SUMMARY AND USE OF SELECTED FLUVIAL SEDIMENT-DISCHARGE FORMULAS

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CONVERSION FACTORS

Inch-pound units used in this report may be converted to International system of units (SI) by using the following conversion factors:

Multiply inch-pound units	By	To obtain SI units
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
foot (ft)	0.3048	meter (m)
feet per second (ft/s)	0.3048	meters per second (m/s)
inch (in.)	25.40	millimeter (mm)
pound (lb)	0.4536	kilogram (kg)
pounds per second (lb/s)	0.4536	kilogram per second (kg/s)
pound per foot (lb/ft)	1.488	kilogram per meter (kg/m)
pound per square foot (lb/ft^2)	4.882	kilogram per square meter (kg/m^2)
pound per cubic foot (lb/ft^3)	16.017	kilogram per cubic meter (kg/m^3)
slugs per cubic foot	515.5	kilogram per cubic meter (kg/m^3)
square foot (ft^2)	0.0929	square meter (m^2)
square foot per second (ft^2/s)	0.0929	square meter per second (m^2/s)
ton per day (t/d)	0.9078	metric ton per day (t/d)

International system of units (SI) used in this report may be converted to inch-pound units by using the following conversion factors:

Multiply SI units	By	To obtain inch-pound units
liter per second (l/s)	0.03531	cubic foot per second (ft^3/s)
meter (m)	3.281	foot (ft)
millimeter (mm)	0.03937	inch (in.)
ton per cubic meter (t/m^3)	0.0312	ton per cubic foot (t/ft^3)
ton per second (t/s)	2205.0	pounds per second (lb/s)

To convert degree Celsius (°C) used in this report to degree Fahrenheit (°F), use the following equation:

$$^{\circ}F = 9/5(^{\circ}C) + 32.$$

SUMMARY AND USE OF SELECTED FLUVIAL SEDIMENT-DISCHARGE FORMULAS

H. H. Stevens, Jr. and C. T. Yang

ABSTRACT

Two versions of computer programs for inputting data and computing fluvial sediment discharge by five described bedload formulas and eight described bed-material formulas are presented. The FORTRAN 77 language versions are for use on the Prime computer, and the BASIC language versions are for use on microcomputers. A review of published formula-comparison studies indicate that the bedload formulas of Schoklitsch (1934) and Meyer-Peter and Müller (1948); and the bed-material formulas of Yang (1973) for sand and Ackers and White (1973), Engelund and Hansen (1967), and Yang (1984) for gravel are the most reliable. Suggested procedures are presented for formula selection when field data are available and when they are absent. Documentation and listings for both versions of the programs are included in the report.

INTRODUCTION

The selection of an appropriate discharge formula for fluvial sediment, hereafter called sediment, is very important in order to accurately predict sediment discharges in rivers and estuaries, particularly in areas where energy resources are being developed, or in waterways in which contaminents are associated with sediments. Numerous sediment-discharge formulas have been proposed in the literature, and extensive summaries compiled by Alonso (1980), American Society of Civil Engineers (1975), Bathurst (1985), Brownlie (1981), Schulits and Hill (1968), White, Milli, and Crabbe (1978), and Yang and Molinas (1982). This report describes 13 sediment discharge formulas, presents comparisons between measured and computed results from the formulas, and provides information to help select formulas for different flow and sediment conditions. Selection of the formulas was based on; 1) theoretical background, 2) extent of testing by original author and independent investigator(s), and 3) extent of use by engineers and researchers.

This report also describes two computer programs. Program DISDATA enables keyboard entry of discharge data and storage into a data file, and program SEDDISCH reads the data from the data file and computes the sediment discharge by all formulas selected by the user from the 13 described formulas. Both programs are written in FORTRAN 77 and MS-BASIC[1] for use on a variety of computers. An explanation of the text symbols and corresponding computer program variable names are presented in the section "text symbols and program variables". Program listings and examples of output from programs DISDATA and SEDDISCH are included at the back of the report in Supplemental Data Sections A through G.

DESCRIPTION OF FLUVIAL SEDIMENT-DISCHARGE FORMULAS

Fluvial sediment discharge rates depend on a large number of variables. Because of the wide variation in many of the influencing variables, most formulas have been developed based on one or two dominant variables such as water discharge, average flow velocity, water surface slope, shear stress, stream power, and unit stream power. Yang (1988) described the basic approaches used in the development of sediment transport formulas as deterministic, probabilistic, and regression.

Formulas derived from the deterministic approach assume there is an invariant correlation between dependent and independent variables. An advantage of this approach is that when values of the independent variables are given, sediment discharge rates or concentrations can be computed directly. A disadvantage of this approach is that if the assumed relation is inexact, does not exist, or exists only during certain conditions, computed results may be inaccurate. The general form of many early deterministic formulas is:

$$G_s = A\ (P - P_c)^B \qquad (1)$$

[1] Microsoft BASIC language developed by the Microsoft Corporation. The use of trade names in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

where G_s = the sediment discharge;

A = a parmeter related to flow and sediment characteristics;

P = the independent variable, such as water discharge, mean velocity, water slope, shear stress, stream power, or unit stream power;

c = a subscript to denote the "critical" value of P at incipient motion; and

B = an exponent related to flow and sediment characteristics.

One well-known formula of this type is the Schoklitsch (1934) formula (See page 5).

Another approach used to develop sediment-transport formulas has been to base rates on predictions of particle motion derived from probability considerations. Equations to define the beginning and ceasing of sediment motion, as well as the average rate of sediment discharge can be formulated. Einstein's (1950) bedload function is the most prominent formula based on the probabilistic approach.

The third approach, regression analyses, is used mainly to obtain empirical relations between sediment discharge rates and some flow and sediment parameters. An advantage of using the regression approach is that it can give quick site-specific relations provided reliable data are available for analysis. A disadvantage is that the technique does not provide much physical meaning or explanation of the sediment-discharge process. A formula obtained purely from regression analysis can be applied only to conditions which are similar to those used in obtaining the regression formula.

Investigators have relied extensively on dimensional analysis. The usual approach is to correlate sediment concentration or a dimensionless transport rate with a principal, and perhaps other, dimensionless parameters. Examples of principal dimensionless parameters are the mobility number of Ackers and White (1973) combining shear stress and grain shear stress, and the unit stream power of Yang (1973) which combines velocity and slope.

Thirteen sediment-discharge formulas are included in this report. They represent some of the more commonly used formulas developed from the deterministic and probabilistic approaches. Because they may be restrictive in their application, formulas developed entirely by regression analysis are not included. The formulas are divided into two groups; five bedload discharge formulas, and eight bed-material discharge formulas. A summary of the sediment-discharge formulas presented in this report are given in Table 1.

Table 1.--Summary of sediment-discharge formulas presented in this report

Author of formula	Date	Bedload (B) or bed-material (B-M)	Type of formula[1]	Sediment type[2]	Sediment size[3]
Ackers and White	1973	B-M	D	S	S,G
Colby	1964	B-M	D	S	S
Einstein (bedload)	1950	B	P	M	S,G
Einstein (bed-material)	1950	B-M	P	M	S
Engelund and Hansen	1967	B-M	D	S	S
Kalinske	1947	B	D	M	S
Laursen	1958	B-M	D	M	S
Meyer-Peter and Müller	1948	B	D	S	S,G
Rottner	1959	B	D	S	S
Schoklitsch	1934	B	D	M	S,G
Toffaleti	1968	B-M	D	M	S
Yang (sand)	1973	B-M	D	O	S
Yang (gravel)	1984	B-M	D	O	G

[1] Deterministic (D) or Probabilistic (P)
[2] Single size fraction (S), mixture (M) or optional (O)
[3] Sand (S) or gravel (G)

First, the equation(s), terminology, and units (metric or inch-pound) proposed by the original author(s) are presented for each formula, then the final equations are expressed in inch-pound units except sediment size is expressed in millimeters (mm). A value of 2.65 is used for the specific gravity of the sediment (S_g).

Bedload Discharge Formulas

Five bedload discharge formulas are presented in this section. Bedload discharge is the discharge of sediment that moves in essentially continuous contact with the bed.

Schoklitsch Formula

Schoklitsch (1934) developed a bedload formula based mainly on Gilbert's (1914) flume data with median sediment sizes ranging from 0.3 to 5 mm. The basis for this formula, (Schulits, 1935) is that bed material begins to move at some critical discharge and that the bedload discharge is proportional to the rate of work done by the part of the tractive force in excess of that needed to overcome the resistance along the wetted perimeter. If A is the cross-sectional area of flow, and A_o is the cross-sectional area of the flow that is just sufficient to move the bed material, with no change in width, the effective part of the tractive force in moving bed material is $\gamma S(A-A_o)$. Also if the velocity of the tractive force is proportional to the mean velocity of flow, V, then the rate of work done by the effective part of the tractive force is $C_1 V\gamma S(A-A_o)$ or $C_1\gamma S(Q-Q_o)$. Since the bed load G_s is proportional to the work rate, G_s is equal to $C_1\gamma S(Q-Q_o)$. The constant C_1 is a function of slope and particle size. The final formula for unigranular material is:

$$G_s = \frac{86.7}{\sqrt{D}} S^{3/2}(Q - W q_o) \qquad (2)$$

in which

$$q_o = \frac{0.00532D}{S^{4/3}} \qquad (3)$$

where G_s = the bedload discharge, in pounds per second (lb/s);
D = the mean grain diameter, in inches (in.);
S = the energy gradient, in feet (ft) per ft;
Q = the water dischargn cubic feet per second (ft^3/s);
W = the width, in ft; and
q_o = the critical discharge, in ft^3/s per ft of width.

The formula is applied to mixtures (Schulits, 1935) by summing the computed bedload discharges for all size fractions; the discharge for each size fraction is computed using the mean diameter and the fraction of the sediment in the size fraction. Converting the equation for use with mixtures and changing the grain diameter from in. to ft and the bedload discharge from lb/s to lb/s per ft of width gives:

$$g_s = \sum_{i=1}^{n} i_b \frac{25}{\sqrt{D_{si}}} S^{3/2}(q - q_o) \qquad (4)$$

in which

$$q_o = \frac{0.0638D_{si}}{S^{4/3}} \qquad (5)$$

where g_s = the bedload discharge, in lb/s per ft of width;

i_b = the fraction, by weight, of bed material in a given size fraction;

D_{si} = the mean grain diameter, in ft, of sediment in size fraction, i;

q = the water discharge, in ft^3/s per ft of width;

q_o = the critical discharge, in ft^3/s per ft of width, for sediment of diameter D_{si}; and

n = the number of size fractions in the bed-material mixture.

Kalinske Formula

The formula developed by Kalinske (1947) for computing bedload discharge of unigranular material is based on the continuity equation which states that the bedload discharge is equal to the product of the average velocity of the particles in motion, the weight of each particle, and the number of particles. The average particle velocity is related to the ratio of the critical shear (critical tractive force) to the total shear. The specific weight of a particle is a constant, and the number of particles in motion is related to the shear stress applied to the bed area. The formula can be applied to sand mixtures by summing the computed bedload discharge for all size fractions. For each fraction, the proportion of the bed subject to the shear is expressed as a function of the mean diameters and fractions, be weight, of all particles occupying the entire bed area subject to shear.

The formula is:

$$g_s = \sum_{i=1}^{n} V_* \gamma_s D_{si} P_i \, 7.3 \left(\frac{\bar{U}_g}{\bar{U}} \right) \tag{6}$$

in which

$$V_* = \frac{\sqrt{\tau_o}}{\rho} \tag{7}$$

$$\frac{\bar{U}_g}{\bar{U}} = f \left(\frac{\tau_{ci}}{\tau_o} \right) \tag{8}$$

$$\tau_{ci} = 12 \, D_{si} \tag{9}$$

$$P_i = \frac{0.35}{m} \left(\frac{i_b}{D_{si}} \right) \tag{10}$$

where g_s = the bedload discharge, in lb/s per ft of width;

n = the number of size fractions in the bed-material mixture;

V_* = the shear velocity, in feet per second (ft/s);

γ_s = the specific weight of the sediment in pounds per cubic foot (lb/ft^3);

D_{si} = the mean grain diameter, in ft, of sediment in size fraction, i;

p_i = the proportion of the bed area occupied by the particles in size fraction, i;

$\bar{U}_g$ = the average velocity, in ft/s, of particles in size fraction, i;

$\bar{U}$ = the mean velocity of flow, in ft/s, at the grain level;

τ_o = the total shear at the bed, in pounds per square foot (lb/ft^2), which equals 62.4dS;

d = the mean depth, in ft;

S = the energy gradient, in ft per ft;

ρ = the density of water, in slugs per ft^3;

f denotes function of;

τ_{ci} = the critical tractive force, in lb/ft^2;

m = the summation of values of i_b/D_{si} for all size fractions in the bed-material mixture; and

i_b = the fraction, by weight, of bed material in a given size fraction.

Using the values of 165.36 for γ_s and 1.94 for ρ, the formula is:

$$g_s = 25.28 \sqrt{\tau_o} \sum_{i=1}^{n} \tau_{ci} \frac{\frac{i_b}{D_{si}}}{m} \left[\frac{\bar{U}_g}{\bar{U}}\right] . \quad (11)$$

Values of $\bar{U}_g/\bar{U}$ are shown in Kalinske's (1947) figure 2 which expresses the relation between $\bar{U}_g/\bar{U}$ and τ_{ci}/τ_o for a value of $\sigma/\bar{U}$ equal to 1/4; where σ is the standard deviation of the instantaneous fluid velocity at the grain level about $\bar{U}$. The curve can be approximated by the following equation:

$$\text{Log} \frac{\bar{U}_g}{\bar{U}} = -0.068 - 1.1328 \left[\frac{\tau_{ci}}{\tau_o}\right] + 0.94 \left[\frac{\tau_{ci}}{\tau_o}\right]^2 - 1.206 \left[\frac{\tau_{ci}}{\tau_o}\right]^3 +$$

$$0.567 \left[\frac{\tau_{ci}}{\tau_o}\right]^4 - 0.0975 \left[\frac{\tau_{ci}}{\tau_o}\right]^5 . \quad (12)$$

Meyer-Peter and Müller Formula

Meyer-Peter and Müller (1948) developed an empirical formula for the bedload discharge in natural streams. The original form of the formula in metric units for a rectangular channel is:

$$\gamma \frac{Q_s}{Q} \left[\frac{K_s}{K_r}\right]^{3/2} d\ S = 0.047\ \gamma'_s\ D_m + 0.25 \left[\frac{\gamma}{g}\right]^{1/3} g_s^{2/3} \quad (13)$$

in which

$$D_m = \sum_{i=1}^{n} D_{si}\ i_b \quad (14)$$

where γ = the specific weight of water and equals 1 metric ton per cubic meter (t/m^3);

Q_s = that part of the water discharge apportioned to the bed, in liters per second (l/s);

Q = the total water discharge, in l/s;

K_s = Strickler's (1923) coefficient of bed roughness, and is equal to one divided by Manning's roughness coefficient (n_s);

K_r = the coefficient of particle roughness, and is equal to $26/D_{90}^{1/6}$;

D_{90} = the particle size, in meters (m), for which 90 percent of the bed mixture is finer;

d = the mean depth, in m;

S = the energy gradient, in m per m;

γ'_s = the specific weight of sediment under water and equals 1.65 t/m^3 for quartz;

D_m = the effective diameter of bed-material mixture, in m;

g = the acceleration of gravity and equals 9.815 meters per second per second (m/s/s);

g_s = the bedload discharge measured under water, in metric tons per second (t/s) per per meter (m) of width;

n = the number of size fractions in the bed material;

D_{si} = the mean grain diameter, in m, of the sediment in size fraction, i; and

i_b = the fraction, by weight, of bed material in a given size fraction.

Converting the formula to English units gives:

$$g_s = \left[0.368\ \frac{Q_s}{Q}\left(\frac{D_{90}^{1/6}}{n_s}\right)^{3/2} d\ S - 0.0698\ D_m\right]^{3/2} \qquad (15)$$

where g_s = the bedload discharge for dry weight, in lb/s per ft of width;

Q_s and Q are water discharges, in ft^3/s;

D_{90} and D_m are in mm;

d is in ft; and

n_s = Manning's roughness value for the bed of the stream.

For wide and smooth channels, the value of Q_s/Q is equal to 1, and the value of n_s is computed by the Manning equation converted to foot/pound units;

$$n_s = \frac{1.486\ d^{2/3}\ S^{1/2}}{V} \tag{16}$$

where V = the mean velocity, in ft/s.

Sheppard (1960) presented equations for evaluating Q_s/Q and n_s when the bank roughness must be considered.

For rectangular channel;

$$n_s = n_m\left[1 + \frac{2d}{W}\left\{1 - \left(\frac{n_w}{n_m}\right)^{3/2}\right\}\right]^{2/3} \tag{17}$$

and

$$\frac{Q_s}{Q} = \frac{1}{1 + \frac{2d}{W}\left(\frac{n_w}{n_s}\right)^{2/3}} \tag{18}$$

where n_w = the roughness value for the channel sides;

n_m = the roughness value for the total channel; and

W = the top width, in ft.

For trapezoidal channel;

$$n_s = n_m\left[1 + \frac{2d(1 + H^2)^{1/2}}{B}\left\{1 - \left(\frac{n_w}{n_m}\right)^{3/2}\right\}\right]^{2/3} \tag{19}$$

and

$$\frac{Q_s}{Q} = \frac{1}{1 + \frac{2d(1 + H^2)^{1/2}}{B}\left(\frac{n_w}{n_s}\right)^{2/3}} \tag{20}$$

in which

$$H = \frac{W - B}{2d} \tag{21}$$

where B is the bottom width, in ft; and

H is the channel side slope, in ft per ft.

The computer program computes the effective diameter of the bed-material mixture, D_m, from the entered sediment size-fraction data. However, the program does not compute the bedload discharge by size fractions.

Rottner Formula

Rottner (1959) developed an equation to express bedload discharge in terms of the flow parameters based on dimensional considerations and emperical coefficients. Using the data compiled by Johnson (1943), Rottner applied a regression analysis to determine the effect of a relative roughness parameter D_{50}/d. Rottner's equation is dimensionally homogeneous so that it can be presented directly in English units.

$$g_s = \gamma \left[(S_g-1)g\ d^3\right]^{1/2}\left\{\frac{V}{\sqrt{(S_g-1)g\ d}}\left[0.667\left(\frac{D_{50}}{d}\right)^{2/3} - 0.14\right] - 0.778\left(\frac{D_{50}}{d}\right)\right\} \quad (22)$$

where g_s = the bedload discharge, in lb/s per ft of width;
γ_s = the specific weight of sediment, in lb/ft^3;
S_g = the specific gravity of the sediment;
g = the acceleration of gravity, in feet per second per second (ft/s/s);
d = the mean depth, in ft;
V = the mean velocity, in ft/s; and
D_{50} = the particle size, in ft, at which 50 percent of the bed material by weight is finer.

In his derivation, wall and bed form effects were excluded, and Rottner stated that the equation may not be applicable when small quantities of bed material are being moved.

Einstein Bedload Formula

The bedload relation developed by Einstein (1950) is derived from the concept of probabilities of particle motion. A complete description of the complex procedure will not be presented here; however, the equations used in computing the bedload discharge are presented.

Einstein's method includes a trial-and-error procedure for computing the mean velocity, V, and splitting the hydraulic radius, R_b, into components pertaining to the effects of grain resistance, R_b', and the effects of channel bed-form resistance, R_b''. The computer program uses an equation presented by Einstein and Barbarossa (1952) in which R_b', in ft, is computed directly by

$$R_b' = \left[\frac{V\ (D_{65})^{1/6}}{7.66\ \sqrt{g\ S}}\right]^{3/2} \tag{23}$$

where V = the measured mean velocity, in ft/s;

D_{65} = the particle size, in ft, at which 65 percent of the bed material by weight is finer;

g = the acceleration of gravity, in ft/s/s; and

S = the energy gradient, in ft per ft.

Then R_b is set equal to the mean depth, d, in ft; R_b'' is set equal to R_b minus R_b'; and the following variables are computed:

$$\delta' = 11.6\ \nu/U_*' \tag{24}$$

where δ' = the laminar sublayer thickness, in ft, for U_*' ;

ν = the kinematic viscosity, in square ft^2/s; and

U_*' = the shear velocity, in ft/s, with respect to the grain.

in which

$$U_*' = \sqrt{R_b'\ S\ g} \tag{25}$$

A dimensionless transition parameter (small x) is obtained from Einstein's (1950) figure 4 that shows the relationship between D_{65}/δ' and x. Subroutine FIG4 of the computer program uses a series of semilogarithmic equations to approximate Einsteins figure 4. Then Δ, the apparent roughness diameter, is set equal to D_{65}/x. Next the characteristic grain size of the mixture (capital X) is computed by:

$$X = 0.77\ \Delta \text{ if } \Delta/\delta'>1.8\ \text{, or} \tag{26}$$

$$X = 1.39\ \delta' \text{ if } \Delta/\delta'<1.8 \tag{27}$$

and a pressure correction, Y, due to the transition from smooth to rough conditions is obtained from Einstein's (1950) figure 8 that shows the relationship between D_{65}/δ' and Y. Subroutine FIG8 of the computer program uses a series of power functions to approximate Einstein's figure 8. Then the logarithm function (β_x) is computed by:

$$\beta_x = \log\ (10.6\ X/\Delta) \tag{28}$$

The bedload discharge is computed for each size fraction in the bed-material mixture by first obtaining the "hiding factor" for grains in the bed mixture, ξ, from Einstein's (1950) figure 7 that shows the relationship between D_{si}/X and ξ where D_{si} is the grain diameter, in ft, of sediment in size fraction, i. Subroutine FIG7 of the computer program uses a series of power functions to approximate Einstein's figure 7. Then the adjusted intensity of shear on particles of a grain size fraction, ψ_*, is computed by:

$$\psi_* = \xi \; Y \left(\frac{1.025}{\beta_x}\right)^2 \psi \tag{29}$$

in which

$$\psi = \frac{1.65 \; D_{si}}{R_b' \; S} \tag{30}$$

where ψ = the intensity of shear on the particles of a size fraction. Next the intensity of transport for the individual grain size (ϕ_*) is obtained from Einstein's (1950) figure 10 that shows the relationship between ϕ_* and ψ_*. Subroutine FIG10 of the computer program uses a series of power functions to approximate Einsteins figure 10. Finally the bedload discharge for the size fraction, $i_B q_B$, in lb/s per ft of width, is computed from

$$i_B q_B = 1200 \; \phi_* \; (D_{si})^{3/2} \; i_b \; . \tag{31}$$

where i_b = the fraction, by weight, of bed material in a given size fraction.

The total bedload discharge, in lb/s per ft of width, is the sum of the bedload discharges from all size fractions.

Bed-Material Discharge Formulas

Eight bed-material formulas are presented in this section. Bed-material discharge is the discharge of sediment which is derived from and readily exchanges with the particles in the bed material; particles comprising the bed-material discharge move both as bedload and in suspension. Some investigators equate bed-material discharge to total-sediment discharge even though it does not include the wash load (also called the fine-material load).

Laursen Formula

The equation developed by Laursen (1958) to compute the mean concentration of bed-material discharge is based on empirical relations:

$$\bar{C} = \sum_{i=1}^{n} i_b \left(\frac{D_{si}}{d}\right)^{7/6} \left(\frac{\tau'_o}{\tau_c} - 1\right) f \left(\frac{V_*}{\omega_i}\right) \tag{32}$$

in which

$$\tau'_o = \frac{\rho V^2}{58} \left(\frac{D_{50}}{d}\right)^{1/3} \tag{33}$$

$$\tau_c = Y_c \, \rho \, g \, (S_g - 1) \, D_{si} \tag{34}$$

where $\bar{C}$ = the concentration of bed-material discharge, in percent by weight;

n = the number of size fractions in the bed material;

i_b = the fraction, by weight, of bed material in a given size fraction;

D_{si} = the mean grain diameter, in ft, of the sediment in size fraction, i;

d = the mean depth, in ft;

τ'_o = Laursen's bed shear stress due to grain resistence;

τ_c = critical shear stress for particles of a size fraction;

f denotes function of;

V_* = the shear velocity, in ft/s;

ω_i = the fall velocity, in ft/s, of sediment particles of diameter D_{si};

ρ = the density of water, in slugs per ft^3;

V = the mean velocity, in ft/s;

D_{50} = the particle size, in ft, at which 50 percent of the bed material by weight is finer;

Y_c = a coefficient relating critical tractive force to sediment size;

g = acceleration of gravity, in ft/s/s; and

S_g = the specific gravity of sediment.

The density, ρ, has been introduced into the original τ'_o equation presented by Laursen so that the equation is dimensionally homogeneous, and Laursen's coefficient has been changed accordingly.

Substituting for τ'_o and τ'_c in equation 32 and converting $\bar{C}$ to C gives:

$$C = 10^4 \sum_{i=1}^{n} i_b \left(\frac{D_{si}}{d}\right)^{7/6} \left[\frac{V^2}{58\ Y_c\ D_{si}\ (S_g - 1)\ g} \left(\frac{D_{50}}{d}\right)^{1/3} - 1\right] f \left(\frac{V_*}{\omega_i}\right) \quad (35)$$

where C = the concentration of bed material-discharge, in parts per million by weight.

Values of $f(V_*/\omega_i)$ are shown in Laursen's (1958) figure 14, which expresses the relation between V_*/ω_i and $f(V_*/\omega_i)$. The computer program uses a series of equations to approximate Laursen's figure 14.

The value of Y_c was related by Laursen to D_{si}/δ as follows:

$$Y_c = 0.04 \quad \text{for} \quad \frac{D_{si}}{\delta} > 0.1 \quad (36)$$

$$Y_c = 0.08 \quad \text{for} \quad 0.1 > \frac{D_{si}}{\delta} > 0.03 \quad (37)$$

$$Y_c = 0.16 \quad \text{for} \quad 0.03 > \frac{D_{si}}{\delta} \quad (38)$$

in which δ = the thickness, in ft, of the laminar sublayer;

$$\delta = 11.6 \left(\frac{\nu}{V_*}\right) \quad (39)$$

where ν = kinematic viscosity, in square feet per second (ft^2/s).

Laursen's formula was developed using natural sediments with a specific gravity of 2.65, and medium diameters that ranged from 0.011 to 4.08 mm.

Engelund and Hansen Formula

Engelund and Hansen (1967) applied Bagnold's (1966) stream power concept and the similarity principle to derive the following sediment transport equation:

$$f'\phi = 0.1\ \theta^{5/2} \tag{40}$$

in which

$$f' = \frac{2\ g\ S\ d}{V^2} \tag{41}$$

$$\phi = \frac{g_s}{\gamma_s \sqrt{(S_g - 1)\ g\ D_{50}^3}} \tag{42}$$

$$\theta = \frac{d\ S}{(S_g - 1)\ D_{50}} \tag{43}$$

where f' = the friction factor;
ϕ = the dimensionless sediment discharge;
θ = a dimensionless shear parameter;
g = the acceleration of gravity, in ft/s/s;
S = the energy gradient, in ft per ft;
d = the mean depth, in ft;
V = the mean velocity, in ft/s;
g_s = the bed-material discharge, in lb/s per ft of width;
D_{50} = the particle size, in ft, at which 50 percent of the bed material by weight is finer;
S_g = the spcific gravity of the sediment; and
γ_s = the specific weight of sediment, in lb/ft^3.

Substituting for f', ϕ, and θ in the equation 40 gives:

$$g_s = \frac{0.05\ \gamma_s\ V^2\ d^{1/2}\ S^{3/2}}{D_{50}\ g\ (S_g-1)^2} \tag{44}$$

The authors stated that the equation can be used with moderately sorted bed materials having mean fall diameters larger than 0.15 mm.

Colby Formula

Colby (1964) presented a graphical method to determine the discharge of sand size bed material that ranged from 0.1 to 0.8mm. Carl Nordin (U.S. Geological Survey, written commun., 1986) derived a series of equations to represent Colby's (1964) figure 24 and figure 26.

The bed-material discharge (g_s), in lb/s per ft of width, at a water temperature of 15.6 degrees Celsius (°C) (Colby's, 1964, figure 26) is

$$g_s = A\ (V - V_c)^B\ 0.672 \tag{45}$$

in which

$$V_c = 0.4673\ d^{0.1}\ D_{50}^{0.33} \tag{46}$$

where V = the mean velocity, in ft/s;

V_c = the critical velocity, in ft/s;

d = the mean depth, in ft;

D_{50} = the particle size, in mm, at which 50 percent of the bed material by weight is finer;

A = a coefficient; and

B = an exponent.

The value of the exponent B is equal to 2.5 when $(V - V_c)$ is less than 1. Otherwise it is computed by:

$$B = 1.453\ D_{50}^{(-0.138)} \tag{47}$$

The value of the coefficient A is determined by the following series of power equations based on mean depth for 5 values of D_{50}:

$$\text{For } D_{50} \text{ of } 0.1 \text{ mm} \qquad A = 1.453\ d^{0.61} \tag{48}$$

$$\text{For } D_{50} \text{ of } 0.2 \text{ mm} \qquad A = 1.329\ d^{0.48} \tag{49}$$

$$\text{For } D_{50} \text{ of } 0.3 \text{ mm} \qquad A = 1.4\ d^{0.3} \tag{50}$$

For D_{50} of 0.4 mm $\quad A = 1.26\ d^{0.3}$, and (51)

For D_{50} of 0.8 mm $\quad A = 1.099\ d^{0.3}$. (52)

Colby's (1964) figure 24 presents two adjustment coefficients, AF and CF, for determinining the bed-material discharge for temperatures other than 15.6 °C. The computer program uses a series of equations to approximate Colby's curves of depth compared to AF for water temperatures of 0, 5, 10, 20, 30, and 40 °C. AF is equal to 1 for a water temperature of 15.6 °C. The value of AF for intermediate temperatures are determined by interpolation. Colby's curve of D_{50} compared to CF gives the following values of CF:

For D_{50} of 0.1 mm $\quad CF = 0.64$ (53)

For D_{50} of 0.2 mm $\quad CF = 1$ (54)

For D_{50} of 0.3 mm $\quad CF = 1$ (55)

For D_{50} of 0.4 mm $\quad CF = 0.88$, and (56)

For D_{50} of 0.8 mm $\quad CF = 0.2$. (57)

Applying the two coefficients, the equation to compute g_s for the five D_{50} values becomes:

$$g_s = A\ (V - V_c)^B\ [1 + (AF - 1)\ CF]\ 0.672\ . \qquad (58)$$

The value of g_s for intermediate D_{50} values are determined by logarithmic interpolation.

Ackers and White Formula

Ackers and White (1973) developed a general sediment-discharge function in terms of three dimensionless groups; D_{gr} (size), F_{gr} (mobility), and G_{gr} (discharge). The dimensionless grain diameter D_{gr} is expressed as:

$$D_{gr} = D_{50} \left[\frac{g (S_g - 1)}{\nu^2}\right]^{1/3} \tag{59}$$

where D_{50} = the particle size, in ft, at which 50 percent of the bed material by weight is finer;

g = the acceleration of gravity, in ft/s/s;

S_g = the specific gravity of the sediment; and

ν = the kinematic viscosity, in ft^2/s.

