United States
Department of
Agriculture

Forest Service

**Northeastern Forest
Experiment Station**

General Technical
Report NE-194

Using Open-Top Pipe Culverts to Control Surface Water on Steep Road Grades

James N. Kochenderfer

Abstract

An open-top culvert constructed from used pipe can effectively control surface water on steep sections of "minimum-standard" roads where broad-based dips are not recommended. Open-top pipe culverts are resistant to damage and are relatively permanent. The cost of an open-top culvert is comparable to that of a graveled broad-based dip.

The Author

JAMES N. KOCHENDERFER is a research forester with the Northeastern Forest Experiment Station's Timber and Watershed Laboratory at Parsons, West Virginia.

Manuscript received for publication 6 June 1994

USDA FOREST SERVICE
5 RADNOR CORP CTR STE 200
PO BOX 6775
RADNOR PA 19087-8775

March 1995

Introduction

Land managers have long recognized that water must be controlled on forest access roads to maintain their usefulness and prevent undesirable impacts on other resources. On higher standard roads, surface water is controlled by maintaining a crowned road surface which diverts water from road surfaces into ditches or from the lower edges of roads. On lower standard roads, surface water traditionally has been controlled with open-top culverts constructed from wood (Haussman 1960) or by broad-based dips (USDA For. Serv. 1940; Hewlett and Douglass 1968). Wooden open-top culverts performed well when kept repaired and cleaned but were easily damaged by logging equipment, and they required frequent cleaning on most woods roads to remain effective. Broad-based dips are used widely but generally are not recommended for road grades steeper than 10 percent (Kochenderfer 1977). Constructing dips on steep road grades often results in dips that are difficult for loaded trucks to traverse. Also, broad-based dips are difficult to construct where road grades exceed 10 percent.

As a result, there is a need for an effective way to control water on unditched lower standard roads with steep grades. In the Appalachian Mountains, where there are many obstacles to road construction that need to be avoided, it often is difficult to access timber resources and maintain roads on gentle grades. This paper describes a culvert that can be used on steep road sections to intercept and carry surface water from roadways.

Methods

For the past 2 years we have been constructing open-top culverts from used heavy wall (5/16-inch-thick) steel pipe. Several of these culverts were installed on steep sections of "minimum-standard" forest truck roads (Kochenderfer et al. 1984) around the Fernow Experimental Forest near Parsons, West Virginia. Culvert dimensions are shown in Figure 1.

The open-top pipe culverts were constructed in the following manner. The pipe was first marked with a chalk line to make two parallel lines 3 inches apart. Then slots 3 inches wide and 24 inches long were marked on the pipe with a welding marker. Sections 6 inches long were left between each slot for reinforcement so that the slots would not be squeezed together by heavy truck traffic. The slots were cut out with a cutting torch (Fig. 2). These culverts effectively intercepted surface water and carried it from road surfaces during the largest storms encountered during the 2-year period. We found that slots of this size do not damage tires and are wide enough to allow culverts to be cleaned. We made a simple tool to clean open-top culverts that works much better than a mattock (Fig. 3).

Culverts were installed both manually (Fig. 4) and with a small bulldozer (Fig. 5). Each culvert was installed so that the culvert top was about 3 inches below the surface of the roadbed. The roadbed was then beveled back about 18 inches on each side of the culvert. The culverts were about 20 feet long and skewed downslope as far as possible. It was

