

# **design data 28**



## **HYDRAULICS OF CULVERTS: PRECAST CONCRETE BOX SECTIONS 7-FOOT THROUGH 10-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 costs 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.*

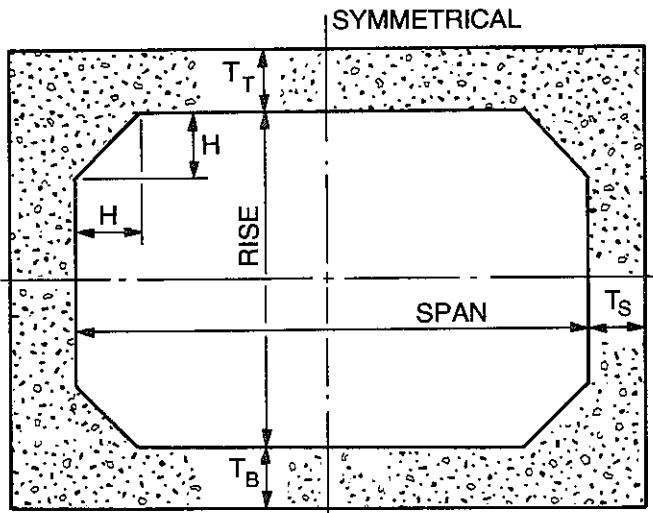
The hydraulic design of culverts establishes the minimum size which has sufficient capacity to discharge a required flow within an allowable headwater depth. When the culvert outlet is not submerged, the two principal types of flow that must be considered are flow under inlet control and flow under outlet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

**TABLE I: Standard Box Sizes**

**FIGURE 1:** Standard Box Section



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

The graph plots Span (feet) on the x-axis (ranging from 3 to 12) against Rise (feet) on the y-axis (ranging from 2 to 12). The data points form a series of diagonal lines, indicating that for a fixed rise, the span must be a multiple of 12 feet. The lines are labeled with their respective rise values: 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, and 12. The area under these lines is shaded black.

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

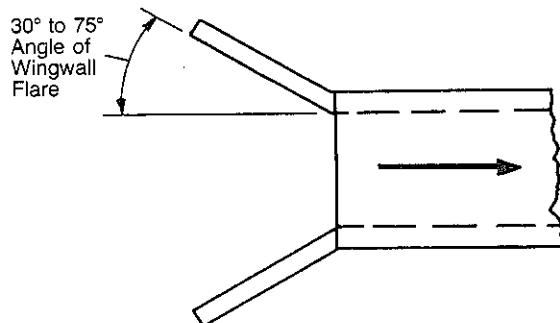
Performance curves for the hydraulic design of the standard precast concrete box culvert are presented in Figures 3 through 22. These curves correlate discharge-headwater depth and are based on nomographs included in Hydraulic Engineering Circular Number 5, Federal Highway Administration, with a recommended 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.

**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

**FIGURE 2: Wingwall Flare**



#### EXAMPLE

**Given:** An 800-foot long box culvert is to be installed on a 0.5 percent slope. Due to minimum cover requirements, the maximum rise is limited to 8 feet. It is required to carry a maximum flow of 1,000 cubic feet per second with an allowable headwater depth of 15 feet.

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

**Solution:** Investigate three concrete box culvert sections, 8 × 8-foot, 9 × 7-foot and 10 × 6-foot, which meet the maximum rise limit of 8 feet.

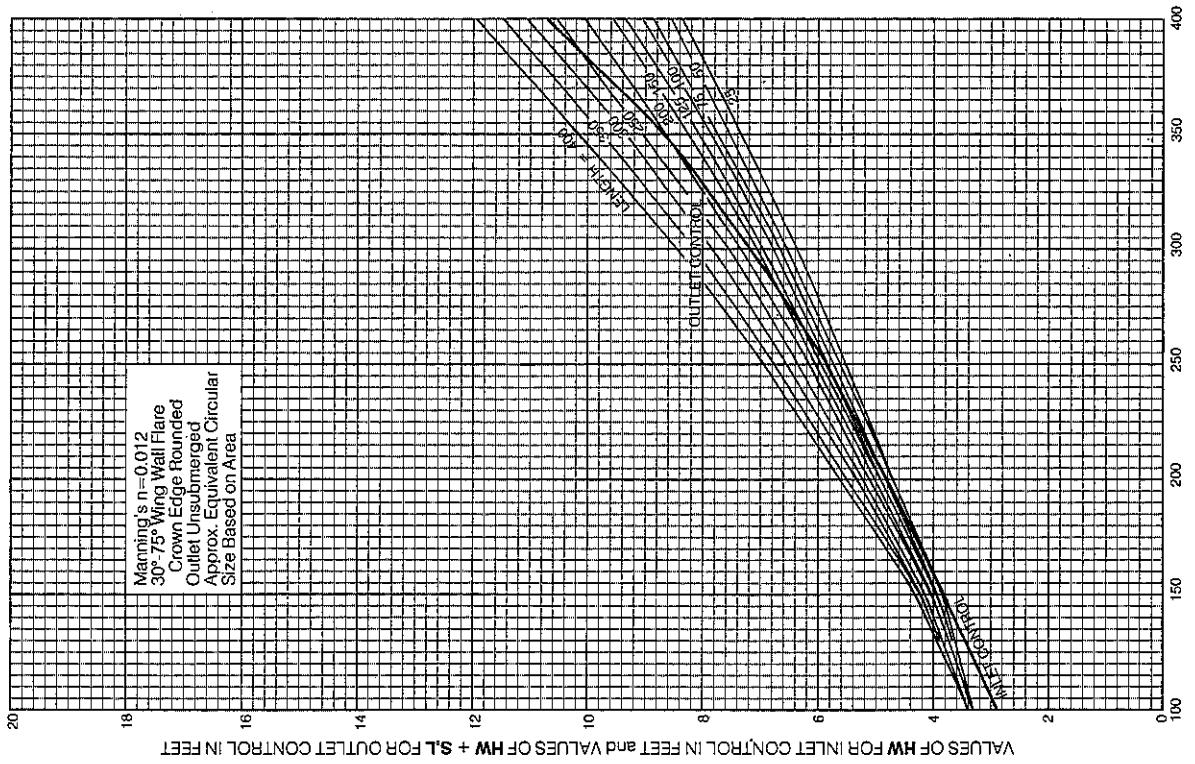
Enter Figure 11: 8 × 8-foot concrete box section, and project a vertical line from  $Q = 1,000$  to the inlet control curve and the outlet control curve for  $L = 800$  feet. Project horizontally to the vertical scale and read a headwater depth of 14.8 feet for inlet control and a value of 17.5 feet for outlet control. To obtain outlet control headwater depth, subtract the value ( $S_0 \times L$ ) from the outlet control value:  $17.5 - (0.005 \times 800) = 13.5$  feet for the outlet control headwater depth. Therefore inlet control governs.

Entering Figure 14: 9 × 7-foot concrete box section and proceeding in a similar manner, read a headwater depth of 14.7 feet for inlet control and obtain 13.1 feet for the outlet control headwater depth with inlet control governing.