Ackers and White considered that coarse sediments are transported mainly as bedload, and only a part of the shear stress on the channel bed is effective in causing the movement of coarse sediments, even though fine sediments are considered to be tranported as suspended load, and the total shear stress is effective in causing the movement of the fine sediments. They defined a dimensionless mobility number, F_{gr}, as:

$$F_{gr} = \frac{V_*^n}{\sqrt{g D_{50} (S_g - 1)}} \left[\frac{V}{\sqrt{32} \log\left(\frac{\alpha d}{D_{50}}\right)}\right]^{1-n} \tag{60}$$

where d = the mean depth, in ft;

V_* = the shear velocity, in ft/s;

V = the mean velocity, in ft/s;

α = the coefficient in the rough turbulent equation with a value of 10; and

n = the transition exponent depending on sediment size.

Then they developed the following dimensionless expression for general sediment transport, G_{gr}, based on Bagnold's (1966) stream power concept:

$$G_{gr} = \frac{X d}{S_g D_{50}} \left(\frac{V_*}{V}\right)^n \tag{61}$$

where X is the sediment-discharge concentration expressed as the mass flux per unit of mass flow rate. Transposing the equation to solve for X, and converting X to C gives:

$$C = 10^6 \frac{G_{gr} S_g D_{50} \left(\frac{V}{V_*}\right)^n}{d} \qquad (62)$$

where C = the concentration of bed-material discharge, in parts per million by weight.

Using flume data from other investigators, Ackers and White developed a new general transport function, G_{gr}, and evaluated the associated coefficients. The equation is:

$$G_{gr} = C_A \left(\frac{F_{gr}}{A} - 1\right)^m \qquad (63)$$

where A = the value of the Froude number at nominal initial motion;

m = the exponent in the sediment transport function; and

C_A = the coefficient in the sediment transport function.

The values of n, A, m and C_A were evaluated for two size ranges of bed material. The values for the intermediate size range, D_{gr} = 1 (0.04 mm silt size) to D_{gr} = 60 (2.5 mm sand size) were ;

$$n = 1.00 - 0.56 \log D_{gr} , \qquad (64)$$

$$A = \frac{0.23}{\sqrt{D_{gr}}} + 0.14 , \qquad (65)$$

$$m = \frac{9.66}{D_{gr}} + 1.34 , \text{ and} \qquad (66)$$

$$\log C_A = 2.86 \log D_{gr} - (\log D_{gr})^2 - 3.53 . \qquad (67)$$

The values for the coarse size range with D_{gr} greater than 60 were:

$$n = 0.00 , \qquad (68)$$

$$A = 0.17 , \qquad (69)$$

$$m = 1.5 , \text{ and} \qquad (70)$$

$$C_A = 0.025 . \qquad (71)$$

Fine size material with D_{gr} less than 1 exhibit cohesive properties and conventional sediment transport equations do not apply.

Ackers and White suggested that D_{35}; the particle size, in ft, at which 35 percent of the bed material by weight is finer; be used in place of D_{50} for graded and coarse sediments.

The following procedure is used to calculate the concentration of bed-material discharge:

1. The value of D_{gr} is computed using equation 59.
2. Values of A, C_A, n, and m associated with the computed D_{gr} value are determined using either equations 64-67 or 68-71.
3. The value of the particle mobility, F_{gr}, is computed using equation 60.
4. The value of G_{gr} is computed using equation 63.
5. The bed-material discharge concentration, C, is computed using equation 62.

Yang Sand Formula

Yang (1973) derived an equation to compute concentration of the bed-material discharge, for sand bed streams, based on dimensional analysis and the concept of unit stream power. He defined unit stream power as the rate of potential energy dissipated per unit weight of water, which is expressed by the velocity and slope product, VS. Yang and Molinas (1982) showed that the basic form of the unit stream power equation can also be derived from well-established theories in fluid mechanics and turbulence. Yang's dimensionless unit stream power equation is:

$$\log C = 5.435 - 0.286 \log \frac{\omega D_{50}}{\nu} - 0.457 \log \frac{V_*}{\omega} + \left(1.799 - 0.409 \log \frac{\omega D_{50}}{\nu} - 0.314 \log \frac{V_*}{\omega}\right) \log \left(\frac{V S}{\omega} - \frac{V_{cr} S}{\omega}\right) \quad (72)$$

in which the dimensionless critical velocity at incipient motion can be expressed as:

$$\frac{V_{cr}}{\omega} = \frac{2.5}{\log \frac{V_* D_{50}}{\nu} - 0.06} + 0.66 \quad \text{for} \quad 1.2 < \frac{V_* D_{50}}{\nu} < 70 \qquad (73)$$

and

$$\frac{V_{cr}}{\omega} = 2.05 \quad \text{for} \quad 70 \leq \frac{V_* D_{50}}{\nu} \qquad (74)$$

where C = the concentration of bed-material discharge, in parts per million by weight;

ω = the average fall velocity, in ft/s, of sediment particles of diameter D_{50};

D_{50} = the particle size, in ft, at which 50 percent of the bed material by weight is finer;

ν = the kinematic viscosity, in ft^2/s;

V_* = the shear velocity, in ft/s;

V = the average velocity, in ft/s;

S = the energy slope, in ft/ft; and

V_{cr} = the average flow velocity, in ft/s, at incipient motion.

Coefficients for the equation were determined by multiple regression analysis of 463 sets of laboratory data on flow and sediment parameters associated with discharge of bed materials consisting of sand that had a median sieve diameter that ranged from 0.015 to 1.71 mm. The term VS/ω is the dimensionless unit stream power. The lower boundary of 1.2 in equation 73 for $V_* D_{50}/\nu$ is based on the minimum values of data used in the calibration of coefficients. This limit prevents the value of V_{cr}/ω from going to infinity. The fall velocities of the sediment particles are determined from Figure 2 presented in the U.S. Inter-Agency Committee on Water Resources, Subcommittee on Sedimentation (1957).

Moore and Burch (1986) applied the unit stream power theory to the study of sediment transport in sheet and rill flows. They found that Yang's (1973) equation can accurately predict sediment discharge in the sand size range provided that a constant critical dimensionless velocity at incipient motion is used in place of equation 73 or 74. They further showed that good agreement between the computed and measured results of clay discharge in rills when the effective aggregate diameters were used in the equation.

The procedure is suitable for computing the discharge of graded material. The concentration is computed for each size fraction by using the mean diameter and fall velocity in the size fraction. Then the total bed-material discharge concentration for the graded material is obtained from:

$$C = \sum_{i=1}^{n} i_b \, C_i \tag{75}$$

where n = the number of size fractions in the bed material;

i_b = the fraction, by weight, of bed material in a given size fraction; and

C_i = the computed concentration in the size fraction, i.

Yang Gravel Formula

Yang (1984), using the same dimensional analysis and multiple regression methods as was used to derive discharge rates in sand bed streams (Yang, 1973), derived an equation to compute the bed-material discharge concentration, in gravel bed streams. The same definition of unit stream power is used in both the sand and gravel transport equations. Yang's dimensionless unit stream power equation for gravel transport is:

$$\log C = 6.681 - 0.633 \log \frac{\omega D_{50}}{\nu} - 4.816 \log \frac{V_*}{\omega} + \left(2.784 - 0.305 \log \frac{\omega D_{50}}{\nu} - 0.282 \log \frac{V_*}{\omega}\right) \log \left(\frac{V S}{\omega} - \frac{V_{cr} S}{\omega}\right) \tag{76}$$

in which the dimensionless critical velocity at incipient motion is the same as that for sand transport; namely:

$$\frac{V_{cr}}{\omega} = \frac{2.5}{\log \frac{V_* D_{50}}{\nu} - 0.06} + 0.66 \quad \text{for} \quad 1.2 < \frac{V_* D_{50}}{\nu} < 70 \tag{77}$$

and

$$\frac{V_{cr}}{\omega} = 2.05 \quad \text{for} \quad 70 \le \frac{V_* D_{50}}{\nu} \tag{78}$$

where C = the concentration of bed material discharge, in parts per million by weight;

ω = the average fall velocity, in ft/s, of sediment particles of diameter D_{50};

D_{50} = the particle size, in ft, at which 50 percent of the bed material by weight is finer;

ν = the kinematic viscosity, in ft^2/s;

V_* = the shear velocity, in ft/s;

V = the average velocity, in ft/s;

S = the energy slope, in ft per ft; and

V_{cr} = the average flow velocity, in ft/s, at incipient motion.

Coefficients for the equation were determined by multiple regression analysis of 166 sets of laboratory data on flow and sediment paramters associated with discharge of bed materials consisting of gravel that had a median sieve diameter that ranged from 2.46 to 7.01 mm. The fall velocities of the sediment particles are determined from Figure 2 presented in the U.S. Inter- Agency Committee on Water Resources, Subcommittee on Sedimentation (1957). Figure 2 can be used to determine velocities of particles as large as 10 mm in diameter. The fall velocity of the sediment particles larger 10 mm are computed by the equation developed by Rubey (1933).

Similar to the method for graded-sand transport, the concentration of gravel bed-material discharges is computed for each size fraction by using the mean diameter and fall velocity of the size fraction. Then the total bed-material discharge concentration, C, for the graded material is obtained from:

$$C = \sum_{i=1}^{n} i_b \, C_i \qquad (79)$$

where n = the number of size fractions in the bed material;

i_b = the fraction, by weight, of bed material in a given size fraction;

C_i = the computed concentration in the size fraction, i.

Einstein Formula

Einstein (1950) presented a method to combine his computed bedload discharge with a computed suspended bed-material discharge to yield the total bed-material discharge. A complete description of the procedure will not be presented; however, the equations used in computing the suspended bed-material discharge are presented. The computation of $i_B q_B$ values and other variables defined in the section "Einstein Bedload Formula" (page 11) are not redefined here.

First, a parameter of total transport, P, is computed by:

$$P = 2.3026 \log \frac{30.2 \text{ X } R_b}{D_{65}} . \tag{80}$$

Then the suspended bed-material discharge is computed for each size fraction by integrating the product of the flow velocity and the suspended-sediment concentration from the surface down to the bed layer, A, which is a dimensionless distance defined by:

$$A = 2 \ D_{si} \ / \ R_b . \tag{81}$$

The velocity distribution is defined from Keulegan's (1938) equation and the suspended-sediment concentration distribution is given by:

$$C_y = C_a \left(\frac{d - y}{y} \ \frac{a}{d - a} \right)^Z \tag{82}$$

where C_y and C_a are the concentration at points y and a above the bed, in parts per million by weight;

d = the total depth, in ft; and

Z = the exponent of suspended-sediment distribution.

in which

$$Z = \frac{\omega_i}{0.4 \ V'_*} \tag{83}$$

where ω_i is the fall velocity, in ft/s, of sediment particles of diameter D_{si}.

Values of Einstein's suspended-sediment discharge integrals I_1 and I_2 are computed with subroutine POWER of the computer program using calculated values A and Z. Subroutine POWER first evaluates the Einstein J_1 and J_2 integral functions by a procedure developed by Li (1974). The method is based on expanding the integral functions in the form of a power series. The J values then are converted to I values by multiplying them by FACT; where

$$FACT = 0.216 \frac{A^{Z-1}}{(1-A)^Z} \quad . \tag{84}$$

The total bed-material discharge for the size fraction, $i_T q_T$, in lb/s per ft of width is then computed from:

$$i_T q_T = i_B q_B \; (PI_1 + I_2 + 1) \quad . \tag{85}$$

The total bed-material discharge, in lb/s per ft of width, is the sum of the bed-material discharges from all size fractions.

Toffaleti Formula

The procedure to determine bed-material discharge developed by Toffaleti (1968) is based on the concepts of Einstein (1950) with three modifications: (1) velocity distribution in the vertical is obtained from an expression different from that used by Einstein; (2) several of Einstein's correction factors are adjusted and combined; and (3) the height of the zone of bedload transport is changed from Einstein's two grain diameters. Toffaleti defines his bed-material discharge as total river sand discharge even though he defines the range of bed-size material from 0.062 to 16 mm.

Toffaleti presented his procedure by the following series of equations and definitions:
Computation is initiated by evaluating the following variables which are common to all size fractions:

$$Z_v = 0.1198 + 0.00048 \; TDF \tag{86}$$

where Z_v = the exponent of velocity distribution; and

TDF = the water temperature, in degrees Fahrenheit (°F). The computer program converts the entered temperature, in °C.

$$SI = S\ d\ C_z \quad (87)$$

in which

$$C_z = 260.67 - 0.667\ TDF \quad (88)$$

where SI = a variable used in the later evaluation of ZOM, the exponent of suspended-sediment concentration distribution in the middle zone;

S = the energy gradient, in ft per ft;

d = the mean depth, in ft; and

C_z = a temperature related parameter used in evaluating ZOM.

$$YA = d/11.24 \quad (89)$$

where YA = the distance, in ft, from the bed to the upper limit of the lower zone.

$$YB = d/2.5 \quad (90)$$

where YB = the distance, in ft, from the bed to the upper limit of the middle zone.

$$C_v = 1 + Z_v \quad (91)$$

where C_v = a velocity distribution parameter.

$$U2 = \frac{V}{\sqrt{g\ D_{65}\ S}} \quad (92)$$

where U2 = a parameter for evaluating U'_*, the shear velocity with respect to the grain;

V = mean velocity, in ft/s;

g = the acceleration of gravity, in ft/s/s; and

D_{65} = the particle size, in ft, at which 65 percent of the bed material by weight is finer.

$$U3 = \frac{V^3}{g \nu S} \tag{93}$$

where U3 = a parameter for evaluating U'_*; and

ν = the kinematic viscosity, in ft^2/s.

U1, a parameter for evaluating U''_*, is related to V and U'_*, and is obtained from Toffaleti's (1968) figure 3 which shows the relationship between U2 and U3 and U1. The computer program evaluates U1 by a series of semilogarithmic equations to approximate Toffaleti's figure 3. Then:

$$U'_* = V/U1 \tag{94}$$

A correction factor, A, replaces Einstein's (1950) ξ, Y, and θ, and is evaluated by computing PAM:

$$PAM = P^{1/3}/AM \tag{95}$$

in which

$$P = 10^5 \nu, \text{ and} \tag{96}$$

$$AM = 10\ U'_* . \tag{97}$$

Then the value of A is obtained from Toffaleti's (1968) figure 4 that shows the relationship between PAM and A. The computer program uses a series of power functions to approximate Toffaleti's figure 4. Lastly, T, a parameter that includes the constants and those components of the shear force that are a function of water temperatures, is computed by;

$$T = (0.051 + 0.00009\ TDF)\ 1.1 . \tag{98}$$

The bedload discharge, GBL, and bed-material discharge, GT, in tons per day, are computed for each size fraction. Bed-material discharge is the sum of the discharges from the three zones: (1) lower zone, GA, from 0 to YA feet, (2) middle zone, GB, from YA to YB feet, and (3) upper zone, GC, from YB to d feet. First, the value of GF, the discharge, in t/d per ft of width, moving in the vertical section between levels from 2 times the grain diameter, DD, to YA, and with the assumption that the bed is composed entirely of one size fraction, is computed. GF for the first size fraction (0.00029 feet) is

$$GF = \frac{1.905}{\left(\frac{T\ A}{V^2}\right)^{5/3}} \text{ ; and} \qquad (99)$$

GF for each succeeding coarser size fraction is reduced by division by $2^{5/3}$ or 3.175. The exponents in the point-discharge equations for the lower, middle, and upper zones (F1, F2, and F3), and the exponents in the integrated discharge equations for the lower, middle, and upper zones (F4, F5, and F6) are computed by:

$$ZOM = \frac{\omega_i\ V}{SI} \qquad (100)$$

where ω_i = the fall velocity, in ft/s, of sediment particles of mean size D_{si}; and

D_{si} = the mean grain diameter, in ft, of the sediment in size fraction i.

The fall velocities of the sediment particles are determined from Figure 2 presented in the U.S. Inter-Agency Committee on Water Resources, Subcommittee on Sedimentation (1957). If the computed value of ZOM is greater than 1.5 Z_v, ZOM is set equal to 1.5 Z_v. The F1 to F6 values are then computed by:

$$F1 = 0.756\ ZOM - Z_v \qquad (101)$$

$$F2 = ZOM - Z_v \qquad (102)$$

$$F3 = 1.5\ ZOM - Z_v \qquad (103)$$

$$F4 = 1 - F1 \qquad (104)$$

$$F5 = 1 - F2 \text{ , and} \qquad (105)$$

$$F6 = 1 - F3 \text{ .} \qquad (106)$$

Next the bedload discharge concentration, C, is computed by;

$$C = i_b \; W \; X \tag{107}$$

in which

$$X = \frac{F4 \; GF}{YA^{F4} - DD^{F4}} \; , \text{ and} \tag{108}$$

$$DD = 2 \; D_{si} \tag{109}$$

where i_b = the fraction, by weight, of bed material in a given size range; and

W = the width, in ft.

Bedload discharge, GBL, in t/d, for the sand fraction is:

$$GBL = C \; DD^{F4} \; . \tag{110}$$

The concentration of the discharge in the bed-load layer (UBL), in lb/ft^3, assuming a bed composed entirely of the size fraction being considered, is computed as

$$UD = C_v \; V \left(\frac{DD}{d}\right)^{Z_v} \; , \text{ and} \tag{111}$$

$$UBL = \frac{X \; DD^{F4}}{43.2 \; UD \; DD} \; . \tag{112}$$

If the computed value of UBL is greater than 100, the bedload discharge is multiplied by 100/UBL. Bed-material discharges for the three zones are computed by:

$$GA = \frac{C}{F4} \left(YA^{F4} - DD^{F4}\right) + GBL \tag{113}$$

$$GB = \frac{C}{F5} \; YA^{(F2 - F1)} \left(YB^{F5} - YA^{F5}\right) \; , \text{ and} \tag{114}$$

$$GC = \frac{C}{F6} \; YA^{(F2 - F1)} \; YB^{(F3 - F2)} \left(d^{F6} - YB^{F6}\right) \; . \tag{115}$$

Then the total bed-material discharge, GT, for the size fraction is the sum of GA, GB, and GC.

The total bedload discharge, in t/d, is the sum of the GBL's for all size fractions; and the bed-material discharge, in t/d, is the sum of the GT's for all size fractions.

EVALUATION OF SEDIMENT-DISCHARGE FORMULAS

Investigators need to select a reliable sediment-discharge formula. Selection may be complicated because computed results from different formulas may differ drastically from each other and from actual measurements. The potential accuracy of a formula or procedure may be judged from the general assumptions and theoretical basis used to develope the method, from the similarity between the experimental conditions used to develop parameters and relation of the method to real field conditions, and from direct comparison with field measurements. The previous section, "Description of fluvial sediment-discharge formulas", presented the general assumptions used and theoretical basis of the 13 formulas presented in this report. Comparisons by different investigators of computed and measured results for these 13 sediment discharge formulas are given in this section to assist in the selection of a formula. The discrepancy ratio, defined as the ratio between computed and measured sediment discharges, is used as an indicator of the accuracy of a formula.

Schulits and Hill (1968) made comparisons of sediment discharges computed from 14 bedload transport formulas and sediment discharges measured in flumes and rivers. Of the five bedload formulas presented in this report, they recomended the Schoklitsch (1934) formula and the Meyer-Peter and Müller (1948) formula.

White, Milli and Crabbe (1975, 1978) made detailed comparisons of discharges computed from sediment discharge formulas and measured discharges from 1,270 flume experiments and field surveys. The median particle size of the bed material present in measurements ranged from 0.04 to 4.94 mm. The formulas were divided into groups according to their general performance. Results of nine of the formulas that are presented in this report were:

A. Formulas with about 60 or more percent of the computed discrepancy ratios in the range 1/2 to 2 with little scatter within the sets.

Ackers and White (1973)
Engelund and Hansen (1967)
Rottner (1959)

B. Formulas with 35 to 50 percent of the computed discrepancy ratios in the range 1/2 to 2 with little scatter within the sets.

Einstein bedload (1950)
Einstein (1950)
Toffaleti (1968)

C. Formulas with 35 to 50 percent of the computed discrepancy ratios in the range 1/2 to 2 but with substantial scatter within the data sets.

Laursen (1958)

D. All other formulas.

Kalinske (1947)
Meyer-Peter and Müller (1948)

White, Milli, and Crabbe (1975, 1978) rated the Ackers and White (1973) formula as the most reliable formula.

In Yang's (1976) discussion of the comparisons made by White, Milli, and Crabbe (1975), Yang used 1,247 field and laboratory measurements which essentially duplicated the set used by White, Milli, and Crabbe (1975). Ninety-one percent of the discrepancy ratios of discharges computed with Yang's (1973) formula and measured discharges ranged from 1/2 to 2. Yang's comparisons seems to be consistent with the verifications made by Alonso (1980), American Society of Civil Engineers (1982), and Yang and Molinas (1982).

Alonso (1980) compared discharges computed with eight sediment-discharge formulas with discharges measured during 40 field surveys and 225 flume experiments. The data used by Alonso were collected with special facilities so that total bed-material discharges were measured accurately. Consequently, there is no uncertainty on the amount of unmeasured discharge near the river bed. The median particle size of the bed material in the measurements ranged from 0.10 to 1.35 mm. Results for five of the formulas presented in this report are given in table 2. The Yang (1973) formula was the most reliable for the entire range of flow conditions and gave consistent discrepancy ratios. Both Ackers and White (1973) and

Table 2.--Statistical summary of discrepancy ratios of five sediment-discharge formulas[1]

Author of formula	Number of tests	Discrepancy ratio[2] Mean	95%-confidence limits of the mean		Standard deviation	Percentage of tests with ratio ranging 1/2 to 2
			Field data			
Ackers and White (1973)	40	1.27	1.05	1.48	0.68	87.8
Engelund and Hansen (1967)	40	1.46	1.28	1.64	0.56	82.9
Laursen (1958)	40	0.65	0.49	0.80	0.48	56.1
Yang (1973)	40	1.01	0.89	1.13	0.39	92.7
Meyer-Peter and Müller (1948)	40	0.24	0.22	0.27	0.09	0
			[3]Flume data with d/D > 70			
Ackers and White (1973)	177	1.34	1.24	1.54	1.29	73.0
Engelund and Hansen (1967)	177	0.73	0.63	0.83	0.68	51.1
Laursen (1958)	177	0.81	0.73	0.88	.51	71.4
Yang (1973)	177	0.99	0.93	1.08	0.60	79.8
Meyer-Peter and Müller (1948)	177	0.40	0.39	0.47	0.49	18.5
			[4]Flume data with d/D < 70			
Ackers and White (1973)	48	1.12	0.93	1.28	0.52	89.6
Engelund and Hansen (1967)	48	0.75	0.59	0.90	0.50	66.7
Laursen (1958)	48	1.04	0.76	1.32	0.99	79.2
Yang (1973)	48	0.90	0.79	1.05	0.51	85.4
Meyer-Peter and Müller (1948)	48	1.03	1.00	1.27	0.83	72.9

[1] Modified from Alonso, 1980, p. 431.

[2] Ratio between computed and measured sediment discharges.

[3] Ratio between mean depth (d), in ft, and sediment diameter (D), in ft.

[4] Shallow flow where surface wave-effect becomes significant. Most sediment transport formulas do not account for interaction with the surface waves.

Engelund and Hansen (1967) formulas produced reasonable values of discrepancy ratios. Alonso included the bedload-discharge formula of Meyer-Peter and Müller in table 2 even though the others are bed-material discharge formulas.

The American Society of Civil Engineers Task Committee on Relations Between Morphology of Small Streams and Sediment Yield (1982) endorsed the work of Alonso (1980) and ranked the accuracy of the eight formulas evaluated by Alonso. Their ranking of five of the formulas presented in this report was:

1. Yang (1973)
2. Laursen (1958)
3. Ackers and White (1973)
4. Engelund and Hansen (1967)
5. Meyer-Peter and Müller (1948)

Yang and Molinas (1982) made detailed comparisons of computed discharges from seven sediment discharge formulas and measured discharges from 1,259 sets of flume experiments and field surveys. The median particle size of the bed material in these measurements varied from 0.15 to 1.71 mm. Results of comparisons for four of the formulas that were presented in this report are given in table 3. Yang's (1973) formula gave discharges that compared best with discharges from the laboratory experiments and field surveys. Colby's (1964) formula gave the least accurate results for the shallow flow conditions in the laboratory.

Brownlie (1981) made detailed comparisons, based on data from about 1000 flume experiments and field observations, of computed discharges from 13 sediment bedload discharge and bed-material discharge formulas and measured discharges. The median particle size of the bed material in the data ranged from 0.086 to 1.44 mm. Results of seven of the formulas presented in this report are given in table 4. A parameter that is log-normally distributed can be described by its geometric mean and geometric standard deviation. The geometric mean and geometric standard deviation were calculated by taking the antilogs of the mean and standard deviation respectively, of the logarithms of ratios of computed to observed discharge concentrations. For the ratio of calculated to observed concentration, geometric mean and geometric standard deviation values of 1 would indicate

Table 3.--Summary of comparisons of accuracies of four bed-material discharge formulas[1]

Author of formula	Discrepancy ratio[2]						Number of tests
	Mean	Percent of data in range of variation				Standard deviation	
		0.75-1.25	0.5-1.5	0.25-1.75	0.5-2.0		
			Laboratory data				
Colby (1964)	0.31	4	10	29	10	0.64	865
Yang (1973)	1.01	55	85	95	92	0.44	1093
Engelund and Hansen (1967)	0.88	26	59	91	65	0.72	1093
Ackers and White (1973)	1.28	37	68	84	86	0.69	1093
			River data[3]				
Colby (1964)	0.61	13	29	71	33	0.66	102
Yang (1973)	1.13	48	77	92	90	0.43	166
Engelund and Hansen (1967)	1.51	34	58	72	79	0.75	166
Ackers and White (1973)	1.50	31	61	75	80	0.80	166
			All data				
Colby (1964)	0.34	5	12	33	12	0.64	967
Yang (1973)	1.03	54	84	95	92	0.44	1259
Engelund and Hansen (1967)	0.96	27	59	88	67	0.72	1259
Ackers and White (1973)	1.31	36	67	83	85	0.71	1259

[1] Modified from Yang and Molinas, 1982, p. 785.

[2] Ratio between computed and measured sediment concentration.

[3] The discrepancy ratio for most river data should be greater than 1.0 because part of the suspended bed-material discharge is in the unmeasured zone.

Table 4.--Geometric mean and geometric standard deviation of the ratios of computed to observed concentrations from seven sediment discharge formulas, for laboratory experiments and field observations[1]

[Mean: Geometric mean. S.D.: Geometric standard deviation.

Author of formula	Number of tests	Laboratory		Field	
		Mean	S.D.	Mean	S.D.
Ackers and White (1973)	998	1.150	1.758	0.694	2.027
Einstein (1950)	950	0.628	4.059	0.420	3.719
Engelund and Hansen (1967)	999	1.236	2.064	0.916	1.997
Laursen (1958)	972	1.296	2.532	0.420	3.098
Rottner (1959)	999	0.920	2.101	0.603	1.904
Toffaleti (1968)	995	1.166	2.749	0.854	2.572
Yang (1973)	993	1.215	1.710	0.471	3.077

[1] Modified from Brownlie, 1981, p. 188.

perfect agreement. The geometric standard deviation will be greater than or less than 1, depending on whether the formula tends to over-predict or under-predict. The Ackers and White (1973) and the Engelund and Hansen (1967) formulas gave the most satisfactory geometric standard deviation for combined laboratory experiments and field observations.

Yang (1984) compared concentrations computed from four sediment discharge formulas and measured gravel concentrations. The median particle size of the bed material in 167 data sets ranged from 2.46 to 7.01 mm. The results are given in table 5. Concentrations computed by the Meyer-Peter and Müller (1948) formula for the 35 observations by Casey (Johnson, 1943) showed poor correlation with measured concentrations.

Comparisons of bed-material discharges computed by seven formulas presented in this report and observed bed-material discharge from the Niobrara River near Cody, Nebraska, (Colby and Hembree, 1955) are shown in figure 1. Comparisons of bedload discharges computed by five formulas presented in this report are shown in figure 2. The median particle size of the bed material in the Niobrara River data was 0.28 mm. Similar comparisons of data from Mountain Creek (Einstein, 1944) are shown in figures 3 and 4.

Table 5.--Summary of comparisons of accuracies of four gravel transport formulas[1]

Author of formula	Discrepancy ratio[2]				Corre-lation coeffi-cient	Stand-ard devia-tion	Mean error in per-cent
	Mean	Percent of data in range					
		0.75-1.25	0.5-1.5	0.25-1.75			
Yang (1984)	1.05	47	75	92	0.92	0.51	5
Engelund and Hansen (1967)	0.85	13	40	86	0.93	0.99	-15
Ackers and White (1973)	1.21	44	76	83	0.93	0.89	21
Meyer-Peter and Müller (1948)	1.86	61	81	87	0.91	8.98	86

[1] Modified from Yang, 1984, p. 1789-90.

[2] Ratio between computed and measured concentration.

The median particle size of the Mountain Creek bed material was 0.90 mm. A summary of the accuracies of the four comparisons are given in table 6. Computed results of Yang (1973), Ackers and White (1973) and Toffaletti (1968) bed-material formulas agree most closely with the Niobrara observations; and results of Yang (1973), Engelund and Hansen (1967) and Ackers and White (1973) bed-material formulas agree most closely with the Mountain Creek observations. Because the D_{50} value of the Mountain Creek data is at the upper limit of the Colby formula, the formula computed values were extremely low. In figure 2 the computed results from different bedload formulas are less than the observed Niobrara bed-material discharges as expected. However, figure 4 shows that computed results from the bedload formulas proposed by Kalinske, Einstein, and Rottner are greater than the observed Mountain Creek bed-material discharges, which indicates an over estimation of the bedload discharge.

