out, 2) a decreased frequency of culvert blockage from debris and sediment deposition, and 3) the decreased possibility of road washouts. In sum, for permanently or frequently used forest access roads, using an 18-inch culvert or larger will often prove to be the most cost-effective choice.

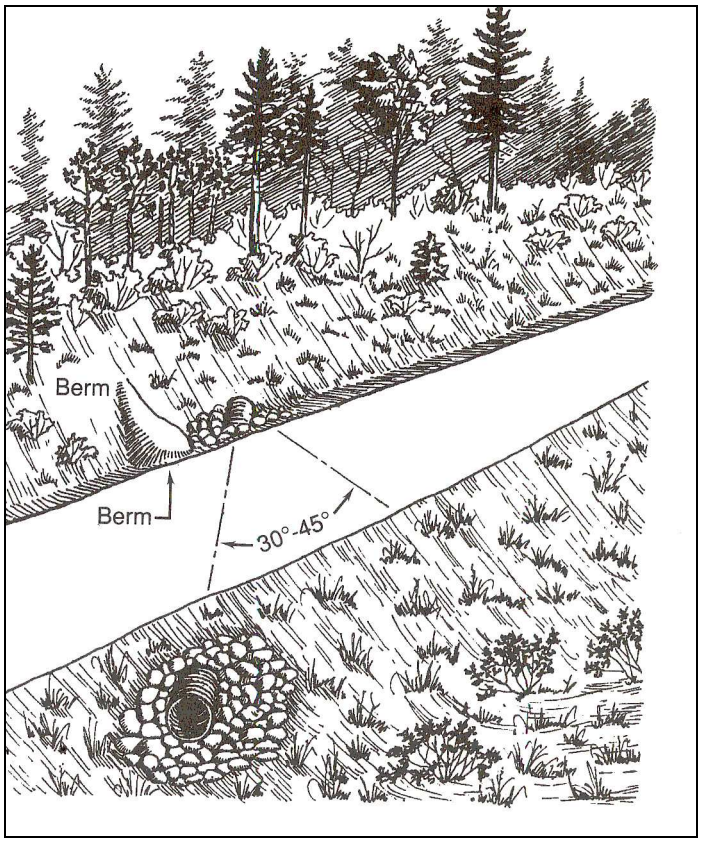


Figure 11. Upland Cross-Drainage Culvert.
(Re-printed courtesy of Wisconsin DNR)

8. STREAM CROSSINGS

As described in section "2. Laws and Permits", installing a new or upgrading an existing stream crossing requires a permit from DEQ prior to installation. This is through the DEQ/US Army Corps of Engineers (USACE) joint permit application process.

It is best to work with local DEQ staff when developing plans for stream crossings from the outset. This will result in less time and effort for the landowner or their designated agent during the permit application and review process. Information regarding this application is available at www.michigan.gov/jointpermit. Permit requirements apply to intermittent streams (flows only occur during certain times of the year, particularly spring during snowmelt), as well as permanently flowing streams. Streams have an area with a defined streambed and bank and visible evidence of a continued flow or continued occurrence of water. While dry for much of the year, intermittent streams are important during frequent rains in the spring. Because of these frequent rain events, intermittent streams provide essential habitat for trout and other fish during spawning runs. Therefore, protect them as carefully as you would a permanent flowing stream.

It is against DEQ regulations to transport felled logs or heavy machinery through even the smallest, shallowest dry streambed. Instead, there are two placement techniques for stream crossings that work best, depending on the circumstances -- a pipe culvert installation, or a portable bridge.

Portable Bridges

Portable bridges, often referred to as temporary bridges, are the preferred method when a stream crossing is required to skid or transport timber products and the stream crossing will be temporary in nature (defined by DEQ as a permitted crossing in place less than 2 years). These bridges can be constructed out of laminated, pressure treated wood (see Figure 12) or can be prefabricated folding metal structures (see Figure 13).

These bridges are generally designed to support skidders and forwarders, but may also be constructed sturdy enough to support tandem axle haul trucks, as they transport wood products from the landing to the mill.

