APPENDIX A

SUPPORTING INFORMATION FOR CULVERT DESIGN

The following graphs are supplementary information to those presented in part three chapter 5 of this manual. The graphs listed below provide design and for special shaped, special inlet conditions, and additional materials for culverts.

- Inlet Control nomographs - figures A-1 through A-5.

- Outlet Control head (H) nomographs - figures A-6 through A-9.

- Outlet Control Critical Depth (d_c) graphs - figures A-10 through A-13.

- Culvert Capacity Charts - figures A-14 through A-28.

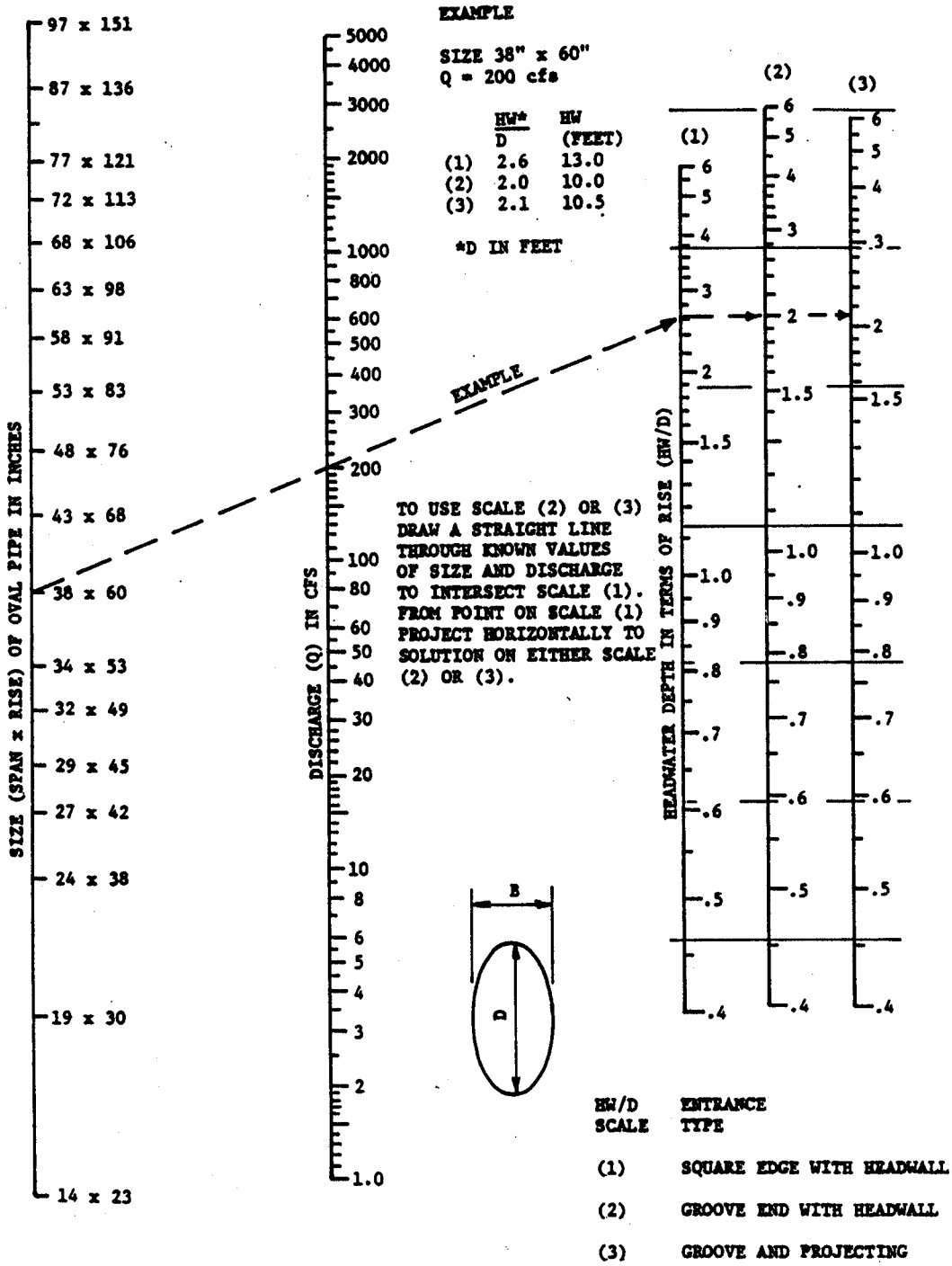

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FIGURE A-1. HEADWATER DEPTH FOR OVAL SMOOTH PIPE CULVERTS, LONG AXIS VERTICAL WITH INLET CONTROL

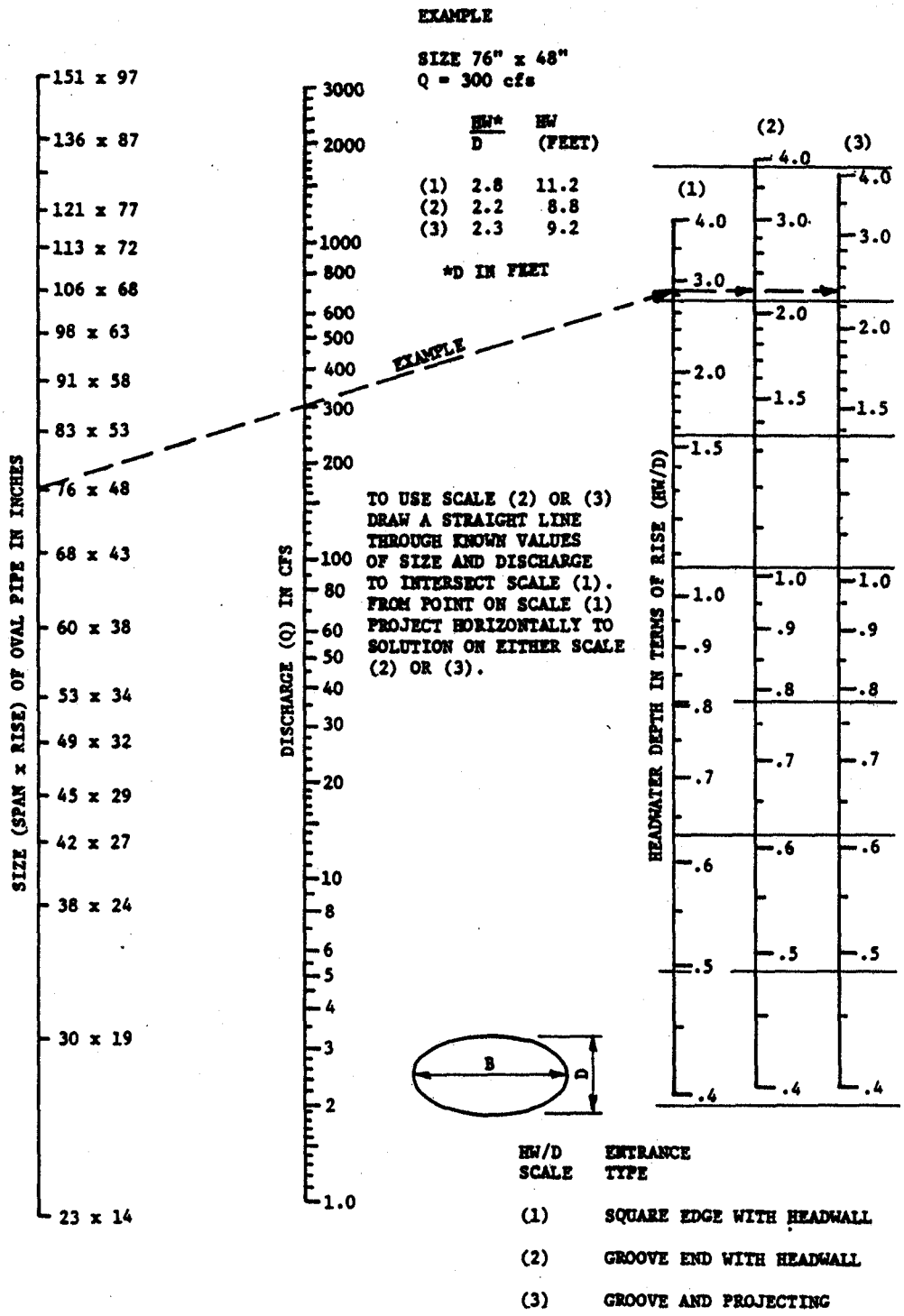

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FIGURE A-2. HEADWATER DEPTH FOR OVAL SMOOTH PIPE CULVERTS, LONG AXIS HORIZONTAL WITH INLET CONTROL

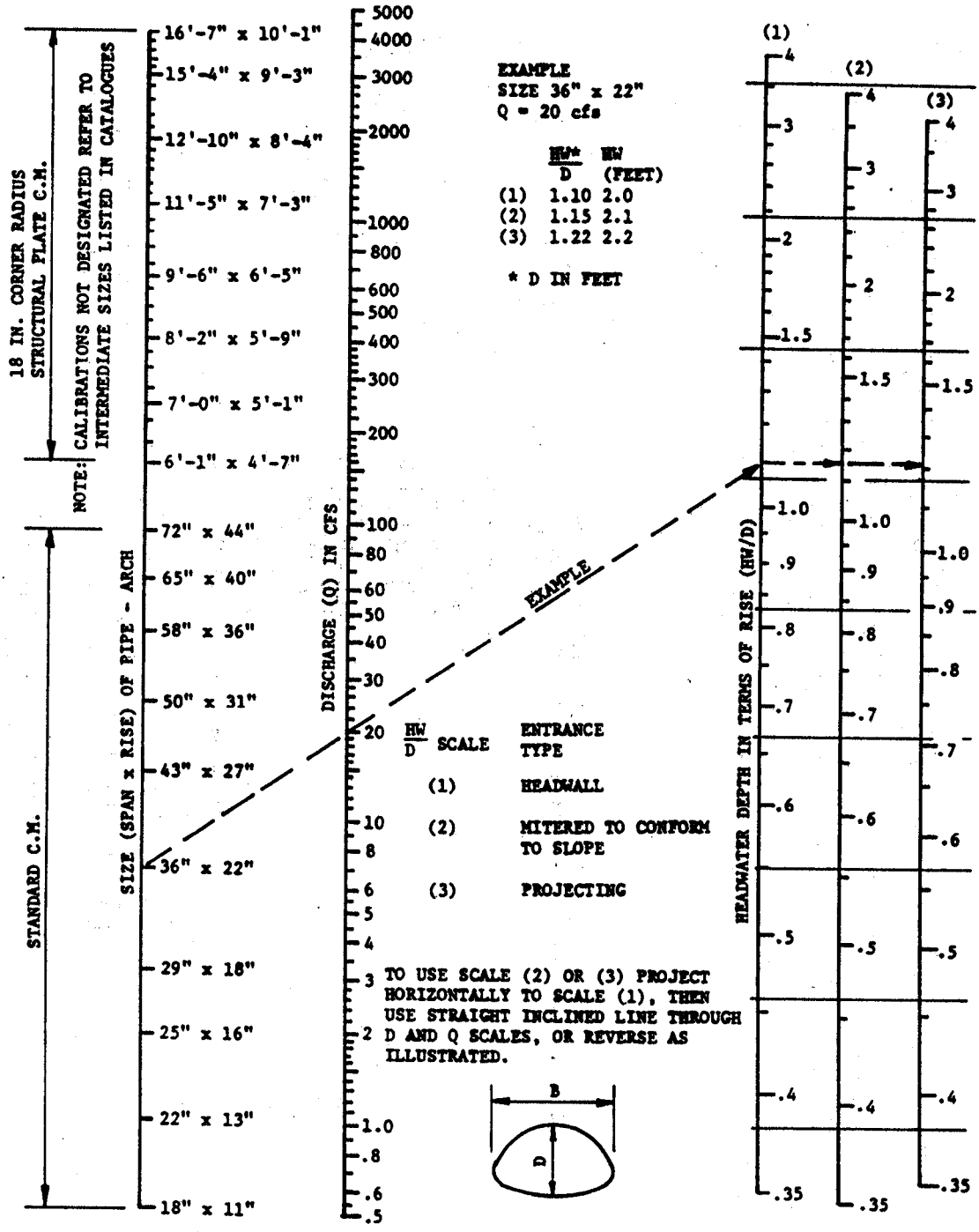

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FIGURE A-3. HEADWATER DEPTH FOR STRUCTURAL PLATE AND CORRUGATED PIPE ARCH CULVERTS WITH INLET CONTROL

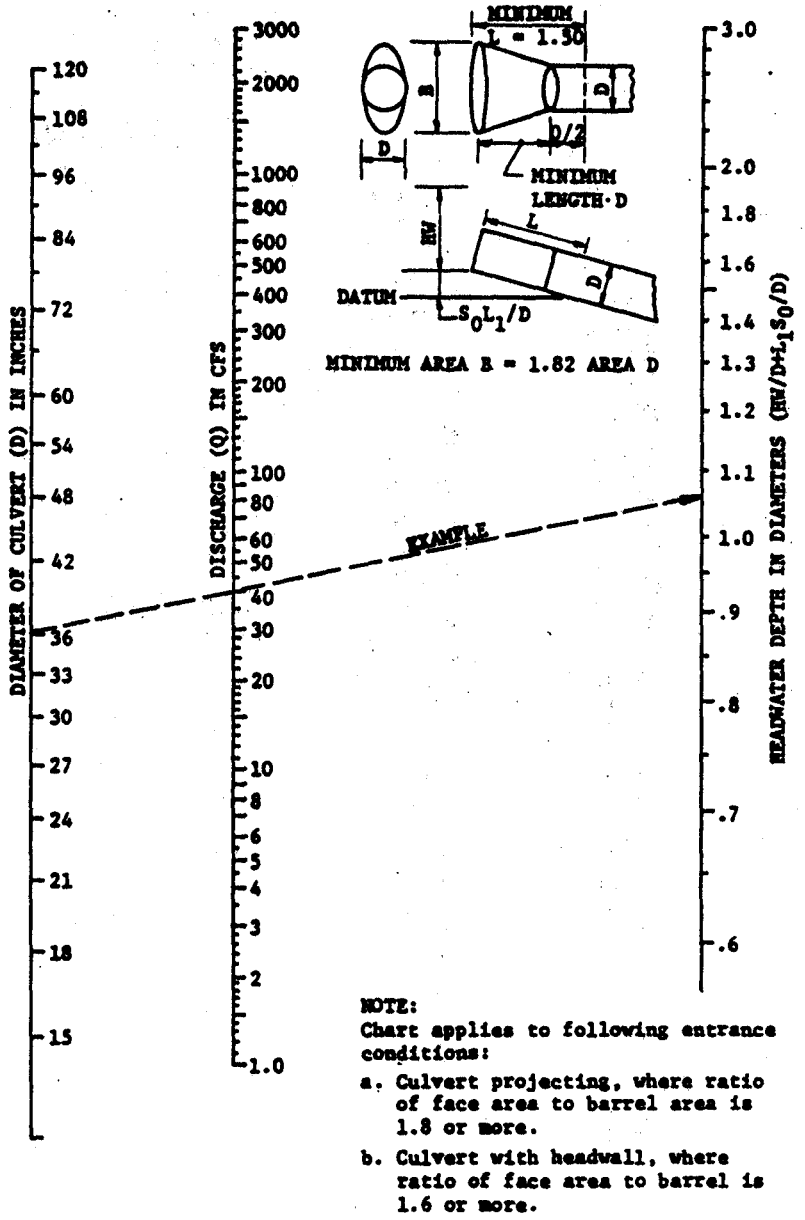

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FIGURE A-4. HEADWATER DEPTH FOR CORRUGATED PIPE CULVERTS WITH TAPERED INLET, INLET CONTROL

