percent, and be vegetated. When swales are used for roadside drainage, curb cuts shall be provided no less frequently than one per each 100 feet of curb.

Drop inlets in swales shall be spaced no closer than once per each 300 feet.

### 10.3.4 Bermed Swales

A bermed swale or infiltration swale is a grassed swale constructed with berms or swale blocks across the swale to impound shallow pools of water, slowing flow and providing additional opportunities for particle settling and stormwater infiltration.

**Design Criteria**

Swale blocks or earthen berms built across the swale shall be constructed with a 2-inch diameter PVC pipe through the berm to prevent long-term ponding of water. Berms shall be shaped with a depressed spillway in the center of the flow stream to discourage overtopping and erosion at either end of the berm.

Berms shall be no taller than 8 inches and spaced no closer than 60 feet. The top of a downstream berm shall not be at a higher elevation than the base of the next upstream berm.

Drop inlets in swales shall be spaced no closer than once per each 300 feet.
10.3.5 Biofiltration Swales

A biofiltration swale is a version of a bioretention system without the pipe underdrain system. This practice encourages infiltration from the swale bottom, through a planting bed, to the underlying soil. See Figure 10-3.

Design Criteria
Biofiltration swales shall be designed to have the following characteristics:

- trapezoidal or parabolic shape;
- bottom width of 2 feet;
- side slopes no steeper than 3:1;
- longitudinal slope of 1 to 2 percent (up to 4 percent slope can be used with berms constructed as required for bermed swales);
- length, width, depth, and slope necessary to provide surface storage of the design volume with a maximum ponded depth of 18 inches;
- vegetated in accordance with requirements for vegetated channels with grass lining;
- capacity to convey the 100-year design storm with at least 6 inches of freeboard; and
- a soil bed 36 inches deep having the width of the swale bottom.

Plan the soil bed to consist of soils that have a permeability of at least 0.5 feet per day (USCS soils ML, SM or SC). If native soils do not satisfy these criteria, a prepared soil bed can be designed.

An alternative to the above criteria is to size the filter bed (i.e., planting soil bed) for a biofiltration swale consistent with a bioretention system.

10.3.6 Terraforming

Terraforming is a term for special grading practices such as terracing and berming that are intended to promote infiltration. Bermed swales are a special case of terraforming. Terraforming can range from a small depression in permeable soil to an extensive series of bermed terraces. A simple example is given in Figure 10-4.
10.3.7 Infiltration Basins

Infiltration basins may be used in locations that have at least 5 feet of soil, with a permeability of at least 0.5 inches/hour underlying the device. The underlying 5 feet of soil must also be above the seasonal high water table.

If soils do not meet the permeability requirement, they can be modified by mixing sand and gravel in the top 5 feet of the soil underlying the device. If native soils are to be modified with sand or gravel, provide a design that shows the depth of soil to be modified and the total quantity of gravel or soil to be added. Include soil test data documenting the permeability of the soils before and after modification.

If desired, large infiltration basins can be designed much like an extended detention pond for storm peak control. The outlet structure and detention storage volumes are designed to be above the level needed to store the design treated volume. The difference is that an infiltration basin does not have an extended detention outlet. Instead the treated volume is allowed to infiltrate into the soils underlying the basin. If the infiltration basin is not intended for peak flow control, it shall be designed so that volumes exceeding the treated volume can discharge through an overflow weir or pipe. For small excavated basins of less than one-fourth acre, volumes exceeding the treated volume may be allowed to overflow onto the ground surface without use of an overflow structure, if proper erosion control measures are implemented.

Design Criteria
Test soils prior to designing an infiltration basin to ensure that the site is capable of infiltration. Obtain a minimum of three soil test borings or test pits to verify that the soil is at least 5 feet deep below the base elevation and has a permeability of at least 0.5 inch/hour.

Design the floor of the basin to be as flat as possible to promote infiltration. Provide side slopes not greater than 3:1 (h:v).

Provide a sediment forebay at the inlet to the basin with a depth of at least 4 feet and a volume of at least 10 percent of the treated volume.

Size the basin to store the design treated volume before discharging through the peak flow control outlet. If the basin is intended only for water quality treatment, design an outlet that allows volumes in excess of the treated volume to discharge to a surface water conveyance.

If a base flow will be discharged into the infiltration basin, design a low flow orifice to allow base flow to pass through.

Adjust the storage depth so that the basin will completely drain the treated volume in 72 hours.

When using an infiltration basin for peak flow control, provide a minimum of 1 foot of freeboard above the 100-year design storm high water elevation.

Impoundment depths shall not exceed 15 feet and storage volumes shall not exceed 25 acre-feet.
Design earthen embankments with side slopes not steeper than 3:1 (horizontal to vertical).

Design basins to be placed outside the receiving stream except when a basin is designed as a regional detention basin and HWU has approved its use as a regional basin.

Reserve adequate access from public or private right-of-way by establishing a maintenance easement. Design the access to be at least 10 feet wide, with a slope not greater than 5:1 (h:v). Design the access way to connect to the embankment so that equipment can access the top of the embankment on a slope not greater than 5:1 (h:v).

**Specifications**

Embayment, outlet, and emergency spillway specifications are the same as those for detention basins.

Excavate the basin with light equipment having tracks or over-sized tires to minimize compaction of the underlying soils. After the basin is excavated to the final design depth, deeply till the basin floor with a rotary tiller or disc harrow to restore infiltration rates. After tilling, apply a leveling drag.

Establish vegetation immediately after achieving final grade and preparing the infiltration bed. Stabilize the floor of the basin with a dense cover of water-tolerant herbaceous species consistent with requirements of bioretention systems.

### 10.3.8 Vegetated Filter Strips

A vegetated filter is a practice that relies upon the use of vegetation to filter out sediment and other pollutants from stormwater runoff. These filters also provide an opportunity for stormwater runoff to infiltrate. Vegetated filters can be used as water quality devices. Vegetated filters can be used for small subareas of a larger development in order to reduce the total volume to be treated by other devices in the development.

A filter strip is a practice that relies upon sheet flow across the entire width of the vegetated area. The vegetation is typically grass; however, other ground cover can be used if it provides for dense vegetation. Filter strips are typically used at the edge of a parking lot or other paved surface.

**Design Criteria**

Design a filter strip to have a width matching the width of the area draining to the filter.

Design a filter strip to have a smooth transition with the area draining to it so that sheet flow can be developed across the filter.

Design filter strips to have a minimum slope of 2 percent and a maximum slope of 6 percent.

Provide a dense turf or other comparable vegetated ground cover over the whole filter area.
When the contributing area draining to the filter strip is impervious, do not allow the overland flow length of the impervious surface to exceed 75 feet.

When the contributing area draining to the filter strip is pervious, do not allow the overland flow length of the contributing surface to exceed 150 feet.

### 10.3.9 Riparian Buffers

Riparian buffers are vegetated zones of trees and/or shrubs adjacent to and upgradient from perennial or intermittent streams, lakes, ponds, and wetlands. In the ideal scenario, native riparian buffers would exist adjacent to all receiving waters. However, in many agricultural areas the native riparian buffer has been partially or fully removed to create pasture or cropland right up to the top of streambank. Existing riparian buffers will not be considered for storm water quality, but restoration or reforestation of altered riparian buffers will be given consideration.

**Design Criteria**

Design a plan for riparian buffer reforestation/revegetation in accordance with Ky. Division of Water Criteria.

A buffer zone planting plan must be included with the improvement plans. The plan shall also provide for maintenance of the buffer zone until such time as trees and shrubs are established and the upgradient drainage area is permanently stabilized.
10.4 SAND AND ORGANIC FILTERS

In general usage, stormwater filters are a diverse group of techniques for treating stormwater quality with each using some sort of filtering media such as sand, soil, gravel, peat, compost, or vegetation. Filters will include systems with a designed filter bed composed of sand, gravel, compost, or peat and an outlet to the stormwater drainage system or a receiving stream. Systems described in this section include: surface sand filters, underground sand filters, perimeter sand filters, and organic filters.

10.4.1 Applicability

Filters can be used for water quality treatment, but are not appropriate for peak flow (quantity) control.

10.4.2 General Design Criteria

Design criteria in this section apply to all filtration devices in this section.

Provide a pretreatment cell to allow sedimentation prior to the filter bed and reduce clogging.

Locate inlet and outlet structures at extreme ends of the pretreatment cell.

Design the pretreatment or sedimentation cell to have a minimum depth of 3 feet to minimize resuspension and turbulence.

Design the bottom of the pretreatment cell to be nearly level to facilitate sedimentation.

Design the surface area of the pretreatment cell (in square feet) to be at least 0.0081 times the treated volume (in cubic feet) for areas with 75 percent or more impervious surface. For areas with less than 75 percent impervious surface, design the surface area of the pretreatment cell (in square feet) to be at least 0.066 times the treated volume (in cubic feet). The order of magnitude difference in the two factors derives from the fact that areas with higher percentages of impervious surface (i.e., 75 percent or more) tend to have a greater proportion of coarse grained sediments, which have a higher settling velocity.

Size the pretreatment cell with a minimum length to width ratio of 2:1.

The length to width ratio of the pretreatment cell can be less than 2:1 if baffles are provided to obtain a flow length equivalent to or greater than would be obtained with a 2:1 ratio or if the pretreatment cell is part of a larger impoundment that would make the 2:1 ratio impractical.

Design each filtering device for a capture or storage volume equal to or greater than ¾ times the treated volume.

Design filtration systems to be off-line by using a flow-splitter or other device to divert flows in excess of the treated volume around the filtration systems.
Provide sufficient access to the device for construction and maintenance. Provide an access ramp with a maximum slope of 10 percent for vegetated ramps, 15 percent if the slope is stabilized with crushed stone, or 25 percent if paved.

Construct exposed piping and accessories out of durable, strong materials to avoid susceptibility to damage by vandalism.

Provide access manholes and/or grates to underground and below grade structures for each subsurface chamber. Provide manhole diameters of sufficient size to meet confined space access criteria by use of a portable extension ladder. Provide a 5-foot minimum height clearance (from the top of the sand layer to the bottom of slab) for all fixed permanent underground structures. Provide lifting rings or other suitable elements to lift and replace structure top slabs.

Construct the underground sand filter with a dewatering gate valve located just above the top of the sand filter bed. Should the filter bed and/or underdrain system clog completely, the gate valve can be opened to dewater the filter chamber for needed maintenance.

10.4.3 Surface Sand Filter

A surface sand filter is shown in Figure 10-5. This system is constructed of reinforced concrete with a pretreatment (sedimentation) chamber and a filter bed chamber with a sand filter and underdrain system. Figure 10-5 also shows a flow diversion chamber at the inlet end of the structure. The filter bed has an 18-inch to 24-inch sand layer which traps or strains pollutants before runoff is collected in an underdrain system (gravel and perforated pipe) and conveyed to the receiving stream, channel or pipe. The filter bed surface may have a sand or grass cover.