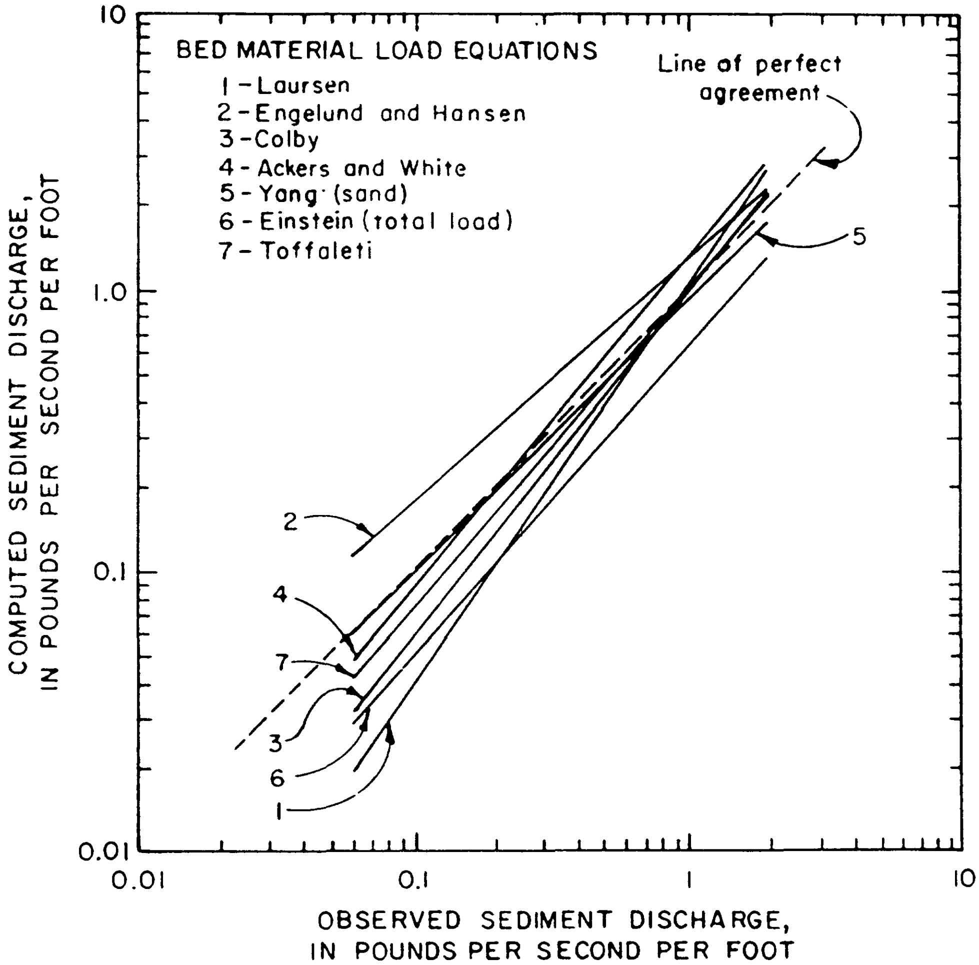

Figure 1.-- Comparison of bed-material discharges computed by seven formulas presented in this report to observed bed-material discharge, Niobrara River near Cody, Nebraska (Data from Colby and Hembree, 1955)

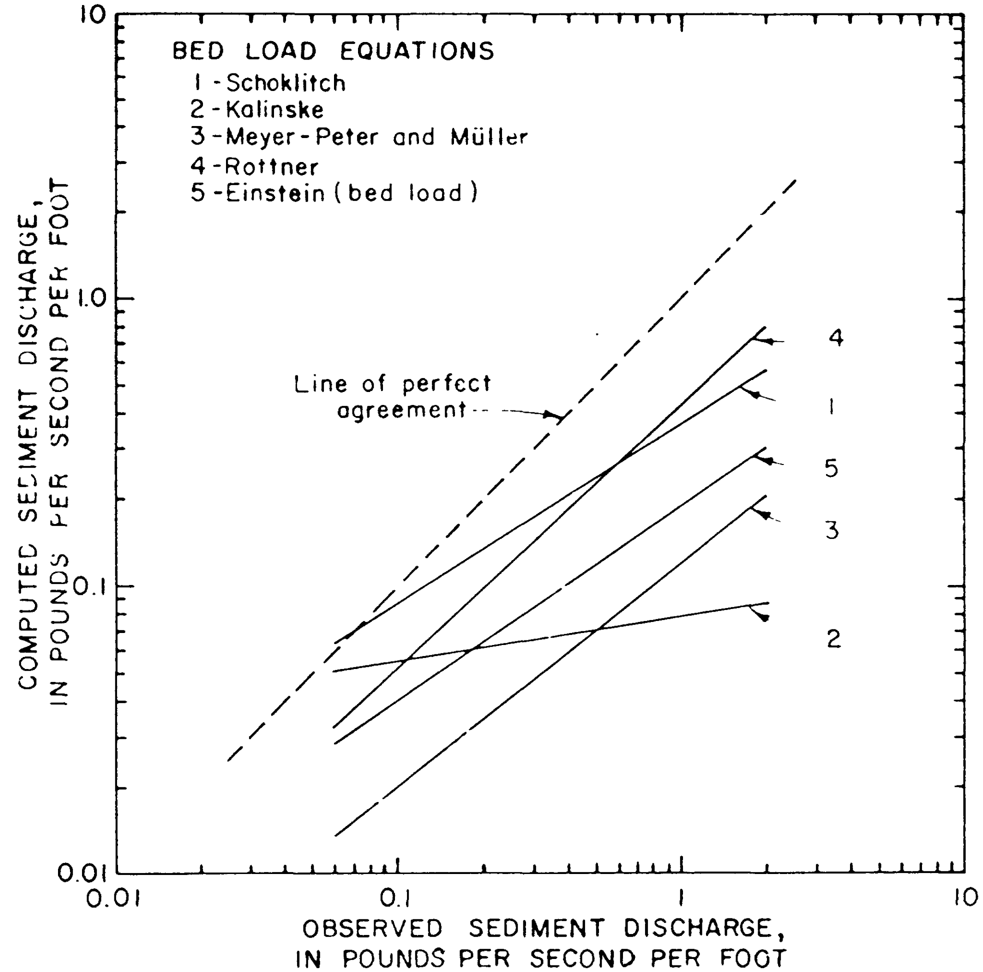

Figure 2.-- Comparison of bedload discharges computed by five formulas presented in this report to observed bed-material discharge, Niobrara River near Cody, Nebraska (Data from Colby and Hembree, 1955)

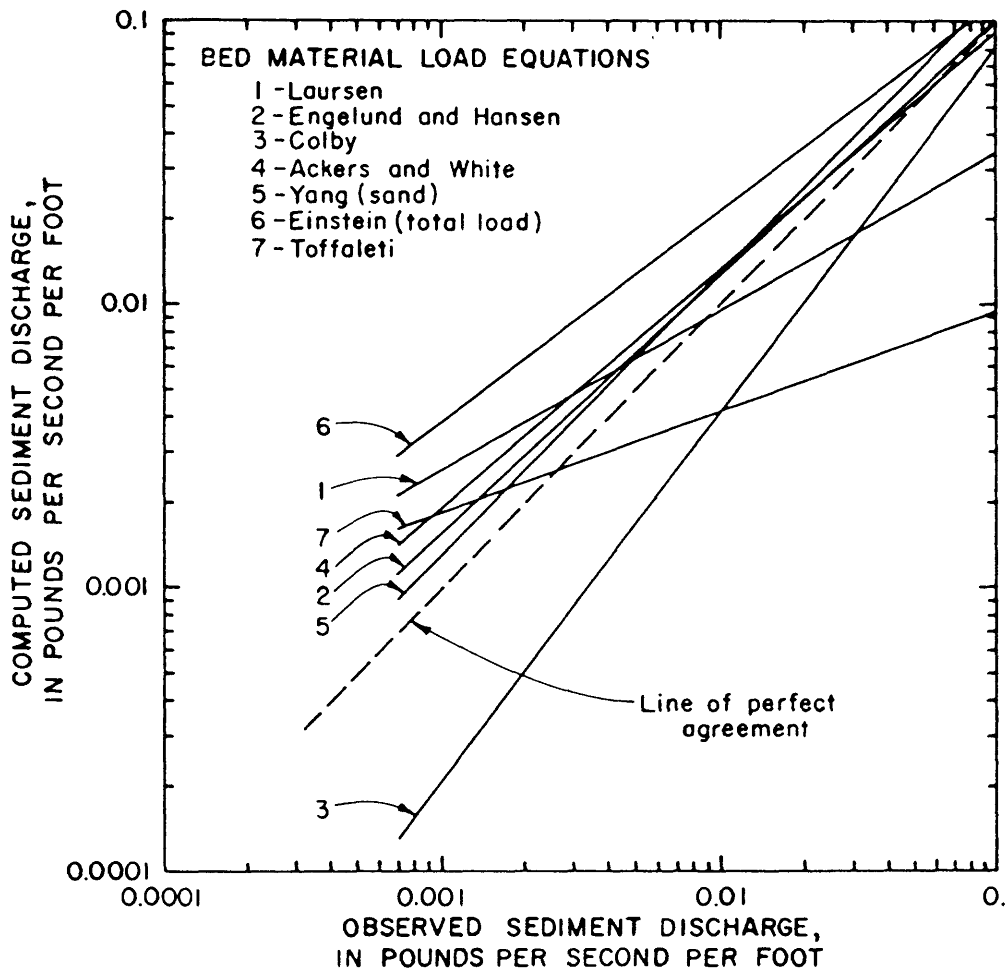

Figure 3.-- Comparison of bed-material discharges computed by seven formulas presented in this report to observed bed-material discharge, Mountain Creek (Data from Einstein, 1944)

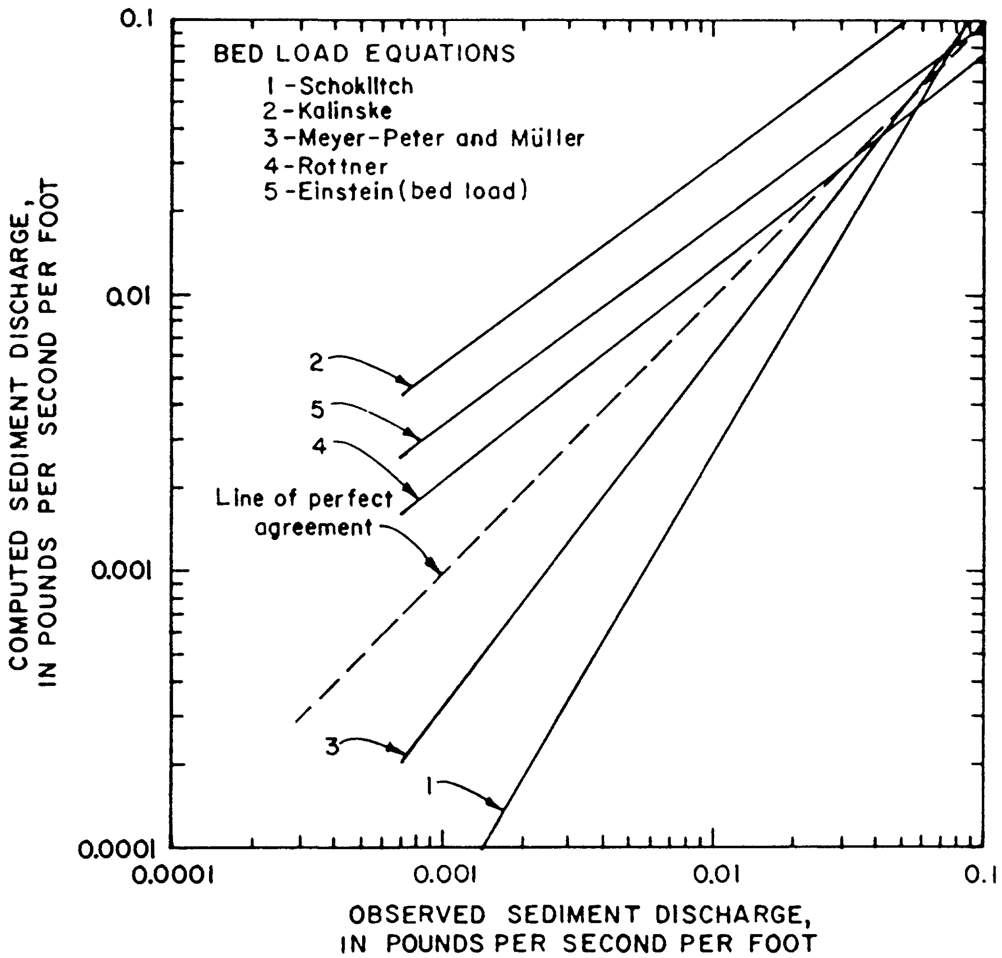

Figure 4.-- Comparison of bedload discharges computed by five formulas presented in this report to observed bed-material discharge, Mountain Creek (Data from Einstein, 1944)

Table 6.--Summary of comparisons of accuracies of seven bed-material formulas and five bedload formulas presented in this report

Author of formula	Discrepancy ratio[1]							
	Niobrara River data[2] 25 tests D_{50} 0.28 mm				Mountain Creek Data[3] 60 tests D_{50} 0.90 mm			
	Minimum	Maximum	Mean	Standard deviation	Minimum	Maximum	Mean	Standard deviation
Bed-material formulas								
Laursen (1958)	0.27	1.39	0.70	0.35	3.27	4.25	1.25	0.62
Engelund & Hansen (1967)	0.97	2.68	1.51	0.37	0.72	3.12	1.36	0.38
Colby (1964)	0.35	1.25	0.78	0.24	0.00	0.69	0.40	0.17
Ackers and White (1973)	0.53	1.58	1.07	0.31	0.60	3.00	1.46	0.45
Yang (1973)	0.56	1.52	0.94	0.21	0.75	2.38	1.33	0.33
Einstein (1950)	0.30	0.98	0.57	0.16	0.96	6.38	2.51	0.85
Toffaleti (1968)	0.47	1.88	0.88	0.32	0.10	2.75	0.68	0.48
Bedload formulas								
Schoklitsch (1934)	0.38	1.30	0.59	0.22	0.00	1.20	0.28	0.29
Kalinske (1947)	0.08	0.74	0.25	0.18	1.41	9.00	3.63	1.22
Meyer-Peter & Müller (1948)	0.11	0.31	0.16	0.05	0.00	1.10	0.58	0.26
Rottner (1959)	0.28	0.80	0.47	0.11	0.57	3.25	1.44	0.46
Einstein (1950)	0.19	0.62	0.29	0.10	0.79	5.26	2.17	0.76

[1] Ratio between computed and measured sediment concentration.

[2] From Colby and Hembree (1955)

[3] From Einstein (1944)

The comparisons of accuracy of different formulas made by different investigators as given in tables 1-5 show more consistency when laboratory data with high degree of measurement accuracy are used. However, when field data are used, there seems to be a lack of consistency in the degree of accuracy rated by the investigators. This may be caused by the variance in the measurement accuracy of the selected field data. The comparison studies indicate that the most accurate bed-material formulas are:

Yang (1973) for sand,
Ackers and White (1973),
Engelund and Hansen (1967), and
Yang (1984) for gravel.

The best bedload formulas are:

Schoklitsch (1934), and
Meyer-Peter and Müller (1948)

SELECTION OF A SEDIMENT-DISCHARGE FORMULA

Sediment-discharge rates depend on such variables as flow velocity; energy slope; water temperature; size, gradation, and shape of the bed material and suspended-sediment particles; channel geometry and pattern; extent of bed surface covered by coarse material; rate of supply of fine material; and bed configuration. Large-scale variables such as hydrologic, geologic, and climatic conditions also affect the rate of sediment transport. Because of the range and number of variables, it is not possible to select a sediment transport formula that satisfactorily encompasses all the conditions that an investigator would encounter. A specific formula may be more accurate than others when applied to a particular river but it may not be accurate for other rivers. The following procedure, based on Yang (1988) with minor modifications, helps assist in the selection of a sediment transport formula.

1. Determine the type of field data available or measurable within the time, budget, and manpower limitations.
2. Examine all experimental and field data used to develop and verify each formula and select those formulas that are based on independent variables determined from step 1.
3. Compare the field situation and the limitations of formulas selected in step 2. If more than one formula can be used, calculate the rate of sediment discharge by each formula and

compare results.

4. Decide which formulas best agree with available measured sediment discharges and use these formulas to estimate the rate of sediment discharge during flow conditions when actual measurements are not available.
5. Consideration may be made of the following formulas in the absence of any measured sediment discharges for comparison:
   a. Meyer-Peter and Müller (1948) formula when the bed material is coarser than 5 mm.
   b. Einstein (1950) formula when bedload is a substantial part of the total-sediment discharge.
   c. Toffaleti (1968) formula for large sand-bed rivers.
   d. Colby (1964) formula for rivers with depths less than 10 feet and median bed-material values less than 0.8 mm.
   e. Yang (1973) sand formula for sand bed rivers.
   f. Yang (1984) formula for gravel transport when most of the bed material ranges from 2 to 10 mm.
   g. Acker and White (1973) or Engelund and Hansen (1967) formula for sand bed streams having subcritical flow.
   h. Laursen (1958) formula for shallow rivers with fine sand or coarse silt.
   i. Other formulas from the 13 presented in this report according to their degree of accuracy presented in the section "Evaluation of sediment discharge formulas".

To develop an empirical sediment discharge curve in the absence of a satisfactory sediment discharge formula, or to verify the sediment discharge trend from a selected formula use available data from the stream sediment discharge station and plot measured sediment discharge or concentration against water discharge, velocity, slope, depth, shear stress, stream power, or unit stream power. The curve with the least scatter and systematic deviation should to be selected as the sediment rating curve for the station.

COMPUTER PROGRAMS

Two versions of computer programs DISDATA and SEDDISCH are presented. The FORTRAN 77 language versions are for use on the Prime computer, and the BASIC language versions are for use on microcomputers.

Program DISDATA

The FORTRAN program for entering discharge data is organized in the form of a main program called DISDATA, six executable subroutines, and one BLOCK DATA subprogram (see Supplemental Data Section A). The counterpart BASIC program (see Supplemental Data Section C) contains minor variations of the FORTRAN program because of differences between the two computer languages. Both versions are interactive and the user is prompted for specific input. The main difference between the two versions is that the FORTRAN data file is random access; data sets are read and stored individually and the maximum number of data sets in the file is not fixed. The BASIC data file is sequential access; all data sets are read or stored in a single disk operation. To prevent loss of data, the BASIC program stores data on the disk whenever 10 data sets are entered into memory. The maximum number of data sets allowable in a single sequential file is 30.

When a listing of the data file is requested, the FORTRAN version of the program stores the listing on a file named DISDATA.LIST and later the listing is printed using a line printer. The BASIC version directs the output to be printed directly by an 80 column line printer without intermediate storage.

Data Input

Discharge data are entered by keyboard and are stored in a file called DISCH.DAT or a user-specified file. The following variables form a data set:

LOC - Location name, or other identifiers such as date and time;
W - Top width, in ft;
Y - Mean depth, in ft;

V - Mean velocity, in ft/s;

S - Water surface slope, in ft per ft;

TEMP - Water temperature, in ^{o}C;

D35 - Particle size, in mm, at which 35 percent of the bed material by weight is finer. Enter zero if not required.

D50 - Particle size, in mm, at which 50 percent of the bed material by weight is finer.

D65 - Particle size, in mm, at which 65 percent of the bed material by weight is finer. Enter zero if not required.

D90 - Particle size, in mm, at which 90 percent of the bed material by weight is finer. Enter zero if not required.

Stevens and Hubbell (1986) presented a computer program to compute D35, D50, D65 and D90 from particle size data.

Bed-material particle size data are entered depending on the value of the option code, NSZ, selected at the start of the run:

1. No size distribution data to be entered. Zero values are given to the percent-in-class variables (PCT) for the following 11 size fractions:
   1. 0.016 - 0.062 mm
   2. 0.062 - 0.125 mm
   3. 0.125 - 0.250 mm
   4. 0.250 - 0.500 mm
   5. 0.500 - 1.000 mm
   6. 1.000 - 2.000 mm
   7. 2.000 - 4.000 mm
   8. 4.000 - 8.000 mm
   9. 8.000 - 16.000 mm
   10. 16.000 - 32.000 mm
   11. 32.000 - 64.000 mm.
2. Percent-finer values (PF) are entered for 11 sizes from 0.062 to 64 mm. Zeroes are entered for the percent-finer value for all sizes for which no value was defined. Percent-in-class values are computed.
3. Percent-in-class values are entered for 11 sizes from 0.062 to 64 mm. Zeros are entered for the percent-in-class value for all sizes for which no value was defined. Two data files, each

containing one data set, are shown in Section E of the supplemental data at the back of this report. Size fraction data were not entered in file REPT2.DAT.

Program Description

The program is initiated by opening a data file called DISCH.DAT or a user-named file. A file-option code, NFL, is entered to do one of the following functions:

1. Is to start a new data file;
2. Is to add to an existing data file.

If NFL > 1, the number of data sets, NSET, is read from the data file; otherwise, NSET is set to 0.

A program option code, NC, is entered to do one of the following functions:

0. Is to end run;
1. Is to add data;
2. Is to correct one or more data sets;
3. Is to display data on screen; and
4. Is to list data on printer.

When NC = 0, the data file is closed and the run ends.
When NC = 1, data sets are added by the following procedure:

A. The value of NSZ, the size fraction input option is entered.
    1. Is for no size fraction data to be entered;
    2. Is to enter percent-finer values, PF, for the 11 size diameters; and
    3. Is to enter percent-in-class values, PCT, for the 11 size fractions.

B. The option to enter more data is selected (1 for yes or 2 for no). If the response is no, the program goes back for another entry of the program-option code, NC.

C. NSET is increased by one.

D. Subroutine DAIN is accessed to enter a set of data as follows:
    1. Values of LOC, width, depth, velocity, slope, temperature, D35, D50, D65, and D90 are entered;
    2. Percent finer, PF, and percent-in-class, PCT, values are set to zero;
    3. If NSZ = 1, the program goes to step E;

4. If NSZ = 2, percent finer values are entered and the program goes to step E; or
5. If NSZ = 3, percent-in-class values are entered and the program goes to step E.

E. After subroutine DALIST is accessed to list the data set on the screen, an option code is entered.
1. Is to accept the data as correct;
2. Is to reenter the entire data set; and
3. Is to correct part of the data set.

If the data set is correct, option 1, subroutine DAWRITE is accessed to write the data set on the data file, and the program goes back to step B for another data set. If the entire data set is to be reentered, option 2, the program goes back to step D. With option 3, subroutine DACORR is called. In subroutine DACORR, one of the following options is selected by entering the corresponding data-correction number:

0. Is to end corrections and go back to E;
1. Is to change LOC;
2. Is to change width;
3. Is to change depth;
4. Is to change velocity;
5. Is to change slope;
6. Is to change temperature;
7. Is to change D35;
8. Is to change D50;
9. Is to change D65;
10. Is to change D90; and

11-21. Are to change PCT values 1-11.

For numbers 1-21, after the current value is displayed, a new value is entered; then the above menu is redisplayed so a new data-correction number can be selected.

Data sets are corrected (NC = 2) by the following procedure:

A. The number of the data set to be corrected is entered; a value of 0 ends the corrections, and the program goes back for another entry of the program option code, NC. Otherwise in sequence, subroutine DAREAD is accessed called to input the data set from the data file, subroutine DALIST is accessed to list the data set on the screen, and subroutine DACORR is accessed to permit values in the data set to be corrected. Correction procedures are identical to those previously described in step E.

B. Lastly, subroutine DALIST is accessed to list the corrected data set. If the data set still is not correct, the appropriate "change" option is selected. Otherwise, 0 is entered, and subroutine DAWRITE is accessed to write the data set on the data file. The program then goes back to step A.

Data sets are listed on the screen (NC = 3) in the following manner:

A. The starting and ending numbers of the data sets to be listed are entered. A starting value of 0 ends the listing, and the program goes back for another entry of the program option code, NC.

B. For each data set, subroutine DAREAD is accessed to input the data set from the data file, and subroutine DALIST is accessed to list the data set on the screen. The display is held on the screen until any number key is pressed. At the end of the last data set the program goes back to A.

Data sets are listed by the printer (NC = 4) by the following sequence:

A. The starting and ending numbers of the data sets to be printed are entered. A starting value of 0 ends the printing and the program goes back for another entry of the program-option code, NC.

B. For each data set, subroutine DAREAD is accessed to input the data set from the data file. The data set then is directed to an output file called DISDATA.LIST in the FORTRAN version of the program, or to a line printer in the BASIC version. At the end of the last data set the program goes back to A. The file DISDATA.LIST is printed using the line printer. Output from two data files that each contain one data set are shown in Supplemental Data Section E.

Program SEDDISCH

The FORTRAN program for computing sediment discharge is organized in the form of a main program called SEDDISCH and 20 subroutines (See Supplemental Data Section B). Program variables and counterpart text symbols used in the equations describing the sediment discharge formulas are defined in the section "Text symbols and program variables". The BASIC program (See Supplemental Data Section D) contains minor variations from the FORTRAN program because of the differences between the two languages: however, the FORTRAN program description can be used in addition to the program variable definitions (See section "Text symbols and program variables") to understand the BASIC program.

Program output

Output from the FORTRAN version of program SEDDISCH is stored on a file named DISCH.OUT or a user-specified file, and later the output is printed using the line printer. The BASIC version directs the output to be printed directly by an 80-column line printer without intermediate storage.

FORTRAN-version outputs from three runs are shown in Supplemental Data Section F. The initial section of the output lists the input data and some of the computed variables. Run 1 (p. F1-F2) shows output from data file REPT1.DAT with size fraction listing. Run 2 (p. F3) also shows output from data file REPT1.DAT with only totals listed. Run 3 (p. F4), using data file REPT2.DAT, shows the results when size-fraction data are not entered.

Program description

Program SEDDISCH is begun by entering the value of NTYPE, the option number for the type(s) of sediment transport formulas to be used.

1. Is for bed-material discharge formulas.
2. Is for bedload discharge formulas.
3. Is for both types of discharge formulas.

LSF, the size fraction listing option is set equal to zero for no size fraction output listing. If NTYPE = 1 or NTYPE = 3 the numbers of the bed-material discharge formulas to be used are entered. The maximum number of formula numbers is 12. Formula numbers are:

1. Laursen formula (uses size fractions);
2. Engelund and Hansen formula (uses D50);
3. Colby formula (uses D50);
4. Ackers and White formula (using D50);
5. Ackers and White formula (using D35);
6. Yang sand formula (using D50);
7. Yang sand formula (using size fractions);
8. Yang gravel formula (using D50);

9. Yang gravel formula (using size fractions);
10. Combine 7 and 9 (uses size fractions);
11. Einstein formula (uses size fractions); and
12. Toffaleti formula (uses size fractions).

If NTYPE = 2 or NTYPE = 3, the numbers of the bedload discharge formulas to be used are entered. The maximum number of formula numbers is 8. Formula numbers are:

1. Schoklitsch formula (uses size fractions);
2. Kalinske formula (uses size fractions);
3. Meyer-Peter and Müller formula (uses size fractions) Use QS/Q = 1 and NS computed from equation;
4. Meyer-Peter and Müller formula (uses size fractions) For rectangular channel and enter roughness values;
5. Meyer-Peter and Müller formula (uses size fractions) For trapezoidal channel and enter roughness values;
6. Rottner formula (uses D50);
7. Einstein bedload formula (uses size fractions); and
8. Toffaleti formula - bedload part (uses size fractions).

For each formula selected that uses size fractions, the value of LSF is increased by 1. If LSF>0 at the end of the formula selection, an opportunity is given to change the value of LSF to 0 for no size-fraction output listing.

The program next accesses the data file created by program DISDATA -- either DISCH.DAT or the counterpart user-specified file; opens an output file -- either DISCH.OUT or user-specified file; reads the number of data sets, NSAMP; and starts a computation loop (NS=1,NSAMP) for each data set.

The data set is read from the data file, and the following variables are computed:

1. XNU, Kinematic viscosity;
2. FV50, fall velocity of D50 computed by the Rubey (1933) equation;
3. U, Shear velocity; and
4. Q, water discharge.

Then the data set and computed variables are written on the output file.

If NTYPE = 1 or NTYPE = 3, the bed-material discharges are computed with the indicated formulas by accessing the appropriate subroutine(s). If NTYPE = 2 or NTYPE = 3, the bedload discharges are computed with the indicated formulas by accessing the appropriate subroutine(s). The computed sediment concentration, C, sediment discharge per unit width, UGS, and sediment discharge, GS, are written on the output file. If LSF>0 the data are written for each size fraction for formulas that compute values for each size fraction (See Supplemental Data Section F, p. F1-F2.).

The program then goes back to read another set of data from the data file. When all data sets have been computed, the program terminates.

SUMMARY

The assumptions used and theoretical basis of thirteen fluvial sediment-discharge formulas, five bedload discharge formulas and eight bed-material discharge formulas, are presented. Selection of the formulas was based on; 1) has some theoretical background, 2) has been tested by original author and independent investigator(s), and 3) has been commonly used by engineers and researchers. A review of comparisons made by different investigators of measured flume and field data with computed results from the formulas indicate that the bedload formulas of Schoklitch (1934) and Meyer-Peter and Müller (1948); and the bed-material formulas of Yang (1973), Ackers and White (1973), and Engelund and Hansen (1967) for sand, and Yang (1984) for gravel are the most reliable. A procedure, based on comparisons of data used to develop the formula with available data and a review of the formula background, is given to aid in the selection of an appropriate formula for given situations.

FORTRAN 77 language and BASIC language versions of computer programs are presented for inputing data (DISDATA) and for computing sediment discharge (SEDDISCH) by formulas selected by the user from the 13 described formulas.

