

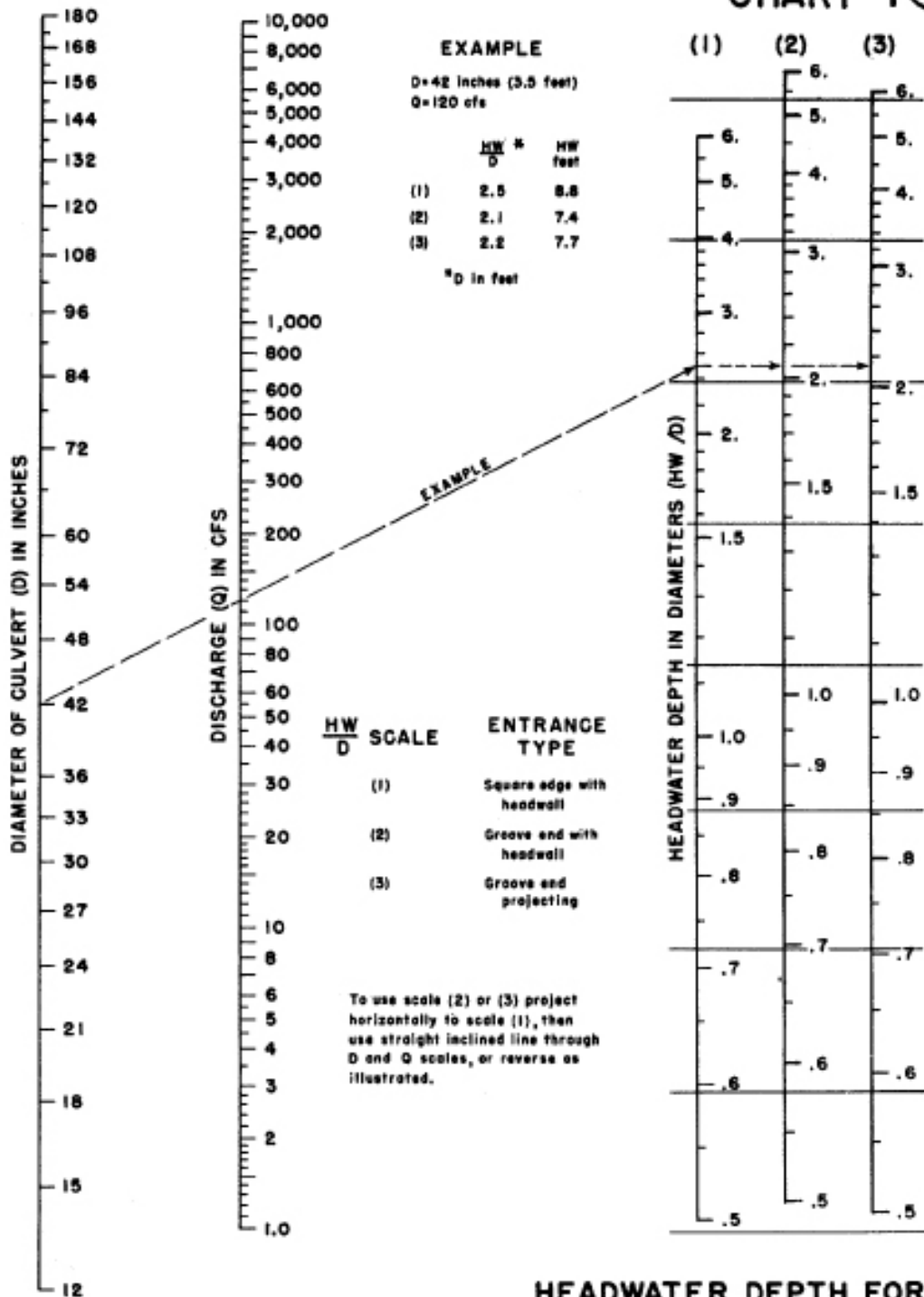
**Appendix 5-C**  
**Culvert Design Charts**

The following charts are taken from *Hydraulic Design of Highway Culverts*, FHWA, Hydraulic Design Series No. 5, September 1985.

Chart	Shape	Control Section	Material	Type
1	Circular	Inlet	Concrete	
2	Circular	Inlet	Metal	
3	Circular	Inlet	Metal	Beveled Ring Control
4	Circular	Critical		
5	Circular	Outlet	Concrete	$n = 0.012$
6	Circular	Outlet	Metal	$n = 0.024$
7	Circular	Outlet	Metal	$n = 0.0328$ to $0.0302$
8	Box	Inlet	Concrete	
9	Box	Inlet	Concrete	Wingwalls $18^\circ$ to $33.7^\circ$ and $45^\circ$
10	Box	Inlet	Concrete	$90^\circ$ Headwall, Beveled Edges
11	Box	Inlet	Concrete	Skewed Headwalls, Beveled Edges
12	Box	Inlet	Concrete	Flared Wingwalls Normal and Skewed
13	Box	Inlet	Concrete	Offset Flared Wingwalls, Beveled Edge
14	Box	Critical		
15	Box	Outlet	Concrete	$n = 0.012$
16	C.M.Box	Inlet	Metal	Rise/Span $< 0.3$
17	C.M.Box	Inlet	Metal	$0.3 \leq$ Rise/Span $< 0.4$
18	C.M.Box	Inlet	Metal	$0.4 \leq$ Rise/Span $< 0.5$
19	C.M.Box	Inlet	Metal	Rise/Span $\geq 0.5$
20	C.M.Box	Critical		
21	C.M.Box	Outlet	Metal	Concrete Bottom, Rise/Span $< 0.3$
22	C.M.Box	Outlet	Metal	Concrete Bottom, $0.3 \leq$ Rise/Span $< 0.4$
23	C.M.Box	Outlet	Metal	Concrete Bottom, $0.4 \leq$ Rise/Span $< 0.5$
24	C.M.Box	Outlet	Metal	Concrete Bottom, Rise/Span $\geq 0.5$
25	C.M.Box	Outlet	Metal	Metal Bottom, Rise/Span $< 0.3$
26	C.M.Box	Outlet	Metal	Metal Bottom, $0.3 \leq$ Rise/Span $< 0.4$
27	C.M.Box	Outlet	Metal	Metal Bottom, $0.4 \leq$ Rise/Span $< 0.5$
28	C.M.Box	Outlet	Metal	Metal Bottom, Rise/Span $> 0.5$
29	Elliptical	Inlet	Concrete	Horizontal
30	Elliptical	Inlet	Concrete	Vertical
31	Elliptical	Critical	Concrete	Horizontal
32	Elliptical	Critical	Concrete	Vertical
33	Elliptical	Outlet	Concrete	Horizontal and Vertical
34	Pipe Arch	Inlet	Metal	
35B	Pipe Arch	Inlet	Metal	18 in. Corner Radius
36	Pipe Arch	Inlet	Metal	31 in. Corner Radius
37	Pipe Arch	Critical		Standard
38	Pipe Arch	Critical		Structural Plate
39	Pipe Arch	Outlet	Metal	$n = 0.024$
40	Pipe Arch	Outlet	Metal	18 in. Corner Radius
41	Arch	Inlet	Metal	$0.3 \leq$ Rise/Span $< 0.4$
42	Arch	Inlet	Metal	$0.4 \leq$ Rise/Span $< 0.5$

43	Arch	Inlet	Metal	Rise/Span > 0.5
44	Arch	Critical		
45	Arch	Outlet	Metal	Concrete Bottom, $0.3 \leq \text{Rise/Span} < 0.4$
46	Arch	Outlet	Metal	Concrete Bottom, $0.4 \leq \text{Rise/Span} < 0.5$
47	Arch	Outlet	Metal	Concrete Bottom, Rise/Span > 0.5
48	Arch	Outlet	Metal	Earth Bottom, $0.3 \leq \text{Rise/Span} < 0.4$
49	Arch	Outlet	Metal	Earth Bottom, $0.4 \leq \text{Rise/Span} < 0.5$
50	Arch	Outlet	Metal	Earth Bottom, Rise/Span > 0.5
51	Long Span		Inlet	Metal Circular or Elliptical
52	Long Span		Inlet	Metal High and Low Profile Arch
53	Long Span		Critical	Metal Circular or Elliptical
54	Long Span		Critical	Metal High and Low Profile
55	Circular	Inlet		Throat Control, Side Tapered
56	Circular	Inlet		Face Control, Side Tapered
57	Box	Inlet	Concrete	Throat Control, Side Tapered
58	Box	Inlet	Concrete	Face Control, Side Tapered
59	Box	Inlet	Concrete	Face Control, Slope Tapered

