Sloped and Mitered Concrete Headwalls

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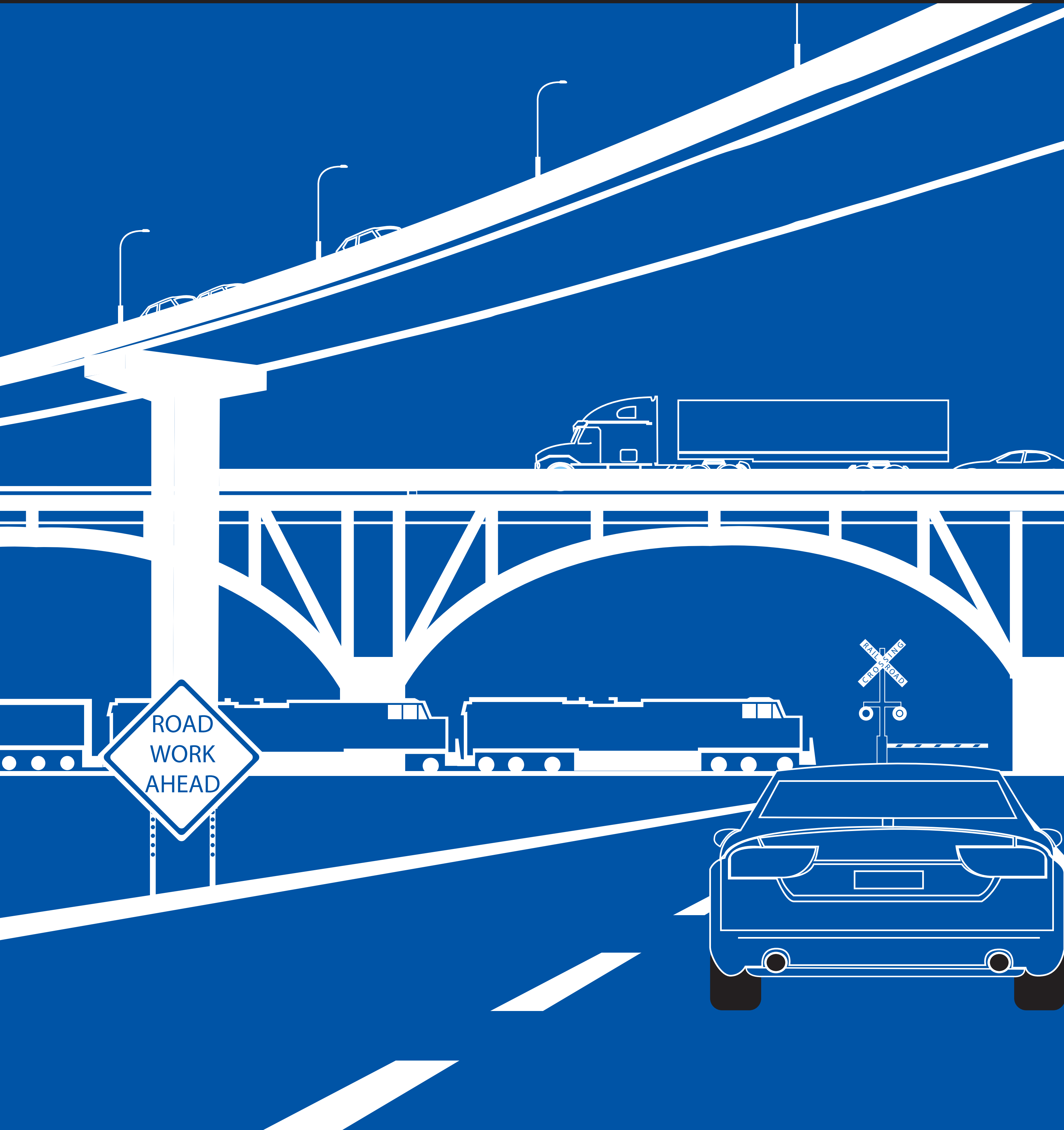

Kentucky Transportation Center
College of Engineering, University of Kentucky, Lexington, Kentucky

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Kentucky Transportation Cabinet
Commonwealth of Kentucky

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Research Report
KTC-18-12/SPR17-537-1F

Sloped and Mitered Concrete Headwalls

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16. Abstract
The Kentucky Transportation Cabinet (KYTC) currently uses several pipe culvert end treatments, including standard headwalls, slope and flared headwalls, sloped and parallel headwalls, and safety metal ends. These treatments, however, can pose a safety hazard to motorists and those performing landscaping work (e.g., mowing). Crash statistics from 2012 through 2016 for Kentucky reveal that 49 fatalities and 148 incapacitating injuries occurred in incidents where culverts/headwalls were coded as the first harmful event on the police report. One solution to the safety hazards associated with standard pipe culvert headwalls is to use sloped and mitered concrete headwalls instead. To evaluate the viability of sloped and mitered concrete headwalls for widespread use, Kentucky Transportation Center (KTC) researchers reviewed industry guidance and best practices; observed, documented, and analyzed several projects on which sloped and mitered concrete headwalls were used; developed cost comparisons for sloped and mitered concrete headwalls and conventional headwalls, and evaluated specifications for sloped and mitered concrete headwalls adopted by other states. Sloped and mitered concrete headwalls conform with industry guidance and protect against significant vehicle damage. Observations of sloped and mitered concrete headwalls used on KYTC projects attested to the importance of establishing and applying unambiguous design and construction criteria. Specifically, the grade should be set before a slope and mitered headwall is installed. Furthermore, adding grate bars will improve performance as will securing pipe ends to the headwall. A sample of headwalls should be chosen for long-term monitoring purposes, with inspections conducted each year. Overall, sloped and mitered concrete headwalls are an attractive option given they can be installed quickly and without special equipment, their robust performance, and low cost compared to standard pipe culvert headwalls.

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Introduction

The Kentucky Transportation Cabinet (KYTC) generally uses the following pipe culvert end treatments: standard headwalls, slope and flared headwalls, sloped and parallel headwalls, and safety metal ends. Each end treatment has a typical slope; when the embankment slope varies from the headwall slope, the embankment slope is warped to fit the headwall. Portions of the headwalls that project above the ground and the embankment warping around the headwall present safety hazards to vehicles that leave the roadway, increasing the possibility of a vehicle overturning and injury to passengers. In addition, right of way (ROW) mowing activities have trouble traversing these areas. A recent incident involving a sloped and flared headwall illustrates these hazards — a tractor with a bush hog struck a headwall hidden under grass, overturning the tractor, injuring the KYTC operator, and damaged KYTC equipment.

Using a paved-to-slope type headwall with a mitered pipe end is one solution to this problem. These headwalls are cast in pace to match the embankment slope, eliminating the need to warp the embankment around the drainage end treatment and provide a traversable slope. Installation can be performed without special equipment, and a traversable grate can be installed when required. KYTC currently lacks a standard drawing for this type of headwall. The Cabinet does have a standard detail for sloped and mitered concrete headwalls and use this end treatment on select projects involved with the Highway Safety Improvement Program (HSIP).

This report examines previous research undertaken on sloped and mitered concrete headwalls, identifies the current construction standard of practice used by state departments of transportation (DOTs), documents the installation of sloped and mitered concrete headwalls on select HSIP projects, and offers justifications for using this type of culvert end treatment in Kentucky.

Literature Review

There is ample support for use of a paved-to-slope type headwall in the literature. The *AASHTO Roadway Design Guide* instructs agencies to “design or modify drainage structures so they are traversable or present a minimal obstruction to an errant vehicle.” The preferred method is to make cross drain structures traversable. For parallel structures, the preferred method is to eliminate the structure altogether. If the structure cannot be removed, a traversable design should be used. Single barrel cross drain pipes less than or equal to 36 inches in diameter can be mitered to the embankment slope without further modification. Cross drain pipes with a diameter greater than 36 inches can be made traversable by installing bar grates perpendicular to the direction of traffic on 30-inch-centers, but these should not decrease the hydraulic capacity of the pipe. Parallel pipe end treatments require grate bars installed on 24-inch centers.

Wilson, in NCHRP Synthesis 321: *Roadway Safety Tools for Local Agencies*[1], recommends eliminating hazardous concrete culvert headwalls by either breaking the headwall off at ground level or building up the soil to the level of the headwall top surface. Using paved-to-slope type headwalls in lieu of obtrusive headwalls would create a safely traversable surface and remove the need to correct these hazardous types of headwalls. The FHWA *Maintenance of Drainage Features for Safety*[2] also recommends replacing

[1] Wilson, Eugene M., Ph.D., consultant. NCHRP Synthesis 321: *Roadway Safety Tools for Local Agencies.* Washington, D.C.: Transportation Research Board, 2003.

[2] McGee, Hugh W., P.E., Daniel Nabors, P.E., and Timothy Baughman, P.E., eds. *Maintenance of Drainage Features for Safety, A Guide for Local Street and Highway Maintenance Personnel*. Tech. FHWA-SA-09-024. U.S. Department of Transportation, Federal Highway Administration, 2009.

potentially hazardous headwalls which extend above the surrounding ground with traversable culvert end treatments.

Safety grates (i.e., safety pipe runners) can be installed across mitered headwalls to further improve safety. Sicking et al. present their results of crash testing in *Safety Grates for Cross-Drainage Culverts*[3]. The simulated safety grate constructed for their tests consisted of 4-inch diameter schedule 40 steel pipes spaced at 30 inches to create a 20-ft x 20-ft unsupported span across a mock culvert. Crash test results were favorable, and Sicking et al. conclude that safety grates, as recommended by the AASHTO *Roadside Design Guide*, provide acceptable safety performance on slopes as steep as 3:1. Their results also support safety grates as the safety treatment for cross-drainage culverts with the highest cost-to-benefit ratio.

Methodology

At the time this report was completed, no route-specific crash statistics were available. Instead, the report presents a review of network-level crash statistics from 2012 to 2016 for Kentucky. The crash statistics are based on the KABCO injury scale, which law enforcement uses to classify the resultant injury severity of accidents. The two classifications of most concern are *K* and *A*, which are fatalities and incapacitating injuries, respectively. The remaining classifications — *B*, *C*, and *O* — refer to non-incapacitating injury, possible injury but not evident, and no injury detected, respectively. Each crash report identifies the location of the object struck during the first harmful event, second harmful event, and most harmful event. To understand the dangers posed by headwalls, the Kentucky Transportation Center (KTC) research team compared the number of crashes involving fixed objects to those which involved headwalls. For this project fixed objects were identified as the following: bridge pier abutment, bridge parapet end, bridge rail, fence, cable barrier, concrete barrier, culvert headwall, curbing, fire hydrant, guardrail end, guardrail face, light support, mailbox, median support, other fixed object, other non-movable object, other post/pole/support, overhead sign post, sign post, traffic signal support, tree, and utility pole.

Researchers selected two HSIP projects to document the installation of sloped and mitered concrete headwalls. The first project was KY 1600 in Hardin County (CID 16-4207) from MP 3.315 to MP 8.528. Researchers observed the construction of the sloped and mitered concrete headwalls and documented the installation of select headwalls. Documentation consisted of spot checks of the headwall slope, width, length, edge width, reinforcement type and configuration, and slab thickness, along with taking photos of the installation and headwalls. The second project was KY 54 in Ohio County (CID 17-4006) from MP 0.000 to MP 6.018. The only documentation of this project was photographs of the finished headwalls.

KTC researchers compared the cost of sloped and mitered concrete headwalls to standard headwalls of the same size. Four projects were selected to make this comparison, including the aforementioned KY 1600 project and the KY 54 project. Two other HSIP projects were examined to generate cost comparisons — the KY 1304 project (HSIP 9010, CID 17-4001) and the US 460 project (HSIP 4601, CID 17-4114). Researchers looked up the awarded unit bid costs for each project and compared the cost for each size headwall and type of headwall.

Researchers learned that the Kentucky standard for sloped and mitered concrete headwalls is based on the Florida Department of Transportation's (DOT) Cross Drain Mitered End Section Standard, but that other states may be using a similar structure. Therefore, the final portion of this report highlights other states

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[3] Sicking, Dean L., Robert W. Bielenberg, John R. Rohde, John D. Reid, Ronald K. Faller, and Karla A. Polivka. "Safety Grates for Cross-Drainage Culverts." *Transportation Research Record* 2060 (2008): 67-73.

using a sloped and mitered concrete headwall and compare their designs with Kentucky's design. A survey was sent out to DOT officials in each state asking about their state's use of sloped and mitered concrete headwalls and if the they had any construction specifications, standard drawings, or standard details. Six states responded — Oregon, Idaho, Illinois, New Jersey, South Dakota, and Virginia. Only Oregon confirmed the use of sloped and mitered concrete headwalls. An online specification search identified Oklahoma and Texas as other DOTs using this type of headwall. Researchers then found and compared the details or standards developed in these states to Kentucky's detail.

Findings

Kentucky Crash Statistics

The research team analyzed Kentucky crash statistics from 2012 to 2016 to find the percentage of accidents involving fixed objects. There were 770 fatalities associated with a fixed object for the first harmful event, and 49 of those were related to a culvert/headwall. Fixed objects accounted for 2,428 incapacitating injuries; 148 were attributed to a culvert/headwall. The second harmful event identified 668 fatalities associated with a fixed object, with 48 of these being associated with a culvert/headwall.

Table 1 KABCO Crash Data for Fixed Objects and Headwalls From 2012-2016

	First Event					
	K	A	B	C	O	Totals
Fixed Object	770	2,428	6,273	8,198	58,917	61,966
Headwall	49	148	353	456	1,645	2,651

	Second Event					
	K	A	B	C	O	Totals
Fixed Object	668	1,873	4,526	5,495	20,139	45,504
Headwall	48	111	211	261	728	1,359

	Most Harmful Event					
	K	A	B	C	O	Totals
Fixed Object	846	1	0	15	7	1,189
Headwall	46	0	0	0	0	46

KY 1600 Project

Researchers made two initial observations on the KY 1600 project. The first pertained to the construction sequence for the sloped and mitered concrete headwall. Construction of the headwall preceded the final grading, and the contractor performing the installation was required to set the grade of the headwalls. The contractor expressed apprehension regarding this to researchers during their first day at the job site. KYTC's sloped and mitered concrete headwall detail (see Appendix B) has dimensions for 4:1 and 6:1 headwall installations. Sixteen headwalls were checked for slope, and 11 of those were installed on a slope steeper than a 4:1. The second observation was that headwalls for skewed pipes were installed in-line with the pipe rather than perpendicular to the roadway (Figure 1).

Figure 1 Headwall Installed on a Skew at STA 170+76 RT

Several issues arise due to this incorrect installation. It creates a launch point and potentially transforms a traversable slope into one that is non-traversable. Headwalls like the one mentioned above were reconstructed (Figure 2) to conform to the sloped and mitered concrete headwall detail and the intent of the project.

Figure 2 Reconstructed Headwall at STA 170+76 RT

Other ways in which this installation deviated from the standard detail were the minimum 3 foot-slab length past the crown of the headwall and the use of No. 5S deformed rebar rather than 6” x 6” - W2.9 x W2.9 welded wire fabric.

How far past the crown of the pipe a slab projects dictates the amount of earthen cover on the pipe. The detail gives the dimensions for the length of the headwall from the toe to the crown. If constructing a headwall on a 4:1 only using the longitudinal section and the dimension and quantities table, there will be less than 5 inches of cover over the pipe when the headwall is projected the minimum 3 feet past the crown (Figure 3). Straight concrete headwalls and sloped and flared headwalls, which are used for pipes up to 27 inches in diameter, provide cover depths of 18 and 9 inches, respectively. Pipe culvert headwalls provide 12 to 13 inches of cover for pipes 30 to 42 inches in diameter. Given the proximity of these sloped and mitered concrete headwalls to the roadway the area may require future monitoring, especially for larger diameter pipes.

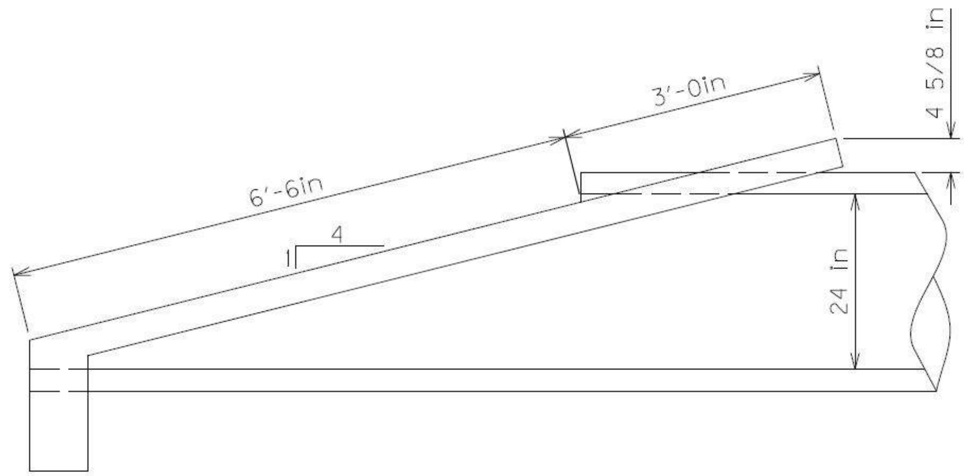


Figure 3 Depth of Cover For 24 Inch Pipe With 3-inch Wall Thickness

Comparing the amount of steel per foot, the use of No. 5 rebar does not appear to be an issue. The amount of reinforcing steel per foot when using the specified 6” x 6” - W2.9 x W2.9 welded wire fabric is 0.058 square inch per foot and No. 5 rebar on 12-inch centers each way has an area of 0.31 square inch.

The headwalls were constructed with the correct slab width and thickness specified by the detail. The raw metal exposed by mitering the CMP was protected. Before application of protection, evidence appeared of a separation between the mitered pipe end and the headwall (Figure 4), but there did not appear to be any signs that the pipe ends were secured to the headwall.

Construction of the headwalls generally took three days depending on whether they required grate bars. Multiple headwalls were formed in one day. Excavation, forming, placement of the reinforcement, and bedding took place one day, then pouring and finishing the concrete occurred the next day. Finishing the pipe and adding the grate bars occupied the final day. However, activities from excavation to finishing of the concrete could take place in one day.

Figure 4 Separation Between Headwall and Pipe End

The detail used does not distinguish between a headwall for a pipe crossing beneath a road and a headwall for a pipe that runs parallel to the road (e.g., an entrance pipe). This distinction is important because it determines the alignment and separation of the grate bars. Though it appears the grate bars were installed according to the detail, they were not installed in a manner that would allow a vehicle to traverse the headwall. Figure 5 shows the finished headwall with grate bars for a 36-inch pipe. This pipe is larger than 30 inches, and there is not a grate bar perpendicular to traffic as recommended by AASHTO. Appendix A contains the remaining photo documentation and notes.

Figure 5 Grate Bars on 36-inch Sloped and Mitered Concrete Headwall

KY 54 Project

This project used the sloped and mitered concrete headwall as well as the safety type box inlet. The project had been completed when it was selected for this study, however, the project proposal contained pictures of existing headwalls on the project which illustrate the roadway improvement provided by the sloped and mitered concrete headwall. The project also used a revised detail (see Appendix C) for the sloped and mitered concrete headwall.

Figure 6 shows an existing straight headwall adjacent to the roadway with an inlet ditch 3-4 feet below the roadway grade. Figure 7 captures the improvement to the clear zone, which included extending the existing pipe, regrading of the foreslope, and installing a sloped and mitered concrete headwall. The headwall projecting above grade was removed and the slope is now traversable. This was a typical type of improvement for this project. Appendix A includes additional photos and notes.