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TEXT SYMBOLS AND PROGRAM VARIABLES

TEXT SYMBOL	PROGRAM VARIABLE	
A	AA	Value of the Froude number at nominal initial motion (Ackers and White, 1973)
A	AVAL	Dimensionless distance of the lower limit of integration (Einstein, 1950)
A	A	A correction factor which replaces Einstein's (1950) ξ, Y, and θ (Toffaleti, 1968)
A	A	Coefficient (Colby, 1964)
AF	AF	Temperature adjustment coefficient (Colby, 1964)
AM	AM	U_*' times 10 (Toffaleti, 1968)
B	B	Bottom width of trapezoidal channel, in feet (Meyer-Peter and Müller, 1948)
B	B	Exponent (Colby, 1964)
$\bar{C}$	---	Mean concentration of bed-material discharge, in percent by weight (Laursen, 1958)
C	C	Concentration of bed-material discharge, in parts per million by weight
---	CI	Concentration of bed-material discharge for a size fraction, in parts per million by weight
CF	CF	Temperature adjustment coefficient (Colby, 1964)
C_A	CA	Coefficient in the general function (Ackers and White, 1973)
C_a	---	Suspended-sediment concentration at distance "a" above the bed (Einstein, 1950)
C_i	CI	Computed sediment concentration in the size fraction, i
C_v	CV	Velocity distribution parameter (Toffaleti, 1968)
C_y	---	Suspended-sediment concentration at distance "y" above the bed (Einstein, 1950)
C_z	CZ	A temperature related parameter used in evaluating ZOM (Toffaleti, 1968)

TEXT SYMBOL	PROGRAM VARIABLE	
D	---	Mean grain diameter, in in. (Schoklitsch, 1934)
DD	DD	Two times the bed sediment grain diameter (Toffaleti, 1968)
D_{si}	DFT	Mean grain diameter , in ft, of the sediment in size fraction, i, or meters in the original equation of Meyer-Peter and Müller (1948)
D_{35}	D35	Particle size, in mm, at which 35 percent of the bed material by weight is finer
D_{35}	DF35	Particle size, in ft, at which 35 percent of the bed material by weight is finer
D_{50}	D50	Median grain diameter or particle size, in mm, at which 50 percent of the bed material by weight is finer
D_{50}	DF50	Median grain diameter or particle size, in ft, at which 50 percent of the bed material by weight is finer
D_{65}	D65	Particle size, in mm, at which 65 percent of the bed material by weight is finer
D_{65}	DF65	Particle size, in ft, at which 65 percent of the bed material by weight is finer
D_{90}	D90	Particle size, in mm, at which 90 percent of the bed material by weight is finer, or meters in original equation of Meyer-Peter and Müller (1948)
D_m	DM	Effective diameter, in mm, of the bed-material mixture, or meters in original equation of Meyer-Peter and Müller (1948)
D_{gr}	DGR	Dimensionless grain diameter (Ackers and White, 1973)
d	Y	Mean depth, in ft, or meters in original equation of Meyer-Peter and Müller (1948)
f	---	Denotes function of
F1	F1	Exponent in the point-discharge equation in the lower zone (Toffaleti, 1968)
F2	F2	Exponent in the point-discharge equation in the middle zone (Toffaleti, 1968)
F3	F3	Exponent in the point-discharge equation in the upper zone (Toffaleti, 1968)

TEXT SYMBOL	PROGRAM VARIABLE	
F4	F4	Exponent of the integrated-discharge equation in the lower zone (Toffaleti, 1968)
F5	F5	Exponent of the integrated-discharge equation in the middle zone (Toffaleti, 1968)
F6	F6	Exponent of the integrated-discharge equation in the upper zone (Toffaleti, 1968)
F_{gr}	---	Dimensionless sediment mobility number (Ackers and White, 1973)
---	FV50	Fall velocity of D_{50}, in ft/s, computed by Rubey equation
f'	---	Friction factor (Engelund and Hansen, 1967)
G_s	---	Bedload discharge, in lb/s (Schoklitsch, 1934)
GA	GA	Integrated bed-material discharge, in t/d, for a size fraction in the lower zone; bed to YA (Toffaleti, 1968)
GB	GB	Integrated bed-material discharge, in t/d, for a size fraction in the middle zone; YA to YB (Toffaleti, 1968)
GBL	UGSI	Bedload discharge, in t/d (Toffaleti, 1968)
GC	GC	Integrated bed-material discharge, in t/d, for a size fraction in the upper zone; YB to surface (Toffaleti, 1968)
GF	GFB	Discharge, in t/d per ft of width, moving in the vertical section between levels from 2 times the grain diameter to YA, and with the assumption that the bed is composed entirely of one sand fraction (Toffaleeti, 1968)
G_{gr}	GGR	Dimensionless sediment transport rate (Ackers and White)
G_T	UGSI	Bed-material discharge, in t/d (Toffaleti, 1968)
g	G	Acceleration of gravity, in ft/s/s or m/s/s in original equation of Meyer-Peter and Müller (1948)
g_s	UGS	Sediment discharge, in lb/s per ft of width, or t/s per m of width in original equation of Meyer-Peter and Müller (1948)

TEXT SYMBOL	PROGRAM VARIABLE	
---	UGSI	Sediment discharge, in lb/s per ft of width, for a size fraction
---	GS	Sediment discharge, in t/d
H	H	Side slope of a trapezoidal channel, in ft per ft (Meyer-Peter and Müller, 1948)
i_b	PCT	Fraction, by weight, of bed material in a given size fraction
$i_B q_B$	UNITBD	Bedload discharge for a size fraction, in lb/s per ft of width (Einstein, 1950)
$i_T q_T$	UGSI	Bed-material discharge for a size fraction, in lb/s per ft of width (Einstein, 1950)
I_1	FI1	Integral value (Einstein, 1950)
I_2	FI2	Integral value (Einstein, 1950)
J_1	FJ1	Integral function (Einstein, 1950)
J_2	FJ2	Integral function (Einstein, 1950)
K_s	---	Coefficient of bed roughness (Meyer-Peter and Müller, 1948)
K_r	---	Coefficient of particle roughness (Meyer-Peter and Müller, 1948)
---	LOC	Location name or other identifiers such as date and time
m	S1	Summation of all size fractions of i_b/D_{si} for all size fractions in the bed-material mixture (Kalinske, 1947)
m	AM	Exponent in the sediment transport function (Ackers and and White, 1973)
n	---	Number of size fractions in the bed-material mixture
n	AN	Transition exponent depending on sediment size (Ackers and White, 1973)
---	NC	Program DISDATA option code
n_s	NS	Manning's roughness value for the bed
n_m	NM	Roughness value for the total channel for Meyer-Peter and Müller (1948) equation (Sheppard, 1960)
---	NSZ	Bed-material size data entry option code
---	NFL	Program file option code
---	NSET	Number of data sets in the data file

TEXT SYMBOL	PROGRAM VARIABLE	
n_w	MW	Roughness value for the channel sides for Meyer-Peter and Müller (1948) equation (Sheppard, 1960)
P	P	Parameter of total transport (Einstein, 1950)
P	---	Kinematic viscosity times 10 (Toffaleti, 1968)
p_i	---	The proportion of the total bed area occupied by the sediment particles in size fraction, i (Kalinske, 1947)
--	PF	Bed-material percent-finer values
PAM	PAM	Parameter used to evaluate A (Toffaleti, 1968)
Q	Q	Water discharge, in ft^3/s, or l/s in original equation of Meyer-Peter and Müller (1948)
Q_s	QS	That part of the water discharge apportioned to the bed, in ft^3/s, or l/s in original equation of Meyer-Peter and Müller (1948)
q	---	Water discharge, ft^3/s per ft of width
q_o	---	Critical water discharge, in ft^3/s per ft of width, for sediment diameter D_{si} (Schoklitsch, 1934)
R_b	RB	Hydraulic radius, in ft (Einstein, 1950)
R_b'	RBP	Hydraulic radius with respect to the grain, in ft (Einstein, 1950)
R_b''	RBPP	Hydraulic radius for channel irregularities, in ft (Einstein, 1950)
S	S	Energy gradient, in ft per ft
S_g	SG	Specific gravity of the bed sediment
SI	SI	Variable used in the evaluation of ZOM (Toffaleti, 1968)
---	TEMP	Water temperature, in °C
T	T	A parameter that includes the constants and those components of the shear force that are a function of water temperature (Toffaleti, 1968)
TDF	TDF	Water temperature, in °F (Toffaleti, 1968)
$\bar{U}_g$	---	Average velocity of particles, in ft/s, in a size fraction, i (Kalinske, 1947)
$\bar{U}$	---	Mean velocity of flow, in ft/s, at the grain level (Kalinske, 1947)

TEXT SYMBOL	PROGRAM VARIABLE	
U'_*	SVP	Shear velocity, in ft/s, with respect to the grain (Einstein, 1950, and Toffaleti, 1968)
UBL	UBL	Concentration of the bedload layer, in lb/ft^3, considering the bed composed entirely of the sand fraction under consideration (Toffaleti, 1968)
UD	UD	Point velocity at y=2D (Toffaleti, 1968)
U1	U1	Correlation of V and U'_* (Toffaleti, 1968)
U2	U2	Parameter for evaluating U'_* (Toffaleti, 1968)
U3	U3	Parameter for evaluating U'_* (Toffaleti, 1968)
V	V	Mean velocity, in ft/s
V_*	U	Shear velocity, in ft/s
V_c	VC	Critical velocity, in ft/s (Colby, 1964)
V_{cr}	---	Average flow velocity, in ft/s, at incipient motion (Yang, 1973, and Yang, 1984)
W	W	Top width of channel, in ft
x	XR	Dimensionless transition parameter (Einstein, 1950)
X	---	Sediment discharge concentration in mass flux per unit mass flow rate (Ackers and White, 1973)
X	CAPX	Characteristic grain size of the mixture (Einstein, 1950)
Y	CAPY	Pressure correction in transition from smooth to rough (Einstein, 1950)
YA	YA	Distance, in ft, from the bed to the upper limit of the lower zone (Toffaleti, 1968)
YB	YB	Distance, in ft, from the bed to the upper limit of the middle zone (Toffaleti, 1968)
Y_c	YC	Coefficient relating critical tractive force to sediment size (Laursen, 1958)
Z	ZC	Exponent of suspended distribution (Einstein, 1950)
Z_v	ZV	Exponent of velocity distribution (Toffaleti, 1968)
ZOM	ZOM	Exponent of sand concentration distribution in the middle zone (Toffaleti, 1968)
α	---	Coefficient in the rough turbulent equation with a value of 10 (Ackers and White, 1973)
β_x	BETAX	Logarithmic function (Einstein, 1950)

TEXT SYMBOL	PROGRAM VARIABLE	
γ	---	Specific weight of water, in lb/ft^3, or 1 t/m^3 in original equation of Meyer-Peter and Müller, 1948
γ_s	GMS	Specific weight of sediment, in lb/ft^3
γ'_s	---	Specific weight of sediment under water, and equals 1.65 t/m^3 in the original equation of Meyer-Peter and Müller (1948)
δ	DELTA	Thickness, in ft, of the laminar sublayer (Laursen, 1958)
δ'	DELTA	Laminar sublayer thickness, in ft, for U'_* (Einstein, 1950)
Δ	DELT	Apparant roughness parameter (Einstein, 1950)
θ	---	Dimensionless shear parameter (Engelund and Hansen, 1967)
ρ	---	Density of water, in slugs per ft^3
τ_o	TO	Total shear at the bed, in lb/ft^3
τ_{ci}	T1	Critical tractive force, in lb/ft^2, for sediment in a size fraction, i (Kalinske, 1947)
τ_c	---	Critical shear stress for particles of a size fraction Laursen, 1958)
τ'_o	---	Bed shear stress due to grain resistence (Laursen, 1958)
ν	XNU	Kinematic viscosity, in ft^2/s
ξ	XI	"Hiding factor" for grains in the bed mixture (Einstein, 1950)
ϕ	---	Dimensionless sediment discharge (Engelund and Hansen, 1967)
ϕ_*	PHI	Intensity of transport for individual grain size (Einstein, 1950)
ψ	---	Intensity of shear on the particles of a size fraction (Einstein, 1950)
ψ_*	PSIS	Adjusted intensity of shear on particles of a size fraction (Einstein, 1950)
ω	FV	Fall velocity, in ft/s, of sediment particles of diameter D_{50}
ω_i	FVI	Fall velocity, in ft/s, of sediment particles of diameter D_{si}

SUPPLEMENTAL DATA--SECTION A.

FORTRAN PROGRAM DISDATA LISTING

```
      PROGRAM DISDATA
C
C     ENTER SEDIMENT DISCHARGE PROGRAM DATA TO INPUT FILE DISCH.DATA
C             OR USER SPECIFIED FILE.
C
      COMMON /AA/ LOC,VAR(9),PCT(11),PF(11),SIZELO(11),SIZEHI(11),
     1 LABEL(10),NREC
      CHARACTER*80 LOC
      CHARACTER*20 DFILE
      CHARACTER*5 LABEL
      CHARACTER*1 RSP
    1 FORMAT (1H0,'SET NUMBER',I4)
    2 FORMAT (1H1,'DATA STORED ON FILE ',A20 / 1H )
    3 FORMAT (1H ,I2,2X,A5,1X,A80)
    4 FORMAT (1H ,3(I2,2X,A5,F10.3,7X),I2,2X,A5,F13.7)
    5 FORMAT (1H ,4(I2,2X,A5,F10.3,7X),I2,2X,A5,F10.3)
    6 FORMAT (1H ,2(I2,2F9.3,F7.2,5X),I2,2F9.3,F7.2)
    7 FORMAT (A20)
    8 FORMAT ('DATA STORED ON FILE  ',A20,'   NUMBER DATA SETS = ',I4)
    9 FORMAT ('ENTER SET NUMBER   MAX =',I4,'   0 TO END')
   10 FORMAT ('NUMBER DATA SETS =',I4)
   11 FORMAT ('ENTER START SET NUMBER   MAX =',I4,'   0 TO END')
   12 FORMAT ('ENTER END SET NUMBER   MAX =',I4)
   13 FORMAT (1H ,5X,'0. END RUN USING ',A20 / 1H ,5X,'1. ADD DATA TO ',
     1 A20 / 1H ,5X,'2. CORRECT DATA IN ',A20 / 1H ,5X,'3. DISPLAY DATA
     2IN ',A20 / 1H ,5X,'4. PRINT DATA IN ',A20 )
   14 FORMAT (1H ,'   PERCENT IN INDICATED SIZE FRACTION, IN MM')
   15 FORMAT (1H ,5X,'1. ',A20,' IS A NEW FILE' / 1H ,5X,'2. ',A20,
     1 ' IS AN EXISTING FILE')
      DFILE='DISCH.DAT'
      CALL CLSCR(25)
      WRITE (1,*) 'ESTABLISH FILE NAME:'
      WRITE (1,*) '             '
      WRITE (1,*) '      1 TO USE DISCH.DAT'
      WRITE (1,*) '      2 TO ENTER FILE NAME'
      CALL CLSCR(3)
      WRITE (1,*) 'ENTER NUMBER OF SELECTION'
      READ (1,*) I
      IF (I.LT.2) GO TO 30
      CALL CLSCR(10)
      WRITE (1,*) 'ENTER DESIRED FILE NAME'
      READ (1,7) DFILE
   30 CALL CLSCR(10)
      WRITE (1,15) DFILE,DFILE
      CALL CLSCR(3)
      WRITE (1,*) 'ENTER NUMBER OF SELECTION'
      READ (1,*) NFL
      IF (NFL.GT.1) GO TO 40
      NSET=0
      NREC=1
      OPEN (10,FILE=DFILE,STATUS='NEW',ACCESS='DIRECT',RECL=40)
```

```
      GO TO 100
   40 NSZ=1
      OPEN (10,FILE=DFILE,STATUS='OLD',ACCESS='DIRECT',RECL=40)
      READ (10,REC=1) NSET
   50 CALL CLSCR(25)
      WRITE (1,13) DFILE,DFILE,DFILE,DFILE,DFILE
      CALL CLSCR(3)
      WRITE (1,*) 'ENTER NUMBER OF SELECTION'
      CALL CLSCR(10)
      READ (1,*) NC
      IF (NC.GT.4) GO TO 50
      IF (NC.GT.0) GO TO 80
      CALL CLSCR(10)
      WRITE (1,8) DFILE,NSET
      WRITE (10,REC=1) NSET
      CLOSE (10)
      CALL CLSCR (5)
      WRITE (1,*) 'END OF RUN'
      CALL EXIT
   80 GO TO (90,200,300,400),NC
   90 NREC=NSET*3+1
C     ENTER DATA
  100 CALL CLSCR(25)
      WRITE (1,*) 'METHOD OF ENTERING SIZE FRACTION'
      WRITE (1,*) '                 '
      WRITE (1,*) '     1. NO SIZE FRACTION DATA TO BE ENTERED'
      WRITE (1,*) '     2. DATA ENTERED BY PERCENT FINER VALUES'
      WRITE (1,*) '     3. DATA ENTERED BY PERCENT IN SIZE FRACTION'
      CALL CLSCR(5)
      WRITE (1,*) 'ENTER NUMBER OF SELECTION'
      READ (1,*) NSZ
      IF (NSZ.GT.3) GO TO 100
      IF (NFL.EQ.1.OR.NC.EQ.1) GO TO 120
  110 CALL CLSCR(25)
      WRITE (1,*) 'INPUT MORE DATA:  1 FOR YES  2 FOR NO'
      READ (1,*) I
      IF (I.EQ.1) GO TO 120
      IF (NFL.GT.1) GO TO 50
      WRITE (10,REC=1) NSET
      CLOSE (10)
      GO TO 40
  120 NSET=NSET+1
  130 CALL DAIN (NSZ,NPF)
  140 CALL DALIST (NSET,NSZ)
      WRITE (1,*) '
      WRITE (1,*) '   1 FOR DATA OK'
      WRITE (1,*) '   2 TO RE-ENTER COMPLETE SET OF DATA'
      WRITE (1,*) '   3 TO CORRECT PART OF DATA SET'
      WRITE (1,*) 'ENTER NUMBER'
      READ (1,*) I
      GO TO (160,130,150),I
  150 CALL DACORR (NSET,NSZ,NPF)
      GO TO 140
```

```
  160 IF (NSZ.NE.2) GO TO 180
      PCT(1)=PF(1)
      DO 170 I=2,NPF
      PCT(I)=PF(I)-PF(I-1)
  170 CONTINUE
  180 CALL DAWRITE
      GO TO 110
C     CORRECT DATA
  200 CALL CLSCR(25)
      WRITE (1,9) NSET
      READ (1,*) NS
      IF (NS.EQ.0) GO TO 50
      IF (NS.GT.NSET) GO TO 200
      NREC=(NS-1)*3+1
      CALL DAREAD
      CALL DACORR (NS,NSZ,NPF)
      NREC=(NS-1)*3+1
      CALL DAWRITE
      GOTO 200
C     LIST DATA ON SCREEN
  300 CALL CLSCR(25)
      WRITE (1,11) NSET
      READ (1,*) NS1
      IF (NS1.EQ.0) GO TO 50
      IF (NS1.GT.NSET) GO TO 300
      NREC=(NS1-1)*3+1
  310 CALL CLSCR(3)
      WRITE (1,12) NSET
      READ (1,*) NS2
      IF (NS2.GT.NSET) GO TO 310
      DO 320 NS=NS1,NS2
      CALL DAREAD
      CALL DALIST (NS,NSZ)
      WRITE (1,*) '
      WRITE (1,*) 'PUSH CARRIAGE RETURN TO CONTINUE'
      READ (1,'(A)') RSP
  320 CONTINUE
      GO TO 300
C     LIST DATA ON PRINTER
C     OUTPUT IS ON FILE DISDATA.LIST
  400 OPEN (11,FILE='DISDATA.LIST',STATUS='NEW')
      WRITE (11,2) DFILE
  410 CALL CLSCR(25)
      WRITE (1,11) NSET
      READ (1,*) NS1
      IF (NS1.EQ.0) GO TO 490
      IF (NS1.GT.NSET) GO TO 410
      NREC=(NS1-1)*3+1
  420 CALL CLSCR(3)
      WRITE (1,12) NSET
      READ (1,*) NS2
      IF (NS2.GT.NSET) GO TO 420
      DO 480 NS=NS1,NS2
```

```
      CALL DAREAD
      WRITE (11,1) NS
      I=1
      WRITE (11,3) I,LABEL(I),LOC
      WRITE (11,4) (I,LABEL(I),VAR(I-1),I=2,5)
      WRITE (11,5) (I,LABEL(I),VAR(I-1),I=6,10)
      WRITE (11,14)
      DO 430 I=11,20,3
      J1=I
      J2=I+2
      IF (I.EQ.20) J2=21
      WRITE (11,6) (J,SIZELO(J-10),SIZEHI(J-10),PCT(J-10),J=J1,J2)
  430 CONTINUE
  480 CONTINUE
      GO TO 410
  490 CLOSE (11)
      GO TO 50
      END
```

```
      BLOCK DATA
      COMMON /AA/ LOC,VAR(9),PCT(11),PF(11),SIZELO(11),SIZEHI(11),
     1 LABEL(10),NREC
      CHARACTER*80 LOC
      CHARACTER*5 LABEL
      DATA LABEL /'  LOC','WIDTH','DEPTH',' VEL.','SLOPE','TEMP.',
     1'  D35','  D50','  D65','  D90'/
      DATA SIZELO /0.016,0.062,0.125,0.25,0.5,1.,2.,4.,8.,16.,32./
      DATA SIZEHI /0.062,0.125,0.25,0.5,1.,2.,4.,8.,16.,32.,64./
      END
```

```
      SUBROUTINE DAIN (NSZ,NPF)
C     INPUT ONE SET OF DATA
      COMMON /AA/ LOC,VAR(9),PCT(11),PF(11),SIZELO(11),SIZEHI(11),
     1 LABEL(10),NREC
      CHARACTER*80 LOC
      CHARACTER*5 LABEL
    1 FORMAT (A80)
    2 FORMAT (F10.0)
    3 FORMAT ('ENTER PCT FINER THAN ',F6.3,' MM')
    4 FORMAT ('ENTER PCT MATERIAL FOR ',F6.3,' TO ',F6.3,
     1 ' MM   (0 FOR NONE)')
      CALL CLSCR(25)
      WRITE (1,*) 'ENTER LOCATION NAME (MAX 80 CHARACTERS)'
      READ (1,1,ERR=999) LOC
      WRITE (1,*) 'ENTER TOP WIDTH  (FT)'
      READ (1,2,ERR=999) VAR(1)
      WRITE (1,*) 'ENTER AVERAGE DEPTH  (FT)'
      READ (1,2,ERR=999) VAR(2)
      WRITE (1,*) 'ENTER AVERAGE VELOCITY  (FT/SEC)'
```

```
      READ (1,2,ERR=999) VAR(3)
      WRITE (1,*) 'ENTER WATER SURFACE SLOPE  (FT/FT)'
      READ (1,2,ERR=999) VAR(4)
      WRITE (1,*) 'ENTER WATER TEMPERATURE  (DEG C)'
      READ (1,2,ERR=999) VAR(5)
      WRITE (1,*) 'ENTER D35  (MM)  OR 0 FOR NONE'
      READ (1,2,ERR=999) VAR(6)
      WRITE (1,*) 'ENTER D50  (MM)'
      READ (1,2,ERR=999) VAR(7)
      WRITE (1,*) 'ENTER D65  (MM)  OR 0 FOR NONE'
      READ (1,2,ERR=999) VAR(8)
      WRITE (1,*) 'ENTER D90  (MM)  OR 0 FOR NONE'
      READ (1,2,ERR=999) VAR(9)
      CALL CLSCR(5)
      DO 40 I=1,11
      PF(I)=0
      PCT(I)=0
   40 CONTINUE
      IF (NSZ-2) 90,50,70
   50 NPF=0
   60 NPF=NPF+1
      WRITE (1,3) SIZEHI(NPF)
      READ (1,2,ERR=999) PF(NPF)
      IF (PF(NPF).GT.99.9) RETURN
      IF (NPF.LT.11) GO TO 60
      RETURN
   70 DO 80 I=1,11
      WRITE (1,4) SIZELO(I),SIZEHI(I)
      READ (1,2,ERR=999) PCT(I)
   80 CONTINUE
   90 RETURN
  999 WRITE (1,*) 'STOPPED ON INPUT ERROR'
      ENDFILE (10)
      CLOSE (10)
      CALL EXIT
      END


      SUBROUTINE DAWRITE
C     WRITE ONE SET OF DATA TO FILE
      COMMON /AA/ LOC,VAR(9),PCT(11),PF(11),SIZELO(11),SIZEHI(11),
     1 LABEL(10),NREC
      CHARACTER*80 LOC
      CHARACTER*5 LABEL
      NREC=NREC+1
      WRITE (10,REC=NREC) LOC
      NREC=NREC+1
      WRITE (10,REC=NREC) (VAR(I),I=1,9)
      NREC=NREC+1
      WRITE (10,REC=NREC) (PCT(I),I=1,11)
      RETURN
      END
```

```
      SUBROUTINE DAREAD
C     READ ONE SET OF DATA FROM FILE
      COMMON /AA/ LOC,VAR(9),PCT(11),PF(11),SIZELO(11),SIZEHI(11),
     1 LABEL(10),NREC
      CHARACTER*80 LOC
      CHARACTER*5 LABEL
      NREC=NREC+1
      READ (10,REC=NREC,ERR=100,END=200) LOC
      NREC=NREC+1
      READ (10,REC=NREC,ERR=100,END=200) (VAR(I),I=1,9)
      NREC=NREC+1
      READ (10,REC=NREC,ERR=100,END=200) (PCT(I),I=1,11)
      RETURN
  100 WRITE (1,*) 'ENDING WITH READ ERROR'
      CLOSE (10)
      CALL EXIT
  200 WRITE (1,*) 'STOPPED AT END-OF-FILE'
      CLOSE (10)
      CALL EXIT
      END
```

```
      SUBROUTINE DACORR (NSET,NSZ,NPF)
C     CORRECT ONE SET OF DATA
      COMMON /AA/ LOC,VAR(9),PCT(11),PF(11),SIZELO(11),SIZEHI(11),
     1 LABEL(10),NREC
      CHARACTER*80 LOC
      CHARACTER*5 LABEL
    2 FORMAT (A80)
    3 FORMAT ('OLD ',A5,' VALUE IS ',F10.7)
    4 FORMAT ('OLD ',A5,' VALUE IS ',F10.3)
    5 FORMAT ('OLD PERCENT VALUE IS ',F7.2)
    6 FORMAT ('OLD PCT FINER VALUE IS ',F7.2)
  100 CALL DALIST (NSET,NSZ)
      WRITE (1,*) '          '
      WRITE (1,*) 'ENTER VALUE NUMBER (1-21)  0 TO END'
      READ (1,*) L
      IF (L.EQ.0) RETURN
      IF (L.GT.21) GO TO 100
      IF (L.GT.1) GO TO 110
      WRITE (1,*) 'OLD LOCATION NAME IS '
      WRITE (1,2) LOC
      WRITE (1,*) 'ENTER NEW LOCATION NAME'
      READ (1,2) LOC
      GOTO 100
  110 IF (L.GT.10) GO TO 140
      IF (L.NE.5) GO TO 120
      WRITE (1,3) LABEL(L),VAR(L-1)
      GO TO 130
  120 WRITE (1,4) LABEL(L),VAR(L-1)
  130 WRITE (1,*) 'ENTER NEW VALUE'
      READ (1,*) VAR(L-1)
```

```
      GO TO 100
  140 I=L-10
      IF (NSZ.EQ.2) GO TO 150
      WRITE (1,5) PCT(I)
      WRITE (1,*) 'ENTER NEW VALUE'
      READ (1,*) PCT(I)
      GO TO 100
  150 WRITE (1,6) PF(I)
      WRITE (1,*) 'ENTER NEW VALUE'
      READ (1,*) PF(I)
      IF (PF(I).GT.99.9.OR.I.GT.NPF) NPF=I
      GO TO 100
      END


      SUBROUTINE DALIST (NSET,NSZ)
C     LIST ONE SET OF DATA ON SCREEN
      COMMON /AA/ LOC,VAR(9),PCT(11),PF(11),SIZELO(11),SIZEHI(11),
     1 LABEL(10),NREC
      CHARACTER*80 LOC
      CHARACTER*5 LABEL
    1 FORMAT ('SET NUMBER',I4)
    2 FORMAT (I2,2X,A5,1X,A80)
    3 FORMAT (I2,2X,A5,F10.3,10X,I2,2X,A5,F12.7)
    4 FORMAT (I2,2X,A5,F10.3,10X,I2,2X,A5,F10.3)
    5 FORMAT (I2,2F9.3,F7.2,6X,I2,2F9.3,F7.2)
    6 FORMAT (I2,F9.3,F7.2,6X,I2,F9.3,F7.2)
      CALL CLSCR(25)
      WRITE (1,1) NSET
      I=1
      WRITE (1,2) I,LABEL(I),LOC
      WRITE (1,4) (I,LABEL(I),VAR(I-1),I=2,3)
      WRITE (1,3) (I,LABEL(I),VAR(I-1),I=4,5)
      WRITE (1,4) (I,LABEL(I),VAR(I-1),I=6,10)
      IF (NSZ.EQ.2) GO TO 60
      WRITE (1,*) '   PERCENT IN INDICATED SIZE FRACTION IN MM'
      WRITE (1,5) (I,SIZELO(I-10),SIZEHI(I-10),PCT(I-10),I=11,21)
      RETURN
   60 WRITE (1,*) '   PERCENT FINER FOR INDICATED SIZE IN MM'
      WRITE (1,6) (I,SIZEHI(I-10),PF(I-10),I=11,21)
      RETURN
      END


      SUBROUTINE CLSCR(N)
C
C     MOVE CURSER DOWN N LINES
C
      DO 10 I=1,N
      WRITE (1,*)
   10 CONTINUE
```

```
      RETURN                                                            CLSC  80
      END                                                               CLSC  90
```

SUPPLEMENTAL DATA--SECTION B.