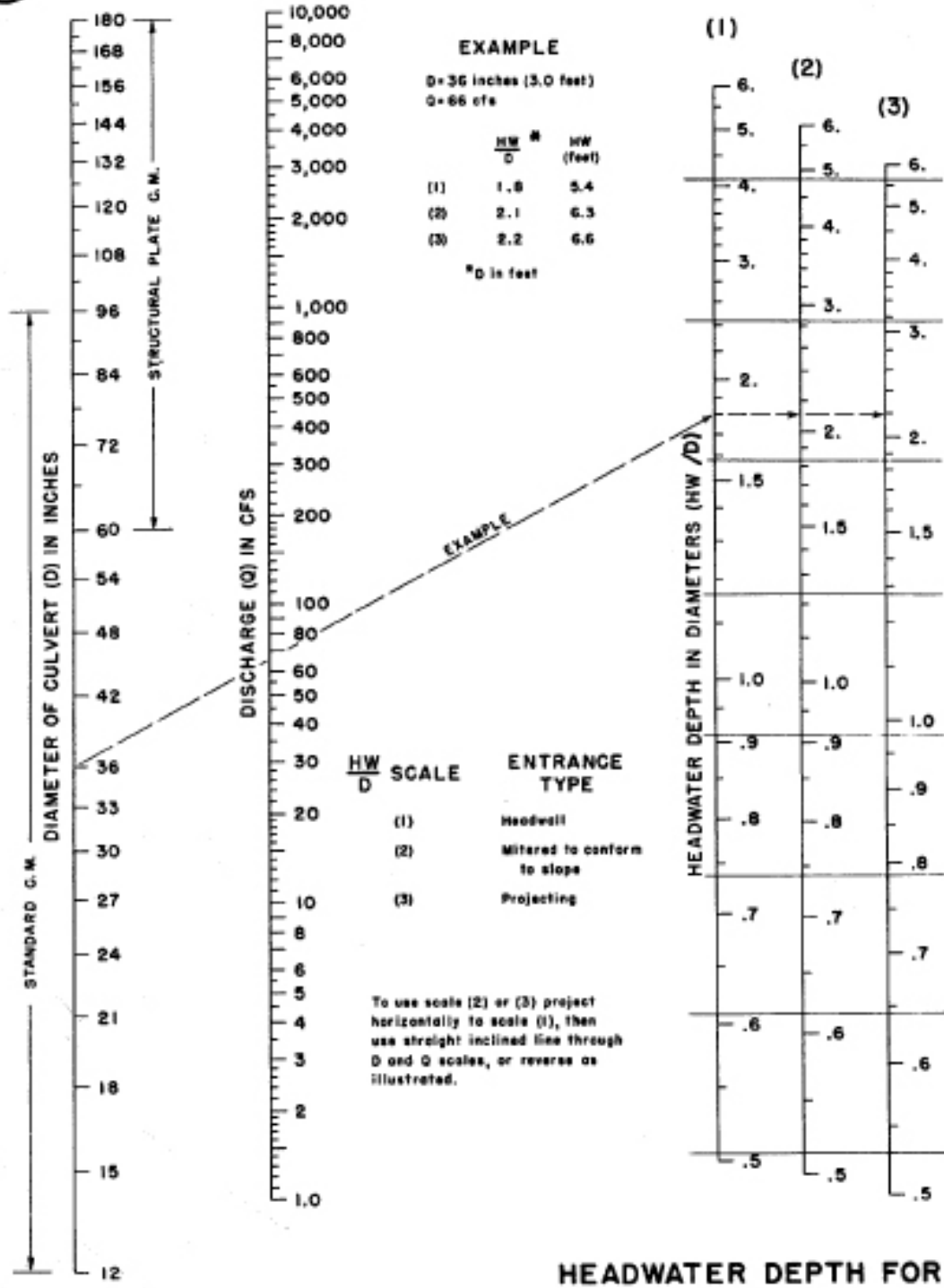
# CHART 1



HEADWATER SCALES 2 & 3  
REVISED MAY 1964

**HEADWATER DEPTH FOR  
CONCRETE PIPE CULVERTS  
WITH INLET CONTROL**

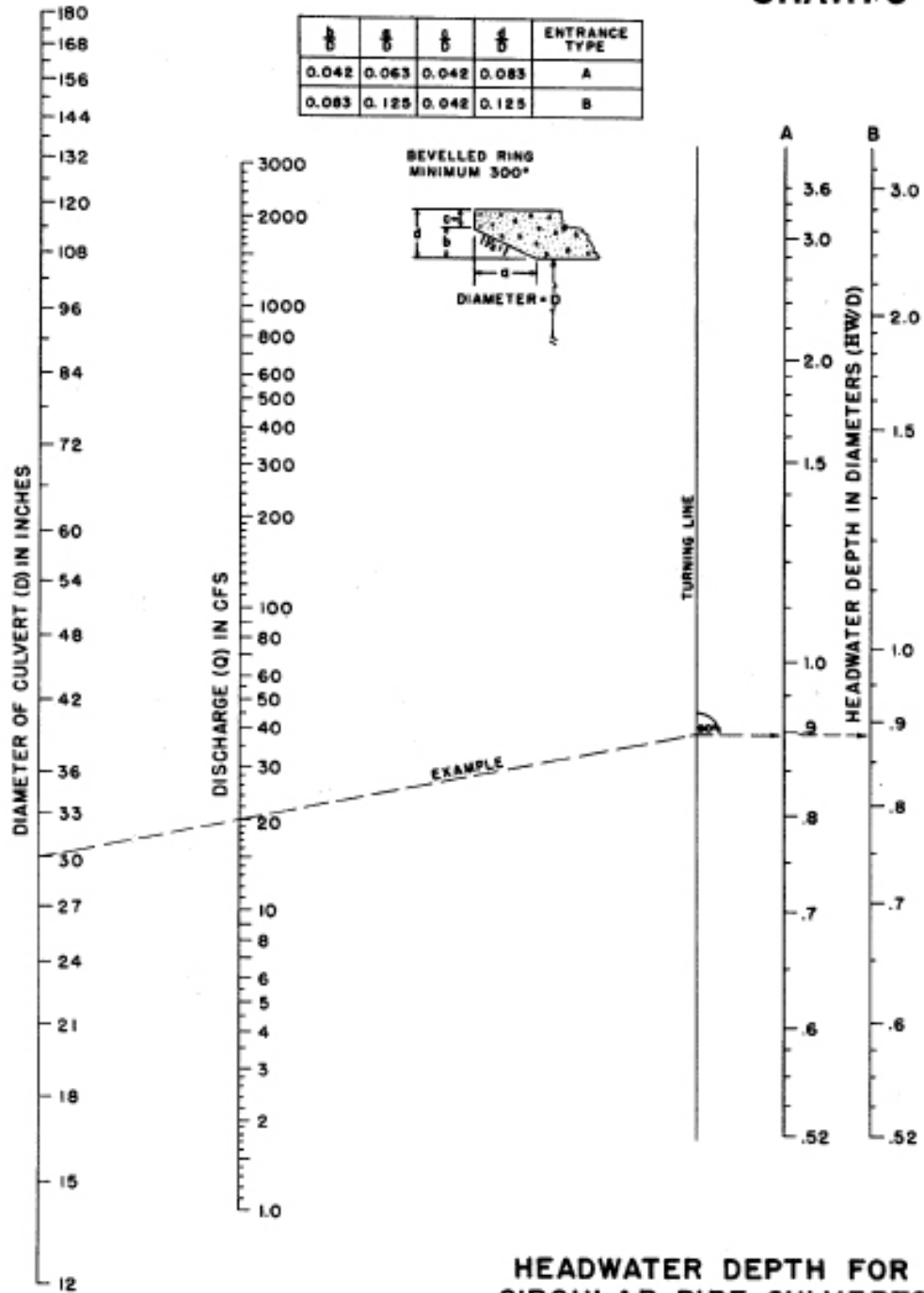
# CHART 2



**HEADWATER DEPTH FOR C. M. PIPE CULVERTS WITH INLET CONTROL**

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**CHART 3**

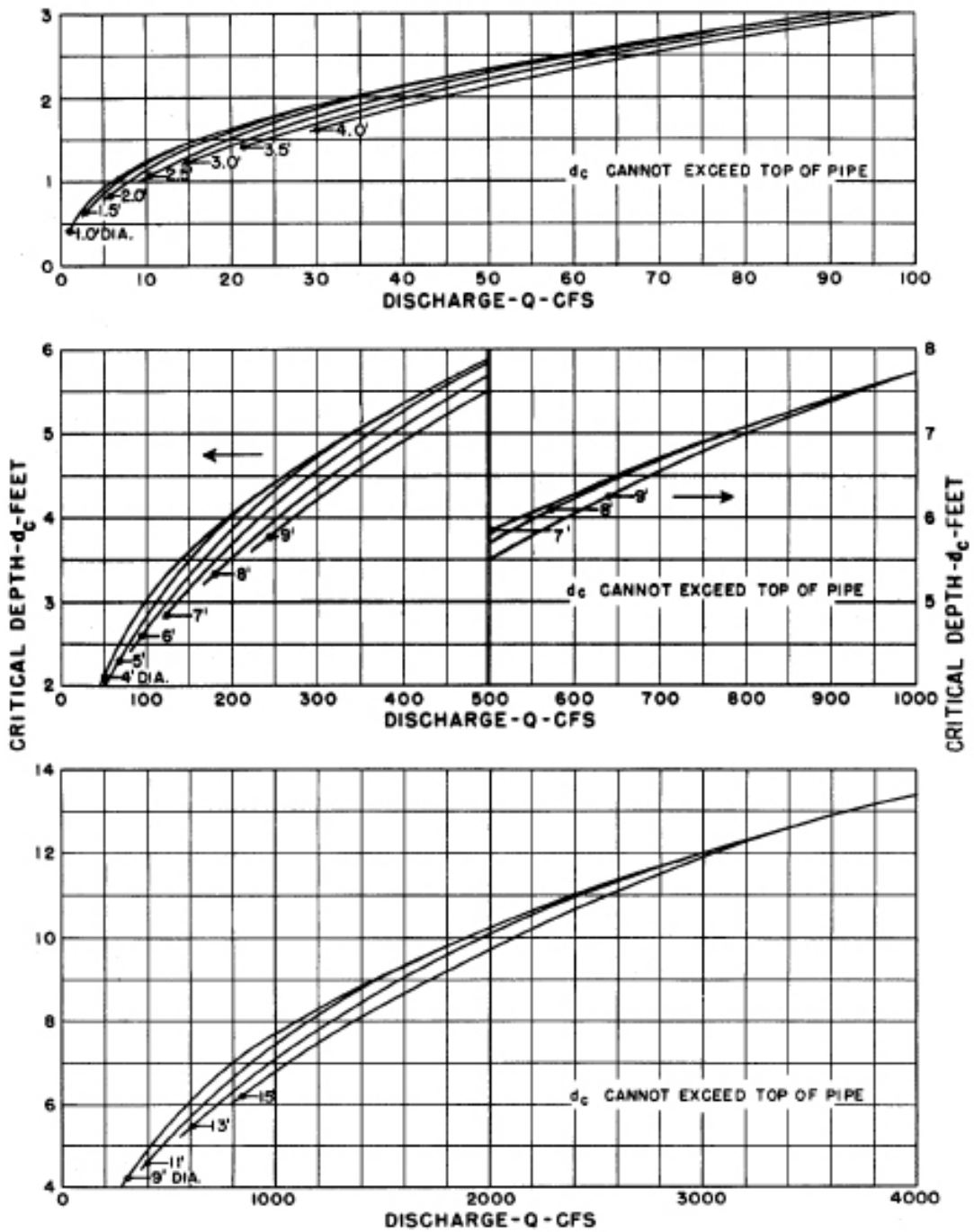


FEDERAL HIGHWAY ADMINISTRATION  
MAY 1973

**HEADWATER DEPTH FOR  
CIRCULAR PIPE CULVERTS  
WITH BEVELED RING  
INLET CONTROL**



**CHART 4**

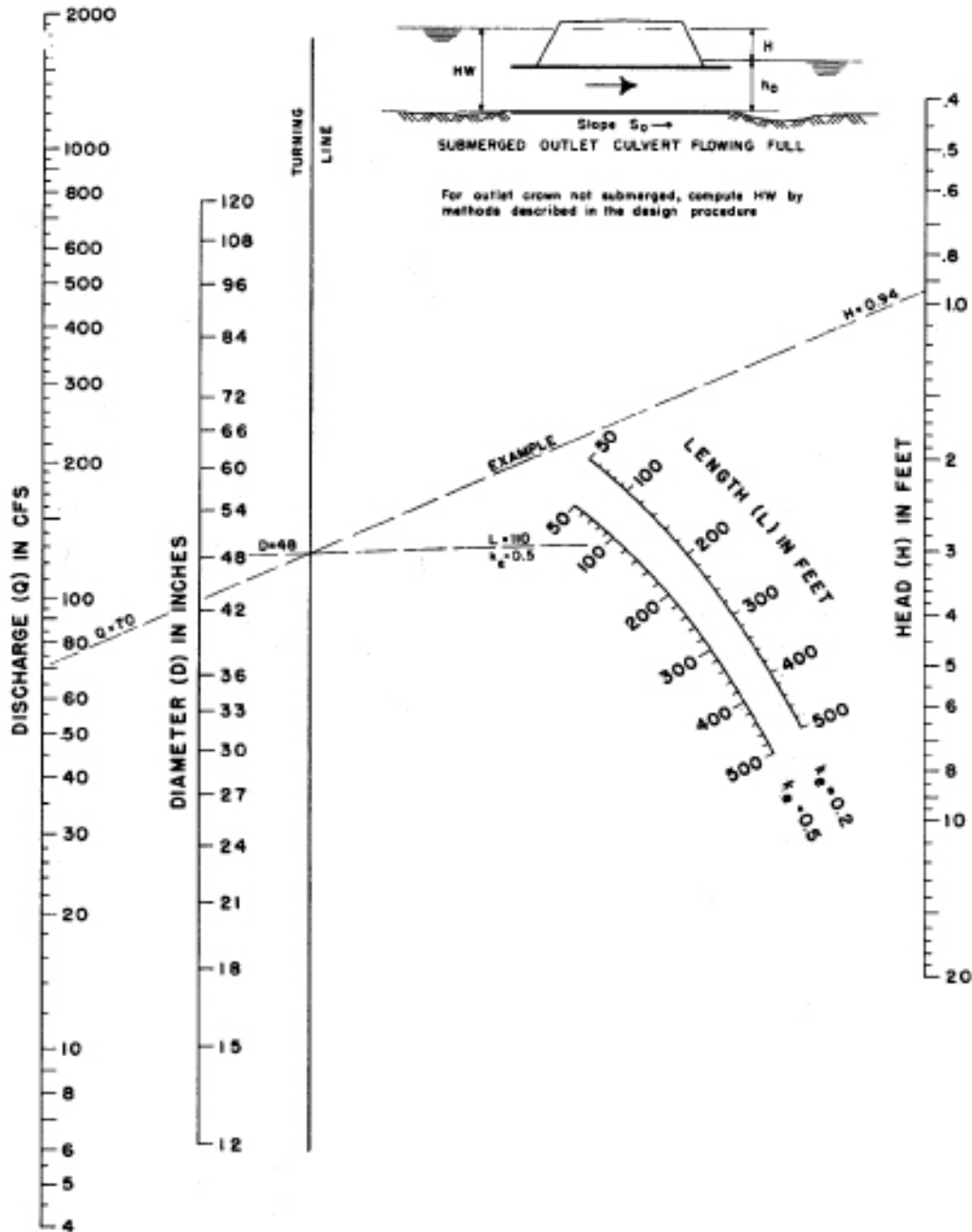


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JAN. 1964

**CRITICAL DEPTH  
CIRCULAR PIPE**



# CHART 5

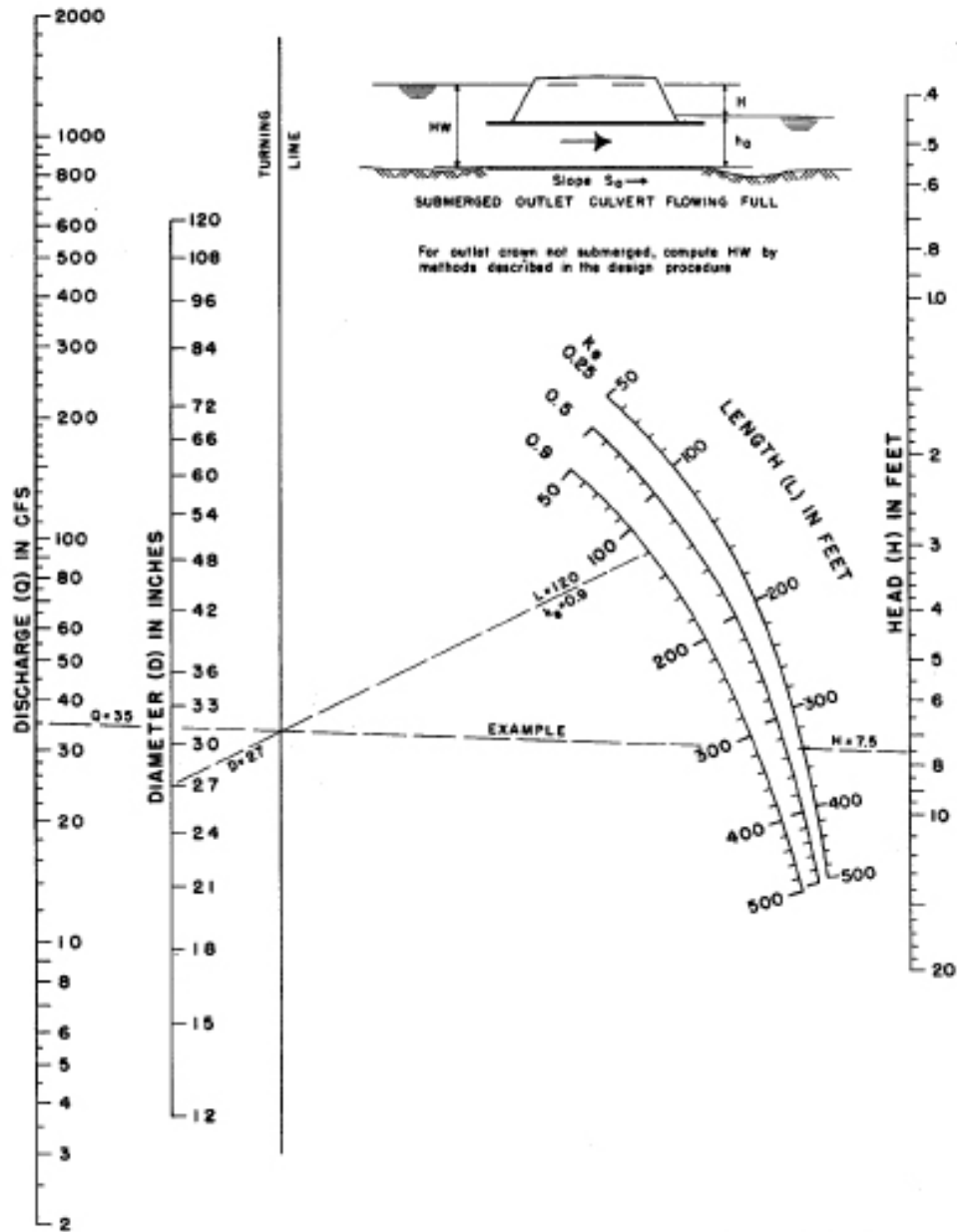


**HEAD FOR  
 CONCRETE PIPE CULVERTS  
 FLOWING FULL  
 n = 0.012**





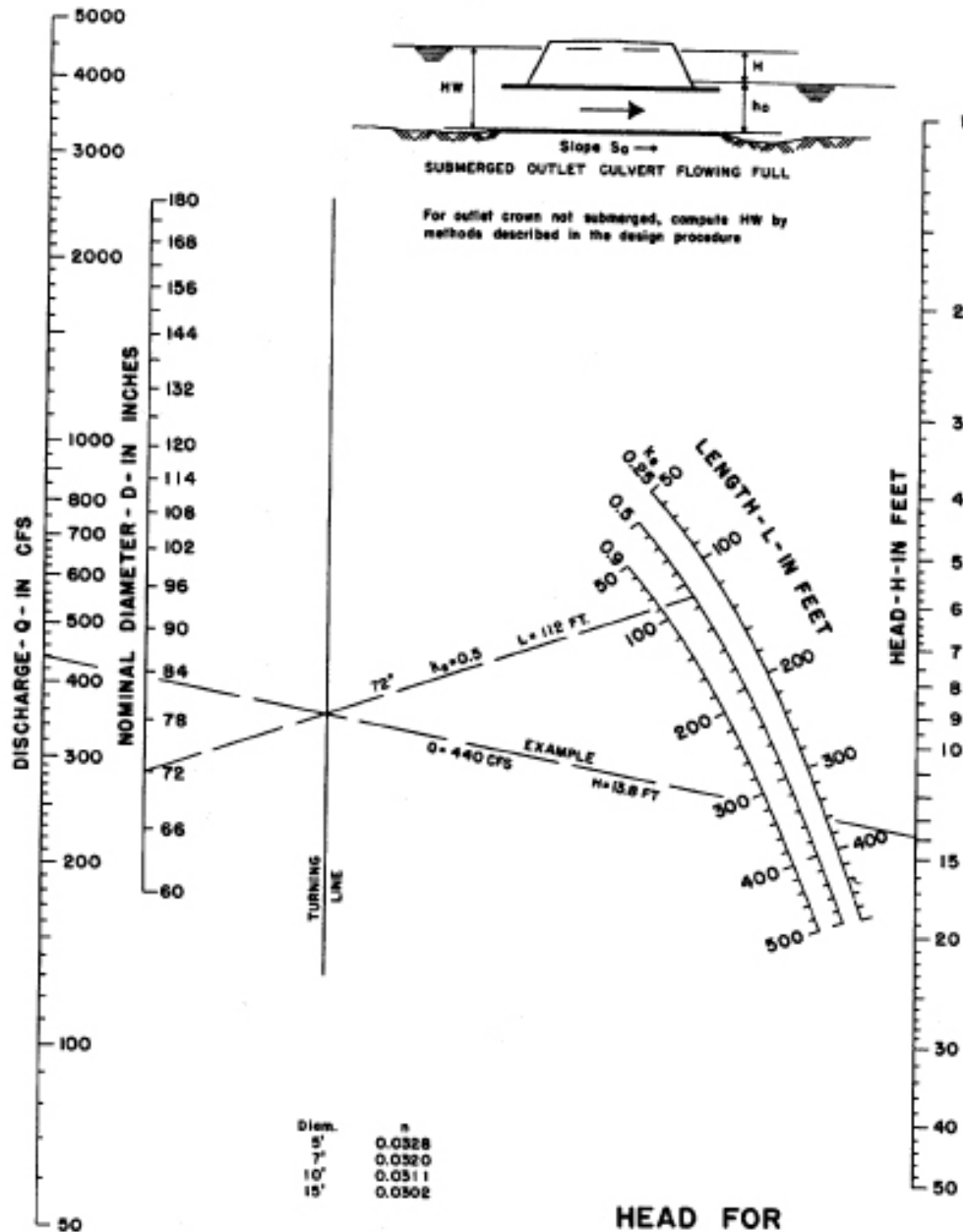
# CHART 6



**HEAD FOR  
STANDARD  
C. M. PIPE CULVERTS  
FLOWING FULL  
n = 0.024**

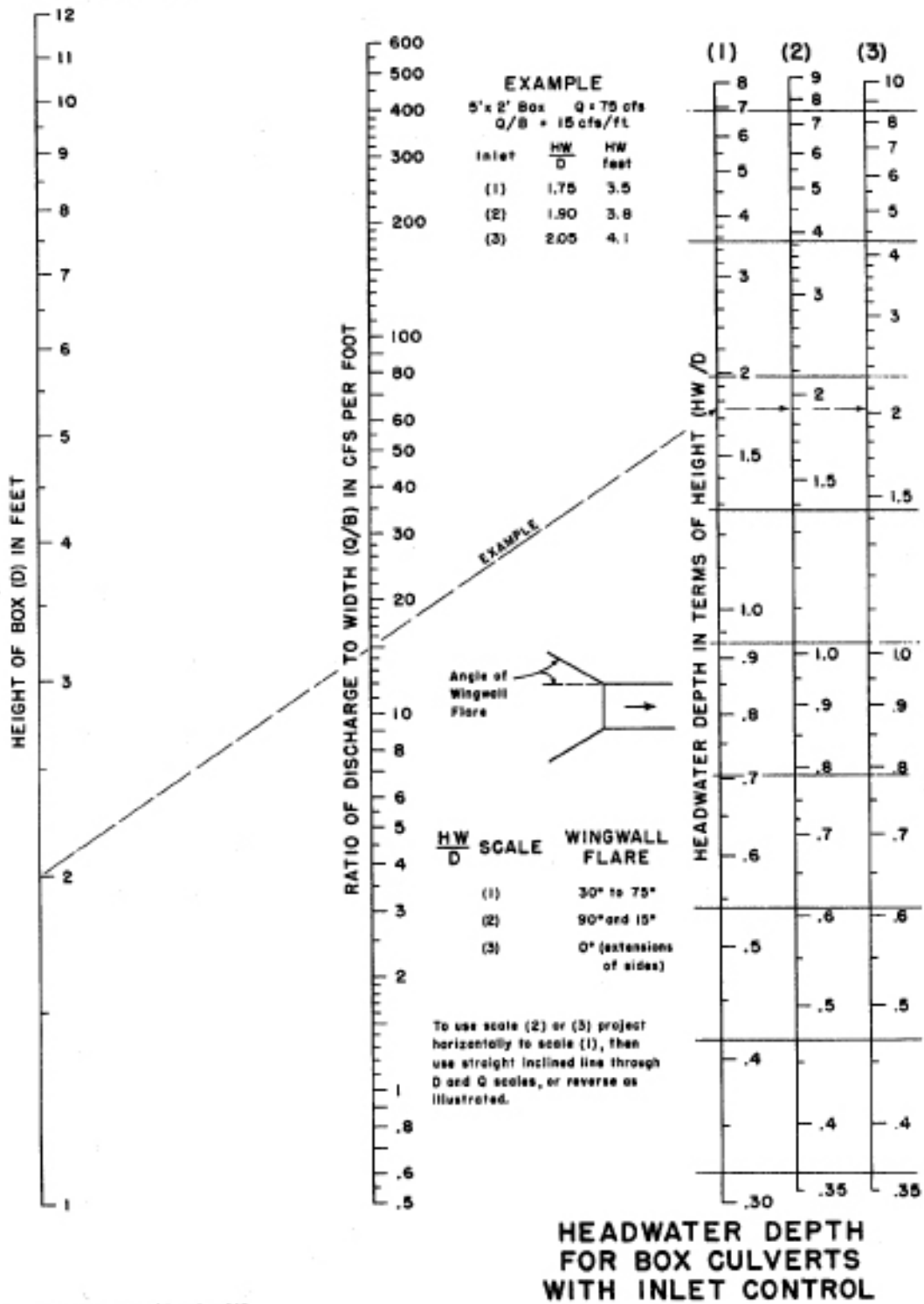
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CHART 7



BUREAU OF PUBLIC ROADS JAN. 1963

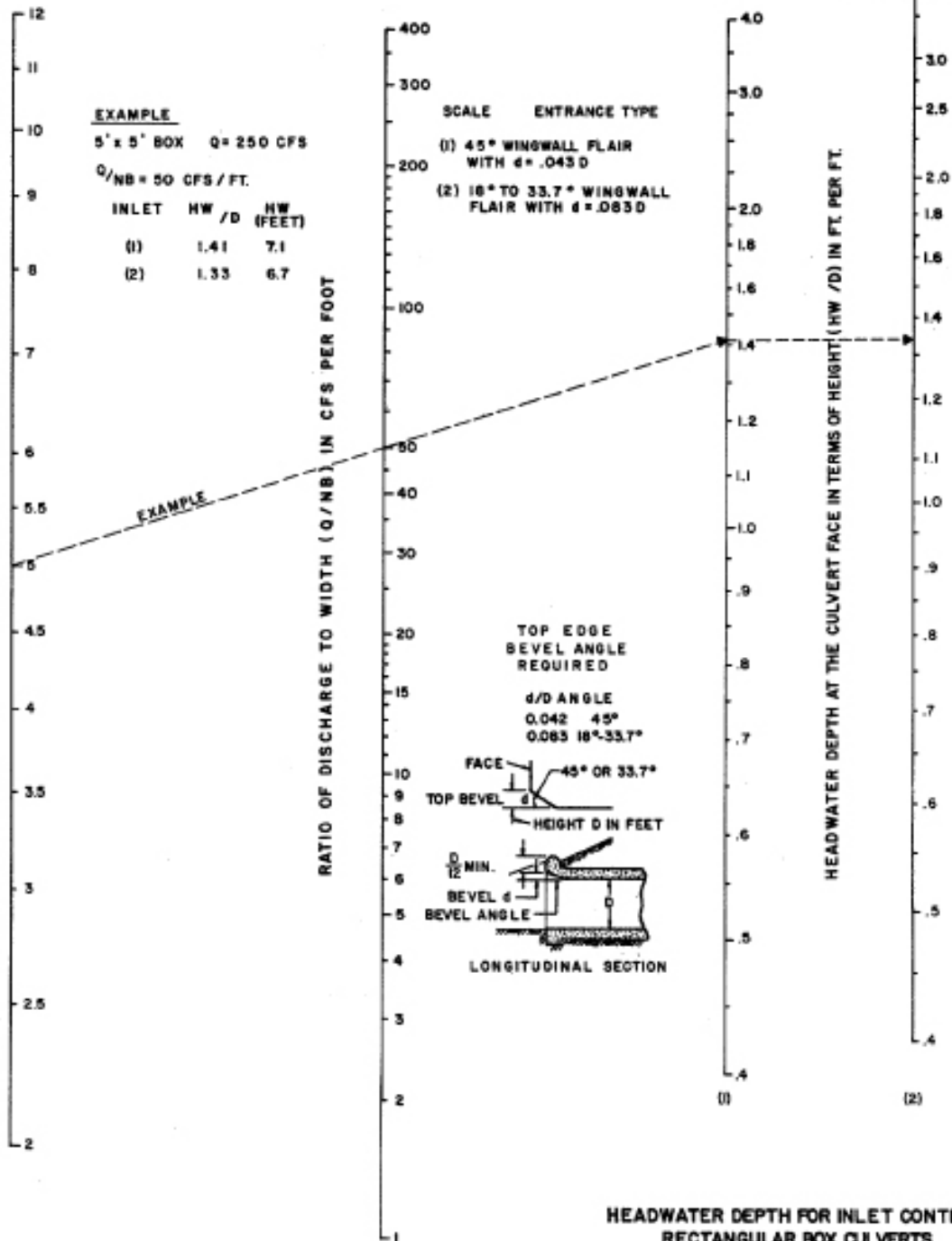
**CHART 8**



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### CHART 9



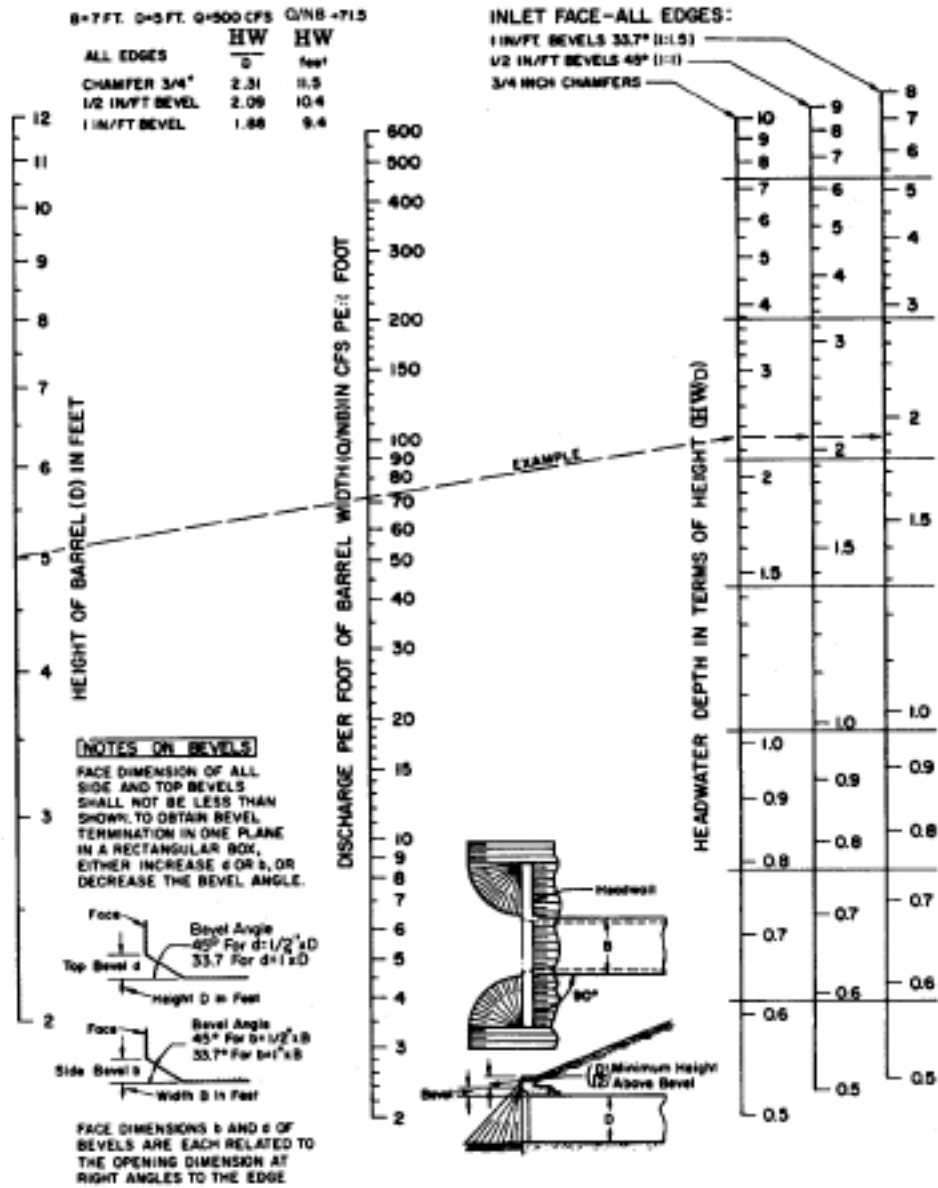


# CHART 10

## EXAMPLE

B=7 FT. D=5 FT. Q=500 CFS Q/NB = 71.5

	HW	HW
	feet	feet
ALL EDGES	0	0
CHAMFER 3/4"	2.31	11.5
1/2 IN/FT BEVEL	2.09	10.4
1 IN/FT BEVEL	1.86	9.4

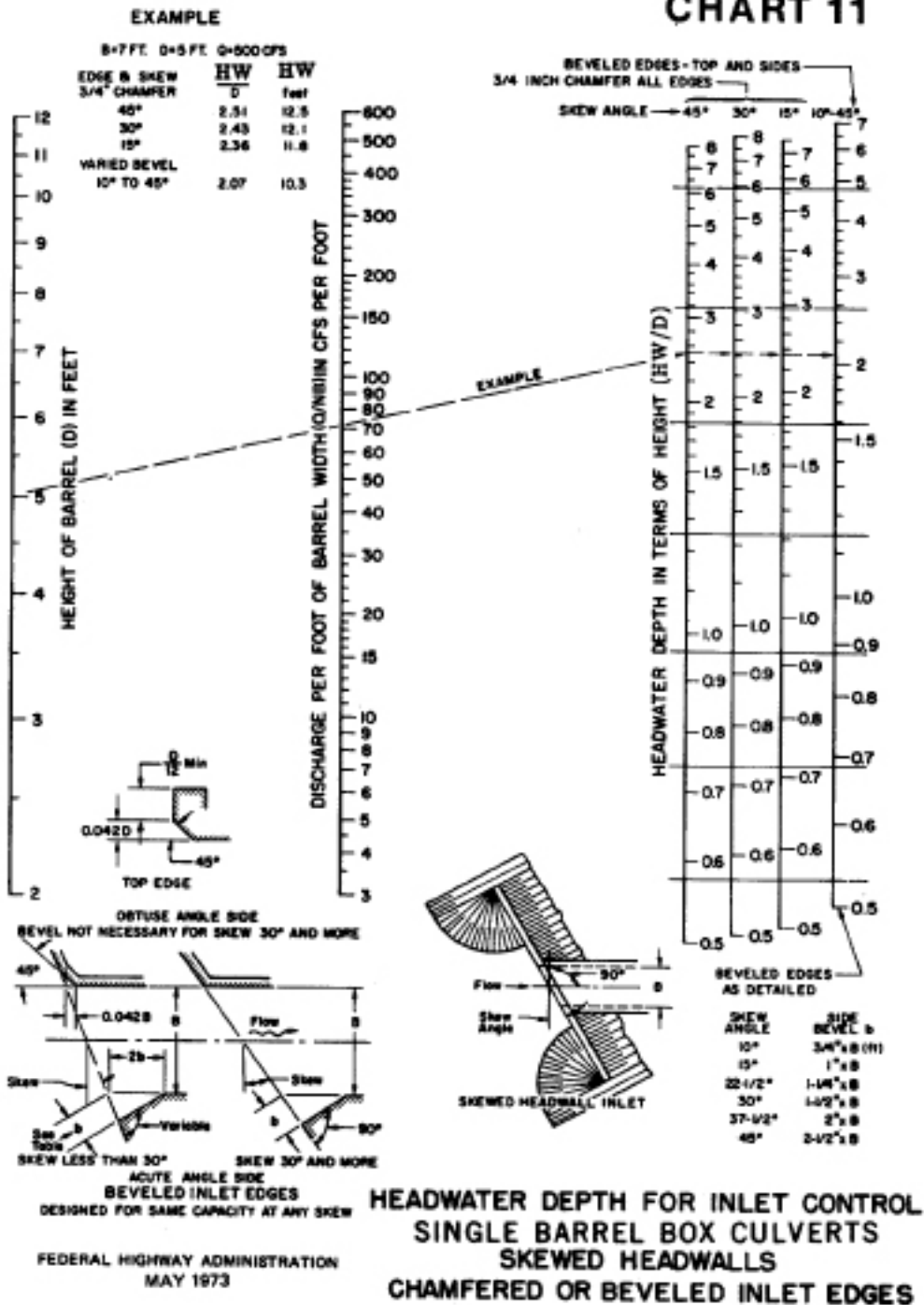


### HEADWATER DEPTH FOR INLET CONTROL RECTANGULAR BOX CULVERTS 90° HEADWALL CHAMFERED OR BEVELED INLET EDGES

FEDERAL HIGHWAY ADMINISTRATION  
 MAY 1973



# CHART 11



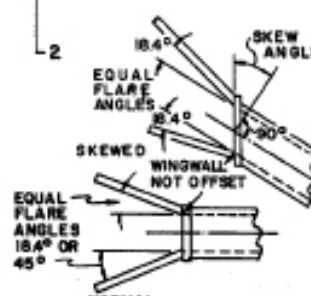
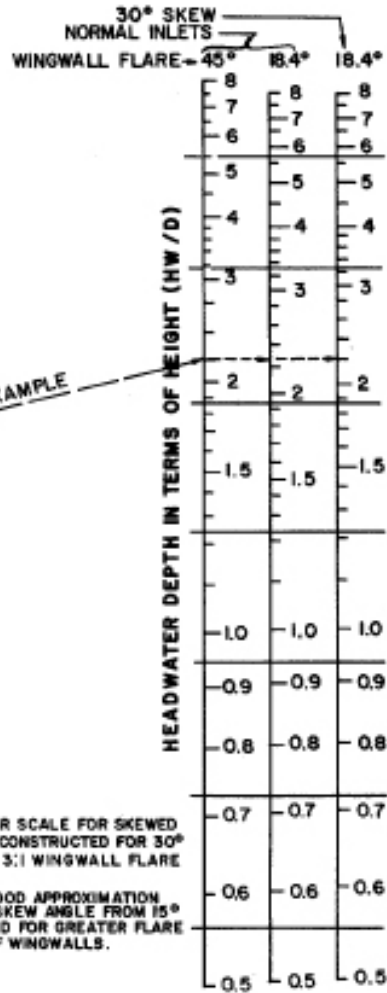
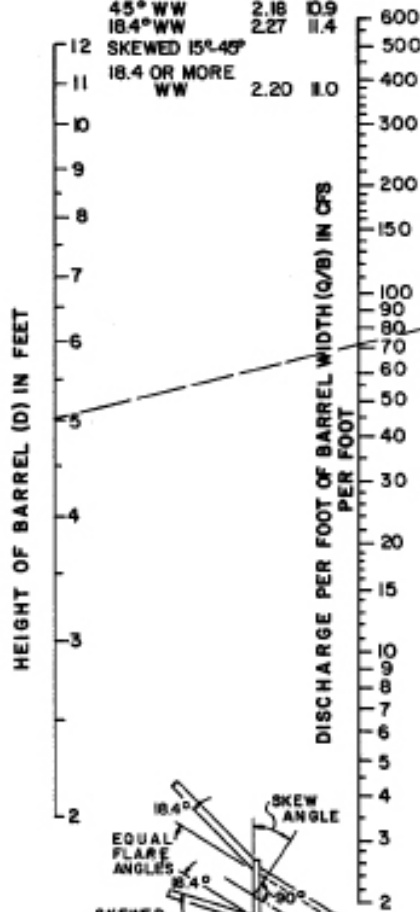


# CHART 12

**EXAMPLE**

B = 7 FT. D = 5 FT. Q = 500 CFS  
 $\frac{Q}{B} = 71.5$

INLET & WW	HW D	HW FT
NORMAL		
45° WW	2.18	10.9
18.4° WW	2.27	11.4
SKEWED 15°-45°		
18.4 OR MORE WW	2.20	11.0



NOTE:  
 HEADWATER SCALE FOR SKEWED INLETS IS CONSTRUCTED FOR 30° SKEW AND 3:1 WINGWALL FLARE (18.4°)  
 ALSO A GOOD APPROXIMATION FOR ANY SKEW ANGLE FROM 15° TO 45° AND FOR GREATER FLARE ANGLES OF WINGWALLS.

WINGWALL INLETS  
 BUREAU OF PUBLIC ROADS  
 OFFICE OF R & D AUGUST 1968

**HEADWATER DEPTH FOR INLET CONTROL  
 RECTANGULAR BOX CULVERTS  
 FLARED WINGWALLS  
 NORMAL AND SKEWED INLETS  
 3/4" CHAMFER AT TOP OF OPENING**

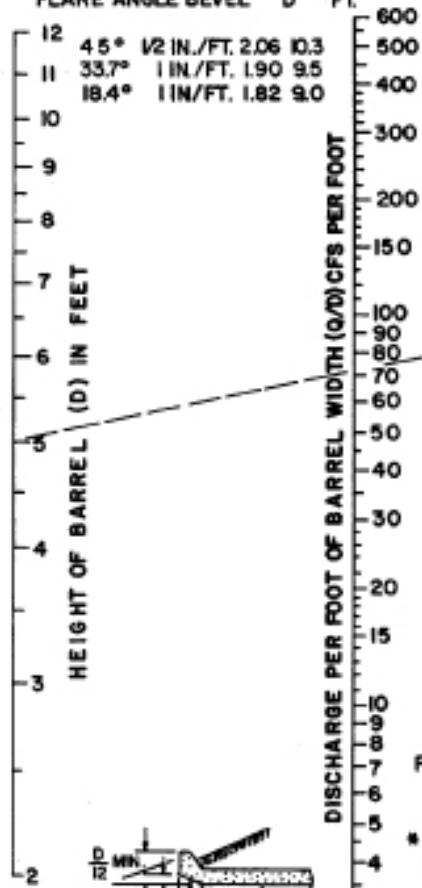


# CHART 13

**EXAMPLE**

B = 7 FT. D = 5 FT. Q = 600 C.F.S.  
 $\frac{Q}{B} = 71.5$

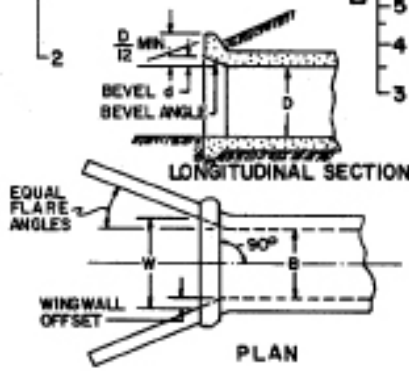
WINGWALL TOP EDGE FLARE ANGLE	TOP EDGE BEVEL	HW / D	HW / FT
45°	1/2 IN./FT.	2.06	10.3
33.7°	1 IN./FT.	1.90	9.5
18.4°	1 IN./FT.	1.82	9.0



**WINGWALLS**

FLARE	ANGLE	MIN. OFFSET
1:1	45°	3/4" x B (FT.)
1:1.5	33.7°	1" x B
* 1:2	26.6°	1-1/4" x B
1:3	18.4°	1-1/2" x B

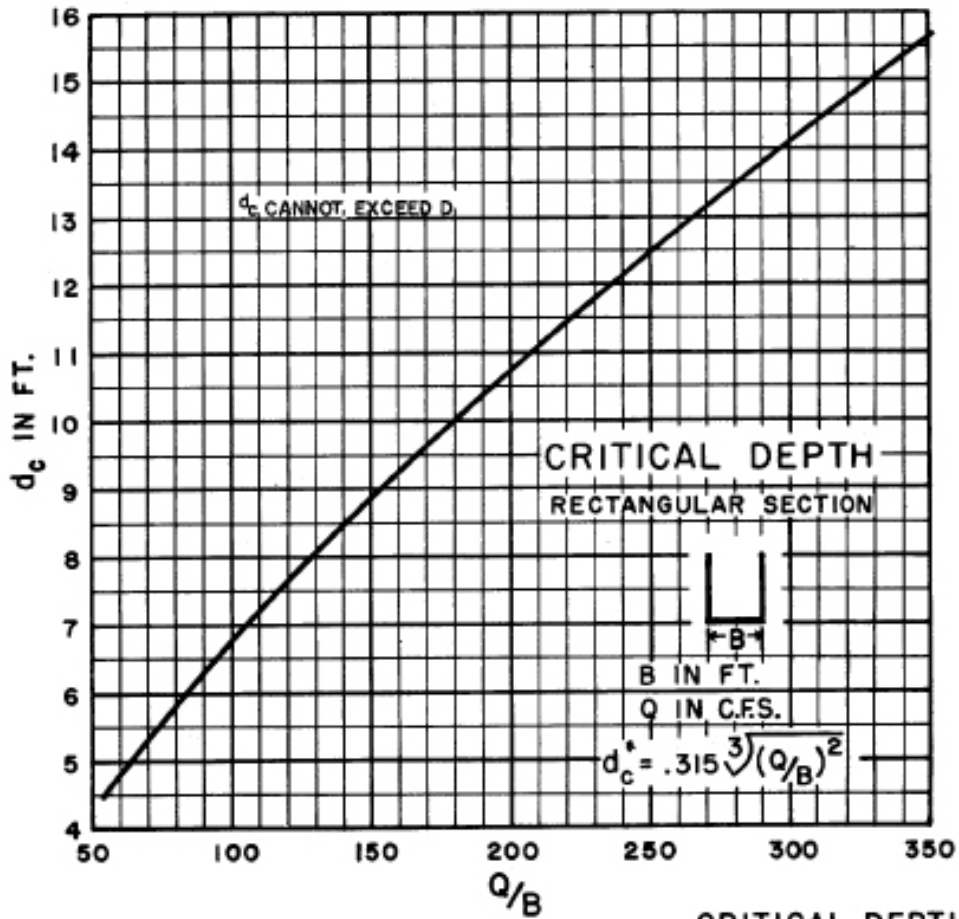
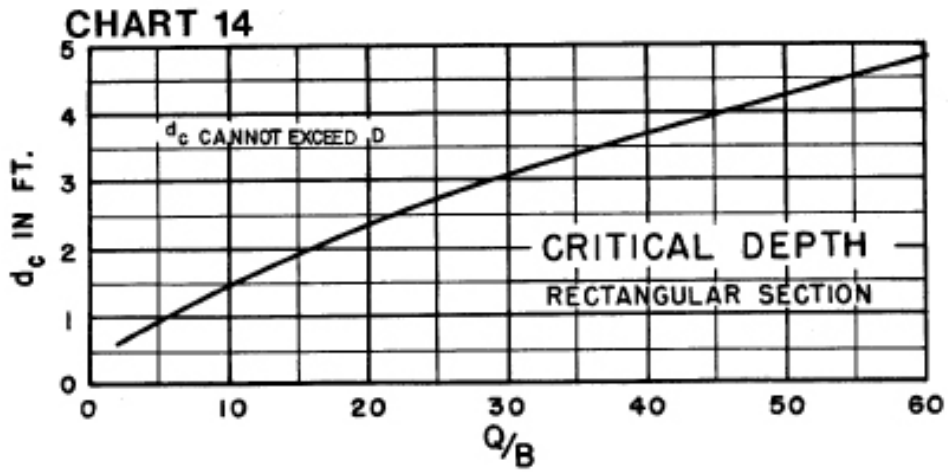
\* USE 33.7° x 0.0083D TOP EDGE BEVEL AND READ HW ON SCALE FOR 18.4° WW