Figure 6 Existing Headwall

Figure 7 New Headwall and Improvements to the Clear Zone

Pipe ends were secured to the headwall per the detail, but the raw metal from the mitered ends of the pipe was not protected (Figure 8).

Figure 8 Mitered Pipe End Secured to Headwall

There is a discontinuity in the slope in at Station 68+75 RT,. The depression is located above the pipe and around the headwall (Figure 9). This pipe was not included in the proposal, and there was no designed pipe profile sheet. The pipe was within the limits of a superelevation improvement and might have been added later.

Figure 9 Depression Above Pipe

The safety type Box inlet was the second type of headwall used on this project. Although not a part of this monitoring effort, there was a common observation in 6 of the 7 headwalls. Figure 10 shows a safety type box inlet for a 24-inch pipe. The detail illustrates a grate that is 6.5-feet long and extends to the structure's toe. The grates on a majority of these type of headwalls have blockages ranging from 25% to 75%.

Figure 10 Safety Type Box Inlet Grate Blocked

Debris collects on the grate because it extends to the toe. This will require periodic maintenance as it could encourage water to pond and overtop the roadway (depending on site conditions) or compromise the roadway embankment by allowing the embankment material to remain saturated. Since these headwalls are installed parallel to the roadway and an approaching vehicle must be able to traverse the grate from the toe, one solution is to leave a sufficiently large opening at the toe of the headwall to let smaller debris pass. AASHTO recommends a the lower grate bar on parallel drainage to be 4 to 8 inches above the flowline of the headwall.

Headwall Cost Comparison

Table 1 lists the awarded unit bid prices for each headwall type by project. The most accurate form of cost comparison would be to compare the cost of the same sized sloped and mitered concrete headwall and a standard pipe culvert headwall from the same project. However, while the KY 54 project has both types of the same size headwall, including the safety box type inlet, the KY 1600 project lacks standard pipe culvert headwalls. Sloped and mitered concrete headwall were roughly 2/3 the cost of the standard pipe culvert headwall and a little over 1/2 of the cost of the safety type box inlet. Cost comparisons were also developed for two additional HSIP projects, the KY 1304 project (HSIP 9010, CID 17-4001) and the US 460 project (HSIP 4601, CID 17-4114). These projects had both headwall types of the same size. The price of sloped and mitered concrete headwalls ranged from 45% to 70% of the cost of the comparable pipe culvert headwall for these projects. Neither the KY 1304 project nor the US 460 project used safety type box inlets.

Table 2 Headwall Cost Comparison

Headwall Type	KY 1600 Project		KY 54 Project		KY 1304 Project		US 460 Project	
	Unit Bid	Qty	Unit Bid	Qty	Unit Bid	Qty	Unit Bid	Qty
18" S&M	$1,400	30	$1,900	9	$1,180	7	$1,040	1
18" SBI	-	-	$3,400	2	-	-	-	-

18" PC	-	-	$2,600	5	$1,650	7	$1,600	1
24" S&M	$1,800	11	$1,900	7	$1,300	7	$750	4
24" SBI			$3,500	2				
24" PC	-	-	$3,000	4	$1,800	7	$1,655	2
30" S&M	$2,000	8	-	-	$1,350	4	-	-
30" PC	-	-	-	-	-	-	-	-
36" S&M	$2,500	3	-	-	$1,375	1	-	-
36" PC	-	-	-	-	$2,500	2	-	-
42" S&M	$2,800	3	-	-	-	-	-	-
42" PC	-	-	-	-	-	-	-	-

Review of State DOT Details

A review of state DOT materials turned up limited results. No state standard specification mentions mitered to slope headwalls. However, the research team located either design details or standard drawings from the Florida, Oklahoma, Oregon, and Texas DOTs.

The Florida DOT's 2014 Design Standards include drawings for a cross drain mitered end section either on a 2:1 or 4:1 miter slope for pipes up to 72 inches in diameter depending on pipe material type. The end section can be used with round reinforced concrete pipe (RCP), corrugated metal pipe (CMP), high density polyethylene pipe (HDPE), polyvinyl-chloride pipe (PVC), and polypropylene pipe (PPP). Single and double barrel installations are permitted for elliptical RCP and arch CMP. The concrete slab must consist of Class NS concrete. Slab thickness can be 3 or 5.5 inches, but 5.5 inches is typical. The concrete is reinforced with 6 x 6 - W1.4 x W1.4 welded wire fabric. Slab dimensions vary with pipe size and mitered slope, but the length should be sufficient to provide adequate cover over the crown of the pipe with the slab bridging the crown. Slab width should extend 1.5 feet past the pipe on both sides. The upper corners of the headwall are to be rounded or beveled. The pipe joint's location under the headwall is also controlled. The detail also provides guidance on the use dissimilar materials when extending an existing pipe and adding the headwall. The detail, however, does not mention the use grates. Refer to Appendix D for more information.

The Oklahoma DOT design standards include culvert end treatments — both single and double pipe installations — and at 4:1 and 6:1 safety slopes. Concrete slab dimensions are similar to Florida's detail and must be constructed of Class A concrete 4 inches thick and reinforced with No. 4 bars. Safety grates are required for all side drains, with the grates running transverse to the face of the headwall on 30-inch centers max. Cross drains larger than 30 inches require that grate bars run longitudinally with the headwall. The grate bars are 3-inch schedule 40 steel pipe. Refer to Appendix E for more detail.

The Texas and Oregon DOTs both allow the use of a similar headwall on pipe up to 60 inches and 72 inches, respectively. Slab thickness is 4 inches and like Oklahoma, both agencies require use of a pipe runner down the long axis of the headwall to ensure the headwall is traversable for pipes larger than 30 inches. The Oregon DOT calls for 4 x 4 - W4 x W4 welded wire fabric or No.4 rebar on 18-inch centers each way. It also requires the placement of anchor bolts around the perimeter on a maximum of 18-inch centers.

Table 2 compares the revised KYTC sloped and mitered concrete headwall detail used on the KY 54 project to similar headwall standards from other states. It does not compare the requirements for pipes on a skewed condition, but the Texas DOT has comprehensive dimensions for skewed pipe installations. The Florida, Oklahoma, and Texas DOT standards distinguish between cross drains and side drains, which affect requirements and the alignment of grate bars. The required class of concrete is also not specified in the detail, however, Class A concrete is to be used. Florida and Oklahoma's DOTs require additional concrete above the crown of the pipe. If cover depth is a concern, adding protection to the crown should be considered.

Table 3 DOT Headwall Detail Summary Comparison

	KY	FLA	OK	TX	OR
Pipe Sizes	15" - 42"	15" - 72"	18" - 48"	12" - 60"	12" - 72"
Pipe Material	not specified	RCP, CMP, HDPE, PVC, PPP	not specified	RCP, CMP	RCP, CMP, HDPE, PVC, PPP
Slope	3:1, 4:1, 6:1	2:1, 4:1	4:1, 6:1	3:1, 4:1, 6:1	3:1, 4:1, 6:1
Concrete Type	not specified	NS	A	not specified	commercial grade
Slab Thickness	5.5"	3", 5.5"	4"	4"	4"
Extra Thickness Above Crown	no	yes	yes	no	no
Slab Length Past Crown	3'	varies	varies	varies	varies
Slab Width Past Pipe	2'	1.5'	2'	not specified	1.5'
Slab Reinforcement	WWF 6"x6"W2.9 xW2.9	WWF 6"x6"W1.4 xW1.4	No.4 bar	not specified	WWF 4"x4"W4xW4 or No.4 bar 18" CCEW
Requires Grate (cross drains)	36" - 42"	not specified	36" - 48"	> 30"	36" - 72"
Requires Grate (side drain)	36" – 42"	n/a	18" - 48"	not specified	not specified
Grate Size	2.5" ID	n/a	3.0"	varies	4.5" OD
Grate Material	Sch40 galv. steel	n/a	Sch40 galv. steel	Galv. steel grade B	extra strong galv. steel
Parallel Grate Spacing	24" max	n/a	30"	24"	n/a

Summary & Recommendations

NCHRP Synthesis 321: *Roadway Safety Tools for Local Agencies* recommends mitigating the exposed portions of a headwall, while the FHWA suggests using a traversable headwall design to replace headwalls that are potentially hazardous. The *AASHTO Roadside Design Guide* endorses using traversable headwalls for cross drain pipes and parallel pipes with the toe of the foreslope and ditch being traversable, as this produces considerable safety benefits. Sloped and mitered concrete headwalls meet the criteria outlined in industry guidance by fabricating a traversable slope from one that is non-traversable, removing vertically projecting obstructions created by traditional headwalls, eliminating launch points on foreslopes, doing away with the opening an errant vehicle can drop into if traversing a headwall, and improving the safety of mowing operations.

Between 2012 and 2016, KABCO crash statistics for Kentucky indicated there were 49 fatalities and 148 incapacitating injuries in which culverts/headwalls were the location for the first harmful event. Sloped and mitered concrete headwalls are designed improve the safety of the roadway by providing a traversable slope for vehicles and reducing the likelihood of severe incidents shown in the statistics above.

The research team observed several issues on the KY 1600 project. The embankment's final grade was not set when the headwalls were installed, leaving the contractor responsible for installation to set the grade of the headwalls. An incorrect headwall alignment was used for pipes on a skew. Inadequate cover was placed over the pipe when field modifying the headwall and/or using the guidance in the detail to construct the headwall. There was evidence of the pipe ends separating from the headwall and that they had not been secured to the headwall. Lastly, grate bars perpendicular to traffic were not installed on the pipes with larger diameters. Issues observed on this project resulted from the convergence of several factors, including vague construction methods, lack of guidance on the standard detail for grate bars and skewed pipes, and inexperience by all parties with constructing this type of end treatment. Based on its analysis of the KYTC 1600 project, the research team suggests having the grade established before installing sloped and mitered concrete headwalls, adding grate bars, securing pipe ends to the headwall, and identifying select headwalls for long-term monitoring, with inspections being conducted annually.

The KY 54 project lacked skewed pipes, and pipe diameters were less than 30 inches. As such, grate bars were unneeded for the sloped and mitered concrete headwall. Although the pipe ends were secured to the headwall, the exposed metal was not protected. Before and after photographs show the improved embankment slope conditions resulting from the use of the sloped and mitered concrete headwall. Most the safety type box inlets have debris built up on the grate, which could cause maintenance and safety issues. Based on its examination of the KY 54 project, the research team recommends that exposed raw metal on the pipe ends be protected and the grates on the safety type box inlets undergo regular maintenance. Consideration should also be given to altering the grate length of safety type box inlets so as to reduce the blockage potential from debris.

DOTs in Florida, Oklahoma, Texas, and Oregon are a few of the agencies that use a headwall similar to the sloped and mitered concrete headwall. Kentucky limits the use of this type of end treatment to pipes 42 inches in diameter and smaller, whereas the other states permit installation of the headwall on pipes with larger diameters. In Florida and Oklahoma, concrete must be added above the crown of the pipe. If cover depth is a concern, requiring added protection to the crown should be considered. In Kentucky and Florida, a slab thickness of 5.5 inches is used rather than a 4-inch-thick slab. This allows dimensional lumber to be used as a form. KYTC requires the smallest grate bar diameter at 2.5 inches. Other states use mandate grate bars on the range of 3 to 4.5 inches. AASHTO recommends the minimum of a 3-inch ID for the perpendicular grate bar with a span less than 12 feet. The greater the span the larger the pipe ID. If this type of headwall is to be used for side drains, the detail must be clear on the requirements and alignment of the grate bars for both types of applications. However, consideration of mowing operations may influence grate bar requirements.

A review of the awarded unit bid cost for the various headwall types found that sloped and mitered concrete headwalls are more cost effective than standard precast pipe end treatments and multiple headwalls can be constructed in two or three days. Maintenance operations will benefit from their use due to their being less expensive and taking less time to install than other headwall types. If problems arise with existing headwall, maintenance personnel will be able to install a sloped and mitered concrete headwall more rapidly than waiting for the fabrication and delivery of a precast headwall. In addition, installation of sloped and mitered concrete headwalls can be accomplished without any special equipment.

Appendix A Hardin County and Ohio County Photos

County	Hardin
Route	KY-1600
Headwall #	1s
Station	105+85 Left
Diameter	24
Skew	2°37’ RT
Comments	Pipe installed. Headwall formwork constructed. Rebar installed. Pipe mitered to slope. Vegetation established. Headwall slope was 3:1. Contractor constructing headwalls remarked that keeping grade of headwall at 4:1 or better was problematic. Some pipes needed to be extended. 3-foot minimum length of slab beyond pipe crown would be difficult to attain in areas where embankment slope was steeper.

County	Hardin
Route	KY-1600
Headwall #	1n
Station	105+85 Right
Diameter	24
Skew	2°37’ RT
Comments	Pipe installed. No. 5S rebar used rather than welded wire fabric. Pipe needed to be extended to achieve 4:1. Pipe mitered to slope. Vegetation established. Headwall slope was 4:1.

County	Hardin
Route	KY-1600
Headwall #	2n
Station	161+97 Right
Diameter	30
Skew	35°05' LT
Comments	Headwall was not constructed perpendicular to the roadway. Pipe extended and joint located within mitered section of pipe. 3-foot minimum length beyond crown not achieved. Headwall was reconstructed perpendicular to roadway. Pipe mitered to headwall. Grate bars were added. Skewed headwall: slope was 3:1, length was 9 feet, width was 6.5 feet, edge width was 2 feet, slab thickness was 4-inches, length of slab above crown was 1.25 feet.

County	Hardin
Route	KY-1600
Headwall #	2s
Station	161+97 Left
Diameter	30
Skew	35°05' LT
Comments	Headwall was not constructed perpendicular to the roadway. 3-foot minimum length beyond crown not achieved. Headwall was reconstructed perpendicular to roadway. Pipe mitered to headwall. Grate bar was added. Skewed headwall: slope was 4:1, length was 8 feet, width was 6.5 feet, edge width was 2 feet, slab thickness was 4-inches, length of slab above crown was 1.75 feet.

County	Hardin
Route	KY-1600
Headwall #	3n
Station	164+71 Right
Diameter	42
Skew	3°06' LT
Comments	Exposure at end is greater than 3.25-inches. 3-foot minimum length beyond crown not achieved. Pipe mitered to headwall. Metal grate bars were added on 24-inch centers. No longitudinal bar though the pipe is over 30 inches in diameter. Headwall: slope was 4:1, length was 11 feet, width was 7.5 feet, edge width was 2 feet, slab thickness was 4-inches, length of slab above crown was 1.75 feet.

County	Hardin
Route	KY-1600
Headwall #	3s
Station	164+71 Left
Diameter	42
Skew	3°06’ LT
Comments	Headwall was not constructed perpendicular to the roadway. 3-foot minimum length beyond crown not achieved. Pipe Mitered to headwall. Metal grate bars were added on 24-inch centers. No longitudinal bar though the pipe is over 30 inches in diameter. Headwall: slope was 3:1, length was 10.5 feet, width was 7.5 feet, edge width was 2 feet, slab thickness was 4-inches, length of slab above crown was 2 feet, grates spaced on 24-inch centers.

County	Hardin	
Route	KY-1600	
Headwall #	4n	
Station	170+76 Right	
Diameter	36	
Skew	27°47’ RT	
Comments	Headwall was not constructed perpendicular to the roadway. Pipe mitered to headwall. Metal grate bars were added on 24-inch centers. Headwall: slope was 3:1, length was 11.5 feet, width was 7 feet, edge width was 2 feet, slab thickness was 5.5-inches, grates spaced on 24-inch centers.	
		

County	Hardin
Route	KY-1600
Headwall #	4s
Station	170+76 Left
Diameter	36
Skew	27°47’ RT
Comments	Headwall was not constructed perpendicular to the roadway. 3-foot minimum length beyond crown not achieved. Headwall was reconstructed perpendicular to roadway. Pipe mitered to headwall. Grate bars were added. No longitudinal bar though the pipe is over 30 inches in diameter. Headwall: slope was 2.5:1, length was 7.5 feet, width was 7 feet, edge width was 2 feet, slab thickness was 5.5-inches, length of slab above crown was 2.5 feet, grates spaced on 24-inch centers.

County	Hardin
Route	KY-1600
Headwall #	5n
Station	212+97 Right
Diameter	18
Skew	31°14’ LT
Comments	Headwall was not constructed perpendicular to the roadway. Headwall was reconstructed perpendicular to roadway. Headwall: slope was 2:1, length was 6.5 feet, width was 5.5 feet, edge width was 2 feet, slab thickness was 4-inches, length of slab above crown was 5 feet.

County	Hardin
Route	KY-1600
Headwall #	5s
Station	212+97 Left
Diameter	18
Skew	31°14’ LT
Comments	Headwall was not constructed perpendicular to the roadway. Headwall was reconstructed perpendicular to roadway. Pipe not mitered to headwall. Headwall: slope was 4:1, length was 6.5 feet, width was 5.5 feet, edge width was 2 feet, slab thickness was 4-inches, length of slab above crown was 4 feet.

County	Hardin
Route	KY-1600
Headwall #	7n
Station	308+53 Right
Diameter	36
Skew	44°19’
Comments	Existing pipe extended. Pipe end mitered to slope of headwall. Single grate bar installed.

County	Hardin
Route	KY-1600
Headwall #	8n
Station	348+16 Right
Diameter	30
Skew	12°51’ RT
Comments	Headwall formed. Granular backfill installed. No. 5S rebar used for reinforcement. Final grading. Headwall: slope was 3:1

County	Hardin
Route	KY-1600
Headwall #	8s
Station	348+16 Left
Diameter	30
Skew	12°51’ RT
Comments	Headwall was not constructed perpendicular to the roadway. Formwork to final grading. Pipe mitered to headwall. Headwall: slope was 4:1.

County	Hardin
Route	KY-1600
Headwall #	9n
Station	361+79 Right
Diameter	24
Skew	0°
Comments	Pipe extended. Formed and No. 5S rebar installed on ~ 12-inch spacing. Final grading around headwall. Headwall: slope was 3:1. Rebar spacing was approximately 12-inches.

County	Hardin
Route	KY-1600
Headwall #	9s
Station	361+79 Left
Diameter	24
Skew	0°
Comments	Headwall formed. Final grading around headwall. Treatment of raw metal. Headwall: slope was 3:1.

County	Hardin
Route	KY-1600
Headwall #	10n
Station	367+68 Right
Diameter	18
Skew	4°31’ LT
Comments	Existing pipe extended. Headwall formed and rebar installed. Final grading. Small portion of pipe exposed was not mitered. Headwall: slope was 2.5:1.

County	Hardin	
Route	KY-1600	
Headwall #	10s	
Station	367+68 Left	
Diameter	18	
Skew	4°31’ LT	
Comments	Headwall poured. Pipe end mitered and final grading. Exposed raw metal protected. Headwall: slope was 3.5:1, length was 7 feet, width was 5.5 feet, edge width was 2 feet, slab thickness was 4-inches, length of slab above crown was 3 feet.	
		

County	Hardin
Route	KY-1600
Headwall #	11n
Station	183+65 Right
Diameter	15
Skew	6°57' RT
Comments	3-foot minimum length beyond crown not achieved. Finished headwall and pipe mitered to slope of headwall. Separation between headwall and pipe.

County	Hardin	
Route	KY-1600	
Headwall #	11s	
Station	183+65 Left	
Diameter	15	
Skew	6°57’ RT	
Comments	3-foot minimum length beyond crown not achieved. Headwall formed and rebar installed.	

County	Hardin
Route	KY-1600
Headwall #	12n
Station	356+20 Right
Diameter	18
Skew	4°39’ RT
Comments	Headwall formwork installed. Granular fill material placed. Rebar installed and concrete poured. Seeding Final grading around headwall. Pipe mitered to slope of headwall.

