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design data 34

american concrete pipe association

HYDRAULICS OF CULVERTS: PRECAST CONCRETE BOX SECTIONS 11-FOOT AND 12-FOOT SPANS

Reinforced concrete box culverts have been designed and used for many years because of special waterway requirements, unusual load conditions at certain locations, or designer preference. As labor costs continue to rise, so do the cost associated with cast-in-place reinforced concrete. As the volume of highway traffic increases, so does the cost of inconvenience and delay associated with cast-in-place construction methods. American Society for Testing and Materials Standard C789, Precast Reinforced Concrete Box Sections for Culverts, Storm Drains and Sewer Pipe, and Standard C850, Precast Reinforced Concrete Box Sections for Culverts, Storm Drains, and Sewers with Less Than 2 Feet of Cover Subjected to Highway Loadings, were developed to provide a standard product for these applications and an opportunity for specifiers to utilize the inherent advantages of a precast product. For any project, the use of precast concrete pipe, which has recognized superior hydraulic, structural and construction advantages, should be thoroughly evaluated. The availability and construction details of box sections should be discussed with local concrete pipe producers.

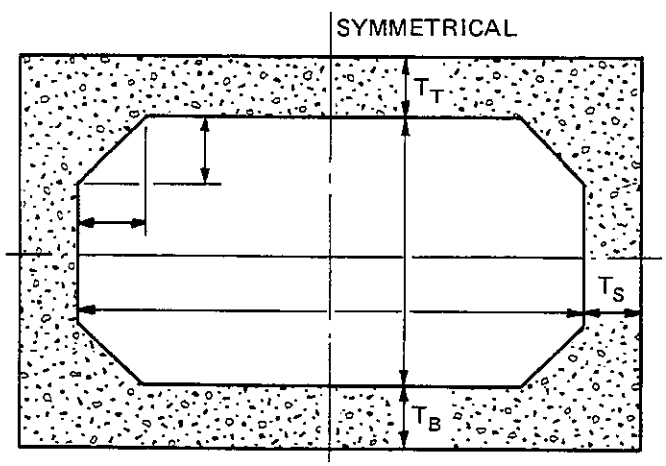
The hydraulic design of culverts establishes the minimum size which has sufficient capacity to discharge a required flow within an allowable headwater depth. When the culvert outlet is not submerged, the two principal types of flow that must be considered are flow under inlet control and flow under outlet control.

For any given headwater depth and box culvert size, the capacity of a box culvert operating under inlet control is dependent entirely on the inlet geometry. Therefore, if a box culvert 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 with the primary limiting factor being surface roughness. A precast concrete box culvert has an interior surface which results in a minimum of frictional resistance to flow and provides superior hydraulic efficiency.

The standard precast concrete box section produced under Standards C789 and C850 is shown in Figure 1, and standard sizes and thicknesses in Tables I and II. Generally, box culverts are designed with wing walls and a wing wall flare of 30-75 degrees as shown in Figure 2 encompasses a

FIGURE 1: Standard Box Section.



NOTE: The haunch dimension H, is equal to the wall thickness T_S.

FIGURE 2: Wing Wall Flare.

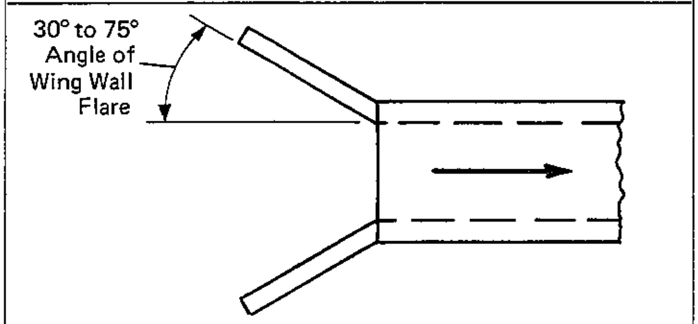


TABLE I: Standard Box Sizes.

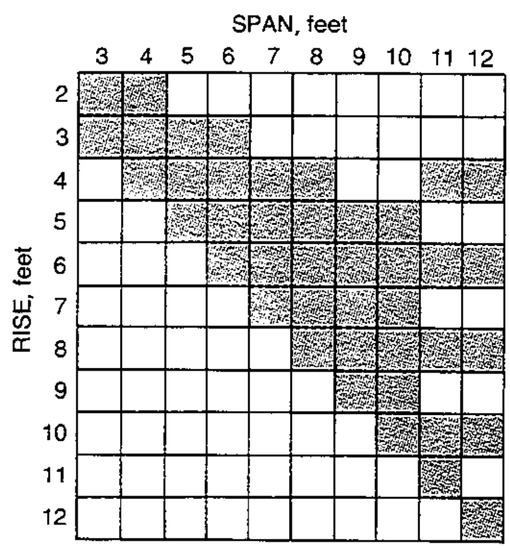


TABLE II: Standard Thicknesses.