BUREAU OF PUBLIC ROADS  
 OFFICE OF R & D AUGUST 1968

**HEADWATER DEPTH FOR INLET CONTROL  
 RECTANGULAR BOX CULVERTS  
 OFFSET FLARED WINGWALLS  
 AND BEVELED EDGE AT TOP OF INLET**



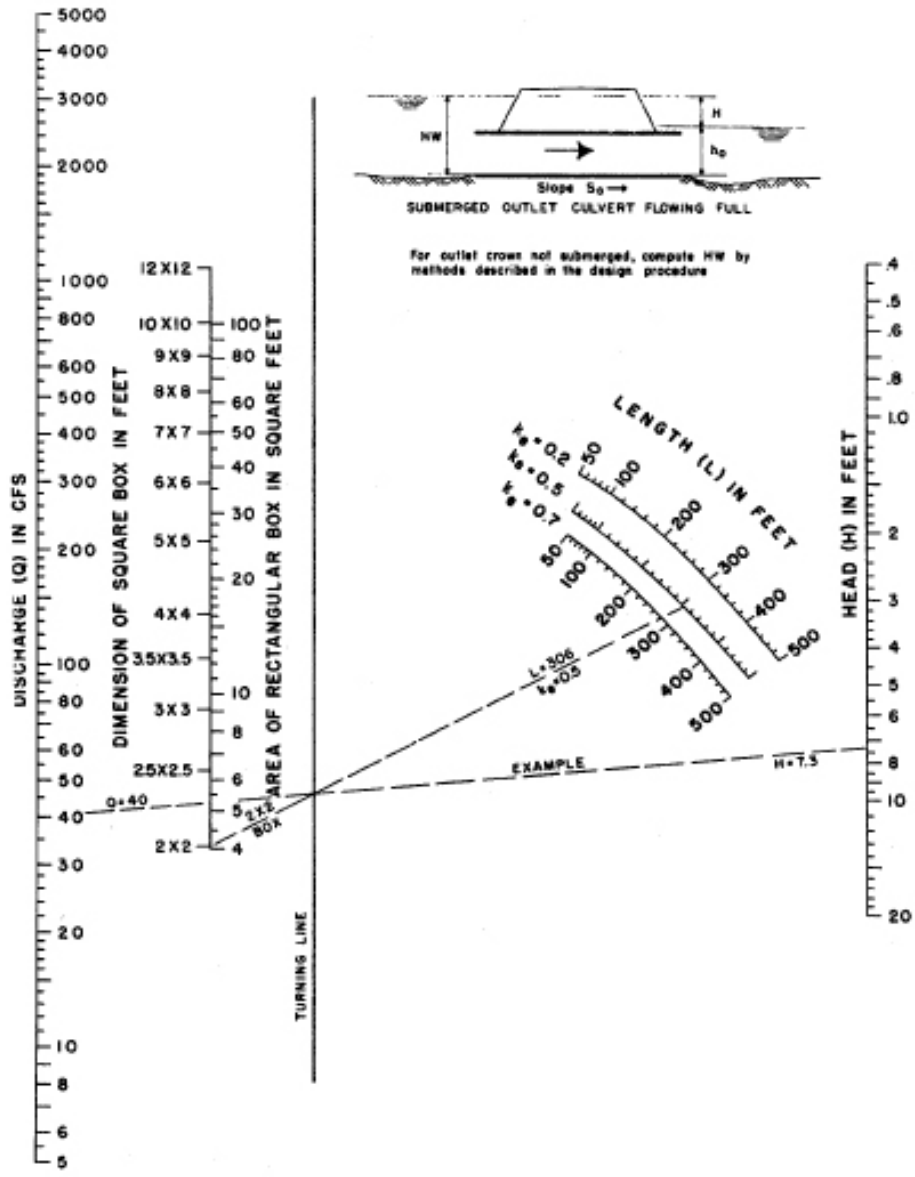


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CRITICAL DEPTH  
RECTANGULAR SECTION



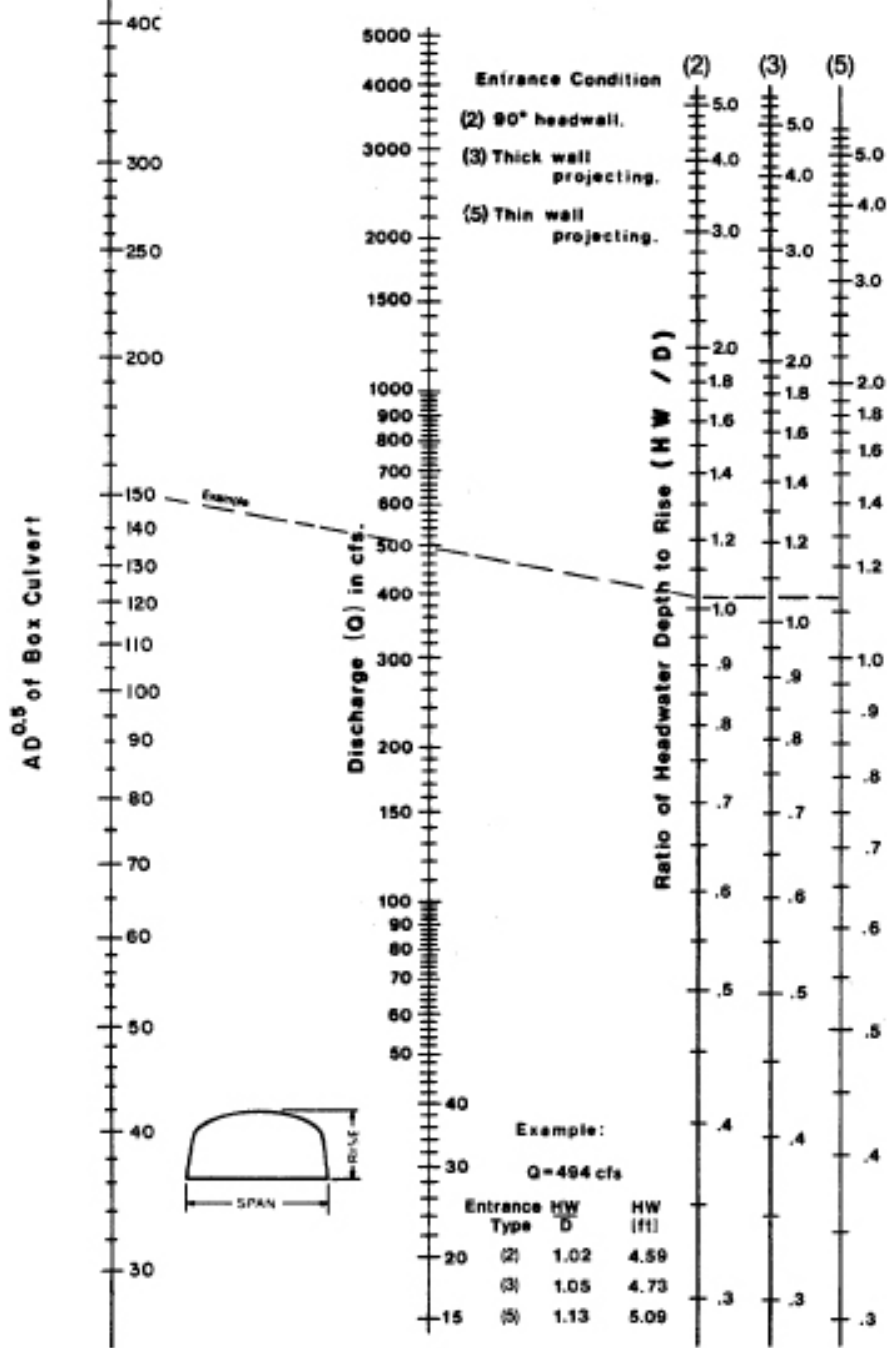
# CHART 15



**HEAD FOR  
CONCRETE BOX CULVERTS  
FLOWING FULL  
n = 0.012**

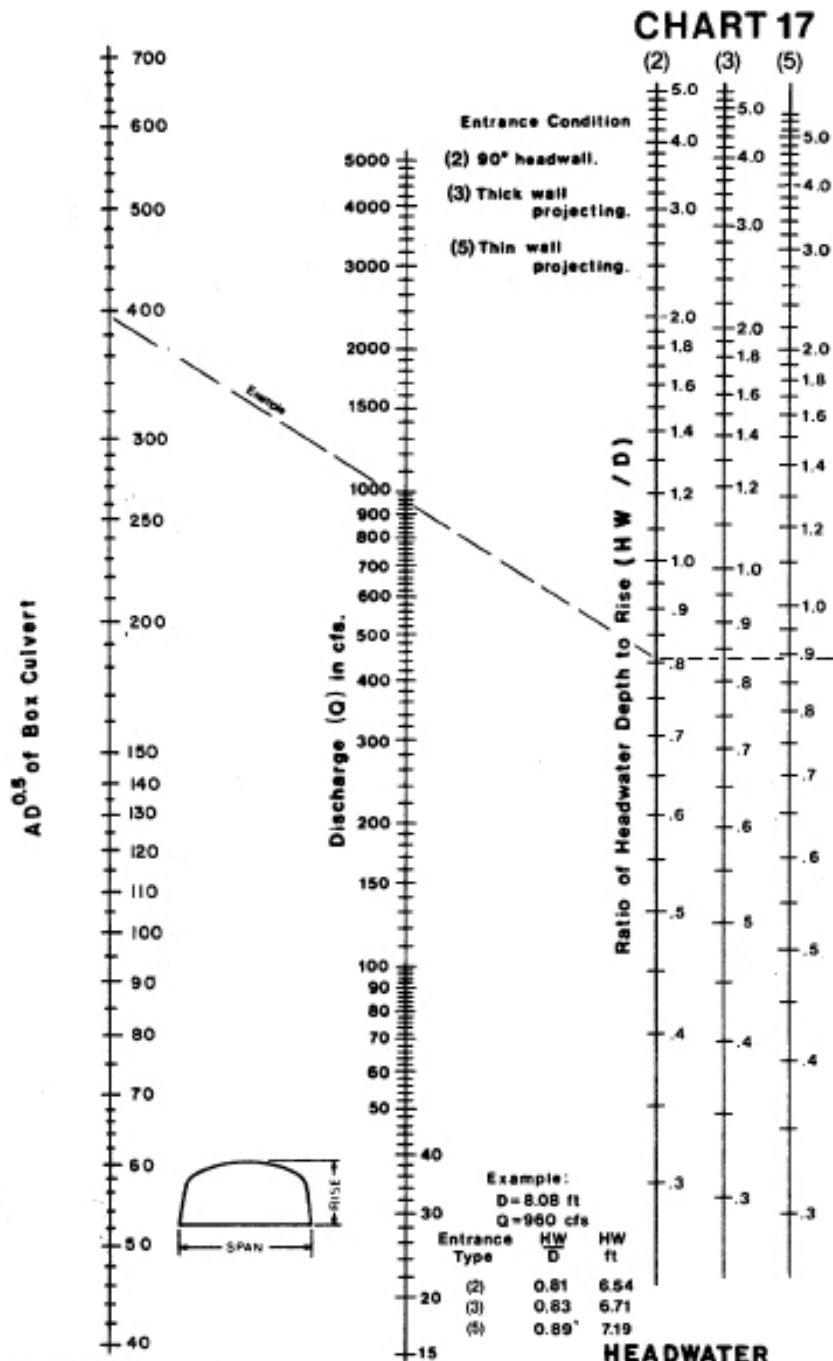


# CHART 16



Nomographs adapted from material furnished by Kaiser Aluminum and Chemical Corporation

**HEADWATER DEPTH  
FOR C.M. BOX CULVERTS  
RISE / SPAN < 0.3  
WITH INLET CONTROL**



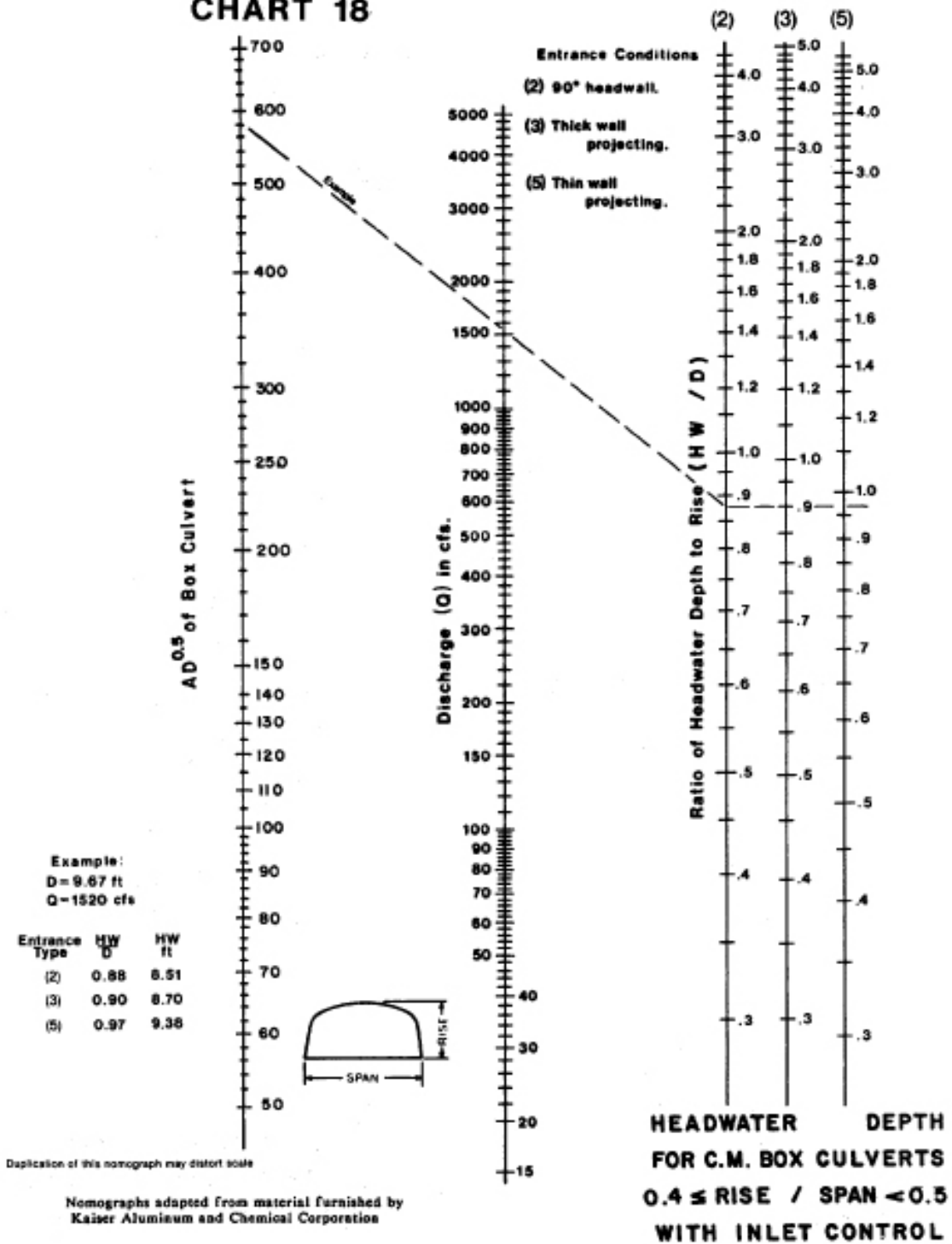
Distortion of this nomograph may distort scale

Nomographs adapted from material furnished by Kaiser Aluminum and Chemical Corporation

**HEADWATER DEPTH  
 FOR C.M. BOX CULVERTS  
 0.3 ≤ RISE / SPAN < 0.4  
 WITH INLET CONTROL**

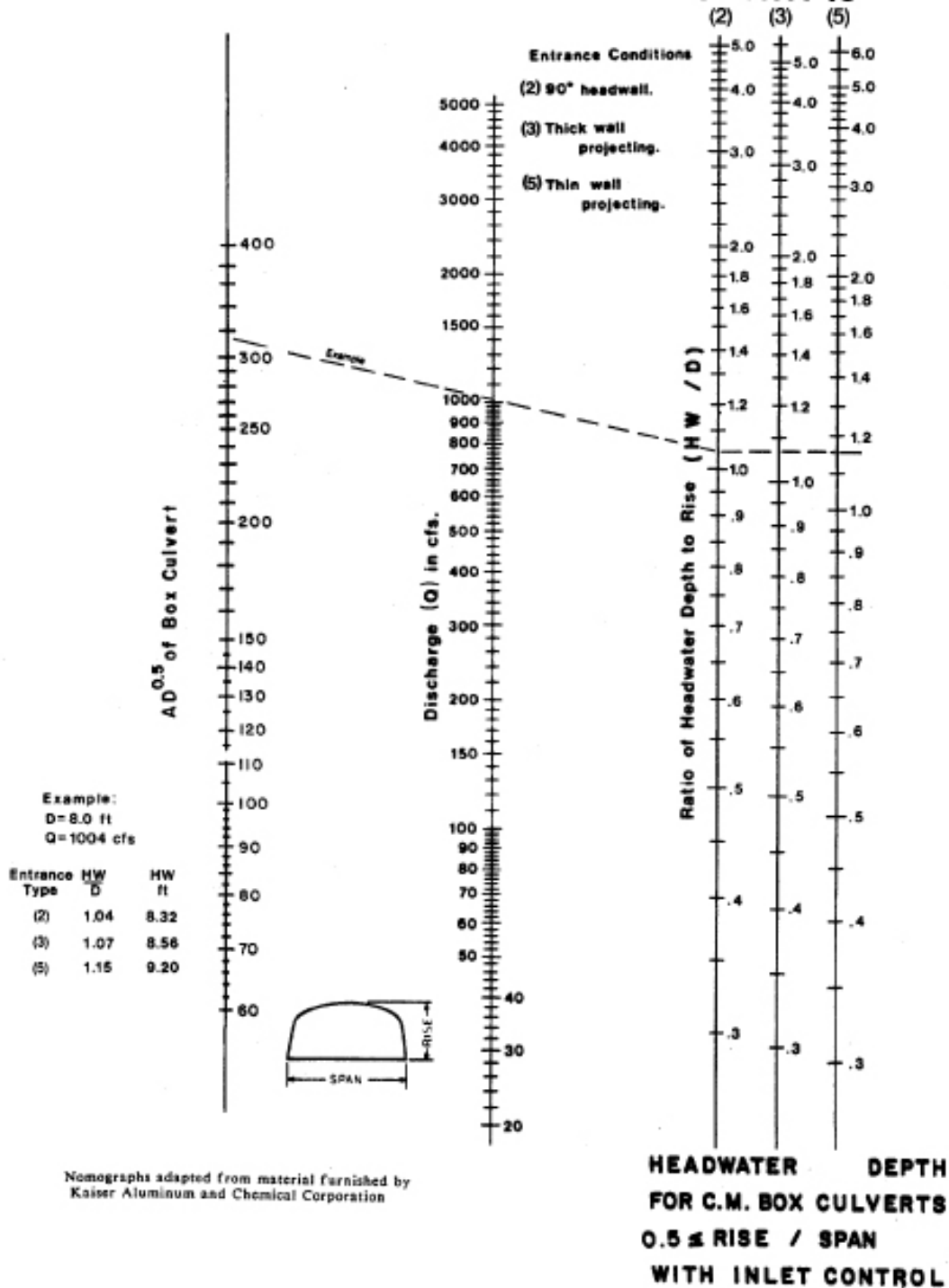


### CHART 18





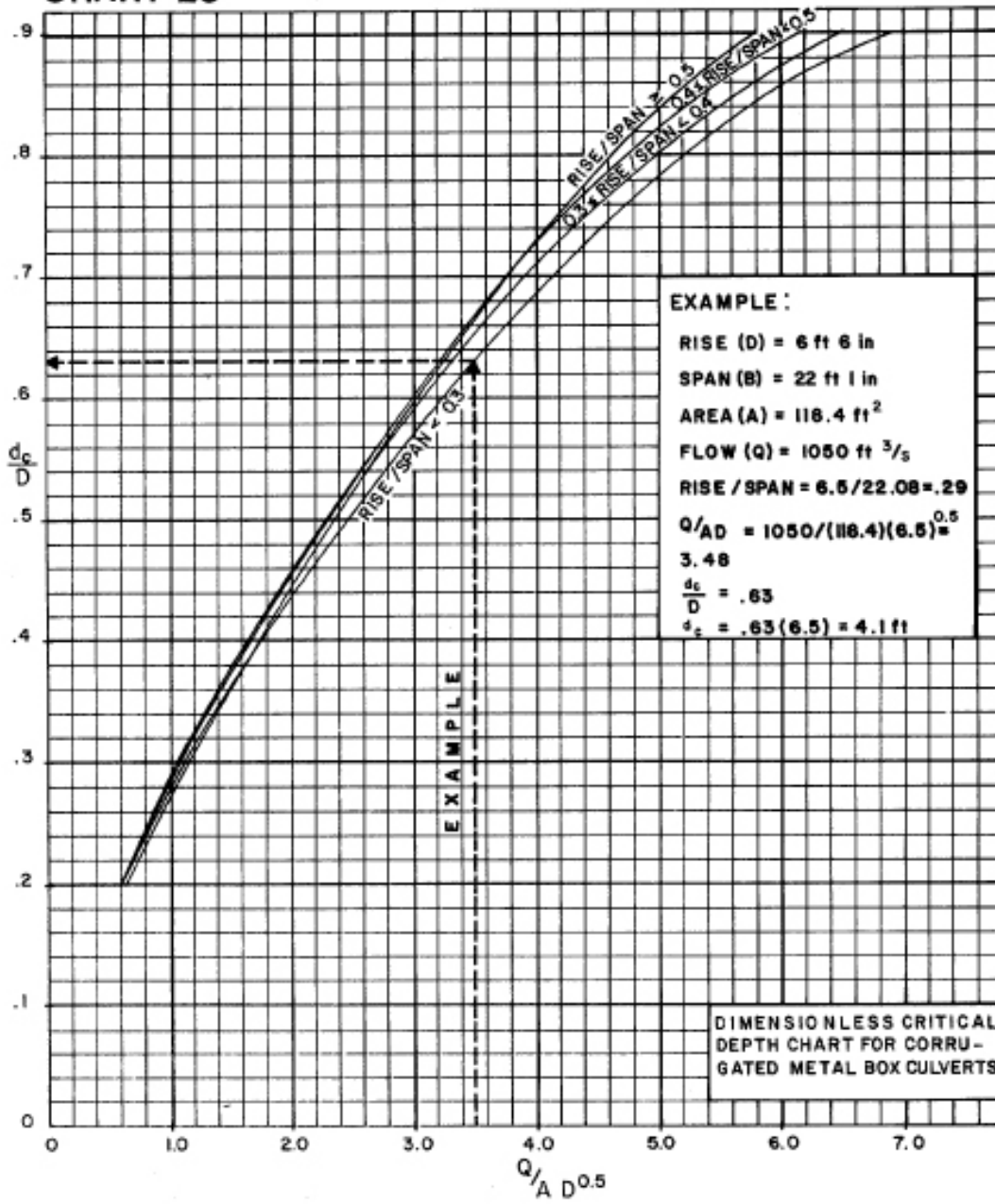
### CHART 19



Nomographs adapted from material furnished by Kaiser Aluminum and Chemical Corporation

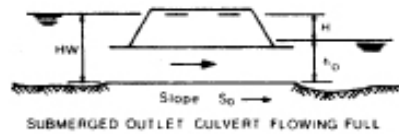
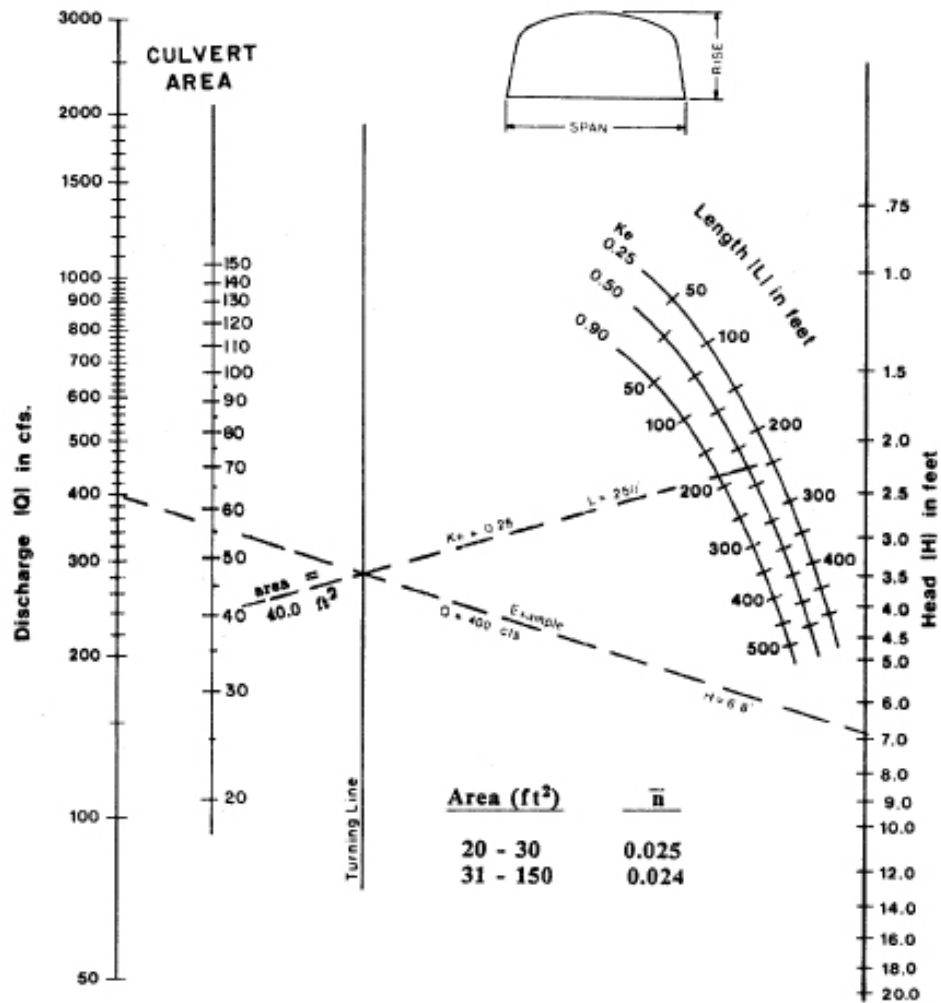


CHART 20





### CHART 21



**HEAD FOR  
C. M. BOX CULVERTS  
FLOWING FULL  
CONCRETE BOTTOM  
RISE / SPAN < 0.3**

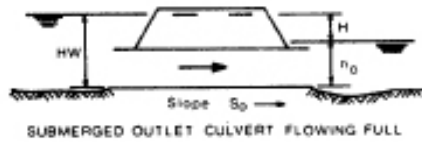
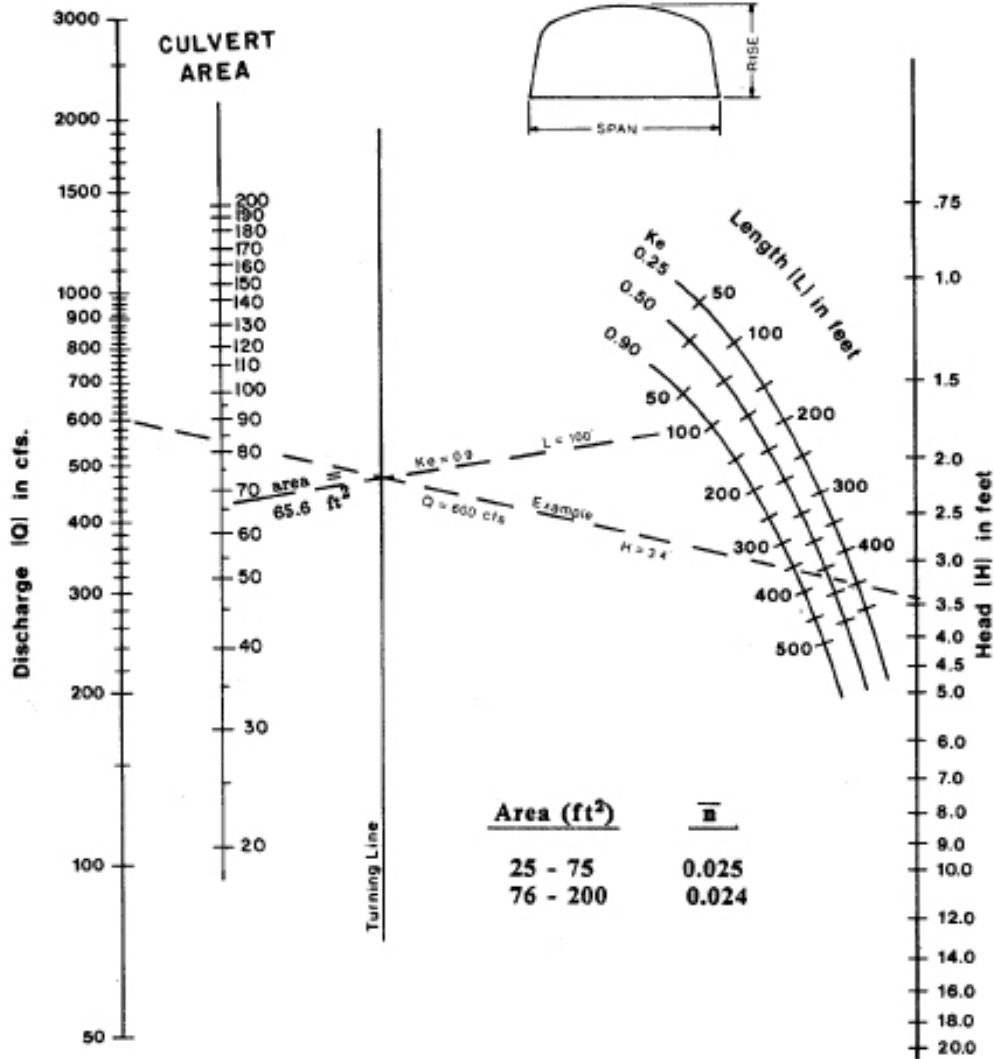
Nomographs adapted from material furnished by  
Kaiser Aluminum and Chemical Corporation

