PDHonline Course H145 (4 PDH)

Stable Channel Analysis and Design

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2020

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Overview

- Estimating Channel Velocity
- Method of Maximum Permissible Velocity (soil, riprap, & veg)
- Method of Maximum Tractive force (soil, riprap, & veg)
- Geometric Design of Channels
- Slope Revetment (riprap, gabion, and articulated concrete block)
- HEC-RAS Stable Channel Design Tool

References

- Sediment Transport Technology, Water and Sediment Dynamics, Simon & Senturk,
- Open Channel Hydraulics, V.T. Chow, McGraw-Hill
- Sediment Transport, Theory and Practice, Yang, McGraw-Hill
- USGS Water-Supply Paper 2339, "Guide for Selecting Manning's Roughness Coefficients for Natural Channels and Flood Plains," by George J. Arcement, Jr., and Verne R. Schneider
- Design of Riprap Revetment, Hydraulic Engineering Circular No. 11 (HEC-11), Federal Highway Administration (FHWA)
- Design of Roadside Channels with Flexible Linings, Hydraulic Engineering Circular No. 15 (HEC-15), Federal Highway Administration (FHWA)
- Articulated Concrete Block, Revetment Design, Factor of Safety Method, National Concrete Masonry Association, TEK 11-12
- Hydraulic Stability of Articulated Concrete Block Revetment Systems During Overtopping Flow, 1989, FHWA-RD-89-199
- Standard Guide For Analysis And Interpretation Of Test Data For Articulating Concrete Block (ACB) Revetment Systems In Open Channel Flow, 2008, ASTM 7276-08

ESTIMATING CHANNEL VELOCITY

Channel Velocity Estimates

- Average Channel Velocity (Manning's Equation)

$$\bar{v} = \frac{1.49}{n} R^{2/3} S_f^{\ 1/2}$$

  - v = Average channel velocity (fps)
  - R = Hydraulic radius = Area/wetted perimeter (feet)
  - S_f = Friction slope (feet/foot)
  - $S_f = S_o$ = Channel bottom slope (feet/foot) for uniform flow
  - n = Manning's 'n' (roughness) value (see subsequent pages)

Manning’s ‘n’ Values

- The Manning roughness coefficient is often assumed constant regardless of flow depth. At very shallow depths, the effects of the roughness in the channel bottom are more pronounced producing higher n-values. However, assuming the channel bottom and banks have similar cover, the n-value quickly decreases with increased depth to nearly constant until reaching bank full. In overbank floodplain areas, n-values typically vary significantly with depth.

- Manning’s equation is commonly used to compute the friction slope (S_f) at each cross-section when developing water surface profiles under gradually varied flow conditions using the direct-step or standard-step methods.

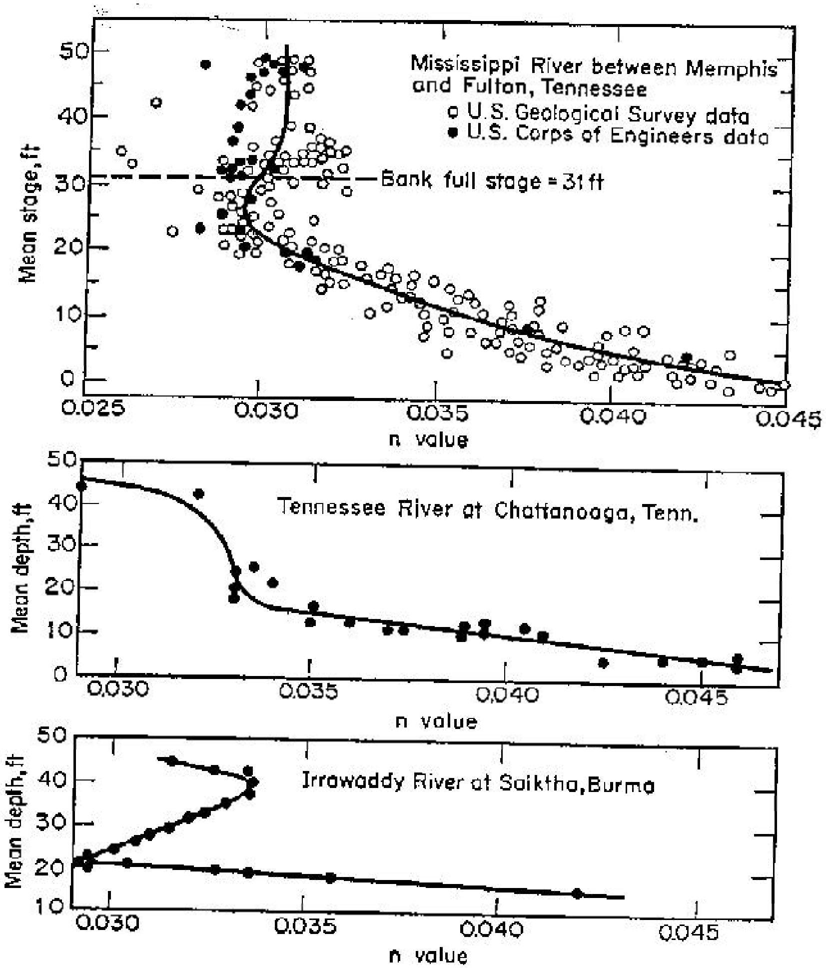
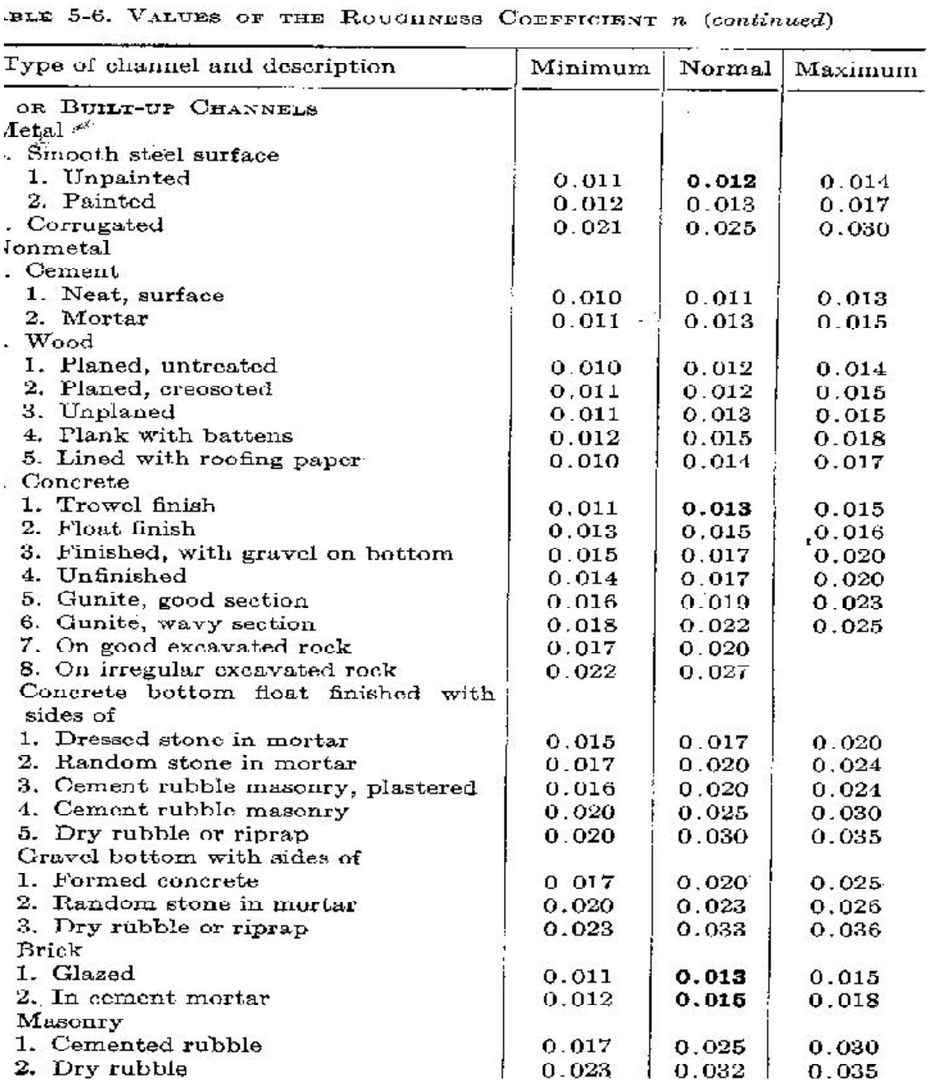


Fig. 5-4. Variations of the n value with the mean stage or depth.

Manning's 'n' Values



BLE 5-6. VALUES OF THE ROUGHNESS COEFFICIENT *n* (*continued*)

Type of channel and description	Minimum	Normal	Maximum
OR BUILT-UP CHANNELS			
etal			
Smooth steel surface			
1. Unpainted	0.011	**0.012**	0.014
2. Painted	0.012	0.013	0.017
Corrugated	0.021	0.025	0.030
onmetal			
Cement			
1. Neat, surface	0.010	0.011	0.013
2. Mortar	0.011	0.013	0.015
Wood			
1. Planed, untreated	0.010	0.012	0.014
2. Planed, creosoted	0.011	0.012	0.015
3. Unplaned	0.011	0.013	0.015
4. Plank with battens	0.012	0.015	0.018
5. Lined with roofing paper	0.010	0.014	0.017
Concrete			
1. Trowel finish	0.011	**0.013**	0.015
2. Float finish	0.013	0.015	0.016
3. Finished, with gravel on bottom	0.015	0.017	0.020
4. Unfinished	0.014	0.017	0.020
5. Gunite, good section	0.016	0.019	0.023
6. Gunite, wavy section	0.018	0.022	0.025
7. On good excavated rock	0.017	0.020	
8. On irregular excavated rock	0.022	0.027	
Concrete bottom float finished with sides of			
1. Dressed stone in mortar	0.015	0.017	0.020
2. Random stone in mortar	0.017	0.020	0.024
3. Cement rubble masonry, plastered	0.016	0.020	0.024
4. Cement rubble masonry	0.020	0.025	0.030
5. Dry rubble or riprap	0.020	0.030	0.035
Gravel bottom with sides of			
1. Formed concrete	0.017	0.020	0.025
2. Random stone in mortar	0.020	0.023	0.026
3. Dry rubble or riprap	0.023	0.033	0.036
Brick			
1. Glazed	0.011	**0.013**	0.015
2. In cement mortar	0.012	**0.015**	0.018
Masonry			
1. Cemented rubble	0.017	0.025	0.030
2. Dry rubble	0.023	0.032	0.035

Manning's 'n' Values

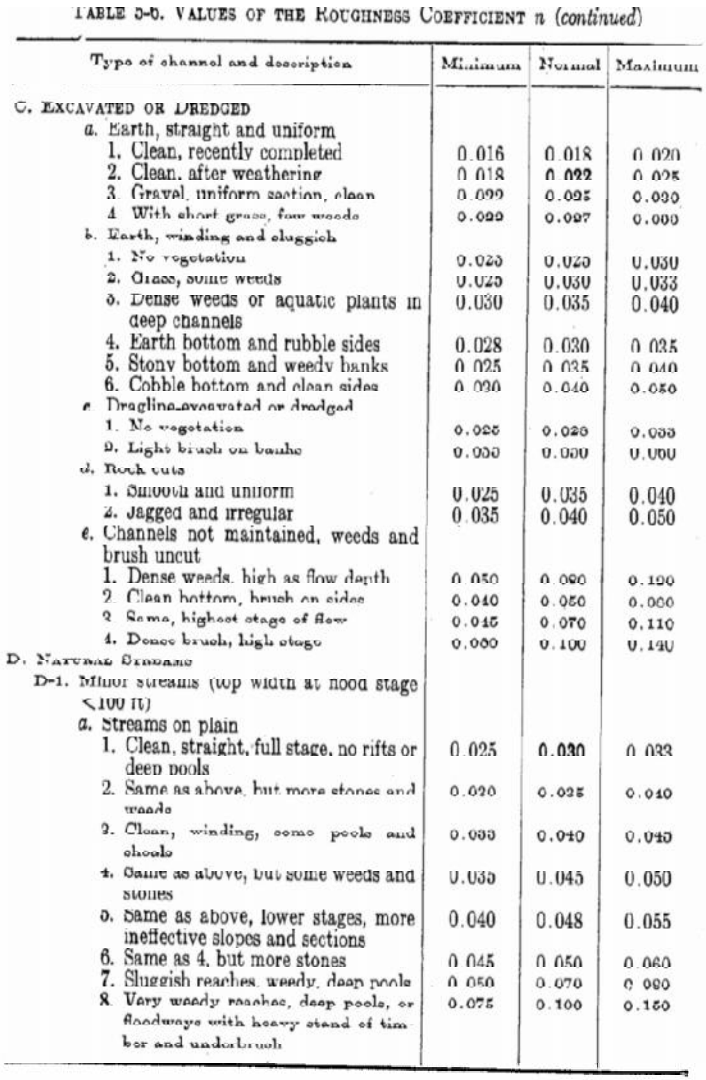


TABLE 5-6. VALUES OF THE ROUGHNESS COEFFICIENT *n* (*continued*)

Type of channel and description	Minimum	Normal	Maximum
C. EXCAVATED OR DREDGED			
a. Earth, straight and uniform			
1. Clean, recently completed	0.016	0.018	0.020
2. Clean, after weathering	0.018	0.022	0.025
3. Gravel, uniform section, clean	0.022	0.025	0.030
4. With short grass, few weeds	0.022	0.027	0.033
b. Earth, winding and sluggish			
1. No vegetation	0.023	0.025	0.030
2. Grass, some weeds	0.025	0.030	0.033
3. Dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
4. Earth bottom and rubble sides	0.028	0.030	0.035
5. Stony bottom and weedy banks	0.025	0.035	0.040
6. Cobble bottom and clean sides	0.030	0.040	0.050
c. Dragline-excavated or dredged			
1. No vegetation	0.025	0.028	0.033
2. Light brush on banks	0.035	0.050	0.060
d. Rock cuts			
1. Smooth and uniform	0.025	0.035	0.040
2. Jagged and irregular	0.035	0.040	0.050
e. Channels not maintained, weeds and brush uncut			
1. Dense weeds, high as flow depth	0.050	0.080	0.120
2. Clean bottom, brush on sides	0.040	0.050	0.080
3. Same, highest stage of flow	0.045	0.070	0.110
4. Dense brush, high stage	0.080	0.100	0.140
D. NATURAL STREAMS			
D-1. Minor streams (top width at flood stage <100 ft)			
a. Streams on plain			
1. Clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
2. Same as above, but more stones and weeds	0.030	0.035	0.040
3. Clean, winding, some pools and shoals	0.033	0.040	0.045
4. Same as above, but some weeds and stones	0.035	0.045	0.050
5. Same as above, lower stages, more ineffective slopes and sections	0.040	0.048	0.055
6. Same as 4, but more stones	0.045	0.050	0.060
7. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
8. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150

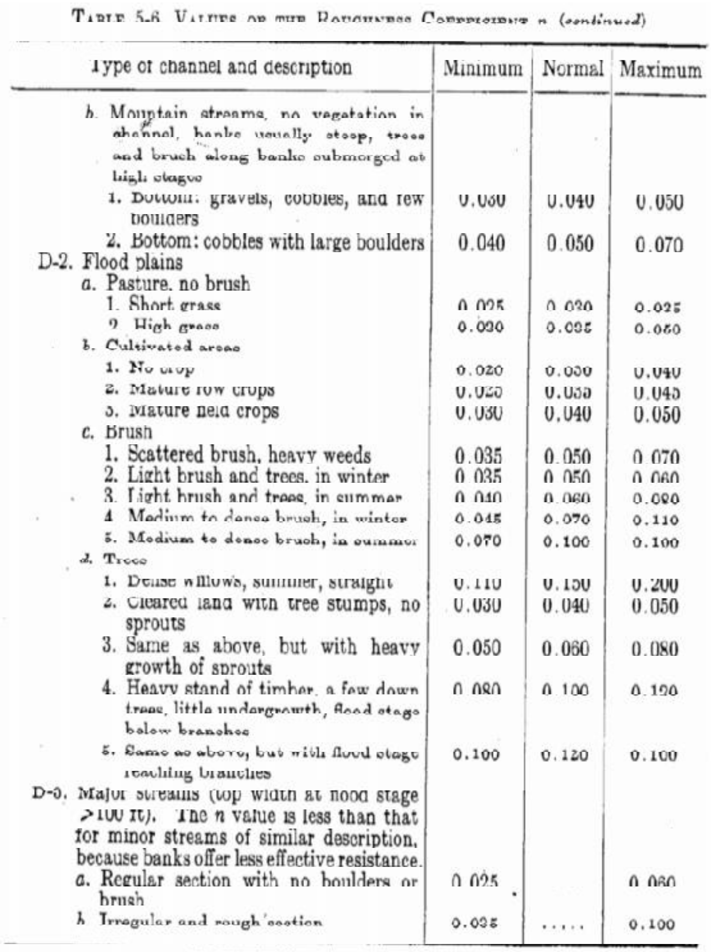


TABLE 5-6. VALUES OF THE ROUGHNESS COEFFICIENT *n* (*continued*)

Type of channel and description	Minimum	Normal	Maximum
b. Mountain streams, no vegetation in channel, banks usually steep, trees and brush along banks submerged at high stages			
1. Bottom: gravels, cobbles, and few boulders	0.030	0.040	0.050
2. Bottom: cobbles with large boulders	0.040	0.050	0.070
D-2. Flood plains			
a. Pasture, no brush			
1. Short grass	0.025	0.030	0.035
2. High grass	0.030	0.035	0.050
b. Cultivated areas			
1. No crop	0.020	0.030	0.040
2. Mature row crops	0.025	0.035	0.045
3. Mature field crops	0.030	0.040	0.050
c. Brush			
1. Scattered brush, heavy weeds	0.035	0.050	0.070
2. Light brush and trees, in winter	0.035	0.050	0.060
3. Light brush and trees, in summer	0.040	0.060	0.080
4. Medium to dense brush, in winter	0.045	0.070	0.110
5. Medium to dense brush, in summer	0.070	0.100	0.160
d. Trees			
1. Dense willows, summer, straight	0.110	0.150	0.200
2. Cleared land with tree stumps, no sprouts	0.030	0.040	0.050
3. Same as above, but with heavy growth of sprouts	0.050	0.060	0.080
4. Heavy stand of timber, a few down trees, little undergrowth, flood stage below branches	0.080	0.100	0.120
5. Same as above, but with flood stage reaching branches	0.100	0.120	0.160
D-3. Major streams (top width at flood stage >100 ft). The *n* value is less than that for minor streams of similar description, because banks offer less effective resistance.			
a. Regular section with no boulders or brush	0.025		0.060
b. Irregular and rough section	0.035	.....	0.100

Manning’s ‘n’ Values for Gravel/Stone Lined Channels

- Relationship for Manning's roughness coefficient, n, that is a function of the flow depth and the relative flow depth (d_a/D_{50}) for gravel/stone lined channels. This relationship is used to compute Manning’s n in FHWA’s HEC-15.