SPAN, Feet	T_T, inches		T_B, inches		T_S, inches	
	C789	C850	C789	C850	C789	C850
3	4	7	4	6	4	4
4	5	7½	5	6	5	5
5	6	8	6	7	6	6
6	7	8	7	7	7	7
7	8	8	8	8	8	8
8	8	8	8	8	8	8
9	9	9	9	9	9	9
10	10	10	10	10	10	10
11	11	11	11	11	11	11
12	12	12	12	12	12	12

majority of installations. The precast concrete box sections commonly have a tongue and groove joint configuration similar to precast concrete pipe. The entrance loss coefficient, k_e, is 0.2 for concrete pipe with the groove end projecting. The box section groove also provides basically a rounded crown edge and therefore, an entrance loss coefficient of 0.2 should apply.

Performance curves for the hydraulic design of standard precast concrete box culverts are presented in Figures 3 through 12. These curves correlate discharge-headwater depth and are based on nomographs included in Hydraulic Engineering Circular Number 5, Federal Highway Administration, with a recommended roughness coefficient of 0.012. 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.

A complete discussion of the hydraulics of culverts is presented in Design Data 8, Hydraulics of Culverts; 12-inch through 21-inch Diameter Pipe and specifics on the hydraulic properties of precast concrete box sections in Design Data 26, Hydraulic Capacity of Precast Concrete Boxes.

EXAMPLE

Given: A 200-foot long precast reinforced box culvert is to be installed on a one percent slope under a 4-lane divided highway at the low point of a vertical curve in the highway profile. There will be a minimum of one foot of cover over the box section and the lowest elevation on the highway pavement will be 10 feet above the invert elevation of the entrance of the culvert. The culvert is required to carry a maximum flow of 800 cubic feet per second. Pipe producers in the area have forms available for 12-foot span box sections.

Find: Size of precast concrete box section required and type of control.

Solution: The allowable headwater is assumed to be 10 feet, since headwater depth in excess of 10 feet will flood the roadway and no information is available about the upstream channel.

The first trial size is obtained by dividing the allowable headwater by two. Since 10/2 is equal to 5 feet and no standard size is available with a rise of 5 feet, use a rise of 6 feet.

Enter Figure 9 for a 12-foot span at Q equal to 800 cubic feet per second on the horizontal scale and project a vertical line to the inlet control curve. Project a horizontal line to the vertical scale and read the inlet control headwater depth of 9 feet. Since this value is smaller than the allowable headwater depth, try the next smaller size box section.

Enter Figure 8 for a 12-foot span at Q equal to 800 cubic feet per second, proceed in a similar manner and read the inlet control headwater depth of 13.0 feet. Since this value is greater than the maximum allowable, check the 12 × 6-foot box, Figure 9, for outlet control.

Entering Figure 9 at Q equal to 800 cubic feet per second and projecting a vertical line to the outlet control curve for L equal to 200 feet and projecting a horizontal line to the vertical scale, the outlet control plus slope times length is 8.7. Subtracting slope times length would result in 6.7 feet, a lower value than the inlet control headwater depth of 9 feet. Therefore, inlet control governs.

Answer: A 12-foot × 6-foot box section will carry the discharge with a headwater depth of 9 feet and operate under inlet control.

FIGURE 3: Culvert Capacity—11 × 4-foot (Span × Rise) Box Section, Equivalent 88-inch Circular.

