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DISSERTATION

**SEDIMENT TRANSPORT RELATIONS
IN ALLUVIAL CHANNELS**

Submitted by
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In partial fulfillment of the requirements
for the Degree of Doctor of Philosophy
Colorado State University
Fort Collins, Colorado
Spring, 2000

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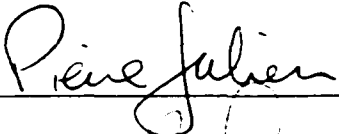
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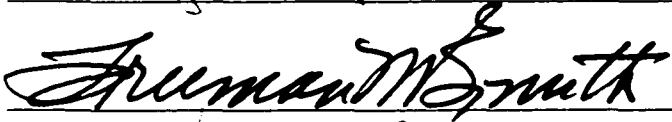
WE HEREBY RECOMMEND THAT THE DISSERTATION PREPARED UNDER OUR SUPERVISION BY ROBERT J. KODOATIE ENTITLED SEDIMENT TRANSPORT RELATIONS IN ALLUVIAL CHANNELS BE ACCEPTED AS FULFILLING IN PART REQUIREMENTS FOR THE DEGREE OF DOCTOR PHILOSOPHY.


Committee on Graduate Work












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ABSTRACT
SEDIMENT TRANSPORT RELATIONS
IN ALLUVIAL CHANNELS

This dissertation presents new methods for predicting sediment transport in alluvial channels. The new methods were developed based on simple equations and easy-to-apply parametric relationships and can be applied to a wide range of river conditions. Modifications of Posada (1995), Simons et al. (1981) and Laursen (1958) equations and Laursen graph with a wide range of field and flume data are presented.

The first step was to test the applicability of 10 selected sediment transport relations, including Einstein (1950), Laursen (1958), Bagnold (1966), Toffaletti (1969), Shen & Hung (1972), Ackers & White (1973), Yang (1973), Brownlie (1981), Karim & Kennedy (1981) and Karim (1998) using field data of alluvial rivers. Review and evaluation of some of the comparison results between computed and measured sediment discharges by previous researchers were conducted. A summary of the selected equations which had the best fit of sediment transport to the measured values is also presented.

The relation and correlation of hydraulic geometry and sediment characteristics to the sediment transport rates were examined carefully. Velocity, slope, flow depth, and dimensionless unit stream power which have best correlation for various river-beds and river channel sizes to the measured sediment transport rate were used to modify one or two existing equations. Using statistical approaches and non-linear optimization, simple

sediment transport relations were developed so they can be easily applied and be used for practical purposes.

A total of 4532 data sets from 33 river systems in the United States of America, South America, and Asia were used for analysis and verification. The field data were divided randomly into two groups; one for analysis and the other for validation and verification. In addition, 919 sets of laboratory data from 19 sources were added to verify the proposed methods.

The data were divided according to the mean diameter particle of river-bed materials ranging from silt to gravel, including silt-bed rivers, very fine to fine sand-bed rivers, medium to very coarse sand-bed rivers, and gravel-bed rivers. The data also were grouped according to river size, including small rivers, intermediate rivers and large rivers.

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List of Symbols

A	parameter related to flow and sediment characteristics in Equation (5.1)
A_c	parameter in Equation (2.31) and a function of $(10^5 v)^{1.3} / 10u_c'$ given in Figure 2.11.a
a	coefficient in Equations (6.1) and (6.3) and power coefficient in Equation (6.26)
B	parameter that can be water discharge Q, average flow velocity u, water surface slope S_w , energy slope S_f , shear stress τ , stream power τu , unit stream power uS , etc. in Equation (5.1)
B_c	critical condition parameter related to B at incipient motion in Equation (5.1)
b, c	coefficients in Equations (6.1) and (6.3)
C	sediment concentration percent by weight
C_{AW1}	parameter in Equations (2.35) and (2.37) and is dependent on sediment size
C_{AW2} , C_{AW3} , & C_{AW4}	parameters in Equation (2.37) and depend on the dimensionless particles diameter d_s .
C_{aw5}	the sediment mobility in Ackers & White's method and is described by Equation (2.35)
C_c	correlation coefficient and is defined by Equation (2.75)
C_F	the correction factor
C_i	concentration distribution in Equation (2.19)
C_{k1} , C_{k2} , C_{k3}	parameters in the sediment transport equation proposed by Karim & Kennedy (1981) and defined in Equations (2.53), (2.54), and (2.55), respectively
C_{s1}	coefficient in Equation (5.3)

c_{s1}, c_{s2}, c_{s3}	coefficients based on mean particle diameter (d_{50}) ranging from sand to fine gravel (0.1 mm – 5.0 mm) in Equation (5.3)
C_t	total average sediment concentration in weight per unit volume
C_{ui}, C_{mi}, C_{li}	concentration distribution of the upper, middle and lower zones and given by Equation (2.19)
C_w	total sediment concentration in Ackers & White's method and is expressed in Equation (2.37)
C_z	variable in Equation (2.20) and is given by $C_z = 260.67 - 0.667T$
D	parameter related to flow and sediment characteristics in Equation (5.1)
d	flow depth
d	power coefficient of slope to be analyzed in Equation (6.1)
d_*	the dimensionless grain diameter is expressed as $d_* = \left[\frac{(G-1)g}{v^2} \right]^{1/3}$
d_{50}	mean diameter of sediment
d_{50}/δ	ratio of the median grain size to the laminar sublayer and defined as $\frac{d_{50}}{\delta} = \frac{u_*' d_{50}}{11.6v}$
d_{84}	particle size of which 84% of the bed is finer
d_i	geometric mean diameter of particle of the i^{th} size
d_s	particle diameter of bed material
e_B	the bed-load transport efficiency in Bagnold's method and determined from Figure 2.8a.
F_g	the grain Froude number in Brownlie's method and is defined by Equation (2.55)
F_g'	the grain Froude number in Brownlie's method that divides the upper and lower flow regime data for slope less than 0.006 which is defined as $F_g = F_g' = 1.74S^{-1/3}$
$f\left(\frac{u_*'}{\omega_i}\right)$	functional relation of u_*'/ω_i defined on Plate 16 Copeland & Thomas (1989) or roughly plotted in Figure 6.6.

$f\left(\frac{u_*}{\omega_i}\right)$	functional relation of u^*/ω_i given in Figure 2.7
I_1 and I_2	integrals of Einstein's form of suspended sediment equation and defined by Equation (2.6)
G	the specific gravity
i	data set or point number
k	correction factor of Equation (2.31) and is given in Figure 2.11b
k_s	coefficient of roughness for the bed or roughness coefficient according to Strickler
L_b	bed load which is defined as the transport of sediment particles that mostly close or maintain in contact with the bed in Equation (2.1)
L_{bm}	the capacity limited bed material load in Equation (2.1)
L_m	measurement sediment in Equation (2.1)
L_s	suspended load defined as the suspended sediment passing through a stream cross section above the bed layer in Equation (2.1)
L_T	the total load in Equation (2.1)
L_u	unmeasured sediment that is the sum of bed load and fraction of suspended load below the lowest sampling elevation in Equation (2.1)
L_w	wash load which is the range of fine particle not found in the bed ($d_s < d_{10}$), and is determined by available bank and upslope supply in Equation (2.1)
M_i	coefficient in Equations (2.23), (2.24) and (2.25) and is given by Equation (2.26)
n	Manning's roughness coefficient
n	number sediment size fractions
N	total number of data sets in Equations (2.72), (2.73) and (2.74)
P_{ai}	are the areal function of bed material in i^{th} size fraction in Karim's method and expressed by Equation (2.69)
P_{bi}	the volumetric fraction of sediments in i^{th} fraction in Karim's method
P_E	transport parameter due to Einstein and defined as $P_E = 2.303 \log \frac{30.2d}{\Delta}$
p_i	fraction of bed material for diameter particle size d_i

p_{si}, p_{bi}	The fraction of suspended material and fraction of bed material of d_i in Equation (6.4), respectively
Q_s	the total sediment discharge defined in Equation (5.1)
q^*	dimensionless unit discharge $\frac{q}{\sqrt{gd_{50}^3}}$
q_b	the unit discharge of bed sediment load
q_{bi}	bed load discharge in Einstein's approach
q_{bi}	the bed load discharge in Toffaletti's method and is given by Equation (2.33)
q_s	the unit discharge of suspended sediment load
q_{si}	sediment discharge per unit width for the i^{th} fraction for non-uniform sediment discharge developed by Karim (1998) and is expressed in Equation (2.67)
q_{si}	the unit suspended load discharge in Einstein's approach
q_{sti}	suspended load discharge per unit width in lower zone of Toffaletti's method and is expressed in Equations (2.25), (2.30) and (2.31)
$q_{sui}, q_{smi}, q_{sti}$	suspended load discharge per unit width in upper and middle zones respectively of Toffaletti's method and those are given by the Equations (2.23) and (2.24)
q_T	the total unit discharge expressed in dry weight per unit time and width for any system of unit
q_t	the unit sand discharge (Mg/m/day) in Equation (5.2) or (ft^3/ft of width/s) in Equation (5.3)
q_{ti}	the unit bed material discharge for a given size fraction in Einstein's approach
q_{ti}	the total unit bed-material load discharge in Toffaletti's method for the sediment of size d_i and is given by Equation (2.34)
$\overline{R_D}$	the mean discrepancy ratio defined by Equation (2.72)
r^*	hydraulic radius of bed grain roughness
R_b^*	the bed hydraulic radius associated with the grain roughness

R_g	the grain Reynolds number in Brownlie's method and defined by $R_g = \frac{\sqrt{gd_{50}^3}}{\nu}$
S	channel slope
s	scattering of the discrepancy ratio s defined by Equation (2.74)
Sh	parameter of sediment concentration in Shen & Hung method and is expressed in Equation (2.49)
S_{pe}	sepecific stream power which is defined as $S_{pe} = \gamma QS/w$
T	the water temperature
T_t	Parameter in Equation (2.31) and is given by $T_t = 1.10(0.051+0.00009T)$
u	the mean velocity
u_*	shear velocity $\sqrt{\tau_o/\rho}$
u_*'	the shear velocity due to grain roughness in Toffaletti's method and is of function of u^3/gvS and $u/\sqrt{gd_{65}S}$ with $d_{65} \cong k_s$ as given in Figure 2.10
u_c	the average velocity at incipient in motion
uS	the unit stream power
uS/ω	the dimensionless unit steam power.
u_x	the velocity profile is represented by the power relation of Toffaletti's method and defined as $u_x = (1 + \eta_v)u(y/d)^{\eta_v}$
X	the characteristics grain size of the mixture in Einstein's method which given by Equation (2.11)
X_i	computed sedimentation in Equations (2.72), (2.74), and (2.75)
\bar{X}	average of computed sedimentation in Equation (2.75)
x	correction factor in the logarithmic velocity distribution related to the apparent roughness of the bed surface Δ and is determined from Figure 2.3. for values $k_s/\delta' = 11.6\nu/u_*$
x	equal to u_*/ω_i in Equation (6.24)
Y	parameter in Equation (2.52) and defined as $Y = \left(\sqrt{\frac{\rho_s - \rho}{\rho}} R_g \right)^{-0.6}$

Y	the correction factor for the lift coefficient in Einstein's method given as a function of d_{65}/δ (see Figure 2.6b). It describes the change in the lift coefficient for mixtures of sizes of bed material that contributes to various bed roughness conditions
Y_i	measured sedimentation in Equations (2.72), (2.74), and (2.75)
\bar{Y}	average of measured sedimentation in Equation (2.75)
y	equal to $\text{Log } f(u_*'/\omega_{i*})$ in Equation (6.24)
z_i	the exponent in Equation (21.9) is given by $z_i = \frac{\omega_i u}{C_z d S}$

Greek Symbols

ρ	density of water
γ	specific weight of water
ν	the kinematic viscosity of water
α	coefficient of dynamic solid fraction in Bagnold's method and can be determined from Figure 2.8b.
ξ	correction factor defined by Einstein and given as function of D/X (see Figure 2.5)
Δ	the apparent roughness of the bed surface and equal to k_s/x with $k_s \cong D_{65}$
ρ	the density of water
ν	the kinematic viscosity of water
η	the sheltering factor in Karim's method and defined in Equation (2.70)
τ	the total shear stress
δ	thickness of laminar sublayer
η_v	the exponent in Equation (2.17) and is given by the empirical relation $\eta_v = 0.1198 + 0.00048T$
ϕ_*	dimensionless sediment transport function in Equation (2.8) of Einstein's method
ψ_*	flow intensity function defined in Equation (2.9)

τ_{*c}	the critical Shields parameter in Brownlie's method is calculated by $\tau_{*c} = 0.22Y + 0.06(10)^{-7.7Y}$ as defined by Brownlie.
τ'	the shear stress associated with grain roughness
δ'	thickness of laminar sub-layer
τ''	the shear stress associated with form shear stress
η_1, η_2, η_3	coefficients in Equations (2.23), (2.24) and (2.25), respectively and are given by the expressions of $\eta_1 = 1 + \eta_v - 1.5z_i$, $\eta_2 = 1 + \eta_v - z_i$, $\eta_3 = 1 + \eta_v - 0.758z_i$
τ_{ci}	critical shear stress for sediment size d_i
τ_{ci}	critical shear stress for sediment size d_i
σ_D	standard deviation
ω	fall velocity
ω_i	the fall velocity of the sediment size d_i
τ_o	the shear stress
τ_o'	bed shear stress due to grain size
τ_o''	bed shear stress due to grain size
$\tau_o u$	the stream power
γ_s	specific weight of sediment
ρ_s	density of solid particle
ϕ_i	the weighing function for i^{th} fraction of Equation (2.67)
ψ	shear intensity parameter defined in Equation (2.10)

Chapter 1

INTRODUCTION

1.1. Background

The mechanics of sediment transport comprise a technical science in which the processes of erosion, transportation and deposition of sediment take place under gravity, water flow, waves and wind (Wang et al., 1997). Engineers and geomorphologists have been studying sediment transport in rivers for many decades and the study still continues since this subject involves complex interactions among many interrelated variables (Simons & Senturk, 1992; Ackers & White, 1973 & 1980).

Many sediment transport relationships for alluvial rivers have been proposed during the last 50 years based upon simplified and idealized assumptions. Due to the complexity, most existing equations are empirical and semi-empirical and/or heavily based on assumptions which are not yet justified (Cao et al., 1997; Pacheco-Ceballos, 1989; Tywoniuk, 1972). Some methods have been developed based on theoretical considerations and/or statistical interpretations of data, and some based on the physics of particle motion. Other methods have been developed from experimental work, some were derived empirically, and some represent a combination of theories, experiments and empirical methods.

Investigations of sediment movement have been conducted in the laboratory using granulated coal, glass or synthetic material. On the other hand, in practice engineers have

dealt with a variety of granular materials in applying the governing laws of the transport and movement of sediments (Bogardi, 1978). Besides, in nature, three-dimensional time-dependent phenomena have still to be studied, for which the available knowledge is mostly not yet sufficient (Overbeek, 1979; Borah et al., 1982a & 1982b). However, field verification data have not been used to validate the various relationships to a significant degree (Simons and Senturk, 1992).

Although methods and procedures in water resources development have become increasingly improved, sedimentation problems, as have been recognized by most investigators, are still complex and warrant further investigation (Williams & Julien, 1989). During the development, none of the methods could calculate precisely the sediment transport and give satisfactory results, which encompass all conditions. In other words, there is no single equation which can calculate sediment transport for the entire range of conditions in the field (Alonso et al., 1982; Shen & Hung, 1983; Steven and Yang, 1989; Simons & Senturk, 1992; Julien, 1995). As a result, calculations of sediment transport using existing methods for specific rivers with the same input data will produce a wide range of results. It can be concluded that although the various problems in sediment study should be solved gradually and separately, every sediment study should be continuously checked and compared with other related investigations (Bogardi, 1965). Because of the complexity, analysis of the best by comparison of several sediment transport equations is often academic (ASCE Task, 1982). Specific equations are based upon limited data and they may not fit the whole spectrum of data from flumes, canals and rivers (Yang and Wan, 1991). Therefore, engineering judgment

must be used and factors/parameters related to best fit of available data are very important.

Rivers carrying huge sediment loads are easily found throughout the world. Most sediment transport equations can accurately predict the sediment movement in small rivers since this measurement is relatively easy. However, due to the difficulty of gathering information and data for large rivers, extrapolation of methods to estimate sediment loads may not give proper and accurate results (Posada, 1995). As a result, the subject of total sediment load transport in large rivers is still challenging and needs further investigation.

1.2. Purpose

The purpose of this study is to test the applicability of selected sediment transport relations with field data and to modify one or two existing equations or to create one or more new equations of total load sediment transport.

1.3. Objectives

The objectives of the study include:

1. To use all of the field data to test the applicability of the ten sediment transport equations for alluvial rivers.
2. To analyze the correlation of hydraulic geometry and sediment characteristics in their contribution to the sediment transport rates.
3. To modify one or two existing equations and to create one or more new equations of total load sediment transport.
4. To apply the modified equations and possible new equations to selected rivers

5. To acquaint the engineering profession with limitations of reviewed total load equations of bed material transport.

1.4. Scope

The scope of this study includes:

Utilize the ten sediment transport equations developed from 1950 to 1998 by various authors and field data from rivers and to determine the applicability of these equations.

The sediment transport equations include:

1. Methods based on energy and stream power concepts, including those of: Einstein (1950), Laursen (1958), Bagnold (1966), Toffaletti (1969), Ackers & White (1973), and Yang (1973).
2. Methods based on regression analysis of comprehensive data sets, including those of: Shen & Hung (1972), Brownlie (1981a), Karim and Kennedy (1981), and Karim (1998).

Field data sets from various rivers (33 river systems) were used. These field data include: 1) ACOP Canal and 2) CHOP Canals in Pakistan, 3) American canals, 4) the Atchafalaya River, 5) the Amazon River & the Orinoco River, 6) Black River, 7) India canals, 8) the Chippewa River, 9) the Chulitna River, 10) the Colorado River, 11) the Hii River, 12) the Middle Loup River, 13) the Mississippi River, 14) Mountain Creek, 15) the Niobrara River near Cody, 16) the North Fork Toutle River, 17) the North Saskatchewan River & the Elbow River, 18) Oak Creek, 19) the Red River, 20) the Rio Grande River, 21) Rio Grande Convey Channel, 22) the Rio Grande River in Columbia, 23) Rio Magdalena and Canal del Dique, 24) River data of Leopold, 25) Rivers in Portugal, 26) the Snake River and the Clearwater River, 27) the Susitna River, 28) the Toutle River.

29) the Trinity River, 30) the Wisconsin River, 31) the Yampa River, 32) the Yangtze River and 33) the Yellow River in China.

Additionally, 919 sets of laboratory data from 19 sources were selected to verify the proposed methods, including 1) Barton & Lin (1955), 2) Brooks (Vanoni and Brooks, 1957), 3) Franco (1968), 4) Guy, Simons & Richardson (1966), 5) Kalinske & Hsia (1945), 6) Kennedy & Brooks (1963), 7) Laursen (1958), 8) Meyer-Peter & Muller (1948), 9) Nomicos 1 (in Toffaleti, 1968; Vanoni & Brooks, 1957), 10) Nomicos 2 (in Vanoni & Brooks, 1957), 11) Onishi, Jain & Kennedy (1976), 12) Stein (1965), 13) Straub (Straub, 1954 & Straub et al., 1958), 14) Taylor & Vanoni (1972), 15) Vanoni & Hwang (1967), 16) Vanoni & Brooks (1957), 17) Wilcock & Southard (1988), 18) Williams (1970), 19) Willis, Coleman and Ellis (1972).

1.5. Outline

The dissertation consists of 9 chapters. Chapter 1 presents the introduction to the dissertation including, the background, objectives, scope and outline of the dissertation. Chapter 2 consists of a comprehensive review of the literature related to the theories, the problems under examination and the statistical methods which are used.

Chapter 3 presents the source, compilation, and selection of field data. Chapter 4 analyzes the existing sediment transport relations. Computation of sediment discharge is obtained by using the selected field data and the selected sediment transport equations. Evaluation and comparison of the results are presented. Statistical approaches were used

including a regression analysis, accuracy, and comparison (Nakato, 1990; Yang & Wan, 1991; Wu (1999); and Bechteler & Vetter, 1989).

Chapter 5 presents a comprehensive review of comparison and evaluation of some sediment transport relations with emphasis on the ten selected sediment transport relations. This chapter also provides the summary analysis of previous authors.

In Chapter 6, new proposed methods are presented and discussed based on results of the evaluation and examination of the existing sediment relations discussed in Chapter 5, and the conceptual and theoretical considerations. Selection of dimensionless parameters was conducted and the statistical approach and non-linear optimization were used to compare and to evaluate the proposed and the existing methods. Comparison and evaluation of sediment transport relations are presented and a summary of overall results is given.

Chapter 7 consists of verification and validation of the proposed methods. Chapter 8 contains conclusions from main results and Chapter 9 presents recommendations.

Chapter 2

LITERATURE REVIEW

2.1. Background

As stated earlier, the transport of sediment in rivers depends upon many interrelated variables. There is no single equation that can be applied for all conditions. Simons and Senturk (1992), based on their extensive laboratory and field experience, presented recommendations to be considered in sediment transport analysis. Some of the recommendations include:

1. Examine the available transport equations and determine which ones are best for a specific river system.
2. Calculate the rates of transport equations using selected relationships and compare the results with field data.
3. Select the relationships which best agree with field observations and if data are available, refine this relationship so that it is site specific.

Additionally, Simons (1999) also recommended that if the river will be used for very important purposes, such as dams, navigation, etc., more field observation should be conducted so that the chosen sediment transport relation could be extended to a wider range of river conditions.

Einstein (1964) has stated that two conditions must be satisfied by every sediment particle which passes a particular cross section of the stream:

1. It must have been eroded somewhere in the watershed above the cross section.
2. It must be transported by the flow from the place of erosion to the cross section.

These conditions will affect the sediment transport rate depending on two relative magnitude controls: the transport capacity of the channel and the availability of material in its watershed (Einstein, 1964). For engineering purposes there are two sources of sediment transported by a stream: the bed material that makes up the stream bed, and the fine material that comes from the banks and the watershed as washload (Richardson et al., 1990). This distinction is important because the bed material is transported at the capacity of the stream and as a function of measurable hydraulic variables.

When a river reaches equilibrium, its transport capacities for water and sediment are in balance with the rates supplied (Chang, 1986). In fact, most rivers are subject to some kind of control or disturbance, natural or man-made, that give rise to non-equilibrium conditions (Jaramillo & Jain, 1984).

Total sediment load can be divided into three equations (Julien, 1995):

1. by type of movement

$$(L_T = L_b + L_s) \quad (2.1a)$$

2. by method of measurement

$$(L_T = L_m + L_u) \quad (2.1b)$$

3. by source of sediment (see Figure 2.2)

$$(L_T = L_w + L_{bm}) \quad (2.1c)$$

in which

L_T = the total load

L_b = bed load which is defined as the transport of sediment particles that are close to or maintain contact with the bed

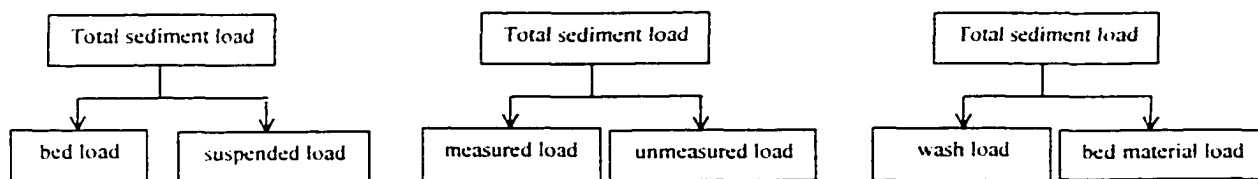
L_s = suspended load defined as the suspended sediment passing through a stream cross section above the bed layer

L_m = measured sediment

L_u = unmeasured sediment that is the sum of bed load and fraction of suspended load below the lowest sampling elevation

L_w = wash load which is the fine particles not found in the bed material ($d_s < d_{10}$), and originates from available bank and upslope supply

L_{bm} = the capacity limited bed material load



a. By type of movement

b. By method of measurement

c. By source of sediment

Figure 2.1. Classification of sediment transport in streams (rivers)

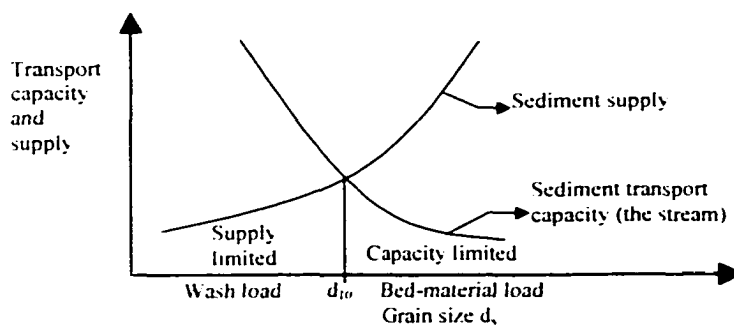


Figure 2.2. Sediment transport capacity and supply curves (Shen, 1971a; Simons & Senturk, 1992; Julien, 1995)

As shown in Figure 2.2. the supply limited and the capacity limited are bounded by d_{10} . Einstein (1950) defined that the largest sediment size of washload is arbitrarily chosen as the grain diameter d_{10} of which 10% of the total bed sediment is finer. Fine sediment load by definition is the load of silts and clays, which have diameters smaller than 0.0625 mm (Woo et al., 1986). Many engineers assume that the smallest size of bed material load is equal to or greater than 0.0625 mm (Simons & Senturk, 1992). However, in large concentrations of fine sediments in suspension, fine sediments can be found in large proportion of the bed with d_{10} much smaller than 0.0625 mm (Woo et al., 1986). Traditionally, the carrying capacity of wash load should be subtracted from the total carrying capacity of bed material load. However, Qiwei et al. (1989) suggested, besides the carrying capacity of wash load, the flow discharge percent of wash load should also be subtracted.

Julien (1995) stated that it is virtually impossible to determined total sediment load of a stream from any of Equations (2.1). Although many equations have been developed there is no sediment transport equation in open channel flow that is truly and fully accurate. In other words, a “universal sediment transport equation” is not or may never be available (Simons and Senturk, 1992). In practice, several sediment equations can be used and the results might be compared with field data to find the most appropriate equation for a specific stream system.

Engineers now use several equations and compare the results with field observation to gain appropriate equations at a selected field site.

The total load sediment transport equations can be classified into three parts (Julien, 1995).

1. Equations which are based on advection-diffusion such as Einstein (1950), Toffaletti (1969), Colby (1964), and Simons-Li-Fullerton (1981). These last two methods are simplifications of Einstein's methods.
2. Equations which are based on energy and stream power concepts. Examples of these are Laursen (1958), Bagnold (1966), Engelund & Hansen (1967), Ackers & White (1973), and Yang (1973).
3. Equations which are based on regression analysis of comprehensive data sets including Shen & Hung (1972), Brownlie (1981), Karim & Kennedy (1981), Karim (1998).

Wu and Molinas (1996) classified the fractional sediment transport into four categories:

1. Direct computation by size fraction approach including Einstein (1950), Laursen (1958) and Toffaletti (1969).
2. Shear stress correction approach. Some examples of this approach are Ashida and Michiue (1973), Parker et al. (1982), Diplas (1987) and Wilcock (1997).
3. Bed material fractional approach including Molinas and Yang (1986) and Karim (1998).
4. Transport capacity approach including Li (1988), Karim & Kennedy (1981) and Dou et al. (1987).

However, Wu (1999) stated that none of the four groups based on fractional approach satisfies the prediction of sediment transport in rivers.

The equations based on energy and power concepts (six equations) and based on regression analysis (four equations) were tested and applied to alluvial rivers with a wide variety of sediment characteristics and hydraulic geometry data. The results from these equations were compared to the field data collection.

2.2. Total Load Equations Based on Advection-Diffusion, Energy Balance and Stream Power Concepts

Six equations for this total load were reviewed according to the year they were developed: Einstein (1950), Laursen (1958), Bagnold (1966), Toffaletti (1969), Ackers & White (1973), and Yang (1973).

2.2.1 Einstein's Method

Einstein (1950) initiated the indirect approach of determining the bed material load by summing up the bed load and the suspended load. He was also among the first to introduce the idea of effective shear stress. The total shear stress is considered to consist of two parts: the shear stress associated with grain roughness τ' and the shear stress associated with form shear stress τ'' .

$$\tau = \tau' + \tau'' \quad (2.2)$$

The grain shear stress is effective to transport sediment and it is the shear stress that would yield the mean velocity if all the resistances were due to grain roughness. For the known values of velocity and hydraulic radius (or depth in the case of large width depth ratios), the effective shear stress can be computed directly from any assumed velocity equation and grain roughness parameter. This idea has carried forward in most

proposed sediment transport relations since then, except for those that are directly based on velocity or on both depth and velocity. Einstein's method is still viewed as a landmark from a theoretical point of view. It introduced some fundamental concepts in sediment transport that were later modified or simplified by others for the computation of sediment transport, despite the complexity of the diffusion based procedure and some uncertainties regarding arbitrarily determined coefficients (Julien, 1995; Yang, 1996).

In Einstein's approach, the unit bed material discharge for a given size fraction q_{ti} was the sum of unit bed load discharge q_{bi} and the unit suspended load discharge q_{si} and is expressed as

$$q_u = q_{bi} + q_{si} \quad (2.3)$$

The unit suspended load discharge is expressed as

$$q_{si} = q_{bi} (P_E I_1 + I_2) \quad (2.4)$$

Accordingly, Equation (2.3) can be rewritten

$$q_u = q_{bi} (1 + P_E I_1 + I_2) \quad (2.5)$$

in which

I_1 and I_2 = integrals of Einstein's form of suspended sediment equation and defined by

Equation (2.6). These relations are plotted in Figure 2.3.

$$I_1 = 0.216 \frac{E^{z-1}}{(1-E)^z} \int_E^1 \left(\frac{1-y}{y} \right)^z dy \quad (2.6a)$$

$$I_2 = 0.216 \frac{E^{z-1}}{(1-E)^z} \int_E^1 \left(\frac{1-y}{y} \right)^z \ln y dy \quad (2.6b)$$

and

$$P_E = 2.303 \log \frac{30.2d}{\Delta} \quad (2.7)$$

in which:

P_E = transport parameter defined as

d = flow depth

Δ = the apparent roughness of the bed surface and equal to k_s/x with $k_s \cong D_{65}$

x = correction factor and is determined from Figure 2.4. for values $k_s/\delta^* = 11.6\nu/u_*$.

k_s = roughness coefficient according to Strickler

δ^* = thickness of laminar sub-layer

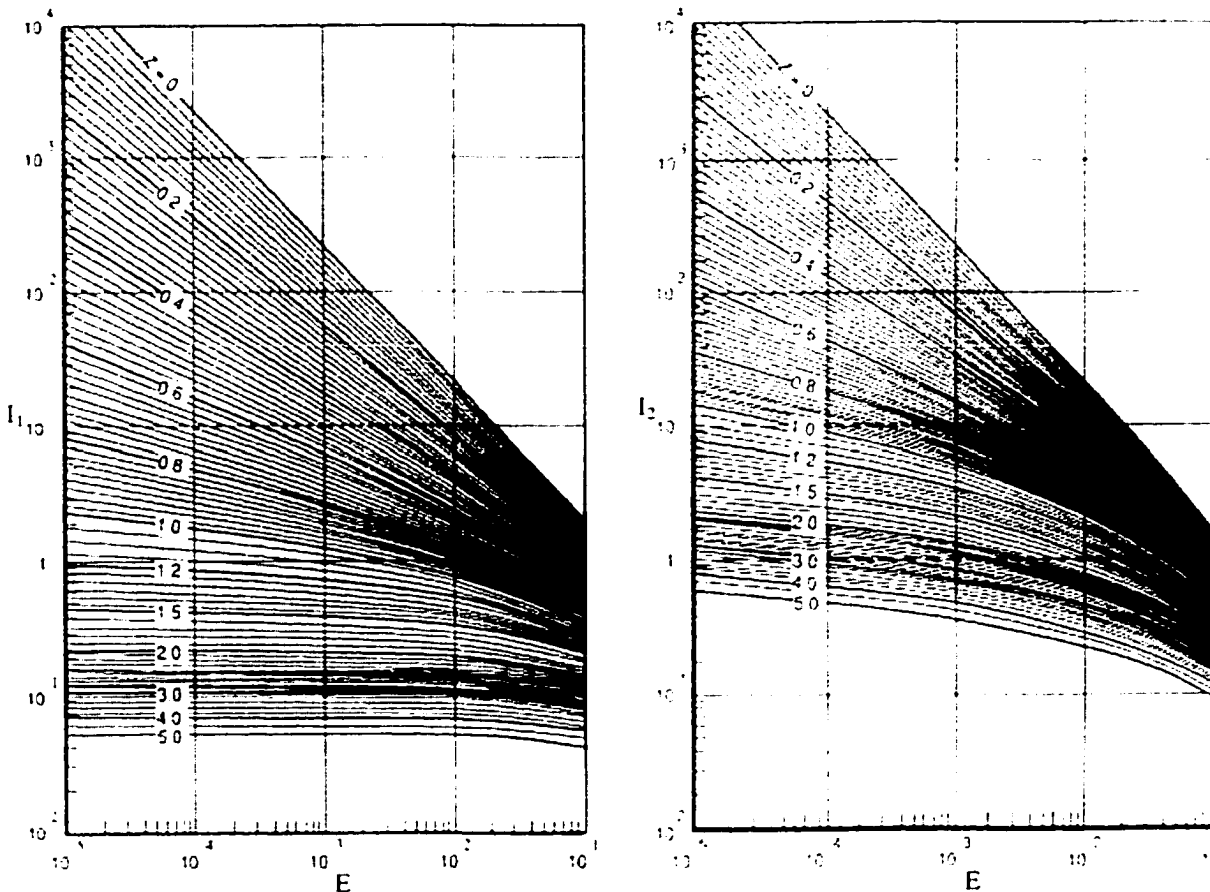


Figure 2.3. Function of I_1 and I_2 of Equation (2.6) in terms of E for values of z (Einstein, 1950)

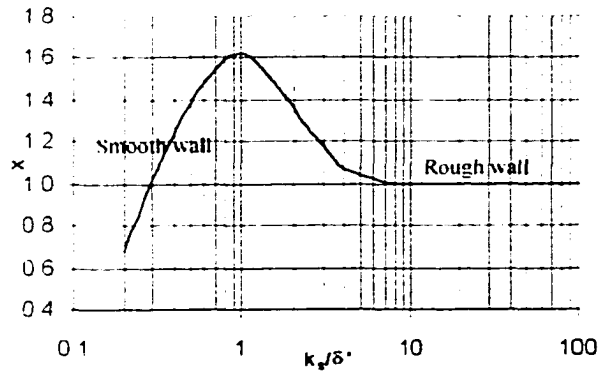


Figure 2.4. Relation between x and k_s/δ (Einstein, 1950)

Equation (2.5) relates the bed-load transport to suspended load transport for all size fractions. The effects of other size fractions on transport rate of a given size are accounted for through the treatments in bed load computation. The bed load can be obtained from the relations between dimensionless sediment transport function ϕ_s to the flow intensity function ψ_s by the following expression

$$1 - \frac{1}{\sqrt{\pi}} \int_{(1.7)\psi_s}^{(1.7)\psi_s + 2} e^{-t^2} dt = \frac{43.5\phi_s}{1 + 43.5\phi_s} \quad (2.8)$$

This equation is plotted in Figure 2.5.

The flow intensity function ψ_s is expressed as

$$\psi_s = \xi Y \left(\frac{\log(10.6)}{\log(10.6 X/\Delta)} \right)^2 \psi \quad (2.9a)$$

in which

$$\psi = \frac{(\gamma_s - \gamma)d_s}{\tau} \quad (2.9b)$$

ξ = sheltering function or hiding correction factor defined by Einstein and given as function of d_s/X (see Figure 2.6a).

d_s = particle diameter

X = the characteristics grain size of the mixture which is given by

$$X = 0.77\Delta \quad \text{if} \quad \Delta/\delta' > 1.80 \quad (2.10a)$$

$$X = 1.39\delta \quad \text{if} \quad \Delta/\delta' < 1.80 \quad (2.10b)$$

The bed material particles smaller than X seem to hide between the other particle or in the laminar sublayer. and the lift they experience must be corrected by ξ (Simons and Senturk, 1992).

Y = pressure correction factor for the lift coefficient given as a function of d_{65}/δ' (see Figure 2.6b). It describes the change in the lift coefficient for mixtures of sizes of bed material that contributes to various bed roughness conditions.

The logarithmic velocity distribution is given by

$$\frac{u}{u_*'} = 5.75 \log \left(30.2 \frac{0.35X}{\Delta} \right) \quad (2.11)$$

in which

u_*' = the shear velocity due to grain roughness and equals $\sqrt{gR_b'S}$

R_b' = the bed hydraulic radius associated with the grain roughness

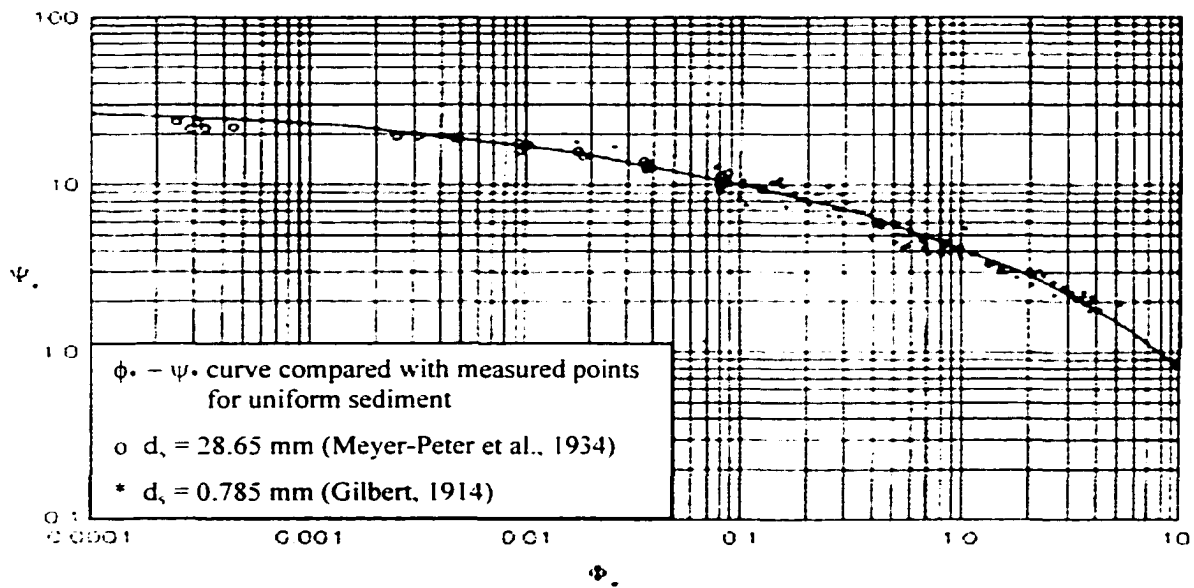
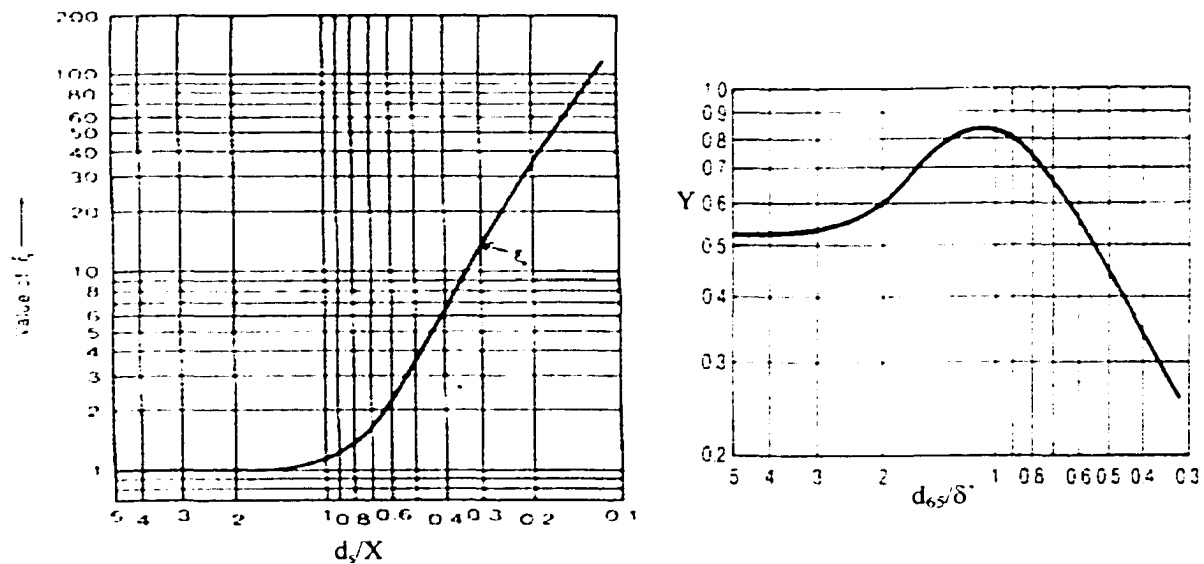


Figure 2.5. Relationship between ϕ - and ψ - for Einstein's bed-load function (Einstein, 1950)



a. Sheltering function or hiding factor ξ

b. Pressure correction factor Y

Figure 2.6. Hiding factor ξ and pressure correction factor Y in Einstein's bed-load function as used in Equation (2.9) (Einstein, 1950)

Most of the concern has centered around the sheltering function or hiding factor ξ . In principle, it is intended to account for difference in mobility of the various grain

sizes in the mixture compared to their mobility in beds of respective uniform grain size (Wu, 1999). In general, Einstein's method over-predicts the transport rates of finer sizes and under-predicts the transport rates of coarser fractions (Misri et al., 1984 and Wu, 1999). It was also found that this method would often over or under estimate computing suspended sediment transport capacity and may need to be improved by modifying its proportionality factor (Cao et al., 1997).

2.2.2 Laursen's Method

Based on flume experimental data, Laursen (1958) proposed a sediment transport equation from the relationship between the condition of flow and the resulting sediment discharge. His equation for a given size fraction is written (ASCE Task Committee, 1971)

$$C_t = 0.01\gamma \sum_i p_i \left(\frac{d_i}{d}\right)^{-6} \left(\frac{\tau_{o,i}}{\tau_{o,c}} - 1\right) f\left(\frac{u_*}{\omega_i}\right) \quad (2.12)$$

in which:

C_t = total average sediment concentration in weight per unit volume

γ = specific weight of water

p_i = fraction of bed material for diameter particle size d_i

u_* = the shear velocity

d_i = particle diameter of size fraction i

d = flow depth

G = specific gravity

$\tau_{o,i}$ = bed shear stress due to grain size

τ_{ci} = critical shear stress for sediment size d_i

ω_i = fall velocity of particle size d_i

$\frac{u_*'}{\omega_i}$ = ratio of shear to fall velocities

$f\left(\frac{u_*'}{\omega_i}\right)$ = functional relation for values of $\frac{u_*'}{\omega_i}$ given in Figure 2.7

The bed shear stress due to grain size τ_o' in lb/ft^2 (Laursen's bed shear stress) is expressed as

$$\tau_o' = \frac{\rho u^2}{58} \left(\frac{d_{50}}{d} \right)^{1/3} \quad (2.13)$$

in which:

ρ = the density of water

u = the mean velocity

d_{50} = mean diameter of sediment

In Equation (2.12), the parameter $(\tau_o'/\tau_{ci} - 1)$ is important to the determination of bed-load, and the parameter (u_*'/ω_i) relates to the suspended load.

For a median particle size between 0.088 mm and 4.08 mm and with $G = 2.65$ (Yang, 1996)

$$\tau_{ci} = 4d_i \quad (2.14)$$

in which τ_{ci} is in lb/ft^2 and d_i is in ft.

Then, the total dry weight of sediment discharge per unit time and width q_T is

$$q_T = qC_t \quad (2.15)$$

in which:

q = the unit discharge of water

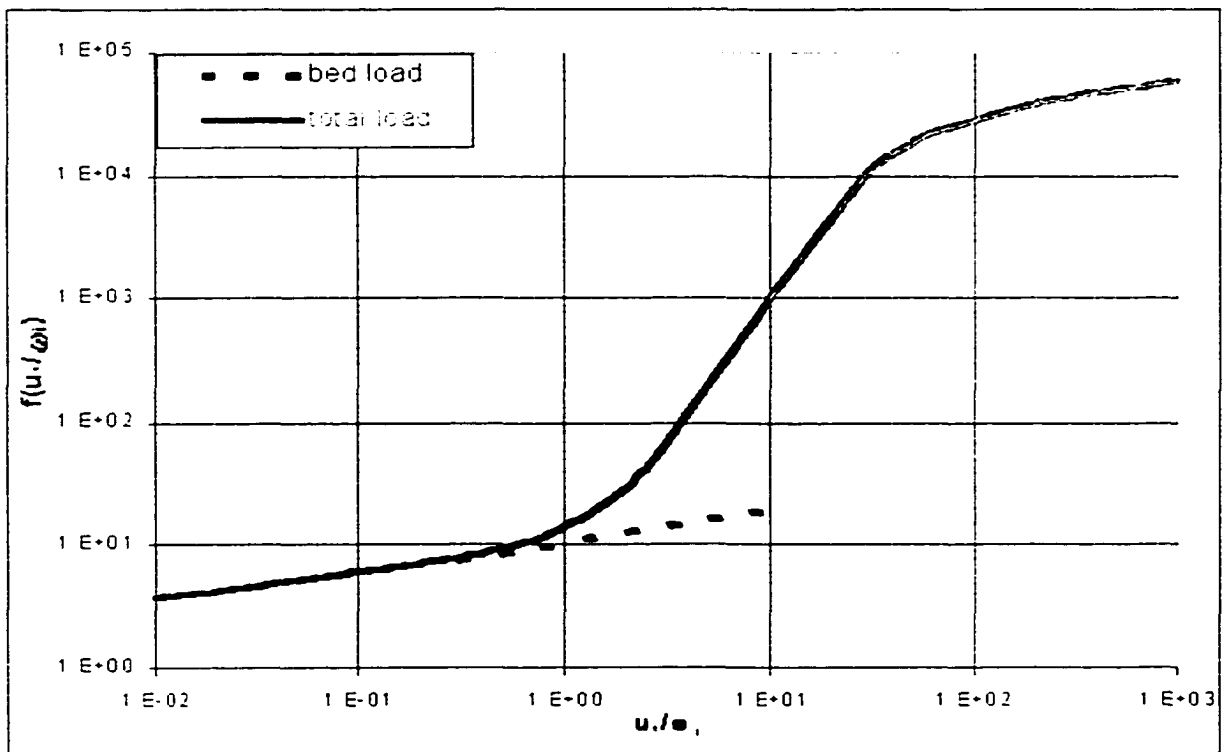


Figure 2.7. Functional $f(u/\omega)$ for Laursen's Method (Laursen 1958)

The range of flume experimental data used by Laursen is summarized as follows

- Depth of flow ranged from about 0.25 to about 1.00 foot
- Percentage error of the smallest depth was in the order of 1 %
- Slope ranged from 0.0004 to about 0.0018 for coarser sand and from 0.0008 to about 0.0012 for the finer sand.
- Percentage error of slope as large as 10% is possible.
- The slope was proved as the most sensitive index because it was affected by both the non uniformity of flow and the roughness of the bed.
- Mean diameter had the range of 0.011 to 4.08 mm

- This method is intended to apply only to natural sediments with specific gravity of 2.65 (ASCE Task Committee. 1971c)
- About 216 lab data from several investigators were used

Although the measurements were all made in laboratory flumes under controlled condition. an attempt by the author to apply the Laursen graph to field data was conducted. Field data published by Einstein for Mountain Creek in South Carolina, West Goose Creek in Mississippi and by USGS for the Niobrara River near Cody, Nebraska were used to predict the sediment load. Comparing the result to the measured value was only good for Niobrara River, but fair for mountain Creek and West Goose Creek (Simons and Senturk. 1992).

2.2.3 Bagnold's Method

Bagnold (1966) proposed a sediment transport equation for a combination of bed load and suspended load based on the concept of energy balance. He also considered the relationship between the rate of energy available in a stream system and the rate of work being done by the system in transporting sediment. For the bed load he stated that the rate of doing work is the product of available stream power ($\tau_o u$) and efficiency e_B . The total load of the equation is the sum of bed load and suspended load and is given as

$$q_T = q_b + q_s = \frac{\tau_o u}{G - 1} \left(\frac{e_B}{\tan \alpha} + 0.01 \frac{u}{\omega} \right) \quad (2.16)$$

in which:

q_T = the total unit discharge expressed in dry weight per unit time and width for any system of units

q_b = the unit discharge of bed sediment load

q_s = the unit discharge of suspended sediment load

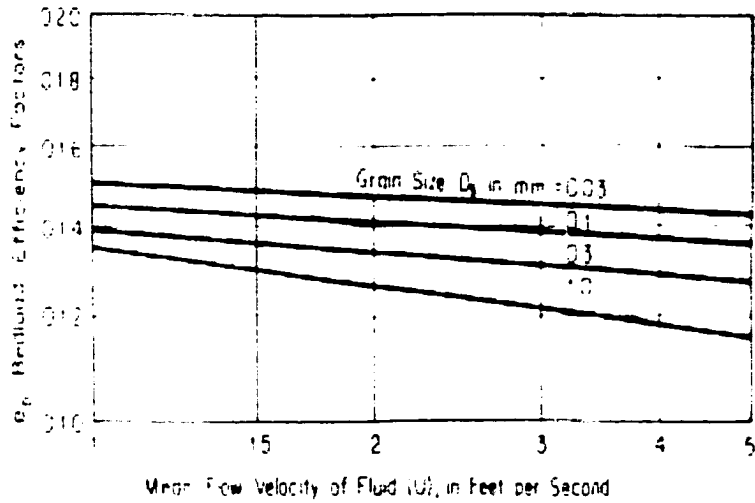
τ_0 = the shear stress

$\tau_0 u$ = the stream power

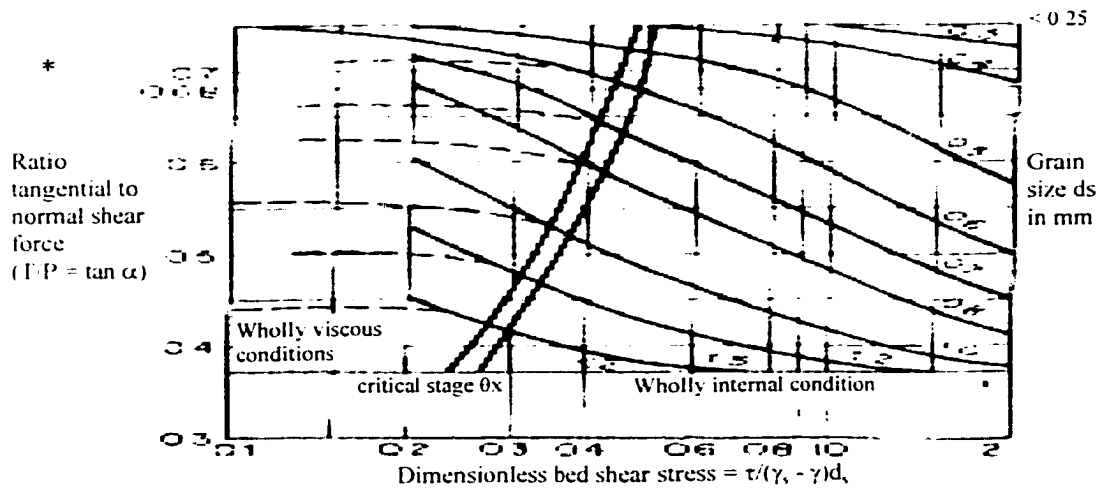
u = the mean velocity

ω = the fall velocity

e_B and α can be determined from Figure 2.8.



a. estimation e_B



b. estimation of α

Figure 2.8. Estimation of e_B and α for various conditions (Bagnold, 1966)

Note that this equation is valid with the assumption that the mean velocity of both the fluid and the suspended sediment is approximately equal.

Simons and Senturk (1992) stated that Equation (2.16) is applicable for fully turbulent flow and for large transport rates.

2.2.4 Toffaletti's Method

Toffaletti (1969) developed a procedure to calculate total load equation based on the concept of Einstein (1950) and Einstein and Chien (1953). There are three main differences between Toffaletti's and Einstein's methods (Simons and Senturk, 1992).

Those are:

1. Toffaletti utilized the velocity distribution in vertical
2. Toffaletti developed the Einstein's correction factors into one combination
3. Toffaletti utilized the relation of dimensionless transport function ϕ_* and the flow intensity function ψ_* of Einstein's method at other than the two grain diameters above the bed ($d_s = 28.65$ mm and $d_s = 0.785$ mm).

The depth is divided into four zones: upper, middle, lower, bed zones respectively, see Figure 2.9.

The velocity profile is represented by the power relation

$$u_x = (1 + \eta_x) u(y/d)^n \quad (2.17)$$

in which:

u = the mean velocity

y = the depth of flow under investigation

d = the whole depth of flow

The exponent η_v is given by the empirical relation

$$\eta_v = 0.1198 + 0.00048T \quad (2.18)$$

in which:

T = the water temperature °F

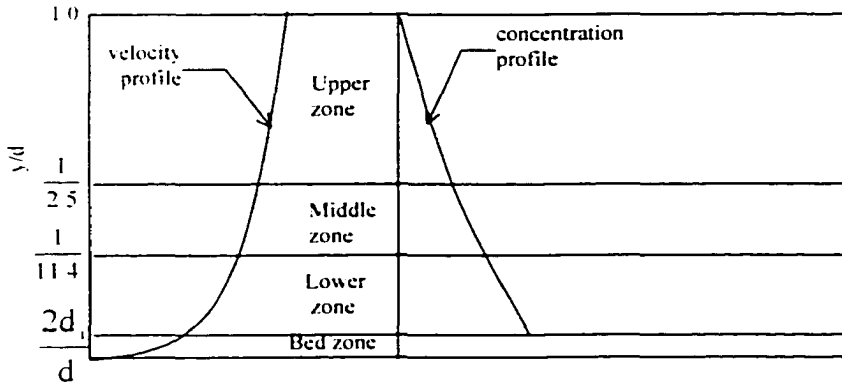


Figure 2.9. Toffaleti's (1969) velocity, concentration and sediment discharge relations

The concentration distribution of the upper, middle and lower zones is given by the following equations

$$C_i = C_{ui} \left(\frac{y}{d} \right)^{-1.5z_i} \quad (2.19a)$$

$$C_i = C_{mi} \left(\frac{y}{d} \right)^{-z_i} \quad (2.19b)$$

$$C_i = C_{li} \left(\frac{y}{d} \right)^{-0.756z_i} \quad (2.19c)$$

The coefficients of C_{ui} and C_{mi} in Equations (2.19) can be expressed in terms of C_{li} in Equation (2.19c) based on the continuous distribution of the sediment concentration profile. The exponent z_i is given by

$$z_i = \frac{\omega_i u}{C_z d S} \quad (2.20)$$

in which:

$$C_z = 260.67 - 0.667T \quad (2.21)$$

ω_i = the fall velocity of the sediment size d_i

S = the slope of the real stream/canal

Note that the value $z_i = 1.5\eta_v$ when it is less than η_v .

The unit sediment discharge q_s for river is given by the relation

$$q_s = \int_a^d u C dy \quad (2.22)$$

Using a combination of Equation (2.19) and Equation (2.22), one can obtain the suspended load discharge per unit width in upper, middle and lower zones respectively.

and those are given by the following relations

$$q_{smi} = \frac{M_1}{\eta_1} \left(\frac{d}{11.24} \right)^{0.244z_i} \left(\frac{d}{2.5} \right)^{0.5z_i} \left[d^{\eta_1} - \left(\frac{d}{2.5} \right)^{\eta_1} \right] \quad (2.23)$$

$$q_{smi} = \frac{M_1}{\eta_2} \left(\frac{d}{11.24} \right)^{0.244z_i} \left[\left(\frac{d}{2.5} \right)^{\eta_2} - \left(\frac{d}{11.24} \right)^{\eta_2} \right] \quad (2.24)$$

$$q_{sh} = \frac{M_1}{\eta_3} \left[\left(\frac{d}{11.24} \right)^{1+\eta_v - 0.758z_i} - (2d_i)^{\eta_3} \right] \quad (2.25)$$

in which:

$$M_1 = 43.2p_i C_b (1 + \eta_v) u d^{0.758z_i - \eta_v} \quad (2.26)$$

$$\eta_1 = 1 + \eta_v - 1.5z_i \quad (2.27)$$

$$\eta_2 = 1 + \eta_v - z_i \quad (2.28)$$

$$\eta_3 = 1 + \eta_v - 0.758z_i \quad (2.29)$$

p_i = the fraction by weight of the bed material with mean d_i

An empirical equation for q_{sLi} is given by

$$q_{sLi} = \frac{0.600p_i}{\left(T_T A_c k / u^2\right)^{5/3} (d_i / 0.00058)^{5/3}} \quad (2.30)$$

If $d_i < 0.00029$ ft, this equation reduces to

$$q_{sLi} = \frac{1.095}{\left(T_T A_c k / u^2\right)^{5/3}} \quad (2.31)$$

in which:

$$T_T = 1.10(0.051 + 0.00009T) \quad (2.32)$$

A_c = a function of $(10^5 v)^{1/3} / 10u_*'$ given in Figure 2.11.a

u_*' = the shear velocity due to grain roughness and is of function of u^3/gvS and

$$u / \sqrt{gd_{65}S} \quad \text{with } d_{65} \cong k_s \text{ as given in Figure 2.10}$$

k = correction factor and is given in Figure 2.11b

C_{Li} is obtained by setting q_{sLi} from Equation (2.25) equal to the value given by Equation (2.30) or Equation (2.31) since C_{Li} is the only unknown in the resulting equation.

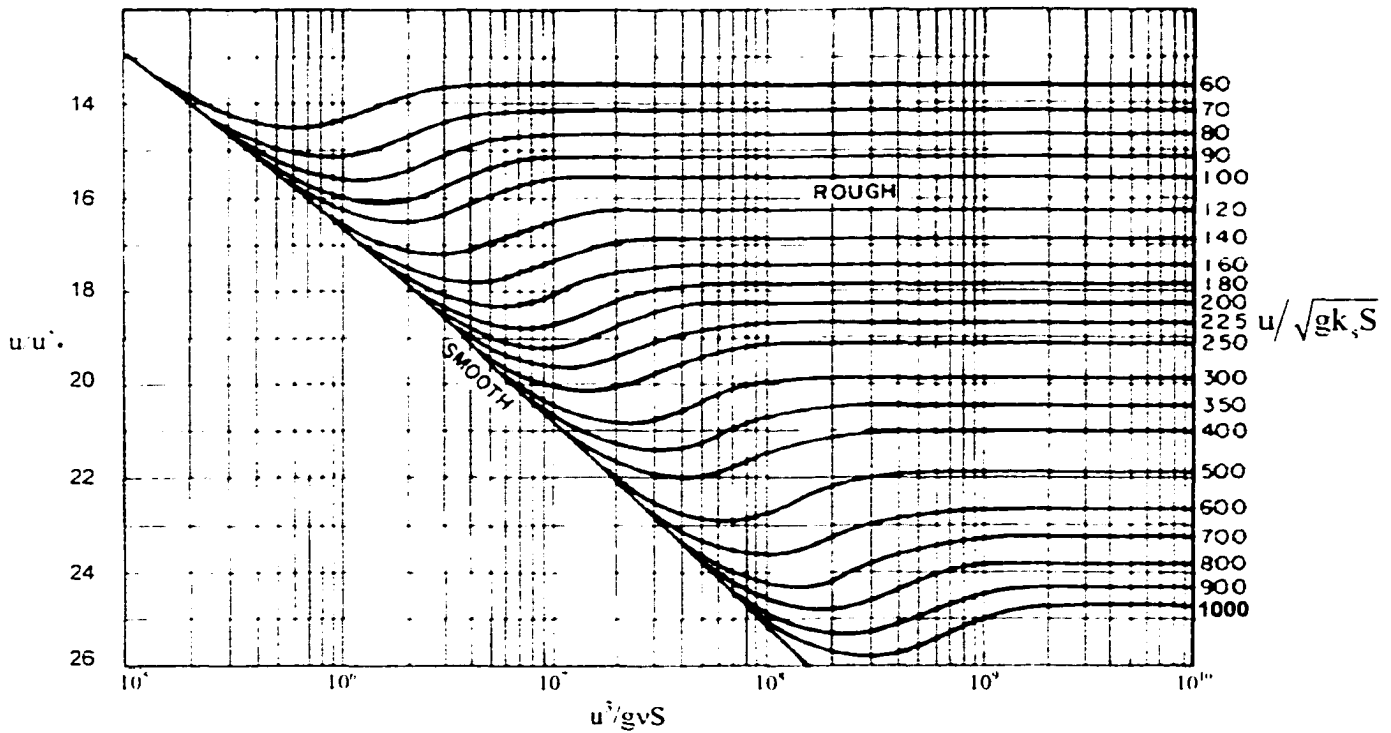
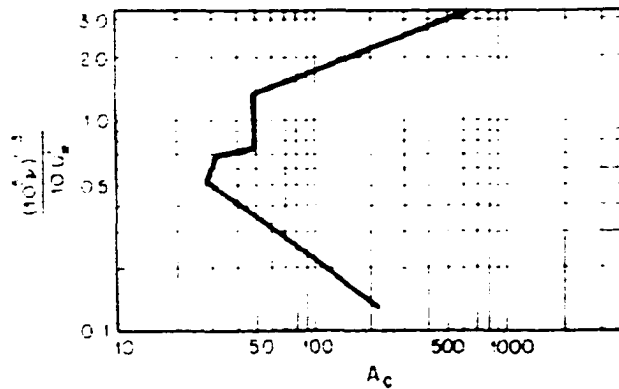
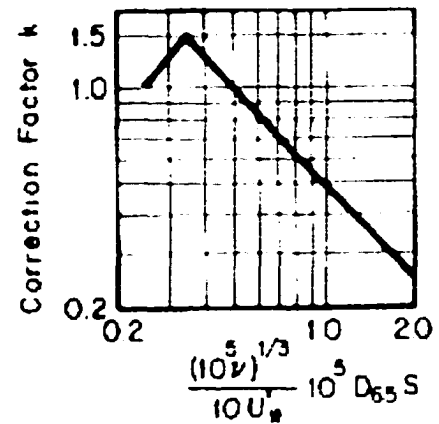


Figure 2.10. Curves for the graphical solution of the Einstein-Barbarossa equations (1952) for determination of R' (Vanoni and Brook, 1957)



a. Evaluation of factor A_c



b. Correction factor k

Figure 2.11. Evaluation of factor A_c and correction factor k (Toffaletti, 1969)

The bed load discharge q_{bi} is given by

$$q_{bi} = M_i (2d_i)^{n_i} \quad (2.33)$$

in which

M_i is given by Equation (2.26)

η_3 is given by Equation (2.29)

Then the unit bed-material load discharge for the sediment of size d_i is given by

$$q_{ii} = q_{bi} + q_{sui} + q_{smi} + q_{sli} \quad (2.34)$$

The procedure was applied by Toffaletti to a total of 600 cases including 339 cases of river data and 282 cases of model studies. The data include (Toffaletti, 1969):

- for river data:
 - 1) the Atchafalaya River at Simmesport, Louisiana.
 - 2) the Mississippi River at Tarbert Landing.
 - 3) the Mississippi River at St. Louis, Missouri.
 - 4) the Red River at Alexandria, Louisiana.
 - 5) the Rio Grande River near Bernalillo, New Mexico.
 - 6) the Middle Loup River at Dunning, Nebraska.
 - 7) the Niobrara River near Cody, Nebraska.
- model studies:
 - 1) John F. Kennedy (1961), California Institute of Technology.
 - 2) V.A. Vanoni and N.H. Brooks (1957), California Institute of Technology.
 - 3) G.N. Nomicos, California Institute of Technology.
 - 4) H.A. Einstein and Ning Chien (1953b), University of California, Institute Eng. Research.
 - 5) H.P. Guys, D.B. Simons, and E.V. Richardson (1966), Colorado State University.
 - 6) U.S. Engineer Waterway Experiment Station (not published).

The results of comparison of computed versus measured loads that covered a very wide range of conditions shows the proposed method to be consistently satisfactory for

all conditions tested. Although, there are some cases that show wide discrepancy in the comparison. However, Toffaletti stated that consideration to the degree of accuracy of the reported data should be taken into account.

2.2.5 Ackers and White's Method

Ackers in 1972 developed the theory for total load sediment transport based on Bagnold's stream power concept. The dimensional analysis and physical argument in deriving the form of the functional relationship were used. Ackers and White summarized the theory in 1973. Their theory was tested mostly against flume data and limited comparisons with field data. They proposed the general total load that determines the rate of transport rate in terms of three dimensionless parameters: sediment mobility, grain size and sediment transport.

The sediment mobility is described by the ratio of the effective shear force on unit area of the bed to the immersed weight of a layer of grains (Ackers & White, 1973 and 1980). They stated that only part of the shear stress on the channel bed is effective in causing the movement of coarse sediment. For fine sediment, however, suspended load movement predominates and the total shear stress contributes effectively to sediment motion. Accordingly, the sediment mobility is described by the equation

$$C_{AWS} = u_*^{C_{AWI}} \left[\frac{u}{\sqrt{32} \log(10d/d_s)} \right]^{1-C_{AWI}} \quad (2.35)$$

in which

C_{AWI} is dependent on sediment size. It is zero for coarse sediment and unity for fine sediment.

The dimensionless grain size was derived by eliminating shear stress from the two Shields parameters; or from the drag coefficient and Reynolds Number of a settling particle by eliminating the settling velocity; or dimensionally, with immersed weight of an individual grain, fluid density, and viscosity as the variables (Ackers and White, 1973 and 1980). This variable is therefore generally applicable to coarse, transitional, and fine sediments. The dimensionless grain diameter d_* is expressed as

$$d_* = \left[\frac{(G-1)g}{\nu^2} \right]^{1.3} \quad (2.36)$$

Then the total sediment concentration by weight is given by

$$C_w = C_{AW2} G \frac{d_s}{d} \left(\frac{u}{u_*} \right)^{C_{AW1}} \left(\frac{C_{AW5}}{C_{AW3}} - 1 \right)^{C_{AW4}} \quad (2.37)$$

in which

C_{AW1} , C_{AW2} , C_{AW3} , and C_{AW4} depend on the dimensionless particle diameter d_* .

The relationships for C_{AW1} , C_{AW2} , C_{AW3} , and C_{AW4} obtained using flume data for particle sizes ranging from 0.04 mm to 4.0 mm are

For $1.0 < d_* < 60.0$,

$$C_{AW1} = 1.0 - 0.56 \log d_* \quad (2.38)$$

$$\log C_{AW2} = 2.86 \log d_* - (\log d_*)^2 - 3.53 \quad (2.39)$$

$$C_{AW3} = \frac{0.23}{d_*^{1/2}} + 0.14 \quad (2.40)$$

$$C_{AW4} = \frac{9.66}{d_s} + 1.34 \quad (2.41)$$

For $d_s > 60.0$,

$$C_{AW1} = 0, \quad C_{AW2} = 0.025, \quad C_{AW3} = 0.17, \quad C_{AW4} = 1.50 \quad (2.42)$$

Incipient motion occurs when $C_{AW3} = C_{AW5}$. Such a condition agrees well with Shields' criterion for coarse sediment, whereas for fine material, it gives between Shields and White (Julien, 1995). For the motion of fine and very fine sand, this method tends to overestimate the concentration.

2.2.6 Yang's Method

In the derivation of sediment transport, Yang (1972) concluded that the assumption that sediment transport rate could be determined from water discharge, average flow velocity, energy slope, or shear stress is questionable. In other words, the generality and applicability of the sediment transport equation derived from one or more of these assumptions are also questionable.

Yang introduced the unit stream power defined as the potential energy dissipation per unit weight of water and it is the product of velocity and slope. In other words, the rate of energy dissipation used in transporting sediment should be related to the rate of sediment being transported (Yang & Kong, 1991).

Yang (1973) considered that the relevant variables to determine the total sediment concentration include the unit stream power, shear velocity, kinematic viscosity, fall velocity and the median particle diameter. The equation for the total load sediment concentration can be expressed as

$$C_t = \phi \left(\frac{uS}{\omega}, \frac{u_*}{\omega}, \frac{\omega d}{\nu} \right) \quad (2.43)$$

From the analysis of 463 data sets from the laboratory flume for the dimensionless regression relationships for the total sediment concentration C_t in ppm by weight are

1. For sand (Yang, 1973)

$$\begin{aligned} \log C_{\text{ppm}} = & 5.435 - 0.286 \log \frac{\omega d_s}{\nu} - 0.457 \log \frac{u_*}{\omega} + \\ & \left(1.799 - 0.409 \log \frac{\omega d_s}{\nu} - 0.314 \log \frac{u_*}{\omega} \right) \log \left(\frac{uS}{\omega} - \frac{u_c S}{\omega} \right) \end{aligned} \quad (2.44)$$

This equation has a correlation coefficient of 0.971 and a standard error of estimate of 0.188 in term of logarithmic units for the 463 sets of laboratory data.

2. For gravel (Yang, 1984)

$$\begin{aligned} \log C_{\text{ppm}} = & 6.681 - 0.633 \log \frac{\omega d_s}{\nu} - 4.816 \log \frac{u_*}{\omega} + \\ & \left(2.784 - 0.305 \log \frac{\omega d_s}{\nu} - 0.282 \log \frac{u_*}{\omega} \right) \log \left(\frac{uS}{\omega} - \frac{u_c S}{\omega} \right) \end{aligned} \quad (2.45)$$

in which dimensionless critical velocity u_c/ω at incipient motion can be expressed as

$$\frac{u_c}{\omega} = \frac{2.5}{\log \frac{u_* d_s}{\nu} - 0.06} + 0.66 \quad (2.46)$$

for $1.2 < \frac{u_* d_s}{\nu} < 70$ (smooth, transition to rough)

and

$$\frac{u_c}{\omega} = 2.05 \quad (2.47)$$

for $\frac{u \cdot d_s}{\nu} \geq 70$ (hydraulically rough)

These equations are dimensionless including the total sediment concentration C_{ppm} in ppm by weight.

in which

u_c = the average velocity at incipient in motion

uS = the unit stream power

uS/ω = the dimensionless unit stream power.

For these equations, flume and field data range from 0.137 to 1.71 mm particle size and water depth of 0.037 to 49.9 feet were used to develop the equation. However, most of the data cover medium to coarse sands at flow depths rarely exceeding 3 ft.

The basic form of Equations (2.44) and (2.45) can be also derived theoretically from turbulence theories (Yang & Molinas, 1982). They made a step-by-step derivation to show and prove that the sediment concentration is indeed related directly to unit stream power.

2.3. Total Load Equations Based on Regression Analysis

Four equations based on regression analysis from data were evaluated. These are: the Shen & Hung method (1972), the Brownlie method (1981), the Karim & Kennedy method (1981), and the Karim method (1998).

2.3.1 Shen and Hung's Method

The assumption of this method is that sediment transport is such a complex phenomenon that no single Reynolds number, Froude number, or a combination of these parameters can be utilized to describe sediment motion under all conditions (Simons and Senturk, 1992). They recommended a regression equation based on available data for engineering analysis of sediment transport. They selected the sediment concentration as the dependent variable and the fall velocity in ft/s of the median diameter of bed material, flow velocity u in ft/s, and energy slope as independent variables. The concentration of sediment in ppm is given as a power series of the flow parameter, based on 587 sets of data in the sand-size range of particle diameter of the river-bed.

$$\log C_{\text{ppm}} = (-107.404.459 + 324.214.747\text{Sh} - 326.309.589\text{Sh}^2 + 109.503.872\text{Sh}^3) \quad (2.48)$$

in which

$$\text{Sh} = \left(\frac{uS^{0.57159}}{\omega^{0.31988}} \right)^{0.00750189} \quad (2.49)$$

The fall velocity of the sediment particles was corrected to the actual measured water temperature but no attempt was made to include the effect of significant concentrations of fine sediment on bed-material transport. It is important not to round coefficients and exponents of Equation (2.48) and Equation (2.49).

The procedure was applied by Shen & Hung to a total of 587 cases including 63 cases of 2 river data and 524 cases of 11 model studies. The data include (Shen & Hung, 1971 ; Shen, 1971b):

- for river data:

- 1) the Middle Loup River at Dunning, Nebraska (see Hubbel & Matejka, 1959), and
- 2) the Niobrara River near Cody, Nebraska (see Colby & Hembree, 1955).

- model studies:

- 1) H.A. Einstein and Ning Chien (1953b), University of California, Institute Eng. Research,
- 2) G.N. Nomicos, California Institute of Technology (Nomicos, 1954-55),
- 3) V.A. Vanoni and N.H. Brooks (1957), California Institute of Technology,
- 4) G.N. Nomicos, California Institute of Technology (Nomicos, 1956),
- 5) John F. Kennedy (1961), California Institute of Technology,
- 6) Stein (1965),
- 7) H.P. Guys, D.B. Simons, and E.V. Richardson (1966), Colorado State University,
- 8) Williams (1967),
- 9) U.S. Engineer Waterway Experiment Station (Toffaletti, 1969),
- 10) Lee (1969) and
- 11) Schneider (1969).

This equation applies quite well to flume data, but tends to predict a lower sediment bed-material concentration than the measured values for large rivers like the Rio Grande River, the Mississippi River, the Atchafalaya River, the Red River, and some large canals in Pakistan (Simons and Senturk, 1992).

2.3.2 Brownlie's Method

Brownlie (1981a) proposed the following equation for the sediment concentration,

C_{ppm} :

$$C_{ppm} = 7115c_B \left(\frac{u - u_c}{\sqrt{(G-1)gd_s}} \right)^{1.978} S_f^{0.6601} \left(\frac{R_h}{d_s} \right)^{-0.3301} \quad (2.50)$$

and

$$F_{g0} = \frac{u_c}{\sqrt{(G-1)gd_s}} = 4.596\tau_{*c}^{0.529} S_f^{-0.1405} \sigma_g^{-0.1606} \quad (2.51)$$

in which

u = the mean velocity

u_c = velocity given in terms of Shields dimensionless critical shear stress τ_{*c} .

F_{g0} = critical grain Froude number

τ_{*c} = the critical Shields parameter

R_h = hydraulic radius

S_f = the friction slope

σ_g = the geometric standard deviation of the bed material, and is unity for uniform material

c_B = the coefficient, is unity for laboratory data and 1.268 for field data

The critical Shields parameter is calculated by the following equation as defined by Brownlie.

$$\tau_{*c} = 0.22Y + 0.06(10)^{-7.7Y} \quad (2.52)$$

in which

$$Y = \left(\sqrt{\frac{\rho_s - \rho}{\rho}} R_g \right)^{-0.6} \quad (2.53)$$

in which

R_g = the grain Reynolds number defined by.

$$R_g = \frac{\sqrt{gd_{50}^3}}{\nu} \quad (2.54)$$

ν = the kinematic viscosity of water

Flow Regime (Bed form configuration)

Brownlie stated that for a given set of independent variable, there are two possible solutions of hydraulic radius R_h , one for the upper flow regime and the other for the lower flow regime. Accordingly, a way to decide which flow regime is needed in alluvial channel analysis. The flow regime is based on four dimensionless quantities: grain Froude number (F_g); ratio of the median grain size to the laminar sublayer (d_{50}/δ); bed slope (S) and the geometric bed material gradation coefficient (σ_g). These four quantities account for both bedform configuration and grain roughness in a channel cross section.

Brownlie defined the grain Froude number and the ratio of the median grain size of the particles to thickness of the laminar sublayer as

$$F_g = \frac{u}{\sqrt{(G-1)gd_s}} = \frac{u\sqrt{\rho}}{\sqrt{(\rho_s - \rho)gd_s}} \quad (2.55)$$

$$\frac{d_{50}}{\delta} = \frac{u_*' d_{50}}{11.6\nu} \quad (2.56)$$

in which

δ = thickness of laminar sublayer

u_*' = the shear velocity, assumed to be equal to u_*

ν = the kinematic viscosity of water

Brownlie plotted the grain Froude number versus slope for all upper and lower flow regime data as shown in Figure 2.12.

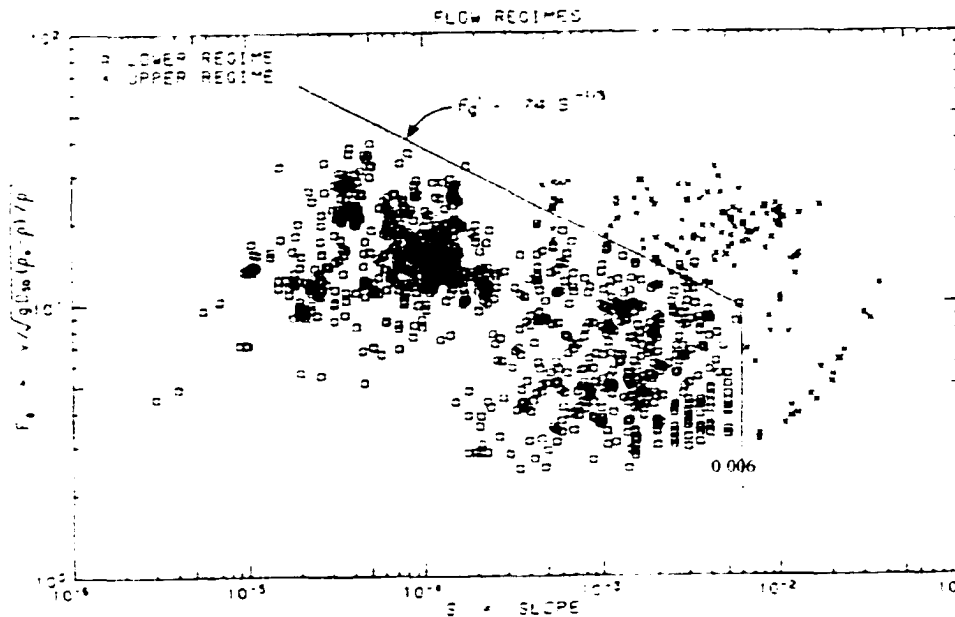


Figure 2.12. Determination of flow regimes – grain Froude number, F_g , plotted versus slope, S (after Brownlie, 1981a)

From this figure, it is obvious that beyond the slope of $S = 0.006$ only upper regime exist. For slope less than 0.006 an approximate dividing line of upper and lower flow regime data can be defined by

$$F_g = F_g' = 1.74S^{-1.3} \quad (2.57)$$

This line represents the threshold between lower flow regime and upper flow regime. However, the overlap along this line indicates that an additional variable will be needed to improve the definition of transition zone.

The relationship between F_g/F_g' and D_{50}/δ for transition data with $S < 0.006$ is plotted in Figure 2.13. The transition zone can be defined by the following equations.

- lower limit of the upper flow regime

$$\log \frac{F_g}{F_g'} = -0.02469 + 0.1517 \log \frac{d_{50}}{\delta} + 0.8381 \left(\log \frac{d_{50}}{\delta} \right)^2 \quad \text{for} \quad \frac{d_{50}}{\delta} < 2 \quad (2.58a)$$

$$\log \frac{F_g}{F_g'} = \log 1.25 \quad \text{for } \frac{d_{50}}{\delta} \geq 2 \quad (2.58b)$$

- upper limit of the lower flow regime

$$\log \frac{F_g}{F_g'} = -0.2026 + 0.07026 \log \frac{d_{50}}{\delta} + 0.9330 \left(\log \frac{d_{50}}{\delta} \right)^2 \quad \text{for } \frac{d_{50}}{\delta} < 2 \quad (2.59a)$$

$$\log \frac{F_g}{F_g'} = \log 0.8 \quad \text{for } \frac{d_{50}}{\delta} \geq 2 \quad (2.59b)$$

Between these values (as also shown in Figure 2.13) lies the transition regime.

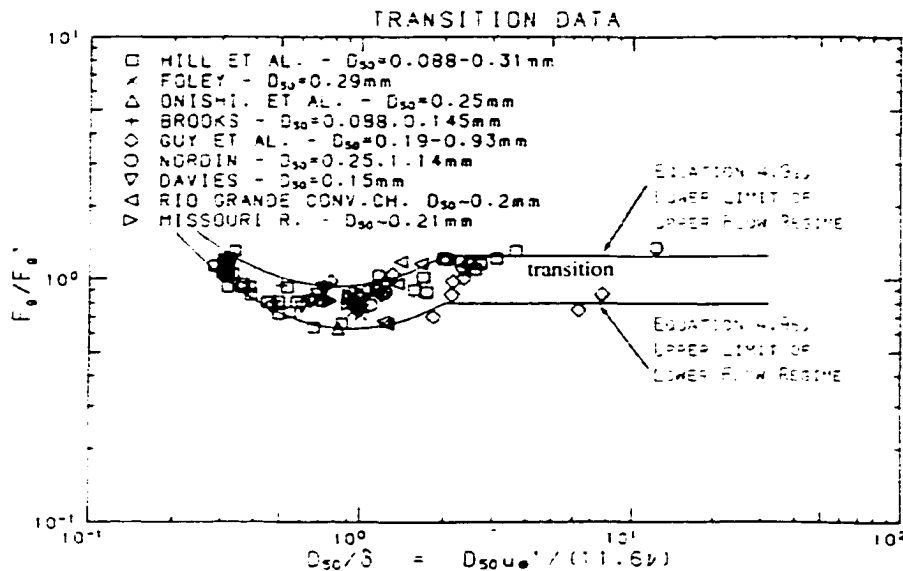


Figure 2.13. Viscous effect on the transition zone from lower to upper flow regimes (after Brownlie, 1981a)

Considering the bed form configuration in wide channels with $d \cong R_h$, the flow depth for the lower flow regime can be calculated from,

$$\frac{R_h S_f}{d_{50}} = 0.3724 (q \cdot S_f)^{0.6539} S_f^{0.09188} \sigma_g^{0.1050} \quad (2.60)$$

and for the upper flow regime.

$$\frac{R_h S_f}{d_{50}} = 0.2836(q \cdot S_f)^{0.6248} S_f^{0.08750} \sigma_g^{0.08013} \quad (2.61)$$

in which

$$q_* = \text{dimensionless unit discharge} = \frac{q}{\sqrt{g d_{50}^3}}$$

Inserting the results of $\frac{R_h}{d_{50}}$ from Equations (2.60) and (2.61) into Equation (2.50)

with $d_s = d_{50}$ one can obtain the sediment concentration for both the lower and the upper flow regimes, respectively.

The data used in development the method were from laboratory data (18 sources) and field data (11 river systems). The laboratory data, have a total of 480 sets of data, including: 1) Barton & Lin (1955) 26 data, 2) Brooks (1957) (in Vanoni & Brooks, 1957) 6 data, 3) Costello (1974) 11 data, 4) Daves (1971) 69 data, 5) Foley (1975) 9 data, 6) Guy et al. (1966) 74 data, 7) Nordin (1976) 33 data, 8) Onishi et al. (1976) 14 data, 9) Pratt (1970) 25 data, 10) Singh (1960) 20 data, 11) Stein (1965) 44 data, 12) Straub (1954) & Straub et al. (1958) 21 data, 13) Taylor (1971) 12 data, 14) Vanoni & Brooks (1957) 14 data, 15) Vanoni & Hwang (1967) 6 data, 16) Williams (1970) 5 data, 17) Willis (1972) 77 data, 18) Znamenskaya (1963) 14 data. The range of data includes:

- velocity (m/s) max 2.017 and min 0.224
- depth (m) max 0.585 and min 0.035
- slope max 0.01695 and min 0.00269
- d_{50} max 1.349 mm and min 0.088 mm (very fine sand to very coarse sand)
- C_{ppm} max 39,263 and min 11

The field data, have a total of 519 sets of data, including: 1) the Atchafalaya River 63 data, 2) the Colorado River 30 data, 2) the Hii River 22 data, 4) the Middle Loup River 38 data, 5) the Mississippi River at St Louis 111 data, 6) the Mississippii River at Tarbert Landing 53 data, 7) the Mountain Creek 75 data, 8) the Niobrara River 40 data, 9) the Red River 29 data, 10) Rio Grande Convey Channel 8 data, and 11) Rio Grande at Bernalillo 50 data. The range of data includes:

- velocity (m/s) max 2.423 and min 0.366
- depth (m) max 17.282 and min 0.108
- slope max 0.001799 and min 0.00001
- d_{50} max 1.44 and min 0.086 (very fine sand to very coarse sand)
- C_{ppm} max 5.830 min 12.

The restriction of input data is shown in Table 2.1. (Brownlie, 1981a):

Table 2.1. Restriction input data used in developing Brownlie's method

No.	Parameter	Symbol	Restriction	Reason
1.	Median grain size	d_{50}	$0.062 < d_{50} < 2.0$	Sand only
2.	Geometric standard deviation of bed particles	σ_g	$\sigma_g < 5$	Eliminate Bimodal distributions
3.	Width to depth ratio	w/d	w/d > 4 (lab data)	Reduce side-wall effect
4.	Relative roughness	r/ d_{50}	r/ d_{50} > 100	Eliminate shallow water effects
5.	Concentration, ppm	C	C > 10	Accuracy problems associated with low concentration

2.3.3 Karim and Kennedy's Method

They carried out a regression analysis of the sediment data from laboratory flumes and natural streams. A total of 608 sets of flume data and 339 sets of river data were used. The sediment transport equation proposed by Karim and Kennedy (1981) is

$$\log \frac{q_t}{\gamma_s \sqrt{(G-1)gd_s^3}} = -2.28 + 2.97c_{k1} + 0.30c_{k2}c_{k3} + 1.06c_{k1}c_{k3} \quad (2.62)$$

in which

$$c_{k1} = \log \frac{u}{\sqrt{(G-1)gd_s}} \quad (2.63)$$

$$c_{k2} = \log \left(\frac{d}{d_s} \right) \quad (2.64)$$

$$c_{k3} = \log \left(\frac{u_* - u_{*c}}{\sqrt{(G-1)gd_s}} \right) \quad (2.65)$$

They found good predictions for a large amount of flume and field data.

2.3.4 Karim's Method

Karim (1998) proposed the sediment discharge for non-uniform bed sediments. The theory behind this is that the evolution of a stream bed is not only determined by the total sediment discharge but also by how much sediment in each size fraction is transported by the flow.

The total sediment discharge per unit width q_s for uniform sediments, developed by Karim and Kennedy (1981, 1983) can be rewritten as

$$\frac{q_s}{\sqrt{g(G-1)d_{50}^3}} = 0.00139 \left(\frac{u}{\sqrt{g(G-1)d_{50}}} \right)^{2.97} \left(\frac{u_*}{\omega} \right)^{1.47} \quad (2.66)$$

For non-uniform sediment discharge Karim (1998) developed a new sediment discharge per unit width for the i^{th} fraction, q_{si} ,

$$q_{si} = q_s d_i \phi_i \quad (2.67)$$

in which

ϕ_i = the weighing function for i^{th} fraction and is expressed as

$$\phi_i = P_{ai} \eta \quad (2.68)$$

in which P_{ai} and η are the areal function of bed material in i^{th} size fraction and the sheltering factor respectively. These functions proposed by Karim were expressed as:

$$P_{ai} = \frac{P_{bi}}{\sum_{i=1}^n \frac{P_{bi}}{d_i}} \quad (2.69)$$

and

$$\eta = 1.15 \frac{\omega_{50}}{u_*} \left(\frac{d_i}{d_{50}} \right)^{0.60 \frac{\omega_{50}}{u_*}} \quad (2.70)$$

in which:

P_{bi} = the volumetric fraction of sediments in i^{th} fraction

n = number sediment size fractions

From Equation (2.66) through Equation (2.70) the expression for sediment discharge (volumetric) per unit width for i^{th} size fraction can be written as

$$\frac{q_{si}}{\sqrt{g(G-1)d_i^3}} = 0.00139 \left(\frac{u}{\sqrt{g(G-1)d_i}} \right)^{2.97} \left(\frac{u_*}{\omega_i} \right)^{1.47} \frac{P_{bi}}{\sum_{i=1}^N \frac{P_{bi}}{d_i}} 1.15 \frac{\omega_{50}}{u_*} \left(\frac{d_i}{d_{50}} \right)^{0.60 \frac{\omega_{50}}{u_*}} \quad (2.71)$$

in which:

u_* = the bed shear velocity

u = the mean flow velocity

ω_i = the fall velocity of particles in i^{th} fraction

ω_{50} = the fall velocity of particles with median size d_{50} .

d_i = sediment size of the i^{th} fraction

G = the specific gravity

This equation was evaluated by applying 194 sets of flume and field data including one set of laboratory data from Einstein & Chien (1953) 26 data, and four sets of river data including: the Missouri River (US Army Corps of Engineers 1979) 60 data, the Niobrara River (Colby & Hembree, 1955) 30 data, the Middle Loup River (Hubbel & Matejka, 1959) 59 data, and the Sacramento River (Nakato, 1990) 19 data.

However the equations of Brownlie, and of Karim and Kennedy deserve further testing (Julien, 1995).

2.4. Statistical Approach

A comparison between computed results and field data was conducted and examined. From this comparison, ranking for the best fit from the sediment relations was tabulated. There are many different statistical parameters which can be used to test the goodness of fit of equations and different results could be obtained by selecting different statistical parameters (Yang et al., 1996).