Studies conducted by the U.S. Forest Service and University of Auburn on the Talledega National Forest showed that installing a portable bridge resulted in 98% less sediment entering the stream, compared to installing a culvert.

The key advantages over culverts are:

- Minimize stream siltation
- Meet or exceed most BMP standards
- Keep wood and other debris out of waterways
- Reusable
- Minimize erosion
- Keep streams clear of debris after installation
- Provide unimpeded fish passage
- No impacts on the stream bottom

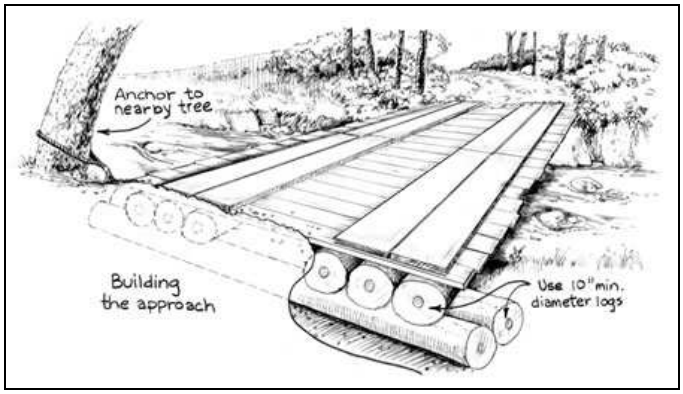


Figure 12. Example of a Wooden Portable Bridge.

(Re-printed courtesy of the University of Minnesota Extension Service.)

Figure 13. Example of a Portable Folding Metal Bridge.

Crossing Streams Using Culverts

Culverts are another option for crossing streams. However, use of culverts instead of portable bridges increases the amount of sediment deposition during installation and removal, as well as increasing the likelihood of impeding fish passage. They are made from corrugated metal pipe or other suitable material (e.g. hard plastic) and placed under a haul road or major skid road to transmit flows from permanent streams and small intermittent streams. Culvert installation and placement requires that the persons responsible for installation and removal take extra care and attention to reduce sediment deposition to the stream as much as possible. It is important to work with local DEQ staff on how to meet permit requirements.

Culvert Installation and Placement

When installation of a portable bridge is not an option, the culvert can be installed using the following BMP specifications:

- Install culverts so that there is no change in the stream bottom elevation. This will allow for unimpeded fish migration (see Figure 14).
- Place barriers or rock from the upstream culvert end to the stream banks to direct flow into the culvert.
- Place barriers or rock at the downstream culvert end to the stream banks.
- Firmly compact fill materials around culverts, particularly around the bottom half. Fill material should be a minimum of 1 foot over the pipe, at a depth specified by the culvert manufacturer, or one-half the diameter of the culvert (see Figure 15).
- Use riprap around the inlet and outlet of the culvert, as well as geotextile underneath the riprap to prevent stream flows from eroding and undercutting the culvert (see Figure 16).
- Pipe length should be long enough so both ends extend 2 feet beyond side slope (cross drainage culverts require only 1 foot beyond side slope).

- The pipe diameter is matched to expected high water flows.

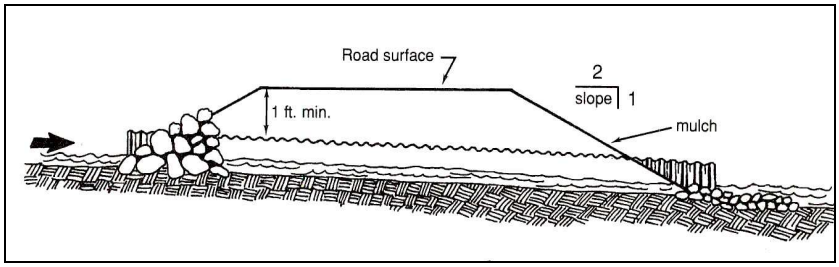


Figure 14. Culvert Installation Without Change in Stream Bottom Elevation.