Surface sand filters are open at the top, which provides easy access for maintenance, but renders these unsuitable in areas easily accessible to the general public, especially small children. Control access to surface sand filters by enclosing them in an eight-foot chain link fence. Such a configuration is most suitable to industrial and warehousing facilities rather than commercial/retail establishments where aesthetic impact is significant. Even for industrial sites consider proximity to residential areas and other locations frequented by children.

**Design Procedures**

Size the pretreatment chamber in accordance with design criteria in 10.4.2.

Size the area of the filter bed using the following equation:

\[ A_f = \frac{WQV*(d_f)}{[k*(h_f + d_f)(t_f)]} \]

where:
- \( A_f \) = surface area of the sand filter bed (ft²)
- \( WQV \) = water quality treatment volume (ft³)
- \( d_f \) = sand filter bed depth (ft)
- \( k \) = coefficient of permeability for sand bed (ft/day)
- \( h_f \) = average height of water above the sand bed (ft); \( h_f = 0.5 \times h_{max} \)
\( t_f = \) time required for the WQV to filter through the sand bed (days).

Note:
- set \( d_f \) such that 1.5 feet \( \leq d_f \leq \) 2 feet
- \( h_f \) can vary depending on the site conditions, but six feet is the maximum value.
- Use 1.7 days (i.e., 40 hours) for the filter bed draw-down time \( (t_f) \).
- Use \( k = 3.5 \) ft/day.

Design the underdrain system beneath the filter bed to be at least six inches deep, with at least two inches of gravel over drain pipes and pipe slopes of at least 0.5 percent.

Design the underdrain system to ensure that the flow through rate of the filter bed is controlled by the filter media rather than the underdrain system.

Calculate the minimum volume which must be stored within the device as \( V_{min} = 75\% \) treated volume.

Compute the water volume within the filter bed as \( V_f = A_f * 0.35 * (d_f + d_u) \), where \( d_f \) is the depth of the sand bed and \( d_u \) is the depth of the gravel underdrain. The constant 0.35 represents the porosity of the sand and gravel. Figure 10-6 provides an illustration of the parameters used for calculating storage volume.

Compute the temporary storage volume above the filter bed as \( V_{f-temp} = 2 * h_f * A_f \).

Compute the remaining volume required for the pretreatment chamber as \( V_s = V_{min} - (V_f + V_{f-temp}) \). Check that \( V_s \) is approximately 50 percent of \( V_{min} \). If it is not, decrease \( h_f \) and recompute. Note that changing \( h_f \) will change the computed \( A_f \).

Calculate the height in the pretreatment chamber, \( h_s \), as \( h_s = V_s / A_s \).

Check that \( h_s \) is greater than \( 2 * h_f \) and \( h_s \) is greater than 3 feet. If not, adjust \( h_f \) and repeat computation.

Design a junction box flow splitter with either a pipe or weir overflow to the stormwater system. Set the invert of the overflow to the elevation of the design water level in the pretreatment chamber. Design the overflow to convey the peak discharge anticipated from the 10-year storm.

Design the structural concrete components in accordance with design loads and site soil conditions.

**Specifications**

Select sand to meet AASHTO M-6 or ASTM C-33 requirements for medium aggregate concrete sand with size range of 0.02 to 0.04 inches.
Select underdrain gravel to meet AASHTO classification M-43 with size range of 0.5 to 2 inches.

Select geotextile fabric to have a minimum puncture strength of 125 pounds (ASTM D-751), minimum mullen burst strength of 400 psi (ASTM D-1117), and minimum tensile strength of 300 pounds (ASTM D-1682). Geotextile fabric shall have an opening size equivalent to U.S. sieve size #80 and shall provide a minimum flow rate of 125 gallons/minute per square foot.

Select underdrain piping to meet AASHTO M-278 requirements for Schedule 40 PVC pipe. Provide 3/8-inch perforations on 6-inch centers with four holes per row.

Construct the base of the sand filter structure on undisturbed soil or rock. If disturbed soil must be used as a base, recompact it to 95 percent of maximum standard dry density in 6-inch compacted lifts.

Do not allow runoff to enter the sand filter bed until the upstream drainage area is completely stabilized and site construction is completed. The sedimentation pond may serve as a temporary sediment control pond during site construction with the provision that overflows will bypass the filtration bed.

Construct the top of the filter bed completely level.

Store materials which might be damaged during construction (such as perforated PVC piping, geotextiles, etc.) in a safe location and handle carefully.

Construct overflow weirs, multiple orifices and flow distribution slots completely level to ensure adequate distribution of design flows.

Construct the main collector pipe for underdrain systems at a minimum slope of 0.5 percent. Provide observation and clean-out pipes for all underdrain piping.

**10.4.4 Underground Sand Filter**

Underground sand filters are suitable for intensely developed urban areas where space is at a premium. These systems are also suitable in locations that are easily accessible to the public. Figure 10-7 shows an underground sand filter. In this design, the sand filter is placed in a three chamber underground vault accessible by manholes or grate openings. The first chamber is a 3-feet deep 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.
**Design Procedures**

Design procedures are consistent with those described previously for a surface sand filter with the following exceptions. See Figure 10-8 for an illustration of the volume parameters.

After computing the minimum volume which must be stored ($V_{\text{min}}$) and the volume in the filter bed ($V_f$), compute the minimum wet pool volume in the settling basin as $V_w = 3 \text{ ft} * A_s$.

Compute the temporary storage volume required within both chambers as $V_{\text{temp}} = V_{\text{min}} - (V_f + V_w)$.

Compute the total surface area of both chambers as $(A_f + A_s)$.

Calculate the height of temporary storage needed as $h_{\text{temp}} = V_{\text{temp}} / (A_f + A_s)$.

Check that $h_{\text{temp}}$ is greater than or equal to $2h_f$. If not, decrease $h_f$ and recalculate volume requirements.

**Specifications**

Specifications are consistent with those provided for surface sand filters with the following addition.

To help extend the design life of the sand filter bed for the underground sand filter, place a wide mesh geotextile screen on the surface of the filter bed to trap the large quantities of trash, litter, and organic detritus associated with highly urban areas. During maintenance operations the screen is rolled up, removed and cleaned, and reinstalled.

**10.4.5 Perimeter Sand Filter**

The perimeter sand filter consists of two parallel trench-like chambers that are typically installed along the perimeter of a parking lot. Figure 10-9 shows a perimeter sand filter. Parking lot runoff enters the first chamber that has a shallow permanent pool of water. The first trench provides pretreatment before the runoff spills into the second trench, 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 a bypass drop inlet.

**Design Procedures**

Design procedures are consistent with those described previously for a surface sand filter with the following exceptions. See Figure 10-10 for an illustration of the volume parameters.

After computing the minimum volume which must be stored ($V_{\text{min}}$) and the volume in the filter bed ($V_f$), calculate the minimum wet pool volume in the pretreatment basin as $V_w = A_s * 2 \text{ ft}$.

Calculate the temporary storage volume required as $V_{\text{temp}} = V_{\text{min}} - (V_f + V_w)$. 
Compute the total surface area of both chambers as \((A_f + A_s)\).

Check that \(h_{\text{temp}}\) is greater than or equal to \(2h_f\). If not, decrease \(h_f\) and recompute areas and volumes. Note that changing \(h_f\) will change the required \(A_f\).

**Specifications**
Specifications are consistent with those given for a surface sand filter.

**10.4.6 Organic Filters**

Organic filters are designed consistent with surface or underground filters except that the sand filter bed is replaced or modified with organic media. There are two basic options for organic filters: a peat-sand system and a compost system.

In the peat-sand system the filter bed is a minimum of 24 inches deep over the underdrain system. This 24-inch bed consists of a 6-inch sand layer overlain by an 18-inch layer of peat-sand mix.

The compost filter system consists of a fabricated leaf compost filtration bed overlying the underdrain system. The compost must be mature and humic so that the organic material is no longer rapidly decaying, and it must be locally available at a reasonable cost.

**Design Procedures**
Design procedures are consistent with those given previously for surface sand filters or underground sand filters except that the coefficient of permeability, \(k\), for the organic filter is modified. For a peat-sand system, use \(k = 2.75\) ft/day. For a compost system, use \(k = 8\) ft/day.

**Specifications**
For peat-sand filter beds, select a fibric peat that is shredded, uniform, and clean.

For peat-sand filter beds, combine equal volumes of peat and sand and mix to obtain uniform distribution of peat and sand. Sand specifications are given in Section 10.4.3.

For peat-sand filter beds, place a 6-inch layer of sand over the gravel underdrain. Separate the sand layer from the gravel layer with geotextile fabric. Select sand and geotextile consistent with specifications in Section 10.4.3. Above the 6-inch sand layer, place 18 inches of the 50/50 peat-sand mixture. Construct the filter bed so that the surface of each layer is level. Provide nominal compaction of the gravel and sand layers using a mechanical tamper. Do not compact the sand-peat layer.

For a compost filter bed, select compost that is mature and humic, composed of leaf medium rather than general yard waste compost.

For a compost filter bed, place a minimum of 18 inches above the geotextile overlying the underdrain system. Do not compact the compost filter bed.
10.5 PREFABRICATED TREATMENT DEVICES

Several manufacturers produce devices, which are effective in removing suspended solids and floating 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. The devices that have been approved for use include the Stormceptor, by Stormceptor Corporation, Vortechs System, by Vortechnics, and CDS Units.

10.5.1 Stormceptor

The Stormceptor is a vertically oriented stormwater separator that removes oil, sediment, and some other pollutants from urban runoff. It is designed to replace a manhole in a typical storm drain system, but it cannot be used as an inlet (with flow into top). The Stormceptor’s built-in by-pass features prevent trapped sediment from being flushed out during high intensity rainstorms. Figure 10-11 shows a typical Stormceptor.

Applicability
Stormceptors can be used to satisfy water quality treatment requirements that have not been satisfied by infiltration devices.

Design Criteria
Design Stormceptors in accordance with the manufacturer’s literature and specific requirements of this manual. In the case of apparent conflicts, requirements of this manual shall govern.

10.5.2 Vortechs System

The Vortechs Stormwater Treatment System is a horizontally oriented stormwater separator that removes oil, sediment, and some other pollutants from urban runoff. It is built of pre-cast concrete and designed to be installed below grade. The Vortechs System’s internal baffle design prevents trapped sediment from being washed out during large storms. Figure 10-12 shows a typical Vortechs System.

Applicability
Vortechs Systems can be used to satisfy water quality treatment requirements that have not been satisfied by infiltration practices.

Design Criteria
Design Vortechs Systems in accordance with the manufacturer’s literature and specific requirements of this manual. In the case of apparent conflicts, this manual shall govern.
10.6  DETENTION PONDS

A detention pond is a traditional stormwater quantity control device that is designed for peak discharge control. Detention ponds are designed to completely drain after the design storm passes. Figure 10-13 illustrates a detention pond.

10.6.1  Applicability

Detention ponds are not effective as water quality treatment devices and can only be used for water quantity control (i.e., detention).

10.6.2  Design Criteria

Design outlet structures so that detention volume is released within 24 hours.

