SECTION 110 - CULVERTS AND BRIDGES

110.1 CULVERTS
- 110.1.1 Horizontal Alignment
- 110.1.2 Bends and Junctions
- 110.1.3 Vertical Alignment
- 110.1.4 Clearance from Other Utilities
- 110.1.5 Allowable Sizes
- 110.1.6 Construction Materials
- 110.1.7 Inlet and Outlet Requirements
- 110.1.8 Outlet Requirements

110.2 BRIDGES
- 110.2.1 Horizontal Alignment
- 110.2.2 Freeboard Requirements

110.3 HYDRAULIC ANALYSIS
- 110.3.1 Peak Runoff Rates
- 110.3.2 Design Storm
- 110.3.3 Backwater Requirements
- 110.3.4 Hydraulic Analysis

110.4 FLOODPLAIN DEVELOPMENT PERMIT REQUIREMENTS
- 110.4.1 Letters of Map Revision

110.5 DRIVEWAY CULVERTS
110.6 LOW WATER CROSSINGS
110.7 REFERENCES

Figure 110.1 Standard Headwalls With 30 & 45 Degree Wingwalls
Figure 110.2 Standard Straight Concrete Headwall
Figure 110.3 Standard U-Shaped Headwall
Figure 110.4 Low Water Crossing For Private Drives

SECTION 110 - CULVERTS AND BRIDGES

This section covers the design of culverts and bridges for conveyance of stormwater runoff under public or private roads and drives.

Where culverts and bridges are designed under the Bridge Replacement and Rehabilitation Program (BRRP), designs shall be done in accordance with the requirements of the Missouri Department of Transportation (MODOT) and the Federal Highway Administration (FHWA). It is intended that the requirements of this section are in conformance with the requirements of the BRRP, unless otherwise noted herein.

Definitions

Culvert - a short closed conduit in which open channel or pressure flow can occur, and whose capacity can be controlled by the culvert entrance (inlet control) or by the culvert barrel or downstream channel (outlet control). Flow typically enters culverts directly from an open channel, whereas the majority of flow in storm sewers enters through inlets. Culverts typically run transverse to the roadway. Storm sewers run parallel with as well as transverse to the street alignment.

Culverts having an open area of twenty (20) square feet or more located under County roads are inventoried as County bridges. Plans for these culverts must comply with the requirements of the Bridge Replacement & Rehabilitation Program.

Bridge - an open span structure through which pressure flow cannot generally occur.

110.1 CULVERTS

110.1.1 Horizontal Alignment

Culverts shall be positioned to match the alignment of the existing watercourse to the greatest degree practical. Relocating existing stream channels to match the culvert alignment shall be avoided unless specifically approved.

110.1.2 Bends and Junctions

Changes in direction, grade, size or material are not allowed within the culvert barrel, unless approved in writing by the Stormwater Engineer.

110.1.3 Vertical Alignment

Culverts shall be placed such that the vertical alignment of the invert matches the slope of the existing water course to the greatest extent practical. The recommended minimum slope for culverts is 0.5% (five-tenths percent). Culvert grades may not be less than the minimum friction slope required to convey the design flow, unless specifically approved. Maximum recommended grade is 10% (ten percent).

The top of the culvert pipe shall be located a minimum of twelve inches (12") below the pavement or curb subgrade, or greater if required to meet minimum cover and strength requirements to withstand an AASHTO HS-20 loading for the type of pipe specified.

A reduction in minimum clearance may be allowed when necessary in order to minimize rock excavation or to provide clearance from existing utilities, with written approval of the Stormwater Engineer and if located within public road right-of-way, written approval from the Highway Administrator is also required.

Where necessary to minimize rock excavation, cast-in-place reinforced concrete box culverts may be designed such that the top slab serves as a bridge deck. In these cases the top slab grade shall be designed to match the vertical alignment of the roadway. Top slab thickness shall be increased by two inches (2") to provide a wearing surface provided. If asphalt pavement is specified, top of the slab may be located two inches (2") below finished pavement grade to allow for placement of an asphalt wearing surface. Structural design of the culvert shall include allowance for the wearing surface weight.

