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design data 11

american concrete pipe association

HYDRAULICS OF CULVERTS: 96-Inch Through 144-Inch Diameter Pipe

The hydraulic design of culverts establishes the minimum pipe size which has sufficient capacity to discharge a required flow within an allowable headwater depth. For circular culverts, one of the principal factors influencing hydraulic capacity is pipe diameter. Other hydraulic factors such as pipe length, slope, surface roughness and inlet geometry also influence capacity depending on whether the culvert is operating under inlet control or outlet control.

For any given headwater depth and pipe diameter, the capacity of a culvert operating under inlet control is limited by the degree of contraction of the flow at the entrance. Therefore, if a culvert pipe is to function as an efficient hydraulic structure under inlet control conditions, an inlet geometry which results in minimum contraction of the flow at the entrance is of utmost importance. In outlet control, all of the hydraulic factors affect culvert capacity. The primary factor limiting culvert capacity when operating under outlet control is surface roughness. A culvert pipe with an interior surface which results in a minimum of frictional resistance to flow is necessary for hydraulic efficiency.

The geometric shape of the socket end of a concrete culvert pipe provides a more efficient entrance than the sharp edge of a corrugated metal pipe with or without a headwall. In addition, the relative smoothness of concrete pipe enables it to maintain equivalent discharge capacity at lower headwater depths than can be maintained by corrugated metal pipe.

The significance of these hydraulic advantages of concrete pipe is illustrated by the performance curves presented in *Figures 1 through 14.* The curves correlate discharge-headwater depth and are based on nomographs included in *Hydraulic Engineering Circular Number 5,* Hydraulics Branch, Bridge Division, Office of Engineering and Operations, Bureau of Public Roads.

The headwater depths for inlet-controlled flow are read directly from the performance curves. For outlet-controlled flow it is necessary to subtract the product of the culvert length and slope from the headwater depth.

The following example illustrates the proper use of the curves. A complete discussion of the hydraulics of culverts is presented in Design Data 8.

EXAMPLE

Given: A 500-foot-long highway culvert is to be installed on a 1.2 percent slope. The culvert will be required to carry a discharge of 900 cubic feet per second within an allowable headwater depth of 16 feet.

Find: Size of concrete pipe and corrugated metal pipe required and type of control.

Solution: Enter *Figure 1: 96-Inch Diameter Concrete Pipe,* and project a vertical line from Q = 900 to the inlet control curve and outlet control curve representing L = 500 feet. Read headwater depth of 15.7 feet for inlet control and 17.7 feet for outlet control. To obtain outlet control headwater depth, subtract $S_o \times L$ from the outlet control figure: $17.7 - (0.012 \times 500) = 11.7$ feet; therefore, inlet control governs.

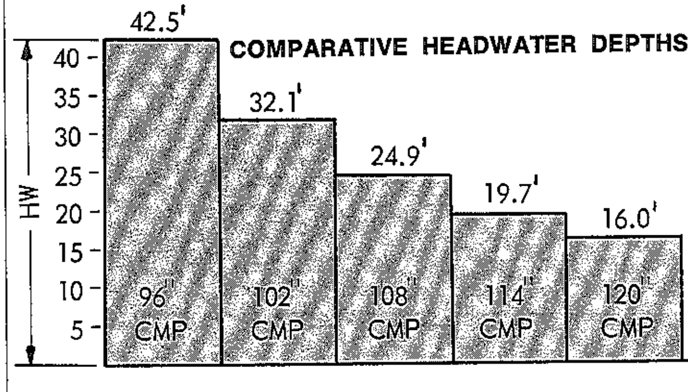
Repeat the same procedure for corrugated metal pipe until a pipe size is found which will handle the design discharge within the allowable headwater depth. From *Figures 2, 4, 6 and 8* it is apparent the 96, 102, 108 and 114-inch diameter corrugated metal pipes are too small; therefore, try the next larger size.

From *Figure 10: 120-inch Diameter Corrugated Metal Pipe,* Headwater for inlet Control = 13.1 feet. Headwater for Outlet Control = $22.0 - (0.012 \times 500) = 16.0$ feet; therefore, outlet control governs.

Answer: A 96-inch diameter concrete pipe or a 120-inch diameter corrugated metal pipe will carry the design discharge within the allowable headwater depth of 16 feet. The concrete pipe is in inlet control and the corrugated metal pipe is in outlet control.

The difference in required headwater depths between 96-inch concrete pipe and corrugated metal pipe in sizes 96-inch through 120-inch is illustrated in the accompanying figure. This example shows that a **corrugated metal pipe four sizes larger than concrete pipe is necessary** to meet the allowable headwater requirements. Comparing the 96-inch corrugated metal and concrete pipe sizes indicates that the same diameter corrugated metal pipe must operate at a headwater depth **270%** greater than concrete pipe.