- This equation applies where $1.5 \le d_a/D_{50} \le 185$.

$$n = \frac{\left(\alpha d_a^{1/6}\right)}{2.25 + 5.23 \log\left(d_a / D_{50} \right)}$$

- Where,

  n= Manning's roughness coefficient
  d_a= average flow depth in the channel, ft
  D_{50} = median riprap/gravel size, ft
  α= unit conversion constant, 0.262 (0.319 (SI))

Manning's 'n' Values for Grass Lined Channels

$$n = \alpha C_n \tau_0^{-0.4} = \alpha C_n (\gamma R S)^{-0.4}$$

$$C_n = \alpha C_s^{0.10} h^{0.528}$$

Table 4.1. Retardance Classification of Vegetal Covers

Retardance Class	Cover[1]	Condition
A	Weeping Love Grass	Excellent stand, tall, average 760 mm (30 in)
	Yellow Bluestem Ischaemum	Excellent stand, tall, average 910 mm (36 in)
B	Kudzu	Very dense growth, uncut
	Bermuda Grass	Good stand, tall, average 300 mm (12 in)
	Native Grass Mixture (little bluestem, bluestem, blue gamma, and other long and short midwest grasses)	Good stand, unmowed
	Weeping lovegrass	Good stand, tall, average 610 mm (24 in)
	Lespedeza sericea	Good stand, not woody, tall, average 480 mm (19 in)
	Alfalfa	Good stand, uncut, average 280 mm (11 in)
	Weeping lovegrass	Good stand, unmowed, average 330 mm (13 in)
	Kudzu	Dense growth, uncut
	Blue Gamma	Good stand, uncut, average 280 mm (11 in)
C	Crabgrass	Fair stand, uncut 250 to 1200 mm (10 to 48 in)
	Bermuda grass	Good stand, mowed, average 150 mm (6 in)
	Common Lespedeza	Good stand, uncut, average 280 mm (11 in)
	Grass-Legume mixture--summer (orchard grass, redtop, Italian ryegrass, and common lespedeza)	Good stand, uncut, 150 to 200 mm (6 to 8 in)
	Centipede grass	Very dense cover, average 150 mm (6 in)
	Kentucky Bluegrass	Good stand, headed, 150 to 300 mm (6 to 12 in)
D	Bermuda Grass	Good stand, cut to 60 mm (2.5 in) height
	Common Lespedeza	Excellent stand, uncut, average 110 mm (4.5 in)
	Buffalo Grass	Good stand, uncut, 80 to 150 mm (3 to 6 in)
	Grass-Legume mixture—fall, spring (orchard grass, redtop, Italian ryegrass, and common lespedeza)	Good stand, uncut, 100 to 130 mm (4 to 5 in)
	Lespedeza sericea	After cutting to 50 mm (2 in) height. Very good stand before cutting.
E	Bermuda Grass	Good stand, cut to height, 40 mm (1.5 in)
	Bermuda Grass	Burned stubble

[1] Covers classified have been tested in experimental channels. Covers were green and generally uniform.

where,

C_n= Grass roughness coefficient

C_s= Density-stiffness coefficient

h= Stem height (ft)

α= Unit conversion constant, 0.262 (0.319 (SI))

t_0 = Average bottom shear (psf)

γ = Unit Weight of Water, typically 62.4 #/cf

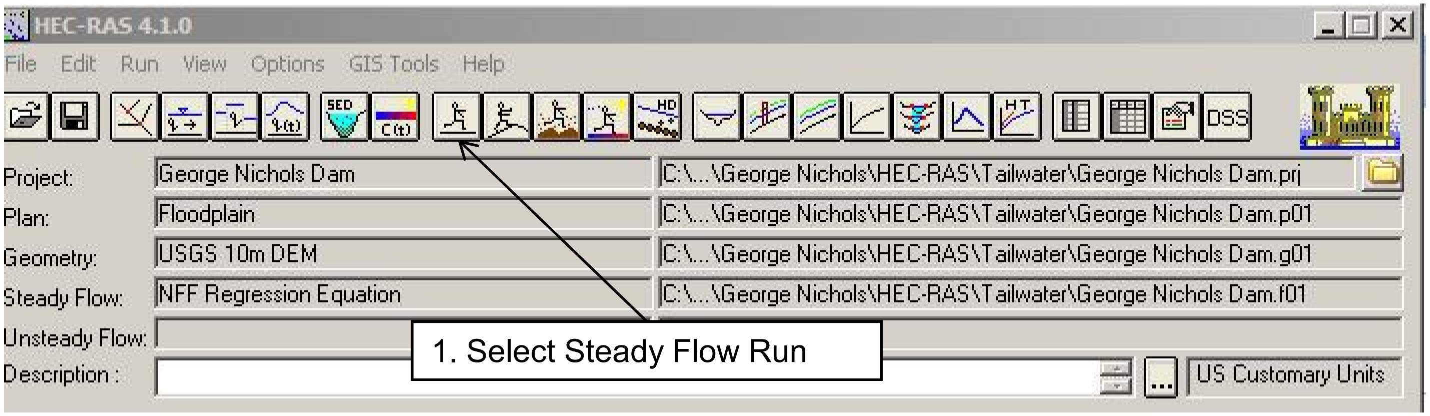
Table 4.4 (SI). Grass Roughness Coefficient, C_n, for SCS Retardance Classes

Retardance Class	A	B	C	D	E
Stem Height, mm	910	610	200	100	40
C_s	390	81	47	33	44
C_n	0.605	0.418	0.220	0.147	0.093

Table 4.4 (CU). Grass Roughness Coefficient, C_n, for SCS Retardance Classes

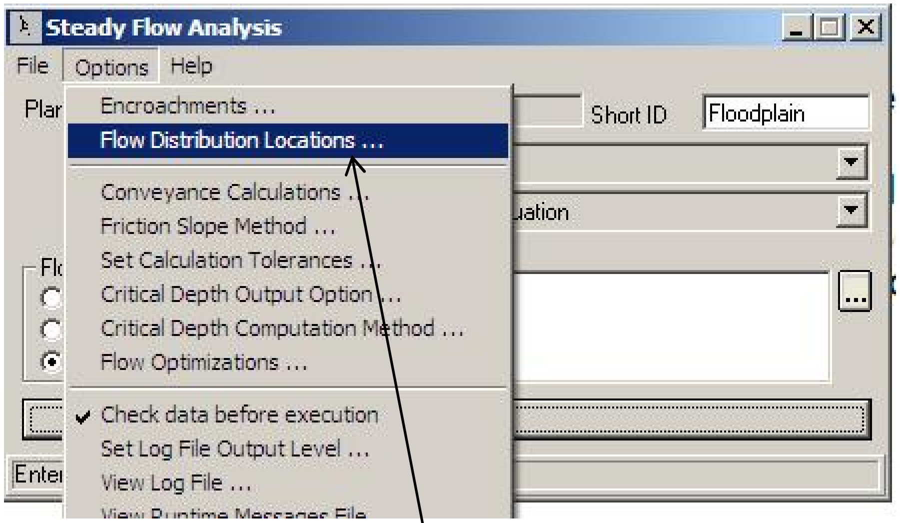
Retardance Class	A	B	C	D	E
Stem Height, in	36	24	8.0	4.0	1.6
C_s	33	7.1	3.9	2.7	3.8
C_n	0.605	0.418	0.220	0.147	0.093

Depth-Averaged Velocity in Conveyance Tubes from HEC-RAS (1D, Steady-Flow)



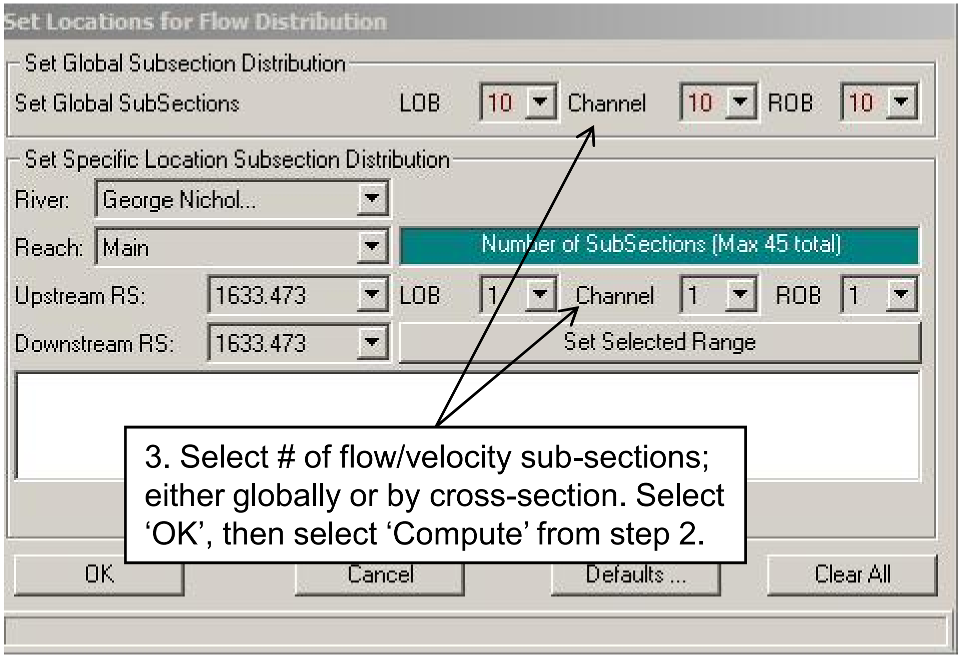
Project: George Nichols Dam — C:\...\George Nichols\HEC-RAS\Tailwater\George Nichols Dam.prj
Plan: Floodplain — C:\...\George Nichols\HEC-RAS\Tailwater\George Nichols Dam.p01
Geometry: USGS 10m DEM — C:\...\George Nichols\HEC-RAS\Tailwater\George Nichols Dam.g01
Steady Flow: NFF Regression Equation — C:\...\George Nichols\HEC-RAS\Tailwater\George Nichols Dam.f01
Unsteady Flow:
Description :
US Customary Units

1. Select Steady Flow Run



Short ID: Floodplain

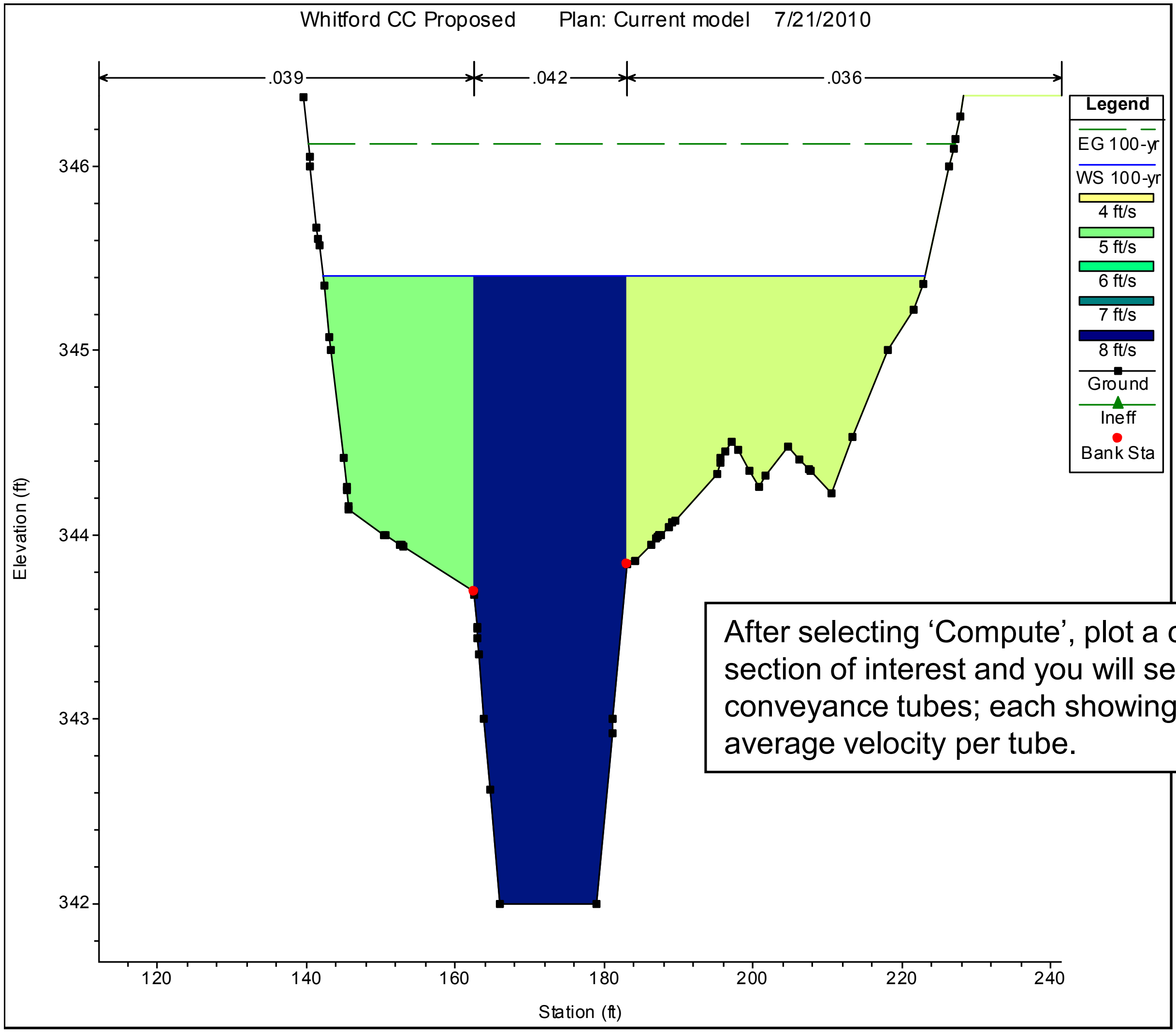
2. Select Flow Dist'n Locations



Set Global SubSections: LOB 10, Channel 10, ROB 10
River: George Nichol...
Reach: Main
Upstream RS: 1633.473 — LOB 1, Channel 1, ROB 1
Downstream RS: 1633.473

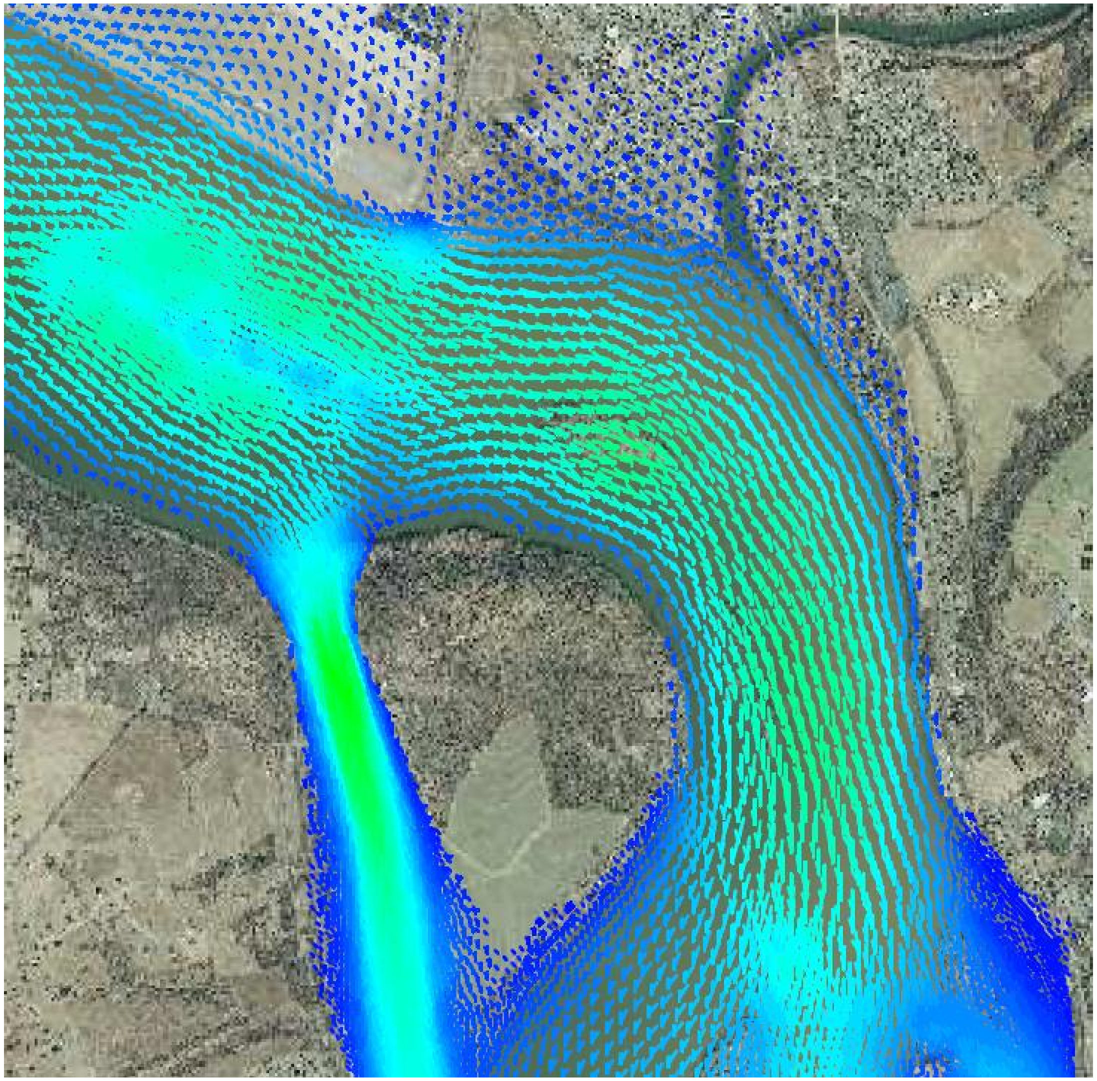
3. Select # of flow/velocity sub-sections; either globally or by cross-section. Select 'OK', then select 'Compute' from step 2.

Depth-Averaged Velocity in Conveyance Tubes from HEC-RAS (1D, Steady-Flow)



After selecting 'Compute', plot a cross-section of interest and you will see conveyance tubes; each showing the average velocity per tube.

Vertically-Averaged Velocity from 2D Flow Model



EVALUATING EROSIVENESS BASED ON MAXIMUM VELOCITY METHOD

Method of Maximum Velocity – Non-Cohesive Soil

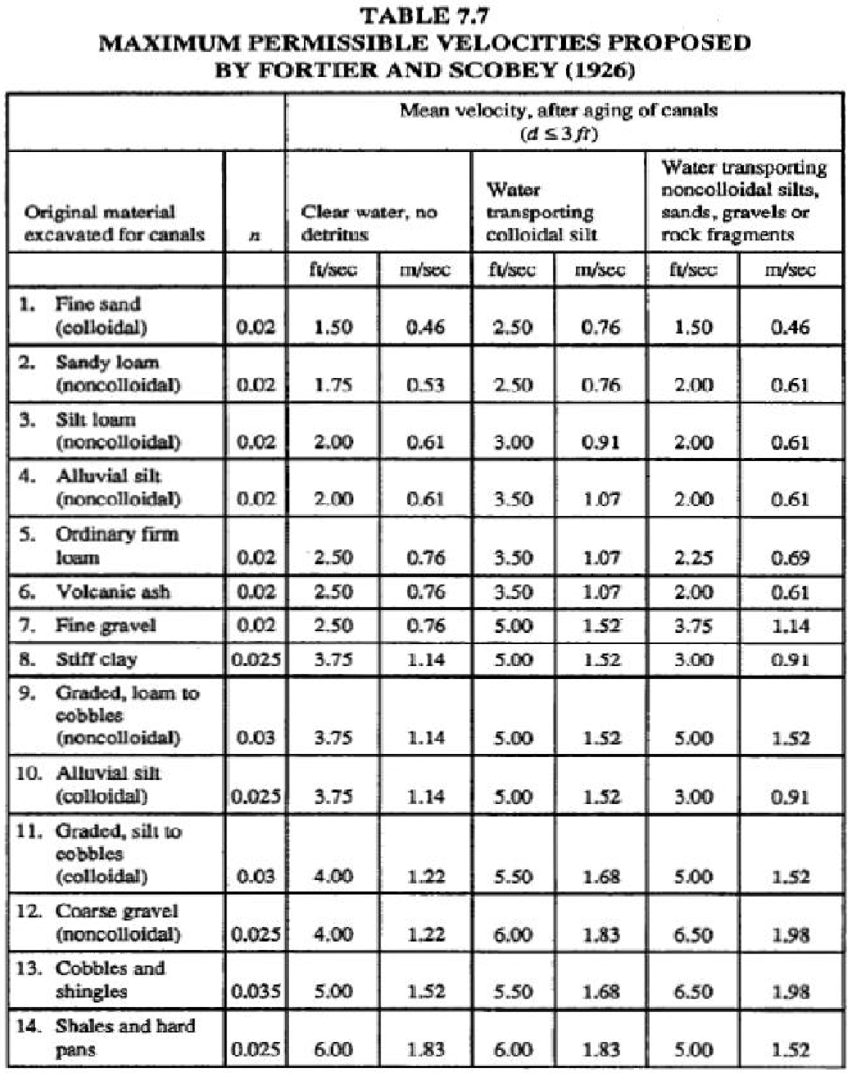


TABLE 7.7
MAXIMUM PERMISSIBLE VELOCITIES PROPOSED
BY FORTIER AND SCOBEY (1926)

