Ontario

MINISTRY OF TRANSPORTATION

MTO Hydrotechnical Design Charts

January 2023

Standards & Contracts Branch

Highway Design Office

Summary List of Design Charts

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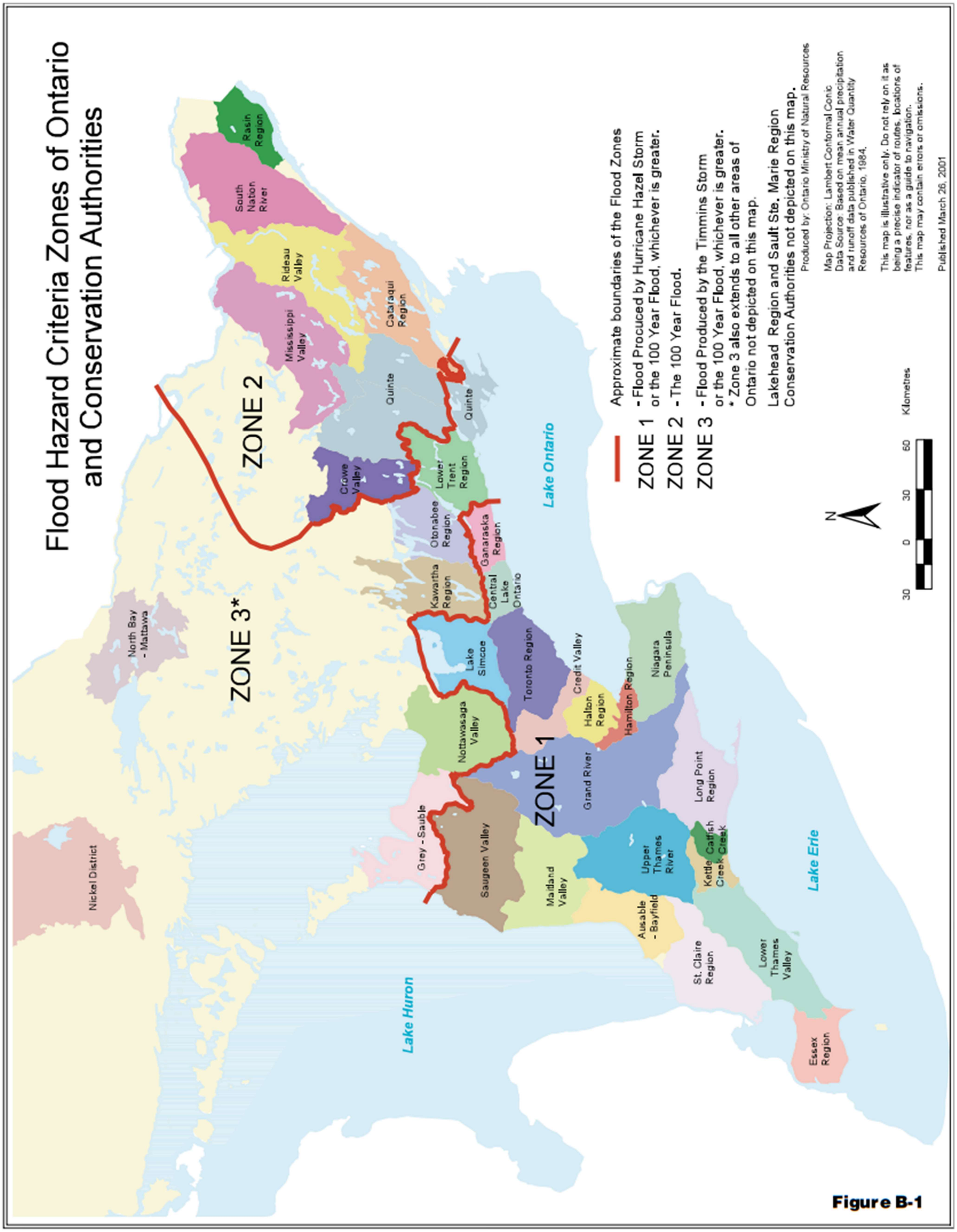
Design Chart 1.02: Flood Hazard Criteria Zones of Ontario & Conservation Authorities



Source: Ontario Ministry of Natural Resources and Forestry

Design Chart 1.03: Hurricane Hazel

	Depth (mm)	Depth (inches)	Percent of 12 hour
First 36 hours	73	2.90	
37th hour	6	.25	3
38th hour	4	.17	2
39th hour	6	.25	3
40th hour	13	.50	6
41st hour	17	.66	8
42nd hour	13	.50	6
43rd hour	23	.91	11
44th hour	13	.50	6
45th hour	13	.50	6
46th hour	53	2.08	25
47th hour	38	1.49	18
48th hour	13	.50	6
	285	11.21	100

Drainage Area (km^2)	Percentage
0 to 25	100.0
26 to 45	99.2
46 to 65	98.2
66 to 90	97.1
91 to 115	96.3
116 to 140	95.4
141 to 165	94.8
166 to 195	94.2
196 to 220	93.5
221 to 245	92.7
246 to 270	92.0
271 to 450	89.4
451 to 575	86.7
576 to 700	84.0
701 to 850	82.4
851 to 1000	80.8
1001 to 1200	79.3
1201 to 1500	76.6
1501 to 1700	74.4
1701 to 2000	73.3
2001 to 2200	71.7
2201 to 2500	70.2
2501 to 2700	69.0
2701 to 4500	64.4
4501 to 6000	61.4
6001 to 7000	58.9
7001 to 8000	57.4

Source: Ministry of Transportation - MTO (1989)

Design Chart 1.04: Timmins Storm

	Depth		Percent of 12 hour
	(mm)	(inches)	
1st hour	15	0.6	8
2nd hour	20	0.8	10
3rd hour	10	0.4	6
4th hour	3	0.1	1
5th hour	5	0.2	3
6th hour	20	0.8	10
7th hour	43	1.7	23
8th hour	20	0.8	10
9th hour	23	0.9	12
10th hour	13	0.5	6
11th hour	13	0.5	7
12th hour	8	0.3	4
	193	7.6	100

Drainage Area (km^2)	Percentage
0 to 25	100.0
26 to 50	97
51 to 75	94
76 to 100	90
101 to 150	87
151 to 200	84
201 to 250	82
251 to 375	79
376 to 500	76
501 to 750	74
751 to 1000	70
1001 to 1250	68
1251 to 1500	66
1501 to 1800	65
1801 to 2100	64
2101 to 2300	63
2301 to 2600	62
2601 to 3900	58
3901 to 5200	56
5201 to 6500	53
6501 to 8000	50

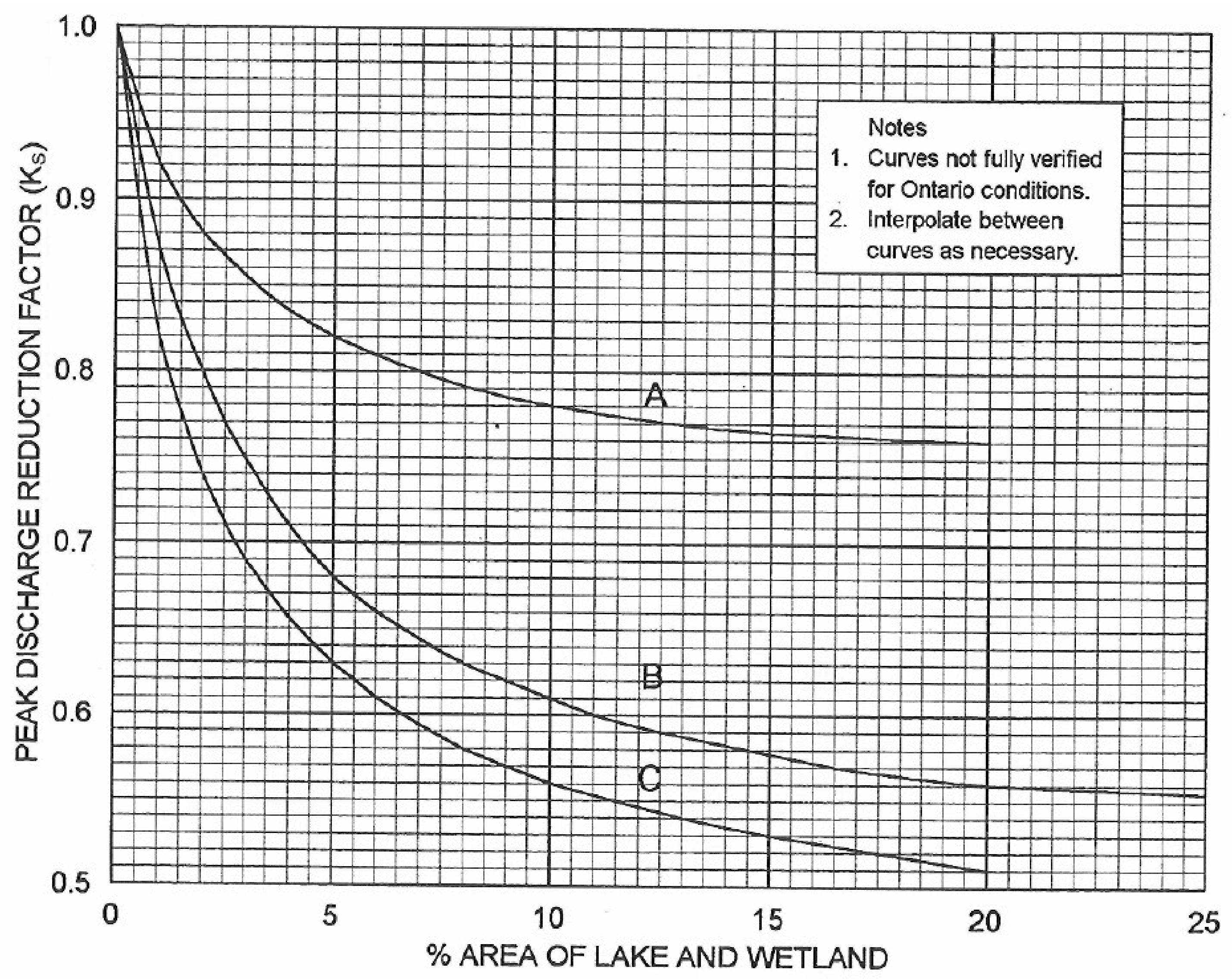
Source: MTO (1989)

Design Chart 1.05: SCS Type II Distribution

6 hour			12 hour			24 hour		
Time end'g, hour	F_{inc} (%)	F_{cum} (%)	Time end'g, hour	F_{inc} (%)	F_{cum} (%)	Time end'g, hour	F_{inc} (%)	F_{cum} (%)
0	0	0	0	0	0	0	0	0
0.5	2	2	2	5	5	2	2.2	2.2
1	3	5	3	3	8	4	2.6	4.8
1.5	3	8	3.5	2	10	6	3.2	8.0
2	5	13	4	2	12	7	-	-
2.5	6	19	4.5	3	15	8	4.0	12.0
2.75	15	34	5	4	19	8.5	-	-
3	39	73	5.5	6	25	9	2.7	14.7
3.5	11	84	5.75	12	37	9.5	1.6	16.3
4	5	89	6	33	70	9.75	-	-
4.5	4	93	6.5	9	79	10	1.8	18.1
5	3	96	7	4	83	10.5	2.3	20.4
6	4	100	7.5	3	86	11	3.1	23.5
			8	3	89	11.5	4.8	28.3
			10	7	96	11.75	10.4	38.7
			12	4	100	12	27.6	66.3
						12.5	7.2	73.5
						13	3.7	77.2
						13.5	0.7	77.9
						14	4.1	82.0
						16	6.0	88.0
						20	7.2	95.2
						24	4.8	100

Source: Ministry of Natural Resources – MNR (1986)

Design Chart 1.06: Peak Discharge Reduction Factor to Allow for Storage



Curve A - Significant portion of flow passes through detention areas in upper reaches, or elsewhere in basin not in path of flow.

Curve B - Significant portion of flow passes through detention areas distributed throughout basin or in the middle reaches only.

Curve C - Most of detention is located in path of flow at lower end of basin.

Design Chart 1.07: Runoff Coefficients

- Urban for 5 to 10-Year Storms

Land Use		Runoff Coefficient	
		Min.	Max.
Pavement	- asphalt or concrete	0.80	0.95
- brick		0.70	0.85
Gravel roads and shoulders		0.40	0.60
Roofs		0.70	0.95
Business	- downtown	0.70	0.95
- neighbourhood		0.50	0.70
- light		0.50	0.80
- heavy		0.60	0.90
Residential	- single family urban	0.30	0.50
- multiple, detached		0.40	0.60
- multiple, attached		0.60	0.75
- suburban		0.25	0.40
Industrial	- light	0.50	0.80
- heavy		0.60	0.90
Apartments		0.50	0.70
Parks, cemeteries		0.10	0.25
Playgrounds (unpaved)		0.20	0.35
Railroad yards		0.20	0.35
Unimproved areas		0.10	0.30
Lawns - Sandy soil			
- flat, to 2%		0.05	0.10
- average, 2 to 7%		0.10	0.15
- steep, over 7%		0.15	0.20
- Clayey soil			
- flat, to 2%		0.13	0.17
- average, 2 to 7%		0.18	0.22
- steep, over 7%		0.25	0.35

For flat or permeable surfaces, use the lower values. For steeper or more impervious surfaces, use the higher values. For return period of more than 10 years, increase above values as 25-year - add 10%, 50-year - add 20%, 100-year - add 25%.

The coefficients listed above are for unfrozen ground.

Design Chart 1.07: Runoff Coefficients (Continued)

- Rural

Land Use & Topography[3]	Soil Texture		
	Open Sand Loam	Loam or Silt Loam	Clay Loam or Clay
CULTIVATED			
Flat 0 - 5% Slopes	0.22	0.35	0.55
Rolling 5 - 10% Slopes	0.30	0.45	0.60
Hilly 10- 30% Slopes	0.40	0.65	0.70
PASTURE			
Flat 0 - 5% Slopes	0.10	0.28	0.40
Rolling 5 - 10% Slopes	0.15	0.35	0.45
Hilly 10- 30% Slopes	0.22	0.40	0.55
WOODLAND OR CUTOVER			
Flat 0 - 5% Slopes	0.08	0.25	0.35
Rolling 5 - 10% Slopes	0.12	0.30	0.42
Hilly 10- 30% Slopes	0.18	0.35	0.52
BARE ROCK	COVERAGE[3]		
	30%	50%	70%
Flat 0 - 5% Slopes	0.40	0.55	0.75
Rolling 5 - 10% Slopes	0.50	0.65	0.80
Hilly 10- 30% Slopes	0.55	0.70	0.85
LAKES AND WETLANDS	0.05		

2 Terrain Slopes

3 Interpolate for other values of % imperviousness

Sources: American Society of Civil Engineers -ASCE (1960)
U.S. Department of Agriculture (1972)

Design Chart 1.08: Hydrologic Soil Groups

- Based on Surficial Geology Maps

Map Ref.No.	Soil Type or Texture	Hydrologic Soil Group (Tentative)
	Ground Moraine	
1a	Usually sandy till, stony, varying depth. (Most widespread type in Shield).	Usually B (shallow); may be A or AB
1b	Clayey till, varying depth.	BC-C
	End or Interlobate Moraine	
2a	Sand & stones, deep. (May be rough topography).	A
2b	Sand & stones capped by till, deep.	A-C depending on type of till.
2c	Sand & stones, deep. (Smoother topography).	A
	Kames & Eskers	
3a	Sand & stones, deep. (May be rough topography).	A
3b	Sand & stones capped by till, deep.	A-C depending on type of till.
3c	Sand & stones, deep. (Smoother topography).	A
	Lacustrine	
4a	Clay & silt, in lowlands.	BC-C
4b	Fine sand, in lowlands.	AB-B
4c	Sand, in lowlands.	AB
4d	Sand (deltas & valley trains).	A-AB
	Outwash	
5	Sand, some gravel, deep.	A
	Aeolian	
6	Very fine sand & silt, shallow. (Loess)	B
	Bedrock	
7	Bare bedrock (normally negligible areas).	Varies according to rock type.

Source: Ministry of Natural Resources – MNR

Design Chart 1.08: Hydrologic Soil Groups (Continued)

- Based on Soil Texture

Sands, Sandy Loams and Gravels	
- overlying sand, gravel or limestone bedrock, very well drained	A
- ditto, imperfectly drained	AB
- shallow, overlying Precambrian bedrock or clay subsoil	B
Medium to Coarse Loams	
- overlying sand, gravel or limestone, well drained	AB
- shallow, overlying Precambrian bedrock or clay subsoil	B
Medium Textured Loams	
- shallow, overlying limestone bedrock	B
- overlying medium textured subsoil	BC
Silt Loams, Some Loams	
- with good internal drainage	BC
- with slow internal drainage and good external drainage	C
Clays, Clay Loams, Silty Clay Loams	
- with good internal drainage	C
- with imperfect or poor external drainage	C
- with slow internal drainage and good external drainage	D

Source: U.S. Department of Agriculture (1972)

Design Chart 1.09: Soil/Land Use Curve Numbers

Land Use	Treatment or Practice	Hydrologic Condition[4]	Hydrologic Soil Group			
			A	B	C	D
Fallow	Straight row	---	77	86	91	94
Row crops	"	Poor	72	81	88	91
	"	Good	67	78	85	89
	Contoured	Poor	70	79	84	88
	"	Good	65	75	82	86
	" and terraced	Poor	66	74	8	82
	" " "	Good	62	71	78	81
Small grain	Straight row	Poor	65	76	84	88
		Good	63	75	83	87
	Contoured	Poor	63	74	82	85
		Good	61	73	81	84
	" and terraced	Poor	61	72	79	82
		Good	59	70	78	81
Close-seeded legumes[2] or rotation meadow	Straight row	Poor	66	77	85	89
	" "	Good	58	72	81	85
	Contoured	Poor	64	75	83	85
	"	Good	55	69	78	83
	" and terraced	Poor	63	73	80	83
	" and terraced	Good	51	67	76	80
Pasture or range		Poor	68	79	86	89
		Fair	49	69	79	84
	Contoured	Good	39	61	74	80
	"	Poor	47	67	81	88
	"	Fair	25	59	75	83
		Good	6	35	70	79
Meadow		Good	30	58	71	78
Woods		Poor	45	66	77	83
		Fair	36	60	73	79
		Good	25	55	70	77
Farmsteads		---	59	74	82	86
		---	72	82	87	89
		---	74	84	90	92

For average anticedent soil moisture condition (AMC II)
[2] Close-drilled or broadcast.

[4] The hydrologic condition of cropland is good if a good crop rotation practice is used; it is poor if one crop is grown continuously.

Source: U.S. Department of Agriculture (1972)

Design Chart 1.09: Soil/Land Use Curve Numbers (Continued)

Land Use or Surface	Hydrologic Soil Group						
	A	AB	B	BC	C	CD	D
Fallow (special cases only)	77	82	86	89	91	93	94
Crop and other improved land	66** (62)	70** (68)	74	78	82	84	86 AMC I
Pasture & other unimproved land	58* (38)	62* (51)	65	71	76	79	81
Woodlots and forest	50* (30)	54* (44)	58	65	71	74	77
Impervious areas (paved)							98
Bare bedrock draining directly to stream by surface flow							98
Bare bedrock draining indirectly to stream as groundwater (usual case)							70
Lakes and wetlands							50

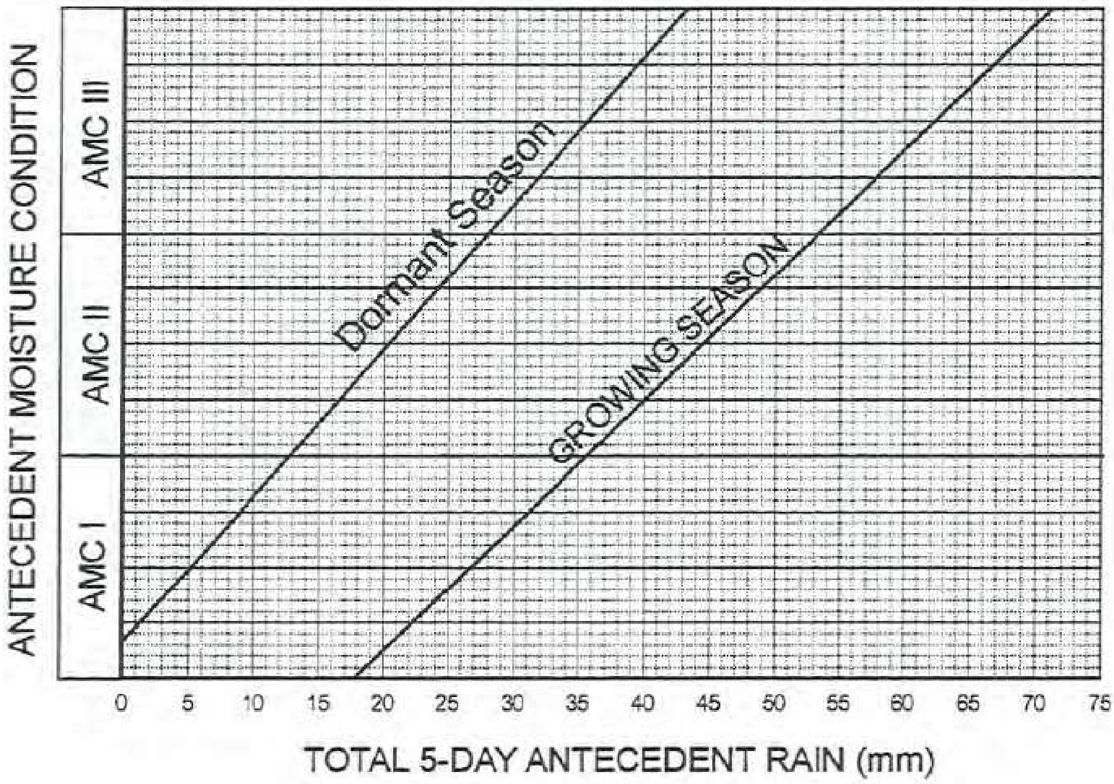
Notes

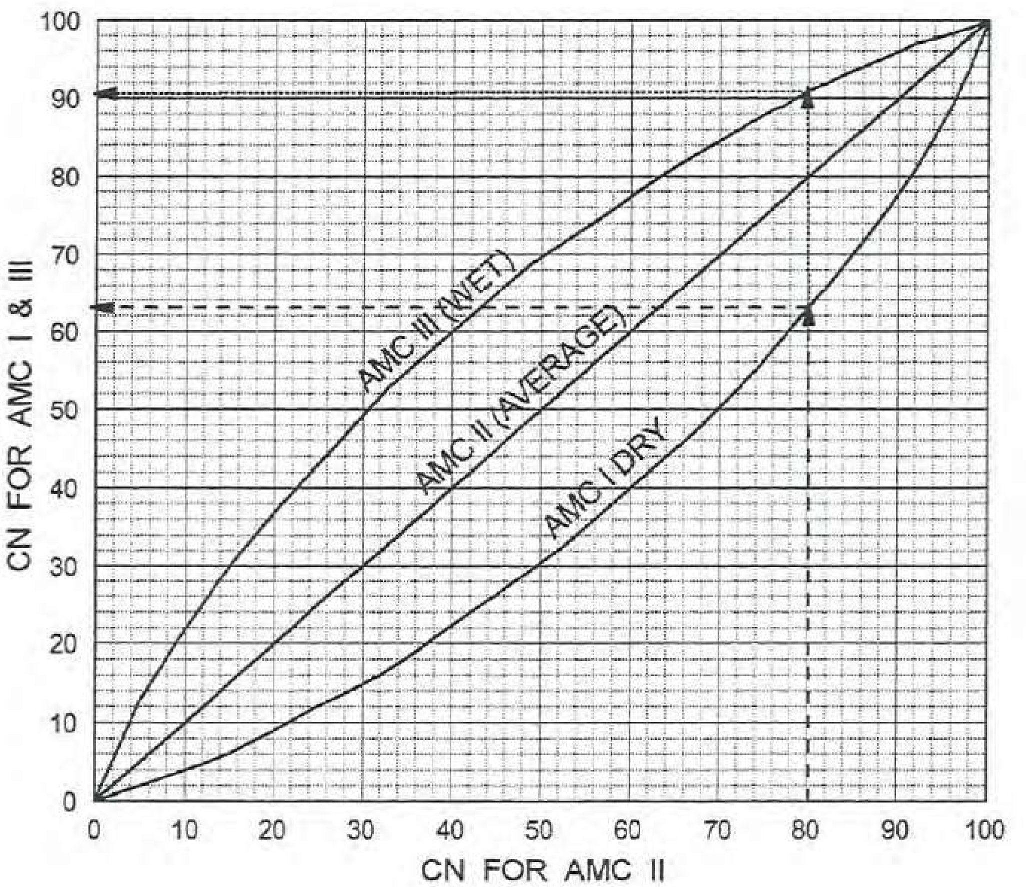
(i) All values are based on AMC II except those marked by * (AMC III) or ** (mean of AMC II and AMC III).

(ii) Values in brackets are AMC II and are to be used only for special cases.

(iii) Table is not applicable to frozen soils or to periods in which snowmelt contributes to runoff.

Design Chart 1.10: Antecedent Moisture Condition

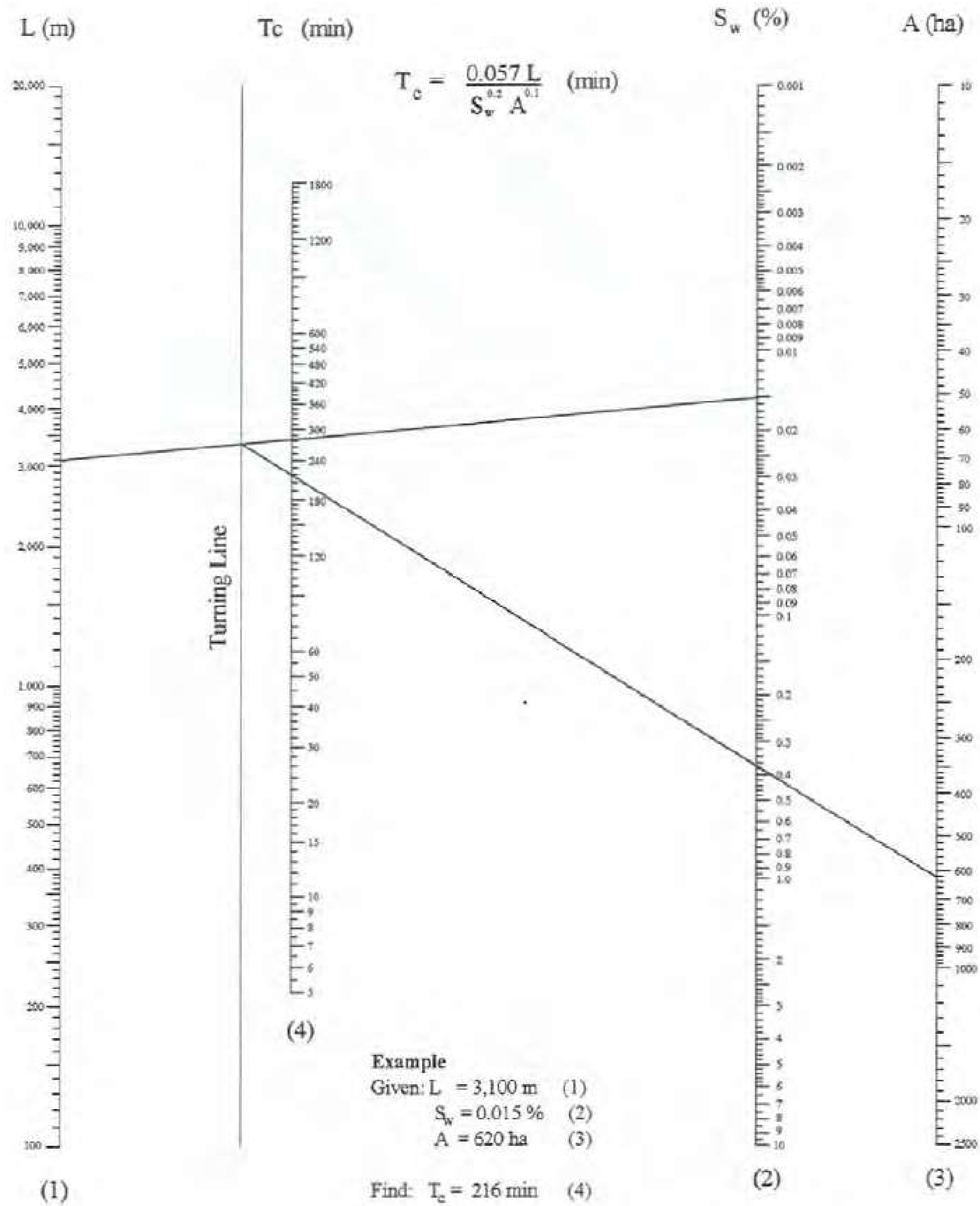




EXAMPLE

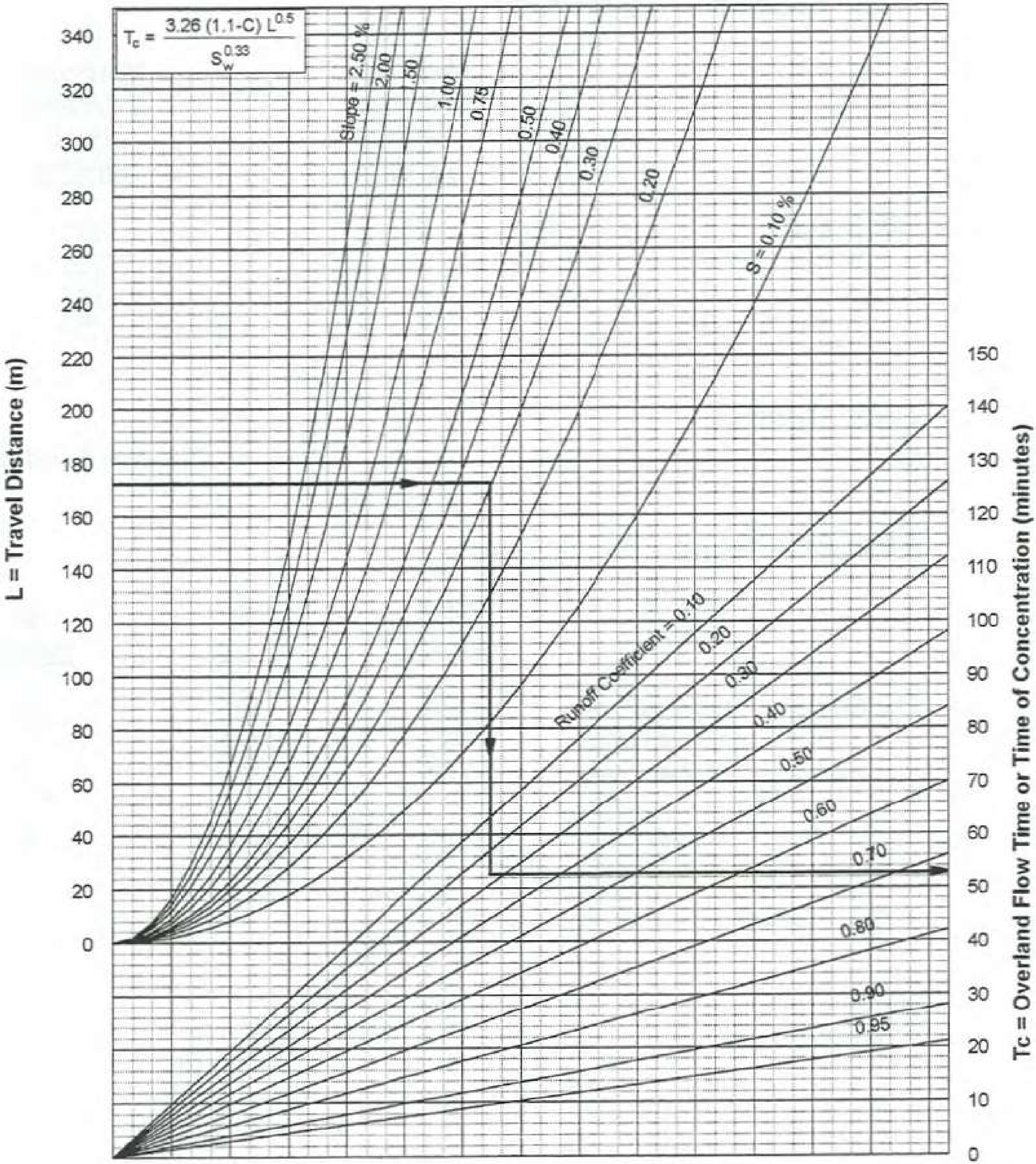
AMC II CN = 80
AMC I CN = 63
AMC III CN = 91

Design Chart 1.11: Time of Concentration - Bransby Williams Method



Source: French R., et al (1974)

Design Chart 1.12: Time of Concentration - Airport Method



Source: U.S. Department of Transportation (1970)

Design Chart 1.13: Infiltration Parameters

Horton Equation - Typical Values

		Minimum Infiltration Rate (mm/hr)	Maximum* Infiltration Rate (mm/hr)
Soil Group	A	25	250
	B	13	200
	C	5	125
	D	5	75

Decay Parameter 2 hr^{-1}

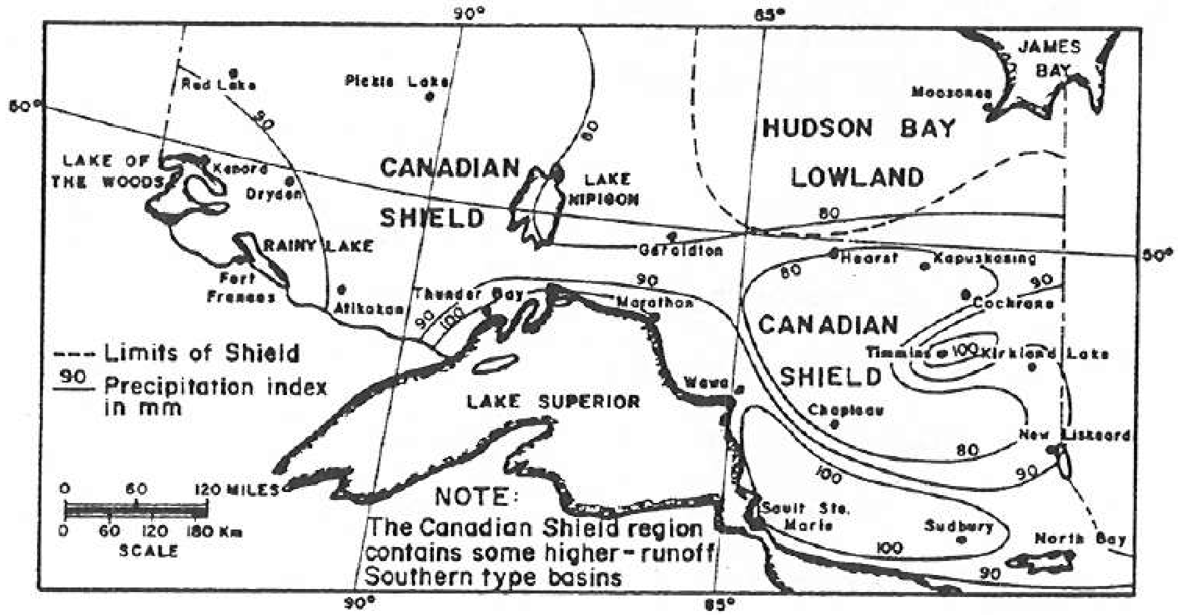
*Dry Soil Conditions

Green-Ampt Method - Typical Values

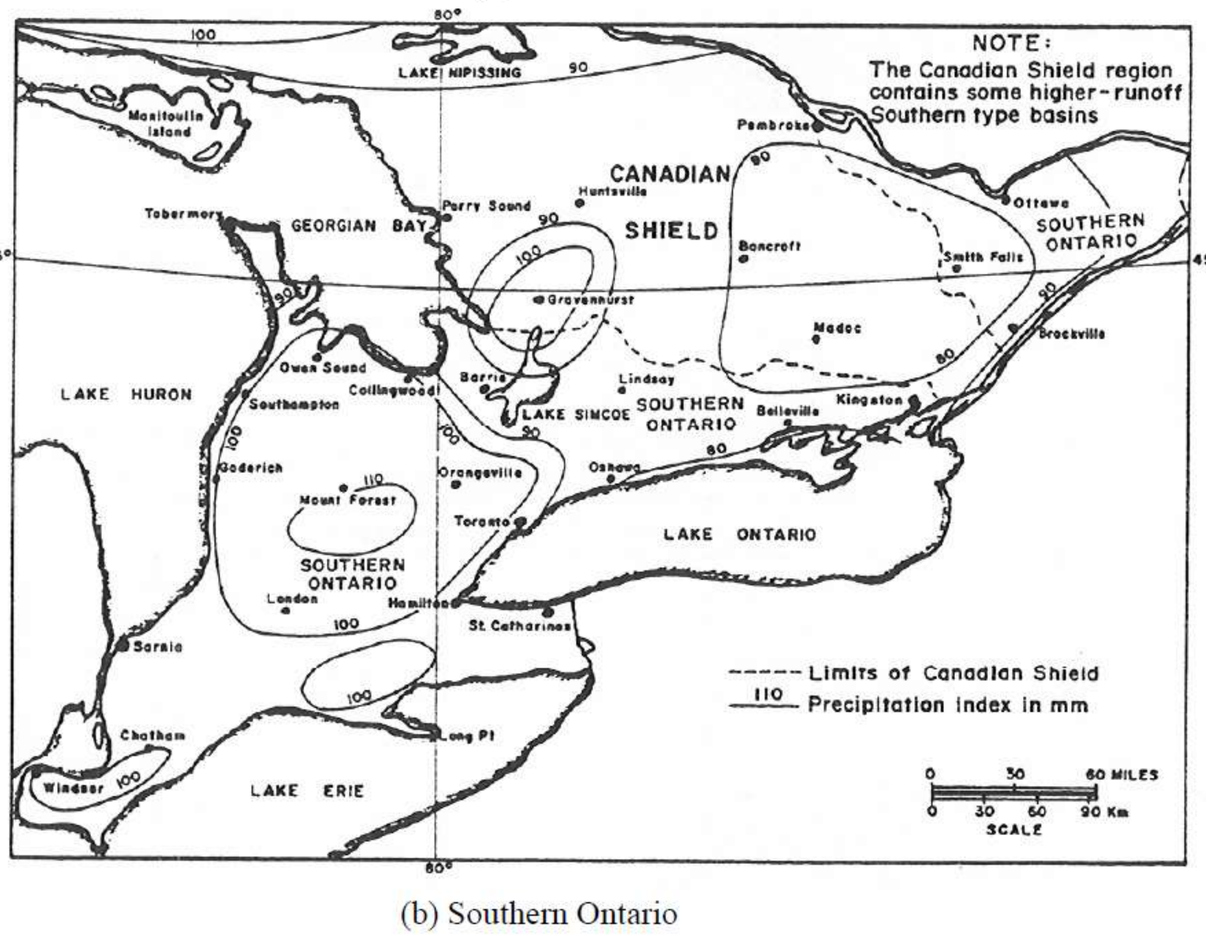
		IMD (mm/mm)	S_u (mm)	K_s (mm/hr)
Soil Group	A (sand)	0.34	100	25
	B (silt loam)	0.32	300	13
	C (sand clay loam)	0.26	250	5
	D (clay)	0.21	180	3

Source: M.L. Terstriep and J.B. Stall (1974)
U.S. EPA (1989)

Design Chart 1.14: Hydrologic Regions and Precipitation Index



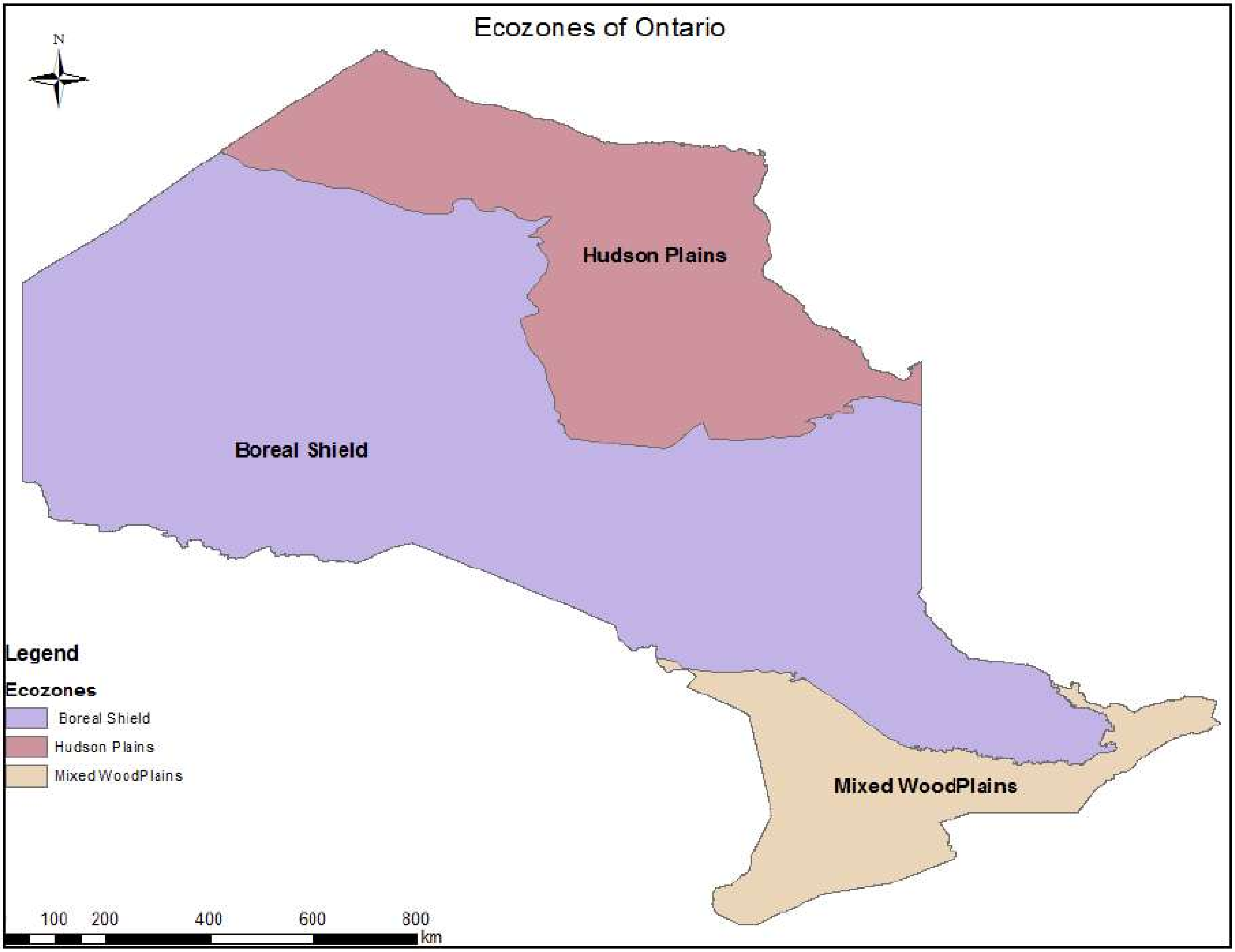
(a) Northern Ontario



(b) Southern Ontario

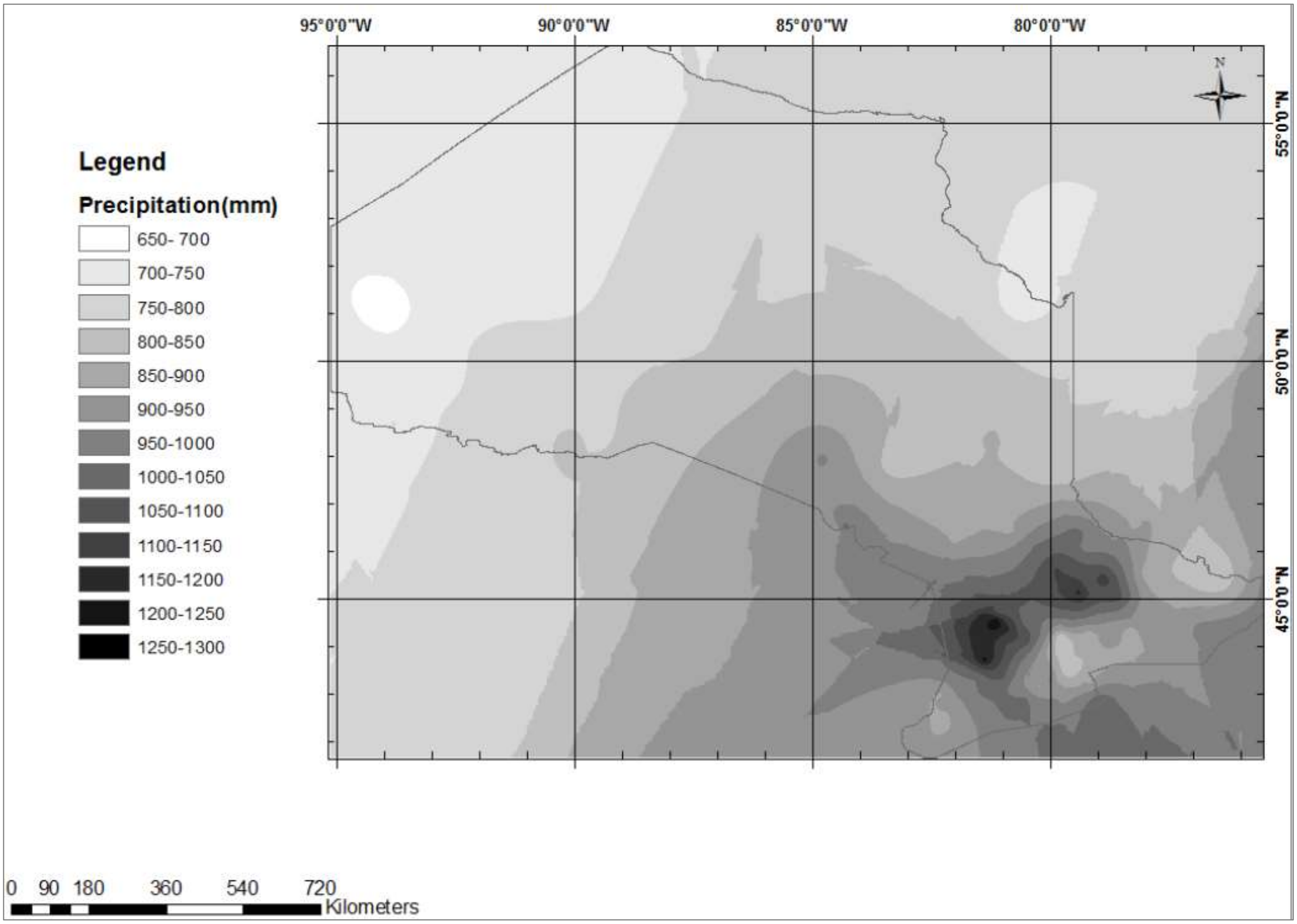
Source: MTO (1985)

Design Chart __: Ecozones of Ontario



Source: Errata Sheet No. DMM1997-3 (Date of Issue: 31 March 2016)

Design Chart __: Isohyetal Map of Ontario



Source: Errata Sheet No. DMM1997-3 (Date of Issue: 31 March 2016)

Design Chart 1.15: Typical Watershed Classes

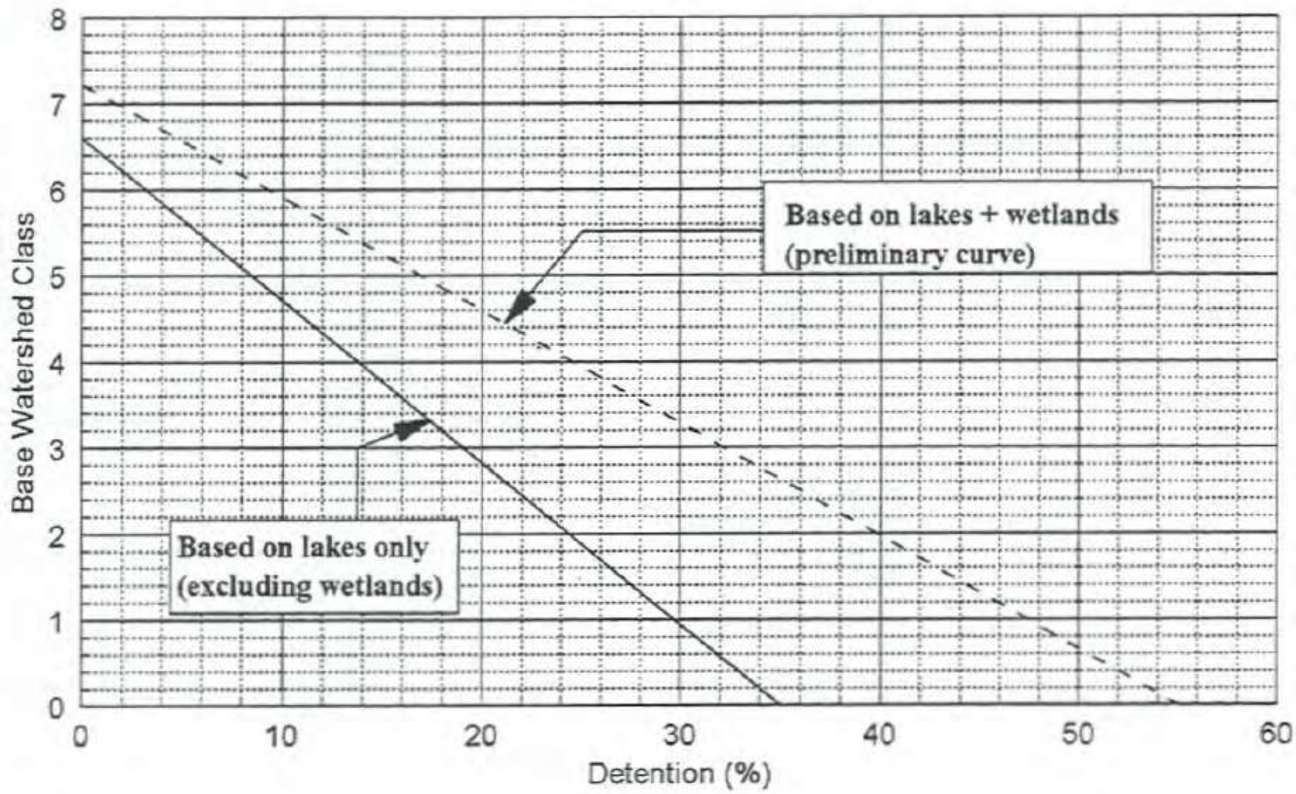
W/Shed Class	Predominant Soil Type	Land Use	Storage %
	SOUTHERN TYPE BASIN		
10	Clay Loam	Crop and pasture with some woodlots	Neg.
9	Medium textured loam	As class 10	"
8	Medium textured loam	Mostly wooded	"
	Medium loam on limestone	As class 10	"
	Shallow sandy loam	As class 10	"
7	Open sand soil	As class 10	"
	Shallow sandy loam	Mostly wooded	"
6	Deep sand or sand loam	" "	"
			% lakes
	SHIELD TYPE		
6	Shallow sandy loam on Precambrian bedrock, with some exposed bedrock.	Mostly wooded	3%
5	"	" "	8%
4	"	" "	14%
3	"	" "	19%
2	"	" "	25%
1	"	" "	30%

Class Coefficient, C

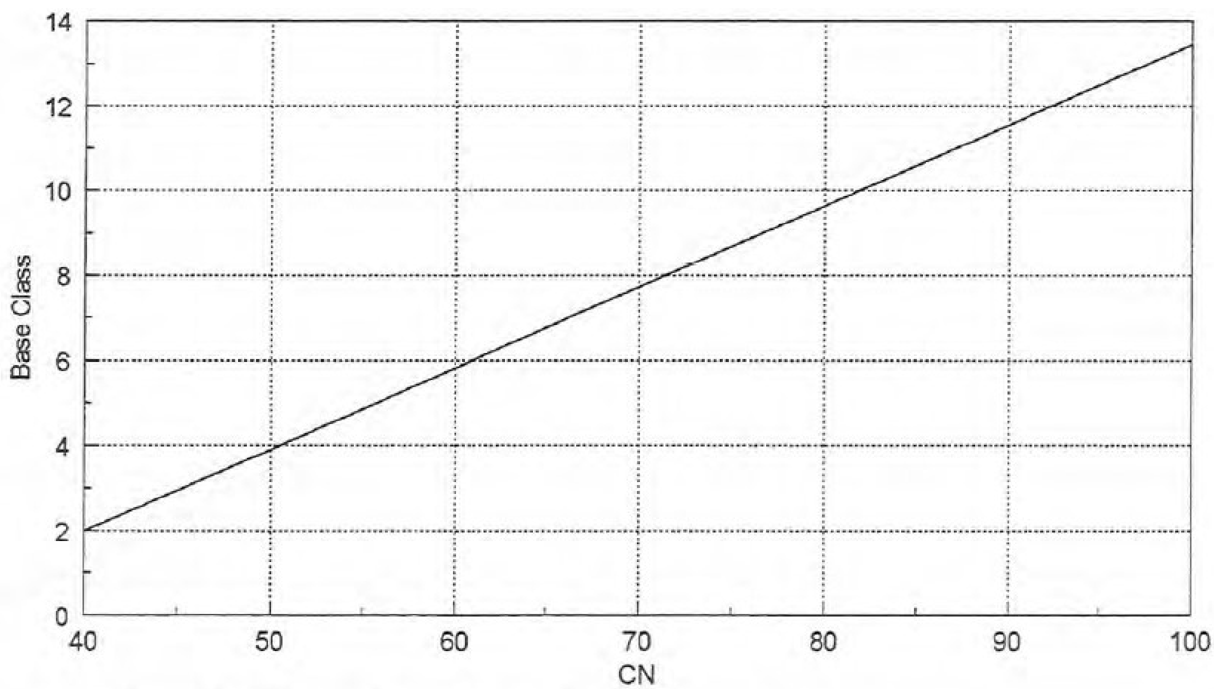
Watershed Class	Coefficient, C
1	0.15
2	0.22
3	0.31
4	0.44
5	0.63
6	0.90
7	1.29
8	1.84
9	2.62
10	3.74
11	5.34
12	7.63

Source: Whitely, et al (1995)

Design Chart 1.16: Base Class Chart Determination - Northern Basins



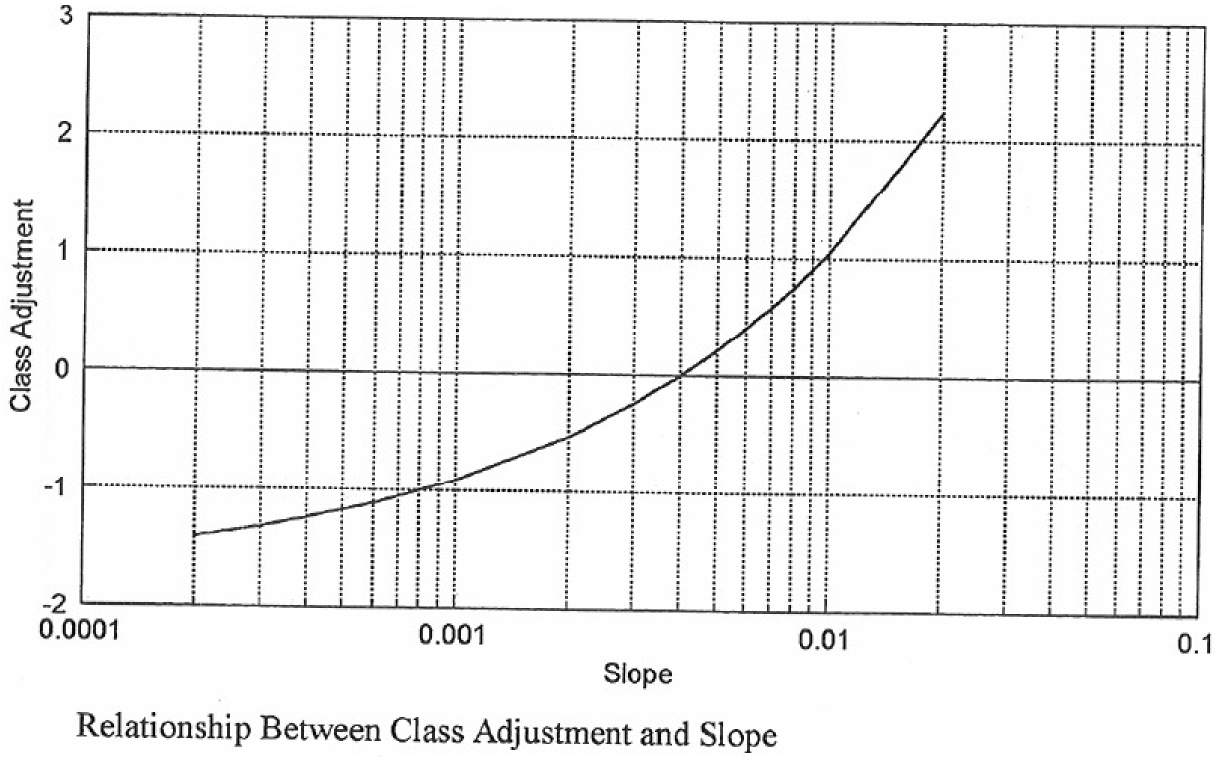
Design Chart 1.17: Base Class Determination - Southern Watersheds



Relationship Between Base Class and CN

Source: Whitely, et al (1995)

Design Chart 1.18: Base Class Adjustment for Slope - Southern Basin



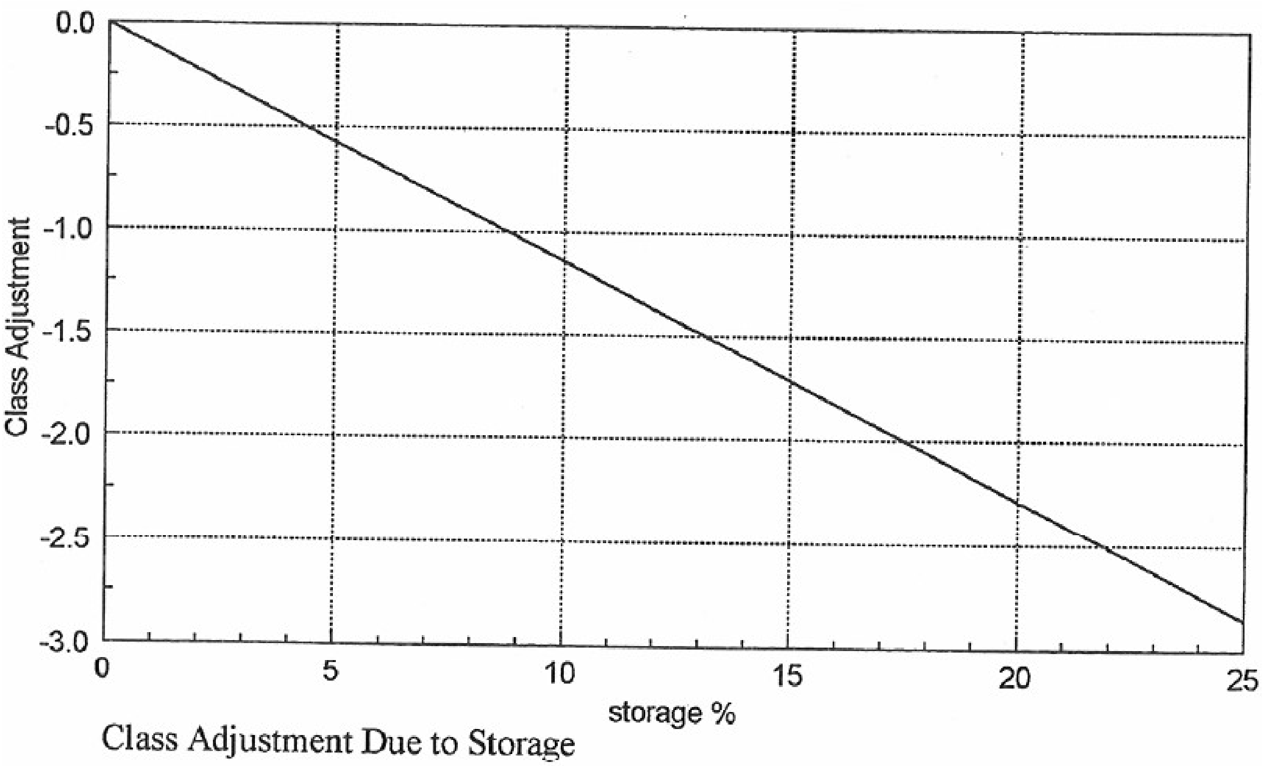
Source: Whitely, et al (1995)

Design Chart 1.18b: Base Class Adjustment for Location of Storage in Watershed- Shield Areas

Location of Storage in Northern Shield Areas	Class Adjustment Factor
Top 1/3 of the Watershed	+0.5
Lower 1/3 of the Watershed	-0.5
Well distributed or within the middle 1/3 of the Watershed	Zero

Source: Errata Sheet No. DMM1997-2 (Date of Issue: 2 February 2016)

Design Chart 1.19: Base Class Adjustment for Detention - Southern Basins



Source: Whitely, et al (1995)

Design Chart 1.19b: Frequency Conversion Factor for Modified Index Flood Method

Frequency Conversion

The results of the Modified Index Flood Method are given for the 25-year return period. Flows with other return periods are determined using the frequency conversions in the table below.

Basin Type	Return Period (years)					
	2.33	5	10	25	50	100
Non-detentive type Southern Basins	0.50	0.67	0.82	1.00	1.13	1.27
Shield and Detentive type Southern Basins	0.54	0.70	0.84	1.00	1.12	1.25
North Shores of Lake Erie and Ontario	0.41	0.62	0.79	1.00	1.16	1.32

Source: Errata Sheet No. DMM1997-1 (Date of Issue: 5 April 2016)

Design Chart 1.20: Regional Regression Factors - Northern Ontario Method

T (years)	2	2.33	5	10	25	50	100
CS	Value of K_T						
0.5	-0.09	0.09	0.81	1.34	1.93	2.32	2.67
0.6	-0.10	0.08	0.80	1.34	1.95	2.36	2.74
0.7	-0.11	0.07	0.79	1.34	1.97	2.40	2.80
0.8	-0.12	0.05	0.78	1.33	1.98	2.43	2.86
0.9	-0.13	0.05	0.77	1.33	1.99	2.46	2.90
1.0	-0.13	0.04	0.77	1.33	2.00	2.48	2.93
1.1	-0.16	0.00	0.72	1.30	2.04	2.59	3.14
1.2	-0.16	0.00	0.72	1.30	2.04	2.59	3.14
1.3	-0.18	-0.01	0.70	1.29	2.05	2.63	3.21
1.4	-0.18	-0.02	0.68	1.28	2.06	2.66	3.27
1.5	-0.19	-0.03	0.67	1.27	2.06	2.68	3.31
1.6	-0.20	-0.04	0.66	1.26	2.07	2.70	3.35
1.7	-0.20	-0.05	0.65	1.25	2.07	2.71	3.39
1.8	-0.21	-0.05	0.64	1.24	2.07	2.73	3.42
1.9	-0.21	-0.06	0.63	1.23	2.07	2.74	3.45
2.0	-0.21	-0.07	0.62	1.22	2.06	2.75	3.48
2.1	-0.22	-0.07	0.61	1.21	2.06	2.76	3.50
2.2	-0.22	-0.08	0.60	1.20	2.06	2.76	3.53
2.3	-0.22	-0.08	0.59	1.20	2.06	2.77	3.55
2.4	-0.22	-0.08	0.58	1.19	2.05	2.77	3.56
2.5	-0.23	-0.09	0.57	1.18	2.05	2.78	3.58
2.6	-0.23	-0.09	0.56	1.17	2.04	2.78	3.59
2.7	-0.23	-0.09	0.56	1.16	2.04	2.78	3.61
2.8	-0.23	-0.10	0.55	1.15	2.03	2.78	3.62
2.9	-0.23	-0.10	0.54	1.15	2.03	2.79	3.63
3.0	-0.24	-0.10	0.54	1.14	2.03	2.79	3.64
3.1	-0.24	-0.10	0.53	1.13	2.02	2.79	3.65

Source: Watt (1994)

Design Chart __: Coefficients of the Regression Model and Output Summary

Table 1: Coefficients of the Regression Model and Output summary

T	x	a	b	c	Adjusted R^2	Standard error (log units)
Boreal Shield						
2	-10.870	0.839	-4.633	3.583	0.965	0.159
10	-8.583	0.795	-4.522	2.917	0.954	0.174
25	-7.834	0.779	-4.510	2.703	0.947	0.183
50	-7.371	0.769	-4.520	2.572	0.942	0.189
100	-6.967	0.759	-4.541	2.457	0.937	0.195
Mixed wood Plains (South)						
2	-5.483	0.756	-3.061	1.837	0.824	0.147
10	-4.139	0.734	-3.780	1.491	0.790	0.165
25	-3.680	0.728	-4.017	1.372	0.769	0.177
50	-3.397	0.724	-4.162	1.299	0.752	0.186
100	-3.151	0.721	-4.287	1.236	0.736	0.195

Source: Errata Sheet No. DMM1997-3 (Date of Issue: 31 March 2016)

Design Chart __: Range of Quantile Estimates

Table 2: Range of Quantile Estimates

T	Standard error (log units)	Range of Quantiles	
		Lower limit	Upper limit
Boreal Shield			
2	0.159	-31%	44%
10	0.174	-33%	49%
25	0.183	-34%	52%
50	0.189	-35%	55%
100	0.195	-36%	57%
Mixed wood Plains			
2	0.147	-29%	40%
10	0.165	-32%	46%
25	0.177	-33%	50%
50	0.186	-35%	53%
100	0.195	-36%	57%

Source: Errata Sheet No. DMM1997-3 (Date of Issue: 31 March 2016)

Design Chart __: Range of Parameters used for Equation Development

Table 3: Range of Parameters used for equation development

Range of parameters used to establish the equations					
	Minimum	**Maximum**	**Mean**	**Median**	**Standard deviation**
Boreal Shield (No. of stations=43)					
Area (km^2)	1.80	4416.77	908.36	404.53	1189.88
Water Area (km^2)	0.168	892.81	143.24	52.00	205.93
Precipitation (mm)	705	1056	866	848	101
Mixed Wood Plains (No. of stations=75)					
Area (km^2)	13.16	1230.39	243.00	163.91	241.97
Water Area (km^2)	0.02	104.33	18.30	12.56	20.29
Precipitation (mm)	813	1219	965	962	94

Source: Errata Sheet No. DMM1997-3 (Date of Issue: 31 March 2016)

Design Chart 2.01: Manning Roughness Coefficient

	Manning Roughness Coefficients
I. Sewers	
A. Concrete pipe storm sewers	0.011 - 0.013
B. Verified clay pipe	0.012 - 0.014
C. Steel pipe (smooth)	0.009 - 0.011
D. Monolithic concrete:	
1. Wood forms, rough	0.015 - 0.017
2. Wood forms, smooth	0.012 - 0.014
3. Steel forms	0.012 - 0.013
E. Cemented rubble masonry walls:	
1. Concrete floor and top	0.017 - 0.022
2. Natural floor	0.019 - 0.025
F. Laminated treated wood	0.015 - 0.017
G. Smooth walled polyethylene pipe	0.011 - 0.013
Corrugated interior polyethylene pipe (tentative)	0.024
H. Corrugated steel pipe or pipe arch	
68 x 13 mm corrugation (riveted, annular)	
Unpaved	0.024
25% paved	0.021
100% paved	0.012
68 x 13 mm helical	
Unpaved: 600 to 1525 mm ϕ range:	0.016 - 0.024
25% paved: 600 to 1525 mm ϕ range:	0.015 - 0.021
100% paved: all sizes	0.012
68 x 25 mm riveted (annular)	
Unpaved	0.027
25% paved	0.023
100% paved	0.012
76 x 25 mm helical	
Unpaved: 900 to 1980 mm dia.:	0.021 - 0.027
25% paved: 900 to 1980 mm dia.:	0.019 - 0.023
100% paved: all sizes	0.012
152 x 51 mm corrugation (annular)	
Unpaved 1550 - 4500 mm dia.or	0.030 - 0.033
1900 to 5050 mm span	0.026
25% paved	
II. Road Gutters	0.012
A. Concrete gutter, trowelled finish	
B. Asphalt pavement:	0.013
1. Smooth texture	0.016
2. Rough texture	
C. Concrete gutter with asphalt pavement:	
1. Smooth	0.013
2. Rough	0.015

Design Chart 2.01: Manning Roughness Coefficient (Continued)

	Manning Roughness Coefficients
D. Concrete pavement:	
1. Float finish	0.014
2. Broom finish	0.016
E. Brick	0.016
For gutters with small slope where sediment may accumulate, increase values by 0.002.	
III. Lined Open Channels	
A. Concrete, with surfaces as indicated:	
1. Formed, no finish	0.013 - 0.017
2. Trowel finish	0.012 - 0.014
3. Float finish	0.013 - 0.015
4. Float finish, some gravel on bottom	0.015 - 0.017
5. Gunite, good section	0.016 - 0.019
6. Gunite, wavy section	0.018 - 0.022
B. Concrete bottom float-finished, sides as indicated:	
1. Dressed stone in mortar	0.015 - 0.017
2. Random stone in mortar	0.017 - 0.020
3. Cement rubble masonry	0.020 - 0.030
4. Dry rubble (riprap)	0.020 - 0.030
C. Gravel bottom, sides as indicated:	
1. Formed concrete	0.017 - 0.020
2. Random stone mortar	0.020 - 0.023
3. Dry rubble (riprap)	0.023 - 0.033
D. Asphalt	
1. Smooth	0.013
2. Rough	0.016
E. Wood, planed, clean	0.011 - 0.013
F. 1. Good section	0.017 - 0.020
2. Irregular section	0.022 - 0.027
G. Riprap	0.035 - 0.040
H. Rock cut	0.025 - 0.045
IV. Unlined Open Channels	
A. Earth, uniform section:	
1. Clean, recently completed	0.016 - 0.018
2. Clean, after weathering	0.018 - 0.020
3. With short grass, few weeds	0.022 - 0.027
4. In gravelly, soil, uniform section, clean	0.022 - 0.025
B. Earth, fairly uniform section:	
1. No vegetation	0.022 - 0.025
2. Grass, some weeds	0.030 - 0.035
3. Dense weeds in deep channels	0.030 - 0.035
4. Sides clean, gravel bottom	0.025 - 0.030
5. Sides clean, cobble bottom	0.030 - 0.040

Design Chart 2.01: Manning Roughness Coefficient (Continued)

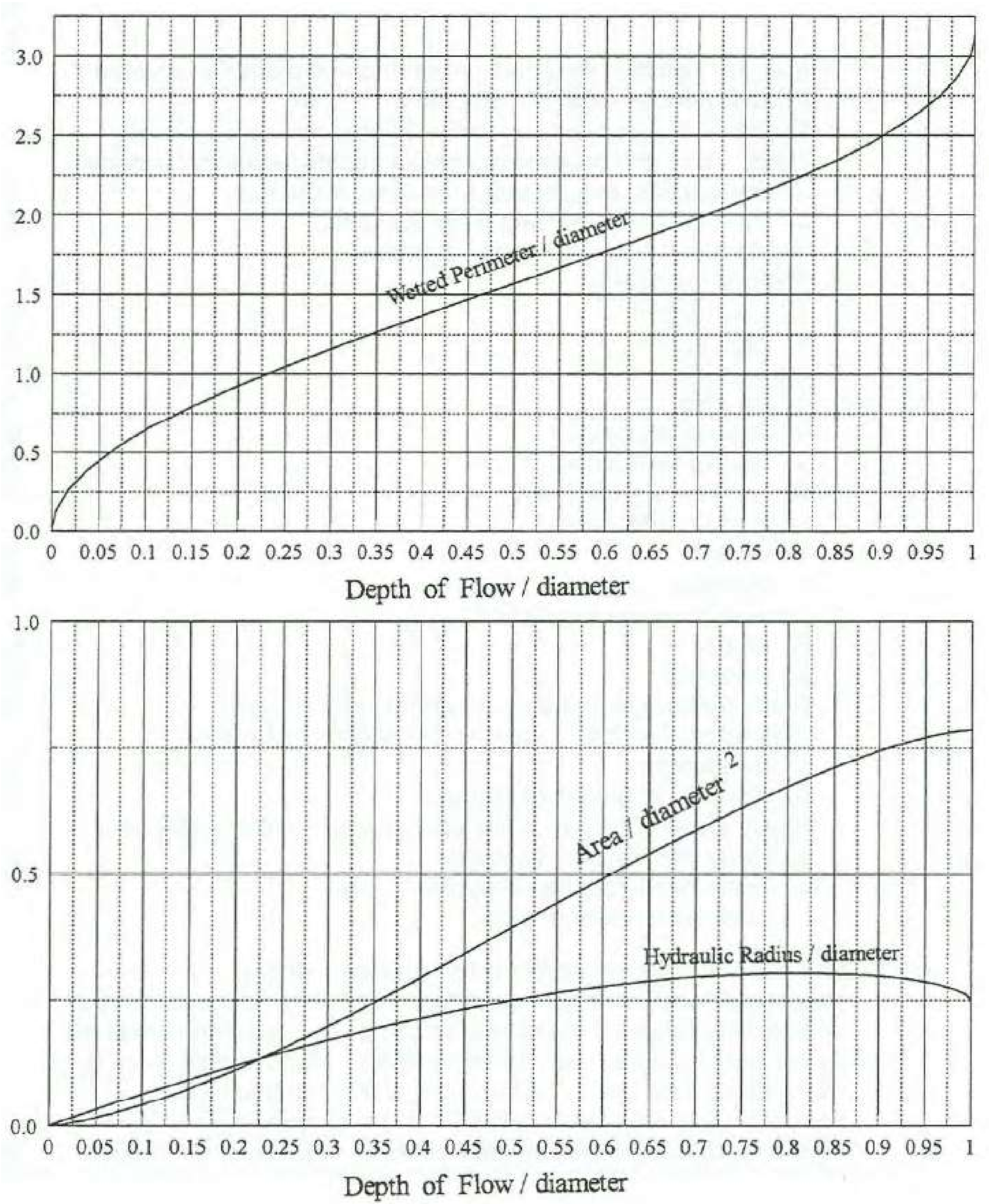
			Manning Roughness Coefficients
C. Dragline excavated or dredged:			
1. No vegetation			0.028 -0.033
2. Light brush on banks			0.035 -0.050
D. Rock:			
1. Based on design section			0.035
2. Based on actual mean section:			
a. Smooth and uniform			0.035 -0.040
b. Jagged and irregular			0.040 -0.045
E. Channels not maintained, vegetation uncut:			
1. Dense weeds, high as flow depth			0.08 - 0.12
2. Clean bottom, brush on sides			0.05 - 0.08
3. Clean bottom, brush on sides, high stage			0.07 - 0.11
4. Dense brush, high stage			0.10 - 0.14
V. Grassed Channels and Swales[2]			
Depth of Flow:	Up to 0.2 m	0.2 - 0.5 m	
Velocity	0.6 m/s 1.8 m/s	0.6 m/s 1.8 m/s	
A. Kentucky bluegrass:			
1. Mowed to 0.05 m			
2. Length 0.1 to 0.15 m	0.07 - 0.045	0.050 - 0.035	
B. Good stand, any grass:	0.090 - 0.060	0.060 - 0.040	
1. Length 0.30 m			
2. Length 0.60 m	0.180 - 0.090	0.120 - 0.070	
C. Fair stand, any grass:	0.300 - 0.190	0.200 - 0.100	
1. Length 0.30 m			
2. Length 0.60 m	0.140 - 0.080	0.100 - 0.060	
	0.250 - 0.130	0.170 - 0.090	
VI. Natural Watercourses			
A. Minor stream (surface width at flood stage < 30 m).			
1. Fairly regular section:			
a. Some grass and weeds, little or no brush			0.030 -0.035
b. Dense growth of weeds, depth of flow materially greater than weed height			0.035 -0.050
c. Some weeds, light brush on banks			0.035 -0.050
d. Some weeds, heavy brush on banks			0.050-0.070
e. Some weeds, dense willows on banks			0.060-0.080
f. For trees within channel with branches submerged at high stage, add 0.01 to 0.02 to above values.			