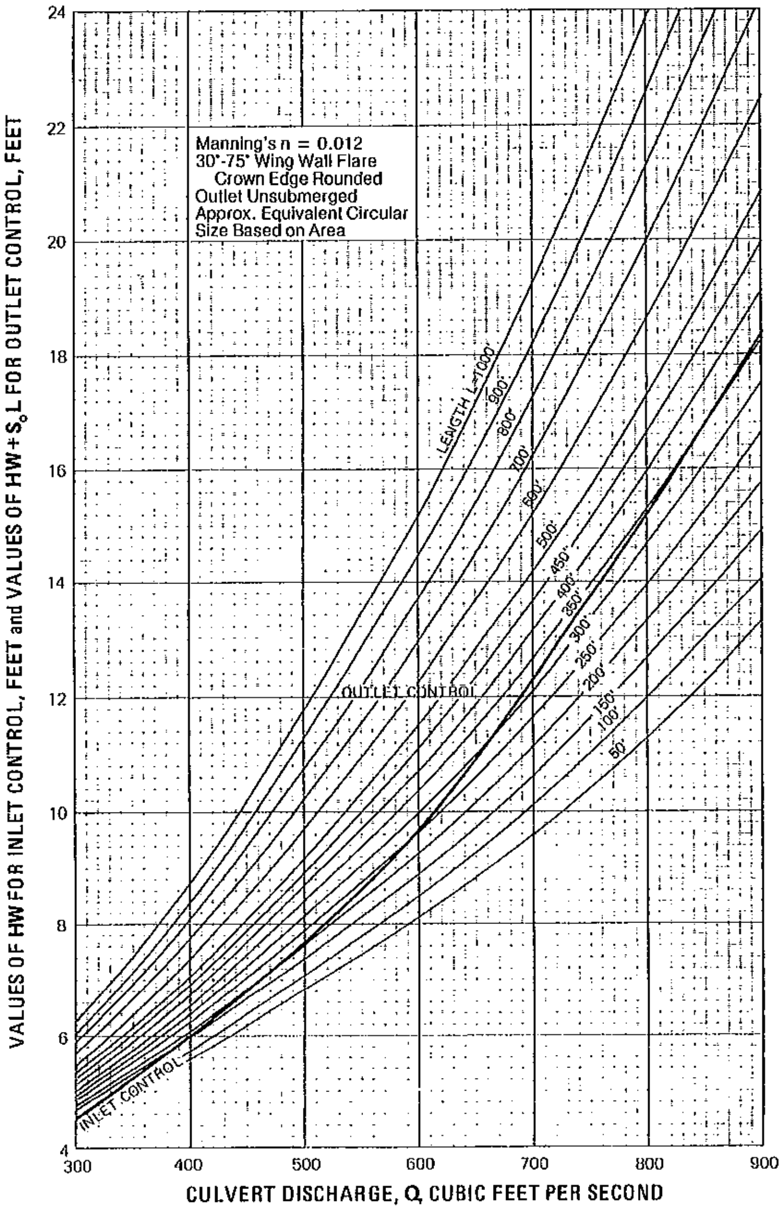
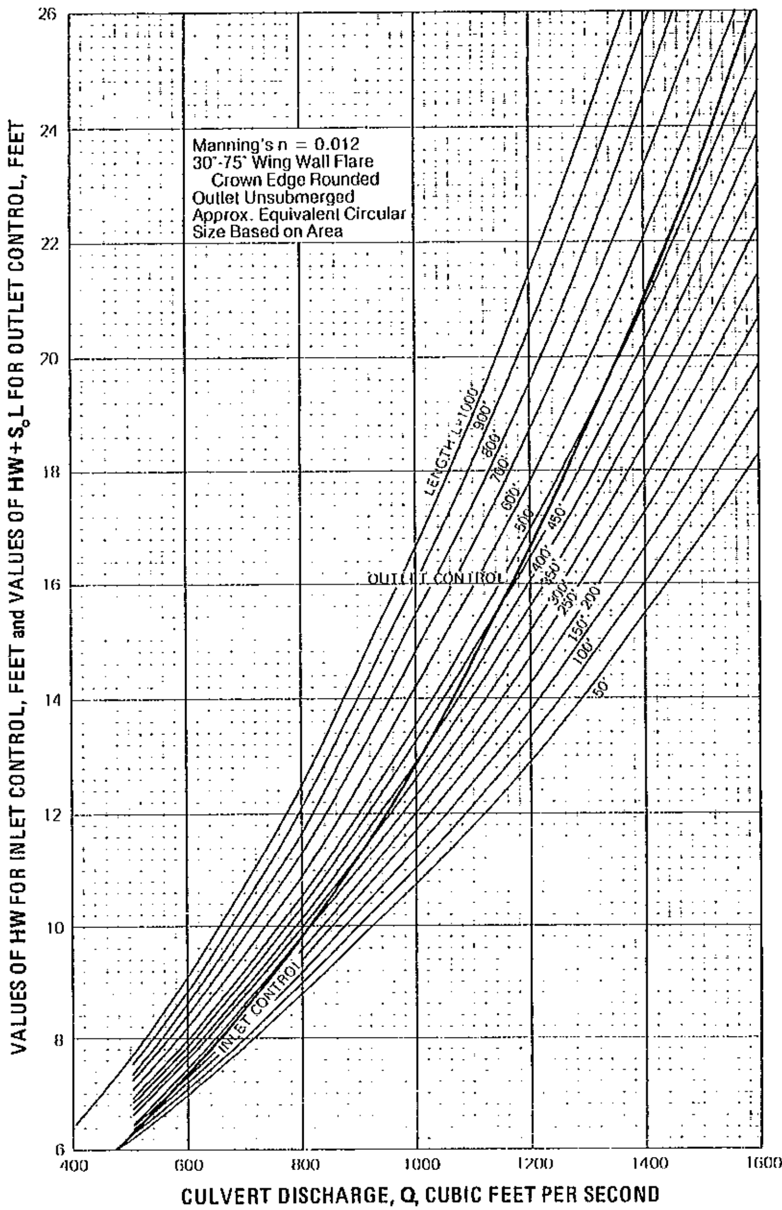


FIGURE 4: Culvert Capacity—11 x 6-foot (Span × Rise) Box Section, Equivalent 108-inch Circular.



Interpolate for intermediate culvert length

FIGURE 5: Culvert Capacity—11 × 8-foot (Span × Rise) Box Section, Equivalent 126-inch Circular.