Duplication of this nomograph may distort scale





# CHART 22



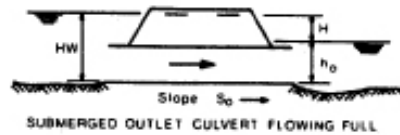
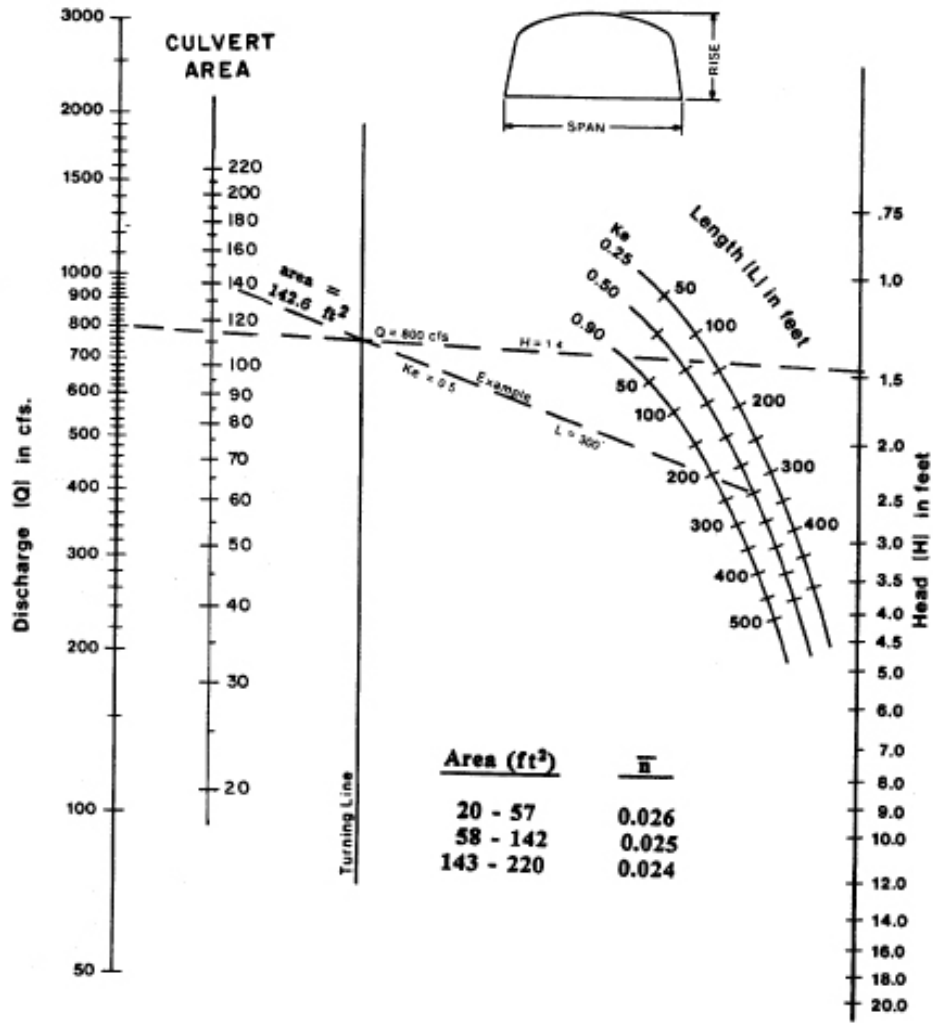
**HEAD FOR  
C. M. BOX CULVERTS  
FLOWING FULL  
CONCRETE BOTTOM  
 $0.3 \leq \text{RISE} / \text{SPAN} < 0.4$**

Nomographs adapted from material furnished by Kaiser Aluminum and Chemical Corporation

Duplication of this nomograph may distort scale



**CHART 23**

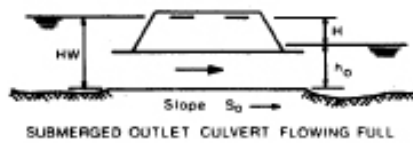
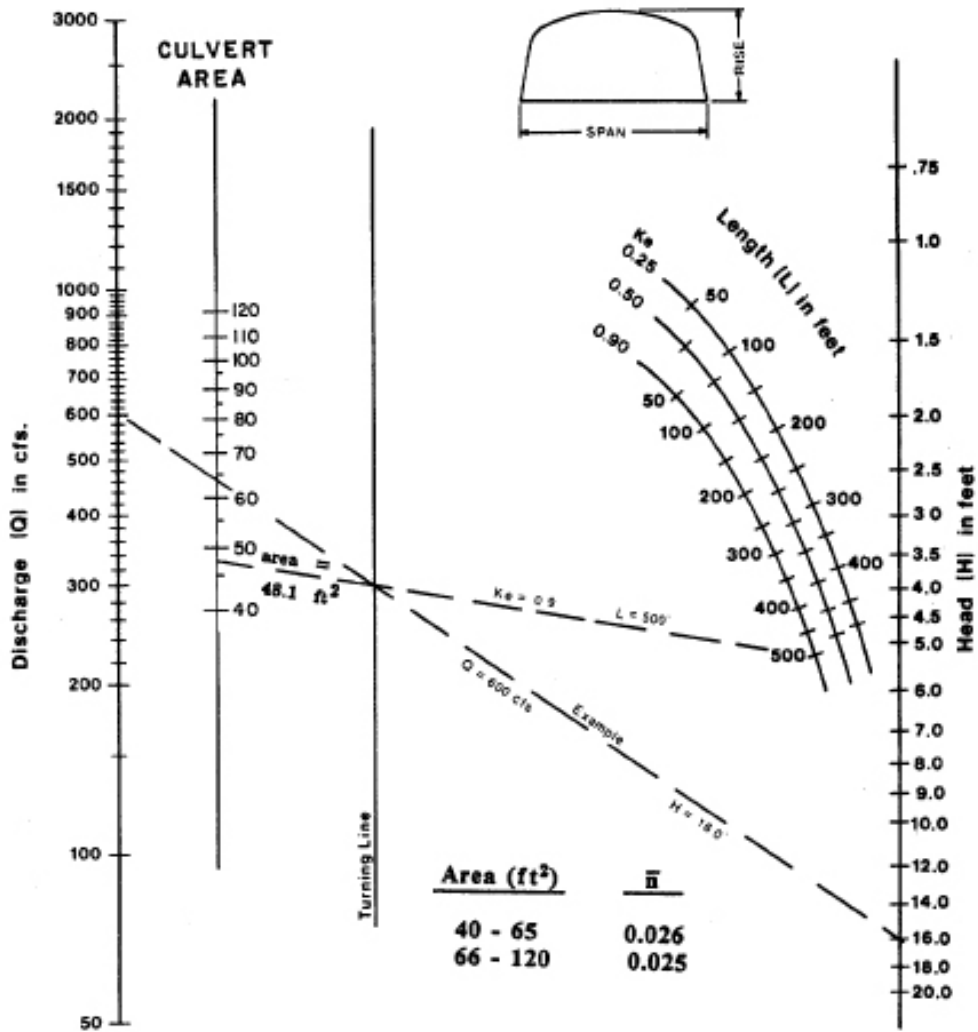


**HEAD FOR  
C. M. BOX CULVERTS  
FLOWING FULL  
CONCRETE BOTTOM  
0.4 ≤ RISE / SPAN < 0.5**

Nomographs adapted from material furnished by Kaiser Aluminum and Chemical Corporation  
Duplication of this nomograph may distort scale



### CHART 24



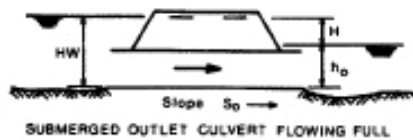
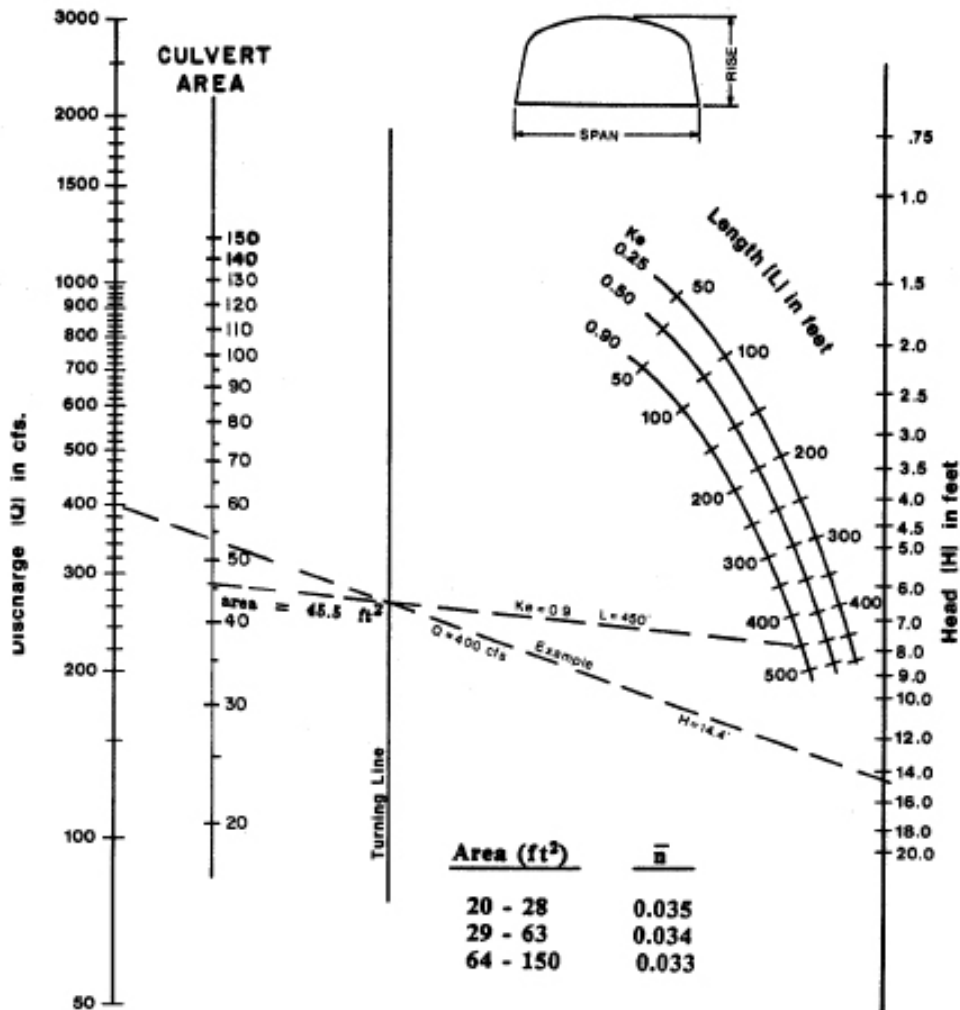
**HEAD FOR  
C. M. BOX CULVERT  
FLOWING FULL  
CONCRETE BOTTOM  
 $0.5 \leq \text{RISE} / \text{SPAN}$**

Nomographs adapted from material furnished by Kaiser Aluminum and Chemical Corporation

Duplication of this nomograph may distort scale



### CHART 25



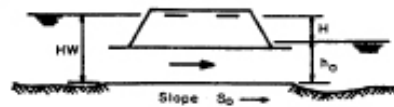
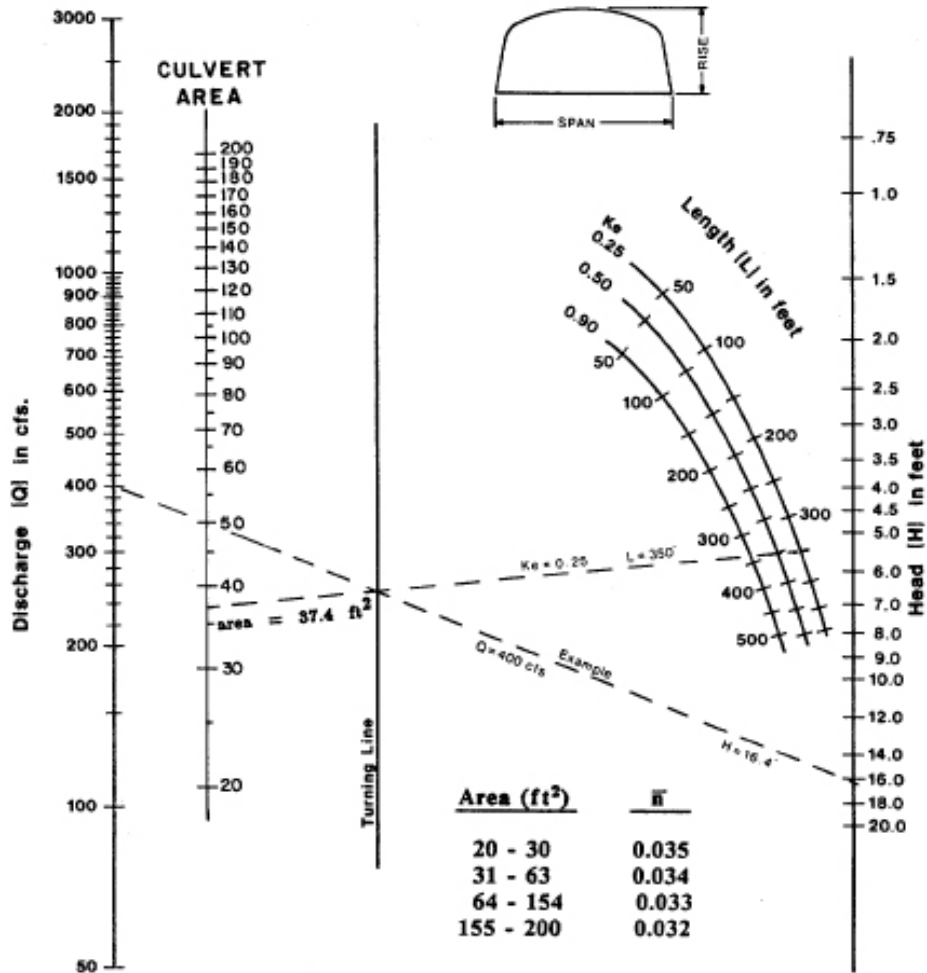
**HEAD FOR  
 C. M. BOX CULVERTS  
 FLOWING FULL  
 CORRUGATED METAL BOTTOM  
 RISE / SPAN  $\leq$  0.3**

Graphs adapted from material furnished by  
 Aluminum and Chemical Corporation

Use of this nomograph may distort scale



### CHART 26



SUBMERGED OUTLET CULVERT FLOWING FULL

**HEAD FOR  
C. M. BOX CULVERTS  
FLOWING FULL**

**CORRUGATED METAL BOTTOM**

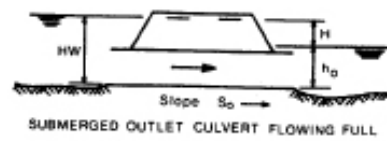
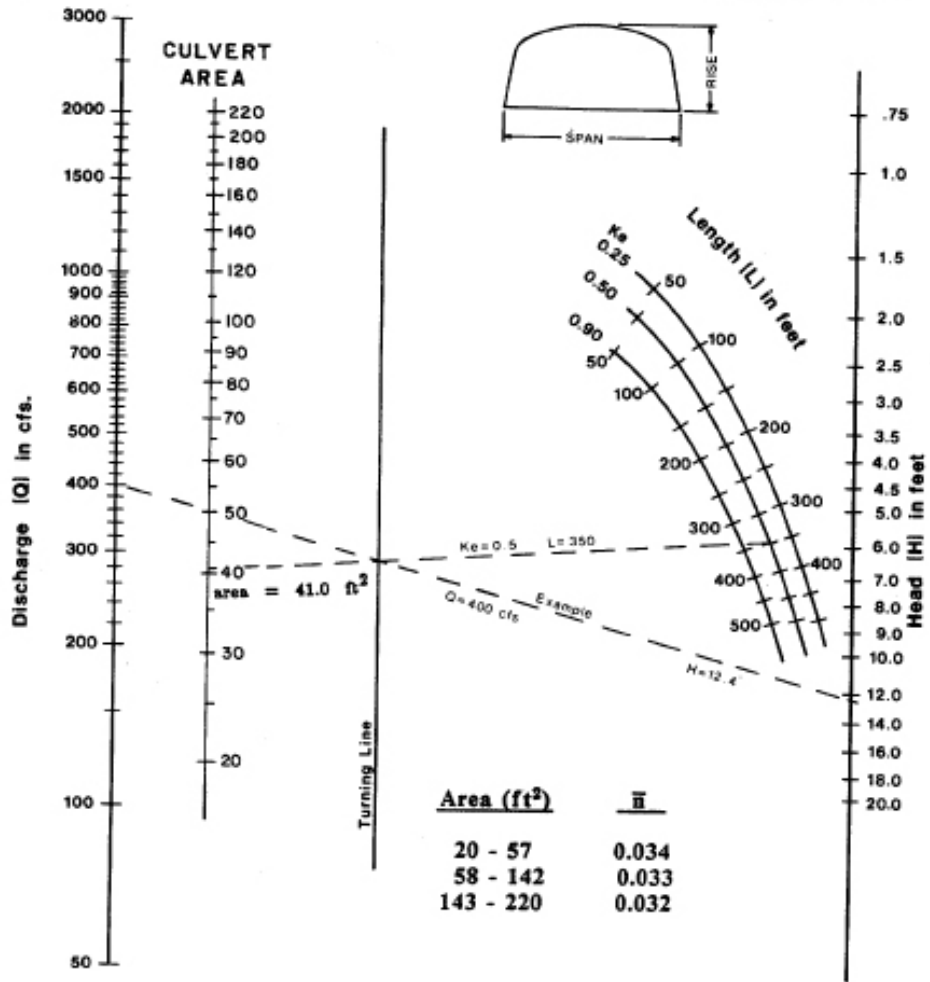
**0.3 ≤ RISE / SPAN < 0.4**

Nomographs adapted from material furnished by Kaiser Aluminum and Chemical Corporation

Duplication of this nomograph may distort scale



**CHART 27**



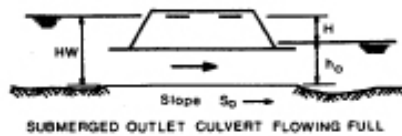
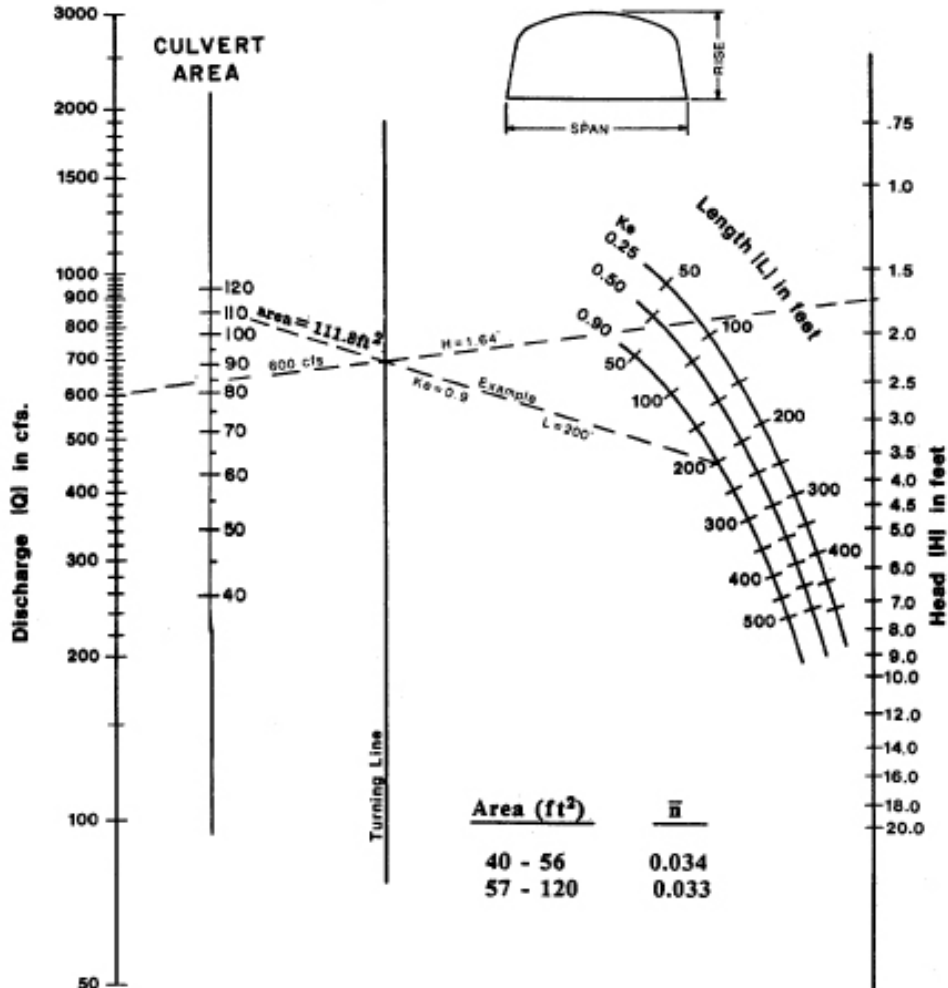
**HEAD FOR  
C. M. BOX CULVERTS  
FLOWING FULL  
CORRUGATED METAL BOTTOM  
0.4 ≤ RISE / SPAN ≤ 0.5**

Nomographs adapted from material furnished by Kaiser Aluminum and Chemical Corporation

Duplication of this nomograph may distort scale



**CHART 28**



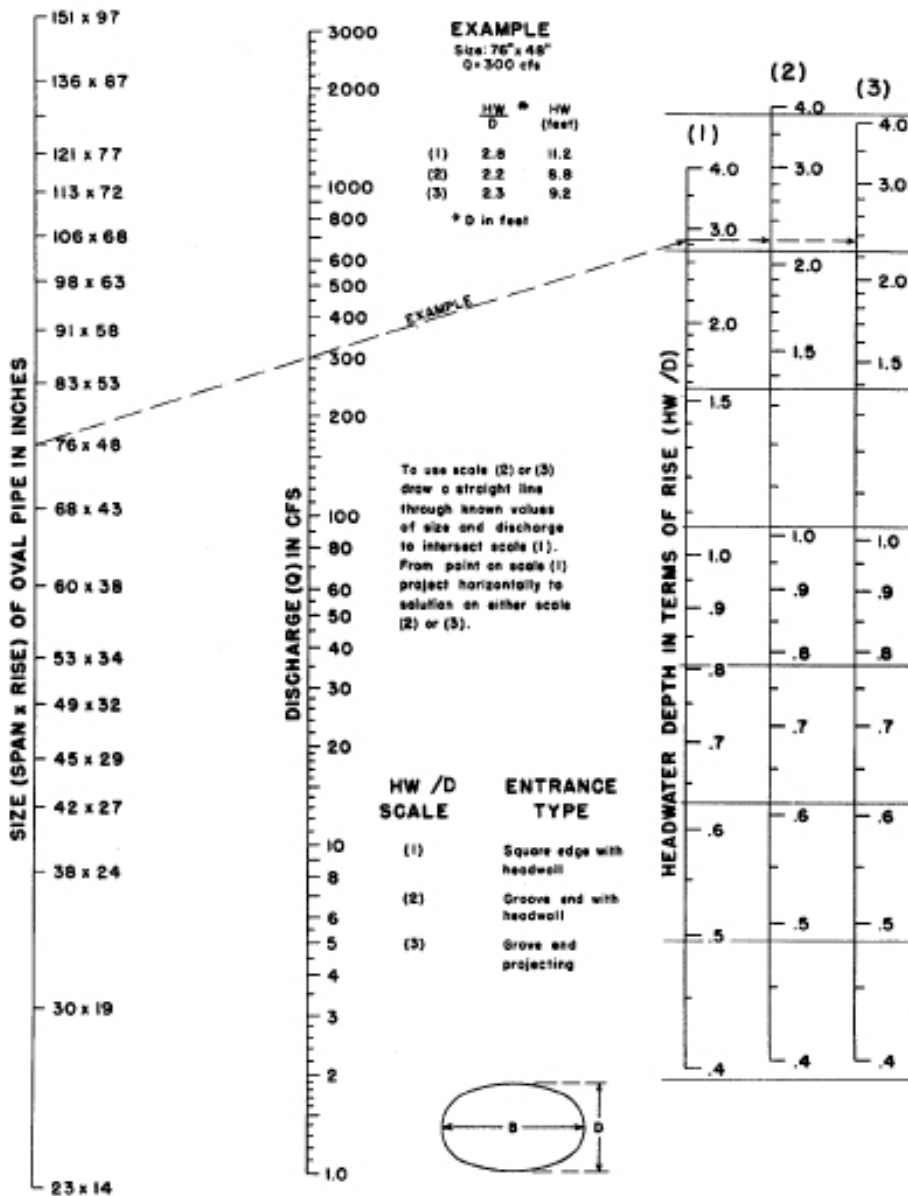
**HEAD FOR  
C. M. BOX CULVERTS  
FLOWING FULL  
CORRUGATED METAL BOTTOM  
0.5 ≤ RISE / SPAN**

Nomographs adapted from material furnished by Kaiser Aluminum and Chemical Corporation

