Draft Stormwater Manual

Hardin County Fiscal Court

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Chapter 1.0 General Requirements

1.1 Introduction

The purpose of the Stormwater Manual is to:

1. provide standards for the design and construction of stormwater infrastructure
2. set policy on floodplain management
3. outline the items that must be submitted to the Planning Commission as required by the Post-Construction Runoff Control Ordinance
4. provide design criteria to engineers for the following
   - water quantity (flood control) best management practices (BMPs)
   - water quality BMPs as required by the Post-Construction Runoff Control Ordinance
   - drainage system infrastructure such as open channels, pipes, culverts, and inlets

The manual includes requirements for the stormwater infrastructure that is routinely designed and constructed. However, more comprehensive methods of analysis and design may be required for unusual conditions not specifically covered in this manual or where otherwise appropriate from an engineering standpoint to assure public safety and quality in infrastructure design and construction.

1.2 Definitions

Flood Protection Elevation – the elevation necessary to protect structures from flooding

Stream - intermittent and perennial streams represented on the USGS 7.5 minute topographic maps as either solid or dashed blue line streams. Channels not shown as a solid or dashed blue line shall be considered a stream if they have a drainage area of at least 50 acres.

Local Floodplain - the portion of land adjacent to a stream covered with water during the 100-year storm. It shall be determined using the procedures outlined in Chapter 3 of this manual. The local floodplain shall be shown on plans and plats submitted to the Planning Commission.

FEMA floodplain – Floodplain shown on Flood Insurance Rate Maps

1.3 General Criteria for New Development

1.3.1 Watershed Studies

When required by the Planning Commission, a watershed study shall be conducted to evaluate the impact of a given development on the downstream drainage system and to define the local floodplain. The criteria for conducting watershed studies are given in Chapter 3.

1.3.2 Construction in Streams or Floodplains

In general, construction activities such as filling and excavation shall not be allowed in streams or floodplains. Only the following activities shall be undertaken:

- temporary sediment ponds
- roadways and utilities
- sanitary sewers
- storm sewers
- water quantity or water quality BMPs
- pedestrian crossings and trails

1.3.3 Lot Drainage in Residential Development

Channels shall be constructed for drainage areas greater than 1 acre in residential developments. The channel shall be designed to carry the 100-year storm. 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 Stormwater Management Plan. The design criteria are contained in Chapter 8.

1.3.4 Maintenance of Drainage Easements

The Court shall be responsible for maintaining the major structural items in the county road right of way. These items include pipes, channels, and headwalls.

What about mowing the right of way along county roads? Property owner or County

What about maintenance of detention basins on private property? I suggest making the County responsible for the embankment and the pipe through it, and make the property owner responsible for mowing.

1.3.5 Class C Impoundments

Construction of Class C Impoundments (50 acre feet of volume or 25 feet high) as defined by the Kentucky Division of Water shall be prohibited. Proposed new impoundments shall be evaluated to determine the hazard classification.

1.3.6 Offsite Drainage Problems

Where offsite stormwater problems are known to exist, the Planning Commission may require the developer to consider these problems and integrate solutions determined through the Watershed Studies discussed above. For example, in areas where downstream flooding is known to be a problem, the Planning Commission may require that peak flows from a new development be less than pre-development peak flows.

1.3.7 National Flood Insurance Program

Construction within the 100-year FEMA floodplain shall comply with the requirements of the National Flood Insurance Program and the requirements of the Commonwealth of Kentucky. The local floodplain coordinator shall be contacted for a list of requirements.

1.3.8 Vegetative Buffer Strip

A vegetative buffer strip along each side of the stream shall be left undisturbed. The strip shall be 25 feet wide on each side of the stream and shall be measured from the stream bank.

1.4 Water Quantity Criteria for New Development

1.4.1 Peak Flow Design Criteria

Detention ponds shall be designed and constructed to maintain pre-development peak flows from new development projects. The design storms used for this analysis are contained in Chapter 5.

1.4.2 Exemptions from Quantity Controls

Sites may be exempted from providing quantity controls if a watershed study demonstrates to the Planning Commission that detention ponds are not needed to protect downstream property. To evaluate the downstream effects, the Engineer shall conduct a watershed study to determine the flood levels using the 100-year 1-hour storm. The study area shall extend downstream to a point 10 times the area of the proposed development. Sites may be exempted if

- the increase in the downstream water level is insignificant (less than 0.1')
- the downstream drainage system has sufficient capacity to receive any increase in runoff for the 100-year storm. Sufficient capacity for a pipe system shall be defined as no overflows at inlets or manholes. Sufficient capacity for an open channel system shall be a defined as an open channel wide enough to carry the flow.

Developments containing less than 1 acre of impervious area shall not require water quantity controls.