110.1.4 Clearance from Other Utilities

Clearance from other utilities shall be the same as specified in Section 109.1.4 for storm sewers.

110.1.5 Allowable Sizes

The minimum allowable inside diameter or least dimension for any culvert is fifteen inches (15").

110.1.6 Construction Materials

Culverts under public and private roads shall be constructed of any of the materials allowed for storm sewers in Section 109.2 with the following restrictions:

Urban Areas (all zoning districts except the A-1, Agriculture District): Any of the concrete pipe types given in Section 109.2, precast concrete box culverts, or cast-in place reinforced concrete box culverts.

Rural Areas (A-1, Agriculture zoning district) or County roads in urban areas which have not yet been upgraded to urban standards: Any of the concrete or corrugated metal pipe or box culvert types given in Section 109.2.

110.1.7 Inlet and Outlet Requirements

Urban Areas: A cast-in-place concrete headwall, or a pre-fabricated flared end section of the same type of material as the culvert pipe shall be provided at the inlet and outlet ends of all culverts under public and private streets, and driveway entrances. Flared end sections and headwalls shall have a toewall extending a minimum of eighteen inches (18") below grade at their downstream end to prevent undercutting.

Rural Areas and County roads in urban areas which have not yet been upgraded to urban standards: Flared end sections and headwalls recommended, but not required.

Typical headwalls are shown in Figures 110.1, 110.2 and 110.3.

110.1.8 Outlet Requirements

Culvert outlets shall be designed to allow expansion of flow and reduction of velocity without undue risk of erosion downstream, and allowing for proper construction and maintenance of cut or embankment slopes at the outlet.

An erosion resistant lining of concrete or grouted riprap shall be provided for a distance equal to five (5) times the diameter of the culvert pipe or the box culvert width, downstream of the headwall apron or flared end section. The width of the grouted riprap shall be a minimum of two (2) times the pipe diameter or box culvert width or five feet (5'), whichever is less. Where velocity exceeds fifteen feet (15') per second at the culvert outlet, an energy dissipator may be required. Energy dissipators shall be designed as set forth in the ASCE design manual (Reference 109.4).

Outlet velocity should be limited to a maximum of fifteen feet (15') per second for the design storm. The maximum outlet velocity for the 2-year storm shall be ten feet (10') per second. Where the outlet velocity for the design storm cannot be limited to fifteen feet (15') per second, a stilling basin or energy dissipator must be provided. Energy dissipators shall be MODOT standard impact type. Other types must be approved by the Stormwater Engineer.

110.2 BRIDGES

This section covers hydraulic design requirements for bridges. Geometric and structural design requirements are addressed in the County Road Standards and BRRP Standards.

110.2.1 Horizontal Alignment

Bridge abutments and piers shall generally be aligned to match the alignment of the existing watercourse. Relocation of existing stream channels shall be avoided unless specifically approved.

110.2.2 Freeboard Requirements

The bottom of the bridge superstructure must allow sufficient clearance (freeboard) over the design high water elevation to allow the passage of drift through the bridge opening. Minimum freeboard requirements are as follows:

Drainage area less than twenty (20) square miles: Two feet (2')

Drainage area twenty (20) square miles or more: Three feet (3')

For bridges on grade, the required freeboard may be reduced at the low end of the span provided the minimum freeboard is maintained for at least fifty percent (50%) of the span. For bridges for which funded or credit is received through the BRRP, a variance must be obtained from MODOT for any reduction in freeboard.

110.3 HYDRAULIC ANALYSIS

110.3.1 Peak Runoff Rates

Peak runoff rate shall be computed using the methods given in Section 104. Methods for computing design flow rates for bridges and culverts are listed below:

A. Drainage Areas two hundred (200) acres or more:

1. U.S. Geological Survey, Magnitude and Frequency of Missouri Floods, Water Resources Report #23, 1968 and addenda. (for sites located near a U.S.G.S. gaging station).

2. Rural Areas: U.S. Geological Survey, Technique for Estimating the 2- to 500-year Flood Discharge on the Unregulated Streams in Rural Missouri, Report 95-4321, 1995.

