APPENDIX C

CULVERT DESIGN NOMOGRAPHS

Culvert Design Nomographs

Note:	Design Nomographs are given in SI and English Units. For example, Chart 1A is in SI Units and Chart IB is in English Units. English design charts have a small symbol in the upper outside corner representing the shape involved. SI charts have the chart number in a box.

Chart	**Circular Culverts**
1A, 1B	*Headwater Depth for Concrete Pipe Culverts With Inlet Control*
2A, 2B	Headwater Depth for C.M. Pipe Culverts with Inlet Control
3A, 3B	Headwater Depth for Circular Pipe Culverts with Beveled Ring Control
4A, 4B	Critical Depth - Circular Pipe
5A, 5B	Head for Concrete Pipe Culverts, Flowing Full, n = 0.012
6A, 6B	Head for Standard C.M. Pipe Culverts, Flowing Full, n = 0.024
7A, 7B	Head for Structural Plate Corrugated Metal Pipe Culverts Flowing Full, n = 0.0328 to 0.0302

Chart	**Concrete Box Culverts**
8A, 8B	*Headwater Depth for Box Culverts with Inlet Control*
9A, 9B	Headwater Depth for Inlet Control Rectangular Box Culverts, Flared Wingwalls 18° to 33.7° and 45° with Beveled Edge at Top of Inlet
10A, 10B	Headwater Depth for Inlet Control, Rectangular Box Culverts, 90° Headwall, Chamfered or Beveled Inlet Edges
11A, 11B	Headwater Depth for Inlet Control, Single Barrel Box Culverts, Skewed Headwalls, Chamfered or Beveled Inlet Edges
12A, 12B	Headwater Depth for Inlet Control, Rectangular Box Culverts, Flared Wingwalls, Normal and Skewed Inlets, Chamfered at Top of Opening (12A: *19 mm*; 12B: *3/4 inch*)
13A, 13B	Headwater Depth for Inlet Control, Rectangular Box Culverts, Offset Flared Wingwalls and Beveled Edge at Top of Inlet
14A, 14B	Critical Depth – Rectangular Section
15A, 15B	Head for Concrete Box Culverts, Flowing Full, n = 0.012

Chart	**Concrete Metal Box Culverts**
16A, 16B	*Headwater Depth for C.M. Box Culverts, Rise/Span < 0.3 with Inlet Control*
17A, 17B	Headwater Depth for C.M. Box Culverts, 0.3 ≤ Rise/Span < 0.4 with Inlet Control
18A, 18B	Headwater Depth for C.M. Box Culverts, 0.4 ≤ Rise/Span < 0.5 with Inlet Control
19A, 19B	Headwater Depth for C.M. Box Culverts, 0.5 ≤ Rise/Span with Inlet Control
20A, 20B	Dimensionless Critical Depth Chart for Corrugated Metal Box Culverts
21A, 21B	Head for C.M. Box Culverts, Flowing Full with Concrete Bottom, Rise/Span < 0.3
22A, 22B	Head for C.M. Box Culverts, Flowing Full with Concrete Bottom, 0.3 ≤ Rise/Span < 0.4
23A, 23B	Head for C.M. Box Culverts, Flowing Full with Concrete Bottom, 0.4 ≤ Rise/Span < 0.5
24A, 24B	Head for C.M. Box Culverts, Flowing Full with Concrete Bottom, 0.5 ≤ Rise/Span
25A, 25B	Head for C.M. Box Culverts, Flowing Full with C.M. Bottom, Rise/ Span < 0.3
26A, 26B	Head for C.M. Box Culverts Flowing Full with C.M. Bottom, 0.3 ≤ Rise/Span < 0.4
27A, 27B	Head for C.M. Box Culverts Flowing Full with C.M. Bottom, 0.4 ≤ Rise/Span < 0.5
28A, 28B	Head for C.M. Box Culverts Flowing Full with C.M. Bottom, 0.5 ≤ Rise/Span

Chart	**Elliptical Culverts**
29A, 29B	*Headwater Depth for Oval Concrete Pipe Culverts, Long Axis Horizontal with Inlet Control*
30A, 30B	Headwater Depth for Oval Concrete Pipe Culverts, Long Axis Vertical with Inlet Control
31A, 31B	Critical Depth - Oval Concrete Pipe, Long Axis Horizontal
32A, 32B	Critical Depth - Oval Concrete Pipe, Long Axis Vertical
33A, 33B	Head for Oval Concrete Pipe Culverts, Long Axis Horizontal or Vertical, Flowing Full, n=0.012

Chart	Pipe/Arch Culverts
34A, 34B	Headwater Depth for C.M. Pipe-Arch Culverts with Inlet Control
35A, 35B	Headwater Depth for Inlet Control, Structural Plate Pipe-Arch Culverts, Radius Corner Plate, Projecting or Headwall Inlet, Headwall with or without Edge Bevel, (35A: *457mm*; 35B: *18-in*)
36A, 36B	Headwater Depth for Inlet Control, Structural Plate Pipe-Arch Culverts, Radius Corner Plate, Projecting or Headwall Inlet, Headwall with or without Edge Bevel, (36A: *787mm*; 36B: *31-in*)
37A, 37B	Critical Depth - Standard Corrugated Metal Pipe-Arch
38A, 38B	Critical Depth - Structural Plate Corrugated Metal Pipe-Arch (Corner Radius - 38A: *457mm*; 38B: *18-in*)
39A, 39B	Head for Standard C.M. Pipe-Arch Culverts, Flowing Full, n = 0.024
40A, 40B	Head for Structural Plate C.M. Pipe-Arch Culverts, Flowing Full, n = 0.0327 - 0.0306 (Corner Radius - 40A: *457mm*; 40B: *18-in*)

Chart	Arch Culverts
41A, 41B	Headwater Depth for C.M. Arch Culverts with Inlet Control, 0.3 ≤ Rise/Span < 0.4
42A, 42B	Headwater Depth for C.M. Arch Culverts with Inlet Control, 0.4 ≤ Rise/Span < 0.5
43A, 43B	Headwater Depth for C.M. Arch Culverts with Inlet Control, 0.5 ≤ Rise/Span
44A, 44B	Dimensionless Critical Depth Chart for Corrugated Metal Arch Culverts
45A, 45B	Head for C.M. Arch Culverts, Flowing Full, Concrete Bottom, 0.3 ≤ Rise/Span < 0.4
46A, 46B	Head for C.M. Arch Culverts, Flowing Full, Concrete Bottom, 0.4 ≤ Rise/Span < 0.5
47A, 47B	Head for C.M. Arch Culverts, Flowing Full, Concrete Bottom, 0.5 < Rise/Span
48A, 48B	Head for C.M. Arch Culverts, Flowing Full, Earth Bottom, 0.3 ≤ Rise/Span < 0.4
49A, 49B	Head for C.M. Arch Culverts, Flowing Full with Earth Bottom, 0.4 ≤ Rise/Span < 0.5
50A, 50B	Head for C.M. Arch Culverts, Flowing Full with Earth Bottom, 0.5 ≤ Rise/Span

Chart	Long Span Culverts
51A, 51B	*Inlet Control, Headwater Depth for Circular or Elliptical Structural Plate, C.M. Conduits*
52A, 52B	Inlet Control, Headwater Depth for C.M. High and Low Profile Structural Plate Arches
53A, 53B	Dimensionless Critical Depth Chart for Structural Plate Ellipse, Long Axis Horizontal
54A, 54B	Dimensionless Critical Depth Chart for Structural Plate Low and High Profile Arches

Chart	Circular Tapered Inlets
55A, 55B	Throat Control for Side-Tapered Inlets to Pipe Culvert (Circular Section Only)
56A, 56B	Face Control for Side-Tapered Inlets to Pipe Culverts (Non-Rectangular Section Only)

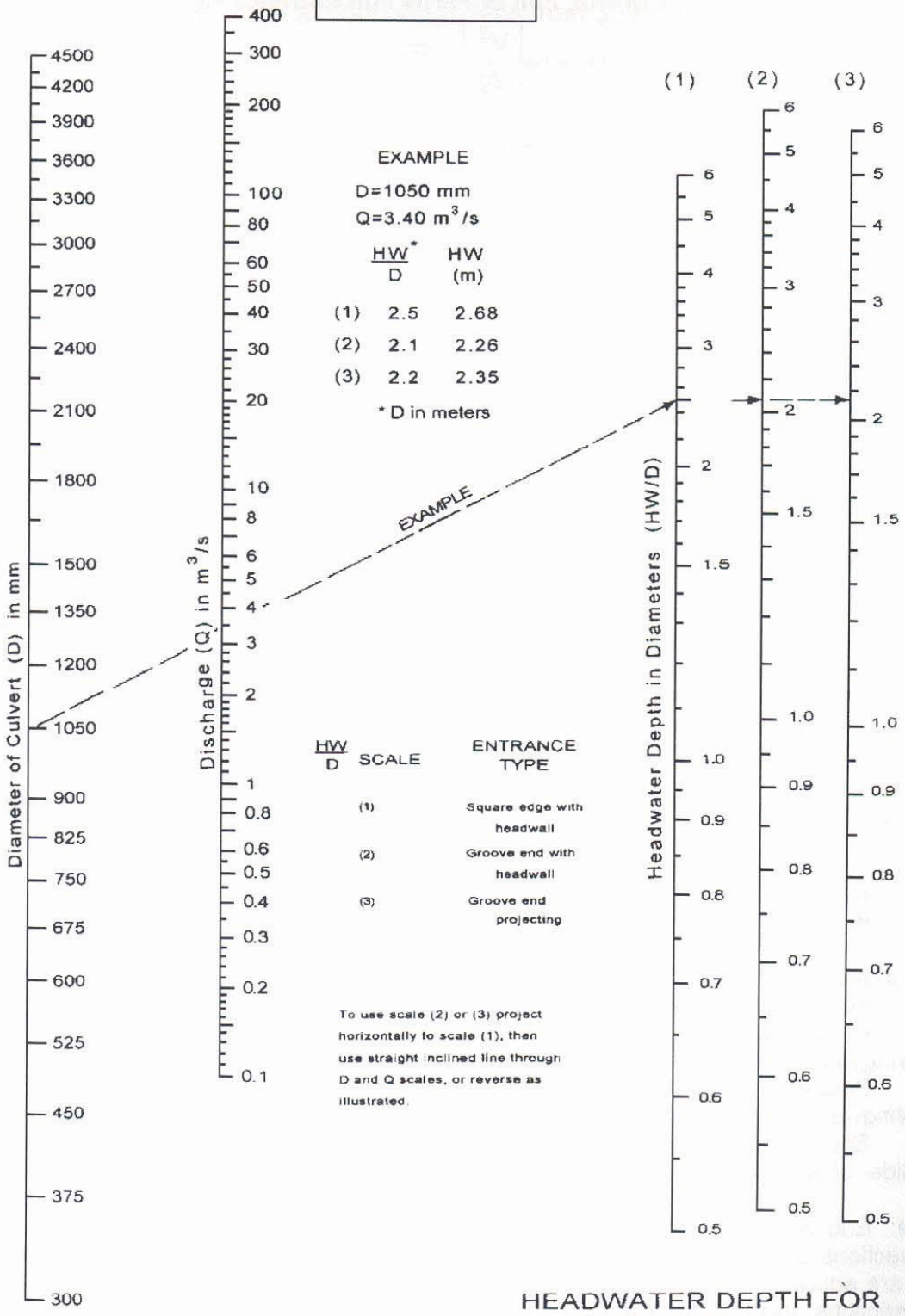
Chart	Rectangular Tapered Inlets
57A, 57B	Throat Control for Box Culverts with Tapered Inlets
58A, 58B	Face Control for Box Culverts with Side-Tapered Inlets
59A, 59B	Face Control for Box Culverts with Slope-Tapered Inlets

Chart	Roadway Overtopping Coefficients
60A, 60B	Discharge Coefficients for Roadway Overtopping

Design Forms

Culvert Design Form **(61)**
Tapered Inlet Design Form **(62)**
Slope-Tapered Inlet with Mitered Face - Design Form **(63)**
Storage Routing Calculation Form **(64)**
Water Surface Profile Computation Form **(65)**

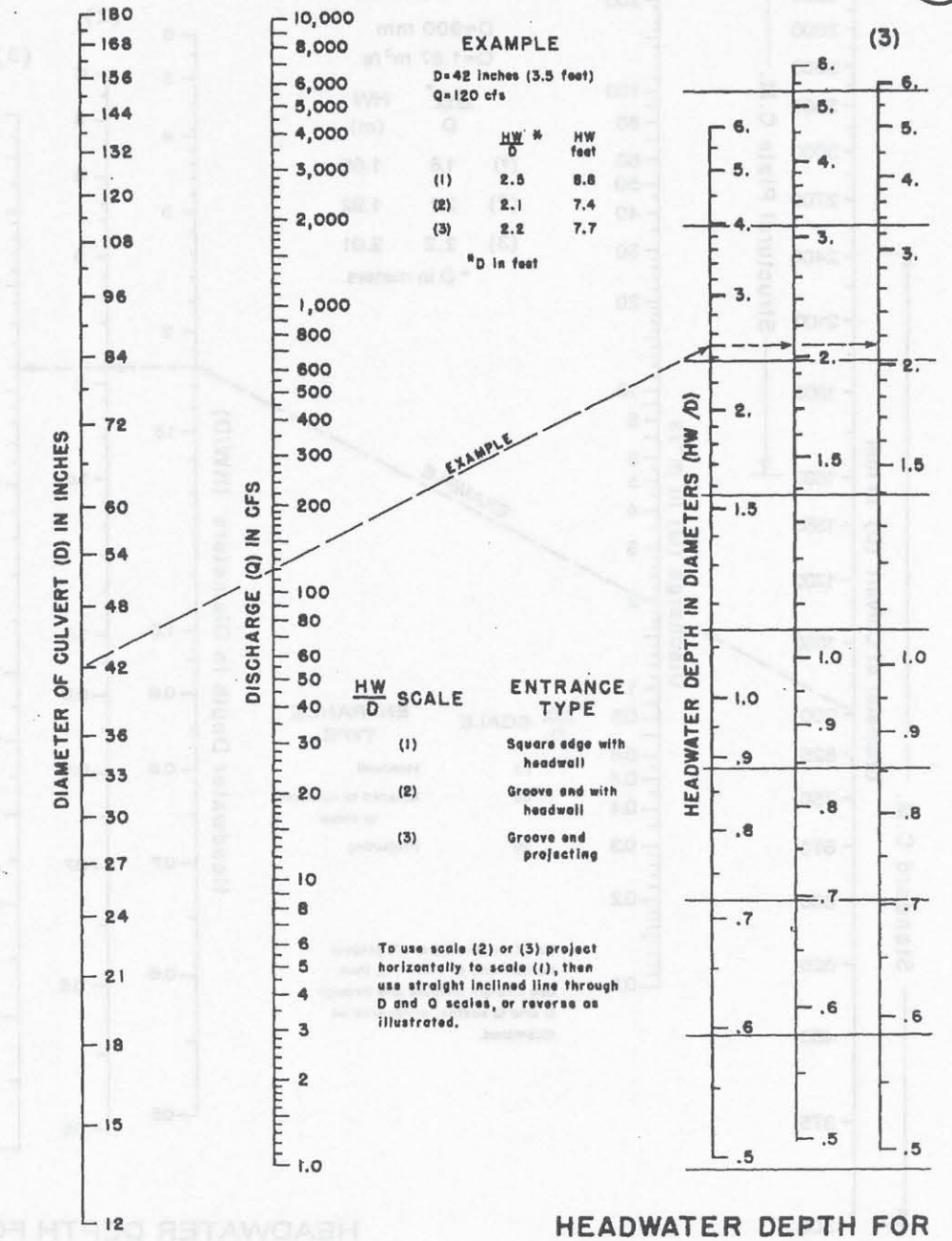
CHART 1A



Adapted from
Bureau of Public Roads Jan 1963

HEADWATER DEPTH FOR CONCRETE PIPE CULVERTS WITH INLET CONTROL

CHART 1B

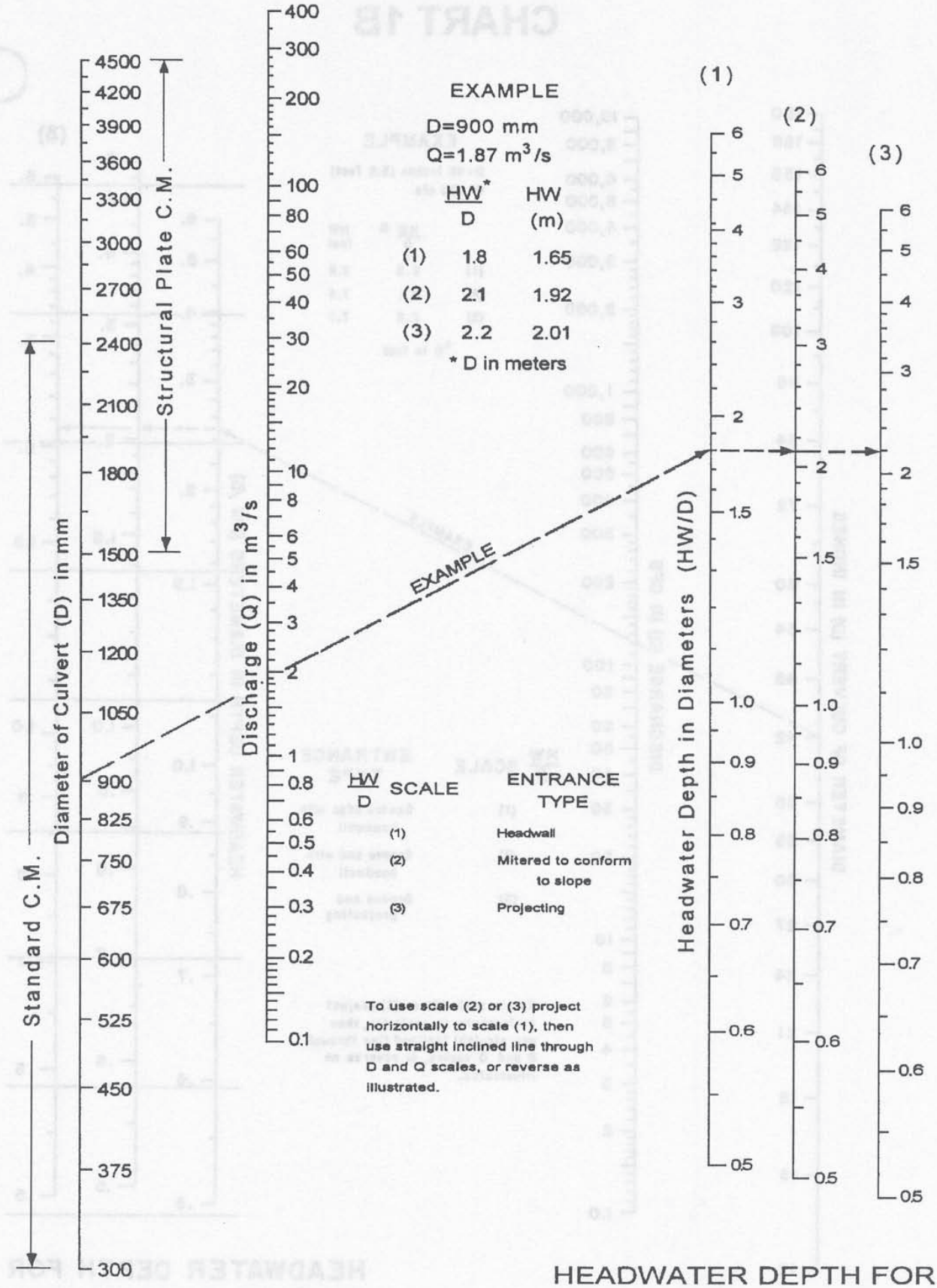


HEADWATER SCALES 2&3
REVISED MAY 1964

BUREAU OF PUBLIC ROADS JAN. 1963

HEADWATER DEPTH FOR CONCRETE PIPE CULVERTS WITH INLET CONTROL

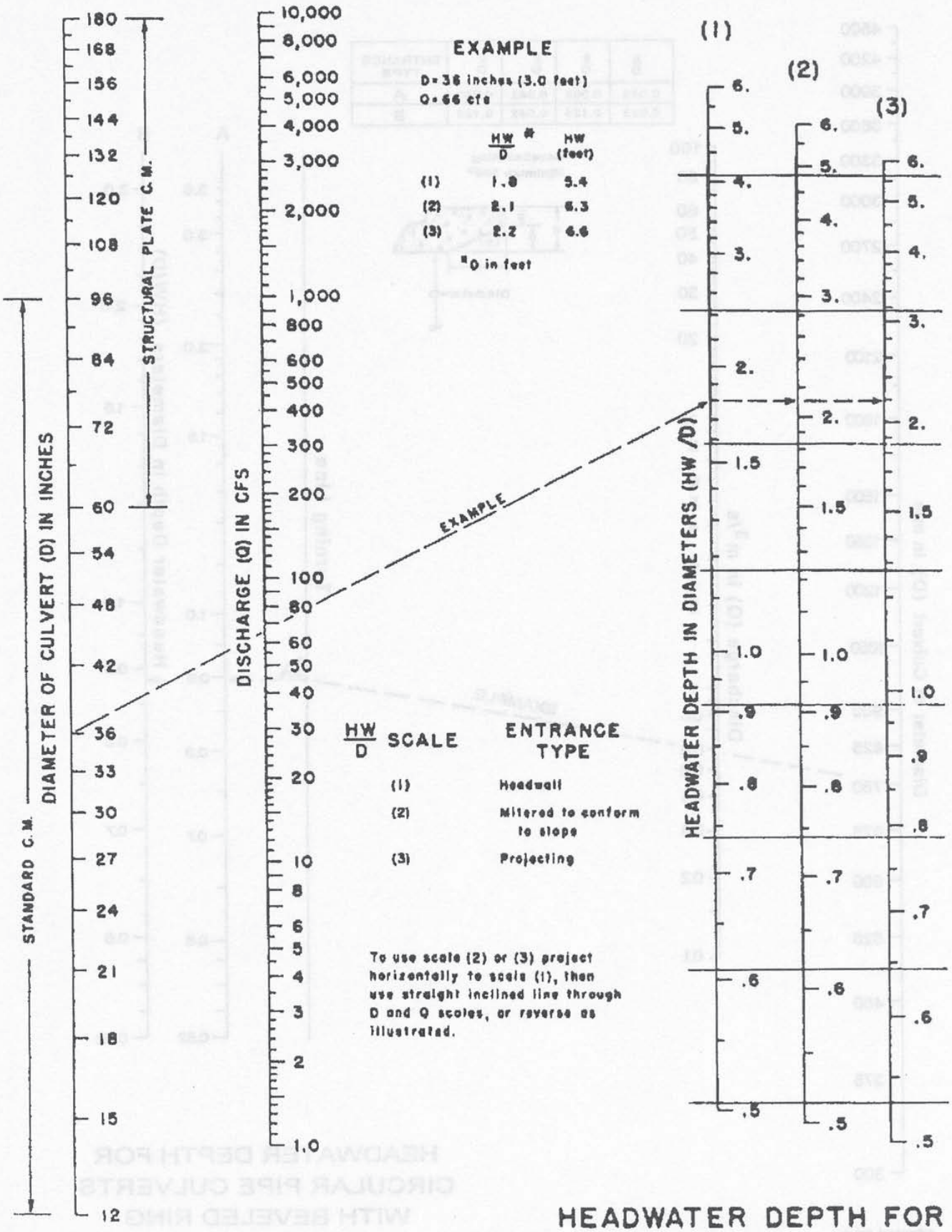
CHART 2A



Adapted from
Bureau of Public Roads Jan. 1963

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

CHART 2B

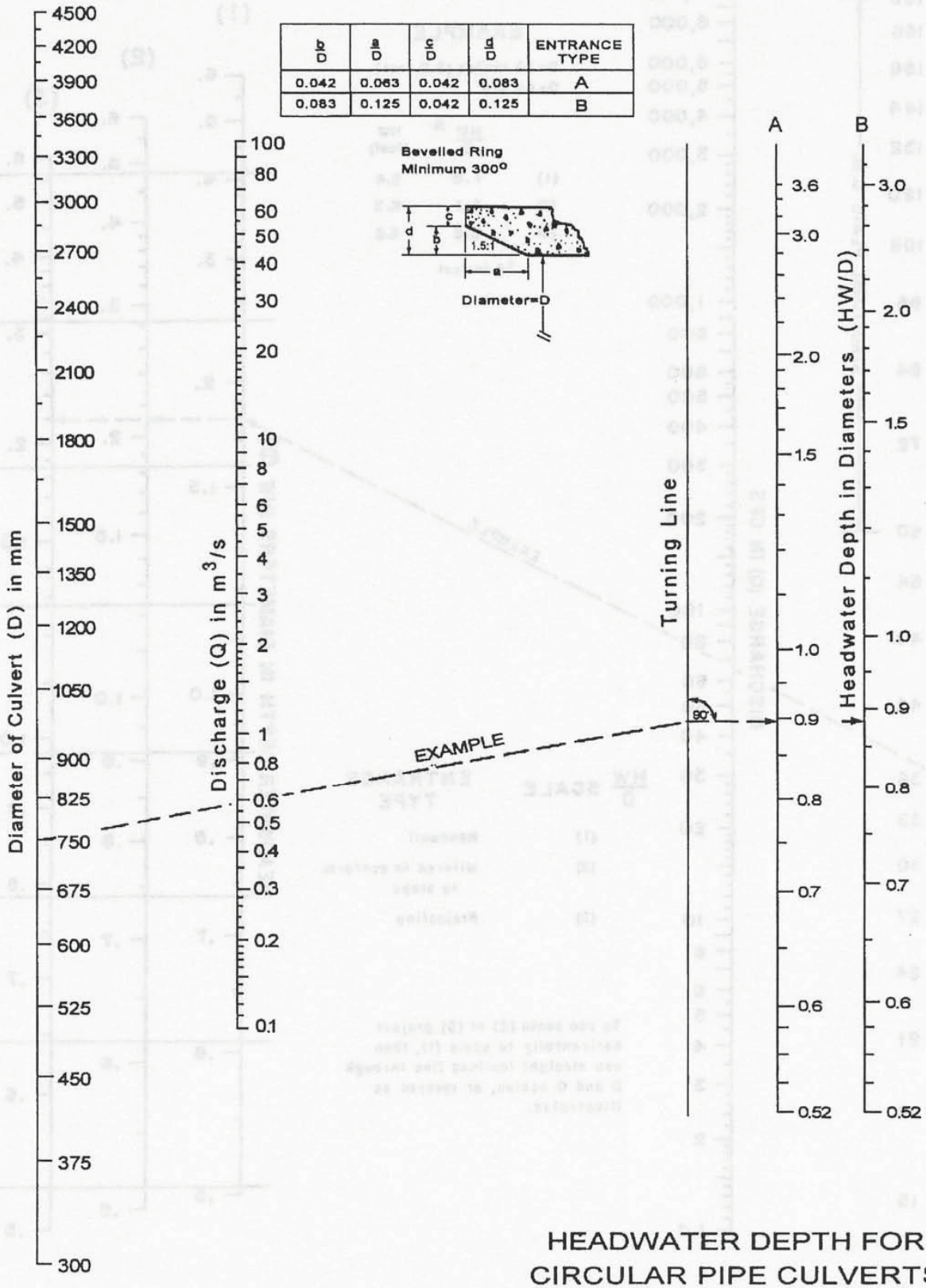


HEADWATER DEPTH FOR C. M. PIPE CULVERTS WITH INLET CONTROL

BUREAU OF PUBLIC ROADS JAN. 1963

CHART 3A

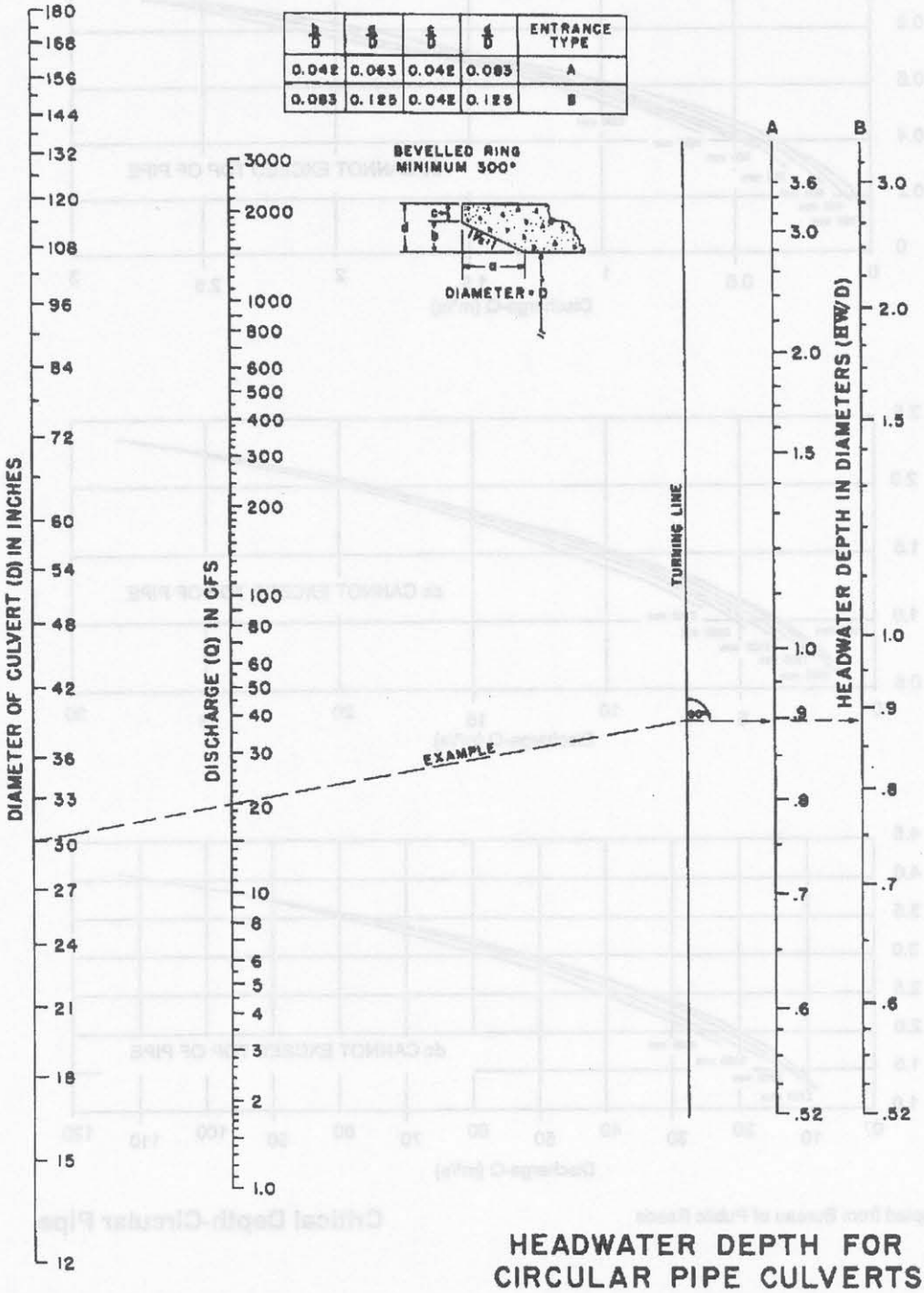
b/D	a/D	c/D	d/D	ENTRANCE TYPE
0.042	0.063	0.042	0.083	A
0.083	0.125	0.042	0.125	B



HEADWATER DEPTH FOR CIRCULAR PIPE CULVERTS WITH BEVELED RING INLET CONTROL

Adapted from
Federal Highway Administration May 1973

CHART 3B

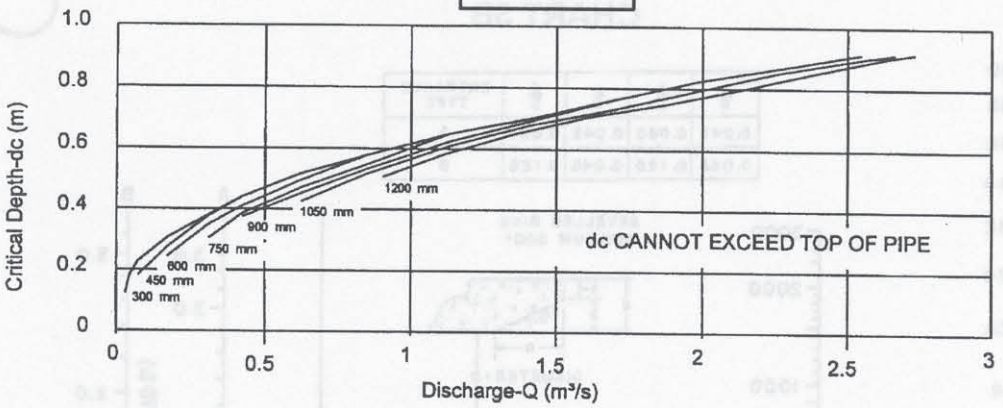


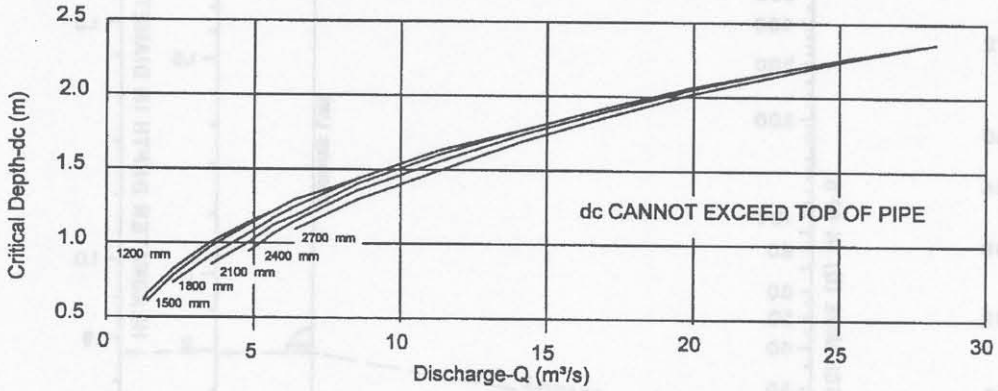
b/D	a/D	c/D	d/D	ENTRANCE TYPE
0.042	0.063	0.042	0.083	A
0.083	0.125	0.042	0.125	B