COMPARATIVE HEADWATER DEPTHS



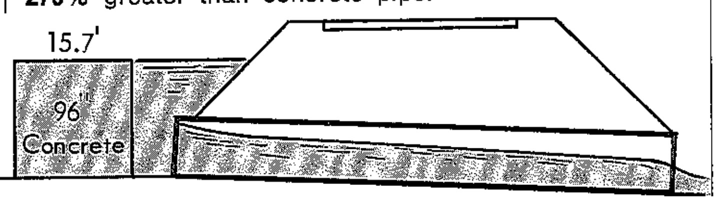


FIGURE 1: 96-Inch Diameter Concrete Pipe

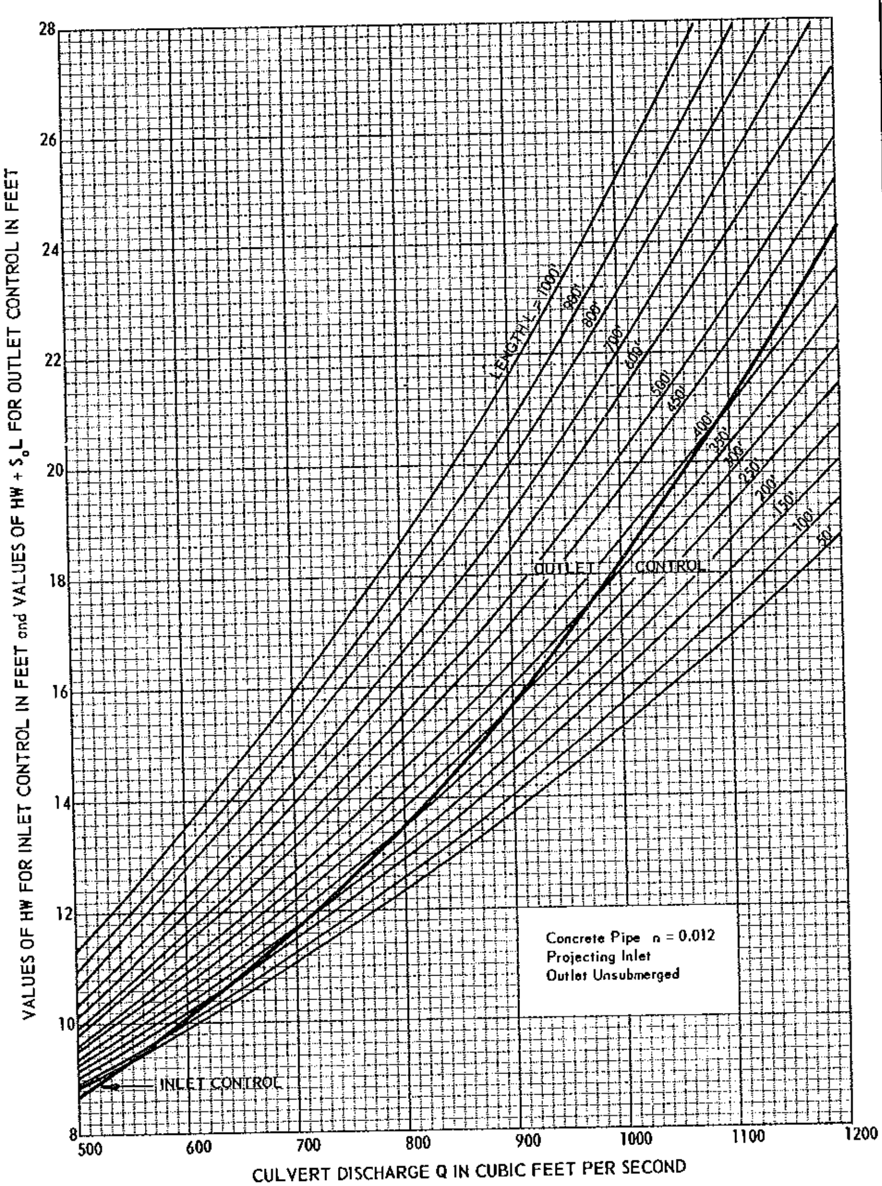
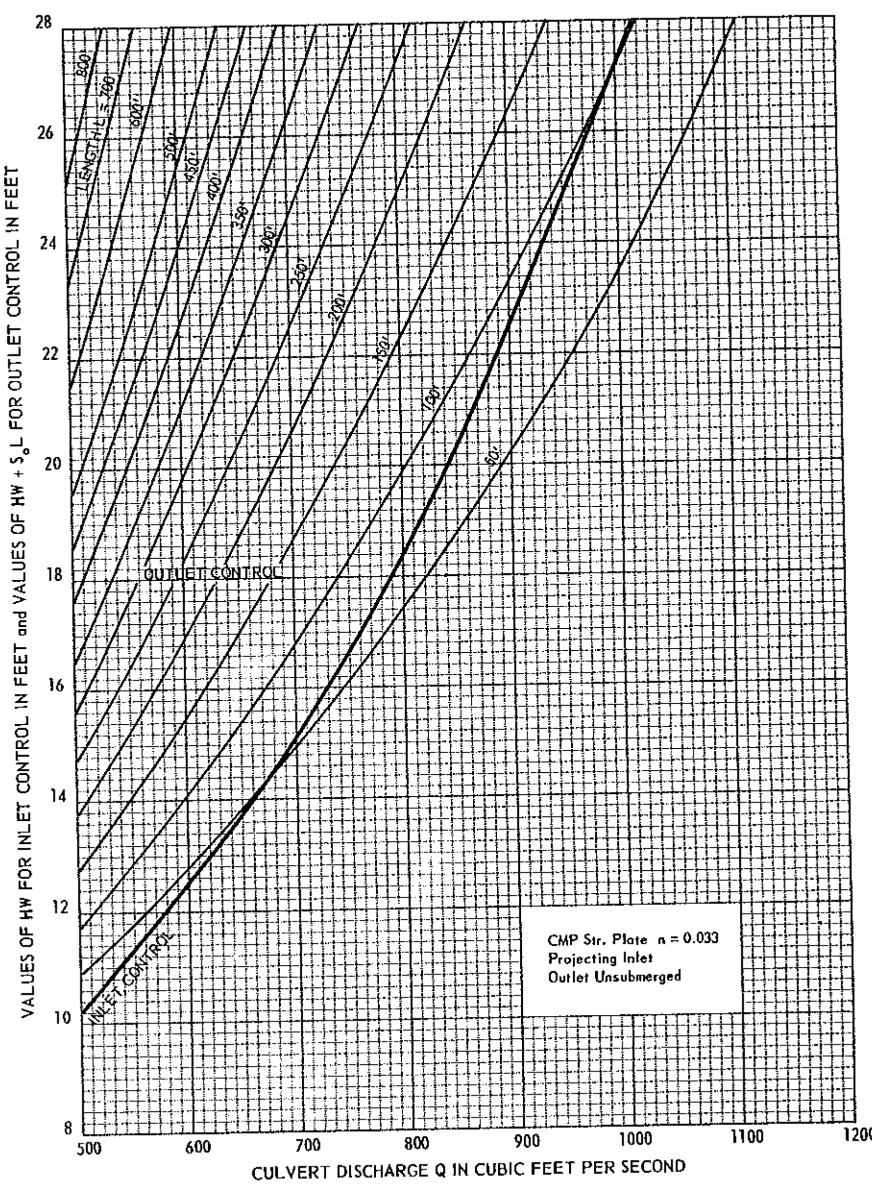


