APPENDIX E

Sediment Transport Functions – Sample Calculations

The following sample calculations were the basis for the algorithms used in the HEC-RAS sediment transport functions. They were computed for a single grain size, however they were adapted in the code to account for multiple grain sizes.

Ackers-White Sediment Transport Function

by Ackers-White (ASCE Jour. Of Hyd, Nov 1973)

Input Parameters

Temperature, F	T = 55	Average Velocity, ft/s	V = 2
Kinetic viscosity, ft^2/s	$\nu = 0.00001315$	Discharge, ft^3/s	Q = 5000
Depth, ft	D = 10	Unit Weight water, lb/ft^3	$\gamma_w = 62.385$
Slope	S = 0.001	Overall d50, ft	$d_{50} = 0.00232$
Median Particle Diamter, ft	$d_{si} = 0.00232$		
Specific Gravity of Sediment,	s = 2.65		

Constants

Acceleration of gravity, ft/s^2 g = 32.2

Solution

*note: Ackers-White required the use of d_{35} as the representative grain size for computations in their original paper. In the HEC-RAS approach, the median grain size will be used as per the 1993 update. The overall d_{50} is used for the hiding factor computations.

Hiding Factor from Profitt and Sutherland has been added for this procedure, but will be included as an option in HEC-RAS.

Computations are updated as per Acker's correction in Institution of Civil Engineers Water Maritime and Energy, Dec 1993.

Dimensionless grain diameter,

$$d_{gr} = d_{si} \cdot \left[\frac{g \cdot (s-1)}{\nu^2} \right]^{\frac{1}{3}} \qquad d_{gr} = 15.655$$

Shear velocity u,

$$u_{star} = \sqrt{g \cdot D \cdot S} \qquad u_{star} = 0.567$$

Sediment size-related transition exponent n,

$$n = \begin{cases} 1 & \text{if } d_{gr} \le 1 \\ \left(1 - .056 \cdot \log\left(d_{gr}\right)\right) & \text{if } 1 < d_{gr} \le 60 \\ 0 & \text{if } d_{gr} > 60 \end{cases} \qquad n = 0.331$$

Initial motion parameter A,

$$A = \begin{cases} \left(\frac{0.23}{\sqrt{d_{gr}}} + 0.14\right) & \text{if } d_{gr} \le 60 \\ 0.17 & \text{otherwise} \end{cases} \qquad A = 0.198$$

Sediment mobility number F_{gr},

$$\alpha = 10 \quad \text{(assumed value used in HEC6 and SAM)} \qquad \alpha = 10$$

$$F_{gr} = \frac{u_{star}{}^{n}}{\sqrt{g \cdot d_{si} \cdot (s-1)}} \cdot \left(\frac{V}{\sqrt{32} \cdot \log\left(\alpha \cdot \frac{D}{d_{si}}\right)}\right)^{1-n} \qquad F_{gr} = 0.422$$

Hiding Factor HF,

Shield's Mobility Parameter θ,

$$\theta = \frac{u_{star}{}^{2}}{g \cdot (s-1) d_{50}} \qquad \theta = 2.612$$

$$dRatio = \begin{cases} 1.1 & \text{if } \theta \le 0.04 \\ (2.3 - 30 \cdot \theta) & \text{if } 0.04 < \theta \le 0.045 \\ (1.4 - 10 \cdot \theta) & \text{if } 0.045 < \theta \le 0.095 \\ 0.45 & \text{otherwise} \end{cases} \qquad dRatio = 0.45$$

$$dAdjust = d_{50} \cdot dRatio \qquad dAdjust = 1.044 \times 10^{-3}$$

$$HFRatio = \frac{d_{si}}{dAdjust} \qquad HFRatio = 2.222$$

$$HF = \begin{vmatrix} 1.30 \quad \text{if HFRatio} \geq 3.7 \\ (0.53 \cdot \log(\text{HFRatio}) + 1) \quad \text{if } 0.075 \leq \text{HFRatio} < 3.7 \\ 0.40 \quad \text{otherwise} \end{vmatrix}$$

