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Cross Drain Update



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INTRODUCTION

Cross drain techniques such as open-top cross drains and surface water diverters using conventional materials have been in use for years. New cross drain techniques are emerging due to the availability of new materials and field innovations. The objective of this report is to disseminate information on new materials and techniques. Many of the techniques or materials may not be necessarily new, however, the application of the materials or techniques is innovative. Some of the materials presented in this report are subject to local availability. Some of the techniques presented in this report are being developed and have not been applied in the field.

REPORT OVERVIEW

A synopsis of the information contained in the report is provided in Table 1. Further discussion is included in the following pages. When available, cost information is provided. This information should only be used as a reference. Prices and rates vary from location to location. Definitions of terms used in this document are included in appendix A; a cost summary for open-top pipe culverts is included in Appendix B.

BACKGROUND

Two methods were used to gather information for this report: a market search, including publications in print and on the Internet; and a survey to Forest Service personnel. Since the method or technique for using cross drains are specific to local geography and conditions, information about the local conditions were included. Both search methods yielded techniques. Some of the techniques presented in this report are not new, however, the techniques were included to disseminate the information and perhaps stimulate new applications of these methods.

OPEN-TOP PIPE CULVERT

Information for this section was taken from *Using Open-Top Pipe Culverts to Control Surface Water on Steep Road Grades* by James N. Kochenderfer, Northeastern Forest Experiment Station, General Technical Report NE-194, with the author's permission. These open-top pipe culverts have been installed and used successfully on "minimum standard" forest truck roads around the Fernow Experimental Forest near Parsons, West Virginia.

Open-top pipe culverts are effective in controlling surface water on portions of minimum-standard roads where road grades exceed 10 percent. The open-top pipe culvert is not recommended as the

Table 1—Summary of cross drain techniques.

Techniques	Description	Material	Page
Open-top pipe culvert	Steel pipe with sections removed to collect and channel surface damage	Heavy walled (5/16 inch/ 8mm) steel pipe	1
Portable road spillway	Steel grid on top of concrete abutment	Steel concrete	4
Metal water bar	Using a "W" beam guardrail as a water bar	Standard "W" beam guardrail	6
Rubber water diverter	Flexible surface drainage structure	Conveyor belt or rubber skirting	7
Pre-cast concrete trough	Open top drain using concrete	Pre-cast concrete	8
Alternative materials	Alternative materials to CMP	Polyethylene, used steel pipe	8
Driveable and durable "hump"	Series of water diverters of varying heights	Rubber, plastic, concrete, wood, etc.	10

primary means of water control but as a supplemental device that can be used on steep road sections where broad base dips are not recommended. Open-top pipe culverts offer land managers an alternative to crowning and ditching roadbeds for water control. Unlike culverts constructed from wood, the open-top pipe culvert is a relatively permanent water control device; however, these culverts may be relocated and used on other roads as the need arises. The cost of an open-top pipe culvert is comparable to that of a gravel broad-based dip.

Material

- Steel pipe: 8-inch (200 mm) or 10-inch (250 mm) diameter heavy walled, 5/16 inch (8 mm) wall thickness.

Construction

Using a chalk line, mark two parallel lines three inches (75 mm) apart along the length of the steel pipe. The lines create longitudinal borders for the inlet slots. Mark slot locations within the two parallel lines. A welding marker works well for marking the slots. Twenty-four-inch long by 3-inch-wide slots (600 mm by 75 mm) work well with an 8-inch (200 mm) diameter pipe, see figure 1. Larger slots may be used in larger diameter pipes. Experience has shown that slots this size do not damage tires and are wide enough to allow the pipe to be cleaned. A spacing of at least 6 inches (150 mm) between slots will prevent the pipe from collapsing under a heavy wheel load. At least 18 inches (450 mm) of solid pipe must be left at both ends. The solid ends provide structural rigidity.

Installation

The open-top pipe culverts have been installed with a downslope skew ranging from 45 to 65 degrees with an average of 54 degrees skew and average road grade of 12 percent. It is important to minimize skew to improve its self-cleaning capability. Skew in this document is measured from the road centerline, see figure 2.

