CHAPTER 4

DESIGN OF CULVERTS

4.5 Culvert Design Example

4.5.1 Introduction

The following example problem illustrates the procedures to be used in designing culverts using the nomographs.

4.5.2 Example

Size a culvert given the following example data which were determined by physical limitations at the culvert site and hydraulic procedures described elsewhere in this handbook.

4.5.3 Example Data

Input Data

Discharge for 2-yr flood = 35 cfs

Discharge for 100-yr flood = 70 cfs

Allowable H_w for 100-yr discharge = 7.0 ft

Length of culvert = 100 ft

Natural channel invert elevations – inlet = 15.50 ft, outlet = 15.35 ft

Culvert slope = 0.015 ft/ft

Tailwater depth for 100-yr discharge = 4.0 ft

Tailwater depth is the normal depth in downstream channel

Entrance type = Groove end with headwall

4.5.4 Computations

4.5.4.1 Assume a culvert velocity of 5 ft/s.

Required flow area = 70 cfs/5 ft/s = 14 sq, ft (for the 100-yr recurrence flood).

4.5.4.2 The corresponding culvert diameter is about 48 in.

This can be calculated by using the formula for area of a circle:

Area = $(3.14D^2)/4$ or D = $(\text{Area times } 4/3.14)^{0.5}$.

Therefore: D = $((14 \text{ sq ft} \times 4)/3.14)^{0.5} \times 12 \text{ in./ft}) = 50.7$ in.

4.5.4.3 A grooved end culvert with a headwall is selected for the design.

Using the inlet control nomograph (Figure 4.4.5-1), with a pipe diameter of 48 in. and a discharge of 70 cfs; read a HW/D value of 0.93.

4.5.4.4 The depth of headwater (HW) is (0.93) x (4) = 3.72 ft which is less than the allowable headwater of 4.5 ft.

4.5.4.5 The culvert is checked for outlet control by using Figure 4.4.5-2.

With an entrance loss coefficient K_e of 0.20, a culvert length of 100 ft, and a pipe diameter of 48 in., an H value of 0.77 ft is determined.

The headwater for outlet control is computed by the equation:

$HW = H + h_O - LS$

For the tailwater depth lower than the top of culvert,

$h_O = T_W$ or ½ (critical dept in culvert + D) which ever is greater.

$h_O = 3.0$ ft or $h_O = ½ (2.55 + 4.0) = 3.28$ ft

The headwater depth for outlet control is:

$HW = H + hO - LS = 0.77 + 3.28 - (100) \times (0.0015) = 3.90$ ft

Since HW for outlet control (3.90 ft) is greater than the HW for inlet control (3.72 ft), outlet control governs the culvert design.

Thus, the maximum headwater expected for a 100-yr recurrence flood is 3.90 ft, which is less than the allowable headwater of 4.5 ft.

4.5.4.6 Estimate outlet exit velocity. Since this culvert is on outlet control and discharges into an open channel downstream, the culvert will be flowing full at the flow depth in the channel.

Using the 100-year design peak discharge of 70 cfs and the area of a 48 inch or 4.0 ft diameter culvert.

The exit velocity will be:

$Q = VA$

Therefore: $V = 70 / (3.14(4.0)^2)/4 = 5.6$ ft/s

Check for minimum velocity using the 2-year flow of 35 cfs.

Therefore: $V = 35 / (.14(4.0)^2)/4 = 2.8$ ft/s > minimum – OK

Figure 4.6.2-1 provides a convenient form to organize culvert design calculations.

For an example of a design which incorporates roadway overtopping, see Appendix A – example application of the HY8 Culvert Analysis Microcomputer Program.

END OF SECTION 4.5