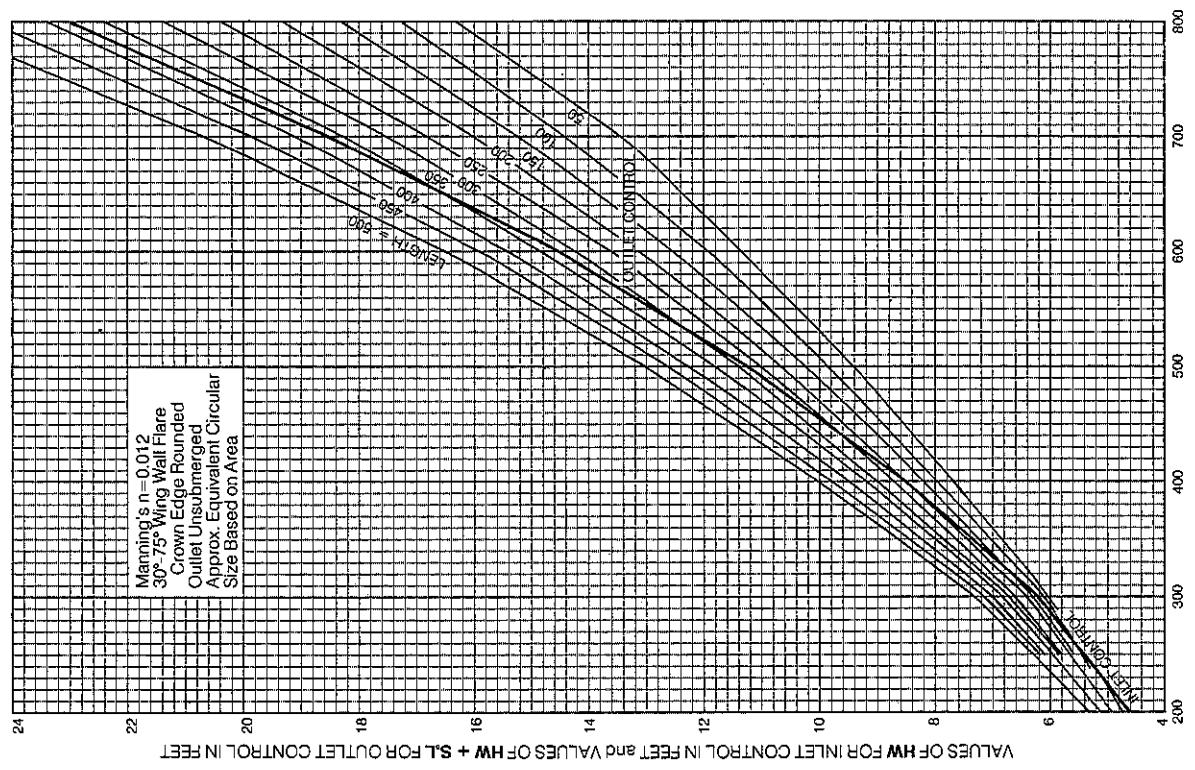
Entering Figure 18: 10 × 6-foot concrete box section and again proceeding in a similar manner, read a headwater depth of 14.4 feet for inlet control and obtain 13.5 feet for the outlet control headwater depth with inlet control governing.

**Answer:** Therefore, each of the concrete box culvert sections, 8 × 8-foot, 9 × 7-foot and 10 × 6-foot, will carry the design discharge within the allowable headwater depth of 15 feet and is under inlet control.

**FIGURE 3: Culvert Capacity—7 x 4-foot Precast Box Section  
Equivalent 71-inch Circular**



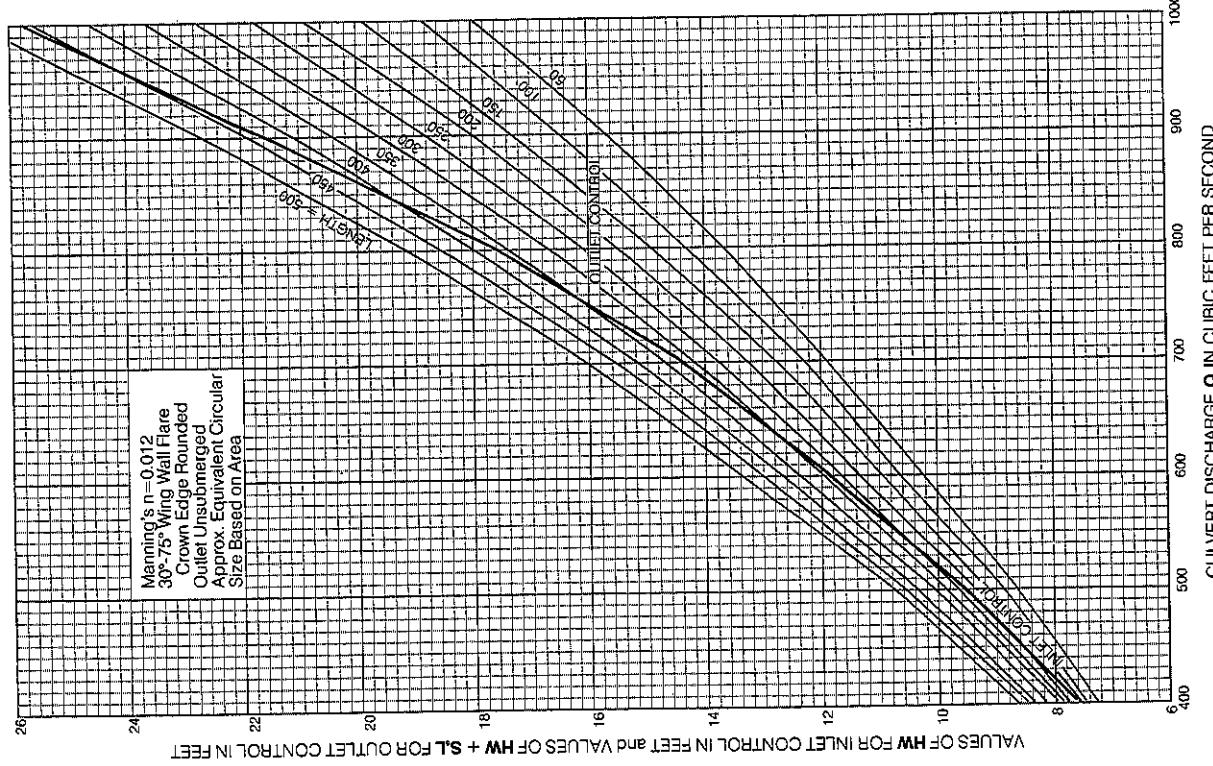
**FIGURE 4: Culvert Capacity—7 x 5-foot Precast Box Section  
Equivalent 79-inch Circular**



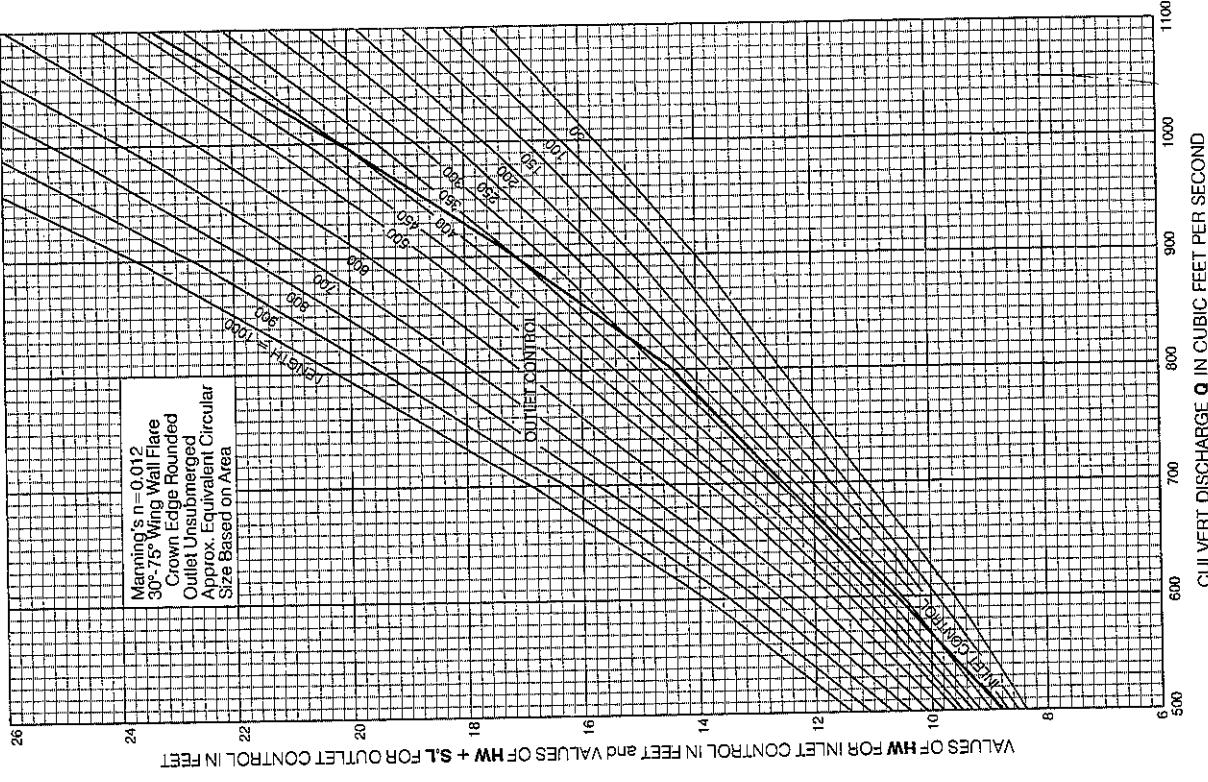
Interpolate for intermediate culvert lengths