FORTRAN PROGRAM SEDDISCH LISTING

```
      PROGRAM SEDDISCH
C
C     COMPUTE BED MATERIAL & BED LOAD DISCHARGE BY SELECTED FORMULAS
C
      COMMON CI,DIA(11),DFT(11),D35,DF35,D50,DF50,D65,DF65,D90,DF90,G,
     1 GMS,IOS,LSF,FV50,PCT(11),S,SG,SIZELO(11),SIZEHI(11),SUMP,TEMP,U,
     2 UGSI,V,W,XNU,Y
      CHARACTER*80 LOC
      CHARACTER*20 DFILE,OFILE
      DIMENSION NOSEL(2,12),NOS(2)
    1 FORMAT (1H ,5X,'1.  BED-MATERIAL DISCHARGE FORMULAS' / 1H ,5X,'2.
     1 BEDLOAD DISCHARGE FORMULAS' / 1H ,5X,'3.  BOTH TYPES OF FORMULAS
     2 ')
    2 FORMAT (1H ,10X,'BED-MATERIAL DISCHARGE FORMULA OPTIONS:' / 1H  /
     1 1H ,' 1.  LAURSEN FORMULA   (USES SIZE FRACTIONS)' / 1H ,' 2.  EN
     2GELUND AND HANSEN FORMULA  (USES D50)' / 1H ,' 3.  COLBY FORMULA
     3 (USES D50)' / 1H ,' 4.  ACKERS AND WHITE FORMULA   (USING D50)' /
     4 1H ,' 5.  ACKERS AND WHITE  FORMULA   (USING D35)' / 1H ,' 6.  YA
     5NG SAND FORMULA   (USING D50)' / 1H ,' 7.  YANG SAND FORMULA   (US
     6ING SIZE FRACTIONS)' / 1H ,' 8.  YANG GRAVEL FORMULA   (USING D50)
     7' / 1H ,' 9.  YANG GRAVEL FORMULA   (USING SIZE FRACTIONS)' /
     8 1H ,'10.  COMBINE 7 AND 9   (USES SIZE FRACTIONS)'/ 1H ,'11.  EIN
     9STEIN FORMULA   (USES SIZE FRACTIONS)' / 1H ,'12.  TOFFALETI FORMU
     1LA   (USES SIZE FRACTIONS)' )
    3 FORMAT (1H ,'ENTER FORMULA NUMBER FOR COMPUTATION NUMBER',I4,
     1 '   (0 TO END)' )
    4 FORMAT (1H ,10X,'BEDLOAD DISCHARGE FORMULA OPTIONS:' / 1H  / 1H ,
     1 '1.  SCHOKLITSCH FORMULA   (USES SIZE FRACTIONS)' / 1H ,'2.  KALI
     2NSKE FORMULA   (USES SIZE FRACTIONS)' / 1H ,'3.  MEYER-PETER AND M
     3ULLER FORMULA   (USES SIZE FRACTIONS)' / 1H ,'    USE QS/Q=1 AND N
     4S COMPUTED FROM EQUATION' / 1H ,'4.  MEYER-PETER AND MULLER FORMUL
     5A   (USES SIZE FRACTIONS)' / 1H ,'    FOR RECTANGULAR CHANNEL AND
     6ENTER ROUGHNESS VALUES' / 1H ,'5.  MEYER-PETER AND MULLER FORMULA
     7  (USES SIZE FRACTIONS)' / 1H ,'    FOR TRAPEZOIDAL CHANNEL AND EN
     8TER ROUGHNESS VALUES' / 1H ,'6.  ROTTNER FORMULA   (USES D50)' / 1
     9H ,'7.  EINSTEIN BEDLOAD FORMULA   (USES SIZE FRACTIONS)' / 1H ,'8
     1.  TOFFALETTI FORMULA - BEDLOAD PART   (USES SIZE FRACTIONS)')
    5 FORMAT (1H ,'LIST RESULTS BY:' / 1H  / 1H ,'     1.  FOR EACH FRAC
     1TION AND TOTAL' / 1H ,'     2.  TOTAL ONLY' )
    6 FORMAT (1H ,'ESTABLISH DATA FILE NAME:' / 1H  / 1H ,'     1.  USE
     1PROGRAMMED FILE NAME (DISCH.DAT)' / 1H ,'     2.  PROVIDE FILE NAM
     2E' )
    7 FORMAT (A20)
    8 FORMAT (1H ,'ESTABLISH OUTPUT FILE NAME:' / 1H  / 1H ,'     1.  US
     1E PROGRAMMED FILE NAME (DISCH.OUT)' / 1H ,'     2.  PROVIDE FILE N
     2AME' )
    9 FORMAT (1H1)
   10 FORMAT (1H ,A80 / 1H  / 1H ,'TOP WIDTH',12X,F8.2,' FEET     WATER
     1 SURF. SLOPE',6X,F10.7,' FT/FT' / 1H ,'MEAN DEPTH',13X,F6.2,' FEET
     2',6X,'D50',18X,F6.3,' MILLIMETERS' / 1H ,'MEAN VELOCITY',9X,F5.2,'
     3 FT/SEC',6X,'KINEMATIC VISCOCITY',9X,F11.8 / 1H ,'WATER DISCHARGE'
```

```
     4,5X,F10.2,' CFS',6X,'SED. FALL VELOCITY',7X,F7.4,' FT/SEC' / 1H ,
     5 'WATER TEMPERATURE',7X,F4.1,' DEG C' )
   11 FORMAT (1H0,10X,'COMPUTED BED-MATERIAL CONCENTRATION AND DISCHARGE
     1 ' / 1H0,'FORMULA',42X,'CONC.   UNIT DISCH   DISCHARGE' / 1H ,50X,
     2 'PPM    LBS/SEC/FT   TONS/DAY' / 1H  )
   12 FORMAT (1H0,10X,'COMPUTED BEDLOAD CONCENTRATION AND DISCHARGE' /
     1 1H0,'FORMULA',42X,'CONC.   UNIT DISCH   DISCHARGE' / 1H ,50X,'PPM
     2    LBS/SEC/FT   TONS/DAY' / 1H  )
   13 FORMAT (1H0 / 1H0,'* * * * * * * * * * * * * * * * * * * * * * * *
     1 * * * * * * * * * * * * * * * * *' / 1H0)
   14 FORMAT (1H0,'*** READ ERROR ON FILE ',A20,' ***' )
   15 FORMAT (1H0,'*** END-OF-FILE ON FILE ',A20,' ***' )
   16 FORMAT (1H ,'OUTPUT ON FILE ',A20 / 1H ,'END OF RUN' )
C
      DATA SIZELO/0.016,.062,.125,.25,.5,1,2,4,8,16,32/
      DATA SIZEHI/0.062,0.125,0.25,0.5,1,2,4,8,16,32,64/
      DO 20 I=1,11
      DIA(I)=(SIZELO(I)*SIZEHI(I))**.5
      DFT(I)=DIA(I)/304.8
   20 CONTINUE
      SG=2.65
      G=32.1725
      GMS=165.76
C
C     ENTER FORMULA NUMBERS TO BE COMPUTED
C
      NOS(1)=0
      NOS(2)=0
      LSF=0
   30 CALL CLSCR(25)
      WRITE (1,1)
      CALL CLSCR(3)
      WRITE (1,*) 'ENTER NUMBER FOR TYPE(S) OF FORMULAS TO BE USED'
      READ (1,*) NTYPE
      IF (NTYPE.GT.3) GO TO 30
      IF (NTYPE.EQ.2) GO TO 60
      K=0
      N=1
   40 CALL CLSCR(25)
      WRITE (1,2)
      CALL CLSCR(3)
      WRITE (1,3) N
      READ (1,*) I
      IF (I.GT.12) GO TO 40
      IF (I.EQ.0) GO TO 50
      IF (I.EQ.1.OR.I.EQ.7.OR.I.GT.8) LSF=LSF+1
      K=K+1
      N=N+1
      NOSEL(1,K)=I
      IF (N.LE.12) GO TO 40
   50 NOS(1)=K
   60 IF (NTYPE.EQ.1) GO TO 90
      K=0
```

```
      N=1
   70 CALL CLSCR(25)
      WRITE (1,4)
      CALL CLSCR(3)
      WRITE (1,3) N
      READ (1,*) I
      IF (I.GT.8) GO TO 70
      IF (I.EQ.0) GO TO 80
      IF (I.LE.3.OR.I.GT.6) LSF=LSF+1
      K=K+1
      N=N+1
      NOSEL(2,K)=I
      IF (N.LE.8) GO TO 70
   80 NOS(2)=K
   90 IF (LSF.EQ.0) GO TO 110
  100 CALL CLSCR(25)
      WRITE (1,5)
      CALL CLSCR(3)
      WRITE (1,*) 'ENTER LISTING SELECTION NUMBER'
      READ (1,*) I
      IF (I.GT.2) GO TO 100
      IF (I.GT.1) LSF=0
C
C     ESTABLISH DATA & OUTPUT FILES
C
  110 DFILE='DISCH.DAT'
      CALL CLSCR(25)
      WRITE (1,6)
      CALL CLSCR(3)
      WRITE (1,*) 'ENTER NUMBER OF SELECTION'
      READ (1,*) I
      IF (I.EQ.1) GO TO 120
      CALL CLSCR(10)
      WRITE (1,*) 'ENTER DESIRED FILE NAME '
      READ (1,7) DFILE
  120 OPEN (5,FILE=DFILE,STATUS='OLD',FORM='UNFORMATTED')
      OFILE='DISCH.OUT'
      CALL CLSCR(25)
      WRITE (1,8)
      CALL CLSCR(3)
      WRITE (1,*) 'ENTER NUMBER OF SELECTION'
      READ (1,*) I
      IF (I.EQ.1) GO TO 130
      CALL CLSCR(10)
      WRITE (1,*) 'ENTER DESIRED FILE NAME '
      READ (1,7) OFILE
  130 OPEN (6,FILE=OFILE,STATUS='NEW')
      WRITE (6,9)
C
C     READ DATA AND COMPUTE DESIRED DISCHARGES
C
      READ (5) NSAMP
      DO 700 NS=1,NSAMP
```

```
      SUMP=0
      READ (5,ERR=1000,END=1010) LOC
      READ (5,ERR=1000,END=1010) W,Y,V,S,TEMP,D35,D50,D65,D90
      READ (5,ERR=1000,END=1010) (PCT(I),I=1,11)
      DO 140 I=1,11
      SUMP=SUMP+PCT(I)
      PCT(I)=PCT(I)/100.
  140 CONTINUE
      COMP1=1.0334+.03672*TEMP+.0002058*TEMP*TEMP
      XNU=.00002/COMP1
      DF35=D35/304.8
      DF50=D50/304.8
      DF65=D65/304.8
      DF90=D90/304.8
      COMP2=6.*XNU
      FV50=((36.064*DF50**3+COMP2**2)**.5-COMP2)/DF50
      U=(G*Y*S)**(.5)
      Q=W*Y*V
      CALL CLSCR(25)
      WRITE (1,10) LOC,W,S,Y,D50,V,XNU,Q,FV50,TEMP
      CALL CLSCR(4)
      WRITE (6,10)LOC,W,S,Y,D50,V,XNU,Q,FV50,TEMP
      IF (NTYPE.EQ.2) GO TO 400
      WRITE (6,11)
      DO 300 NO=1,NOS(1)
      IOS=NOSEL(1,NO)
      GO TO (150,160,170,180,180,190,200,190,200,200,210,220),IOS
C
C     LAURSEN FORMULA   (USES SIZE FRACTIONS)
C
  150 CALL LASN
      GO TO 300
C
C     ENGELUND AND HANSEN FORMULA
C
  160 CALL ENG
      GO TO 300
C
C     COLBY FORMULA
C
  170 CALL COLBY
      GO TO 300
C
C     ACKERS AND WHITE FORMULA
C
  180 CALL ACK
      GO TO 300
C
C     YANG SAND & GRAVEL FORMULAS USING D50
C
  190 CALL YAG50
      GO TO 300
C
```

```
C     YANG SAND & GRAVEL FORMULAS USING SIZE FRACTIONS
C
  200 CALL YAGFR
      GO TO 300
C
C     EINSTEIN FORMULA   (USES SIZE FRACTIONS)
C
  210 CALL EINS (1)
      GO TO 300
C
C     TOFFALETI FORMULA   (USES SIZE FRACTIONS)
C
  220 CALL TOFF (1)
  300 CONTINUE
      WRITE (6,*) '          '
  400 IF (NTYPE.EQ.1) GO TO 610
      WRITE (6,12)
      DO 600 NO=1,NOS(2)
      IOS=NOSEL(2,NO)
      GO TO (410,420,430,430,430,440,450,460),IOS
C
C     SCHOKLITSCH FORMULA   (USES SIZE FRACTIONS)
C
  410 CALL SCHOK
      GO TO 600
C
C     KALINSKE FORMULA
C
  420 CALL KALIN
      GO TO 600
C
C     MEYER-PETER AND MULLER FORMULA   (USES SIZE FRACTIONS)
C
  430 CALL MEYER
      GO TO 600
C
C     ROTTNER FORMULA
C
  440 CALL ROTTNER
      GO TO 600
C
C     EINSTEIN BEDLOAD FORMULA   (USES SIZE FRACTIONS)
C
  450 CALL EINS (2)
      GO TO 600
C
C     TOFFALETI FORMULA - BEDLOAD PORTION   (USES SIZE FRACTIONS)
C
  460 CALL TOFF (2)
  600 CONTINUE
  610 WRITE (6,13)
  700 CONTINUE
      GO TO 1020
```

```
 1000 WRITE (6,14) DFILE
      GO TO 1020
 1010 WRITE (6,15) DFILE
 1020 ENDFILE (6)
      CLOSE (5)
      CLOSE (6)
      CALL CLSCR(25)
      WRITE (1,16) OFILE
      CALL CLSCR(5)
      CALL EXIT
      END


      SUBROUTINE PRFRAC (I)
C
C     PRINT DISCHARGES BY SIZE FRACTION
C
      COMMON CI,DIA(11),DFT(11),D35,DF35,D50,DF50,D65,DF65,D90,DF90,G,
     1 GMS,IOS,LSF,FV50,PCT(11),S,SG,SIZELO(11),SIZEHI(11),SUMP,TEMP,U,
     2 UGSI,V,W,XNU,Y
    1 FORMAT (1H ,'          SIZE RANGE      FRACTION' / 1H ,'       IN M
     1ILLIMETERS     IN BED' )
    2 FORMAT (1H ,6X,2F8.3,F10.3,13X,F9.2,F13.4)
C
      IF (I.GT.0) GO TO 100
      WRITE (6,1)
      RETURN
  100 WRITE (6,2) SIZELO(I),SIZEHI(I),PCT(I),CI,UGSI
      RETURN
      END


      SUBROUTINE CLSCR (N)
C
C     MOVE CURSOR DOWN N LINES
C
      DO 10 I=1,N
      WRITE (1,*) '          '
   10 CONTINUE
      RETURN
      END


      SUBROUTINE FVEL (D,T,FV)
C
C     COMPUTE REPORT 12 SEDIMENT FALL VELOCITY, IN FT/SEC
C
C     INPUT DIAMETER IS IN FEET    TEMPERATURE IS IN DEG C
C     MAX DIA IS 0.0328 FEET (10 MM)       MAX TEMP IS 40 DEG C
C
```

```
      DIMENSION AF(6,13),ZF(2)
      DATA (AF(I,1),I=1,6)/.00001,.001,.0001,.0001,.0001,.0001/
      DATA (AF(I,2),I=1,6)/.06,.24,.32,.4,.49,.57/
      DATA (AF(I,3),I=1,6)/.1,.6,.76,.92,1.1,1.26/
      DATA (AF(I,4),I=1,6)/.2,1.8,2.2,2.5,2.85,3.2/
      DATA (AF(I,5),I=1,6)/.4,4.6,5.3,5.8,6.3,6.7/
      DATA (AF(I,6),I=1,6)/.8,9.5,10.5,11.0,11.6,12/
      DATA (AF(I,7),I=1,6)/1.5,16.1,16.9,17.5,17.9,18.1/
      DATA (AF(I,8),I=1,6)/2.0,19.9,20.3,20.7,21.1,21.5/
      DATA (AF(I,9),I=1,6)/3.0,25.3,25.6,25.9,26.2,26.5/
      DATA (AF(I,10),I=1,6)/7.0,39.5,39.5,39.5,39.5,39.5/
      DATA (AF(I,11),I=1,6)/8.0,41.5,41.5,41.5,41.5,41.5/
      DATA (AF(I,12),I=1,6)/9.0,43.5,43.5,43.5,43.5,43.5/
      DATA (AF(I,13),I=1,6)/10.0,45.0,45.0,45.0,45.0,45.0/
C
      DFV=D*304.8
      SF=T/10.
      KT=INT(SF)+1
      PT=SF-FLOAT(KT)+1.
      DL=ALOG10(DFV)
      DO 30 I=1,11
      IF (DFV.LE.AF(1,I)) GO TO 40
   30 CONTINUE
   40 I=I-1
      CF=ALOG10(AF(1,I))
      EF=ALOG10(AF(1,I+1))
      PD=(DL-CF)/(EF-CF)
      DO 50 L=1,2
      K=L+KT
      ZF(L)=(1.-PD)*ALOG10(AF(K,I))+PD*ALOG10(AF(K,I+1))
   50 CONTINUE
      RF=(1.-PT)*ZF(1)+PT*ZF(2)
      FV=10**RF/30.48
      RETURN
      END


      SUBROUTINE LASN
C
C     LAURSEN FORMULA
C
      COMMON CI,DIA(11),DFT(11),D35,DF35,D50,DF50,D65,DF65,D90,DF90,G,
     1 GMS,IOS,LSF,FV50,PCT(11),S,SG,SIZELO(11),SIZEHI(11),SUMP,TEMP,U,
     2 UGSI,V,W,XNU,Y
    1 FORMAT (1H ,'LAURSEN',38X,'SIZE FRACTION DATA NOT GIVEN')
    2 FORMAT (1H ,'LAURSEN')
    3 FORMAT (1H ,'LAURSEN',38X,F9.2,F13.4,F12.2)
    4 FORMAT (1H ,7X,'TOTAL',33X,F9.2,F13.4,F12.2)
C
      IF (SUMP.GT.0) GO TO 100
      WRITE (6,1)
      RETURN
```

```
100 IF (LSF.EQ.0) GO TO 110
    WRITE (6,2)
    CALL PRFRAC(0)
110 C=0
    UGS=0
    DELTA=11.6*XNU/U
    DO 200 I=2,11
    IF (PCT(I).LE.0) GO TO 200
    COMP1=6.*XNU
    FVI=((36.064*DFT(I)**3+COMP1**2)**.5-COMP1)/DFT(I)
    RV=U/FVI
    RVL=LOG10(RV)
    IF (RV.GT.0.3) GO TO 120
    FV=10.718*RV**.243
    GO TO 160
120 IF (RV.GT.3) GO TO 130
    FV=10.**(.855*RVL+.62*RVL*RVL+1.2)
    GO TO 160
130 IF (RV.GT.20.) GO TO 140
    FV=4.773*RV**2.304
    GO TO 160
140 IF (RV.GT.200.) GO TO 150
    FV=10.**(3.764*RVL-.803*RVL*RVL+.147)
    GO TO 160
150 FV=9680.5*RV**.2531
160 RY=DFT(I)/DELTA
    IF (RY.GT.0.03) GO TO 170
    YC=.16
    GO TO 190
170 IF (RY.GT.0.1) GO TO 180
    YC=.08
    GO TO 190
180 YC=.04
190 F1=(DFT(I)/Y)**1.1667
    F2=V*V/(58.*YC*DFT(I)*(SG-1)*G)
    F3=(DF50/Y)**.3333
    CI=10000*PCT(I)*F1*(F2*F3-1)*FV
    IF (CI.LT.0.) CI=0
    C=C+CI
    UGSI=.0000625*CI*Y*V
    UGS=UGS+UGSI
    IF (LSF.GT.0) CALL PRFRAC(I)
200 CONTINUE
    GS=UGS*43.2*W
    IF (LSF.GT.0) GO TO 210
    WRITE (6,3) C,UGS,GS
    RETURN
210 WRITE (6,4) C,UGS,GS
    RETURN
    END
```

```
      SUBROUTINE ENG
C
C     ENGELUND AND HANSEN FORMULA
C
      COMMON CI,DIA(11),DFT(11),D35,DF35,D50,DF50,D65,DF65,D90,DF90,G,
     1 GMS,IOS,LSF,FV50,PCT(11),S,SG,SIZELO(11),SIZEHI(11),SUMP,TEMP,U,
     2 UGSI,V,W,XNU,Y
    1 FORMAT (1H ,'ENGELUND & HANSEN',28X,F9.2,F13.4,F12.2)
C
      UGS=.05*GMS*V*V*Y**1.5*S**1.5/(DF50*G**.5*(SG-1)**2)
      C=16000*UGS/(Y*V)
      GS=UGS*43.2*W
      WRITE (6,1) C,UGS,GS
      RETURN
      END
```

```
      SUBROUTINE COLBY
C
C     COLBY FORMULA
C
      COMMON CI,DIA(11),DFT(11),D35,DF35,D50,DF50,D65,DF65,D90,DF90,G,
     1 GMS,IOS,LSF,FV50,PCT(11),S,SG,SIZELO(11),SIZEHI(11),SUMP,TEMP,U,
     2 UGSI,V,W,XNU,Y
      DIMENSION CY(7,7),CF(5)
    1 FORMAT (1H ,'COLBY',40X,'D50 LT 0.1 OR D50 GT 0.8')
    2 FORMAT (1H ,'COLBY',40X,F9.2,F13.4,F12.2)
      DATA CF/.64,1,1,.88,.2/
      DATA (CY(1,I),I=1,7)/.1,.2,.3,.4,.8,0,0/
      DATA (CY(2,I),I=1,7)/.61,.48,.3,.3,.3,0,0/
      DATA (CY(3,I),I=1,7)/1.453,1.329,1.4,1.26,1.099,0,0/
      DATA (CY(4,I),I=1,7)/.01,5,10,15.6,20,30,40/
      DATA (CY(5,I),I=1,7)/.1057,.0845,.0469,0,-.0277,-.0654,-.1155/
      DATA (CY(6,I),I=1,7)/.0735,.0166,.0014,0,-.0164,-.061,-.0763/
      DATA (CY(7,I),I=1,7)/.0118,.0202,.0135,0,0,0,0/
C
      IF (D50.GE.0.1.AND.D50.LE.0.8) GO TO 10
      WRITE (6,1)
      RETURN
   10 VC=.4673*Y**.1*D50**.333
      DIFF=V*.3048-VC
      B=2.5
      IF (DIFF.GE.1.0) B=1.453*D50**(-.138)
      X=LOG10(Y)
      N=0
   20 N=N+1
      IF (TEMP.GT.CY(4,N)) GO TO 20
      F1=CY(5,N-1)+CY(6,N-1)*X+CY(7,N-1)*X*X
      F2=CY(5,N)+CY(6,N)*X+CY(7,N)*X*X
      AF=F1+(F2-F1)*(LOG10(TEMP)-LOG10(CY(4,N-1)))/(LOG10(CY(4,N))-
     1 LOG10(CY(4,N-1)))
      AF=10**(AF)
```

```
      N=0
   30 N=N+1
      IF (D50.GT.CY(1,N)) GO TO 30
      A=CY(3,N-1)*Y**(CY(2,N-1))
      F1=A*DIFF**B*(1+(AF-1)*CF(N-1))*.672
      A=CY(3,N)*Y**(CY(2,N))
      F2=A*DIFF**B*(1+(AF-1)*CF(N))*.672
      UGS=LOG10(F1)+(LOG10(F2)-LOG10(F1))*(LOG10(D50)-LOG10(CY(1,N-1)))
     1 /(LOG10(CY(1,N))-LOG10(CY(1,N-1)))
      UGS=10**UGS
      C=16000*UGS/(Y*V)
      GS=UGS*43.2*W
      WRITE (6,2) C,UGS,GS
      RETURN
      END


      SUBROUTINE ACK
C
C     ACKERS AND WHITE FORMULA
C
      COMMON CI,DIA(11),DFT(11),D35,DF35,D50,DF50,D65,DF65,D90,DF90,G,
     1 GMS,IOS,LSF,FV50,PCT(11),S,SG,SIZELO(11),SIZEHI(11),SUMP,TEMP,U,
     2 UGSI,V,W,XNU,Y
    1 FORMAT (1H ,'ACKERS & WHITE  (USING D35)',18X,'D35 NOT GIVEN')
    2 FORMAT (1H ,'ACKERS & WHITE  (USING D50)',18X,F9.2,F13.4,F12.2)
    3 FORMAT (1H ,'ACKERS & WHITE  (USING D35 = ',F5.3,' MM )',6X,F9.2,
     1 F13.4,F12.2)
    4 FORMAT (1H ,'ACKERS & WHITE  (USING D50)',18X,'COMPUTED CONCENTRAT
     1ION LESS THAN ZERO')
    5 FORMAT (1H ,'ACKERS & WHITE  (USING D35)',18X,'COMPUTED CONCENTRAT
     1ION LESS THAN ZERO')
      D=DF50
      IF (IOS.EQ.4) GO TO 110
      IF (DF35.GT.0.) GO TO 100
      WRITE (6,1)
      RETURN
  100 D=DF35
  110 DGR=D*((G*(SG-1)/(XNU*XNU))**.3333)
      P=LOG10(DGR)
      IF (DGR.GT.60) GO TO 120
      AN=1-.56*P
      AA=.23/SQRT(DGR)+.14
      AM=9.66/DGR+1.34
      CA=2.86*P-P*P-3.53
      CA=10**CA
      GO TO 130
  120 AN=0
      AA=.17
      AM=1.5
      CA=.025
  130 F1=U**AN/(SQRT(G*D*(SG-1)))
```

```
      F2=(V/(SQRT(G)*LOG10(10.*Y/D)))**(1-AN)
      F3=F1*F2/AA-1
      IF (F3.LE.0) GO TO 160
      GGR=CA*F3**AM
      C=(GGR*D*SG*(V/U)**AN)/Y
      C=C*10**6.
      UGS=.0000625*C*Y*V
      GS=UGS*43.2*W
  140 IF (IOS.EQ.5) GO TO 150
      WRITE (6,2) C,UGS,GS
      RETURN
  150 WRITE (6,3) D35,C,UGS,GS
      RETURN
  160 IF (IOS.EQ.5) GO TO 170
      WRITE (6,4)
      RETURN
  170 WRITE (6,5)
      RETURN
      END
```

```
      SUBROUTINE YAG50
C
C     YANG SAND & GRAVEL FORMULAS USING D50
C
      COMMON CI,DIA(11),DFT(11),D35,DF35,D50,DF50,D65,DF65,D90,DF90,G,
     1 GMS,IOS,LSF,FV50,PCT(11),S,SG,SIZELO(11),SIZEHI(11),SUMP,TEMP,U,
     2 UGSI,V,W,XNU,Y
    1 FORMAT (1H ,'YANG SAND  (USING D50)',23X,F9.2,F13.4,F12.2)
    2 FORMAT (1H ,'YANG GRAVEL  (USING D50)'21X,F9.2,F13.4,F12.2)
C
      FV=FV50
      IF (DF50.GE.0.0328) GO TO 100
      CALL FVEL (DF50,TEMP,FV)
  100 R=U*DF50/XNU
      F1=2.05
      IF (R.GE.70.) GO TO 110
      F1=.66+2.5/(LOG10(R)-.06)
  110 F2=LOG10(FV*DF50/XNU)
      F3=LOG10(U/FV)
      C=0
      F4=V*S/FV-F1*S
      IF (F4.LE.0.) GO TO 140
      IF (IOS.EQ.8) GO TO 120
      C=5.435-.286*F2-.457*F3+(1.799-.409*F2-.314*F3)*LOG10(F4)
      GO TO 130
  120 C=6.681-.633*F2-4.816*F3+(2.784-.305*F2-.282*F3)*LOG10(F4)
  130 C=10.**C
  140 UGS=.0000625*C*Y*V
      GS=UGS*43.2*W
      IF (IOS.EQ.8) GO TO 150
      WRITE (6,1) C,UGS,GS
```

```
      RETURN
  150 WRITE (6,2) C,UGS,GS
      RETURN
      END


      SUBROUTINE YAGFR
C
C     YANG SAND & GRAVEL FORMULAS USING SIZE FRACTIONS
C
      COMMON CI,DIA(11),DFT(11),D35,DF35,D50,DF50,D65,DF65,D90,DF90,G,
     1 GMS,IOS,LSF,FV50,PCT(11),S,SG,SIZELO(11),SIZEHI(11),SUMP,TEMP,U,
     2 UGSI,V,W,XNU,Y
    1 FORMAT (1H ,'YANG SAND  (USING SIZE FRACTIONS)',12X,'SIZE FRACTION
     1 DATA NOT GIVEN' )
    2 FORMAT (1H ,'YANG GRAVEL  (USING SIZE FRACTIONS)',10X,'SIZE FRACTI
     1ON DATA NOT GIVEN' )
    3 FORMAT (1H ,'YANG MIXTURE  (USING SIZE FRACTIONS)',9X,'SIZE FRACTI
     1ON DATA NOT GIVEN' )
    4 FORMAT (1H ,'YANG SAND  (USING SIZE FRACTIONS)' )
    5 FORMAT (1H ,'YANG GRAVEL  (USING SIZE FRACTIONS)' )
    6 FORMAT (1H ,'YANG MIXTURE  (USING SIZE FRACTIONS)' )
    7 FORMAT (1H ,'YANG SAND  (USING SIZE FRACTIONS)',12X,F9.2,F13.4,
     1 F12.2 )
    8 FORMAT (1H ,'YANG GRAVEL  (USING SIZE FRACTIONS)',10X,F9.2,F13.4,
     1 F12.2 )
    9 FORMAT (1H ,'YANG MIXTURE  (USING SIZE FRACTIONS)',9X,F9.2,F13.4,
     1 F12.2 )
   10 FORMAT (1H ,7X,'TOTAL',33X,F9.2,F13.4,F12.2 )
C
      IF (SUMP.GT.0.) GO TO 130
      IF (IOS-9) 100,110,120
  100 WRITE (6,1)
      RETURN
  110 WRITE (6,2)
      RETURN
  120 WRITE (6,3)
      RETURN
  130 IF (LSF.EQ.0) GO TO 180
      IF (IOS-9) 140,150,160
  140 WRITE (6,4)
      GO TO 170
  150 WRITE (6,5)
      GOTO 170
  160 WRITE (6,6)
  170 CALL PRFRAC(0)
  180 C=0
      UGS=0
      DO 250 I=2,11
      IF (PCT(I).LE.0) GO TO 250
      D=DFT(I)
      IF (D.LE.0.0328) GO TO 190
```

```
      COMP1=6.*XNU
      FV=((36.064*D**3+COMP1**2)**.5-COMP1)/D
      GO TO 200
  190 CALL FVEL (D,TEMP,FV)
  200 R=U*D/XNU
      F1=2.05
      IF (R.GE.70.) GO TO 210
      F1=.66+2.5/(LOG10(R)-.06)
  210 F2=LOG10(FV*D/XNU)
      F3=LOG10(U/FV)
      CI=0
      F4=V*S/FV-F1*S
      IF (F4.LE.0) GO TO 240
      IF (IOS.EQ.9) GO TO 220
      IF (IOS.EQ.10.AND.I.GT.6) GO TO 220
      CI=5.435-.286*F2-.457*F3+(1.799-.409*F2-.314*F3)*LOG10(F4)
      GO TO 230
  220 CI=6.681-.633*F2-4.816*F3+(2.784-.305*F2-.282*F3)*LOG10(F4)
  230 CI=10**CI*PCT(I)
  240 C=C+CI
      UGSI=.0000625*CI*Y*V
      UGS=UGS+UGSI
      IF (LSF.GT.0) CALL PRFRAC(I)
  250 CONTINUE
      GS=UGS*43.2*W
      IF (LSF.GT.0) GO TO 290
      IF (IOS-9) 260,270,280
  260 WRITE (6,7) C,UGS,GS
      RETURN
  270 WRITE (6,8) C,UGS,GS
      RETURN
  280 WRITE (6,9) C,UGS,GS
      RETURN
  290 WRITE (6,10) C,UGS,GS
      RETURN
      END


      SUBROUTINE SCHOK
C
C     SCHOKLITSCH FORMULA
C
      COMMON CI,DIA(11),DFT(11),D35,DF35,D50,DF50,D65,DF65,D90,DF90,G,
     1 GMS,IOS,LSF,FV50,PCT(11),S,SG,SIZELO(11),SIZEHI(11),SUMP,TEMP,U,
     2 UGSI,V,W,XNU,Y
    1 FORMAT (1H ,'SCHOKLITSCH',34X,'SIZE FRACTION DATA NOT GIVEN')
    2 FORMAT (1H ,'SCHOKLITSCH')
    3 FORMAT (1H ,'SCHOKLITSCH',34X,F9.2,F13.4,F12.2)
    4 FORMAT (1H ,7X,'TOTAL',33X,F9.2,F13.4,F12.2)
C
      IF (SUMP.GT.0) GO TO 100
      WRITE (6,1)
```

```
      RETURN
  100 IF (LSF.EQ.0) GO TO 110
      WRITE (6,2)
      CALL PRFRAC(0)
  110 C=0
      UGS=0
      F1=25.*S**1.5*V*Y
      F2=1.6*S**.17
      DO 130 I=1,11
      IF (PCT(I).LE.0) GO TO 130
      CI=0
      UGSI=0
      F3=DFT(I)**.5
      X=F1/F3-F2*F3
      IF (X.LE.0) GO TO 120
      UGSI=X*PCT(I)
  120 UGS=UGS+UGSI
      CI=16000*UGSI/(Y*V)
      C=C+CI
      IF (LSF.GT.0) CALL PRFRAC(I)
  130 CONTINUE
      GS=UGS*43.2*W
      IF (LSF.GT.0) GO TO 210
      WRITE (6,3) C,UGS,GS
      RETURN
  210 WRITE (6,4) C,UGS,GS
      RETURN
      END


      SUBROUTINE KALIN
C
C     KALINSKE FORMULA
C
      COMMON CI,DIA(11),DFT(11),D35,DF35,D50,DF50,D65,DF65,D90,DF90,G,
     1 GMS,IOS,LSF,FV50,PCT(11),S,SG,SIZELO(11),SIZEHI(11),SUMP,TEMP,U,
     2 UGSI,V,W,XNU,Y
      DIMENSION RAT(11),A(6)
    1 FORMAT (1H ,'KALINSKE',37X,'SIZE FRACTION DATA NOT GIVEN')
    2 FORMAT (1H ,'KALINSKE')
    3 FORMAT (1H ,'KALINSKE',37X,F9.2,F13.4,F12.2)
    4 FORMAT (1H ,7X,'TOTAL',33X,F9.2,F13.4,F12.2)
      DATA A/-.068,-1.1328,.94,-1.206,.567,-.0975/
C
      IF (SUMP.GT.0) GO TO 100
      WRITE (6,1)
      RETURN
  100 IF (LSF.EQ.0) GO TO 110
      WRITE (6,2)
      CALL PRFRAC(0)
  110 S1=0
      DO 120 I=1,11
```

```
      RAT(I)=PCT(I)/DFT(I)
      S1=S1+RAT(I)
  120 CONTINUE
      C=0
      UGS=0
      T0=62.4*Y*S
      F1=25.28*T0**.5/S1
      DO 130 I=1,11
      IF (PCT(I).LE.0) GO TO 130
      T1=12.*DFT(I)
      X=T1/T0
      F2=A(1)+A(2)*X+A(3)*X**2+A(4)*X**3+A(5)*X**4+A(6)*X**5
      F2=10.**(F2)
      UGSI=F1*T1*RAT(I)*F2
      UGS=UGS+UGSI
      CI=16000*UGSI/(Y*V)
      C=C+CI
      IF (LSF.GT.0) CALL PRFRAC(I)
  130 CONTINUE
      GS=UGS*43.2*W
      IF (LSF.GT.0) GO TO 210
      WRITE (6,3) C,UGS,GS
      RETURN
  210 WRITE (6,4) C,UGS,GS
      RETURN
      END


      SUBROUTINE MEYER
C
C     MEYER-PETER AND MULLER FORMULA
C
      COMMON CI,DIA(11),DFT(11),D35,DF35,D50,DF50,D65,DF65,D90,DF90,G,
     1 GMS,IOS,LSF,FV50,PCT(11),S,SG,SIZELO(11),SIZEHI(11),SUMP,TEMP,U,
     2 UGSI,V,W,XNU,Y
      CHARACTER*45 LABEL(3)
    1 FORMAT (1H ,'MEYER-PETER & MULLER',25X,'SIZE FRACTION DATA NOT GIV
     1EN')
    2 FORMAT (1H ,'MEYER-PETER AND MULLER   ',A45)
    3 FORMAT (1H ,'MEYER-PETER & MULLER')
    4 FORMAT (1H ,'MEYER-PETER & MULLER      BOT WIDTH =',F8.2 )
    5 FORMAT (1H ,2X,A45 / 1H ,'  D90 =',F7.3,' MM    M-P DM =',F7.3 )
    6 FORMAT (1H ,'  NW =',F7.3,'    NM =',F7.3 )
    7 FORMAT (1H ,'  QS/Q =',F7.3,'    NS =',F8.4,14X,F9.2,F13.4,F12.2)
      DATA LABEL/'QS/Q=1 AND NS=STRICKLER ROUGHNESS','RECTANGULAR CHANNE
     1L AND COMPUTE NS AND QS/Q','TRAPEZOIDAL CHANNEL AND COMPUTE NS AND
     2 QS/Q'/
C
      IF (SUMP.GT.0) GO TO 100
      WRITE (6,1)
      RETURN
  100 DM=0.0
```

```
      DO 110 I=1,11
      DM=DM+PCT(I)*DIA(I)
  110 CONTINUE
      UGS=0.0
      IF (IOS.GT.3) GO TO 120
      QSQ=1.0
      RNS=1.486*Y**.667*S**.5/V
      GO TO 150
  120 WRITE (1,2) LABEL(IOS-2)
      WRITE (1,*) 'ENTER MANNING"S N FOR CHANNEL SIDES (NW)'
      READ (1,*) RNW
      WRITE (1,*) 'ENTER MANNING"S N FOR TOTAL STREAM  (NM)'
      READ (1,*) RNM
      IF (IOS.EQ.5) GO TO 130
      WRITE (1,*) '          '
      F1=2.*Y/W
      GO TO 140
  130 WRITE (1,*) 'ENTER BOTTOM WIDTH, IN FEET'
      READ (1,*) BW
      WRITE (1,*) '          '
      F2=(W-BW)/2./Y
      F1=2*Y*(1.+F2**2)**.5/BW
  140 RNS=RNM*(1.+F1*(1.-(RNW/RNM)**1.5))**.667
      QSQ=1./(1.+F1*(RNW/RNS)**1.5)
  150 UGS=0.0
      X=.368*QSQ*(D90**.1667/RNS)**1.5*Y*S-.0698*DM
      IF (X.GT.0.0) UGS=X**1.5
      C=16000*UGS/(Y*V)
      GS=UGS*43.2*W
      IF (IOS.EQ.5) GO TO 160
      WRITE (6,3)
      GO TO 170
  160 WRITE (6,4) BW
  170 WRITE (6,5) LABEL(IOS-2),D90,DM
      IF (IOS.GT.3) WRITE (6,6) RNW,RNM
      WRITE (6,7) QSQ,RNS,C,UGS,GS
      RETURN
      END


C     SUBROUTINE ROTTNER
C
C     ROTTNER FORMULA
C
      COMMON CI,DIA(11),DFT(11),D35,DF35,D50,DF50,D65,DF65,D90,DF90,G,
     1 GMS,IOS,LSF,FV50,PCT(11),S,SG,SIZELO(11),SIZEHI(11),SUMP,TEMP,U,
     2 UGSI,V,W,XNU,Y
    1 FORMAT (1H ,'ROTTNER',38X,F9.2,F13.4,F12.2)
C
      R=(DF50/Y)**.667
      F1=V/(7.286*Y**.5)
      F2=.667*R+.14
```

```
      UGS=1204.8*Y**1.5*(F1*F2-.778*R)**3
      C=16000*UGS/(Y*V)
      GS=UGS*43.2*W
      WRITE (6,1) C,UGS,GS
      RETURN
      END


       SUBROUTINE EINS (NLD)
C
C      EINSTEIN FORMULA
C
      COMMON CI,DIA(11),DFT(11),D35,DF35,D50,DF50,D65,DF65,D90,DF90,G,
     1 GMS,IOS,LSF,FV50,PCT(11),S,SG,SIZELO(11),SIZEHI(11),SUMP,TEMP,U,
     2 UGSI,V,W,XNU,Y
    1 FORMAT (1H ,'EINSTEIN',37X,'SIZE FRACTION DATA NOT GIVEN' )
    2 FORMAT (1H ,'EINSTEIN' )
    3 FORMAT (1H ,'EINSTEIN' / 1H ,'  D35 =',F7.3,' MM    D65 =',F7.3,
     1 ' MM' )
    4 FORMAT (1H ,'  D35 =',F7.3,' MM    D65 =',F7.3,' MM',9X,F9.2,
     1 F13.4,F12.2)
    5 FORMAT (1H ,7X,'TOTAL',33X,F9.2,F13.4,F12.2)
C
      IF (SUMP.GT.0) GO TO 100
      WRITE (6,1)
      RETURN
  100 IF (LSF.GT.0) GO TO 110
      WRITE (6,2)
      GO TO 120
  110 WRITE (6,3) D35,D65
      CALL PRFRAC(0)
  120 RB=Y
      C=0
      UGS=0
      RBP=(V*DF65**.1667/(7.66*(G*S)**.5))**1.5
      RBPP=RB-RBP
      SVP=(G*RBP*S)**.5
      DELTA=11.6*XNU/SVP
      X9=DF65/DELTA
      CALL FIG4 (X9,XR)
      DELT=DF65/XR
      COMP1=DELT/DELTA
      IF (COMP1.LT.1.8) GO TO 130
      CAPX=.77*DELT
      GO TO 140
  130 CAPX=1.39*DELTA
  140 CALL FIG8 (X9,CAPY)
      BETAX=ALOG10(10.6*CAPX/DELT)
      PVALUE=2.3026*ALOG10(30.2*XR*RB/DF65)
      COMP1=6*XNU
      DO 200 I=1,11
      IF (PCT(I).LE.0) GO TO 200
```

```
      X9=DFT(I)/CAPX
      CALL FIG7 (X9,XI)
      PSIS=XI*CAPY*(1.025/BETAX)**2*(1.65*DFT(I)/(RBP*S))
      CALL FIG10 (PSIS,PHI)
      UNITBD=1200*PHI*DFT(I)**1.5*PCT(I)
      UGSI=UNITBD
      IF (NLD.EQ.2) GO TO 150
      FVI=((36.064*DFT(I)**3+COMP1**2)**.5-COMP1)/DFT(I)
      ZC=FVI/(.4*SVP)
      AVAL=2.*DFT(I)/RB
      VALI1=0.0
      VALI2=0.0
      CALL POWER (AVAL,ZC,VALI1,VALI2)
      UGSI=UNITBD*(PVALUE*VALI1+VALI2+1.0)
  150 UGS=UGS+UGSI
      CI=16000*UGSI/(Y*V)
      C=C+CI
      IF (LSF.GT.0) CALL PRFRAC(I)
  200 CONTINUE
      GS=UGS*43.2*W
      IF (LSF.GT.0) GO TO 210
      WRITE (6,4) D35,D65,C,UGS,GS
      RETURN
  210 WRITE (6,5) C,UGS,GS
      RETURN
      END


      SUBROUTINE FIG4 (X,Y)
C
C     THIS SUBROUTINE APPROXIMATES EINSTEINS FIGURE 4 WHERE:
C                    X = F (KS / DELTA)
C
      DIMENSION FX(8),FA(8),FB(8)
      DATA FX /0.5,0.65,0.9,1.15,1.4,3.2,5.0,8.4/
      DATA FA /1.9,1.75,1.62,1.61,1.63,1.72,1.42,1.25/
      DATA FB /1.72,1.23,0.57,0.0,-0.47,-1.11,-0.52,-0.27/
      I=0
      Y=0.4
      IF (X.LT.0.135) RETURN
      IF (X.LT.8.4) GO TO 100
      Y=1.0
      RETURN
  100 I=I+1
      IF (X.GT.FX(I)) GO TO 100
      Y=FB(I)*ALOG10(X)+FA(I)
      RETURN
      END


      SUBROUTINE FIG7 (X,Y)
```

```
C
C     THIS SUBROUTINE APPROXIMATES EINSTEINS FIGURE 7 WHERE:
C                       XI = F(D/X)
C
      DIMENSION FX(6),FA(6),FB(6)
      DATA FX /0.2,0.4,0.65,0.8,1.0,1.45/
      DATA FA /1.17,0.741,0.661,0.952,1.15,1.15/
      DATA FB /-2.1,-2.39,-2.51,-1.66,-0.817,-0.376/
      I=0
      IF (X.LT.1.45) GO TO 100
      Y=1
      RETURN
  100 I=I+1
      IF (X.GT.FX(I)) GO TO 100
      Y=FA(I)*X**(FB(I))
      RETURN
      END
```

```
      SUBROUTINE FIG8 (X,Y)
C
C     THIS SUBROUTINE APPROXIMATES EINSTEINS FIGURE 8 WHERE:
C                     Y = F (KS / DELTA)
C
      DIMENSION FX(6),FA(6),FB(6)
      DATA FX /0.66,0.84,1.1,1.3,2.2,3.1/
      DATA FA /0.997,0.911,0.814,0.858,0.957,0.714/
      DATA FB /1.18,0.966,0.323,-0.218,-0.635,-0.263/
      I=0
      IF (X.LT.3.1) GO TO 100
      Y=.53
      RETURN
  100 I=I+1
      IF (X.GT.FX(I)) GO TO 100
      Y=FA(I)*X**(FB(I))
      RETURN
      END
```

```
      SUBROUTINE FIG10 (X,Y)
C
C     THIS SUBROUTINE APPROXIMATES EINSTEINS FIGURE 10 WHERE:
C                         PHI = F (PSI)
C
      DIMENSION FX(7),FA(7),FB(7)
      DATA FX /0.77,2.12,4.1,6.1,11.0,16.7,22.5/
      DATA FA /7.56,5.35,4.1,4.1,4.6,5.66,9.28/
      DATA FB /1.01,1.19,1.67,2.3,3.23,4.26,7.81/
      I=0
      IF (X.LT.22.5) GO TO 100
      Y=(13.1/X)**12.66
```

```
      RETURN
  100 I=I+1
      IF (X.GT.FX(I)) GO TO 100
      Y=(FA(I)/X)**FB(I)
      RETURN
      END


      SUBROUTINE POWER (A,Z,FI1,FI2)
C
C     THIS SUBROUTINE EVALUATE I1 AND I2 INTEGRALS
C
      N=1
      FJ1=0.0
      FJ2=0.0
      FI1=0.0
      FI2=0.0
      COEFF=.216*A**(Z-1.0)/(1.0-A)**Z
      ALG=ALOG(A)
      C=1.0
      D=-Z
      E=D+1.0
      FN=1.0
      AEX=A**E
      GO TO 120
  110 N=N+1
      C=C*D/FN
      D=E
      E=D+1.0
      FN=FLOAT(N)
      AEX=A**E
  120 IF (ABS(E).LE.0.001) GO TO 130
      FJ1=FJ1+C*(1.0-AEX)/E
      FJ2=FJ2+C*((AEX-1.0)/E**2-AEX*ALG/E)
      GO TO 140
  130 FJ1=FJ1-C*ALG
      FJ2=FJ2-0.5*C*ALG**2
  140 IF (N.EQ.1) GO TO 150
      CJ1=ABS(1.0-XJ1/FJ1)
      CJ2=ABS(1.0-XJ2/FJ2)
      IF (CJ1.LE.0.001.AND.CJ2.LE.0.001) GO TO 160
  150 XJ1=FJ1
      XJ2=FJ2
      GO TO 110
  160 FI1=COEFF*FJ1
      FI2=COEFF*FJ2
      RETURN
      END


      SUBROUTINE TOFF (NLD)
```

```
C
C     TOFFALETI FORMULA
C
      COMMON CI,DIA(11),DFT(11),D35,DF35,D50,DF50,D65,DF65,D90,DF90,G,
     1 GMS,IOS,LSF,FV50,PCT(11),S,SG,SIZELO(11),SIZEHI(11),SUMP,TEMP,U,
     2 UGSI,V,W,XNU,Y
      DIMENSION DIP(18)
    1 FORMAT (1H ,'TOFFALETI',36X,'SIZE FRACTION DATA NOT GIVEN')
    2 FORMAT (1H ,'TOFFALETI    D65 =',F6.2,' MM')
    3 FORMAT (1H ,'TOFFALETI    D65 =',F6.2,' MM',18X,F9.2,F13.4,F12.2)
    4 FORMAT (1H ,7X,'TOTAL',33X,F9.2,F13.4,F12.2)
      DATA DIP/0,.37,.71,.99,1.21,1.34,1.41,1.38,1.27,1.11,.94,.78,.65,
     1 .55,.49,.45,.42,.4/
C
      IF (SUMP.GT.0) GO TO 100
      WRITE (6,1)
      RETURN
  100 IF (LSF.EQ.0) GO TO 110
      WRITE (6,2) D65
      CALL PRFRAC(0)
  110 TDF=1.8*TEMP+32
      ZV=.1198+.00048*TDF
      CZ=260.67-.667*TDF
      YA=Y/11.24
      YB=Y/2.5
      CV=1.+ZV
      SI=S*Y*CZ
      U3=V**3/(XNU*G*S)
      U2=V/(DF65*G*S)**.5
      F1=ALOG(U3)
      F2=4.083*ALOG(U2)-3.76
      F3=1.864*F1-9.09
      IF (F3.GE.F2) GO TO 120
      U1=F3
      GO TO 160
  120 FI=(F2+9.09)/1.864
      FI=(F1-FI)*.43429
      IF (TI.LT.1.7) GO TO 130
      U1=F2+.4
      GO TO 130
  130 F6=FI*10.
      DO 140 I=1,17
      F5=FLOAT(I)
      F1=F5-F6
      IF (F5.GE.F6) GO TO 150
  140 CONTINUE
  150 J=F5
      F1=1.-F1
      F5=DIP(J)+F1*(DIP(J+1)-DIP(J))
      U1=F2+F5
  160 AM=10.*V/U1
      PAM=(XNU*100000.)**.3333/AM
      F1=100000.*PAM*S*DF65/G
```

```
      T=(.051+.00009*TDF)*1.1
      IF (PAM.GT.0.5) GO TO 170
      A=9.8/(PAM**1.515)
      GO TO 210
  170 IF (PAM.GT.0.66) GO TO 180
      A=41.*PAM**.55
      GO TO 210
  180 IF (PAM.GT.0.72) GO TO 190
      A=228.*PAM**4.68
      GO TO 210
  190 IF (PAM.GT.1.3) GO TO 200
      A=49.
      GO TO 210
  200 A=23.5*PAM**2.8
  210 IF (F1.LE.0.25) GO TO 230
      IF (F1.LE.0.35) GO TO 220
      A=A*.5/F1**1.05
      GO TO 230
  220 A=A*5.2*F1**1.19
  230 IF (A.LT.16.) A=16.
      CT=0
      UGS=0
      DO 300 I=2,9
      IF (I.GT.2) GO TO 240
      GFB=1.905/(T*A/(V*V))**1.667
      GO TO 250
  240 GFA=GFB
      GFB=GFA/3.175
  250 IF (PCT(I).LE.0.) GO TO 300
      FV=1.6
      IF (I.LT.9) CALL FVEL (DFT(I),TEMP,FV)
      ZOM=FV*V/SI
      IF (ZOM.LT.(1.5*ZV)) ZOM=1.5*ZV
      F1=.756*ZOM-ZV
      F2=ZOM-ZV
      F3=1.5*ZOM-ZV
      F4=1.-F1
      F5=1.-F2
      F6=1.-F3
      YAF4=YA**F4
      C=PCT(I)*W
      DD=2.*DFT(I)
      DDF4=DD**F4
      UD=CV*V*(DD/Y)**ZV
      X=F4*GFB/(YAF4-DDF4)
      UGSI=X*DDF4
      UBL=UGSI/(43.2*UD*DD)
      IF (UBL.LE.100.) GO TO 260
      UGSI=UGSI*100/UBL
  260 UGSI=C*UGSI
      IF (NLD.EQ.2) GO TO 270
      GA=UGSI+C*GFB
      C=C*X
```

```
      YAF2=YA**(F2-F1)
      YAF5=YA**F5
      CF5=C/F5
      YBF3=YB**(F3-F2)
      YBF6=YB**F6
      CF6=C/F6
      CF4=C/F4
      GB=CF5*YAF2*(YB**F5-YAF5)
      GC=CF6*YAF2*YBF3*(Y**F6-YBF6)
      UGSI=GA+GB+GC
  270 UGSI=UGSI/(43.2*W)
      UGS=UGS+UGSI
      CI=16000*UGSI/(Y*V)
      CT=CT+CI
      IF (LSF.GT.0) CALL PRFRAC(I)
  300 CONTINUE
      GS=UGS*43.2*W
      IF (LSF.GT.0) GO TO 310
      WRITE (6,3) D65,CT,UGS,GS
      RETURN
  310 WRITE (6,4) CT,UGS,GS
      RETURN
      END
```