1.4.3 Capacity of the Proposed Drainage System

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

1.4.4 Flood Protection Elevation

All residential, commercial, and industrial structures shall be constructed at or above the Flood Protection Elevation. The Flood Protection Elevation (FPE) shall be determined by the Engineer and shall be all of the following

- two feet above the local floodplain elevation
- two feet above the FEMA base flood (100-year) elevation
- two feet above the embankment crest of detention ponds

For all new structures, the lowest floor elevation above ground level shall be at or above the FPE. Crawl space entrances, foundation vents, basement windowsills, the top landing of outside stairways leading to basements, and other openings to the structure shall be at or above the FPE.

TABLE 1- 1
FLOW CRITERIA FOR STORMWATER FACILITIES

Stormwater Appurtenance	Design Storm Criteria	Manual Reference Section
Road Inlets on Grade	Spacing is based on allowable spread of water at a rainfall intensity of 4 inches per hour.	Chapter 6
Road Inlets in Sags	Top of Curb: 10-year Back of Sidewalk: 100-year	Chapter 6
Storm Sewers	10-year and 100-year	Chapter 6
Culverts	100-year	Chapter 7
Constructed Channels	100-year	Chapter 8

1.4.5 Setback from Floodplain
The wall of any principal or accessory structure shall be located a minimum of 25 feet from the local floodplain or FEMA floodplain.

1.5 Water Quality Criteria for New Development

1.5.1 Water Quality Volume Criteria
The water quality volume (WQV) to be treated shall be equal to ½" multiplied by the site area.

For residential development projects 1 acre or greater, the following BMPs shall be used BMPs as described in Chapter 10.

- Vegetated filter strips
- Extended detention ponds
- Swales

For commercial development projects 1 acre or greater, the criteria is as follows:

- Treat the water quality volume equal to the first ½" of runoff using a combination of bioretention, extended detention ponds or swales as described in Chapter 9, or
- Pass the runoff through a hydrodynamic separator as described in Chapter 9.

1.5.2 Exemptions from Quality Controls
The following development sites are exempted:

- New residential subdivisions having lots 30,000 square feet and larger

- Commercial sites (including high density residential) that disturb less than 1 acre of land.
- Single-Family residential construction that disturbs less than 1 acre of land if the lot is not part of a larger subbdivision development

1.5.3 Culvert Outlet Velocity Criteria

The design velocity at the culvert outlet shall be reduced to match the natural stream velocity.

1.5.4 Erosion Control

Erosion and sediment controls shall be designed and constructed in accordance with the Hardin County Erosion Control Handbook.

Chapter 2.0 Permits

2.1 Permits

The following permits shall be obtained from federal and state agencies and submitted to the Planning Commission before beginning construction.

2.2 Kentucky Division of Water Floodplain Construction Permit

Pursuant to Kentucky law, dams or other improvements obstructing the movement of water in the floodplain are often regulated by the Kentucky Division of Water (KDOW). A Floodplain Construction Permit is required from the KDOW prior to the construction, reconstruction, relocation, or improvement of any dam, embankment, levee, dike, bridge, fill, or other obstructions across or along any stream or in the floodway of any stream. Permits are required for any such activity in designated 100-year floodplains or areas known to be flood prone. A permit from the KDOW is also required to deposit or cause to be deposited any matter that will in any way restrict or disturb the flow of water in the channel or in the floodway of any stream. In addition, a KDOW permit is required prior to the construction of structures qualifying as dams.

2.3 KPDES General Permit for Stormwater Construction Activities

See the Hardin County Construction Site Runoff Control Ordinance.

2.4 Federal Emergency Management Agency (FEMA)

FEMA manages the National Flood Insurance Program (NFIP) based on maps showing floodplains and flood hazard areas. As part of the agreement for making flood insurance available, the NFIP requires the County to adopt floodplain management ordinances containing certain minimum requirements intended to reduce future flood losses. Contact the local floodplain coordinator for a list of requirements for construction in a FEMA floodplain.

2.5 401 and 404 Permits – KDOW and U.S. Army Corps of Engineers

The KDOW has a permitting program (401 permit) related to construction which impacts the stream channel. In addition, the U.S. Army Corps of Engineers (COE) has requirements for projects that impact waters of the United States, including wetlands. Where the KDOW 401 or COE 404 permits, including coverage under the COE Nationwide Permits, are required, construction shall not begin until evidence of the 401 and/or 404 permits or a determination that no permit is required is provided to the Planning Commission.

Chapter 3.0 Watershed Studies

3.1 Watershed Studies

Watershed studies shall be conducted to:

- determine the effects of a proposed development on the public drainage system
- establish the local floodplain

3.1.1 Required Data

Watershed Size
Determine the size of the watershed in acres.