**FIGURE 5: Culvert Capacity—7 x 6-foot Precast Box Section  
Equivalent 87-inch Circular**

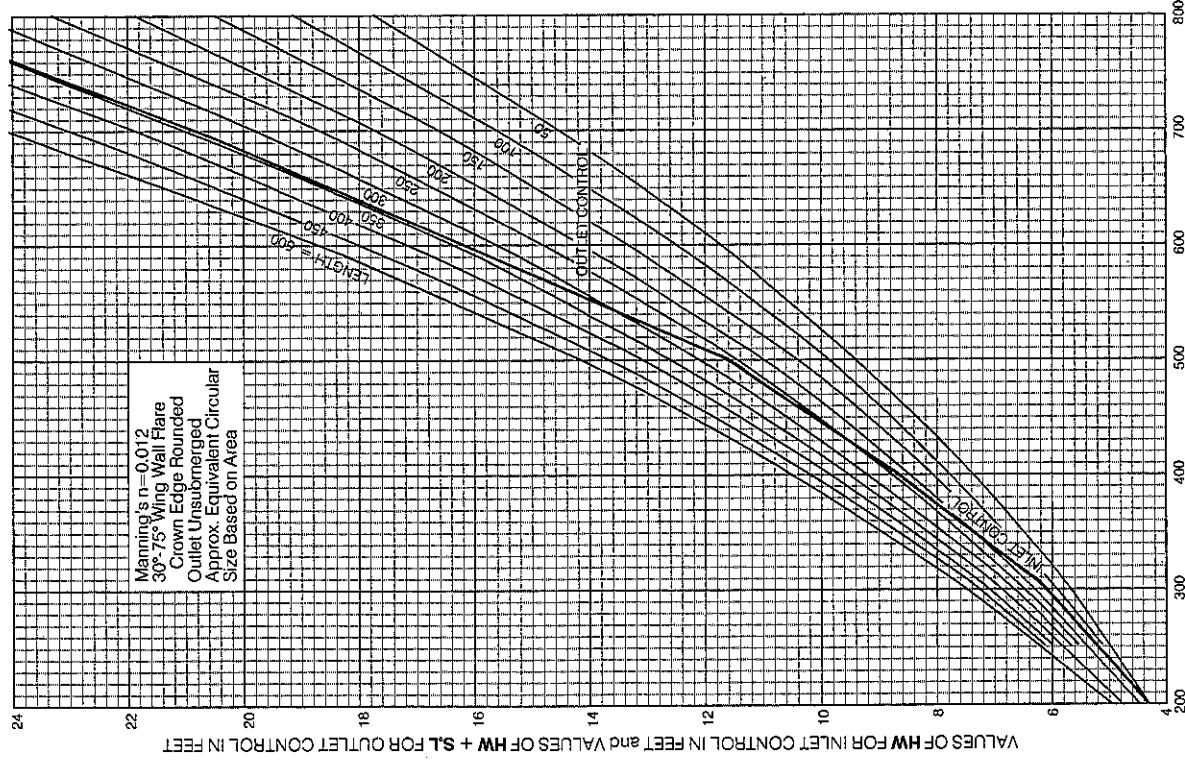
**FIGURE 6: Culvert Capacity—7 x 7-foot Precast Box Section  
Equivalent 94-inch Circular**



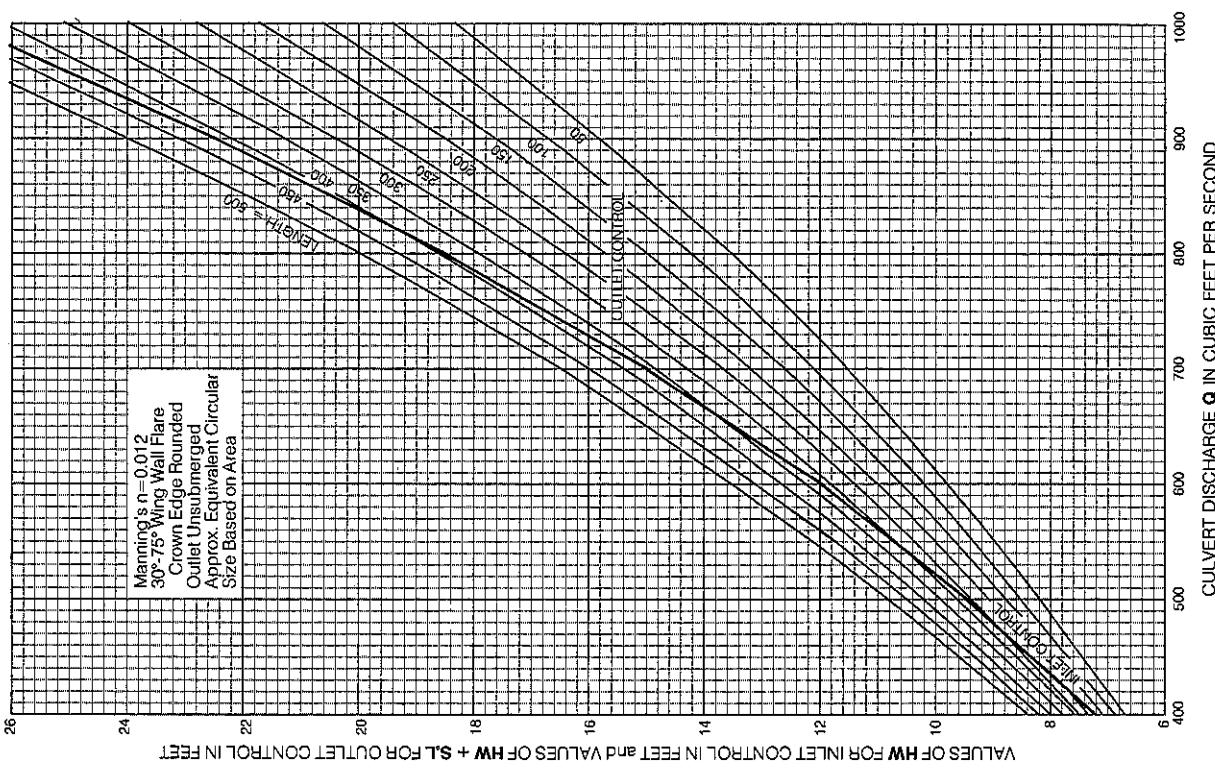
Interpolate for intermediate culvert lengths