Installation of the culvert maybe done manually or with the use of a small dozer. The culvert is installed with the top of the pipe 3 inches (75 mm) below the surface. The roadbed is then beveled back about 18 inches (450 mm) on each side of the culvert. The skew and depth is better controlled when installed manually. However, a 10-inch (250 mm) diameter pipe weighs about 31 pounds per foot (46 kg/m) and an 8-inch (200 mm) diameter pipe weighs about 25 pounds per foot (37 kg/m); therefore a typical culvert section would weigh between 500 and 600 pounds (227 kg and 272 kg). Two people can move and position the culvert by sliding or rolling. Lifting the culvert requires a small dozer. Once installed, the outfall may be armored with rocks and a half-round plastic pipe.



Figure 1—Using a cutting torch to cut slots in a heavy walled pipe.

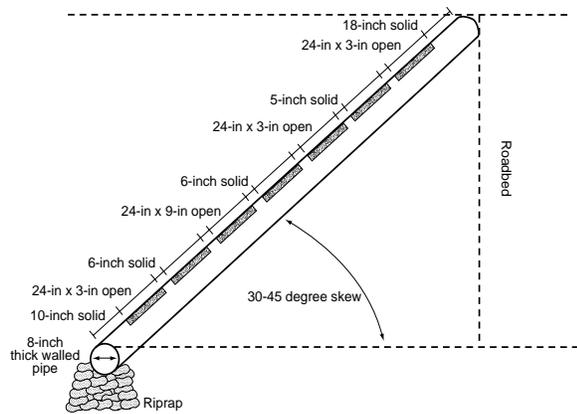


Figure 2—Layout and dimensions of an open-top pipe culvert.

Discussion

These open-top pipe culverts are being used in central Appalachia. The average culvert length is 20 feet (6 m). The 20-foot (6 m) length allows for enough skew on a 15-foot (4.6 m) wide road. Both 8-inch (200 mm) and 10-inch (250 mm) diameter pipe were used. The 8-inch (200 mm) was

preferred because it is generally less expensive, requires a shallower trench, and is easier to maneuver by hand than the larger pipe.

While these culverts will function well on steeper grades, it is still desirable to keep road grades low to facilitate water control and provide an acceptable degree of utility. These culverts also can be used where rocky subgrades might prohibit construction of broad-based dips and on road sections between landings and highways to prevent water from running on to highways.

A tool for cleaning open-top pipe culverts is shown in figure 3.

It is important to use proper spacing so that water can be handled in small amounts. For design, use local cross drain spacing formulas for open-top-drains.



Figure 3—A tool for cleaning open-top pipe culverts is made by bending a 5-foot (1.5 m) piece of 3/4-inch (19 mm) pipe two ways and welding to it a 4- by 5-inch (100 by 127 mm) shaped piece of metal cut from a pipe.

PORTABLE ROAD SPILLWAY

The Portable Road Spillway is a prefabricated cross drain that is portable and re-usable. It works on the principle of diverting silt and debris encountered in typical surface runoff into a series of pre-established settling ponds. Two photographs of Portable Road Spillways are shown in figures 4a and 4b; an illustration of a typical application is shown in figure 5. The settling ponds are constructed on the low side of the road

top of precast L-shaped abutments. It is constructed in three separate sections: two concrete abutments, and one steel top grid. The concrete abutments are made of 3000 psi (20 MPa) redi-mix concrete reinforced by #5 grade 40 rebar. When fully assembled, each abutment weighs 10,000 pounds (4536 kg). The 2500 pound (1134 kg) steel top grid is constructed of structural grade steel. See figure 6.



Figure 4a and 4b—Two views of the Portable Road Spillway.

spillway and are made out of native material found at the site. The settling ponds slow the movement of water from the natural drainage system along with water collected from roadway runoff. Sediment and debris are settled out within the settling ponds before water is discharged to the local water course. Heavy equipment traffic typically associated with logging and mining roads is easily handled by the Portable Road Spillway.

Material

- Structural steel tubing, either 20 foot (6 m) or 24 foot (7.2 m)
- #5 Grade 40 rebar
- Type 10 Portland Cement redi-mix precast

Construction

The Portable Road Spillway is distributed by RayMac Environmental Services. The spillway consists of a structural steel tubing grid setting on