Design Chart 2.01: Manning Roughness Coefficient (Continued)

			Manning Roughness Coefficients
	2.	Irregular section with pools, slight channel meander; channels (a) to (e) above, add 0.01 to 0.02.	
	3.	Mountain streams, no vegetation in channel, banks usually steep, trees and brush along banks submerged at high stage:	
		a. Bottom of gravel, cobbles, and few boulders	0.040 - 0.050
		b. Bottom of cobbles with large boulders	0.050 - 0.070
B.	Flood plains (adjacent to natural streams):		
	1.	Pasture, no brush:	
		a. Short grass	0.030 - 0.035
		b. High grass	0.035 - 0.050
	2.	Cultivated areas:	
		a. No crop	0.030 - 0.040
		b. Mature row crops	0.035 - 0.045
		c. Mature field crops	0.040 - 0.050
	3.	Heavy weeds, scattered	0.050 - 0.070
	4.	Light brush and trees:	
		a. Winter	0.050 - 0.060
		b. Summer	0.060 - 0.080
	5.	Medium to dense vegetation:	
		a. Winter	0.070 - 0.110
		b. Summer	0.010 - 0.160
	6.	Dense willows, summer, not bent over by current	0.150 - 0.200
	7.	Cleared land with tree stumps, 250 - 370 per hectare	
		a. No sprouts	0.040 - 0.050
		b. With heavy growth of sprouts	0.060 - 0.080
	8.	Heavy stand of timber, a few down trees, little undergrowth:	
		a. Flood depth below branches	0.100 - 0.120
		b. Flood depth reaches branches (n increases with depth)	0.120 - 0.160
C.	Major stream (surface width at flood stage > 30 m): Roughness coefficient is usually less than for minor streams of similar description on account of less effective resistance offered by irregular banks or vegetation on banks. Roughness values may be somewhat reduced. Follow general recommendations if possible. The roughness value for larger streams of mostly regular section, with no boulders or brush, may be in the range.		0.028 - 0.033

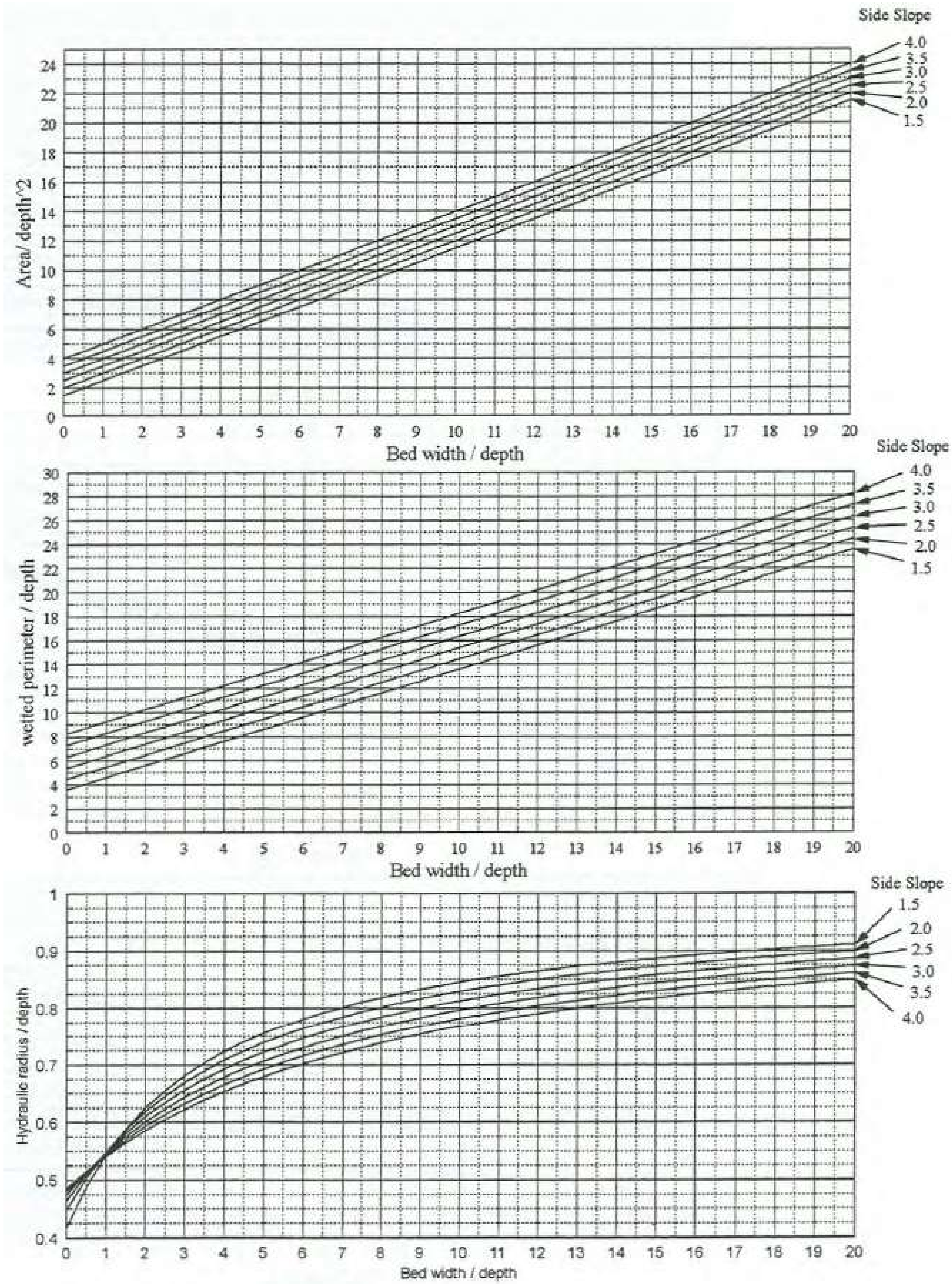
Sources: American Iron and Steel Institute (1980); Herr, L.A. et al, (1965)
Searcy, j.k. (1969); Bradley, J.N. (1978)

Design Chart 2.02: Hydraulic Elements of Circular Pipes



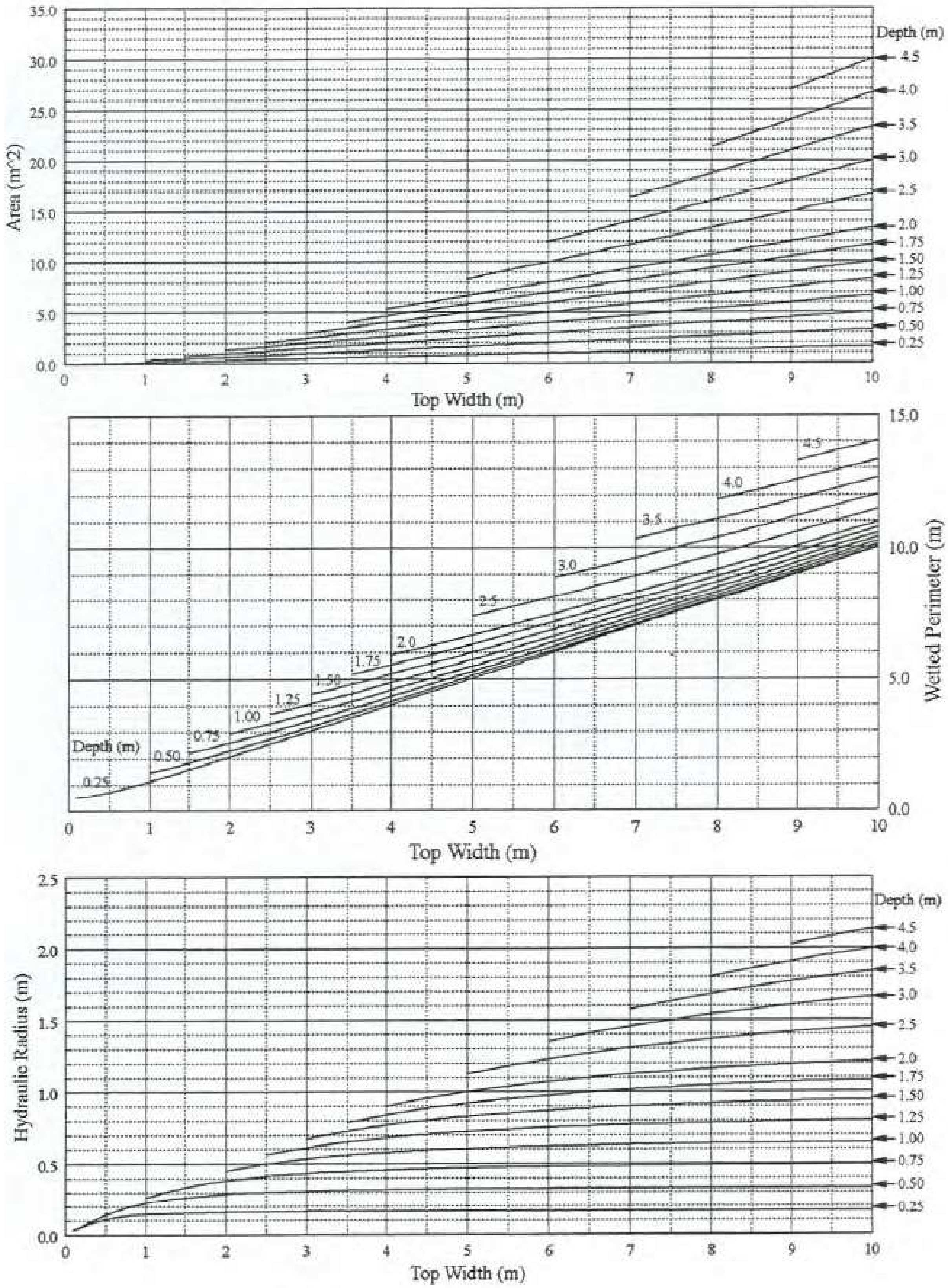
Source: MTO (1996)

Design Chart 2.03: Hydraulic Elements of Trapezoidal Channels



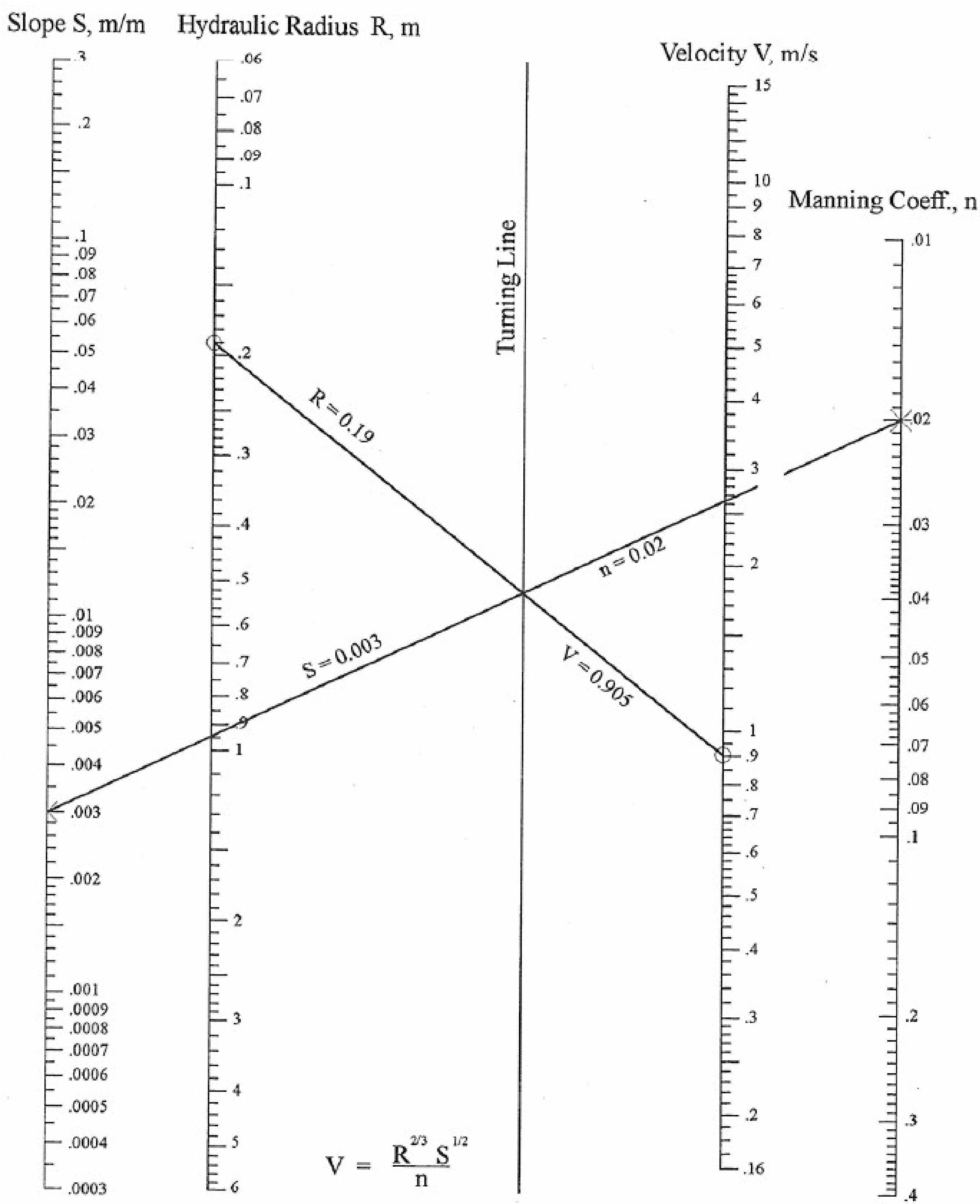
Source: MTO (1996)

Design Chart 2.04: Hydraulic Elements of Parabolic Channels



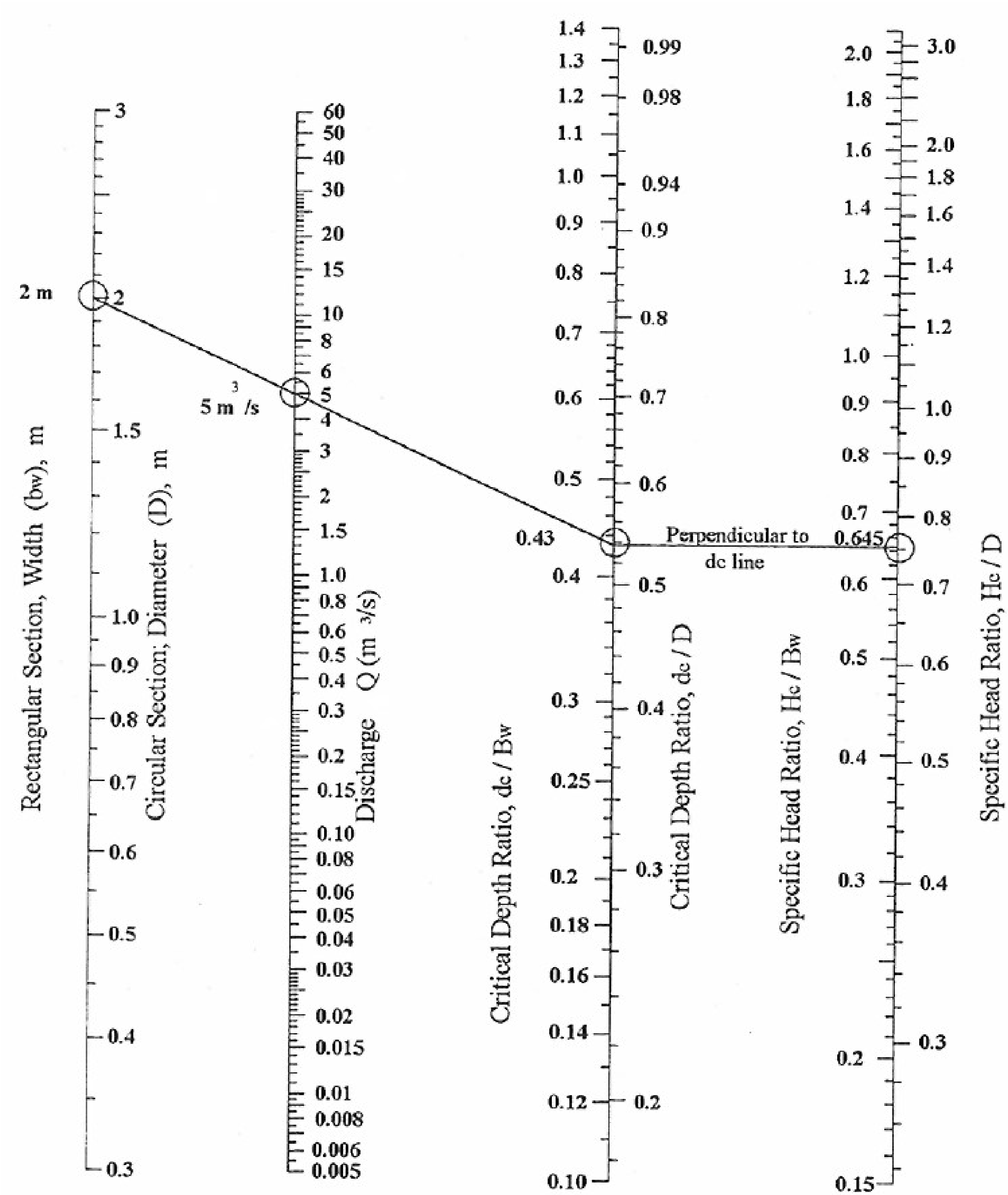
Source: MTO (1996)

Design Chart 2.05: Solving for Manning Equation



Source: Roads and Transportation Association of Canada (1982)

Design Chart 2.05: Solving for Critical Depth



(Note: Original converted to metric units.)

Source: American Society of Civil Engineers (1976)

Design Chart 2.07: Transition Loss of Coefficients: Bridges and Channels

SITUATION	K(ent)	K(ext)
Natural Reach (normal cross-section change)	0.1	0.3
Bridge (fills placed beyond normal channel width)	0.3	0.5
Guide Banks (each)	0.2	0.4
Groynes (each)	0.3	0.5
Dikes	0.1	0.2
Channel Bends		
Gradual	0.1	0.2
Medium	0.2	0.3
Severe	0.3	0.4
Flow Separation per obstruction (pier)	0.1	0.1

Source: U.S. Army Corps of Engineers (1991)

Design Chart 2.08: Transition Loss Coefficients: Culverts

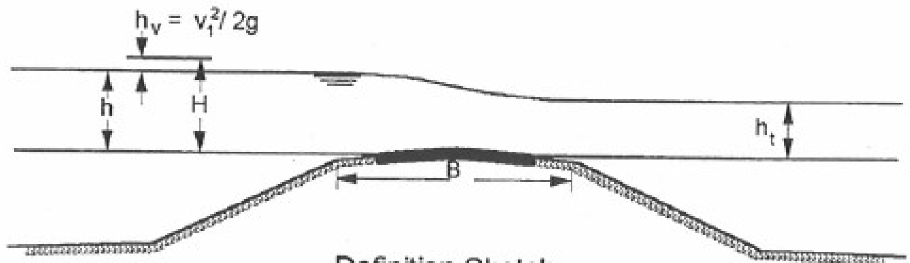
TYPE OF BARREL AND INLET

Pipe, Concrete	**Ke**
Projecting from fill, socked end	0.2
Projecting from fill, square cut end	0.5
Headwall or headwall and wingwalls	
Socket end or pipe	0.2
Square-edge	0.5
Rounded (radius = 1/ 12D)	0.2
Miltered to conform to fill slope	0.7
End-Section conforming to fill slope (standard precast)	0.5
Bevelled edges, 33.7° or 45° bevels	0.2
Side-tapered or slope-tapered inlets	0.2
Pipe, or Pipe-Arch, Corrugated Steel	
Projecting from fill	0.9
Headwall or headwall and wingwalls, square edge	0.5
Mitered to conform to fill slope	0.7
End-Section conforming to fill slope (standard prefab)	0.5
Bevelled edges, 33.7° or 45° bevels	0.25
Side-tapered or slope-tapered inlets	0.2
Box, Reinforced Concrete	
Headwall	
Square-edged on 3 edges	0.5
Rounded on 3 edges to radius 1/12	
Barrel dimension, or bevelled edges on 3 sides	0.2
Wingwalls at 30° to 75° to barrel	
Square-edged at crown	0.4
Crown edge rounded to radius 1/12	
barrel dimension, or bevelled top edge	0.2
Wingwalls at 10° to 25° to barrel	
Square-edged at crown	0.5
Wingwalls parellel (extension of sides)	
Square edged at crown	0.7
Side-tapered or slope-tapered inlet	0.2
Projecting	
Square-edge	0.7*
Bevelled edges, 33.7° or 45° bevels	0.2*

* Estimated

Source: Harrison et al (1972), Herr et al (1977)

Design Chart 2.09: Solving for Weir Flow

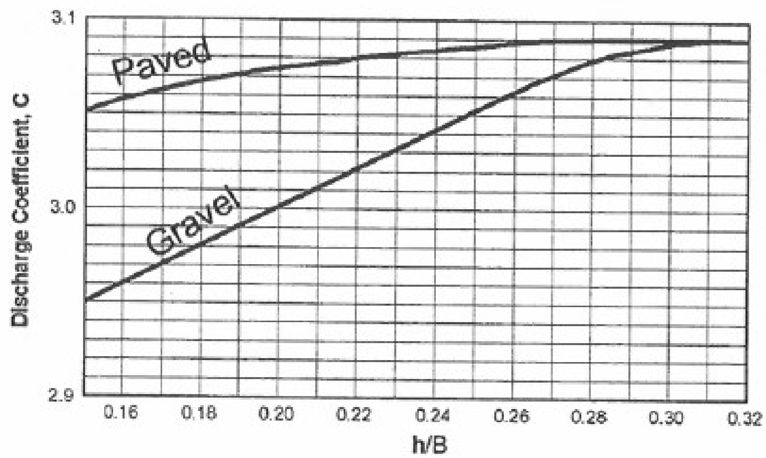


Definition Sketch

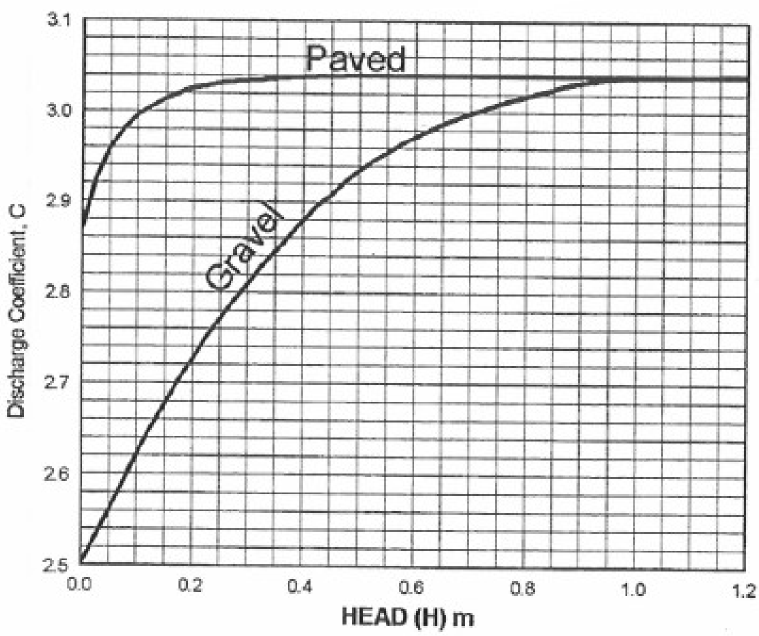
$$Q = \Sigma\, 0.55\, CLH^{1.5} k_t\ m^3/s$$

where ;

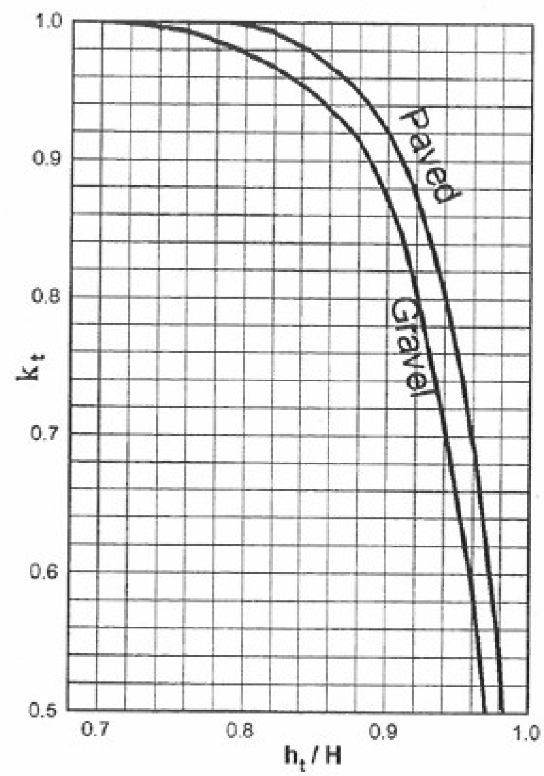
- Q = total overflow,
- C = discharge coefficient (given by chart (a) or (b)),
- L = length of overflow subsection along embankment, m,
- H = total head, m,
- k_t = submergence factor (given by chart (c))



(a) Discharge coefficient C for h / B > 0.15 (free flow)



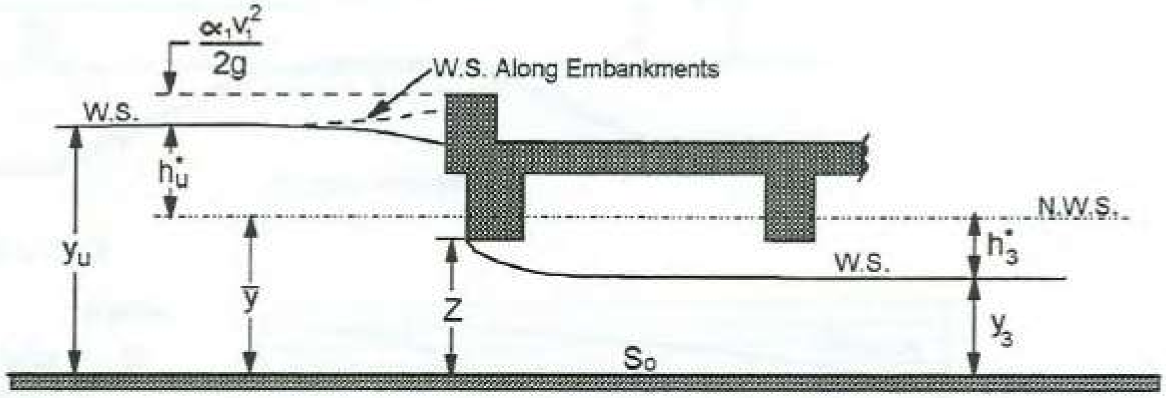
(b) Discharge coefficient C for h / B < 0.15 (free flow)

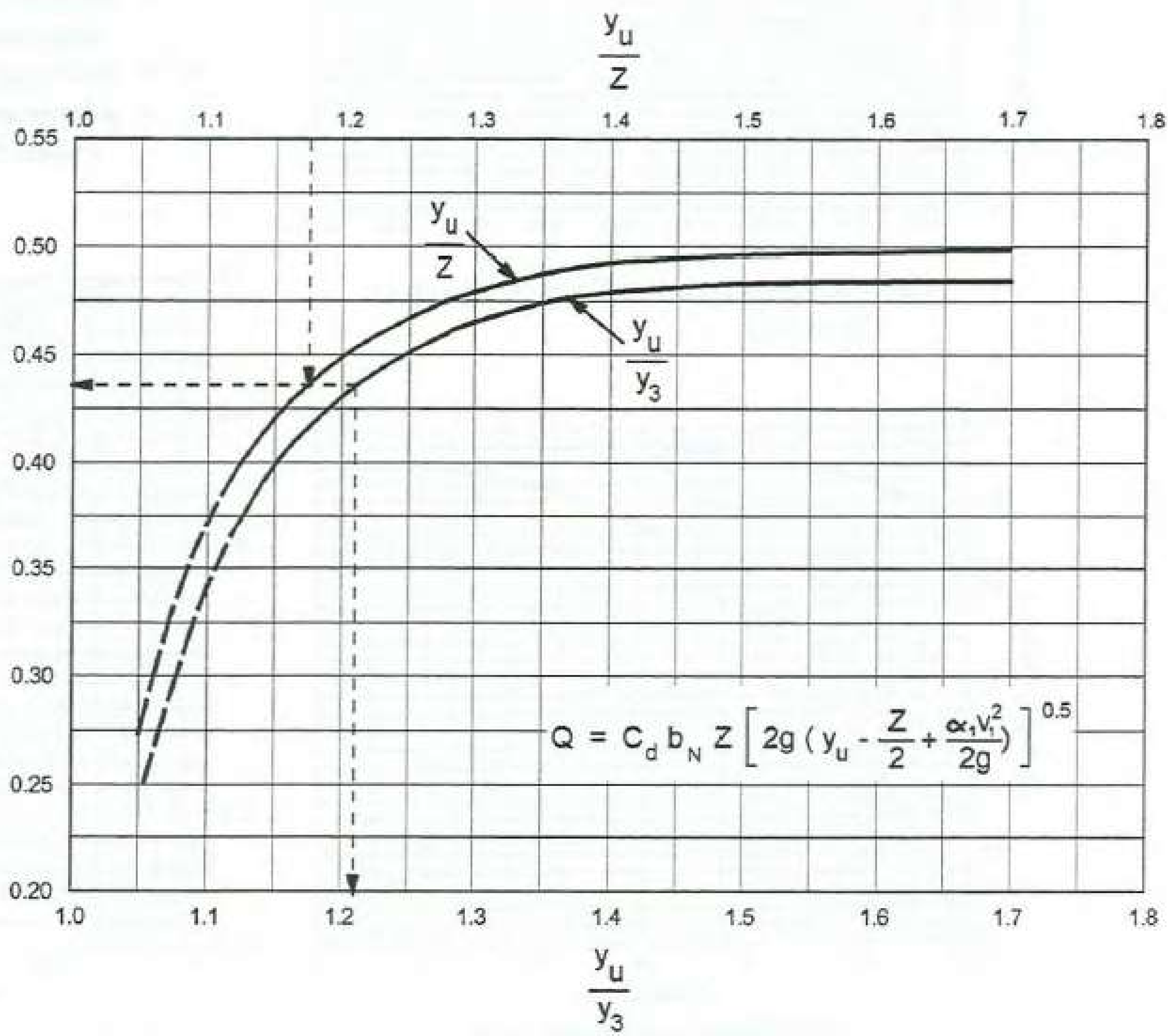


(c) Adjustment factor k_t for submerged flow

Design Chart 2.10: Solving for Pressure Flow

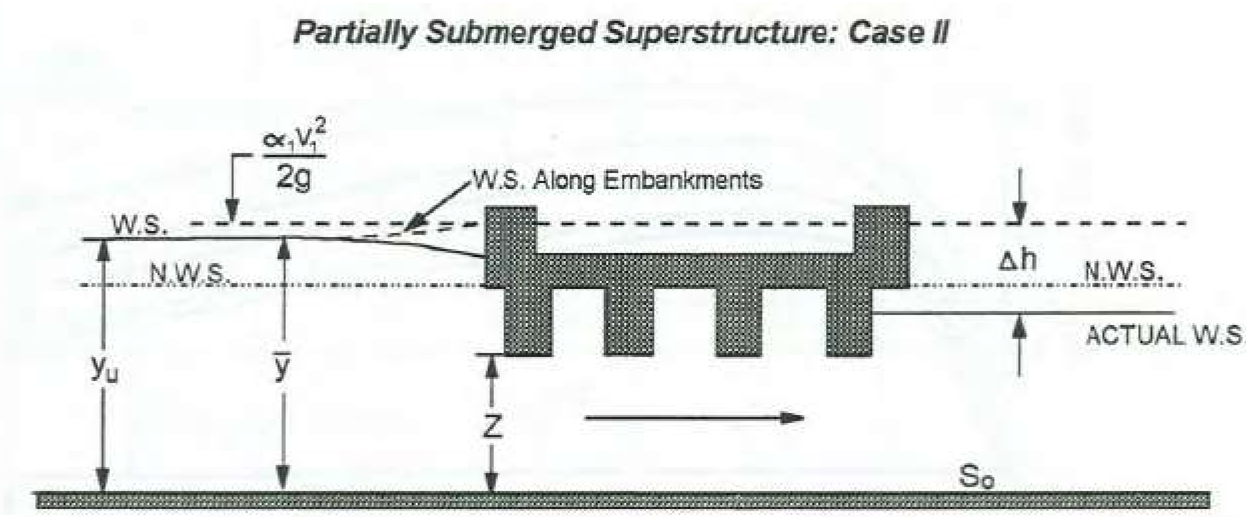
Partially Submerged Superstructure: Case I

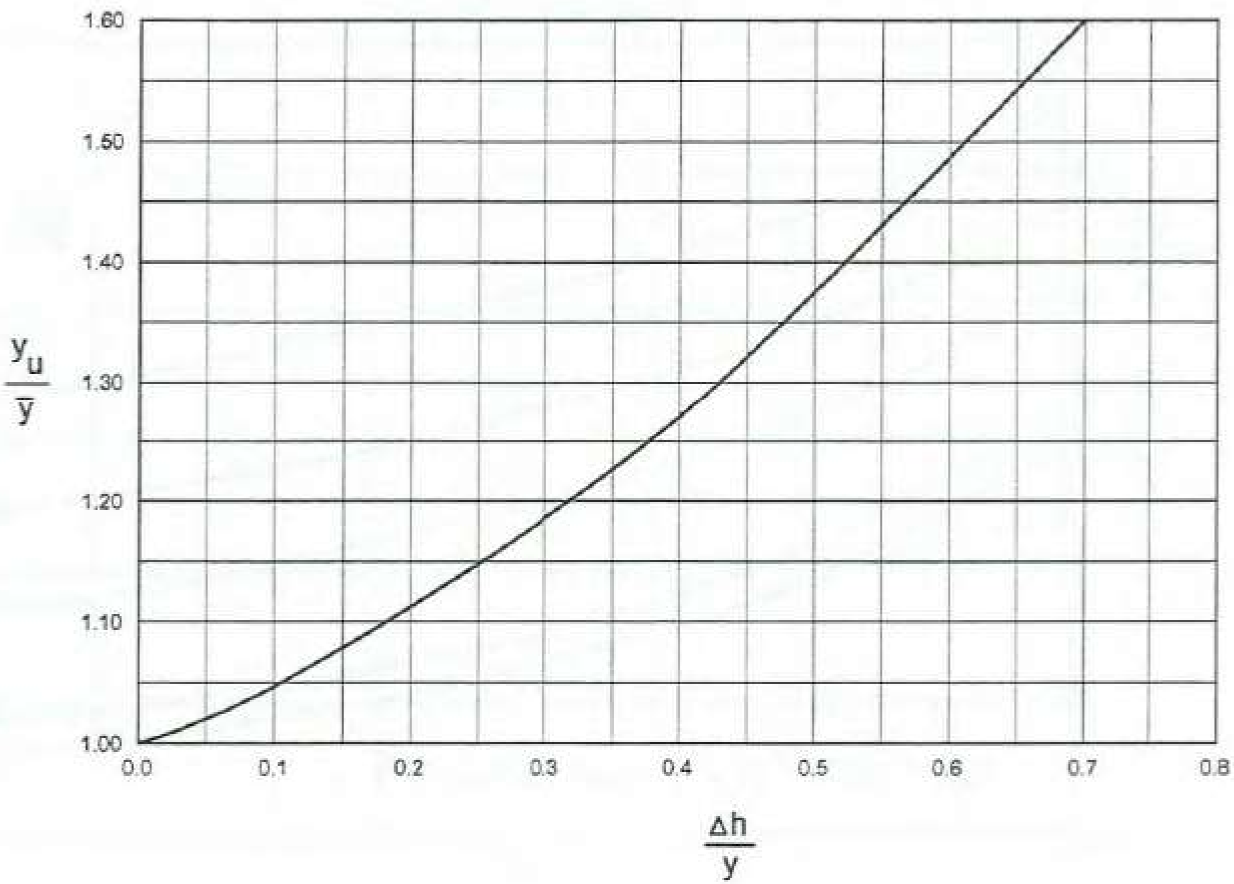




Source: Bradley (1973)

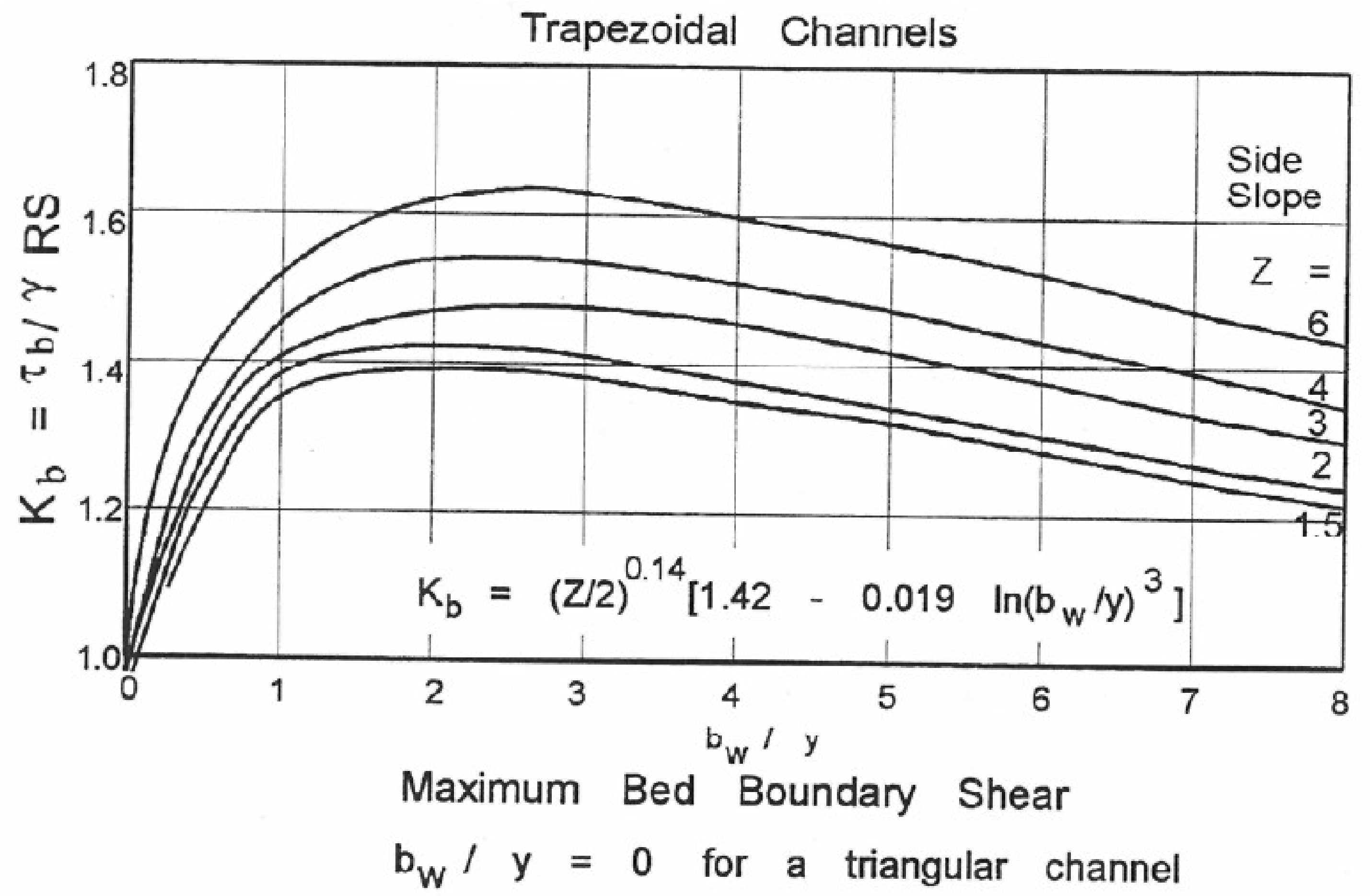
Design Chart 2.10: Solving for Pressure Flow (Continued)



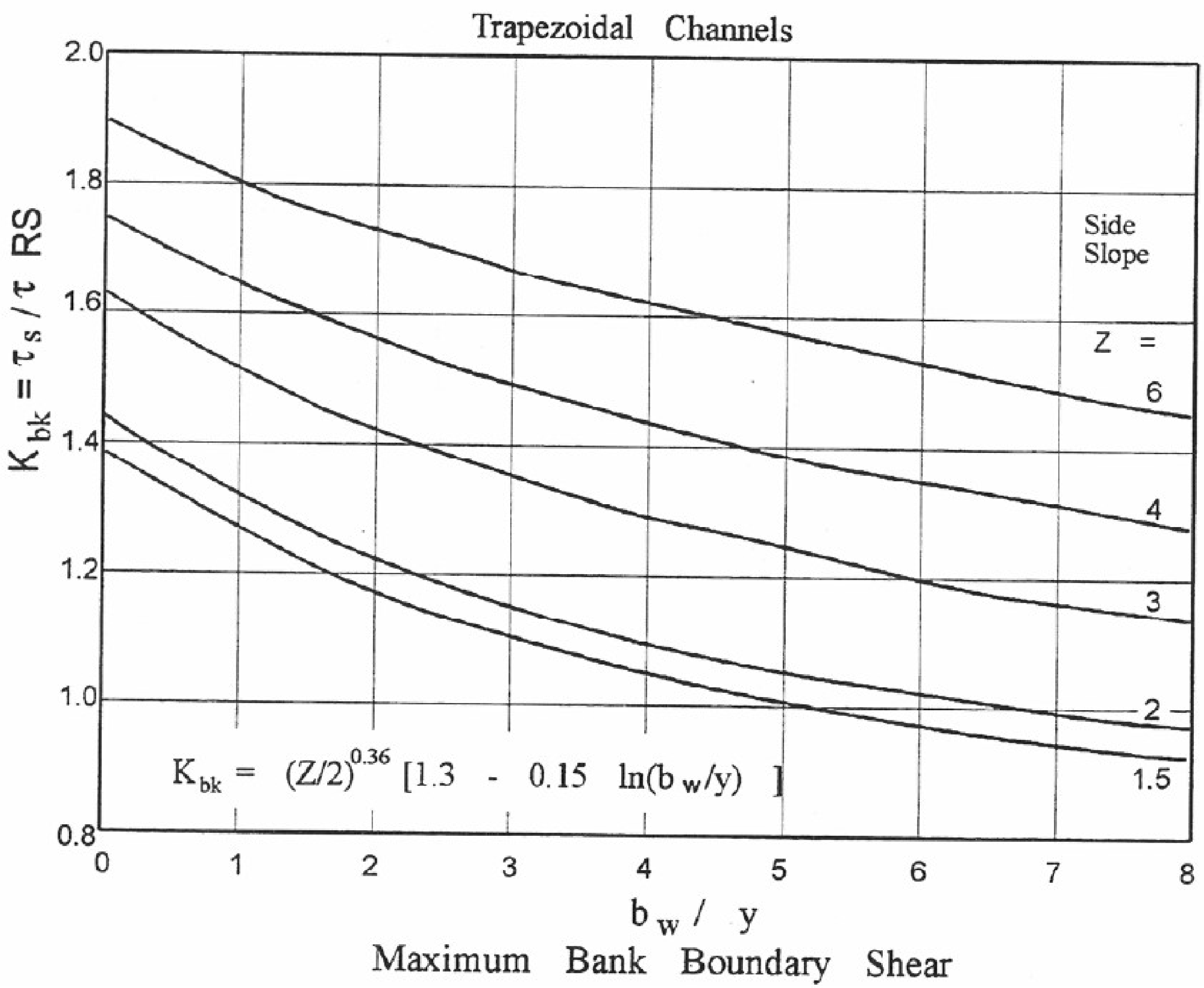


Source: Bradley (1973)

Design Chart 2.11: Coefficients of Boundary Shear on Channel Bed

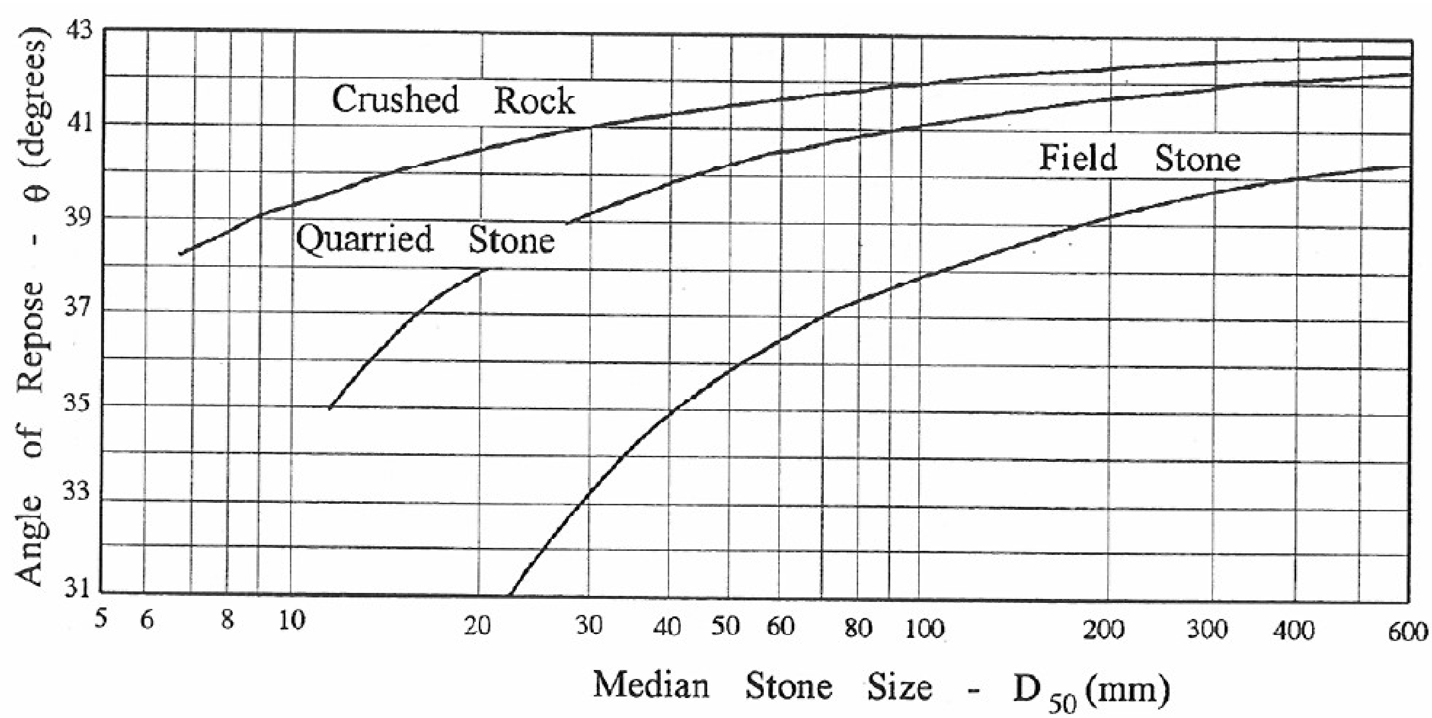


Design Chart 2.12: Coefficients of Boundary Shear on the Side Slope



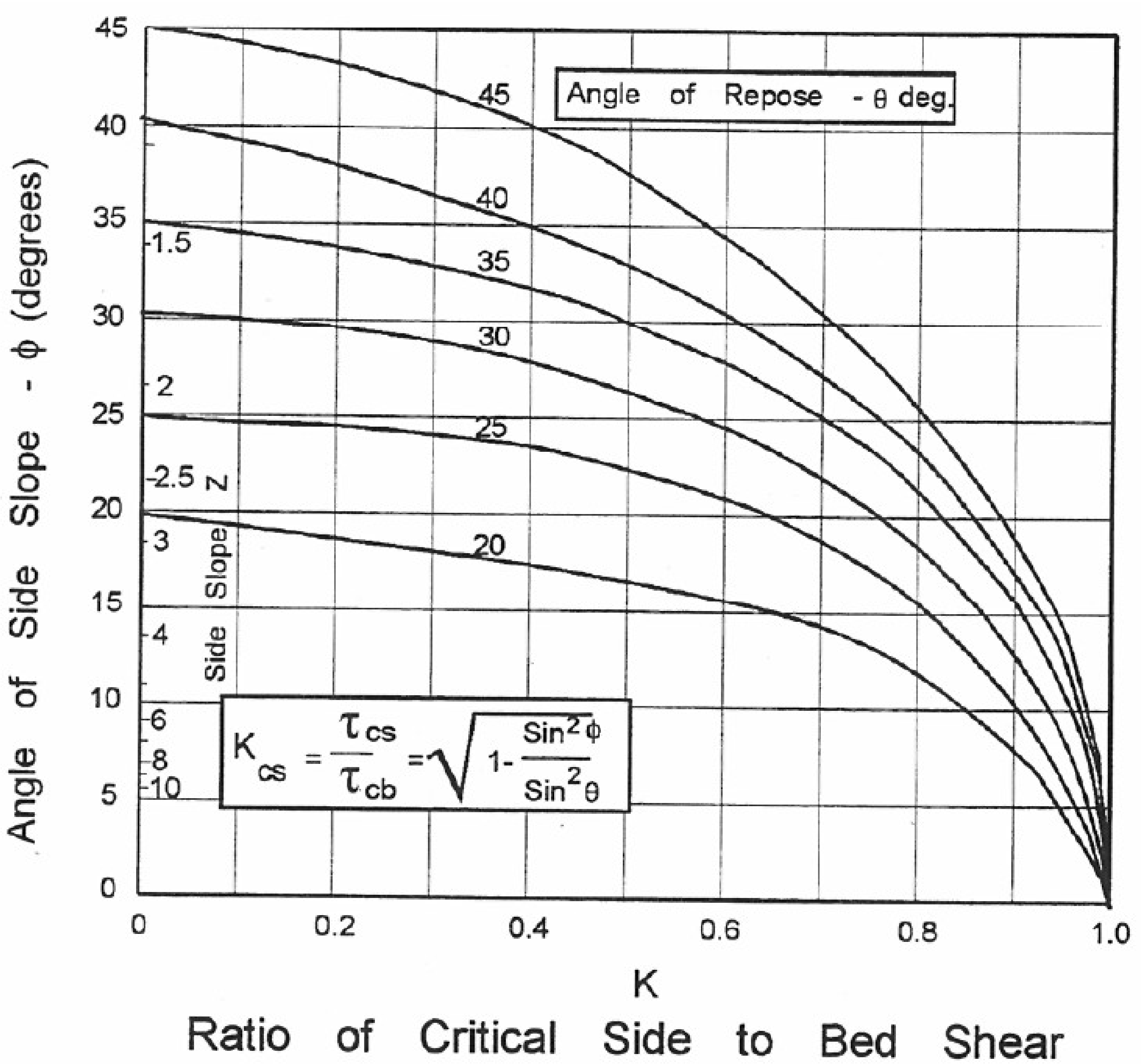
Source: After Tentative Design Procedures for Riprap Lined Channels, 1970, A.G. Anderson, A.S. Paintal and J.T. Davenport, National Cooperative Highway Research Program Report 108.

Design Chart 2.13: Determining Angle of Repose



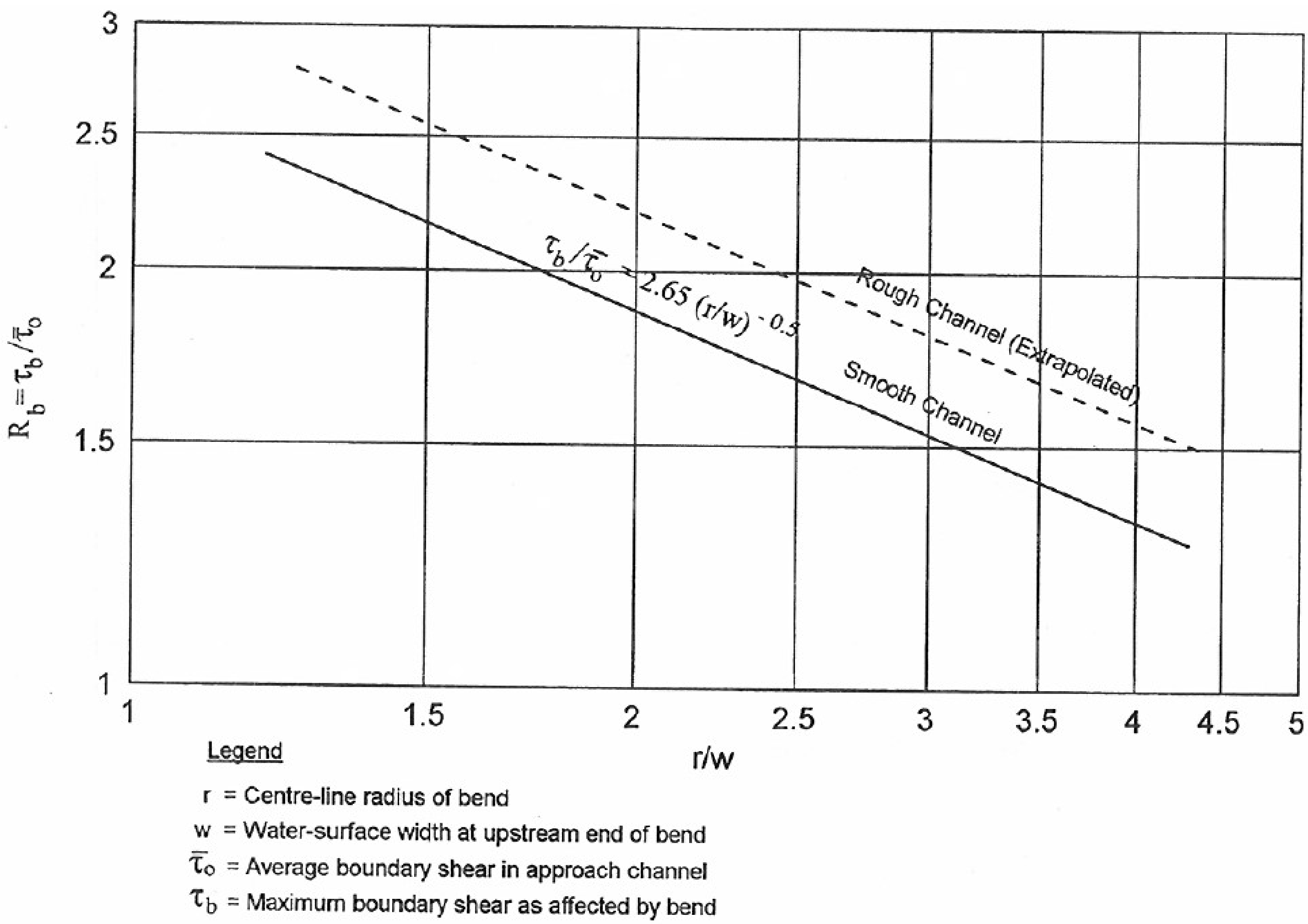
Source: After Tentative Design Procedures for Riprap Lined Channels, 1970, A.G. Anderson, A.S. Paintal and J.T. Davenport, National Cooperative Highway Research Program Report 108.

Design Chart 2.14: Coefficients of Resisting Shear on Side Slopes



Source: After Tentative Design Procedures for Riprap Lined Channels, 1970, A.G. Anderson, Paintal and J.T. Davenport, National Cooperative Highway Research Program Report 108.

Design Chart 2.15: Shear Coefficient for Outside of Channel Bends



Source: U.S. Army Corps of Engineers (1970)

Design Chart 2.16: Permissible Shear for Lining Materials

Vegetative			**Permissible Unit Shear Stress (kg / m^2)**	
Class A			18	
Class B			10	
Class C			4.9	
Class D			2.9	
Class E			1.7	
Gravel Riprap	1"	25 mm	1.6	Estimates only. Permissible shear stress is dependent on several factors including flow depth, velocity, bank side slope, etc.
	2"	50 mm	3.2	
Rock Riprap	6"	150 mm	9.8	
	12"	300 mm	20	

Note: Class A, B, C, D and E shown on Design Chart 2.23

Source: U.S. Department of Transportation (1988)

Design Chart 2.17: Maximum Permissive Flow Velocities - Native Material/Linings

		Velocity	
Material	Clear water (m/s)	Water carrying fine silts (m/s)	Water carrying sand and gravel (m/s)
Fine sand (noncolloidal)	0.45	0.75	0.50
Sandy loam (noncolloidal)	0.50	0.75	0.60
Silt loam (noncolloidal)	0.60	0.90	0.60
Ordinary firm loam	0.75	1.10	0.70
Volcanic ash	0.75	1.10	0.60
Fine gravel	0.75	1.50	1.15
Stiff clay (very colloidal)	1.15	1.50	0.90
Graded, loam to cobbles (noncolloidal)	1.15	1.50	0.50
Graded, silt to cobbles (colloidal)	1.20	1.70	1.50
Alluvial silts (noncolloidal)	0.60	1.10	1.60
Alluvial silts (collodial)	1.15	1.50	0.90
Coarse gravel (noncolloidal)	1.20	1.85	2.00
Cobbles and Shingles	1.50	1.70	2.00
Shales and hard plans	1.85	1.85	1.50

For sinuous channels multiply allowable velocity by 0.95 for slightly sinuous, by 0.9 for moderately sinuous channels, and by 0.8 for highly sinuous channels.
Source: American Society of Civil Engineers - ASCE (1926)

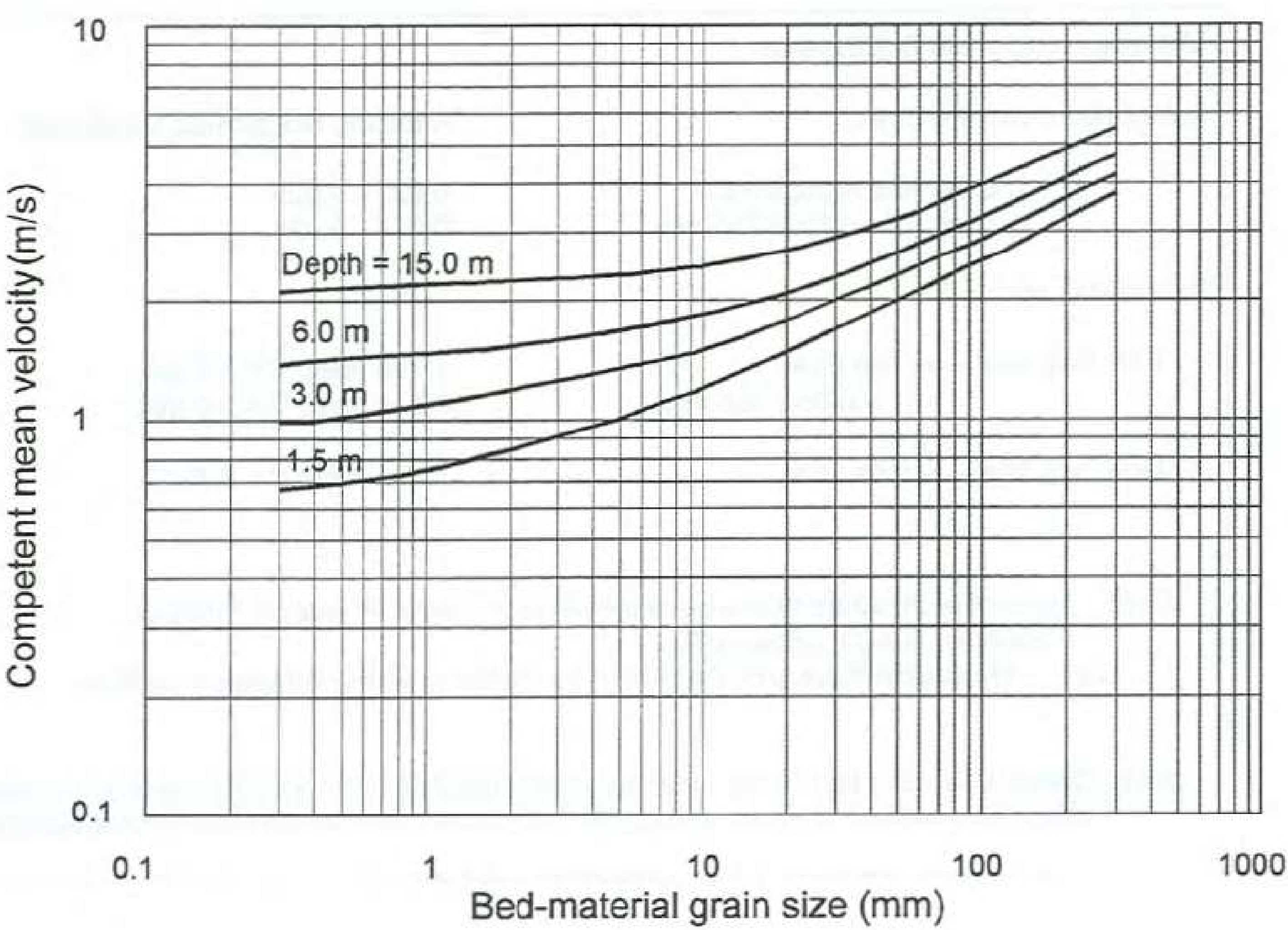
- Vegetal Linings

		Velocity	
Cover	Slope range (%)	Erosion resistant soils (m/s)	Easily eroded soils (m/s)
Bermuda grass	0-5	2.4	1.8
	5-10	2.1	1.5
	over 10	1.8	1.2
Buffalo grass	0-5	2.1	1.5
Kentucky Bluegrass	5-10	1.8	1.2
Smooth Brome	over 10	1.5	0.9
Grass mixture	0-5[3]	1.5	1.2
	1-10[3]	1.2	0.9
Lespedeza Sericea	0-5[4]	1.1	0.8
Common Lespedeza[5] Sudan grass[5]	0-5[4]	1.1	0.8

Use flow velocities over 1.5 m/s only where good cover and proper maintenance can be obtained.
Do not use on slopes steeper than 10 percent.
Use on slopes steeper than 5 percent is not recommended.
Annuals, used on mild slopes or as temporary protection until permanent covers are established.
Note: Permissible average flow velocities should be based on local experience whenever possible.

Source: U.S. Department of Agriculture (1954)

Design Chart 2.18: Permissible Velocity Chart: Cohesionless Soil



Source: Neill (1973)

Design Chart 2.19: Hydraulic Characteristics of Terrafix Blocks

Manning Roughness Coefficients

Articulated Concrete Block	Manning Roughness Coefficient
1. Long Axis Across Flow	0.021 - 0.023
2. Long Axis in Flow Direction	0.019 - 0.021

Critical Velocity[2]

T-60 long axis - across flow	1.1 m deep V = 8.8 m/s
- in flow direction	1.1 m deep V = 9.0 m/s
T-45 long axis - across flow	1.5 m deep V = 8.4 m/s

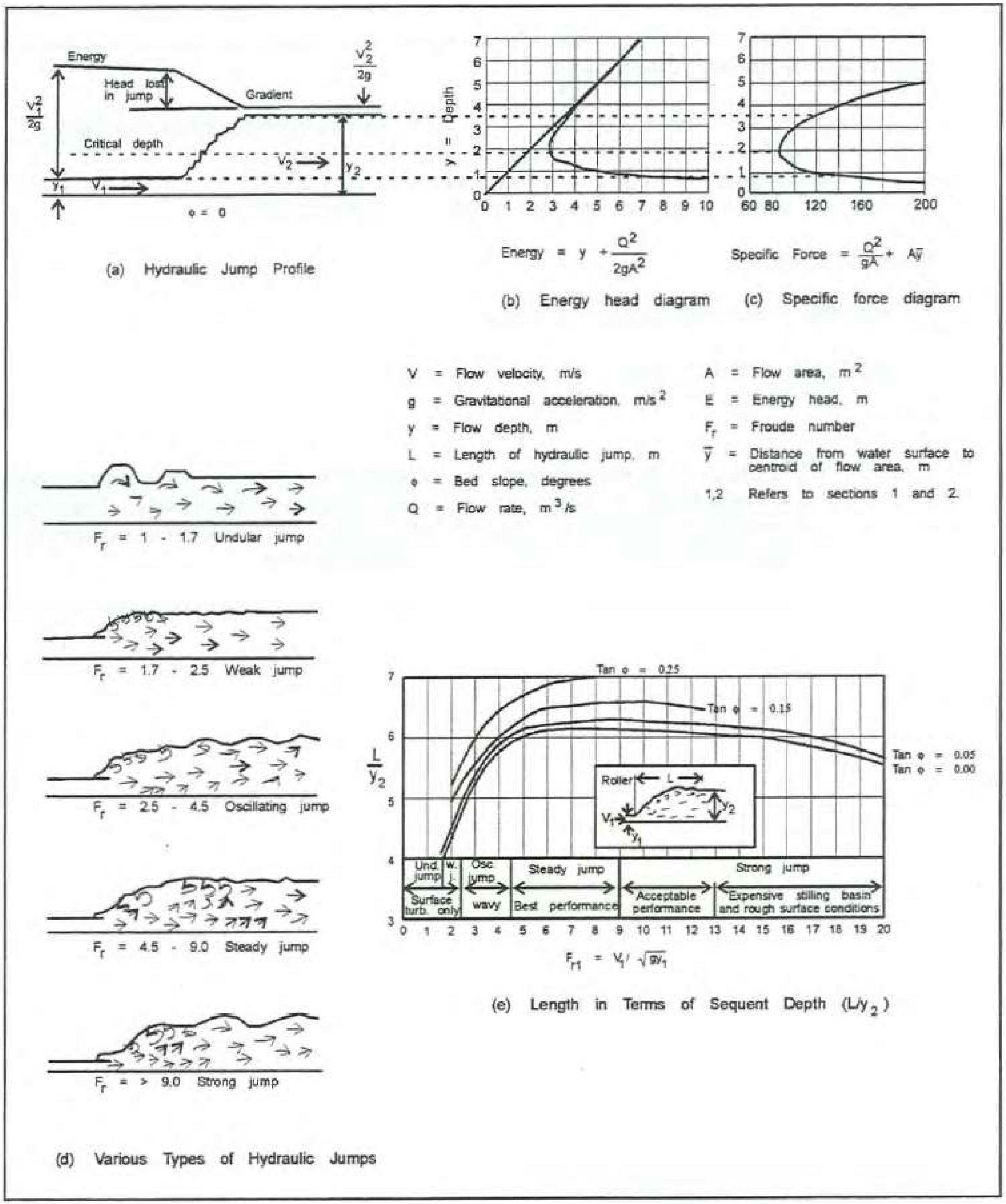
[1] K. Hill. Hydraulics Research Division of the National Water Research Institute. Report No. 79-03, January 79.

[2] Y.L. Lau. Hydraulics Research Division of the National Water Research Institute.

Note: Critical flow velocities under ideal laboratory conditions as provided by manufacturers. The designer is cautioned when utilizing the critical flow velocities for design applications.

Sources: Hill (1979); Lau (1979)

Design Chart 2.20: Hydraulic Jump Length



Source: After Hydraulic Design of Stilling Basins and Energy Dissipators, 1974, A.J. Peterka.