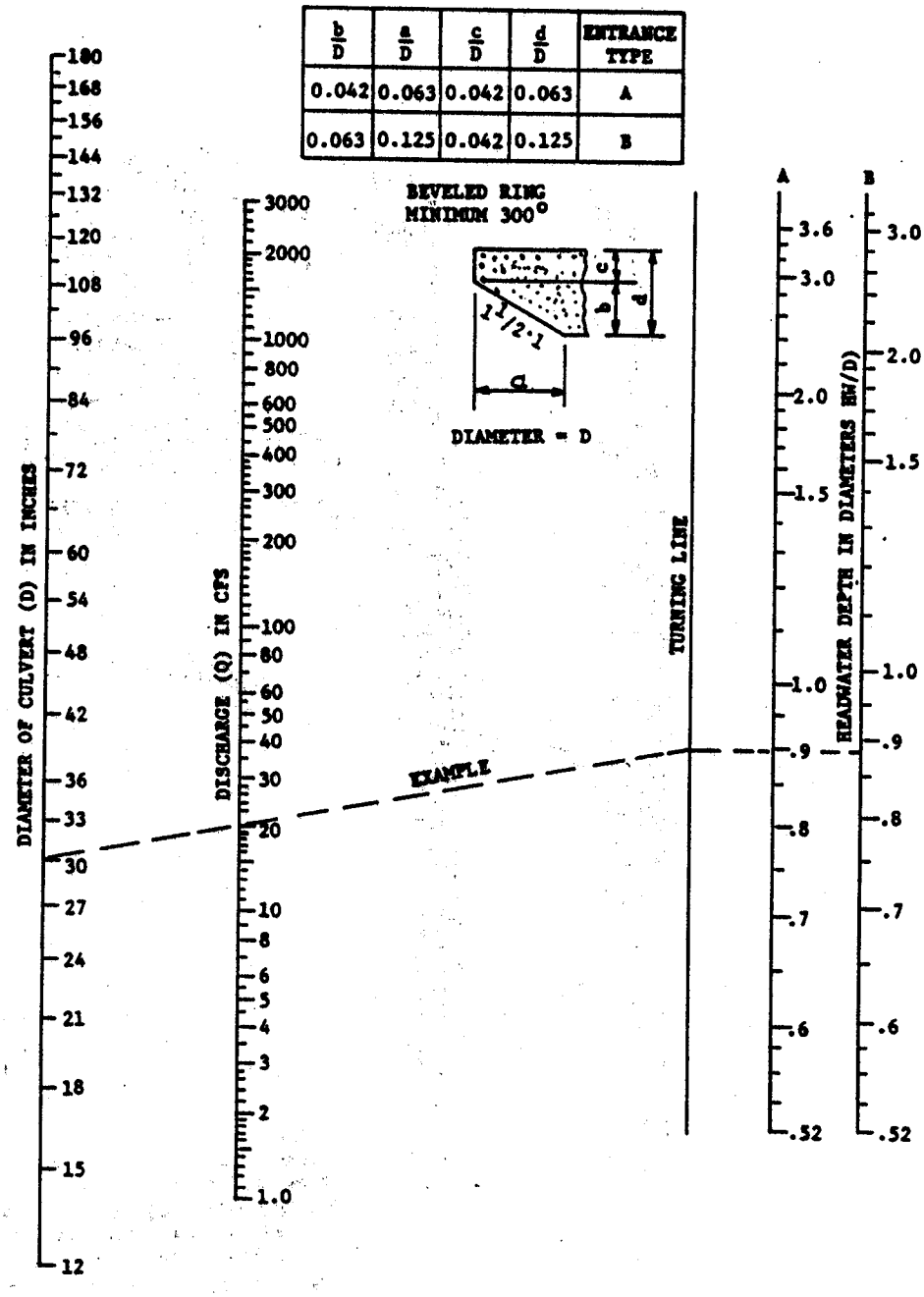

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FIGURE A-5. HEADWATER DEPTH FOR CIRCULAR PIPE CULVERTS WITH BEVELED RING, INLET CONTROL

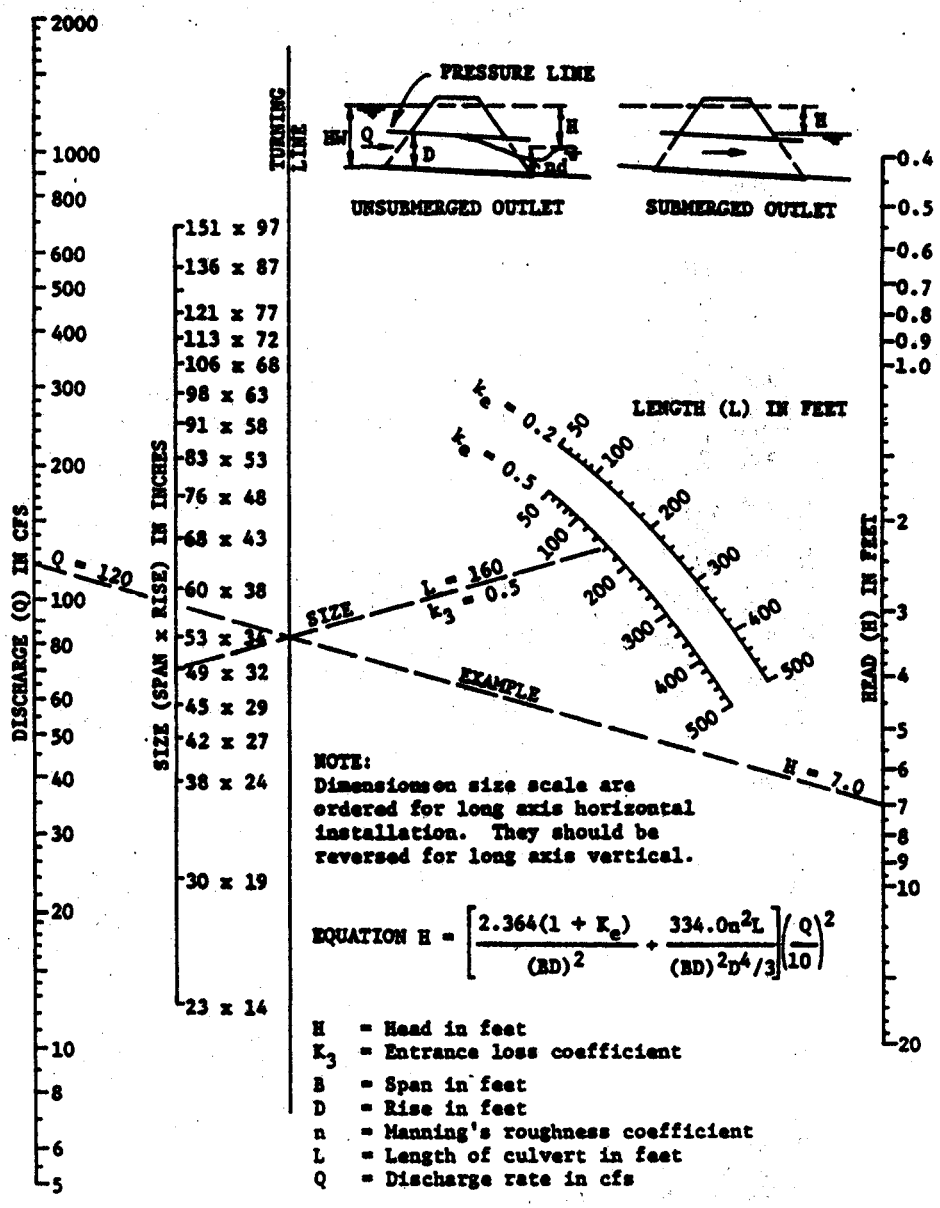

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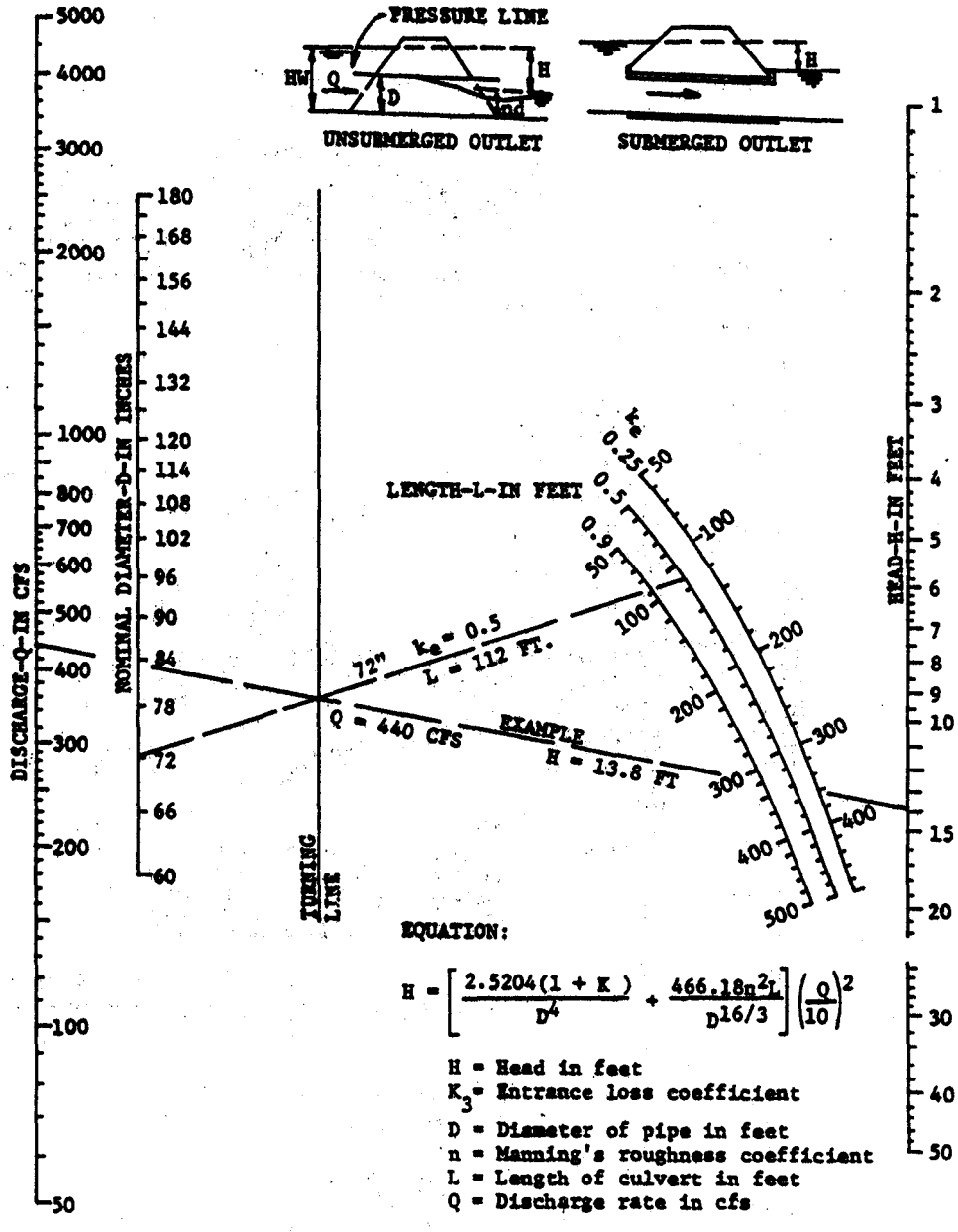
FIGURE A-6. HEAD FOR OVAL SMOOTH PIPE CULVERTS LONG AXIS HORIZONTAL OR VERTICAL FLOWING FULL n = 0.012



EQUATION:

$$H = \left[\frac{2.5204(1 + K)}{D^4} + \frac{466.18n^2L}{D^{16/3}}\right]\left(\frac{Q}{10}\right)^2$$

H = Head in feet
K_3 = Entrance loss coefficient
D = Diameter of pipe in feet
n = Manning's roughness coefficient
L = Length of culvert in feet
Q = Discharge rate in cfs

NOTE:
Computed for actual diameters given in fabricators' catalogs.

Diam.	n
5'	0.0328
7'	0.0320
10'	0.0311
15'	0.0302

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FIGURE A-7. HEAD FOR STRUCTURAL PLATE PIPE CULVERTS FLOWING FULL n = 0.0328 TO 0.0302