Statistical approaches were used including the mean discrepancy ratio $\overline{R_D}$ (Bechteller & Vetter, 1989; Wu, 1999; Nakato, 1990; Yang & Wan, 1991; and Hydraul-Tech, Inc., 1998), standard deviation σ_D (Yang and Wang, 1991 and Hydraul-Tech, Inc., 1998), scattering of the discrepancy ratio s (Bechteller & Vetter, 1989), and the

correlation coefficient C_c (Hydrau-Tech.Inc., 1998). The equations for each parameter are in the following

$$\overline{R_D} = \sum \frac{R_i}{N}, \quad R_i = \frac{X_i}{Y_i} \quad (2.72)$$

$$\sigma_D = \sqrt{\frac{\sum (R_i - \overline{R})^2}{N-1}} \quad (2.73)$$

$$\log s = \frac{1}{N} \sum \log \frac{X_i}{Y_i} \quad (2.74)$$

$$C_c = \frac{\sum (X_i - \overline{X})(Y_i - \overline{Y})}{\sqrt{\sum (X_i - \overline{X})^2 \sum (Y_i - \overline{Y})^2}} \quad (2.75)$$

in which:

X_i = computed sedimentation

Y_i = measured sedimentation

\overline{X} = average of computed sedimentation

\overline{Y} = average of measured sedimentation

i = data set or point number

N = total number of data sets

J = total number of point in a given data set

For perfect fit, those values in Equation (2.72) through Equation (2.75) are

$$\overline{R_D} = 1, \sigma_D = 0, s = 0, \text{ and } C_c = 1.$$

Chapter 3

SOURCES OF DATA

3.1. Location of Rivers

A total of 4532 sets of field data were selected and used to determine and analyse the sediment transports in several kinds of river-bed and river sizes. The data also represent a wide variety of locations, including rivers in the USA, in South America, and in Asia. The river data include:

1. ACOP Canals (Pakistan Canal)

A total of 151 sets of river data were collected and recorded by Mahmood et al. (1979) on five canals in Pakistan. The data include: discharge (l/s), width (m), depth (m), slope, D_{50} (mm), gradation, specific gravity, concentration of sediment (ppm), temperature ($^{\circ}\text{C}$) and type of bed-form.

2. CHOP Canals (West Pakistan Canal)

A total of 33 data sets of nine canals in West Pakistan were collected by Chaudry et al. (1970) under the Canal and Headworks Observation Program (CHOP) of the West Pakistan Water and Power Development Authority, 1962 – 1964, Lahore, West Pakistan.. The data include: discharge (l/s), width (m), depth (m), slope, D_{50} (mm), gradation, specific gravity, concentration of sediment (ppm), and temperature ($^{\circ}\text{C}$).

3. American Canals

Simons (1957) obtained a total of 24 sets of canal data in Colorado, Nebraska and Wyoming. However, only 13 completed sets of data were used in this study

The data include: discharge (cfs), width (ft), depth (ft), slope, D_{50} (mm), concentration of sediment (ppm), temperature ($^{\circ}$ F) and sediment size distribution (%).

4. Atchafalaya River

A total of 72 data sets were obtained from Toffaletti (1968) on the Atchafalaya River at Simmesport, Louisiana (see Table B1 and B2 of Toffaletti, 1968).

The concentration is the combination of the measured suspended load and unmeasured load calculated by Toffaletti's procedure. Total suspended sand discharge was determined by the Luby method. The given concentration is for sand particle (>0.0625 mm). The data include: date of survey, discharge (cfs), width (ft), radius (ft), slope (ft/ft), D_{65} (mm), concentration of sediment (ppm), temperature ($^{\circ}$ F), measured suspended bed-material load (t/day), measured suspended bed-material load plus unmeasured (t/day), measured suspended load concentration (ppm) sediment size distribution, measured suspended bed-material concentration (ppm), sediment size distribution for measured suspended sediment and bed- material, and height of unsampled zone (ft).

5. Amazon & Orinoco Rivers

A total of 114 data of the Amazon and Orinoco River systems can be found in Posada (1995). The river systems include: the Amazon, Orinoco, Apure Rivers and their tributaries.

The data include: date of survey (yymmdd), discharge (m^3/s), width (m), depth (m), median bed diameter (mm), slope (m/m), suspended sediment concentration (mg/l), temperature ($^{\circ}\text{C}$), sediment size distribution for suspended load, bed-material load and total load (%), unsampled height (m). Values of the median diameters were estimated by graphical interpolation, assuming a log-normal distribution of particle sizes.

Total load discharge is the sum of suspended sediment discharge in the measured zone plus the sediment discharge computed with Modified Einstein Procedure for the unmeasured zone. The MEP was developed by Colby and Hembree (1955).

6. Black River

A total of 17 data sets were collected on the Black River near Gallesville, Wisconsin USA (Williams & Rosgen, 1989). However, only 7 completed sets of data were used in this study. The measurement was conducted during 1977 through 1979. The data include: date of measurement, water discharge at the time of the bed load measurement and at the time of the suspended load measurement (m^3/s), width (m), depth (m), mean velocity (m/s), water temperature ($^{\circ}\text{C}$), suspended load (kg/s) and bed load (kg/s), bed load particle size distribution and bed material particle distribution. The water discharges were determined in some cases from rating curves (velocity and depth from hydraulic geometry, and width from bed load measurement) and in other cases by direct

measurement (the latter also providing v , w and d). The suspended load was determined with a common depth integrating discharge-weighted sampler (Guy and Norman, 1970). The bed load was sampled with a pressure-difference sampler called the Helley-Smith bed load sampler (Helley and Smith, 1971).

7. India Canal

Chitale (1966) obtained 32 sets of canal data in India. The data include: discharge (l/s), width (m), depth (m), slope, D_{50} (mm), specific gravity, concentration of sediment (ppm), temperature ($^{\circ}\text{C}$).

8. Chippewa River

A total of 66 data sets were collected on the Chippewa River near Caryville, at Durand and near Pepin, Wisconsin USA by Williams and Rosgen (1989). However, only 47 completed sets of data were used in this study, including the Chippewa River near Caryville 15 data, Chippewa River at Durand 14 data and Chippewa River near Pepin 18 data. The measurements were conducted during 1976 through 1979. The data include: date of measurement, water discharge at the time of the bed load measurement and at the time of the suspended load measurement (m^3/s), width (m), depth (m), mean velocity (m/s), water temperature ($^{\circ}\text{C}$), suspended load (kg/s) and bed load (kg/s), bed load particle size distribution and bed material particle distribution. On the Chippewa River near Caryville and at Durand, the water discharges were determined in some cases from rating curves (velocity and depth from hydraulic geometry, and width from bed load measurement) and in other cases by direct measurement (the latter also providing v , w

and d). On the Chippewa River near Pepin the water discharges, velocities, widths and depths were determined from a direct (current-meter) discharge measurement. The suspended load was determined with a common depth integrating discharge-weighted sampler (Guy and Norman, 1970). The bed load was sampled with a pressure-difference sampler called the Helley-Smith bed load sampler (Helley and Smith, 1971).

9. Chulitna River

A total of 43 data sets were collected on the Chulitna River below Canyon near Talkeetna, Alaska, USA (Williams & Rosgen, 1989). However, only 4 completed sets of data were used in this study. The measurement was conducted during 1982 through 1985. The data include: date of measurement, water discharge at the time of the bed load measurement and at the time of the suspended load measurement (m^3/s), width (m), depth (m), mean velocity (m/s), water temperature ($^{\circ}\text{C}$), suspended load (kg/s) and bed load (kg/s), suspended load particle distribution, bed load particle size distribution and bed material particle distribution. The water discharges were determined in some cases from rating curves (with velocities and widths and depths by the rating curve-area technique) and in other cases by direct measurement (the latter also providing v, w and d). The suspended load was determined with a common depth integrating discharge-weighted sampler (Guy and Norman, 1970). The bed load was sampled with a pressure-difference sampler called the Helley-Smith bed load sampler (Helley and Smith, 1971).

10. Colorado River

A total of 131 data sets from the Colorado River were collected by USBR (1958). A summary of the variables is as follows: discharge (l/s), width (m), depth (m), slope, D_{50} (mm), gradation, specific gravity, concentration of sediment (ppm), and temperature ($^{\circ}\text{C}$).

11. Hii River

Shinohara and Tsubaki (1959) collected 38 data sets on the Hii River in Japan. Records numbers 1 to 8 were collected from a station at Igaya, 9 to 12 from a station at Kurihara, 13 to 18 from a station at side channel A, 19 and 20 from a station at side channel B, and 21 to 23 from a station at side channel C. The rest the of records are for accompanying laboratory experiments made in a wooden flume. The data include: discharge (l/s), width (m), depth (m), slope, D_{50} (mm), gradation, specific gravity, concentration of sediment (ppm), and type of bed forms.

12. Middle Loup River

Hubbel and Matejka (1959) collected 32 sets of data on the Middle Loup River at Dunning, Nebraska (Section E). The data are from Table 1 (Pages 89-90), Table 3 (Pages 99-100), and Table 4 (Pages 104-105). To provide sufficient turbulence to cause the entire sediment loads to become suspended, a turbulence flume was constructed at the bridge on State Route 2. Accordingly, it was possible to measure the total load with suspended load samplers. The data include: date of survey (yymmdd), stage 1 (m), unit discharge 1 (m^2/s), stage 2 (m), unit discharge 2 (m^2/s), width (m), depth (m), slope

(m/m), concentration of sediment (ppm), temperature ($^{\circ}\text{C}$), sediment size distribution for suspended load and bed-material load concentration (%), and sediment size distribution for measured suspended sediment and bed-material (%).

Stage 1 (m) and unit discharge 1 (m^2/s) were at the time of water discharge measurement. Stage 2 (m) and unit discharge 2 (m^2/s) were at the time of suspended sediment discharge measurement.

13. Mississippi River

There are three kinds of data in this river: two sets of data from Toffaletti (1968) and one set of data from Posada (1995). Data from Toffaletti (1968) include 53 sets of data at Tarbert Landing and 111 sets of data at Saint Louis, Missouri. The sediment and hydraulic geometry parameters are the same as for the Atchafalaya River.

A total of 85 data sets on the Upper and Lower Mississippi Rivers and their tributaries can be found in Posada (1995). The data include: date of survey (yymmdd), discharge (m^3/s), width (m), depth (m), median bed diameter (mm), slope (m/m), suspended sediment concentration (mg/l), temperature ($^{\circ}\text{C}$), sediment size distribution for suspended load, bed-material load and total load (%), and unsampled height (m). Values of the median diameters were estimated by graphical interpolation, assuming a log-normal distribution of particle sizes.

Total load discharge is the sum of suspended sediment discharge in the measured zone plus the sediment discharge computed with Modified Einstein Procedure (MEP) for the unmeasured zone. The MEP was developed by Colby and Hembree (1955).

14. Mountain Creek River

Einstein (1944) obtained 100 sets of data on the Mountain Creek. Records No. 1 to 81 were collected on the Mountain Creek, a tributary of the Enoree River in Greenville County, South Carolina, August through November 1941. Records No. 82 to 100 were obtained on the West Goose Creek in Tallahatchie River basin about 4 miles west of Oxford, March 26 and 27, 1942. The data include: wetted perimeter (m), area (m^2), mean velocity (ft/s), slope (m/m), D_{50} (mm), gradation, specific gravity, total load concentration (ppm), and temperature ($^{\circ}C$). Width was taken to be equivalent to the wetted perimeter of the bed. Depth was derived from area and width. The cross section was assumed to be trapezoidal and the discharge was obtained by multiplying width times depth times mean velocity.

15. Niobrara River near Cody

Colby and Hembree (1955) took a total of 51 sets of field measurements on the Niobrara River near Cody from July 13, 1949 through July 8, 1953. Nineteen sets of data were obtained at the gauging station section and the contracted section and 32 sets of data were collected at the gauging station only.

This river has a natural contracted section (which was used to measure the sediment concentration), cut in bedrock, and its cross section is almost rectangular. The stream flow observation point was located 580 m upstream of this contracted section. Turbulence occurred sufficiently in the contracted section to make the suspended load nearly the same as the total sediment load.

The data include: date of survey (yymmdd), stage 1 (ft), discharge 1 (cfs), discharge 2 (cfs), area (ft²), width (ft), depth (ft), velocity (ft/s), slope (ft/mile), concentration of sediment (ppm), temperature (°F), sediment size distribution for suspended load and bed-material load concentration (%), and sediment size distribution total load (%).

Stage 1 and discharge 1 were measured at the time of water discharge measurement and discharge 2 was taken at the time of suspended sediment discharge measurement.

16. North Fork Toutle River

A total of 10 sets of data were collected on the North Fork Toutle River near Kid Valley, Washington, USA (Williams & Rosgen, 1989). However, only 2 completed sets of data were used in this study. The measurement was conducted from 1985 through 1987. The data include: date of measurement, water discharge at the time of the bed load measurement and at the time of the suspended load measurement (m^3/s), width (m), depth (m), mean velocity (m/s), water temperature (°C), suspended load (kg/s) and bed load (kg/s), bed load particle size distribution and bed material particle distribution. The water discharges were determined by direct measurement (the latter also providing v, w and d). The suspended load was determined with a common depth integrating discharge-weighted sampler (Guy and Norman, 1970). The bed load was sampled with a pressure-difference sampler called the Helley-Smith bed load sampler (Helley and Smith, 1971).

17. North Saskatchewan River & Elbow River

Samide (1971) collected 55 sets of data on the North Saskatchewan River at Nordegg Bridge and Elbo River near the Bragg Creek Village. The data include: discharge (l/s), width (m), depth (m), slope, D_{50} (mm), gradation, specific gravity, and concentration of sediment (ppm). Temperature measurements were not published, but the values given by Peterson and Howells (1973) have been retained.

18. Oak Creek

A total of 17 data from Oak Creek were obtained from the much larger data of Milhous (1973). The data include: discharge (l/s), hydraulic radius (m), energy slope (m/m), D_{50} (mm), gradation, specific gravity, concentration of sediment (ppm), particle size distribution, and temperature ($^{\circ}\text{C}$). The equivalent depth and width were determined using the combination of hydraulic radius and the Manning n values in Figure 9 of Milhous (1973).

19. Red River

A total of 30 data sets were obtained from Toffaletti (1968) on the Red River at Alexandria, Louisiana (Table B1 and B2). The data collected are the same as on the Atchafalaya River.

20. Rio Grande River

Nordin and Beverage (1965) collected 293 sets of data from 6 stations on the Rio Grande River in New Mexico. Measurement of hydraulic geometry parameters and sediment load were held at the following stations: Otowi Bridge near San Idelfson for Records No. 1 through 18. Cochiti for Records No. 19 through 88. San Felipe for Records No. 89 through 158. near Bernalillo for Records No. 159 through 216. Albuquerque for Records No 217 through 270, and near Belen for Records No 271 through 293.

The data include: discharge (l/s), width (m), depth (m), slope, D_{50} (mm), gradation, concentration of sediment (ppm), temperature ($^{\circ}\text{C}$), and measured suspended load (ppm). The bed material load is the sum of measured suspended load plus unmeasured load computed by the Modified Einstein Procedure.

21. Rio Grande Convey Channel

A total of 9 sets of data from the Oak Creek were obtained from the much larger data set of Culbertson et al. (1972). The data include:

From Table 1 at pages J26-27: date of survey (yymmdd), section number, discharge (m^3/s), flow area (ft^2), surface width (ft), depth (m), slope (m/m), type of bedform, concentration of sediment (mg/l), temperature ($^{\circ}\text{C}$).

From Table 4 at pages J38-40: sediment size distribution bed-material load concentration (%), sediment size distribution for total load (%), D_{50} (mm) for both total load and bed material load. The total load was assumed to be equal to the suspended load measured at the Weir (Sec. 194).

22. Rio Grande River near Bernalillo

A total of 38 data sets were obtained from Toffaletti (1968) on the Rio Grande River near Bernalillo. The data collected are the same as on the Atchafalaya River.

23. Rio Magdalena and Canal del Dique

A total of 113 sets of data were collected on the Rio Magdalena and Canal del Dique. Columbia by Nedeco (1973). Records No. 1 to 52 were obtained from 10 stations on the Rio Magdalena. Records No. 53 to 113 were collected at 10 stations on the Canal del Dique. The data include: discharge (l/s), width (m), depth (m), slope, D_{50} (mm), specific gravity, concentration of sediment (ppm), and temperature ($^{\circ}\text{C}$). The gradation parameter is based on the median and 65 percentile particle sizes with the assumption of log-normal distribution.

24. River Data of Leopold

Leopold (1969) collected totals of 72 sets of data. The data can also be found in Brownlie (1981b). The data include: discharge (l/s), width (m), depth (m), slope, D_{50} (mm), specific gravity, concentration of sediment (ppm), and temperature ($^{\circ}\text{C}$).

25. Rivers in Portugal

A total of 219 data sets of rivers in Portugal were collected by Da Cunha (1969). The data include: discharge (l/s), width (m), depth (m), slope (m/m), D_{50} (mm), gradation, and concentration of sediment (ppm).

26. Snake & Clearwater Rivers

A total of 21 sets of data were collected on the Snake and Clearwater Rivers in the vicinity of Lewiston, Idaho by Seitz (1976). Records No. 1 Through 11 were obtained on the Snake River near Anatone, Washington and Records No. 12 through 21 were obtained on the Clearwater River at Spalding, Idaho. The data include: discharge (l/s), width (m), depth (m), slope, D_{50} (mm), gradation, concentration of sediment (ppm), and temperature ($^{\circ}\text{C}$).

27. Susitna River

A total of 38 data sets were collected on the Susitna River near Talkeetna, Alaska, Alaska, USA (Williams & Rosgen, 1989). However, only 2 completed sets were used in this study. The measurement was conducted from 1982 through 1985. The data include: date of measurement, water discharge at the time of the bed load measurement and at the time of the suspended load measurement (m^3/s), width (m), depth (m), mean velocity (m/s), water temperature ($^{\circ}\text{C}$), suspended load (kg/s) and bed load (kg/s), suspended load particle distribution, bed load particle size distribution and bed material particle size distribution. The water discharges were determined from a rating curve: velocities, widths and depths, where given, determined by the rating curve-area technique). The Suspended load was determined with a common depth integrating discharge-weighted sampler (Guy and Norman, 1970). The bed load was sampled with a pressure-difference sampler called the Helley-Smith bed load sampler (Helley and Smith, 1971).

28. Toutle River

A total of 31 data sets were collected on the Toutle River near Silver Lake, Washington, USA (Williams & Rosgen, 1989). However, only 9 completed sets of data were used in this study. The measurement was conducted during the period 1985 through 1987. The data include: date of measurement, water discharge at the time of the bed load measurement and at the time of the suspended load measurement (m^3/s), width (m), depth (m), mean velocity (m/s), water temperature ($^{\circ}\text{C}$), suspended load (kg/s) and bed load (kg/s), bed load particle size distribution and bed material particle size distribution. The water discharges were determined by direct measurement (the latter also providing v , w and d). The suspended load was determined with a common depth integrating discharge-weighted sampler (Guy and Norman, 1970). The bed load was sampled with a pressure-difference sampler called the Helley-Smith bed load sampler (Helley and Smith, 1971).

29. Trinity River

A total of 4 data sets were collected by Knott (1974). Records No. 1 and 2 were obtained on the North Fork of the Trinity River near Helena, Montana and Records No. 3 and 4 were obtained on the South Fork of the Trinity River below Hyampom. The data include: discharge (l/s), width (m), depth (m), slope, D_{50} (mm), gradation, and concentration of sediment (ppm). The temperature values were obtained from the USGS series Water Resources Data for California.

30. Wisconsin River

A total of 20 data sets were collected on the Wisconsin River at Muscoda, Wisconsin, USA (Williams & Rosgen, 1989). However, only 9 complete sets of data were used in this study. The measurement was conducted from 1977 through 1979. The data include: date of measurement, water discharge at the time of the bed load measurement and at the time of the suspended load measurement (m^3/s), width (m), depth (m), mean velocity (m/s), water temperature ($^{\circ}\text{C}$), suspended load (kg/s) and bed load (kg/s), bed load particle size distribution and bed material particle size distribution. The water discharges were determined in some cases from the rating curves (velocity and depth from hydraulic geometry, and width from bed load measurement) and in other cases by direct measurement (the latter also providing v, w and d). The suspended load was determined with a common depth integrating discharge-weighted sampler (Guy and Norman, 1970). The bed load was sampled with a pressure-difference sampler called the Helley-Smith bed load sampler (Helley and Smith, 1971).

31. Yampa River

A total of 24 data sets were collected on the Yampa River at Deerlodge Park, Colorado, USA (Williams & Rosgen, 1989). However, only 11 completed sets of data were used in this study. The measurements were conducted during the period 1982 through 1983. The data include: date of measurement, water discharge at the time of the bed load measurement and at the time of the suspended load measurement (m^3/s), width (m), depth (m), mean velocity (m/s), water temperature ($^{\circ}\text{C}$), suspended load (kg/s) and bed load (kg/s), bed load particle size distribution and bed material particle size

distribution. The water discharges were determined in some cases from the rating curves (velocity and depth from hydraulic geometry and width from bed load measurement) and in other cases by direct measurement (the latter also providing v , w and d). The suspended load was determined with a common depth integrating discharge-weighted sampler (Guy and Norman, 1970). The bed load was sampled with a pressure-difference sampler called the Helley-Smith bed load sampler with orifice six inches high and twelve inches wide (Helley and Smith, 1971).

32. Yangtze River

A total of 40 data sets on the Yangtze River were collected (Long and Liang, 1994). The data include: date of survey (yymmdd), discharge (m^3/s), width (m), depth (m), slope (m/m), concentration of sediment (kg/m^3), temperature ($^{\circ}C$), sediment size distribution for suspended load and bed-material load concentration (%).

33. Yellow River (lower)

A total of 2326 sets of data were collected on the Yellow River (Lower) at seven stations and these data can be found in Long and Liang (1994). Records No. 1 through 339 were obtained at Huayuankou station (HYK), Records No. 440 through 593 were obtained at Jiahetan station (JHT), Records No. 594 through 898 were obtained at Gaocun station (GC), Records No. 899 through 1209 were obtained at Sunkou station (SK), Records No. 1210 through 1605 were obtained at Aishan station (AS), Records No. 1606 through 1958 were obtained at Luokou station (LK), and Records No. 1959 through 2326 were obtained at Lijin station LJ.

The data include: Station code, date of survey (yymmdd), discharge (m^3/s), width (m), depth (m), slope (m/m), concentration of sediment (kg/m^3), temperature ($^{\circ}C$), sediment size distribution for suspended load and bed-material load (%), bed material and suspended load (kg/s), load by size fraction computed by MEP (kg/s) and total load computed by MEP (kg/s).

3.2. Field Data compilation

The data for each river used different formats and different units: for example the unit of discharge variable in some river data used l/s, while other river data used m^3/s . Before using the data for analysis, compilation is needed and the SI units are used. The format units used for all variables are shown in the following table.

Table 3.1. The units for variables

No.	Variable	Unit
1.	Date of measurement	yymmdd
2.	Water discharge	m^3/s
3.	Channel width	m
4.	Flow depth	m
5.	Flow velocity	m/s
6.	Mean bed diameter, d_{50}	mm
7.	Water surface slope	m/m
8.	Water temperature	$^{\circ}C$
9.	Transported sediment concentration	C_{ppm}

Not all sets of data are used for the analysis since in some cases there are no sufficient variables. For example, from the total of 151 sets of data of the ACOP Canal, only 142 sets of data are used because 9 sets of data have no concentration value.

The entire field data were divided into two categories of applications: Group 1 for analysis of the ten existing equations and the new proposed equations, Group 2 for

verification and validation of the proposed methods. To get these groups, the river data sets are divided into two parts in random order.

The data are summarized in Table 3.2. The complete data are given in Appendix A.

Table 3.2. Summary of field data

No	Code	Name of River		Date of Measurement	Water Discharge Q	Channel width w	Flow Depth h	Flow velocity v	Mean bed diameter ds	W S Sw	temp °C	Trans Sed Conce Cppm	Total Data	Data Used	Source	also found in
				yyymmdd	m ³ /s	m	m	m/s	mm	m/m						
1	ACP	Acop Canal (Pakistan)	max	n a	27	35	0.76	1.02	0.083	0.00045	12	5	151	142	Mahmood et al (1979)	Brownlie (1981b)
			min	n a	529	140	4.3	0.88	0.364	0.000166	36	2.083				
2	CHO	Chops Canal in Pakistan	max	n a	28	24	1.31	0.88	0.09	0.000051	11	116	33	33	Chaudhry et al (1970)	Brownlie (1981b)
			min	n a	428	122	3.41	1.03	0.311	0.000254	29	1.317				
3	AMC	American Canal	max	n a	1	3	0.8	0.48	0.005	0.000058	21	44	13	12	Simons (1957)	Brownlie (1981b)
			min	n a	29	22	2.59	0.51	0.042	0.000330	28	448				
4	ATC	Atchafalaya	max	590723	382	305	6.1	0.21	0.088	0.000002	5	1	72	72	Toffaletti (1968)	Brownlie (1981b)
			min	650730	14188	503	14.75	1.91	0.354	0.000051	34	567				
5	AMO	Amazon & Orinoco	max	760614	9	1	0.93	9.25	0.024	0.000014	26	0.1	114	85	Posada (1995)	
			min	870215	235000	3338	68	1.04	1.129	0.000400	33	852				
6	BCA	Black Canal	min	771108	20	72	0.55	0.4	0.365	0.000110	5.5	53	17	7	Williams & Rosgen (1989)	
			max	79053	163	122	1.9	1	0.53	0.000290	21	1.147				
7	CHI	India Canal	max	n a	1	4	0.67	0.4	0.02	0.000057	n a	512	32	32	Chitale (1966)	Brownlie (1981b)
			min	n a	242	79	3.56	0.86	0.082	0.000165	n a	5.758				
8	CHP	Chippewa River	min	76901	30.6	124	0.61	0.2	0.4	0.000093	3	3	66	47	Williams & Rosgen (1989)	
			max	79911	884	277	3.2	1.1	15.5	0.000580	26	357				
9	CHU	Chulitna River	min	72782	925	98.5	1.7	1.5	2.5	0.000680	4	450	43	4	Williams & Rosgen (1989)	
			max	84518	261	123	3.1	2.5	24.5	0.001400	5.5	1.183				
10	COL	Colorado River	max	n a	77532	91	0.85	1000.7	0.155	0.000037	7	18	131	100	USBR (1958)	Brownlie (1981b)
			min	n a	557445	255	3.89	563.08	0.695	0.000407	27	769				
11	HII	Hii River	max	n a	2	8	0.31	0.73	0.21	0.000840	n a	116	38	38	Shinohara & Tsubaki (1979)	Brownlie (1981b)
			min	n a	2	8	0.4	0.74	1.46	0.011300	n a	5.039				
12	MID	Middle Loup River	max	500301	9	37	0.25	0.98	0.223	0.000928	1	411	38	15	Hubbel & Matajka (1959)	Brownlie (1981b)
			min	520924	13	46	0.41	0.7	0.35	0.001458	31	1.831				
13	MIS	Mississippi River	max	510523	1512	456	4.66	0.71	0.088	0.000018	2	7	164	164	Toffaletti (1968)	Brownlie (1981b)
			min	650908	28830	1109	17.28	1.5	0.25	0.000134	34	511				
13b	POS	Missi River (Posada)	max	870720	332	184	6.16	0.33	0.172	0.000003	3	0.2	85	85	Posada (1995)	
			min	900625	34100	1337	5.54	4.6	0.993	0.000177	31	370				
14	MOU	Mountain Creek	max	n a	0	3	0.04	0.49	0.899	0.001360	15	27	100	100	Einstein (1944)	Brownlie (1981b)
			min	n a	1	4	0.44	0.79	0.286	0.003150	26	2.601				
15	NIO	Niobrara River near Cody	max	490713	6	21	0.42	0.66	0.209	0.001136	1	257	51	19	Colby & Hembree (1955)	Brownlie (1981b)
			min	521211	16	22	0.58	1.27	0.268	0.001799	28	1.600				
16	NFT	North Fork Toutle River	min	86119	124	56	0.85	2.4	6.9	0.003700	6.5	13266	10	2	Williams & Rosgen (1989)	
			max	86226	137	59	0.85	2.6	8.6	0.004100	8.5	16.364				

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Table 3.2. continued

17	NSR	North Saskat & Elbo River	max	n a	5	3	0.73	2.11	13.61	0.001580	13	4	55	55	Samide (1971)	Brownlie (1981b)
			min	n a	39	6	2.74	2.34	76.11	0.007450	18	760				
18	OAK	Oak Creek	max	n a	1	4	0.31	1.03	8.2	0.009700	5	7	17	17	Milhous (1973)	Brownlie (1981b)
			min	n a	3	6	0.53	1.09	27	0.012600	7	184				
19	RED	Red River	max	581105	190	130	3	0.49	0.089	0.000066	3	8	30	29	Toffaletti (1968)	Brownlie (1981b)
			min	641230	1538	183	7.38	1.14	0.106	0.000082	35	500				
20	RGR	Rio Grande River	max	n a	0.064	8	0.16	0.4	0.173	0.000690	0	2	293	289	Nordin & Beverage (1965)	Brownlie (1981b)
			min	n a	286	122	3.12	0.75	1.909	0.002460	29	11,400				
21	RGC	Rio Grande Convey Channel	max	650512	25	20	0.89	1.41	0.11	0.000520	3	906	33	9	Culbertson et al. (1972)	Brownlie (1981b)
			min	660504	37	27	1.5	0.89	0.16	0.001110	18	3,049				
22	RIO	Rio Grande in Columbia	max	520425	35	41	0.33	2.61	0.106	0.000740	14	463	38	38	Toffaletti (1968)	Brownlie (1981b)
			min	610503	286	197	1.46	0.99	0.338	0.000890	27	4,530				
23	NED	Rio Magda & Canal del Dique	max	n a	29	27	1.32	0.81	0.1	0.000003	30	3	113	75	Nedeco (1973)	Brownlie (1981b)
			min	n a	10200	845	13.28	0.91	1.08	0.000620	30	3,000				
24	LEO	River data of Leopold	max	n a	83334	89	0.85	1100.9	0.14	0.000037	6	11	72	55	Leopold (1969)	Brownlie (1981b)
			min	n a	499296	251	4.11	485.38	0.814	0.000340	27	564				
25	POR	Rivers in Portugal	max	n a	29	70	0.46	0.91	2.204	0.000540	10	27	219	219	Da Cunha (1969)	Brownlie (1981b)
			min	n a	660	189	2.44	1.43	2.603	0.000970	10	351				
26	SNK	Snake & Clearwater Rivers	max		971	137	4.02	1.76	0.4	0.000245	6	4	21	17	Seitz (1978)	Brownlie (1981b)
			min		3511	198	5.91	3	33	0.001210	15	33				
27	SUS	Susitna River	min	82726	796	186	2.4	1.8	34	0.001400	2	189	38	2	Williams & Rosgen (1989)	
			max	831004	2770	308	4.4	2.1	35	0.002400	9.5	1,462				
28	TOU	Toutle River	min	85402	43.2	24.5	0.76	1.7	0.7	0.001900	4	1721	31	9	Williams & Rosgen (1989)	
			max	87128	253.5	69	1.5	2.7	4.75	0.005500	12	23,007				
29	TRI	Tnnity River	max	n a	40	30	0.85	1.55	3.4	0.002600	6	36	4	3	Knott (1974)	Brownlie (1981b)
			min	n a	83	54	1.2	1.28	11.8	0.003000	8	675				
30	WIS	Wisconsin River	min	32477	86.9	219	0.82	0.5	0.4	0.000280	7.5	22	20	9	Williams & Rosgen (1989)	
			max	81578	714	310	2.6	0.9	0.49	0.000410	26	110				
31	YAM	Yampa River	min	83407	26.3	9.1	0.65	0.6	0.45	0.000400	5	599	24	11	Williams & Rosgen (1989)	
			max	71283	447	93	3.9	1.3	0.7	0.000870	20	2,933				
32	YAN	Yangtze River	max	820917	4080	1210	3.56	0.95	0.025	0.000009	8	77	40	40	Long & Liang (1995)	
			min	851102	41200	1530	13.3	2.02	0.063	0.000084	26	1,214				
33	YEL	Yellow River	max	560509	8	55	0.53	0.27	0.018	0.000010	0	67	2326	1112	Long & Liang (1995)	
			min	901220	13600	3190	11.29	0.38	0.081	0.000900	32	482,408				
		Total data	min		0.064	1	0.04	0.21	0.005	0.000002	0	0.1	4,532	2,946		
			max		557,445	3,338	68	9.25	76.11	0.012600	36	482,408				

Based on sediment size four kinds of river data were analyzed:

1. gravel-bed rivers ($2 \text{ mm} < d_s < 64 \text{ mm}$).
2. very fine to fine sand-bed rivers ($0.062 - 0.250 \text{ mm}$)
3. medium to very coarse sand-bed rivers ($0.250 - 2.00 \text{ mm}$).
4. silt-bed rivers (sediment size $0.004\text{mm} < d_s < 0.0625 \text{ mm}$).

According to the size of river (in terms of width and depth) the data were divided into three different types of river including:

1. small river with width $\leq 10 \text{ m}$ and depth $\leq 1 \text{ m}$.
2. intermediate river with $10 \text{ m} < \text{width} \leq 50 \text{ m}$ and $1 \text{ m} < \text{depth} \leq 3 \text{ m}$.
3. large rivers with width $> 50 \text{ m}$ and depth $> 3 \text{ m}$.

3.3. Laboratory data

Although the main purpose is to propose new methods of sediment transport relation in the field, laboratory data were used for verification (in Chapter 6) of the new method. A total of 919 sets of laboratory data from 19 sources were selected, including:

1. Barton & Lin (1955) 30 data sets.
2. Brooks (Vanoni & Brooks, 1957) 21 data sets
3. Guy, Simons & Richardson (1966) 290 data sets.
4. Franco (1968) 19 data sets.
5. Kalinske & Hsia (1945) 9 data sets.
6. Kennedy & Brooks (1963) 9 data sets.
7. Laursen (1958) 24 data sets.
8. Meyer-Peter & Muller 139 data sets (Meyer, Peter & Muller, 1948 and Brownlie, 1981b)
9. Nomicos 1 (in Toffaleti, 1968; Vanoni & Brooks, 1957) 12 data sets,
10. Nomicos 2 (in Vanoni & Brooks, 1957) 26 data sets.

11. Onishi, Jain & Kennedy (1976) 14 data sets.
12. Stein (1965) 57 data sets.
13. Straub (1954 & 1958) 24 data sets.
14. Taylor & Vanoni (1972) 6 data sets.
15. Vanoni & Brooks (1957) 15 data sets.
16. Vanoni & Hwang (1967) 16 data sets.
17. Williams (1970) 83 data sets.
18. Willis, Coleman and Ellis (1972) 96 data sets.
19. Wilcock & Southard (1988) 29 data sets

The range of the laboratory data includes:

discharge (m^3/s)	: 0.001 – 4.614
width (m)	: 0.267 – 2.438
depth (m)	: 0.008 – 1.092
velocity (m/s)	: 0.188 – 5.547
particle sediment size, d_{50} . (mm)	: 0.011 – 28.60
slope	: 0.00015 – 0.0331
temperature of water $^{\circ}\text{C}$: 1.67 – 48.0
concentration (C_{ppm})	: 0.0036 – 110.998.8

The complete data are given in Appendix B.

Chapter 4

ANALYSIS

4.1. General

In this chapter the ten sediment relations were used to calculate the total load of sediment using the data in Group 1. Total load of sediment was calculated using mean diameter of river bed (uniform sediment size).

To make sure that the applicability of the existing equations were programmed correctly, references of other calculations were used as follows:

- Julien (1995) for programming: Einstein, Bagnold, Shen & Hung, Ackers & White, Yang, Brownlie, and Karim & Kennedy,
- Yang (1996) for programming: Einstein, Laursen, Bagnold, Toffaletti, Shen & Hung, Ackers & White, Yang, and Karim & Kennedy,
- Wu (1999) for programming: Laursen, Toffaletti, Ackers & White, Yang, Karim & Kennedy, and Karim,
- Simons and Senturk (1992) for programming: Einstein, Laursen, Bagnold, Toffaletti, and Yang,
- Nakato (1990) for programming: Toffaletti, Ackers & White, Yang, and Karim & Kennedy.

4.2. Computation of Sediment Discharge

Based on the sediment size four kinds of river data were analyzed:

1. gravel-bed rivers ($2 \text{ mm} < d_s < 64 \text{ mm}$)
2. very fine to fine sand-bed rivers ($0.062 - 0.250 \text{ mm}$)
3. medium to very coarse sand-bed rivers ($0.250 - 2.00 \text{ mm}$)
4. silt-bed rivers river (sediment size $0.020 \text{ mm} < d_s < 0.062 \text{ mm}$).

According to the size of river (in terms of width and depth) the data were divided into different types of river including:

1. small river with width $\leq 10 \text{ m}$ and depth $\leq 1 \text{ m}$.
2. intermediate river with $10 \text{ m} < \text{width} \leq 50 \text{ m}$ and $1 \text{ m} < \text{depth} \leq 3 \text{ m}$.
3. large river with width $> 50 \text{ m}$ and depth $> 3 \text{ m}$.

The C_{ppm} measured and computed are shown in figures. The discrepancy ratio $\overline{R_D}$, standard deviation σ_D , scattering s and correlation coefficient C_c , between measured and computed sediment discharges are shown in tables. Three kinds of correlation coefficient C_c were computed including: C_{ppm} computed and C_{ppm} measured, parameters and C_{ppm} measured, and parameters and C_{ppm} computed.

4.2.1 Gravel-Bed Rivers

The mean diameter of particle size has the range of 3.40 mm (very fine gravel) to 76.11 mm (very coarse gravel).

Three river data sets were examined including: Saskatchewan & Elbow Rivers (55 data), Trinity River (3 data) and Oak Creek (17 data). Saskatchewan & Elbow, and Trinity Rivers were used for computation of the sediment discharge (Group 1). The Oak

Creek and the laboratory data of Meyer-Peter-Muller (1948) containing 139 data were used for validation and verification.

The river data show a wide range of hydraulic geometric data, including:

- discharge : 1.331 – 82.48 m³/s
- width : 3.05 – 53.95 m
- depth : 0.307 – 2.74 m
- slope : 0.00158 – 0.0126

The results for computational total sediment discharge (C_{ppm}) using the selected equations was summarized in figures and tables. The discrepancy ratio $\overline{R_D}$, standard deviation σ_D and scattering s of C_{ppm} , both computed and measured, were computed. Three kinds of coefficient of correlation C_c were computed including: C_{ppm} measured and C_{ppm} computed, parameters and C_{ppm} measured and parameters and C_{ppm} computed. Results of computation of each parameter are shown in Tables 4.1 and 4.2.

Table 4.1. Discrepancy ratio $\overline{R_D}$, standard deviation σ_D , and scattering s , between C_{ppm} computed and measured for gravel-bed rivers

	Bagn old	Ackers White	Yang' 73	Shen Hung	Brown lie	Karim &Ken	Laurs en	Karim	Toffa letti	Einstein
Discrepancy Ratio, $\overline{R_D}$	12.30	0.33	0.10	68.95	4.25	23.45	7.16	4.52	0.01	18.18
standard deviation, σ_D	12.30	1.47	0.21	68.07	6.68	25.85	13.66	4.45	0.01	24.38
scattering, s	0.92	-1.90	-1.34	1.67	0.34	1.17	0.30	0.45	-3.09	1.09

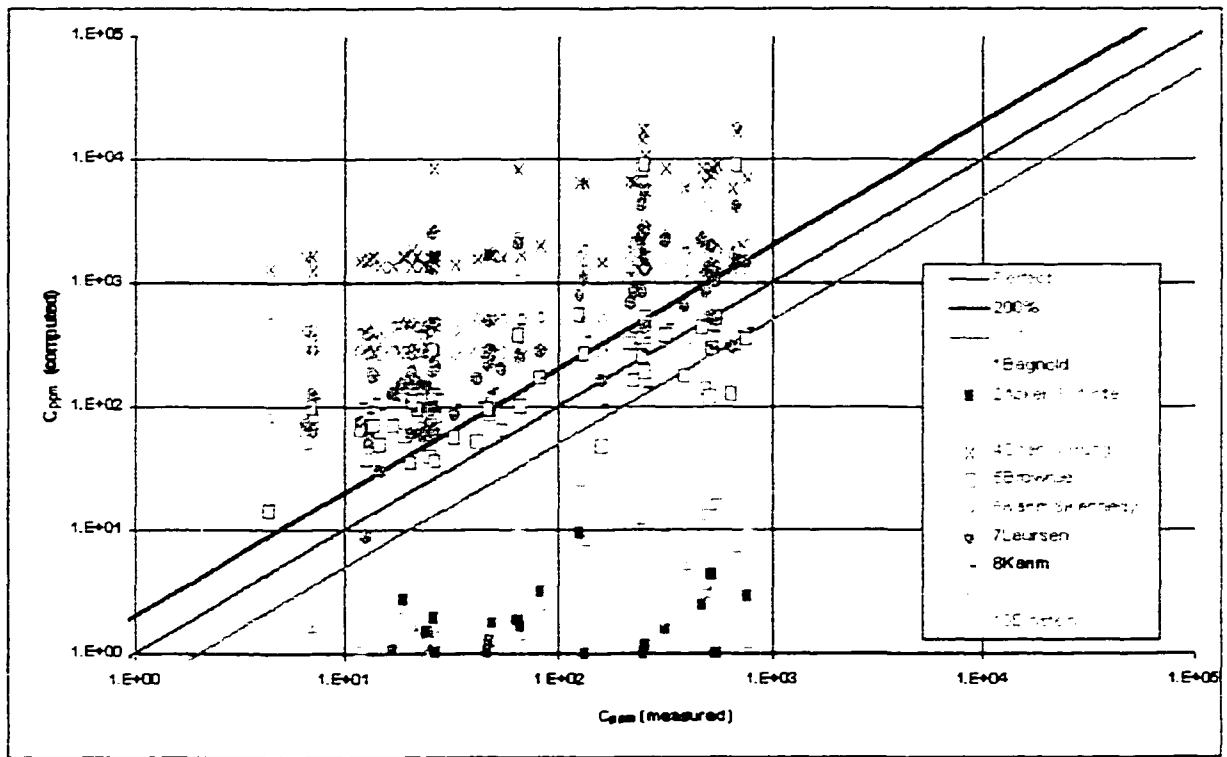


Figure 4.1. C_{ppm} computed and measured for gravel-bed rivers

Table 4.2. Correlation coefficient C_c among C_{ppm} computed, C_{ppm} measured and hydraulic geometry and sediment characteristic parameters for gravel-bed rivers

C _{ppm} Measured	Bagnold	Ackers	White	Yang'73	Shen	Brownlie	Karim	Kenn	Laur	Karim	Toffa	Eins	Q	w	d	v	d _s	S _w	temp	t _c	u _*	u	v	d*	ω
	meas.								sen		leiti	lein	(m ² /s)	(m)	(m)	(m/s)	(mm)	°C	(N/m ²)	(m/s)	(m/s)	(m/s)	(m ² /s)	(m/s)	(m/s)
1	1																								
Bagnold	0.70																								
Acker-White	0.22	0.61																							
Yang'73	0.29	0.65	0.99																						
Shen & Hung	0.70	0.96	0.67	1																					
Brownlie	0.29	0.66	0.98	0.73	0.74																				
Karim-Kennedy	0.32	0.75	0.94	0.95	0.79	0.98																			
Laursen	0.50	0.87	0.77	0.81	0.94	0.82																			
Karim	0.18	0.23	0.04	0.05	0.27	0.04																			
Toffaletti	0.08	0.09	0.22	0.26	0.18	0.24																			
Einstein	0.05	0.14	0.19	0.19	0.18	0.19																			
Q (m ² /s)	-0.30	-0.09	0.60	0.59	0.04	0.62																			
w (m)	0.06	0.48	0.90	0.89	0.54	0.93																			
d (m)	-0.71	-0.81	-0.21	-0.26	-0.73	-0.25																			
v (m/s)	0.37	0.70	0.86	0.89	0.82	0.92																			
d _s (mm)	0.33	0.11	-0.45	-0.44	0.07	-0.44																			
S _w	0.73	0.71	-0.08	-0.01	0.63	-0.02																			
Temp (°C)	-0.52	-0.74	-0.66	-0.70	-0.81	-0.70																			
t _c (N/m ²)	0.65	0.53	-0.21	-0.14	0.50	-0.15																			
u _* (m/s)	0.65	0.54	-0.22	-0.15	0.49	-0.16																			
v (m/s)	0.51	0.75	0.71	0.75	0.82	0.75																			
d*	0.29	0.07	-0.47	-0.46	0.02	-0.46																			
ω (m/s)	0.24	-0.03	-0.61	-0.60	-0.08	-0.60																			

4.2.2 Sand-bed Rivers

The mean diameter of particle size has the range of very fine sand (0.062 – 0.125 mm) to very coarse sand (1.00 – 2.00 mm).

A total of 2503 sets of data of 23 rivers were used, including:

1. Amazon and Orinoco River systems 85 data sets
2. American Canal 12 data
3. Atchafalaya River 72 sets
4. Colorado River 100 data sets
5. Hii River 38 data sets
6. India Canal 14 data sets
7. Middle Loup River 15 data sets
8. Mississippi River (Posada) 85 data sets
9. Mississippi River at St Louis 111 data sets
10. Mississippi River at Tarbert Landing 53 data sets
11. Mountain Creek 100 data sets
12. Niobrara River 19 data sets
13. Pakistan Canal 142 data sets
14. Portugal River 219 data sets
15. Red River 29 data sets
16. Rio Grande (Nordin) 289 data sets
17. Rio Grande Convey Canal 9 data sets
18. Rio Grande near Bernalillo 38 data sets
19. Rio Magdalena & Canal del Dique 75 data sets

20. River Data of Leopold 55 data sets
21. Snake & Clearwater River 17 data sets
22. West Pakistan (CHOP) Canal 33 data sets
23. Yellow River 893 data sets

The computation was performed for two kinds of sand-bed rivers: very fine to fine sand-bed rivers (0.062 – 0.250 mm) and medium to very coarse sand-bed rivers (0.250 – 2.00 mm).

1. Very fine to fine sand-bed rivers (0.062 – 0.250 mm)

A total of 1405 data sets were used to compute the total sediment load using selected sediment transport equations. The river data show a wide range of hydraulic geometric data, including:

- discharge : 0.00094 – 235,000 m³/s
- width : 0.35 – 3,190 m
- depth : 0.02 – 68.00 m
- slope : 0.0000021 – 0.0113

The data were divided into two groups: Group 1 (706 data) for computation and Group 2 (699) for validation and verification. Results of computational total sediment discharge using the selected equations were summarized in figures and tables.

The C_{ppm} measured and computed are shown in Figure 4.2.

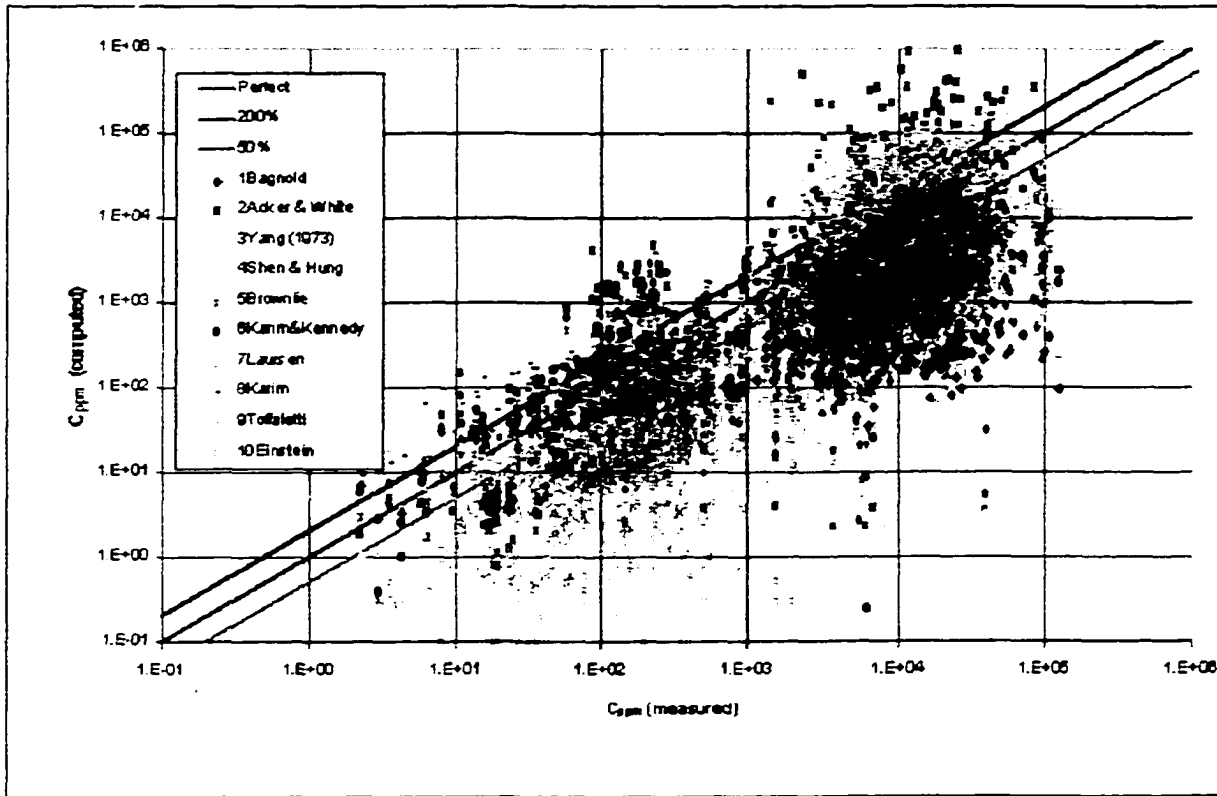


Figure 4.2. C_{ppm} computed and measured for very fine to fine sand-bed rivers

The discrepancy ratio $\overline{R_D}$, standard deviation σ_D and scattering s of C_{ppm} , both computed and measured, were computed. Three kinds of coefficient of correlation C_c were computed including: C_{ppm} measured and C_{ppm} computed, parameters and C_{ppm} measured and parameters and C_{ppm} computed. Results of computation of each parameter are shown in Tables 4.3 and 4.4.

Table 4.3. Discrepancy ratio $\overline{R_D}$, standard deviation σ_D , and scattering s , between C_{ppm} computed and measured for very fine to fine sand-bed rivers

	Bagnold	Ackers White	Yang 73	Shen Hung	Brownlie	Karim & Ken	Laursen	Karim	Toffaletti	Einstein
Discrepancy Ratio $\overline{R_D}$	0.21	5.31	0.30	0.32	0.51	0.90	0.36	1.28	2.56	0.63
standard deviation σ_D	0.44	22.21	0.70	0.87	0.88	1.92	0.59	1.72	3.52	1.05
scattering s	-1.16	-0.06	-0.93	-0.93	-0.58	-0.51	-0.74	-0.08	0.16	-0.90

Table 4.4. Correlation coefficient C_c , among C_{ppm} computed, C_{ppm} measured and hydraulic geometry and sediment characteristic parameters for very fine to fine sand-bed rivers

Cppm	Cppm meas	Bagnold	Ackers White	Yang'73	Shen Hung	Brownlie	Karim Kenn	Laur sen	Karim	Toffa letti	Eins tein	Q (m ³ /s)	w (m)	d (m)	v (m/s)	d _s (mm)	S _w	temp °C	τ _o (N/m ²)	u. (m/s)	v (m ² /s)	d. (m/s)	(^u) (m/s)	
Measured	1																							
Bagnold	0.36	1																						
Acker-White	0.19	0.54	1																					
Yang'73	0.37	0.85	0.73	1																				
Shen & Hung	0.51	0.83	0.57	0.93	1																			
Brownlie	0.58	0.76	0.49	0.86	0.97	1																		
Karim-Kennedy	0.38	0.70	0.68	0.90	0.86	0.79	1																	
Laursen	0.36	0.78	0.70	0.92	0.84	0.79	0.75	1																
Karim	0.48	0.78	0.62	0.87	0.91	0.90	0.74	0.95	1															
Toffaletti	0.52	0.55	0.32	0.56	0.67	0.73	0.40	0.67	0.78	1														
Einstein	0.49	0.66	0.53	0.76	0.86	0.88	0.73	0.79	0.90	0.65	1													
Q (m ³ /s)	0.02	-0.03	0.02	0.02	0.02	0.03	0.05	0.01	0.01	0.01	0.04	1												
w (m)	0.37	0.26	0.11	0.31	0.37	0.44	0.22	0.32	0.38	0.45	0.29	0.44	1											
d (m)	-0.18	-0.29	-0.02	-0.16	-0.22	-0.24	-0.07	-0.16	-0.22	-0.24	-0.12	0.71	0.09	1										
v (m/s)	0.58	0.38	0.23	0.43	0.66	0.76	0.42	0.48	0.68	0.67	0.74	0.16	0.43	-0.06	1									
d _s (mm)	-0.33	-0.25	-0.15	-0.27	-0.34	-0.39	-0.20	-0.42	-0.52	-0.53	-0.41	0.18	-0.25	0.40	-0.45	1								
S _w	-0.03	0.56	0.02	0.12	0.08	0.02	0.05	0.01	-0.01	-0.05	-0.02	-0.05	-0.10	-0.15	-0.17	0.26	1							
Temp (°C)	0.17	-0.05	0.01	0.03	0.05	0.13	0.10	-0.07	-0.02	0.13	0.09	0.08	0.11	0.06	0.06	-0.02	-0.03	1						
τ _o (N/m ²)	0.16	0.39	0.31	0.47	0.52	0.42	0.54	0.29	0.29	0.09	0.33	0.31	0.11	0.31	0.26	0.30	0.08	-0.01	1					
u. (m/s)	0.16	0.40	0.28	0.46	0.52	0.44	0.50	0.29	0.30	0.12	0.34	0.28	0.11	0.28	0.28	0.30	0.09	0.00	0.98	1				
v (m ² /s)	-0.17	0.01	-0.01	-0.05	-0.07	-0.15	-0.11	0.06	0.00	-0.15	-0.12	-0.08	-0.12	-0.04	-0.08	0.02	0.00	-0.98	-0.01	-0.02	1			
d. (m/s)	-0.28	-0.26	-0.15	-0.26	-0.33	-0.36	-0.17	-0.42	-0.51	-0.48	-0.38	0.22	-0.21	0.42	-0.43	0.95	0.24	0.27	0.26	0.27	-0.27	1		
(^u) (m/s)	-0.30	-0.24	-0.14	-0.26	-0.33	-0.37	-0.18	-0.40	-0.51	-0.49	-0.38	0.21	-0.22	0.42	-0.44	0.97	0.26	0.17	0.28	0.28	-0.17	0.99	1	

2. Medium to very coarse sand-bed rivers (0.250 – 2.00 mm)

A total of 1098 data sets were used to compute the total sediment load using selected sediment transport equations. The river data show a wide range of hydraulic geometric data, including:

- discharge : 0.0474 – 151,000 m³/s
- width : 0.8 – 3,338 m
- depth : 0.0396 – 65.00 m
- slope : 0.0000138 – 0.00315

The data were divided into two groups: Group 1 (552 data) for computation and Group 2 (546) for validation and verification. The C_{ppm} measured and computed are shown in Figure 4.3.

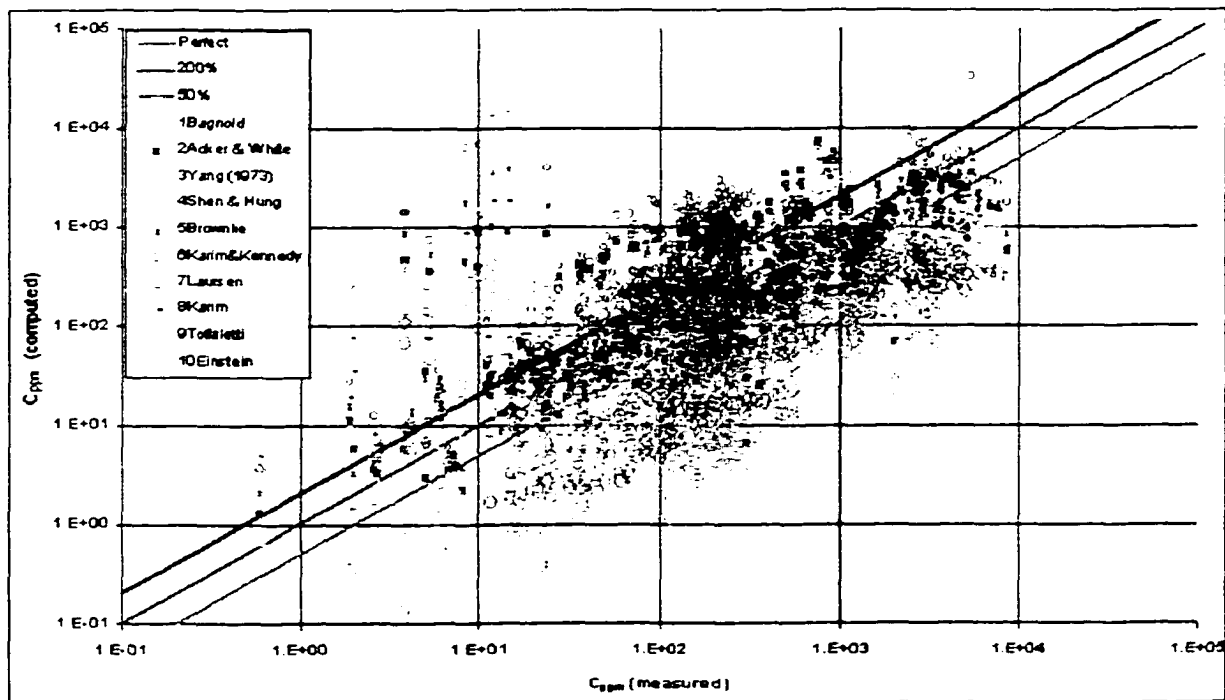


Figure 4.3. C_{ppm} computed and measured for medium to very coarse sand-bed rivers

The discrepancy ratio \overline{R}_D , standard deviation σ_D and scattering s of C_{ppm} , both computed and measured, were computed. Three kinds of coefficient of correlation C_c were computed including: C_{ppm} measured and C_{ppm} computed, parameters and C_{ppm} measured and parameters and C_{ppm} computed. Results of computation of each parameter are shown in Tables 4.5 and 4.6.

Table 4.5. Discrepancy ratio \overline{R}_D , standard deviation σ_D , and scattering s , between C_{ppm} computed and measured for medium to very coarse sand-bed rivers

	Bagnold	Ackers	Yang	Shen	Brow	Karim	Laurs	Kari	Toffal	Einst
	d	White	73	Hung	nlie	&Ken	en	m	etti	ein
Discrepancy Ratio \overline{R}_D	1.68	2.85	3.22	5.46	4.86	12.06	0.6	2.68	0.93	2.56
standard deviation σ_D	5.66	9.06	16.01	34.71	26.28	85.91	2.49	14.04	3.09	15.93
scattering s	-0.26	0.02	-0.07	-0.16	0.08	0.28	-0.70	-0.14	-0.53	-0.44

Table 4.6. Correlation coefficient C_c among C_{ppm} computed, C_{ppm} measured and hydraulic geometry and sediment characteristic parameters for medium to very coarse sand-bed rivers

C _{ppm}	Measured	Bagnold	Ackers	White	Yang ⁷³	Shen	Brownlie	Karim	Laur	Karim	Toffa	Eins	Q	w	d	v	d _t	S _w	temp	t _o	u.	u.	d.	ω
	meas				Hung		Kenn	sen	sen	lefti	lein	(m ³ /s)	(m)	(m)	(m/s)	(mm)	°C	(N/m ²)	(m/s)	(m/s)	(m ² /s)	(m/s)	(m/s)	
C _{ppm}	1																							
Measured		1																						
Bagnold	0.40		1																					
Acker-White	0.56	0.76		1																				
Yang ⁷³	0.51	0.85	0.91		1																			
Shen & Hung	0.54	0.71	0.85	0.95		1																		
Brownlie	0.60	0.69	0.94	0.93	0.96		1																	
Karim-Kennedy	0.42	0.54	0.62	0.82	0.91	0.80		1																
Laur	0.36	0.83	0.86	0.80	0.65	0.74	0.45		1															
Karim	0.66	0.69	0.92	0.87	0.85	0.93	0.71	0.79		1														
Toffa	0.58	0.44	0.74	0.59	0.60	0.73	0.43	0.57	0.77		1													
Einstein	0.43	0.68	0.85	0.75	0.67	0.79	0.46	0.86	0.81	0.78		1												
Q (m ³ /s)	-0.14	-0.31	-0.18	-0.20	-0.17	-0.16	-0.10	-0.15	-0.14	-0.09	-0.13		1											
w (m)	-0.17	-0.42	-0.23	-0.27	-0.22	-0.20	-0.14	-0.22	-0.19	-0.12	-0.18	0.85		1										
d (m)	-0.26	-0.58	-0.32	-0.35	-0.27	-0.26	-0.14	-0.31	-0.26	-0.18	-0.25	0.75	0.70		1									
v (m/s)	0.30	-0.01	0.39	0.40	0.57	0.56	0.53	0.12	0.42	0.37	0.28	0.29	0.23	0.43		1								
d _t (mm)	-0.18	0.02	-0.21	-0.13	-0.15	-0.19	-0.09	-0.10	-0.18	-0.14	-0.04	0.03	0.00	-0.04	-0.18		1							
S _w	0.25	0.94	0.55	0.64	0.46	0.44	0.31	0.74	0.48	0.28	0.56	-0.32	-0.44	-0.61	-0.25	0.22		1						
Temp (°C)	0.02	-0.13	-0.11	-0.15	-0.16	-0.10	-0.12	-0.01	0.00	0.06	0.05	0.11	0.20	0.05	-0.15	0.19	-0.03		1					
t _o (N/m ²)	0.08	0.19	0.20	0.47	0.60	0.41	0.69	0.02	0.19	0.03	0.07	0.07	0.01	0.15	0.65	-0.12	-0.01	-0.29		1				
u. (m/s)	0.11	0.13	0.21	0.42	0.54	0.39	0.57	-0.03	0.15	0.04	0.02	0.10	0.05	0.20	0.70	-0.20	-0.08	-0.34	0.95		1			
u (m ² /s)	-0.05	0.08	0.06	0.11	0.14	0.06	0.09	-0.03	-0.04	-0.09	-0.09	-0.09	-0.15	-0.02	0.15	-0.19	-0.01	-0.99	0.28	0.34		1		
d.	-0.16	0.00	-0.21	-0.15	-0.17	-0.20	-0.11	-0.10	-0.18	-0.12	-0.03	0.04	0.02	-0.05	-0.21	0.98	0.21	0.37	-0.18	-0.27	-0.37		1	
ω (m/s)	-0.18	-0.03	-0.24	-0.16	-0.17	-0.20	-0.10	-0.12	-0.19	-0.14	-0.05	0.09	0.07	0.03	-0.15	0.98	0.17	0.33	-0.12	-0.22	-0.33		1	

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4.2.3 Silt-bed Rivers

284 sets of data of 3 rivers with range of mean diameter of particle size of 0.020 mm to 0.062 mm, including:

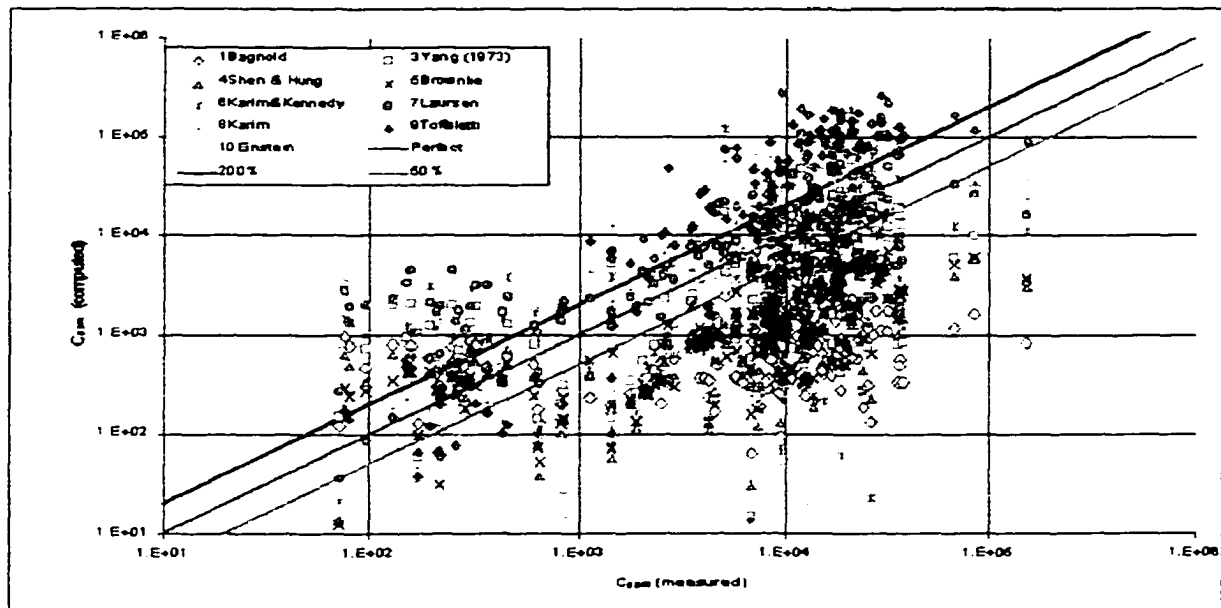
1. Yellow River 219 data sets, including measurements at: Huayuankou station (HYK) 45 data sets, Jiahetan station (JHT) 33 data sets, Gaocun station (GC) 24 data sets, Sunkou station (SK) 13 data sets, Aishan station (AS) 36 data sets, Luokou station (LK) 40 data sets, Lijin station (LJ) 28 data sets.
2. Yangtze River 40 data sets
3. India Canal 25 data sets

The river data show a wide range of hydraulic geometric data, including:

- discharge : 1.152 – 41,200 m³/s
- width : 4.3 – 3,110 m
- depth : 0.53 – 13.30 m
- slope : 0.000009 – 0.00087

The data were divided into two groups: Group 1 (143 data) for computation and Group 2 (141) for verification.

The C_{ppm} measured and computed are shown in Figure 4.4.



Note: Method of Ackers and White has very high values (not plotted). As noted by Julien (1995) this method is not good for very fine material.

Figure 4.4. C_{ppm} computed and measured for silt-bed rivers

The discrepancy ratio \overline{R}_D , standard deviation σ_D and scattering s of C_{ppm} , both computed and measured, were computed. Three kinds of coefficient of correlation C_c were computed including: C_{ppm} measured and C_{ppm} computed, parameters and C_{ppm} measured and parameters and C_{ppm} computed. Results of computation of each parameter are shown in Tables 4.7 and 4.8.

Table 4.7. Discrepancy ratio \overline{R}_D , standard deviation σ_D , and scattering s , between C_{ppm} computed and measured for silt-bed rivers

	Bagnold	Ackers White	Yang & Hung	Shen & Hung	Brow nlie	Karim & Ken	Laurs en	Kari m	Toffal etti	Einst ein
Discrepancy Ratio \overline{R}_D	0.56	too high	1.66	0.52	0.41	1.74	3.01	1.72	4.21	1.06
standard deviation σ_D	1.59	too high	4.27	1.14	0.65	3.86	5.36	1.73	4.06	2.00
scattering s	-0.98	-	-0.54	-0.74	-0.69	-0.53	0.05	0.08	0.43	-0.78

Table 4.8. Correlation coefficient C_c among C_{ppm} computed, C_{ppm} measured and hydraulic geometry and sediment characteristic parameters for silt-bed rivers

C _{ppm}	C _{ppm} meas.	Bagnold	Ackers White	Yang'73	Shen Hung	Brownlie	Karim Kenn	Laur sen	Karim	Toffa letti	Eins tein	Q (m ³ /s)	w (m)	d (m)	v (m/s)	d _s (mm)	S _w	temp °C	τ _o (N/m ²)	u (m/s)	v (m ² /s)	d.	ω (m/s)	
Measured	1																							
Bagnold	0.25	1																						
Acker-White	-0.10	0.01	1																					
Yang'73	0.20	0.95	-0.03	1																				
Shen & Hung	0.35	0.94	-0.07	0.90	1																			
Brownlie	0.38	0.89	-0.09	0.86	0.99	1																		
Karim-Kennedy	0.20	0.84	-0.04	0.83	0.90	0.85	1																	
Laursen	0.29	0.94	-0.08	0.93	0.91	0.90	0.73	1																
Karim	0.36	0.93	-0.11	0.88	0.98	0.97	0.84	0.94	1															
Toffaletti	0.48	0.66	-0.12	0.59	0.72	0.76	0.45	0.76	0.78	1														
Einstein	0.36	0.74	-0.08	0.68	0.88	0.90	0.79	0.73	0.88	0.63	1													
Q (m ³ /s)	0.04	0.20	0.07	0.14	0.18	0.15	0.23	0.09	0.11	0.02	0.18	1												
w (m)	0.23	0.39	0.07	0.35	0.33	0.32	0.21	0.39	0.31	0.35	0.15	0.57	1											
d (m)	-0.23	-0.08	0.15	-0.13	-0.13	-0.17	0.03	-0.24	-0.22	-0.33	-0.05	0.82	0.11	1										
v (m/s)	0.46	0.48	-0.13	0.39	0.67	0.72	0.53	0.50	0.69	0.69	0.83	0.20	0.14	-0.03	1									
d _s (mm)	0.29	-0.09	-0.22	-0.03	0.13	0.21	0.05	0.03	0.16	0.24	0.21	-0.46	-0.14	-0.63	0.34	1								
S _w	0.32	0.83	-0.08	0.80	0.85	0.82	0.70	0.81	0.81	0.59	0.61	-0.03	0.35	-0.35	0.35	0.29	1							
Temp (°C)	0.26	0.19	-0.16	0.19	0.30	0.37	0.24	0.18	0.25	0.36	0.36	0.16	0.08	0.07	0.45	0.08	0.18	1						
τ _o (N/m ²)	0.20	0.67	0.06	0.55	0.73	0.66	0.78	0.48	0.63	0.31	0.69	0.41	0.17	0.31	0.52	-0.01	0.61	0.22	1					
u (m/s)	0.21	0.66	0.08	0.53	0.70	0.63	0.70	0.47	0.61	0.33	0.67	0.44	0.18	0.36	0.51	-0.06	0.60	0.24	0.98	1				
v (m ² /s)	-0.21	-0.18	0.16	-0.18	-0.29	-0.34	-0.23	-0.17	-0.23	-0.33	-0.34	-0.20	-0.10	-0.11	-0.42	-0.02	-0.15	-0.98	-0.21	-0.24	1			
d.	0.35	-0.01	-0.23	0.04	0.24	0.33	0.13	0.09	0.24	0.35	0.33	-0.34	-0.09	-0.52	0.48	0.91	0.32	0.48	0.08	0.04	-0.43	1		
ω (m/s)	0.32	-0.06	-0.20	0.00	0.19	0.28	0.10	0.04	0.19	0.30	0.29	-0.32	-0.09	-0.48	0.46	0.91	0.28	0.45	0.06	0.03	-0.39	0.99	1	

4.2.4 Small Rivers (width < 10 m, and depth < 1.0 m)

A total of 163 data sets of rivers with range of width from 0.35 to 9.60 m and range of depth from 0.02 to 0.94 m including:

1. American Canal 3 data sets
2. Hii River 38 data sets
3. India Canal 3 data sets
4. Mountain Creek 100 data sets
5. Rio Grande (Nordin) 3 data sets
6. Saskatchewan & Elbow River 16 data sets

The river data show a wide range of hydraulic geometric data, including:

- discharge : 0.0009 – 7.35 m³/s
- mean bed material diameter: 0.042 mm (coarse silt) – 57.67 mm (very coarse gravel)
- slope : 0.000115 – 0.0113

The data were divided into two groups: Group1 (82 data) for computation and Group 2 (81) for verification.

The C_{ppm} measured and computed are shown in Figure 4.5.

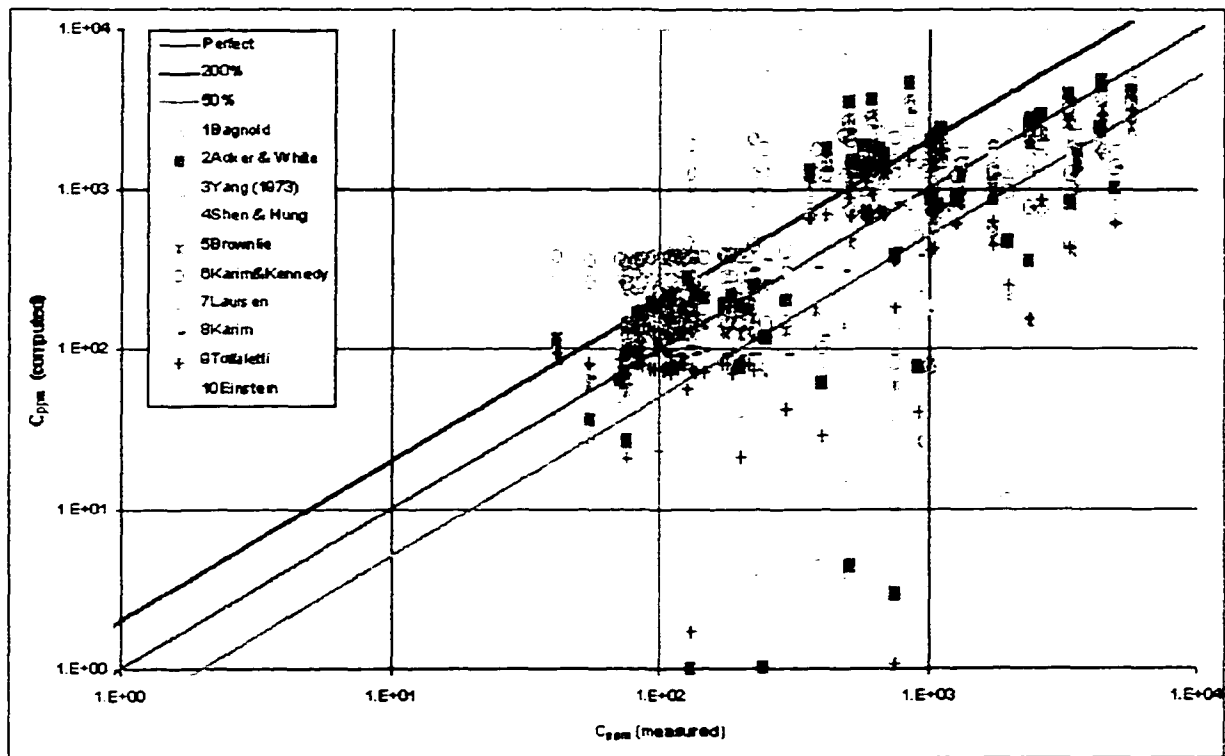


Figure 4.5. C_{ppm} computed and measured for small rivers

The discrepancy ratio \overline{R}_D , standard deviation σ_D and scattering s of C_{ppm} , both computed and measured were computed. Three kinds of coefficient of correlation C_c were computed including: C_{ppm} measured and C_{ppm} computed, parameters and C_{ppm} measured and parameters and C_{ppm} computed. Results of computation of each parameter are shown in Tables 4.9. and 4.10.

Table 4.9. Discrepancy ratio \overline{R}_D , standard deviation σ_D , and scattering s , between C_{ppm} computed and measured for small rivers

	Bagnold	Ackers & White	Yang 73	Shen Hung	Brownlie	Karim & Ken	Laursen	Karim	Toffaletti	Einstein
Discrepancy Ratio \overline{R}_D	2.05	1.45	1.38	3.57	1.18	3.01	1.43	1.19	0.68	3.48
standard deviation σ_D	1.78	1.31	0.9	8.59	1.01	2.62	1.39	0.89	0.53	3.81
scattering s	0.17	-0.18	-0.06	0.10	-0.09	0.31	-0.19	-0.01	-0.61	0.11

Table 4.10. Correlation coefficient C_c among C_{ppm} computed, C_{ppm} measured and hydraulic geometry and sediment characteristic parameters for small rivers

C _{ppm}	C _{ppm} meas.	Bagnold	Ackers	White	Yang73	Shen Hung	Brownlie	Karim Kenn	Laur sen	Karim	Toffa letti	Eins tein	Q (m ³ /s)	w (m)	d (m)	v (m/s)	d _s (mm)	S _w	temp °C	τ _o (N/m ²)	u. (m/s)	v. (m ² /s)	d. (m/s)
Measured	1																						
Bagnold	0.76	1																					
Acker-White	0.61	0.42	1																				
Yang73	0.85	0.65	0.89	1																			
Shen & Hung	0.16	0.55	0.16	0.14	1																		
Brownlie	0.53	0.40	0.98	0.83	0.24	1																	
Karim-Kennedy	0.60	0.70	0.82	0.78	0.68	0.85	1																
Laur sen	0.63	0.55	0.88	0.83	0.50	0.88	0.92	1															
Karim	0.76	0.62	0.95	0.95	0.25	0.92	0.85	0.91	1														
Toffaletti	0.79	0.54	0.89	0.97	0.15	0.83	0.77	0.88	0.95	1													
Einstein	0.18	0.31	0.69	0.43	0.65	0.79	0.83	0.77	0.61	0.46	1												
Q (m ³ /s)	-0.17	0.24	-0.26	-0.29	0.88	-0.17	0.28	0.10	-0.17	-0.25	0.35	1											
w (m)	-0.67	-0.75	-0.28	-0.56	-0.20	-0.21	-0.41	-0.33	-0.46	-0.46	0.00	0.04	1										
d (m)	-0.21	0.02	-0.31	-0.36	0.64	-0.26	0.06	-0.02	-0.22	-0.30	0.17	0.88	0.12	1									
v (m/s)	-0.16	0.24	-0.11	-0.19	0.93	0.00	0.42	0.23	-0.07	-0.15	0.54	0.96	0.05	0.77	1								
d _s (mm)	-0.14	0.28	-0.25	-0.25	0.87	-0.17	0.31	0.10	-0.16	-0.22	0.31	0.96	-0.02	0.76	0.94	1							
S _w	0.63	0.97	0.22	0.46	0.61	0.22	0.59	0.39	0.42	0.34	0.24	0.38	-0.71	0.13	0.36	0.43	1						
Temp (°C)	-0.23	-0.52	-0.18	-0.17	-0.72	-0.23	-0.54	-0.42	-0.29	-0.16	-0.48	-0.62	0.26	-0.50	-0.61	-0.60	-0.55	1					
τ _o (N/m ²)	-0.11	0.34	-0.22	-0.22	0.92	-0.13	0.35	0.15	-0.12	-0.20	0.39	0.98	-0.05	0.78	0.97	0.97	0.48	-0.63	1				
u. (m/s)	-0.07	0.38	-0.18	-0.17	0.94	-0.09	0.39	0.18	-0.08	-0.16	0.41	0.97	-0.09	0.77	0.97	0.96	0.51	-0.64	1.00	1			
v. (m ² /s)	0.18	0.49	0.12	0.12	0.75	0.18	0.51	0.38	0.23	0.11	0.46	0.68	-0.21	0.54	0.67	0.66	0.54	-0.99	0.68	0.69	1		
d. (m/s)	-0.14	0.28	-0.25	-0.25	0.87	-0.17	0.30	0.09	-0.17	-0.23	0.31	0.96	-0.02	0.76	0.95	1.00	0.43	-0.59	0.97	0.96	0.65	1	
τ _o (N/m ²)	-0.23	0.19	-0.34	-0.34	0.84	-0.25	0.22	0.02	-0.27	-0.31	0.28	0.95	0.03	0.74	0.95	0.98	0.36	-0.52	0.97	0.96	0.59	0.98	

4.2.5 Intermediate Rivers (10 m < width < 50 m, and 1.0 m < depth < 3 m)

A total of 127 sets of data of rivers with range of width from 10.58 to 49.68 m and range of depth from 1.01 to 2.96 m including:

1. Amazon and Orinoco River systems 4 data sets
2. American Canal 4 data sets
3. India Canal 19 data sets
4. Pakistan Canal 64 data sets
5. Rio Grande (Nordin) 19 data sets
6. Rio Grande Convey 8 data sets
7. Southam Rivers 7 data sets
8. Trinity 1 datum set
9. West Pakistan (CHOP) Canal 1 datum set

The river data show a wide range of hydraulic geometric data including:

- discharge : 6.42 – 268.72 m³/s
- mean bed material diameter: 0.021 mm (medium silt) – 4.20 mm (fine gravel)
- slope : 0.000020 – 0.00280

The data were divided into two groups: Group 1 (66 data) is for computation and Group 2 (61) is for verification.

The C_{ppm} measured and computed are shown in Figure 4.6.

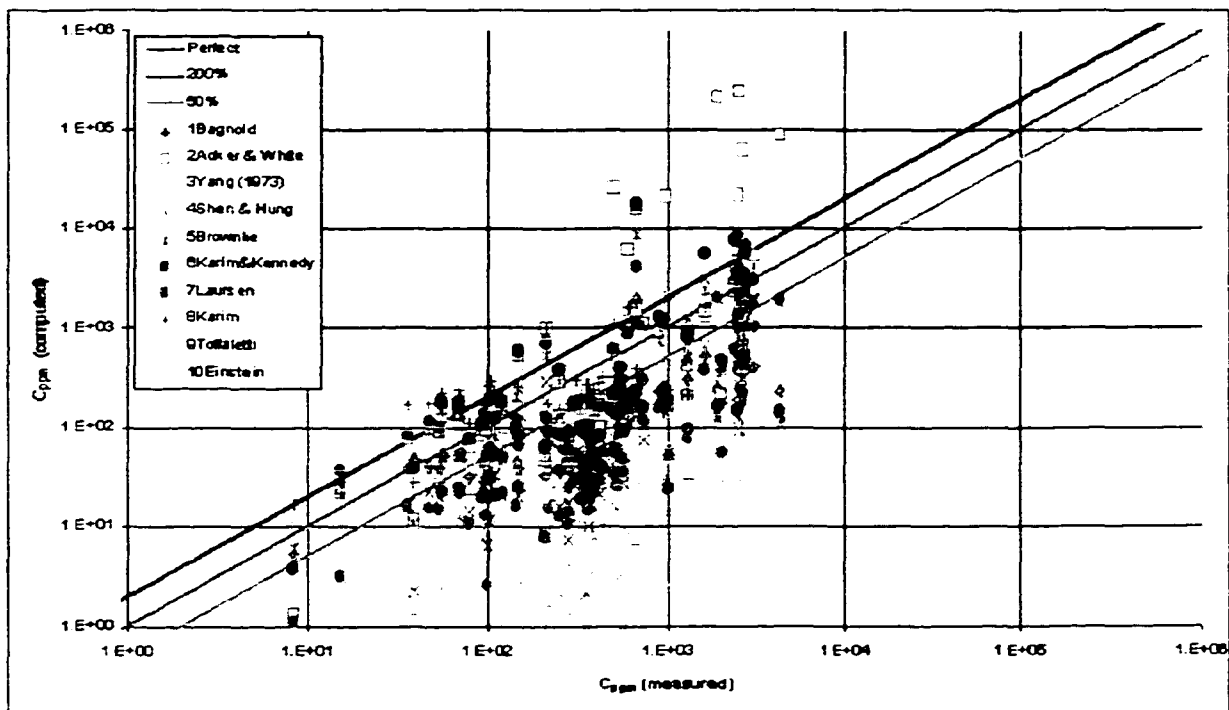


Figure 4.6. C_{ppm} computed and measured for intermediate rivers

Discrepancy ratio \overline{R}_D , standard deviation σ_D and scattering s of C_{ppm} computed and measured were computed. Three kinds of coefficient of correlation C_c were computed including: C_{ppm} measured and C_{ppm} computed, parameters and C_{ppm} measured and parameters and C_{ppm} computed. Results of computation of each parameter are shown in Tables 4.11. and 4.12.

Table 4.11. Discrepancy ratio \overline{R}_D , standard deviation σ_D , and scattering s , between C_{ppm} computed and measured for intermediate rivers

	Bagnold	Ackers White	Yang' 73	Shen Hung	Brown lie	Kari m&K en	Laursen	Karim	Toffa letti	Einst ein
Discrepancy Ratio \overline{R}_D	0.36	6.37	0.38	0.76	0.94	1.44	0.37	1.37	0.94	0.22
standard deviation σ_D	0.44	19.07	0.33	3.09	1.70	3.35	0.80	1.14	0.85	0.49
scattering s	-0.63	0.02	-0.59	-0.70	-0.32	-0.19	-0.91	-0.01	-0.26	-1.36

Table 4.12. Correlation coefficient C_c among C_{ppm} computed, C_{ppm} measured and hydraulic geometry and sediment characteristic parameters for intermediate rivers

C _{ppm}	C _{ppm} meas.	Bagnold	Ackers White	Yang'73	Shen Hung	Brownlie	Karim Kenn	Laur sen	Karim	Toffa letti	Eins tein	Q (m ³ /s)	w (m)	d (m)	v (m/s)	d _s (mm)	S _w	temp °C	τ _o (N/m ²)	u. (m/s)	v (m ² /s)	d. (m)	ω (m/s)	
Measured	1																							
Bagnold	0.46	1																						
Acker-White	0.41	0.08	1																					
Yang'73	0.70	0.55	0.00	1																				
Shen & Hung	0.25	0.97	-0.05	0.41	1																			
Brownlie	0.38	0.96	-0.07	0.61	0.96	1																		
Karim-Kennedy	0.38	0.95	-0.06	0.63	0.95	1.00	1																	
Laursen	0.52	0.78	0.49	0.23	0.70	0.65	0.63	1																
Karim	0.76	0.43	0.33	0.73	0.25	0.43	0.42	0.54	1															
Toffaletti	0.64	0.36	0.23	0.67	0.21	0.39	0.39	0.46	0.95	1														
Einstein	0.18	0.83	-0.09	0.40	0.87	0.88	0.86	0.60	0.34	0.40	1													
Q (m ³ /s)	-0.20	0.08	-0.31	0.12	0.18	0.21	0.21	-0.24	-0.20	-0.22	0.20	1												
w (m)	-0.39	-0.19	-0.40	-0.10	-0.05	-0.05	-0.04	-0.50	-0.47	-0.43	-0.10	0.76	1											
d (m)	-0.44	-0.46	0.10	-0.54	-0.38	-0.45	-0.45	-0.23	-0.36	-0.35	-0.37	0.42	0.29	1										
v (m/s)	0.25	0.93	-0.11	0.44	0.97	0.95	0.93	0.62	0.25	0.21	0.89	0.35	0.03	-0.31	1									
d _s (mm)	0.02	0.81	-0.11	0.12	0.89	0.77	0.75	0.56	-0.10	-0.11	0.77	0.15	0.00	-0.31	0.87	1								
S _w	0.47	0.87	-0.12	0.73	0.82	0.87	0.87	0.44	0.31	0.25	0.68	0.20	-0.01	-0.59	0.83	0.72	1							
Temp (°C)	-0.56	-0.57	-0.10	-0.54	-0.45	-0.51	-0.49	-0.47	-0.57	-0.47	-0.35	0.08	0.30	0.34	-0.46	-0.31	-0.54	1						
τ _o (N/m ²)	0.44	0.83	-0.11	0.72	0.78	0.81	0.82	0.39	0.26	0.18	0.62	0.29	0.04	-0.48	0.80	0.69	0.98	-0.52	1					
u. (m/s)	0.47	0.78	-0.13	0.77	0.71	0.78	0.79	0.32	0.32	0.24	0.60	0.32	0.07	-0.51	0.76	0.61	0.97	-0.53	0.98	1				
v (m ² /s)	0.54	0.61	0.05	0.56	0.51	0.56	0.53	0.49	0.59	0.49	0.43	-0.04	-0.26	-0.38	0.53	0.36	0.56	-0.96	0.54	0.56	1			
d. (m)	0.00	0.79	-0.13	0.11	0.87	0.74	0.72	0.52	-0.13	-0.14	0.76	0.15	0.01	-0.34	0.85	1.00	0.72	-0.26	0.69	0.61	0.32	1		
ω (m/s)	0.04	0.71	-0.20	0.22	0.78	0.69	0.67	0.35	-0.16	-0.16	0.69	0.17	0.07	-0.45	0.78	0.93	0.78	-0.24	0.76	0.71	0.30	0.96	1	

4.2.6 Large Rivers (width > 50 m and depth > 3 m)

A total of 754 sets of data of rivers with range of width from 51.51 to 3.338 m and range of depth from 3.01 to 62.3 m including:

1. Amazon and Orinoco River Systems 63 data sets
2. Atchafalaya River 72 data sets
3. Colorado River 14 data sets
4. India Canal 9 data sets
5. Mississippi River 248 data sets
6. Pakistan Canal 32 data sets
7. Red River 28 data sets
8. Rio Magdalena & Canal del Dique 35 data sets
9. River Data of Leopold 14 data sets
10. Snake & Clearwater River 17 data sets
11. West Pakistan (CHOP) Canal 7 data sets
12. Yangtze River 40 data sets
13. Yellow River 175 data sets

The river data show a wide range of hydraulic geometric data including:

- discharge : 107 – 235,000 m³/s
- mean bed material diameter: 0.02 mm (medium silt) – 1.15 mm (very coarse sand)
- slope : 0.0000021 – 0.00121

The data were divided into two groups: Group 1 (380 data) for computation and Group 2 (374) for verification.

The C_{ppm} measured and computed are shown in Figure 4.7.