SUPPLEMENTAL DATA--SECTION C.

BASIC PROGRAM DISDATA LISTING

```
10 REM PROGRAM DISDATA
20 REM ENTER SEDIMENT DISCHARGE PROGRAM DATA TO INPUT FILE
30 REM MAXIMUM NUMBER OF DATA SETS IN A FILE IS 30.
40 REM STORES DATA ON SEQUENTIAL FILE DFILE$ AFTER EACH 10 ENTERED DATA SETS
50 DIM VAR(30,9),PCT(30,11),LO$(30),SIZELO(11),SIZEHI(11),PF(11)
60 LABEL$=" LOCWIDTHDEPTH VEL.SLOPETEMP.  D35  D50  D65  D90"
70 DATA .016,.062,.125,.25,.5,1,2,4,8,16,32
80 FOR I=1 TO 11 : READ SIZELO(I) : NEXT I
90 DATA .062,.125,.25,.5,1,2,4,8,16,32,64
100 FOR I=1 TO 11 : READ SIZEHI(I) : NEXT I
110 DFILE$="DISCH.DAT"
120 NN=25 : GOSUB 2520
130 PRINT "TURN ON PRINTER" : PRINT : PRINT "ESTABLISH FILE NAME:" : PRINT
140 PRINT "     1. USE PROGRAMMED FILE NAME (DISCH.DAT)"
150 PRINT "     2. PROVIDE FILE NAME"
160 NN=5 : GOSUB 2520
170 INPUT "ENTER NUMBER OF SELECTION --> ",I
180 IF I<2 THEN 210
190 NN=10 : GOSUB 2520
200 INPUT "DESIRED FILE NAME --> ",DFILE$
210 NN=10 : GOSUB 2520
220 PRINT "      1. ";DFILE$;" IS A NEW FILE"
230 PRINT "      2. ";DFILE$;" IS AN EXISTING FILE"
240 NN=3 : GOSUB 2520
250 INPUT "ENTER NUMBER OF SELECTION --> ",NFL
260 IF NFL>1 THEN 290
270 NO=0 : ND=0
280 GOTO 550
290 REM LOAD DATA FROM DISK * * * * * * * * * * * * * * * * * * * * * * * * *
300 NSZ=1
310 OPEN "I",#1,DFILE$
320 INPUT #1,NO
330 FOR N=1 TO NO
340 INPUT #1,LO$(N)
350 FOR I=1 TO 9 : INPUT #1,VAR(N,I) : NEXT I
360 FOR I=1 TO 11 : INPUT #1,PCT(N,I) : NEXT I
370 NEXT N
380 CLOSE
390 NN=25 : GOSUB 2520
400 PRINT "     0. END RUN USING FILE ";DFILE$
410 PRINT "     1. ADD DATA TO ";DFILE$
420 PRINT "     2. CORRECT DATA IN ";DFILE$
430 PRINT "     3. DISPLAY DATA IN ";DFILE$
440 PRINT "     4. PRINT DATA IN ";DFILE$
450 NN=5 : GOSUB 2520
460 INPUT "ENTER NUMBER OF SELECTION --> ",NC
470 IF NC>4 THEN 390
480 IF NC>0 THEN 530
490 NN=10 : GOSUB 2520
500 PRINT "FILE  ";DFILE$; : PRINT USING "  HAS ## DATA SETS";NO
510 PRINT : PRINT "END OF RUN"
```

```
520 END
530 ON NC GOTO 550,1230,1520,1670
540 REM ENTER DATA * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
550 NN=25 : GOSUB 2520
560 PRINT "METHOD OF ENTERING SIZE FRACTION DATA:"
570 PRINT
580 PRINT "     1. NO SIZE FRACTION DATA TO BE ENTERED"
590 PRINT "     2. DATA ENTERED BY PERCENT FINER VALUES"
600 PRINT "     3. DATA ENTERED BY PERCENT IN SIZE FRACTION"
610 NN=5 : GOSUB 2520
620 INPUT "ENTER NUMBER OF SELECTION --> ",NSZ
630 IF NSZ>3 THEN 550
640 IF NFL=1 OR NC=1 THEN 690
650 IF NO=30 THEN 1280
660 NN=25  : GOSUB 2520
670 PRINT : INPUT "ENTER MORE DATA  1 FOR YES  OR  2 FOR NO";I
680 IF I>1 THEN 1280
690 NO=NO+1 : ND=ND+1
700 IF ND<11 THEN 730
710 GOSUB 1120
720 ND=0
730 NN=25 : GOSUB 2520
740 PRINT "DATA SET NO. ";NO; : PRINT "    MAX = 30" : PRINT
750 PRINT : PRINT "ENTER LOCATION NAME  (MAX 80 CHARACTERS)"
760 LINE INPUT LO$(NO)
770 PRINT : INPUT "ENTER TOP WIDTH  (FT) --> ",VAR(NO,1)
780 PRINT : INPUT "ENTER AVERAGE DEPTH  (FT) --> ",VAR(NO,2)
790 PRINT : INPUT "ENTER AVERAGE VELOCITY (FT/SEC) --> ",VAR(NO,3)
800 PRINT : INPUT "ENTER WATER SURFACE SLOPE (FT/FT) --> ",VAR(NO,4)
810 PRINT : INPUT "ENTER WATER TEMPERATURE  (C) --> ",VAR(NO,5)
820 PRINT : INPUT "ENTER D35  (MM) OR 0 FOR NONE --> ",VAR(NO,6)
830 PRINT : INPUT "ENTER D50  (MM) --> ",VAR(NO,7)
840 PRINT : INPUT "ENTER D65  (MM) OR 0 FOR NONE --> ",VAR(NO,8)
850 PRINT : INPUT "ENTER D90  (MM) OR 0 FOR NONE --> ",VAR(NO,9)
860 NN=5 : GOSUB 2520
870 FOR I=1 TO 11 : PF(I)=0 : PCT(NO,I)=0 : NEXT I
880 ON NSZ GOTO 980,890,950
890 NPF=0
900 NPF=NPF+1
910 PRINT USING "ENTER PCT FINER THAN ##.### MM";SIZEHI(NPF); : INPUT " --> ";PF
(NPF)
920 IF PF(NPF)>99.9 THEN 980
930 IF NPF<11 THEN 900
940 GOTO 980
950 FOR I=1 TO 11
960 PRINT USING "ENTER % MATERIAL FOR ##.###";SIZELO(I); : PRINT USING "  TO #
#.### MM  (0 FOR NONE)";SIZEHI(I); : INPUT " --> ",PCT((NO,I)
970 NEXT I
980 N=NO : GOSUB 2120
990 PRINT
1000 PRINT "    1 FOR DATA SET OK"
1010 PRINT "    2 TO RE-ENTER COMPLETE DATA SET"
1020 PRINT "    3 TO CORRECT PART OF DATA SET"
```

```
1030 PRINT : INPUT "ENTER NUMBER --> ",I
1040 IF I>3 THEN 980
1050 ON I GOTO 1060,730,1300
1060 IF NSZ<>2 THEN 650
1070 PCT(NO,1)=PF(1)
1080 FOR I=2 TO NPF
1090 PCT(NO,I)=PF(I)-PF(I-1)
1100 NEXT I
1110 GOTO 650
1120 REM STORE DATA ON DISK * * * * * * * * * * * * * * * * * * * * * * * * * * *
1130 OPEN "O",#1,DFILE$
1140 WRITE #1,NO
1150 FOR N=1 TO NO
1160 WRITE #1,LO$(N)
1170 FOR I=1 TO 9 : WRITE #1,VAR(N,I) : NEXT I
1180 FOR I=1 TO 11 : WRITE #1,PCT(N,I) : NEXT I
1190 NEXT N
1200 CLOSE
1210 RETURN
1220 END
1230 REM CORRECT DATA * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
1240 NN=25 : GOSUB 2520
1250 PRINT USING "ENTER SET NUMBER  MAX = ##";NO; : PRINT "   0 TO END"; : INPUT
 " --> ",N
1260 IF N>NO THEN 1240
1270 IF N>0 THEN 1300
1280 GOSUB 1120
1290 GOTO 390
1300 GOSUB 2120
1310 PRINT : INPUT "ENTER VALUE NUMBER (1-21)  0 FOR NEW SET --> ",L
1320 IF L>21 THEN 1300
1330 IF L>0 THEN 1360
1340 IF NC=2 THEN 1240
1350 GOTO 980
1360 IF L>1 THEN 1410
1370 PRINT : PRINT "OLD LOCATION NAME IS " : PRINT LO$(N)
1380 PRINT "ENTER NEW LOCATION NAME  (MAX 80 CHARACTERS)"
1390 LINE INPUT LO$(N)
1400 GOTO 1300
1410 IF L>10 THEN 1450
1420 PRINT : PRINT "OLD ";MID$(LABEL$,(L-1)*5+1,5);" VALUE IS ";VAR(N,L-1)
1430 INPUT "ENTER NEW VALUE --> ",VAR(N,L-1)
1440 GOTO 1300
1450 I=L-10
1460 IF NSZ=2 THEN 1490
1470 PRINT : PRINT "OLD PERCENT VALUE IS ";PCT(N,I) : INPUT "ENTER NEW VALUE -->
 ",PCT(N,I)
1480 GOTO 1300
1490 PRINT : PRINT "OLD PCT FN VALUE IS ";PF(I) : INPUT "ENTER NEW VALUE --> ",P
F(I)
1500 IF PF(I)>99.9 OR I>NPF THEN NPF=I
1510 GOTO 1300
1520 REM LIST DATA ON SCREEN  * * * * * * * * * * * * * * * * * * * * * * * * * *
```

```
1530 NN=25 : GOSUB 2520
1540 PRINT "ENTER START SET NUMBER TO BE LISTED    0 TO END LISTING ";
1550 INPUT "--> ",NS1
1560 IF NS1=0 THEN 390
1570 IF NS1>NO THEN 1530
1580 NN=3 : GOSUB 2520
1590 PRINT USING "ENTER END SET NUMBER TO BE LISTED     MAX = ##";NO;
1600 INPUT "--> ",NS2
1610 IF NS2>NO THEN 1580
1620 FOR N=NS1 TO NS2
1630 GOSUB 2120
1640 PRINT : PRINT "PRESS ANY KEY TO CONTINUE"; : S$=INPUT$(1)
1650 NEXT N
1660 GOTO 1530
1670 REM LIST DATA ON PRINTER * * * * * * * * * * * * * * * * * * * * * * * * * * *
1680 LPRINT "DATA STORED ON FILE ";DFILE$ : LPRINT
1690 NS=0
1700 NN=25 : GOSUB 2520
1710 PRINT "ENTER START SET NUMBER TO BE PRINTED   0 TO END PRINTING ";
1720 INPUT "--> ",NS1
1730 IF NS1=0 THEN 390
1740 IF NS1>NO THEN 1700
1750 NN=3 : GOSUB 2520
1760 PRINT USING "ENTER END SET NUMBER TO BE PRINTED    MAX = ## ";NO;
1770 INPUT "--> ",NS2
1780 IF NS2>NO THEN 1750
1790 FOR N=NS1 TO NS2
1800 NS=NS+1
1810 LPRINT "SET NUMBER  "N
1820 LPRINT " 1    LOC ";LO$(N)
1830 NR=1 : NL=1
1840 FOR I=1 TO 9 STEP 2
1850 NR=NR+1 : NL=NL+5
1860 LPRINT USING "##  ";NR; : LPRINT MID$(LABEL$,NL,5); : LPRINT USING "######.
###";VAR(N,I);
1870 IF I=9 THEN LPRINT : GOTO 1950
1880 NR=NR+1 : NL=NL+5
1890 LPRINT SPC(10); : LPRINT USING "##  ";NR; : LPRINT MID$(LABEL$,NL,5);
1900 IF I=3 THEN 1930
1910 LPRINT USING "######.###";VAR(N,I+1)
1920 GOTO 1940
1930 LPRINT USING "######.#######";VAR(N,I+1)
1940 NEXT I
1950 LPRINT "   PERCENT IN INDICATED SIZE FRACTION IN MM"
1960 FOR I=1 TO 11 STEP 2
1970 NR=NR+1
1980 LPRINT USING "##";NR; : LPRINT USING "#####.###";SIZELO(I),SIZEHI(I);
1990 LPRINT USING "####.##";PCT(N,I); : LPRINT SPC(6);
2000 IF I=11 THEN LPRINT : GOTO 2050
2010 NR=NR+1
2020 LPRINT USING "##";NR; : LPRINT USING "#####.###";SIZELO(I+1),SIZEHI(I+1);
2030 LPRINT USING "####.##";PCT(N,I+1)
2040 NEXT I
```

```
2050 IF NS=3 THEN 2080
2060 LPRINT : LPRINT : LPRINT
2070 GOTO 2100
2080 LPRINT CHR$(12);
2090 NS=0
2100 NEXT N
2110 GOTO 1700
2120 REM LIST ONE SET OF DATA ON SCREEN * * * * * * * * * * * * * * * * * * *
2130 NN=25 : GOSUB 2520
2140 PRINT "SET NUMBER  "N
2150 PRINT " 1    LOC ";LO$(N)
2160 NR=1 : NL=1
2170 FOR I=1 TO 9 STEP 2
2180 NR=NR+1 : NL=NL+5
2190 PRINT USING "##  ";NR; : PRINT MID$(LABEL$,NL,5); : PRINT USING "######.###
";VAR(N,I);
2200 IF I=9 THEN PRINT : GOTO 2280
2210 NR=NR+1 : NL=NL+5
2220 PRINT SPC(10); : PRINT USING "##  ";NR; : PRINT MID$(LABEL$,NL,5);
2230 IF I=3 THEN 2260
2240 PRINT USING "######.###";VAR(N,I+1)
2250 GOTO 2270
2260 PRINT USING "######.#######";VAR(N,I+1)
2270 NEXT I
2280 IF NSZ=2 THEN 2400
2290 PRINT "   PERCENT IN INDICATED SIZE FRACTION IN MM"
2300 FOR I=1 TO 11 STEP 2
2310 NR=NR+1
2320 PRINT USING "##";NR; : PRINT USING "#####.###";SIZELO(I),SIZEHI(I);
2330 PRINT USING "####.##";PCT(N,I); : PRINT SPC(6);
2340 IF I=11 THEN PRINT : GOTO 2390
2350 NR=NR+1
2360 PRINT USING "##";NR; : PRINT USING "#####.###";SIZELO(I+1),SIZEHI(I+1);
2370 PRINT USING "####.##";PCT(N,I+1)
2380 NEXT I
2390 RETURN
2400 PRINT "   PERCENT FINER FOR INDICATED SIZE IN MM"
2410 FOR I=1 TO 11 STEP 2
2420 NR=NR+1
2430 PRINT USING "##";NR; : PRINT USING "#####.###";SIZEHI(I);
2440 PRINT USING "####.##";PF(I); : PRINT SPC(10);
2450 IF I=11 THEN PRINT : GOTO 2500
2460 NR=NR+1
2470 PRINT USING "##";NR; : PRINT USING "#####.###";SIZEHI(I+1);
2480 PRINT USING "####.##";PF(I+1)
2490 NEXT I
2500 RETURN
2510 END
2520 REM SUBROUTINE TO MOVE CURSOR DOWN NN LINES * * * * * * * * * * * * * * *
2530 FOR LL=1 TO NN : PRINT : NEXT LL
2540 RETURN
2550 END
```

SUPPLEMENTAL DATA--SECTION D.

