3.6 Culvert Design

Culvert drainage design encompasses the selection of culvert materials, backfill requirements, scour protection, roadway alignment and adequate sizing to pass the expected flows. The information contained in this chapter is focused on design considerations, site selection, and design flows relevant to non-major stream crossing culverts.

Log culvert design and ford design are covered in the following sections:

- 3.6.1 Log Culvert Design
- 3.6.2 Ford Design & Construction on Non-Fish Streams

If the site is a fish stream or a potential fish stream, consult the Fish-Stream Crossing Guidebook (PDF, 4.2MB) for site and design requirements.

3.6.3 Design Considerations

Design stream culverts to pass the highest peak flow of the stream that can be reasonably be expected based on the anticipated length of time the culvert will remain on the site. For culverts anticipated to remain on site less than three (3) years, design for a peak flow return period of 10 years and all others for the 100-year peak flow return period. Note that there is no consideration of replacing the structure after these periods.

Determine the culvert length (measured along the invert) from the distance between the toes of the embankment, plus 1m in gravelly soils or 2m in silty soils.

3.6.4 Cross Drain Culverts

Cross drain culverts are used to carry ditchwater from one side of the road to the other and spaced at intervals necessary to minimize erosion of the roadside ditchline.

Use the distances in Table 3-6 as a guide to the maximum spacing for cross-drain culverts between established watercourses.

Table 3-6 Guidelines for maximum culvert spacing for forest roads

Erosion hazard	Slight	Moderate	High
More than 50% by soil type	Hardpan, rock, course gravels	Fine gravels	Sands, silts, clays
Road gradient			

0-3%	350m	300m	200m
3-6%	300m	200m	150m
6-9%	250m	150m	100m
9-12%	200m	100m	75m
12%+	150m	100m	100m + rock line the ditch

Reduce the spacing between culverts as required to prevent excessive accumulation of water in the ditches, particularly at road junctions, along road segments with steep uphill side slopes, and along areas of seepage or piping in cuts.

Determine the composition of the slope on which the culvert will discharge. If extensive erosion or mass-wasting may occur, change the location to suit the situation.

Skew cross-drainage culverts to the road centreline by 3° for each 1% road gradient that the road exceeds 3% (to a maximum of 45°).

3.6.5 Culverts on Non-Fish-Bearing Streams

For stream culverts not classified as major culverts or those installed on non-fish- bearing streams, record a minimum amount of information during the road location survey to assist in sizing such a stream culvert for the maximum design flow. In deeply incised channels, ensure that the culvert width is at least the same as the stream channel width. Prepare site plans where conditions are such that there are complex horizontal and vertical or other control issues requiring higher level design and installation procedures.

In planning the layout of the structure:

- Choose an appropriate location, along a stream reach with uniform or uniformly varying flow close to the proposed crossing, to measure a cross- section. Sketch the cross-section of the stream gully, showing evidence of the high water level, present water level, and the depth of the stream across the bottom. Extend the cross-section back from the stream an appropriate distance to show the terrain that affects the proposed crossing and road alignment.
- Note any visual evidence of high water.
- Measure and record the average gradient of the stream at the crossing and at the cross-section if the two are taken at different locations.
- Record the soil type, soil profile, parent material, and substrate material at the crossing and describe the stream bottom.
- Describe the stream channel (debris loading, bank stability, crossing location on a fan, bedload problem, etc.).

3.6.6 Factors Affecting Runoff

The runoff and behaviour of a stream depends on many factors, most of which are not readily available or calculable, such as:

- rainfall (cloudbursts; hourly and daily maxima);
- snowpack depth, distribution, and snowmelt;
- contributory watershed area, shape, and slope;
- topography and aspect;
- ground cover;
- soil and subsoil;
- weather conditions;
- harvesting and road or other upslope development;
- drainage pattern (stream order, branchiness; lakes and swamps); and
- stream channel shape, length, cross-section, slope, and "roughness."

Because topography, soil, and climate combine in infinite variety, design drainage structures individually from available data for each site. In addition, consult those individuals who have long experience in maintaining drainage structures in the area.

3.6.7 High Water Estimation Method for Stream Culverts

Limit application of this method for determining the Q100 from site information to non-major stream culverts. It is not appropriate for use as the sole method for "professional" designs.

This method assumes that the high water width represents the mean annual flood cross-sectional flow area for the stream (Q2); and that the Q100 cross-sectional flow area is three times this. It also assumes that the discharge is not sensitive to influences from pipe slope, roughness, or other factors.

The high water width is defined as the horizontal distance between the stream banks on opposite sides of the stream, measured at right angles to the general orientation of the banks. The point on each bank from which width is measured is usually indicated by a definite change in vegetation and sediment texture. Above this border, the soils and terrestrial plants appear undisturbed by recent stream erosion. Below this border, the banks typically show signs of both scouring and sediment deposition. Determine the high water width from recent visible high water mark indicators, which would approximate the mean annual flood cross- section. This point is not necessarily the top of bank, particularly in the case of an incised stream.