Design Chart 2.21: Hydraulic Characteristics of Concrete Blocks with Cables

Manning Roughness Coefficients

Articulated Concrete Block	Manning Roughness Coefficient
1. CC35 in 1.5 m deep flow subcritical	0.024 - 0.026
2. CC70 in 1.5 m deep flow subcritical	0.028 - 0.032

Critical Velocity

CC35 in 1.5 m deep flow V = 5.7 m/s

CC70 in 1.5 m deep flow V = 8.0 m/s

NOTE: The product consists of cable connected truncated concrete pyramids bonded to a geotextile base. It is normal to have grass between the blocks. These design data are for bed slopes of less than 2% with secure anchoring of the upstream edge. The critical velocity must be reduced for steeper slopes.

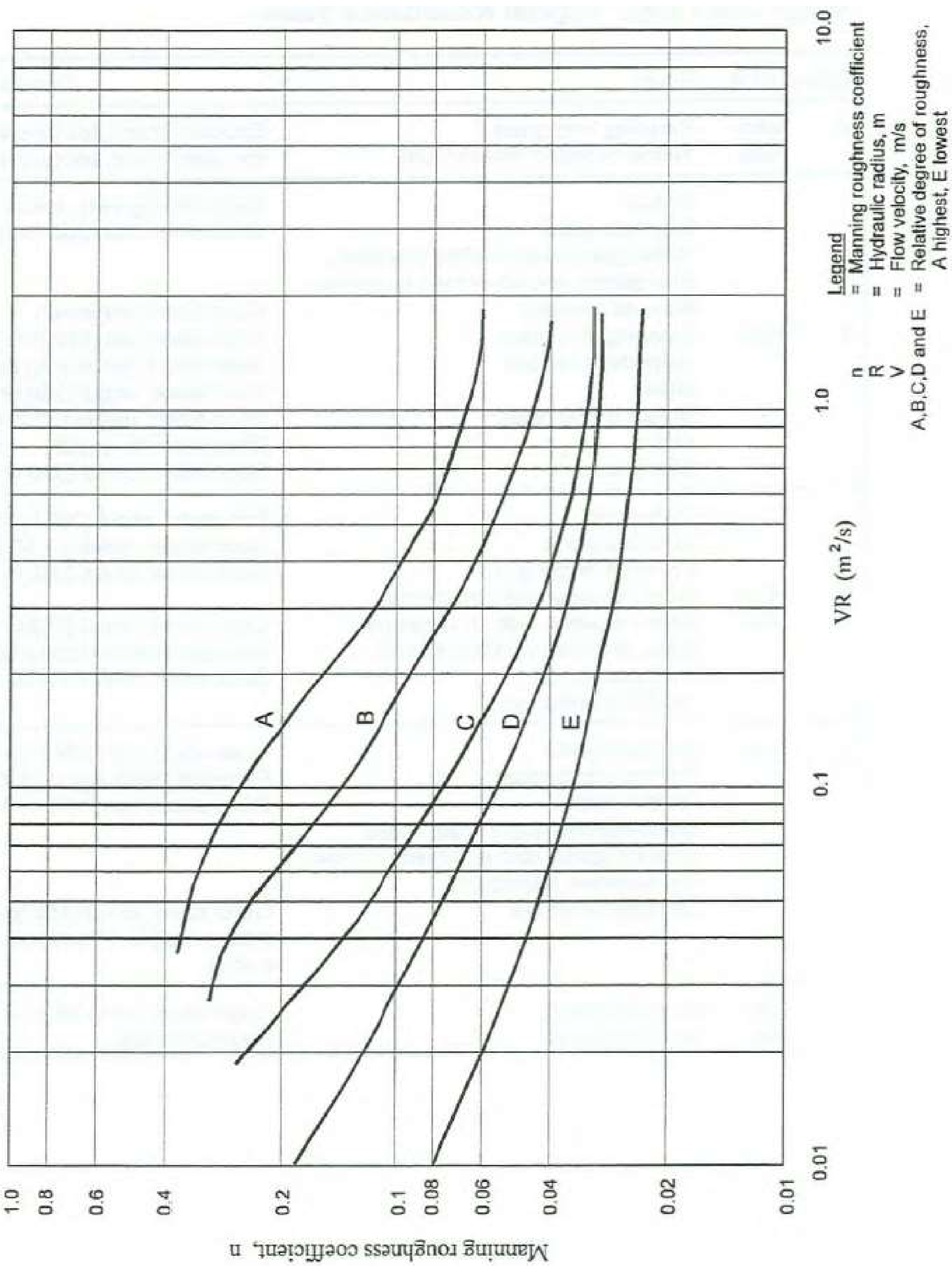
Source: McCorquodale et al (1988); McCorquodale (1991)

Design Chart 2.22: Vegetal Retardance Table

Retardance	Cover	Condition
A Very High	Weeping love grass	Excellent stand, tall (average height 760 mm)
	Yellow bluestem ischaemum	Excellent stand, tall (average height 910 mm)
B High	Kudzu	Very dense growth, uncut
	Bermuda grass	Good stand, tall (300 mm)
	Native grass mixture (little bluestem, blue grama, and other long and short Midwest grasses)	Good stand, unmowed
	Weeping love grass	Good stand, tall (610 mm)
	Lespedeza sencea	Good stand, not woody, tall (480 mm)
	Alfalfa	Good stand, uncut (280 mm)
	Weeping love grass	Good stand, mowed (330 mm)
	Kudzu	Dense growth, uncut
	Blue grama	Good stand, uncut (330 mm)
C Moderate	Crab grass	Fair stand, uncut (250 to 1220 mm)
	Bermuda grass	Good stand, mowed (150 mm)
	Common lespedeza	Good stand, uncut (280 mm)
	Grass-legume mixture-summer (orchard grass, redtop, Italian rye grass, and common lespedeza)	Good stand, uncut (150 to 200 mm)
	Centipede grass	Very dense cover (150 mm)
	Kentucky bluegrass	Good stand, headed (150 to 300 mm)
D Low	Bermuda grass	Good stand, cut to 64 mm
	Common lespedeza	Excellent stand, uncut (110 mm)
	Buffalo grass	Good stand, uncut (76 to 150 mm)
	Grass-legume mixture-fall, spring (orchard grass, redtop, Italian rye grass and common lespedeza)	Good stand, uncut (100 to 130 mm)
	Lespedeza sericea	After cutting to 50 mm, very good stand before cutting
E Very Low	Bermuda grass	Good stand, cut to 38 mm
	Bermuda grass	Burned stubble

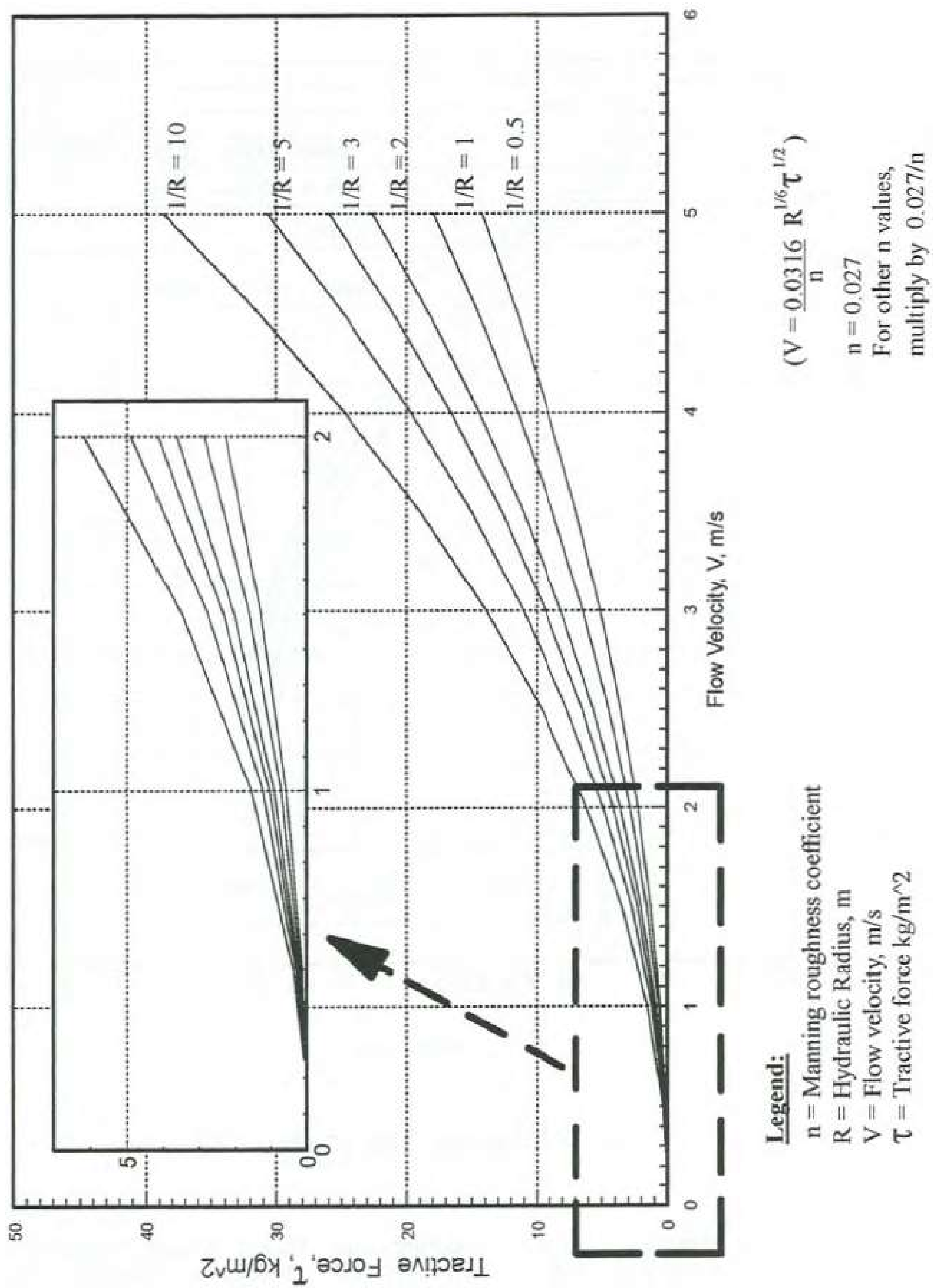
Source: U.S. Department of Agriculture (1954)

Design Chart 2.23: Vegetal Retardance Curves

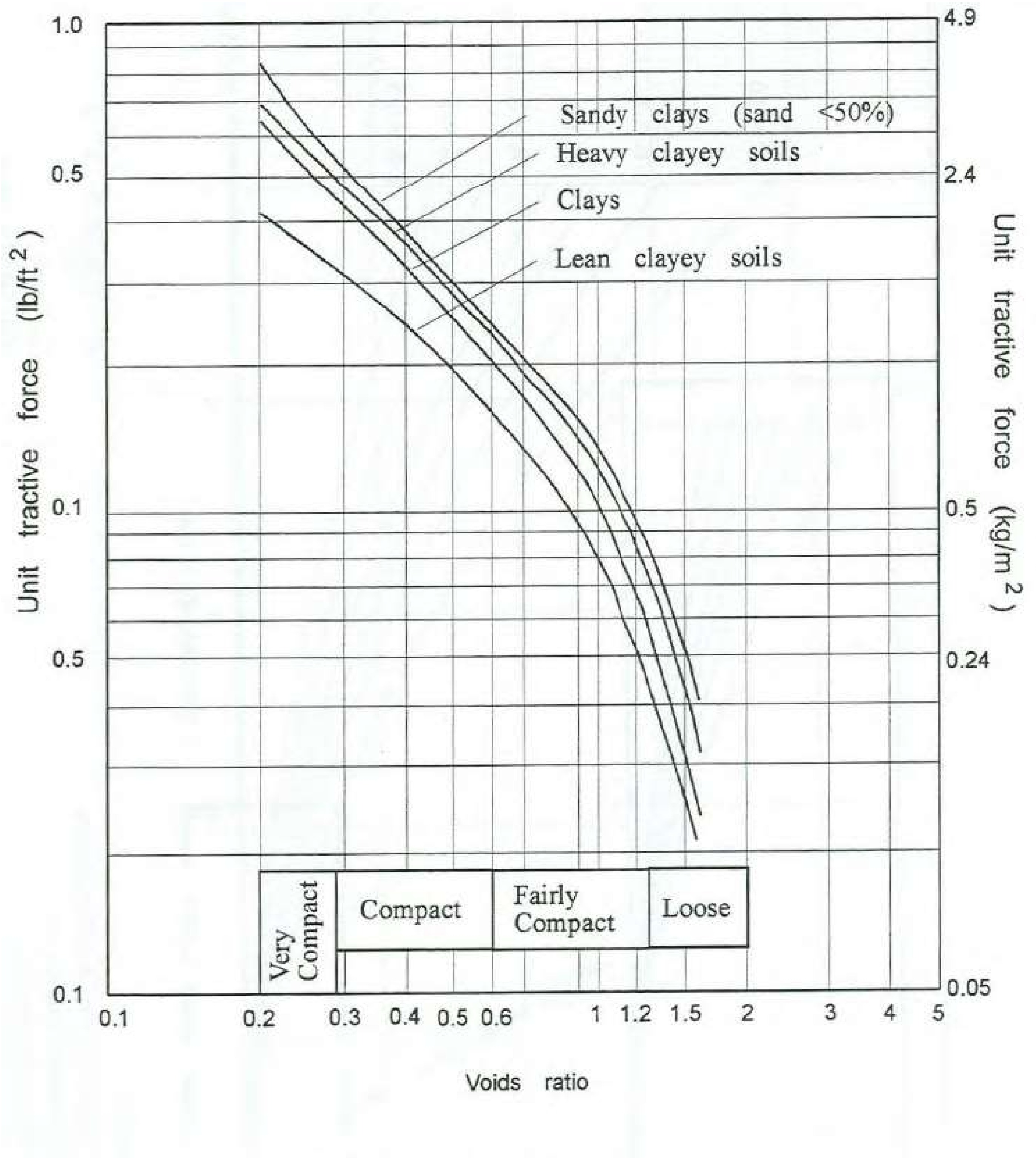


Source: F.C. Sobey (1939)

Design Chart 2.24: Tractive Force - Velocity Relationships



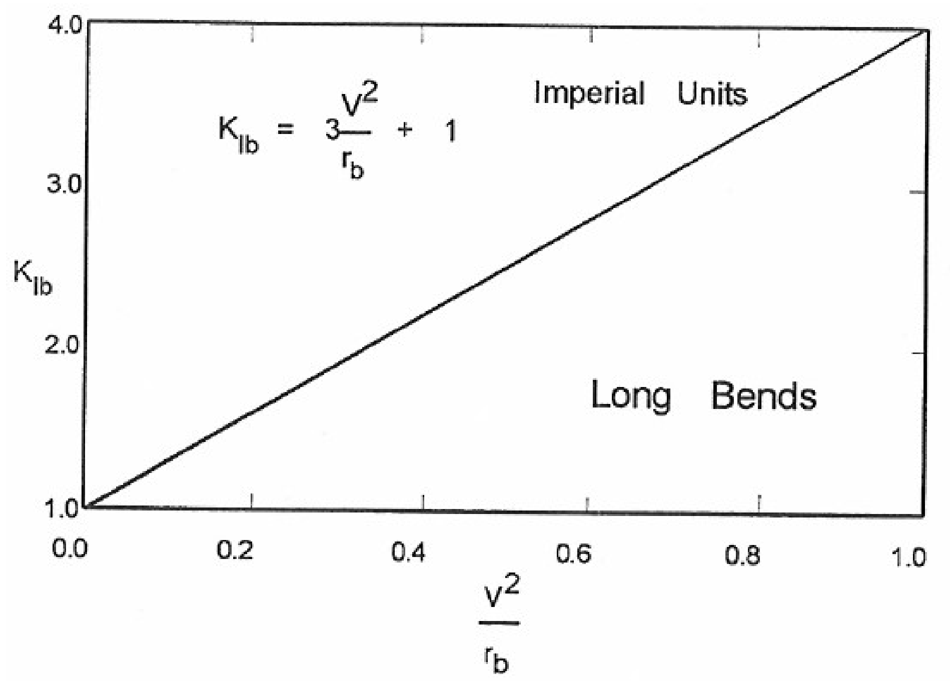
Design Chart 2.25: Permissible Unit Tractive Force



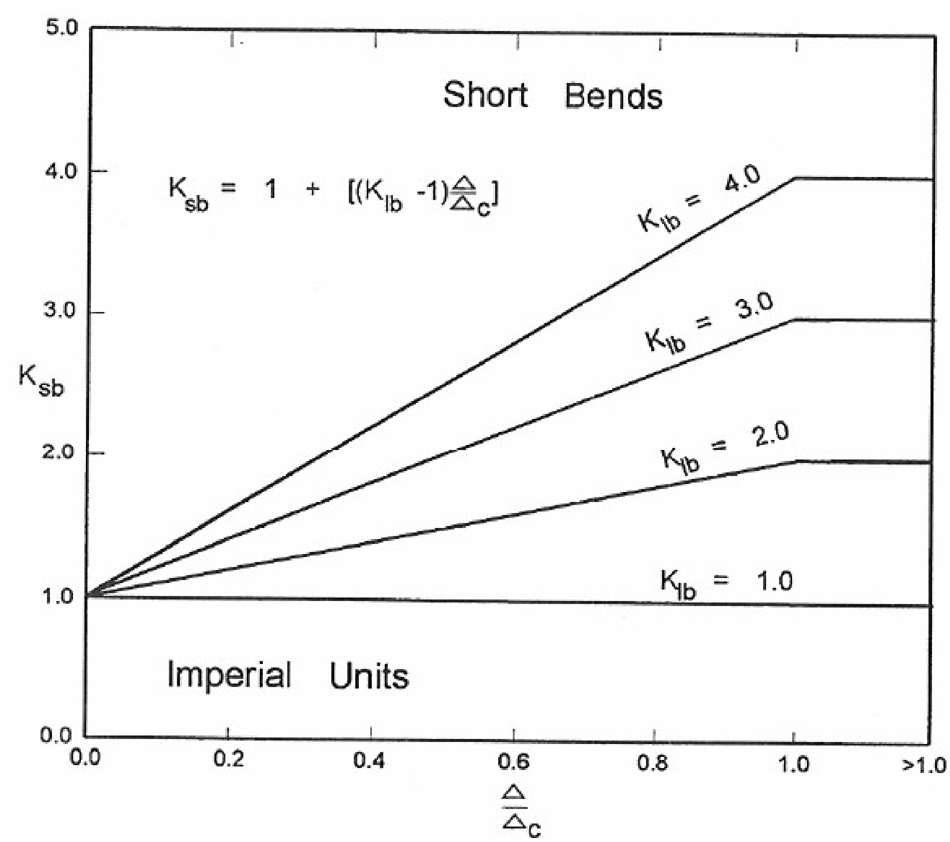
(b) Permissible Unit Tractive Force

Source: After Tentative Design Procedures for Riprap Lined Channels, 1970, A.G. Anderson, A.S. Paintal and J.T. Davenport, National Cooperative Highway Research Program Report 108.

Design Chart 2.26: Ratio of Shear in Long Bends to Straight Reach

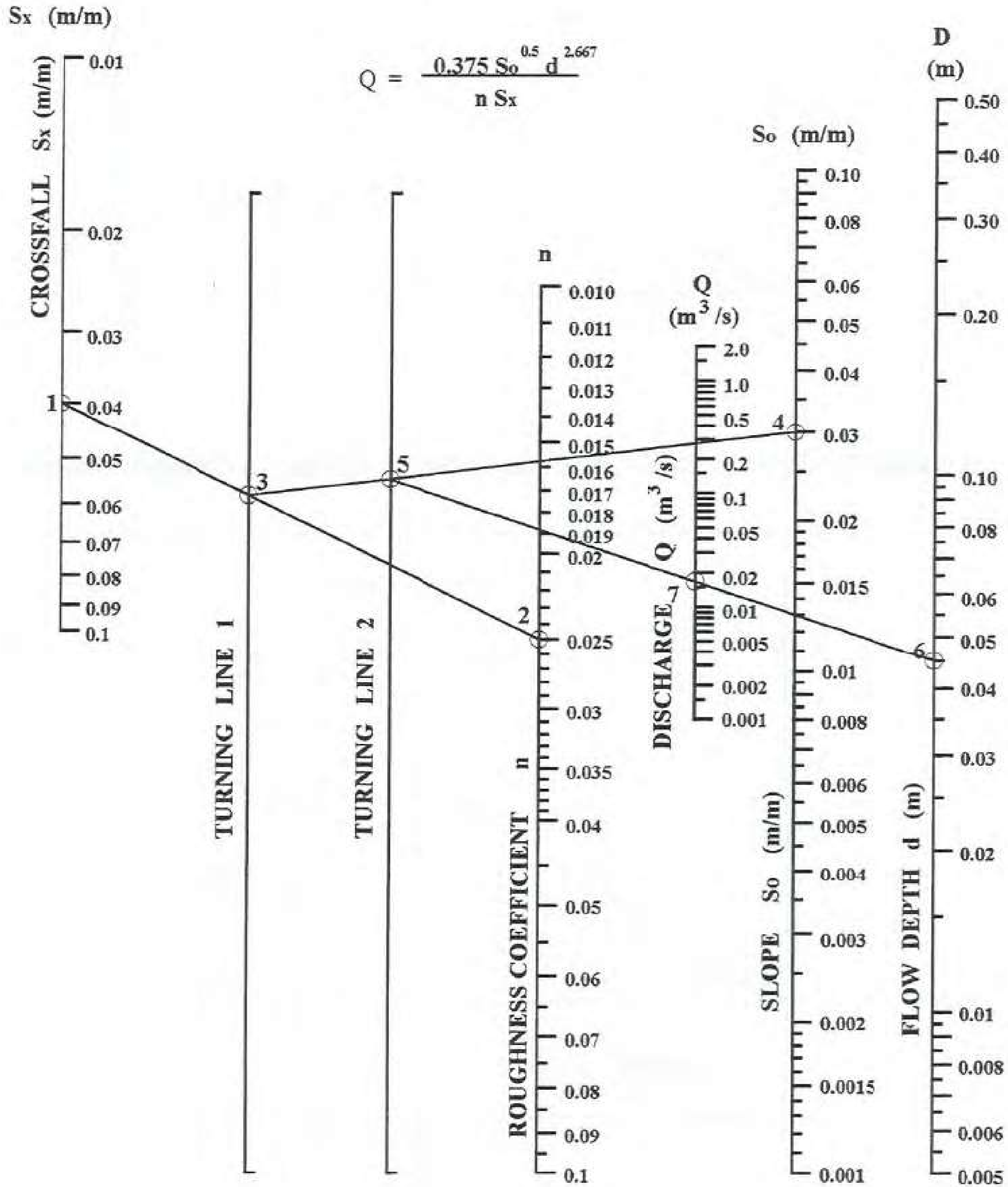


Design Chart 2.27: Ratio of Shear in Short Bends to Straight Reach

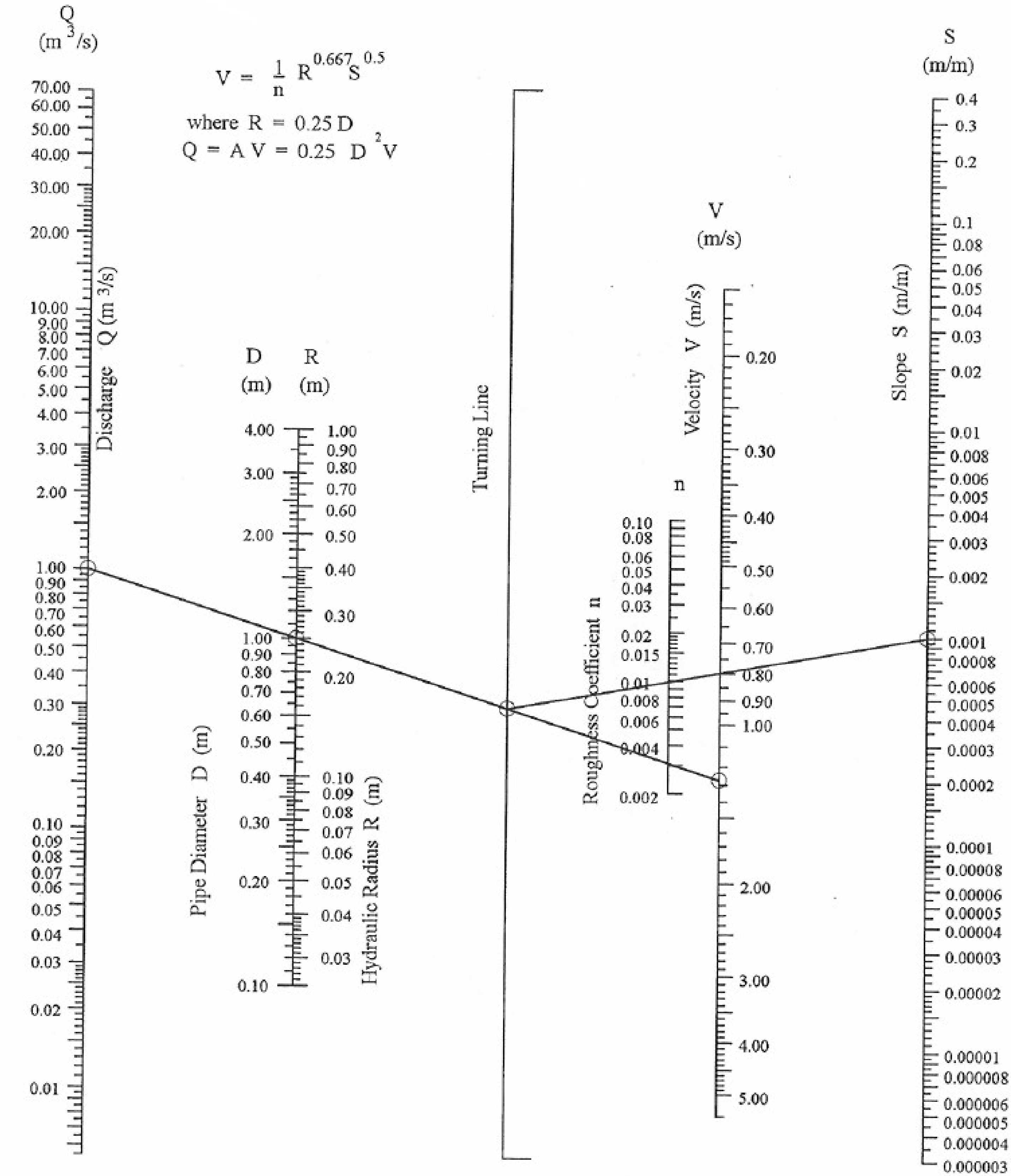


Source: After Tentative Design Procedures for Riprap Lined Channels, 1970, A.G. Anderson, A.S. Paintal and J.T. Davenport, National Cooperative Highway Research Program Report 108.

Design Chart 2.28: Nomograph: Triangular Channels

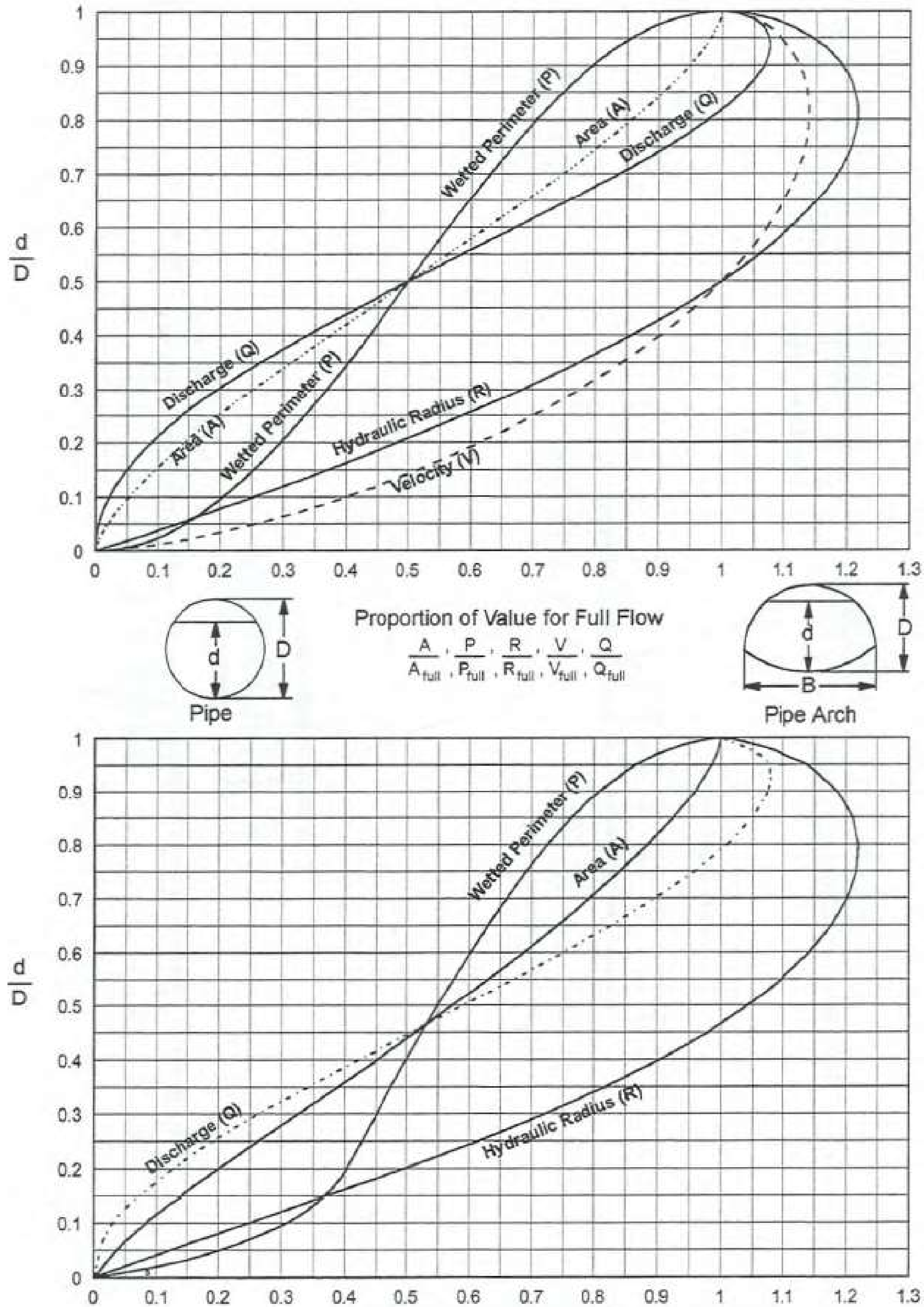


Design Chart 2.29: Nomograph: Circular Pipes - Flowing Full



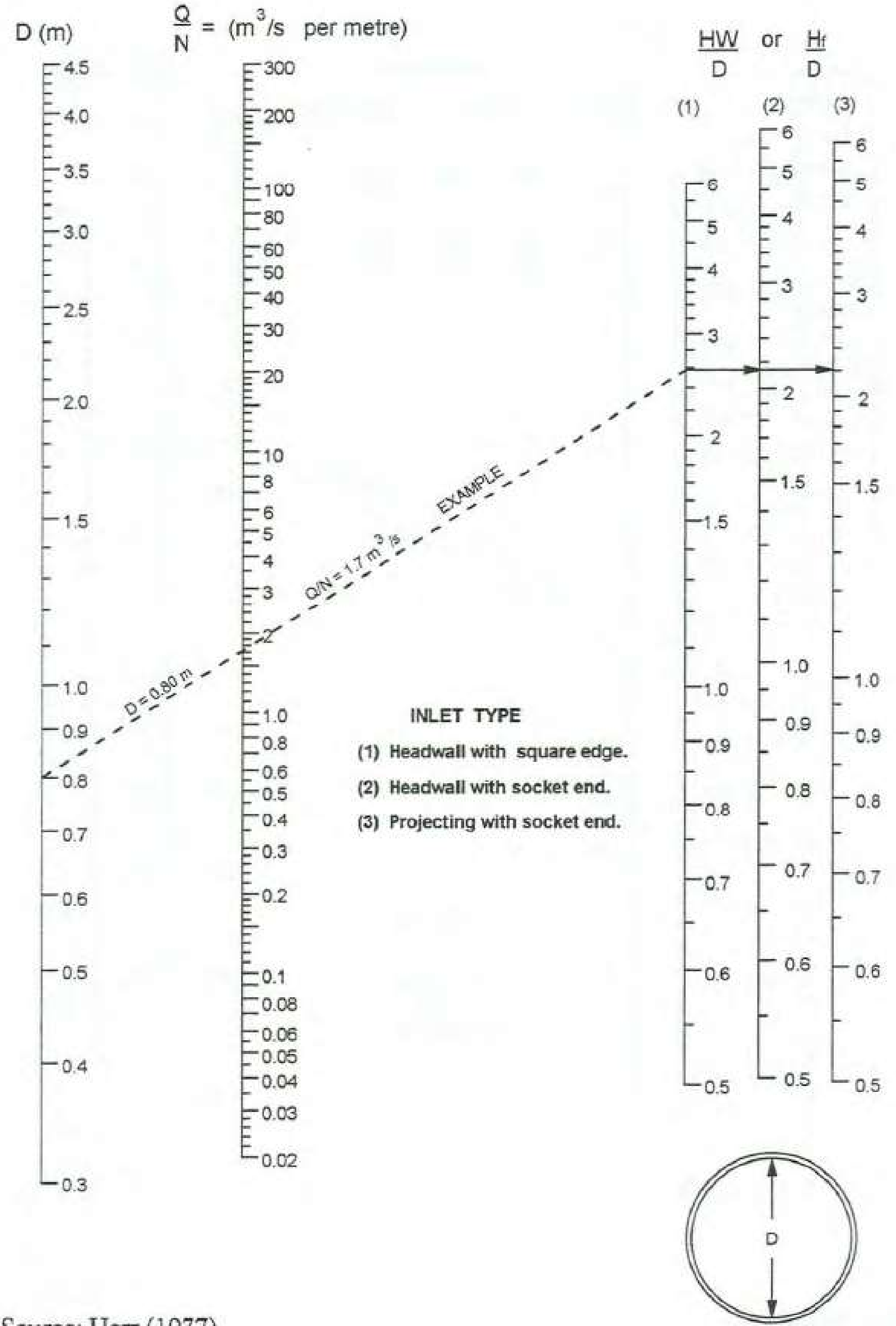
Source: American Iron and Steel Institute (1980)

Design Chart 2.30: Nomograph: Part-Full Flow for Pipes and Arches



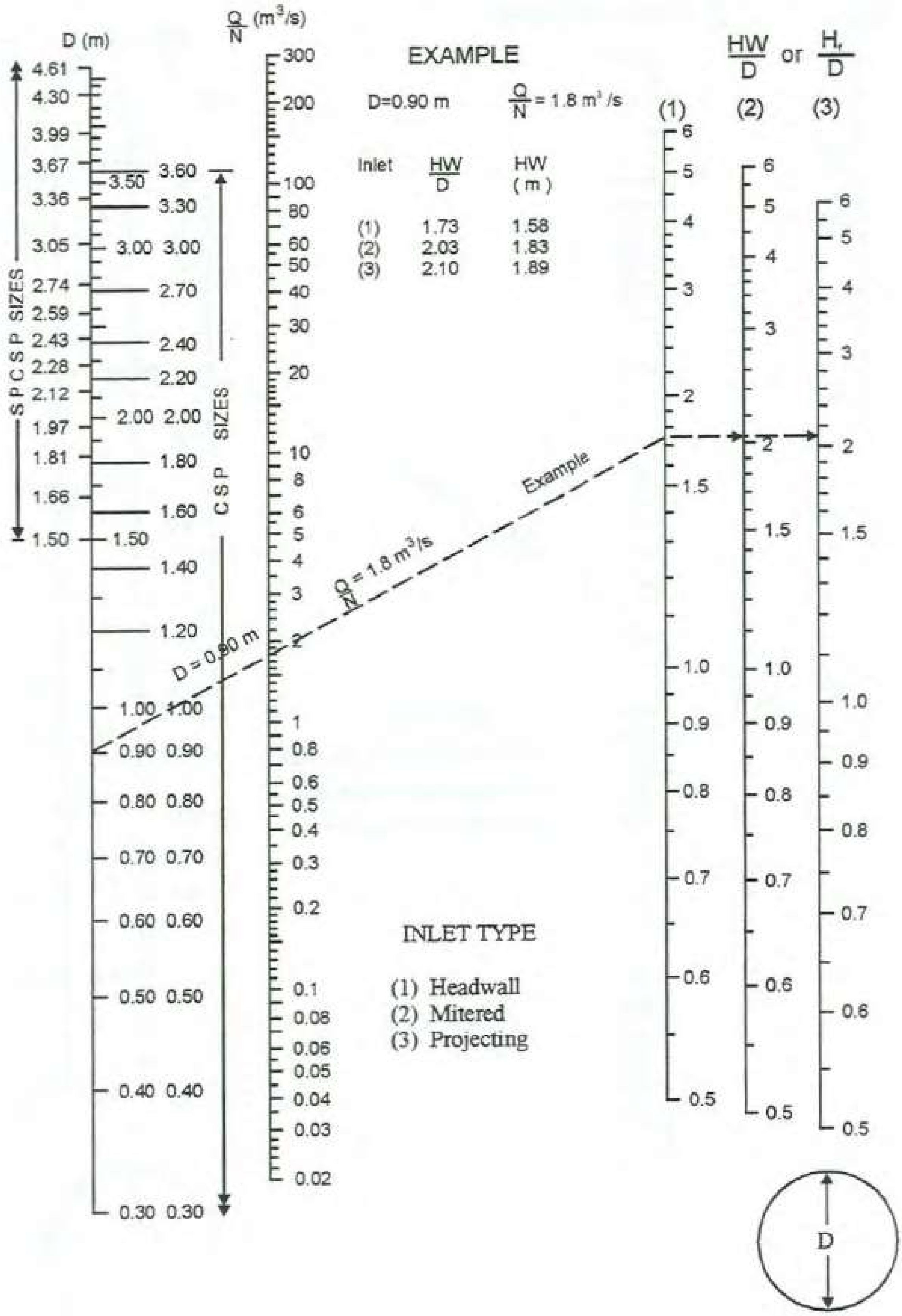
Source: American Iron and Steel Institute (1980)

Design Chart 2.31: Inlet Control: Circular Pipes



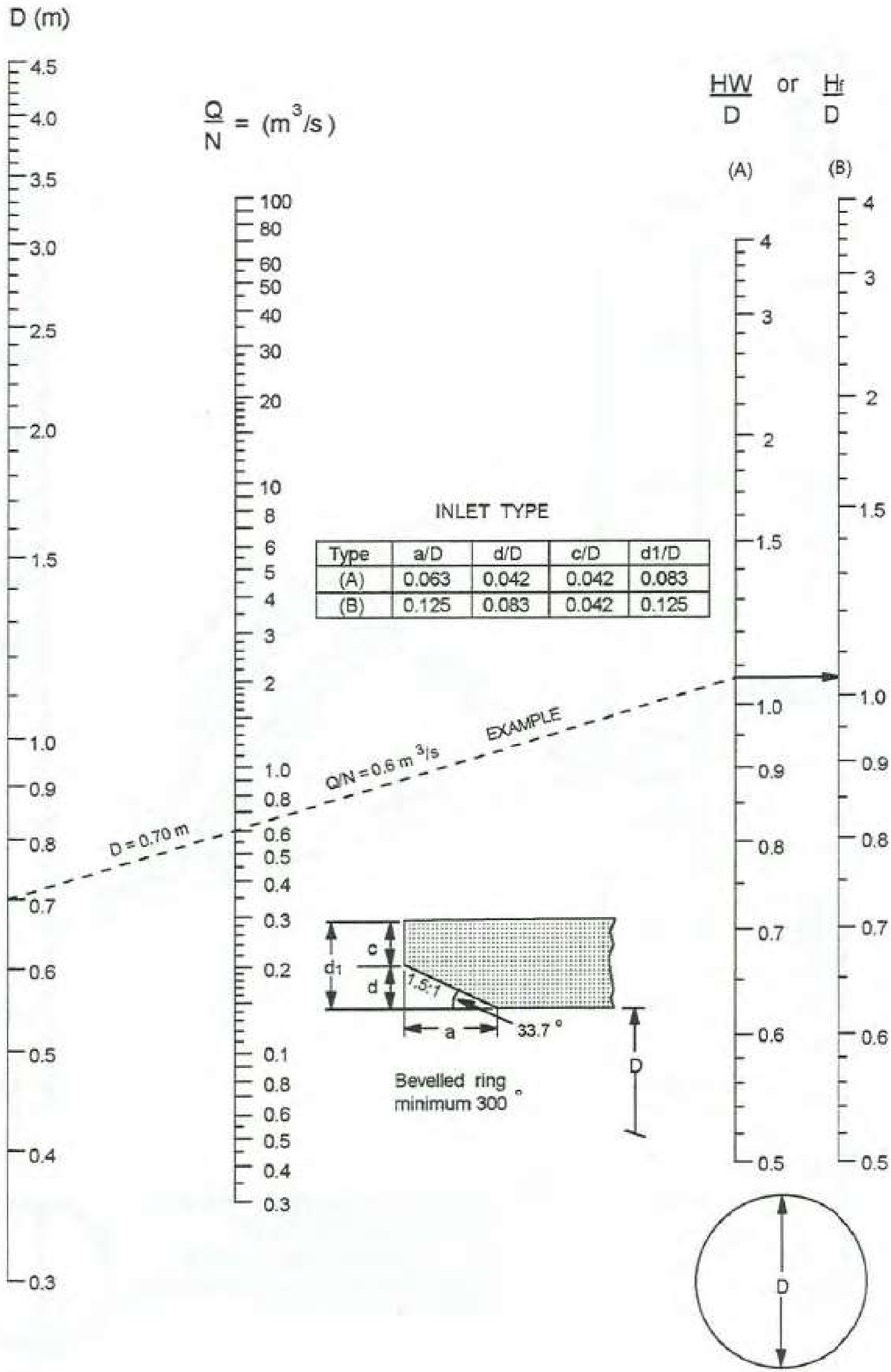
Source: Herr (1977)

Design Chart 2.32: Inlet Control: Circular CSP and SPCSP Culverts



Source: Herr (1977)

Design Chart 2.33: Inlet Control: Circular Culverts - Bevelled End

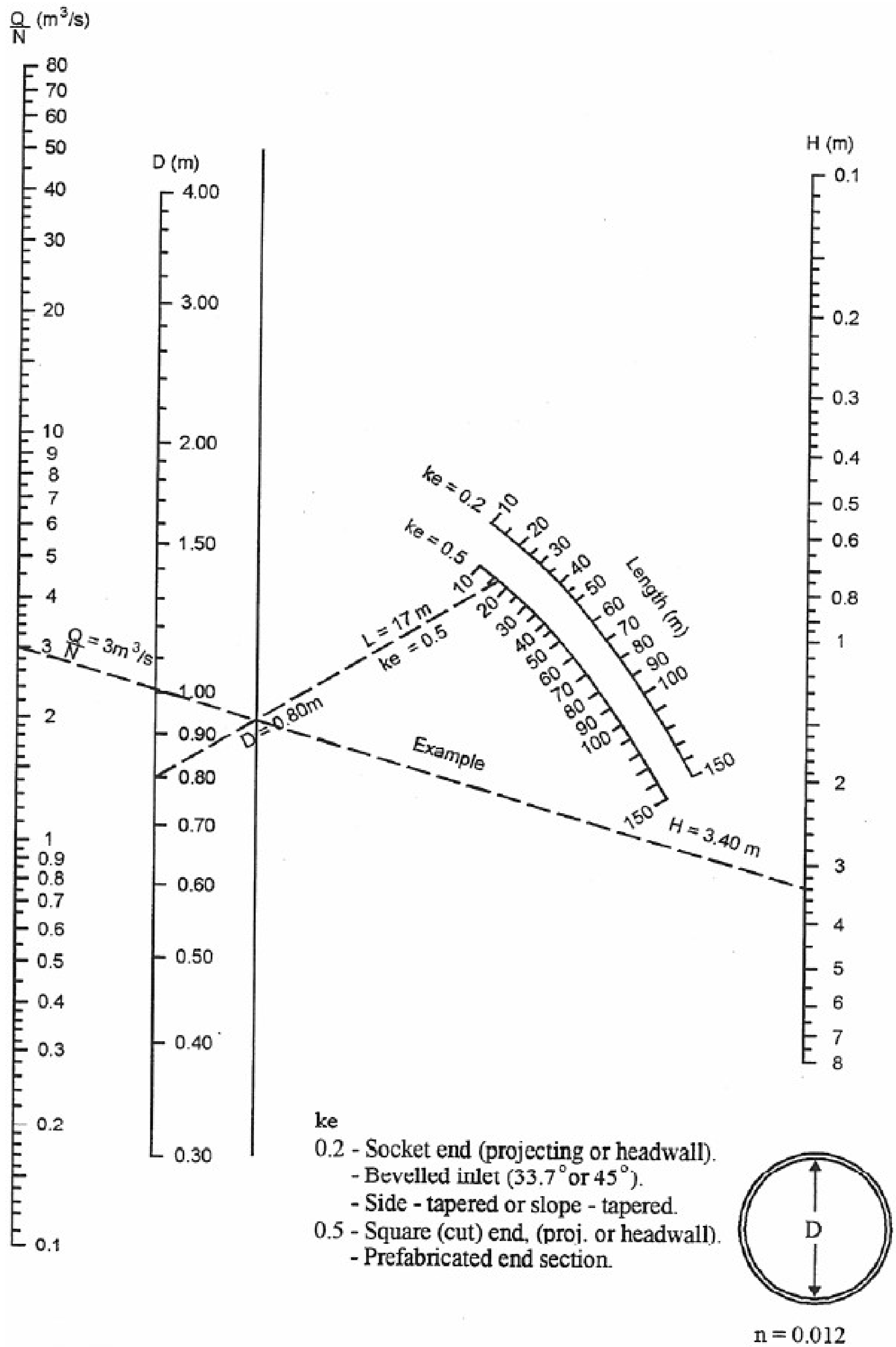


INLET TYPE

Type	a/D	d/D	c/D	d1/D
(A)	0.063	0.042	0.042	0.083
(B)	0.125	0.083	0.042	0.125

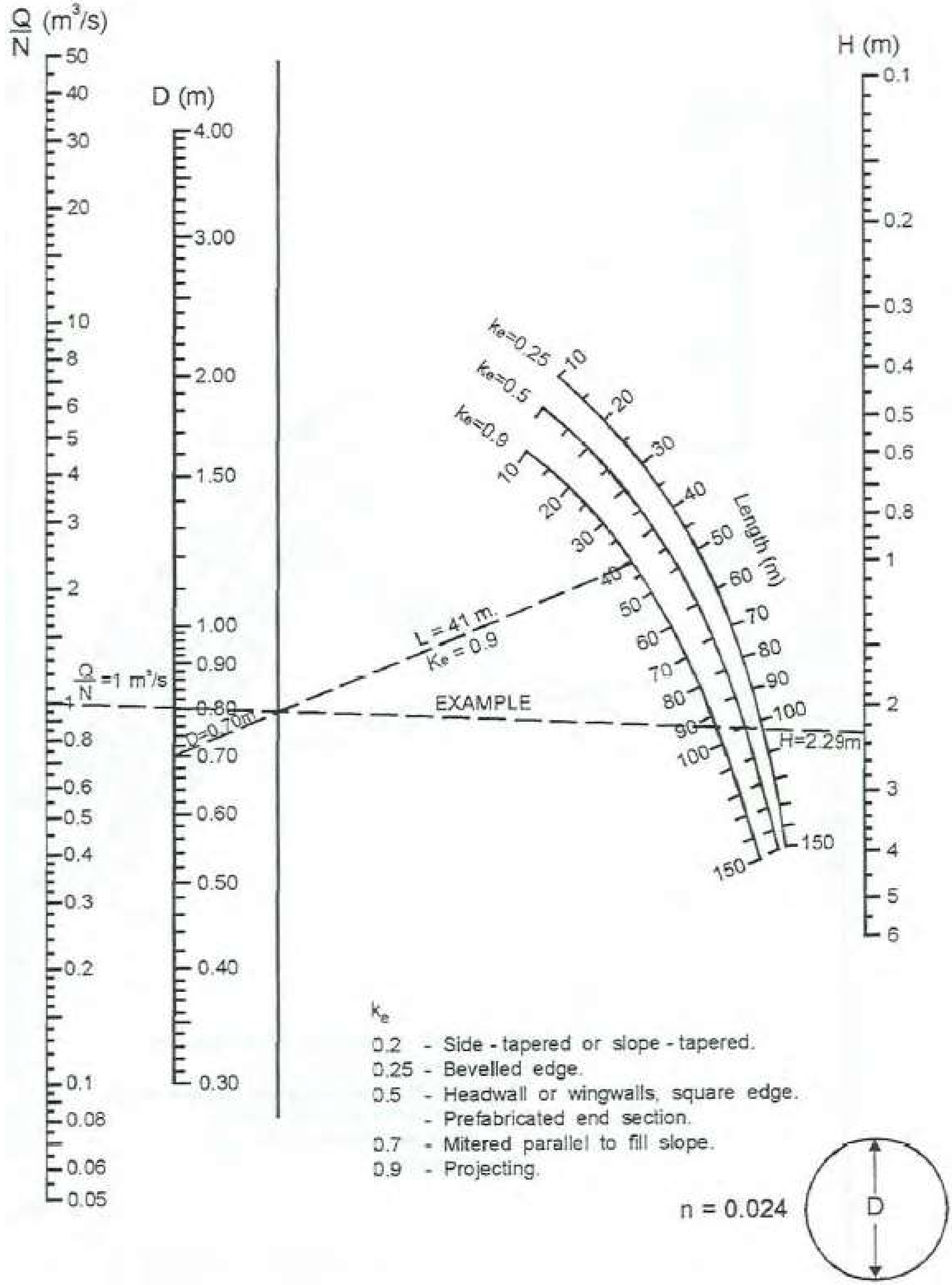
Source: Herr (1977)

Design Chart 2.34: Outlet Control: Concrete Circular Pipe/Culvert - Flowing Full



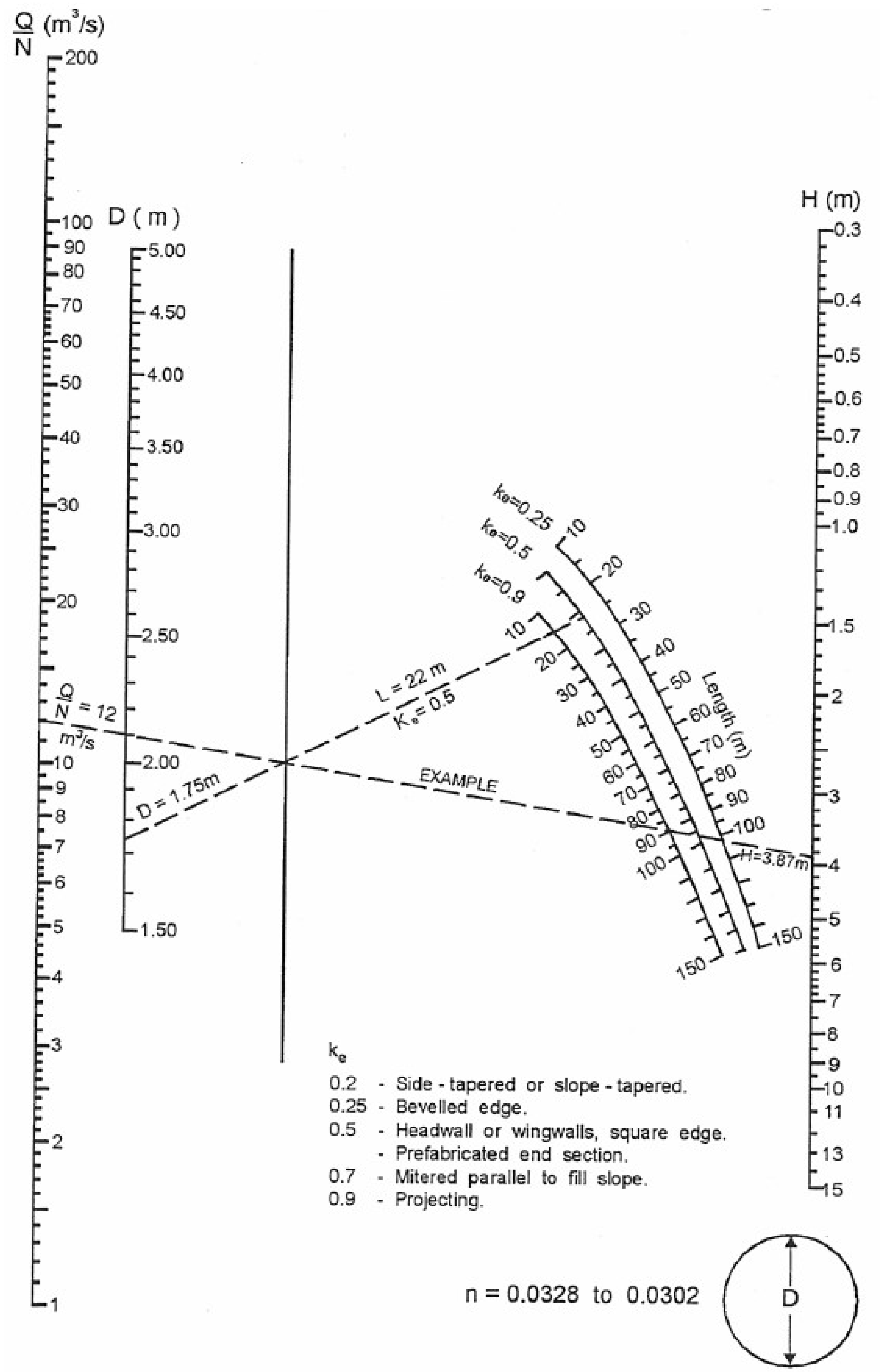
Source: Herr (1977)

Design Chart 2.35: Outlet Control: CSP Culvert - Flowing Full



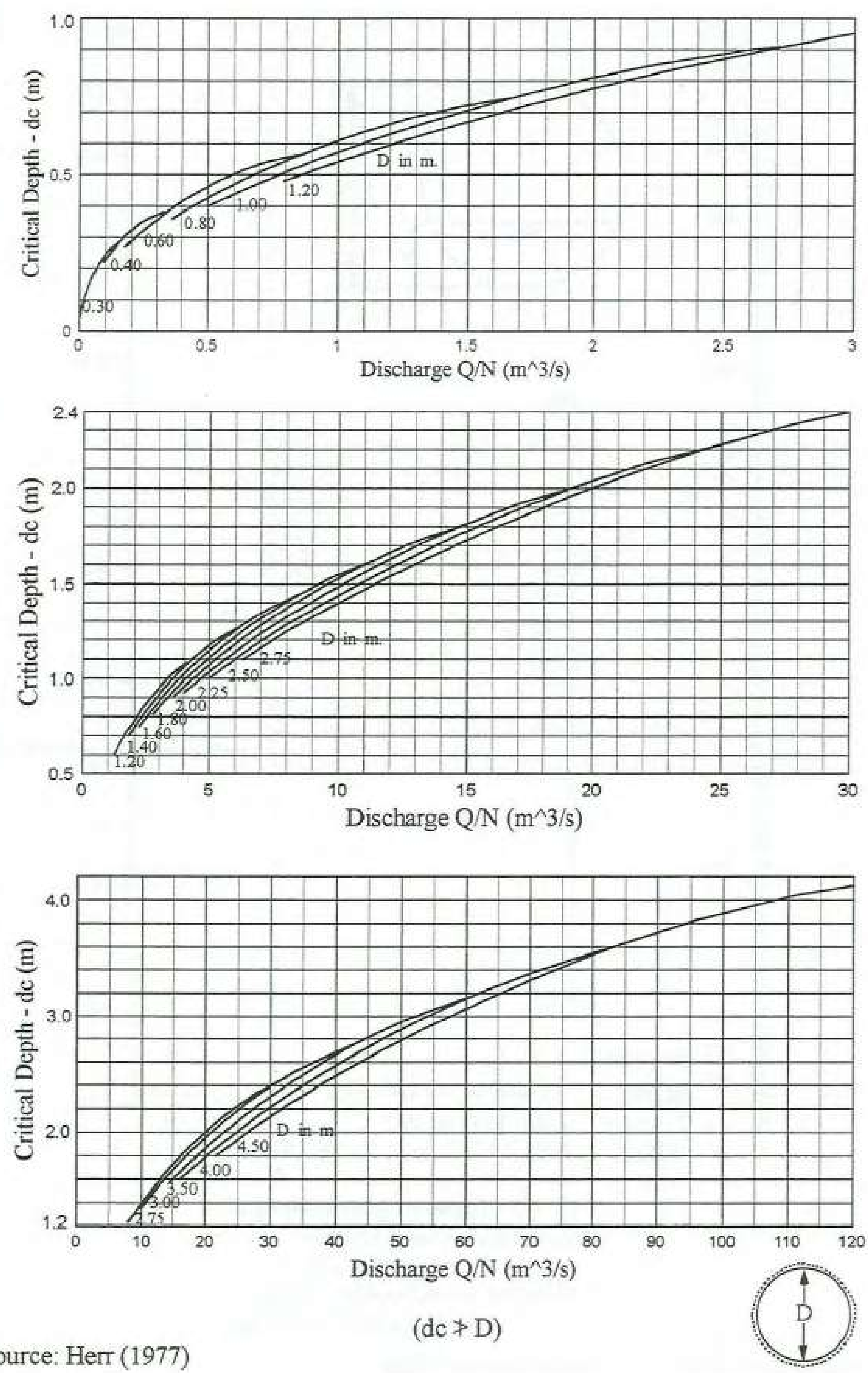
Source: Herr (1977)

Design Chart 2.36: Outlet Control: SPCSP Culvert - Flowing Full



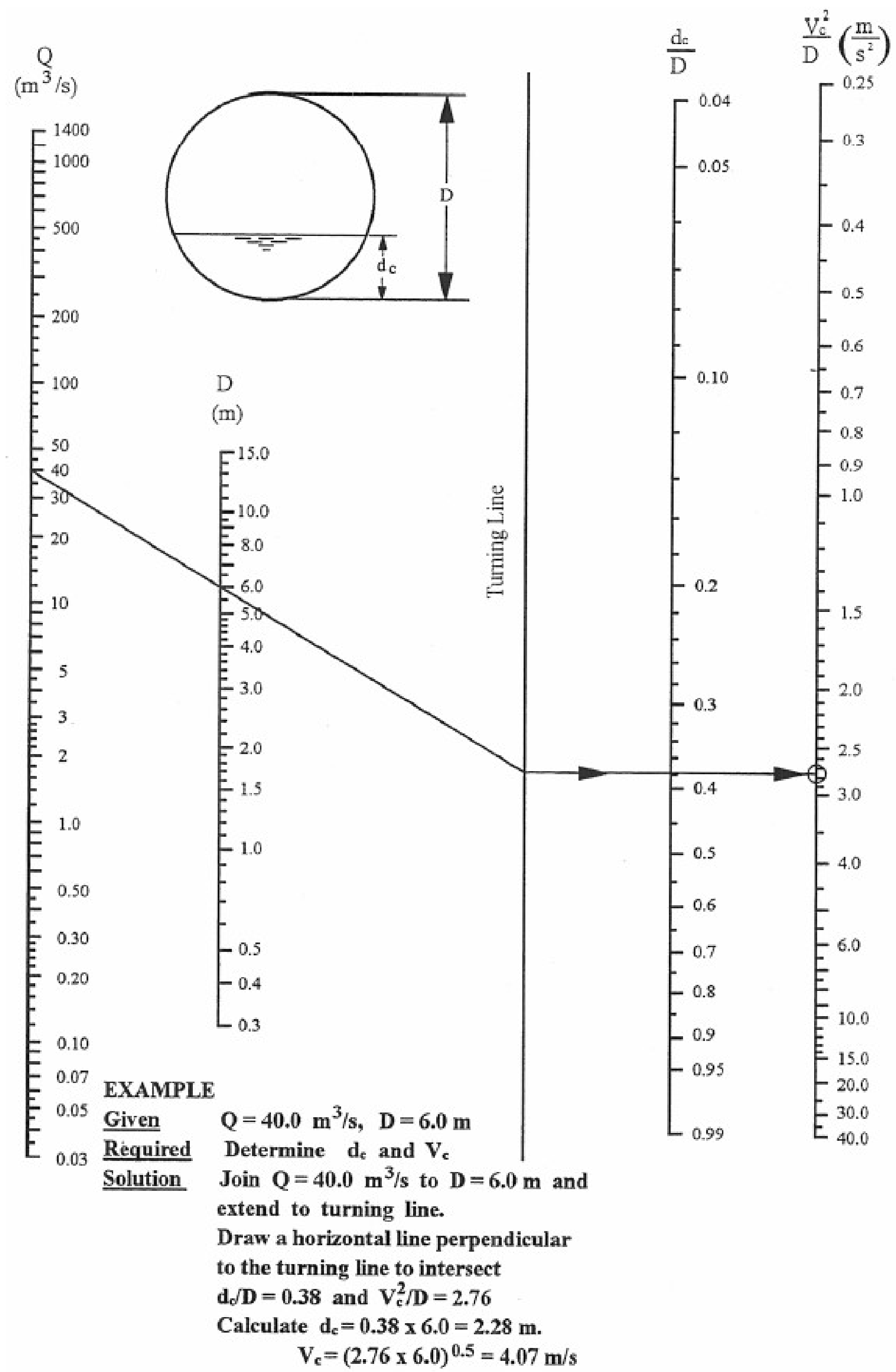
Source: Herr (1977)

Design Chart 2.37: Critical Depth Chart for Circular Pipes



Source: Herr (1977)

Design Chart 2.38: Critical Depth - Velocity relationships: Circular Pipes



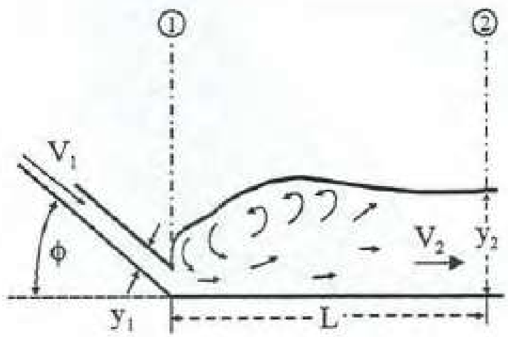
Source: American Iron and Steel Institute

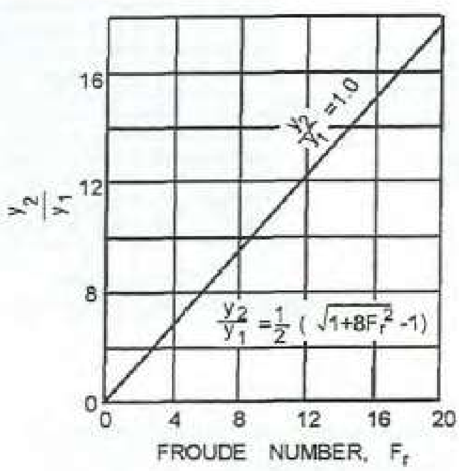
Design Chart 2.39: USBR Energy Dissipator Type I/Vertical Drop

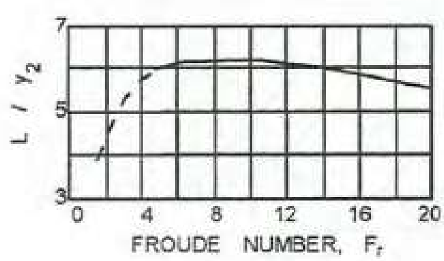
Jump occurs on flat floor with no chute blocks, baffle piers or end sill in basin. Usually not a practical basin because of excessive length.

Elements and characteristics of jumps for complete range of Froude Numbers.

For use in stilling basins with Froude Numbers less than 2.5.



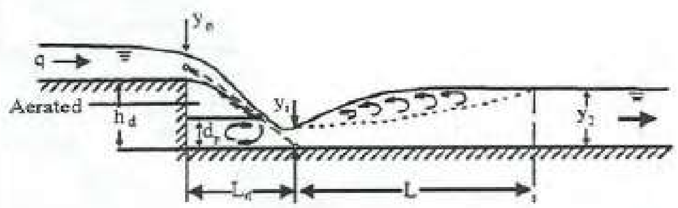




VERTICAL DROP

For small drops of up to 1.0 m.

Jump starts at a distance of L_d, which varies with vertical drop distance, h_d, and is influenced by nappe pool depth, d_p.



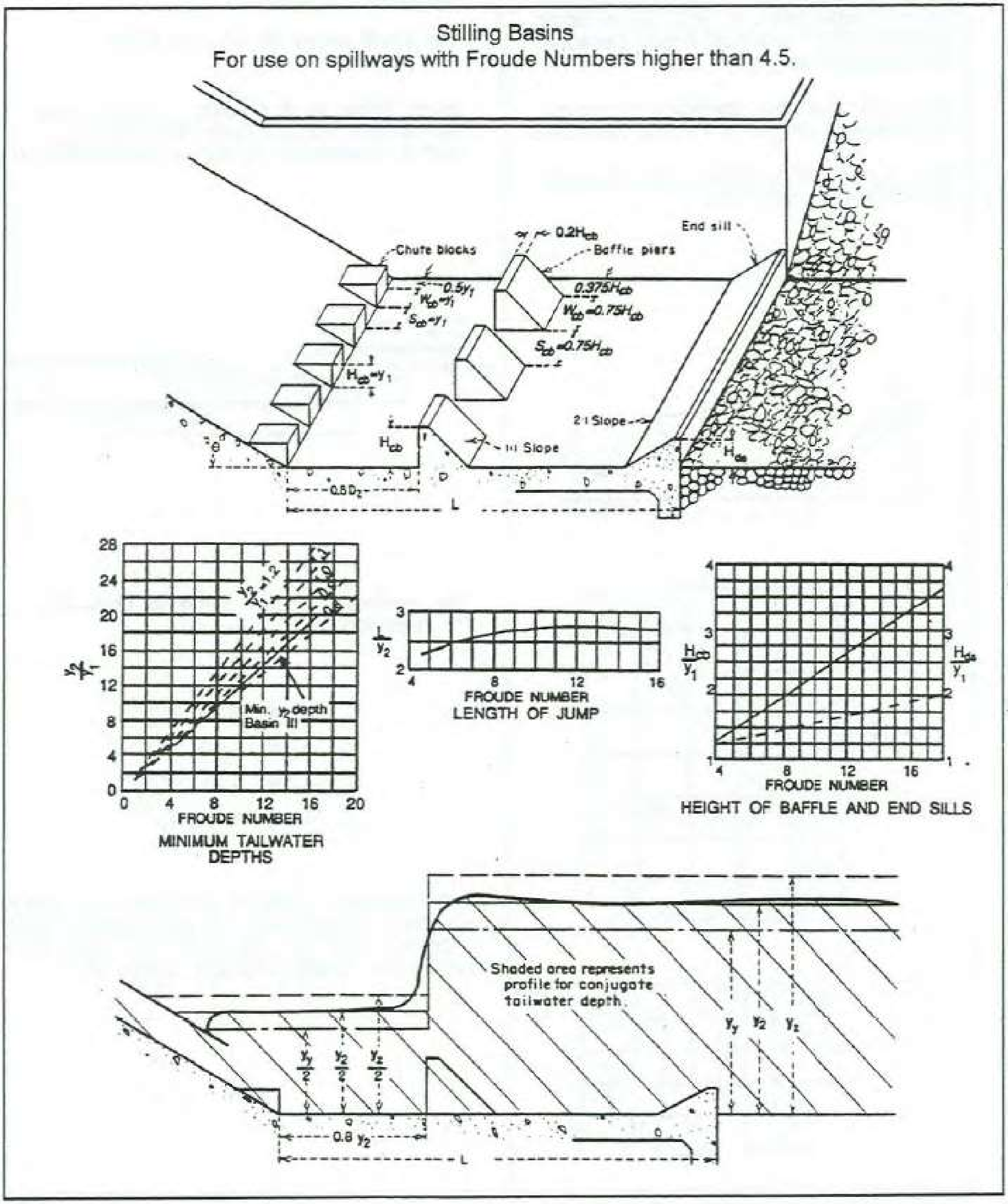
The geometry of the jump is described by the following:

$$L_d / h_d = 4.30 \; D_d^{0.27}$$
$$d_p / h_d = 1.00 \; D_d^{0.22}$$
$$y_1 / h_d = 0.54 \; D_d^{0.425}$$
$$y_2 / h_d = 1.66 \; D_d^{0.27}$$

If the tailwater depth is less than y_2, the jump will move downstream. If the tailwater depth is greater than y_2, the jump will move back on the nappe, raising the pool depth, d_p.