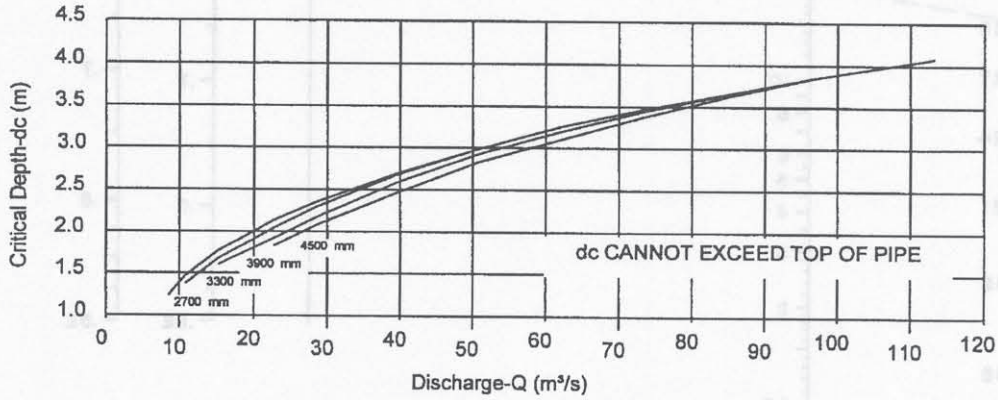
FEDERAL HIGHWAY ADMINISTRATION
MAY 1973

HEADWATER DEPTH FOR CIRCULAR PIPE CULVERTS WITH BEVELED RING INLET CONTROL

CHART 4A



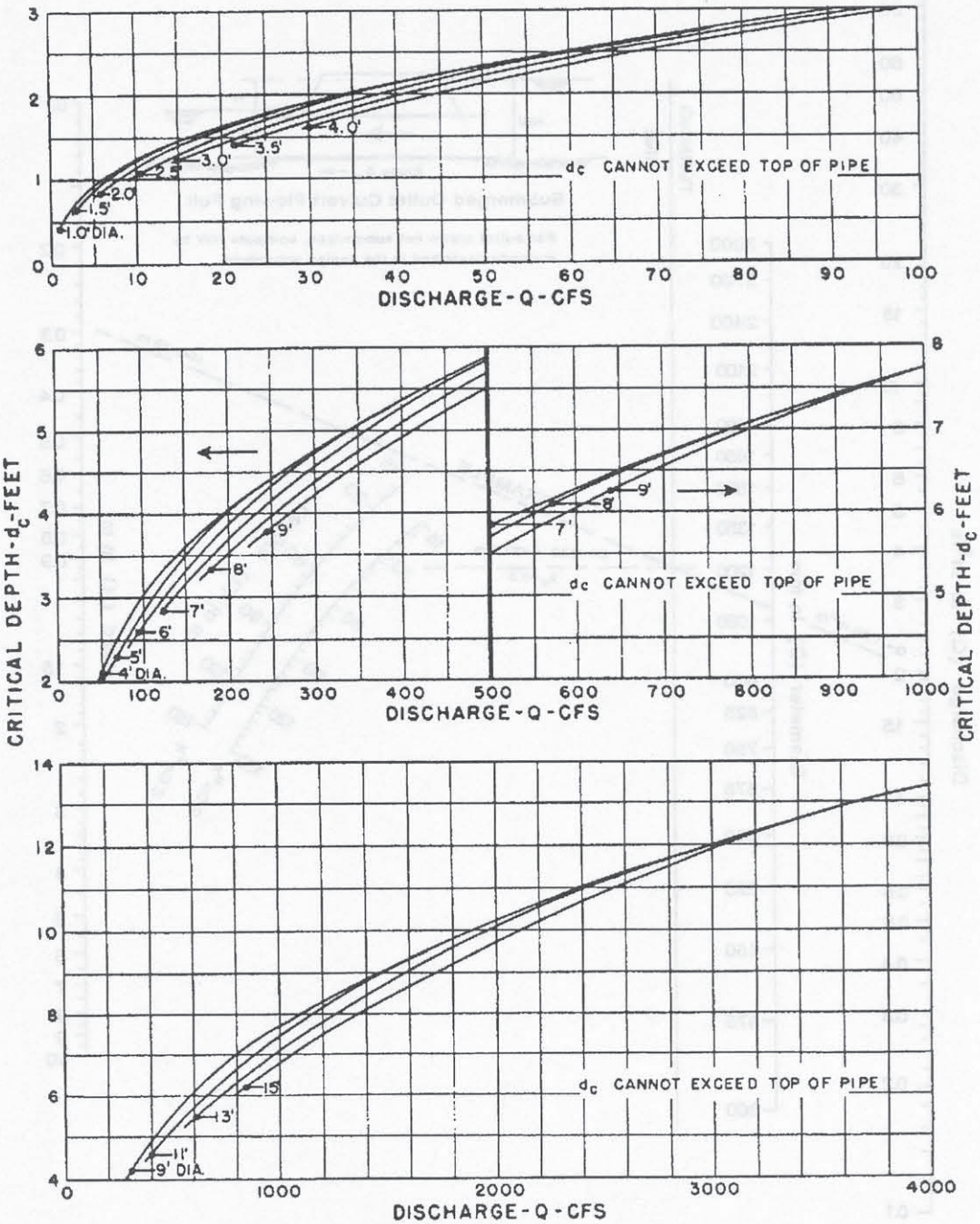




Adapted from Bureau of Public Roads

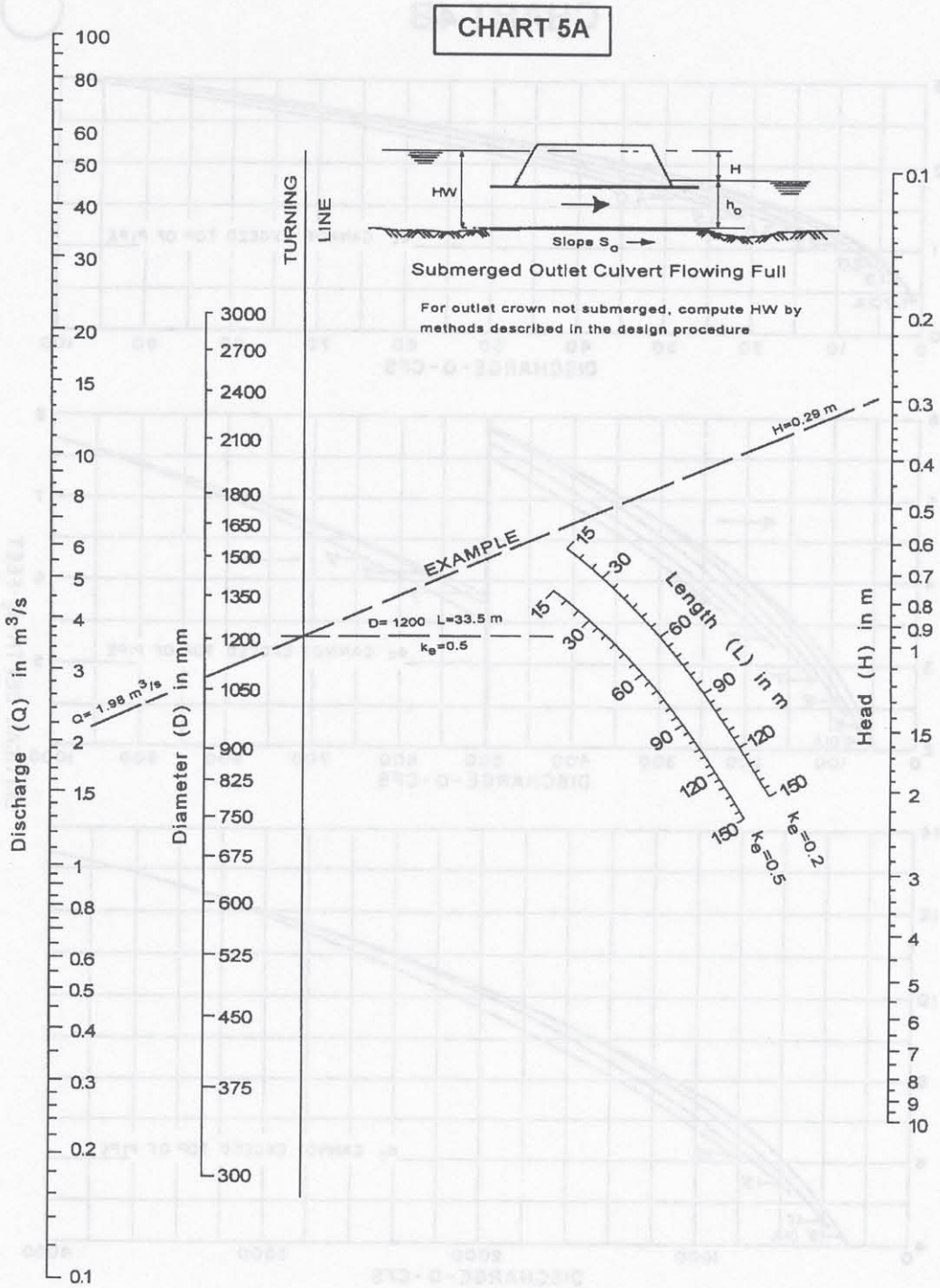
Critical Depth-Circular Pipe

CHART 4B



BUREAU OF PUBLIC ROADS
JAN. 1964

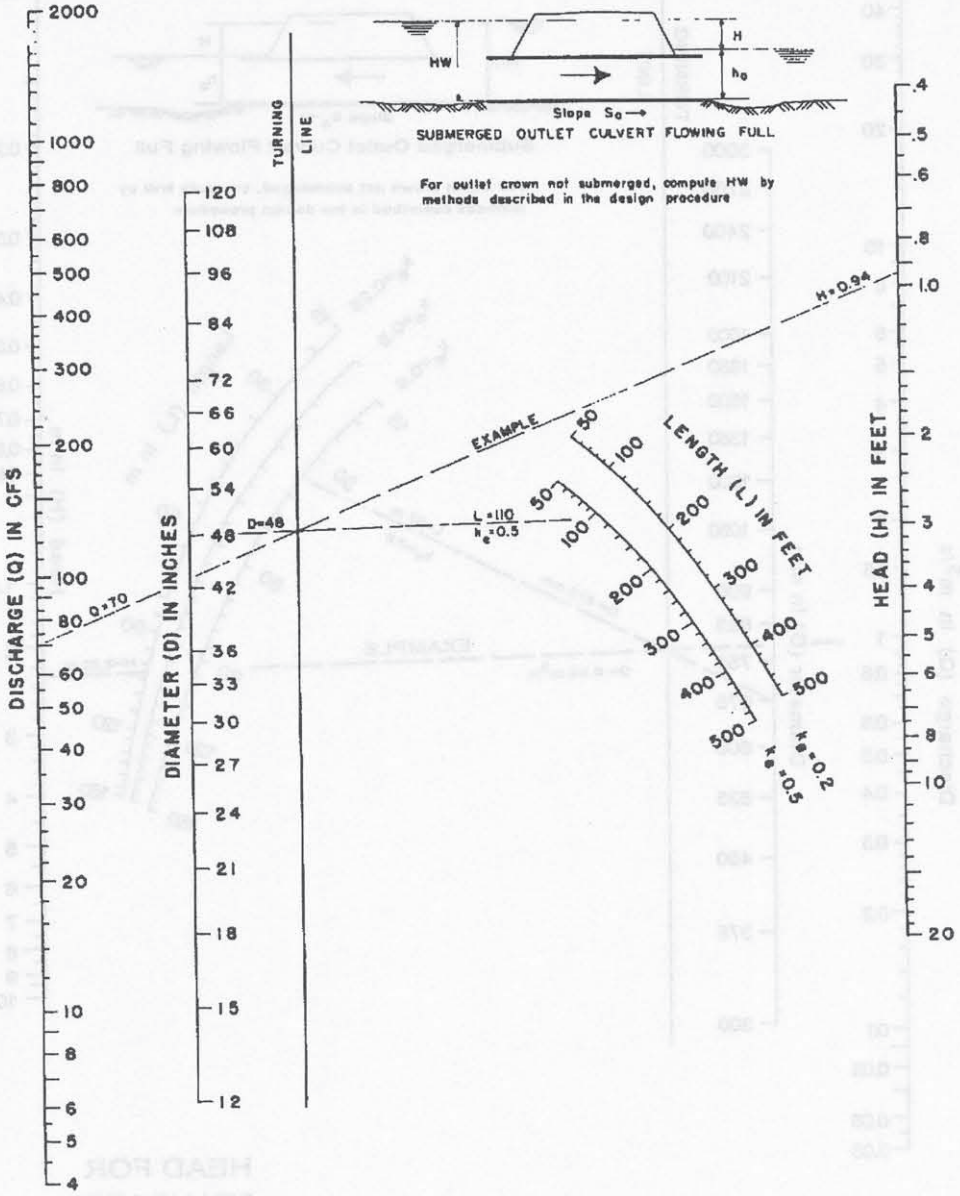
CRITICAL DEPTH
CIRCULAR PIPE



Adapted from
Bureau of Public Roads Jan. 1963

HEAD FOR
CONCRETE PIPE CULVERTS
FLOWING FULL
n=0.012

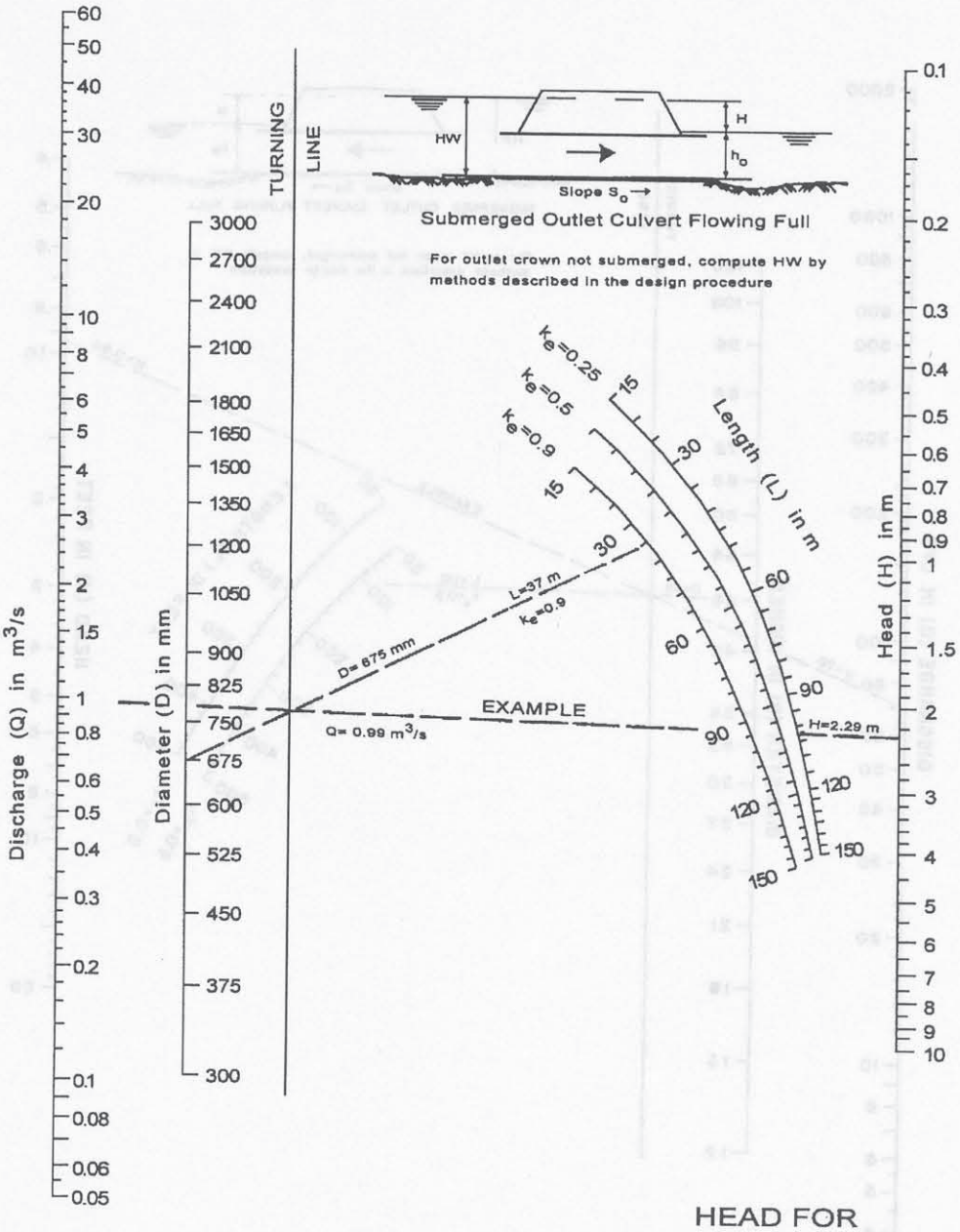
CHART 5B



HEAD FOR
CONCRETE PIPE CULVERTS
FLOWING FULL
n=0.012

BUREAU OF PUBLIC ROADS JAN. 1963

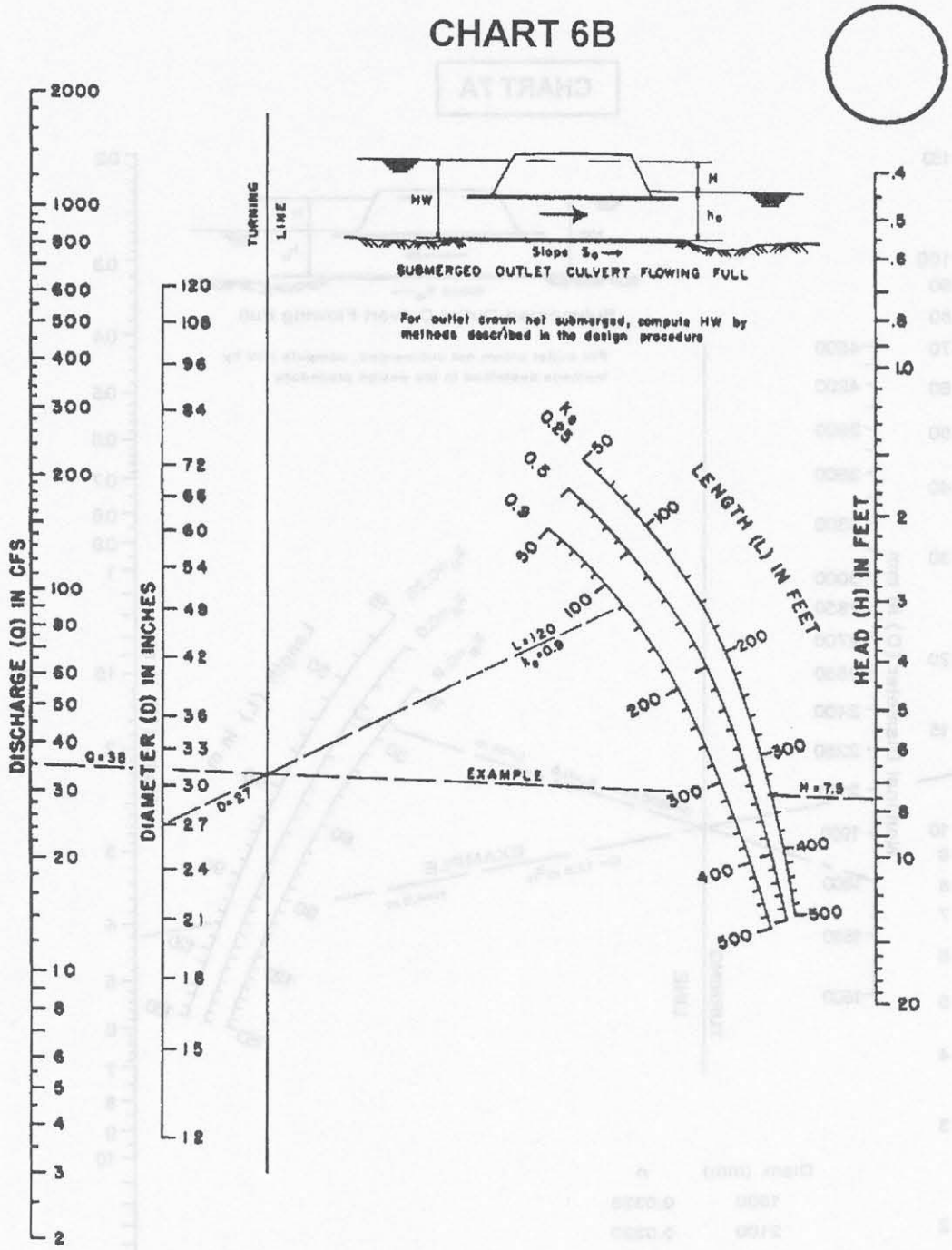
CHART 6A



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

Adapted from
Bureau of Public Roads Jan. 1963

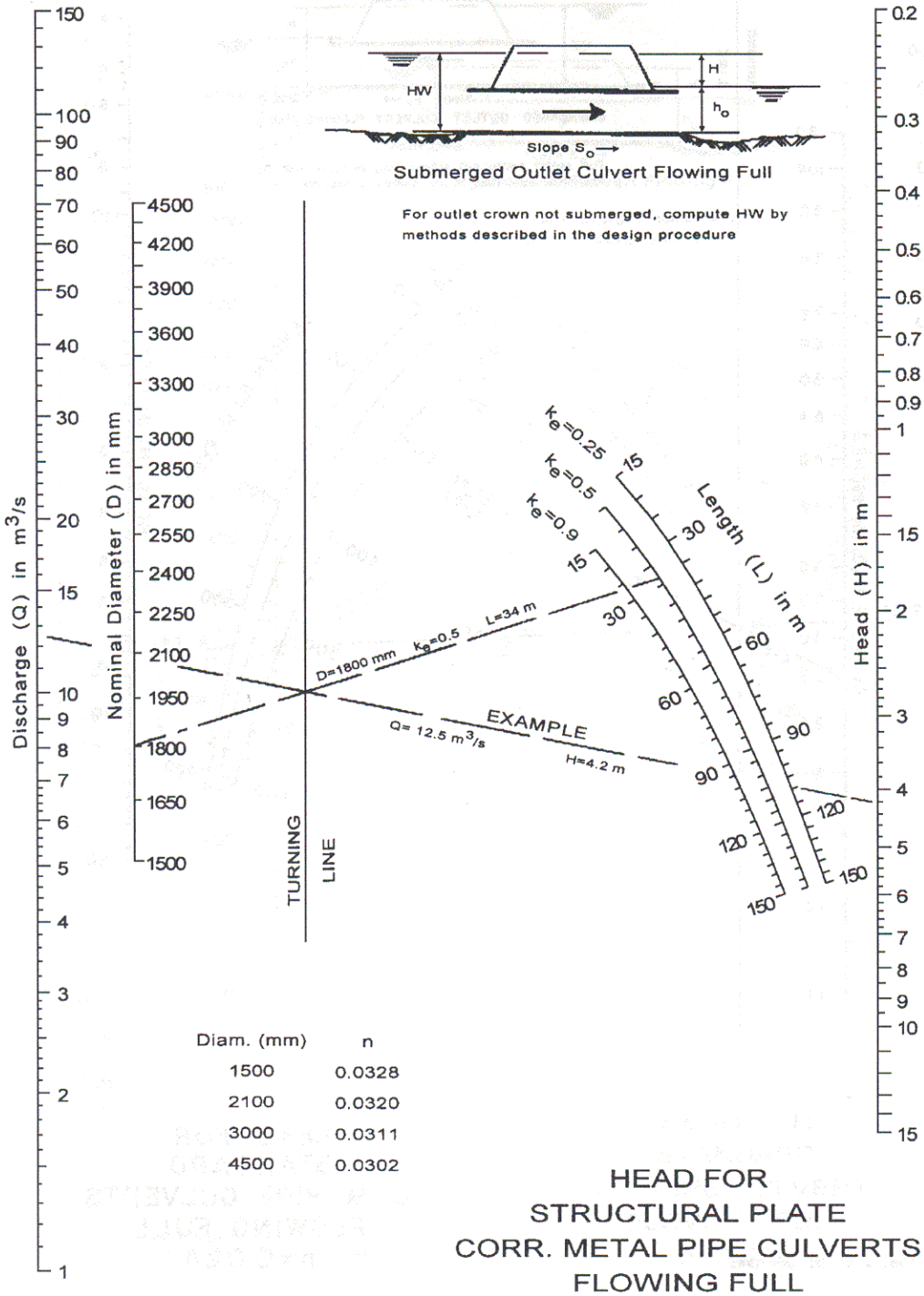
CHART 6B



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

BUREAU OF PUBLIC ROADS JAN. 1963

CHART 7A

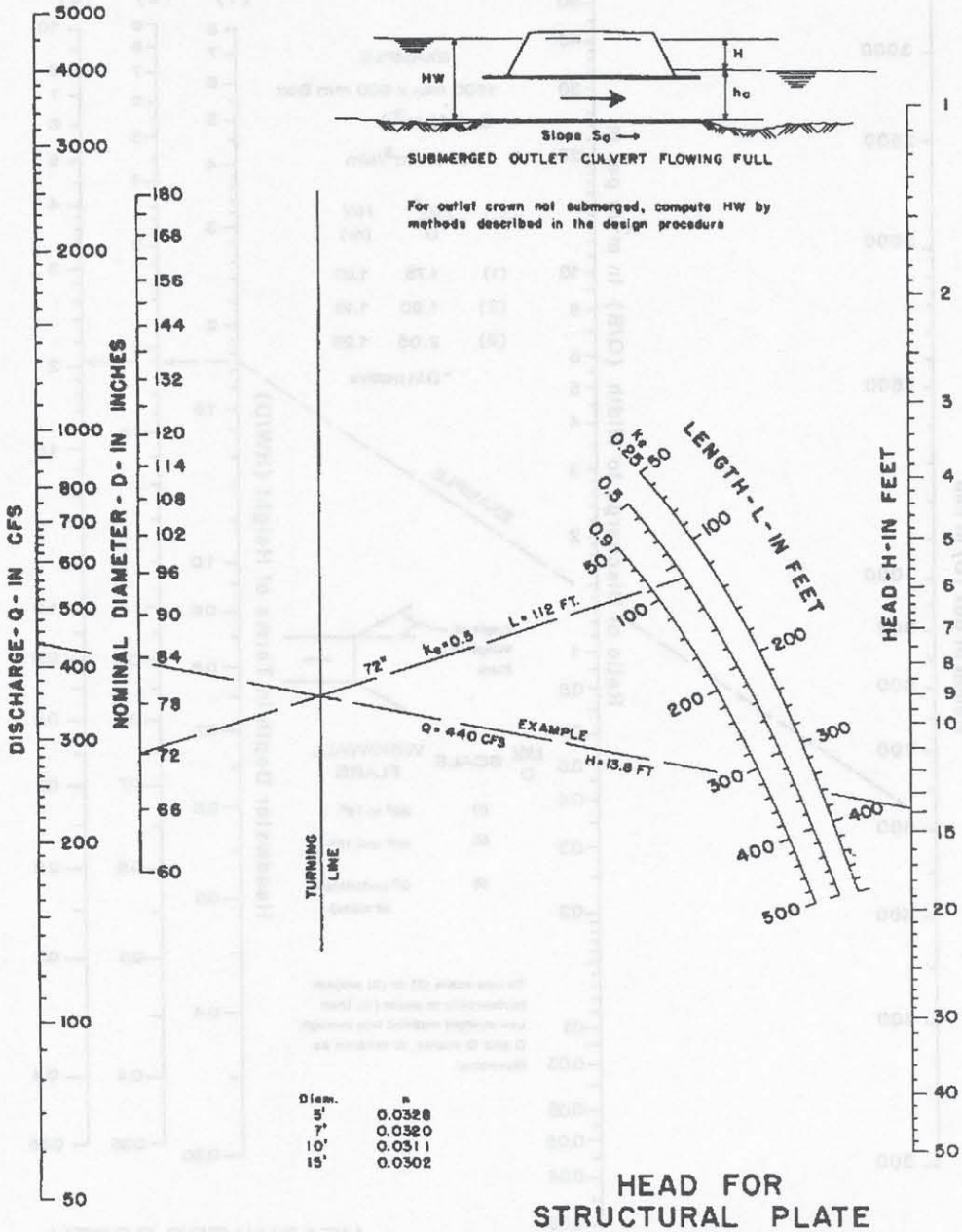


Diam. (mm)	n
1500	0.0328
2100	0.0320
3000	0.0311
4500	0.0302

HEAD FOR
STRUCTURAL PLATE
CORR. METAL PIPE CULVERTS
FLOWING FULL
n=0.0328 TO 0.0302

Adapted from
Bureau of Public Roads Jan. 1963

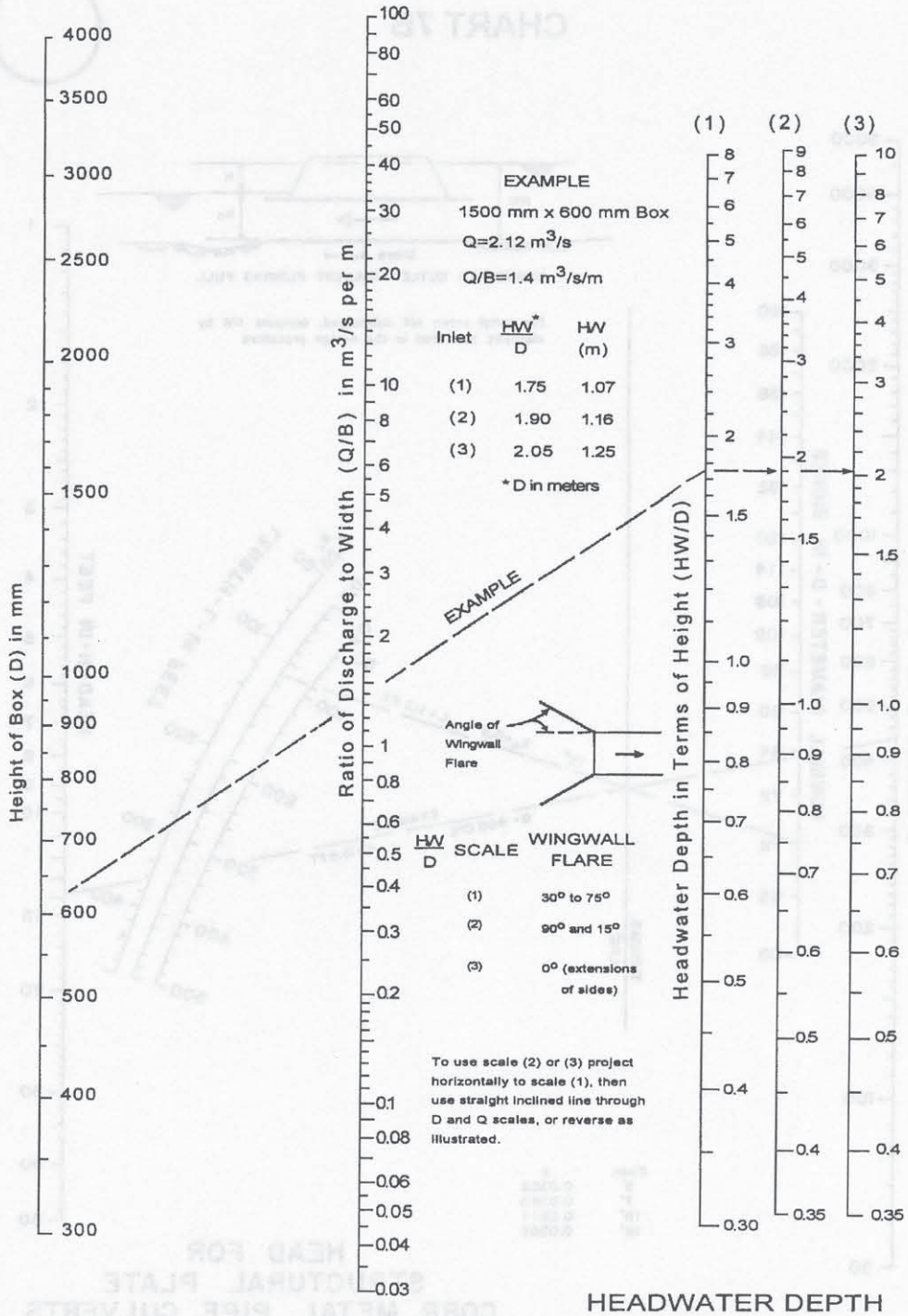
CHART 7B



HEAD FOR
STRUCTURAL PLATE
CORR. METAL PIPE CULVERTS
FLOWING FULL
n = 0.0328 TO 0.0302

BUREAU OF PUBLIC ROADS JAN. 1963

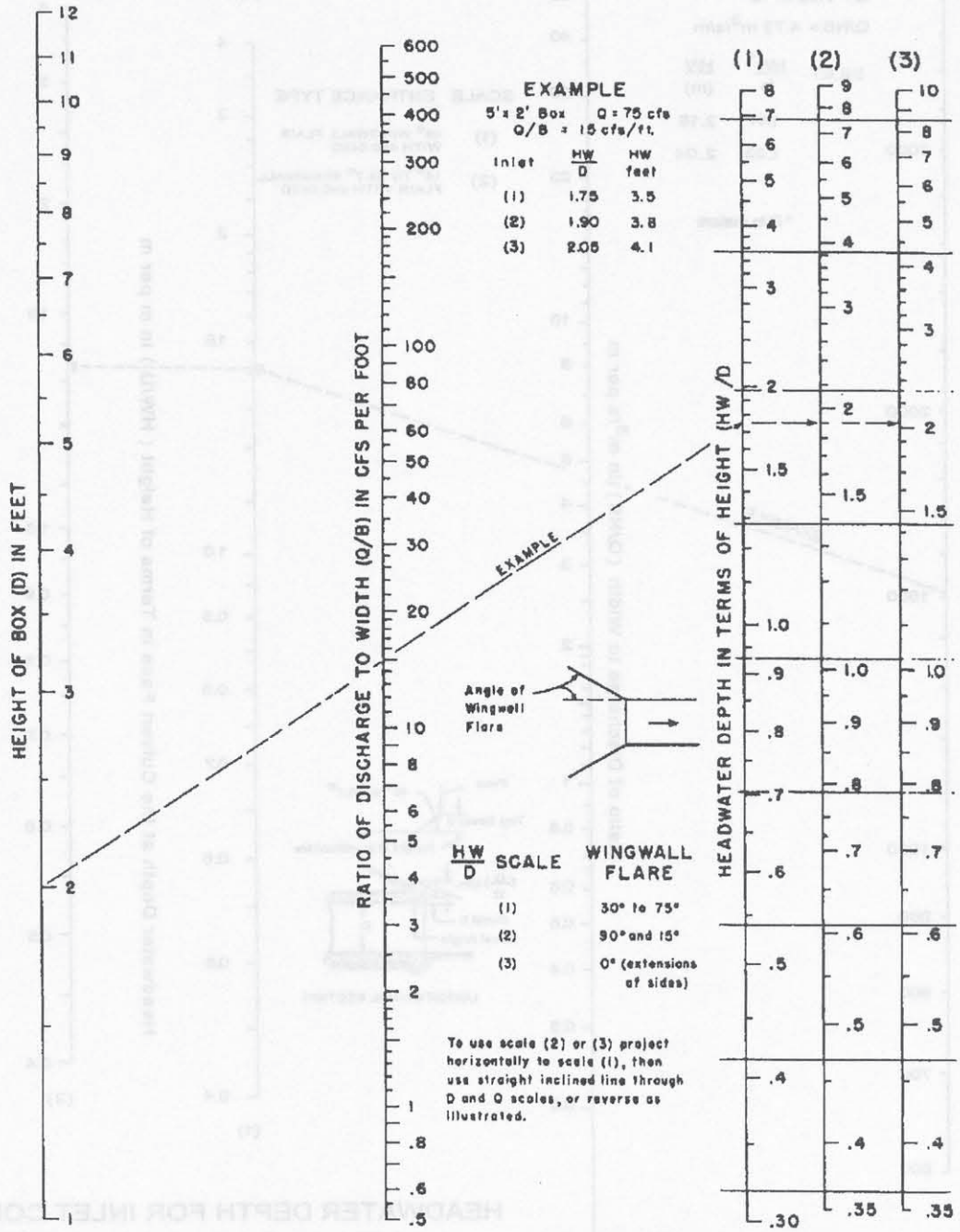
CHART 8A



Adapted from
Bureau of Public Roads Jan. 1963

HEADWATER DEPTH
FOR BOX CULVERTS
WITH INLET CONTROL

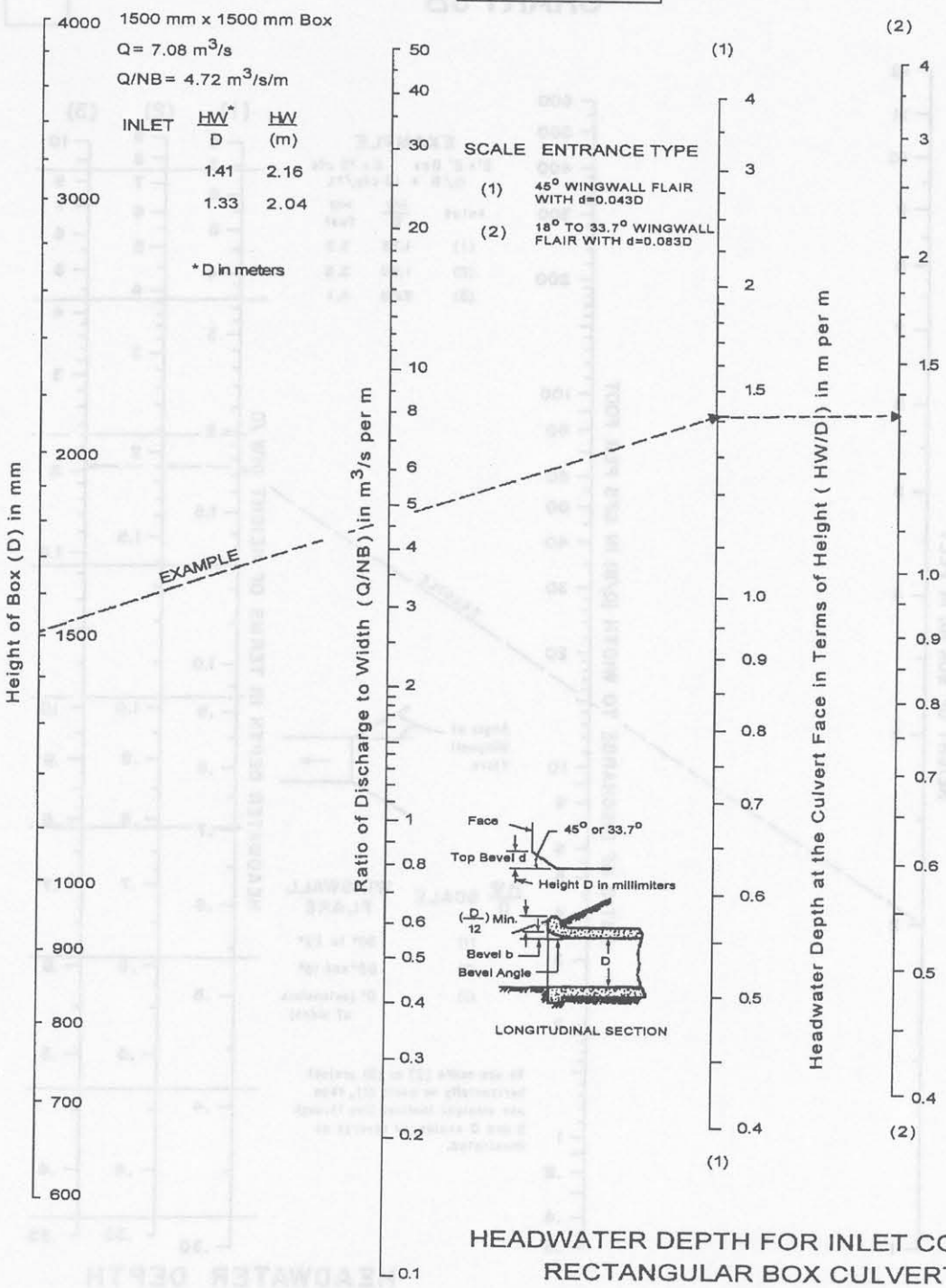
CHART 8B



HEADWATER DEPTH FOR BOX CULVERTS WITH INLET CONTROL

BUREAU OF PUBLIC ROADS JAN. 1963

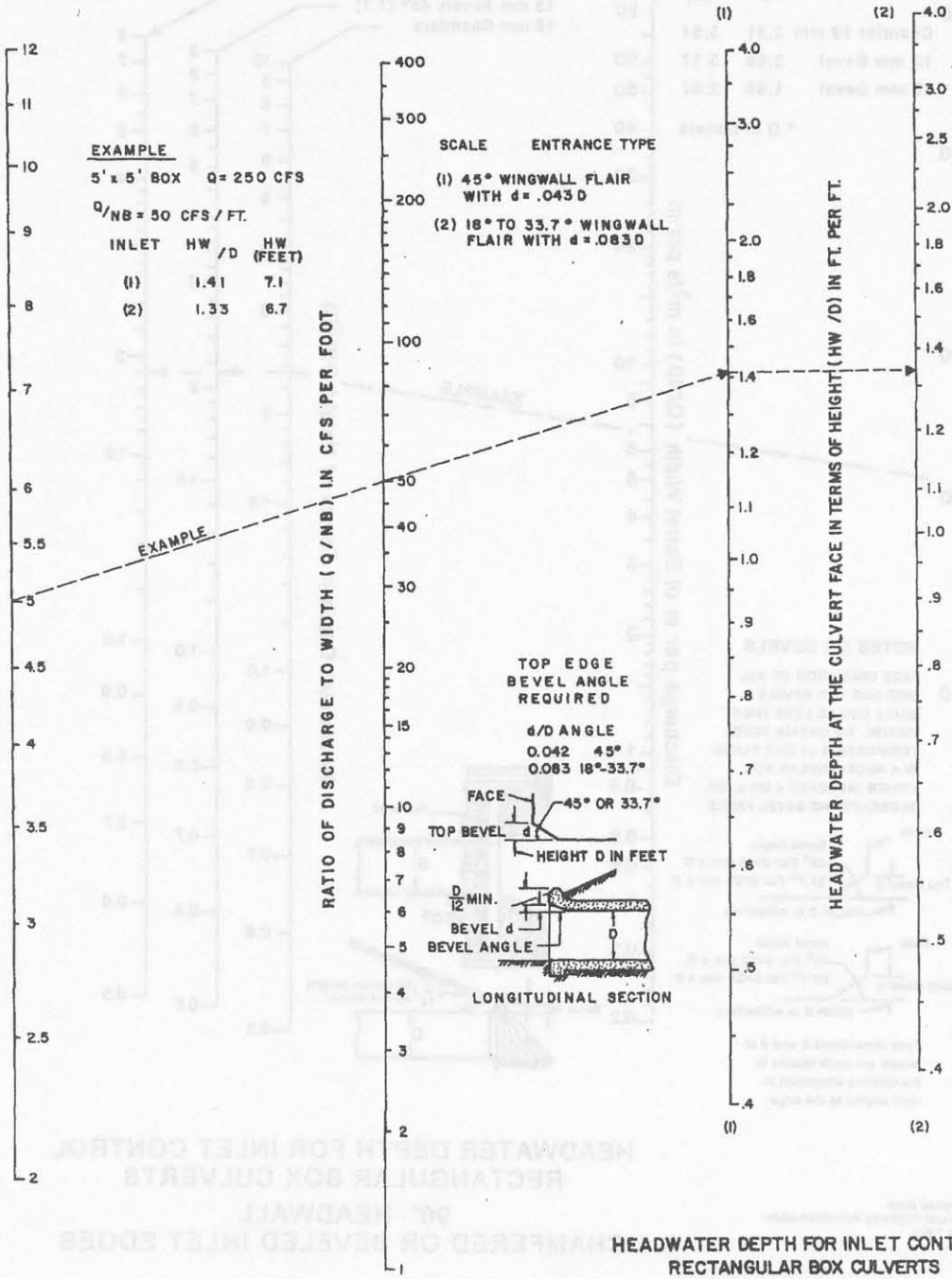
CHART 9A



HEADWATER DEPTH FOR INLET CONTROL
RECTANGULAR BOX CULVERTS

FLARED WINGWALLS 18° TO 33.7° AND 45°
WITH BEVELED EDGE AT TOP OF INLET

CHART 9B



HEADWATER DEPTH FOR INLET CONTROL
RECTANGULAR BOX CULVERTS
FLARED WINGWALLS 18° TO 33.7° & 45°
WITH BEVELED EDGE AT TOP OF INLET

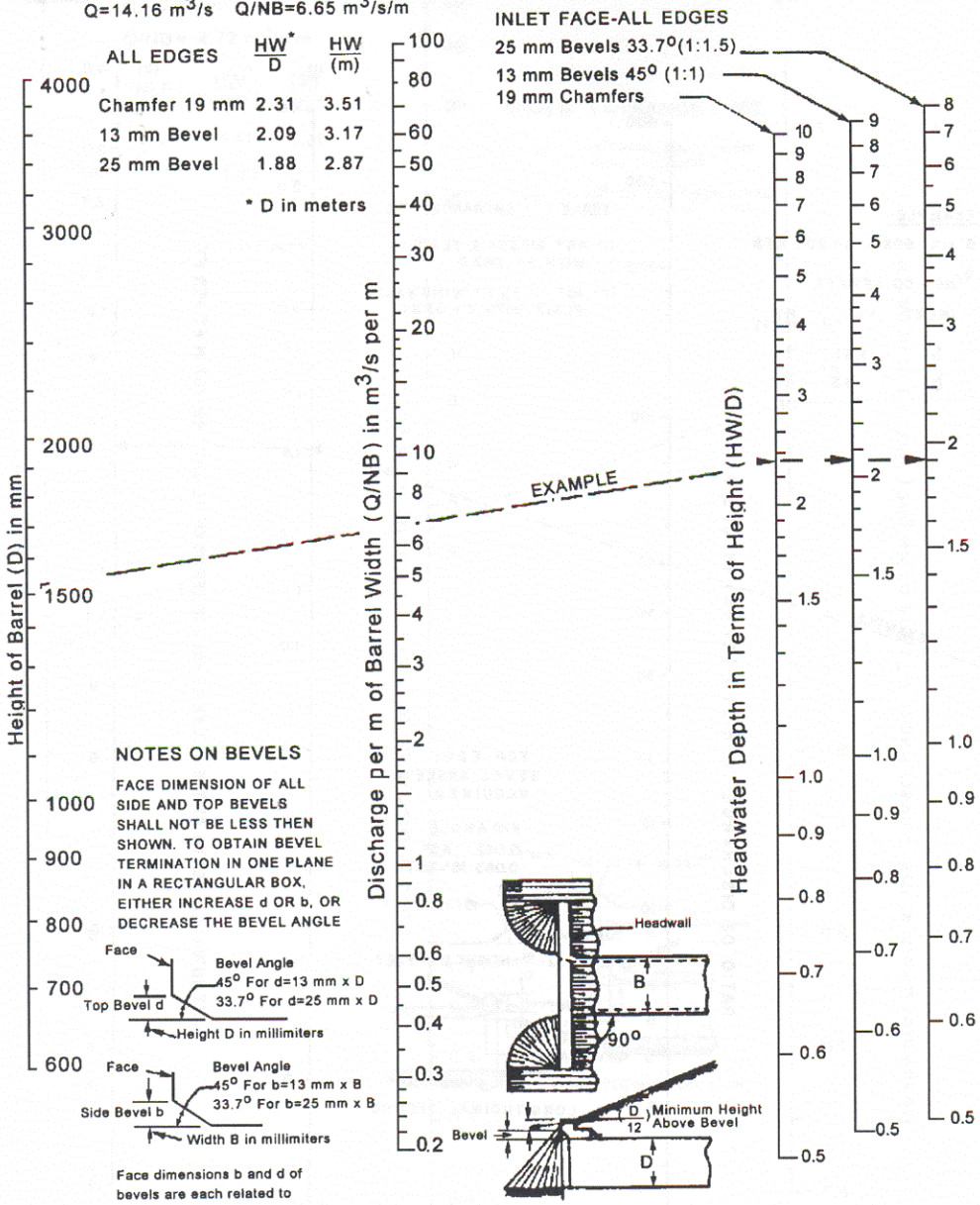
CHART 10A

EXAMPLE

B=2.13 m D=1.52 m
Q=14.16 m^3/s Q/NB=6.65 $m^3/s/m$

ALL EDGES	HW* / D	HW (m)
Chamfer 19 mm	2.31	3.51
13 mm Bevel	2.09	3.17
25 mm Bevel	1.88	2.87

* D in meters



NOTES ON BEVELS

FACE DIMENSION OF ALL SIDE AND TOP BEVELS SHALL NOT BE LESS THEN SHOWN. TO OBTAIN BEVEL TERMINATION IN ONE PLANE IN A RECTANGULAR BOX, EITHER INCREASE d OR b, OR DECREASE THE BEVEL ANGLE

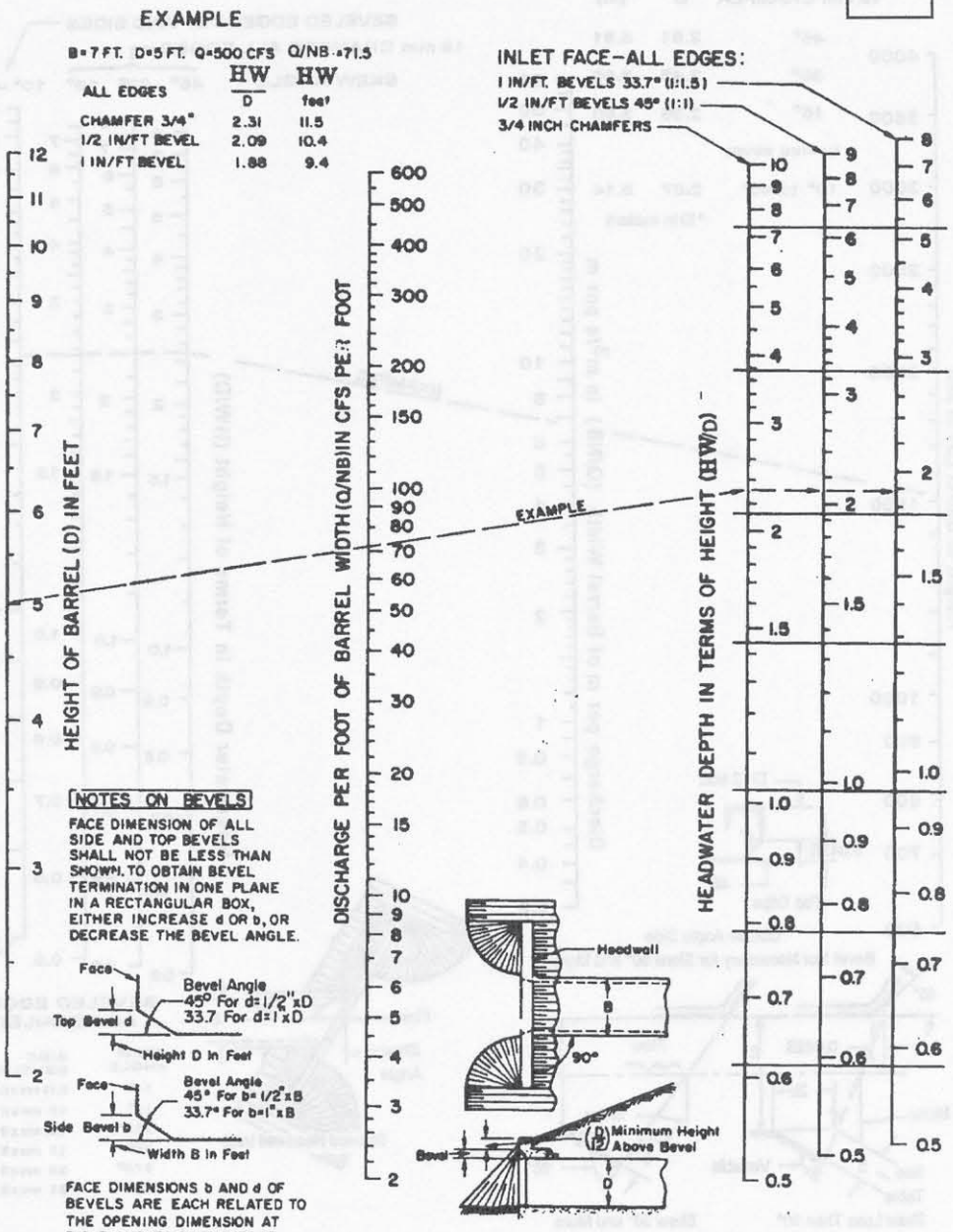
Face dimensions b and d of bevels are each related to the opening dimension at right angles to the edge

HEADWATER DEPTH FOR INLET CONTROL RECTANGULAR BOX CULVERTS

90° HEADWALL CHAMFERED OR BEVELED INLET EDGES

Adapted from
Federal Highway Administration
May 1973

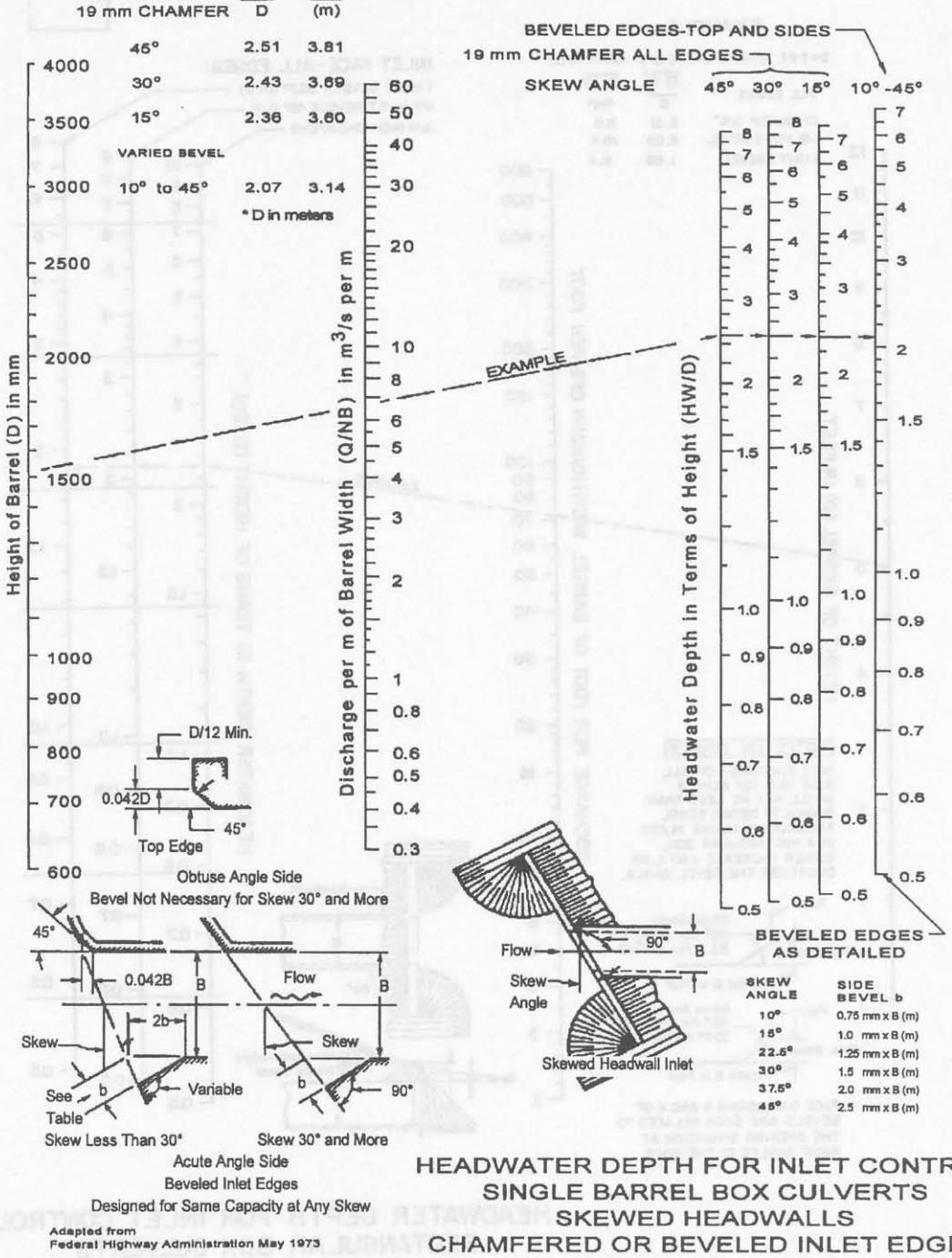
CHART 10B



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

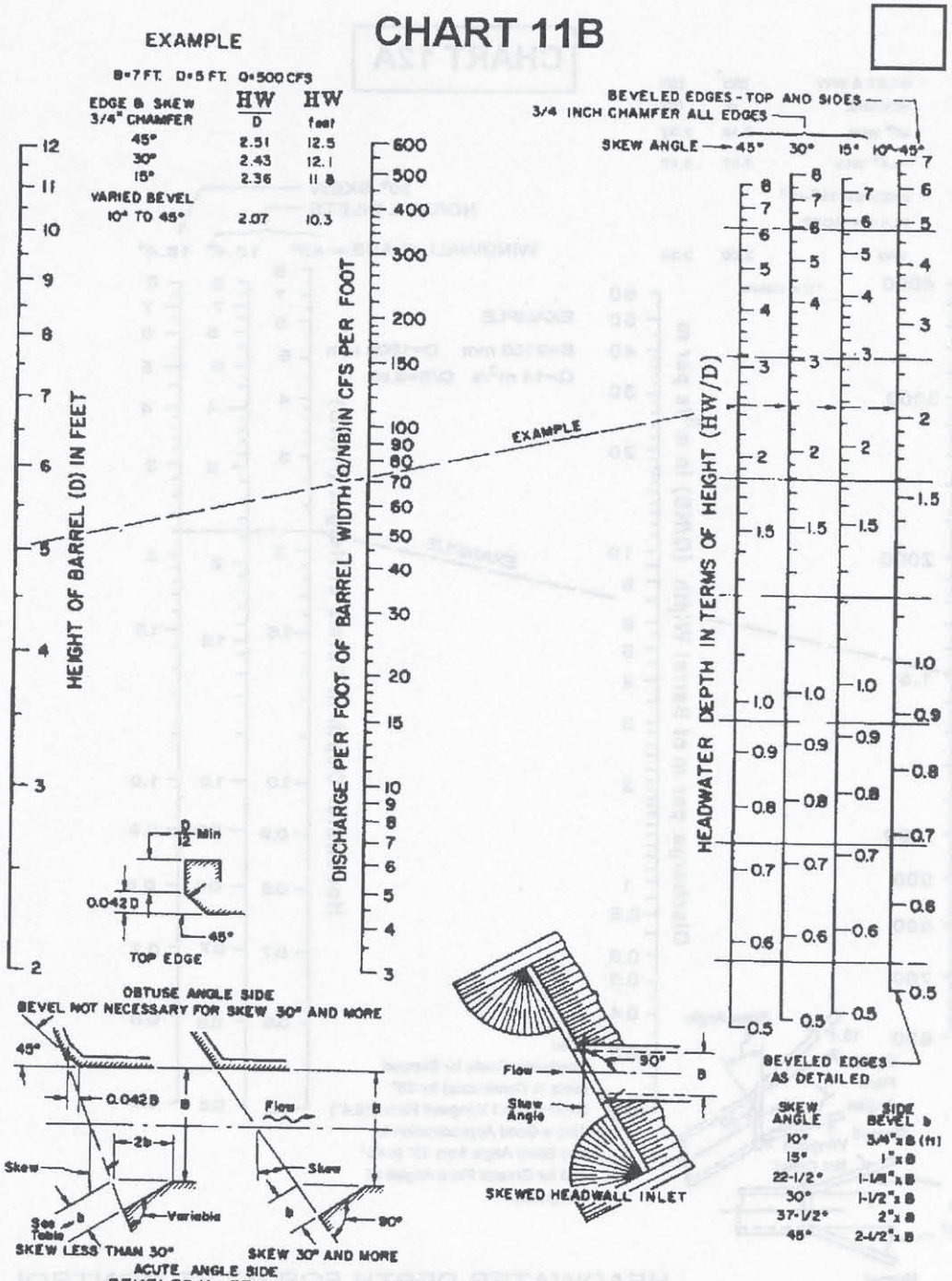
FEDERAL HIGHWAY ADMINISTRATION
MAY 1973

CHART 11A



HEADWATER DEPTH FOR INLET CONTROL
SINGLE BARREL BOX CULVERTS
SKEWED HEADWALLS
CHAMFERED OR BEVELED INLET EDGES

CHART 11B



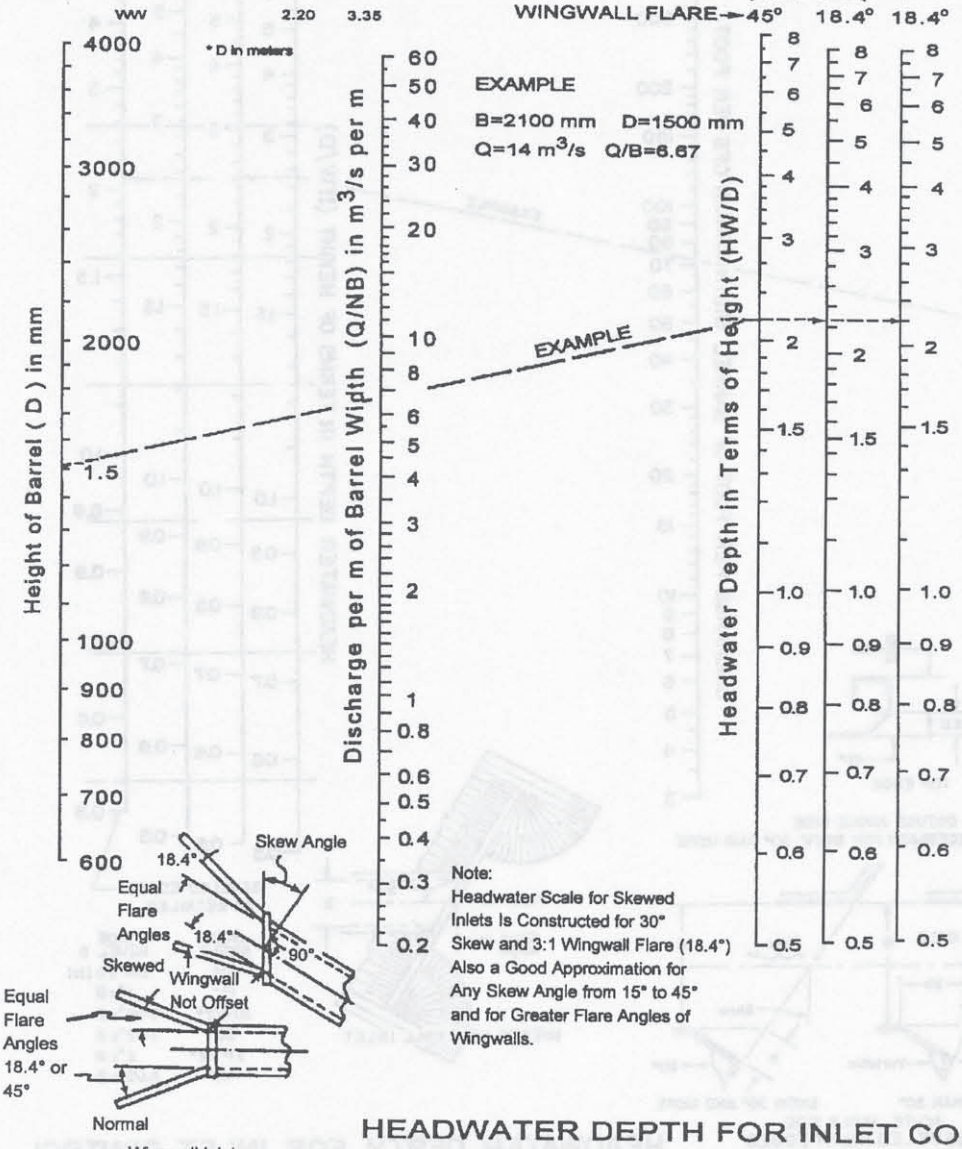
FEDERAL HIGHWAY ADMINISTRATION
MAY 1973

HEADWATER DEPTH FOR INLET CONTROL
SINGLE BARREL BOX CULVERTS
SKEWED HEADWALLS
CHAMFERED OR BEVELED INLET EDGES

CHART 12A

INLET & WW	HW* / D	HW (m)
NORMAL		
45° WW	2.18	3.32
18.4° WW	2.27	3.47
SKEWED 15°-45°		
18.4 OR MORE		
WW	2.20	3.35

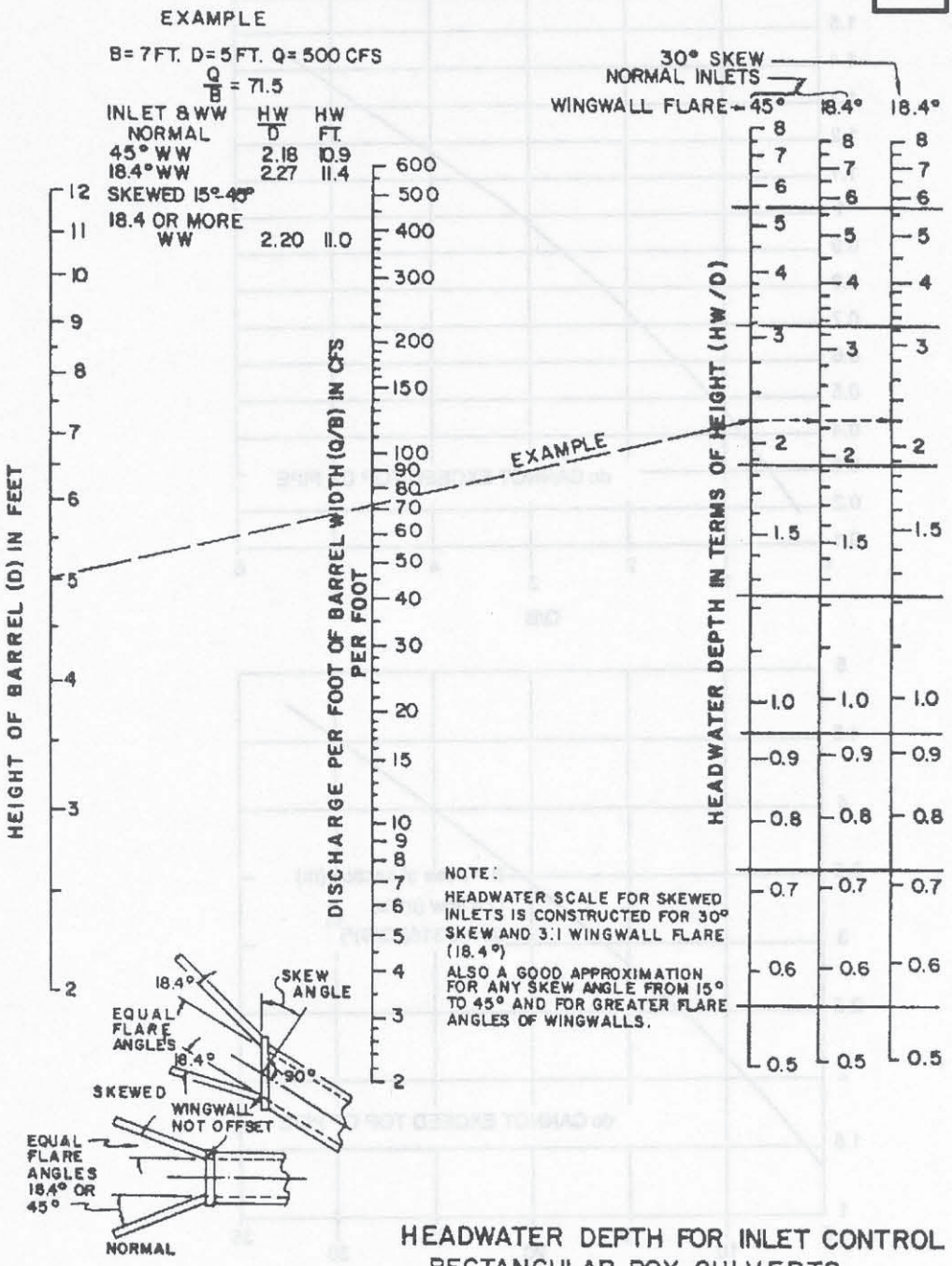
*D in meters



Adapted from
Bureau of Public Roads Office of R & D
August 1968

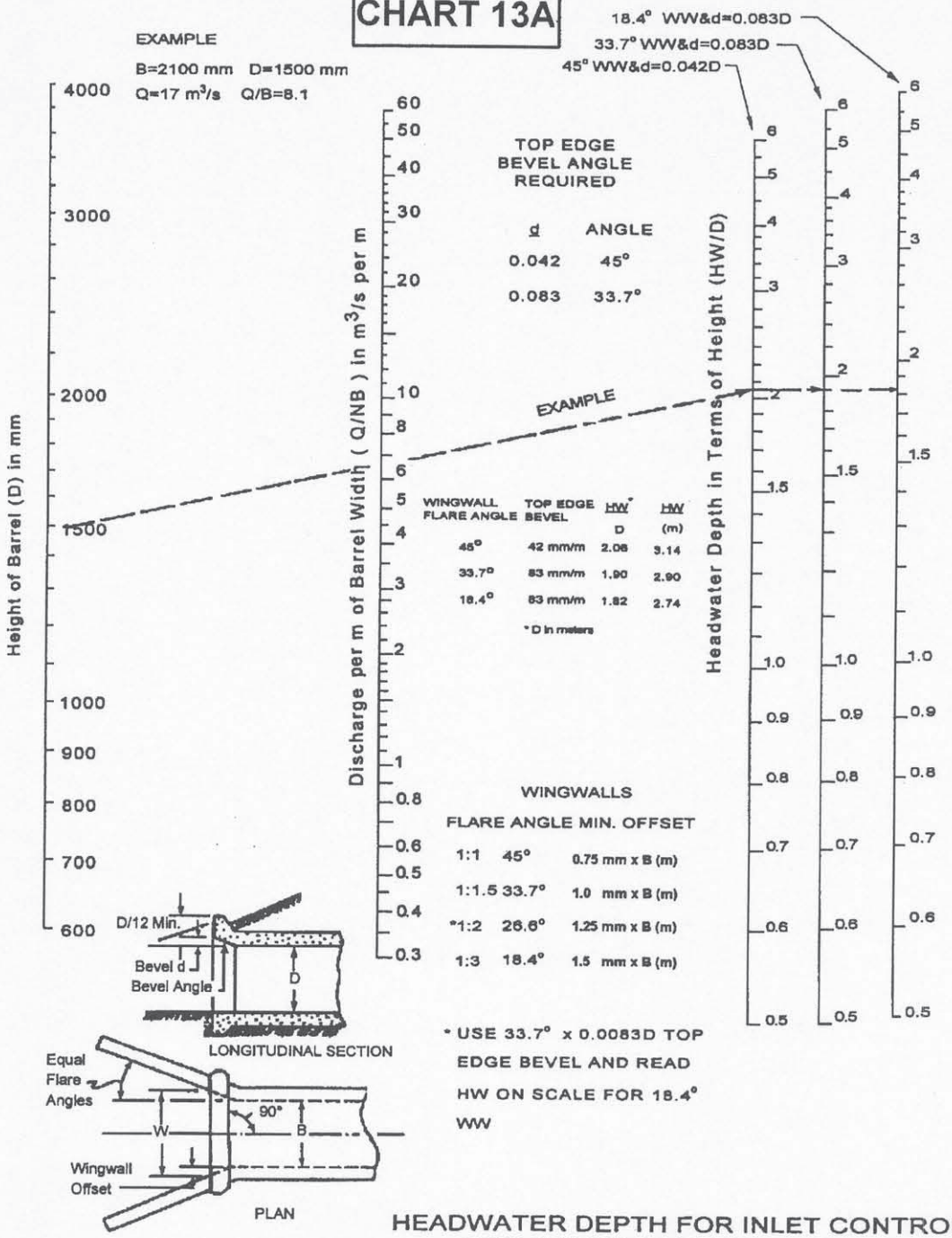
HEADWATER DEPTH FOR INLET CONTROL
RECTANGULAR BOX CULVERTS
FLARED WINGWALLS
NORMAL AND SKEWED INLETS
19 mm CHAMFERED AT TOP OF OPENING