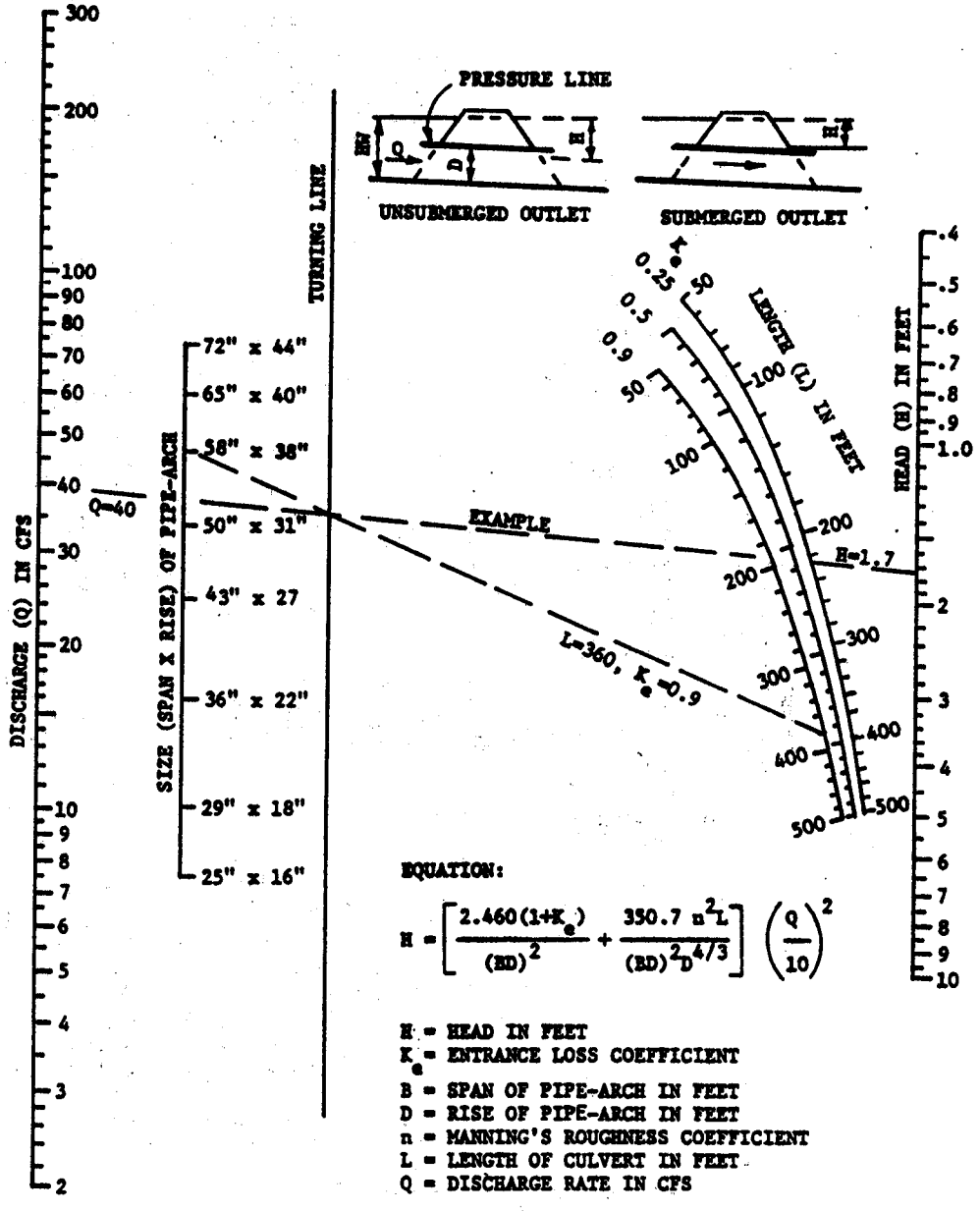

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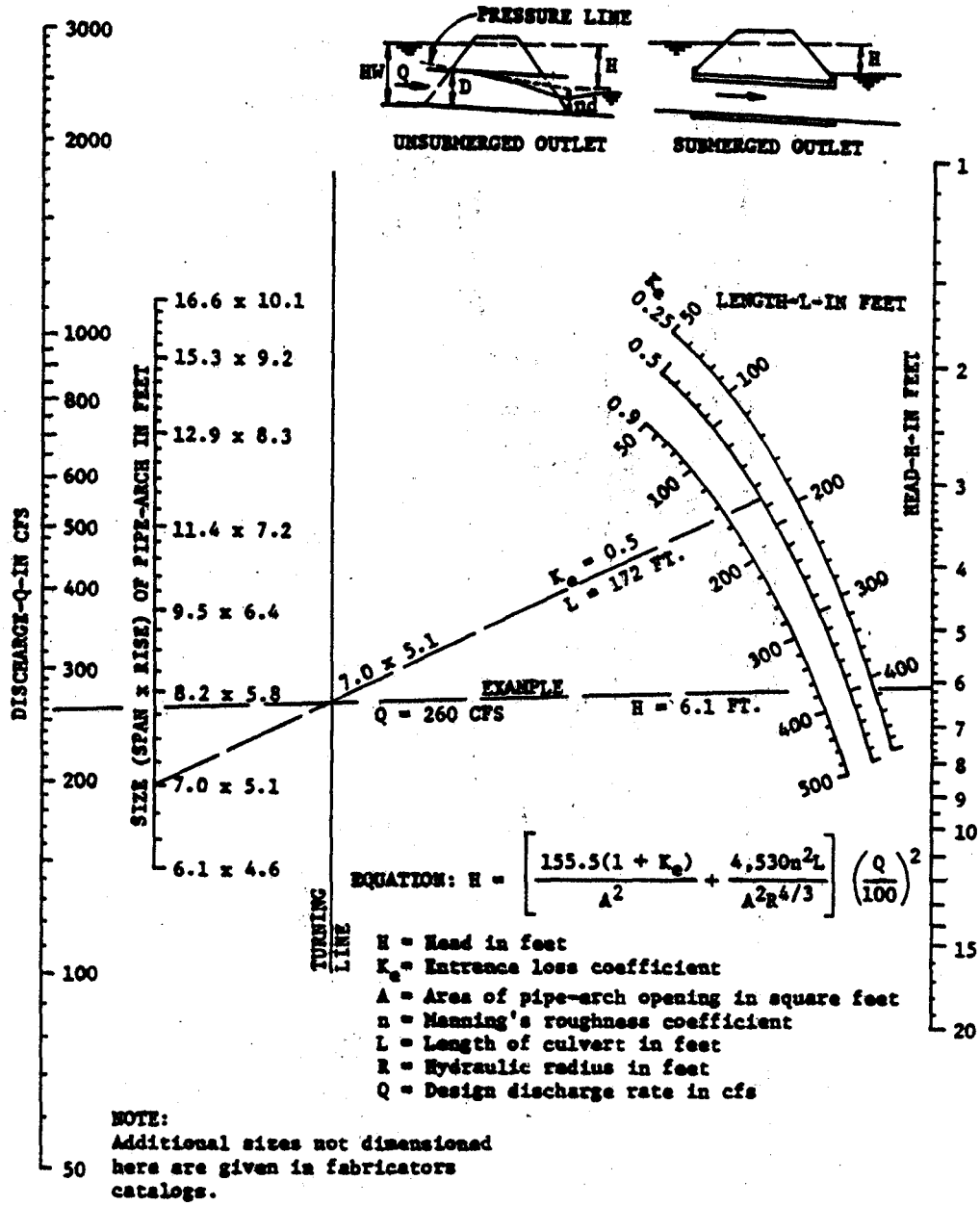
FIGURE A-8. HEAD FOR CORRUGATED PIPE-ARCH CULVERT FLOWING FULL n = 0.024



SIZE	n
6.1 x 4.6	0.0327
8.2 x 5.8	0.0321
11.4 x 7.2	0.0315
16.6 x 10.1	0.0306

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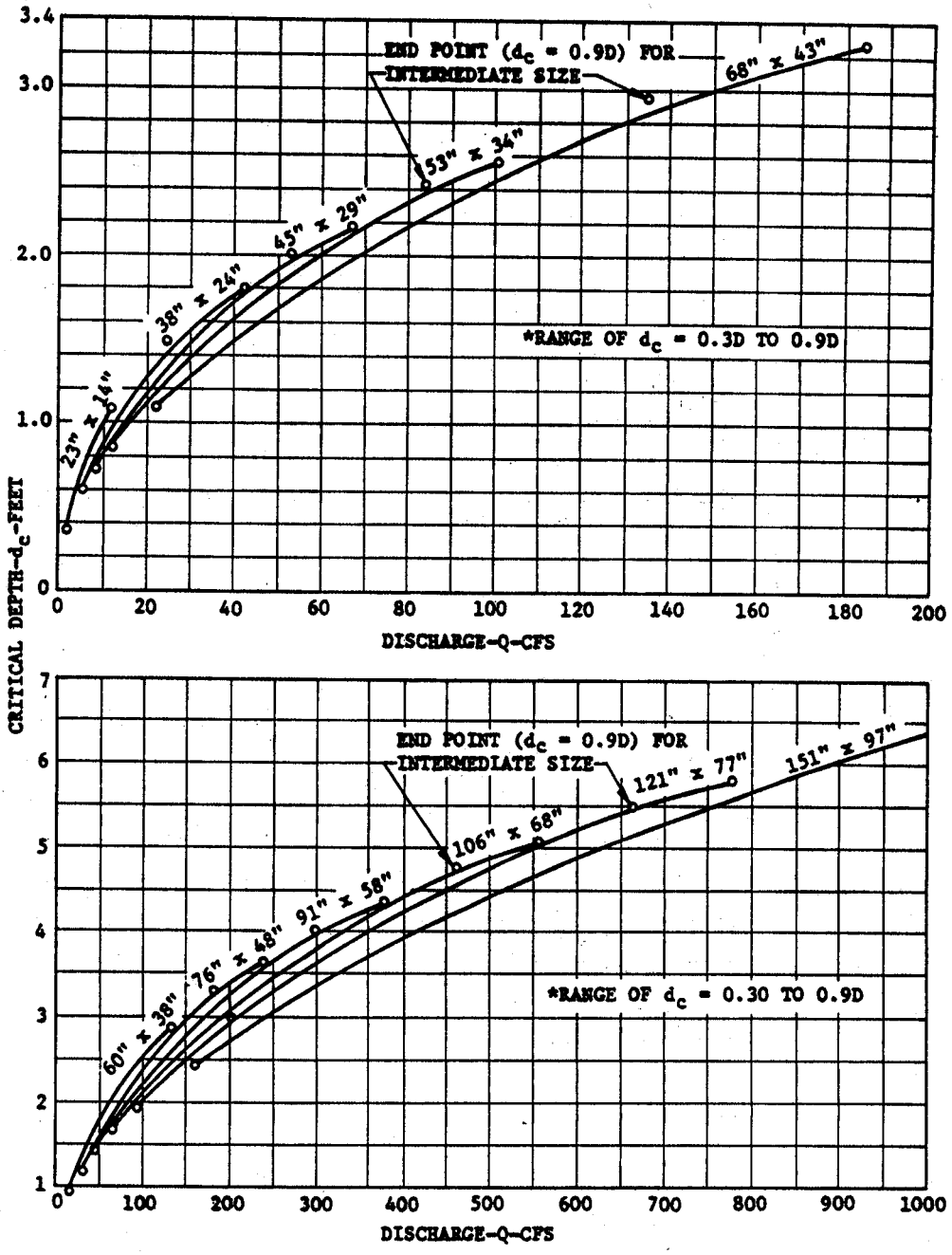
FIGURE A-9. HEAD FOR FIELD-BOLTED STRUCTURAL PLATE PIPE-ARCH CULVERTS 18-INCH CORNER RADIUS FLOWING FULL n = 0.327 TO 0.0306



*NOTE: For values of d_c above curve, use d_c = D

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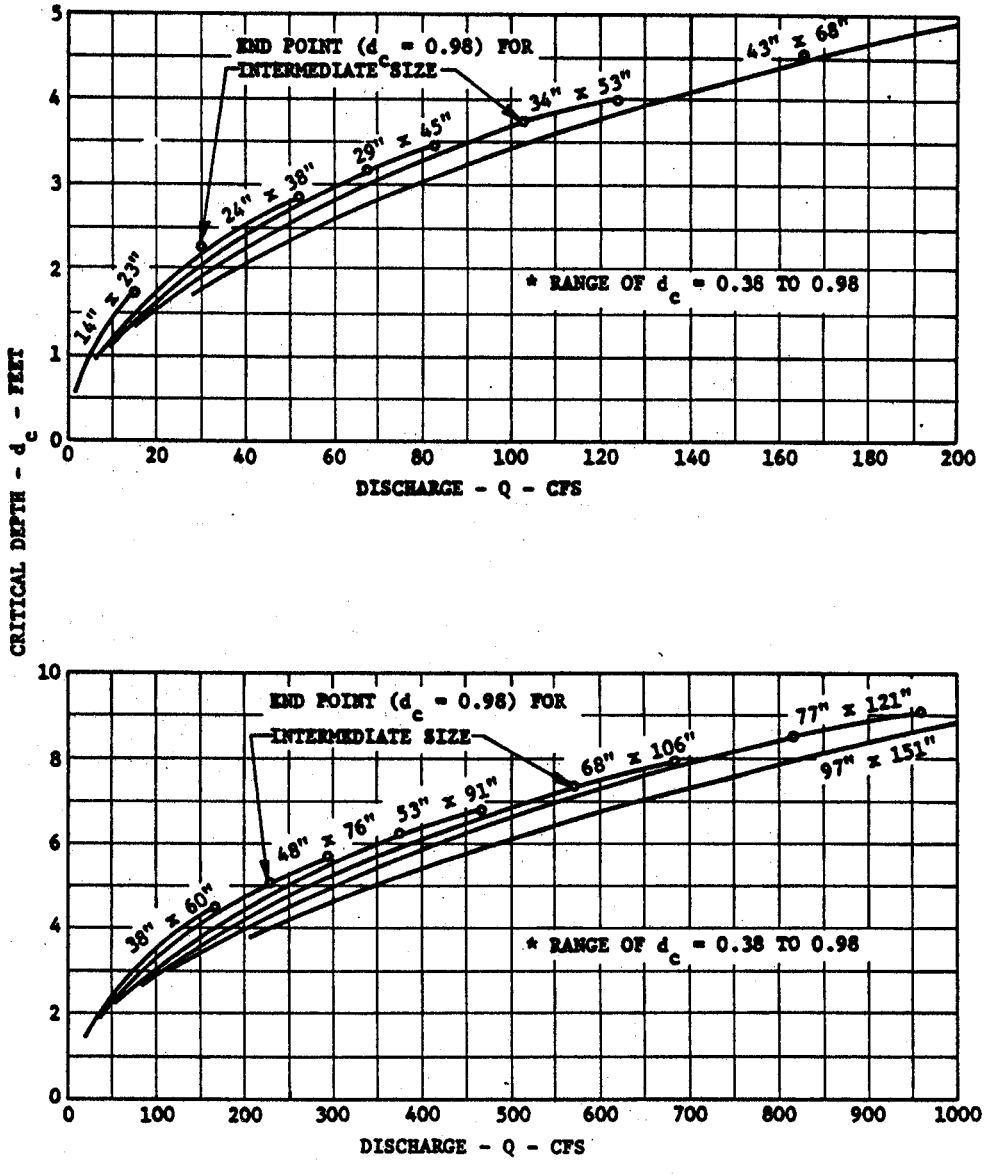
FIGURE A-10. OVAL SMOOTH PIPE LONG AXIS HORIZONTAL CRITICAL DEPTH