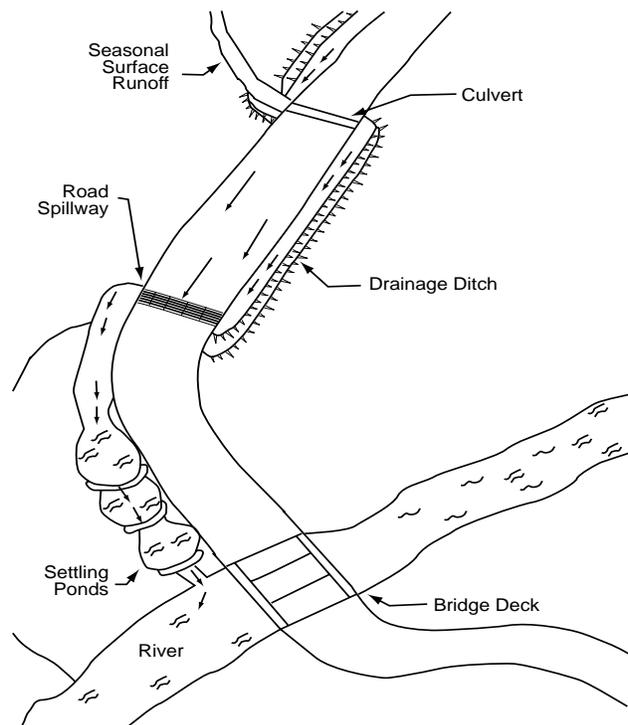


Figure 5—Typical application of the Portable Road Spillway.

Installation

The entire Portable Road Spillway can be transported to the site in a standard dump truck. An excavator is used to dig a trench across the road to accommodate the spillway and place the abutments. Once the proper separation of abutments has been established, the excavator places the steel grid on top of the abutments and backfills the trench. See figure 7.

Maintenance

The steel grid may be removed to clear the trench of obstruction and sludge. Depending on the amount of debris or sediment, a small excavator may be necessary to clean out the trench.

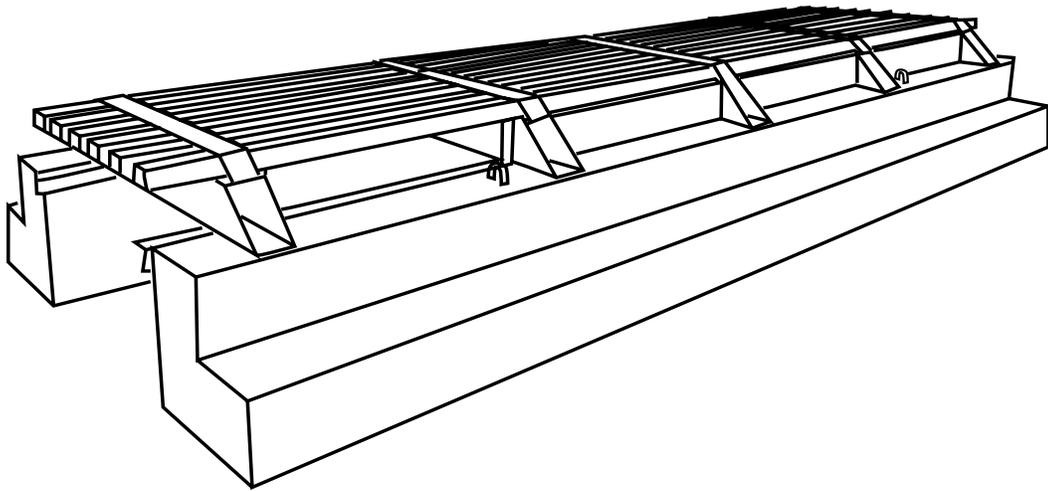


Figure 6—Portable Road Spillway assembly.

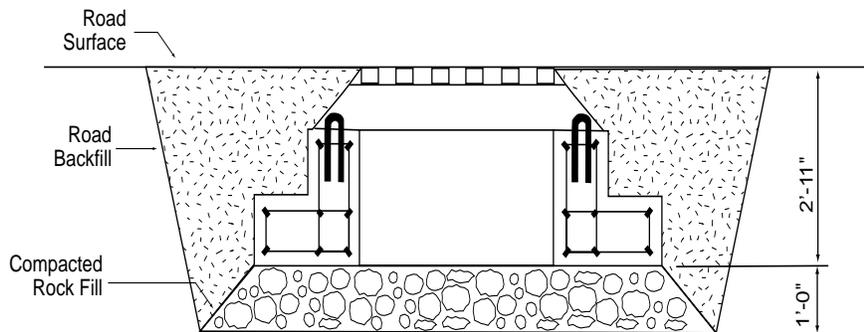


Figure 7—Sectional view of the Portable Road Spillway.