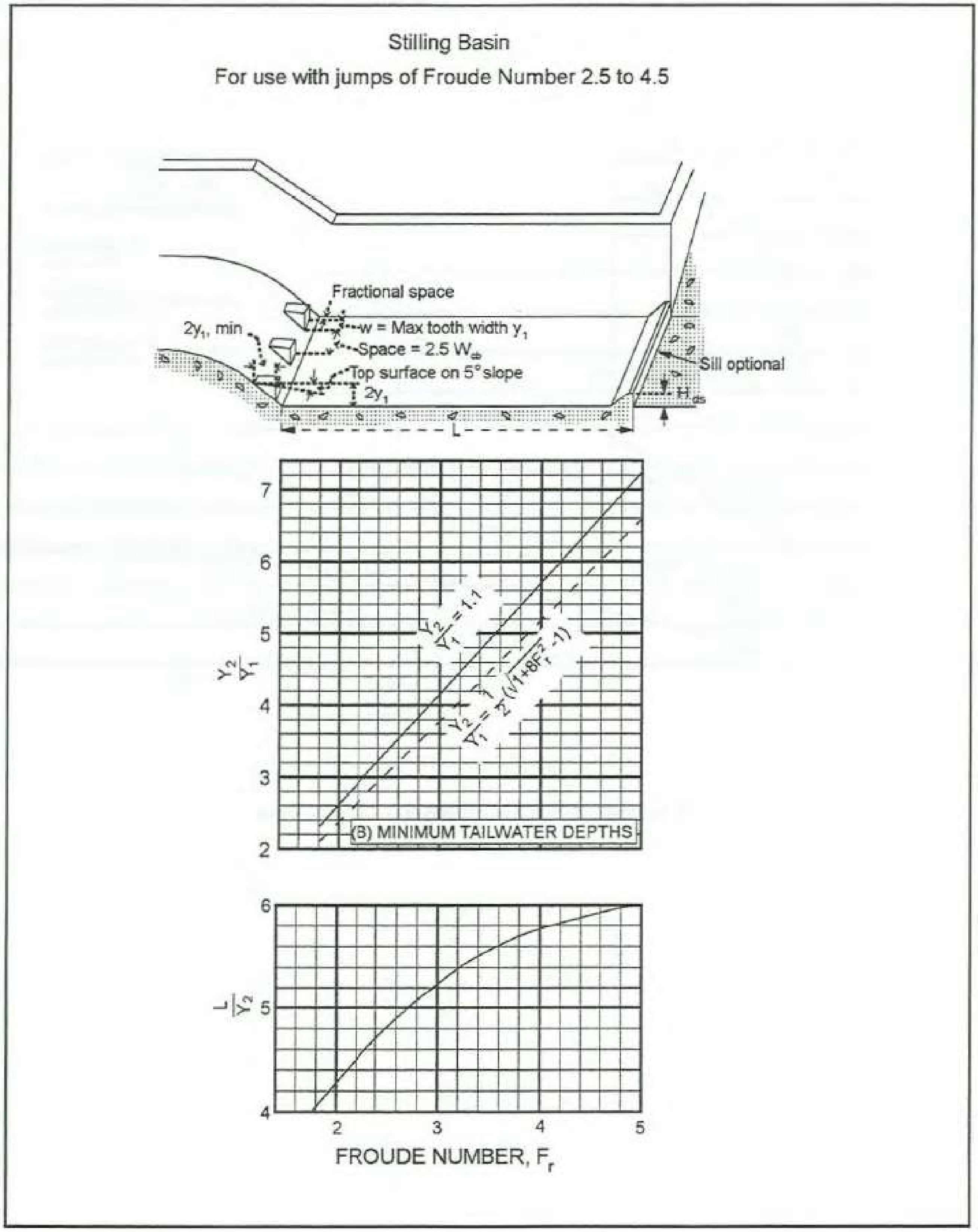
Source: A.J. Peterka (1974), RTAC Drainage Manual Volume 1 (1962)

Design Chart 2.40: USBR Energy Dissipator, Type III



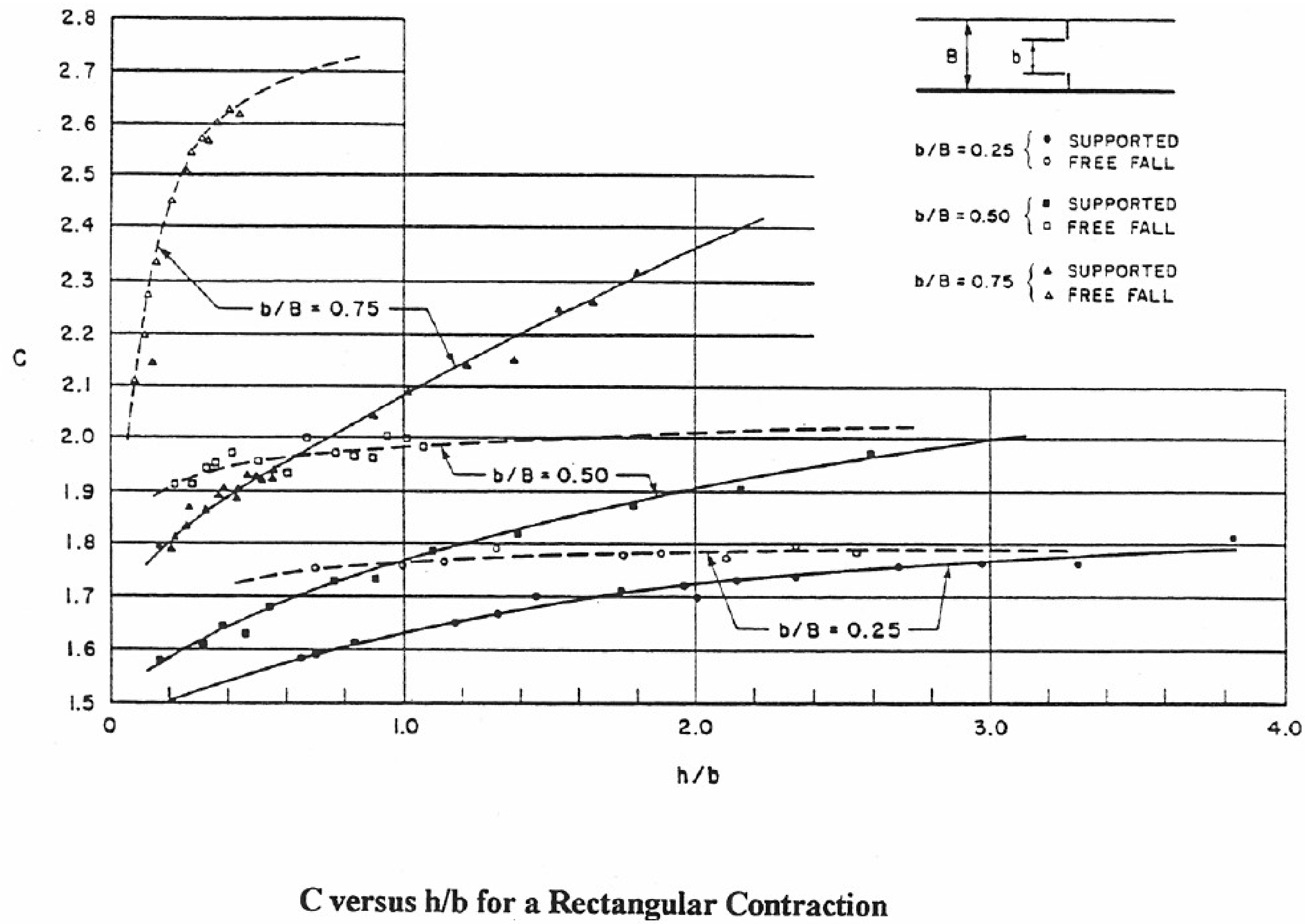
Source: A.J. Peterka (1974)

Design Chart 2.41: USBR Energy Dissipator, Type IV



Source: A.J. Peterka (1974)

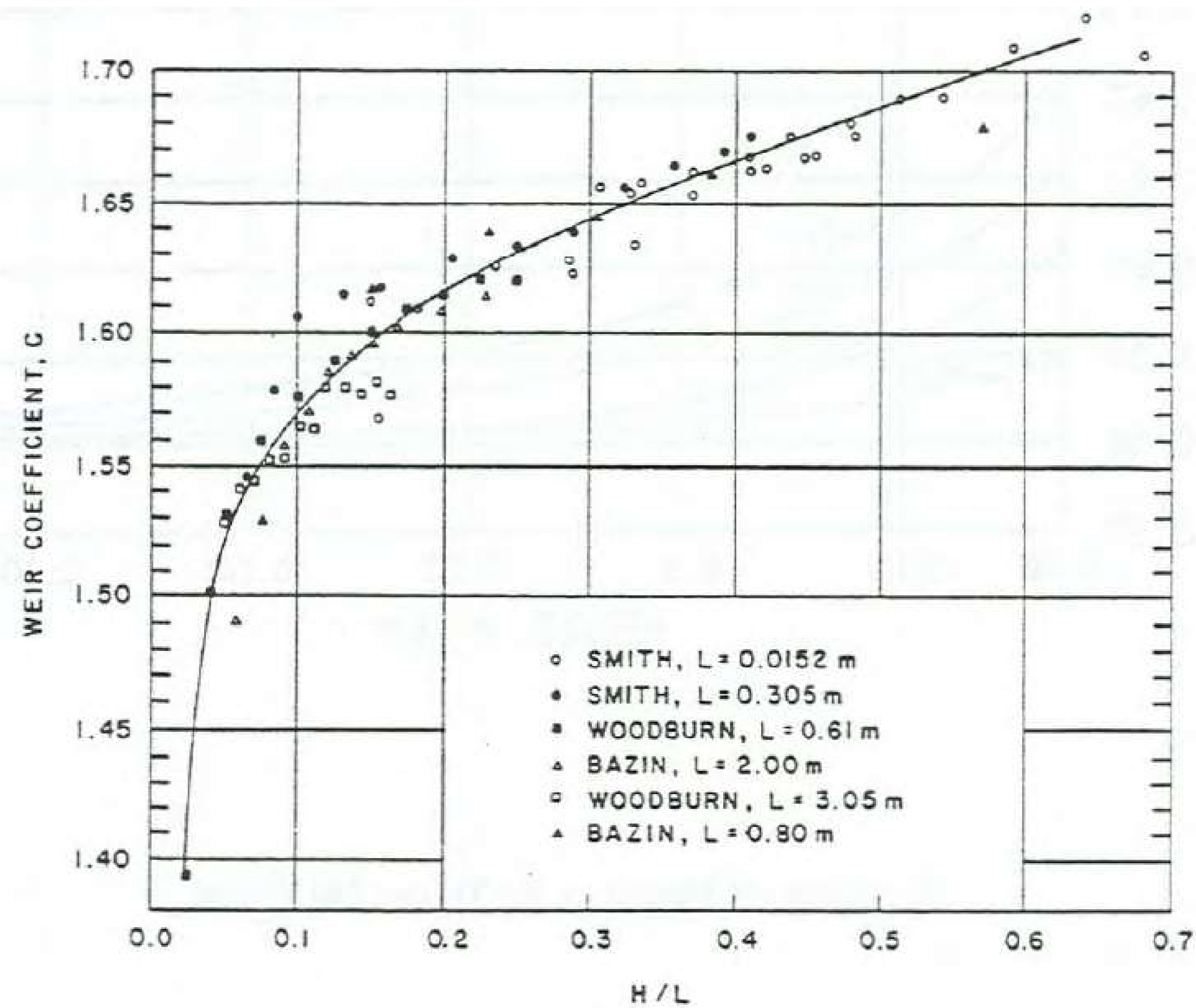
Design Chart 2.42: C vs h/b for Rectangular Contraction of Sharp Crested Weirs



C versus h/b for a Rectangular Contraction

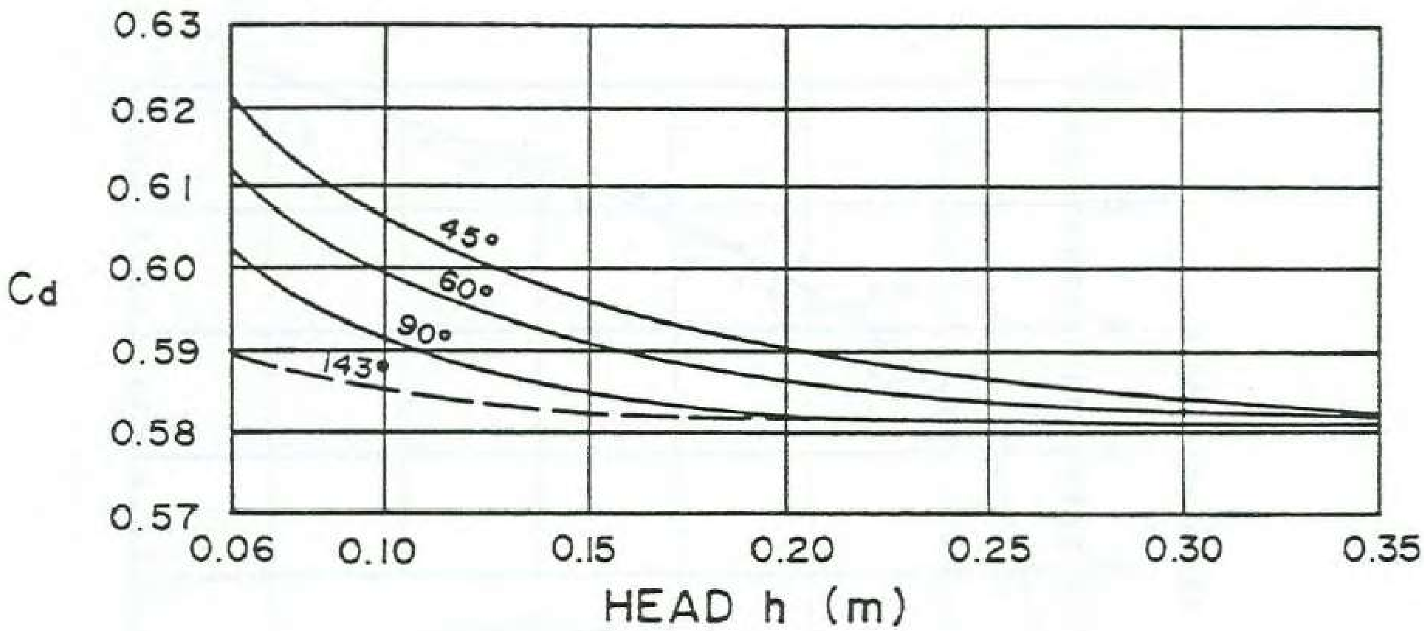
Source: C.D. Smith (1985)

Design Chart 2.43: Coefficient of Discharge for Rectangular Broad Crested Weir



Source: C.D. Smith (1985)

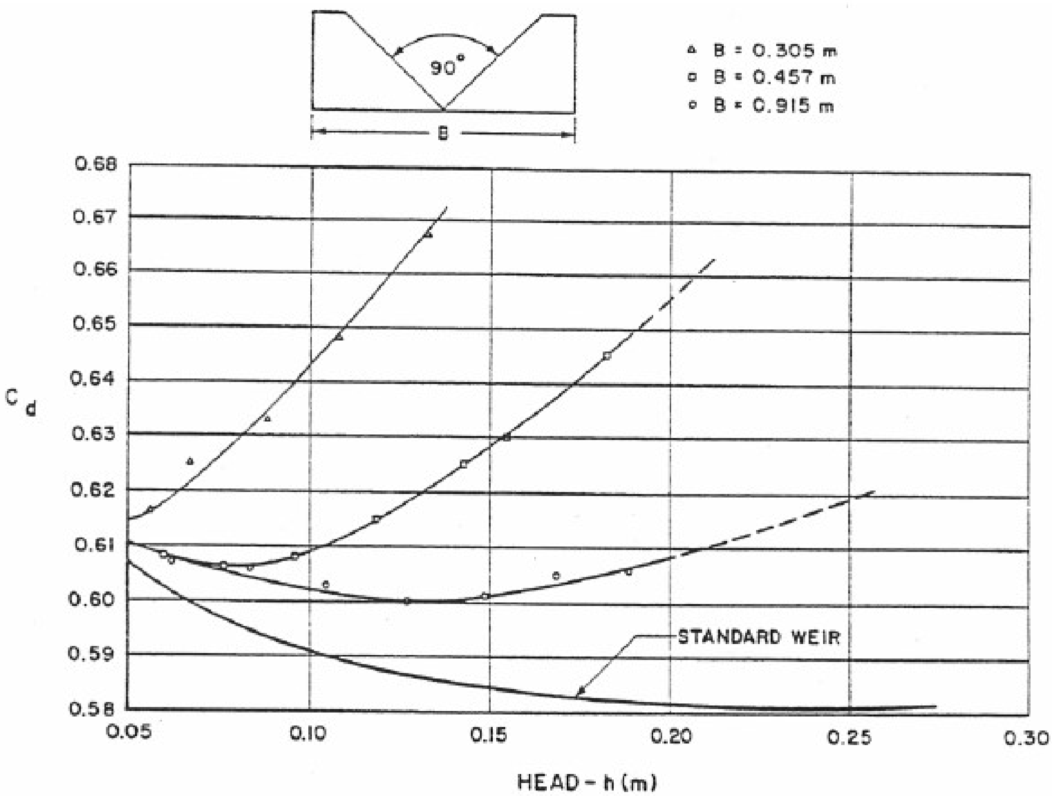
Design Chart 2.44: Coefficient of Discharge for Triangular Sharp Crested Weir



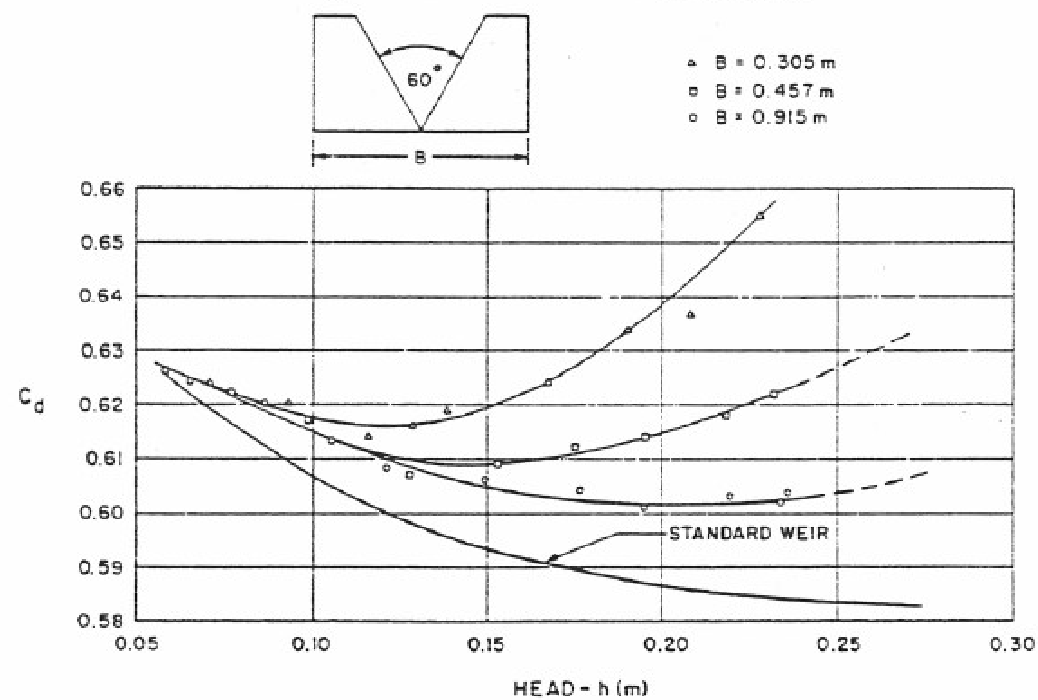
Coefficient of Discharge for Triangular Weirs.

Source: C.D. Smith (1985)

Design Chart 2.45: Coefficient of Discharge for 90° & 60° V-notch Contraction



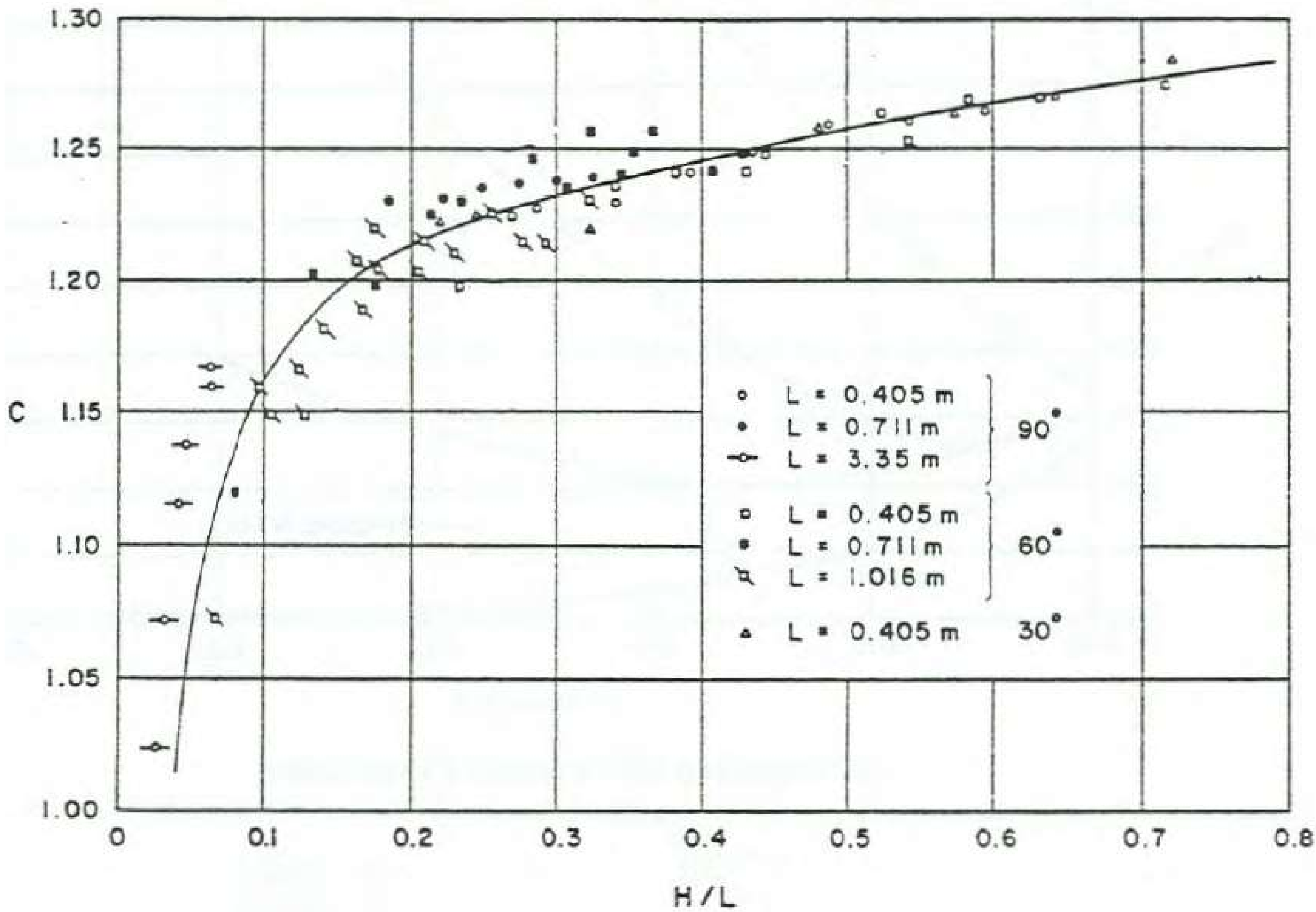
C_d vs h for a 90° V-notch Contraction



C_d vs h for a 60° V-notch Contraction

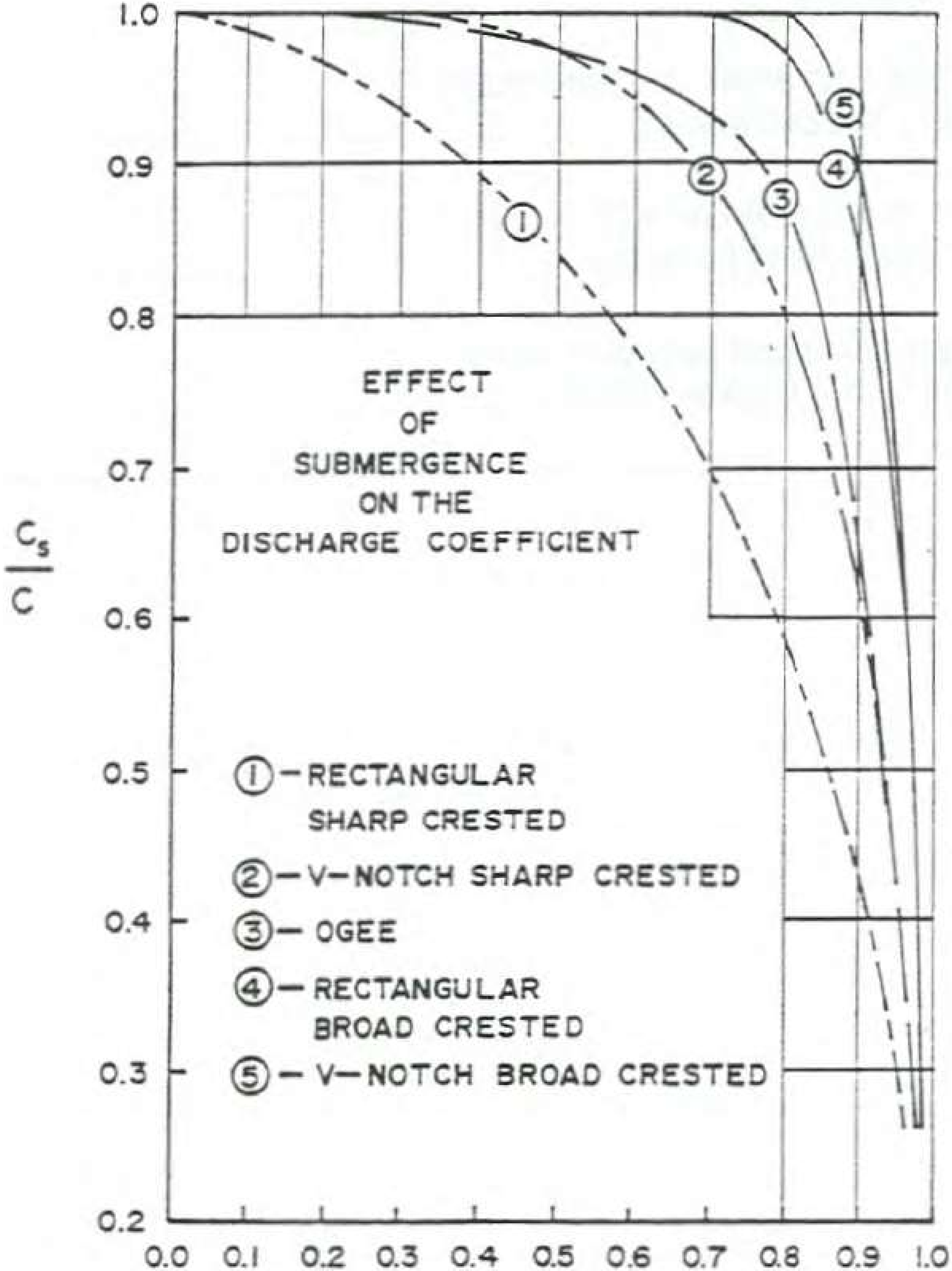
Source: C.D. Smith (1985)

Design Chart 2.46 Coefficient of Discharge for Triangular Broad Crested Weir



Source: C.D. Smith (1985)

Design Chart 2.47: Effect of Submergence on Weir Coefficient

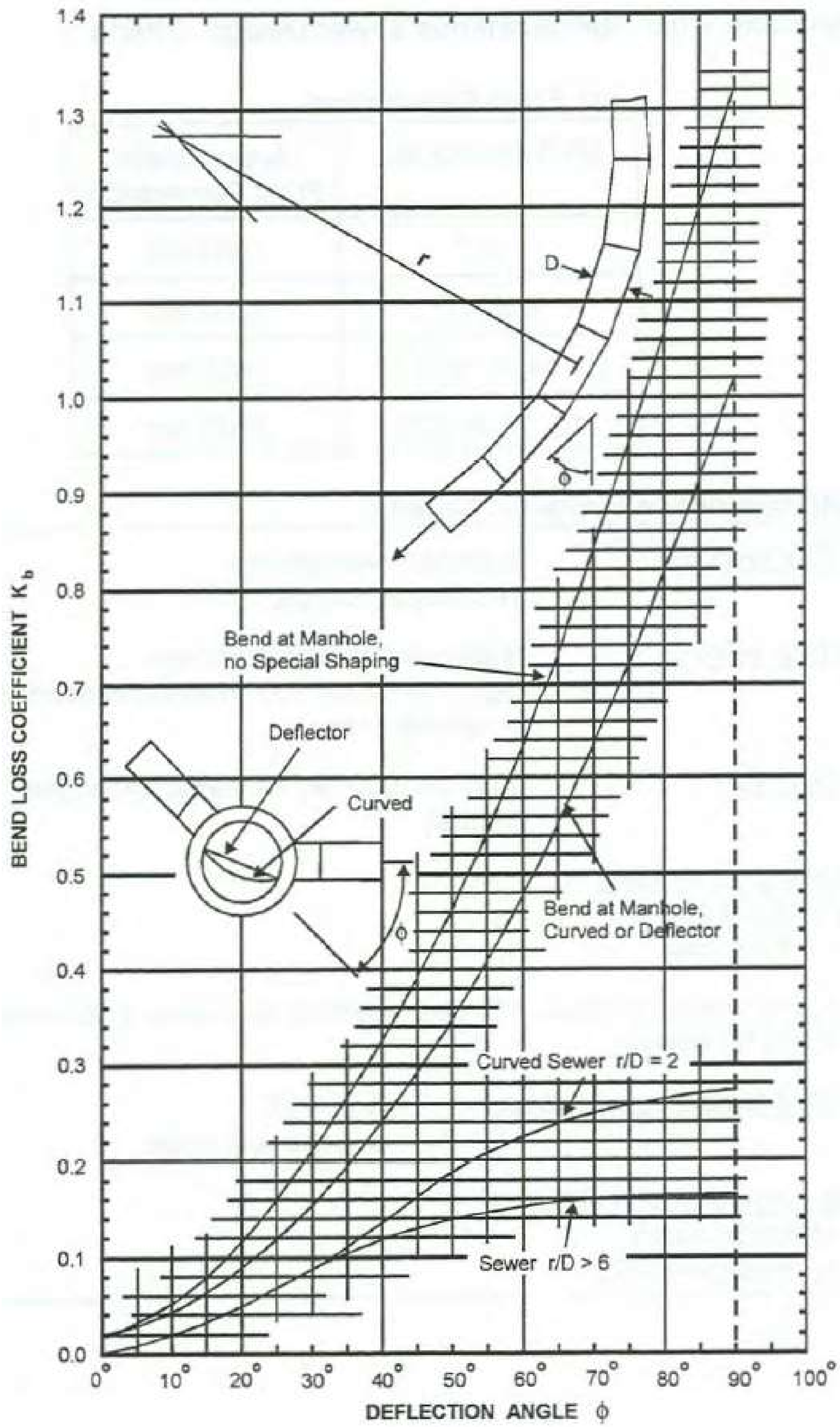


Source: C.D. Smith (1985)

Design Chart 4.01: Sewer Inlet Times

Paved areas draining directly to closely spaced inlets	5 to 10 min.
Paved areas with small unpaved areas, more widely spaced inlets	10 min.
Largely impervious areas with some pervious, fairly flat slopes	10 to 15 min.
Mixed impervious and pervious areas, flat grades, widely spaced inlets	20 to 30 min.

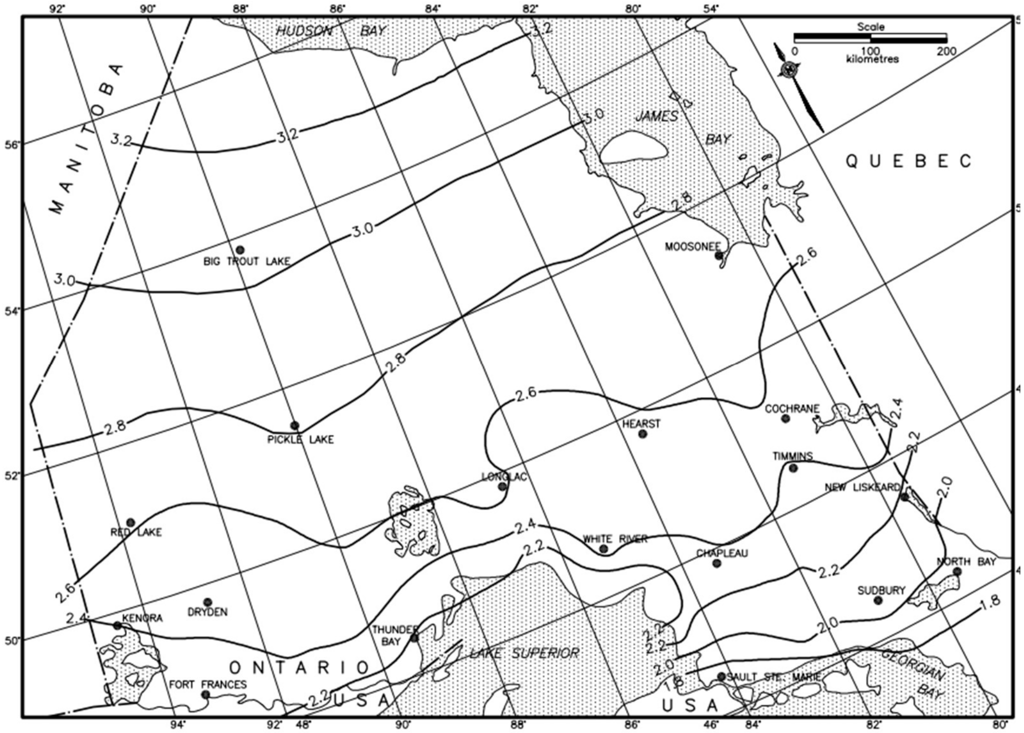
Design Chart 4.02: Sewer Bend Loss Coefficients



Design Chart 4.03: Miscellaneous Sewer Design Criteria

(a) Frost Penetration

The following maps are to be used to determine the approximate frost penetration depth as shown in meters.



Northern Ontario

Southern Ontario

Source: MTO publication "Aspects of Prolonged Exposure of Pavements to Sub-Zero Temperatures" 1981

(b) Miscellaneous Hydraulic Criteria

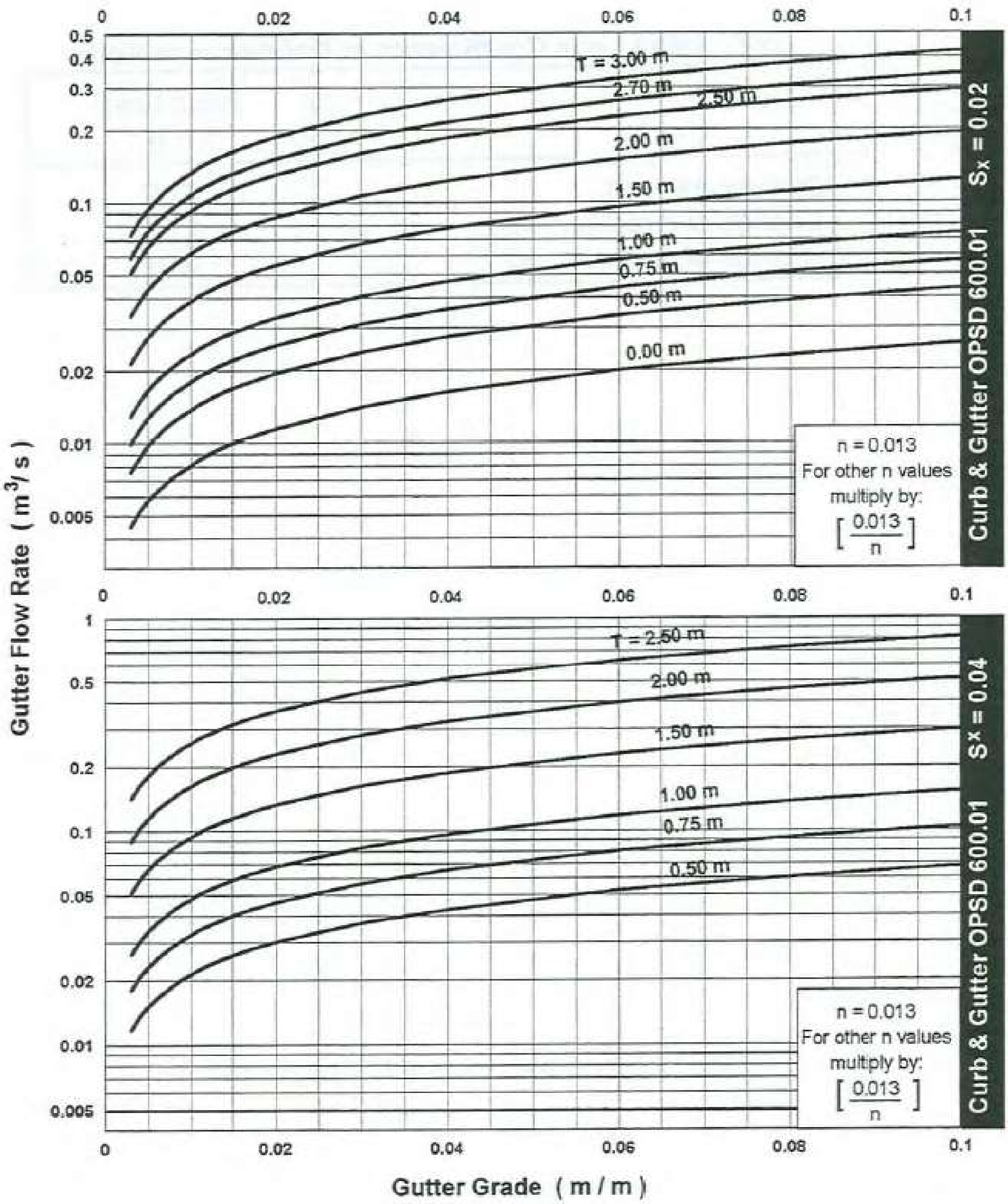
Minimum flow velocity	-	in smooth-walled pipe	0.75 m/s
	-	in corrugated pipe	0.9 m/s
Maximum flow velocity	-	relatively non-abrasive flow	10.0 m/s
	-	highly abrasive flow (may be exceeded in special cases)	5.0 m/s
Minimum pipe size criteria)	-	(may be modified to match municipal	300 mm
Maximum manhole spacing			
Pipe diam. < 1200 mm			100-150 m
Pipe diam. ∃ 1200 mm			200-350 m*
* Use the higher value for pipes with self-cleaning velocity and no sharp bends, and the lower value for others.			
Maximum inlet (catchbasin) spacing	-	first inlet	150 m
	-	subsequent inlets	100-150 m
Catchbasin connections to sewers			
Desirable minimum slope			0.015 m/m
Desirable mimimum velocity			1.5 m/m

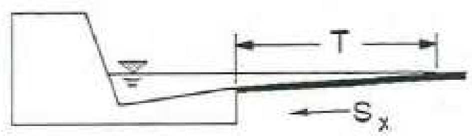
(c) Head Loss Coefficients at Maintenance Holes

	Head Loss (m)
Straight-through	0.02
Change of direction 45E	0.04
Change of direction 90E	0.07

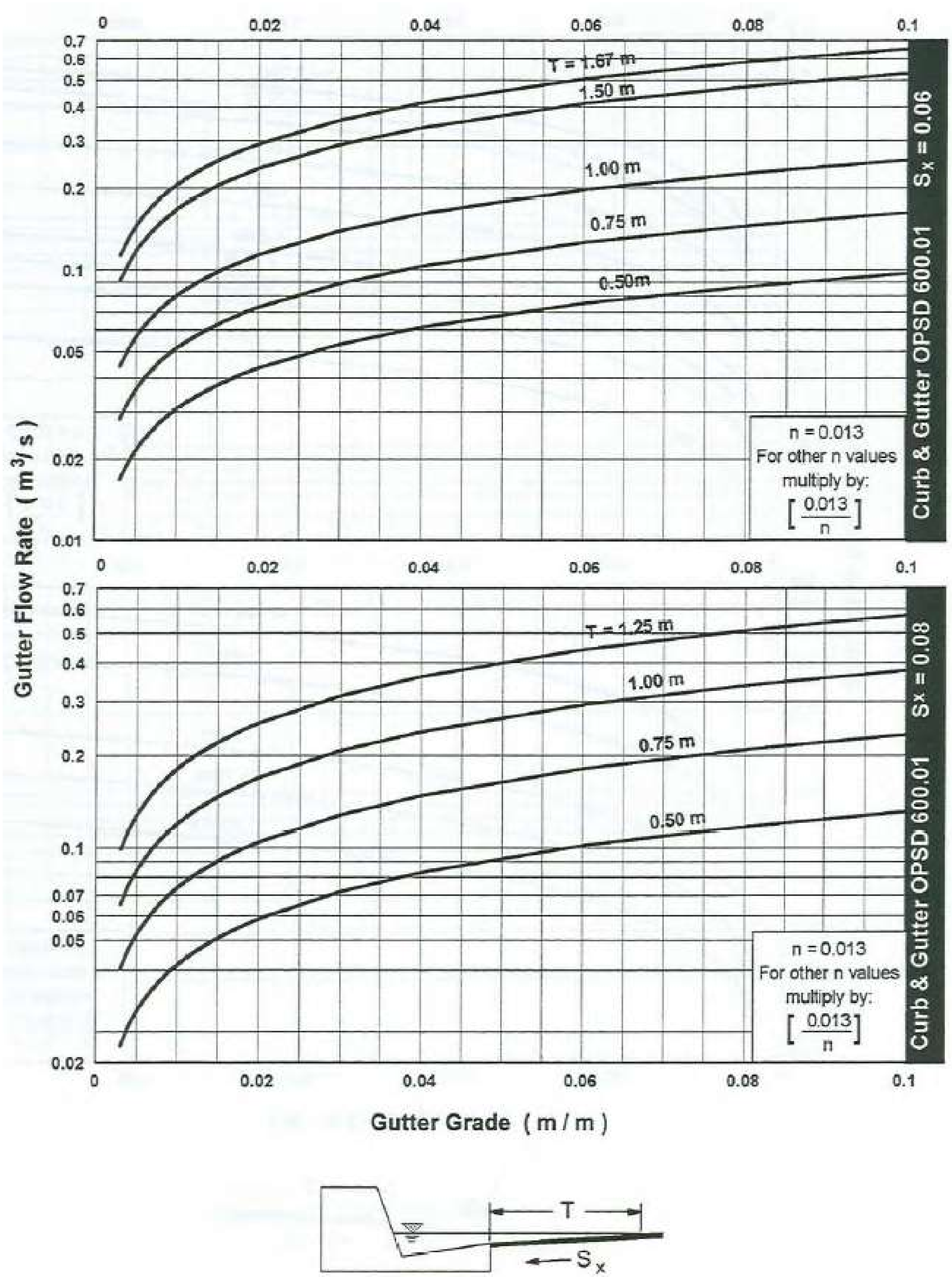
Source: American Iron and Steel Institution (1980)

Design Chart 4.04 Gutter Flow Rate - Curb & Gutter OPSD 600.01

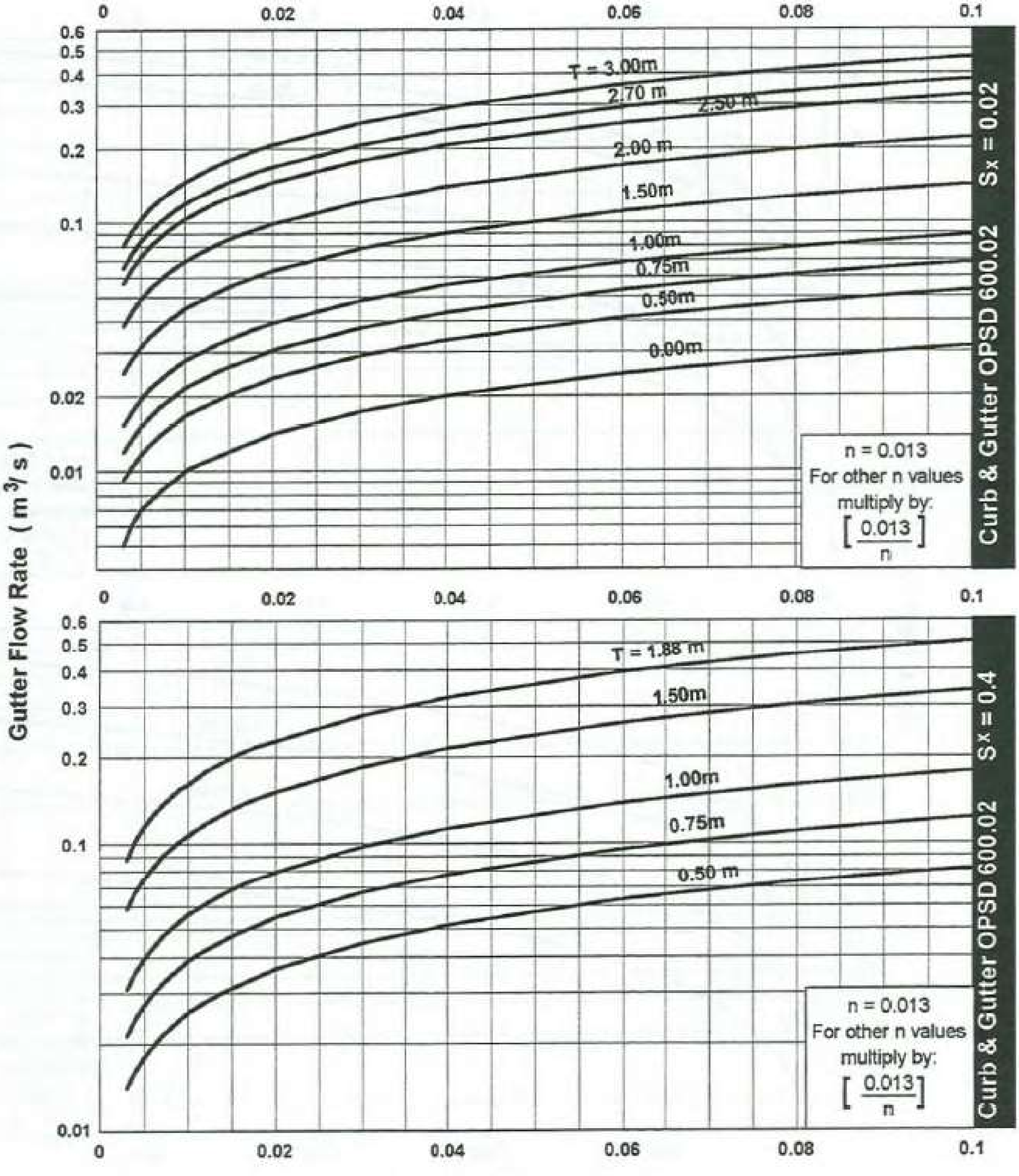


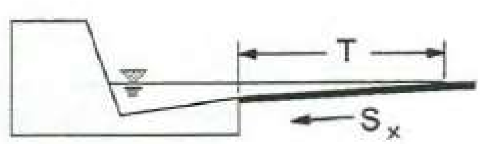


Design Chart 4.05: Gutter Flow Rate - Curb & Gutter OPSD 600.01

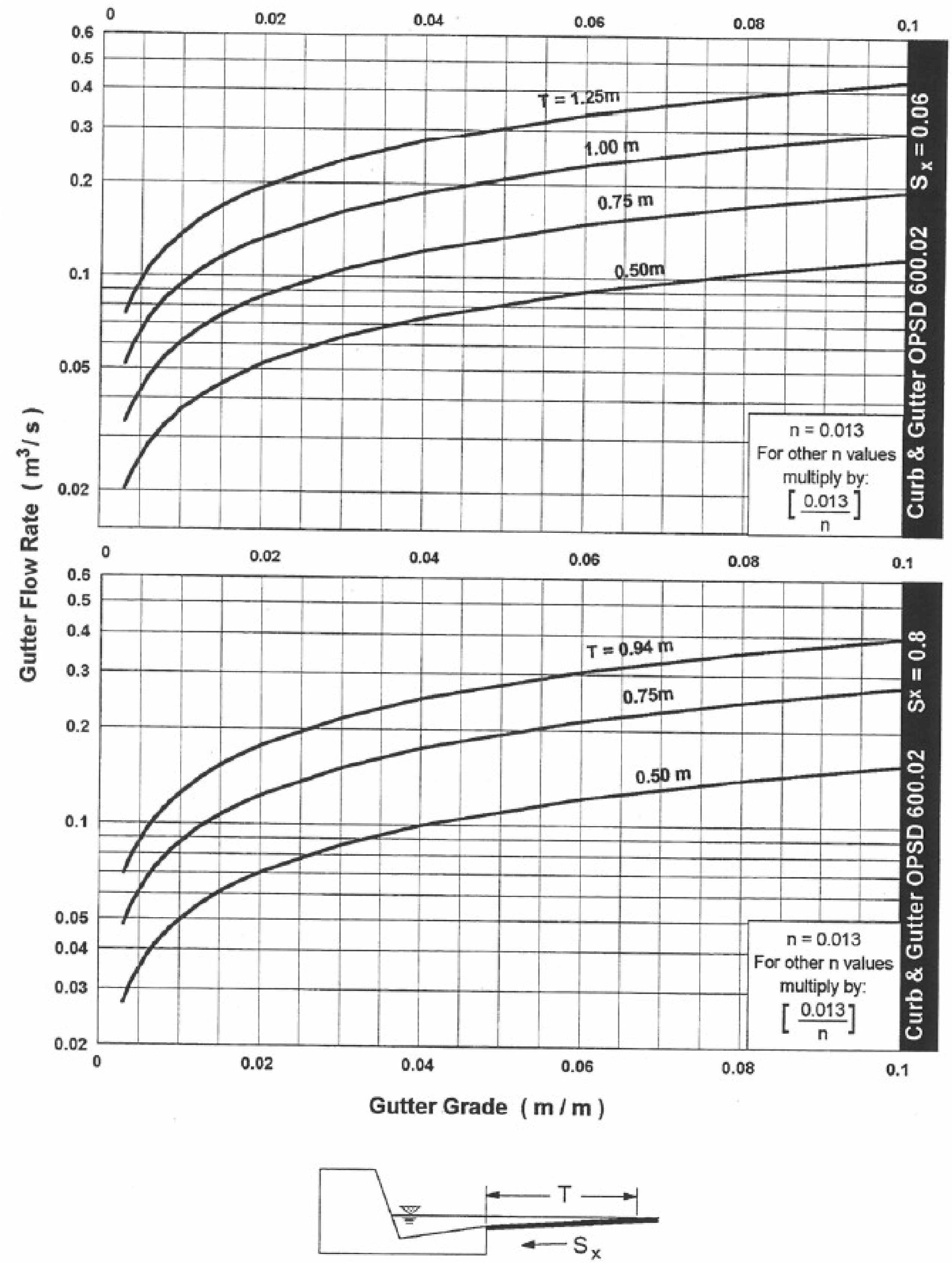


Design Chart 4.06: Gutter Flow Rate - Curb & Gutter OPSD 600.02

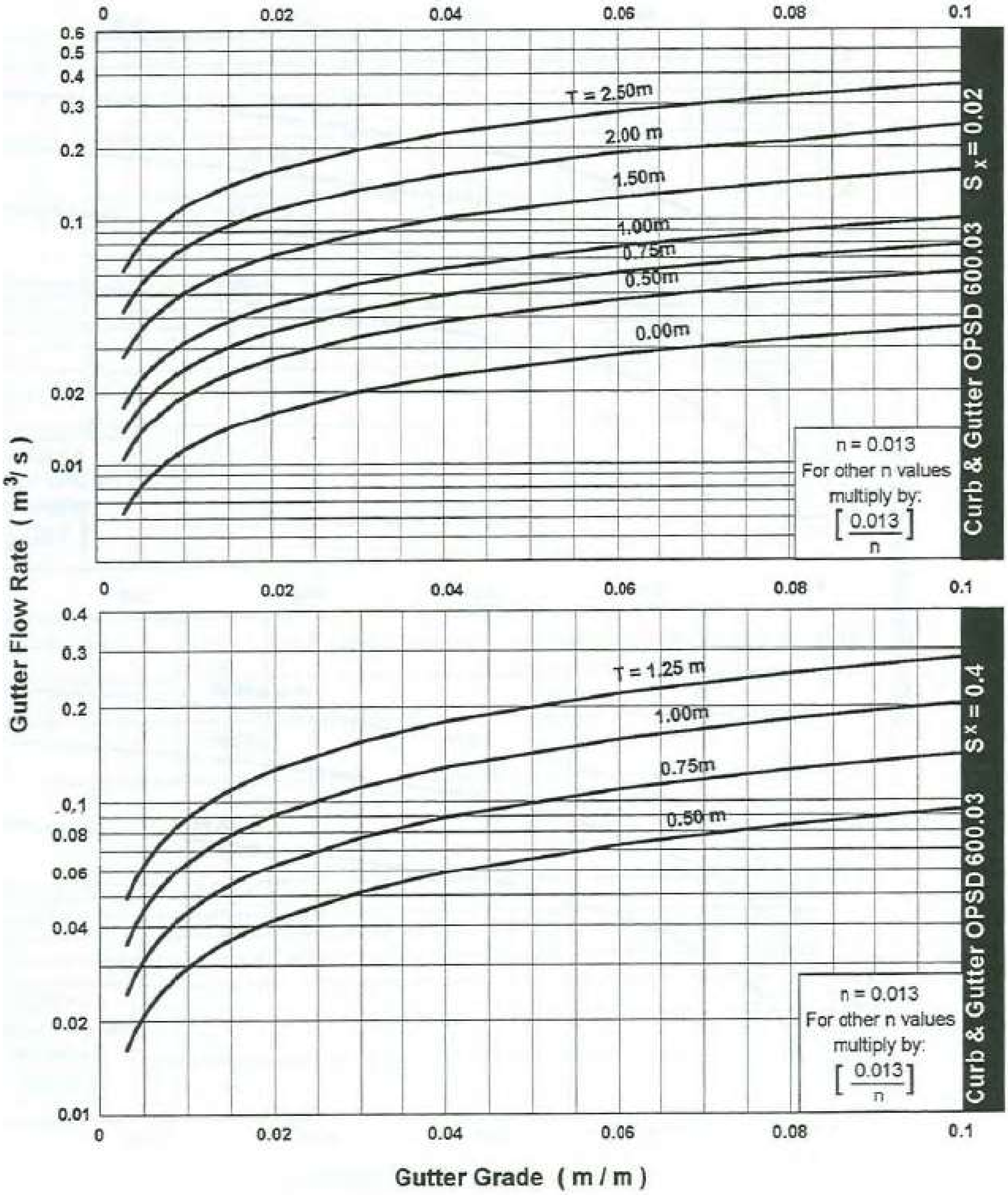


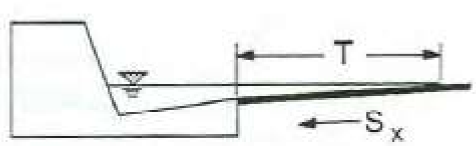


Design Chart 4.07: Gutter Flow Rate - Curb & Gutter OPSD 600.02

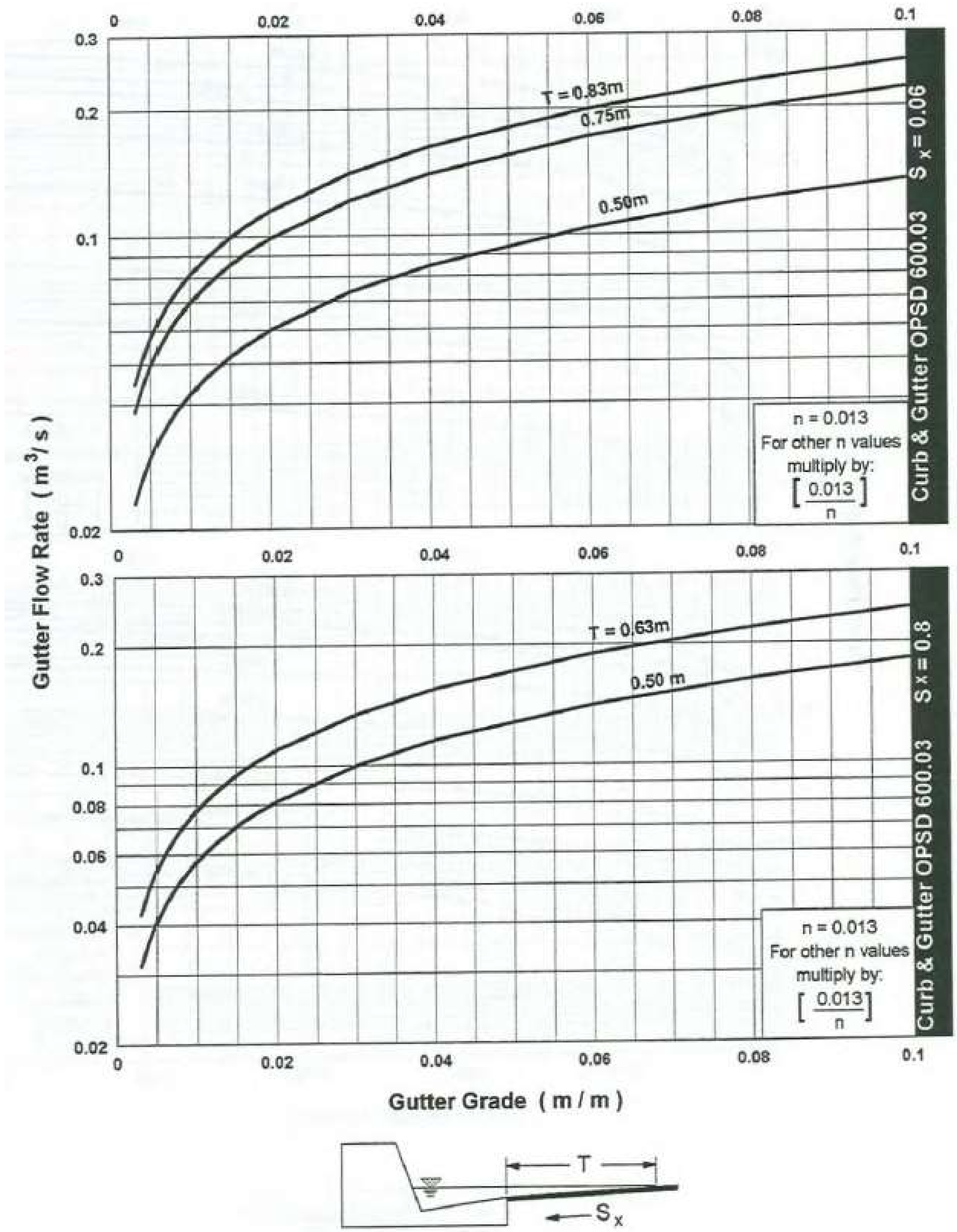


Design Chart 4.08 Gutter Flow Rate - Curb & Gutter OPSD 600.03

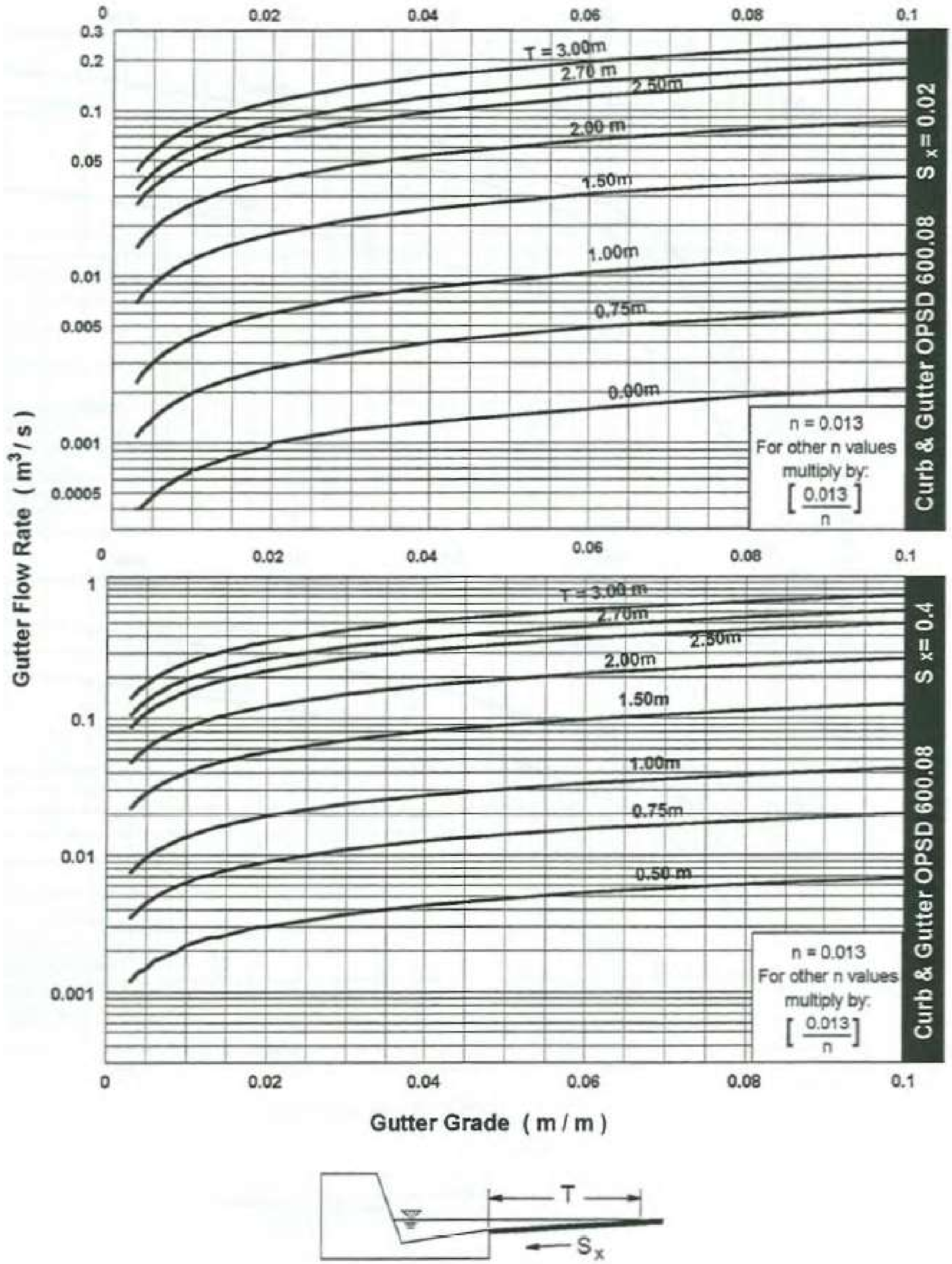




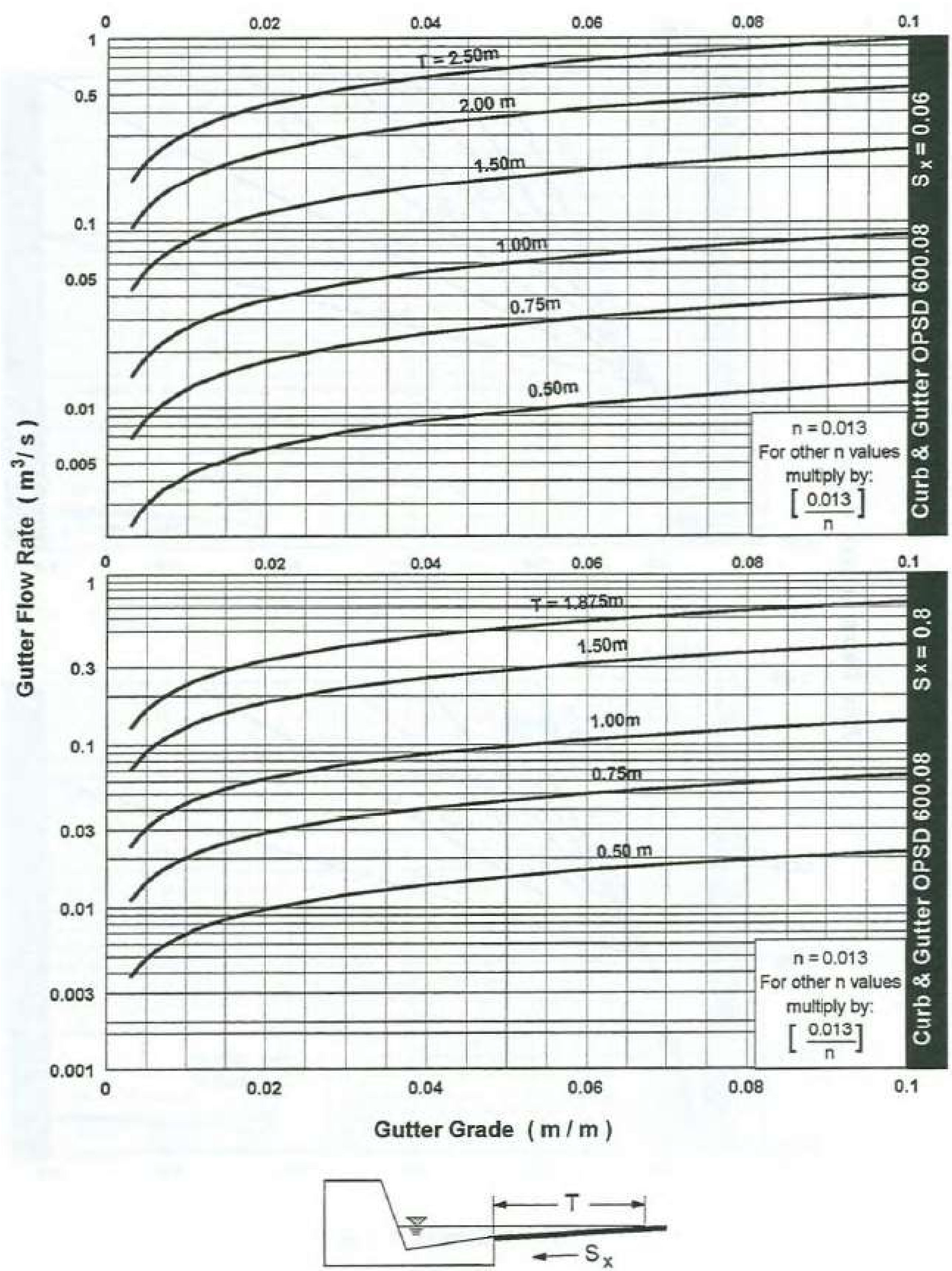
Design Chart 4.09: Gutter Flow Rate - Curb & Gutter OPSD 600.03



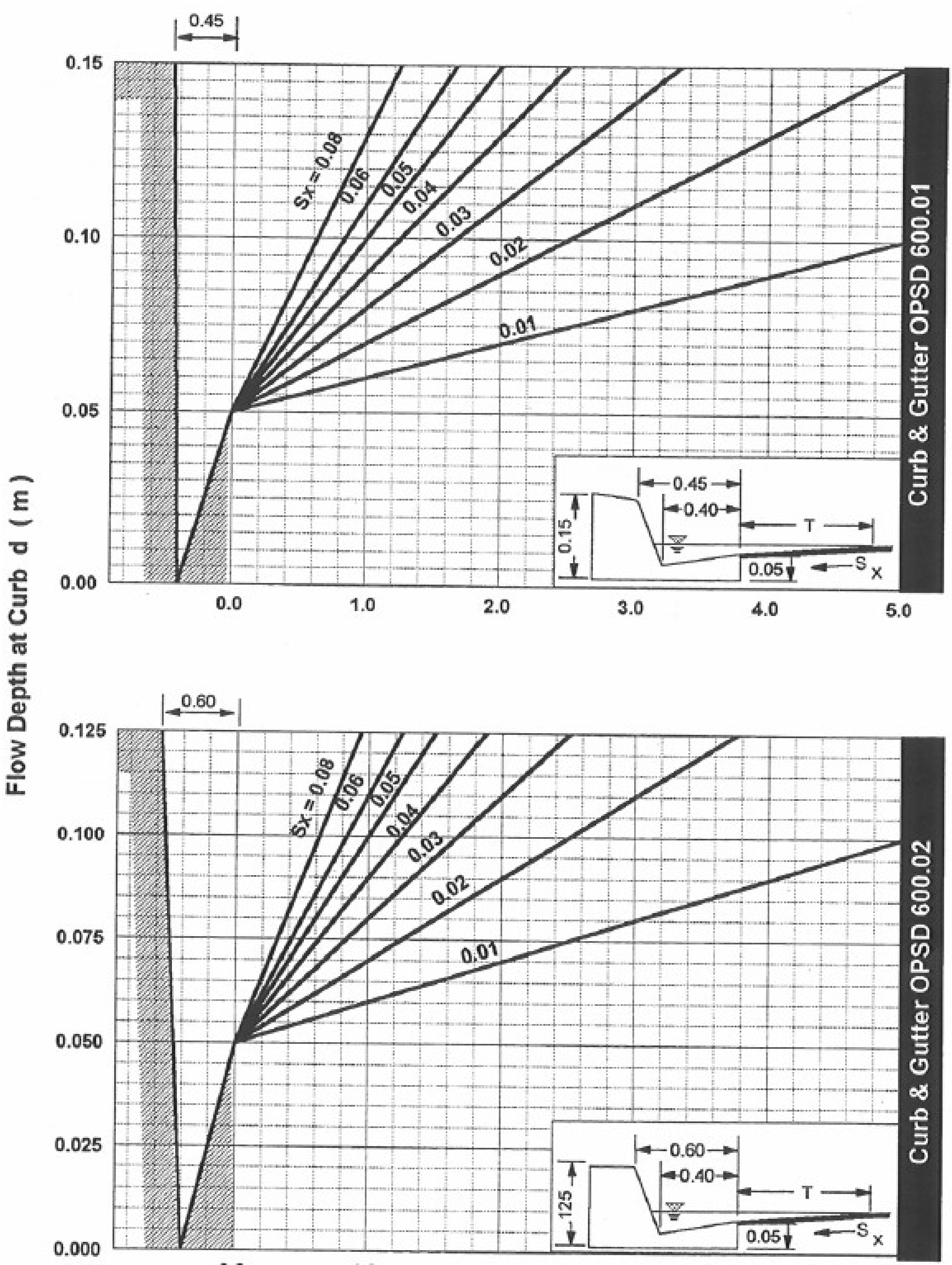
Design Chart 4.10: Gutter Flow Rate - Curb & Gutter OPSD 600.08



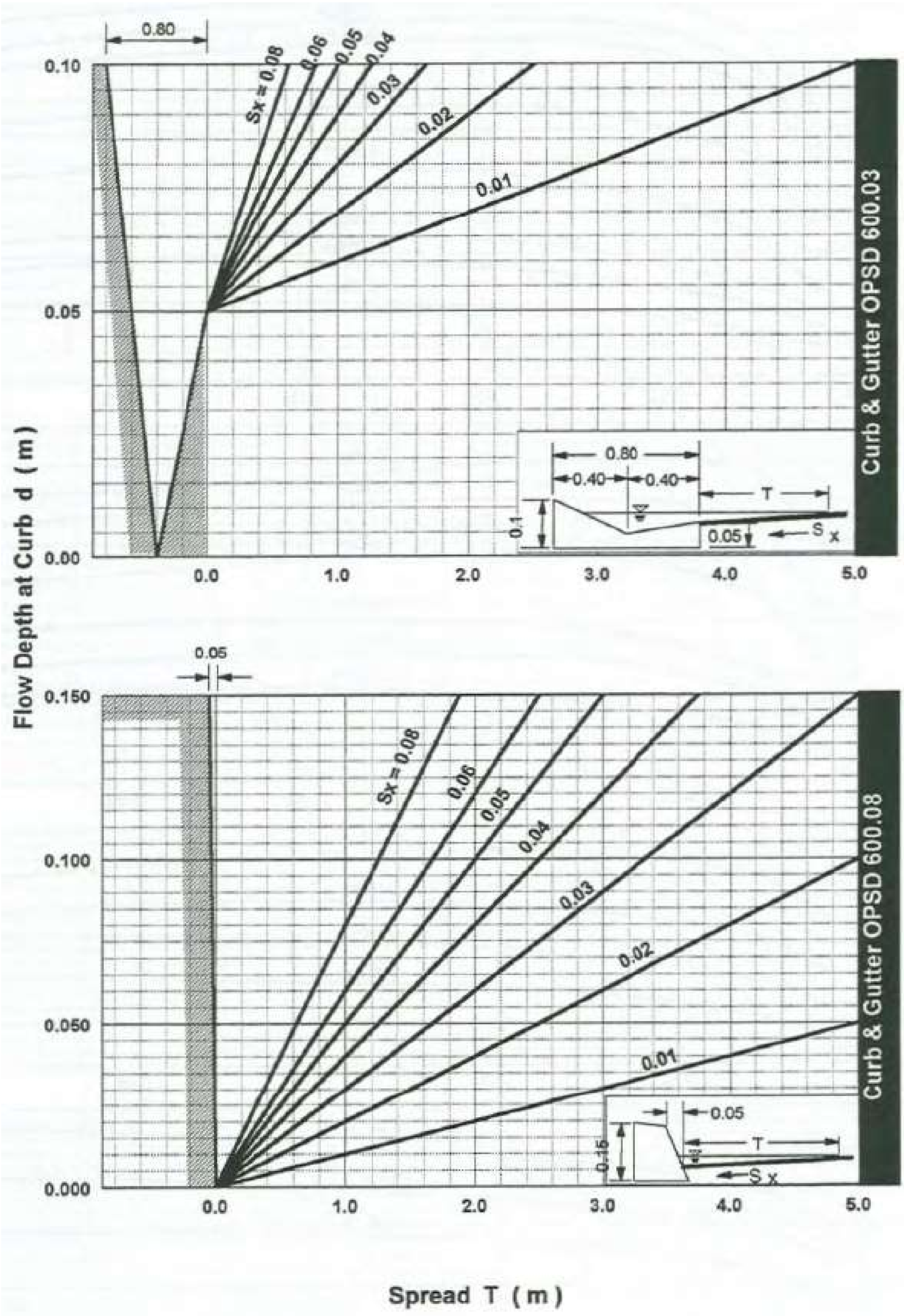
Design Chart 4.11: Gutter Flow Rate - Curb & Gutter OPSD 600.08