* NOTE: FOR VALUES OF d_c ABOVE CURVE, USE d_c = D

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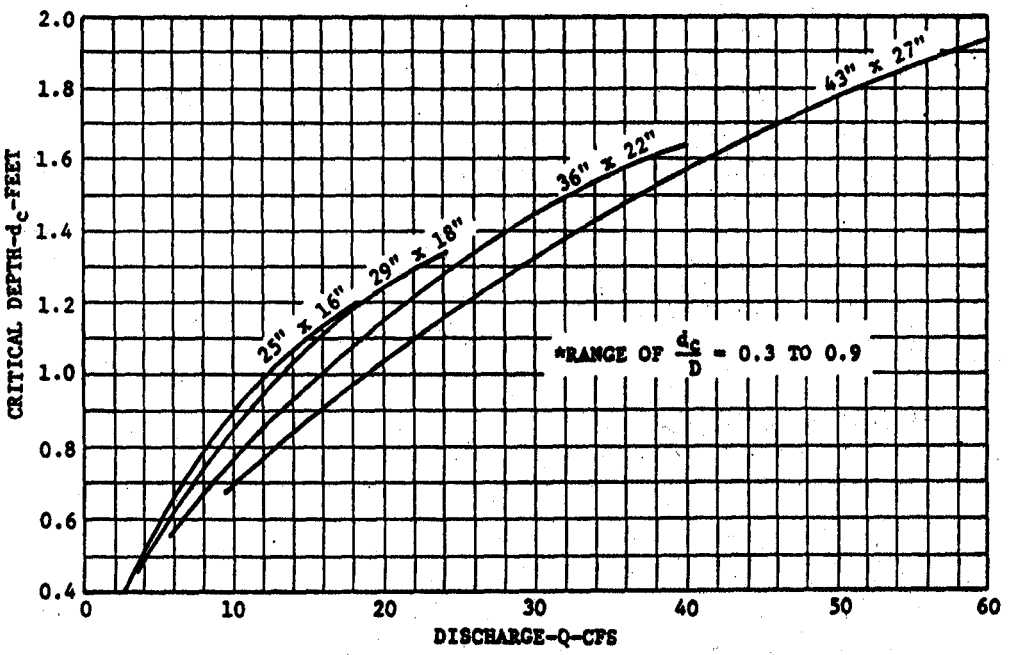
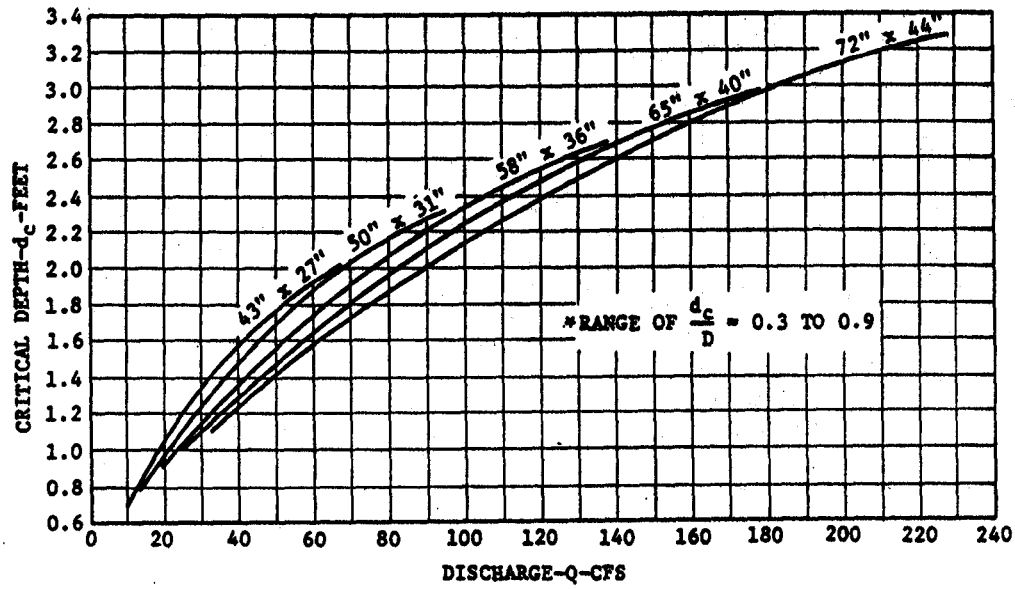
FIGURE A-11. OVAL SMOOTH PIPE LONG AXIS VERTICAL CRITICAL DEPTH





*NOTE: FOR VALUES OF d_c ABOVE CURVE, USE d_c = D

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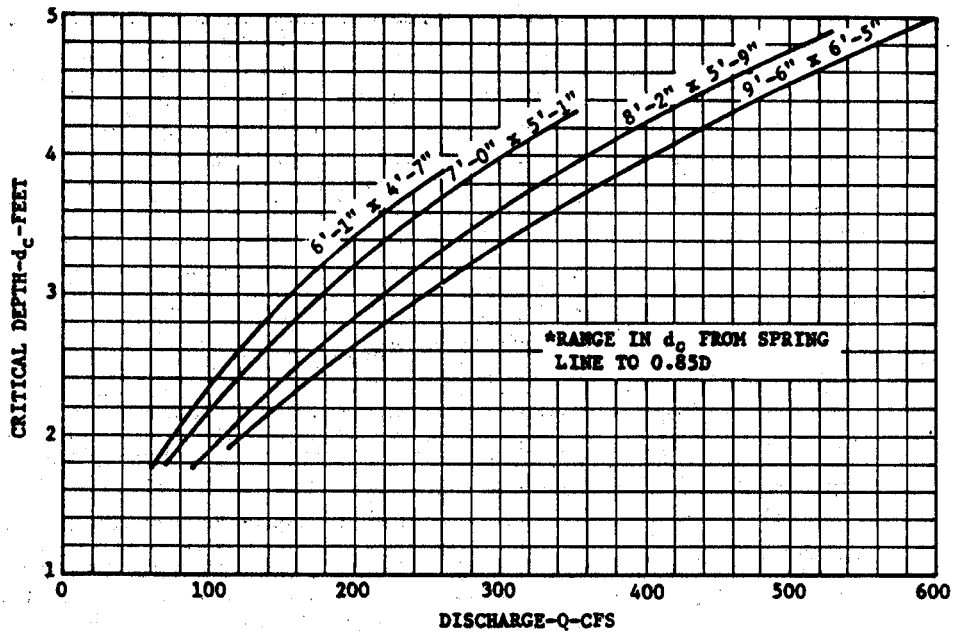
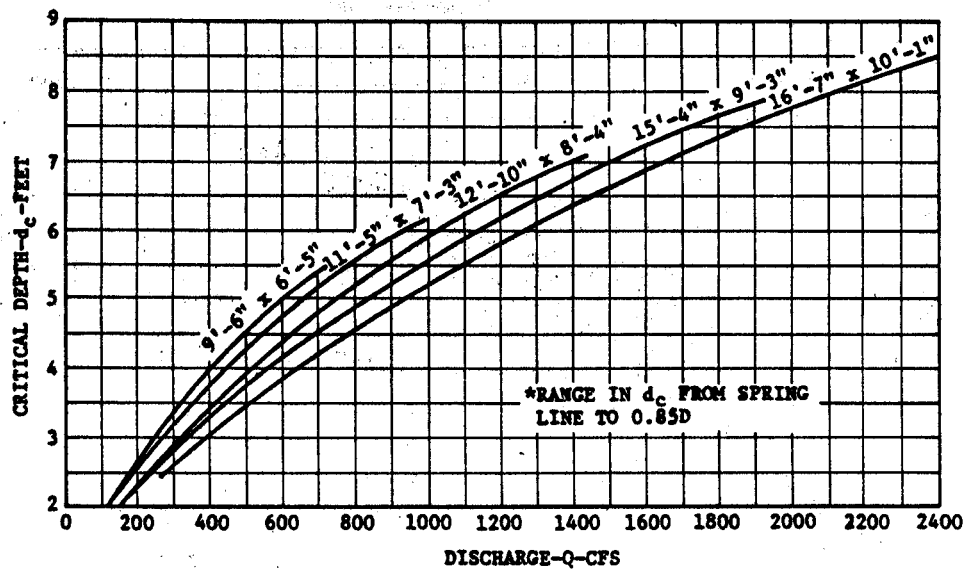
FIGURE A-12. CORRUGATED PIPE-ARCH CRITICAL DEPTH





*NOTE: FOR VALUES OF d_c ABOVE CURVE, USE d_c = D

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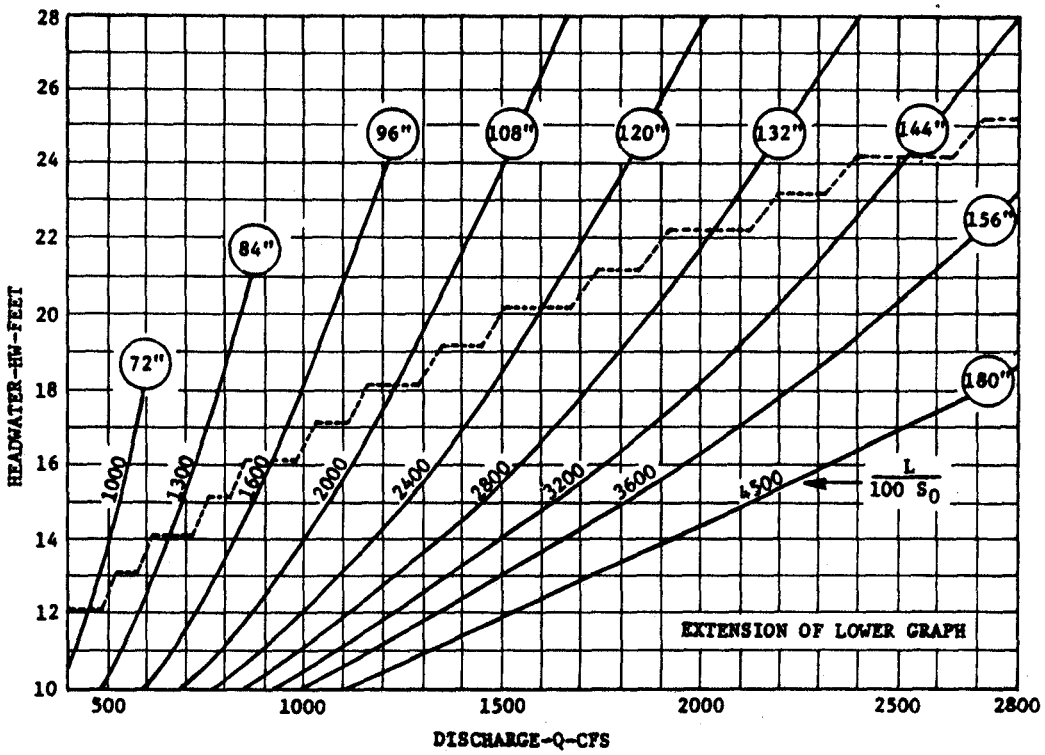
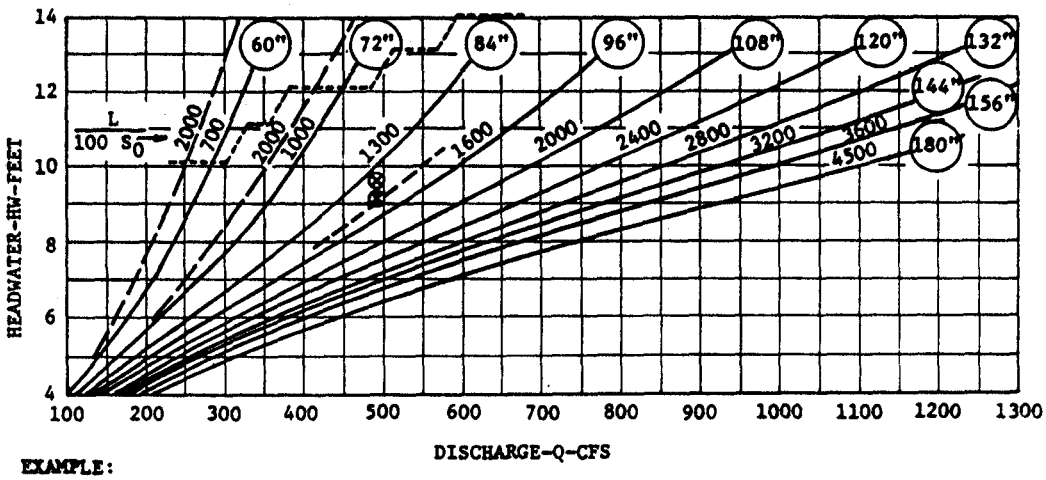
FIGURE A-13. STRUCTURAL PLATE PIPE-ARCH CRITICAL DEPTH





EXAMPLE:

⊗ **GIVEN:**
490 CFS; AHW = 9.6 FT.
L = 60 FT.; S_0 = 0.000

⊗ **SELECT 90"** ($\frac{L}{D}$ = 8)
HW = 9.2 FT.

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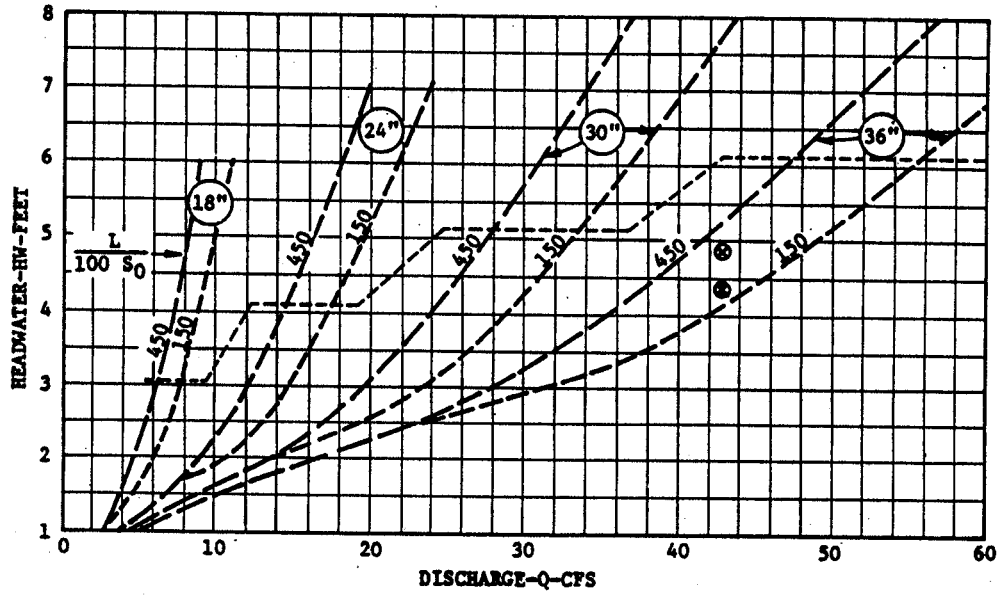
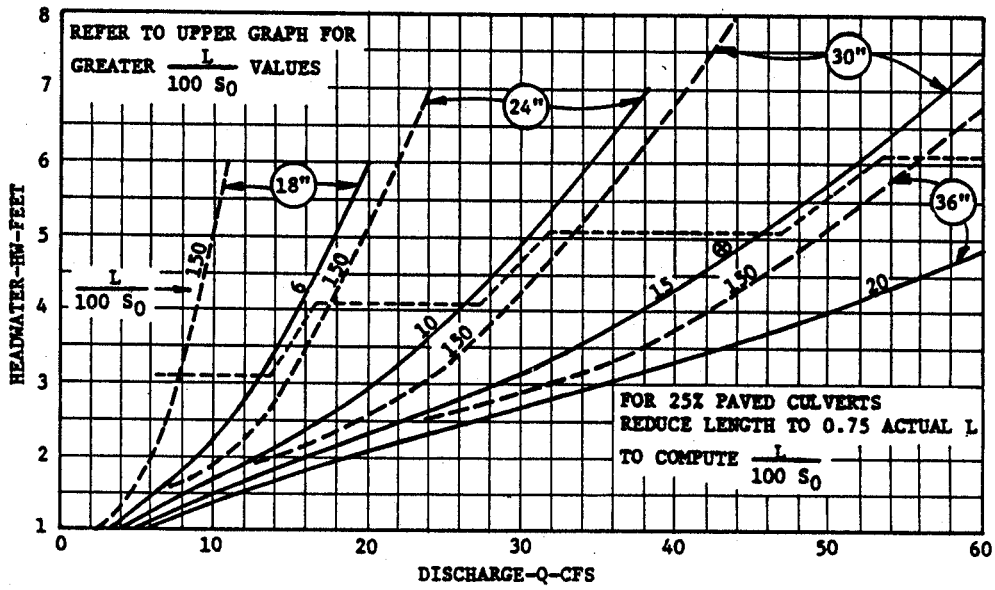
FIGURE A-14. CULVERT CAPACITY CIRCULAR SMOOTH PIPE GROOVE-EDGED ENTRANCE 60" TO 180"





EXAMPLE:

⊗ GIVEN:
43 CFS; AHW = 4.9 FT.
L = 72 FT.; S_0 = 0.003

⊗ SELECT 36" UNPAVED
HW = 4.4 FT.