$HF = 1.184$

Adjust Sediment Mobility Number for Hiding Factor

$$\mathrm{F_{gr}} = \mathrm{HF} \cdot \mathrm{F_{gr}}$$

$F_{gr} = 0.5$

Check for too fine sediment based on F_{gr} and A,

$$\text{Check} = \frac{\mathrm{F_{gr}}}{\mathrm{A}}$$

Check = 2.522

Sediment transport function exponent m,

$$\mathrm{m} = \begin{vmatrix} \left(\frac{6.83}{\mathrm{d_{gr}}} + 1.67\right) \quad \text{if } \mathrm{d_{gr}} \leq 60 \\ 1.78 \quad \text{otherwise} \end{vmatrix}$$

m = 2.106

Check for too fine sediment based on m,

$$Check = \begin{vmatrix} 0 \quad \text{if m} > 6 \\ Check \quad \text{otherwise} \end{vmatrix}$$

Check = 2.522

Sediment transport function coefficient C,

$$\mathrm{C} = \begin{vmatrix} 10^{2.79 \cdot \log(\mathrm{d_{gr}}) - 0.98 (\log(\mathrm{d_{gr}}))^2 - 3.46} \quad \text{if } \mathrm{d_{gr}} \leq 60 \\ 0.025 \quad \text{otherwise} \end{vmatrix}$$

$C = 0.0298$

Transport parameter G_{gr},

$$G_{gr} = C \cdot \left(\frac{F_{gr}}{A} - 1\right)^m$$

$G_{gr} = 0.072$

Sediment flux X, in parts per million by fluid weight,

$$X = \frac{G_{gr} s d_{si}}{D\left(\frac{u_{star}}{V}\right)^n}$$

$X = 6.741 \times 10^{-5}$

Sediment Discharge, lb/s

$$G = \gamma_w Q X$$

$G = 21.027$

Sediment Discharge, tons/day

$$G_s = \frac{86400}{2000} \cdot G \qquad G_s = 908$$

Check to make sure particle diameter and mobility functions are not too low,

$$G_s = \begin{vmatrix} G_s & \text{if Check } > 1 \\ 0 & \text{otherwise} \end{vmatrix} \qquad G_s = 908$$

Engelund Hansen Sediment Transport Function

by Vanoni (1975), and Raudkivi (1976)

Input Parameters

Temperature, F	T = 55	Average Velocity, ft/s	V = 5.46
Kinematic viscosity, ft^2/s	ν = 0.00001315		
Depth, ft	D = 22.9	Unit Weight water, lb/ft^3	γ_w = 62.385
Slope	S = 0.0001		
Median Particle Diamter, ft	d_{si} = 0.00232	Channel Width, ft	B = 40
Specific Gravity of Sediment,	s = 2.65		

Constants

Acceleration of gravity, ft/s^2 $g = 32.2$

Solution

Bed level shear stress τ_o,

$$\tau_\circ = \gamma_w \cdot D \cdot S \qquad \tau_\circ = 0.143$$

Fall diameter d_f,

$$d_f = \begin{cases} \left(-69.07 \cdot d_{si}^{\,2} + 1.0755 \cdot d_{si} + 0.000007\right) & \text{if } d_{si} \le 0.00591 \\ \left(0.1086 \cdot d_{si}^{\,0.6462}\right) & \text{otherwise} \end{cases} \qquad d_f = 2.13 \times 10^{-3}$$

Sediment discharge lb/s,

$$g_s = 0.05 \cdot \gamma_w \cdot s \cdot V^2 \cdot \sqrt{\frac{d_f}{g \cdot (s-1)}} \cdot \left[\frac{\tau_\circ}{(\gamma_w \cdot s - \gamma_w) \cdot d_f}\right]^{\frac{3}{2}} \cdot B \qquad g_s = 32.82$$

Sediment discharge ton/day,

$$G_s = g_s \cdot \frac{86400}{2000} \qquad G_s = 1418$$

Laursen-Copeland Sediment Transport Function

by Copeland (from SAM code, 1996)