METAL WATER BAR

The metal water bar is an innovative example of using a standard “W” beam guardrail. It combines two common cross drain techniques, the water bar and an open top drain.

Material

- Standard “W” beam guardrail, nominal thickness of 0.135 inches (3.4 mm)
- Mild steel flat bar 1/4-inch (6.4 mm) thick by 4 inches (100 mm) wide.

Construction

Construct anchors as shown in figure 8 using the 1/4-inch (6.4 mm) steel bars. Weld the completed anchors to the “W” beam guardrail evenly spaced as shown in figure 8. Guardrail length comes standard in 12.5 foot (3.8 m) or 25 foot (7.5 m) length. Cut-off excess length to achieve appropriate length, remembering the additional needed for the skew angle. The smaller the skew angle the longer the length has to be over the length of the road. The length will be determined by the following formula:

$$\text{Length} = \text{road width} / \text{sine}(\text{skew angle}) + \text{installation tolerance}$$

When using 12.5 foot (3.8 m) lengths, the two pieces should be butt-welded or overlapped with the downgrade section underneath the upgrade section. All holes on the guardrail must be permanently plugged. All non-galvanized, non-treated areas must be painted with primer.

Installation

Install the metal water bar with a maximum 60 degree downslope skew. The installation can either be done manually or with the help of a dozer for the heavy lifting. Measure the maximum height of the metal bar assembly once constructed. This will determine the depth of the trench to be dug. The depth of the trench should be about 3-inches (75 mm) deeper than the maximum height of the assembly. A trench wider than the width of the water bar assembly is necessary to not only more accurately position the water bar but also to allow for a margin of error. The water bar is installed with the top of the ‘W’ beam about 3-inches (75 mm) below the road surface. Once installed, the road could be beveled back about 18 inches (450 mm).

A rock outfall may be constructed at the end of the water bar using 3-inch to 12-inch (75 mm to 300 mm) diameter rocks. The outfall should be approximately 2-foot (0.6 m) wide and at least 6-inches (150 mm) deep.

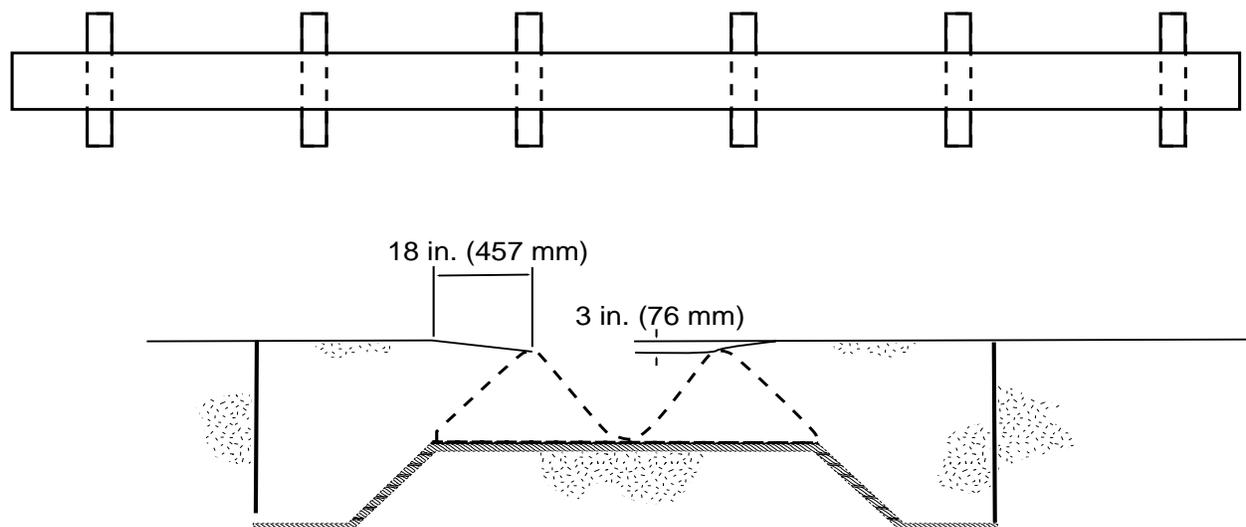


Figure 8—Metal water bar construction details.

