Appendix B
Plates

Plate No.	Title
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B-2	Special Concrete Channel Cross Sections
B-3	Open Channel Flow, Resistance Coefficients
B-4	Open Channels, C-n-R-k Relation, $0.008 < n < 0.04$
B-5	Open Channels, C-n-R-k Relation, $0.03 < n < 0.15$
B-6	Depth vs Specific Energy
B-7	Flow Stability vs Froude Number
B-8	Varied Flow Profile, Standard Step Method, Sample Computation Using Manning's n
B-9	Varied Flow Profile, Standard Step Method, Sample Computation Using k and Chezy C
B-10	Classification of Flow Through Bridges
B-11	Classification of Flow Through Bridges, Rectangular Section
B-12	Trapezoidal Section, Momentum Method, Example Curves
B-13	Momentum Method, Example Computations, Trapezoidal Section
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B-22	Transition Design Curves, Rectangular Channels
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B-29	Stone Stability, Velocity vs Stone Diameter
B-30	Stone Stability, Velocity vs Stone Diameter
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Plate No.	Title
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B-36	Side Slope Velocity Distribution in Channel Bends
B-37	Depth Averaged Velocity versus D_{30} and Depth
B-38	Correction for Unit Stone Weight
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B-40	Correction for Vertical Velocity Distribution in Bend and Riprap Thickness
B-41	Riprap End Protection
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B-44	Rock Stabilizer
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B-46	Sheet Pile Stabilizer, Derrick Stone Size
B-47	Sheet Piling Stabilizer, Energy Loss
B-48	Details and Design Chart for Typical Drop Structure
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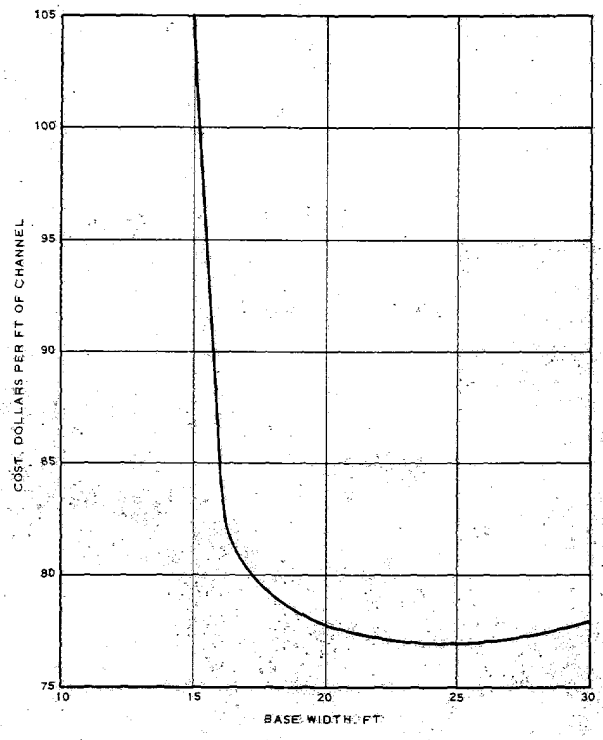
B-53	Open Channel Confluence, Standing Waves-Rapid Flow
B-54	Maximum Wave Height, Channel Junction
B-55	Tapered Junction Walls
B-56	Typical Confluence Layouts, Rectangular Channels
B-57	Confluence Design Chart
B-58	Side Channel Spillway Inlet

WIDTH FT	d_n FT	AREA SQ FT	V_n FPS	Δ_Y FT	AIR[a] %	TOTAL DEPTH FT	FREE-BOARD FT	WALL HEIGHT FT	COST PER FOOT, DOLLARS EXCAVATION	CONCRETE	r/W	BRIDGES	TOTAL
REACH 1: STA 1098+00 TO STA 860+00; Q = 8000 CFS; n = 0.014; S = 0.03900; r_c = 6000													
10	15.6	156	51.3	0.14	10	17.3	2.0	19.3			1.00		
15	9.7	146	54.8	0.23	10	10.9	2.0	12.9	18.50	81.00	1.50	3.00	104.00
20	7.3	146	54.8	0.31	10	8.4	2.0	10.4	14.50	57.00	2.00	4.50	78.00
25	6.0	150	53.3	0.37	10	7.0	2.0	9.0	14.50	54.50	2.50	5.50	77.00
30	5.2	156	51.3	0.41	10	6.2	2.0	8.2	14.00	54.50	3.00	6.50	78.00

[a]UNIFORM AIR ENTRAINMENT ASSUMED FOR PURPOSE OF COMPUTATION DEMONSTRATION OF BULKING. SEE PARAGRAPH 4-2 FOR METHOD OF ESTIMATING AIR ENTRAINMENT.

a. COMPUTATION FOR COST CURVE



b. COST CURVE

COST COMPUTATIONS
RECTANGULAR CONCRETE CHANNEL

PLATE B-1

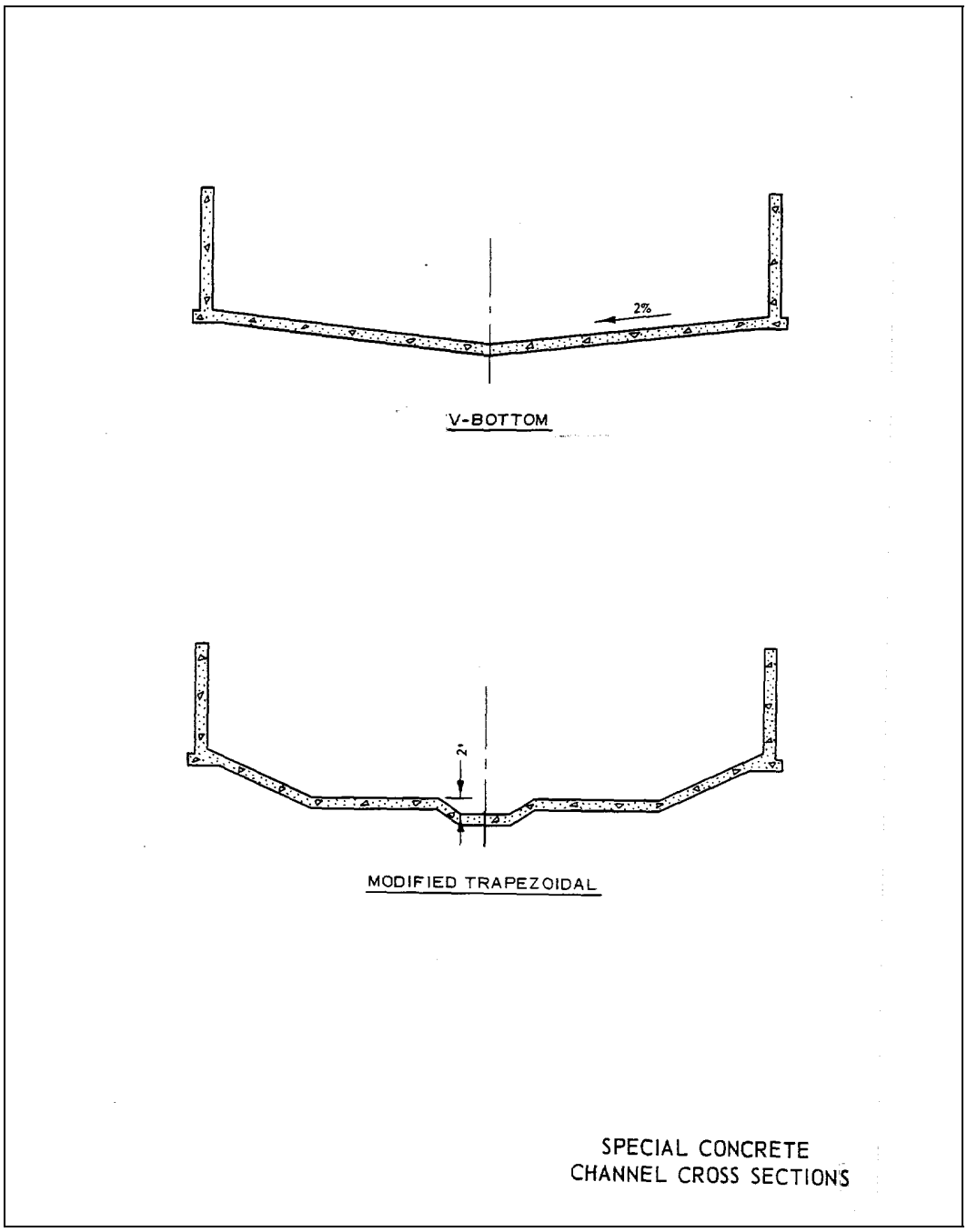

2%
V-BOTTOM
2'
MODIFIED TRAPEZOIDAL
SPECIAL CONCRETE
CHANNEL CROSS SECTIONS

PLATE B-2

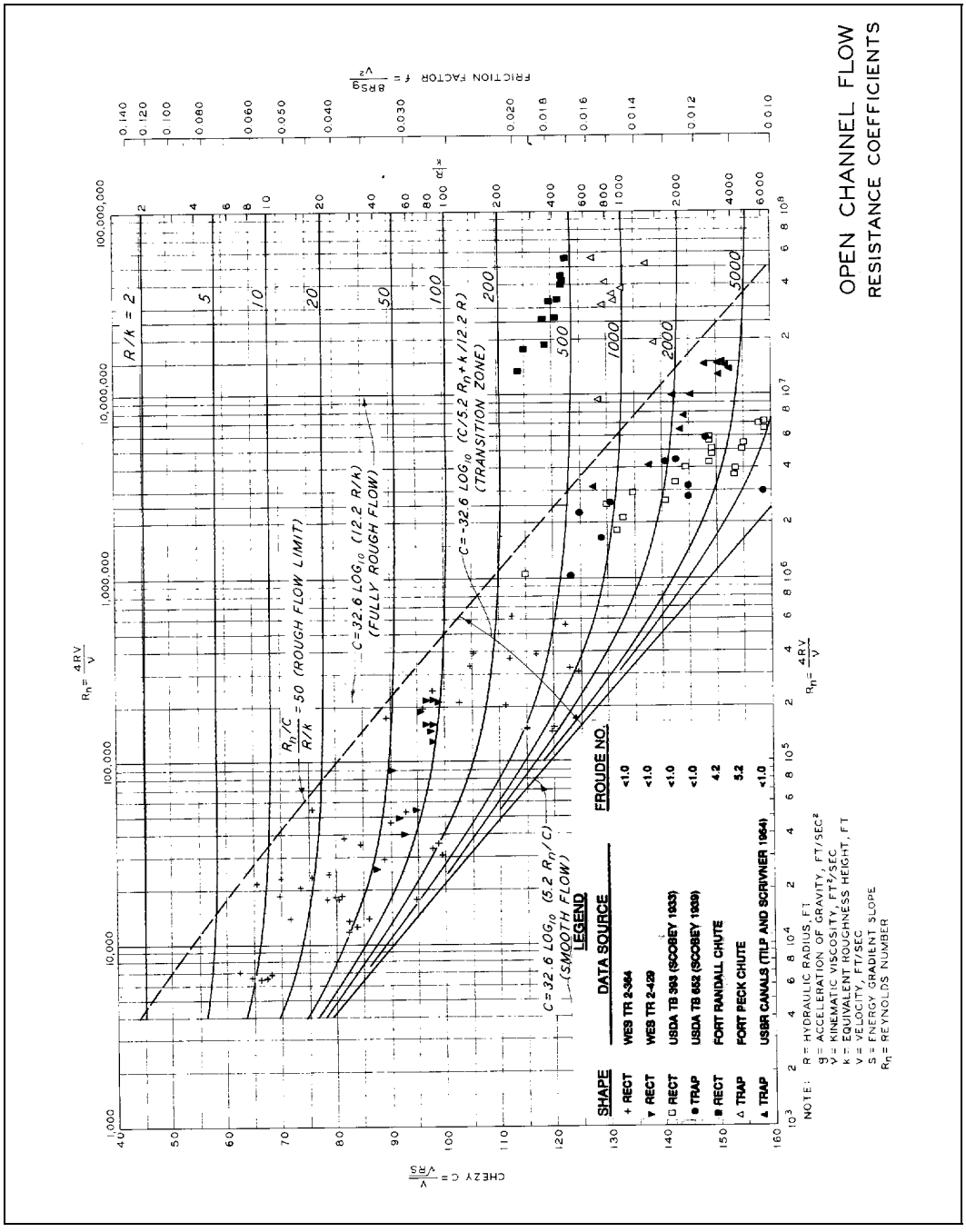
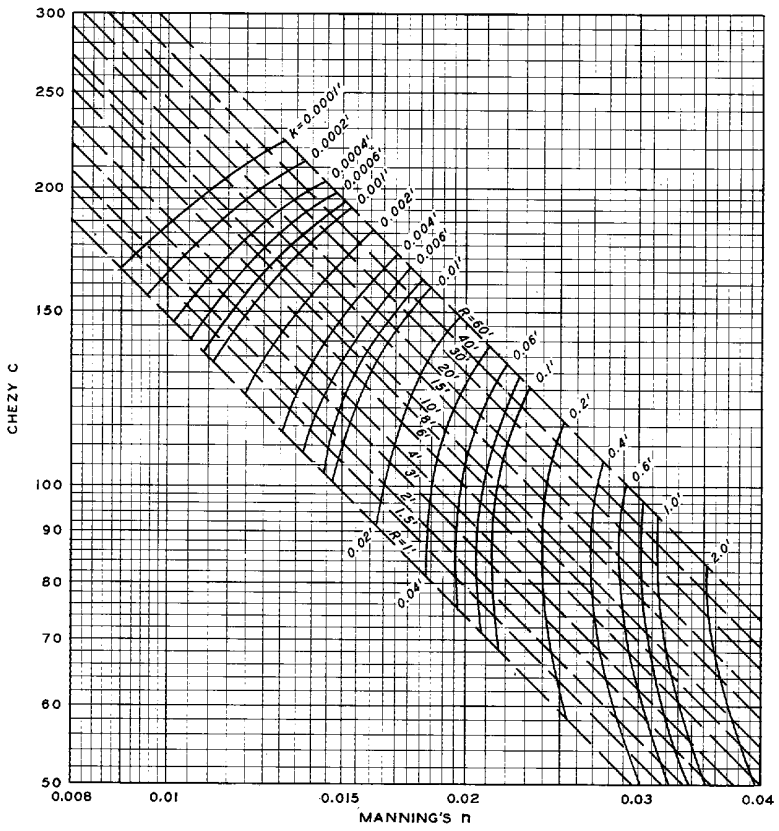

OPEN CHANNEL FLOW
RESISTANCE COEFFICIENTS
FRICTION FACTOR $f = \frac{8RSg}{V^2}$
$R_n = \frac{4RV}{\nu}$
CHEZY $C = \frac{V}{\sqrt{RS}}$
R/k = 2
5
10
20
50
100
200
500
1000
2000
5000
R_n/C / R/k = 50 (ROUGH FLOW LIMIT)
C=32.6 LOG10 (12.2 R/k) (FULLY ROUGH FLOW)
C=32.6 LOG10 (5.2 R_n/C) (SMOOTH FLOW)
C=32.6 LOG10 (C/5.2 R_n+k/12.2 R) (TRANSITION ZONE)
LEGEND
SHAPE | DATA SOURCE | FROUDE NO.
+ RECT | WES TR 2-364 | <1.0
▼ RECT | WES TR 2-429 | <1.0
□ RECT | USDA TB 393 (SCOBEY 1933) | <1.0
● TRAP | USDA TB 652 (SCOBEY 1939) | <1.0
■ RECT | FORT RANDALL CHUTE | 4.2
△ TRAP | FORT PECK CHUTE | 5.2
▲ TRAP | USBR CANALS (TILP AND SCRIVNER 1964) | <1.0
NOTE:
R = HYDRAULIC RADIUS, FT
g = ACCELERATION OF GRAVITY, FT/SEC²
ν = KINEMATIC VISCOSITY, FT²/SEC
k = EQUIVALENT ROUGHNESS HEIGHT, FT
V = VELOCITY, FT/SEC
S = ENERGY GRADIENT SLOPE
R_n = REYNOLDS NUMBER

PLATE B-3



BASIC EQUATIONS

$C = 32.6 \log_{10} 12.2R/k$

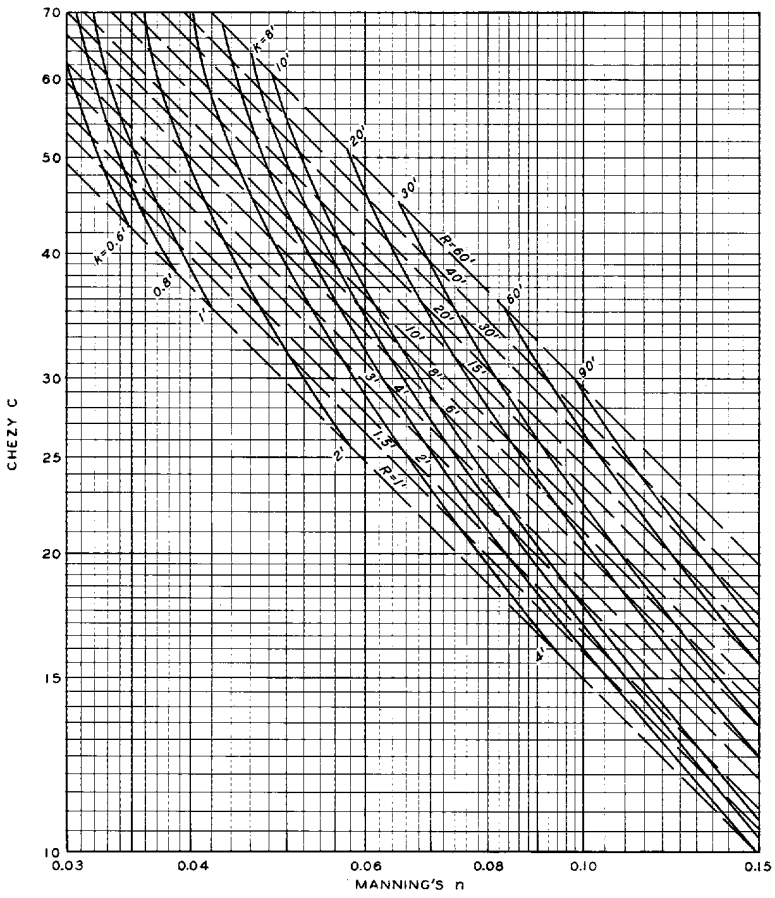
$n = \frac{R^{1/6}}{23.85 + 21.95 \log_{10} R/k}$

WHERE:

C = CHEZY COEFFICIENT
n = MANNING'S RESISTANCE COEFFICIENT
R = HYDRAULIC RADIUS, FT
k = EQUIVALENT ROUGHNESS HEIGHT, FT

OPEN CHANNELS
C-n-R-k RELATION
$0.008 < n < 0.04$

PLATE B-4



BASIC EQUATIONS

$C = 32.6 \log_{10} 12.2R/k$

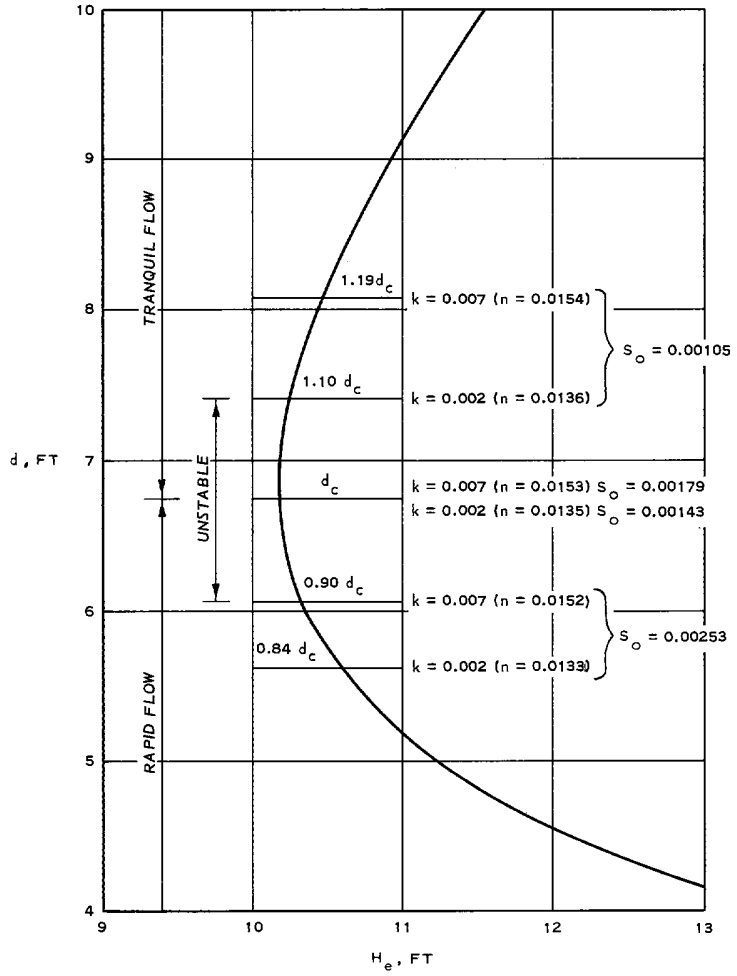
$n = \frac{R^{1/6}}{23.85 + 21.95 \log_{10} R/k}$

WHERE:

C = CHEZY COEFFICIENT
n = MANNING'S RESISTANCE COEFFICIENT
R = HYDRAULIC RADIUS, FT
k = EQUIVALENT ROUGHNESS HEIGHT, FT

OPEN CHANNELS
C-n-R-k RELATION
$0.03 < n < 0.15$

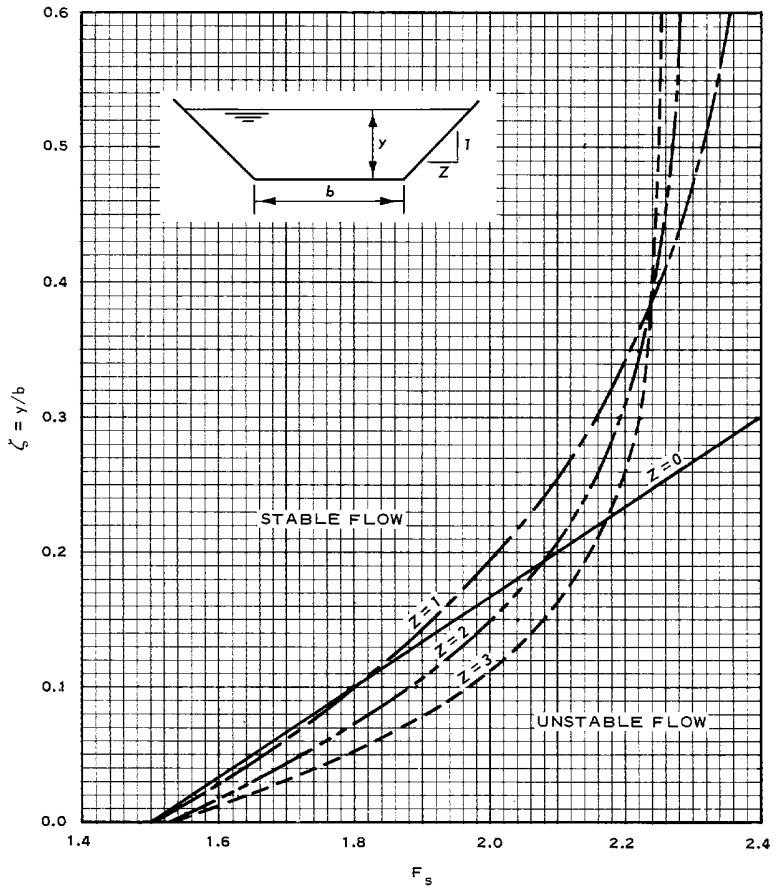
PLATE B-5



NOTE: q = 100 CFS/FT
$H_e = d + \alpha V^2/2g$
k = EQUIVALENT ROUGHNESS HEIGHT, FT
n = MANNING'S n
S_o = INVERT SLOPE
d = DEPTH
d_c = CRITICAL DEPTHS

DEPTH
VS
SPECIFIC ENERGY

PLATE B-6



EQUATIONS:

$$F_s = \frac{\xi}{g^{1/2}\zeta^{3/2}(1 + z\zeta)}$$

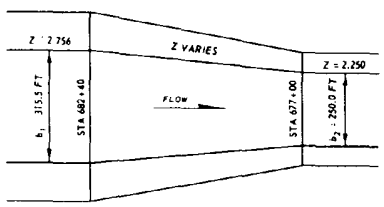
$$\xi = \frac{Q}{b^{5/2}}$$

NOTE: GRAPH FOR USE WITH EQUATION 2-10 TO COMPUTE MANNING'S n

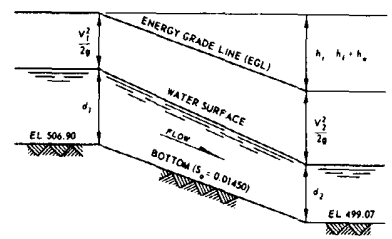
FLOW STABILITY VS FROUDE NUMBER

PLATE B-7

① STATION FT	② BOTTOM EL FT	③ b FT	④ Z	⑤ WATER SURFACE EL FT	⑥ d ⑤ - ② FT	⑦ A = (b + Zd)d SQ FT	⑧ V = Q/A FPS	⑨ $h_v = V^2/2g$ FT	⑩ EL EGL ⑤ + ⑨ FT	⑪ $2d(Z^2+1)^{1/2}$ FT	⑫ WP = ③ + ⑪ FT	⑬ R = ⑦ / ⑫ FT	⑭ $1/2.211R^{4/3}$	⑮ $S_f = n^2V^2$ ⑭	⑯ AVG S_f	⑰ L FT	⑱ h_f ⑯ × ⑰ FT	⑲ h_e FT	⑳ h_t ⑱ + ⑲ FT	㉑ EL EGL CHECK ⑩ FT
682+40	506.90	315.5	2.756	520.70	13.80	4880	19.98	6.20	526.90	80.92	396.4	12.31	0.0159	0.00124						526.90
															0.00153	40	0.06	0.35	0.41	
682+00	506.32	310.6	2.720	518.82	12.50	4307	22.64	7.96	526.78	72.45	383.1	11.24	0.0180	0.00181	0.00141	40	0.06	0.22	0.28	526.49
				519.32	13.00	4498	21.68	7.30	526.62	75.35	386.0	11.65	0.0172	0.00158						526.62
															0.00192	100	0.19	0.42	0.61	
681+00	504.87	298.5	2.625	516.87	12.00	3960	24.62	9.41	526.28	67.42	365.9	10.82	0.0189	0.00225	0.00182	100	0.18	0.32	0.50	526.01
				517.17	12.30	4069	23.96	8.91	526.07	69.10	367.6	11.07	0.0183	0.00205						526.12
															0.00225	100	0.23	0.26	0.49	
680+00	503.42	286.4	2.530	515.42	12.00	3801	25.65	10.22	525.64	65.29	351.7	10.81	0.0189	0.00245						525.63
															0.00258	100	0.26	0.20	0.46	
679+00	501.97	274.2	2.436	513.92	11.95	3625	26.90	11.24	525.16	62.94	337.1	10.75	0.0191	0.00271						525.17
678+00	500.52	262.1	2.342	512.02	11.50	3324	29.33	13.36	525.38						0.00282	100	0.28	0.19	0.47	
				512.52	12.00	3482	28.00	12.17	524.69	61.12	323.2	10.77	0.0190	0.00292						524.70
															0.00307	100	0.31	0.24	0.55	
677+00	499.07	250.0	2.250	511.07	12.00	3324	29.33	13.36	524.43	59.09	309.1	10.75	0.0191	0.00322	0.00300	100	0.30	0.17	0.47	524.15
				511.22	12.15	3370	28.93	13.00	524.22	59.83	309.8	10.88	0.0188	0.00308						524.23