Input Parameters

Temperature, F	T = 55	Average Velocity, ft/s	V = 5.46
Kinematic viscosity, ft^2/s	$\nu = 0.00001315$	Discharge, ft^3/s	Q = 5000
Depth, ft	D = 22.90	Unit Weight water, lb/ft^3	$\gamma_w = 62.385$
Slope	S = 0.0001	84% Particle diameter, ft	$d_{84} = 0.00294$
Median Particle Diamter, ft	$d_{si} = 0.00232$		
Specific Gravity of Sediment	s = 2.65		

Constants

Acceleration of gravity, ft/s^2 $g = 32.2$

Solution

*Note: the difference between the final result presented here and the result in SAM is due to the method for determining fall velocity. Rubey is used here, whereas SAM computes a value based on a drag coefficient determined from Reynolds number. Calculation routine taken from SAM.

Because the grain distribution is reduced to standard grade sizes representing each present grade class, the d_{84} will equal the standard grade size, d_{si}, in this procedure.

$$d_{84} = d_{si}$$

Grain-related hydraulic radius R

$$R' = \frac{0.0472 \cdot V^{\frac{3}{2}} \cdot (3.5 \cdot d_{84})^{\frac{1}{4}}}{(g \cdot S)^{\frac{3}{4}}} \qquad R' = 14.189$$

R' = 15.248

$$u'_* = \sqrt{g \cdot R' \cdot S} \qquad u'_* = 0.222$$

$$FNRP = \left(\frac{V}{u'_*}\right) - 3.28 - 5.75 \cdot \log\left(\frac{R'}{d_{84}}\right)$$

$$FNRP = 5.195 \times 10^{-4}$$

$$DFNRP = \frac{V + 5 \cdot u_*^{'}}{2.0 \cdot u_*^{'} \cdot R'} \qquad DFNRP = 0.972$$

$$\mathrm{RPRI2} = \mathrm{R'} + \frac{\mathrm{FNRP}}{\mathrm{DFNRP}} \qquad RPRI2 = 15.249$$

$$\Delta \mathrm{R} = \left|\mathrm{RPRI2} - \mathrm{R'}\right| \qquad \Delta R = 5.345 \times 10^{-4}$$

$$\mathrm{R'} = \begin{vmatrix} \mathrm{R'} & \text{if } \Delta \mathrm{R} \le 0.001 \\ \mathrm{RPRI2} & \text{otherwise} \end{vmatrix}$$

$$R' = 15.248$$

Grain-related bed shear stress τ'_{b} ,

$$\tau'_b = R' \cdot \gamma_w \cdot S \qquad \tau'_b = 0.095$$

$$\tau_b = D \cdot \gamma_w \cdot S \qquad \tau_b = 0.143$$

$$\tau'_b = \begin{vmatrix} \tau'_b & \text{if } \tau'_{\mathrm{b}} < \tau_{\mathrm{b}} \\ \tau_{\mathrm{b}} & \text{otherwise} \end{vmatrix} \qquad \tau'_b = 0.095$$

$$u_*^{'} = \sqrt{\frac{\tau'_b \cdot g}{\gamma_w}} \qquad u_*^{'} = 0.222$$

$$\mathrm{RRP} = \left(\frac{\mathrm{d_{si}}}{\mathrm{R}}\right)^{1.16667} \qquad RRP = 2.187 \times 10^{-5}$$

Dimensionless bed shear stress τ_{b}^{*},

$$\tau_b^* = \frac{\tau'_b}{\gamma_w \cdot (s-1) \cdot d_{si}} \qquad \tau_b^* = 0.398$$

Shield's parameter for course grains θ^*,

$$\theta^* = 0.647 \cdot \tau_b^* + 0.0064$$

$$\theta^* = \begin{vmatrix} 0.02 & \text{if } \theta^* < 0.02 \\ \theta^* & \text{otherwise} \end{vmatrix} \qquad \theta^* = 0.264$$