Provide an emergency spillway sized to discharge the peak runoff from the 100-year storm assuming the principal spillway is clogged, without overtopping the crest of the pond.

Provide a minimum of 1 foot of freeboard above the calculated high water elevation for the 100-year design storm, assuming the principal spillway is not clogged.

Embankment heights shall not exceed 20 feet (measured from the downstream toe) and storage volumes shall not exceed 25 acre-feet. Regional facilities may exceed these limits, but they must comply with the applicable requirements of the Kentucky Division of Water.

Design earthen embankments with side slopes not steeper than 3:1 (horizontal to vertical).

Provide anti-seep collars where the spillway barrel passes through the embankment. Stabilize earthen embankments immediately with temporary or permanent vegetation.

Design ponds to be placed outside the receiving stream except when a pond is designed as a regional detention pond and HWU has approved its use as a regional pond.

Reserve adequate access from public or private right-of-way by establishing a maintenance easement. Design the access to be at least 10 feet wide and not steeper than 5:1 (h:v). Design the access way to connect to the embankment so that equipment can access the top of the embankment on a slope not steeper than 5:1 (h:v).

Outlet works may be a combination of pipes, weirs, and orifices and drop inlets, but design any outlet pipes to be at least 15 inches in diameter to facilitate maintenance.

Design ponds to have a minimum bottom slope of two percent with a pilot channel for low flow.

10.6.3  Design Procedures

Size the outlet structure for the maximum allowable peak discharge at the estimated peak stage.
Develop a stage-storage curve for the proposed pond.

Develop a stage-discharge curve for all outlet control structures.

Perform flood routing calculations using the post-development hydrographs determined for the design storms.

Design the emergency spillway to handle the 100-year peak discharge from the post-development hydrograph with no conveyance through the primary outlet structure.

Evaluate the downstream effects of detention outflow to ensure that the routed hydrograph does not adversely affect downstream flooding problems.

Evaluate the control structure outlet velocity and provide channel and bank stabilization if the velocities are greater than the natural stream velocities.

### 10.6.4 Material Specifications

Construct embankments of ML, CL, MH, or CH soils as determined in accordance with the Unified Soil Classification System (USCS).

Determine the maximum standard dry density (ASTM D698) of at least two distinct samples of the soils to be used for embankment construction.

All conduits used for principal spillways shall be reinforced concrete pipe (RCP). The conduits shall be sealed with rubber gaskets to form a flexible watertight seal under all conditions of service. All pipes shall meet the requirements set forth in the Kentucky Transportation Cabinet’s Standard Specifications for Road and Bridge Construction, latest edition. The Design Engineer shall be responsible for determining the size and grade of pipe to be used.

Anti-seep collars shall be provided on all conduits through earthen embankments, foundations, and abutments. The number and size of anti-seep collars shall be determined based on guidance set forth in the Kentucky Department for Environmental Protection, Division of Water’s Engineering Memorandum No. 5, Design Criteria for Dams and Associated Structures.

All stone shall meet the requirements set forth in the Kentucky Transportation Cabinet’s Standard Specifications for Road and Bridge Construction, latest edition.

Gradation of stone material will be performed in accordance with ASTM C-33. Tests shall be performed on every 5 tons of stone installed or at least once per installation location in locations where less than 5 tons are placed.

All geotextiles shall meet the requirements for performance and strength as set forth by the design engineer. Any alternative material used on the project shall be approved by the design engineer.
The following tests shall be performed and included in the manufacturer’s certifications for each shipment of geotextile or every 500 square yards (or once per lot if manufacturer’s records show multiple rolls came from same lot), whichever is less:

- Mass per unit area per ASTM D-5261
- Grab tensile strength per ASTM D-4632
- Trapezoidal tear strength per ASTM D-4533
- Burst Strength per ASTM D-3786
- Puncture strength per ASTM D-4833
- Thickness per ASTM D-5199
- Apparent opening size per ASTM D-4751
- Permittivity per ASTM D-4491
- Ultraviolet light resistance per ASTM D-4355

In the case that a more recent testing standard has been released, then that standard shall be used in lieu of the listed testing standards.

10.6.5 Construction Specifications

Verify areas to be backfilled are free of debris, snow, ice, or water, and ground surfaces are not frozen.

When necessary, compact subgrade surfaces to density requirements for the backfill material and prepare subgrade or previous layer of compacted fill prior to placement of additional fill by scarifying or diskig.

Cut out soft areas of subgrade not readily capable of in situ compaction. Backfill with subsoil and compact to density equal to requirements for subsequent backfill material.

Backfill areas to contours and elevations. Use materials that are not frozen. The Contractor shall keep the foundation and subgrade free from water or unacceptable materials after the fill operations have started.

Backfill systematically, as early as possible, to allow minimum time for natural settlement. Do not backfill over porous, wet, or spongy subgrade surfaces.

Place and compact soil fill materials in continuous layers not exceeding eight (8) inches loose depth. Compact soil fill materials to 95 percent of maximum dry density. Field density tests shall be performed on each lift. Areas that fail to meet the requirements will be reworked as necessary to meet the requirements and then tested again. This process shall be repeated until the compaction requirements are met.

Tests shall be performed on each 400 square feet of surface area and on each lift of the surface area. Maintain optimum moisture content of backfill material to attain required compaction density as specified. Material deposited on the fill that is too wet shall be removed or spread and permitted to
dry, assisted by disking or blading, if necessary, until the moisture content is reduced to the specified limits.

All crushed stone fill and crushed stone backfill under structures and pavements adjacent to structures shall be DGA crushed stone per Kentucky Highway Department Standard Specifications for Road and Bridge Construction, unless indicated otherwise. Stone fill and backfill materials shall be placed in layers not exceeding six (6) inches in thickness and compacted to 95 percent of maximum dry density.

Backfill shall not be placed against or on structures until they have attained sufficient strength to support all loads to which subjected without distortion, cracking, or damage. Deposit soil evenly around the structure.

Slope grade away from structures minimum two (2) inches in ten (10) feet, unless noted otherwise.

Make changes in grade gradual. Blend slopes into level areas.

Remove surplus excavation materials to designated areas.


The pipe trench shall be overexcavated six (6) inches and properly backfilled prior to laying pipe. In no case shall pipe be laid on solid or blasted rock.

Pipe bedding material shall be placed in six (6) inch loose lifts and compacted to 95 percent maximum dry density at ± 2 percent of the optimum moisture content.

When the subgrade is found to be unstable or to include ashes, cinders, refuse, organic material, or other unsuitable material, such material shall be removed to the depth ordered by the Design Engineer and replaced under the directions of the Design Engineer with clean, stable backfill material. When the bottom of the trench or the subgrade is found to consist of material that is unstable to such a degree that, in the judgment of the Design Engineer it cannot be removed, a foundation for the pipe and/or other appurtenance shall be constructed using piling, timber, concrete, or other materials as the direction of the Design Engineer.

All pipe shall be laid true to the lines and grades indicated on the Drawings. The pipe shall be laid straight between changes in alignment and at uniform grade between changes in grade. Pipe shall be fitted and matched so that when laid to grade, it will provide a smooth and uniform invert.

The pipe shall be thoroughly swabbed out to insure its being clean immediately prior to placement. Any piece of pipe or fitting which is known to be defective shall not be laid. If any defective pipe or fitting shall be discovered after the pipe is laid, it shall be removed and replaced with a satisfactory pipe or fitting.
The interior of the pipe, as the work progresses, shall be cleaned of dirt, jointing materials, and superfluous materials of every description. When laying of pipe is stopped for any reason, the exposed end of such pipe shall be closed with a plug fitted into the pipe bell so as to exclude earth or other material. Other precautions shall be taken to prevent flotation of pipe by runoff into trench.

All pipe shall be laid starting at the lowest point and installed so that the spigot ends point in the direction of flow.

All joint surfaces shall be cleaned immediately before jointing the pipe. The bell or groove shall be lubricated in accordance with the manufacturer’s recommendation. Each pipe unit shall then be carefully pushed into place without damage to pipe or gasket. All pipes shall be provided with home marks to insure proper gasket seating. Details of gasket installation and joint assembly shall follow the direction of the manufacturer’s of the joint material and of the pipe. The resulting joints shall be watertight and flexible. No solvent cement joints shall be allowed.

After the embankment has been built to final grade, scarify or till the top and side slopes to a depth of 6 inches to prepare a seed bed. Immediately seed and mulch with temporary or permanent seed according to the season.
10.7 EXTENDED DETENTION PONDS

In these standards an extended detention pond is a dry detention pond that is equipped with an outlet structure that provides extended detention time (typically 24 – 72 hours) for a specific water quality treatment volume. Figure 10-14 illustrates an extended detention pond.

10.7.1 Applicability

Extended detention ponds can be used for both water quality treatment and water quantity management.

In locations with continuous dry weather flow, an extended detention pond will tend to be continuously wet. In this instance, quantify the base flow so that the peak flow and water quality control structures can be designed accordingly.

10.7.2 Design Criteria

The minimum drainage area for extended detention ponds shall be 10 acres.

Design the extended detention outlet so that the design treatment volume requires at least 40 hours to discharge. This will provide an average extended detention time of approximately 24 hours and will ensure effective detention of storms producing less runoff than the treatment volume.

The design treatment volume is to be calculated to be 1.5 times the required treatment volume.

Design extended detention pond with two stages. The lower stage would be the extended detention pool sized for the design treatment volume. The upper stage would be larger in area and sized for storm peak control.

Design the bottom slopes with a two percent minimum slope to promote drainage.

When a base flow into the pond exists, design the lower stage as a wetland marsh. In this case, provide a permanent pool of 6 to 12 inches below the design treatment volume. See Section 10.9 for a list of wetland plants.

Provide an emergency spillway sized to discharge the peak runoff from the 100-year storm assuming the principal spillway is clogged.

Provide a minimum of 1 foot of freeboard above the 100-year design storm high water elevation.

Embankment heights shall not exceed 20 feet (measured from the downstream toe) and storage volumes shall not exceed 25 acre-feet. Regional facilities may exceed these limits, but they must comply with the applicable requirements of the Kentucky Division of Water.

Design earthen embankments with side slopes not steeper than 3:1 (horizontal to vertical).
Provide anti-seep collars where the spillway barrel passes through the embankment. Stabilize earthen embankments immediately with temporary or permanent vegetation.

Design ponds to be placed outside the receiving stream except when a pond is designed as a regional detention pond.

Reserve adequate access from public or private right-of-way by establishing a maintenance easement. Design the access to be at least 10 feet wide and not steeper than 5:1 (h:v) or less. Design the access way to connect to the embankment so that equipment can access the top of the embankment on a slope not greater than 5:1 (h:v).

10.7.3 Design Procedures

Design procedures for stormwater quantity and peak discharge control are the same for extended detention ponds and traditional dry detention ponds, except that the design treatment volume will be retained longer in the extended detention pond. To design the storm detention volume and peak control structure for an extended detention pond, follow the procedures given in section 10.6.3 and assume for design purposes that the elevation of the dry pond bottom corresponds to the elevation of the surface of the design treatment volume (i.e., the top of the extended detention pool).