Duplication of this nomograph may distort scale



# CHART 29



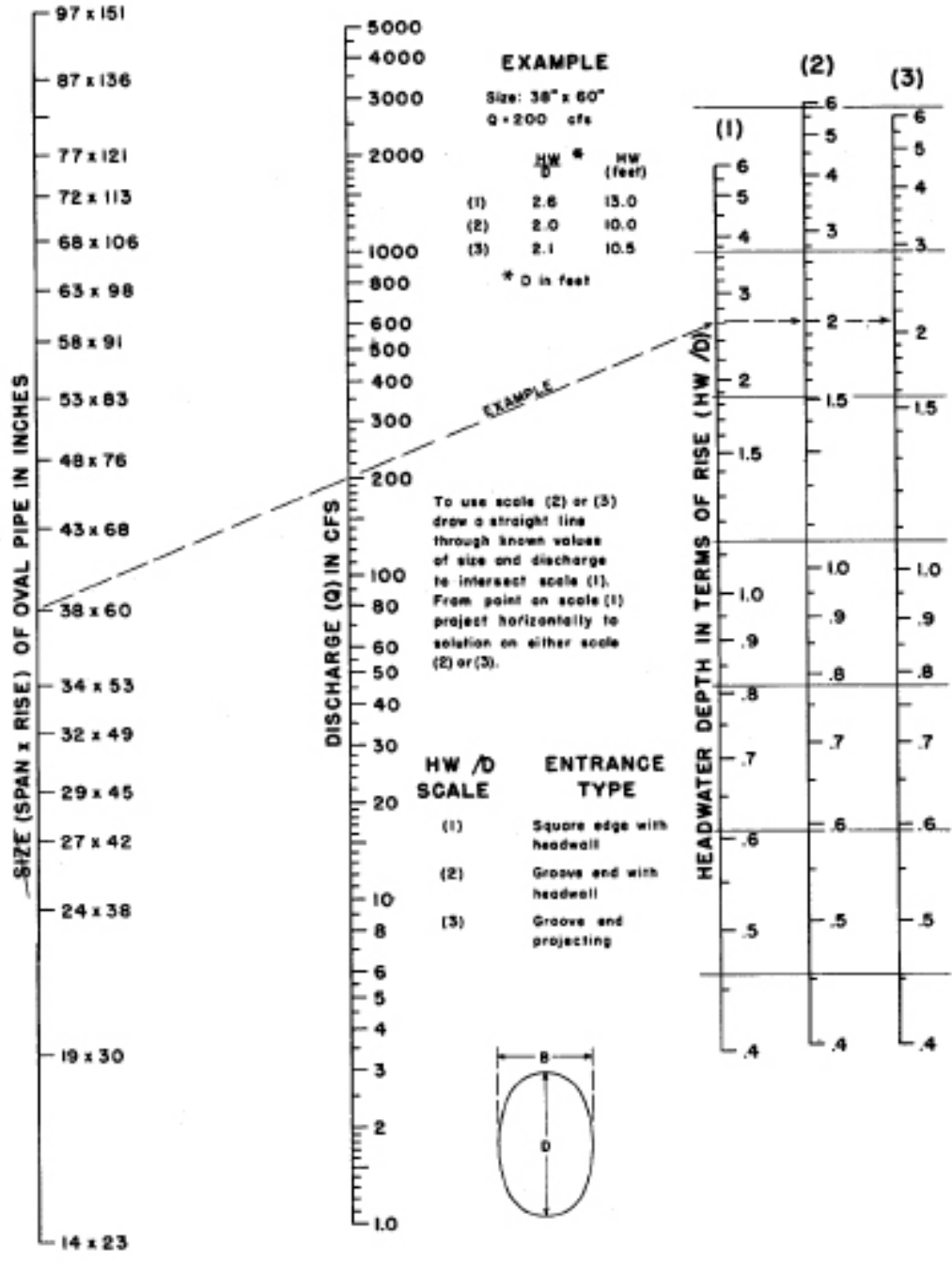
## HEADWATER DEPTH FOR OVAL CONCRETE PIPE CULVERTS LONG AXIS HORIZONTAL WITH INLET CONTROL

BUREAU OF PUBLIC ROADS JAN. 1963



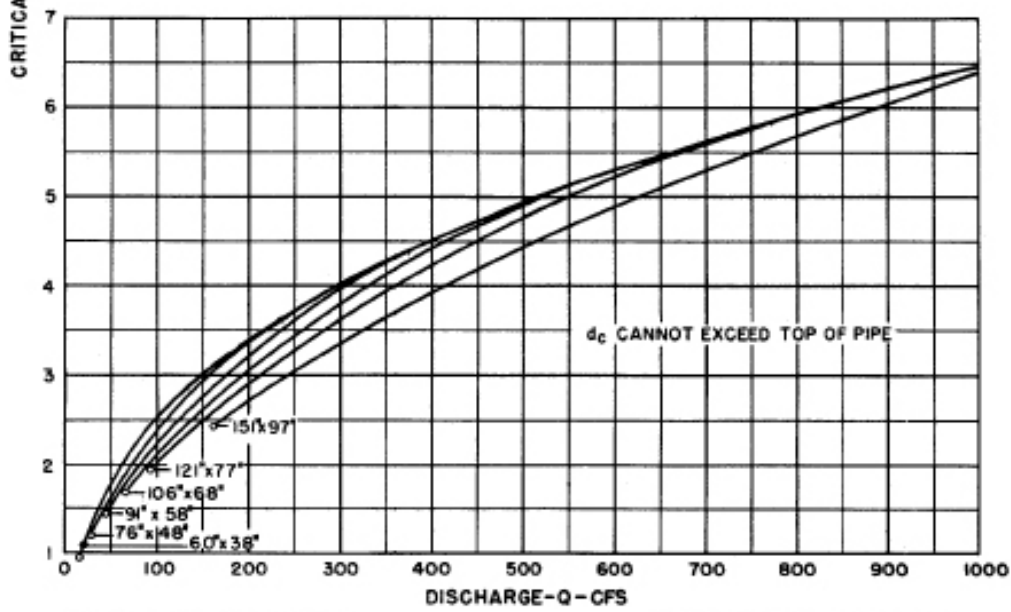
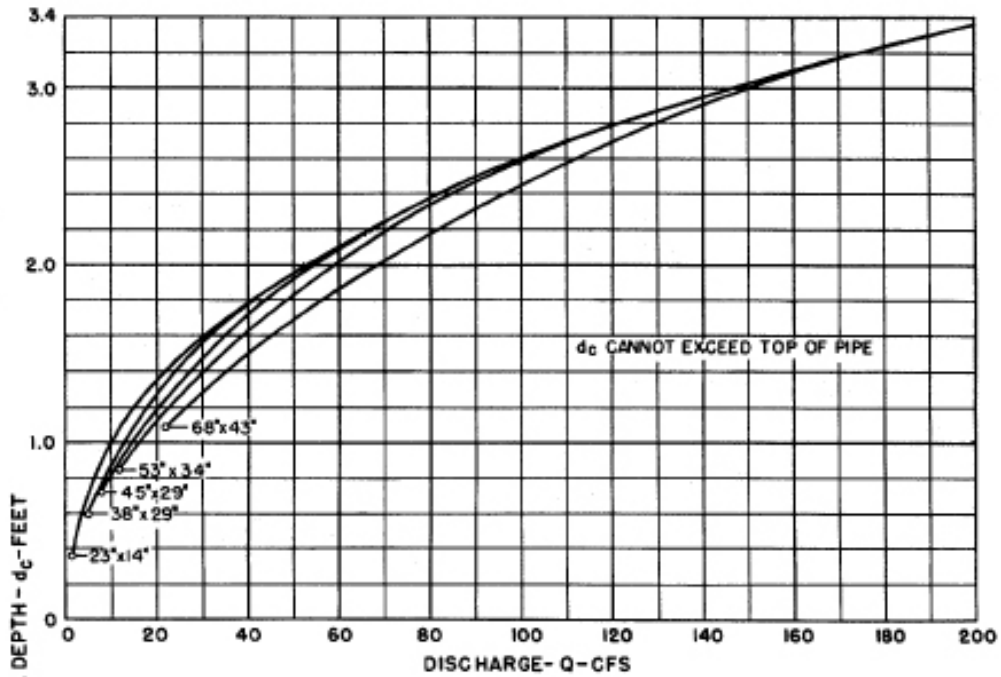


# CHART 30



**HEADWATER DEPTH FOR OVAL CONCRETE PIPE CULVERTS LONG AXIS VERTICAL WITH INLET CONTROL**

CHART 31

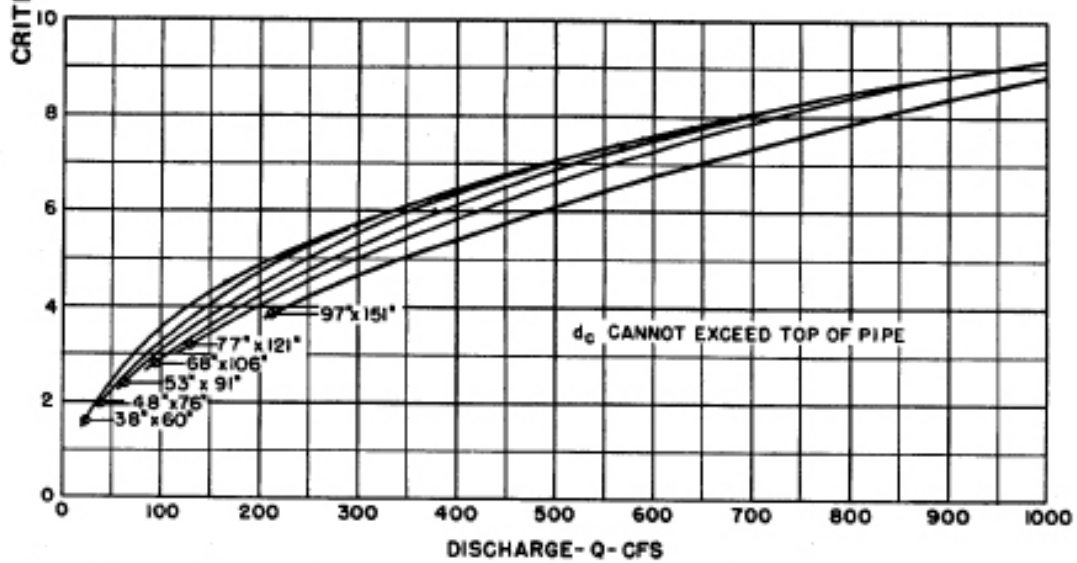
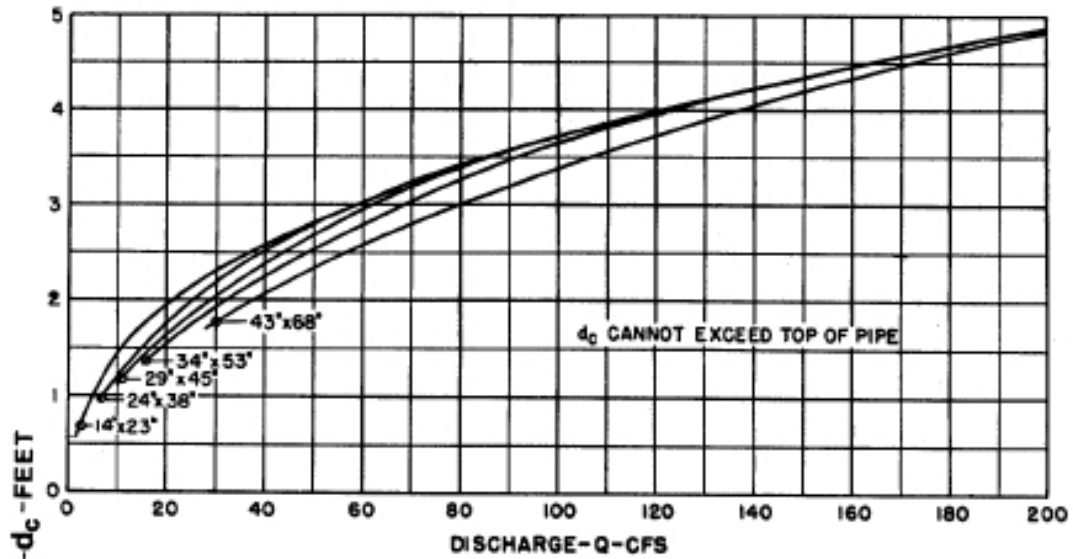


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JAN. 1964

CRITICAL DEPTH  
OVAL CONCRETE PIPE  
LONG AXIS HORIZONTAL



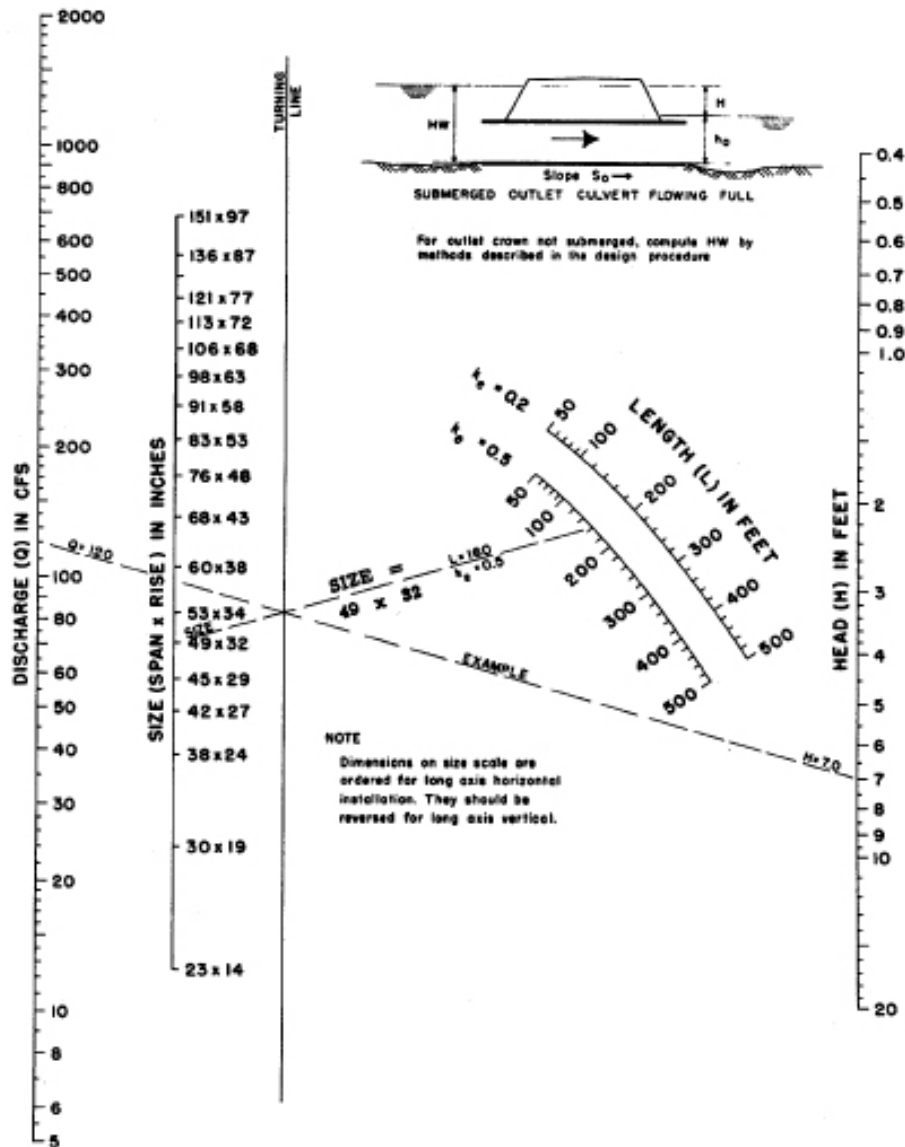
**CHART 32**



BUREAU OF PUBLIC ROADS  
JAN. 1964

**CRITICAL DEPTH  
OVAL CONCRETE PIPE  
LONG AXIS VERTICAL**

CHART 33

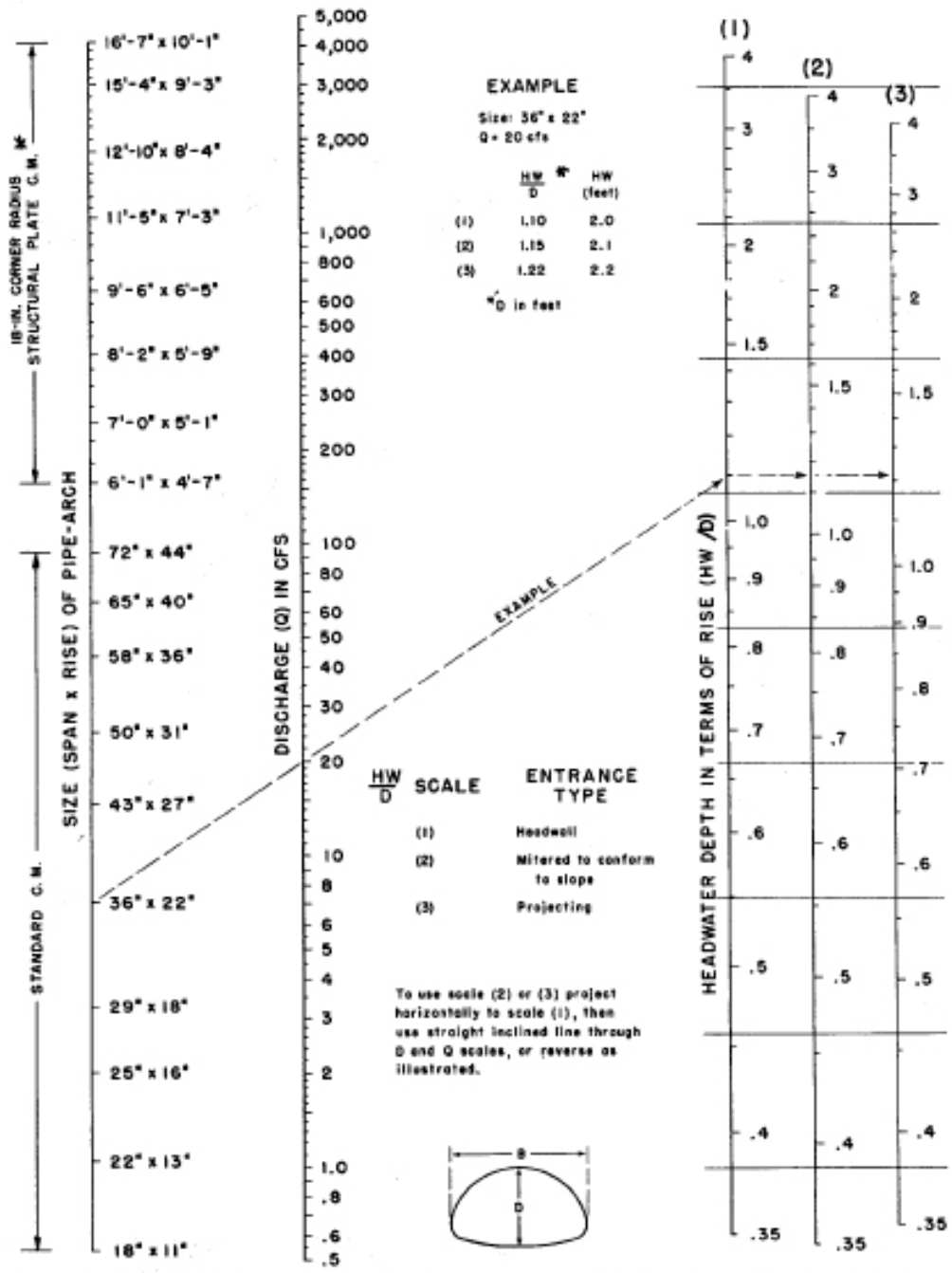


**HEAD FOR  
 OVAL CONCRETE PIPE CULVERTS  
 LONG AXIS HORIZONTAL OR VERTICAL  
 FLOWING FULL  
 n = 0.012**

BUREAU OF PUBLIC ROADS JAN. 1963



# CHART 34

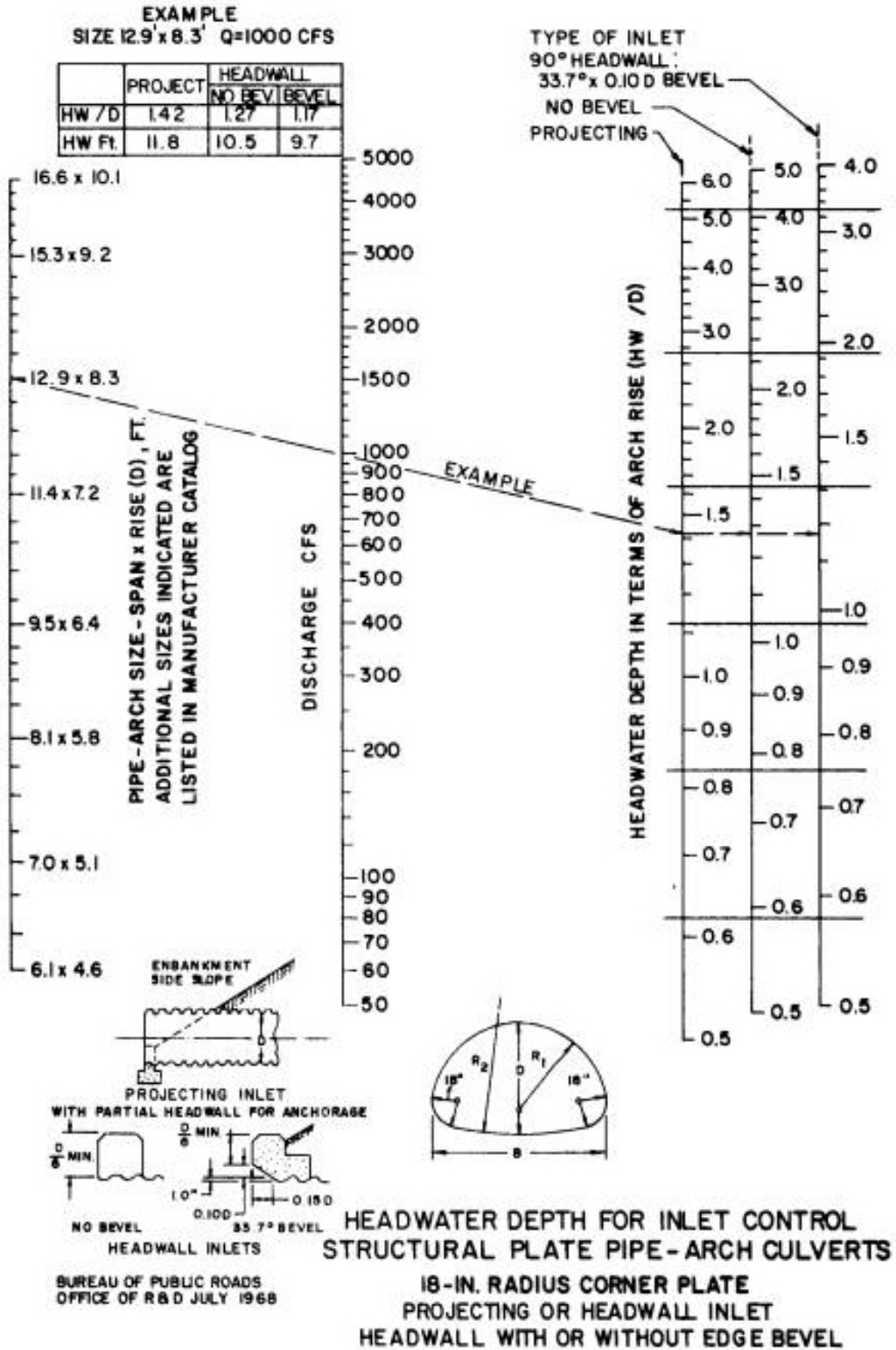


\* ADDITIONAL SIZES NOT DIMENSIONED ARE LISTED IN FABRICATOR'S CATALOG  
BUREAU OF PUBLIC ROADS JAN. 1963

## HEADWATER DEPTH FOR C. M. PIPE-ARCH CULVERTS WITH INLET CONTROL



# CHART 35 B



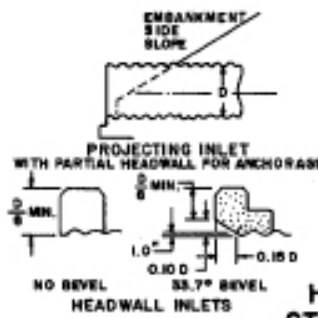
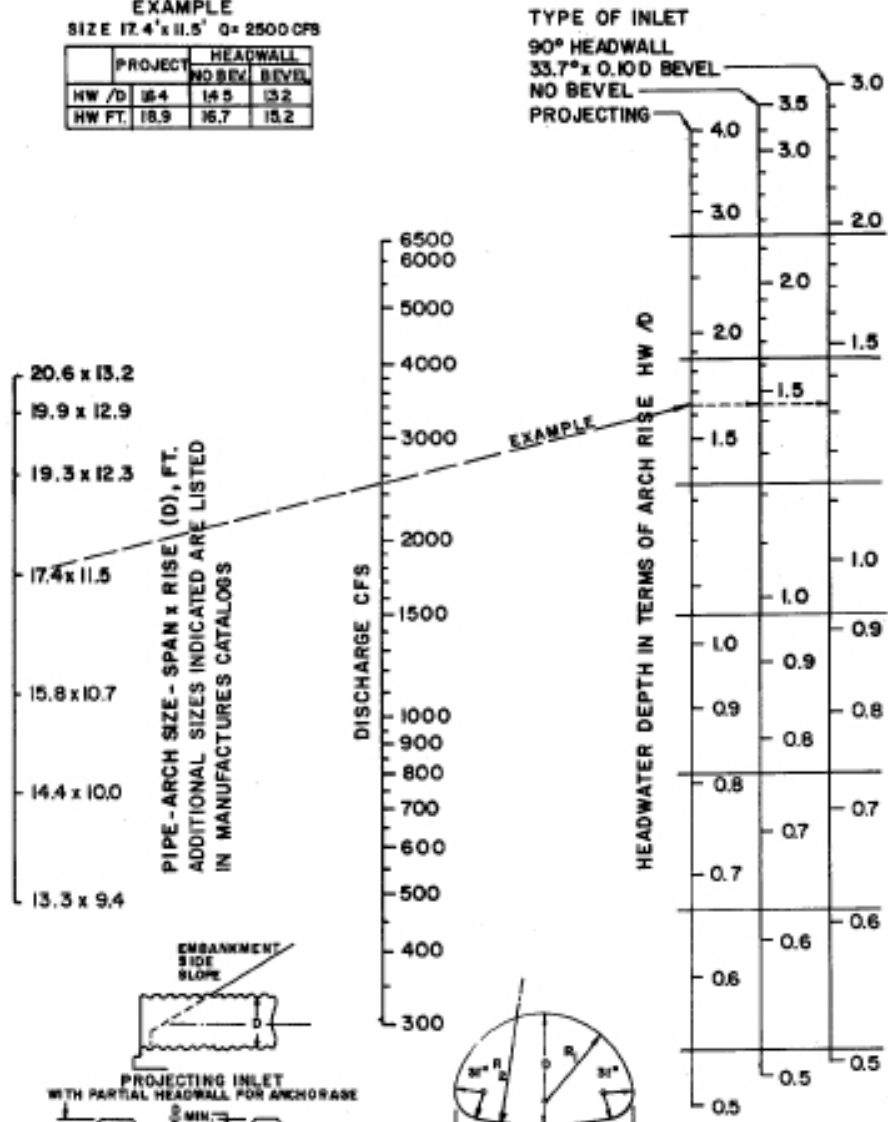
BUREAU OF PUBLIC ROADS  
 OFFICE OF R & D JULY 1968



# CHART 36

EXAMPLE  
 SIZE 17.4' x 11.5' Q = 2500 CFS

PROJECT	HEADWALL	
	NO BEVEL	BEVEL
HW / D	16.4	14.5
HW FT.	18.9	15.2

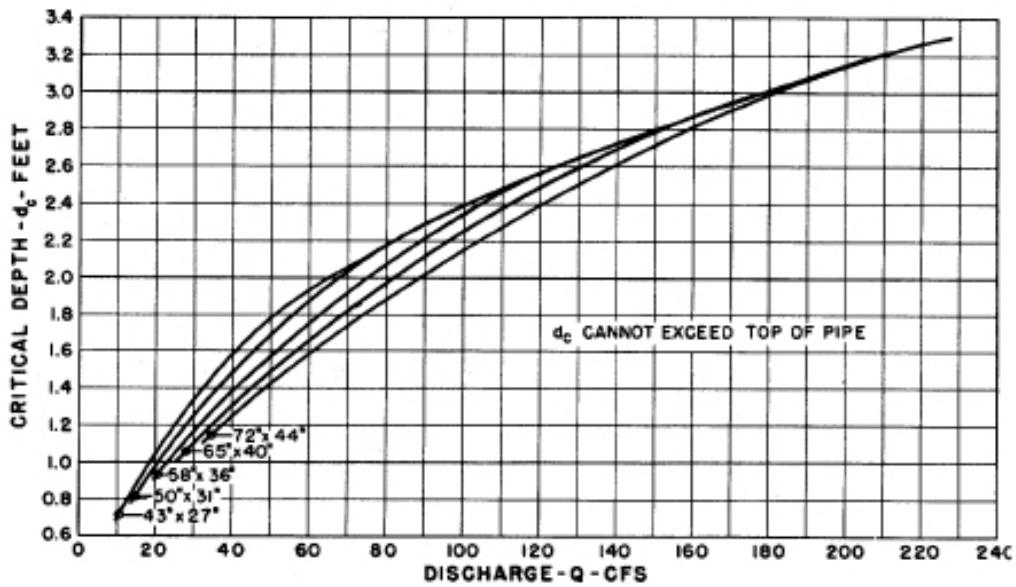
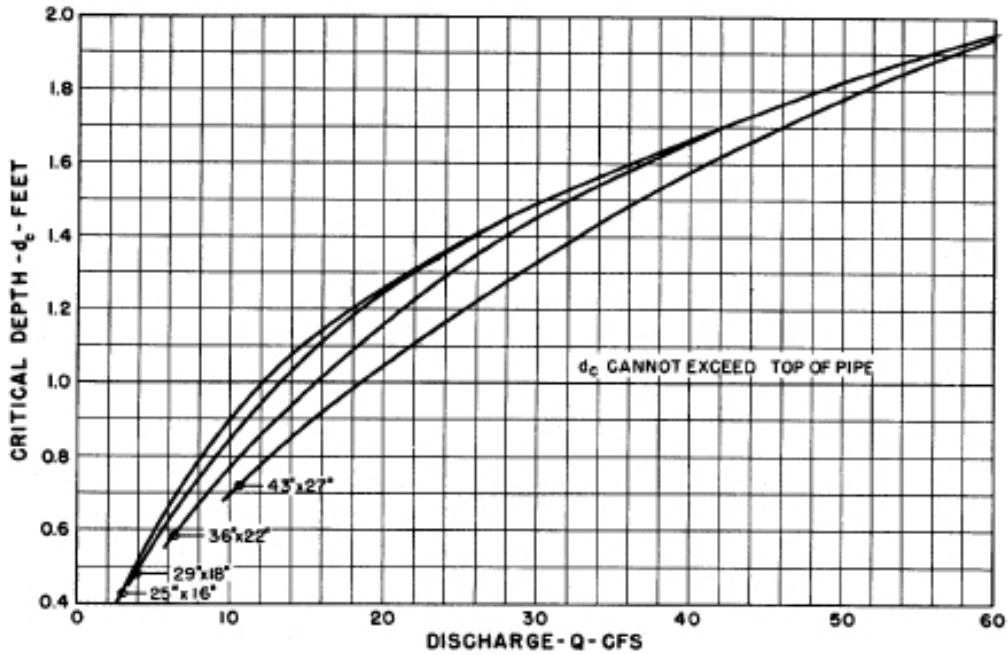