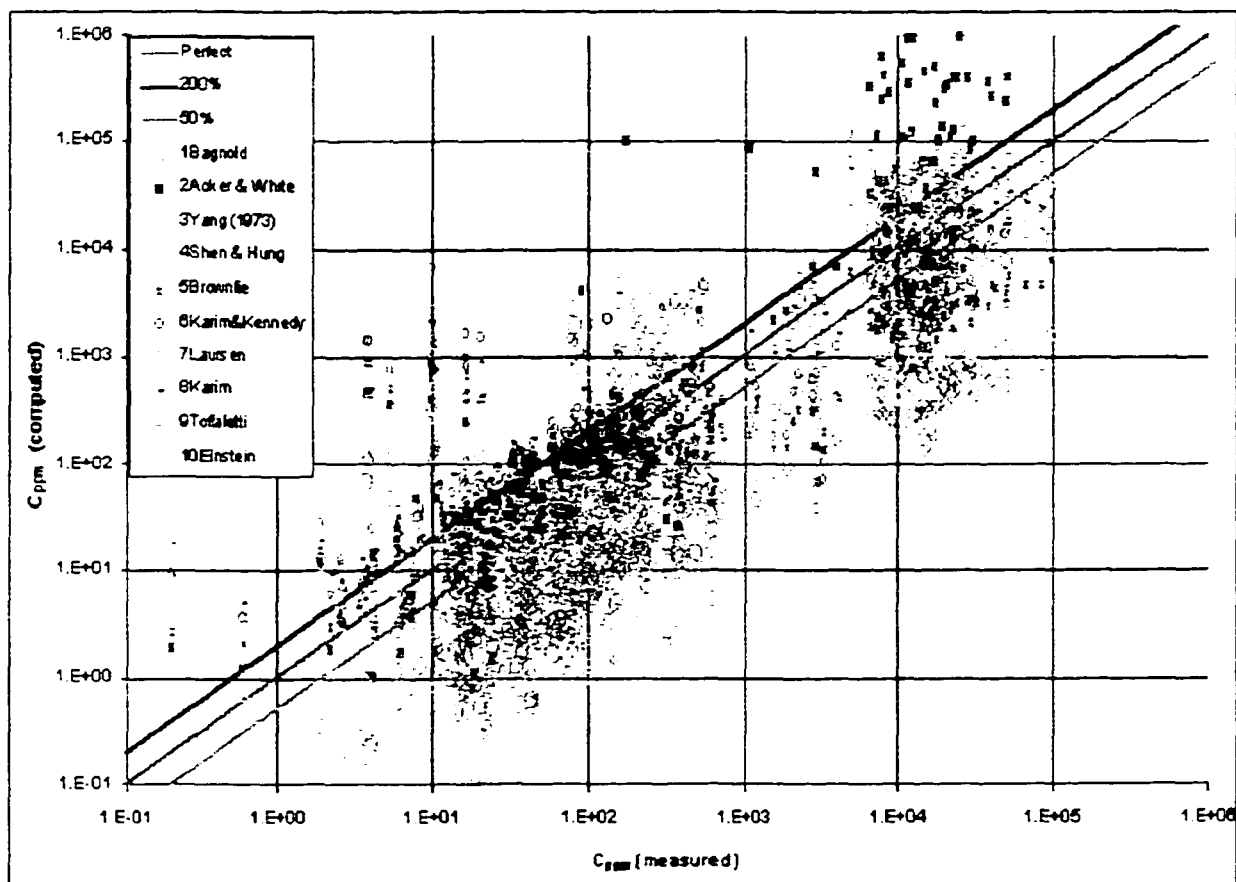


Figure 4.7. C_{ppm} computed and measured for large rivers

The discrepancy ratio $\overline{R_D}$, standard deviation σ_D and scattering s of C_{ppm} computed and measured were computed. Three kinds of coefficient of correlation C_c were computed including: C_{ppm} measured and C_{ppm} computed, parameters and C_{ppm}

measured and parameters and C_{ppm} computed. Results of computation of each parameter are shown in Tables 4.13 and 4.14.

Table 4.13. Discrepancy ratio \overline{R}_D , standard deviation σ_D , and scattering s , between C_{ppm} computed and measured for large rivers

	Bagnold	Ackers White	Yang 73	Shen Hung	Brownlie	Karim & Ken	Laursen	Karim	Toffal etti	Einste in
Discrepancy Ratio \overline{R}_D	1.04	too high	2.32	3.59	3.97	7.43	1.13	3.22	1.90	2.05
standard deviation σ_D	3.74	too high	11.55	25.19	22.81	46.44	3.99	13.47	4.43	11.39
scattering s	-0.61	0.71	-0.49	-0.82	-0.18	0.05	-35.46	0.04	-0.02	-0.82

Table 4.14. Correlation coefficient C_c among C_{ppm} computed, C_{ppm} measured and hydraulic geometry and sediment characteristic parameters for large rivers

C _{ppm}	C _{ppm} meas.	Bagnold	Ackers White	Yang'73	Shen Hung	Brownlie	Karim Kenn	Laur sen	Karim	Toffa letti	Eins tein	Q (m ³ /s)	w (m)	d (m)	v (m/s)	d _s (mm)	S _w	temp °C	τ _o (N/m ²)	u. (m/s)	v (m ² /s)	d. (m/s)	m (m/s)
Measured	1																						
Bagnold	0.63	1																					
Acker-White	-0.03	0.15	1																				
Yang'73	0.58	0.94	0.07	1																			
Shen & Hung	0.76	0.91	-0.01	0.88	1																		
Brownlie	0.80	0.86	-0.03	0.82	0.98	1																	
Karim-Kennedy	0.63	0.86	-0.02	0.92	0.90	0.85	1																
Laur sen	0.68	0.94	0.01	0.94	0.93	0.90	0.85	1															
Karim	0.71	0.91	-0.03	0.92	0.96	0.94	0.89	0.97	1														
Toffaletti	0.70	0.79	-0.03	0.78	0.85	0.88	0.70	0.88	0.91	1													
Einstein	0.73	0.83	-0.03	0.80	0.94	0.95	0.83	0.89	0.94	0.82	1												
Q (m ³ /s)	-0.04	-0.08	-0.03	-0.06	-0.06	-0.06	-0.03	-0.06	-0.06	-0.06	-0.04	1											
w (m)	-0.02	-0.08	-0.02	-0.05	-0.06	-0.06	-0.03	-0.06	-0.06	-0.05	-0.04	0.81	1										
d (m)	-0.28	-0.29	-0.03	-0.22	-0.31	-0.33	-0.20	-0.26	-0.29	-0.31	-0.28	0.78	0.59	1									
v (m/s)	0.66	0.67	-0.06	0.60	0.82	0.86	0.62	0.69	0.76	0.75	0.80	0.15	0.05	-0.16	1								
d _s (mm)	-0.37	-0.48	-0.09	-0.34	-0.41	-0.43	-0.32	-0.42	-0.41	-0.41	-0.40	0.16	0.22	0.28	-0.27	1							
S _w	0.39	0.41	-0.02	0.39	0.54	0.51	0.43	0.37	0.40	0.34	0.38	-0.15	-0.19	-0.39	0.52	0.10	1						
Temp (°C)	0.15	0.04	-0.10	0.06	0.09	0.13	0.10	0.08	0.09	0.12	0.13	0.19	0.22	0.09	0.10	-0.05	-0.02	1					
τ _o (N/m ²)	0.19	0.24	-0.03	0.26	0.36	0.32	0.31	0.20	0.23	0.15	0.23	0.27	0.12	0.17	0.47	0.29	0.80	-0.04	1				
u. (m/s)	0.22	0.27	-0.03	0.28	0.38	0.35	0.33	0.24	0.27	0.19	0.28	0.30	0.17	0.17	0.52	0.28	0.75	-0.04	0.96	1			
v (m ² /s)	-0.16	-0.08	0.10	-0.09	-0.12	-0.15	-0.12	-0.11	-0.12	-0.15	-0.15	-0.17	-0.19	-0.07	-0.12	0.10	0.01	-0.98	0.04	0.03	1		
d. (m/s)	-0.35	-0.47	-0.09	-0.34	-0.40	-0.42	-0.31	-0.41	-0.40	-0.40	-0.39	0.20	0.27	0.29	-0.26	0.97	0.09	0.13	0.27	0.26	-0.09	1	
m (m/s)	-0.41	-0.53	-0.09	-0.38	-0.46	-0.48	-0.35	-0.46	-0.46	-0.46	-0.45	0.22	0.28	0.34	-0.31	0.98	0.04	0.02	0.27	0.27	0.02	0.97	1

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4.3. Discussion and Summary of Overall Results

4.3.1 Discussion of Overall Results

The discrepancy ratio of C_{ppm} measured and C_{ppm} computed are summarized in Table 4.15.

Table 4.15. Discrepancy ratio \overline{R}_D between C_{ppm} computed and measured for several river-beds and river sizes.

	Bagnold	Ackers & White	Yang 73	Shen & Hung	Brownlie	Karim & Kennedy	Laursen	Karim	Toffaletti	Einstein
gravel-bed rivers	12.30	0.33	0.10	68.95	4.25	23.45	7.16	4.52	0.01	18.18
m-c sand-bed rivers	1.68	2.85	3.22	5.46	4.86	12.06	0.60	2.68	0.93	2.56
f-vf sand-bed rivers	0.21	5.31	0.30	0.32	0.51	0.90	0.36	1.28	2.56	0.63
silt-bed rivers	0.56	too high	1.66	0.52	0.41	1.74	3.01	1.72	4.21	1.06
small rivers	2.05	1.45	1.38	3.57	1.18	3.01	1.43	1.19	0.68	3.48
intermediate rivers	0.36	6.37	0.38	0.76	0.94	1.44	0.37	1.37	0.94	0.22
large-rivers	1.04	too high	2.32	3.59	3.97	7.43	1.13	3.22	1.90	2.05

note : blue is the best for river-beds, and red is the best for river sizes.

In more detail, data in the range of the discrepancy ratio are summarized in Tables 4.16 to 4.22.

Table 4.16. Range in percent of discrepancy ratio of gravel-bed rivers for each method

	< 0.50	0.5 - 0.75	0.75 - 1.25	1.25 - 1.50	1.50 - 2.00	>2.00
Bagnold	-	-	-	-	5%	95%
Ackers & V	95%	-	-	-	-	5%
Yang (1973)	97%	-	3%	-	-	-
Shen & Hu	-	-	-	-	-	100%
Brownlie	12%	3%	16%	5%	10%	53%
Karim&Ker	-	-	-	-	-	100%
Laursen	3%	2%	3%	-	10%	81%
Karim	2%	12%	14%	5%	2%	66%
Toffaletti	100%	-	-	-	-	-
Einstein	-	-	-	-	2%	98%

Table 4.17. Range of discrepancy ratio (%) of medium to very coarse sand-bed rivers for each method

	< 0.50	0.5 - 0.75	0.75 - 1.25	1.25 - 1.50	1.50 - 2.00	>2.00
Bagnold	50%	8%	16%	7%	5%	14%
Ackers & W	25%	18%	20%	4%	8%	25%
Yang (1973)	39%	14%	11%	4%	6%	26%
Shen & Hu	43%	15%	11%	5%	3%	23%
Brownlie	19%	15%	24%	6%	8%	27%
Karim&Ken	10%	11%	17%	7%	11%	43%
Laursen	75%	9%	6%	2%	3%	5%
Karim	36%	21%	24%	5%	4%	11%
Toffaletti	60%	13%	14%	3%	3%	6%
Einstein	63%	11%	9%	1%	3%	13%

Table 4.18. Range of discrepancy ratio (%) of very fine to fine sand-bed rivers for each method

	< 0.50	0.5 - 0.75	0.75 - 1.25	1.25 - 1.50	1.50 - 2.00	>2.00
Bagnold	89%	3%	4%	1%	1%	2%
Ackers & W	35%	10%	16%	5%	6%	28%
Yang (1973)	89%	3%	4%	1%	1%	3%
Shen & Hu	89%	5%	2%	0%	1%	2%
Brownlie	77%	6%	8%	2%	3%	5%
Karim&Ken	66%	7%	10%	3%	3%	11%
Laursen	80%	9%	7%	1%	2%	2%
Karim	28%	15%	25%	8%	9%	14%
Toffaletti	17%	8%	16%	7%	11%	40%
Einstein	62%	10%	14%	3%	5%	6%

Table 4.19. Range of discrepancy ratio (%) of silt-bed rivers for each method

	< 0.50	0.5 - 0.75	0.75 - 1.25	1.25 - 1.50	1.50 - 2.00	>2.00
Bagnold	84%	1%	3%	3%	2%	7%
Ackers & W	15%	1%	5%	1%	3%	76%
Yang (1973)	68%	6%	8%	1%	2%	15%
Shen & Hu	81%	3%	5%	1%	1%	6%
Brownlie	82%	4%	7%	1%	1%	5%
Karim&Ken	66%	7%	3%	1%	1%	21%
Laursen	19%	10%	22%	5%	11%	33%
Karim	17%	11%	18%	14%	12%	27%
Toffaletti	8%	8%	8%	2%	9%	66%
Einstein	54%	10%	13%	4%	3%	17%

Table 4.20. Range of discrepancy ratio (%) of small rivers for each method

	< 0.50	0.5 - 0.75	0.75 - 1.25	1.25 - 1.50	1.50 - 2.00	>2.00
Bagnold	12%	9%	16%	11%	12%	40%
Ackers & W	23%	10%	21%	5%	21%	21%
Yang (1973)	20%	6%	16%	13%	22%	23%
Shen & Hu	16%	11%	23%	17%	11%	22%
Brownlie	24%	15%	29%	10%	9%	13%
Karim&Ken	10%	6%	11%	1%	9%	63%
Laursen	20%	11%	23%	10%	16%	21%
Karim	13%	21%	39%	6%	6%	15%
Toffaletti	45%	22%	20%	5%	7%	1%
Einstein	22%	2%	2%	-	5%	68%

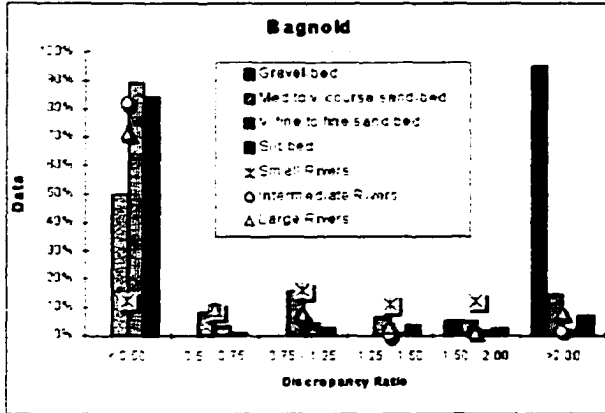
Table 4.21. Range of discrepancy ratio (%) of intermediate rivers for each method

	< 0.50	0.5 - 0.75	0.75 - 1.25	1.25 - 1.50	1.50 - 2.00	>2.00
Bagnold	82%	9%	6%	-	2%	2%
Ackers & W	41%	6%	15%	3%	8%	27%
Yang (1973)	70%	14%	15%	2%	-	-
Shen & Hu	73%	8%	11%	5%	3%	2%
Brownlie	53%	12%	12%	5%	9%	9%
Karim&Ken	45%	12%	9%	9%	3%	21%
Laursen	85%	6%	5%	2%	2%	2%
Karim	20%	24%	14%	11%	11%	21%
Toffaletti	44%	14%	15%	6%	6%	15%
Einstein	88%	5%	5%	-	2%	2%

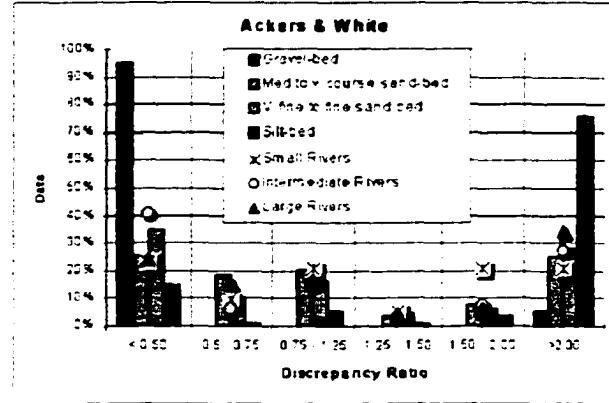
Table 4.22. Range of discrepancy ratio (%) of large rivers for each method

	< 0.50	0.5 - 0.75	0.75 - 1.25	1.25 - 1.50	1.50 - 2.00	>2.00
Bagnold	72%	9%	7%	3%	1%	8%
Ackers & W	24%	15%	16%	4%	6%	34%
Yang (1973)	65%	13%	9%	2%	2%	9%
Shen & Hu	79%	10%	4%	1%	1%	5%
Brownlie	41%	11%	21%	6%	8%	13%
Karim&Ken	27%	9%	18%	7%	11%	29%
Laursen	83%	3%	5%	1%	-	8%
Karim	17%	22%	23%	8%	11%	20%
Toffaletti	22%	16%	26%	7%	8%	20%
Einstein	76%	4%	6%	2%	4%	9%

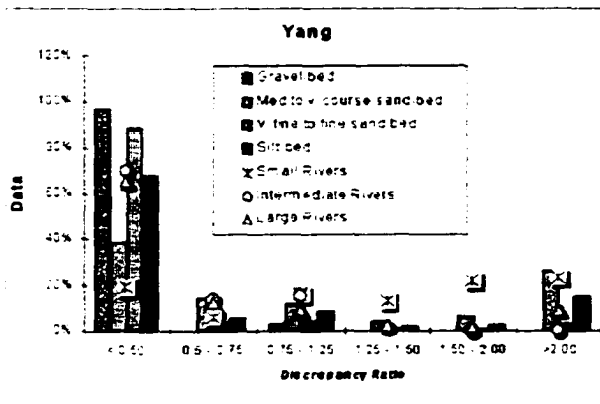
The relation between data (%) and the discrepancy ratio of each method for various particle diameters of bed material and various channel sizes are also shown graphically in Figure 4.8.



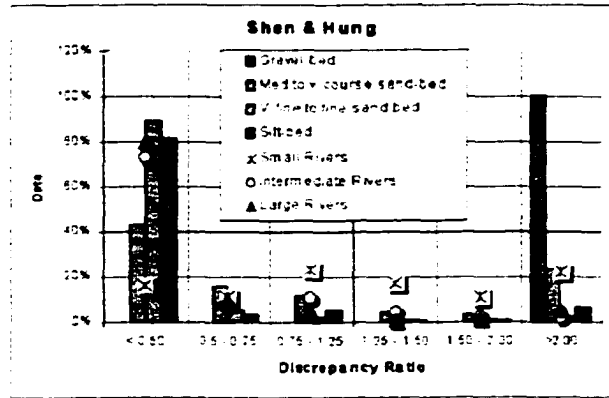
a. Bagnold's method



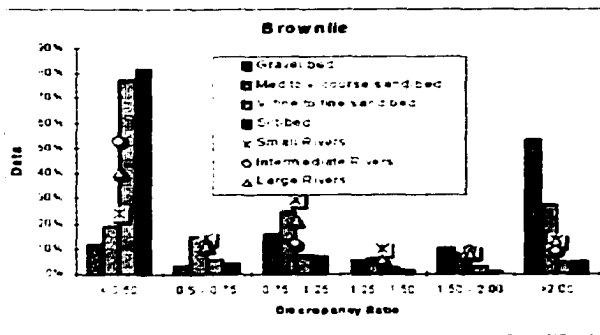
b. Ackers & White's method



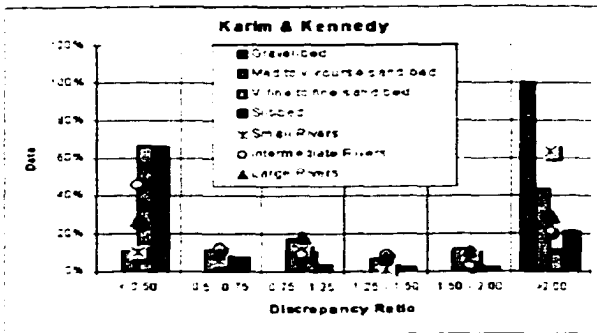
c. Yang's method



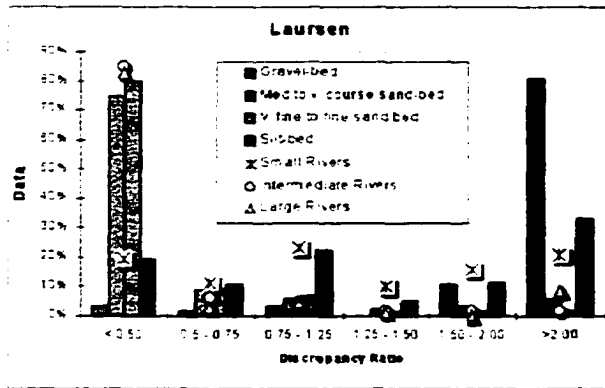
d. Shen & Hung's method



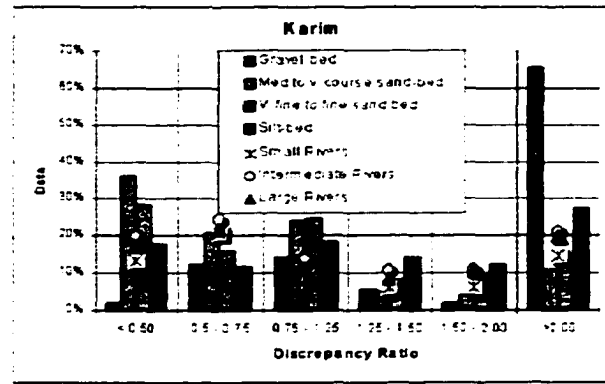
e. Brownlie's method



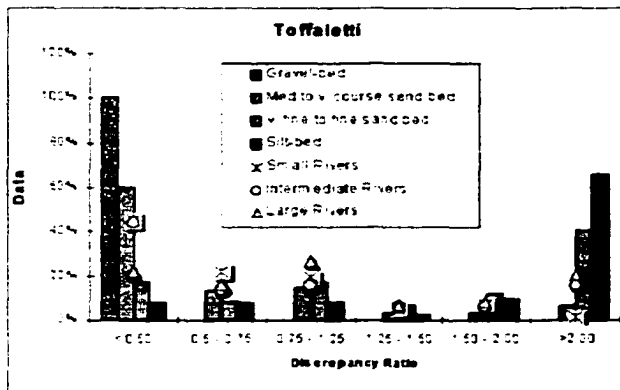
f. Karim & Kennedy's method



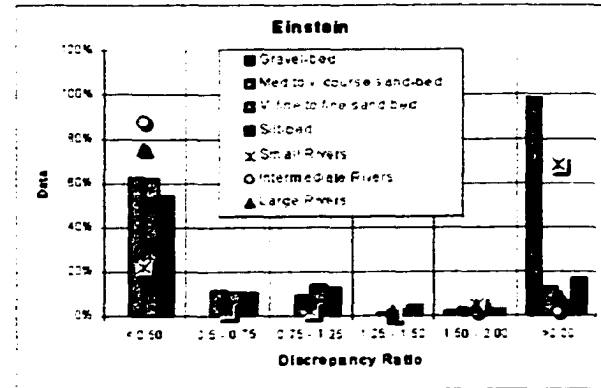
g. Laursen's method



h. Karim's method



i. Toffaletti's method



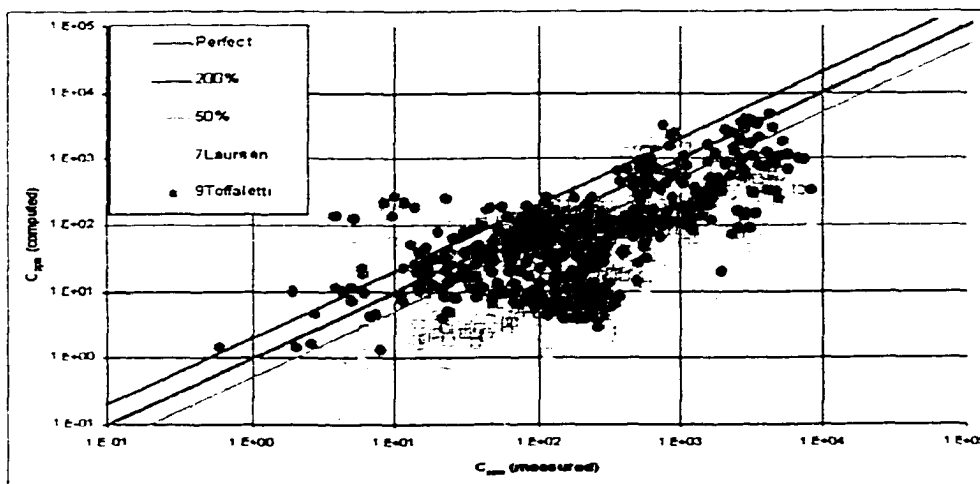
j. Einstein's method

Figure 4.8. The relation between data (%) and the discrepancy ratio of each method for various particle diameters of river-bed material and various channel sizes

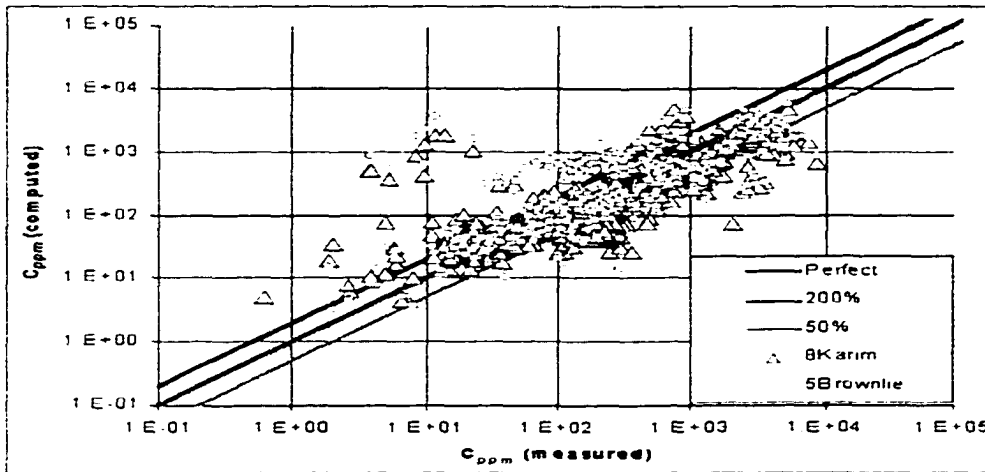
For gravel-bed rivers, Ackers & White followed by Brownlie, are the closest to the C_{ppm} measured although the discrepancy ratio, standard deviation and correlation coefficient do not indicate the closest value. For example, as shown in Table 4.15, the discrepancy ratio ($\overline{R_D}$) of Ackers & White is only 0.33 (best value if $\overline{R_D}=1$). However, the closest Pearson correlation coefficient C_{ppm} computed to measured are Bagnold and Shen & Hung both with C_c of 0.70 (see Table 4.2). Visually, in Figure 4.1, Brownlie

has computed C_{ppm} that is the closest to the C_{ppm} measured. Hence, for gravel-bed rivers, it is difficult to decide which method is the best. One possible reason is that gravel-bed rivers generally are characterized by bimodal sediment distribution (ASCE Task Committee, 1992). It also should be noted that gravel-bed streams display a much wider range of grain sizes compared to sand-bed streams (Duo et al. 1989). Accordingly, using a uniform particle diameter to describe the mobility of bed mixture in gravel-bed streams may not be appropriate (Diplas, 1987).

For medium to very coarse sand-bed rivers, from Table 4.15., Toffaletti ($\overline{R_D}=0.93$), and then Laursen ($\overline{R_D}=0.60$) and Bagnold ($\overline{R_D}=1.68$) are the closest to the C_{ppm} measured. However, based on the Pearson correlation coefficient Karim ($C_c = 0.66$) followed by Brownlie ($C_c = 0.60$) have the closest values compared to measured values. Visually, the best relations are shown in Figure 4.9.



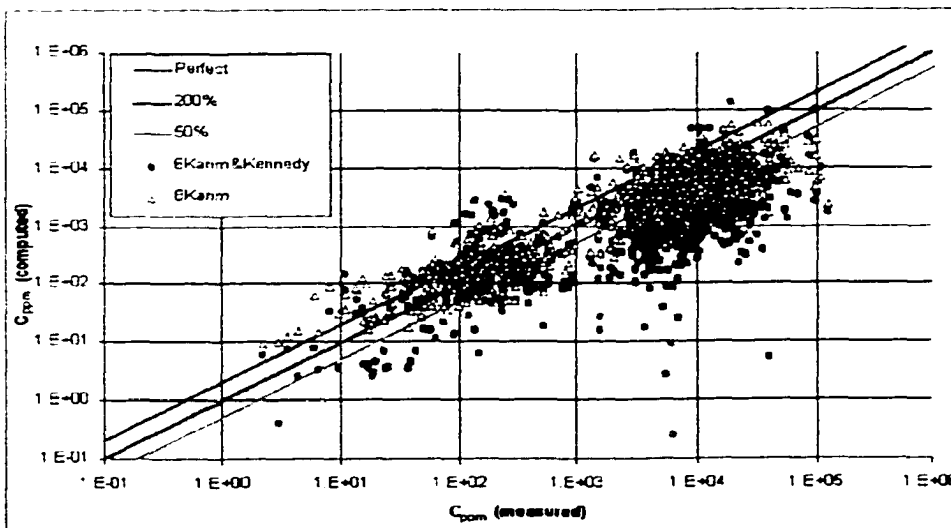
a. Based on discrepancy ratio



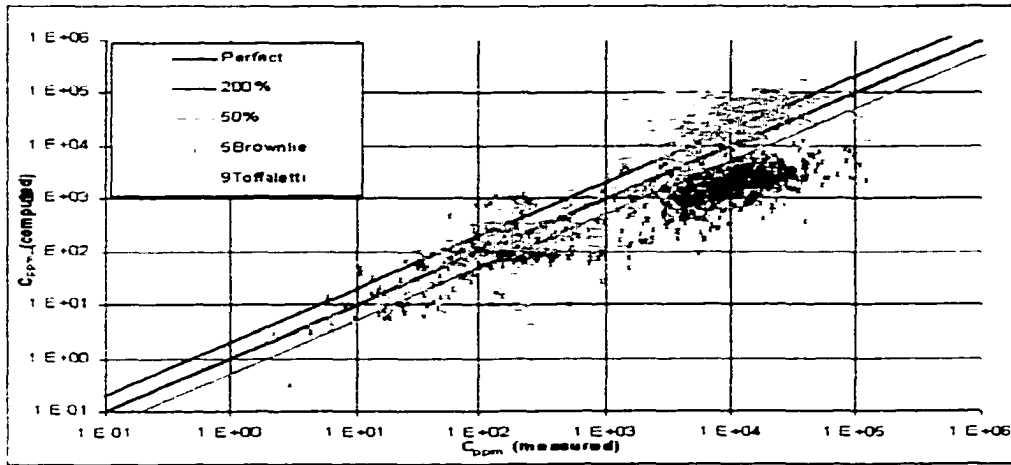
b. Based on correlation coefficient

Figure 4.9. The best relations for C_{ppm} computed and measured based on discrepancy ratio and correlation coefficient for medium to very coarse sand-bed rivers.

For very fine to fine sand-bed rivers, from Table 4.15., Karim & Kennedy ($\overline{R_D} = 0.90$), followed by Karim ($\overline{R_D} = 1.28$) are the closest to the C_{ppm} measured. On the other hand, from Table 4.4. Brownlie ($C_c = 0.58$) and Toffaletti ($C_c = 0.52$) have the highest correlation to the C_{ppm} measured. Visually, the best relations are shown in Figure 4.10.



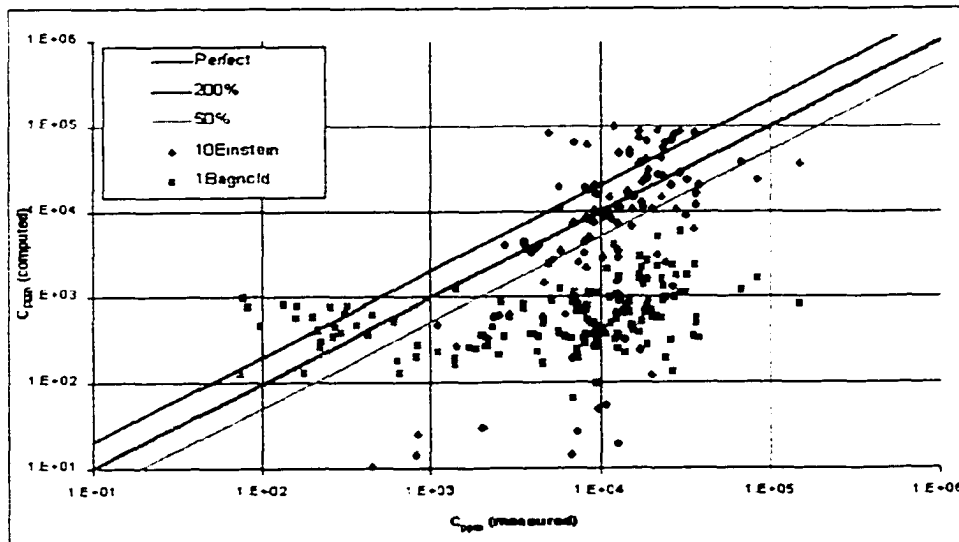
a. Based on discrepancy ratio



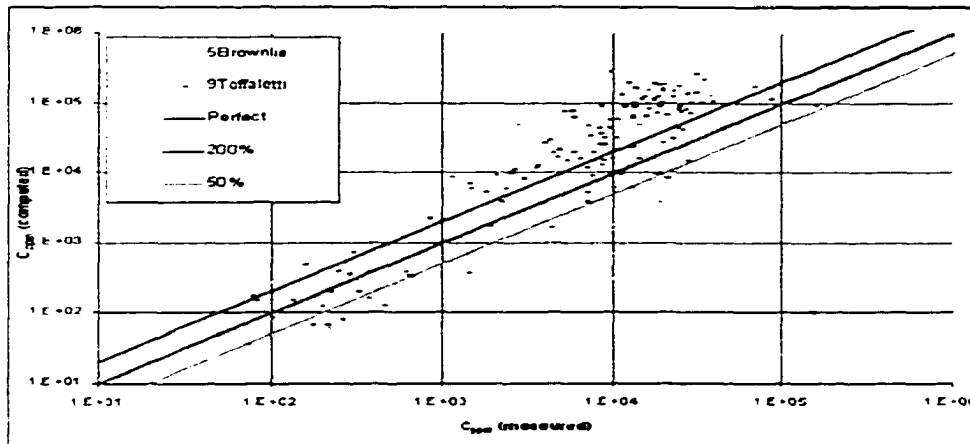
b. Based on Correlation coefficient

Figure 4.10. The best relations for C_{ppm} computed and measured based on discrepancy ratio and correlation coefficient for very fine to fine sand-bed rivers.

For silt-bed rivers, based on Table 4.15., Einstein ($\overline{R_D}=1.06$) and Bagnold ($\overline{R_D}=0.56$) have the closest to the C_{ppm} measured. However, from Table 4.8., Toffaletti ($C_c = 0.48$) and Brownlie ($C_c = 0.38$) have the highest correlation to the C_{ppm} measured. Visually, the best relations are shown in Figure 4.11.



a. Based on discrepancy ratio



b. Based on correlation coefficient

Figure 4.11. The best relations for C_{ppm} computed and measured based on discrepancy ratio and correlation coefficient for silt-bed rivers.

It should be noted that the Yellow River contributes about 63 % of the data for very fine to fine sand-bed rivers and about 77 % of the data for silt-bed rivers. This river is an extremely heavily sediment-laden river and floods at hyperconcentrations of sediment frequently occur (Qi Pu and Yean, 1993; Ye Qingchao, 1995; Zhao et al., 1995; Junfeng, 1989; Li et al., 1997). Accordingly, the characteristics of hydraulic geometry and sediment are not the same as in the case of common alluvial rivers.

Brownlie ($\overline{R_D}=1.18$) and Karim ($\overline{R_D}=1.19$) give the closest results for small rivers. In intermediate rivers C_{ppm} computed for Toffaletti ($\overline{R_D}=0.94$) and Brownlie ($\overline{R_D}=0.94$) are the closest to the C_{ppm} measured. In large rivers Bagnold ($\overline{R_D}=1.04$) and Laursen ($\overline{R_D}=1.13$) have the closest results to the C_{ppm} measured.

4.3.2 Summary of Overall Results

Some summaries of the applicability of each method for various particle diameters of river-bed materials and various channel sizes can be drawn:

1. Bagnold's method

Bagnold's method is relatively good and applicable for silt-bed rivers ($\overline{R_D} = 0.56$) and large rivers ($\overline{R_D} = 1.04$). The parameter that has relatively good correlation for various river-beds and river sizes is the slope. It over-predicts for coarse material of river-beds but under-predicts for finer bed material of rivers.

2. Ackers & White's method

Ackers & White's method is applicable for gravel-bed rivers, although it under-predicts ($\overline{R_D} = 0.33$). It much over-predicts for silt-bed rivers: the C_{ppm} are too high. This method has a tendency to increase the C_{ppm} as the mean diameter of the river-bed becomes finer. This tendency also occurs when the river size increases.

3. Yang's method

Compare to other methods, Yang's method has no consistency in results for both several kinds of particle diameter of river-bed material and river sizes. For example, it under-predicts for gravel-bed rivers, but over-predicts for medium to very coarse sand-bed rivers and then it under-predicts for silt-bed rivers. This phenomena also occur for river sizes. However, the range of the discrepancy ratio $\overline{R_D}$ for several kinds of particle diameter of river-bed materials and for river sizes is from 0.10 up to 3.22.

4. Shen & Hung's method

It over-predicts for coarse materials of river-beds (from medium sand to gravel-bed rivers). However it under-predicts for finer materials (from silt to fine sand-bed rivers).

This equation applies quite well to small rivers, but tends to predict a lower sediment bed-material concentration than the measured values for large rivers and the results of C_{ppm} computed by this method agree well to what Simons and Senturk (1992) stated about this equation for some large rivers.

5. Brownlie's method

This method is applicable for small ($\overline{R_D} = 1.18$) to intermediate rivers ($\overline{R_D} = 0.94$), but over-predicts for large rivers. This equation also over-predicts for coarse materials but under-predicts for finer materials.

6. Karim & Kennedy's method

This method is good for very fine to fine sand-bed rivers ($\overline{R_D} = 0.90$) but it over-predicts for coarse material. It is relatively good for intermediate rivers ($\overline{R_D} = 1.44$) and some large rivers.

7. Laursen's method

Laursen method under predicts for sand-bed channels but over-predicts for gravel bed and silt-bed channels. It mostly under-predicts for intermediate to large rivers but over-predicts for small rivers.

8. Karim's method

It is relatively good for sand-bed channels, but over-predicts for gravel and silt-bed rivers. It is also applicable for river sizes, although for some large rivers it over predicts.

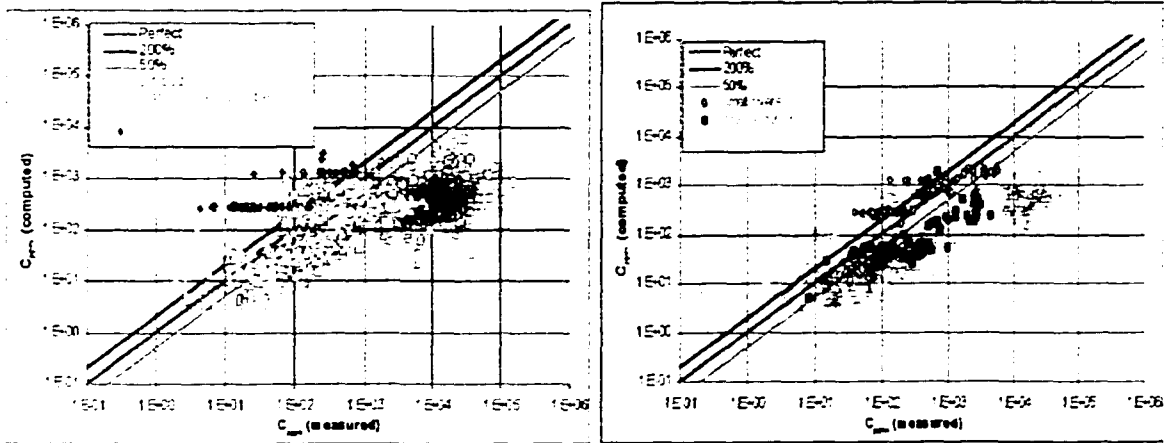
9. Toffaletti's method

It under predicts for gravel-bed rivers. However, this method is relatively good for medium to very coarse sand-bed channels ($\overline{R_D} = 0.93$). This method also has a tendency to increase the C_{ppm} as the mean diameter of the river-bed becomes finer. This tendency also occurs when the river size increases.

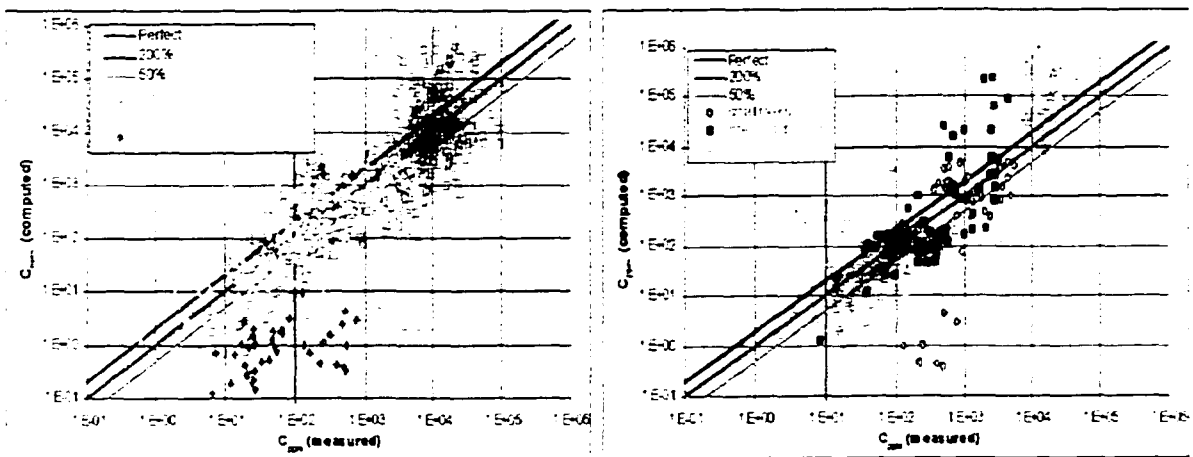
10. Einstein's method

It is applicable for silt bed channel ($\overline{R_D} = 1.06$). However, it over-predicts for gravel-bed channels. It under-predicts for intermediate rivers and most large rivers. However, it over-predicts for small rivers and some large rivers.

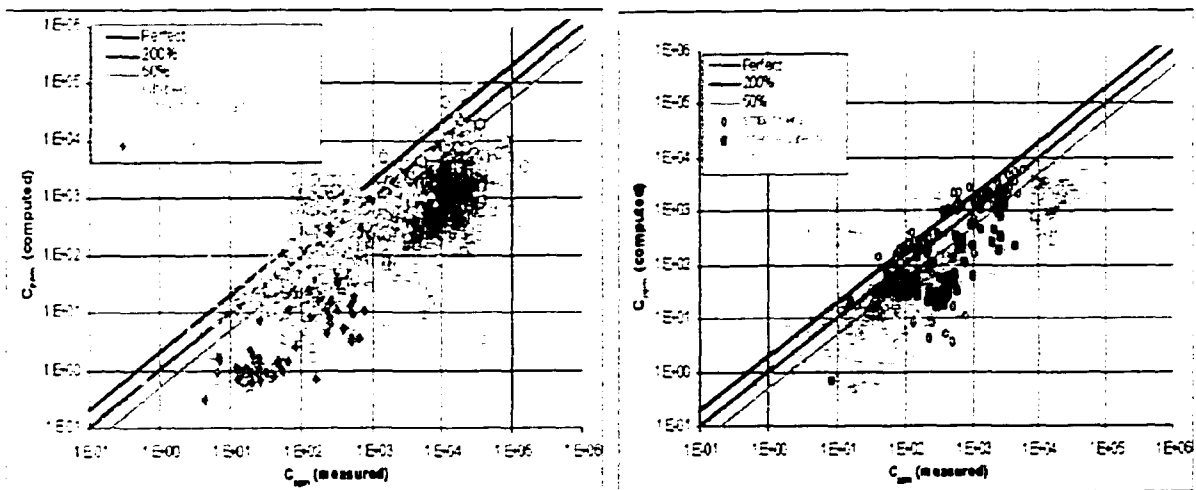
Comparison of C_{ppm} measured and C_{ppm} computed by each method for several kinds of partiel diameter of river-bed material and several river sizes is shown in Figure 4.12.



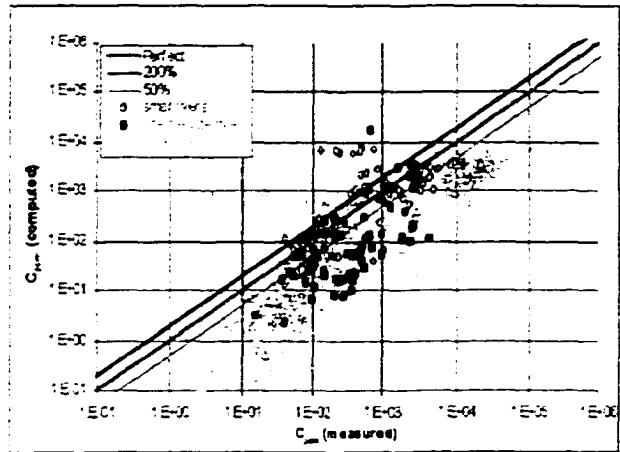
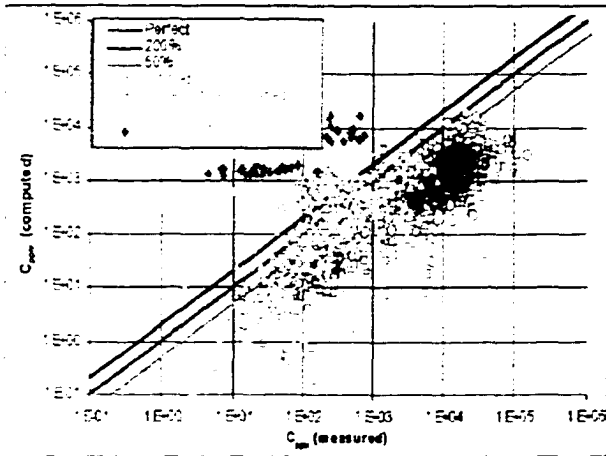
a. Bagnold's method



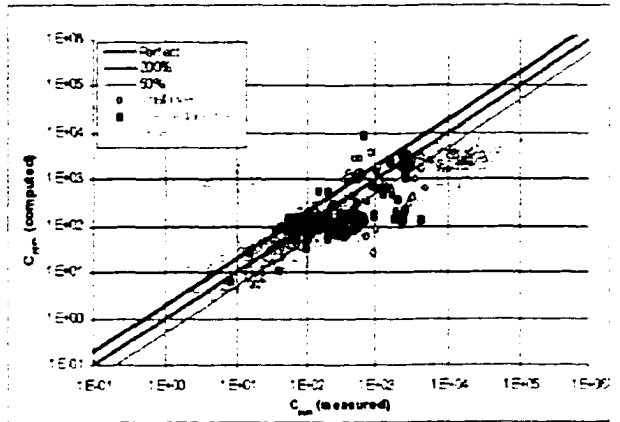
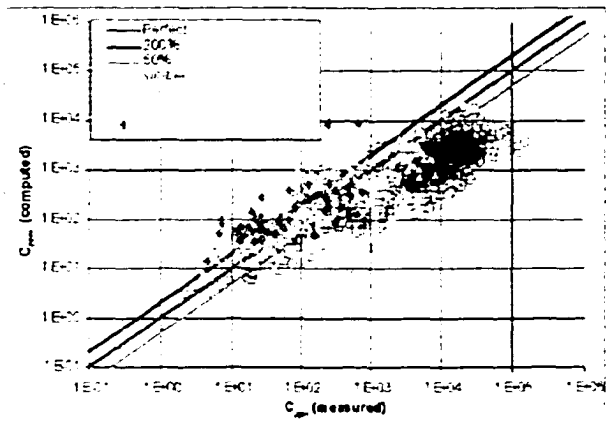
b. Ackers & White's method (silt-bed rivers not plotted because values are too high)



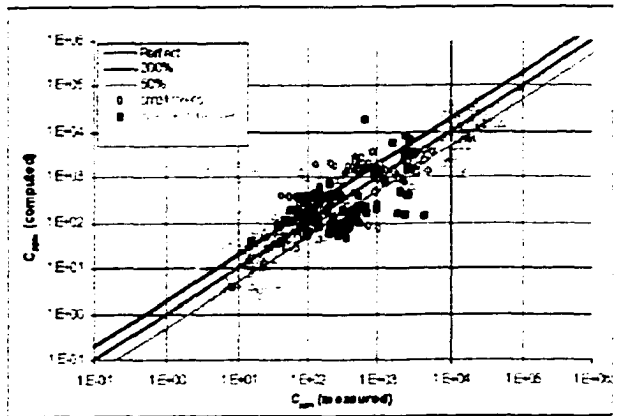
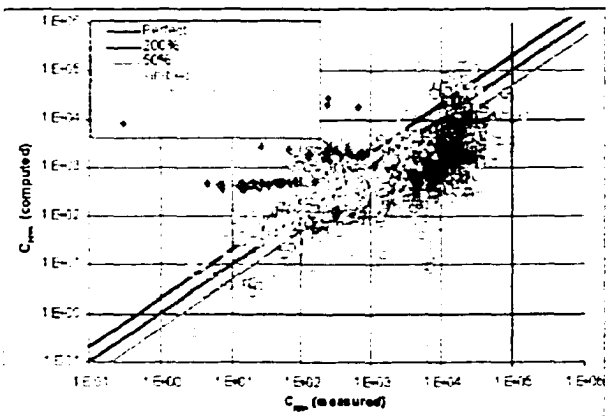
c. Yang's method



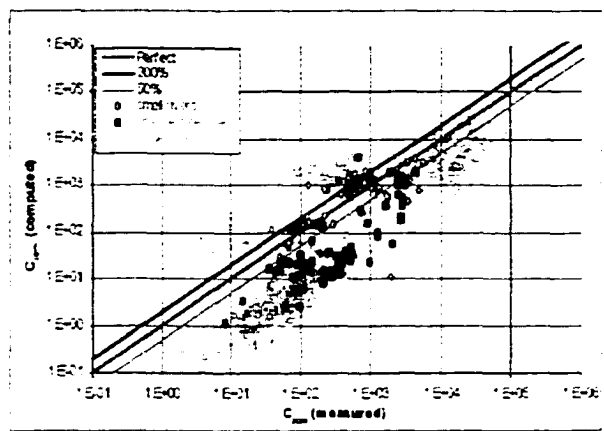
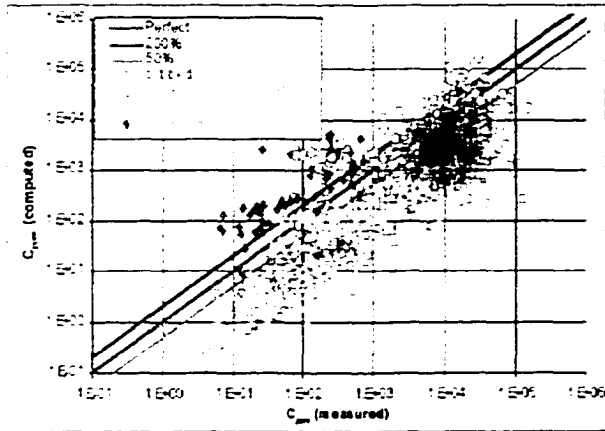
d. Shen & Hung's method



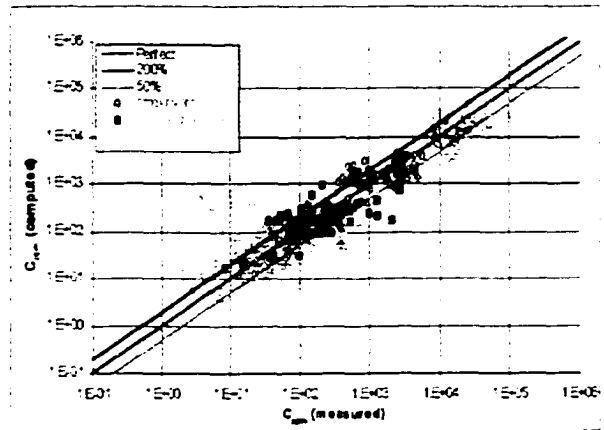
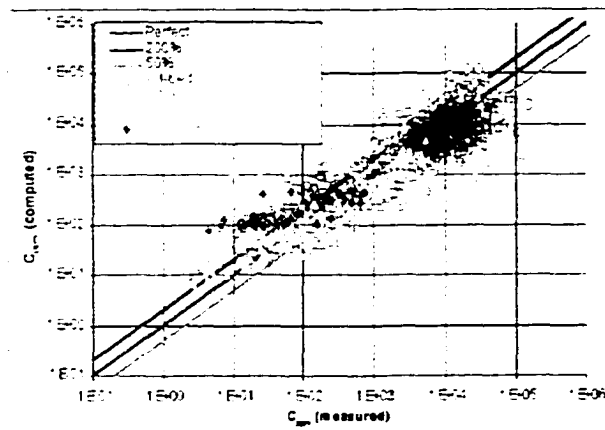
e. Brownlie's method



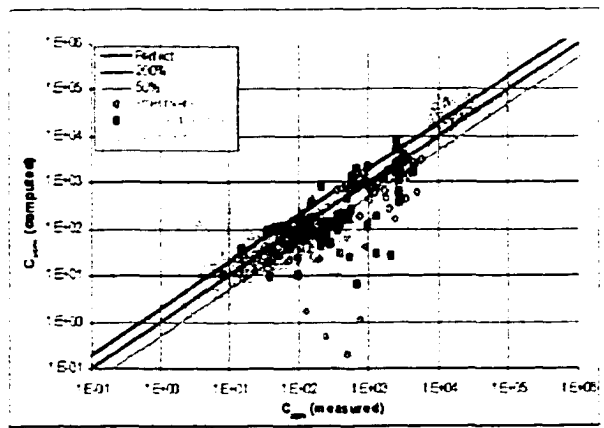
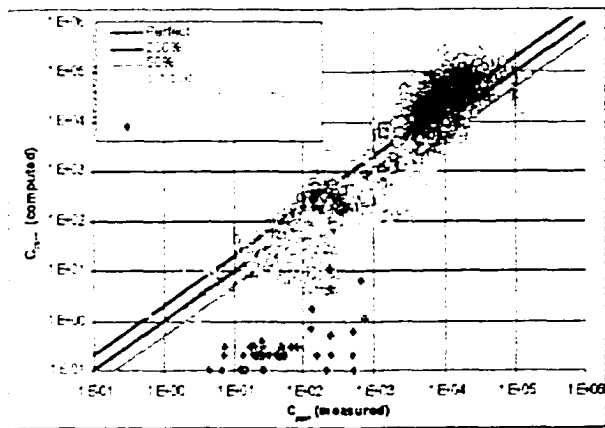
f. Karim & Kennedy's method



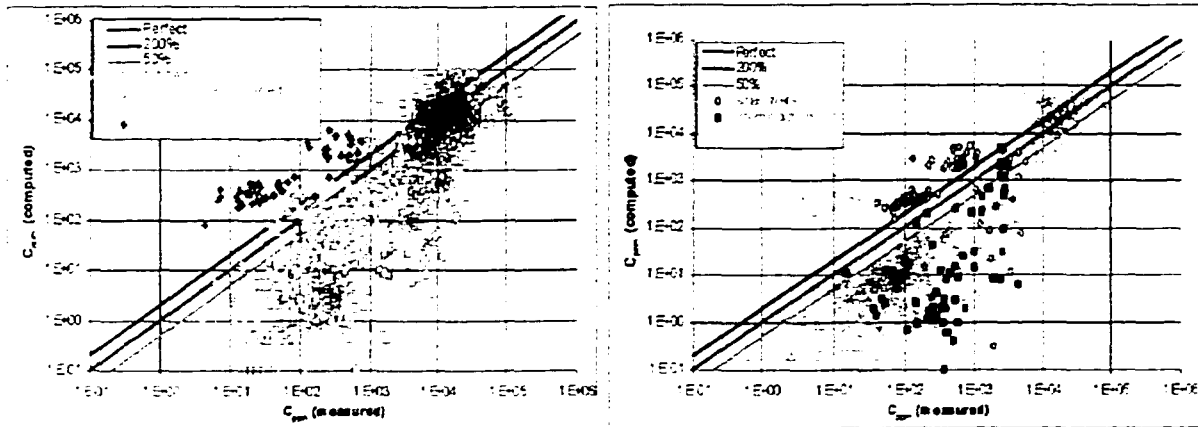
g. Laursen's method



h. Karim's method



i. Toffaletti's method



j. Einstein's method

Figure 4.12. Comparison of C_{ppm} measured and C_{ppm} computed by each method for several kinds of particle diameter of river-bed material and several river sizes

4.4. Laursen Graph

The relation between u_* / ω_i and $f(u_* / \omega_i)$ for three kinds of sediment size and channel size were plotted on the original Laursen Graph. The results are shown in Figures 4.13 and 4.14.

From Figure 4.13 and Figure 4.14 consistent relations between u_* / ω_i and $f(u_* / \omega_i)$ for different sizes of bed diameter and channel size occur. Based on this relation, modifications of the Laursen method were developed. Details of the modification are shown in Chapter 6.

1. Based on diameter of the river-bed material

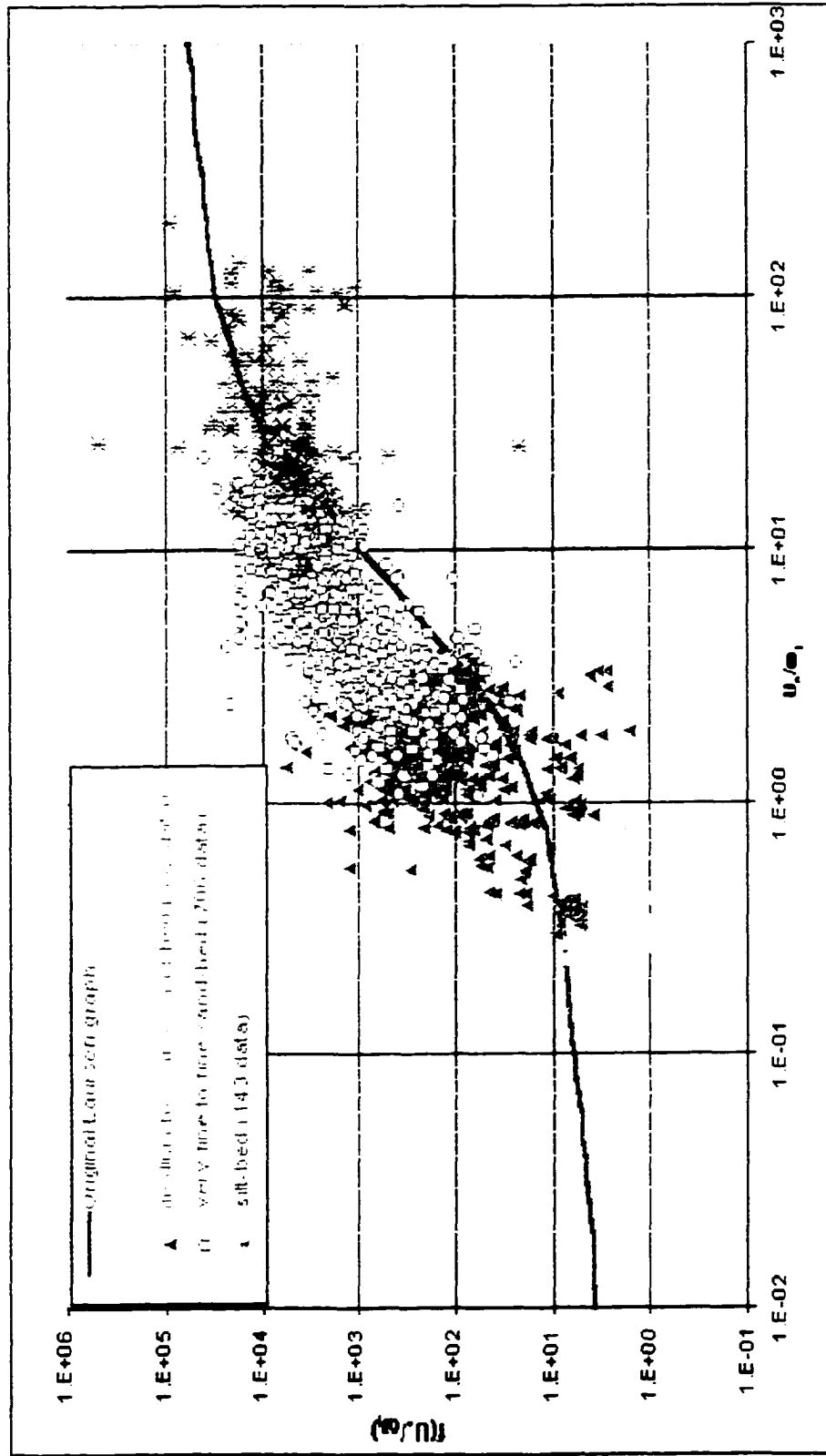


Figure 4.13. Plotting u/ω_c and $f(u/\omega_c)$ for several sizes of river-bed material diameter data for Group I with Laursen graph

2. Based on the size of rivers

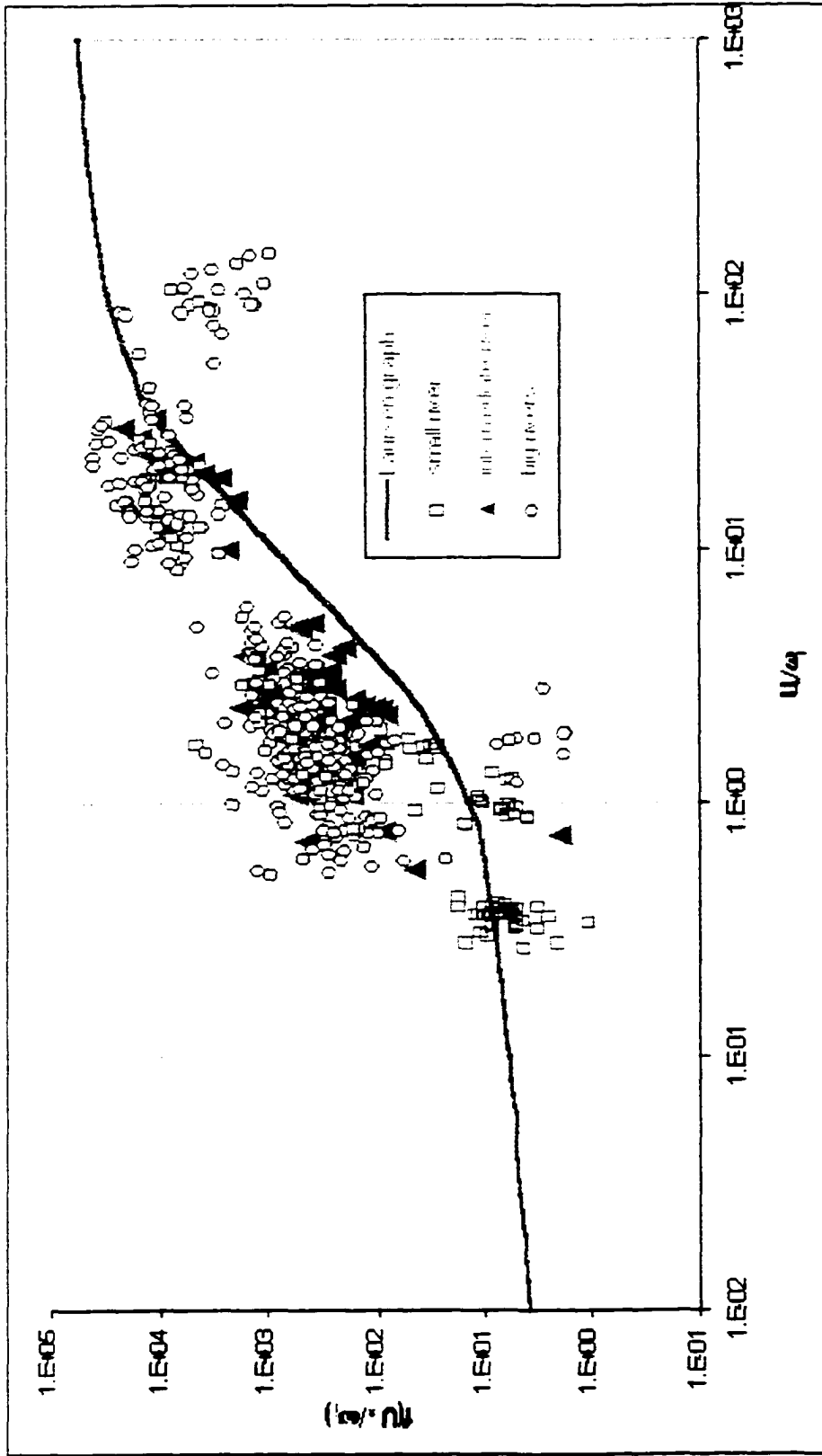


Figure 4.14. Plotting u/ω_i and $f(u/\omega_i)$ for several river sizes data for Group 1 with Laursen graph

Chapter 5

SUMMARY ANALYSIS OF PREVIOUS AUTHORS

5.1. Basic Forms and Assumptions

This chapter presents a comprehensive review of comparison and evaluation of some sediment transport relations with emphasis on the ten selected sediment transport equations. The purpose of this review is to find basically the knowledge of sediment transport behind the mathematical derivations and also to determine the interrelationships among them. Judgements on the validity of assumptions used on the derivation and comparisons with the measured data are discussed. A summary of comparison results from previous authors is also presented.

The majority of sediment transport equations were derived and developed from the assumption that the sediment transport rates are determined by dominant variables. Since sedimentation problems are very complex, selecting dominant variables is one of the most important steps in developing new sediment transport equations (Lu, 1978). In fact, until now the general relationship between channel morphology and the grain size of sediment in the channel is an important, but poorly known aspect of alluvial rivers (Dade and Friend, 1998).

Even a relatively simple and general concept of bed load and suspended load requires consideration of many factors that are interrelated in complex ways (Colby,

1964). Additionally, Colby stated that the interrelationships among four such dominant variables including total shear, velocity, stream power and effective shear parameter on the bed sediment vary widely if the resistance to flow varies. Yang & Simons (1996) stated that the size of sediments, fall velocity of a single or a group of particles, and characteristics of deposited sediments are important. Nakato (1990) stated that the mean flow depth is one of the most critical independent variables in estimating sediment discharges. Therefore, the fate of reliable sediment discharge predictions mostly depends on the accuracy of the mean depth measurement. Wang et al. (1995) stated that the bed load transport rate is mainly a function of shear stress, particle diameter and the specific gravity. Zernial and Laursen (1963) stated that sediment load is a unique function of the flow, fluid and bed-material characteristics. Accordingly, the uncertainty of sediment load for a given discharge can be related to these functions.

Selection of a sediment transport relation for a specific condition and application might be based on any number of criteria, including simplicity, accuracy, and available data, depending on user requirements (ASCE Task Committee, 1982). However, evaluation of this type needs a database that becomes a serious limitation, especially when field data are used.

With the exception of probabilistic and regression approaches the equations of sediment transport can be classified into the basic form (Simons & Senturk, 1992 and Yang, 1996)

$$Q_s = A(B - B_c)^D \quad (5.1)$$

in which:

Q_s = the sediment discharge

A = parameter related to flow and sediment characteristics

B = parameter that can be water discharge Q, average flow velocity u, water surface slope

S_w , energy slope S_f , shear stress τ , stream power τu , unit stream power uS , etc..

B_c = critical condition parameter related to B at incipient motion

D = parameter related to flow and sediment characteristics

The unit discharge of sand is mainly a function of mean velocity, and the depth and particle size gives the secondary effect (Colby, 1964 and Posada, 1995). In the simplest form, the sediment transport in sand-bed rivers varies as a function of the velocity to about the fifth power (Simons & Simons, 1987 and Posada, 1995). Using data from the Mississippi River (85 sets of data) and Amazon & Orinoco River Systems (114 sets of data), Posada proposed a new sediment discharge relation for sand-bed rivers as a function of velocity,

$$q_t = 30u^5 \quad (5.2)$$

in which

q_t = the unit sand discharge (Mg/m/day)

u = the mean velocity (m/s)

Using Equation (5.2), Posada computed the unit sand discharge q_t for the data of the Mississippi River and Amazon & Orinoco River Systems and compared the results to the measured values. About 70 % of the data for the Mississippi River and Amazon & Orinoco River Systems have discrepancy ratio $\overline{R_D}$ between 0.5 and 2.0. However, this relation fails when it is plotted with additional data (2503 sets of data from 23 river

systems) for sand-bed rivers (see Sub-chapter 4.2.2). A scatter of the result is shown in Figure 5.1.

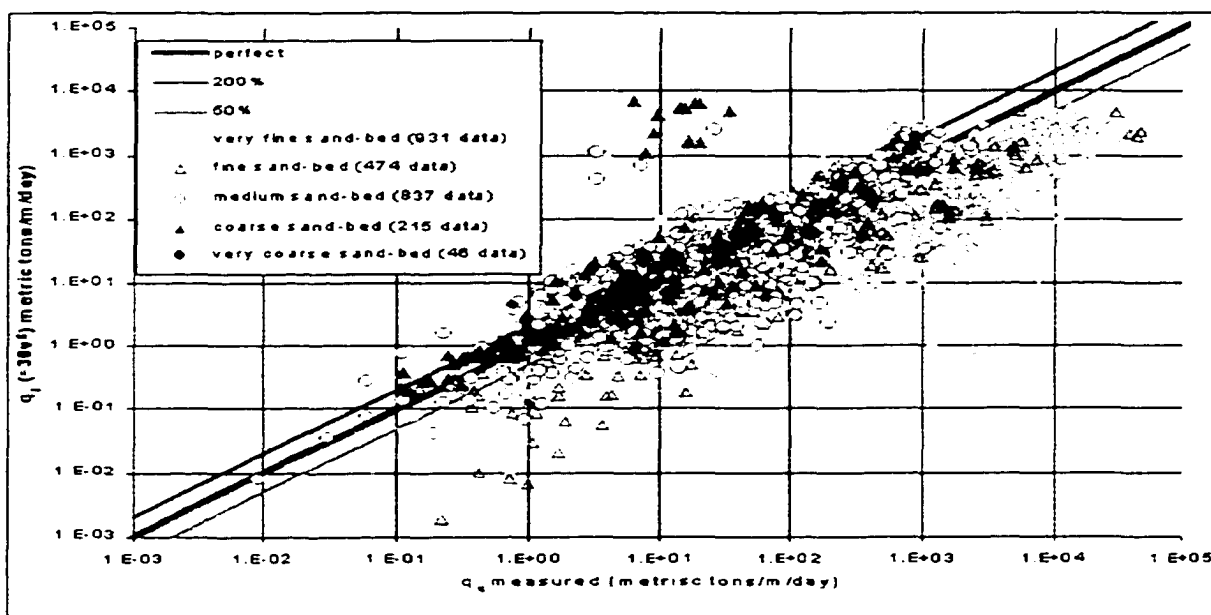


Figure 5.1. Relation of unit sediment discharge q_s from measured and computed results using Equation (5.2) for 2503 sets of field data

The Pearson correlation coefficient of q_s computed using Equation (5.2) and q_s measured is shown in Table 5.1.

Table 5.1. Pearson correlation coefficient between q_s measured and q_s computed using Equation (5.2)

	q_s (computed using Eq. (5.2))	q_s (measured)
q_s (computed using Eq. (5.2))	1.00	0.66
q_s (measured)	0.66	1.00

About 60 % of the computed unit sediment discharge is 50 % less than the measured unit sediment discharge. Only 33 % of q_s (computed) are between 70 % and 200 % of q_s measured and 7 % of q_s (computed) are greater than 200 % of q_s measured. Accordingly, the application of Equation (5.2) for a wide variety of river data is still questionable.

Simons et al. (1981) proposed an efficient method of evaluating sediment discharge. The method is based on the relationships of flow depth, velocity, particle diameter and gradation coefficient, and it can be easily applied to sand and fine gravel-bed canals. These power relationships were developed by Simons et al. from a computer solution of Meyer-Peter & Muller bed load transport equation and the integration of the Einstein method for suspended bed sediment discharge (Julien, 1995) and written as

$$q_t = c_{s1} d^{c_{s2}} u^{c_{s3}} \quad (5.3)$$

in which

q_t = unit sediment transport rate (ft³/ft width/s)

d = flow depth (ft)

u = velocity in (ft/s)

c_{s1} , c_{s2} , c_{s3} = coefficients based on mean particle diameter (d_{50}) ranging from sand to fine gravel (0.1 mm – 5.0 mm). The values of these coefficients can also be found in Table 11.1.. Julien (1995).

Equation (5.3) was obtained for steep sand and gravel-bed channels under supercritical flow (Simons et al., 1981; Julien, 1995).

More than one value of sediment discharge can be obtained for the same value of Q , u , S_w , S_f , or τ (Yang, 1996). For example, for a given value of Q , two (or more) different values of total sediment discharges can be obtained. Gilbert (1914) stated that there is no correlation at all between water discharge and sediment discharge. Accordingly, the validity of the assumption that total sediment discharge of a given particle could be determined by those parameters is questionable.

Yang (1996) stated that the stream power τu as the independent variable has a correlation to the sediment discharge. Furthermore, the unit stream power uS has a stronger correlation and is directly related to suspended load and bed load as well as total load. This relationship does not only exist in straight channels but also in channels that are in process of changing their patterns from straight to meandering and to braided channels (Yang, 1977 & 1996; Vanoni, 1978; Yang & Molinas, 1982). In dimensionless form of the unit stream power uS/ω , further improvement of correlation to the sediment discharge occurred (Yang & Kong, 1991).

However, as plotted in Figure 5.2. for the total data sets of 1459 in Group 1 (for gravel bed rivers, medium to coarse sand bed rivers, very fine to fine sand-bed rivers and silt bed rivers) only the dimensionless unit stream power uS/ω tends to have better correlation to the sediment discharge. Figure 5.2a and Figure 5.2b show that scatter occurs for the relation between stream power and C_{ppm} (measured) and between unit stream power and C_{ppm} (measured) respectively.

From Figure 5.2c, although increasing the dimensionless stream power tends to increase the sediment discharge, the erratic behavior of sediment load in streams on the basis of variations of both sediment characteristics and hydraulic geometry still occur (Zernial and Laursen, 1963).

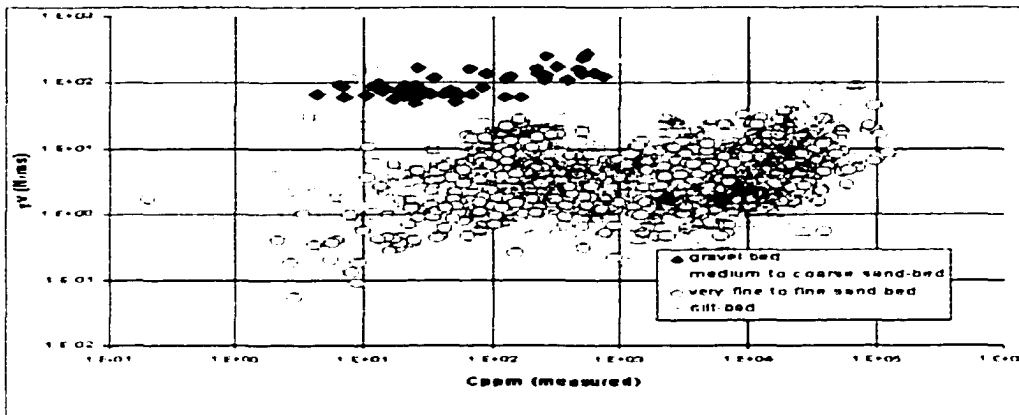


Figure 5.2a. Relation between C_{ppm} (measured) and stream power for several river-beds using data in Group 1

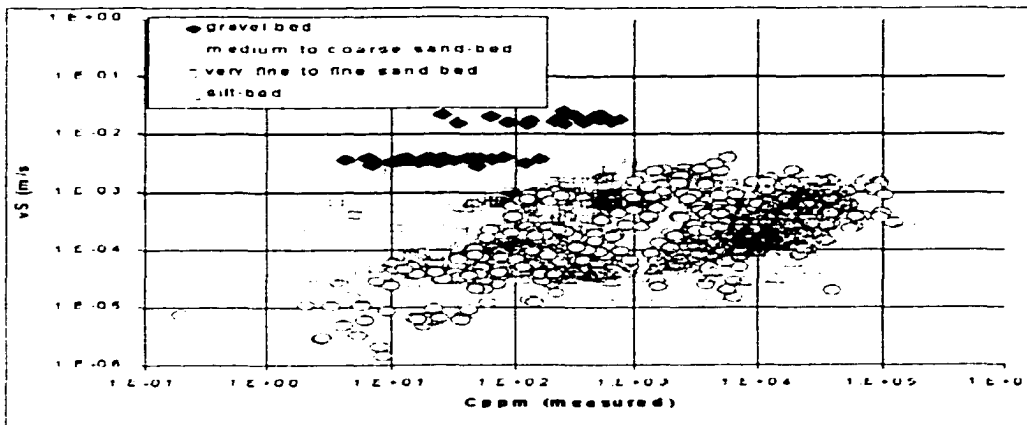


Figure 5.2b. Relation between C_{ppm} (measured) and unit stream power for several diameters of river-bed materials using data in Group 1

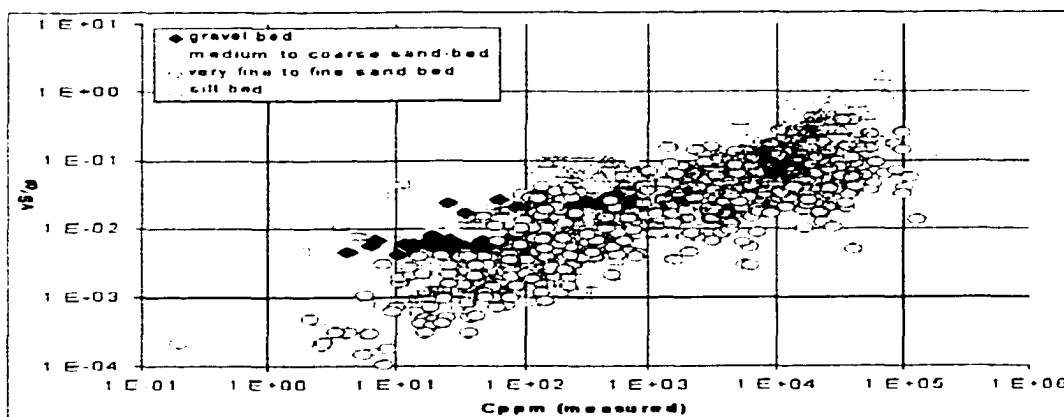


Figure 5.2c. Relation between C_{ppm} (measured) and dimensionless unit stream power for several particle diameters of river-bed materials using data in Group 1

For fine to coarse sand-bed rivers it is difficult to differentiate the relation between uS/ω and C_{ppm} , since as shown Figure 5.2c for the same value of C_{ppm} measured the fine sand bed-rivers have the same value of uS/ω for coarse sand-bed rivers. However, reduction of mean diameter of river-beds (from gravel-bed rivers to silt-bed rivers) tends to increase the sediment concentration. The Pearson correlation coefficient is shown in Tables 5.2a, b, and c.

Table 5.2. Pearson correlation coefficient between C_{ppm} measured and uS/ω , uS and τu for several kinds of river-bed

Gravel-bed rivers	C_{ppm} measured	uS/ω	uS (m/s)	τu (N/ms)
C_{ppm} measured	1			
uS/ω	0.71	1		
uS (m/s)	0.69	0.95	1	
τu (N/ms)	0.67	0.82	0.88	1

a. Gravel-bed rivers

medium to coarse sand-bed rivers	C_{ppm} measured	uS/ω	uS (m/s)	τu (N/ms)
C_{ppm} measured	1			
uS/ω	0.58	1		
uS (m/s)	0.45	0.90	1	
τu (N/ms)	0.33	0.23	0.29	1

b. medium to coarse sand-bed rivers

very fine to fine sand-bed rivers	C_{ppm} measured	uS/ω	uS (m/s)	τu (N/ms)
C_{ppm} measured	1			
uS/ω	0.74	1		
uS (m/s)	0.76	0.87	1	
τu (N/ms)	0.18	0.40	0.46	1

c. very fine to fine sand-bed rivers

silt-bed rivers	C_{ppm} measured	uS/ω	uS (m/s)	τu (N/ms)
C_{ppm} measured	1			
uS/ω	0.45	1		
uS (m/s)	0.62	0.74	1	
τu (N/ms)	0.30	0.74	0.78	1

d. silt-bed rivers

The parameters in Table 5.2. will be considered as one or more variables of the new proposed method.

5.2. Evaluations and Comparisons for Sediment Transport Relations

Many researchers have presented comparisons and evaluations between computed and measured sediment discharges. Some of the results are presented in the following sub-chapter with emphasis on the ten selected sediment equations.

1. Alonso et al. (1982)

They examined the sediment transport relations for total load and the equations include: Ackers & White (1973), Einstein-Meyer {hybrid method discussed in Alonso et al. (1982)}, Engelund-Hansen (1967), Laursen (1958), Yang (1973), and for bed load: Bagnold (1956), Meyer-Peter-Muller (1948), and Yalin (1963).

A total of 40 field data sets, 523 laboratory data sets and 176 tests of overland flow on concave slope were used and compared to the computed sediment transport. The bed material ranges from very fine to coarse sand particles. The data are divided into two groups: channel flows and sheet flows.

The best three equations for channels with sediment sizes from fine to very coarse sand were Yang (1973), Laursen (1958) and Ackers & White (1973). However, for silt-bed rivers, Laursen was the best.

2. Bechteler and Vetter (1989)

Fifteen total sediment transport models were compared. The equations include: Ackers-White (1973), Bagnold (1966), Bishop-Simons-Richardson (1965), Einstein

(1950), Engelund-Hansen (1967), Graf-Acaroglu (1968), Karim-Kennedy (1981), Laursen (1958), Pernecker-Vollmers (1965), Raju-Garde-Bhardwaj (Raju et al. 1981), Toffaletti (1969), van Rijn (1984), Yang (1973), Yang (1979), and Zanke (1982).

Seven river systems data with different regimes were used and compared to the computed sediment transport. The rivers included the Rhine River, the Mississippi River at St Louis (two sets of data), the Rio Grande River, Rio Puerco, Fivemile Creek, and the Niobrara River. However, the river data were not specifically defined and only suspended load was measured. The bed-load was evaluated by the procedure after Meyer-Peter & Muller (1949). The author concluded that the bed load was only a small part of the sediment load transported in rivers. Accordingly, no significant error for the determination of the total load occurred.

The best three equations were Karim Kennedy (1983), Yang (1979), and Bagnold (1966). Note that Yang (1979) is a modification of Yang (1973) for low sediment concentration and for relatively small value of dimensionless critical unit stream power ($u_{cr}S/\omega$).

3. Brownlie (1981a)

Brownlie developed a new sediment transport relation (see Sub-chapter 2.3.2) and compared his equation to 13 sediment transport relations, including Ackers & White (1973), Bagnold (1966), Bishop et al. (1965), Einstein (1950), Engelund & Fredsoe (1976), Engelund & Hansen (1967), Graf (1971), Laursen (1958), Ranga Raju et al. (1981), Rottner (1959), Shen & Hung (1971), Toffaletti (1969), and Yang (1973).

The laboratory data comprise a total of 480 sets of data from 18 sources, and the field data comprise a total of 519 sets of data from 11 river systems. Brownlie only

developed a sand-bed rivers equation with mean diameter particle from very fine sand to very coarse sand (D_{50} min 0.088 mm and max 1.349 mm).

The best three for laboratory data were Brownlie (1981a), Ackers & White (1973) and Shen & Hung (1971). The best three for field data are Brownlie (1981a), Engelund & Hansen (1967) and Toffaletti (1969) or Bagnold (1966).

4. German Association for Water Resources and Land Improvement (1990)

Fifteen total sediment transport models were compared. The equations include: Ackers-White (1973), Bagnold (1966), Bishop-Simons-Richardson (1965), Einstein (1950), Engelund-Hansen (1967), Graf-Acaroglu (1968), Karim-Kennedy (1981), Laursen (1958), Pernecker-Vollmers (1965), Ranga Raju-Garde-Bhardwaj (1981), Toffaletti (1969), van Rijn (1984), Yang (1973), Yang (1979), and Zanke (1982).

A total of 1500 sets of laboratory data and 300 sets of field data from seven rivers (six rivers in the USA and one river in Germany) were used. Details of laboratory field data were not given. Total bed material load (ignoring wash load) is the sum of bed load determined by Meyer-Peter and Muller and suspended load calculated from field measurement of velocity and concentration distributions.

The best three were Yang (1979), Bagnold (1966) and Karim & Kennedy (1981).

5. Lau and Krishnappan (1985)

Four sediment transport relations were analyzed, including Ackers & White (1973), Bagnold (1966), Einstein (1950a), and Yang (1976).

All data were flume data with particle diameter of sediment of 0.15 mm (sand), specific gravity of 2.65. Range of flow depth was 0.065 m to 0.13 m, with slope of 0.00059 to 0.001.

The best three were Ackers & White (1973), Yang (1976) and Bagnold (1966).

6. Mau and Brooks (1991)

In the discussion of "Test of Selected Sediment-Transport Formulas by T. Nakato (1990)", Mau & Brooks (1991) considered two cases in computing the sediment discharge by Brownlie (19981a). The first was to compute the sediment discharge using Brownlie's relation. The regime and flow depth were first predicted using a separate friction relation based upon the input variables: sediment characteristics (D_{16} , D_{50} , D_{84} , D_{90} , γ_s), fluid characteristics (γ, ν) and flow characteristics (q, S). The predicted depth then was used to calculate the velocity. Finally these parameters were used to calculate the sediment discharge. The second case was used the measured values of depth and velocity in order to calculate the sediment discharge.

The best methods for predicting sediment transport appeared to be Ackers & White (1973), Toffaletti (1969), Karim & Kennedy (1981) and Brownlie (1981a). When Brownlie's method is used to compute both depth and sediment discharge, the errors are more slight than using the measured depth. Hence, Mau and Brook concluded that others formulas also would presumably show an increase in error if they were based on predicted rather than the measured depths.

7. Nakato (1990)

Nakato investigated sediment transport relations and compared the results to field measurements, including Ackers-White (1973), Einstein and Brown (Brown, 1950), Engelund and Fredsoe (1976), Engelund and Hansen (1967), Inglis and Lacey (Inglis, 1968), Karim-Kennedy (1981), Meyer, Peter & Muller (1948), Schoklitsch (Shulits, 1935), Toffaletti (1969), van Rijn (1984a,b), and Yang (Yang & Stall, 1976).

These formulas were compared to field data measured at two USGS gauging stations along Sacramento River in California. The bed material sizes range from fine sand to coarse gravel. Although one river data were used to test the applicability of selected formulas, the author stated that the results are judged to be indicative of those for typical natural rivers with range of bed materials from sand-bed to gravel bed rivers. Besides, the mean flow depth is one of the most critical independent variables in estimating sediment discharges.

The best three in this comparison were Toffaletti (1969), Yang and Karim & Kennedy (1981).

Nakato also concluded that prediction of sediment discharges in natural rivers is a difficult task and more rigorous numerical model calibrations based on field data should be done. Besides, Nakato also hoped that practical hydraulic engineers would develop the habit of looking up several sediment transport equations and evaluate them on the basis of field data before making the final choice alternative.

8. Stevens and Yang (1989)

Steven and Yang analysed 13 sediment transport formulas. The formulas were divided into two groups: five bed-load discharge formulas and eight total bed material formulas. The first group included Einstein (1944), Kalinske (1947), Meyer-Peter & Muller (1948), Rottner (1959), Schoklitsch (Shulits, 1935). The bed material formulas included Ackers & White (1973), Colby (1964), Einstein (1950a), Engelund & Hansen (1967), Laursen (1958), Toffaletti (1969), Yang (1973), and Yang (1984) for gravel.

Two river data sets were used including 19 sets of Niobrara River data (Colby and Hembree, 1955) and 100 sets of Mountain Creek data (Einstein, 1944). Ranges of bed material diameter of these rivers were 0.215 – 0.349 (fine to medium sand) and 0.286 – 0.899 mm (medium to coarse sand), respectively.

The best three for Niobrara River data were Yang (1973), Ackers & White and Toffaletti. The best three for Mountain Creek data were Yang (1973), Engelund-Hansen (1967) and Ackers & White (1973).

9. Raphael (1996)

In developing a sediment transport relation for gravel-bed rivers, Raphael (1996) compared six sediment transport relations, including Einstein Bed Load Formula (1950), Meyer-Peter & Muller (1948), Modified Laursen by Copeland (1989), Parker (Parker et al., 1982 and Parker, 1990), Schoklitsch (1934), and Yang (1984) formula for gravel equation. He used a total 187 sets of data from ten gravel-bed river systems, including the Toutle, North Fork Toutle, Susitna, Tanana, Oak Creek, Clearwater, Chippewa near Durand, Chippewa near Caryville and Granite Creek Rivers.

The best three for these gravel-bed rivers were Yang (1984), Schoklitsch (1934) and Parker.

10. Rijn (1984b)

The author developed methods to calculate bed-load transport, q_b , (Rijn, 1984a) and suspended load, q_s , (Rijn, 1984b). The total sediment load, q_t , is the sum of the bed load and the suspended load. Rijn's method for total load was compared to Ackers & White (1973), Engelund & Hansen (1967) and Yang (1973).

A total of 783 sets of data were used which contained 486 field data sets and 297 flume data sets. Field data of various conditions were used, including the Rio Grande River near Bernalillo, Atchafalaya River near Simmesport, Mississippi River near Tarbert Landing, Mississippi River near St. Louis, Red River near Alexandria, Middle Loup River, India Canals, Pakistan Canals and Niobrara River. The range of these field data were: particle diameter 0.090 to 0.400 mm (very fine to medium sand), velocity 0.4 to 2.4 m/s, flow depth 0.3 to 17 m. Flume data were used including Guy et al. (1966), Oxford, Stein (1965), Southampton A & B, Barton & Lin (1955). The range of these flume data were: particle diameter 0.100 to 0.480 mm (fine to medium sand), velocity 0.4 to 1.3 m/s, flow depth 0.1 to 0.4 m. The width depth ratio and the Froude number for all data were larger than 3 and smaller than 0.9, respectively.