Sand Filter Outlet

Figure 10-15 illustrates the outlet configuration that shall be used to regulate discharge of the extended detention pool.

To size this device pick a preliminary configuration and check it using the falling head permeability equation. Set $t$ equal to 24 hours and calculate $k$. If the calculated $k$ varies significantly from 3.543 ft/hr adjust the filter dimensions and recalculate.

The falling head equation is:

$$k = 2.303 \times (aL/At) \times \log (H/h)$$

where:
- $k =$ coefficient of permeability (ft/hr),
- $a =$ average surface area of extended detention pool (ft$^2$),
- $L =$ depth of sand (ft),
- $A =$ surface area of filter = width of sand layer * length of sand layer (ft$^2$),
- $t =$ time (hr),
- $H =$ height of water over the perforated pipe with full extended detention pool (ft), and
- $h =$ height of filter from the top of the perforated pipe to the top of the sand (ft).

Size the sand filter trenches relative to the underdrain pipe such that the sand filter controls the discharge rate rather than the drain pipe. Provide calculations demonstrating that the underdrain pipe will convey the design flow rate under gravity flow conditions.
10.7.4 Specifications

Specifications are the same as those provided in section 10.6.
10.8 WET PONDS

In this manual, wet pond refers to a basin designed for both water quality and water quantity management and which has a permanent pool. Figure 10-16 illustrates a wet pond.

10.8.1 Applicability

Wet ponds can be used for water quantity management and water quality treatment.

10.8.2 Design Criteria

Design retention ponds to have a contributing drainage area of at least 10 acres and a surface area of at least one-fourth of an acre.

When using a wet pond with a permanent pool for water quality control, size the permanent pool to at least equal the design treatment volume.

Design the permanent pool to have an average depth between 3 feet and 6 feet and a maximum depth of no more than 8 feet.

Design wet ponds to be wedge-shaped with the narrow end at the inlet and the wide end at the embankment.

Provide a minimum length to width ratio of 3:1 or provide gabion baffles to extend the flow path to a length that meets or exceeds the path that would be achieved using a 3:1 length to width ratio.

Provide irregular shorelines so that the permanent pool has a natural appearance.

Provide a 10-foot wide, 12-inch deep, underwater bench around the perimeter except at the embankment.

Provide safety benches at least 10 feet wide around the perimeter above the permanent pool. Design these benches to have a slope not greater than 10:1 (h:v).

Design a liner for the permanent pool using on-site soils or other materials. Document that the proposed soils are suitable for use as a liner by providing soil classification data (Unified Soil Classification System) and standard moisture-density data (proctor density test). Design soil liners to be at least 6 inches thick.

Provide an emergency spillway sized to discharge the peak runoff from the 100-year storm.

Provide a minimum of 1 foot of freeboard above the 100-year design storm high water elevation.
Embankment heights shall not exceed 20 feet (measured from the downstream toe) and storage volumes shall not exceed 25 acre-feet. Regional facilities may exceed these limits, but they must comply with the applicable requirements of the Kentucky Division of Water.

Design earthen embankments with side slopes not steeper than 3:1 (horizontal to vertical).

Provide anti-seep collars where the spillway barrel passes through the embankment. Stabilize earthen embankments immediately with temporary or permanent vegetation in accordance with requirements of erosion control regulations.

Design ponds to be placed outside the receiving stream except when a pond is designed as a regional detention pond.

Reserve adequate access from public or private right-of-way by establishing a maintenance easement. Design the access to be at least 10 feet wide and no steeper than 5:1 (h:v). Design the access way to connect to the embankment so that equipment can access the top of the embankment on a slope no steeper than 5:1 (h:v).

10.8.3 Design Procedures

Design of the stormwater detention volume and peak control structure for a wet pond is similar to procedures given for a traditional dry detention pond. The permanent pool is sized to match the design treatment volume, which allows for effective water quality treatment. For quantity control, the pond must have capacity to hold the stormwater detention volume above the permanent pool. That portion of the stormwater detention volume equal to the design treatment volume is called the extended detention volume. That volume must be discharged slowly to protect the receiving stream from increased flood frequency. See Figure 10-17.

Reverse Slope Pipe

This section describes the design procedure for sizing a reverse slope pipe to discharge that portion of the stormwater detention volume equal to the design treatment volume. Figure 10-17 illustrates a reverse slope pipe.

Select a pipe diameter, length, and material and use the energy equation to calculate the discharge. The energy equation can be written as:

\[ Q = \frac{A (2gH)^{0.5}}{(1 + K_e + K_b + K_c L)^{0.5}} \]

where:
- \( Q \) = discharge (ft\(^3\)/s),
- \( A \) = cross-sectional area of pipe (ft\(^2\)),
- \( g = 32.2 \) ft/s\(^2\),
- \( H \) = head above discharge end of pipe (ft\(^2\)),
- \( K_e \) = entrance loss coefficient,
- \( K_b \) = bend loss coefficient (0 for no bends),
- \( K_c \) = head loss coefficient for pipe, and
- \( L \) = pipe length (ft).
Assume that the design treatment volume is placed above the permanent pool and calculate the corresponding height above the permanent pool. This is the head value, H, corresponding to the treatment volume.

Calculate the discharge (Q) at 0.25-foot intervals from the top of the design treatment volume (extended detention pool) to the bottom of the extended detention pool (i.e., top of permanent pool).

Calculate the average discharge for each 0.25-foot increment by averaging the Q calculated at the top and bottom of each increment.

Use the stage-storage curve for the ponds to determine the storage volume in cubic feet corresponding to each 0.25-foot increment of depth.

Divide each incremental storage volume by its corresponding average discharge to calculate the time required for each incremental volume to be discharged through the selected pipe.

Sum the incremental discharge durations to determine if the total design treatment volume required 24 hours to discharge. If not, adjust the pipe size and recalculate.

10.8.4 Specifications

Specifications are the same as those provided in section 10.6.
10.9 CONSTRUCTED WETLANDS

Constructed wetlands can provide a very effective management measure for mitigation of pollution from runoff, 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 that is constructed to mitigate impacts to a natural wetland (per a Corps of Engineers permit) or a wetland that is constructed as part of a wastewater treatment system. In this regulation, a constructed wetland is a device constructed in accordance with the following criteria and procedures to treat and control stormwater.

10.9.1 Applicability

Constructed wetlands can be used for both water quality and water quantity management or for water quality only. For management of water quantity a wetland would be constructed much like a wet pond with a 6 to 12 inch deep permanent pool. The most important criteria in determining applicability of a constructed wetland is the existence of a base flow that can be used to supply the permanent pool.

10.9.2 Design Criteria

For water quality control, size the extended detention pool above the permanent pool equal to the design treatment volume.

Design the extended detention outlet so that at least 24 hours would be required to release the design treatment volume.

For storm water quantity control, determine the necessary detention volume, and design the peak control outlet consistent with the design criteria and design procedures for detention ponds in Section 10.6. The extended detention volume is a portion of the total detention volume rather than being an addition to it.

Size the surface area of the wetland according to procedures described in the following section.

Provide a sediment forebay. Design the forebay to be 4 to 6 feet deep and have a volume of at least 10 percent of the design treatment volume at the inlet to the constructed wetland.

Use a reverse slope pipe as the extended detention outlet and protect it from blockage using aggregate as shown in Figure 10-17.

Provide a micropool at the extended detention outlet so that the reverse slope outlet pipe can be placed 1 foot below the permanent pool surface. Design the micropool to be 4 to 6 feet deep with a volume of at least 10 percent of the treatment volume.

Provide a drain with a valve at the base of the micropool.
Design the permanent pool, with the exception of the sediment forebay and the outlet micropool, to be 3 to 12 inches deep with an average depth of 6 to 9 inches.

Design the grades in the constructed wetland so that the wetland will drain to the micropool at the outlet if the micropool is drained. Providing the ability to drain the wetland will facilitate maintenance and revegetation if necessary.

Design the wetland to have low marsh and high marsh in the permanent pool. Low marsh refers to a zone with 6 to 12 inches of permanent pool, while high marsh refers to a zone with zero to 6 inches of permanent pool. Design the wetland so that low marsh and high marsh each represent 35 to 45 percent of the total surface area. Design so that the total deep pool (i.e., the micropool plus the sediment forebay) represents 10 to 20 percent of the surface area.

Design the wetland to have a length-to-width ratio of at least 2:1.

Reserve adequate access from public or private right-of-way by establishing a maintenance easement. Design the access to be at least 10 feet wide and no steeper than 5:1 (h:v). Design the easement to provide access to the sediment forebay and the outlet micropool.

Check the velocity of design storm flows at the inlet to the wetland and provide a stable entrance to prevent erosion.

Design a planting plan that shows 40 to 50 percent of the shallow (12 inches or less) wetland planted with wetland vegetation. Table 10-2 provides a list of suitable varieties generally available in this region. Plan to include a minimum of three emergent wetlands species as the majority planting with at least three additional emergent species comprising the remaining planting.

10.9.3 Design Procedures

Use Table 10-3 to determine the minimum surface area required based upon the size of the watershed draining to the wetland. Values in Table 10-3 are based upon expected nitrogen and phosphorus loading rates in urban areas and the maximum loading per acre that a constructed wetland can effectively treat.

Procedures for sizing the reverse slope pipe outlet at the micropool are consistent with procedures for wet retention ponds given in Section 10.8.
### TABLE 10-2
NATIVE HERBACEOUS SPECIES SUITABLE FOR WET PONDS AND CONSTRUCTED WETLANDS