Watershed Land Use
Describe the existing and anticipated future land use in the watershed.

Streams, Rivers, Ponds, Lakes, and Wetlands
At all streams, rivers, ponds, lakes, and wetlands that will affect or may be affected by future development, collect the following data:

- boundary (perimeter) and elevation of the water surface
- water elevation for design storms specified in this manual
- description of the principal spillway, including dimensions, elevations, material, and operational characteristics
- profile along top of any dam and a typical cross section of the dam
- identification of wetlands and sinkholes within the project boundaries or downstream of project in a location which may be impacted by stormwater runoff

Roughness Coefficients
Estimate roughness coefficients, in the form of Manning's n values, for the entire flood limits of the stream within the reach to be evaluated. A tabulation of Manning's n values with descriptions of their applications can be found in Chapter 8.

Stream Profile
Obtain streambed profile data to determine the average slope.

Stream Cross-Sections
Obtain stream cross-section data where stage-discharge-volume relationships will be necessary.

Existing Structures
- Investigate any structures that may cause backwater or retard stream flow.
- Evaluate the manner in which existing structures have been functioning with regard to such things as scour, overtopping, damage, and debris.
- For bridges, determine span lengths, height, type of piers, and substructure orientation.

- For culverts, determine the size, inlet and outlet geometry, slope, end treatment, culvert material, and flow line profile.
- Take photographs of high water debris lines.
- Determine outlet structure (principal and emergency spillway) dimensions, material, inlet condition, headwater and backwater conditions, slope, and invert elevations.
- Determine an elevation profile along the top of the embankment for simple outlet structures.
- Take photographs of all structures.
- Inventory the sinkholes and their condition, and identify any sources of obstruction or local contamination. Take photographs to document the conditions of the sinkholes.

Acceptable Flood Levels
Determine the lowest opening elevation of structures where flooding is known to occur.

Flood History
Evaluate the history of past floods and their effect on existing structures. Information may be obtained from newspaper accounts, local residents, flood marks, or other evidence of the height of historical floods. Obtain recorded flood data from the following agencies:

- U.S. Army Corps of Engineers
- U.S.G.S.
- Kentucky Division of Water

3.1.2 Documentation

Document the field review with dated field notes and photographs initialed by the reviewer. Include the documentation with the project plans and calculations submitted to the Planning Commission.

3.2 Runoff Models

3.2.1 General

HEC-HMS or a similar program shall be used to develop a hydrologic model.

3.2.2 Subbasin Data

Subbasin data shall be collected in accordance with the following requirements:

- Delineate watershed subbasins so that average subbasin size is 10-50 acres and maximum subbasin size does not exceed 200 acres.
- Determine percent imperviousness from Table 3-1.

TABLE 3- 1
LAND USE IMPERVIOUSNESS

Land Use	Percent Impervious
Residential	
1/8 acre lots	65
1/4 acre lots	38
1/3 acre lots	30
1/2 acre lots	25
1 acre lots	20
Commercial	85
Industrial	72

3.2.3 Open Channel and Pipe Data

Collect the following data:

- Length
- Size of the channel or pipe
- Manning's n
- Upstream and downstream invert elevations
- Slope

3.2.4 Storage Structures

Stage-storage-discharge relationships shall be determined for all structures that provide significant flood storage, such as detention basins and roadway crossings over streams.

3.3 Floodplain Analysis

Once the runoff model is complete, the local floodplain shall be determined with the United States Army Corps of Engineers' HEC-RAS computer program. This program will also provide results to indicate roadway and structure flooding. The design storm for floodplain analysis is contained in Chapter 5.

Chapter 4.0 Documentation

An important part of the design or analysis of any hydraulic facility is the documentation because of:

- the importance of public safety
- future reference by engineers (when improvements, changes, or rehabilitations are made to the drainage facilities)
- information leading to the development of defense in matters of litigation
- public information

4.1 Required Information

4.1.1 Design Plans

Design drawings shall be 24 x 36" in size. Plan view drawings shall be at a scale of 1"=50' with existing and proposed 2' contours. Profile sheets shall be at a scale of 1"=50' horizontal and 1"=5' vertical. The following information shall be shown:

- a map showing all drainage areas and subareas used to size hydraulic structures
- proposed inlet, storm sewer, culvert, and manhole system and their sizing calculations
- proposed stormwater best management practices
- proposed channels and their sizing calculations
- local floodplain
- FEMA floodplain
- sinkholes
- caves
- springs
- ponds
- streams
- wetlands
- existing and proposed underground utilities

Hydrology
Submit the peak discharge and hydrographs for design storms

Inlets, Storm Sewers, and Manholes
Submit the following items:

- computations for inlets and pipes, including hydraulic grade lines
- drainage area map
- a schematic indicating storm drain system layout
- pipe lengths, slopes, diameters, and material
- grate elevations
- separate sheets for details

Plan View:

- street layout, lot lines
- catch basins: type and invert elevation
- pipes: sizes, type, class, slope, and designation
- manholes: size and type
- headwalls: type and invert elevation
- sanitary sewer crossings
- culvert size and shape
- other utility line crossings

Profile View:

- underground utility crossings
- existing and proposed ground surfaces
- curb inlets: elevations and type
- manholes: elevations and type
- pipes with size, grade, type, class, length
- headwall type and elevation
- all crossings (with elevations) of sanitary sewers and underground utilities
- all street sections at crossings and all regrade contours
- capacity and proposed flows in pipes
- hydraulic grade lines
- manholes
- inlet and outlet elevations of pipes
- copies of all computer analyses, with input data listed and output clearly identified

Culverts and Bridges
Submit the following items:

- culvert performance curves
- allowable headwater elevation and basis for its selection
- cross-section(s) used in the design highwater determinations
- roughness coefficient assignments (Manning's n values)
- observed highwater, dates, and discharges
- stage discharge curves
- type of culvert entrance condition
- culvert outlet appurtenances
- copies of all computer analyses, with input data listed and output clearly identified
- roadway geometry (plan and profile)

Open Channels
Submit the following items:

- profiles

- cross-section(s) used in the design water surface determinations and their locations
- roughness coefficient assignments (Manning's n values)
- channel velocities
- water surface profiles through the reach for the design 100-year storm
- design analysis of materials proposed for the channel bed and banks
- copies of all computer analyses, with input data listed and output clearly identified

Stormwater Best Management Practices
Submit the following items:

- design calculations and schematics
- complete drainage area map, delineating area draining to each practice and denoting total area and impervious area draining to each device
- separate detail sheet for detention/retention basins
- detail sheets for water quality treatment devices
- embankment cross section
- top of embankment elevation
- peak stages
- emergency spillway details
- principal spillway details
- other utilities

4.1.2 Composite Drainage Plan

This plan is intended to aid homebuilders and commercial/industrial builders. The following information shall be shown on the Composite Drainage Plan.

- surface drainage easements on each lot
- flow arrows that indicate the direction of surface drainage
- sanitary sewers and manholes
- storm sewers and manholes
- surface inlets, curb inlets, open channels, and stormwater best management practices
- Flood Protection Elevation
- Non-buildable areas such as sinkholes, floodplains, vegetative buffer strips, and wetlands

4.2 Record Drawings

A record drawing of all stormwater structures shall be submitted at the end of construction. Plan view drawings shall be at a scale of 1"=50' with 2' contours. Profile sheets shall be at a scale of 1"=50' horizontal and 1"=5' vertical. Drawings shall be 24" x 36" in size.

Chapter 5.0 Hydrology

5.1 Introduction

The purpose of this section is to describe approved methods of hydrologic analysis for watershed studies and for the design of stormwater facilities.

5.2 Approved Methods

The Corps of Engineers HEC-HMS program or similar model that uses NRCS methods may be used to generate peak flows and runoff hydrographs.

The Rational Method shall be used to compute peak flows for drainage areas less than or equal to 100 acres when designing inlets, storm sewers, culverts, and channels.

5.3 Design Rainfall Event

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

TABLE 5- 1
DESIGN STORMS

Design Storm	Stormwater Facility					
	Local Floodplains[2]	Detention Ponds[1]	Inlets	Storm Pipes	Culverts	Open Channels
10-yr 1-hr		●	●	●		
100-yr 1-hr	●	●	●	●	●	●
100-yr 6-hr	●	●				

1. Detention ponds shall be designed to reduce post-development peak flows to pre-development peak flows for the 10-yr 1-hr, 100-yr 1-hr, and 100-yr 6-hr storms.
2. The local floodplain shall be based on the storm that produces the higher water surface elevation.

5.4 HEC-HMS 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 NRCS 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, Natural Resources Conservation Service.

Storage Routing

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

Watershed Delineation

- Watersheds shall be subdivided into areas with homogenous land use. The subwatersheds shall have an average size of 10-50 acres, and a maximum size of 200 acres.

