CULVERTS

Culverts seem to be simple hydraulic structures but in fact are among the most complicated because of the wide variety of flow conditions that can occur in them. Flow can be gradually varied or rapidly varied and also a function of time. A culvert can flow full, in which case it operates under pressure-flow conditions as in pipe flow, or it can flow partly full, as an open channel. The open channel flow can be supercritical or subcritical, and its analysis may include computation of a gradually varied flow profile or a hydraulic jump. Culverts flow full when the outlet is submerged due to high tailwater but also may flow full for a very high headwater with the outlet unsubmerged. In both full and partly full flow, the submergence of the inlet or outlet is an important criterion in determining the type of flow that occurs. Perhaps the most important distinguishing characteristic of a culvert flow is whether it is under inlet or outlet control. In the case of inlet control, the head-discharge relation is determined entirely by the inlet geometry, including the inlet area, edge rounding, and shape. Tailwater conditions are immaterial for inlet control. In outlet control, on the other hand, the head-discharge relation is affected not only by the inlet but also by the barrel roughness, length, slope, shape, and area as well as the tailwater elevation. These influences on inlet and outlet control are summarized in Table 6-1. Inlet control generally occurs for short, steep culverts with a free outlet, while outlet control prevails for long, rough-barreled culverts with high tailwater conditions.

Culvert design usually is based on the selection of a design discharge determined from frequency analysis. Interstate highway culverts, for example, may be designed to carry the 100 year peak discharge. The culvert is sized to limit the headwater resulting from the design discharge to a specified value to prevent overtopping the highway embankment. Once the design culvert size is determined, its performance may be analyzed over a wide range of discharges, including discharges that overtop the embankment. This analysis can be summarized by a plot of the complete head-discharge relation, called the *performance curve*. This step is important to accurately determine whether the culvert operates under inlet or outlet control for the design discharge. The design process is based on a selected peak discharge in steady flow, and a conservative approach is taken in which both inlet and outlet control head-discharge relationships are checked to determine the limiting control.

TABLE 6-1
Factors influencing culvert performance

Factor	Inlet Control	Outlet Control
Headwater elevation	x	x
Inlet area	x	x
Inlet edge configuration	x	x
Inlet shape	x	x
Barrel roughness		x
Barrel area		x
Barrel shape		x
Barrel length		x
Barrel slope		x
Tailwater elevation		x

Source: Data from Federal Highway Administration (1985).

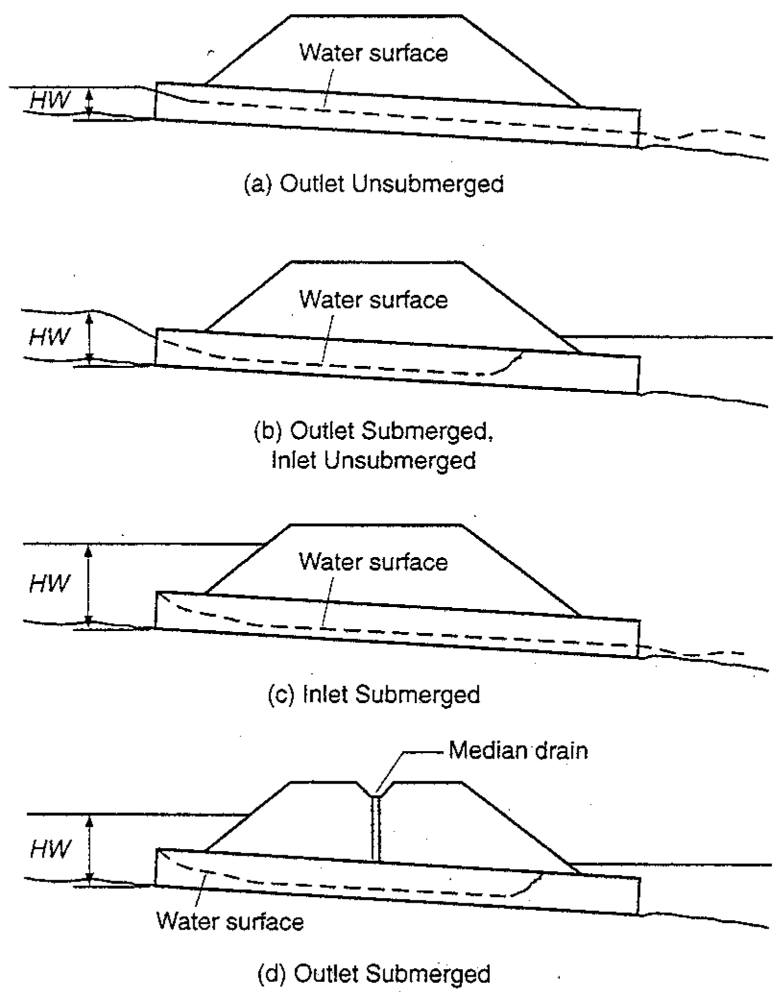

FIGURE 6.11
Types of inlet control (Federal Highway Administration 1985).