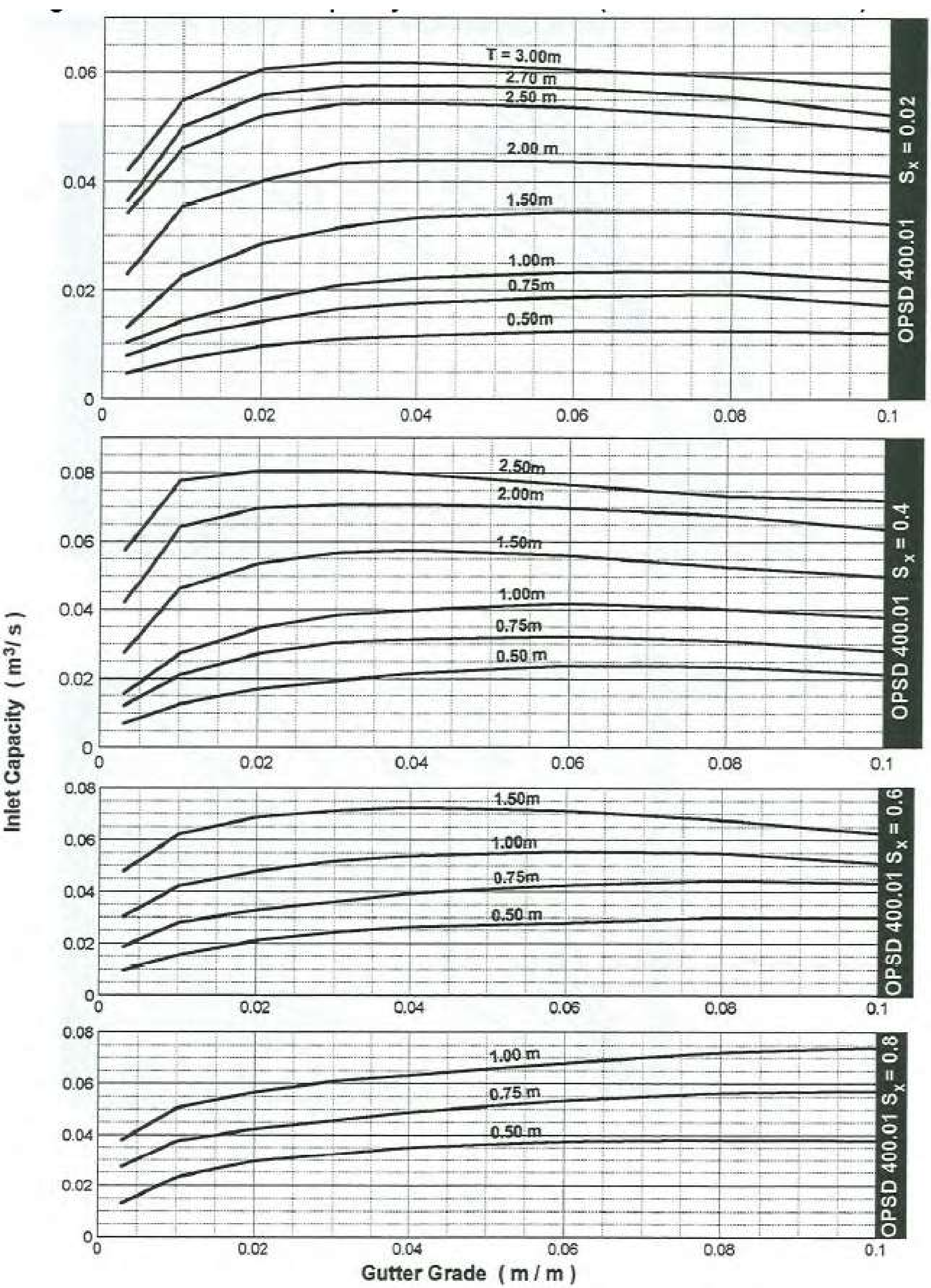
Design Chart 4.12: Curb & Gutter Flow Depth - OPSD 600.01, 600.02



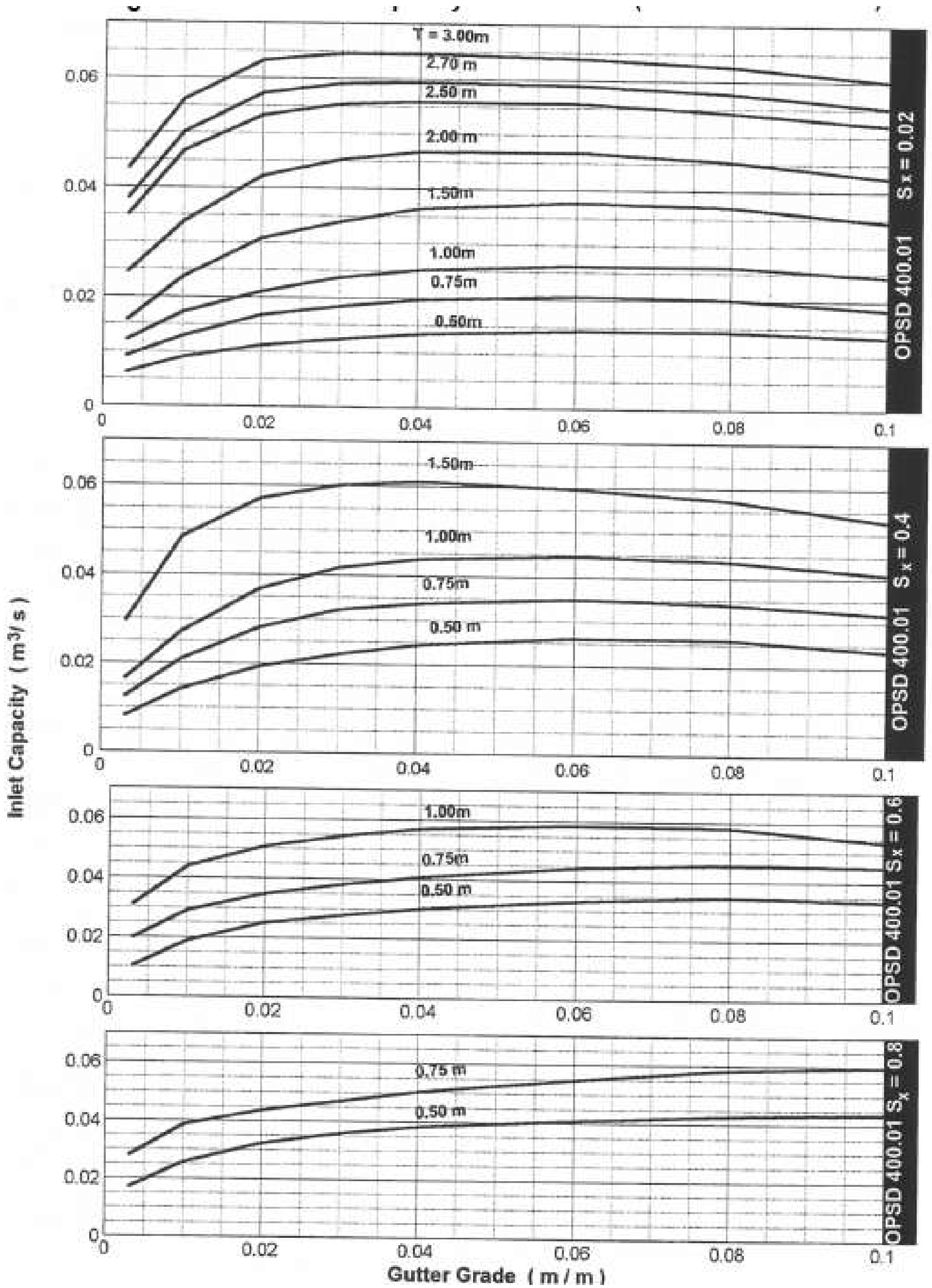
Design Chart 4.13: Curb & Gutter Flow Depth - OPSD 600.03, 600.08



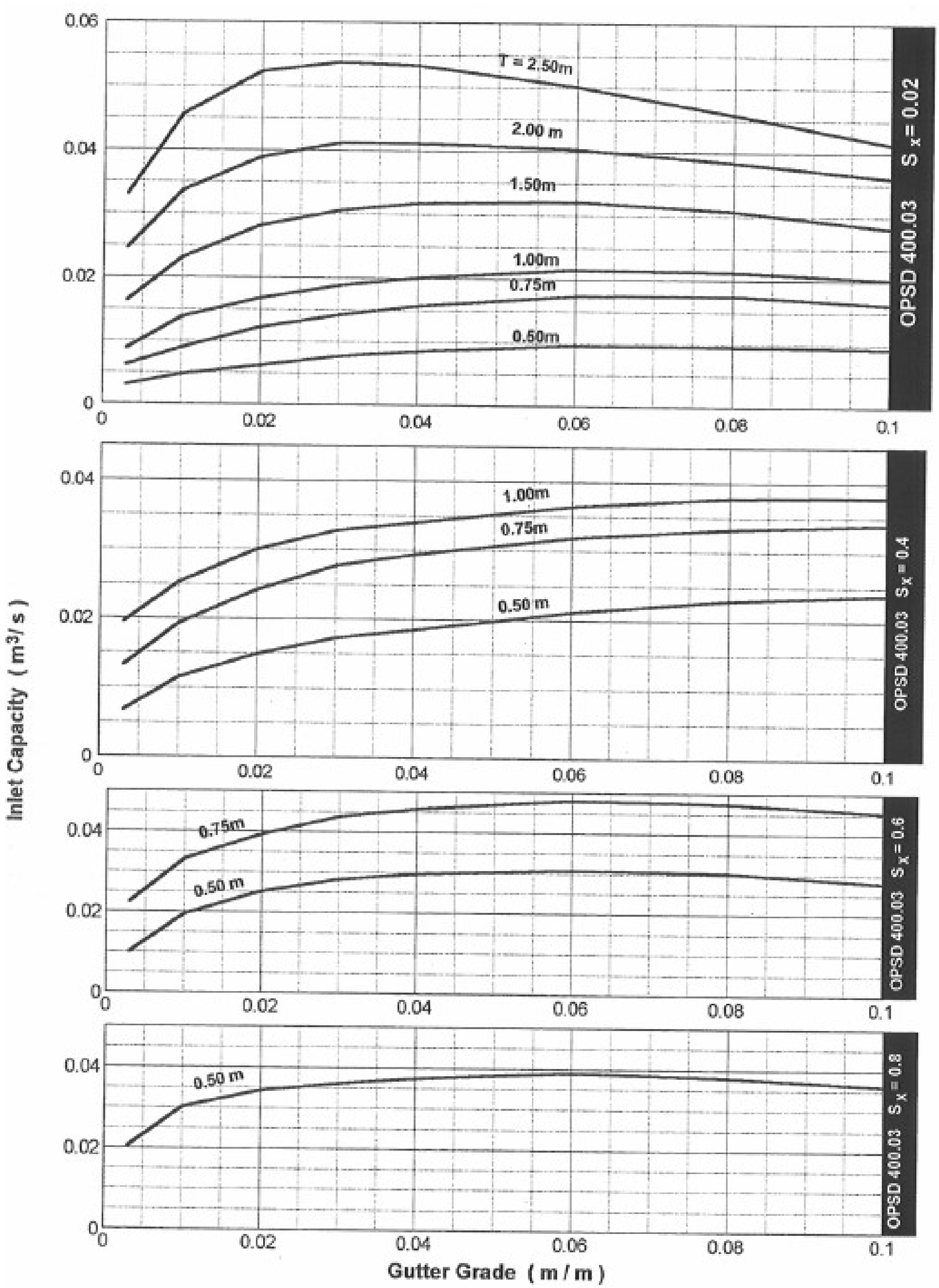
Design Chart 4.14: Inlet Capacity OPSD 400.01 (C & G OPSD 600.01)



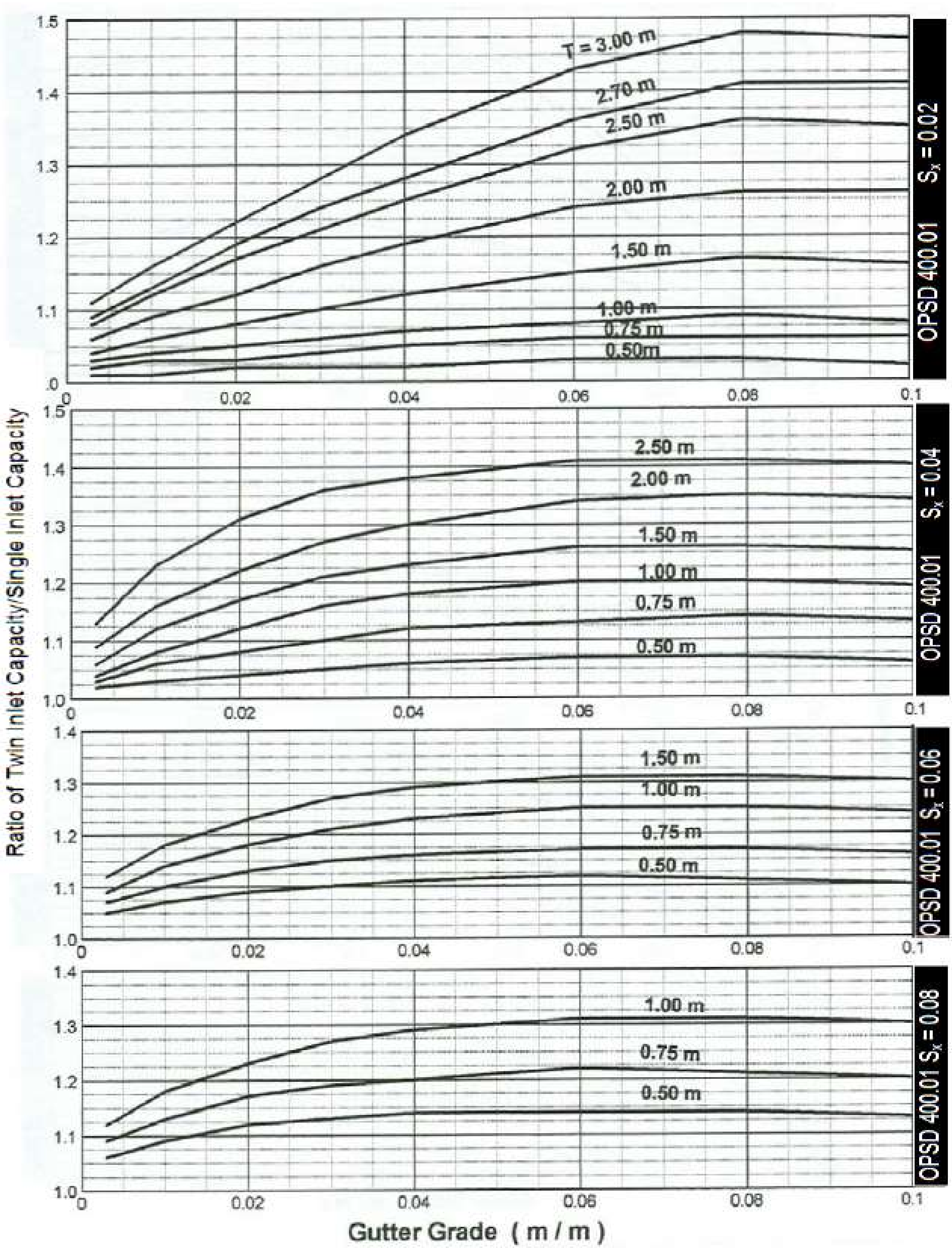
Design Chart 4.15: Inlet Capacity OPSD 400.01 (C & G OPSD 600.02)



Design Chart 4.16: Inlet Capacity OPSD 400.03 (C & G OPSD 600.03)

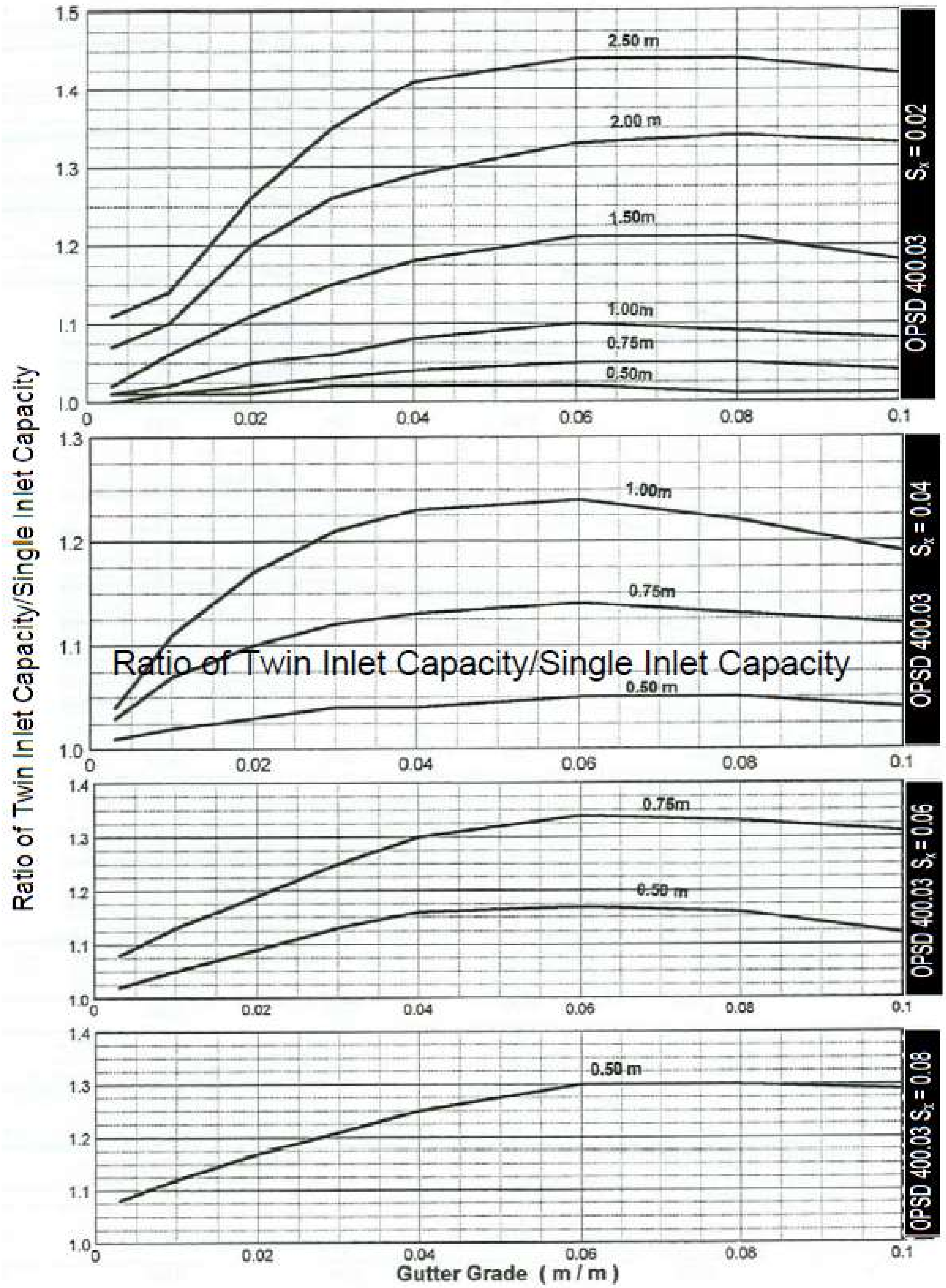


Design Chart 4.17: Twin Inlet Capacity OPSD 400.01



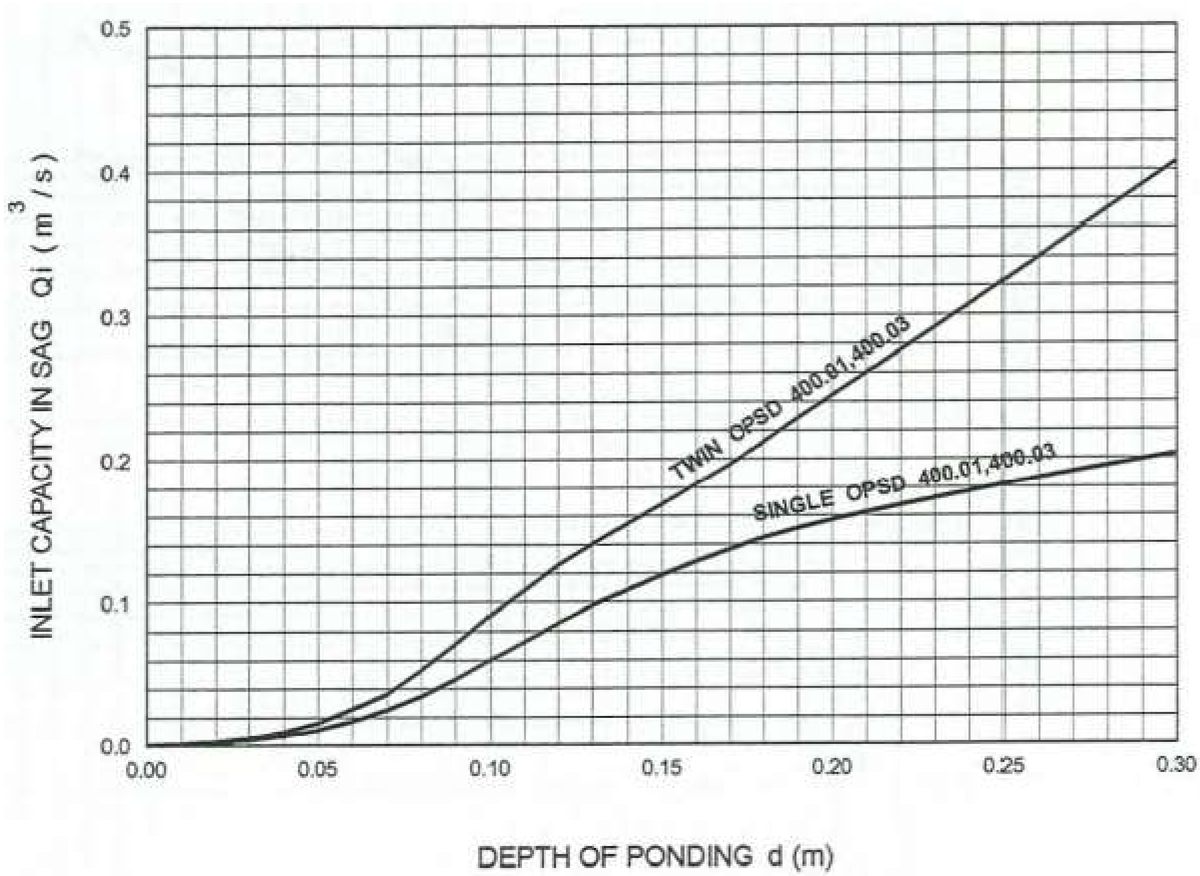
Source: Errata Sheet No. DMM1997-4 (September 2018))

Design Chart 4.18: Twin Inlet Capacity OPSD 400.03

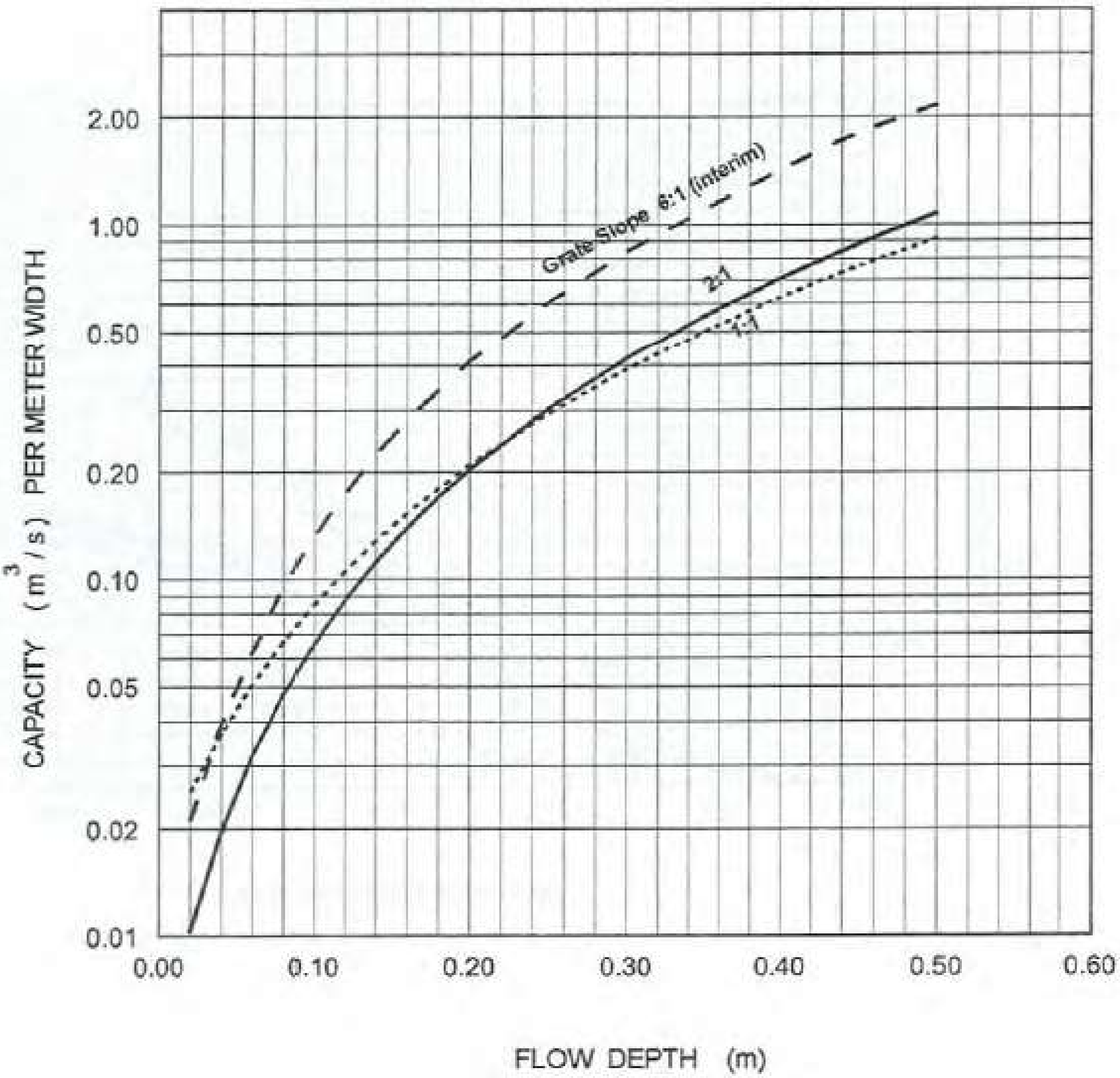


Source: Errata Sheet No. DMM1997-5 (September 2018)

Design Chart 4.19: Inlet Capacity at Road Sag



Design Chart 4.20: Ditch Inlet Capacity



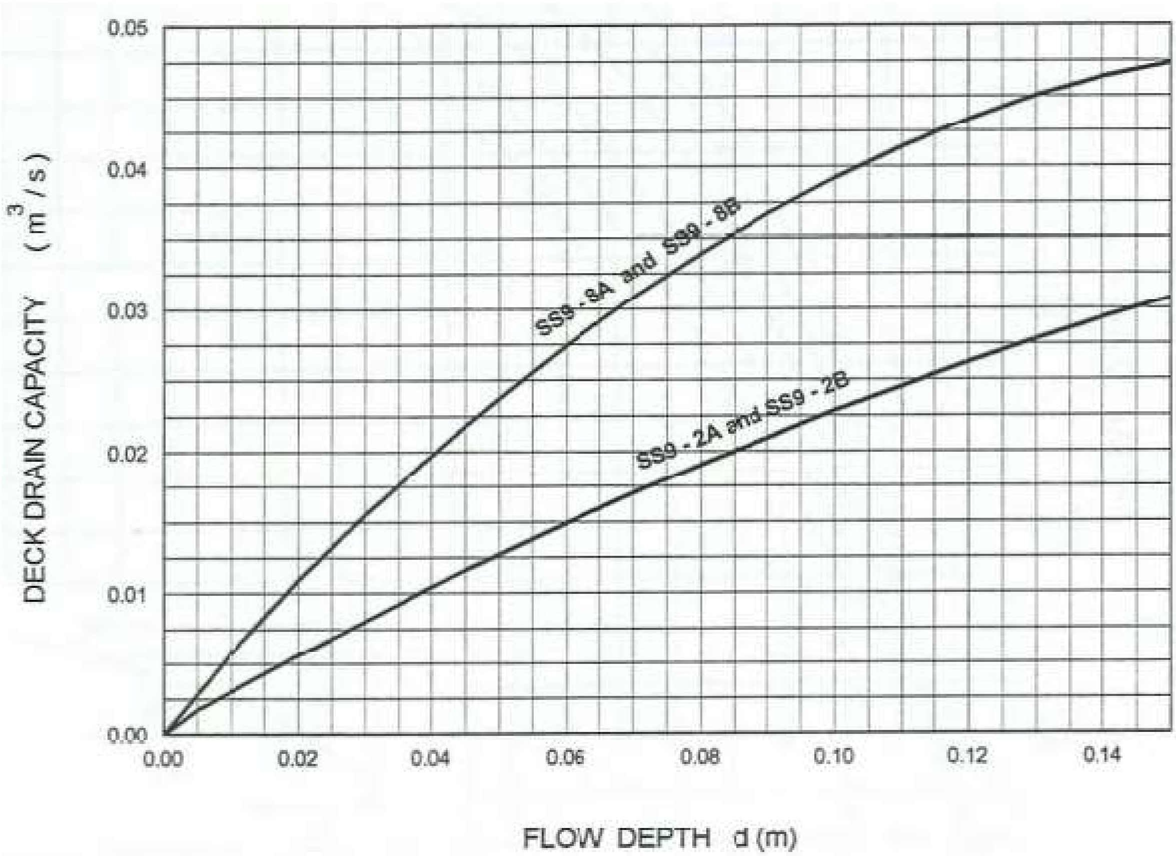
Notes:

1. Curves apply to grate Type 403.01, but may be used for straight - bar inlets without significant loss of accuracy.

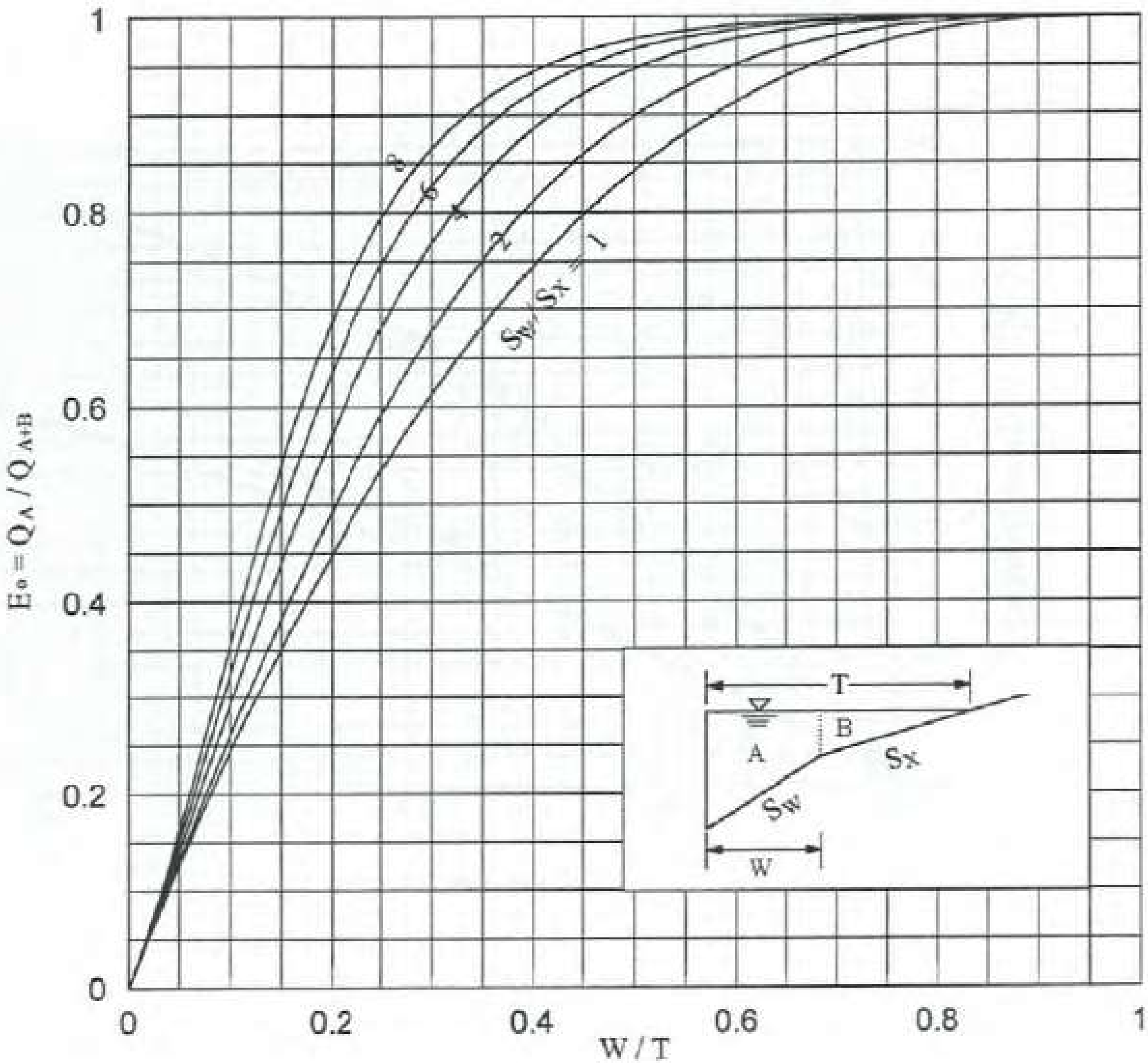
2. Capacities given by curves are for unobstructed grates only. For design use working capacity ≯ 0.5 x unobstructed capacity.

3. Capacities of grates operating in high velocity flows are less than indicated.

Design Chart 4.21: Bridge Inlet Capacity

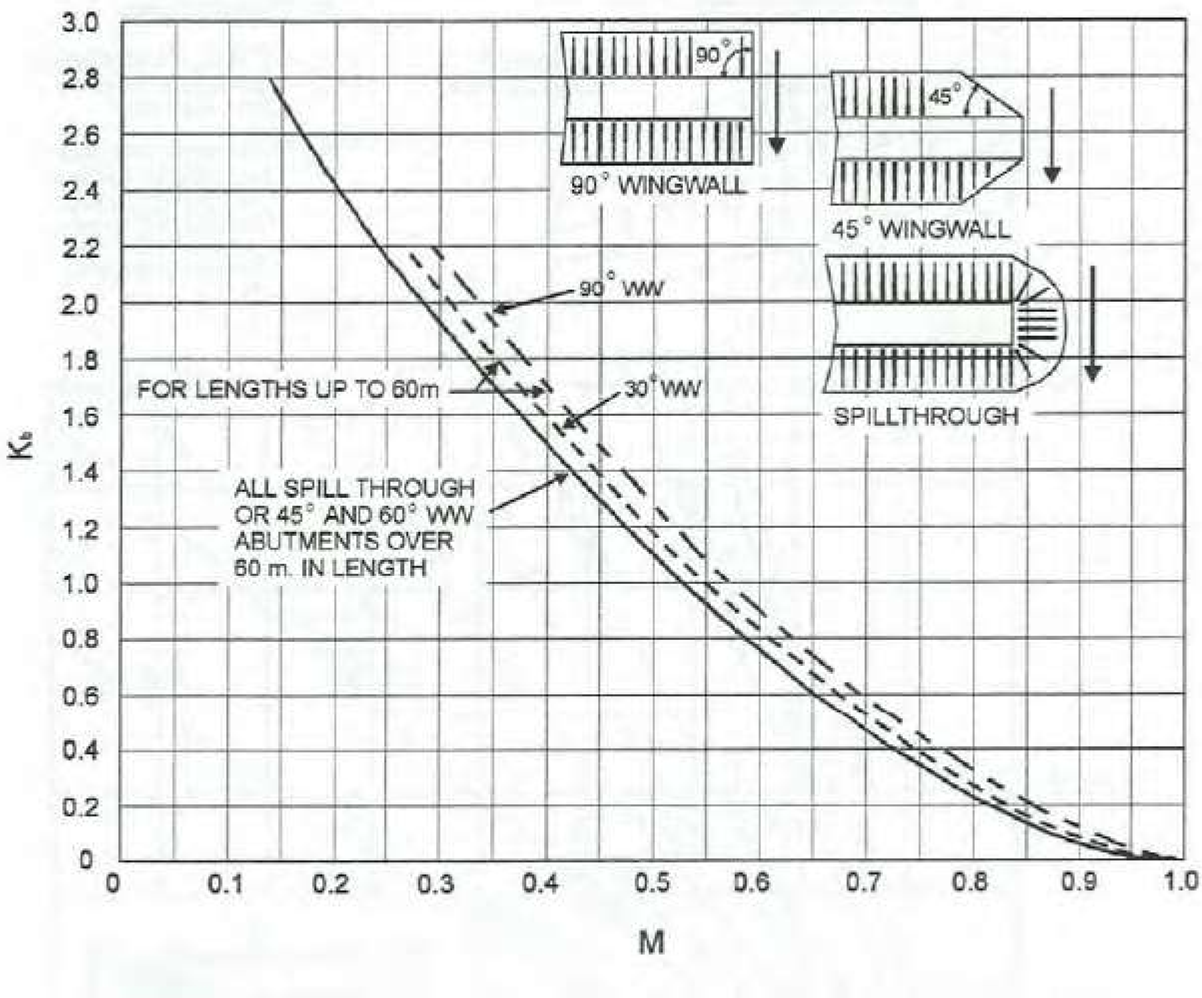


Design Chart 4.22: Ratio of Frontal Flow to Total Gutter Flow



Source: Hec-12

Design Chart 5.01: Base Coefficient - Bridge Backwater

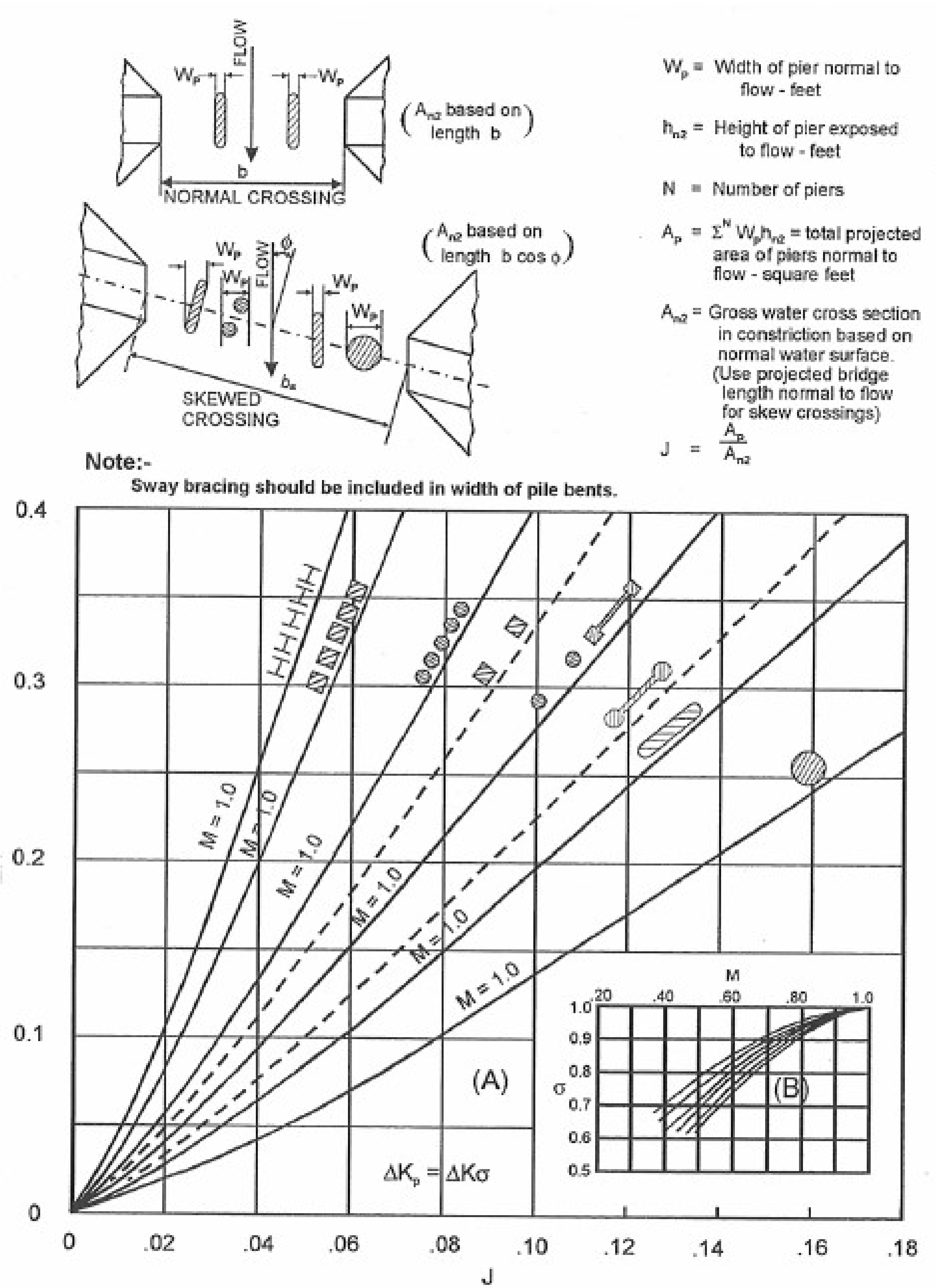


Conveyance Ratio M

$$M = \frac{\text{Unimpeded Flow through bridge opening, } m^3/s}{\text{Total flow from opening and flood plain, } m^3/s}$$

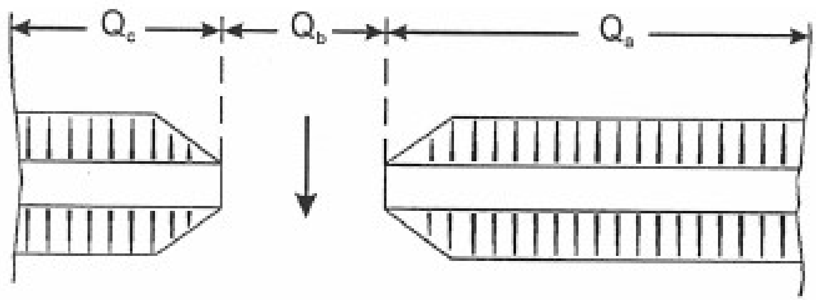
Source: Bradley (1978)

Design Chart 5.02: Pier Coefficient - Bridge Backwater



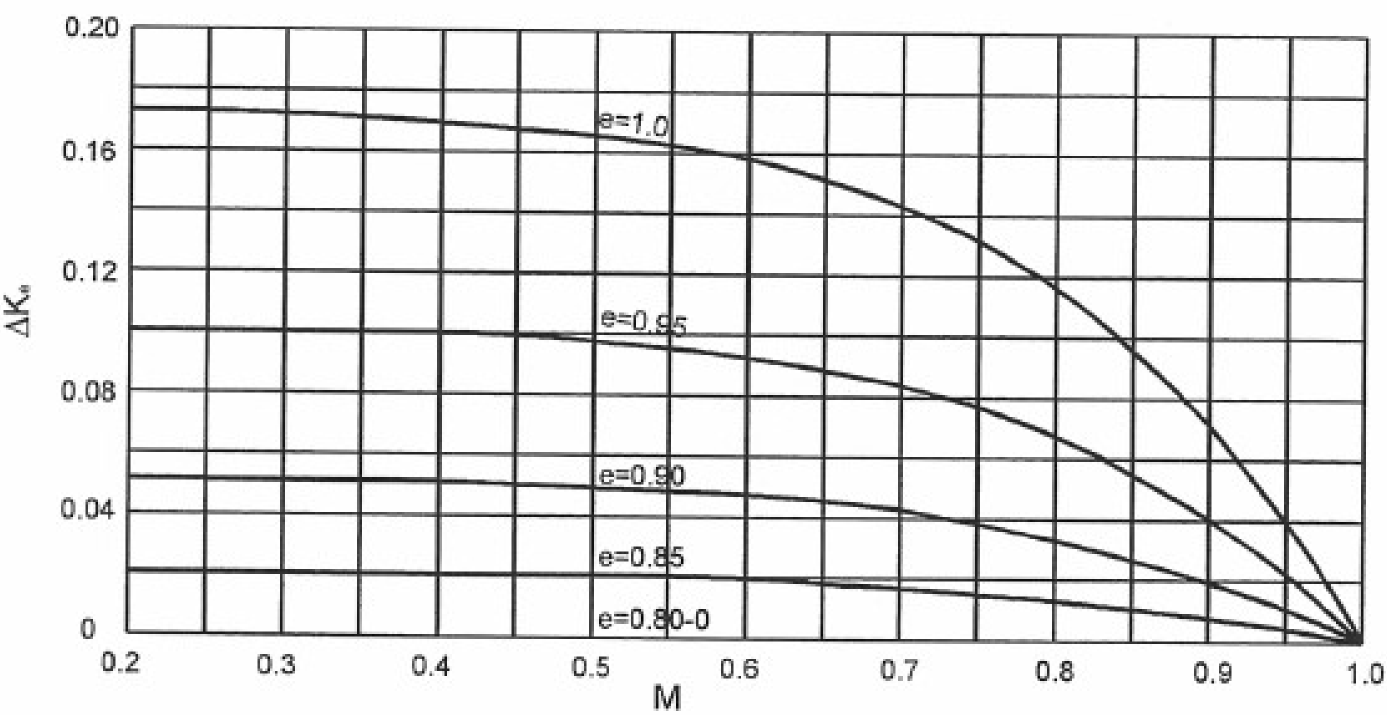
Source: Bradley (1978)

Design Chart 5.03: Eccentricity Coefficient - Bridge Backwater



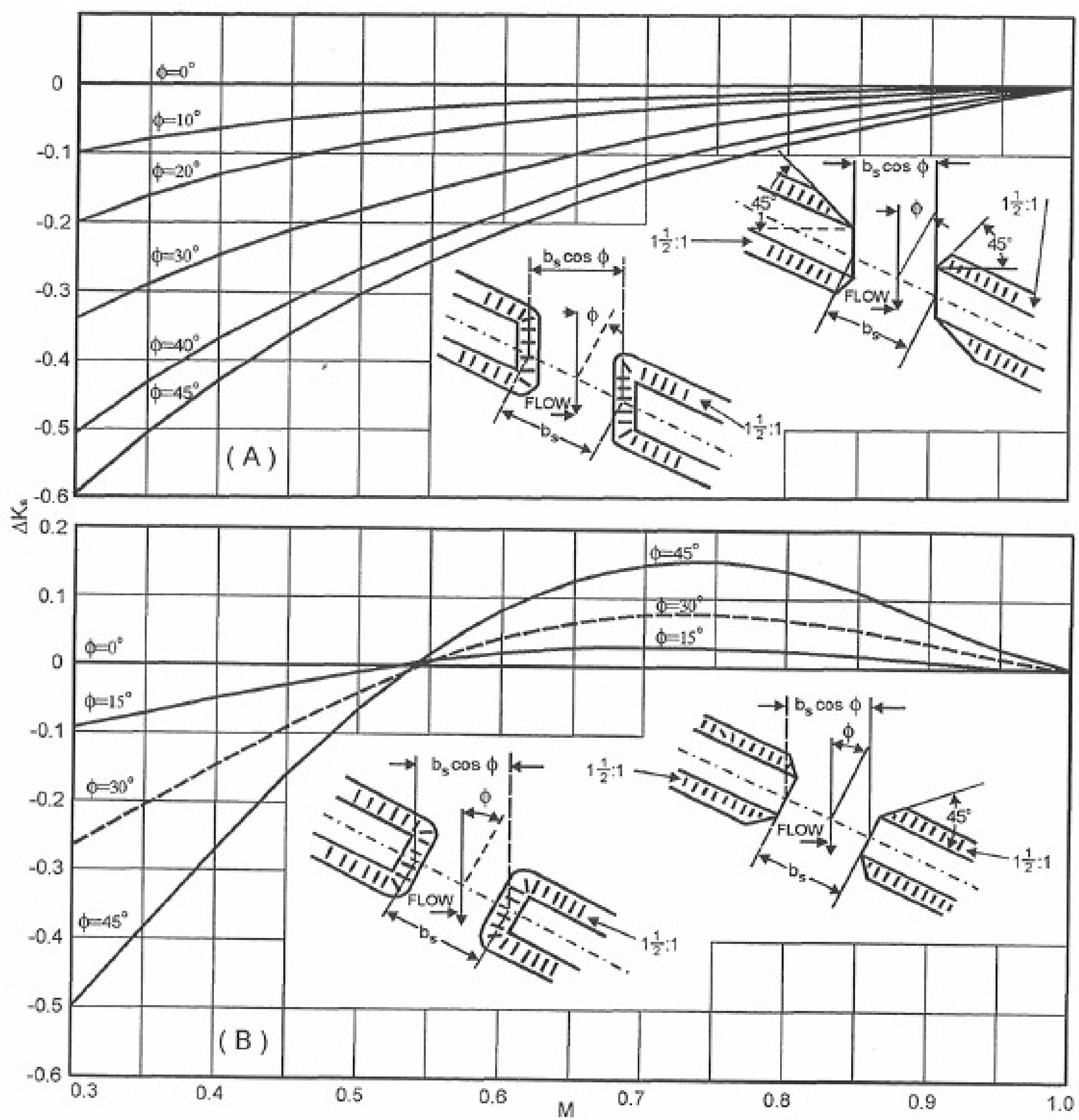
$e = (1 - \frac{Q_c}{Q_a})$ where $Q_c < Q_a$ or

$e = (1 - \frac{Q_a}{Q_c})$ where $Q_a < Q_c$



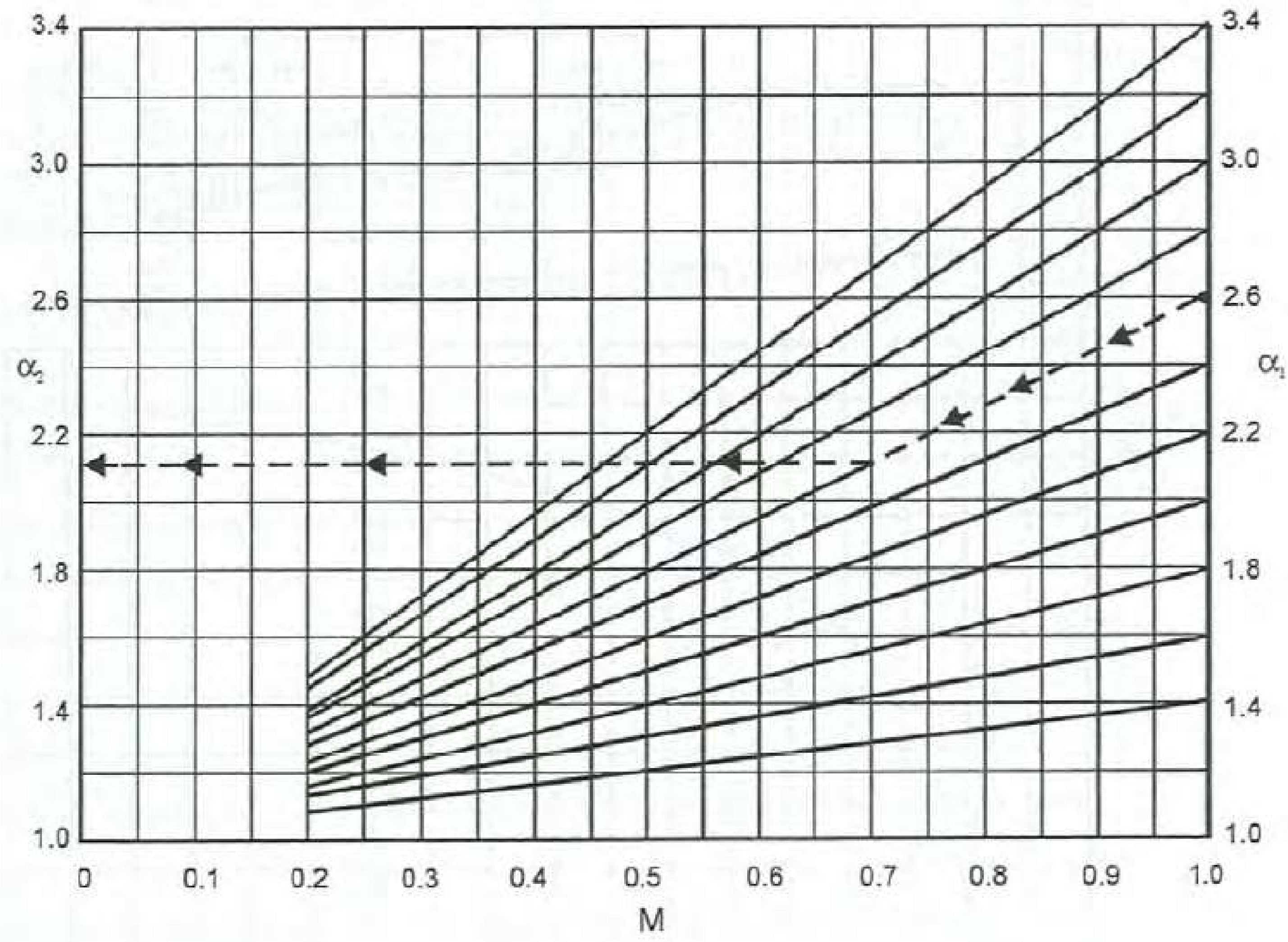
Source: Bradley (1978)

Design Chart 5.04: Skew Coefficient - Bridge Backwater



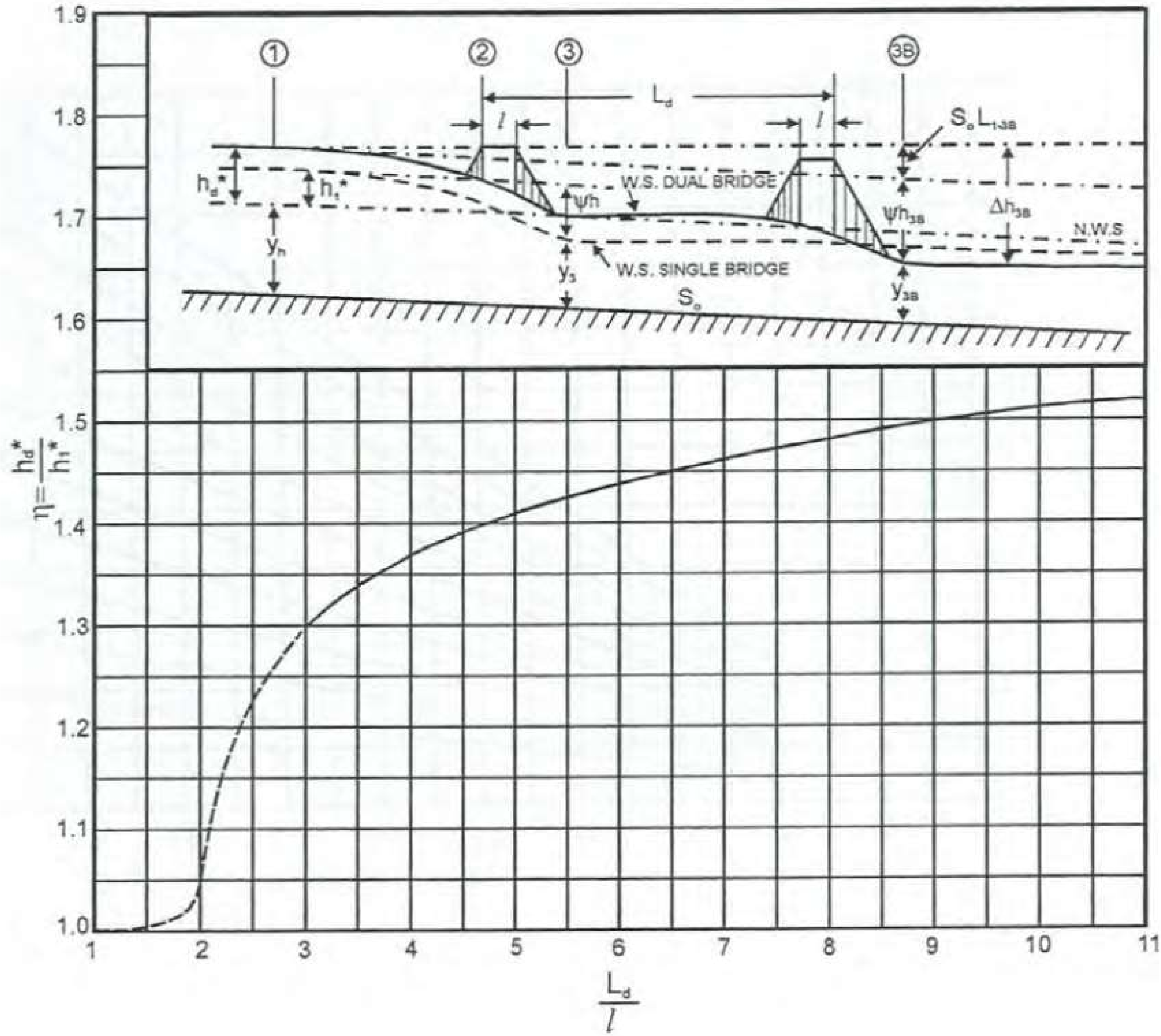
Source: Bradley (1978)

Design Chart 5.05: Velocity Head Coefficient - Bridge Backwater



Source: Bradley (1978)

Design Chart 5.06: Backwater Adjustment for Parallel Bridges



Source: Bradley (1978)

Design Chart 5.07: Competent Velocity Table - Cohesive Soils

Depth of Flow (m)	Soil Scourability **		
	High (m/s)	Medium (m/s)	Low (m/s)
1.0	0.5	0.9	1.6
1.5	0.6	1.0	1.8
3.0	0.6	1.2	2.0
6.0	0.7	1.3	2.3
15.0	0.8	1.5	2.6

* Competent velocities should be based on local experience whenever possible, taking into account saturation & weathering.

** It is not considered advisable to relate the tabulated values to soil property indices because of the strong effect of satuaration and weathering on the scourability of soils. However the following tentative relationship to soil consistency is offered as a rough guide.

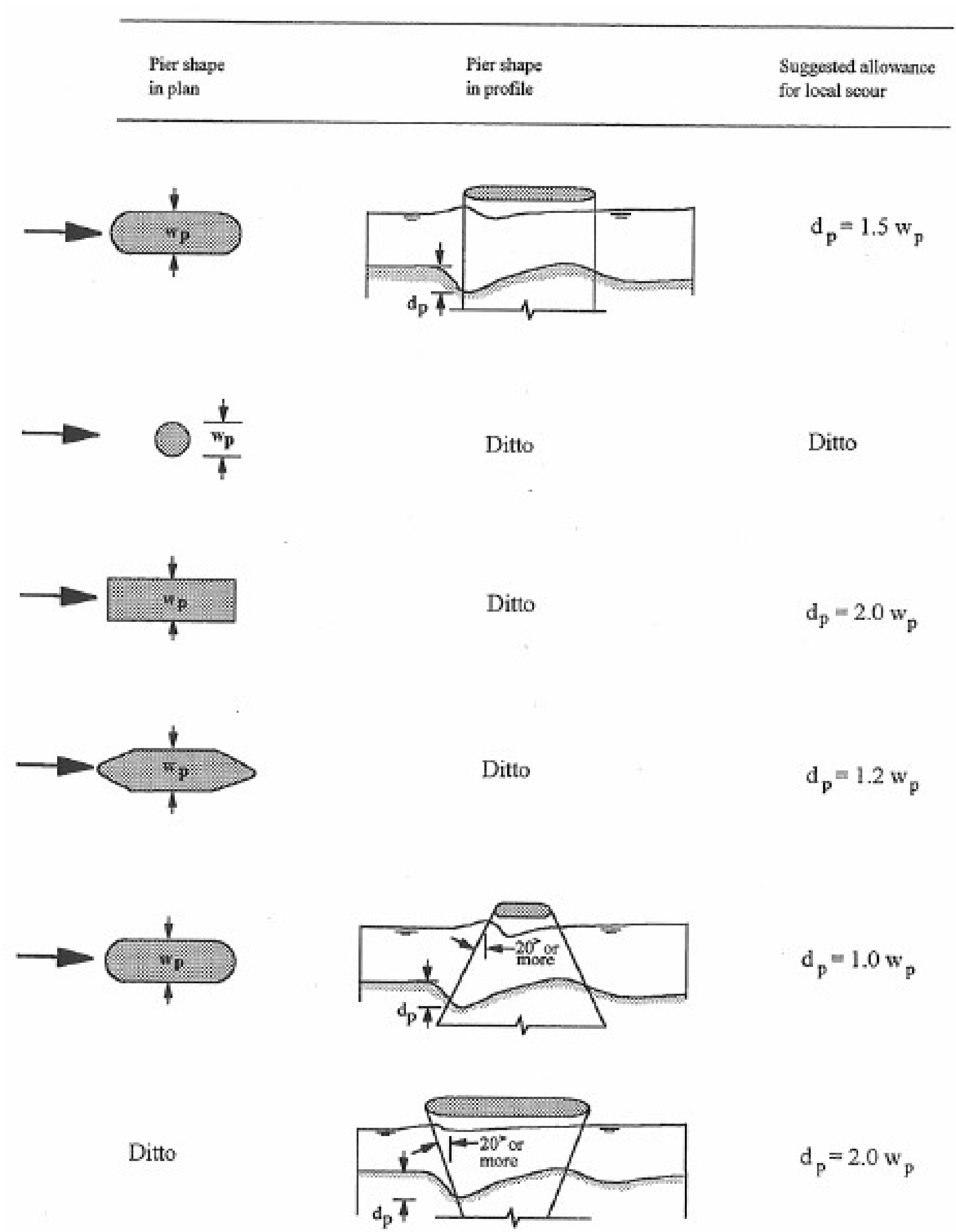
High scourablility .... very soft to soft clays
Medium scourability .... firm to stiff clays
Low scourability..................... very stiff to hard calys, some glacial tills.

Soil consistency can be judged by the following field tests applied with the soil at or near its natural water content.

Very soft:	easily penetrated several centimeters by fist
Soft:	easily penetrated several centimeters by thumb
Firm:	moderate effort required to penetrate several centimeters by thumb
Stiff:	readily indented , but penetrated only be great effort by thumb
Very stiff:	redily indented by thumbnail
Hard:	indented with difficulty by thumbnail

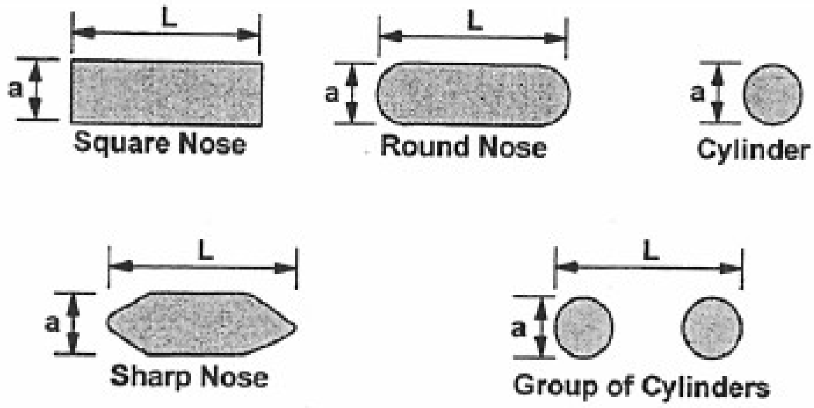
Source: Neill (1993)

Design Chart 5.08: Estimating Local Pier Scour



Source: Neill (1973)

Design Chart 5.09: Pier Shape Correction Factors (K1 and K2)



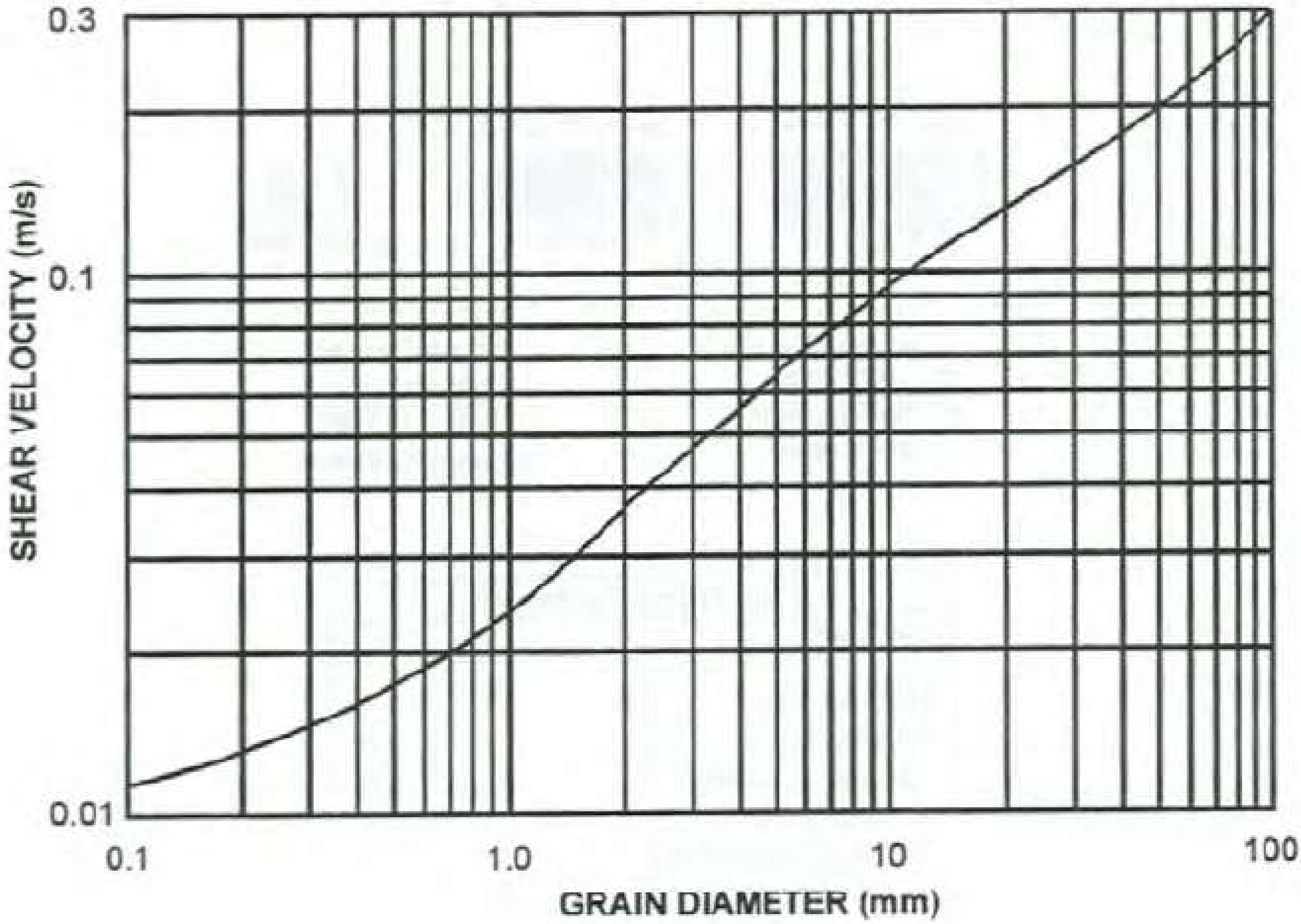
Pier Shape Factor k_1	
Shape	**k_1**
Square Nose	1.1
Round Nose	1.0
Circular Cylinder	1.0
Sharp Nose	0.9
Group of Cylinders	1.0

Correction Factor k_2			
Angle	**k_2**		
	L/a=4	**L/a=8**	**L/a=12**
0	1.0	1.0	1.0
15	1.5	2.0	2.5
30	2.0	2.5	3.5
45	2.3	3.3	4.3
90	2.5	3.9	5.0
Angle = skew angle of flow			

Note: The correction factor k_1 for pier nose shape should be determined using the table for angle of attack up to 5 degrees. For greater angles, pier nose shape loses its affect and k_1 should be considered as 1.0.