3. Urban Areas: U.S. Geological Survey, Technique for Estimating the Flood-Peak Discharges for Urban Basins in Missouri, Report 86-4322, 1986.

4. Flood Insurance Studies: For streams for which peak flow rates have been determined as a part of the Greene County Flood Insurance Study (FIS), discharge rates developed for the FIS shall be used.

B. Drainage Areas less than two hundred (200) acres:

The Rational Method (Section 104.5) or a more detailed method may be used.

110.3.2 Design Storm

The return storm frequency to be used in determining the peak discharge rate used for the design of a bridge or culvert is follows:

A. Drainage Areas one (1) square mile or more:

Road Classification	Return Period (years) *	
Rural - secondary arterial	100	(1%)
Rural - collector	100	(1%)
Rural - local	25	(4%)
Urban - primary arterial	100	(1%)
Urban - secondary arterial	100	(1%)
Urban - collector	100	(1%)
Urban - local	100	(1%)

* Annual Exceedance Probability in parentheses.

B. Drainage Areas less than one (1) square mile:

Road Classification	Return Period (years) *	
All urban streets	25	(4%)
Rural, ADT < 400	5 **	(20%)
Rural, ADT <1700	10	(10%)
Rural, ADT >1700, <5000	25	(4%)
Rural, ADT >=5000	50	(2%)

** The 10-year storm must be used for bridges for which funding or credit is received through the BRRP.

110.3.3 Backwater Requirements

Greene County participates in the National Flood Insurance Program. Where any portion of the bridge or culvert structure or approach road is located within a floodplain area designated on the Flood Insurance Rate Maps (FIRM) for Unincorporated Greene County, floodplain requirements set forth in Article XIX, Floodplain Management Ordinance, of the Greene County Zoning Regulations must be met.

A. Outside of FEMA designated floodplains or within un-numbered Zone A floodplains.

Bridges and culverts must be designed such that the water surface elevation produced by the 100-year peak discharge rate is not increased by more than one foot (1') at the upstream right-of-way line or the upstream limit of a recorded drainage easement.

If the effect of the proposed construction would place the floor elevation of any existing structure less than one foot (1') above the estimated high water elevation for the 100-year storm, the allowable backwater must be reduced to maintain the minimum one foot (1') of freeboard, or the structure must be elevated, removed or relocated outside of the area inundated by the Base (100-year) Flood under post-project conditions.

B. Floodplains with designated floodways.

Bridges and culverts must be designed such that the "Base Flood Elevation (BFE) without Floodway" is not increased by more than one foot (1') at any point, and the "Base Flood Elevation with Floodway" is not increased at any point.

110.3.4 Hydraulic Analysis

A. Outside of FEMA designated floodplains or within un-numbered Zone A floodplains.

1. Culverts

Hydraulic analysis of culverts shall be done in accordance with the procedures set forth in the Federal Highway Administration Hydraulic Design Series No. 5 (HDS-5) (Reference 109.3).

The maximum allowable headwater depth for the design storm shall not be higher than one foot (1') below the elevation of the roadway shoulder line at the low point in the roadway profile.

2. Bridges

Hydraulic analysis of bridges may be done in accordance with the procedures of the Federal Highway Administration Bridge Waterways Analysis Model, WSPRO (HY-7) (Reference 110.1) or any of the methods set forth below. Water surface profile models shall extend a sufficient distance downstream to account for backwater effect which may effect the design of the bridge waterway opening and upstream a sufficient distance to match the pre-project water surface elevations.

B. Floodplains with designated floodways

Hydraulic analysis of both bridges and culverts must be done using the Corps of Engineers' Water Surface Profiles program (HEC-2) (Reference 110.2) or River Analysis System (HEC-RAS) (Reference 110.3). Analysis must be done in accordance with FEMA requirements. Water surface profile models must tie into the effective Flood Insurance Study (FIS) model both upstream and downstream.(NOTE: FEMA may not accept HEC-RAS analyses for amendments or revisions to Flood Insurance Rate Maps. FEMA does not accept WSPRO models for map amendments or revisions).