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Scientific Name</th>
<th>Water Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barnyard grass</td>
<td>Echinochloa crusgalli</td>
<td>transitional</td>
</tr>
<tr>
<td>Switch Grass</td>
<td>Panicum virgatum</td>
<td>transitional</td>
</tr>
<tr>
<td>Swamp Milkweed</td>
<td>Asclepias incarnata</td>
<td>transitional</td>
</tr>
<tr>
<td>Giant Cane</td>
<td>Arundinaria gigantea</td>
<td>transitional</td>
</tr>
<tr>
<td>Jewelweed</td>
<td>Impatiens capensis</td>
<td>transitional</td>
</tr>
<tr>
<td>River oats</td>
<td>Chasmanthium latifolia</td>
<td>transitional</td>
</tr>
<tr>
<td>Deertongue</td>
<td>Panicum clandestinum</td>
<td>transitional</td>
</tr>
<tr>
<td>Boneset</td>
<td>Eupatorium perfoliatum</td>
<td>transitional</td>
</tr>
<tr>
<td>Sedges</td>
<td>Carex spp.</td>
<td>shallow</td>
</tr>
<tr>
<td>Soft rush</td>
<td>Juncus effusus</td>
<td>shallow</td>
</tr>
<tr>
<td>Rice cutgrass</td>
<td>Leersia oryzoides</td>
<td>shallow</td>
</tr>
<tr>
<td>Flat sedges</td>
<td>Cyperus spp.</td>
<td>shallow</td>
</tr>
<tr>
<td>Blue iris</td>
<td>Iris virginicus</td>
<td>shallow</td>
</tr>
<tr>
<td>Panic grass</td>
<td>Panicum agrostoides</td>
<td>shallow</td>
</tr>
<tr>
<td>Wool grass</td>
<td>Scirpus cyperinus</td>
<td>shallow</td>
</tr>
<tr>
<td>Pink smartweed</td>
<td>Polygonum pennsylvanica</td>
<td>shallow</td>
</tr>
<tr>
<td>Green bulrush</td>
<td>Scirpus atrovirens</td>
<td>mid</td>
</tr>
<tr>
<td>Pickerelweed</td>
<td>Pontedeca cordata</td>
<td>mid</td>
</tr>
<tr>
<td>Duck potato</td>
<td>Sagittaria latifolia</td>
<td>mid</td>
</tr>
<tr>
<td>Arrow arum</td>
<td>Peltandra virginica</td>
<td>mid</td>
</tr>
<tr>
<td>Bur-reed</td>
<td>Sparganium euryacarpum</td>
<td>mid</td>
</tr>
<tr>
<td>Wild rice</td>
<td>Zinzania aquatica</td>
<td>mid</td>
</tr>
<tr>
<td>Spike rushes</td>
<td>Eleocharis spp.</td>
<td>mid</td>
</tr>
<tr>
<td>Water plantain</td>
<td>Alisima subcordatum</td>
<td>mid</td>
</tr>
<tr>
<td>Three square sedge</td>
<td>Scirpus americanus</td>
<td>mid</td>
</tr>
<tr>
<td>Yellow water crowfoot</td>
<td>Ranunculus flabellaris</td>
<td>deep</td>
</tr>
<tr>
<td>White water buttercup</td>
<td>Ranunculus longirostris</td>
<td>deep</td>
</tr>
<tr>
<td>Water lotus</td>
<td>Nelumbo lutea</td>
<td>deep</td>
</tr>
<tr>
<td>Spaderdock</td>
<td>Nuphar luteum</td>
<td>deep</td>
</tr>
<tr>
<td>White water lily</td>
<td>Nymphaea tuberosa</td>
<td>deep</td>
</tr>
<tr>
<td>Duckweed</td>
<td>Lemna spp.</td>
<td>floating</td>
</tr>
</tbody>
</table>

**Note:** transitional = seasonally flooded edge; shallow = 0 – 6 inches, semi-flooded pool; mid = 6 – 20 inches, permanent pool; deep = 20 – 60 inches, permanent pool; floating = non rooted
### TABLE 10-3
WETLAND SURFACE AREA

<table>
<thead>
<tr>
<th>% Impervious Surface</th>
<th>Surface Area in Acres per Acre of Watershed</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>0.025</td>
</tr>
<tr>
<td>20</td>
<td>0.031</td>
</tr>
<tr>
<td>30</td>
<td>0.037</td>
</tr>
<tr>
<td>40</td>
<td>0.042</td>
</tr>
<tr>
<td>50</td>
<td>0.049</td>
</tr>
<tr>
<td>60</td>
<td>0.055</td>
</tr>
<tr>
<td>70</td>
<td>0.060</td>
</tr>
<tr>
<td>80</td>
<td>0.066</td>
</tr>
<tr>
<td>90</td>
<td>0.072</td>
</tr>
<tr>
<td>100</td>
<td>0.078</td>
</tr>
</tbody>
</table>

**Note:** Use linear interpolation for percent impervious values between those given in the table.
STORMWATER MANUAL
FIGURE 10-1
BIORETENTION SYSTEM

MAINTAIN LEVEL SECTION
PEA GRAVEL/GRASS INTERFACE

SLOTTED CURB
INFLOW POINTS

6" DROP @ CURB
OPENING (TYP.)

ASPHALT PAVING

RUNOFF

SHEET FLOW

PLANT MATERIAL

BIORETENTION
AREA

UNDERDRAIN
SYSTEM
CLEAN-OUTS

PONDING
LIMITS

OVERFLOW STORM DRAIN
INLET (ABOVE MAX.
PONDING DEPTH)

SHALLOW PONDING
AREA – 6" DEPTH MAX.

PEA GRAVEL CURTAIN DRAIN
FOR OVERFLOW
MIN. WIDTH OF 8"

8" DEEP PEA GRAVEL UNDERDRAIN WITH
COLLECTOR PIPES TO STORM DRAINAGE
SYSTEM OR RECEIVING WATERS

4" DIA. PERFORATED PVC PIPE IN
UNDERDRAIN SYSTEM CONNECTED TO
SOLID PIPE TO STORM DRAINAGE SYSTEM

4" OF PEA GRAVEL OVER PIPE

12" SAND BED

MULCH LAYER

4' MIN.
PLANTING SOIL BED

4:1 V MAX.
SLOPE

AT SOIL/SAND INTERFACE,
ROTO-TILL APPROX. 6" OF
SAND/SOIL TO
AVOID A SHARP EDGE
PROVIDE 3" MIN. DROP TO SOIL SURFACE SO THAT GRASS BUILDUP DOES NOT BLOCK CURB CUT

ASPHALT PAVING

MIN. AREA TO BE PROTECTED BY SOD

RUNOFF

5' MIN

ELEVATION VIEW
N.T.S.

24"

12"

6"

3" MIN. DROP TO SOIL SURFACE

ISOMETRIC VIEW
N.T.S.
NOTE:
If longitudinal slope exceeds 2 percent, construct a berm at the downstream end of biofiltration swale. Construct berm so that it is 12 to 18 inches high in center with a level top across the planting bed. Construct the berm to have side slopes no greater than 2 horizontal to 1 vertical.
NOTE: STRUCTURAL CONCRETE DESIGNED FOR LOAD AND SOIL CONDITIONS.

MINIMUM WATER QUALITY TREATMENT VOLUME ($V_{\text{min}}$)

OVERFLOW WEIR OR PIPE

INFLOW SLOTS

INFLOW PIPE

SEDIMENT TRAP

PERFORATED PVC STANDPIPE WITH LOW FLOW ORIFICE

FLOW DISTRIBUTION VAULT AND OVERFLOW WEIR (1' MIN. DEPTH)

DEPTH OF SEDIMENT CHAMBER (3' min.) ($h_r$)

DRAWDOWN TIME = 24 HR

BYPASS WEIR

TEMP. STORAGE OVER SAND BED (2$h_r$)

18"–24" SAND BED ($d_s$)

GRavel BLANKET UNDERDRAIN PIPE AT 0.5% MIN. SLOPE

SOURCE: CLAYTOR AND SCHUELER, 1996
$V_{\text{TOTAL}} = V_s + V_{f-temp} + V_f$

CHECK THAT $V_{\text{TOTAL}} \geq V_{\text{MIN}} = 0.75 \times \text{WQV}$

SOURCE: CLAYTOR AND SCHUELER, 1996
(3) - 30" MANHOLE OPENINGS WITH MH STEPS TO BOTTOM (TYP.)

SAND FILTRATION BED CHAMBER

OVERFLOW WEIR

DIVERTED RUNOFF (WQV) ONLY

OUTLET CHAMBER

PLAN

(3) 6" PERFORATED PVC COLLECTION PIPES (EQUALLY SPACED) IN 8" GRAVEL BED

MINIMUM WATER QUALITY TREATMENT VOLUME \( V_{\text{min}} \)

(ALUMINUM ACCESS DOORS)

INFLOW

FREEBOARD

5' MIN. HEIGHT CLEARANCE

OVERFLOW WEIR

RVC - CLEANOUT STANDPIPE (NO - PERFORATIONS)

STORAGE OVER SAND BED & ABOVE WET POOL (2x\( h_r \))

OUTLET TO STORM DRAIN SYSTEM

GATE VALVE FOR DEWATERING

NOTE: STRUCTURAL CONCRETE DESIGNED FOR LOAD AND SOIL CONDITIONS

1" FILTER GRAVEL ABOVE FILTER FABRIC

11" GRAVEL/PIPE UNDERDRAIN (6" PERFORATED PVC) FILTER CLOTH

24" SAND BED (\( h_r \))

SECTION A-A

SOURCE: CLAYTOR AND SCHUELER, 1996
PLAN

SECTION

\[ V_{\text{TOTAL}} = V_w + V_{\text{temp}} + V_t \]

CHECK THAT \( V_{\text{TOTAL}} \geq V_{\text{MIN}} = 0.75 \times WQV \)

SOURCE: CLAYTOR AND SCHUELER, 1996
CAST-STEEL GRATE-INLET OPENINGS

PROVIDE 2 ALUMINUM ACCESS DOORS/100' LENGTH A

OVERFLOW BYPASS WEIR

PROVIDE MULTIPLE OUTLETS 5' CENTERS TO AVOID CLOGGING POTENTIAL

EQUALLY SPACED SLOTS FOR INTAKE TO SAND BED

SAND FILTRATION BED CHAMBER

UNDERDRAIN/OUTLET SYSTEM

PLAN

SEGMENTED PRE-CAST LIDS WITH LIFTING RINGS

OVERFLOW BYPASS WEIR

REMOVABLE STEEL GRATE-INLET

PAVING

WET SEDIMENTATION CHAMBER 2' DEEP

LIFTING RINGS

2 ALUM. ACCESS DOORS/100'

OVERFLOW BYPASS WEIR

REMOVABLE STEEL GRATE-INLET

MINIMUM WATER QUALITY TREATMENT VOLUME

TEMPORARY STORAGE OVER SAND BED AND ABOVE WET POOL (2xh_1)

18" SAND BED (d_s)

4" PERF. PVC IN 6" GRAVEL BED

MANIFOLD COLLECTION PIPE (NOT PERFORATED)

FILTER FABRIC

SECTION A-A

SOURCE: CLAYTOR AND SCHUELER, 1996
STORMWATER MANUAL

FIGURE 10-10

PERIMETER SAND FILTER SCHEMATIC

PLAN

SECTION A-A

\[ V_{\text{TOTAL}} = V_w + V_{\text{temp}} + V_f \]

CHECK THAT \( V_{\text{TOTAL}} \geq V_{\text{MIN}} = 0.75 \times \text{WQV} \)

SOURCE: CLAYTOR AND SCHUELER, 1996
STORMWATER MANUAL

FIGURE 10-11

DETECTION POND

PLAN VIEW

DETENTION TIME: 24 HOURS
MAX. TOTAL DETENTION VOLUME = 25 ACRE-FEET

PROFILE VIEW

2% OR GREATER SLOPE FOR DRAINAGE

STORMWATER STORAGE

MINIMUM 25 FOOT BUFFER

ACCESS ROAD FOR MAINTENANCE

EMERGENCY SPILLWAY

SIDE SLOPES 3H:1V MAX

EMBANKMENT

STABILIZED OUTLET

BARRIER

LOW FLOW CHANNEL

STABILIZED INLET

RISER

3H:1V MAX. SLOPE

ANTIM SEEP COLLARS

MAX. SLOPE

OUTFLOW

20' MAX.
STORMWATER MANUAL

FIGURE 10-12
EXTENDED DETENTION POND

PLAN VIEW

STABILIZED INLET

TOP STAGE (NORMALLY DRY, MAINTAINED AS MEADOW)

SAND FILTER OUTLET

BOTTOM STAGE

SIDE SLOPES 3H:1V MAX

EMBANKMENT

STABILIZED OUTLET

MINIMUM 25 FOOT BUFFER

ACCESS ROAD FOR MAINTENANCE

EMERGENCY SPILLWAY

DETENTION TIME: 24 HOURS
MAX. TOTAL DETENTION VOLUME = 25 ACRE- FEET

PROFILE VIEW

INFLOW

TOP STAGE (NORMALLY DRY) STORMWATER STORAGE

2% OR GREATER SLOPE FOR DRAINAGE

BOTTOM STAGE SIZED FOR WQV LESS CREDIT FOR OTHER MEASURES

RISER

MAX SLOPE

3H:1V MAX SLOPE

ANTI SEEP COLLARS

OUTFLOW

20' MAX.
EXTENDED DETENTION OUTLET SHOWING SAND FILTER

PLAN VIEW
N.T.S.