CHART 12B



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

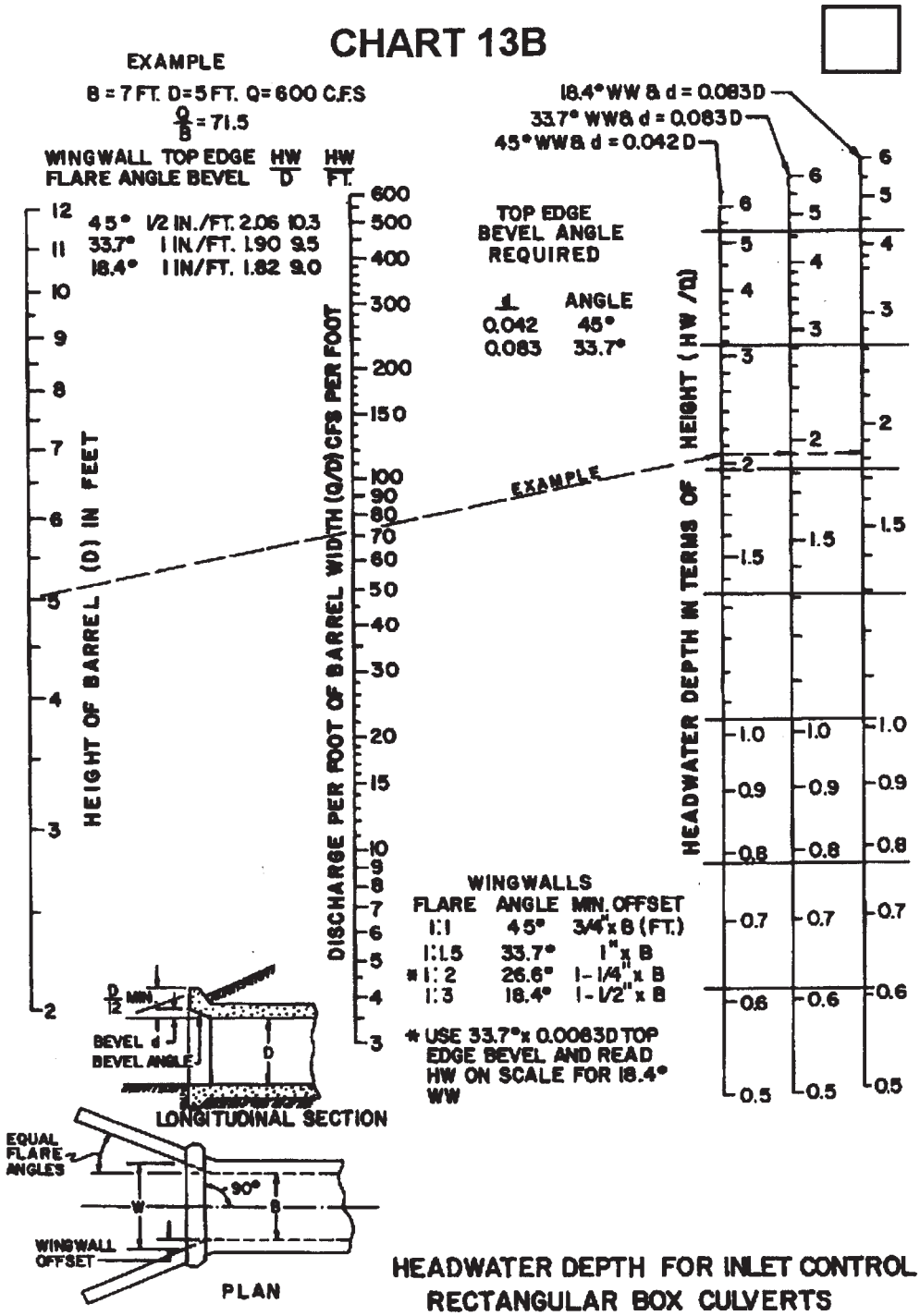
CHART 13A



Adapted from
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

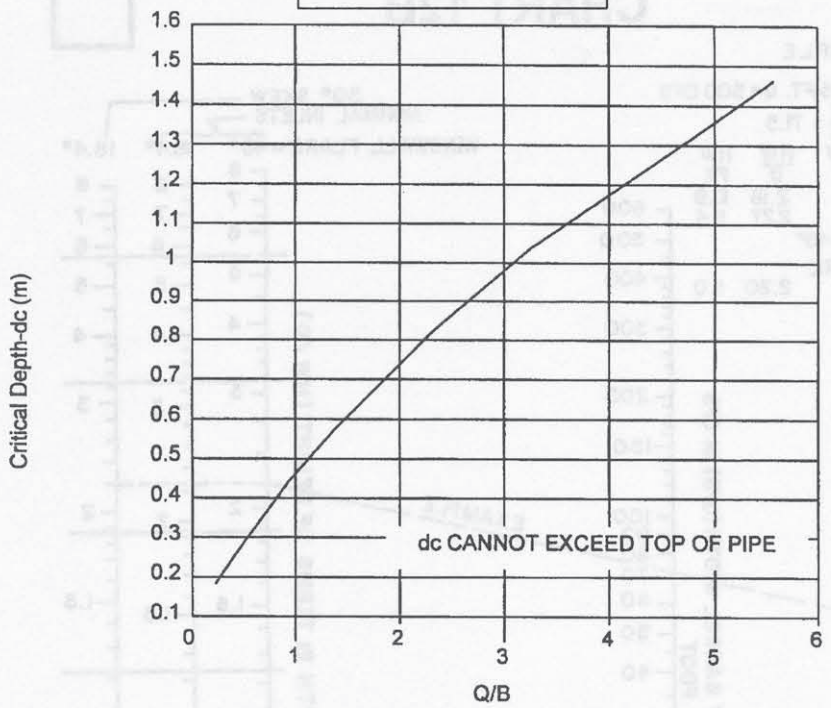
CHART 13B

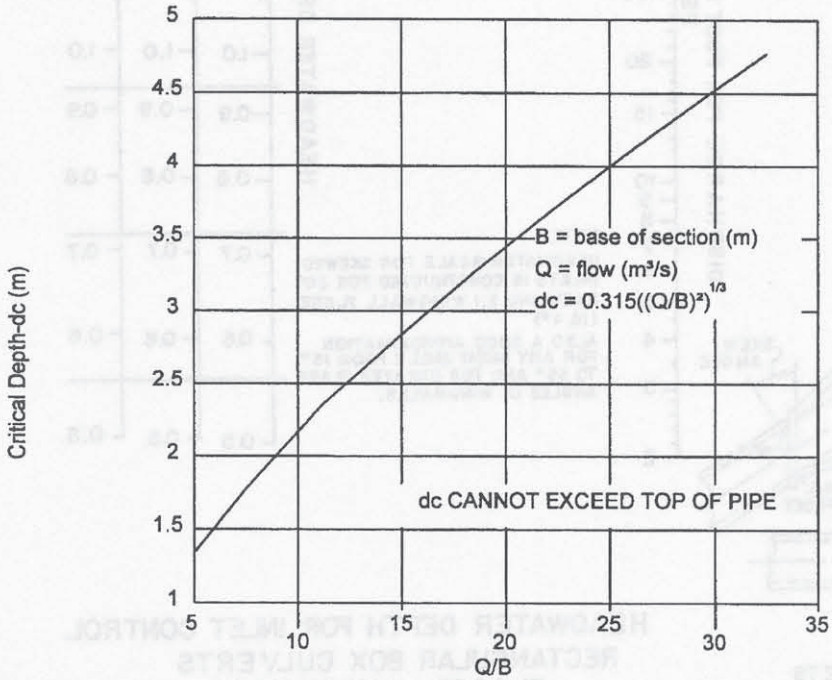


BUREAU OF PUBLIC ROADS
OFFICE OF R & D AUGUST 1968

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

CHART 14A

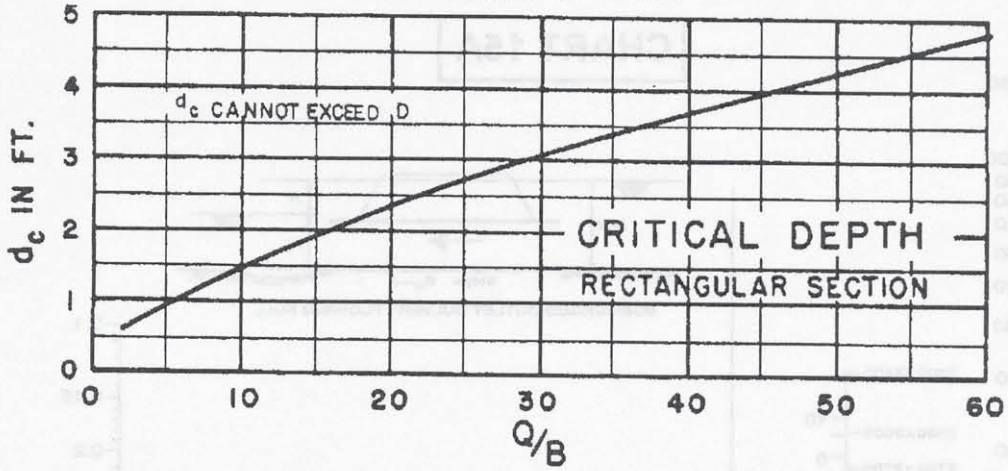


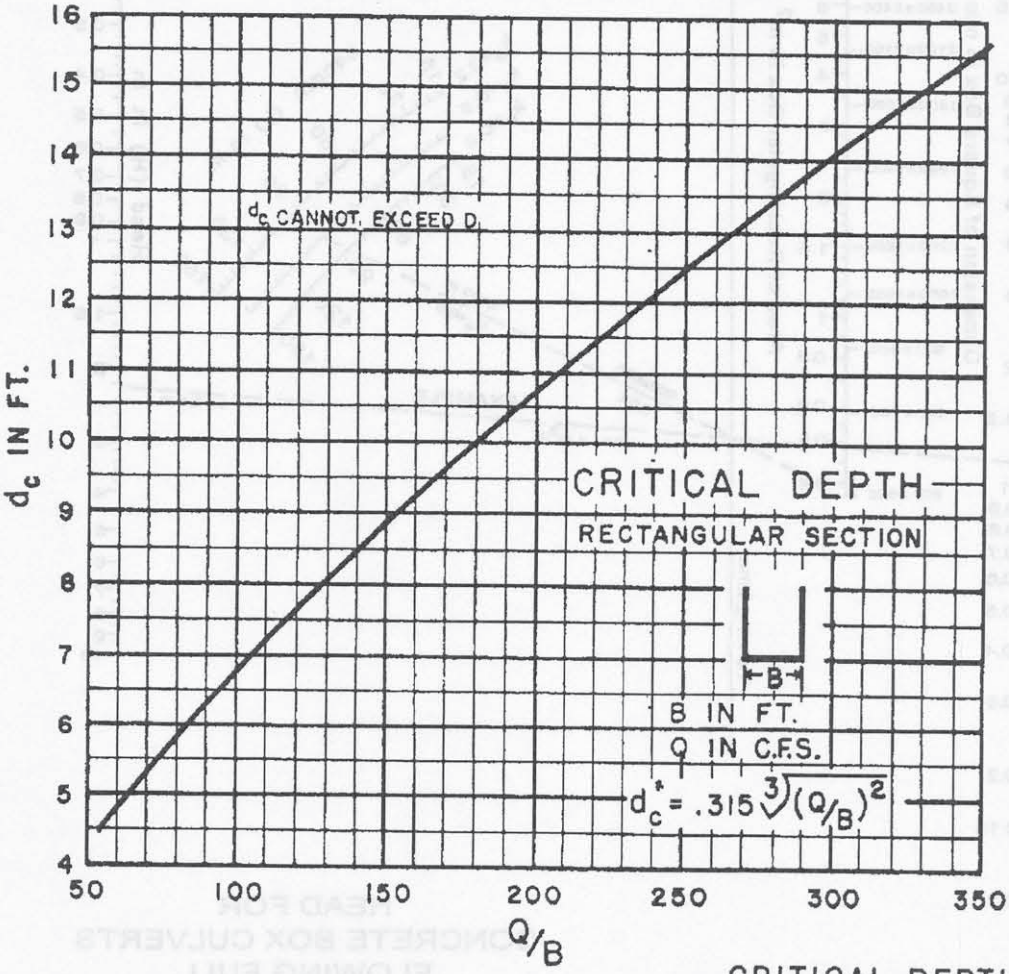


Adapted from Bureau of Public Roads

Critical Depth-Rectangular Section

CHART 14B

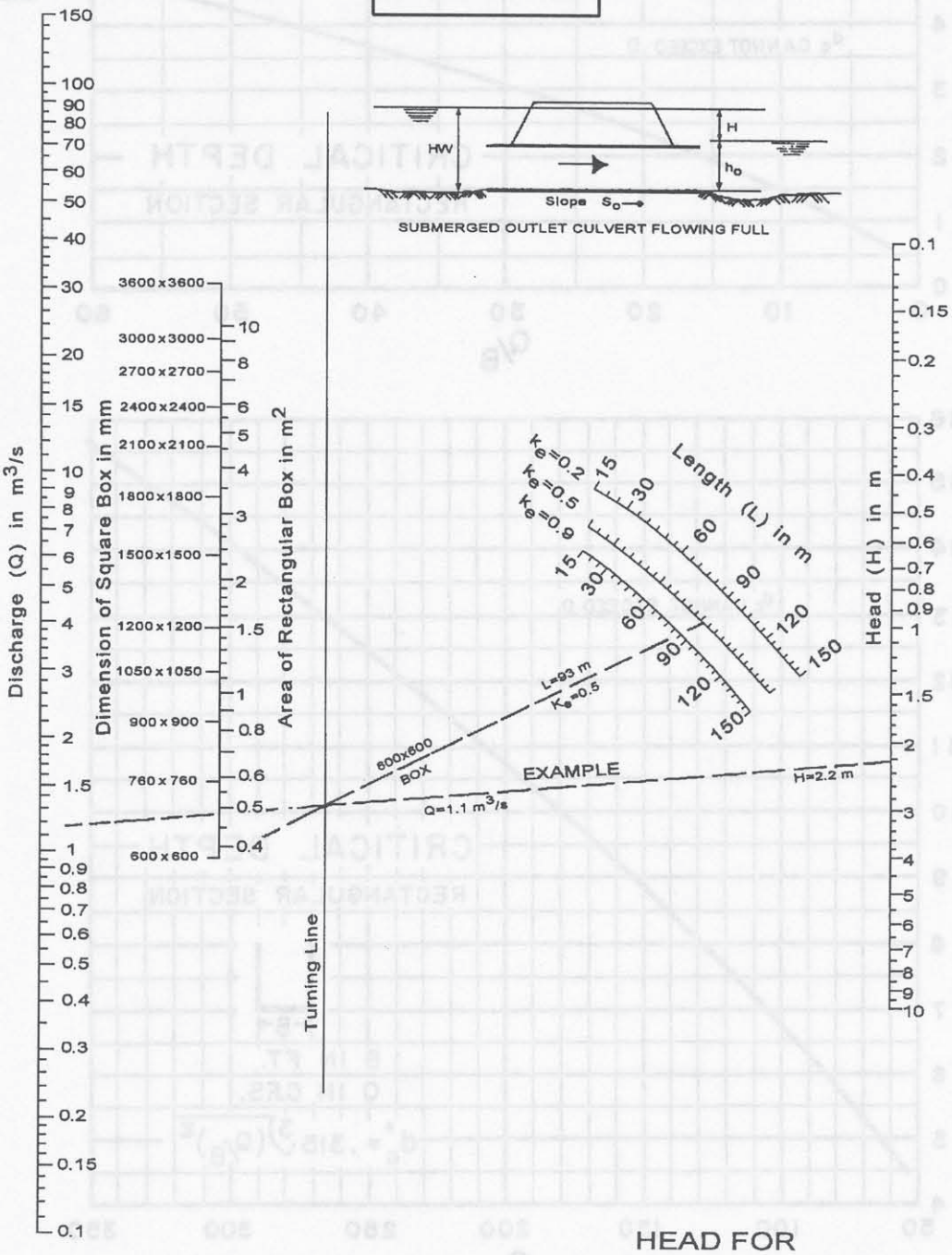




BUREAU OF PUBLIC ROADS JAN 1963

CRITICAL DEPTH
RECTANGULAR SECTION

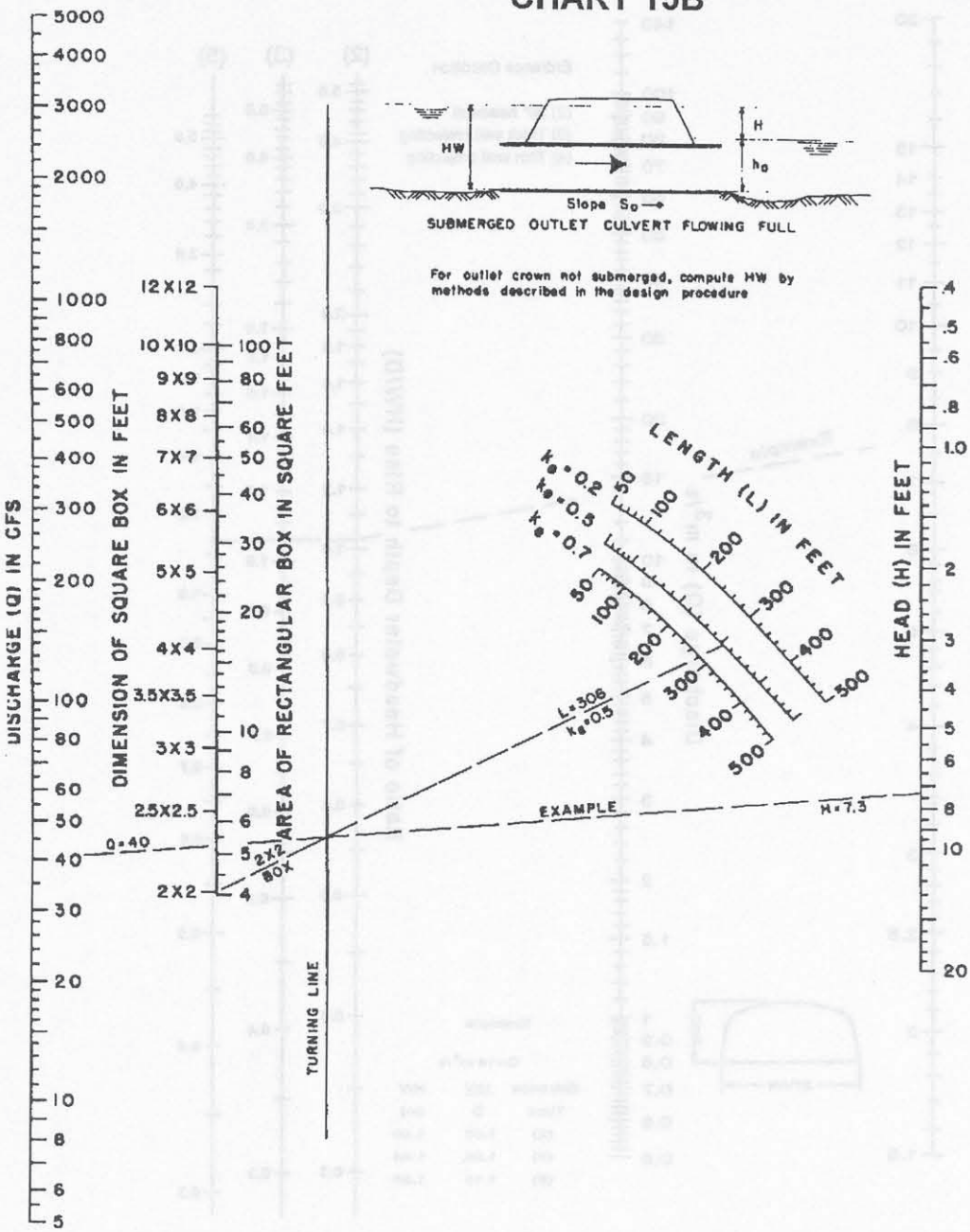
CHART 15A



HEAD FOR
CONCRETE BOX CULVERTS
FLOWING FULL
n=0.012

Adapted from
Burea of Public Roads Jan. 1963

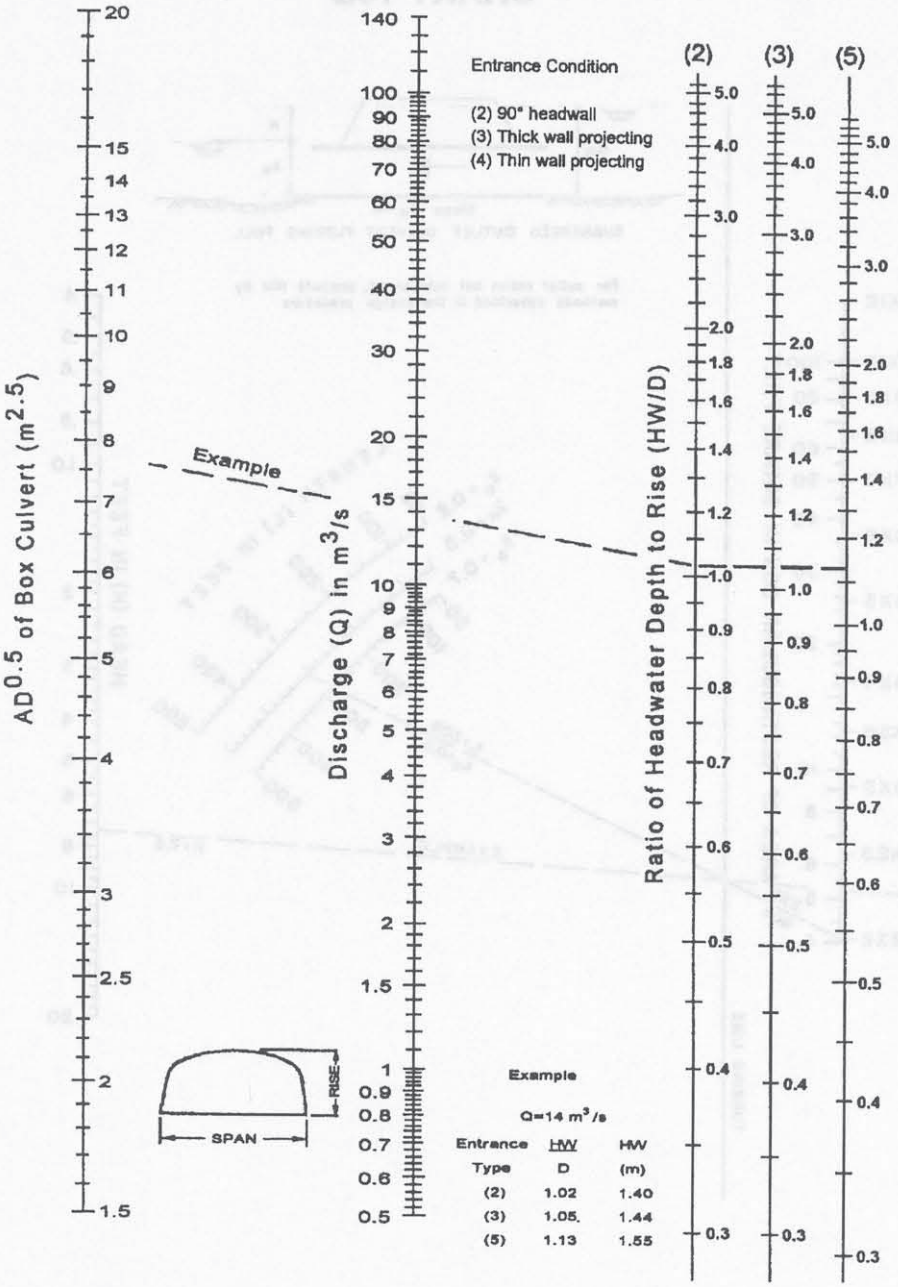
CHART 15B



HEAD FOR
CONCRETE BOX CULVERTS
FLOWING FULL
n = 0.012

AU OF PUBLIC ROADS JAN. 1963

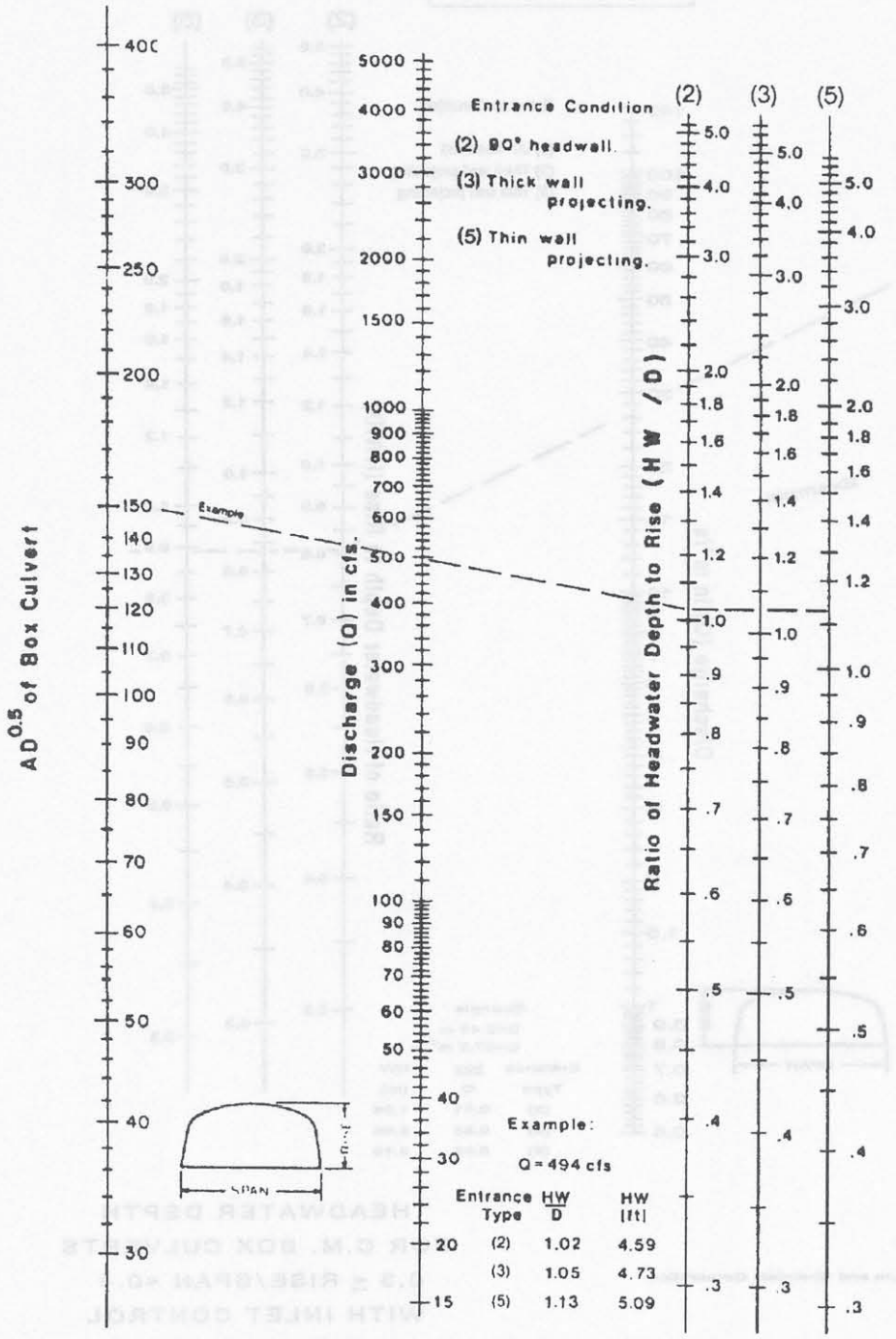
CHART 16A



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

Adapted from
Kaiser Aluminium and Chemical Corporation

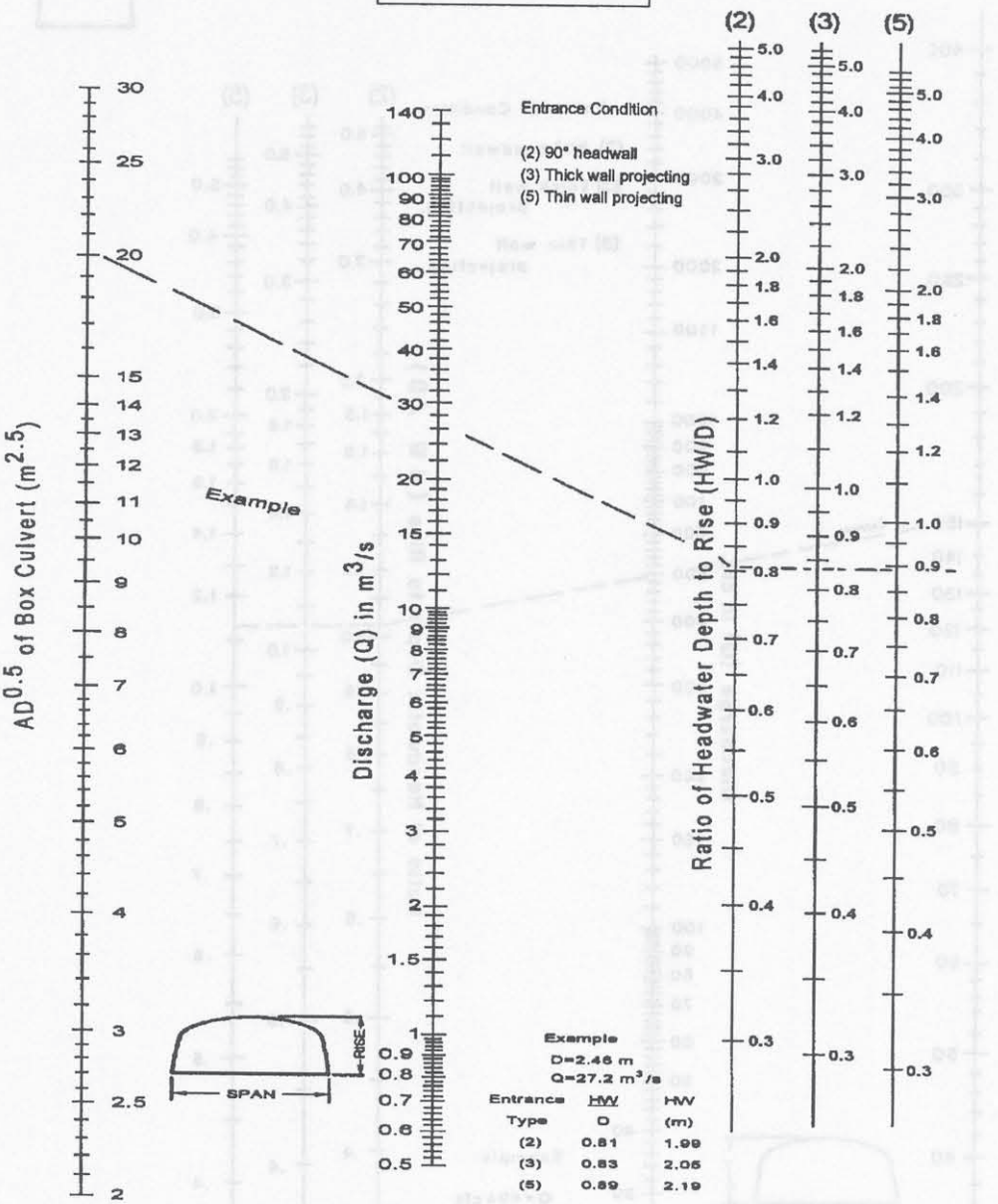
CHART 16B



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

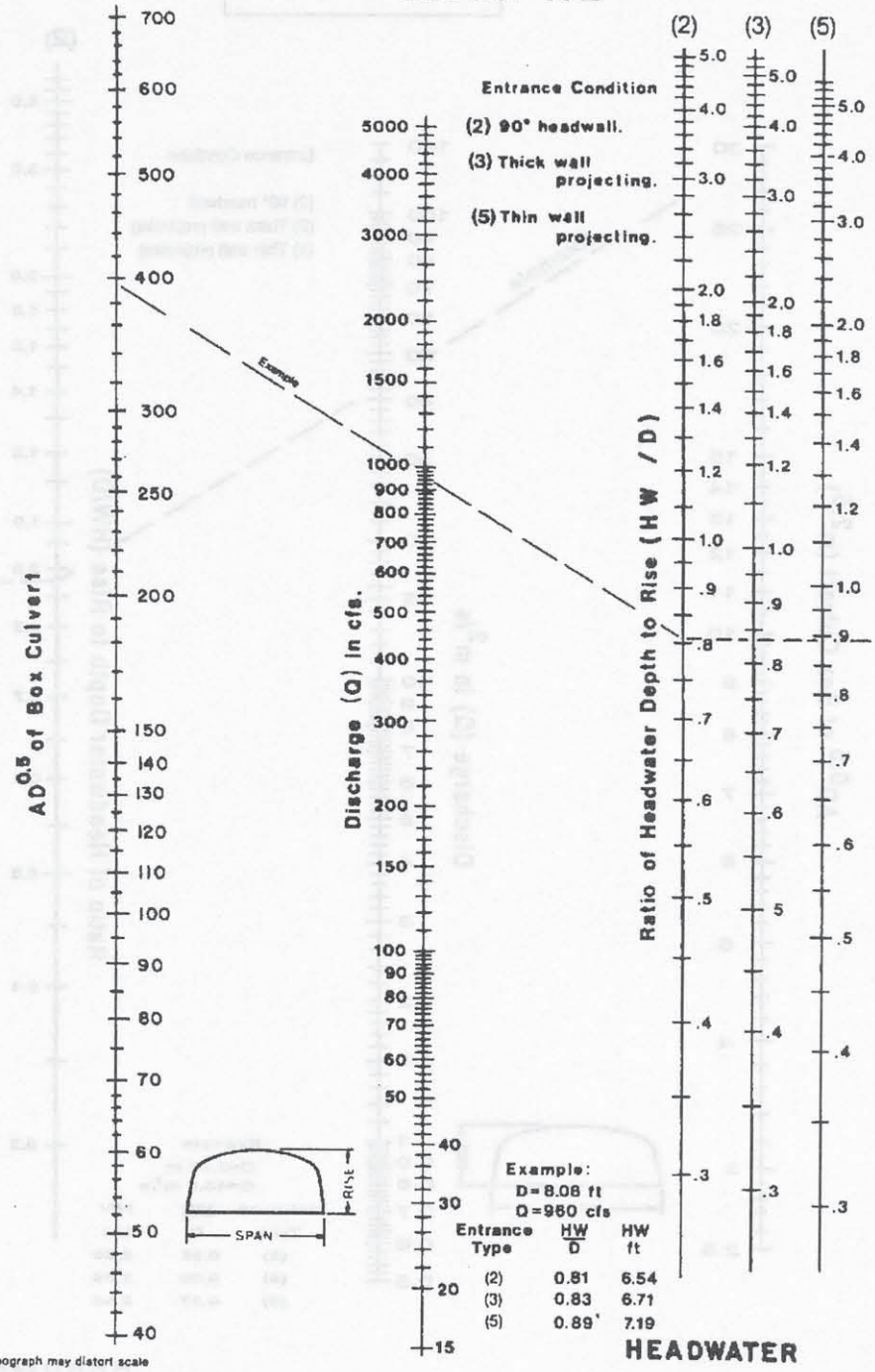
CHART 17A



Adapted from
Kaiser Aluminium and Chemical Corporation

HEADWATER DEPTH
FOR C.M. BOX CULVERTS
$0.3 \leq$ RISE/SPAN <0.4
WITH INLET CONTROL

CHART 17B



Duplication of this nomograph may distort scale

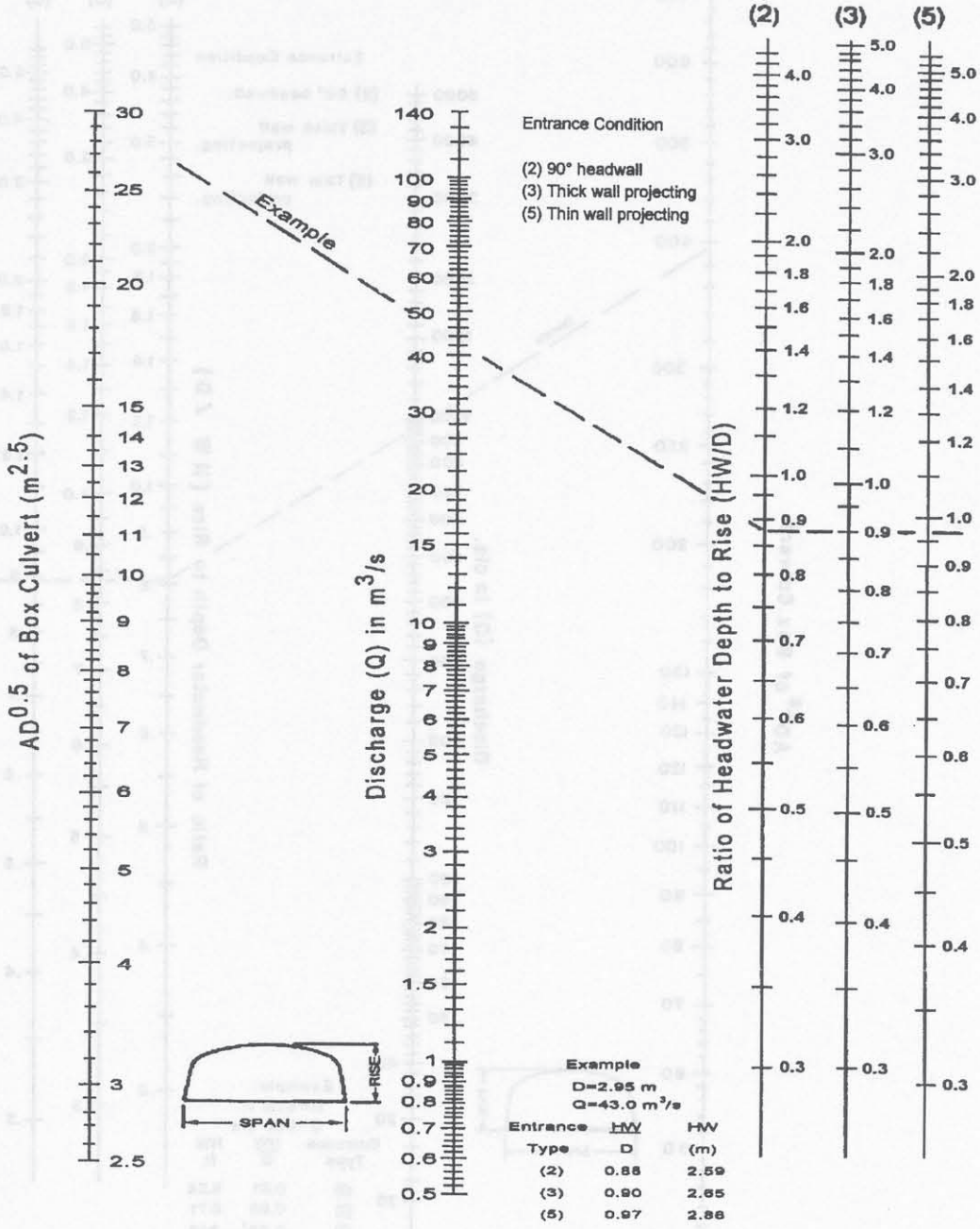
Nomographs adapted from material furnished by Kaiser Aluminum and Chemical Corporation

HEADWATER DEPTH FOR C.M. BOX CULVERTS

0.3 ≤ RISE / SPAN < 0.4

WITH INLET CONTROL

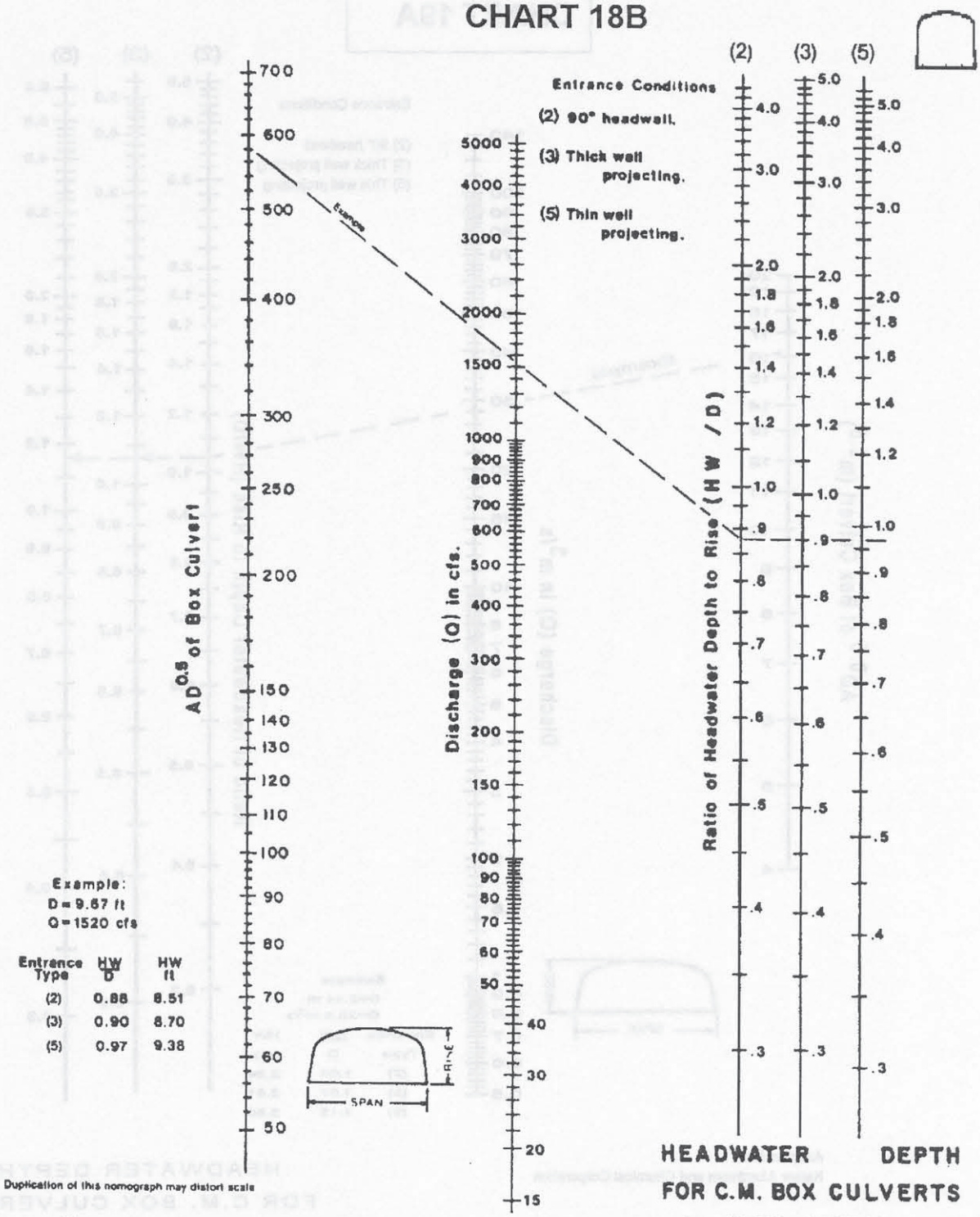
CHART 18A



Adapted from
Kaiser Aluminium and Chemical Corporation

HEADWATER DEPTH
FOR C.M. BOX CULVERTS
$0.4 \leq$ RISE/SPAN < 0.5
WITH INLET CONTROL

CHART 18B



Example:
D = 9.67 ft
Q = 1520 cfs

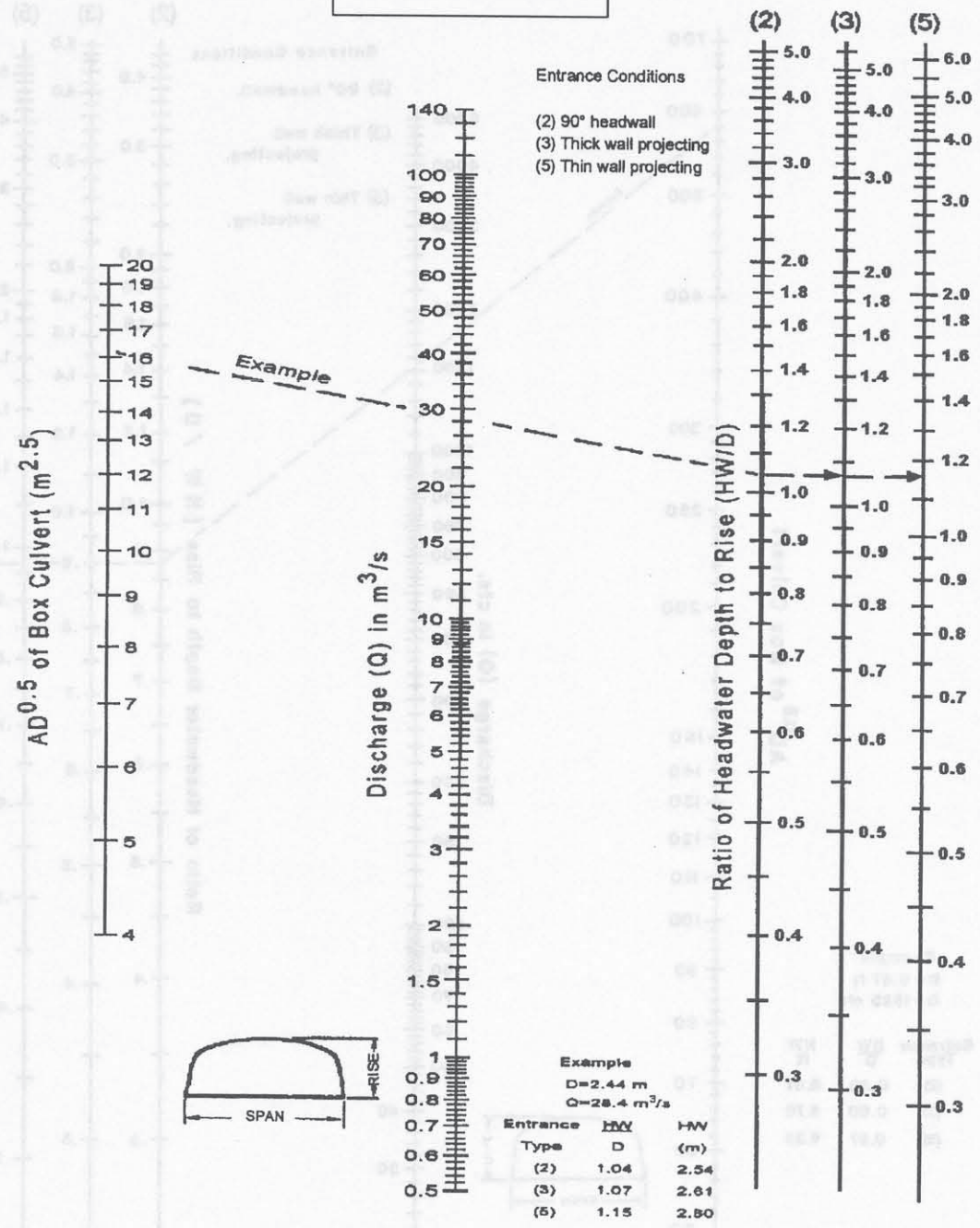
Entrance Type	HW/D	HW ft
(2)	0.88	8.51
(3)	0.90	8.70
(5)	0.97	9.38

Duplication of this nomograph may distort scale

Nomographs adapted from material furnished by Kaiser Aluminum and Chemical Corporation

HEADWATER DEPTH
FOR C.M. BOX CULVERTS
0.4 ≤ RISE / SPAN < 0.5
WITH INLET CONTROL

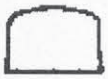
CHART 19A

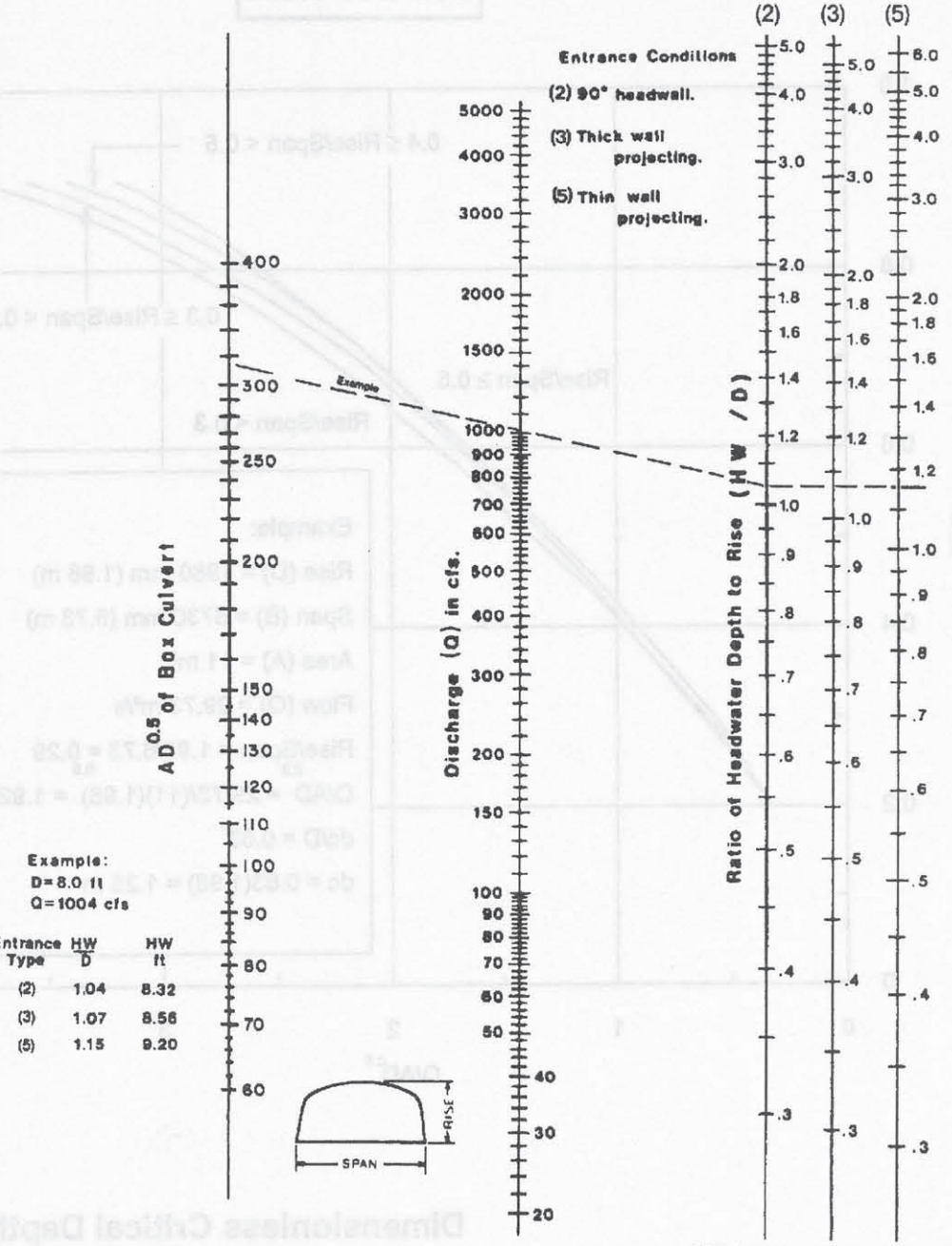


Adapted from
Kaiser Aluminium and Chemical Corporation

HEADWATER DEPTH
FOR C.M. BOX CULVERTS
0.5 ≤ RISE/SPAN
WITH INLET CONTROL

CHART 19B

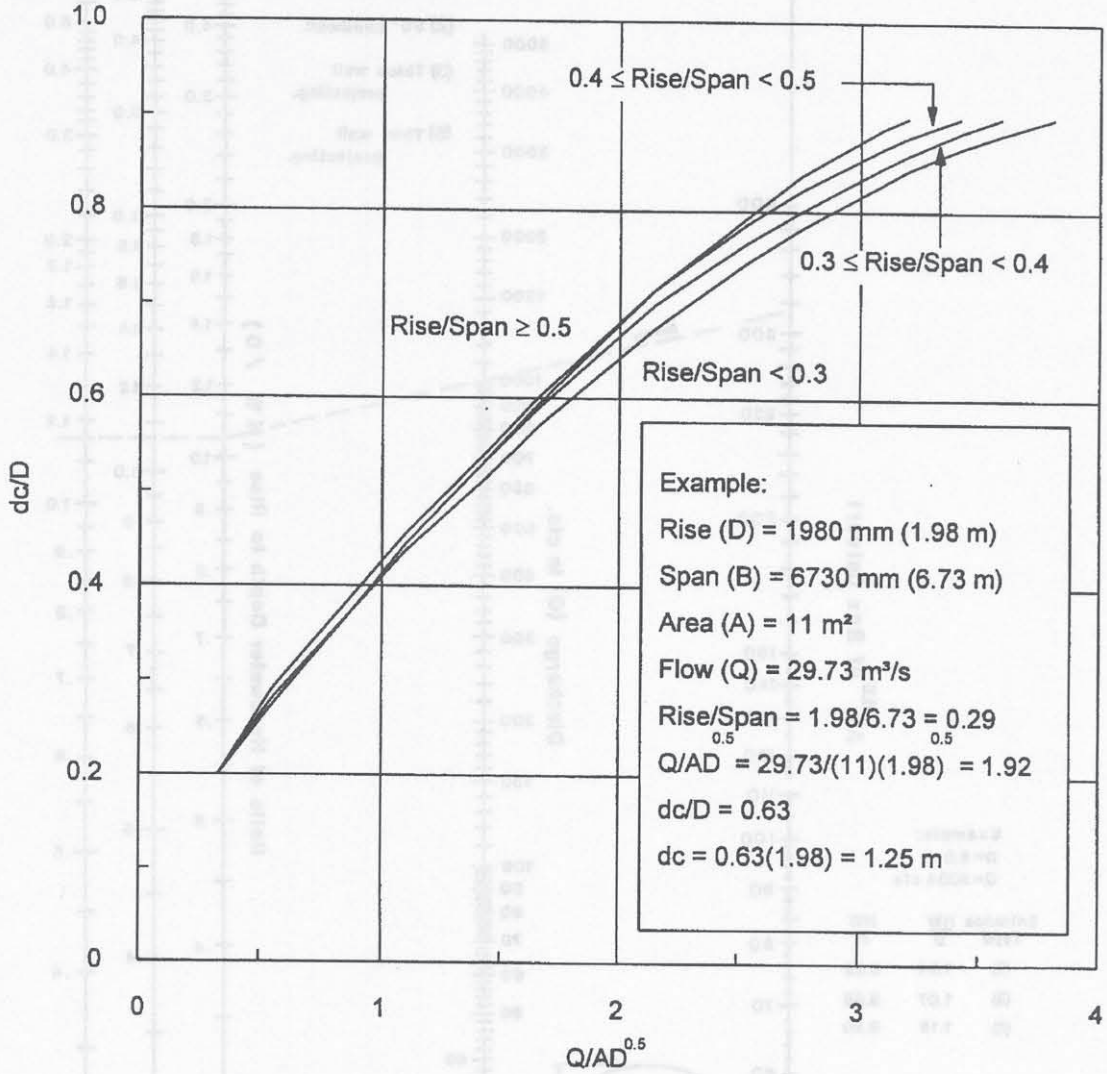




Nomographs adapted from material furnished by Kaiser Aluminum and Chemical Corporation

HEADWATER DEPTH FOR C.M. BOX CULVERTS
0.5 ≤ RISE / SPAN
WITH INLET CONTROL

CHART 20A



Dimensionless Critical Depth Chart for Corrugated Metal Box Culverts

CHART 20B

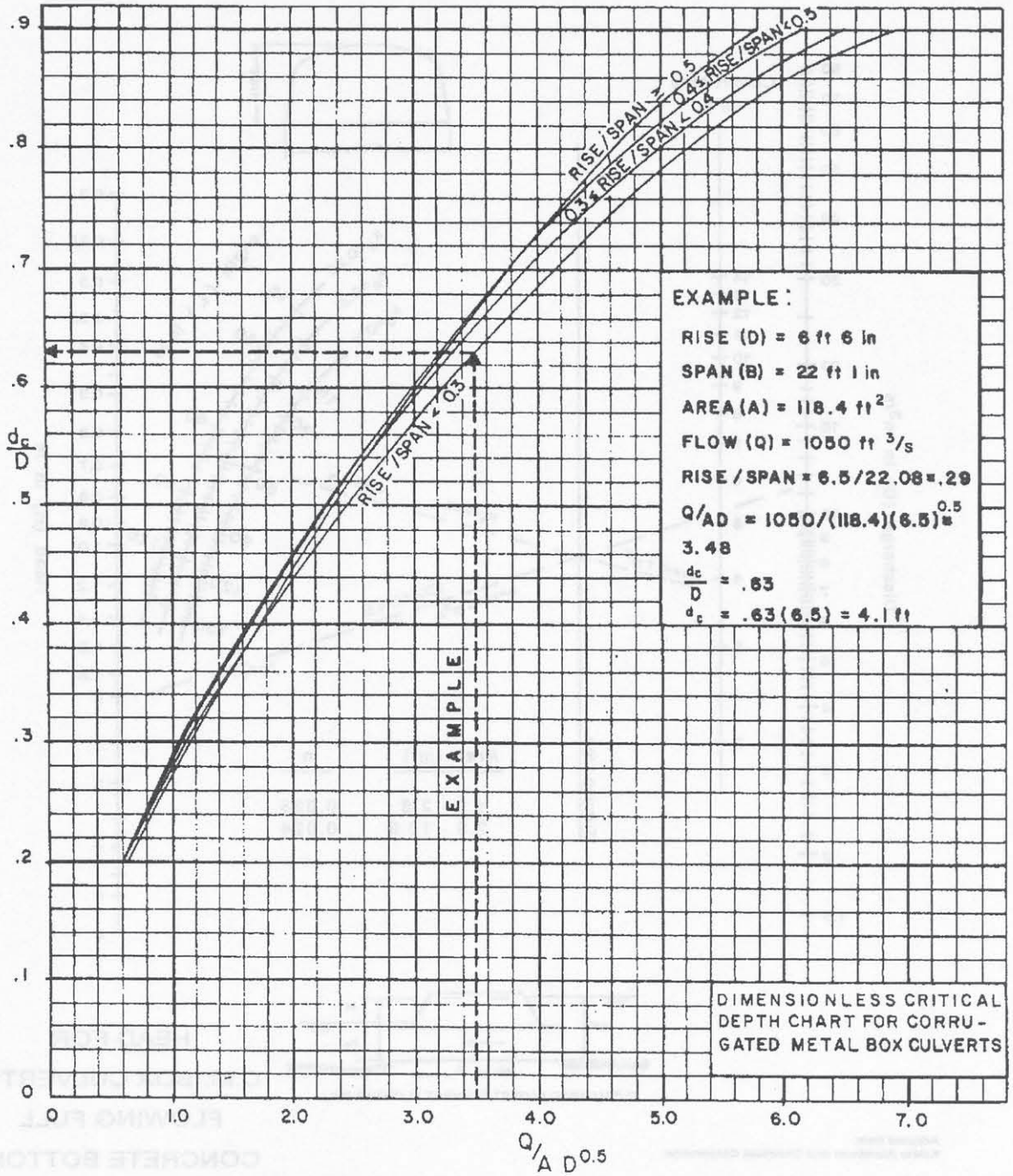
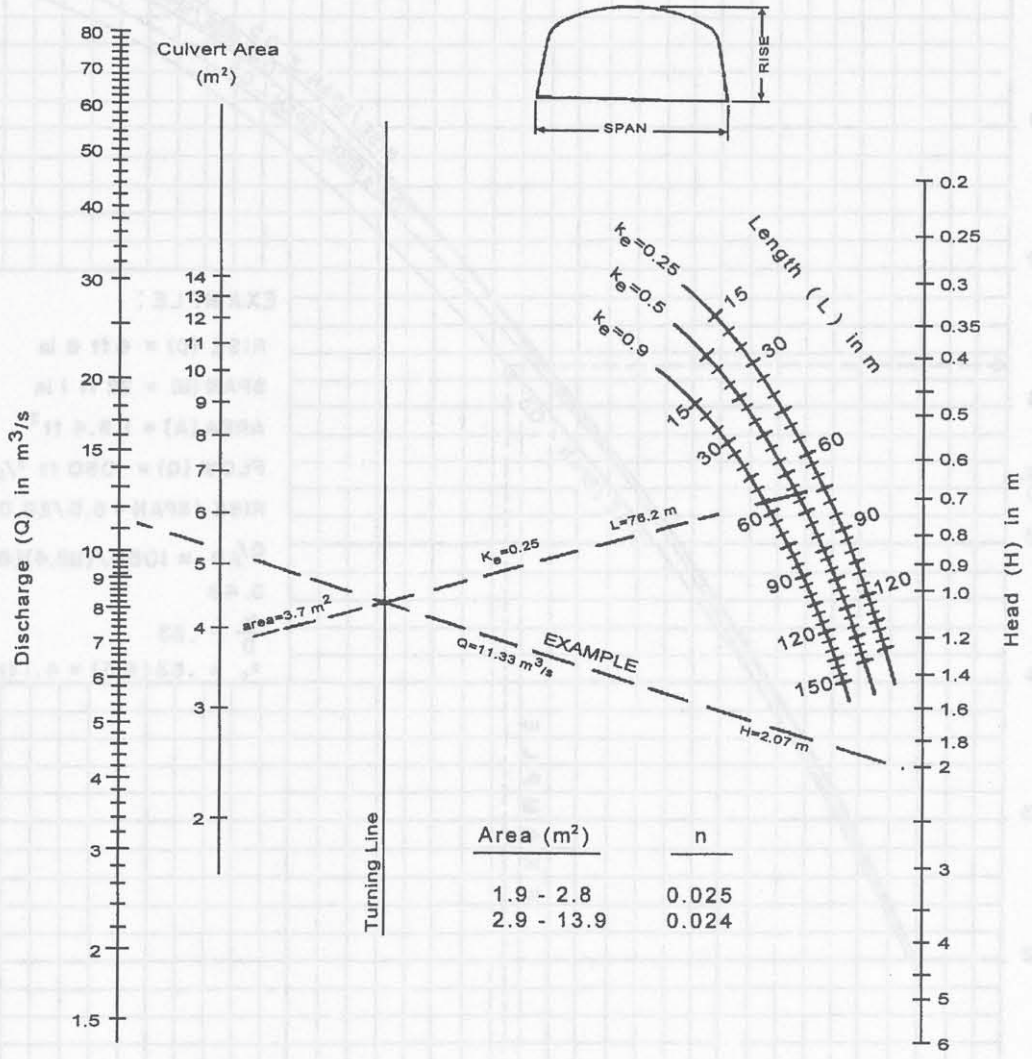
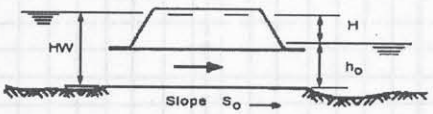

RISE/SPAN ≥ 0.5
0.4 ≤ RISE/SPAN < 0.5
0.3 ≤ RISE/SPAN < 0.4
RISE/SPAN < 0.3
EXAMPLE
EXAMPLE:
RISE (D) = 6 ft 6 in
SPAN (B) = 22 ft 1 in
AREA (A) = 118.4 ft²
FLOW (Q) = 1050 ft³/s
RISE / SPAN = 6.5/22.08 = .29
Q/AD = 1050/(118.4)(6.5)^0.5 = 3.48
dc/D = .63
dc = .63(6.5) = 4.1 ft
DIMENSIONLESS CRITICAL DEPTH CHART FOR CORRUGATED METAL BOX CULVERTS
dc/D
Q/A D^0.5
0
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
2.0
3.0
4.0
5.0
6.0
7.0

CHART 21A



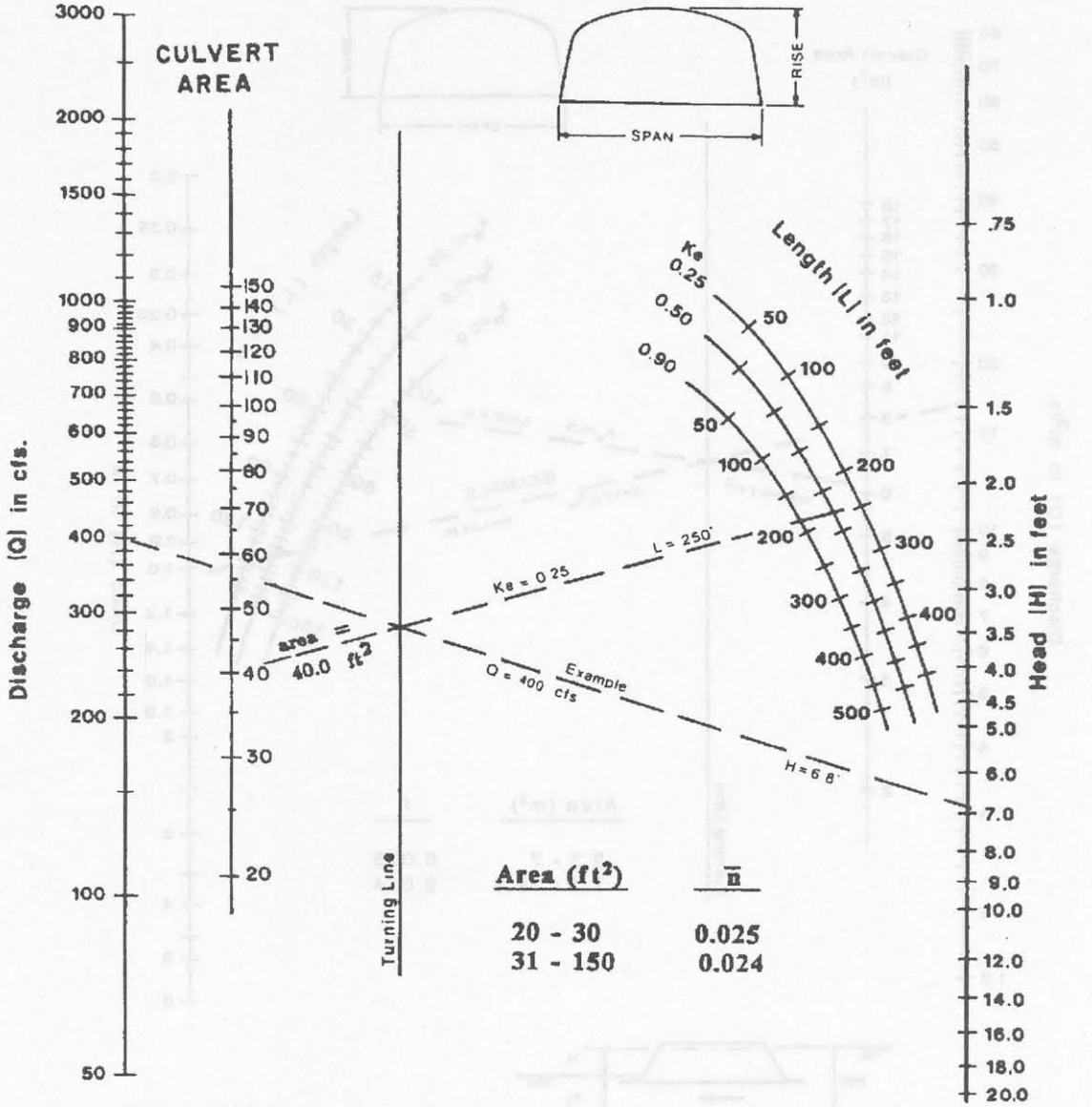


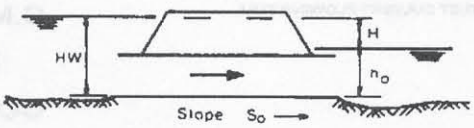
SUBMERGED OUTLET CULVERT FLOWING FULL

Adapted from
Kaiser Aluminum and Chemical Corporation

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

CHART 21B





SUBMERGED OUTLET CULVERT FLOWING FULL

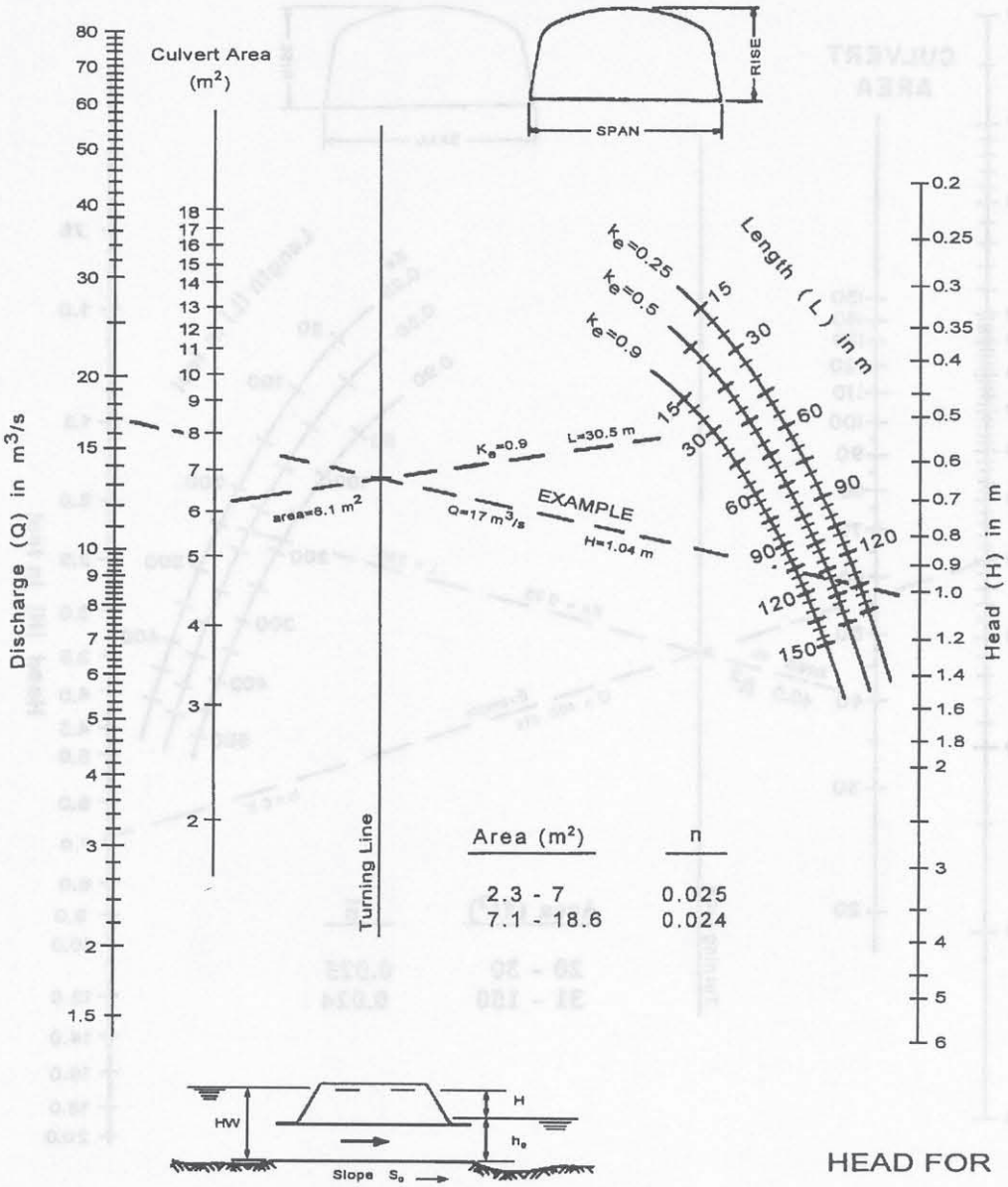
HEAD FOR C. M. BOX CULVERTS FLOWING FULL CONCRETE BOTTOM

RISE / SPAN < 0.3

Nomographs adapted from material furnished by Kaiser Aluminum and Chemical Corporation

Duplication of this nomograph may distort scale

CHART 22A

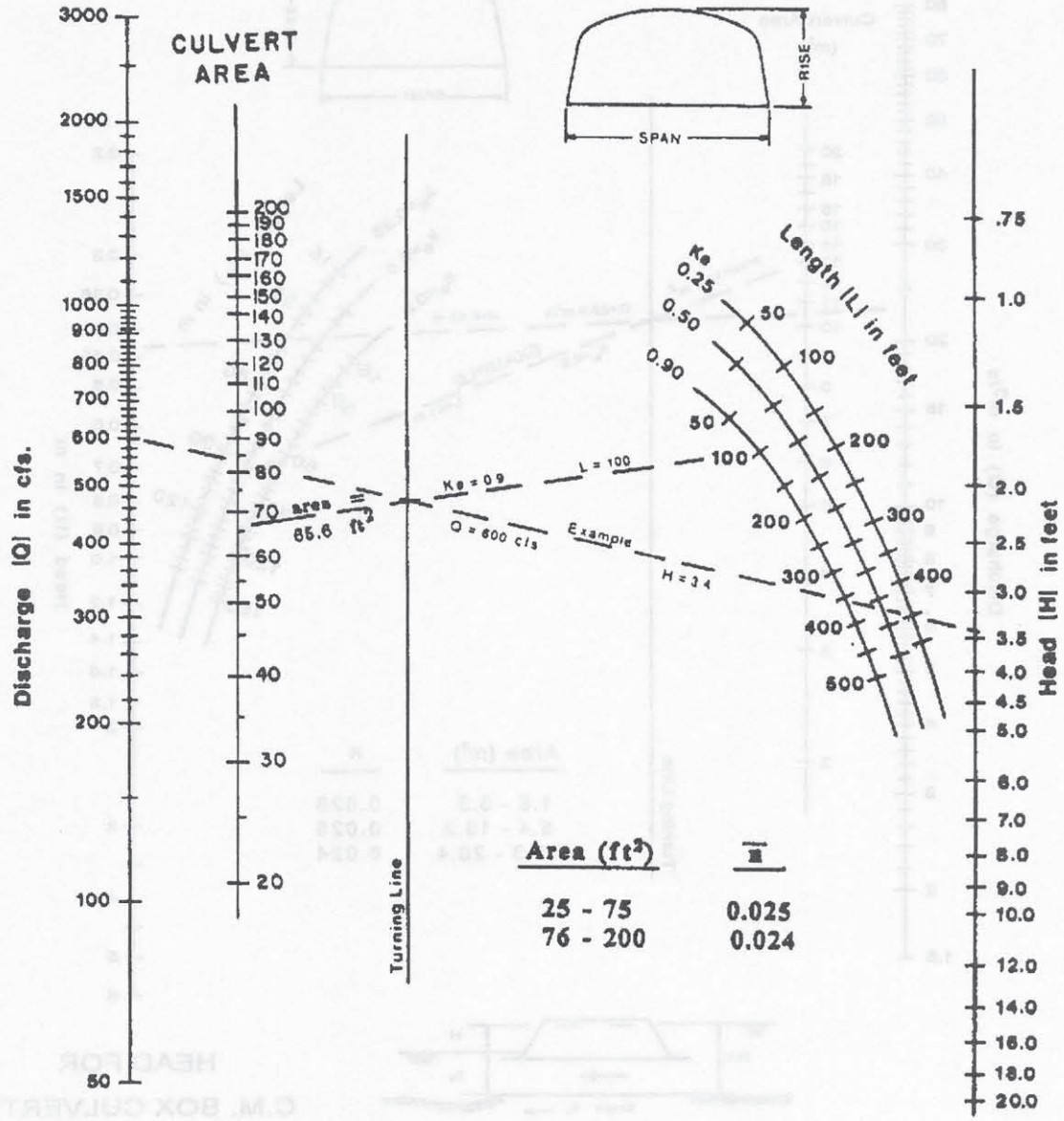


SUBMERGED OUTLET CULVERT FLOWING FULL

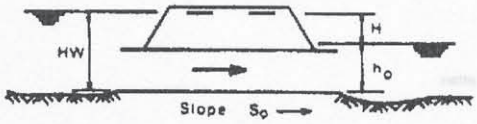
HEAD FOR
C.M. BOX CULVERTS
FLOWING FULL
CONCRETE BOTTOM
$0.3 \leq$ RISE/SPAN < 0.4