		Mean velocity, after aging of canals ($d \leq 3\ ft$)					
Original material excavated for canals	n	Clear water, no detritus		Water transporting colloidal silt		Water transporting noncolloidal silts, sands, gravels or rock fragments	
		ft/sec	m/sec	ft/sec	m/sec	ft/sec	m/sec
1. Fine sand (colloidal)	0.02	1.50	0.46	2.50	0.76	1.50	0.46
2. Sandy loam (noncolloidal)	0.02	1.75	0.53	2.50	0.76	2.00	0.61
3. Silt loam (noncolloidal)	0.02	2.00	0.61	3.00	0.91	2.00	0.61
4. Alluvial silt (noncolloidal)	0.02	2.00	0.61	3.50	1.07	2.00	0.61
5. Ordinary firm loam	0.02	2.50	0.76	3.50	1.07	2.25	0.69
6. Volcanic ash	0.02	2.50	0.76	3.50	1.07	2.00	0.61
7. Fine gravel	0.02	2.50	0.76	5.00	1.52	3.75	1.14
8. Stiff clay	0.025	3.75	1.14	5.00	1.52	3.00	0.91
9. Graded, loam to cobbles (noncolloidal)	0.03	3.75	1.14	5.00	1.52	5.00	1.52
10. Alluvial silt (colloidal)	0.025	3.75	1.14	5.00	1.52	3.00	0.91
11. Graded, silt to cobbles (colloidal)	0.03	4.00	1.22	5.50	1.68	5.00	1.52
12. Coarse gravel (noncolloidal)	0.025	4.00	1.22	6.00	1.83	6.50	1.98
13. Cobbles and shingles	0.035	5.00	1.52	5.50	1.68	6.50	1.98
14. Shales and hard pans	0.025	6.00	1.83	6.00	1.83	5.00	1.52

Method of Maximum Velocity – Cohesive Soil

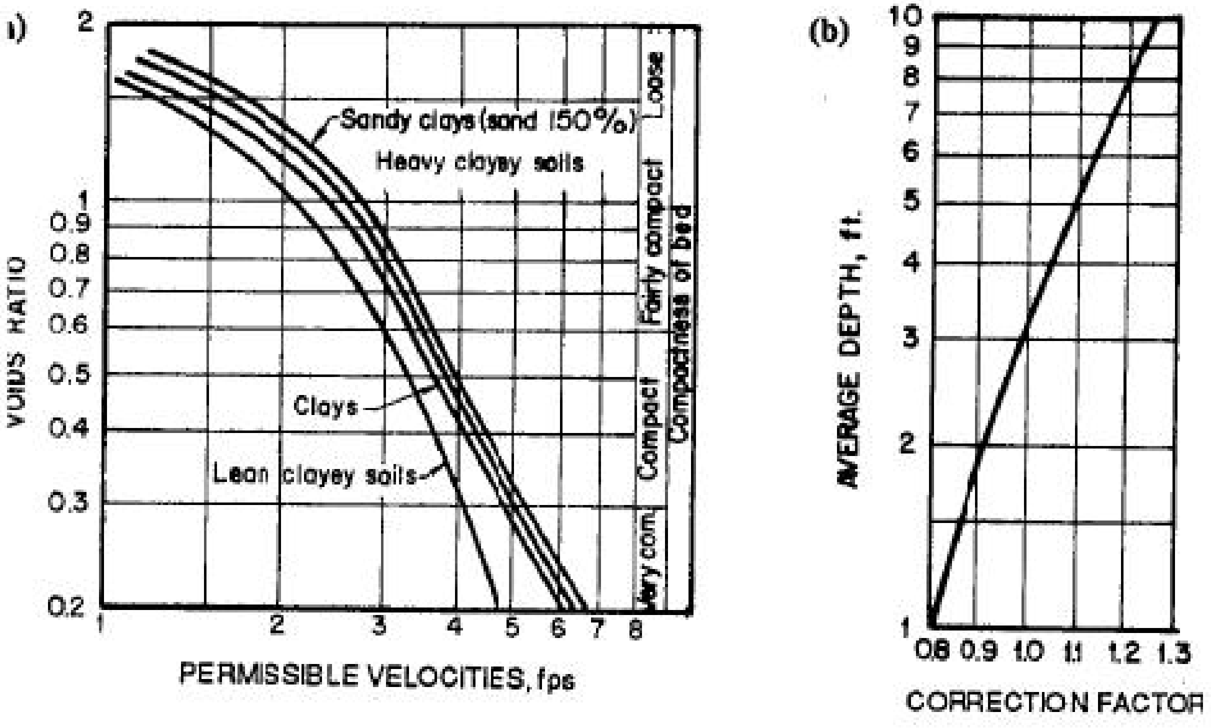


Fig. 7.27 a. Curves showing U.S.S.R. data on permissible velocities for cohesive soils, 1936. b. Curves showing U.S.S.R. corrections of permissible velocity as a function of depth for both cohesive and nonadhesive materials, 1936.

Method of Maximum Velocity – Vegetation

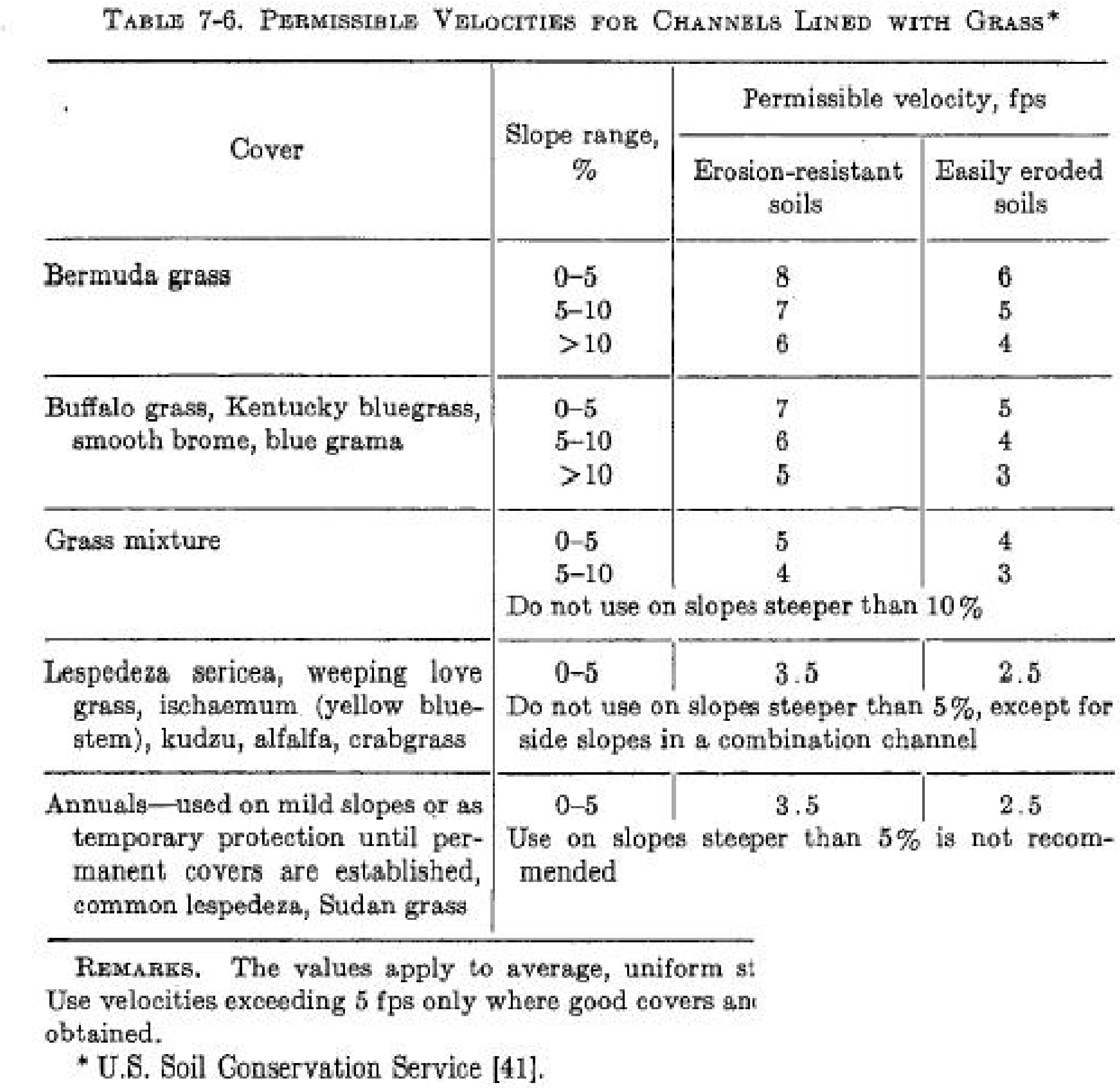


TABLE 7-6. PERMISSIBLE VELOCITIES FOR CHANNELS LINED WITH GRASS*

Cover	Slope range, %	Permissible velocity, fps	
		Erosion-resistant soils	Easily eroded soils
Bermuda grass	0–5	8	6
	5–10	7	5
	>10	6	4
Buffalo grass, Kentucky bluegrass, smooth brome, blue grama	0–5	7	5
	5–10	6	4
	>10	5	3
Grass mixture	0–5	5	4
	5–10	4	3
	Do not use on slopes steeper than 10%		
Lespedeza sericea, weeping love grass, ischaemum (yellow bluestem), kudzu, alfalfa, crabgrass	0–5	3.5	2.5
	Do not use on slopes steeper than 5%, except for side slopes in a combination channel		
Annuals—used on mild slopes or as temporary protection until permanent covers are established, common lespedeza, Sudan grass	0–5	3.5	2.5
	Use on slopes steeper than 5% is not recommended		

REMARKS. The values apply to average, uniform st
Use velocities exceeding 5 fps only where good covers an
obtained.

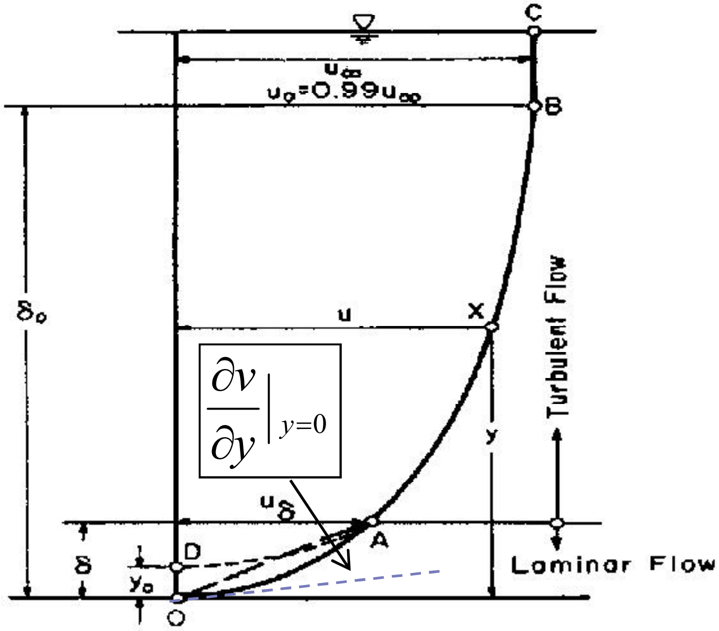
* U.S. Soil Conservation Service [41].

EVALUATING EROSIVENESS BASED ON MAXIMUM TRACTIVE FORCE/SHEAR METHOD

Method of Maximum Tractive Force
Shear Stress in Fluids

- Fluids (liquid and gases) moving along solid boundary will incur a shear stress on that boundary. The ‘no-slip condition’ requires that the velocity of the fluid at the boundary (relative to the boundary) is zero, but at some height from the boundary the velocity must equal that of the fluid.
- For all **Newtonian fluids** in **laminar flow**, shear stress is proportional to the **strain rate** in the fluid where the **viscosity** is the constant of proportionality. However, for non-Newtonian, this is no longer the case; for these fluids, the viscosity is not constant. The shear stress, for a Newtonian fluid, at a surface element parallel to a flat plate, at the point y, is given by:

$$\tau(y) = \mu \frac{\partial v}{\partial y}$$



- Where
  - μ = Dynamic viscosity
  - v = Velocity
  - y = Height above the boundary

- Shear stress at the boundary is:

$$\tau(y=0) = \mu \left.\frac{\partial v}{\partial y}\right|_{y=0}$$

Method of Maximum Tractive Force
Estimating Average Bottom Shear

- From the Momentum Equation for non-uniform flow:

$$\frac{Qw}{g}\left(\beta_2 v_2 - \beta_1 v_1\right) = P_1 - P_2 + W\sin\theta - F_f$$

- Solving for the friction force (F_f) and considering that the applied shear (tractive) force equals the friction force:

$$F_f = \tau_0 A_0 = -\frac{Q\gamma}{g}\left(\beta_2 v_2 - \beta_1 v_1\right) + P_1 - P_2 + W\sin\theta$$

- Assuming negligible change in depth and cross sectional area between sections:

$$P_1 = P_2 \qquad \beta_1 v_1 = \beta_2 v_2$$

- Therefore:

$$\tau_0 A_0 = W\sin\theta = \gamma\bar{A}L\sin\theta \Rightarrow \tau_0 = \frac{\gamma\bar{A}L\sin\theta}{W_p L} = \gamma R\sin\theta$$

- Assuming a relatively small friction slope, the average tractive force on wetted area in psf is:

$$\tau_0 = \gamma R S_0$$

- Assuming a wide channel (B/y > 10), where R ~ y, the average tractive force on wetted area in psf is:

$$\tau_0 = \gamma y S_0$$

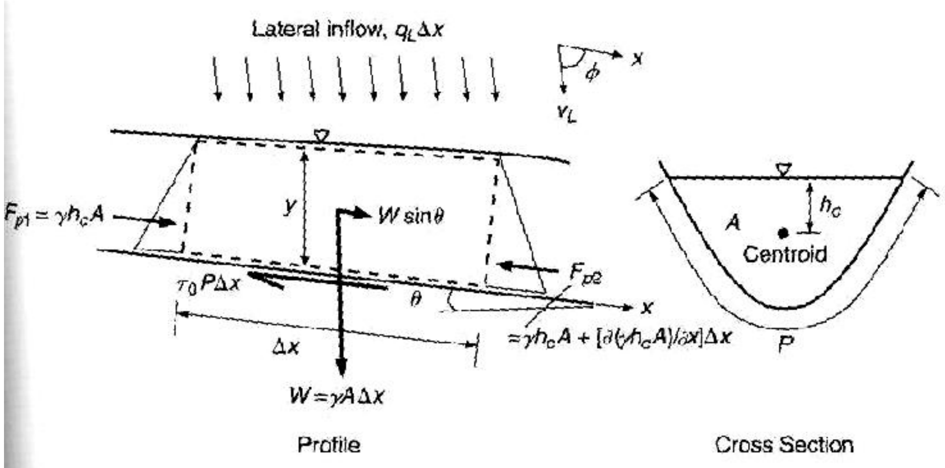


FIGURE 7.3
Control volume for derivation of unsteady momentum equation.

Method of Maximum Tractive Force – Applied Ave. Bottom Shear

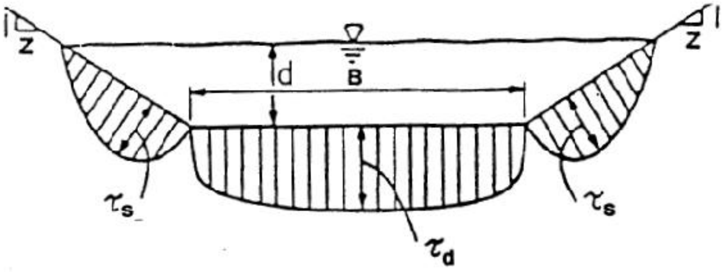


Figure 18. Typical Distribution of Shear Stress.

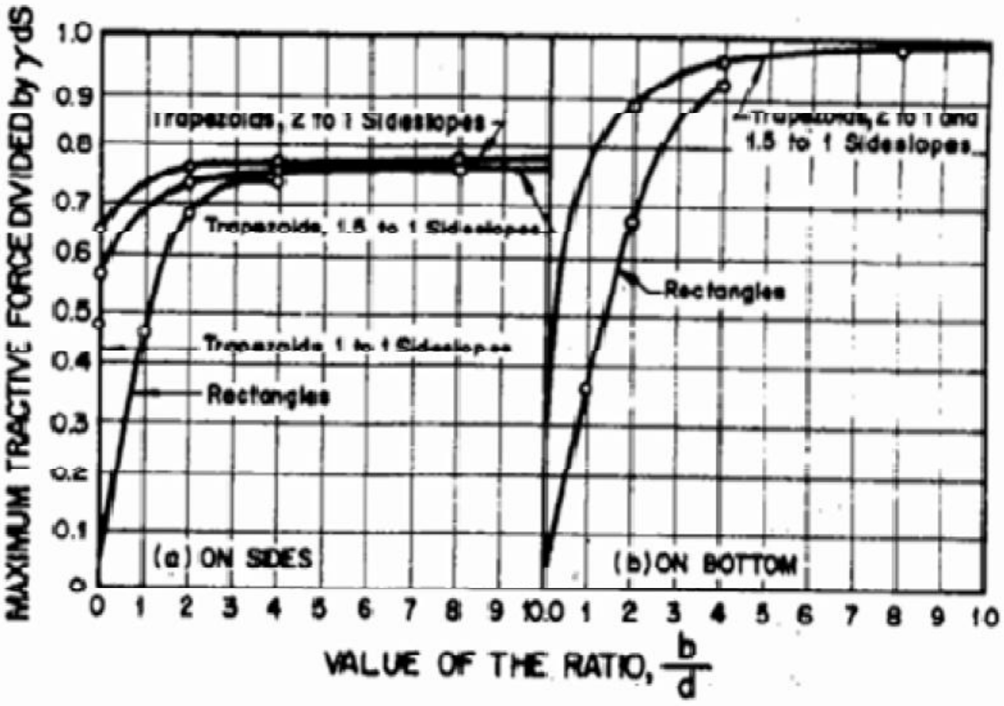
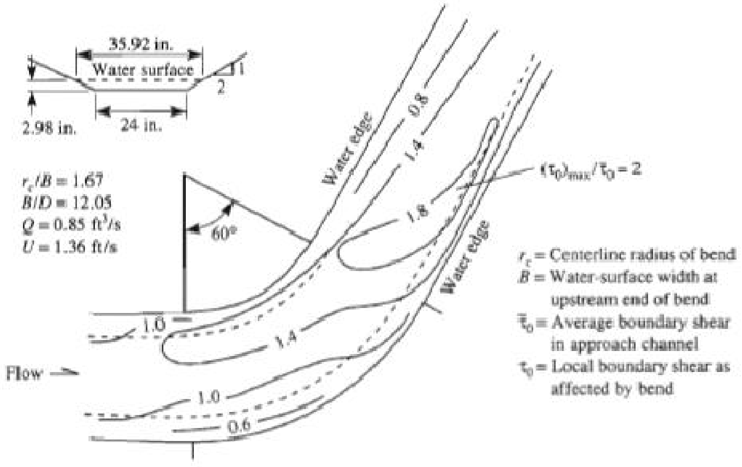
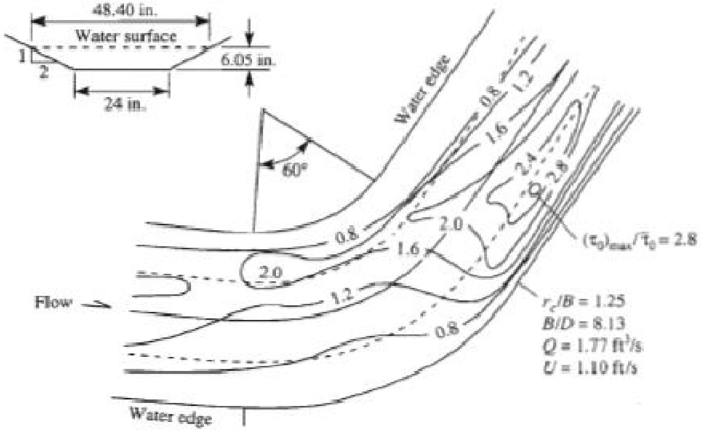


Fig. 7.26 Variation of τ in a trapezoidal cross section.