FIGURE 2: 96-Inch Diameter Corrugated Metal Pipe



Interpolate for intermediate culvert lengths

FIGURE 3: 102-Inch Diameter Concrete Pipe

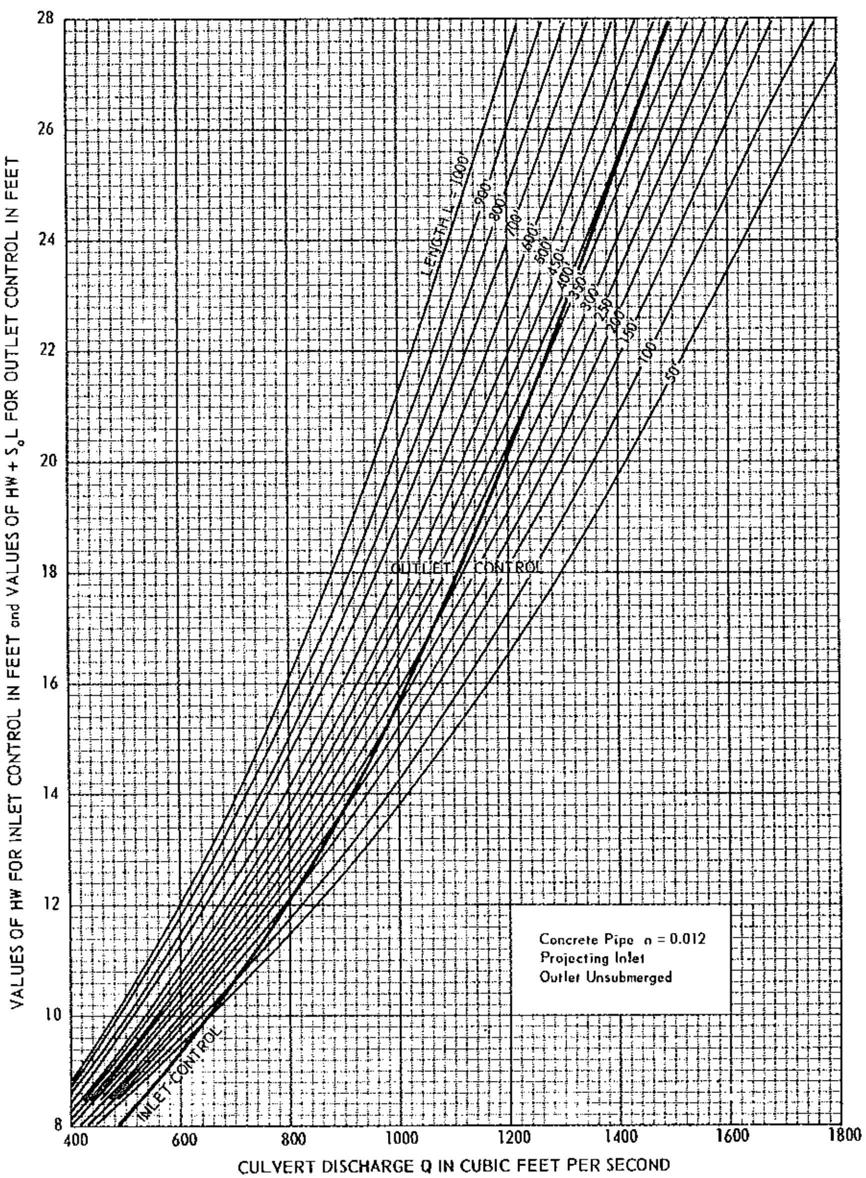
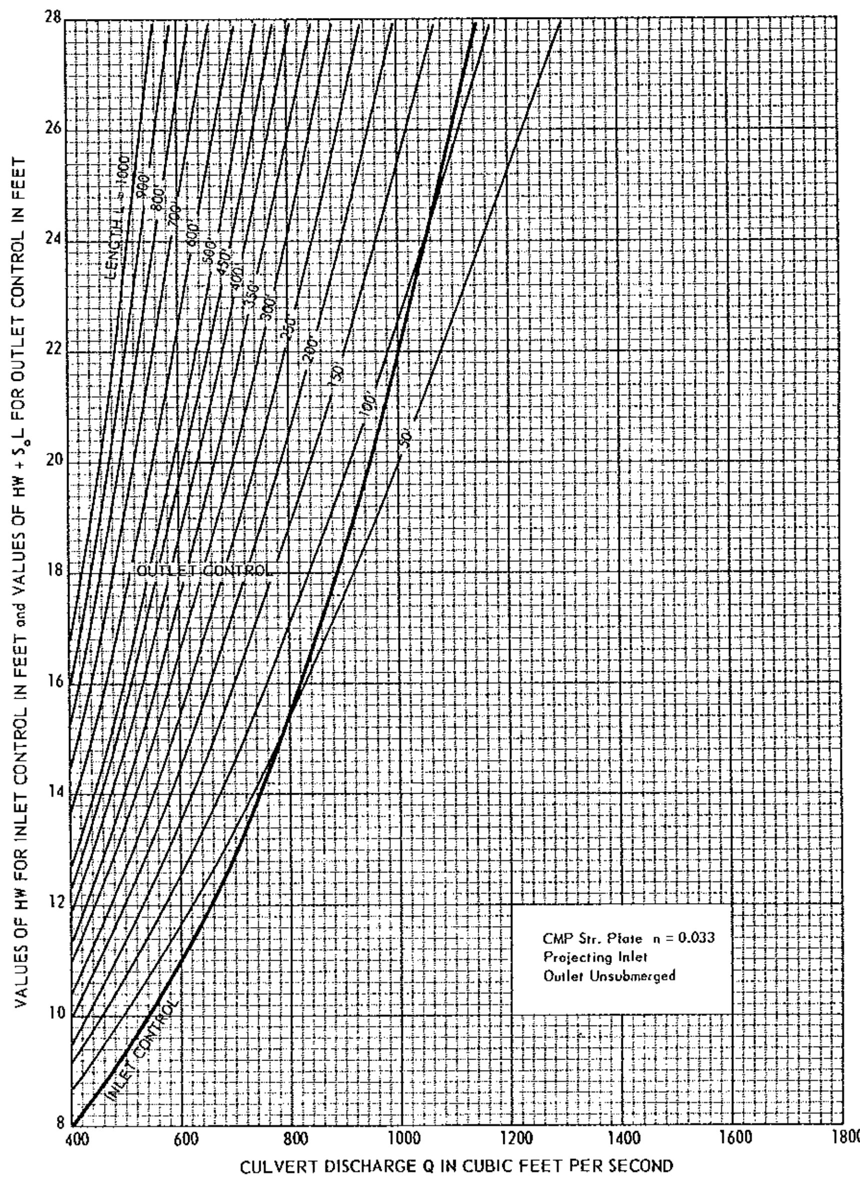