The best three must be divided into three parts: field data, flume data and total data. The best three for field data were Rijn (1984), Engelund & Hansen (1967), and Ackers & White (1973). The best three for flume data were Yang (1973), Ackers & White (1973) and Rijn (1984). The best three for total data were Rijn (1984), Ackers & White (1973), and Engelund & Hansen (1967).

Rijn also stated some conclusions:

- Yang (1973) must have serious systematic errors for large flow depth
- The sediment transport theory should also comprise a bed-roughness predictor as stated by ASCE Task Committee (1971)
- The dimensionless grain diameter is the characteristic parameter for sediment transport.
- It is difficult to predict the total load with accuracy less than a factor of 2.
- It is better and possible to develop simple approximation method to calculate sediment transport rate rather than complicated numerical solution methods with a slightly higher accuracy.

11. Vanoni (1975)

Vanoni (1975) compared the measured and the computed sediment discharges from thirteen equations from field data (Niobrara River and Colorado River). The equations include: Blench (1966), Colby (1964), Duboys (Brown 1950), Einstein's bed-load function (Einstein 1950a), Einstein-Brown (Brown 1950), Engelund-Hansen (1967), English-Lacey (Inglis, 1968), Laursen (1958), Meyer-Peter (Meyer-Peter-Muller, 1948), Meyer-Peter-Muller (1948), Schoklitch (Shulits, 1935), Shields (1936), and Toffaletti (1969).

The range of Niobrara River data were: discharge ($5.86 - 16 \text{ m}^3/\text{s}$), width (21.03 to 21.95 m), depth (0.42 – 0.58 m), mean bed diameter (0.215 – 0.349 mm) and slope (0.001136 – 0.0018). The range of Colorado River data were: discharge (77.53 – 500.16

m³/s), width (92.64 to 254.55 m), depth (1.13 – 3.89 m), mean bed diameter (0.155 – 0.695 mm) and slope (0.000037 – 0.00041).

The comparison of computed and measured values for the Niobrara river were re-plotted by Yang & Stall (1976), Julien (1995), Yang (1977) and discussed by Williams (1995). The comparison of computed and measured values for the Colorado River were replotted by Julien (1995) and discussed by Julien (1995) and William (1995).

For the Niobrara River: it was difficult to judge which ones are the best three of sediment transport relations. However, from the plotted graph shown in Yang & Stall (1976), Julien (1995) and Yang (1977), the equations, which have closest agreement to the measured value were Laursen (1958) and Toffaletti (1969).

For the Colorado River: it was also difficult to judge which ones are the best three of sediment transport relations. However, from the plotted graph shown in Julien (1995), the equations which have closest agreement to the measured value were Engelund & Hansen (1967), and Einstein & Brown. Julien (1995) also added the methods of Karim and Kennedy (1981) and Ackers and White (1973) which have also the closest agreement to the measured value.

Accordingly, with only two river system data the judgment may not be representative if the sediment transport relations are applied to other rivers.

12. White et al. (1975)

They compared eight sediment transport relations including: Ackers and White (1973), Bagnold (1966), Bishop et al. (1965), Einstein's bed-load function (Einstein 1950a), Engelund and Hansen (1967), Meyer-Peter (Meyer-Peter-Muller, 1948), Rottner (1959), and Toffaletti (1969).

A Total of 1280 flume and field data sets were used including 840 flume data sets with sand bed rivers. 180 flume data sets with light weight material and 260 field data sets. Range of particle sizes is from 0.04 to 68 mm. Only data with F_r less than 0.8 were used.

In comparison of the selected equations, they used four dimensionless parameters including dimensionless grain size (d_*), dimensionless mobility number (F_{gr}), dimensionless flow depth (d/d_{50}), and relative density (s), since they postulated that these parameters are the basic quantity for sediment transport.

The best three of the comparison using the full data were Ackers & White (1973), Engelund & Hansen (1967) and Rottner (1959).

It should be noted that when using the dimensionless grain size as the prime indicator, Ackers & White (1973) was the most reliable with 68 % of data falling in the range. This is not surprising since the development of Ackers & White used this parameter as the basis of its development. They also pointed out that Engelund & Hansen equation tends to over predict the sediment transport at low shear stress.

13. Williams (1995)

In developing a numerical index to determine which sediment transport relation to be used for any given condition, the author compared four sediment transport relations including, Ackes & White (1973), Brownlie (1981a), Engelund & Hansen (1967), and Yang Unit Stream Power (1973, 1979 & 1984).

A total of 3,739 flume and field data sets were used, including flume and field data compiled by Brownlie (1981b). The flume data were obtained from 38 sources, the field data were from 18 river systems. The range of mean bed diameter (d_{50}) was greater

than 0.062 mm but less than 2.00 mm (sand only). Range of standard deviation of sediment sizes was less than 5. The sediment concentration (C_{ppm}) was greater than 10. The range of the ratio of hydraulic radius to mean bed diameter (r/d_{50}) was greater than 100. These last two restrictions, as stated by the author, were to eliminate bimodal distribution and to avoid shallow water effects.

Some conclusions have been made by the author for each sediment transport relation.

1. Ackers & White (1973)

- although slightly over-estimate but good for flume data
- not good for particle < 0.125 mm
- over-predict for medium sand and small flow depth (< 1 foot)
- under-predict for field data
- not applicable for large flow depths

2. Brownlie (1981a)

- limited for $d/d_{50} > 100$
- best when used Brownlie's flow depth predictor
- best for low velocity, small depth and medium sand
- over-estimate for flume data with concentration less than 50 ppm

3. Engelund & Hansen (1967)

- over predict at low shear stress
- good for light weight sediments ($s < 2.65$)

- good for fine sediment
- under-estimate generally for flume data but over-predict if C_{ppm} less than 100
- over-estimate for flume data with d_{50} less than 0.15 mm except for velocity > 3 f/s
- over-predict for field data but under-estimate for medium sand

Additionally, Nordin & McLean (1989) stated that this equation would give a reliable prediction over a very wide range of flow and bed roughness conditions, so long as the bed sediments contain a fairly narrow range of sizes so that a uniform particle diameter could representative the mixtures.

4. Yang

- not good for fine sediments (< 0.125 mm)
- good for medium sands
- over-estimate for coarse sands
- good for flume and small rivers
- under-predict for large flow depths
- not good for light weight sediment ($s < 2.65$)

14. Wu (1999)

Wu (1999) proposed a new method for predicting fractional transport rate of bed material load in sand-bed channels. His method was developed based on the concept of the transport capacity fraction approach. He compared his method to nine selected sediment transport relations including Ackers & White (1973), Einstein (1950), Engelund

& Hansen (1967), Karim & Kennedy (1981), Karim (1998), Laursen (1958), Li (1988), Toffaletti (1969), and Yang (1973).

Wu used a total 118 sets of field data and flume data (containing 891 data points) to develop his new method and compared to the selected sediment transport relations. The field data included 19 sets of Niobrara River data and 15 sets of Middle Loup River data. The flume data included 29 sets of Einstein data (1978), 22 sets of Einstein & Chien data (1953b) and 33 sets of Samaga et al. data (1986a, 1986b). The range of data were:

- median diameter 0.10 – 0.90 mm (sand only),
- geometric standard deviation 1.3 – 3.0.
- flow discharge 0.0056 to 16.06 m³/s
- velocity 0.49 to 1.41 m/s
- flow depth 0.056 – 0.58 m
- slope 0.00093 – 0.013

For verification Wu used 48 sets of independent data (containing 327 data points) of both field data and flume data. The field data included 9 sets of Rio Grande Convey Canal data and 19 sets of Yellow River data at Tuchengzi station. The flume data included 20 sets of White & Day data (1982). The range of data were:

- median diameter 0.055 – 2.065 mm,
- width 2.46 – 807 m
- flow discharge 0.196 – 3,980.000 m³/s
- velocity 0.49 to 1.41 m/s
- flow depth 0.437 – 2.808 m

- slope 0.000078 – 0.0011

The best sediment transport relations using field data and flume data were: Wu (1999), Karim & Kennedy (1981), Yang (1973), Engelund & Hansen (1967). The best relation using the verification data of field and flume data were Wu (1999), Engelund & Hansen (1967), Yang (1973), and Li (1988).

15. Yang and Molinas (1982)

The authors stated that application of basic fluid mechanics and turbulence theories in open channel flow proved that suspended sediment concentration at a given depth is a function of the turbulence production rate at that depth. Besides, total sediment concentration can be expressed as a function of unit stream power.

They compared seven total load equations including Ackers & White (1973), Colby (1964), Engelund & Hansen (1967), Maddock (1976), Shen & Hung (1971), Yang (1973), Yang (1979). Yang (1973) is a dimensionless unit stream power equation to calculate the total sediment concentration which includes criteria for incipient motion and Yang (1979) is a dimensionless unit stream power equation to calculate the total sediment concentration without any criteria for incipient motion (Yang, 1996; Yang & Molinas, 1982). Yang (1979) concluded that for sediment higher than 100 ppm by weight both Yang (1973, 1979) are equally accurate, but for flows with low sediment concentration Yang (1973) should be used because as the rate of sediment transport decreases the need to include incipient motion criteria increases.

A total of 1,259 sets of data from flume data and field data were used. The flume data were 1,093 sets; however, there was no specification of these data. A total of 166 sets of data from five river systems were used for analyzing and comparison including,

Mountain Creek (Einstein, 1944), Niobrara River (Colby & Hembree, 1955), Middle Loup River (Hubbel & Matejka, 1959), Rio Grande River (Nordin, 1964), and the Mississippi River at St. Louis (Jordan, 1965). The range of data were:

- median diameter 0.15 – 1.71 mm (fine to very coarse sand)
- width 0.134 – 532 m
- velocity 0.23 to 1.91 m/s
- flow depth 0.01 – 15.2 m
- slope 0.000043 – 0.0279.

The best equations can be divided into three groups: flume data, field data and total data. The best relations for flume data include Yang (1979), Yang (1973) and Maddock (1976). The best relations for field data were Yang (1979), Yang (1973) and Shen & Hung (1971). The best relations for all data were Yang (1979), Yang (1973) and Shen & Hung (1971).

Some notes were pointed by the authors including:

- The sediment transport relations which used the unit stream power produce better results
- Colby (1964) should not be applied to laboratory data and this method also underestimates the total bed material loads in natural rivers
- Shen & Hung and Maddock equations are only good for flume data and small stream but not for large rivers
- Engelund & Hansen (1967) can predict the sediment discharge in flume data with reasonable accuracy

16. Yang and Wan (1991)

They made a comparison of overall accuracy as well as the accuracy within different range of sediment concentration. Froude number and slope for seven sediment transport relations including Ackers & White (1973), Colby (1964), Einstein (1950), Engelund & Hansen (1967), Laursen (1958), Toffaletti (1969), Yang (1973).

A total of 1,438 sets of data from flume data and field data were used. The flume data were 1,119 sets of data including Guy et al. (1966) 285 sets of data, Gilbert (1914) 637 sets of data, Nomicos (1956) 12 sets of data, Vanoni & Brooks (1957) 14 sets of data, Kennedy (1961) 41 sets of data, Stein (1965) 42 sets of data, Williams (1967) 37 sets of data, Schneider (1971) 31 sets of data and White & Day (1982) 20 sets of data.

The range of the data were:

- median diameter 0.19 – 7.01 mm (fine sand to fine gravel)
- velocity 0.74 – 6.45 ft/s
- flow depth 0.074 – 2.82 ft
- slope 0.0001 – 0.0279.

A total of 319 sets of data from five river systems were used for analysis and comparison including, Mountain Creek (Einstein, 1944) 81 sets of data, Niobrara River (Colby & Hembree, 1955) 49 sets of data, Middle Loup River (Hubbel & Matejka, 1959) 79 sets of data, Rio Grande River (Nordin, 1964) 59 sets of data, and the Mississippi River at St. Louis (Jordan, 1965) 51 sets of data. The range of data were:

- median diameter 0.130 – 0.925 mm (fine to coarse sand)
- velocity 1.20 to 7.82 ft/s

- flow depth 0.27 – 40.4 ft
- slope 0.000043 – 0.00192.

The best relations for flume data were Yang (1973), Engelund & Hansen (1967), and Ackers & White (1973). The best relations for field data were Yang (1973), Toffaletti (1969) and Einstein (1950).

The authors also made a comparison of accuracy of methods according to the concentration, Froude number, and energy slope using both laboratory data and field data. This information is summarized in Tables 3 to 8 in Yang & Wan (1991) and could be used by the engineers as a reference for selecting the sediment transport relation to solve engineering problems under different flow and sediment conditions.

5.3. Overall Results of Comparison C_{ppm} Measured and Computed with Field Data

Most sediment transport relations have their own limitation of applicability, which implies the range of data used in the formula calibration and development; however, this limitation generally is not considered in the application (Woo and Yoo, 1991).

However, based on comparison by previous authors and the result analyzed in Chapter four, a summary of the comparison among measured and computed of sediment discharges is shown Table 5.3a. This table shows that it is a difficult task to judge and to select the best sediment transport relations for all conditions. Even between formulas accounting for both bed and suspended load (or the total bed material transport), the variations are appreciable and by experience errors of 100 % are to be expected (Raudkivi, 1967).

Table 5.3a. Summary comparison among measured and computed sediment discharges by previous authors and the results of analyzing the selected sediment transport relations

No	Author	Method to be Compared	Total method	Field data	Fume data	Diameter particle (mm)	The best	Bed river	Remark
1	Alonso et al. (1982)	AW EiM Eh La Yang73 Ba MPM Ya	8	216	523	0.062 - 1.00	Yang73 Laursen Acers & White	sand	the best for all Laursen
2	Bechtel and Vetter (1989)	AW Ba BSR E:50 EH Gr KK La PV RGB To vRab Yang73 Yang79 Za	15	0 rivers		+0.062	Karim & Kennedy Yang79 Yang73 Baghdad	sand	
3	Brownie (1981a)	AW Ba Bro BSR E:50 EF EH Gr La RGB Ho SH To Yang73	14	519	480	0.088 - 1.349	lab data Brownie Acers & White and Shen & Hung field data Brownie Engelund Hansen Toffaletti or Baghdad	sand	
4	German Ass. W. RALL (1990)	AW Ba BSR E:50 EH Gr KK La PV RGB To vRab Yang73 Yang79 Za	15	300	1500	na	Yang79 Baghdad Karim & Kennedy	sand	
5	Lau and Krishnappan (1985)	AW Ba E:50 Yang76	4		fume	0.15	Acers White Yang76 Baghdad	sand	
6	Mau and Brooks (1991)	AW E:B EF EH IL KK MPM Sc To vRab Yang76	11	1 river		0.2 - 18.7	Acers White Toffaletti Karim & Kennedy Brownie	sand to gravel	
7	Nakato (1990)	AW E:B EF EH IL KK MPM Sc To vRab Yang76	11	1 river		0.2 - 18.7	Toffaletti Yang76 Karim & Kennedy	sand to gravel	
8	Stevens and Yang (1989)	Ei44 Ka MPM Ro Sc AW Co E:50 Eh La To Yang73 Yang84	13	1 river (19 data)		0.215 - 0.349	Yang73 Acers White Toffaletti	fine to med sand	
9	Rajput (1996)	E:50 MPM MLaC P Sc Yang84	6	1 river (100 data)		0.286 - 0.899	Yang73 Engelund Hansen Acers White	mesh to coarse sand	
10	Rijn (1984a)	AW Eh vRab Yang73	4	10 rivers (187 data)	4 sources 297 data	0.700 - 72.190	Rajput Yang84 Schoklitsch Parker	gravel	
11	Vanou (1975)	Bi Co Du E:50 E:B EH IL La MP MPM Sc Sh To	13	1 river (19 data)		0.100 - 0.480	Yang73 Acers White Rijn (1984)	fine to med sand	total Rijn (1984) AW EH
12	White et al. (1975)	AW Ba Bi E:50 EH MP Ro Tu	6	1 river (100 data)		0.215 - 0.349	Laursen Toffaletti	fine to med sand	
13	Williams (1995)	AW Bro Eh Yang	4	1 river (100 data)		0.155 - 0.695	Engelund Hansen Einstein Brown	fine to coarse sand	
14	Wu (1999)	AW Ba Bi E:50 EH MP Ro Tu	6	260	1020	0.04 - 68	Acers White Engelund Hansen Rutter	coarse silt to gravel	total data 3 379
15	Yang and Moines (1982)	AW Bro Eh Yang	4	18 rivers	38 sources	0.062 - 2.600	Acers White good for fume under predict for field Brownie best for med sand v & d small over for fume C50m = 50 Engelund Hansen good for fine sand under for lab over for field	sand	total data 3 379
16	Wu (1999)	AW E:50 EH KK Ri La Li To Yang73 Wu	10	4 river data	4 sources	0.100 - 0.900	Yang73 good for med sand for fume and small river not for fine Wu Karim Kennedy Yang73 Engelund Hansen	sand	total data 1 218
17	Yang and Moines (1982)	AW Co EH Ma SH Yang73 Yang79	7	5 rivers (168 data)	1 093 data (no spec)	0.150 - 1.710	investigation Wu Engelund Hansen Yang73 Li field data Yang79 Yang73 Shen Hung fume data Yang79 Yang73 Maddock lab data Yang79 Yang73 Shen Hung	fine to v coarse sand	
18	Yang and Wan (1991)	AW Co E:50 EH La To Yang73	7	5 rivers 319 data	9 Sources 1 438 data	0.130 - 0.925	Yang73 Toffaletti Einstein	fine to coarse sand	
19	Present study	AW Ba Bro E:50 KK Ri La SH To Yang73	10	33 rivers	18 Sources	0.190 - 7.010	Yang73 Engelund Hansen Acers White	fine sand to fine gravel	
						2.00 - 64.00	Acers White Brownie Karim	gravel	total data
						0.062 - 0.250	Toffaletti Laursen Baghdad	mesh to coarse sand	2946 field 918 Fume
						0.250 - 2.00	Karim Kennedy Karim Einstein 50	very fine to med sand	
						0.020 - 0.062	Einstein Baghdad Shen Hung	silt	The best is based on
							small rivers Brownie Karim Yang73	small rivers	Discrepancy ratio only
							intermediate rivers Brownie Toffaletti Shen Hung	intermediate rivers	
							big rivers Baghdad Laursen Toffaletti	big rivers	

*) abbreviation stands for:

1	Acers & White (1973)	AW	15	Graf-Ackert (1988)	GTA	29	Hollmer (1959)	Ro
2	Baghdad (1956)	BA	16	Inglis and Lacey (Inglis 1968)	IL	30	Schoklitsch (1934)	Sc
3	Bishop-Simons-Richardson (1965)	BSR	17	Kalinske (1947)	Ka	31	Shen & Hung (1971)	SH
4	Blensch (1966)	Bl	18	Karim & Kennedy (1981)	KK	32	Shields (1936)	Sh
5	Brownie (1981a)	Bro	19	Karim (1998)	Kr	33	Toffaletti (1989)	To
6	Colby (1984)	Co	20	Laursen (1958)	La	34	van Rijn (1984a) for bed load	vRa
7	Dubois (Brown 1950)	Du	21	Li (1988)	Li	35	van Rijn (1984b) for suspended load	vRb
8	Einstein (1944)	Ei44	22	Maddock (1976)	Ma	36	Wu (1999)	Wu
9	Einstein (1950)	Ei50	23	Meyer-Peter & Muller (1948)	MPM	37	Yalin (1983)	Ya
10	Einstein and Brown (Brown 1950)	EiB	24	Meyer-Peter (Meyer-Peter-Muller 1948)	MP	38	Yang (1973)	Yang73
11	Einstein-Meyer (Alonso et al. 1975)	EiM	25	Modified Laursen by Copeland (1989)	MLaC	39	Yang (1978)	Yang78
12	Engelund & Fredsoe (1976)	EF	26	Parker (Parker et al. 1982 and Parker 1980)	P	40	Yang (1979)	Yang79
13	Engelund & Hansen (1967)	EH	27	Pernecker-Vollmers (1965)	PV	41	Yang (1984) for gravel	Yang84
14	Graf (1971)	Gr	28	Raju-Garde-Bhardwaj (Raju et al. 1981)	RGB	42	Zanke (1982)	Za

Table 5.3a also shows that from the comparison of sediment discharge measured and computed by 16 previous authors and this present study, more than 50 sediment transport relations have been developed. However, none of these equations fit the whole spectrum of data from flumes, canals and rivers. In other words, as stated by Simons and Senturk (1992), a single universal sediment transport equation is not or may never be available.

Accurate field measurements are difficult to achieve. In conditions with combine bed-load and suspended load transport, bed-load sampling in rivers is complicated (Gaweesh and Rijn, 1994). Errors associated with measuring devices and the extreme temporal variations in transport rate are on of the feature characteristics of bed material movements (Knighton, 1998; Hubbell, 1987; Gomez, 1991).

Hence, foremost among the needs of improvement sedimentation research probably is the need for refinement of the procedures of measurement and the development of more convenient and inexpensive measuring devices for practical purposes (Renard and Hickok, 1967; Simons and Senturk, 1992).

However, an attempt to draw conclusions about the applicability of the selected sediment transport relation is shown in Table 5.3b.

Table 5.3b. Summary of the applicability of the selected sediment transport relations based on comparison by the results of previous authors and the results analyzed in Chapter Four

Method	gravel	med to v. coarse sand	v. fine to fine sand	silt	small rivers	interme. rivers	large rivers	field data	flume data
1 Acker & White	x	x						x	x
2 Bagnold		x	x	x			x	x	x
3 Brownlie	x	x			x	x		x	x
4 Einstein			x	x					x
5 Karim	x		x		x				
6 Kanm & Kennedy	x	x	x					x	x
7 Laursen		x	x	x			x	x	x
8 Shen & Hung		x	x			x		x	x
9 Toffaletti		x	x			x	x	x	
10 Yang '73 & '84	x	x			x			x	x

Chapter 6

DEVELOPMENT OF PROPOSED METHOD

The primary objective of this study was to create one or more new equations of total load sediment transport. Using statistical approaches and non-linear optimization, simple sediment transport relations were developed so they can be easily applied and be used for practical purposes. Field data were used to test the applicability of existing (selected) sediment transport equations for alluvial rivers and to investigate how the hydraulic geometry and sediment characteristics correlate to the sediment transport rate.

Using the results of computation in Chapter 4, discussion of theory and applicability of the selected sediment transport equations in Chapter 2, and summary analysis comparison of sediment discharge measured and computed from some sediment transport relations by previous authors, dominant variables were examined carefully. The selected variables were used to propose new methods in determination of sediment discharge or to modify one of the selected sediment transport relations.

An attempt to modify simple sediment transport equations such as Posada (1995) and Simons et al. (1981) is presented. Additionally, from analyzing of the ten selected sediment transport relations, Laursen (1958) was chosen to be modified since it has a functional relation between u_*'/ω and $f(u_*'/\omega)$ for a wide range of bed material sizes.

6.1. New Proposed Method Based on Modification of Posada (1995)

As stated earlier, any proposed new equation should be relatively simple and easy to be applied in the field. Therefore, a new sediment transport relation is developed based upon Posada (1995).

Equation (5.2) on page 113 (Posada, 1995) can be analyzed in more detail. Using this equation and the data in Group 1 the relationship between measured and computed of the unit sediment discharge is shown in Figure 6.1 and Table 6.1. The discrepancy ratio and the correlation coefficient are shown in Table 6.1.

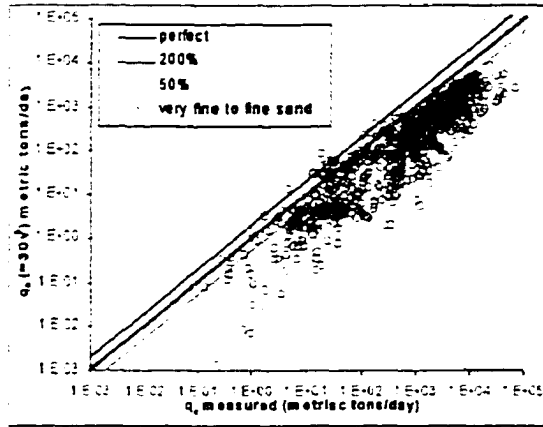
Table 6.1. Discrepancy ratio and correlation coefficient between q_s measured and q_s computed using Equation (5.2)

	Gravel-bed rivers	med. to v coarse sand-bed rivers	v fine to fine sand-bed rivers	silt-bed rivers	small rivers	intermediate rivers	large rivers
Discrepancy Ratio $\overline{R_D}$	312.46	1.12	0.33	0.18	0.19	0.43	0.12
Correlation coefficient C_c	0.218	0.727	0.682	0.511	0.859	0.752	0.714

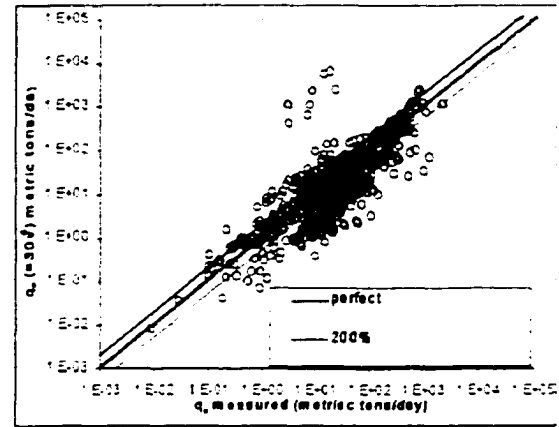
Posada developed her equations using a total of 119 data sets (114 data of Amazon & Orinoco River Systems and 85 data of Mississippi River). The range of hydraulic data and particle diameter is shown in Table 6.2.

Table 6.2. Range of data used by Posada (1995) to develop Equation (5.2)

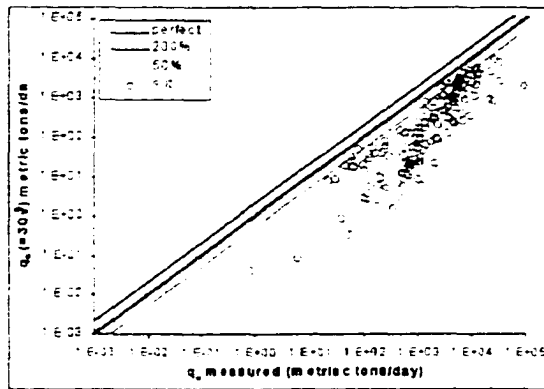
width		depth		
1 m	> 20 m	< 1m	1 m < d < 3 m	> 3 m
2.51%	97.49%	0.50%	10.05%	89.45%
Mean bed material diameter				
< 0.125 mm	0.125 - 0.250 mm	0.250 - 2.000 mm		
5.88%	31.93%	77.39%		



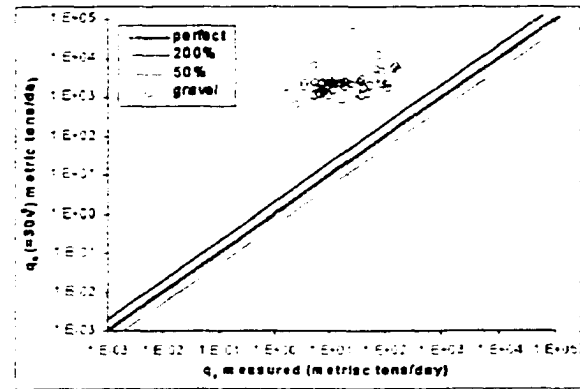
a. very fine to fine sand-bed rivers



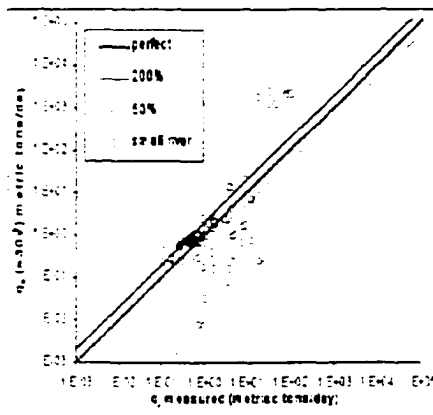
b. medium to very coarse sand bed rivers



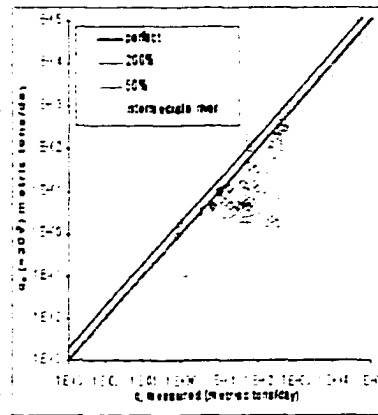
c. silt



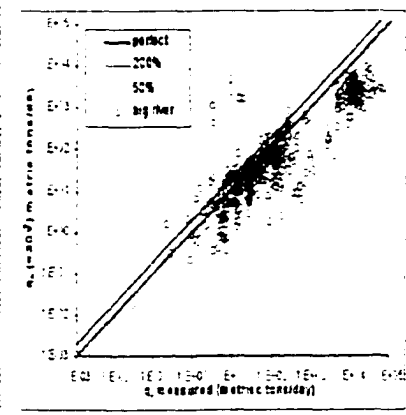
d. gravel



e. small river



f. intermediate river



g. large river

Figure 6.1. Detail relationship of unit sediment discharge q , from measured and computed results using Equation (5.2) for several bed-rivers and channel sizes using data in Group 1.

It can be seen from Table 6.2 that Posada developed her sediment transport relation in large rivers and using mostly medium to very coarse mean bed material (77.39 %). Accordingly, as shown in Figure 6.1b it is not surprising that the unit sediment discharges computed by Equation (5.2) fit quite well for those conditions. For medium to very coarse sand bed rivers the discrepancy ratio between q_s measured and q_s computed is 1.12. However, it is only 0.33 for very fine to fine sand-bed rivers, it is 0.18 for silt-bed rivers and it is 312.46 for gravel (much over-prediction). The equation gives relatively better results for large rivers compared to small and intermediate rivers.

As shown in Table 5.2. and Figure 5.2 the unit stream power (uS) and the dimensionless unit stream power (uS/ω) have relatively strong correlation to the measured sediment discharge (C_{ppm}). Considering these two parameters and the correlation coefficient for each variable of hydraulic geometry and the sediment characteristics shown in Tables 4.2., 4.4., 4.6. and 4.8., Equation (5.2) using non-linear optimization, and the field data for different kinds of river beds can be modified. The procedures of analyzing Equation (5.2) are as follows.

1. Selection of statistical parameters

The objective of this selection is to test the goodness of fit of the new equation. Three parameters were selected including the discrepancy ratio $\overline{R_D}$, the correlation coefficient C_c , and graphical comparison between the unit sediment discharge q_s measured and computed.

2. Selection of hydraulic geometry and sediment characteristic variables

This selection is based on the correlation coefficient C_c between each hydraulic geometry and sediment characteristic variable. The analysis has been done and the results

are tabulated as shown in Tables 4.2., 4.4., 4.6. and 4.8. For silt-bed rivers the Pearson correlation coefficient are summarized as follows (see Table 4.8);

C (measured)	Q	w	d	v	d ₅₀	S _w	T	τ ₀	u	u	d	ω	
ppm	m ³ /s	m	m	m	mm		°C	(N/m ²)	m/s	m ² /s		m/s	
C (measured)	1.00	0.04	0.23	-0.23	0.46	0.29	0.32	0.26	0.20	0.21	-0.21	0.35	0.32

Table 6.3. Pearson correlation coefficient C_c between C_{ppm} measured and hydraulic geometry and sediment characteristic variables for silt-bed rivers data in Group 1

3. Selection of variables that will be added to Equation (5.2)

From Tables 5.2, 6.3 and Figure 5.2, the variables of velocity u , flow depth h and slope S are selected to be added to Equation (5.2). Accordingly, for silt-bed rivers Equation (5.2) is modified to become

$$q_t = a(30u^5)(u^b h^c S^d) \quad (6.1)$$

in which

a = coefficient to be analyzed

b, c, d = power coefficients of velocity, depth and slope to be analyzed.

4. Non-linear Optimization

In Microsoft Excel Solver for non-linear optimization software, Equation (6.1) is proposed using silt-bed river data in group 1. The Microsoft Excel Solver is used to optimize Equation (6.1) by finding the values of “ b, c and d ” in iteration procedures with constraints: the correlation coefficient C_c is optimum (close to 1) and the trends of all silt-bed river data in graphical comparison between the unit sediment discharge q_s measured and computed are almost forms line with angle 45 degree to the horizontal line. The results are optimized to get $\overline{R_D}$ close to one by changing the value of “ a ”

(iteration procedures using “goal seek tool” in Microsoft Excel Solver). The description above is illustrated in Figure 6.2a.

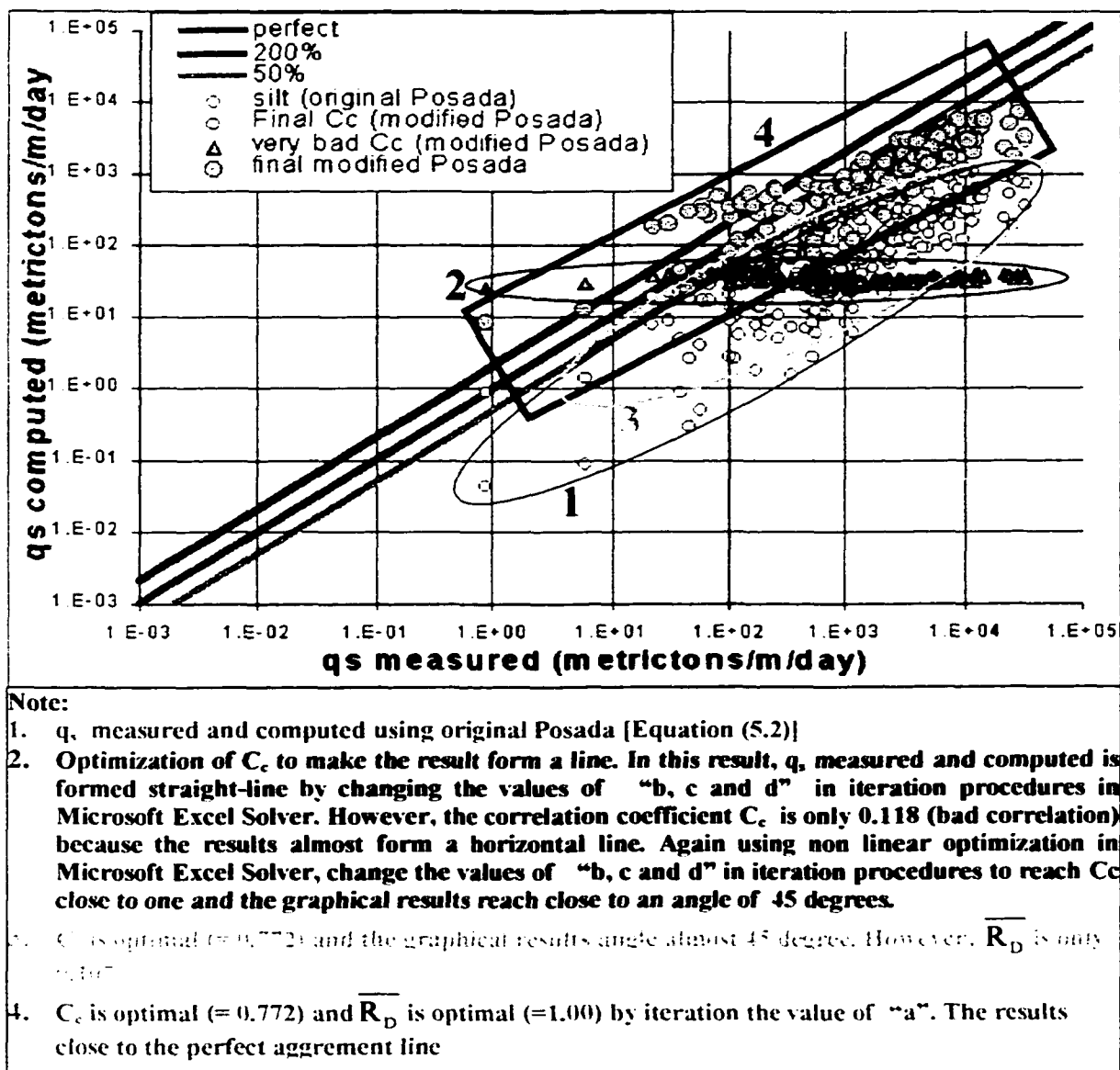


Figure 6.2a. Step of non-linear optimization to modify Equation (5.2) for silt-bed rivers using data in Group 1

The final result of the optimization for silt-bed river data in Group 1 is $a = 9.380$, $b = -2.738$, $c = 0.182$ and $d = 0$. Accordingly, for Silt-bed rivers, Equation (6.1) can be rewritten as

$$q_t = 9.380(30u^5)(u^{-2.378}h^{0.182}) \quad (6.2)$$

Similarly, the new equations for very fine to fine sand-bed, medium to very coarse sand-bed and gravel-bed rivers follow the procedure of calculation above.

Summary result of coefficients a, b, c, for several river-beds are shown in Table 6.4.

Table 6.4. Parameters of a, b, c, d of Equation (6.1) for several river-bed materials using data in Group 1

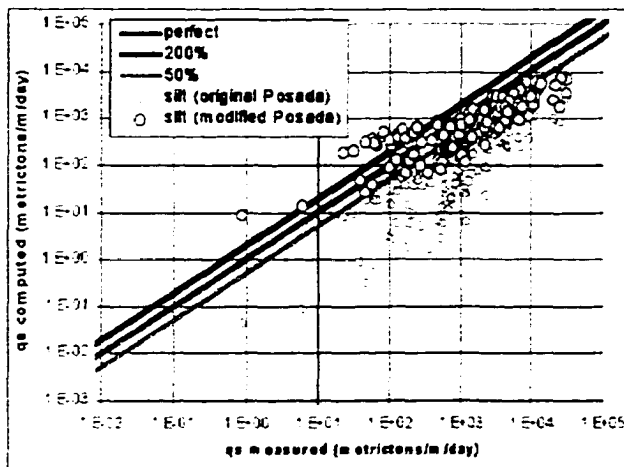
	a	b	c	d
silt-bed rivers	9.380	-2.378	0.182	0
very fine to fine-bed rivers	94.32	-1.354	0.406	0.412
medium to v coarse sand-bed rivers	70.78	-1.700	0.468	0.613
gravel-bed rivers	14,396.16	-4.000	1.000	2.000

Discrepancy ratio and correlation coefficient of original Posada and modified Posada are shown in Table 6.5.

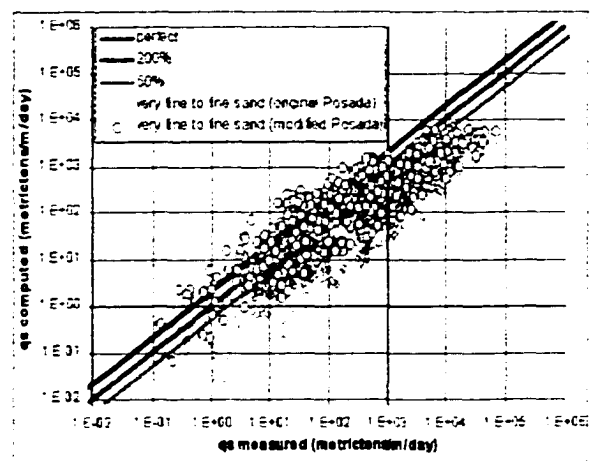
Table 6.5. Discrepancy ratio and correlation coefficient of original Posada and modified Posada using data in Group 1

	Original Posada		modified Posada	
	$\overline{R_D}$	C_c	$\overline{R_D}$	C_c
Silt bed rivers	0.18	0.7567	1.00	0.7724
very fine to fine sand-bed rivers	0.33	0.6843	1.00	0.7242
medium to very coarse sand-bed rivers	1.12	0.7274	1.00	0.8146
gravel-bed rivers	312.46	0.2175	1.00	0.7625

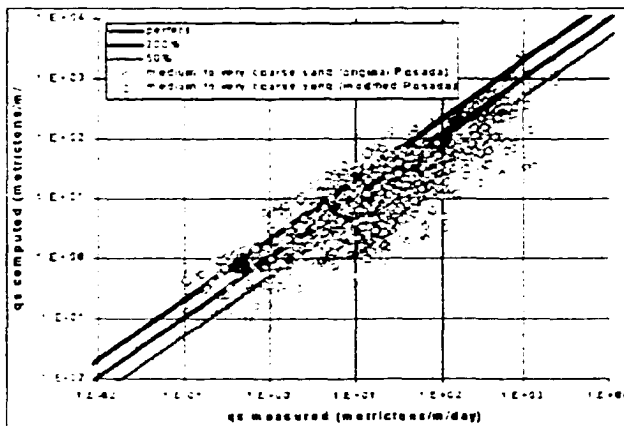
The comparison between original Posada and modified Posada using the data in Group 1 for various river-beds can also be seen in Figure 6.2b.



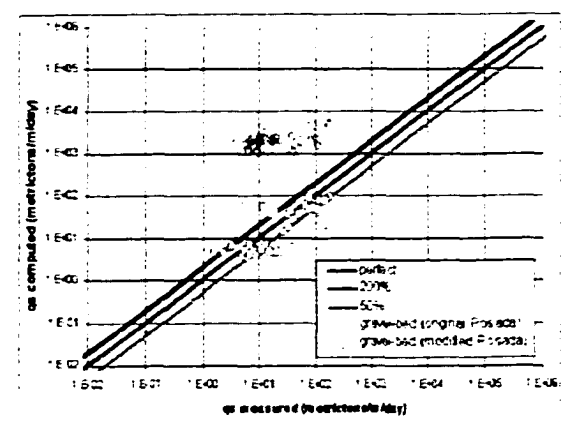
a. silt-bed rivers



b. very fine to fine sand-bed rivers



c. medium to very coarse sand-bed rivers



d. gravel-bed rivers

Figure 6.2b. Comparison among q_s measured and q_s computed using original Posada and modified Posada for various particle diameters of river-bed materials using data in Group 1.

6.2. New Proposed Method Based on Modification of Simons et al. (1981)

Equation (5.3) (Simons et al., 1981), which was obtained for steep sand and gravel-bed channel under supercritical flow, was analyzed and modified to obtain a new

sediment transport rate with various ranges of hydraulic geometry and sediment conditions. The range of parameter this equation was developed is shown in Table 6.6.

Table 6.6. Range of parameters Equation (5.3) was developed by Simons et al. (1981)

Parameter	Value range	SI Units
Froude number	1 – 4	-
Velocity	1.98 – 7.92	m/s
Bed slope	0.005 – 0.040	00.000
unit discharge, q	3.05 – 60.96	m/s
particle size, d ₅₀	> 0.062	mm

Using statistical approach, non-linear optimization, and the field data for different kinds of river bed Equation (5.3) can be modified. The procedures of analyzing Equation (5.3) are as the same as the procedures of modified Posada equation.

$$q_t = a(c_{s1}d^{c_{s2}}u^{c_{s3}})u^bS^c \quad (6.3)$$

in which:

q_t = total unit sediment discharge (ft³/s/ft width)

c_{s1} = coefficient

c_{s2} = power of depth related to diameter of river-bed materials

c_{s3} = power of velocity related to diameter of river-bed materials

d = flow depth (ft)

u = velocity (ft/s)

S = Slope

a, b, c = coefficient of Equation (6.3)

Coefficients a, b, c for several river-beds are shown in Table 6.7.

Table 6.7. Parameters a, b and c of Equation (6.3) for several river-beds using data in Group 1

	a	b	c
silt-bed rivers	24.26	-1.00	0.250
very fine to fine-bed rivers	8.26	0.750	0.250
medium to very coarse sand-bed rivers	3.30	0	0.200

Using this equation and the data in group1 the relationship between measured and computed of the unit discharge is shown in Figure 6.3.

Discrepancy ratio $\overline{R_D}$ and correlation coefficient C_c of original Simons et al. and modified Simons et al. are shown in Table 6.8.

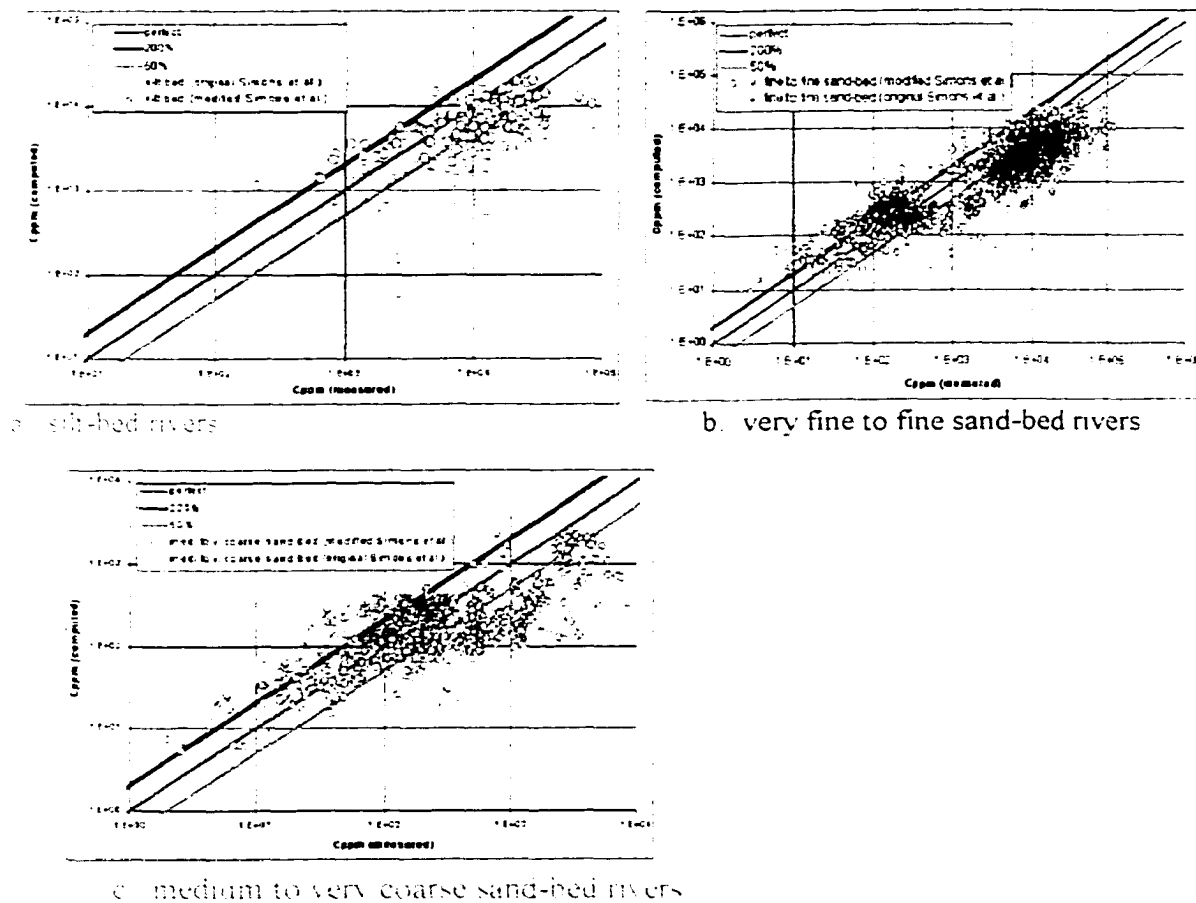


Figure 6.3. Comparison among q_s measured and computed using original Simons et al. and modified Simons et al. for various particle diameters of river-bed materials using data in Group 1

Table 6.8. Discrepancy ratio $\overline{R_D}$ and correlation coefficient C_c of original Simons et al. and modified Simons et al. using data in Group 1

	Original Simons et al.		modified Simons et al.	
	$\overline{R_D}$	C_c	$\overline{R_D}$	C_c
Silt bed rivers	0.51	0.3613	1.00	0.4024
very fine to fine sand-bed rivers	1.27	0.5930	1.00	0.6058
medium to very coarse sand-bed rivers	1.54	0.6547	1.00	0.6553

Extension of the coefficients c_{s1} , c_{s2} and c_{s3} for gravel-bed rivers produces theoretically very large amount of sediment rates, which does not make any sense. Hence, for particle diameter of river-beds greater than 5.00 mm, the Simons et al. method was not to be modified.

6.3. Modification of Laursen's Method

Modification of Laursen's method were conducted by Madden (1985) and by Copeland (1989). A brief description of these modifications is presented before the modification in this present study. Comparison among these modifications are also presented.

6.3.1 Modification by Madden (1985)

In the Arkansas River channel design studies Madden (1985) modified the Laursen method. The sediment transport relation by Laursen was adopted because it is expressed in terms which permit separating readily the effects of the various parameters which are generally considered to govern the bed material load, hydraulic geometry, and sediment characteristics.

The range of data in the modification of Laursen is shown in Table 6.9.

Table 6.9. Data range used in developing Laursen transport function (Waterways Experiment Station, 1998)

Parameter	data range
1. Median particle size range, mm	0.04 – 4.8
2. Multiple size classes	yes
3. Velocity, fps	0.85 – 7.7
4. Depth, ft	0.25 – 54
5. Slope, ft per ft	0.00001 - 0.1
6. Width, ft	3 – 3640
7. Water Temperature, °F	36 – 90

The modified Laursen by Madden is a multiple grain size function for sand bed transport that has been used for mixtures of sand and gravel (Waterways Experiment Station, 1998). The modification of the Laursen graph is based on three sets of special measurements on the Arkansas River: near Dardanelle in June-July 1957 and April 1958, and near Morrilton in April 1958. The results of the Missouri River measurement by Bondurant (1958) were used as a reference. Madden discovered that the rating curves calculated from the original Laursen resulted in loads considerably smaller than the curves developed from the longer term measurements, but the curves did parallel each other. In the Arkansas River planning studies, a new graph of the Laursen method was developed using Laursen's parameters but based on Arkansas River data only. Two versions of the modified Laursen's graph were developed at different times as shown in Figure 6.4.

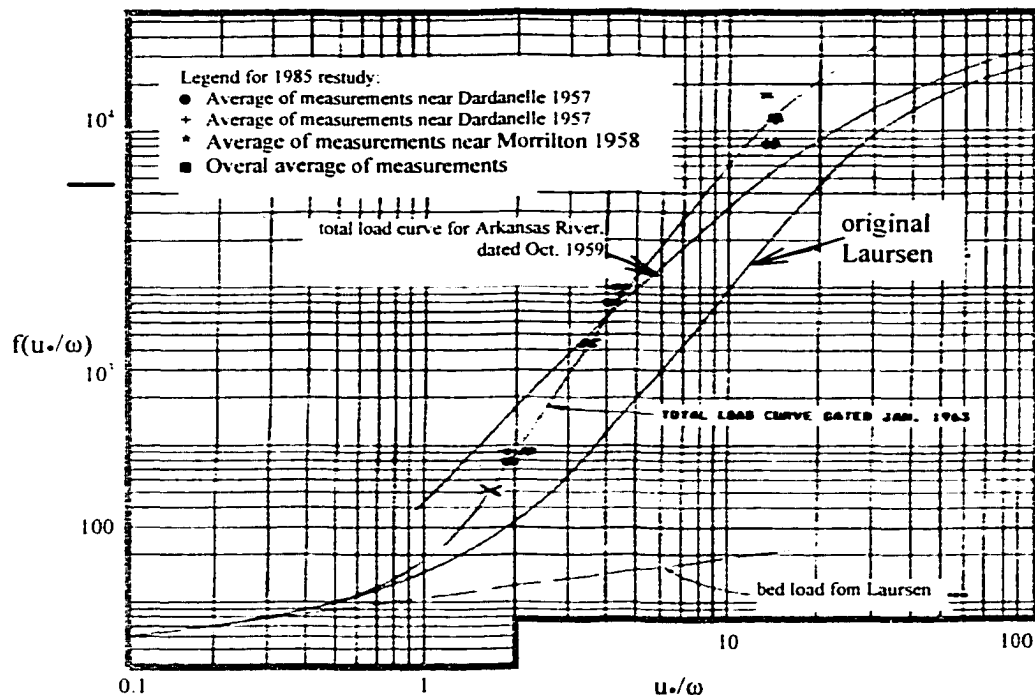


Figure 6.4. Development of the Laursen graph for the Arkansas River project planning studies (Madden, 1964)

The procedure for developing the functional relationship used the equation

$$f\left(\frac{u_*}{\omega}\right) = \frac{C/p_{si}}{p_{bi} \left(\frac{d_i}{d}\right)^{7.6} \left(\frac{\tau_{oi}'}{\tau_{ci}} - 1\right)} \quad (6.4)$$

in which

C = sediment concentration of each grain size class, percent by weight

u_* = shear velocity = $\sqrt{\tau_o/\rho}$

ω = fall velocity

d_i = diameter particle sediment of size fraction i

d = flow depth

p_{si}, p_{bi} = The fraction of suspended material and fraction of bed material of d_i , respectively

$$\tau_o = \gamma R S_f \cong \gamma d S_o = 28.25 \frac{n^2 u^2}{d^{1/3}} \quad (6.5)$$

$$\tau_o' = \left(\frac{u^2 d_{50}}{30 d} \right)^{1/3} \quad (6.6)$$

$$\tau_c = 4d_s \quad \text{in general. but } \tau_c > 4d_s \quad \text{for } d_s < 0.088\text{mm} \quad (6.7)$$

$$q_t = 27qC \quad (6.8)$$

Values $f(u./\omega)$ for suspended sediment corresponding to each value of $(u./\omega)$, but values $f(u./\omega)$ for bed-load were calculated from the equation

$$f(u./\omega) = 10.7378(u./\omega)^{0.25301} \quad (6.9)$$

which was deduced from Laursen's curve labeled "bed load".

The bed load was added to the suspended load to obtain value $f(u./\omega)$ applicable to the total bed material load.

The final revision of the modified Laursen graph by Madden is shown in Figure 6.5.

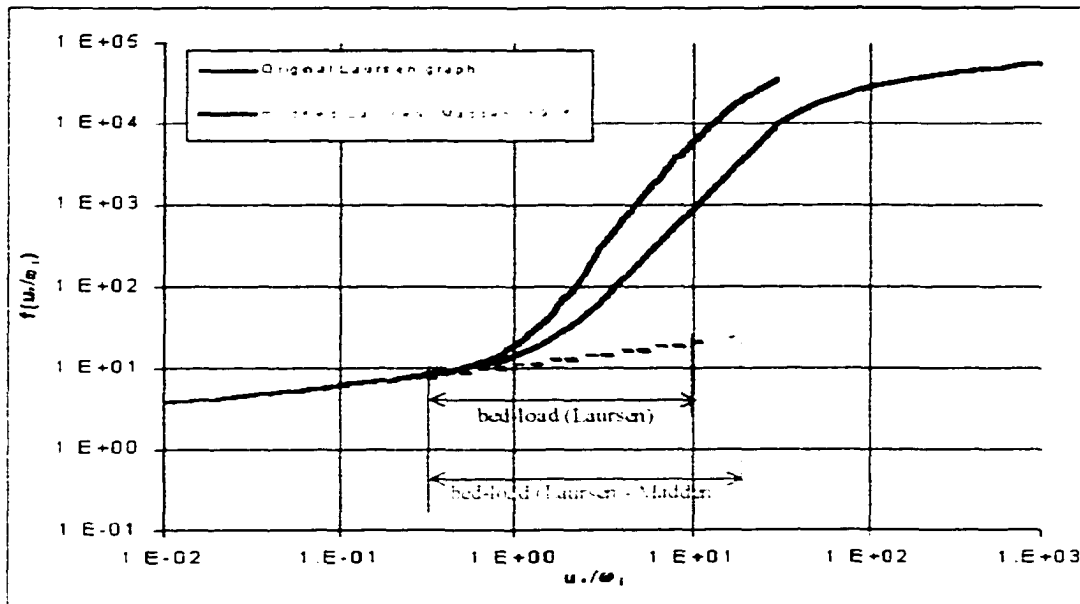


Figure 6.5. Modified Laursen graph by Madden (1985)

Adjustment factor related to the Froude number was added to the Laursen equation, and hence the modified Laursen equation by Madden (1985) becomes,

$$C_t = \sum_i p_b \left(\frac{d_i}{d} \right)^{7.6} \left(\frac{\tau_o'}{\tau_{ci}} - 1 \right) f \left(\frac{u_*}{\omega_i} \right) \left(\frac{0.1616}{F_r^{0.904}} \right) \quad (6.10)$$

6.3.2 Modification by Copeland (1989)

Copeland and Thomas (1989) modified the Laursen (1958) method to be used in streams both sand-bed rivers and extending to larger gravel-bed rivers. The parameter of (u_*/ω_i) was modified by the authors using additional sand-bed rivers and gravel-bed rivers. The original Laursen equation was also modified using the grain hydraulic roughness to compute the grain shear stress. Copeland & Thomas introduced a variable critical shear stress in the modified Laursen sediment transport relation to enhance the mobility of larger particles (gravels) in the presence of smaller particles.

The original Laursen's bed shear stress due to grain size τ_o' in lb/ft² as expressed in Equation (2.13) can be rewritten as

$$\tau_o' = \frac{\rho u^2}{58} \left(\frac{d_{50}}{d} \right)^{1/3} \quad (6.11)$$

The grain shear stress is calculated from the grain hydraulic roughness. Copeland computed this roughness using the Limerinos (1970) equation, as restructured by Burkham & Dawdy (1976), as expressed.

$$\frac{u}{u_*'} = 3.28 + 5.75 \log \frac{r'}{d_{84}} \quad (6.12)$$

in which

$$u_*' = \sqrt{gr'S} \quad (6.13)$$

$$r' = \frac{(un)^{1.5}}{1.811S^{0.75}} \quad (6.14)$$

$$n = 0.34k_s^{1.6} \quad (6.15)$$

in which

n = Manning's roughness coefficient

k_s = coefficient of roughness for the bed

u = the mean velocity

u_*' = the grain shear velocity

r' = hydraulic radius of bed grain roughness

d_{84} = particle size of which 84% of the bed is finer

S = slope

Accordingly, the bed shear stress due to grain size τ_o' in Equation (6.11) is calculated by inserting the mean velocity u computed from Equation (6.12).

The bed load transport is a function of the ratio of the applied grain size to the critical shear stress and is expressed as $(\tau_o'/\tau_{ci} - 1)$.

For turbulent flows over rough boundaries, the critical shear stress τ_{ci} varies linearly with particle size since the Shield parameter remains constant (Julien, 1995). Highway Research Board (1970) plotted the relationship between critical shear stress and median grain size d_{50} on a flat horizontal surface (also found in Figure 7.7. in Julien, 1995). Paintal (1970) found that the critical stress varied with the applied shear stress, decreasing significantly when the dimensionless shear stress was less than 0.05. The dimensionless shear stress for the i^{th} τ_{oi}' size class is defined as

$$\tau_{oi}' = \frac{\tau_o'}{(\gamma_s - \gamma)d_i} \quad (6.16)$$

in which

τ_o' = the bed shear stress due to grain size

γ_s = specific weight of sediment

γ = specific weight of water

d_i = geometric mean diameter of particle of the i^{th} size

The critical dimensionless shear stress is defined by

$$\tau_{ci}' = \frac{\tau_{ci}}{(\gamma_s - \gamma)d_i} \quad (6.17)$$

Laursen (1958) assumed a constant critical dimensionless shear stress $\tau_{ci}' = 0.039$ for all particle sizes. However, according to Julien (1995), this value is the threshold of

motion for very fine gravel and is to be equivalent to a value of 0.2 for the ratio of shear to fall velocity (u^*/ω).

According to Copeland the critical dimensionless shear stress varies between 0.02 and 0.039. The lower limit was adopted from the research of Andrews (1983). When τ_{ci}^* is greater than 0.050, it should be taken 0.039 as recommended by Laursen. The lower limit of τ_{ci}^* is:

$$\tau_{ci}^* = 0.647\tau_{oi}^* + 0.0062 \quad (6.18)$$

and, hence the critical shear stress is calculated by:

$$\tau_{ci} = \tau_{ci}^* (\gamma_s - \gamma) d_i \quad (6.19)$$

The modification of the critical dimensionless shear stress indicates that the potential transport of coarser particles (such as gravel) is increased as the initiation of motion for these particles at lower shear stresses.

The difference between the original Laursen and modified Laursen by Copeland for suspended load is that in the original Laursen the suspended transport rate is the ratio between total shear velocity to grain fall velocity (u^*/ω_i), while in modified Laursen by Copeland the suspended transport rate is the ratio of grain shear velocity to grain fall velocity (u'^*/ω_i).

The modified Laursen equation by Copeland (1989) can be written as

$$C_t = 0.01\gamma \sum_i p_i \left(\frac{d_i}{d} \right)^{7.6} \left(\frac{\tau_{oi}^*}{\tau_{ci}^*} - 1 \right) f \left(\frac{u'^*}{\omega_i} \right) \quad (6.20)$$

in which:

C_t = total average sediment concentration in weight per unit volume

γ = specific weight of water

p_i = fraction

u_*' = grain shear velocity

d = flow depth

d_i = diameter particle of the i^{th} size fraction

τ_{o*} = bed shear stress due to grain size

τ_{ci} = critical shear stress for sediment size d_i

ω_i = fall velocity of particle size d_i

$f\left(\frac{u_*'}{\omega_i}\right)$ = functional relation defined on Plate 16 Copeland & Thomas (1989) or roughly

plotted in Figure 6.6.

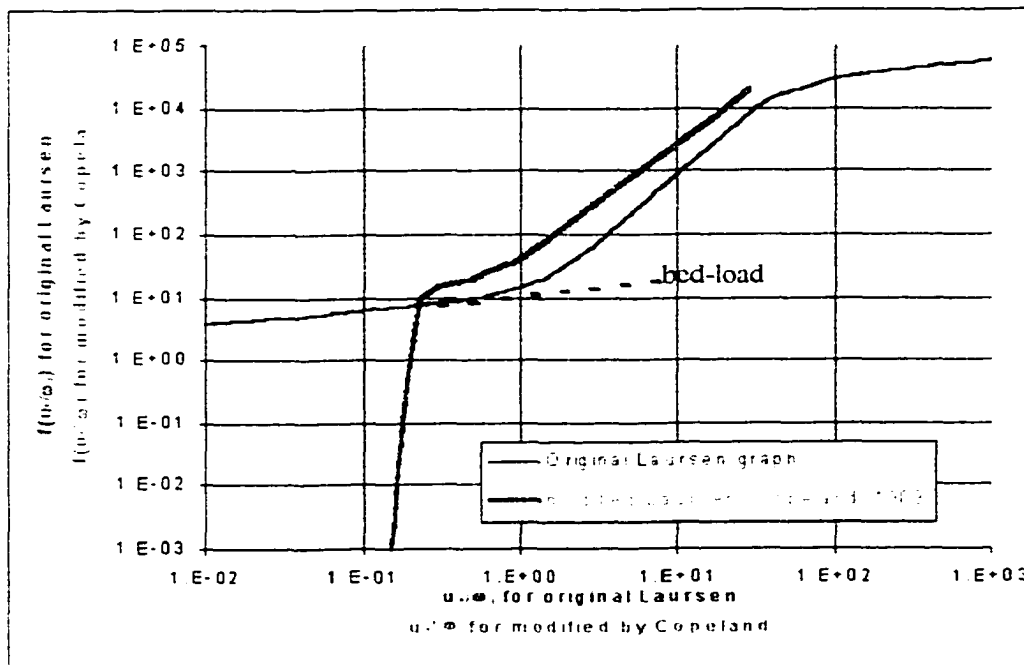


Figure 6.6. Modified Laursen graph by Copeland (1989)

The range of data used in the development of the Laursen transport function is shown in Table 6.10.

Table 6.10. Data range used in development of the Laursen transport function by Copeland (Copeland & Thomas, 1989; and Waterways Experiment Station, 1998)

Parameter	River data	Flume data
1. Median particle size range, mm	0.08 - 0.70	0.011 - 29
2. Multiple size classes	yes	yes
3. Velocity, fps	0.068 - 7.8	0.70 - 9.4
4. Depth, ft	0.67 - 54	0.03 - 3.6
5. Slope, ft per ft	0.0000021 - 0.0018	0.00025 - 0.025
6. Width, ft	63 - 3640	0.25 - 6.6
7. Water Temperature, °F	32 - 93	46 - 83

The modified Laursen by Copeland was applied by Raphelt (1996) to ten river systems including the Toutle, North Fork Toutle, Susitna, Tanana, Oak Creek, Clearwater, Chippewa near Durand, Chippewa near Caryville and Granite Creek Rivers. From a total of 187 sets of gravel-bed river data, 147 sets of data were above the measured values, 39 sets of data were within the range of accuracy compared to the measured values (discrepancy ratio of computed to measured values is in the range of 0.2 to 5) and only 1 set of data were below the range of accuracy. Raphelt (1996) concluded that modified Laursen by Copeland significantly over-predicted gravel bed transport for individual grain size. The maximum over prediction is as much as 6000 times higher than the measured value. The data within the range of accuracy all had d_{50} of bed material either sand or very fine gravel. The lowering of the critical dimensionless shear stress without accounting for the probability of grains to move, and without the hiding factor, probably are the reasons for the over-prediction of modified Laursen by Copeland for gravel-bed transport with $d_{50} > 4.00$ mm.

6.3.3 New Proposed Method Based on Modification of Laursen (1958)

The total average sediment concentration, C_t using Laursen can be computed using Equation (2.2). This equation is rewritten

$$C_t = 0.01\gamma \sum_i p_i \left(\frac{d_i}{d} \right)^{7.6} \left(\frac{\tau_o'}{\tau_{ci}} - 1 \right) f \left(\frac{u_*}{\omega_i} \right) \quad (6.21)$$

Since the calculation is using the mean bed diameter (uniform material), d_{50} , this equation reduces to

$$C_t = 0.01\gamma \left(\frac{d_{50}}{d} \right)^{7.6} \left(\frac{\tau_o'}{\tau_{ci}} - 1 \right) f \left(\frac{u_*}{\omega_{50}} \right) \quad (6.22)$$

From Chapter 4, the comparison between C_{ppm} measured and computed is summarized in Figures 6.7 and 6.8.

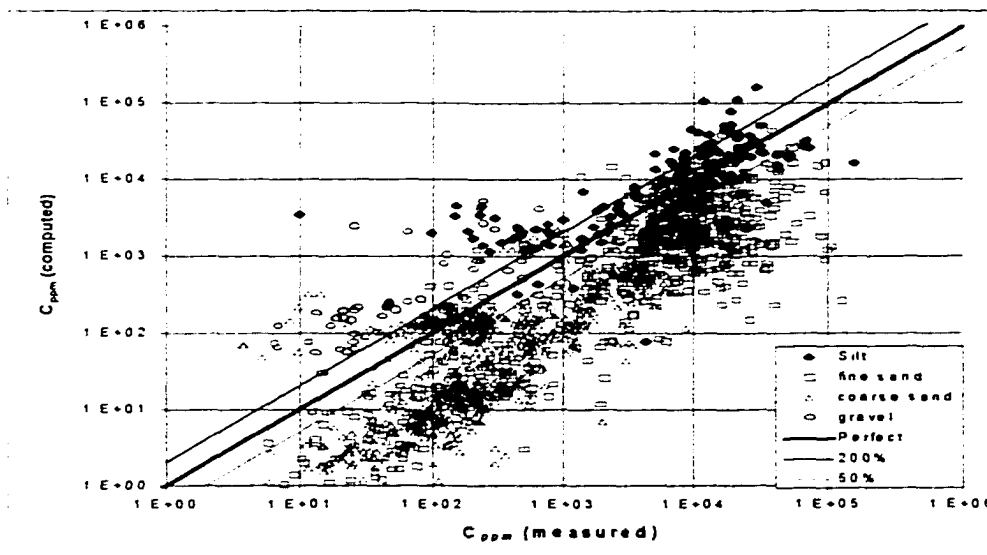


Figure 6.7. Comparison C_{ppm} (measured) and computed (Laursen method) for various riverbeds

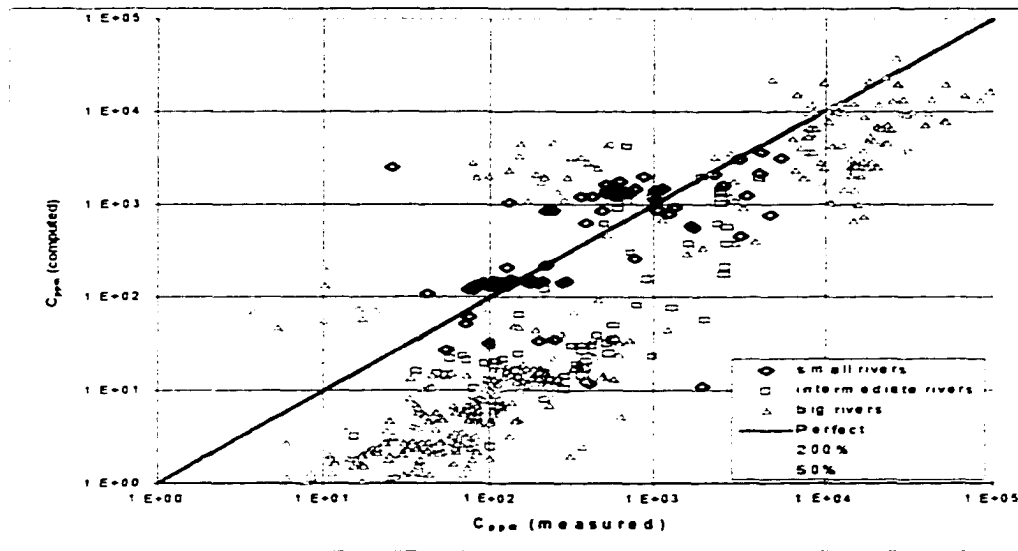


Figure 6.8. Comparison C_{ppm} (measured) and computed (Laursen method) for various channel sizes

From Figures 6.7. and 6.8., and Tables 4.15 to 4.22 it can be seen that for various river-beds and channel sizes, summaries can be given:

1. Silt-bed rivers

Most of the C_{ppm} computed is greater than C_{ppm} measured with discrepancy ratio of 3.01. Range of discrepancy ratio of 0.5 up to 2 is 48 %, discrepancy ratio less than 0.5 is 19 % and discrepancy ratio greater than 2 is 33 % (for detail see Table 4.19 and Figure 4.8g). However, only 22 % has discrepancy ratio of 0.75 – 1.25.

2. Very fine to fine-bed rivers

Most of the C_{ppm} computed is much smaller than C_{ppm} measured with discrepancy ratio of 0.36. Range of discrepancy ratio of 0.5 up to 2 is only 19 %, discrepancy ratio

less than 0.5 is 80 % and discrepancy ratio greater than 2 is only 2 % (for detail see Table 4.18 and Figure 4.8g). However, only 7 % has discrepancy ratio of 0.75 – 1.25.

3. Medium to coarse bed rivers

Most of the C_{ppm} computed is smaller than C_{ppm} measured with discrepancy ratio of 0.60. Range of discrepancy ratio of 0.5 up to 2 is only 20 %, discrepancy ratio less than 0.5 is 75 % and discrepancy ratio greater than 2 is only 5 % (for detail see Table 4.17 and Figure 4.8g). However, only 6 % has discrepancy ratio of 0.75 – 1.25.

4. Gravel bed rivers

Most of the C_{ppm} computed is much greater than C_{ppm} measured with discrepancy ratio of 7.16. Range of discrepancy ratio is shown in Table 4.16.

Range of discrepancy ratio of 0.5 up to 2 is only 15 %, discrepancy ratio less than 0.5 is only 3 % and discrepancy ratio greater than 2 is 81% (for detail see Table 4.16 and Figure 4.8g). However, only 3 % has discrepancy ratio of 0.75 – 1.25.

5. Small rivers

Most of the C_{ppm} computed is greater than C_{ppm} measured with discrepancy ratio of 1.43. Range of discrepancy ratio of 0.5 up to 2 is 60 %, discrepancy ratio less than 0.5 is 20 % and discrepancy ratio greater than 2 is only 21 % (for detail see Table 4.20 and Figure 4.8g). Discrepancy ratio of 0.75 – 1.25 is about 23 %.

6. Intermediate rivers

Most of the C_{ppm} computed is smaller than C_{ppm} measured with discrepancy ratio of 0.37. Range of discrepancy ratio of 0.5 up to 2 is only 15 %. discrepancy ratio less than 0.5 is 85 % and discrepancy ratio greater than 2 is only 2 % (for detail see Table 4.21 and Figure 4.8g). Discrepancy ratio of 0.75 – 1.25 is only about 5 %.

7. Large rivers

Most of the C_{ppm} computed is much smaller than C_{ppm} measured with discrepancy ratio of 1.13. Range of discrepancy ratio of 0.5 up to 2 is only 9 %. discrepancy ratio less than 0.5 is 83 % and discrepancy ratio greater than 2 is only 8 % (for detail see Table 4.22 and Figure 4.8g). However, only 5 % has discrepancy ratio of 0.75 – 1.25.

6.3.3.1 Modified Laursen Graph

Bondurant (1958) proposed a modification of the Laursen graph. He plotted the relationship between (u/ω) and $f(u/\omega)$ in the Laursen graph from the Missouri River data at Omaha and at Kansas City. At the lower part of Laursen graph, Bondurant (1958) modification fit quite well with the Laursen graph. However, between the upper part and the lower part, the values of u/ω_i for the Missouri River data deviate sharply from those of Laursen graph. This deviation seems quite well compare to the value of u/ω_i from various river-bed rivers (see Figure 6.9.).

Data of the original graph plotted roughly from Laursen data and modification proposed by Bondurant (1958) are shown in Figure 6.9.

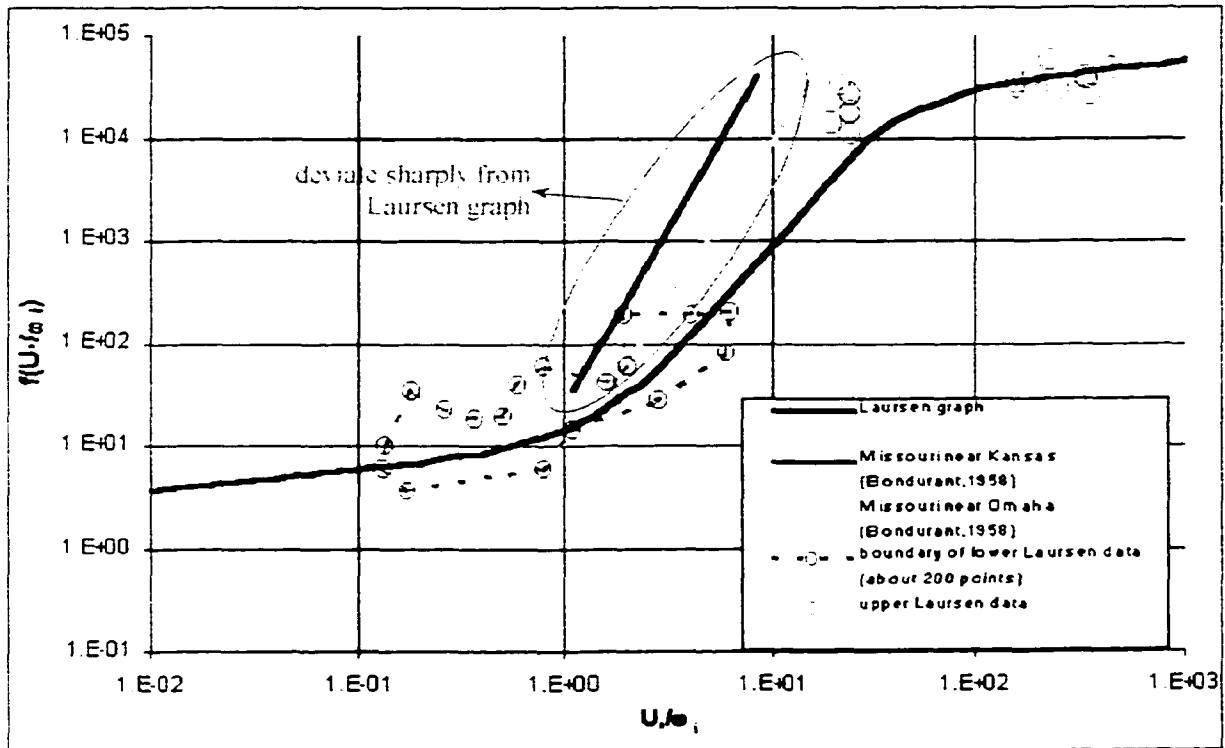


Figure 6.9. Points of Laursen data and values of the relation between u/ω_i and $f(u/\omega_i)$ from Missouri River (after Laursen, 1958 and Bondurant, 1958)

Sediment transport can be subdivided into three zones describing the dominant mode of transport: bed load, mixed load and suspended load (Julien, 1995; Middleton & Southard, 1984; Dade & Friend, 1998). The parameters u/ω and d_{50}/d in Equation (6.22) are also indicators how the mode of the sediment transport.

Figure 6.10. shows the ratio of suspended load to total as function of u/ω and d/d_{50} .

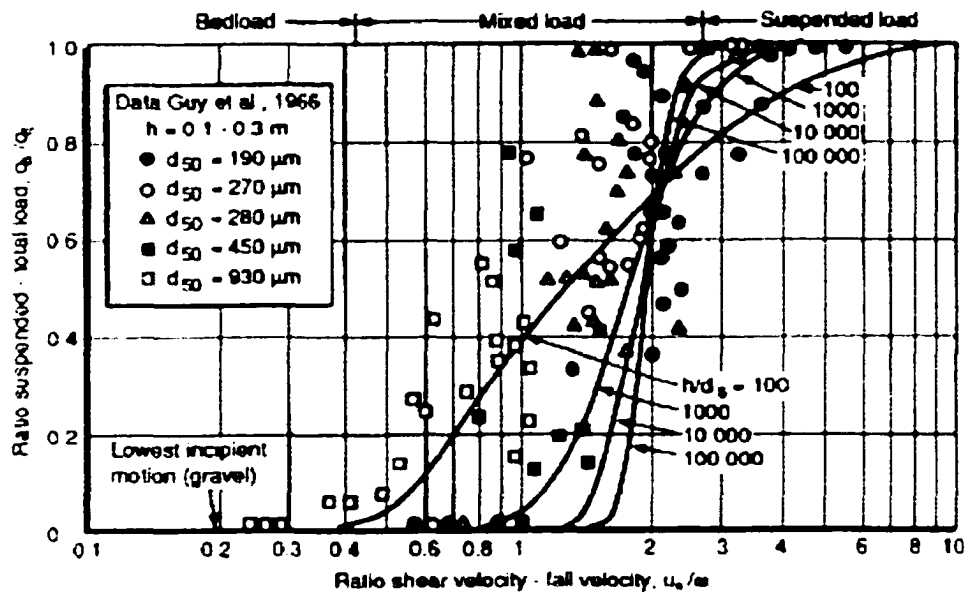


Figure 6.10. Ratio of suspended load to total load versus ratio shear to fall velocities and dimensionless flow depth d/d_{50} (Julien, 1995)

Julien (1995) stated that for turbulent flow over rough boundaries that generally occurs in natural streams, the incipient motion corresponds to $u^*/\omega = 0.2$. Furthermore, bed load will be dominant for u^*/ω less than about 0.4. Mixed load or transition zone is found where $0.4 < u^*/\omega < 2.5$. In this zone, bed-load and suspended load contribute the total load. When $u^*/\omega > 2.5$, the suspended load is dominant and effects of gravity on particles are negligible compared with turbulent mixing. Dade & Friend (1998) gave a slight different criterion of mode of sediment transport compared to Julien (1995). Dominant suspended load occurs when $u^*/\omega > 3.33$, u^*/ω of mixed load is in the range of $0.33 - 3.33$, and dominant bed load is when $u^*/\omega \leq 0.33$. In mode of suspended load, less than approximately 10 – 20 % total sediment load is bed load. However, in mode of bed load, more than about 80 – 90 % is bed load. In mobile boundary channel, these

different modes of sediment transport cause the changes of flow condition (Ansley, 1965).

However, all modes of bed material transport can occur simultaneously over a wide range of flow conditions, even though one could dominate at any given stage (Knighton, 1998).

Table 6.11. summarizes the modes of sediment transport given shear and fall velocities.

Table 6.11. Modes of sediment transport given shear and fall velocities

u_* / ω	Julien (1995)	u_* / ω	Dade & Friend (1998)
< 0.2	no motion for all possible grain sizes	≤ 0.33	predominant bed load
0.2	lowest possible incipient motion for turbulent flow over rough boundaries	$0.33 < u_* / \omega < 3.333$	mixed load
0.2 - 0.4	sediment transport as bed-load	≥ 3.333	predominant suspended load
0.4 - 2.5	sediment transport as mixed-load		
>2.5	sediment transport as suspended-load		
25	$C_{0.8} = 0.75 C_{0.2}$		
100	$C_{0.8} = 0.93 C_{0.2}$		
400	$C_{0.8} = 0.98 C_{0.2}$		

note: $C_{0.8}$ is the concentration at $y = 0.8 d$

Figure 6.11. shows the mode of sediment transport plotted in original Laursen graph.

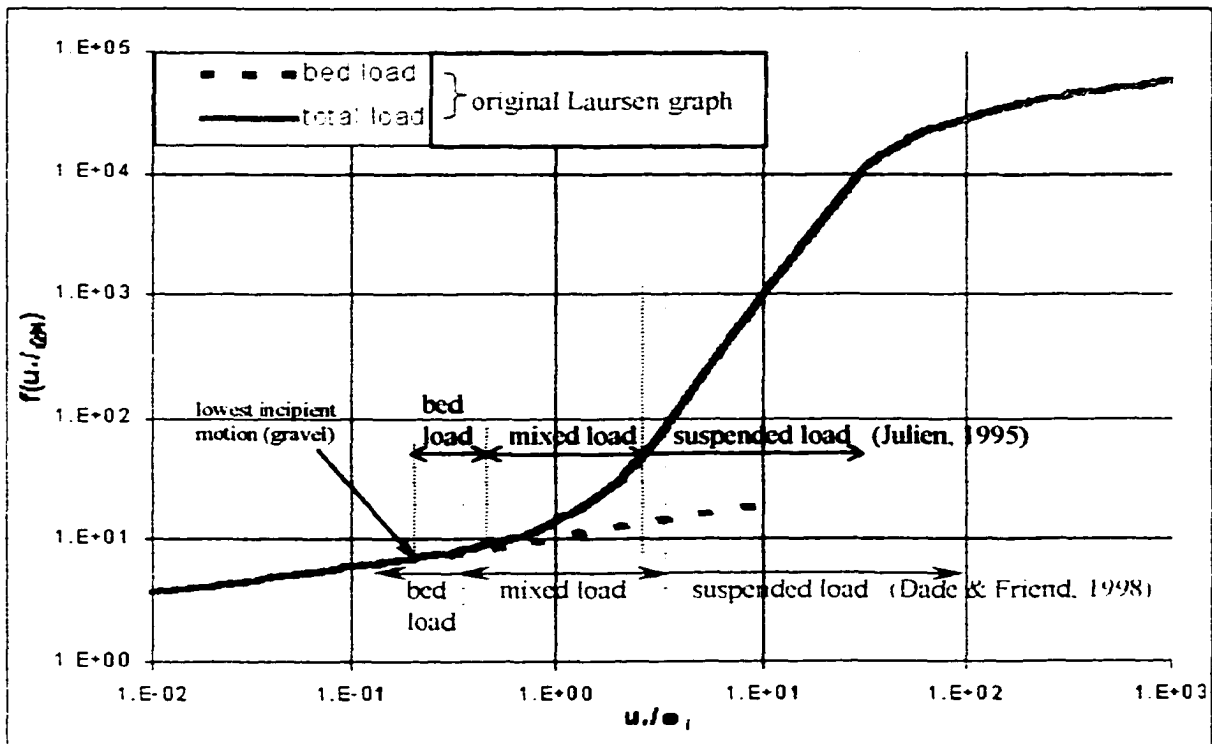


Figure 6.11. Modes of sediment transport plotted in original Laursen graph (Laursen, 1958; Julien, 1995; and Dade & Friend, 1998)

The parameter $(\tau_o'/\tau_{ci} - 1)$ in Equation (6.22) is important to the determination of bed-load, and the parameter $u./\omega$ relates to the suspended load. When there is no suspended load, the value of $f(u./\omega_i)$ is unity. If the lowest part of Laursen graph is assumed to be linear, therefore this part could be extended to get the value $u./\omega$ for $f(u./\omega_i)$ equals to unity. This extension is shown in Figure 6.12.

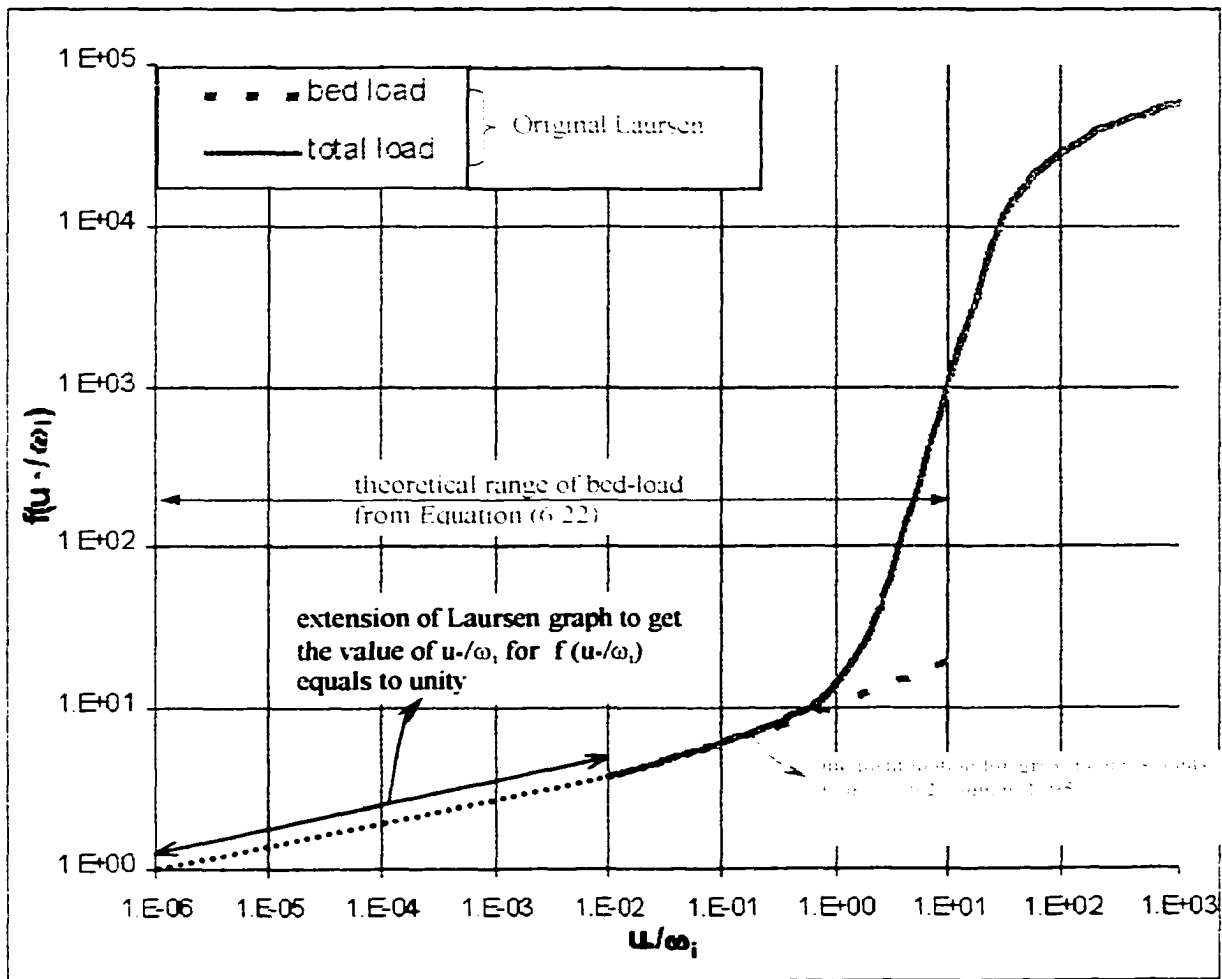


Figure 6.12. Theoretical range of bed load from Laursen method {Equation (6.22)}

From Figure 6.12. we can say that theoretically the bed-load (from original Laursen graph) has value of u/ω_i in the range from 10^{-6} (very small and can be assumed to be zero) to eight. However, as stated by Julien (1995) and shown in Figure 6.10, in natural streams the incipient motion for gravel corresponds to $u/\omega = 0.2$.

Equation (6.22) can be rewritten as

$$f\left(\frac{u_*}{\omega_{s0}}\right) = \frac{C_t}{0.01\gamma\left(\frac{d_{s0}}{d}\right)^{7.6}\left(\frac{\tau_{o'}}{\tau_{ci}} - 1\right)} \quad (6.23)$$

Using Equation (6.23) and field data the relationship between u_* / ω_i and $f(u_* / \omega_i)$ can be plotted on the original Laursen Graph. The results for different sizes of river-bed particles and different of channel sizes are shown Figure 4.13 and Figure 4.14 in Chapter Four.

Plotting u_* / ω_i and $f(u_* / \omega_i)$ of several kinds of river-bed diameter data in Group 1 graph (re-plotting of Figure 4.13) and modes of sediment transport into Laursen graph (combining Figure 4.13 and Figure 6.11) are shown in Figure 6.13.