110.4 FLOODPLAIN DEVELOPMENT PERMIT REQUIREMENTS

A Floodplain Development Permit must be obtained from the County for any construction within numbered or unnumbered Zone A floodplain areas.

110.4.1 Letters of Map Revision

A Letter of Map Revision (LOMR) or Conditional Letter of Map Revision (CLOMR) must be obtained from FEMA for any construction in a designated floodway which produces any increase in the base flood elevation "without floodway" (the BFE shown on the FIRM maps).

110.5 DRIVEWAY CULVERTS

A permit is required from the Greene County Highway Department for installation of any driveway culvert in public road right-of-way. Driveway culverts for small drainage areas shall be the size recommended by the Greene County Highway Department. For culvert sizes greater than thirty inches (30") in diameter, the culvert size shall be determined by a registered engineer. Driveway culverts shall be designed to pass the peak runoff rate from a two-year storm without overtopping the drive and have sufficient capacity such that in conjunction with surface flow in the roadway, the peak flow from 100-year storm is contained in the road right-of-way.

Driveway culverts can be constructed of any of the pipe materials listed in Section 109.2. Culverts eighteen inches (18") or less in diameter or least dimension shall have one (1) cleanout provided at every fifty feet (50') interval. Flared end sections or headwalls are recommended but not required.

110.6 LOW WATER CROSSINGS

Low water crossings are permitted only on private drives. A typical low water crossing is shown in Figure 110.4. Hydraulic analysis is not required if no fills are constructed for the driveway, and the top of the drive is one foot (1') less in elevation than the grade at the nominal top of the channel bank at the upstream end of the property upon which the low water crossing is built, or a drainage easement is obtained up to the point where the stream bottom grade is equal to the top of the low water crossing.

Where this condition cannot be met, a hydraulic analysis must be prepared by a registered engineer demonstrating that the water surface elevation for the 100-year storm has not increased more than one foot (1') at the upstream property line or upstream end of the drainage easement.

Low water crossings shall be provided with a minimum of one (1) fifteen inch (15") diameter culvert. It is recommended that the maximum depth of the 25-year peak flow rate limited to twelve inches (12") over the driveway for drainage areas up to one (1) square mile. For drainage areas greater than or equal to one (1) square mile, it is recommended that the depth of the 100-year storm be limited to eighteen inches (18") .