PLAN
(NO SCALE)



PROFILE
(NO SCALE)

NOTE

Q = 97,500 CFS

$S_f = n^2V^2/2.21R^{4/3}$

n (MANNING'S) = 0.014

Z = SIDE SLOPE (HORIZONTAL TO VERTICAL)

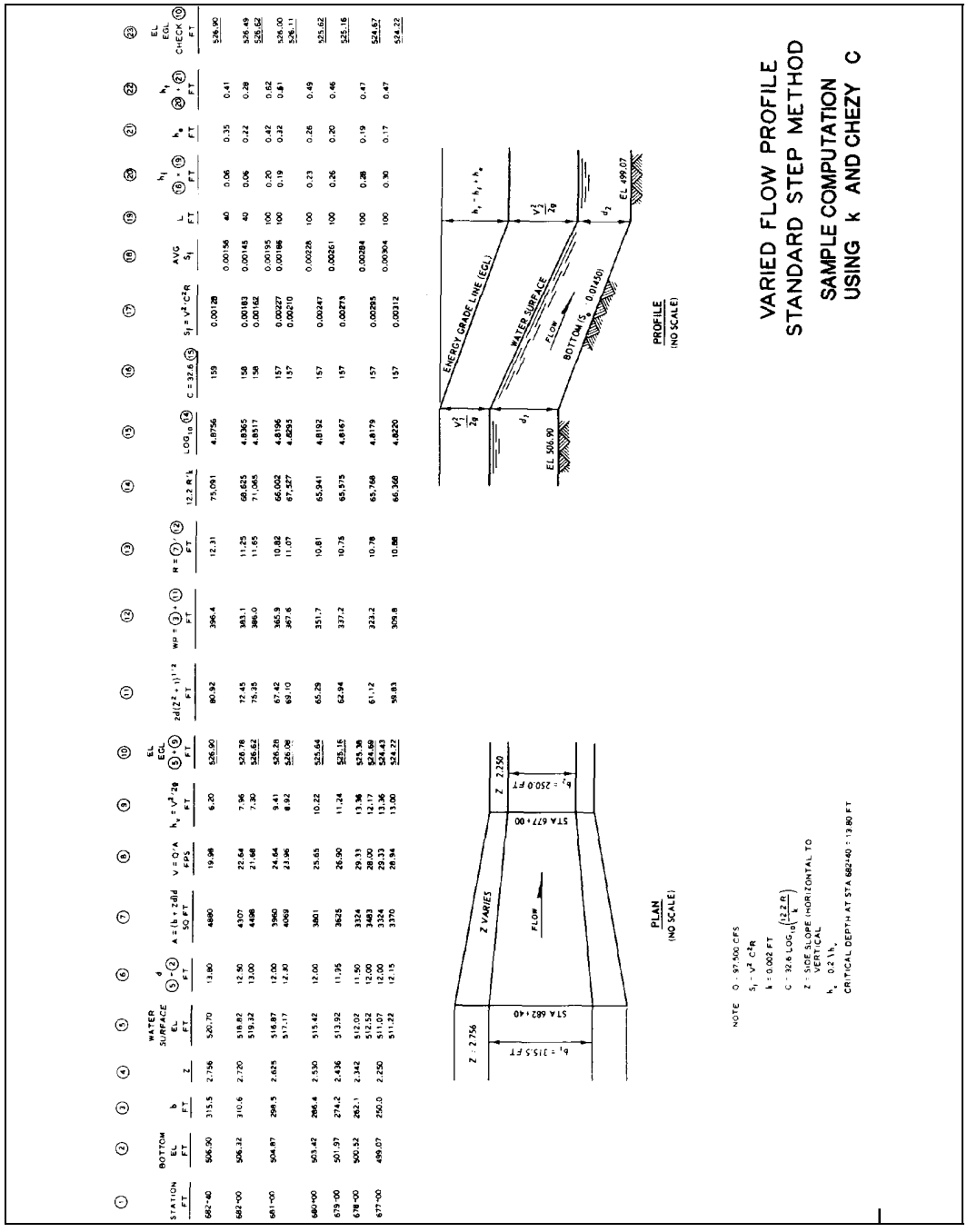
$h_e = 0.2\,\Delta h_v$

CRITICAL DEPTH AT STA 682+40 = 13.80 FT

VARIED FLOW PROFILE
STANDARD STEP METHOD

SAMPLE COMPUTATION
USING MANNING'S n

PLATE B-8

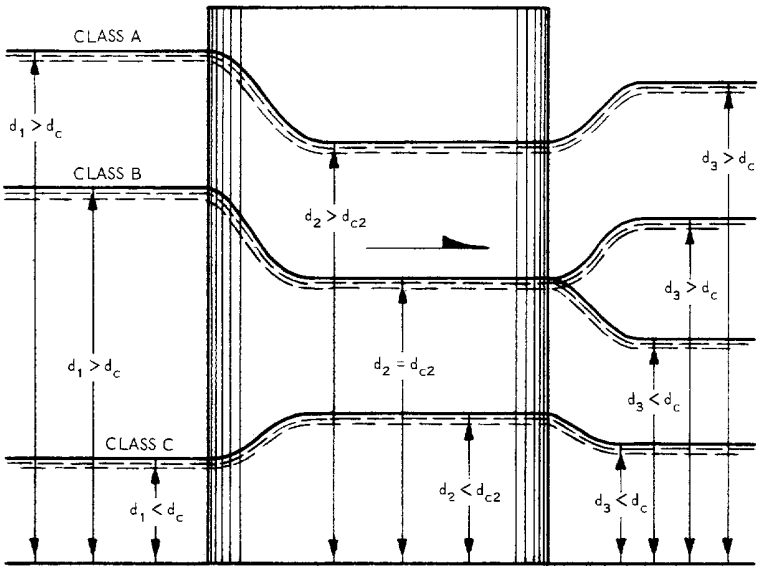


① STATION FT	② BOTTOM EL FT	③ b FT	④ Z	⑤ WATER SURFACE EL FT	⑥ d (5)-(2) FT	⑦ A = ½(b + Zd)d SQ FT	⑧ V = Q/A FPS	⑨ $h_v = V^2/2g$ FT	⑩ EL EGL (5)+(9) FT	⑪ $zd(Z^2+1)^{1/2}$ FT	⑫ WD = (3)+(11) FT	⑬ R = (7)/(12) FT	⑭ 12.2 R^1/6	⑮ LOG_{10} (14)	⑯ C = 32.6 (15)	⑰ $S_f = V^2/C^2R$	⑱ AVG S_f	⑲ L FT	⑳ h_f (18)·(19) FT	㉑ h_e FT	㉒ h_v (8)·(21) FT	㉓ EL EGL CHECK (10) FT
682+40	506.90	315.5	2.756	520.70	13.80	4880	19.98	6.20	526.90	80.92	396.4	12.31	75.091	4.8756	159	0.00128						526.90
																	0.00156	40	0.06	0.35	0.41	
682+00	506.32	310.6	2.720	518.82	12.50	4307	22.64	7.96	526.78	72.45	383.1	11.25	68.625	4.8365	158	0.00183						526.49
				519.32	13.00	4498	21.68	7.30	526.62	75.35	386.0	11.65	71.065	4.8517	158	0.00162	0.00145	40	0.06	0.22	0.28	526.62
																	0.00195	100	0.20	0.42	0.62	
681+00	504.87	298.5	2.625	516.87	12.00	3960	24.64	9.41	526.28	67.42	365.9	10.82	66.002	4.8196	157	0.00227	0.00186	100	0.19	0.22	0.41	526.00
				517.17	12.30	4069	23.96	8.92	526.09	69.10	367.6	11.07	67.327	4.8295	157	0.00210						526.11
																	0.00228	100	0.23	0.26	0.49	
680+00	503.42	286.4	2.530	515.42	12.00	3801	25.65	10.22	525.64	65.29	351.7	10.81	65.941	4.8192	157	0.00247	0.00261	100	0.26	0.20	0.46	525.62
679+00	501.97	274.2	2.436	513.92	11.95	3625	26.90	11.24	525.16	62.94	337.2	10.75	65.979	4.8167	157	0.00273						525.16
																	0.00284	100	0.28	0.19	0.47	
678+00	500.52	262.1	2.342	512.02	11.50	3324	29.33	13.36	525.38		323.2	10.28	65.768	4.8179	157	0.00295						524.67
				512.52	12.00	3483	28.00	12.17	524.69	61.12							0.00304	100	0.30	0.17	0.47	
677+00	499.07	250.0	2.250	511.07	12.00	3324	29.33	13.36	524.43		309.8	10.88	66.368	4.8220	157	0.00312						524.22
				511.22	12.15	3370	28.94	13.00	524.22	58.83												

NOTE Q = 97,500 CFS
$S_f = V^2/C^2R$
k = 0.002 FT
$C = 32.6 \log_{10}(12.2R/k)$
Z = SIDE SLOPE (HORIZONTAL TO VERTICAL)
$h_e = 0.2\,h_v$
CRITICAL DEPTH AT STA 682+40 = 13.80 FT

VARIED FLOW PROFILE
STANDARD STEP METHOD
SAMPLE COMPUTATION
USING k AND CHEZY C

PLATE B-9

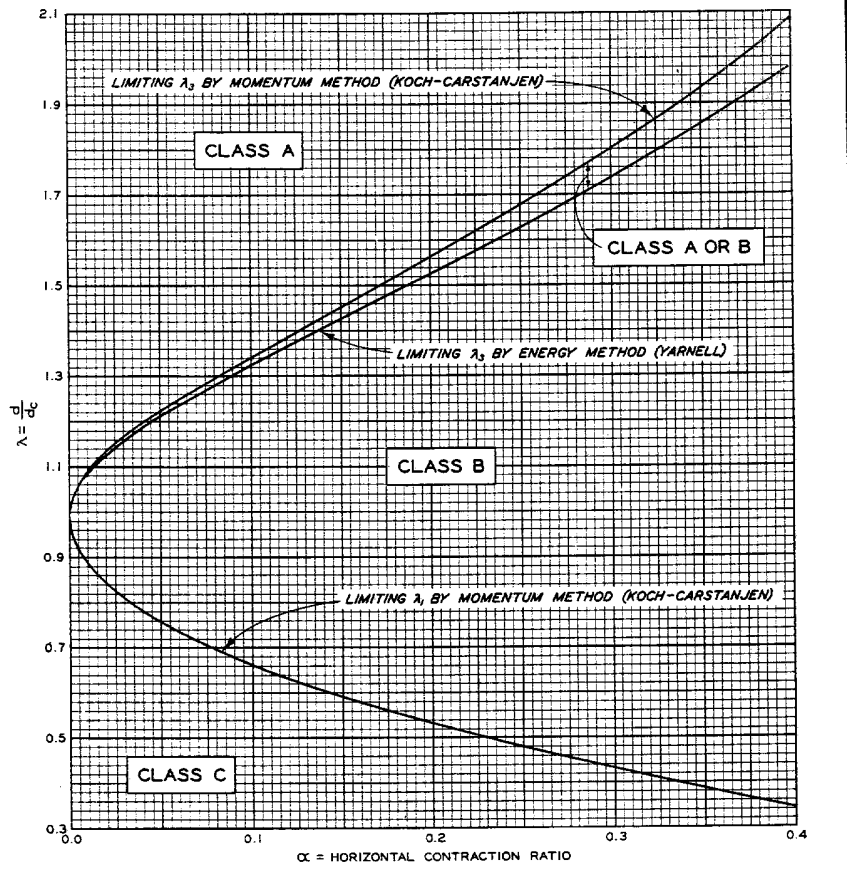


ELEVATION

NOTE: d_1 = UPSTREAM DEPTH
d_2 = DEPTH WITHIN PIER SECTION
d_3 = DOWNSTREAM DEPTH
d_c = CRITICAL DEPTH WITHIN THE UNOBSTRUCTED CHANNEL SECTION
d_{c2} = CRITICAL DEPTH WITHIN THE PIER SECTION

CLASSIFICATION OF
FLOW THROUGH BRIDGES

PLATE B-10



EQUATIONS FOR LIMITING λ

λ_3 – ENERGY METHOD (YARNELL) (CHOW 1959)

$$\alpha = 1 - \left[\frac{3\lambda_3^2}{2\lambda_3^3 + 1}\right]^{3/2}$$

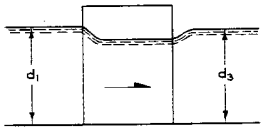
λ_3 – MOMENTUM METHOD (KOCH 1926)

$$\alpha = 1 - \left[\frac{3\lambda_3}{(1-\alpha)\lambda_3^3 + 2}\right]^{3}$$

λ_1 – MOMENTUM METHOD (KOCH 1926)

$$\alpha = 1 - \left[\frac{3\lambda_1}{\lambda_1^3 + 2}\right]^{3/4}$$

NOTE: $\lambda_1 = d_1/d_c$
$\lambda_3 = d_3/d_c$
d_1 = UPSTREAM WATER DEPTH
d_3 = DOWNSTREAM WATER DEPTH
d_c = CRITICAL DEPTH WITHIN THE UNOBSTRUCTED CHANNEL SECTION
α = HORIZONTAL CONTRACTION RATIO (Σ PIER WIDTHS + CHANNEL WIDTH)
d = DEPTH WITHOUT BRIDGE PIERS



DEFINITION SKETCH

CLASSIFICATION OF FLOW THROUGH BRIDGES
RECTANGULAR SECTION

PREPARED BY U. S. ARMY ENGINEER WATERWAYS EXPERIMENT STATION, VICKSBURG, MISSISSIPPI

PLATE B-11

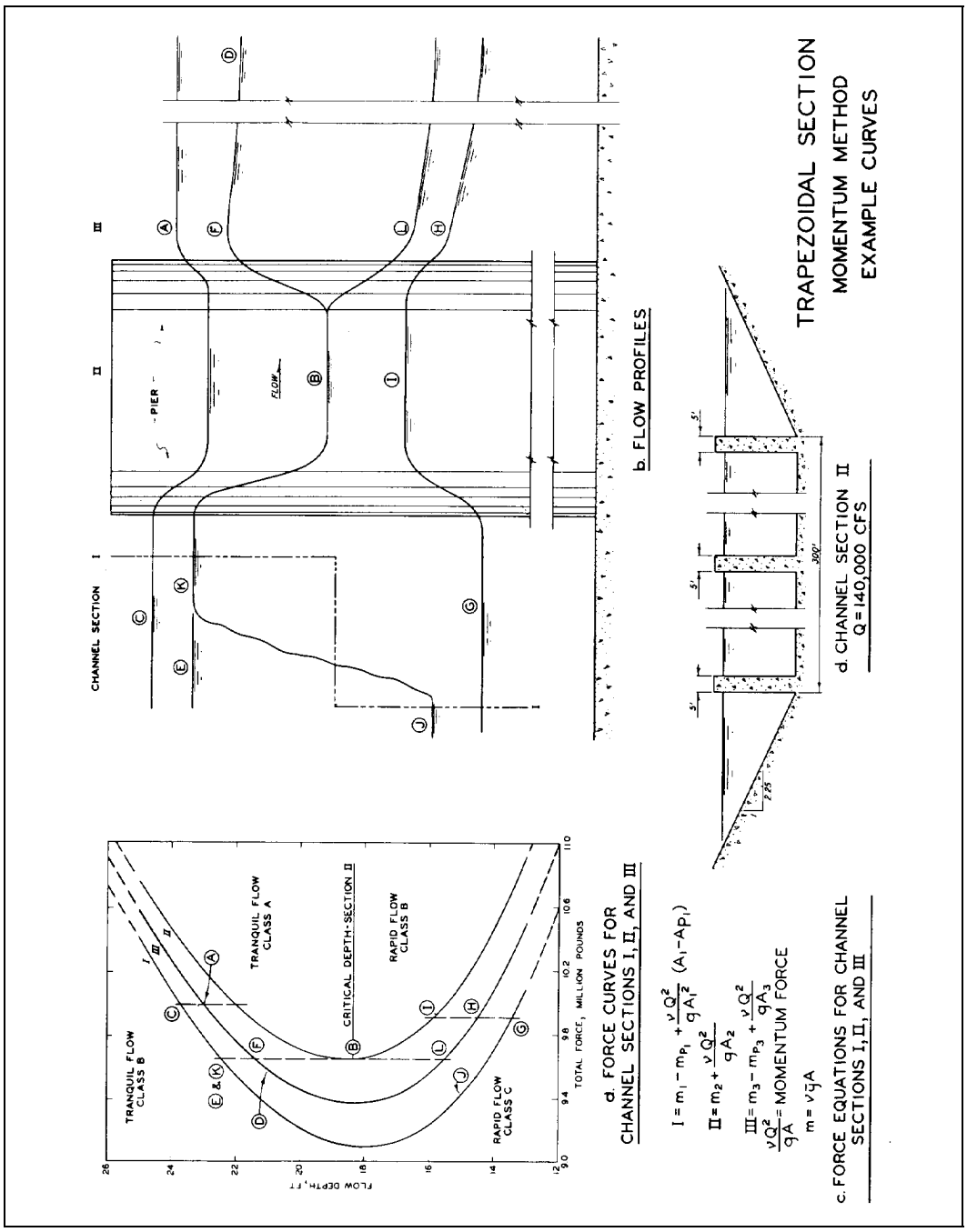

TRAPEZOIDAL SECTION
MOMENTUM METHOD
EXAMPLE CURVES
CHANNEL SECTION
PIER
FLOW
b. FLOW PROFILES
d. CHANNEL SECTION II
Q=140,000 CFS
300'
5'
2.5
c. FORCE EQUATIONS FOR CHANNEL SECTIONS I, II, AND III
$I = m_1 - m_{P_1} + \frac{\nu Q^2}{g A_1^2}(A_1 - A_{P_1})$
$II = m_2 + \frac{\nu Q^2}{g A_2}$
$III = m_3 - m_{P_3} + \frac{\nu Q^2}{g A_3}$
$\frac{\nu Q^2}{gA}$ = MOMENTUM FORCE
$m = \nu g A$
d. FORCE CURVES FOR CHANNEL SECTIONS I, II, AND III
TRANQUIL FLOW CLASS B
TRANQUIL FLOW CLASS A
CRITICAL DEPTH-SECTION II
RAPID FLOW CLASS B
RAPID FLOW CLASS C
FLOW DEPTH, FT
TOTAL FORCE, MILLION POUNDS

PLATE B-12

GIVEN

Q = 140,000 CFS
CHANNEL WIDTH B = 300 FT
SIDE SLOPE = 1:2.25
PIER WIDTH = 5 FT
NO. OF PIERS = 3

SPECIFIC FORCE EQUATIONS

$$I = m_1 - m_{p_1} + \frac{\gamma Q^2}{g A_1^2}\left(A_1 - A_{p_1}\right)$$

$$II = m_2 + \frac{\gamma Q^2}{g A_2}$$

$$III = m_3 - m_{p_3} + \frac{\gamma Q^2}{g A_3}$$

SOLVE FORCE EQUATIONS FOR ASSUMED VALUES OF FLOW DEPTH d

FOR d = CONSTANT: $m_1 = m_3$, $m_{p_1} = m_{p_3}$, $m_1 - m_{p_1} = m_2$,

$A_1 = A_3$, $A_{p_1} = A_{p_3}$, $A_1 - A_{p_1} = A_3 - A_{p_3} = A_2$

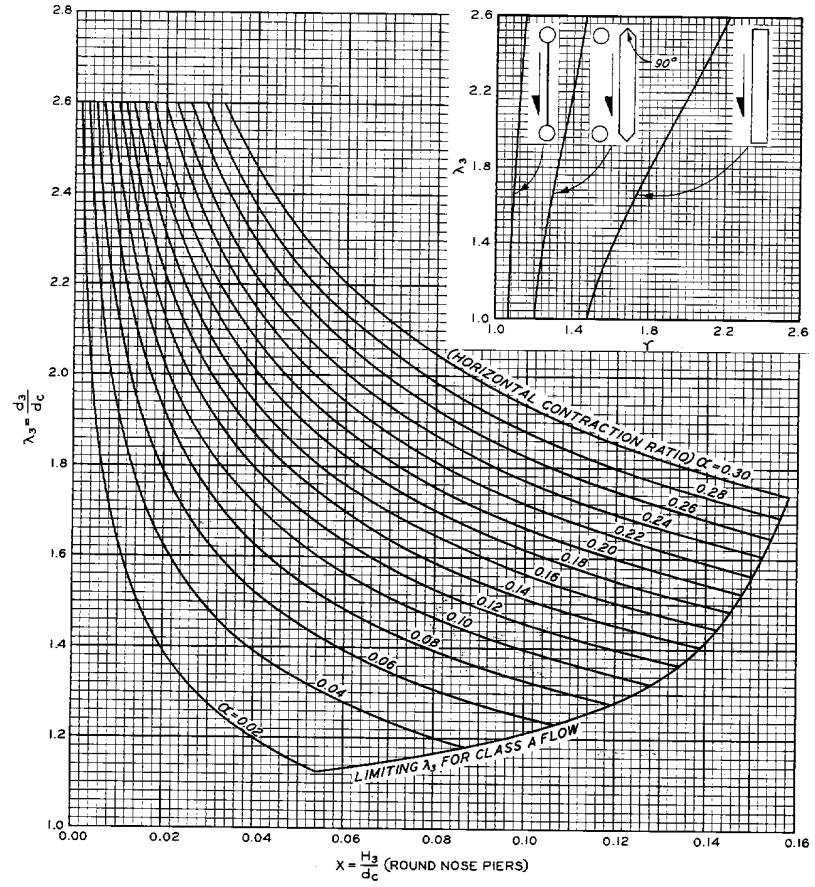
① d UNITS (FT)	② $A_1 = A_3$ UNITS (FT^2)	③ $m_1 = m_3$ MILLIONS (LB)	④ $A_{p_1} = A_{p_3}$ UNITS (LB)	⑤ $m_{p_1} = m_{p_3}$ MILLIONS (LB)	⑥ $A_1 - A_{p_1}$ UNITS (FT^2)	⑦ $m_1 - m_{p_1}$ MILLIONS (LB)
13	4280	1.687	195	0.079	4085	1.608
14	4641	1.966	210	0.092	4431	1.874
15	5006	2.267	225	0.105	4781	2.162
16	5376	2.592	240	0.120	5136	2.472
17	5750	2.940	255	0.135	5495	2.804
18	6129	3.311	270	0.152	5859	3.159
19	6512	3.706	285	0.169	6227	3.537
20	6900	4.125	300	0.188	6600	3.937
21	7292	4.568	315	0.207	6977	4.361
22	7689	5.037	330	0.227	7359	4.810
23	8090	5.530	345	0.248	7745	5.282
24	8496	6.048	360	0.270	8136	5.778
25	8906	6.592	375	0.293	8531	6.299

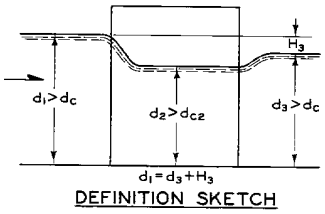
⑧ $\frac{\gamma Q^2}{g\left(A_1 - A_{p_1}\right)}$ MILLIONS (LB)	⑨ $\frac{\gamma Q^2}{g A_3}$ MILLIONS (LB)	⑩ $\frac{\gamma Q^2\left(A_1 - A_{p_1}\right)}{g A_1^2}$ MILLIONS (LB)	⑪ I ⑦ + ⑩ MILLIONS (LB)	⑫ II ⑦ + ⑧ MILLIONS (LB)	⑬ III ⑦ + ⑨ MILLIONS (LB)
9.313	8.889	8.484	10.092	10.921	10.497
8.586	8.197	7.826	9.700	10.460	10.071
7.957	7.600	7.258	9.420	10.119	9.762
7.407	7.077	6.761	9.232	9.879	9.549
6.923	6.616	6.323	9.126	9.727	9.420
6.493	6.207	5.934	9.093	9.652	9.366
6.109	5.842	5.586	9.123	9.646	9.379
5.764	5.514	5.274	9.211	9.701	9.451
5.458	5.217	4.992	9.353	9.819	9.578
5.170	4.948	4.735	9.545	9.980	9.758
4.912	4.703	4.502	9.784	10.194	9.984
4.676	4.478	4.288	10.066	10.454	10.256
4.459	4.272	4.092	10.391	10.758	10.571

NOTE: m = HYDROSTATIC FORCE = $\gamma \bar{y} A$, LB
γ = SPECIFIC WEIGHT OF WATER, LB
$\bar{y}$ = DISTANCE FROM WATER SURFACE TO CENTER OF GRAVITY, FT
A = CROSS-SECTION AREA, SQ FT
$\frac{\gamma Q^2}{gA}$ = MOMENTUM FORCE, LB
g = ACCELERATION OF GRAVITY, FT/SEC^2

**MOMENTUM METHOD
EXAMPLE COMPUTATIONS
TRAPEZOIDAL SECTION**

PLATE B-13





DEFINITION SKETCH

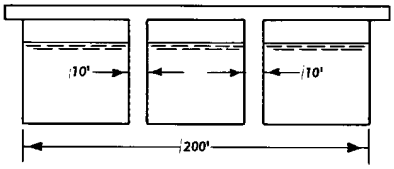
NOTE: d_c = CRITICAL DEPTH WITHIN THE UNOBSTRUCTED CHANNEL SECTION
d_{c2} = CRITICAL DEPTH WITHIN THE PIER SECTION
$H_3 = X d_c$ (ROUND NOSE PIERS)
$H_3 = X d_c \Upsilon$ (INDICATED SHAPES)

RECTANGULAR SECTION
ENERGY METHOD
CLASS A FLOW

PLATE B-14

GIVEN:

Rectangular channel section
Round nose piers
Channel discharge (Q) = 40,000 cfs
Channel width (W_c) = 200 ft
Total pier width (W_p) = 20 ft
Depth without bridge piers (d) = 14.3 ft



COMPUTE:

1. Horizontal contraction ratio (α)

$$\alpha = \frac{W_p}{W_c} = \frac{20}{200} = 0.10$$

2. Discharge (q) per ft of channel width

$$q = \frac{Q}{W_c} = \frac{40{,}000}{200} = 200 \text{ cfs}$$

3. Critical depth (d_c) in unobstructed channel
   From Chart 610-8, d_c = 10.8 ft
   for q = 200 cfs.

4. $\lambda = d/d_c = 14.3/10.8$
   $= 1.324$

5. Flow classification
   On Plate 11, intersection
   of α = 0.10 and λ = 1.324 is
   in zone marked Class A or B.

6. Upstream depth (d_1)
   a. Class A flow - Energy Method

   $d_1 = d_3 + H_3$ (Plate 14)

   $H_3 = Xd_c$

   X = 0.127 for α = 0.10
   and $\lambda_3 = \lambda = 1.324$

   $H_3 = 0.127 \times 10.8 = 1.37$

   $d_1 = 14.3 + 1.37 = 15.67$ ft

   b. Class B flow - Momentum Method

   $d_1 = \lambda_1 d_c$ (Plate 16)
   $\lambda_1 = 1.435$ for α = 0.10

   $d_1 = 1.435 \times 10.8 = 15.50$ ft

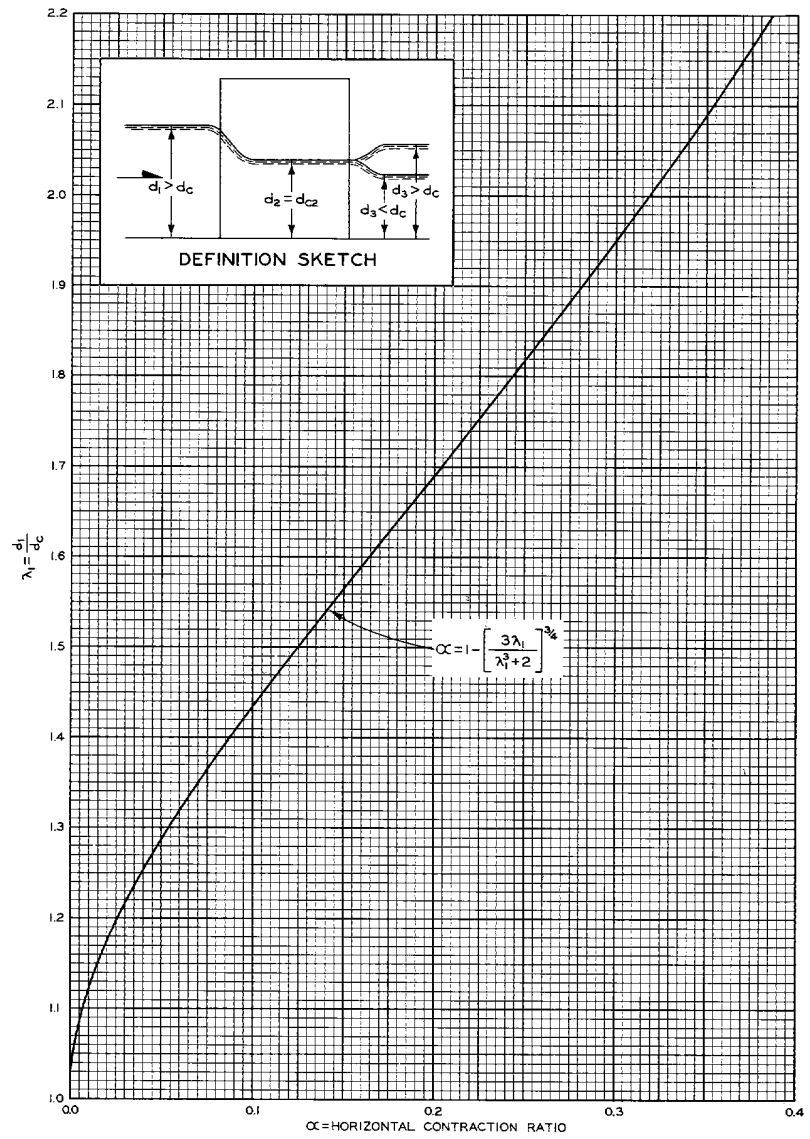
   c. Class B flow - Energy Method

   $d_1 = \lambda_1 d_c$ (Plate 17)
   $\lambda_1 = 1.460$ for α = 0.10

   $d_1 = 1.460 \times 10.8 = 15.77$ ft

RECTANGULAR SECTION
ENERGY METHOD
SAMPLE COMPUTATION

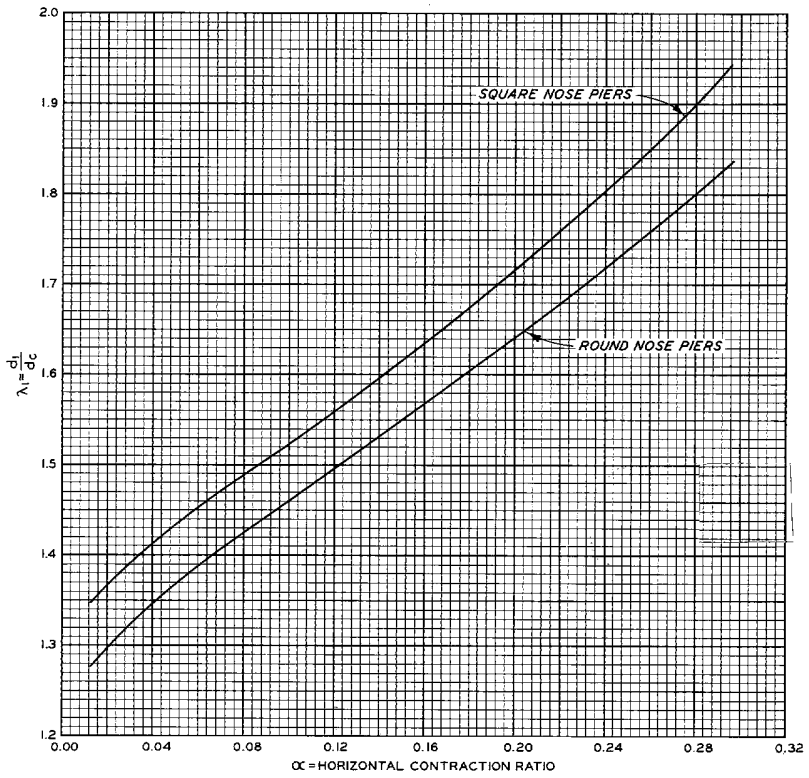
PLATE B-15



NOTE: λ_1 = d_1/d_c
d_1 = UPSTREAM WATER DEPTH
d_c = CRITICAL DEPTH WITHIN THE UNOBSTRUCTED CHANNEL SECTION
d_{c2} = CRITICAL DEPTH WITHIN THE PIER SECTION
α = HORIZONTAL CONTRACTION RATIO

RECTANGULAR SECTION
MOMENTUM METHOD
CLASS B FLOW

PLATE B-16

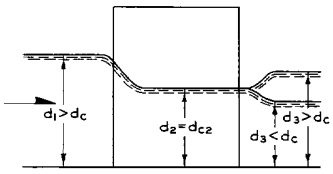


EQUATIONS

$$\frac{1}{(1-\alpha)^{2/3}} = \frac{1}{3\lambda_L^2} + \frac{2\lambda_L}{3}$$

$$\lambda_1 = \lambda_L + \frac{0.5 + K_B(5.5\,\alpha^3 + 0.08)}{2\lambda_1^2}$$

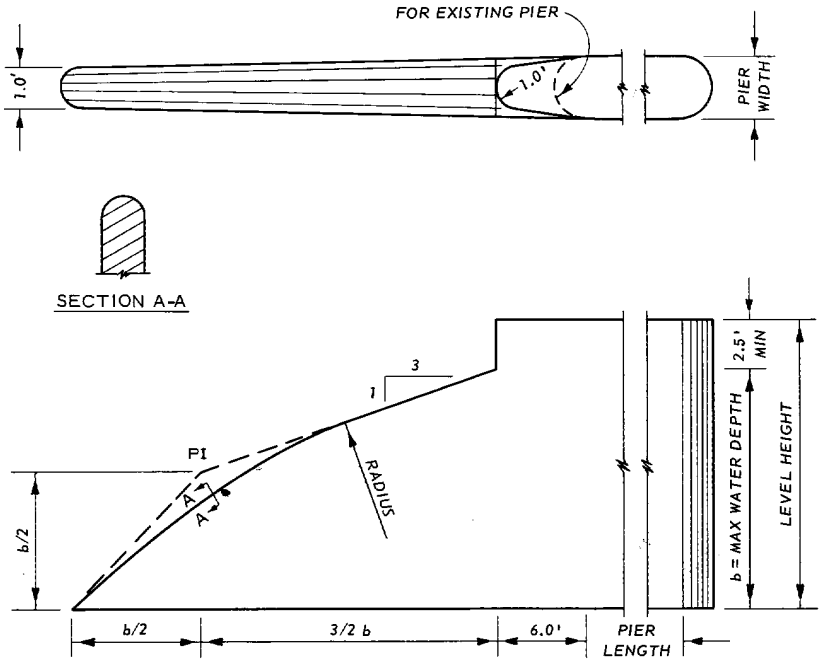
NOTE: λ_1 = d_1/d_c
λ_3 = d_3/d_c
λ_L = LIMITING λ_3 BY ENERGY METHOD
d_1 = UPSTREAM WATER DEPTH
d_3 = DOWNSTREAM WATER DEPTH
d_c = CRITICAL DEPTH WITHIN THE UNOBSTRUCTED CHANNEL SECTION
d_{c2} = CRITICAL DEPTH WITHIN THE PIER SECTION
α = HORIZONTAL CONTRACTION RATIO
K_B = YARNELL PIER-SHAPE COEFFICIENT
(1.0 FOR ROUND NOSE)
(5.0 FOR SQUARE NOSE)



DEFINITION SKETCH

RECTANGULAR SECTION
ENERGY METHOD
CLASS B FLOW

PLATE B-17



DESIGN FOR
BRIDGE PIER EXTENSION

PLATE B-18

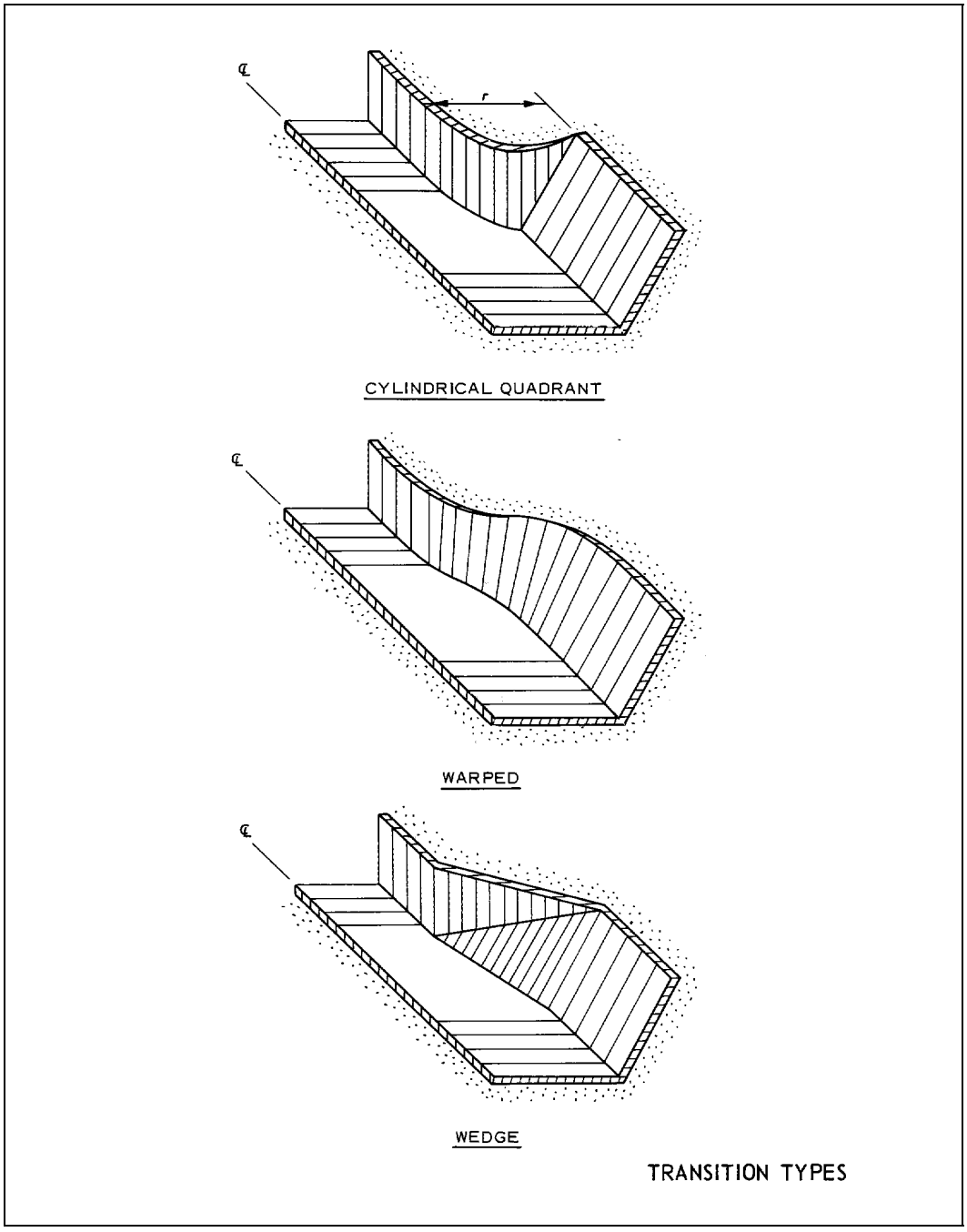
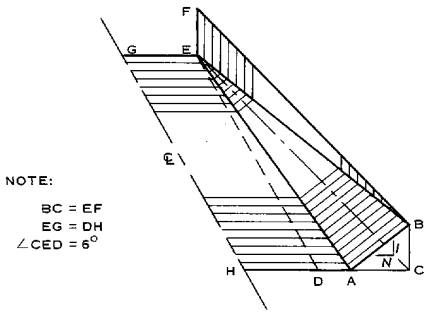


PLATE B-19

TABLE OF GEOMETRIC VALUES

N	AD/BC	DE/BC	AE/BC	CE/BC	BE/BC	ANG AEC[a]	ANG BEC[a]
2.0	0.4000	22.8344	22.8379	22.9602	22.9820	4.9964	2.4939
2.0	0.6000	24.7373	24.7446	24.8735	24.8936	4.6106	2.3022
2.0	0.8000	26.6402	26.6522	26.7869	26.8056	4.2799	2.1380
2.0	1.0000	28.5438	28.5605	28.7002	28.7177	3.9935	1.9955
2.0	1.2000	30.4459	30.4695	30.6136	30.6299	3.7429	1.8709
2.0	1.4000	32.3488	32.3790	32.5269	32.5423	3.5219	1.7609
2.0	1.6000	34.2516	34.2890	34.4403	34.4548	3.3255	1.6632
2.5	0.4000	27.5916	27.5945	27.7436	27.7616	5.1694	2.0643
2.5	0.6000	29.4945	29.5006	29.6569	29.6738	4.8346	1.9312
2.5	0.8000	31.3973	31.4075	31.5703	31.5861	4.5404	1.8143
2.5	1.0000	33.3002	33.3152	33.4836	33.4986	4.2799	1.7106
2.5	1.2000	35.2031	35.2235	35.3970	35.4111	4.0477	1.6182
2.5	1.4000	37.1059	37.1323	37.3103	37.3237	3.8393	1.5353
2.5	1.6000	39.0088	39.0416	39.2237	39.2364	3.6513	1.4604
3.0	0.4000	32.3488	32.3512	32.5269	32.5423	5.2916	1.7609
3.0	0.6000	34.2516	34.2569	34.4403	34.4548	4.9964	1.6632
3.0	0.8000	36.1545	36.1633	36.3536	36.3674	4.7324	1.5757
3.0	1.0000	38.0574	38.0705	38.2670	38.2801	4.4948	1.4969
3.0	1.2000	39.9602	39.9783	40.1803	40.1928	4.2799	1.4257
3.0	1.4000	41.8631	41.8865	42.0937	42.1056	4.0846	1.3609
3.0	1.6000	43.7660	43.7952	44.0070	44.0184	3.9063	1.3017

[a] DEGREES

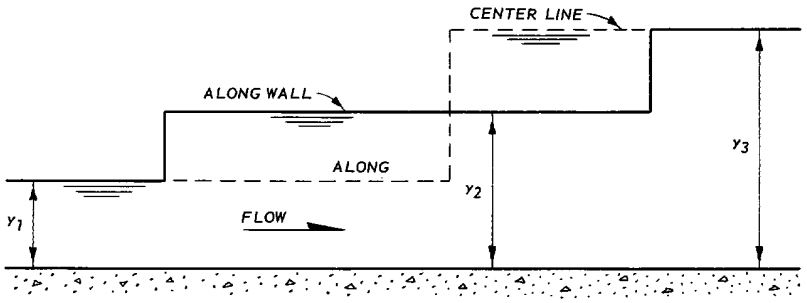


NOTE:
BC = EF
EG = DH
∠CED = 6°

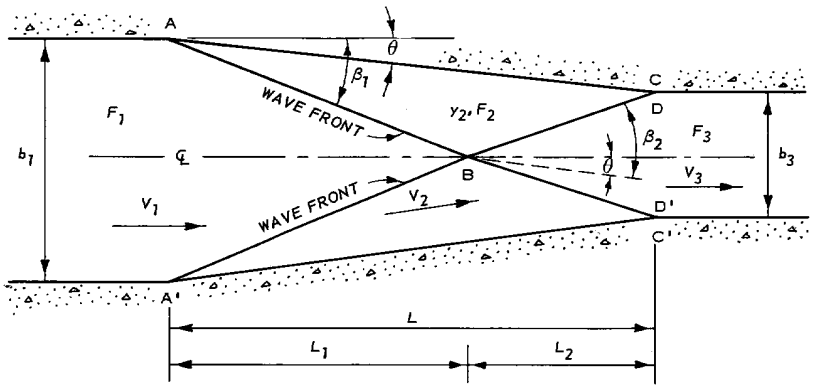
DEFINITION SKETCH

WEDGE-TYPE TRANSITION GEOMETRY

PLATE B-20



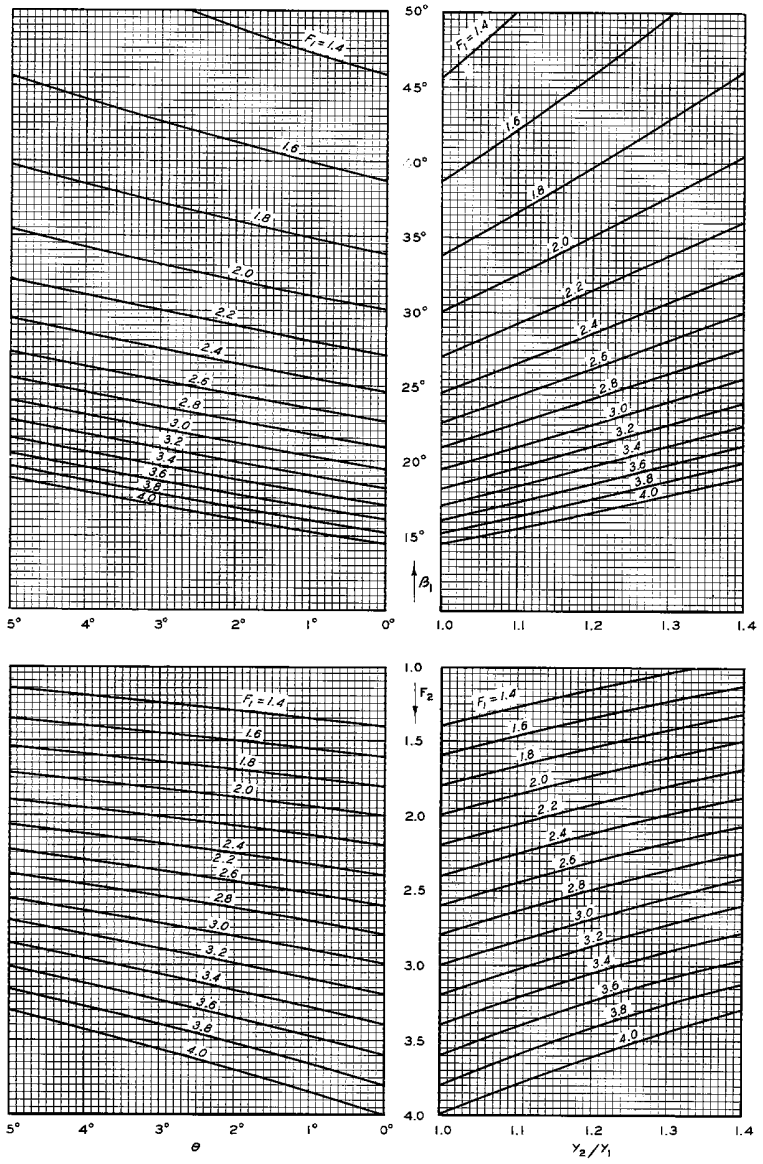
a. SCHEMATIC PROFILE



b. PLAN

TRANSITIONS
RECTANGULAR CHANNELS

PLATE B-21



NOTE: SEE PLATE 21 FOR DEFINITION OF SYMBOLS.

TRANSITION DESIGN CURVES
RECTANGULAR CHANNELS

PLATE B-22

GIVEN

FROUDE NO. $F_1 = 3.5$
FLOW DEPTH $y_1 = 5$ FT
CHANNEL WIDTH $b_1 = 160$ FT
CHANNEL WIDTH $b_3 = 140$ FT

REQUIRED

CONVERGENCE ANGLE θ
FROUDE NO. F_3
FLOW DEPTH y_3
TRANSITION LENGTH $L = L_1 + L_2$

PROCEDURE

ASSUME VALUES OF θ AND BY REPETITIVE USE OF PLATE 22 SOLVE EQUATIONS 2-25, 2-26, AND 2-27 UNTIL $L = L_1 + L_2$. IF COL 6 IS GREATER THAN COL 9, CONTINUE COMPUTATION USING VALUE OF θ WITH F_2 IN SAME MANNER AS WAS DONE WITH F_1. TO COMPUTE COL 11 THROUGH 18, EACH SUBSCRIPT IN PLATE 22 IS ASSUMED TO BE INCREASED BY ONE UNIT.

COMPUTATION

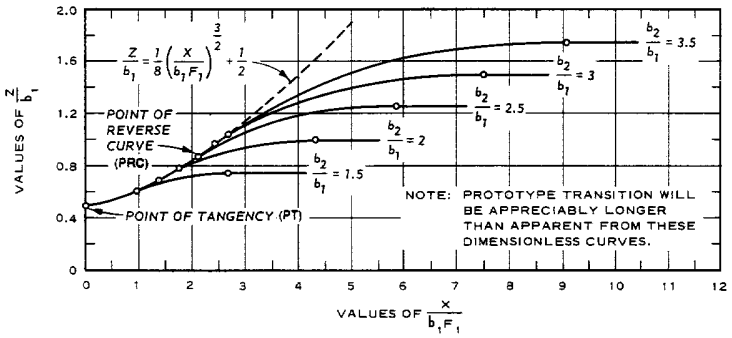
① θ	② $\frac{y_2}{y_1}$	③ y_2, FT	④ β_1, DEG	⑤ TAN θ	⑥ L, FT $= (b_1 - b_3) \div 2$ (TAN θ)
3.0	1.20	6.00	19.2	0.0524	191
2.0	1.12	5.60	18.3	0.0349	287
1.3	1.07	5.35	17.6	0.0227	441
1.2	1.06	5.30	17.5	0.0209	478

⑦ TAN β	⑧ $\frac{b_1}{2}$, FT	⑨ L_1, FT = ⑧ ÷ ⑦	⑩ F_2	⑪ $\frac{y_3}{y_2}$	⑫ y_3, FT
0.348	80	230	($L_1 > L$; ASSUME SMALLER θ)		
0.331	80	242	3.25	1.12	6.27
0.319	80	251	3.34	1.08	5.78
0.315	80	254	3.35	1.08	5.72

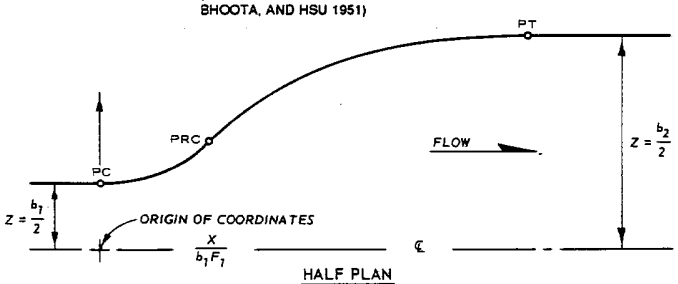
⑬ β_2	⑭ F_3	⑮ $\frac{b_3}{2}$	⑯ TAN $(\beta_2 - \theta)$	⑰ L_2, FT = ⑮ ÷ ⑯	⑱ $L_1 + L_2$, FT
---	---	---	---	---	---
19.7	3.05	70	0.319	219	461 > L
18.5	3.20	70	0.310	226	477 > L
18.2	3.22	70	0.306	229	483 ≈ L

RECTANGULAR TRANSITIONS
EXAMPLE OF DESIGN COMPUTATION

PLATE B-23



a. GENERALIZED DESIGN CURVES
(REPRODUCED FROM FIG. 59, ROUSE, BHOOTA, AND HSU 1951)



HALF PLAN
(NO SCALE)

POINTS	$\frac{Z}{b_1}$	$\frac{X}{b_1F_1}$
PC	$\frac{1}{2}$	0
PRC	$\frac{11}{60}\left(\frac{b_2}{b_1}\right) + \frac{19}{60}$	$\left[\frac{22}{15}\left(\frac{b_2}{b_1} - 1\right)\right]^{2/3}$
PT	$\frac{1}{2}\frac{b_2}{b_1}$	$\frac{13}{4}\left(\frac{b_2}{b_1}\right) - \frac{9}{4}$
PC TO PRC	$\frac{1}{8}\left(\frac{X}{b_1F_1}\right)^{3/2} + \frac{1}{2}$	0 TO $\left(\frac{X}{b_1F_1}\right)_{PRC}$
PRC TO PT	$\frac{b_2}{2b_1} - q\left[\left(\frac{X}{b_1F_1}\right)_{PT} - \frac{X}{b_1F_1}\right]^r$	$\left(\frac{X}{b_1F_1}\right)_{PRC}$ TO $\left(\frac{X}{b_1F_1}\right)_{PT}$

WHERE

$$q = \frac{\frac{b_2}{2b_1} - \left(\frac{Z}{b_1}\right)_{PRC}}{\left[\left(\frac{X}{b_1F_1}\right)_{PT} - \left(\frac{X}{b_1F_1}\right)_{PRC}\right]^r} \quad \text{AND} \quad r = \frac{\left(\frac{X}{b_1F_1}\right)_{PT} - \left(\frac{X}{b_1F_1}\right)_{PRC}}{\frac{b_2}{2b_1} - \left(\frac{Z}{b_1}\right)_{PRC}} \left(\frac{3}{16}\right)\left(\frac{X}{b_1F_1}\right)^{1/2}_{PRC}$$

b. EQUATIONS APPROXIMATING CURVES

NOTE: TRANSITION COORDINATES CAN BE SCALED FROM CURVES OR COMPUTED FROM EQUATIONS USING b_1, b_2, AND F_1.