TYPICAL SECTION
N.T.S.

OPEN CHANNEL

INLET TO BASIN STABILIZED DOWN TO THE DEWATERING ELEVATION OR LOWER

PRINCIPAL SPILLWAY

RISER

SOLID-WALLED PIPE THROUGH EMBANKMENT

STABILIZED OUTLET

VALVE

EMERGENCY SPILLWAY

SAND FILTERS (LENGTH AND NUMBER OF BRANCHES MAY VARY)

9" MINIMUM DEPTH OF CLEAN SAND

3" MINIMUM DEPTH OF KTC NO. 57 STONE

10" MINIMUM

4" DIA. PERFORATED PVC PIPE

6" MINIMUM DEPTH OF KTC NO. 57 STONE

H' IN CALCULATIONS

GEOTEXTILE

H' IN CALCULATIONS
PLAN VIEW

10' SAFETY BENCH

EXTENDED DETENTION OUTLET SIZED CONSISTENT WITH REVERSE - SLOPE PIPE PROCEDURE

TOTAL STORMWATER DETENTION VOLUME

EXTENDED DETENTION VOLUME = WQV

3H:1V MAX. SLOPE
PEAK CONTROL ORIFICE
RISER WITH TRASH HOOD

10' MIN.

SAFETY BENCH MAX. SLOPE 10H:1V, MIN. WIDTH 10'

PROFILE VIEW

SEDIMENT FOREBAY PLANTED AS MARSH

MAXIMUM VOLUME = 25 ACRE-FeET

DRAIN PIPE WITH VALVE TO ALLOW DewaterING OF PERMANENT POOL

GRAVEL TO PROTECT DRAIN PIPE FROM CLOGGING

EMBANKMENT

BARREL

STABILIZED OUTLET

STABILIZED INLET

FOREBAY 10' AQUATIC BENCH WEDGE-SHAPED PERMANENT POOL

EMERGENCY SPILLWAY

EMBANKMENT

ANTI SEEP COLLARS

WET POND

STORMWATER MANUAL

FIGURE 10-14
CHAPTER 12

MAINTENANCE MANUAL
FOR
STORMWATER BEST MANAGEMENT PRACTICES
CHAPTER 12
MAINTENANCE MANUAL
FOR
STORMWATER BEST MANAGEMENT PRACTICES

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APPENDICES

Appendix 12A – Inspection Checklists

12-A-1
12.1 INTRODUCTION

This manual for maintaining BMPs has been developed as a part of Henderson’s watershed management program. The manual includes

- a brief discussion of each BMP.
- a listing of the mechanisms used to protect water quality.
- a listing of the maintenance required.
- a listing of the inspection required.

The manual also includes a checklist for use in inspection of each practice or type of practice. The completed checklists will be placed in the HWU Geographical Information System (GIS) as data tables associated with the location of each BMP.

Responsibilities for maintaining BMPs are covered in Chapter 1 of this manual. Inspection of BMPs will be the responsibility of HWU unless specifically indicated otherwise in writing.
12.2 DRY DETENTION POND

12.2.1 Description

An area used to detain stormwater for a relatively short period of time to reduce downstream peak discharge rates. The area should go dry between storms. This is the traditional type of detention system used in “drainage” programs for many years to help provide flood protection. Any sediment that collects in the bottom of the basin reduces the capacity for flood control.

12.2.2 Pollutant Removal Mechanisms

Settling or sedimentation of larger, heavier particles is the primary mechanism. In some systems, limited infiltration may occur.

12.2.3 Operation, Maintenance, and Inspection

Operation
Successful operation depends on maintaining the storage volume, the discharge rate, and, in many cases, the system’s infiltration capability.

Maintenance
Activities necessary to maintain the functioning of a dry detention system include:

- Frequent removal of accumulated solids, debris, and litter from the detention area, especially from the low flow channel. Sediments should be removed when they are dry and have cracked, separating from the bottom and vegetation.
- Removal of debris from vegetated area to prevent damage to vegetation and to maintain visual appearance.
- Removal of debris from the bottom of the pond to reduce clogging of outlet structures, trash racks, and other mechanical components.
- Mowing.
- Removal of vegetation, such as small trees, which can damage the embankment.
- Vegetative stabilization of eroding sides or bottom.

Inspection
Inspections are necessary to assure proper discharge, prevention of soggy bottoms, assure healthy vegetative growth, and to monitor accumulation of sediments. Inspections should include the following:

- Obstructions of the inlet or outlet devices by trash and debris.
- Excessive erosion or sedimentation.
- Cracking or settling of the dam.
- Low spots in the bottom of an extended detention facility.
- Deterioration of pipes.
- Condition of the emergency spillway.
• Stability of the side-slopes, up and downstream channel conditions.
• Signs of vandalism.
12.3  DRY EXTENDED DETENTION POND

12.3.1 Description

A dry detention system with 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 systems may be designed as either on-line or off-line facilities. 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. To improve stormwater treatment, the second stage can be designed and managed as a shallow marsh.

12.3.2 Pollution Removal Mechanisms

- Settling or sedimentation, especially of larger, heavier particles and some smaller particles, is the primary mechanism.
- Plant uptake and bacterial activity in two-stage systems with a shallow marsh.
- In some systems, limited infiltration may occur.

12.3.3 Operation, Maintenance, and Inspection

Operation
Successful operation depends on maintaining the storage volume, the discharge rate, and, in many cases, the system’s infiltration capability.

Maintenance
Activities necessary to maintain the functioning of a dry extended detention system include:

- Frequent removal of accumulated solids, debris, and litter from the detention area, especially the low flow channel if included. Sediments should be removed when they are dry and have cracked, separating from the bottom and vegetation.
- Removal of debris from the control device since it typically will have a small orifice.
- Mowing and removal of vegetation. The use of low growing, native grasses is recommended to minimize mowing frequency.
- Irrigation and fertilizing, which should only be used when necessary.
- Vegetative stabilization of eroding sides or bottom.
- Management of aquatic plants if portions of the basin have been designed as a constructed wetland.

Inspection
Inspections are necessary monthly and after large storms to assure proper discharge, prevention of soggy bottoms, assure healthy vegetative growth, and to monitor accumulation of sediments. Inspections should include the following:

- Obstructions of the inlet or outlet devices by trash and debris.
- Excessive erosion or sedimentation.
- Cracking or settling of the dam.
- Low spots in the bottom of an extended detention facility.
- Deterioration of pipes.
- Condition of the emergency spillway.
- Stability of the side-slopes, up and downstream channel conditions.
- Signs of vandalism.
12.4 WET DETENTION POND

12.4.1 Description

A detention system with a permanent pool of water which is completely or partially displaced by stormwater from the contributing drainage area. Water is temporarily stored before gradually discharging it. A wet detention system is essentially a small lake with rooted wetland vegetation in the littoral zone.

12.4.2 Pollutant Removal Mechanisms

- Settling or sedimentation.
- Chemical flocculation, which occurs when heavier sediment particles overtake and coalesce with smaller, lighter particles to form a still larger particle.
- Dissolved stormwater pollutants are reduced by a variety of biological processes including filtering, adsorption onto bottom sediments, uptake by aquatic plants including algae, and metabolism by microorganisms inhabiting bottom sediments and aquatic plants.
- Removal of stormwater pollutants primarily occurs during the relatively long quiescent period between storm.

12.4.3 Operation, Maintenance, and Inspection

Operation
Successful operation depends on good design, construction, and maintenance, especially of the discharge structure and littoral zone vegetation.

Maintenance
Activities necessary to maintain the functioning of wet detention system can be broken down into two categories: routine and corrective.

Specific routine maintenance activities include:

- Grass mowing and removal from side slopes and the embankment.
- Removal of trees, brush, and animal burrows from the embankment.
- Vegetative cover stabilization to prevent erosion of side slopes and the embankment.
- Removal and disposal of trash and debris, especially from inlet or outlet structures.
- Monitoring and periodic removal of nuisance species in the littoral zone.
- Thinning and transplanting of thriving littoral zone plants as needed to maintain good growth throughout the littoral zone.
- Monitoring for mosquitoes and introduction of natural predators as needed.
- Monitoring of sediment accumulations in forebays or in the pond bottom.
- Monitoring of channel erosion in downstream conveyances.
Specific corrective maintenance activities include:

- Pond dewatering and removal of accumulated sediments. The frequency will depend on a variety of factors including use of pretreatment BMPs or forebays, contributing drainage area, land use, 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.
- Structural repairs to inlets, outlets, or discharge structure, including the emergency spillway.
- Repairs to the dam, embankment, or slopes to prevent erosion or piping.
- Repairs to fences, if applicable.

**Inspection**

Inspections are necessary monthly and after large storms to assure proper discharge, monitor accumulations of trash and debris, monitor sediment accumulations in forebays or inlets, and determine mowing or vegetation removal needs, and determine health of littoral zone vegetation. Inspections should include the following:

- Obstructions of the inlet or outlet devices by trash and debris.
- Excessive erosion or sedimentation.
- Cracking or settling of the dam.
- Low spots in the bottom of an extended detention facility.
- Deterioration of pipes.
- Condition of the emergency spillway.
- Stability of the side-slopes, up and downstream channel conditions.
- Signs of vandalism.

Monitor pond sediment accumulations annually. This can be done by coring, installation of a permanent measuring device such as a “yardstick,” or even by mapping the pond bathymetry in larger ponds.
12.5 CONSTRUCTED WETLANDS

12.5.1 Description

A runoff storage and treatment area constructed in uplands which is vegetated with aquatic macrophyte plants native to the area. These systems attempt to incorporate properties of natural wetlands such as shallow, sheet flow through dense, diverse assemblage of wetland plants which also serve as habitat for microorganisms.

12.5.2 Pollutant Removal Mechanisms

- Settling or sedimentation.
- Adsorption to sediments, vegetation, or detritus
- Filtration by plants.
- Microbial uptake and/or transformations.
- Uptake by wetland plants or algae.
- Extended detention.
- Removal of stormwater pollutants primarily occurs during the relatively long quiescent period between storms.