RUBBER WATER DIVERTERS

Rubber skirting or used conveyor belts are used to make water diverters. The water diverters direct water off the surface of the road. Like the other cross drains the skew angle is critical to the function of the water diverter. Rubber diverters require minimal maintenance, however the diverters may be damaged by grading operations. Using an object marker to identify location reduces the likelihood of damage from a motor grader.

Material

- Rubber skirting: 5 ply, 1/2-inch thick by 12-inches wide by 20-foot long (13 mm by 300 mm by 6 m).
- Timber: 4-inch by 8-inch by 20-foot (100 mm by 200 mm by 6 m) rough sawn No. 2 or better, pressure treated for a design life of 20 years.
- Lag screws: 11, 3/8-inch by 2 inches (9.5 mm by 0.6 m) with 3/8-inch (9.5 mm) washers.
- Object marker: 1, type 2A, 6-foot (1.8 m) long.

Construction

Secure the rubber skirting on the 4-inch (100 mm) face of the pressure treated timber using the lag screws and washers. Figure 9 illustrates the construction of the diverter.

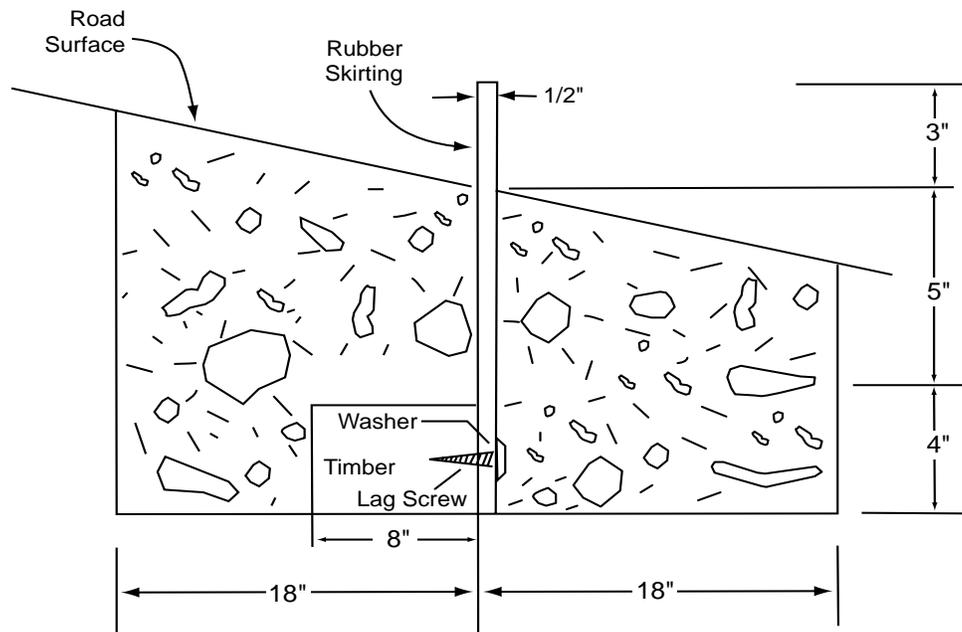


Figure 9—Rubber water diverter detail.

An alternate method of construction uses conveyor belt.

Material

- Conveyor belt: 7/6-inch by 12-inch wide by 20-foot long (11 mm by 300 mm by 6 m).
- Timber: 2-foot by 6-foot by 20-foot (0.6 m by 1.8 m by 6 m) rough sawn No. 2 or better, pressure treated for a design life of 20 years.

Construction

The bottom of the conveyor belt is “sandwiched” between the boards.

Installation

Install the rubber diverter with a maximum 60 degree downslope skew. A trench is dug approximately 36 inches (900 mm) wide. The diverter is installed so that approximately 3 to 4 inches (75 mm to 100 mm) is above the road surface. The density of the backfill must equal or exceed the density of the surrounding material. The backfill material must be either the same as the road, or crushed aggregate. Figure 10 provides installation details.