Adapted from
Kaiser Aluminum and Chemical Corporation

CHART 22B



Area (ft^2)	$\bar{n}$
25 - 75	0.025
76 - 200	0.024



SUBMERGED OUTLET CULVERT FLOWING FULL

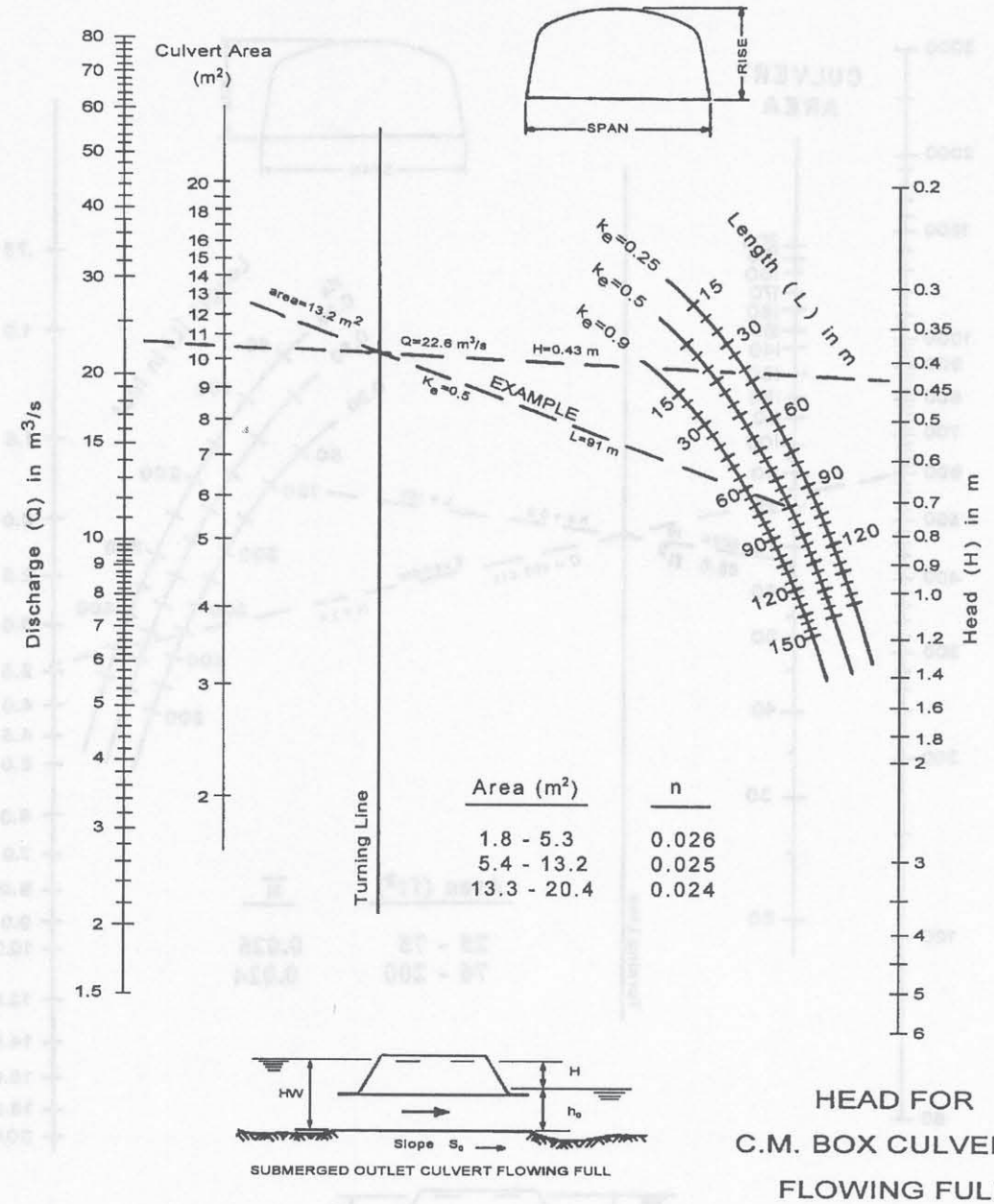
HEAD FOR C. M. BOX CULVERTS FLOWING FULL CONCRETE BOTTOM

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 23A

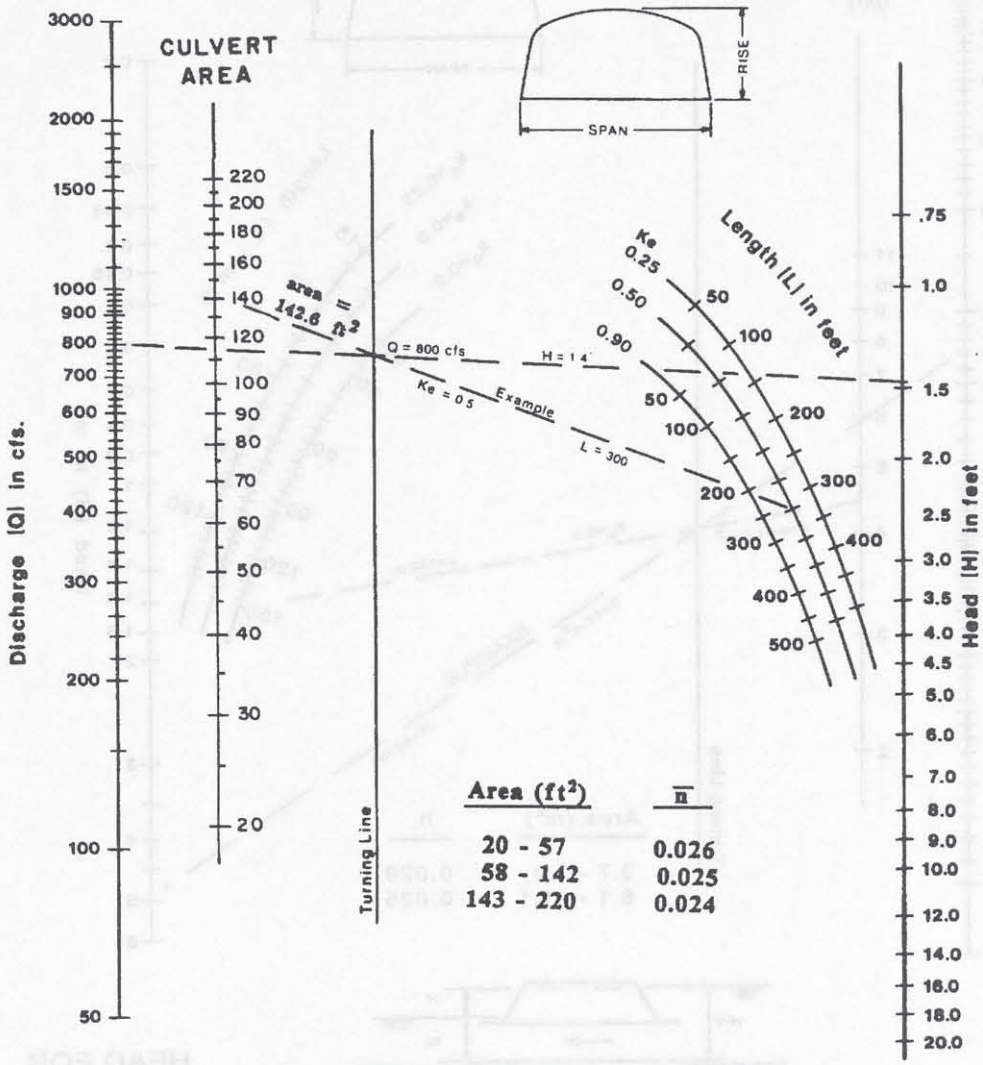


SUBMERGED OUTLET CULVERT FLOWING FULL

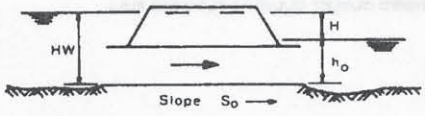
HEAD FOR
C.M. BOX CULVERTS
FLOWING FULL
CONCRETE BOTTOM
$0.4 \leq$ RISE/SPAN < 0.5

Adapted from
Kaiser Aluminum and Chemical Corporation

CHART 23B



Area (ft^2)	$\bar{n}$
20 - 57	0.026
58 - 142	0.025
143 - 220	0.024



SUBMERGED OUTLET CULVERT FLOWING FULL

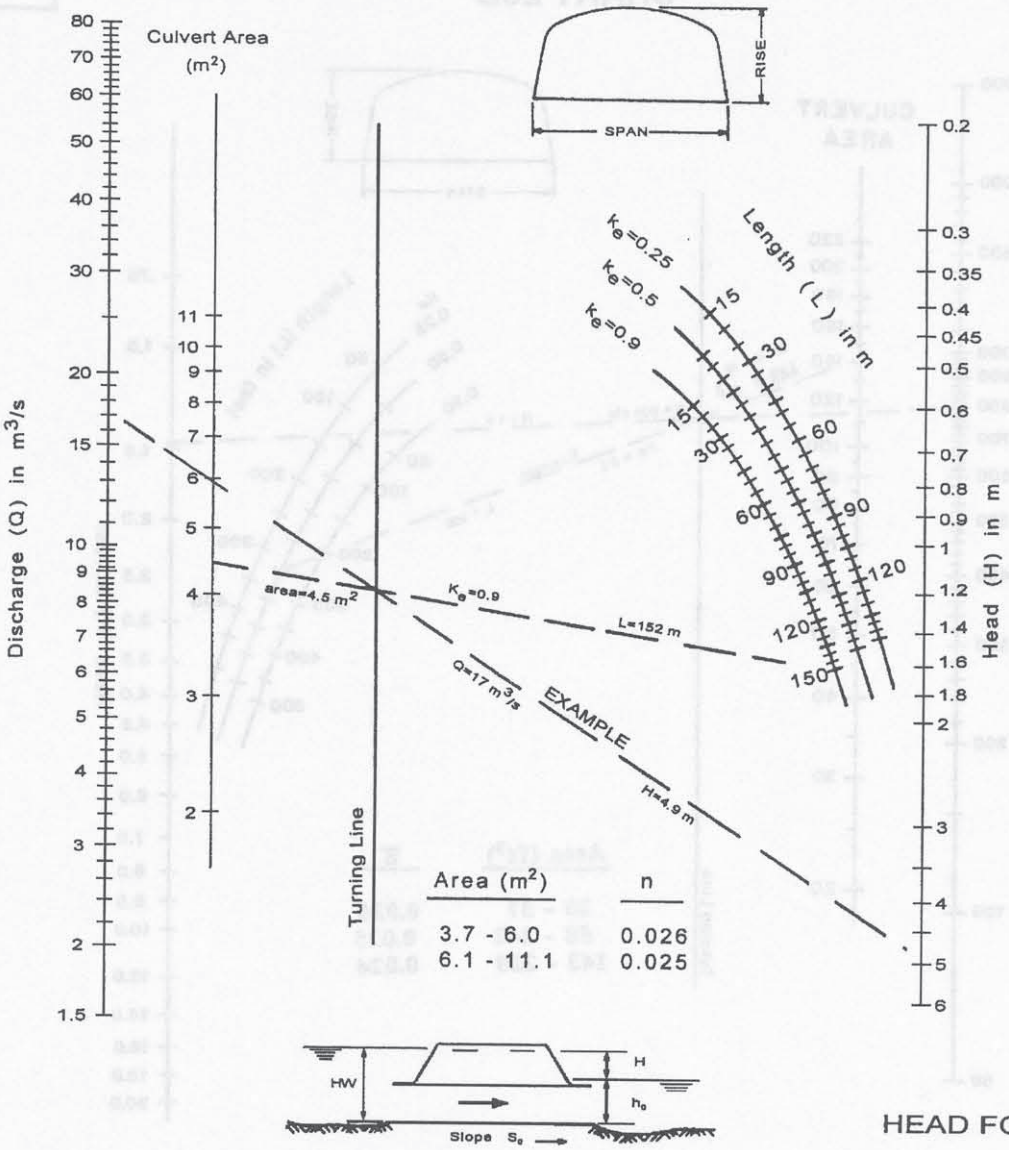
HEAD FOR C.M. BOX CULVERTS FLOWING FULL CONCRETE BOTTOM

$0.4 \leq$ RISE/SPAN < 0.5

Nomographs adapted from material furnished by Kaiser Aluminum and Chemical Corporation

Duplication of this nomograph may distort scale

CHART 24A

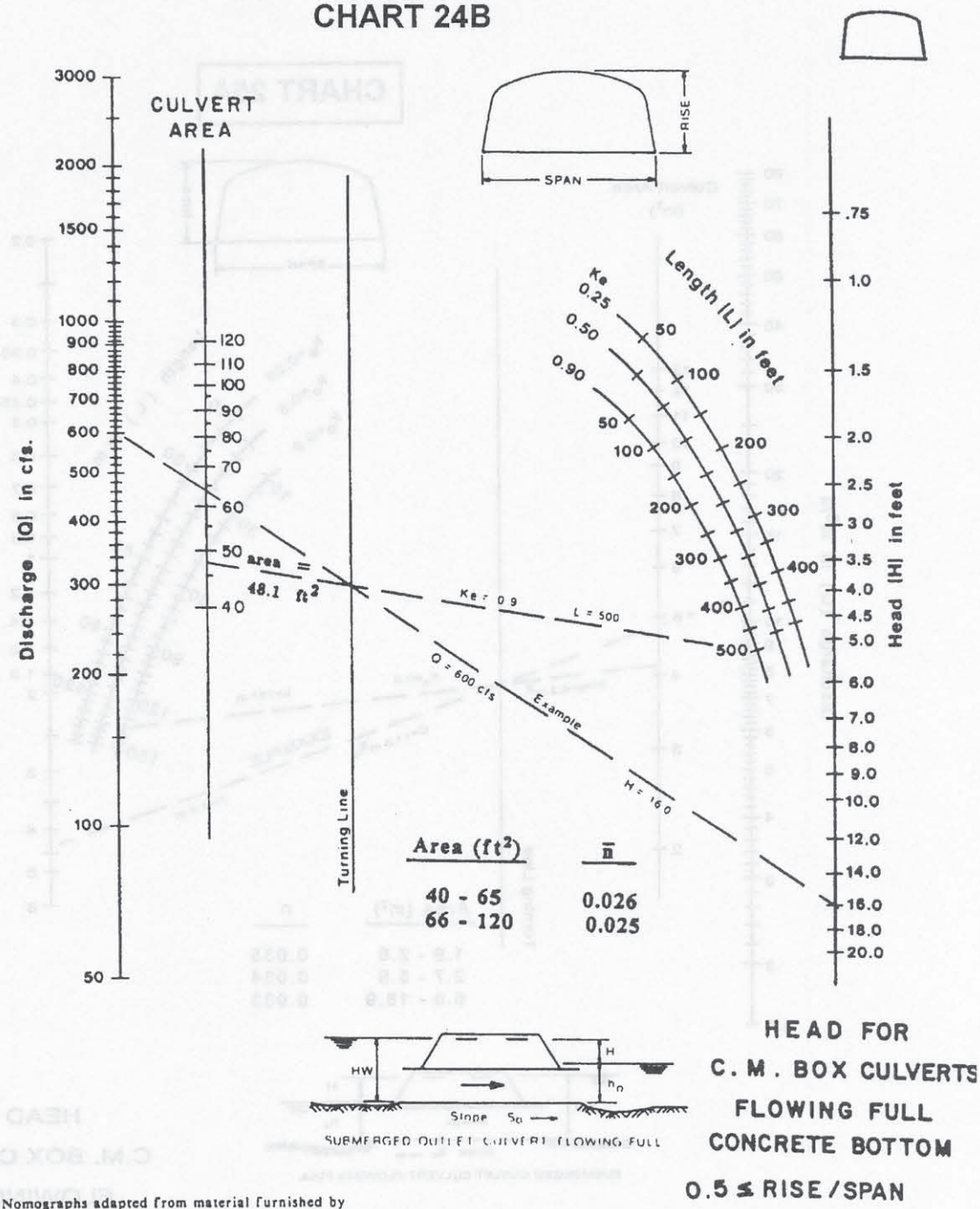


SUBMERGED OUTLET CULVERT FLOWING FULL

Adapted from
Kaiser Aluminum and Chemical Corporation

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

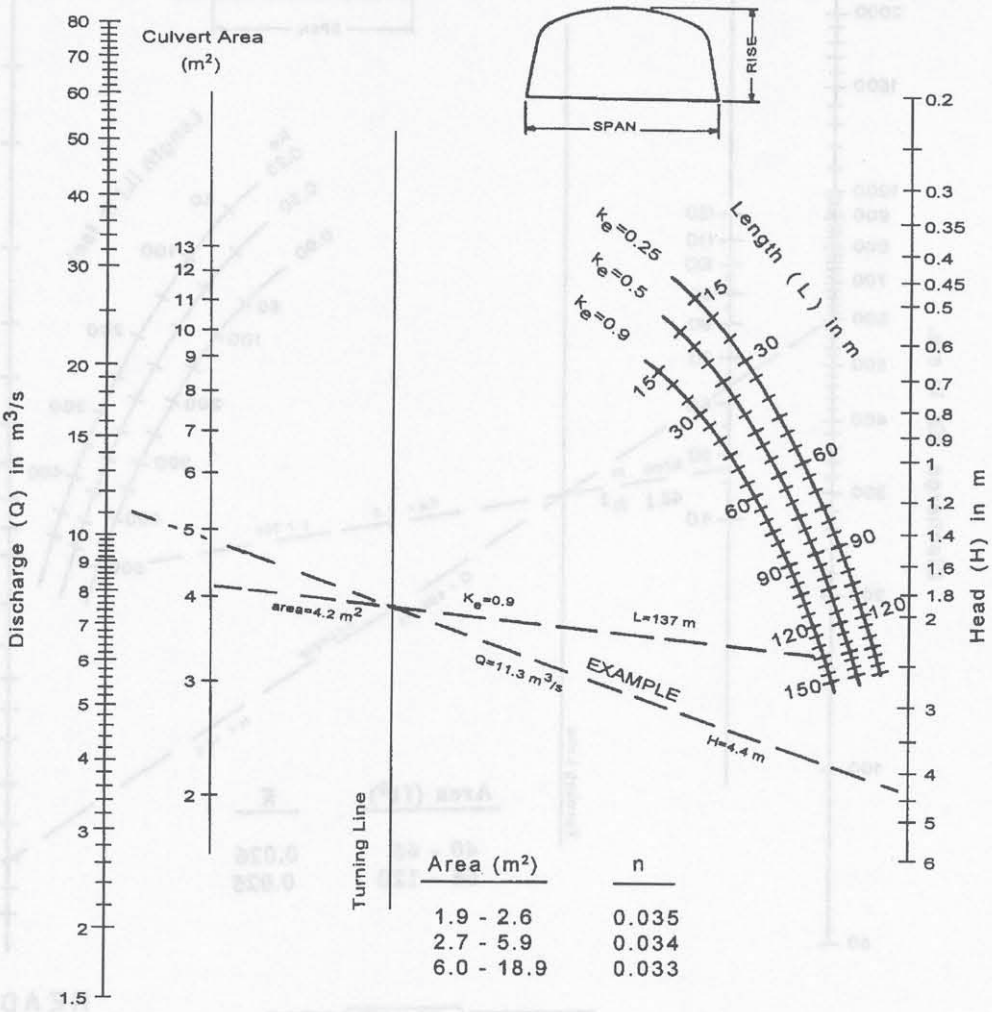
CHART 24B



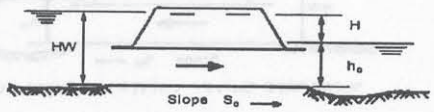
Nomographs adapted from material furnished by Kaiser Aluminum and Chemical Corporation

Duplication of this nomograph may distort scale

CHART 25A



Area (m²)	n
1.9 - 2.6	0.035
2.7 - 5.9	0.034
6.0 - 18.9	0.033

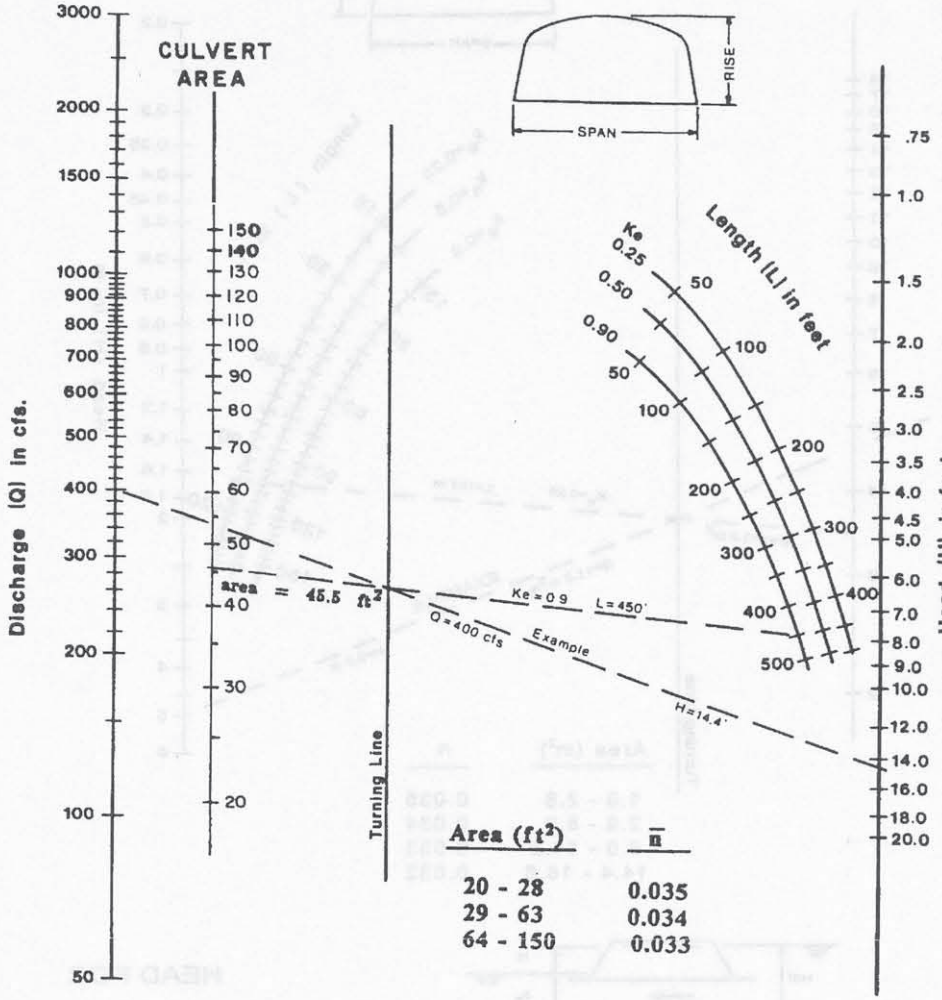


SUBMERGED OUTLET CULVERT FLOWING FULL

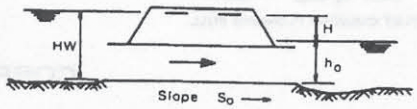
HEAD FOR
C.M. BOX CULVERTS
FLOWING FULL
CORRUGATED METAL BOTTOM
RISE/SPAN < 0.3

Adapted from
Kaiser Aluminum and Chemical Corporation

CHART 25B



Area (ft^2)	$\bar{n}$
20 - 28	0.035
29 - 63	0.034
64 - 150	0.033



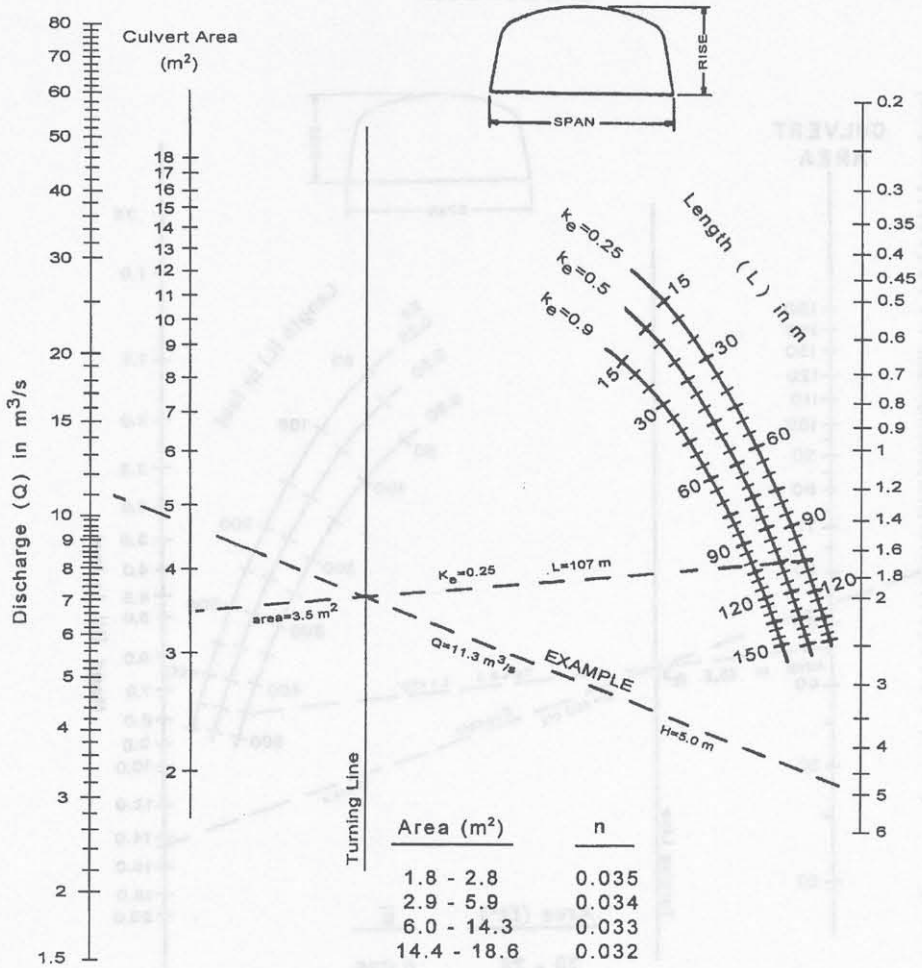
SUBMERGED OUTLET CULVERT FLOWING FULL

HEAD FOR
C. M. BOX CULVERTS
FLOWING FULL
CORRUGATED METAL BOTTOM
RISE / SPAN < 0.3

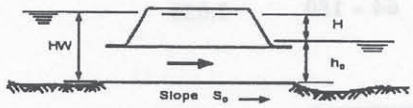
Nomographs adapted from material furnished by Kaiser Aluminum and Chemical Corporation

Duplication of this nomograph may distort scale

CHART 26A



Area (m²)	n
1.8 - 2.8	0.035
2.9 - 5.9	0.034
6.0 - 14.3	0.033
14.4 - 18.6	0.032

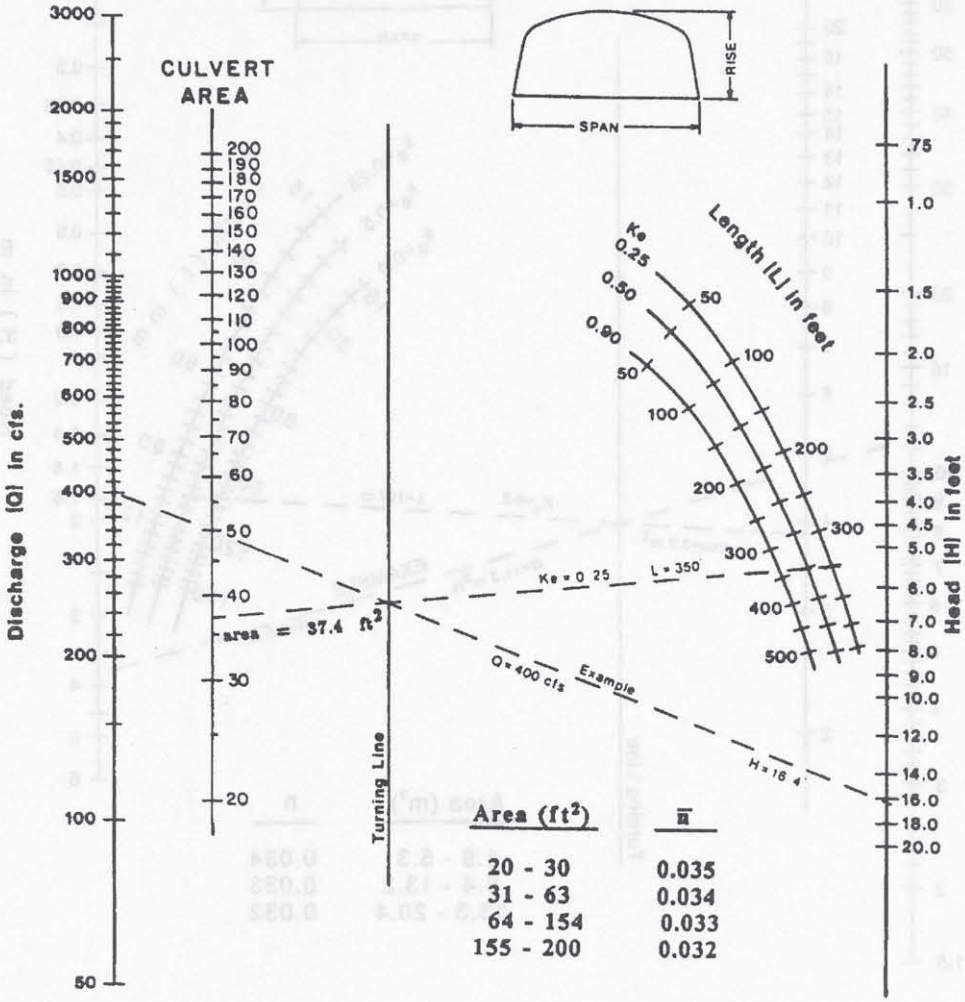


SUBMERGED OUTLET CULVERT FLOWING FULL

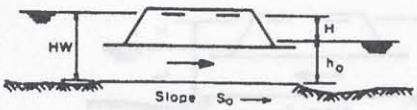
HEAD FOR
C.M. BOX CULVERTS
FLOWING FULL
CORRUGATED METAL BOTTOM
$0.3 \leq$ RISE/SPAN < 0.4

Adapted from
Kaiser Aluminum and Chemical Corporation

CHART 26B



Area (ft^2)	$\bar{n}$
20 - 30	0.035
31 - 63	0.034
64 - 154	0.033
155 - 200	0.032



SUBMERGED OUTLET CULVERT FLOWING FULL

HEAD FOR C. M. BOX CULVERTS FLOWING FULL

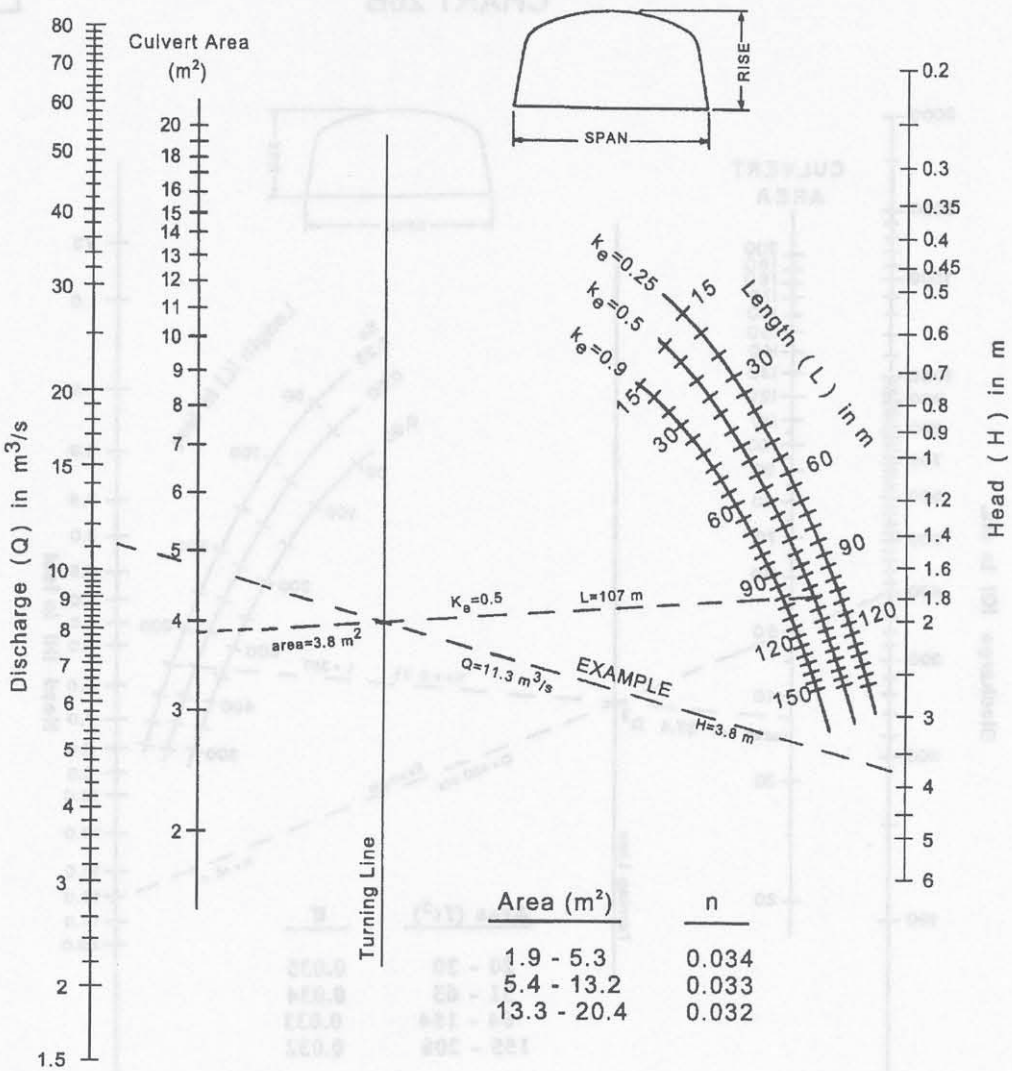
CORRUGATED METAL BOTTOM

0.3 ≤ RISE/SPAN < 0.4

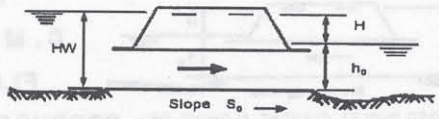
Nomographs adapted from material furnished by Kaiser Aluminum and Chemical Corporation

Duplication of this nomograph may distort scale

CHART 27A



Area (m²)	n
1.9 - 5.3	0.034
5.4 - 13.2	0.033
13.3 - 20.4	0.032

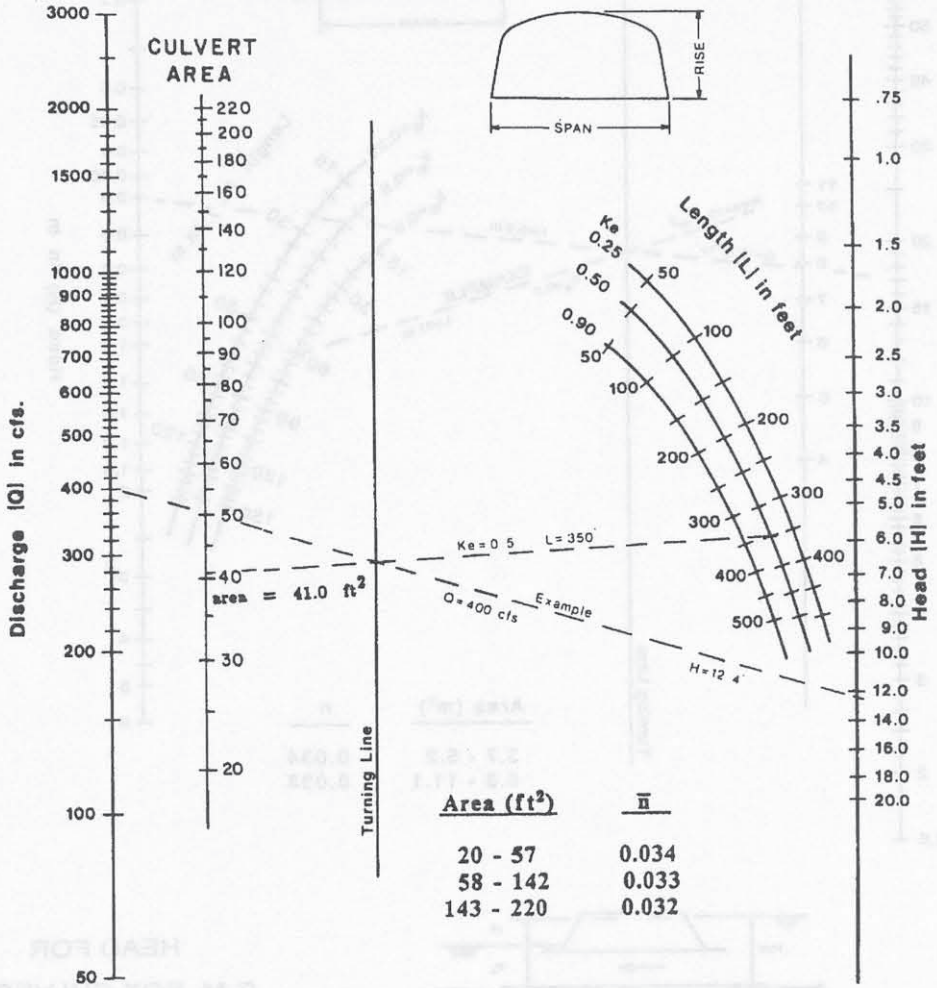


SUBMERGED OUTLET CULVERT FLOWING FULL

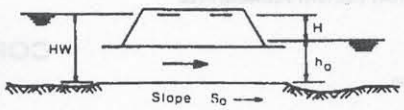
Adapted from
Kaiser Aluminum and Chemical Corporation

HEAD FOR
C.M. BOX CULVERTS
FLOWING FULL
CORRUGATED METAL BOTTOM
$0.4 \leq$ RISE/SPAN < 0.5

CHART 27B



Area (ft^2)	$\bar{n}$
20 - 57	0.034
58 - 142	0.033
143 - 220	0.032



SUBMERGED OUTLET CULVERT FLOWING FULL

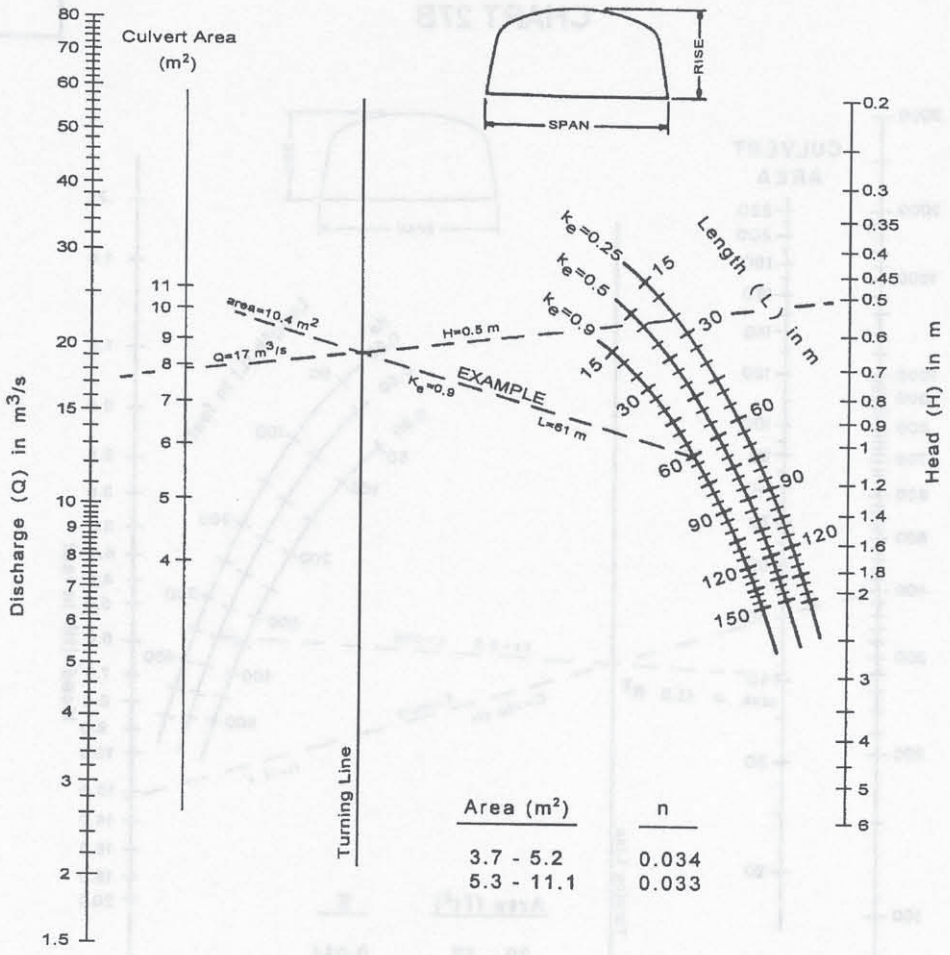
HEAD FOR C. M. BOX CULVERTS FLOWING FULL CORRUGATED METAL BOTTOM

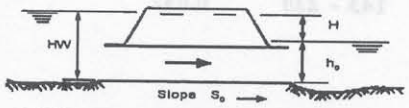
$0.4 \leq$ RISE/SPAN < 0.5

Nomographs adapted from material furnished by Kaiser Aluminum and Chemical Corporation

Duplication of this nomograph may distort scale

CHART 28A



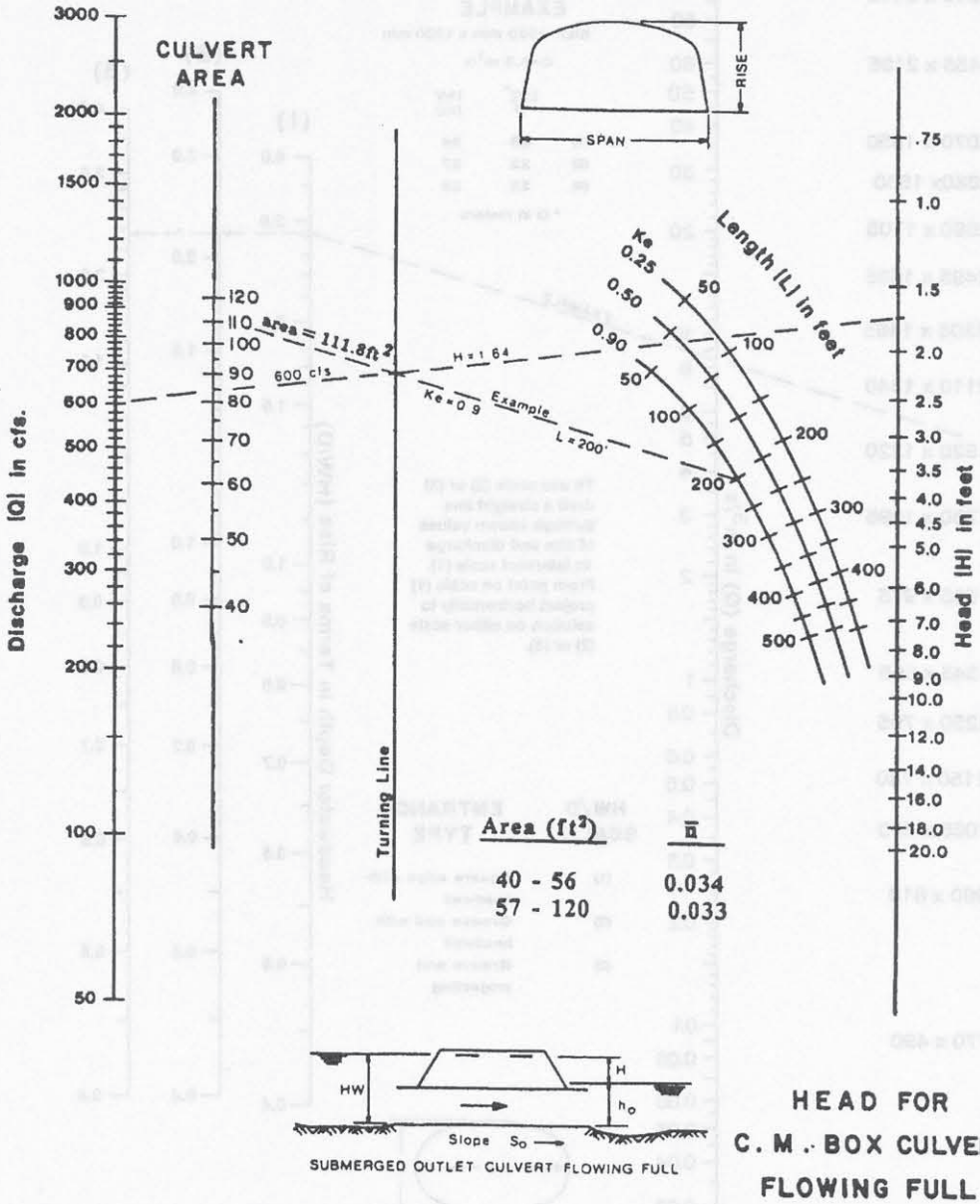


SUBMERGED OUTLET CULVERT FLOWING FULL

Adapted from
Kaiser Aluminum and Chemical Corporation

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

CHART 28B

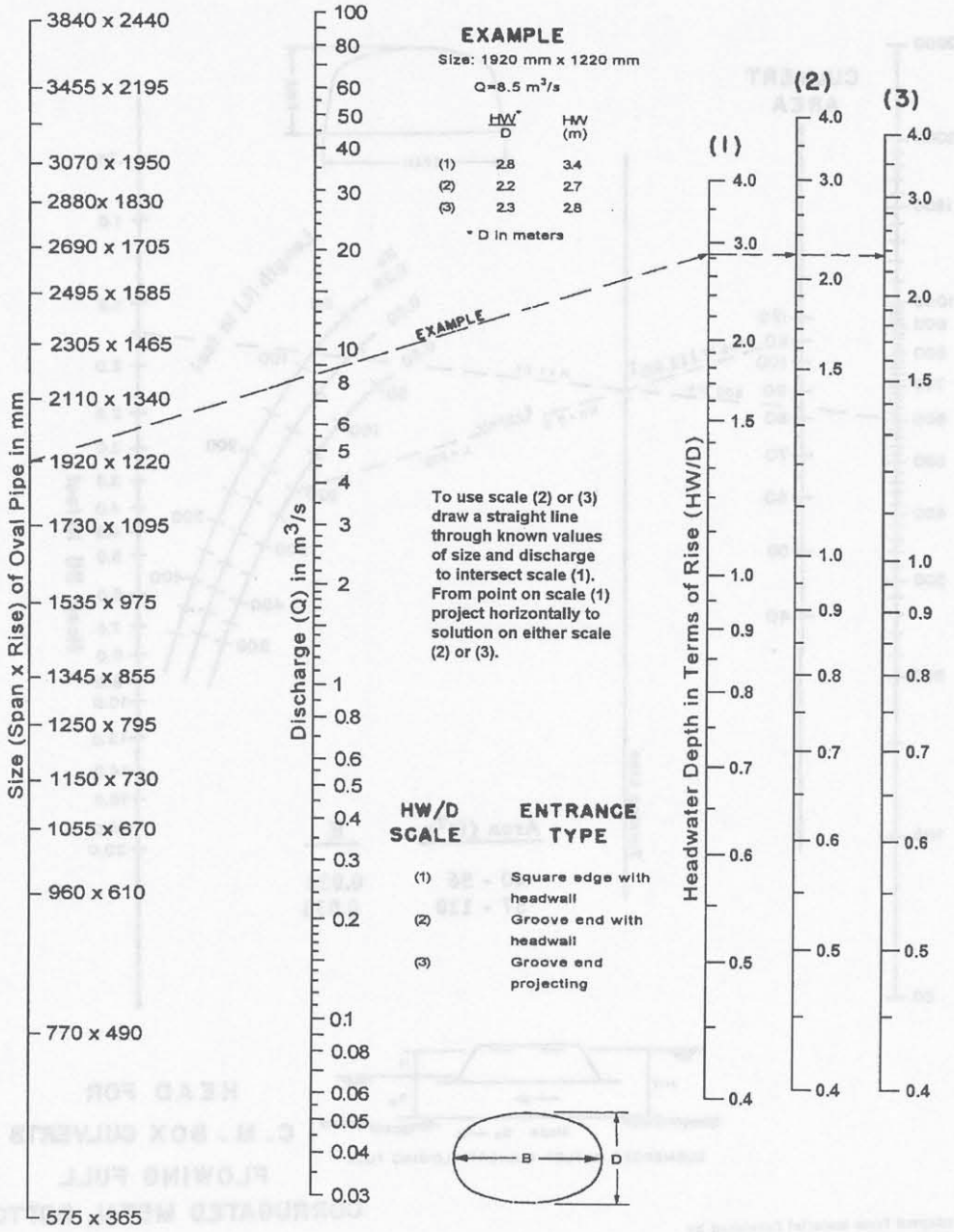


HEAD FOR
C. M. BOX CULVERTS
FLOWING FULL
CORRUGATED METAL BOTTOM
0.5 ≤ RISE/SPAN

Nomographs adapted from material furnished by Kaiser Aluminum and Chemical Corporation