**HEADWATER DEPTH FOR INLET CONTROL  
 STRUCTURAL PLATE PIPE-ARCH CULVERTS**  
 31-IN. RADIUS CORNER PLATE  
 PROJECTING OR HEADWALL INLET  
 HEADWALL WITH OR WITHOUT EDGE BEVEL

BUREAU OF PUBLIC ROADS  
 OFFICE OF R&D JULY 1956



CHART 37



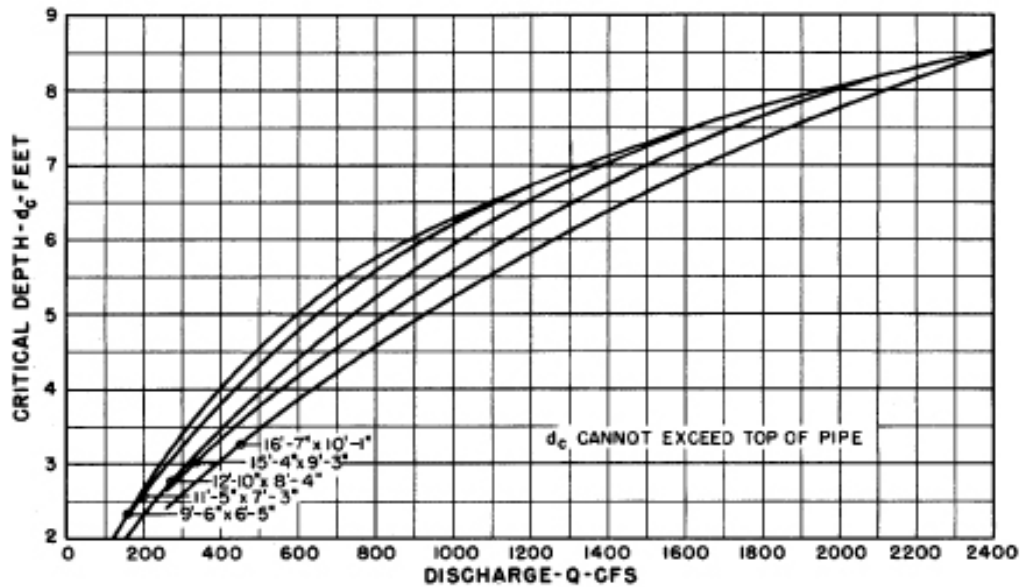
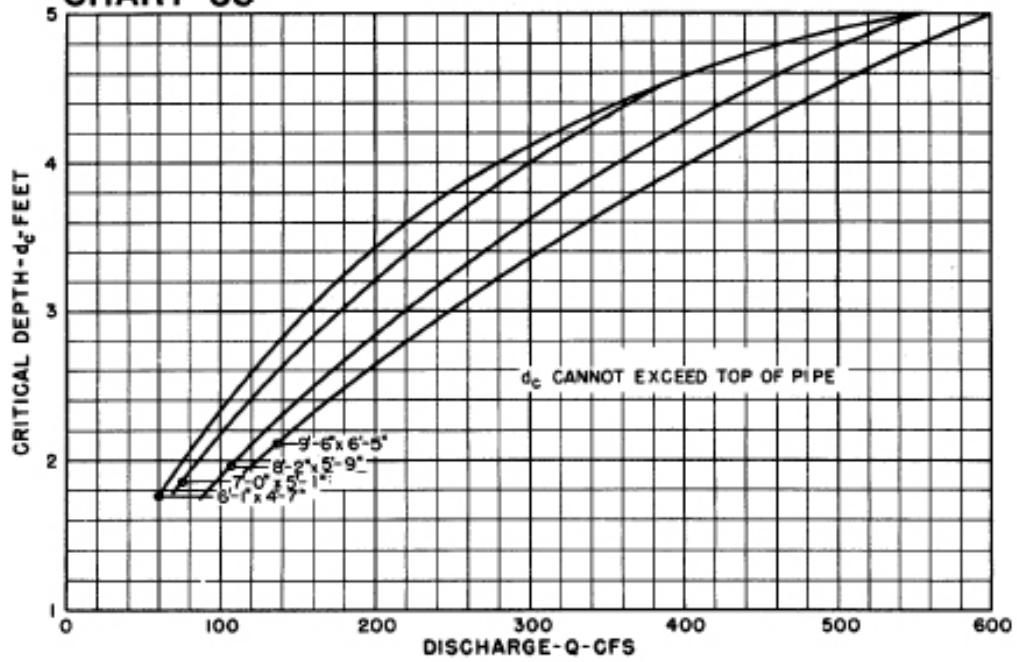
BUREAU OF PUBLIC ROADS  
JAN. 1964

**CRITICAL DEPTH  
STANDARD C.M. PIPE-ARCH**





**CHART 38**

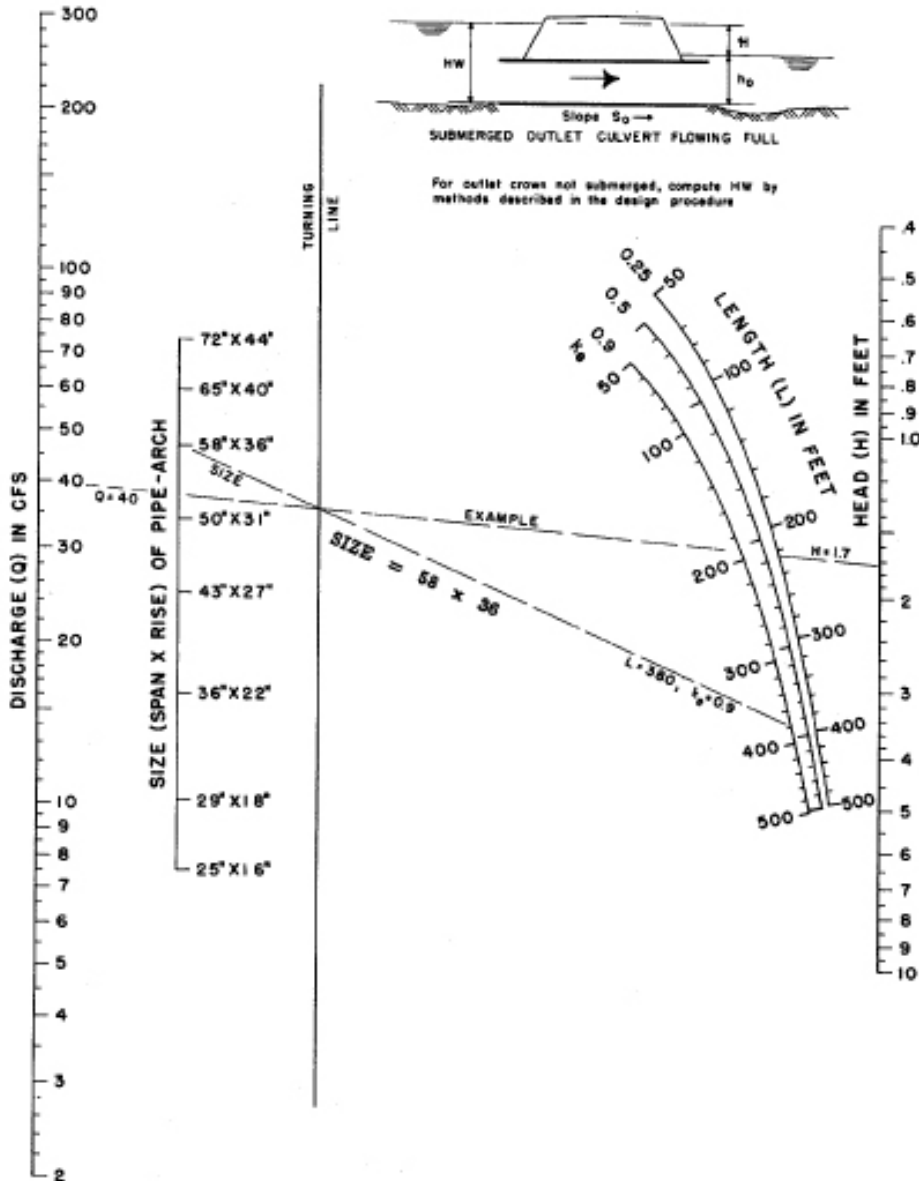


BUREAU OF PUBLIC ROADS  
JAN. 1964

**CRITICAL DEPTH  
STRUCTURAL PLATE  
C. M. PIPE - ARCH  
18 INCH CORNER RADIUS**



# CHART 39

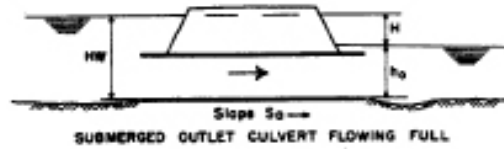


**HEAD FOR  
STANDARD C. M. PIPE-ARCH CULVERTS  
FLOWING FULL  
n=0.024**

BUREAU OF PUBLIC ROADS JAN. 1963

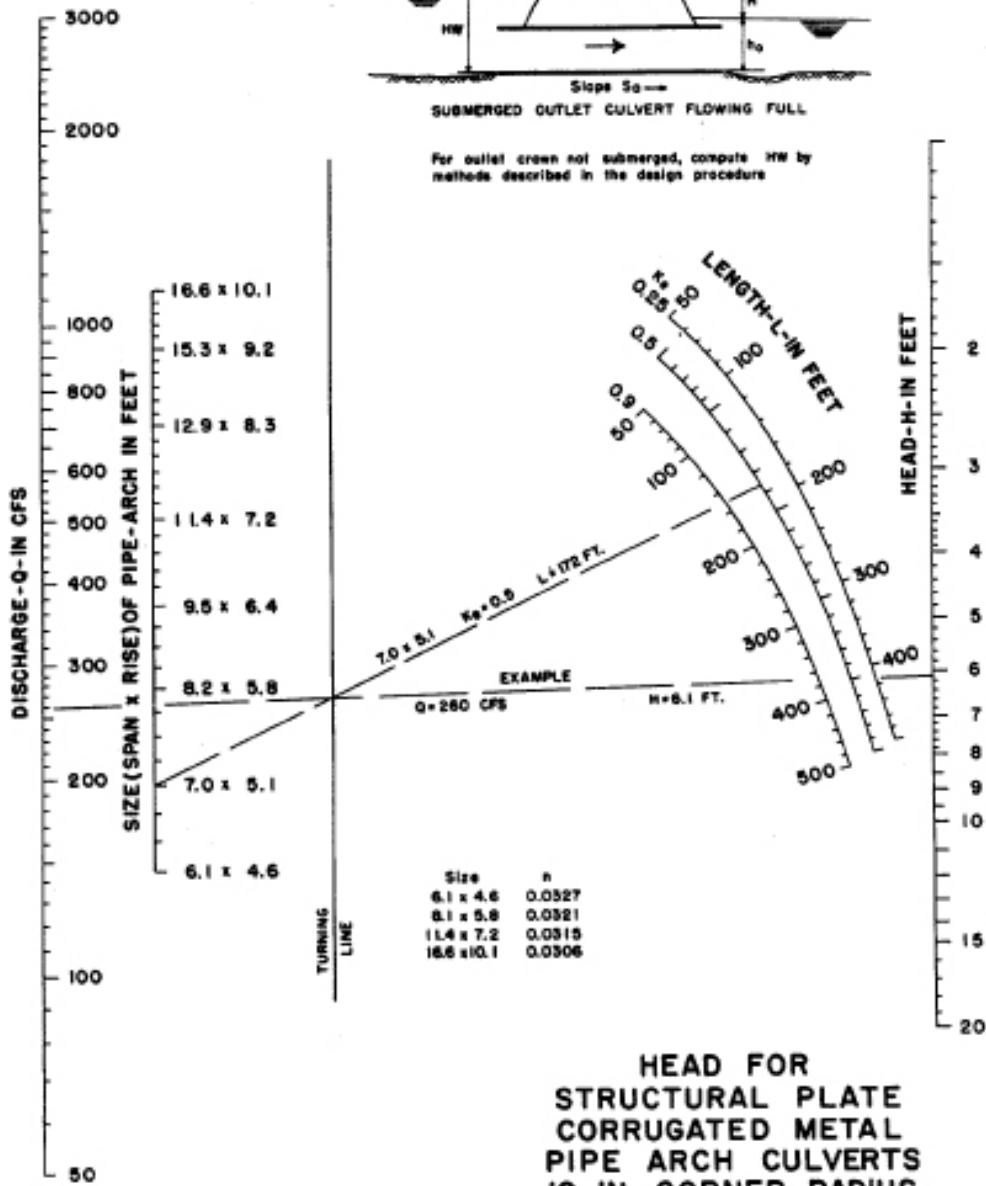


### CHART 40



SUBMERGED OUTLET CULVERT FLOWING FULL

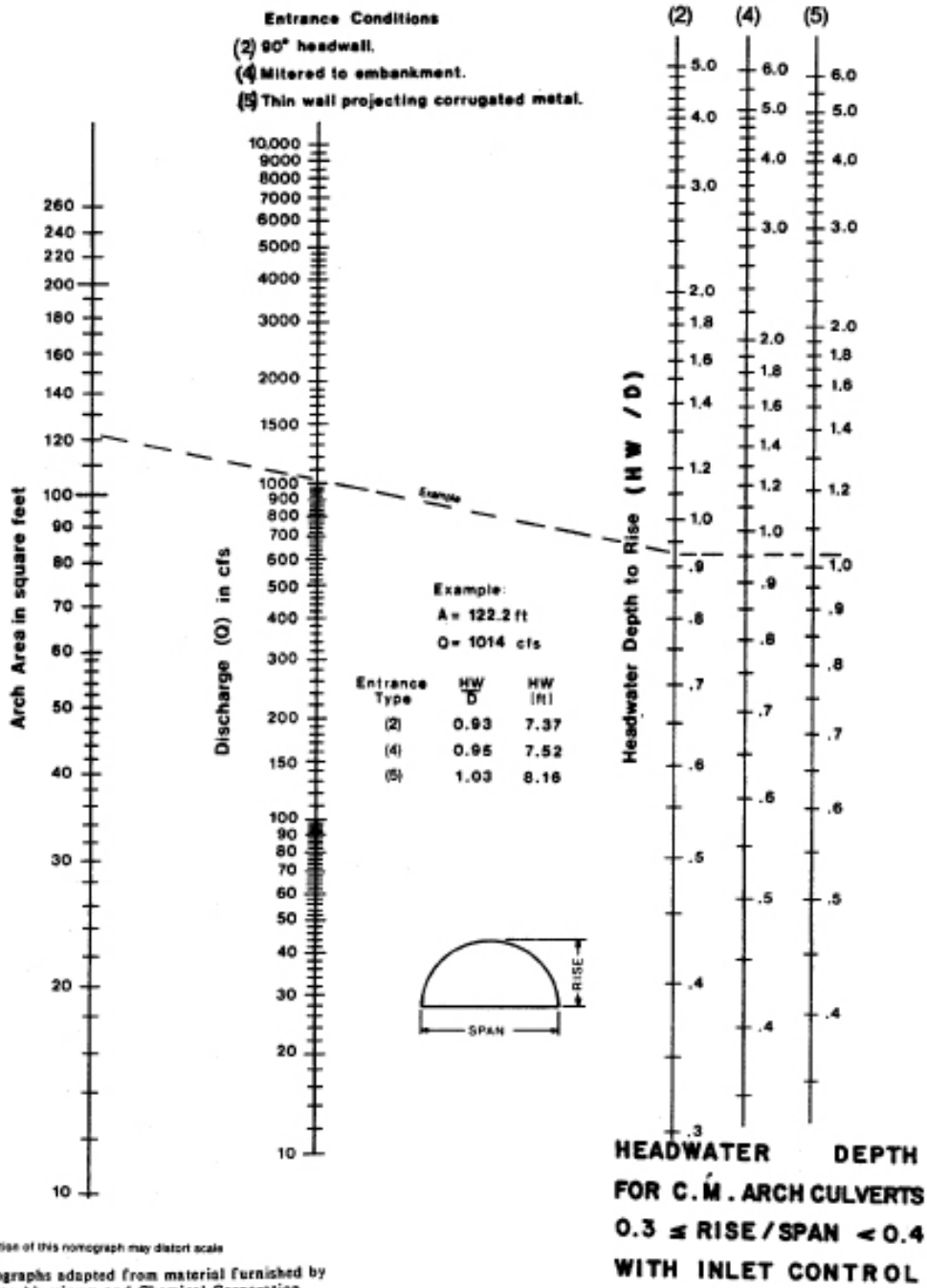
For outlet crown not submerged, compute HW by methods described in the design procedure



Size	n
6.1 x 4.6	0.0327
8.1 x 5.8	0.0321
11.4 x 7.2	0.0315
16.6 x 10.1	0.0306

**HEAD FOR  
STRUCTURAL PLATE  
CORRUGATED METAL  
PIPE ARCH CULVERTS  
18 IN. CORNER RADIUS  
FLOWING FULL  
n=0.0327 TO 0.0306**

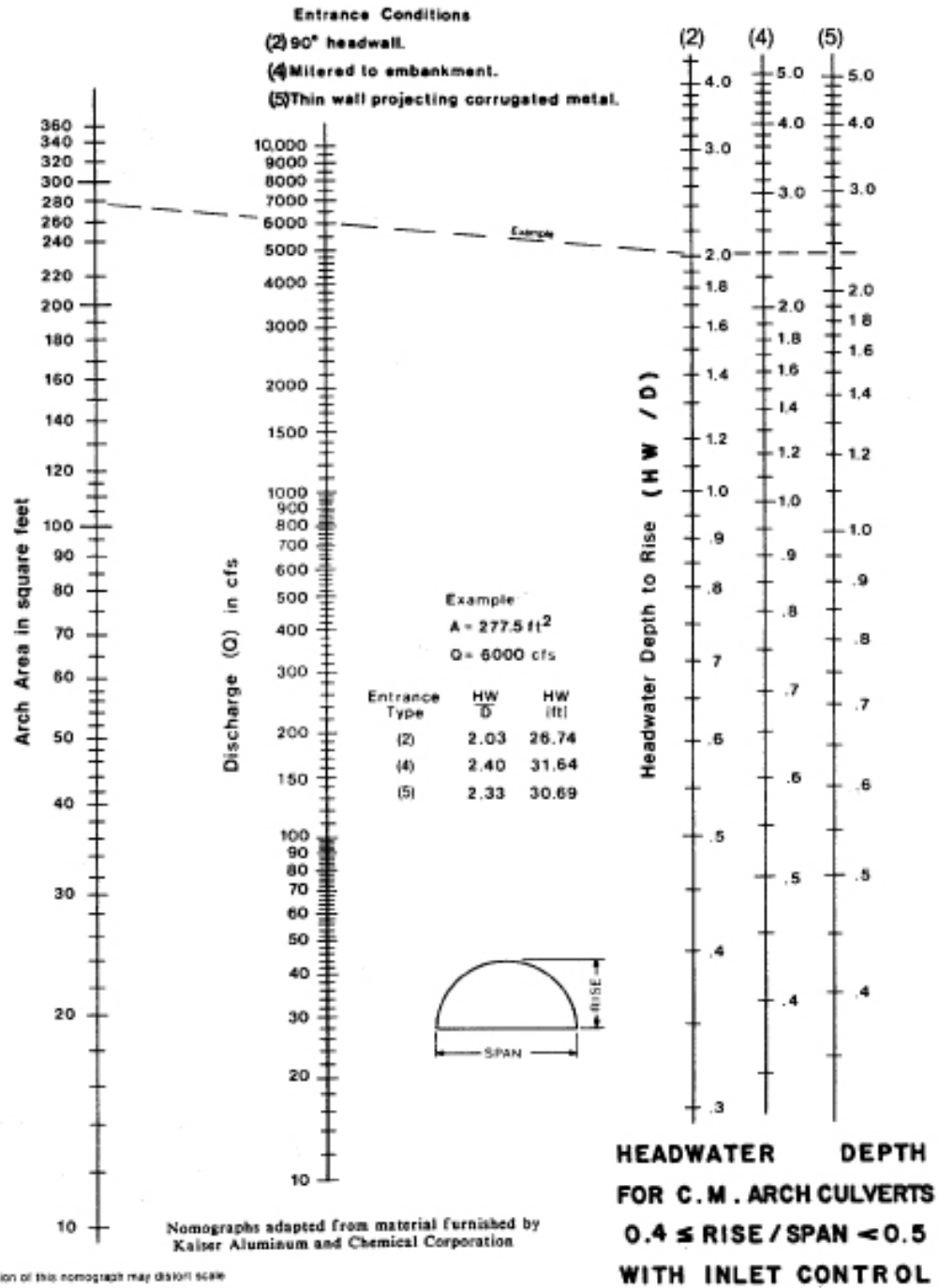
# CHART 41



Duplication of this nomograph may distort scale  
 Nomographs adapted from material furnished by  
 Kaiser Aluminium and Chemical Corporation

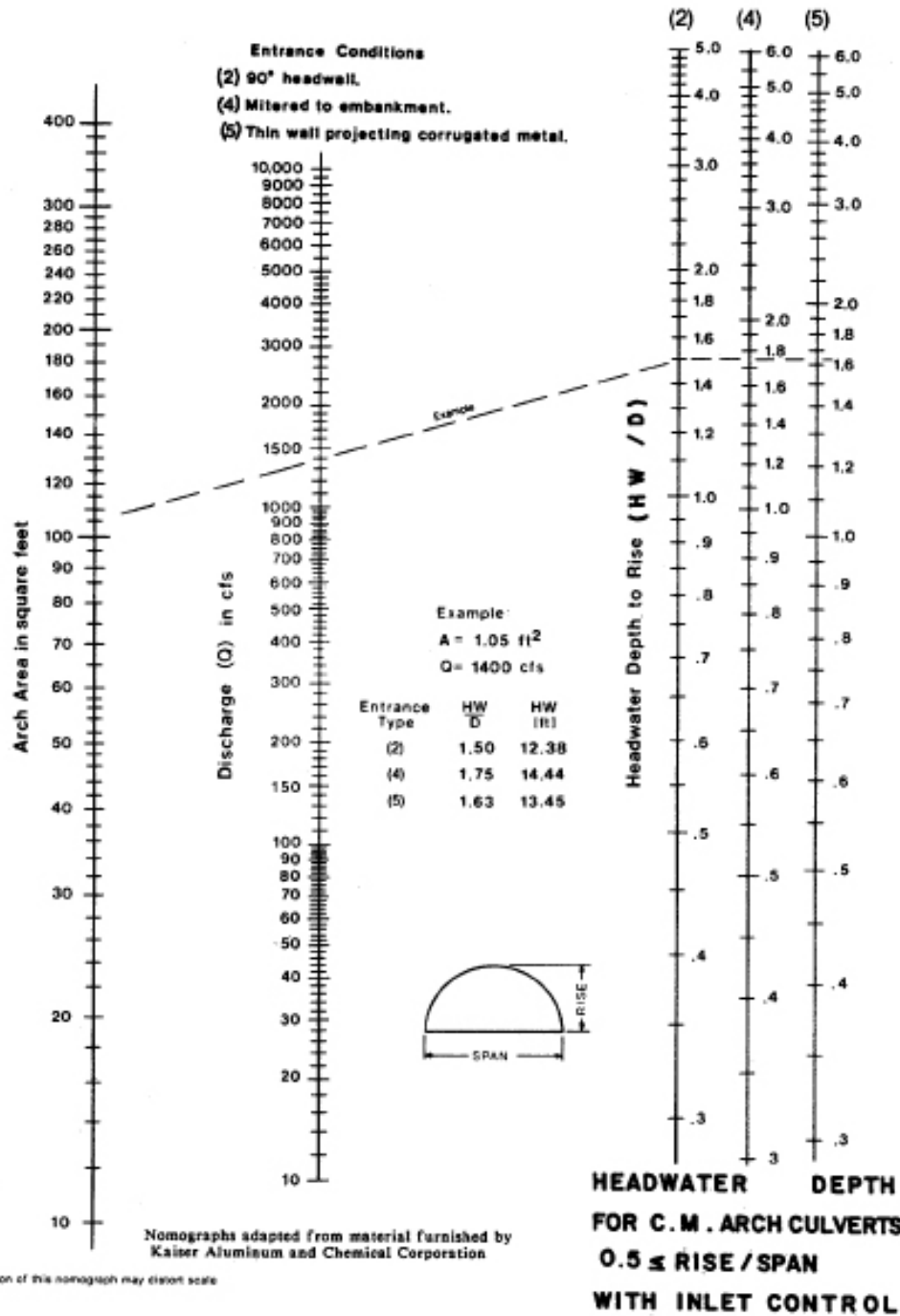


# CHART 42



Duplication of this nomograph may distort scale

# CHART 43

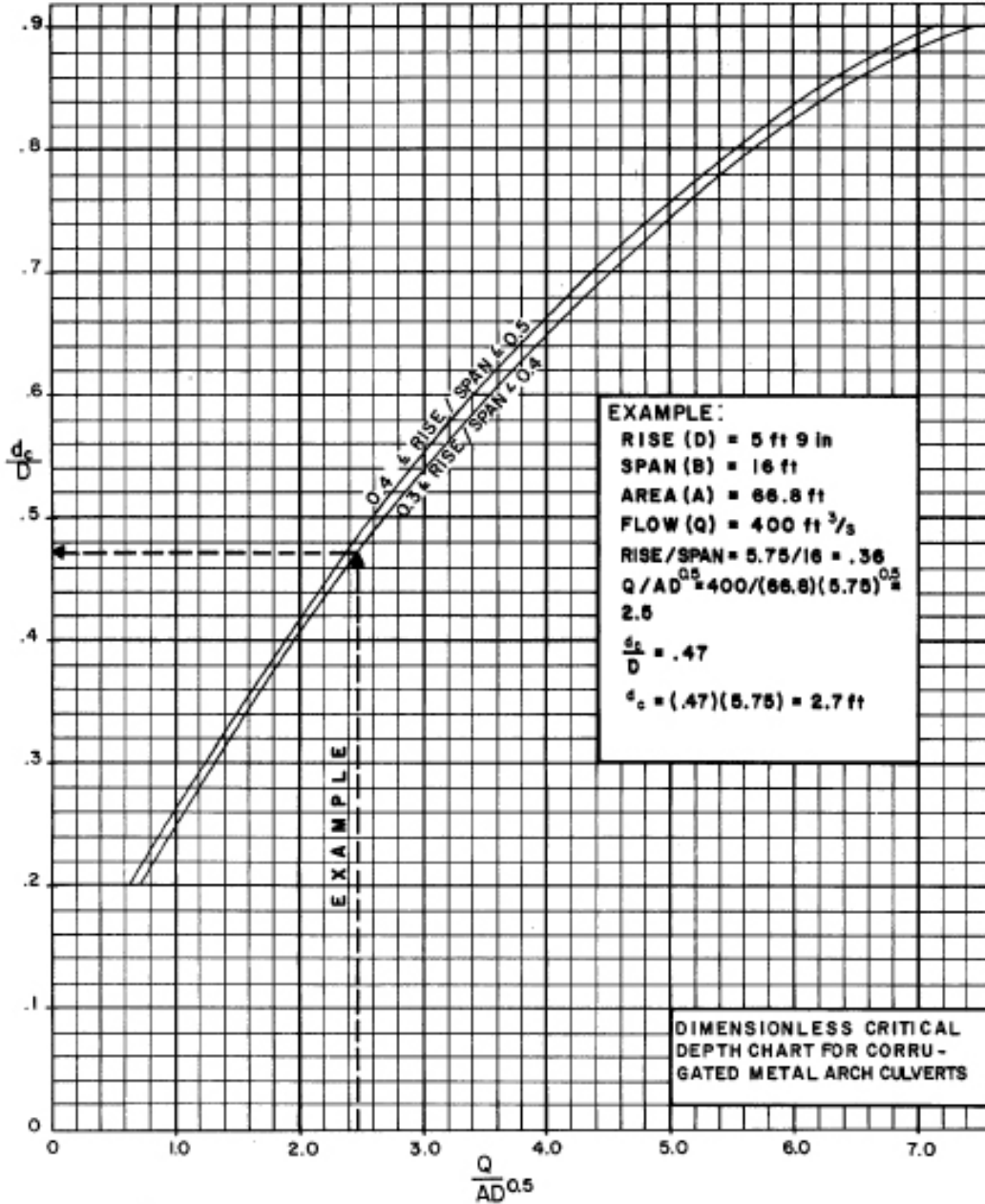


Nomographs adapted from material furnished by Kaiser Aluminum and Chemical Corporation