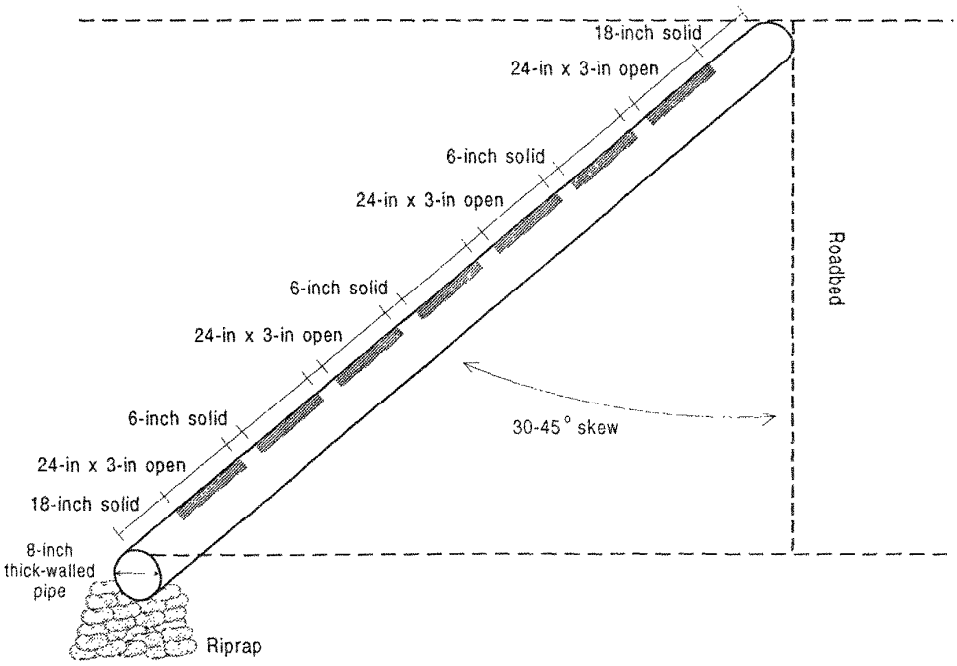

Figure 1.--Layout and dimensions of an open-top pipe culvert.

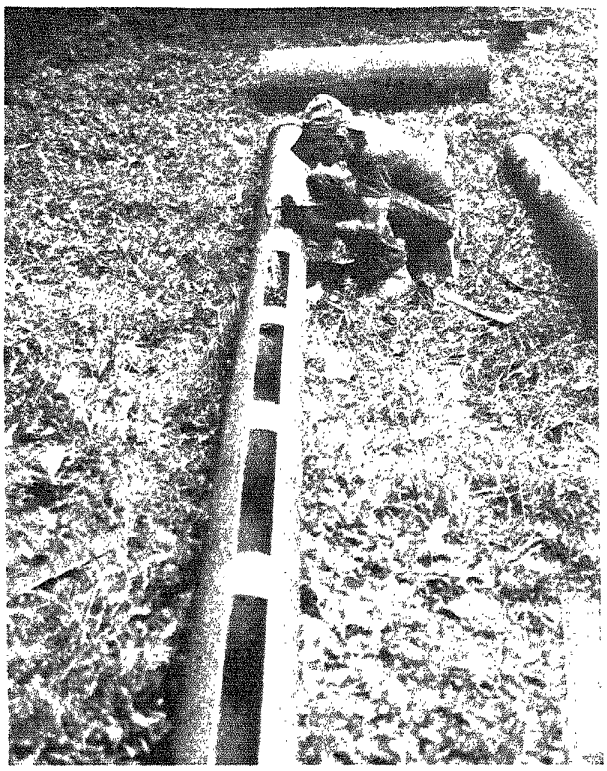

Figure 2.–Using a cutting torch to cut slots in a heavy walled pipe.

easier to achieve the proper depth and maximize skew with manual installation. Two persons can maneuver a culvert into position but cannot lift it. The 10-inch-diameter pipe that was used weighed about 31 pounds per foot and the 8-inch-diameter pipe weighed about 25 pounds per foot. Thus, each 20-foot culvert weighed 500 to 600 pounds. In some cases where the bulldozer was used for installation, culverts were not skewed sufficiently, resulting in some of them protruding past the edges of roadbeds. Using the small dozer usually resulted in a trench wider and deeper than necessary. In both types of installations, culverts were placed on a level bed prepared using 1/2-inch gravel. Gravel and fill dirt was tamped by hand along each side of the culverts.