Critical shear stress, τ_{cr}

$$\tau_{cr} = \begin{vmatrix} \left[\theta^* \cdot \gamma_w \cdot (s-1) \cdot d_{si}\right] & \text{if } \tau_b^* \le 0.05 \\ \left[0.039 \cdot \gamma_w \cdot (s-1) \cdot d_{si}\right] & \text{otherwise} \end{vmatrix} \qquad \tau_{cr} = 9.315 \times 10^{-3}$$

Shear stress mobility parameter TFP,

$$\text{TFP} = \frac{\tau'_b}{\tau_{cr}} - 1 \qquad \text{TFP} = 9.214$$

Fall velocity ω,

Use Rubey's equation, Vanoni p. 169

$$F_1 = \sqrt{\frac{2}{3} + \frac{36 \cdot \nu^2}{g \cdot d_{si}^3 \cdot (s-1)}} - \sqrt{\frac{36 \cdot \nu^2}{g \cdot d_{si}^3 \cdot (s-1)}} \qquad F_1 = 0.725$$

$$\omega = F_1 \cdot \sqrt{(s-1) \cdot g \cdot d_{si}} \qquad \omega = 0.255$$

Particle velocity ratio SF,

$$SF = \frac{u'_*}{\omega} \qquad SF = 0.870$$

Particle velocity ratio parameter Ψ,

$$\Psi = \begin{vmatrix} \left[7.04 \cdot 10^{15} \cdot (SF)^{22.99}\right] & \text{if SF} \le 0.225 \\ (40.0 \cdot SF) & \text{if } 0.225 < \text{SF} \le 1.0 \\ \left(40 \cdot SF^{1.843}\right) & \text{if SF} > 1.0 \end{vmatrix} \qquad \Psi = 34.804$$

Sediment transport G_s, tons/day

$$G_s = 0.432 \cdot \gamma_w \cdot Q \cdot \text{RRP} \cdot \text{TFP} \cdot \Psi \qquad G_s = 945$$

Meyer-Peter Muller Sediment Transport Function

by Vanoni (1975), and Schlichting's Boundary Layer Theory, 1968

Input Parameters

Temperature, F	T = 55	Average Velocity, ft/s	V = 5.46
Kinematic viscosity, ft^2/s	$\nu = 0.00001315$	Discharge, ft^3/s	Q = 5000
Depth, ft	D = 22.9	Unit Weight water, lb/ft^3	$\gamma_w = 62.385$
Slope	S = 0.0001	Overall d50, ft	$d_{90} = 0.00306$
Median Particle Diamter, ft	$d_{si} = 0.00232$	Channel Width, ft	B = 40
Specific Gravity of Sediment,	s = 2.65		

Constants

Acceleration of gravity, ft/s^2 $\quad g = 32.2$

Solution

Shear velocity u,

$$u_* = \sqrt{g \cdot D \cdot S} \qquad u_* = 0.272$$

Shear Reynold's number, R_s,

$$R_s = \frac{u_* \cdot d_{90}}{\nu} \qquad R_s = 63.189$$

Schlichting's B coefficient, Bcoeff

$$BCoeff = \begin{vmatrix} (5.5 + 2.5 \cdot \ln(R_s)) \quad \text{if } R_s \le 5 \\ \begin{bmatrix} 0.297918 + 24.8666 \cdot \log(R_s) - 22.9885 \cdot (\log(R_s))^2 \ldots \\ + 8.5199 \cdot (\log(R_s))^3 - 1.10752 \cdot (\log(R_s))^4 \end{bmatrix} \quad \text{if } 5 < R_s \le 70 \\ 8.5 \quad \text{otherwise} \end{vmatrix}$$

Friction factor due to sand grains f',

$$f' = \left(\frac{2.82843}{BCoeff - 3.75 + 2.5 \cdot \ln\left(2 \cdot \frac{D}{d_{90}}\right)} \right)^2$$