Duplication of this nomograph may distort scale

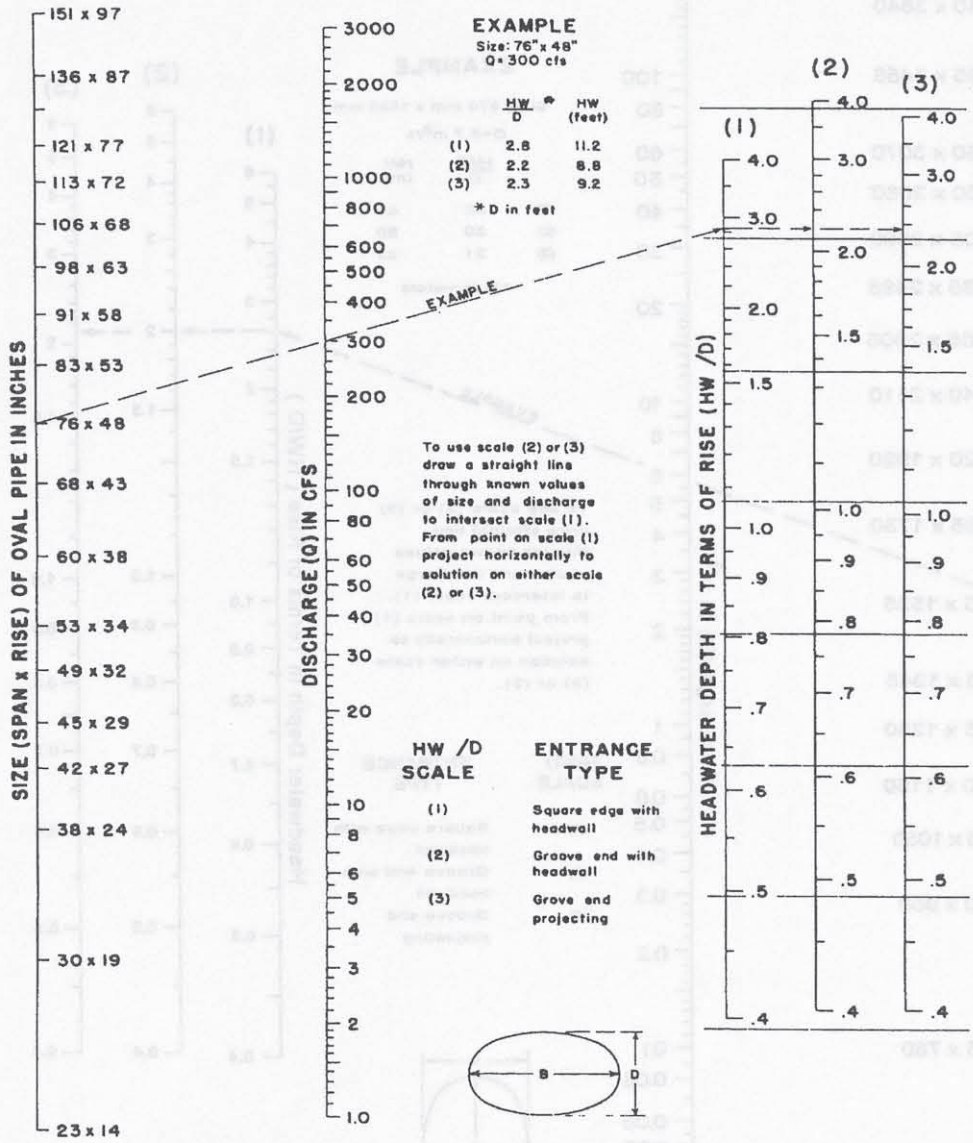
CHART 29A



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

Adapted from
Bureau of Public Roads Jan. 1963

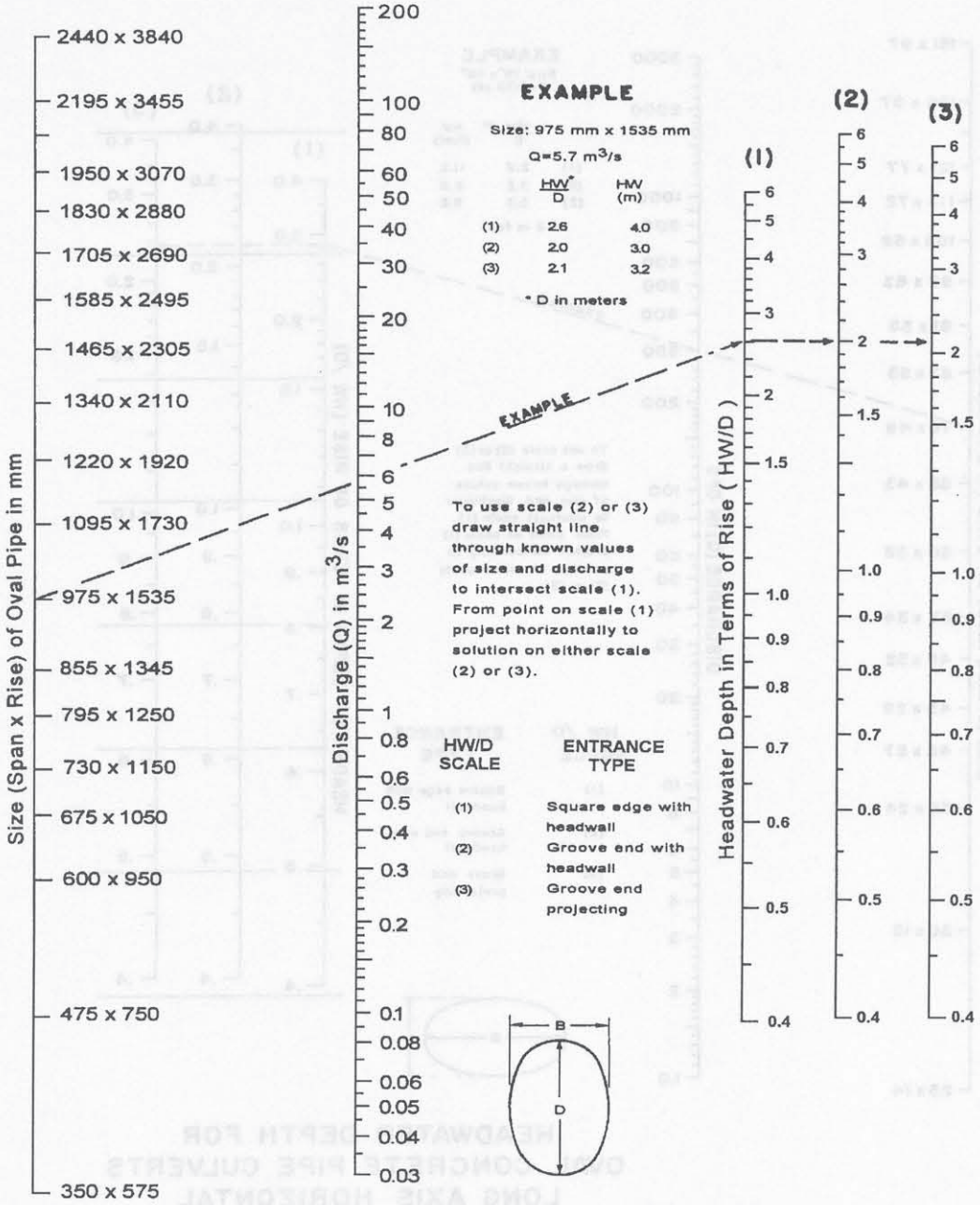
CHART 29B



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

BUREAU OF PUBLIC ROADS JAN. 1963

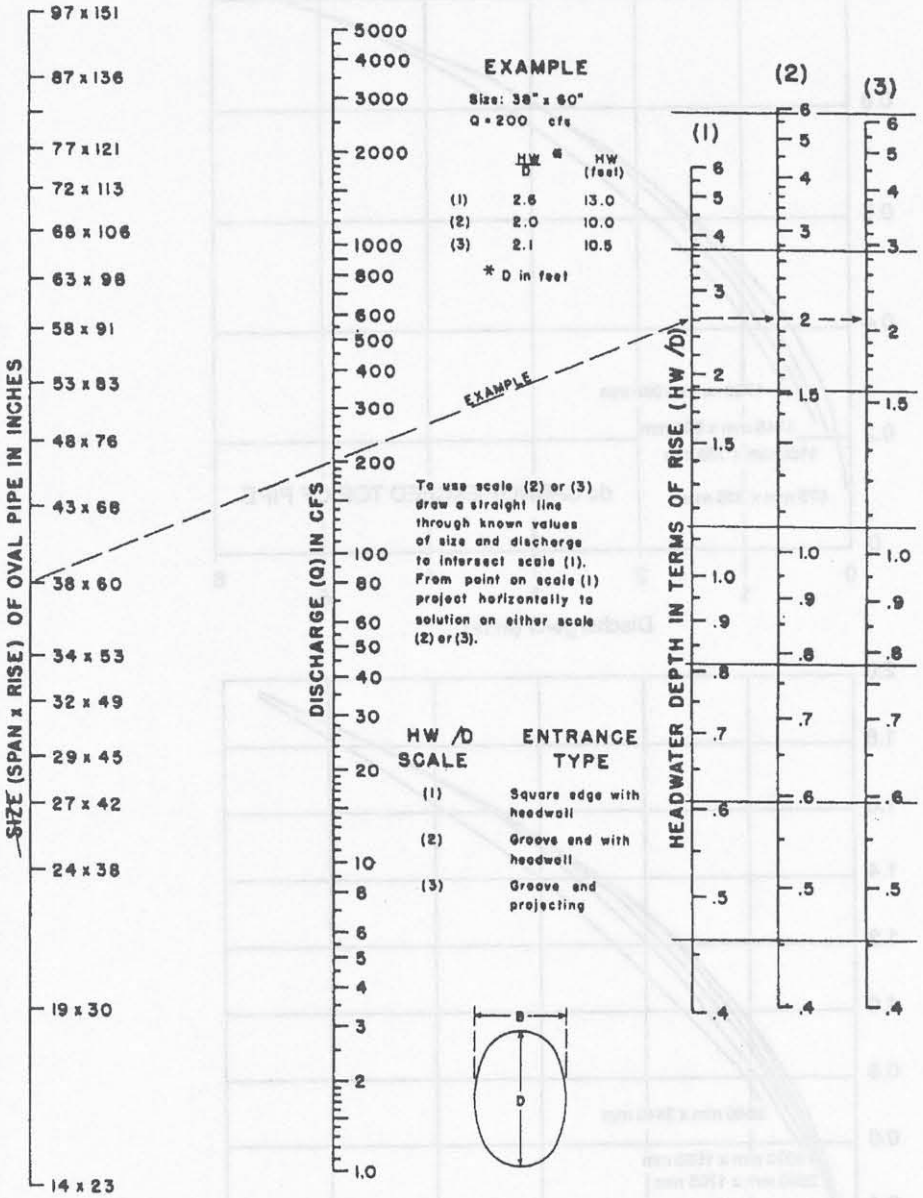
CHART 30A



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

Adapted from
Bureau of Public Roads Jan. 1963

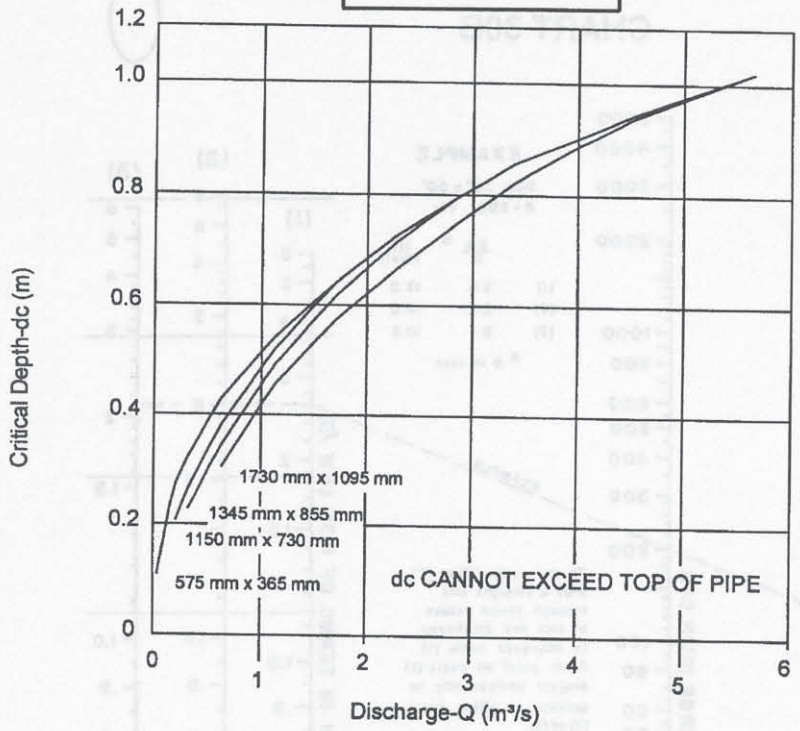
CHART 30B

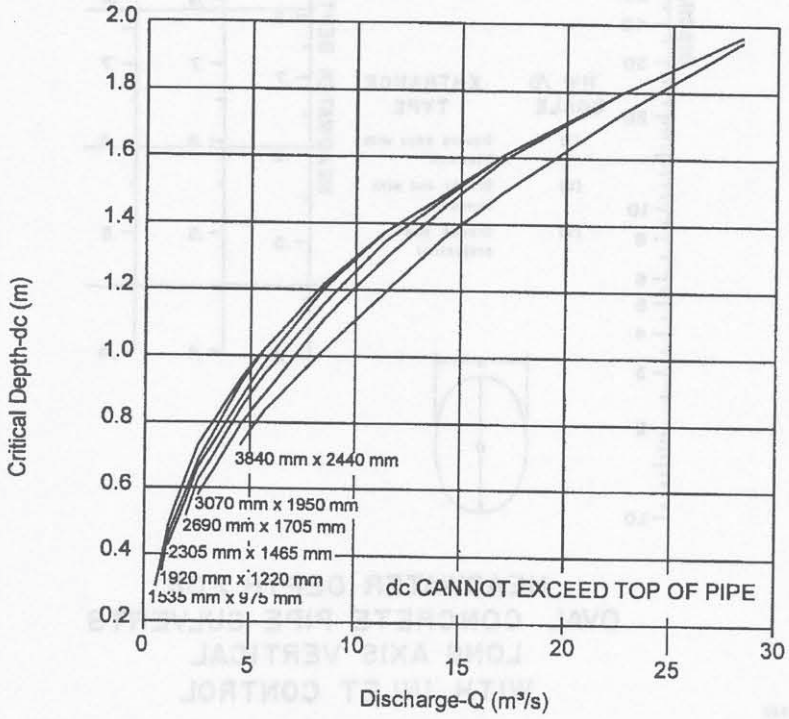


HEADWATER DEPTH FOR
OVAL CONCRETE PIPE CULVERTS
LONG AXIS VERTICAL
WITH INLET CONTROL

BUREAU OF PUBLIC ROADS JAN. 1963

CHART 31A

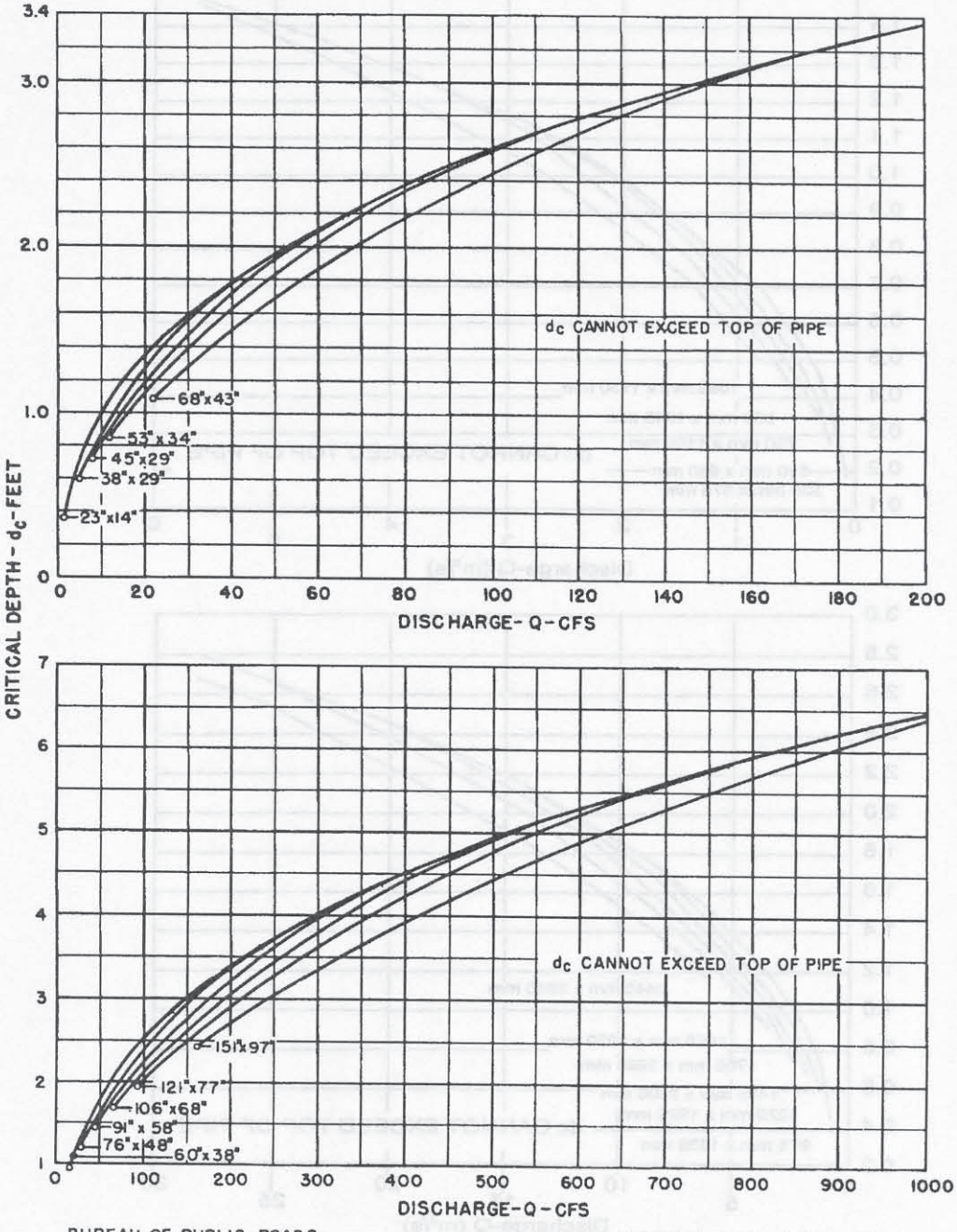




Adapted from Bureau of Public Roads

Critical Depth-Oval Concrete Pipe
Long Axis Horizontal

CHART 31B

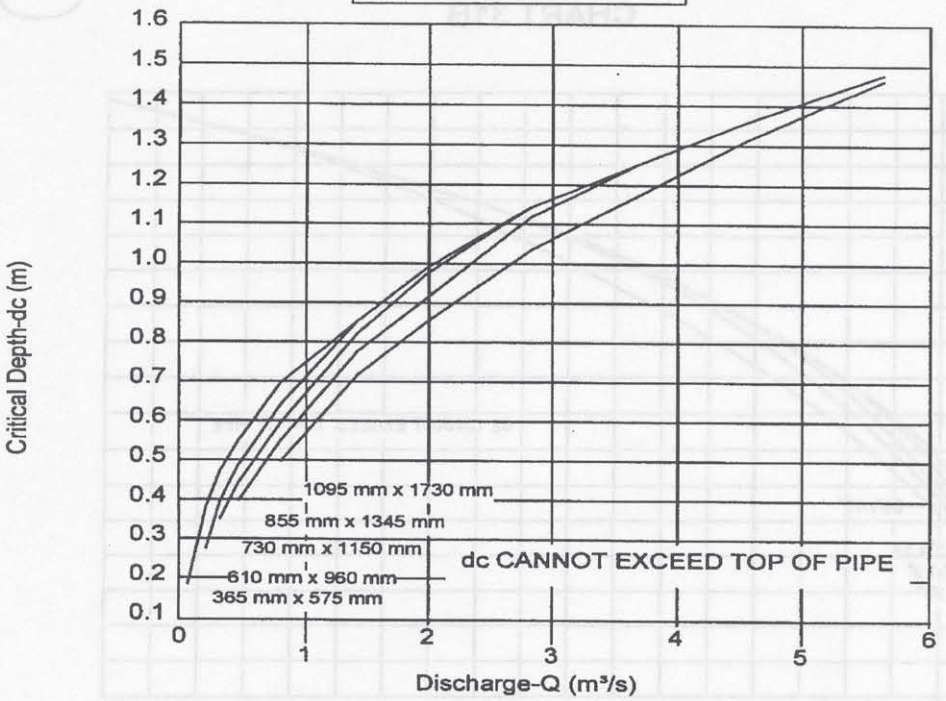


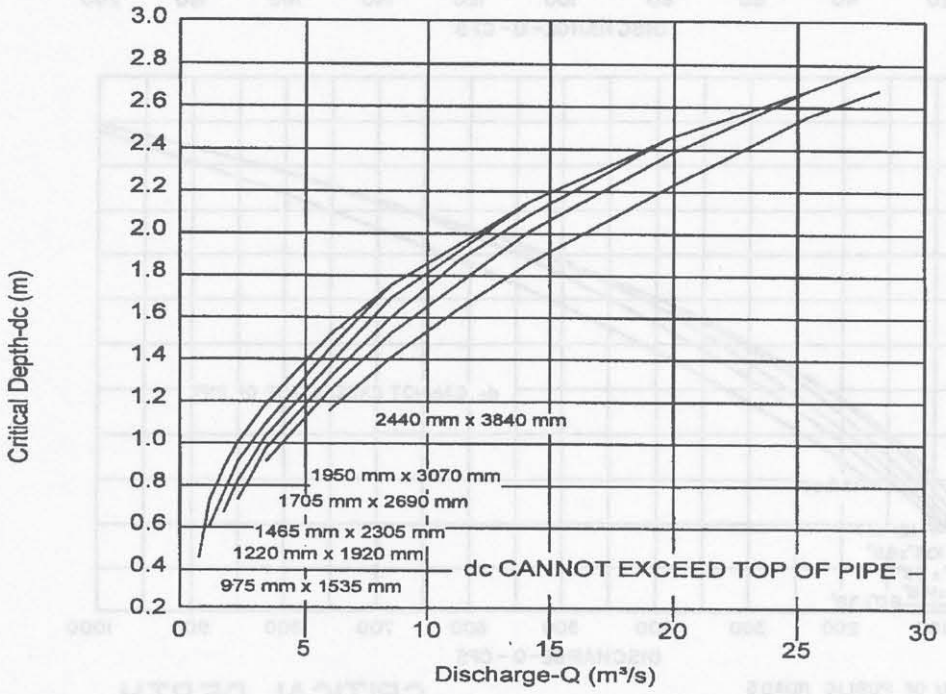
BUREAU OF PUBLIC ROADS

JAN. 1964

CRITICAL DEPTH
OVAL CONCRETE PIPE
LONG AXIS HORIZONTAL

CHART 32A

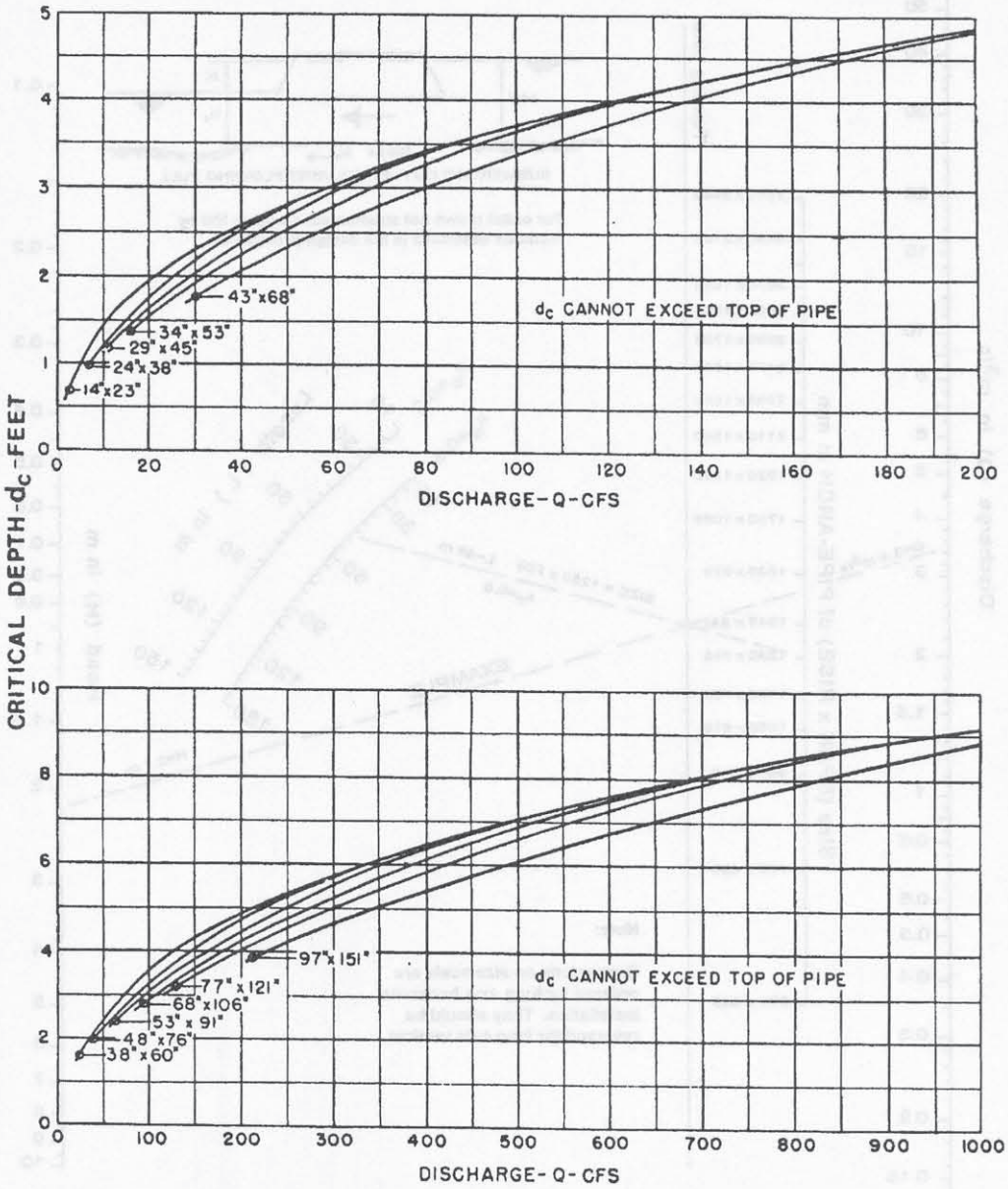




Adapted from Bureau of Public Roads

Critical Depth-Oval Concrete Pipe
Long Axis Vertical

CHART 32B

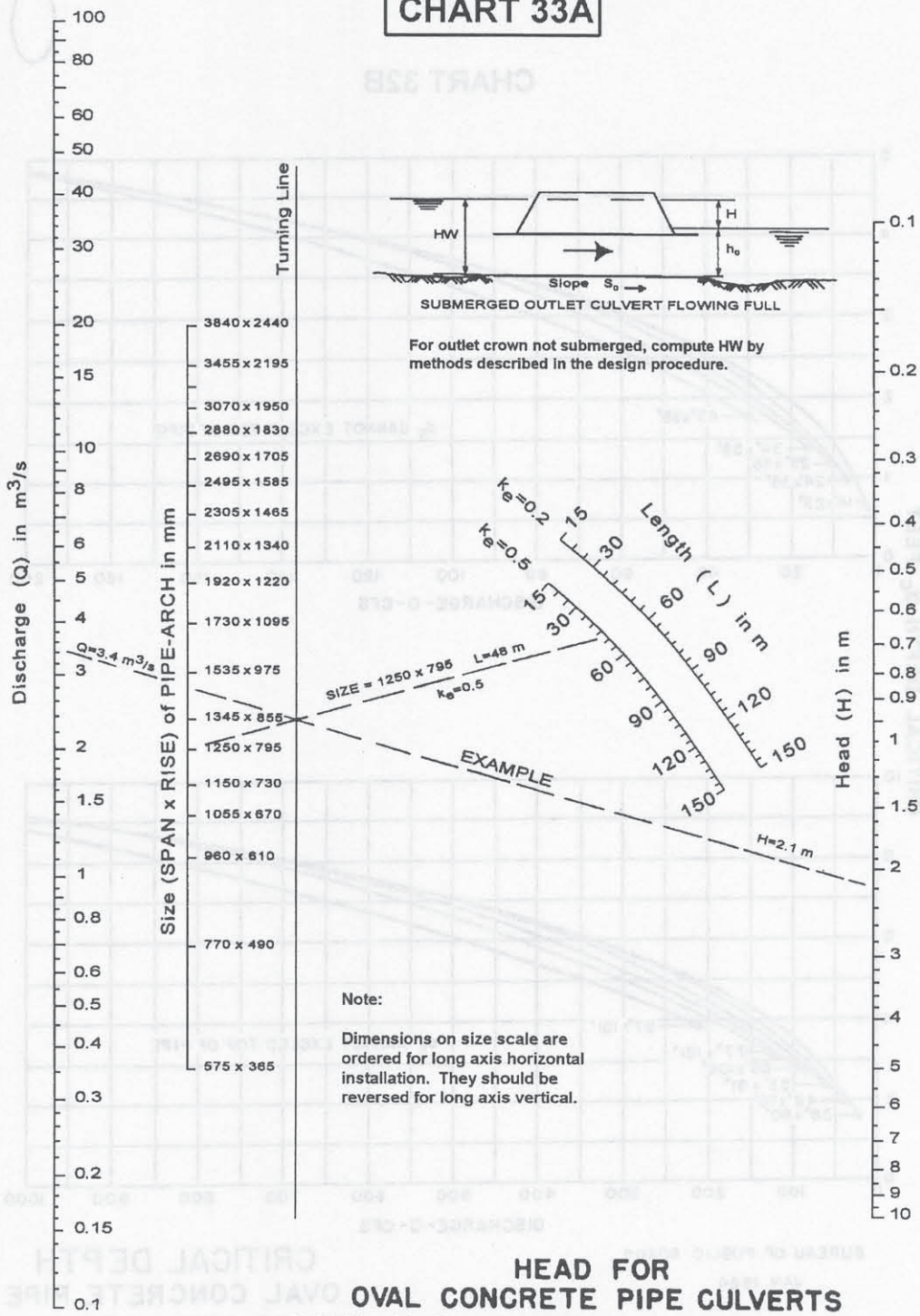


BUREAU OF PUBLIC ROADS

JAN. 1964

CRITICAL DEPTH
OVAL CONCRETE PIPE
LONG AXIS VERTICAL

CHART 33A

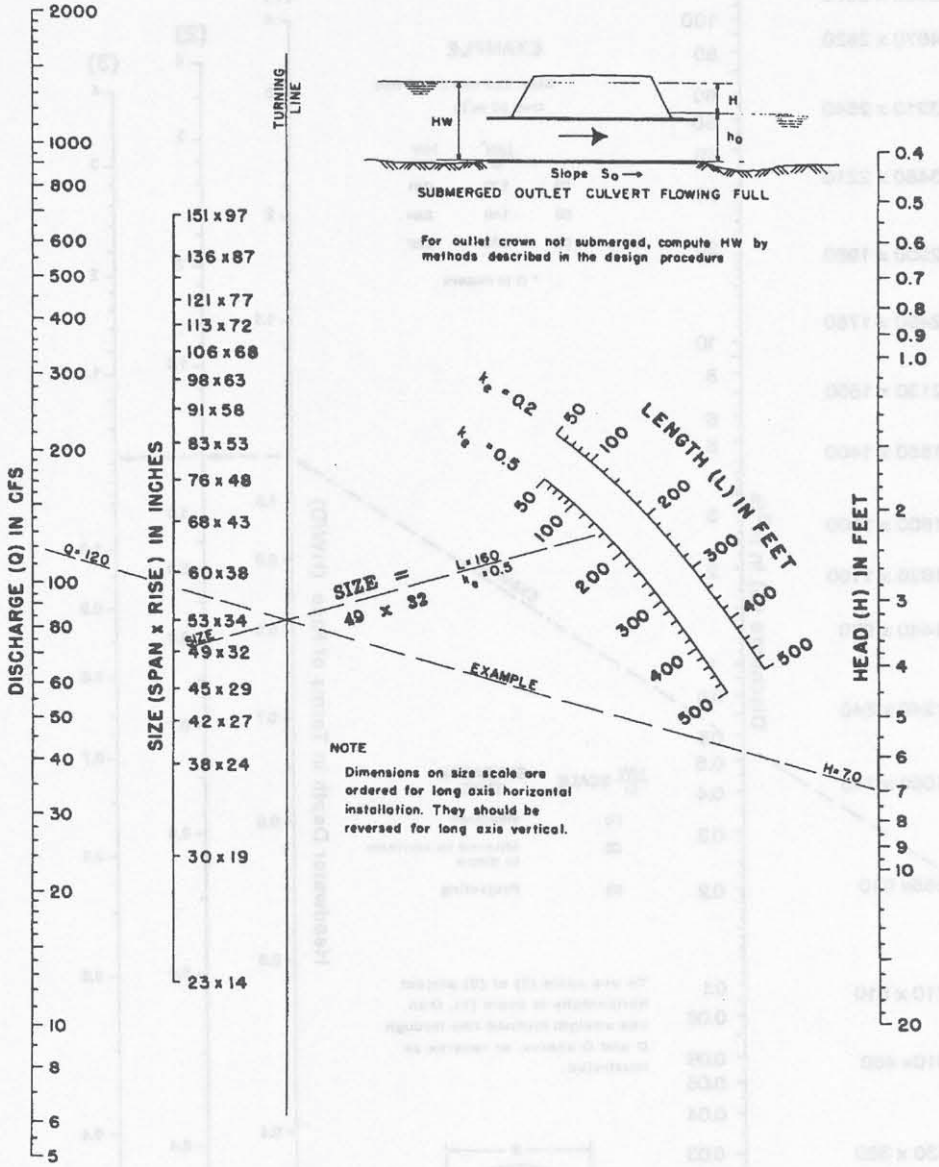


HEAD FOR OVAL CONCRETE PIPE CULVERTS LONG AXIS HORIZONTAL OR VERTICAL FLOWING FULL

n = 0.012

Adapted from
Bureau of Public Roads Jan. 1963

CHART 33B

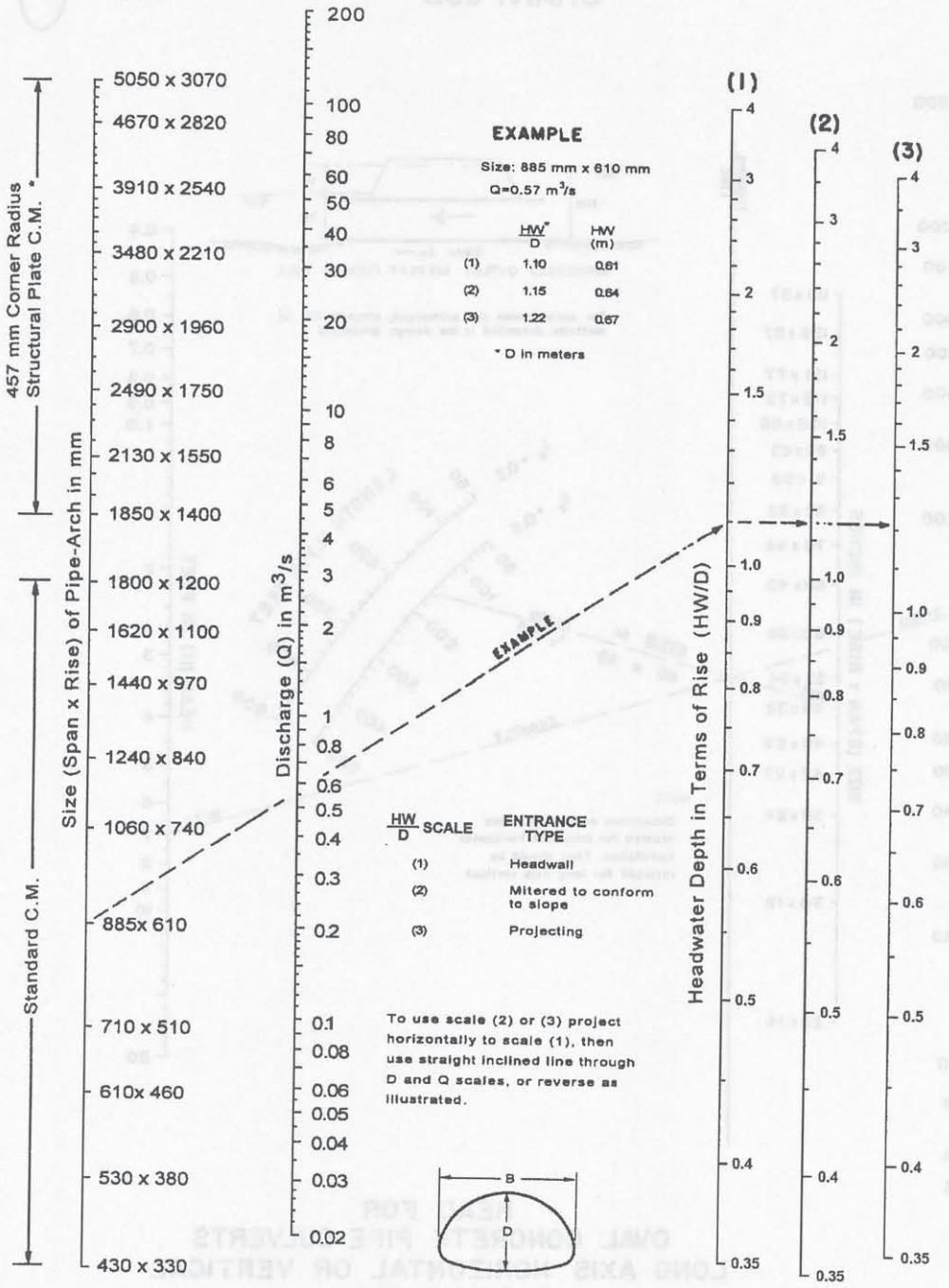


HEAD FOR OVAL CONCRETE PIPE CULVERTS LONG AXIS HORIZONTAL OR VERTICAL FLOWING FULL

n = 0.012

BUREAU OF PUBLIC ROADS JAN. 1963

CHART 34A

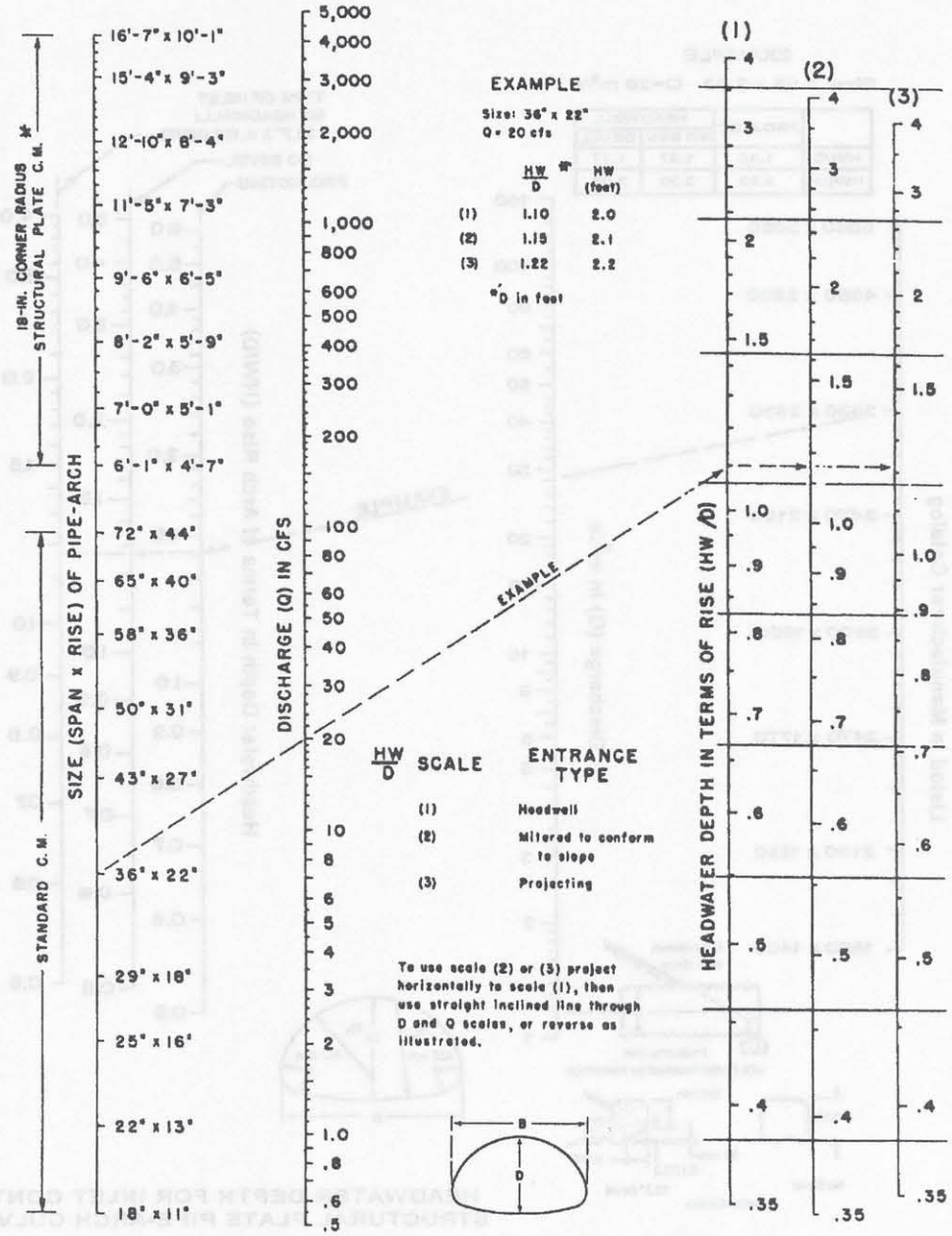


* Additional sizes not dimensioned are listed in fabricator's catalog

Adapted from
Bureau of Public Roads Jan. 1963

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

CHART 34B



*ADDITIONAL SIZES NOT DIMENSIONED ARE LISTED IN FABRICATOR'S CATALOG

BUREAU OF PUBLIC ROADS JAN. 1963

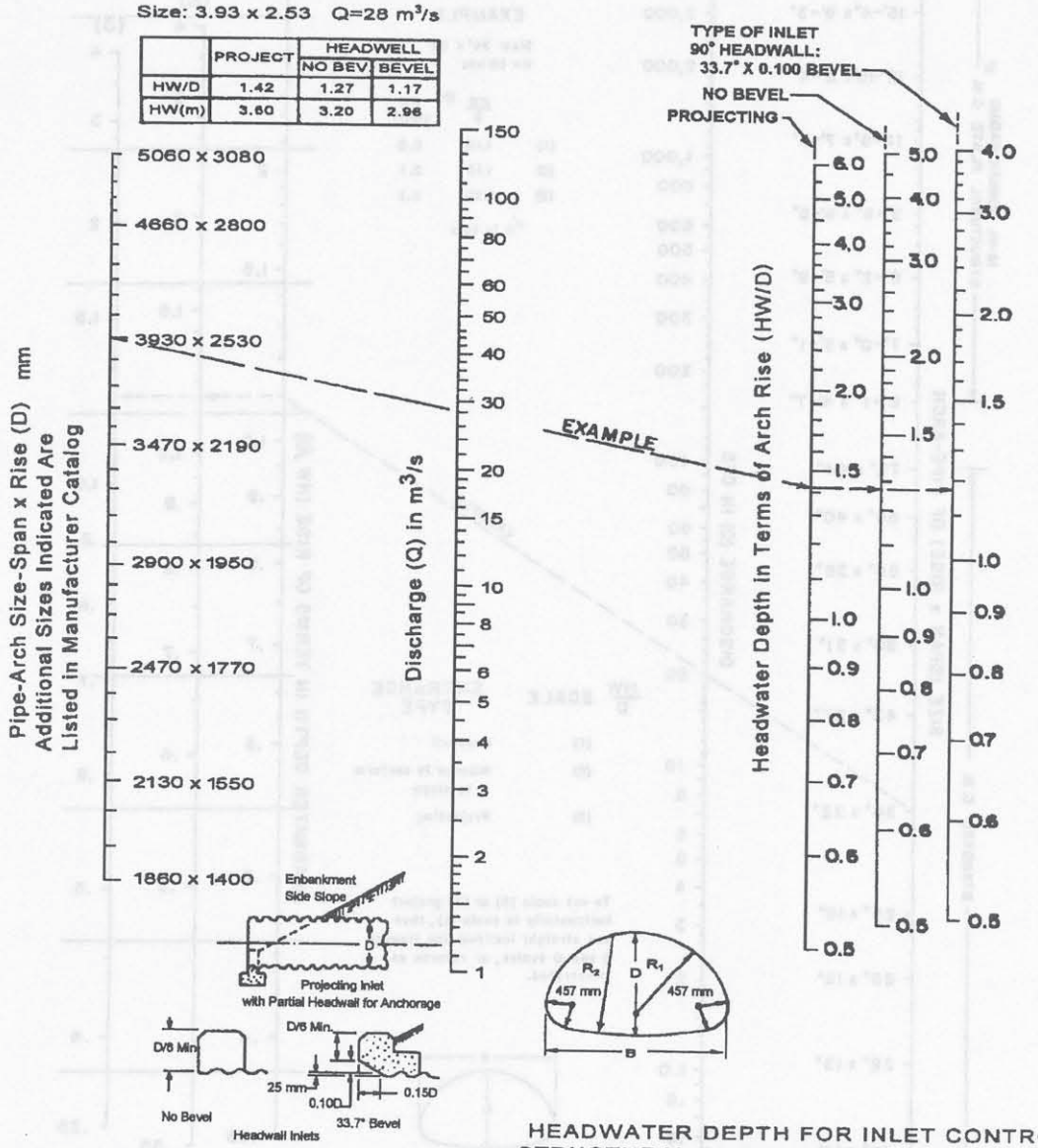
HEADWATER DEPTH FOR C. M. PIPE-ARCH CULVERTS WITH INLET CONTROL

CHART 35A

EXAMPLE

Size: 3.93 x 2.53 Q=28 m^3/s

	PROJECT	HEADWELL	
		NO BEV.	BEVEL
HW/D	1.42	1.27	1.17
HW(m)	3.60	3.20	2.96

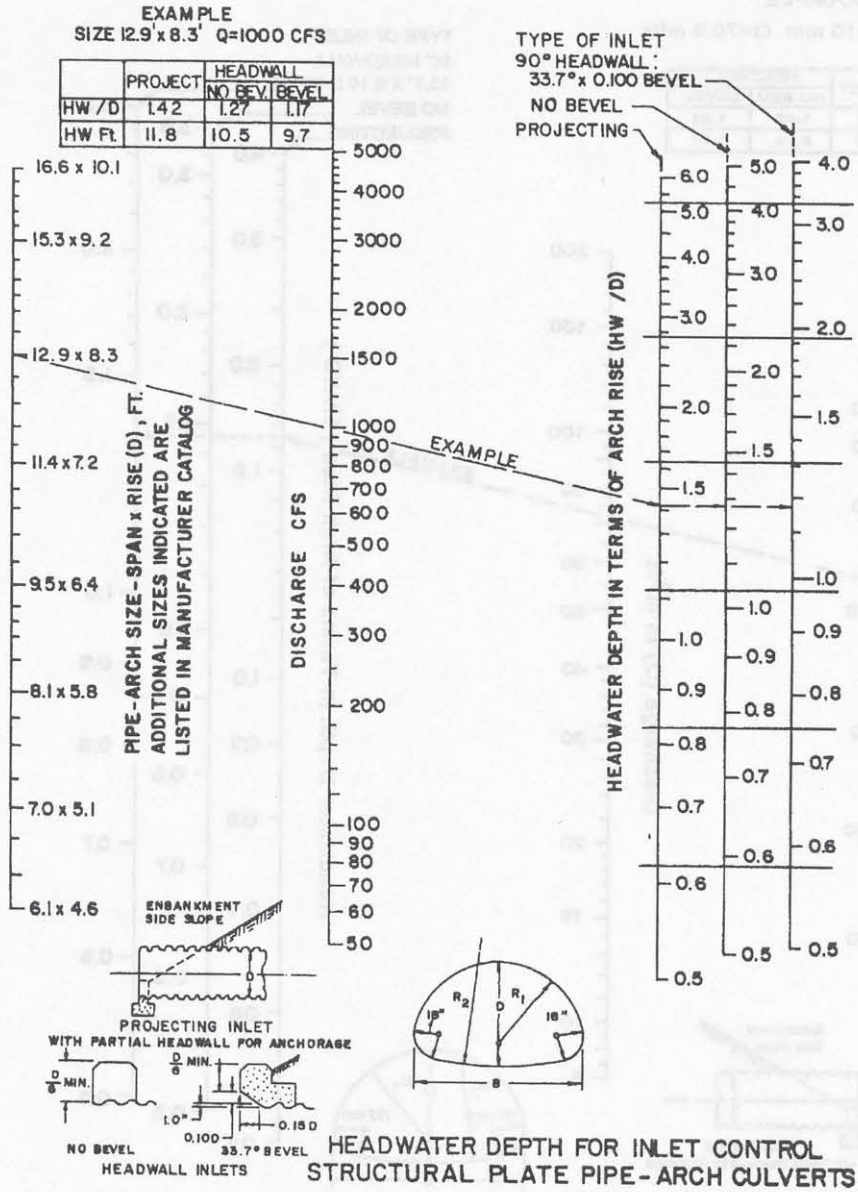


HEADWATER DEPTH FOR INLET CONTROL
STRUCTURAL PLATE PIPE-ARCH CULVERTS

457 mm RADIUS CORNER PLATE
PROJECTING OR HEADWALL INLET
HEADWALL WITH OR WITHOUT EDGE BEVEL

Adapted from
Bureau of Public Roads Office of R&D
July 1968

CHART 35B



HEADWATER DEPTH FOR INLET CONTROL
STRUCTURAL PLATE PIPE-ARCH CULVERTS

18-IN. RADIUS CORNER PLATE
PROJECTING OR HEADWALL INLET
HEADWALL WITH OR WITHOUT EDGE BEVEL

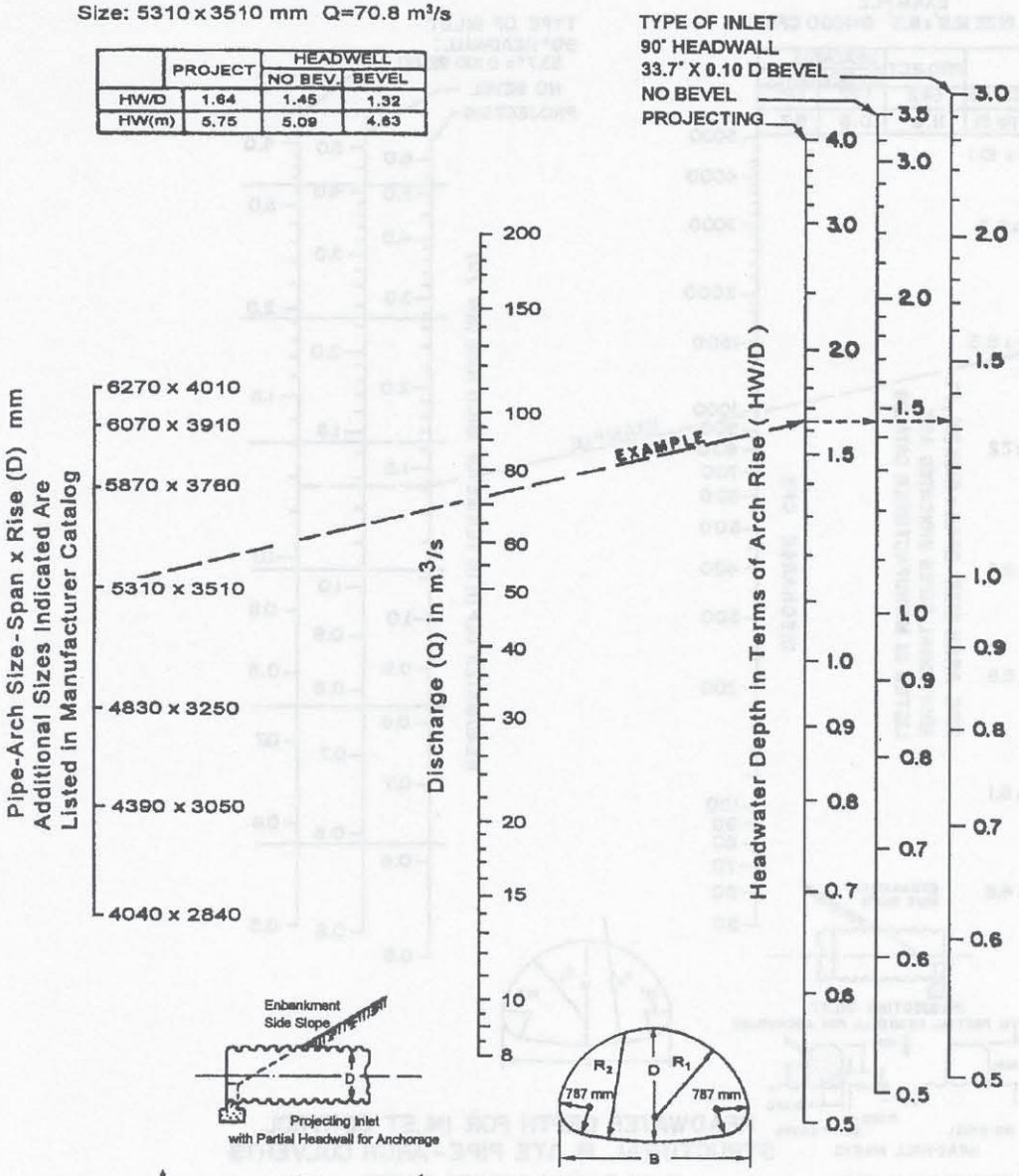
BUREAU OF PUBLIC ROADS
OFFICE OF R&D JULY 1968

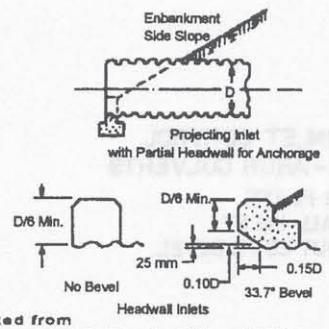
CHART 36A

EXAMPLE

Size: 5310 x 3510 mm Q=70.8 m³/s

	PROJECT	HEADWELL	
		NO BEV.	BEVEL
HW/D	1.64	1.45	1.32
HW(m)	5.75	5.09	4.63



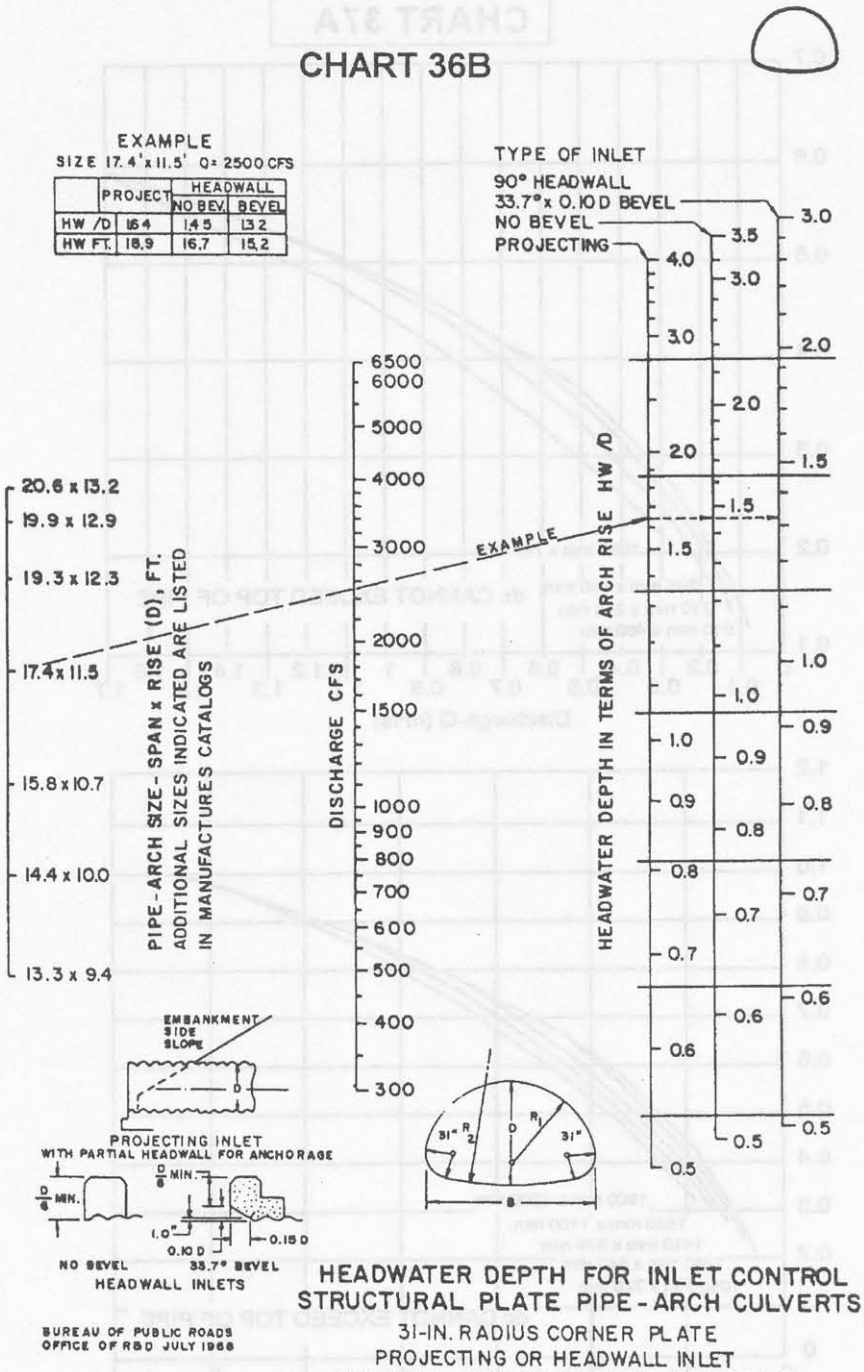


Adapted from
Bureau of Public Roads Office of R&D
July 1968

HEADWATER DEPTH FOR INLET CONTROL
STRUCTURAL PLATE PIPE-ARCH CULVERTS

787 mm RADIUS CORNER PLATE
PROJECTING OR HEADWALL INLET
HEADWALL WITH OR WITHOUT EDGE BEVEL

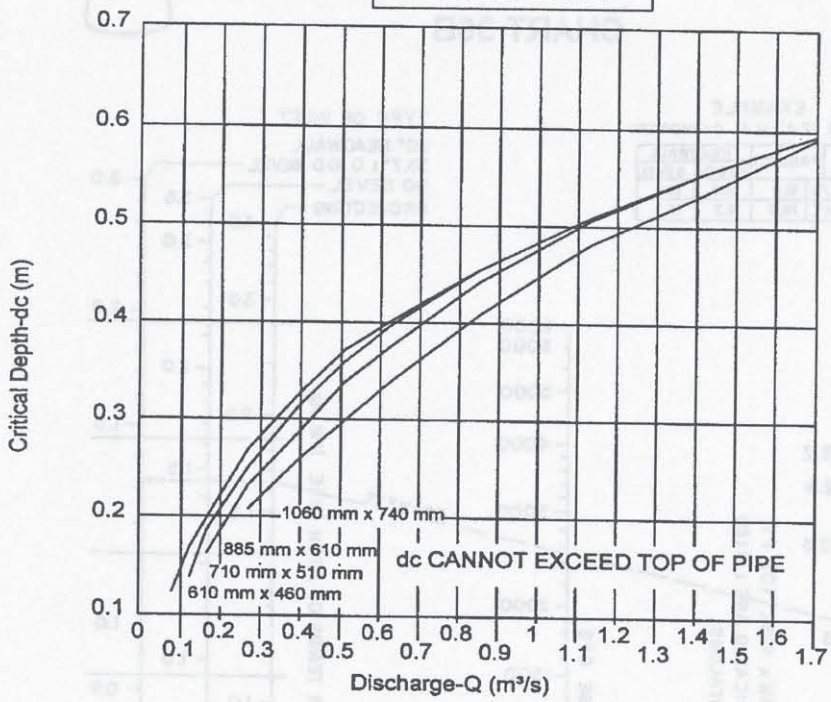
CHART 36B

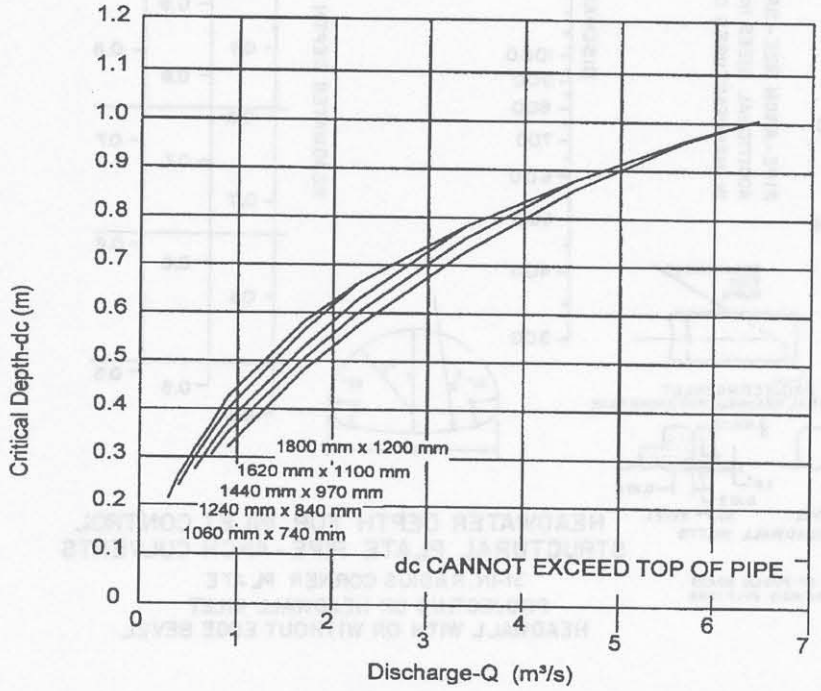


HEADWATER DEPTH FOR INLET CONTROL
STRUCTURAL PLATE PIPE-ARCH CULVERTS
31-IN. RADIUS CORNER PLATE
PROJECTING OR HEADWALL INLET
HEADWALL WITH OR WITHOUT EDGE BEVEL