Source: U.S. FHWA – Hydraulic Circular No. 18 (1991)

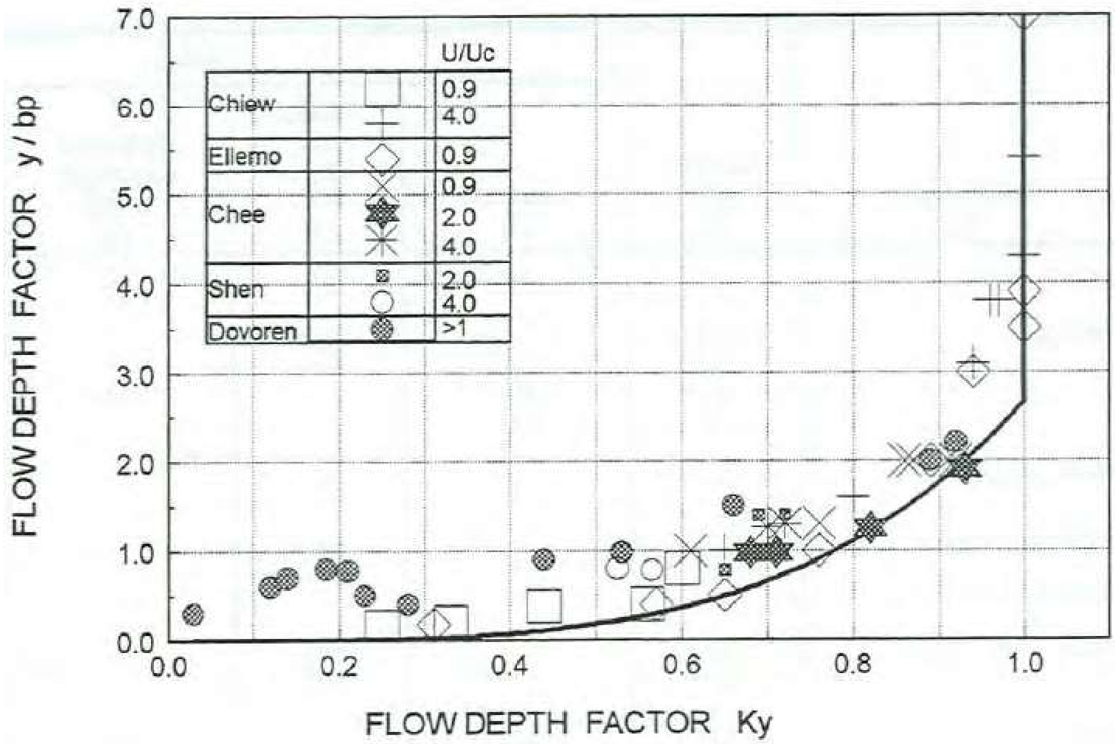
Design Chart 5.10: Shield's Chart



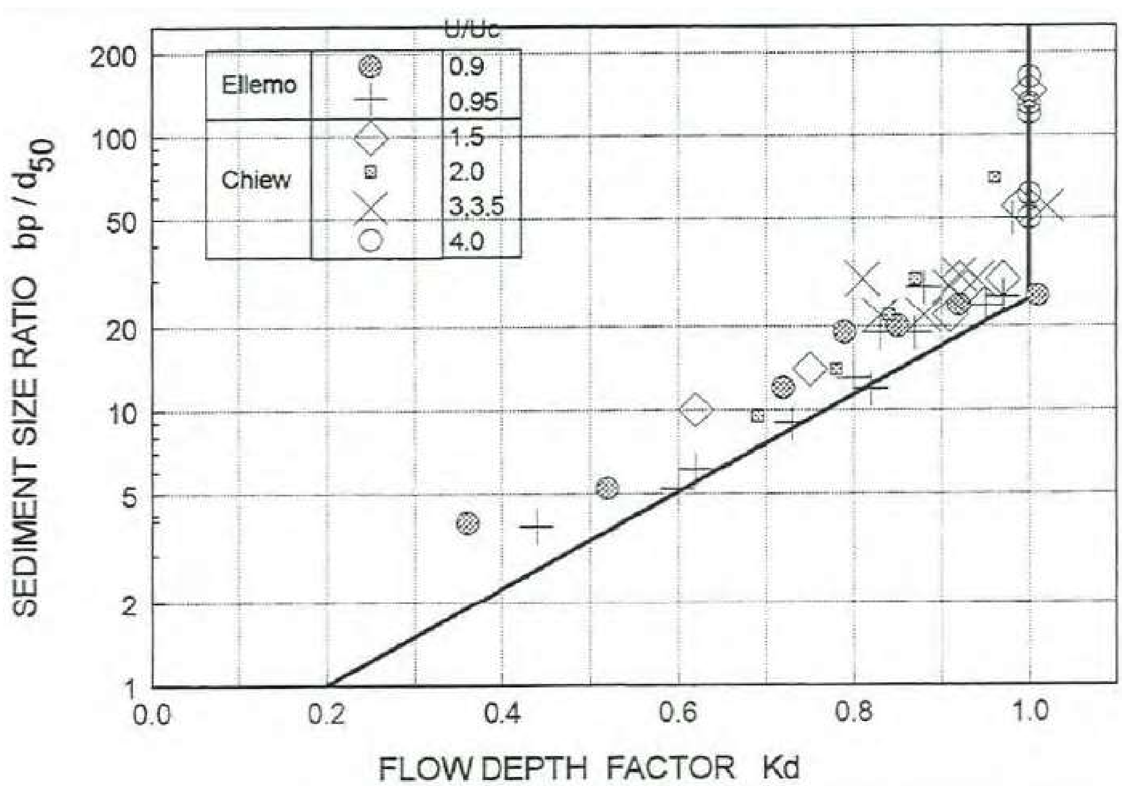
Shields Chart for Threshold Condition of Uniform Sediments in Water

Source: Melville & Sutherland (1988)

Design Chart 5.11: Flow Depth Factors (ky)



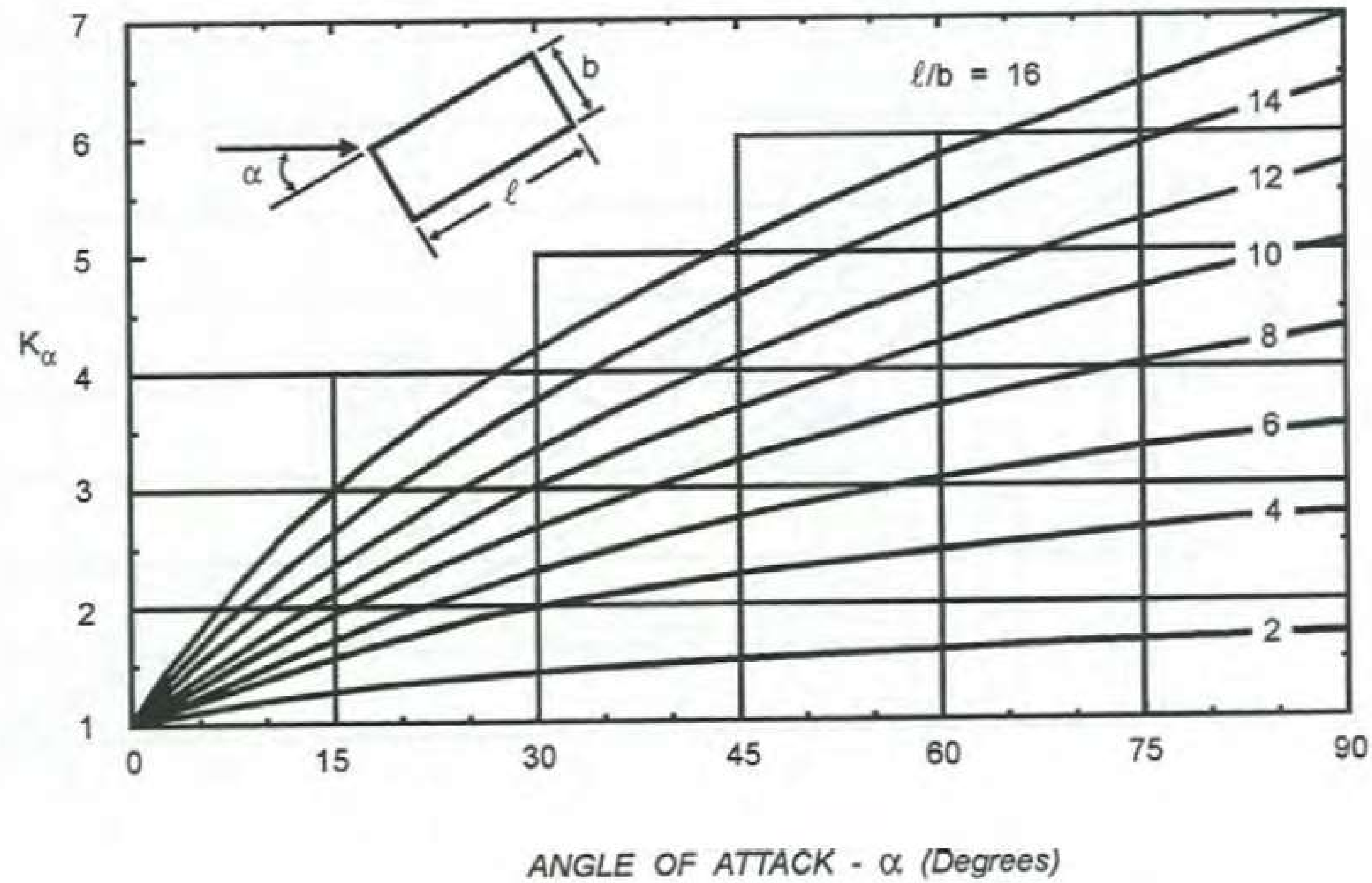
Design Chart 5.12: Sediment Size Factor (kd)



Design Chart 5.13: Pier Shape Correction

		Reference			
Shape in plan (1)	Length/ width (2)	Tison (1940) (3)	Laurens and Toch (1956) (4)	Chabert and Engeldinger (1956) (5)	Venkatadri (1965) (6)
Circular	1.0	1.0	1.0	1.0	1.0
Lenticular	2.0	-	0.97	-	-
	3.0	-	0.76	-	-
	4.0	0.67	-	0.73	-
	7.0	0.41	-	-	-
Parabolic nose	-	-	-	-	0.56
Triangular nose, 60E	-	-	-	-	0.75
Triangular nose, 90E	-	-	-	-	1.25
Elliptic	2.0	-	0.91	-	-
	3.0	-	0.83	-	-
Ogival	4.0	0.86	-	0.92	-
Joukowski	4.0	-	-	0.86	-
	4.1	0.76	-	-	-
Rectangular	2.0	-	1.11	-	-
	4.0	1.40	-	1.11	-
	6.0	-	1.11	-	-

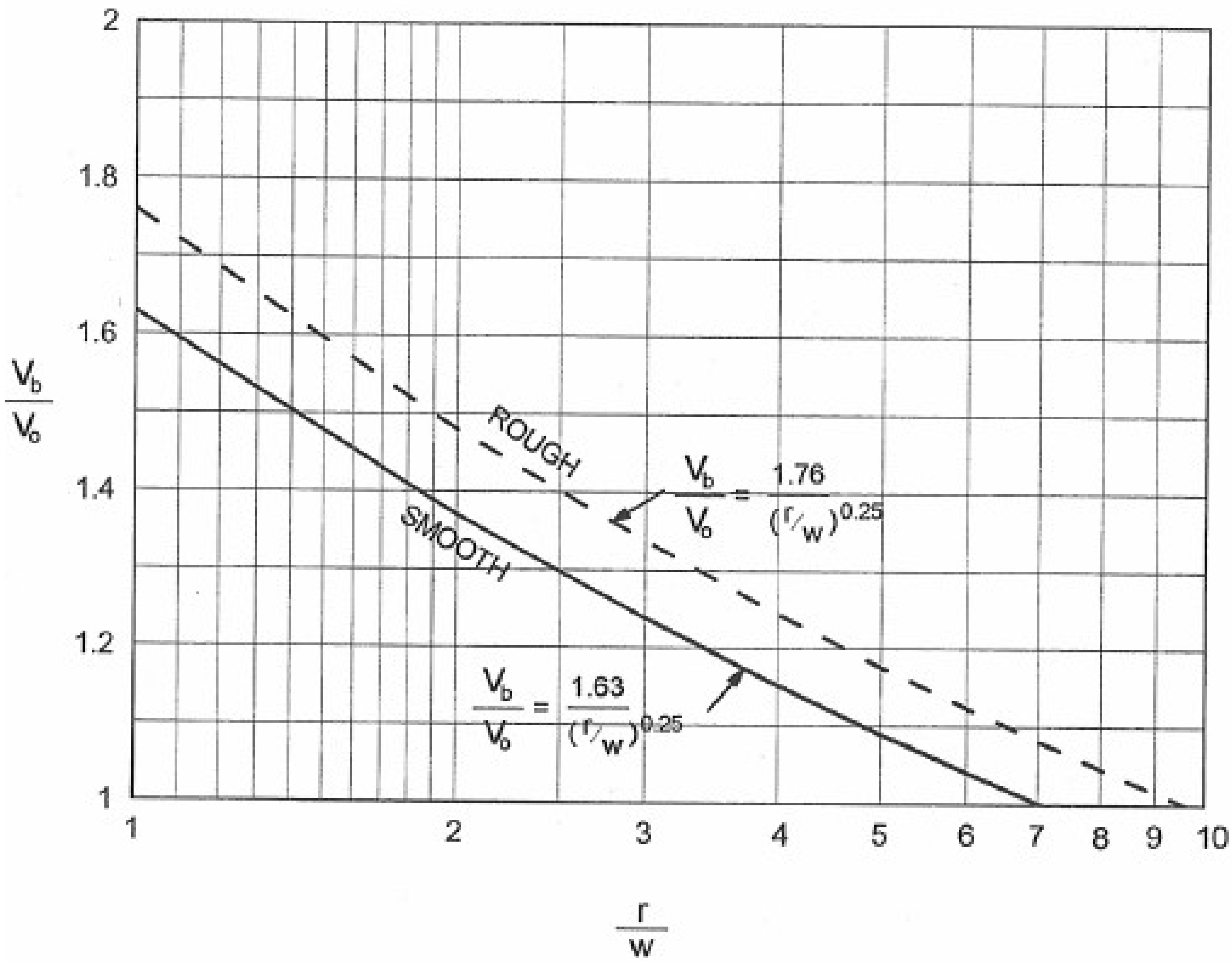
Design Chart 5.14: Pier Alignment Factors



Alignment Factor K_{α} for Piers Not Aligned with Flow

Source: Melville and Sutherland (1988)

Design Chart 5.15: Flow Velocity - Channel Curvature Chart

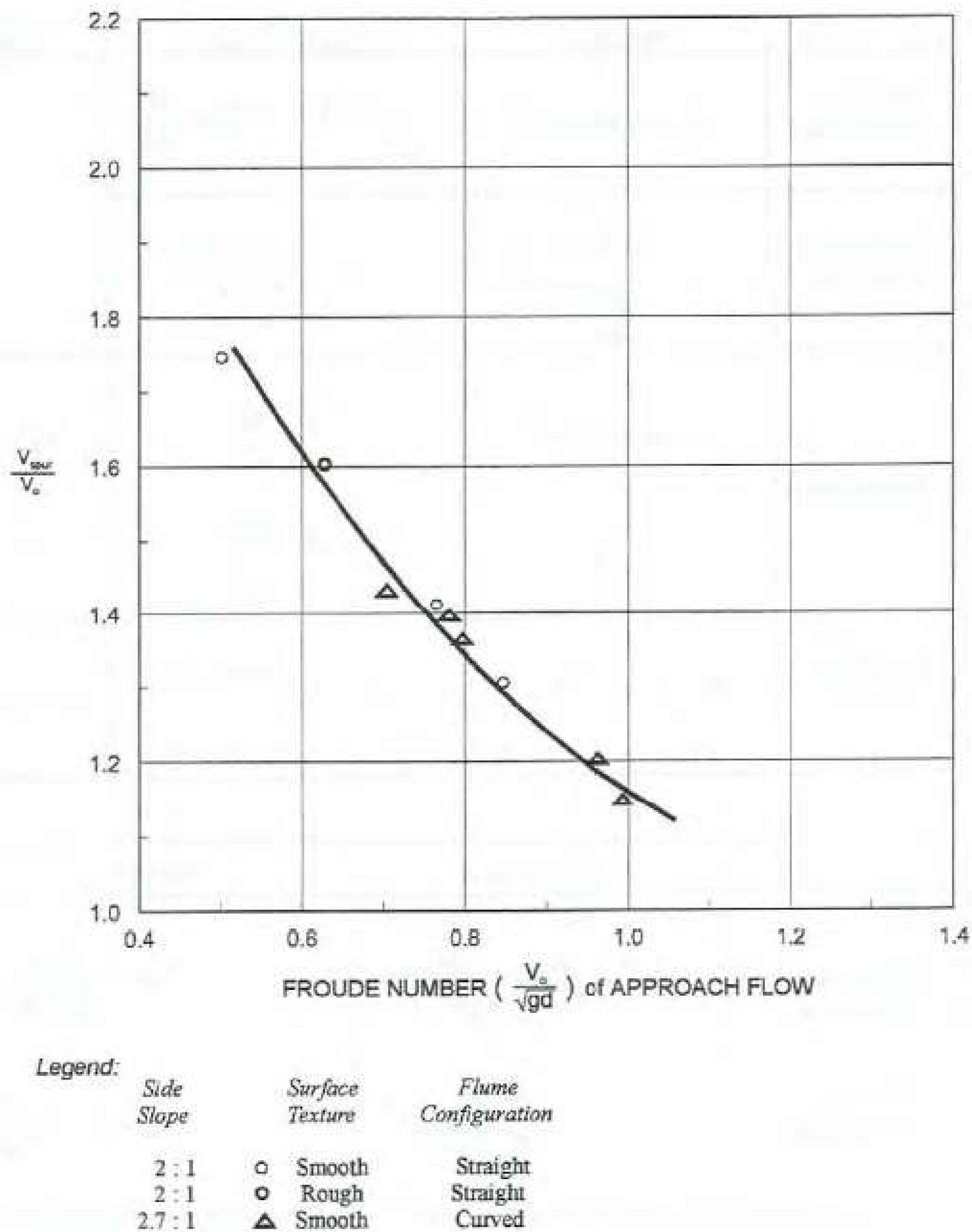


Legend:

V_b - Maximum velocity in bend
V_o - Average approach velocity
r - Centerline radius of bend
w - Average channel width

Source: Melville and Sutherland (1988)

Design Chart 5.16: Local Acceleration Chart – Groynes



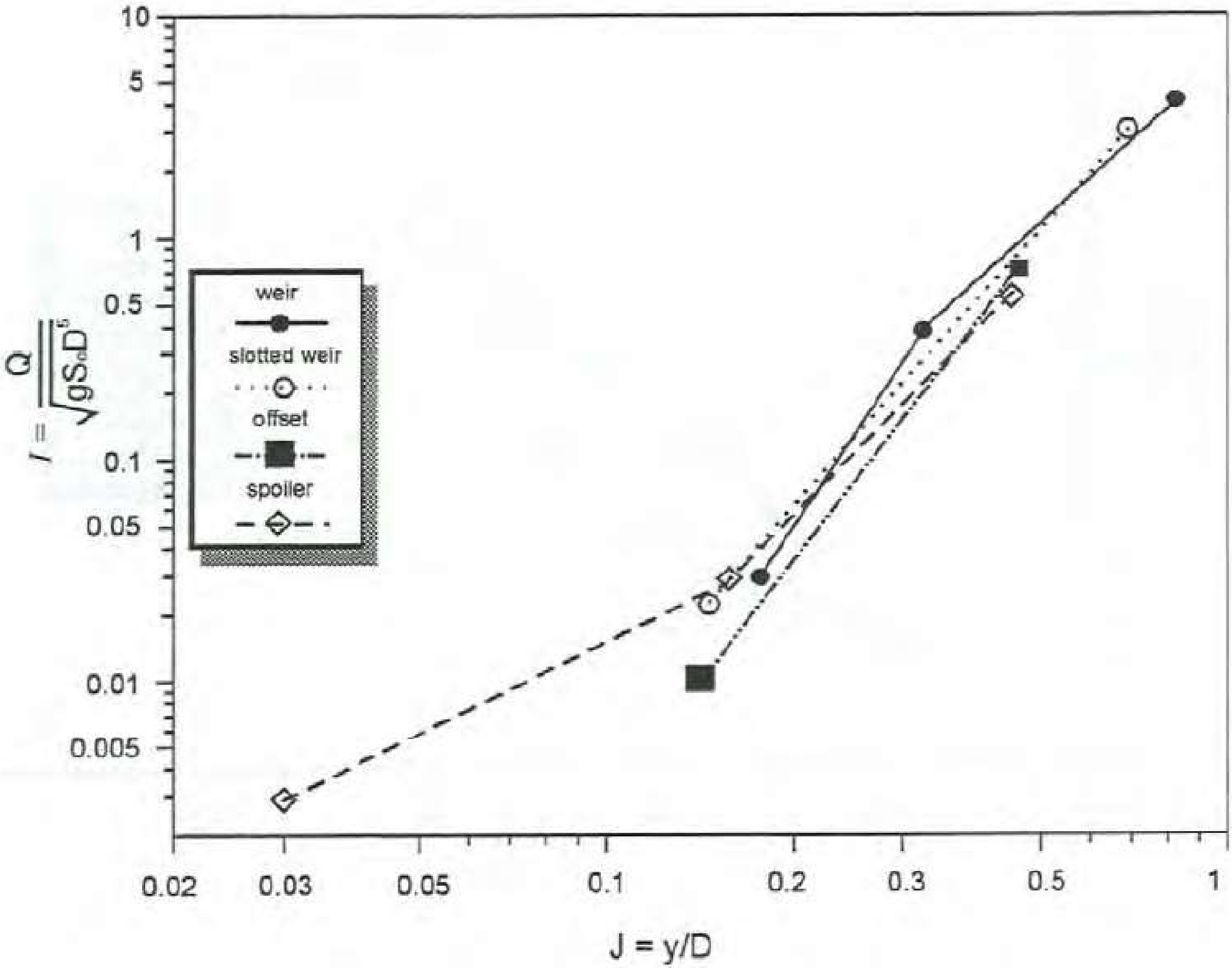
Source: Northwest Hydraulic Consultants (1974)

Design Chart 5.17: Hydraulic Relationships for Fish Passage

	Manning n	Darcy-Weisbach f	Chezy C
Bottom Roughness	$n_b = 0.041\ D_{50}^{\frac{1}{6}}$	$\frac{1}{f^{\frac{1}{2}}} = 0.76 + 1.98 \log (\frac{R}{d_{50}})$	
Composite Coefficient	$n = (\frac{\sum_{i=c,b} P_i\, n_i^{\frac{3}{2}}}{\sum_{i=c,b} P_i})^{\frac{2}{3}}$	$f = \frac{P_c f_c + P_b f_b}{P_c + P_b}$	
Conversions	$n = (\frac{f}{8\ g})^{\frac{1}{2}} R^{\frac{1}{6}}$ $n = \frac{R^{\frac{1}{6}}}{C}$	$f = \frac{8g}{C^2}$ $f = \frac{8gn^2}{R^{\frac{1}{3}}}$	$C = (\frac{8g}{f})^{\frac{1}{2}}$ $C = \frac{R^{\frac{1}{6}}}{n}$
Continuity equation	$Q = \frac{1}{n} A_w R^{\frac{2}{3}} S_o^{\frac{1}{2}}$	$Q = A_w (\frac{8gRS_o}{f})^{1/2}$	$Q = CA_w (RS)^{1/2}$

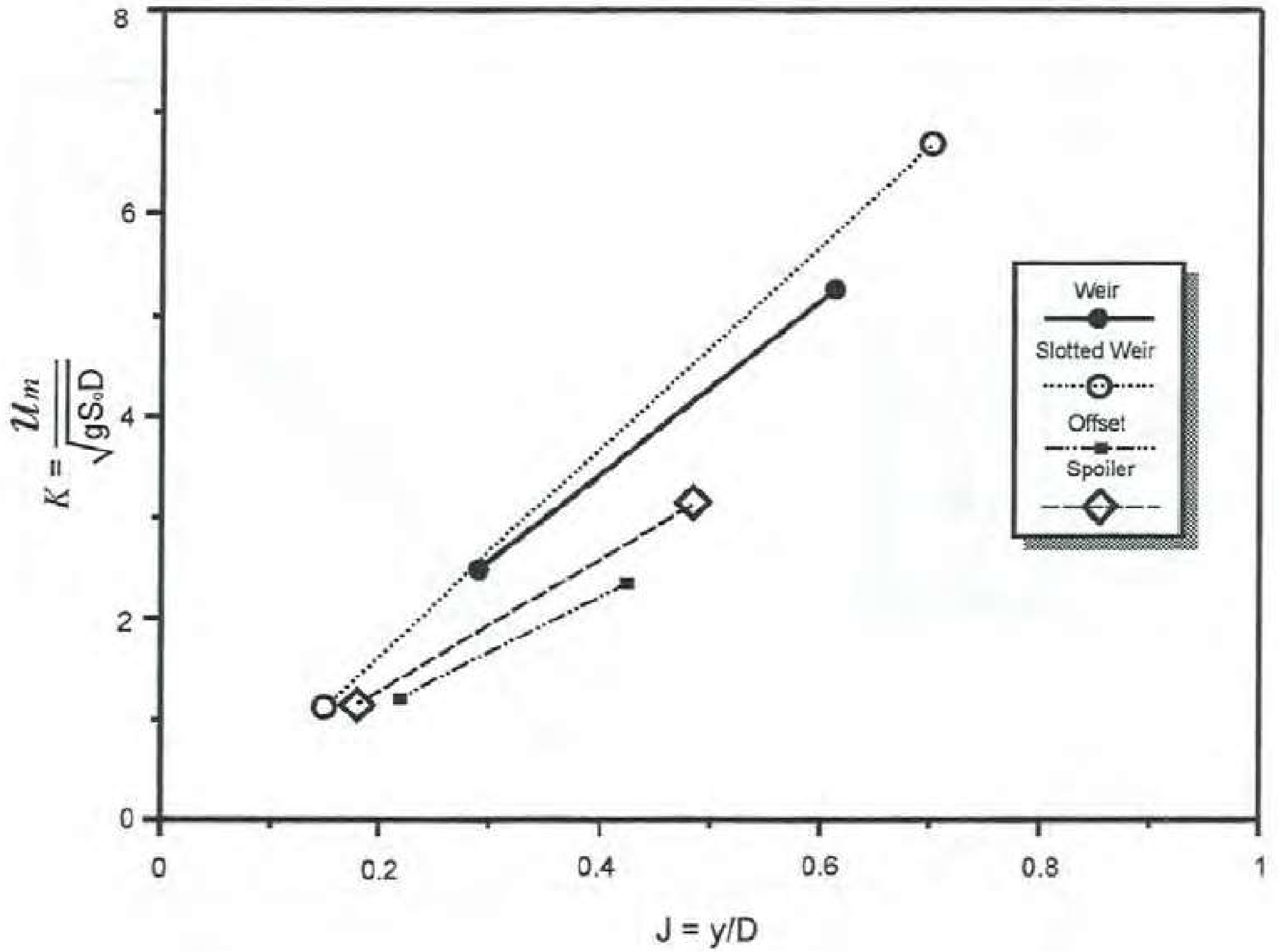
	Discharge	Velocity
Dimensionless equation	$Q_* = \frac{Q}{\sqrt{gS_o D^5}}$	$U_* = \frac{u_m}{\sqrt{gS_o D}}$
Depth relationship	$Q_* = a (\frac{y}{D})^b$	$U_* = a + b (\frac{y}{D})$

Design Chart 5.18: Hydraulic Relationship of " I "



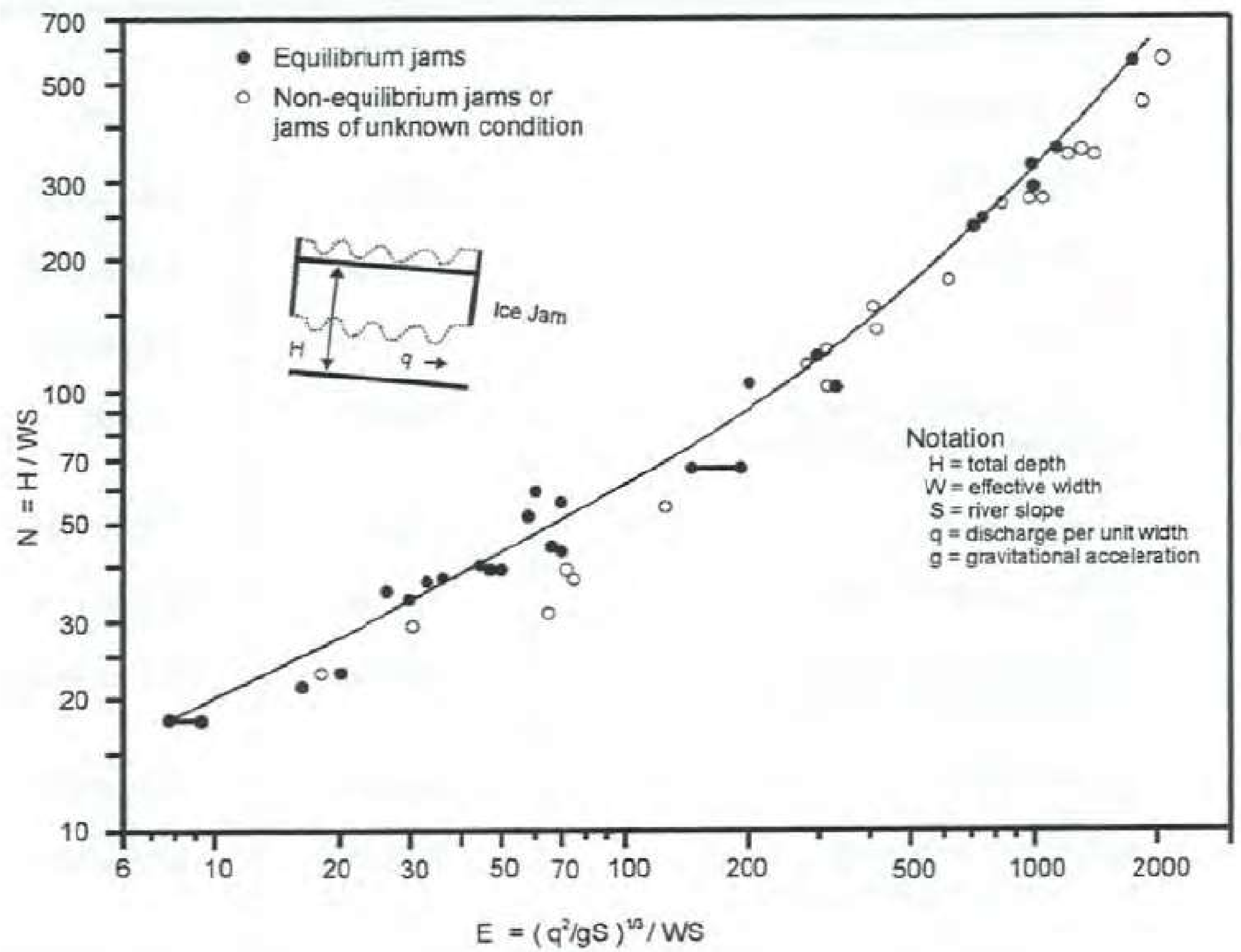
Source: Bender (1995)

Design Chart 5.19: Hydraulic Relationship " K "



Source: Bender (1995)

Design Chart 5.20: Fully Developed Ice Jam: Dimensionless Rating Curve



Source: Beltaos (1983)

Design Chart 5.21: Correction Factors for Wave Run-up

Slope Surface Characteristics	Placement	r
Smooth, impermeable	------------	1.00
Concrete blocks	Fitted	0.90
Basalt blocks	Fitted	0.85 to 0.90
Gobi blocks	Fitted	0.85 to 0.90
Grass	------------	0.85 to 0.90
One layer of quarrystone (impermeable foundation)	Random	0.80
Quarrystone	Fitted	0.75 to 0.80
Rounded quarrystone	Random	0.60 to 0.65
Three layers of quarrystone (impermeable foundation)	Random	0.60 to 0.65
Quarrystone	Random	0.50 to 0.55
Concrete armor units (~ 50 percent void ratio)	Random	0.45 to 0.50

Source: U.S. Army Corps of Engineers (1984)

Design Chart 5.22: Suggested Kp for Armour for Wave Protection

No-damage Criteria and Minor Overtopping							
Armour Units	n^3	Placement	Structure Trunk K_D [2] Breaking Wave	Structure Trunk K_D [2] Nonbreaking Wave	Structure Head K_D Breaking Wave	Structure Head K_D Nonbreaking Wave	Structure Head Slope Cot θ
Quarrystone Smooth rounded Smooth rounded Rough angular	 2 >3 1	 Random Random Random [4]	*1.2* *1.6* [4]	2.4 *3.2* *2.9*	*1.1* *1.4* [4]	1.9 *2.3* *2.3*	1.5 to 3.0 [5] [5]
Rough angular	2	Random	2.0	4.0	*1.9* *1.6* 1.3	3.2 2.8 2.3	1.5 2.0 3.0
Rough angular Rough angular Parallelepiped [7]	>3 2 2	Random Special [6] Special [1]	*2.2* 5.8 7.0 - 20.0	*4.5* 7.0 *8.5 - 24.0*	*2.1* *5.3* ----	*4.2* 6.4	[5] [5]
Tetrapod and Quadripod	2	Random	7.0	8.0	*5.0* *4.5* *3.5*	6.0 5.5 4.0	1.5 2.0 3.0
Tribar	2	Random	*9.0*	10.0	*8.3* *7.8* 6.0	9.0 8.5 6.5	1.5 2.0 3.0
Dolos	2	Random	15.8 [8]	31.8 [8]	*8.0* 7.0	*16.0* *14.0*	2.0 [9] 3.0
Modified Cube Hexapod Toskane Tribar Quarrystone (K_{RR}) Graded Angular	2 2 2 1 -	Random Random Random Uniform Random	*6.5* *8.0* *11.0* 12.0 2.2	7.5 9.5 22.0 15.0 2.5	---- *5.0* ---- *7.5* ----	*5.0* *7.0* ---- *9.5* ----	[5] [5] [5] [5]

1 Caution: Those K_D values shown in *italics* are unsupported by test results and are only provided for preliminary design purposes.
2 Applicable to slopes ranging from 1 on 1.5 to 1 on 5.
3 n is the number of units comprising the thickness of the armour layer.
4 The use of single layer of quarrystone armour units is not recommended for structures subject to breaking waves, and only under special conditions for structures subject to nonbreaking waves. When it is used, the stone should be carefully placed.
5 Until more information is available on the variation of K_D value with slope, the use of K_D should be limited to slopes ranging from 1on 1.5 to 1 on 3. Some armour units tested on a structure head indicate a K_D - slope dependence.
6 Special placement with long axis of stone placed perpendicular to structure face.
7 Parallelepiped-shaped stone: long slab-like stone with the dimension about 3 times the shortest dimension (Markle and Davidson, 1979).
8 Refers to no-damage criteria (<5 percent displacement, rocking, etc.); if no rocking (<2 percent) is desired, reduce K_D 50 percent (Zwamborn and Van Niekerk, 1982).
9 Stability of Dolosse on slopes steeper than 1 on 2 should be substantiated by site-specific model tests.

Source: U.S. Army Corps of Engineers (1984)

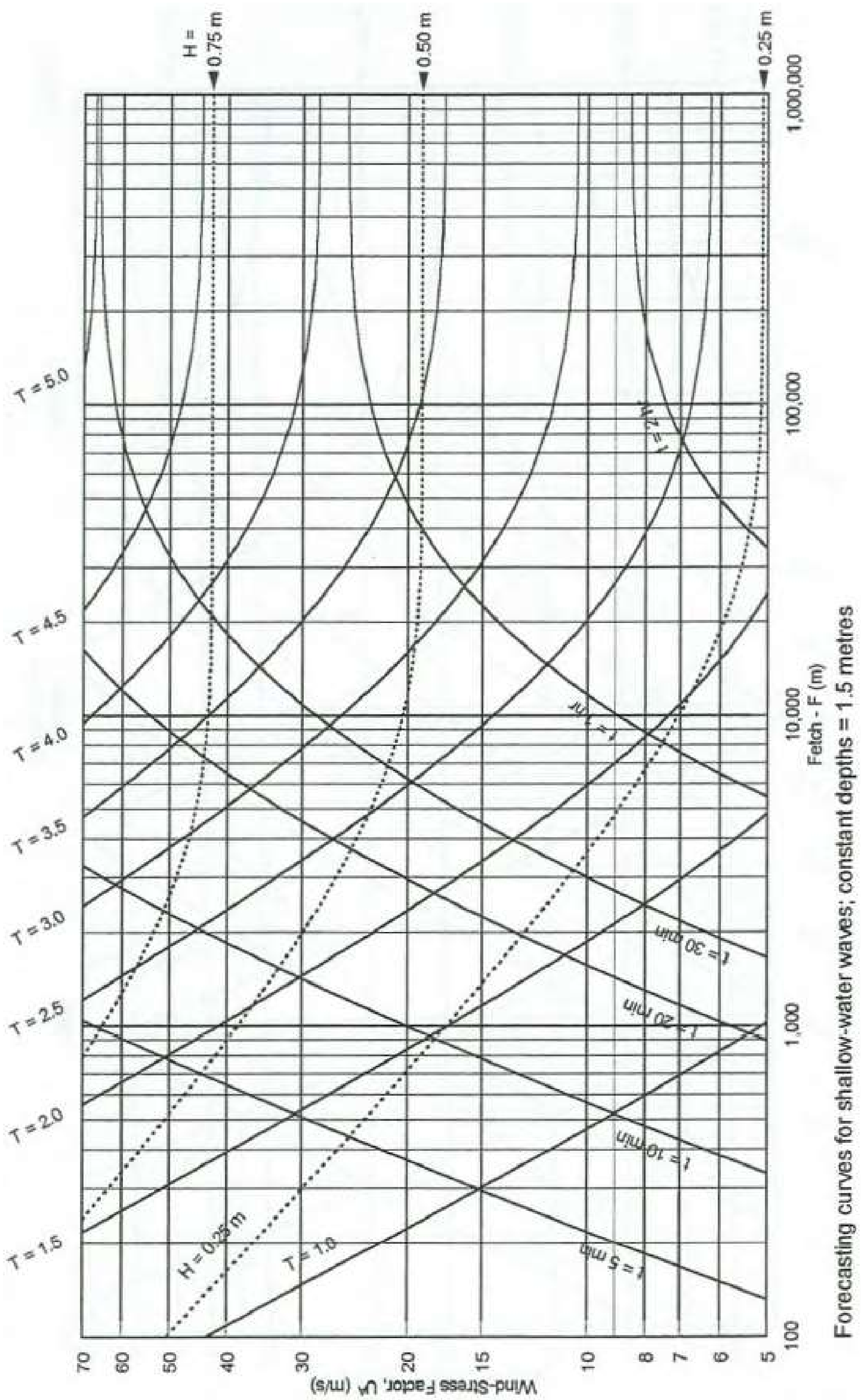
Design Chart 5.23: Layer Coefficient and Porosity for Armour for Wave

Armour Unit	n	Placement	Layer Coefficient k_Δ	Porosity (P) %
QuarryStone (smooth) [1]	2	Random	1.02	38
QuarryStone (rough) [2]	2	Random	1.00	37
QuarryStone (rough) [2]	> 3	Random	1.00	40
QuarryStone (parallelepiped) [6]	2	Special	------	27
Cube (modified) [1]	2	Random	1.10	47
Tetrapod [1]	2	Random	1.04	50
Quadripod [1]	2	Random	0.95	49
Hexipod [1]	2	Random	1.15	47
Tribar [1]	2	Random	1.02	54
Dolos [4]	2	Random	0.94	56
Toskane [5]	2	Random	1.03	52
Tribar [1]	1	Uniform	1.13	47
Quarrystone [7]	Graded	Random	-----	37

1 Hudson (1974).
2 Carver (1983).
3 Hudson (1961a).
4 Carver and Davidson (1977).
5 Carver (1978).
6 Layer thickness is twice the average long dimension of the parallelepiped stones. Porosity is estimated from tests on one layer of uniformly placed modified cubes.
7 The minimum layer thickness should be twice the cubic dimension of the W_{50} riprap. Check to determine that the graded layer thickness is $\geq$ 1.25 the cubic dimension of the W_{max} riprap.

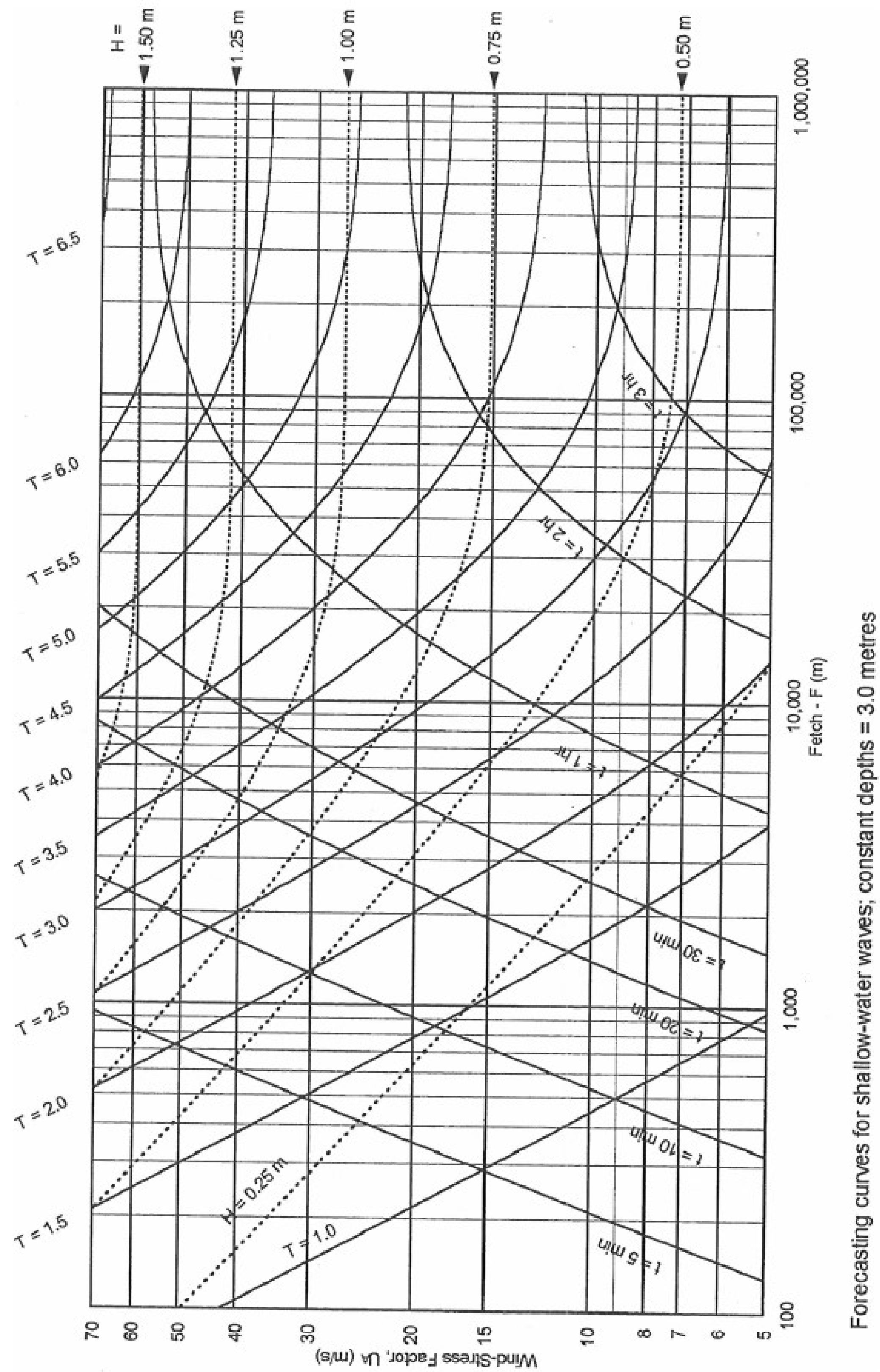
Source: U.S. Army Corps of Engineers (1984)

Design Chart 5.24: Forecasting Curves for Waves



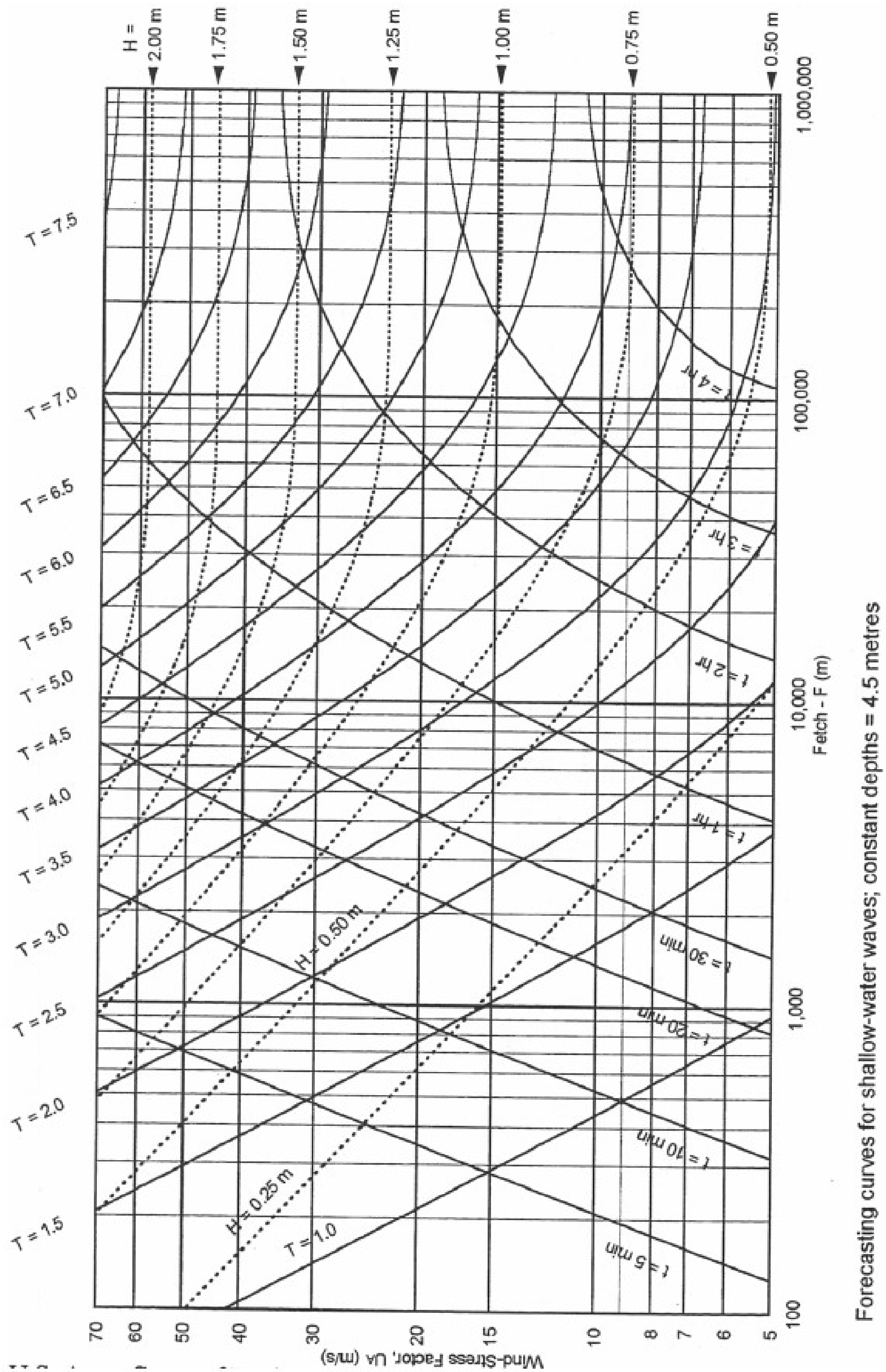
Source: U.S. Army Corps of Engineers (1984)

Design Chart 5.25: Forecasting Curves for Waves



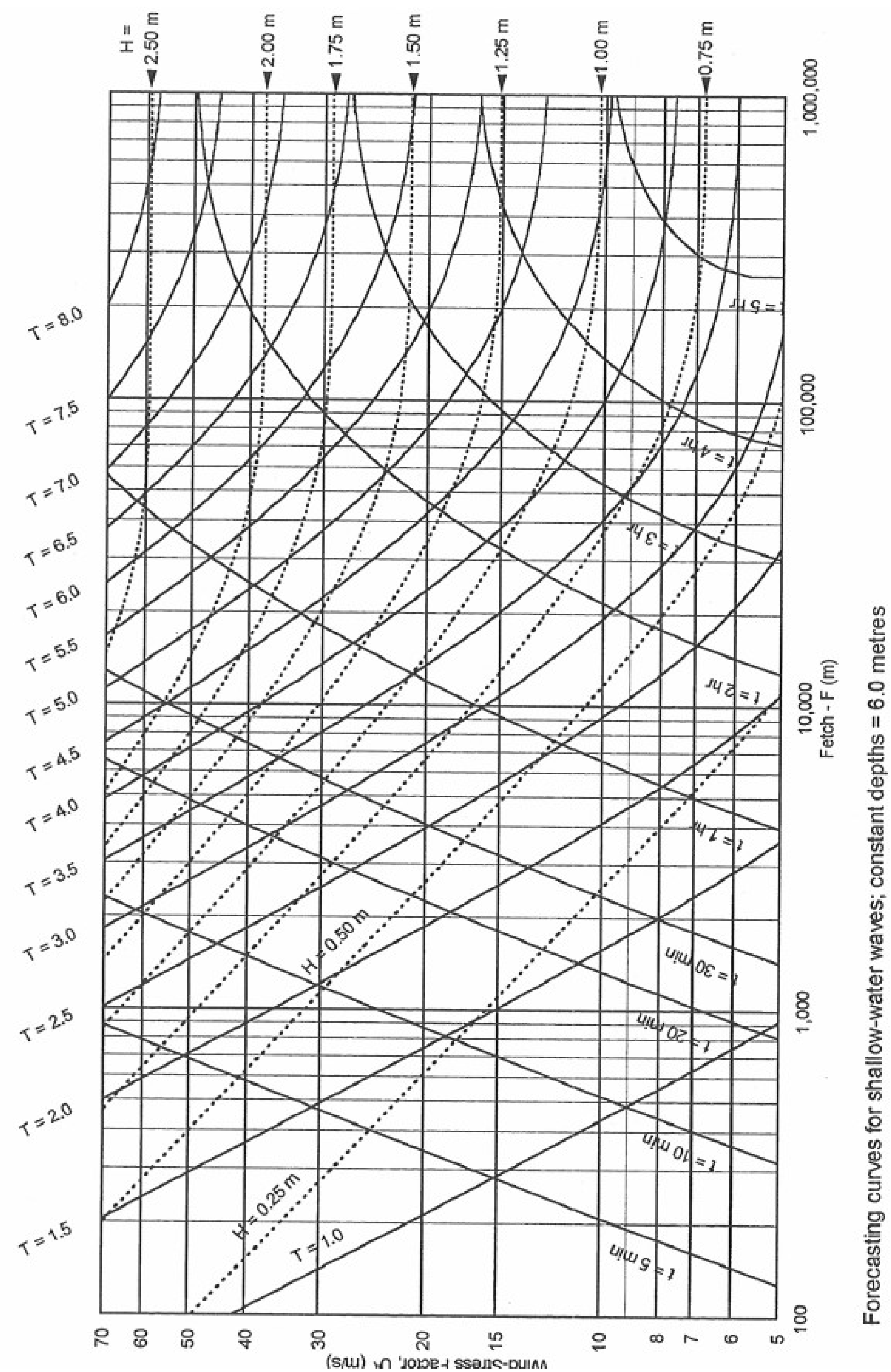
Source: U.S. Army Corps of Engineers (1984)

Design Chart 2.26: Forecasting Curves for Waves



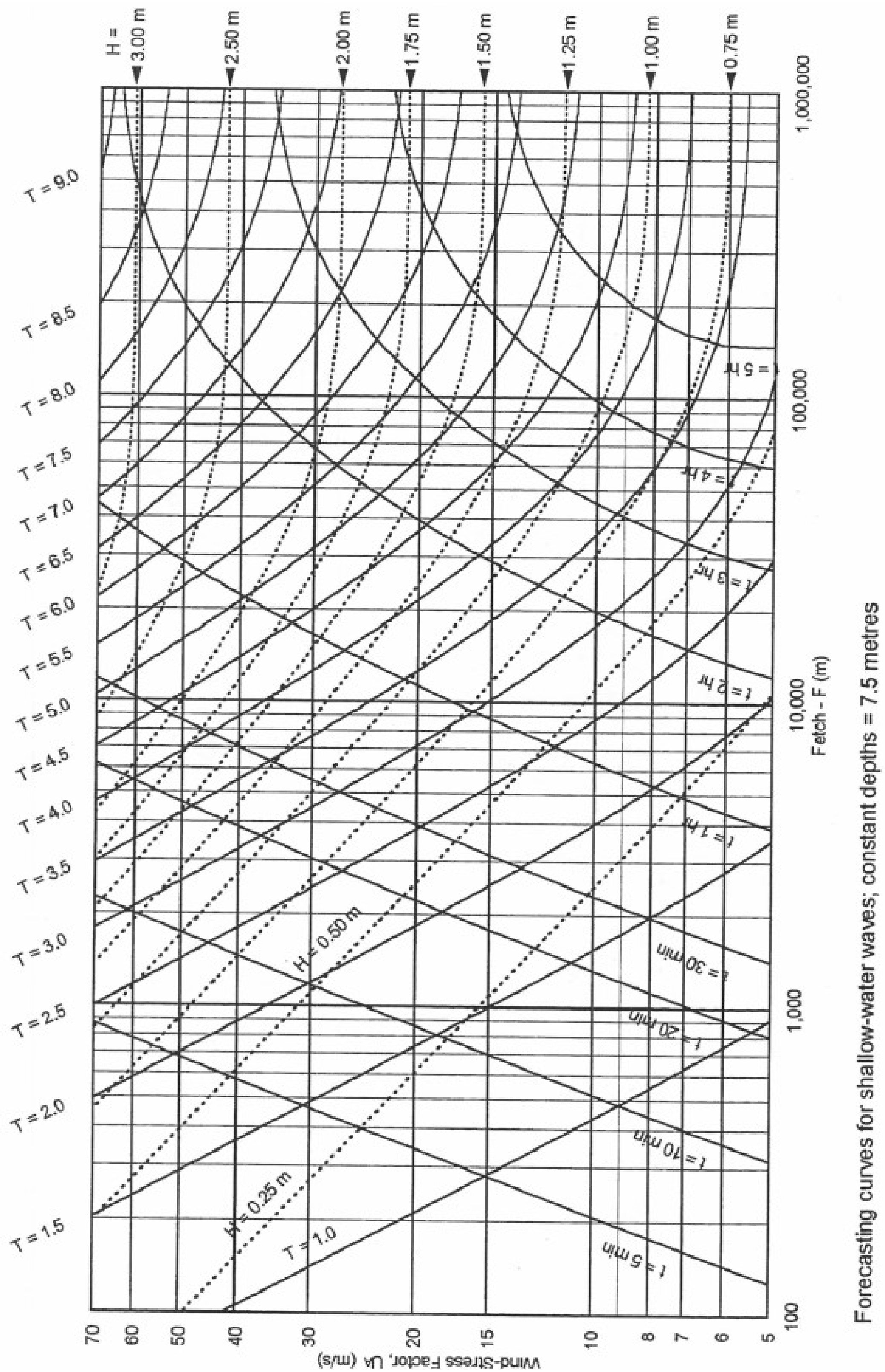
Source: U.S Army Corps of Engineers (1984)

Design Chart 5.27: Forecasting Curves for Waves



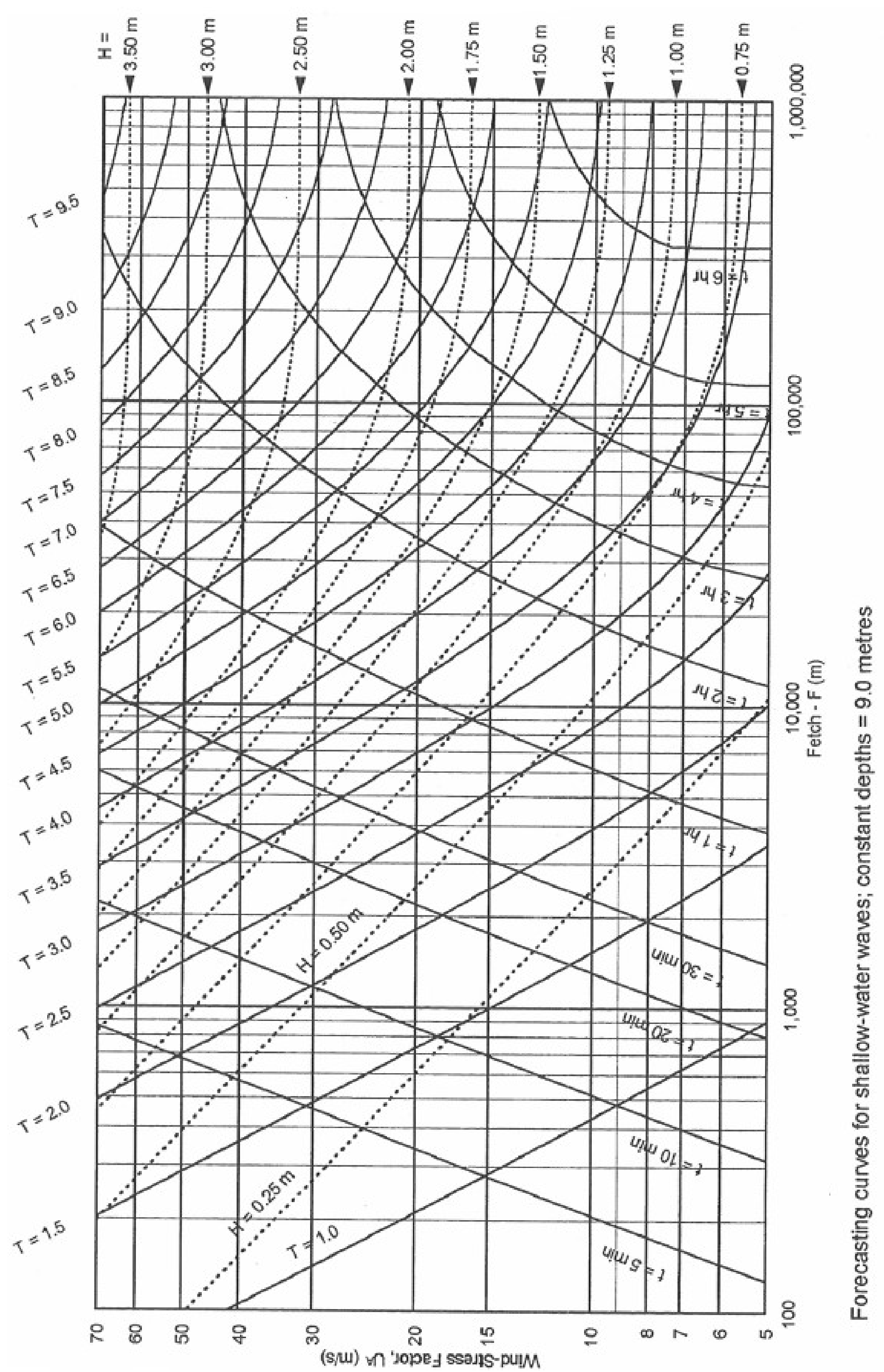
Source: U.S. Army Corps of Engineers (1984)

Design Chart 5.28: Forecasting Curves for Waves



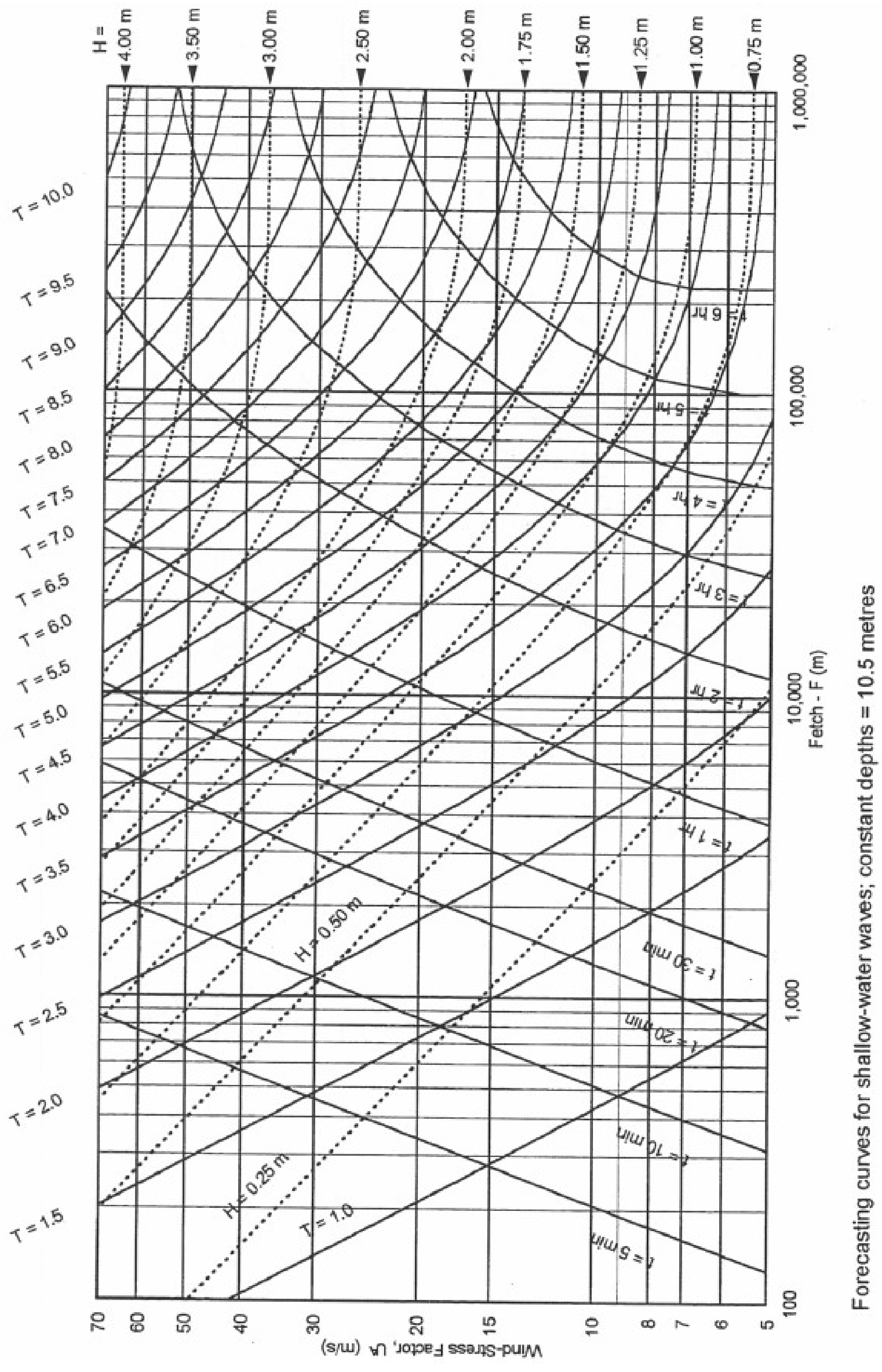
Source: U.S. Army Corps of Engineers (1984)

Design Chart 5.29: Forecasting Curves for Waves



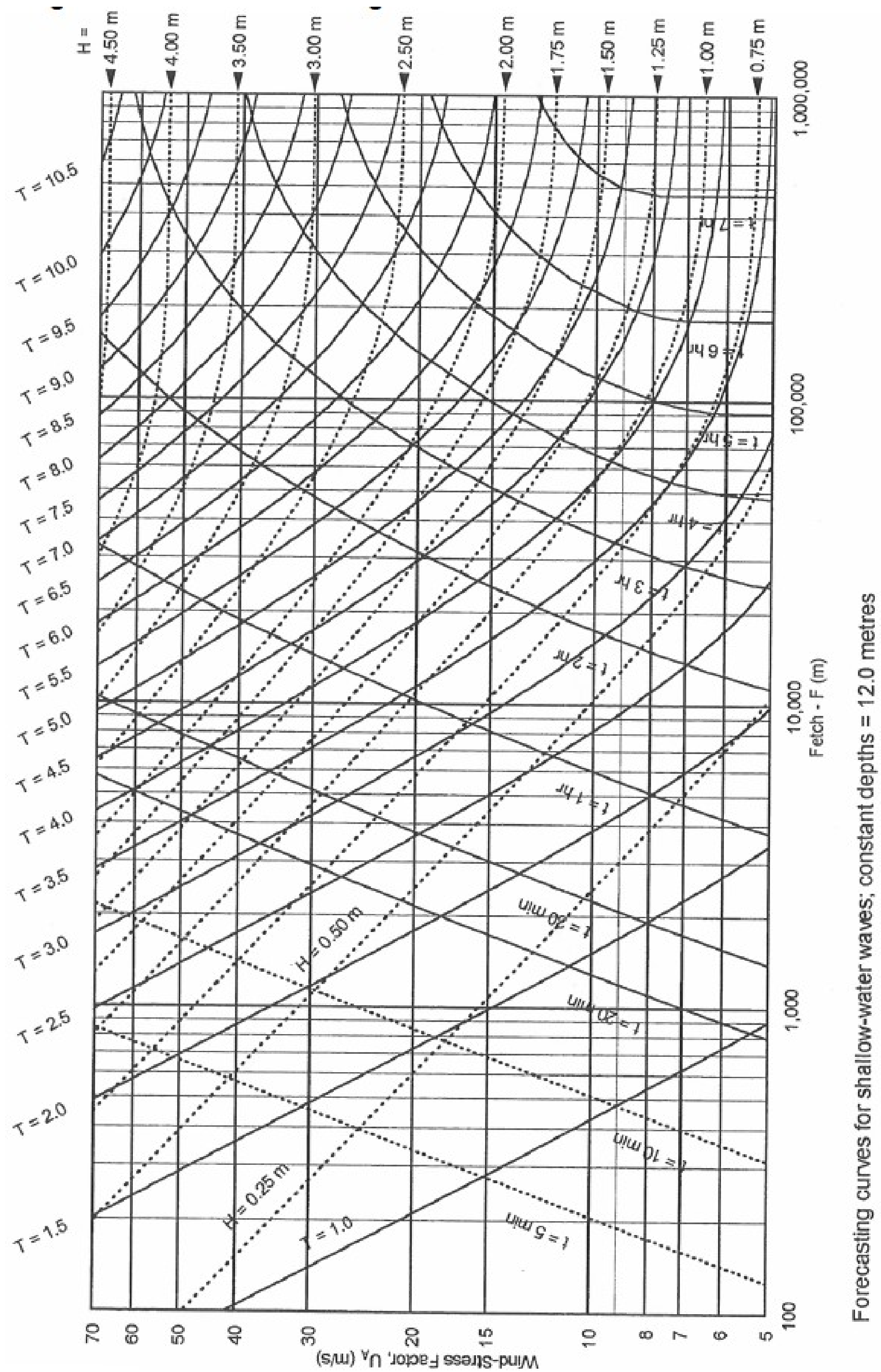
Source: U.S. Army Corps of Engineers (1984)

Design Chart 5.30: Forecasting Curves for Waves



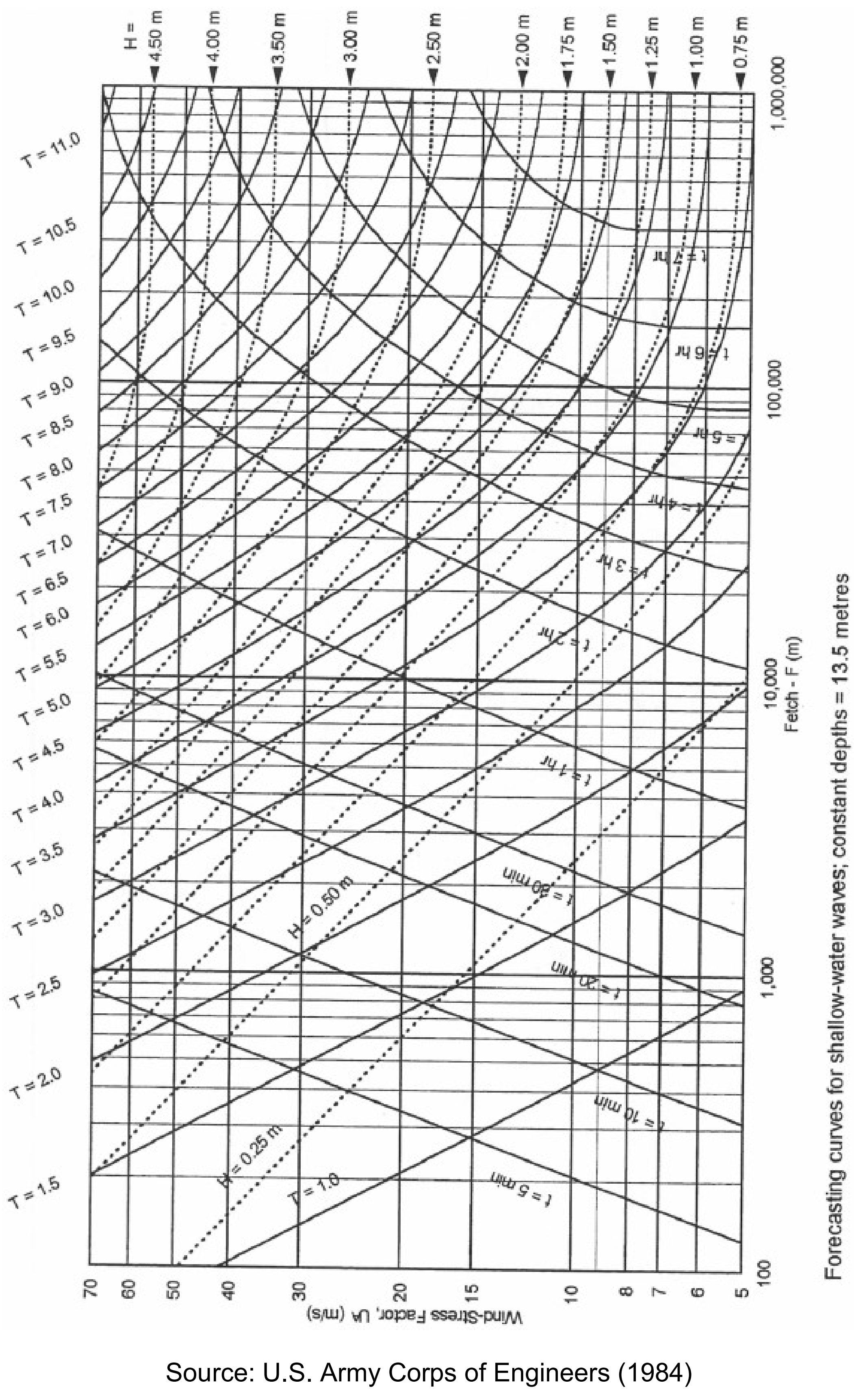
Source: U.S. Army Corps of Engineers (1984)

Design Chart 5.31: Forecasting Curves for Waves



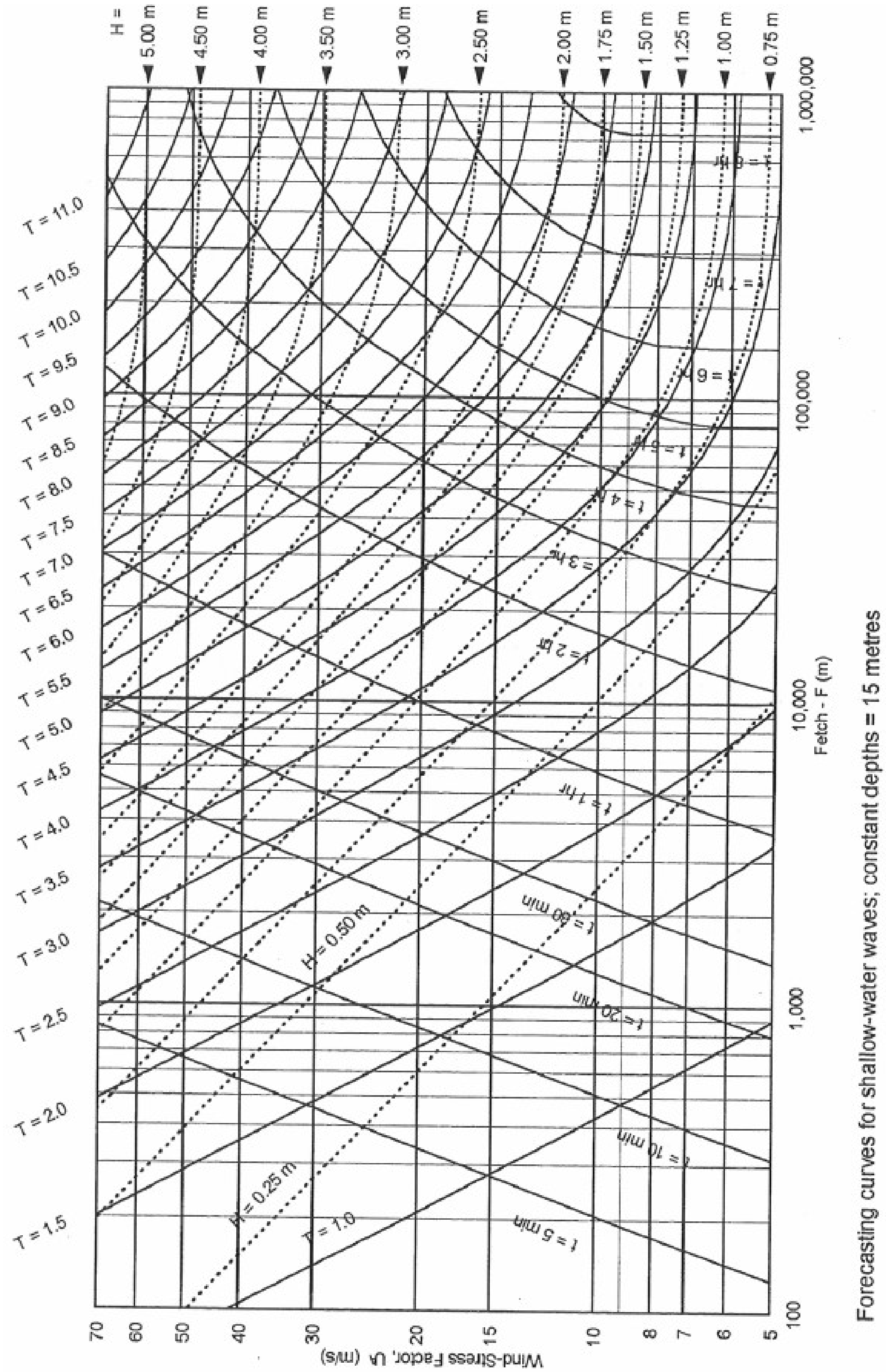
Source: U.S. Army Corps of Engineers (1984)