**FIGURE 7: Culvert Capacity—8 x 4-foot Precast Box Section  
Equivalent 76-inch Circular**

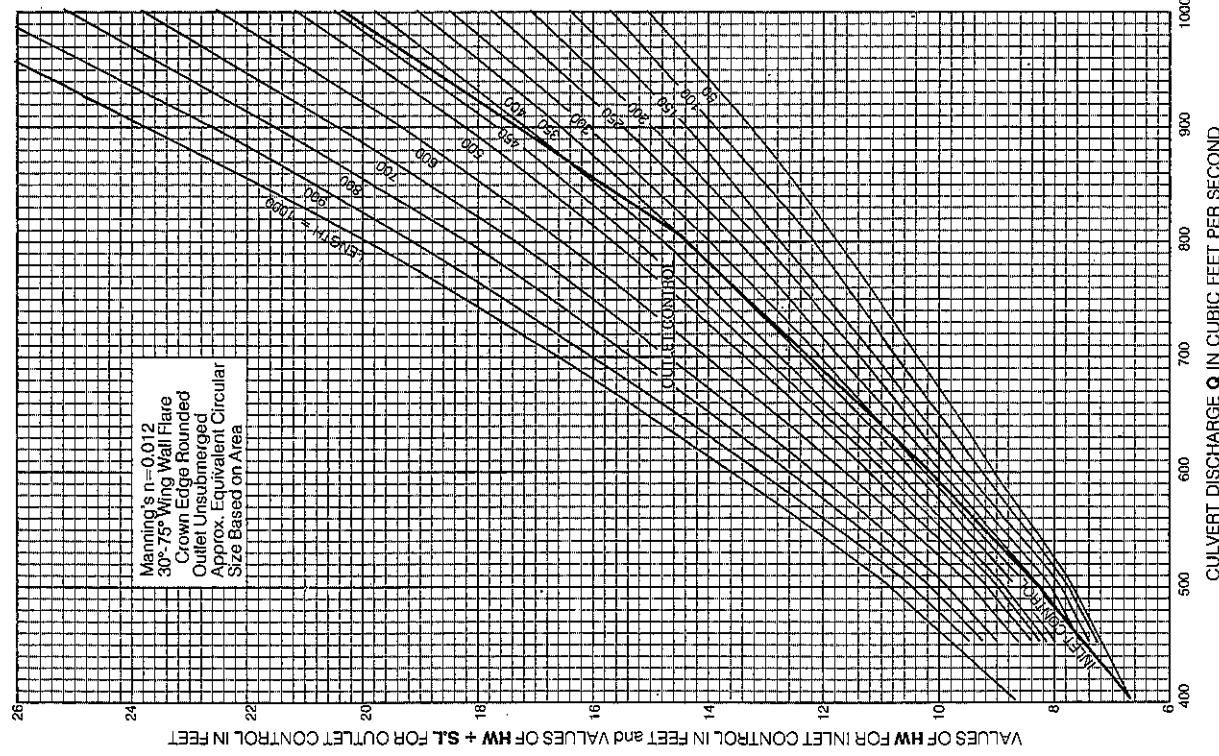


**FIGURE 8: Culvert Capacity—8 x 5-foot Precast Box Section  
Equivalent 85-inch Circular**



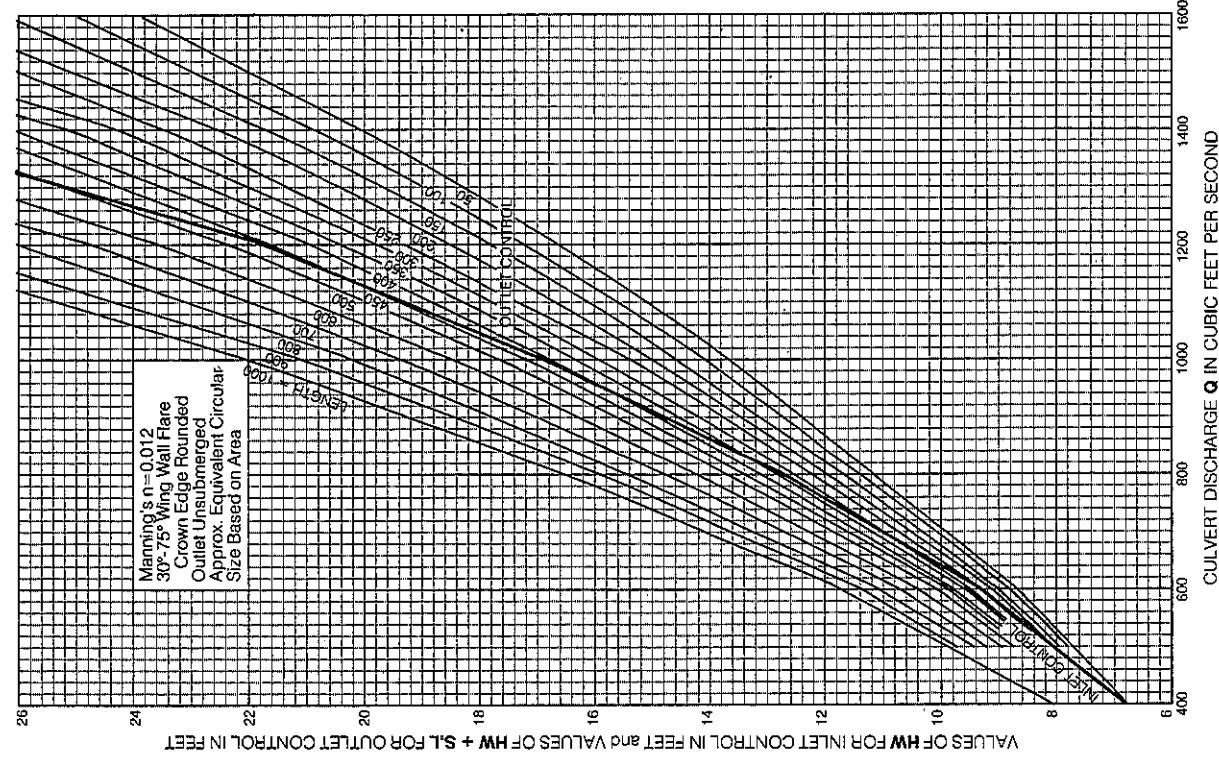
Interpolate for intermediate culvert lengths