FIGURE 4: 102-Inch Diameter Corrugated Metal Pipe



Interpolate for intermediate culvert lengths

FIGURE 5: 108-Inch Diameter Concrete Pipe

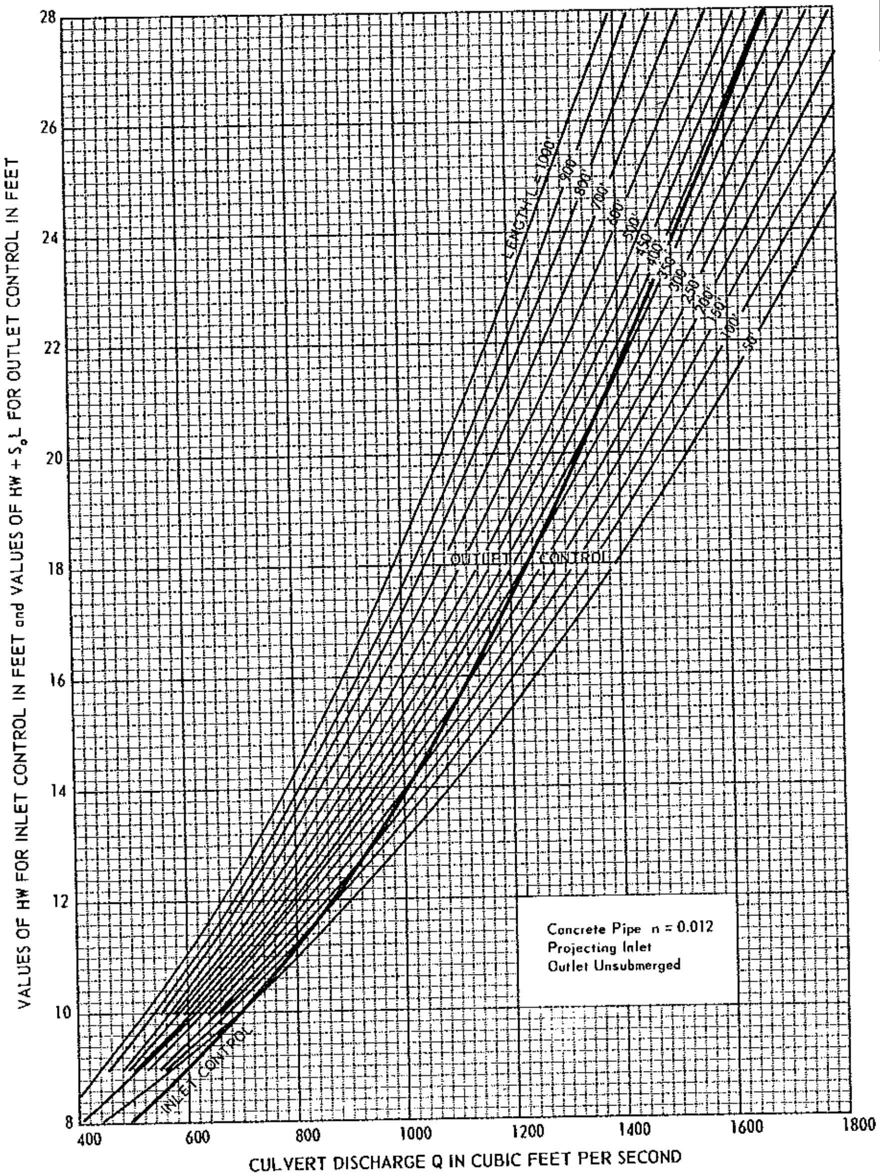
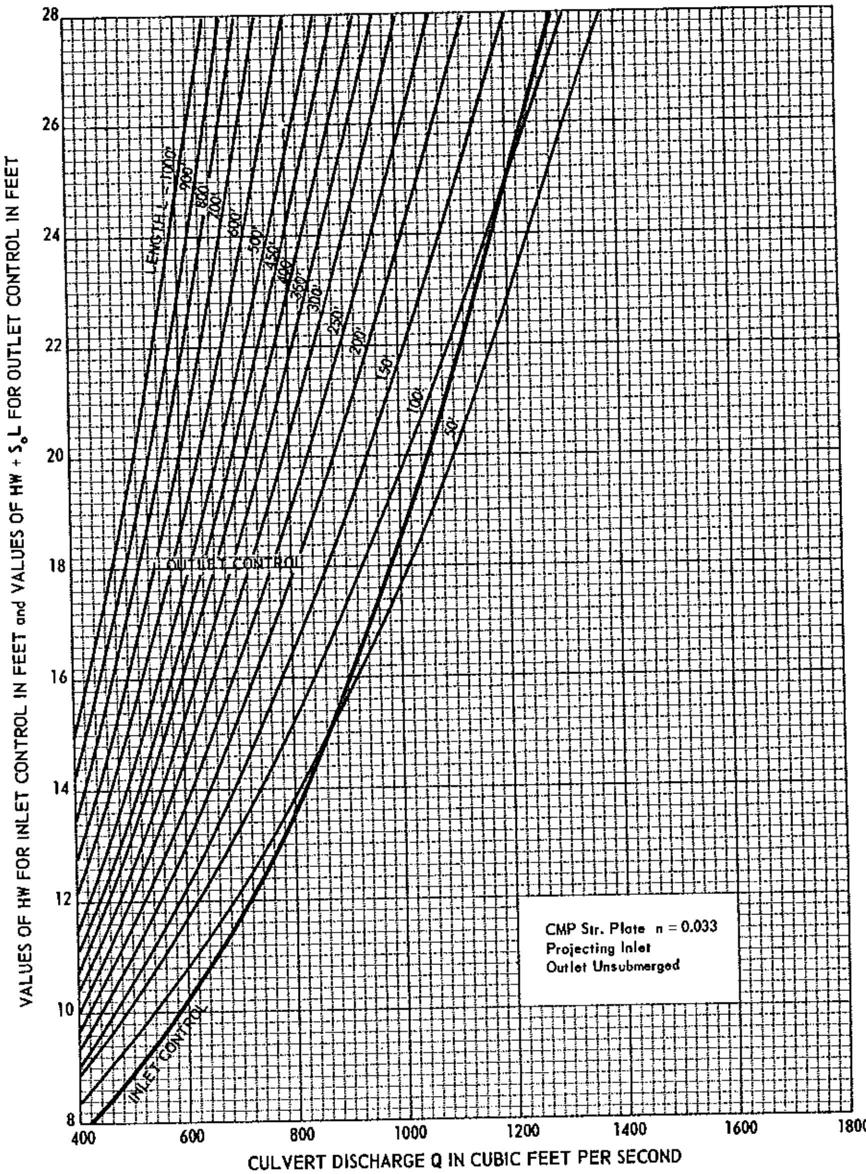