$f' = 9.565 \text{ X } 10^{-3}$

Nikaradse roughness ratio RKR,

$$RKR = \sqrt{\frac{f'}{8}} \cdot \frac{V}{\sqrt{g \cdot D \cdot S}}$$

$RKR = 0.695$

Sediment discharge lb/s,

$$g_s = \left[\frac{(RKR)^{\frac{3}{2}} \cdot \gamma_w \cdot D \cdot S - 0.047 \cdot (\gamma_w \cdot s - \gamma_w) \cdot d_{si}}{0.25 \cdot \left(\frac{\gamma_w}{g}\right)^{\frac{1}{3}} \cdot \left(\frac{\gamma_w \cdot s - \gamma_w}{\gamma_w \cdot s}\right)^{\frac{2}{3}}} \right]^{\frac{3}{2}} \cdot B$$

$g_s = 7.073$

Sediment discharge ton/day,

$$G_s = g_s \cdot \frac{86400}{2000}$$

$G_s = 306$

Toffaleti Sediment Transport Function

by Vanoni, for single grain size

Input Parameters

Slope,	$S = 0.0001$	Temperature, F	$T = 55$
Hydraulic Radius, ft	$R = 10.68$	viscosity, ft^2/s	$\nu = 0.00001315$
Width, ft	$B = 40$	Median Particle Size, ft	$d_{si} = 0.00232$
Velocity, ft/s	$V = 5.46$	65% finer Particle Size, ft	$d_{65} = 0.00257$
		Fraction of Total Sediment	$p_i = 1$
		Unit Weight of Water, lb/ft^3	$\gamma_w = 62.385$

Constants

Acceleration of gravity, ft/s^2 $g = 32.2$

Solution

Nikaradse Roughness Value, using d_{65}, as per Einstein, 1950, p.

$$k_s = d_{65} \qquad k_s = 2.57 \times 10^{-3}$$

Grain-related shear velocity as per Einstein, 1950, p. 10

Guess $u'_{*try} = 0.199$ Assume hydraulically rough grain first.

$$r' = \frac{u'^{2}_{*try}}{g \cdot S}$$

r' = 12.298

$$u'_* = \frac{V}{\left(5.75 \cdot \log\left(12.27 \cdot \frac{r'}{k_s}\right)\right)}$$

Check $u'_* = 0.199$

Check for hydraulically rough or smooth grains…

Guess $u'_{*try} = 0.169$

$$r' = \frac{{u'_{*try}}^2}{g \cdot S} \qquad\qquad r' = 8.87$$

$$\delta' = \frac{11.6 \cdot \nu}{u'_{*try}} \qquad\qquad \delta' = 9.026 \times 10^{-4}$$

Check = $\frac{k_s}{\delta'}$ Check = 2.847 $\frac{k_s}{\delta'} = 2.847$

$$u'_* = \begin{cases} \dfrac{V}{\left(5.75 \cdot \log\left(3.67 \cdot \dfrac{r' \cdot u'_{*try}}{\nu}\right)\right)} & \text{if Check} < 5 \quad \text{Smooth} \\ u'_* \quad \text{otherwise} & \text{Rough} \end{cases}$$