110.7 REFERENCES

1. Bridge Waterways Analysis Model (WSPRO) (March 1990) Federal Highway Administration, HY-7, Washington, D.C.

2. HEC-2 Water Surface Profiles, September 1990, U.S. Army Corps of Engineers, Hydrologic Engineering Center.

3. HEC-RAS River Analysis System, Users' Manual and Hydraulic Reference Manual, Version 1.0, 1995.

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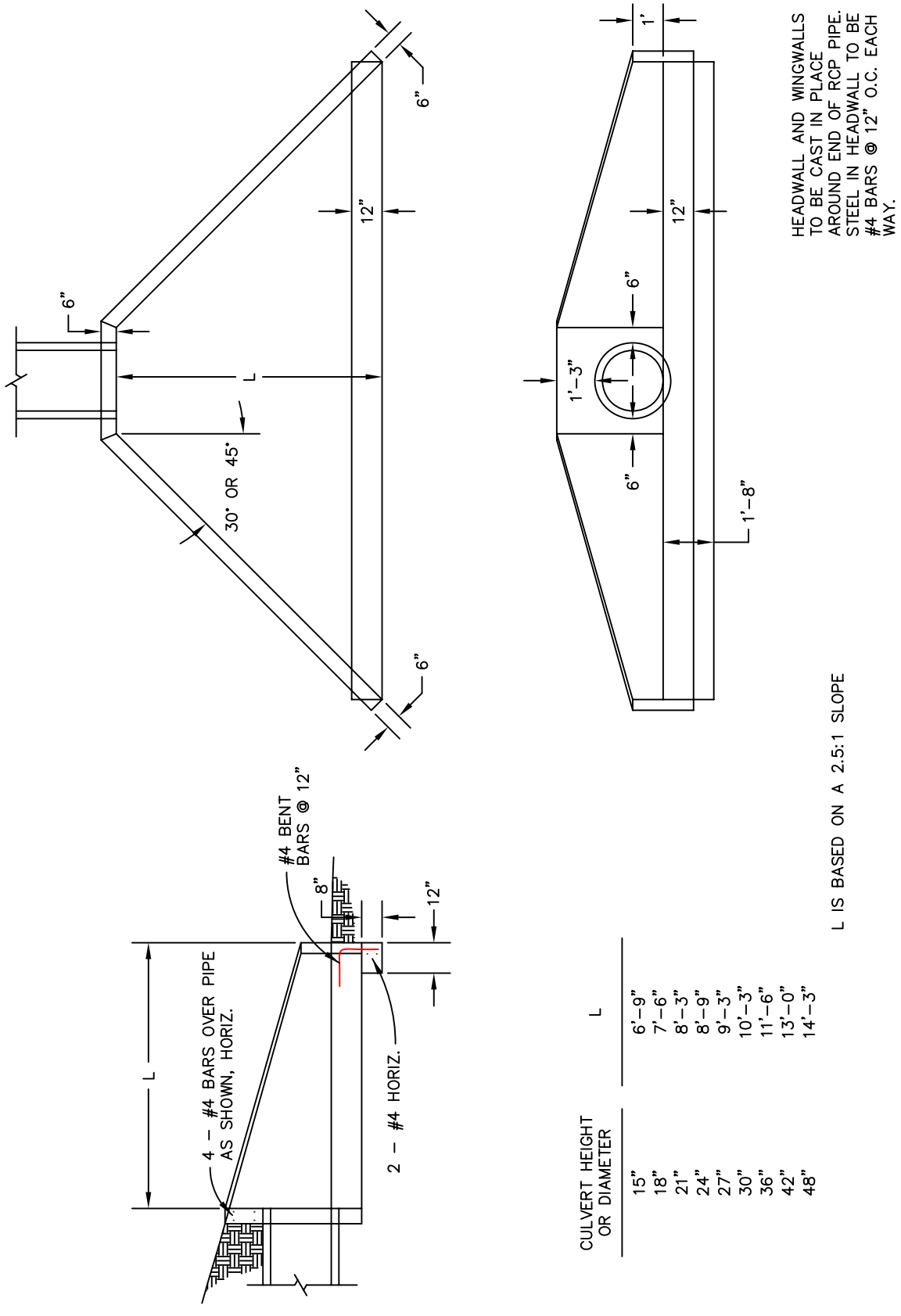

CULVERT HEIGHT OR DIAMETER	L
15"	6'-9"
18"	7'-6"
21"	8'-3"
24"	8'-9"
27"	9'-3"
30"	10'-3"
36"	11'-6"
42"	13'-0"
48"	14'-3"