Results and Discussion

Characteristics of 15 open-top pipe culverts installed on "minimum-standard" roads are summarized in Table 1. The average culvert length of 20 feet provided enough skew where roadbeds averaged 15 feet in width. Both 8- and 10-inch pipe were used. The 8-inch size was preferred because it usually is cheaper, requires a shallower trench, and is easier to maneuver by hand than larger pipe. Downslope skew ranged from 25 to 45 degrees and averaged about 36 degrees on the installed culverts. It is important to maximize skew as much as is practical so that culverts are largely self-cleaning. Because these pipe culverts are smoother and do not require cross bracing, they are not as susceptible to plugging as the old wooden open-top culverts. Grade averaged about 8 percent on these culverts, which were

Figure 3.–A tool for cleaning open-top culverts is made by bending a 5-foot piece of 3/4-inch pipe two ways and welding to it a 4- by 5-inch shaped piece of metal cut from a pipe.

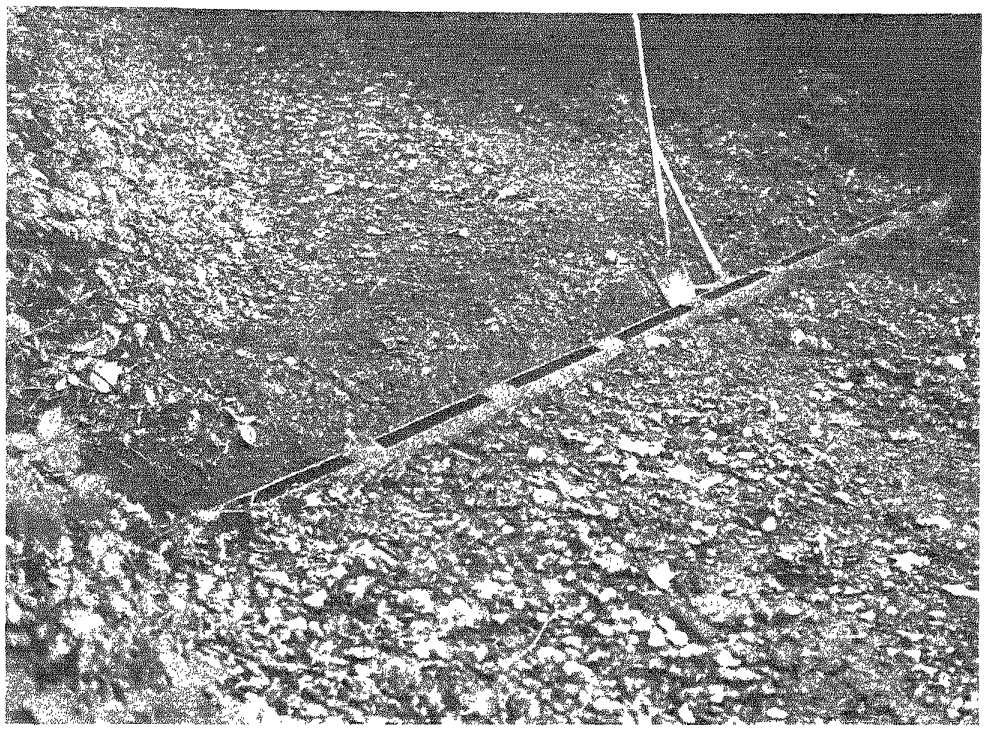

Figure 4.--Installing open-top pipe culverts manually minimized disturbance to roadbeds. It also was easier to install culverts to the proper depth and skew by hand.