12.5.3 Operation, Maintenance, and Inspection

Operation
Successful operation depends on good design, construction, and maintenance, especially of the sediment forebays, wetland vegetation, and the discharge structure.

Maintenance
Activities necessary to maintain the long term functioning of a constructed wetland system include the following:

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

Inspection
• Inspect quarterly and after large storms to assure proper discharge, monitor accumulations of trash and debris, monitor sediment accumulations in forebays or inlets, and determine mowing or vegetation removal needs, and determine health of wetland vegetation.

• Closely monitor the wetland plant community, both during the growing season and, if needed, during the dry season, to assure healthy growth of desired plants. Remove exotic or nuisance species as soon as they appear to limit their establishment and extent of propagation. Thin or transplant plants from areas where they are growing densely and use them to further establishment or growth in areas with less vigorous plant growth.

• Monitor sediment accumulations in forebays semiannually. Sediments should be removed when 25% of the storage volume of the forebay has been lost.
12.6 BIOFILTRATION PRACTICES

12.6.1 Description
Biofiltration is a term used to describe the generally simultaneous processes of filtration, infiltration, adsorption, ion exchange, and biological uptake of pollutants from runoff as it flows through a vegetated stormwater management system. Biofiltration practices include vegetated swales, filter strips, and bioretention areas. Swales are conveyances where the flow passes through vegetation at some specified depth. Filter strips are broad surfaces which receive flow as a well distributed thin sheet. Bioretention practices capture sheet flow from impervious surfaces and treat it by infiltration, filtration, plant uptake, and microbial processes as the runoff flows through native forest or landscaped areas.

12.6.2 Pollutant Removal Mechanisms
- Infiltration, ion exchange, and adsorption
- Settling
- Vegetative filtration and uptake
- Microbial action
- The degree to which the various pollutant removal mechanisms operate depends on soil properties, condition and types of plants, depth, water velocity, slope, and residence time.

12.6.3 Operation, Maintenance, and Inspection

Operation
Successful operation depends proper design, especially estimation of hydraulic resistance times and infiltration rates, proper construction and regular maintenance.

Maintenance
Activities necessary to maintain the functioning of biofiltration practices include:

- Vegetation removal to maintain adequate hydraulic functioning. Biofilter turf grass height should not exceed six inches nor be less than two inches. Excessively long grass can flatten when water flows over it, preventing sedimentation. Additionally, if not removed, decaying vegetation could release captured nutrients and other pollutants.
- Frequent removal of accumulated solids, debris, and litter. Sediments should be removed when they reach 20 % of the design depth in any spot, cover or hinder the growth of vegetation, or otherwise interfere with the operation. Maintenance workers should give special attention to sediment accumulation in the upper portion of swales after major storm events. Sediment and large debris should be removed from biofilters at least twice annually and more frequently if needed.
- Vegetative stabilization of eroding sides or bottom, or of bare areas created when removing sediments. Fertilizer use should be minimized. Vegetation should be
maintained and replanted early enough in the growing season so that it is well established before the rainy season or before the prime growing period ends.

- If swale blocks are used to promote infiltration or sedimentation, special attention needs to be paid to their maintenance. Sediments need to be carefully removed without damaging the swale block or its associated vegetation.

- If curb cuts are used as inflows to biofilters, sediments and vegetation growths should be removed from the curb cut when they begin to interfere with the inflow.

- Roadside shoulder scraping and ditch cleaning should be based on hydraulic necessity, not simply a timed schedule. When these operations are performed, only the amount of sediment to restore hydraulic capacity should be removed. More importantly, the shoulder and swale should be revegetated immediately to minimize erosion and restore treatment effectiveness. Operations should be done in the dry season.

**Inspection**

Inspect semiannually and, when possible, after large storms to assure proper flow, vegetative growth, and to monitor accumulation of sediments, trash, and debris.
12.7 INFILTRATION PRACTICES

12.7.1 Description
A family of practices in which the “treatment volume” is infiltrated into the soil rather than discharged off-site. Infiltration practices include basins and dry wells.

12.7.2 Pollutant Removal Mechanisms

The primary “treatment” mechanism is the infiltration and evaporation of runoff. This reduces the total volume of stormwater leaving the site, thereby reducing the total pollutant loading. Ancillary benefits of reducing stormwater volume include a decrease in stream channel erosion and loss of stream habitat.

Pollutant removal occurs as runoff passes through the soil profile and/or the vegetation root mass. Pollutants are trapped, bound, or decomposed in the vegetation, its roots, and in the spaces between the soil particles, while runoff passes into the ground. Soils must have an appropriate infiltration rate, contain sufficient organic matter, and maintain aerobic conditions to minimize migration of pollutants into the ground water.

12.7.3 Operation, Maintenance, and Inspection

Operation
Infiltration practices all depend on the ability of stormwater to pass through the vegetation and soil into the ground. Therefore, long term operation of the practice depends on maintaining its permeability.

Maintenance
Maintenance activities will include:

- Removal of accumulated solids
- Mowing and removal of vegetation
- Vegetative stabilization of eroding sides or bottom
- Rototilling, diskng, or aerating the bottom or bottom vegetation
- Clearing materials that have accumulated in the discharge structure
- Cleaning pretreatment BMPs (i.e., swales, sediment sumps) so they can continue to protect the infiltration practice.

Inspection

- Inspect the facility semiannually (just before the wet season and at the end of it) and after large storms. If there is still water in the BMP after 72 hours (or after 24-36 hours for vegetated systems), it is time to clean it and restore its percolation capacity. Cleanout frequency will depend on whether the practice is on-line or off-line, vegetated or not vegetated, its design storage capacity, sediment loading, and use of pretreatment BMPs.
- Eroding sides or bottoms need to be revegetated as soon as possible
- Revegetated the contributing area where needed to stabilize and reduce generation of particulates
12.8 MODULAR PAVEMENT

12.8.1 Description
Pavement consisting of strong structural materials having regularly interspersed void areas which are filled with pervious materials such as sand, gravel, or sod. Generally used in low-volume traffic areas such as the outer parts of parking lots or in parking lots serving parks or recreational areas.

12.8.2 Pollutant Removal Mechanisms

- Percolation of rainfall and runoff through the voids into the underlying permeable base and then into the soil.
- Filtration of rainfall and runoff by the vegetation that can grow in the voids.

12.8.3 Operation, Maintenance, and Inspection

Operation
Successful operations depend on maintaining the percolation rate of the void spaces and the underlying base and soils. Keys to assuring long-term performance are accurate estimation of the soil’s percolation rate, proper construction, and regular maintenance.

Maintenance
Activities necessary to maintain the performance of modular pavements include:

- “Good housekeeping” practices by the users to minimize the production and transport of sediment onto the modular pavement. This includes vegetative stabilization of adjacent areas which may erode and become a source of sediments.
- Replacement of base and underlying soils if they become clogged and water ponding persists.
- When turf is incorporated into the installation, normal turf maintenance will be necessary. However, mowing is seldom required in areas of frequent traffic and fertilizers and pesticides should be used sparingly since this may adversely affect concrete products and groundwater.

Inspection
- All modular pavements should be inspected several times in the first few months after construction to assure that they are working correctly and were installed properly. Inspections should be conducted after storms to check for long duration surface ponding that may indicate local or widespread clogging.
12.9 STORMWATER FILTERS

12.9.1 Description
A family of stormwater treatment practices which typically consist of a storage BMP in conjunction with a filtering device. The most common filter media is sand, but filters have been made of peat/sand mixtures and even from leaf compost.

12.9.2 Pollutant Removal Mechanisms

- Settling or sedimentation.
- Filtration by sand or other filter media.
- Microbial uptake and/or transformations.

12.9.3 Operation, Maintenance, and Inspection

Operation
Successful operation depends on good design, construction, and most importantly, on regular maintenance, especially of the filter media. With stormwater filters, the question is not whether the filter will clog, but when.

Maintenance
Activities necessary to maintain the long term functioning of stormwater filtrations systems include:

- Grass mowing and removal from side slopes and the embankment.
- Removal of trees, brush, and animal burrows from the embankment.
- Vegetative cover stabilization to prevent erosion of side slopes and the embankment.
- Removal and disposal of trash and debris, especially from inlet or outlet structures.
- Removal of sediments and other materials that accumulate in pretreatment practices, such as sediment traps and forebays.
- Periodic scraping and aeration of the filter media, with partial removal.

Inspection
- Inspect monthly and after large storms to assure proper discharge, monitor accumulations of trash and debris, monitor sediment, accumulations in forebays or inlets, and determine mowing or vegetation removal needs, and determine whether the filter media is clogging.
- Closely monitor clogging of the filter media to determine when maintenance is needed.
- Monitor sediment accumulations in sediment traps semiannually. Sediments should be removed when 25% of the storage volume has been lost.
APPENDIX 12A
INSPECTION CHECKLISTS
# Henderson Water Utility

## Operation and Maintenance Inspection Report for Stormwater Management Ponds

### BMP Name/GIS Number

- Subdivision

### Inspection Name

- Address

### Inspection Date

- Stormwater Pond

<table>
<thead>
<tr>
<th>Normal Pool</th>
<th>Watershed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Items Inspected

<table>
<thead>
<tr>
<th>I.</th>
<th>Pond Components</th>
<th>Checked</th>
<th>No</th>
<th>Maintenance Needed</th>
<th>Yes</th>
<th>No</th>
<th>Inspection Frequency</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.</td>
<td>Embankment and emergency spillway</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>1. Vegetation and ground cover adequate</td>
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</tr>
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<td>2. Embankment erosion</td>
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<td></td>
<td>3. Animal burrows</td>
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<td>4. Unauthorized plantings</td>
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<td></td>
<td>5. Cracking, bulging, or sliding of dam</td>
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</tr>
<tr>
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<td>b. Downstream face</td>
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<td></td>
<td>c. At or beyond toe</td>
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<td>Downstream</td>
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<tr>
<td></td>
<td>d. Emergency spillway</td>
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<tr>
<td></td>
<td>6. Pond, toe &amp; chimney drains clear and functioning</td>
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<td>7. Seeps/leaks on downstream face</td>
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<td></td>
<td>8. Slope protection or riprap failures</td>
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<tr>
<td></td>
<td>9. Vertical and horizontal alignment of top of dam as per “As-Built” plans</td>
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<td></td>
<td>10. Emergency spillway clear of obstructions and debris</td>
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<td></td>
<td>11. Other (specify)</td>
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</tr>
<tr>
<td>B.</td>
<td>Riser and principal spillway</td>
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<tr>
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<td>1. Low flow orifice obstructed</td>
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<td></td>
<td>2. Low flow trash rack</td>
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<tr>
<td></td>
<td>a. Debris removal necessary</td>
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<td></td>
<td>b. Corrosion control</td>
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<tr>
<td></td>
<td>3. Weir trash rack maintenance</td>
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<td>a. Debris removal necessary</td>
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<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>b. Corrosion control</td>
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<tr>
<td></td>
<td>4. Excessive sediment accumulation inside riser</td>
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<td></td>
<td>5. Concrete/masonry condition riser and barrels</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td></td>
<td>a. Cracks or displacement</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