Applied Shear on Curved Channels (from USACE)



(a) Smooth channel



(b) Rough channel

FIGURE 2.15
Boundary shear distributions in curved trapezoidal channels (Ippen and Drinker, 1962).

$$\frac{(\tau_o)_{\max}}{\bar{\tau}_o} = 2.65\left(\frac{r_c}{B}\right)^{-0.5}$$

Applied Shear on Curved Channels (from FHWA's HEC-15)

$$\tau_b = K_b \tau_d$$

$$K_b = 2.00 \qquad R_c/T \leq 2$$

$$K_b = 2.38 - 0.206\left(\frac{R_c}{T}\right) + 0.0073\left(\frac{R_c}{T}\right)^2 \qquad 2 < R_c/T < 10$$

$$K_b = 1.05 \qquad R_c/T \geq 10$$

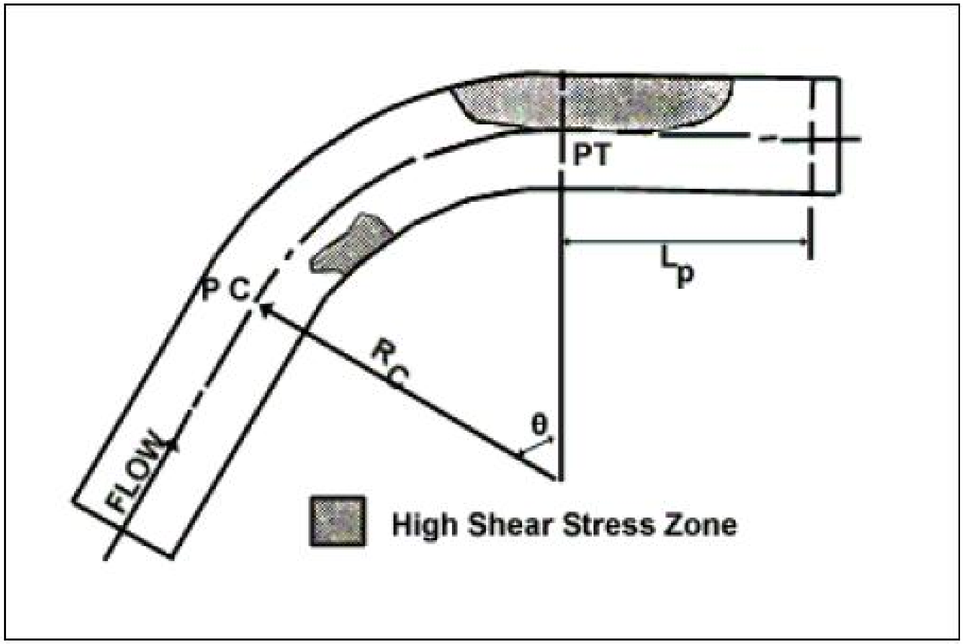


Figure 3.3. Shear Stress Distribution in a Channel Bend (Nouh and Townsend, 1979)

where,

t_b= Side shear stress on the channel (psf)

K_b= Ratio of channel bend to bottom shear stress

t_d= Shear stress in the approach channel (psf)

R_c= Radius of curvature of the bend to the channel centerline (ft)

T= Channel top (water surface) width (ft)

Method of Maximum Tractive Force – Critical (Permissible) Shear for Non-Cohesive Soil (from USGS)

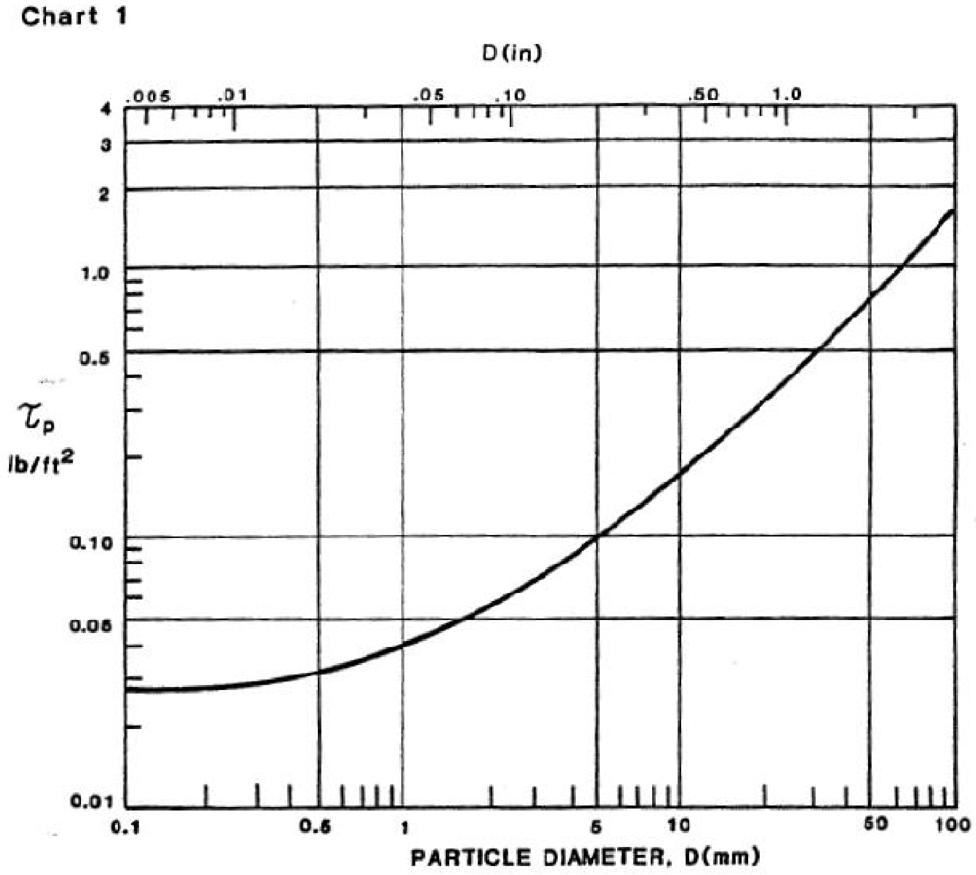
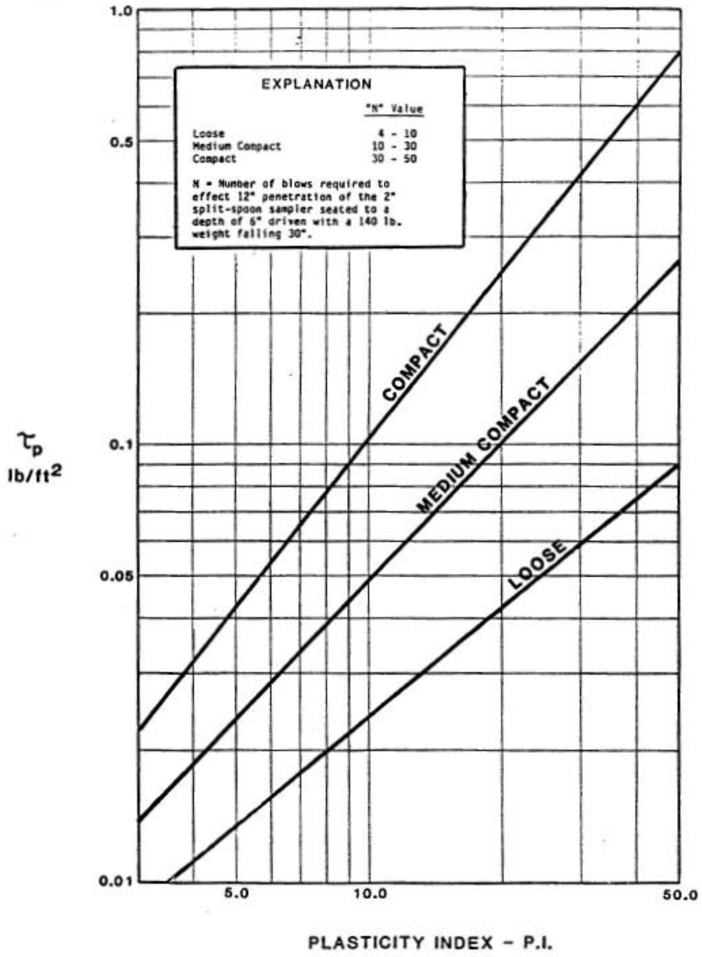


Chart 1. Permissible shear stress for non-cohesive soils. (after 15)

Method of Maximum Tractive Force – Critical (Permissible) Shear for Cohesive Soil (from USGS)

Chart 2



EXPLANATION

	"N" Value
Loose	4 - 10
Medium Compact	10 - 30
Compact	30 - 50

N = Number of blows required to effect 12" penetration of the 2" split-spoon sampler seated to a depth of 6" driven with a 140 lb. weight falling 30".

Chart 2. Permissible shear stress for cohesive soils. (after 16)

Method of Maximum Tractive Force – Vegetation & Riprap (from FHWA's HEC-15)

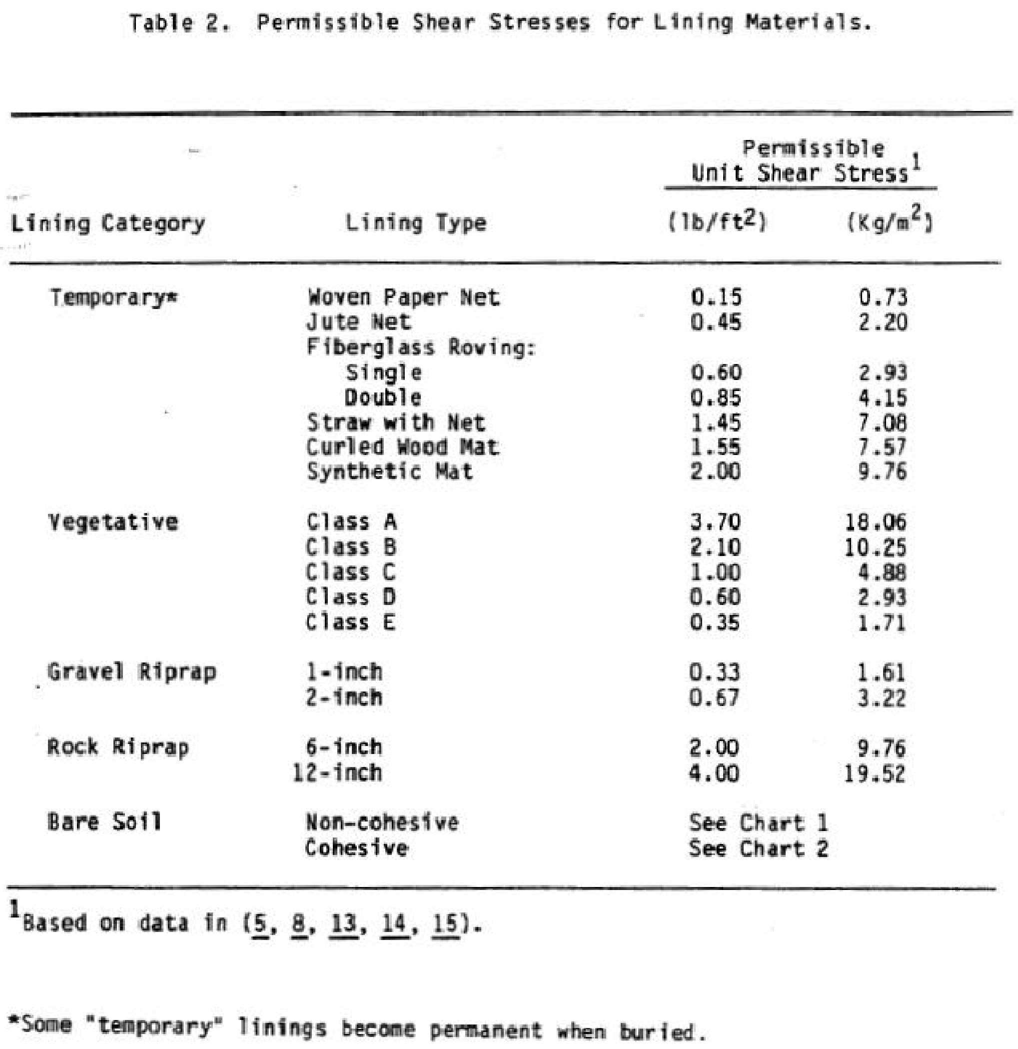


Table 2. Permissible Shear Stresses for Lining Materials.

Lining Category	Lining Type	Permissible Unit Shear Stress[1] (lb/ft^2)	Permissible Unit Shear Stress[1] (Kg/m^2)
Temporary*	Woven Paper Net	0.15	0.73
	Jute Net	0.45	2.20
	Fiberglass Roving:		
	Single	0.60	2.93
	Double	0.85	4.15
	Straw with Net	1.45	7.08
	Curled Wood Mat	1.55	7.57
	Synthetic Mat	2.00	9.76
Vegetative	Class A	3.70	18.06
	Class B	2.10	10.25
	Class C	1.00	4.88
	Class D	0.60	2.93
	Class E	0.35	1.71
Gravel Riprap	1-inch	0.33	1.61
	2-inch	0.67	3.22
Rock Riprap	6-inch	2.00	9.76
	12-inch	4.00	19.52
Bare Soil	Non-cohesive	See Chart 1	
	Cohesive	See Chart 2	

---

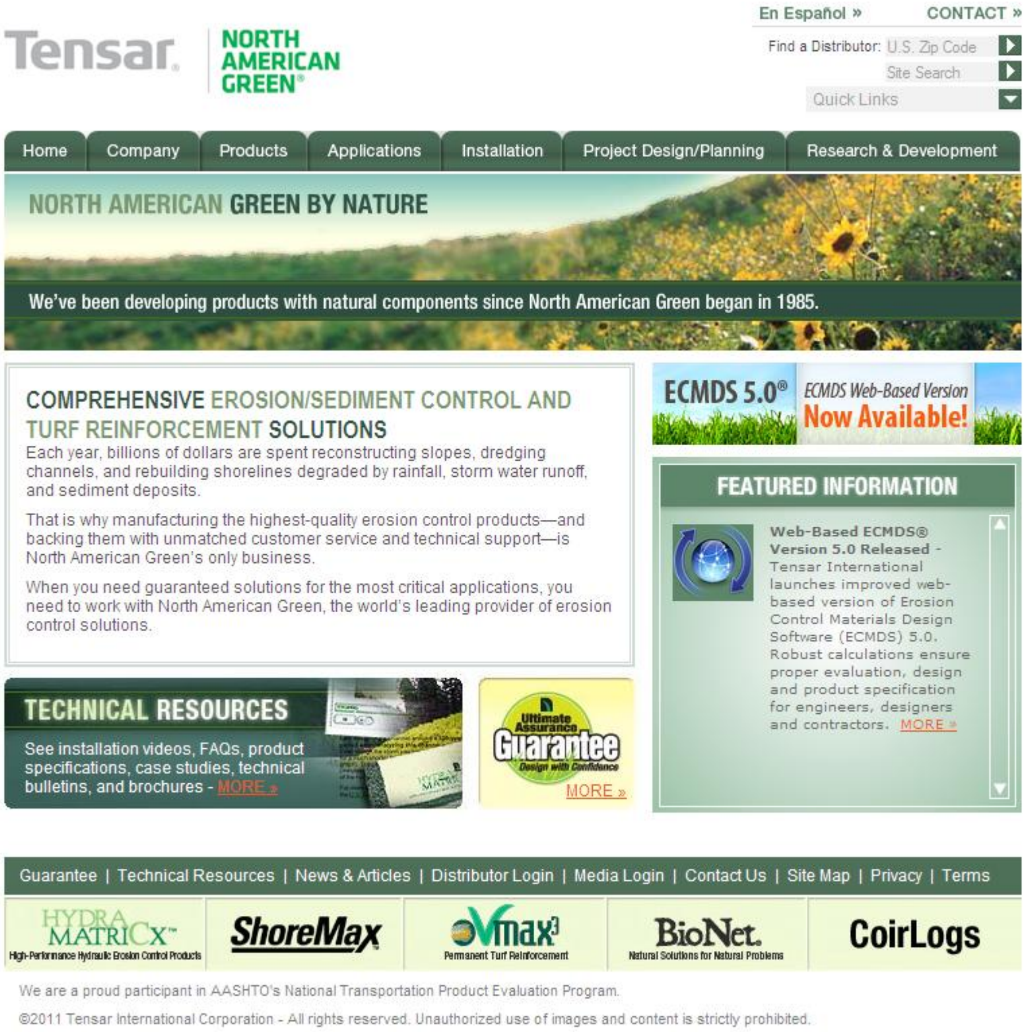
[1] Based on data in (5, 8, 13, 14, 15).

*Some "temporary" linings become permanent when buried.

For riprap:

$$\tau_p = 4.0 D_{50}$$

Design of Stable Channels
North American Green Software Demo (from HEC-15)



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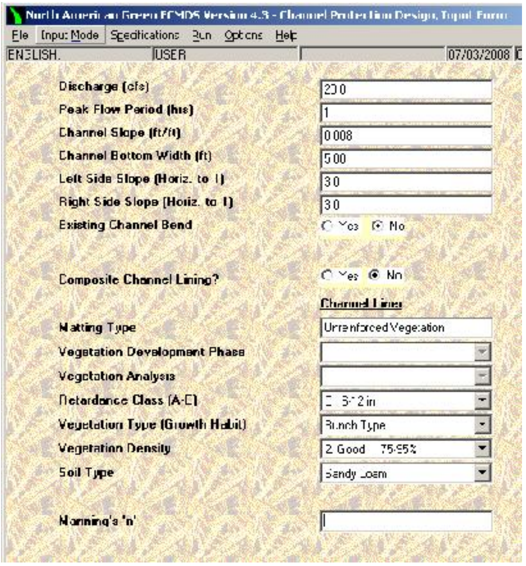
Design of Stable Channels
North American Green Software Demo



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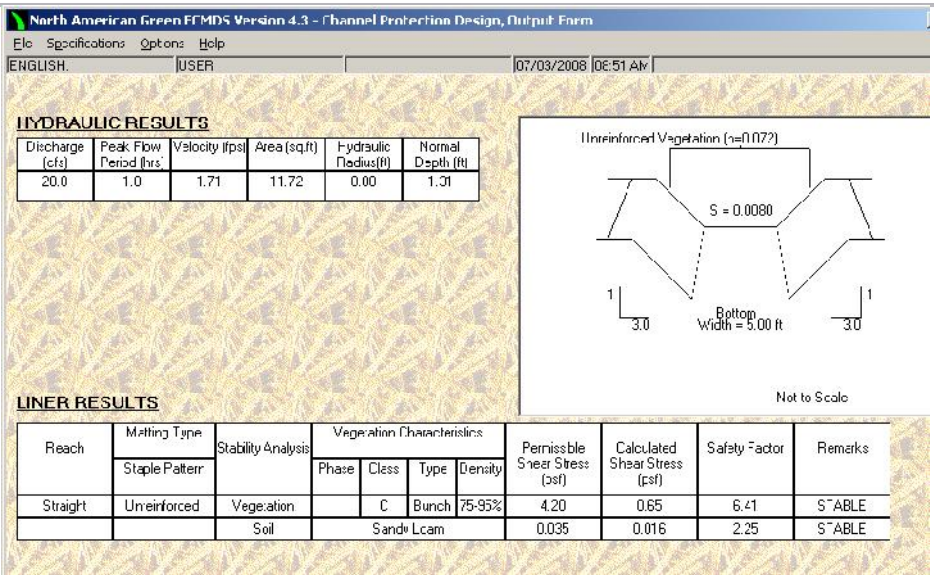
Discharge (cfs)	20.0
Peak Flow Period (hrs)	1
Channel Slope (ft/ft)	0.008
Channel Bottom Width (ft)	5.00
Left Side Slope (Horiz. to 1)	3.0
Right Side Slope (Horiz. to 1)	3.0
Existing Channel Bend	○ Yes ● No
Composite Channel Lining?	○ Yes ● No
	Channel Liner
Matting Type	Unreinforced Vegetation
Vegetation Development Phase	
Vegetation Analysis	
Retardance Class (A-E)	C 6-12 in
Vegetation Type (Growth Habit)	Bunch Type
Vegetation Density	2 Good 75-95%
Soil Type	Sandy Loam
Manning's 'n'	