County	Hardin
Route	KY-1600
Headwall #	12s
Station	356+20 Left
Diameter	18
Skew	4°39’ RT
Comments	Headwall formwork installed. Granular fill material placed. Rebar installed. Final grading around headwall. Pipe mitered to slope of headwall and exposed raw metal protected.

County	Hardin
Route	KY-1600
Headwall #	13n
Station	375+41 Right
Diameter	18
Skew	3°25’ RT
Comments	Headwall formwork installed. Granular fill material placed. Rebar installed. Final grading around headwall.

County	Hardin
Route	KY-1600
Headwall #	13s
Station	375+41 Left
Diameter	18
Skew	3°25’ RT
Comments	Headwall formwork installed. Granular fill material placed. Rebar installed. Concrete being finished. Pipe did not extend to end of headwall. Final grading around headwall.

County	Ohio
Route	KY-54
Headwall #	1 Northside
Station	26+80 Left
Diameter	24
Skew	
Comments	Existing headwall replaced by safety type box inlet. Inlet blocked approximately 40%.

County	Ohio
Route	KY-54
Headwall #	1 Southside
Station	26+80 Right
Diameter	
Skew	
Comments	Existing headwall replaced by safety type box inlet. Inlet more than 50% blocked. Grate extends to toe of headwall.

County	Ohio
Route	KY-54
Headwall #	2
Station	33+20
Diameter	
Skew	no
Comments	Pipe mitered to headwall and secured to headwall. No evidence of added protection applied to the cut end of the pipe.

County	Ohio	
Route	KY-54	
Headwall #	3 Northside	
Station	Approx. 50+60 Left	
Diameter	18	
Skew	no	
Comments	Inlet replaced by safety type box inlet. The safety type box inlet grate was covered ~40% by debris.	

County	Ohio
Route	KY-54
Headwall #	3 Southside
Station	Approx. 50+60 Right
Diameter	18
Skew	no
Comments	Outlet replaced by mitered to slope headwall. CMP was secured to headwall. No evidence of added protection applied to the cut end of the pipe.

County	Ohio	
Route	KY-54	
Headwall #	4	
Station	Approx. 68+75	
Diameter		
Skew		
Comments	Mitered to slope headwall installed. Depression above headwall. Slope of headwall could have been increased.	
		

County	Ohio
Route	KY-54
Headwall #	5
Station	89+25
Diameter	
Skew	
Comments	Inlet was replaced by safety type box inlet and outlet was replaced by mitered to slope headwall. CMP was secured to headwall. No evidence of added protection applied to the cut end of the pipe.

County	Ohio
Route	KY-54
Headwall #	6 Northside
Station	109+15 Left
Diameter	15
Skew	no
Comments	Outlet sloped and flared headwall replaced by mitered to slope headwall. CMP was secured to headwall. No evidence of added protection applied to the cut end of the pipe.

County	Ohio	
Route	KY-54	
Headwall #	6 Southside	
Station	109+15 Right	
Diameter	15	
Skew	no	
Comments	Inlet sloped and flared headwall replaced by safety type box inlet Debris build up at inlet at toe of grate.	
		

County	Ohio	
Route	KY-54	
Headwall #	7	
Station	Approx. 123+00	
Diameter		
Skew	no	
Comments	Pipe mitered to slope of headwall and secured to headwall. No evidence of added protection applied to the cut end of the pipe.	

County	Ohio
Route	KY-54
Headwall #	8
Station	Approx. 199+60
Diameter	24
Skew	no
Comments	Existing headwall replaced by mitered to slope headwall. CMP was secured to headwall. No evidence of added protection applied to the cut end of the pipe.

County	Ohio
Route	KY-54
Headwall #	9
Station	241+20
Diameter	
Skew	no
Comments	Double safety box inlet installed. Inlet is already blocked 50% and water is ponding.

County	Ohio
Route	KY-54
Headwall #	10 Southside
Station	Approx. 316+30 Right
Diameter	18
Skew	no
Comments	Existing outlet headwall replaced by mitered to slope headwall.

County	Ohio	
Route	KY-54	
Headwall #	10 Northside	
Station	Approx. 316+30 Left	
Diameter	18	
Skew	no	
Comments	Existing inlet headwall replaced by mitered to slope headwall.	

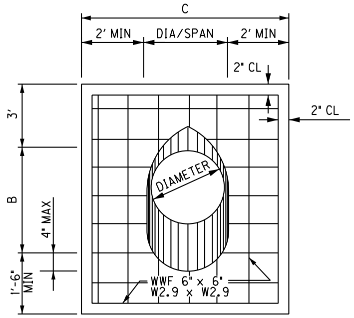
County	Ohio
Route	KY-54
Headwall #	11
Station	Approx. 317+10
Diameter	
Skew	no
Comments	Pipe mitered to headwall and secured to headwall. No evidence of added protection applied to the cut end of the pipe.

County	Ohio
Route	KY-54
Headwall #	12 Northside
Station	319+10 Left
Diameter	18
Skew	no
Comments	Existing inlet headwall replaced by safety type box inlet. Inlet blocked 25%.

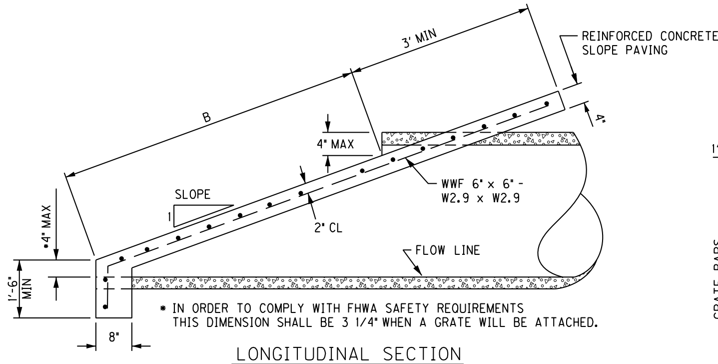
County	Ohio
Route	KY-54
Headwall #	12 Southside
Station	319+10 Right
Diameter	18
Skew	no
Comments	Existing outlet headwall replaced by mitered to slope headwall on a 3:1 slope.

Appendix B Hardin County Detail

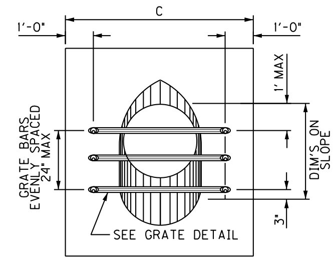
COUNTY OF	ITEM NO.	SHEET NO.
HARDIN	04-9000.00	



END ELEVATION SINGLE BARREL

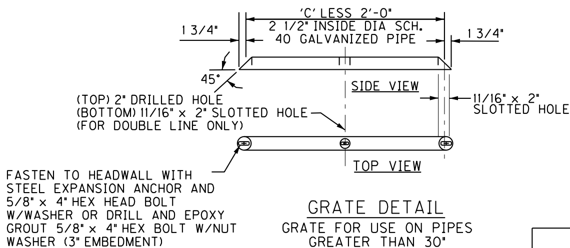


LONGITUDINAL SECTION



END ELEVATION

SHOWN WITH GRATE.
GRATE FOR USE ON PIPES
GREATER THAN 30"

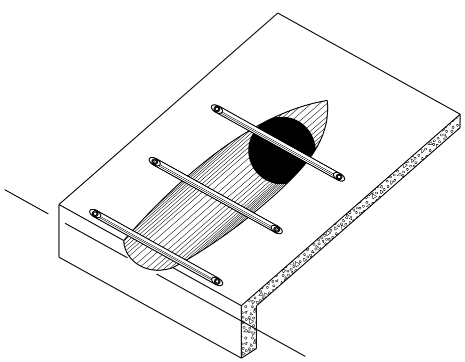


GRATE DETAIL

GRATE FOR USE ON PIPES
GREATER THAN 30"

DIMENSIONS AND QUANTITIES

PIPE SIZE	AREA SQ FT	SLOPE	B	C	CU YDS ONE BARREL
15" Ø	1.2	4:1	2'-5"	5'-3"	0.92
18" Ø	1.8	4:1	4'-4"	5'-6"	1.14
24" Ø	3.1	4:1	6'-6"	6'-0"	1.42
30" Ø	4.9	4:1	8'-9"	6'-6"	1.70
36" Ø	7.1	4:1	11'-0"	7'-0"	1.99
42" Ø	9.6	4:1	13'-1"	7'-6"	2.27
15" Ø	1.2	6:1	3'-7"	5'-3"	1.14
18" Ø	1.8	6:1	6'-4"	5'-6"	1.45
24" Ø	3.1	6:1	9'-8"	6'-0"	1.84
30" Ø	4.9	6:1	12'-11"	6'-6"	2.23
36" Ø	7.1	6:1	16'-3"	7'-0"	2.62
42" Ø	9.6	6:1	19'-5"	7'-6"	3.01



PERSPECTIVE

TYPICAL SLOPE PAVED
HEADWALL WITH GRATE

NOTES:

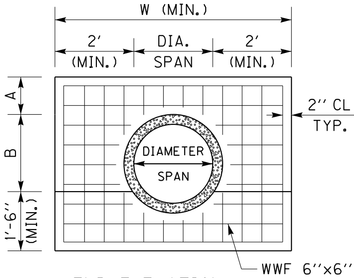
1. THE FILL IS TO BE PLACED AND ALL SHORING REMOVED BEFORE THE SLOPE PAVING IS PLACED.
2. QUANTITIES SHOWN INCLUDE TWO (2) SLOPE PAVED HEADWALLS WITH TOE WALLS.
3. DIMENSIONS AND QUANTITIES SHOWN APPLIES TO CONCRETE, CORRUGATED METAL PIPE, AND CORRUGATED HDPE PIPE. CONCRETE QUANTITIES ARE SUFFICIENT WHEN HEADWALLS FOR ARCH PIPE IS DESIRABLE.
4. PIPE SHALL BE MITERED AFTER CONCRETE SLOPE PAVING HAS BEEN PLACED AND SUFFICIENTLY CURED (SOME HAND FINISHING MAY BE NECESSARY).
5. CONTRACTOR SHALL INSURE THROUGH MECHANICAL MEANS OR OTHER APPROVED DEVICES THAT CONNECTION BETWEEN MITERED PIPE END AND CONCRETE WILL NOT BE DETACHED. CORRUGATED HDPE PIPE SHALL HAVE 1/2"Ø x 6" GALVANIZED HOOK BOLTS WITH WASHERS LOCATED AT 30" O.C. FOR THE TOE AND 1/2"Ø x 6" GALVANIZED THREADED HEX HEAD BOLTS WITH WASHERS LOCATED ON 2'-0" CENTERS FOR SIDES. ANCHOR BOLTS INTO CONCRETE.
6. SLOPE PAVED HEADWALL WITHOUT GRATE SHALL BE CLASS 1. SLOPE PAVED HEADWALL WITH GRATE SHALL BE CLASS 2.
7. A 24" PIPE WITH GREATER THAN A 30° SKEW AND A PIPE GREATER THAN 30" IN DIAMETER SHALL HAVE A CLASS 2 END TREATMENT.
8. PIPE FOR GRATE SHALL BE SCHEDULE 40, GALVANIZED IN ACCORDANCE WITH AASHTO M 111 AFTER FABRICATION. ALL BOLTS AND HARDWARE SHALL BE RUST RESISTANT: STAINLESS STEEL, ZINC COATED, OR STEEL THAT HAS BEEN GALVANIZED IN ACCORDANCE WITH AASHTO M 232.
9. ANY RAW METAL EXPOSED BY FIELD CUTTING AND/OR DRILLING OF THE PIPE FOR GRATE SHALL BE TREATED WITH A COLD GALVANIZING COMPOUND SPRAY.
10. BID ITEM AND UNIT TO BID: 24575ES610 - HEADWALL (SLOPED & MITERED CONCRETE - SIZE) - EACH

NOT TO SCALE

KY 1600
SLOPED & MITERED
CONCRETE HEADWALL DETAIL

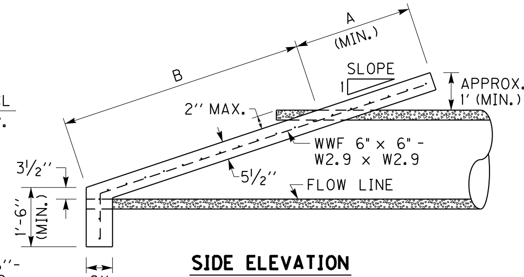
Appendix C Ohio County Detail

COUNTY OF	ITEM NO.	SHEET NO.



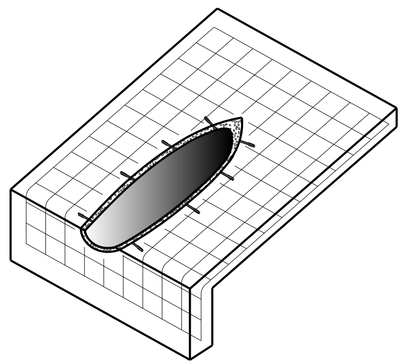
END ELEVATION

SHOWN WITH WOVEN WIRE REINFORCEMENT



SIDE ELEVATION

SHOWN WITHOUT GRATE



ISOMETRIC VIEW

SHOWN WITH WOVEN WIRE REINFORCEMENT AND WEDGE ANCHORS

~ NOTES ~

BID ITEM AND UNIT TO BID: 24575ES610
HEADWALL (SLOPED & MITERED CONCRETE-FOR __ INCH PIPE) - EACH

1. THE EMBANKMENT FILL MATERIAL IS TO BE PLACED, COMPACTED, AND GRADED AROUND THE PIPE BEFORE THE CONCRETE SLOPE PAVING IS PLACED. THE INTENT IS FOR THE SLOPED & MITERED HEADWALL TO MATCH THE FINAL EMBANKMENT SLOPE.
2. THE PIPE SHALL BE MITERED AFTER THE CONCRETE SLOPE PAVING HAS BEEN PLACED AND SUFFICIENTLY CURED. THE PIPE SHOULD BE MITERED AS CLOSE TO FLUSH WITH THE SLOPE PAVING AS POSSIBLE, AND NO HIGHER THAN 2″ ABOVE THE SLOPE PAVING. HAND FINISHING AND/OR CUTTING MAY BE NECESSARY.
3. THE DIMENSION 'A' IS BASED ON THE FINAL GRADED SLOPE. THE DIMENSION 'B' IS BASED ON CIRCULAR REINFORCED CONCRETE PIPE AT 0° SKEW FOR THE LISTED SLOPE. THE DIMENSION 'W' IS BASED ON THE DIAMETER, OR SPAN, OF THE PIPE. NOTE: THE HEADWALL DIMENSIONS AND CONCRETE QUANTITIES MAY VARY BASED ON THE FINAL GRADED SLOPE, PIPE SKEW, AND/OR TYPE OF PIPE.
4. WOVEN WIRE REINFORCEMENT (WWF 6″x6″ - W2.9xW2.9) IS REQUIRED FOR THE SLOPE PAVING AND TOE WALL. UTILIZE 2″ CLEARANCE FROM ALL EDGES.
5. CONCRETE QUANTITIES SHOWN ARE FOR ONE (1) HEADWALL.
6. AFTER THE PIPE HAS BEEN MITERED, ANCHOR THE PIPE TO THE CONCRETE SLOPE PAVING BY CORE DRILLING AND INSTALLING 1/2″ DIAMETER x 7″ LENGTH STEEL WEDGE ANCHORS (3″ MINIMUM EMBEDMENT) ON 18″ CENTERS ALONG THE SIDES OF THE PIPE. HOLE SIZE & DEPTH, TORQUE, & INSTALLATION PROCEDURES PER RECOMMENDATION OF ANCHOR MANUFACTURE. NOTE: STEEL WEDGE ANCHORS ARE NOT REQUIRED FOR REINFORCED CONCRETE PIPE.
7. THE FOLLOWING SITUATIONS REQUIRE A HEADWALL WITH A GRATE:
-24″ DIAMETER PIPE ON GREATER THAN 30° SKEW
-30″ DIAMETER PIPE ON GREATER THAN 15° SKEW
-PIPE WITH GREATER THAN 30″ DIAMETER.
-ELLIPTICAL PIPE GREATER THAN 24″ EQUIVALENT DIAMETER
SEE SHEET 2 FOR GRATE DETAILS
8. ALL BOLTS AND HARDWARE SHALL BE RUST RESISTANT: ZINC PLATED, STAINLESS STEEL, OR STEEL THAT HAS BEEN GALVANIZED IN ACCORDANCE WITH AASHTO M 232.

DIMENSIONS AND CONCRETE QUANTITIES

PIPE SIZE	3:1 SLOPE				4:1 SLOPE				6:1 SLOPE				GRATE REQUIRED
	A	B	W	CU. YDS. CONCRETE	A	B	W	CU. YDS. CONCRETE	A	B	W	CU. YDS. CONCRETE	
15″	3′	3′-7½″	5′-3″	0.74	4′	4′-8¾″	5′-3″	0.93	6′	6′-11¾″	5′-3″	1.29	NO
18″	3′	4′-5¾″	5′-6″	0.85	4′	5′-10″	5′-6″	1.05	6′	8′-7¼″	5′-6″	1.48	NO
24″	3′	6′-2½″	6′-0″	1.05	4′	8′-1″	6′-0″	1.32	6′	11′-11″	6′-0″	1.87	SEE 7
30″	3′	7′-10¾″	6′-6″	1.43	4′	10′-3¾″	6′-6″	1.80	6′	15′-2½″	6′-6″	2.28	SEE 7

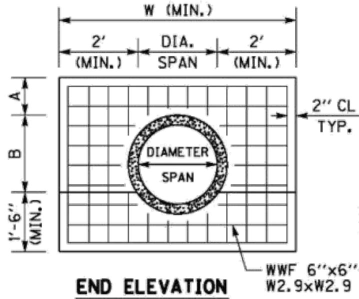
NOTE: CONCRETE QUANTITIES ARE LISTED FOR INFORMATIONAL PURPOSES ONLY.