Check u'_* =0.169

Check for Transitional regime

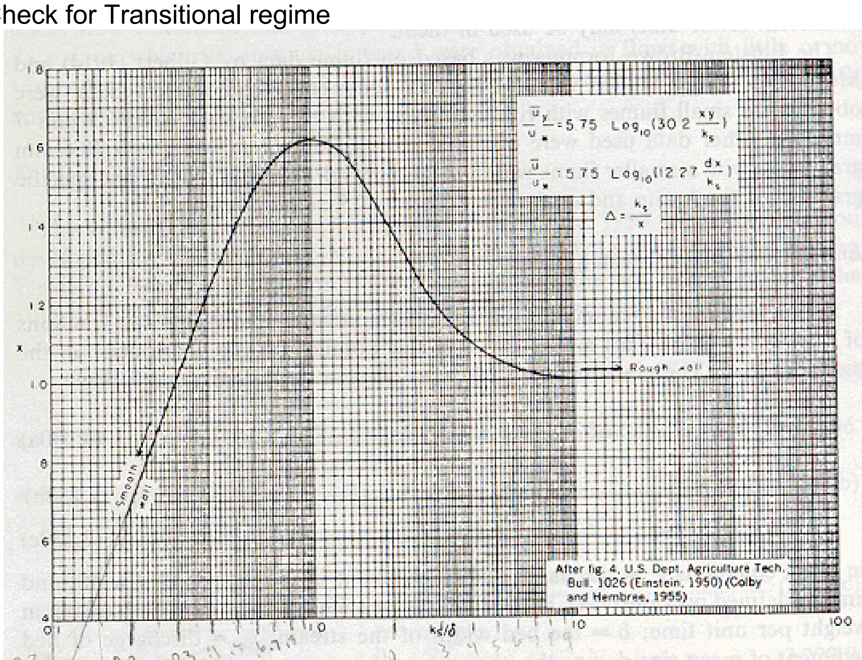

FIG. 2.97.—Factor *x* in Velocity Distribution Equation

$\Phi = \frac{k_s}{\delta'}$ $\Phi = 2.847$ $\Phi = 3.416$

x = 1.14 from figure 2.97, Vanoni, page 196

$$u'_* = \begin{cases} \dfrac{V}{5.75 \cdot \log\left(12.27 \cdot \dfrac{r' \cdot x}{k_s}\right)} & \text{if } 0.1 < \Phi < 10 \\ u'_* & \text{otherwise} \end{cases}$$

$\delta' = \frac{11.6 \cdot v}{u'_*}$ $\Phi = \frac{k_s}{\delta'}$ $\Phi = 3.416$

$u'_* = 0.203$

****Note: Einstein's method for determining u'^* was compared with Toffaleti's graphical approach. Results showed that the two methods are in acceptable agreement, with differences on the order of less than 3%. Einstein's approach was selected for its established reputation and its relative simplicity.

Toffaleti coefficients, A and k_4,

$$A_{factor} = \frac{\left(10^5 \cdot \nu\right)^{\frac{1}{3}}}{10 \cdot u'_*}$$ $A_{factor} = 0.54$

$$A = \begin{cases} \left(9.5987 \cdot A_{factor}^{-1.5445}\right) & \text{if } A_{factor} \le 0.5 \\ \left(39.079 \cdot A_{factor}^{0.481}\right) & \text{if } 0.5 < A_{factor} \le 0.66 \\ \left(221.85 \cdot A_{factor}^{4.660}\right) & \text{if } 0.66 < A_{factor} \le 0.72 \\ 48 & \text{if } 0.72 < A_{factor} \le 1.3 \\ \left(22.594 \cdot A_{factor}^{2.872}\right) & \text{if } A_{factor} > 1.3 \end{cases}$$ A = 29.065

$$k_{4Factor} = \frac{\left(10^5 \cdot \nu\right)^{\frac{1}{3}}}{10 \cdot u'_*} \cdot 10^5 \cdot S \cdot d_{65}$$ $K_{4Factor} = 0.014$

$$k_4 = \begin{vmatrix} (1.0) \quad \text{if } k_{4Facotr} \le 0.25 \\ \left(5.315 \cdot k_{4Factor}^{\ 1.205}\right) \quad \text{if } 0.25 \langle k_{4Factor} \le 0.35 \\ \left(0.510 \cdot k_{4Factor}^{\ -1.028}\right) \quad \text{if } k_{4Factor} \rangle 0.35 \end{vmatrix}$$ $k_4 = 1$

$$Ak_4 = A \cdot k_4$$

Check for too low values for the product Ak_4,

$$Ak_4 = \begin{vmatrix} 16 \quad \text{if } Ak_4 \langle 16 \\ Ak_4 \quad \text{if } Ak_4 \ge 16 \end{vmatrix}$$ $Ak_4 = 29.065$