Design Chart 5.32: Forecasting Curves for Waves



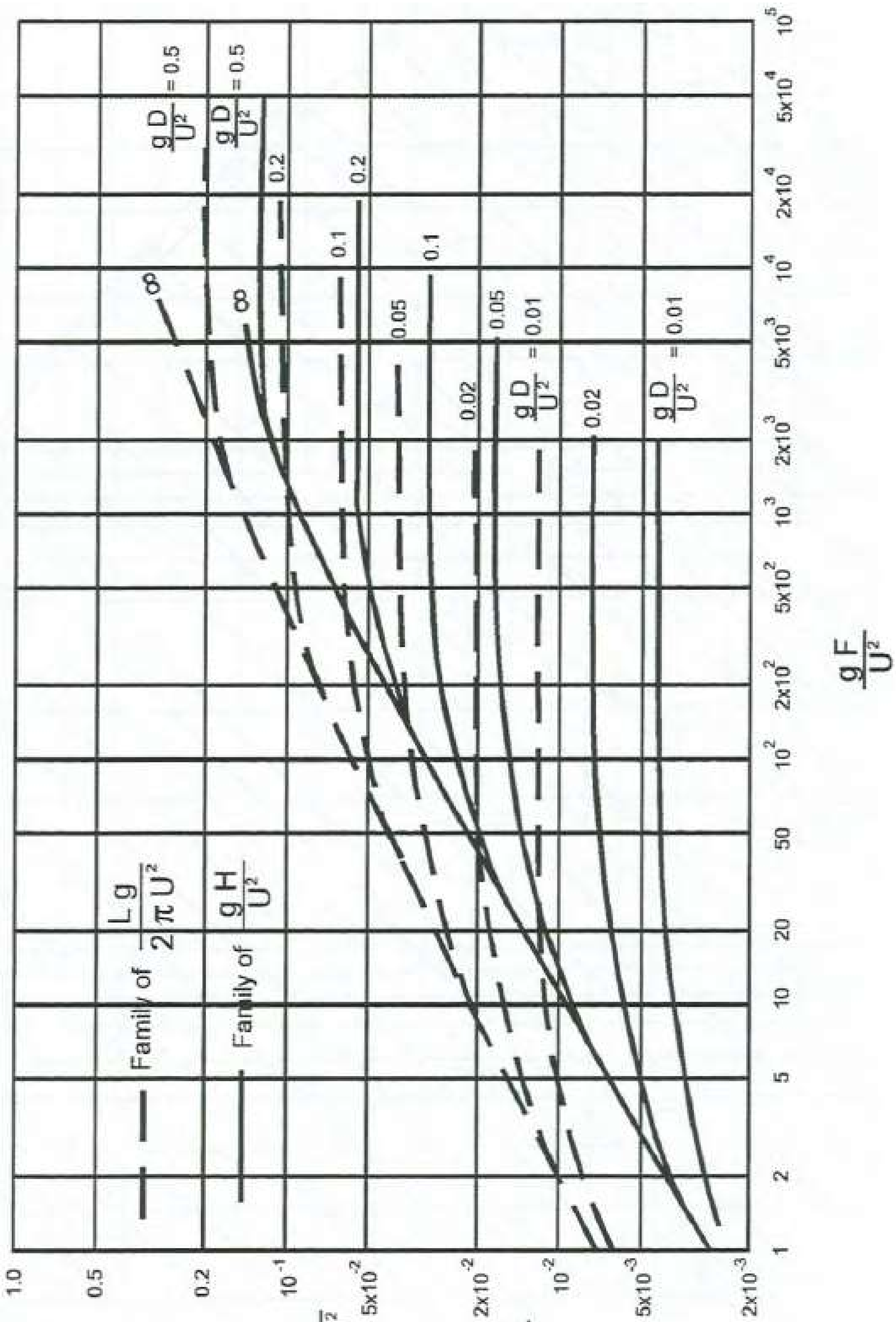
Source: U.S. Army Corps of Engineers (1984)

Design Chart 5.33: Forecasting Curves for Waves



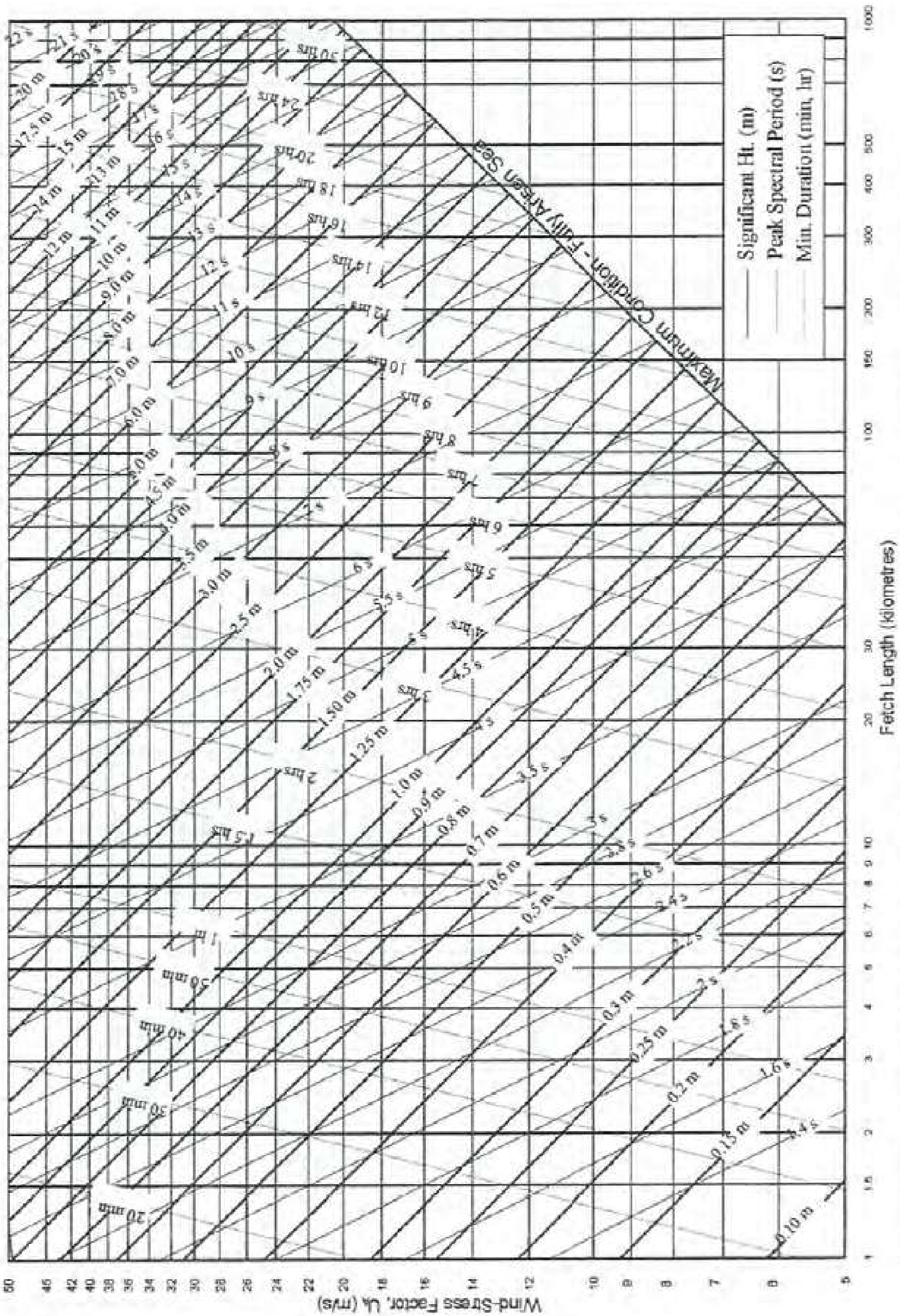
Source: U.S. Army Corps of Engineers (1984)

Design Chart 5.34: Wind - Wave Relationships



Source: (After Thijsse and Schijf)

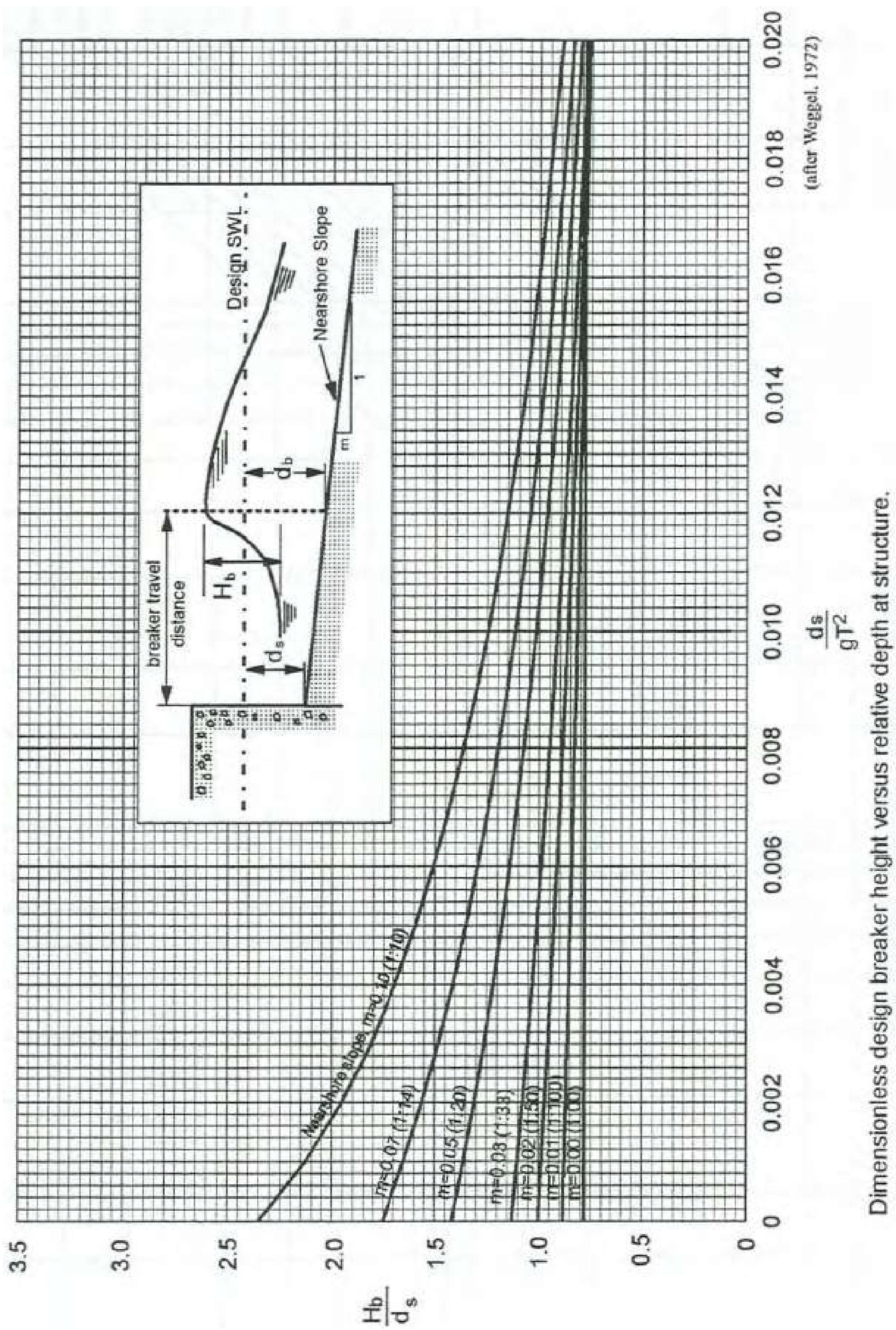
Design Chart 5.35: Significant Waves Prediction Curves



Nomograms of deepwater significant wave prediction curves as functions of windspeed, fetch length, and wind duration.

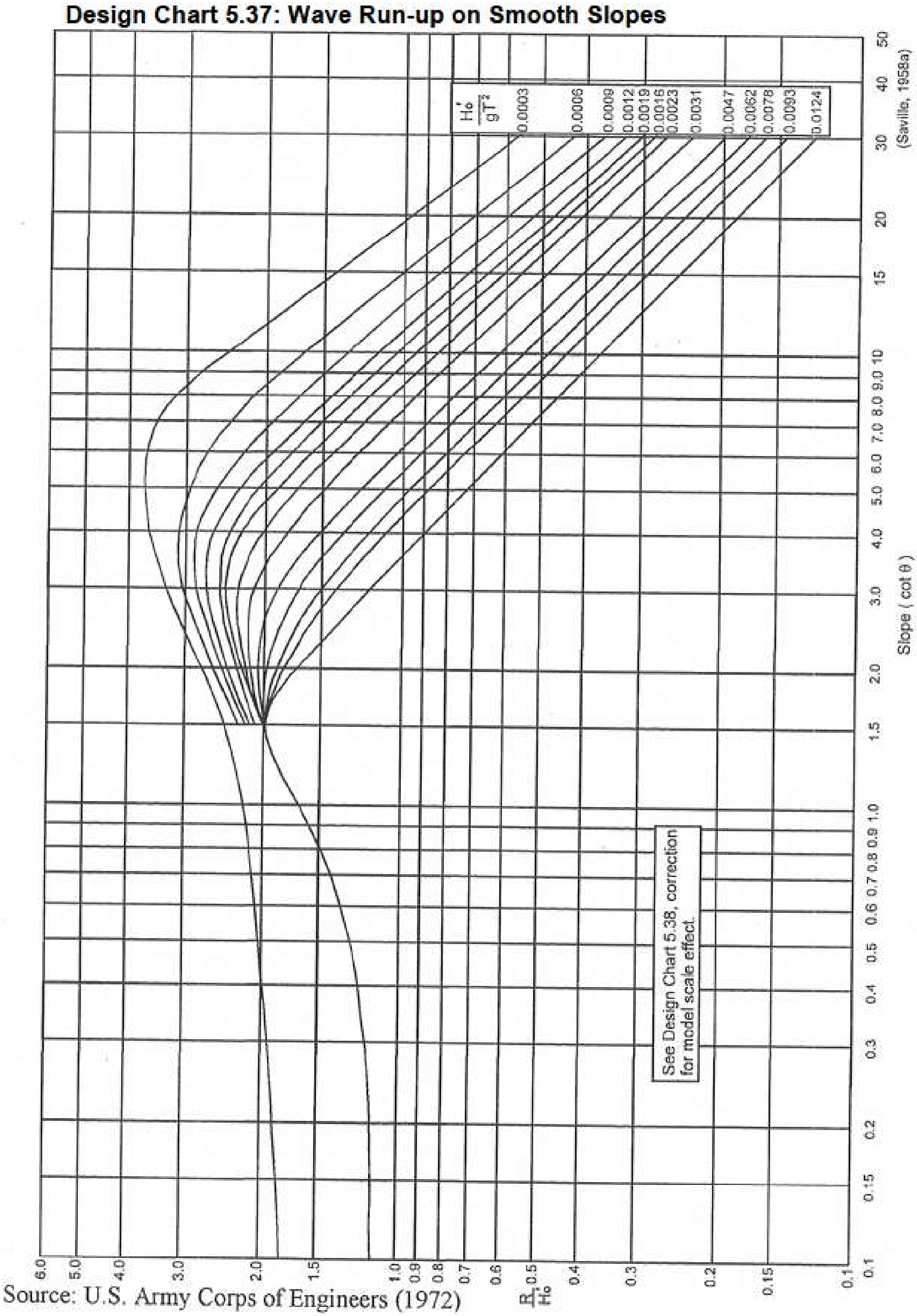
Source: U.S. Army Corps of Engineers (1984)

Design Chart 5.36: Dimensionless Breaker Height vs. Depth Relationship



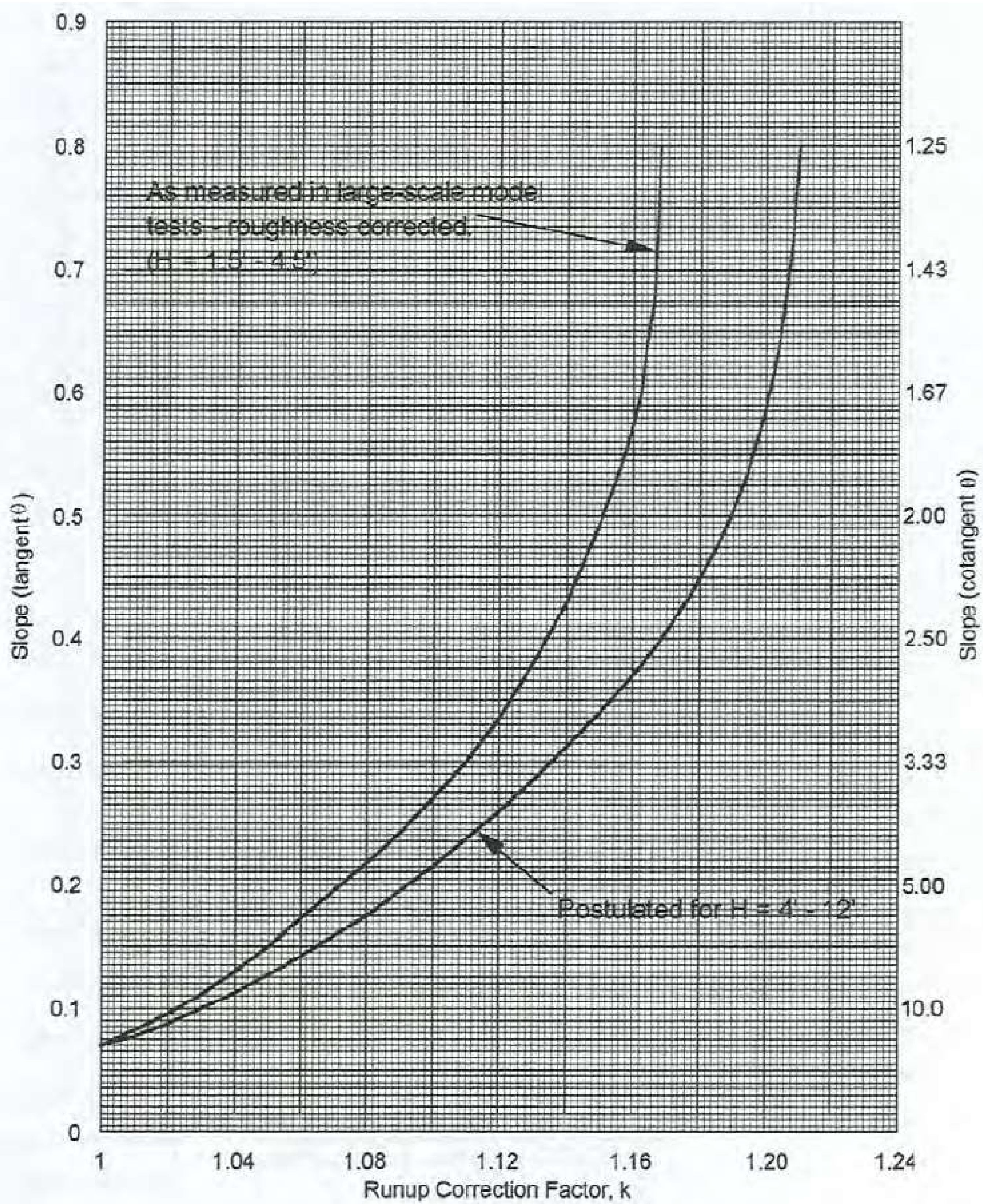
Source: U.S. Army Corps of Engineers (1984)

Design Chart 5.37: Wave Run-up on Smooth Slopes



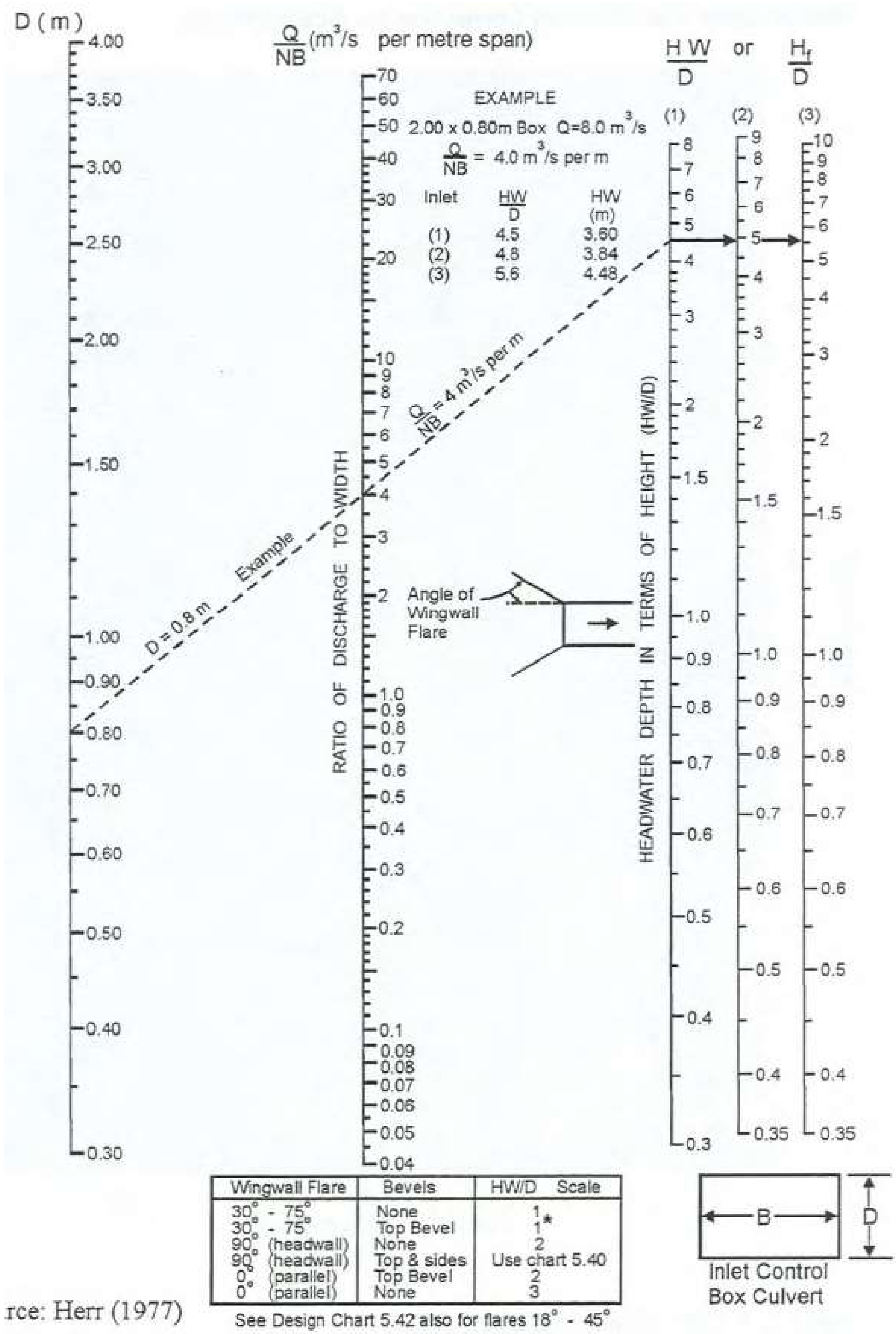
Source: U.S. Army Corps of Engineers (1972)

Design Chart 5.38: Run-up Correction for Scale Effects



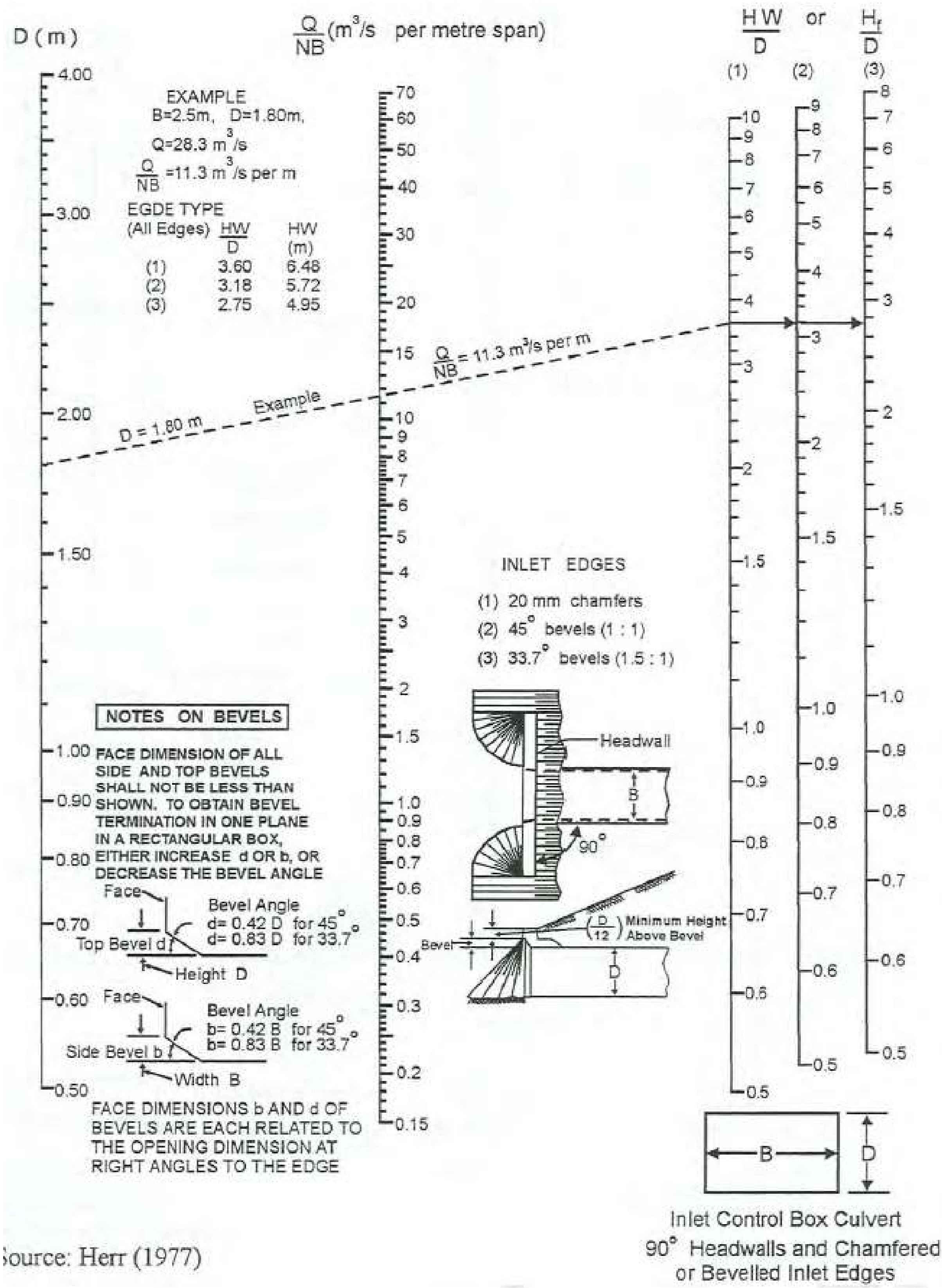
Source: U.S. Army Corps of Engineers (1984)

Design Chart 5.39: Inlet Control: Box Culvert



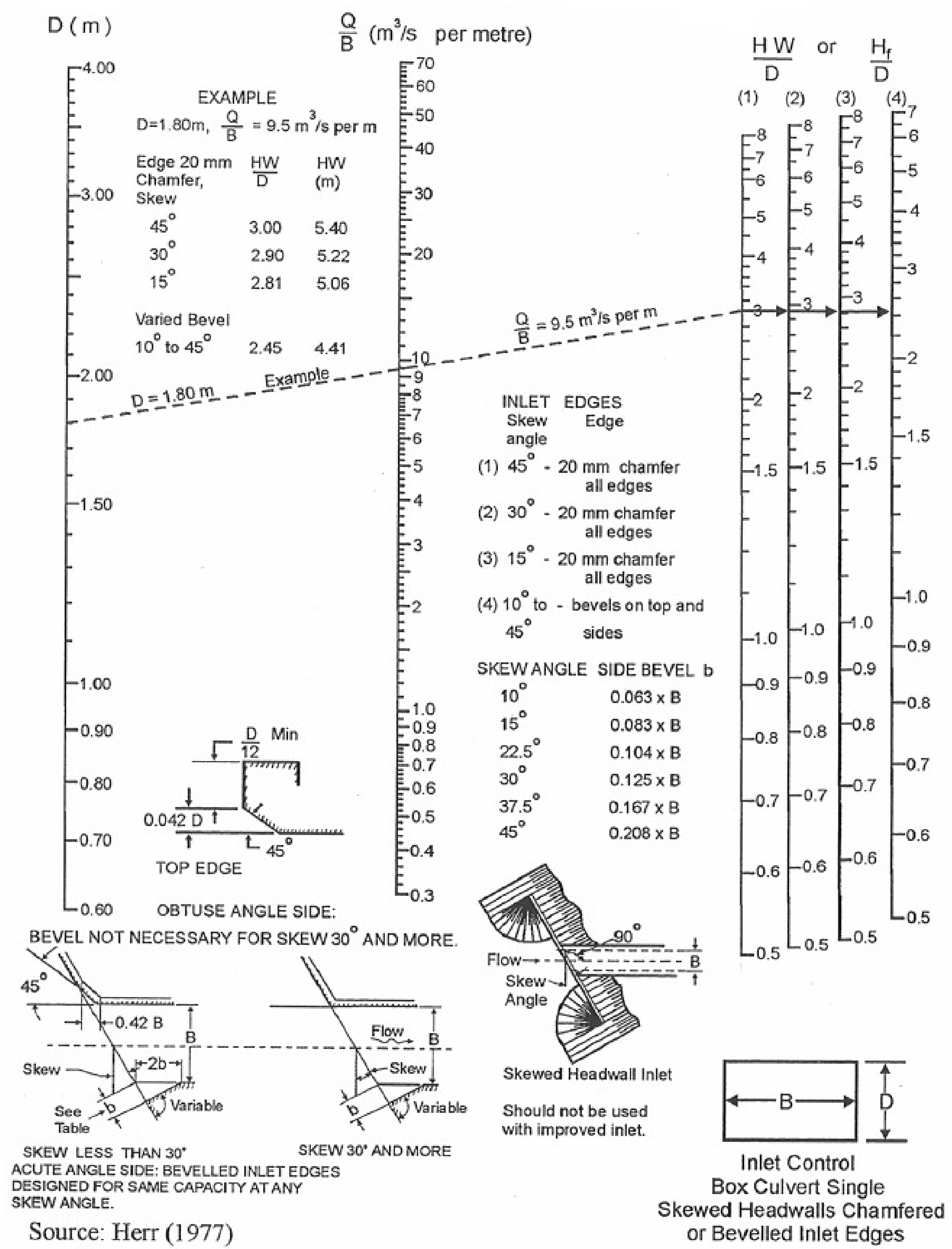
Source: Herr (1977)

Design Chart 5.40: Inlet Control: Box Culverts with Chamfered/Bevelled Edges



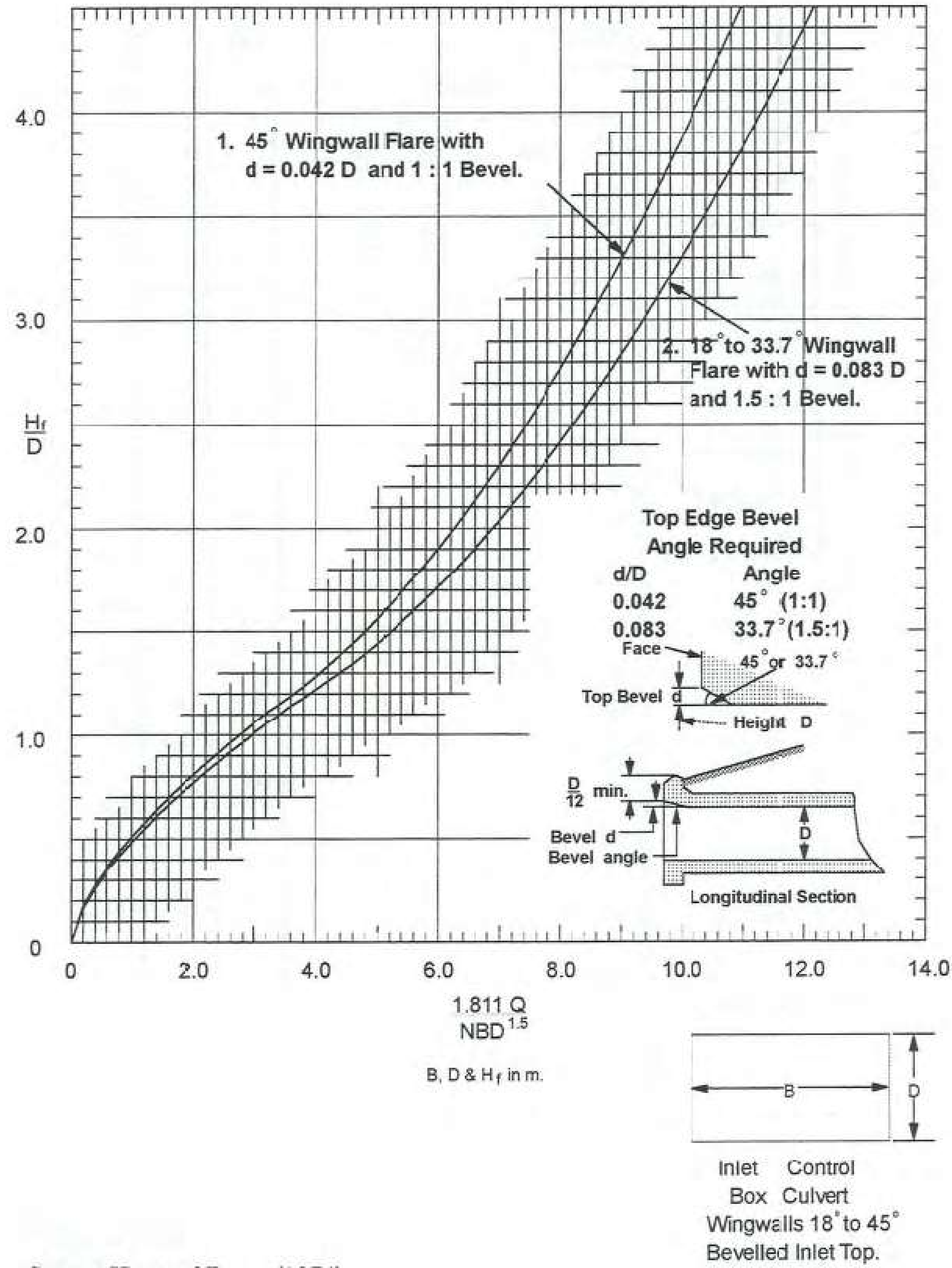
Source: Herr (1977)

Design Chart 5.41: Inlet Control: Box Culverts, Skewed Headwalls



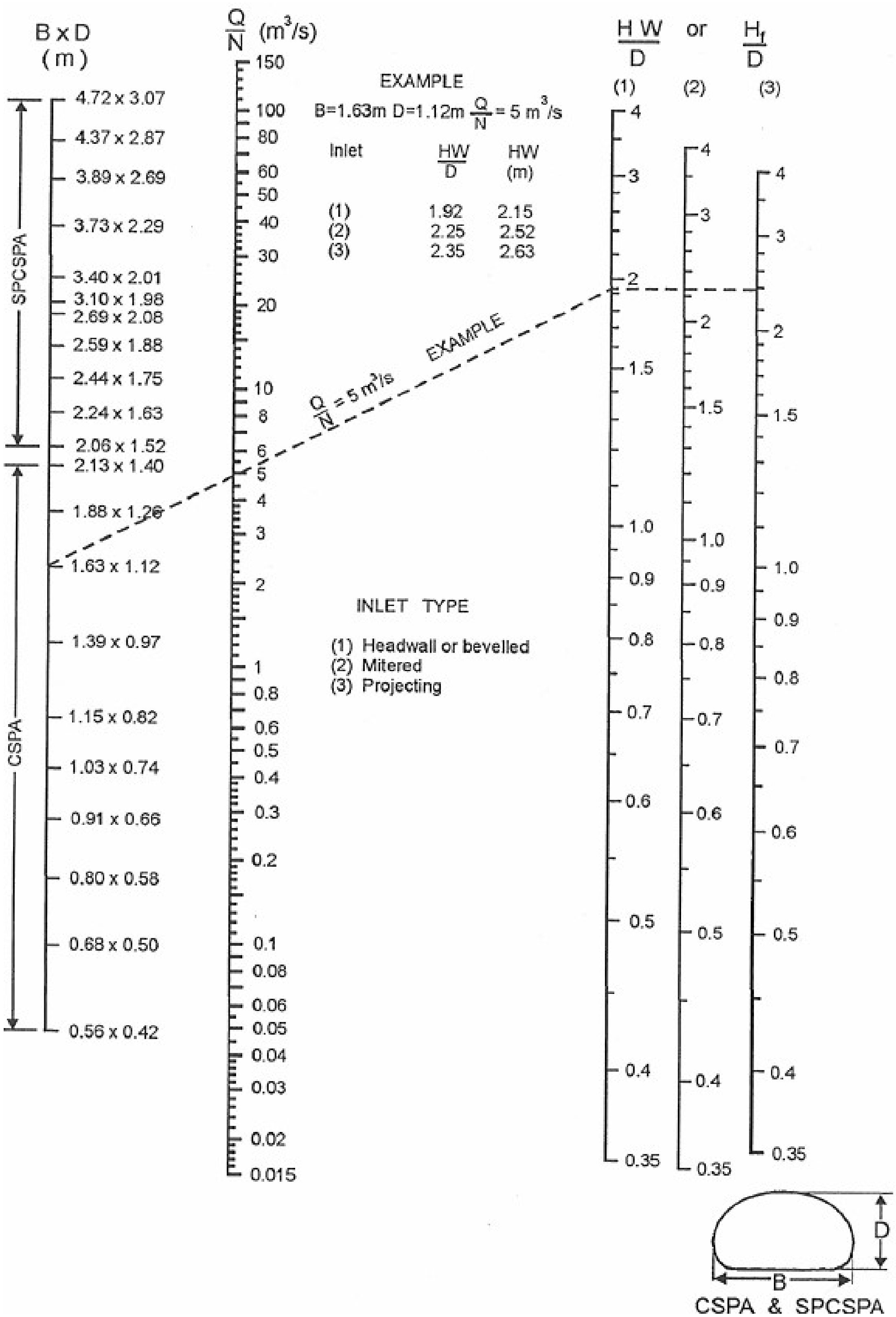
Source: Herr (1977)

Design Chart 5.42: Inlet Control Box Culverts, Wing Walls



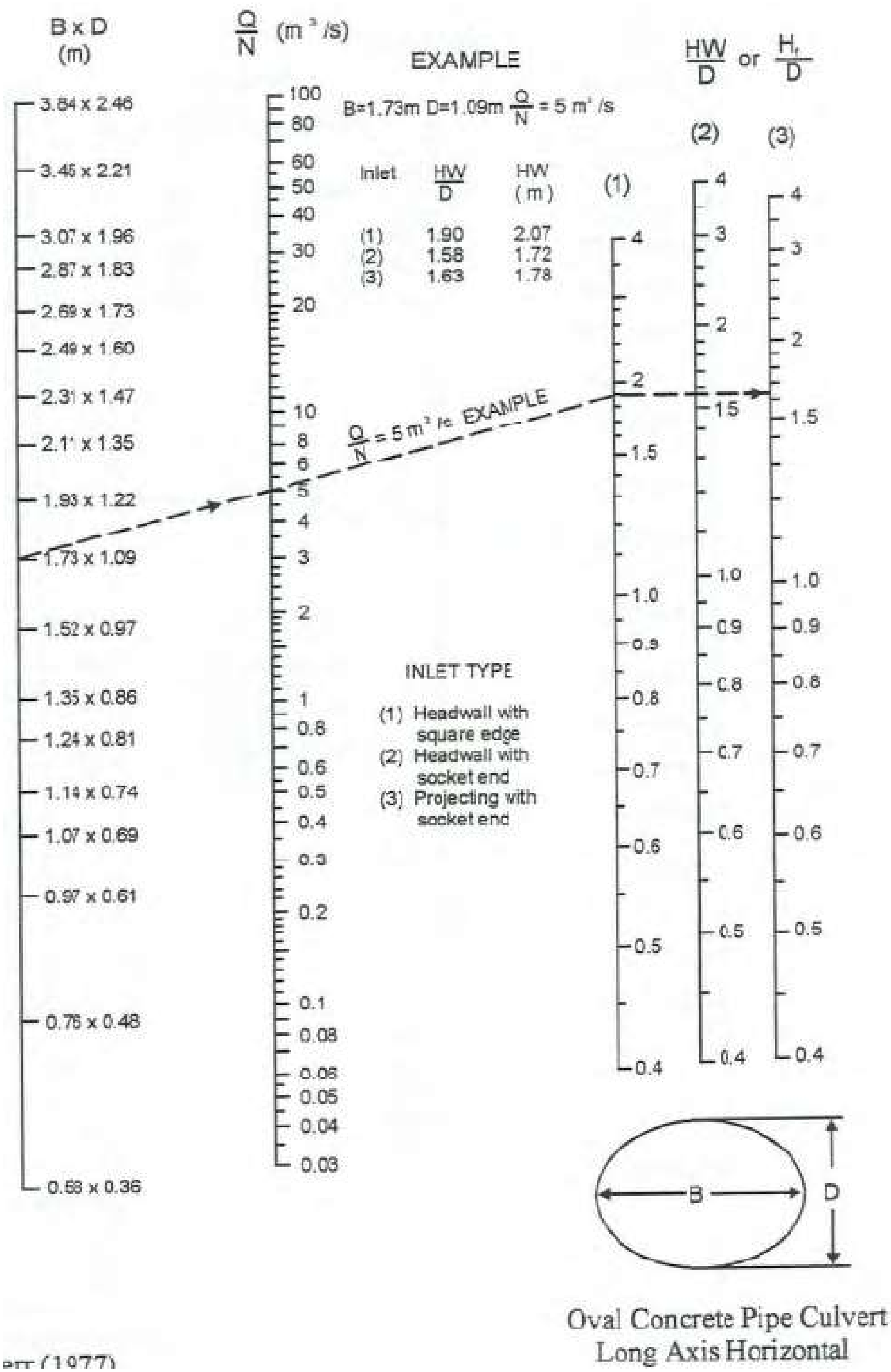
Source: Herr and Bossy (1974)

Design Chart 5.43: Inlet Control: Steel Pipe Arch Culverts



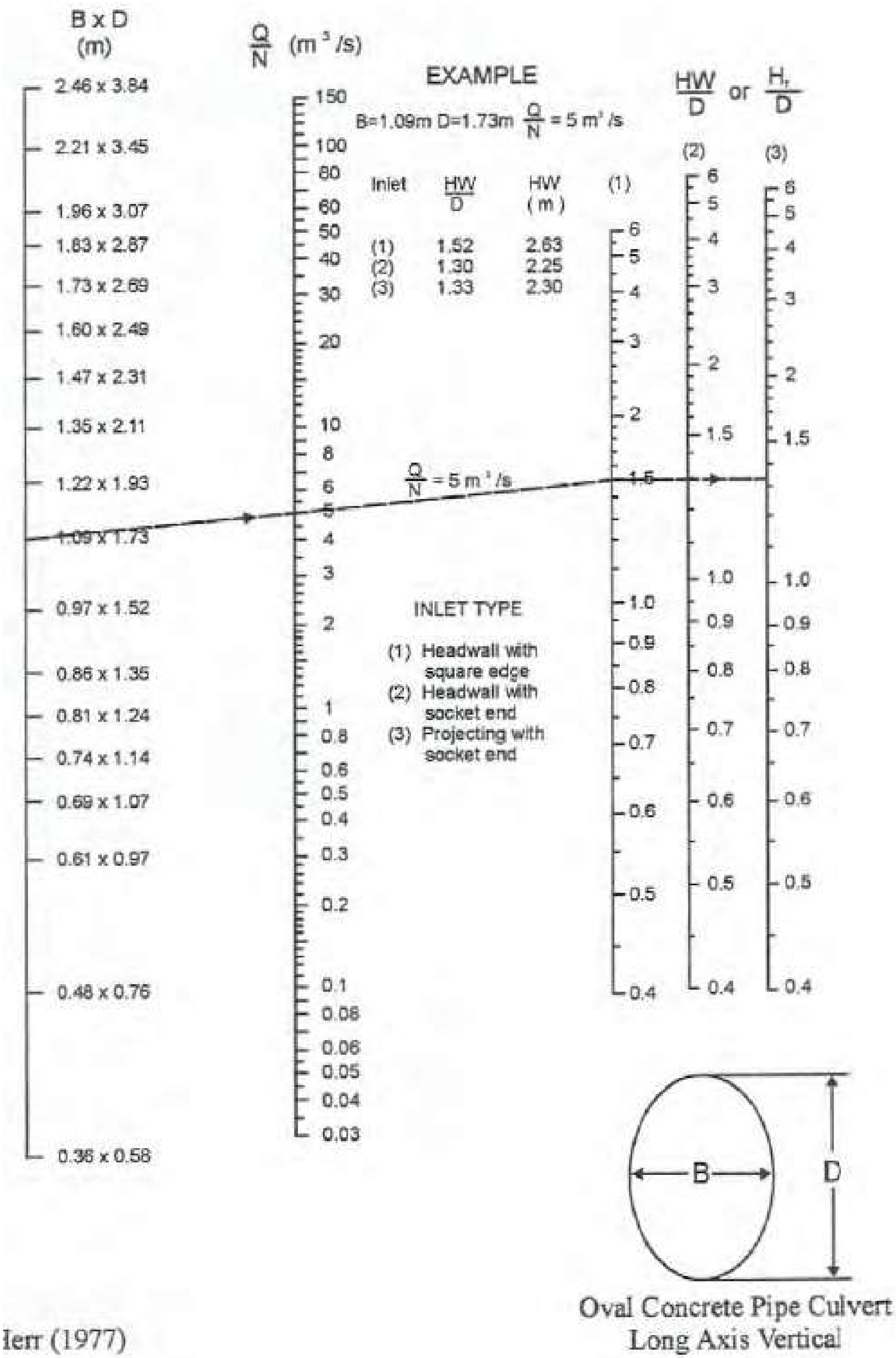
Source: Herr (1977)

Design Chart 5.44: Inlet Control: Concrete Horizontal Ellipse Culverts



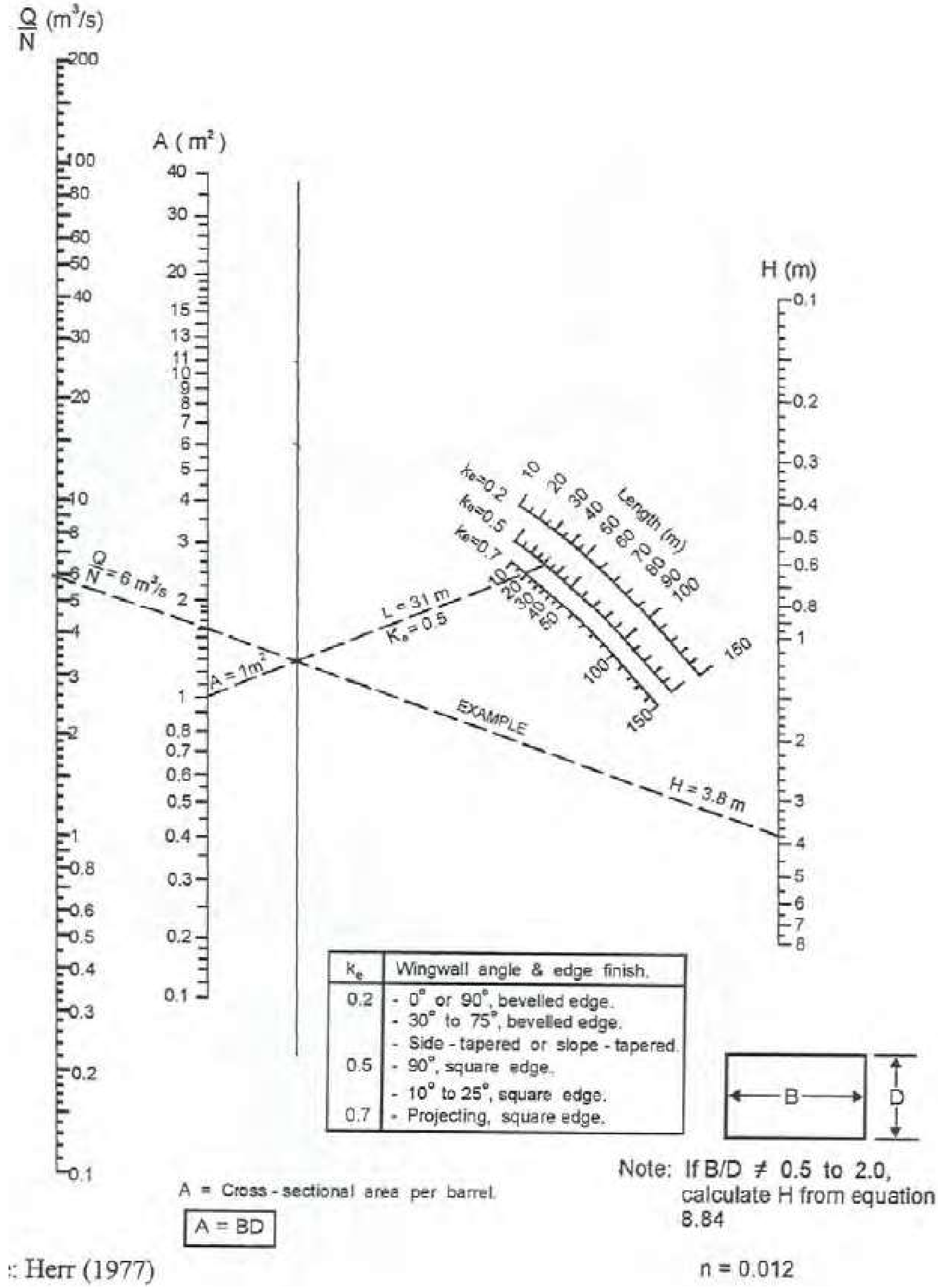
Source: Herr (1977)

Design Chart 5.45: Inlet Control: Concrete Vertical Ellipse Culverts



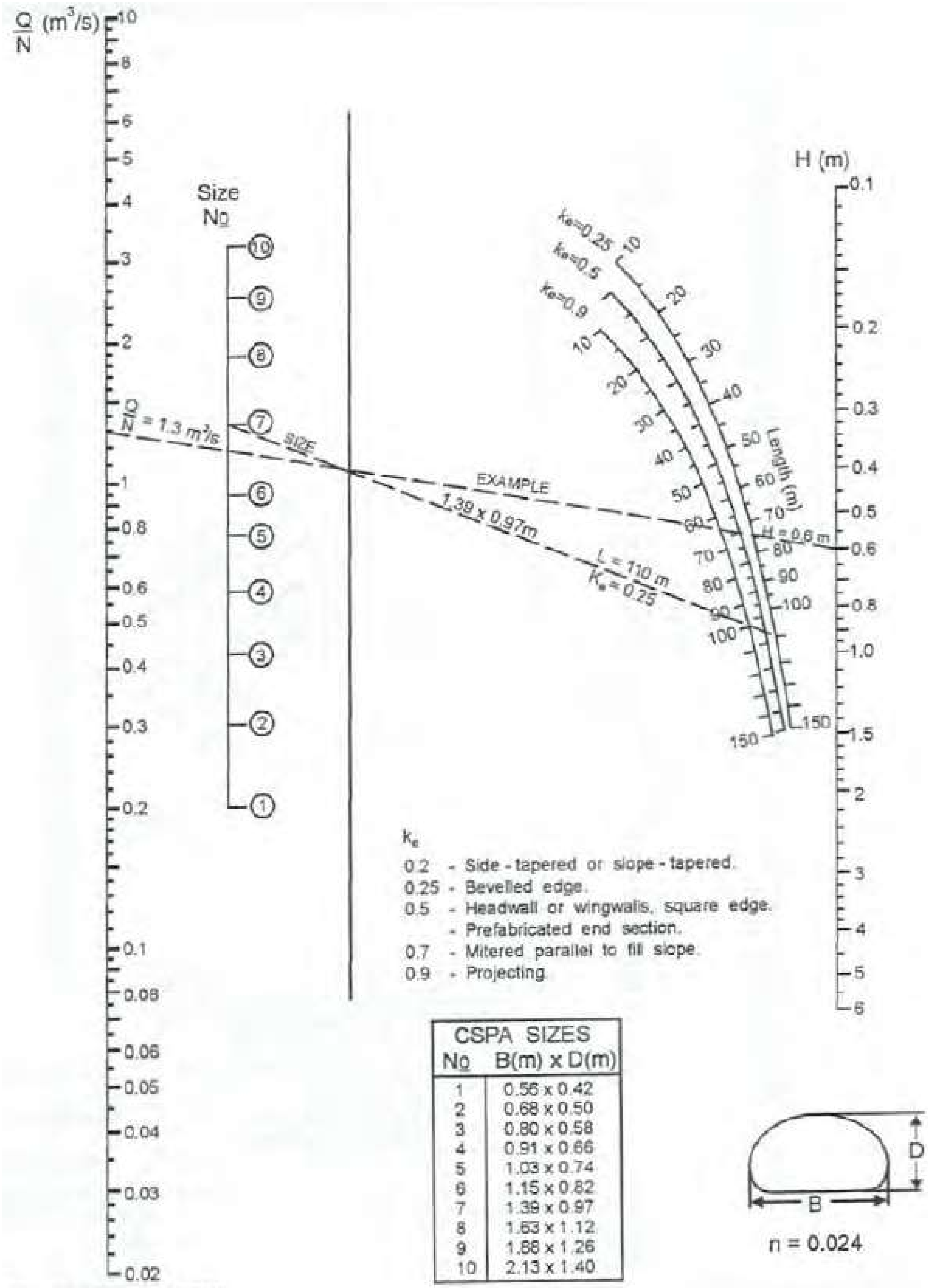
Source: Herr (1977)

Design Chart 5.46: Outlet Control: Concrete Box Culvert Flowing Full



Source: Herr (1977)

Design Chart 5.47: Outlet Control: Pipe Arch CSP Culvert - Flowing Full

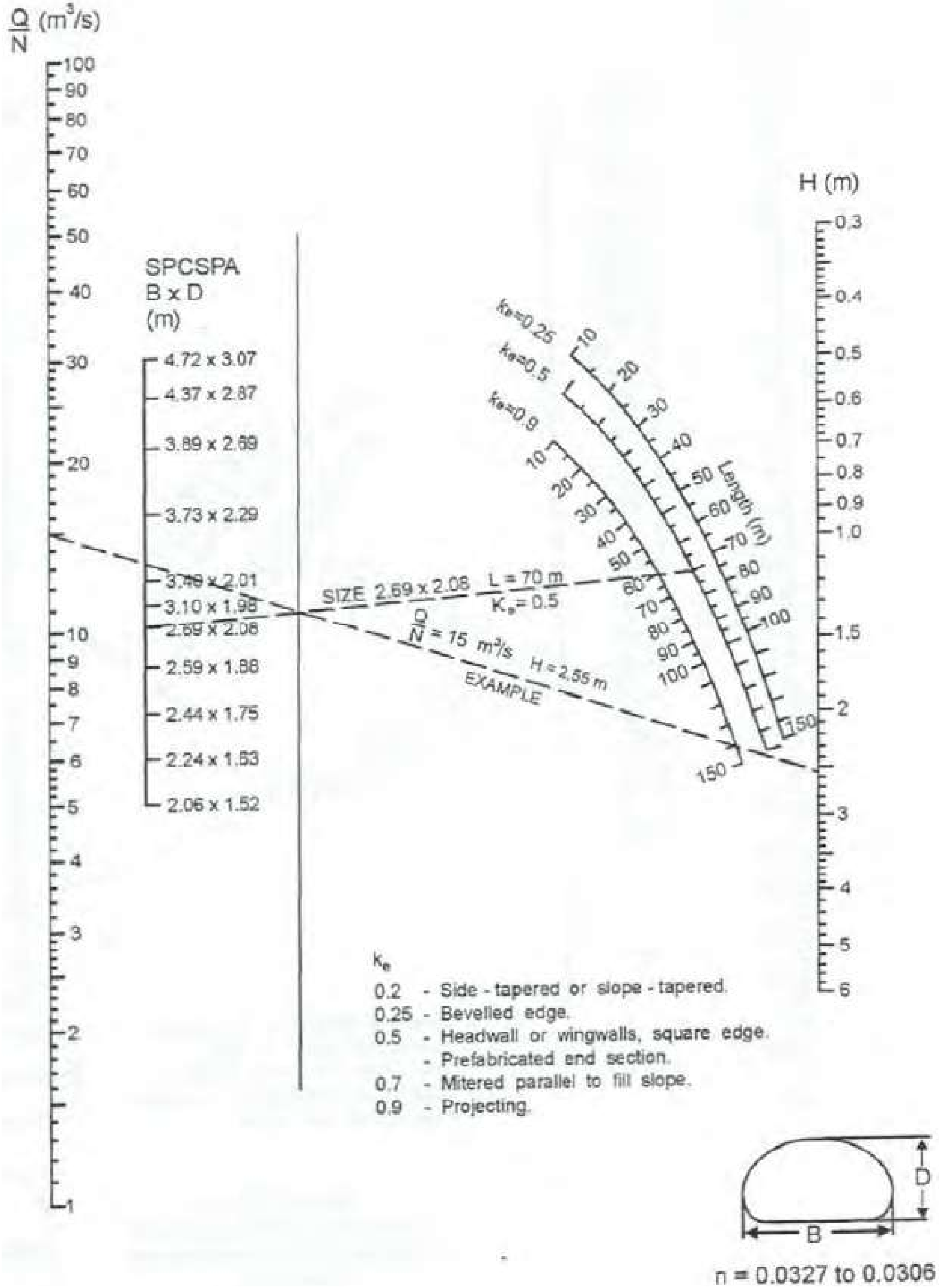


CSPA SIZES

No	B(m) x D(m)
1	0.56 x 0.42
2	0.68 x 0.50
3	0.80 x 0.58
4	0.91 x 0.66
5	1.03 x 0.74
6	1.15 x 0.82
7	1.39 x 0.97
8	1.63 x 1.12
9	1.88 x 1.26
10	2.13 x 1.40

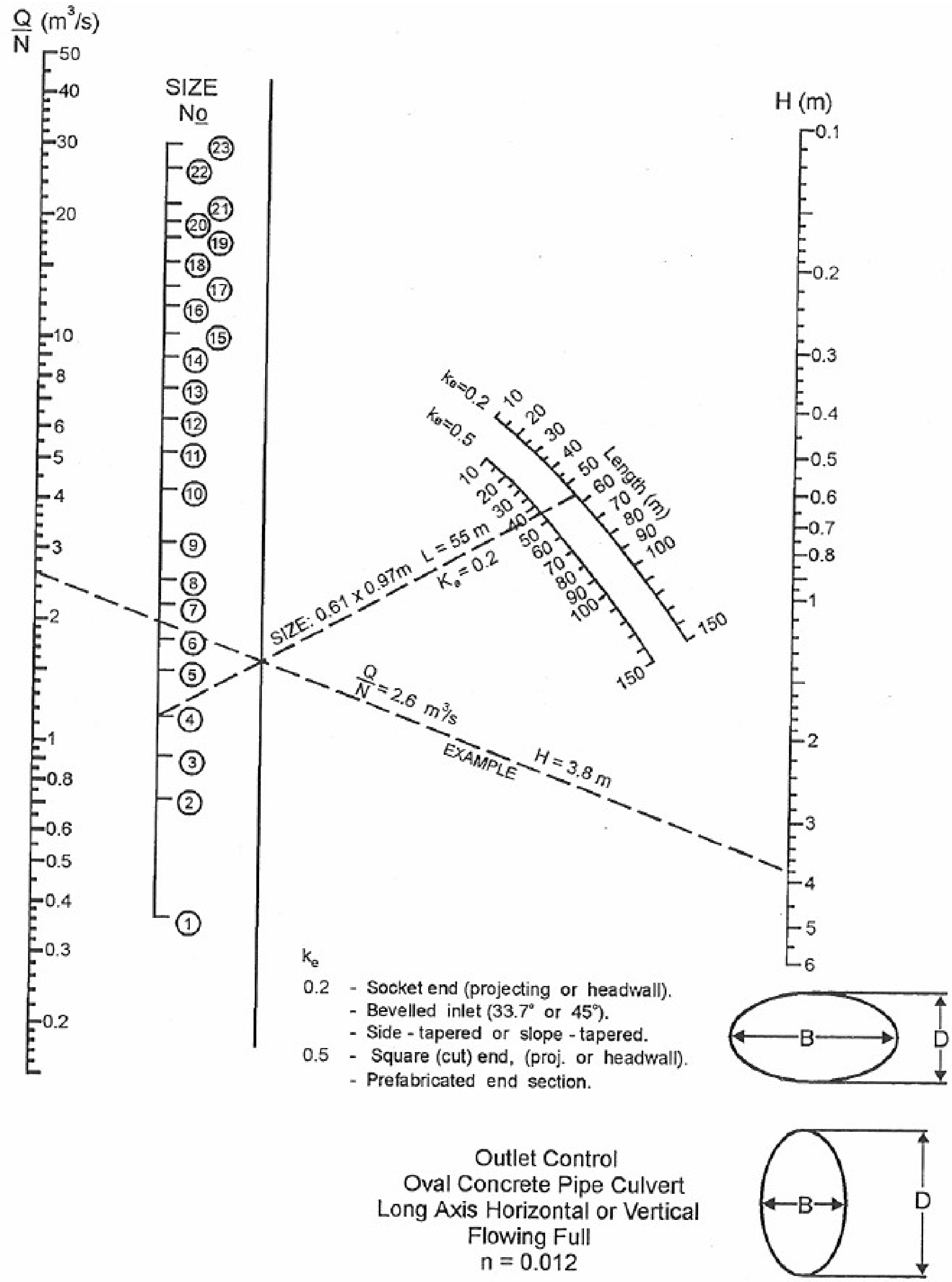
Source: Herr (1977)

Design Chart 5.48: Outlet Control: Pipe Arch SPCSP Culvert - Flowing Full



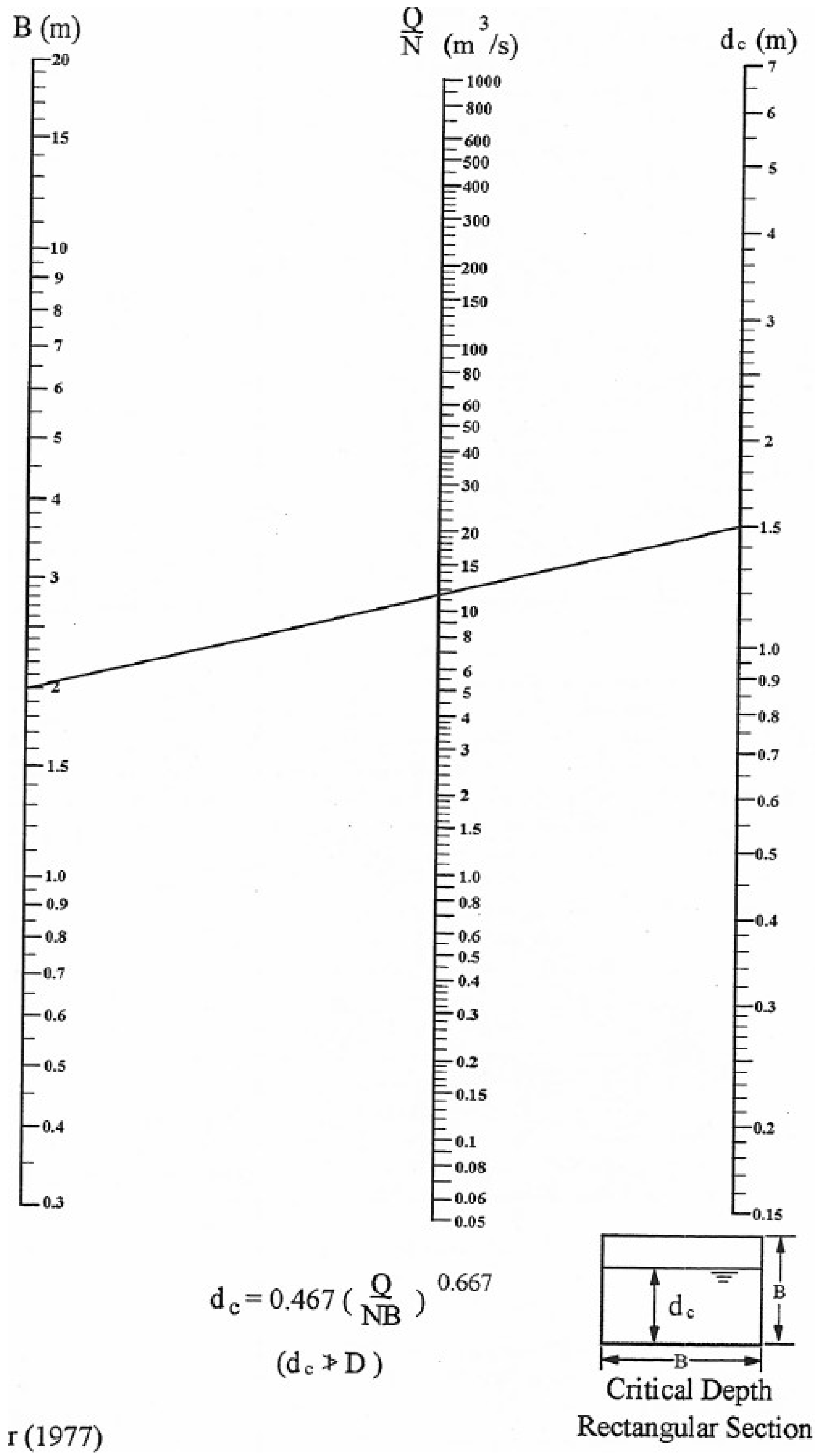
Source: Herr (1977)

Design Chart 5.49: Outlet Control: Elliptical Concrete Culvert



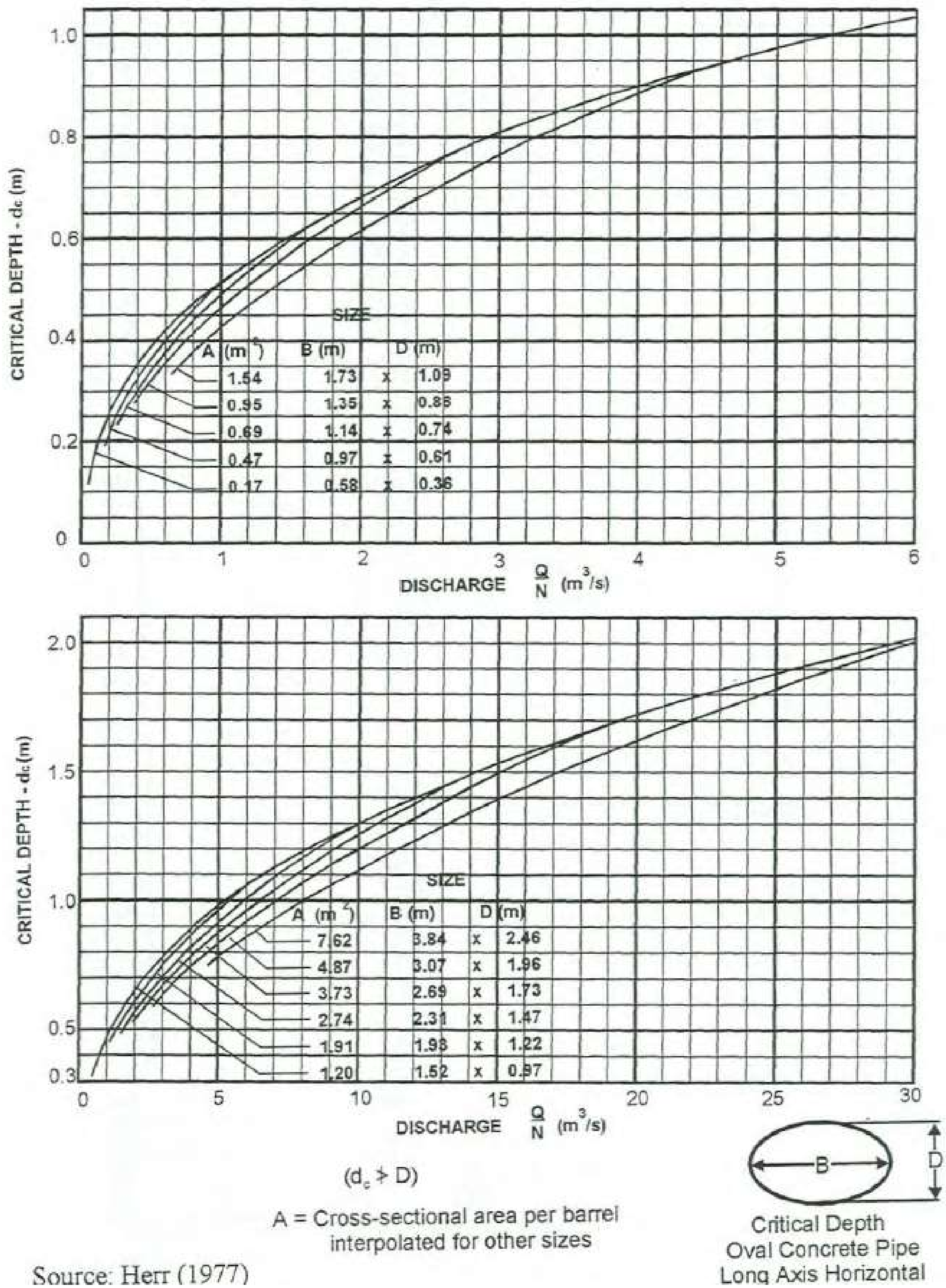
Source: Herr (1977)