(Reprinted courtesy of the Wisconsin Department of Natural Resources)

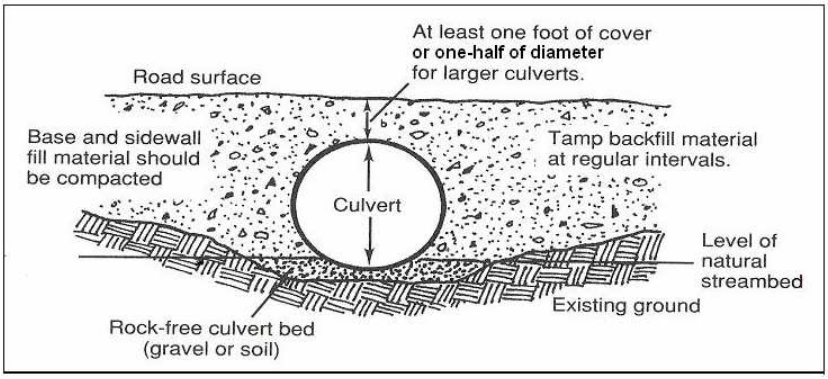


Figure 15. Illustrations and Instructions for Installation of a Stream Crossing Culvert.

(Reprinted courtesy of the Wisconsin Department of Natural Resources)

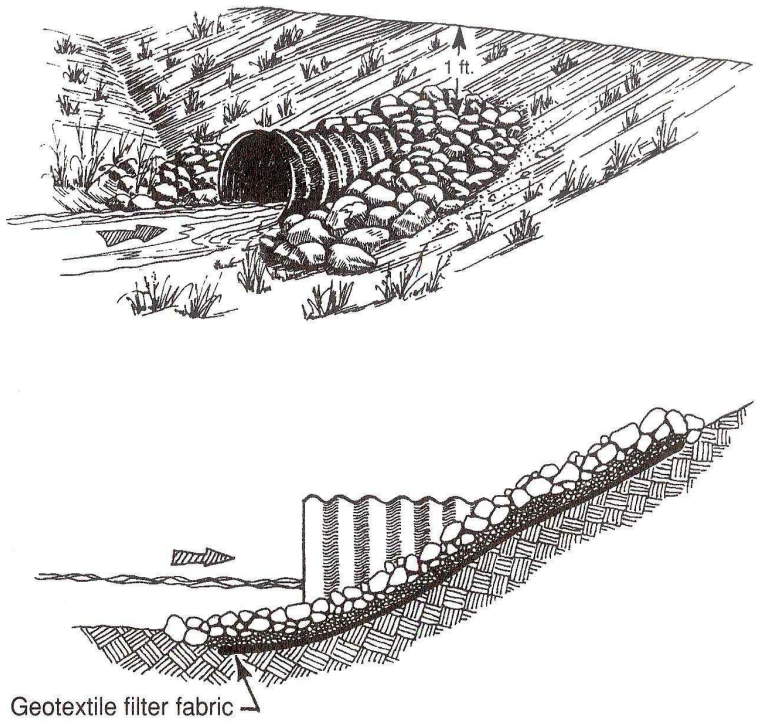


Figure 16. Illustration of Proper Use of Riprap & Geotextile Around Inlet of Stream Crossing Culverts.

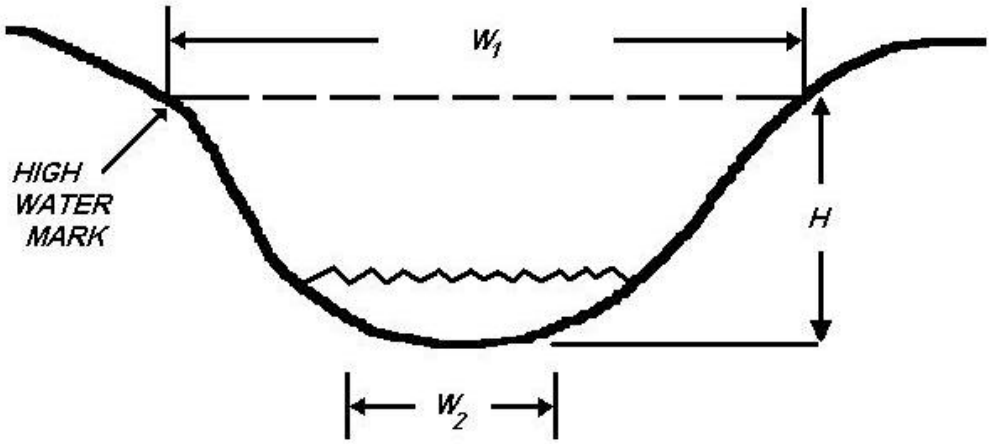
(Edited and re-printed courtesy of the Wisconsin Department of Natural Resources)