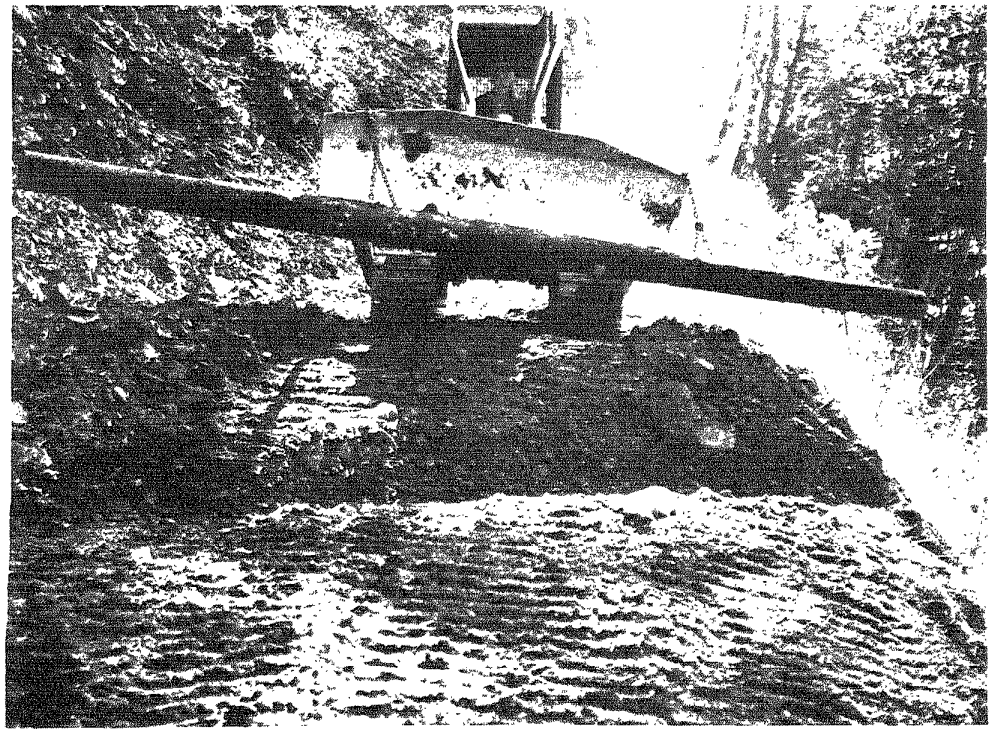

Figure 5.--Installing open-top culverts with a small bulldozer was less costly but resulted in more disturbance to roadbeds.

Table 1.–Characteristics of 15 open-top pipe culverts installed on "minimum-standard" roads in the central Appalachians

Culvert no.	Pipe diameter	Pipe length	Downslope skew	Culvert grade	Roadbed width	Road grade
	Inches	*Feet*	*Degrees*	*Percent*	*Feet*	*Percent*
1	10	18	25	6.0	15.0	10.0
2	10	18	34	7.0	15.5	10.0
3	10	17	30	7.0	15.5	12.0
4	8	20	45	8.0	13.0	11.0
5	8	20	40	12.0	13.0	19.0
6	8	21.5	44	14.0	13.0	18.0
7	8	22	40	12.0	15.0	19.0
8	10	19	32	8.0	15.0	11.0
9	10	22	41	7.0	16.0	9.0
10	8	22	32	5.0	17.0	11.0
11	8	20	36	9.0	14.0	11.0
12	8	19	37	7.0	14.0	11.0
13	8	19	32	5.0	14.0	11.0
14	8	19	35	6.0	14.0	11.0
15	8	20	31	8.0	17.0	8.0
Total		296.5	534	121.0	221.0	182.0
Mean		19.8	35.6	8.1	14.7	12.1

Figure 6.--An open-top culvert installed on a "minimum-standard" road in the central Appalachians.

installed on road sections where road grade ranged from 8 to 19 percent and averaged about 12 percent. A properly installed open-top pipe culvert is shown in Figure 6.

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. Open-top culverts are not the preferred water-control device on gentle roads, but are a useful alternative on unavoidable steep road sections where broad-based dips are not recommended. These culverts also can be used where excessive rock might prohibit construction of broad-based dips and on short road sections between landings and highways to prevent water from running onto highways. Where it is desirable to close roads to vehicle traffic, the culverts can be removed and used on other roads.

Open-top pipe culverts are similar to broad-based dips in that water cannot run past them so long as they are maintained properly. When a combination of ditches and buried culverts are used to control surface water, roadbeds must be crowned properly. Otherwise, surface water will bypass culverts, often running down roadways for extended distances and damaging roadbeds.