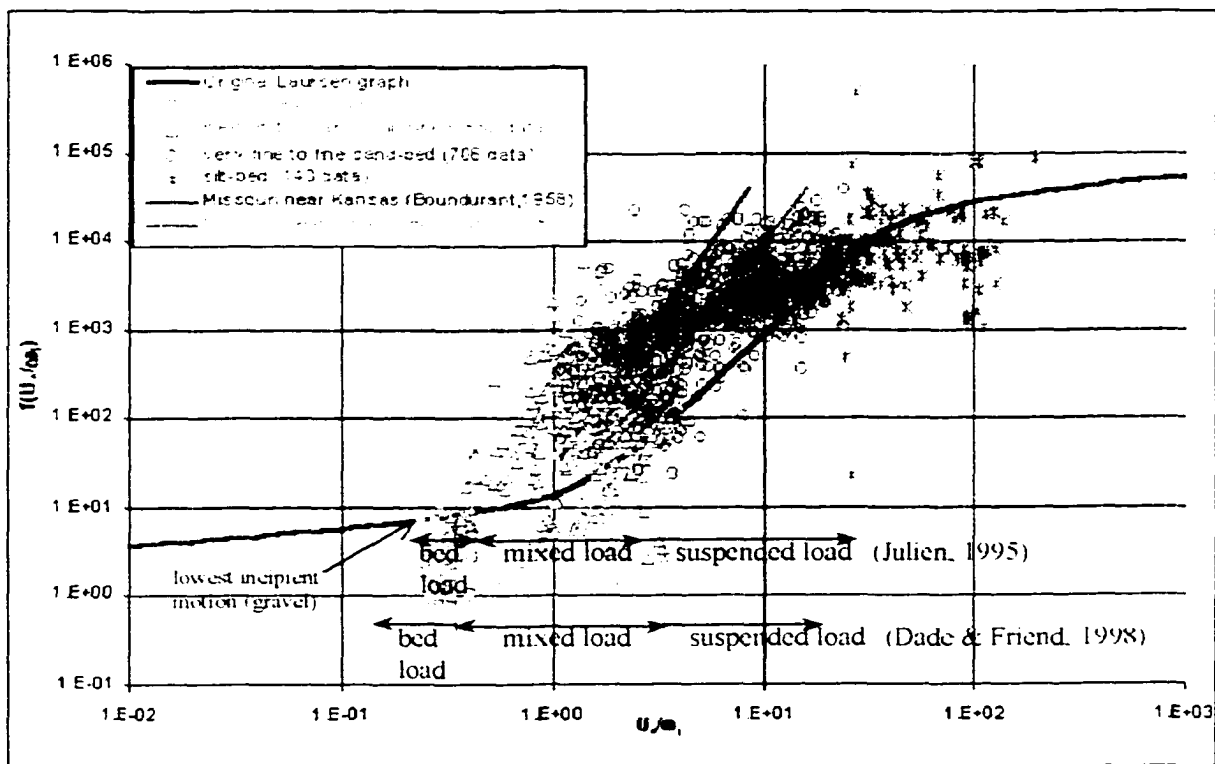


Figure 6.13. Plotting u_* / ω_i and $f(u_* / \omega_i)$ for several diameters of river bed data from Group 1, graphs and modes of sediment transport defined by Julien (1995) and Dade & Friend (1998) into Laursen graph

It can be seen that for various mean bed diameters there is a consistent tendency of the relation between u_* / ω_i and $f(u_* / \omega_i)$. Lowest incipient motion zone occurs for gravel-bed rivers, the bed load zone consists mostly gravel-bed materials with small

amount of coarse-bed materials. The mixed load zone is mostly medium to very coarse sand-bed materials and relatively small amount of very fine to fine sand-bed materials. In suspended load zone mixture of very fine to fine sand-bed materials and silt-bed materials occurs. However, although there is also a consistent tendency of the relation between u_* / ω_i and $f(u_* / \omega_i)$ for various channel sizes (see Figure 4.14.), scatter result still exists.

From Figure 6.13. modification of Laursen graph could be developed. Relation of u_* / ω_i and $\log f(u_* / \omega_i)$ is plotted in Figure 6.14.

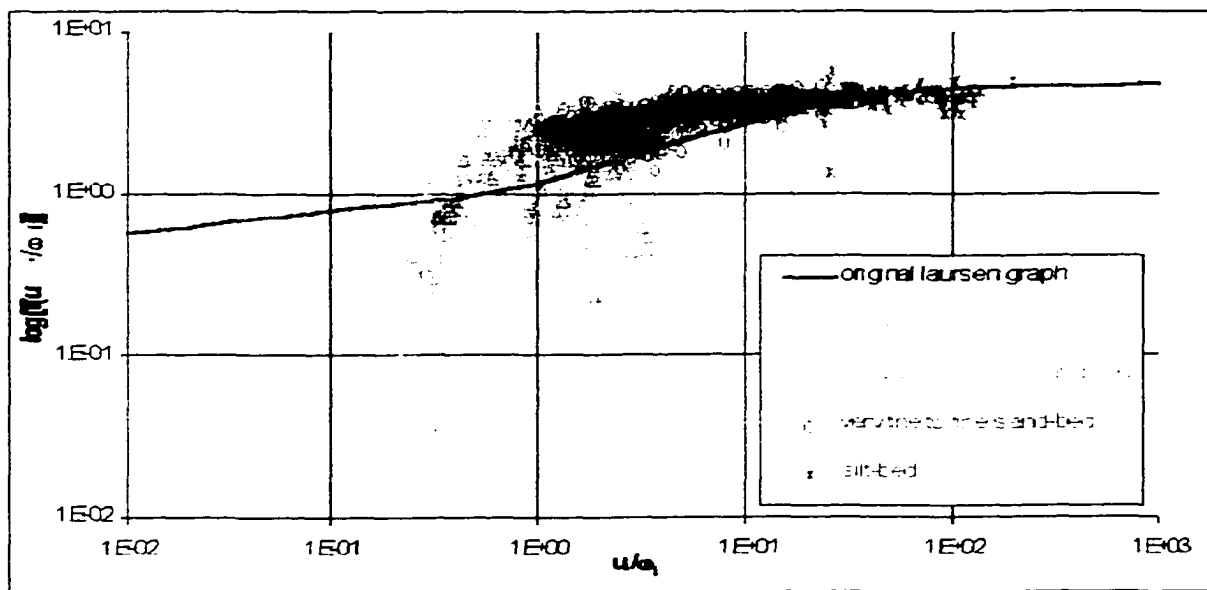


Figure 6.14. Relation of u_* / ω_i and $\log f(u_* / \omega_i)$

The proposed modified Laursen graph is shown in Figure 6.15. The vertical line shown in the bed load zone in Figure 6.15. indicates that prediction of bed load could not be fairly accurate. Hence, calculating bed load accurately is still problematic since the formulas proposed so far do not provide a good fit to all data (Garg et al., 1971). Besides, bed-load sampling in river is rather complicated and taking samples at only one location may lead to a large error of about 50 % (Gaweesh and Rijn, 1994; Hubbel, 1989).

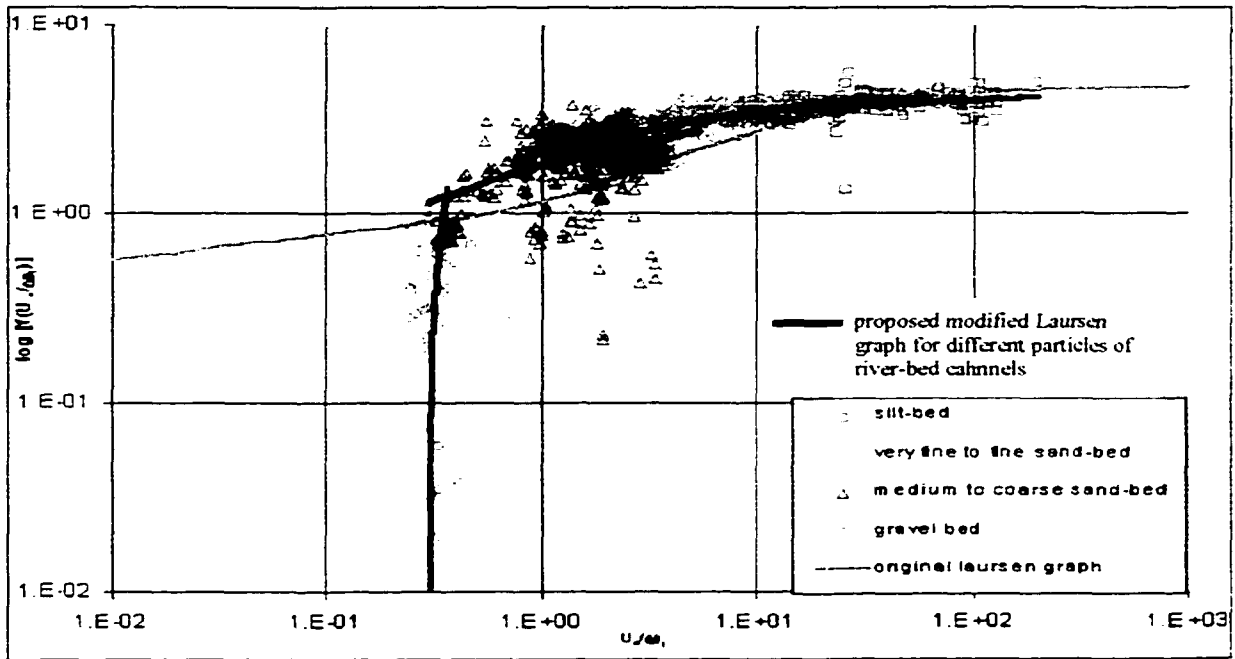


Figure 6.15. Proposed Laursen graph modification

The equations for each line in Figure 6.15. for silt-bed, very fine to fine sand-bed, medium to coarse sand-bed and gravel-bed rivers are

$$y = 0.2003\text{Ln}(x) + 3.1192 \quad (6.24a)$$

$$y = 0.6031\text{Ln}(x) + 2.1116 \quad (6.24b)$$

$$y = 0.5553\text{Ln}(x) + 1.8086 \quad (6.24c)$$

$$y = 7.1575\text{Ln}(x) + 8.479 \quad (6.24d)$$

in which

$$y = \text{Log } f(u_i/\omega_i)$$

$$x = u_i/\omega_i,$$

With Figure 6.15 and Equation (6.24), the original Laursen equation {(Equation (6.21))} is modified to become

$$C_t = 0.01\gamma \left(\frac{d_{50}}{d} \right)^{7/6} \left(\frac{\tau_{o'}'}{\tau_{c50}} - 1 \right) 10^{\left(\frac{u_*'}{\omega_{50}} \right)} \quad (6.25)$$

This equation is called modified Laursen 1.

Among the variables which have the relations to the C_{ppm} measured, the dimensionless unit stream power has a strong relation (see Figure 5.2.). The range of this dimensionless unit stream power, uS/ω , when compared to C_{ppm} measured is 0.0000426 to 0.403. The range of dimensionless mean diameter particle size d_{50}/d is 0.00000197 to 0.00616. These relationships are plotted in Figure 6.16.

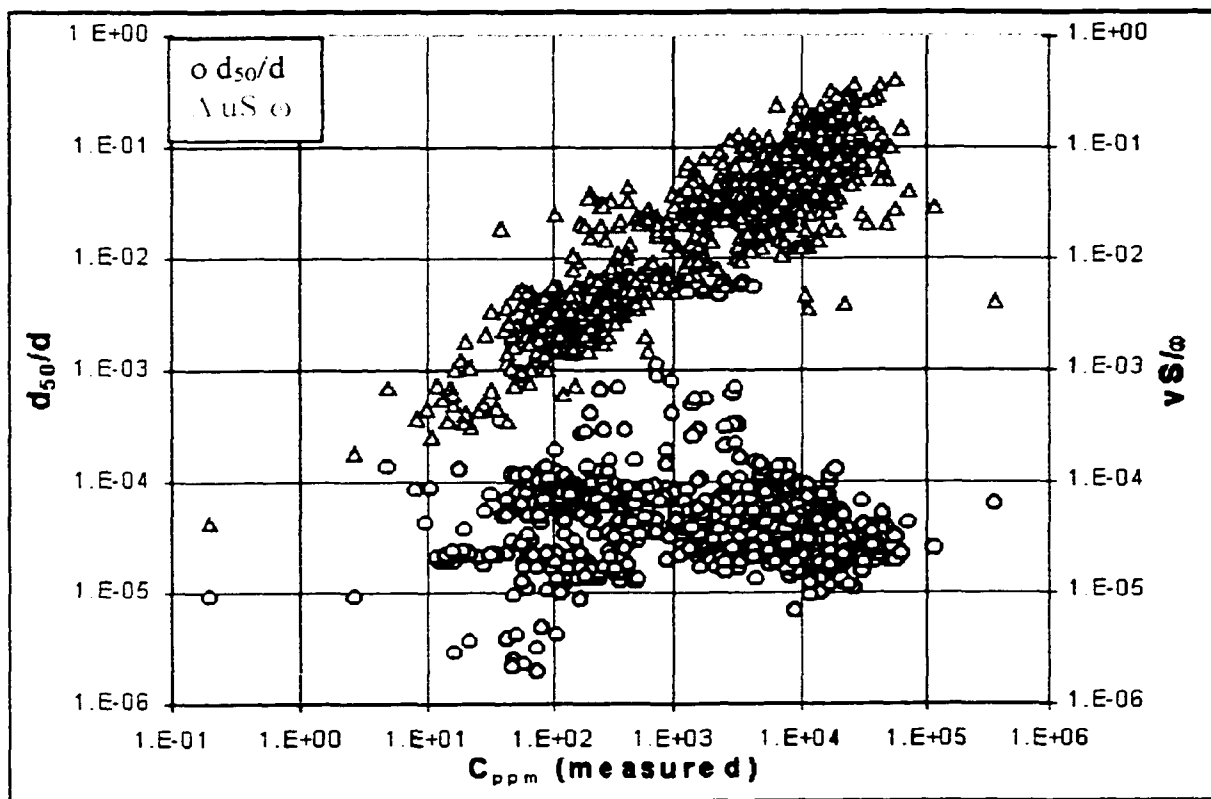


Figure 6.16. Range of dimensionless unit stream power and dimensionless flow depth compared to C_{ppm} measured.

Accordingly, the dimensionless unit stream power, using regression analyses and non-linear optimization technique can be added as another variable into Equation (6.25). Therefore, the equation can be rewritten

$$C_t = 0.01\gamma \left(\frac{d_{50}}{d}\right)^{7.6} \left(\frac{\tau_o'}{\tau_{c50}} - 1\right) 10^{\left(\frac{u_*'}{\omega_{*c}}\right)} \left(\frac{uS}{\omega}\right)^a \quad (6.26)$$

This equation is so-called modified Laursen 2.

in which

a = the variable according to mean bed particle size as shown in Table 6.12.

Table 6.12. Value of “a” in Equation (6.26) for various bed materials

River-bed materials	a
gravel	0
medium to very coarse sand	-0.2
very fine to fine sand	0.078
silt	0.06

6.3.3.2 Statistical Analysis of Modified Laursen Equation Using Data in Group 1

Using modified Laursen 1 and Figure 6.15, comparison of C_{ppm} computed and measured for various river-beds data in Group 1 are summarized in Figure 6.17 and Table 6.13.

In Chapter 7, validations of modified Laursen 1 and 2 are done using data in Group 2 and additional data of Rivers in USA (see Section 7.1. on page 179) for both based on mean diameter of river-beds and channel sizes.

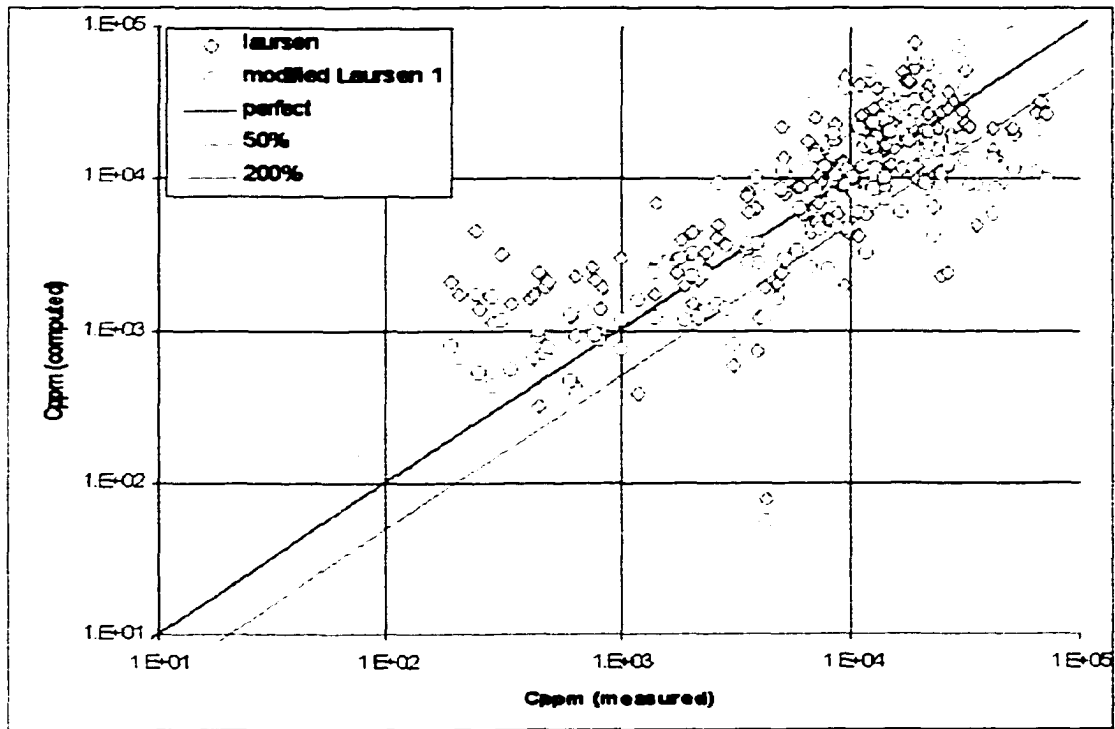


Figure 6.17a. Comparison C_{ppm} measured and computed using Laursen and modified Laursen 1 for silt-bed river data of Group1.

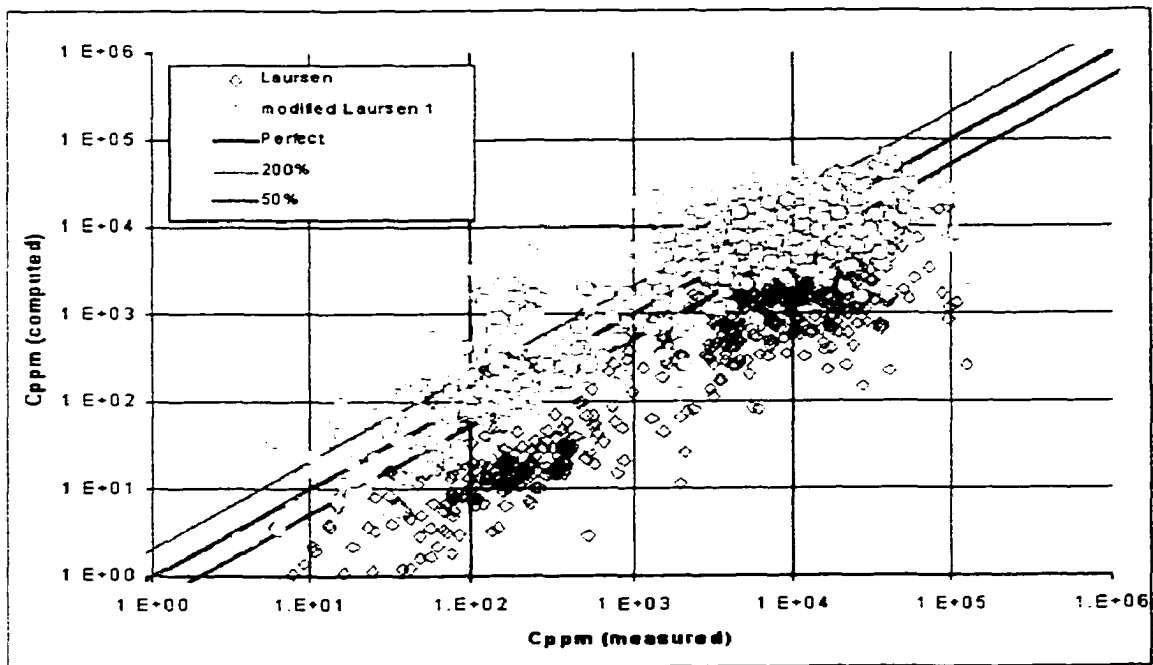


Figure 6.17b. Comparison C_{ppm} measured and computed using Laursen and modified Laursen 1 for very fine to fine-bed river data of Group1.

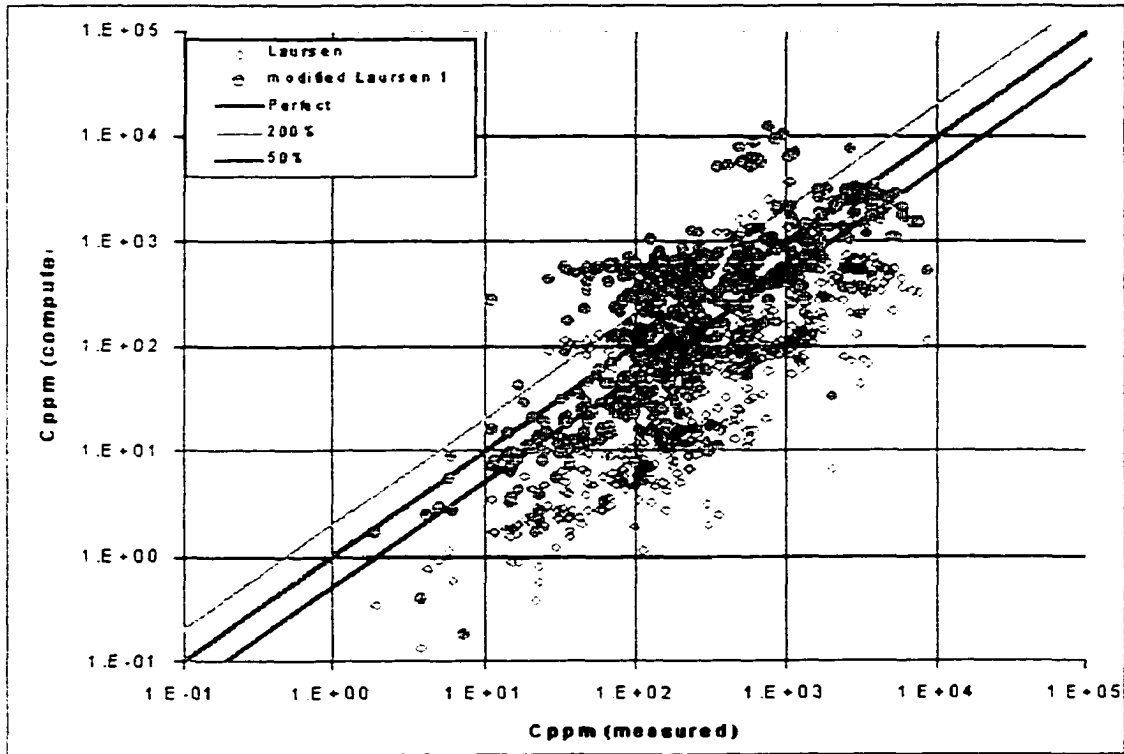


Figure 6.17c. Comparison C_{ppm} measured and computed using Laursen and modified Laursen 1 for medium to coarse sand-bed river data of Group 1.

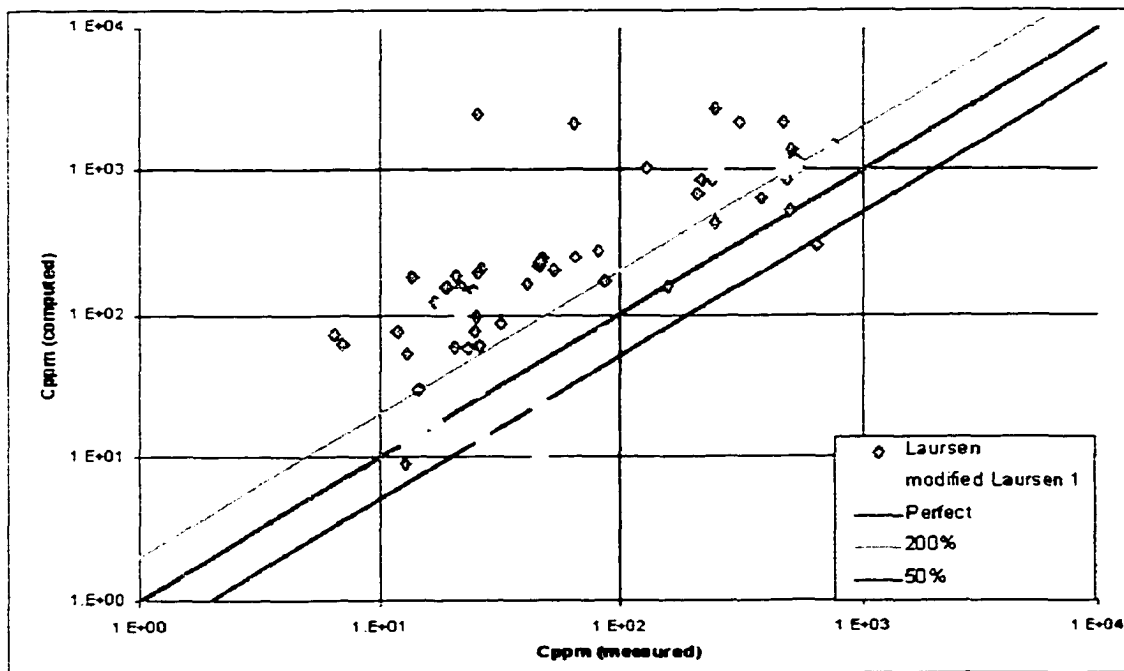


Figure 6.17d. Comparison C_{ppm} measured and computed using Laursen and modified Laursen 1 for gravel-bed river data of Group 1.

Table 6.13. Comparison discrepancy ratio between C_{ppm} measured and C_{ppm} computed by Laursen and modified Laursen 1 using data in Group 1.

	Discrepancy Ratio (Laursen)	Discrepancy Ratio (Modified Laursen 1)
silt-bed rivers	2.001	1.263
v fine to fine sand-bed rivers	0.345	1.447
med to v coarse sand-bed rivers	0.342	1.466
gravel bed rivers	4.379	3.003

6.3.4 Comparison Original and Modified Laursen's Methods

1. Original Laursen equation is expressed {see Equation (2.12)}

$$C_t = 0.01\gamma \sum_i p_i \left(\frac{d_i}{d} \right)^{7.6} \left(\frac{\tau_{o'}}{\tau_{ci}} - 1 \right) f \left(\frac{u_*'}{\omega_i} \right)$$

2. Modified Laursen equations are the following

a. **By Madden (1985) {see Equation (6.10)}**

$$C_t = \sum_i p_b \left(\frac{d_i}{d} \right)^{7.6} \left(\frac{\tau_{o'}}{\tau_{ci}} - 1 \right) f \left(\frac{u_*'}{\omega_i} \right) \left(\frac{0.1616}{F_r^{0.904}} \right)$$

b. **By Copeland (1989) {see Equation (6.20)}**

$$C_t = 0.01\gamma \sum_i p_i \left(\frac{d_i}{d} \right)^{7.6} \left(\frac{\tau_{o'}}{\tau_{ci}} - 1 \right) f \left(\frac{u_*'}{\omega_i} \right)$$

c. **Proposed method from the present study:**

two new modifications were developed labeled modified Laursen 1 and modified Laursen 2.

• **modified Laursen 1 {see Equation (6.25)}**

$$C_t = 0.01\gamma \left(\frac{d_{50}}{d} \right)^{7/6} \left(\frac{\tau_o'}{\tau_{c50}} - 1 \right) 10^{f\left(\frac{u_*}{\omega_{c50}}\right)}$$

- **modified Laursen 2 {see Equation (6.26) and Table 6.12}**

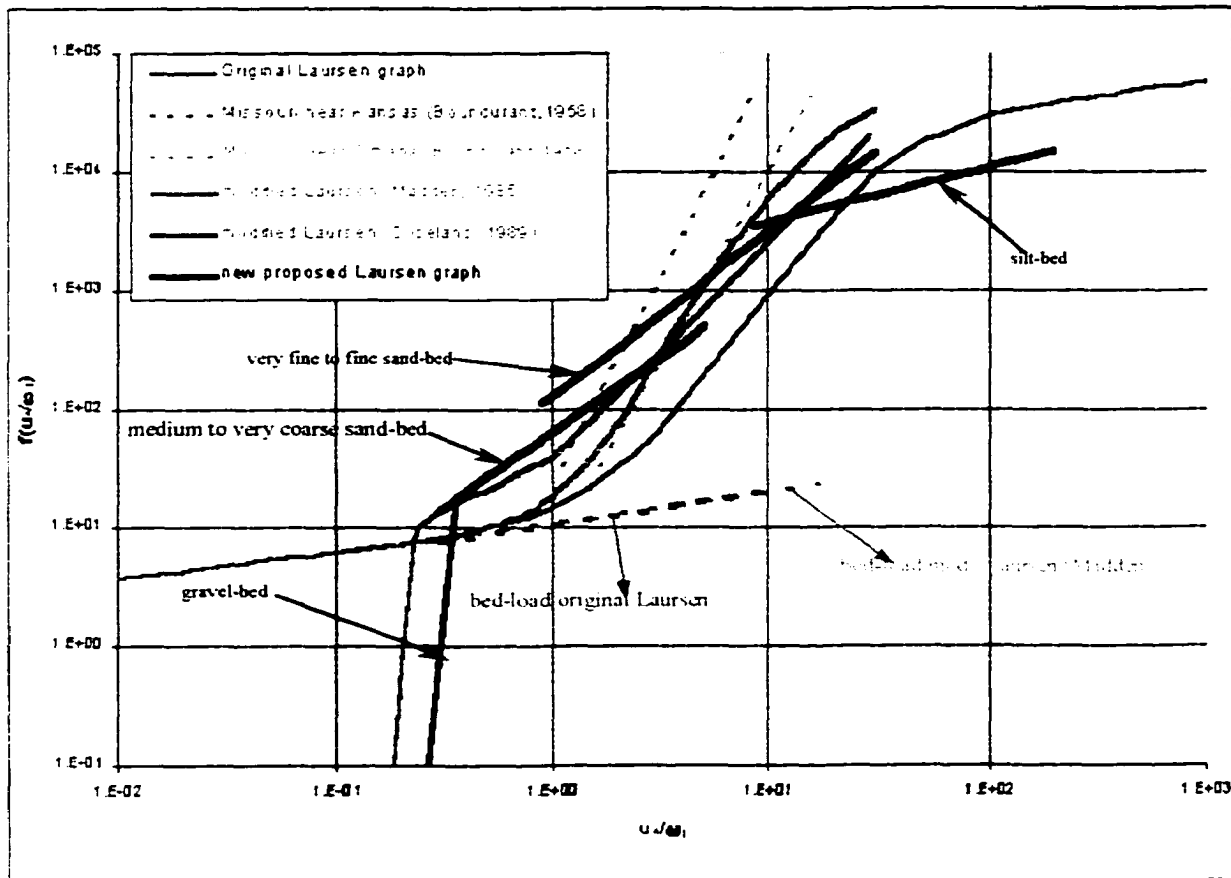
$$C_t = 0.01\gamma \left(\frac{d_{50}}{d} \right)^{7/6} \left(\frac{\tau_o'}{\tau_{c50}} - 1 \right) 10^{f\left(\frac{u_*}{\omega_{c50}}\right)} \left(\frac{uS}{\omega} \right)^a$$

The difference among those modifications is summarized in Table 6.14.

Table 6.14. Comparison among modified Laursens (in general)

Modified by Madden	Modified by Copeland	Modified by Kodoatic
1. Used the same equation but adding adjustment factor related to Froude Number	1. Instead of grain shear stress Copeland used grain hydraulic roughness	1. Used the same equation but adding dimensionless stream power as the adjustment factor
2. Used the modified graph	2. Used modified graph	2. Used modified graph but more specific by using diameter of bed material from silt to gravel
3. Used size fraction	3. Used size fraction	3. diameter (no fraction) which is simpler
4. Used Arkansas River data	4. Used both rivers and flume data (not specified)	4. Used 33 river systems and 18 sources of flume data (total data more than 5300 sets of data)
5. Graph is higher than the original for sand bed, but not specified for gravel and silt	5. Graph is higher than the original for sand bed, but for silt not specified, graph for gravel is smaller than new proposed	5. Graph is higher than the original for sand bed (for sand bed is more specific for very fine to fine sand and medium to very coarse sand), but smaller for silt compared to original, graph for gravel is proposed

A comparison of original and modified Laursen graphs is shown in Figure 6.18.



Note: Copeland used u_*'/ω_i and $f(u_*'/\omega_i)$ instead of u_*'/ω_i and $f(u_*'/\omega_i)$

Figure 6.18. Comparison among original Laursen graph with modified Laursen graphs by previous authors and new proposed Laursen graph.

Chapter 7

VERIFICATION AND VALIDATION

7.1. General

To verify the validity of sediment transport relations developed in Chapter 6, data in Group 2 were used. A comparison between C_{ppm} new proposed method and existing sediment transport relations which produce best relations to C_{ppm} measured also were presented. Note that because sets of data for gravel-bed rivers were relatively small, the laboratory data of Meyer, Peter and Muller (1948) containing 139 sets of data were used for validation and verification. The other verifications used the field data of Group 2.

1. Gravel-bed rivers

The mean diameter of particle size has the range of 2.69 mm (very fine gravel) to 28.65 mm (coarse gravel).

The data have a wide range of hydraulic geometric data, including:

- discharge : 0.001 – 4.614 m³/s
- width : 0.1 – 2.0 m
- depth : 0.01 – 1.092 m
- slope : 0.0004 – 0.0227

2. Sand-bed rivers

The sand-bed rivers were divided into two kinds of sand-bed: very fine to fine sand-bed rivers (0.062 mm – 0.5 mm) and medium to very coarse sand-bed rivers (0.5 mm – 2.00 mm).

□ Very fine to fine sand-bed rivers (0.062 – 0.250 mm)

Total data of 692 of Group 2 from 23 river systems as mention in Section 4.2.2. were used. The hydraulic geometric data are:

- discharge : 0.003673 – 235.000 m³/s
- width : 0.346 – 3.090 m
- depth : 0.0341 – 68.00 m
- slope : 0.0000027 – 0.00769

□ Medium to very coarse sand-bed rivers (0.251 mm – 1.990 mm)

Total data of 546 of Group 2 from 23 river systems as mention in Section 4.2.2. and additional data of 68 data from rivers in the USA were used. The additional data of rivers in USA included: 7 sets of data of the Black River near Galesville, Wisconsin. 3 sets of data of the Chippewa River near Caryville, Wisconsin, 14 sets of data of the Chippewa River at Durand, Wisconsin, 18 sets of data of the Chippewa River near Pepin Wisconsin, 6 sets of data of the Toutle River at Tower Road near Silver Lake, Washington, 9 sets of data of the Wisconsin River at Muscoda, Wisconsin and 11 sets of data of the Yampa River at Deerlodge Park, Colorado.

The hydraulic geometric data have the range:

- discharge : 0.0075 – 151,000 m³/s
- width : 1.00 – 2,608 m
- depth : 0.061 – 65.00 m
- slope : 0.0000138 – 0.0029

3. Silt-bed rivers

Total of 141 data sets of Group 2 from 3 river systems as mention in Section 4.2.3. were used.

The hydraulic geometric data are:

- discharge : 1.15 – 41,200 m³/s
- width : 4.3 – 3,110 m
- depth : 0.55 – 13.10 m
- slope : 0.0000120 – 0.00087

4. Small Rivers (width < 10 m, and depth < 1.0 m)

A total of 81 data sets of Group 2 rivers from 6 river systems as mentioned in Section 4.2.4. were used.

The hydraulic geometric data are:

- discharge : 0.2268 – 7.35 m³/s
- mean bed diameter : 0.042 mm (coarse silt) – 57.51 mm (very coarse gravel)
- slope : 0.000115 – 0.00745

5. Intermediate Rivers (10 m < width < 50 m, and 1.0 m < depth < 3 m)

A total of 61 data sets of Group 2 from 9 river systems as mentioned in Section 4.2.5. were used.

The hydraulic geometric data are:

- discharge : 17.50 – 268.72 m³/s
- mean bed diameter : 0.021 (medium silt) – 1.91 mm (very coarse sand)
- slope : 0.000058 – 0.0024

6. Large Rivers (width > 50 m and depth > 3 m)

A total of 374 data sets of Group 2 rivers from 13 river systems as mentioned in Section 4.2.6. were used.

The hydraulic geometric data are:

- discharge : 107 – 235.000 m³/s
- mean bed diameter : 0.02 mm (medium silt) – 1.05 mm (very coarse sand)
- slope : 0.0000027 – 0.000121

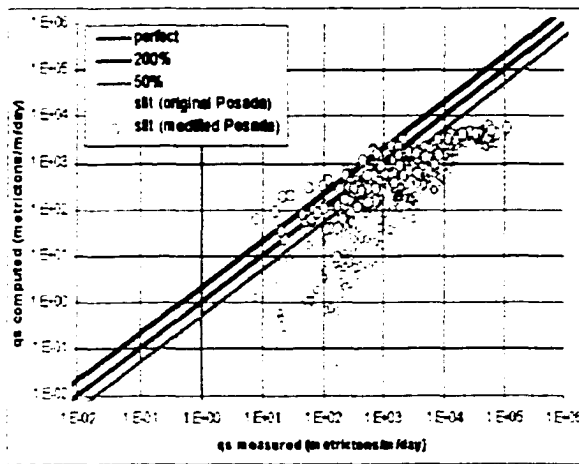
7.2. Modified Posada (1995)

Equation (6.1) was verified using data in Group 2. As a result of this verification, discrepancy ratio and correlation coefficient of original Posada and modified Posada are shown in Table 7.1.

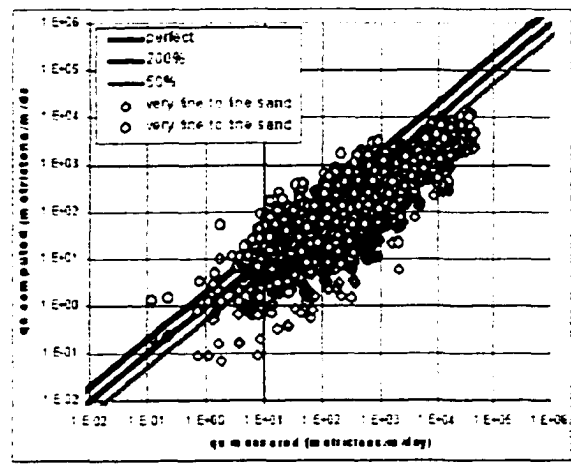
Table 7.1. Discrepancy ratio and correlation coefficient of original Posada and modified Posada using data in Group 2

	Original Posada		modified Posada	
	$\overline{R_D}$	C_c	$\overline{R_D}$	C_c
Silt-bed rivers	0.12	0.8393	0.88	0.8018
very fine to fine sand-bed rivers	0.33	0.7845	1.01	0.8239
medium to very coarse sand-bed rivers	1.12	0.7511	1.07	0.8006
gravel-bed rivers	13.516	0.8357	0.47	0.9591

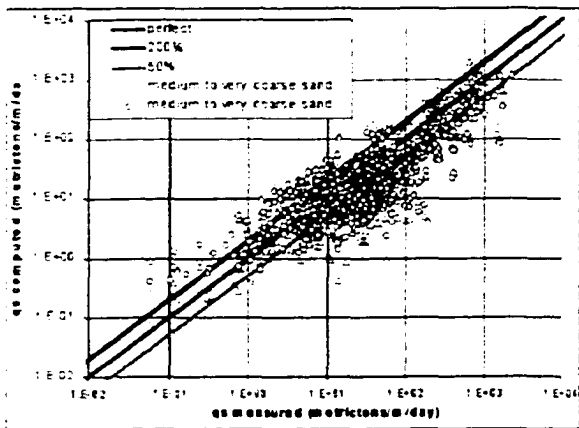
The comparison between original Posada and modified Posada using the data in Group 2 for various river-beds can also be seen in Figure 7.1.



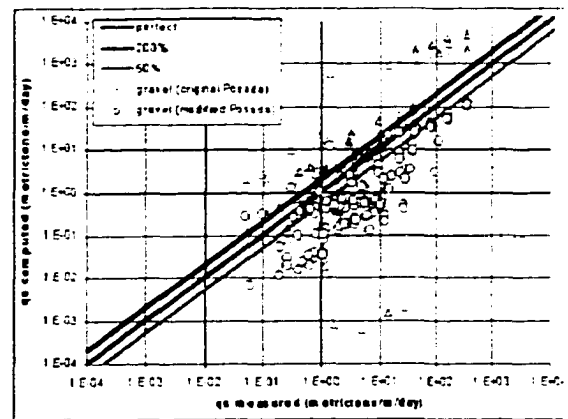
a. Silt-bed rivers



b. Very fine to fine sand-bed rivers



c. Medium to very coarse sand-bed rivers



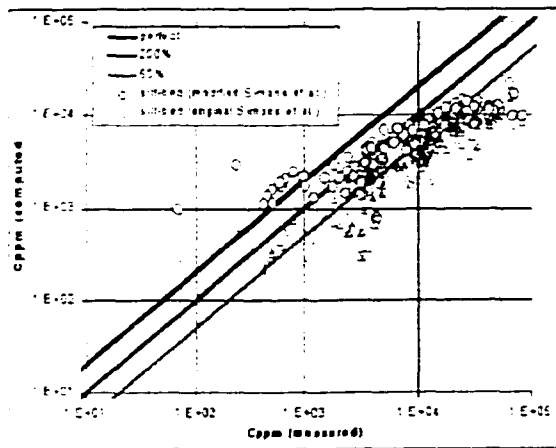
d. Gravel-bed rivers

Figure 7.1. Verification of Equation (6.1) for several diameters of river bed data from Group 2

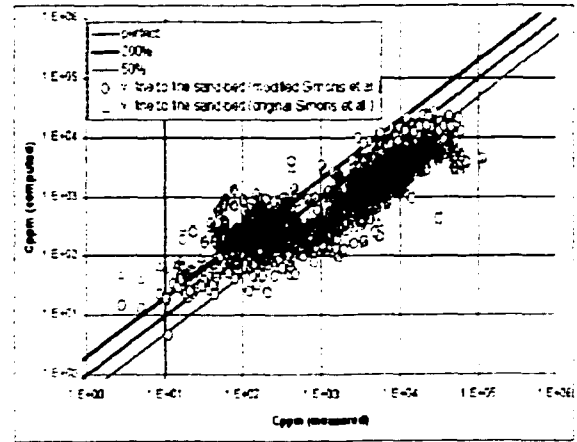
7.3. Modified Simons et al. (1981)

Equation (6.3) was verified using data in Group 2. As a result of this verification, discrepancy ratio and correlation coefficient of original Simons et al. and modified Simons et al. are shown in Table 7.2.

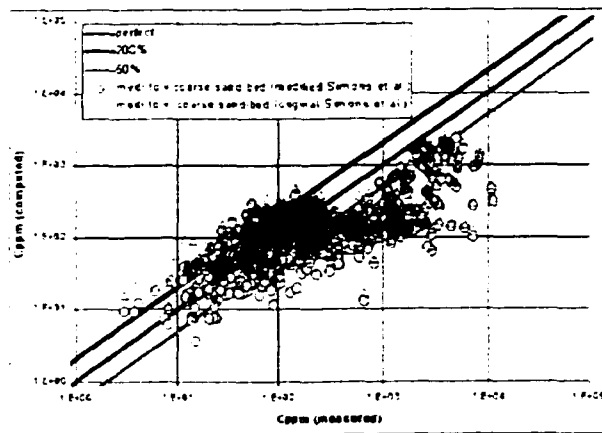
The comparison between original Simons et al. and modified Simons et al. using the data in Group 2 for various river-beds can also be seen in Figure 7.2.



a. Silt-bed rivers



b. Very fine to fine sand-bed rivers



c. Medium to very coarse sand-bed rivers

Figure 7.2. Verification of Equation (6.3) for several diameters of river bed data from Group 2

Table 7.2. Discrepancy ratio and correlation coefficient of original Simons et al. and modified Simons et al. using data in Group 2

	Original Simons et al.		modified Simons et al.	
	$\overline{R_D}$	C_c	$\overline{R_D}$	C_c
silt-bed rivers	0.399	0.258	1.01	0.285
very fine to fine sand-bed rivers	1.281	0.684	1.08	0.6605
medium to very coarse sand-bed rivers	1.364	0.627	0.85	0.6601

7.4. Modified Laursen (1958)

Using the proposed method and data in Group 2 the sediment discharge for each kind of river bed was computed and the results are summarized in the following.

1. Gravel-bed rivers

The relationship between u_* / ω_i and $f(u_* / \omega_i)$ from Meyer-Peter-Muller data for gravel-bed materials is still in the range of the relationship between u_* / ω_i and $f(u_* / \omega_i)$ from data in Group 1 (see Figure 7.3).

However, using Figure 7.3. and trend line analysis in Excel software, Equation (6.24d) can be modified into

$$y = 3.4943 \ln(x) + 4.112 \quad (7.1)$$

with $R^2 = 0.8817$

in which

$$y = \text{Log } f(u_* / \omega_i)$$

$$x = u_* / \omega_i,$$

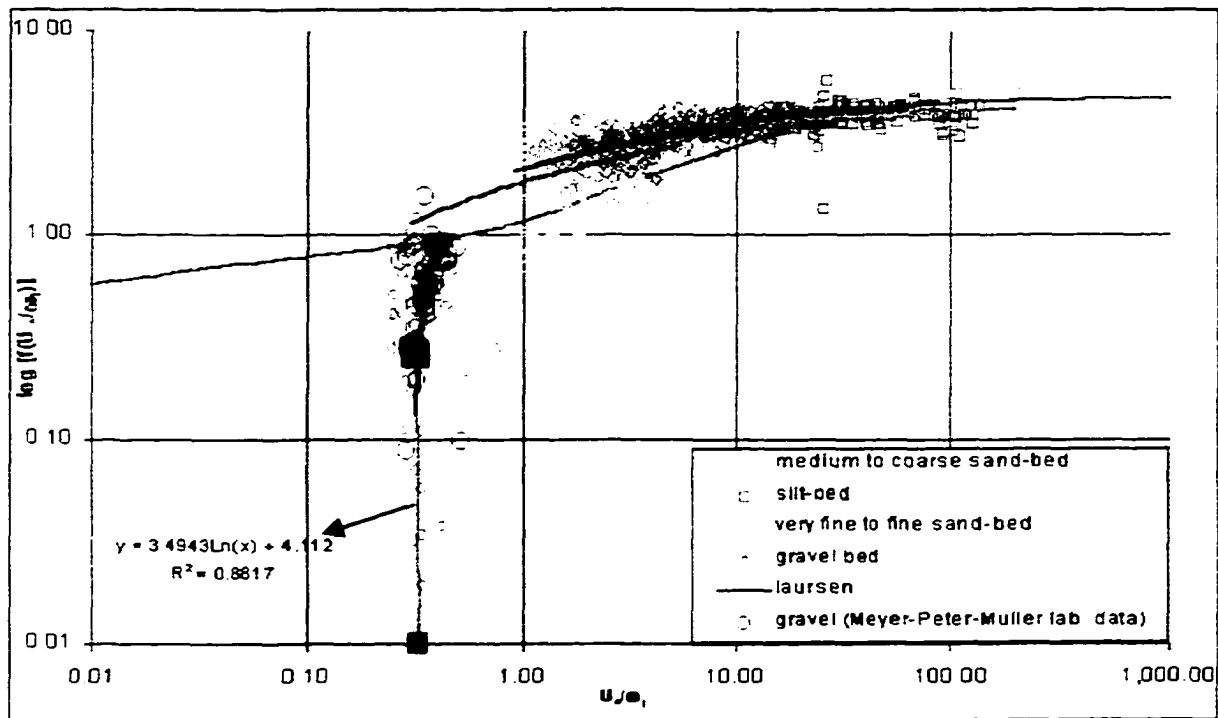


Figure 7.3. Relationships between $u_* \omega_i$ and $\log(u_* \omega_i)$ for gravel-bed rivers (group1) and gravel-bed Meyer-Peter-Muller laboratory data (group2).

Using this equation and Equation (6.26) with variable $a = 0$ {Equation (6.26) is the same as Equation (6.25) or modified Laursen 2 is the same as modified Laursen 1}, comparison of C_{ppm} measured and C_{ppm} computed by modified Laursen was plotted in Figure 7.4.

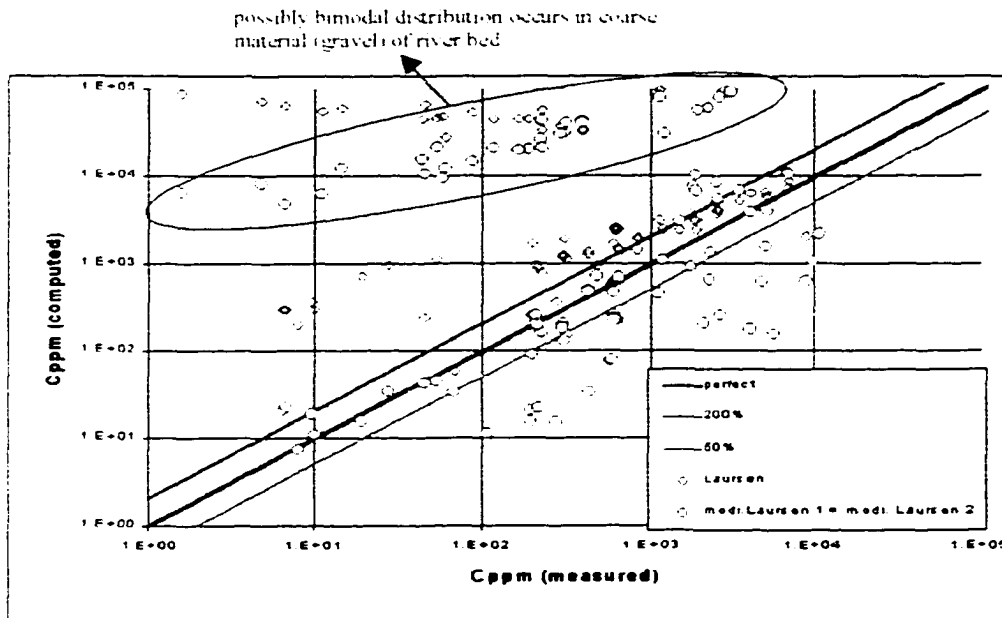


Figure 7.4. C_{ppm} measured and computed using proposed method for gravel-bed rivers using data Group 2

The original Laursen graph produces C_{ppm} computed mostly greater than C_{ppm} measured. The modified Laursen graph as shown in Figure 7.4. shifted the C_{ppm} computed to become closer to the C_{ppm} measured. However, two ranges of values occur when the C_{ppm} computed is compared to C_{ppm} measured. These phenomena possibly due to the fact that although d_{50} is gravel, some sand particles still exist in the river-bed hiding behind the gravel particles in the bed. This condition produces bimodal distribution when the grain size versus probability is plotted, because as stated by ASCE Task Committee (1992), cobble-gravel stream beds are characterized by bimodal distribution: a surficial layer of cobble and gravel overlies a poorly graded mixture of coarse and finer material (sand). This layer is relatively stable during most flows in some stream and some sands move over this layer throughout. Conversely, these phenomena also happen in medium to very coarse sand-bed rivers. Although d_{50} is in the range of sand-bed, some gravel materials still exist.

Accordingly, since only a few data of Group 2 (only lab data) and the occurrence of bimodal distribution, for gravel-bed rivers, further research should be done to develop the best relationship between C_{ppm} measured and computed. The results could be compared to Meyer-Peter and Muller formula since this method was preceded by almost 20 years of experimental work and probably is the most widely used in engineering practise particularly in European countries (Bogardi, 1978; Simons & Senturk, 1992).

2. Medium to very coarse sand-bed rivers

From computation C_{ppm} for data in Group 1 using existing sediment transport relation, Toffaletti are the best with discrepancy ratio of 0.93 (See Figure 4.3 and Table 4.5). Comparisons C_{ppm} measured and C_{ppm} computed using original Laursen, modified Laursen 1, modified Laursen 2 {Equation (6.26) with $a = -0.2$ } and the best existing relation for medium to very coarse sand-bed rivers (Toffaletti, $\overline{R}_D = 0.93$) are shown in Figure 7.5.

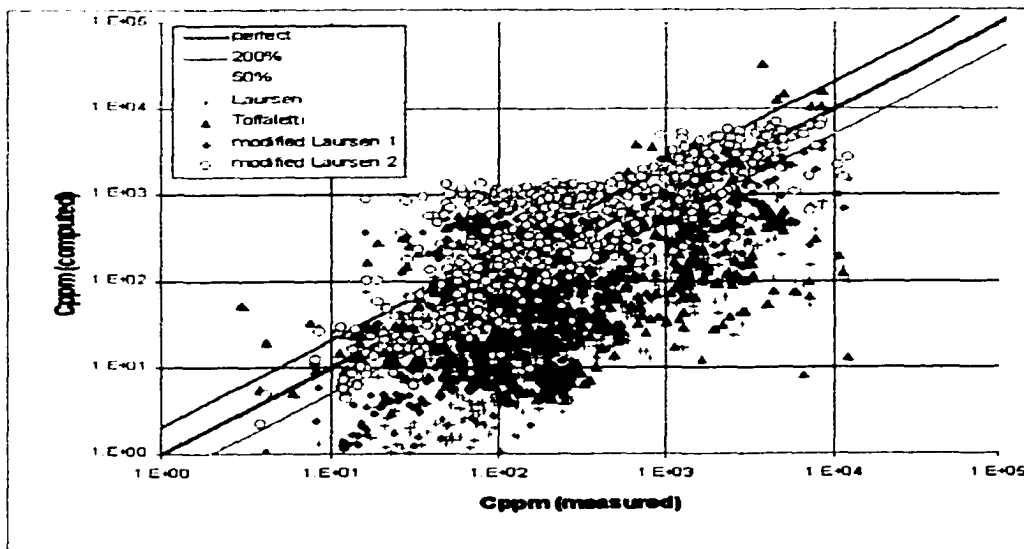


Figure 7.5. Comparison C_{ppm} measured and C_{ppm} computed using original Laursen, modified Laursen 1, modified Laursen 2 and Toffaletti for medium to very coarse sand bed-rivers data in Group 2

The discrepancy ratios between C_{ppm} measured and computed are shown in Table 7.3.

Table 7.3. Discrepancy ratio, \overline{R}_D , between C_{ppm} computed and measured for medium to very coarse sand-bed rivers data in Group 2

	Modified Laursen 1	Modified Laursen 2	Laursen method	Toffaletti
Discrepancy ratio \overline{R}_D	0.98	1.57	0.24	0.89

Although the discrepancy ratio of modified Laursen 2 is greater than modified Laursen 1, visually from Figure 7.5, it seems that modified Laursen 2 is much better than the other methods. This is possibly due to error in measurement causing some results for the comparison to fall outside of the range of good correlation. For example, Brownlie (1981c) reported some field data sets contained a number of errors and Rijn (1982) also mentioned that India Canal data contained a 12 % error in sediment concentration.

Accordingly, for this river-bed modified Laursen 1 or Laursen 2 are recommended to be used.

3. Very fine to fine sand-bed rivers

From computation C_{ppm} for data in Group1 using existing sediment transport relation Karim & Kennedy are the best with discrepancy ratio of 0.90 (See Figure 4.2. and Table 4.3.).

Comparisons of C_{ppm} measured and C_{ppm} computed using original Laursen, modified Laursen 1, modified Laursen 2 {Equation (6.26) with $a = 0.078$ } and the best existing relation for very fine to fine sand-bed rivers (Karim and Kennedy, $\overline{R}_D = 0.90$) are shown in Figure 7.6.

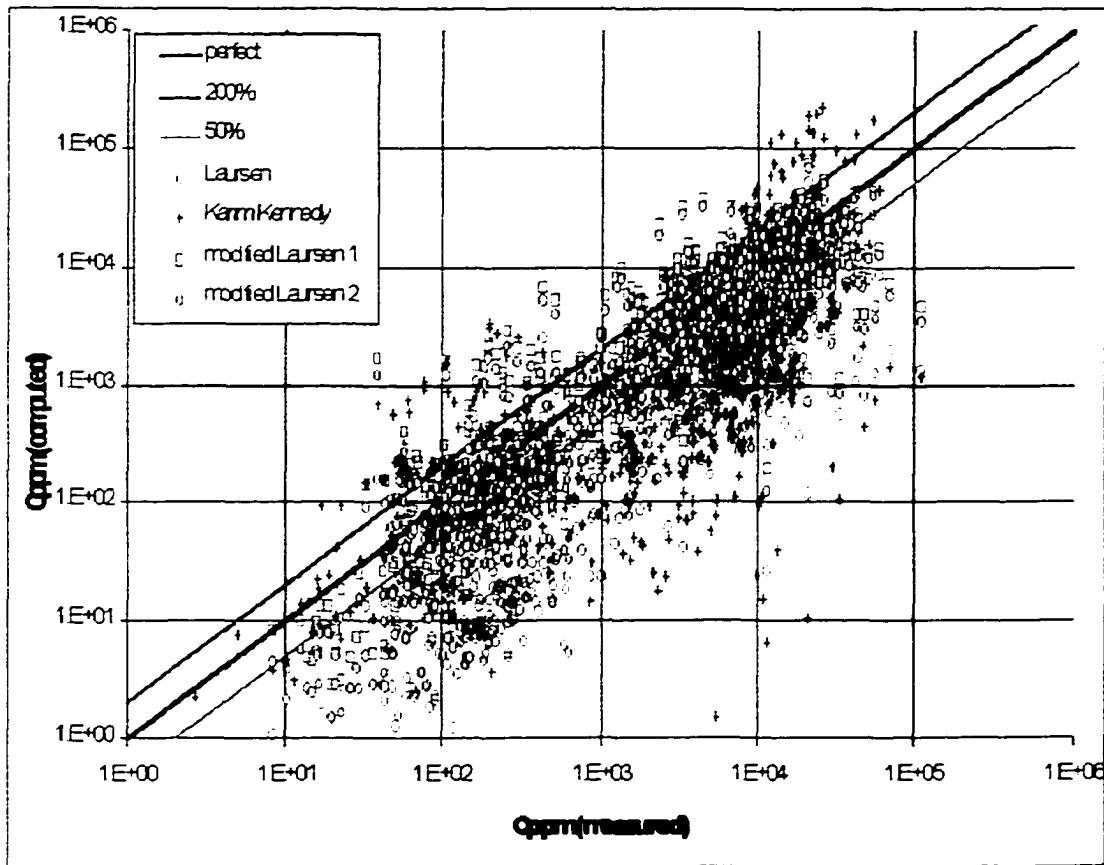


Figure 7.6. Comparison C_{ppm} measured and C_{ppm} computed using original Laursen, modified Laursen 1, modified Laursen 2 and Karim & Kennedy for very fine to fine sand-bed rivers data in Group 2

The discrepancy ratios between C_{ppm} measured and computed are shown in Table 7.4.

Table 7.4. Discrepancy ratio, $\overline{R_D}$, between C_{ppm} computed and measured very fine to fine sand-bed rivers for data in Group 2

	Modified Laursen 1	Modified Laursen 2	Laursen method	Karim & Kennedy
Discrepancy ratio $\overline{R_D}$	1.32	1.01	0.36	1.11

From Figure 7.6 and Table 7.4. it seems that C_{ppm} computed using modified Laursen 2 fits quite well with C_{ppm} measured. Hence, for very fine to fine sand-bed rivers, this proposed modified Laursen can be used.

4. Silt-bed rivers

From the results of computation C_{ppm} for data in Group 1, Einstein is the best with discrepancy ratio of 1.06 (See Figure 4.4 and Table 4.7). Comparisons C_{ppm} measured and C_{ppm} computed using original Laursen, modified Laursen 1 (Equation (6.25)), modified Laursen 2 {Equation (6.26) with $a = 0.06$ } and the best existing sediment transport relation for silt-bed rivers (Einstein) are shown in Figure 7.7.

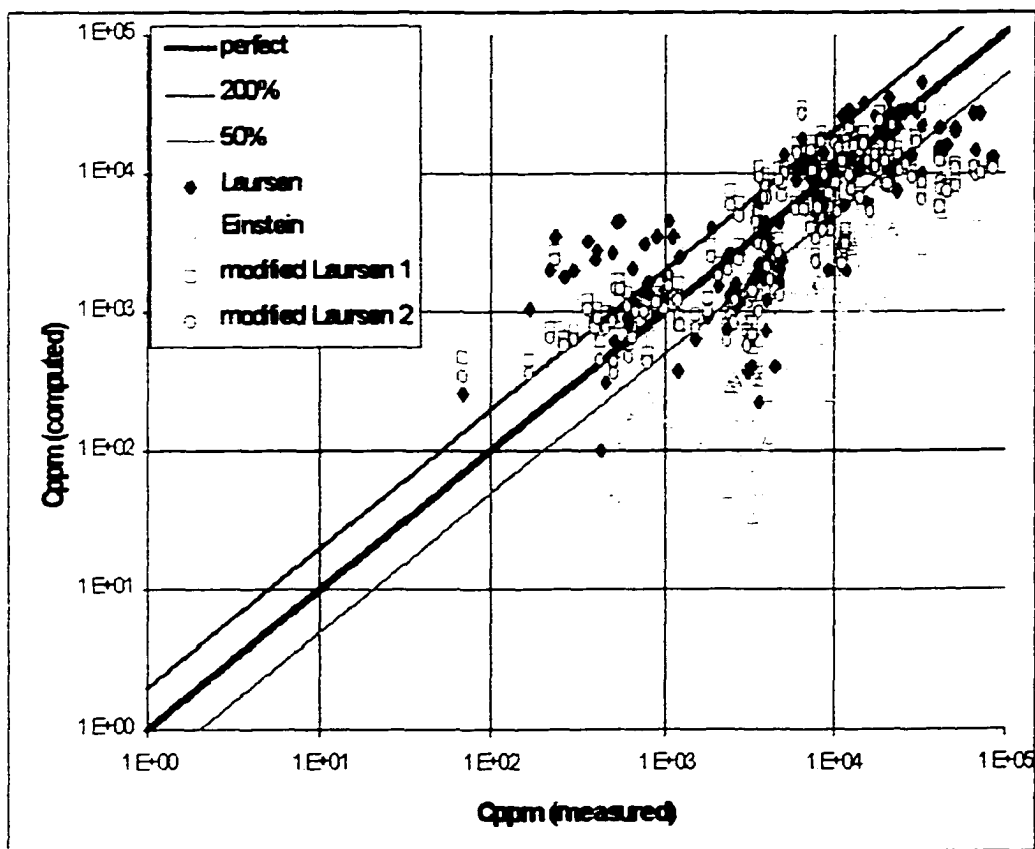


Figure 7.7. Comparison C_{ppm} measured and C_{ppm} computed using original Laursen, modified Laursen 1, modified Laursen 2 and Einstein for silt-bed rivers data in Group 2

The discrepancy ratio between C_{ppm} measured and computed are shown in Table 7.5.

Table 7.5. Discrepancy ratio $\overline{R_D}$ between C_{ppm} computed and measured for silt-bed rivers data in Group 2

	Modified Laursen 1	Modified Laursen 2	Laursen method	Einstein
Discrepancy ratio $\overline{R_D}$	1.17	0.99	1.45	0.50

It is obvious from Figure 7.7 and Table 7.5 that Modified Laursen 2 produces the closest results to the C_{ppm} measured compared to Modified Laursen 1, Laursen method, and Einstein. Hence, for silt-bed rivers, modified Laursen 2 is recommended to be used to calculate the sediment discharge.

5. Channel Size

As stated in the previous chapter the analysis of sediment transport relations is also divided based on channel size into three main categories: small rivers, intermediate rivers and large rivers. From Figure 4.14, the relationships between u_* / ω_i and $f(u_* / \omega_i)$ for these three kinds of channel size from data in Group 1 seem to follow the proposed modified Laursen graph. Validation for this consistency is examined using data in Group 2 for three kinds of channel size. The relationships between u_* / ω_i and $f(u_* / \omega_i)$ from data of Group 2 for these three kinds of channel size are plotted with the Laursen graph and are shown in Figure 7.8.

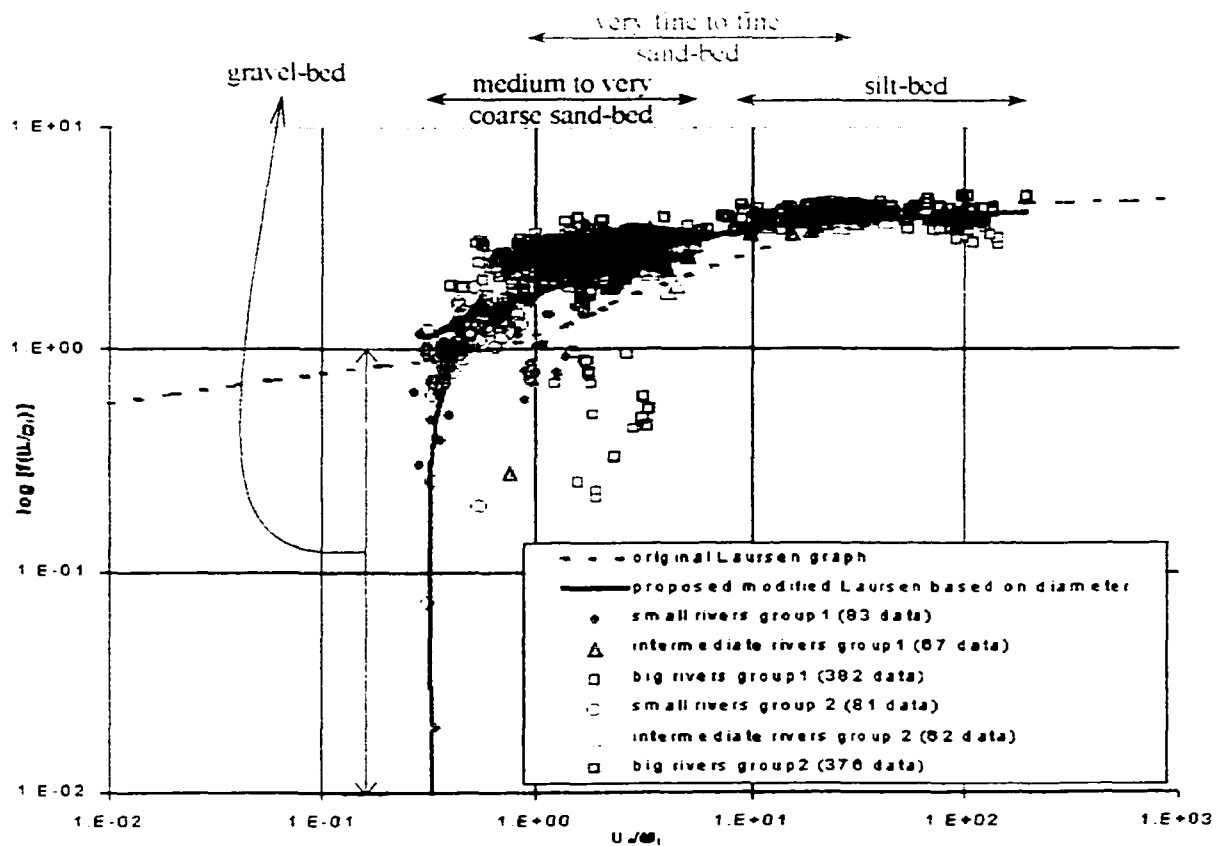


Figure 7.8. Relationships between u^*/ω_i and $\log(u^*/\omega_i)$ for various river size and proposed modified Laursen graph.

From Figure 7.8 it can be concluded that consistency of the relationships between u^*/ω_i and $\log(u^*/\omega_i)$ is quite good for several kinds of river size based on data in Group 2. This figure also shows that for different kinds of mean bed sediment size (from silt to gravel) the proposed modified Laursen graph works well. However, although for gravel-bed the field data and laboratory data tend to have the same values of the u^*/ω_i and $\log(u^*/\omega_i)$ relationships, further research should be done since available data for this river-bed type are not as many as the sand-bed rivers.

7.5. Verification Using Laboratory Data

7.5.1 General

The new proposed methods (modified Posada, Simons et al. and Laursen) were developed for various conditions using field data. However, the applicability of these methods were verified using laboratory data.

For a long time, experiments involving laboratory-scale alluvial channels is an important component of the study of river channel developments, evolutions and geometric forms (Leopold & Wolman, 1957; Wolman & Brush, 1961; and Schumm & Kahn, 1972). However, Dade & Friend (1998) pointed out an important limitation of this approach. When they plotted the relationship of shield parameter (τ_*) and grain Reynolds number (Re_*), note that mixed load and bed load from laboratory data have lower values of Re_* for the same τ_* compared to the same load obtained from rivers.

in which

$$\tau_* = \frac{\rho S d}{(\rho_s - \rho) d_s} \quad (7.2)$$

$$Re_* = \frac{u_* d_s}{\nu} \quad (7.3)$$

in which

ρ = density of water

S = channel slope

d = flow depth

d_s = particle diameter of bed material

u_* = shear velocity

ρ_s = density of solid particle

ν = kinematic viscosity of transporting fluids

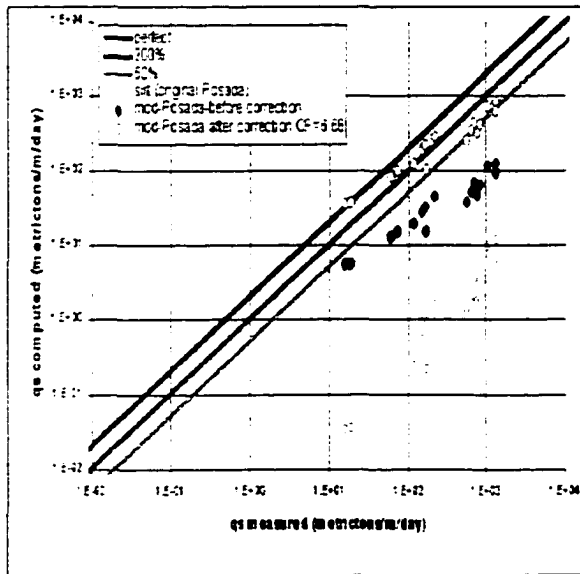
In fact, the form of laboratory scale channels appears to be near critical condition for sediment transport. This difference between experimental and natural channels is due in part to the relatively small Reynolds numbers of laboratory scale. Open channel flows, when Re is less than about 10^4 , do not fully develop the turbulence patterns (Schlichting, 1979). The mixing created by the turbulence is not only responsible for the transfer of momentum and shear, but also for that of suspended matter (Holtorff, 1983; Kikkawa & Ishikawa, 1978).

Brownlie (1981a), during the development of his equation for sediment transport relation, used a coefficient of C_B to distinguish laboratory data and field data, since field data tended to have slightly higher sediment concentration than laboratory for a similar range of dimensionless numbers. The values of C_B for laboratory data and field data are unity and 1.268 respectively. However, no theoretical description is found in his dissertation.

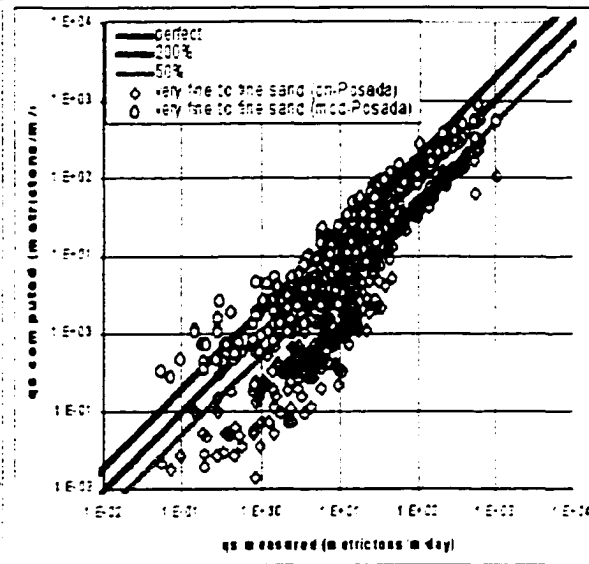
A total of 780 sets of laboratory data from 18 sources (see Sub-chapter 3.3) were used to verify the new methods.

7.5.2 Modified Posada

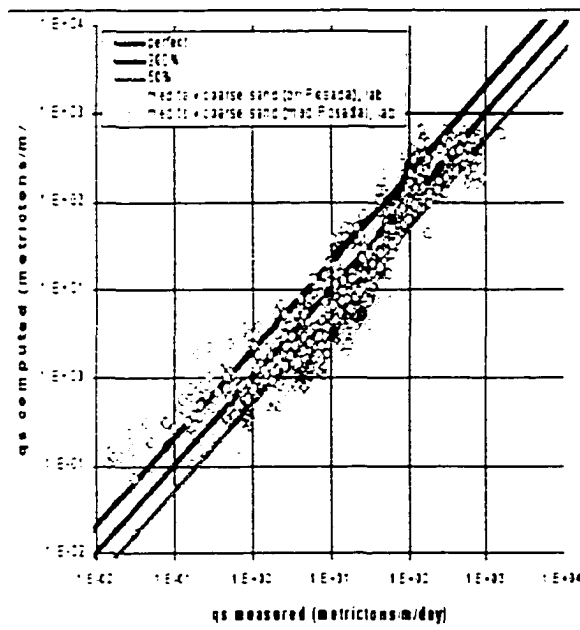
Comparison unit sediment transport discharges q_s , measured and q_s , computed from modified Posada using laboratory data are shown in Figure 7.9 and Table 7.6.



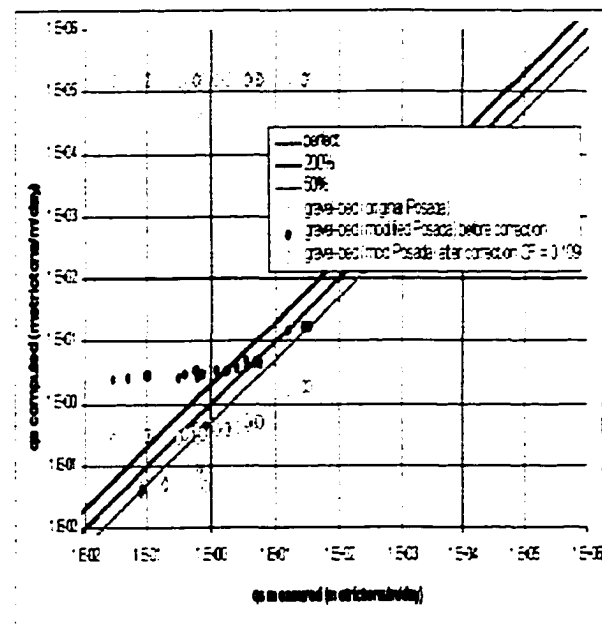
a. silt-bed



b. very fine to fine sand-bed



c. medium to very coarse sand-bed



d. gravel-bed

Figure 7.9. Verification of Modified Posada using laboratory data for several kinds of channel-bed

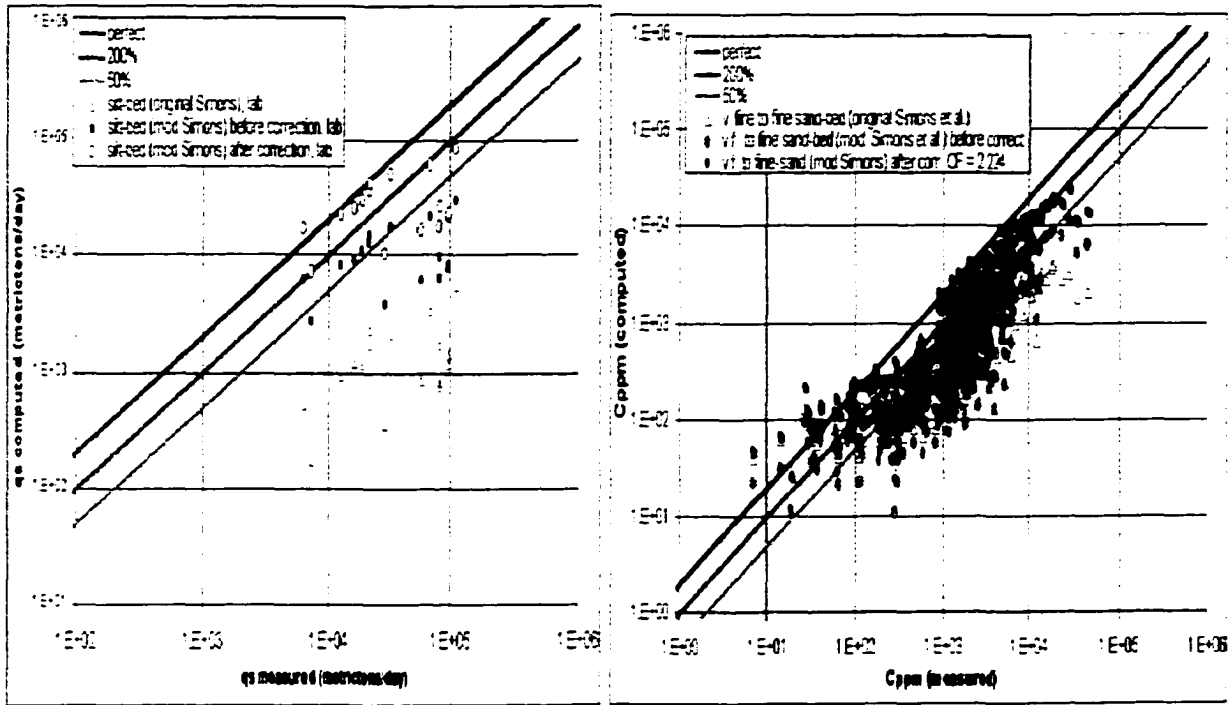
Table 7.6. Discrepancy ratio $\overline{R_D}$ and Coefficient Correlation C_c between q_s computed and measured from Modified Posada using laboratory data

River-bed	Original Posada		Modified Posada without correction Factor		Modified Posada with Correction Factor	
	$\overline{R_D}$	C_c	$\overline{R_D}$	C_c	$\overline{R_D}$	C_c
silt-bed	0.004	0.885	0.150	0.944	1.000	0.944
v. fine to fine sand-bed	0.277	0.890	1.440	0.929	-	-
med to v. coarse sand-bed	1.060	0.755	1.230	0.812	-	-
gravel-bed	too high	0.297	9.150	0.950	1.000	0.950

As shown in Figure 7.9 and Table 7.6, the modified Posada can be applied to the laboratory data. However, a correction factor C_F has to be added for silt-bed data, since as described in Section 7.5.1, the silt-bed channels from laboratory data did not (possibly) develop fully turbulent as the silt-bed data from field data. To increase the discrepancy ratio $\overline{R_D}$ from 0.150 to become 1.00, a value C_F of 6.66 should be added to the Modified Posada for silt-bed channel from laboratory data. No correction factor was needed for the Modified Posada for sand-bed channels from laboratory data. However, for gravel-bed channel a value of 0.109 was added to the Modified Posada.

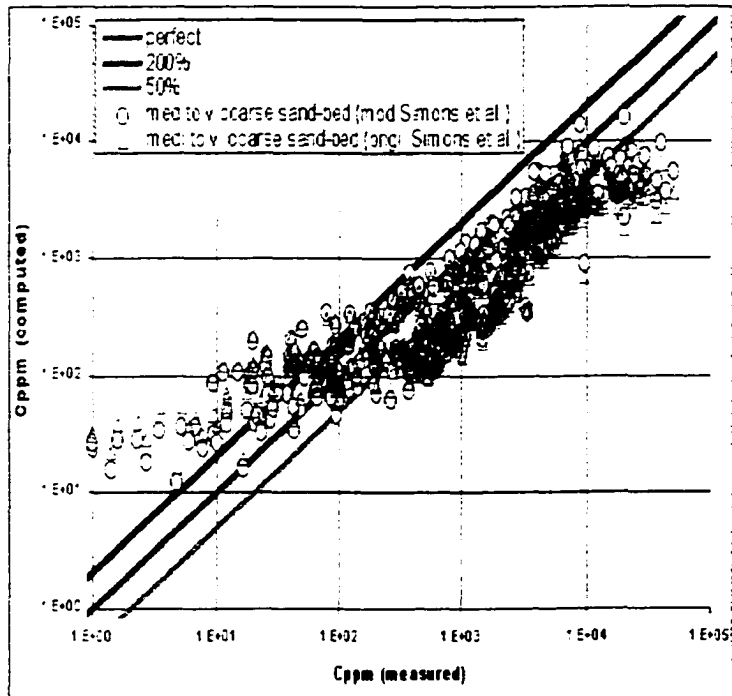
7.5.3 Modified Simons et al.

A comparison sediment transport discharges C_{ppm} measured and C_{ppm} computed from modified Simons et al. using laboratory data are shown in Figure 7.10 and Table 7.7.



a. Silt-bed

b. Very fine to fine sand-bed



c. Medium to very coarse sand-bed

Figure 7.10. Verification of Modified Simons et. al using laboratory data for several kinds of channel-bed

Table 7.7. Discrepancy ratio $\overline{R_D}$ and Coefficient Correlation C_c between C_{ppm} computed and C_{ppm} measured from Modified Simons et al. using laboratory data

River-bed	Original Simons et al.		Modified Simons et al. without correction Factor		Modified Simons et al. with Correction Factor	
	$\overline{R_D}$	C_c	$\overline{R_D}$	C_c	$\overline{R_D}$	C_c
silt-bed	0.044	0.451	0.362	0.314	1.000	0.314
v. fine to fine sand-bed	0.463	0.733	0.450	0.828	1.000	0.828
med to v. coarse sand-bed	1.407	0.704	1.190	0.700	-	-

As shown in Figure 7.10 and Table 7.7, the modified Simons et al. can be applied to the laboratory data. However, a correction factor C_F has to be added for silt-bed data, since as described in Section 7.5.1, the laboratory data silt-bed channels may have fully developed the turbulence patterns as the silt-bed data from field data. To increase the discrepancy ratio $\overline{R_D}$ from 0.362 to become 1.00, a value C_F of 2.761 should be added to the Modified Simons for silt-bed channel from laboratory data and for very fine to fine sand bed channel, to increase the discrepancy ratio $\overline{R_D}$ from 0.450 to become 1.00, value C_F of was 2.224. No correction factor was added to the Modified Simons for medium to very coarse sand-bed channels from laboratory data.

7.5.4 Modified Laursen

The values $f(u_*'/\omega)$ from laboratory data (780 sets of data) seem to follow the theoretical explanation in Section 7.5.1 (see Figure 7.11). The values of $f(u_*'/\omega)$ are less than the values of $f(u_*'/\omega)$ from field data for the same value of u_*'/ω . Correction should be made when the modified Laursen will be used in the experimental lab. Constants of 1.1 and 1.3 as correction factors C_F for silt bed and for sand-bed rivers, respectively, have to be added to laboratory data to achieve the modified Laursen graph. Hence, the correction

factors C_F (Brownlie used C_B) for silt bed and for sand-bed rivers are: $C_F = 1/1.1 = 0.91$ for silt bed rivers and $C_F = 1/1.3 = 0.77$ for sand-bed rivers. These correction factors also indicate that the smaller the bed material diameter the smaller the turbulence because of the more stream lined bed forms.

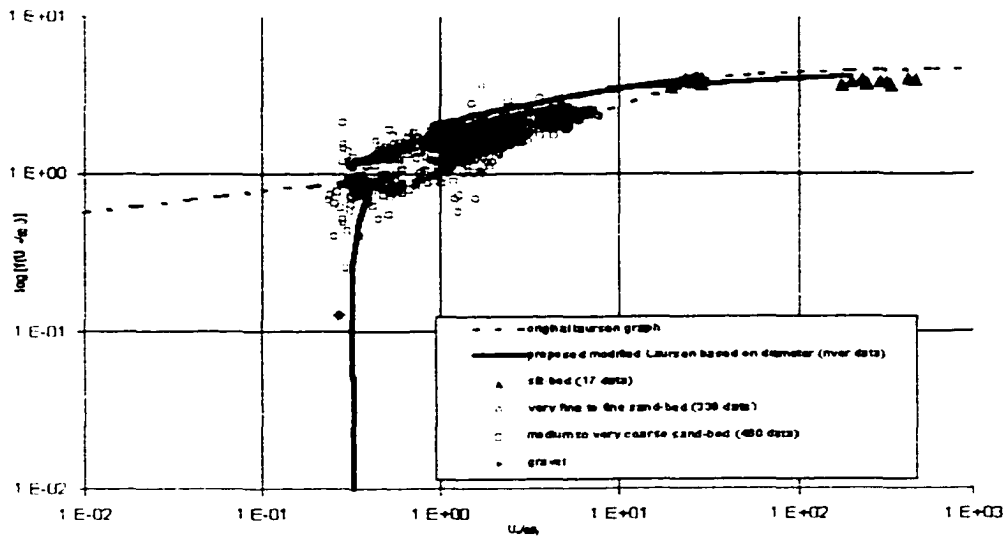


Figure 7.11. Relationships between u/ω_i and $f(u/\omega_i)$ from laboratory data

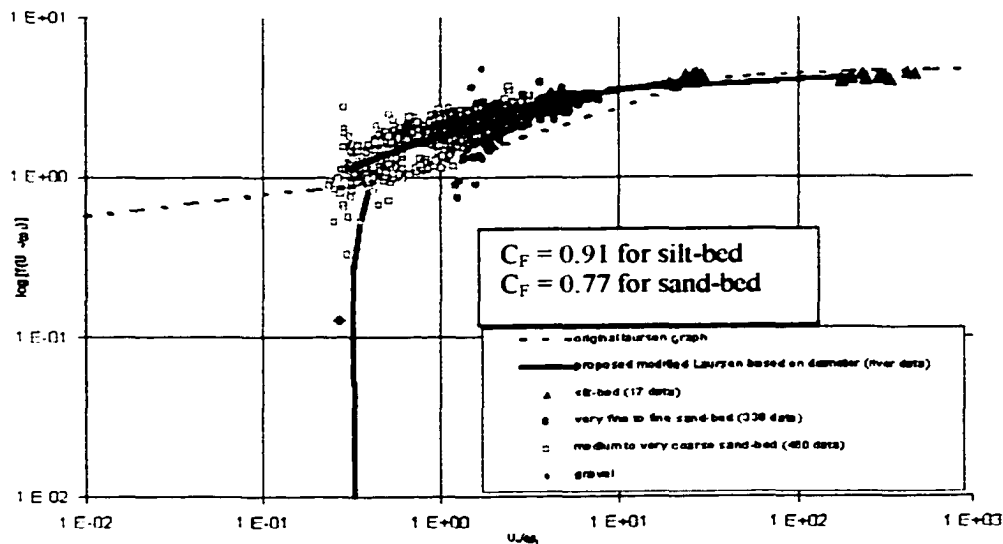


Figure 7.12. Verification and correction for proposed method using various laboratory data (780 sets of data from 18 sources)

A plot of the field data and lab data after correction of the relationships u_*'/ω and $f(u_*'/\omega)$ into the Laursen graph shows that the modification laboratory data seems to fit quite well with the laboratory data for several kinds of river-beds (see Figure 7.13).

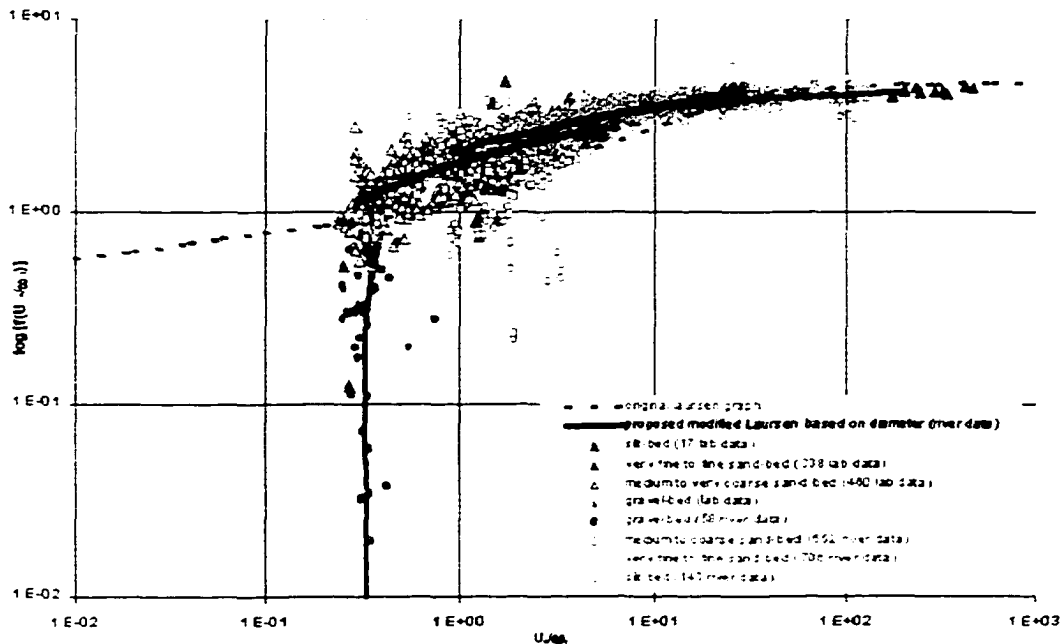


Figure 7.13. Comparison of field and modified laboratory data for the relationship between u_*'/ω and $f(u_*'/\omega)$ for several kinds of river-bed.

Comparison C_{ppm} measured and C_{ppm} computed for several diameters of river-bed material using laboratory data are shown in Figure 7.14. Simons (1957) were also used in this comparison. Simons (1957) data were very carefully collected on straight and uniform sections with very good weather condition. Although the data were very limited (only 12 sets of data) but they were the most accurate field data (Albertson, 1999).

Figure 7.14 shows that laboratory and Simons (1957) data seem to fit quite well with the new proposed method based on modification of Laursen for several kinds of river-beds (see also Figure 7.13).