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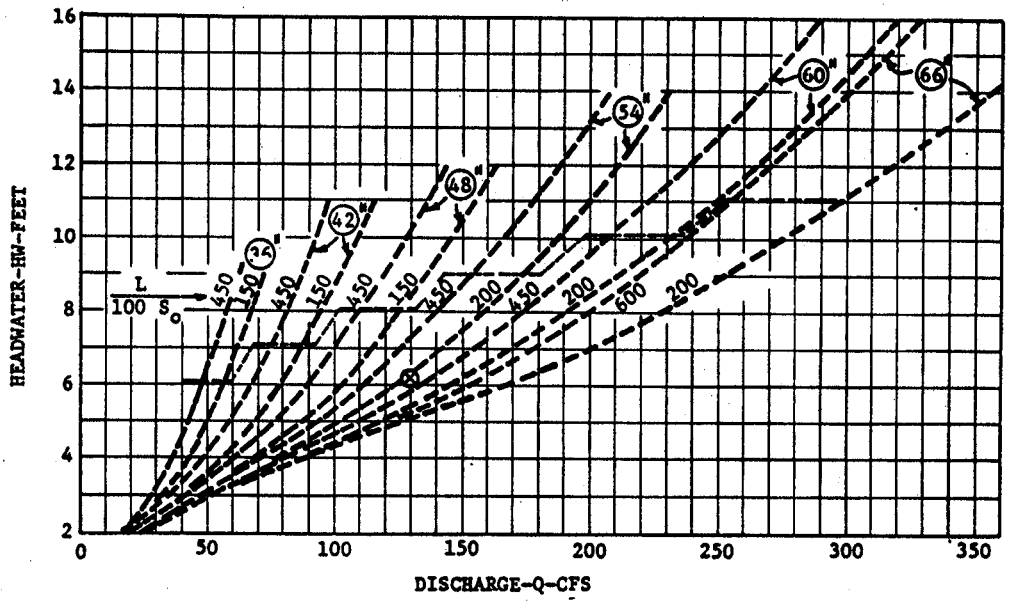
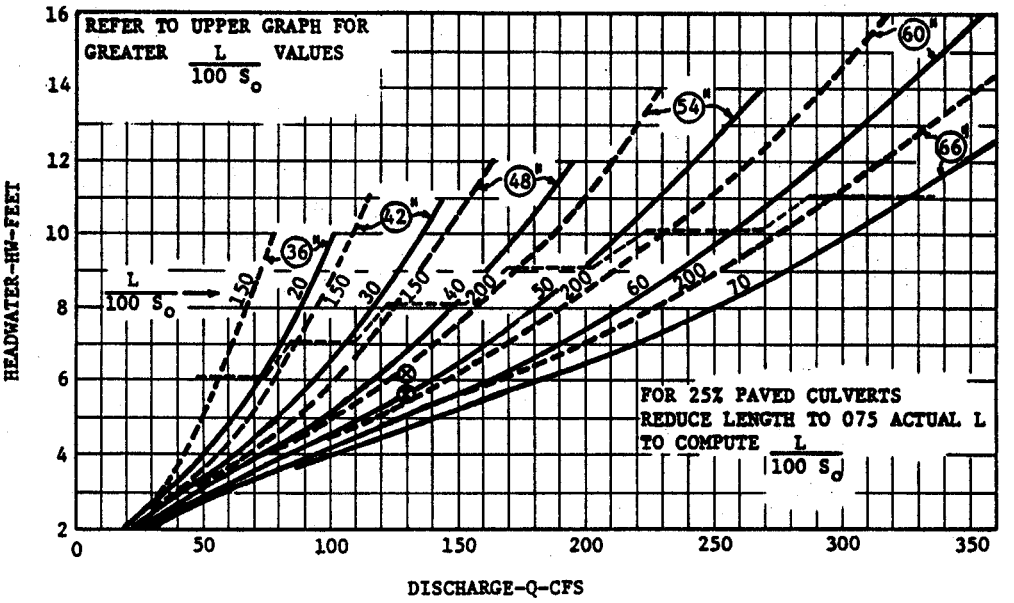
FIGURE A-15. CULVERT CAPACITY STANDARD CIRCULAR CORRUGATED PIPE HEADWALL ENTRANCE 18" TO 36"





EXAMPLE

⊗ GIVEN:
130 CFS; AHW=6.2 FT.
L=120 FT; S_0=0.0025

● SELECT 54" UNPAVED
HW = 5.6 FT.

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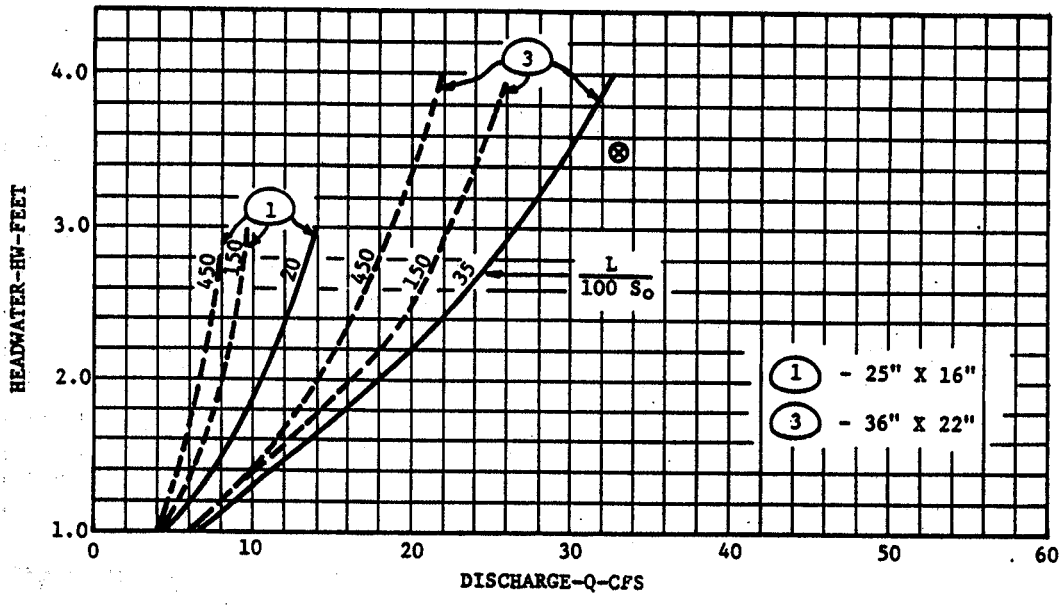
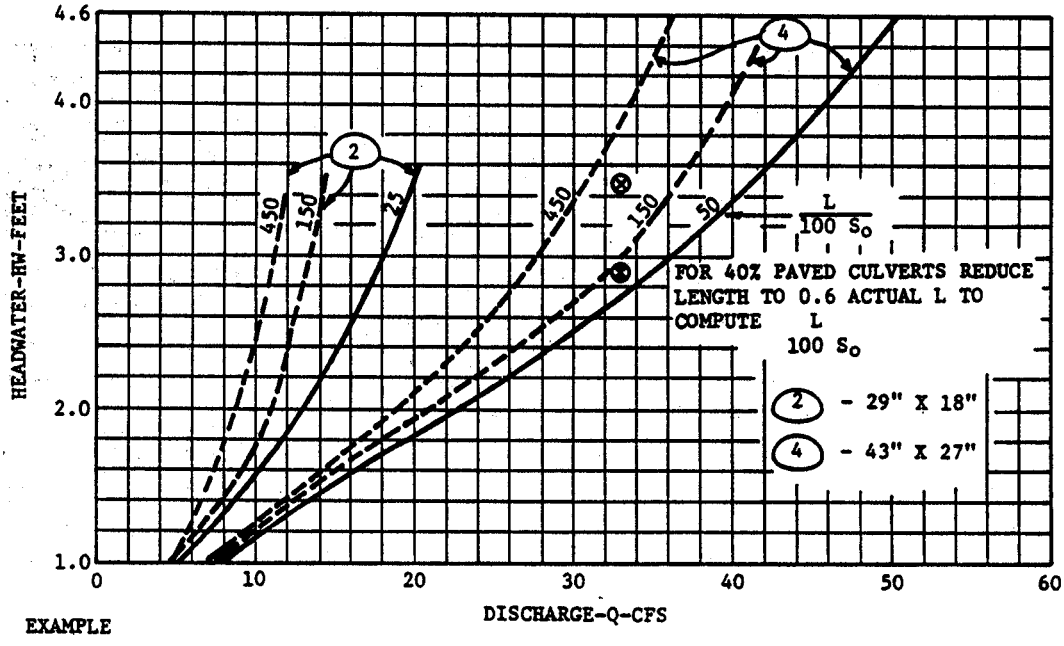
FIGURE A-16. CULVERT CAPACITY STANDARD CIRCULAR CORRUGATED PIPE HEADWALL ENTRANCE 36" TO 66" ○





EXAMPLE

⊗ GIVEN:
33 CFS; AHW=3.5 FT.
L = 60 FT.; S_o = 0.005

⊗ SELECT NO. 4, 43" X 27"
HW = 2.9 FT.
UNPAVED INVERT

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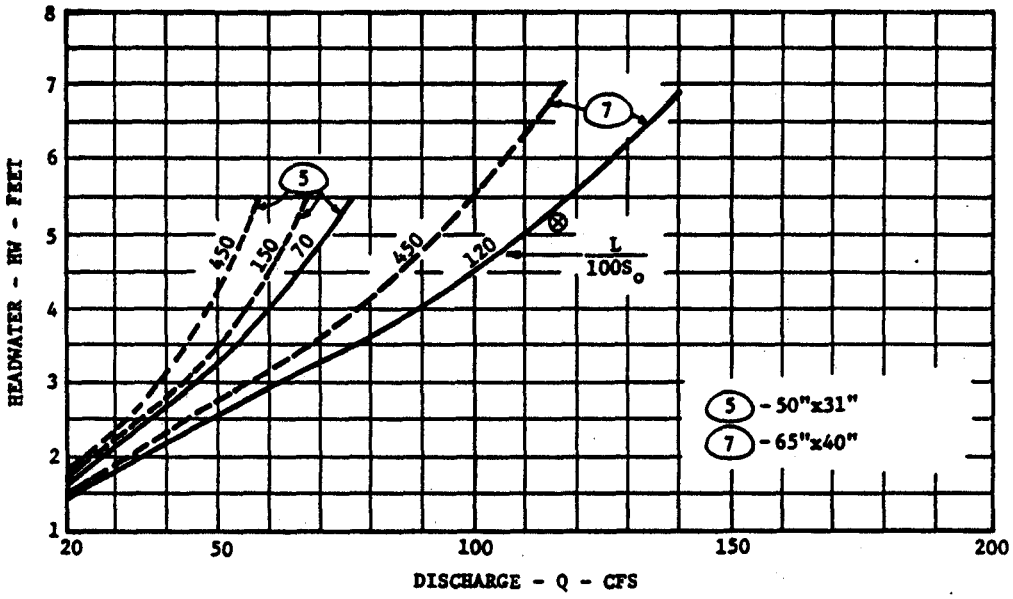
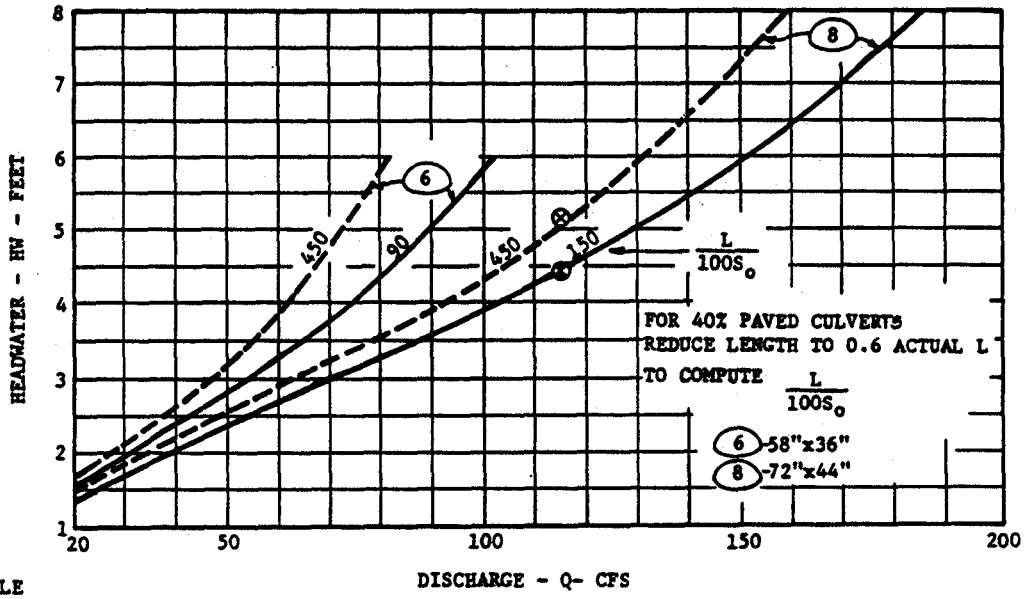
FIGURE A-17. CULVERT CAPACITY STANDARD CORRUGATED PIPE-ARCH PROJECTING ENTRANCE 25" BY 16" TO 43" BY 27"