SEE SHEET 2 FOR DIMENSIONS OF HEADWALLS FOR PIPE OVER 30″ DIAMETER

NOT TO SCALE

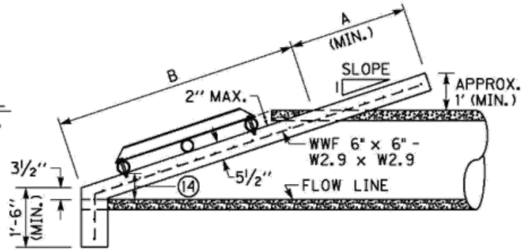
KENTUCKY
DEPARTMENT OF HIGHWAYS

SLOPED & MITERED
CONCRETE HEADWALL
(SHEET 1 OF 2)



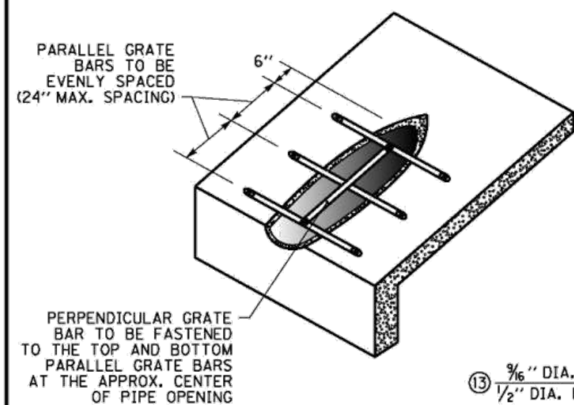
END ELEVATION

SHOWN WITH WOVEN WIRE REINFORCEMENT



SIDE ELEVATION

SHOWN WITH GRATE



ISOMETRIC VIEW

SHOWING HEADWALL WITH GRATE

~ NOTES ~

BID ITEM AND UNIT TO BID: 24575ES610
HEADWALL (SLOPED & MITERED CONCRETE-FOR _ INCH PIPE) - EACH

SEE SHEET 1 FOR NOTES 1 THRU 5

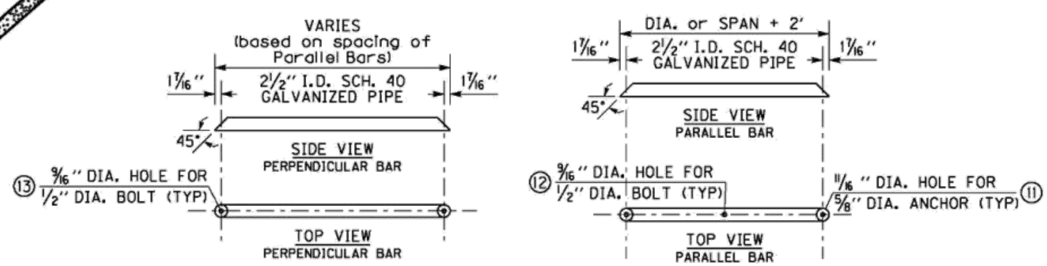
7. THE FOLLOWING SITUATIONS REQUIRE A HEADWALL WITH A GRATE:
   - 24″ DIAMETER PIPE ON GREATER THAN 30° SKEW
   - 30″ DIAMETER PIPE ON GREATER THAN 15° SKEW
   - PIPE WITH GREATER THAN 30″ DIAMETER.
   - ELLIPTICAL PIPE GREATER THAN 24″ EQUIVALENT DIAMETER
8. ALL BOLTS AND HARDWARE SHALL BE RUST RESISTANT: ZINC PLATED, STAINLESS STEEL, OR STEEL THAT HAS BEEN GALVANIZED IN ACCORDANCE WITH AASHTO M 232.
9. THE PIPE USED TO CONSTRUCT THE GRATE SHALL BE STEEL, SCHEDULE 40, CONFORMING TO ASTM A53, AND GALVANIZED IN ACCORDANCE WITH AASHTO M 111 AFTER FABRICATION.
10. ANY RAW METAL EXPOSED BY FIELD CUTTING AND/OR DRILLING SHALL BE TREATED WITH A COLD GALVANIZING COMPOUND.

(11) FASTEN PARALLEL BARS TO HEADWALL WITH ⅝″ DIA. x 4½″ LENGTH STEEL WEDGE ANCHORS, MINIMUM EMBEDMENT = 2¾″ HOLE SIZE AND DEPTH, TORQUE, & INSTALLATION PROCEDURES PER RECOMMENDATION OF ANCHOR MANUFACTURE

(12) CENTER BOLT HOLE SHALL ONLY BE DRILLED IN THE TOP AND BOTTOM PARALLEL BARS.

(13) FASTEN THE PERPENDICULAR BAR TO THE TOP AND BOTTOM PARALLEL BARS WITH ½″ DIA. x 4″ LENGTH HEX HEAD BOLTS, HEX HEAD NUTS, & FLAT WASHERS.

(14) THE BOTTOM PARALLEL BAR IS TO BE PLACED SO THAT IT IS APPROX. 6″ ABOVE THE FLOWLINE OF THE PIPE.



PIPE FOR GRATE DETAILS

SEE NOTE 6 TO DETERMINE IF GRATE IS REQUIRED

NOT TO SCALE

DIMENSIONS AND CONCRETE QUANTITIES

PIPE SIZE	3:1 SLOPE A	3:1 SLOPE B	3:1 SLOPE W	3:1 SLOPE CU. YDS. CONCRETE	4:1 SLOPE A	4:1 SLOPE B	4:1 SLOPE W	4:1 SLOPE CU. YDS. CONCRETE	6:1 SLOPE A	6:1 SLOPE B	6:1 SLOPE W	6:1 SLOPE CU. YDS. CONCRETE	GRATE REQUIRED
36″	3′	9′-7½″	7′-0″	1.51	4′	12′-6½″	7′-0″	1.91	6′	18′-6″	7′-0″	2.42	YES
42″	3′	11′-4″	7′-6″	1.76	4′	14′-9¼″	7′-6″	2.23	6′	21′-9½″	7′-6″	3.19	YES

NOTE: CONCRETE QUANTITIES ARE LISTED FOR INFORMATIONAL PURPOSES ONLY.

SEE SHEET 1 FOR DIMENSIONS OF HEADWALLS FOR PIPE 30″ DIAMETER & LESS

COUNTY OF	ITEM NO.	SHEET NO.

KENTUCKY
DEPARTMENT OF HIGHWAYS

SLOPED & MITERED CONCRETE HEADWALL
(SHEET 2 OF 2)

Appendix D Florida DOT Detail

DIMENSIONS AND QUANTITIES

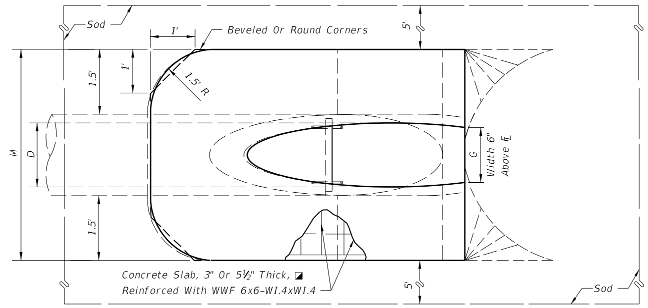
	D	X	A	B	C	E	F	G	H ■	M Single Pipe	M Double Pipe	M Triple Pipe	M Quad. Pipe	N	5½" CONCRETE SLAB (CY) ◪ Single Pipe	5½" CONCRETE SLAB (CY) ◪ Double Pipe	5½" CONCRETE SLAB (CY) ◪ Triple Pipe	5½" CONCRETE SLAB (CY) ◪ Quad. Pipe	SODDING (SY) Single Pipe	SODDING (SY) Double Pipe	SODDING (SY) Triple Pipe	SODDING (SY) Quad. Pipe
1:2 Slope	15"	2'-7"	1.92'	2.18'	4.10'	2.06'	5'	1.22'	2.9'	4.63'	7.21'	9.79'	12.37'	1.19'	0.38	0.58	0.77	0.96	21	24	27	30
	18"	2'-10"	1.97'	2.74'	4.71'	2.56'	6'	1.41'	3.4'	4.92'	7.75'	10.58'	13.42'	1.21'	0.44	0.65	0.87	1.09	22	25	28	31
	24"	3'-5"	2.06'	3.85'	5.91'	3.56'	7'	1.73'	3.4'	5.50'	8.92'	12.33'	15.75'	1.25'	0.54	0.83	1.12	1.42	24	28	32	35
	30"	4'-3"	2.15'	4.95'	7.10'	4.56'	8'	2.00'	3.4'	6.08'	10.33'	14.58'	18.83'	1.29'	0.66	1.09	1.50	1.91	26	31	35	40
	36"	5'-1"	2.25'	6.08'	8.33'	5.56'	9'	2.24'	3.4'	6.67'	11.75'	16.83'	21.92'	1.33'	0.81	1.38	1.95	2.51	28	34	39	45
	42"	6'-0"	2.34'	7.21'	9.55'	6.56'	10'	2.45'	3.4'	7.25'	13.25'	19.25'	25.25'	1.38'	0.97	1.70	2.45	3.19	30	37	43	50
	48"	6'-9"	2.43'	8.33'	10.76'	7.56'	11'	2.65'	3.4'	7.83'	14.58'	21.33'	28.08'	1.42'	1.13	2.04	2.93	3.84	32	39	47	54
	54"	7'-8"	2.52'	9.44'	11.96'	8.56'	12'	2.83'	3.4'	8.42'	16.08'	23.75'	31.42'	1.46'	1.31	2.44	3.58	4.72	34	42	51	59
	60"	8'-6"	2.62'	10.56'	13.18'	9.56'	14'	3.00'	4.4'	9.00'	17.50'	26.00'	34.50'	1.50'	1.51	2.89	4.28	5.68	36	45	55	64
	66"	9'-2"	2.71'	11.68'	14.39'	10.56'	15'	3.18'	4.4'	9.58'	18.75'	27.92'	37.08'	1.54'	1.68	3.25	4.84	6.43	38	48	58	68
	72"	10'-0"	2.80'	12.80'	15.60'	11.56'	16'	3.30'	4.4'	10.16'	20.16'	30.16'	40.16'	1.58'	1.89	3.74	5.59	7.45	40	51	62	73
1:4 Slope	15"	2'-7"	2.27'	4.09'	6.36'	4.03'	8'	1.22'	4.0'	4.63'	7.21'	9.79'	12.37'	1.19'	0.57	0.87	1.15	1.44	23	26	29	32
	18"	2'-10"	2.36'	5.12'	7.48'	5.03'	9'	1.41'	4.0'	4.92'	7.75'	10.58'	13.42'	1.21'	0.66	0.99	1.31	1.65	25	28	31	35
	24"	3'-5"	2.53'	7.18' △	9.71'	7.03' △	11'	1.73'	4.0'	5.50'	8.92'	12.33'	15.75'	1.25'	0.85	1.30	1.75	2.20	28	32	36	40
	30"	4'-3"	2.70'	9.25'	11.95'	9.03'	13'	2.00'	4.0'	6.08'	10.33'	14.58'	18.83'	1.29'	1.10	1.74	2.39	3.05	31	36	41	46
	36"	5'-1"	2.87'	11.31' ◇	14.18'	11.03' ◇	15'	2.24'	4.0'	6.67'	11.75'	16.83'	21.92'	1.33'	1.32	2.21	3.08	3.96	34	40	46	52
	42"	6'-0"	3.05'	13.37'	16.42'	13.03'	17'	2.45'	4.0'	7.25'	13.25'	19.25'	25.25'	1.38'	1.58	2.76	3.91	5.09	38	44	51	58
	48"	6'-9"	3.22'	15.43'	18.65'	15.03'	19'	2.65'	4.0'	7.83'	14.58'	21.33'	28.08'	1.42'	1.85	3.30	4.73	6.17	41	48	56	63
	54"	7'-8"	3.39'	17.49'	20.88'	17.03'	21'	2.83'	4.0'	8.42'	16.08'	23.75'	31.42'	1.46'	2.14	3.95	5.77	7.58	44	52	61	69
	60"	8'-6"	3.56'	19.55'	23.11'	19.03'	23'	3.00'	4.0'	9.00'	17.50'	26.00'	34.50'	1.50'	2.45	4.66	6.87	9.07	47	56	66	75
	66"	9'-2"	3.73'	21.62'	25.35'	21.03'	25'	3.18'	4.0'	9.58'	18.75'	27.92'	37.08'	1.54'	2.88	5.54	8.18	10.84	49	59	69	80
	72"	10'-0"	3.91'	23.68'	27.59'	23.03'	27'	3.30'	4.0'	10.16'	20.16'	30.16'	40.16'	1.58'	3.54	6.61	9.87	13.13	52	63	74	85

◪ See General Note No. 5.
See Sheet 5 For 3" Slab Quantities

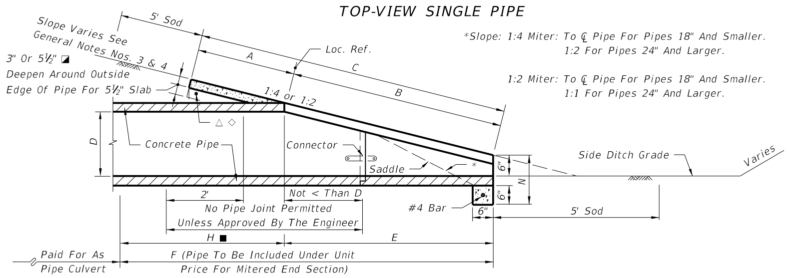
■ Values shown for estimating pipe quantities and are for information only.

B	E	
△ 6.42'	△ 6.25'	Dimensions permitted to allow use of 8' standard pipe lengths.
◇ 10.40'	◇ 10.10'	Dimensions permitted to allow use of 12' standard pipe lengths.

△ ◇ Concrete slab shall be deepened to form bridge across crown of pipe. See section below.



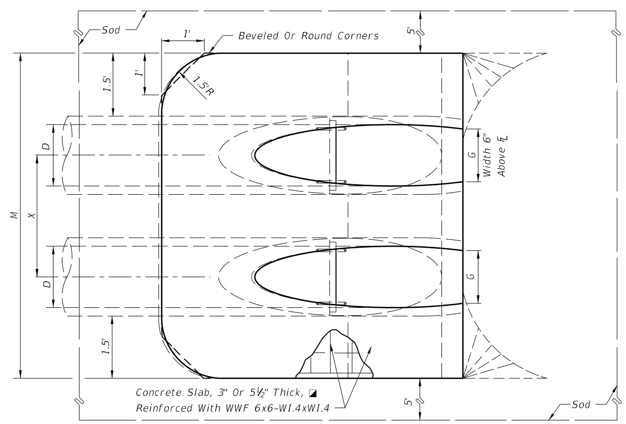
TOP-VIEW SINGLE PIPE



*Slope: 1:4 Miter: To ℄ Pipe For Pipes 18" And Smaller.
1:2 For Pipes 24" And Larger.

1:2 Miter: To ℄ Pipe For Pipes 18" And Smaller.
1:1 For Pipes 24" And Larger.

SECTION



TOP-VIEW MULTIPLE PIPE

NOTE: See sheet 6 for details and notes.

SINGLE AND MULTIPLE ROUND CONCRETE PIPE

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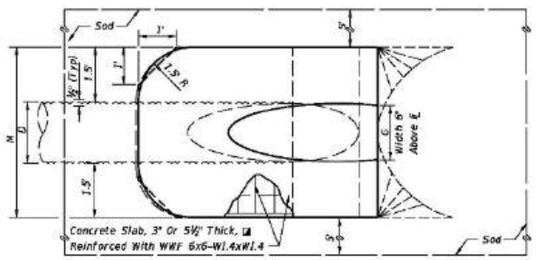
LAST REVISION	REVISION	DESCRIPTION:	FDOT 2014 DESIGN STANDARDS	CROSS DRAIN MITERED END SECTION	INDEX NO.	SHEET NO.
07/01/02					272	1 of 6

	D	X	A	B	C	E	F	G	H ■	M Single Pipe	M Double Pipe	M Triple Pipe	M Quad. Pipe	N	5½" CONCRETE SLAB (CY) ◪ Single Pipe	Double Pipe	Triple Pipe	Quad. Pipe	SODDING (SY) Single Pipe	Double Pipe	Triple Pipe	Quad. Pipe
1:2 Slope	15"	2'-7"	2.5'	1.68'	4.18'	1.5'	5.0'	1.23'	3.5'	4.33'	6.92'	9.50'	12.08'	1.04'	0.35	0.54	0.74	0.94	21	24	27	29
	18"	2'-10"	2.5'	2.24'	4.74'	2.0'	6.0'	1.41'	4'	4.58'	7.42'	10.25'	13.08'	1.04'	0.38	0.62	0.87	1.12	22	25	28	31
	24"	3'-5"	2.5'	3.35'	5.85'	3.0'	7.0'	1.73'	4'	5.08'	8.50'	11.92'	15.33'	1.04'	0.47	0.76	1.05	1.34	23	27	31	35
	30"	4'-3"	2.5'	4.47'	6.97'	4.0'	8.0'	2.00'	4'	5.58'	9.83'	14.08'	18.33'	1.04'	0.57	0.96	1.37	1.77	25	30	35	39
	36"	5'-1"	2.5'	5.59'	8.09'	5.0'	9.0'	2.24'	4'	6.08'	11.17'	16.25'	21.33'	1.04'	0.67	1.19	1.72	2.26	27	33	38	44
	42"	6'-0"	2.5'	6.71'	9.21'	6.0'	10.0'	2.45'	4'	6.58'	12.58'	18.58'	24.58'	1.04'	0.78	1.48	2.17	2.87	29	36	42	49
	48"	6'-9"	2.5'	7.83'	10.33'	7.0'	11.0'	2.65'	4'	7.08'	13.83'	20.58'	27.33'	1.04'	0.89	1.71	2.54	3.36	31	38	46	53
	54"	7'-8"	2.5'	8.94'	11.44'	8.0'	12.0'	2.83'	4'	7.58'	15.25'	22.92'	30.58'	1.04'	1.02	2.06	3.10	4.14	33	41	50	58
	60"	8'-6"	2.5'	10.06'	12.56'	9.0'	13.0'	3.00'	4'	8.08'	16.58'	25.08'	33.58'	1.04'	1.14	2.38	3.63	4.89	34	44	53	63
1:4 Slope	15"	2'-7"	2.5'	3.09'	5.59'	3.0'	7.0'	1.23'	4'	4.33'	6.92'	9.50'	12.08'	1.04'	0.44	0.68	0.91	1.15	22	25	28	31
	18"	2'-10"	2.5'	4.12'	6.62'	4.0'	8.0'	1.41'	4'	4.58'	7.42'	10.25'	13.08'	1.04'	0.49	0.77	1.03	1.31	24	27	30	33
	24"	3'-5"	2.5'	6.18'	8.68'	6.0'	10.0'	1.73'	4'	5.08'	8.50'	11.92'	15.33'	1.04'	0.65	1.09	1.38	1.77	27	30	34	38
	30"	4'-3"	2.5'	8.25'	10.75'	8.0'	12.0'	2.00'	4'	5.58'	9.83'	14.08'	18.33'	1.04'	0.81	1.34	1.90	2.44	29	34	39	44
	36"	5'-1"	2.5'	10.31'	12.81'	10.0'	14.0'	2.24'	4'	6.08'	11.17'	16.25'	21.33'	1.04'	0.97	1.68	2.41	3.14	32	38	44	49
	42"	6'-0"	2.5'	12.37'	14.87'	12.0'	16.0'	2.45'	4'	6.58'	12.58'	18.58'	24.58'	1.04'	1.13	2.08	3.06	4.02	35	42	48	55
	48"	6'-9"	2.5'	14.43'	16.93'	14.0'	18.0'	2.65'	4'	7.08'	13.83'	20.58'	27.33'	1.04'	1.29	2.49	3.69	4.88	38	46	53	60
	54"	7'-8"	2.5'	16.49'	18.99'	16.0'	20.0'	2.83'	4'	7.58'	15.25'	22.92'	30.58'	1.04'	1.48	2.98	4.47	5.98	41	49	58	66
	60"	8'-6"	2.5'	18.55'	21.05'	18.0'	22.0'	3.00'	4'	8.08'	16.58'	25.08'	33.58'	1.04'	1.66	3.49	5.31	7.13	44	53	63	72

DIMENSIONS AND QUANTITIES

◪ See General Note No. 5. See Sheet 5 For 3" Slab Quantities

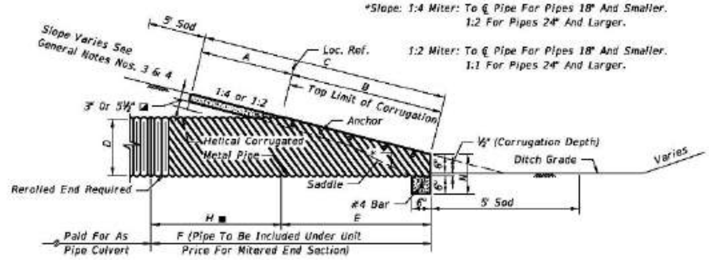
■ Values shown for estimating pipe quantities and are for information only



TOP VIEW-SINGLE PIPE

*Slope: 1:4 Miter: To ℄ Pipe For Pipes 18" And Smaller.
1:2 For Pipes 24" And Larger.

1:2 Miter: To ℄ Pipe For Pipes 18" And Smaller.
1:1 For Pipes 24" And Larger.