BASIC PROGRAM SEDDISCH LISTING

```
10 REM PROGRAM SEDDISCH
20 REM
30 REM COMPUTE BED-MATERIAL DISCHARGE & BEDLOAD DISCHARGE BY SELECTED FORMULAS
40 REM
50 DIM PCT(11),SIZELO(11),SIZEHI(11),DIA(11),DFT(11),NOSEL(2,12),AF(6,13),ZF(2),
NOS(2),TEMP(11),FG4(24),FG7(18),FG8(18),FG10(21),DIP(18),LABEL$(3),CY(7,7),CF(5)
60 DEF FNL(X)=LOG(X)/2.30259
70 GOSUB 1960
80 NOS(1)=0 : NOS(2)=0 : LSF=0
90 REM ENTER FORMULA NUMBERS TO BE COMPUTTED * * * * * * * * * * * * * * * * *
100 NN=25 : GOSUB 2600
110 PRINT "     1. BED-MATERIAL DISCHARGE FORMULAS"
120 PRINT "     2. BEDLOAD DISCHARGE FORMULAS"
130 PRINT "     3. BOTH TYPES OF FORMULAS"
140 NN=3 : GOSUB 2600
150 INPUT "ENTER NUMBER FOR TYPE(S) OF FORMULAS TO BE USED --> ",NTYPE
160 IF NTYPE>3 THEN 100
170 IF NTYPE=2 THEN 410
180 K=0 : N=1
190 NN=25 : GOSUB 2600
200 PRINT TAB(10);"BED-MATERIAL DISCHARGE FORMULA OPTIONS:" : PRINT
210 PRINT " 1. LAURSEN FORMULA  (USES SIZE FRACTIONS)"
220 PRINT " 2. ENGELUND AND HANSEN FORMULA  (USES D50)"
230 PRINT " 3. COLBY FORMULA  (USES D50)"
240 PRINT " 4. ACKERS AND WHITE FORMULA   (USING D50)"
250 PRINT " 5. ACKERS AND WHITE FORMULA   (USING D35)"
260 PRINT " 6. YANG SAND FORMULA   (USING D50)"
270 PRINT " 7. YANG SAND FORMULA   (USING SIZE FRACTIONS)"
280 PRINT " 8. YANG GRAVEL FORMULA   (USING D50)"
290 PRINT " 9. YANG GRAVEL FORMULA   (USING SIZE FRACTIONS)"
300 PRINT "10. COMBINE 7 AND 9  (USES SIZE FRACTIONS)"
310 PRINT "11. EINSTEIN FORMULA   (USES SIZE FRACTIONS)"
320 PRINT "12. TOFFALETI FORMULA   (USES SIZE FRACTIONS)"
330 NN=3 : GOSUB 2600
340 PRINT USING "ENTER FORMULA NUMBER FOR COMPUTATION NUMBER ##    (0 TO END)";
N; : INPUT " --> ",I
350 IF I>12 THEN 190
360 IF I=0 THEN 400
370 IF I=1 OR I=7 OR I>8 THEN LSF=LSF+1
380 K=K+1 : N=N+1 : NOSEL(1,K)=I
390 IF N<=12 THEN 190
400 NOS(1)=K
410 IF NTYPE=1 THEN 640
420 K=0 : N=1
430 NN=25 : GOSUB 2600
440 PRINT TAB(10);"BEDLOAD DISCHARGE FORMULA OPTIONS:" : PRINT
450 PRINT " 1. SCHOKLITSCH   (USES SIZE FRACTIONS)"
460 PRINT " 2. KALINSKE   (USES SIZE FRACTIONS)"
470 PRINT " 3. MEYER-PETER AND MULLER   (USES SIZE FRACTIONS)"
480 PRINT "    USE QS/Q=1 AND NS COMPUTED FROM EQUATION"
490 PRINT " 4. MEYER-PETER AND MULLER   (USES SIZE FRACTIONS)"
```

```
500 PRINT "     FOR RECTANGULAR CHANNEL AND ENTER ROUGHNESS VALUES"
510 PRINT " 5. MEYER-PETER AND MULLER   (USES SIZE FRACTIONS)"
520 PRINT "     FOR TRAPEZOIDAL CHANNEL AND ENTER ROUGHNESS VALUES"
530 PRINT " 6. ROTTNER FORMULA  (USES D50)"
540 PRINT " 7. EINSTEIN BEDLOAD FORMULA   (USES SIZE FRACTIONS)"
550 PRINT " 8. TOFFALETI FORMULA - BEDLOAD PART  (USES SIZE FRACTIONS)"
560 NN=3 : GOSUB 2600
570 PRINT USING "ENTER FORMULA NUMBER FOR COMPUTATION NUMBER ##     (0 TO END)";
N; : INPUT " --> ",I
580 IF I>8 THEN 430
590 IF I=0 THEN 630
600 IF I<3 OR I>6 THEN LSF=LSF+1
610 K=K+1 : N=N+1 : NOSEL(2,K)=I
620 IF N<=8 THEN 430
630 NOS(2)=K
640 IF LSF=0 THEN 740
650 NN=25 : GOSUB 2600
660 PRINT "LIST RESULTS OF FORMULAS THAT COMPUTE BY SIZE FRACTION" : PRINT
670 PRINT "      1. FOR EACH SIZE FRACTION AND TOTAL"
680 PRINT "      2. TOTAL ONLY"
690 NN=3 : GOSUB 2600
700 INPUT "ENTER LISTING SELECTION NUMBER --> ",I
710 IF I>2 THEN 650
720 IF I>1 THEN LSF=0
730 REM INPUT DATA * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
740 DFILE$="DISCH.DAT"
750 NN=25 : GOSUB 2600
760 PRINT "TURN ON PRINTER" : PRINT : PRINT "ESTABLISH FILE NAME:" : PRINT
770 PRINT "      1. USE PROGRAMMED FILE NAME (DISCH.DAT)"
780 PRINT "      2. PROVIDE FILE NAME"
790 NN=3 : GOSUB 2600
800 PRINT "ENTER NUMBER OF SELECTION "; : INPUT "--> ",I
810 IF I=1 THEN 840
820 NN=10 : GOSUB 2600
830 PRINT "ENTER DESIRED FILE NAME "; : INPUT "--> ",DFILE$
840 OPEN "I",#1,DFILE$
850 INPUT #1,NSAMP
860 FOR NS=1 TO NSAMP
870 SUMP=0
880 INPUT #1,L$
890 INPUT #1,W,Y,V,S,TEMP,D35,D50,D65,D90
900 INPUT #1,PCT(1),PCT(2),PCT(3),PCT(4),PCT(5),PCT(6),PCT(7),PCT(8),PCT(9),PCT(
10),PCT(11)
910 FOR I=1 TO 11 : SUMP=SUMP+PCT(I) : PCT(I)=PCT(I)/100! : NEXT I
920 COMP1=1.0334+.03672*TEMP+.0002058*TEMP*TEMP
930 XNU=.00002/COMP1
940 DF35=D35/304.8 : DF50=D50/304.8 : DF65=D65/304.8 : DF90=D90/304.8
950 COMP1=6*XNU
960 FV50=((36.064*DF50+COMP1).5-COMP1)/DF50
970 U=(G*Y*S).5
980 Q=W*Y*V
990 NN=25 : GOSUB 2600 : PRINT "DATA SET NUMBER ";NS : PRINT
1000 PRINT L$ : PRINT
```

```
1010 PRINT "TOP WIDTH";SPC(12); : PRINT USING "#####.## FEET";W;
1020 PRINT USING "      WATER SURF. SLOPE      ##.####### FT/FT";S
1030 PRINT "MEAN DEPTH";SPC(13); : PRINT USING "###.## FEET";Y;
1040 PRINT "      D50";SPC(18); : PRINT USING "##.### MILLIMETERS";D50
1050 PRINT "MEAN VELOCITY";SPC(9); : PRINT USING "##.## FT/SEC";V;
1060 PRINT USING "      KINEMATIC VISCOCITY          ##.#########";XNU
1070 PRINT "WATER DISCHARGE";SPC(5); : PRINT USING "#######.## CFS";Q;
1080 PRINT USING "      SED. FALL VELOCITY      ##.#### FT/SEC";FV50
1090 PRINT "WATER TEMPERATURE";SPC(7); : PRINT USING "##.# DEG C";TEMP
1100 NN=4 : GOSUB 2600
1110 LPRINT L$ : LPRINT
1120 LPRINT "TOP WIDTH";SPC(12); : LPRINT USING "#####.## FEET";W;
1130 LPRINT USING "      WATER SURF. SLOPE      ##.####### FT/FT";S
1140 LPRINT "MEAN DEPTH";SPC(13); : LPRINT USING "###.## FEET";Y;
1150 LPRINT "      D50";SPC(18); : LPRINT USING "##.### MILLIMETERS";D50
1160 LPRINT "MEAN VELOCITY";SPC(9); : LPRINT USING "##.## FT/SEC";V;
1170 LPRINT USING "      KINEMATIC VISCOCITY          ##.#########";XNU
1180 LPRINT "WATER DISCHARGE";SPC(5); : LPRINT USING "#######.## CFS";Q;
1190 LPRINT USING "      SED. FALL VELOCITY      ##.#### FT/SEC";FV50
1200 LPRINT "WATER TEMPERATURE";SPC(7); : LPRINT USING "##.# DEG C";TEMP
1210 IF NTYPE=2 THEN 1570
1220 LPRINT
1230 LPRINT TAB(10);"COMPUTED BED-MATERIAL CONCENTRATION AND DISCHARGE"
1240 LPRINT
1250 LPRINT "FORMULA";SPC(42);"CONC.   UNIT DISCH   DISCHARGE"
1260 LPRINT TAB(51);"PPM    LBS/SEC/FT   TONS/DAY"
1270 LPRINT
1280 FOR NO=1 TO NOS(1)
1290 IOS=NOSEL(1,NO)
1300 ON IOS GOTO 1310,1340,1370,1400,1400,1430,1460,1430,1460,1460,1490,1530
1310 REM LAURSEN FORMULA * * * * * * * * * * * * * * * * * * * * * * * * * * *
1320 GOSUB 2870
1330 GOTO 1560
1340 REM ENGELUND AND HANSEN FORMULA * * * * * * * * * * * * * * * * * * * * *
1350 GOSUB 3400
1360 GOTO 1560
1370 REM COLBY FORMULA * * * * * * * * * * * * * * * * * * * * * * * * * * * *
1380 GOSUB 3480
1390 GOTO 1560
1400 REM ACKERS AND WHITE FORMULA  * * * * * * * * * * * * * * * * * * * * * *
1410 GOSUB 3790
1420 GOTO 1560
1430 REM YANG SAND & GRAVEL FORMULAS USING D50 * * * * * * * * * * * * * * * *
1440 GOSUB 4190
1450 GOTO 1560
1460 REM YANG SAND & GRAVEL FORMULAS USING SIZE FRACTIONS  * * * * * * * * * *
1470 GOSUB 4480
1480 GOTO 1560
1490 REM EINSTEIN FORMULA  * * * * * * * * * * * * * * * * * * * * * * * * * *
1500 NLD=1
1510 GOSUB 6280
1520 GOTO 1560
1530 REM TOFFALETI FORMULA * * * * * * * * * * * * * * * * * * * * * * * * * *
```

```
1540 NLD=1
1550 GOSUB 7550
1560 NEXT NO
1570 IF NTYPE=1 THEN 1870
1580 LPRINT
1590 LPRINT TAB(12);"COMPUTED BEDLOAD CONCENTRATION AND DISCHARGE"
1600 LPRINT
1610 LPRINT "FORMULA";SPC(42);"CONC.   UNIT DISCH   DISCHARGE"
1620 LPRINT TAB(51);"PPM    LBS/SEC/FT   TONS/DAY"
1630 LPRINT
1640 FOR NO=1 TO NOS(2)
1650 IOS=NOSEL(2,NO)
1660 ON IOS GOTO 1670,1700,1730,1730,1730,1760,1790,1830
1670 REM SCHOKLITCH FORMULA * * * * * * * * * * * * * * * * * * * * * * * * *
1680 GOSUB 5090
1690 GOTO 1860
1700 REM KALINSKE FORMULA * * * * * * * * * * * * * * * * * * * * * * * * * *
1710 GOSUB 5380
1720 GOTO 1860
1730 REM MEYER-PETER AND MULLER FORMULA * * * * * * * * * * * * * * * * * * *
1740 GOSUB 5720
1750 GOTO 1860
1760 REM ROTTNER FORMULA * * * * * * * * * * * * * * * * * * * * * * * * * * *
1770 GOSUB 6170
1780 GOTO 1860
1790 REM EINSTEIN BEDLOAD FORMULA * * * * * * * * * * * * * * * * * * * * * *
1800 NLD=2
1810 GOSUB 6280
1820 GOTO 1860
1830 REM TOFFALETI FORMULA  (BEDLOAD PORTION) * * * * * * * * * * * * * * * *
1840 NLD=2
1850 GOSUB 7550
1860 NEXT NO
1870 LPRINT : LPRINT
1880 LPRINT "* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
 * * * * * *"
1890 LPRINT : LPRINT
1900 NEXT NS
1910 CLOSE 1
1920 NN=25 : GOSUB 2600
1930 PRINT "END OF RUN"
1940 NN=15 : GOSUB 2600
1950 END
1960 REM SUBROUTINE TO INPUT DATA STATEMENTS * * * * * * * * * * * * * * * * *
1970 DATA 0.016,.062,.125,.25,.5,1,2,4,8,16,32
1980 FOR I=1 TO 11 : READ SIZELO(I) : NEXT I
1990 DATA 0.062,0.125,0.25,0.5,1,2,4,8,16,32,64
2000 FOR I=1 TO 11 : READ SIZEHI(I) : NEXT I
2010 FOR I=1 TO 11
2020 DIA(I)=(SIZELO(I)*SIZEHI(I)).5
2030 DFT(I)=DIA(I)/304.8
2040 NEXT I
2050 SG=2.65
```

```
2060 GMS=165.36
2070 G=32.1725
2080 DATA .00001,.001,.0001,.0001,.0001,.0001
2090 DATA .06,.24,.32,.4,.49,.57
2100 DATA .1,.6,.76,.92,1.1,1.26
2110 DATA .2,1.8,2.2,2.5,2.85,3.2
2120 DATA .4,4.6,5.3,5.8,6.3,6.7
2130 DATA .8,9.5,10.5,11,11.6,12
2140 DATA 1.5,16.1,16.9,17.5,17.9,18.1
2150 DATA 2,19.9,20.3,20.7,21.1,21.5
2160 DATA 3,25.3,25.6,25.9,26.2,26.5
2170 DATA 7,39.5,39.5,39.5,39.5,39.5
2180 DATA 8,41.5,41.5,41.5,41.5,41.5
2190 DATA 9,43.5,43.5,43.5,43.5,43.5
2200 DATA 10,45,45,45,45,45
2210 FOR I=1 TO 13
2220 READ AF(1,I),AF(2,I),AF(3,I),AF(4,I),AF(5,I),AF(6,I)
2230 NEXT I
2240 DATA -.068,-1.1328,.94,-1.206,.567,-.0975
2250 READ AK0,AK1,AK2,AK3,AK4,AK5
2260 DATA .5,1.9,1.72,.65,1.75,1.23,.9,1.62,.57,1.15,1.61,0,1.4,1.63,-.47,3.2,1.
72,-1.11,5,1.42,-.52,8.4,1.25,-.27
2270 FOR I=1 TO 24 : READ FG4(I) : NEXT I
2280 DATA .2,1.17,-2.1,.4,.741,-2.39,.65,.661,-2.51,.8,.952,-1.66,1,1.15,-.817,1
.45,1.15,-.376
2290 FOR I=1 TO 18 : READ FG7(I) : NEXT I
2300 DATA .66,.997,1.18,.84,.911,.966,1.1,.814,.323,1.3,.858,-.218,2.2,.957,-.63
5,3.1,.714,-.263
2310 FOR I=1 TO 18 : READ FG8(I) : NEXT I
2320 DATA .77,7.56,1.01,2.12,5.35,1.19,4.1,4.1,1.67,6.1,4.1,2.3,11,4.6,3.23,16.7
,5.66,4.26,22.5,9.28,7.81
2330 FOR I=1 TO 21 : READ FG10(I) : NEXT I
2340 DATA 0,.37,.71,.99,1.21,1.34,1.41,1.38,1.27,1.11,.94,.78,.65,.55,.49,.45,.4
2,.4
2350 FOR I=1 TO 18 : READ DIP(I) : NEXT I
2360 DATA .64,1,1,.88,.2
2370 FOR I=1 TO 5 : READ CF(I) : NEXT I
2380 DATA .1,.2,.3,.4,.8,0,0
2390 DATA .61,.48,.3,.3,.3,0,0
2400 DATA 1.453,1.329,1.4,1.26,1.099,0,0
2410 DATA .01,5,10,15.6,20,30,40
2420 DATA .1057,.0845,.0469,0,-.0277,-.0654,-.1155
2430 DATA .0735,.0166,.0014,0,-.0164,-.061,-.0763
2440 DATA .0118,.0202,.0135,0,0,0,0
2450 FOR I=1 TO 7
2460 READ CY(I,1),CY(I,2),CY(I,3),CY(I,4),CY(I,5),CY(I,6),CY(I,7)
2470 NEXT I
2480 RETURN
2490 END
2500 REM SUBROUTINE TO PRINT DISCHARGES BY SIZE FRACTION * * * * * * * * * * *
2510 IF NSF>0 THEN 2550
2520 LPRINT "          SIZE RANGE      FRACTION"
2530 LPRINT "        IN MILLIMETERS     IN BED"
```

```
2540 RETURN
2550 LPRINT TAB(6); : LPRINT USING "####.###";SIZELO(I),SIZEHI(I);
2560 LPRINT USING "######.###";PCT(I); : LPRINT SPC(13);
2570 LPRINT USING "#######.##";CI; : LPRINT USING "########.####";UGSI
2580 RETURN
2590 END
2600 REM SUBROUTINE TO MOVE CURSOR DOWN NN LINES * * * * * * * * * * * * * * *
2610 FOR LL=1 TO NN : PRINT : NEXT LL
2620 RETURN
2630 END
2640 REM SUBROUTINE TO COMPUTE REPORT 12 SED FALL VEL, IN FT/SEC * * * * * * *
2650 REM INPUT DIAMETER IS IN FEET     TEMPERATURE IS IN DEG C * * * * * * * *
2660 REM MAX DIA IS 0.0328 FEET  (10 MM)   MAX TEMP IS 40 DEG C  * * * * * * *
2670 DFV=D*304.8
2680 SF=TEMP/10!
2690 KT=INT(SF)+1
2700 PT=SF-KT+1!
2710 DL=FNL(DFV)
2720 FOR M=1 TO 11
2730 IF DFV <= AF(1,M) THEN 2750
2740 NEXT M
2750 M=M-1
2760 CF=FNL(AF(1,M))
2770 EF=FNL(AF(1,M+1))
2780 PD=(DL-CF)/(EF-CF)
2790 FOR L=1 TO 2
2800 K=L+KT
2810 ZF(L)=(1!-PD)*FNL(AF(K,M))+PD*FNL(AF(K,M+1))
2820 NEXT L
2830 RF=(1!-PT)*ZF(1)+PT*ZF(2)
2840 FV=(10RF)/30.48
2850 RETURN
2860 END
2870 REM LAURSEN FORMULA * * * * * * * * * * * * * * * * * * * * * * * * * * *
2880 IF SUMP>0 THEN 2910
2890 LPRINT "LAURSEN";SPC(38);"SIZE FRACTION DATA NOT GIVEN"
2900 RETURN
2910 IF LSF>0 THEN LPRINT "LAURSEN" : NSF=0 : GOSUB 2500
2920 C=0 : UGS=0
2930 DELTA=11.6*XNU/U
2940 FOR I=2 TO 11
2950 IF PCT(I)=0 THEN 3300
2960 COMP1=6*XNU
2970 FVI=((36.064*DFT(I)+COMP1).5-COMP1)/DFT(I)
2980 RV=U/FVI
2990 RVL=FNL(RV)
3000 IF RV>.3 THEN 3030
3010 FV=10.718*RV.243
3020 GOTO 3130
3030 IF RV>3 THEN 3060
3040 FV=10(.855*RVL+.62*RVL+1.2)
3050 GOTO 3130
3060 IF RV>20 THEN 3090
```

```
3070 FV=4.773*RV.304
3080 GOTO 3130
3090 IF RV>200 THEN 3120
3100 FV=10(3.764*RVL-.803*RVL+.147)
3110 GOTO 3130
3120 FV=9680.5*RV.2531
3130 RY=DFT(I)/DELTA
3140 IF RY>.03 THEN 3170
3150 YC=.16
3160 GOTO 3210
3170 IF RY>.1 THEN 3200
3180 YC=.08
3190 GOTO 3210
3200 YC=.04
3210 F1=(DFT(I)/Y)(7/6)
3220 F2=V*V/(58!*YC*DFT(I)*(SG-1)*G)
3230 F3=(DF50/Y)(1/3)
3240 CI=10000*PCT(I)*F1*(F2*F3-1)*FV
3250 IF CI<=0 THEN CI=0
3260 C=C+CI
3270 UGSI=.0000625*CI*Y*V
3280 UGS=UGS+UGSI
3290 IF LSF>0 THEN NSF=I : GOSUB 2500
3300 NEXT I
3310 GS=UGS*43.2*W
3320 IF LSF>0 THEN 3350
3330 LPRINT "LAURSEN";SPC(38);
3340 GOTO 3360
3350 LPRINT "       TOTAL";SPC(33);
3360 LPRINT USING "######.##";C; : LPRINT USING "########.####";UGS;
3370 LPRINT USING "#########.##";GS
3380 RETURN
3390 END
3400 REM ENGELUND AND HANSEN FORMULA * * * * * * * * * * * * * * * * * * * * *
3410 UGS=.05*GMS*V*V*Y.5*S.5/(DF50*G.5*(SG-1))
3420 C=16000*UGS/(Y*V)
3430 GS=UGS*43.2*W
3440 LPRINT "ENGELUND & HANSEN";SPC(28); : LPRINT USING "######.##";C;
3450 LPRINT USING "########.####";UGS; : LPRINT USING "#########.##";GS
3460 RETURN
3470 END
3480 REM COLBY FORMULA * * * * * * * * * * * * * * * * * * * * * * * * * * * *
3490 IF D50>=.1 AND D50<=.8 THEN 3520
3500 LPRINT "COLBY";SPC(40);"D50 LT 0.1 OR D50 GT 0.8"
3510 RETURN
3520 VC=.4673*Y.1*D50.333
3530 DIFF=V*.3048-VC
3540 B=2.5
3550 IF DIFF>=1 THEN B=1.453*D50(-.138)
3560 X=FNL(Y)
3570 N=0
3580 N=N+1
3590 IF TEMP>CY(4,N) THEN 3580
```

```
3600 F1=CY(5,N-1)+CY(6,N-1)*X+CY(7,N-1)*X*X
3610 F2=CY(5,N)+CY(6,N)*X+CY(7,N)*X*X
3620 AF=F1+(F2-F1)*(FNL(TEMP)-FNL(CY(4,N-1)))/(FNL(CY(4,N))-FNL(CY(4,N-1)))
3630 AF=10(AF)
3640 N=0
3650 N=N+1
3660 IF D50>CY(1,N) THEN 3650
3670 A=CY(3,N-1)*Y(CY(2,N-1))
3680 F1=A*DIFFB*(1+(AF-1)*CF(N-1))*.672
3690 A=CY(3,N)*Y(CY(2,N))
3700 F2=A*DIFFB*(1+(AF-1)*CF(N))*.672
3710 UGS=FNL(F1)+(FNL(F2)-FNL(F1))*(FNL(D50)-FNL(CY(1,N-1)))/(FNL(CY(1,N))-FNL(C
Y(1,N-1)))
3720 UGS=10GS
3730 C=16000*UGS/(Y*V)
3740 GS=UGS*43.2*W
3750 LPRINT "COLBY";SPC(40); : LPRINT USING "######.##";C;
3760 LPRINT USING "########.####";UGS; : LPRINT USING "#########.##";GS
3770 RETURN
3780 END
3790 REM ACKERS AND WHITE FORMULA  * * * * * * * * * * * * * * * * * * * * *
3800 D=DF50
3810 IF IOS=4 THEN 3860
3820 IF DF35>0 THEN 3850
3830 LPRINT "ACKERS & WHITE  (USING D35)";SPC(18);"D35 NOT GIVEN"
3840 RETURN
3850 D=DF35
3860 DGR=D*((G*(SG-1)/(XNU*XNU)).3333)
3870 P=FNL(DGR)
3880 IF DGR>60 THEN 3950
3890 AN=1-.56*P
3900 AA=.23/SQR(DGR)+.14
3910 AM=9.66/DGR+1.34
3920 CA=2.86*P-P*P-3.53
3930 CA=10CA
3940 GOTO 3990
3950 AN=0
3960 AA=.17
3970 AM=1.5
3980 CA=.025
3990 F1=UAN/(SQR(G*D*(SG-1)))
4000 F2=(V/(SQR(G)*FNL(10!*Y/D)))(1-AN)
4010 F3=F1*F2/AA-1
4020 IF F3<0 THEN 4080
4030 GGR=CA*F3AM
4040 C=(GGR*D*SG*(V/U)AN)/Y
4050 C=C*10
4060 UGS=.0000625*C*Y*V
4070 GS=UGS*43.2*W
4080 IF IOS=5 THEN 4110
4090 LPRINT "ACKERS & WHITE  (USING D50)";SPC(18);
4100 GOTO 4120
```

```
4110 LPRINT "ACKERS & WHITE  (USING D35 = "; : LPRINT USING "#.### MM )";D35; :
LPRINT SPC(6);
4120 IF F3<0 THEN 4160
4130 LPRINT USING "######.##";C; : LPRINT USING "########.####";UGS;
4140 LPRINT USING "#########.##";GS
4150 RETURN
4160 LPRINT "COMPUTED CONCENTRATION LESS THAN ZERO"
4170 RETURN
4180 END
4190 REM YANG SAND & GRAVEL FORMULAS USING D50 * * * * * * * * * * * * * * * * *
4200 REM USES REPORT 12 FALL VEL. WITH MAX DIA = 10 MM * * * * * * * * * * * * *
4210 FV=FV50
4220 IF DF50>=.0328 THEN 4250
4230 D=DF50
4240 GOSUB 2640
4250 R=U*DF50/XNU
4260 F1=2.05
4270 IF R>=70 THEN 4290
4280 F1=.66+2.5/(FNL(R)-.06)
4290 F2=FNL(FV*DF50/XNU)
4300 F3=FNL(U/FV)
4310 C=0
4320 F4=V*S/FV-F1*S
4330 IF IOS=8 THEN 4380
4340 IF F4<=0 THEN 4360
4350 C=5.435-.286*F2-.457*F3+(1.799-.409*F2-.314*F3)*FNL(F4)
4360 LPRINT "YANG SAND  (USING D50)";SPC(23);
4370 GOTO 4410
4380 IF F4<=0 THEN 4400
4390 C=6.681-.633*F2-4.816*F3+(2.784-.305*F2-.282*F3)*FNL(F4)
4400 LPRINT "YANG GRAVEL  (USING D50)";SPC(21);
4410 C=10C
4420 UGS=.0000625*C*Y*V
4430 GS=UGS*43.2*W
4440 LPRINT USING "######.##";C; : LPRINT USING "########.####";UGS;
4450 LPRINT USING "#########.##";GS
4460 RETURN
4470 END
4480 REM YANG SAND & GRAVEL FORMULAS USING SIZE FRACTIONS  * * * * * * * * * *
4490 IF SUMP>0 THEN 4580
4500 ON (SGN(IOS-9)+2) GOTO 4510,4530,4550
4510 LPRINT "YANG SAND  (USING SIZE FRACTIONS)";SPC(12);
4520 GOTO 4560
4530 LPRINT "YANG GRAVEL  (USING SIZE FRACTIONS)";SPC(10);
4540 GOTO 4560
4550 LPRINT "YANG MIXTURE  (USING SIZE FRACTIONS)";SPC(9);
4560 LPRINT "SIZE FRACTION DATA NOT GIVEN"
4570 RETURN
4580 IF LSF=0 THEN 4660
4590 ON (SGN(IOS-9)+2) GOTO 4600,4620,4640
4600 LPRINT "YANG SAND  (USING SIZE FRACTIONS)"
4610 GOTO 4650
4620 LPRINT "YANG GRAVEL  (USING SIZE FRACTIONS)
```

```
4630 GOTO 4650
4640 LPRINT "YANG MIXTURE  (USING SIZE FRACTIONS)"
4650 NSF=0 : GOSUB 2500
4660 C=0 : UGS=0
4670 FOR I=2 TO 11
4680 IF PCT(I)=0 THEN 4940
4690 D=DFT(I)
4700 IF D<=.0328 THEN 4740
4710 COMP1=6*XNU
4720 FV=((36.064*D+COMP1).5-COMP1)/D
4730 GOTO 4750
4740 GOSUB 2640
4750 R=U*D/XNU
4760 F1=2.05
4770 IF R>=70 THEN 4790
4780 F1=.66+2.5/(FNL(R)-.06)
4790 F2=FNL(FV*D/XNU)
4800 F3=FNL(U/FV)
4810 CI=0
4820 F4=V*S/FV-F1*S
4830 IF F4<=0 THEN 4900
4840 IF IOS=9 THEN 4880
4850 IF IOS=10 AND I>6 THEN 4880
4860 CI=5.435-.286*F2-.457*F3+(1.799-.409*F2-.314*F3)*FNL(F4)
4870 GOTO 4890
4880 CI=6.681-.633*F2-4.816*F3+(2.784-.305*F2-.282*F3)*FNL(F4)
4890 CI=10CI*PCT(I)
4900 C=C+CI
4910 UGSI=.0000625*CI*Y*V
4920 UGS=UGS+UGSI
4930 IF LSF>0 THEN NSF=I : GOSUB 2500
4940 NEXT I
4950 GS=UGS*43.2*W
4960 IF LSF>0 THEN 5040
4970 ON (SGN(IOS-9)+2) GOTO 4980,5000,5020
4980 LPRINT "YANG SAND  (USING SIZE FRACTIONS)";SPC(12);
4990 GOTO 5050
5000 LPRINT "YANG GRAVEL  (USING SIZE FRACTIONS)";SPC(10);
5010 GOTO 5050
5020 LPRINT "YANG MIXTURE  (USING SIZE FRACTIONS)";SPC(9);
5030 GOTO 5050
5040 LPRINT "       TOTAL";SPC(33);
5050 LPRINT USING "######.##";C; : LPRINT USING "#######.####";UGS;
5060 LPRINT USING "#########.##";GS
5070 RETURN
5080 END
5090 REM SCHOKLITSCH FORMULA * * * * * * * * * * * * * * * * * * * * * * * * *
5100 IF SUMP>0 THEN 5130
5110 LPRINT "SCHOKLITSCH";SPC(34);"SIZE FRACTION DATA NOT GIVEN"
5120 RETURN
5130 IF LSF>0 THEN LPRINT "SCHOKLITSCH" : NSF=0 : GOSUB 2500
5140 F1=25*S.5*V*Y
5150 F2=1.6*S.17
```

```
5160 C=0 : UGS=0
5170 FOR I=1 TO 11
5180 IF PCT(I)=0 THEN 5280
5190 CI=0 : UGSI=0
5200 F3=DFT(I).5
5210 X=F1/F3-F2*F3
5220 IF X<0 THEN 5240
5230 UGSI=X*PCT(I)
5240 UGS=UGS+UGSI
5250 CI=16000*UGSI/(Y*V)
5260 C=C+CI
5270 IF LSF>0 THEN NSF=I : GOSUB 2500
5280 NEXT I
5290 GS=UGS*43.2*W
5300 IF LSF>0 THEN 5330
5310 LPRINT "SCHOKLITSCH";SPC(34);
5320 GOTO 5340
5330 LPRINT "       TOTAL";SPC(33);
5340 LPRINT USING "######.##";C; : LPRINT USING "########.####";UGS;
5350 LPRINT USING "#########.##";GS
5360 RETURN
5370 END
5380 REM KALINSKE FORMULA  * * * * * * * * * * * * * * * * * * * * * * * * * * *
5390 IF SUMP>0 THEN 5420
5400 LPRINT "KALINSKE";SPC(37);"SIZE FRACTION DATA NOT GIVEN"
5410 RETURN
5420 IF LSF>0 THEN LPRINT "KALINSKE" : NSF=0 : GOSUB 2500
5430 S1=0
5440 FOR I=1 TO 11
5450 TEMP(I)=PCT(I)/DFT(I)
5460 S1=S1+TEMP(I)
5470 NEXT I
5480 T0=62.4*Y*S
5490 F1=25.28*T0.5/S1
5500 C=0 : UGS=0
5510 FOR I=1 TO 11
5520 IF PCT(I)=0 THEN 5620
5530 T1=12*DFT(I)
5540 X=T1/T0
5550 F2=AK0+AK1*X+AK2*X+AK3*X+AK4*X+AK5*X
5560 F2=10(F2)
5570 UGSI=F1*T1*TEMP(I)*F2
5580 UGS=UGS+UGSI
5590 CI=16000*UGSI/(Y*V)
5600 C=C+CI
5610 IF LSF>0 THEN NSF=I : GOSUB 2500
5620 NEXT I
5630 GS=UGS*43.2*W
5640 IF LSF>0 THEN 5670
5650 LPRINT "KALINSKE";SPC(37);
5660 GOTO 5680
5670 LPRINT "       TOTAL";SPC(33);
5680 LPRINT USING "######.##";C; : LPRINT USING "########.####";UGS;
```

```
5690 LPRINT USING "#########.##";GS
5700 RETURN
5710 END
5720 REM MEYER-PETER AND MULLER FORMULA  * * * * * * * * * * * * * * * * * * * * * * * * *
5730 LABEL$(1)="QS/Q=1 AND NS=STRICKLER ROUGHNESS"
5740 LABEL$(2)="RECTANGULAR CHANNEL AND COMPUTE NS AND QS/Q"
5750 LABEL$(3)="TRAPEZOIDAL CHANNEL AND COMPUTE NS AND QS/Q"
5760 IF SUMP>0 THEN 5790
5770 LPRINT "MEYER-PETER & MULLER";SPC(25);"SIZE FRACTION DATA NOT GIVEN"
5780 RETURN
5790 DM=0
5800 FOR I=1 TO 11
5810 DM=DM+PCT(I)*DIA(I)
5820 NEXT I
5830 UGS=0
5840 IF IOS>3 THEN 5880
5850 QSQ=1
5860 RNS=1.486*Y.667*S.5/V
5870 GOTO 6010
5880 PRINT "MEYER-PETER AND MULLER   ";LABEL$(IOS-2)
5890 INPUT "ENTER MANNING'S N FOR CHANNEL SIDES (NW) --> ",RNW
5900 INPUT "ENTER MANNING'S N FOR TOTAL STREAM  (NM) --> ",RNM
5910 IF IOS=5 THEN 5950
5920 PRINT
5930 F1=2*Y/W
5940 GOTO 5990
5950 INPUT "ENTER BOTTOM WIDTH, IN FEET --> ",BW
5960 PRINT
5970 F2=(W-BW)/2/Y
5980 F1=2*Y*(1+F2).5/BW
5990 RNS=RNM*(1+F1*(1-(RNW/RNM).5)).667
6000 QSQ=1/(1+F1*(RNW/RNS).5)
6010 UGS=0
6020 F1=.368*QSQ*(D90.1667/RNS).5*Y*S-.0698*DM
6030 IF F1>0 THEN UGS=F1.5
6040 C=16000*UGS/(Y*V)
6050 GS=UGS*43.2*W
6060 IF IOS=5 THEN 6090
6070 LPRINT "MEYER-PETER & MULLER"
6080 GOTO 6100
6090 LPRINT "MEYER-PETER & MULLER      BOT WIDTH = "; : LPRINT USING "####.##";B
W
6100 LPRINT "  ";LABEL$(IOS-2)
6110 LPRINT USING "  D90 = ##.### MM";D90; : LPRINT USING "    M-P DM = ##.### M
M";DM
6120 IF IOS>3 THEN LPRINT USING "  NW = ##.###";RNW; : LPRINT USING "    NM = ##
.###";RNM
6130 LPRINT USING "  QS/Q = ##.###";QSQ; : LPRINT USING "    NS = ##.####";RNS;
: LPRINT SPC(14); : LPRINT USING "######.##";C;
6140 LPRINT USING "#######.####";UGS; : LPRINT USING "#########.##";GS
6150 RETURN
6160 END
6170 REM ROTTNER FORMULA * * * * * * * * * * * * * * * * * * * * * * * * * * *
```

```
6180 R=(DF50/Y).667
6190 F1=V/(7.286*Y.5)
6200 F2=.667*R+.14
6210 UGS=1204.8*Y.5*(F1*F2-.778*R)
6220 C=16000*UGS/(Y*V)
6230 GS=UGS*43.2*W
6240 LPRINT "ROTTNER";SPC(38); : LPRINT USING "######.##";C;
6250 LPRINT USING "########.####";UGS; : LPRINT USING "#########.##";GS
6260 RETURN
6270 END
6280 REM EINSTEIN FORMULA * * * * * * * * * * * * * * * * * * * * * * * * * * *
6290 IF SUMP>0 THEN 6320
6300 LPRINT "EINSTEIN";SPC(37);"SIZE FRACTION DATA NOT GIVEN"
6310 RETURN
6320 LPRINT "EINSTEIN"
6330 IF LSF>0 THEN LPRINT USING "  D35 = ##.### MM";D35; : LPRINT USING "    D65
 = ##.### MM";D65 : NSF=0 : GOSUB 2500
6340 RB=Y : CT=0 : UGS=0
6350 RBP=(V*DF65.1667/(7.66*(G*S).5)).5
6360 RBPP=RB-RBP
6370 SVP=(G*RBP*S).5
6380 DELTA=11.6*XNU/SVP
6390 X9=DF65/DELTA
6400 GOSUB 6800
6410 DELT=DF65/XR
6420 COMP1=DELT/DELTA
6430 IF COMP1<1.8 THEN 6460
6440 CAPX=.77*DELT
6450 GOTO 6470
6460 CAPX=1.39*DELTA
6470 GOSUB 7020
6480 BETAX=FNL(10.6*CAPX/DELT)
6490 PVALUE=2.3026*FNL(30.2*XR*RB/DF65)
6500 COMP1=6*XNU
6510 FOR I=1 TO 11
6520 IF PCT(I)=0 THEN 6710
6530 X9=DFT(I)/CAPX
6540 GOSUB 6920
6550 PSIS=XI*CAPY*(1.025/BETAX)*(1.65*DFT(I)/(RBP*S))
6560 X9=PSIS
6570 GOSUB 7120
6580 UNITBD=1200*PHI*DFT(I).5*PCT(I)
6590 UGSI=UNITBD
6600 IF NLD=2 THEN 6670
6610 FVI=((36.064*DFT(I)+COMP1).5-COMP1)/DFT(I)
6620 Z=FVI/(.4*SVP)
6630 A=2*DFT(I)/RB
6640 FI1=0 : FI2=0
6650 GOSUB 7220
6660 UGSI=UNITBD*(PVALUE*FI1+FI2+1)
6670 UGS=UGS+UGSI
6680 CI=16000*UGSI/(Y*V)
6690 CT=CT+CI
```

```
6700 IF LSF>0 THEN NSF=I : GOSUB 2500
6710 NEXT I
6720 GS=UGS*43.2*W
6730 IF LSF>0 THEN 6760
6740 LPRINT USING "  D35 = ##.### MM";D35; : LPRINT USING "    D65 = ##.### MM";
D65; : LPRINT SPC(9); : LPRINT USING "######.##";CT;
6750 GOTO 6770
6760 LPRINT "      TOTAL";SPC(33); : LPRINT USING "######.##";CT;
6770 LPRINT USING "########.####";UGS; : LPRINT USING "#########.##";GS
6780 RETURN
6790 END
6800 REM SUBROUTINE FIG 4  * * * * * * * * * * * * * * * * * * * * * * * * * * *
6810 J9=-2
6820 XR=.4
6830 IF X9<.135 THEN 6860
6840 IF X9<8.4 THEN 6870
6850 XR=1
6860 RETURN
6870 J9=J9+3
6880 IF X9>FG4(J9) THEN 6870
6890 XR=FG4(J9+2)*FNL(X9)+FG4(J9+1)
6900 RETURN
6910 END
6920 REM SUBROUTINE FIG 7  * * * * * * * * * * * * * * * * * * * * * * * * * * *
6930 J9=-2
6940 IF X9<1.45 THEN 6970
6950 XI=1
6960 RETURN
6970 J9=J9+3
6980 IF X9>FG7(J9) THEN 6970
6990 XI=FG7(J9+1)*X9(FG7(J9+2))
7000 RETURN
7010 END
7020 REM SUBROUTINE FIG 8  * * * * * * * * * * * * * * * * * * * * * * * * * * *
7030 J9=-2
7040 IF X9<3.1 THEN 7070
7050 CAPY=.53
7060 RETURN
7070 J9=J9+3
7080 IF X9>FG8(J9) THEN 7070
7090 CAPY=FG8(J9+1)*X9(FG8(J9+2))
7100 RETURN
7110 END
7120 REM SUBROUTINE FIG 10 * * * * * * * * * * * * * * * * * * * * * * * * * * *
7130 J9=-2
7140 IF X9<22.5 THEN 7170
7150 PHI=(13.1/X9).66
7160 RETURN
7170 J9=J9+3
7180 IF X9>FG10(J9) THEN 7170
7190 PHI=(FG10(J9+1)/X9)FG10(J9+2)
7200 RETURN
7210 END
```

```
7220 REM SUBROUTINE POWER  * * * * * * * * * * * * * * * * * * * * * * * * * * *
7230 N=1 : FJ1=0 : FJ2=0 : FI1=0 : FI2=0
7240 FACT=.216*A(Z-1)/(1-A)Z
7250 ALG=LOG(A)
7260 C=1
7270 D=-Z
7280 E=D+1
7290 NN=1
7300 AEX=A
7310 GOTO 7380
7320 N=N+1
7330 C=C*D/NN
7340 D=E
7350 E=D+1
7360 NN=N
7370 AEX=A
7380 IF ABS(E)<=.001 THEN 7420
7390 FJ1=FJ1+C*(1-AEX)/E
7400 FJ2=FJ2+C*((AEX-1)/E-AEX*ALG/E)
7410 GOTO 7440
7420 FJ1=FJ1-C*ALG
7430 FJ2=FJ2-.5*C*ALG
7440 IF N=1 THEN 7480
7450 CJ1=ABS(1-XJ1/FJ1)
7460 CJ2=ABS(1-XJ2/FJ2)
7470 IF CJ1<=.001 AND CJ2<=.001 THEN 7510
7480 XJ1=FJ1
7490 XJ2=FJ2
7500 GOTO 7320
7510 FI1=FACT*FJ1
7520 FI2=FACT*FJ2
7530 RETURN
7540 END
7550 REM TOFFALETI FORMULA * * * * * * * * * * * * * * * * * * * * * * * * * * *
7560 IF SUMP>0 THEN 7590
7570 LPRINT "TOFFALETI";SPC(36);"SIZE FRACTION DATA NOT GIVEN"
7580 RETURN
7590 IF LSF=0 THEN 7620
7600 LPRINT USING "TOFFALETI    D65 = ##.### MM";D65
7610 NSF=0 : GOSUB 2500
7620 TDF=1.8*TEMP+32
7630 ZV=.1198+.00048*TDF
7640 CZ=260.67-.667*TDF
7650 YA=Y/11.24
7660 YB=Y/2.5
7670 CV=1!+ZV
7680 SI=S*Y*CZ
7690 U3=V/(XNU*G*S)
7700 U2=V/(DF65*G*S).5
7710 F1=LOG(U3)
7720 F2=4.083*LOG(U2)-3.76
7730 F3=1.864*F1-9.09
7740 IF F3>F2 THEN 7770
```

```
7750 U1=F3
7760 GOTO 7910
7770 FI=(F2+9.09)/1.864
7780 FI=(F1-FI)*.43429
7790 IF TI<1.7 THEN 7820
7800 U1=F2+.4
7810 GOTO 7910
7820 F6=FI*10!
7830 FOR F5=1! TO 17!
7840 F1=F5-F6
7850 IF F5>=F6 THEN 7870
7860 NEXT F5
7870 J=F5
7880 F1=1!-F1
7890 F5=DIP(J)+F1*(DIP(J+1)-DIP(J))
7900 U1=F2+F5
7910 AM=10!*V/U1
7920 PAM=(XNU*100000!).3333/AM
7930 F1=100000!*PAM*S*DF65/G
7940 T=(.051+.00009*TDF)*1.1
7950 IF PAM>.5 THEN 7980
7960 A=9.8/(PAM.515)
7970 GOTO 8080
7980 IF PAM>.66 THEN 8010
7990 A=41!*PAM.55
8000 GOTO 8080
8010 IF PAM>.72 THEN 8040
8020 A=228!*PAM.68
8030 GOTO 8080
8040 IF PAM>1.3 THEN 8070
8050 A=49!
8060 GOTO 8080
8070 A=23.5*PAM.8
8080 IF F1<=.25 THEN 8130
8090 IF F1<=.35 THEN 8120
8100 A=A*.5/F1.05
8110 GOTO 8130
8120 A=A*5.2*F1.19
8130 IF A<16! THEN A=16!
8140 CT=0 : UGS=0
8150 FOR I=2 TO 9
8160 IF I>2 THEN 8190
8170 GFB=1.905/(T*A/(V*V)).667
8180 GOTO 8210
8190 GFA=GFB
8200 GFB=GFA/3.175
8210 IF PCT(I)=0 THEN 8620
8220 IF I=9 THEN FV=1.6 : GOTO 8250
8230 D=DFT(I)
8240 GOSUB 2640
8250 ZOM=FV*V/SI
8260 IF ZOM<(1.5*ZV) THEN ZOM=1.5*ZV
8270 F1=.756*ZOM-ZV
```

```
8280 F2=ZOM-ZV
8290 F3=1.5*ZOM-ZV
8300 F4=1!-F1
8310 F5=1!-F2
8320 F6=1!-F3
8330 YAF4=YAF4
8340 C=PCT(I)*W
8350 DD=2!*DFT(I)
8360 DDF4=DDF4
8370 UD=CV*V*(DD/Y)ZV
8380 X=F4*GFB/(YAF4-DDF4)
8390 UGSI=X*DDF4
8400 UBL=UGSI/(43.2*UD*DD)
8410 IF UBL<=100 THEN 8430
8420 UGSI=UGSI*100/UBL
8430 UGSI=C*UGSI
8440 IF NLD=2 THEN 8570
8450 GA=UGSI+C*GFB
8460 C=C*X
8470 YAF2=YA(F2-F1)
8480 YAF5=YAF5
8490 CF5=C/F5
8500 YBF3=YB(F3-F2)
8510 YBF6=YBF6
8520 CF6=C/F6
8530 CF4=C/F4
8540 GB=CF5*YAF2*(YBF5-YAF5)
8550 GC=CF6*YAF2*YBF3*(YF6-YBF6)
8560 UGSI=GA+GB+GC
8570 UGSI=UGSI/(43.2*W)
8580 UGS=UGS+UGSI
8590 CI=16000*UGSI/(Y*V)
8600 CT=CT+CI
8610 IF LSF>0 THEN NSF=I : GOSUB 2500
8620 NEXT I
8630 GS=UGS*43.2*W
8640 IF LSF>0 THEN 8670
8650 LPRINT USING "TOFFALETI    D65 = ##.### MM";D65; : LPRINT SPC(17);
8660 GOTO 8680
8670 LPRINT "        TOTAL";SPC(33);
8680 LPRINT USING "######.##";CT; : LPRINT USING "########.####";UGS;
8690 LPRINT USING "#########.##";GS
8700 RETURN
8710 END
```