It is important to use proper spacing so that water can be handled in small amounts. The spacing formula recommended by Hewlett and Douglass (1968) for broad-based dips also can be used for open-top pipe culverts:

$$\text{Spacing} = 400/\text{slope \%} + 100 \text{ feet}$$

For example, on a 10 percent grade, culverts should be placed 140 feet apart.

One problem encountered with this type of culvert is that water is discharged at the top of road fills, making it necessary to protect fills against erosion. Two relatively low-cost methods were used to accomplish this. On some steep fills, a 10-foot section of 15-inch-diameter plastic culvert that had been cut in half was attached to culvert outlets; the lower end was weighted down with a large rock (Fig. 7). This method worked well, but its appearance did not blend well with the natural surroundings. We also used native stone riprap below most culvert outlets to prevent fill erosion (Fig. 8). However, on steep fills, it was difficult to get the rock to lay properly so that enough rock could be placed below culvert outlets to protect road fills. It often was necessary to dig benches on steep fills for the rock to lay on.

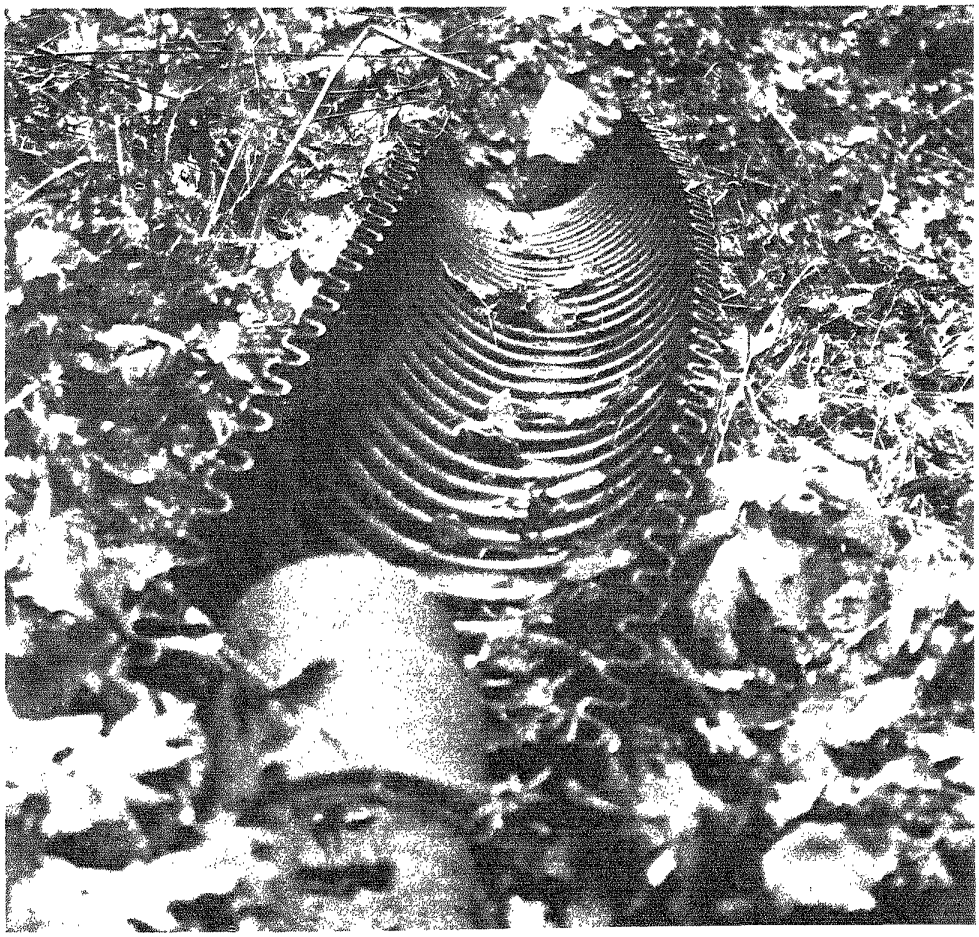

Figure 7.--A half-round plastic culvert attached to the end of an open-top pipe culvert to prevent fill erosion.