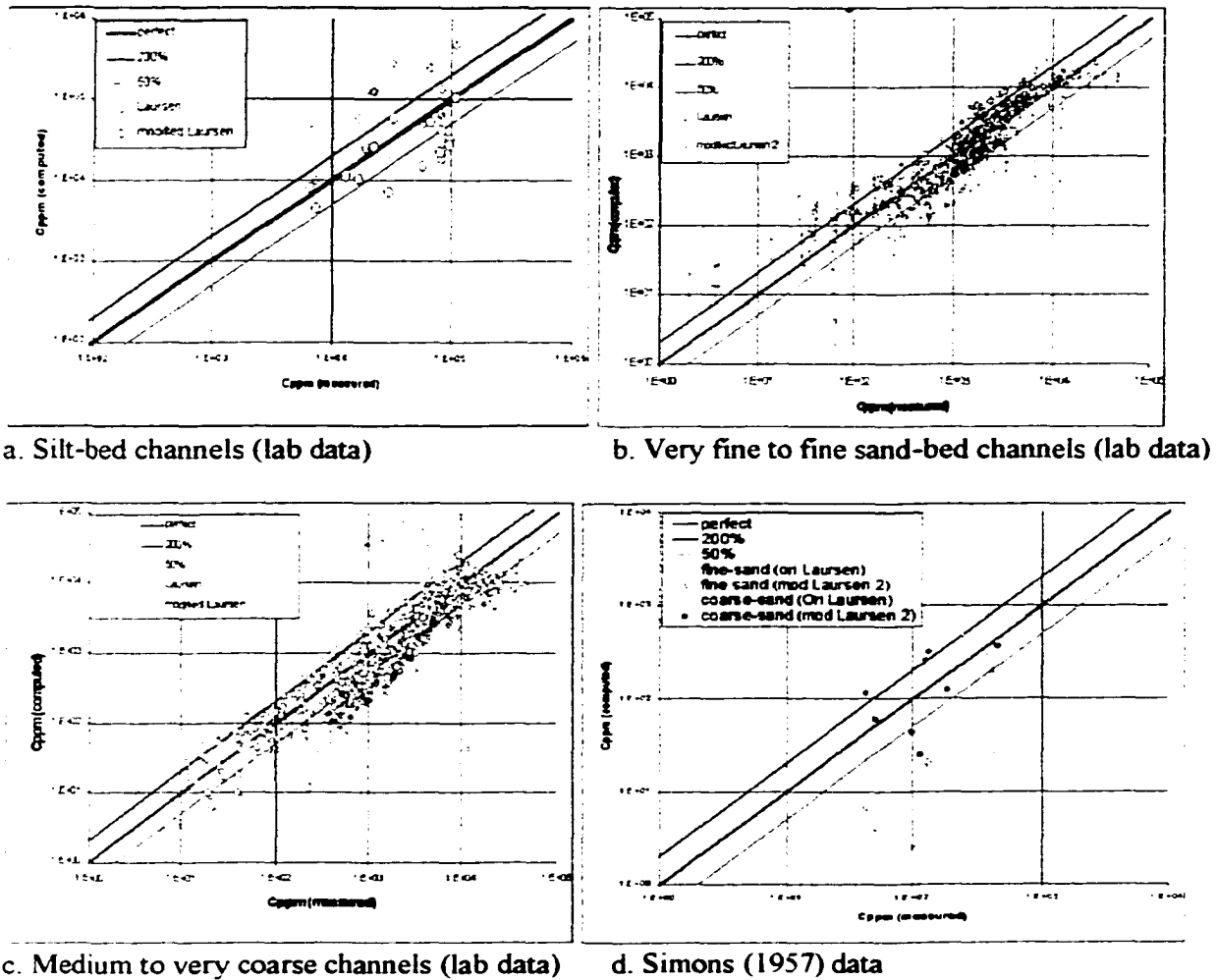


Figure 7.14. Comparison between C_{ppm} measured and original Laursen and comparison between C_{ppm} measured and C_{ppm} modified Laursen for several diameters of river-bed material using laboratory data and Simons (1957) data

7.6. Bedform

The bed configuration in alluvial channels can be divided into two sub divisions, including lower regime and upper regime based on the shape, resistance to flow and mode of transport (Simons & Richardson, 1966). The bed configuration that may form in alluvial channel in the lower regime includes: plane bed without sediment movement, ripples, dunes, washout dunes or transition. The bed configuration that may form in

alluvial channel in the upper regime includes: plane bed with sediment movement, antidune standing waves, antidune breaking waves, chutes and pools. Alluvial channels under quasi-steady conditions will adopt some definite bed configuration that dominates on the magnitude of hydraulic resistance and naturally this resistance would vary with the changes in the bed. (Engelund, 1966; Garde & Rangaraju, 1966).

The antidune is the characteristic of the bed formation and the transition from fully suspended flow to flow with a bed formation for supercritical flow of sand-water mixtures (Ansley, 1965). Different bed form in alluvial channels has been considered as an instability factor in a flat bed flow (Hill et al., 1969). Their experimental results show that the flow depth has no effect on the value of critical shear stress at which the flat bed becomes unstable. The turbulence phenomena in rivers may still be the instigator of the development of bed form (Vanoni & Brooks, 1957). If the bed Reynolds number ($u \cdot d / \nu$) reduces, the frequency of eddies to penetrate the bed decreases. However, the laminar sublayer never becomes a perfect insulator.

Accordingly, flow regime (bed configuration) at least should be considered in the development of sediment transport relations in alluvial streams (Garde & Albertson, 1958; Bishop et al., 1965, and Albertson, 1999).

In verification of the proposed method the flow regime should be included. However, from the 33 river data only 5 river systems were observed with regard to flow regime: American Canals collected by Simons (1957), Pakistan Canals collected by Mahmood et al. (1979), Rio Grande Conveyance Channel, the Niobrara River, and the Hii River. In American Canals, Pakistan Canals, Rio Grande Convey and the Niobrara

River the bed forms were dunes, transition and plane bed with sedimentation. The bed forms in the Hii River, however, were only ripples and dunes.

American Canals consist of only 12 data. Pakistan Canals consist of 142 data, but the data with bed form observed were only 30 sets of data. The Rio Grande Conveyance Channel consists of only 9 sets of data. Data of Niobrara River were 40 sets and the Hii River consists of 38 sets of data. Hence, the total field data with bed form observation were 139 sets. Additionally, laboratory studies with a total of 780 sets of data from 18 sources were selected. These data were described in detail in Section 3.3.

The comparison of C_{ppm} measured and C_{ppm} computed using modified Laursen 2 for each bed form condition is shown in Figure 7.15.

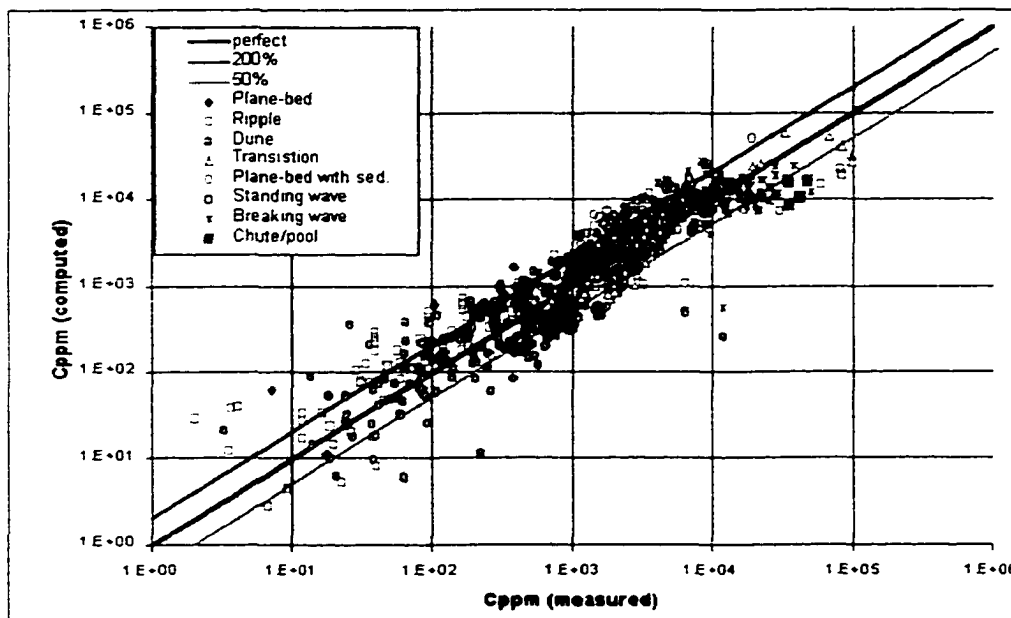


Figure 7.15. Comparison between C_{ppm} measured and C_{ppm} computed by modified Laursen 2 for several bed-forms using 780 sets of laboratory data.

From this figure it can be concluded that the C_{ppm} computed tends to increase from plane bed to transition in the lower regime. However, in ripple some values has

C_{ppm} computed quite high. In the upper regime the C_{ppm} also has a tendency to increase from plane bed with sediment movement to chute (or pool). However, some values of C_{ppm} in ripples (lower regime) are higher than C_{ppm} in chute (or pool) zone.

Considering the conditions of bed forms in term of lower regime and upper regime Figure 7.16 shows the comparison C_{ppm} measured and C_{ppm} computed by modified Laursen 2 for lower regime and upper regime. From Figure 7.16, the distinction between lower and upper for both methods is quite clear. For both methods, the lower regime mostly has lower value of C_{ppm} than the upper regime. The treshhold between the upper regime and the lower regimes lies on sediment concentration of about 1000 C_{ppm} . This value agrees with what Watson et al. (1998) have observed. A substantial increase in stability is found as disturbed channels evolve to sediment transport capacity less than about 1,000 – 1,200 ppm in a severely incised sand bed in northern Mississippi.

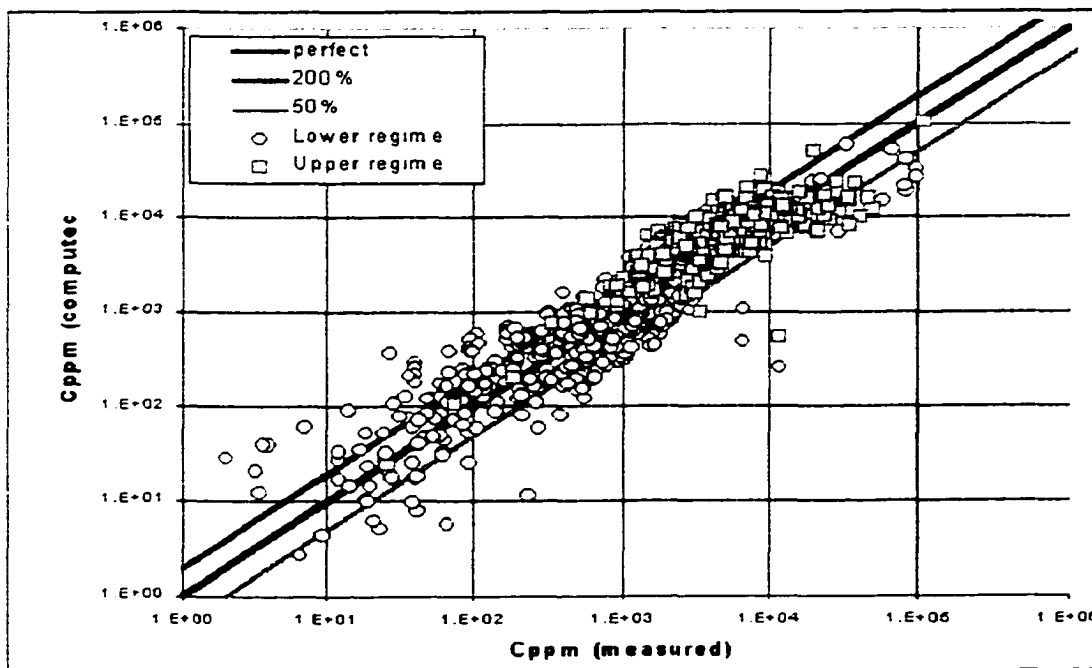


Figure 7.16. Comparison between C_{ppm} measured and C_{ppm} computed by modified Laursen 2 in the lower and upper regimes using laboratory data

Plotting slope versus sediment concentration (Figure 7.17.) indicates that beyond a slope of $S = 0.006$, only upper regime exists. At sediment concentration about 1.000 ppm mixed conditions between lower regime and upper regime occur. Accordingly, the sediment concentration can also be related to a threshold of specific stream power, S_{pc} , which is defined as $S_{pc} = \gamma QS/w$ (Bledsoe, 1999).

When the slope S versus grain Froude number F_g are plotted (Figure 7.18), the results of flow regimes mostly agree with the Brownlie data as plotted in Figure 2.12. Plane bed without sediment, ripples and dunes that characterize the lower flow regime occur below the line of F_g^* . Antidunes and chutes/pools that characterize the upper flow regime lie above the line.

The transition zone exists between washout dunes to plane bed with sediment transport (Simons and Richardson, 1966). These two kinds of bed configuration as shown in Figure 7.18, mostly follow the line of F_g^* . However, some values of plane bed with sediment transport are much below of the line.

The shift from lower to upper regime represents an abrupt and significant decrease in bed roughness, with a corresponding decrease in depth, and increase in flow velocity and sediment transport (Bledsoe, 1999).

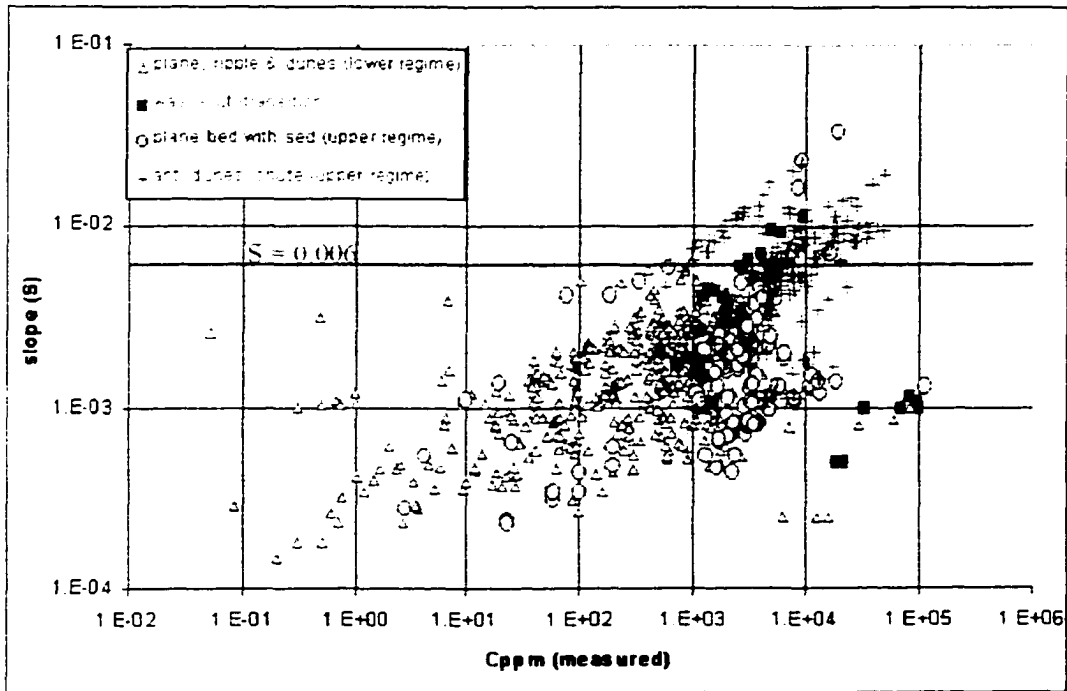


Figure 7.17. Slope versus sediment concentration C_{ppm}

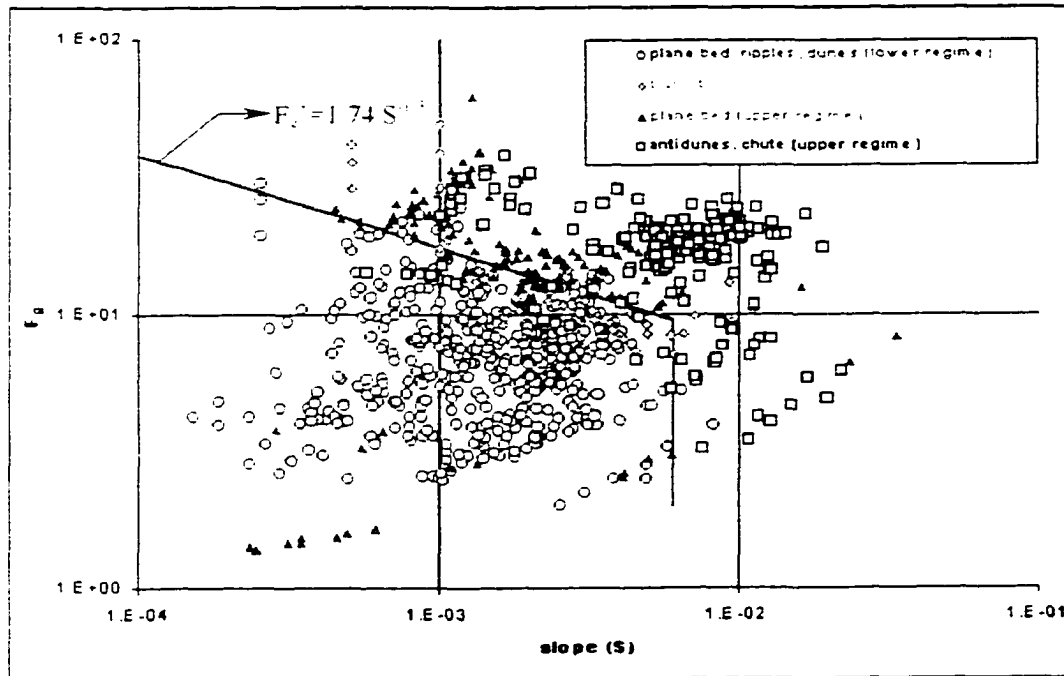


Figure 7.18. Determination of flow regime – grain Froude number F_g plotted versus slope (S) using laboratory data

Chapter 8

CONCLUSIONS

8.1. General

In this dissertation, new methods for predicting the sediment transport rates of bed-material in alluvial channels are presented. The proposed methods were developed based on the Posada method (1995), the Simons et al. method (1981), and the Laursen method (1958).

A total of 33 river systems including rivers in the USA, South America and Asia with a total of 4532 sets of data (after compilation, 2946 sets of data) were used. The summary and range of field data include:

Table 8.1. Summary of Field Data

Parameter	min	max
Discharge (m ³ /s)	0.064	557,445
Width (m)	1	3,338
Flow depth (m)	0.04	68
Flow velocity (m/s)	0.21	9.25
Mean bed diameter (mm)	0.005	76.113
Slope	0.000002	0.0126
Temperature (°C)	0	36
Transported sediment (C _{ppm})	0.1	482,409
Range of bed form	ripple	plane bed upper regime

Note: Bed form was observed only in 5 canals and rivers including American, Pakistan Canals, and Rio Grande Conveyance Channel and the Niobrara and the Hii Rivers.

The data were divided into two groups in random order; one for analysis and development of new methods and the other for verification and validation.

Additionally, 919 sets of laboratory data from 19 sources were selected to verify the proposed methods. The laboratory data are summarized as follows:

Table 8.2. Summary of Laboratory Data

Parameter	min	max
Discharge (m ³ /s)	0.001	4.614
Width (m)	0.267	2.438
Flow depth (m)	0.008	1.092
Flow velocity (m/s)	0.188	5.547
Mean bed diameter (mm)	0.011	28.60
Slope	0.00015	0.03310
Temperature (°C)	1.67	48.00
Transported sediment (C _{ppm})	0.0036	110,998.8
Bed form	plane bed without sed.	chute or pools

8.2. Ten Sediment Transport Relations

First, the 10 sediment transport relations were used to calculate the sediment transport rates for gravel-bed rivers, medium to very coarse sand-bed rivers, very fine to fine sand-bed rivers and silt-bed rivers. These relations were also used to compute the sediment transport rates for small rivers (width ≤ 10 m and depth ≤ 1 m), intermediate rivers (10 m < width ≤ 50 m and 1 m < depth ≤ 3 m), and large rivers (width > 50 m and depth > 3 m). The following conclusion can be drawn from the results of computational sediment discharge (C_{ppm}):

1. Gravel-bed rivers (2 mm < d_s < 64 mm)

Compared to the measured values, none of the selected sediment relations can accurately predict the sediment discharge. The closest values based on the discrepancy ratio are Ackers & White ($\overline{R_D}=0.33$) and Brownlie ($\overline{R_D}=4.25$). However, based on the

Pearson correlation coefficient for computed to measured C_{ppm} , the best are Bagnold and Shen & Hung, both with C_c of 0.70 (see Table 4.2). On the other hand, as indicated in Figure 4.1., although Brownlie was developed for sand-bed rivers, it has the closest value to C_{ppm} measured. Hence, for gravel-bed rivers, it is difficult to decide which method is the best.

2. Medium to very coarse sand-bed rivers ($0.250 \text{ mm} < d_s < 2.00 \text{ mm}$)

Toffaletti ($\overline{R_D}=0.93$), and then Laursen ($\overline{R_D}=0.60$) and Bagnold ($\overline{R_D}=1.68$) are the closest to the C_{ppm} measured. However, based on the Pearson correlation coefficient Karim ($C_c = 0.66$) followed by Brownlie ($C_c = 0.60$) have the highest values compared to measured values. Visually, the best relations are shown in Figure 4.8.

3. Very fine to fine sand-bed rivers ($0.062 \text{ mm} < d_s < 0.250 \text{ mm}$)

Karim & Kennedy ($\overline{R_D}=0.90$), followed by Karim ($\overline{R_D}=1.28$) are the closest to the C_{ppm} measured. On the other hand, as shown in Table 4.4., Brownlie ($C_c = 0.58$) and Toffaletti ($C_c = 0.52$) have the highest correlation to the C_{ppm} measured. Visually, the best relations are shown in Figure 4.9.

4. Silt-bed rivers ($0.004 \text{ mm} < d_s < 0.062 \text{ mm}$)

Einstein ($\overline{R_D}=1.06$) and Bagnold ($\overline{R_D}=0.56$) have the closest results to the C_{ppm} measured. However, as shown in Table 4.8., Toffaletti ($C_c = 0.48$) and Brownlie ($C_c = 0.38$) have the closest correlation to the C_{ppm} measured. Visually, the best relations are shown in Figure 4.10.

5. Small rivers (width \leq 10 m and depth \leq 1 m)

Brownlie ($\overline{R_D}=1.18$) and Karim ($\overline{R_D}=1.19$) give the closest results. However, as shown in Table 4.10., Yang ($C_c = 0.85$) followed by Toffaletti ($C_c = 0.79$) have the highest correlation to the C_{ppm} measured.

6. Intermediate rivers (10 m < width \leq 50 m and 1 m < depth \leq 3 m)

Toffaletti ($\overline{R_D}=0.94$) and Brownlie ($\overline{R_D}=0.94$) are the closest to the C_{ppm} measured. However, from Table 4.12., Karim ($C_c = 0.76$) followed by Yang ($C_c = 0.70$) have the highest correlation to the C_{ppm} measured.

7. Large rivers (width > 50 m and depth > 3 m)

Bagnold ($\overline{R_D}=1.04$) and Laursen ($\overline{R_D}=1.13$) have the closest results to the C_{ppm} measured. However, from Table 4.14., Brownlie ($C_c = 0.80$) and Shen & Hung ($C_c = 0.76$) have the highest correlation to the C_{ppm} measured.

It should be noted that for silt-bed rivers and for very fine to fine sand-bed rivers, the Yellow River contributes about 77 % and 63 % of the data, respectively. As reported by many authors, this river is an extremely heavily sediment-laden river and floods at hyperconcentrations of sediment frequently occur. Accordingly, the characteristics of hydraulic geometry and sediment will not be the same as in the case of common alluvial rivers.

From Table 4.15. it can be seen that both Ackers & White and Toffaletti have a tendency to increase the C_{ppm} as the mean diameter of river becomes finer. This tendency

also occurs when river size increases. The applicability the selected sediment transport relations based on comparison between measured and computed sediment transport rates by previous authors and the results analyzed in this study is summarized in Table 5.3b.

8.3. New Proposed Methods

8.3.1 Based on Modification of Posada Method (1995)

In a comparison to measured value the proposed method expressed in Equation (6.1) and Table 6.4 gives best prediction for the data in Group 1 (see Table 6.5 and Figure 6.2b). The proposed method is also considerably improved over existing relationships when it was verified by data in Group 2 (see Table 7.1 and Figure 7.1).

8.3.2 Based on Modification of Simons et al. Method (1981)

Compared to measured value, the new proposed method expressed in Equation (6.3) and Table 6.7 gives best prediction for the data in Group 1 (see Table 6.7 and Figure 6.3). The proposed method is also considerably improved over existing relationships when it was verified by data in Group 2 (see Table 7.2 and Figure 7.2). Although Simons et al. was obtained under supercritical flow and for steep sand and gravel-bed rivers, the proposed method can be applied to sub-critical flow for various sand-bed and silt-bed rivers.

8.3.3 Based on Modification of Laursen Method (1958)

The Laursen method was modified in both the Laursen graph and Laursen equation. The Laursen graph was modified and expressed in Figure 7.8. for various river-beds and channel sizes. The Laursen equation was modified and expressed in Equation

(6.25) (so-called modified Laursen 1) and in Equation 6.26 (so-called modified Laursen 2) with Table (6.12).

Based on comparisons of the new proposed Laursen graph to Laursen graph modified by Madden (1985) and Copeland (Copeland and Thomas. 1989) as expressed in Figure 5.20, some conclusions can be drawn:

□ Gravel-bed rivers

Only the new proposed and Copeland graphs plotted the Laursen's functional relation. However, the new proposed produce smaller of $f(u_* / \omega_i)$ for the same value of u_* / ω_i than the Copeland graph, although both are parallel.

□ Sand-bed rivers

all modifications produce considerably higher values than the Laursen graph. However, the proposed method is plotted more specifically according to particle size ranging from very fine sand to very coarse sand-bed rivers.

□ Silt-bed rivers

Only the new proposed Laursen graph plotted the Laursen's functional relation for this kind of river-bed with values lower than the original Laursen graph.

The modification of Laursen by Madden and Copeland produced a modified equation but still using size fraction. However, the new proposed method is simpler because it uses uniform bed particle, d_{50} , (no size fraction) for the whole flow depth.

Although the new proposed methods produce best results compared to other methods, errors in estimation of sediment transport load can be as large as one order of magnitude (Julien, 1999). This is due to the complexity of parameters and variables involved in sedimentation.

These three new proposed methods indicate that using a wider range of data it may also be possible to modify the other sediment transport relations.

8.4. Laboratory Data

Modified Posada can be applied in the laboratory data with correction factors C_F of 6.66 for silt-bed streams, no correction for sand-bed streams and 0.109 for gravel bed.

Modified Simons et al. can be applied in the laboratory data with correction factors C_F of 6.66 for silt-bed streams, 2.224 for very fine to fine sand bed channels and no correction factor for medium to very coarse sand-bed channels.

Modified Laursen can be applied in the laboratory data with correction factors of 0.91 for silt-bed streams and 0.77 for sand-bed streams. No correction factor is added into the gravel-bed channels.

8.5. Bedform

From Figure 7.15, it can be concluded that in the lower regime the C_{ppm} computed tends to increase from plane bed to transition. However, in the ripple zone some values have C_{ppm} computed quite high. In the upper regime the C_{ppm} also has a tendency to increase from plane bed with sediment movement to chute (or pool). From Figure 7.16, it can be concluded that the lower regime mostly has lower values of C_{ppm} than the upper regime.

The threshold between the upper regime and the lower regimes lies on sediment concentration of 1,000 C_{ppm} . Accordingly, the sediment concentration can also be related

to a threshold of specific stream power, ω . Plotting slope versus sediment concentration (Figure 7.18) indicates that beyond a slope of $S = 0.006$, only upper regime exists.

8.6. Overall Conclusions

Some major contributions of the present research were developed from a wide range of field and laboratory data. These contributions are:

- The applicability of the ten sediment transport relations in various river beds and channels sizes.
- The study also indicates that there is no universal sediment transport equation available for all conditions, including various river-beds and river sizes.
- This study shows the modifications of Posada (1995), Simons et al. (1981) and Laursen (1958) methods. Although a wide variety of field data were used and the new proposed methods produce better results compared to other methods. However, errors in estimation of sediment transport load can be as large as one order of magnitude.
- Eventhough the modifications were developed using field data, they can be also applied in the laboratory by adding a correction factor.
- The new proposed methods indicate that using a wider range of data it may also be possible to modify other sediment transport relations.

Chapter 9

RECOMMENDATIONS

Some recommendations can be drawn from this study:

1. Applicability of the new proposed methods in the present study should be tested for a wider range of sediment conditions, especially for gravel-bed and silt-bed rivers. The results for gravel-bed rivers could be compared to Meyer-Peter and Muller.
2. Since the Yellow River, with hyper-concentrations of sediment, dominates the data for fine-sand to silt-bed rivers, further research related to hyper-concentrations of sediment of this kind of river-bed should be conducted.
3. Selection of parameters to evaluate sediment transport models in terms of accuracy and validation should be conducted.
4. This study does not include the effect of water temperature. As stated by Hong et al., 1984, temperature changes from 30° C to 15° C has no effect on the sediment discharge. However, the effect will become more pronounced with further temperature decrease. About 40 % of the data involve temperatures lower than 15° C. Accordingly, further research should be conducted on sediment transport relations involving water temperature especially for this range of data.

5. Since field data are used as the data base for developing new sediment transport relations, improvement and refinement of the procedures of measurement for practical purposes should be done to obtain more accurate field data.
6. Modification can also be applied for any sediment transport equation using a wider range of data. Therefore, for engineering purposes, the steps of sediment transport analysis are as follows (Simons & Senturk, 1992, also strongly recommended by Simons, 1999):
 - Examine the available transport equations and determine which ones are best for a specific river system.
 - Calculate the rates of transport using selected relationships and compare the results with field data.
 - Select the relationship which best agrees with field observations and if data are available, refine and modify this relationship so that it is site specific.
 - If the river will be used for very important purposes, such as dams, navigation, etc., additional field observation should be conducted so that the chosen sediment transport relation could be extended to a wider range of flow conditions.
7. Most sediment transport relations have been developed under the condition of steady uniform flow, but, research on the condition of unsteady flow is fairly limited (McDowell, 1989; Song & Graf, 1997). The basic equations for unsteady flow can be derived from the equation of motion of sediment-laden water, continuity for sediment and continuity for water (Chang & Richards, 1971; Lyn, 1987; Palaniappan et al., 1998). Increased research should be conducted for this condition.

8. Research should be conducted for predicting total bed material transport rate for several kinds of river-bed with more data especially on gravel-bed and silt-bed rivers.
9. Since flow regime should be considered in the development of sediment transport relations in alluvial streams and mostly only laboratory data have been used for verification, investigation should be conducted with more field data on bed configuration.

References

1. Ackers, P., 1972. *Sediment Transport in Channels: An Alternative Approach*. Hydraulic Research Station, Wallingford.
2. Ackers, P., and White, W.R., 1973. *Sediment Transport: New Approach and Analysis*. J. Hyd. Div. ASCE, 99, no. HY11:p. 2041-60.
3. Ackers, P., and White, W.R., 1980. *Bed Material Transport: a Theory for Total Load and Its Verification*. Proc. of the Int. Symp. On River Sed., ed. By the Chinese Society of Hydraulic Eng. Vol.. I, Beijing
4. Albertson, Maurice L., October 1999. *Personal Communication*. Engineering Research Center, Colorado State University.
5. Alonso, C.V., Neibling, W.H., and Foster, G.R., 1982. *Estimating Sediment Transport Capacity in Watershed Modeling*. Transactions, American Society of Agriculture Engineering, Vol. 24, No. 5, p.1211-1220 and 1260.
6. Andrews, E.D., 1983. *Entrainment of Gravel from Naturally Sorted River-bed Material*. USGS, Geological Society of America Bulletin, Vol. 94, p. 1225-31.
7. Ansley, Ralph W., 1965. *Sediment Transport in Supercritical Flow*. J. Hyd. Division, Vol. 91, No. HY6 p. 57-65.
8. ASCE Task Committee for the Preparation of the Manual on Sedimentation of the Sed. Committee of the Hydraulics Div., 1971a. *Sedimentation Engineering*. Ed. Vito A. Vanoni. Headquarters of the Society ASCE, New York.
9. ASCE Task Committee of the Hyd. Div., 1971c. *Sediment Transportation Mechanics: H. Sediment Discharge Formulas*. J. Hyd. Division., Vol. 97, No. HY4 p.523-567.

10. ASCE Task Committee of the Hyd. Div., 1971b. Sediment Transportation Mechanics: F. Hydraulic Relations for Alluvial Streams. J. Hyd. Division., Vol. 97, No. HY1 p.101-141.
11. ASCE Task Committee on Sediment Transport and Aquatic Habitat. Sed. Committee, 1992. Sediment and Aquatic Habitat in River Systems. J. Hyd. Eng., Vol. 118, No. 5. p. 669-687.
12. Ashida, K., and Michiue, M., 1973. Study on Bed Load Transport Rate in Open Channel Flows. International Symposium on River Mechanics. IAHR, Bangkok, Thailand. p. A36-1-12.
13. Bagnold, R.A., 1966. An Approach to the Sediment Transport Problem from General Physics. Professional Paper 422-I. USGS, Washington, D.C.
14. Barton, J. R., and Lin P. P., 1955. A Study of the Sediment Transport in Alluvial Channels. Report No. 55JRB2, Colorado A & M College, Fort Collins, Colorado, 45 P.
15. Bechteler, W., Vetter, M., 1989. Comparison of Existing Sediment Transport Models. Proc. of the Fourth Int. Symposium on River Sedimentation Vol. I and II. Int. Res. and Training Center on Erosion and Sed. China Ocean Press.
16. Bishop, A.A., Simons, D.B. and Richardson, E.V., 1965. Total Bed Material Transport. J. Hyd. Div., Vol. 91, No.HY2 p. 175-191.
17. Bledsoe, B.P., 1999. Specific Stream Power as an Indicator of Channel Pattern, Stability and Response to Urbanization. Ph.D. Dissertation, Colorado State University.
18. Blench, T., 1966. Mobile Bed Fluviology. Department of Technical Services, University of Alberta, Edmonton, Canada.
19. Bogardi, J., 1965. European Concepts of Sediment Transportation. J. Hyd. Division, Vol. 91, No. HY1 p. 29-54.

20. Bogardi, J., 1978. **Sediment Transport in Alluvial Streams.** Akademiai Kiado, Budapest.
21. Bondurant, D.C., 1958. Discussion of "the Total Sediment Load of Streams by E.M. Laursen (1958)". **Journal of the Hydraulics Division, ASCE, Vol. 84, No. HY6, Paper 1856 p. 59-64.**
22. Borah, D.K., Alonso, C.V., and Prasad, S.N., 1982a. **Routing Graded Sediments in Streams: Formulation J. Hyd. Div., Vol. 108, No.HY12 p. 1486-1503.**
23. Borah, D.K., Alonso, C.V., and Prasad, S.N., 1982b. **Routing Graded Sediments in Streams: Applications. J. Hyd. Div., Vol. 108, No.HY12 p. 1504-17.**
24. Brown, C.B., 1950. **Sediment Transportation. Eng. Hydraulics.** Edited by Hunter Rouse, John Wiley and Sons, New York.
25. Brownlie, W.R., 1981a. **Prediction of Flow Depth and Sediment Discharge in Open Channel. Report no. KH-R-43A. W.M. Keck Laboratory, California Institute of Technology, Pasadena.**
26. Brownlie, W.R., 1981b. **Compilation of Alluvial Channel Data: Laboratory and Field. Report No. KH-R-43B, W. M. Keck Laboratory of Hydraulics and Water Resources Division of Engineering and Applied Science, California Institute of Technology, Pasadena, California.**
27. Brownlie, W.R., 1981c. **Discussion of Total Load Transport in Alluvial Channels. . J. Hyd. Division, ASCE, HY12**
28. Brownlie, W.R., 1983. **Flow Depth in Sand Bed Channels. J. Hyd. Eng., Vol. 109, No. 7 p. 959-990.**
29. Burkham, D.E., and Dawdy, D.T., 1976. **Resistance Equation for Alluvial Channel Flow. J. Hyd. Div., Proceed. ASCE, Vol. 102, No. HY10.**

30. Cao, Zhixian, Wang, Wensheng, and Dong, J., 1997. Suspended Sediment Transport Capacity of Open Channel Flow. *International of Journal of Sediment Research* Vo. 12, No. 3, p. 1-10.
31. Chang, F.M. and Richards, D.L., 1971. Deposition of Sediment in Transient Flow. *J. Hyd. Division.*, Vol. 97, No. HY6 p. 837-849.
32. Chang, H.H., 1986. River Channel Changes: Adjustments of Equilibrium. *J. Hyd. Eng.*, Vol. 112, No.1 p. 43-55.
33. Chang, H.H., 1994. Section of Gravel Transport Formula for Stream Modeling. *J. Hyd. Eng.*, Vol. 120, No.5 p. 646-651.
34. Chaudry, H.M., Smith, K.V.H., and Vigil, H., 1970. Computation of Sediment Transport in Irrigation Canals. *Proc. Institution of Civil Engineers*, Vol. 45, Paper 7241, pp 79-101.
35. Cheong, H.F., and Shen, H.W., 1983. Statistical Properties of Sediment Movement. *J. Hyd. Eng.*, Vol. 109, No.12 p. 1577-88.
36. Chitale, S.V., 1966. *Hydraulics of Stable Channels*. Central Water and Power Commission, Ministry of Irrigation and Power, Government of India.
37. Colby, B.R., 1964. Practical Computations of Bed-material Discharge. *J. Hyd. Division*, Vol. 90, No. HY2 p. 217-246.
38. Colby, B.R., 1964a. Discharge of Sands and Mean Velocity Relationships in Sand-bed Streams. Professional Paper 462-A. U.S. Geology Survey. Washington, D.C..
39. Colby, B.R., and Hembree, C.H., 1955. Computations of Total Sediment Discharge, Niobrara River near Cody, Nebraska. USGS Water-Supply Paper No. 1357. Government Printing Office Washington, D.C., 187 p.

40. Copeland, Ronald R. and Thomas, W.A. 1989. Corte Madera Creek Sediment Study Numerical Investigation. US Army Engineer Waterways Experiment Station, Vicksburg, MS. TR HL-89-6
41. Costello, W.R., 1974. Development of Bed Configuration in Coarse Sands. Reprt 74-1. Depart. of Earth and Planetary Science, Massachusetts Inst. of Tech., Cambridge, Massachusetts.
42. Culbertson. J. K.. Scott, C. H., and Bennett, J. P., 1972. Summary of Alluvial-Channel Data From Rio Grande Conveyance Channel, New Mexico, 1965-69. U. S. Geological Survey Professional Paper 562-J.
43. Da Cunha, L.V., 1969. River Mondego, Portugal. Personal Communication by Brownlie, Laboratorio Nacional De Engenharia Civil, Lisboa.
44. Dade. W. Brian. and Friend, Pe.F., 1998. Grain Size, Sediment-Transport Regime, and Channel Slope in Alluvial Rivers. The Journal of Geology, Vol. 106 p. 661 - 675. Copyright by The University of Chicago.
45. Daves, T.R., 1971. Summary of Experimental Data for Flume Tests over Plate Sand. Depart. of Civil Eng., University of Southampton.
46. DeVantier, B.A., and Larock, B.E., 1983. Sediment Transport in Stratified Turbulent Flow. J. Hyd. Eng., Vol. 109, No.12 p. 1622-35.
47. Diplas, P., 1987. Bed-load Transport in Gravel-Bed Streams. J. Hyd. Eng., Vol. 113, No. 3 p. 277-292.
48. Dou, G., Zhao, S., and Huang, Y., 1987. A Study on Two Dimensional Mathematical Model of Total Load Transport in Streams. Proc. of the National Symp. on Math. model of Sed. Transport (in Chines), Wuhan, China.
49. Duo, G., Shuyou, C., and Zhuanyi, Zhang, 1989. Transport Characteristics of Gravel Bed-load with a Wide Size Distribution. Proc. of the Fourth Int.

Symposium on River Sedimentation Vol. I and II. Int. Res. And Training Center on Erosion and Sed. China Ocean Press.

50. Egiazaroff, I.V., 1965. Calculation of Nonuniform Sediment Concentrations. J. Hyd. Division, Vol. 91, No. HY4 p. 225-247.
51. Einstein, H.A., 1944. Bed Load Transportation in Mountain Creek. US Soil Conservation Service, SCS-TP-55, 50 p.
52. Einstein, H.A., 1950a. The Bed-load Function for Sediment Transport in Open Channel Flow. SCS Technical Bulletin, No. 1026 US. Depart. of Agriculture, Washington, D.C.
53. Einstein, H.A., 1950b. Estimating Quantity of Sediment Supplied to Streams in and to a Coast. Proc. Coastal Eng. Conference, p. 137-139.
54. Einstein, H.A., 1964. Sedimentation, Part II: River Sedimentation. In Handbook of Applied Hydrology sec.17, ed. Chow, V.T. McGraw-Hill, New York.
55. Einstein, H.A., 1978. Sediment Transport Data in Laboratory Flumes. International Research and Training Center on Erosion and Sedimentation, Publication, Circular, Beijing, China.
56. Einstein, H.A., and Chien, N., 1953a. Effects of Heavy Sediment Concentration Near Bed on Velocity and Sediment Distribution. MRD Series no. 8. University of California, Berkeley. Institute of Engineering Research, Omaha, Neb. Corps of Engineer, US Army of Engineering Div., Missouri River.
57. Einstein, H.A., and Chien, N., 1953b. Transport of Sediment Mixtures with Large Ranges of Grain Size. MRD Sediment Series No. 2 US. Army Engineer Div., Missouri River, Corps of Engineers, Omaha, Neb.
58. Einstein, H.A., and Barbarosa, N.L., 1952. River Channel Roughness. Trans. ASCE, Vol. 117, p. 1121-1131.

59. Engelund, F., 1966. Hydraulic Resistance of Alluvial Streams. J. Hyd. Div., Vol. 92, No.HY2 p. 315-327.
60. Engelund, F., 1967. Closure to Hydraulic Resistance of Alluvial Streams. J. Hyd. Div., Vol. 93, No.HY4 p. 287-296.
61. Engelund, F., and Fredsoe, J., 1976. A Sediment Transport Model for Straight Alluvial Channel. Nordic Hydrology, Vol. 7, p. 293-306.
62. Engelund, F., and Hansen, E., 1967. A Monograph on Sediment Transport Alluvial Streams. Copenhagen: Teknik Forlag, 1967.
63. Foley, M.G., 1975. scour and Fill in Ephemeral Streams. W.M. Keck Laboratory Report No. KH-R-33, Cal. Inst. of Tech., Pasadena, California.
64. Franco, J. J., 1968. Effects of Water Temperature on Bed-Load Movement. Journal of the Waterways and Harbors Division, ASCE, Vol. 94, No. WW3, p. 343-352.
65. Garde, R.J. and Rangaraju, K.G., 1966. Resistance Relationships for Alluvial Channel Flow. J. Hyd.Div., Vol. 92, No. HY4 p. 77-100.
66. Garde, R.J., and Albertson, M.L., 1958. Discussion of "the Total Sediment Load of Streams by E.M. Laursen (1958)". Journal of the Hydraulics Division, ASCE, Vol. 84, No. HY6, Paper 1856 p. 59-64.
67. Garg, S.P., Agrawal, A.K., Singh, P.R., 1971. Bed Load Transportation in Alluvial Channels. J. Hyd. Division., Vol. 97, No. HY5 p.653-664.
68. Gaweesh, Moustafa T.K. and Rijn, Leo C. van, 1994. Bed Load Sampling in Sand Bed Rivers. J. Hyd. Eng., Vol. 120, No. 12 p. 1364-84.
69. German Association for Water Resources and Land Improvement, 1990. Sediment Transport in Open Channels – Calculation Procedures for the Engineering Practice, Bulletin 17, Verlag Paul Parey, Hamburg/Berlin, Germany.

70. Gilbert, K.G., 1914. The Transportation of Debris by Running Waters. USGS Professional Paper 86.
71. Gomez, B., 1991. Bed-load Transport. *Earth-Science Reviews* 31, p. 89 – 132.
72. Graf, W.E., and Acaroglu, E.R., 1968. Sediment Transport in Conveyance System. *Bul. of International Ass. of Scientific Hydrology*, Vol. 13, No. 2.
73. Graf, W.H., 1971. *Hydraulic of Sediment Transport*. McGraw-Hill Book Co.
74. Guy, H.P., and Norman, V.W., 1970. Field methods for measurement of fluvial sediment. *USGS Techniques of Water Res. Investigation*, bk 3, chap. C2. 59p.
75. Guy, H.P., Simons, D.B., and Richardson, E.V., 1966. Summary of Alluvial Channel Data From Flume Experiments, 1956-61. U.S. Geological Survey Professional Paper 462-I.
76. Helley, E.J., and Smith, W., 1971. Development and Calibration of a Pressure-Difference Bed-load Sampler. *USGS Open-File Report*. 18p. Menlo Park, CA.
77. Highway Research Board, 1970. Tentative Design Procedure for Riprap-Lined Channels. Report No. 108. Washington, D.C.: National Academy of Sciences. National Cooperative Highway Research Program.
78. Hill, H.M., Srinivasan, V.S., and Unny, T.E., 1969. Instability of Flat Bed in Alluvial Channel. *J. Hyd. Division.*, Vol. 95, No. HY5 p.1545-1558.
79. Holtorff, Gerd, 1983. Steady Bed Material in Alluvial Channels. *J. Hyd. Eng.*, Vol. 109, No. 3 p. 368-384.
80. Hong, Rou-Jai, Karim, M.F. and Kennedy, J.F., 1984. Low Temperature Effects on Flow in Sand-bed Streams. *J. Hyd. Eng.*, Vol. 110, No. 2 p. 109-125.
81. Hsu, S.M., and Holly, F.M., 1992. Conceptual Bed-load Transport Model and Verification for Sediment Mixtures. *J. Hyd. Eng.*, Vol. 118, No. 8 p. 1135-52.

82. Hubbell, D.W., 1984. Discussion of Remodified Einstein Procedure for Sediment Load. *J. Hyd. Eng.*, Vol. 110, No. 4 p. 556-559.
83. Hubbell, D.W., 1987. Bed-load Sampling Analysis. In Thorne, C.R., Bathurst, J.C., and Hey, R.D. (eds), "Sediment Transport in Gravel-bed Rivers" Chichester, Wiley, p. 89 – 106.
84. Hubbell, D.W., and Matejka, D.Q., 1959. Investigation of Sediment Transportation. Middle Loup River at Dunning, Nebraska. U.S. Geological Survey Water-Supply Paper No. 1476.
85. Hydrau-Tech, Inc., 1998. *Visually Interactive Sediment Transport Computation Model for Window 95/98*. Fort Collin, Colorado.
86. Inglis, C.C., 1968. Discussion of Systematic Evaluation of River Regime, by Neill, C.R., and Galey, V.J.. *J. of Waterway and Harbour Div., ASCE*, Vol. 94, No. 1, p. 109-114.
87. Jaramillo, W.F., and Jain, S.C., 1984. Aggradation and Degradation of Alluvial-Channel Beds. *J. Hyd. Eng.*, Vol. 110, No. 8 p. 1072-85.
88. Jordan, P.R., 1965. Fluvial Sediment of the Mississippi River at St. Louis, Missouri. USGS Water Supply Paper 1802, 89 p.
89. Julien P.Y., September 1999. Personal Communication. Engineering Research Center, Colorado State University.
90. Julien, P.Y., 1995. *Erosion and Sedimentation*. Cambridge University Press.
91. Junfeng, Zhi, 1989. Distribution of Sediment in Yellow River Basin. Proc. of the Fourth Int. Symposium on River Sedimentation Vol. I and II. Int. Res. And Training Center on Erosion and Sed. China Ocean Press.

92. Kalinske, A. A., and Hsia, C. H., 1945. Study of Transportation of Fine Sediment by Flowing Water. Bulletin No. 29, Iowa University Studies in Engineering, the University of Iowa, Iowa City, Iowa.
93. Kalinske, A.A., 1947. Movement of Sediment as Bed Load in Rivers. American Geophysical Union Transactions, Vol. 28 p. 615 – 620.
94. Karim, F. and Kennedy, J.F., 1981. Computer-based Predictors for Sediment Discharge and Friction Factor of Alluvial Streams. Report no. 242. Iowa Institute of Hydraulic Research, University of Iowa.
95. Karim, M.F. and Kennedy, J.F., 1987. Velocity and Sediment Concentration Profiles in River Flows. J. Hyd. Eng., Vol. 113, No. 2 p.159-178.
96. Karim, M.F., 1998. Bed Material Discharge Prediction for Non-uniform Bed Sediments. J. Hyd. Eng., ASCE, Vol. 124, No. 6, p. 597-604.
97. Kennedy, J. F., 1961. Stationary Waves and Antidunes in Alluvial Channels. Reprt No. KH-R-2, W.M. Keck Laboratory of Hydraulics and Water Resources, Div. of Eng., Cal. Inst. of Tech.
98. Kennedy, J. F., 1983. Reflections on Rivers, Research and Rouse. J. Hyd. Eng., Vol. 109, No.10 p. 1254-1271.
99. Kennedy, J. F., and Brooks, N. H., 1963. Laboratory Study of an Alluvial Stream at Constant Discharge. Proceedings of the Federal Inter-Agency Sedimentation Conference, Miscellaneous Publication No.970, Pasadena, California, p.320-330.
100. Kikkawa, H., and Ishikawa, T., 1978. Total Load of Bed Materials in Open Channels. J. Hyd. Division., Vol. 104, No. HY7 p.1045-1059.
101. Knighton, David, 1998. Fluvial Forms and Processes – A New Perspective. John Wiley and Sons Inc., New York.

102. Knott, J.M., 1974. Sediment Discharge in Trinity River Basin, California. Water-Resource Investigation 49-73, USGS, p. 62.
103. Lau, Y.L., and Krishnappan, B.G., 1985. Sediment Transport Under Ice Cover. J. Hyd. Eng., ASCE, Vol. 54, No. 1, p. 1-36.
104. Laursen, E. M., 1958. The Total Sediment Load of Streams. Journal of the Hyd. Division, ASCE, Vol. 84, No. HY1, Paper 1530, p. 1-36
105. Lee, B.K., 1969. Laboratory Study of an Alluvial Stream at One Footh Depth. M.S. Thesis, Colorado State University, Fort Collins.
106. Leopold, L.B., 1969. Sediment Transport Data for Various US Rivers. Personal Communication by Brownlie.
107. Leopold, L.B., and Wolman, M.G., 1957. River Channel Patterns: Braided, Meandering and Straight. USGS. Prof. Paper 282-B, 85 p.
108. Leopold, L.G., Wolman, M.G., and Miller, J.P., 1964. Fluvial Processes in Geomorphology. W.H. Freeman and Co., San Fransisco. 522 p.
109. Li, Wenxue, Pu Qi, and Sun, Zanying, 1997. Deformation of Riverbed and the Characteristics of Sediment Transport During Hyperconcentrated Flood in the Yellow River. International of Journal of Sediment Research Vol. 12, No. 3, p. 72-79.
110. Limerinos, J.T., 1970. Determination of Manning Coefficient from Measured Bed Roughness in Natural Channels. Water Supply Paper 1898b, USGS.
111. Long, Y., and Liang, G., 1994. Data Base of Sediment Transport in The Yellow River. Tech. Report No. 94001, Institute of Hydraulic Research, Yellow River Conservation Commission, Zhengzhou, P.R. China, 15 p.
112. Lu, J. Yau., 1978. A Sediment Transport Equation from Non-linear Regression Analysis. Master Thesis, Colorado State University, Fort Collins, CO.

113. Lyn, Dennis A., 1987. Unsteady Sediment Transport Modeling. J. Hyd. Eng., Vol. 113, No. 1 p.1-15.
114. Madden, E.B., 1964. Channel Design for Modified Sediment Regime Conditions on the Arkansas River – Chapter III. Symposium on Channel Stabilization Problems. Technical Report No. 1, Vol. 2, prepared for Committee on Channel Stabilization. Corps of Engineers. US Army Engineer Waterways Experiment Station. Vicksburg, Mississippi.
115. Madden, Edward B. 1985. Modified Laursen Method for Estimating Bed-material Sediment Load. Prepared for U.S. Army Corps of Engineers; monitored by Hydraulics Laboratory, U.S. Army Engineer Waterways Experiment Station. HL-93-3.
116. Maddock, T. Jr., 1976. Equations for Resistance to Flow and Sediment Transport in Alluvial Channels. Water Resources Research, Vol. 12, No.1, p. 11 – 21.
117. Maddock, T. Jr., 1983. Discussion of Sediment Transport and Unit Stream Power Function. J. Hyd. Eng., Vol. 109, No.12 p. 1779-81.
118. Mahmood, et al., 1979. Selected Equilibrium-State Data from ACOP Canals. Civil, Mechanical and Environmental Engineering Department Report No. EWR-79-2, George Washington University, Washington, D.C., 494 p.
119. Mau, R.E. and Brooks, N.H., 1991. Discussion of Test of Selected Sediment Transport Formulas by Nakato, T.. J. Hyd. Eng., Vol. 117, No. 9 p. 1226-33.
120. McDowell, D.M., 1989. A General Formula for Estimation of the Rate of Transport of Non-cohesive Bed Load. J. Hyd. Research, Vol. 27 No. 3.
121. Meyer, Peter E., and Muller, R., 1948. Formulas for Bed-load Transport. Proc. Second Congress of IAHR, Stockholm, Sweden.
122. Middleton, G.V., and Southard, J.B., 1984. Mechanics of Sediment Movement. Short Course No. 3: Tulsa, OK, Soc. Econ. Paleont. and Mineral, 401 p.

123. Milhous, R.T., 1973. Sediment Transport in a Gravel Bottom Stream. PhD. Dissertation, Oregon State University, 232p.
124. Misri, R.L., Garde, R.J. and Rangaraju, K.G., 1984. Bed Load Transport of Coarse Nonuniform Sediment. J. Hyd. Eng., Vol. 110, No. 3 p. 312-28.
125. Molinas, A. and Wu, Baosheng, 1998. Effect of Size Gradation on Transport of Sediment Mixtures. J. Hyd. Eng., Vol. 124, No. 8 p. 786-793.
126. Molinas, A., and Yang, C.T. 1986. Computer Program User's Manual for GSTARS (General Stream Tube Model for Alluvial River Simulation. US. Depart. of Interior, USBR, Eng. Research Center, Denver, CO.. p. 142
127. Nakato, T., 1987. Discussion of Modeling of River Channel Changes. J. Hyd. Eng., Vol. 113, No. 2 p. 262-265.
128. Nakato, T., 1990. Test of Selected Sediment Transport Formulas. J Hyd. Eng., Vol. 116, No. 3, p. 362-379.
129. Nakato, T., 1991. Closure of Test of Selected Sediment Transport Formulas. J. Hyd. Eng., Vol. 117, No. 9 p. 1235-37.
130. Nedeco, 1973. Rio Magdalena and Canal del Dique Project. Mission Tecnica Colombo-Holandesa. Nedeco Report, Nedeco, the Hague.
131. Nordin, C.F., and Beverage, J.P., 1965. Sediment Transport in the Rio Grande, New Mexico. Professional Paper 462-F, USGS, Washington, D.C., 35 p.
132. Nordin, C.F., and McLean, D.G., 1989. Application of Engelund-Hansen Transport Equation in Mathematical Models. Proc. of the Fourth Int. Symposium on River Sedimentation Vol. I and II. Int. Res. and Training Center on Erosion and Sed. China Ocean Press.

133. Onishi, Y., Jain, S. C., and Kenndey, J. F., 1976. Effects of Meandering in Alluvial Streams. *Journal of the Hydraulics Division, ASCE*, Vol. 102, No. HY7, P.899-917.
134. Overbeek, H.J., 1979. Erosion and Sedimentation. Lecture Notes. Asian Institute of Technology, Bangkok, Thailand.
135. Pacheco-Ceballos, R., 1989. Transport of sediments: Analytical Solution. *J. Hyd. Research*, Vol. 27, No. 4 p. 501 – 518.
136. Paintal, A.S., 1970. Concept of Critical Shear Stress in Loose Boundary Open Channels. *J. Hyd. Research* No. 1 p. 90 –113.
137. Palaniappan, A.B., Garde, R.J., and Godbole, P.N., 1998. On the Prediction of Transient Bed Level due to Aggradation and Degradation Including Armoring. *International of Journal of Sediment Research* Vol. 13, No. 1, p. 51-67.
138. Parker, G., 1990. Surface-Based Bed-load Transport Relation for Gravel Rivers. *J. Hyd. Research*, Vol. 28, No. 4, p. 417-37.
139. Parker, G., and Coleman, N.L., 1986. Simple Model of Sediment-laden Flows. *J. Hyd. Eng.*, Vol. 112, No. 5 p. 356-375.
140. Parker, G., Klingeman, P.C, and McLean, D.G., 1982. Bed-load and Size Distribution in Paved Gravel Bed Streams. *J. Hyd. Division*, Vol. 108, No. HY4 p. 544-571.
141. Pernecker, L., and Vollmers, H.J., 1965. Neue Betrachtungsmöglichkeiten des Feststofftrans-portes in offenen Gerinnen. *Die Wasserwirtschafft*, 55. Jg., p. 386-391.
142. Peterson, A.W., and Howells, R.F., 1973. A Compendium of Solids Transport Data for Mobile Boundary Channels. Report No HY-1973-ST3, Department of Civil Eng., University of Alberta, Canada.

143. Posada-G, Lilian. 1995. Transport of Sands in Deep Rivers. Ph.D. Dissertation. Depart. of Civil Eng., Colorado State University
144. Pratt. C.J., 1970. Summary of Experimental Data for Flume Test over 0.49 Sand. Depart of Civil Eng. University of Southampton.
145. Qi Pu, and Sun Zanying, 1995. Analysis of Channel Scouring and Deposition of the Lower Yellow River. International of Journal of Sediment Research Vol. 10. No. 2. p. 21-34.
146. Qi Pu, and Zhao Yean, 1993. Characteristic of Sediment Transport and Channel Formation by Floods at Hyperconcentrations of Sediment in The Yellow River. International of Journal of Sediment Research Vol. 8, No. 1, p. 69-84.
147. Qiwei, Han. Mingmin. He, and Yucheng, Wang, 1989. A Discussion on Distinction Between Wash Load and Bed Material Load. Proc. of the Fourth Int. Symposium on River Sedimentation Vol. I and II. Int. Res. And Training Center on Erosion and Sed. China Ocean Press.
148. Rahuel, J.L., Holly, F.M., Chollet, J.P., Belleudy, P.J., and Yang, G., 1989. Modeling of Riverbed Evolution for Bed-load Sediment Mixtures. J. Hyd. Eng., Vol. 115, No. 11 p. 1521-42.
149. Raju. Kittur G. Ranga, Garde, R.J. and Bhardwaj, R.C., 1981. Total Load Transport in Alluvial Channel. J. Hyd. Division., Vol. 107, No. HY2 p. 179-191.
150. Raphelt, Nolan K., 1996. An Examination of Gravel Bed-load Functions Applied to Observed Gravel Bed-load Discharge Measurements of Selected Streams. Ph.D. Dissertation. Depart. Of Civil Eng., Colorado State University
151. Raudkivi, A.J., 1967. Loose Boundary hydraulics. Pergamon Press Ltd.
152. Renard, K.G., and Hickok, R.B., 1967. Sedimentation Research Needs in Semiarid Regions. J. Hyd. Division, Vol. 93, No. HY1 p. 45-60.

153. Richardson, E.V, Simons, D.B., and Julien, P.Y., 1990. *Highways in the River Environment*. USDOT Federal Highway Administration.
154. Rijn, L.C., 1986. *Mathematical Modeling of Suspended Sediment in Nonuniform Flows* J. Hyd. Eng., Vol. 112, No. 6 p. 433-455.
155. Rijn, Leo C. van, 1983. *Discussion of Sediment Transport and Unit Stream Power Function*. J. Hyd. Eng., Vol. 109, No.12 p. 1785-87.
156. Rijn, Leo C. van, 1984a. *Sediment Transport Part I: Bed Load Transport*. J. Hyd. Eng., Vol. 110, No.10 p. 1431-1456.
157. Rijn, Leo C. van, 1984b. *Sediment Transport Part II: Suspended Load Transport*. J. Hyd. Eng., Vol. 110, No.11 p. 1613-1641.
158. Rijn, Leo C. van, 1984c. *Sediment Transport Part III: Bed Forms and Alluvial Roughness*. J. Hyd. Eng., Vol. 110, No.12 p. 1733-54.
159. Rottner, J., 1959. *A Formula for Bed-Load Transport*. La Houille Blanche No. 3, p. 301 – 307.
160. Samaga, B.R., Rangaraju, K.G, and Garde, R.J., 1986a. *Bed Load Transport of Sediment Mixtures*. J. Hyd. Eng., Vol. 112, No. 11 p.1003-18.
161. Samaga, B.R., Rangaraju, K.G, and Garde, R.J., 1986b. *Suspended Load Transport of Sediment Mixtures*. J. Hyd. Eng., Vol. 112, No. 11 p.1019-35.
162. Samide, G.W., 1971. *Sediment Transport Measurements*. Master Thesis presented in University of Alberta.
163. Schlichting, H., 1979. *Boundary Layer Theory*. McGraw-Hill, 817p., New York.
164. Schneider, V. R., 1969. *Personal Communication by H.W. Shen*.
165. Schumm, S.A., and Kahn, H.R., 1972. *Experimental Study of Channel Patterns*. Geo. Soc. America Bull. v. 83, p. 1755-77.

166. Seitz, H.R., 1976. *Suspended and Bed Load Sediment Transport in the Snake and Clearwater Rivers in the Vicinity of Lewiston, Idaho*, File Report 76-886, USGS, Boise, Idaho, p. 77.
167. Shen, H.W. and Hung, C.S., 1972. *An Engineering Approach to Total Bed-material Load by Regression Analysis*. Proc. Sedimentation Symposium, ed. H.W. Shen. Berkeley, Cali.: Water Resources Pub., 1972, chap. 14.
168. Shen, H.W., 1971a. *Wash Load and Bed Load*. Chapter 11 of *River Mechanics Vol. I and II* edited by Shen H.W., Colorado State University.
169. Shen, H.W., 1971b. *Total Sediment Load*. Chapter 13 of *River Mechanics Vol. I and II* edited by Shen H.W., Colorado State University.
170. Shen, H.W., and Cheong, Hin Fatt., 1979. *Closure of Statistical Properties of Sediment Bed Profiles*. J. Hyd. Eng., Vol. 105, No. 8 p. 1037-1039.
171. Shen, H.W., and Hung, C.S., 1983. *Remodified Einstein Procedure for Sediment Load*. J. Hyd. Eng., Vol. 109, No. 4 p. 565-578.
172. Shen, H.W., and Hung, C.S., 1984. *Closure of Remodified Einstein Procedure for Sediment Load*. J. Hyd. Eng., Vol. 110, No. 4 p. 559.
173. Shen, Xianchen, 1997. *Effect of Suspended Sediment on the Transport and Transformation 4-Nitrochlorobenzene in the Yellow River*. International of Journal of Sediment Research Vol. 12, No. 1, p. 42-51.
174. Shields, A., 1936. *Anwendung der Aenlichkeitsmechanik und der Turbulenzforschung auf die Geschiebebewegung*. Mitteilungen der Preussischen Versuchsanstalt fur Wasserbau and Schiffbau, No. 26, Berlin, Germany. Translated into English by Otto, W.P., and Uchelen, van J.C., Calif. Institute of Technology, Pasadena, California.

175. Shinohara, K., and Tsubaki, T., 1979. On the Characteristics of Sand Waves Formed Upon Beds of the Open Channels and Rivers. Reprinted from Reports of Res. Institute of Applied Mechanics, Kyushu University, Vol. VII, No. 25.
176. Shulits, S., 1935. The Schoklitsch Bed-load Formula. Engineering, 139, p. 644-646.
177. Shults, Sam. and Hill, Raph D., Jr., 1968. Bed-load Formulas: Part A - A Selection of Bed-load Formulas, Part B - Program Listings for Bed-load Formulas. For Soil and Water Conservation Research Div. Agricultural Research Service US Dept. of Agriculture. Hydraulics Lab. Bulletin, Dept. C.E. The Pennsylvania State University.
178. Simons, D. B., 1957. Theory of Design of Stable Channels in Alluvial Materials. Ph.D. dissertation presented to the Colorado State University, Fort Collins, Colorado.
179. Simons, D. B., 1999. Personal Communication. Simons & Associates, Fort Collins, Colorado.
180. Simons, D.B., and Senturk, Fuad, 1992. Sediment Transport Technology – Water and Sediment Dynamics. Water Resources Publications, Littleton, CO.
181. Simons, D.B., and Simons, R.K., 1987. Differences Between Gravel and Sand-bed Rivers. Sediment Transport in Gravel-Bed Rivers. Ed. by C.R Thorne, J.C. Bathurst and R.D. Hey. A Wiley-Interscience Publication, John Wiley & Sons.
182. Simons, D.B., Li, R.M., and Fullerton, W., 1981. Theoretically Derived Sediment Transport Equations for Prima County, Arizona. Prepared for Prima County DOT and Flood Control District, Tuscon, Ariz.. Fort Collins, CO.: Simons, Li and Assoc..
183. Singh, B., 1960. Transport of Bed-Load in Channels with Special Reference to Gradient Form. PhD. dissertation presented to the University of London, London, England.

184. Smart, G.M., 1983. Sediment Transport Formula for Steep Channels. J. Hyd. Eng., Vol. 110, No. 3 p. 267-276.
185. Song, Charles C.S., and Yang, C.T., 1979. Velocity Profiles and Minimum Stream Power. J. Hyd. Division, Vol. 105, No. HY8, p. 981-998.
186. Song, Charles C.S., Zheng, Yifan, and Yang, C.T., 1995. Modeling of River Morphologic Changes. International of Journal of Sediment Research Vol. 12, No. 2, p. 1-20.
187. Song, T., and Graf, W.H., 1997. Experimental Study of Bed-load Transport in Unsteady Open Channel Flow. International of Journal of Sediment Research Vol. 12, No. 3, p. 63-71.
188. Stein, R. A., 1965. Laboratory Studies of Total Load and Apparent Bed Load. Journal of Geophysical Research, Vol. 70, No. 8, April 15, 1965, p.1831-1842.
189. Steven, H.H. Jr., and Yang, C.T., 1989. Summary and Use of Selected Fluvial Sediment discharge Formula. USGS. Water Res. Investigations Report 89-4026. Denver, Colorado.
190. Straub, L. G., 1954. Transportation Characteristics Missouri River Sediment. M.R.D. Sediment Series No. 4, St. Anthony Falls Hydraulic Laboratory, Minneapolis, Minnesota.
191. Straub, L. G., Anderson, A. G., and Flammer, G. H., 1958. Experiments on the Influence of Temperature on the Sediment Load. M.R.D. Sediment Series No. 10. St. Anthony Falls Hydraulic Laboratory, Minneapolis, Minnesota.
192. Taylor, B. D., 1971. Temperature Effects in Alluvial Streams. W.M. Keck Laboratory of Hydraulics and Water Resources Report KH-R-27, California Institute of Technology, Pasadena.

193. Taylor, B. D., and Vanoni, V. A., 1972. Temperature Effects in High Transport, Salt-Bed Flows. *Journal of The Hydraulics Division*, Vol. 98, No. HY12, p.2191-2206.
194. Thomson, J., 1876. On the Origins and Winding of River in Alluvial Plains. *Proc. Royal Soc. Lond.*, 25(5) 5-8.
195. Toffaleti, F. B., 1968. A Procedure for Computation of the Total River Sand Discharge and Detailed Distribution, Bed to Surface. Technical Report 5, Corps of Engineers, U. S. Army, Wicksburg.
196. Toffaleti, F.B., 1969. Definitive Computations of Sand Discharge in Rivers. *J. Hyd. Division.*, Vol. 95, No. HY1 p. 225-248.
197. Tywoniuk, N., 1972. Sediment Discharge Computation Procedures. *J. Hyd. Division.* Vol. 98, No. HY3. Proc. Paper 8783, p. 521-540.
198. United State Department of the Interior, Bureau of Reclamation (USBR), 1958. Total Sediment Transport Program. Lower Colorado River Basin. Interim Report, p. 175.
199. US Army Corps of Engineers, 1979. Verifications of Sediment Transport Functions: Missouri River. Data Listings, Apendices I, IV, and V, Omaha, Nebraska.
200. Vanoni, V. A., and Brooks, N. H., 1957. Laboratory Studies of the Roughness and Suspended Load of Alluvial Streams. Report No. E-68, Sedimentation Laboratory, California Institute of Technology, Pasadena, California.
201. Vanoni, V.A and Hwang, L.S., 1967. Relation Between Bed Forms and Friction in Streams. *J. Hyd. Division*, Vol. 93, No. HY3 p. 121-144.
202. Vanoni, V.A., 1978. Predicting Sediment Discharge in Alluvial Channel. *Water Supply Management*, Pergamon Press, Oxford, p. 399-417.

203. Vanoni, V.A., ed., 1975. Sedimentation Engineering. ASCE Manuals and Reports on Engineering Practice – No. 54 ASCE, New York.
204. Vanoni, Vito A., and Brooks, Norman H., 1957. Discussion of Mechanics of Sediment-Ripple Formation by Hsin-Kuan Liu. J. Hyd. Div. ASCE no. HY1:p. 1558 17-31.
205. Vanoni, Vitto A., 1984. Fifty Years of Sedimentation. J. Hyd. Eng., Vol. 110, No. 8 p. 1022-1057.
206. Wang, Shang-yi, 1983. The Principle and Application of Sediment Effective Power. J. Hyd. Eng., Vol. 110, No. 3 p. 97-107.
207. Wang. Shiqiang, Zhang, Ren, and Hui Yujia. 1995. New Equations of Sediment Transport Rate. International of Journal of Sediment Research Vol. 10, No. 3. p. 1-18.
208. Wang. Zhaoyin, Lin, Bingnan, Nestmann, F., 1997. Prospect and New Problems of Sediment Research. International of Journal of Sediment Research Vol. 12, No. 1, p. 1-15.
209. Waterways Experiment Station (WES) US Army Corps of Engineers, 1998. SAM Hydraulic Design Package for Channels – Chapter 3. WES Coastal and Hydraulic Laboratory, Vicksburg, Mississippi.
210. Watson, C.C., Thorton, C.I., Bledsoe, B.P., and Konzinski, P.B., 1998. Demonstration Erosion Control Monitoring Sites 1997 Evaluation. Report for USAE, Waterways Experiment Station, Vicksburg, MS, 129 pp.
211. White, W. R., and Day, T. J., 1982. Transport of Graded Gravel Bed Material. Gravel-bed Rivers. Edited by R. D. Hey, J. C. Bathurst, and C. R. Thorn, John Wiley & Sons Ltd, pp. 181-223.
212. White, W. R., Milli, H., and Crabbe, A.D., 1975. Sediment Transport Theories: a Review. Proc. Inst. Civil Eng. Part 2, 59, p. 265 – 92.

213. Wieprecht, Silke, 1998. Effect of Riverbed Width on Sediment Transport. International of Journal of Sediment Research Vol. 13, No. 1, p. 11-19.
214. Wilcock. P. R., and Southard J. B., 1988. Experimental Study of Incipient Motion in Mixed-Size Sediment. Journal of Water Resources Research. Vol. 24, No. 7, p. 1137-1151.
215. Wilcock. P.R., 1997. The Components of Fractional Transport Rate. Water Res. Research.. Vol. 33, No. 1, p. 247-258.
216. William, D.T., 1995. Selection and Predictability of Sand Transport Relations Based Upon a Numerical Index. Ph.D. Dissertation. Depart. of Civil Eng., Colorado State University, Fort Collins, CO.
217. William. D.T., and Julien, P.Y., 1989. Applicability Index for Sand Transport Equations. J. Hyd. Eng., Vol. 115, No. 11 p. 1578-81.
218. Williams. G.P., 1967. Flume Experiments on Transport of Coarse Sand. U.S. Geological Survey Professional Paper 562-B. 31 p.
219. Williams, G.P., 1970. Flume Width and Water Depth Effects in Sediment-Transport Experiments. U. S. Geological Survey Professional Paper 562-H.
220. Williams, Garnett P., and Rosgen, David L., 1989. Measured Total Sediment Loads (Suspended Loads and Bed Loads) for 93 United Streams. Open – File Reports (USGS) Section 89 – 67, Denver Colorado.
221. Willis, J. C., Coleman, N. L., and Ellis, W. M., 1972. Laboratory Study of Transport of Fine Sand. Journal of the Hydraulics Division, ASCE, Vol. 98, No. HY3, Paper 8765, p. 489-501.
222. Willis. J.C., 1979. Suspended Load from Error-Function Models. J. Hyd. Division, Vol. 105, No. HY7, p. 801-816.

223. Wilson, K.C., 1987. Analysis of Bed-Load Motion at High Shear Stress. J. Hyd. Eng., Vol. 113, No. 1 p. 97-103.
224. Wolman, M.G., and Brush, 1961. Factors Controlling the Size and Shape of Streams Channels in Coarse Non-cohesive Sands. USGS. Prof. Paper 282 G, 27 p.
225. Woo, H., and Richardson, E.V., 1987. Discussion of Bed Load and Suspended Load. J. Hyd. Eng., Vol. 113, No. 4 p. 550-552.
226. Woo, H., and Yoo, K., 1991. Discussion of Test of Selected Sediment Transport Formulas by Nakato, T.. J. Hyd. Eng., Vol. 117, No. 9 p. 1233-35.
227. Woo, H.S., Julien, P.Y., and Richardson, E.V. 1986. Washload and Fine Sediment Load. J. Hyd. Eng., Vol. 112, No. 6 p. 541-545.
228. Woo, Hyoseop, and Yoo, K., 1991. Discussion of Test of Selected Sediment-Transport Formulas by T. Nakato (1990). J. Hyd. Eng., Vol. 117, No. 9 p. 1233-35.
229. Wu, Baosheng and Molinas, A.. 1996. Modeling of Alluvial River Sediment Transport. Proc. of the Int. Conference on Reservoir Sedimentation, Vol. I. Ed. by Albertson, M.L., Molinas, A., and Hotchkiss., Colorado State University, Fort Collins, CO, USA., p. 281-325.
230. Wu, Baosheng, 1999. Fractional Transport of Bed-Material Load in Sand-bed Channels. Ph.D. Dissertation. Depart. of Civil Eng., Colorado State University.
231. Yalin, M.S., 1963. An Expression for Bed Load Transportation. J. Hyd. Division, Vol. 89, No. HY3 p. 221-250.
232. Yalin, M.S., 1963. An Expression for Bed-load Transportation. J. Hyd. Div., ASCE, Vol.89, No 3., p. 221-250.
233. Yalin, M.S., and Karahan, E., 1979. Incipient of Sediment Transport. J. Hyd. Division, Vol. 105, No. HY11, p. 1433-1443.

234. Yang, C. T. and Molinas, Albert, 1982. Sediment Transport and Unit Stream Power Function. J. Hyd. Division., Vol. 108, No. HY6 p. 774-793.
235. Yang, C. T. and Molinas, Albert, 1983. Closure of Sediment Transport and Unit Stream Power Function. J. Hyd. Division., Vol. 109, No. HY12 p. 1787-90.
236. Yang, C. T. and Wan, Schenggan, 1991. Comparison of Selected Bed Material Load Formulas. J. Hyd. Eng., Vol. 117, No. 8 p. 973-989.
237. Yang, C. T., 1972. Unit Stream Power and Sediment Transport. J. Hyd. Division., Vol. 98, No. HY10 p. 1805-1826.
238. Yang, C. T., 1973. Incipient Motion and Sediment Transport. J. Hyd. Division., Vol. 99, No. HY10 p. 1679-1704.
239. Yang, C. T., 1977. The Movement of Sediment in Rivers. Geophysical Survey 3, D. Reidel, Dordrecht. p. 39 – 68.
240. Yang, C. T., 1984. Unit Stream Power Equation for Gravel. J. Hyd. Eng., Vol. 110, No. 12 p. 1783-97.
241. Yang, C. T., 1996. Sediment Transport Theory and Practice. McGraw -Hill Companies, Inc.
242. Yang, C. T., Molinas, A. and Wu, Baosheng, 1996. Sediment Transport in The Yellow River. J. Hyd. Eng., Vol. 122, No. 5 p. 273-244.
243. Yang, C.T., 1976. Minimum Unit Stream Power and Fluvial Hydraulics. J. Hyd. Division, Vol. 102, No. HY7 p. 919-934.
244. Yang, C.T., 1979. Unit Stream Power Equations for Total Load. J. Hydrology, Vol. 40, p. 123-138. Amsterdam, The Netherlands.
245. Yang, C.T., 1980. Sediment Transport and River Engineering. Proc. of the Int. Symp. On River Sed., ed. By the Chines Society of Hydraulic Eng. Vol.. I, Beijing.

246. Yang, C.T., and Simons, D.B., 1996. Sediment Transport. Proceeding of the International Conference on Reservoir Sedimentation Vol. 1. Ed. by. M.L. Albertson, A. Molinas and Rollin Hotchkiss, sponsored by Colorado State University, ICCORES, UNESCO, Fort Collins, Colorado, p. 74-98.
247. Yang, C.T., and Stall, J.B., 1976. Applicability of Unit Stream Power Equation. J. Hyd. Division, Vol. 102, No. HY5 p. 559-568.
248. Yang, C.T., and Stall, J.B., 1976. Closure of Applicability of Unit Stream Power Equation. J. Hyd. Division, Vol. 104, No. HY7 p. 1095-1103.
249. Yang, C.T., 1977. The movement of Sediment in Rivers. Geophysical Survey 3. D. Reidel, Dordrecht, p. 39-68
250. Yang, C.T., and Kong, X., 1991. Energy Dissipation Rate and Sediment Transport. J. Hyd. Research, Vol. 29, No. 4, p. 457-474.
251. Ye Qingchao, 1995. Researches on Environmental Changes and Water and Sediment Transport of The Yellow River Basin. International of Journal of Sediment Research Vol. 10, No. 1, p. 1-12.
252. Yeh, Keh-Chia, and Deng, Sen-Long, 1998. Uncertainty and Sensitivity Analyses of Sediment Transport Formulas. International of Journal of Sediment Research Vol. 13, No. 1, p. 20-33.
253. Zanke, U., 1982. Grundlagen der Sedimentbewegung. Springer Verlag, Berlin, Heiderberg, New York.
254. Zernial, G.A., and Laursen, E.M., 1963. Sediment Transporting Characteristic of Streams. J. Hyd. Division, Vol. 89, No. HY1 p. 117-137.
255. Zhang, H., and Kahawita, R., 1987. Discussion of Aggradation and Degradation of Alluvial-Channel Beds. J. Hyd. Eng., Vol. 113, No. 2 p. 272-273.

256. Zhao, Y., Pan Xiandi and Fan Zuoying, 1995. Water and Sediment Inflow of Hyperconcentrated Floods and the Associated Channel Aggradation in the Yellow River. *International of Journal of Sediment Research* Vol. 10, No. 1, p. 69-82.
257. Zhou, W., Zeng, Q., Zhaou, H., and Chen Jianguo, 1995. Sediment Transport Behaviour for Different Size Group in the Lower Yellow River. *International of Journal of Sediment Research* Vol. 10, No. 3, p. 51-68.
258. Znamenskaya, N.S., 1963. Experimental Study of the Dune Movement of Sediment. *Transactions of the State Hydrologic Inst. (Trudy GGI)* No. 108, p. 89 – 111. Translated by L.G. Robbins.