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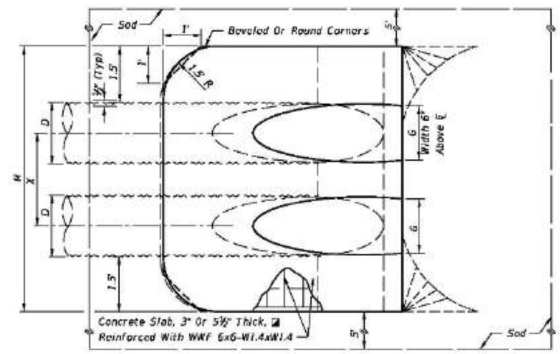


TOP VIEW-MULTIPLE PIPE

NOTE: See Sheet 6 For Details And Notes.

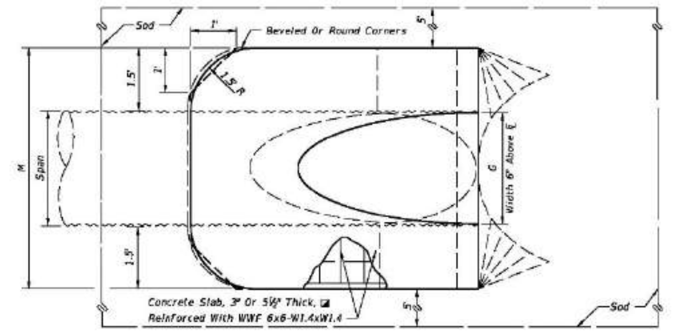
SINGLE AND MULTIPLE ROUND CORRUGATED METAL PIPE

LAST REVISION 07/01/02	REVISION	DESCRIPTION:	FDOT 2014 DESIGN STANDARDS	CROSS DRAIN MITERED END SECTION	INDEX NO. 272	SHEET NO. 2 of 6

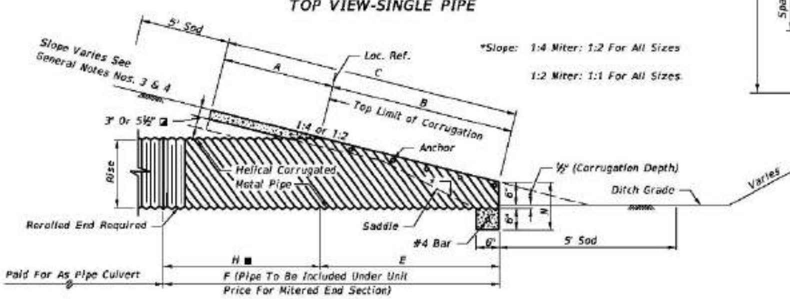
1974 AASHTO			DIMENSIONS AND QUANTITIES								M					5½" CONCRETE SLAB (CY) ◪				SODDING (SY)			
	SPAN	RISE	X	A	B	C	E	F	G	H ■	Single Pipe	Double Pipe	Triple Pipe	Quad. Pipe	N	Single Pipe	Double Pipe	Triple Pipe	Quad. Pipe	Single Pipe	Double Pipe	Triple Pipe	Quad. Pipe
1:2 Slope	17"	13"	2'-6"	2.5'	1.30'	3.80'	1.17'	4'	1.39'	2.8'	4.50'	7.00'	9.50'	12.00'	1.04'	0.41	0.61	0.81	1.02	21	23	26	29
	21"	15"	2'-10"	2.5'	1.68'	4.17'	1.50'	5'	1.76'	3.5'	4.83'	7.67'	10.50'	13.33'	1.04'	0.43	0.66	0.88	1.10	22	25	28	31
	28"	20"	3'-5"	2.5'	2.61'	5.11'	2.33'	6'	2.22'	3.7'	5.42'	8.83'	12.25'	15.67'	1.04'	0.51	0.78	1.06	1.33	23	27	30	34
	35"	24"	4'-0"	2.5'	3.35'	5.85'	3.00'	7'	2.55'	4.0'	6.00'	10.00'	14.00'	18.00'	1.04'	0.57	0.90	1.22	1.55	24	29	33	38
	42"	29"	4'-9"	2.5'	4.29'	6.79'	3.83'	8'	2.97'	4.2'	6.58'	11.33'	16.08'	20.83'	1.04'	0.64	1.04	1.46	1.87	26	31	37	42
	49"	33"	5'-6"	2.5'	5.03'	7.53'	4.50'	9'	3.34'	4.5'	7.17'	12.67'	18.17'	23.67'	1.04'	0.73	1.23	1.72	2.22	28	34	40	46
	57"	38"	6'-4"	2.5'	5.96'	8.46'	5.33'	10'	3.65'	4.7'	7.83'	14.17'	20.50'	26.83'	1.04'	0.83	1.44	2.04	2.64	29	36	44	51
	64"	43"	7'-1"	2.5'	6.89'	9.39'	6.17'	11'	3.89'	4.8'	8.42'	15.50'	22.58'	29.67'	1.04'	0.95	1.67	2.39	3.11	31	39	47	55
	71"	47"	7'-10"	2.5'	7.64'	10.14'	6.83'	12'	4.14'	5.2'	9.00'	16.83'	24.67'	32.50'	1.04'	1.05	1.89	2.74	3.57	33	41	50	59
1:4 Slope	17"	13"	2'-6"	2.5'	2.41'	4.91'	2.33'	7'	1.39'	4.7'	4.50'	7.00'	9.50'	12.00'	1.04'	0.48	0.71	0.95	1.18	22	25	27	30
	21"	15"	2'-10"	2.5'	3.09'	5.59'	3.00'	8'	1.76	5.0'	4.83'	7.67'	10.50'	13.33'	1.04'	0.52	0.80	1.09	1.31	23	26	29	32
	28"	20"	3'-5"	2.5'	4.81'	7.31'	4.67'	9'	2.22'	4.3'	5.42'	8.83'	12.25'	15.67'	1.04'	0.61	0.92	1.27	1.59	25	29	33	37
	35"	24"	4'-0"	2.5'	6.18'	8.68'	6.00'	11'	2.55'	5.0'	6.00'	10.00'	14.00'	18.00'	1.04'	0.73	1.14	1.55	1.97	28	32	37	41
	42"	29"	4'-9"	2.5'	7.90'	10.40'	7.67'	12'	2.97'	4.3'	6.58'	11.33'	16.08'	20.83'	1.04'	0.87	1.39	1.92	2.45	30	35	41	46
	49"	33"	5'-6"	2.5'	9.28'	11.78'	9.00'	14'	3.34'	5.0'	7.17'	12.67'	18.17'	23.67'	1.04'	1.00	1.66	2.30	2.96	32	38	45	51
	57"	38"	6'-4"	2.5'	11.00'	13.50'	10.67'	16'	3.65'	5.3'	7.83'	14.17'	20.50'	26.83'	1.04'	1.18	2.00	2.82	3.64	35	42	49	56
	64"	43"	7'-1"	2.5'	12.71'	15.21'	12.33'	17'	3.89'	4.7'	8.42'	15.50'	22.58'	29.67'	1.04'	1.36	2.39	3.38	4.38	38	45	53	61
	71"	47"	7'-10"	2.5'	14.09'	16.59'	13.67'	19'	4.14'	5.3'	9.00'	16.83'	24.67'	32.50'	1.04'	1.50	2.65	3.81	4.97	40	48	57	66

◪ See General Note No. 5.
See Sheet 5 For 3" Slab Quantities

■ Values shown for estimating pipe quantities and are for information.

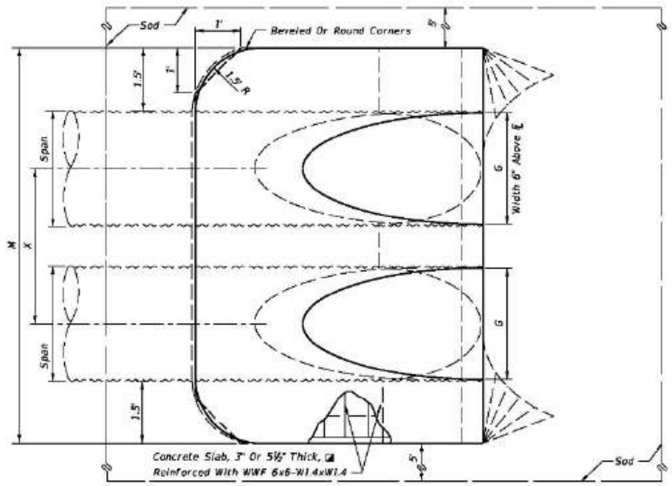


TOP VIEW-SINGLE PIPE



*Slope: 1:4 Miter: 1:2 For All Sizes
1:2 Miter: 1:1 For All Sizes

SECTION



TOP VIEW-MULTIPLE PIPE

NOTE: See Sheet 6 For Details And Notes.

SINGLE AND MULTIPLE CORRUGATED METAL PIPE-ARCH

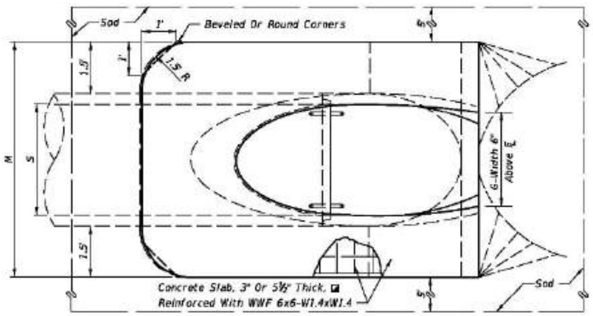
LAST REVISION 07/01/02	REVISION	DESCRIPTION:	FDOT 2014 DESIGN STANDARDS	CROSS DRAIN MITERED END SECTION	INDEX NO. 272	SHEET NO. 3 of 6

DIMENSIONS & QUANTITIES

Slope	Rise R	Span S	X	A	B	C	E	F	G	H ■	M Single Pipe	M Double Pipe	M Triple Pipe	M Quad. Pipe	N	5½" Conc. Slab (CY) ◪ Single Pipe	5½" Conc. Slab (CY) ◪ Double Pipe	5½" Conc. Slab (CY) ◪ Triple Pipe	5½" Conc. Slab (CY) ◪ Quad. Pipe	Sodding (SY) Single Pipe	Sodding (SY) Double Pipe	Sodding (SY) Triple Pipe	Sodding (SY) Quad. Pipe
1:2 Slope	12"	18"	2'-10"	1.97'	1.62'	3.59'	1.56'	4'	1.50'	2.4'	4.92'	7.75'	10.58'	13.42'	1.21'	0.30	0.49	0.67	0.85	21	24	27	30
	14"	23"	3'-4"	2.01'	1.99'	4.00'	1.89'	5'	1.90'	3.1'	5.38'	8.71'	12.04'	15.38'	1.23'	0.37	0.59	0.81	1.02	22	26	29	33
	19"	30"	4'-0"	2.11'	2.92'	5.03'	2.73'	6'	2.37'	3.3'	6.04'	10.04'	14.04'	18.04'	1.27'	0.50	0.80	1.09	1.39	24	28	33	37
	24"	38"	5'-0"	2.20'	3.85'	6.05'	3.56'	7'	2.85'	3.4'	6.79'	11.79'	16.79'	21.79'	1.31'	0.62	1.03	1.45	1.86	26	31	37	42
	29"	45"	5'-11"	2.34'	4.79'	7.13'	4.39'	8'	3.19'	3.6'	7.50'	13.42'	19.33'	25.25'	1.38'	0.75	1.30	1.84	2.39	28	34	41	47
	34"	53"	7'-0"	2.43'	5.72'	8.15'	5.23'	9'	3.57'	3.8'	8.25'	15.25'	22.25'	29.25'	1.42'	0.90	1.61	2.32	3.03	30	37	45	53
	38"	60"	7'-10"	2.52'	6.46'	8.98'	5.89'	9'	3.95'	3.1'	8.92'	16.75'	24.58'	32.42'	1.46'	1.03	1.89	2.74	3.60	31	40	49	57
	43"	68"	8'-11"	2.62'	7.39'	10.01'	6.73'	10'	4.28'	3.3'	9.67'	18.58'	27.50'	36.42'	1.50'	1.19	2.26	3.33	4.40	33	43	53	63
	48"	76"	9'-11"	2.71'	8.33'	11.04'	7.56'	11'	4.59'	3.4'	10.42'	20.33'	30.25'	40.17'	1.54'	1.38	2.65	3.93	5.21	35	46	57	68
	53"	83"	10'-8"	2.80'	9.26'	12.06'	8.39'	12'	4.77'	3.6'	11.08'	21.75'	32.42'	43.08'	1.58'	1.55	3.03	4.50	5.96	37	49	61	73
	58"	91"	11'-8"	2.90'	10.19'	13.09'	9.23'	13'	5.01'	3.8'	11.83'	23.50'	35.17'	46.83'	1.63'	1.75	3.47	5.20	6.93	39	52	65	78
1:4 Slope	12"	18"	2'-10"	2.36'	3.06'	5.42'	3.03'	5'	1.50'	2.0'	4.92'	7.75'	10.58'	13.42'	1.21'	0.45	0.68	0.92	1.14	23	26	29	32
	14"	23"	3'-4"	2.44'	3.75'	6.19'	3.70'	6'	1.90'	2.3'	5.38'	8.71'	12.04'	15.38'	1.23'	0.53	0.83	1.13	1.42	24	28	32	35
	19"	30"	4'-0"	2.62'	5.47'	8.09'	5.36'	8'	2.37'	2.6'	6.04'	10.04'	14.04'	18.04'	1.27'	0.74	1.15	1.57	1.98	27	32	36	40
	24"	38"	5'-0"	2.79'	7.18'	9.97'	7.03'	10'	2.85'	3.0'	6.79'	11.79'	16.79'	21.79'	1.31'	0.97	1.57	2.19	2.81	30	36	41	47
	29"	45"	5'-11"	3.05'	8.90'	11.95'	8.70'	12'	3.19'	3.3'	7.50'	13.42'	19.33'	25.25'	1.38'	1.22	2.07	2.92	3.77	33	40	46	53
	34"	53"	7'-0"	3.22'	10.62'	13.84'	10.36'	13'	3.57'	2.6'	8.25'	15.25'	22.25'	29.25'	1.42'	1.48	2.62	3.77	4.92	36	44	52	59
	38"	60"	7'-10"	3.39'	11.99'	15.38'	11.70'	15'	3.95'	3.3'	8.92'	16.75'	24.58'	32.42'	1.46'	1.72	3.12	4.53	5.92	38	47	56	65
	43"	68"	8'-11"	3.56'	13.71'	17.27'	13.36'	17'	4.28'	3.6'	9.67'	18.58'	27.50'	36.42'	1.50'	2.02	3.78	5.56	7.32	41	51	61	71
	48"	76"	9'-11"	3.73'	15.43'	19.16'	15.03'	19'	4.59'	4.0'	10.42'	20.33'	30.25'	40.17'	1.54'	2.34	4.49	6.64	8.79	44	55	66	77
	53"	83"	10'-8"	3.91'	17.15'	21.06'	16.70'	20'	4.77'	3.3'	11.08'	21.75'	32.42'	43.08'	1.58'	2.66	5.17	7.66	10.16	47	59	71	83
	58"	91"	11'-8"	4.08'	18.87'	22.95'	18.36'	22'	5.01'	3.6'	11.83'	23.50'	35.17'	46.83'	1.63'	3.02	5.98	8.95	11.90	50	63	76	89

◪ See General Note No. 3.
See Sheet 5 For 3" Slab Quantities

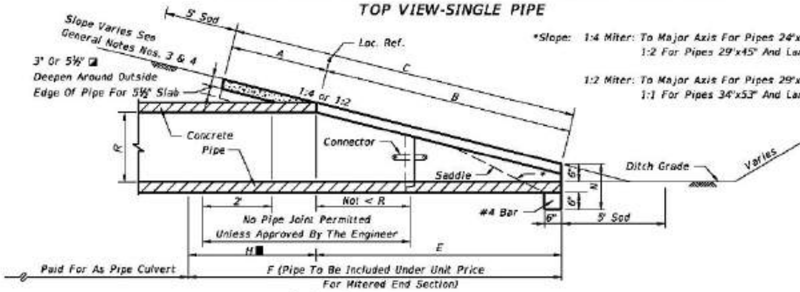
■ Values shown for estimating pipe quantities and are for information only.



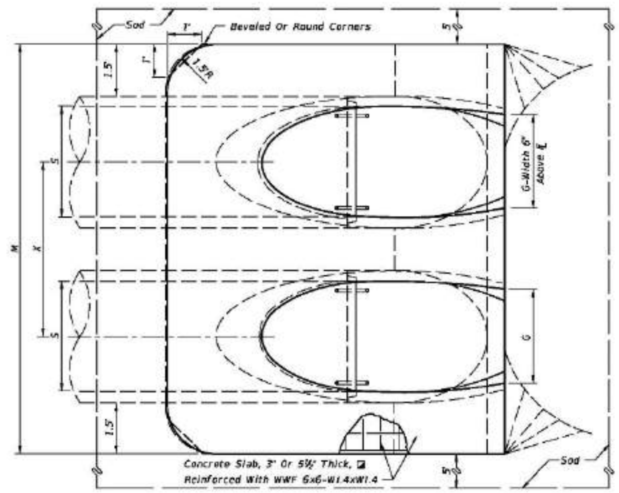
TOP VIEW-SINGLE PIPE

*Slope: 1:4 Miter: To Major Axis For Pipes 24"x38" And Smaller.
1:2 For Pipes 29"x45" And Larger.

1:2 Miter: To Major Axis For Pipes 29"x45" And Smaller.
1:1 For Pipes 34"x53" And Larger.



SECTION



NOTE: See Sheet 6 For Details And Notes.