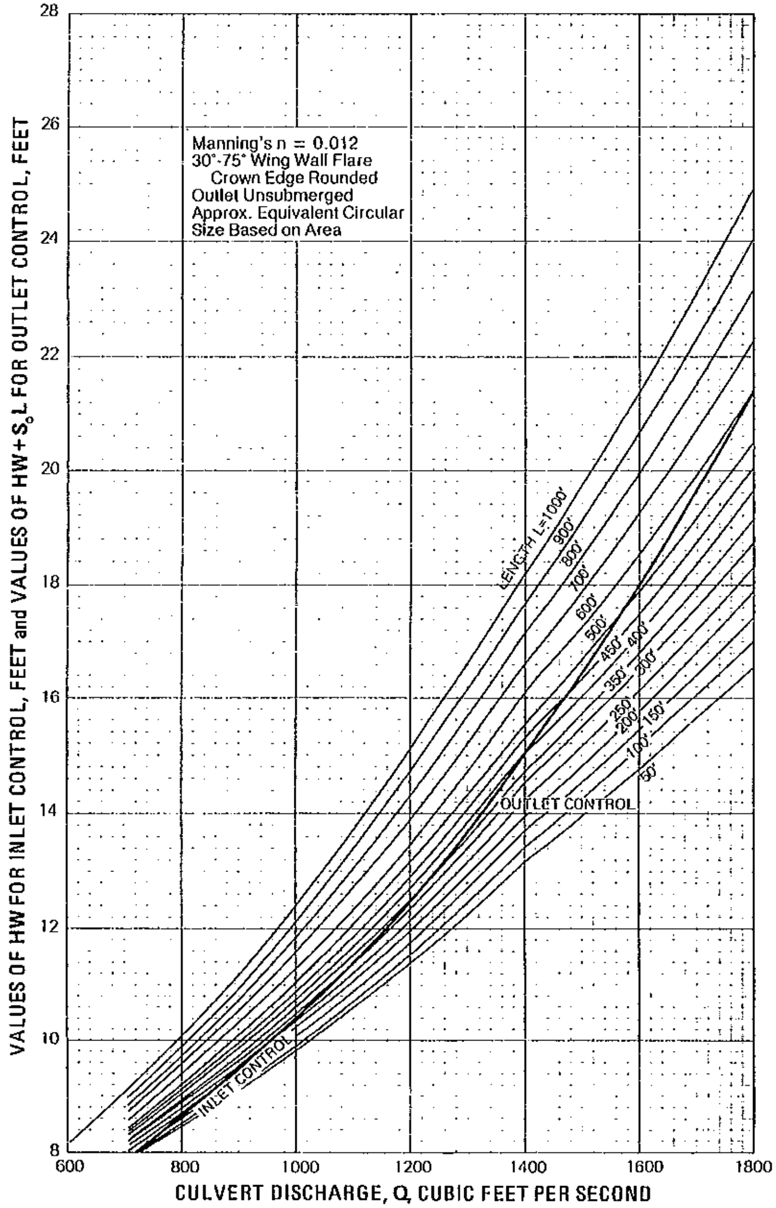
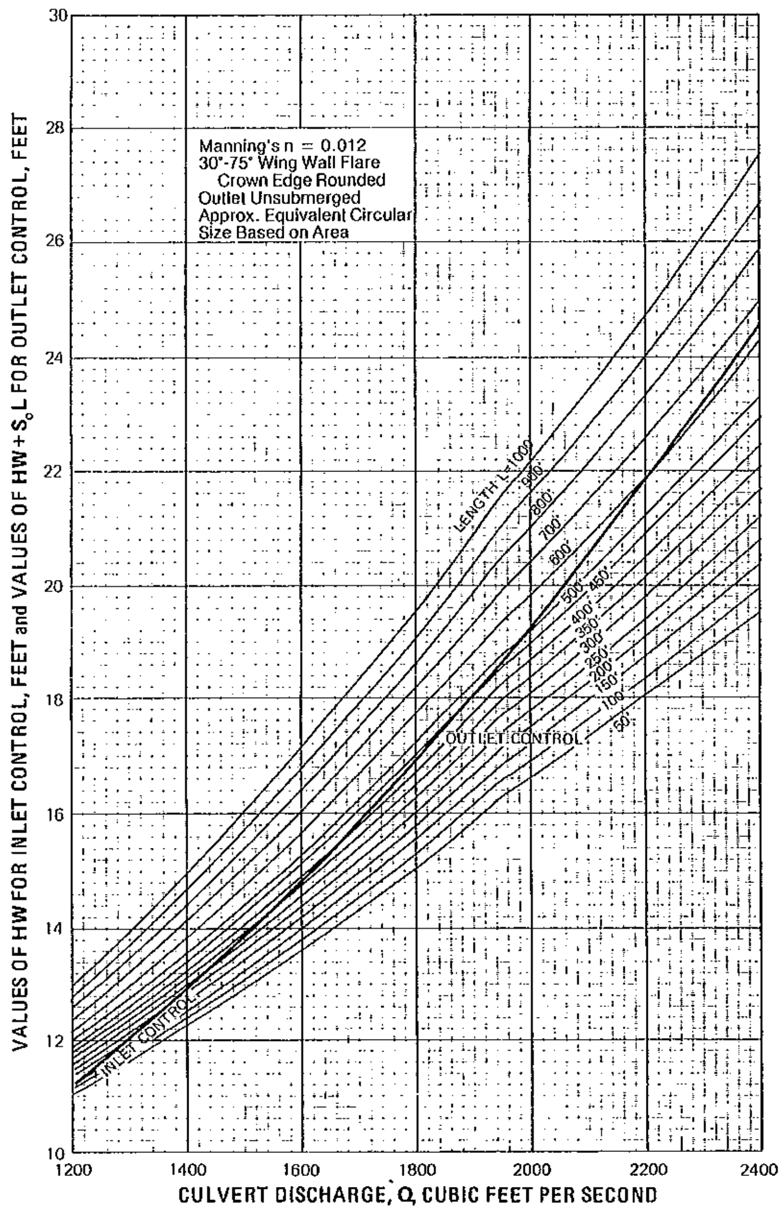