More Coefficients,

$$T_T = 1.10 \cdot (0.051 + 0.00009 \cdot T)$$ $T_T = 0.062$

$$n_V = 0.1198 + 0.00048 \cdot T$$ $n_V = 0.146$

$$c_z = 260.67 - 0.667 \cdot T$$ $c_Z = 223.985$

Fall Velocity for Medium Sand from Toffaleti Tables at 55 degrees F,

$$w_i = 0.340$$

$$z_i = \frac{w_i \cdot V}{c_z \cdot R \cdot S}$$ $z_i = 7.76$

$$z_i = \begin{vmatrix} (1.5 \cdot n_V) \quad \text{if } z_i < n_V \\ z_i \quad \text{otherwise} \end{vmatrix}$$ $z_i = 7.76$

Empirical Relationship for g_{ssLi},

$$g_{ssLi} = \frac{0.600 \cdot p_i}{\left(\frac{T_T \cdot Ak_4}{V^2}\right)^{\frac{5}{3}} \cdot \left(\frac{d_{si}}{0.00058}\right)^{\frac{5}{3}}}$$ $g_{ssLi} = 6.473$

$$M_i = \frac{g_{ssLi}}{\left[\frac{\left(\frac{R}{11.24}\right)^{1+n_V-0.756 \cdot z_i} - (2 \cdot d_{si})^{1+n_V-0.756 \cdot z_i}}{1 + n_V - 0.756 \cdot z_i}\right]}$$ $M_i = 2.948 \text{ X } 10^{-10}$

Concentration,

$$C_{Li} = \frac{M_i}{43.2 \cdot p_i \cdot (1+n_V) \cdot V \cdot R^{0.756 \cdot z_i - n_V}}$$

C_{Li} = 1.425 X 10^{-18}

Check for unrealistically high concentration and adjust M_i if necessary,

$$C_{2d} = C_{Li} \cdot \left(\frac{2 \cdot d_{si}}{R}\right)^{-0.756 \cdot z_i}$$

$C_{2d} = 75.536$

$$C_{Li} = \begin{cases} C_{Li} & \text{if } C_{2d} < 100 \\ \dfrac{100}{\left(\dfrac{2 \cdot d_{si}}{R}\right)^{-0.756 \cdot z_i}} & \text{if } C_{2d} \ge 100 \end{cases}$$

C_{Li} = 1.425 X 10^{-18}

$$M_i = C_{Li} \cdot \left[43.2 \cdot p_i \cdot (1+n_V) \cdot V \cdot R^{0.756 \cdot z_i - n_V}\right]$$

M_i = 2.948 X 10^{-10}

Bed Load Transport,

$$g_{sbi} = M_i \cdot (2 \cdot d_{si})^{(1+n_V - 0.756 z_i)}$$

$g_{sbi} = 30.555$

Lower Layer Transport,

$$g_{ssLi} = M_i \cdot \left[\frac{\left(\dfrac{R}{11.24}\right)^{(1+n_V-0.756 \cdot z_i)} - (2 \cdot d_{si})^{(1+n_V-0.756 \cdot z_i)}}{1 + n_V - 0.756 \cdot z_i}\right]$$

$g_{ssLi} = 6.473$

Middle Layer Transport,

$$g_{ssMi} = M_i \cdot \frac{\left(\dfrac{R}{11.24}\right)^{0.244 \cdot z_i} \cdot \left[\left(\dfrac{R}{2.5}\right)^{1+n_V-z_i} - \left(\dfrac{R}{11.24}\right)^{1+n_V-z_i}\right]}{1+n_V-z_i}$$

g_{ssMi} = 5.674 X 10^{-1}

Upper Layer Transport,

$$g_{ssUi} = M_i \cdot \frac{\left(\dfrac{R}{11.24}\right)^{0.244 \cdot z_i} \cdot \left(\dfrac{R}{2.5}\right)^{0.5 \cdot z_i} \cdot \left[R^{(1+n_V-1.5 \cdot z_i)} - \left(\dfrac{R}{2.5}\right)^{1+n_V-1.5 \cdot z_i}\right]}{1+n_V-1.5 \cdot z_i}$$