- Locate a relatively uniform stream reach in close proximity to the proposed culvert location. Note that this not an averaging process that would be used for determining the stream channel width for the purpose of assessing stream habitat impacts. A uniform stream reach would have a consistent cross-section, bed materials, and channel slope. It would also be relatively straight.
- Estimate the visible high water stream width and cross-sectional area.
    a. Measure (in metres) the high water width at a relatively uniform reach of the stream, representative of the mean annual flood (W1) and at the stream bottom (W2). See Figure 3-4: High water width cross-sectional area.
    b. Measure the depth of the stream at several spots across the opening to obtain the average depth (D) in metres.

c. Calculate the cross-sectional area of the stream, A = (W1 + W2)/2 x D.

- Calculate the area of the required culvert opening, Ac = A x 3.0.
- Size the pipe (see Table 3-7), using the smallest pipe area that exceeds the required area, or select an opening size for a log culvert that will be greater than Ac.

Cross check the high water width method if field or other evidence of an approximate 10-year flood is available. In this case, the area of the Q10 flood can be multiplied by 2 to estimate the minimum culvert area for the Q100 flood.

Example

If	W1 = 1.2 m W2 = 0.8 m D = 0.5 m stream cross-sectional area A = 0.5 m2
Then	Ac = 0.5 x 3.0 = 1.5 m2
Therefore	(from Table 3-7), the required pipe culvert size = 1400 mm.

Figure 3-4 High water width cross-sectional area

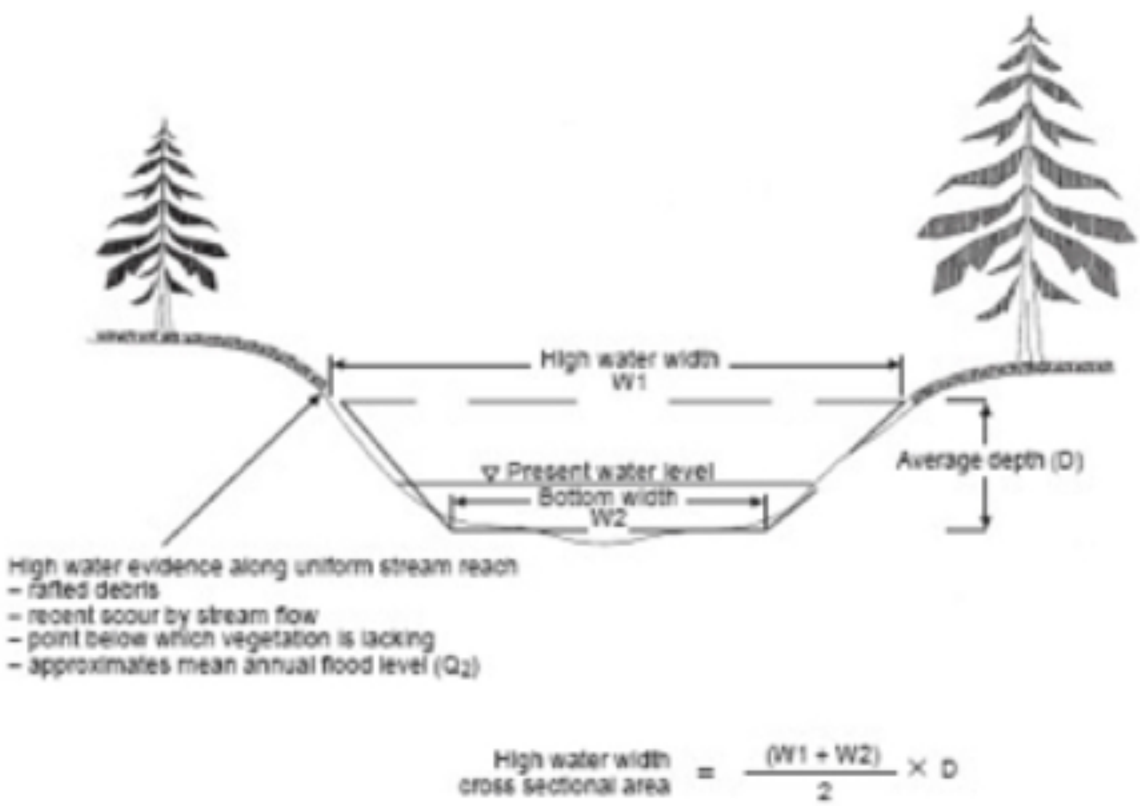

Table 3-7 Round pipe culvert area (Ac) versus pipe diameter

Ac (m2)	Pipe diameter (mm)
1.0.13	400
0.20	500
0.28	600
0.50	800
0.64	900
0.79	1000
1.13	1200
1.54	1400
2.01	1600
2.54	1800

3.6.8 Road Junctions

Ensure that a junctioning road has a minimum vertical curve with a K value of 1, and a minimum horizontal curve radius of 20 m or widening for sidetracking of vehicles. Where possible, design roads that junction other roads at right angles whenever possible to allow traffic to turn both ways and provide adequate site distance for oncoming traffic based on the road design speeds. On steeper slopes where a perpendicular junction cannot be obtained, ensure that the junction is designed so that the existing road width is not reduced.

For showing junctions and railway and utility crossings, use the road standard drawings, subject to any variations required by the appropriate agency.

3.6.9 Other Structures

The design of bridges, major culverts, cattleguards, retaining walls and other specialized structures that fall within the practice of a professional engineer are covered in Chapter 4: Design & Construction of Bridges & Major Culverts. Incorporate these designs into the road design.