GREENE COUNTY MISSOURI – STORM WATER DESIGN STANDARDS

STANDARD HEADWALLS
WITH 30 & 45 DEGREE WINGWALLS

FIGURE 110.1

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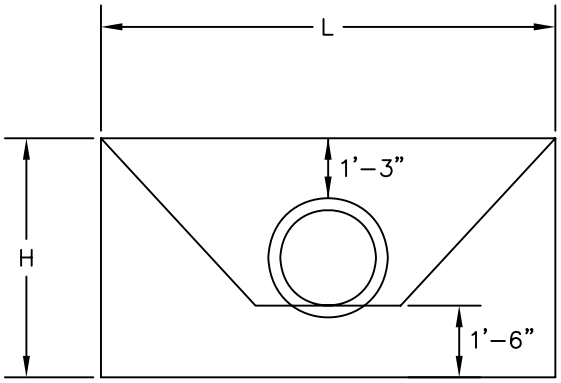
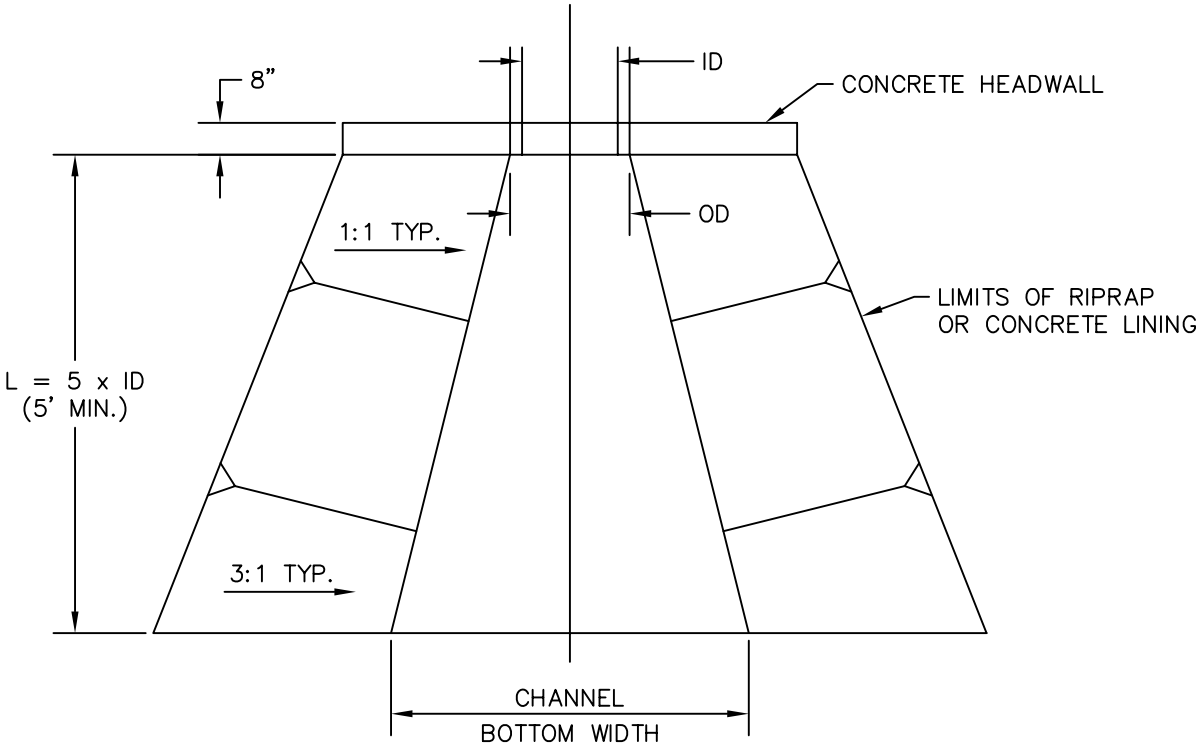
DATE: 04/05/99

PIPE DIAMETER	L	H
15"	7'–0"	4'–3"
18"	8'–0"	4'–6"
21"	8'–9"	4'–9"
24"	9'–6"	5'–0"
27"	10'–6"	5'–3"
30"	11'–6"	5'–6"
36"	13'–0"	6'–0"
42"	14'–6"	6'–6"
48"	16'–0"	7'–3"