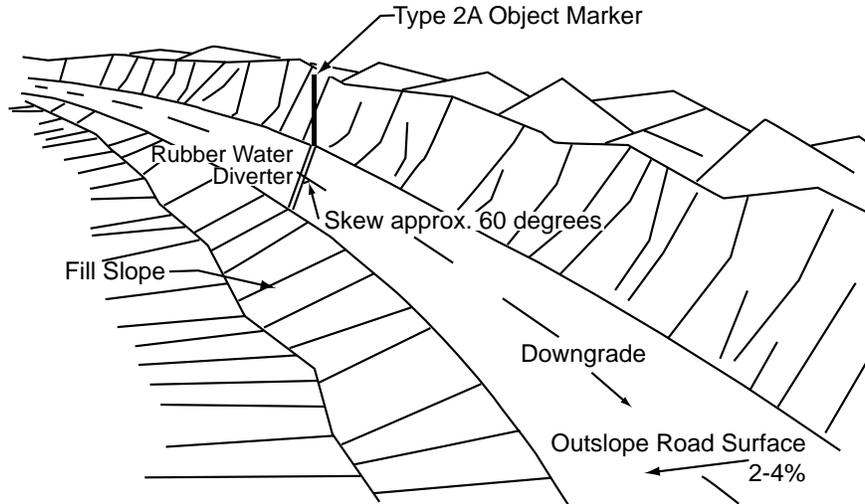


Figure 10—Installation detail of rubber water diverter.

PRE-CAST CONCRETE TROUGH

This cross drain device could be classified under open-top drains. Similar to the devices in the open-top category, this concrete trough allows surface water to accumulate through the open top. See figure 11.

Material

- Concrete: 10 cubic feet (0.3 cubic meters) for a 7-inch by 14-inch by 14-foot (176 mm by 350 mm by 4 m) trough.
- #4 Grade 40 rebar

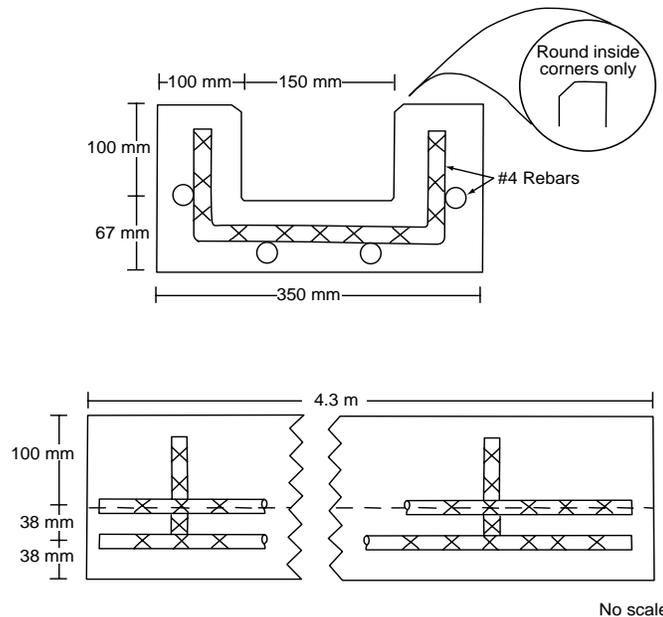
Installation

The soil around both sides of the cross drain must be compacted. The concrete trough must be installed with a maximum 60 degree skew and at least a 4 percent fall.

ALTERNATIVE CULVERT MATERIALS TO CORRUGATED METAL PIPE

Polyethylene Pipe

Polyethylene pipe has approximately twice the service life of corrugated metal pipe and is lighter and easier to install. The anticipated service life of



No scale

Figure 11—Construction and installation details of pre-cast concrete trough.

high density polyethylene (HDPE) is approximately 75 years. Corrugated steel has an anticipated service life of 40 years. HDPE is strong enough to endure soil pressures at depth up to 100 feet, and is tough enough to handle abrasive runoff.

Two polyethylene products were evaluated for this project: Advance Drainage Systems (ADS) N-12 and ADS N-12 HC. ADS N-12 is a HDPE drainage pipe available in diameters ranging from 4 inches to 36 inches (100 mm to 900 mm). The pipe is a combination of an angular corrugated exterior for strength and smooth inner wall for maximum flow capacity. ADS N-12 HC comes in 10-inch (250 mm), 12-inch (300 mm), 15-inch (380 mm), 18-inch (380 mm), 24-inch (600 mm), 30-inch (760 mm), 36-inch (900 mm), 42-inch (1 m) and 48-inch (1.2 m) diameters. The N-12 HC has

smooth inner and outer walls and a “honeycomb” wall section for structural strength and ring stiffness. The HDPE pipe withstands vertical pressure by transferring the load to the surrounding soil. N-12 and N-12 HC will support HS-20 live loads under 12 inches (300 mm) of cover. This is equivalent to values specified for corrugated metal and concrete pipe. HS-20 loading designation is specified by American Association of State Highway and Transportation Officials. The HS-20 live loading is comparable to a 3-axle truck with an 8,000 pound (3630 kg) load on the front axle and 32,000 pound (14,500 kg) load on the two rear axles. Maximum cover will vary with conditions, but can usually extend from 30 feet to 50 feet (9 m to 15 m). Table 2 provides a weight comparison of HDPE, clay or concrete, and corrugated metal pipe. Figure 12 graphically represents corrosion resistance (recommended pH range).