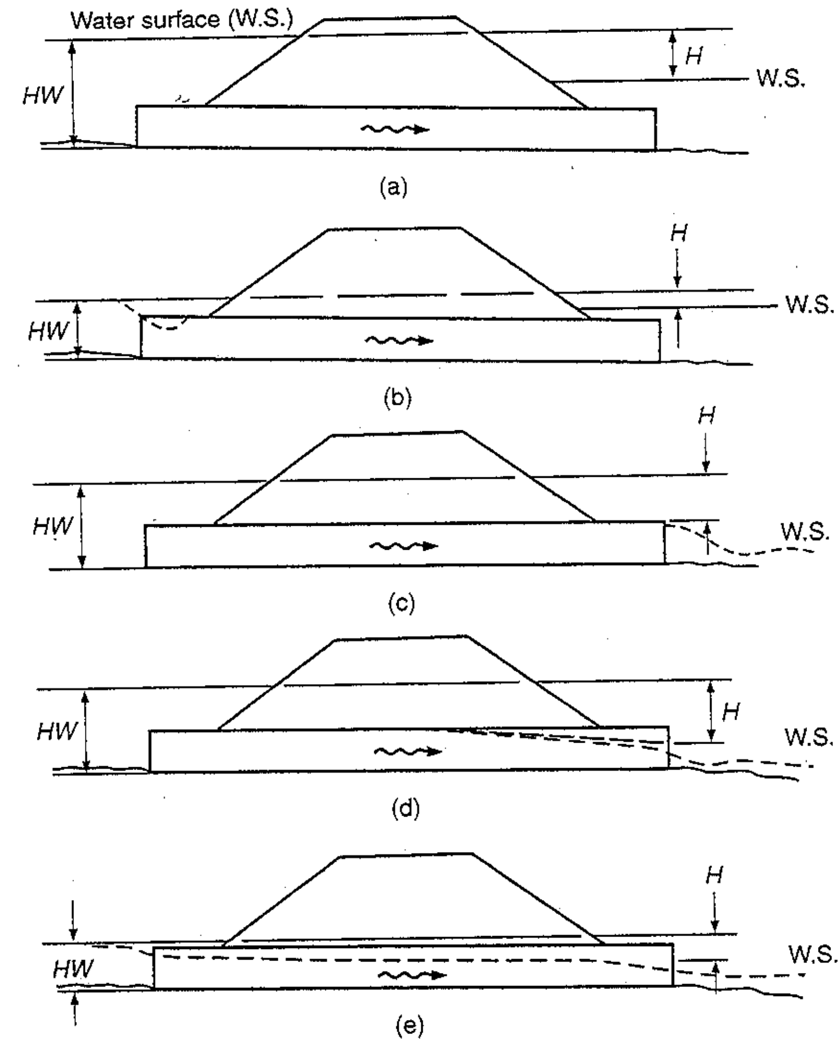

FIGURE 6.12
Types of outlet control (Federal Highway Administration 1985).

SOURCE: Sturm, T.W., Open Channel Hydraulics, McGraw-Hill, 2001

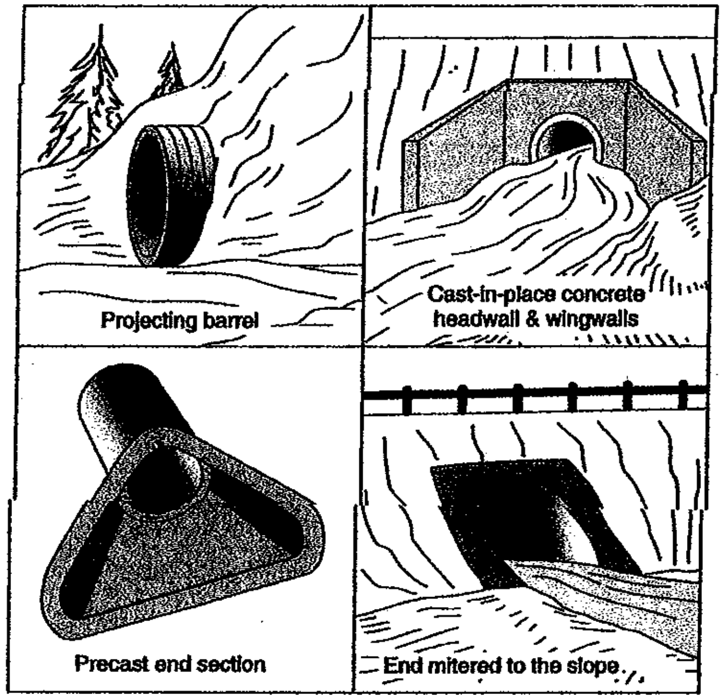

Figure 16.2.1 Four standard inlet types (schematic) (from Normann et al. (1985)).