REINFORCEMENT: #4's @ 12", EACH WAY



GREENE COUNTY MISSOURI – STORM WATER DESIGN STANDARDS

STANDARD STRAIGHT CONCRETE HEADWALL

FIGURE 110.2

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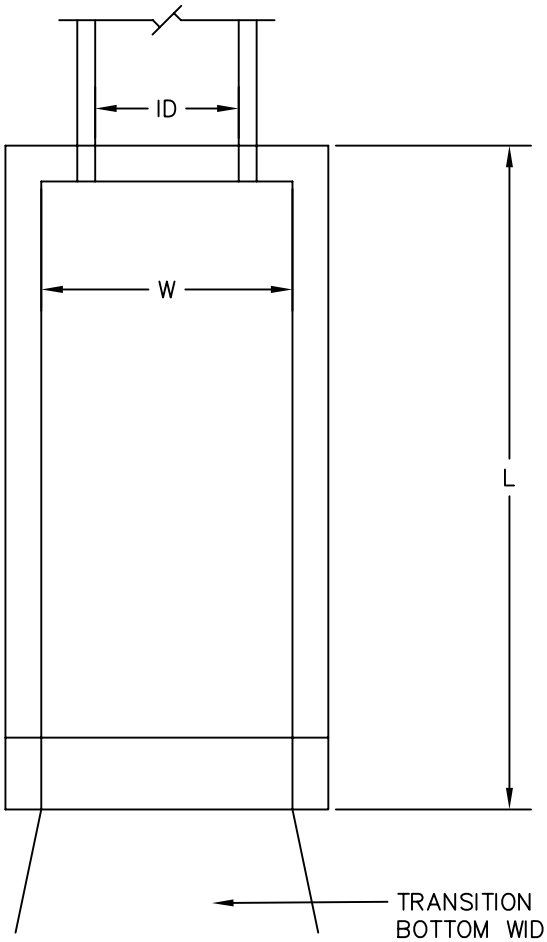
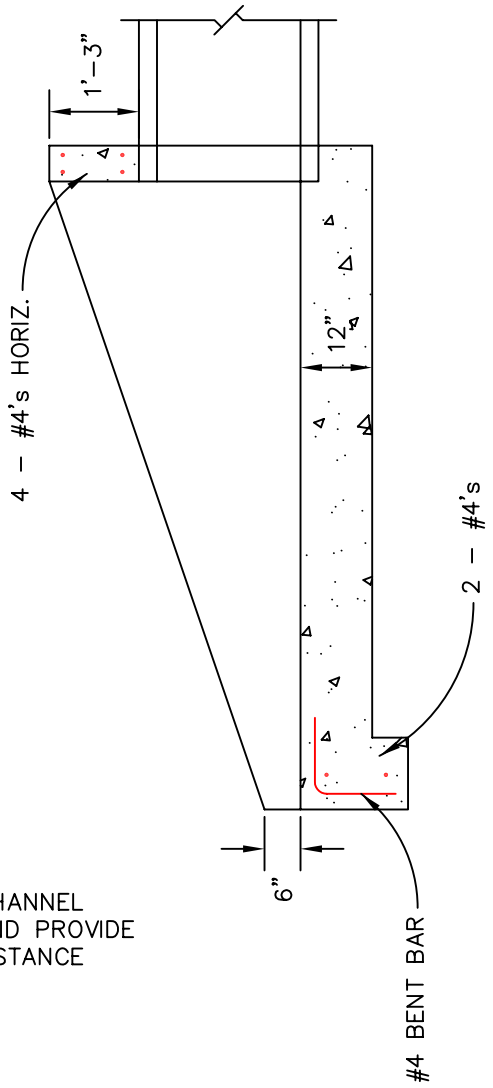
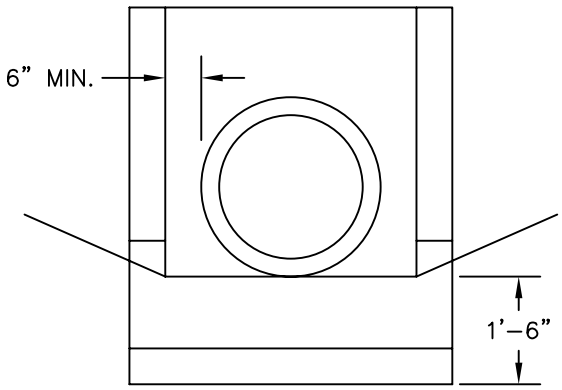




TRANSITION TO CHANNEL BOTTOM WIDTH AND PROVIDE RIPRAP FOR A DISTANCE OF 5 x ID.