FIGURE 6: Culvert Capacity—11 × 10-foot (Span × Rise) Box Section, Equivalent 140-inch Circular.



Interpolate for intermediate culvert length

FIGURE 7: Culvert Capacity—11 × 11-foot (Span × Rise) Box Section, Equivalent 148-inch Circular.

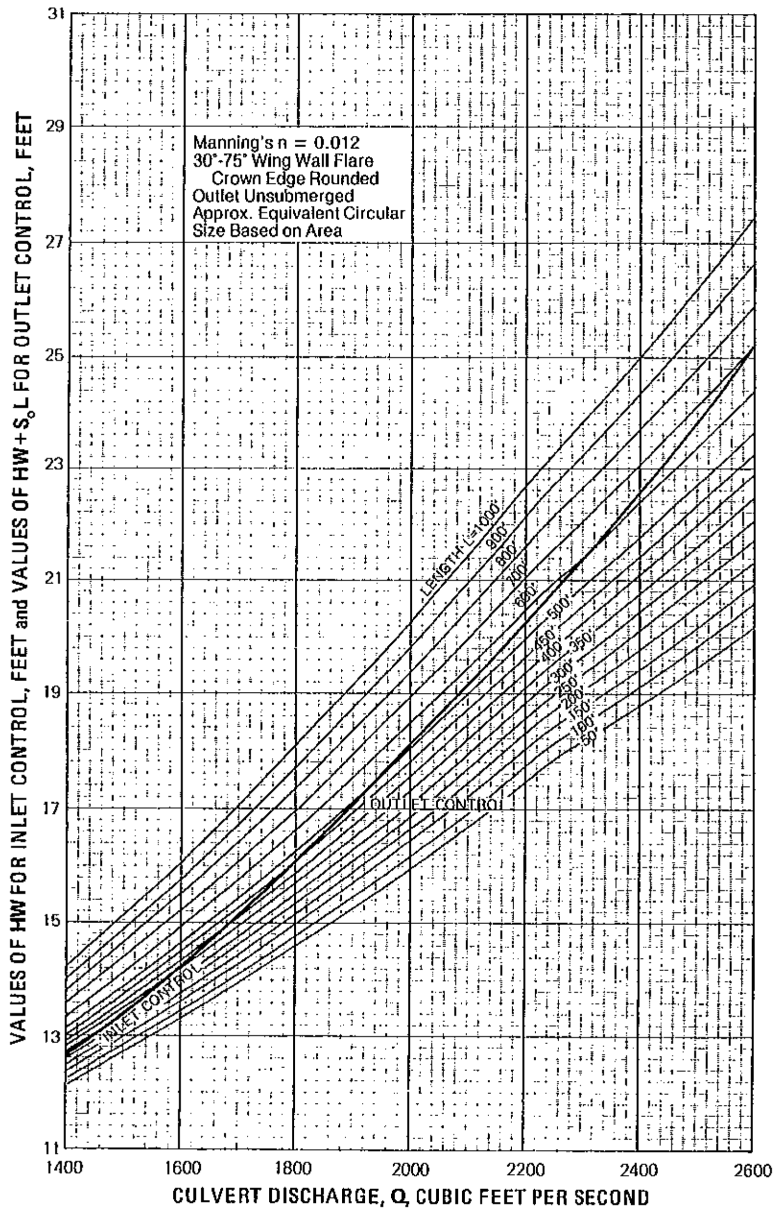
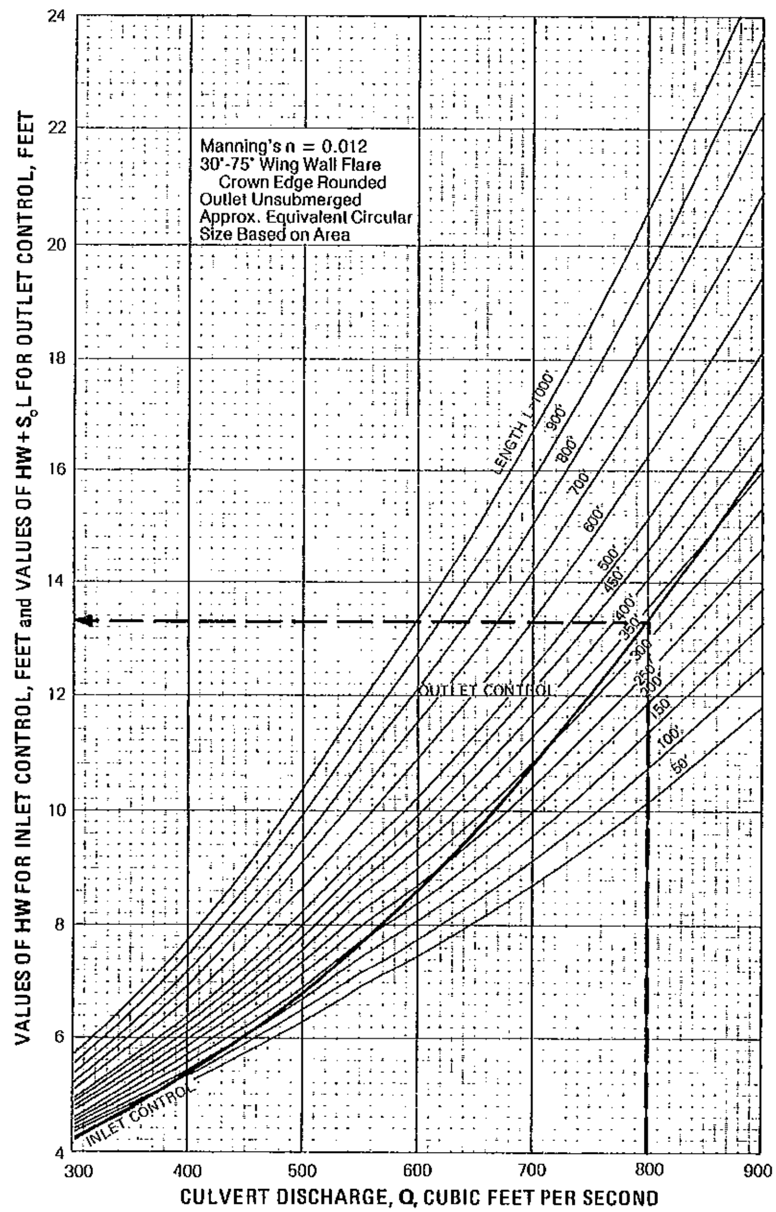