**FIGURE 9: Culvert Capacity—8 x 6-foot Precast Box Section  
Equivalent 93-inch Circular**

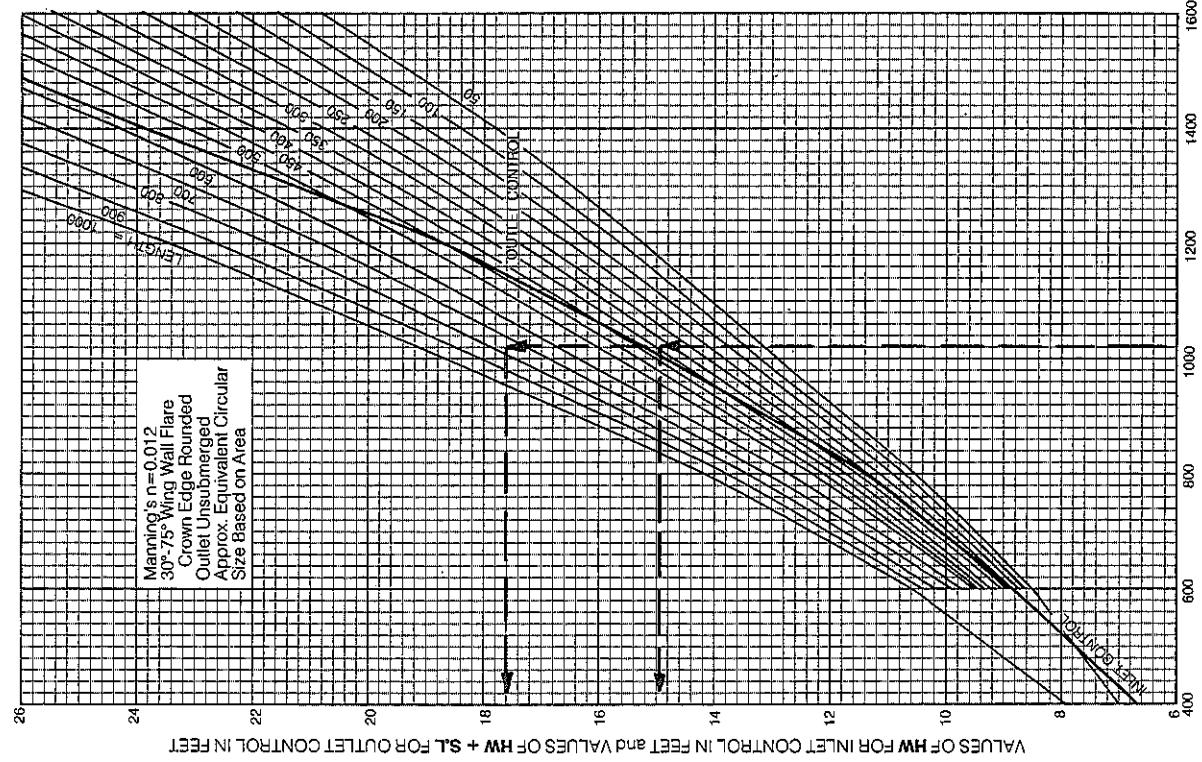


Interpolate for intermediate culvert lengths

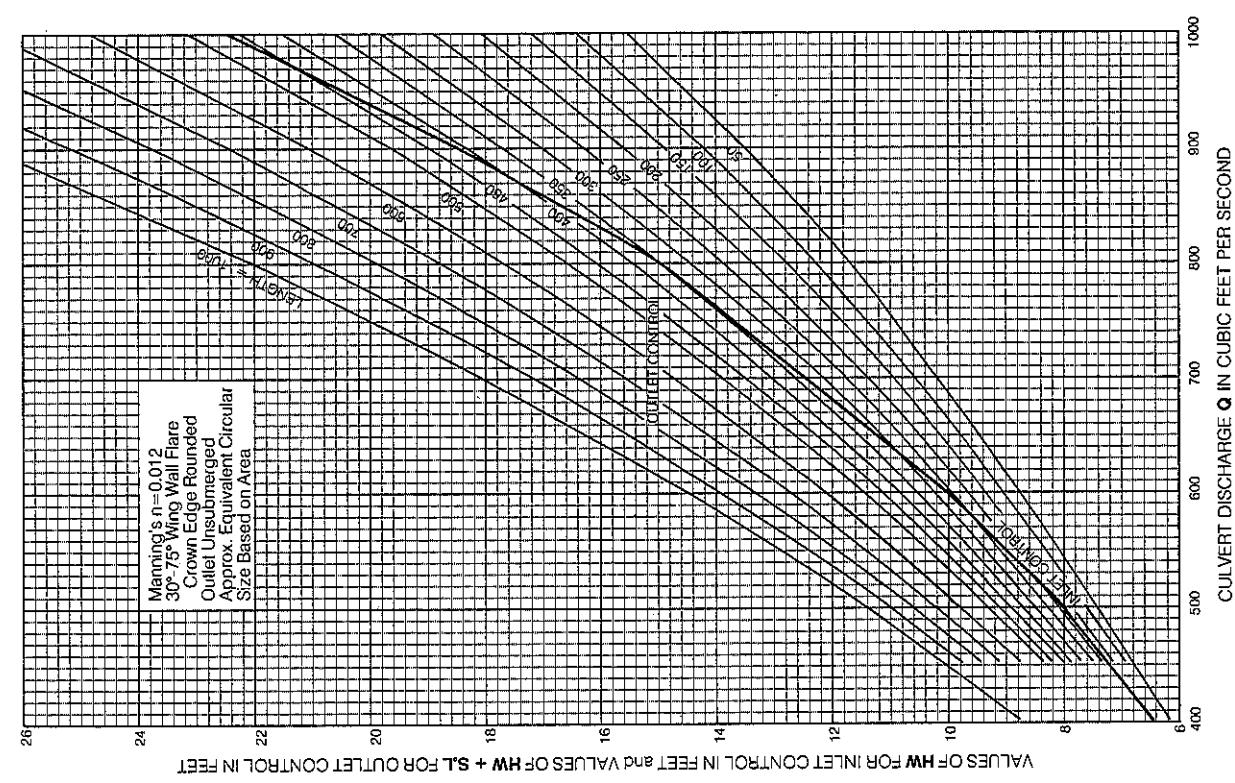
**FIGURE 10: Culvert Capacity—8 x 7-foot Precast Box Section  
Equivalent 101-inch Circular**