Table 2—Weight comparison of three pipe types by inside diameter.

Inside Diameter inches (mm)	ADS N-12 / N-12 HC HDPE Pipe lb/ft (kg/m)	Clay or Concrete lb/ft (kg/m)	Corrugated Metal lb/ft (kg/m)
15 (380)	4.6 (7)	103 (153)	12.9 (19)
18 (450)	8.4 (12.5)	131 (195)	15.8 (23.5)
24 (600)	11.5 (17)	217 (323)	19.4 (29)
30 (760)	15.4 (23)	384 (571.5)	30.0 (45)
36 (900)	18.1 (27)	524 (780)	36.0 (54)
42 (1000)	26.5 (38)	650 (967)	57.0 (85)
48 (1200)	32.0 (48)	780 (1161)	65.0 (97)

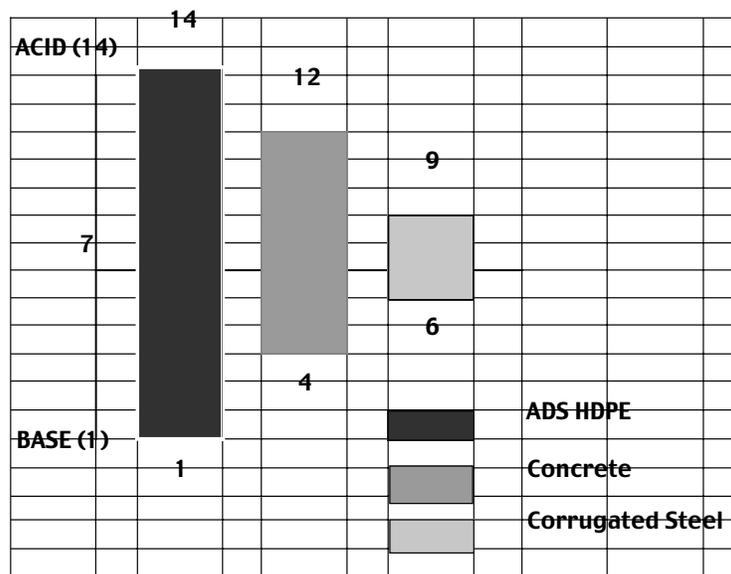


Figure 12—Corrosion resistance (recommended pH range).

Used Gas Pipe

Used gas pipe has been utilized in the Allegheny National Forest of Region 9 where the pipe is available locally. The wall on the steel pipe is four times greater than that of conventional corrugated metal pipe (CMP). Thicker walls allow the pipe to be installed in areas where the minimum coverage of 12 inches (300 mm) for CMP or HDPE pipe is difficult to achieve. Although the procurement and installation costs are higher than for new CMP the anticipated service life is longer.

Driveable and Durable “Hump”

This cross drain technique is a concept. It is included in this report to generate interest and possible implementation. Like the rubber water diverter, the hump diverts surface flow off the road while requiring minimal modification to the road

profile. Several stages would allow for sedimentation while still preserving diversion capability and extending periods between required maintenance. Hump length and height should be tailored to road grade, climate, expected flows, soil type, and design vehicle. Possible materials for experimentation include rubber, rubber strapping, plastic, concrete and wood. Figure 13 provides an illustration of the concept.

CONCLUSION

The application of cross drain techniques will have varying results due to local geographical conditions. The techniques are presented to provide information on products which have been successful in other areas and also to stimulate innovative applications.