→



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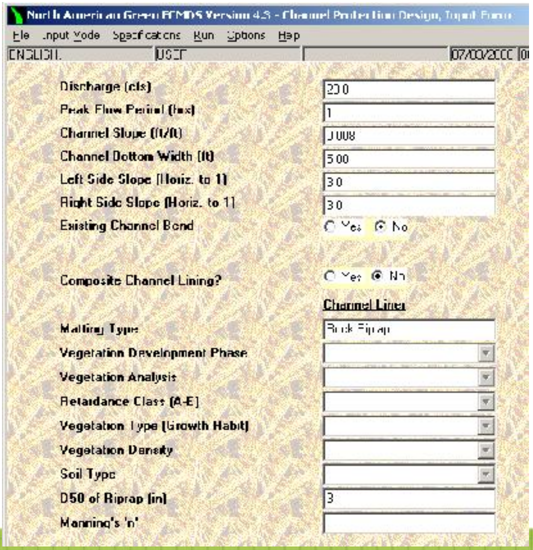
HYDRAULIC RESULTS

Discharge (cfs)	Peak Flow Period (hrs)	Velocity (fps)	Area (sq.ft)	Hydraulic Radius(ft)	Normal Depth (ft)
20.0	1.0	1.71	11.72	0.00	1.31

LINER RESULTS

Reach	Matting Type	Stability Analysis	Vegetation Characteristics				Permissible Shear Stress (psf)	Calculated Shear Stress (psf)	Safety Factor	Remarks
	Staple Pattern		Phase	Class	Type	Density				
Straight	Unreinforced	Vegetation		C	Bunch	75-95%	4.20	0.65	6.41	STABLE
		Soil	Sandy Loam				0.035	0.016	2.25	STABLE



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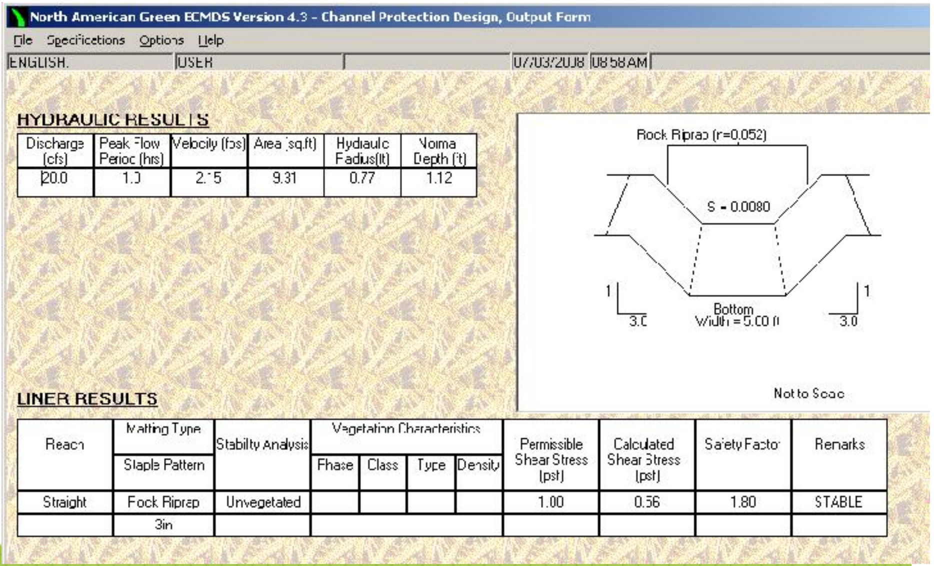
Discharge (cfs)	20.0
Peak Flow Period (hrs)	1
Channel Slope (ft/ft)	0.008
Channel Bottom Width (ft)	5.00
Left Side Slope (Horiz. to 1)	3.0
Right Side Slope (Horiz. to 1)	3.0
Existing Channel Bend	○ Yes ● No
Composite Channel Lining?	○ Yes ● No
	Channel Liner
Matting Type	Rock Riprap
Vegetation Development Phase	
Vegetation Analysis	
Retardance Class (A-E)	
Vegetation Type (Growth Habit)	
Vegetation Density	
Soil Type	
D50 of Riprap (in)	3
Manning's 'n'	

→



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HYDRAULIC RESULTS

Discharge (cfs)	Peak Flow Period (hrs)	Velocity (fps)	Area (sq.ft)	Hydraulic Radius(ft)	Normal Depth (ft)
20.0	1.0	2.15	9.31	0.77	1.12

LINER RESULTS

Reach	Matting Type	Stability Analysis	Vegetation Characteristics				Permissible Shear Stress (psf)	Calculated Shear Stress (psf)	Safety Factor	Remarks
	Staple Pattern		Phase	Class	Type	Density				
Straight	Rock Riprap	Unvegetated					1.00	0.56	1.80	STABLE
	3in									

STABLE CHANNEL GEOMETRY

Stable Channel Geometry (from USBR)

Side slopes (USBR)

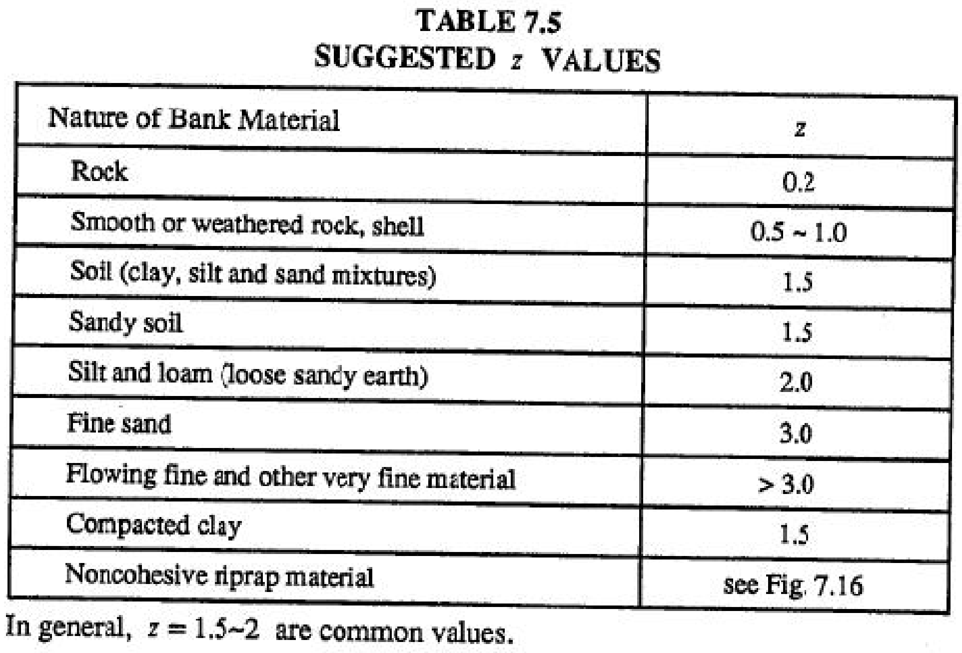


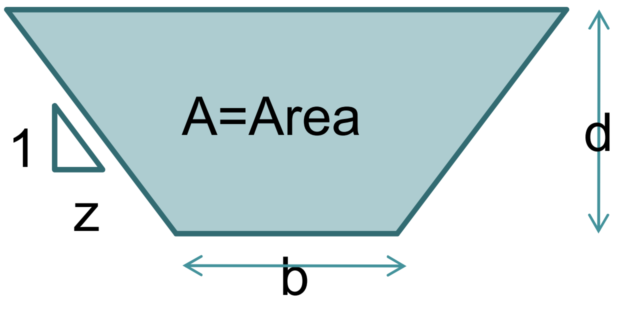
TABLE 7.5
SUGGESTED *z* VALUES

Nature of Bank Material	z
Rock	0.2
Smooth or weathered rock, shell	0.5 ~ 1.0
Soil (clay, silt and sand mixtures)	1.5
Sandy soil	1.5
Silt and loam (loose sandy earth)	2.0
Fine sand	3.0
Flowing fine and other very fine material	> 3.0
Compacted clay	1.5
Noncohesive riprap material	see Fig. 7.16

In general, $z = 1.5 \sim 2$ are common values.

Dimensions of trapezoidal sections (USBR)

$$d = 0.5\sqrt{A} \qquad \frac{b}{d} = 4 - z$$



Stable Channel Geometry – Freeboard (from PADEP)

Freeboard (Critical Slope Method – PADEP)

$$S_c = \frac{14.56 n^2 D_m}{R^{4/3}}$$

$$D_m = \frac{A}{T}$$

- Uniform flow at or near critical depth is unstable due to waves present at the water's surface.
- Sufficient freeboard must be provided to prevent waves from overtopping the channel.
- Flow is considered "unstable" when S_o is between $0.7S_c$ and $1.3S_c$. If unstable flow exists, compute minimum freeboard as ➔

$$F = \frac{0.025V}{3D} = 0.075VD$$

- For a stable channel, the minimum freeboard should be 25% of the flow depth.
- Generally, freeboard should not be less than 0.5 feet

Stable Channel Geometry – Ideal Stable Cross Section

From the USBR, ideal section geometry to evenly distribute shear:

Equation for bank curves

$$y = d_{\max} \cos\left(\frac{\tan\phi}{d_{\max}} x \right)$$

Equations for geometry

$$d_{\max} = \frac{\tau_c}{0.97 \gamma S_f} \qquad A = \frac{2 d_{\max}^2}{Tan\ \phi} \qquad \frac{T}{2} = \frac{d_{\max}\left(\pi/2\right)}{Tan \phi}$$

Equations for velocity

$$v = \frac{1}{n}\left(\frac{d_{\max} \cos\phi}{E(\sin\phi)} \right)^{2/3} S^{1/2} \qquad E(\sin\phi) = \left(\frac{\pi}{2}\right)\left(1 - \frac{1}{4}\sin^2\phi\right)$$

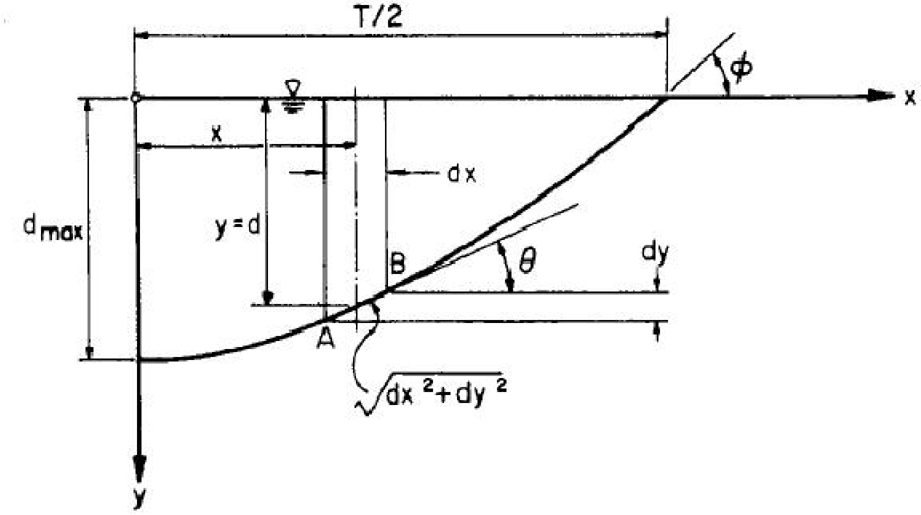


Fig. 7.28 Elements of an ideal, stable section.

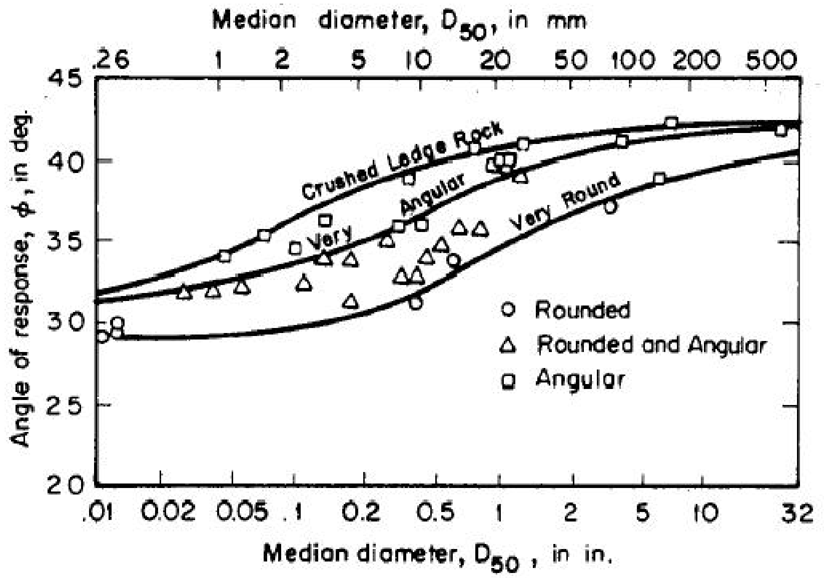


Fig. 7.16 Angle of repose for dumped riprap (after Simons, 1957).

Stable Channel Geometry – Ideal Stable Cross Section

Example:

Given:
$g=9.81\ m/s^2$; $S_f=0.0006$; $n=0.022$; $\gamma=1000\ kg/m^3$; $D_{50}=12\ mm$;
$Q=10\ m^3/sec$

For a given lining type, it was determined that:

$\tau_c = 0.9\ kg/m^2$

Solution:

$$d_{\max} = \frac{\tau_c}{0.97\gamma S_f}$$

$$d_{\max} = \frac{0.9}{0.97 \times 0.0006 \times 10^3} = 1.55\ m \qquad 7.148$$

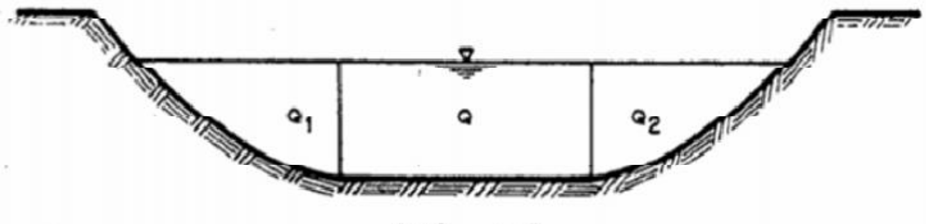
2. Compute A

$$A = \frac{2 \times \overline{1.55}^2}{0.73} = 6.58\ m^2 \qquad 7.146$$

3. Compute U

$$U = \frac{1}{0.022}\left[\frac{1.55 \cos\phi}{\left(\frac{\pi}{2}\right)\left(1 - \frac{1}{2}\sin^2\phi\right)}\right]^{2/3} S^{1/2} \qquad 7.147$$

$$U = 1.017\text{~}1.02\ m/\sec$$



$Q = Q_{given} - Q_{comp}$

$Q_1 + Q_2 = Q_{comp}$

Compute Q

$$Q_{comp} = 1.02 \times 6.58 = 6.71 < 10.00\ m^3/\sec$$

Compute the discharge of central part

$$Q_{cent} = 10.00 - 6.71 = 3.29\ m^3/\sec$$

Compute the width of the central part B using Manning's equation, noting that

$$A = Bd_{\max} = \frac{Q}{V} \Rightarrow A_{cent} = B \times 1.55 = \frac{Q_{cent}}{U} \Leftarrow V = \frac{1}{n} R^{2/3} S_f^{1/2}$$

so

$$B = \frac{0.022 \times 3.29}{1.55^{5/3} \times 0.0006^{1/2}} = 1.42\ m$$

$$B = \frac{nQ_{cent}}{1.49\, d_{\max}^{5/3} S^{1/2}}$$

English

$$B = \frac{nQ_{cent}}{d_{\max}^{5/3} S^{1/2}}$$

Metric

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Stable Channel Geometry – Stable Channel Slope

Where there is insufficient amount of coarse material to develop an armor layer, degradation will continue until the channel reaches a stable slope. Refer to example on next page.

$$S_L = \frac{(0.19)(d_{50})(n/d_{90}^{1/6})^{3/2}}{d} \qquad A_g = \frac{V_g}{B} \qquad D_g = \left(\frac{64 A_g \Delta S}{39}\right)^{1/2} \qquad L_g = \frac{13 D_g}{8 \Delta S}$$

where

A_g = volume of material to be degraded per unit channel width (sf)

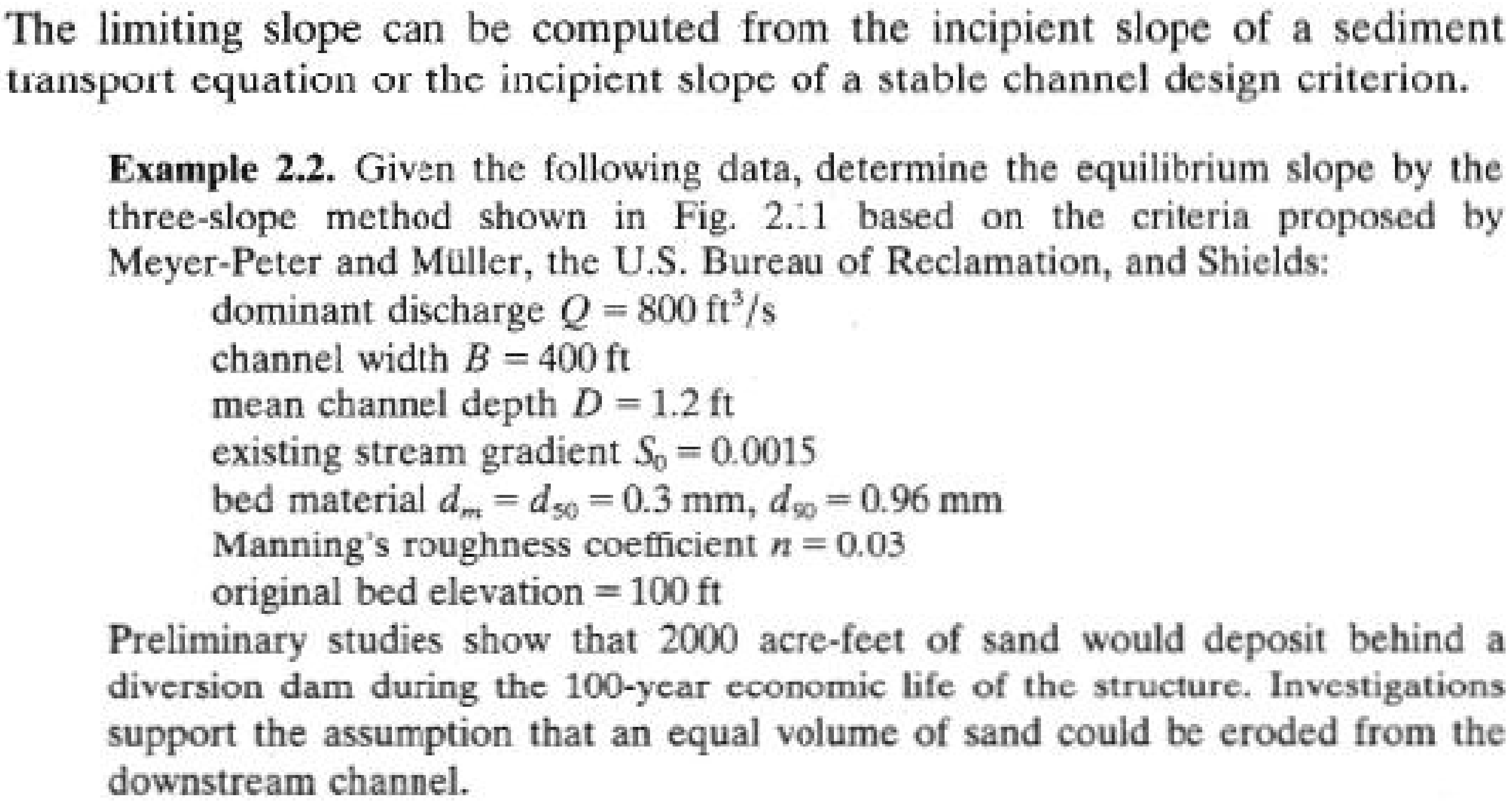
$\Delta S = S_o - S_L$

S_L = Limiting slope (Meyer-Peter-Muller Method)

d = Mean flow depth (feet)

d_{50} & d_{90} = Particle diameter at 50% and 90% passing (mm)

Stable Channel Geometry – Stable Channel Slope



The limiting slope can be computed from the incipient slope of a sediment transport equation or the incipient slope of a stable channel design criterion.