TOP VIEW - MULTIPLE PIPE

SINGLE AND MULTIPLE ELLIPTICAL CONCRETE PIPE

LAST REVISION	REVISION	DESCRIPTION:	FDOT 2014 DESIGN STANDARDS	CROSS DRAIN MITERED END SECTION	INDEX NO.	SHEET NO.
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QUANTITIES FOR 3" THICK CONCRETE SLABS (CY)

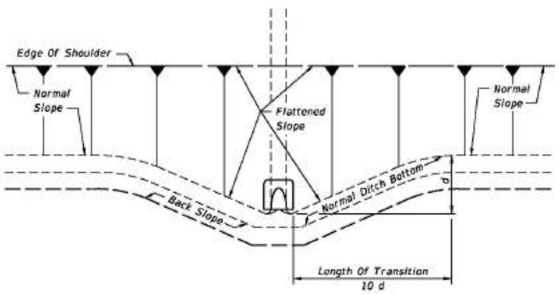
	D	ROUND-CONCRETE Single Pipe	Double Pipe	Triple Pipe	Quad. Pipe
1:2 Slope	15"	0.27	0.41	0.54	0.67
	18"	0.31	0.45	0.60	0.75
	24"	0.39	0.59	0.79	1.00
	30"	0.46	0.76	1.04	1.32
	36"	0.55	0.94	1.33	1.71
	42"	0.66	1.15	1.66	2.15
	48"	0.76	1.37	1.96	2.57
	54"	0.87	1.62	2.38	3.14
	60"	0.99	1.90	2.81	3.73
	66"	1.11	2.15	3.21	4.27
	72"	1.24	2.46	3.68	4.90
1:4 Slope	15"	0.40	0.61	0.80	1.00
	18"	0.47	0.69	0.91	1.14
	24"	0.60	0.90	1.21	1.52
	30"	0.76	1.19	1.63	2.07
	36"	0.89	1.48	2.05	2.63
	42"	1.05	1.82	2.57	3.34
	48"	1.21	2.15	3.07	4.00
	54"	1.39	2.55	3.72	4.88
	60"	1.59	3.02	4.44	5.86
	66"	1.91	3.66	5.40	7.15
	72"	2.12	4.18	6.24	8.30

	D	ROUND-CMP Single Pipe	Double Pipe	Triple Pipe	Quad. Pipe
1:2 Slope	15"	0.24	0.37	0.51	0.64
	18"	0.26	0.43	0.61	0.78
	24"	0.32	0.52	0.72	0.91
	30"	0.38	0.64	0.91	1.18
	36"	0.44	0.78	1.13	1.48
	42"	0.51	0.96	1.41	1.87
	48"	0.57	1.09	1.63	2.15
	54"	0.65	1.32	1.99	2.66
	60"	0.71	1.49	2.28	3.07
1:4 Slope	15"	0.31	0.47	0.63	0.79
	18"	0.34	0.53	0.71	0.90
	24"	0.44	0.69	0.92	1.18
	30"	0.53	0.88	1.25	1.60
	36"	0.62	1.07	1.53	2.00
	42"	0.71	1.30	1.92	2.52
	48"	0.80	1.54	2.29	3.02
	54"	0.91	1.83	2.74	3.67
	60"	1.02	2.15	3.27	4.39

	Span	Rise	CMP-ARCH Single Pipe	Double Pipe	Triple Pipe	Quad. Pipe
1:2 Slope	17"	13"	0.33	0.49	0.65	0.81
	21"	15"	0.33	0.50	0.67	0.83
	28"	20"	0.37	0.56	0.76	0.95
	35"	24"	0.40	0.62	0.84	1.07
	42"	29"	0.43	0.70	0.98	1.25
	49"	33"	0.49	0.82	1.15	1.48
	57"	38"	0.55	0.95	1.35	1.75
	64"	43"	0.62	1.10	1.57	2.05
	71"	47"	0.69	1.24	1.80	2.35
1:4 Slope	17"	13"	0.38	0.56	0.74	0.92
	21"	15"	0.39	0.59	0.80	0.95
	28"	20"	0.43	0.64	0.88	1.10
	35"	24"	0.49	0.77	1.05	1.33
	42"	29"	0.57	0.92	1.27	1.62
	49"	33"	0.65	1.08	1.50	1.93
	57"	38"	0.76	1.30	1.83	2.37
	64"	43"	0.87	1.55	2.18	2.83
	71"	47"	0.95	1.68	2.43	3.17

	Rise	Span	ELLIPTICAL-CONCRETE Single Pipe	Double Pipe	Triple Pipe	Quad. Pipe
1:2 Slope	12"	18"	0.19	0.33	0.45	0.57
	14"	23"	0.25	0.40	0.55	0.69
	19"	30"	0.34	0.55	0.75	0.95
	24"	38"	0.43	0.71	1.00	1.28
	29"	45"	0.52	0.90	1.27	1.65
	34"	53"	0.62	1.11	1.60	2.09
	38"	60"	0.70	1.29	1.87	2.46
	43"	68"	0.81	1.54	2.26	2.99
	48"	76"	0.93	1.79	2.66	3.53
	53"	83"	1.04	2.04	3.03	4.02
	58"	91"	1.17	2.33	3.49	4.66
1:4 Slope	12"	18"	0.30	0.45	0.61	0.76
	14"	23"	0.36	0.56	0.76	0.95
	19"	30"	0.51	0.79	1.08	1.36
	24"	38"	0.68	1.10	1.53	1.96
	29"	45"	0.86	1.45	2.04	2.63
	34"	53"	1.02	1.91	2.60	3.39
	38"	60"	1.18	2.14	3.10	4.05
	43"	68"	1.38	2.58	3.79	4.99
	48"	76"	1.59	3.05	4.51	5.97
	53"	83"	1.80	3.50	5.19	6.88
	58"	91"	2.04	4.04	6.05	8.05

LAST REVISION 07/01/00	REVISION	DESCRIPTION:	FDOT 2014 DESIGN STANDARDS	CROSS DRAIN MITERED END SECTION	INDEX NO. 272	SHEET NO. 5 of 6



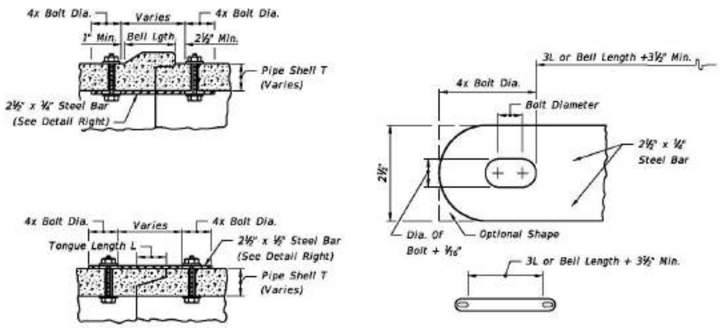
PLAN

NOTE: See General Note 4

SLOPE AND DITCH TRANSITIONS

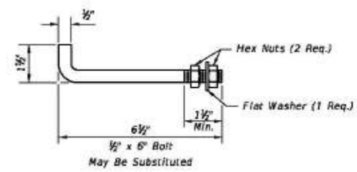
GENERAL NOTES

1. Unless otherwise designated in the plans, concrete pipe mitered end sections may be used with any type of cross drain pipe; corrugated steel pipe mitered end sections may be used with any type of cross drain pipe except aluminum pipe; and, corrugated aluminum mitered end sections may be used with any type of cross drain pipe except steel pipe. When bituminous coated metal pipe is specified for cross drain pipe, mitered end sections shall be constructed with like pipe or concrete pipe. When the mitered end section pipe is dissimilar to the cross drain pipe, a concrete jacket shall be constructed in accordance with Standard Index 280.
2. Corrugated polyethylene pipe (HDPE), polyvinyl-chloride pipe (PVC) and polypropylene pipe (PPP) for cross drain applications shall utilize either corrugated metal or concrete mitered end sections (MES). When used in conjunction with corrugated (MES), connection shall be by either a formed metal band specifically designated to join HDPE or PVC pipe, with metal pipe or other coupler approved by the State Drainage Engineer. When used in conjunction with a concrete (MES), connection shall be by concrete jacket constructed in accordance with Index No. 280.
3. Mitered end sections for pipe sizes 15", 18" and 24" round or equivalent pipe arch or elliptical pipe are permitted within the clear zone. When the slope intersection permits, the mitered end section may be located with the culvert opening as close as 8' beyond the outside edge of the shoulder.
4. Slope and ditch transitions shall be used when the normal roadway slope must be flattened to place end section outside clear zone. See detail left.
5. The reinforced concrete slab shall be constructed for all sizes of cross drain pipe and cast in place with Class NS concrete. Slabs shall be 5½" thick unless 3" thickness called for in plans.
6. Concrete pipe used in the assembly of mitered end sections shall be selective lengths to avoid excessive connections.
7. Corrugated metal pipe galvanizing that is damaged during beveling and perforating for mitered end section shall be repaired.
8. That portion of corrugated metal pipe in direct contact with the concrete slab and extending 12" beyond shall be bituminous coated prior to placing of the concrete.
9. When existing multiple cross drain pipes are spaced other than the dimensions shown in this detail, or have non-parallel axes, or have non-uniform sections, the mitered end sections will be constructed either separately as single pipe mitered end sections or collectively as multiple pipe end sections as directed by the Engineer; however, mitered end sections will be paid for each based on each independent pipe end.
10. The cost of all pipe(s), fasteners, reinforcing, connectors, anchors, concrete, sealants, jackets, and coupling bands shall be included in the cost for the mitered end section. Sodding shall be paid for separately under the contract unit price of Performance Turf, SY.
11. Mitered end sections shall be paid for under the contract unit price for Mitered End Section (CD), Each, based on each independent pipe end.



All bars, bolts, nuts and washers are to be galvanized steel.
Bolt diameters shall be ⅝" for 15" to 36" pipe and ¾" for 42" to 72" pipe.
Two connectors required per joint, located 60° right and left of bottom center of pipe.
Bolt holes in pipe shell are to be drilled.

CONCRETE PIPE CONNECTOR



Anchors required for CMP only.

Anchor, washer and nuts to be galvanized steel.

Bend anchor where required to center in concrete slab. Damaged surfaces to be repaired after bending. Anchors are to be spaced a distance equal to four (4) corrugations. Place the anchors in the outside crest of corrugation.

Flat washers to be placed on inside wall of pipe.

Holes in the mitered end pipe are to be drilled or punched; burning not permitted.

ANCHOR DETAIL

SPECIAL DETAILS AND NOTES

LAST REVISION 07/01/12	REVISION	DESCRIPTION:	FDOT 2014 DESIGN STANDARDS	CROSS DRAIN MITERED END SECTION	INDEX NO. 272	SHEET NO. 6 of 6

Appendix E Oklahoma DOT Detail

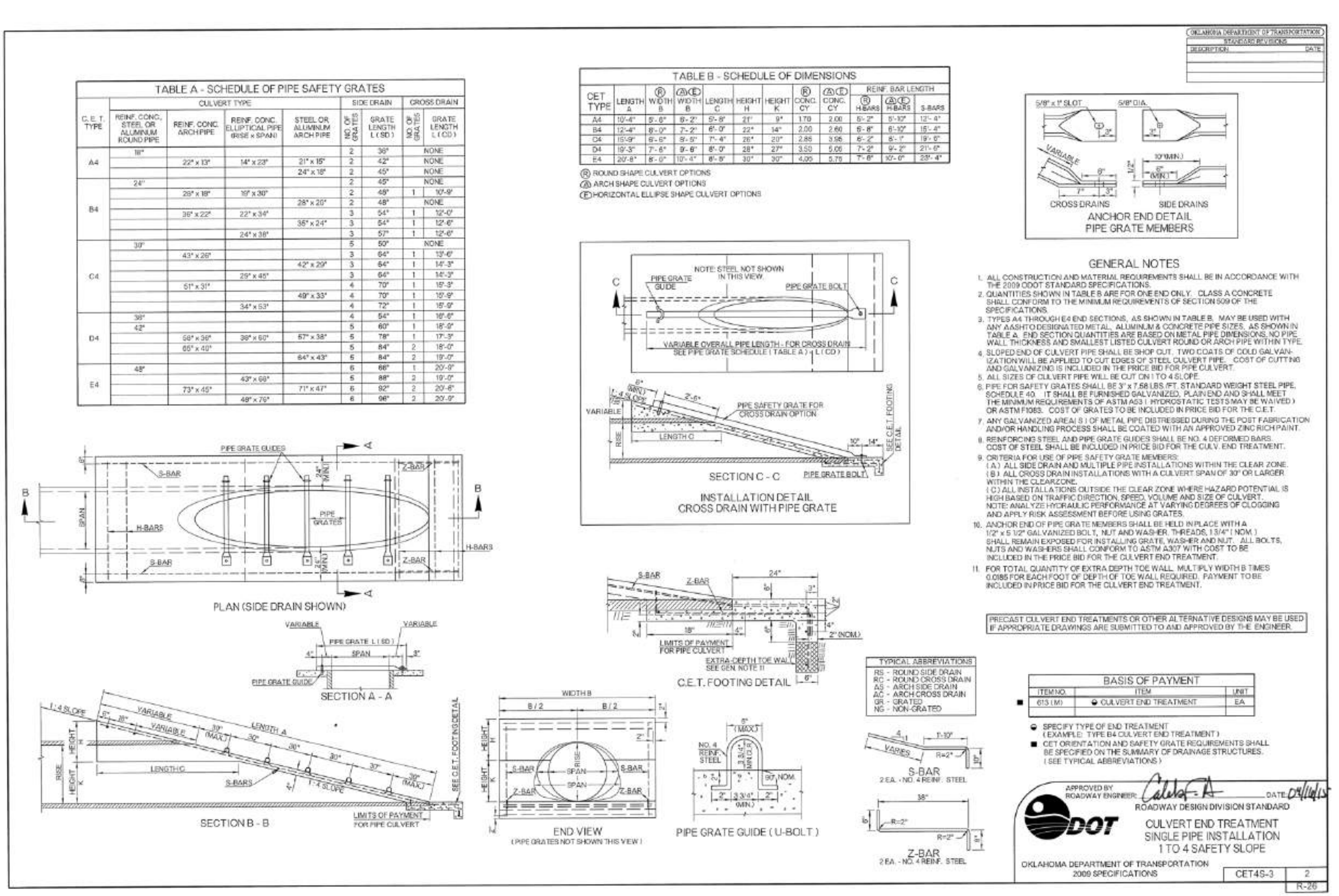


TABLE A - SCHEDULE OF PIPE SAFETY GRATES

C. E. T. TYPE	CULVERT TYPE: REINF. CONC., STEEL OR ALUMINUM ROUND PIPE	REINF. CONC. ARCH PIPE	REINF. CONC. ELLIPTICAL PIPE (RISE x SPAN)	STEEL OR ALUMINUM ARCH PIPE	SIDE DRAIN: NO. OF GRATES	GRATE LENGTH L (SD)	CROSS DRAIN: NO. OF GRATES	GRATE LENGTH L (CD)
A4	18"				2	36"	NONE	
		22" x 13"	14" x 23"	21" x 15"	2	42"	NONE	
				24" x 18"	2	45"	NONE	
B4	24"				2	45"	NONE	
		28" x 18"	19" x 30"		2	48"	1	10'-9"
				28" x 20"	2	48"	NONE	
		36" x 22"	22" x 34"		3	54"	1	12'-0"
				35" x 24"	3	54"	1	12'-6"
			24" x 38"		3	57"	1	12'-6"
C4	30"				5	50"	NONE	
		43" x 26"			3	64"	1	13'-6"
				42" x 29"	3	64"	1	14'-3"
			29" x 45"		3	64"	1	14'-3"
		51" x 31"			4	70"	1	15'-3"
				49" x 33"	4	70"	1	15'-9"
			34" x 53"		4	72"	1	15'-9"
D4	36"				4	54"	1	16'-6"
	42"				5	60"	1	16'-0"
		58" x 36"	38" x 60"	57" x 38"	5	78"	1	17'-3"
		65" x 40"			5	84"	2	18'-0"
				64" x 43"	5	84"	2	19'-0"
E4	48"				6	66"	1	20'-0"
			43" x 68"		5	88"	2	19'-0"
		73" x 45"		71" x 47"	6	92"	2	20'-6"
			48" x 76"		6	96"	2	20'-0"

TABLE B - SCHEDULE OF DIMENSIONS

CET TYPE	LENGTH A	Ⓡ WIDTH B	ⒶⒺ WIDTH B	LENGTH C	HEIGHT H	HEIGHT K	Ⓡ CONC. CY	ⒶⒺ CONC. CY	REINF. BAR LENGTH: Ⓡ H-BARS	ⒶⒺ H-BARS	S-BARS
A4	10'-4"	5'-6"	6'-2"	5'-8"	21"	9"	1.70	2.00	5'-2"	5'-10"	12'-4"
B4	12'-4"	6'-0"	7'-2"	6'-0"	22"	14"	2.00	2.60	5'-8"	6'-10"	15'-4"
C4	15'-9"	6'-6"	8'-5"	7'-4"	26"	20"	2.86	3.96	6'-2"	8'-1"	19'-6"
D4	19'-3"	7'-6"	9'-6"	8'-0"	28"	27"	3.50	5.06	7'-2"	9'-2"	21'-6"
E4	20'-8"	8'-0"	10'-4"	8'-8"	30"	30"	4.05	5.76	7'-8"	10'-0"	23'-4"

Ⓡ ROUND SHAPE CULVERT OPTIONS
Ⓐ ARCH SHAPE CULVERT OPTIONS
Ⓔ HORIZONTAL ELLIPSE SHAPE CULVERT OPTIONS

GENERAL NOTES

1. ALL CONSTRUCTION AND MATERIAL REQUIREMENTS SHALL BE IN ACCORDANCE WITH THE 2009 ODOT STANDARD SPECIFICATIONS.
2. QUANTITIES SHOWN IN TABLE B ARE FOR ONE END ONLY. CLASS A CONCRETE SHALL CONFORM TO THE MINIMUM REQUIREMENTS OF SECTION 509 OF THE SPECIFICATIONS.
3. TYPES A4 THROUGH E4 END SECTIONS, AS SHOWN IN TABLE B, MAY BE USED WITH ANY AASHTO DESIGNATED METAL, ALUMINUM & CONCRETE PIPE SIZES, AS SHOWN IN TABLE A. END SECTION QUANTITIES ARE BASED ON METAL PIPE DIMENSIONS, NO PIPE WALL THICKNESS AND SMALLEST LISTED CULVERT ROUND OR ARCH PIPE WITHIN TYPE.
4. SLOPED END OF CULVERT PIPE SHALL BE SHOP CUT. TWO COATS OF COLD GALVANIZATION WILL BE APPLIED TO CUT EDGES OF STEEL CULVERT PIPE. COST OF CUTTING AND GALVANIZING IS INCLUDED IN THE PRICE BID FOR PIPE CULVERT.
5. ALL SIZES OF CULVERT PIPE WILL BE CUT ON 1 TO 4 SLOPE.
6. PIPE FOR SAFETY GRATES SHALL BE 3" x 7.58 LBS./FT. STANDARD WEIGHT STEEL PIPE, SCHEDULE 40. IT SHALL BE FURNISHED GALVANIZED, PLAIN END AND SHALL MEET THE MINIMUM REQUIREMENTS OF ASTM A53 (HYDROSTATIC TESTS MAY BE WAIVED) OR ASTM F1083. COST OF GRATES TO BE INCLUDED IN PRICE BID FOR THE C.E.T.
7. ANY GALVANIZED AREA(S) OF METAL PIPE DISTRESSED DURING THE POST FABRICATION AND/OR HANDLING PROCESS SHALL BE COATED WITH AN APPROVED ZINC RICH PAINT.
8. REINFORCING STEEL AND PIPE GRATE GUIDES SHALL BE NO. 4 DEFORMED BARS. COST OF STEEL SHALL BE INCLUDED IN PRICE BID FOR THE CULV. END TREATMENT.
9. CRITERIA FOR USE OF PIPE SAFETY GRATE MEMBERS:
   (A) ALL SIDE DRAIN AND MULTIPLE PIPE INSTALLATIONS WITHIN THE CLEAR ZONE.
   (B) ALL CROSS DRAIN INSTALLATIONS WITH A CULVERT SPAN OF 30" OR LARGER WITHIN THE CLEARZONE.
   (C) ALL INSTALLATIONS OUTSIDE THE CLEAR ZONE WHERE HAZARD POTENTIAL IS HIGH BASED ON TRAFFIC DIRECTION, SPEED, VOLUME AND SIZE OF CULVERT.
   NOTE: ANALYZE HYDRAULIC PERFORMANCE AT VARYING DEGREES OF CLOGGING AND APPLY RISK ASSESSMENT BEFORE USING GRATES.
10. ANCHOR END OF PIPE GRATE MEMBERS SHALL BE HELD IN PLACE WITH A 1/2" x 5 1/2" GALVANIZED BOLT, NUT AND WASHER. THREADS, 1 3/4" (NOM.) SHALL REMAIN EXPOSED FOR INSTALLING GRATE, WASHER AND NUT. ALL BOLTS, NUTS AND WASHERS SHALL CONFORM TO ASTM A307 WITH COST TO BE INCLUDED IN THE PRICE BID FOR THE CULVERT END TREATMENT.
11. FOR TOTAL QUANTITY OF EXTRA DEPTH TOE WALL, MULTIPLY WIDTH B TIMES 0.0185 FOR EACH FOOT OF DEPTH OF TOE WALL REQUIRED. PAYMENT TO BE INCLUDED IN PRICE BID FOR THE CULVERT END TREATMENT.

PRECAST CULVERT END TREATMENTS OR OTHER ALTERNATIVE DESIGNS MAY BE USED IF APPROPRIATE DRAWINGS ARE SUBMITTED TO AND APPROVED BY THE ENGINEER.