BUREAU OF PUBLIC ROADS
OFFICE OF R&D JULY 1968

CHART 37A

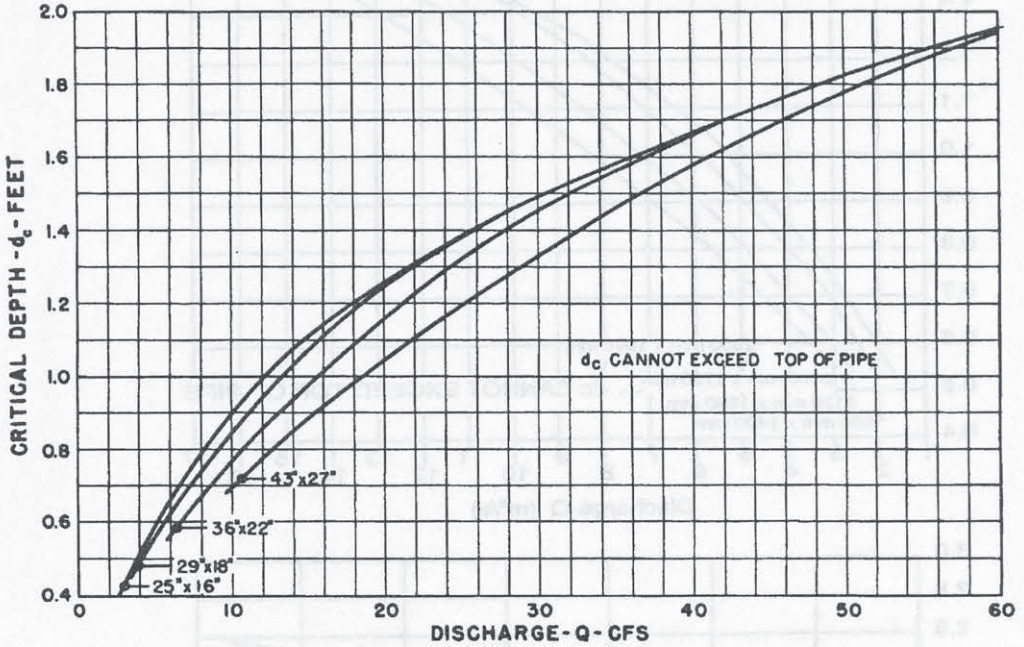


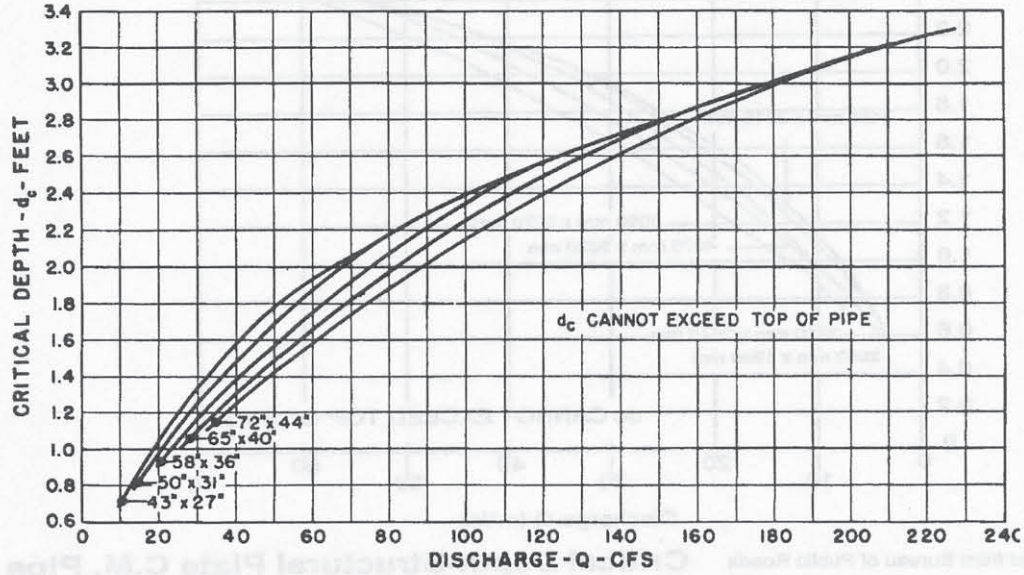


Adapted from Bureau of Public Roads

Critical Depth-Standard C.M. Pipe Arch

CHART 37B



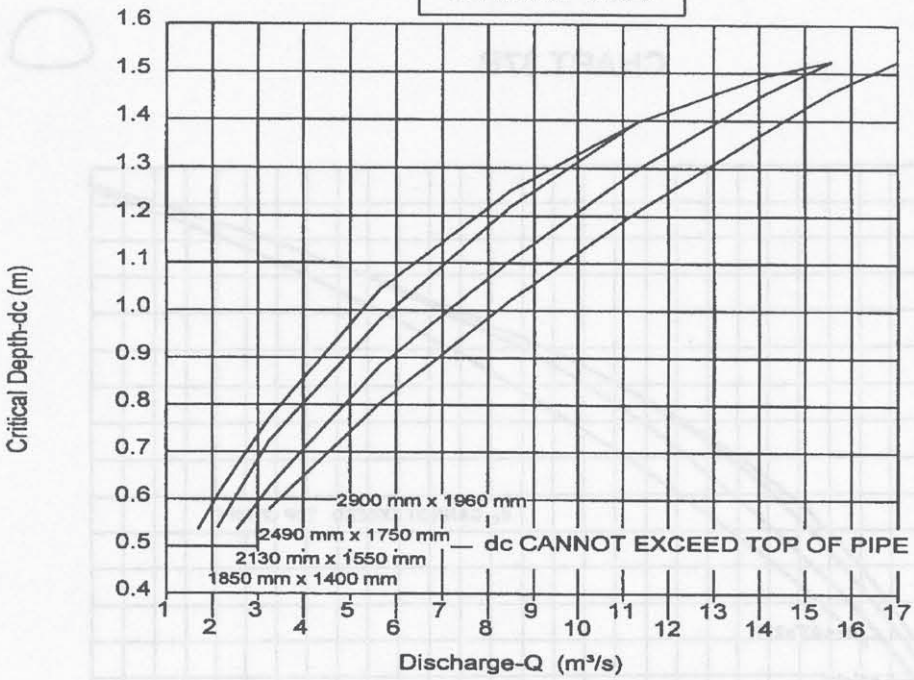


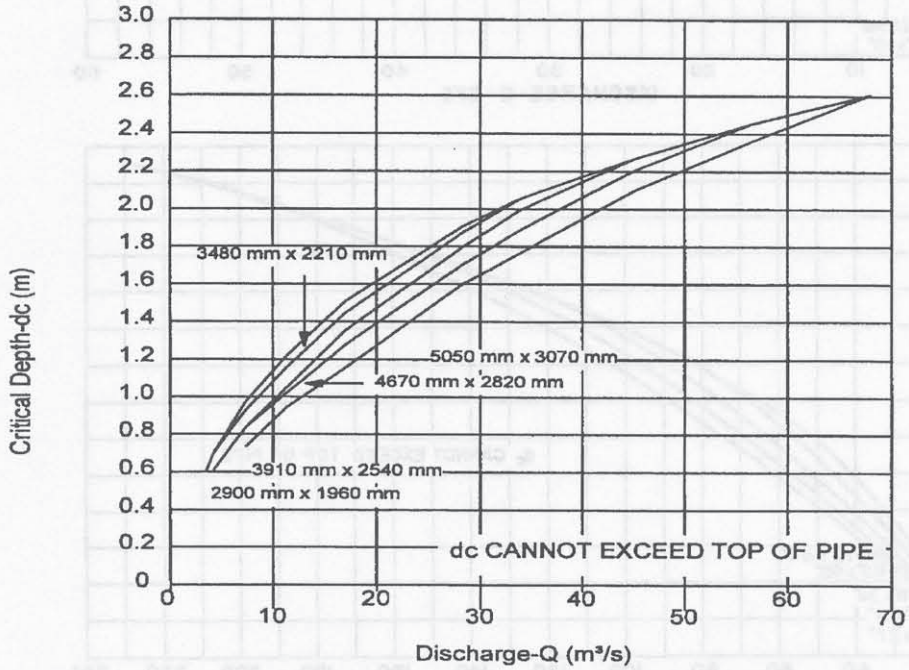
BUREAU OF PUBLIC ROADS

JAN. 1964

CRITICAL DEPTH
STANDARD C.M. PIPE-ARCH

CHART 38A

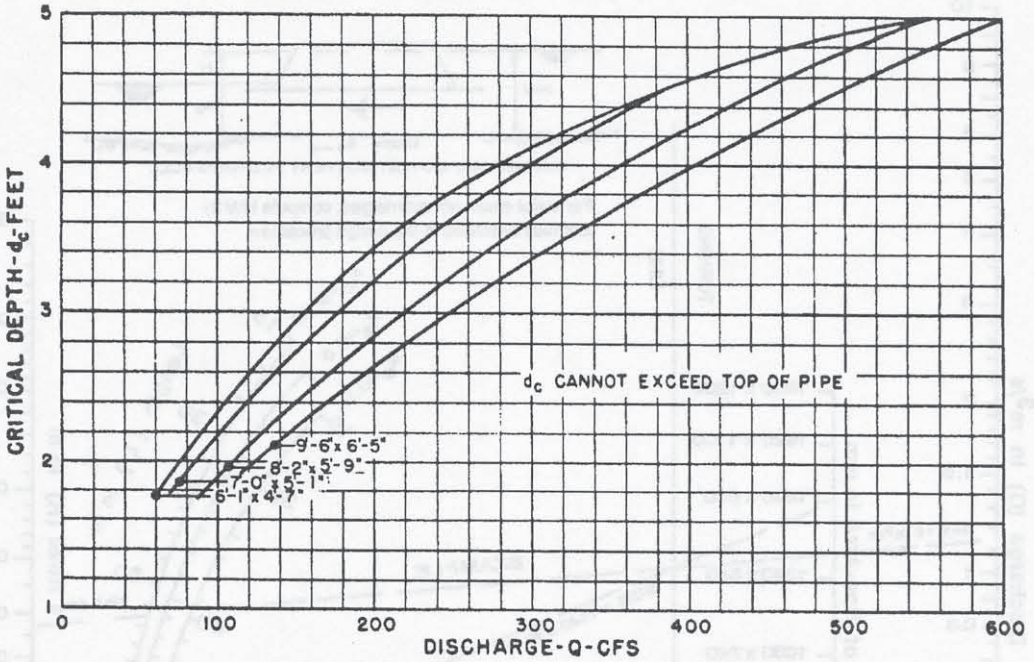


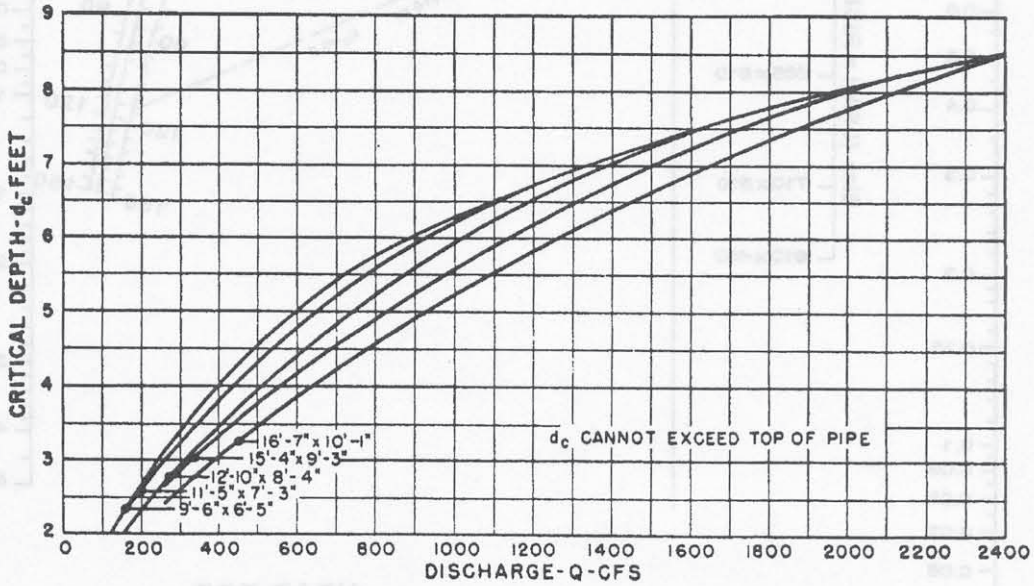


Adapted from Bureau of Public Roads

Critical Depth-Structural Plate C.M. Pipe Arch, 457 mm Corner Radius

CHART 38B

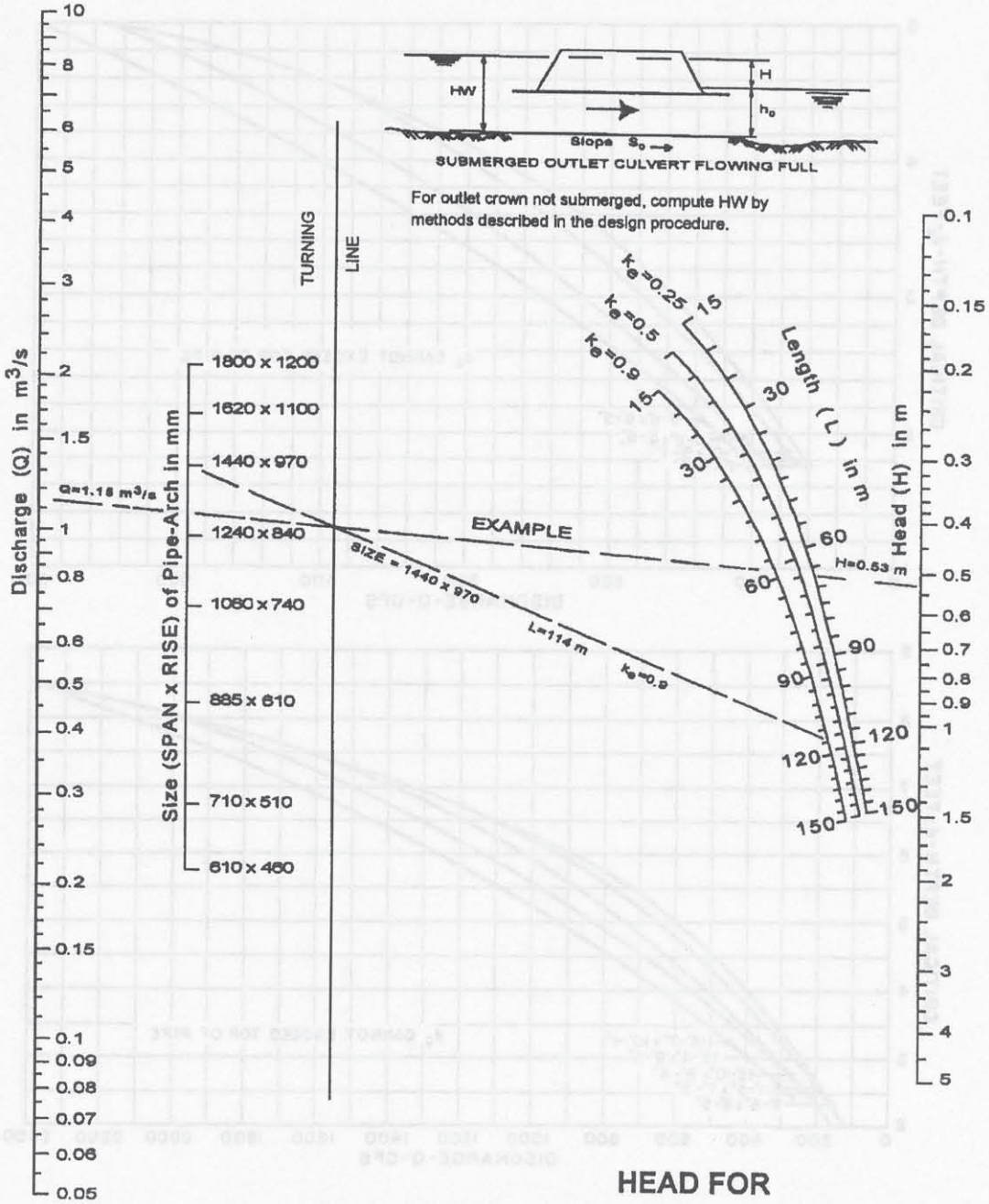




BUREAU OF PUBLIC ROADS
JAN. 1964

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

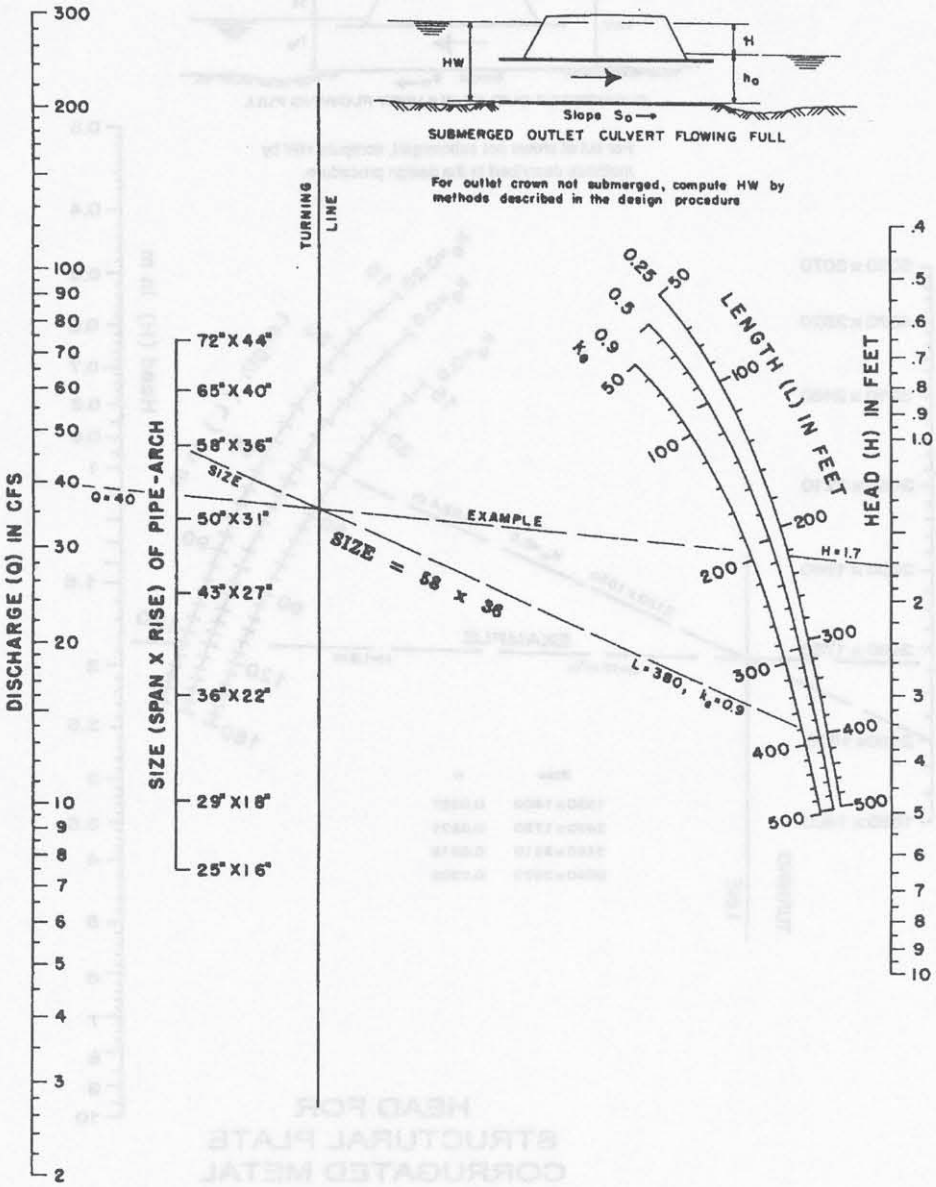
CHART 39A



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

Adapted from
Bureau of Public Roads Jan. 1963

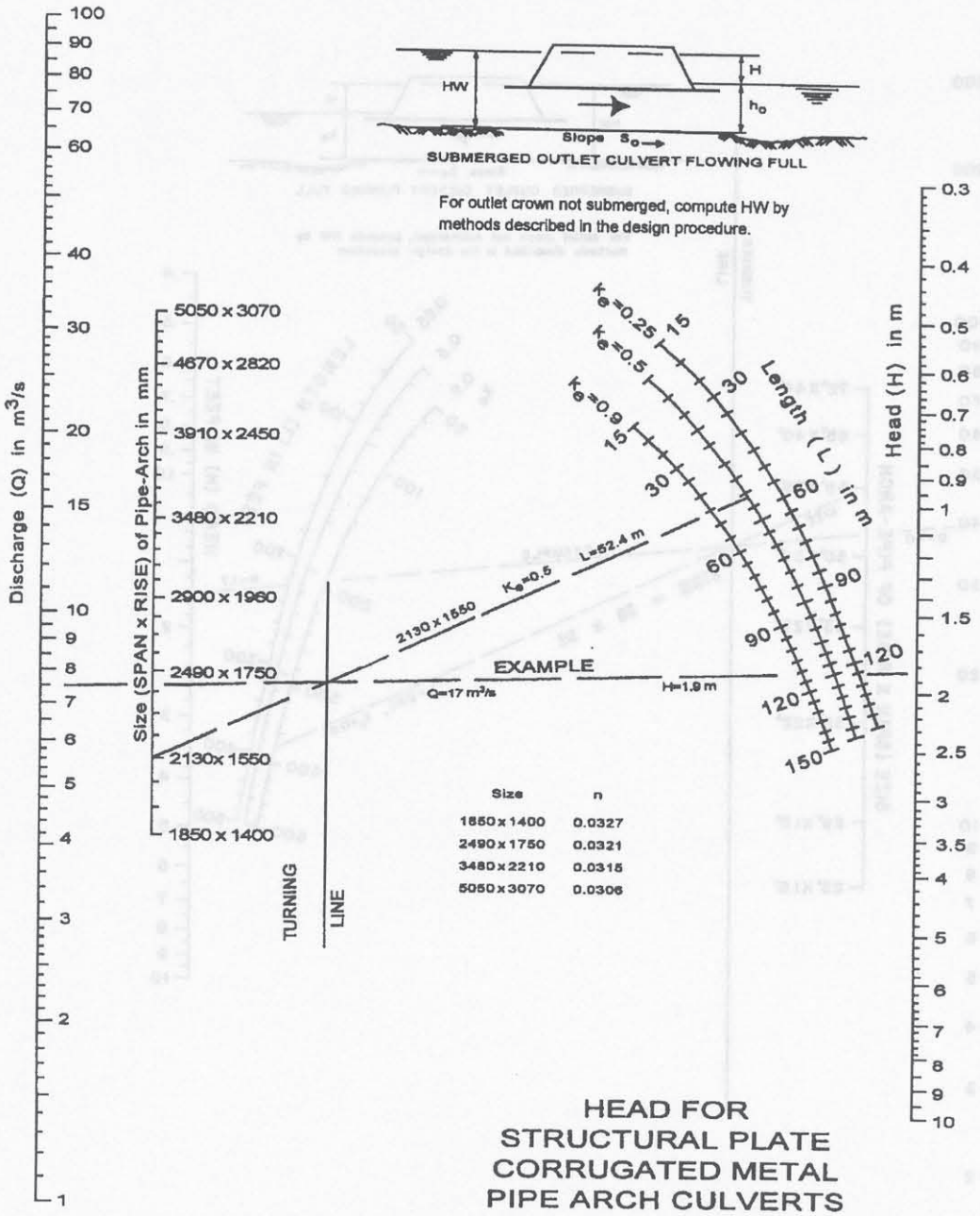
CHART 39B



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

BUREAU OF PUBLIC ROADS JAN. 1963

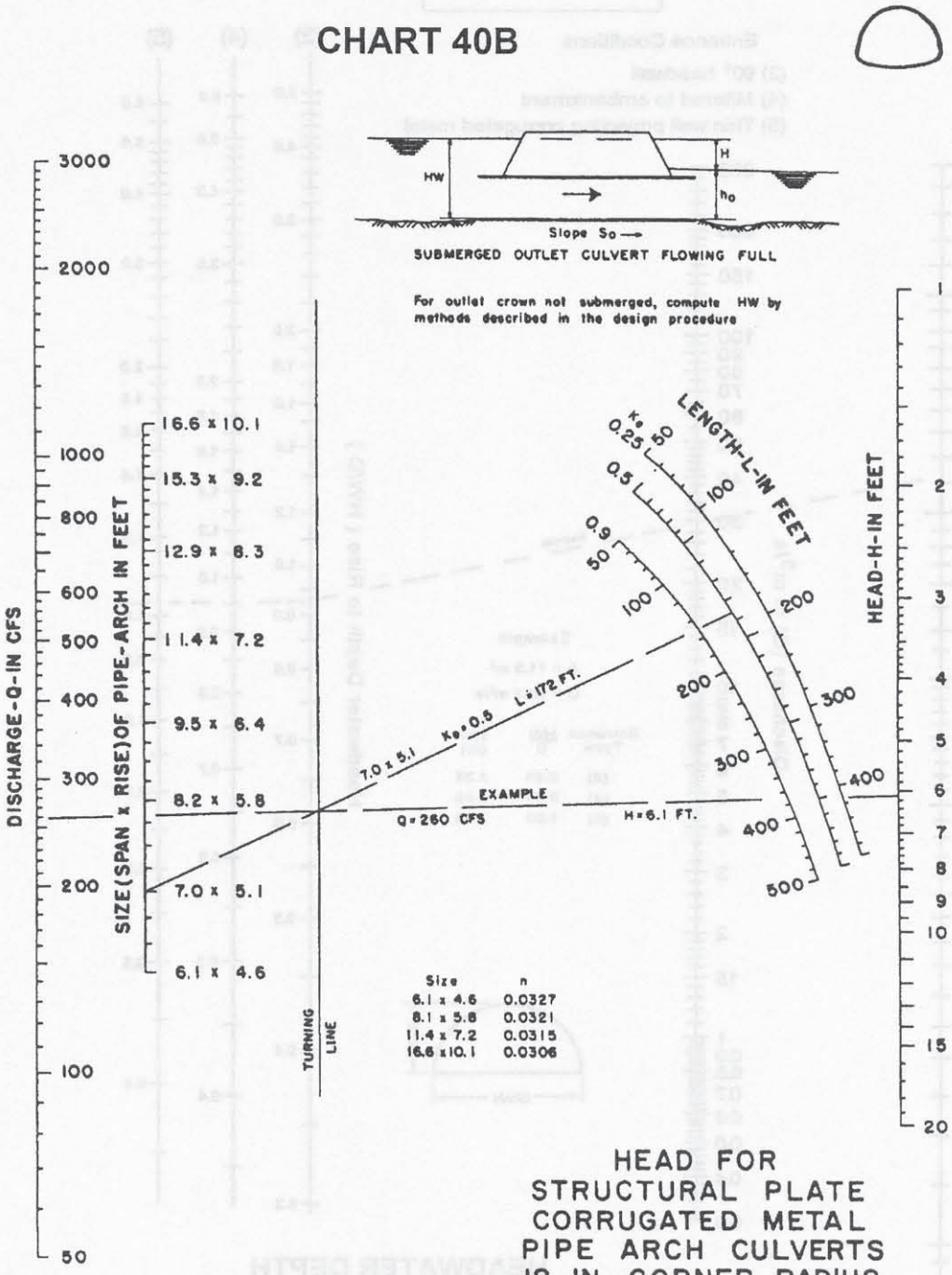
CHART 40A



HEAD FOR
STRUCTURAL PLATE
CORRUGATED METAL
PIPE ARCH CULVERTS
457 mm CORNER RADIUS
FLOWING FULL
n=0.0327 TO 0.0306

Adapted from
Bureau of Public Roads Jan. 1963

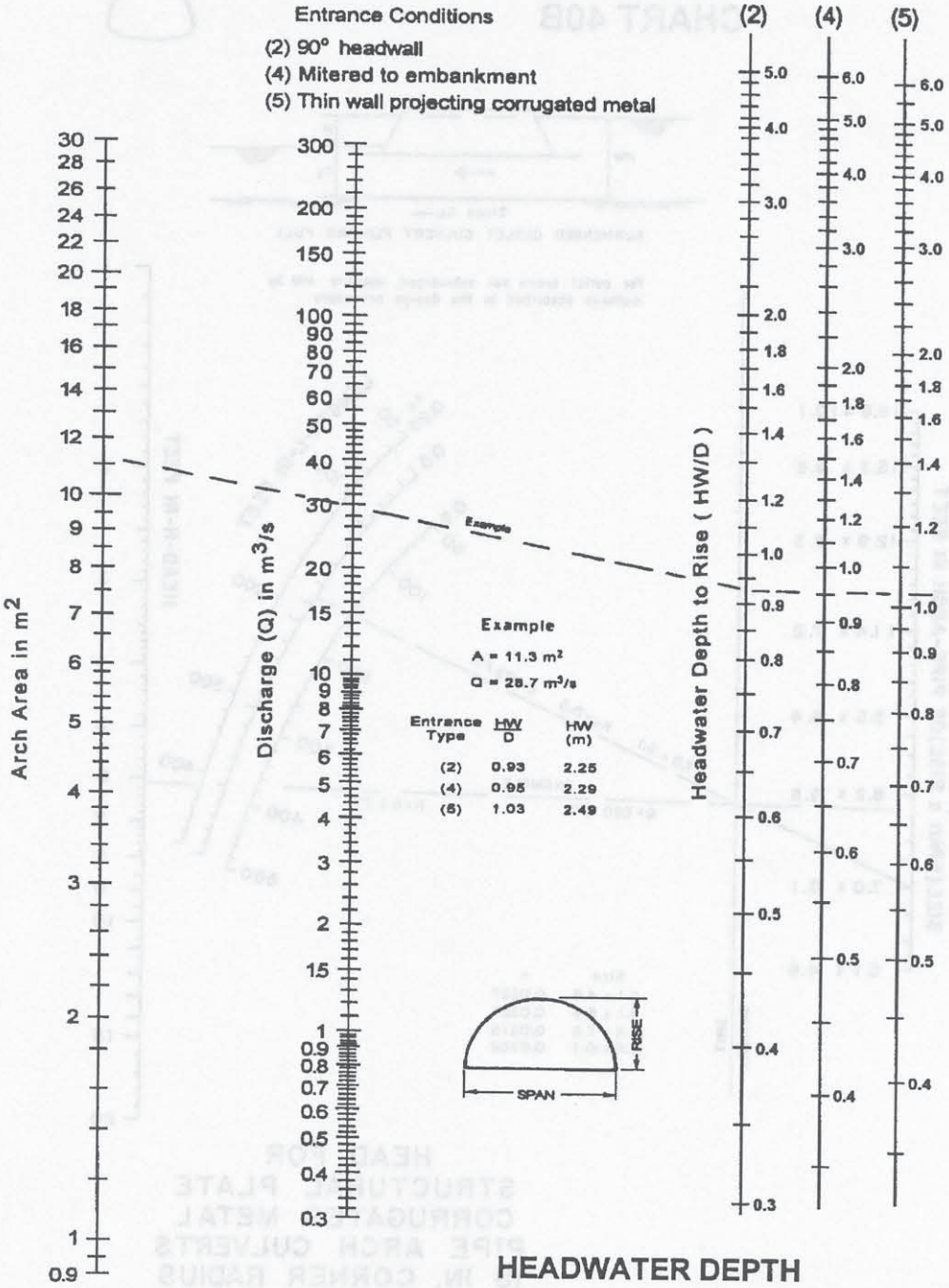
CHART 40B



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

BUREAU OF PUBLIC ROADS JAN. 1963

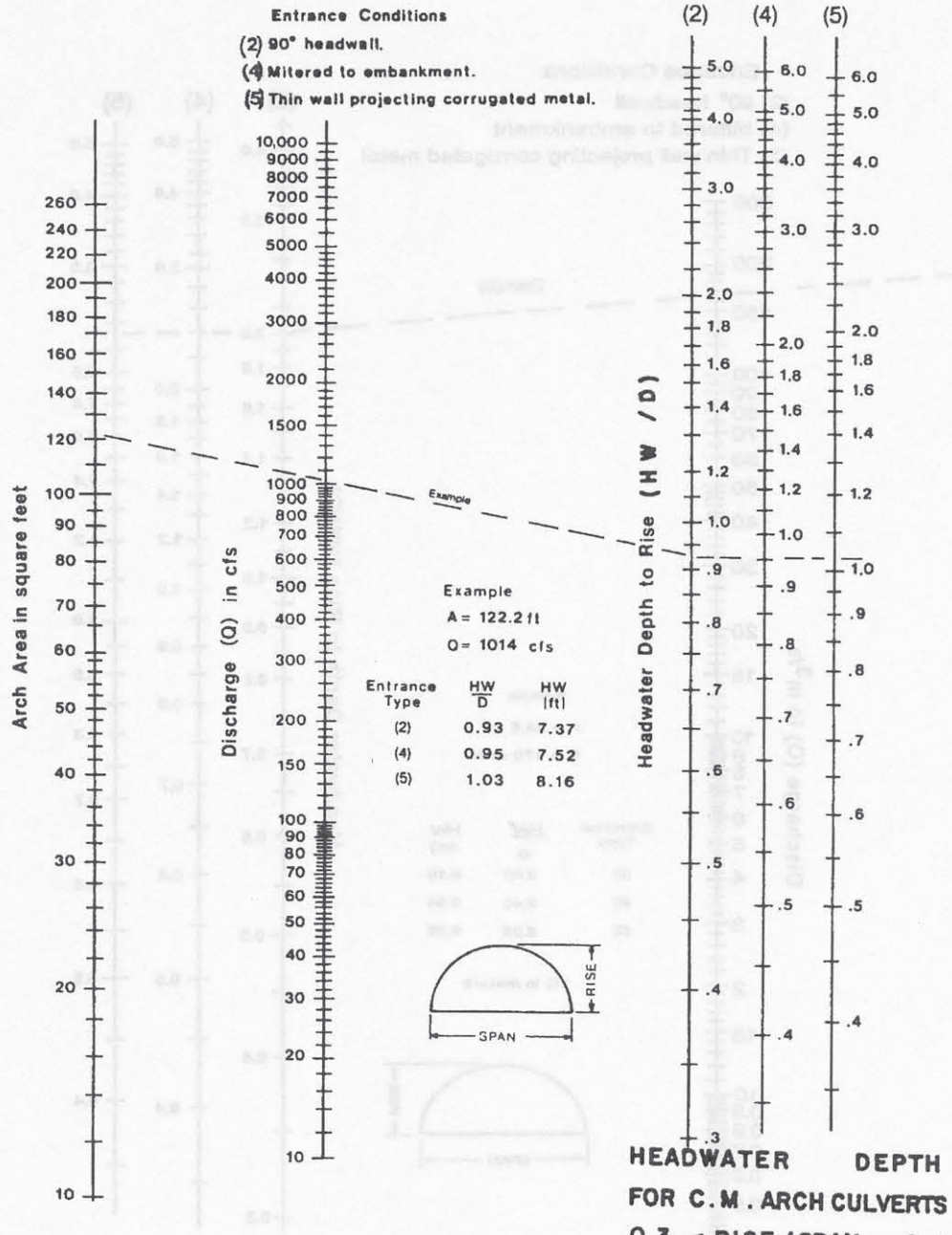
CHART 41A



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

Nomographs adapted from material furnished by Kaiser Aluminum and Chemical Corporation

CHART 41B

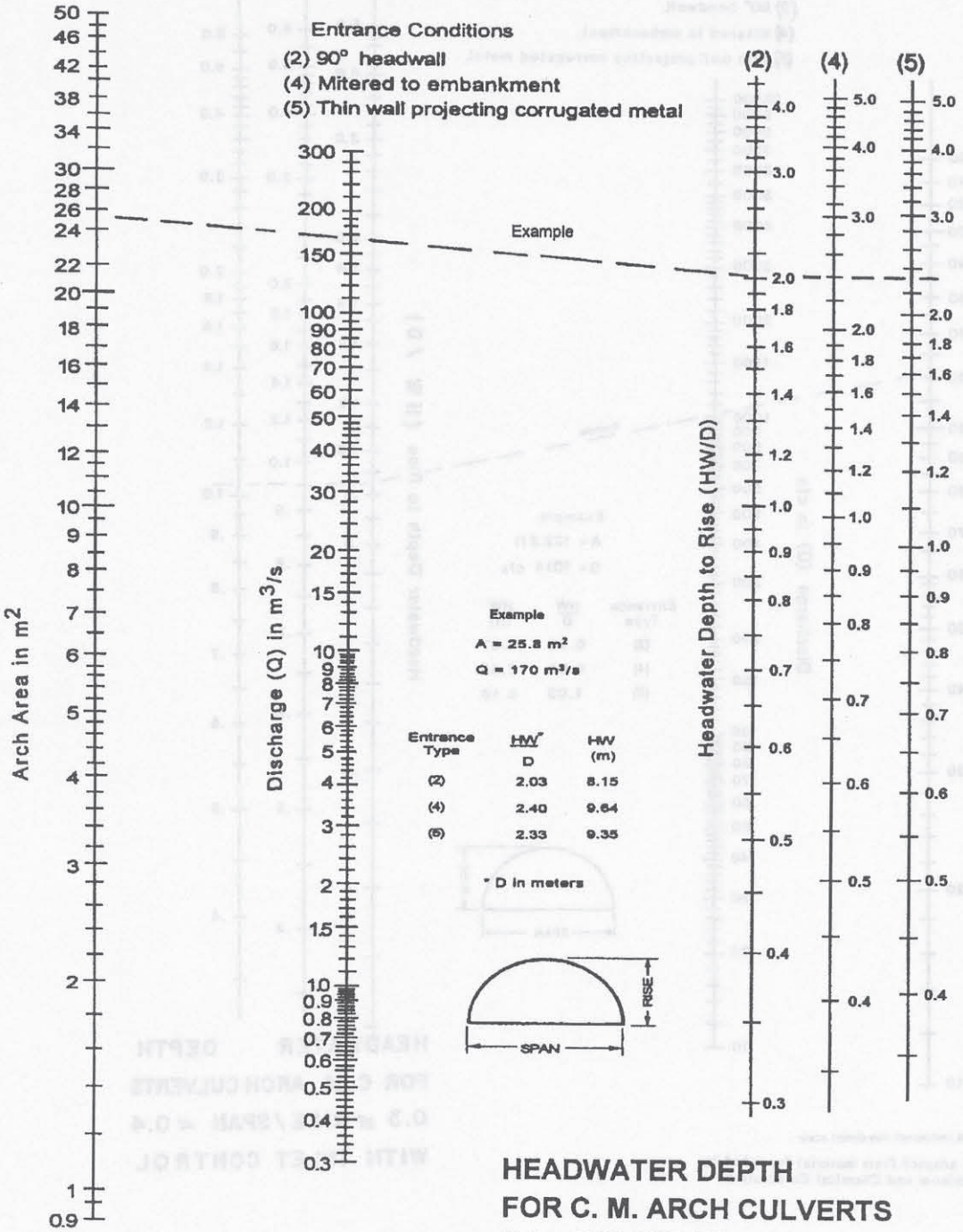


HEADWATER DEPTH FOR C.M. ARCH CULVERTS
0.3 ≤ RISE / SPAN < 0.4
WITH INLET CONTROL

Duplication of this nomograph may distort scale

Nomographs adapted from material furnished by Kaiser Aluminum and Chemical Corporation

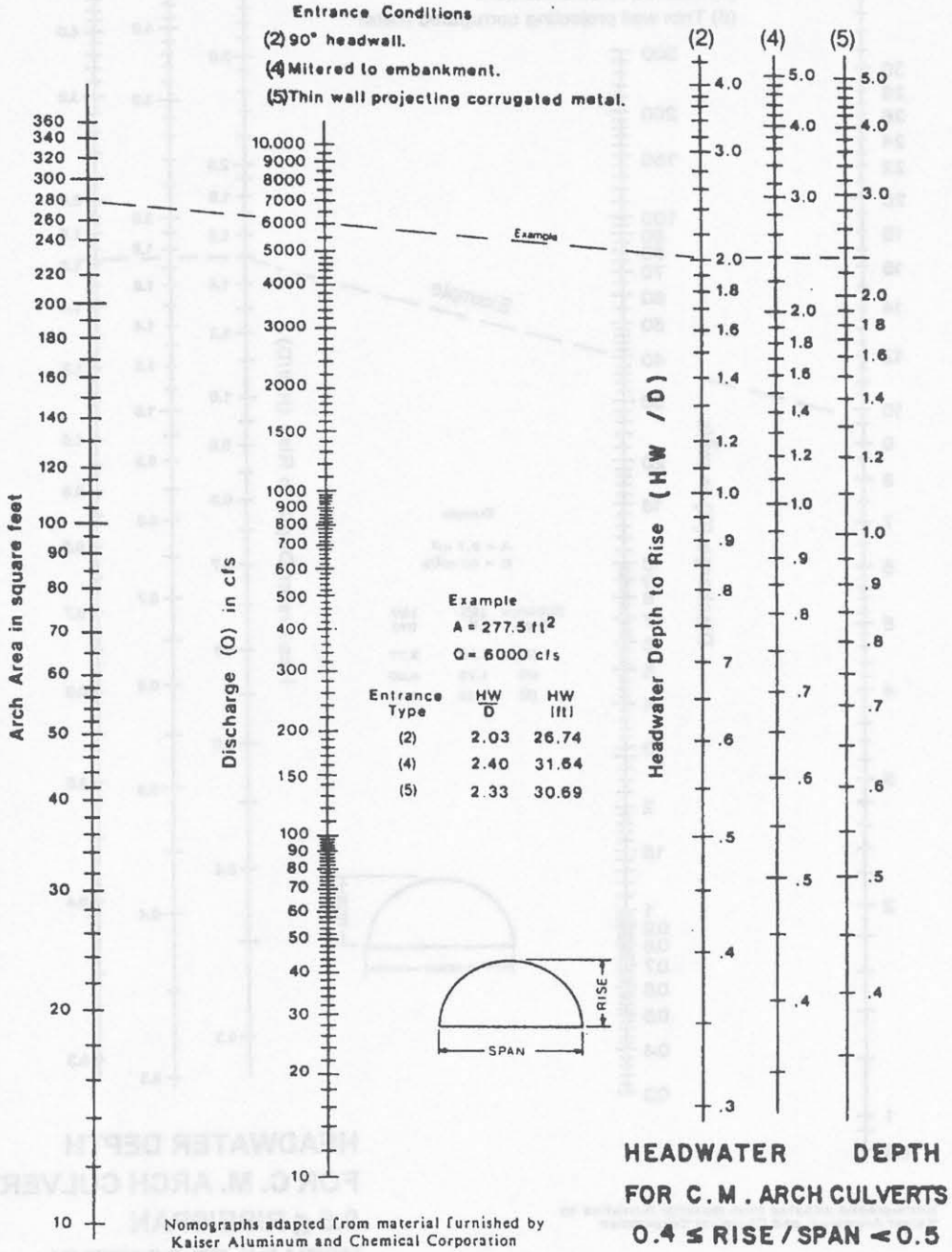
CHART 42A



Nomographs adapted from material furnished by Kaiser Aluminum and Chemical Corporation

HEADWATER DEPTH FOR C. M. ARCH CULVERTS
0.4 ≤ RISE/SPAN < 0.5
WITH INLET CONTROL

CHART 42B

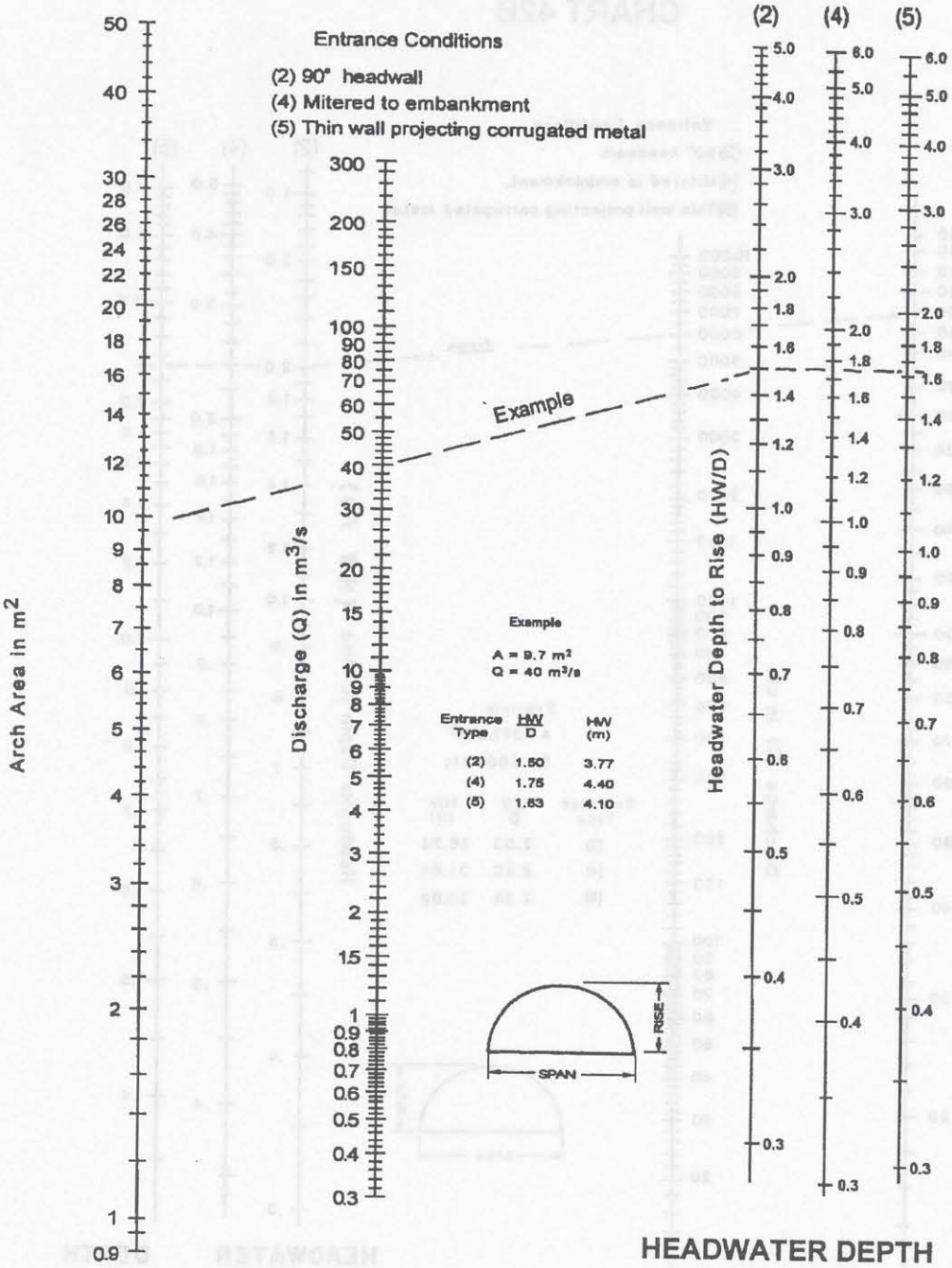


Nomographs adapted from material furnished by Kaiser Aluminum and Chemical Corporation

Duplication of this nomograph may distort scale

HEADWATER DEPTH FOR C.M. ARCH CULVERTS
0.4 ≤ RISE / SPAN < 0.5
WITH INLET CONTROL

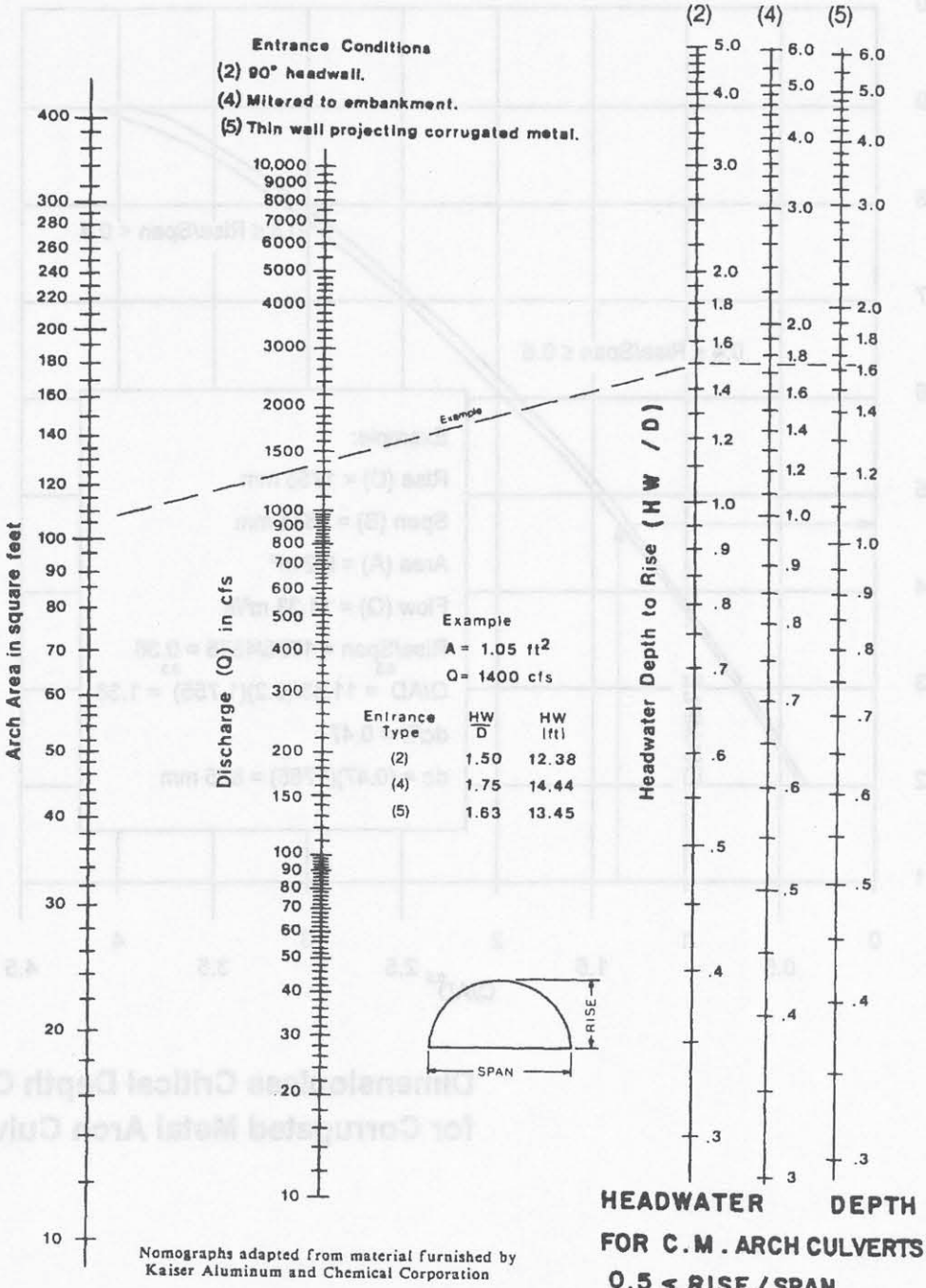
CHART 43A



Nomographs adapted from material furnished by Kaiser Aluminum and Chemical Corporation

HEADWATER DEPTH FOR C. M. ARCH CULVERTS 0.5 ≤ RISE/SPAN WITH INLET CONTROL

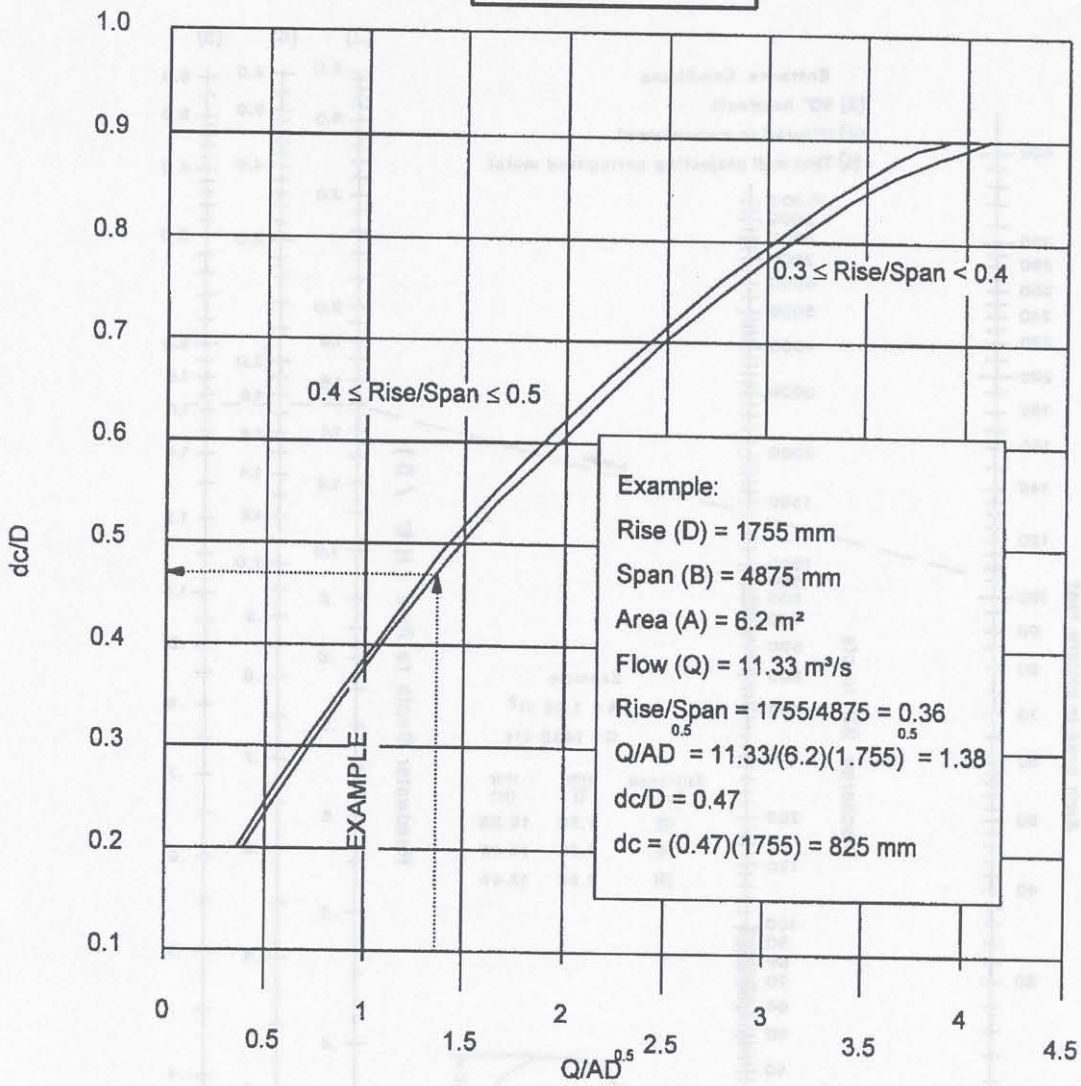
CHART 43B



Nomographs adapted from material furnished by Kaiser Aluminum and Chemical Corporation

Duplication of this nomograph may distort scale

CHART 44A



Dimensionless Critical Depth Chart for Corrugated Metal Arch Culverts

CHART 44B

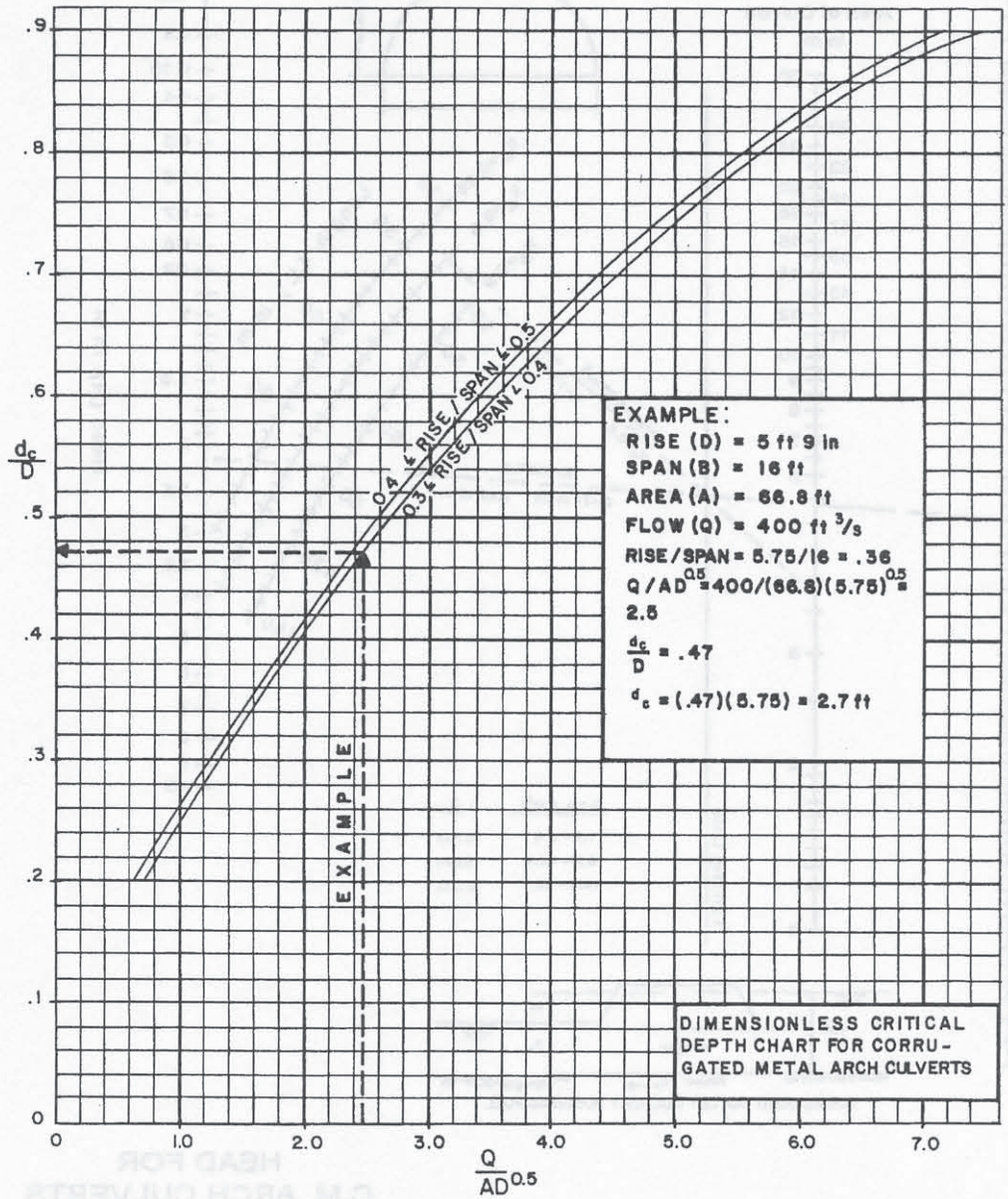
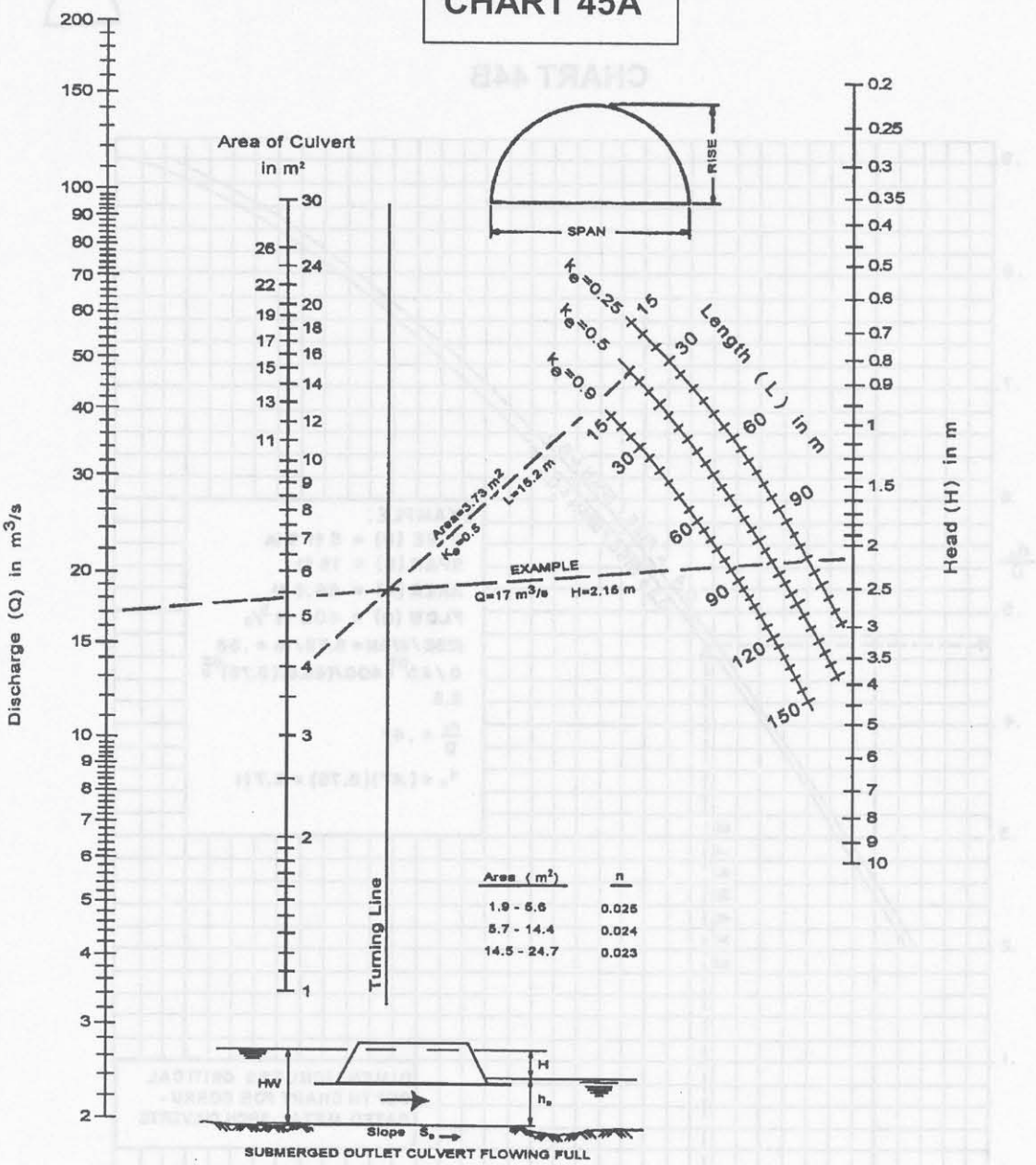

.9
.8
.7
.6
.5
.4
.3
.2
.1
0
$\frac{d_c}{D}$
0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
$\frac{Q}{AD^{0.5}}$
0.4 ≤ RISE / SPAN ≤ 0.5
0.3 ≤ RISE / SPAN < 0.4
EXAMPLE
EXAMPLE:
RISE (D) = 5 ft 9 in
SPAN (B) = 16 ft
AREA (A) = 66.8 ft
FLOW (Q) = 400 ft ^{3}/s
RISE/SPAN = 5.75/16 = .36
$Q/AD^{0.5} = 400/(66.8)(5.75)^{0.5} =$
2.5
$\frac{d_c}{D} = .47$
$d_c = (.47)(5.75) = 2.7$ ft
DIMENSIONLESS CRITICAL DEPTH CHART FOR CORRUGATED METAL ARCH CULVERTS

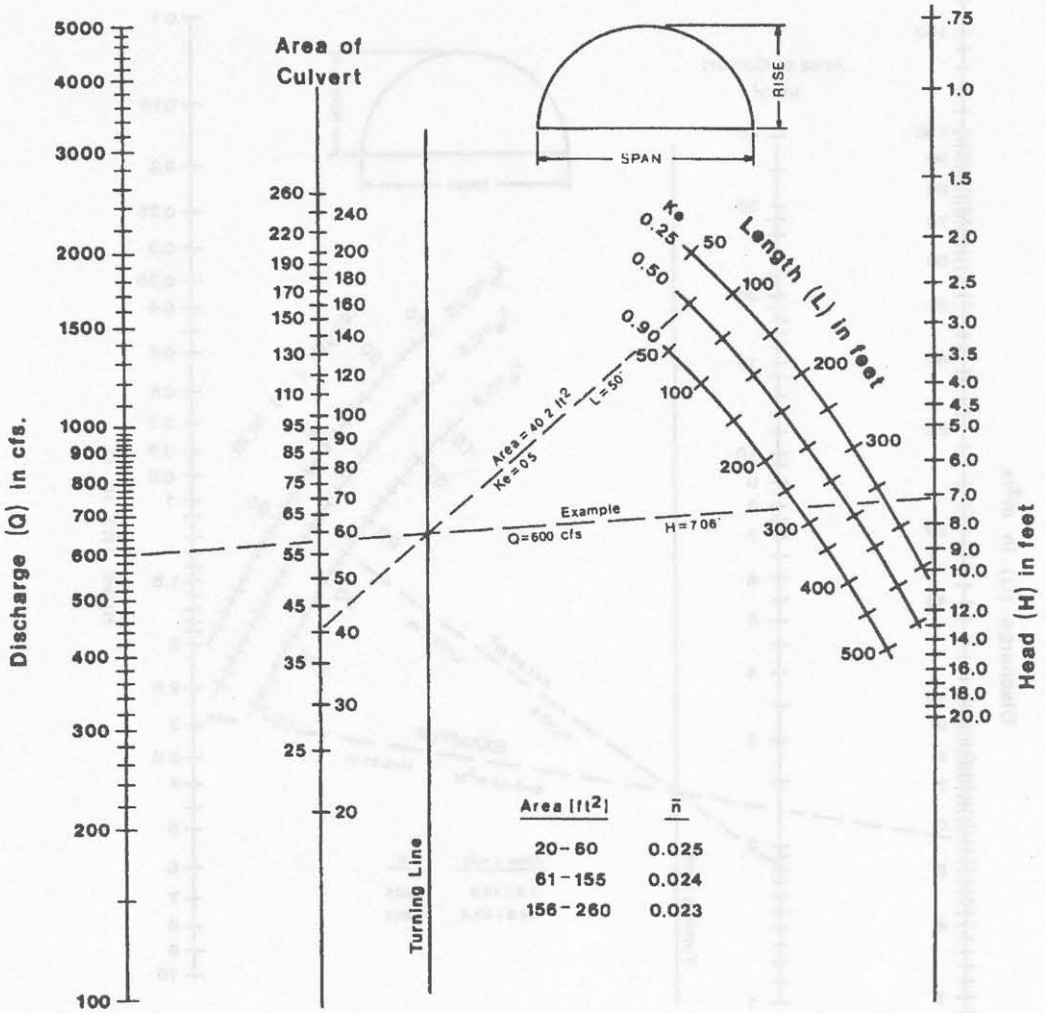
CHART 45A



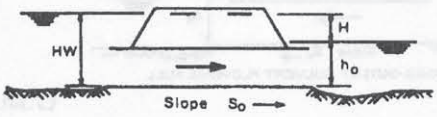
HEAD FOR
C.M. ARCH CULVERTS
FLOWING FULL
CONCRETE BOTTOM
$0.3 \leq$ RISE/SPAN < 0.4

Adapted from material furnished by
Kaiser Aluminum and Chemical Corporation

CHART 45B



Area [ft²]	n̄
20-60	0.025
61-155	0.024
156-260	0.023



SUBMERGED OUTLET CULVERT FLOWING FULL

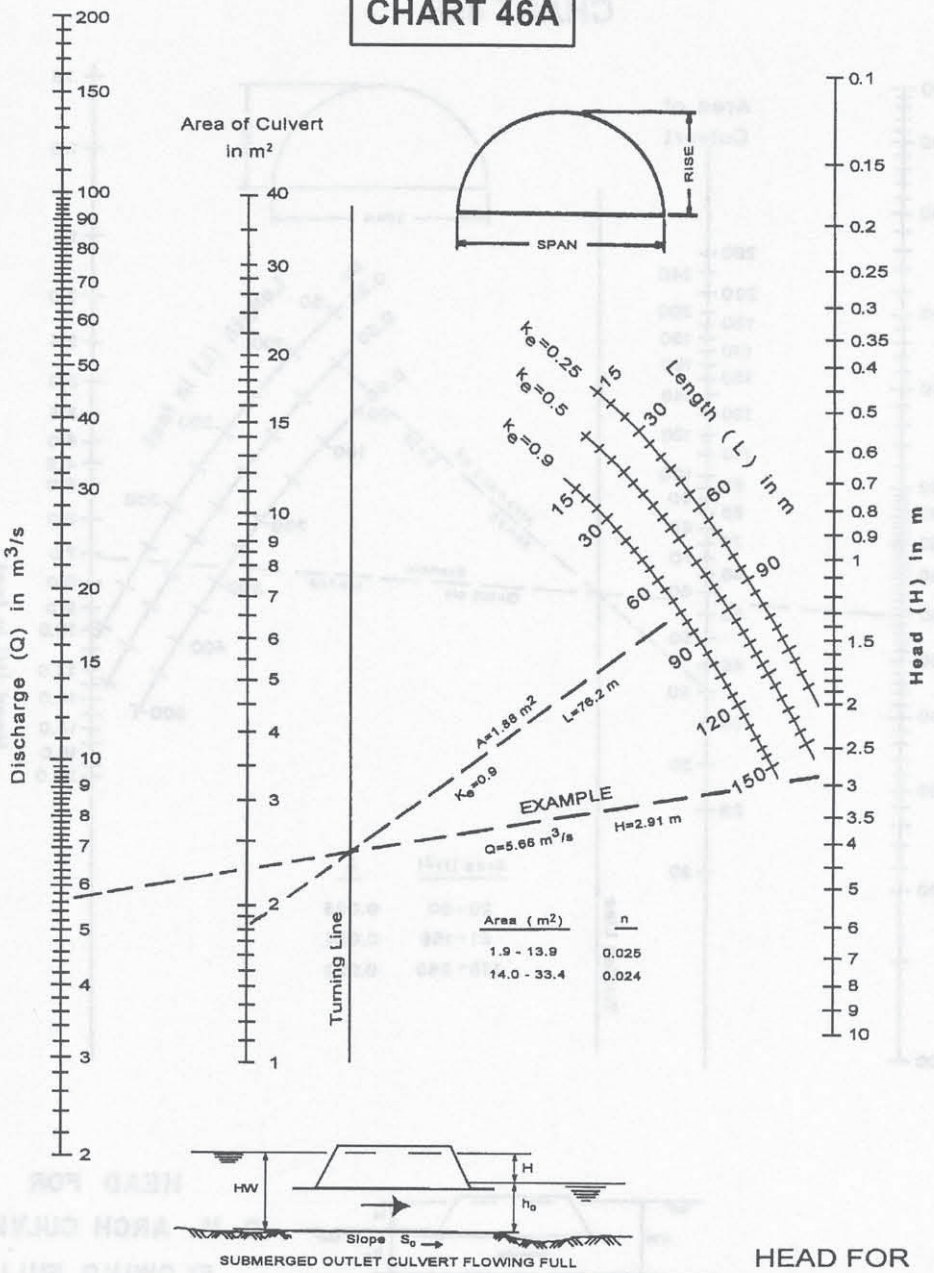
HEAD FOR C.M. ARCH CULVERTS FLOWING FULL CONCRETE BOTTOM

0.3 ≤ RISE / SPAN < 0.4

Nomographs adapted from material furnished by Kaiser Aluminum and Chemical Corporation