TABLE 5- 2
CURVE NUMBERS

Land Use	Percent Impervious	Hydrologic Soil Group			
		A	B	C	D
Urban Areas					
Parking Lots, Roofs, Driveways, and Streets	100	98	98	98	98
Commercial Development	85	89	92	94	95
Industrial Development	72	81	88	91	93
Residential Development:					
1/8 acre lots or less	65	77	85	90	92
1/4 acre lots	38	61	75	83	87
1/3 acre lots	30	57	72	81	86
1/2 acre lots	25	54	70	80	85
1 acre lots	20	51	68	79	84
Pervious Areas					
Lawns, Parks, Golf Courses, Cemeteries, etc.	-	39	61	74	80
Pasture for Grazing (not mowed)	-	39	61	74	80
Meadows (mowed for hay)	-	30	58	71	78
Brushy Areas	-	30	48	65	73
Woods	-	30	55	70	77

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 NRCS Soil Survey, assume the subwatershed is 50% Group B soils and 50% Group C soils.

5.5 Rational Method

The following equation may be used for drainage areas less than or equal to 100 acres.

Q = CIA

where:

Q = peak flow in cubic feet per second
C = runoff coefficient (determine by a weighted calculation using 0.95 for impervious areas and 0.2 for pervious areas)
A = drainage area
I = rainfall intensity

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

TABLE 5- 3
TIME OF CONCENTRATION VERSUS RAINFALL INTENSITY

Time of Concentration (minutes)	Intensity (inches/hour)	
	10 yr.	**100 yr.**
10	5.1	6.5
15	4.3	5.4
30	3.1	4.2
60	2.0	2.9

The time of concentration shall be determined using the method described in Technical Release No. 55 published by the U.S. Department of Agriculture, Natural Resources Conservation Service. The minimum time of concentration shall be 10 minutes.

APPENDIX 5- 1
DESIGN STORM DISTRIBUTIONS

1-HOUR RAINFALL DISTRIBUTIONS

Minutes	Cumulative Rainfall (Inches)	
	10-year	100-year
0	0.00	0.00
3	0.24	0.34
6	0.44	0.63
9	0.66	0.95
12	0.86	1.23
15	1.09	1.55
18	1.27	1.81
21	1.43	2.04
24	1.55	2.21
27	1.63	2.32
30	1.69	2.41
33	1.75	2.50
36	1.79	2.55
39	1.85	2.64
42	1.89	2.70
45	1.93	2.76
48	1.95	2.78
51	1.97	2.81
54	1.99	2.84
57	1.99	2.84
60	2.01	2.87

6-HOUR RAINFALL DISTRIBUTION

Minutes	Cumulative Rainfall (Inches)
	100-year
0	0.00
20	0.16
40	0.37
60	0.58
80	0.93
100	1.36
120	1.81
140	2.32
160	2.86
180	3.30
200	3.67
220	3.97
240	4.19
260	4.36
280	4.50
300	4.62
320	4.69
340	4.75
360	4.85

Chapter 6.0 Inlets/Storm Sewers/Manholes

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 used for street drainage shall be designed as follows:

- Space inlets on grade to limit the spread of water as follows, based on an intensity of 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
- The depth of water in a sag shall be limited to the
  - Top of curb using an intensity of 4 inches per hour
  - Back of sidewalk using an intensity of 6.5 inches per hour (100 year storm with a 10 minute time of concentration)
- Space inlets to prevent concentrated water from flowing across the road
- 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.
- The headwater for the 100-year storm is 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, the headwater for the 100-year storm is at least 12” below the edge of pavement and sidewalk.

6.1.4 Storm Sewers

Storm sewers 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 overflows at inlets and manholes do not occur for the 100-year storm.
- Use a minimum pipe size of 15 inches.
- Provide a minimum slope of 0.5%
- Provide a minimum velocity of 3 feet per second at full flow.
- Provide a minimum cover of 18 inches.
- Construct storm sewers of reinforced concrete pipe.

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

6.1.5 Manholes

- Place manholes at the following locations:
  - where 2 storm sewers intersect
  - at changes in pipe size
  - where the slope changes
  - where horizontal alignment changes
- Space manholes no more than 300 feet apart for pipes 42” diameter or less, and no more than 400’ apart for pipes 48” diameter and larger
- 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

Use a software program based on the hydraulic methods used by the KYTC or FHWA for highway drainage. For more information, go to the FHWA Urban Drainage Design Manual (HEC22).

6.2.2 Curb Inlets in Low Points

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

Q = CLd1.5

where:
Q = flow in cfs
C = 3.0
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.

$Q = CA(2gd)^{0.5}$

where:
Q = flow (cfs)
C = 0.67
A = clear area of opening (ft^2)
d = head on center of 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 ≤ 0.4', use the weir flow equation:

$Q = C\,Pd^{1.5}$

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

For d ≥ 1.0', use the orifice flow equation:

$Q = CA\sqrt{2gd}$

where:
C = 0.67
A = clear opening area of the grate (ft^2)
g = 32.2 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.

6.3 Storm Sewer Design Procedures

Use a software program based on the hydraulic methods used by KYTC or FHWA for highway drainage.