TYPICAL ABBREVIATIONS
RS - ROUND SIDE DRAIN
RC - ROUND CROSS DRAIN
AS - ARCH SIDE DRAIN
AC - ARCH CROSS DRAIN
GR - GRATED
NG - NON-GRATED

BASIS OF PAYMENT

	ITEM NO.	ITEM	UNIT
■	613 (M)	◒ CULVERT END TREATMENT	EA

◒ SPECIFY TYPE OF END TREATMENT (EXAMPLE: TYPE B4 CULVERT END TREATMENT)
■ CET ORIENTATION AND SAFETY GRATE REQUIREMENTS SHALL BE SPECIFIED ON THE SUMMARY OF DRAINAGE STRUCTURES. (SEE TYPICAL ABBREVIATIONS)

APPROVED BY ROADWAY ENGINEER: Caleb F. A DATE 04/10/15
ROADWAY DESIGN DIVISION STANDARD
CULVERT END TREATMENT
SINGLE PIPE INSTALLATION
1 TO 4 SAFETY SLOPE
OKLAHOMA DEPARTMENT OF TRANSPORTATION
2009 SPECIFICATIONS
CET4S-3 | 2
R-26

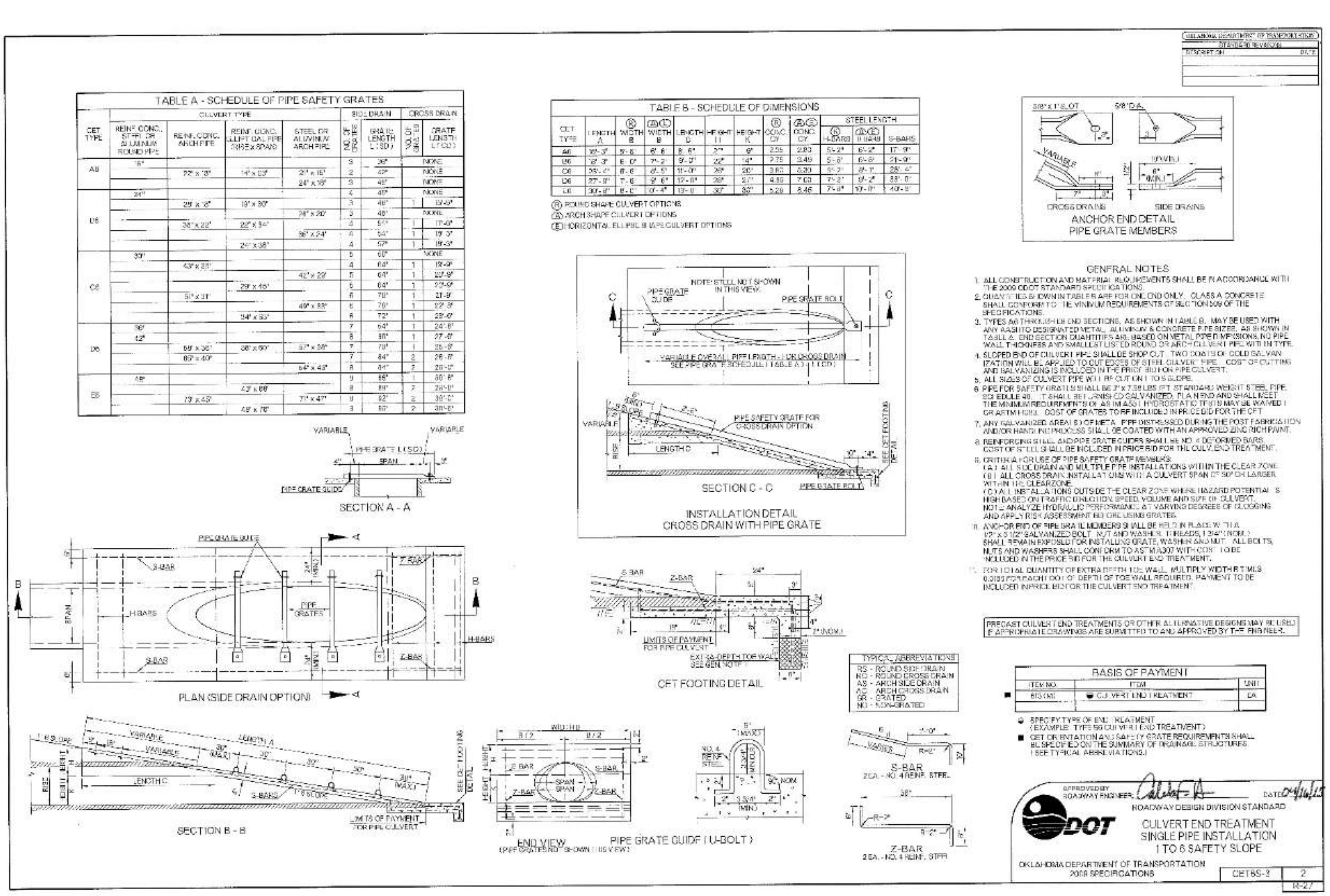
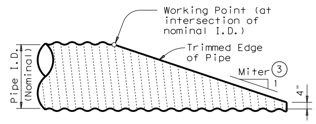


TABLE A - SCHEDULE OF PIPE SAFETY GRATES
TABLE B - SCHEDULE OF DIMENSIONS
ANCHOR END DETAIL
PIPE GRATE MEMBERS
GENERAL NOTES
SECTION A - A
SECTION C - C
INSTALLATION DETAIL
CROSS DRAIN WITH PIPE GRATE
PLAN (SIDE DRAIN OPTION)
CET FOOTING DETAIL
TYPICAL ABBREVIATIONS
BASIS OF PAYMENT
SECTION B - B
END VIEW
PIPE GRATE GUIDE (U-BOLT)
S-BAR
Z-BAR
ROADWAY DESIGN DIVISION STANDARD
CULVERT END TREATMENT
SINGLE PIPE INSTALLATION
1 TO 6 SAFETY SLOPE
OKLAHOMA DEPARTMENT OF TRANSPORTATION
2009 SPECIFICATIONS

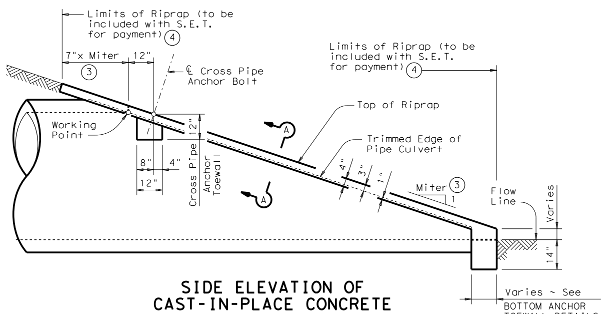
Appendix F Texas DOT Detail



NOTE: All Pipe Runners, calculations, and dimensions are based on the pipe culverts mitered as shown in this detail. Alternate styles of mitered ends will require that appropriate adjustments be made to the values presented on this standard.

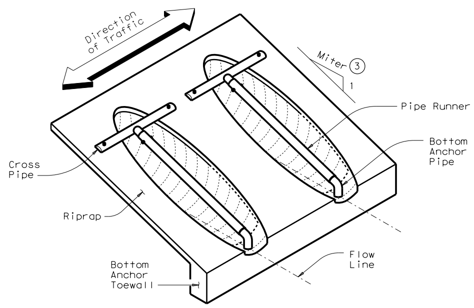
SIDE ELEVATION OF TYPICAL PIPE CULVERT MITER

(Showing Corrugated Metal Pipe Culvert. Details of Concrete Pipe Culvert are similar.)



SIDE ELEVATION OF CAST-IN-PLACE CONCRETE

(Showing Concrete Pipe Culvert. Details of Corrugated Metal Pipe Culvert are similar. Pipe Runners not shown for clarity)



ISOMETRIC VIEW OF TYPICAL INSTALLATION

(Showing installation with no skew.)

CROSS PIPE LENGTHS & PIPE RUNNER LENGTHS (1)(2)

Nominal Culvert I.D.	Pipe Culvert Spa ~ G	Cross Pipe Length	Pipe Runner Length											
			3:1 Side Slope				4:1 Side Slope				6:1 Side Slope			
			0° Skew	15° Skew	30° Skew	45° Skew	0° Skew	15° Skew	30° Skew	45° Skew	0° Skew	15° Skew	30° Skew	45° Skew
24"	1'- 7"	3'- 5"	N/A	N/A	N/A	5'-10"	N/A	N/A	N/A	8'- 1"	N/A	N/A	N/A	12'- 9"
27"	1'- 8"	3'- 8"	N/A	N/A	5'- 5"	6'-11"	N/A	N/A	7'- 7"	9'- 7"	N/A	N/A	11'-11"	14'-11"
30"	1'-10"	3'-11"	N/A	N/A	6'- 4"	8'- 0"	N/A	N/A	8'- 9"	11'- 0"	N/A	N/A	13'- 8"	17'- 0"
33"	1'-11"	4'- 2"	6'- 2"	6'- 5"	7'- 3"	9'- 1"	8'- 6"	8'-10"	10'- 0"	12'- 5"	13'- 3"	13'- 9"	15'- 5"	19'- 2"
36"	2'- 1"	4'- 5"	6'-11"	7'- 3"	8'- 2"	10'- 2"	9'- 6"	9'-11"	11'- 2"	13'-10"	14'- 9"	15'- 3"	17'- 2"	21'- 3"
42"	2'- 4"	4'-11"	8'- 6"	8'-10"	9'-11"	12'- 4"	11'- 7"	12'- 0"	13'- 6"	16'- 8"	17'- 9"	18'- 5"	20'- 8"	25'- 7"
48"	2'- 7"	5'- 5"	10'- 1"	10'- 5"	11'- 9"	N/A	13'- 7"	14'- 2"	15'-10"	N/A	20'- 9"	21'- 6"	24'- 2"	N/A
54"	3'- 0"	5'-11"	11'- 8"	12'- 1"	N/A	N/A	15'- 8"	16'- 3"	N/A	N/A	23'-10"	24'- 8"	N/A	N/A
60"	3'- 3"	6'- 5"	13'- 3"	N/A	N/A	N/A	17'- 9"	N/A	N/A	N/A	26'-10"	N/A	N/A	N/A

TYPICAL PIPE CULVERT MITERS (3)

Side Slope	0° Skew	15° Skew	30° Skew	45° Skew
3:1	3:1	3.106:1	3.464:1	4.243:1
4:1	4:1	4.141:1	4.619:1	5.657:1
6:1	6:1	6.212:1	6.928:1	8.485:1

CONDITIONS WHERE PIPE RUNNERS ARE NOT REQUIRED (2)

Nominal Culvert I.D.	Single Pipe Culvert	Multiple Pipe Culverts
12" thru 21"	Skews thru 45°	Skews thru 45°
24"	Skews thru 45°	Skews thru 30°
27"	Skews thru 30°	Skews thru 15°
30"	Skews thru 15°	Skews thru 15°
33"	Skews thru 15°	Always required
36"	Normal (No Skew)	Always required
42" to 60"	Always required	Always required

STANDARD PIPE SIZES & MAX PIPE RUNNER LENGTHS (1)

Pipe Size	Pipe O.D.	Pipe I.D.	Max Pipe Runner Length
2" STD	2.375"	2.067"	N/A
3" STD	3.500"	3.068"	10'- 0"
4" STD	4.500"	4.026"	19'- 8"
5" STD	5.563"	5.047"	34'- 2"

ESTIMATED CONCRETE RIPRAP QUANTITIES (CY) (5)

Nominal Culvert I.D.	3:1 Side Slope				4:1 Side Slope				6:1 Side Slope			
	0° Skew	15° Skew	30° Skew	45° Skew	0° Skew	15° Skew	30° Skew	45° Skew	0° Skew	15° Skew	30° Skew	45° Skew
12"	0.4	0.4	0.5	0.5	0.5	0.5	0.5	0.6	0.7	0.7	0.7	0.8
15"	0.5	0.5	0.5	0.6	0.6	0.6	0.6	0.7	0.7	0.7	0.8	0.9
18"	0.5	0.5	0.6	0.6	0.6	0.7	0.7	0.8	0.8	0.8	0.9	1.0
21"	0.6	0.6	0.6	0.7	0.7	0.7	0.8	0.9	0.9	0.9	1.0	1.2
24"	0.6	0.7	0.7	0.8	0.8	0.8	0.8	1.0	1.0	1.0	1.1	1.3
27"	0.7	0.7	0.8	0.9	0.8	0.9	0.9	1.1	1.1	1.1	1.2	1.4
30"	0.8	0.8	0.8	0.9	0.9	0.9	1.0	1.2	1.2	1.2	1.3	1.6
33"	0.8	0.8	0.9	1.0	1.0	1.0	1.1	1.3	1.3	1.4	1.5	1.7
36"	0.9	0.9	0.9	1.1	1.1	1.1	1.2	1.4	1.4	1.5	1.6	1.8
42"	1.0	1.0	1.1	1.3	1.2	1.3	1.3	1.6	1.6	1.7	1.8	2.1
48"	1.1	1.1	1.2	N/A	1.4	1.4	1.5	N/A	1.9	1.9	2.1	N/A
54"	1.3	1.3	N/A	N/A	1.6	1.6	N/A	N/A	2.1	2.1	N/A	N/A
60"	1.4	N/A	N/A	N/A	1.7	N/A	N/A	N/A	2.3	N/A	N/A	N/A

(1) Size of Pipe Runner shall be as shown in the tables. Cross Pipe shall be the same size as the Pipe Runner. Cross Pipe Stub Out and Bottom Anchor Pipe shall be the next smaller size pipe as shown in the STANDARD PIPE SIZES table.

(2) This standard allows for the placement of only one pipe runner across each culvert pipe opening. In order to limit the clear opening to be traversed by an errant vehicle, the following conditions must be met:

For 60" culvert pipes, the skew must not exceed 0°.
For 54" culvert pipes, the skew must not exceed 15°.
For 48" culvert pipes, the skew must not exceed 30°.
For all culvert pipe sizes 42" and less, the skew must not exceed 45°.

If the above conditions cannot be met, the designer should consider using a safety end treatment with flared wings. For further information, refer to the TxDOT "Roadway Design Manual".

(3) Miter = Slope of Mitered Pipe Culvert End

(4) Riprap placed beyond the limits shown will be paid as Concrete Riprap in accordance with Item 432, "Riprap".

(5) Quantities shown are for one end of one reinforced Concrete Pipe Culvert. For multiple Pipe Culverts or for Corrugated Metal Pipe Culverts, quantities will need to be adjusted. Riprap quantities are for Contractor's information only.

SHEET 1 OF 2

Texas Department of Transportation | Bridge Division Standard

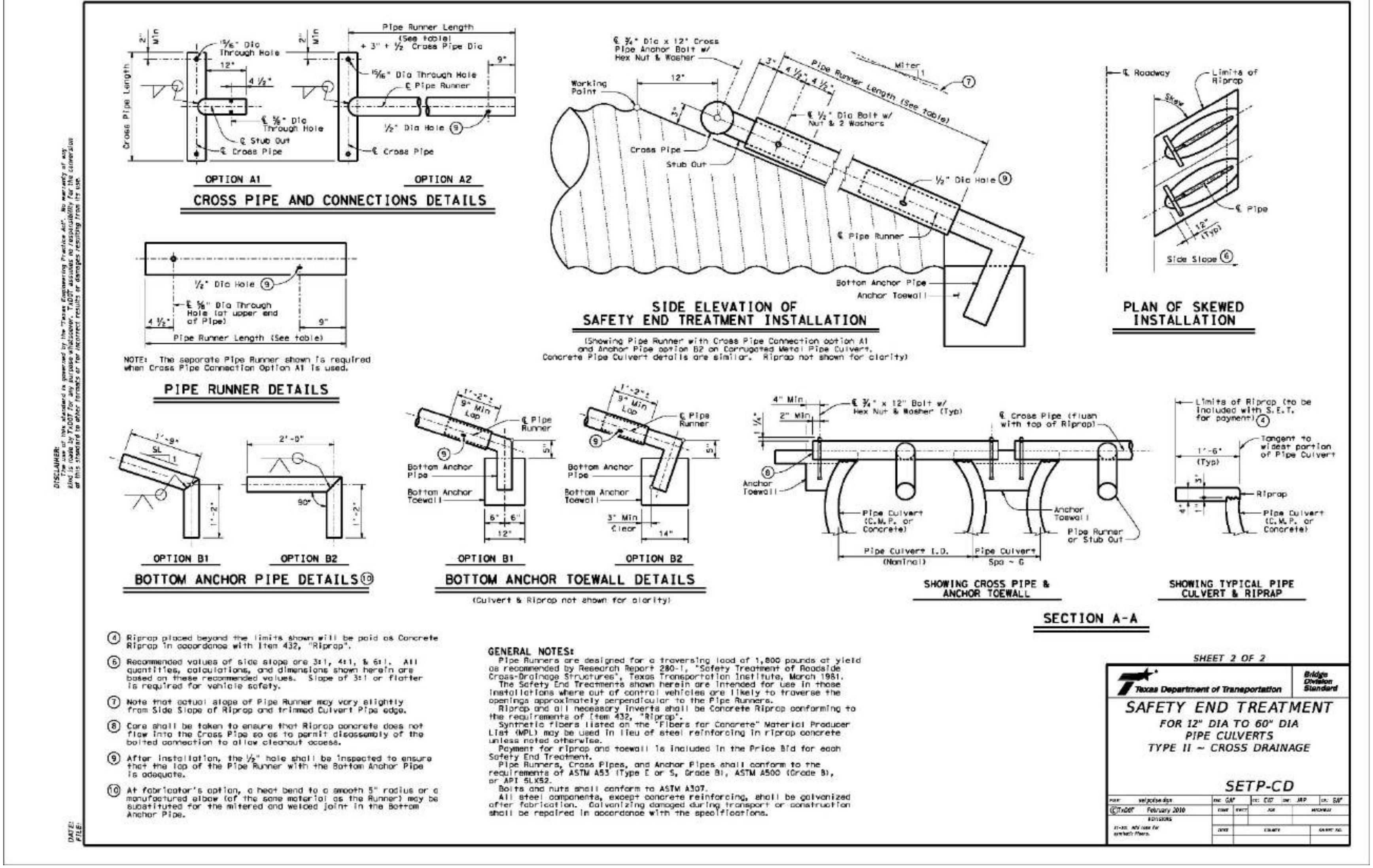
SAFETY END TREATMENT

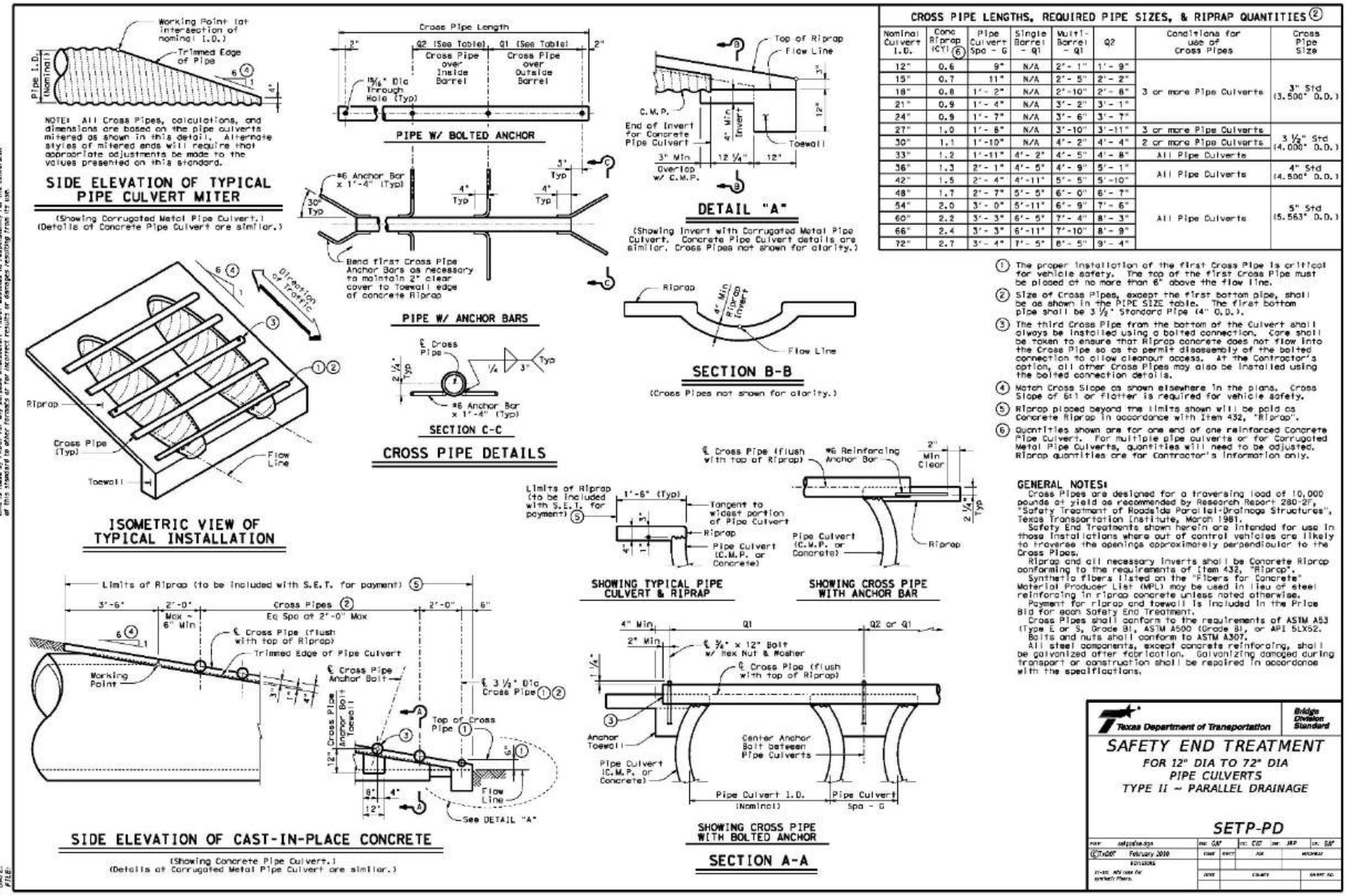
FOR 12" DIA TO 60" DIA
PIPE CULVERTS
TYPE II ~ CROSS DRAINAGE