FIGURE 8: Culvert Capacity—12 × 4-foot (Span × Rise) Box Section, Equivalent 92-inch Circular.



Interpolate for intermediate culvert length

FIGURE 9: Culvert Capacity—12 × 6-foot (Span × Rise) Box Section, Equivalent 113-inch Circular.

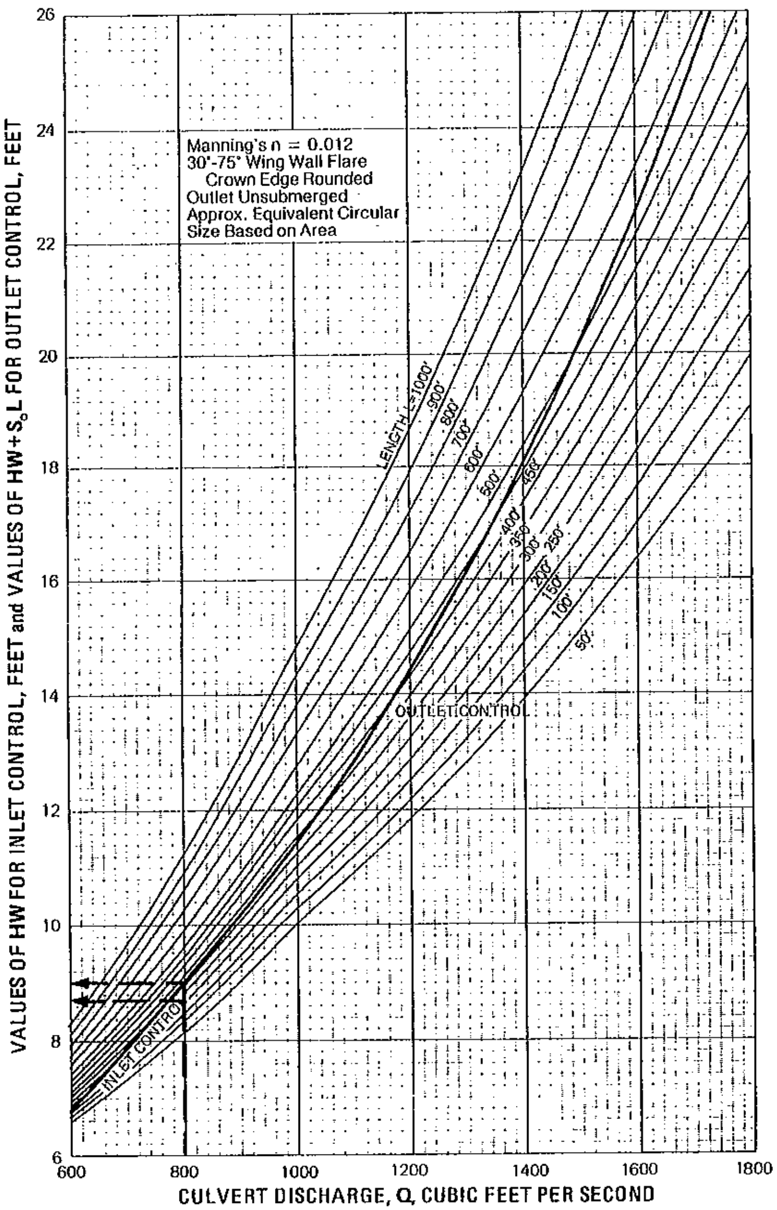