Example 2.2. Given the following data, determine the equilibrium slope by the three-slope method shown in Fig. 2.11 based on the criteria proposed by Meyer-Peter and Müller, the U.S. Bureau of Reclamation, and Shields:

dominant discharge $Q = 800\ \text{ft}^3/\text{s}$
channel width $B = 400$ ft
mean channel depth $D = 1.2$ ft
existing stream gradient $S_0 = 0.0015$
bed material $d_m = d_{50} = 0.3$ mm, $d_{90} = 0.96$ mm
Manning's roughness coefficient $n = 0.03$
original bed elevation = 100 ft

Preliminary studies show that 2000 acre-feet of sand would deposit behind a diversion dam during the 100-year economic life of the structure. Investigations support the assumption that an equal volume of sand could be eroded from the downstream channel.

Stable Channel Geometry – Stable Channel Slope

Solution

Meyer-Peter and Müller method. Limiting slope

$$S_L = \frac{K_1 d_{50}(n/(d_{90}^{1/6}))^{3/2}}{D}$$

$$= \frac{(0.19)(0.3)(0.03/0.96^{1/6})^{3/2}}{1.2} = 0.000\,249$$

$$\Delta S = S_0 - S_L = 0.0015 - 0.000\,249 = 0.001\,25$$

$$A_g = \frac{(2000)(43\,560)}{400} = 217\,800 \text{ ft}^2$$

$$D_g = \left(\frac{64 A_g\,\Delta S}{39}\right)^{1/2} = \left[\frac{(64)(217\,800)(0.001\,25)}{39}\right]^{1/2} = 21.1 \text{ ft}$$

$$L_g = \frac{13 D_g}{8\,\Delta S} = \frac{(13)(21.1)}{8(0.001\,25)} = 27\,430 \text{ ft}$$

$$L_1 = \frac{D_g}{2\,\Delta S} = \frac{21.1}{(2)(0.001\,25)} = 8440 \text{ ft}$$

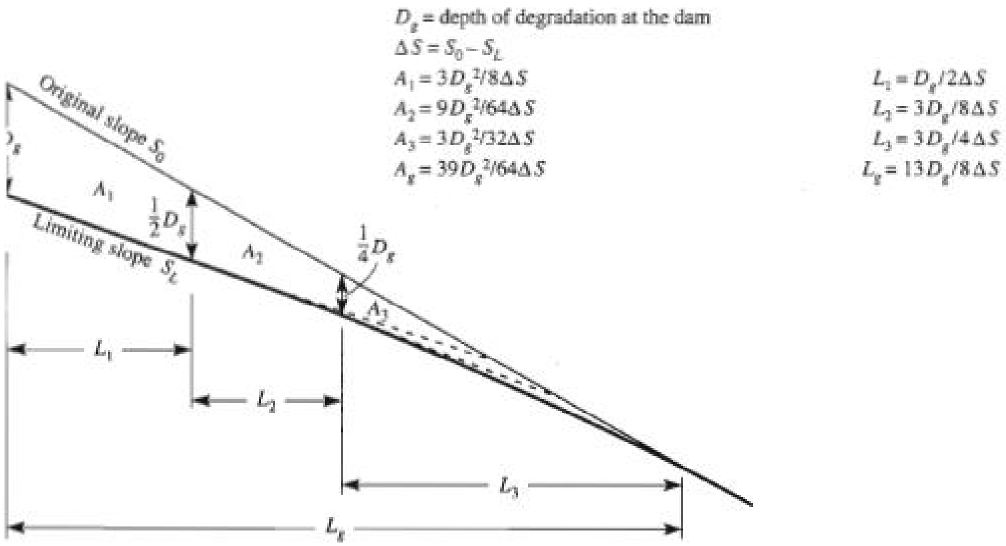
$$L_2 = \frac{3D_g}{8\,\Delta S} = \frac{(3)(21.1)}{(8)(0.001\,25)} = 6330 \text{ ft}$$

$$L_3 = \frac{3D_g}{4\,\Delta S} = \frac{(3)(21.1)}{(4)(0.001\,25)} = 12\,660 \text{ ft}$$

$$A_1 = \frac{3D_g^2}{8\,\Delta S} = \frac{(3)(21.1)^2}{(8)(0.001\,25)} = 133\,563 \text{ ft}^2$$

$$A_2 = \frac{9D_g^2}{64\,\Delta S} = \frac{(9)(21.1)^2}{(64)(0.001\,25)} = 50\,086 \text{ ft}^2$$

$$A_3 = \frac{3D_g^2}{32\,\Delta S} = \frac{(3)(21.1)^2}{(32)(0.001\,25)} = 33\,391 \text{ ft}^2$$



D_g = depth of degradation at the dam
$\Delta S = S_0 - S_L$
$A_1 = 3D_g^2/8\Delta S$
$A_2 = 9D_g^2/64\Delta S$
$A_3 = 3D_g^2/32\Delta S$
$A_g = 39D_g^2/64\Delta S$

$L_1 = D_g/2\Delta S$
$L_2 = 3D_g/8\Delta S$
$L_3 = 3D_g/4\Delta S$
$L_g = 13D_g/8\Delta S$

URE 2.11
graded channel profile by the three-slope method (U.S. Bureau of Reclamation, 1987).

SLOPE REVETMENT DESIGN

Design of Stable Channels
Slope Revetment

Types of slope revetment:

- Riprap
- Gabion
- Grouted rock
- Pre-cast articulated concrete block

Slope Revetment – Riprap (Safety Factor (SF) Method)

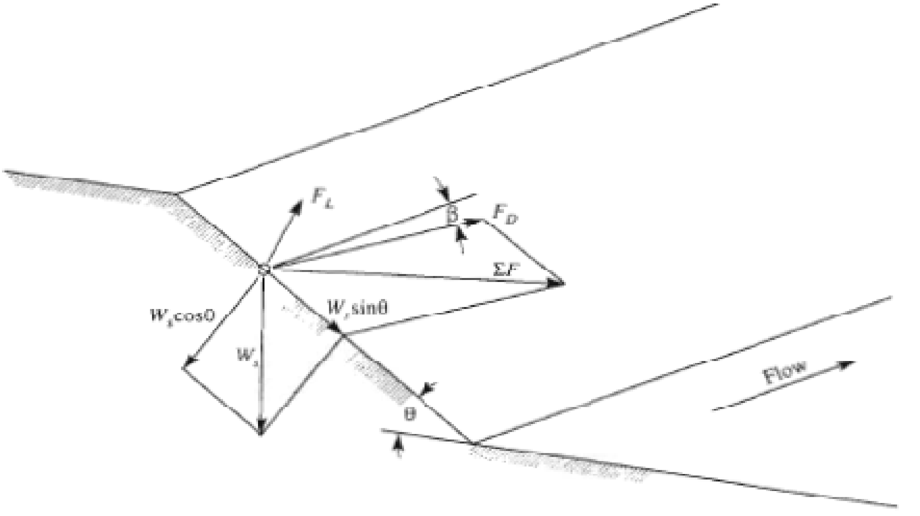
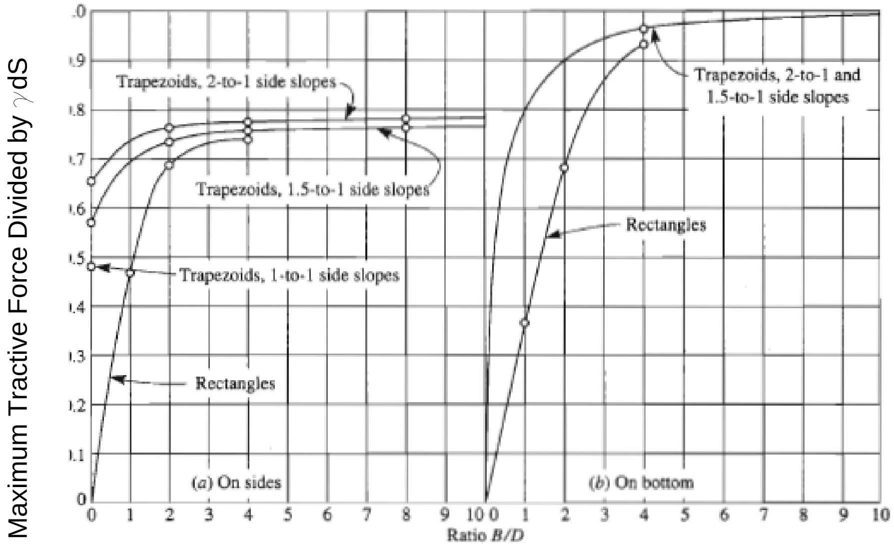


FIGURE 2.12
Forces acting on a particle resting on the side of a trapezoidal channel (Graf, 1971).



URE 2.14
ximum shear stress in a channel (Lane, 1953).

$$SF=\frac{\cos\theta\tan\phi}{\eta'\tan\phi+\sin\theta\cos\beta}$$

$$\eta'=\left(\frac{1+\sin(\lambda+\beta)}{2}\right)\eta$$

$$\eta=\frac{21\tau_o}{(S_s-1)\gamma_w D_{50}}$$

$$\tan\beta=\frac{\cos\lambda}{\left(2\sin\theta/\eta\tan\phi\right)+\sin\lambda}$$

- τ_o = Shear along the side slope (from Lane chart above)
- ϕ = Angle of repose
- λ = Angle between horizontal & velocity vector along the slope plane.

Slope Revetment – Riprap (USBR)

For relatively stable flow (uniform, straight, or mildly curved (curve radius/channel width > 30)), impact from wave action and floating debris minimal, and little or no uncertainty in design parameters); stability factor of 1.2.

Based on $S_g = 2.65$; use specific gravity correction factor if other than 2.65.

Stability factor is used to reflect the uncertainty in the hydraulic conditions and is defined as the ratio of the average tractive force/critical shear of riprap. If other than 1.2, apply the stability factor correction factor in Table 1 below.

$$D_{50} = C_{sg} C_{sf} \frac{0.001 V_a^3}{d_a^{0.5} K_1^{1.5}}$$

Where,

D_{50} = Mean riprap particle size

C = Correction factor

V_a = Average velocity in channel (fps)

D_a = Average flow depth in channel (ft)

θ = Angle of channel bank

φ = Riprap material angle of repose

C = Correction factors

$$K_1 = \left[1 - \frac{\sin^2 \theta}{\sin^2 \phi}\right]^{0.5}$$

$$C_{sg} = \frac{2.12}{\left(S_g - 1\right)^{1.5}}$$

$$C_{sf} = \left(\frac{SF}{1.2}\right)^{1.5}$$

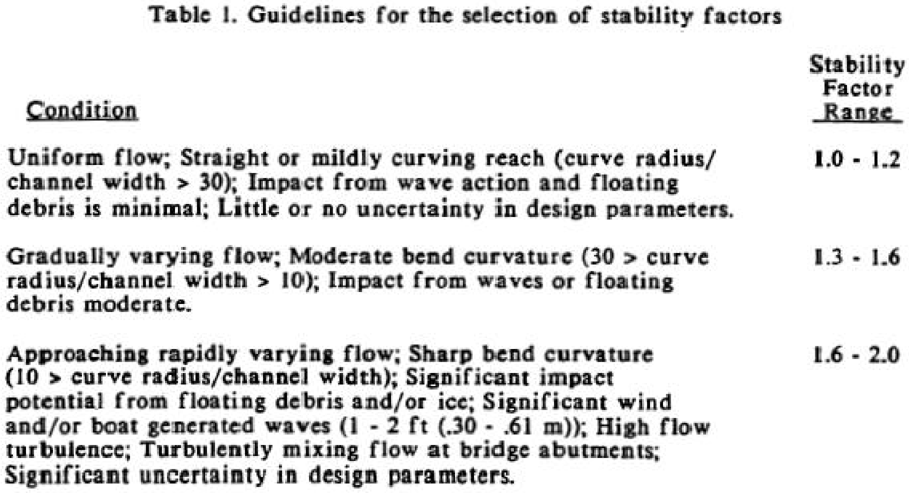


Table 1. Guidelines for the selection of stability factors

Condition	Stability Factor Range
Uniform flow; Straight or mildly curving reach (curve radius/channel width > 30); Impact from wave action and floating debris is minimal; Little or no uncertainty in design parameters.	1.0 - 1.2
Gradually varying flow; Moderate bend curvature (30 > curve radius/channel width > 10); Impact from waves or floating debris moderate.	1.3 - 1.6
Approaching rapidly varying flow; Sharp bend curvature (10 > curve radius/channel width); Significant impact potential from floating debris and/or ice; Significant wind and/or boat generated waves (1 - 2 ft (.30 - .61 m)); High flow turbulence; Turbulently mixing flow at bridge abutments; Significant uncertainty in design parameters.	1.6 - 2.0

Slope Revetment – Riprap

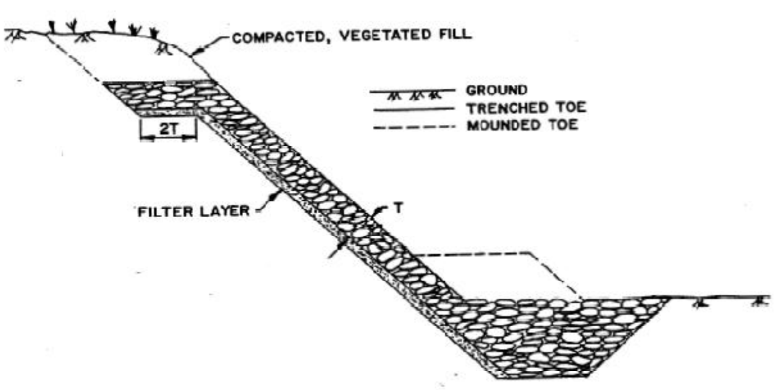


Figure 21. Typical riprap installation: end view (bank protection only).

<u>Design considerations</u>

- Rock gradation
- Filter (granular or fabric)
- Bank slope (maximum recommended is 2:1)
- Bank preparation; cleared and grubbed.
- Thickness
  - D_{100} or $1.5D_{50}$, whichever is greater
  - > 12”
  - Increase thickness by 50% for under-water placement
  - Increase thickness by 6” to 12” where riprap may be subject to attack from floating debris, ice, or large waves.

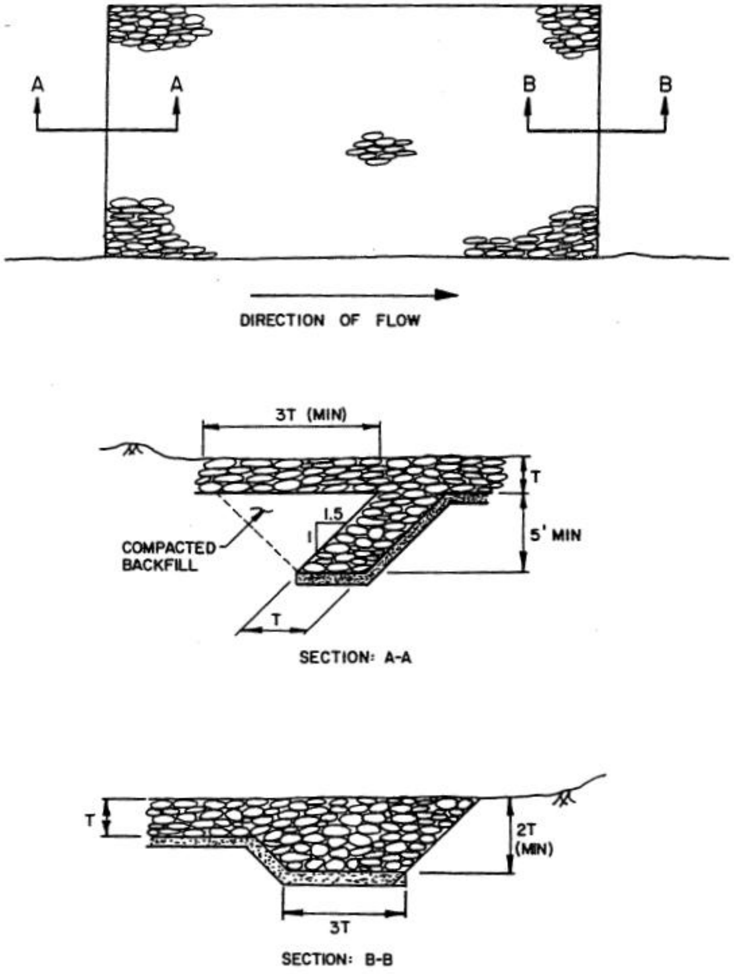


Figure 20. Typical riprap installation: plan and flank details.

Slope Revetment – Gabions

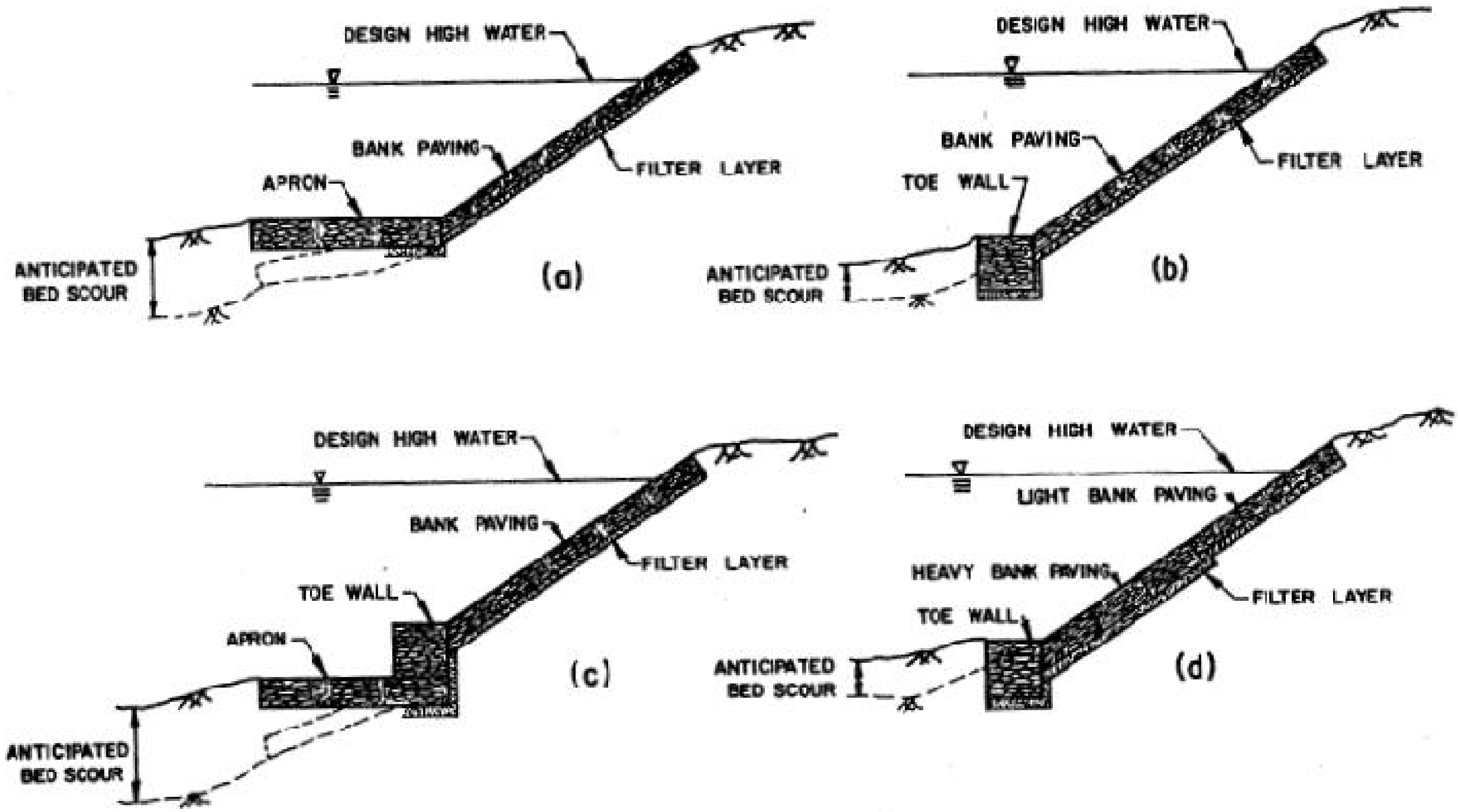


Figure 40. Rock and wire mattress configurations: (a) mattress with toe apron; (b) mattress with toe wall; (c) mattress with toe wall; and (d) mattress of variable thickness. See section A-A of figure 39 for reference.