SUPPLEMENTAL DATA--SECTION E.

EXAMPLES OF PROGRAM DISDATA OUTPUT

```
DATA STORED ON FILE REPT1.DAT

SET NUMBER   1
 1    LOC RIO GRANDE RIVER NR BERNALILLO, NM   SECT A2
 2  WIDTH   272.000         3  DEPTH      2.470         4    VEL.      4.060         5  SLOPE    0.0008900
 6  TEMP.    14.400         7    D35      0.191         8    D50      0.231         9    D65     0.280        10    D90     0.445
   PERCENT IN INDICATED SIZE FRACTION, IN MM
11    0.016     0.062   2.10    12    0.062     0.125   8.70    13    0.125     0.250  45.70
14    0.250     0.500  36.90    15    0.500     1.000   4.80    16    1.000     2.000   0.60
17    2.000     4.000   0.40    18    4.000     8.000   0.30    19    8.000    16.000   0.50
20   16.000    32.000   0.00    21   32.000    64.000   0.00


DATA STORED ON FILE REPT2.DAT

SET NUMBER   1
 1    LOC NIOBRARA RIVER NR CODY, NE
 2  WIDTH    70.000         3  DEPTH      1.560         4    VEL.      2.150         5  SLOPE    0.0012500
 6  TEMP.    20.000         7    D35      0.000         8    D50      0.276         9    D65     0.000        10    D90     0.000
   PERCENT IN INDICATED SIZE FRACTION, IN MM
11    0.016     0.062   0.00    12    0.062     0.125   0.00    13    0.125     0.250   0.00
14    0.250     0.500   0.00    15    0.500     1.000   0.00    16    1.000     2.000   0.00
17    2.000     4.000   0.00    18    4.000     8.000   0.00    19    8.000    16.000   0.00
20   16.000    32.000   0.00    21   32.000    64.000   0.00
```

SUPPLEMENTAL DATA--SECTION F.

EXAMPLES OF PROGRAM SEDDISCH OUTPUT

Run number 1. Output from data file REPT1.DAT with size fraction listing.

```
RIO GRANDE RIVER NR BERNALILLO, NM   SECT A2

TOP WIDTH               272.00 FEET     WATER SURF. SLOPE        0.0008900 FT/FT
MEAN DEPTH                2.47 FEET     D50                    0.231 MILLIMETERS
MEAN VELOCITY           4.06 FT/SEC     KINEMATIC VISCOCITY           0.00001246
WATER DISCHARGE         2727.67 CFS     SED. FALL VELOCITY         0.0939 FT/SEC
WATER TEMPERATURE        14.4 DEG C

          COMPUTED BED-MATERIAL CONCENTRATION AND DISCHARGE

FORMULA                                           CONC.   UNIT DISCH   DISCHARGE
                                                   PPM    LBS/SEC/FT   TONS/DAY

LAURSEN
         SIZE RANGE      FRACTION
       IN MILLIMETERS     IN BED
         0.062   0.125     0.087                 1354.55      0.8490
         0.125   0.250     0.457                  479.02      0.3002
         0.250   0.500     0.369                   92.58      0.0580
         0.500   1.000     0.048                    6.62      0.0041
         1.000   2.000     0.006                    0.44      0.0003
         2.000   4.000     0.004                    0.00      0.0000
         4.000   8.000     0.003                    0.00      0.0000
         8.000  16.000     0.005                    0.00      0.0000
       TOTAL                                     1933.22      1.2117    14237.57
ENGELUND & HANSEN                                1919.65      1.2032    14137.65
ACKERS & WHITE  (USING D50)                      2210.88      1.3857    16282.46
YANG SAND  (USING D50)                           1200.47      0.7524     8841.12
YANG SAND  (USING SIZE FRACTIONS)
         SIZE RANGE      FRACTION
       IN MILLIMETERS     IN BED
         0.062   0.125     0.087                  514.54      0.3225
         0.125   0.250     0.457                  774.49      0.4854
         0.250   0.500     0.369                  291.73      0.1828
         0.500   1.000     0.048                   26.70      0.0167
         1.000   2.000     0.006                    3.09      0.0019
         2.000   4.000     0.004                    2.30      0.0014
         4.000   8.000     0.003                    2.11      0.0013
         8.000  16.000     0.005                    6.60      0.0041
       TOTAL                                     1621.56      1.0163    11942.29
EINSTEIN
  D35 =  0.191 MM    D65 =  0.280 MM
         SIZE RANGE      FRACTION
       IN MILLIMETERS     IN BED
         0.016   0.062     0.021                    2.60      0.0016
         0.062   0.125     0.087                  324.68      0.2035
         0.125   0.250     0.457                  443.75      0.2781
         0.250   0.500     0.369                  303.97      0.1905
         0.500   1.000     0.048                   44.17      0.0277
```

1.000	2.000	0.006	4.28	0.0027	
2.000	4.000	0.004	1.13	0.0007	
4.000	8.000	0.003	0.15	0.0001	
8.000	16.000	0.005	0.00	0.0000	
TOTAL			1124.72	0.7049	8283.25

COMPUTED BEDLOAD CONCENTRATION AND DISCHARGE

FORMULA			CONC. PPM	UNIT DISCH LBS/SEC/FT	DISCHARGE TONS/DAY
SCHOKLITSCH					
SIZE RANGE IN MILLIMETERS		FRACTION IN BED			
0.016	0.062	0.021	21.78	0.0136	
0.062	0.125	0.087	53.22	0.0334	
0.125	0.250	0.457	193.03	0.1210	
0.250	0.500	0.369	105.35	0.0660	
0.500	1.000	0.048	8.80	0.0055	
1.000	2.000	0.006	0.62	0.0004	
2.000	4.000	0.004	0.14	0.0001	
4.000	8.000	0.003	0.00	0.0000	
8.000	16.000	0.005	0.00	0.0000	
TOTAL			382.93	0.2400	2820.18
KALINSKE					
SIZE RANGE IN MILLIMETERS		FRACTION IN BED			
0.016	0.062	0.021	1.93	0.0012	
0.062	0.125	0.087	7.65	0.0048	
0.125	0.250	0.457	37.77	0.0237	
0.250	0.500	0.369	27.10	0.0170	
0.500	1.000	0.048	2.84	0.0018	
1.000	2.000	0.006	0.24	0.0002	
2.000	4.000	0.004	0.07	0.0000	
4.000	8.000	0.003	0.01	0.0000	
8.000	16.000	0.005	0.00	0.0000	
TOTAL			77.61	0.0486	571.55

* *

Run number 2. Output from data file REPT1.DAT with only totals listed.

RIO GRANDE RIVER NR BERNALILLO, NM SECT A2

TOP WIDTH	272.00 FEET	WATER SURF. SLOPE	0.0008900 FT/FT
MEAN DEPTH	2.47 FEET	D50	0.231 MILLIMETERS
MEAN VELOCITY	4.06 FT/SEC	KINEMATIC VISCOCITY	0.00001246
WATER DISCHARGE	2727.67 CFS	SED. FALL VELOCITY	0.0939 FT/SEC
WATER TEMPERATURE	14.4 DEG C		

COMPUTED BED-MATERIAL CONCENTRATION AND DISCHARGE

FORMULA	CONC. PPM	UNIT DISCH LBS/SEC/FT	DISCHARGE TONS/DAY
LAURSEN	1933.22	1.2117	14237.57
ENGELUND & HANSEN	1919.65	1.2032	14137.65
COLBY	1768.79	1.1086	13026.59
ACKERS & WHITE (USING D50)	2210.88	1.3857	16282.46
YANG SAND (USING D50)	1200.47	0.7524	8841.12
YANG SAND (USING SIZE FRACTIONS)	1621.56	1.0163	11942.29
EINSTEIN			
D35 = 0.191 MM D65 = 0.280 MM	1124.72	0.7049	8283.25
TOFFALETI D65 = 0.28 MM	3791.49	2.3764	27923.23

COMPUTED BEDLOAD CONCENTRATION AND DISCHARGE

FORMULA	CONC. PPM	UNIT DISCH LBS/SEC/FT	DISCHARGE TONS/DAY
SCHOKLITSCH	382.93	0.2400	2820.18
KALINSKE	77.61	0.0486	571.55

*

Run number 3. Output from data file REPT2 DAT with only totals listed.

NIOBRARA RIVER NR CODY, NE

TOP WIDTH	70.00 FEET	WATER SURF. SLOPE	0.0012500 FT/FT
MEAN DEPTH	1.56 FEET	D50	0.276 MILLIMETERS
MEAN VELOCITY	2.15 FT/SEC	KINEMATIC VISCOCITY	0.00001081
WATER DISCHARGE	234.78 CFS	SED. FALL VELOCITY	0.1228 FT/SEC
WATER TEMPERATURE	20.0 DEG C		

COMPUTED BED-MATERIAL CONCENTRATION AND DISCHARGE

FORMULA	CONC. PPM	UNIT DISCH LBS/SEC/FT	DISCHARGE TONS/DAY
LAURSEN	SIZE FRACTION DATA NOT GIVEN		
ENGELUND & HANSEN	1125.46	0.2359	713.44
COLBY	316.97	0.0664	200.93
ACKERS & WHITE (USING D50)	531.83	0.1115	337.13
ACKERS & WHITE (USING D35)	D35 NOT GIVEN		
YANG SAND (USING D50)	604.59	0.1267	383.25
YANG SAND (USING SIZE FRACTIONS)	SIZE FRACTION DATA NOT GIVEN		

COMPUTED BEDLOAD CONCENTRATION AND DISCHARGE

FORMULA	CONC. PPM	UNIT DISCH LBS/SEC/FT	DISCHARGE TONS/DAY
SCHOKLITSCH	SIZE FRACTION DATA NOT GIVEN		
KALINSKE	SIZE FRACTION DATA NOT GIVEN		
ROTTNER	266.66	0.0559	169.04

* *

SUPPLEMENTAL DATA--SECTION G.

LOADING AND RUNNING THE PROGRAM ON THE PRIME COMPUTER

After the FORTRAN source code for the two programs (DISDATA.F77 and SEDDISCH.F77) have been entered into the Prime computer, they need to be compiled and loaded before they can be run.

Compiled programs DISDATA.BIN and SEDDISCH.BIN are created by entering and executing in sequence, the commands F77 DISDATA and F77 SEDDISCH.

The compiled programs are loaded by entering and executing the following command sequences:

```
SEG -LOAD            and        SEG -LOAD
$ LO DISDATA                    $ LO SEDDISCH
$ LI                            $ LI
LOAD COMPLETE                   LOAD COMPLETE
$ Q                             $ Q
```

Files DISDATA.SEG and SEDDISCH.SEG are created.

The command SEG DISDATA or SEG SEDDISCH is entered and executed to run the desired program.

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