Figure 8.--Native stone riprap was used below the outlet of an open-top pipe culvert to prevent erosion.

These culverts would not be effective on deeply rutted roads or where truck tires are carrying excessive mud. The culverts evaluated here were installed on roads that had been graveled to some extent or had a high rock content that made them relatively immune to rutting.

While these culverts are highly resistant to damage, edges of the culvert slots can be dented by cleats from bulldozers. While we did not encounter a problem with this, it would be wise to lay boards or poles over the slots if several trips will be made over culverts with bulldozers. Road grader operators need to be aware of culvert locations so that they can lift grader blades when passing over open-top culverts. It probably will be necessary to clean the culverts after roads are graded.

A cost summary is presented in Table 2. The used pipe was purchased from a salvage yard for a delivered price of $5 per foot. It required about an hour to mark and cut out each culvert. Gas costs were based on the oxygen and acetylene gas used to cut out 15 culverts. Costs were lower when culverts were installed with a small dozer, but it was easier to install them properly by hand. The roads where culverts were installed manually were rocky, making installation difficult. A small backhoe might be a better choice for installing these types of culverts. About one-quarter ton of gravel was used on each culvert. Applying additional gravel for several feet on each side of culverts is recommended on most roads. The total cost, including native stone riprap, was $220 for manual installation compared to $194 when a small bulldozer was used (Table 2).

Table 2.--Cost summary (cost/culvert) for 15 open-top pipe culverts installed on "minimum-standard" roads in the central Appalachians

Item	Unit cost	Units	Total cost
	Dollars	*Number*	*Dollars*
Culvert preparation			
Pipe	5.00/ft	20.0	100.00
Labor	10.00/hr	1.0	10.00
Gas	0.20/ft3	55.0	11.00
		Total	121.00
Installation (manual)			
Labor	8.00/hr	8.0	64.00
Gravel	12.00/ton	.025	3.00
Crew vehicle	0.50/mile	10.00	5.00
		Total	72.00
Installation (bulldozer)			
Dozer and operator	30.00/hr	1.00	30.00
Labor	8.00/hr	1.0	8.00
Gravel	12.00/ton	0.25	3.00
Crew vehicle	0.50/mile	10.0	5.00
		Total	46.00
Culvert outlet protection			
Riprap			
Labor	8.00/hr	3.0	24.00
Crew vehicle	0.50/mile	6.0	3.00
		Total	27.00
Half-round plastic	2.50/ft	10.0	25.00
Labor	8.00/hr	1.0	8.00
Crew vehicle	0.50/mile	6.0	3.00
		Total	36.00

Conclusion

Open-top pipe culverts are effective in controlling surface water on portions of "minimum-standard" roads where road grades exceed 10 percent. They are not recommended as the primary means of water control but as a supplemental device that can be used on unavoidable steep road sections where broad-based 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. The cost of an open-top pipe culvert is comparable to that of a graveled broad-based dip.

Literature Cited

Haussman, Richard F. 1960. **Permanent logging roads for better woodlot management.** Upper Darby, PA: U.S. Department of Agriculture, Forest Service, Eastern Region, Division of State and Private Forestry. 38 p.

Hewlett, John D.; Douglass, James E. 1968. **Blending forest uses. Res.** Pap. SE-137. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 15 p.

Kochenderfer, James N. 1970. **Erosion control on logging roads in the Appalachians.** Res. Pap. NE-158. Upper Darby, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 28 p.

Kochenderfer, J. N.; Wendel, G.W.; Smith, H. Clay. 1984. **Cost of and soil loss on "minimum-standard" forest truck roads constructed in the central Appalachians.** Res. Pap. NE-544. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 8 p.

U.S. Department of Agriculture, Forest Service. 1940. **Truck trail handbook.** Washington, DC: U.S. Department of Agriculture, Forest Service, Division of Engineering: 502-559.