6.4 Construction Specifications

All storm drainage structures, including storm sewer pipe, curb box inlets, surface inlets, culvert pipe, and manholes, shall be installed in accordance with the KYTC Standard Specifications for Road and Bridge Construction, latest edition.

Chapter 7.0 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 channels. Culverts are structures narrower than 20’ wide that transport vehicles over streams, channels, and roadside ditches.

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.

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
- 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 Headwalls
All culverts shall be designed with inlet and outlet headwalls.

7.2.6 Outlet Protection
The outlet channel shall be stabilized with a suitable lining to prevent erosion.

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).

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
- 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
- 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

Circular culvert pipe shall be reinforced concrete pipe and shall be installed in accordance with the KYTC Standard Specifications for Road and Bridge Construction, latest edition.

Chapter 8.0 Open Channels

8.1 Introduction

Open channels include roadside channels and stormwater drainage channels with regular geometric cross-sections and lining of natural or synthetic materials to protect against erosion. The design of channels shall consider the frequency and type of maintenance expected and make allowance for access of maintenance equipment.

8.1.1 Design Criteria

Constructed channels shall be designed with stable side slopes. Vegetated channels shall have sideslopes of 3:1 or flatter.

Channel freeboard shall be one foot or two velocity heads (velocity head = $V^2/2g$), whichever is larger.

Channels with bottom widths greater than 10 feet shall have a minimum bottom cross slope of 12 to 1.

Maximum design depth shall be based on the 100-year storm.

8.1.2 Channel Lining

Use channel linings to stabilize the slopes and bottoms of constructed channels. Evaluate vegetative lining first. If a vegetated channel is not stable, other alternatives shall be considered in the order shown below:

- vegetative with a turf reinforced mat (TRM)
- other hard armor such as gabion mattress, dry stone masonry, tri-loc, etc.
- concrete

Where there is a base flow and the channel does not have a natural rock bottom, the bottom of the channel shall have a non-vegetative lining.

8.1.3 Manning's Equation

Use the Manning Equation to design open channels.

$$Q = (1.49/n)AR^{2/3} S^{1/2}$$

Where:

Q = discharge, cfs
n = Manning's roughness coefficient
A = cross-sectional area of flow, ft^2
R = hydraulic radius = A/P, ft
P = wetted perimeter, ft
S = channel slope, ft/ft

Select Manning's n from Tables 8-1 and 8-2.

8.1.4 Tractive Force

After sizing the channel and determining the normal flow depth corresponding to the design storm, check the suitability of the channel lining using the tractive force method. The maximum tractive force at normal flow depth, τd, is calculated as:

$$\tau d \ (lbs/ft2) = 62.4yS$$

Where:

y = normal depth (ft)
S = channel slope.

The critical tractive force, τc, for many linings can be found in Table 8-3. If $\tau d < \tau c$, the lining is acceptable. Options for redesign include selecting a more resistant lining or decreasing the flow velocity by decreasing the channel bed slope or side slopes or increasing the width.

For linings not listed in Table 8-3, use the manufacturer's literature to determine the critical tractive force and submit documentation with the design. For mats, nets, or TRMs use the critical tractive force in the unvegetated condition.

8.1.5 Construction Specifications

All ditches or other depressions to be crossed shall be filled before construction begins or as part of construction, and the earth fill used to fill the depressions shall be compacted using the treads of the construction equipment. All old terraces, fence rows, or other obstructions that will interfere with the successful operation of the channel shall be removed.

The earth materials used to construct the earth fill portions of the channel shall be obtained from the excavated portion of the channel or other source.

The earth fill materials used to construct the channel shall be compacted by running the construction equipment over the fill in such a manner that the entire surface of the fill will be traversed by at least one tread track of the equipment.

The completed channel shall conform to the cross section and grade shown on the design plans.

TABLE 8- 1
MANNING'S n FOR CONSTRUCTED CHANNELS

Lining Type	Manning's n
Concrete	0.013
Grouted Stone	0.030
Stone Masonry	0.032
Bare Soil	0.020
Rock Cut	0.035
Jute Net	0.022
Straw with Net	0.033
Curled Wood Mat	0.035
6-inch D50 Riprap	0.050
12-inch D50 Riprap	0.060
Grass	0.045

TABLE 8- 2
MANNING'S n FOR STREAMS AND FLOODPLAINS

	Manning's n
Streams	0.045
Floodplains	
Pasture, no brush	0.035
Brush	0.10
Trees	0.120

TABLE 8- 3
SUMMARY OF CRITICAL TRACTIVE FORCES FOR VARIOUS PROTECTION MEASURES

Protective Cover	τc(lbs/ft2)
Grass or Grass-legume Mixture Good Stand	1.0
Jute Net	0.45
Straw with Net	1.45
Curled Wood Mat	1.55
Turf Reinforcement Matting (TRM)	6-10
Riprap D50 = 6 inches D50 = 12 inches	 2.50 5.00

8.1.6 Maintenance
Channels shall be inspected regularly to check for points of scour or bank failure; rubbish or channel obstruction; rodent holes; breaching; and excessive wear from pedestrian or construction traffic.