EXAMPLE

⊗ GIVEN:
115 CFS; AHW = 5.2 FT
L = 110 FT, S_o = 0.0055

⊗ SELECT NO. 8, 72"x44"
HW = 4.5 FT.
PAVED INVERT

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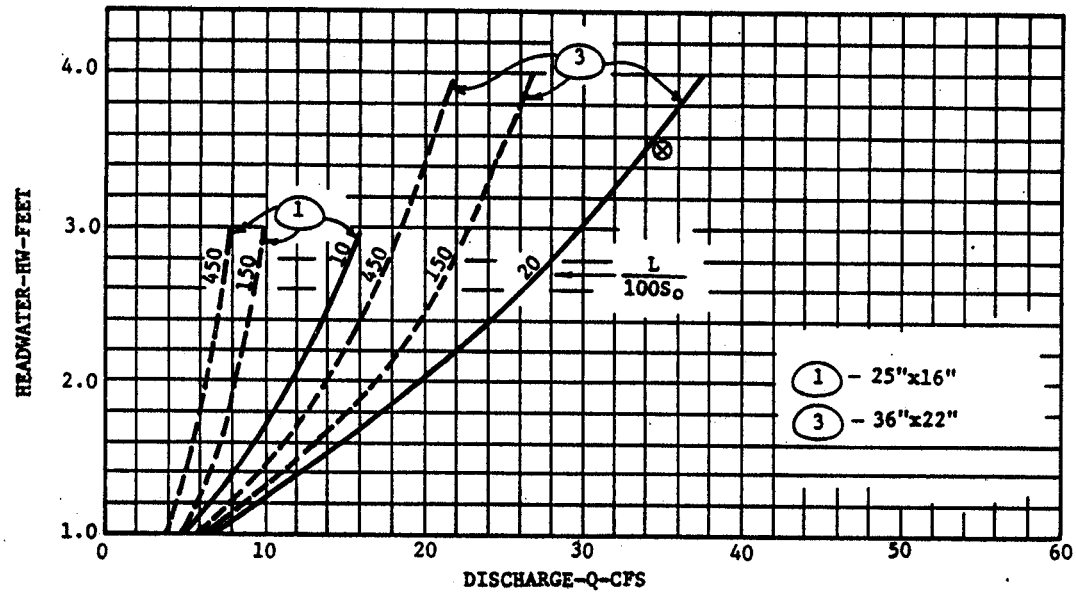
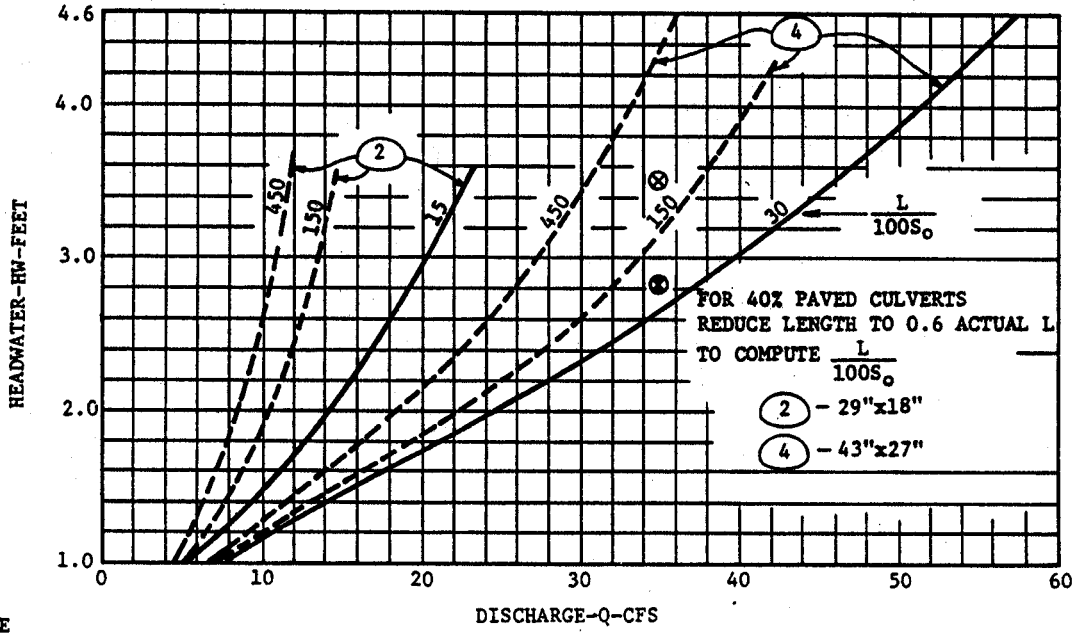
FIGURE A-18. CULVERT CAPACITY STANDARD CORRUGATED PIPE-ARCH PROJECTING ENTRANCE 50" BY 31" TO 72" BY 44"





EXAMPLE

⊗ **GIVEN:**
35 CFS, AHW = 35 FT.
L = 145 FT., S_o = 0.020

⊗ **SELECT NO. 4, 43"x27"**
HW = 2.8 FT.
UNPAVED INVERT

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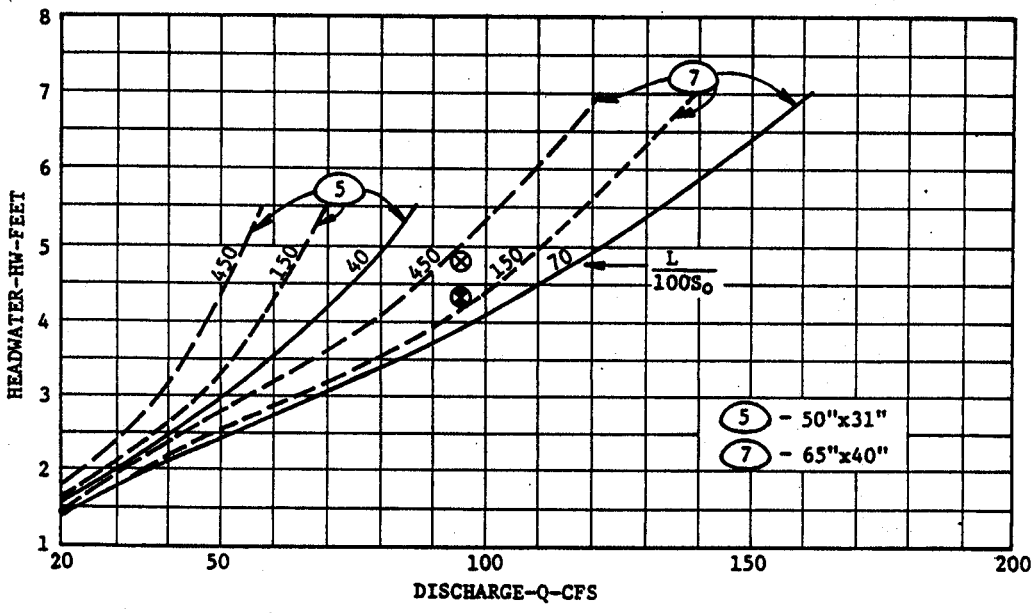
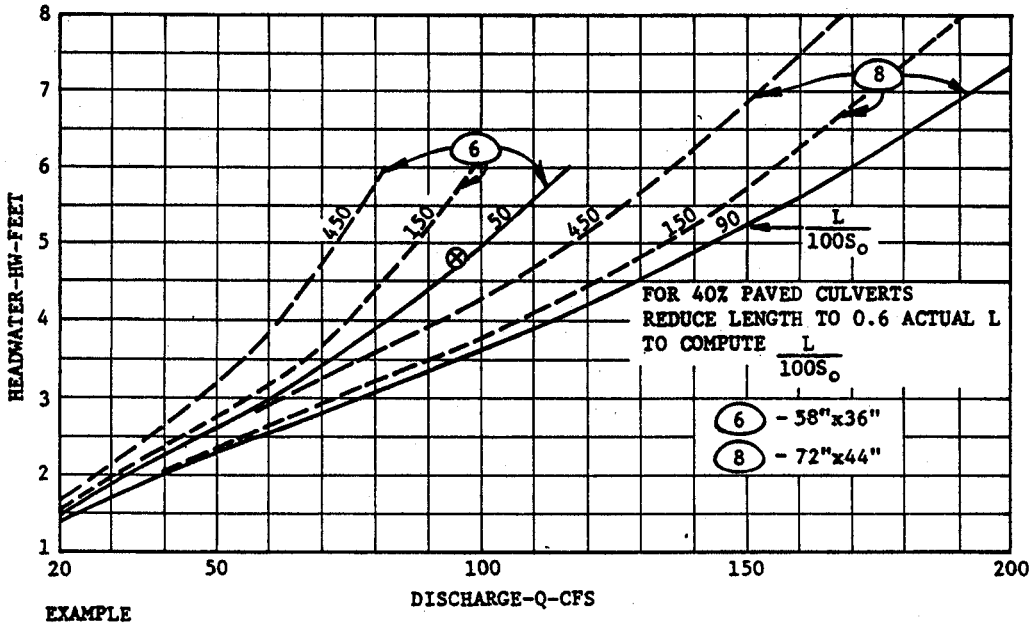
FIGURE A-19. CULVERT CAPACITY STANDARD CORRUGATED PIPE-ARCH HEADWALL ENTRANCE 25" BY 16" TO 43" BY 27"





EXAMPLE

⊗ GIVEN:
95 CFS, AHW = 4.8 FT.
L = 240 FT; S_o = 0.012

⊗ SELECT NO. 7, 65"x40"
HW = 4.3 FT.
UNPAVED INVERT

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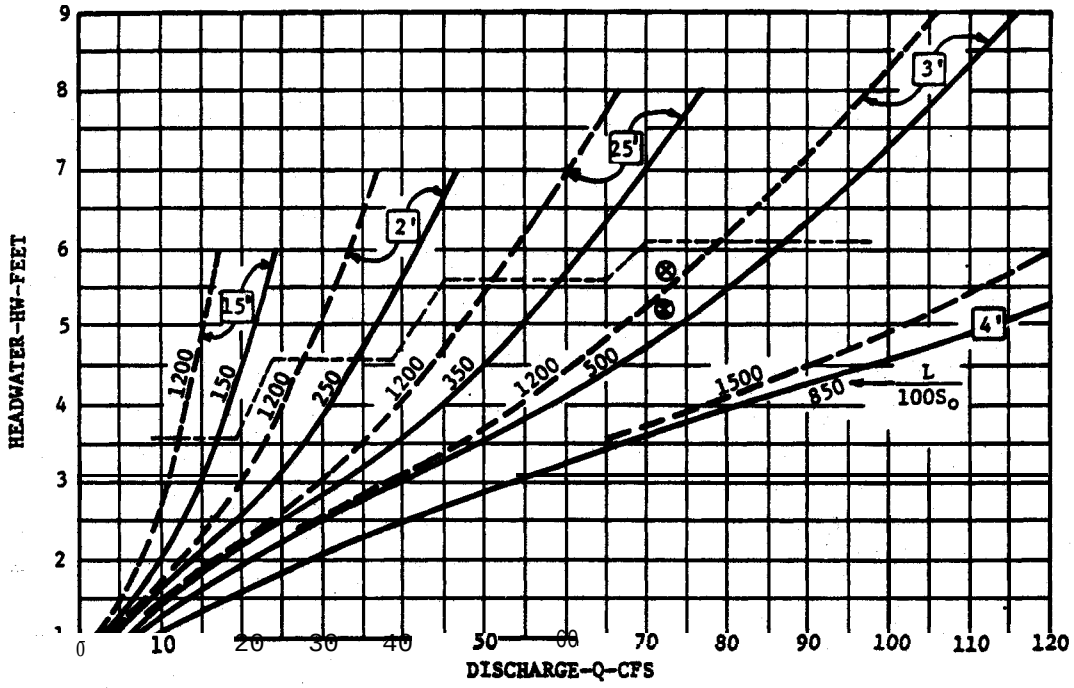
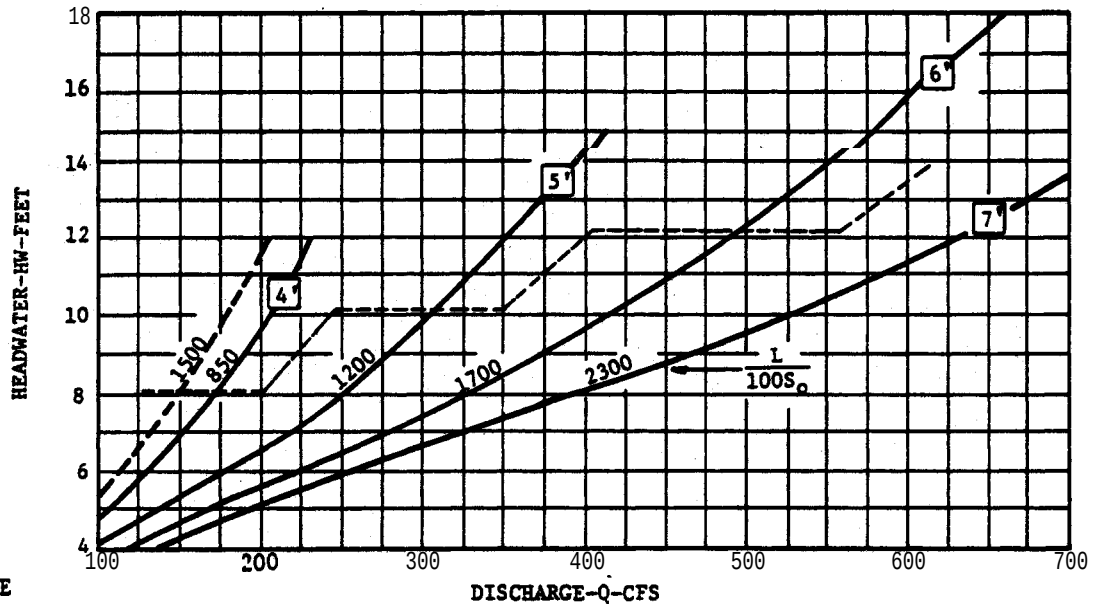
FIGURE A-20. CULVERT CAPACITY STANDARD CORRUGATED PIPE-ARCH HEADWALL ENTRANCE 50" BY 31" TO 72" BY 44"