EXPANDING TRANSITION RECTANGULAR CHANNEL
RAPID FLOW

PLATE B-24

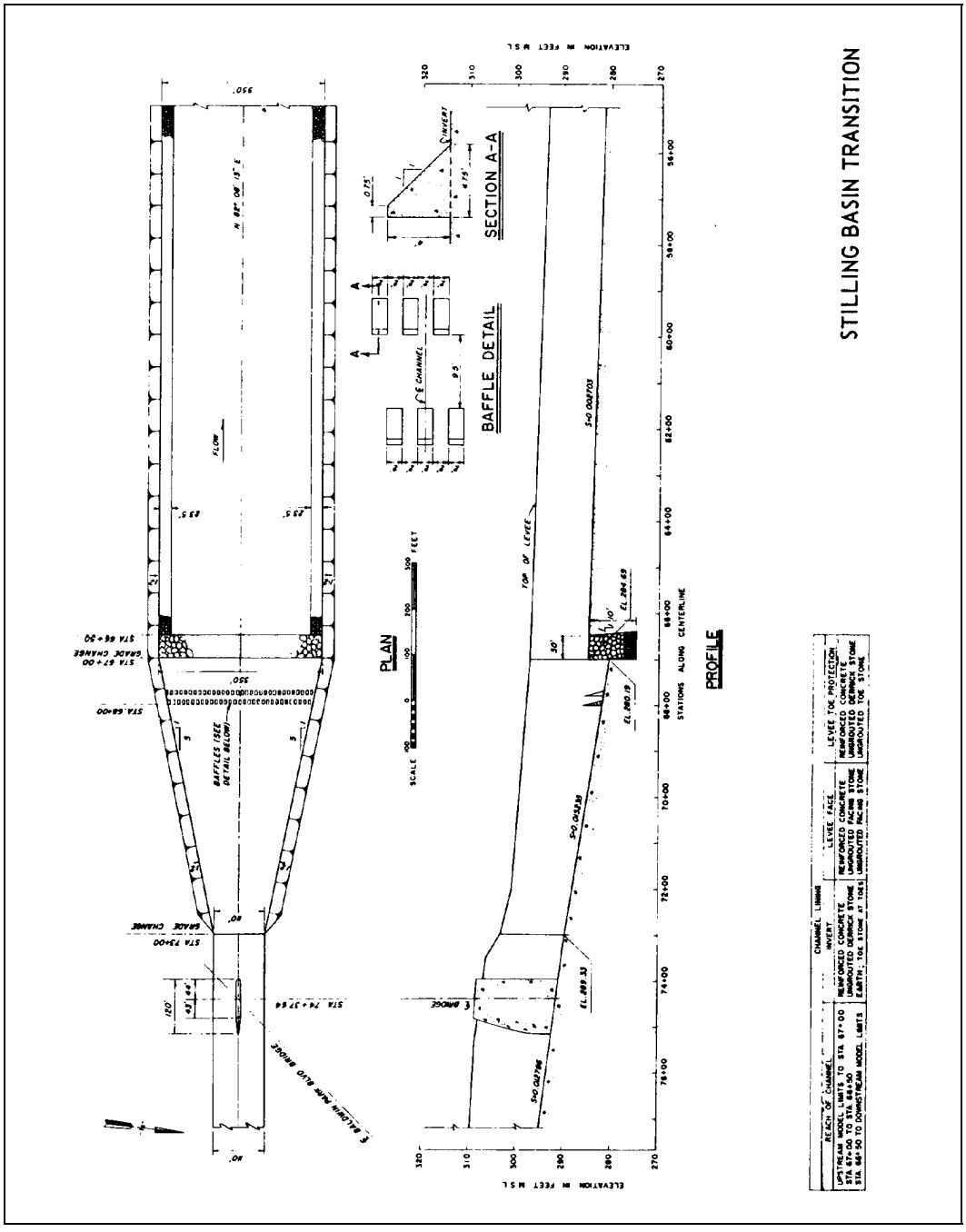

STILLING BASIN TRANSITION
PLAN
PROFILE
SECTION A-A
BAFFLE DETAIL
ELEVATION IN FEET M.S.L.
STATIONS ALONG CENTERLINE
TOP OF LEVEE
FLOW
BAFFLES (SEE DETAIL BELOW)
GRADE CHANGE
STA 67+00
STA 66+50
STA 68+00
STA 73+00
STA 74+37.64
EL 284.69
EL 280.19
EL 289.33
S=0.002703
S=0.012786
S=0.012238
INVERT
CHANNEL LINING
INVERT
LEVEE FACE
LEVEE TOE PROTECTION
REACH OF CHANNEL
UPSTREAM MODEL LIMITS TO STA 67+00
STA 67+00 TO STA 66+50
STA 66+50 TO DOWNSTREAM MODEL LIMITS
REINFORCED CONCRETE
UNGROUTED DERRICK STONE
EARTH; TOE STONE AT TOES
REINFORCED CONCRETE
UNGROUTED FACING STONE
UNGROUTED FACING STONE
REINFORCED CONCRETE
UNGROUTED DERRICK STONE
UNGROUTED TOE STONE

PLATE B-25

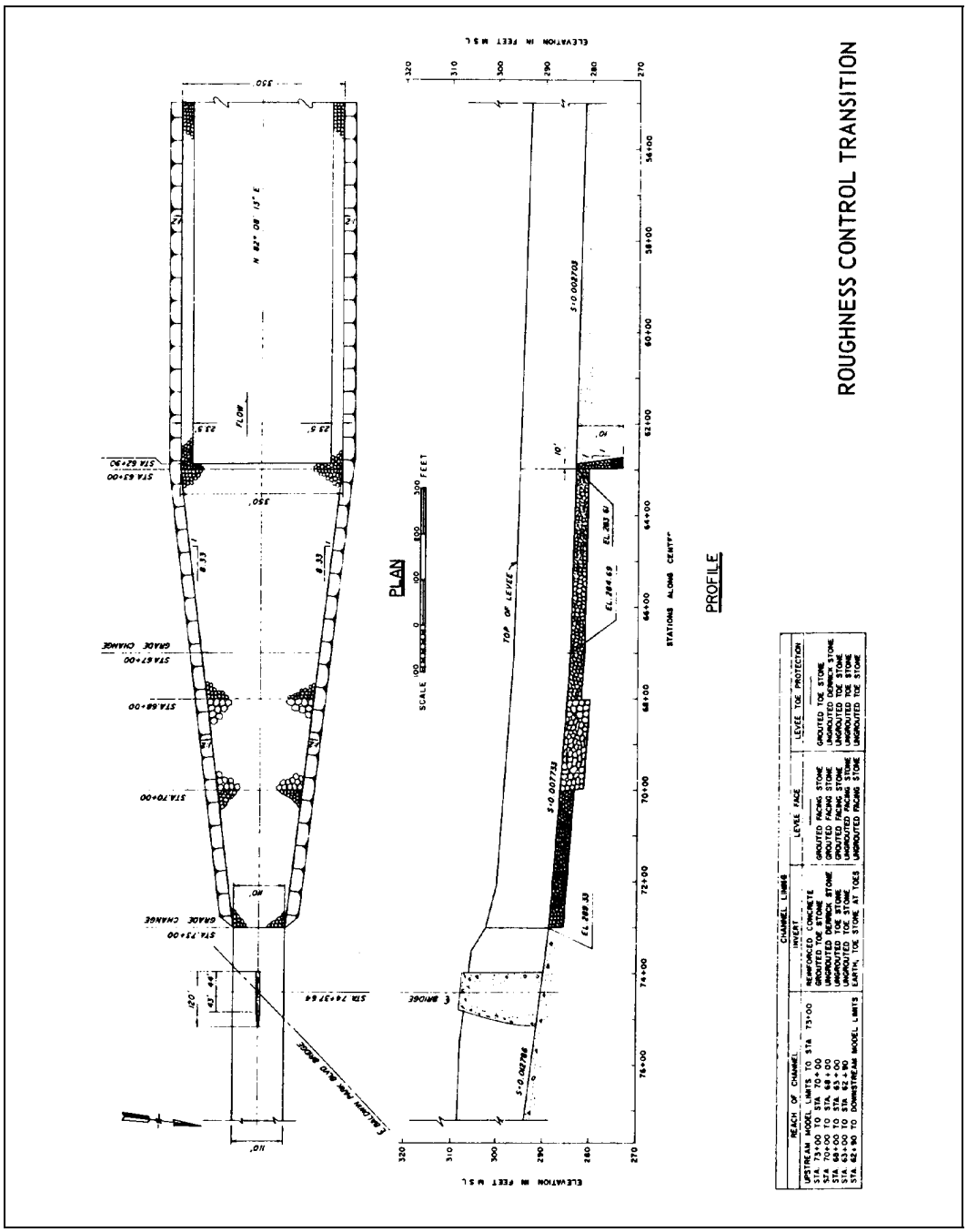
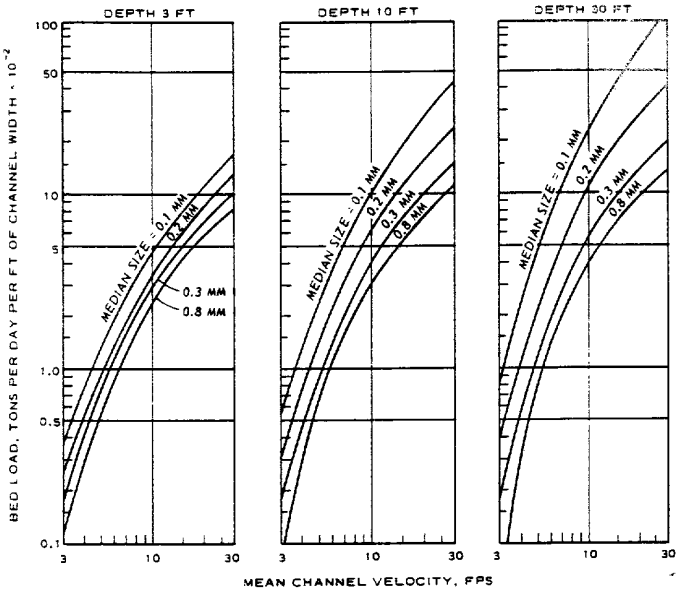

ROUGHNESS CONTROL TRANSITION
PLAN
PROFILE
SCALE
FEET
STATIONS ALONG CENTER
ELEVATION IN FEET M S L
TOP OF LEVEE
CHANNEL LINING
REACH OF CHANNEL
INVERT
LEVEE FACE
LEVEE TOE PROTECTION
UPSTREAM MODEL LIMITS TO STA 73+00
REINFORCED CONCRETE
GROUTED FACING STONE
GROUTED TOE STONE
STA 73+00 TO STA 69+00
REINFORCED CONCRETE
GROUTED FACING STONE
GROUTED TOE STONE
STA 69+00 TO STA 63+00
UNGROUTED STONE
GROUTED FACING STONE
UNGROUTED TOE STONE
STA 63+00 TO STA 62+90
UNGROUTED TOE STONE
UNGROUTED FACING STONE
UNGROUTED TOE STONE
STA 62+90 TO DOWNSTREAM MODEL LIMITS
EARTH, TOE STONE AT TOES
UNGROUTED RUBBLE STONE
UNGROUTED TOE STONE

PLATE B-26



BASIC DATA SOURCES

FIELD DATA		FLUME DATA	
RIVER	LOCATION	INVESTIGATOR	DATE OF TESTS
MIDDLE LOOP[a]	DUNNING, NEBRASKA	GILBERT	1914
NIOBRARA[a]	CODY, NEBRASKA	BARTON AND LIN	1955
ELKHORN	WATERLOO, NEBRASKA	SIMONS, ET AL.	1961
LOWER COLORADO	---	BROOKS	1958
PIGEON ROOST CK.	NORTHERN MISSISSIPPI		
MISSISSIPPI	ST. LOUIS, MO.		
CEDAR	NEBRASKA		
LITTLE BLUE	NEBRASKA		
NORTH LOOP	NEBRASKA		
SOUTH LOOP	NEBRASKA		
RIO GRANDE	NEW MEXICO		
RIO PUERCO	NEW MEXICO		

NOTE: SOURCES OF PUBLISHED FLUME AND FIELD DATA ARE GIVEN IN COLBY (1964A); SOME FIELD DATA HAVE NOT BEEN PUBLISHED. CURVES ARE FOR WATER TEMPERATURE OF 60 F AND NO SUSPENDED FINE SEDIMENT LOAD AND ARE EXTRAPOLATED FROM A PLOT IN THE REFERENCE.

[a] TOTAL LOAD MEASURED FOR THESE TWO STREAMS; SUSPENDED LOAD MEASURED AND BED LOAD COMPUTED FOR OTHER FIELD DATA.

BED-LOAD DISCHARGE

PLATE B-27

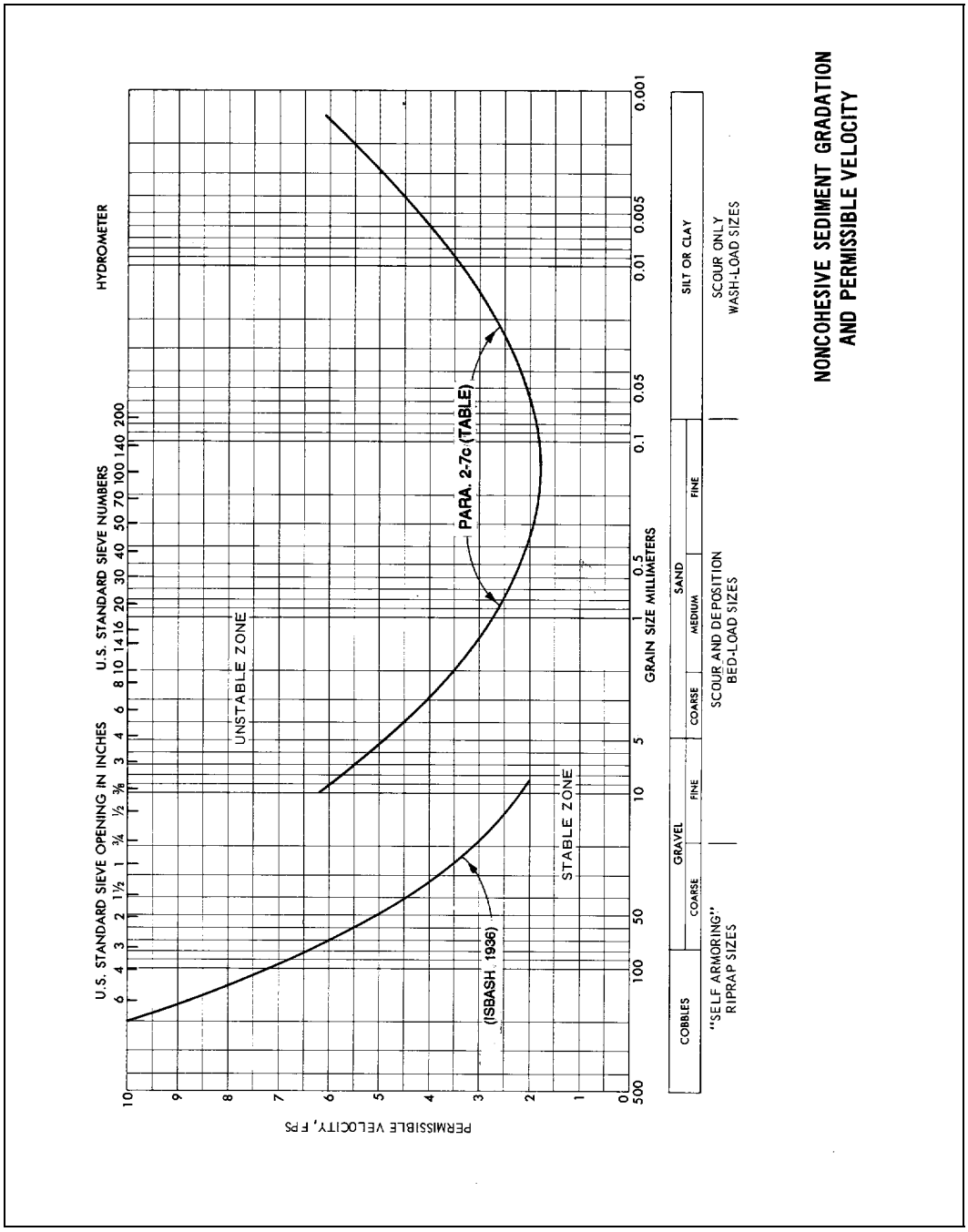

NONCOHESIVE SEDIMENT GRADATION
AND PERMISSIBLE VELOCITY
PERMISSIBLE VELOCITY, FPS
U.S. STANDARD SIEVE OPENING IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
GRAIN SIZE MILLIMETERS
UNSTABLE ZONE
STABLE ZONE
PARA. 2-7c (TABLE)
(ISBASH, 1936)
COBBLES
GRAVEL
SAND
SILT OR CLAY
"SELF ARMORING" RIPRAP SIZES
SCOUR AND DEPOSITION BED-LOAD SIZES
SCOUR ONLY WASH-LOAD SIZES

PLATE B-28

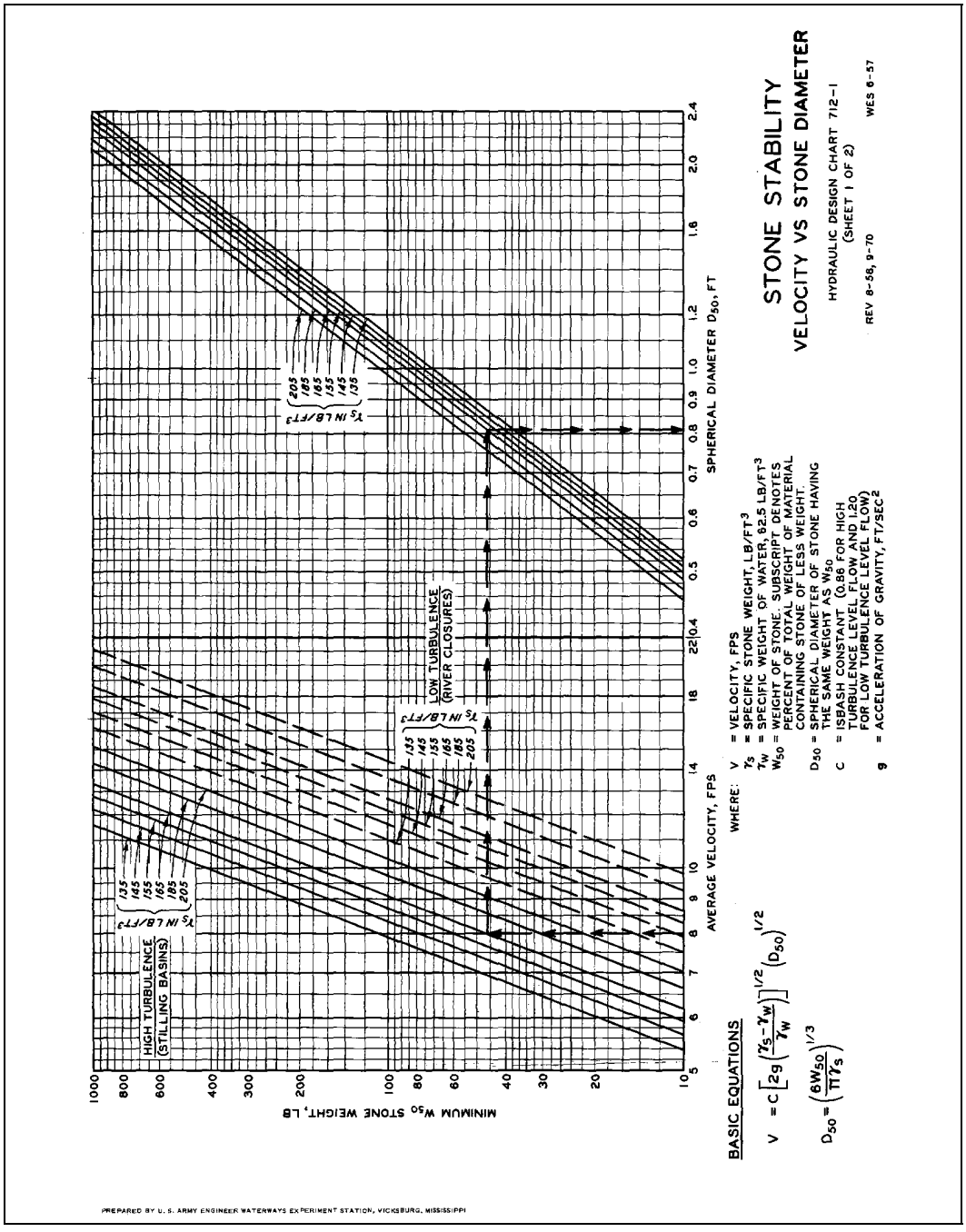

STONE STABILITY
VELOCITY VS STONE DIAMETER
HYDRAULIC DESIGN CHART 712-1
(SHEET 1 OF 2)
REV 8-56, 9-70
WES 6-57
MINIMUM W50 STONE WEIGHT, LB
AVERAGE VELOCITY, FPS
SPHERICAL DIAMETER D50, FT
HIGH TURBULENCE (STILLING BASINS)
LOW TURBULENCE (RIVER CLOSURES)
γs IN LB/FT3
135
145
155
165
185
205
BASIC EQUATIONS
V = C[2g(γs-γw/γw)]^1/2 (D50)^1/2
D50 = (6W50/πγs)^1/3
WHERE:
V = VELOCITY, FPS
γs = SPECIFIC STONE WEIGHT, LB/FT3
γw = SPECIFIC WEIGHT OF WATER, 62.5 LB/FT3
W50 = WEIGHT OF STONE. SUBSCRIPT DENOTES PERCENT OF TOTAL WEIGHT OF MATERIAL CONTAINING STONE OF LESS WEIGHT.
D50 = SPHERICAL DIAMETER OF STONE HAVING THE SAME WEIGHT AS W50
C = ISBASH CONSTANT (0.86 FOR HIGH TURBULENCE LEVEL FLOW AND 1.20 FOR LOW TURBULENCE LEVEL FLOW)
g = ACCELERATION OF GRAVITY, FT/SEC2
PREPARED BY U. S. ARMY ENGINEER WATERWAYS EXPERIMENT STATION, VICKSBURG, MISSISSIPPI

PLATE B-29

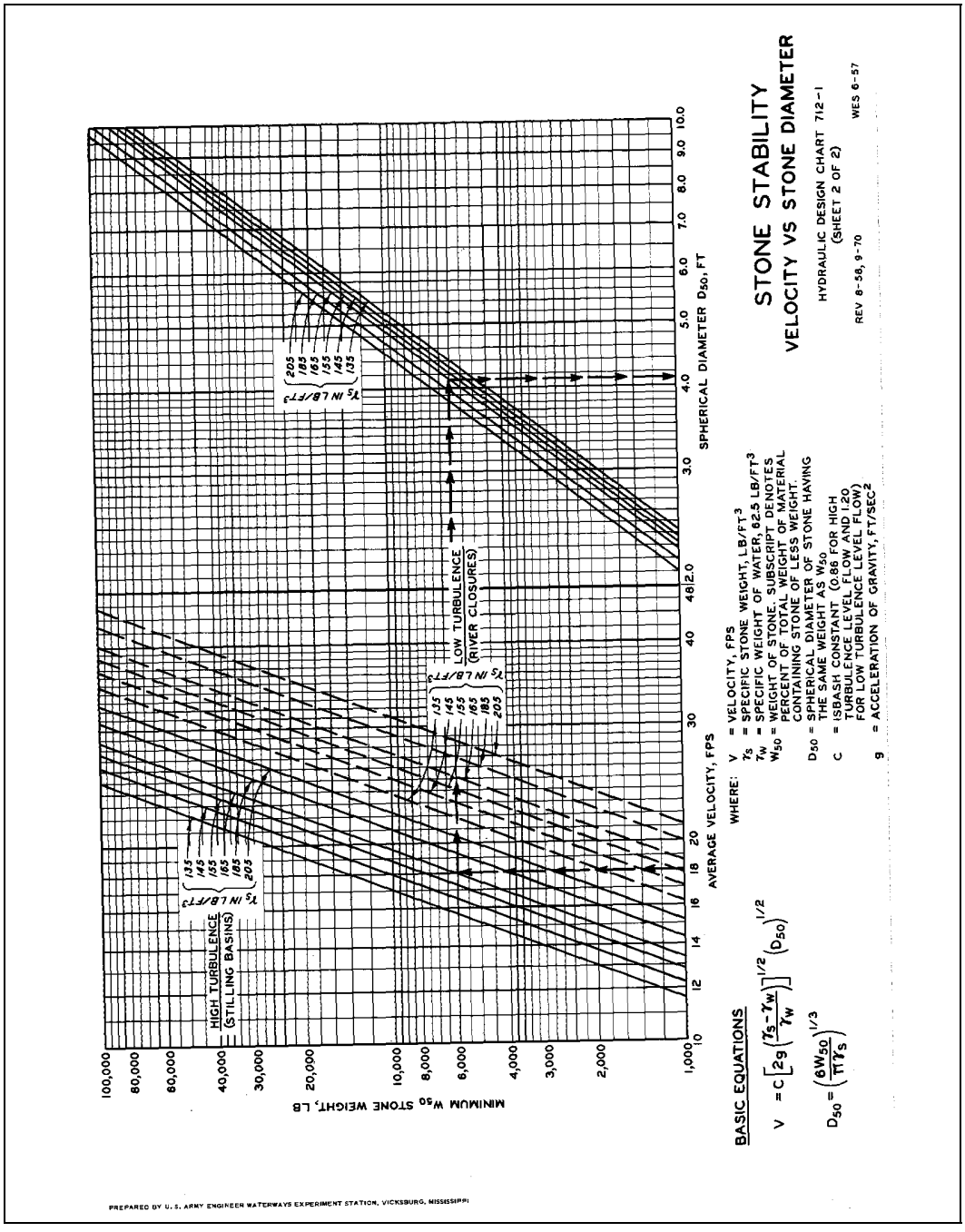
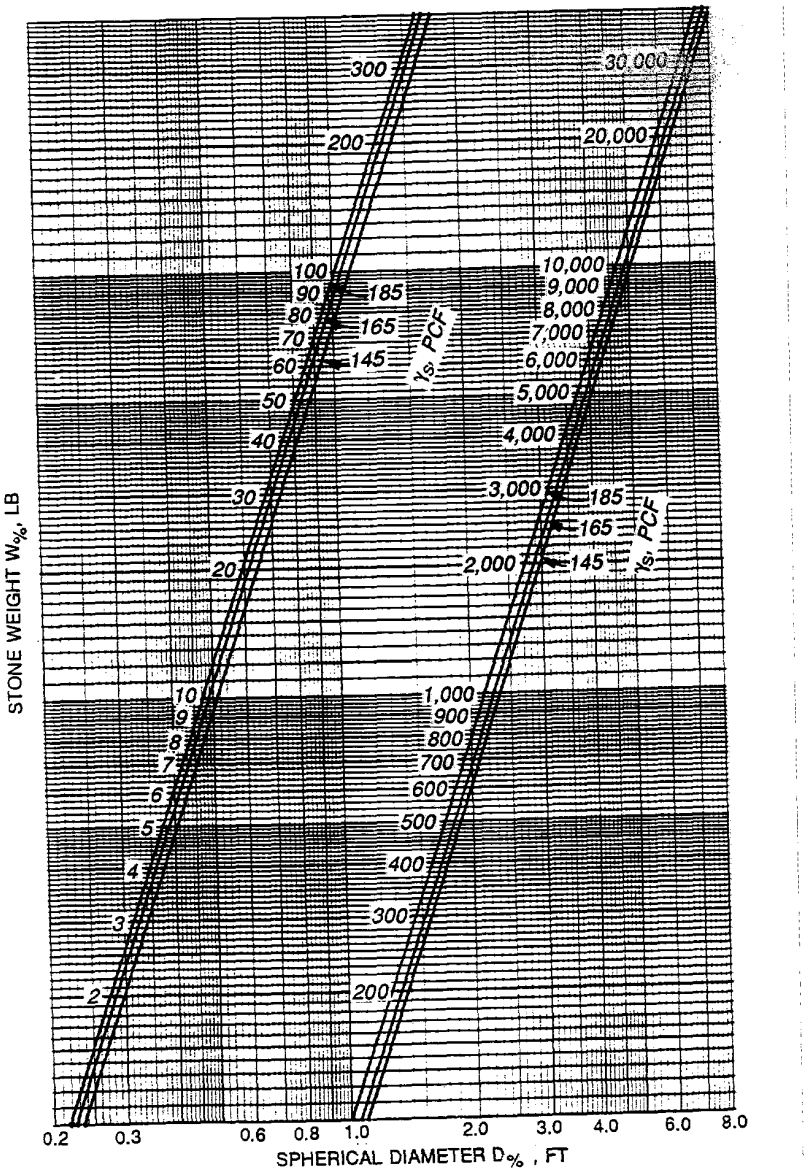