**FIGURE 11: Culvert Capacity—8 x 8-foot Precast Box Section  
Equivalent 108-inch Circular**

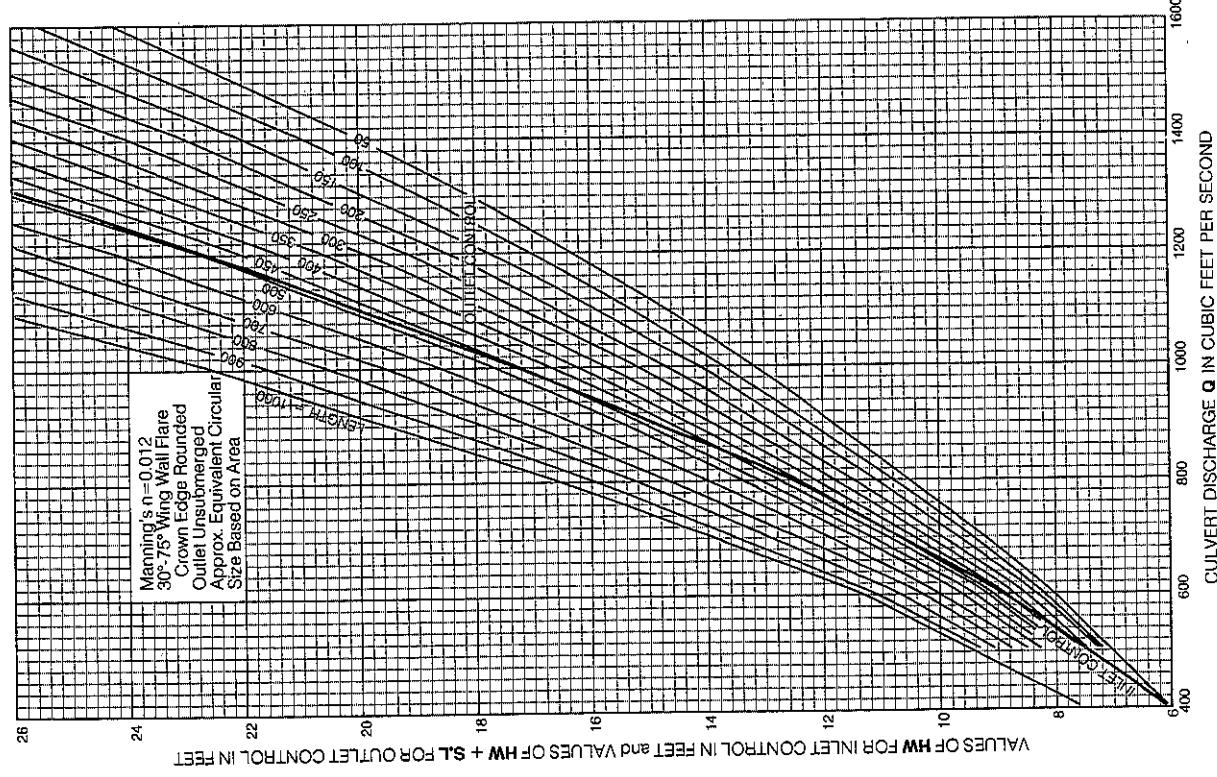


**FIGURE 12: Culvert Capacity—9 x 5-foot Precast Box Section  
Equivalent 90-inch Circular**

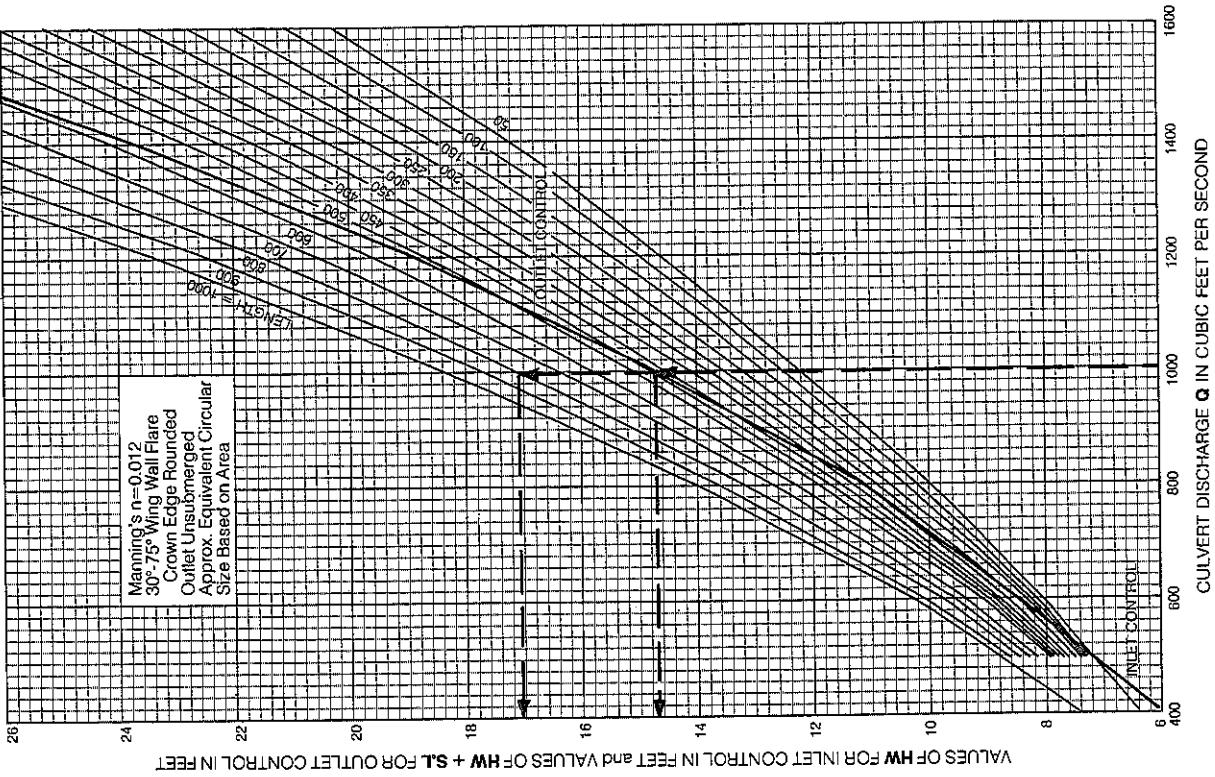


Interpolate for intermediate culvert lengths

**FIGURE 13: Culvert Capacity—9 x 6-foot Precast Box Section  
Equivalent 99-inch Circular**

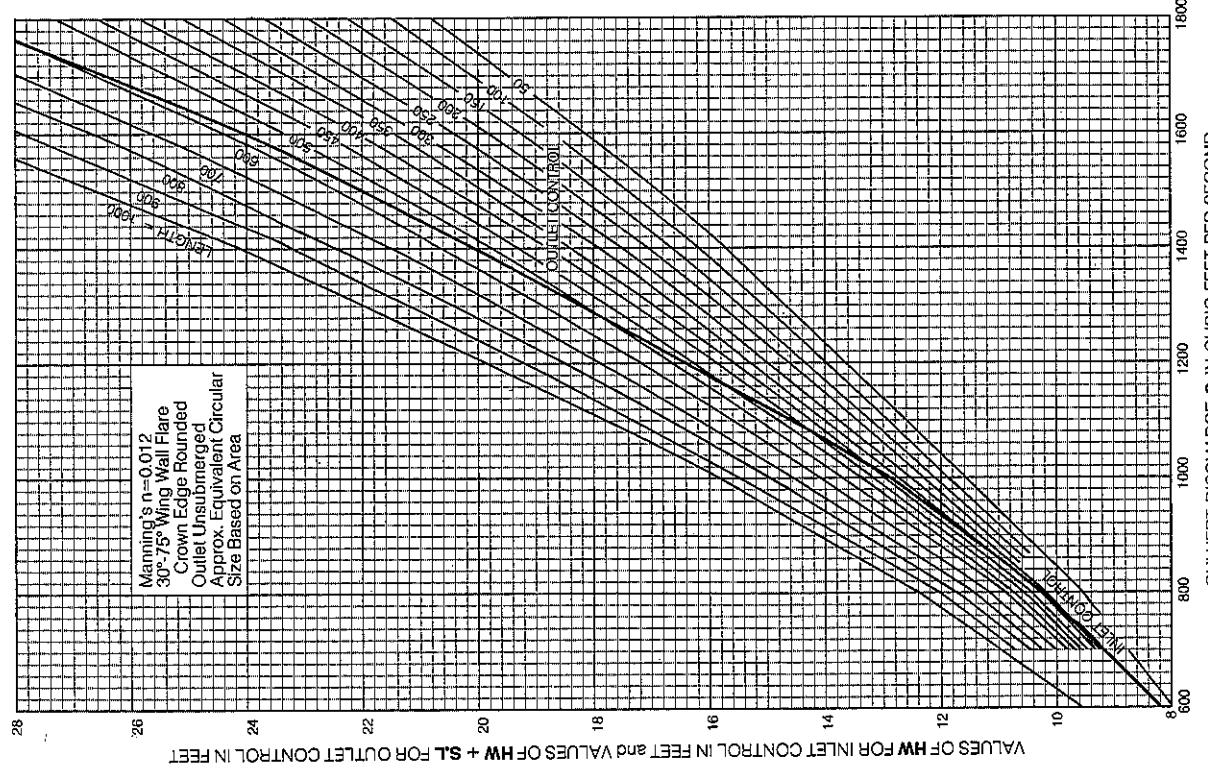


**FIGURE 14: Culvert Capacity—9 x 7-foot Precast Box Section  
Equivalent 107-inch Circular**