APPENDIX A. DETAILS OF FIELD DATA

(28 pages)

Data Source	Date of measurement	Water discharge m ³ /s	Channel width w m	Flow Depth h m	Flow velocity v m/s	Mean bed diameter d _s mm	W/S Slope S _w m.m	Water temp °C	Transported Sediment Concent. ppm	Bed Form
1	2	3	4	5	6	7	8	9	10	11
Ama Apure above El Saman	02/06/87	300.00	135.00	2.47	0.90	0.364	0.000145	29	56	0
Ama Apure above El Saman	05/21/86	1290.00	218.00	5.26	1.12	0.298	0.000146	29	166	0
Ama Apure above Portuguesa	05/19/86	1430.00	263.00	4.95	1.10	0.378	0.000089	29	236	0
Ama Apure at Cano Ruende	02/08/87	252.00	151.00	2.23	0.75	0.584	0.000139	29	34	0
Ama Apure at El Perro	03/16/83	235.00	237.00	1.98	0.50	0.273	0.000030	29	5	0
Ama Apure at El Perro	02/14/87	324.00	244.00	2.38	0.56	0.444	0.000118	29	23	0
Ama Apure at El Perro	05/15/86	800.00	266.00	3.81	0.79	0.296	0.000057	30	65	0
Ama Apure at El Perro	06/06/85	874.00	266.00	4.90	0.67	0.308	0.000030	29	15	0
Ama Apure at El Perro	11/29/82	1040.00	260.00	4.71	0.85	0.227	0.000030	27	72	0
Ama Apure at El Perro	10/10/84	2400.00	233.00	8.73	1.18	0.273	0.000030	29	130	0
Ama Apure at Las Culatas	02/10/87	322.00	235.50	2.71	0.51	0.542	0.000139	29	13	0
Ama Apure at Palmarito	02/02/87	134.00	106.00	2.11	0.60	0.279	0.000218	29	68	0
Ama Apure below Bruzual	02/05/87	293.00	186.00	1.85	0.85	0.896	0.000238	29	43	0
Ama Apure below Bruzual	05/22/86	1190.00	214.00	4.35	1.28	0.438	0.000182	29	220	0
Ama Cano Boqueron below puente Boqueron	02/11/87	32.40	67.00	2.40	0.20	0.220	0.000118	29	10	0
Ama Cano la Tigra, 4 km above mouth	02/02/87	106.00	136.00	1.42	0.55	0.767	0.000225	29	38	0
Ama Cano la Tigra, 4 km above mouth	05/23/86	308.00	140.00	2.45	0.90	0.370	0.000225	29	136	0
Ama Cano Las Garzas, 1 km above mouth	02/09/87	22.10	31.50	1.23	0.57	0.519	0.000139	29	15	0
Ama Cano Las Garzas, 2 km above mouth	02/09/87	52.10	102.50	1.51	0.34	0.424	0.000139	29	8	0
Ama Cano Manati at Manati	02/15/87	185.00	104.00	4.33	0.41	0.185	0.000076	29	46	0
Ama Madeira at Urucurituba	12/11/82	23100.00	1010.00	19.90	1.15	0.089	0.000060	27	89	0
Ama Madeira at Urucurituba	07/11/83	24700.00	1040.00	23.70	1.00	0.196	0.000045	27	11	0
Ama Masparro, 1 km above mouth	02/04/87	8.60	23.00	1.13	0.33	0.282	0.000238	29	39	0
Ama Masparro, 5 km above mouth	05/22/86	52.00	49.50	1.46	0.72	0.296	0.000182	29	194	0
Ama Orinoco at bachaquito	03/09/83	4030.00	1315.00	3.74	0.82	0.532	0.000059	32	6	0
Ama Orinoco at bachaquito	05/30/85	12100.00	2170.00	6.50	0.86	0.492	0.000064	28	15	0
Ama Orinoco at bachaquito	11/19/82	14000.00	2181.00	6.85	0.94	0.487	0.000058	29	17	0
Ama Orinoco at bachaquito	11/18/82	14400.00	2172.00	6.99	0.95	0.499	0.000058	29	17	0
Ama Orinoco at bachaquito	10/15/84	22600.00	2501.00	9.05	1.00	0.493	0.000065	28	24	0
Ama Orinoco at Cabruta-Caicara	08/18/82	59900.00	2560.00	16.50	1.42	0.374	0.000047	29	61	0
Ama Orinoco at Caura mouth	08/19/82	57300.00	2195.00	17.40	1.50	0.396	0.000058	28	60	0
Ama Orinoco at Curiquima-Capuchinos	06/05/85	22100.00	2890.00	7.21	1.06	0.217	0.000044	28	80	0
Ama Orinoco at Curiquima-Capuchinos	10/11/84	34600.00	3270.00	11.00	0.96	0.342	0.000035	29	30	0
Ama Orinoco at Curiquima-Capuchinos	08/17/82	47100.00	3338.00	12.60	1.12	0.375	0.000033	28	37	0
Ama Orinoco at El Almacen	12/05/82	23800.00	2215.00	10.90	0.99	0.428	0.000047	28	8	0
Ama Orinoco at El Almacen	06/24/82	50900.00	2650.00	16.30	1.18	0.350	0.000041	28	59	0
Ama Orinoco at El Almacen	08/22/82	65000.00	2680.00	17.20	1.41	0.431	0.000042	29	82	0
Ama Orinoco at Guarampo-Punta Cuchillo	12/06/82	23000.00	1905.00	15.50	0.78	0.378	0.000039	28	4	0
Ama Orinoco at Guarampo-Punta Cuchillo	06/25/82	49600.00	1910.00	19.60	1.33	0.495	0.000043	28	72	0
Ama Orinoco at Guarampo-Punta Cuchillo	08/23/82	67100.00	2040.00	21.40	1.54	0.426	0.000048	30	75	0
Ama Orinoco at Isla Ceiba	08/15/82	30800.00	2505.00	11.40	1.08	0.404	0.000062	27	29	0
Ama Orinoco at Musinacio	03/19/83	7240.00	1120.00	13.50	0.48	0.427	0.000042	30	0	0
Ama Orinoco at Musinacio	12/03/82	25400.00	1275.00	18.80	1.06	0.489	0.000046	28	16	0
Ama Orinoco at Musinacio	06/22/82	52000.00	1208.00	26.20	1.64	0.338	0.000055	27	82	0
Ama Orinoco at Musinacio	08/20/82	70700.00	1310.00	28.00	1.93	0.499	0.000058	30	58	0
Ama Orinoco at Parguaza	03/12/83	5390.00	918.00	15.10	0.39	0.297	0.000058	31	0	0
Ama Orinoco at Parguaza	11/21/82	17300.00	1227.00	13.80	1.02	0.410	0.000058	29	11	0
Ama Orinoco at Parguaza	10/13/84	27300.00	1150.00	17.20	1.38	0.426	0.000058	28	45	0
Ama Orinoco at Parguaza	08/16/82	43700.00	1333.00	17.80	1.84	0.436	0.000061	27	102	0
Ama Orinoco at San Fernando de Atabapo	05/26/85	2650.00	849.00	3.76	0.83	0.699	0.000037	30	21	0
Ama Orinoco at San Fernando de Atabapo	10/18/84	5260.00	840.00	6.73	0.93	0.911	0.000037	30	8	0
Ama Paguay, 0.5 km above mouth	02/04/87	17.50	22.50	1.10	0.71	0.427	0.000238	29	262	0
Ama Portuguesa at El Sombrento	02/11/87	152.00	67.50	4.66	0.48	0.418	0.000139	29	25	0
Ama Portuguesa at El Sombrento	05/18/86	317.00	77.50	6.14	0.67	0.211	0.000089	29	11	0

1	2	3	4	5	6	7	8	9	10	11
Ama Purus below Beruri	12/06/82	5010.00	580.00	23.40	0.37	0.232	0.000020	27	0	0
Ama Sarare above Puente Remolino	01/30/87	133.00	170.00	1.16	0.68	0.349	0.000400	29	255	0
Ama Sarare above Puente Remolino	05/25/86	272.00	167.50	1.68	0.97	0.211	0.000272	29	851	0
Ama Solimoes at Anori	12/06/82	75700.00	1819.00	21.80	1.84	0.331	0.000026	27	140	0
Ama Solimoes at Ilha Xibeco	11/30/82	66600.00	1720.00	21.80	1.78	0.212	0.000064	27	167	0
Ama Solimoes at Iquitos	07/08/76	38100.00	970.00	23.00	1.71	0.255	0.000069	26	78	0
Ama Solimoes at Iquitos	05/20/77	43600.00	1080.00	23.80	1.70	0.220	0.000069	27	159	0
Ama Solimoes at Jutica	12/03/82	71300.00	3020.00	16.90	1.40	0.192	0.000045	27	164	0
Ama Solimoes at Manacapuru	05/28/77	133000.00	3130.00	27.60	1.54	0.216	0.000033	28	69	0
Ama Solimoes at Manacapuru	06/22/76	140000.00	3100.00	28.10	1.61	0.244	0.000033	26	86	0
Ama Solimoes at Santo Antonio do Ica	11/29/82	65400.00	2160.00	19.00	1.59	0.244	0.000064	27	128	0
Ama Solimoes at Santo Antonio do Ica	05/22/77	83700.00	2129.00	22.00	1.79	0.198	0.000056	27	125	0
Ama Solimoes at Santo Antonio do Ica	06/29/76	86100.00	2100.00	21.90	1.87	0.238	0.000056	26	63	0
Ama Solimoes at Sao Paulo de Olivenca	05/22/77	63600.00	1400.00	23.70	1.92	0.233	0.000058	27	120	0
Ama Solimoes at Vargem Grande	11/27/82	57100.00	1360.00	22.70	1.85	0.196	0.000064	27	174	0
Ama Solimoes below Itapeua	12/05/82	80800.00	1400.00	36.10	1.60	0.154	0.000045	27	110	0
Ama Solimoes below Itapeua	02/22/84	85200.00	1418.00	37.30	1.61	0.120	0.000034	27	78	0
Ama Solimoes below Itapeua	05/26/77	151000.00	1000.00	62.30	2.42	0.409	0.000037	27	47	0
Ama Solimoes below Tupe	12/01/82	62700.00	1530.00	23.90	1.71	0.343	0.000045	27	175	0
Amazon at Costa do Paura	12/12/82	120000.00	2300.00	38.90	1.34	0.141	0.000014	27	23	0
Amazon at Iracema	06/11/77	155000.00	2400.00	45.00	1.44	0.171	0.000019	27	43	0
Amazon at Obidos	12/13/82	123000.00	2200.00	46.20	1.21	0.135	0.000014	27	17	0
Amazon at Obidos	03/04/84	177000.00	2250.00	48.50	1.62	0.122	0.000014	28	49	0
Amazon at Obidos	06/02/77	230000.00	2340.00	55.80	1.76	0.237	0.000020	27	52	0
Amazon at Obidos	06/14/76	235000.00	2600.00	48.90	1.85	0.243	0.000020	26	85	0
Amazon at Obidos (Vertical c)	06/02/77	139.00	1.00	65.00	2.14	0.149	0.000020	27	62	0
Amazon at Obidos (Vertical d)	06/02/77	128.00	1.00	68.00	1.88	0.149	0.000020	27	49	0
Amazon at Obidos (Vertical e)	06/02/77	111.00	1.00	63.00	1.76	0.371	0.000020	27	29	0
Amazon at Obidos (Vertical f)	06/02/77	118.00	1.00	65.00	1.81	0.376	0.000020	27	36	0
Amazon at Obidos (Vertical g)	06/02/77	139.00	1.00	63.00	2.20	0.124	0.000020	27	78	0
Amazon at Sao Jose do Amajari	12/10/82	90600.00	1510.00	44.60	1.35	0.259	0.000014	27	18	0
American Canal	-	1.22	3.19	0.80	0.47	0.229	0.000294	21	406	0
American Canal	-	1.56	3.49	0.80	0.56	0.173	0.000253	21	249	0
American Canal	-	3.20	3.96	1.32	0.61	0.349	0.000110	26	44	0
American Canal	-	4.14	9.33	1.07	0.41	0.318	0.000135	25	254	0
American Canal	-	4.83	10.73	0.89	0.51	0.465	0.000237	26	52	0
American Canal	-	5.01	7.62	0.89	0.74	0.580	0.000330	26	448	0
American Canal	-	5.62	7.59	1.01	0.73	0.715	0.000302	23	123	0
American Canal	-	6.42	12.56	1.01	0.50	0.446	0.000218	28	100	0
American Canal	-	10.47	6.92	1.60	0.95	0.360	0.000114	26	131	0
American Canal	-	12.59	11.73	1.83	0.59	0.096	0.000063	23	370	0
American Canal	-	29.18	22.19	2.53	0.52	0.253	0.000058	22	115	0
American Canal	-	29.40	14.81	2.59	0.77	0.311	0.000120	22	185	0
Atchfalaya River	12/18/53	382.32	304.80	6.10	0.21	0.124	0.000002	31	1	0
Atchfalaya River	03/19/54	637.20	307.85	6.22	0.33	0.161	0.000010	29	6	0
Atchfalaya River	03/24/54	651.36	307.85	6.22	0.34	0.091	0.000004	29	9	0
Atchfalaya River	12/10/53	719.33	307.85	6.25	0.37	0.153	0.000006	29	8	0
Atchfalaya River	06/19/54	843.94	310.90	6.43	0.42	0.127	0.000007	31	3	0
Atchfalaya River	12/03/53	1073.33	313.94	6.89	0.50	0.138	0.000010	26	4	0
Atchfalaya River	04/24/55	1084.66	313.94	6.28	0.55	0.091	0.000009	18	18	0
Atchfalaya River	05/01/55	1138.46	313.94	6.22	0.58	0.091	0.000010	15	23	0
Atchfalaya River	03/10/54	1169.62	313.94	6.83	0.55	0.157	0.000011	28	6	0
Atchfalaya River	01/28/55	1200.77	316.99	6.46	0.59	0.138	0.000010	19	19	0
Atchfalaya River	01/21/55	1214.93	316.99	6.40	0.60	0.130	0.000011	18	25	0
Atchfalaya River	06/25/54	1237.58	313.94	6.74	0.59	0.123	0.000011	30	19	0
Atchfalaya River	07/06/54	1237.58	316.99	6.80	0.57	0.132	0.000011	28	15	0
Atchfalaya River	03/31/54	1240.42	313.94	6.80	0.58	0.155	0.000011	29	17	0
Atchfalaya River	10/08/54	1263.07	316.99	6.61	0.60	0.123	0.000011	26	17	0
Atchfalaya River	03/05/54	1376.35	316.99	7.19	0.60	0.151	0.000010	29	36	0
Atchfalaya River	09/24/54	1393.34	316.99	6.89	0.64	0.119	0.000011	30	38	0
Atchfalaya River	10/15/54	1449.98	316.99	6.92	0.66	0.141	0.000014	26	42	0
Atchfalaya River	11/26/53	1707.70	323.09	7.59	0.70	0.169	0.000014	27	23	0
Atchfalaya River	12/31/54	1770.00	323.09	7.04	0.78	0.144	0.000016	24	62	0
Atchfalaya River	04/07/45	2044.70	321.56	9.97	0.64	0.189	0.000023	28	14	0
Atchfalaya River	11/01/17	2143.82	328.27	9.85	0.66	0.223	0.000015	28	23	0

1	2	3	4	5	6	7	8	9	10	11
Atchafalaya River	01/12/46	2155.15	321.87	10.30	0.65	0.195	0.000017	13	16	0
Atchafalaya River	10/05/45	2177.81	322.48	10.24	0.66	0.241	0.000017	19	20	0
Atchafalaya River	11/15/17	2279.76	331.01	9.94	0.69	0.209	0.000015	25	15	0
Atchafalaya River	06/12/25	2282.59	333.76	9.94	0.69	0.201	0.000022	6	13	0
Atchafalaya River	12/17/44	2288.26	327.96	10.18	0.69	0.208	0.000020	31	26	0
Atchafalaya River	03/24/45	2288.26	327.66	9.88	0.71	0.213	0.000018	29	21	0
Atchafalaya River	09/10/70	2327.90	334.37	9.20	0.76	0.148	0.000018	6	136	0
Atchafalaya River	11/16/26	2359.06	338.33	8.90	0.78	0.261	0.000024	29	23	0
Atchafalaya River	10/20/45	2415.70	327.36	10.58	0.70	0.226	0.000019	14	37	0
Atchafalaya River	05/05/17	2421.36	334.98	9.91	0.73	0.223	0.000017	29	44	0
Atchafalaya River	11/03/00	2475.17	335.89	10.52	0.70	0.215	0.000024	8	155	0
Atchafalaya River	12/31/44	2500.66	329.18	10.45	0.73	0.189	0.000019	29	29	0
Atchafalaya River	01/01/00	2554.46	348.08	9.91	0.74	0.200	0.000027	29	16	0
Atchafalaya River	09/04/53	2730.05	344.42	8.23	0.96	0.177	0.000019	25	67	0
Atchafalaya River	07/07/00	2766.86	349.30	10.49	0.76	0.227	0.000026	17	33	0
Atchafalaya River	08/19/81	3086.88	374.90	9.48	0.87	0.153	0.000027	27	49	0
Atchafalaya River	01/05/55	3285.12	350.52	7.86	1.19	0.103	0.000015	21	225	0
Atchafalaya River	12/05/72	3398.40	373.08	10.52	0.87	0.308	0.000029	19	44	0
Atchafalaya River	08/28/53	3483.36	350.52	9.30	1.07	0.177	0.000020	22	61	0
Atchafalaya River	08/17/55	3540.00	365.76	8.32	1.16	0.130	0.000023	9	208	0
Atchafalaya River	08/05/81	3624.96	390.14	10.09	0.92	0.153	0.000032	34	57	0
Atchafalaya River	12/06/79	3624.96	368.81	8.11	1.21	0.154	0.000024	9	174	0
Atchafalaya River	01/25/46	3851.52	340.46	10.85	1.04	0.305	0.000020	8	122	0
Atchafalaya River	07/22/81	4163.04	396.24	10.55	1.00	0.153	0.000031	33	33	0
Atchafalaya River	03/12/80	4616.16	390.14	9.05	1.31	0.171	0.000028	5	232	0
Atchafalaya River	07/31/55	4984.32	387.10	9.42	1.37	0.143	0.000028	8	252	0
Atchafalaya River	04/15/81	5380.80	405.38	10.88	1.22	0.232	0.000035	26	74	0
Atchafalaya River	04/29/81	5494.08	408.43	11.25	1.20	0.153	0.000036	34	120	0
Atchafalaya River	09/11/44	6598.56	393.19	12.86	1.30	0.211	0.000034	29	146	0
Atchafalaya River	12/20/79	6853.44	402.34	11.00	1.55	0.172	0.000034	7	183	0
Atchafalaya River	01/06/81	7788.00	411.48	10.88	1.74	0.179	0.000038	8	102	0
Atchafalaya River	01/27/81	7986.24	438.91	11.86	1.53	0.188	0.000038	8	207	0
Atchafalaya River	10/29/71	8042.88	406.30	13.62	1.45	0.192	0.000037	26	222	0
Atchafalaya River	06/01/53	8354.40	414.53	12.07	1.67	0.221	0.000043	18	194	0
Atchafalaya River	03/26/80	8439.36	408.43	11.64	1.77	0.169	0.000039	9	404	0
Atchafalaya River	01/13/81	8524.32	435.86	12.80	1.53	0.175	0.000038	8	179	0
Atchafalaya River	04/18/26	8524.32	412.39	13.81	1.50	0.181	0.000040	10	237	0
Atchafalaya River	01/19/81	8665.92	435.86	12.95	1.53	0.286	0.000041	22	156	0
Atchafalaya River	09/03/53	9175.68	417.58	13.38	1.64	0.193	0.000042	12	387	0
Atchafalaya River	01/12/81	9543.84	448.06	13.87	1.54	0.235	0.000045	20	60	0
Atchafalaya River	09/30/80	10223.52	451.10	13.23	1.71	0.199	0.000044	12	343	0
Atchafalaya River	10/06/80	11243.04	454.15	13.17	1.88	0.197	0.000048	15	333	0
Atchafalaya River	01/05/81	11497.92	454.15	13.29	1.91	0.260	0.000050	18	567	0
Atchafalaya River	04/10/71	11639.52	468.78	14.75	1.68	0.274	0.000045	16	232	0
Atchafalaya River	07/16/71	11781.12	469.70	14.54	1.73	0.289	0.000045	21	260	0
Atchafalaya River	10/20/80	12007.68	457.20	13.41	1.96	0.229	0.000051	18	178	0
Atchafalaya River	10/13/80	12149.28	457.20	13.75	1.93	0.235	0.000051	17	280	0
Atchafalaya River	07/22/71	12574.08	476.10	14.20	1.86	0.183	0.000047	21	365	0
Atchafalaya River	10/11/71	13848.48	483.72	14.11	2.03	0.181	0.000050	21	474	0
Atchafalaya River	08/17/98	14188.32	503.22	14.72	1.92	0.193	0.000049	15	501	0
Black River	03/31/78	163	84	1.9	1.0	0.365	0.00018	5.5	123	0
Black River	08/09/78	20.1	72	0.55	0.5	0.400	0.00027	16	101	0
Black River	05/10/78	28.9	94	0.57	0.5	0.405	0.00024	15.5	161	0
Black River	11/08/77	32.3	94	0.77	0.5	0.420	0.00023	10	53	0
Black River	06/13/78	26.1	77	0.75	0.5	0.440	0.00029	21	105	0
Black River	10/28/78	24.2	96	0.58	0.4	0.440	0.00018	8	73	0
Black River	05/31/79	92.9	122	1.5	0.5	0.530	0.00011	18	1,147	0
Chippewa River, Carryville	04/13/77	117	185	1.4	0.5	0.980	0.00013	11.5	8	0
Chippewa River, Carryville	11/16/77	141	185	1.4	0.5	1.100	0.00015	8.5	3	0
Chippewa River, Carryville	04/14/78	374	231	2	0.8	1.990	0.00025	6.5	27	0
Chippewa River, Carryville	05/10/77	51.8	176	0.99	0.3	3.000	0.00011	17	6	0
Chippewa River, Carryville	06/06/78	172	200	1.5	0.6	3.200	0.00019	22	13	0
Chippewa River, Carryville	07/06/77	337	209	2.2	0.8	3.330	0.00023	26	23	0
Chippewa River, Carryville	11/17/76	32	132	1	0.2	3.500	0.000093	4.5	5	0
Chippewa River, Carryville	10/12/77	433	231	2.2	0.9	4.650	0.00025	13	22	0

1	2	3	4	5	6	7	8	9	10	11
Chippewa River, Caryville	10/18/76	30.6	124	1.1	0.2	5.000	0.00011	7	4	0
Chippewa River, Caryville	04/05/78	320	225	1.8	0.8	5.800	0.00023	4.5	19	0
Chippewa River, Caryville	04/17/79	620	245	2.5	1.0	6.000	0.00025	4.5	17	0
Chippewa River, Caryville	10/31/78	123	190	1.3	0.5	7.600	0.00017	10.5	5	0
Chippewa River, Caryville	09/13/77	255	204	1.8	0.7	7.660	0.00021	19	11	0
Chippewa River, Caryville	07/06/78	348	226	1.9	0.8	7.900	0.00025	21	19	0
Chippewa River, Caryville	04/23/79	779	247	2.8	1.1	15.500	0.00025	8	38	0
Chippewa River, Durand	05/10/77	132	188	1	0.7	0.550	0.00033	17.5	47	0
Chippewa River, Durand	03/17/77	219	215	1.3	0.8	0.570	0.00032	3	68	0
Chippewa River, Durand	09/13/77	279	223	1.5	0.9	0.580	0.00034	19	176	0
Chippewa River, Durand	07/06/77	377	225	1.8	0.9	0.600	0.00036	26	101	0
Chippewa River, Durand	04/13/77	139	187	1.1	0.7	0.610	0.00034	15	60	0
Chippewa River, Durand	11/16/77	198	199	1.3	0.8	0.630	0.00031	5	47	0
Chippewa River, Durand	04/17/79	739	239	2.9	1.1	0.640	0.00031	5	75	0
Chippewa River, Durand	11/16/76	51.5	153	0.62	0.6	0.650	0.00032	3	16	0
Chippewa River, Durand	06/06/78	247	224	1.6	0.7	0.680	0.00035	22	19	0
Chippewa River, Durand	10/12/77	479	227	2.2	1.0	0.710	0.00032	13	70	0
Chippewa River, Durand	07/06/78	473	233	2	1.0	0.740	0.00029	24	77	0
Chippewa River, Durand	10/18/76	50.7	160	0.61	0.5	0.870	0.00029	6	28	0
Chippewa River, Durand	08/24/77	53.8	160	0.68	0.5	0.880	0.00032	20	48	0
Chippewa River, Durand	04/23/79	884	244	3.2	1.1	1.300	0.00032	9.5	99	0
Chippewa River, Pepin	05/11/77	110	243	0.95	0.5	0.400	0.00032	18.5	33	0
Chippewa River, Pepin	04/14/77	155	241	1.1	0.6	0.440	0.00041	15	194	0
Chippewa River, Pepin	03/16/77	257	265	1.5	0.7	0.460	0.00045	4.5	201	0
Chippewa River, Pepin	07/24/79	140	247	0.85	0.7	0.475	0.00029	24.5	33	0
Chippewa River, Pepin	07/07/77	399	273	1.6	0.9	0.480	0.00037	25.5	357	0
Chippewa River, Pepin	04/06/78	391	276	1.8	0.8	0.480	0.00028	5	99	0
Chippewa River, Pepin	05/30/79	219	242	1.4	0.7	0.480	0.00017	20.5	58	0
Chippewa River, Pepin	09/11/79	118	229	0.76	0.7	0.480	0.00025	18.5	69	0
Chippewa River, Pepin	09/14/77	295	274	1.3	0.9	0.490	0.00037	18.5	85	0
Chippewa River, Pepin	06/07/78	217	264	1.1	0.7	0.510	0.00024	22.5	63	0
Chippewa River, Pepin	10/19/76	72.5	171	0.75	0.6	0.540	0.00036	6	64	0
Chippewa River, Pepin	09/20/78	320	277	1.5	0.8	0.540	0.00033	19	81	0
Chippewa River, Pepin	11/17/76	70	171	0.76	0.5	0.560	0.00058	4	73	0
Chippewa River, Pepin	11/01/78	187	246	1.2	0.6	0.560	0.00029	7.5	58	0
Chippewa River, Pepin	09/20/76	70.5	171	0.8	0.5	0.580	0.00039	16	102	0
Chippewa River, Pepin	05/16/78	170	261	0.97	0.7	0.600	0.00025	16.5	59	0
Chippewa River, Pepin	09/01/76	76.2	195	0.88	0.5	0.620	0.00039	19	41	0
Chippewa River, Pepin	11/17/77	210	270	1.4	0.6	0.710	0.00036	3.5	70	0
Chulitna River	05/19/83	347	98.5	1.9	1.8	2.500	0.00068	5.5	450	0
Chulitna River	09/13/83	279	101	1.8	1.5	7.650	0.00064	5.5	830	0
Chulitna River	05/18/84	261	100	1.7	1.5	20.500	0.00074	4	693	0
Chulitna River	07/27/82	924.5	123	3.1	2.5	24.500	0.0014	6	1,183	0
Colorado River	-	77.53	103.08	1.13	0.66	0.310	0.000207	11	86	0
Colorado River	-	92.03	130.54	1.49	0.47	0.313	0.000073	11	23	0
Colorado River	-	96.79	95.73	1.91	0.53	0.280	0.000133	13	23	0
Colorado River	-	105.34	130.54	1.51	0.53	0.290	0.000060	11	312	0
Colorado River	-	105.34	106.35	1.40	0.71	0.310	0.000233	13	133	0
Colorado River	-	108.23	106.99	1.37	0.74	0.315	0.000253	10	113	0
Colorado River	-	109.16	95.17	1.55	0.74	0.280	0.000277	9	365	0
Colorado River	-	111.65	96.29	1.99	0.58	0.260	0.000147	10	18	0
Colorado River	-	115.25	136.14	1.37	0.62	0.310	0.000176	12	62	0
Colorado River	-	118.19	99.95	2.01	0.59	0.280	0.000113	13	21	0
Colorado River	-	121.11	107.59	1.48	0.76	0.273	0.000333	12	152	0
Colorado River	-	121.76	108.15	1.59	0.71	0.300	0.000220	11	105	0
Colorado River	-	127.71	132.52	1.68	0.57	0.285	0.000100	10	139	0
Colorado River	-	128.90	106.77	1.51	0.80	0.330	0.000233	11	239	0
Colorado River	-	131.45	107.54	1.57	0.78	0.288	0.000260	12	225	0
Colorado River	-	132.24	136.11	1.45	0.67	0.315	0.000389	12	172	0
Colorado River	-	134.00	136.72	1.47	0.67	0.285	0.000183	11	176	0
Colorado River	-	135.92	106.43	1.67	0.76	0.315	0.000220	9	195	0
Colorado River	-	137.87	92.64	1.93	0.77	0.236	0.000196	13	113	0
Colorado River	-	154.47	110.11	1.86	0.76	0.293	0.000207	15	198	0
Colorado River	-	155.52	109.93	1.93	0.73	0.325	0.000167	20	200	0
Colorado River	-	157.36	134.74	1.94	0.60	0.260	0.000200	11	177	0

1	2	3	4	5	6	7	8	9	10	11
Colorado River	-	158.40	110.32	1.91	0.75	0.300	0.000173	16	193	0
Colorado River	-	166.08	134.58	1.91	0.65	0.285	0.000100	14	193	0
Colorado River	-	169.90	137.42	1.59	0.78	0.320	0.000107	14	143	0
Colorado River	-	173.16	102.77	2.04	0.83	0.250	0.000153	8	289	0
Colorado River	-	175.59	102.43	2.06	0.83	0.335	0.000407	10	316	0
Colorado River	-	178.11	100.97	2.08	0.85	0.340	0.000127	11	73	0
Colorado River	-	181.17	110.67	2.15	0.76	0.340	0.000177	22	304	0
Colorado River	-	181.65	109.79	1.93	0.86	0.315	0.000213	11	413	0
Colorado River	-	183.78	136.17	2.01	0.67	0.270	0.000157	16	68	0
Colorado River	-	184.20	102.43	1.91	0.94	0.300	0.000267	8	230	0
Colorado River	-	187.60	110.69	2.18	0.78	0.360	0.000173	24	276	0
Colorado River	-	191.93	104.83	2.26	0.81	0.430	0.000140	11	192	0
Colorado River	-	194.90	101.49	2.29	0.84	0.290	0.000173	11	112	0
Colorado River	-	196.07	110.06	2.04	0.87	0.300	0.000260	11	78	0
Colorado River	-	198.90	103.28	2.25	0.85	0.295	0.000277	9	474	0
Colorado River	-	203.12	151.82	2.25	0.60	0.245	0.000100	10	262	0
Colorado River	-	209.80	110.90	2.24	0.84	0.345	0.000227	22	212	0
Colorado River	-	210.28	104.23	2.06	0.98	0.310	0.000067	9	604	0
Colorado River	-	216.91	146.03	2.03	0.73	0.220	0.000100	12	145	0
Colorado River	-	217.08	110.92	2.22	0.88	0.330	0.000216	17	242	0
Colorado River	-	219.12	107.58	2.53	0.81	0.270	0.000267	17	316	0
Colorado River	-	219.80	110.59	2.06	0.97	0.340	0.000193	14	160	0
Colorado River	-	220.31	109.44	2.87	0.70	0.315	0.000213	9	182	0
Colorado River	-	221.49	103.95	2.31	0.92	0.320	0.000220	14	325	0
Colorado River	-	221.72	104.27	2.47	0.86	0.285	0.000240	15	477	0
Colorado River	-	223.62	112.22	2.49	0.80	0.355	0.000173	20	109	0
Colorado River	-	226.53	139.33	2.44	0.67	0.290	0.000080	22	164	0
Colorado River	-	228.94	146.62	2.70	0.58	0.230	0.000146	14	189	0
Colorado River	-	234.49	153.28	2.64	0.58	0.155	0.000080	14	94	0
Colorado River	-	239.11	140.22	2.43	0.70	0.205	0.000127	23	253	0
Colorado River	-	240.07	111.68	2.22	0.97	0.370	0.000187	22	151	0
Colorado River	-	241.83	143.79	2.99	0.56	0.200	0.000346	20	264	0
Colorado River	-	243.52	103.01	2.57	0.92	0.300	0.000177	18	283	0
Colorado River	-	245.76	105.79	2.40	0.97	0.280	0.000110	18	178	0
Colorado River	-	254.20	247.28	1.46	0.70	0.270	0.000167	11	394	0
Colorado River	-	269.94	112.79	2.68	0.89	0.340	0.000224	19	148	0
Colorado River	-	272.78	108.45	2.68	0.94	0.695	0.000103	15	178	0
Colorado River	-	274.22	112.51	2.65	0.92	0.370	0.000206	22	255	0
Colorado River	-	279.77	142.12	2.62	0.75	0.200	0.000153	27	168	0
Colorado River	-	279.77	112.77	2.72	0.91	0.400	0.000147	27	202	0
Colorado River	-	288.83	142.10	2.58	0.79	0.225	0.000067	24	181	0
Colorado River	-	293.28	112.23	3.12	0.84	0.280	0.000193	13	573	0
Colorado River	-	293.50	110.28	3.05	0.87	0.275	0.000150	21	159	0
Colorado River	-	294.44	158.25	2.76	0.67	0.210	0.000100	20	106	0
Colorado River	-	296.76	112.78	2.80	0.94	0.395	0.000233	26	87	0
Colorado River	-	301.86	139.97	2.54	0.85	0.395	0.000147	22	230	0
Colorado River	-	303.92	113.05	2.83	0.95	0.320	0.000207	15	328	0
Colorado River	-	307.10	113.61	2.87	0.94	0.295	0.000216	26	199	0
Colorado River	-	308.65	139.54	2.64	0.84	0.320	0.000120	18	90	0
Colorado River	-	310.61	113.09	2.90	0.95	0.350	0.000193	24	166	0
Colorado River	-	315.73	114.01	2.78	1.00	0.335	0.000233	26	302	0
Colorado River	-	324.23	144.34	2.96	0.76	0.265	0.000166	17	264	0
Colorado River	-	324.62	140.97	2.67	0.86	0.400	0.000153	22	193	0
Colorado River	-	324.79	141.75	2.92	0.78	0.240	0.000087	26	111	0
Colorado River	-	328.48	146.97	2.91	0.77	0.200	0.000073	27	228	0
Colorado River	-	330.71	147.69	3.14	0.71	0.230	0.000069	19	152	0
Colorado River	-	334.14	109.06	2.63	1.16	0.240	0.000283	19	160	0
Colorado River	-	335.84	146.54	2.85	0.80	0.225	0.000060	26	233	0
Colorado River	-	343.65	157.90	2.82	0.77	0.195	0.000144	20	338	0
Colorado River	-	344.62	144.79	2.62	0.91	0.320	0.000113	21	140	0
Colorado River	-	344.90	146.37	2.70	0.87	0.340	0.000160	22	115	0
Colorado River	-	345.44	114.35	3.07	0.99	0.360	0.000227	27	201	0
Colorado River	-	348.30	159.88	3.89	0.56	0.180	0.000037	17	57	0
Colorado River	-	348.75	111.59	3.34	0.94	0.260	0.000196	23	172	0
Colorado River	-	358.77	110.15	3.37	0.97	0.250	0.000220	18	355	0

	1	2	3	4	5	6	7	8	9	10	11
Colorado River	-		359.20	146.21	2.96	0.83	0.270	0.000127	25	83	0
Colorado River	-		359.99	116.81	3.09	1.00	0.270	0.000127	16	209	0
Colorado River	-		360.50	114.73	3.14	1.00	0.375	0.000257	27	213	0
Colorado River	-		362.46	117.03	2.83	1.09	0.300	0.000187	13	131	0
Colorado River	-		370.61	111.64	2.62	1.27	0.275	0.000160	20	36	0
Colorado River	-		387.66	149.09	3.08	0.84	0.280	0.000207	26	114	0
Colorado River	-		389.58	114.91	3.63	0.93	0.230	0.000200	20	212	0
Colorado River	-		403.57	253.10	2.30	0.69	0.310	0.000140	19	32	0
Colorado River	-		408.39	112.77	2.87	1.26	0.248	0.000310	18	347	0
Colorado River	-		413.43	148.29	3.37	0.83	0.240	0.000177	17	119	0
Colorado River	-		443.16	162.43	3.59	0.76	0.195	0.000134	19	48	0
Colorado River	-		454.32	160.67	3.31	0.85	0.175	0.000170	17	284	0
Colorado River	-		500.16	254.55	2.19	0.90	0.360	0.000180	19	769	0
Hii River	-		0.00094	0.35	0.02	0.14	0.210	0.008090	20	925	2
Hii River	-		0.00145	0.35	0.02	0.19	0.210	0.011300	20	1,955	2
Hii River	-		0.00199	0.35	0.02	0.23	0.210	0.010700	20	3,316	2
Hii River	-		0.00168	0.35	0.03	0.19	0.210	0.009750	20	2,347	2
Hii River	-		0.00244	0.35	0.03	0.25	0.210	0.009270	20	1,728	2
Hii River	-		0.00303	0.35	0.03	0.28	0.210	0.008040	20	4,878	2
Hii River	-		0.00448	0.35	0.03	0.40	0.210	0.007280	20	4,274	2
Hii River	-		0.00542	0.35	0.03	0.46	0.210	0.008390	20	5,639	2
Hii River	-		0.00440	0.35	0.04	0.35	0.210	0.007080	20	3,546	2
Hii River	-		0.00651	0.35	0.04	0.51	0.210	0.006690	20	3,261	2
Hii River	-		0.00745	0.35	0.04	0.56	0.210	0.006440	20	4,323	2
Hii River	-		0.00367	0.35	0.03	0.31	0.210	0.005820	20	1,249	2
Hii River	-		0.00513	0.35	0.04	0.35	0.210	0.005820	20	1,325	2
Hii River	-		0.00437	0.35	0.04	0.29	0.210	0.007690	20	1,702	2
Hii River	-		0.00775	0.35	0.04	0.50	0.210	0.005150	20	2,342	2
Hii River	-		1.78047	8.00	0.31	0.73	1.440	0.000840	20	121	3
Hii River	-		2.35603	8.00	0.40	0.74	1.440	0.001060	20	167	3
Hii River	-		2.42392	8.00	0.42	0.71	1.440	0.000850	20	116	3
Hii River	-		2.76436	8.00	0.49	0.70	1.440	0.000860	20	117	3
Hii River	-		3.49857	8.00	0.59	0.74	1.440	0.000880	20	299	3
Hii River	-		4.85132	8.00	0.65	0.93	1.440	0.001480	20	271	3
Hii River	-		4.47922	8.00	0.70	0.80	1.440	0.001010	20	154	3
Hii River	-		4.72729	8.00	0.73	0.81	1.440	0.001530	20	191	3
Hii River	-		1.13182	8.00	0.20	0.70	1.330	0.001660	20	553	3
Hii River	-		2.23740	8.00	0.37	0.75	1.330	0.001380	20	207	3
Hii River	-		1.95124	8.00	0.39	0.63	1.330	0.000890	20	136	3
Hii River	-		2.91789	8.00	0.45	0.80	1.330	0.001420	20	167	3
Hii River	-		0.18104	2.00	0.16	0.58	1.260	0.001690	20	296	3
Hii River	-		0.24806	2.00	0.20	0.63	1.260	0.001610	20	284	3
Hii River	-		0.34433	2.00	0.26	0.67	1.260	0.001610	20	275	3
Hii River	-		0.42868	2.00	0.29	0.73	1.260	0.001670	20	283	3
Hii River	-		0.52172	2.00	0.34	0.76	1.260	0.001660	20	243	3
Hii River	-		0.71449	2.00	0.47	0.76	1.260	0.001660	20	242	3
Hii River	-		0.04740	0.80	0.11	0.55	1.260	0.001690	20	225	3
Hii River	-		0.07000	0.80	0.15	0.60	1.260	0.001720	20	127	3
Hii River	-		0.39008	2.00	0.30	0.66	1.460	0.001370	20	222	3
Hii River	-		0.49427	2.00	0.36	0.69	1.460	0.001400	20	210	3
Hii River	-		0.53144	2.00	0.36	0.74	1.460	0.001460	20	270	3
India Canal	-		1.15	4.35	0.67	0.39	0.048	0.000145	20	1,031	0
India Canal	-		1.29	4.31	0.79	0.38	0.064	0.000165	20	760	0
India Canal	-		2.02	5.34	0.94	0.40	0.042	0.000115	20	1,417	0
India Canal	-		3.00	5.78	1.10	0.47	0.046	0.000115	20	3,132	0
India Canal	-		13.19	10.70	1.94	0.64	0.051	0.000100	20	671	0
India Canal	-		13.41	10.58	1.97	0.65	0.050	0.000100	20	981	0
India Canal	-		14.03	14.66	1.72	0.56	0.037	0.000080	20	4,230	0
India Canal	-		14.11	13.49	1.85	0.57	0.036	0.000080	20	1,894	0
India Canal	-		14.81	13.55	1.86	0.59	0.043	0.000080	20	2,467	0
India Canal	-		15.84	17.31	1.57	0.58	0.070	0.000120	20	726	0
India Canal	-		15.87	17.34	1.57	0.58	0.056	0.000120	20	596	0
India Canal	-		19.22	15.95	2.37	0.51	0.048	0.000088	20	512	0
India Canal	-		19.45	16.03	2.38	0.51	0.044	0.000088	20	624	0
India Canal	-		24.59	18.07	2.24	0.61	0.046	0.000120	20	2,517	0

1	2	3	4	5	6	7	8	9	10	11
India Canal	-	27.50	17.89	2.51	0.61	0.039	0.000070	20	822	0
India Canal	-	27.67	17.98	2.52	0.61	0.033	0.000070	20	831	0
India Canal	-	27.89	18.17	2.17	0.71	0.050	0.000112	20	2,601	0
India Canal	-	30.86	20.57	2.37	0.63	0.064	0.000080	20	918	0
India Canal	-	33.74	20.58	2.38	0.69	0.043	0.000080	20	797	0
India Canal	-	59.16	25.49	2.44	0.95	0.021	0.000084	20	5,759	0
India Canal	-	60.72	25.56	2.49	0.95	0.025	0.000084	20	5,182	0
India Canal	-	68.82	25.77	2.55	1.05	0.031	0.000110	20	3,557	0
India Canal	-	68.92	25.68	2.55	1.05	0.035	0.000110	20	3,508	0
India Canal	-	131.39	51.51	3.29	0.77	0.066	0.000065	20	1,593	0
India Canal	-	132.80	51.90	3.29	0.78	0.064	0.000065	20	1,976	0
India Canal	-	153.25	56.02	3.37	0.81	0.024	0.000060	20	2,887	0
India Canal	-	156.05	56.27	3.39	0.82	0.020	0.000060	20	2,601	0
India Canal	-	157.41	56.47	3.35	0.83	0.030	0.000070	20	2,316	0
India Canal	-	158.37	56.61	3.35	0.83	0.039	0.000070	20	2,175	0
India Canal	-	163.72	66.55	3.39	0.73	0.082	0.000057	20	1,519	0
India Canal	-	166.36	66.54	3.41	0.73	0.080	0.000057	20	1,425	0
India Canal	-	242.19	79.10	3.56	0.86	0.057	0.000064	20	1,490	0
MiddleLoup River	09/03/25	9.34	44.81	0.33	0.62	0.282	0.001420	31	648	0
MiddleLoup River	03/15/26	9.46	45.42	0.31	0.67	0.351	0.001288	20	884	0
MiddleLoup River	03/25/97	10.22	44.20	0.33	0.70	0.339	0.001345	10	1,044	0
MiddleLoup River	08/10/70	10.31	43.89	0.32	0.73	0.317	0.001458	24	455	0
MiddleLoup River	03/28/26	10.36	45.11	0.33	0.69	0.274	0.001307	18	816	0
MiddleLoup River	04/25/98	10.39	44.81	0.37	0.62	0.383	0.001288	31	411	0
MiddleLoup River	11/18/70	10.45	43.28	0.36	0.68	0.424	0.001250	22	481	0
MiddleLoup River	12/07/25	10.93	45.11	0.33	0.74	0.334	0.001326	26	494	0
MiddleLoup River	08/17/99	11.30	37.49	0.33	0.92	0.351	0.001174	1	1,637	0
MiddleLoup River	05/05/70	11.30	44.20	0.34	0.75	0.382	0.001250	16	871	0
MiddleLoup River	10/29/69	11.61	42.98	0.29	0.93	0.292	0.001439	4	1,831	0
MiddleLoup River	02/10/70	11.72	44.20	0.30	0.88	0.335	0.001023	11	1,110	0
MiddleLoup River	02/24/99	12.09	46.33	0.31	0.83	0.351	0.001307	4	1,345	0
MiddleLoup River	10/09/69	12.23	43.89	0.30	0.94	0.278	0.000928	4	1,618	0
MiddleLoup River	12/25/71	12.54	45.11	0.25	1.13	0.219	0.001345	3	1,023	0
Missi Arkansas River at Pendleton, ARK	03/23/89	1900.00	380.00	7.08	0.71	0.299	0.000059	12	6	0
Missi Arkansas River at Pendleton, ARK	06/19/89	3590.00	391.00	7.19	1.28	0.290	0.000105	25	154	0
Missi Illinois River at Valley City, IL	06/07/90	1230.00	221.00	6.20	0.90	0.480	0.000040	10	15	0
Missi Illinois River below Meredosia, IL	05/16/88	332.00	228.00	3.61	0.40	0.180	0.000028	22	2	0
Missi Missouri River at Hermann, MO	03/09/89	1480.00	270.00	4.52	1.21	0.381	0.000172	7	187	0
Missi Missouri River at Hermann, MO	05/19/88	1480.00	350.00	4.31	0.98	0.386	0.000173	22	104	0
Missi Missouri River at Hermann, MO	06/07/89	1760.00	270.00	5.18	1.26	0.389	0.000172	23	154	0
Missi Missouri River at Hermann, MO	07/20/87	2640.00	377.00	5.65	1.24	0.379	0.000170	27	212	0
Missi Missouri River at St. Charles, MO	12/02/87	2810.00	428.00	5.30	1.24	0.370	0.000177	6	353	0
Missi Ohio River at Olmsted, IL	05/23/88	3230.00	945.00	5.85	0.58	0.454	0.000029	22	3	0
Missi Ohio River at Olmsted, IL	12/06/87	4200.00	974.00	7.82	0.55	0.393	0.000017	9	1	0
Missi Ohio River at Olmsted, IL	06/11/89	8760.00	1008.00	9.31	0.93	0.606	0.000026	24	4	0
Missi Ohio River at Olmsted, IL	06/14/90	9550.00	1046.00	11.80	0.78	0.570	0.000016	22	7	0
Missi Ohio River at Olmsted, IL	03/03/90	16100.00	1080.00	12.50	1.20	0.659	0.000042	6	12	0
Missi Ohio River at Olmsted, IL	03/16/89	20400.00	1070.00	13.70	1.39	0.556	0.000051	9	34	0
Missi Ohio River at Uniontown, KY	03/01/90	6620.00	761.00	9.84	0.88	0.889	0.000031	6	4	0
Missi Old River near Knox Landing, LA	12/17/87	1830.00	525.00	5.54	0.63	0.340	0.000060	9	6	0
Missi Old River near Knox Landing, LA	08/06/87	2050.00	519.00	4.08	0.97	0.350	0.000045	31	48	0
Missi Old River near Knox Landing, LA	06/04/88	2150.00	515.00	4.06	1.03	0.292	0.000079	25	87	0
Missi Old River near Knox Landing, LA	06/25/89	4880.00	562.00	9.62	0.90	0.246	0.000040	26	77	0
Missi Old River near Knox Landing, LA	03/29/89	6150.00	556.00	11.10	1.00	0.307	0.000042	13	25	0
Missi Wabsh River near New Haven, IL	02/28/90	2340.00	355.00	6.11	1.08	0.798	0.000093	3	46	0
Missi White River at mile 11.5, ARK	07/31/87	332.00	168.00	2.92	0.68	0.378	0.000150	31	15	0
Missi White River at mile 11.5, ARK	05/29/88	438.00	164.00	3.17	0.84	0.334	0.000050	22	25	0
Missi White River at mile 11.5, ARK	12/12/87	519.00	177.00	4.02	0.73	0.393	0.000052	11	101	0
Missi White River at mile 11.5, ARK	06/18/89	860.00	195.00	8.98	0.49	0.373	0.000050	23	3	0
Missi White River at mile 11.5, ARK	03/22/89	1500.00	200.00	10.30	0.73	0.392	0.000053	12	2	0
Missi Yazoo River below Steele Bayou, MS	06/22/89	1070.00	165.00	9.19	0.71	0.561	0.000021	26	7	0
Missi Yazoo River below Steele Bayou, MS	06/22/90	1250.00	200.00	9.75	0.64	0.222	0.000016	28	4	0
Missi Yazoo River below Steele Bayou, MS	03/26/89	1500.00	182.00	10.40	0.79	0.450	0.000037	15	22	0
Mississippi River above Arkansas City, ARK	08/02/87	7630.00	850.00	11.50	0.78	0.284	0.000064	31	17	0
Mississippi River above Arkansas City, ARK	05/30/88	8160.00	838.00	11.00	0.89	0.286	0.000060	24	17	0

1	2	3	4	5	6	7	8	9	10	11
Mississippi River above Arkansas City, ARK	12/13/87	9920.00	904.00	11.00	1.00	0.398	0.000066	9	314	0
Mississippi River above Arkansas City, ARK	06/20/89	23300.00	990.00	15.10	1.56	0.286	0.000069	25	114	0
Mississippi River above Arkansas City, ARK	03/24/89	26800.00	1035.00	15.90	1.63	0.321	0.000066	11	119	0
Mississippi River at Fullton, Tenn.	05/26/88	7170.00	805.00	8.36	1.07	0.380	0.000104	22	34	0
Mississippi River at Fullton, Tenn.	12/08/87	9470.00	844.00	9.67	1.16	0.846	0.000101	9	370	0
Mississippi River at Fullton, Tenn.	06/14/89	15300.00	902.00	11.50	1.47	0.469	0.000098	24	61	0
Mississippi River at Helena, ARK	07/30/87	6850.00	701.00	6.75	1.45	0.370	0.000094	30	85	0
Mississippi River at Helena, ARK	05/28/88	7050.00	754.00	7.36	1.27	0.394	0.000096	23	83	0
Mississippi River at Helena, ARK	12/11/87	8770.00	750.00	7.96	1.47	0.334	0.000095	9	152	0
Mississippi River at Helena, ARK	06/17/89	16900.00	897.00	13.10	1.44	0.441	0.000094	24	84	0
Mississippi River at Helena, ARK	03/07/90	23300.00	855.00	17.30	1.58	0.365	0.000082	7	84	0
Mississippi River at Helena, ARK	03/21/89	25900.00	913.00	16.50	1.72	0.681	0.000085	9	102	0
Mississippi River at St Louis, MO	05/20/88	3350.00	487.00	6.75	1.02	0.386	0.000085	23	36	0
Mississippi River at St Louis, MO	07/22/87	3830.00	482.00	7.35	1.08	0.324	0.000085	28	74	0
Mississippi River at St Louis, MO	03/13/89	3940.00	490.00	6.90	1.17	0.389	0.000085	6	120	0
Mississippi River at St Louis, MO	06/08/89	4760.00	508.00	7.66	1.22	0.443	0.000092	25	83	0
Mississippi River at StLouis	01/15/79	1512.29	455.98	4.94	0.67	0.235	0.000079	3	13	0
Mississippi River at StLouis	09/14/70	1512.29	457.20	4.66	0.71	0.505	0.000072	2	25	0
Mississippi River at StLouis	04/01/36	1560.43	460.25	4.82	0.70	0.296	0.000134	14	26	0
Mississippi River at StLouis	03/16/09	1634.06	459.64	5.18	0.69	0.328	0.000103	2	45	0
Mississippi River at StLouis	05/25/51	1755.84	470.61	6.00	0.62	0.544	0.000072	5	14	0
Mississippi River at StLouis	05/20/54	1767.17	462.69	5.39	0.71	0.268	0.000056	7	21	0
Mississippi River at StLouis	05/26/51	1806.82	470.92	6.10	0.63	0.573	0.000057	5	14	0
Mississippi River at StLouis	11/17/53	1886.11	463.91	5.55	0.73	0.287	0.000052	18	12	0
Mississippi River at StLouis	01/28/27	1886.11	471.53	6.16	0.65	0.598	0.000057	2	21	0
Mississippi River at StLouis	01/27/27	1911.60	472.14	6.19	0.65	0.572	0.000052	2	23	0
Mississippi River at StLouis	08/19/53	2005.06	467.26	5.61	0.77	0.293	0.000052	21	14	0
Mississippi River at StLouis	07/04/26	2064.53	471.83	6.34	0.69	1.152	0.000046	11	15	0
Mississippi River at StLouis	05/12/63	2095.68	464.52	5.64	0.80	0.386	0.000103	17	44	0
Mississippi River at StLouis	04/02/26	2115.50	474.88	6.52	0.68	0.642	0.000052	21	7	0
Mississippi River at StLouis	07/22/81	2208.96	465.43	6.07	0.78	0.299	0.000072	6	30	0
Mississippi River at StLouis	01/24/46	2271.26	469.39	5.97	0.81	0.574	0.000072	2	67	0
Mississippi River at StLouis	11/23/79	2279.76	470.92	6.04	0.80	0.224	0.000072	6	37	0
Mississippi River at StLouis	11/23/79	2279.76	470.92	6.04	0.80	0.224	0.000093	6	36	0
Mississippi River at StLouis	08/28/63	2299.58	470.61	5.55	0.88	0.625	0.000098	9	51	0
Mississippi River at StLouis	08/04/53	2486.50	471.22	6.40	0.82	0.274	0.000056	22	19	0
Mississippi River at StLouis	09/02/18	2628.10	469.39	5.94	0.94	0.549	0.000093	2	70	0
Mississippi River at StLouis	07/12/45	2633.76	469.39	6.64	0.84	0.641	0.000062	18	14	0
Mississippi River at StLouis	04/13/07	2789.52	469.39	6.95	0.86	0.306	0.000069	23	21	0
Mississippi River at StLouis	12/26/80	2832.00	477.62	6.95	0.85	0.299	0.000065	21	31	0
Mississippi River at StLouis	03/31/90	2888.64	472.44	6.95	0.88	0.472	0.000077	25	37	0
Mississippi River at StLouis	09/21/90	2916.96	477.62	6.40	0.95	0.429	0.000062	18	49	0
Mississippi River at StLouis	05/05/17	3001.92	474.88	6.83	0.93	0.511	0.000077	26	48	0
Mississippi River at StLouis	03/15/26	3030.24	480.06	7.74	0.82	0.579	0.000031	24	24	0
Mississippi River at StLouis	05/27/89	3086.88	477.93	6.74	0.96	0.377	0.000093	22	61	0
Mississippi River at StLouis	10/16/45	3115.20	478.54	7.32	0.89	0.646	0.000061	8	27	0
Mississippi River at StLouis	06/14/80	3256.80	472.74	7.35	0.94	0.310	0.000060	27	24	0
Mississippi River at StLouis	07/19/81	3256.80	472.74	7.35	0.94	0.310	0.000062	27	23	0
Mississippi River at StLouis	01/18/91	3398.40	480.97	7.35	0.96	0.350	0.000067	13	70	0
Mississippi River at StLouis	12/15/44	3426.72	478.54	7.99	0.90	0.741	0.000042	28	15	0
Mississippi River at StLouis	01/09/26	3568.32	479.15	6.58	1.13	0.187	0.000079	17	201	0
Mississippi River at StLouis	04/05/00	3624.96	486.16	7.47	1.00	0.429	0.000049	18	37	0
Mississippi River at StLouis	06/21/90	3624.96	475.49	7.53	1.01	0.443	0.000072	26	59	0
Mississippi River at StLouis	04/14/17	3681.60	481.28	7.65	1.00	0.555	0.000077	27	41	0
Mississippi River at StLouis	03/23/45	3766.56	480.97	7.77	1.01	0.643	0.000031	29	17	0
Mississippi River at StLouis	02/26/89	3823.20	486.46	7.56	1.04	0.354	0.000093	13	100	0
Mississippi River at StLouis	01/16/62	3851.52	484.02	7.47	1.07	0.229	0.000108	8	202	0
Mississippi River at StLouis	04/08/00	3851.52	484.63	7.74	1.03	0.469	0.000052	20	36	0
Mississippi River at StLouis	08/12/79	3908.16	481.89	7.77	1.04	0.225	0.000072	16	79	0
Mississippi River at StLouis	08/12/79	3908.16	481.89	7.77	1.04	0.225	0.000088	16	78	0
Mississippi River at StLouis	01/17/17	3993.12	480.36	8.02	1.04	0.500	0.000077	24	62	0
Mississippi River at StLouis	05/02/53	4021.44	480.36	7.99	1.05	0.225	0.000063	24	40	0
Mississippi River at StLouis	09/16/99	4049.76	480.36	8.02	1.05	0.467	0.000046	26	31	0
Mississippi River at StLouis	09/30/16	4134.72	485.24	8.08	1.05	0.447	0.000103	21	67	0
Mississippi River at StLouis	05/01/72	4191.36	482.80	8.35	1.04	0.604	0.000047	28	38	0

1	2	3	4	5	6	7	8	9	10	11
Mississippi River at StLouis	04/20/07	4389.60	483.11	7.99	1.14	0.216	0.000075	6	126	0
Mississippi River at StLouis	04/21/53	4502.88	486.16	8.41	1.10	0.208	0.000066	26	59	0
Mississippi River at StLouis	01/23/53	4531.20	486.16	8.50	1.10	0.220	0.000062	29	69	0
Mississippi River at StLouis	12/02/25	4559.52	496.82	9.63	0.95	0.519	0.000026	26	32	0
Mississippi River at StLouis	08/20/79	4616.16	486.16	8.38	1.13	0.226	0.000072	18	108	0
Mississippi River at StLouis	10/18/52	4701.12	492.25	8.35	1.14	0.243	0.000065	28	81	0
Mississippi River at StLouis	12/13/25	4729.44	497.74	9.24	1.03	0.624	0.000031	26	34	0
Mississippi River at StLouis	02/10/99	4814.40	493.78	9.66	1.01	0.733	0.000025	17	92	0
Mississippi River at StLouis	02/11/89	4871.04	494.39	8.50	1.16	0.306	0.000103	8	106	0
Mississippi River at StLouis	12/28/61	4871.04	497.43	8.56	1.14	0.307	0.000098	19	70	0
Mississippi River at StLouis	06/12/99	4899.36	486.77	8.90	1.13	0.567	0.000046	28	31	0
Mississippi River at StLouis	10/13/71	4956.00	491.95	9.05	1.11	0.472	0.000067	23	39	0
Mississippi River at StLouis	10/03/52	4984.32	491.03	8.50	1.19	0.211	0.000066	27	98	0
Mississippi River at StLouis	07/11/52	5040.96	492.25	8.53	1.20	0.191	0.000062	23	103	0
Mississippi River at StLouis	09/09/25	5040.96	499.87	9.81	1.03	0.610	0.000042	28	25	0
Mississippi River at StLouis	07/10/52	5069.28	492.86	8.56	1.20	0.191	0.000079	21	101	0
Mississippi River at StLouis	09/15/51	5267.52	499.57	9.45	1.12	0.313	0.000053	4	86	0
Mississippi River at StLouis	01/15/53	5324.16	495.30	8.99	1.20	0.225	0.000065	26	72	0
Mississippi River at StLouis	10/26/71	5437.44	497.74	9.33	1.17	0.610	0.000046	23	60	0
Mississippi River at StLouis	01/14/53	5579.04	498.35	9.17	1.22	0.225	0.000072	25	91	0
Mississippi River at StLouis	05/27/25	5607.36	502.92	10.12	1.10	0.697	0.000036	27	45	0
Mississippi River at StLouis	08/16/99	5720.64	499.87	9.66	1.18	0.176	0.000042	6	182	0
Mississippi River at StLouis	08/25/25	5947.20	502.92	10.49	1.13	0.680	0.000042	27	52	0
Mississippi River at StLouis	04/02/81	6060.48	494.39	9.54	1.28	0.324	0.000088	14	112	0
Mississippi River at StLouis	04/02/81	6060.48	494.39	9.51	1.29	0.334	0.000073	16	86	0
Mississippi River at StLouis	04/05/62	6071.81	511.45	9.72	1.22	0.334	0.000108	22	105	0
Mississippi River at StLouis	05/17/99	6202.08	501.70	10.21	1.21	0.345	0.000026	8	167	0
Mississippi River at StLouis	04/28/62	6230.40	501.09	10.06	1.24	0.356	0.000108	25	77	0
Mississippi River at StLouis	03/31/52	6258.72	501.70	9.78	1.28	0.176	0.000063	12	119	0
Mississippi River at StLouis	04/10/71	6258.72	499.87	9.60	1.30	0.417	0.000082	11	106	0
Mississippi River at StLouis	07/03/52	6258.72	504.14	9.97	1.25	0.463	0.000055	9	106	0
Mississippi River at StLouis	04/10/71	6400.32	499.87	9.57	1.34	0.399	0.000086	11	108	0
Mississippi River at StLouis	02/03/99	6626.88	505.97	10.97	1.19	0.733	0.000025	17	132	0
Mississippi River at StLouis	12/02/89	6711.84	499.26	9.48	1.42	0.399	0.000108	26	137	0
Mississippi River at StLouis	10/07/16	6796.80	508.41	9.88	1.35	0.435	0.000098	19	105	0
Mississippi River at StLouis	11/11/98	6796.80	504.75	11.22	1.20	0.723	0.000036	20	86	0
Mississippi River at StLouis	11/28/98	6825.12	505.36	10.00	1.35	0.592	0.000072	21	68	0
Mississippi River at StLouis	10/19/16	6881.76	505.97	9.33	1.46	0.356	0.000118	8	226	0
Mississippi River at StLouis	11/26/72	6910.08	507.19	10.27	1.33	0.239	0.000057	17	112	0
Mississippi River at StLouis	04/08/71	6910.08	495.00	9.88	1.41	0.399	0.000089	11	121	0
Mississippi River at StLouis	09/21/61	7323.55	515.72	9.81	1.45	0.221	0.000118	9	320	0
Mississippi River at StLouis	04/07/71	7363.20	498.65	10.12	1.46	0.399	0.000078	10	128	0
Mississippi River at StLouis	06/18/06	7788.00	507.19	10.21	1.50	0.250	0.000076	2	239	0
Mississippi River at StLouis	03/15/52	7872.96	510.84	11.09	1.39	0.520	0.000060	10	131	0
Mississippi River at StLouis	06/24/16	8127.84	518.16	10.73	1.46	0.427	0.000113	11	104	0
Mississippi River at StLouis	02/16/80	8184.48	514.50	10.42	1.53	0.233	0.000069	19	187	0
Mississippi River at StLouis	06/17/06	8241.12	509.63	10.36	1.56	0.260	0.000093	2	233	0
Mississippi River at StLouis	01/11/62	8411.04	502.92	11.06	1.51	0.295	0.000103	18	175	0
Mississippi River at StLouis	08/30/98	8411.04	495.00	10.85	1.57	0.496	0.000082	13	110	0
Mississippi River at StLouis	02/27/99	8524.32	513.89	10.94	1.52	0.485	0.000072	22	132	0
Mississippi River at StLouis	08/29/98	8524.32	507.80	10.64	1.58	0.496	0.000095	13	104	0
Mississippi River at StLouis	09/02/89	8779.20	510.84	10.67	1.61	0.350	0.000108	23	232	0
Mississippi River at StLouis	08/24/98	9912.00	508.71	11.40	1.71	0.431	0.000105	9	145	0
Mississippi River at StLouis	10/04/97	10166.88	516.64	12.25	1.61	0.632	0.000088	21	214	0
Mississippi River at StLouis	08/22/98	10280.16	513.59	11.40	1.76	0.419	0.000082	9	178	0
Mississippi River at StLouis	11/28/43	10761.60	518.16	11.95	1.74	0.561	0.000108	17	97	0
Mississippi River at StLouis	11/02/98	10959.84	523.04	13.72	1.53	0.758	0.000046	21	236	0
Mississippi River at StLouis	02/14/25	11639.52	505.97	12.07	1.91	0.188	0.000082	4	511	0
Mississippi River at StLouis	04/29/98	13253.76	532.18	15.24	1.63	0.664	0.000077	28	118	0
Mississippi River at StLouis	01/29/25	19087.68	575.46	13.69	2.42	0.475	0.000113	18	329	0
Mississippi River at StLouis	04/15/98	19937.28	548.64	16.76	2.17	0.696	0.000118	25	185	0
Mississippi River at StLouis	04/21/98	21608.16	542.54	17.28	2.30	0.664	0.000134	27	188	0
Mississippi River at Tarbert Lan	01/26/55	4248.00	896.11	7.59	0.62	0.297	0.000018	18	12	0
Mississippi River at Tarbert Lan	04/12/55	4276.32	896.11	7.53	0.63	0.287	0.000022	17	15	0
Mississippi River at Tarbert Lan	04/20/55	4332.96	896.11	7.53	0.64	0.307	0.000022	17	12	0

1	2	3	4	5	6	7	8	9	10	11
Mississippi River at Tarbert Lan	07/01/54	4502.88	908.30	7.68	0.65	0.282	0.000020	28	12	0
Mississippi River at Tarbert Lan	04/27/55	4531.20	899.16	7.50	0.67	0.304	0.000022	18	13	0
Mississippi River at Tarbert Lan	06/23/54	4616.16	908.30	7.77	0.65	0.292	0.000020	31	31	0
Mississippi River at Tarbert Lan	10/20/54	4701.12	908.30	7.59	0.68	0.327	0.000020	24	12	0
Mississippi River at Tarbert Lan	10/13/54	4814.40	911.35	7.83	0.67	0.301	0.000023	26	15	0
Mississippi River at Tarbert Lan	09/22/54	4899.36	908.30	7.83	0.69	0.305	0.000022	29	16	0
Mississippi River at Tarbert Lan	01/19/55	4956.00	905.26	8.11	0.68	0.293	0.000020	18	33	0
Mississippi River at Tarbert Lan	09/30/54	5097.60	911.35	7.92	0.71	0.300	0.000023	28	15	0
Mississippi River at Tarbert Lan	11/22/81	5125.92	908.30	6.74	0.84	0.199	0.000036	34	70	0
Mississippi River at Tarbert Lan	06/18/54	5324.16	914.40	8.23	0.71	0.292	0.000020	31	16	0
Mississippi River at Tarbert Lan	02/13/82	5494.08	914.40	6.92	0.87	0.198	0.000037	32	49	0
Mississippi River at Tarbert Lan	01/07/55	6456.96	938.78	8.84	0.78	0.302	0.000023	21	34	0
Mississippi River at Tarbert Lan	04/03/54	6541.92	972.31	8.60	0.78	0.292	0.000027	29	20	0
Mississippi River at Tarbert Lan	03/26/54	6938.40	978.41	8.56	0.83	0.292	0.000023	29	22	0
Mississippi River at Tarbert Lan	12/16/53	7448.16	987.55	9.17	0.82	0.292	0.000028	29	21	0
Mississippi River at Tarbert Lan	03/18/54	7504.80	987.55	8.93	0.85	0.292	0.000027	28	29	0
Mississippi River at Tarbert Lan	12/09/53	8042.88	993.65	9.54	0.85	0.294	0.000022	27	20	0
Mississippi River at Tarbert Lan	08/03/81	9827.04	1002.79	8.93	1.10	0.199	0.000041	34	110	0
Mississippi River at Tarbert Lan	03/12/54	10506.72	1033.27	10.61	0.96	0.292	0.000028	29	49	0
Mississippi River at Tarbert Lan	04/13/81	10563.36	1008.89	9.20	1.14	0.188	0.000037	25	97	0
Mississippi River at Tarbert Lan	12/02/53	10591.68	1024.13	10.58	0.98	0.284	0.000032	24	45	0
Mississippi River at Tarbert Lan	03/10/80	10704.96	1014.98	10.27	1.03	0.210	0.000032	6	140	0
Mississippi River at Tarbert Lan	11/25/53	10903.20	1045.46	10.70	0.97	0.253	0.000027	24	33	0
Mississippi River at Tarbert Lan	08/02/55	11639.52	1027.18	14.48	0.78	0.292	0.000032	19	153	0
Mississippi River at Tarbert Lan	12/24/53	11752.80	1042.42	11.13	1.01	0.292	0.000035	28	46	0
Mississippi River at Tarbert Lan	04/27/81	12205.92	1033.27	9.57	1.23	0.179	0.000043	26	106	0
Mississippi River at Tarbert Lan	12/25/79	13933.44	1051.56	11.77	1.13	0.183	0.000035	7	26	0
Mississippi River at Tarbert Lan	12/13/79	14216.64	1054.61	11.46	1.18	0.200	0.000027	8	194	0
Mississippi River at Tarbert Lan	03/24/80	15179.52	1066.80	11.52	1.24	0.198	0.000036	7	151	0
Mississippi River at Tarbert Lan	05/01/81	16340.64	1072.90	12.56	1.21	0.206	0.000033	6	207	0
Mississippi River at Tarbert Lan	01/11/81	16935.36	1085.09	12.37	1.26	0.209	0.000037	6	167	0
Mississippi River at Tarbert Lan	01/18/81	17020.32	1091.18	12.13	1.29	0.205	0.000038	22	262	0
Mississippi River at Tarbert Lan	01/25/81	17416.80	1085.09	12.56	1.28	0.233	0.000033	8	105	0
Mississippi River at Tarbert Lan	01/04/81	18124.80	1088.14	12.89	1.29	0.212	0.000033	7	137	0
Mississippi River at Tarbert Lan	01/15/81	18492.96	1097.28	12.53	1.35	0.199	0.000040	20	204	0
Mississippi River at Tarbert Lan	09/28/80	21013.44	1100.33	12.98	1.47	0.188	0.000032	10	216	0
Mississippi River at Tarbert Lan	01/11/81	21211.68	1100.33	13.23	1.46	0.188	0.000038	19	144	0
Mississippi River at Tarbert Lan	05/30/53	22032.96	1097.28	14.63	1.37	0.188	0.000037	17	59	0
Mississippi River at Tarbert Lan	10/02/80	22061.28	1103.38	13.81	1.45	0.199	0.000035	12	186	0
Mississippi River at Tarbert Lan	01/08/81	22656.00	1103.38	13.44	1.53	0.199	0.000038	18	244	0
Mississippi River at Tarbert Lan	09/05/53	22854.24	1100.33	15.45	1.34	0.290	0.000042	26	77	0
Mississippi River at Tarbert Lan	01/04/81	24298.56	1103.38	14.45	1.52	0.196	0.000037	18	193	0
Mississippi River at Tarbert Lan	10/23/80	24298.56	1103.38	14.69	1.50	0.199	0.000033	17	167	0
Mississippi River at Tarbert Lan	10/09/80	24468.48	1103.38	14.42	1.54	0.199	0.000037	15	136	0
Mississippi River at Tarbert Lan	10/12/80	25969.44	1103.38	14.81	1.59	0.210	0.000035	17	189	0
Mississippi River at Tarbert Lan	06/03/53	26026.08	1103.38	14.97	1.58	0.178	0.000035	18	165	0
Mississippi River at Tarbert Lan	09/10/53	26082.72	1097.28	15.06	1.58	0.282	0.000038	11	199	0
Mississippi River at Tarbert Lan	10/16/80	26309.28	1103.38	14.81	1.61	0.199	0.000036	17	160	0
Mississippi River at Tarbert Lan	05/09/53	26564.16	1097.28	15.67	1.55	0.322	0.000035	11	94	0
Mississippi River at Tarbert Lan	08/29/53	28829.76	1109.47	16.40	1.58	0.299	0.000038	21	101	0
Mississippi River at Thebes, IL	05/22/88	3590.00	525.00	6.13	1.12	0.334	0.000114	23	68	0
Mississippi River at Thebes, IL	03/15/89	4890.00	602.00	7.29	1.11	0.377	0.000128	8	77	0
Mississippi River at Thebes, IL	12/05/87	5190.00	574.00	6.62	1.37	0.378	0.000130	6	209	0
Mississippi River at Thebes, IL	06/10/89	5220.00	609.00	6.60	1.30	0.431	0.000127	25	107	0
Mississippi River at Thebes, IL	06/13/90	12600.00	623.00	11.40	1.77	0.572	0.000109	22	179	0
Mississippi River below Arkansas City, ARK	06/20/90	25500.00	1055.00	15.00	1.61	0.357	0.000080	26	85	0
Mississippi River below Belle Chasse, LA	06/07/88	5570.00	778.00	19.30	0.37	0.172	0.000003	26	0	0
Mississippi River below Belle Chasse, LA	12/20/87	9560.00	776.00	20.30	0.61	0.182	0.000006	13	3	0
Mississippi River below Belle Chasse, LA	06/28/89	20100.00	813.00	21.80	1.13	0.208	0.000020	26	51	0
Mississippi River below Belle Chasse, LA	04/01/89	22500.00	800.00	21.50	1.31	0.224	0.000022	14	93	0
Mississippi River below Belle Chasse, LA	03/14/90	26700.00	881.00	21.20	1.43	0.323	0.000027	13	94	0
Mississippi River below Fullton, Tenn.	03/05/90	22800.00	1260.00	12.10	1.49	0.543	0.000088	8	138	0
Mississippi River below Fullton, Tenn.	03/19/89	24800.00	1337.00	12.10	1.53	0.412	0.000093	9	142	0
Mississippi River below Grafton, IL	06/11/90	5040.00	941.00	6.44	0.83	0.448	0.000036	22	21	0
Mississippi River below Hickman, KY	07/28/87	6270.00	995.00	6.11	1.03	0.479	0.000065	30	19	0

1	2	3	4	5	6	7	8	9	10	11
Mississippi River below Hickman, KY	05/24/88	6790.00	991.00	6.54	1.05	0.385	0.000066	22	34	0
Mississippi River below Hickman, KY	12/07/87	8820.00	1008.00	7.91	1.11	0.444	0.000066	8	70	0
Mississippi River below Hickman, KY	06/12/89	14100.00	1135.00	9.38	1.32	0.408	0.000079	25	46	0
Mississippi River below Hickman, KY	03/04/90	21000.00	1153.00	12.00	1.51	0.993	0.000078	6	79	0
Mississippi River below Hickman, KY	03/17/89	24700.00	1165.00	12.80	1.65	0.686	0.000084	10	120	0
Mississippi River below Memphis, Tenn.	06/18/90	20800.00	1002.00	14.10	1.47	0.457	0.000087	26	61	0
Mississippi River below Vickburg, MS	08/04/87	7750.00	1131.00	7.14	0.96	0.381	0.000067	30	21	0
Mississippi River below Vickburg, MS	06/02/88	7950.00	1129.00	6.81	1.03	0.377	0.000067	25	30	0
Mississippi River below Vickburg, MS	12/15/87	10400.00	1153.00	8.29	1.09	0.321	0.000064	9	91	0
Mississippi River below Vickburg, MS	06/23/89	24800.00	1222.00	13.20	1.53	0.374	0.000064	25	98	0
Mississippi River below Vickburg, MS	03/27/89	26600.00	1210.00	14.50	1.52	0.314	0.000027	12	128	0
Mississippi River below Vickburg, MS	06/23/90	27300.00	1255.00	14.90	1.46	0.392	0.000055	27	58	0
Mississippi River below Vickburg, MS	03/10/90	34100.00	1308.00	15.20	1.72	0.251	0.000060	11	153	0
Mississippi River Chester, IL	07/23/87	4250.00	591.00	6.46	1.11	0.345	0.000089	29	57	0
Mississippi River near St. Francisville, LA	06/05/88	5700.00	900.00	7.59	0.83	0.259	0.000028	25	12	0
Mississippi River near St. Francisville, LA	08/07/87	6190.00	983.00	7.59	0.83	0.266	0.000029	30	14	0
Mississippi River near St. Francisville, LA	12/18/87	8180.00	970.00	9.04	0.93	0.249	0.000031	9	58	0
Mississippi River near St. Francisville, LA	06/26/89	19000.00	1020.00	14.30	1.31	0.244	0.000041	26	77	0
Mississippi River near St. Francisville, LA	03/30/89	23100.00	1010.00	15.60	1.47	0.212	0.000040	14	112	0
Mississippi River near St. Francisville, LA	06/25/90	23200.00	1025.00	15.90	1.42	0.252	0.000040	27	76	0
Mississippi River near St. Francisville, LA	03/12/90	26300.00	1013.00	16.80	1.55	0.267	0.000039	13	115	0
Mississippi River near Winfield, MO	06/05/89	2320.00	562.00	6.16	0.67	0.498	0.000039	24	4	0
Mountain Creek	-	0.06	3.92	0.04	0.41	0.286	0.003150	20	1,046	0
Mountain Creek	-	0.08	3.29	0.06	0.37	0.899	0.001510	20	54	0
Mountain Creek	-	0.09	3.92	0.05	0.50	0.286	0.003110	20	584	0
Mountain Creek	-	0.09	3.92	0.05	0.50	0.286	0.003110	20	360	0
Mountain Creek	-	0.09	3.92	0.05	0.50	0.286	0.003090	20	360	0
Mountain Creek	-	0.09	3.51	0.07	0.39	0.899	0.001610	22	70	0
Mountain Creek	-	0.10	3.55	0.07	0.40	0.899	0.001520	25	73	0
Mountain Creek	-	0.10	3.92	0.05	0.53	0.286	0.003090	20	520	0
Mountain Creek	-	0.11	3.92	0.05	0.55	0.286	0.003090	20	689	0
Mountain Creek	-	0.12	3.76	0.08	0.42	0.899	0.001580	22	41	0
Mountain Creek	-	0.12	3.92	0.05	0.57	0.286	0.003060	20	656	0
Mountain Creek	-	0.13	3.92	0.06	0.59	0.286	0.003060	20	603	0
Mountain Creek	-	0.13	3.92	0.06	0.59	0.286	0.003070	20	573	0
Mountain Creek	-	0.15	3.92	0.06	0.61	0.286	0.003020	20	1,029	0
Mountain Creek	-	0.15	3.92	0.09	0.45	0.899	0.001370	25	79	0
Mountain Creek	-	0.15	3.92	0.09	0.45	0.899	0.001400	25	79	0
Mountain Creek	-	0.16	3.92	0.06	0.63	0.286	0.003020	20	1,092	0
Mountain Creek	-	0.16	3.95	0.09	0.45	0.899	0.001390	25	74	0
Mountain Creek	-	0.16	3.95	0.09	0.45	0.899	0.001370	25	74	0
Mountain Creek	-	0.17	3.98	0.09	0.46	0.899	0.001390	25	83	0
Mountain Creek	-	0.17	3.92	0.07	0.63	0.286	0.002480	20	418	0
Mountain Creek	-	0.18	4.02	0.10	0.47	0.899	0.001600	26	200	0
Mountain Creek	-	0.18	4.02	0.10	0.47	0.899	0.001590	26	178	0
Mountain Creek	-	0.18	4.02	0.10	0.47	0.899	0.001590	26	200	0
Mountain Creek	-	0.18	4.02	0.10	0.47	0.899	0.001590	26	178	0
Mountain Creek	-	0.18	3.92	0.07	0.67	0.286	0.002960	20	1,120	0
Mountain Creek	-	0.19	4.02	0.10	0.47	0.899	0.001480	22	82	0
Mountain Creek	-	0.19	4.02	0.10	0.47	0.899	0.001510	22	109	0
Mountain Creek	-	0.19	4.04	0.10	0.47	0.899	0.001580	26	215	0
Mountain Creek	-	0.19	4.04	0.10	0.47	0.899	0.001580	26	172	0
Mountain Creek	-	0.19	4.04	0.10	0.47	0.899	0.001490	22	85	0
Mountain Creek	-	0.19	4.04	0.10	0.47	0.899	0.001520	22	106	0
Mountain Creek	-	0.19	4.04	0.10	0.47	0.899	0.001550	22	132	0
Mountain Creek	-	0.19	4.04	0.10	0.47	0.899	0.001560	22	95	0
Mountain Creek	-	0.19	4.04	0.10	0.47	0.899	0.001570	22	116	0
Mountain Creek	-	0.20	4.06	0.10	0.48	0.899	0.001480	24	123	0
Mountain Creek	-	0.20	4.08	0.10	0.48	0.899	0.001480	24	119	0
Mountain Creek	-	0.21	4.22	0.13	0.38	0.899	0.001640	20	74	0
Mountain Creek	-	0.21	4.10	0.11	0.48	0.899	0.001480	24	113	0
Mountain Creek	-	0.22	4.12	0.11	0.49	0.899	0.001490	24	92	0
Mountain Creek	-	0.23	4.30	0.14	0.37	0.899	0.001630	25	27	0
Mountain Creek	-	0.23	4.13	0.11	0.49	0.899	0.001490	24	105	0
Mountain Creek	-	0.24	4.15	0.12	0.50	0.899	0.001500	24	136	0

1	2	3	4	5	6	7	8	9	10	11
Mountain Creek	-	0.24	4.15	0.12	0.50	0.899	0.001560	26	186	0
Mountain Creek	-	0.24	3.92	0.08	0.75	0.286	0.002910	20	2,601	0
Mountain Creek	-	0.25	4.16	0.12	0.50	0.899	0.001490	24	146	0
Mountain Creek	-	0.26	4.18	0.12	0.51	0.899	0.001510	24	111	0
Mountain Creek	-	0.27	4.21	0.12	0.52	0.899	0.001510	24	135	0
Mountain Creek	-	0.29	4.33	0.17	0.40	0.899	0.001630	25	42	0
Mountain Creek	-	0.30	4.25	0.13	0.53	0.899	0.001490	24	108	0
Mountain Creek	-	0.30	4.25	0.13	0.53	0.899	0.001570	15	169	0
Mountain Creek	-	0.30	4.25	0.13	0.53	0.899	0.001560	15	161	0
Mountain Creek	-	0.31	4.26	0.14	0.53	0.899	0.001500	24	172	0
Mountain Creek	-	0.31	4.26	0.14	0.53	0.899	0.001570	26	159	0
Mountain Creek	-	0.31	4.26	0.14	0.53	0.899	0.001550	15	178	0
Mountain Creek	-	0.32	4.27	0.14	0.54	0.899	0.001550	25	686	0
Mountain Creek	-	0.32	4.27	0.14	0.54	0.899	0.001570	26	229	0
Mountain Creek	-	0.32	4.27	0.14	0.54	0.899	0.001550	15	216	0
Mountain Creek	-	0.33	4.28	0.14	0.54	0.899	0.001530	15	193	0
Mountain Creek	-	0.33	4.28	0.14	0.54	0.899	0.001550	15	193	0
Mountain Creek	-	0.33	3.92	0.10	0.85	0.286	0.002850	20	620	0
Mountain Creek	-	0.34	4.30	0.14	0.54	0.899	0.001590	26	204	0
Mountain Creek	-	0.35	4.28	0.14	0.57	0.899	0.001360	20	264	0
Mountain Creek	-	0.35	3.92	0.10	0.85	0.286	0.002760	20	508	0
Mountain Creek	-	0.35	4.31	0.15	0.55	0.899	0.001630	26	139	0
Mountain Creek	-	0.35	4.31	0.15	0.55	0.899	0.001560	26	183	0
Mountain Creek	-	0.35	4.31	0.15	0.55	0.899	0.001560	26	171	0
Mountain Creek	-	0.39	4.33	0.16	0.56	0.899	0.001580	26	195	0
Mountain Creek	-	0.39	4.33	0.16	0.56	0.899	0.001580	26	195	0
Mountain Creek	-	0.41	4.33	0.17	0.57	0.899	0.001570	26	169	0
Mountain Creek	-	0.42	4.33	0.20	0.48	0.899	0.001650	25	29	0
Mountain Creek	-	0.43	4.33	0.17	0.58	0.899	0.001590	26	234	0
Mountain Creek	-	0.44	4.33	0.18	0.58	0.899	0.001610	26	258	0
Mountain Creek	-	0.45	4.33	0.18	0.58	0.899	0.001610	26	181	0
Mountain Creek	-	0.45	4.33	0.18	0.58	0.899	0.001630	26	181	0
Mountain Creek	-	0.46	4.33	0.21	0.49	0.899	0.001730	20	146	0
Mountain Creek	-	0.46	3.92	0.12	0.99	0.286	0.002760	20	853	0
Mountain Creek	-	0.65	3.92	0.15	1.13	0.286	0.002750	20	931	0
Mountain Creek	-	0.65	4.33	0.26	0.57	0.899	0.001790	20	149	0
Mountain Creek	-	0.68	4.33	0.27	0.58	0.899	0.001710	25	71	0
Mountain Creek	-	0.70	4.33	0.25	0.65	0.899	0.001600	20	345	0
Mountain Creek	-	0.76	4.33	0.29	0.61	0.899	0.001790	20	208	0
Mountain Creek	-	0.81	4.33	0.30	0.62	0.899	0.001790	20	112	0
Mountain Creek	-	0.85	4.33	0.31	0.63	0.899	0.001770	20	179	0
Mountain Creek	-	0.88	4.33	0.30	0.69	0.899	0.001750	20	317	0
Mountain Creek	-	0.90	4.33	0.32	0.65	0.899	0.001790	20	351	0
Mountain Creek	-	0.93	4.33	0.33	0.66	0.899	0.001790	20	195	0
Mountain Creek	-	0.96	4.33	0.32	0.70	0.899	0.001790	20	384	0
Mountain Creek	-	1.00	3.92	0.19	1.35	0.286	0.002690	20	758	0
Mountain Creek	-	1.01	4.33	0.33	0.71	0.899	0.001770	20	259	0
Mountain Creek	-	1.02	4.33	0.33	0.71	0.899	0.001790	25	573	0
Mountain Creek	-	1.02	4.33	0.33	0.71	0.899	0.001810	20	239	0
Mountain Creek	-	1.02	4.33	0.33	0.71	0.899	0.001800	20	406	0
Mountain Creek	-	1.02	4.33	0.33	0.71	0.899	0.001800	20	239	0
Mountain Creek	-	1.04	4.33	0.35	0.68	0.899	0.001840	25	140	0
Mountain Creek	-	1.35	4.33	0.41	0.77	0.899	0.001870	25	230	0
Mountain Creek	-	1.39	4.33	0.41	0.77	0.899	0.001850	25	491	0
Mountain Creek	-	1.46	4.33	0.43	0.78	0.899	0.001880	25	431	0
Mountain Creek	-	1.48	4.33	0.44	0.78	0.899	0.001920	25	209	0
Mountain Creek	-	1.49	4.33	0.44	0.79	0.899	0.001830	25	277	0
Niobrara River	12/23/25	5.86	21.34	0.44	0.62	0.349	0.001212	23	257	0
Niobrara River	09/16/25	5.91	21.03	0.42	0.67	0.320	0.001250	28	278	0
Niobrara River	09/05/25	6.57	21.34	0.43	0.72	0.280	0.001136	24	372	0
Niobrara River	05/27/25	6.62	21.34	0.47	0.65	0.285	0.001250	21	566	0
Niobrara River	08/17/70	6.65	21.49	0.44	0.71	0.292	0.001288	23	608	0
Niobrara River	03/30/26	6.65	21.18	0.47	0.67	0.300	0.001136	16	567	0
Niobrara River	11/21/70	7.16	21.18	0.46	0.73	0.337	0.001288	22	637	0
Niobrara River	02/22/71	7.22	21.34	0.44	0.77	0.306	0.001174	17	740	0

1	2	3	4	5	6	7	8	9	10	11
Niobrara River	12/10/25	7.53	21.34	0.49	0.72	0.299	0.001155	22	550	0
Niobrara River	07/10/43	7.56	21.49	0.47	0.75	0.304	0.001345	24	825	0
Niobrara River	08/11/70	7.64	21.34	0.48	0.75	0.286	0.001269	18	577	0
Niobrara River	08/20/25	7.78	21.34	0.49	0.74	0.314	0.001288	23	747	0
Niobrara River	01/09/27	9.40	21.34	0.43	1.01	0.334	0.001610	1	940	0
Niobrara River	06/20/71	9.42	21.03	0.48	0.94	0.327	0.001402	16	1,118	0
Niobrara River	03/22/71	9.74	21.34	0.47	0.98	0.262	0.001420	16	1,069	0
Niobrara River	10/11/69	11.35	21.34	0.49	1.09	0.307	0.001705	5	1,267	0
Niobrara River	01/30/70	11.72	21.64	0.49	1.10	0.286	0.001705	7	1,600	0
Niobrara River	06/30/97	12.88	21.64	0.53	1.13	0.314	0.001686	14	1,293	0
Niobrara River	05/07/70	16.05	21.95	0.58	1.27	0.215	0.001799	12	1,488	0
North Fork Tottle River	01/19/86	123.5	56	0.85	2.6	6.900	0.0041	6.5	16,364	0
North Fork Tottle River	02/26/86	137	59	0.85	2.4	8.600	0.0037	8.5	13,266	0
Oak Creek	-	2.01	5.74	0.37	0.94	22.000	0.012600	6	28	0
Oak Creek	-	1.42	5.71	0.31	0.81	16.000	0.012500	6	7	0
Oak Creek	-	1.53	5.68	0.32	0.84	20.000	0.012500	6	8	0
Oak Creek	-	2.61	5.60	0.47	1.00	25.000	0.009700	5	68	0
Oak Creek	-	2.61	5.60	0.47	1.00	17.000	0.009700	5	52	0
Oak Creek	-	2.63	5.65	0.47	1.00	19.000	0.009700	5	41	0
Oak Creek	-	2.83	5.37	0.49	1.07	26.000	0.009800	5	38	0
Oak Creek	-	3.40	5.78	0.53	1.12	24.000	0.009900	5	111	0
Oak Creek	-	1.90	5.75	0.39	0.85	13.000	0.010000	7	15	0
Oak Creek	-	1.81	5.91	0.37	0.83	8.200	0.010000	7	14	0
Oak Creek	-	2.61	5.82	0.45	1.00	27.000	0.010200	6	51	0
Oak Creek	-	2.21	5.31	0.43	0.96	19.000	0.010800	6	184	0
Oak Creek	-	1.53	4.43	0.40	0.85	9.500	0.010500	6	24	0
Oak Creek	-	1.33	4.23	0.39	0.82	11.000	0.010400	6	13	0
Oak Creek	-	1.44	4.46	0.39	0.82	10.000	0.010000	6	15	0
Oak Creek	-	1.76	4.83	0.42	0.87	12.000	0.010000	6	41	0
Oak Creek	-	2.10	5.28	0.43	0.92	23.000	0.010000	6	69	0
Pakistan Canal		27.50	86.26	0.91	0.35	0.128	0.000142	18	15	0
Pakistan Canal		28.77	85.65	0.91	0.37	0.154	0.000124	18	13	0
Pakistan Canal		29.48	93.27	0.76	0.41	0.152	0.000088	17	16	0
Pakistan Canal		29.59	35.66	1.68	0.49	0.085	0.000085	31	103	0
Pakistan Canal		44.00	48.77	1.34	0.67	0.177	0.000145	31	94	0
Pakistan Canal		47.83	46.33	1.80	0.57	0.169	0.000108	32	215	0
Pakistan Canal		48.62	35.66	2.32	0.59	0.116	0.000072	23	32	0
Pakistan Canal		49.64	46.63	1.68	0.63	0.147	0.000110	30	36	0
Pakistan Canal		50.60	35.66	2.23	0.64	0.128	0.000074	24	54	0
Pakistan Canal		51.42	35.66	2.32	0.62	0.114	0.000070	23	76	0
Pakistan Canal	-	51.88	35.36	2.19	0.67	0.123	0.000086	17	422	0
Pakistan Canal	-	51.90	35.66	2.19	0.66	0.136	0.000086	18	386	0
Pakistan Canal		52.13	35.66	2.29	0.64	0.110	0.000075	32	156	0
Pakistan Canal		52.13	49.07	1.43	0.74	0.140	0.000148	31	445	0
Pakistan Canal		52.27	35.36	2.26	0.66	0.121	0.000073	23	58	0
Pakistan Canal		52.41	35.66	2.53	0.58	0.117	0.000076	28	128	0
Pakistan Canal		52.47	35.36	2.29	0.65	0.123	0.000088	24	869	0
Pakistan Canal	-	52.92	35.36	2.16	0.69	0.132	0.000085	18	153	0
Pakistan Canal		54.14	35.36	2.26	0.68	0.112	0.000067	21	61	0
Pakistan Canal	-	54.37	35.36	2.19	0.70	0.129	0.000085	18	367	0
Pakistan Canal	-	54.74	35.66	2.19	0.70	0.124	0.000089	16	560	0
Pakistan Canal	-	55.16	35.97	2.23	0.69	0.112	0.000085	22	289	0
Pakistan Canal	-	55.64	35.66	2.35	0.66	0.113	0.000077	28	511	0
Pakistan Canal	-	56.29	35.97	2.29	0.68	0.138	0.000076	24	184	0
Pakistan Canal		56.80	46.33	1.92	0.64	0.144	0.000109	30	225	0
Pakistan Canal		58.33	35.97	2.47	0.66	0.122	0.000087	29	166	0
Pakistan Canal		61.73	35.66	2.53	0.68	0.127	0.000074	29	79	0
Pakistan Canal		63.77	47.55	2.16	0.62	0.156	0.000150	16	110	0
Pakistan Canal		65.92	46.63	2.16	0.65	0.151	0.000107	25	290	0
Pakistan Canal		67.11	46.94	2.13	0.67	0.152	0.000112	30	54	0
Pakistan Canal		67.71	46.63	2.16	0.67	0.147	0.000110	36	372	0
Pakistan Canal		67.85	46.63	2.13	0.68	0.159	0.000124	25	146	0
Pakistan Canal		68.13	46.03	2.07	0.71	0.149	0.000127	21	529	0
Pakistan Canal		68.78	47.24	2.23	0.65	0.155	0.000147	16	845	0
Pakistan Canal		68.84	47.85	2.19	0.66	0.152	0.000148	15	410	0

	1	2	3	4	5	6	7	8	9	10	11
Pakistan Canal			68.92	124.97	1.46	0.38	0.195	0.000045	19	5	0
Pakistan Canal			69.18	46.94	2.16	0.68	0.164	0.000102	25	262	0
Pakistan Canal			70.03	47.24	2.16	0.68	0.153	0.000116	30	48	0
Pakistan Canal			70.40	46.63	2.16	0.70	0.142	0.000101	25	346	0
Pakistan Canal	-		70.40	46.63	2.32	0.65	0.144	0.000116	29	323	0
Pakistan Canal			70.42	46.63	2.19	0.69	0.143	0.000115	30	82	0
Pakistan Canal			70.71	46.63	2.16	0.70	0.146	0.000099	25	366	0
Pakistan Canal			71.30	46.63	2.10	0.73	0.211	0.000104	24	79	0
Pakistan Canal	-		71.92	46.63	2.32	0.67	0.148	0.000112	28	796	0
Pakistan Canal	-		72.66	46.63	2.32	0.67	0.150	0.000116	25	142	0
Pakistan Canal			72.66	46.63	2.35	0.66	0.156	0.000112	29	310	0
Pakistan Canal			73.60	46.63	2.26	0.70	0.145	0.000111	31	335	0
Pakistan Canal			74.11	46.63	2.23	0.71	0.142	0.000116	32	233	0
Pakistan Canal			74.22	46.63	2.29	0.70	0.155	0.000114	28	333	0
Pakistan Canal			74.30	94.79	1.49	0.52	0.146	0.000142	26	77	0
Pakistan Canal	-		74.84	46.63	2.29	0.70	0.152	0.000107	28	304	0
Pakistan Canal			75.32	46.33	2.29	0.71	0.161	0.000104	28	240	0
Pakistan Canal			75.69	49.07	2.16	0.71	0.193	0.000148	34	98	0
Pakistan Canal			75.86	46.63	2.32	0.70	0.148	0.000115	31	351	0
Pakistan Canal			76.94	69.49	1.83	0.61	0.108	0.000132	27	125	0
Pakistan Canal			77.11	46.33	2.26	0.74	0.149	0.000108	31	289	0
Pakistan Canal			77.28	46.63	2.26	0.73	0.147	0.000109	31	577	0
Pakistan Canal			78.55	46.63	2.32	0.73	0.149	0.000107	32	385	0
Pakistan Canal			78.92	99.67	1.34	0.59	0.167	0.000104	26	88	0
Pakistan Canal	-		79.17	46.94	2.44	0.69	0.142	0.000095	21	383	0
Pakistan Canal			79.60	50.60	2.13	0.74	0.191	0.000154	16	279	0
Pakistan Canal			80.19	49.07	2.04	0.80	0.178	0.000148	25	69	0
Pakistan Canal	-		81.52	49.07	2.13	0.78	0.182	0.000152	20	399	0
Pakistan Canal			83.31	49.07	2.07	0.82	0.179	0.000145	32	122	0
Pakistan Canal			84.02	49.38	2.16	0.79	0.167	0.000146	31	56	0
Pakistan Canal	-		85.21	47.85	2.10	0.85	0.168	0.000132	21	322	0
Pakistan Canal			85.29	88.39	1.46	0.66	0.164	0.000129	26	132	0
Pakistan Canal			86.25	49.68	2.23	0.78	0.186	0.000154	17	167	0
Pakistan Canal	-		86.34	49.38	2.16	0.81	0.170	0.000147	29	1,007	0
Pakistan Canal			86.54	49.68	2.16	0.80	0.207	0.000154	17	71	0
Pakistan Canal			87.50	49.38	2.19	0.81	0.176	0.000144	32	328	0
Pakistan Canal			89.48	49.68	2.16	0.83	0.185	0.000154	16	104	0
Pakistan Canal	-		90.42	49.38	2.13	0.86	0.173	0.000153	21	517	0
Pakistan Canal			90.53	88.39	1.52	0.67	0.148	0.000137	28	183	0
Pakistan Canal			92.79	100.89	1.40	0.66	0.154	0.000106	27	106	0
Pakistan Canal			94.27	88.39	1.46	0.73	0.084	0.000137	28	190	0
Pakistan Canal			96.59	86.56	1.62	0.69	0.131	0.000139	26	331	0
Pakistan Canal			97.44	70.41	2.10	0.66	0.147	0.000134	26	164	0
Pakistan Canal			98.94	86.56	1.65	0.69	0.167	0.000127	26	232	0
Pakistan Canal			99.48	86.56	1.65	0.70	0.192	0.000129	26	289	0
Pakistan Canal			110.12	125.58	1.86	0.47	0.241	0.000086	17	19	0
Pakistan Canal			110.72	71.02	2.16	0.72	0.179	0.000137	26	481	0
Pakistan Canal			130.46	70.41	2.35	0.79	0.125	0.000129	25	297	0
Pakistan Canal			136.32	127.41	1.77	0.61	0.133	0.000086	28	34	0
Pakistan Canal			137.82	69.19	2.38	0.84	0.132	0.000133	28	607	0
Pakistan Canal			138.04	70.41	2.41	0.81	0.118	0.000149	26	563	0
Pakistan Canal			139.74	71.93	2.23	0.87	0.149	0.000107	25	391	0
Pakistan Canal			140.14	70.10	2.35	0.85	0.126	0.000134	28	564	0
Pakistan Canal			146.62	126.49	1.71	0.68	0.198	0.000087	30	48	0
Pakistan Canal			151.24	90.22	1.89	0.89	0.116	0.000152	29	188	0
Pakistan Canal			153.31	70.71	2.10	1.03	0.174	0.000135	30	419	0
Pakistan Canal			153.82	71.63	2.35	0.91	0.144	0.000166	26	584	0
Pakistan Canal			156.48	72.24	2.41	0.90	0.161	0.000149	27	228	0
Pakistan Canal			158.09	118.87	2.23	0.60	0.083	0.000070	28	369	0
Pakistan Canal			166.87	90.53	1.89	0.98	0.179	0.000113	28	319	0
Pakistan Canal			169.08	72.24	2.47	0.95	0.162	0.000121	28	169	0
Pakistan Canal			169.67	70.71	1.89	1.27	0.164	0.000134	30	872	0
Pakistan Canal			179.56	124.36	2.04	0.71	0.223	0.000112	21	52	0
Pakistan Canal			183.83	91.14	2.19	0.92	0.173	0.000138	26	373	0
Pakistan Canal			207.62	126.19	2.16	0.76	0.273	0.000099	14	49	0