SETP-CD

FILE: setpcdse.dgn	DN: GAF	CK: CAT	DW: JRP	CK: GAF
©TxDOT February 2010	CONT	SECT	JOB	HIGHWAY
REVISIONS 11-10: Add note for synthetic fibers.	DIST	COUNTY		SHEET NO.

DATE:
FILE:


CROSS PIPE AND CONNECTIONS DETAILS
OPTION A1
OPTION A2
Pipe Runner Length (See table) + 3" + ½ Cross Pipe Dia
PIPE RUNNER DETAILS
NOTE: The separate Pipe Runner shown is required when Cross Pipe Connection Option A1 is used.
SIDE ELEVATION OF SAFETY END TREATMENT INSTALLATION
(Showing Pipe Runner with Cross Pipe Connection option A1 and Anchor Pipe option B2 on Corrugated Metal Pipe Culvert. Concrete Pipe Culvert details are similar. Riprap not shown for clarity)
PLAN OF SKEWED INSTALLATION
BOTTOM ANCHOR PIPE DETAILS ⑩
OPTION B1
OPTION B2
BOTTOM ANCHOR TOEWALL DETAILS
(Culvert & Riprap not shown for clarity)
SHOWING CROSS PIPE & ANCHOR TOEWALL
SHOWING TYPICAL PIPE CULVERT & RIPRAP
SECTION A-A
④ Riprap placed beyond the limits shown will be paid as Concrete Riprap in accordance with Item 432, "Riprap".
⑥ Recommended values of side slope are 3:1, 4:1, & 6:1. All quantities, calculations, and dimensions shown herein are based on these recommended values. Slope of 3:1 or flatter is required for vehicle safety.
⑦ Note that actual slope of Pipe Runner may vary slightly from Side Slope of Riprap and trimmed Culvert Pipe edge.
⑧ Care shall be taken to ensure that Riprap concrete does not flow into the Cross Pipe so as to permit disassembly of the bolted connection to allow cleanout access.
⑨ After installation, the ½" hole shall be inspected to ensure that the lap of the Pipe Runner with the Bottom Anchor Pipe is adequate.
⑩ At fabricator's option, a heat bend to a smooth 5" radius or a manufactured elbow (of the same material as the Runner) may be substituted for the mitered and welded joint in the Bottom Anchor Pipe.
GENERAL NOTES:
Pipe Runners are designed for a traversing load of 1,800 pounds at yield as recommended by Research Report 280-1, "Safety Treatment of Roadside Cross-Drainage Structures", Texas Transportation Institute, March 1981.
The Safety End Treatments shown herein are intended for use in those installations where out of control vehicles are likely to traverse the openings approximately perpendicular to the Pipe Runners.
Riprap and all necessary inverts shall be Concrete Riprap conforming to the requirements of Item 432, "Riprap".
Synthetic fibers listed on the "Fibers for Concrete" Material Producer List (MPL) may be used in lieu of steel reinforcing in riprap concrete unless noted otherwise.
Payment for riprap and toewall is included in the Price Bid for each Safety End Treatment.
Pipe Runners, Cross Pipes, and Anchor Pipes shall conform to the requirements of ASTM A53 (Type E or S, Grade B), ASTM A500 (Grade B), or API 5LX52.
Bolts and nuts shall conform to ASTM A307.
All steel components, except concrete reinforcing, shall be galvanized after fabrication. Galvanizing damaged during transport or construction shall be repaired in accordance with the specifications.
SHEET 2 OF 2
Texas Department of Transportation
Bridge Division Standard
SAFETY END TREATMENT
FOR 12" DIA TO 60" DIA
PIPE CULVERTS
TYPE II ~ CROSS DRAINAGE
SETP-CD
©TxDOT February 2010



CROSS PIPE LENGTHS, REQUIRED PIPE SIZES, & RIPRAP QUANTITIES (2)

Nominal Culvert I.D.	Conc Riprap (CY) (6)	Pipe Culvert Spa - G	Single Barrel - Q1	Multi-Barrel - Q1	Q2	Conditions for use of Cross Pipes	Cross Pipe Size
12"	0.6	9"	N/A	2'- 1"	1'- 9"	3 or more Pipe Culverts	3" Std (3.500" O.D.)
15"	0.7	11"	N/A	2'- 5"	2'- 2"		
18"	0.8	1'- 2"	N/A	2'-10"	2'- 8"		
21"	0.9	1'- 4"	N/A	3'- 2"	3'- 1"		
24"	0.9	1'- 7"	N/A	3'- 6"	3'- 7"		
27"	1.0	1'- 8"	N/A	3'-10"	3'-11"	3 or more Pipe Culverts	3 ½" Std (4.000" O.D.)
30"	1.1	1'-10"	N/A	4'- 2"	4'- 4"	2 or more Pipe Culverts	
33"	1.2	1'-11"	4'- 2"	4'- 5"	4'- 8"	All Pipe Culverts	
36"	1.3	2'- 1"	4'- 5"	4'- 9"	5'- 1"	All Pipe Culverts	4" Std (4.500" O.D.)
42"	1.5	2'- 4"	4'-11"	5'- 5"	5'-10"		
48"	1.7	2'- 7"	5'- 5"	6'- 0"	6'- 7"	All Pipe Culverts	5" Std (5.563" O.D.)
54"	2.0	3'- 0"	5'-11"	6'- 9"	7'- 6"		
60"	2.2	3'- 3"	6'- 5"	7'- 4"	8'- 3"		
66"	2.4	3'- 3"	6'-11"	7'-10"	8'- 9"		
72"	2.7	3'- 4"	7'- 5"	8'- 5"	9'- 4"		

(1) The proper installation of the first Cross Pipe is critical for vehicle safety. The top of the first Cross Pipe must be placed at no more than 6" above the flow line.

(2) Size of Cross Pipes, except the first bottom pipe, shall be as shown in the PIPE SIZE table. The first bottom pipe shall be 3 ½" Standard Pipe (4" O.D.).

(3) The third Cross Pipe from the bottom of the Culvert shall always be installed using a bolted connection. Care shall be taken to ensure that Riprap concrete does not flow into the Cross Pipe so as to permit disassembly of the bolted connection to allow cleanout access. At the Contractor's option, all other Cross Pipes may also be installed using the bolted connection details.

(4) Match Cross Slope as shown elsewhere in the plans. Cross Slope of 6:1 or flatter is required for vehicle safety.

(5) Riprap placed beyond the limits shown will be paid as Concrete Riprap in accordance with Item 432, "Riprap".

(6) Quantities shown are for one end of one reinforced Concrete Pipe Culvert. For multiple pipe culverts or for Corrugated Metal Pipe Culverts, quantities will need to be adjusted. Riprap quantities are for Contractor's information only.

GENERAL NOTES:

Cross Pipes are designed for a traversing load of 10,000 pounds at yield as recommended by Research Report 280-2F, "Safety Treatment of Roadside Parallel-Drainage Structures", Texas Transportation Institute, March 1981.

Safety End Treatments shown herein are intended for use in those installations where out of control vehicles are likely to traverse the openings approximately perpendicular to the Cross Pipes.

Riprap and all necessary Inverts shall be Concrete Riprap conforming to the requirements of Item 432, "Riprap".

Synthetic fibers listed on the "Fibers for Concrete" Material Producer List (MPL) may be used in lieu of steel reinforcing in riprap concrete unless noted otherwise.

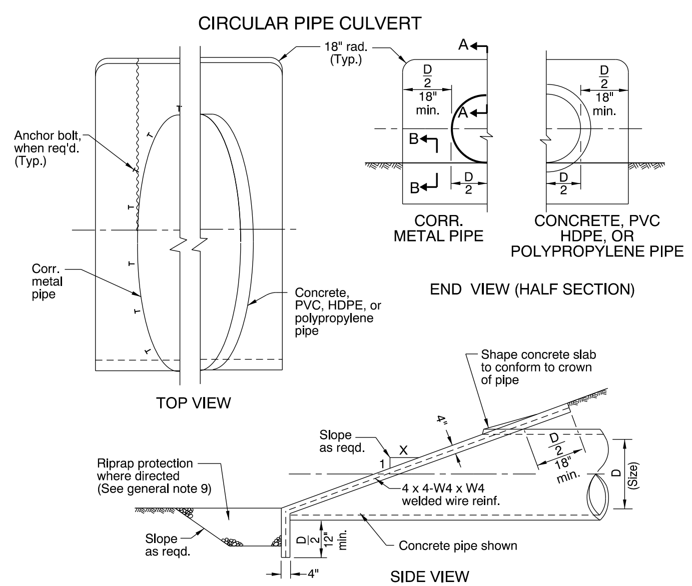
Payment for riprap and toewall is included in the Price Bid for each Safety End Treatment.

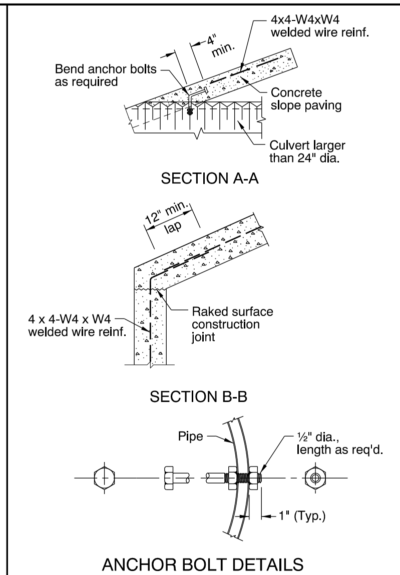
Cross Pipes shall conform to the requirements of ASTM A53 (Type E or S, Grade B), ASTM A500 (Grade B), or API 5LX52.

Bolts and nuts shall conform to ASTM A307.

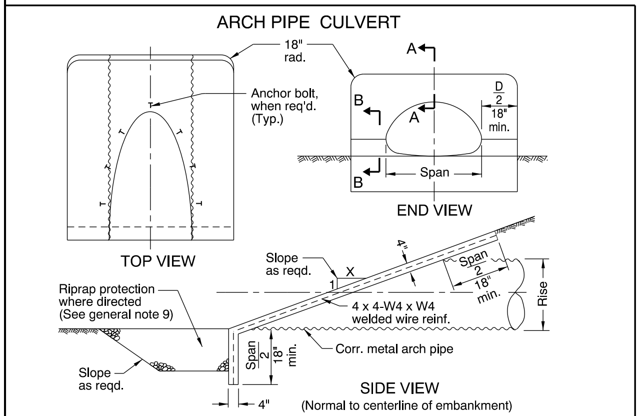
All steel components, except concrete reinforcing, shall be galvanized after fabrication. Galvanizing damaged during transport or construction shall be repaired in accordance with the specifications.

Appendix G Oregon DOT Detail





Anchor bolts to be ASTM A307 galv., equally spaced at a max. of 18" centers around entire perimeter at end of pipes over 24" size. Not required for concrete pipe.



GENERAL NOTES FOR ALL DETAILS:

1. When rock is encountered, cut off wall depth D/2 or span/2 may be reduced to rock line but not less than 12".
2. When using pervious bedding and backfill, it is desirable to prevent seepage and piping by placing impervious material at the inlet. Cutoff collars may be used in lieu of impervious material.
3. For multiple pipe installations, see Std. Drgs. RD300 & RD304.
4. All exposed conc. edges shall be chamfered ¾" unless noted otherwise. Slope paving surface variations shall not exceed ⅜" in 10' .
5. All metal reinforcement shall be placed 1½" clear of nearest face of concrete unless shown or noted otherwise.
6. All concrete shall be commercial grade concrete.
7. Open ends of pipes normally require a site specific design, and may require special treament (Slope ends, culvert embankment protection, paved end slopes, safety end sections, or other measures). See special details or Standard Drawings as called for on plans.
8. See Std. Drg. RD321 for removable safety bars (When reqd.).
9. See Std. Drg. RD317 for culvert embankment protection and riprap pads (When reqd.).

PAVED END SLOPE AREA TABLE

Nominal Pipe Diameter (Inches)	PAVED END SLOPE AREA SQUARE FEET					
	1:3 SLOPE		1:4 SLOPE		1:6 SLOPE	
	Circular Pipe	Arch Pipe	Circular Pipe	Arch Pipe	Circular Pipe	Arch Pipe
12	23	--	26	--	32	--
15	26	23	32	27	41	34
18	30	26	35	30	44	38
21	33	30	39	35	51	45
24	37	33	44	39	57	51
30	47	39	55	46	72	61
36	56	53	67	63	88	83
42	76	67	90	80	119	107
48	98	90	117	108	155	144
54	124	114	148	137	196	184
60	164	137	197	165	264	221

(1) Areas for multiple installations are as shown on the plans.

CALC. BOOK NO. RD07-02

BASELINE REPORT DATE 15-JAN-2016

NOTE: All material and workmanship shall be in accordance with the current Oregon Standard Specifications

The selection and use of this Standard Drawing, while designed in accordance with generally accepted engineering principles and practices, is the sole responsibility of the user and should not be used without consulting a Registered Professional Engineer.

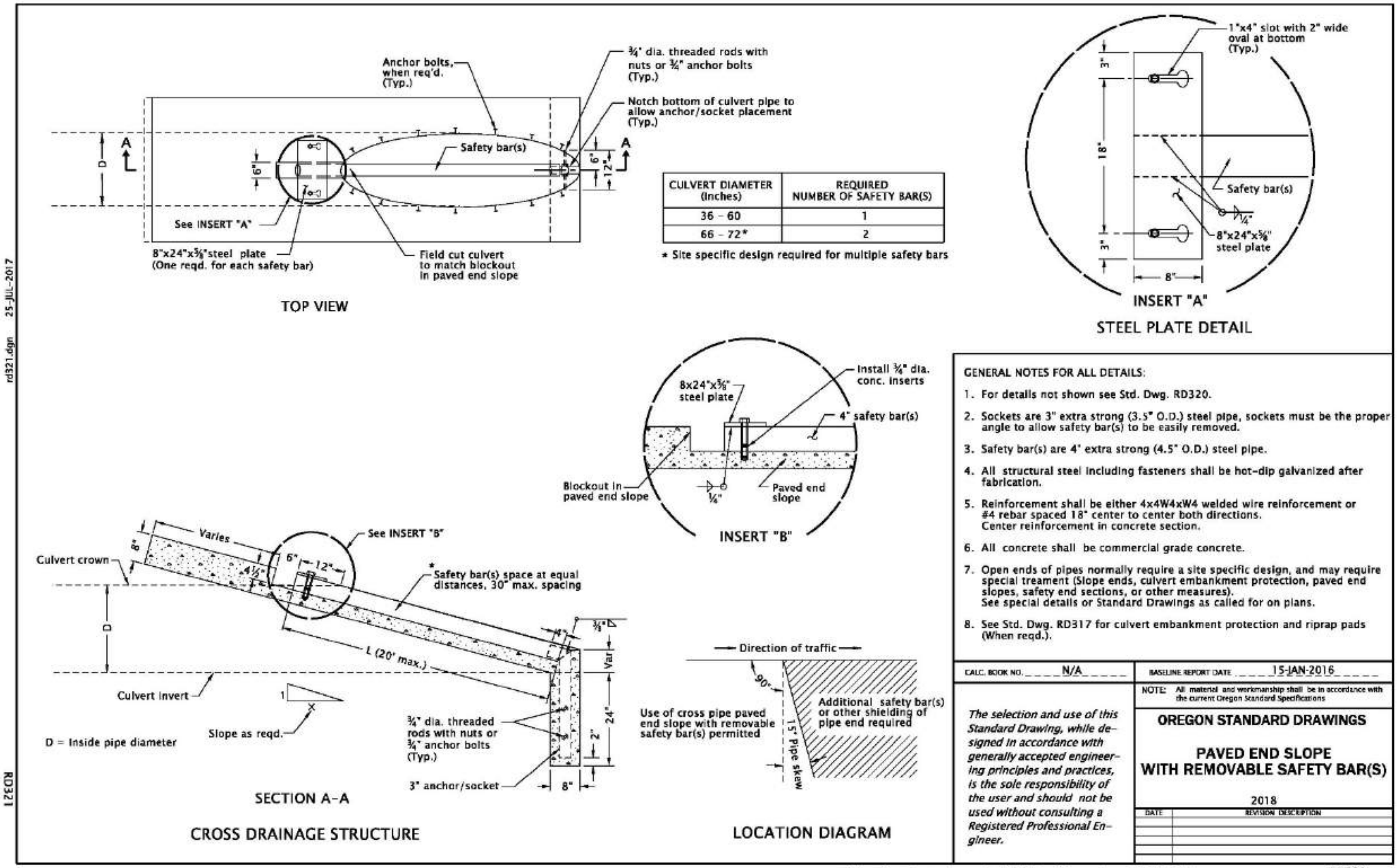
OREGON STANDARD DRAWINGS

PAVED END SLOPE FOR CULVERTS 60" MAXIMUM PIPE SIZE

2015

DATE	REVISION DESCRIPTION
01-2016	REVISED DETAILS & NOTES

Effective Date: June 1, 2016 - November 30, 2016 RD320



Effective Date: June 1, 2018 - November 30, 2018 RD321