STONE STABILITY
VELOCITY VS STONE DIAMETER
HYDRAULIC DESIGN CHART 712-1
(SHEET 2 OF 2)
REV 8-58, 9-70
WES 6-57
MINIMUM W50 STONE WEIGHT, LB
AVERAGE VELOCITY, FPS
SPHERICAL DIAMETER D50, FT
HIGH TURBULENCE (STILLING BASINS)
LOW TURBULENCE (RIVER CLOSURES)
γs IN LB/FT3
135
145
155
165
185
205
BASIC EQUATIONS
V = C[2g((γs-γw)/γw)]^1/2 (D50)^1/2
D50 = (6W50/(πγs))^1/3
WHERE:
V = VELOCITY, FPS
γs = SPECIFIC STONE WEIGHT, LB/FT3
γw = SPECIFIC WEIGHT OF WATER, 62.5 LB/FT3
W50 = WEIGHT OF STONE. SUBSCRIPT DENOTES PERCENT OF TOTAL WEIGHT OF MATERIAL CONTAINING STONE OF LESS WEIGHT.
D50 = SPHERICAL DIAMETER OF STONE HAVING THE SAME WEIGHT AS W50
C = ISBASH CONSTANT (0.86 FOR HIGH TURBULENCE LEVEL FLOW AND 1.20 FOR LOW TURBULENCE LEVEL FLOW)
g = ACCELERATION OF GRAVITY, FT/SEC2
PREPARED BY U. S. ARMY ENGINEER WATERWAYS EXPERIMENT STATION, VICKSBURG, MISSISSIPPI

PLATE B-30



EQUATION:

$$W_{\%} = \frac{\pi \gamma_S D_{\%}^3}{6} \quad \text{OR} \quad D_{\%} = \left(\frac{6W_{\%}}{\pi \gamma_S}\right)^{1/3}$$

STONE WEIGHT VS
SPHERICAL DIAMETER

PLATE B-31

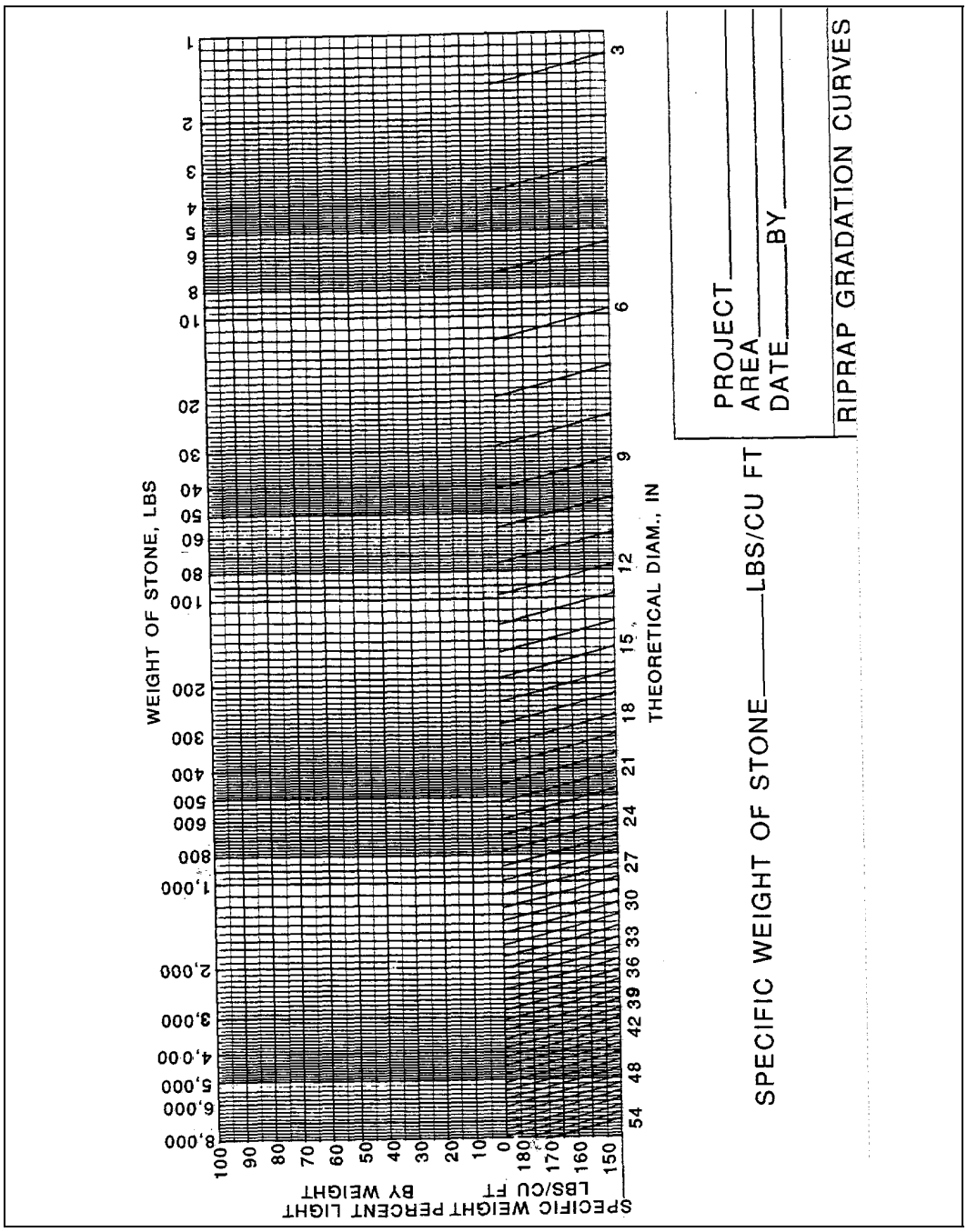
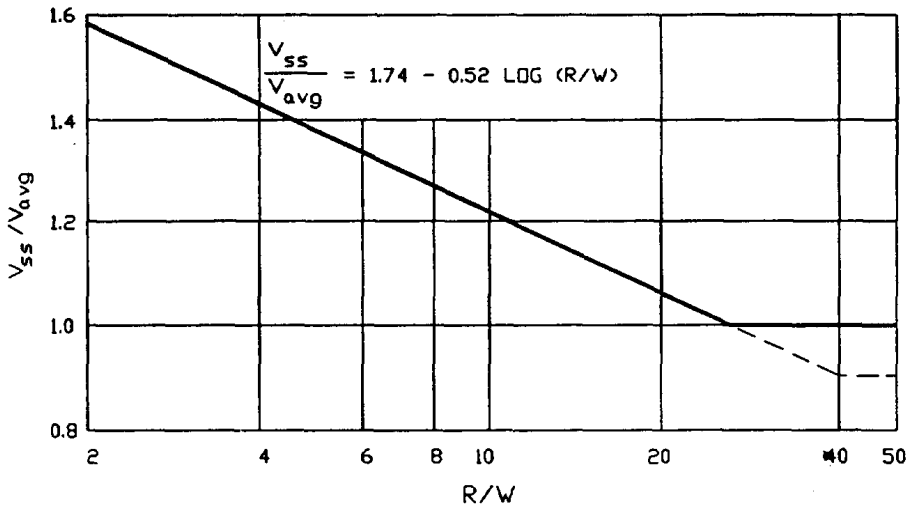

RIPRAP GRADATION CURVES
PROJECT
AREA
DATE
BY
SPECIFIC WEIGHT OF STONE_____LBS/CU FT
WEIGHT OF STONE, LBS
THEORETICAL DIAM., IN
SPECIFIC WEIGHT LBS/CU FT
PERCENT LIGHT BY WEIGHT

PLATE B-32

*



NOTE: V_{ss} IS DEPTH-AVERAGED VELOCITY AT 20 PERCENT OF SLOPE LENGTH UP FROM TOE

RIPRAP DESIGN VELOCITIES
NATURAL CHANNEL

Plate B-33
(Sheet 1 of 2)

*

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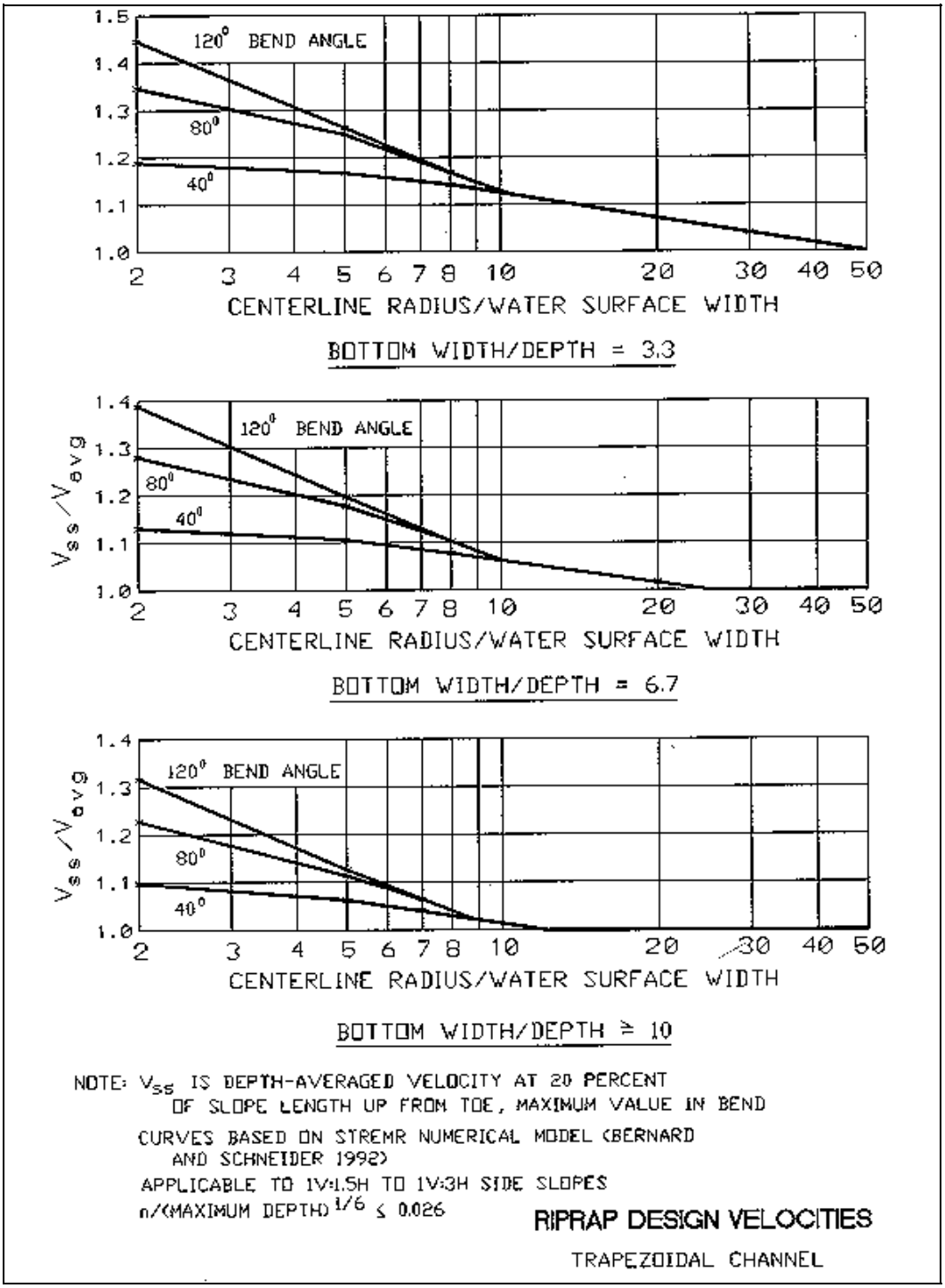

Plate B-33
(Sheet 2 of 2)

*

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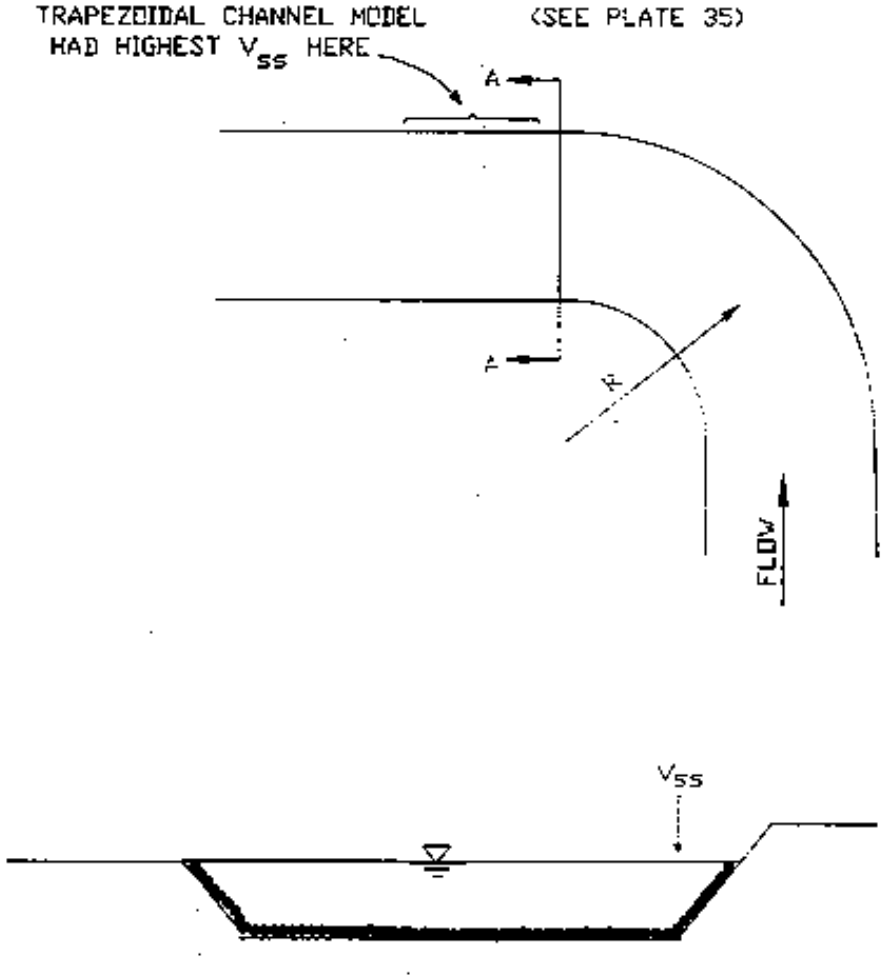

TRAPEZOIDAL CHANNEL MODEL (SEE PLATE 35)
HAD HIGHEST V_{ss} HERE
A
A
R
FLOW
V_{ss}
SECTION A-A
R = CENTER-LINE RADIUS
V_{ss} = DEPTH-AVERAGED VELOCITY IN THE VERTICAL OVER SLOPE AT 20 PERCENT OF SLOPE LENGTH UP FROM TOE.
PARAMETERS USED IN STONE SIZE CALCULATION

Plate B-34

*

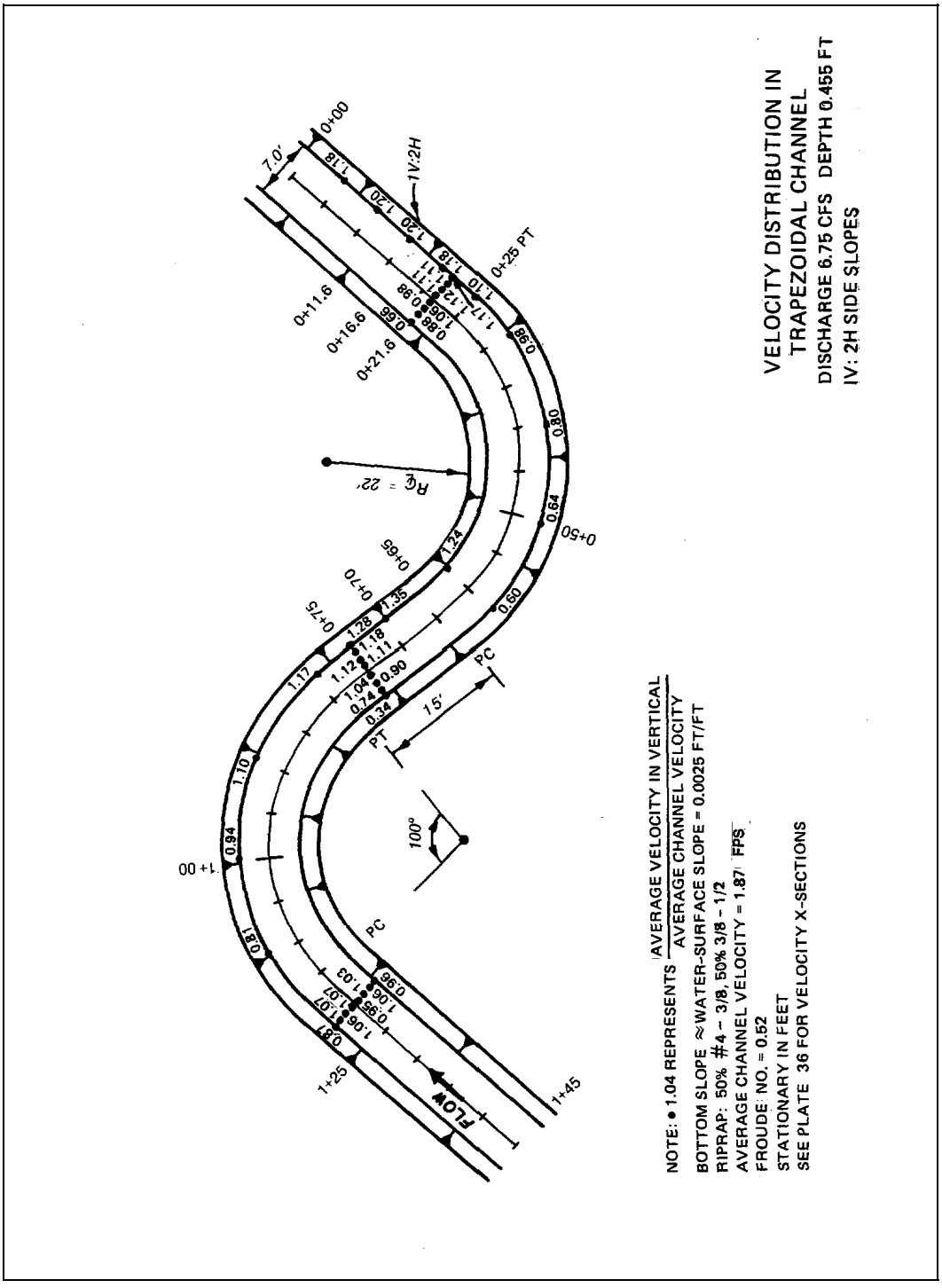
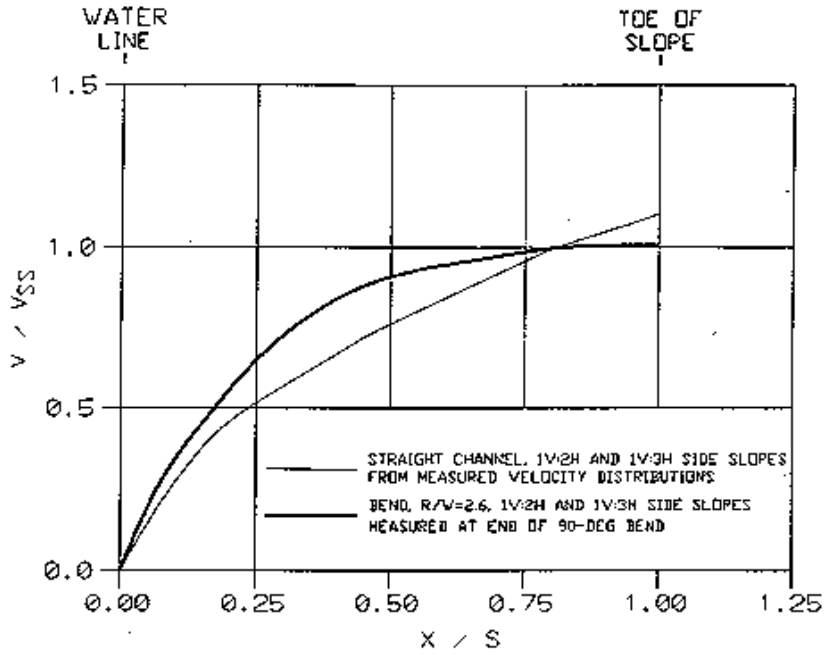

VELOCITY DISTRIBUTION IN
TRAPEZOIDAL CHANNEL
DISCHARGE 6.75 CFS DEPTH 0.455 FT
IV: 2H SIDE SLOPES
NOTE: • 1.04 REPRESENTS AVERAGE VELOCITY IN VERTICAL / AVERAGE CHANNEL VELOCITY
BOTTOM SLOPE ≈WATER-SURFACE SLOPE = 0.0025 FT/FT
RIPRAP: 50% #4 – 3/8, 50% 3/8 – 1/2
AVERAGE CHANNEL VELOCITY = 1.87 FPS
FROUDE NO. = 0.52
STATIONARY IN FEET
SEE PLATE 36 FOR VELOCITY X-SECTIONS
0+00
1+00
1+25
1+45
0+25 PT
0+50
PC
PT
15'
100°
1V:2H
7.0'
FLOW

Plate B-35

*



V = DEPTH-AVERAGED VELOCITY AT X

V_{SS} = DEPTH-AVERAGED VELOCITY AT 20 PERCENT UP SLOPE FROM TOE

X = HORIZONTAL DISTANCE FROM WATER LINE

S = HORIZONTAL DISTANCE FROM WATER LINE TO TOE OF SLOPE

SIDE SLOPE VELOCITY DISTRIBUTION

Plate B-36

*

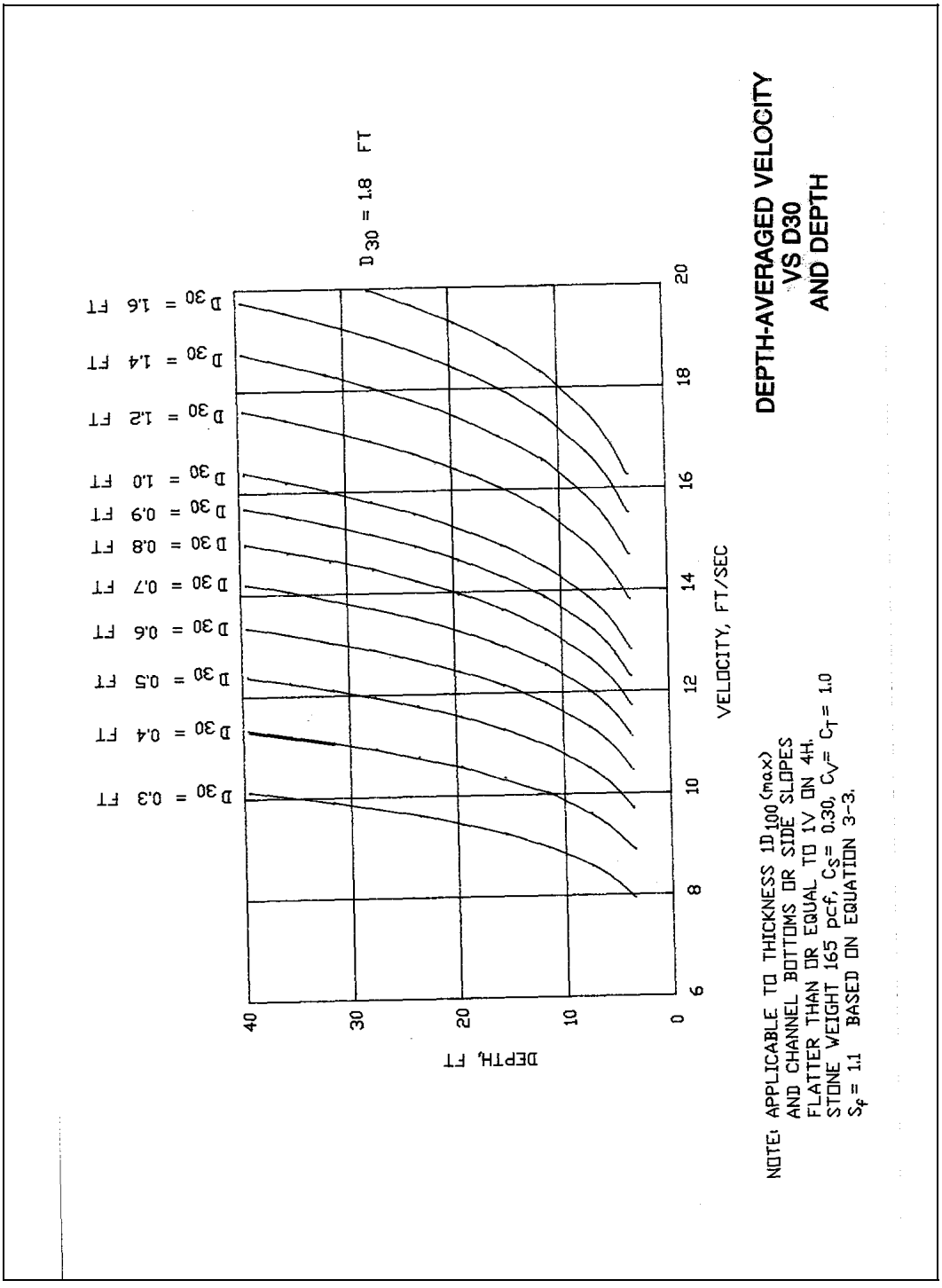
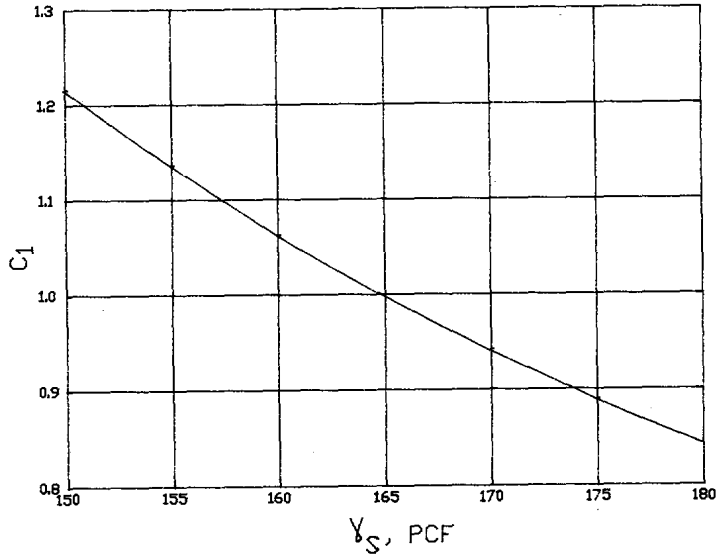