FIGURE 6: 108-Inch Diameter Corrugated Metal Pipe



Interpolate for intermediate culvert lengths

FIGURE 7: 114-Inch Diameter Concrete Pipe

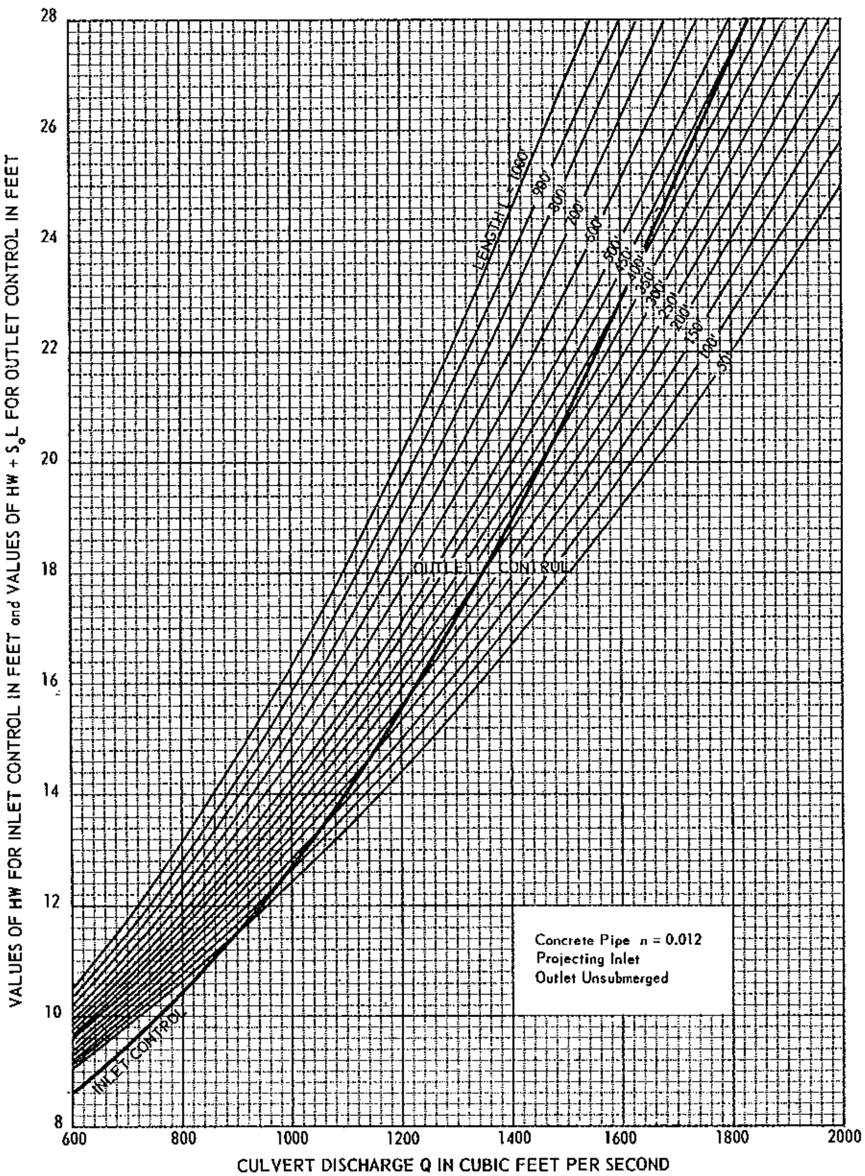
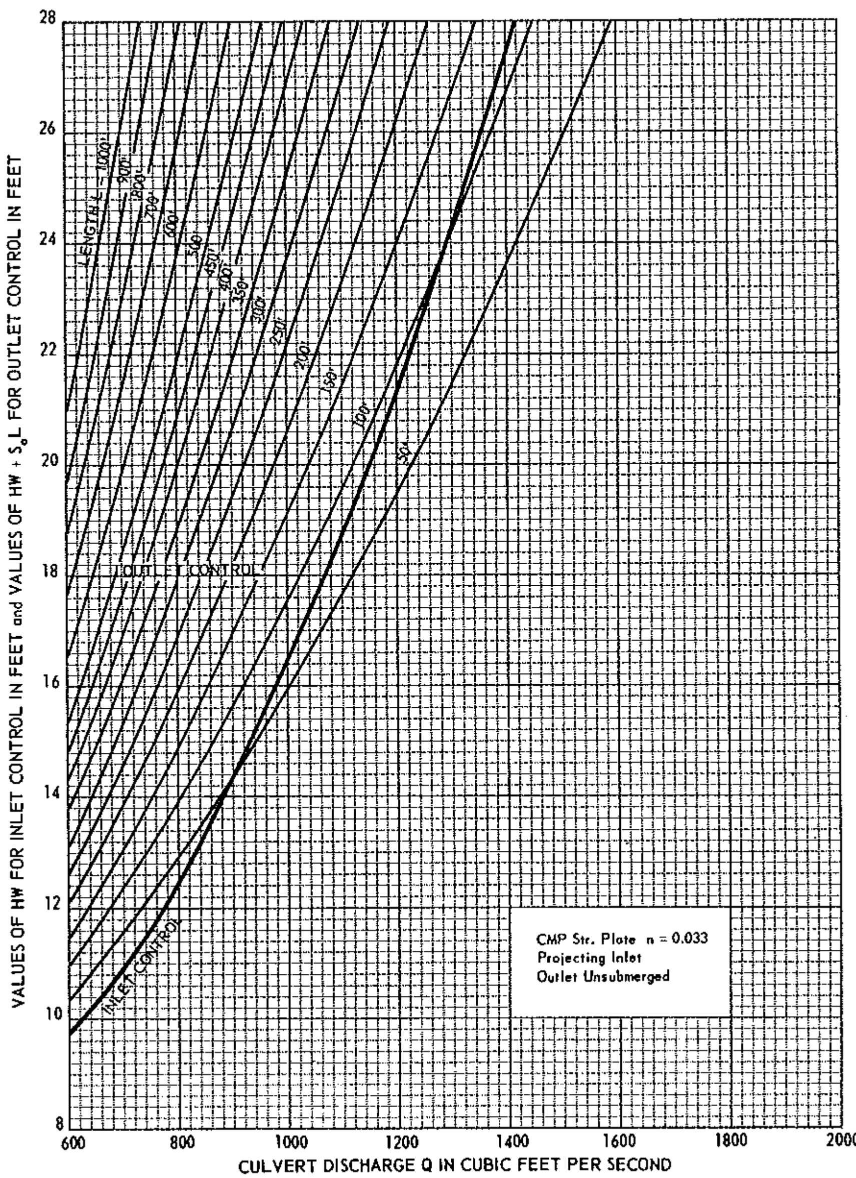