Duplication of this nomograph may distort scale

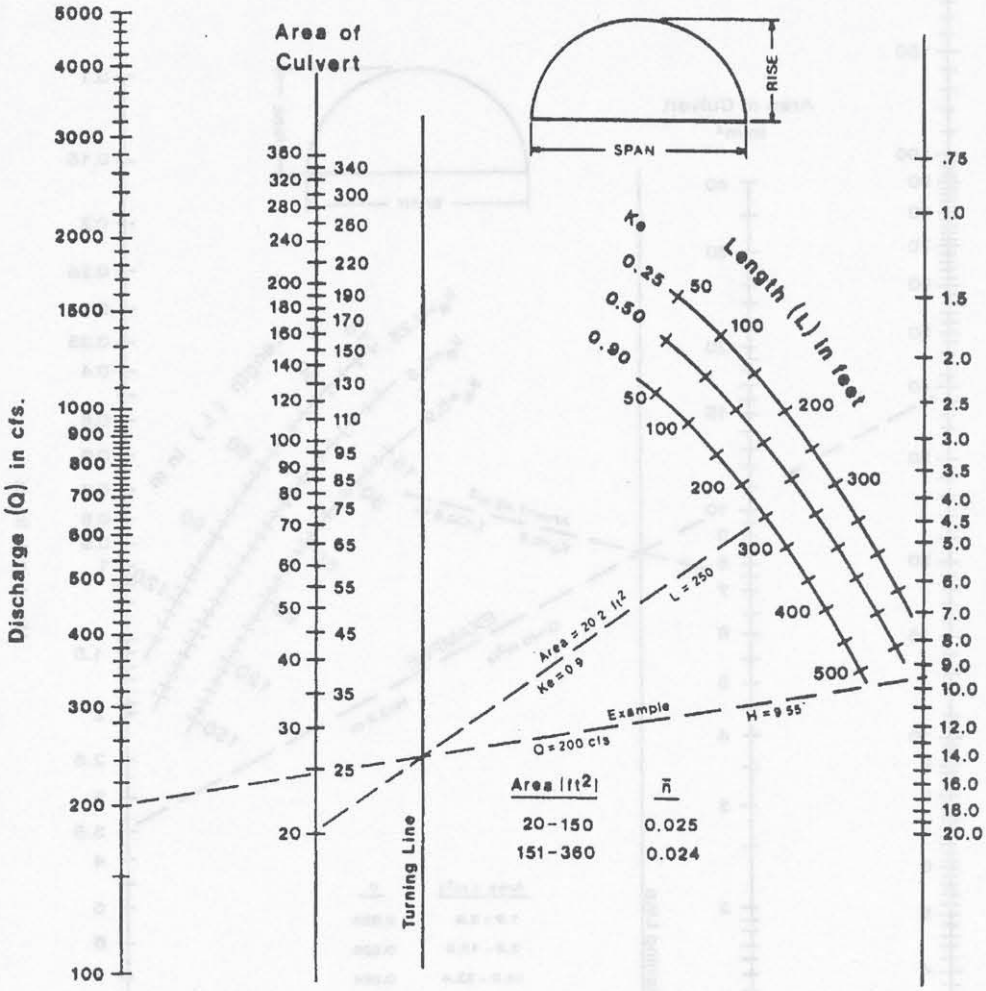
CHART 46A

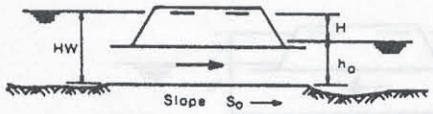


HEAD FOR
C.M. ARCH CULVERTS
FLOWING FULL
CONCRETE BOTTOM
$0.4 \leq$ RISE/SPAN < 0.5

Adapted from material furnished by
Kaiser Aluminum and Chemical Corporation

CHART 46B





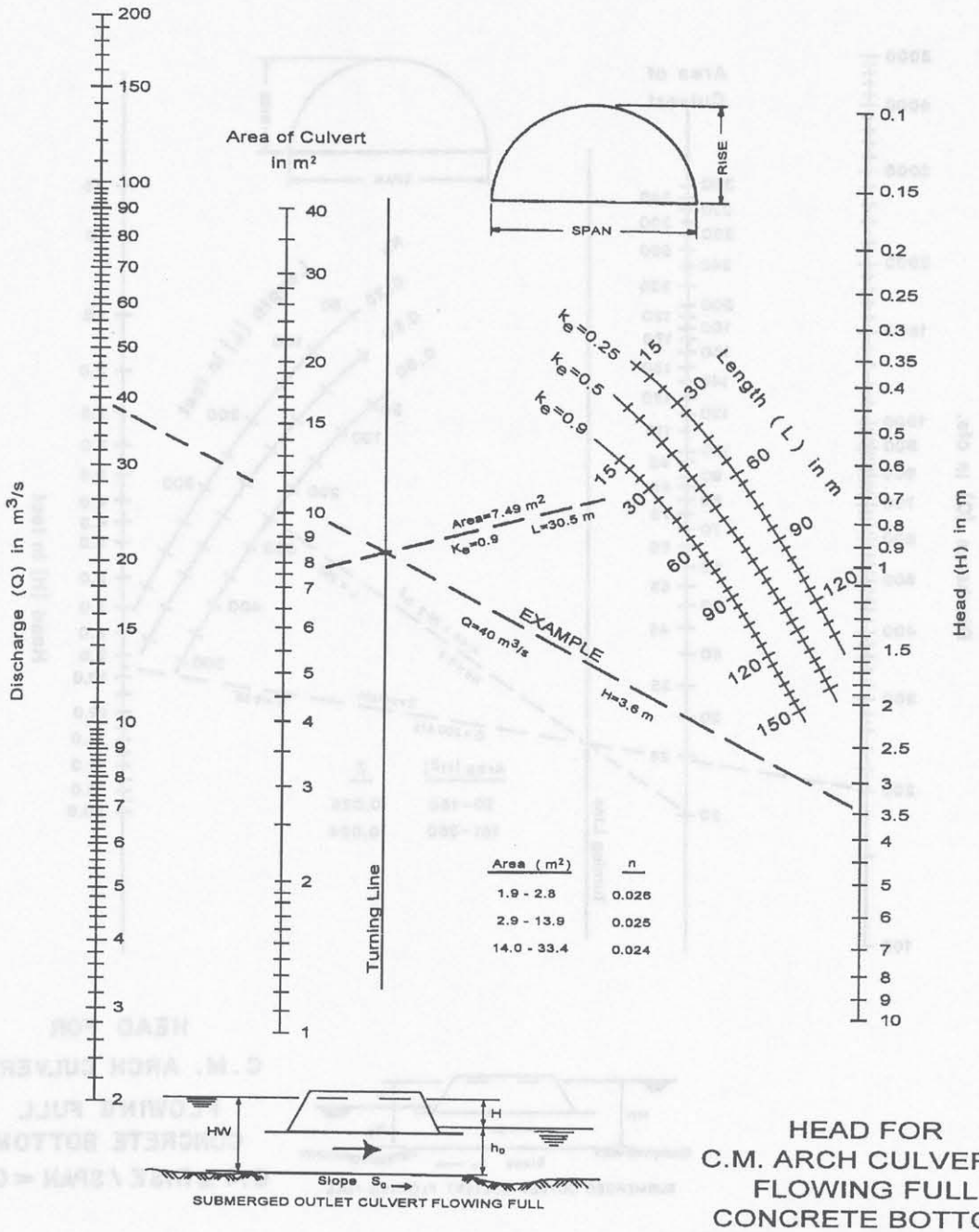
SUBMERGED OUTLET CULVERT FLOWING FULL

HEAD FOR
C.M. ARCH 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 47A

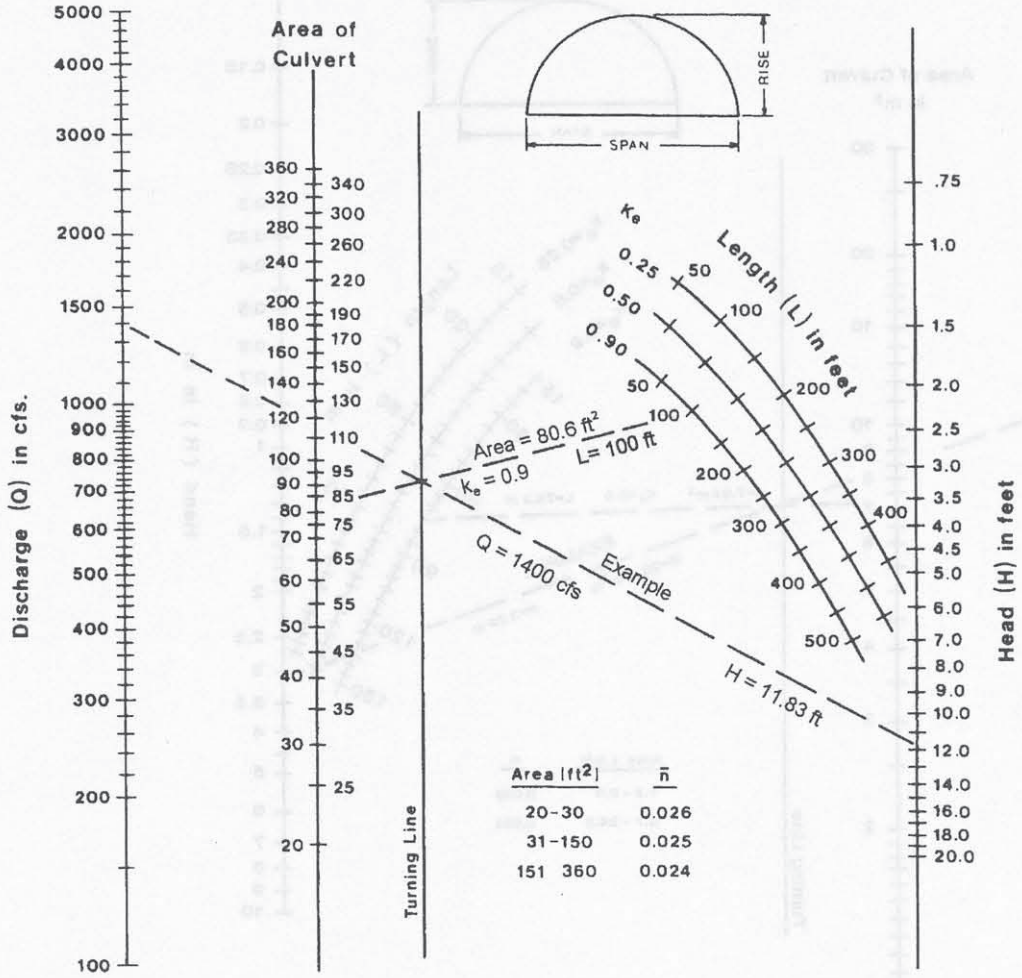


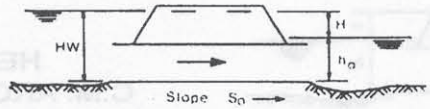
Area (m^2)	n
1.9 - 2.8	0.026
2.9 - 13.9	0.025
14.0 - 33.4	0.024

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

Adapted from material furnished by
Kaiser Aluminum and Chemical Corporation

CHART 47B





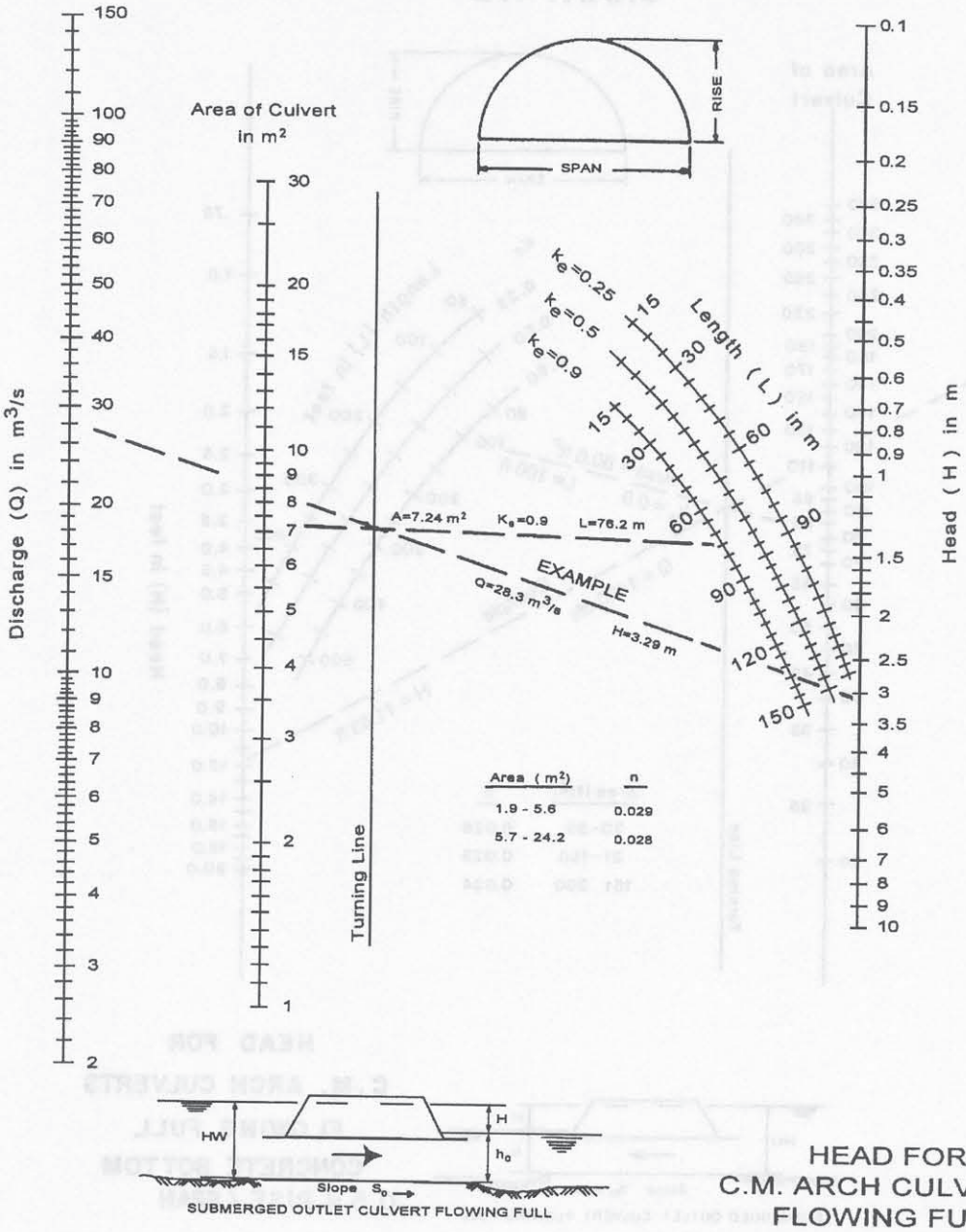
SUBMERGED OUTLET CULVERT FLOWING FULL

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

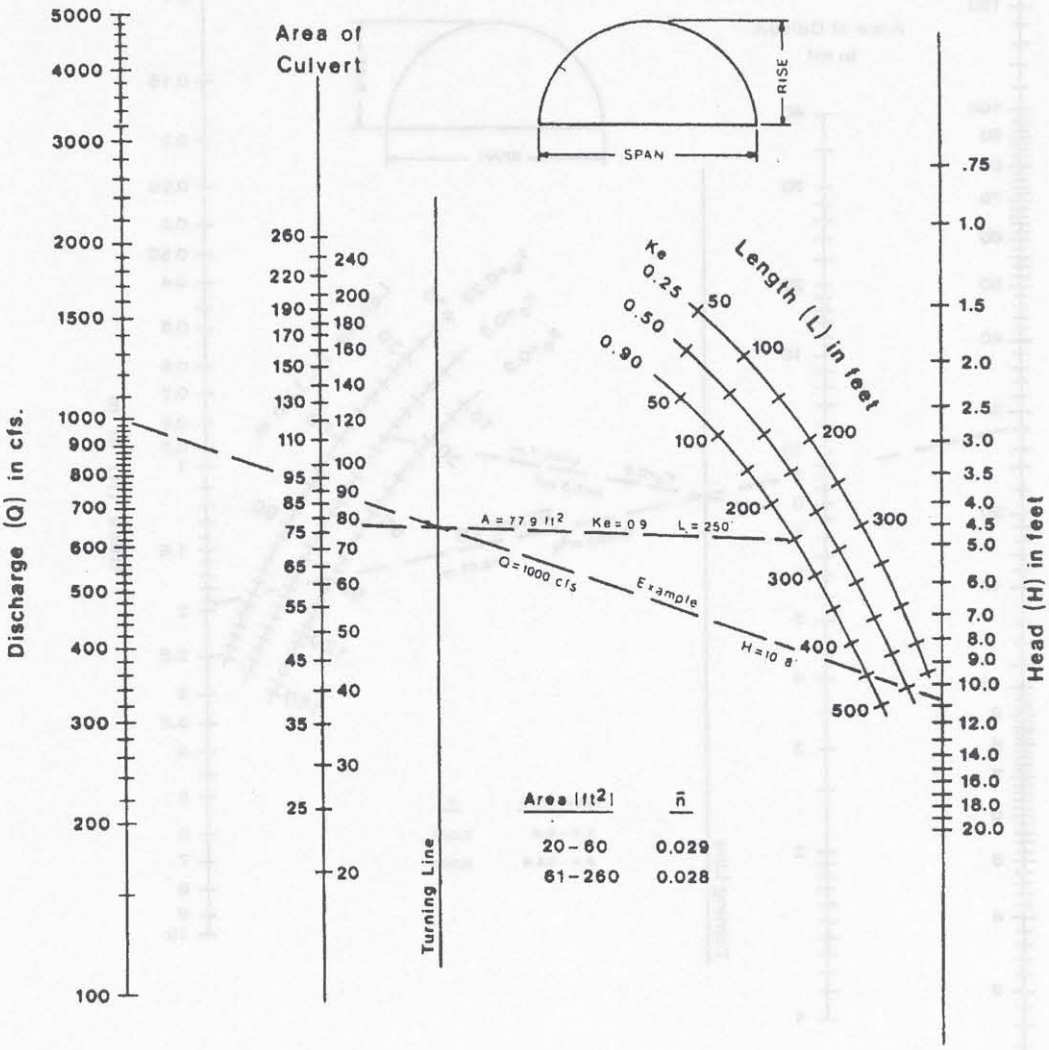
CHART 48A

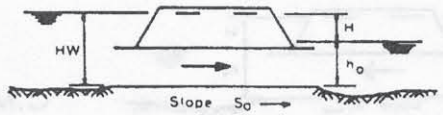


HEAD FOR
C.M. ARCH CULVERTS
FLOWING FULL
EARTH BOTTOM (n_b =0.022)
$0.3 \leq$ RISE/SPAN < 0.4

Adapted from material furnished by
Kaiser Aluminum and Chemical Corporation

CHART 48B





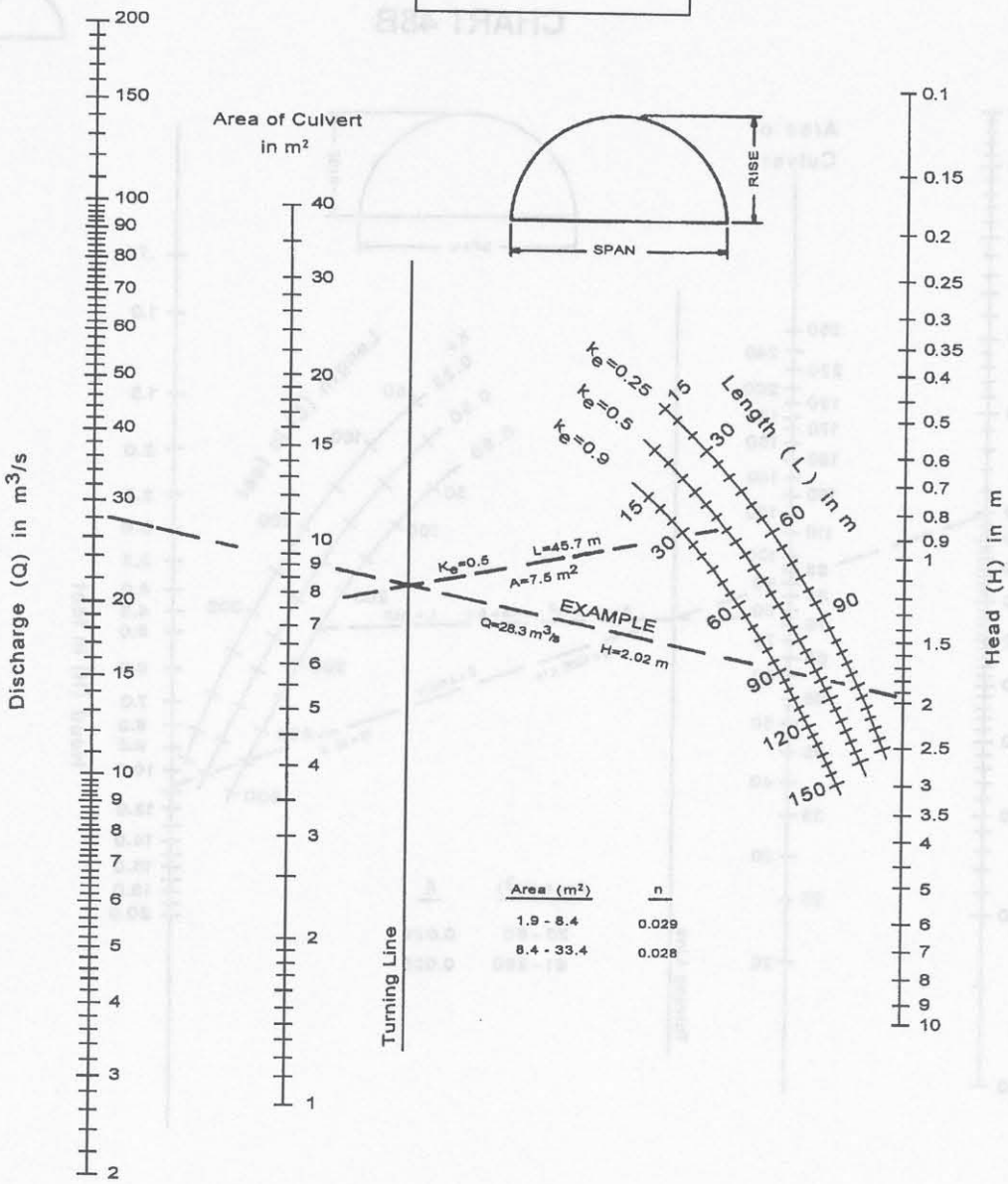
SUBMERGED OUTLET CULVERT FLOWING FULL

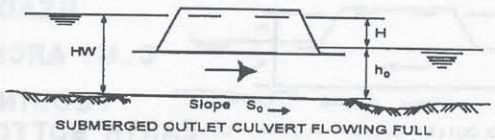
HEAD FOR
C.M. ARCH CULVERTS
FLOWING FULL
EARTH BOTTOM (n_b = 0.022)
0.3 ≤ RISE / SPAN < 0.4

Nomographs adapted from material furnished by Kaiser Aluminum and Chemical Corporation

Duplication of this nomograph may distort scale

CHART 49A



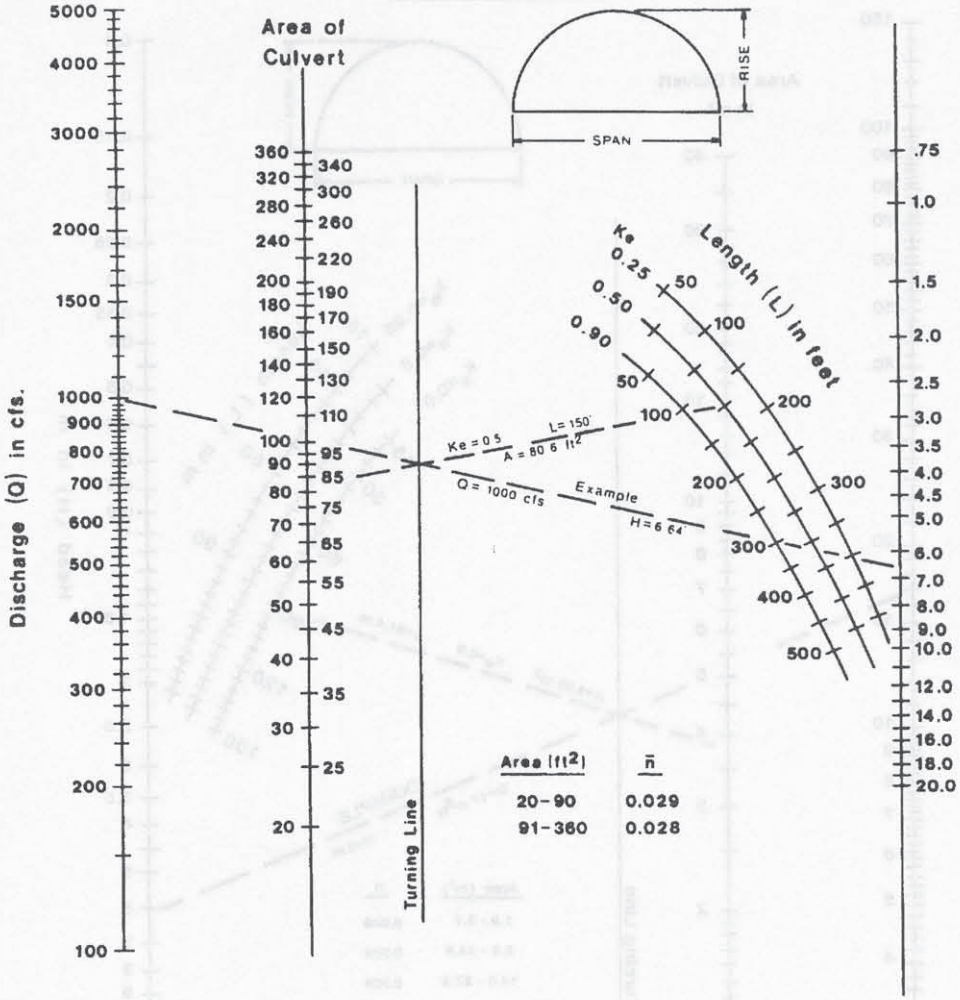


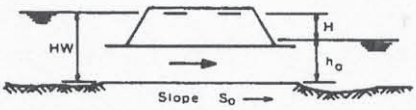
SUBMERGED OUTLET CULVERT FLOWING FULL

Adapted from material furnished by
Kaiser Aluminum and Chemical Corporation

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

CHART 49B





SUBMERGED OUTLET CULVERT FLOWING FULL

HEAD FOR C.M. ARCH CULVERTS FLOWING FULL

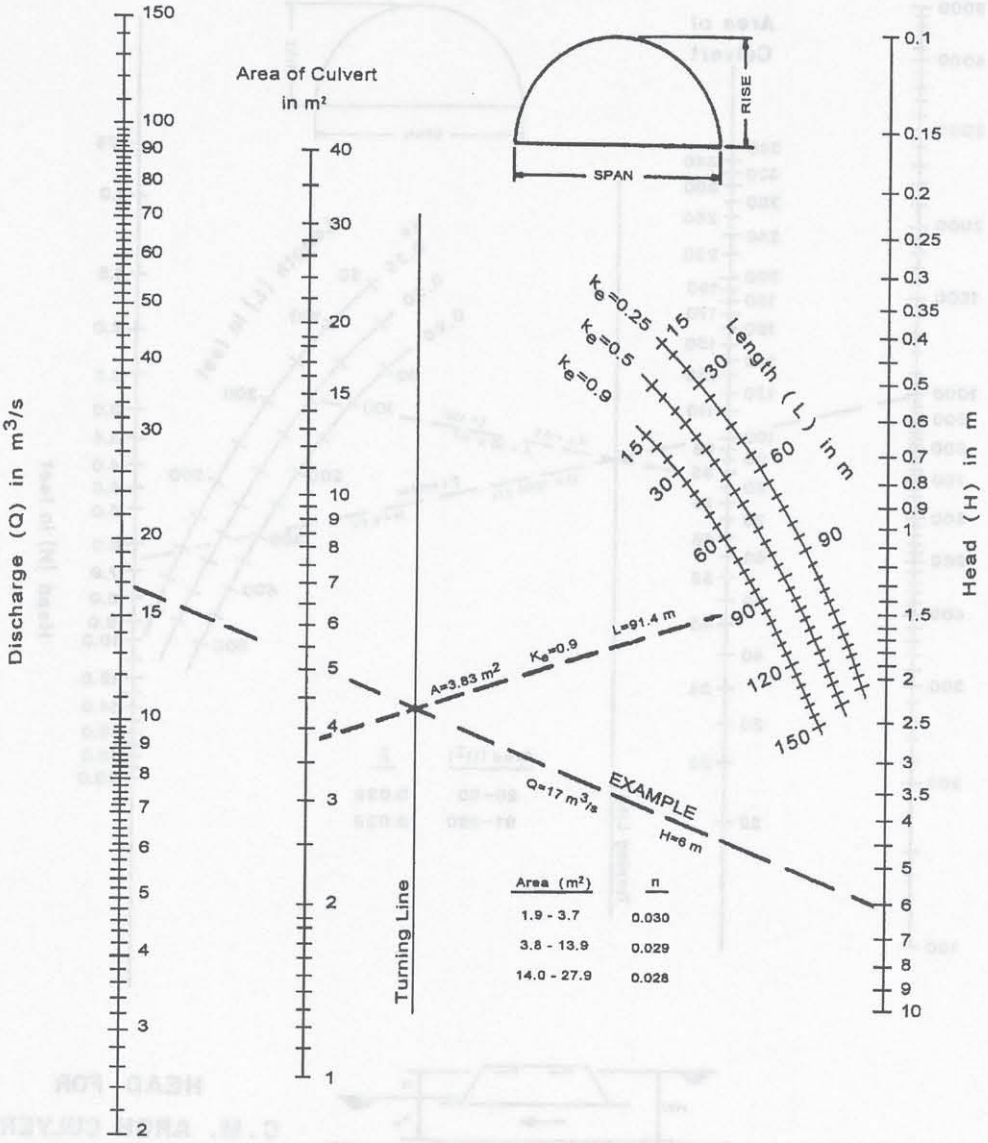
EARTH BOTTOM (n_b = 0.022)

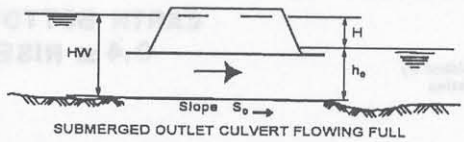
$0.4 \leq$ RISE / SPAN < 0.5

Nomographs adapted from material furnished by Kaiser Aluminum and Chemical Corporation

Duplication of this nomograph may distort scale

CHART 50A



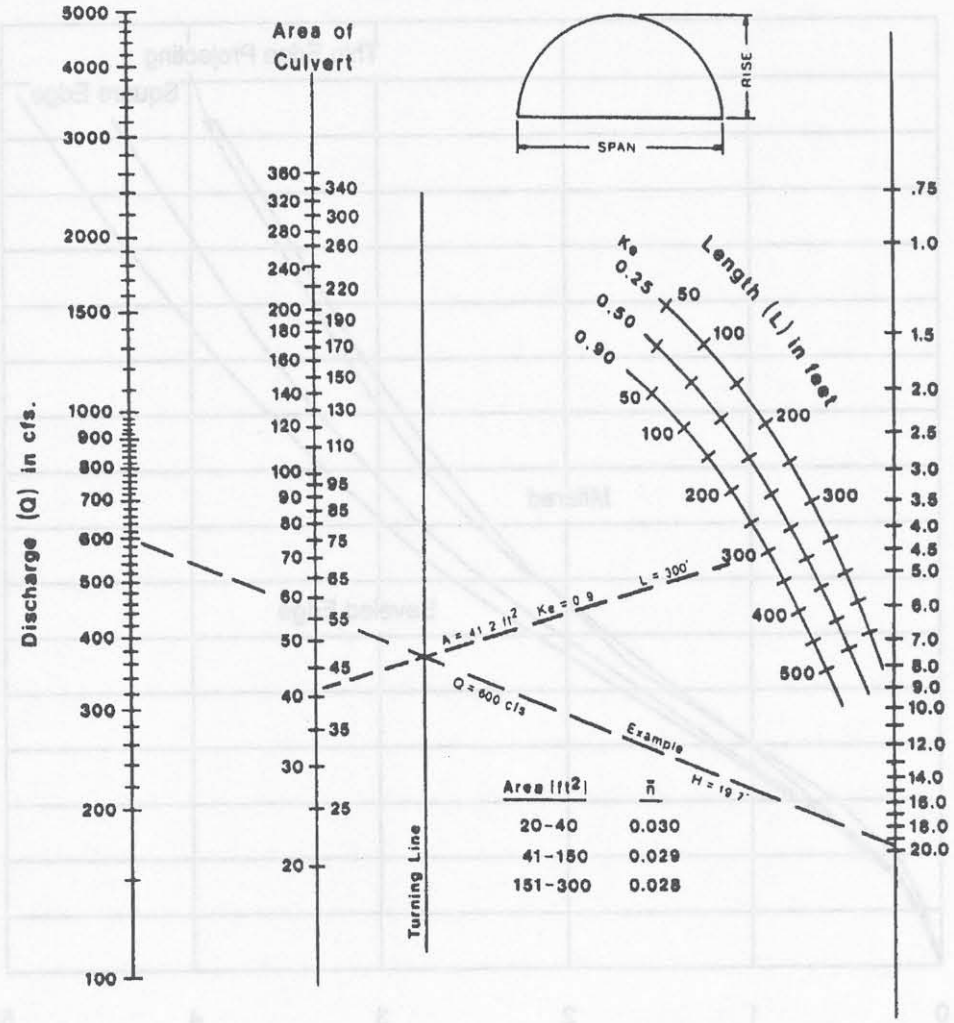


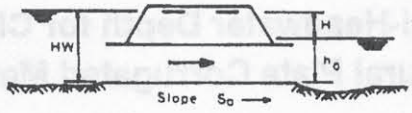
SUBMERGED OUTLET CULVERT FLOWING FULL

Adapted from material furnished by
Kaiser Aluminum and Chemical Corporation

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

CHART 50B





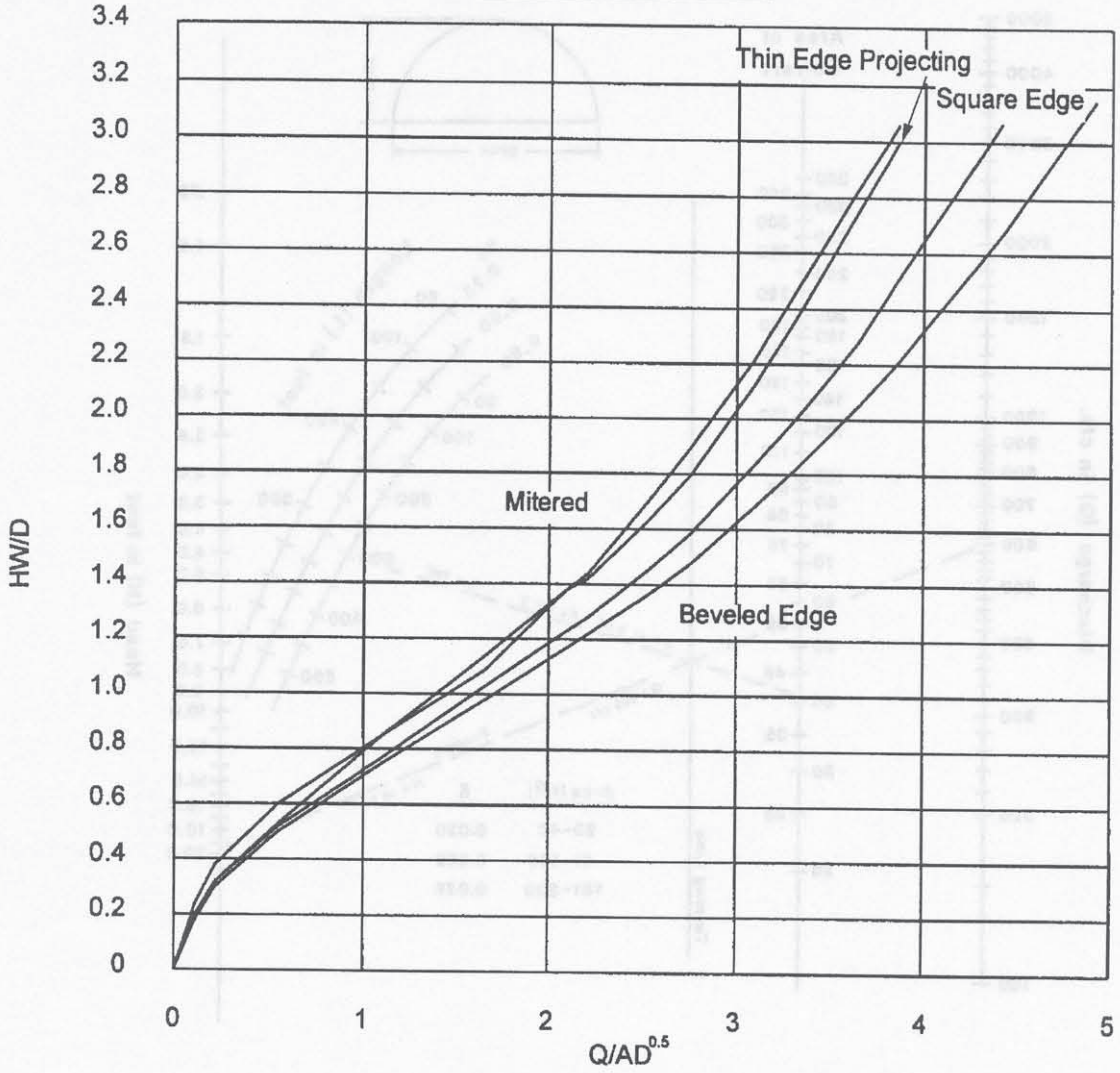
SUBMERGED OUTLET CULVERT FLOWING FULL

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 51A



Inlet Control-Headwater Depth for Circular or Elliptical Structural Plate Corrugated Metal Conduits

(SI Units)

CHART 51B
(English Units)

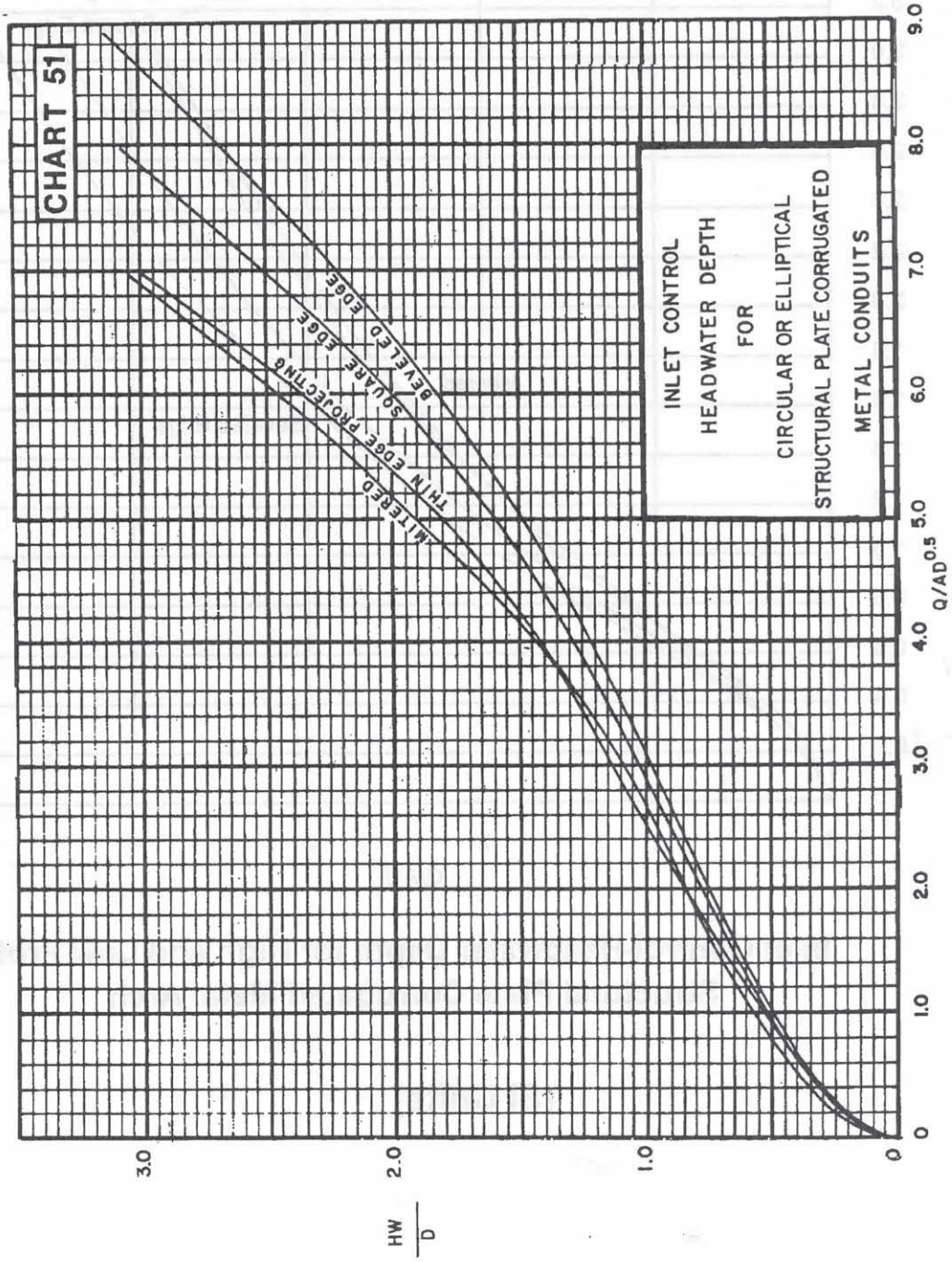
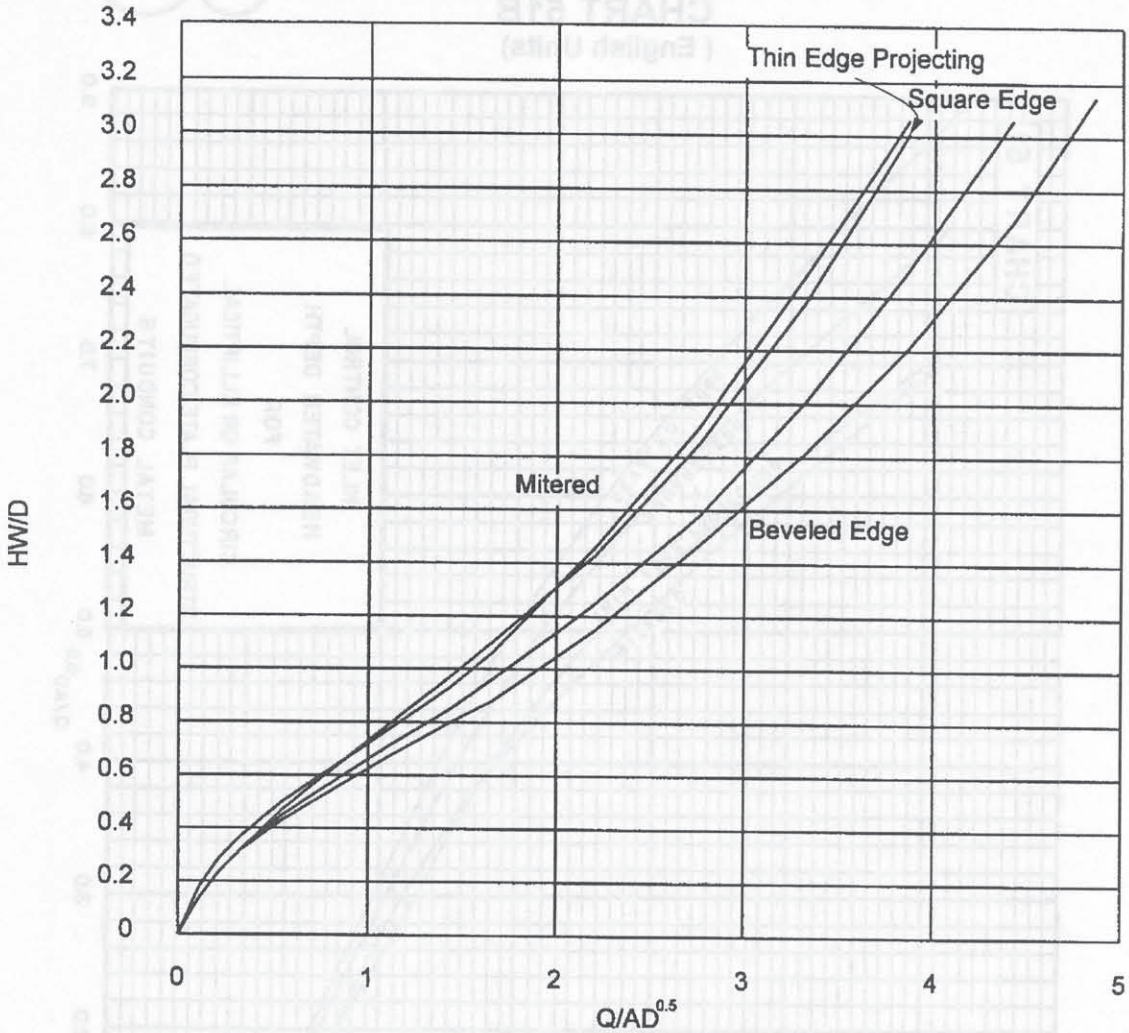


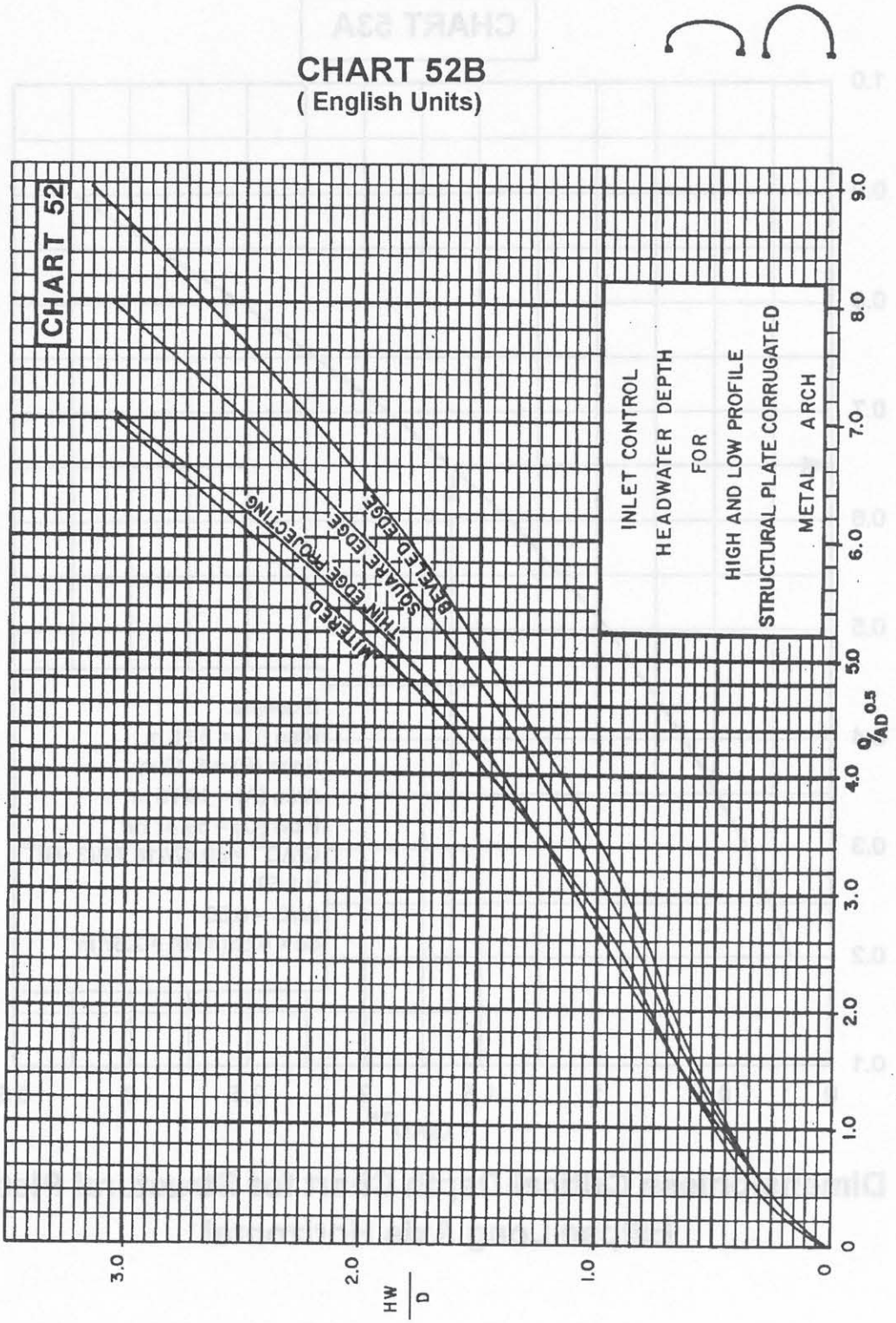
CHART 52A

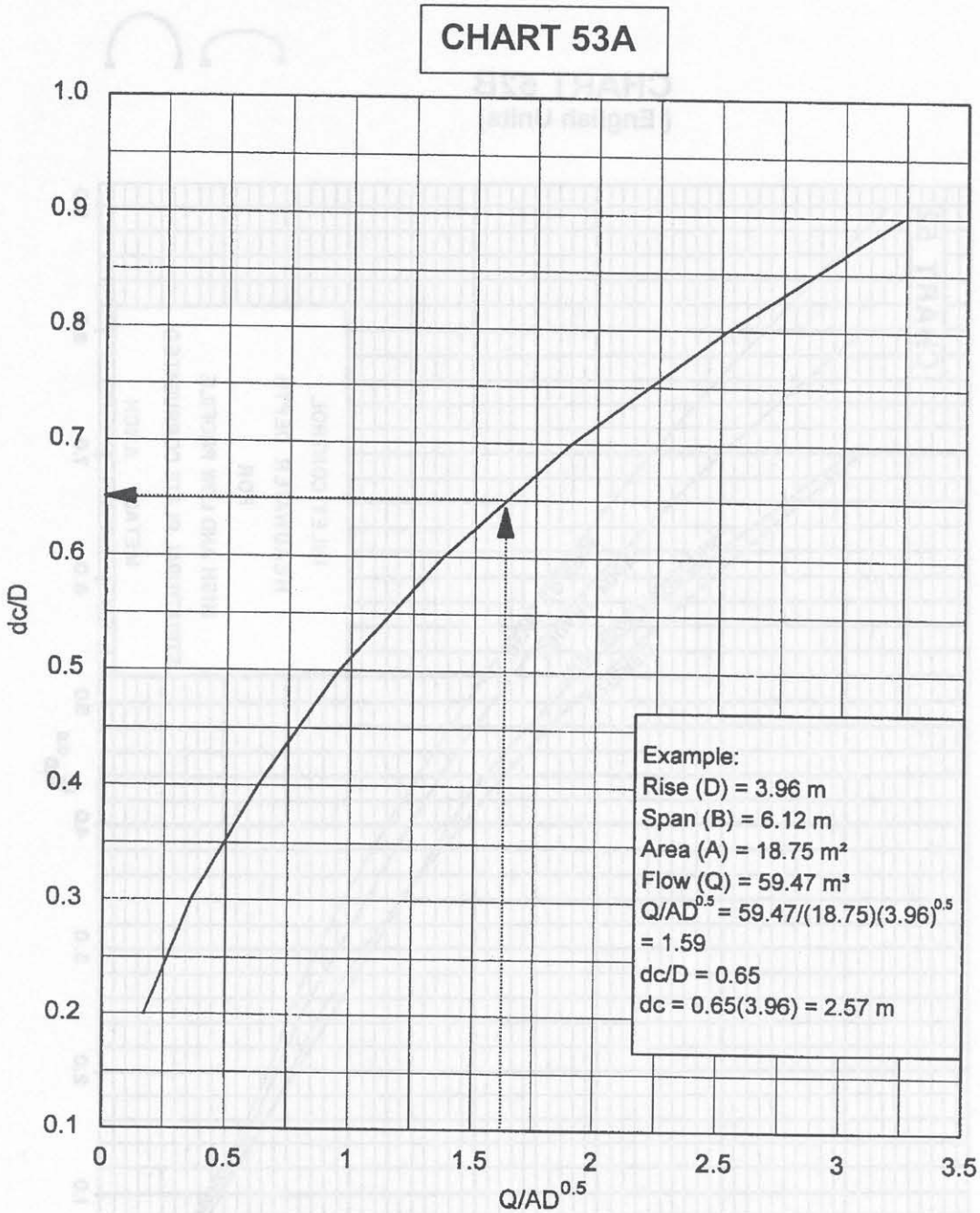


Inlet Control-Headwater Depth for High and Low Profile Structural Plate Corrugated Metal Arch

(SI Units)

CHART 52B
(English Units)





Dimensionless Critical Depth Chart for Structural Plate Ellipse Long Axis Horizontal

CHART 53B

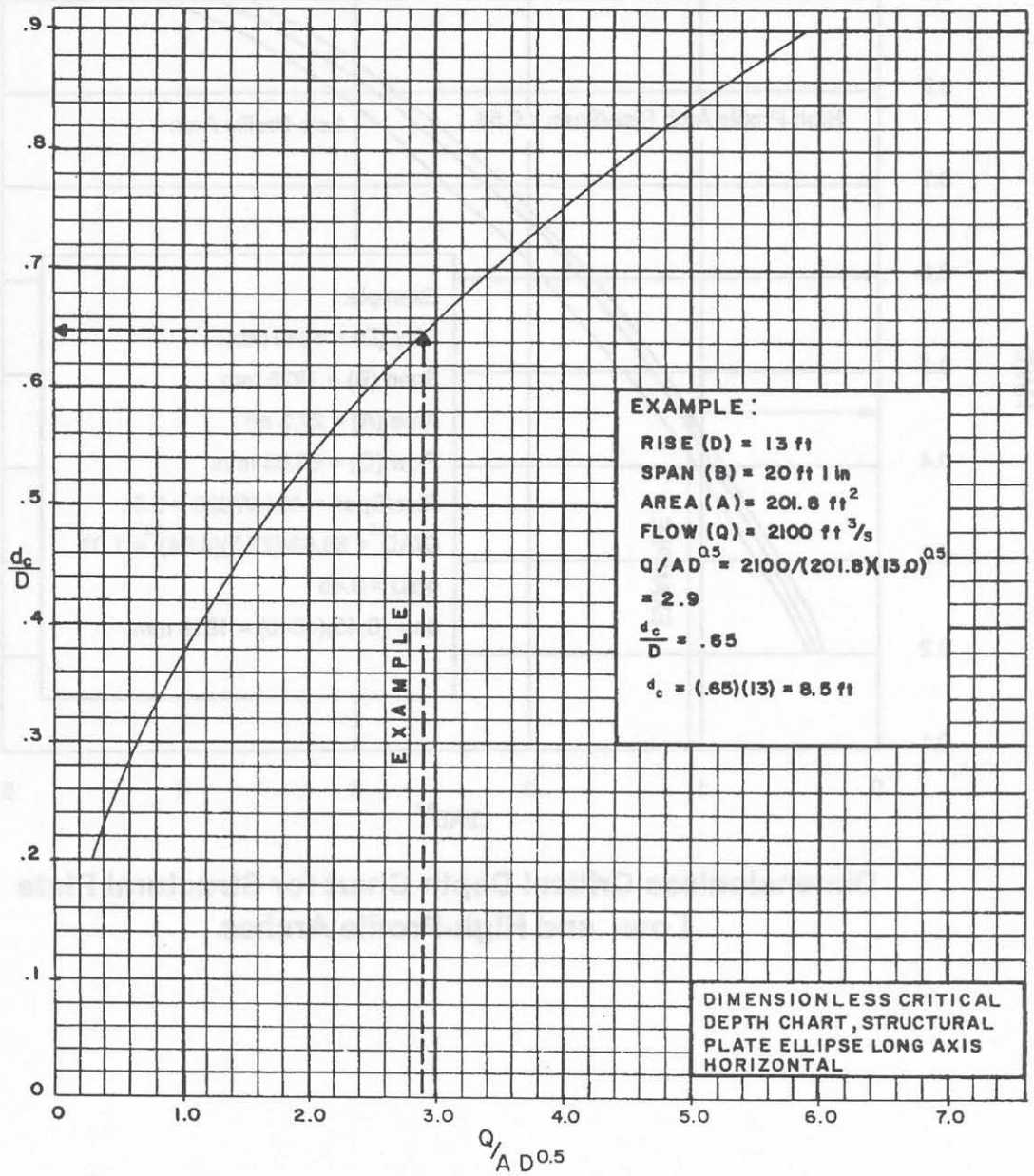
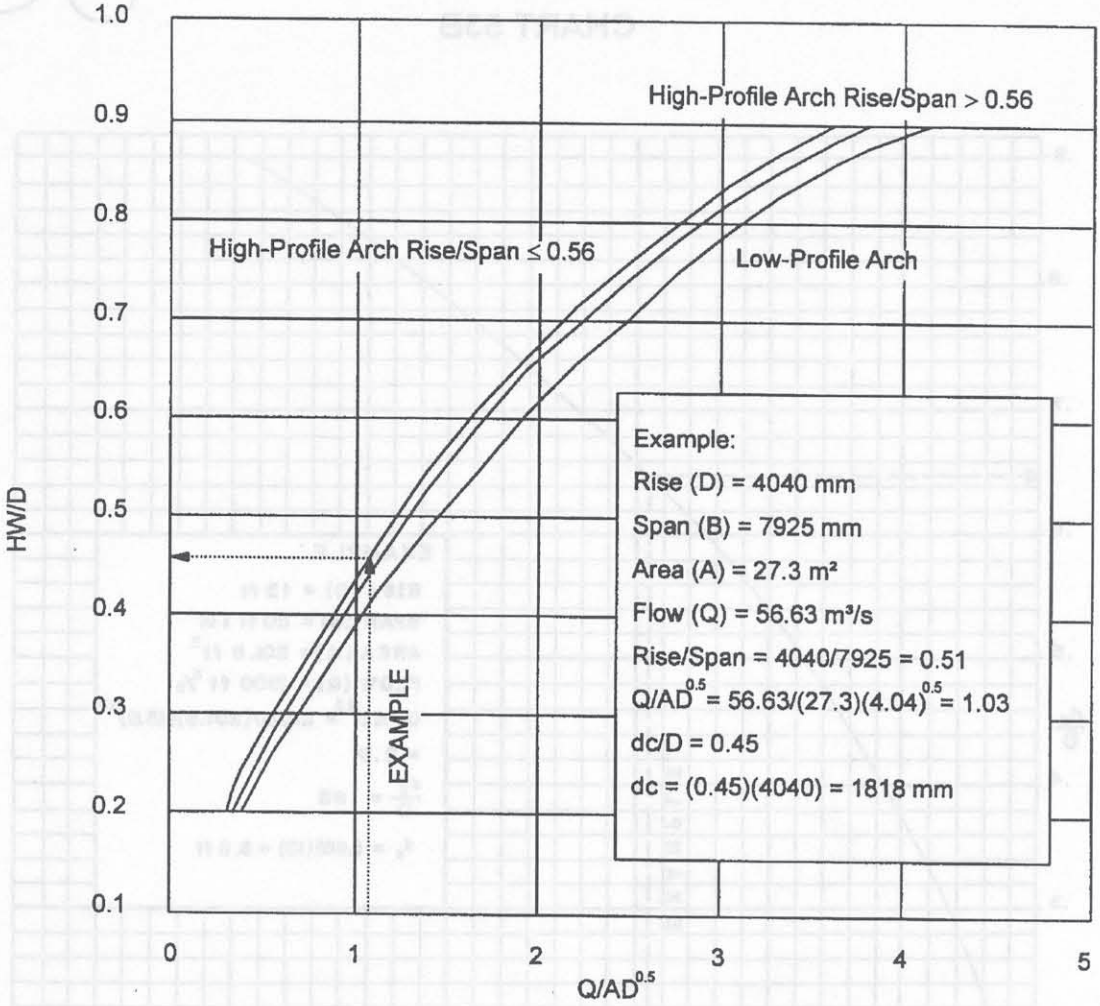

.9
.8
.7
.6
.5
.4
.3
.2
.1
0
$\frac{d_c}{D}$
0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
$Q/A\,D^{0.5}$
EXAMPLE
EXAMPLE:
RISE (D) = 13 ft
SPAN (B) = 20 ft 1 in
AREA (A) = 201.8 ft^2
FLOW (Q) = 2100 ft^3/s
$Q/AD^{0.5} = 2100/(201.8)(13.0)^{0.5}$
= 2.9
$\frac{d_c}{D}$ = .65
d_c = (.65)(13) = 8.5 ft
DIMENSIONLESS CRITICAL DEPTH CHART, STRUCTURAL PLATE ELLIPSE LONG AXIS HORIZONTAL

CHART 54A



Dimensionless Critical Depth Chart for Structural Plate Low- and High-Profile Arches