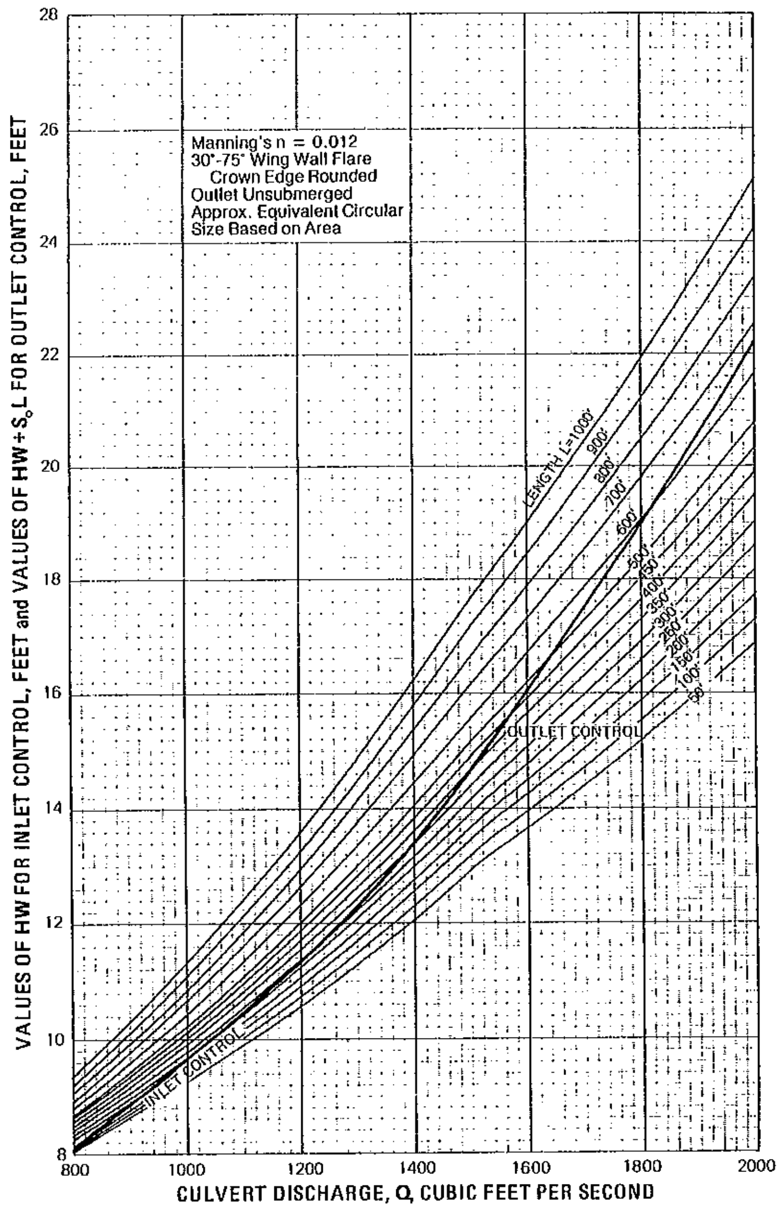


FIGURE 10: Culvert Capacity—12 × 8-foot (Span × Rise) Box Section, Equivalent 131-inch Circular.



Interpolate for intermediate culvert length

FIGURE 11: Culvert Capacity—12 × 10-foot (Span × Rise) Box Section, Equivalent 147-inch Circular.