FIGURE 8: 114-Inch Diameter Corrugated Metal Pipe



Interpolate for intermediate culvert lengths

FIGURE 9: 120-Inch Diameter Concrete Pipe

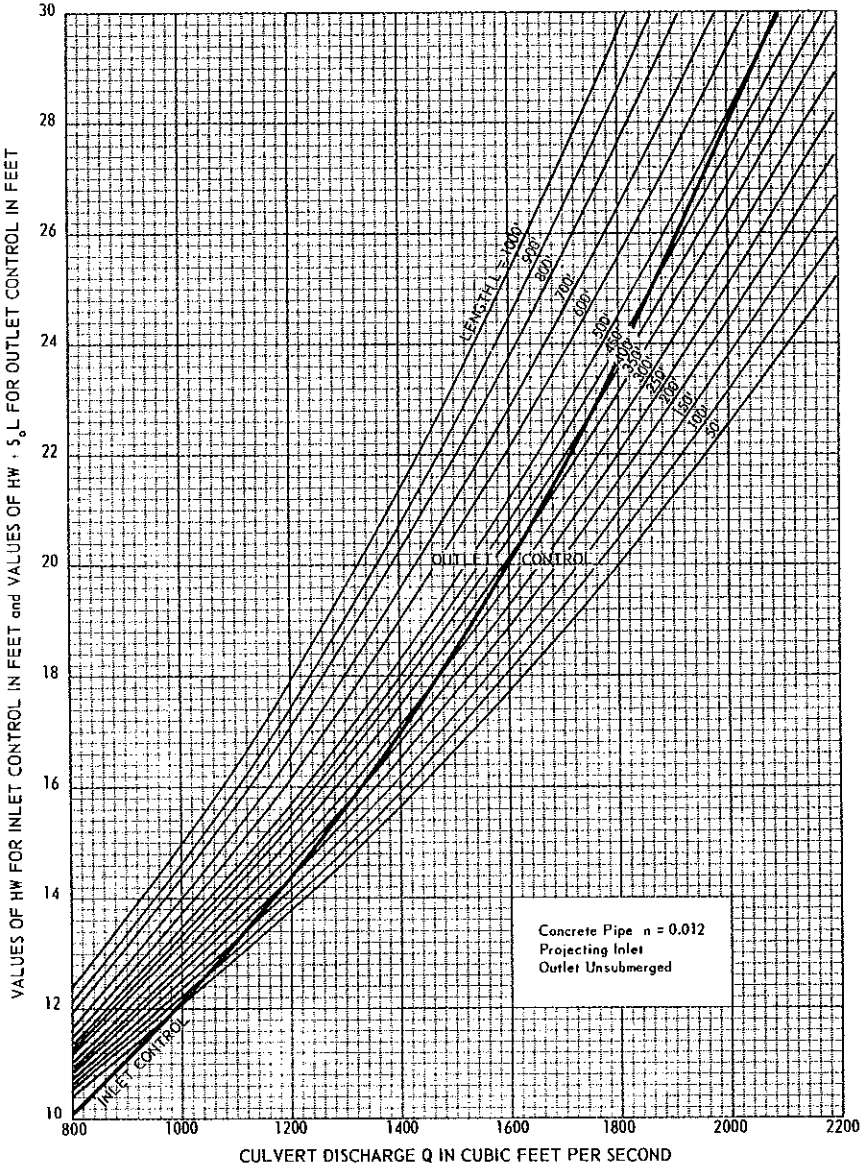
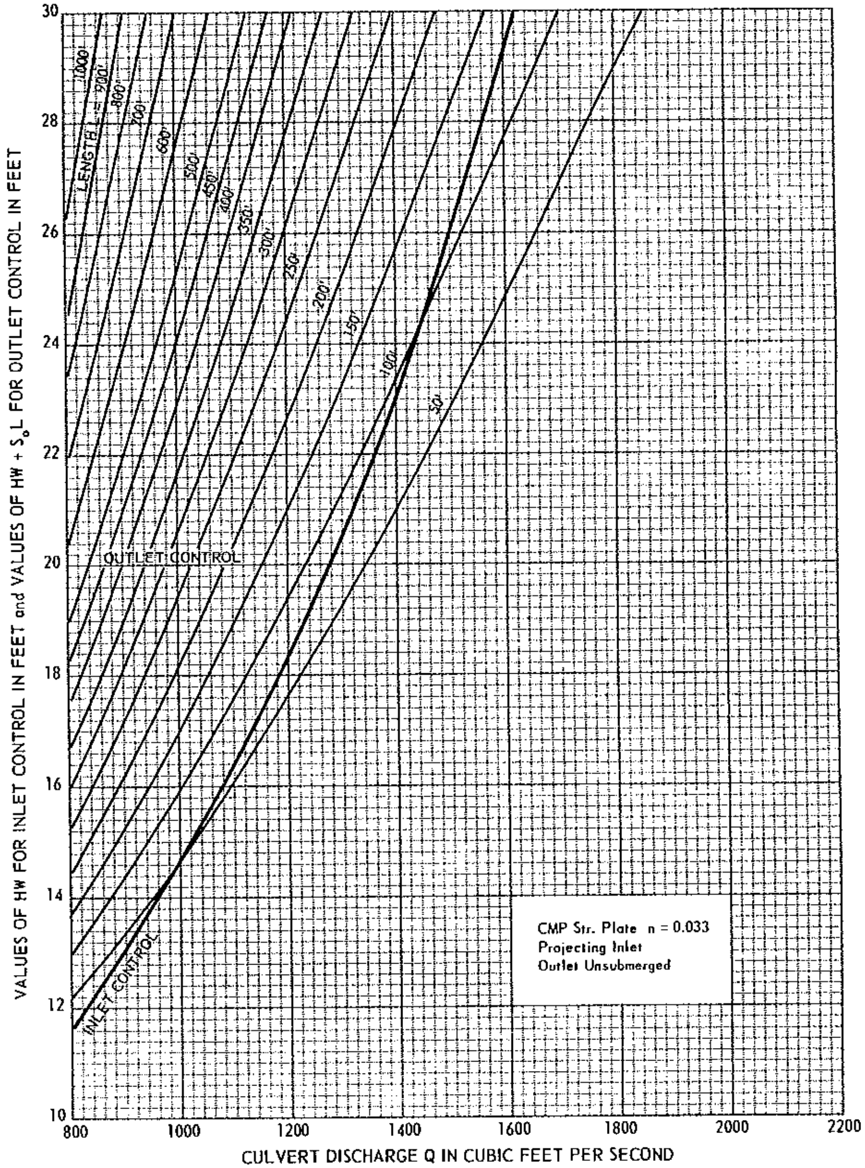