Design Chart 5.50: Critical Depth - Rectangular Sections



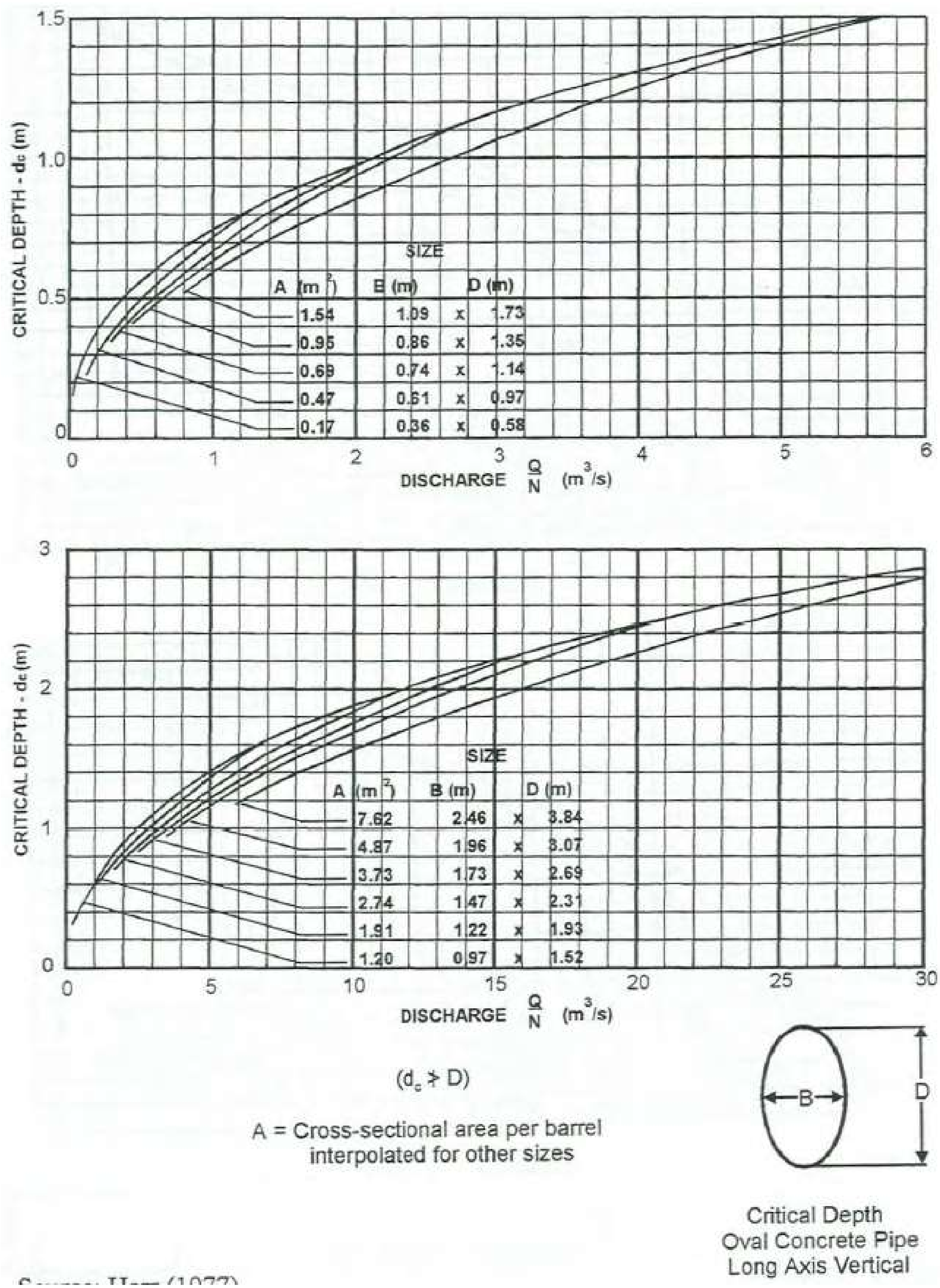
Source: Herr (1977)

Design Chart 5.51: Critical Depth: Horizontal Ellipse Concrete Pipes



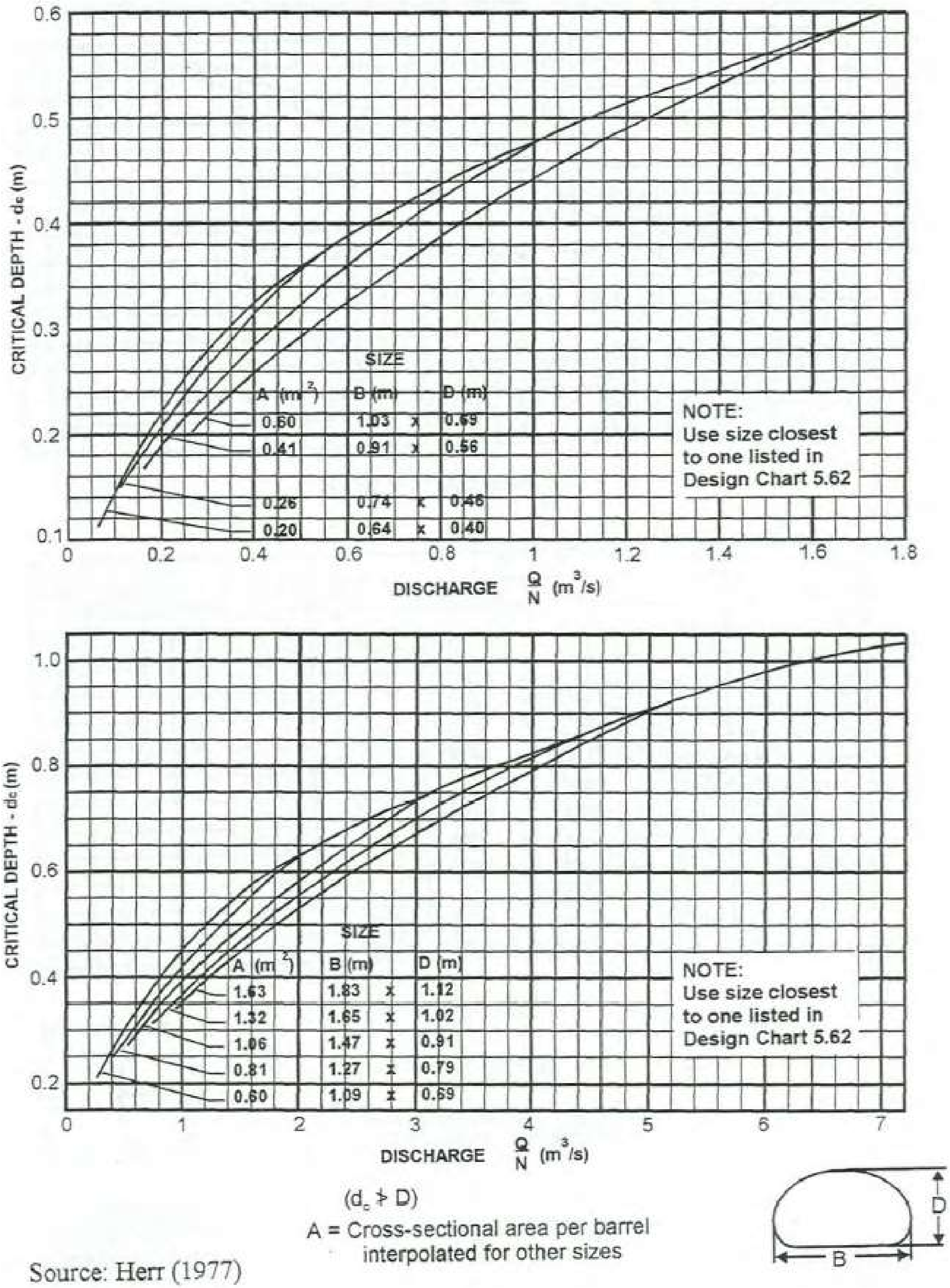
Source: Herr (1977)

Design Chart 5.52: Critical Depth: Vertical Ellipse Concrete Pipes



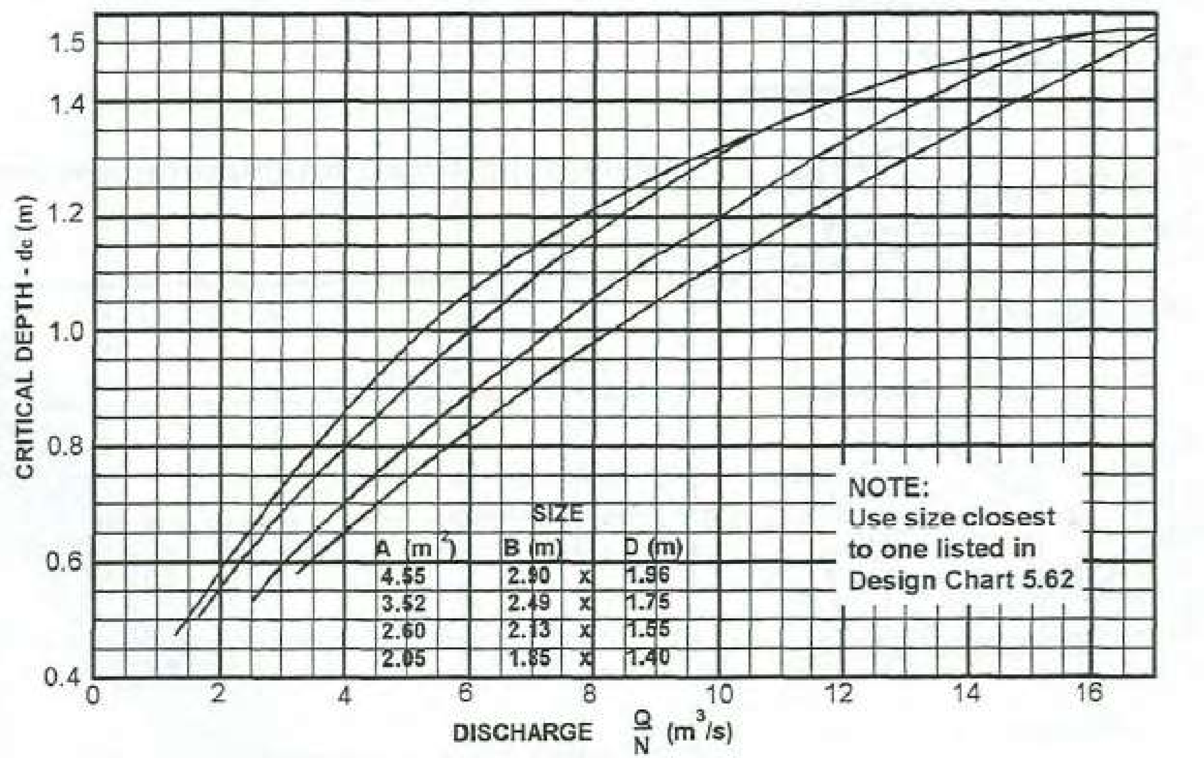
Source: Herr (1977)

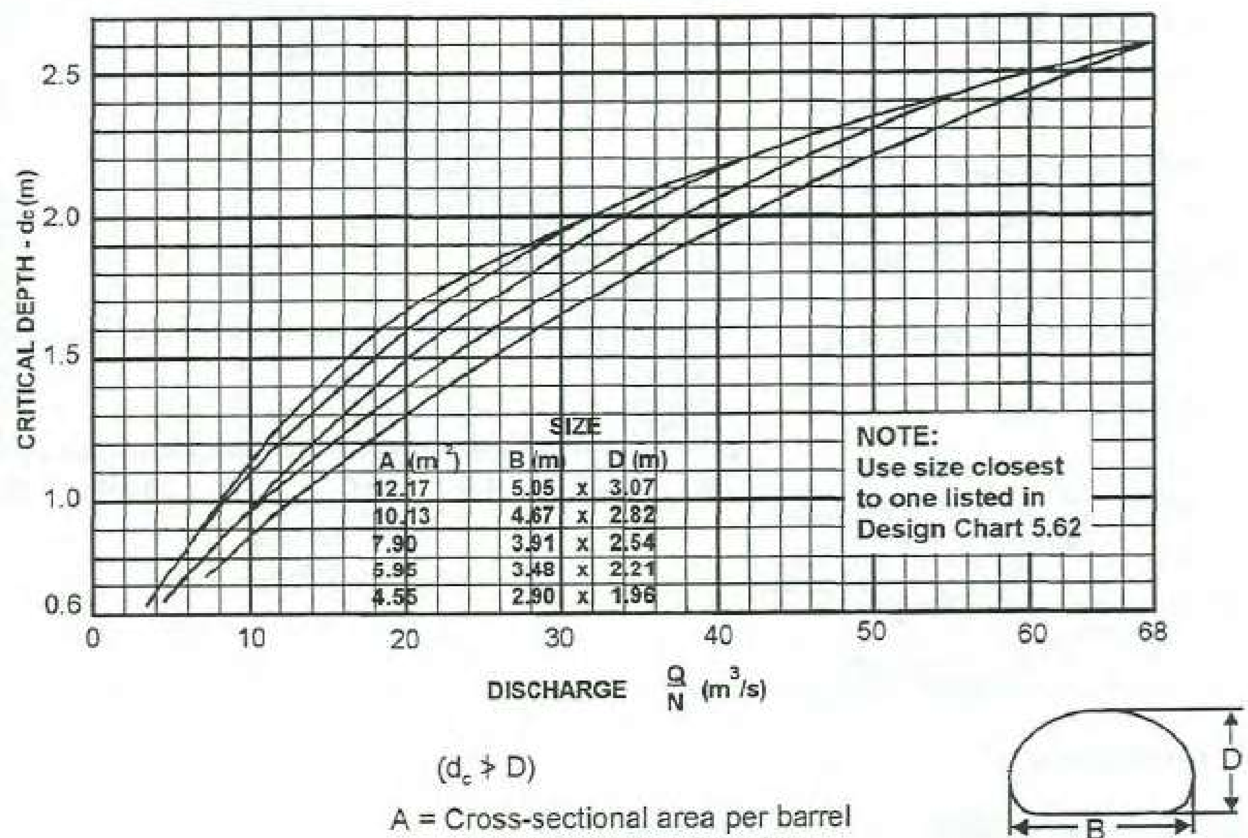
Design Chart 5.53: Critical Depth: CSP Pipe Arch Culverts



Source: Herr (1977)

Design Chart 5.54: Critical Depth: SPCSP Pipe Arch Culverts



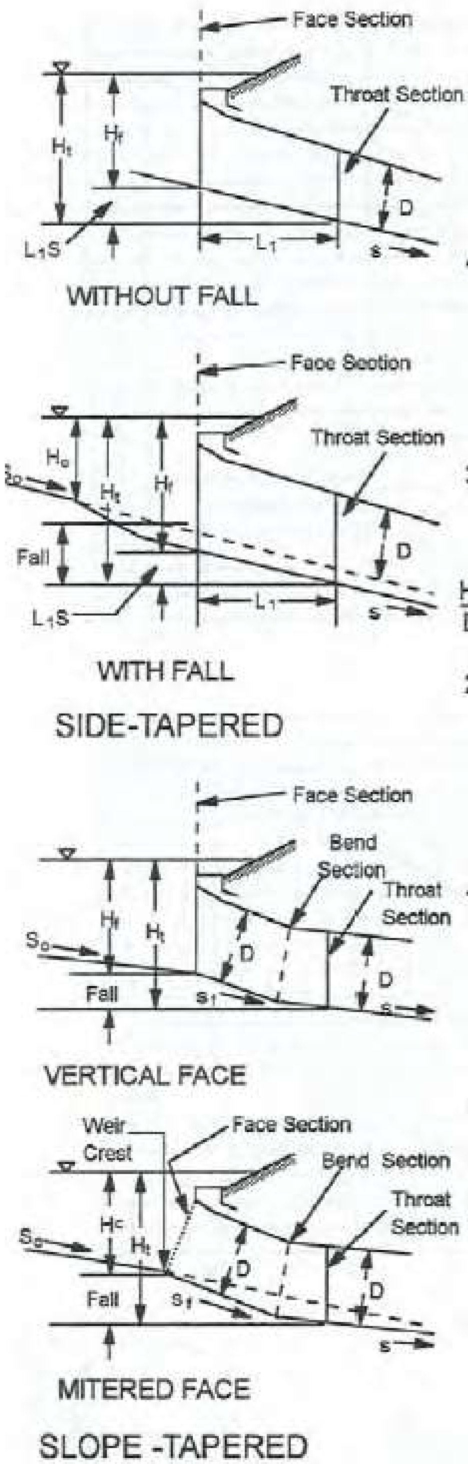


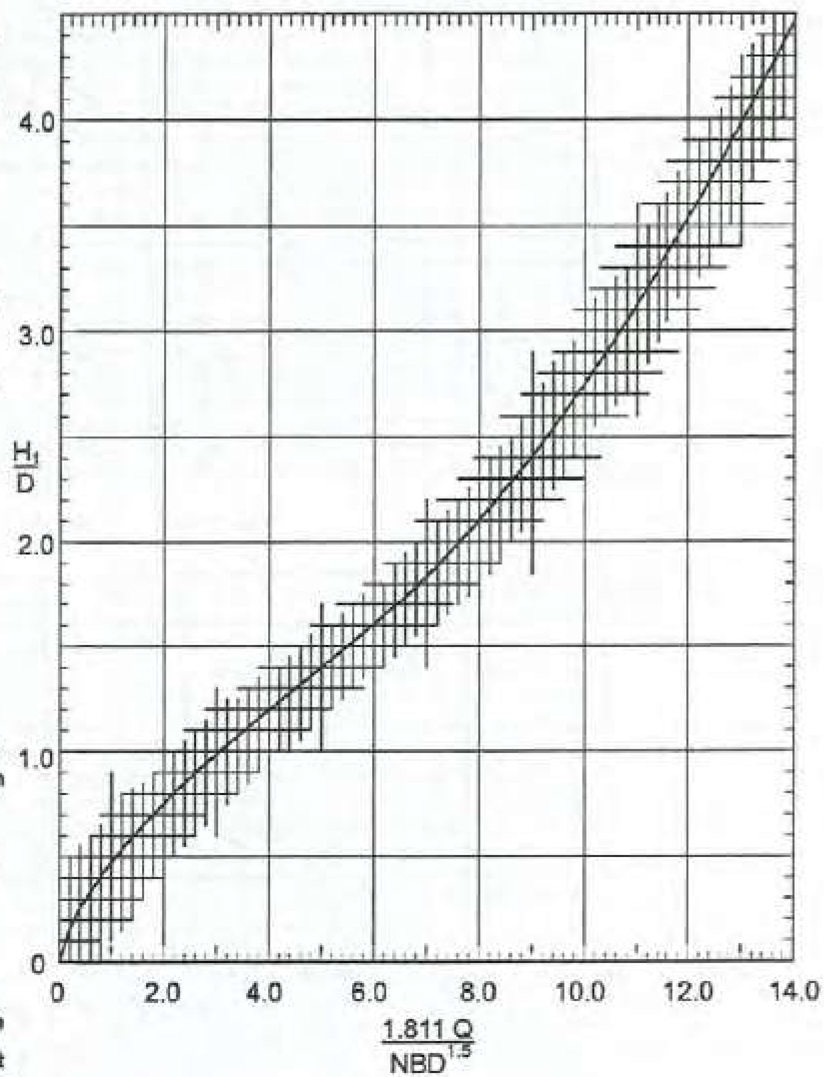
($d_c \ngtr D$)

A = Cross-sectional area per barrel interpolated for other sizes

Source: Herr (1977)

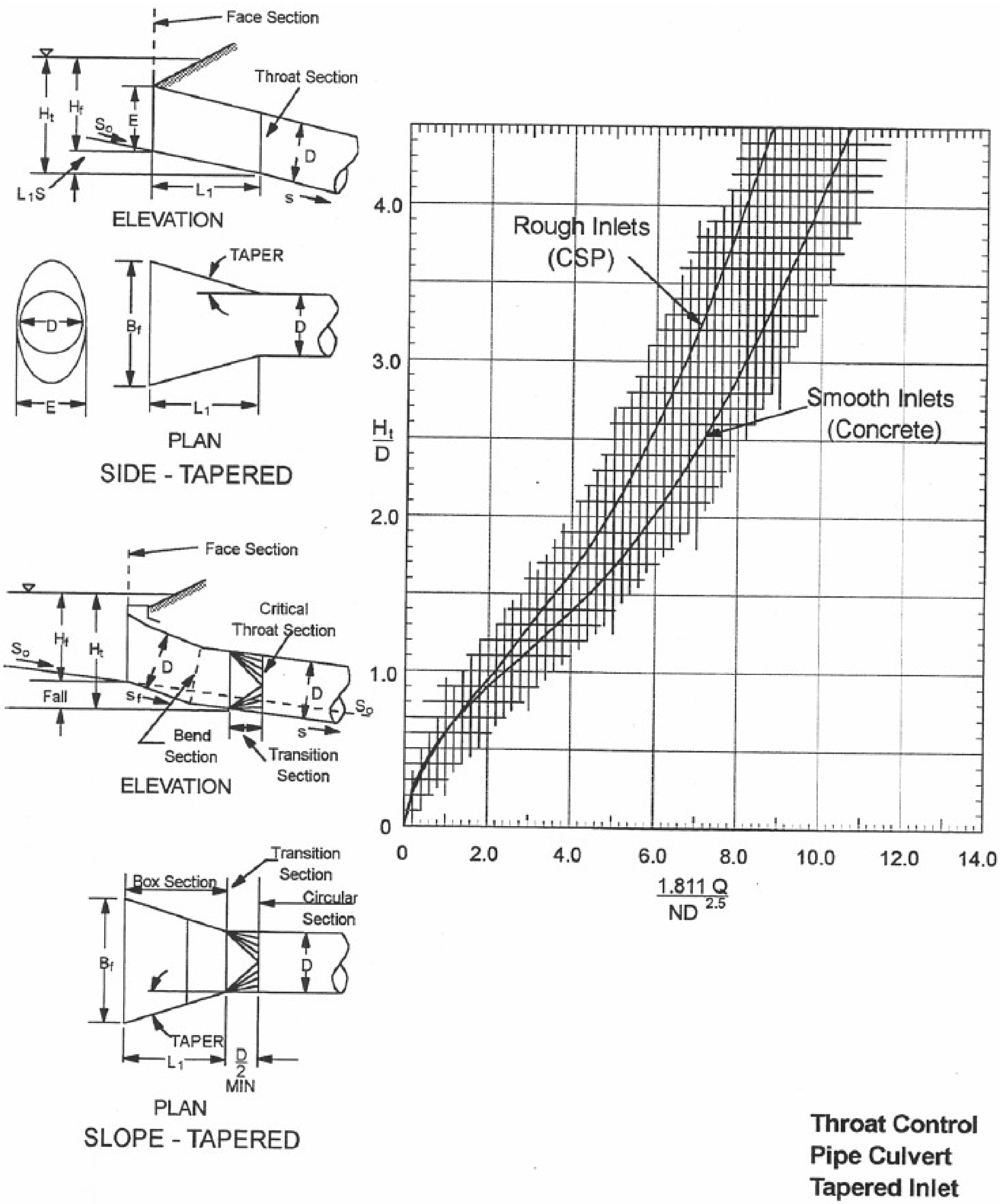
Design Chart 5.55 Tapered Inlets: Throat Control - Box Culverts





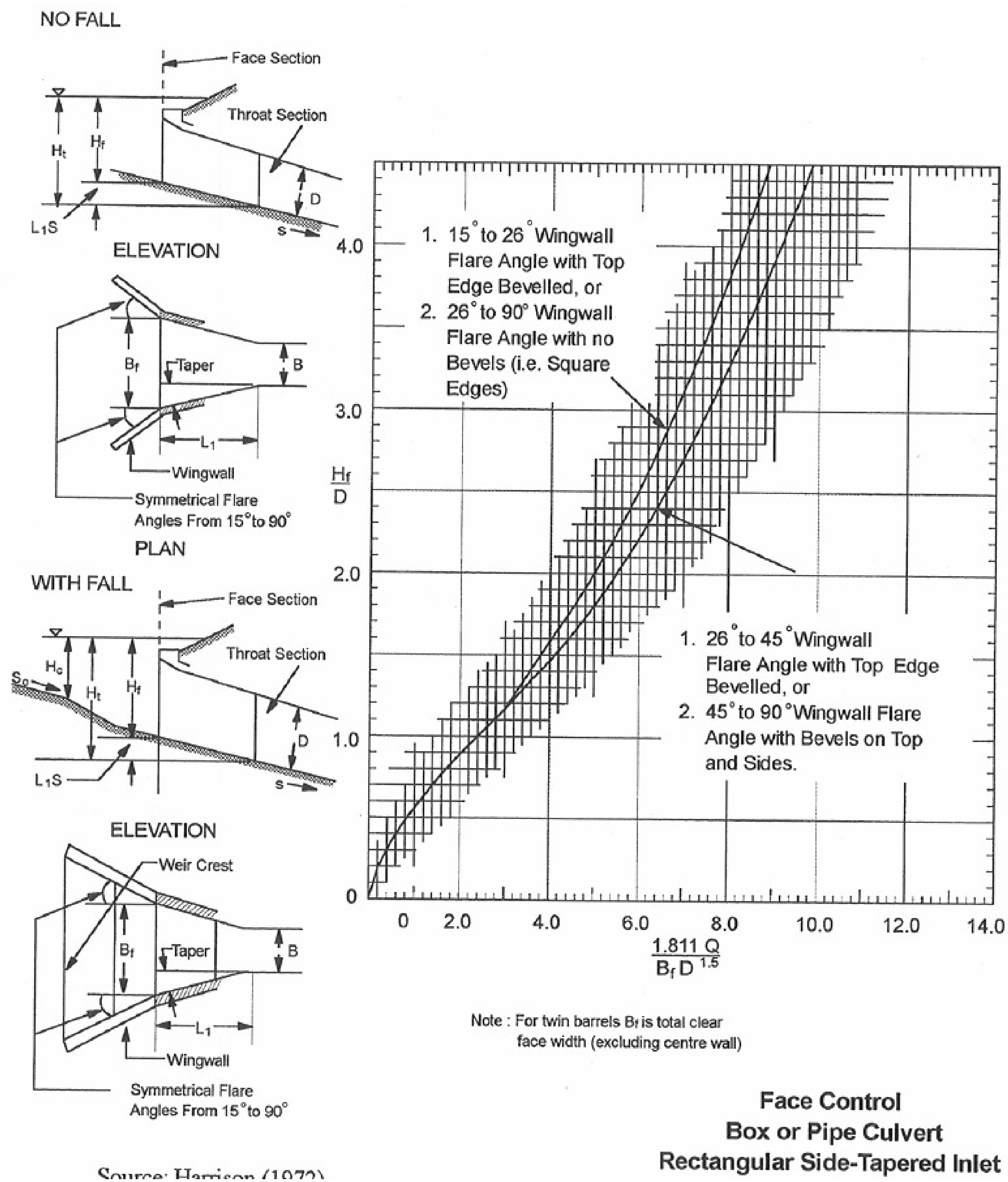
Source: Harrison (1972)

Design Chart 5.56: Tapered Inlets: Throat Control - Circular Culverts



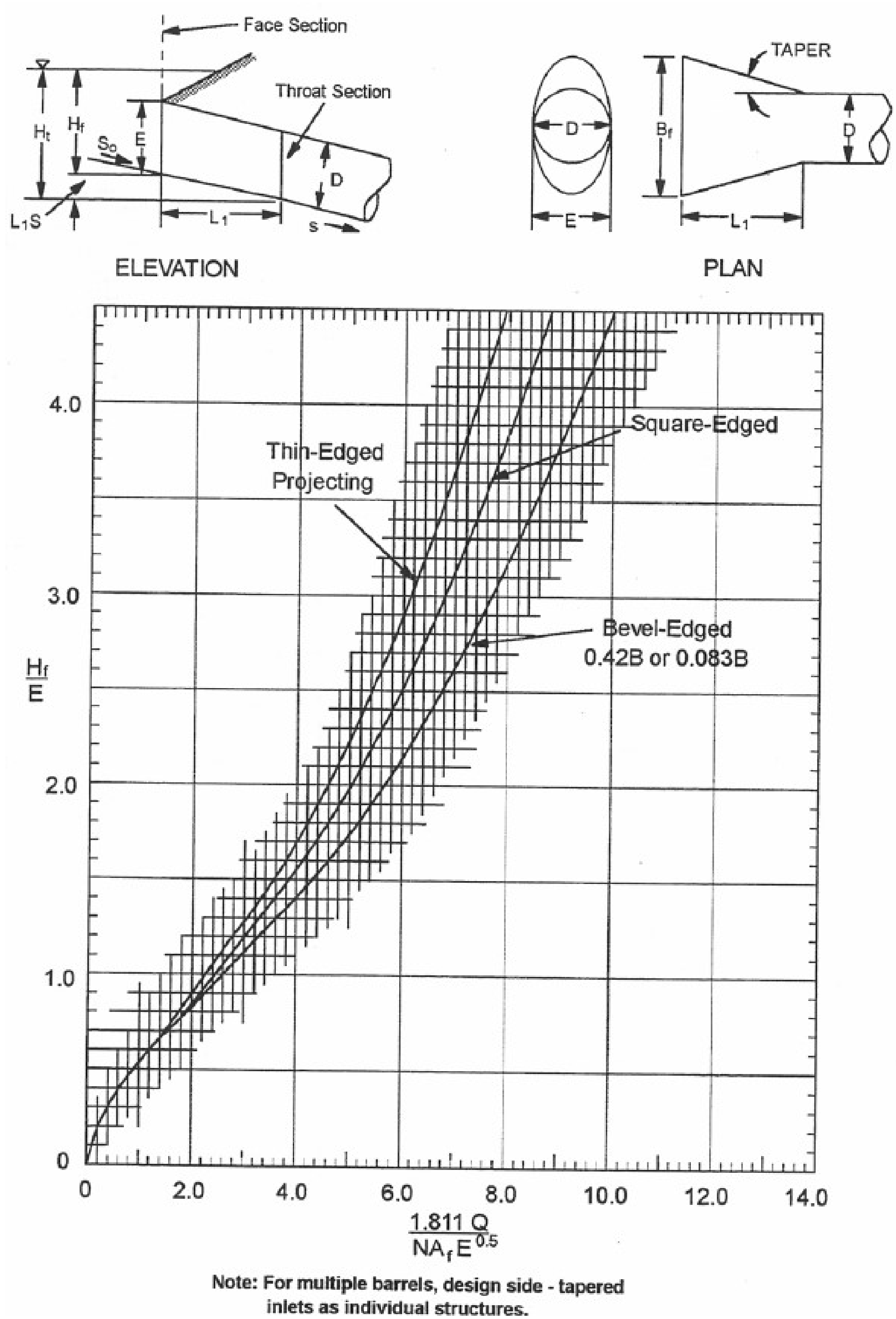
Source: Harrison (1972)

Design Chart 5.57: Side Tapered Inlets: Face Control - Box/Pipe Culverts



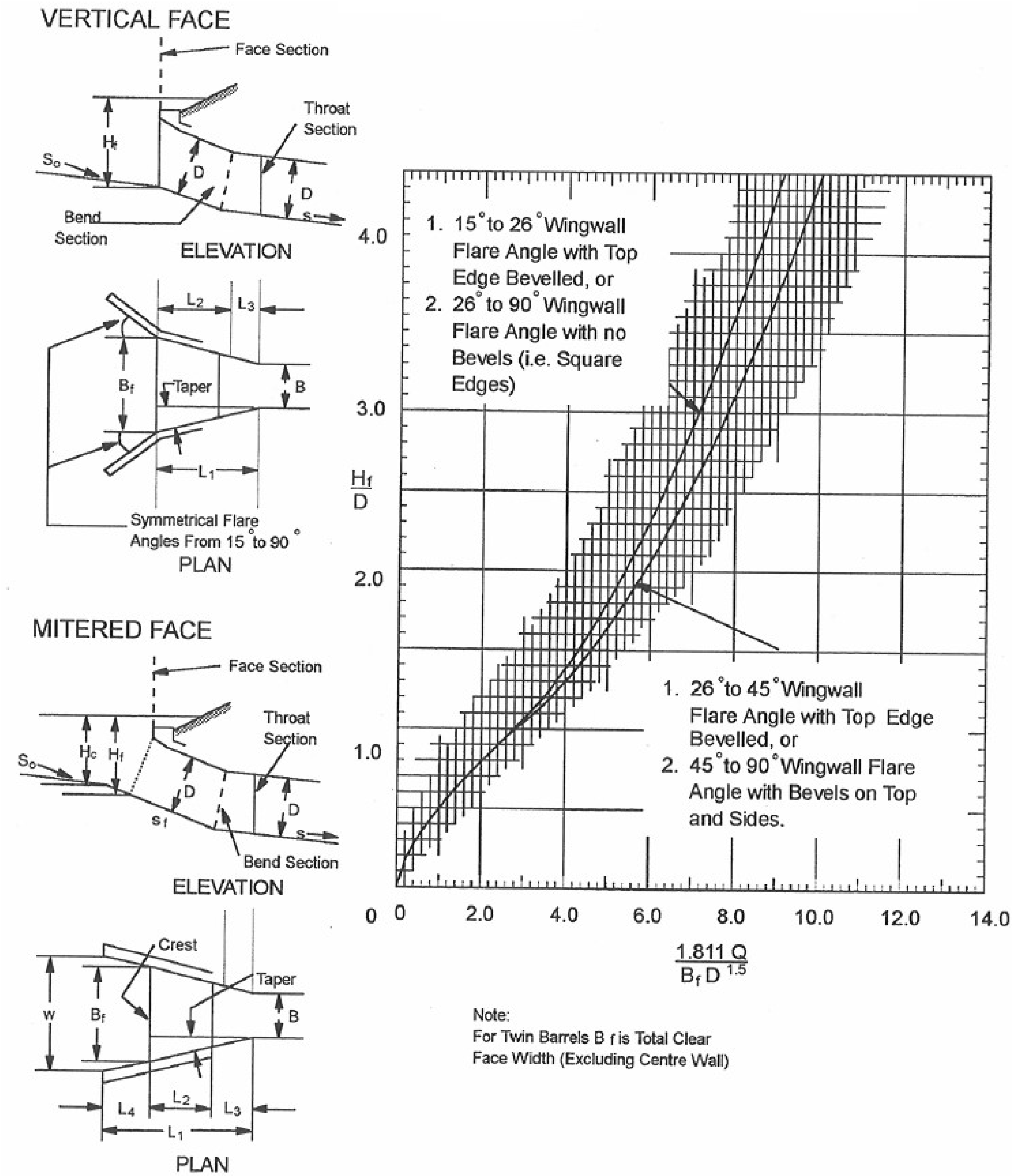
Source: Harrison (1972)

Design Chart 5.58: Side Tapered Inlets: Face Control - Non-Rectangular Pipe



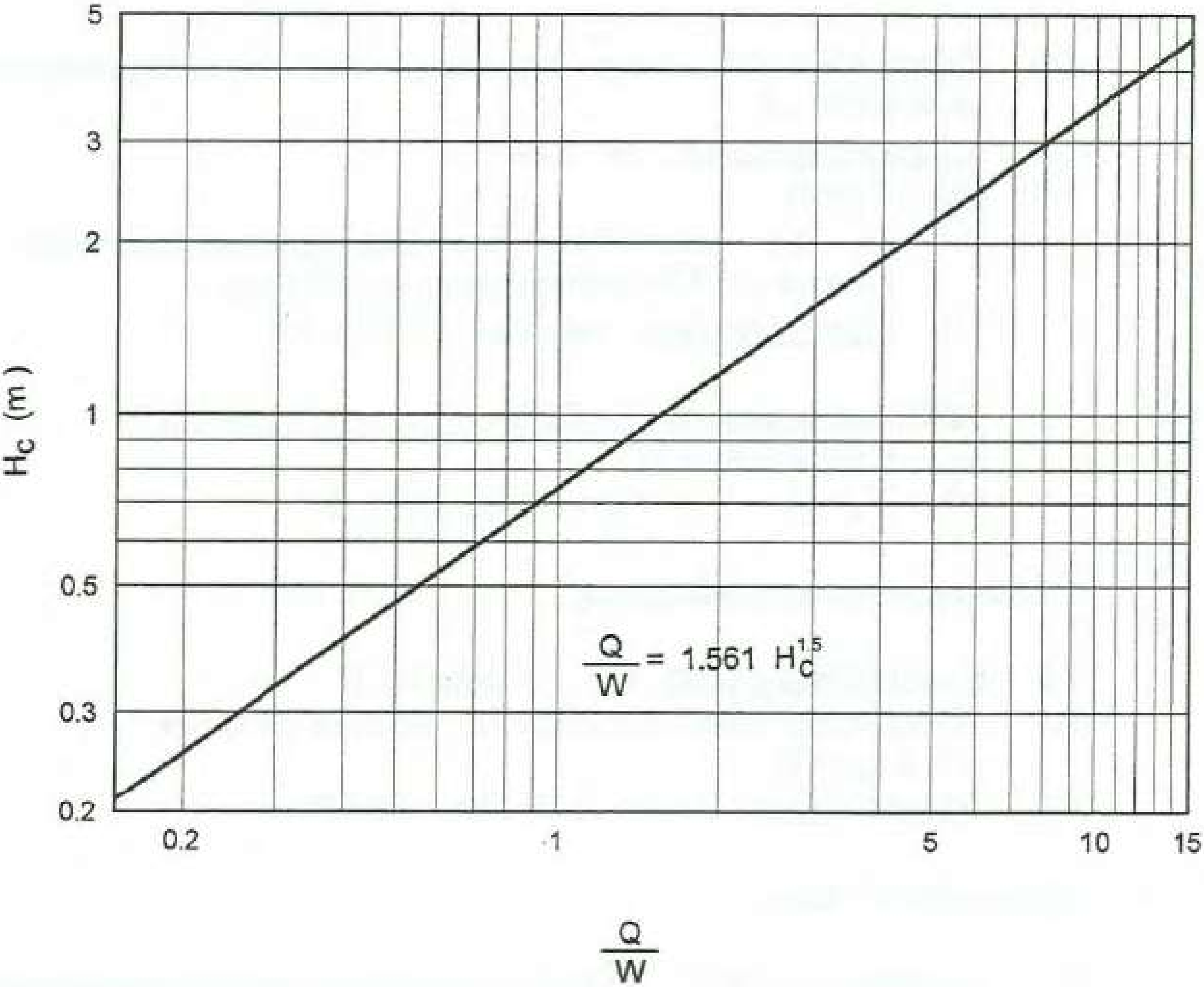
Source: Harrison (1972)

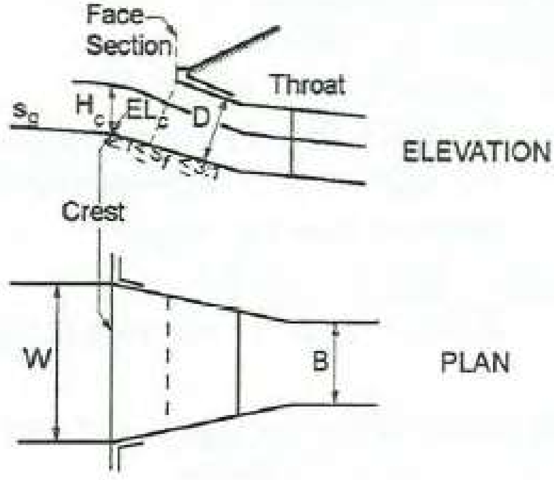
Design Chart 5.59: Rectangular Slope Tapered Inlets: Face Control – Box/Circular Pipe Culverts



Source: Harrison (1972)

Design Chart 5.60: Headwater for Crest Control





Design Chart 5.61: Improved Inlets: Dimensional Requirements

(1) Side-Tapered Inlets

(a) Taper: 4:1 to 6:1. A larger taper may be used, but performance will be underestimated.

(b) Wingwall flare angle: 15E to 90E

(c) Fall (if used):

(i) extend barrel invert slope upstream from face a distance ∃ 0.5 D, before starting the fall slope.

(ii) Slope of fall face: suggested = 2:1 to 3:1.

Additional requirement for fall if not between wingwalls.

(iv) P not less than 3T.

(v) $W_p = B_f + T$, or 4T, whichever is larger.

Additional requirements for pipes.

(d) Height of face section (E): 1.0 D to 1.1 D.

(e) Throat shape: throat of rectangular inlet must be square, with sides = D.

(f) Transition length: square to circular: ∃ 0.5 D.

(2) Slope-Tapered Inlets

(a) Side taper: 4:1 to 6:1. A larger taper can be used, but performance will be underestimated.

(b) Wingwall flare angle: 15E to 90E

(c) Minimum L_3 = 0.5 B.

(d) Fall: height 0.25 D to 1.5 D.

For fall < 0.25 D use side-tapered inlet.

For fall > 1.5 D, estimate friction losses between face and throat.

(e) Slope of Fall: 2:1 to 3:1

If flatter than 3:1 use side-tapered inlet.

Additional requirements for pipes with rectangular inlets.

See (1) (d), (e) and (f) above.

Source: Harrison (1972)

Design Chart 5.62: Dimensions of Corrugated Steel Pipe Arches

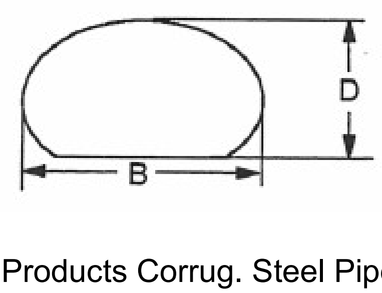
CSPA					SPCSPA				
B (m)	D (m)	A (m^2)	p (m)	R (m)	B (m)	D (m)	A (m^2)	p (m)	R (m)
			*					+	
0.56	0.42	0.19	1.57	0.12	2.06	1.52	2.49	5.86	0.42
0.68	0.50	0.27	1.88	0.14	2.24	1.63	2.90	6.34	0.46
0.80	0.58	0.37	2.20	0.17	2.44	1.75	3.36	6.83	0.49
0.91	0.66	0.48	2.51	0.19	2.59	1.88	3.87	7.32	0.53
1.03	0.74	0.61	2.83	0.22	2.69	2.08	4.49	7.81	0.57
1.15	0.82	0.74	3.14	0.24	3.10	1.98	4.83	8.30	0.58
1.39	0.97	1.06	3.77	0.28	3.40	2.01	5.28	8.78	0.60
1.63	1.12	1.44	4.40	0.33	3.73	2.29	6.61	9.76	0.68
1.88	1.26	1.87	5.03	0.37	3.89	2.69	8.29	10.74	0.77
2.13	1.40	2.36	5.65	0.42	4.37	2.87	9.76	11.71	0.83
					4.72	3.07	11.38	12.69	0.90
				**	5.05	3.33	13.24	13.66	0.97
					5.49	3.53	15.10	14.64	1.03
					5.89	3.71	17.07	15.62	1.09
					6.25	3.91	19.18	16.59	1.16
					7.04	4.06	22.48	18.06	1.24
					7.62	4.24	25.27	19.28	1.31

Note: dimensions are shown in metres for direct use in calculations.

* Based on equivalent round diameter.

\+ Based on manufacturers' periphery hole spaces.

** Limit of nomographs.



Source: Metric Standards and Design Data for CSP and SPCSP Products Corrug. Steel Pipe Inst. (1982)

Design Chart 5.63: Fetch Wind Speed Correction Factor

Fetch Length, km	Correction Factor
0	1.00
1	1.09
2	1.15
3	1.20
5	1.25
10+	1.30

Design Chart 6.01: Soil Erodibility Factors

Soil Texture	Organic Content					
	Under 0.5%		0.5% to 2%		2.1% to 4%	
	K	Sediment Yield	K	Sediment Yield	K	Sediment Yield
Sand	.05	L	.03	L	.02	L
Fine sand	.16	L	.14	L	.10	L
Very fine sand	.42	H	.36	M	.28	M
Loamy sand	.12	L	.10	L	.08	L
Loamy fine sand	.24	M	.20	M	.16	L
Loamy very fine sand	.44	H	.38	M	.30	M
Sandy loam	.27	M	.24	M	.19	L
Fine sandy loam	.35	M	.30	M	.24	M
Very fine sandy loam	.47	H	.41	H	.33	M
Loam	.38	M	.34	M	.29	M
Silt loam	.48	H	.42	H	.33	M
Silt	.60	H	.52	H	.42	H
Sandy clay loam	.27	M	.25	M	.21	M
Clay loam	.28	M	.25	M	.21	M
Silty clay loam	.37	M	.32	M	.26	M
Sandy clay	.14	L	.13	L	.12	L
Silty clay	.25	M	.23	M	.19	L
Clay	0.13 - 0.29 (L to M)					

NOTE:
At critical locations apply Thaw Factor where prolonged surface thawing is expected.

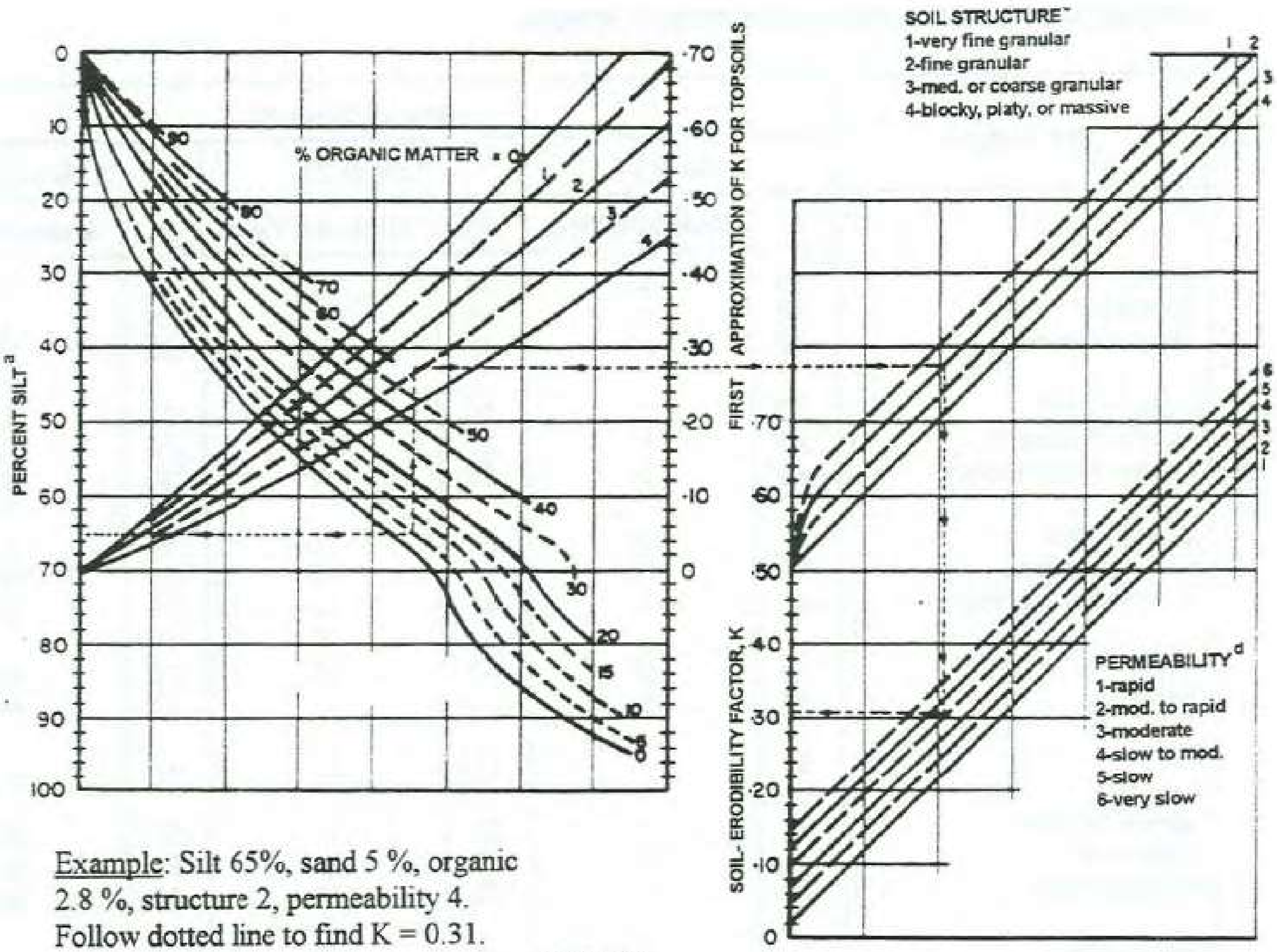
Thaw Factor

Predominantly sand soils	1.3
Predominantly loam soils	1.1
Predominantly clay soils	1.4

At critical locaions, for periods in which prolonged surface thawing is expected, multiply K values by the above factors.

Source: University of Guelph (various years); Dickinson, et. Al (1982)

Design Chart 6.02: Wischmeier Nomograph



Example: Silt 65%, sand 5 %, organic 2.8 %, structure 2, permeability 4. Follow dotted line to find K = 0.31.

NOTES

a. Silt defined as 2 um to 75 um in MTO soil classification system.

b. Sand was originally defined as 0.10 mm to 2.00 mm in Wischmeier's nomograph.

c. Soil Structure Equivalents

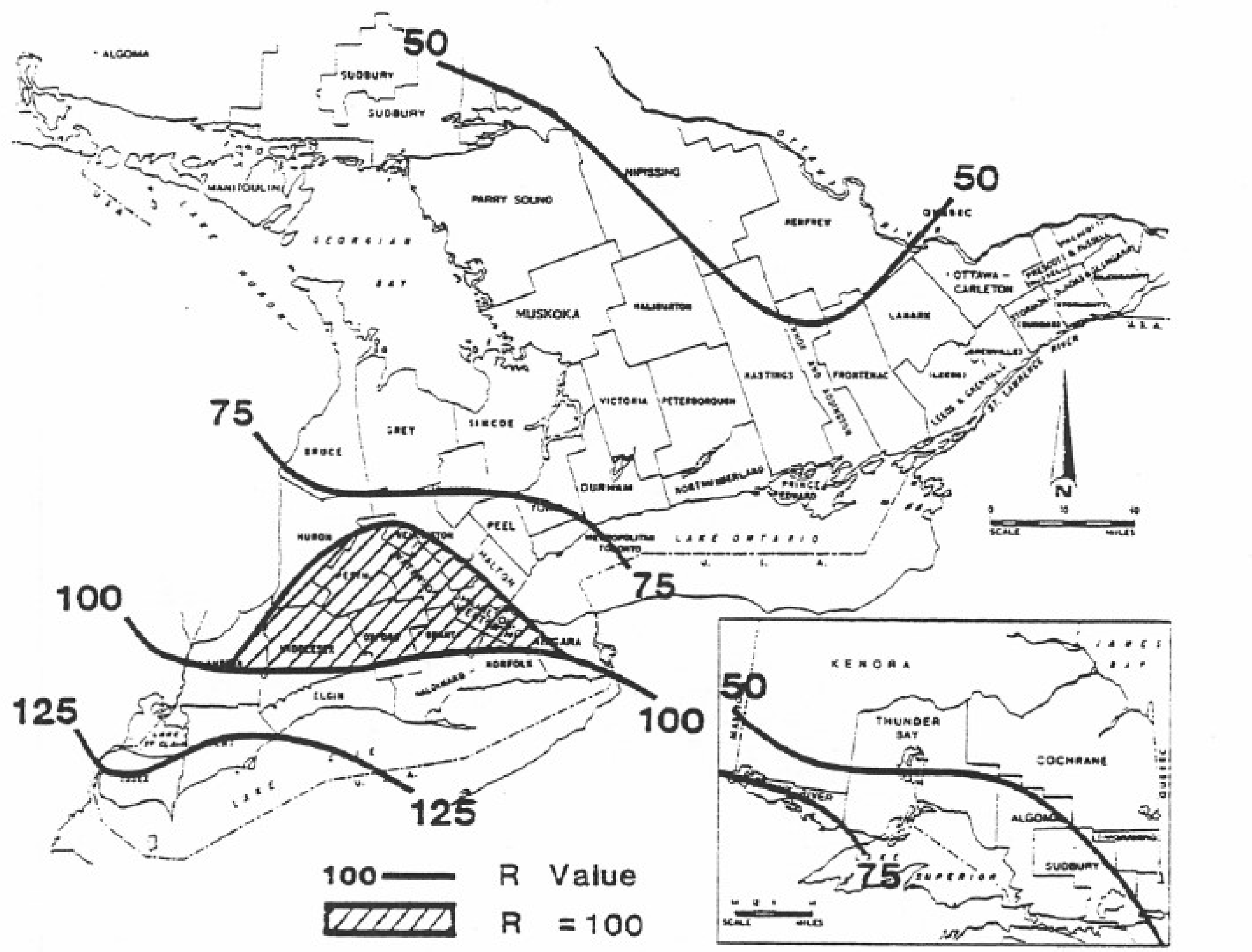
1.	Very fine granular	Very fine sand
2.	Fine granular	Fine or medium sand
3.	Medium or coarse granular	Coarse sand or gravel
4.	Blocky, platey or massive	Clay

d. Permeability Equivalents

1.	Rapid	Gravel
2.	Rapid to moderate	Sand
3.	Moderate	Sandy loam
4.	Moderate to slow	Clay loam
5.	Slow	Silty clay
6.	Very slow	Light to heavy clay

Source: Wischmeier, W.H. e al. (1971)

Design Chart 6.03: Average Rainfall Factors for Ontario



Dickenson and Wall, University of Guelph and Ontario Pedological Institute (Pers. comm.)

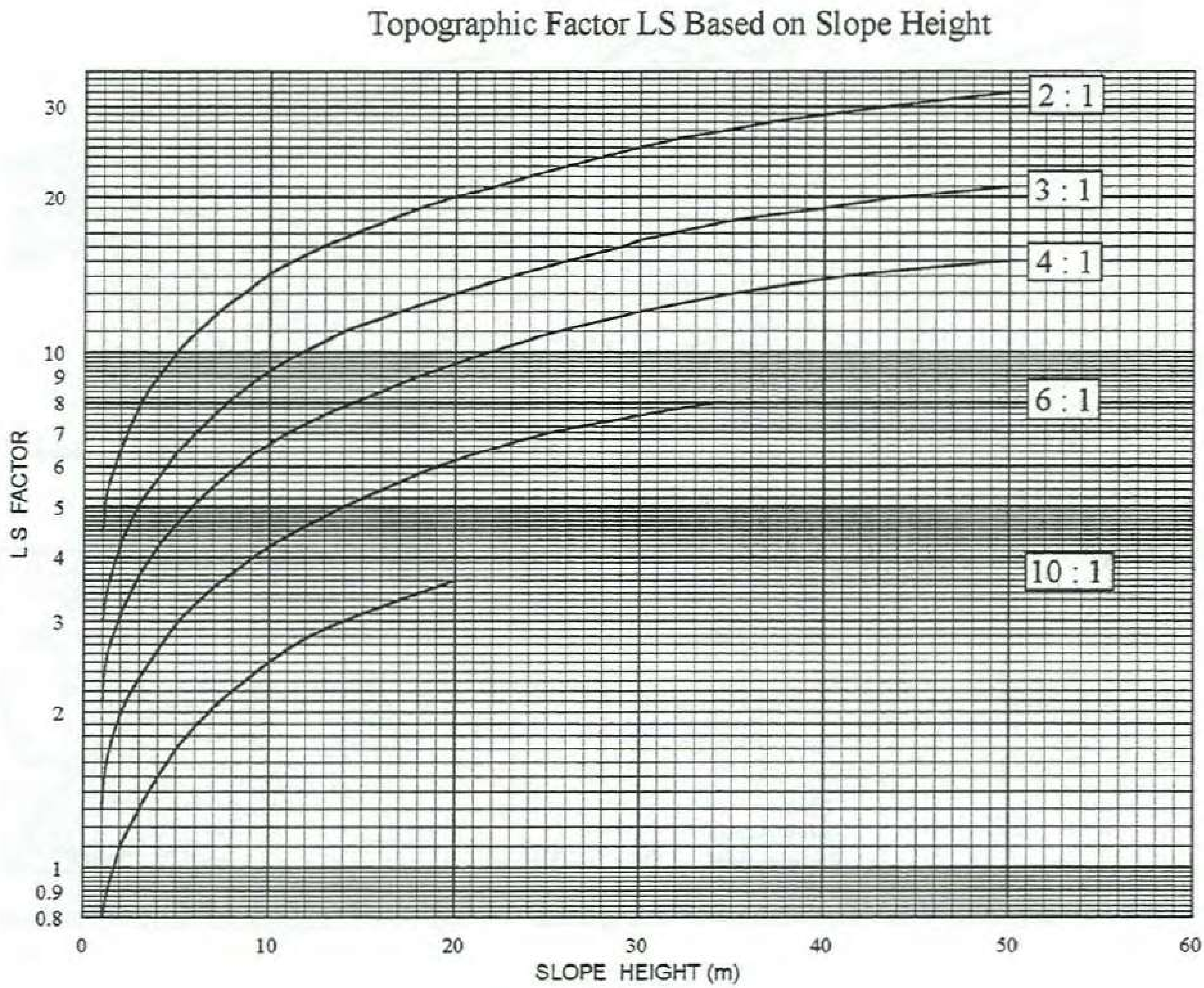
Note: 1. R Values include an allowance for snowmelt
2. See discussion on R value in Chapter 8 for units

Monthly Distribution of Annual R Factor

January	2%	July	19%
February	2%	August	18%
March	3%	September	11%
April	6%	October	7%
May	8%	November	6%
June	15%	December	3%

Note: Values include an allowance for snowmelt.

Design Chart 6.04: Topographic Factors



Source: Israelson (1980)

Design Chart 6.05: Erosion Control Factors

Typical VM Factors*

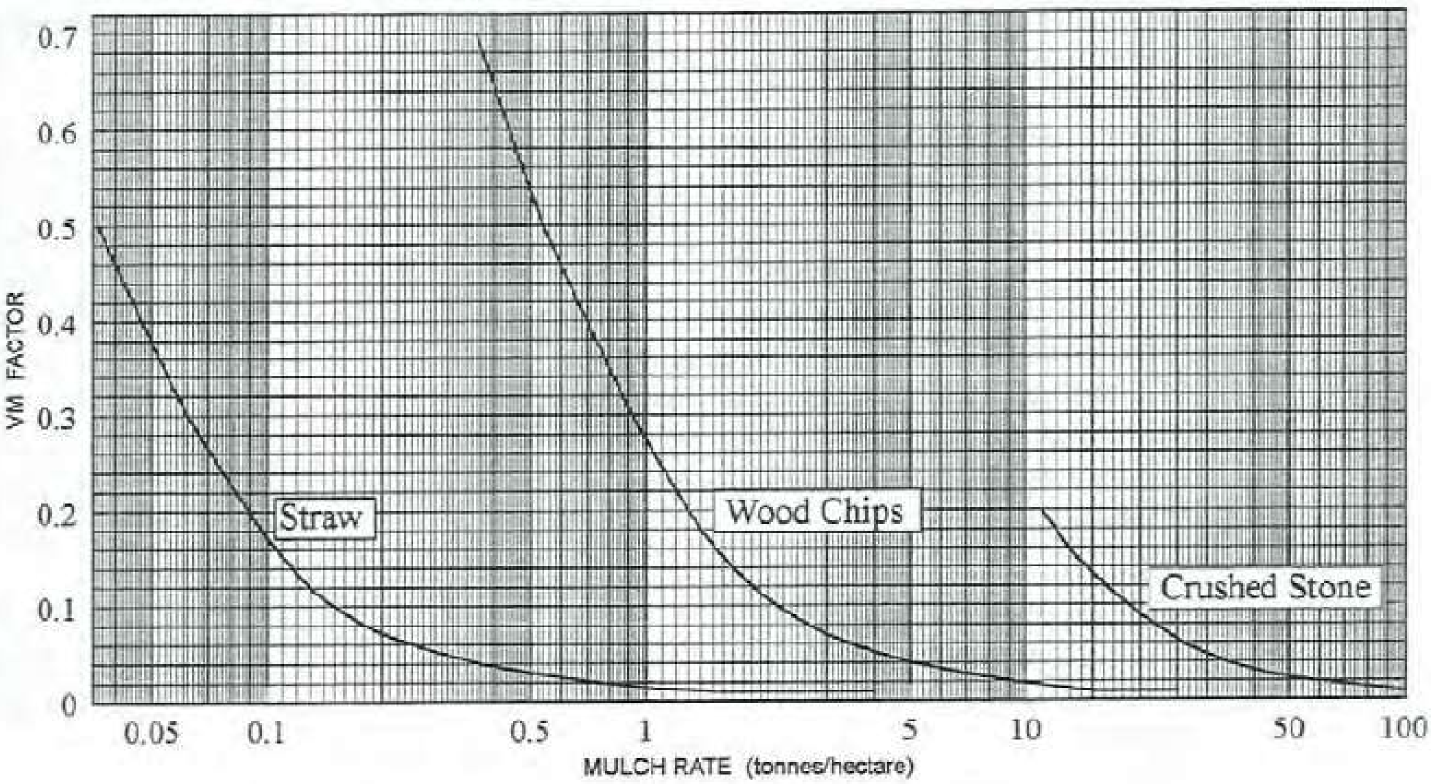
		Range	Average
1.	**Bare Soil**		
	After removal of root zone (normal design value)		1.00
	Freshly disced to 150 - 200 mm		1.00
	Undisturbed, except scraped		1.0±
	Scarified only		1.0±
	Loose to 300 mm deep, smooth		0.90
	Loose to 300 mm deep, rough	0.66 - 1.30	0.80
	Compacted, bulldozer scraped up and down	0.76 - 1.31	1.30
	Compacted, bulldozer scraped across slope		1.20
	Ditto, except root raked across		0.90
	Rough irregular tracked in all directions		0.90
	Compacted fill		1.5±
2.	Grass	1.24 - 1.71	
	Seeded - up to 60 days**		0.40
	- 60 days to 12 months		0.05
	- after 12 months		0.01
	Sodded		
	Grass with weeds		
		See next page	

**If mulched, use the lower of values given by the seeding and the mulch. Extend the 60 day period for very dry weather conditions.

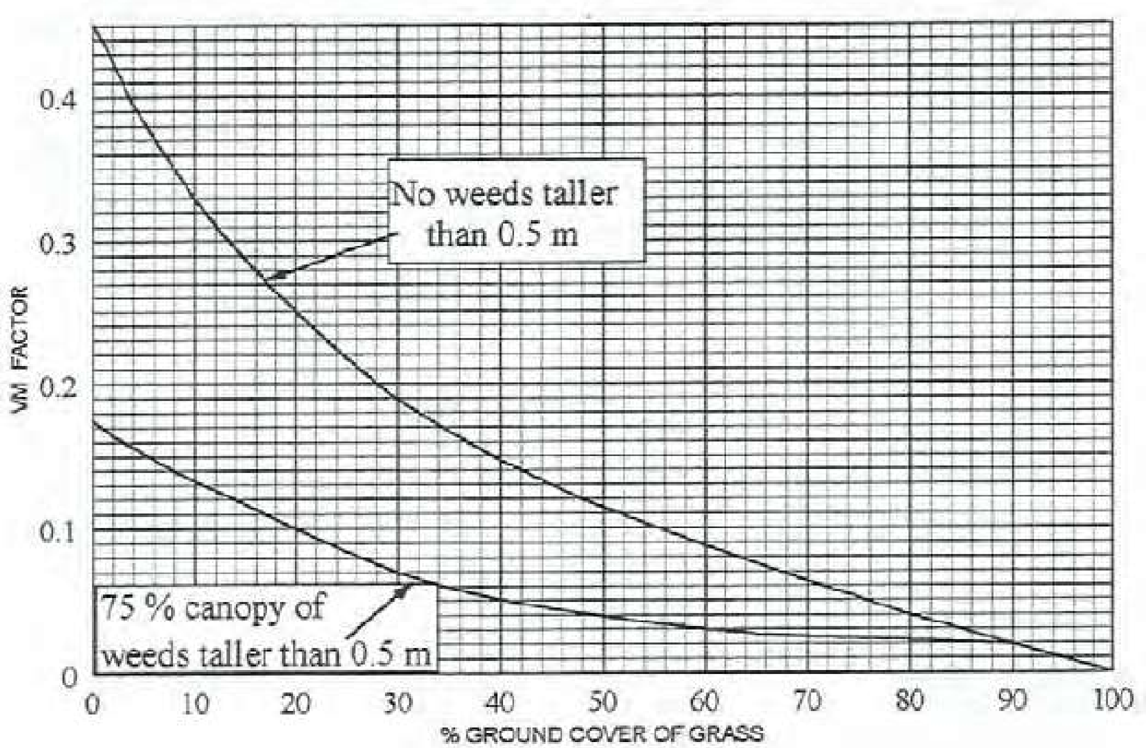
		Range	Average
3.	Mulches		
	Straw, wood chips or crushed stone	See next page	
	Excelsior blanket with plastic net	0.04 - 0.10	0.07
	Emulsified asphalt on bare soil, 1700 L/ha	0.65 - 0.70	0.68
	MTO hydraulic mulches:		
	Type A		
	Type B		
	Type C		
4.	Miscellaneous		
	Brush > 80 % ground cover	0.003 - 0.040	0.02
	Forest, undisturbed, > 75 % ground cover	0.0001 -0.004	0.002

Sources:
1. Various Research Studies
2. Israelson (1980)
3. Provisional based on research sponsored by MTO

Design Chart 6.05: Erosion Control Factors (Continued)



VM Factors For Varying Percentage of Grass Cover



Source: Israelson (1980)

Design Chart 6.06: Provisional Sediment Delivery Ratio for Sheet Flow

Type of Surface	Sheet Flow Travel Distance				
	Up to 3m	3 to 20 m	21 to 50 m	51 to 100 m	over 100 m
Predominantly clay soils	1.0	1.0	1.0	0.8	0.4
Predominantly loam soils	1.0	1.0	0.8	0.4	0.2
Predominantly sand/gravel	1.0	0.8	0.4	0.2	0.0
Heavily vegetated buffer	1.0	0.8	0.4	0	0

Notes:

1. Exclude paved surface from travel distance
2. To be used as a rough guide only; if in doupt use the higher value
3. Reference, Dickinson and Wall, University of Guelph and Ontario Pedological Institute (personal Communications)

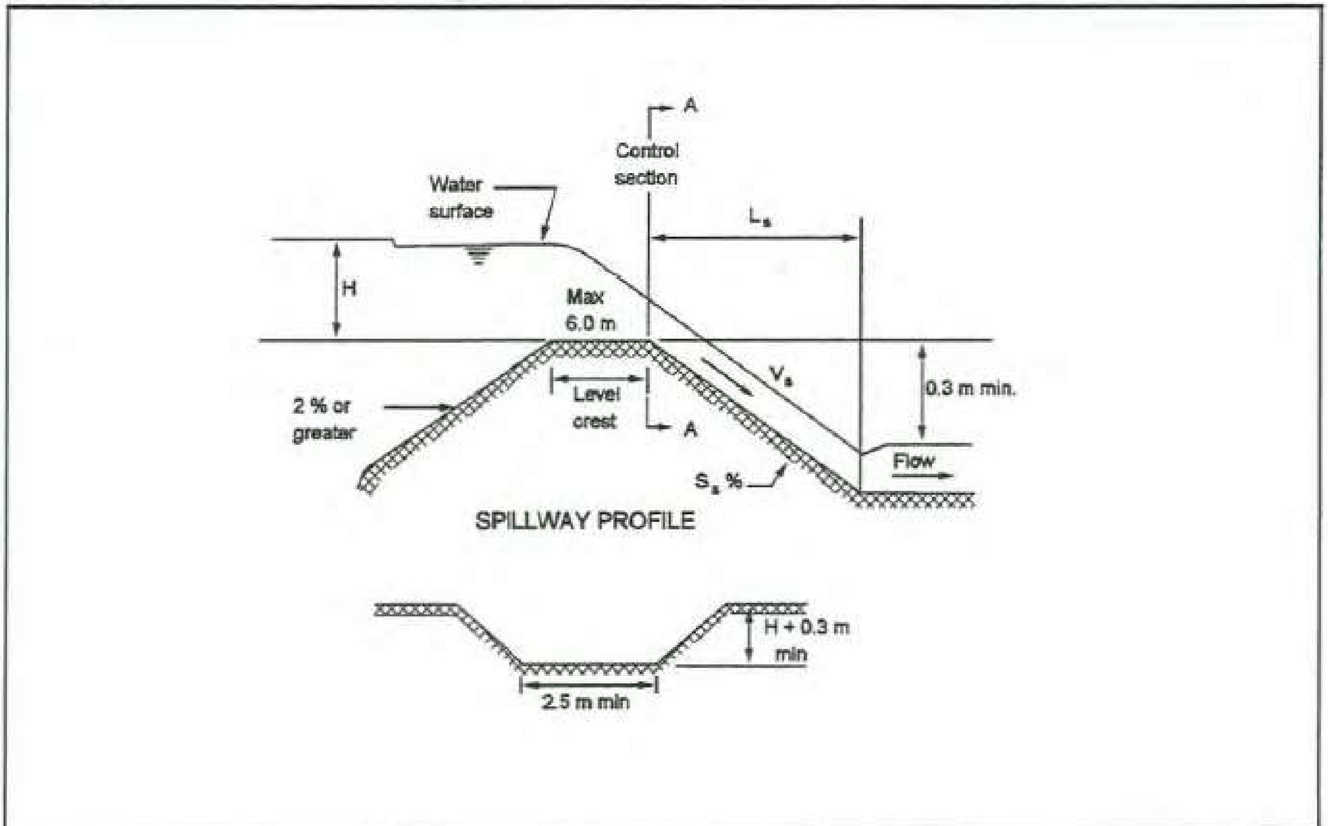
Design Chart 6.07: Design Data for Emergency Spillways

Head H (m)	Spillway Variables	Bottom Width b (m)								
		2.5	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
0.2	Q m3/s	0.28	0.33	0.33	0.64	0.64	0.75	0.86	0.97	1.08
	S_s %	3.6	3.6	3.5	3.5	3.5	3.5	3.5	3.5	3.5
	Vs m/s	0.9	0.95	0.97	0.97	0.97	0.97	0.97	0.97	0.97
	L_s m	12	12	12	12	12	12	12	12	12
0.3	Q	0.54	0.65	0.86	1.06	1.26	1.47	1.68	1.83	2.03
	S_s	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
	Vs	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21
	L_s	15	15	15	16	15	15	16	16	16
0.4	Q	0.92	1.08	1.43	1.71	2.06	2.38	2.64	2.99	3.29
	S_s	2.8	2.8	2.7	2.7	2.7	2.7	2.7	2.7	2.7
	Vs	1.41	1.41	1.41	1.41	1.44	1.44	1.44	1.44	1.44
	L_s	18	18	19	19	19	19	19	20	20
0.5	Q	1.40	1.63	2.08	2.55	3.03	3.46	3.92	4.37	4.79
	S_s	2.6	2.6	2.6	2.5	2.5	2.5	2.5	2.5	2.5
	Vs	1.56	1.56	1.57	1.58	1.60	1.62	1.62	1.62	1.62
	L_s	23	23	23	23	24	24	24	24	24
0.6	Q	1.94	2.26	2.89	3.41	4.16	4.73	5.35	5.49	6.55
	S_s	2.4	2.4	2.4	2.4	2.4	2.3	2.3	2.3	2.3
	Vs	1.72	1.72	1.72	1.72	1.76	1.73	1.76	1.78	1.78
	L_s	27	27	27	27	28	28	28	28	28
0.7	Q	2.63	3.02	3.77	4.58	5.39	6.14	6.93	7.67	8.43
	S_s	2.4	2.4	2.3	2.3	2.3	2.3	2.2	2.2	2.2
	Vs	1.86	1.86	1.86	1.89	1.89	1.91	1.92	1.92	1.92
	L_s	31	31	31	31	32	32	32	32	32

Notes:

- See sheet 2 for sketch and legend
- Table is correct for n=0.04 (grass). For use with other values of n see sheet 2
- Table may be used for spillway lengths (parallel to flow) of 0.6 m or less.
- Spillway sections to right of heavy lines should be used with caution, as they may be poorly proportioned.
- Table is based in the reference *Design of Sedimentation Basins*, U.S Transporation Reseach Board (1980)

Design Chart 6.07: Design Data for Emergency Spillways (Continued)



1. For spillway n values other than 0.04 (grass), use adjustmed Q.
   Adjusted Q = Design Q x Adjusment factor given below.

n	Factor
0.02	0.08
0.03	0.87
0.06	1.18

2. Values of H, S_s, V_s and L_s for givern values of Q (adjusted if necessary) and b are given on sheet 1.

   S_s is minimum slope of spillway downstream from crest.
   L_s is minimum length of spillway downstream from crest
   V_s given bt sheet 1 corresponds to the minimum calue of S_s. If a slope S steeper than S_s is used, calculate corresponding V as follows:

   $V = V_v (S / S_s)^{0.3}$ m/s

3. Maximum velocity for grass-lined spillway ≈ 1.8 m/s