EXAMPLE

⊗ GIVEN:
72 CFS; AHW = 5.7 FT.
L = 200 FT; S_o = 0.002

⊗ SELECT 3' x 3'
HW = 5.2 FT

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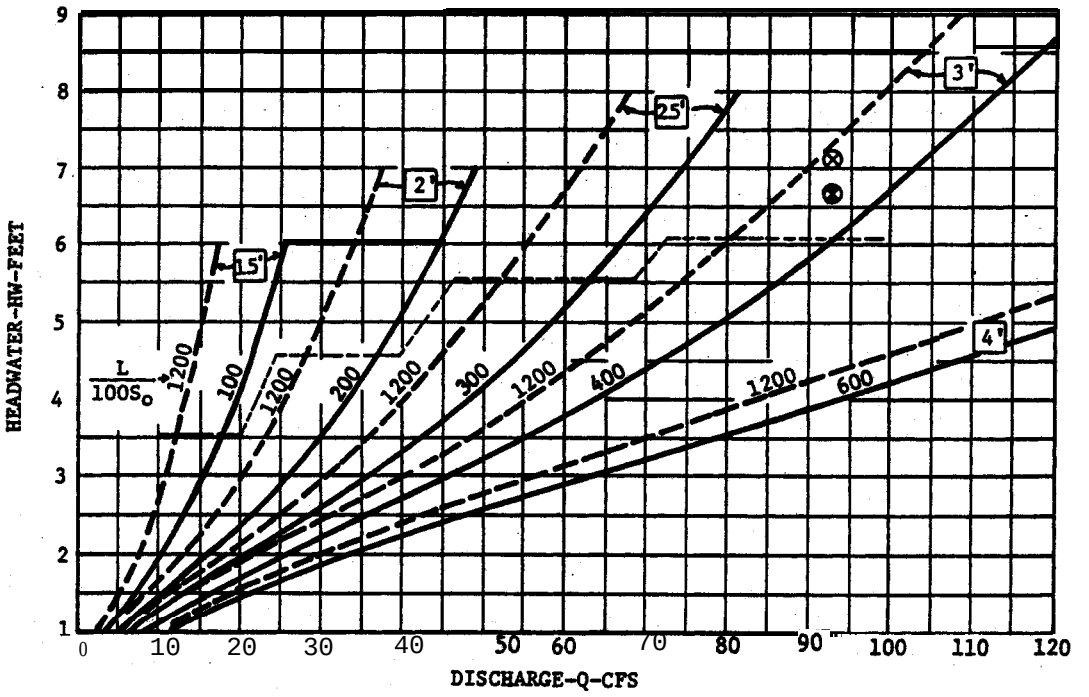
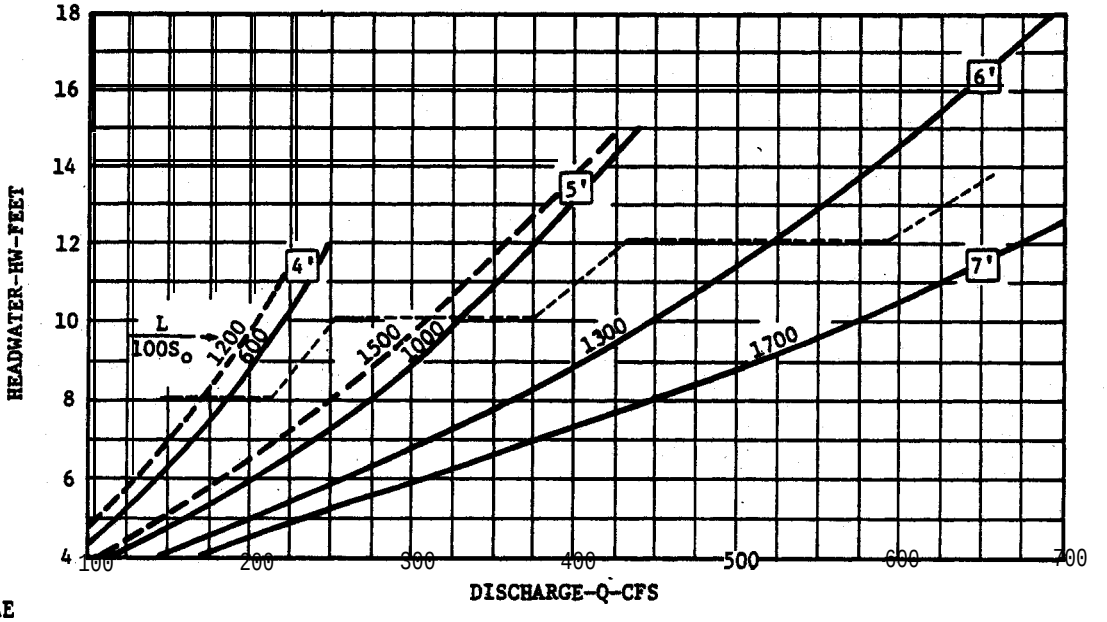
FIGURE A-21. CULVERT CAPACITY SQUARE CONCRETE BOX 90 DEGREES AND 15 DEGREES WINGWALL FLARE 1.5' BY 1.5' TO 7' BY 7'





EXAMPLE

⊗ **GIVEN:**
72 CFS; AHW = 5.7 FT.
L = 200 FT; S_o = 0.002

⊗ SELECT 3' x 3'
?iW = S.2 FT

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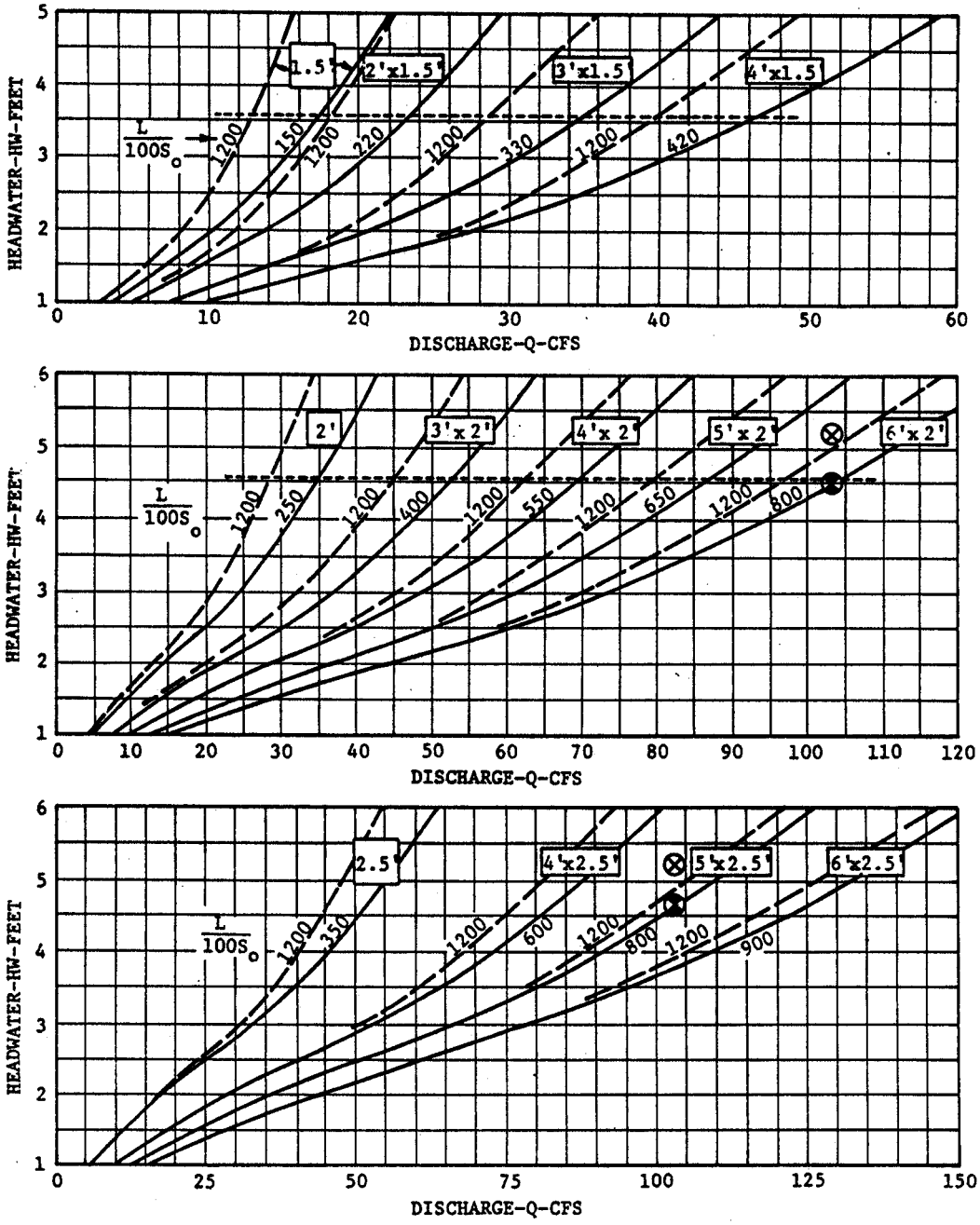
FIGURE A-22. CULVERT CAPACITY SQUARE CONCRETE BOX 30 DEGREES AND 75 DEGREES WINGWALL FLARE 1.5' BY 1.5' TO 7' BY 7' ▣



EXAMPLE:

⊗ GIVEN:
103 CFS; AHW = 5.2 FT
L = 150 FT; S_o = 0.015

⊗ SELECT: 6' x 2', HW = 4.5 FT.
OR 5' x 2.5'; HW = 4.6 FT.

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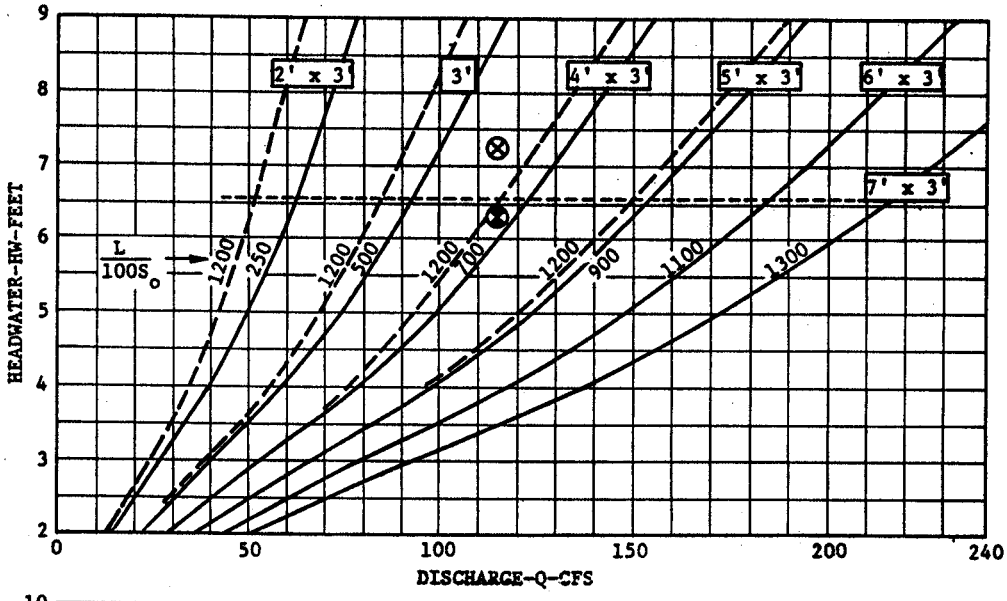
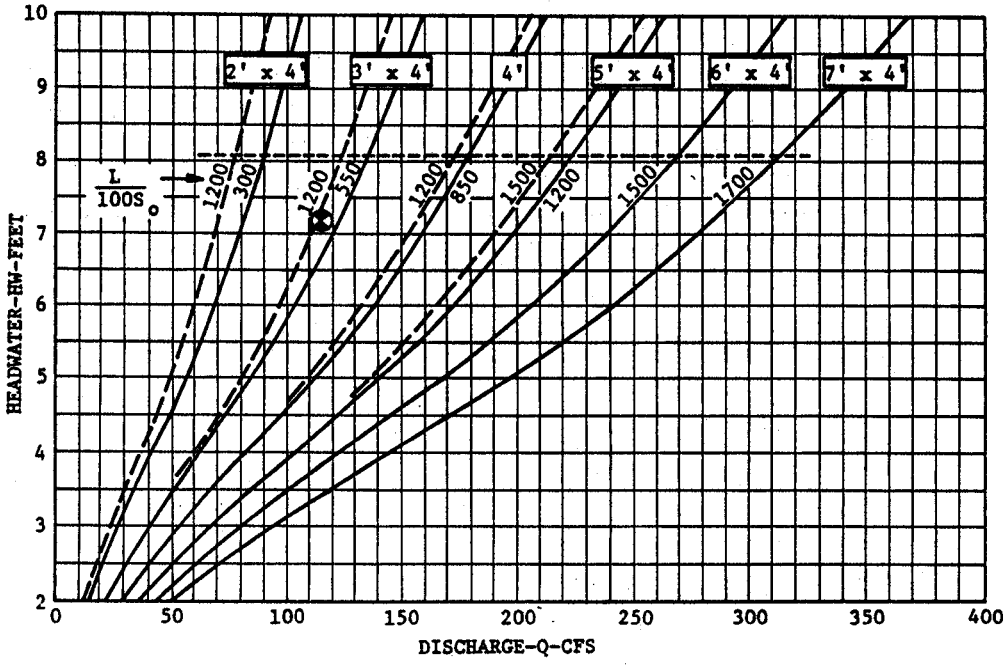
FIGURE A-23. CULVERT CAPACITY RECTANGULAR CONCRETE BOX 90 DEGREES AND 15 DEGREES WINGWELL FLARE 1.5', 2.0' AND 2.5' HEIGHTS





EXAMPLE:

⊗ GIVEN:
115 CFS, AHW = 7.2 FT
L = 300 FT, S_o = 0.003

⊗ SELECT 4' x 3', HW = 6.3 FT
OR 3' x 4', HW = 7.2 FT

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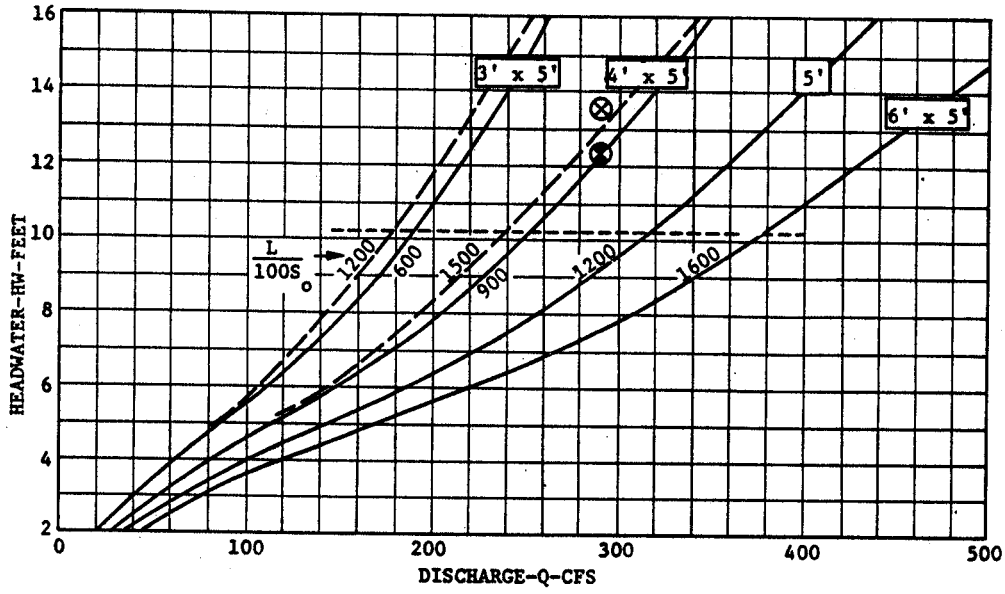
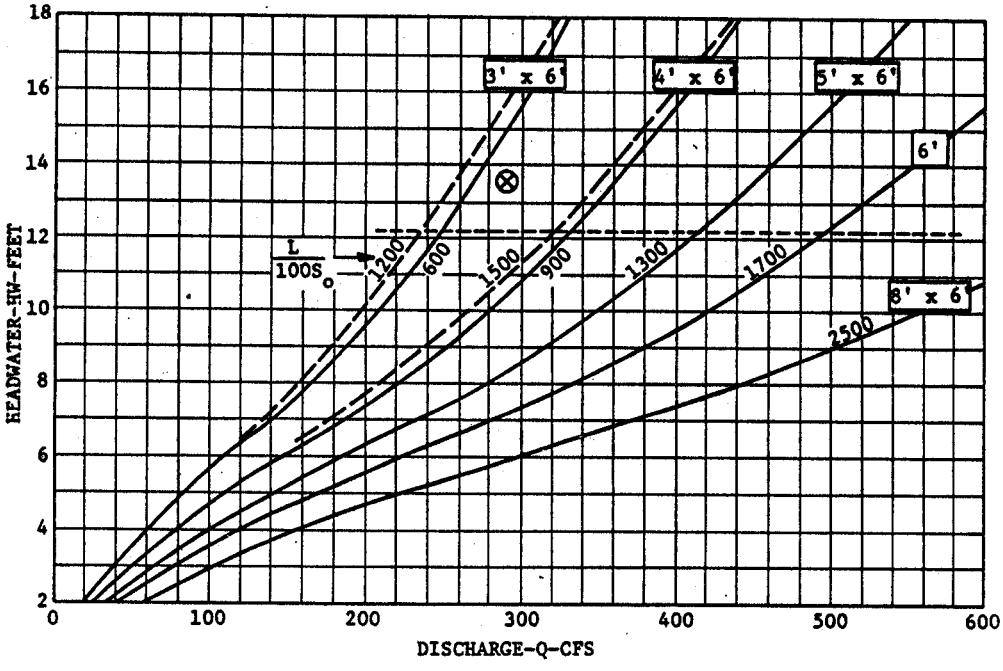
FIGURE A-24. CULVERT CAPACITY RECTANGULAR CONCRETE BOX 90 DEGREES AND 15 DEGREES WINGWALL FLARE 3' AND 4' HEIGHTS ▯ & ▭





EXAMPLE:

⊗ GIVEN:
290 CFS; AHW = 13.5 FT.
L = 250 FT; S_o = 0.010

⊗ SELECT 4' x 5'
HW = 12.3 FT.