Duplication of this nomograph may distort scale

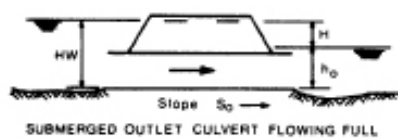
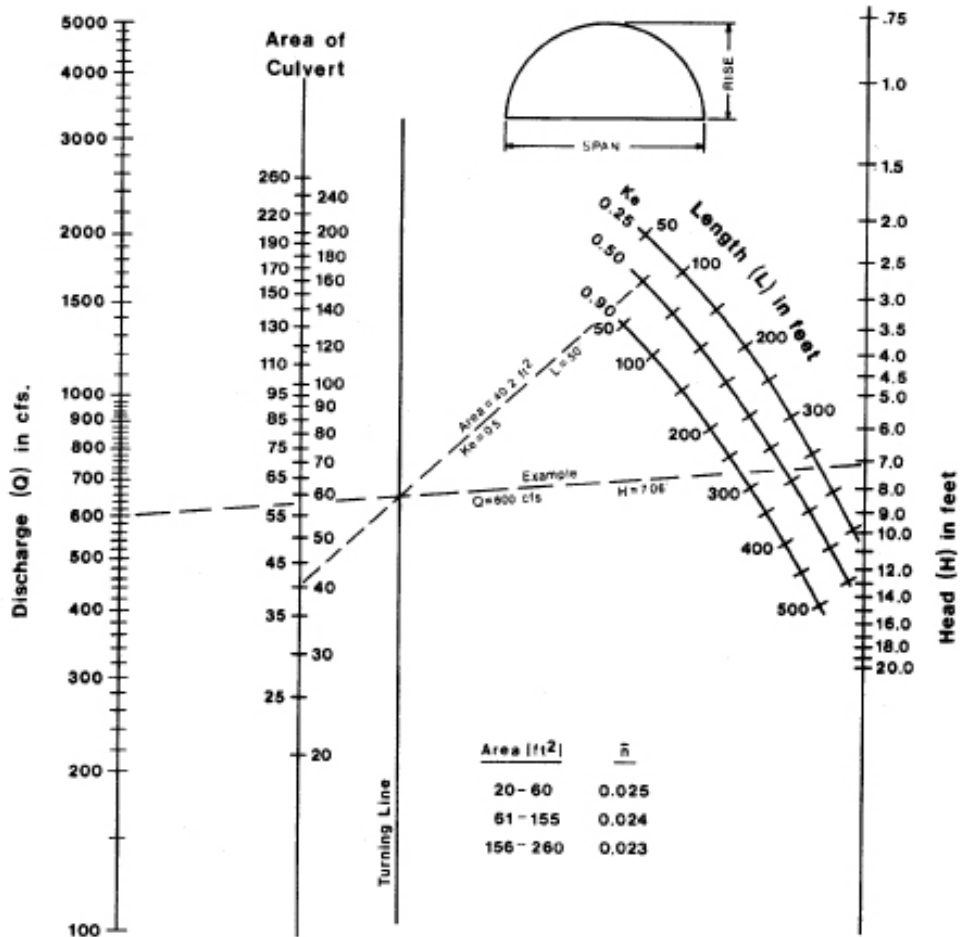


**CHART 44**





### CHART 45



**HEAD FOR  
 C. M. ARCH CULVERTS  
 FLOWING FULL  
 CONCRETE BOTTOM  
 $0.3 \leq \text{RISE} / \text{SPAN} \leq 0.4$**

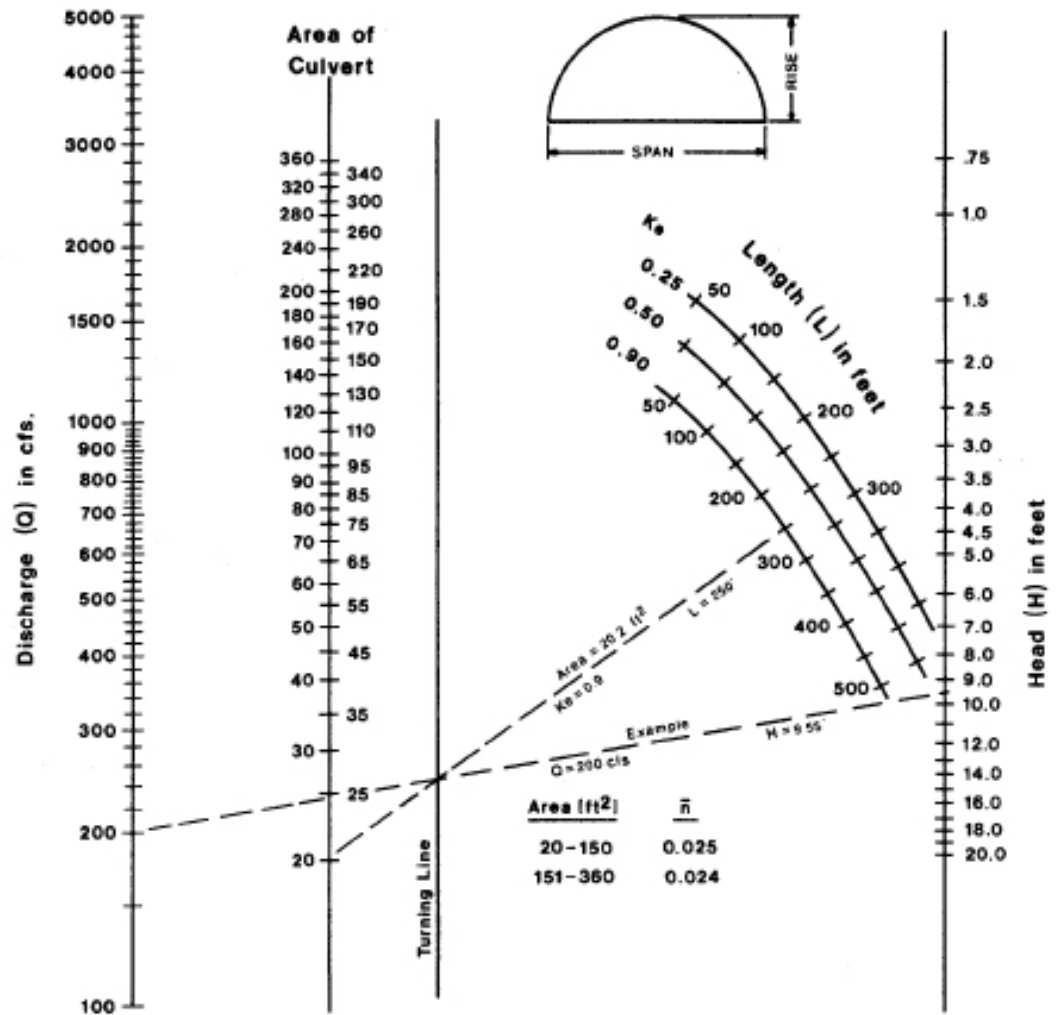
Nomographs adapted from material furnished by  
 Kaiser Aluminium and Chemical Corporation

Duplication of this nomograph may distort scale

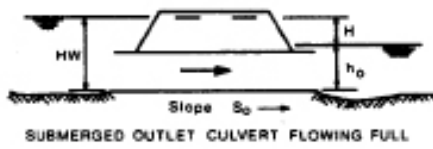




# CHART 46



Area (ft <sup>2</sup> )	$\bar{n}$
20-150	0.025
151-360	0.024



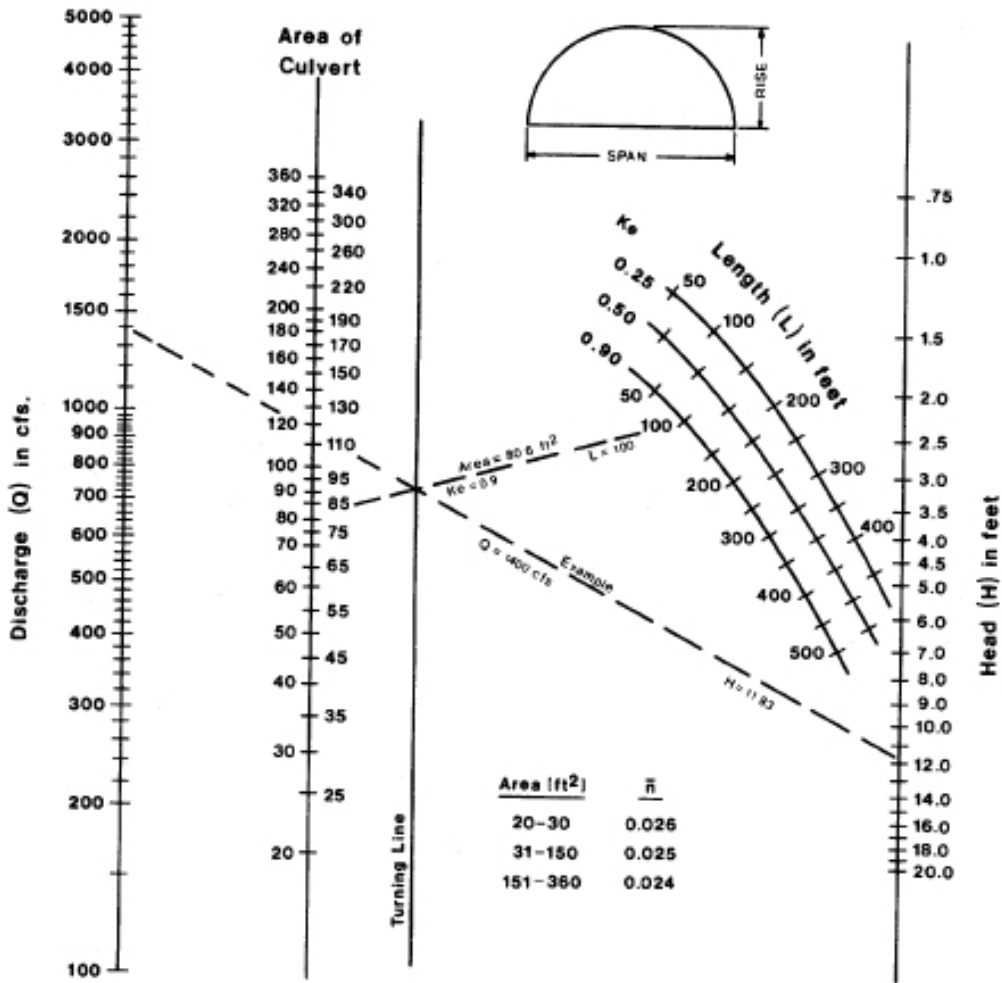
**HEAD FOR  
C.M. ARCH CULVERTS  
FLOWING FULL  
CONCRETE BOTTOM  
 $0.4 \leq \text{RISE} / \text{SPAN} < 0.5$**

Nomographs adapted from material furnished by Kaiser Aluminium and Chemical Corporation

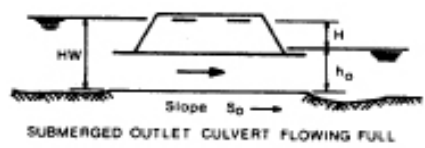
Duplication of this nomograph may distort scale



### CHART 47



Area (ft <sup>2</sup> )	$\bar{n}$
20-30	0.026
31-150	0.025
151-360	0.024



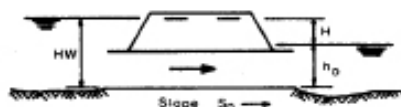
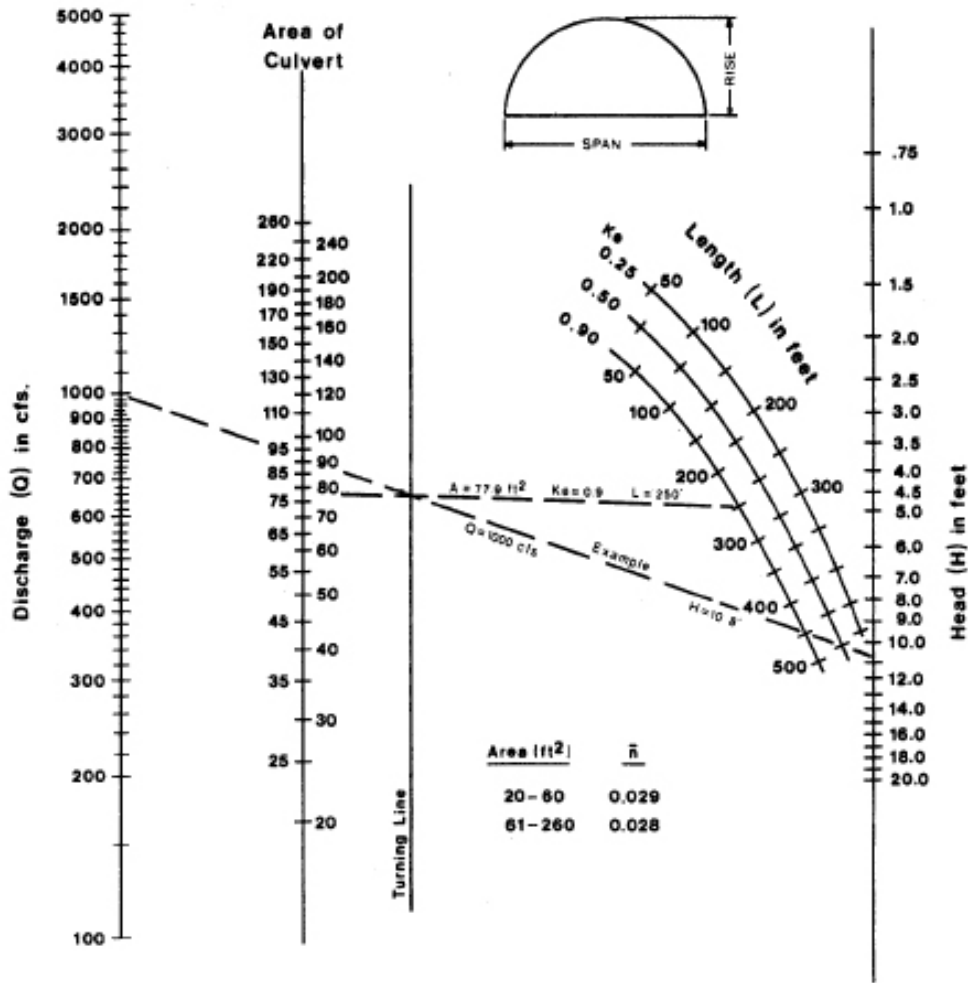
**HEAD FOR  
C.M. ARCH CULVERTS  
FLOWING FULL  
CONCRETE BOTTOM  
0.5 ≤ RISE / SPAN**

Nomographs adapted from material furnished by Kaiser Aluminum and Chemical Corporation

Duplication of this nomograph may distort scale



**CHART 48**

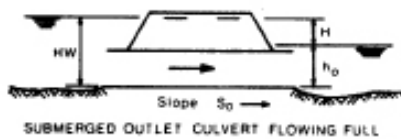
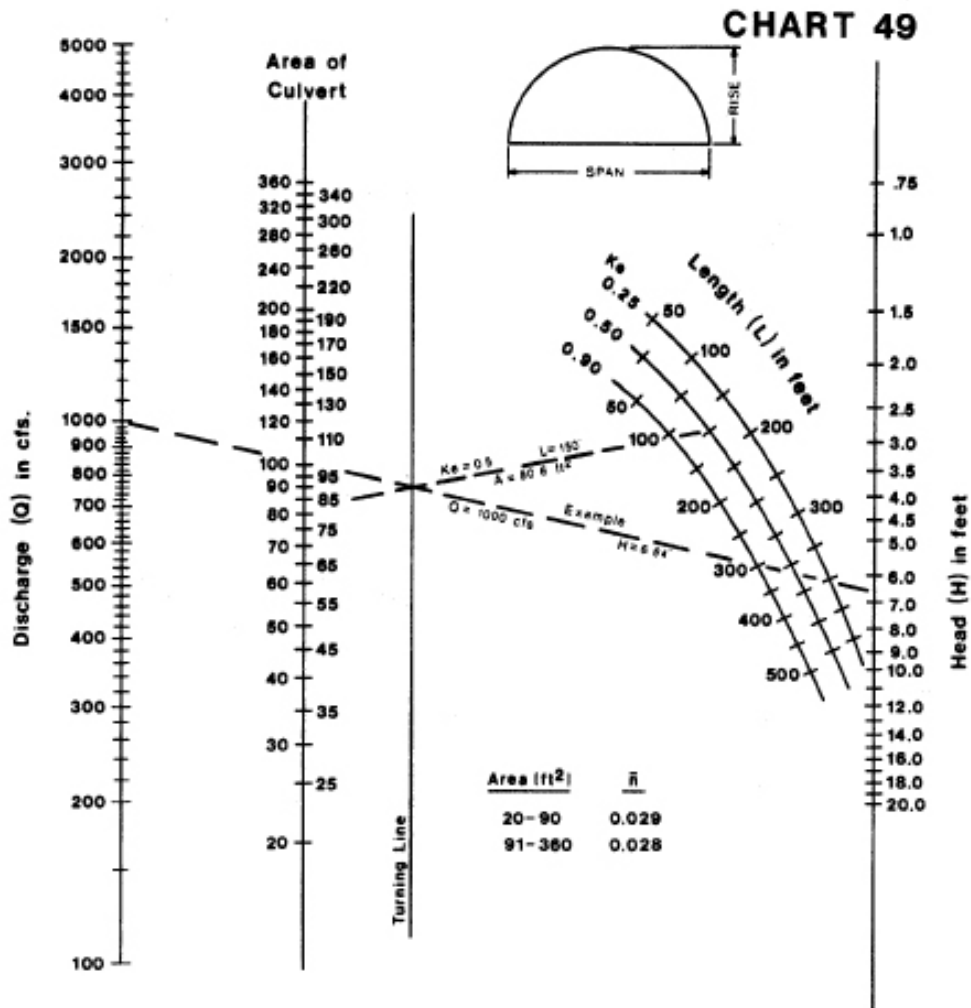


SUBMERGED OUTLET CULVERT FLOWING FULL

**HEAD FOR  
C. M. ARCH CULVERTS  
FLOWING FULL  
EARTH BOTTOM ( $n_b = 0.022$ )  
 $0.3 \leq \text{RISE} / \text{SPAN} < 0.4$**

Nomographs adapted from material furnished by Kaiser Aluminum and Chemical Corporation

Duplication of this nomograph may distort scale

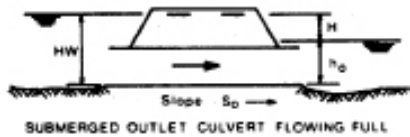
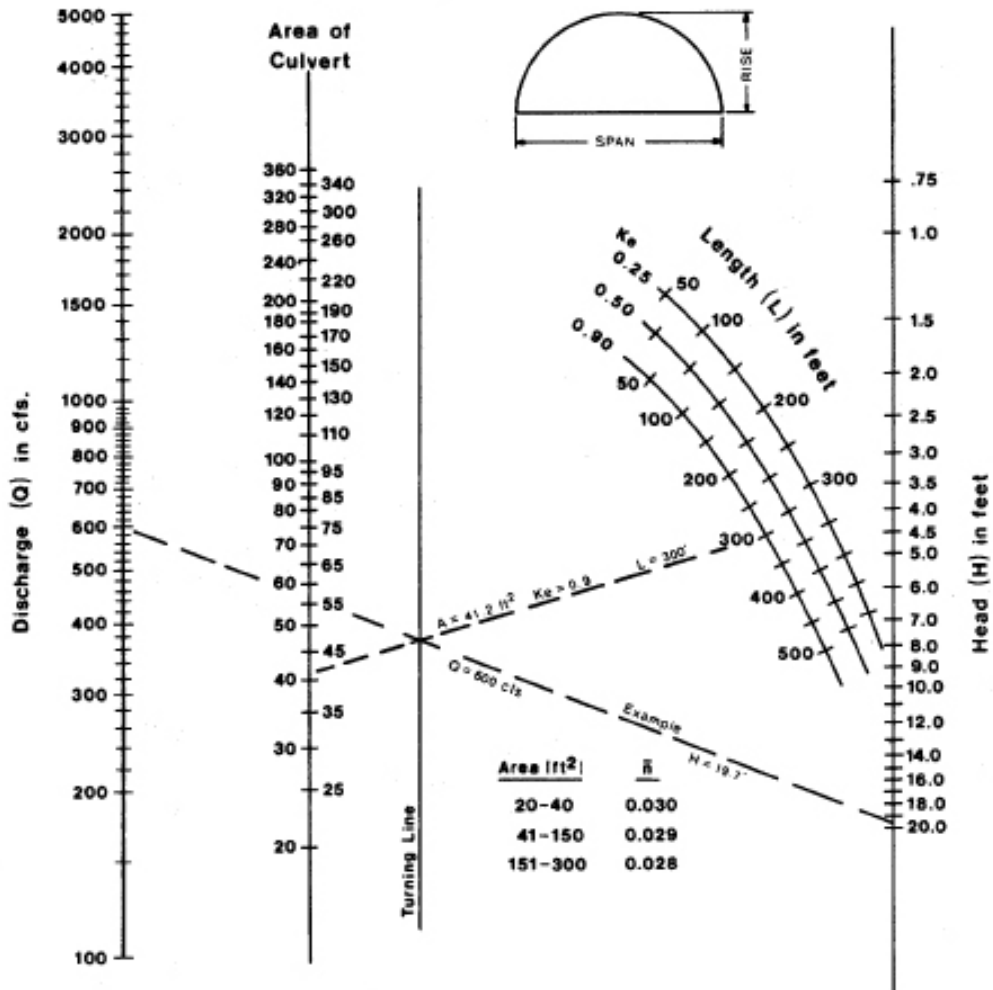


**HEAD FOR  
C. M. ARCH CULVERTS  
FLOWING FULL  
EARTH BOTTOM ( $n_b = 0.022$ )  
 $0.4 \leq \text{RISE} / \text{SPAN} < 0.5$**

Nomographs adapted from material furnished by  
Kaiser Aluminum and Chemical Corporation

Duplication of this nomograph may distort scale

 **CHART 50**



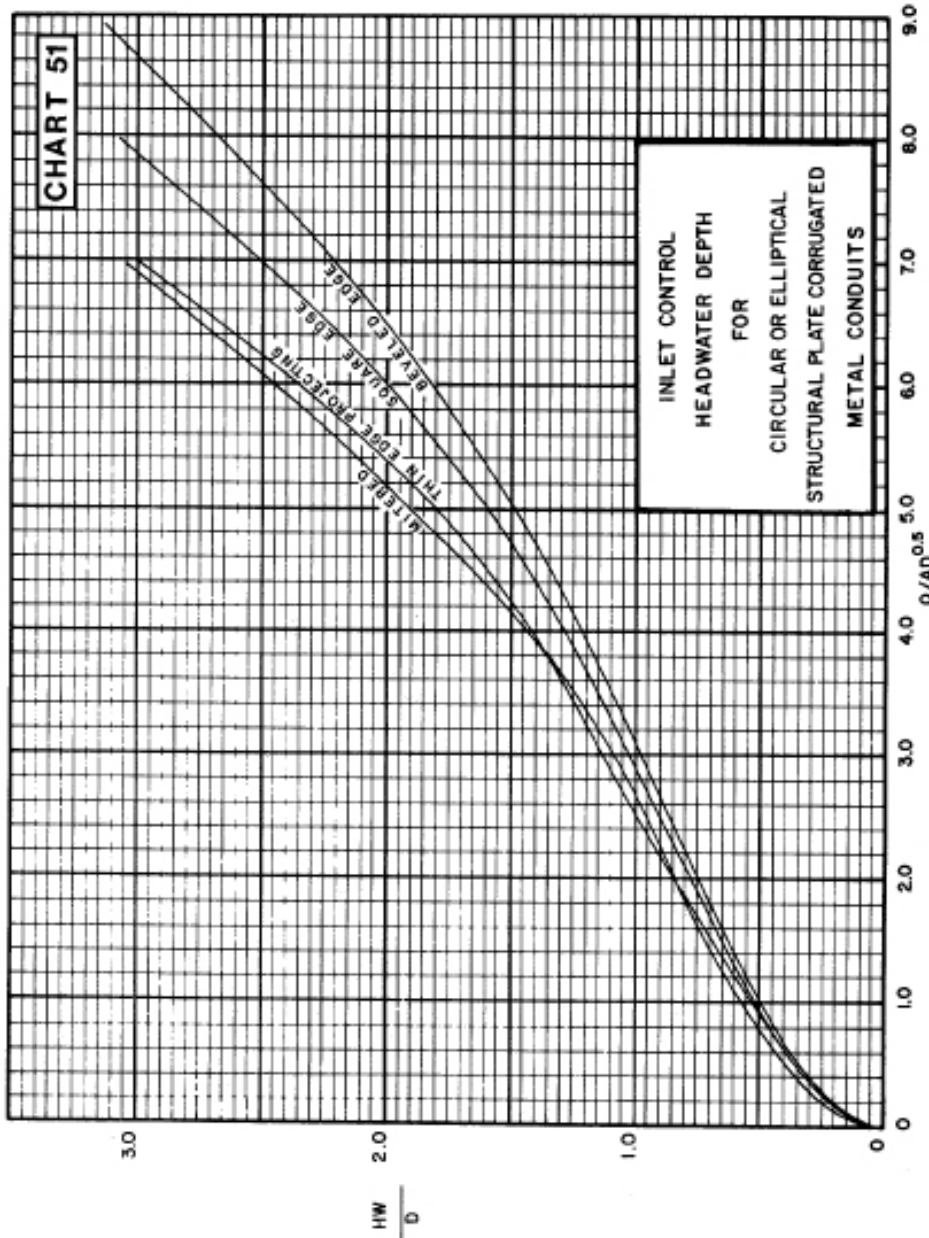
**HEAD FOR  
C. M. ARCH CULVERTS  
FLOWING FULL  
EARTH BOTTOM ( $n_b = 0.022$ )  
0.5 ≤ RISE / SPAN**

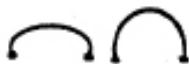
Nomographs adapted from material furnished by  
Kaiser Aluminum and Chemical Corporation