**Inspection Frequency Key:**  
- **A** = Annual  
- **M** = Monthly  
- **S** = After major storm
### Henderson Water Utility

#### Operation and Maintenance Inspection Report for Stormwater Management Ponds

(continued)

<table>
<thead>
<tr>
<th>Items Inspected</th>
<th>Checked</th>
<th>Maintenance Needed</th>
<th>Inspection Frequency</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yes</td>
<td>No</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Items Inspected</th>
<th>Checked</th>
<th>Maintenance Needed</th>
<th>Inspection Frequency</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yes</td>
<td>No</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### I. Pond Components

- 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)

- 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. Other

- 1. Encroachments on pond or
  - easement area

Inspection Frequency Key:  A = Annual, M = Monthly, S = After major storm
Infiltration Basin Maintenance Inspection Report

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Project</th>
<th>Location</th>
<th>Individual Conducting the Inspection</th>
<th>“As Built” Plans available</th>
</tr>
</thead>
</table>

Inspection frequency shown in parentheses after item being considered

<table>
<thead>
<tr>
<th></th>
<th>Satisfactory</th>
<th>Unsatisfactory</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Debris cleanout (Monthly)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Basin bottom clear of debris</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Inlet clear of debris</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Outlet clear of debris</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Emergency spillway clear of debris</td>
<td></td>
</tr>
<tr>
<td>2. Sediment traps or forebays (Annual)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Obviously trapping sediment greater than 50% of storage volume remaining</td>
<td></td>
</tr>
<tr>
<td>3. Vegetation (Monthly)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mowing done when needed</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fertilized per specifications</td>
<td></td>
</tr>
<tr>
<td></td>
<td>No evidence of erosion</td>
<td></td>
</tr>
<tr>
<td>4. Dewatering (Monthly)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Basin dewatered between storms</td>
<td></td>
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<tr>
<td>5. Sediment cleanout of basin (Annual)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>No evidence of sedimentation in basin</td>
<td></td>
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<tr>
<td></td>
<td>Sediment accumulation does not yet require cleanout</td>
<td></td>
</tr>
<tr>
<td>6. Inlets (Annual)</td>
<td></td>
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<tr>
<td></td>
<td>Good condition</td>
<td></td>
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<tr>
<td></td>
<td>No evidence of erosion</td>
<td></td>
</tr>
<tr>
<td>7. Outlets/overflow spillway (Annual, After Major Storm)</td>
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<td></td>
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<tr>
<td></td>
<td>Good condition, no need for repair</td>
<td></td>
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<tr>
<td></td>
<td>No evidence of erosion</td>
<td></td>
</tr>
<tr>
<td>8. Structural repairs (Annual, After Major Storm)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Embankment in good repair</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Side slopes are stable</td>
<td></td>
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<tr>
<td></td>
<td>No evidence of erosion</td>
<td></td>
</tr>
<tr>
<td>9. Fences/access repairs (Annual)</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Fences in good condition</td>
<td></td>
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<tr>
<td></td>
<td>No damage which would allow undesired entry</td>
<td></td>
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<tr>
<td></td>
<td>Access point in good condition</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Locks and gate function adequate</td>
<td></td>
</tr>
</tbody>
</table>

Inspection Frequency Key:  A = Annual, M = Monthly, S = After major storm
Action to be taken:

If any of the answers to the above items are checked unsatisfactory, a time frame shall be established for their correction or repair

- No action necessary. Continue routine inspections__________________
- Correct noted facility deficiencies by_____________________________

Facility repairs were indicated and completed. Site reinspection is necessary to verify corrections or improvements.

- Site reinspection accomplished on______________________________

Site reinspection was satisfactory. Next routine inspection is scheduled for approximately:

______________________________

______________________________
Signature of Inspector
# Infiltration Swale Maintenance Inspection Report

Date__________________________  Time__________________________

Project_________________________________________________________

Location________________________________________________________

Individual Conducting the Inspection_________________ “As Built” Plans available____ Y/N

<table>
<thead>
<tr>
<th>Inspection Item</th>
<th>Inspection Frequency</th>
<th>Satisfactory</th>
<th>Unsatisfactory</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Debris cleanout</td>
<td>(Monthly)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Swales and contributing areas clean</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>of debris</td>
<td></td>
<td></td>
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<tr>
<td>2. Vegetation</td>
<td>(Monthly)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mowing done when needed</td>
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<tr>
<td>Fertilized per specifications</td>
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<td></td>
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<tr>
<td>No evidence of erosion</td>
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<tr>
<td>Minimum mowing depth not exceeded</td>
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<tr>
<td>3. Dewatering</td>
<td>(Monthly)</td>
<td></td>
<td></td>
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<tr>
<td>Swale dewater between storms</td>
<td></td>
<td></td>
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<tr>
<td>4. Check dams or energy dissipators</td>
<td>(Annual, After Major Storm)</td>
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<tr>
<td>No evidence of flow going around</td>
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<td>structures</td>
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<tr>
<td>downstream toe</td>
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<tr>
<td>5. Sediment deposition</td>
<td>(Annual)</td>
<td></td>
<td></td>
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<tr>
<td>Swale clean of sediments</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>6. Outlets/overflow spillway</td>
<td>(Annual, After Major Storm)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Good condition, no need for repair</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No evidence of erosion</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Inspection Frequency Key:**  A = Annual, M = Monthly, S = After major storm

**Action to be taken:**

If any of the answers to the above items are checked unsatisfactory, a time frame shall be established for their correction or repair

No action necessary. Continue routine inspections__________________________
Correct noted facility deficiencies by__________________________

Facility repairs were indicated and completed. Site reinspection is necessary to verify corrections or improvements.

Site reinspection accomplished on__________________________

Site reinspection was satisfactory. Next routine inspection is scheduled for approximately:

________________________________________________________

__________________________
Signature of Inspector
Biofiltration Facility Maintenance Inspection Report

Date_________________________  Time_________________________

Project_____________________________________________________

Location_____________________________________________________

Individual Conducting the Inspection_________________  “As Built” Plans available____ Y/N

<table>
<thead>
<tr>
<th>Inspection Item</th>
<th>Inspection Frequency</th>
<th>Satisfactory</th>
<th>Unsatisfactory</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Debris cleanout</td>
<td>(Monthly)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biofilters and contributing areas</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>clean of debris</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No dumping of yard wastes into</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>biofilter</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Litter (branches, etc.) have been</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>removed</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Vegetation</td>
<td>(Monthly)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plant height not less than design</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>water depth</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fertilized per specifications</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No evidence of erosion</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grass height not greater than</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 inches</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Is plant composition according to</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>approved plans</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No placement of inappropriate plants</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Dewatering</td>
<td>(Monthly)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biofilter dewater between storms</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No evidence of standing water</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Check dams or energy dissipators</td>
<td>(Annual, After Major Storm)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No evidence of sediment buildup</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sumps should not be more than</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50% full of sediment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No evidence of erosion at</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>downstream toe of drop structures</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Sediment deposition</td>
<td>(Annual)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Swale clean of sediments</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sediments should not be &gt; than</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20% of swale design depth</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Outlets/overflow spillway</td>
<td>(Annual, After Major Storm)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Good condition, no need for repair</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No evidence of erosion</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No evidence of any blockages</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Integrity of biofilter</td>
<td>(Annual)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biofilter has not been blocked or</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>filled inappropriately</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Action to be taken:

If any of the answers to the above items are checked unsatisfactory, a time frame shall be established for their correction or repair

   No action necessary. Continue routine inspections____________________
   Correct noted facility deficiencies by______________________________

Facility repairs were indicated and completed. Site reinspection is necessary to verify corrections or improvements.

   Site reinspection accomplished on______________________________

Site reinspection was satisfactory. Next routine inspection is scheduled for approximately:

______________________________

______________________________

Signature of Inspector
Infiltration Paving Maintenance Inspection Report

Date___________________________  Time___________________________

Project_________________________________________________________

Location________________________________________________________

Individual Conducting the Inspection_______________ “As Built” Plans available____ Y/N

---

**Inspection frequency shown in parentheses after item being considered**

1. Debris on infiltration paving parking area  
   Paving area clean of debris  
   (Monthly) ____________________________  ________________  ________________

2. Vegetation  
   Mowing done when needed  
   Fertilized per specifications  
   No evidence of erosion  
   (Monthly) ____________________________  ________________  ________________

3. Dewatering  
   Infiltration paving dewatering between storms  
   (Monthly) ____________________________  ________________  ________________

4. Sediments  
   Area clean of sediments  
   Area vacuum swept on a periodic basis  
   (Monthly) ____________________________  ________________  ________________

5. Structural condition  
   No evidence of surface deterioration  
   No evidence of rutting or spalling  
   (Annual) ____________________________  ________________  ________________

---

**Inspection Frequency Key:**    A = Annual, M = Monthly, S = After major storm

**Action to be taken:**

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   No action necessary. Continue routine inspections__________________________
   Correct noted facility deficiencies by__________________________

Facility repairs were indicated and completed. Site reinspection is necessary to verify corrections or improvements.

   Site reinspection accomplished on__________________________

Site reinspection was satisfactory. Next routine inspection is scheduled for approximately:

________________________________________________________________________

________________________________________________________________________

Signature of Inspector
Filtration Facility Maintenance Inspection Report

Date ____________________  Time ____________________

Project ____________________

Location ____________________

Individual Conducting the Inspection ____________  “As Built” Plans available ___ Y/N ___

**Warning:** If filtration facility has a watertight cover; be careful regarding the possibility of flammable gases within the facility. Care should be taken lighting a match or smoking while inspecting facilities that are not vented.

*Inspection frequency shown in parentheses after item being considered*

<table>
<thead>
<tr>
<th>Item Description</th>
<th>Inspection Frequency</th>
<th>Satisfactory</th>
<th>Unsatisfactory</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Debris cleanout</td>
<td>(Monthly)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Contributing areas clean of debris</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Filtration facility clean of debris</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inlets and outlets clear of debris</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Vegetation</td>
<td>(Monthly)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Contributing drainage area</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stabilized</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No evidence of erosion</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area mowed and clippings removed</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Oil and grease</td>
<td>(Monthly)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No evidence of filter surface clogging</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Activities in drainage area minimize oil &amp; grease entry</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>4. Water retention where required</td>
<td>(Monthly)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water holding chambers at normal pool</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No evidence of leakage</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Sediment deposition</td>
<td>(Annual)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Filtration chamber clean of sediments</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water chambers not more than ½ full of sediments</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Structural components</td>
<td>(Annual)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No evidence of structural deterioration</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Any grates are in good condition</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No evidence of spalling or cracking of structural parts</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Outlets/overflow spillway</td>
<td>(Annual)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Good condition, no need for repair</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No evidence of erosion (if draining into a natural chamber)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Overall function of facility (Annual)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No evidence of flow bypassing</td>
<td>(Annual)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>facility</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
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Signature of Inspector