CHART 54B

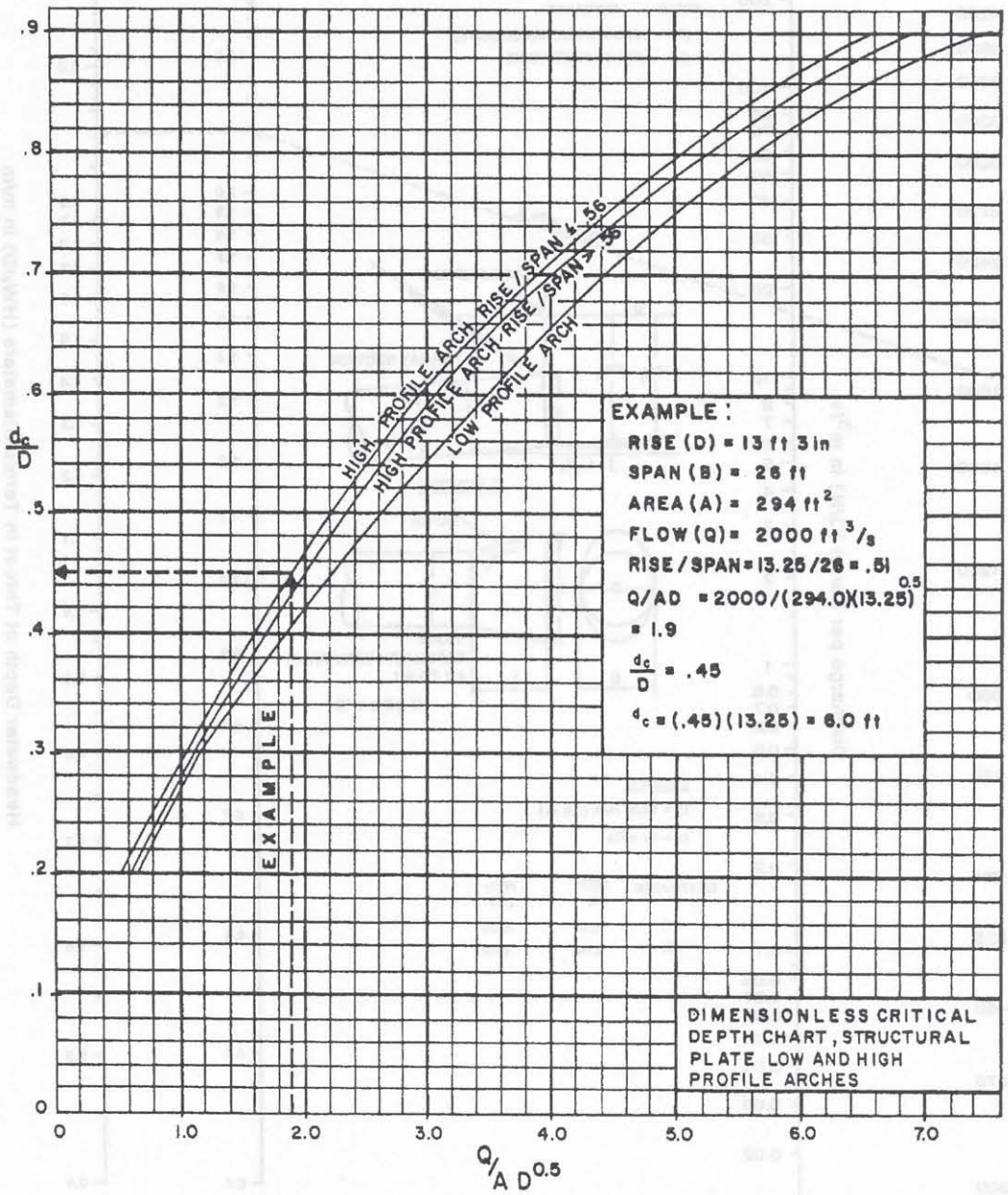
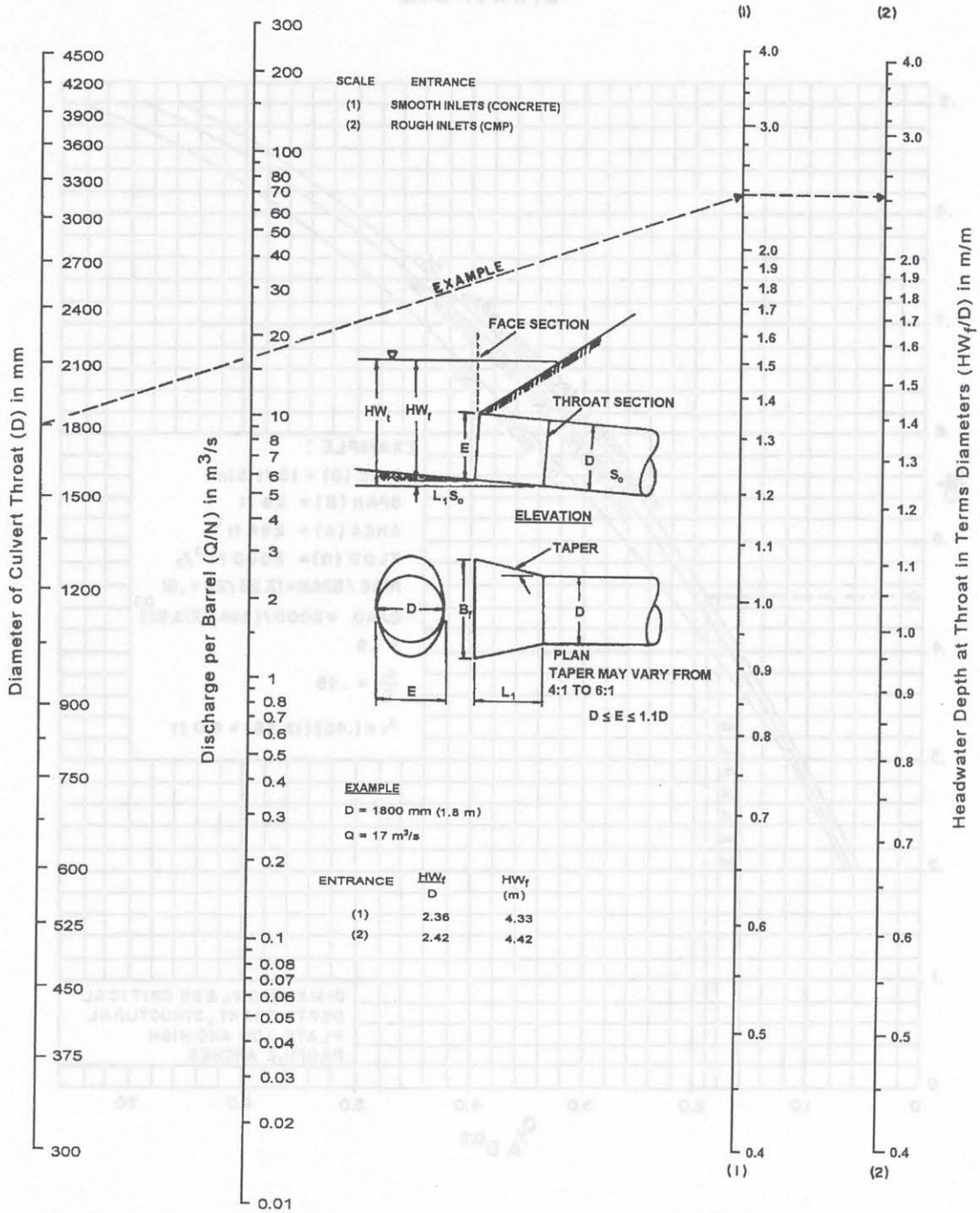
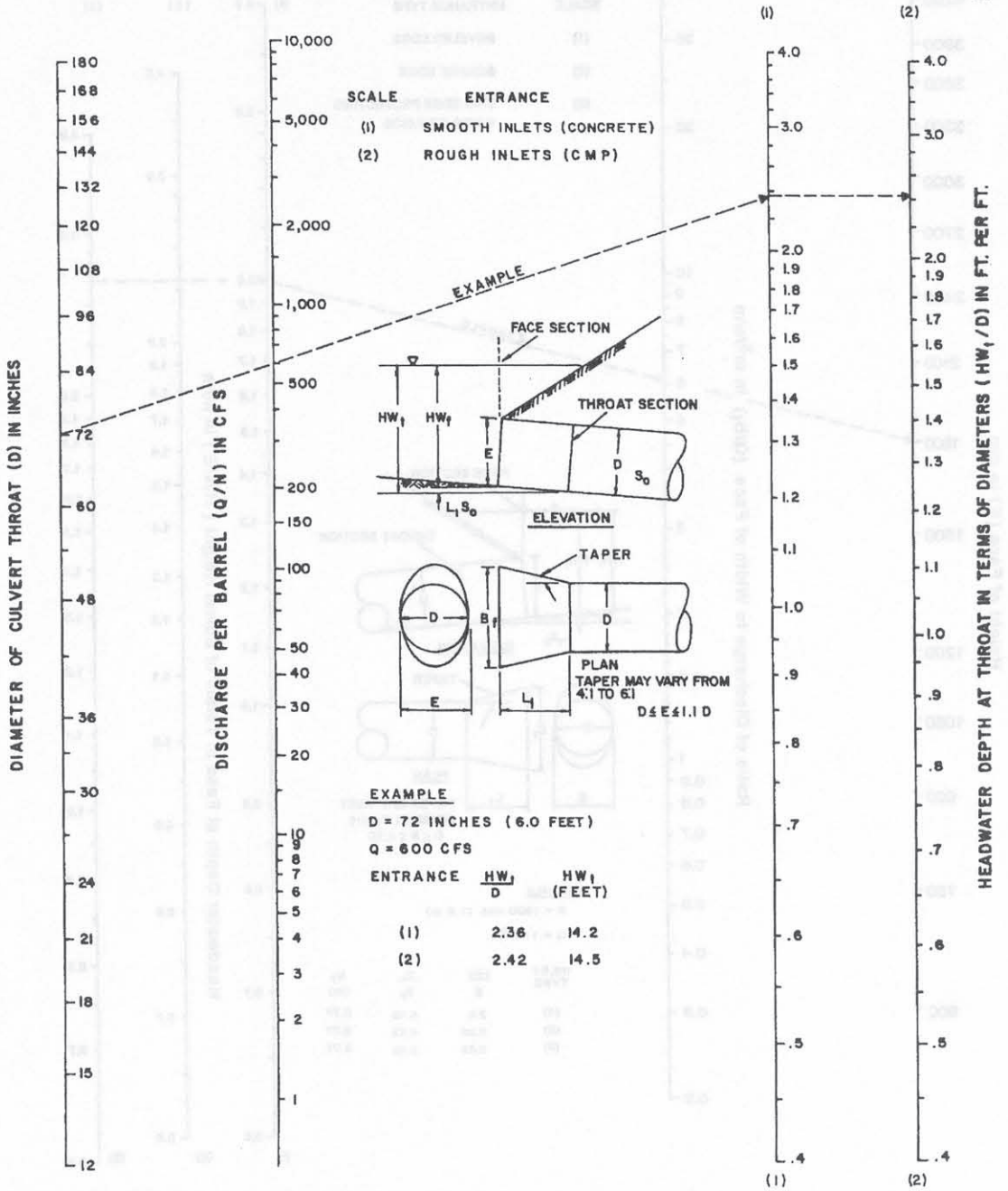

HIGH PROFILE ARCH RISE/SPAN ≤ .56
HIGH PROFILE ARCH RISE/SPAN ≥ .56
LOW PROFILE ARCH
EXAMPLE
EXAMPLE:
RISE (D) = 13 ft 3 in
SPAN (B) = 26 ft
AREA (A) = 294 ft²
FLOW (Q) = 2000 ft³/s
RISE/SPAN = 13.25/26 = .51
Q/AD = 2000/(294.0)(13.25)^0.5
= 1.9
dc/D = .45
dc = (.45)(13.25) = 6.0 ft
DIMENSIONLESS CRITICAL DEPTH CHART, STRUCTURAL PLATE LOW AND HIGH PROFILE ARCHES
dc/D
Q/A D^0.5
0
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
2.0
3.0
4.0
5.0
6.0
7.0

CHART 55A



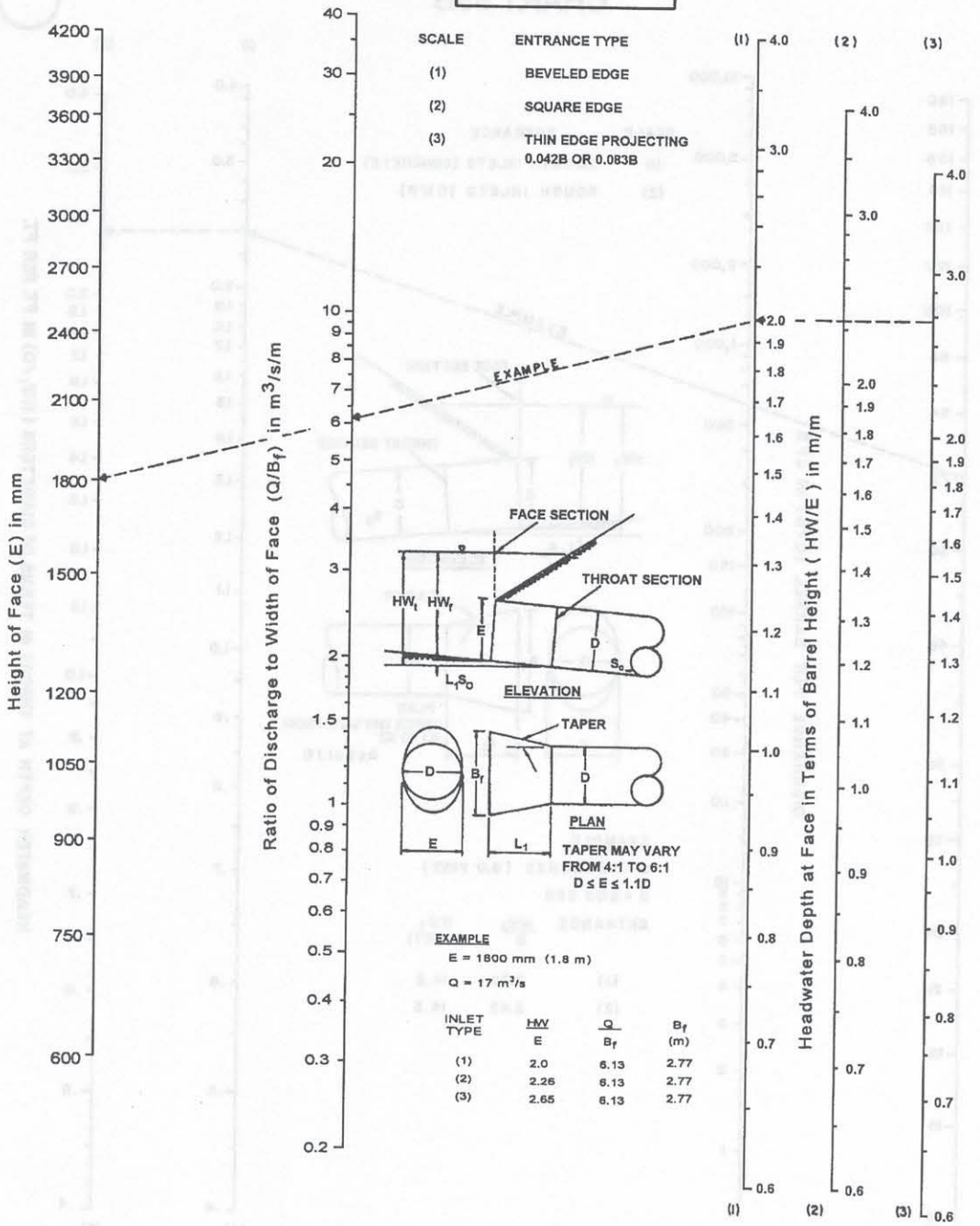
THROAT CONTROL
FOR SIDE-TAPERED INLETS TO PIPE CULVERT
(CIRCULAR SECTION ONLY)

CHART 55B



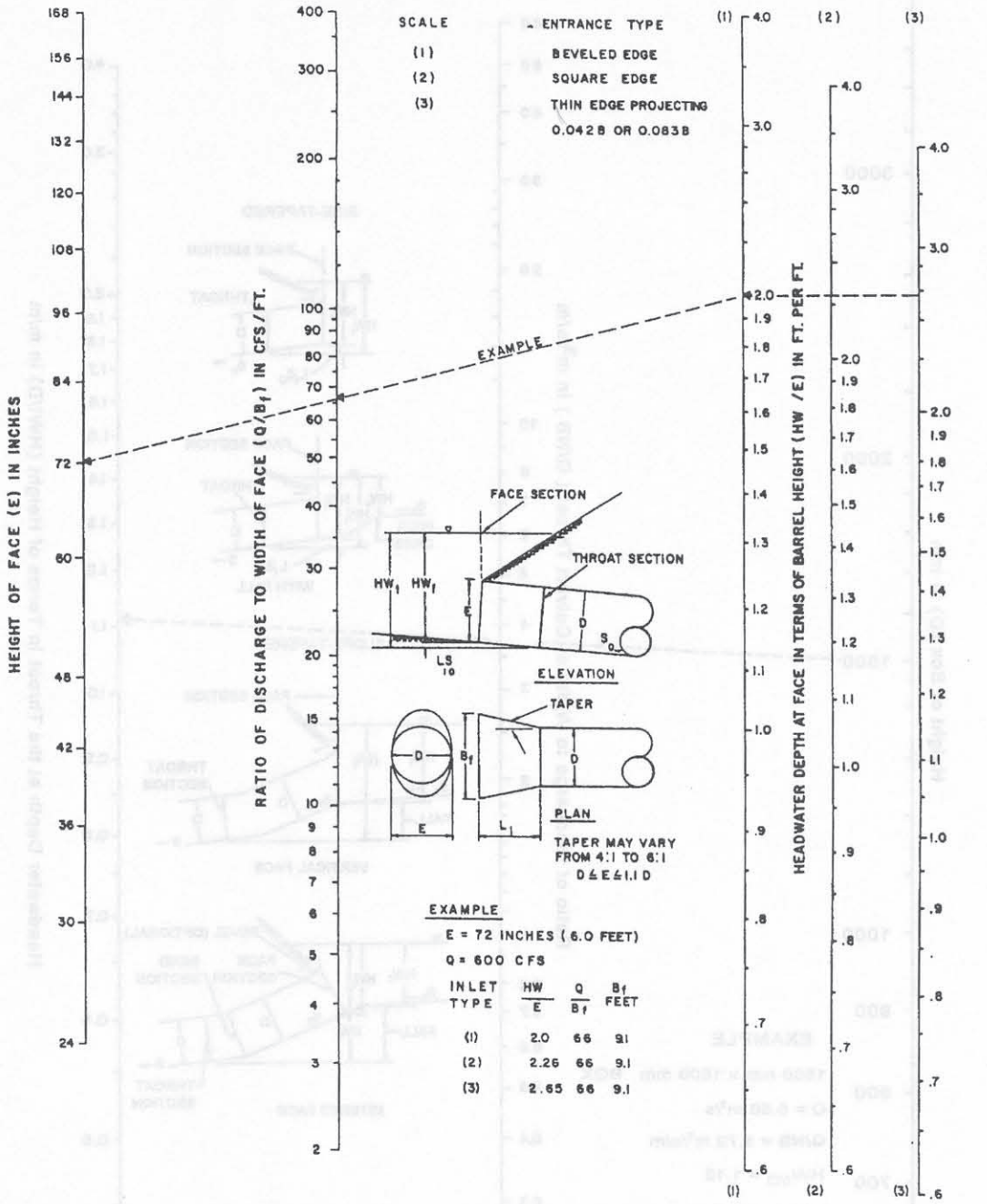
THROAT CONTROL
FOR SIDE-TAPERED INLETS TO PIPE CULVERT
(CIRCULAR SECTION ONLY)

CHART 56A



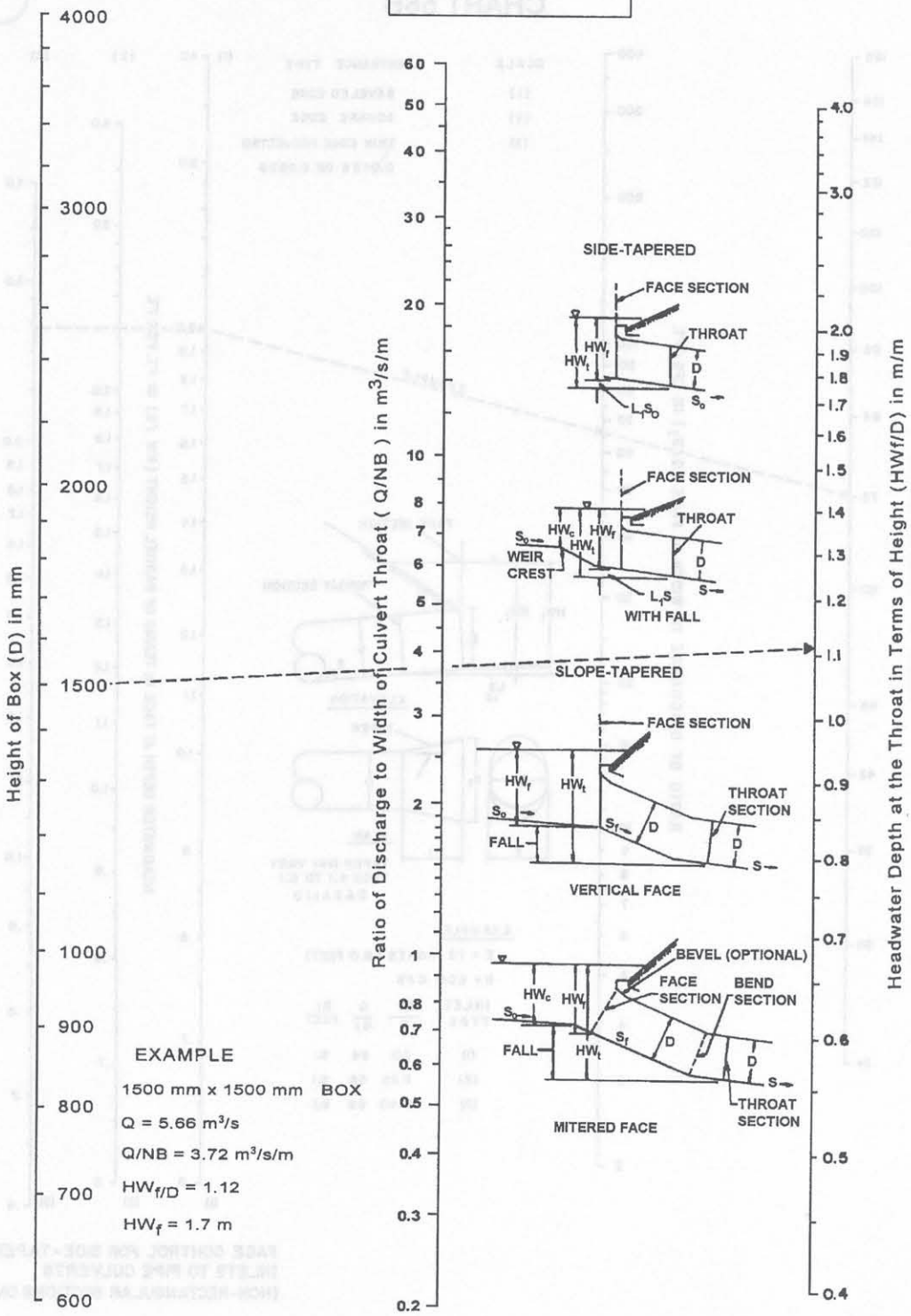
FACE CONTROL FOR SIDE-TAPERED INLETS TO PIPE CULVERTS (NON-RECTANGULAR SECTIONS ONLY)

CHART 56B



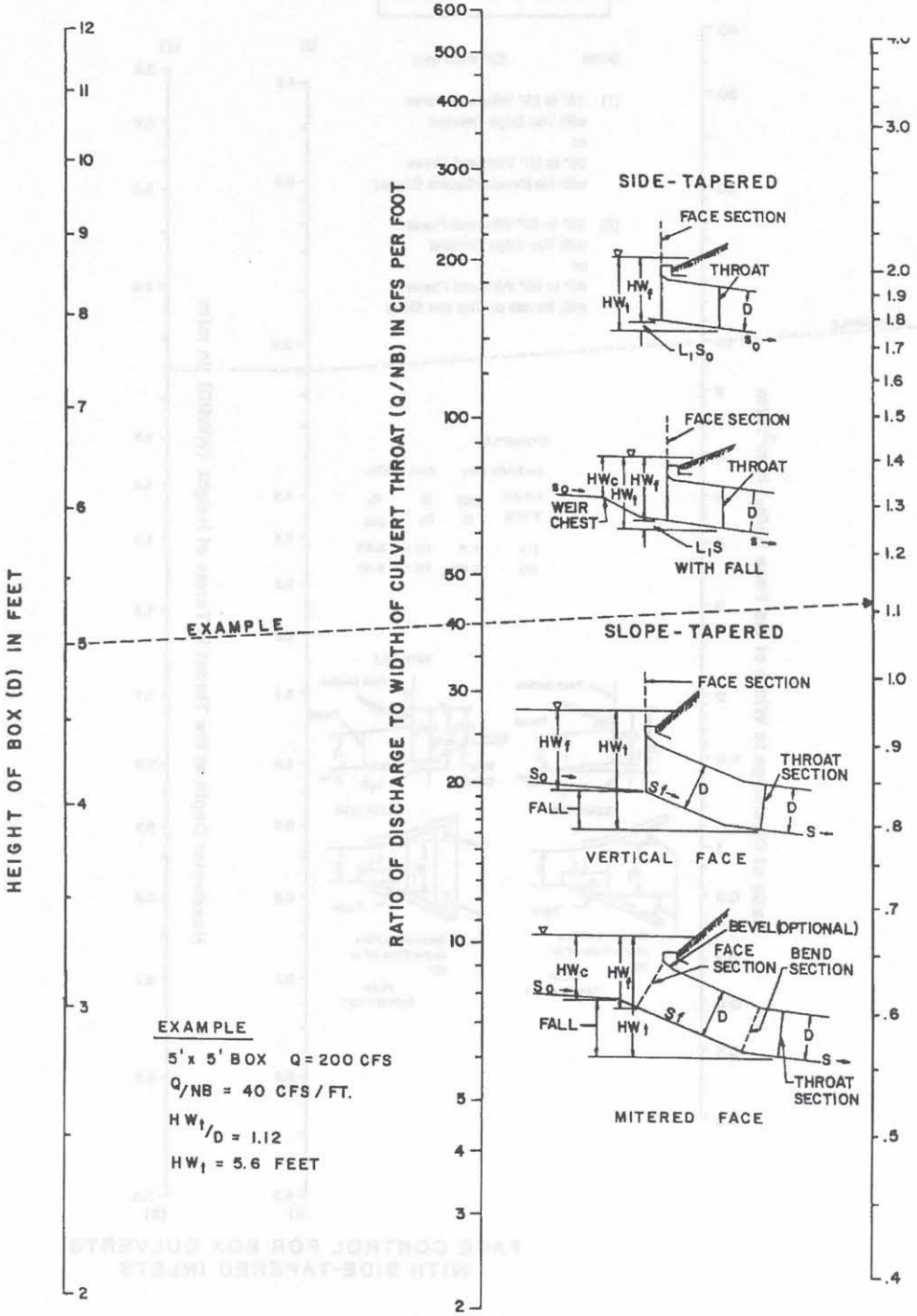
FACE CONTROL FOR SIDE-TAPERED INLETS TO PIPE CULVERTS (NON-RECTANGULAR SECTIONS ONLY)

CHART 57A



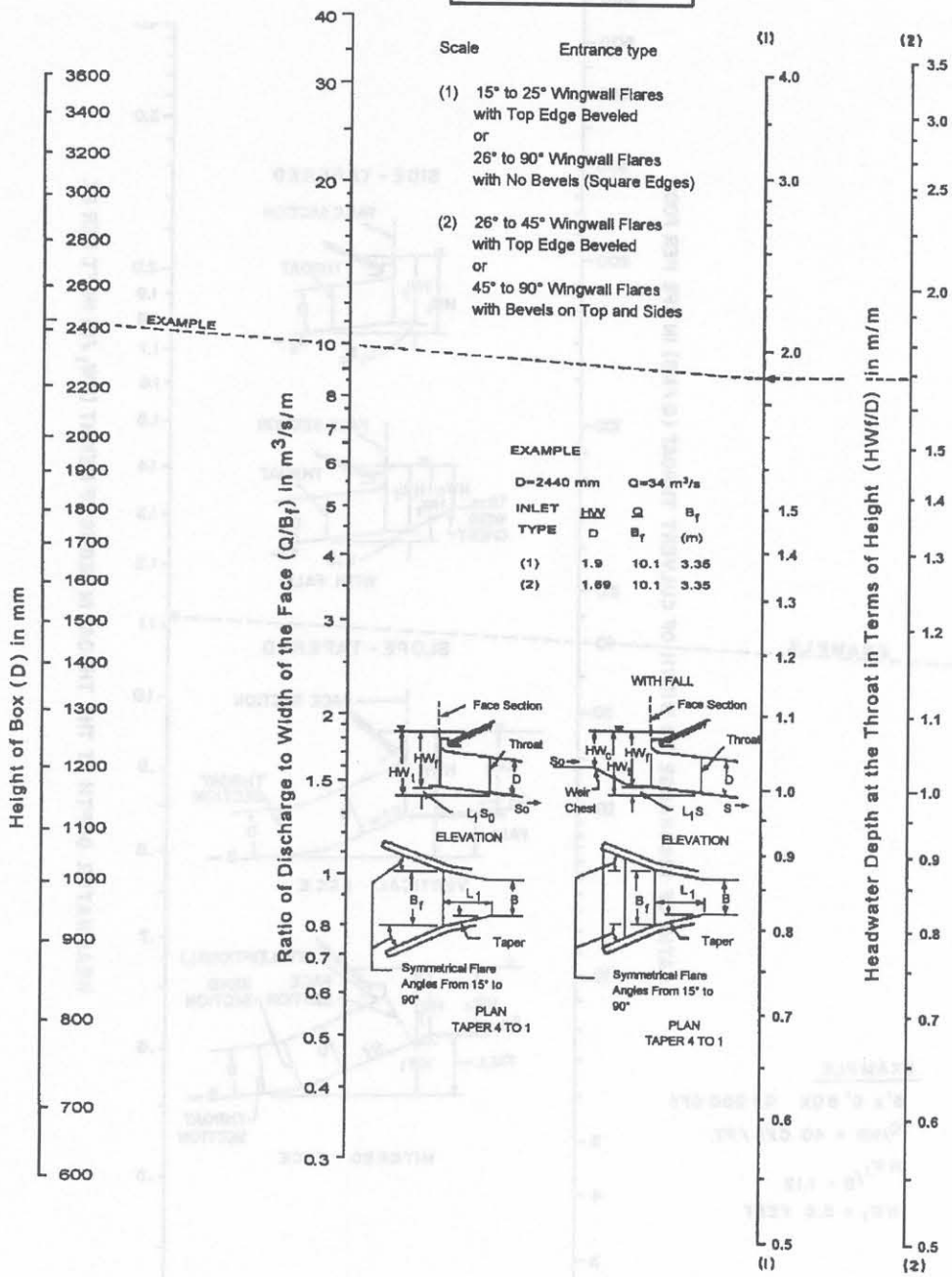
THROAT CONTROL FOR BOX CULVERTS WITH TAPERED INLETS

CHART 57B



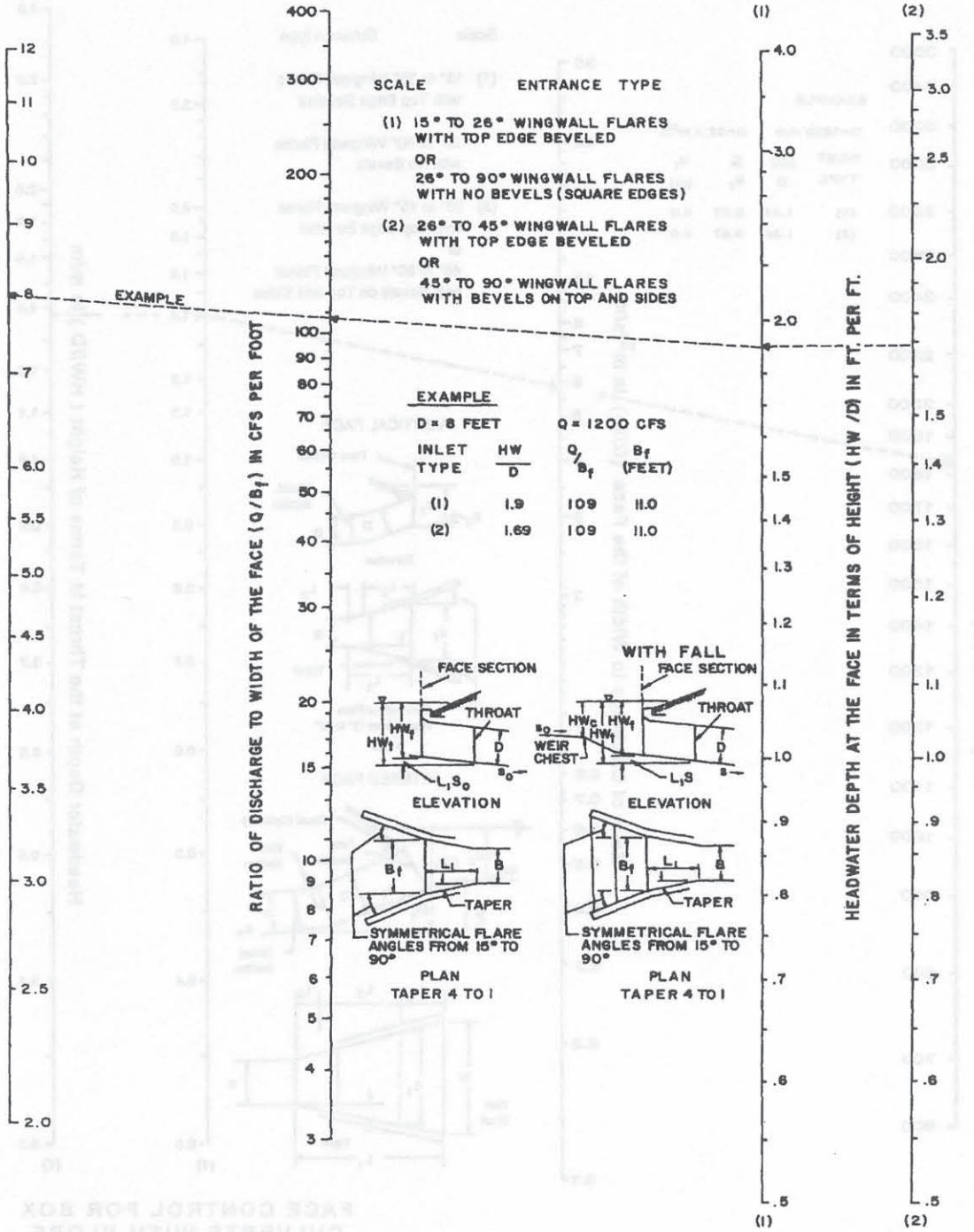
THROAT CONTROL FOR BOX CULVERTS WITH TAPERED INLETS

CHART 58A



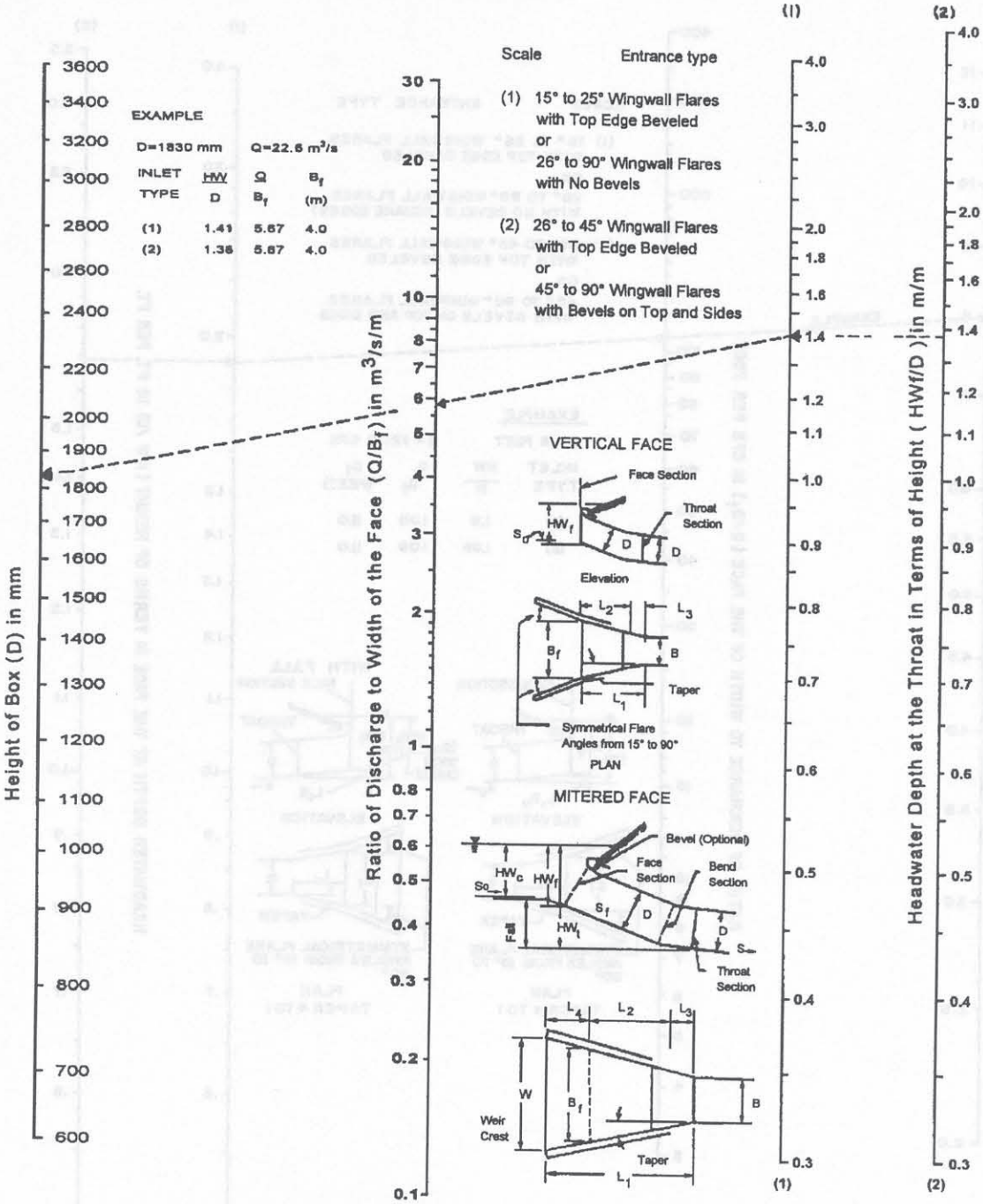
FACE CONTROL FOR BOX CULVERTS WITH SIDE-TAPERED INLETS

CHART 58B



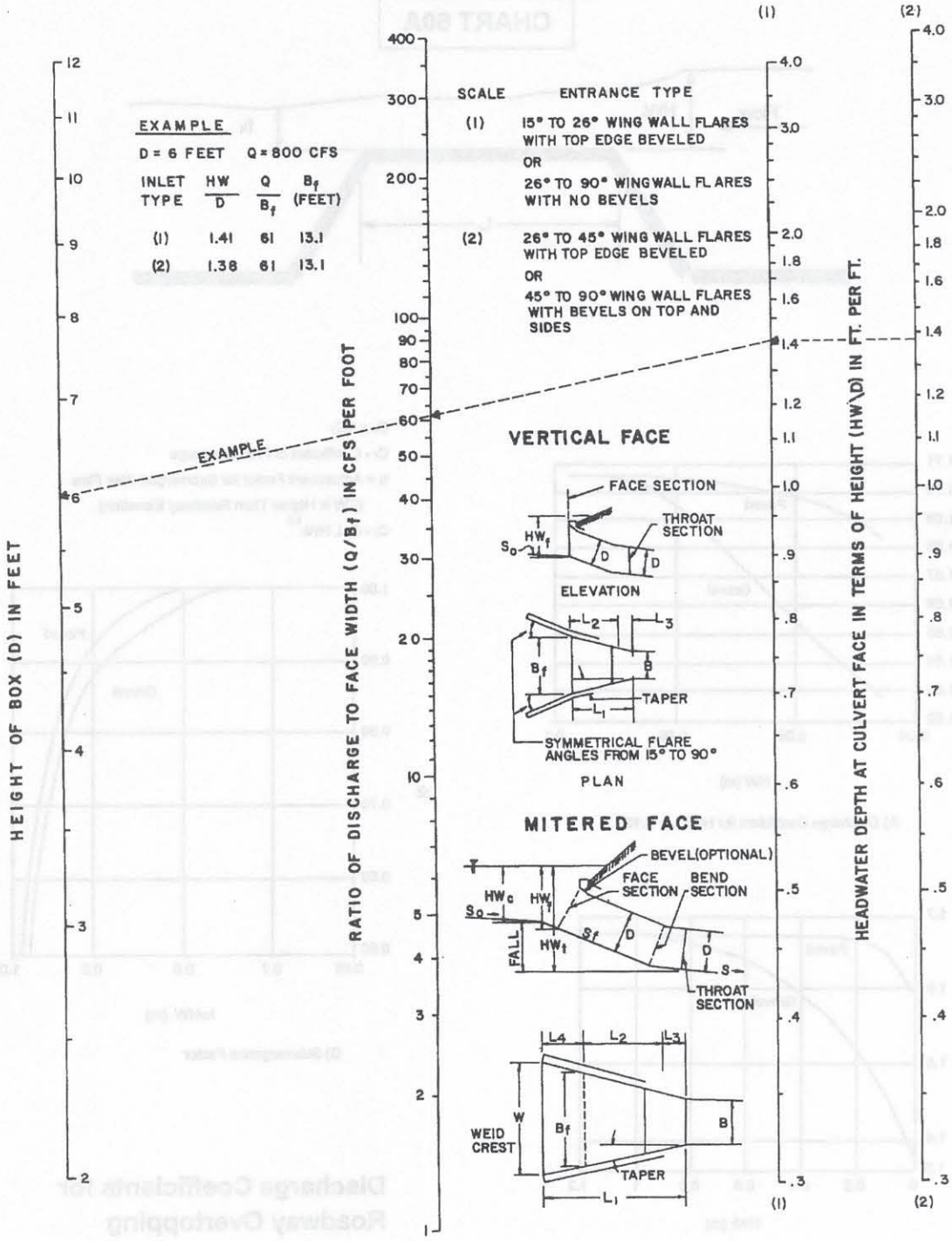
FACE CONTROL FOR BOX CULVERTS WITH SIDE TAPERED INLETS

CHART 59A



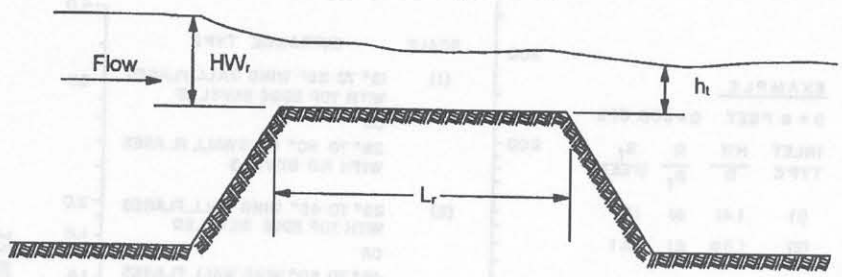
FACE CONTROL FOR BOX CULVERTS WITH SLOPE TAPERED INLETS

CHART 59B



FACE CONTROL FOR BOX CULVERTS WITH SLOPE TAPERED INLETS

CHART 60A



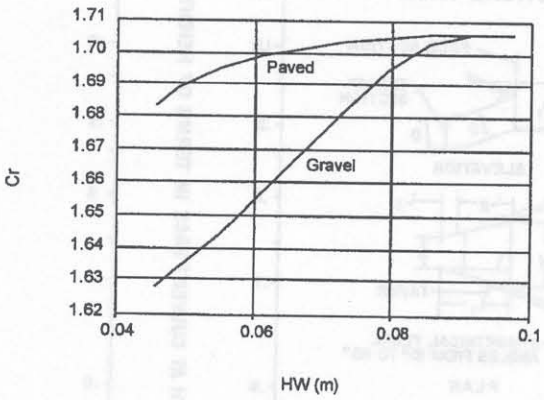
$C_d = k_t C_r$

C_r = Coefficient of Free Discharge

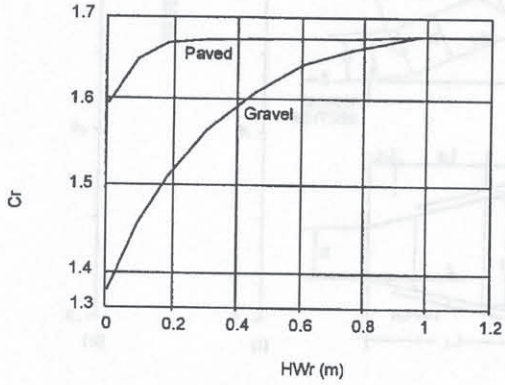
k_t = Adjustment Factor for Submerged Weir Flow

(TW is Higher Than Roadway Elevation)

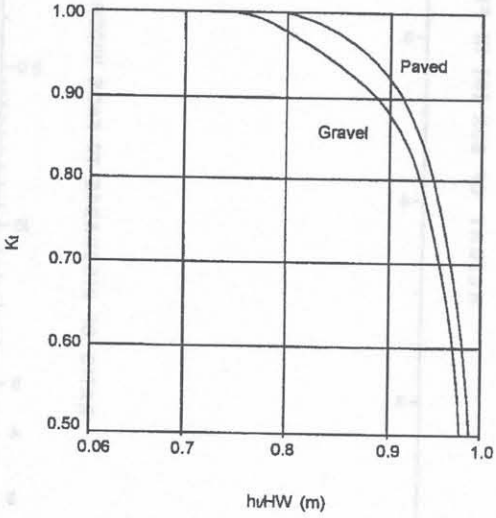
$Q_r = C_d L HW_r^{1.5}$



A) Discharge Coefficient for $HW_r/L_r > 0.15$



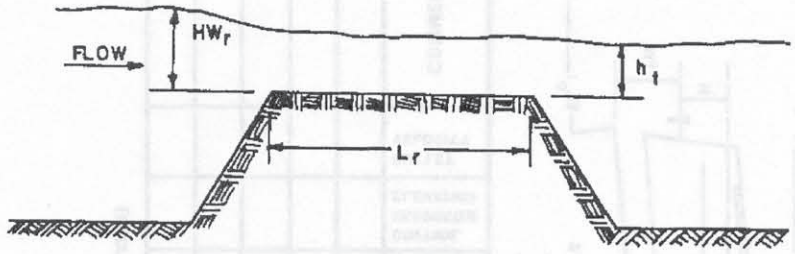
B) Discharge Coefficient for $HW_r/L_r \leq 0.15$

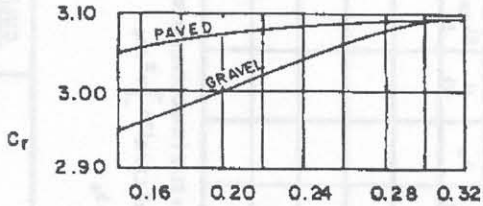


C) Submergence Factor

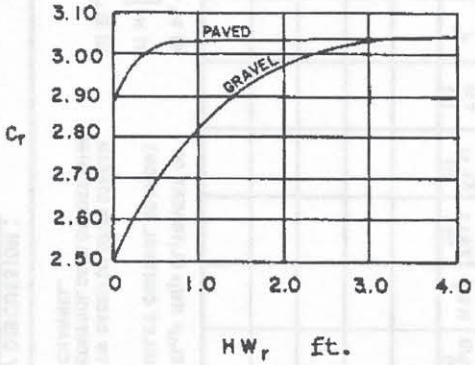
Discharge Coefficients for Roadway Overtopping

CHART 60B





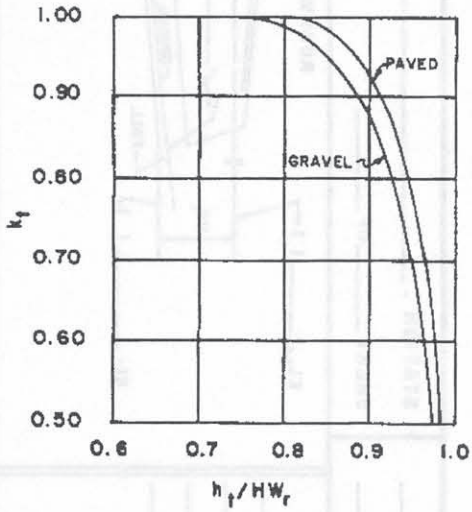
A) DISCHARGE COEFFICIENT FOR $HW_r / L_r > 0.15$



B) DISCHARGE COEFFICIENT FOR $HW_r / L_r \leq 0.15$

$$C_d = k_t C_r$$

$$Q_r = C_d \, L \, H \, W_r^{1.5}$$



C) SUBMERGENCE FACTOR

English Discharge Coefficients for Roadway Overtopping

PROJECT: _____

STATION: _____

SHEET _____ OF _____

CULVERT DESIGN FORM

DESIGNER / DATE: _____ / _____

REVIEWER / DATE: _____ / _____

HYDROLOGICAL DATA

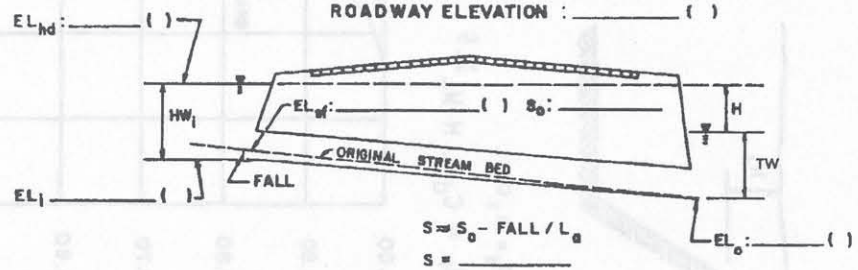
SEE ADD'L. SHTS.

- ☐ METHOD: _____
- ☐ DRAINAGE AREA: _____ ☐ STREAM SLOPE: _____
- ☐ CHANNEL SHAPE: _____
- ☐ ROUTING: _____ ☐ OTHER: _____

DESIGN FLOWS/TAILWATER

R.I. (YEARS)	FLOW( )	TW( )

ROADWAY ELEVATION: _____ ( )



$S \approx S_o - FALL / L_a$

$S =$ _____

$L_a =$ _____

CULVERT DESCRIPTION: MATERIAL - SHAPE - SIZE - ENTRANCE	TOTAL FLOW Q ( )	FLOW PER BARREL Q/N (1)	HEADWATER CALCULATIONS: INLET CONTROL HW_i/D (2)	HW_i	FALL (3)	EL_{hi} (4)	OUTLET CONTROL TW (5)	d_c	$\frac{d_c+D}{2}$	h_o (6)	k_e	H (7)	EL_{ho} (8)	CONTROL HEADWATER ELEVATION	OUTLET VELOCITY	COMMENTS

TECHNICAL FOOTNOTES:

(1) USE Q/NB FOR BOX CULVERTS

(2) $HW_i/D = HW/D$ OR HW_i/D FROM DESIGN CHARTS

(3) $FALL = HW_i - (EL_{hd} - EL_{sf})$; FALL IS ZERO FOR CULVERTS ON GRADE

(4) $EL_{hi} = HW_i + EL_i$ (INVERT OF INLET CONTROL SECTION)

(5) TW BASED ON DOWN STREAM CONTROL OR FLOW DEPTH IN CHANNEL.

(6) $h_o = TW$ or $(d_c + D)/2$ (WHICHEVER IS GREATER)

(7) $H = \left[1 + k_e + (29 n^2 L)/R^{1.33}\right] V^2/2g$

(8) $EL_{ho} = EL_o + H + h_o$

SUBSCRIPT DEFINITIONS:

a. APPROXIMATE
f. CULVERT FACE
hd. DESIGN HEADWATER
hi. HEADWATER IN INLET CONTROL
ho. HEADWATER IN OUTLET CONTROL
i. INLET CONTROL SECTION
o. OUTLET
sf. STREAMBED AT CULVERT FACE
tw. TAILWATER

COMMENTS / DISCUSSION:

CULVERT BARREL SELECTED:

SIZE: _____

SHAPE: _____

MATERIAL: _____ n _____

ENTRANCE: _____

PROJECT: _____

STATION: _____

SHEET _____ OF _____

TAPERED INLET DESIGN FORM

DESIGNER / DATE: _____ / _____

REVIEWER / DATE: _____ / _____

DESIGN DATA:

Q _____ = _____ ( ); EL_{hi} _____ ( )

EL. THROAT INVERT _____ ( )

EL. STREAM BED AT FACE _____

FALL _____ TAPER _____ : 1 (4 : 1 TO 6 : 1)

STREAM SLOPE, S_o = _____ ( )

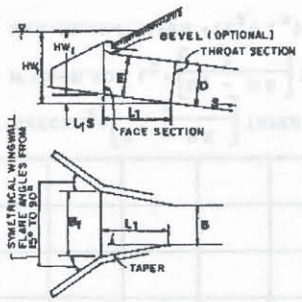
SLOPE OF BARREL, S = _____ ( )

S_f _____ : 1 (2 : 1 TO 3 : 1)

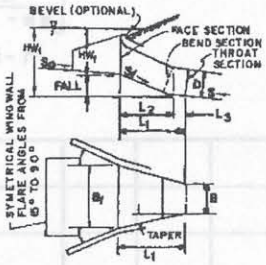
BARREL SHAPE AND MATERIAL: _____

N = _____, B = _____, D = _____

INLET EDGE DESCRIPTION _____



SIDE-TAPERED



SLOPE-TAPERED

COMMENTS

Q ( )	EL_{hi} ( )	EL. THROAT INVERT	EL. FACE INVERT (1)	HW_f (2)	HW_f / E (3)	Q / B_f (4)	MIN. B_f (5)	SELECTED B_f	SLOPE-TAPERED ONLY: MIN. L_3 (6)	L_2 (7)	CHECK L_2 (8)	ADJ. L_3 (9)	ADJ. TAPER (10)	L_1 (11)	SIDE-TAPERED W/ FALL: EL. CREST INV.	HW_c (12)	MIN. W (13)

(1) SIDE-TAPERED: EL. FACE INVERT = EL. THROAT INVERT + 0.3M, 1 ft (APPROX.)
SLOPE-TAPERED: EL. FACE INVERT = EL. STREAM BED AT FACE

(2) HW_f = EL_{hi} - EL. FACE INVERT

(3) $1.1\,D \geq E \geq D$

(4) FROM DESIGN CHARTS

(5) MIN. $B_f = Q/(Q/B_f)$

(6) MIN. $L_3 = 0.5\,NB$

(7) L_2 = (EL. FACE INVERT - EL. THROAT INVERT) S_f

(8) CHECK $L_2 = \left[\frac{B_f - NB}{2}\right] \cdot \text{TAPER} - L_3$

(9) IF (8) > (7), ADJ. $L_3 = \left[\frac{B_f - NB}{2}\right] \cdot \text{TAPER} - L_2$

(10) IF (7) > (8), ADJ. TAPER = $(L_2 + L_3) \Big/ \left[\frac{B_f - NB}{2}\right]$

(11) SIDE-TAPERED: $L = \left[\frac{B_f - NB}{2}\right] \cdot \text{TAPER}$

SLOPE-TAPERED: $L_1 = L_2 + L_3$

(12) HW_c = EL_{hi} - EL. CREST INVERT

(13) MIN. $W = 0.35\,Q / HW_c^{1.5}$

SELECTED DESIGN

B_f _____

L_1 _____

L_2 _____

L_3 _____

BEVELS ANGLE ____°

b = ____ ; d = ____ ( )

TAPER _____ : 1

S_f = _____ : 1

PROJECT : _____

STATION : _____

SHEET _____ OF _____

MITERED INLET DESIGN FORM

DESIGNER / DATE : _____ / _____

REVIEWER / DATE : _____ / _____

DESIGN DATA : N _____ ; B _____ ; D _____

Q _____ = _____ ( ) ; EL_{hi} _____ ( )

EL. THROAT INVERT _____ ( ) EL. STREAM BED AT CREST _____ ( )

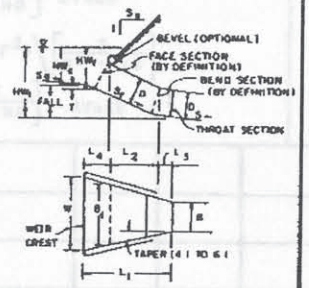
FALL _____ ( ) ; TAPER _____ : (4:1 TO 6:1)

STREAM SLOPE , S_o _____ ( ) ; BARREL SLOPE , S = _____ ( )

SLOPE OF THE EMBANKMENT S_e = _____ : 1 ; S_f _____ : 1 (2:1 TO 3:1)

BARREL SHAPE AND MATERIAL : _____

INLET EDGE DESCRIPTION : _____



SLOPE - TAPERED INLET / MITERED FACE

COMMENTS

Q ( )	EL_{hi}	EL. THROAT INVERT	y (1)	EL. FACE INVERT (2)	HW_f (3)	HW_f / E (4)	Q / B_f (5)	MIN. B_f (6)	SELECTED B_f	MIN. L_3 (7)	L_4 (8)	L_2 (9)	CHECK L_2 (10)	ADJ. L_3 (11)	ADJ. TAPER (12)	L_1 (13)	EL. CREST INV.	HW_c (14)	MIN. W (15)	W (16)

(1) $y = \left[\frac{(S_e \cdot S_f) - 1}{(S_e + S_f)(S_f^2 + 1)^{0.5}}\right] \cdot D$

(2) EL. FACE INVERT = EL. STREAM BED AT CREST - y

(3) HW_f = EL_{hi} - EL. FACE INVERT

(4) 1.1 D ≥ E ≥ 0

(5) FROM DESIGN CHARTS

(6) MIN. $B_f = Q / (Q / B_f)$

(7) MIN. L_3 = 0.5 NB

(8) $L_4 = S_f y + D / S_f$

(9) L_2 = (EL. CREST INVERT - EL. THROAT INVERT) S_f - L_4

*** IF L_2 IS NEGATIVE DO NOT USE THIS INLET

(10) CHECK $L_2 = \left[\frac{B_f - NB}{2}\right]$ TAPER - L_3

(11) IF (10)>(9), ADJ. $L_3 = \left[\frac{B_f - NB}{2}\right]$ TAPER - L_2

(12) IF (9)>(10), ADJ. TAPER = $(L_2 + L_3) / \left[\frac{B - NB}{2}\right]$

(13) $L_1 = L_2 + L_3 + L_4$

(14) HW_c = EL_{hi} - EL. CREST INVERT

(15) MIN. W = $0.35 Q / (HW_c)^{1.5}$

(16) $W = NB + 2 \left[\frac{L_1}{TAPER}\right]$

IF W<MIN. W , ADJUST TAPER

SELECTED DESIGN

B_f _____

L_1 _____

L_2 _____

L_3 _____

L_4 _____

BEVELS ANGLE _____ °

b = _____ ; d = _____ ( )

TAPER _____ : 1

S_f _____ : 1

STORAGE ROUTING FORM

1. INFLOW HYDROGRAPH GENERATION
   a. Hydrograph method used:
   b. Time interval selected for routing: (inflow hydrograph attached)

2. APPROXIMATE FLOW REDUCTION DUE TO ROUTING
   a. Peak inflow: Q_p=_____( )
   b. Upstream storage: S=_____( )
   c. Time to peak: t_p=_____min

$$Q_r = Q_p - \frac{S}{80\,t_p} =$$

3. ELEVATION - DISCHARGE RELATIONSHIP FOR TRIAL CULVERT

ELEVATION ( )								
DISCHARGE ( )								

4. ELEVATION - STORAGE RELATIONSHIP FOR UPSTREAM PONDING

ELEVATION ( )	AREA ( )	INCREMENTAL VOLUME ( )	ACCUMULATED VOLUME ( )

5. STORAGE - OUTFLOW RELATIONSHIP

Elevation ( )	Discharge (O) ( )	Storage (S) ( )	$2s/\Delta t$ ( )	$2s/\Delta t + O$ ( )

6. STORAGE - INDICATION ROUTING TABLE

(1) TIME min	(2) INFLOW (I) ( )	(3) $2s/\Delta t - O$ ( )	(4) $2s/\Delta t + O$ ( )	(5) OUTFLOW (O) ( )

WATER SURFACE PROFILE COMPUTATIONS

Identification: _____ By: _____ Date: _____

Channel Shape Checked by: _____ Date: _____

Manning's n =

Q =

d	A	R	V = Q/A	$\frac{V^2}{2g}$	H = d + $V^2/2g$	(1) Δ H	$R^{2/3}$	$AR^{2/3}$	(2) $S_f = (K_n/AR^{2/3})^2$	$\bar{S}_f = (S_{f1} \cdot S_{f2})^{1/2}$	$S_o - \bar{S}_f$	(3) $\Delta L = \frac{\Delta H}{S_o - \bar{S}_f}$	L = Σ ΔL

(1) SUBTRACT SECOND H FROM FIRST H VALUE

(2) $K_n = \frac{Qn}{}$ =

(3) IF ΔL IS +, PROFILE IS PROGRESSING UPSTREAM
−ΔL DENOTES DOWNSTREAM PROGRESSION

WATER SURFACE PROFILE COMPUTATIONS

Identification: _____ By: _____ Date: _____

Channel Shape Checked by: _____ Date: _____

Manning's n =

Q =

d	A	R	V = Q/A	$\frac{V^2}{2g}$	H = d + $V^2/2g$	(1) Δ H	$R^{2/3}$	$AR^{2/3}$	(2) $S_f = (K_n/AR^{2/3})^2$	$\bar{S}_f = (S_{f1} \cdot S_{f2})^{1/2}$	$S_o - \bar{S}_f$	(3) $\Delta L = \frac{\Delta H}{S_o - \bar{S}_f}$	L = Σ ΔL

(1) SUBTRACT SECOND H FROM FIRST H VALUE

(2) $K_n = \frac{Qn}{}$ =

(3) IF ΔL IS +, PROFILE IS PROGRESSING UPSTREAM
−ΔL DENOTES DOWNSTREAM PROGRESSION