DEPTH-AVERAGED VELOCITY
VS D30
AND DEPTH
NOTE: APPLICABLE TO THICKNESS $1D_{100}$ (max)
AND CHANNEL BOTTOMS OR SIDE SLOPES
FLATTER THAN OR EQUAL TO 1V ON 4H.
STONE WEIGHT 165 pcf, C_S= 0.30, C_V= C_T= 1.0
S_g = 1.1 BASED ON EQUATION 3-3.
VELOCITY, FT/SEC
DEPTH, FT
D_{30} = 1.8 FT
D_{30} = 1.6 FT
D_{30} = 1.4 FT
D_{30} = 1.2 FT
D_{30} = 1.0 FT
D_{30} = 0.9 FT
D_{30} = 0.8 FT
D_{30} = 0.7 FT
D_{30} = 0.6 FT
D_{30} = 0.5 FT
D_{30} = 0.4 FT
D_{30} = 0.3 FT

Plate B-37

*



$D_{30} = C_1 * (D_{30}$ FROM PLATE 37)

WHERE C_1 = CORRECTION FOR UNIT STONE WEIGHT

NOTE: DO NOT MAKE THIS CORRECTION IF
D_{30} COMPUTED FROM EQUATION 3-3

CORRECTION FOR UNIT STONE WEIGHT

Plate B-38

*

*

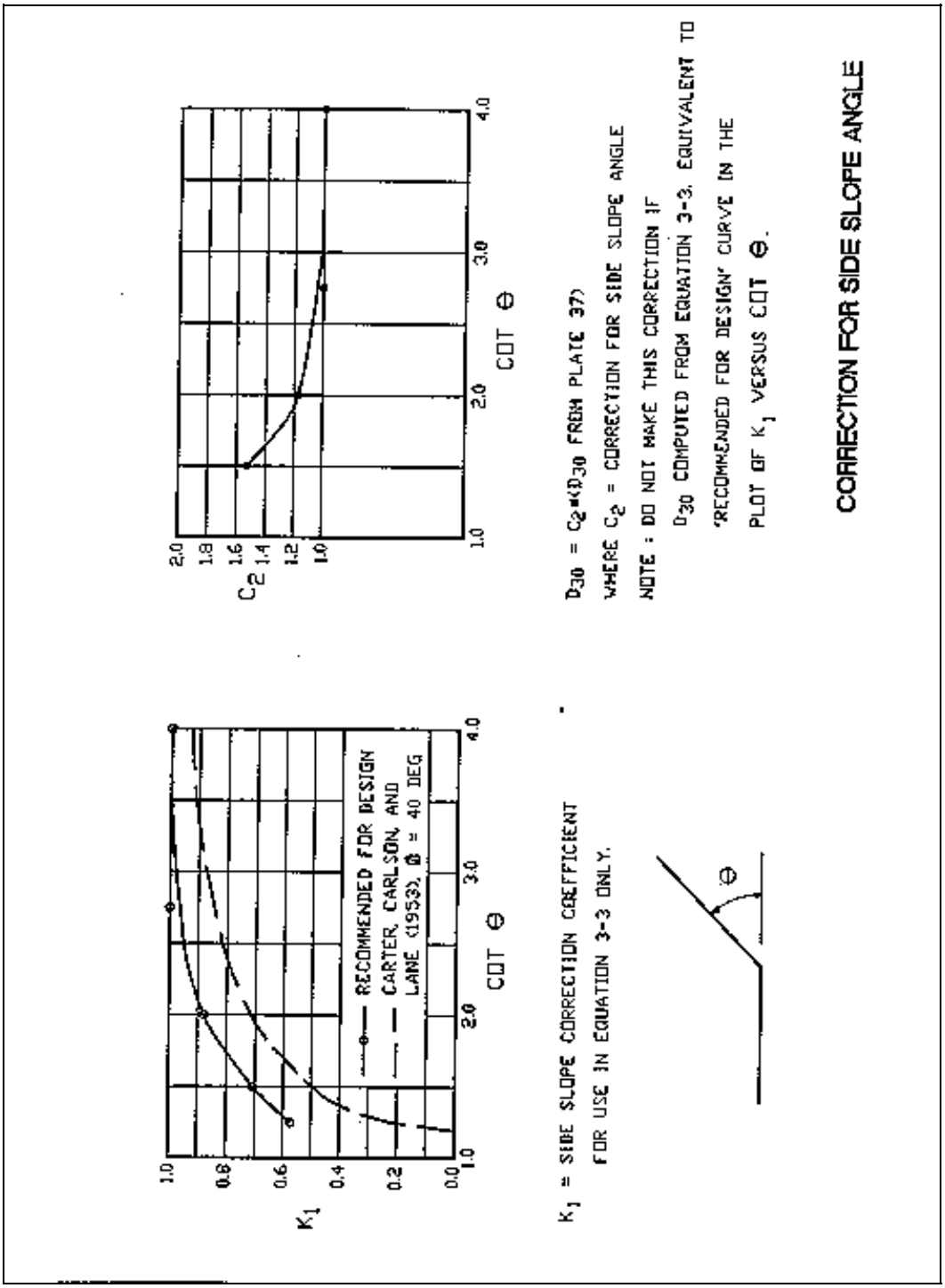

CORRECTION FOR SIDE SLOPE ANGLE
PLOT OF K_1 VERSUS COT θ.
"RECOMMENDED FOR DESIGN" CURVE IN THE
D_{30} COMPUTED FROM EQUATION 3-3, EQUIVALENT TO
NOTE : DO NOT MAKE THIS CORRECTION IF
WHERE C_2 = CORRECTION FOR SIDE SLOPE ANGLE
$D_{30} = C_2 * D_{30}$ FROM PLATE 37)
K_1 = SIDE SLOPE CORRECTION COEFFICIENT
FOR USE IN EQUATION 3-3 ONLY.
C_2
COT θ
K_1
RECOMMENDED FOR DESIGN
CARTER, CARLSON, AND
LANE (1953), θ = 40 DEG
COT θ
θ

Plate B-39

*

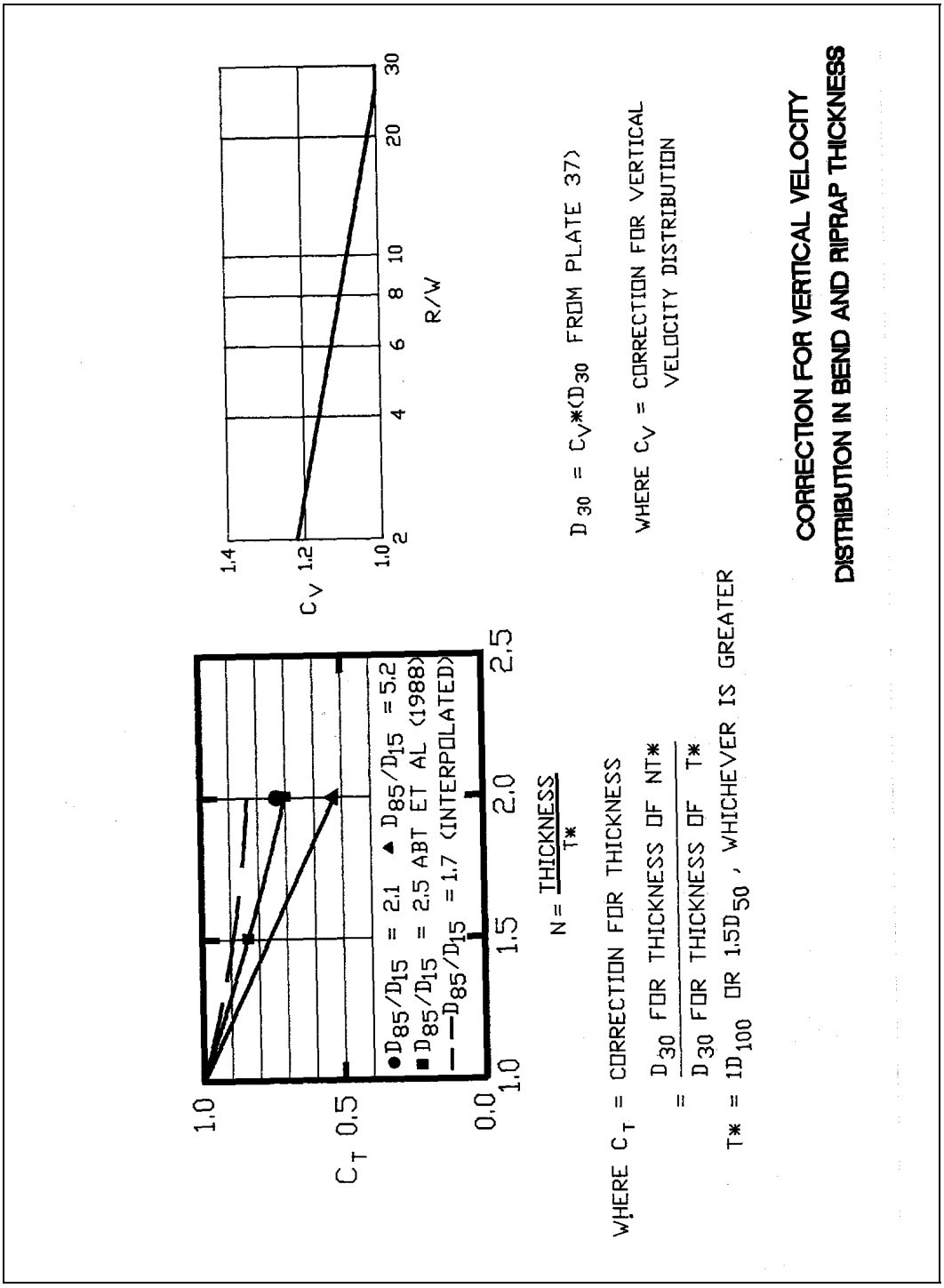

CORRECTION FOR VERTICAL VELOCITY
DISTRIBUTION IN BEND AND RIPRAP THICKNESS
C_V
1.4
1.2
1.0
2
4
6
8
10
20
30
R/W
$D_{30} = C_V * (D_{30}$ FROM PLATE 37)
WHERE C_V = CORRECTION FOR VERTICAL VELOCITY DISTRIBUTION
C_T
1.0
0.5
0.0
1.0
1.5
2.0
2.5
$N = \frac{\text{THICKNESS}}{T*}$
● D_{85}/D_{15} = 2.1 ▲ D_{85}/D_{15} = 5.2
■ D_{85}/D_{15} = 2.5 ABT ET AL (1988)
— — D_{85}/D_{15} = 1.7 (INTERPOLATED)
WHERE C_T = CORRECTION FOR THICKNESS
$= \frac{D_{30} \text{ FOR THICKNESS OF } NT*}{D_{30} \text{ FOR THICKNESS OF } T*}$
$T* = 1D_{100}$ OR $1.5D_{50}$, WHICHEVER IS GREATER

Plate B-40

*

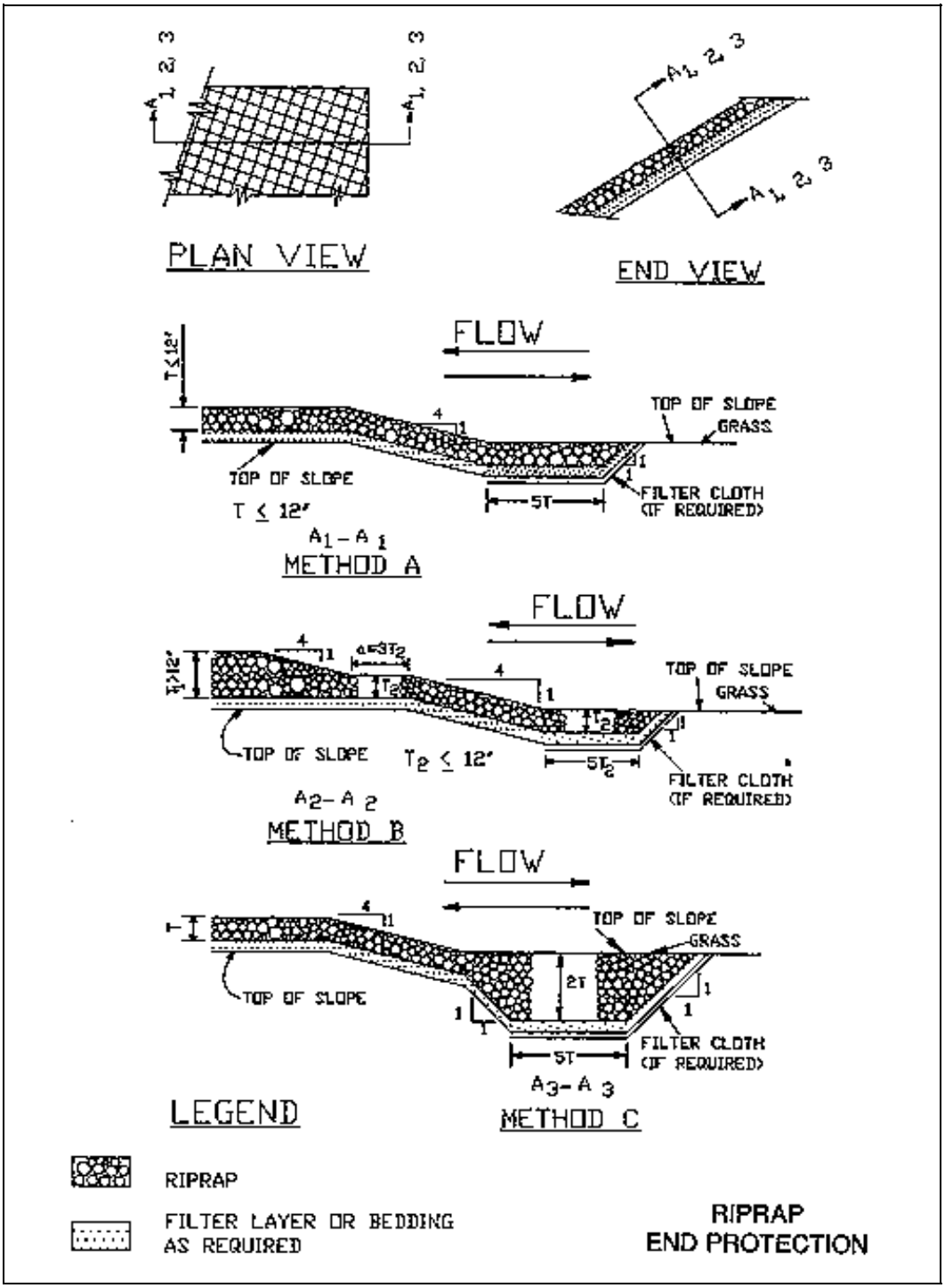

PLAN VIEW
END VIEW
FLOW
TOP OF SLOPE
GRASS
FILTER CLOTH (IF REQUIRED)
T ≤ 12"
A1 – A1
METHOD A
T2 ≤ 12"
A2 – A2
METHOD B
A3 – A3
METHOD C
LEGEND
RIPRAP
FILTER LAYER OR BEDDING AS REQUIRED
RIPRAP END PROTECTION

Plate B-41

*

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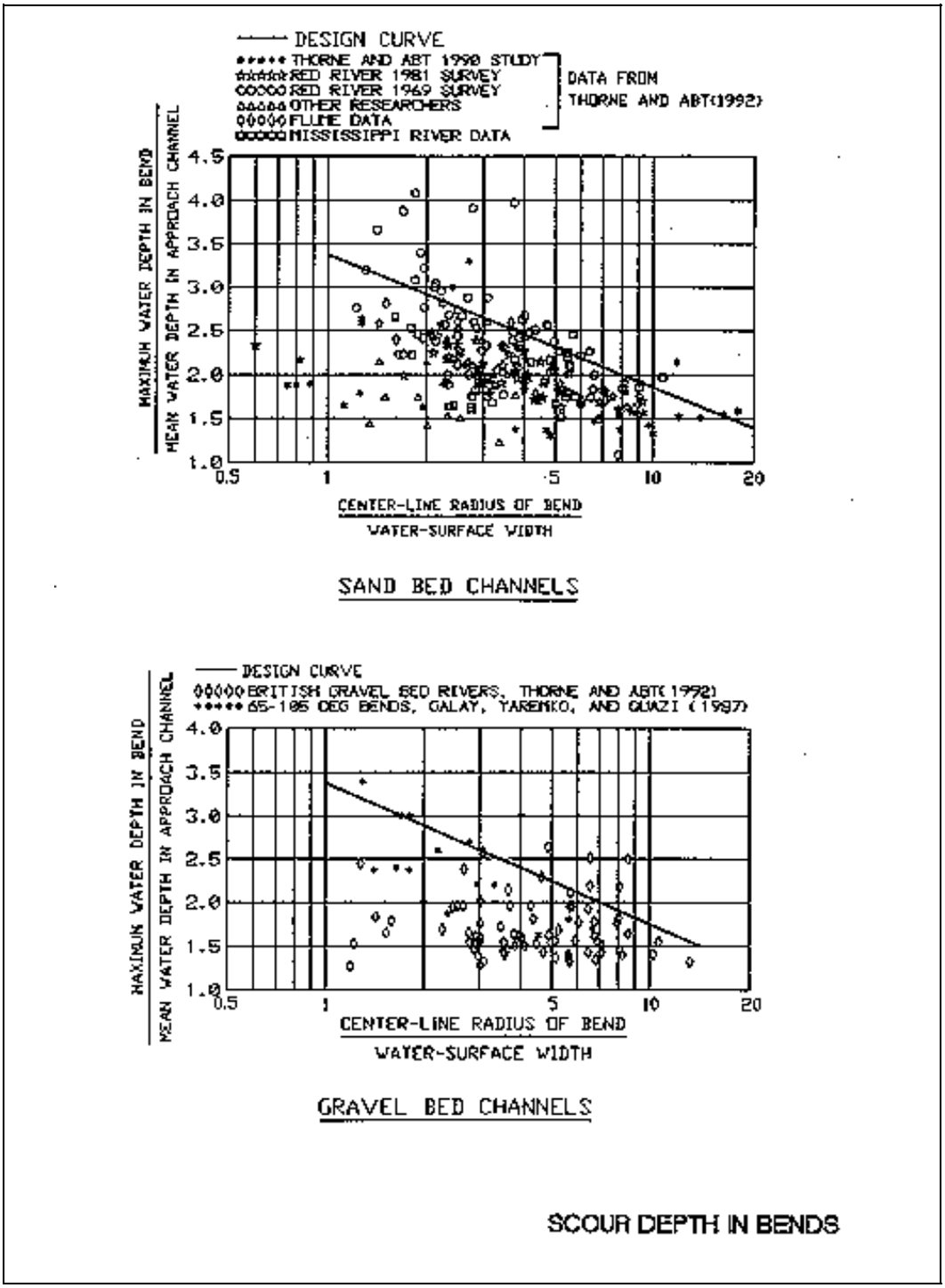
DESIGN CURVE
THORNE AND ABT 1990 STUDY
RED RIVER 1981 SURVEY
RED RIVER 1969 SURVEY
OTHER RESEARCHERS
FLUME DATA
MISSISSIPPI RIVER DATA
DATA FROM THORNE AND ABT(1992)
MAXIMUM WATER DEPTH IN BEND
MEAN WATER DEPTH IN APPROACH CHANNEL
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
1
5
10
20
CENTER-LINE RADIUS OF BEND
WATER-SURFACE WIDTH
SAND BED CHANNELS
DESIGN CURVE
BRITISH GRAVEL BED RIVERS, THORNE AND ABT(1992)
85-105 DEG BENDS, GALAY, YAREMKO, AND GUAZI (1987)
MAXIMUM WATER DEPTH IN BEND
MEAN WATER DEPTH IN APPROACH CHANNEL
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
1
5
10
20
CENTER-LINE RADIUS OF BEND
WATER-SURFACE WIDTH
GRAVEL BED CHANNELS
SCOUR DEPTH IN BENDS

Plate B-41

*

*

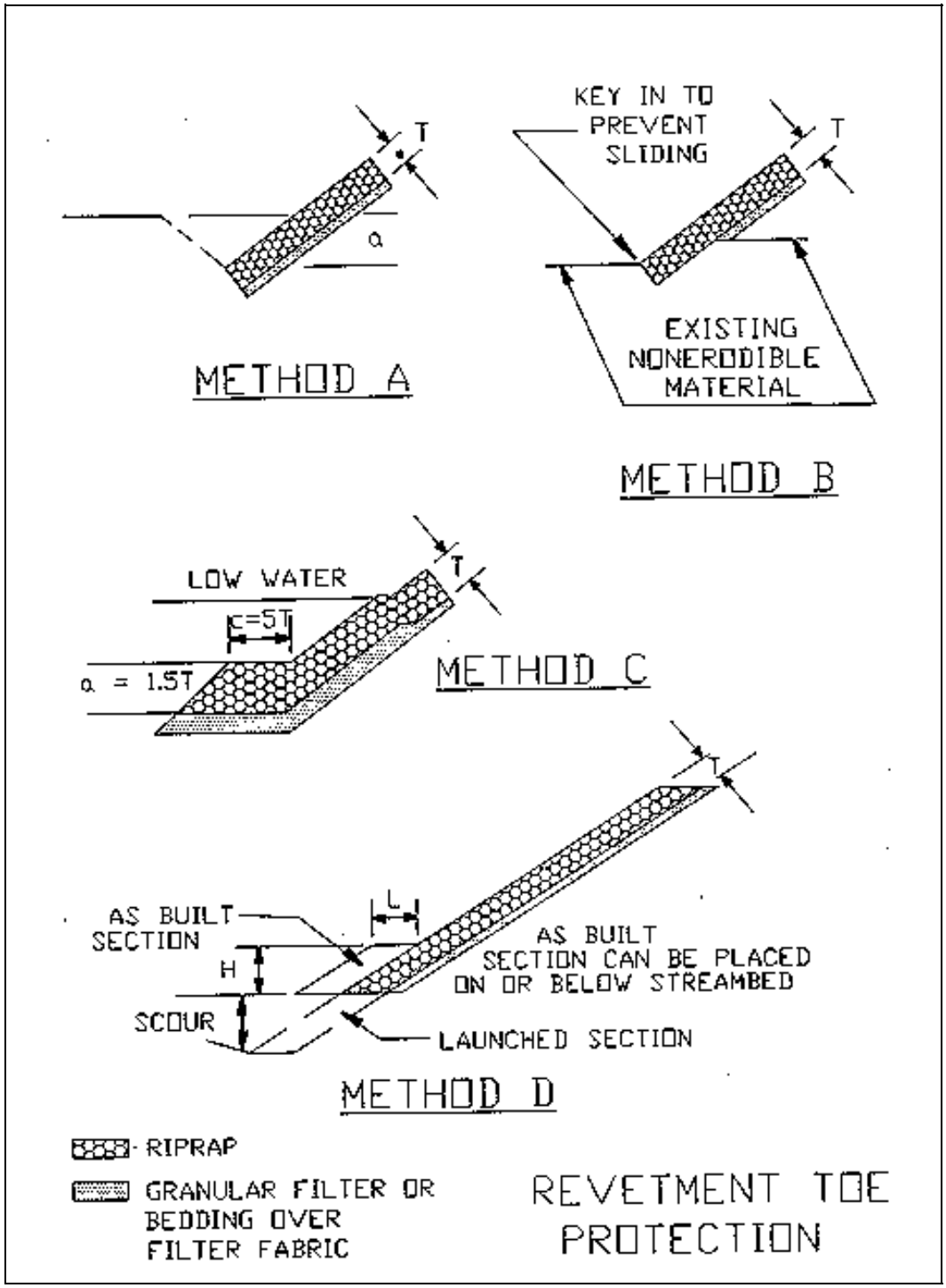
T
a
METHOD A
KEY IN TO PREVENT SLIDING
T
EXISTING NONERODIBLE MATERIAL
METHOD B
LOW WATER
T
L=5T
a = 1.5T
METHOD C
T
AS BUILT SECTION
L
H
SCOUR
AS BUILT SECTION CAN BE PLACED ON OR BELOW STREAMBED
LAUNCHED SECTION
METHOD D
RIPRAP
GRANULAR FILTER OR BEDDING OVER FILTER FABRIC
REVETMENT TOE PROTECTION