g_{ssUi} = 1.72 X 10^{-15}

Total Transport per Unit Width,

$$g_{si} = g_{sbi} + g_{ssLi} + g_{ssMi} + g_{ssUi} \qquad g_{si} = 37.027$$

Total Transport,

$$G = g_{si} \cdot B \qquad \text{G = 1481 tons/day}$$

Yang Sediment Transport Function

by Yang, from ASCE Journal of Hydraulics, Oct 1973, Dec 1984

Input Parameters

Temperature, F	T = 55	Average Velocity, ft/s	V = 5.46
Kinematic viscosity, ft^2/s	$\nu = 0.00001315$	Discharge, ft^3/s	Q = 5000
Hydraulic Radius, ft	R = 10.68	Unit Weight water, lb/ft^3	$\gamma_w = 62.385$
Slope,	S = 0.0001		
Meidan Particle Diamter, ft	$d_{si} = 0.00232$		
Specific Gravity of Sediment	s = 2.65		

Constants

Acceleration of gravity, ft/s^2 g = 32.2

Solution

Shear Velocity, ft/s,

$$u_* = \sqrt{g \cdot R \cdot S}$$ $u_* = 0.185$

Particle Fall Velocity, ft/s,

Use Rubey's equation, Vanoni p. 169

$$F_1 = \sqrt{\frac{2}{3} + \frac{36 \cdot \nu^2}{g \cdot d_{si}^3 \cdot (s-1)}} - \sqrt{\frac{36 \cdot \nu^2}{g \cdot d_{si}^3 \cdot (s-1)}}$$ $F_1 = 0.725$

$$\omega = F_1 \cdot \sqrt{(s-1) \cdot g \cdot d_{si}}$$ $\omega = 0.255$

Shear Reynold's Number,

$$R_s = \frac{u_* \cdot d_{si}}{\nu}$$ $R_s = 32.717$

Critical Velocity, ft/s,

$$V_{cr} = \begin{cases} \omega \cdot \left(\dfrac{2.5}{\log\left(\dfrac{u_* \cdot d_{si}}{\nu}\right) - 0.06} + 0.66 \right) & \text{if } 0 < R_s < 70 \\ (\omega \cdot 2.05) & \text{if } R_s \geq 70 \end{cases}$$ $V_{cr} = 0.606$

Log of Concentration,

$$\log C_t = \begin{cases} \left[5.435 - 0.286 \cdot \log\left(\frac{\omega \cdot d_{si}}{\nu}\right) - 0.457 \cdot \log\left(\frac{u_*}{\omega}\right) \ldots + \left(1.799 - 0.409 \cdot \log\left(\frac{\omega \cdot d_{si}}{\nu}\right) - 0.314 \cdot \log\left(\frac{u_*}{\omega}\right)\right) \cdot \log\left(\frac{V \cdot S}{\omega} - \frac{V_{cr} \cdot S}{\omega}\right) \right] & \text{if } d_{si} < 0.00656 \quad \text{Sand} \\ \left[\left(6.681 - 0.633 \cdot \log\left(\frac{\omega \cdot d_{si}}{\nu}\right) - 4.816 \cdot \log\left(\frac{u_*}{\omega}\right)\right) \ldots + \left(2.784 - 0.305 \cdot \log\left(\frac{\omega \cdot d_{si}}{\nu}\right) - 0.282 \cdot \log\left(\frac{u_*}{\omega}\right)\right) \cdot \log\left(\frac{V \cdot S}{\omega} - \frac{V_{cr} \cdot S}{\omega}\right) \right] & \text{if } d_{si} \geq 0.00656 \quad \text{Gravel} \end{cases}$$

$$\log C_t = 1.853$$

Concentration, ppm

$$C_t = 10^{\log C_t} \qquad C_t = 71.284$$

Sediment Discharge, lb/s

$$G = \frac{\gamma_w \cdot Q \cdot C_t}{1000000} \qquad G = 22.235$$

Sediment Discharge, tons/day

$$G_s = \frac{86400}{2000} \cdot G \qquad G_s = 961$$