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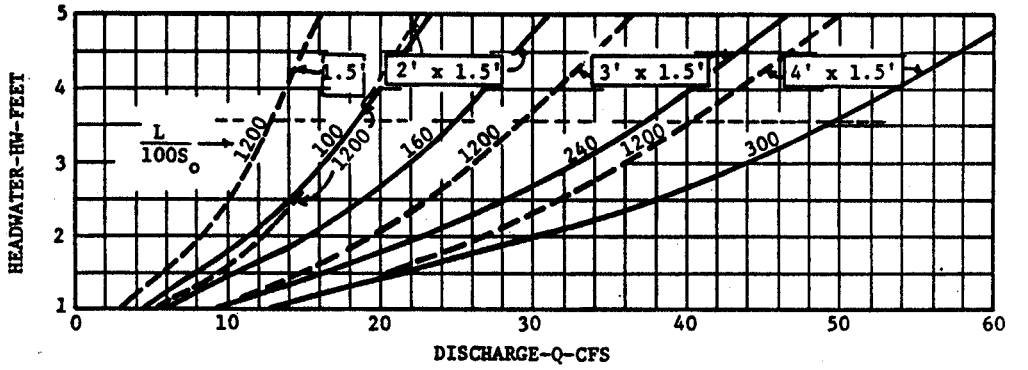
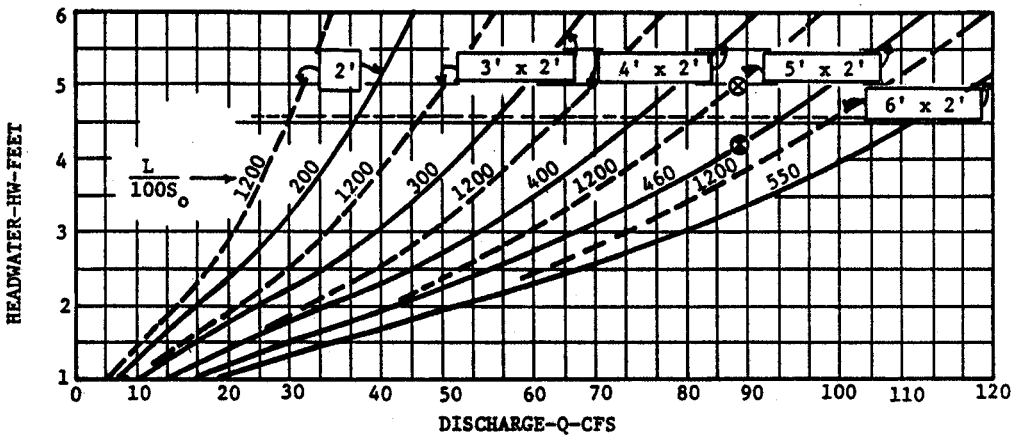
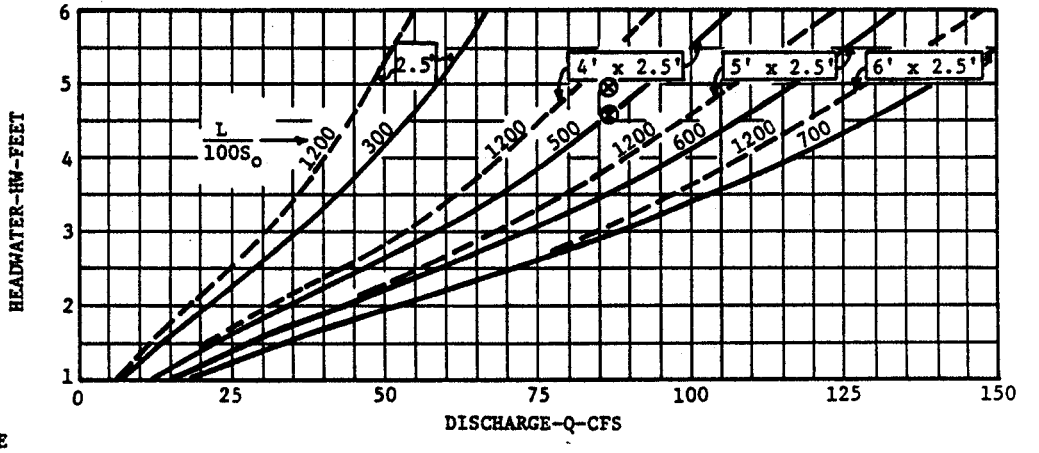
FIGURE A-25. CULVERT CAPACITY RECTANGULAR CONCRETE BOX 90° AND 15° WINGWALL FLARE 5' AND 6' HEIGHTS







EXAMPLE

⊗ GIVEN:
87 CFS, AHW = 5.0 FT.
L = 120 FT., S_o = 0.003

⊗ SELECT 5' x 2', HW = 4.2 FT.
OR 4' x 2.5', HW = 4.6 FT.

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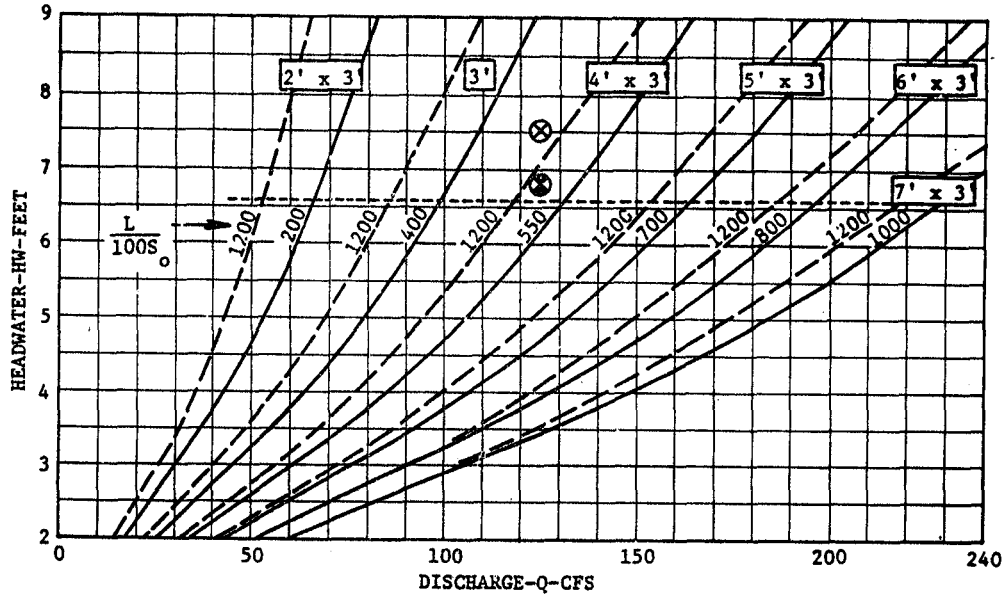
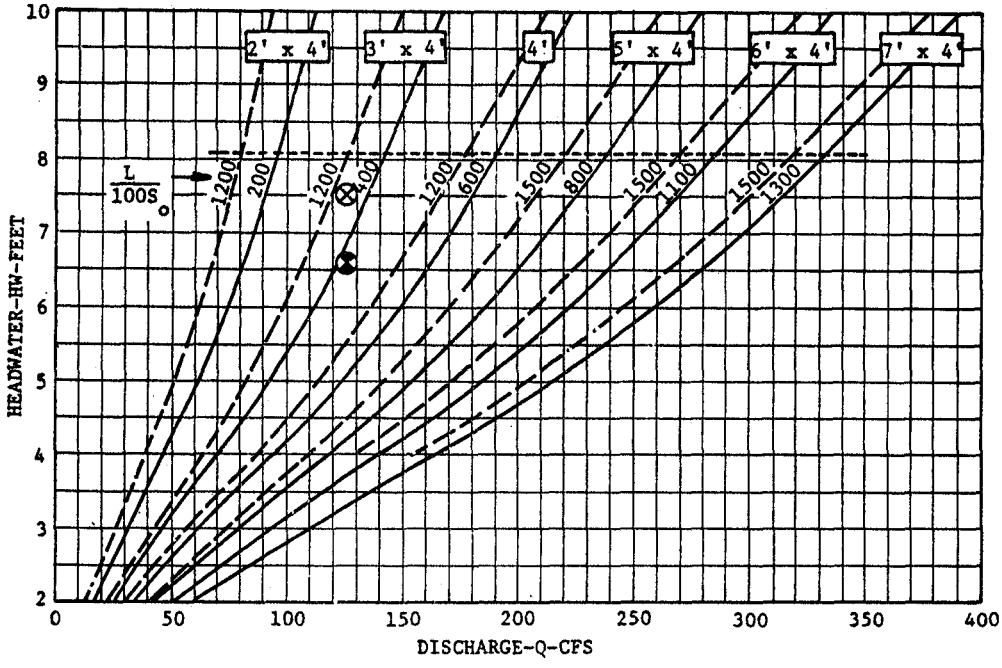
FIGURE A-26. CULVERT CAPACITY RECTANGULAR CONCRETE BOX 30° AND 75° WINGWALL FLARE 1.5', 2.0' AND 2.5' HEIGHTS





EXAMPLE:

⊗ GIVEN:
125 CFS, AHW = 7.5 FT.
L = 400 FT.; S_o = 0.004

⊗ SELECT 4' x 3', HW = 6.8 FT.
OR 3.5 x 4'; HW = 6.6 FT.

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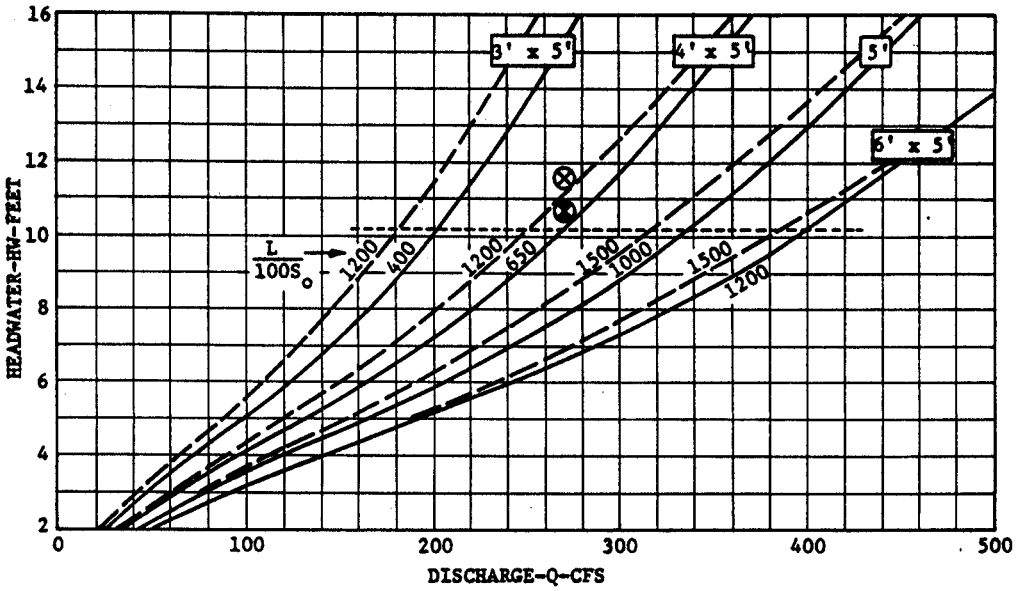
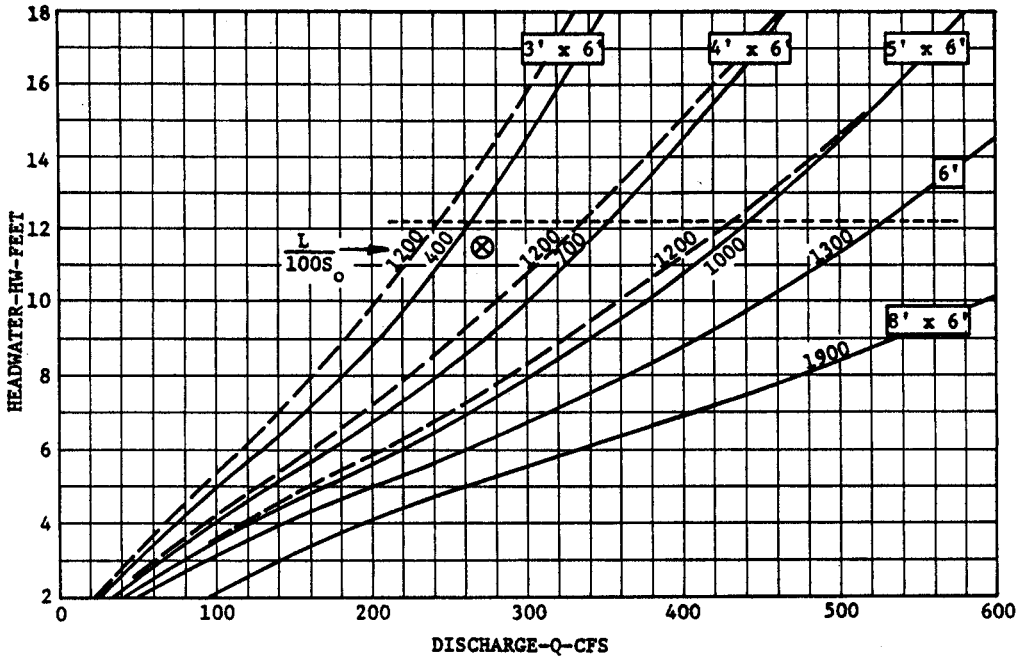
FIGURE A-27. CULVERT CAPACITY RECTANGULAR CONCRETE BOX 30° AND 75° WINGWALL FLARE 3' AND 4' HEIGHTS ▯ & ▭





EXAMPLE:

⊗ GIVEN:
270 CFS, AHW = 11.5 FT.
L = 450 FT., S_o = 0.0005

⊗ SELECT 4' x 5'
HW = 10.7 FT.

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FIGURE A-28. CULVERT CAPACITY RECTANGULAR CONCRETE BOX 30° AND 75° WINGWALL FLARE 5' AND 6' HEIGHTS