FIGURE 10: 120-Inch Diameter Corrugated Metal Pipe



Interpolate for intermediate culvert lengths

FIGURE 11: 132-Inch Diameter Concrete Pipe

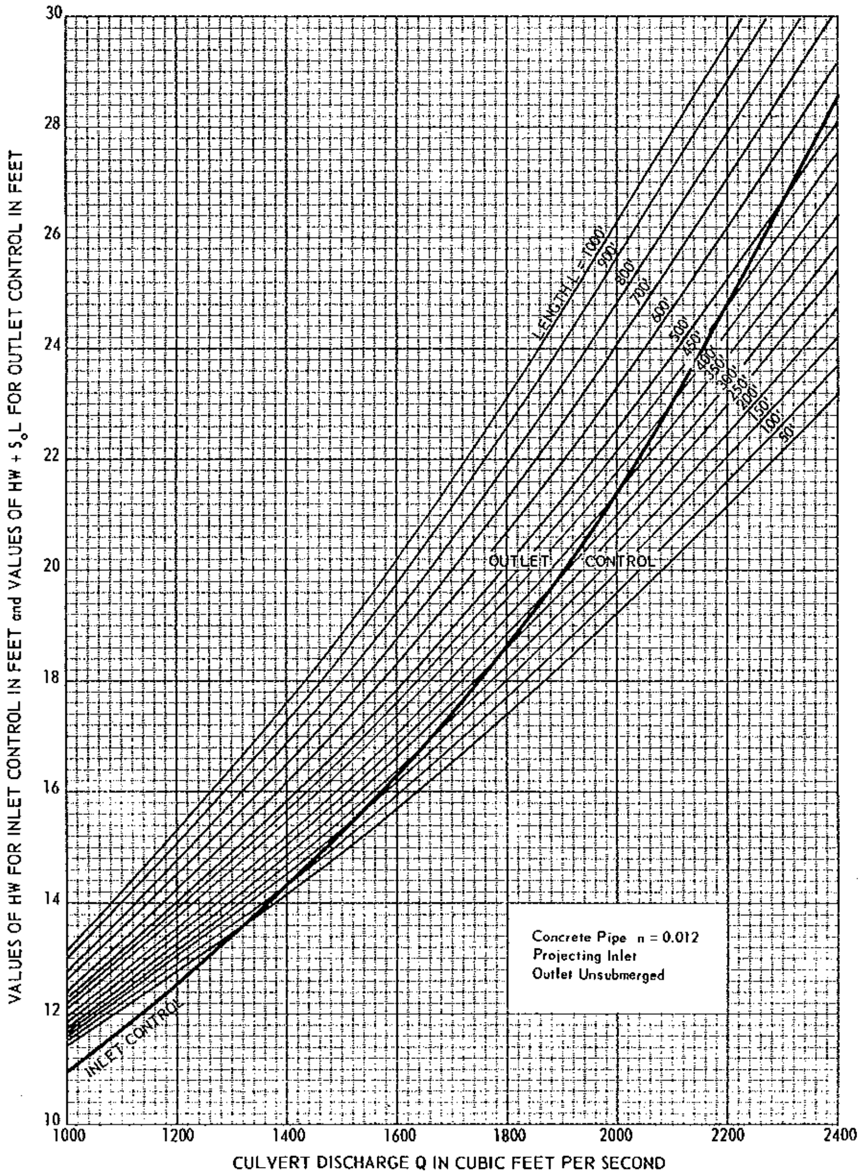
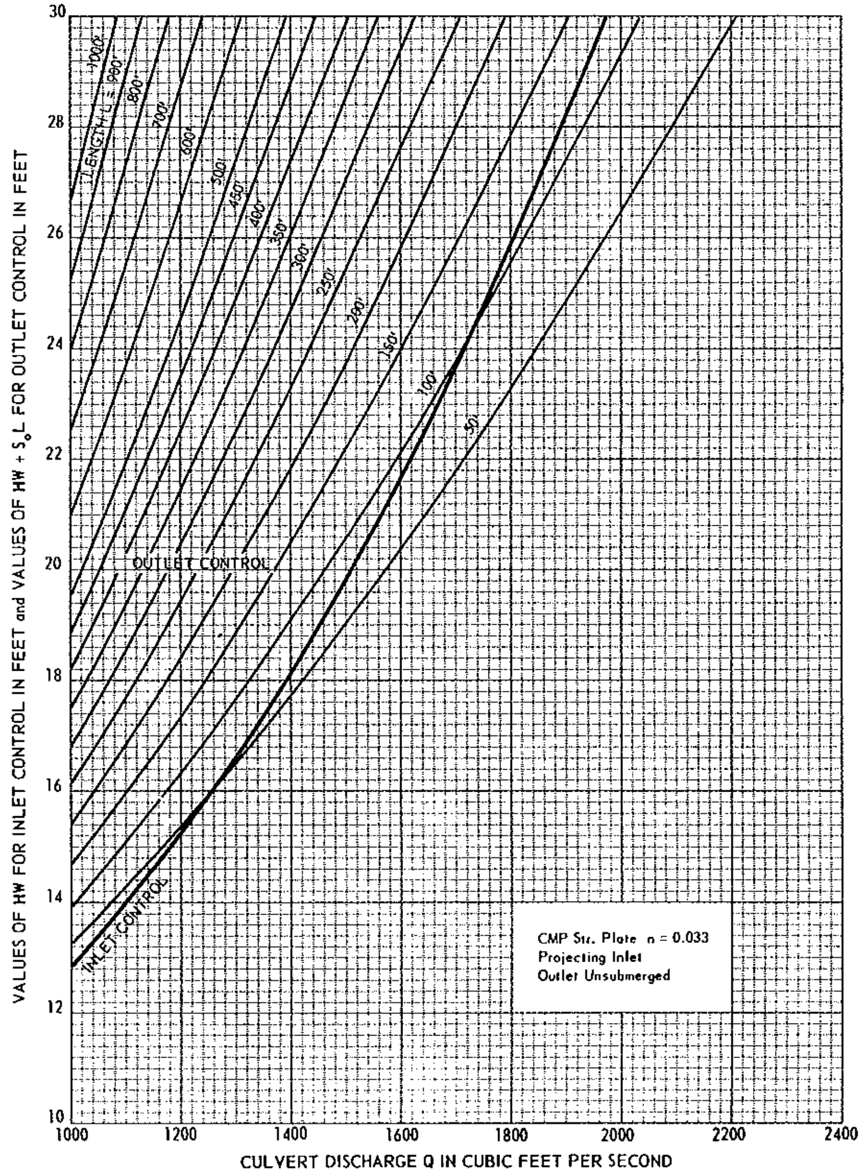