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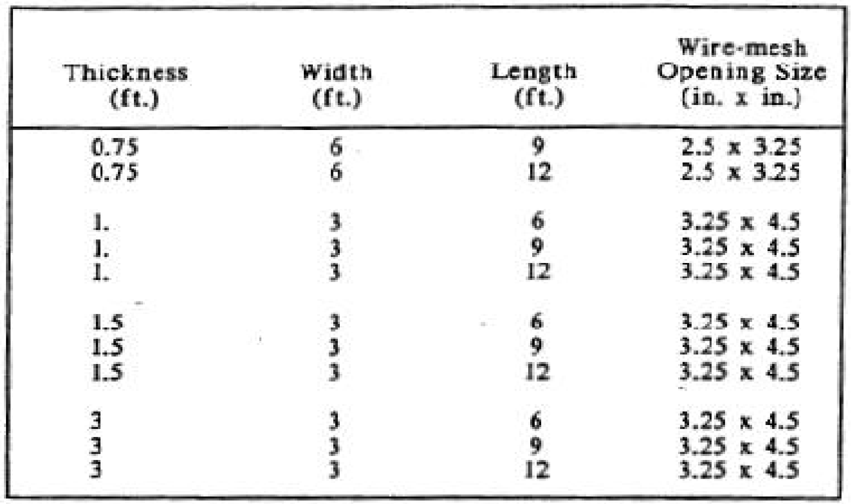
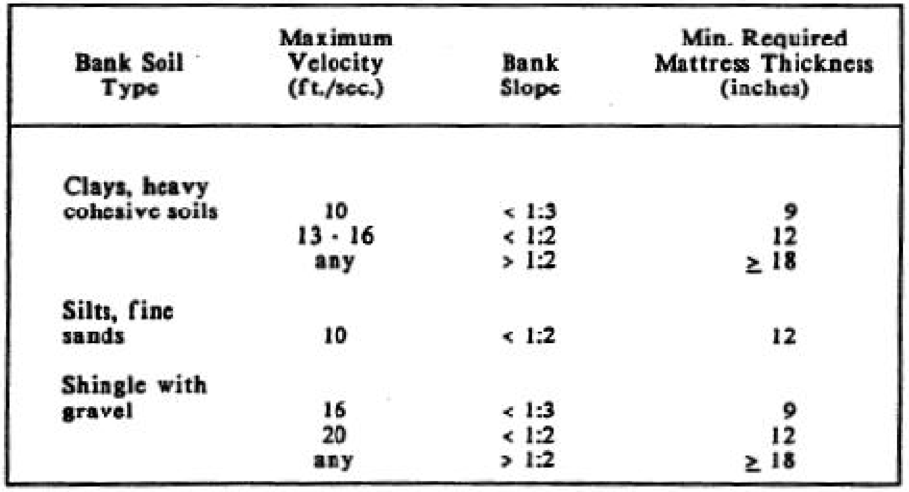
Slope Revetment – Gabions

Table 4. Standard gabion sizes



Thickness (ft.)	Width (ft.)	Length (ft.)	Wire-mesh Opening Size (in. x in.)
0.75	6	9	2.5 x 3.25
0.75	6	12	2.5 x 3.25
1.	3	6	3.25 x 4.5
1.	3	9	3.25 x 4.5
1.	3	12	3.25 x 4.5
1.5	3	6	3.25 x 4.5
1.5	3	9	3.25 x 4.5
1.5	3	12	3.25 x 4.5
3	3	6	3.25 x 4.5
3	3	9	3.25 x 4.5
3	3	12	3.25 x 4.5

Table 5. Criteria for gabion thickness.



Bank Soil Type	Maximum Velocity (ft./sec.)	Bank Slope	Min. Required Mattress Thickness (inches)
Clays, heavy cohesive soils	10	< 1:3	9
	13 - 16	< 1:2	12
	any	> 1:2	≥ 18
Silts, fine sands	10	< 1:2	12
Shingle with gravel	16	< 1:3	9
	20	< 1:2	12
	any	> 1:2	≥ 18

Slope Revetment – Grouted Rock

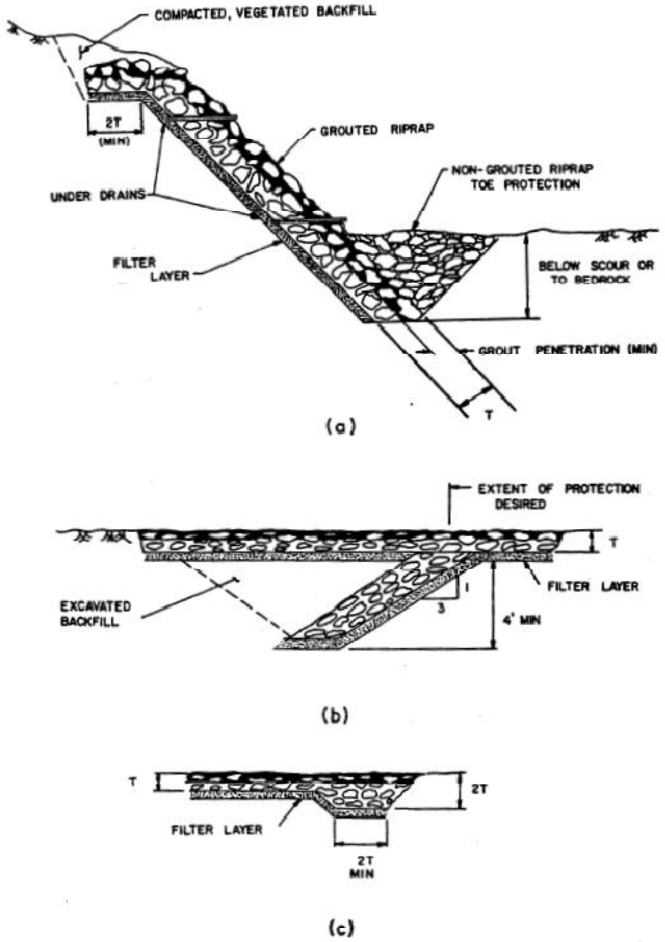


Figure 56. Grouted riprap sections: (a) section A-A; (b) section B-B; and (c) section C-C. (refer to figure 39 for section locations)

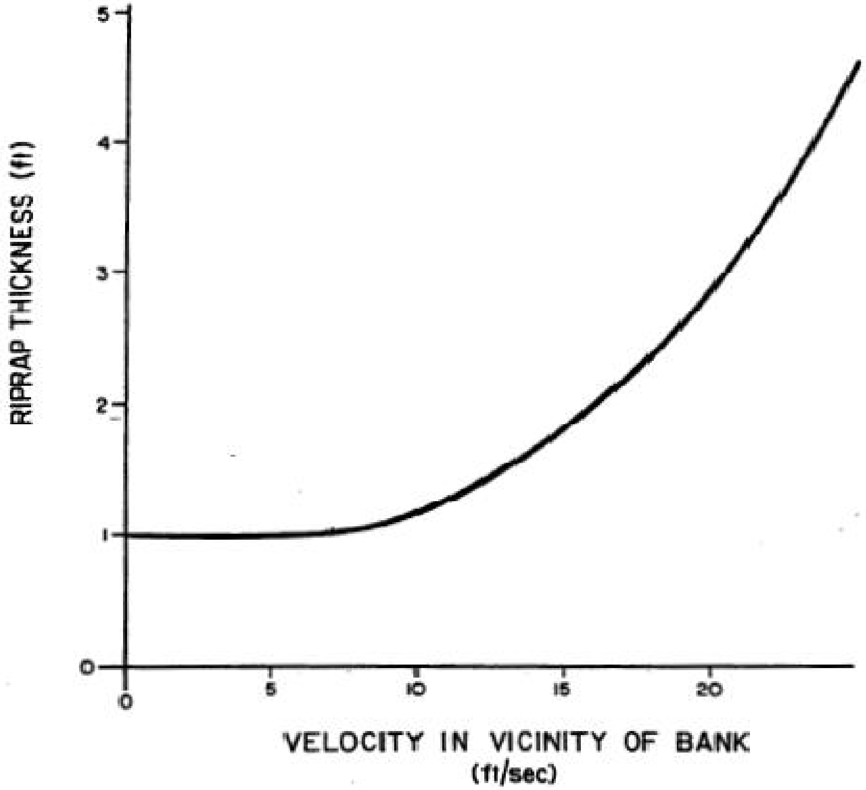


Figure 57. Required blanket thickness as a function of flow velocity.

Slope Revetment – Articulated Concrete Block

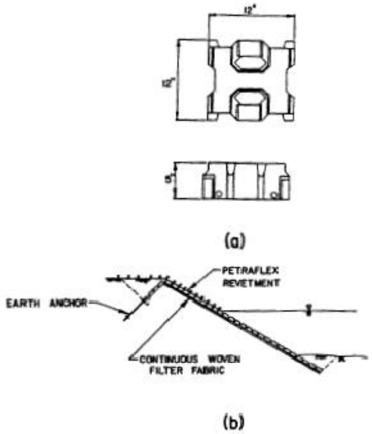


Figure 53. Petraflex (a) block detail and (b) revetment configuration. (see reference section A-A, figure 39)

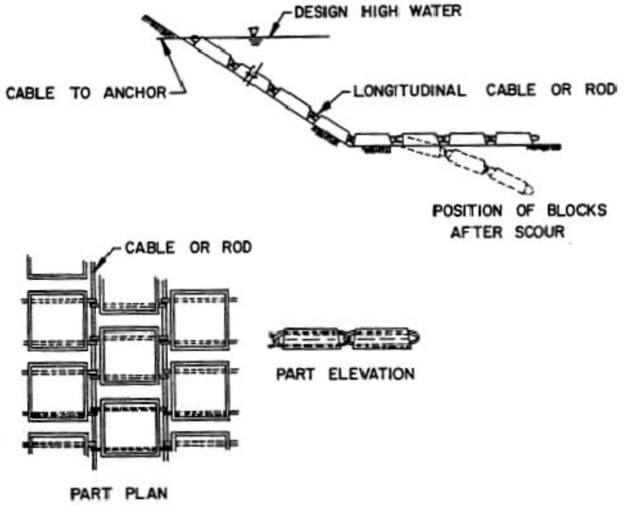
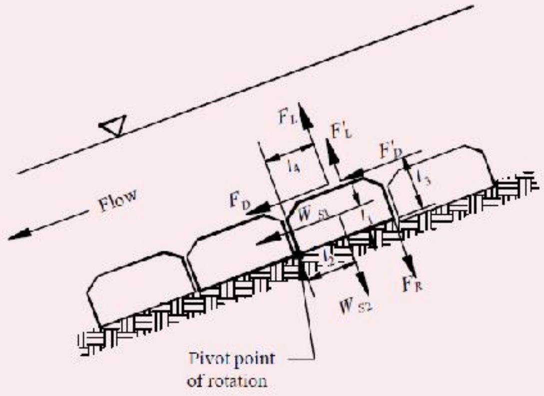


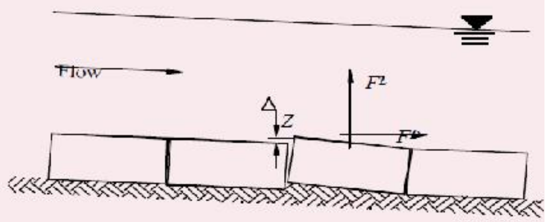
Figure 54. Articulated concrete revetment. (see reference section A-A, figure 39).

Slope Revetment
Articulated Concrete Block (ACB) Safety Factor (SF) Calculation



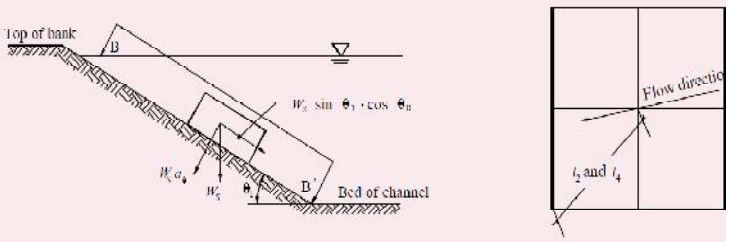
Overturning forces: F_{D}, F_{L}, F'_{D}, F'_{L}, W_{s1}

Restraining forces: F_{R}, W_{s2}



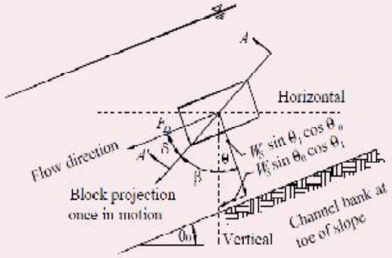
Notes:

1. **Critical shear** obtained from tests conducted per protocol in FHWA-RD-89-199 or ASTM 7276-08.
2. SF is heavily influenced by protrusion, Δz (assumed to be ‘0’ for tapered block).

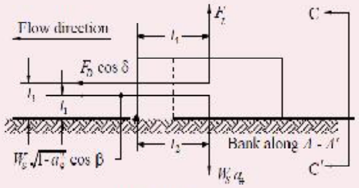


(a) Channel cross-section

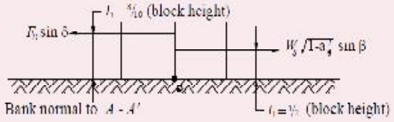
(b) Plan view of unit



(c) Section B - B', view normal to plane of channel bank



(d) Section A - A'



(e) Section C - C' (flow direction normal to page)

$$SF = \frac{(\ell_2/\ell_1)a_\theta}{\sqrt{1-a_\theta^2}\cos\beta + \eta_1(\ell_2/\ell_1) + \dfrac{(\ell_3 F'_D \cos\delta + \ell_4 F'_L)}{\ell_1 W_S}}$$

$\delta + \beta + \theta = 90^\circ$ or $\pi/2$ radians

where:

$$\beta = \arctan\left(\frac{\cos(\theta_0+\theta)}{(\ell_4/\ell_3+1)\dfrac{\sqrt{1-a_\theta^2}}{\eta_0(\ell_2/\ell_1)} + \sin(\theta_0+\theta)}\right)$$

$$\theta = \arctan\left(\frac{\sin\theta_0}{\sin\theta_1}\cdot\frac{\cos\theta_1}{\cos\theta_0}\right) = \arctan\left(\frac{\tan\theta_0}{\tan\theta_1}\right)$$

$\eta_o = \tau_{des}/\tau_c$

$$\eta_1 = \left(\frac{\ell_4/\ell_3 + \sin(\theta_0+\theta+\beta)}{\ell_4/\ell_3+1}\right)\eta_0$$

$$a_\theta = \sqrt{\cos^2\theta_1 - \sin^2\theta_0}$$

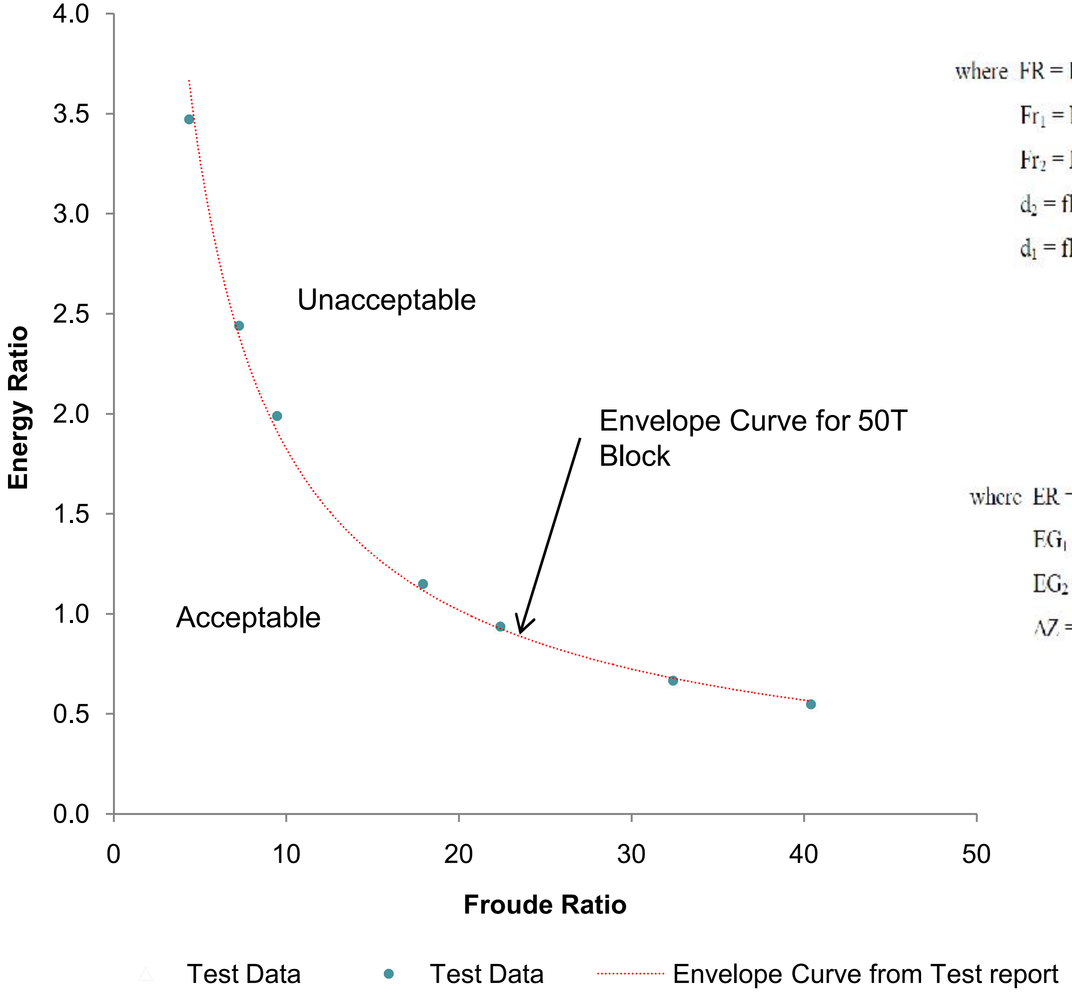
$F'_L = F'_D = 0.5\,\Delta Z\, b_u\, \rho\, V_{des}^2$

$$W_S = W\cdot\left(\frac{S_C - 1}{S_C}\right)$$

$\tau_{des} = \tau_o$ = Ave Bottom Shear (see Page 18)
τ_c = Critical Shear from testing (see note 1)

Note: The equations cannot be solved for $\theta_1 = 0$ (i.e., division by 0); therefore, a negligible side slope must be entered for the case of $\theta_1 = 0$.

Articulated Concrete Block (ACB) Design Stability in a Hydraulic Jump



$$FR = \frac{Fr_1}{Fr_2} = \left(\frac{d_2}{d_1}\right)^{1.5}$$

where FR = Froude ratio

Fr_1 = Froude number at the upstream end of the hydraulic jump;

Fr_2 = Froude number at the downstream end of the hydraulic jump (at the sluice gate);

d_2 = flow depth orthogonal to the bed at the downstream end of the hydraulic jump; and

d_1 = flow depth orthogonal to the bed at the upstream end of the hydraulic jump.

$$ER = \frac{\text{energy loss with a jump}}{\text{energy loss w/out a jump}} = \frac{EG_1 - EG_2}{\Delta Z}$$

where ER = Energy ratio

EG_1 = energy grade elevation at upstream end of the jump;

EG_2 = energy grade elevation at downstream end of the jump; and

ΔZ = change in elevation head from the upstream to downstream end of the jump.