Plate B-43

*

*

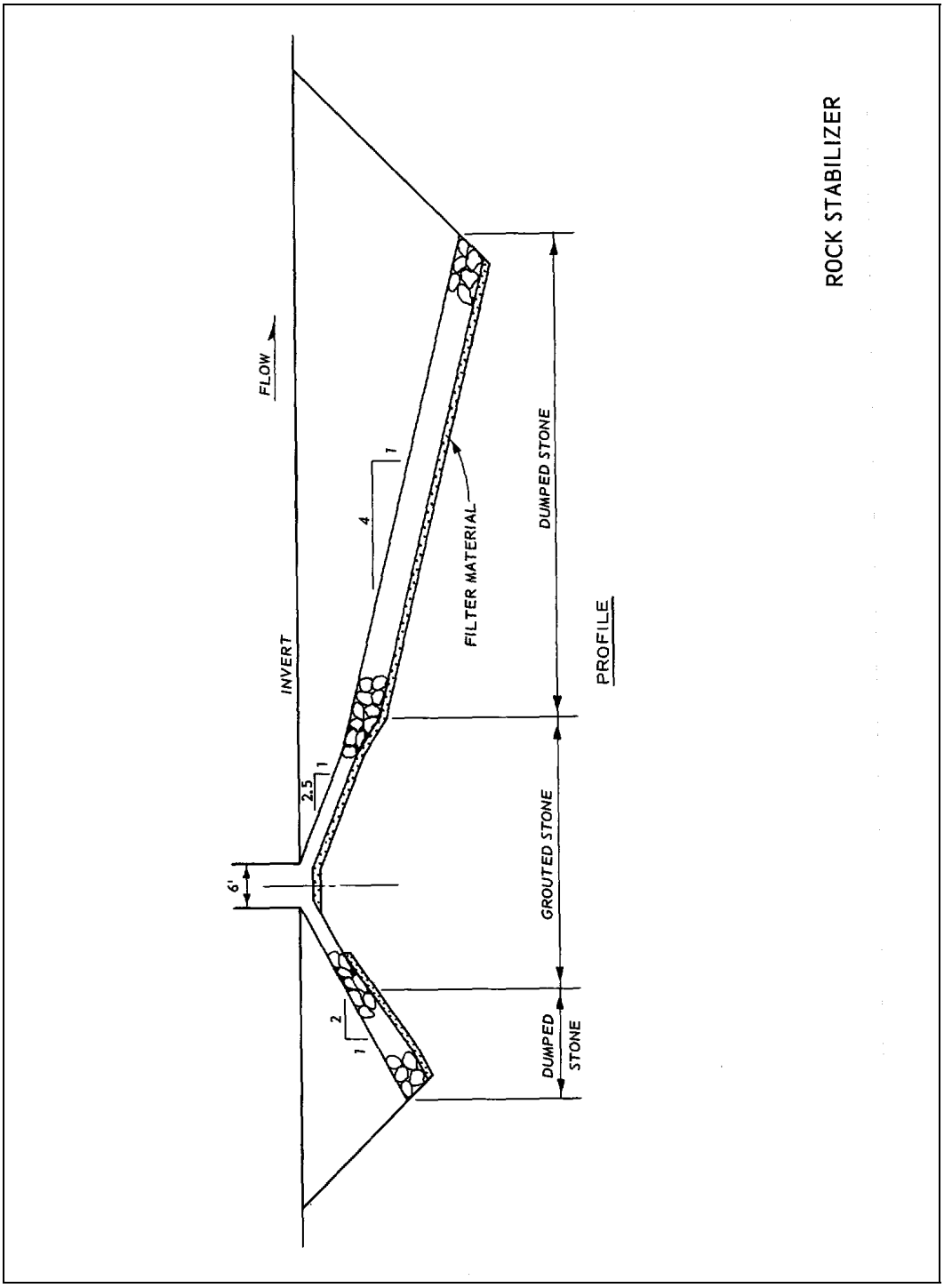
ROCK STABILIZER
FLOW
INVERT
6'
2.5
1
4
1
2
1
FILTER MATERIAL
DUMPED STONE
GROUTED STONE
DUMPED STONE
PROFILE

Plate B-44

*

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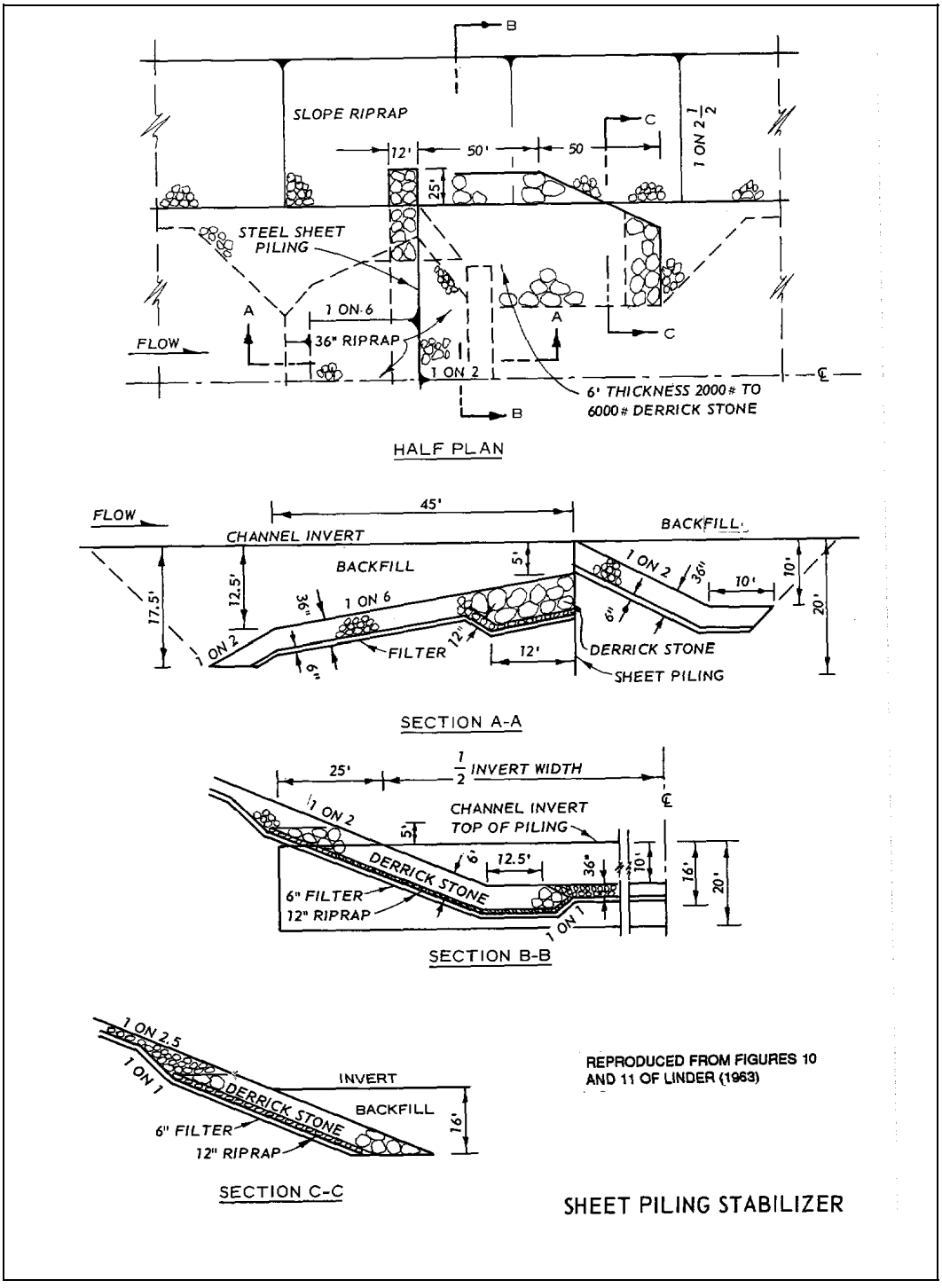
B
SLOPE RIPRAP
C
12'
50'
50
1 ON 2 1/2
25'
STEEL SHEET PILING
A
1 ON 6
A
C
FLOW
36" RIPRAP
1 ON 2
6' THICKNESS 2000# TO 6000# DERRICK STONE
B
HALF PLAN
FLOW
45'
CHANNEL INVERT
BACKFILL
BACKFILL
5'
1 ON 2
36"
10'
10'
12.5'
36"
1 ON 6
17.5'
6"
20'
1 ON 2
FILTER
12"
12'
DERRICK STONE
6"
SHEET PILING
SECTION A-A
25'
1/2 INVERT WIDTH
1 ON 2
CHANNEL INVERT
TOP OF PILING
5'
6'
12.5'
36"
10'
16'
20'
DERRICK STONE
6" FILTER
12" RIPRAP
1 ON 1
SECTION B-B
1 ON 2.5
1 ON 1
INVERT
BACKFILL
DERRICK STONE
6" FILTER
12" RIPRAP
16'
SECTION C-C
REPRODUCED FROM FIGURES 10 AND 11 OF LINDER (1963)
SHEET PILING STABILIZER

Plate B-45

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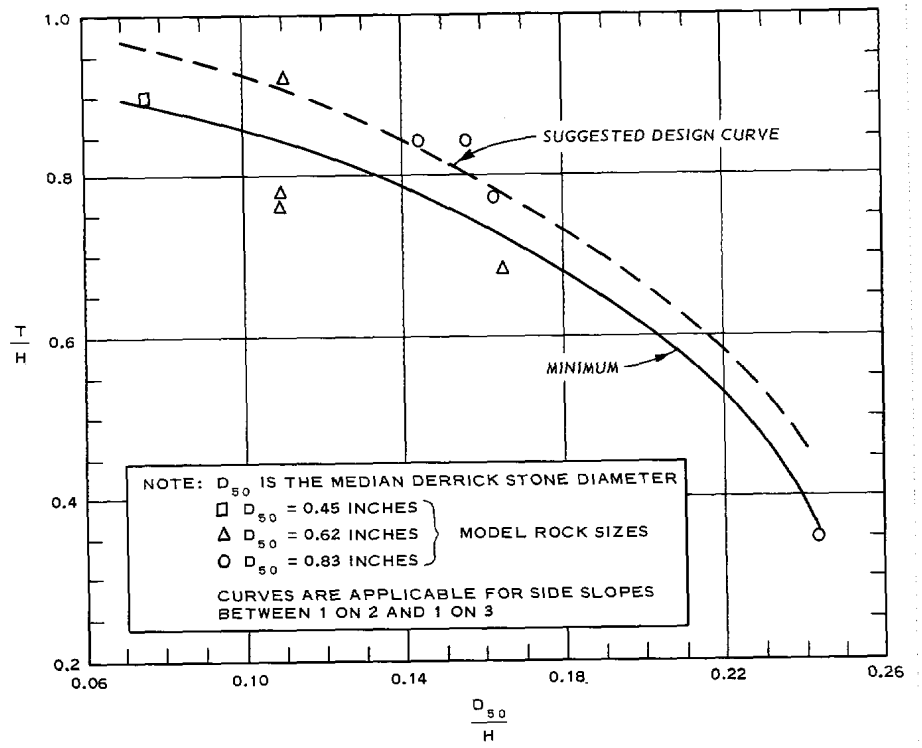
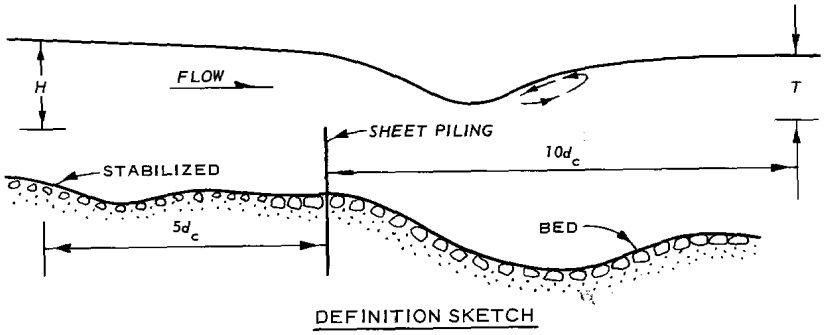
*





DEFINITION SKETCH

GRAPH LIMITED TO

$\frac{T}{d_c} \geq 0.8$

d_c = CRITICAL DEPTH

REPRODUCED FROM FIGURE 17, LINDER (1963)

SHEET PILING STABILIZER
DERRICK STONE SIZE

Plate B-46

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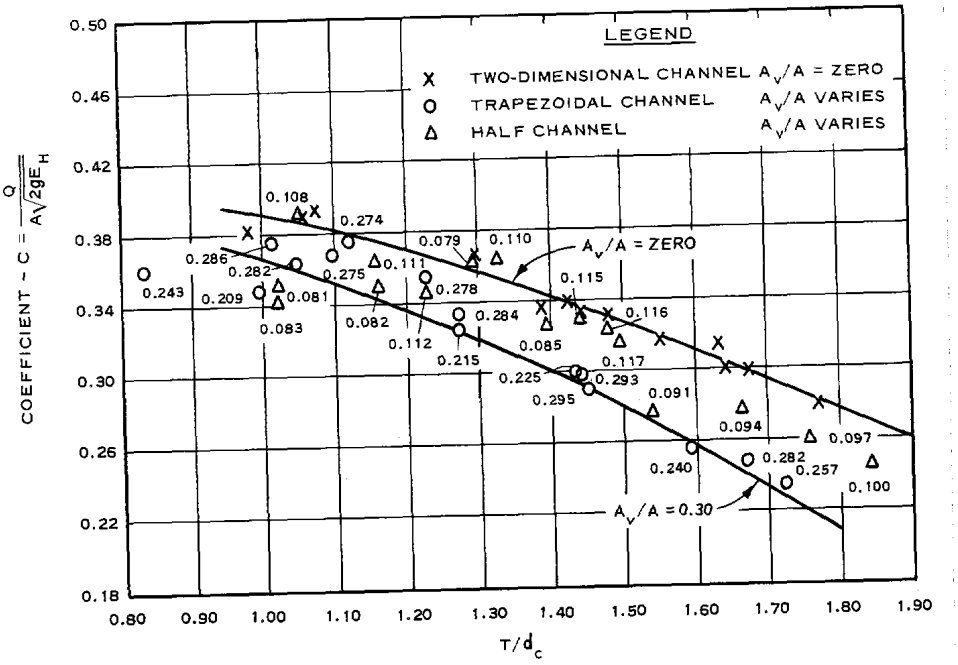


NOTE: $E_H = \frac{Q^2}{2A^2C^2g}$

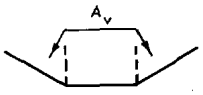
Q = TOTAL DISCHARGE

E_M = ENERGY $\left(\text{TOTAL HEAD, } H + \frac{V^2}{2g}\right)$ ABOVE THE CREST $5d_c$ UPSTREAM OF THE CREST

T = TAILWATER DEPTH ABOVE THE CREST $10d_c$ DOWNSTREAM OF THE CREST

d_c = CRITICAL DEPTH FOR THE TRAPEZOIDAL CREST SECTION

CURVE IS APPLICABLE FOR SIDE SLOPES FROM VERTICAL TO 1 ON 3



A = TOTAL AREA ABOVE THE CREST AT $5d_c$ UPSTREAM OF THE CREST

A_v = AREA. IN THE END SECTIONS OF CREST $5d_c$ UPSTREAM OF THE CREST

NUMBERS BESIDE THE PLOTTED POINTS REPRESENT VALUES OF A_v/A

REPRODUCED FROM FIGURE 16, LINDER (1963)

SHEET PILING STABILIZER
ENERGY LOSS

Plate B-47

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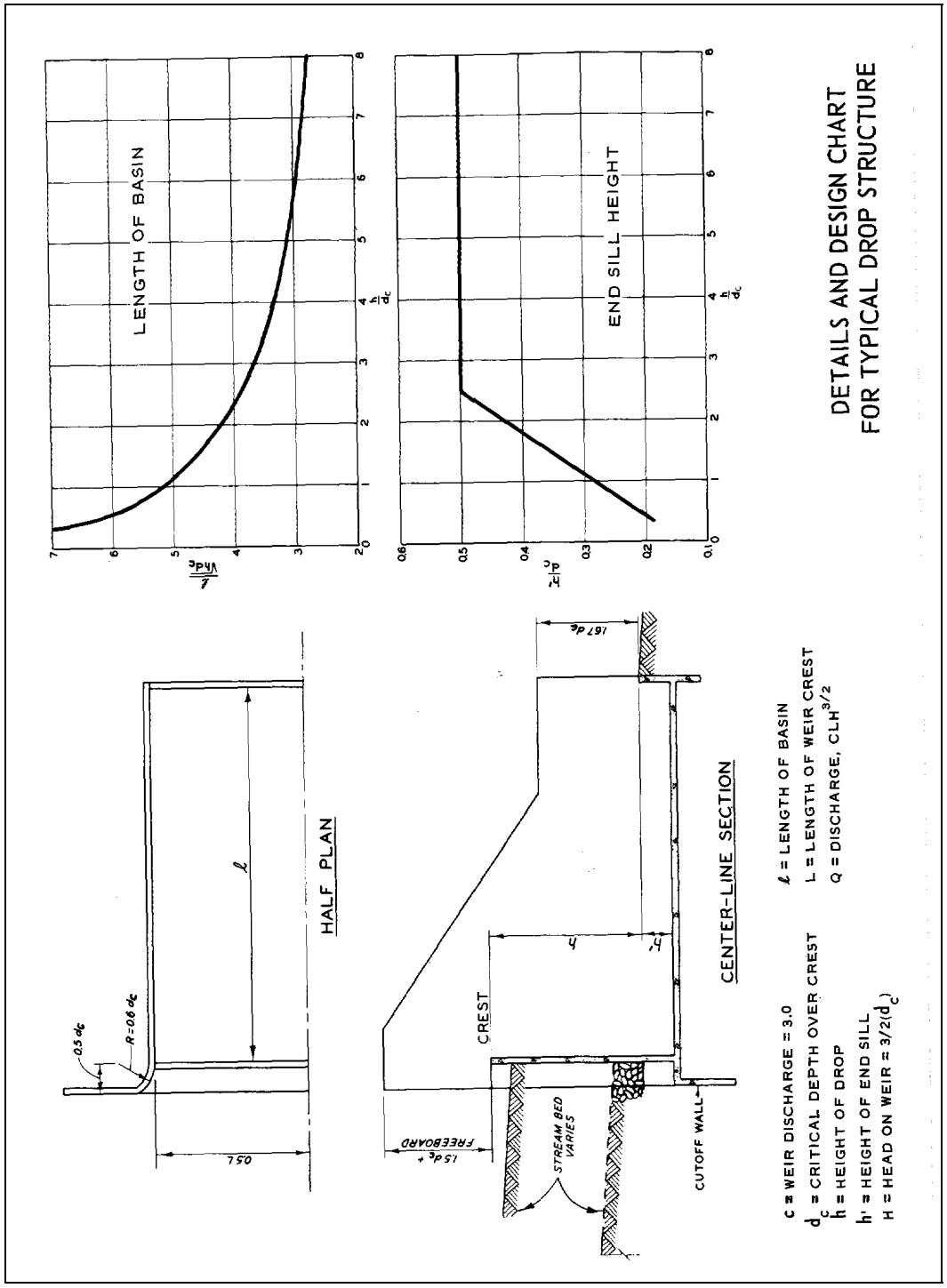
DETAILS AND DESIGN CHART
FOR TYPICAL DROP STRUCTURE
LENGTH OF BASIN
END SILL HEIGHT
HALF PLAN
CENTER-LINE SECTION
CREST
FREEBOARD
STREAM BED VARIES
CUTOFF WALL
C = WEIR DISCHARGE = 3.0
d_c = CRITICAL DEPTH OVER CREST
h = HEIGHT OF DROP
h' = HEIGHT OF END SILL
H = HEAD ON WEIR = 3/2(d_c)
ℓ = LENGTH OF BASIN
L = LENGTH OF WEIR CREST
Q = DISCHARGE, $CLH^{3/2}$

Plate B-48

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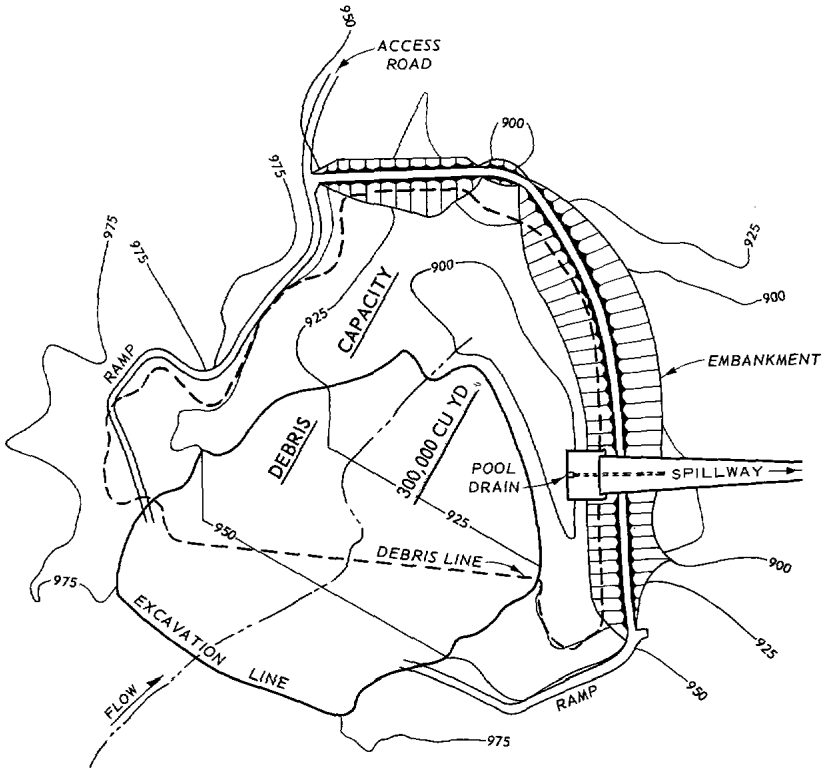

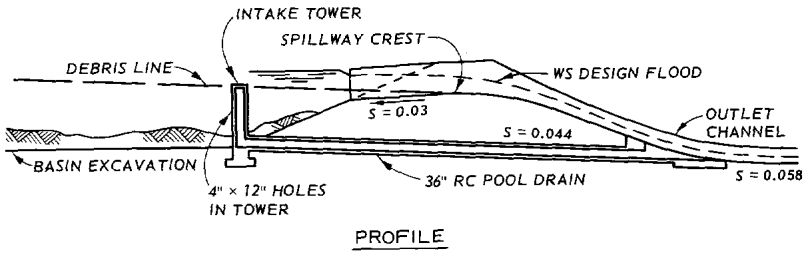

DEBRIS BASIN TYPICAL DESIGN

Plate B-49

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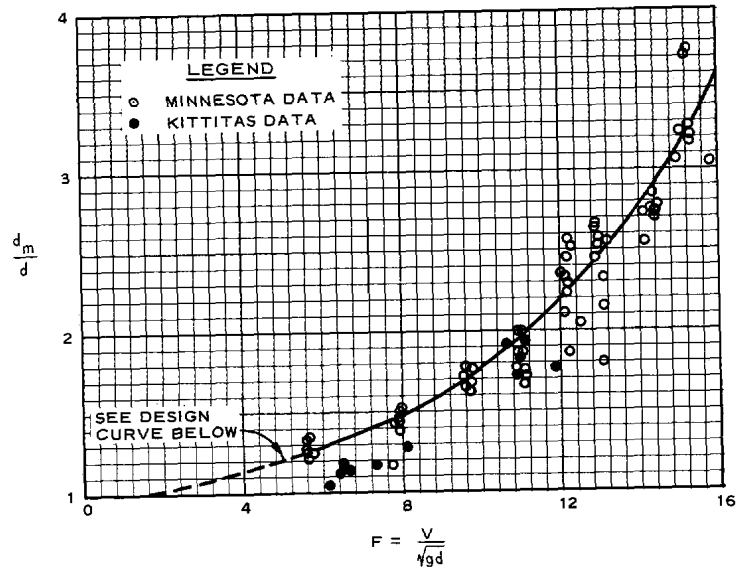
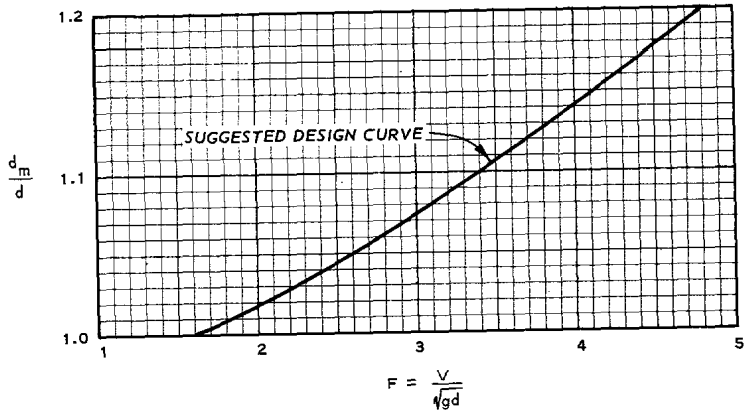


a. EXPERIMENTAL DATA



b. DESIGN CURVE

NOTE: d_m = DEPTH OF WATER AND AIR MIXTURE

d = COMPUTED DEPTH FOR NON-AERATED FLOW

V = COMPUTED VELOCITY FOR NON-AERATED FLOW

g = GRAVITATIONAL ACCELERATION

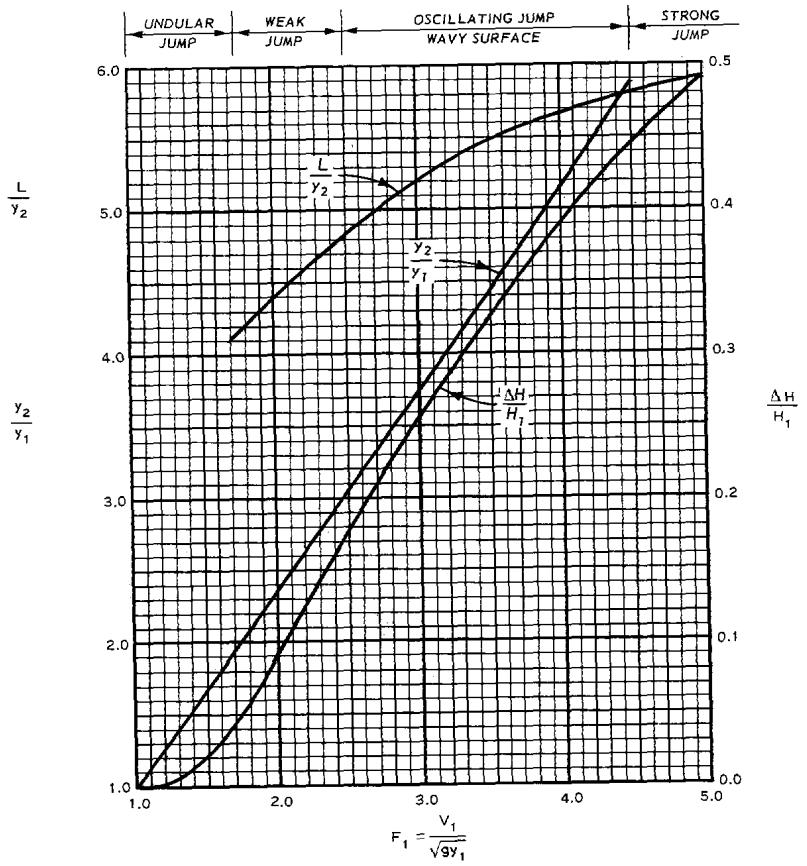
F = FROUDE NUMBER FOR NONAERATED FLOW

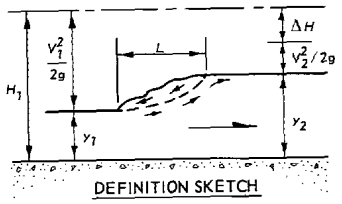
AIR ENTRAINMENT

Plate B-50

*

*





DEFINITION SKETCH

L = JUMP LENGTH
ΔH = ENERGY LOSS
H_1 = TOTAL HEAD
y = SEQUENT DEPTHS

HYDRAULIC JUMP CHARACTERISTICS
RECTANGULAR CHANNELS

Plate B-51

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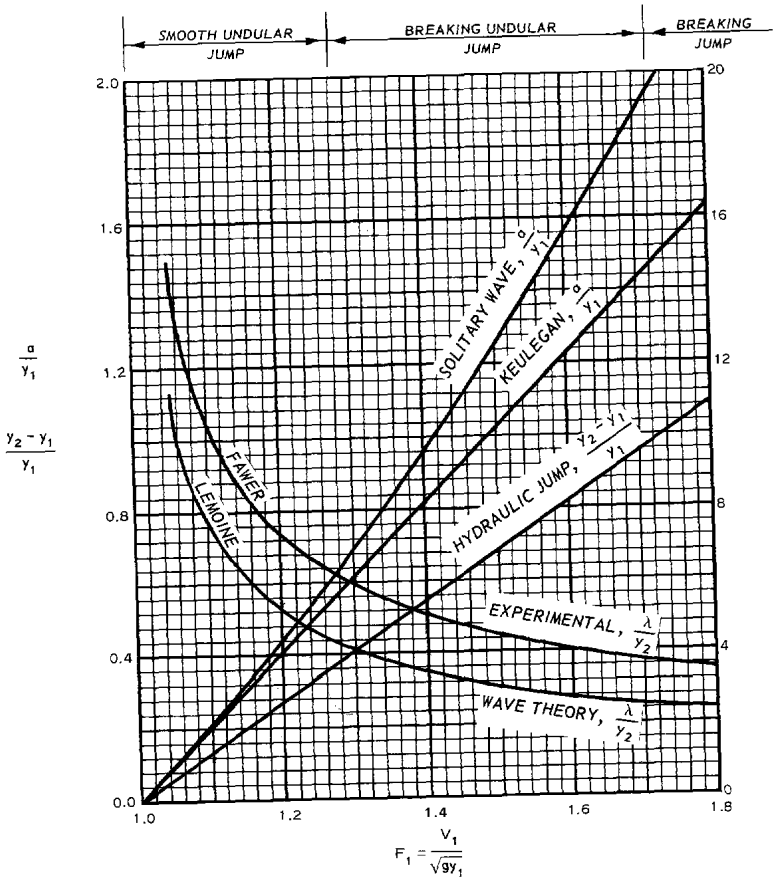

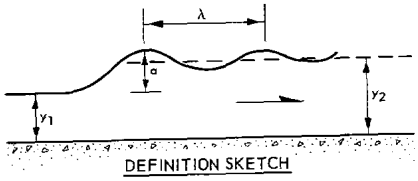

DEFINITION SKETCH

λ – WAVE LENGTH
a – WAVE HEIGHT
y – FLOW DEPTH

NOTE: FAWER AND LEMOINE CURVES FROM JAEGER (1957). KEULEGAN CURVE FROM KEULEGAN AND PATTERSON (1940).