Channels shall be repaired at the time damage is detected. Sediment deposits shall be removed from adjoining vegetative filter strips when they are visible.

Channels shall be reseeded and fertilized as needed to establish vegetative cover.

8.2 Paved Channels

A paved channel shall be used when the flow velocity at design capacity (using vegetative lining) exceeds 12 fps.

8.2.1 Design Criteria
Paved channels shall be designed to carry the peak flow from the 100-year storm.

The outlets of paved channels shall be protected from erosion using a suitable lining material.

Cutoff walls shall be constructed at the beginning and end of each channel except where the channel connects with a catch basin or inlet.

8.2.2 Material Specifications
Paved channels shall be constructed of concrete or interlocking concrete blocks.

8.2.3 Construction Specifications
The subgrade shall be constructed to the required elevations. All soft sections and unsuitable material shall be removed and replaced with suitable material. The subgrade shall be thoroughly compacted and shaped to a smooth, uniform surface. The subgrade shall be moist when pouring concrete.

8.2.4 Maintenance

Before permanent stabilization of the slope, the structure shall be inspected after each rainfall. Any damages to the channel or slope shall be repaired immediately.

Chapter 9.0 Stormwater Best Management Practices (BMPs)

9.1 Introduction

The purpose of this section is to provide design criteria and construction standards for the following:

- Water quantity (flood control) best management practices (BMPs)
- Water quality BMPs as required by the Post-Construction Runoff Control Ordinance

9.2 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 9-1 shows a diagram of a bioretention system designed to receive runoff from a paved area.

9.2.1 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.

9.2.2 Design Criteria

Size the area of the filter bed in accordance with the design WQV 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 9-1, to handle volumes exceeding the design WQV.

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 9-1 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 9-1 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 9-1. 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.

9.2.3 Design Procedures

Size the filter bed using the following equation:

$$Af = V*(df)/[k*(hf + df)(tf)]$$

where:
Af = surface area of the sand filter bed (ft2)
V = treatment or infiltration volume (ft3)
df = planting bed depth (ft)
k = coefficient of permeability for planting bed (ft/day)
hf = average height of water above the planting bed (ft); hf = 0.5 * hmax
tf = time required for V to filter through the planting bed (days).

Note:
df = 4 feet (including sand filter) unless it is increased by designer
k = 0.5 feet/day (median value of a silt loam)
hf = 0.5 * hmax = 3 inches = 0.25 feet
tf = 3 days.

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

9.2.4 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 ponds 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 four 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.

Common Name	**Scientific Name**
Barnyard grass	Echinochloa crusgalli
Switch Grass	Panicum virgatum
Swamp Milkweed	Asclepias incarnate
Giant Cane	Arundinaria gigantean
Jewelweed	Impatiens capensis
River oats	Chasmanthium latifolia
Deertongue	Panicum clandestinum
Boneset	Eupatorium perfoliatum

9.3 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 will provide significant "credits" toward reducing the magnitude of the runoff that must be detained and treated.

9.3.1 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 9-2.

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.

<u>Infiltration Credits</u>

When swales are used, the infiltration credit is 3" times the area of the swale. To obtain this credit, 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 the area of the swale, the width will be the average water surface width corresponding to the flowrate associated with the 100-year storm.

<u>Design Criteria</u>

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 in order to obtain the infiltration credit.

Grassed channels that do not satisfy the design criteria to be considered swales may be given an infiltration credit only for the channel bottom, if the bed slope does not exceed 4 percent.

9.3.2 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.

Infiltration Credit

Infiltration credit for a bermed swale is calculated in the same manner as the credit for a swale, except that the calculated infiltration credit can be increased by 50 percent of the water volume that can be impounded by the berms.

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 no taller than 8 inches and spaced no closer than 60 feet.

Drop inlets in swales shall be spaced no closer than once per each 300 feet in order to obtain the infiltration credit.

Grassed channels that do not satisfy the design criteria to be considered swales may be given an infiltration credit only for the channel bottom, if the bed slope does not exceed 4 percent.

9.3.3 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 9-3.

Infiltration Credit

Infiltration credit for a biofiltration swale is 6” times the area of the swale plus 100 percent of the volume of the ponded water, when designed according to the following criteria. If biofiltration swales are designed consistent with the procedures for bioretention systems, the infiltration credit equals the design treatment volume.