FIGURE 12: 132-Inch Diameter Corrugated Metal Pipe



Interpolate for intermediate culvert lengths

FIGURE 13: 144-Inch Diameter Concrete Pipe

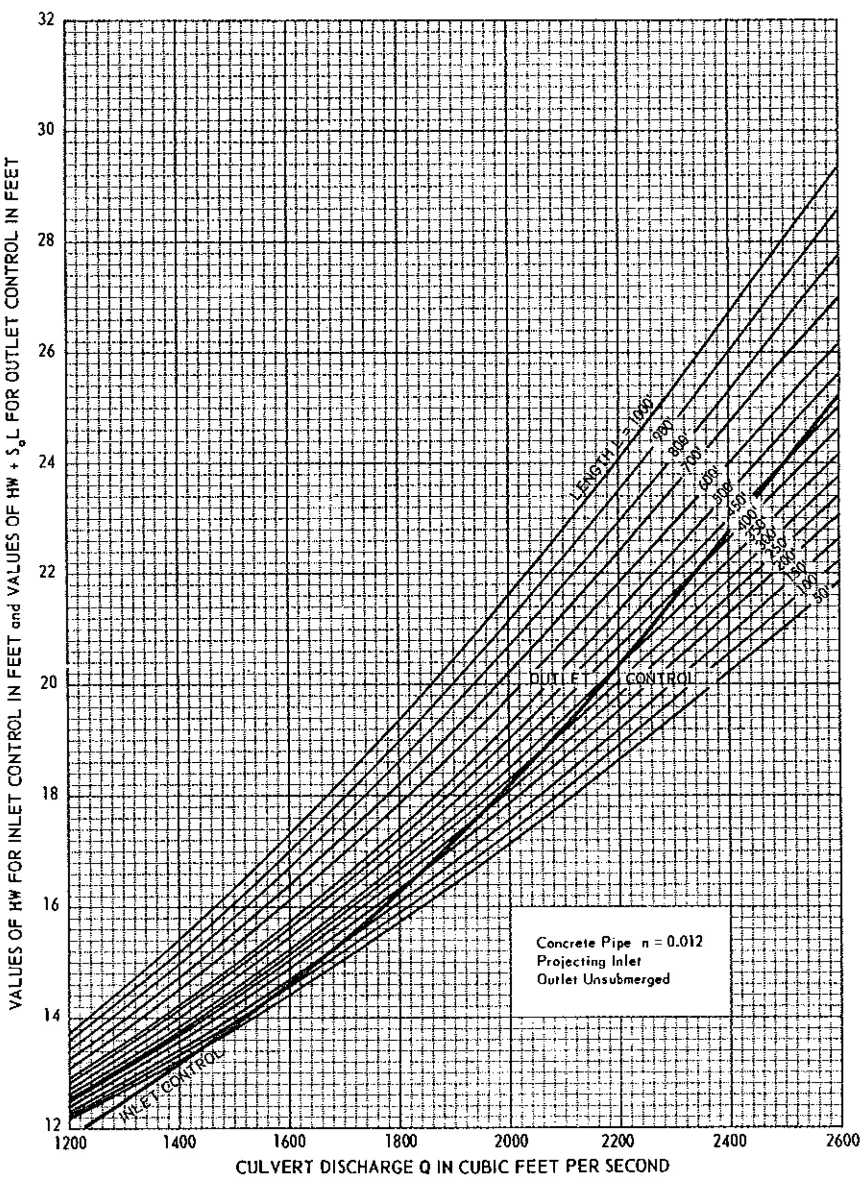
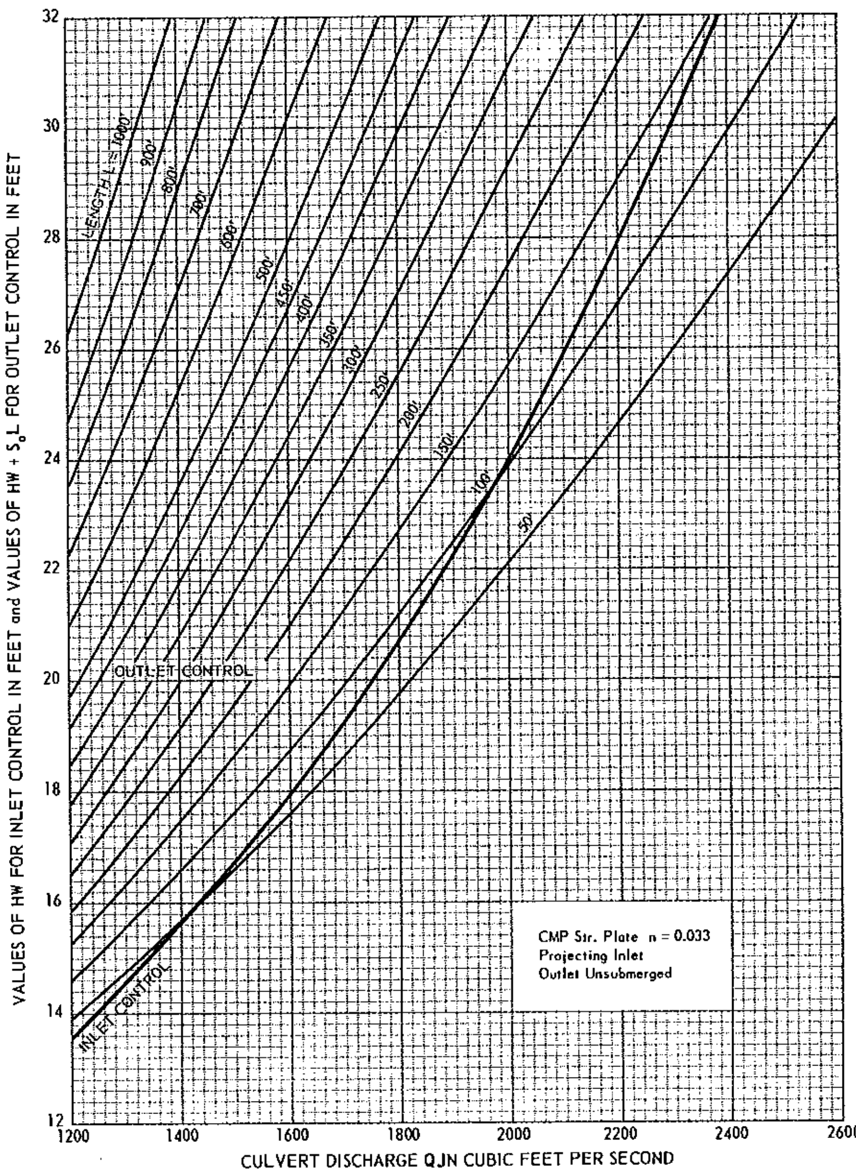


FIGURE 14: 144-Inch Diameter Corrugated Metal Pipe



Interpolate for intermediate culvert lengths

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