UNDULAR JUMP
RECTANGULAR CHANNEL

Plate B-52

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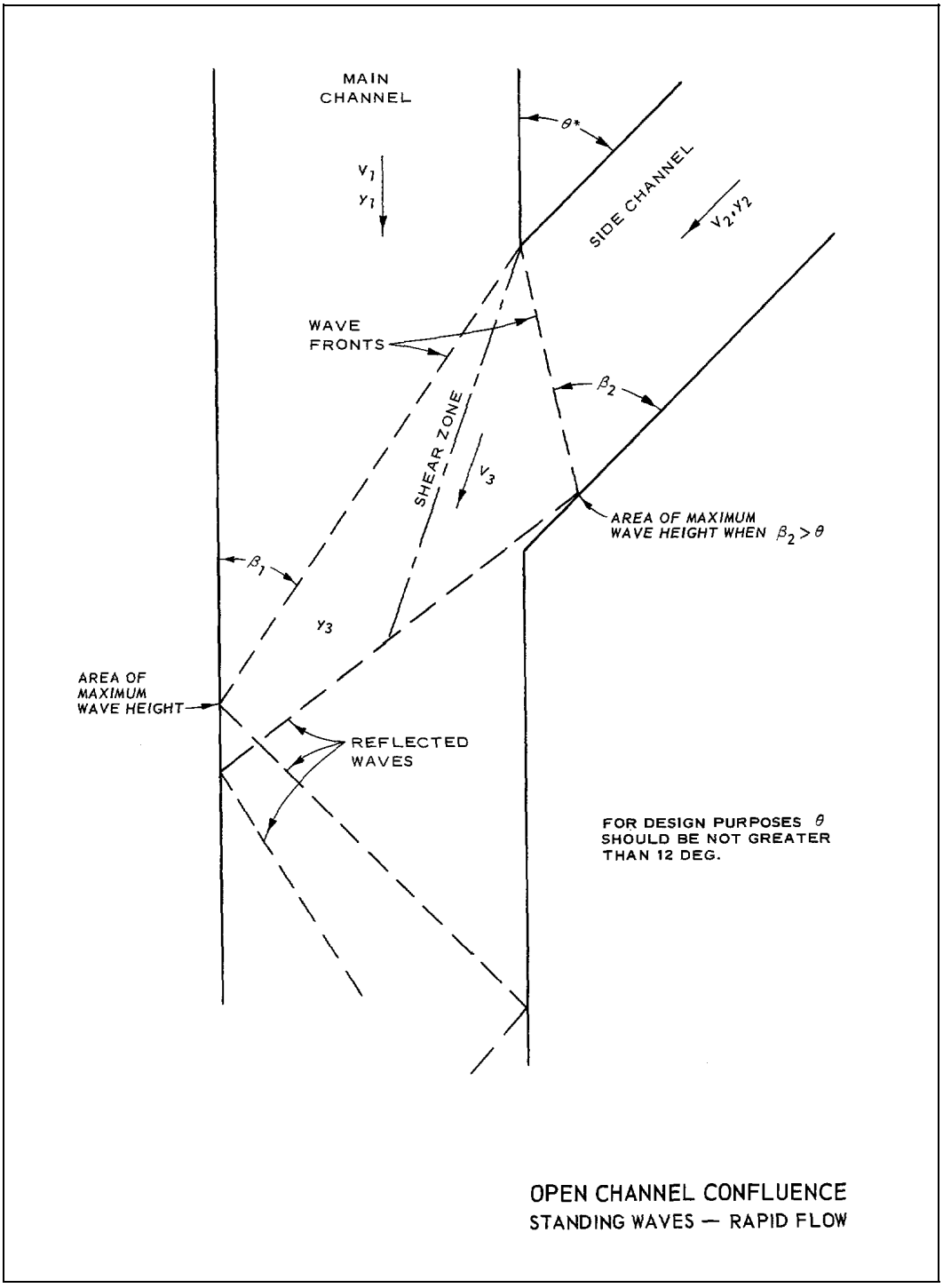
MAIN CHANNEL
θ^*
V_1
y_1
SIDE CHANNEL
V_2, y_2
WAVE FRONTS
β_2
SHEAR ZONE
V_3
AREA OF MAXIMUM WAVE HEIGHT WHEN $\beta_2 > \theta$
β_1
y_3
AREA OF MAXIMUM WAVE HEIGHT
REFLECTED WAVES
FOR DESIGN PURPOSES θ SHOULD BE NOT GREATER THAN 12 DEG.
OPEN CHANNEL CONFLUENCE
STANDING WAVES — RAPID FLOW

Plate B-53

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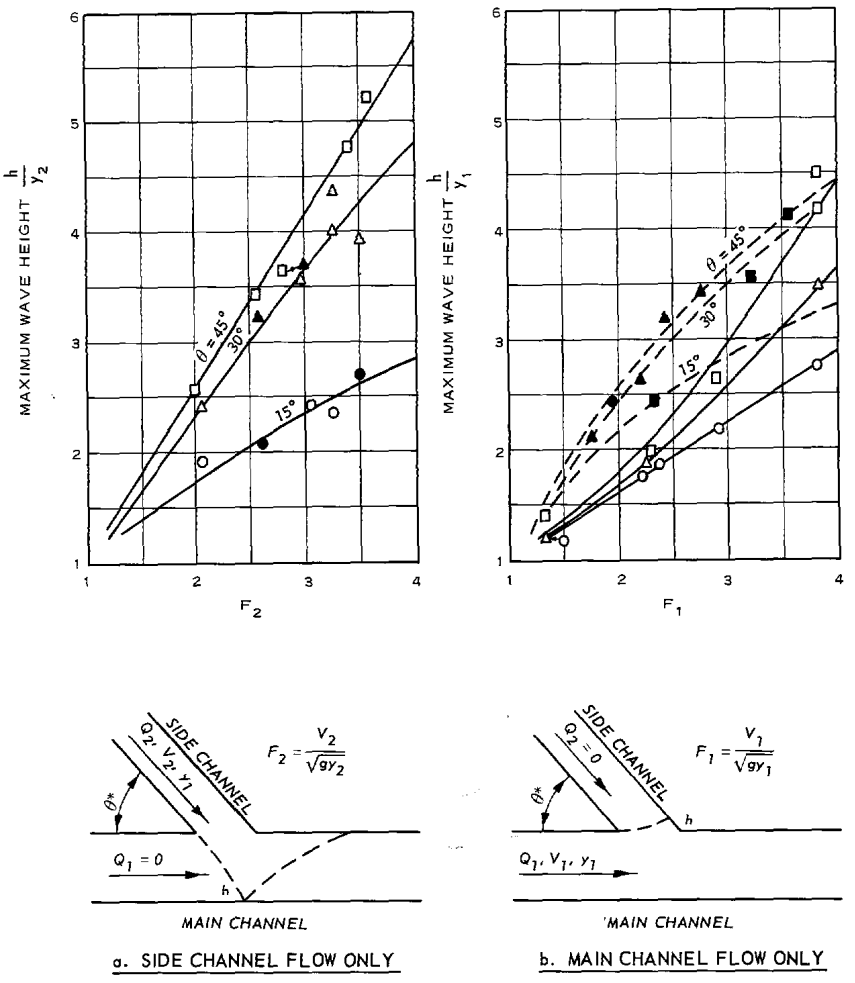

a. SIDE CHANNEL FLOW ONLY

b. MAIN CHANNEL FLOW ONLY

FOR DESIGN PURPOSES θ SHOULD NOT BE GREATER THAN 12 DEG

NOTE: 1. DATA AND CURVES BASED ON FIGURES 10-12, BEHLKE AND PRITCHETT (1966).

2. □ ○ △ TRAPEZOIDAL CHANNELS
■ ● ▲ RECTANGULAR CHANNELS

MAXIMUM WAVE HEIGHT CHANNEL JUNCTION

Plate B-54

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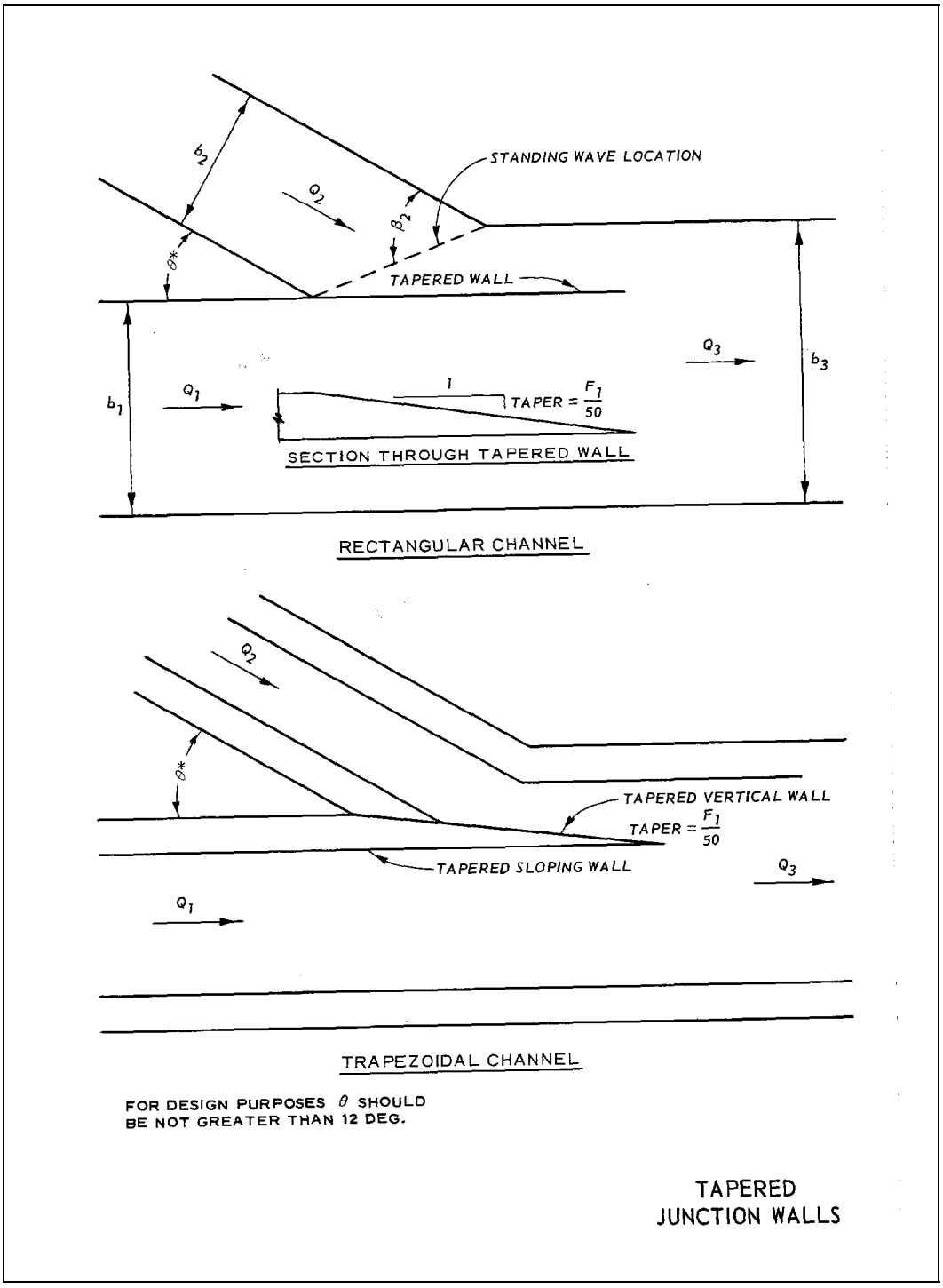
STANDING WAVE LOCATION
TAPERED WALL
SECTION THROUGH TAPERED WALL
RECTANGULAR CHANNEL
TAPERED VERTICAL WALL
TAPERED SLOPING WALL
TRAPEZOIDAL CHANNEL
FOR DESIGN PURPOSES θ SHOULD BE NOT GREATER THAN 12 DEG.
TAPERED JUNCTION WALLS

Plate B-55

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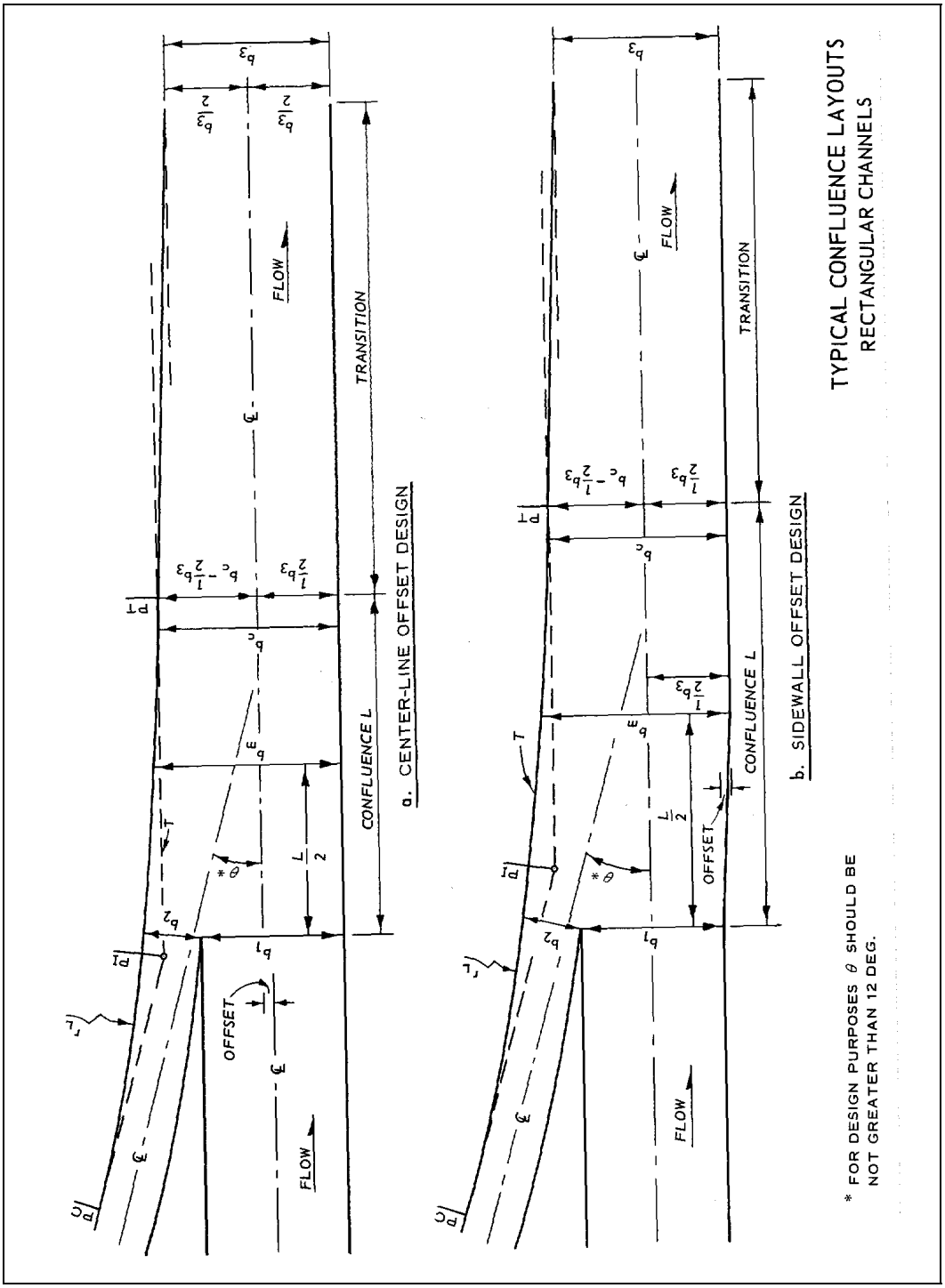
TYPICAL CONFLUENCE LAYOUTS
RECTANGULAR CHANNELS
a. CENTER-LINE OFFSET DESIGN
b. SIDEWALL OFFSET DESIGN
TRANSITION
CONFLUENCE L
FLOW
OFFSET
* FOR DESIGN PURPOSES θ SHOULD BE NOT GREATER THAN 12 DEG.

Plate B-56

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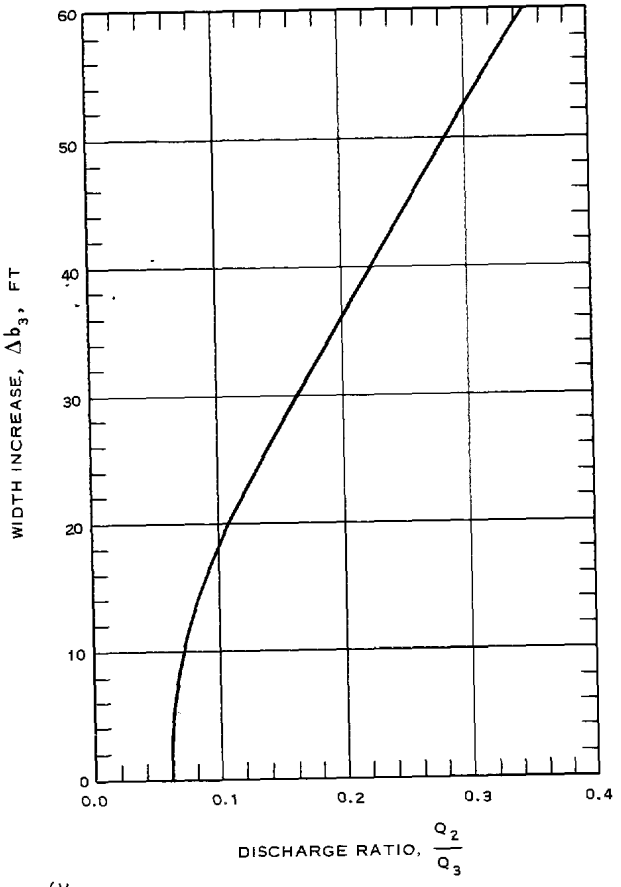

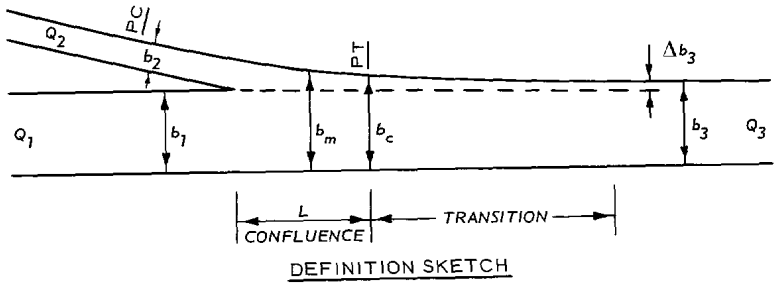

DEFINITION SKETCH

$b_3 = b_1 + \Delta b_3$

$b_c = b_1 + 2\Delta b_3$

$b_m = \frac{b_1 + b_2 + b_c}{2}$

CONFLUENCE DESIGN CHART

Plate B-57

*

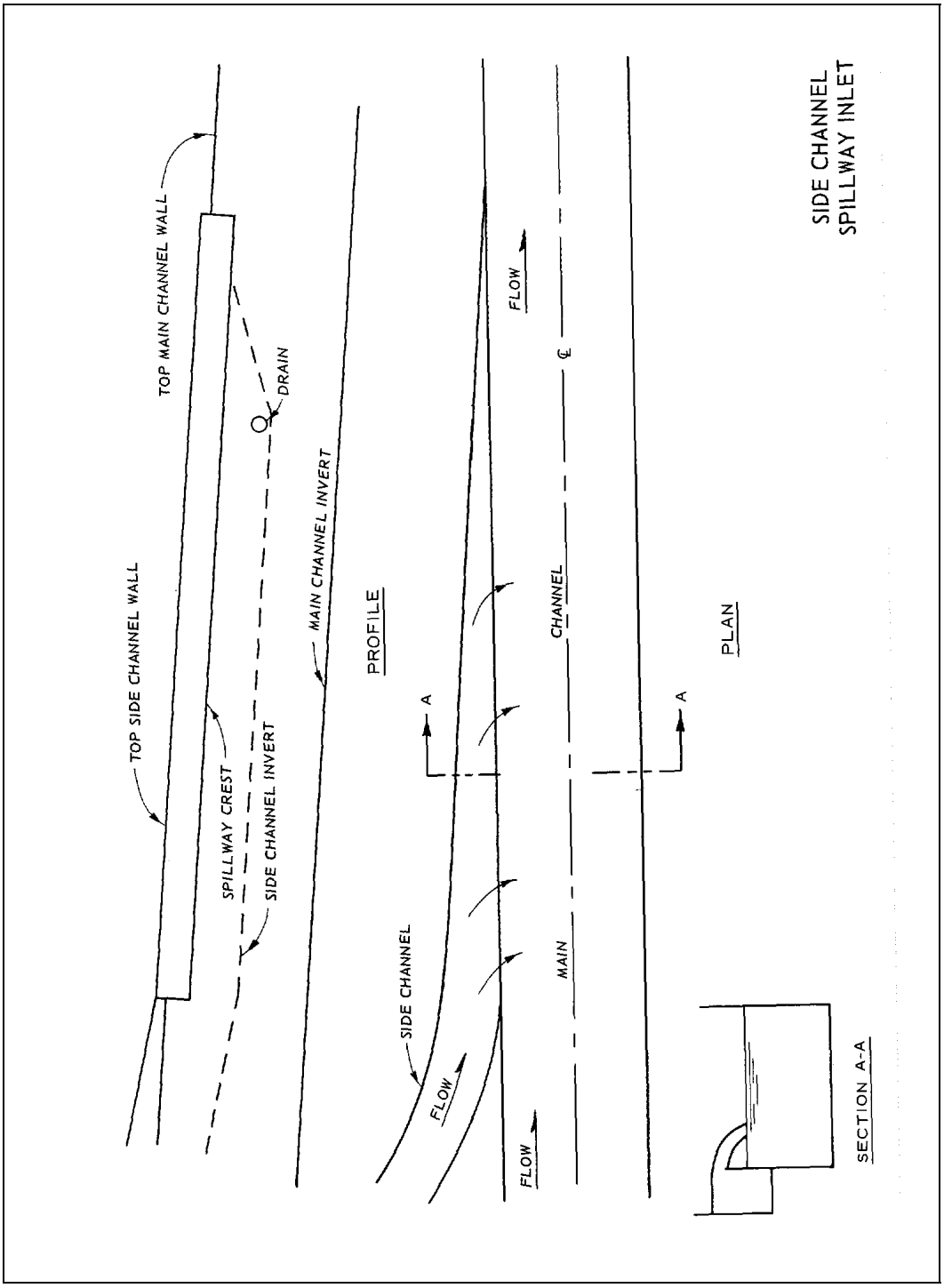
SIDE CHANNEL
SPILLWAY INLET
TOP MAIN CHANNEL WALL
DRAIN
MAIN CHANNEL INVERT
TOP SIDE CHANNEL WALL
SPILLWAY CREST
SIDE CHANNEL INVERT
PROFILE
FLOW
CHANNEL
PLAN
A
A
SIDE CHANNEL
FLOW
MAIN
FLOW
SECTION A-A

Plate B-58