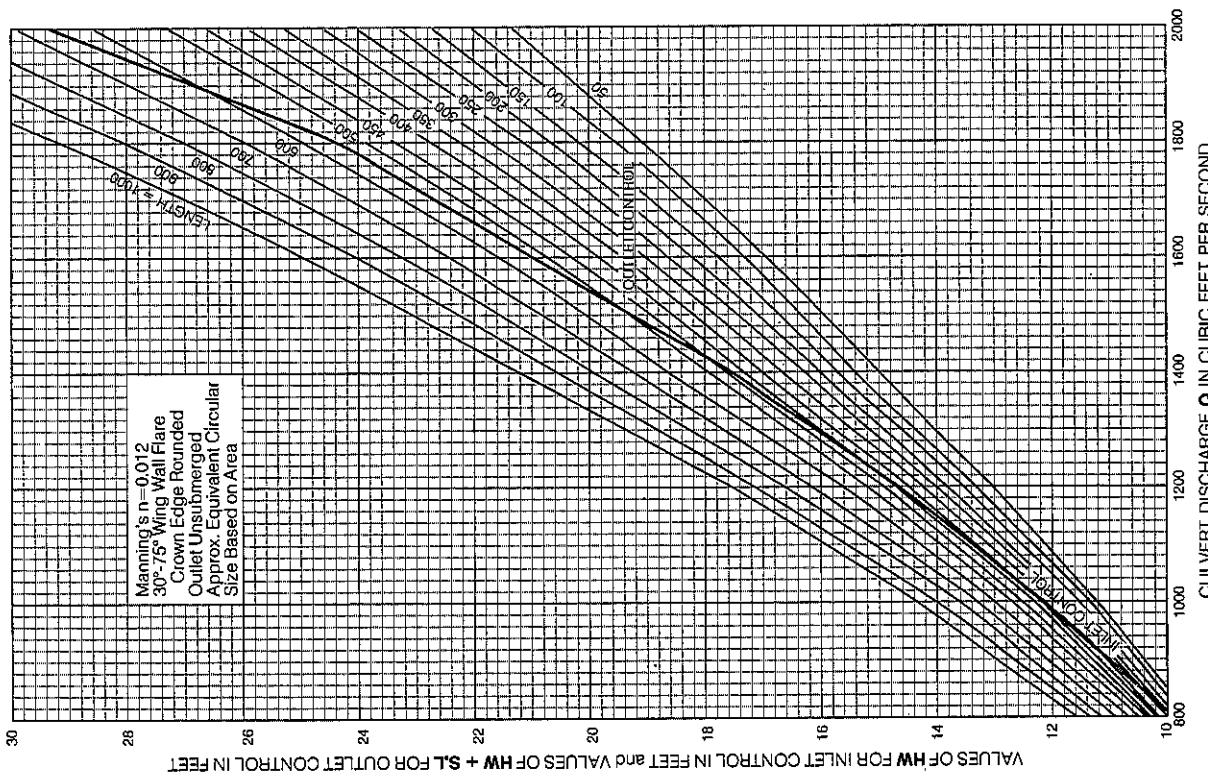


Interpolate for intermediate culvert lengths

**FIGURE 15: Culvert Capacity—9 x 8-foot Precast Box Section  
Equivalent 114-inch Circular**

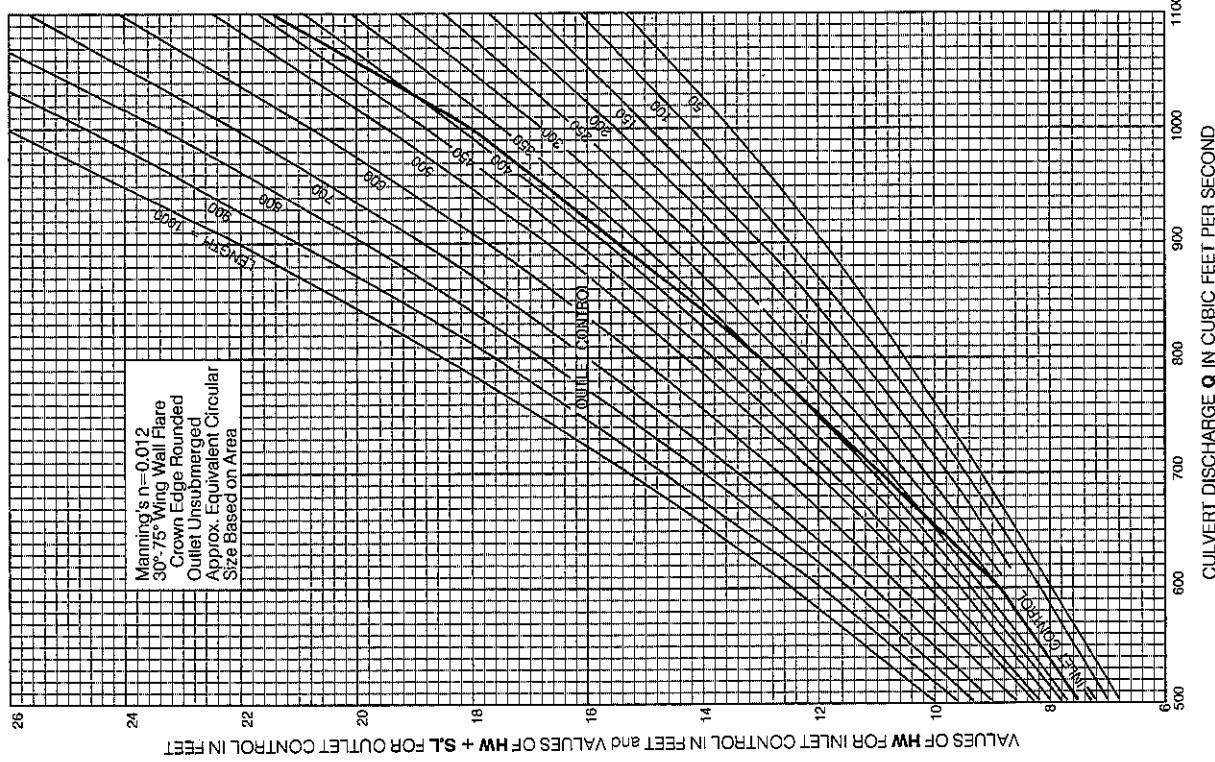


**FIGURE 16: Culvert Capacity—9 x 9-foot Precast Box Section  
Equivalent 121-inch Circular**

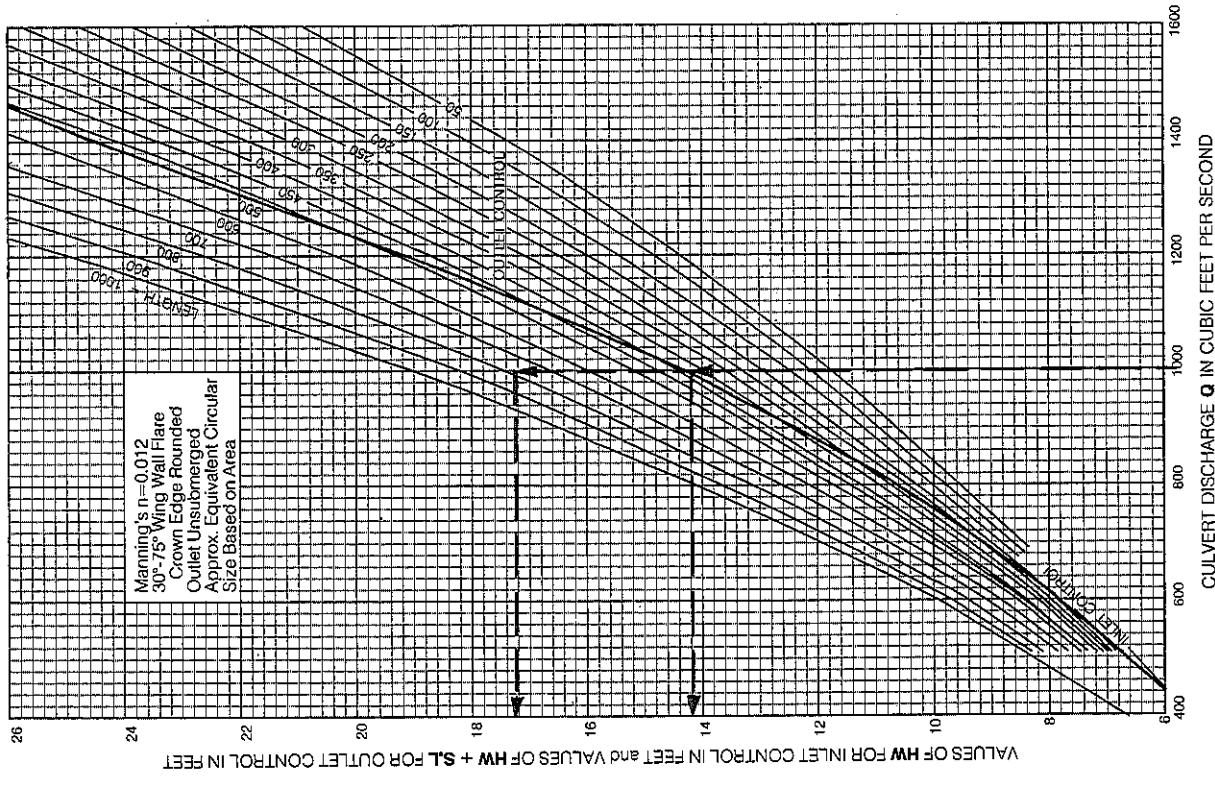


Interpolate for intermediate culvert lengths

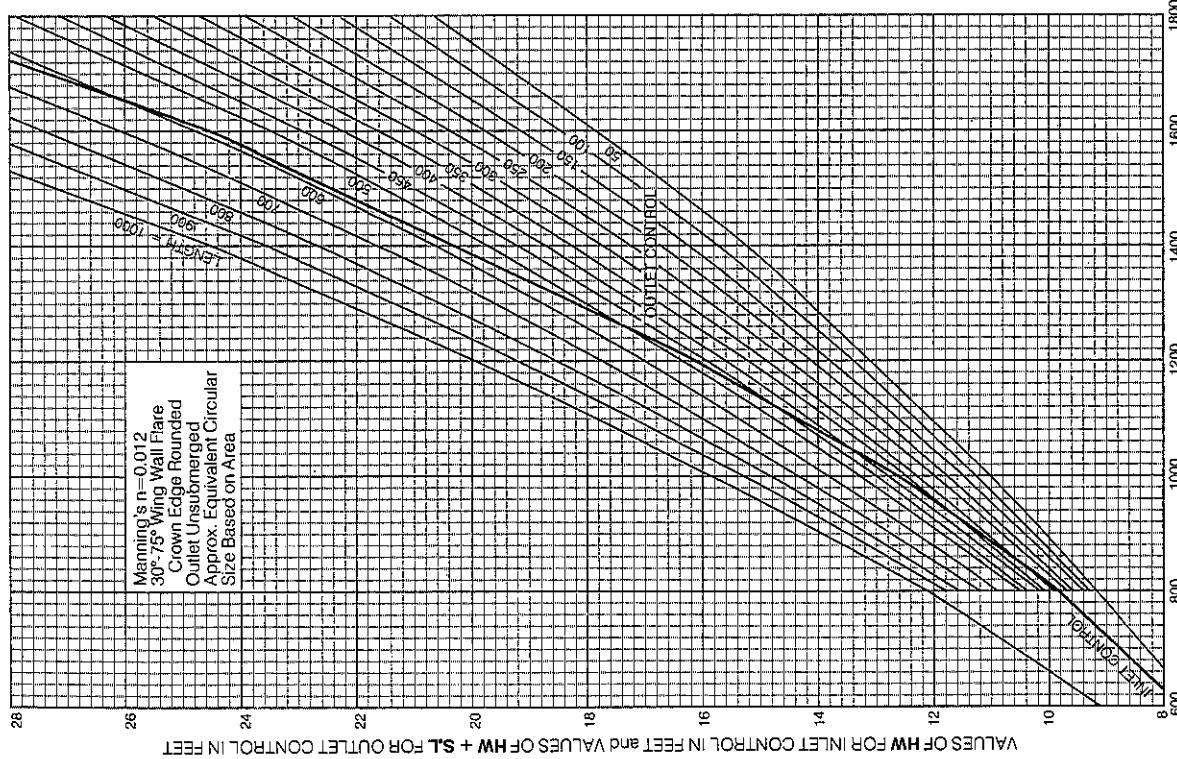
**FIGURE 17: Culvert Capacity—10 x 5-foot Precast Box Section  
Equivalent 94-inch Circular**



