



## Culvert Design

**Course Number:** CE-02-709

**PDH:**5

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## Module 1: Introduction and Overview

### Learning Objectives

By the end of this section, you will be able to:

- **Select** appropriate culvert shapes and materials based on site-specific hydraulic and structural constraints.
- **Identify** the core design parameters required for a complete hydraulic analysis.
- **Evaluate** the impact of inlet configuration, headwater, and tailwater on overall culvert performance.

*Executive Summary:* Culvert design is a dual-discipline process requiring both hydraulic and structural analysis to effectively convey surface water through embankments while supporting significant traffic and earth loads. Success depends on balancing discharge capacity, upstream flood risks, and public safety.

### Design Fundamentals


The primary function of a culvert is the conveyance of surface water across a highway, railroad, or similar embankment. Because they must also support traffic and soil loads, design involves both hydraulic and structural considerations.

### Culvert Geometry and Materials

Performance is significantly influenced by size, shape, and material selection:

- **Circular:** The most common shape used in standard applications.
- **Pipe Arch/Elliptical/Rectangular:** Preferred in scenarios with **limited cover**.
- **Arch:** Utilized where minimizing waterway obstruction is a priority and foundations are structurally adequate.
- **Box (Rectangular):** Ideal for passing **large flows** or fitting low allowable headwater situations, as the span can be increased while decreasing height.

Common materials include **concrete** and **steel** (smooth or corrugated). Selection depends on structural strength, durability, roughness, and resistance to abrasion or corrosion.

 **Design Tip:** Inlet configuration is a critical performance factor. Options range from simple barrel projections to sophisticated headwalls, wingwalls, and apron slabs.



**Photograph CU-1**—Public safety considerations for long culverts should be accounted for with culvert designs such as with this collapsible trash rack at a park-like location.



**Photograph CU-2**—Culverts can be designed to provide compatible upstream conditions for desirable wetland growth.



**Photograph CU-3**—Culverts can be integrated into the urban landscape without negative visual impact.

### Required Design Information

Hydraulic design analyzes the culvert's ability to move flow from one side of an embankment to the other. Engineers must establish several criteria before selecting size and type:

- **Alignment and Grade:** Determining the physical path and slope.
- **Impact Assessment:** Evaluating flood risks and the implications of **embankment overtopping**.
- **Safety and Multipurpose Objectives:** Addressing public safety through debris racks and ensuring alignment with regional drainage master plans.
- **Specialized Measures:** Assessing the need for fish passage or protection against corrosion.



**Photograph CU-4**—Public safety features such as the rack at the entrance to an irrigation ditch and the railing on the wingwalls must be considered.



## Hydraulic Parameters

### Discharge

Design discharge is estimated based on a preselected **storm recurrence interval**. The system must operate within acceptable risk limits at this flow rate. Refer to local policy tables (e.g., DP-1 through DP-3) for specific street overtopping criteria.

### Headwater

Culverts constrict flow, causing a rise in the upstream water surface. **Headwater Depth** is the total flow depth measured from the inlet invert.

**⚠ Safety Constraint:** When selecting design headwater, you must verify that watershed divides are higher than the headwater elevation to prevent unintended flow distribution. Consider life safety, traffic interruption, and the **Headwater/Culvert Depth (HW/D) ratio**.

### Tailwater

This is the flow depth in the downstream channel measured from the outlet invert. Submerged outlets can force a culvert to flow full, significantly altering hydraulic performance. Control factors include downstream structures, reservoir levels, or stages in contributing streams.

### Outlet Velocity

Culvert outlet velocities are typically higher than natural stream velocities, which may lead to **streambed scour** and bank erosion.

**🧮 Calculation Note:** Slope and barrel roughness are the primary factors affecting outlet velocity. If velocities are excessive, consider increasing barrel roughness or implementing energy dissipation devices.

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*Checkpoint Quiz*

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**1. Which culvert shape is most suitable for a site with very low allowable headwater and a requirement for high flow capacity?**

- a) Circular pipe
- b) Standard arch
- c) Rectangular box
- d) Elliptical pipe

**Answer:** (c). A box culvert allows the height to be decreased and the span increased to satisfy low headwater requirements.

**2. Inlet control performance is primarily determined by which of the following?**

- a) Barrel roughness and length
- b) Inlet configuration and headwater depth
- c) Tailwater elevation and slope
- d) Downstream channel obstructions

**Answer:** (b). These are the critical factors for culverts operating under inlet control.

**3. What is the primary reason for performing a field inspection of the downstream channel during the design phase?**

- a) To determine the pipe material coating requirements.
- b) To identify obstructions that might influence tailwater depth.
- c) To measure the exact embankment overtopping height.
- d) To calculate the required watershed divide elevation.

**Answer:** (b). Tailwater is a major factor in determining if a culvert flows full or partially full.



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