PIPE DIAMETER	L	H
15"	6'-9"	2'-9"
18"	7-6"	3'-0"
21"	8'-3"	3'-3"
24"	8'-9"	3'-6"
27"	9'-3"	3'-9"
30"	10'-3"	4'-3"
36"	11'-6"	4'-9"
42"	13'-0"	5'-3"
48"	14'-3"	6'-0"

STANDARD U-SHAPED CONCRETE HEADWALL

FIGURE 110.3

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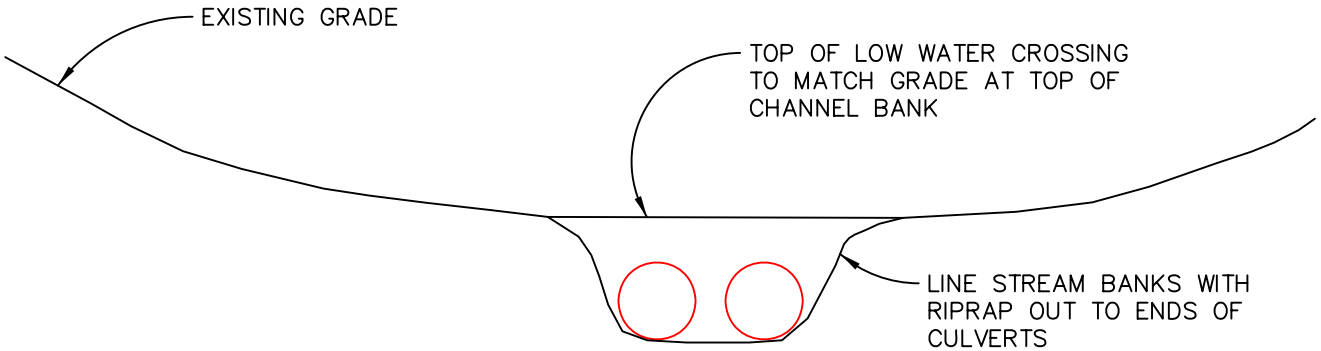

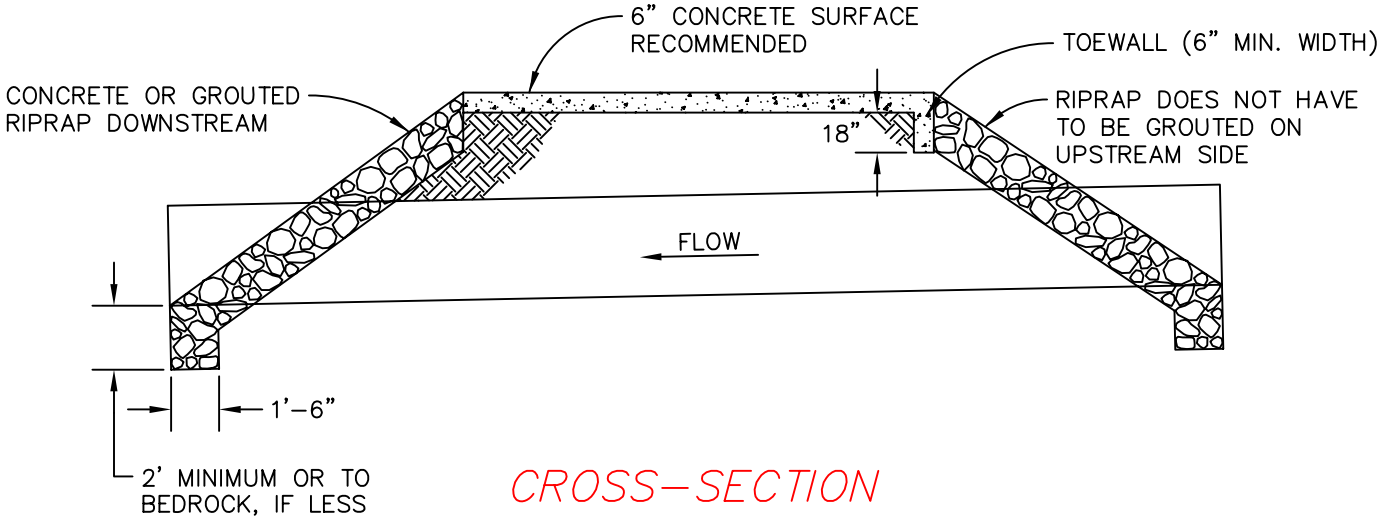

CROSS-SECTION

GREENE COUNTY MISSOURI - STORM WATER DESIGN STANDARDS

LOW WATER CROSSING FOR PRIVATE DRIVEWAYS

FIGURE 110.4

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