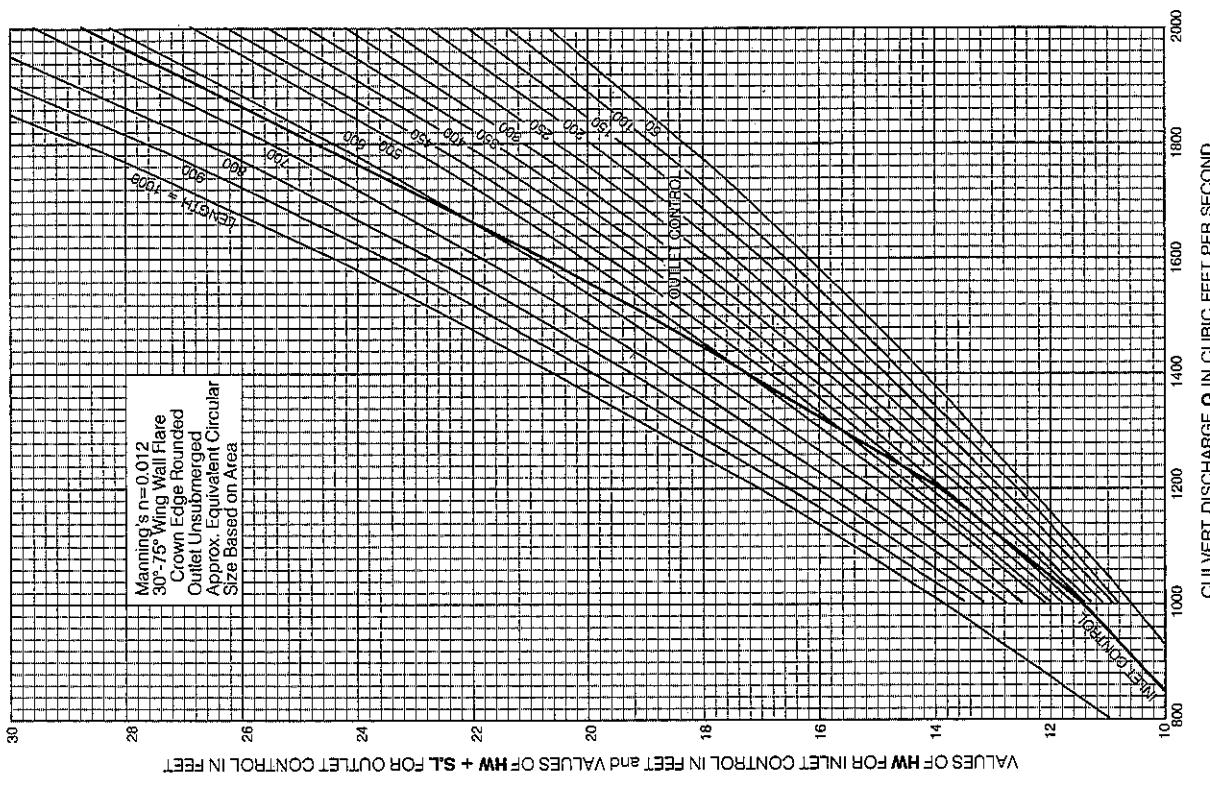
**FIGURE 18: Culvert Capacity—10 x 6-foot Precast Box Section  
Equivalent 104-inch Circular**



**FIGURE 19: Culvert Capacity—10 x 7-foot Precast Box Section  
Equivalent 112-inch Circular**

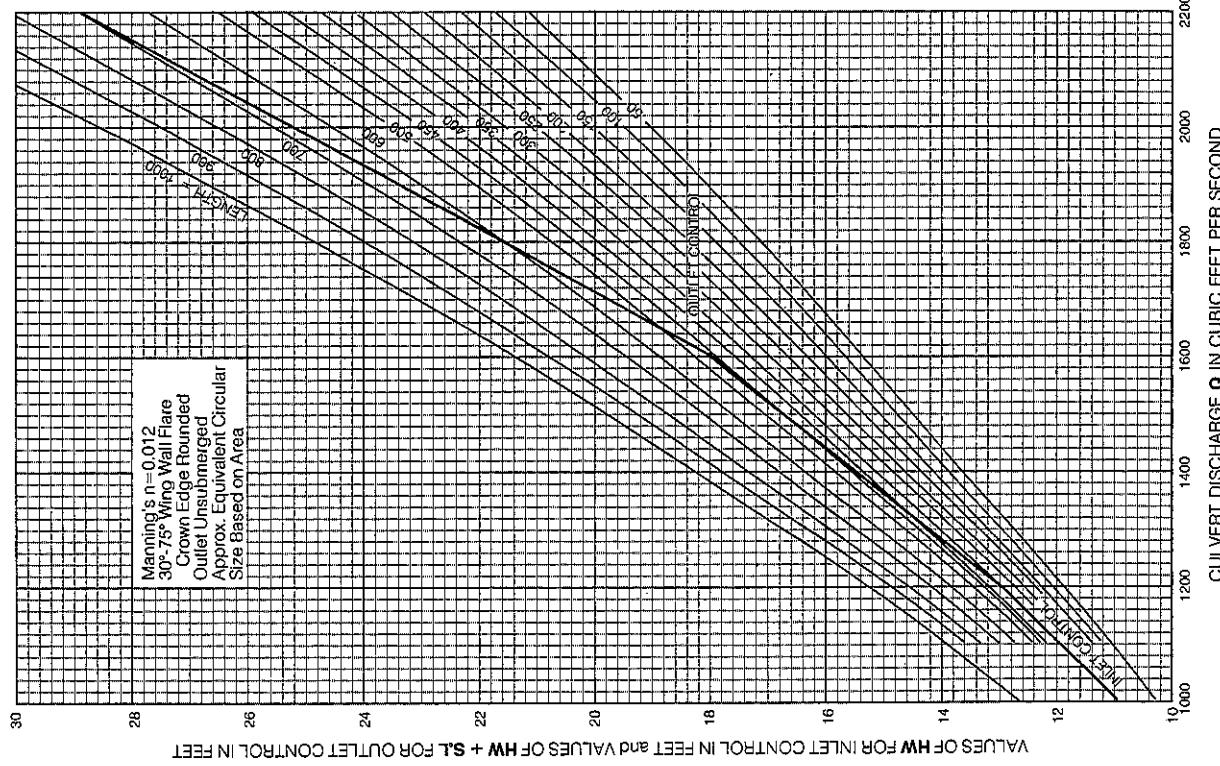


**FIGURE 20: Culvert Capacity—10 x 8-foot Precast Box Section  
Equivalent 120-inch Circular**



Interpolate for intermediate culvert lengths

**FIGURE 21: Culvert Capacity—10 x 9-foot Precast Box Section  
Equivalent 128-inch Circular**



**FIGURE 22: Culvert Capacity—10 x 10-foot Precast Box Section  
Equivalent 135-inch Circular**