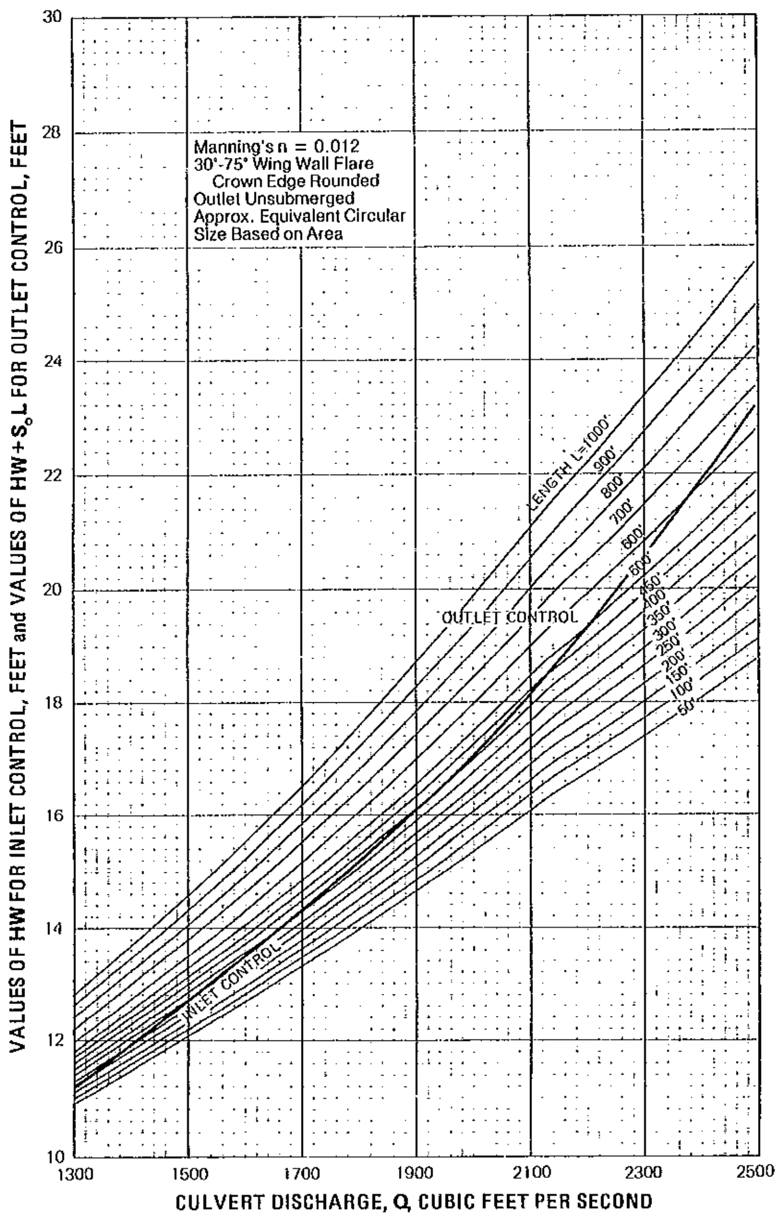
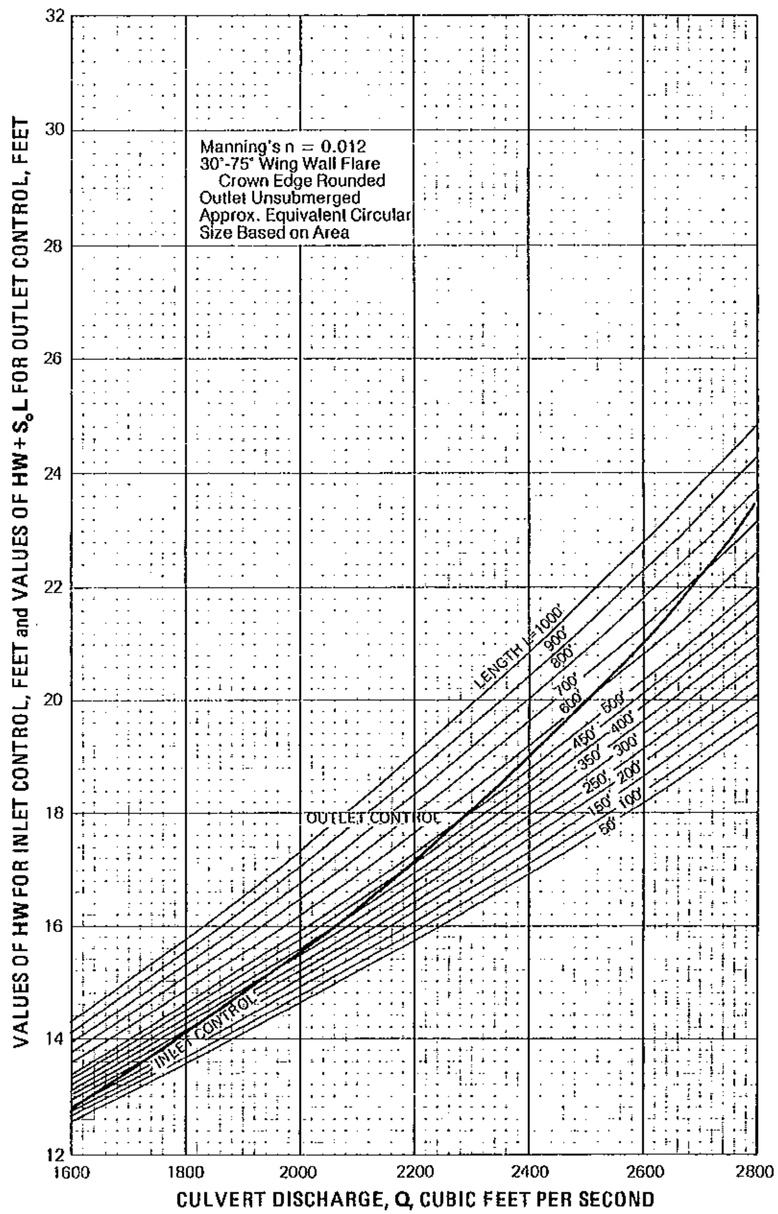


FIGURE 12: Culvert Capacity—12 × 12-foot (Span × Rise) Box Section, Equivalent 161-inch Circular.



Interpolate for intermediate culvert length