Methods for Estimating the Diameter of a Stream Crossing Culvert

Two alternative methods may be employed for estimating the appropriate size of a stream crossing culvert: the traditional “Hasty Method” or the newer “MESBOA” method. Both are described below. The basic principle is that matching the culvert diameter to the width of the stream will maximize the longevity of the culvert, prevent erosion, scouring, pooling, and impaired fish passage.

Using the Hasty Method for Estimating the Diameter of a Stream Crossing Culvert

The “Hasty Method” is a method most frequently employed as it is a field expedient method of estimating the appropriate diameter of a culvert for a particular stream crossing. This method of calculating culvert size includes a safety factor of 100%. Figure 17 is an illustration of how to calculate the pipe diameter from measurements taken in the field. Table 5. shows the conversion of the calculated end area in square feet to the equivalent diameter.



W_1 - CHANNEL WIDTH AT HIGH WATER FT.
W_2 - CHANNEL WIDTH AT BOTTOM FT.
H - HEIGHT OF HIGH WATER ABOVE CHANNEL BOTTOM FT.

CULVERT AREA WITH 100% SAFETY FACTOR SQUARE FEET = $H \times (W_1 + W_2)$

Figure 17. Hasty Method for Calculating Culvert Size

Table 5. Culvert End Area & Diameter

End Area (Square Ft.)	Diameter (Inches)
1.80	18
3.10	24
4.90	30
7.10	36
9.60	42
12.60	48
15.90	54
19.60	60
23.80	66
28.30	72
33.20	78
38.50	84
44.20	90

The MESBOA Method for Installing Stream Crossing Culverts

The MESBOA method, first developed in Minnesota, was a joint effort between the U.S. Forest Service and Minnesota Department of Natural Resources to develop a method that properly sizes, orients and installs culverts based primarily on the stream's physical characteristics. The “MESBOA” is an acronym comprised of the first letter of each of the six steps. The DEQ considers this method as the best method to use when sizing and installing stream crossing

culverts. It was developed to ensure unimpeded fish passage and minimizing the risk of a culvert being washed out during a significant storm event.

The Six Steps in the Sizing and Placement of Culverts

The following are general instructions to apply when using the MESBOA method to determine the appropriate size, length, width and number of culverts needed for a given stream crossing:

1. **M**atch culvert width to bankfull stream width (see Figure 18).
2. **E**xtend culvert length through the side slope toe of the road.
3. **S**et culvert slope the same as stream slope (failure to set culverts on the same slope as the stream is the primary reason that many culverts impede fish passage).
4. **B**ury the culvert 4 to 12 inches into the stream bottom. For culverts 2 to 6 feet in diameter, dig 10 to 18 inches below the stream bottom.
5. **O**ffset multiple culverts.
6. **A**lign the culvert with the stream channel.