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
- 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 this criterion, 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. Then the infiltration credit would be calculated in the same manner as the credit for bioretention.

9.3.4 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.

<u>Design Criteria</u>
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.

<u>Infiltration Credit</u>
The infiltration credit for vegetated filters is 1” times the area of the filter strip.

9.4 Hydrodynamic Separators

Several manufacturers produce devices that 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.

9.4.1 Design Criteria

The treatment devices shall be capable of demonstrating 80% capture of particles in a size range of 2 mm (very coarse sand) to 0.125 mm (very fine sand). The design storm shall have an intensity of 2.1 inches/hour (3-month frequency storm with a time of concentration of 10 minutes).

9.5 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 9-4 illustrates a detention pond.

9.5.1 Applicability

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

9.5.2 Design Criteria

Design detention ponds so that discharge rates do not exceed calculated pre-development peak runoff rates for the storms given in Chapter 5.

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

Design an emergency spillway to pass the 100-year storm assuming the principal spillway is clogged.

Design the pond in accordance with Kentucky Department for Environmental Protection, Division of Water's Engineering Memorandum No. 5, Design Criteria for Dams and Associated Structures.

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

Embankment heights shall not exceed 20 feet (measured from the downstream toe) and storage volumes shall not exceed 25 acre-feet and shall not be less than 0.3-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.

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).

Provide a minimum 25-foot wide buffer strip between the pond and the nearest property line. Landscape the buffer strip with low-maintenance native grasses, shrubs, and trees. Provide a landscaping plan for the pond and the buffer. Objectives of landscaping include improving the appearance for adjacent residents and providing wildlife habitat.

Outlet works may be a combination of pipes, weirs, 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.

9.5.3 Design Procedures

Compute the inflow hydrographs for both pre- and post-developed conditions for the 10-year and 100-year storms given in Chapter 5.

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.

If the routed post-development peak discharge(s) from the design storm(s) exceeds the pre-development discharge, revise the pond volume and/or outlet structure design. Develop a revised stage-storage curve and a revised stage-discharge curve and rerun the flood routing.

Evaluate the downstream effects of detention outflow to ensure that the routed hydrograph does not cause 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.

9.5.4 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.

9.5.5 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 disking.

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.

Pipe bedding shall meet the requirements set forth in the Kentucky Highway Department Standard Specifications for Road and Bridge Construction, latest edition.

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 with ends abutting and 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 cleaned 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.

9.6 Extended Detention Ponds

In this manual, an extended detention pond is a dry detention pond equipped with an outlet structure that provides extended detention time (typically 24 hours) for a specific water quality treatment volume. Figure 9-5 illustrates an extended detention pond.

9.6.1 Applicability

Extended detention ponds can be used for both water quality treatment and water quantity management. For water quality treatment, the extended detention volume is at least equal to the WQV derived minus any credits for infiltration or bioretention.

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.

9.6.2 Design Criteria

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

Design the extended detention outlet so that the "design" WQV requires at least 24 hours to discharge.

To calculate the design WQV, take the full WQV for the site, minus any credits allowed for bioretention and infiltration practices.

Design extended detention ponds with two stages. The lower stage would be the extended detention pool sized for the design WQV. 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.

Design an emergency spillway to pass the 100-year storm assuming the principal spillway is clogged.

Design the pond in accordance with Kentucky Department for Environmental Protection, Division of Water's Engineering Memorandum No. 5, Design Criteria for Dams and Associated Structures.

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

Embankment heights shall not exceed 20 feet (measured from the downstream toe) and storage volumes shall not exceed 25 acre-feet. The minimum storage volume shall be 0.3 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.

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).

Provide a minimum 25-foot wide buffer strip between the pond and the nearest property line. Landscape the buffer strip with low-maintenance native grasses, shrubs, and trees. Provide a landscaping plan for the pond and the buffer. Objectives of landscaping include improving the appearance for adjacent residents and providing wildlife habitat.

9.6.3 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 WQV 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 10.7.3 and assume for design purposes that the elevation of the dry pond bottom corresponds to the elevation of the surface of the design WQV (i.e., the top of the extended detention pool).

Sand Filter Outlet

Figure 9-6 illustrates an outlet configuration that may be used to regulate discharge of the extended detention pool. A perforated riser may also be used.

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 3.54 ft/hr, adjust the filter dimensions and recalculate.

The falling head equation is:

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

where:

k = coefficient of permeability (ft/hr),

a = average surface area of extended detention pool (ft2),

L = depth of sand (ft),

A = surface area of filter = width of sand layer * length of sand layer (ft2),

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.

9.6.4 Specifications

Specifications are the same as for detention ponds.