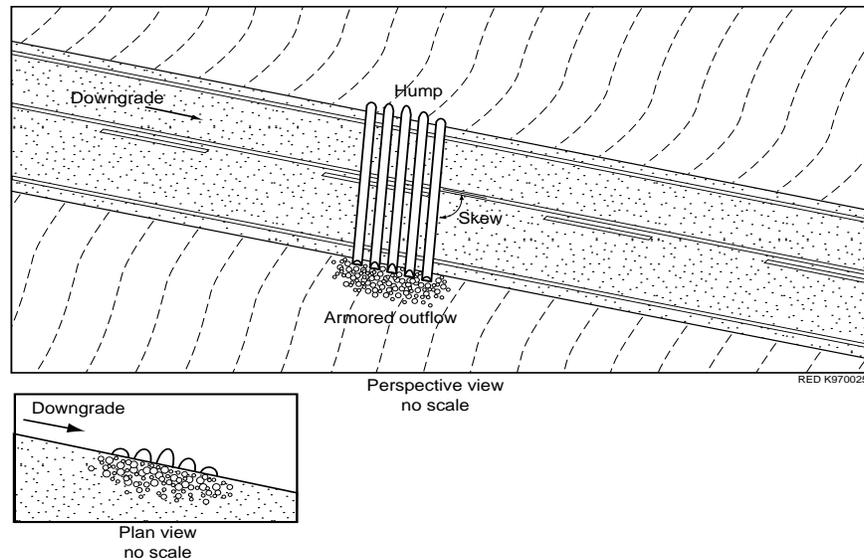


Figure 13—A driveable and durable “hump”.

APPENDICES

Appendix A

Definitions

Armoring - protective covering, such as rock, vegetation, or engineered materials used to protect stream banks, fill or cut slopes, or drainage structure outflows from flowing water energy and erosion.

Cross Drain - a ditch relief culvert or other structure or shaping of the traveled way designed to capture and remove surface water from the traveled way or other road surfaces.

Crown - traveled way surface shaping with the high point in the middle causing surface runoff to flow both towards the uphill shoulder or ditch and the downhill shoulder.

Culvert - a conduit or passageway under a road or other obstruction for the passage of water, debris, sediment, and fish, backfilled with embankment material.

Manning's Roughness Coefficient - dimensionless number indicating surface roughness. A lower number indicates a smoother surface.

Outfall - the outlet end of a culvert.

Outslope - traveled way surface shaping with the high point on the uphill shoulder causing surface runoff to flow towards and over the downhill shoulder.

Pipe - a culvert that is circular in cross section.

Road - a general term denoting a way for purpose of travel by vehicles greater than 50 inches (1.3 m) in width.

Roadbed - the graded portion of a road between the intersection of subgrade and side slopes excluding that portion of the ditch below subgrade.

Sediment - deposition of materials eroded and transported from locations higher in the watershed.

Service Life - the length of time a facility is expected to provide a specified service.

Skew - the angle of deviation from a reference line. In this document, the reference line is the road centerline.

Subgrade - the layers of roadbed that bring up to the top surface, upon which subbase, base, or surface course is constructed. For roads without base course or surface course, that portion of roadbed prepared as the finished wearing surface.

Surface Drainage - the concentration and flow of surface water on roads and related surfaces and in ditches.

Appendix B

Cost Summary for the Open-Top Pipe Culvert

Item	Unit Cost (\$)	Quantity	Total Cost (\$)
Culvert Preparation			
Pipe	5.00/ft	20.0 ft	100.00
Labor	10.00/hr	1.0 hr	10.00
Gas	0.20/ft ³	55.0 ft ³	<u>11.00</u>
		Sub-total	121.00
Installation (manual)			
Labor	8.00/hr	1.0 hr	64.00
Gravel	12.00/ton	1.0 hr	3.00
Crew vehicle	0.50/mile	10.0 mile	<u>5.00</u>
		Sub-total	72.00
Installation (bulldozer)			
Dozer and operator	30.00/hr	1.0 hr	30.00
Labor	8.00/hr	1.0 hr	8.00
Gravel	12.00/ton	0.25 ton	3.00
Crew vehicle	0.50/mile	10.0 mile	<u>5.00</u>
		Sub-total	46.00
Culvert outlet protection			
Riprap			
Labor	8.00/hr	3.0 hr	24.00
Crew vehicle	0.50/mile	6.0 mile	<u>3.00</u>
		Sub-total	27.00
Half-round plastic			
	2.50/ft	10.0 ft	25.00
Labor	8.00/ft	1.0 hr	8.00
Crew vehicle	0.50/mile	6.0 mile	<u>3.00</u>
		Sub-total	36.00
		Total	302.00