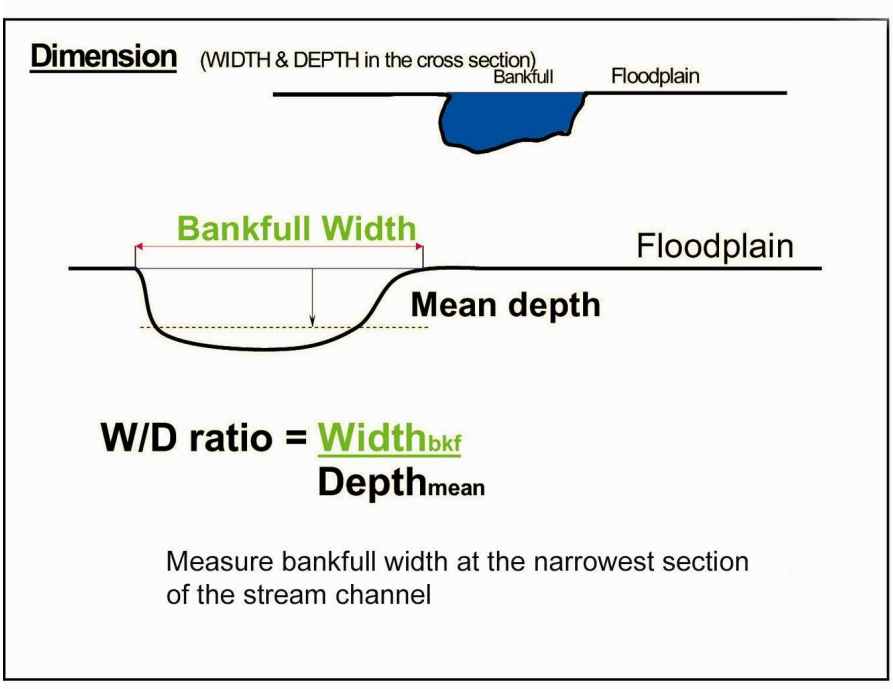


Figure 18. Measuring Bankfull Width.

Guidance Regarding the Application of the MESBOA Method Based on Stream Channel Width and Culvert Diameter

The following is guidance to aid forest managers or loggers as what measurements are needed based on bankfull width of the channel being crossed, stream depth, and the slope of the stream bottom. As the size of both the culvert and channel width increase, so too does the likelihood of having to obtain the services of a professional surveyor and civil engineer, to ensure the culvert is properly sized and installed.

The following guides the efforts or resources that may be required based on culvert diameter and channel width using the MESBOA approach:

- Culverts are 2 to 3 feet in diameter and channel is 2 to 6 feet wide.
  - Need only bankfull width and reasonable estimate of stream bottom slope and burying depth.
- Culverts are 3 to 6 feet in diameter and channel is up to 12 feet wide.
  - Need bankfull width, and accurate longitudinal profile of the stream to have exact slope of the stream and culvert elevation at both the inlet and outlet. Will require the use of level survey equipment.
- Culverts are greater than 6 feet in diameter or wide arch design and channel is greater than 12 feet wide.
  - Need bankfull width, longitudinal profile, and 1-3 cross sections. Use computerized culvert design programs to confirm that all measurements accurately dictate culvert design and installation parameters. Generally applied when stream crossing design requires the involvement of a registered professional civil engineer.

9. RUTTING AND RELATED ISSUES

Rutting occurs when soil strength is not sufficient to support the applied load from vehicle traffic (see Figure 19; Table 2 on page 17 has more on soil susceptibility to erosion). Rutting affects aesthetics, biology, hydrology, site productivity and vehicle safety. In general, rutting can cause soil compaction and loss of forest productivity. Where channelized flow to an open water body occurs, rutting can result in contributing sediment into an open water body. While not always a water quality issue, excessive rutting is certainly a sign that ongoing forest operations need to be modified to prevent further damage to soil and forest resources.

Figure 19. Forest Road Rutting Damage

Table 6 (below) provides guidance on excessive rutting in different areas of a harvest operation, immediate actions to be taken and restoration requirements. The rutting guidance should be applied in relation to the specific area being harvested. Consideration should be given to soils, hydrology, forest type, slope, and other site factors. For example, on certain sites, it may be necessary to change or halt operations before the standards stated are exceeded. Conversely, deep ruts may not be a problem in a landing which will be smoothed and revegetated after a harvest. In addition, excessive rutting in wetlands may require a DEQ permit. To avoid the need for a permit, methods should be employed to avoid and minimize rutting in wetland areas.

Anytime rutting causes sedimentation in a stream, lake or open water wetland, the activity causing the rutting must stop and immediate actions taken to prevent further sediment deposition. Rutting in roads or landings that does not cause sedimentation should be monitored. If ruts begin to exceed the specifications, measures should be taken to prevent further rutting. If further rutting cannot be prevented, the operations should cease until conditions change or until the rutting can be repaired. Off road rutting in the woods may occur