STABLE CHANNEL DESIGN TOOL IN HEC-RAS

Stable Channel Design Tool in HEC-RAS

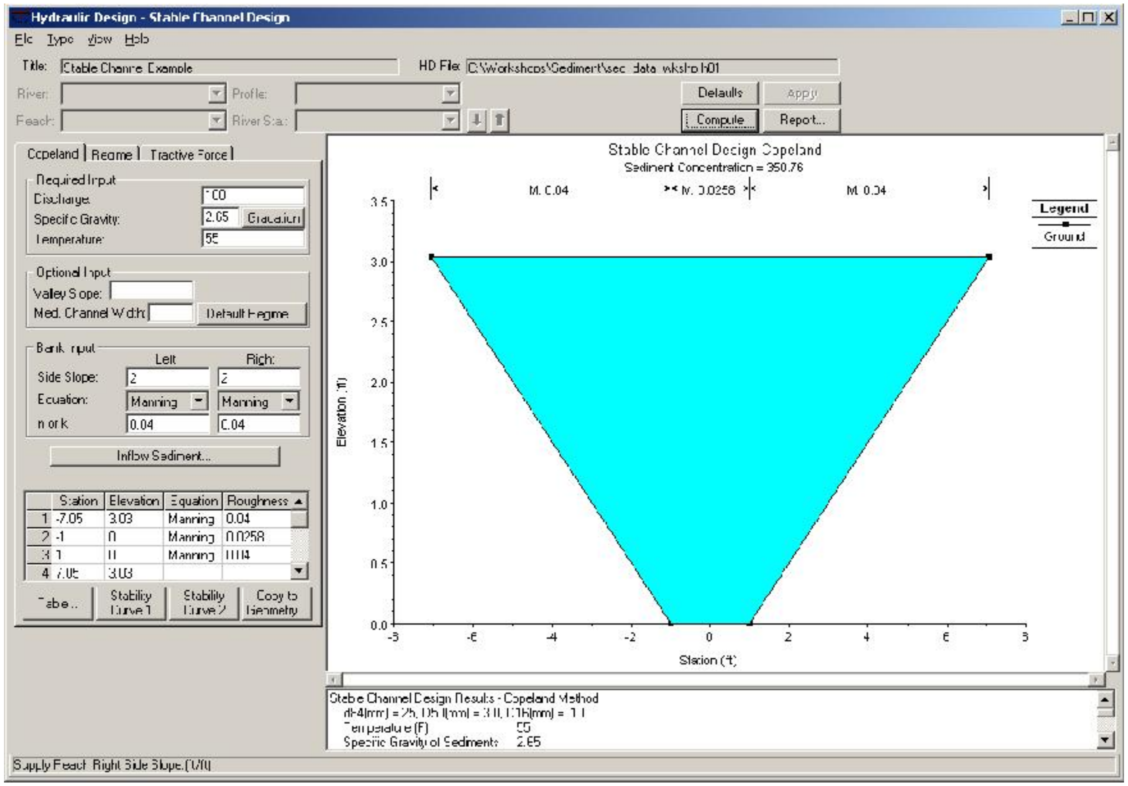
The **Copeland Method** (Copeland, 1994) was developed at the USACE Waterways Experiment Station through physical model testing and field studies of trapezoidal-shaped channels. – Applicable to alluvial channels.

The **Regime Method** is an empirically based technique originally using actual data gathered by British engineers for irrigation canals in India. A stream is stable at the design discharge when there is no net annual gain or loss of sediment through the reach under study. – Applicable for long-term (annual) simulations.

The **Tractive Force Method** is analytically based. Channel stability is achieved as long as the actual shear stress on a selected particle size of the bed material is less than the critical shear stress (that which just initiates motion of the selected bed particle size). – Applicable for use channels lined with gravel or rock.

Stable Channel Design Tool in HEC-RAS Copeland Method

- Defines stability as sediment inflow = sediment outflow
- Inflowing sediment must be established; which can be done by providing a sediment concentration or by allowing RAS to compute the sediment concentration by the geometric and sediment properties of an upstream reach. (Capacity calculation using Brownlies Equation.)



Title: Stable Channel Example

HD File: C:\Workshops\Sediment\sed_data_wkshp.h01

River:

Profile:

Reach:

River Sta.:

Required Input

Discharge: 100

Specific Gravity: 2.65

Temperature: 55

Optional Input

Valley Slope:

Med. Channel Width:

Bank Input

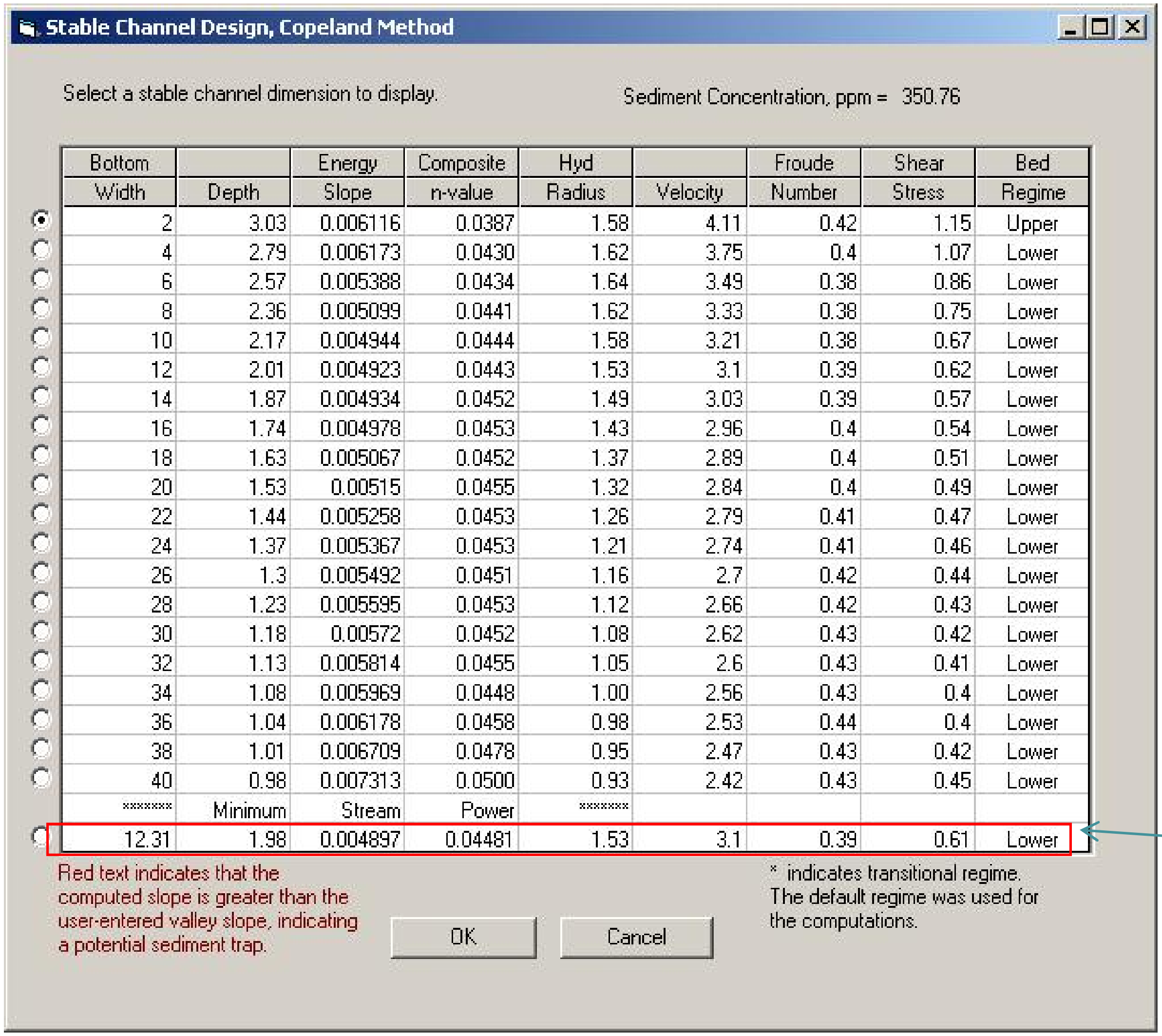
	Left	Right
Side Slope:	2	2
Equation:	Manning	Manning
n or k	0.04	0.04

	Station	Elevation	Equation	Roughness
1	-7.05	3.03	Manning	0.04
2	-1	0	Manning	0.0258
3	1	0	Manning	0.04
4	7.05	3.03		

```
Stable Channel Design Results - Copeland Method
   d84(mm) = 25, D50(mm) = 3.0, D16(mm) = 1.1
   Temperature (F)                 55
   Specific Gravity of Sediment:   2.65
```

Supply Reach Right Side Slope (V/H)

Stable Channel Design Tool in HEC-RAS Copeland Method



Select a stable channel dimension to display.

Sediment Concentration, ppm = 350.76

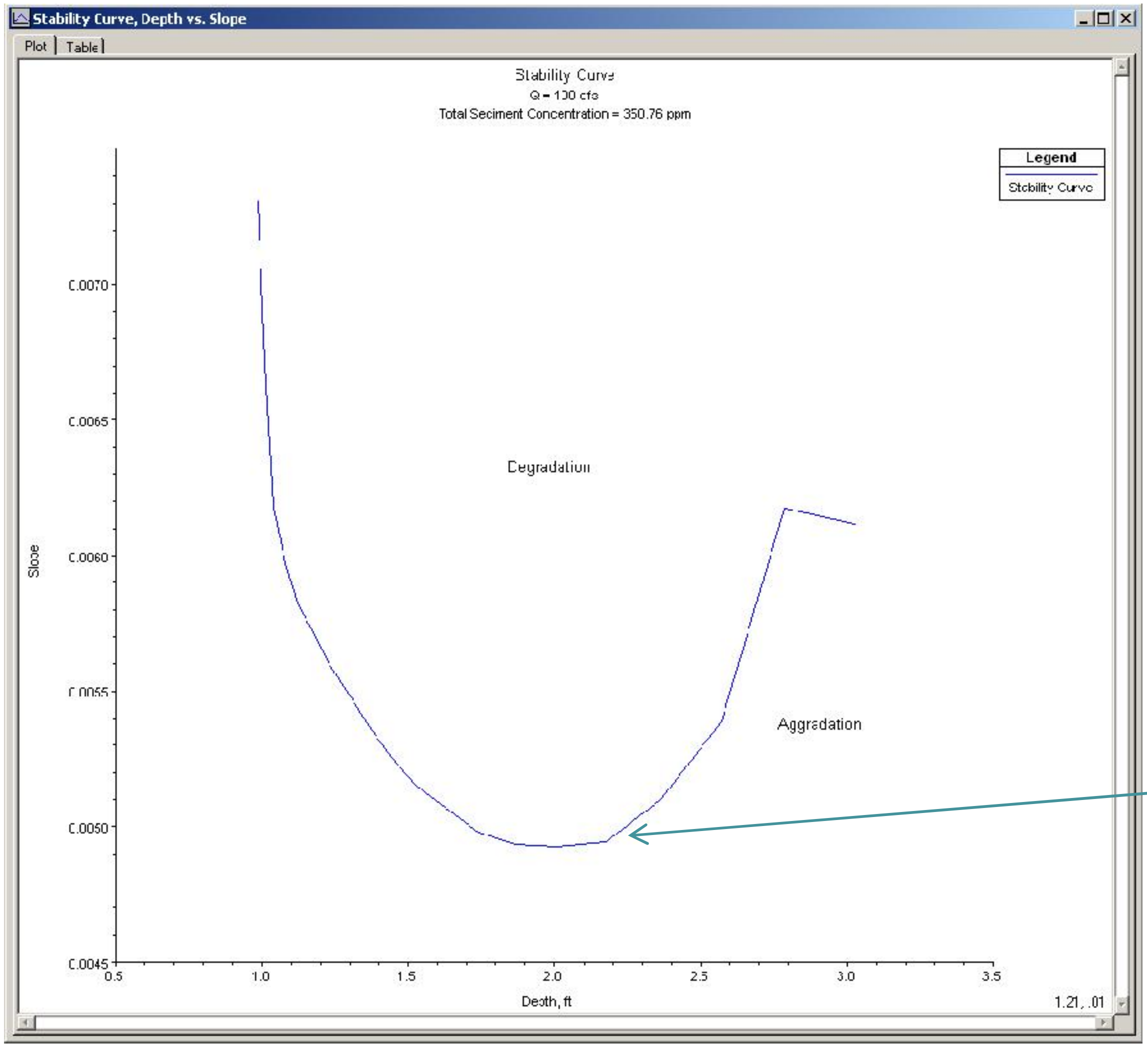
	Bottom Width	Depth	Energy Slope	Composite n-value	Hyd Radius	Velocity	Froude Number	Shear Stress	Bed Regime
●	2	3.03	0.006116	0.0387	1.58	4.11	0.42	1.15	Upper
○	4	2.79	0.006173	0.0430	1.62	3.75	0.4	1.07	Lower
○	6	2.57	0.005388	0.0434	1.64	3.49	0.38	0.86	Lower
○	8	2.36	0.005099	0.0441	1.62	3.33	0.38	0.75	Lower
○	10	2.17	0.004944	0.0444	1.58	3.21	0.38	0.67	Lower
○	12	2.01	0.004923	0.0443	1.53	3.1	0.39	0.62	Lower
○	14	1.87	0.004934	0.0452	1.49	3.03	0.39	0.57	Lower
○	16	1.74	0.004978	0.0453	1.43	2.96	0.4	0.54	Lower
○	18	1.63	0.005067	0.0452	1.37	2.89	0.4	0.51	Lower
○	20	1.53	0.00515	0.0455	1.32	2.84	0.4	0.49	Lower
○	22	1.44	0.005258	0.0453	1.26	2.79	0.41	0.47	Lower
○	24	1.37	0.005367	0.0453	1.21	2.74	0.41	0.46	Lower
○	26	1.3	0.005492	0.0451	1.16	2.7	0.42	0.44	Lower
○	28	1.23	0.005595	0.0453	1.12	2.66	0.42	0.43	Lower
○	30	1.18	0.00572	0.0452	1.08	2.62	0.43	0.42	Lower
○	32	1.13	0.005814	0.0455	1.05	2.6	0.43	0.41	Lower
○	34	1.08	0.005969	0.0448	1.00	2.56	0.43	0.4	Lower
○	36	1.04	0.006178	0.0458	0.98	2.53	0.44	0.4	Lower
○	38	1.01	0.006709	0.0478	0.95	2.47	0.43	0.42	Lower
○	40	0.98	0.007313	0.0500	0.93	2.42	0.43	0.45	Lower
	*******	Minimum	Stream	Power	*******				
○	12.31	1.98	0.004897	0.04481	1.53	3.1	0.39	0.61	Lower

Red text indicates that the computed slope is greater than the user-entered valley slope, indicating a potential sediment trap.

* indicates transitional regime. The default regime was used for the computations.

Minimum Stream Power – Optimal for design

Stable Channel Design Tool in HEC-RAS
Copeland Method

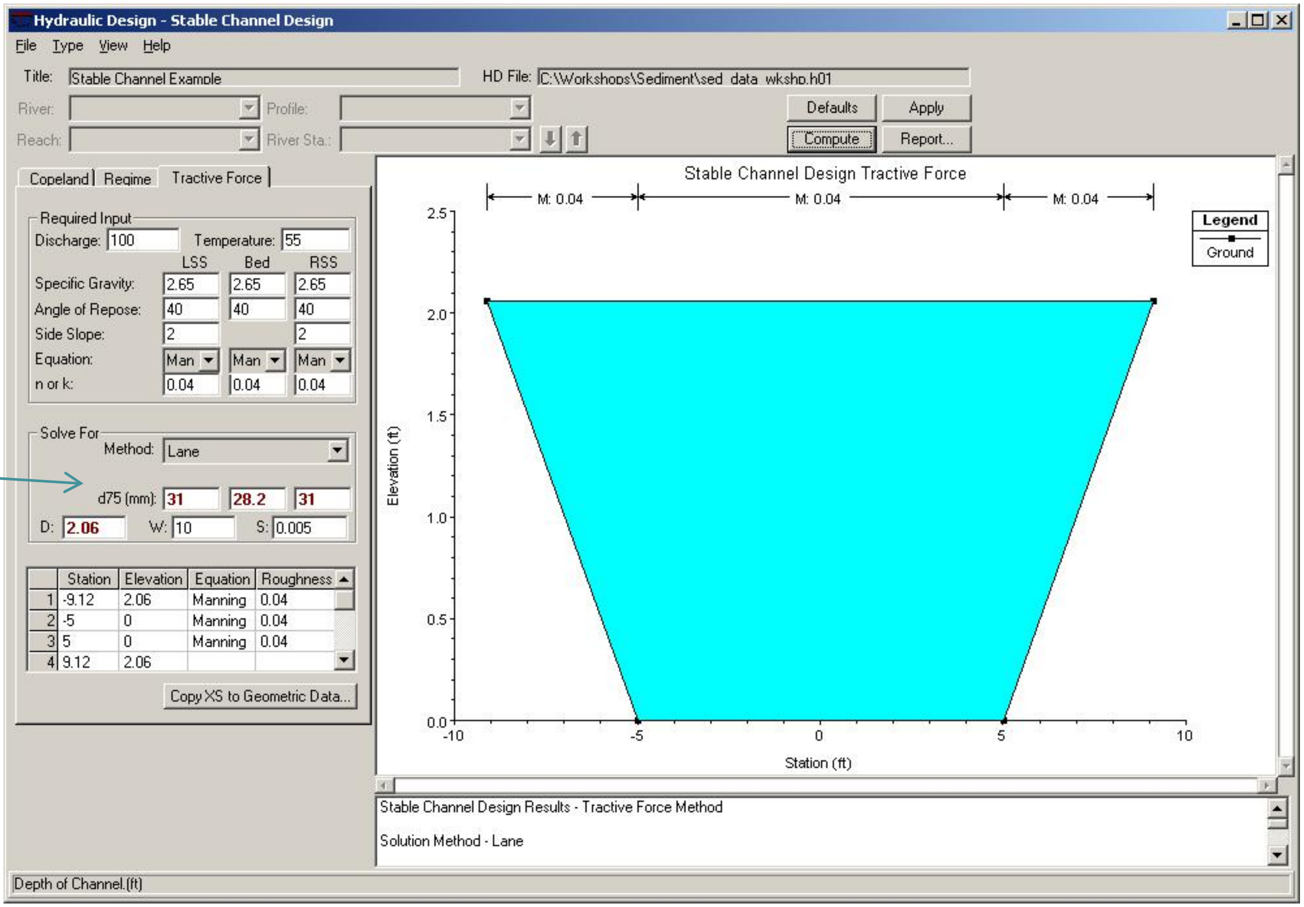


Minimum Stream Power – Optimal for design

Stable Channel Design Tool in HEC-RAS Tractive Force Method

- Input – Discharge, temperature, specific gravity, angle of repose, side slope, and Manning's n.
- Pick 2 of D75, depth, width, and slope to solve; RAS solves the other 2.

Can solve for D75 and any of the following parameters; slope, depth, or width.



Title: Stable Channel Example

HD File: C:\Workshops\Sediment\sed data wkshp.h01

River:

Profile:

Reach:

River Sta.:

Required Input

Discharge: 100

Temperature: 55

	LSS	Bed	RSS
Specific Gravity:	2.65	2.65	2.65
Angle of Repose:	40	40	40
Side Slope:	2		2
Equation:	Man	Man	Man
n or k:	0.04	0.04	0.04

Solve For

Method: Lane

d75 (mm): 31 28.2 31

D: 2.06 W: 10 S: 0.005

	Station	Elevation	Equation	Roughness
1	-9.12	2.06	Manning	0.04
2	-5	0	Manning	0.04
3	5	0	Manning	0.04
4	9.12	2.06		

Stable Channel Design Results - Tractive Force Method

Solution Method - Lane

Depth of Channel (ft)