Duplication of this nomograph may distort scale

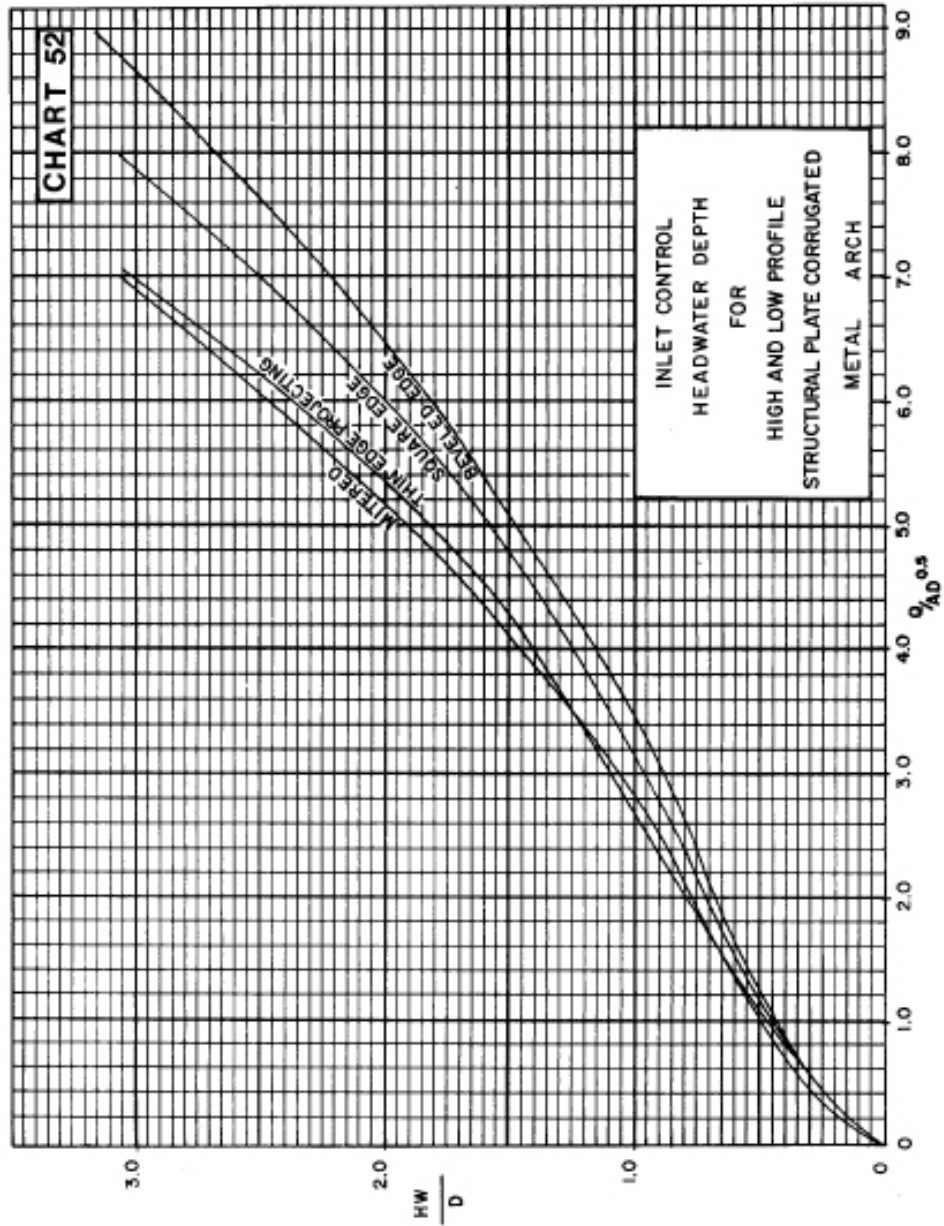


**CHART 51**



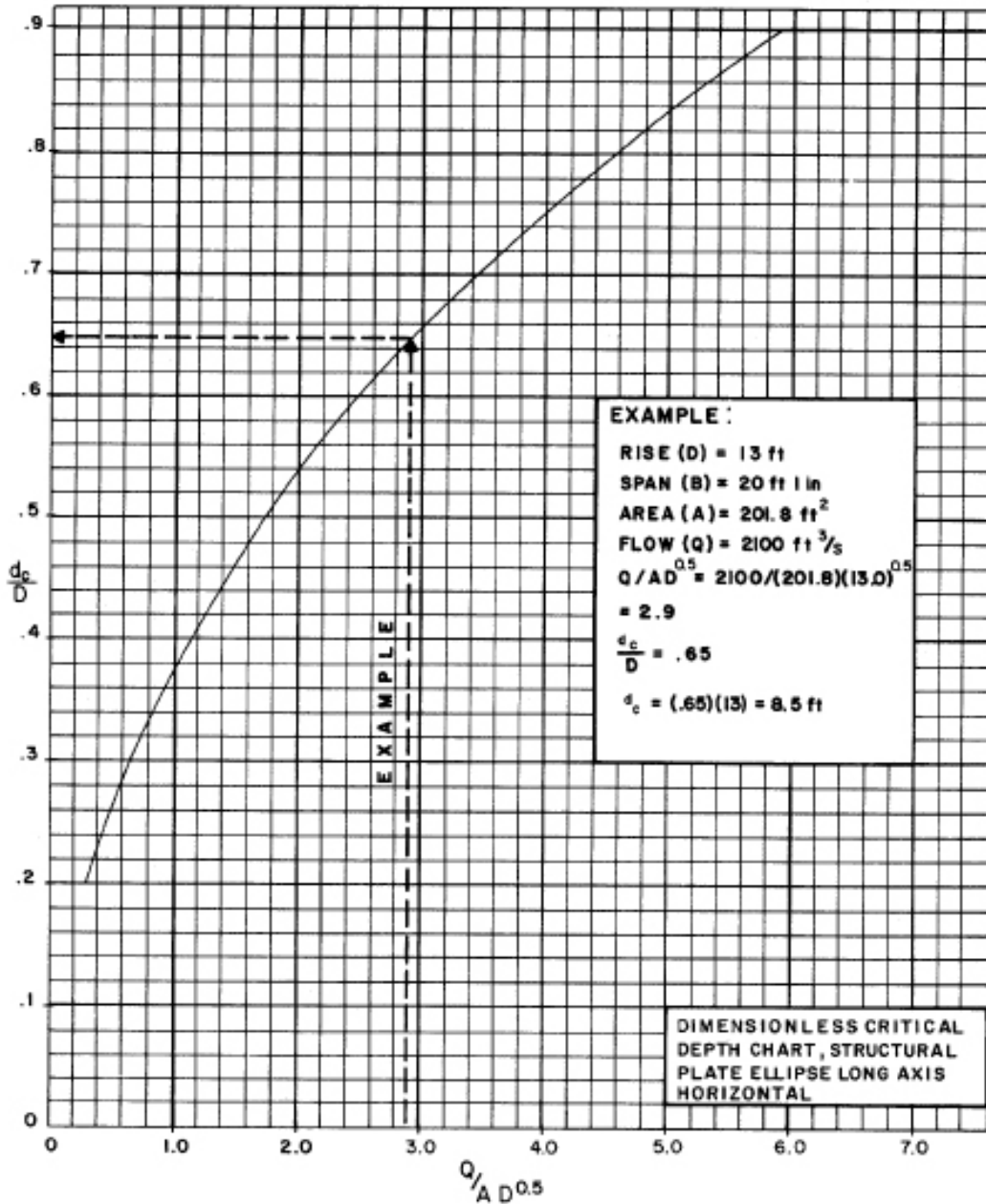


**CHART 52**

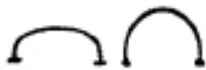




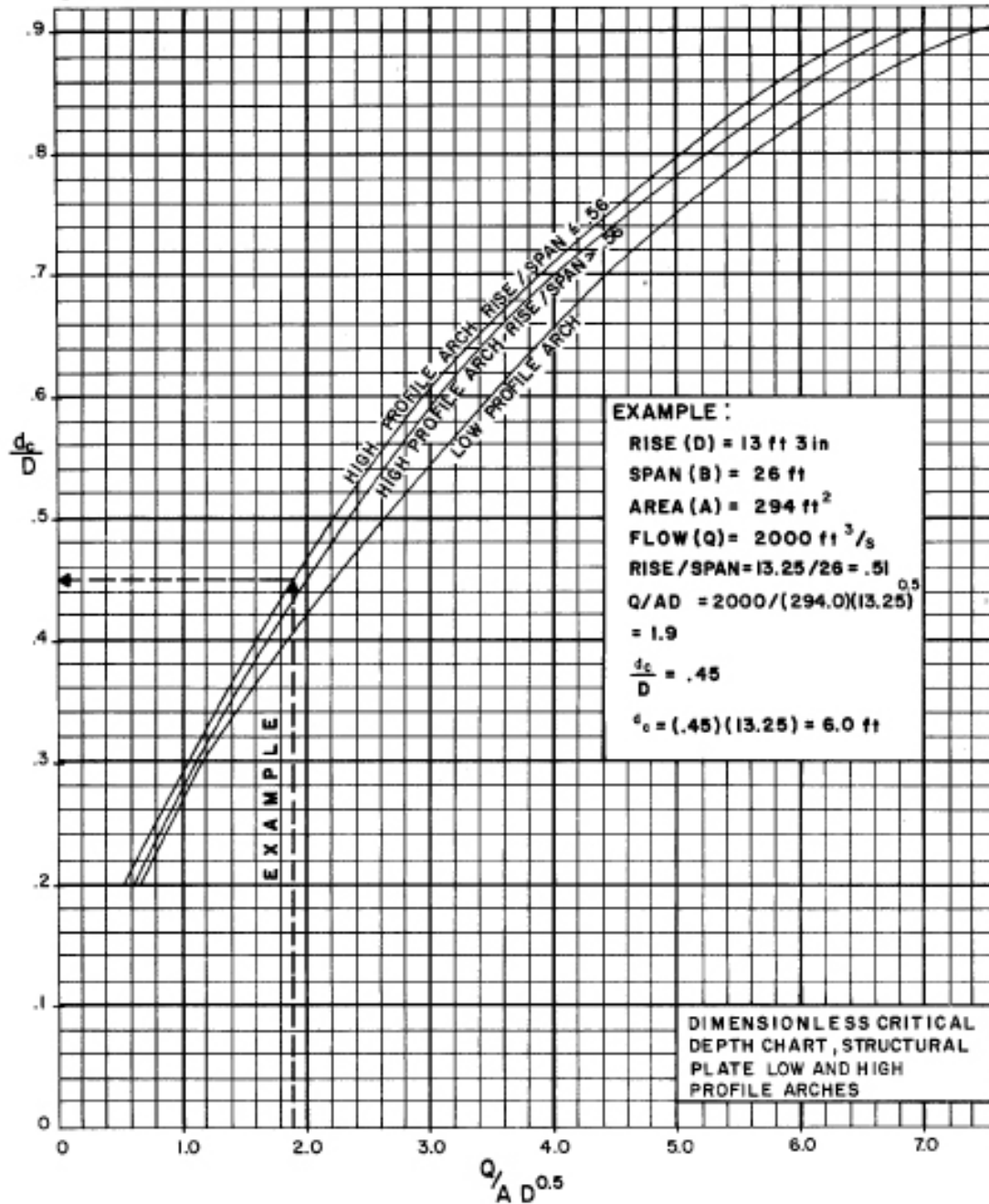
**CHART 53**



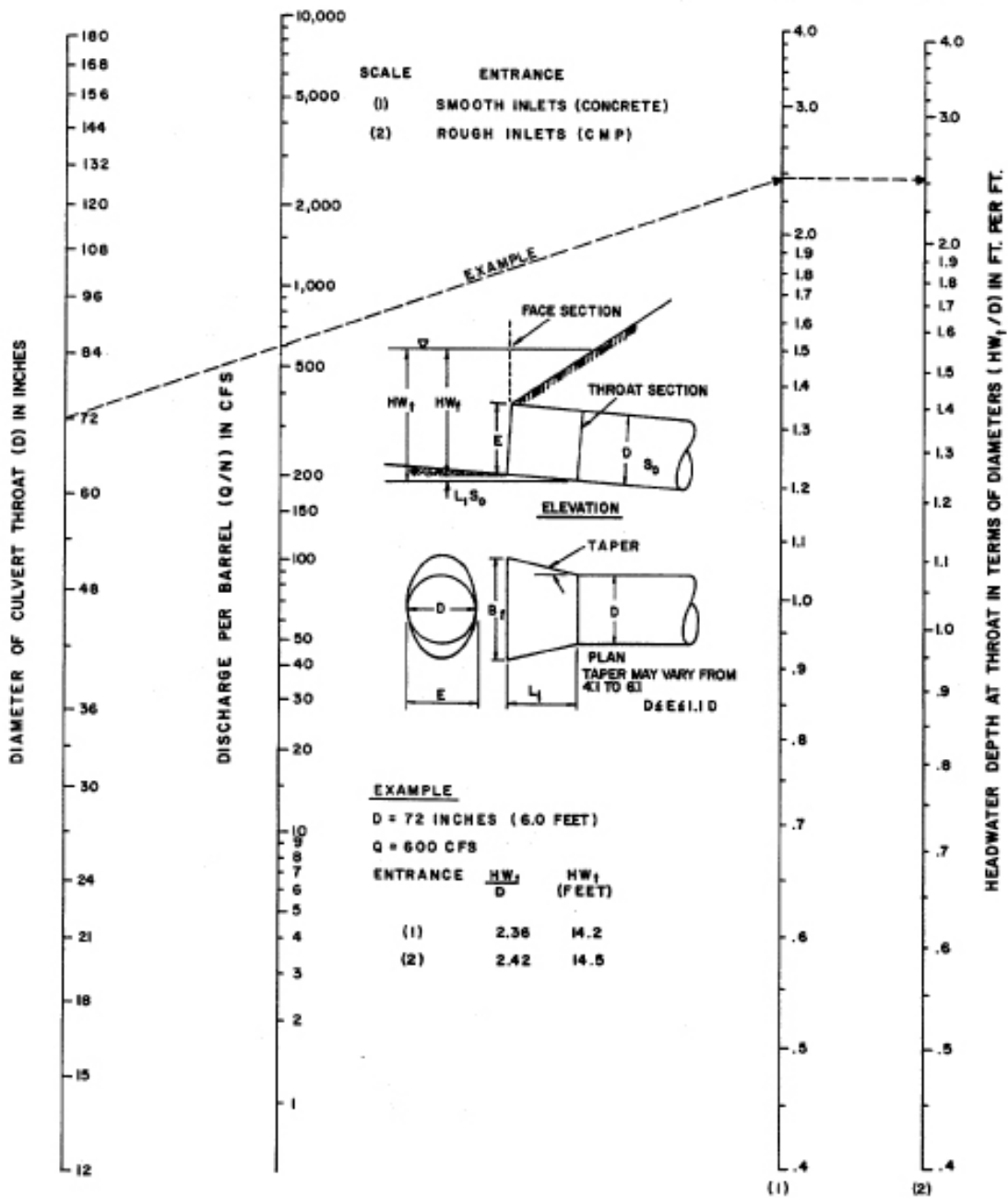




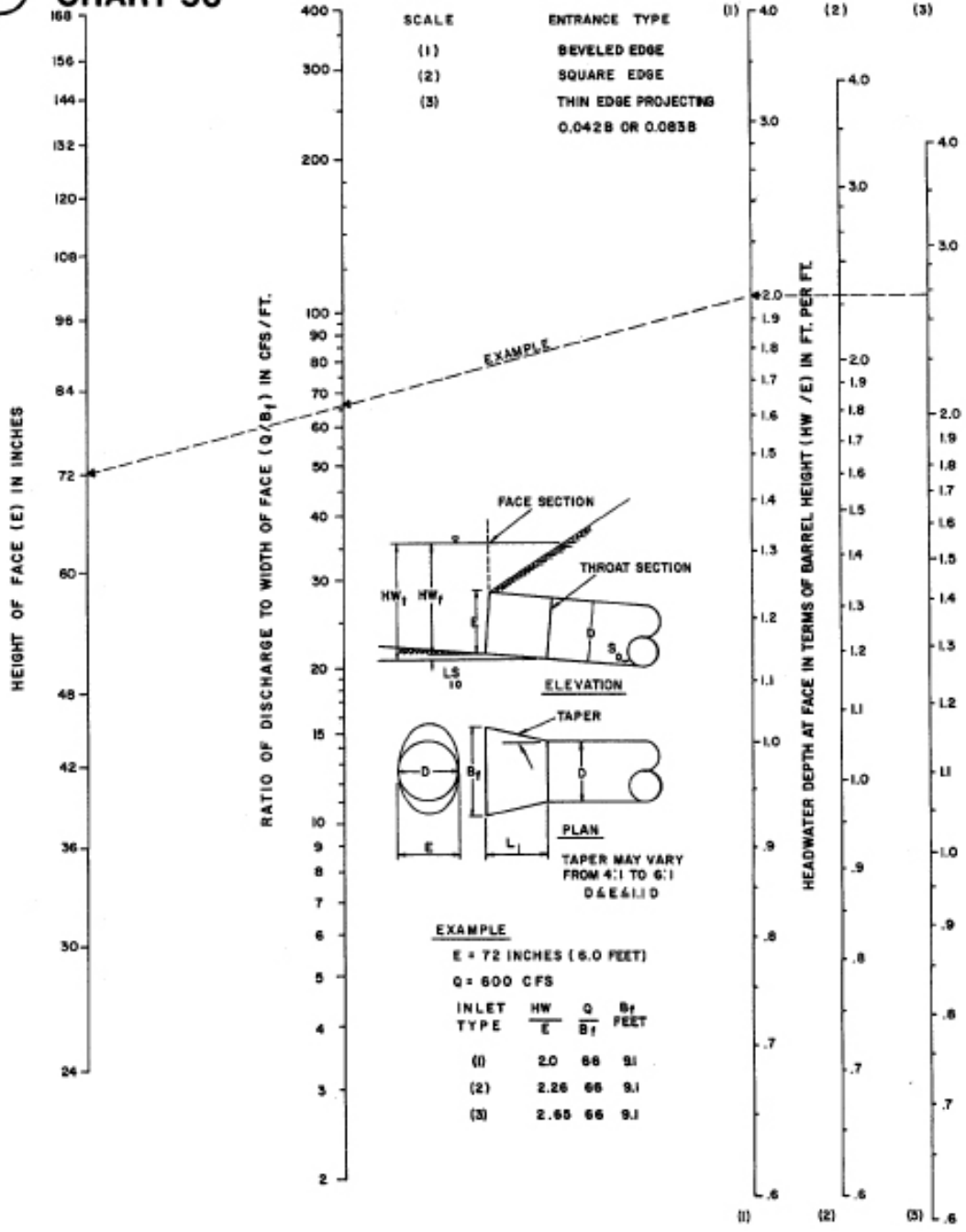
**CHART 54**



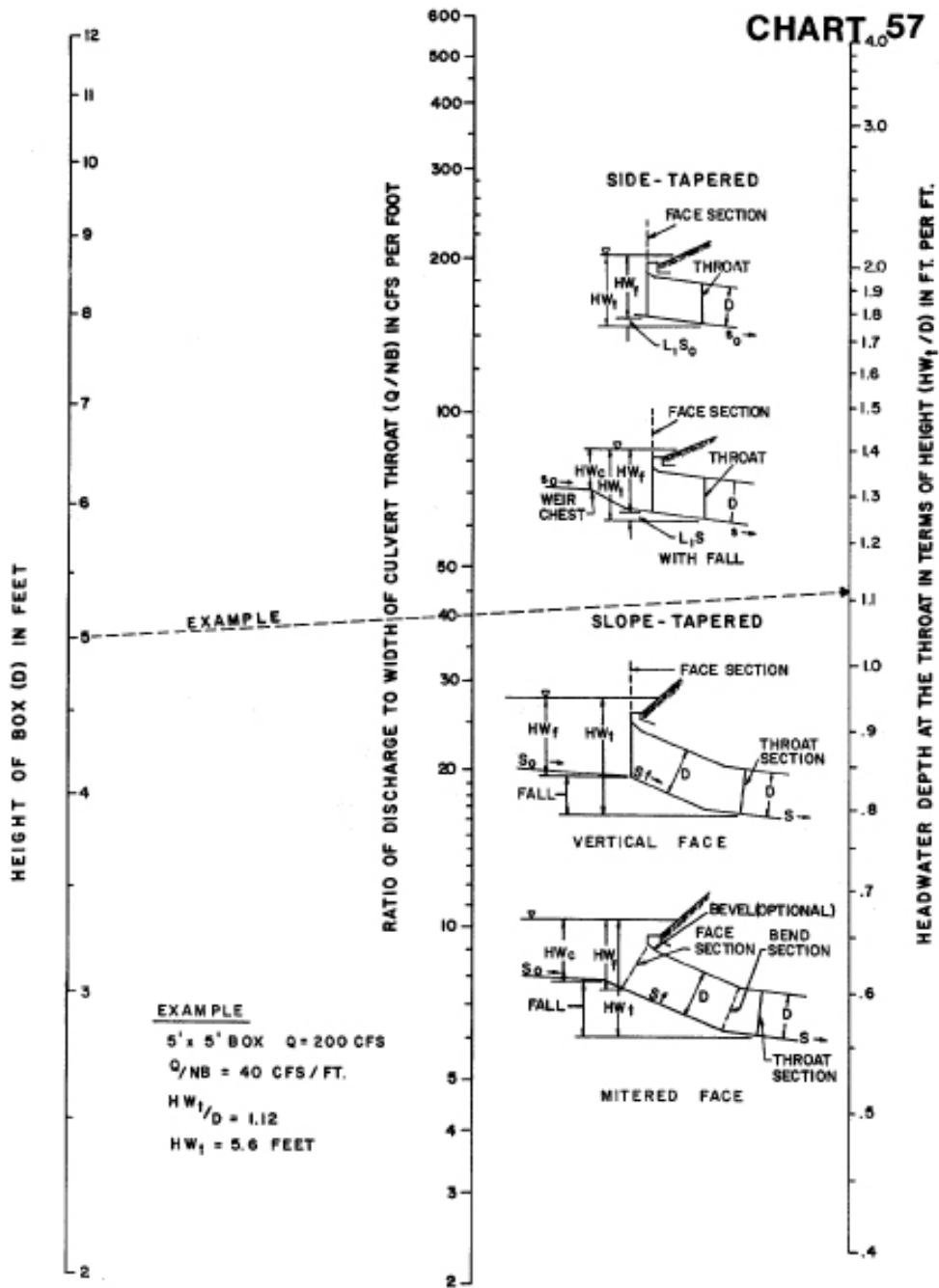
**CHART 55**



**CHART 56**



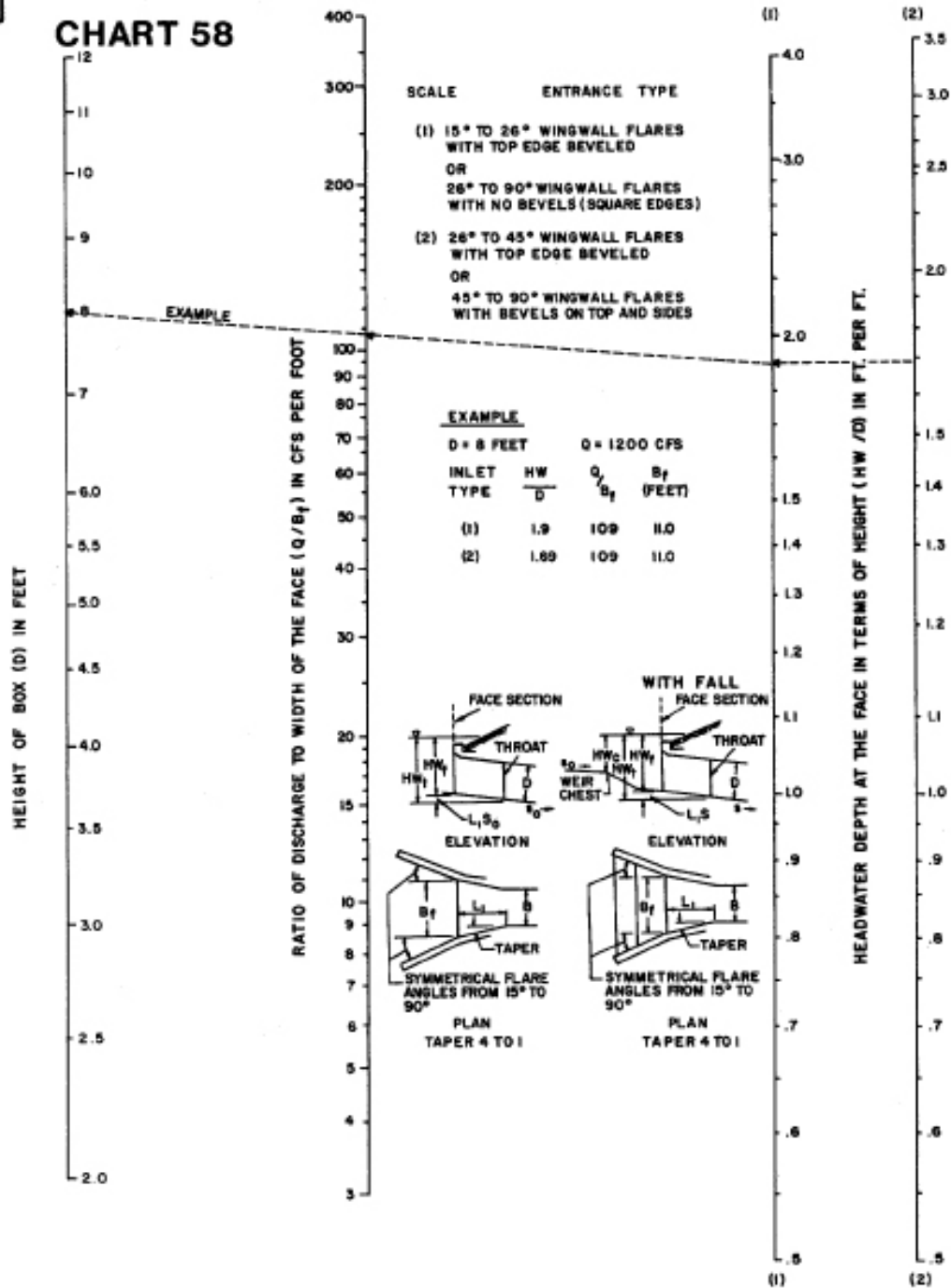
**FACE CONTROL FOR SIDE-TAPERED INLETS TO PIPE CULVERTS (NON-RECTANGULAR SECTIONS ONLY)**



**THROAT CONTROL FOR BOX  
 CULVERTS WITH TAPERED  
 INLETS**

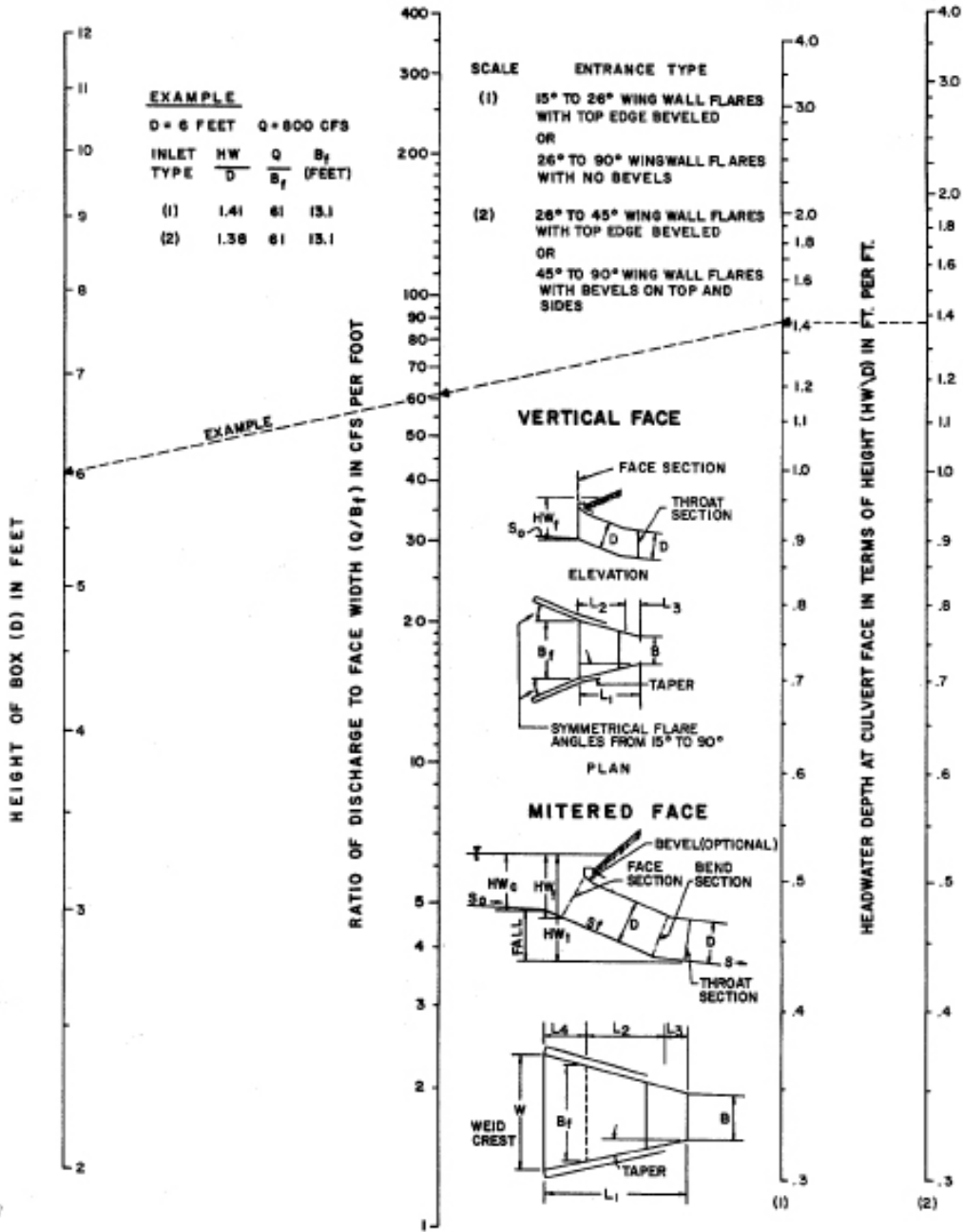


# CHART 58



FACE CONTROL FOR BOX CULVERTS WITH SIDE TAPERED INLETS

# CHART 59



FACE CONTROL FOR BOX CULVERTS WITH SLOPE TAPERED INLETS