River Restoration Toolbox Glossary of Equations and Computations

Iowa Department of Natural Resources

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1.0 Channel Geometry Calculations

1.1 Entrenchment Ratio (ER)

$$ER = \frac{W_{FPA}}{W_{BKF}}$$

where… W_{FPA} = Floodprone Width

W_{BKF} = Bankfull Width

1.2 Bank Height Ratio (BHR)

$$BHR = \frac{LBH}{d_{max}}$$

where… LBH = Low Bank Height

d_{max} = Maximum bankfull depth measured at same location as LBH

1.3 Mean Depth (d_{bkf})

$$d_{bkf} = \frac{A_{BKF}}{W_{BKF}}$$

where… A_{BKF} = Bankfull Cross-Sectional Area

1.4 Width to Depth Ratio (W/D)

$$W/D = \frac{W_{BKF}}{d_{BKF}}$$

1.5 Bankfull Cross Sectional Area (A_{BKF})

$$A_{BKF} = W_{BKF} * d_{BKF}$$

1.6 Channel Sinuosity (k)

$$k = \frac{SL}{VL}$$

where… SL = Stream Length

VL = Valley Length

1.7 Meander Width Ratio (MWR)

$$MWR = \frac{W_{BLT}}{W_{BKF}}$$

where… W_{BLT} = Stream Belt Width

1.8 Regional Curve for Cross Sectional Area (Western Minnesota)

$$A_{BKF} = 4.7456x^{0.6102}$$

where… x = Drainage Area (sq mi)

1.9 Regional Curve for Cross-Sectional Area (Eastern Minnesota)

$$A_{BKF} = 5.3096x^{0.7054}$$

2.0 Hydraulic Calculations

2.1 Continuity Equation, Discharge (Q)

$$Q = VA$$

where… V = Average velocity (ft/s)

A = Cross-sectional area (sq ft)

2.2 Velocity, Manning's (v)

$$V = \frac{1.49R^{\frac{2}{3}}S^{\frac{1}{2}}}{n}$$

where… R = Hydraulic radius (ft)

n = Manning's n

S = Water surface slope (ft/ft)

2.3 Velocity, Darcy-Weisbach (v)

$$V = \sqrt{\frac{8gRS}{f}}$$

where… g = Acceleration due to gravity

f = Darcy-Weisbach friction factor

2.4 Velocity, Chezy (v)

$$V = c\sqrt{RS}$$

where… c = Chezy coefficient

2.5 Velocity, Relative Roughness (v)

$$V = \left[2.83 + 5.66\log\left(\frac{R}{D_{84}}\right)\right]u^*$$

where… D_{84} = Diameter of of the 84th percentile of riffle bed material

u^* = Shear velocity $(gRS)^{\frac{1}{2}}$

2.6 Weir Flow (Q)

$$Q = CLH^{\frac{3}{2}}$$

where… C = Weir discharge coefficient

L = Weir length (ft)

H = Approach head (ft)

Q = Weir flow (cfs)

2.7 Shear Stress (τ)

$$\tau = \gamma RS$$

where… τ = Shear stress (lb/sq ft)

γ = Unit weight of water

R = Hydraulic radius (ft)

S = Slope (ft/ft)

2.8 Stream Power (Ω)

$$\Omega = \gamma QS$$

where… Ω = Stream power (lb/s)

S = Water surface slope (ft/ft)

Q = Discharge (cfs)

2.9 Unit Stream Power (ω)

$$\omega = \left(\frac{\Omega}{w}\right)$$

where… ω = Unit stream power (lb/ft/s)

w = Stream width (ft)

3.0 Moveable Particle Calculations

3.1 Critical Dimensionless Shear Stress, Andrews, Sub-Surface (τ_c^*)

$$\tau_c^* = 0.0834 * \left(\frac{D_{50}}{D_{50}^n}\right)^{-0.872}$$

where… τ_C = Critical dimensionless shear stress

D_{50} = Median size of particle of riffle armor bed surface (mm)

D_{50}^n = Median size of sub-surface particle (mm)

Note: This equation applies when $\frac{D_{50}}{D_{50}^n}$ is between 3 and 7

3.2 Critical Dimensionless Shear Stress, Andrews, Bed Surface (τ_c^*)

$$\tau_c^* = 0.0384 * \left(\frac{D_{max}}{D_{50}}\right)^{-0.887}$$

where… D_{max} = Largest particle of material representative of subsurface (mm)

D_{50} = Median size particle of the bed surface (mm)

Note: This equation applies when $\frac{D_{max}}{D_{50}}$ is between 1.3 and 3

3.3 Required Depth to Entrain Largest Particle (Competency)

$$d = \frac{\tau_c^* \gamma_s D_{max}}{S}$$

where… d = Depth required to entrain largest particle (ft)

D_{max} = Largest particle of material representative of subsurface (mm)

τ_c^* = Critical dimensionless shear stress

γ_s = Submerged specific weight of sediment

S = Slope (ft/ft)

3.4 Required Slope to Entrain Largest Particle (Competency)

$$S = \frac{\tau_c^* \gamma_s D_{max}}{d}$$

3.5 Lanes's Tractive Force (Shear stress)

$$\tau_c = dS = D$$

where… τ_c = Shear stress (kg/sq m)

d = Mean depth (mm)

S = Water surface slope

D = Incipient particle diameter (cm)

4.0 Scour Calculations

Refer to NRCS Technical Supplement 14B – Scour Calculations (Aug 2007) for more information

4.1 Total Scour Depth (z_t)

$$z_t = FS[Z_{ad} + Z_b + Z_b + Z_{bf} + Z_s]$$

where…

z_t	=	Total scour depth
FS	=	Factor of safety
Z_{ad}	=	Bed elevation changes due to reach-scale deposition (aggradation) or bed erosion (degradation)
Z_c	=	Concentration scour
Z_b	=	Scour on outside of bend
Z_{bf}	=	Bedform trough depth
Z_s	=	Local scour depth associated with a structure

Refer to NRCS Technical Supplement 14B for guidance on how to compute each component of scour.

5.0 Permissible Shear and Velocity for Selected Lining Materials

Refer to Stability Thresholds for Stream Restoration Materials by Craig Fischenich (May 2001) for more information. Table 2 within this document is provided below.

Boundary Category	Boundary Type	Permissible Shear Stress (lb/sq ft)	Permissible Velocity (ft/sec)	Citation(s)
Soils	Fine colloidal sand	0.02 - 0.03	1.5	A
	Sandy loam (noncolloidal)	0.03 - 0.04	1.75	A
	Alluvial silt (noncolloidal)	0.045 - 0.05	2	A
	Silty loam (noncolloidal)	0.045 - 0.05	1.75 – 2.25	A
	Firm loam	0.075	2.5	A
	Fine gravels	0.075	2.5	A
	Stiff clay	0.26	3 – 4.5	A, F
	Alluvial silt (colloidal)	0.26	3.75	A
	Graded loam to cobbles	0.38	3.75	A
	Graded silts to cobbles	0.43	4	A
	Shales and hardpan	0.67	6	A
Gravel/Cobble	1-in.	0.33	2.5 – 5	A
	2-in.	0.67	3 – 6	A
	6-in.	2.0	4 – 7.5	A
	12-in.	4.0	5.5 – 12	A
Vegetation	Class A turf	3.7	6 – 8	E, N
	Class B turf	2.1	4 - 7	E, N
	Class C turf	1.0	3.5	E, N
	Long native grasses	1.2 – 1.7	4 – 6	G, H, L, N
	Short native and bunch grass	0.7 - 0.95	3 – 4	G, H, L, N
	Reed plantings	0.1-0.6	N/A	E, N
	Hardwood tree plantings	0.41-2.5	N/A	E, N
Temporary Degradable RECPs	Jute net	0.45	1 – 2.5	E, H, M
	Straw with net	1.5 – 1.65	1 – 3	E, H, M
	Coconut fiber with net	2.25	3 – 4	E, M
	Fiberglass roving	2.00	2.5 – 7	E, H, M
Non-Degradable RECPs	Unvegetated	3.00	5 – 7	E, G, M
	Partially established	4.0-6.0	7.5 – 15	E, G, M
	Fully vegetated	8.00	8 – 21	F, L, M
Riprap	6 – in. d_{50}	2.5	5 – 10	H
	9 – in. d_{50}	3.8	7 – 11	H
	12 – in. d_{50}	5.1	10 – 13	H
	18 – in. d_{50}	7.6	12 – 16	H
	24 – in. d_{50}	10.1	14 – 18	E
Soil Bioengineering	Wattles	0.2 – 1.0	3	C, I, J, N
	Reed fascine	0.6-1.25	5	E
	Coir roll	3 - 5	8	E, M, N
	Vegetated coir mat	4 - 8	9.5	E, M, N
	Live brush mattress (initial)	0.4 – 4.1	4	B, E, I
	Live brush mattress (grown)	3.90-8.2	12	B, C, E, I, N
	Brush layering (initial/grown)	0.4 – 6.25	12	E, I, N
	Live fascine	1.25-3.10	6 – 8	C, E, I, J
	Live willow stakes	2.10-3.10	3 – 10	E, N, O
Hard Surfacing	Gabions	10	14 – 19	D
	Concrete	12.5	>18	H

6.0 Rock Sizing Equations

Refer to US Army Corps of Engineers Engineering Manual EM 1110-2-1601 (July 1991) and revised (June 1994) for more information on rock sizing.

6.1 Rock Sizing, D_{30}

$$D_{30} = \frac{1.95(S^{0.55})(q^{0.667})}{g^{0.333}}$$

where… D_{30} = Size fraction of which 30% of particles are finer

S = Slope (ft/ft)

q = Unit discharge (Q/bottom width) (cfs/ft)

g = Gravitational constant

6.2 Rock Sizing, D_{50}

$$D_{50} = D_{30} * 1.22$$

where… D_{50} = Size fraction of which 50% of particles are finer

6.3 Minimum Rock Thickness (R_T)

$$R_T = D_{100} * 1.5$$

where… D_{100} = Largest size fraction of rock present in gradation

7.0 Buoyancy Calculation

7.1 Buoyancy (F_b)

$$F_b = \rho g V$$

where… g = Gravitational constant

ρ = Density of the liquid (lb/cu ft)

V = Volume of liquid displaced (cu ft)

7.2 Buoyancy (F_b)

$$F_b = \rho g h A$$

where… h = Height of water displaced by a floating object (ft)

A = Surface area of floating object (sq ft)