1	2	3	4	5	6	7	8	9	10	11
Pakistan Canal		222.09	128.02	2.26	0.77	0.226	0.000104	12	97	0
Pakistan Canal		224.44	120.70	2.50	0.74	0.195	0.000082	31	65	0
Pakistan Canal		233.10	140.21	2.07	0.80	0.206	0.000098	12	268	0
Pakistan Canal		267.65	117.35	2.80	0.81	0.313	0.000112	18	65	0
Pakistan Canal		279.80	135.94	2.32	0.89	0.293	0.000112	28	123	0
Pakistan Canal		291.27	128.63	2.59	0.87	0.176	0.000100	23	115	0
Pakistan Canal		297.16	128.32	2.56	0.90	0.154	0.000097	25	2,083	0
Pakistan Canal		297.41	129.24	2.62	0.88	0.187	0.000098	19	229	0
Pakistan Canal		321.51	119.79	3.41	0.79	0.169	0.000088	14	138	0
Pakistan Canal		337.28	116.43	3.20	0.91	0.289	0.000112	14	39	0
Pakistan Canal		342.95	110.95	3.29	0.94	0.250	0.000119	16	33	0
Pakistan Canal		346.71	110.64	3.32	0.94	0.252	0.000123	14	71	0
Pakistan Canal		349.46	111.56	3.41	0.92	0.230	0.000121	15	44	0
Pakistan Canal		349.97	112.17	3.47	0.90	0.205	0.000112	13	106	0
Pakistan Canal		355.72	116.74	3.26	0.93	0.299	0.000109	14	42	0
Pakistan Canal		357.76	111.25	3.54	0.91	0.201	0.000125	15	162	0
Pakistan Canal		362.91	120.09	3.57	0.85	0.272	0.000112	14	116	0
Pakistan Canal		363.33	128.02	2.77	1.02	0.260	0.000093	26	265	0
Pakistan Canal		363.64	110.95	3.44	0.95	0.275	0.000120	16	103	0
Pakistan Canal		371.80	113.39	3.51	0.94	0.234	0.000120	15	493	0
Pakistan Canal		375.65	125.88	3.81	0.78	0.268	0.000116	-1	17	0
Pakistan Canal		380.58	101.50	2.90	1.29	0.182	0.000105	30	57	0
Pakistan Canal		387.69	122.23	3.72	0.85	0.279	0.000107	15	32	0
Pakistan Canal		388.05	121.92	3.66	0.87	0.331	0.000108	-1	18	0
Pakistan Canal		391.06	92.05	3.66	1.16	0.157	0.000150	30	342	0
Pakistan Canal		392.70	119.79	3.57	0.92	0.275	0.000112	14	94	0
Pakistan Canal		393.21	111.86	3.57	0.99	0.242	0.000121	24	108	0
Pakistan Canal		394.77	117.65	3.54	0.95	0.279	0.000113	16	44	0
Pakistan Canal		395.13	113.08	3.81	0.92	0.222	0.000061	27	89	0
Pakistan Canal		404.62	114.30	3.57	0.99	0.197	0.000119	14	614	0
Pakistan Canal		412.04	111.86	3.63	1.02	0.170	0.000119	25	216	0
Pakistan Canal		412.29	118.26	3.63	0.96	0.233	0.000120	23	106	0
Pakistan Canal		412.72	118.26	3.60	0.97	0.220	0.000121	21	57	0
Pakistan Canal		414.47	111.56	3.69	1.01	0.214	0.000121	23	86	0
Pakistan Canal		417.42	112.47	3.66	1.01	0.202	0.000117	25	114	0
Pakistan Canal		423.25	118.26	3.63	0.99	0.258	0.000121	24	59	0
Pakistan Canal		428.15	114.00	3.69	1.02	0.210	0.000122	13	54	0
Pakistan Canal		441.29	120.40	4.08	0.90	0.208	0.000093	23	181	0
Pakistan Canal		451.40	121.92	4.24	0.87	0.202	0.000098	27	67	0
Pakistan Canal		481.92	123.44	4.30	0.91	0.364	0.000079	18	29	0
Pakistan Canal		486.82	123.44	4.27	0.92	0.199	0.000103	29	205	0
Pakistan Canal		528.68	123.44	3.72	1.15	0.113	0.000055	23	95	0
Portugal River	-	29.00	69.65	0.55	0.76	0.311	0.000710	10	34	0
Portugal River	-	30.00	69.65	0.56	0.76	0.328	0.000660	10	40	0
Portugal River	-	33.00	69.70	0.63	0.75	0.277	0.000660	10	37	0
Portugal River	-	35.00	69.60	0.63	0.80	0.438	0.000620	10	35	0
Portugal River	-	36.00	69.70	0.63	0.81	0.397	0.000620	10	58	0
Portugal River	-	36.50	124.25	0.46	0.64	0.575	0.000700	10	38	0
Portugal River	-	37.50	69.70	0.67	0.80	0.235	0.000670	10	39	0
Portugal River	-	38.00	69.70	0.66	0.82	0.453	0.000630	10	102	0
Portugal River	-	40.00	70.40	0.67	0.85	0.174	0.000670	10	96	0
Portugal River	-	40.00	69.70	0.70	0.82	0.303	0.000730	10	48	0
Portugal River	-	40.00	126.65	0.48	0.66	0.395	0.000710	10	28	0
Portugal River	-	41.00	69.70	0.72	0.82	0.378	0.000730	10	62	0
Portugal River	-	42.00	131.35	0.48	0.67	0.444	0.000710	10	49	0
Portugal River	-	42.50	130.50	0.48	0.68	1.056	0.000720	10	27	0
Portugal River	-	44.00	69.70	0.75	0.84	0.424	0.000720	10	76	0
Portugal River	-	45.50	69.70	0.77	0.84	0.396	0.000750	10	96	0
Portugal River	-	48.00	134.45	0.51	0.70	0.337	0.000730	10	27	0
Portugal River	-	50.00	136.00	0.52	0.70	0.705	0.000730	10	48	0
Portugal River	-	56.50	70.40	0.86	0.93	0.460	0.000720	10	61	0
Portugal River	-	58.00	137.25	0.56	0.75	0.424	0.000810	10	50	0
Portugal River	-	58.30	70.40	0.88	0.94	0.516	0.000730	10	107	0
Portugal River	-	59.60	110.00	0.69	0.79	0.374	0.000690	10	48	0
Portugal River	-	60.00	69.90	0.95	0.90	0.286	0.000780	10	75	0

	1	2	3	4	5	6	7	8	9	10	11
Portugal River	-		65.50	70.40	0.96	0.97	0.344	0.000730	10	69	0
Portugal River	-		66.40	70.40	1.09	0.86	0.402	0.000740	10	117	0
Portugal River	-		68.00	145.40	0.60	0.77	0.645	0.000790	10	107	0
Portugal River	-		71.00	138.40	0.59	0.88	0.473	0.000790	10	48	0
Portugal River	-		73.00	146.95	0.65	0.77	0.603	0.000770	10	51	0
Portugal River	-		74.00	70.00	1.09	0.97	0.301	0.000840	10	201	0
Portugal River	-		75.00	70.50	1.11	0.96	0.348	0.000720	10	50	0
Portugal River	-		75.00	70.40	1.13	0.94	0.398	0.000730	10	109	0
Portugal River	-		75.00	155.00	0.63	0.77	0.623	0.000670	10	113	0
Portugal River	-		77.05	70.40	1.08	1.02	0.395	0.000770	10	129	0
Portugal River	-		77.90	70.40	1.10	1.01	0.397	0.000750	10	61	0
Portugal River	-		78.00	70.40	1.16	0.95	0.469	0.000770	10	83	0
Portugal River	-		78.40	114.00	0.79	0.87	0.421	0.000730	10	73	0
Portugal River	-		79.00	70.10	1.15	0.98	0.296	0.000730	10	73	0
Portugal River	-		81.00	70.10	1.18	0.98	0.300	0.000730	10	131	0
Portugal River	-		83.00	70.40	1.15	1.03	0.363	0.000750	10	103	0
Portugal River	-		83.30	102.00	0.93	0.88	1.909	0.000850	10	45	0
Portugal River	-		84.00	70.20	1.20	1.00	0.228	0.000740	10	129	0
Portugal River	-		84.00	70.20	1.21	0.99	0.277	0.000740	10	155	0
Portugal River	-		85.00	161.00	0.66	0.80	0.608	0.000680	10	115	0
Portugal River	-		86.80	70.40	1.20	1.03	0.500	0.000730	10	81	0
Portugal River	-		87.00	161.60	0.68	0.80	0.313	0.000740	10	113	0
Portugal River	-		87.00	70.30	1.23	1.00	0.318	0.000730	10	161	0
Portugal River	-		88.20	173.60	0.59	0.86	0.527	0.000800	10	60	0
Portugal River	-		89.00	173.60	0.60	0.86	0.429	0.000820	10	79	0
Portugal River	-		89.90	140.00	0.72	0.89	0.474	0.000770	10	105	0
Portugal River	-		94.00	70.40	1.33	1.00	0.343	0.000730	10	86	0
Portugal River	-		96.00	70.40	1.35	1.01	0.247	0.000760	10	109	0
Portugal River	-		96.00	70.40	1.30	1.05	0.265	0.000880	10	150	0
Portugal River	-		96.50	70.50	1.39	0.98	0.369	0.000760	10	198	0
Portugal River	-		97.00	163.20	0.72	0.82	0.391	0.000540	10	95	0
Portugal River	-		99.00	70.40	1.33	1.06	0.344	0.000770	10	203	0
Portugal River	-		102.00	70.50	1.46	0.99	0.218	0.000720	10	113	0
Portugal River	-		102.00	70.50	1.45	0.99	0.254	0.000710	10	133	0
Portugal River	-		102.00	70.40	1.40	1.03	0.278	0.000860	10	165	0
Portugal River	-		102.00	173.35	0.71	0.83	0.442	0.000760	10	182	0
Portugal River	-		103.00	70.40	1.40	1.04	0.294	0.000750	10	57	0
Portugal River	-		104.00	70.40	1.38	1.07	0.302	0.000790	10	160	0
Portugal River	-		104.70	140.00	0.82	0.91	0.565	0.000870	10	73	0
Portugal River	-		106.00	70.40	1.41	1.07	0.222	0.000840	10	178	0
Portugal River	-		107.00	70.60	1.50	1.01	0.230	0.000700	10	198	0
Portugal River	-		107.00	70.50	1.41	1.07	0.254	0.000850	10	148	0
Portugal River	-		109.00	70.40	1.44	1.07	0.364	0.000830	10	189	0
Portugal River	-		112.00	70.50	1.46	1.08	0.197	0.000830	10	136	0
Portugal River	-		112.00	164.95	0.82	0.83	0.380	0.000620	10	87	0
Portugal River	-		113.50	70.60	1.53	1.05	0.224	0.000680	10	234	0
Portugal River	-		114.00	70.50	1.48	1.09	0.337	0.000830	10	186	0
Portugal River	-		114.90	182.40	0.65	0.97	0.314	0.000910	10	130	0
Portugal River	-		115.00	178.50	0.76	0.85	0.400	0.000810	10	199	0
Portugal River	-		116.50	70.70	1.56	1.06	0.283	0.000680	10	178	0
Portugal River	-		117.00	70.60	1.47	1.13	0.390	0.000890	10	193	0
Portugal River	-		118.00	179.60	0.78	0.84	0.361	0.000810	10	193	0
Portugal River	-		119.00	70.50	1.51	1.12	0.361	0.000880	10	240	0
Portugal River	-		120.00	70.70	1.50	1.13	0.303	0.000890	10	92	0
Portugal River	-		120.00	166.60	0.87	0.83	0.330	0.000650	10	133	0
Portugal River	-		121.00	70.70	1.56	1.10	0.379	0.000880	10	176	0
Portugal River	-		122.00	70.70	1.61	1.07	0.310	0.000700	10	169	0
Portugal River	-		122.00	140.00	0.91	0.96	1.407	0.000820	10	149	0
Portugal River	-		123.00	70.60	1.54	1.13	0.215	0.000870	10	221	0
Portugal River	-		123.00	70.70	1.57	1.11	0.332	0.000880	10	208	0
Portugal River	-		124.00	70.60	1.56	1.13	0.279	0.000890	10	307	0
Portugal River	-		124.00	70.80	1.62	1.08	0.328	0.000750	10	191	0
Portugal River	-		124.50	182.20	0.79	0.87	0.363	0.000850	10	161	0
Portugal River	-		125.00	180.55	0.80	0.86	0.393	0.000680	10	121	0
Portugal River	-		128.00	70.70	1.59	1.14	0.246	0.000880	10	297	0

1	2	3	4	5	6	7	8	9	10	11
Portugal River	-	128.00	168.50	0.90	0.84	0.416	0.000680	10	135	0
Portugal River	-	128.50	70.80	1.68	1.08	0.332	0.000760	10	242	0
Portugal River	-	130.00	165.15	0.84	0.94	0.356	0.000620	10	130	0
Portugal River	-	131.00	70.80	1.91	0.97	0.336	0.000870	10	181	0
Portugal River	-	133.00	169.40	0.92	0.85	0.247	0.000710	10	190	0
Portugal River	-	133.50	70.80	1.73	1.09	0.379	0.000760	10	205	0
Portugal River	-	134.00	71.00	1.88	1.01	0.397	0.000740	10	111	0
Portugal River	-	135.00	70.70	1.61	1.18	0.314	0.000880	10	266	0
Portugal River	-	135.00	70.90	1.94	0.98	0.374	0.000840	10	239	0
Portugal River	-	137.00	70.90	1.97	0.98	0.215	0.000850	10	282	0
Portugal River	-	137.00	175.80	0.91	0.86	0.243	0.000710	10	168	0
Portugal River	-	137.00	70.80	1.63	1.19	0.329	0.000870	10	287	0
Portugal River	-	137.00	182.80	0.84	0.90	0.331	0.000860	10	105	0
Portugal River	-	137.00	70.80	1.70	1.14	0.452	0.000820	10	81	0
Portugal River	-	138.00	70.90	1.98	0.98	0.237	0.000870	10	245	0
Portugal River	-	138.00	70.90	1.82	1.07	0.399	0.000760	10	67	0
Portugal River	-	139.00	70.80	1.95	1.01	0.325	0.000850	10	240	0
Portugal River	-	140.00	70.80	1.74	1.14	0.414	0.000870	10	270	0
Portugal River	-	141.00	70.90	2.02	0.99	0.274	0.000760	10	209	0
Portugal River	-	141.00	70.80	1.97	1.01	0.276	0.000880	10	283	0
Portugal River	-	141.00	70.80	1.70	1.17	0.291	0.000890	10	216	0
Portugal River	-	141.00	70.80	1.97	1.01	0.368	0.000870	10	213	0
Portugal River	-	141.00	70.70	1.84	1.09	0.408	0.000870	10	253	0
Portugal River	-	141.00	70.70	1.82	1.10	0.454	0.000900	10	227	0
Portugal River	-	142.00	70.90	2.01	0.99	0.495	0.000880	10	246	0
Portugal River	-	142.00	183.00	0.85	0.91	0.610	0.000820	10	180	0
Portugal River	-	143.00	71.00	1.78	1.13	0.445	0.000900	10	351	0
Portugal River	-	143.00	70.90	1.95	1.04	0.544	0.000890	10	204	0
Portugal River	-	144.00	70.90	2.03	1.00	0.201	0.000890	10	252	0
Portugal River	-	146.00	70.80	1.88	1.10	0.348	0.000890	10	260	0
Portugal River	-	146.00	183.25	0.84	0.95	0.361	0.000860	10	187	0
Portugal River	-	146.00	70.80	1.99	1.04	0.372	0.000890	10	228	0
Portugal River	-	147.00	70.70	1.91	1.09	0.300	0.000870	10	223	0
Portugal River	-	147.00	70.80	1.89	1.10	0.342	0.000930	10	319	0
Portugal River	-	148.00	70.70	1.88	1.11	0.233	0.000870	10	221	0
Portugal River	-	148.00	70.80	1.90	1.10	0.293	0.000910	10	240	0
Portugal River	-	149.00	71.10	1.86	1.13	0.420	0.000880	10	271	0
Portugal River	-	150.00	70.70	1.78	1.19	0.238	0.000870	10	201	0
Portugal River	-	150.00	70.70	1.79	1.19	0.293	0.000900	10	255	0
Portugal River	-	150.00	70.90	1.87	1.13	0.354	0.000920	10	282	0
Portugal River	-	150.00	70.80	2.06	1.03	1.077	0.000910	10	174	0
Portugal River	-	151.00	70.80	2.01	1.06	0.330	0.000880	10	148	0
Portugal River	-	151.00	70.90	2.05	1.04	0.336	0.000910	10	272	0
Portugal River	-	151.00	70.80	1.80	1.18	0.371	0.000880	10	199	0
Portugal River	-	151.00	71.10	2.13	1.00	0.372	0.000740	10	147	0
Portugal River	-	151.00	70.80	1.83	1.17	0.380	0.000920	10	232	0
Portugal River	-	151.00	70.70	1.79	1.19	0.536	0.000890	10	220	0
Portugal River	-	151.00	70.80	1.93	1.11	0.340	0.000950	10	168	0
Portugal River	-	152.00	70.70	1.80	1.19	0.232	0.000900	10	202	0
Portugal River	-	152.00	71.10	2.14	1.00	0.311	0.000740	10	193	0
Portugal River	-	152.00	71.10	2.14	1.00	0.362	0.000730	10	153	0
Portugal River	-	152.00	70.70	1.80	1.19	0.433	0.000910	10	239	0
Portugal River	-	152.40	183.00	0.89	0.93	0.339	0.000870	10	68	0
Portugal River	-	153.00	70.90	1.91	1.13	0.294	0.000940	10	346	0
Portugal River	-	153.00	70.90	1.91	1.13	0.318	0.000810	10	203	0
Portugal River	-	153.00	70.90	1.91	1.13	0.439	0.000940	10	247	0
Portugal River	-	154.00	71.20	1.92	1.13	0.291	0.000880	10	149	0
Portugal River	-	156.00	71.20	1.98	1.11	0.377	0.000750	10	127	0
Portugal River	-	157.00	70.90	1.99	1.11	0.270	0.000950	10	227	0
Portugal River	-	157.00	71.40	1.94	1.13	0.312	0.000950	10	238	0
Portugal River	-	158.00	71.00	2.10	1.06	0.329	0.000780	10	152	0
Portugal River	-	158.00	71.10	2.13	1.04	0.375	0.000890	10	232	0
Portugal River	-	158.00	70.80	2.18	1.03	0.513	0.000970	10	171	0
Portugal River	-	159.00	70.80	2.08	1.08	0.343	0.000830	10	136	0
Portugal River	-	159.00	70.80	1.80	1.24	1.000	0.000910	10	260	0

	1	2	3	4	5	6	7	8	9	10	11
Portugal River	-		160.00	70.90	2.05	1.10	0.345	0.000870	10	267	0
Portugal River	-		160.00	176.35	1.00	0.91	0.368	0.000790	10	182	0
Portugal River	-		160.00	70.80	1.87	1.21	0.578	0.000930	10	261	0
Portugal River	-		161.00	70.90	2.02	1.12	0.323	0.000950	10	288	0
Portugal River	-		161.00	71.60	2.10	1.07	0.372	0.000970	10	124	0
Portugal River	-		162.00	70.90	2.10	1.09	0.298	0.000860	10	287	0
Portugal River	-		162.00	70.90	1.95	1.17	0.712	0.000890	10	188	0
Portugal River	-		162.80	183.00	0.98	0.90	0.384	0.000730	10	95	0
Portugal River	-		165.99	71.30	2.03	1.15	0.365	0.000750	10	68	0
Portugal River	-		165.99	70.90	2.16	1.08	0.401	0.000890	10	248	0
Portugal River	-		166.99	183.44	0.96	0.95	0.352	0.000880	10	205	0
Portugal River	-		169.99	71.00	2.21	1.08	0.301	0.000740	10	198	0
Portugal River	-		169.99	176.60	1.04	0.93	0.478	0.000800	10	212	0
Portugal River	-		170.89	183.40	1.02	0.92	0.472	0.000820	10	71	0
Portugal River	-		171.99	183.50	1.00	0.94	0.258	0.000890	10	281	0
Portugal River	-		172.99	183.35	0.89	1.06	0.249	0.000870	10	258	0
Portugal River	-		173.99	71.00	2.21	1.11	0.303	0.000770	10	225	0
Portugal River	-		174.99	71.50	2.15	1.14	0.305	0.000770	10	94	0
Portugal River	-		174.99	70.10	2.35	1.06	0.569	0.000950	10	178	0
Portugal River	-		177.99	176.75	1.08	0.93	0.360	0.000810	10	275	0
Portugal River	-		178.99	71.50	2.19	1.14	0.405	0.000760	10	195	0
Portugal River	-		178.99	71.00	2.13	1.18	0.480	0.000910	10	332	0
Portugal River	-		180.99	71.20	2.26	1.12	0.394	0.000780	10	148	0
Portugal River	-		184.99	183.50	1.06	0.95	0.333	0.000870	10	214	0
Portugal River	-		189.99	71.80	2.29	1.16	0.542	0.000830	10	190	0
Portugal River	-		191.19	183.50	1.09	0.96	0.531	0.000800	10	81	0
Portugal River	-		192.49	181.00	1.14	0.93	0.378	0.000940	10	228	0
Portugal River	-		194.09	182.90	1.09	0.97	0.932	0.000710	10	89	0
Portugal River	-		196.99	183.46	1.12	0.96	0.386	0.000810	10	156	0
Portugal River	-		196.99	176.00	1.16	0.97	0.408	0.000860	10	211	0
Portugal River	-		196.99	71.00	2.16	1.28	0.525	0.000940	10	172	0
Portugal River	-		196.99	183.63	1.11	0.97	1.466	0.000810	10	146	0
Portugal River	-		201.99	177.25	1.18	0.96	0.409	0.000830	10	257	0
Portugal River	-		211.99	177.40	1.21	0.99	0.211	0.000790	10	191	0
Portugal River	-		215.59	183.65	1.16	1.01	0.629	0.000800	10	72	0
Portugal River	-		218.49	183.60	1.22	0.97	0.349	0.000940	10	193	0
Portugal River	-		221.79	183.80	1.18	1.02	0.380	0.000780	10	96	0
Portugal River	-		227.99	184.00	1.32	0.94	0.272	0.000730	10	249	0
Portugal River	-		252.99	184.40	1.43	0.96	0.499	0.000720	10	161	0
Portugal River	-		254.39	183.80	1.35	1.02	0.382	0.000920	10	260	0
Portugal River	-		259.99	183.85	1.36	1.04	0.291	0.000890	10	206	0
Portugal River	-		261.99	185.00	1.52	0.93	0.282	0.000780	10	254	0
Portugal River	-		269.99	184.74	1.50	0.97	0.474	0.000750	10	202	0
Portugal River	-		279.79	184.00	1.36	1.12	0.569	0.000750	10	76	0
Portugal River	-		294.99	184.00	1.60	1.00	0.655	0.000610	10	92	0
Portugal River	-		297.99	185.00	1.63	0.99	0.406	0.000770	10	199	0
Portugal River	-		299.99	185.00	1.65	0.98	0.389	0.000780	10	210	0
Portugal River	-		305.19	184.05	1.49	1.11	0.321	0.000850	10	197	0
Portugal River	-		309.99	184.10	1.68	1.00	1.190	0.000650	10	227	0
Portugal River	-		317.99	185.30	1.70	1.01	0.310	0.000760	10	247	0
Portugal River	-		320.39	184.10	1.55	1.12	0.314	0.000930	10	252	0
Portugal River	-		349.99	184.10	1.73	1.10	0.411	0.000720	10	187	0
Portugal River	-		357.59	184.60	1.74	1.11	0.261	0.000840	10	138	0
Portugal River	-		369.99	186.00	1.83	1.08	0.698	0.000680	10	244	0
Portugal River	-		409.99	187.27	1.86	1.18	0.256	0.000740	10	214	0
Portugal River	-		432.59	187.60	1.76	1.31	0.415	0.000910	10	215	0
Portugal River	-		451.99	187.50	1.99	1.21	0.325	0.000740	10	97	0
Portugal River	-		469.99	187.60	2.04	1.23	0.462	0.000770	10	183	0
Portugal River	-		477.99	187.60	1.85	1.38	0.335	0.000950	10	213	0
Portugal River	-		544.98	188.50	2.13	1.36	0.643	0.000790	10	203	0
Portugal River	-		574.98	187.40	2.15	1.43	0.404	0.000750	10	147	0
Portugal River	-		579.98	187.90	2.33	1.32	0.419	0.000770	10	54	0
Portugal River	-		613.98	188.94	2.32	1.40	0.609	0.000810	10	169	0
Portugal River	-		614.98	188.00	2.38	1.38	0.375	0.000790	10	84	0
Portugal River	-		639.98	187.70	2.44	1.40	0.486	0.000820	10	110	0

1	2	3	4	5	6	7	8	9	10	11
Portugal River		659.98	188.79	2.43	1.44	0.525	0.000820	10	208	0
Red River	07/14/26	190.31	155.75	3.00	0.41	0.149	0.000074	29	26	0
Red River	08/07/72	199.66	139.90	3.51	0.41	0.102	0.000073	29	26	0
Red River	01/03/91	206.74	159.41	3.51	0.37	0.109	0.000077	17	8	0
Red River	09/04/15	206.74	138.99	3.51	0.42	0.110	0.000076	12	36	0
Red River	07/01/25	223.73	130.45	3.38	0.51	0.178	0.000073	8	30	0
Red River	08/16/55	229.39	145.08	3.26	0.48	0.157	0.000077	14	42	0
Red River	03/23/45	242.99	146.30	3.55	0.47	0.115	0.000077	28	43	0
Red River	06/17/25	254.03	146.30	3.17	0.55	0.170	0.000076	6	46	0
Red River	09/25/44	255.73	149.35	3.66	0.47	0.109	0.000078	35	51	0
Red River	12/16/44	263.09	150.57	3.66	0.48	0.100	0.000081	32	33	0
Red River	06/18/44	274.99	160.02	3.72	0.46	0.179	0.000080	32	43	0
Red River	07/13/45	278.10	140.51	3.72	0.53	0.115	0.000077	23	77	0
Red River	06/04/44	331.34	160.32	4.42	0.47	0.159	0.000082	31	21	0
Red River	10/18/45	334.18	155.75	3.78	0.57	0.185	0.000077	19	80	0
Red River	11/27/72	362.50	156.97	3.75	0.62	0.112	0.000077	21	130	0
Red River	06/12/99	396.48	162.76	4.39	0.55	0.111	0.000076	34	80	0
Red River	04/13/17	407.81	162.15	4.18	0.60	0.175	0.000075	31	83	0
Red River	03/20/25	421.97	159.41	3.75	0.71	0.166	0.000077	3	127	0
Red River	05/02/72	461.62	164.90	4.39	0.64	0.119	0.000077	28	153	0
Red River	04/13/26	535.25	166.12	4.11	0.78	0.136	0.000076	20	239	0
Red River	03/06/99	594.72	168.55	5.27	0.67	0.176	0.000076	28	129	0
Red River	11/29/98	702.34	169.16	6.16	0.67	0.202	0.000072	25	68	0
Red River	10/26/00	736.32	165.51	5.15	0.86	0.156	0.000076	7	345	0
Red River	03/20/99	863.76	170.38	5.82	0.87	0.138	0.000075	29	155	0
Red River	08/21/72	926.06	170.38	5.79	0.94	0.126	0.000080	24	239	0
Red River	12/04/98	1019.52	173.13	7.07	0.83	0.161	0.000066	14	170	0
Red River	09/02/70	1115.81	175.26	6.40	0.99	0.224	0.000077	8	286	0
Red River	02/07/98	1297.06	177.70	7.06	1.03	0.166	0.000073	16	293	0
Red River	11/02/97	1537.78	182.88	7.38	1.14	0.212	0.000075	9	500	0
Rio Grande Convey Canal	01/13/81	25.75	21.34	1.30	0.93	0.270	0.000650	15	1,025	3
Rio Grande Convey Canal	01/13/81	25.75	22.86	1.37	0.82	0.280	0.000650	15	1,025	3
Rio Grande Convey Canal	01/14/81	25.19	22.86	1.50	0.74	0.210	0.000650	15	906	3
Rio Grande Convey Canal	01/14/81	25.19	20.12	1.25	1.00	0.230	0.000650	15	906	3
Rio Grande Convey Canal	04/13/81	33.68	22.56	0.89	1.67	0.200	0.000730	17	1,348	4
Rio Grande Convey Canal	05/24/08	36.22	21.34	1.02	1.66	0.210	0.001110	18	2,475	4
Rio Grande Convey Canal	04/14/81	36.51	27.43	0.89	1.50	0.180	0.000520	17	985	5
Rio Grande Convey Canal	09/22/82	35.38	22.56	1.10	1.43	0.180	0.000660	4	2,486	5
Rio Grande Convey Canal	09/23/82	35.38	22.56	1.11	1.42	0.180	0.000590	3	3,049	5
Rio Grande near Bemalillo	03/05/44	35.12	40.54	1.05	0.83	0.302	0.000830	18	783	0
Rio Grande near Bemalillo	03/05/44	35.12	139.90	0.40	0.62	0.302	0.000830	18	463	0
Rio Grande near Bemalillo	06/11/44	57.49	81.69	0.89	0.79	0.281	0.000820	23	598	0
Rio Grande near Bemalillo	06/11/44	57.49	108.81	0.44	1.20	0.281	0.000820	23	867	0
Rio Grande near Bemalillo	09/09/25	57.49	176.78	0.48	0.68	0.338	0.000800	27	596	0
Rio Grande near Bemalillo	09/09/25	58.34	82.30	0.82	0.86	0.272	0.000800	24	924	0
Rio Grande near Bemalillo	11/08/43	59.47	81.99	0.78	0.93	0.317	0.000830	15	1,000	0
Rio Grande near Bemalillo	11/08/43	59.47	192.63	0.33	0.93	0.317	0.000830	17	1,117	0
Rio Grande near Bemalillo	11/14/24	77.31	82.91	0.75	1.24	0.230	0.000890	14	2,517	0
Rio Grande near Bemalillo	06/03/25	78.16	81.99	0.84	1.13	0.312	0.000760	21	1,113	0
Rio Grande near Bemalillo	06/03/25	80.71	112.78	0.73	0.97	0.318	0.000760	21	724	0
Rio Grande near Bemalillo	11/14/24	82.41	195.07	0.36	1.17	0.306	0.000890	18	2,917	0
Rio Grande near Bemalillo	07/01/71	95.16	82.30	0.95	1.22	0.223	0.000830	19	1,724	0
Rio Grande near Bemalillo	07/01/71	110.16	194.46	0.53	1.06	0.214	0.000830	18	1,635	0
Rio Grande near Bemalillo	09/03/89	113.28	81.38	0.90	1.54	0.308	0.000760	19	3,653	0
Rio Grande near Bemalillo	08/29/89	122.91	81.08	0.81	1.86	0.308	0.000760	17	2,978	0
Rio Grande near Bemalillo	08/29/89	124.04	151.79	0.58	1.40	0.308	0.000760	19	2,881	0
Rio Grande near Bemalillo	05/28/25	133.67	106.68	0.75	1.68	0.330	0.000790	23	2,118	0
Rio Grande near Bemalillo	09/03/89	133.95	157.89	0.69	1.22	0.308	0.000760	22	3,621	0
Rio Grande near Bemalillo	05/28/25	136.79	82.91	1.06	1.55	0.328	0.000790	22	1,849	0
Rio Grande near Bemalillo	08/26/89	154.34	158.50	0.65	1.50	0.308	0.000740	21	2,791	0
Rio Grande near Bemalillo	08/26/89	164.26	82.30	1.05	1.91	0.308	0.000740	18	3,588	0
Rio Grande near Bemalillo	09/10/89	168.79	162.15	0.64	1.63	0.308	0.000800	25	2,819	0
Rio Grande near Bemalillo	09/10/89	171.05	83.21	1.04	1.98	0.308	0.000800	23	4,530	0
Rio Grande near Bemalillo	05/25/25	172.75	149.05	0.66	1.74	0.317	0.000830	23	2,415	0
Rio Grande near Bemalillo	05/25/25	173.88	82.91	1.16	1.82	0.293	0.000830	21	2,139	0

1	2	3	4	5	6	7	8	9	10	11
Rio Grande near Bernalillo	02/09/25	180.96	173.74	0.63	1.65	0.347	0.000840	18	2,869	0
Rio Grande near Bernalillo	02/09/25	183.80	82.91	1.11	2.00	0.387	0.000840	17	2,517	0
Rio Grande near Bernalillo	05/16/89	190.59	169.77	0.66	1.71	0.308	0.000800	16	4,337	0
Rio Grande near Bernalillo	05/16/89	194.28	82.30	1.12	2.10	0.308	0.000800	14	3,203	0
Rio Grande near Bernalillo	08/20/89	220.61	154.84	0.83	1.72	0.308	0.000830	22	2,768	0
Rio Grande near Bernalillo	08/20/89	231.09	82.91	1.32	2.11	0.308	0.000830	19	2,343	0
Rio Grande near Bernalillo	05/21/89	235.34	164.90	0.78	1.84	0.308	0.000800	17	3,830	0
Rio Grande near Bernalillo	05/21/89	235.62	82.60	1.36	2.10	0.308	0.000800	16	2,989	0
Rio Grande near Bernalillo	05/29/89	245.82	82.30	1.25	2.38	0.308	0.000790	19	2,818	0
Rio Grande near Bernalillo	05/29/89	246.38	196.60	0.67	1.88	0.308	0.000790	20	3,766	0
Rio Grande near Bernalillo	06/04/89	282.35	194.16	0.80	1.81	0.308	0.000800	20	3,164	0
Rio Grande near Bernalillo	06/04/89	286.03	83.21	1.46	2.35	0.308	0.000800	23	2,449	0
Rio Grande River	-	0.50	8.84	0.16	0.36	0.300	0.000860	26	200	0
Rio Grande River	-	0.68	7.93	0.22	0.39	0.362	0.001100	14	99	0
Rio Grande River	-	0.98	18.59	0.27	0.19	0.352	0.001290	27	2	0
Rio Grande River	-	1.06	11.89	0.23	0.38	0.311	0.000690	23	35	0
Rio Grande River	-	1.36	20.12	0.21	0.33	0.231	0.000690	26	63	0
Rio Grande River	-	1.44	21.64	0.18	0.37	0.452	0.001100	19	53	0
Rio Grande River	-	1.83	16.00	0.43	0.27	0.258	0.001290	25	19	0
Rio Grande River	-	1.92	23.47	0.28	0.29	0.314	0.001290	22	129	0
Rio Grande River	-	1.95	16.76	0.23	0.50	0.265	0.001100	16	651	0
Rio Grande River	-	2.04	9.60	0.42	0.51	0.328	0.001100	26	274	0
Rio Grande River	-	2.09	23.77	0.20	0.43	0.294	0.001100	16	140	0
Rio Grande River	-	2.11	13.72	0.32	0.48	0.297	0.000690	24	128	0
Rio Grande River	-	2.29	17.68	0.28	0.46	0.397	0.001100	18	252	0
Rio Grande River	-	2.30	32.92	0.18	0.40	0.296	0.000860	24	183	0
Rio Grande River	-	2.45	18.59	0.41	0.32	0.304	0.000690	17	48	0
Rio Grande River	-	2.67	24.99	0.32	0.33	0.356	0.000690	13	24	0
Rio Grande River	-	2.79	27.13	0.24	0.43	0.337	0.000860	22	262	0
Rio Grande River	-	2.86	33.53	0.20	0.42	0.370	0.001100	20	143	0
Rio Grande River	-	2.86	25.60	0.37	0.30	0.396	0.001100	9	6	0
Rio Grande River	-	2.92	29.87	0.24	0.40	0.328	0.000690	16	87	0
Rio Grande River	-	2.94	43.28	0.26	0.26	0.343	0.001500	27	5	0
Rio Grande River	-	3.06	21.95	0.29	0.48	0.259	0.000690	26	1,270	0
Rio Grande River	-	3.62	29.26	0.35	0.35	0.277	0.001100	11	63	0
Rio Grande River	-	3.74	26.52	0.34	0.42	0.365	0.001100	7	53	0
Rio Grande River	-	4.05	16.15	0.71	0.35	0.173	0.000690	20	199	0
Rio Grande River	-	4.05	33.53	0.35	0.34	0.211	0.001100	22	97	0
Rio Grande River	-	4.08	26.82	0.36	0.42	0.382	0.001290	22	92	0
Rio Grande River	-	4.36	28.96	0.33	0.46	0.609	0.001290	12	39	0
Rio Grande River	-	4.56	26.21	0.43	0.40	0.409	0.001290	27	24	0
Rio Grande River	-	4.64	19.81	0.45	0.53	0.327	0.000690	12	81	0
Rio Grande River	-	4.79	27.43	0.33	0.53	0.397	0.001500	21	256	0
Rio Grande River	-	4.84	25.60	0.37	0.52	0.243	0.001290	17	248	0
Rio Grande River	-	4.87	29.26	0.41	0.40	0.282	0.001100	28	149	0
Rio Grande River	-	4.90	28.04	0.36	0.49	0.247	0.001290	11	344	0
Rio Grande River	-	5.21	26.21	0.40	0.50	0.284	0.000690	14	229	0
Rio Grande River	-	5.27	14.02	0.59	0.64	0.277	0.000860	27	3,460	0
Rio Grande River	-	5.32	45.72	0.34	0.34	0.325	0.000690	22	11	0
Rio Grande River	-	5.63	24.08	0.45	0.52	0.361	0.000860	24	261	0
Rio Grande River	-	5.80	29.26	0.46	0.43	0.364	0.001100	16	816	0
Rio Grande River	-	5.80	27.43	0.42	0.50	0.368	0.001290	21	585	0
Rio Grande River	-	5.83	35.36	0.30	0.56	0.544	0.001500	23	924	0
Rio Grande River	-	6.03	31.70	0.39	0.49	0.313	0.000690	18	176	0
Rio Grande River	-	6.57	27.13	0.45	0.54	0.478	0.001290	23	234	0
Rio Grande River	-	6.65	39.62	0.32	0.52	0.525	0.001500	18	719	0
Rio Grande River	-	6.68	31.39	0.41	0.51	0.381	0.001100	21	94	0
Rio Grande River	-	6.85	41.15	0.32	0.52	0.299	0.001100	1	594	0
Rio Grande River	-	6.99	46.94	0.26	0.57	0.325	0.001100	9	509	0
Rio Grande River	-	7.14	50.60	0.28	0.50	0.247	0.001500	11	748	0
Rio Grande River	-	7.14	53.34	0.29	0.46	0.291	0.001290	21	149	0
Rio Grande River	-	7.25	32.92	0.37	0.59	0.578	0.001500	27	671	0
Rio Grande River	-	7.42	27.43	0.54	0.50	0.282	0.001290	22	46	0
Rio Grande River	-	7.48	52.43	0.31	0.46	0.321	0.001290	23	472	0
Rio Grande River	-	7.48	44.50	0.34	0.49	0.375	0.001500	21	1,180	0

1	2	3	4	5	6	7	8	9	10	11
Rio Grande River	-	7.50	29.57	0.46	0.55	0.333	0.001100	22	1,070	0
Rio Grande River	-	7.59	23.47	0.53	0.61	0.378	0.001100	7	466	0
Rio Grande River	-	7.65	54.86	0.28	0.49	0.228	0.000860	27	741	0
Rio Grande River	-	7.70	34.75	0.40	0.56	0.525	0.001290	14	374	0
Rio Grande River	-	7.73	37.80	0.36	0.57	0.372	0.001500	7	1,700	0
Rio Grande River	-	7.96	29.87	0.44	0.61	0.357	0.001100	14	637	0
Rio Grande River	-	8.30	48.46	0.35	0.49	0.266	0.001100	8	268	0
Rio Grande River	-	8.32	30.48	0.49	0.56	0.349	0.001290	14	276	0
Rio Grande River	-	8.32	45.72	0.33	0.55	0.438	0.001500	25	496	0
Rio Grande River	-	8.64	45.72	0.32	0.60	0.469	0.001500	16	681	0
Rio Grande River	-	8.75	46.03	0.35	0.54	0.420	0.001500	24	213	0
Rio Grande River	-	8.75	53.95	0.31	0.53	0.629	0.001290	11	43	0
Rio Grande River	-	8.95	35.66	0.41	0.61	0.357	0.000690	4	558	0
Rio Grande River	-	9.00	39.62	0.39	0.58	0.352	0.001100	19	415	0
Rio Grande River	-	9.26	35.05	0.44	0.61	0.415	0.001290	3	1,290	0
Rio Grande River	-	9.34	44.20	0.35	0.60	0.460	0.001500	24	405	0
Rio Grande River	-	9.83	35.05	0.45	0.62	0.378	0.001290	9	877	0
Rio Grande River	-	9.85	54.25	0.35	0.52	0.376	0.001100	6	505	0
Rio Grande River	-	9.97	41.15	0.39	0.62	0.416	0.001290	6	1,700	0
Rio Grande River	-	10.14	52.43	0.33	0.59	0.294	0.001500	1	1,280	0
Rio Grande River	-	10.19	52.43	0.35	0.55	0.343	0.001500	7	1,260	0
Rio Grande River	-	10.22	60.35	0.25	0.67	0.174	0.001500	23	1,550	0
Rio Grande River	-	10.36	39.01	0.44	0.60	0.360	0.001100	22	2,640	0
Rio Grande River	-	10.36	47.24	0.30	0.74	0.414	0.001500	22	3,410	0
Rio Grande River	-	10.45	52.43	0.32	0.62	0.398	0.001500	5	1,190	0
Rio Grande River	-	10.53	38.41	0.41	0.68	0.318	0.001500	11	1,380	0
Rio Grande River	-	10.82	49.07	0.41	0.54	0.351	0.000690	7	557	0
Rio Grande River	-	10.90	31.70	0.41	0.84	0.330	0.001290	4	1,360	0
Rio Grande River	-	10.93	103.02	0.21	0.50	0.235	0.001100	14	729	0
Rio Grande River	-	10.93	22.86	0.56	0.85	0.365	0.001500	0	1,260	0
Rio Grande River	-	10.99	35.05	0.63	0.50	0.248	0.001100	19	204	0
Rio Grande River	-	11.18	74.37	0.34	0.44	0.215	0.000860	16	1,310	0
Rio Grande River	-	11.18	47.24	0.41	0.58	0.337	0.001100	10	406	0
Rio Grande River	-	11.44	80.77	0.28	0.51	0.314	0.000690	25	371	0
Rio Grande River	-	11.50	47.24	0.40	0.61	0.361	0.001100	9	570	0
Rio Grande River	-	11.72	46.63	0.41	0.61	0.575	0.001500	12	320	0
Rio Grande River	-	11.72	36.58	0.48	0.66	0.643	0.001290	9	543	0
Rio Grande River	-	11.78	63.40	0.36	0.52	0.472	0.001290	12	178	0
Rio Grande River	-	11.89	30.48	0.59	0.66	0.211	0.001290	24	244	0
Rio Grande River	-	12.06	33.83	0.43	0.82	0.312	0.001500	7	1,680	0
Rio Grande River	-	12.09	41.15	0.51	0.58	0.372	0.001100	19	574	0
Rio Grande River	-	12.15	41.45	0.47	0.62	0.311	0.001100	14	539	0
Rio Grande River	-	12.18	40.54	0.48	0.62	0.345	0.001100	6	807	0
Rio Grande River	-	12.57	71.93	0.30	0.59	0.234	0.001100	3	996	0
Rio Grande River	-	12.63	53.65	0.46	0.51	0.542	0.001500	15	311	0
Rio Grande River	-	12.83	69.19	0.30	0.61	0.424	0.000790	26	315	0
Rio Grande River	-	12.83	53.04	0.42	0.58	0.445	0.001500	22	1,450	0
Rio Grande River	-	12.86	63.40	0.43	0.47	0.174	0.000690	5	549	0
Rio Grande River	-	12.94	46.63	0.42	0.66	0.395	0.001500	13	367	0
Rio Grande River	-	13.00	82.91	0.33	0.48	0.251	0.000690	23	407	0
Rio Grande River	-	13.14	38.41	0.52	0.66	0.404	0.001290	3	1,800	0
Rio Grande River	-	13.14	37.80	0.50	0.69	0.411	0.001290	2	1,850	0
Rio Grande River	-	13.25	39.01	0.52	0.65	0.389	0.001290	2	1,200	0
Rio Grande River	-	13.54	35.97	0.48	0.79	0.336	0.001500	8	1,300	0
Rio Grande River	-	13.54	39.62	0.51	0.68	0.375	0.001290	6	3,350	0
Rio Grande River	-	13.56	48.77	0.52	0.54	0.318	0.000860	23	562	0
Rio Grande River	-	13.59	54.25	0.38	0.66	0.305	0.001500	6	722	0
Rio Grande River	-	13.70	34.75	0.38	1.03	0.356	0.001290	2	2,000	0
Rio Grande River	-	13.73	53.04	0.39	0.67	0.397	0.001500	2	1,120	0
Rio Grande River	-	13.96	65.23	0.40	0.54	0.302	0.000860	22	759	0
Rio Grande River	-	14.04	79.25	0.31	0.56	0.222	0.000860	24	985	0
Rio Grande River	-	14.07	33.83	0.51	0.82	0.439	0.001500	4	1,730	0
Rio Grande River	-	14.16	54.25	0.46	0.57	0.335	0.001290	21	639	0
Rio Grande River	-	14.24	39.62	0.54	0.66	0.406	0.001290	4	1,390	0
Rio Grande River	-	14.38	32.00	0.60	0.75	0.237	0.001500	11	981	0

1	2	3	4	5	6	7	8	9	10	11
Rio Grande River	-	14.55	49.99	0.53	0.55	0.310	0.001290	24	222	0
Rio Grande River	-	14.58	51.51	0.41	0.69	0.399	0.001500	8	1,360	0
Rio Grande River	-	14.64	37.80	0.56	0.69	0.474	0.001290	3	589	0
Rio Grande River	-	14.81	45.72	0.38	0.85	0.201	0.001500	6	1,660	0
Rio Grande River	-	14.81	52.43	0.46	0.61	0.316	0.001100	27	700	0
Rio Grande River	-	14.98	40.54	0.53	0.70	0.499	0.001290	9	1,330	0
Rio Grande River	-	15.38	62.18	0.47	0.53	0.258	0.000690	3	497	0
Rio Grande River	-	15.60	80.77	0.38	0.51	0.293	0.000860	17	544	0
Rio Grande River	-	15.72	39.62	0.49	0.80	0.391	0.001290	5	1,560	0
Rio Grande River	-	15.74	78.03	0.29	0.70	0.272	0.001290	15	1,640	0
Rio Grande River	-	15.80	108.20	0.26	0.56	0.341	0.001100	2	1,730	0
Rio Grande River	-	15.80	38.10	0.43	0.96	0.380	0.001290	4	1,740	0
Rio Grande River	-	15.91	46.63	0.46	0.74	0.395	0.001500	17	529	0
Rio Grande River	-	15.94	53.65	0.44	0.68	0.453	0.001500	23	1,080	0
Rio Grande River	-	15.97	79.86	0.33	0.61	0.197	0.000860	22	1,520	0
Rio Grande River	-	16.14	68.28	0.40	0.59	0.374	0.001100	10	1,420	0
Rio Grande River	-	16.17	47.85	0.40	0.85	0.294	0.001500	6	1,670	0
Rio Grande River	-	16.23	52.12	0.52	0.60	0.364	0.000860	19	7,240	0
Rio Grande River	-	16.45	54.25	0.43	0.71	0.377	0.001500	9	1,420	0
Rio Grande River	-	16.48	45.42	0.53	0.68	0.327	0.001100	9	1,060	0
Rio Grande River	-	16.51	42.67	0.48	0.81	0.419	0.001290	3	1,850	0
Rio Grande River	-	16.96	45.72	0.54	0.69	0.390	0.001500	19	2,430	0
Rio Grande River	-	17.05	51.51	0.56	0.59	0.319	0.001100	9	1,210	0
Rio Grande River	-	17.05	39.01	0.56	0.78	0.332	0.000860	7	1,270	0
Rio Grande River	-	17.13	64.92	0.29	0.91	0.215	0.001500	4	2,260	0
Rio Grande River	-	17.13	50.60	0.42	0.80	0.344	0.001100	6	1,650	0
Rio Grande River	-	17.27	79.86	0.36	0.60	0.276	0.000860	11	1,100	0
Rio Grande River	-	17.33	89.61	0.34	0.58	0.344	0.000860	26	2,370	0
Rio Grande River	-	17.41	35.05	0.54	0.92	0.354	0.001500	4	1,780	0
Rio Grande River	-	17.64	81.08	0.37	0.58	0.368	0.000860	17	1,310	0
Rio Grande River	-	17.98	103.63	0.34	0.52	0.322	0.001100	17	572	0
Rio Grande River	-	18.43	63.09	0.38	0.77	0.318	0.000690	24	1,350	0
Rio Grande River	-	18.49	77.72	0.40	0.59	0.329	0.000860	18	3,210	0
Rio Grande River	-	18.89	60.05	0.44	0.71	0.298	0.001500	24	876	0
Rio Grande River	-	18.89	62.18	0.53	0.58	0.363	0.001290	18	314	0
Rio Grande River	-	18.97	101.50	0.34	0.56	0.303	0.001100	8	1,060	0
Rio Grande River	-	19.08	85.34	0.33	0.67	1.056	0.001280	24	304	0
Rio Grande River	-	19.14	56.69	0.43	0.79	0.403	0.001100	7	2,460	0
Rio Grande River	-	19.25	49.38	0.54	0.73	0.454	0.001970	24	729	0
Rio Grande River	-	19.37	33.22	0.77	0.76	0.531	0.000920	26	445	0
Rio Grande River	-	20.08	91.44	0.37	0.59	1.466	0.091290	14	273	0
Rio Grande River	-	20.13	80.47	0.37	0.67	0.333	0.001290	23	1,210	0
Rio Grande River	-	20.42	110.34	0.32	0.58	0.328	0.001100	17	851	0
Rio Grande River	-	20.98	85.34	0.39	0.63	0.325	0.000860	18	1,230	0
Rio Grande River	-	21.38	67.97	0.46	0.68	0.397	0.001500	20	553	0
Rio Grande River	-	21.49	72.24	0.44	0.68	0.372	0.000860	8	2,570	0
Rio Grande River	-	21.58	64.62	0.49	0.68	0.402	0.001500	18	667	0
Rio Grande River	-	22.20	89.92	0.38	0.65	0.261	0.001290	25	499	0
Rio Grande River	-	22.28	79.86	0.42	0.67	0.344	0.001500	27	1,120	0
Rio Grande River	-	22.40	99.67	0.44	0.51	0.427	0.001100	23	2,920	0
Rio Grande River	-	24.41	39.01	0.66	0.95	0.452	0.001500	29	3,350	0
Rio Grande River	-	24.44	78.64	0.39	0.80	0.495	0.001500	8	2,110	0
Rio Grande River	-	24.95	91.44	0.41	0.67	0.331	0.001290	19	469	0
Rio Grande River	-	25.00	82.60	0.37	0.81	0.408	0.001290	24	1,410	0
Rio Grande River	-	25.14	61.57	0.52	0.78	0.401	0.001500	21	1,320	0
Rio Grande River	-	25.26	65.53	0.45	0.87	0.379	0.001500	11	1,230	0
Rio Grande River	-	25.54	121.92	0.37	0.57	0.296	0.001100	17	831	0
Rio Grande River	-	25.71	29.57	1.01	0.86	0.569	0.000720	24	551	0
Rio Grande River	-	26.02	73.46	0.44	0.80	0.325	0.001290	11	5,000	0
Rio Grande River	-	26.02	81.08	0.48	0.67	0.363	0.001500	22	596	0
Rio Grande River	-	26.05	83.52	0.43	0.72	0.314	0.000860	16	2,880	0
Rio Grande River	-	26.31	65.23	0.46	0.88	0.332	0.001500	10	1,750	0
Rio Grande River	-	26.56	78.94	0.48	0.69	0.486	0.001290	6	5,990	0
Rio Grande River	-	26.70	71.02	0.40	0.94	0.386	0.001290	19	1,730	0
Rio Grande River	-	27.30	91.44	0.44	0.68	0.462	0.001290	8	4,470	0

1	2	3	4	5	6	7	8	9	10	11
Rio Grande River	-	27.92	80.16	0.39	0.89	0.279	0.000860	19	1,310	0
Rio Grande River	-	27.95	67.97	0.47	0.88	0.369	0.000800	22	2,730	0
Rio Grande River	-	28.32	81.08	0.46	0.76	0.246	0.000860	21	1,810	0
Rio Grande River	-	28.32	80.16	0.52	0.68	0.705	0.001180	24	556	0
Rio Grande River	-	28.88	55.17	0.66	0.79	0.536	0.001000	27	1,230	0
Rio Grande River	-	29.45	74.98	0.41	0.97	0.242	0.001100	24	2,900	0
Rio Grande River	-	29.45	85.34	0.46	0.74	0.698	0.001290	16	2,220	0
Rio Grande River	-	30.86	29.87	1.10	0.94	0.655	0.000810	23	2,000	0
Rio Grande River	-	32.28	46.33	0.62	1.13	0.374	0.001500	23	4,580	0
Rio Grande River	-	32.56	85.04	0.45	0.86	0.360	0.001290	22	2,600	0
Rio Grande River	-	33.13	68.58	0.62	0.78	0.516	0.001500	18	879	0
Rio Grande River	-	33.13	91.44	0.53	0.69	0.610	0.001290	17	1,030	0
Rio Grande River	-	33.41	78.64	0.48	0.89	0.250	0.000690	26	1,500	0
Rio Grande River	-	33.41	43.59	0.85	0.90	0.405	0.001500	14	1,530	0
Rio Grande River	-	35.11	40.54	1.05	0.83	0.310	0.000830	18	1,280	0
Rio Grande River	-	35.39	85.65	0.50	0.83	0.256	0.001290	15	1,930	0
Rio Grande River	-	35.39	80.16	0.45	0.99	0.303	0.001500	14	2,000	0
Rio Grande River	-	36.81	106.68	0.53	0.65	0.348	0.001100	19	1,040	0
Rio Grande River	-	37.94	81.69	0.65	0.71	0.330	0.000860	21	1,200	0
Rio Grande River	-	39.08	99.06	0.37	1.05	0.250	0.001100	24	3,080	0
Rio Grande River	-	40.21	101.19	0.48	0.83	0.233	0.001100	18	1,450	0
Rio Grande River	-	40.21	101.50	0.50	0.80	0.337	0.001100	19	1,060	0
Rio Grande River	-	41.34	34.14	1.03	1.18	0.380	0.000980	15	2,620	0
Rio Grande River	-	43.61	82.30	0.66	0.81	0.340	0.000860	14	1,470	0
Rio Grande River	-	44.74	44.50	0.89	1.13	0.291	0.001500	21	3,290	0
Rio Grande River	-	44.74	83.82	0.47	1.14	0.348	0.000860	15	4,160	0
Rio Grande River	-	45.02	86.56	0.58	0.90	0.339	0.001290	19	1,400	0
Rio Grande River	-	48.42	84.13	0.63	0.91	0.500	0.001500	23	2,090	0
Rio Grande River	-	57.48	81.69	0.89	0.79	0.283	0.000820	23	894	0
Rio Grande River	-	57.76	86.87	0.68	0.97	0.473	0.001180	21	7,230	0
Rio Grande River	-	58.33	82.30	0.82	0.86	0.270	0.000800	24	1,260	0
Rio Grande River	-	59.18	82.30	0.76	0.95	0.336	0.000830	17	1,290	0
Rio Grande River	-	59.18	86.87	0.66	1.03	0.337	0.001340	11	1,630	0
Rio Grande River	-	59.46	81.99	0.78	0.93	0.328	0.000830	15	1,480	0
Rio Grande River	-	60.88	82.30	0.78	0.95	0.342	0.000860	22	1,460	0
Rio Grande River	-	62.30	53.95	0.82	1.40	0.232	0.001150	14	1,540	0
Rio Grande River	-	62.30	55.47	0.83	1.35	0.433	0.000910	24	1,620	0
Rio Grande River	-	63.14	81.38	0.80	0.96	0.224	0.000830	14	1,640	0
Rio Grande River	-	63.43	34.44	1.43	1.29	0.421	0.001630	19	2,690	0
Rio Grande River	-	63.99	81.69	0.71	1.10	0.218	0.000830	17	934	0
Rio Grande River	-	71.07	51.21	0.94	1.47	0.238	0.001080	17	1,450	0
Rio Grande River	-	71.36	99.67	0.60	1.19	0.300	0.001100	24	5,820	0
Rio Grande River	-	72.77	82.30	0.81	1.09	0.348	0.000930	18	1,710	0
Rio Grande River	-	74.19	85.65	0.73	1.19	0.424	0.001370	15	3,300	0
Rio Grande River	-	77.30	82.91	0.75	1.24	0.233	0.000890	14	3,130	0
Rio Grande River	-	77.87	35.05	1.45	1.53	0.384	0.001590	13	1,620	0
Rio Grande River	-	78.15	81.99	0.84	1.13	0.323	0.000760	21	1,520	0
Rio Grande River	-	78.72	36.88	1.62	1.32	1.407	0.001440	11	1,300	0
Rio Grande River	-	80.70	82.60	0.74	1.31	0.265	0.000860	18	2,810	0
Rio Grande River	-	83.53	120.40	0.65	1.06	0.258	0.000690	18	3,350	0
Rio Grande River	-	85.23	43.89	1.21	1.60	0.291	0.001500	16	2,410	0
Rio Grande River	-	86.08	97.54	0.73	1.21	0.189	0.001100	18	3,730	0
Rio Grande River	-	87.21	82.91	0.67	1.58	0.301	0.000860	16	5,050	0
Rio Grande River	-	94.86	87.48	0.77	1.42	0.361	0.001290	17	3,630	0
Rio Grande River	-	95.14	82.30	0.95	1.22	0.230	0.000830	19	2,040	0
Rio Grande River	-	98.26	86.26	0.78	1.47	0.249	0.001290	12	2,920	0
Rio Grande River	-	101.37	49.68	1.22	1.67	0.293	0.001260	17	2,740	0
Rio Grande River	-	101.37	42.67	1.50	1.58	0.380	0.001500	14	2,710	0
Rio Grande River	-	104.20	87.78	0.86	1.38	0.444	0.001370	14	1,820	0
Rio Grande River	-	106.18	101.19	0.84	1.24	0.281	0.001100	21	6,820	0
Rio Grande River	-	107.32	118.87	0.78	1.16	0.289	0.000690	16	4,890	0
Rio Grande River	-	113.26	81.38	0.90	1.54	0.274	0.000760	19	4,390	0
Rio Grande River	-	113.26	39.01	2.33	1.25	0.932	0.001330	14	1,540	0
Rio Grande River	-	114.11	97.54	0.92	1.27	0.298	0.001100	17	7,550	0
Rio Grande River	-	117.51	82.60	0.93	1.53	0.286	0.000860	14	5,830	0

1	2	3	4	5	6	7	8	9	10	11
Rio Grande River	-	118.93	120.40	0.78	1.27	0.224	0.000690	24	2.820	0
Rio Grande River	-	122.89	81.08	0.81	1.86	0.372	0.000760	17	3.610	0
Rio Grande River	-	129.40	82.60	0.92	1.70	0.254	0.000860	23	2.460	0
Rio Grande River	-	134.78	45.42	1.63	1.82	0.712	0.001500	23	3.030	0
Rio Grande River	-	135.92	88.70	0.95	1.61	0.361	0.001290	19	4.740	0
Rio Grande River	-	136.77	82.91	1.06	1.55	0.345	0.000790	22	2.340	0
Rio Grande River	-	141.30	90.53	1.11	1.41	0.603	0.001230	17	10.700	0
Rio Grande River	-	141.58	38.10	2.19	1.70	0.474	0.002310	17	1.690	0
Rio Grande River	-	141.86	57.00	1.36	1.83	1.000	0.001510	19	4.170	0
Rio Grande River	-	143.00	99.06	1.41	1.03	0.327	0.001100	24	8.470	0
Rio Grande River	-	143.28	90.83	1.23	1.28	0.645	0.001130	17	11.400	0
Rio Grande River	-	144.98	57.30	1.37	1.85	0.513	0.001510	19	7.880	0
Rio Grande River	-	146.11	82.60	0.99	1.79	0.278	0.000860	18	4.140	0
Rio Grande River	-	146.11	45.72	1.70	1.88	0.371	0.001500	18	2.620	0
Rio Grande River	-	147.53	39.32	1.91	1.96	0.565	0.002200	16	5.190	0
Rio Grande River	-	151.21	84.13	0.98	1.83	0.254	0.000860	18	3.160	0
Rio Grande River	-	155.74	98.76	1.23	1.28	0.362	0.001100	19	4.990	0
Rio Grande River	-	156.30	90.53	1.01	1.71	0.393	0.001290	17	5.210	0
Rio Grande River	-	164.23	82.30	1.05	1.91	0.362	0.000740	18	3.950	0
Rio Grande River	-	169.90	39.62	2.39	1.79	1.190	0.001960	15	3.060	0
Rio Grande River	-	171.03	83.21	1.04	1.98	0.379	0.000800	23	5.760	0
Rio Grande River	-	173.86	82.91	1.16	1.82	0.300	0.000830	21	2.150	0
Rio Grande River	-	183.77	82.91	1.11	2.00	0.408	0.000840	17	4.330	0
Rio Grande River	-	194.25	82.30	1.12	2.10	0.329	0.000800	14	3.930	0
Rio Grande River	-	207.27	40.23	2.47	2.08	0.314	0.002300	15	5.310	0
Rio Grande River	-	225.40	93.88	1.20	2.00	0.400	0.001290	13	4.220	0
Rio Grande River	-	231.06	82.91	1.32	2.11	0.311	0.000830	19	2.800	0
Rio Grande River	-	235.59	82.60	1.36	2.10	0.303	0.000800	16	4.500	0
Rio Grande River	-	243.23	60.96	1.83	2.18	0.569	0.001680	19	2.310	0
Rio Grande River	-	243.23	41.15	2.73	2.16	1.909	0.002400	17	1.710	0
Rio Grande River	-	245.78	82.30	1.25	2.38	0.394	0.000790	19	5.080	0
Rio Grande River	-	245.78	89.92	1.48	1.85	0.608	0.001270	17	3.140	0
Rio Grande River	-	252.01	99.97	1.25	2.02	0.442	0.001200	14	4.160	0
Rio Grande River	-	252.58	96.32	1.32	1.98	0.623	0.001200	14	2.680	0
Rio Grande River	-	258.81	64.01	1.79	2.26	0.480	0.001800	18	2.020	0
Rio Grande River	-	264.47	39.62	3.12	2.14	0.429	0.002460	14	3.920	0
Rio Grande River	-	268.72	44.20	2.86	2.13	0.527	0.002400	17	1.500	0
Rio Grande River	-	275.23	63.70	1.88	2.30	1.077	0.001930	19	2.460	0
Rio Grande River	-	277.78	102.11	1.34	2.03	0.313	0.001270	16	2.480	0
Rio Grande River	-	285.99	83.21	1.46	2.35	0.301	0.000800	23	2.940	0
Rio Grande River	-	285.99	42.67	3.11	2.15	0.374	0.002350	16	2.700	0
Rio Magdalena & Canal del Dique	-	29.00	27.00	2.21	0.49	0.185	0.000020	30	8	0
Rio Magdalena & Canal del Dique	-	38.00	77.00	2.49	0.20	0.125	0.000003	30	17	0
Rio Magdalena & Canal del Dique	-	51.00	93.00	1.80	0.30	0.120	0.000010	30	3	0
Rio Magdalena & Canal del Dique	-	55.00	39.00	3.08	0.46	0.100	0.000089	30	23	0
Rio Magdalena & Canal del Dique	-	57.00	31.00	3.42	0.54	0.100	0.000020	30	6	0
Rio Magdalena & Canal del Dique	-	68.00	74.00	2.16	0.43	0.120	0.000020	30	9	0
Rio Magdalena & Canal del Dique	-	80.00	30.00	2.57	1.04	0.185	0.000170	30	261	0
Rio Magdalena & Canal del Dique	-	81.00	78.00	1.82	0.57	0.125	0.000035	30	89	0
Rio Magdalena & Canal del Dique	-	82.00	75.00	2.08	0.53	0.125	0.000024	30	148	0
Rio Magdalena & Canal del Dique	-	83.00	108.00	2.47	0.31	0.210	0.000026	30	11	0
Rio Magdalena & Canal del Dique	-	89.00	32.00	2.68	1.04	0.185	0.000170	30	205	0
Rio Magdalena & Canal del Dique	-	95.00	75.00	1.87	0.68	0.125	0.000046	30	119	0
Rio Magdalena & Canal del Dique	-	111.00	41.00	4.12	0.66	0.100	0.000091	30	163	0
Rio Magdalena & Canal del Dique	-	120.00	76.00	3.54	0.45	0.150	0.000020	30	10	0
Rio Magdalena & Canal del Dique	-	126.00	34.00	2.62	1.41	0.185	0.000150	30	152	0
Rio Magdalena & Canal del Dique	-	128.00	35.00	2.96	1.24	0.125	0.000129	30	58	0
Rio Magdalena & Canal del Dique	-	142.00	36.00	3.92	1.01	0.100	0.000068	30	393	0
Rio Magdalena & Canal del Dique	-	150.00	45.00	2.62	1.27	0.125	0.000142	30	216	0
Rio Magdalena & Canal del Dique	-	153.00	41.00	2.63	1.42	0.125	0.000177	30	124	0
Rio Magdalena & Canal del Dique	-	158.00	114.00	2.65	0.52	0.210	0.000036	30	121	0
Rio Magdalena & Canal del Dique	-	169.00	95.00	2.21	0.80	0.120	0.000051	30	163	0
Rio Magdalena & Canal del Dique	-	215.00	100.00	2.93	0.73	0.120	0.000047	30	222	0
Rio Magdalena & Canal del Dique	-	225.00	86.00	2.93	0.89	0.125	0.000041	30	216	0
Rio Magdalena & Canal del Dique	-	228.00	90.00	2.78	0.91	0.120	0.000041	30	169	0

1	2	3	4	5	6	7	8	9	10	11
Rio Magdalena & Canal del Dique	-	232.00	197.00	1.32	0.89	1.080	0.000350	30	99	0
Rio Magdalena & Canal del Dique	-	261.00	198.00	1.57	0.84	1.080	0.000360	30	49	0
Rio Magdalena & Canal del Dique	-	280.00	85.00	3.15	1.05	0.120	0.000077	30	193	0
Rio Magdalena & Canal del Dique	-	284.00	270.00	1.39	0.76	0.265	0.000450	30	412	0
Rio Magdalena & Canal del Dique	-	322.00	69.00	3.78	1.23	0.120	0.000091	30	329	0
Rio Magdalena & Canal del Dique	-	370.00	88.00	3.91	1.08	0.120	0.000089	30	141	0
Rio Magdalena & Canal del Dique	-	421.00	135.00	3.82	0.82	0.210	0.000057	30	626	0
Rio Magdalena & Canal del Dique	-	440.00	85.00	4.47	1.16	0.150	0.000059	30	233	0
Rio Magdalena & Canal del Dique	-	475.00	195.00	2.18	1.12	1.080	0.000460	30	179	0
Rio Magdalena & Canal del Dique	-	478.00	120.00	3.55	1.12	0.210	0.000062	30	267	0
Rio Magdalena & Canal del Dique	-	504.00	190.00	2.46	1.08	1.080	0.000410	30	198	0
Rio Magdalena & Canal del Dique	-	544.00	84.00	5.13	1.26	0.150	0.000089	30	156	0
Rio Magdalena & Canal del Dique	-	567.00	140.00	4.60	0.88	0.210	0.000071	30	591	0
Rio Magdalena & Canal del Dique	-	604.00	284.00	2.08	1.02	0.500	0.000230	30	497	0
Rio Magdalena & Canal del Dique	-	611.00	290.00	2.17	0.97	0.265	0.000450	30	3,000	0
Rio Magdalena & Canal del Dique	-	793.00	290.00	2.79	0.98	0.500	0.000220	30	492	0
Rio Magdalena & Canal del Dique	-	886.00	194.00	3.22	1.42	1.080	0.000570	30	423	0
Rio Magdalena & Canal del Dique	-	979.00	285.00	2.98	1.15	0.500	0.000170	30	464	0
Rio Magdalena & Canal del Dique	-	1140.00	300.00	2.78	1.37	0.500	0.000210	30	570	0
Rio Magdalena & Canal del Dique	-	1250.00	395.00	2.50	1.27	0.920	0.000380	30	304	0
Rio Magdalena & Canal del Dique	-	1260.00	845.00	1.53	0.97	0.405	0.000400	30	293	0
Rio Magdalena & Canal del Dique	-	1310.00	295.00	3.01	1.48	0.500	0.000230	30	710	0
Rio Magdalena & Canal del Dique	-	1370.00	174.00	6.58	1.20	0.375	0.000100	30	2,000	0
Rio Magdalena & Canal del Dique	-	1400.00	622.00	2.03	1.11	1.050	0.000490	30	517	0
Rio Magdalena & Canal del Dique	-	1493.00	437.00	3.09	1.11	0.375	0.000130	30	147	0
Rio Magdalena & Canal del Dique	-	1529.00	415.00	4.06	0.91	0.310	0.000290	30	149	0
Rio Magdalena & Canal del Dique	-	1615.00	400.00	3.38	1.19	0.920	0.000170	30	381	0
Rio Magdalena & Canal del Dique	-	1665.00	400.00	3.05	1.36	0.920	0.000170	30	435	0
Rio Magdalena & Canal del Dique	-	1785.00	295.00	3.69	1.64	0.500	0.000240	30	591	0
Rio Magdalena & Canal del Dique	-	1900.00	605.00	2.28	1.38	1.050	0.000360	30	622	0
Rio Magdalena & Canal del Dique	-	1940.00	785.00	2.00	1.24	0.405	0.000480	30	318	0
Rio Magdalena & Canal del Dique	-	1954.00	451.00	3.53	1.23	0.375	0.000150	30	329	0
Rio Magdalena & Canal del Dique	-	1995.00	434.00	3.88	1.18	0.375	0.000150	30	152	0
Rio Magdalena & Canal del Dique	-	2270.00	620.00	3.42	1.07	1.050	0.000540	30	379	0
Rio Magdalena & Canal del Dique	-	2480.00	415.00	4.15	1.44	0.920	0.000170	30	386	0
Rio Magdalena & Canal del Dique	-	2630.00	785.00	2.80	1.20	0.405	0.000360	30	601	0
Rio Magdalena & Canal del Dique	-	2680.00	450.00	4.44	1.34	0.375	0.000200	30	723	0
Rio Magdalena & Canal del Dique	-	2710.00	610.00	3.94	1.13	1.050	0.000480	30	389	0
Rio Magdalena & Canal del Dique	-	2720.00	400.00	4.62	1.47	0.920	0.000130	30	705	0
Rio Magdalena & Canal del Dique	-	2820.00	410.00	6.35	1.08	0.310	0.000160	30	231	0
Rio Magdalena & Canal del Dique	-	2858.00	410.00	6.57	1.06	0.310	0.000160	30	190	0
Rio Magdalena & Canal del Dique	-	3050.00	460.00	4.78	1.39	0.320	0.000150	30	445	0
Rio Magdalena & Canal del Dique	-	3080.00	446.00	4.66	1.48	0.375	0.000200	30	499	0
Rio Magdalena & Canal del Dique	-	3085.00	415.00	4.69	1.59	0.920	0.000220	30	507	0
Rio Magdalena & Canal del Dique	-	3090.00	798.00	2.64	1.47	0.405	0.000620	30	517	0
Rio Magdalena & Canal del Dique	-	3650.00	570.00	8.82	0.73	0.210	0.000026	30	16	0
Rio Magdalena & Canal del Dique	-	3720.00	620.00	5.19	1.16	1.050	0.000410	30	313	0
Rio Magdalena & Canal del Dique	-	3850.00	405.00	6.94	1.37	0.310	0.000160	30	188	0
Rio Magdalena & Canal del Dique	-	3940.00	410.00	7.62	1.26	0.310	0.000190	30	308	0
Rio Magdalena & Canal del Dique	-	4800.00	565.00	9.29	0.91	0.210	0.000035	30	91	0
Rio Magdalena & Canal del Dique	-	10200.00	582.00	13.28	1.32	0.210	0.000062	30	330	0
River Data of Leopold	-	83.33	238.66	0.96	0.36	0.156	0.000090	12	517	0
River Data of Leopold	-	109.16	92.05	1.60	0.74	0.140	0.000277	9	260	0
River Data of Leopold	-	118.19	96.32	2.10	0.58	0.299	0.000113	13	11	0
River Data of Leopold	-	118.93	104.55	1.50	0.76	0.273	0.000333	12	95	0
River Data of Leopold	-	124.93	95.71	2.09	0.62	0.289	0.000107	13	52	0
River Data of Leopold	-	134.78	104.24	1.65	0.79	0.143	0.000260	12	140	0
River Data of Leopold	-	137.87	88.70	2.01	0.77	0.236	0.000196	14	64	0
River Data of Leopold	-	181.17	106.07	2.25	0.76	0.338	0.000177	22	269	0
River Data of Leopold	-	187.59	106.07	2.27	0.78	0.364	0.000173	24	207	0
River Data of Leopold	-	191.93	100.28	2.36	0.81	0.443	0.000140	11	130	0
River Data of Leopold	-	198.89	98.76	2.36	0.85	0.146	0.000277	9	192	0
River Data of Leopold	-	208.92	102.41	2.65	0.77	0.318	0.000267	17	275	0
River Data of Leopold	-	209.79	106.38	2.34	0.84	0.342	0.000227	22	151	0
River Data of Leopold	-	210.27	99.97	2.15	0.98	0.155	0.000067	9	373	0

1	2	3	4	5	6	7	8	9	10	11
River Data of Leopold	-	216.90	141.73	2.08	0.73	0.220	0.000100	12	98	0
River Data of Leopold	-	219.79	106.38	2.14	0.97	0.167	0.000190	14	117	0
River Data of Leopold	-	219.93	106.38	2.35	0.88	0.163	0.000216	17	151	0
River Data of Leopold	-	220.30	103.33	3.05	0.70	0.156	0.000213	9	153	0
River Data of Leopold	-	223.61	106.99	2.61	0.80	0.352	0.000173	20	76	0
River Data of Leopold	-	239.10	135.33	2.51	0.70	0.203	0.000127	23	270	0
River Data of Leopold	-	240.06	106.99	2.32	0.97	0.370	0.000187	22	77	0
River Data of Leopold	-	241.82	137.77	2.12	0.83	0.204	0.000346	20	152	0
River Data of Leopold	-	243.52	101.50	2.62	0.91	0.301	0.000177	18	379	0
River Data of Leopold	-	245.75	100.58	2.52	0.97	0.288	0.000110	18	115	0
River Data of Leopold	-	267.90	98.76	3.03	0.90	0.390	0.000053	26	72	0
River Data of Leopold	-	269.94	106.99	2.82	0.89	0.167	0.000224	19	94	0
River Data of Leopold	-	272.77	103.02	2.82	0.94	0.814	0.000103	15	168	0
River Data of Leopold	-	279.76	136.55	2.73	0.75	0.229	0.000153	27	142	0
River Data of Leopold	-	279.76	106.99	2.87	0.91	0.391	0.000147	27	119	0
River Data of Leopold	-	288.82	136.55	2.68	0.79	0.227	0.000066	24	147	0
River Data of Leopold	-	293.27	105.46	3.32	0.84	0.274	0.000193	13	470	0
River Data of Leopold	-	293.50	103.63	3.28	0.86	0.276	0.000153	21	113	0
River Data of Leopold	-	294.43	152.40	2.87	0.67	0.211	0.000100	20	86	0
River Data of Leopold	-	296.75	106.99	2.96	0.94	0.391	0.000233	26	50	0
River Data of Leopold	-	301.85	134.72	2.64	0.85	0.420	0.000147	22	214	0
River Data of Leopold	-	303.92	106.99	2.99	0.95	0.319	0.000207	15	245	0
River Data of Leopold	-	307.09	107.59	3.02	0.95	0.293	0.000216	26	159	0
River Data of Leopold	-	308.64	134.11	2.74	0.84	0.344	0.000120	18	63	0
River Data of Leopold	-	324.22	141.43	3.02	0.76	0.262	0.000166	17	233	0
River Data of Leopold	-	330.70	141.12	3.28	0.71	0.224	0.000069	19	146	0
River Data of Leopold	-	334.13	103.63	2.77	1.16	0.264	0.000283	19	114	0
River Data of Leopold	-	335.83	140.82	2.97	0.80	0.294	0.000060	26	206	0
River Data of Leopold	-	343.64	152.10	2.93	0.77	0.195	0.000144	20	280	0
River Data of Leopold	-	344.61	139.29	2.71	0.91	0.345	0.000113	21	110	0
River Data of Leopold	-	344.89	140.82	2.80	0.87	0.371	0.000160	23	93	0
River Data of Leopold	-	348.29	151.49	4.11	0.56	0.177	0.000037	17	49	0
River Data of Leopold	-	348.74	104.55	3.56	0.94	0.261	0.000196	23	110	0
River Data of Leopold	-	358.76	102.72	3.61	0.97	0.249	0.000220	18	244	0
River Data of Leopold	-	362.44	111.25	2.98	1.09	0.356	0.000187	13	71	0
River Data of Leopold	-	362.98	109.73	3.31	1.00	0.389	0.000127	16	169	0
River Data of Leopold	-	403.56	248.72	2.34	0.69	0.308	0.000140	19	48	0
River Data of Leopold	-	408.37	106.68	3.04	1.26	0.318	0.000290	18	277	0
River Data of Leopold	-	413.41	141.12	3.54	0.83	0.244	0.000177	17	90	0
River Data of Leopold	-	454.30	153.62	3.47	0.85	0.172	0.000170	17	208	0
River Data of Leopold	-	499.30	250.55	2.23	0.89	0.321	0.000180	19	564	0
Saskatchewan & Elbow River	-	4.71	3.05	0.73	2.11	29.122	0.007450	18	247	0
Saskatchewan & Elbow River	-	4.71	3.05	0.73	2.11	34.928	0.007450	18	384	0
Saskatchewan & Elbow River	-	4.91	3.05	0.82	1.96	14.086	0.007450	13	126	0
Saskatchewan & Elbow River	-	4.95	3.05	0.79	2.05	57.506	0.007450	18	35	0
Saskatchewan & Elbow River	-	5.25	3.05	0.76	2.26	33.096	0.007450	18	132	0
Saskatchewan & Elbow River	-	5.25	3.05	0.73	2.36	31.008	0.007450	13	760	0
Saskatchewan & Elbow River	-	5.34	3.05	0.85	2.05	30.488	0.007450	18	253	0
Saskatchewan & Elbow River	-	5.69	3.05	0.79	2.36	25.548	0.007450	13	514	0
Saskatchewan & Elbow River	-	5.71	3.05	0.88	2.12	41.227	0.007450	18	87	0
Saskatchewan & Elbow River	-	5.83	3.05	0.79	2.41	49.395	0.007450	13	222	0
Saskatchewan & Elbow River	-	5.97	3.05	0.79	2.47	54.890	0.007450	13	488	0
Saskatchewan & Elbow River	-	6.01	3.05	0.88	2.23	45.102	0.007450	18	644	0
Saskatchewan & Elbow River	-	6.87	3.05	1.01	2.24	27.401	0.007450	18	214	0
Saskatchewan & Elbow River	-	6.88	3.05	0.82	2.74	38.057	0.007450	13	470	0
Saskatchewan & Elbow River	-	6.88	3.05	0.82	2.74	41.335	0.007450	13	64	0
Saskatchewan & Elbow River	-	7.05	3.05	0.79	2.92	57.636	0.007450	13	26	0
Saskatchewan & Elbow River	-	7.35	3.05	0.85	2.83	44.176	0.007450	13	315	0
Saskatchewan & Elbow River	-	9.99	3.05	1.16	2.83	76.113	0.007450	18	505	0
Saskatchewan & Elbow River	-	10.49	3.05	1.19	2.90	50.916	0.007450	13	524	0
Saskatchewan & Elbow River	-	10.80	3.05	1.07	3.32	50.916	0.007450	13	253	0
Saskatchewan & Elbow River	-	11.62	3.05	1.37	2.78	31.164	0.007450	13	546	0
Saskatchewan & Elbow River	-	19.58	6.10	1.55	2.07	22.558	0.001580	13	25	0
Saskatchewan & Elbow River	-	19.88	6.10	1.83	1.78	20.547	0.001580	18	49	0
Saskatchewan & Elbow River	-	22.14	6.10	1.77	2.05	20.188	0.001580	17	17	0

1	2	3	4	5	6	7	8	9	10	11
Saskatchewan & Elbow River	-	24.07	6.10	2.01	1.96	28 307	0.001580	13	122	0
Saskatchewan & Elbow River	-	24.10	6.10	1.71	2.32	31 980	0.001580	13	161	0
Saskatchewan & Elbow River	-	24.16	6.10	1.80	2.20	30 701	0.001580	17	25	0
Saskatchewan & Elbow River	-	24.16	6.10	1.80	2.20	31 916	0.001580	17	20	0
Saskatchewan & Elbow River	-	24.29	6.10	2.16	1.84	13 606	0.001580	18	7	0
Saskatchewan & Elbow River	-	25.16	6.10	2.04	2.02	40 296	0.001580	17	10	0
Saskatchewan & Elbow River	-	26.03	6.10	1.83	2.33	22 001	0.001580	18	48	0
Saskatchewan & Elbow River	-	26.03	6.10	1.83	2.33	24 101	0.001580	18	47	0
Saskatchewan & Elbow River	-	26.03	6.10	1.83	2.33	22 301	0.001580	18	66	0
Saskatchewan & Elbow River	-	26.47	6.10	1.83	2.37	32 530	0.001580	17	41	0
Saskatchewan & Elbow River	-	26.47	6.10	1.83	2.37	29 101	0.001580	17	53	0
Saskatchewan & Elbow River	-	26.54	6.10	1.92	2.27	45 165	0.001580	17	4	0
Saskatchewan & Elbow River	-	26.90	6.10	2.04	2.16	24 644	0.001580	13	32	0
Saskatchewan & Elbow River	-	26.98	6.10	1.98	2.23	18 639	0.001580	17	26	0
Saskatchewan & Elbow River	-	27.91	6.10	1.95	2.35	24 325	0.001580	18	27	0
Saskatchewan & Elbow River	-	29.30	6.10	2.01	2.39	28 132	0.001580	17	14	0
Saskatchewan & Elbow River	-	29.38	6.10	2.01	2.40	30 826	0.001580	18	19	0
Saskatchewan & Elbow River	-	29.55	6.10	2.38	2.04	19 309	0.001580	18	23	0
Saskatchewan & Elbow River	-	30.03	6.10	2.29	2.15	13 993	0.001580	18	19	0
Saskatchewan & Elbow River	-	30.50	6.10	2.07	2.41	24 373	0.001580	18	46	0
Saskatchewan & Elbow River	-	31.08	6.10	2.13	2.39	37 223	0.001580	17	26	0
Saskatchewan & Elbow River	-	31.60	6.10	2.47	2.10	23 807	0.001580	18	15	0
Saskatchewan & Elbow River	-	31.68	6.10	2.26	2.30	21 540	0.001580	17	22	0
Saskatchewan & Elbow River	-	33.11	6.10	2.19	2.47	17 600	0.001580	18	82	0
Saskatchewan & Elbow River	-	34.41	6.10	2.50	2.26	19 593	0.001580	18	7	0
Saskatchewan & Elbow River	-	34.64	6.10	2.53	2.25	24 377	0.001580	18	12	0
Saskatchewan & Elbow River	-	36.43	6.10	2.53	2.36	27 445	0.001580	18	25	0
Saskatchewan & Elbow River	-	36.47	6.10	2.44	2.45	22 727	0.001580	18	21	0
Saskatchewan & Elbow River	-	36.90	6.10	2.53	2.39	31 515	0.001580	18	7	0
Saskatchewan & Elbow River	-	39.14	6.10	2.74	2.34	29 186	0.001580	18	13	0
Saskatchewan & Elbow River	-	39.14	6.10	2.74	2.34	34 141	0.001580	18	13	0
Snake & Clearwater River	-	971.24	137.16	4.21	1.68	0 420	0.000245	6	5	0
Snake & Clearwater River	-	1149.63	138.68	4.45	1.86	0 470	0.000280	6	10	0
Snake & Clearwater River	-	1353.50	140.21	4.69	2.06	0 480	0.000318	9	4	0
Snake & Clearwater River	-	1353.50	140.21	4.69	2.06	0 480	0.000318	9	4	0
Snake & Clearwater River	-	1543.22	141.73	4.02	2.71	0 590	0.000353	7	10	0
Snake & Clearwater River	-	1551.72	141.73	4.94	2.22	0 950	0.000354	12	17	0
Snake & Clearwater River	-	1574.37	142.04	5.00	2.22	0 590	0.000360	11	21	0
Snake & Clearwater River	-	1619.67	142.04	5.06	2.25	0 580	0.000367	11	16	0
Snake & Clearwater River	-	1812.22	142.95	5.21	2.43	0 400	0.000405	10	23	0
Snake & Clearwater River	-	1832.04	176.78	4.36	2.38	0 520	0.000870	8	10	0
Snake & Clearwater River	-	2059.92	190.50	5.27	2.05	0 560	0.001090	15	8	0
Snake & Clearwater River	-	2293.60	145.39	5.67	2.78	0 760	0.000490	10	25	0
Snake & Clearwater River	-	2811.78	188.98	5.21	2.85	0 540	0.001080	11	12	0
Snake & Clearwater River	-	2944.86	192.02	5.33	2.88	0 880	0.001100	15	11	0
Snake & Clearwater River	-	3114.80	193.55	5.49	2.93	0 560	0.001130	13	14	0
Snake & Clearwater River	-	3143.08	193.55	5.55	2.93	0 610	0.001140	13	13	0
Snake & Clearwater River	-	3511.18	198.12	5.91	3.00	0 640	0.001210	12	4	0
Susitna River	10/04/83	796	186	2.4	1.8	34 000	0.0014	2	189	0
Susitna River	07/26/82	2770	308	4.4	2.1	35 000	0.0024	9.5	1,462	0
Toutle River	03/23/85	101.45	61	0.77	1.7	0 595	0.0024	8.5	7,405	0
Toutle River	04/02/85	83.5	61	0.76	1.8	0 700	0.0024	10.5	3,865	0
Toutle River	02/16/86	171	66	1.2	2.2	0 800	0.0029	4.5	4,634	0
Toutle River	04/11/85	93.35	63	0.76	1.9	0 845	0.0026	11	8,506	0
Toutle River	01/28/87	130	64	1.1	1.9	0 950	0.0019	7.5	5,194	0
Toutle River	11/21/86	190	66	1.2	2.3	1 500	0.0027	9.5	8,269	0
Toutle River	11/22/86	253.5	67	1.5	2.7	3 000	0.0028	9.5	7,463	0
Toutle River	06/07/85	250.5	69	1.5	2.5	4 000	0.0055	12	23,007	0
Toutle River	02/11/86	43.2	24.5	1	1.7	4 750	0.002	4	1,721	0
Trinity River	-	39.64	30.18	0.85	4.36	3 400	0.003000	8	243	0
Trinity River	-	82.12	53.95	1.12	5.55	4 700	0.002600	7	250	0
Trinity River	-	82.68	31.70	1.20	5.21	4,200	0.002800	8	675	0
West Pakistan (Chop) Canal	-	27.52	23.77	1.68	0.69	0 200	0.000086	29	286	0
West Pakistan (Chop) Canal	-	109.58	57.91	2.68	0.71	0 110	0.000080	24	146	0
West Pakistan (Chop) Canal	-	112.41	57.30	2.32	0.85	0 200	0.000134	24	595	0

1	2	3	4	5	6	7	8	9	10	11
West Pakistan (Chop) Canal	-	114.96	57.91	2.35	0.85	0.300	0.000140	17	236	0
West Pakistan (Chop) Canal	-	120.91	55.47	2.44	0.89	0.100	0.000200	20	181	0
West Pakistan (Chop) Canal	-	122.04	53.65	2.38	0.96	0.300	0.000185	11	302	0
West Pakistan (Chop) Canal	-	138.47	66.14	2.29	0.92	0.300	0.000165	15	395	0
West Pakistan (Chop) Canal	-	138.47	59.44	2.38	0.98	0.300	0.000179	11	150	0
West Pakistan (Chop) Canal	-	139.03	57.91	2.44	0.98	0.311	0.000176	22	198	0
West Pakistan (Chop) Canal	-	143.85	63.40	2.47	0.92	0.300	0.000238	23	197	0
West Pakistan (Chop) Canal	-	146.11	55.78	2.62	1.00	0.290	0.000182	27	244	0
West Pakistan (Chop) Canal	-	146.68	67.67	2.68	0.81	0.120	0.000232	24	473	0
West Pakistan (Chop) Canal	-	153.47	58.52	2.71	0.97	0.290	0.000165	24	261	0
West Pakistan (Chop) Canal	-	166.75	67.67	2.56	0.96	0.190	0.000051	27	116	0
West Pakistan (Chop) Canal	-	172.44	112.78	1.31	1.17	0.090	0.000194	16	232	0
West Pakistan (Chop) Canal	-	209.26	71.63	3.32	0.88	0.210	0.000127	22	484	0
West Pakistan (Chop) Canal	-	226.53	109.42	2.29	0.91	0.311	0.000185	19	388	0
West Pakistan (Chop) Canal	-	233.61	118.26	2.47	0.80	0.110	0.000214	15	148	0
West Pakistan (Chop) Canal	-	255.41	112.17	2.56	0.89	0.290	0.000207	12	305	0
West Pakistan (Chop) Canal	-	322.80	120.40	2.68	1.00	0.200	0.000196	22	526	0
West Pakistan (Chop) Canal	-	328.47	97.54	3.32	1.01	0.210	0.000188	19	432	0
West Pakistan (Chop) Canal	-	334.13	110.34	2.47	1.23	0.210	0.000159	20	428	0
West Pakistan (Chop) Canal	-	342.62	116.74	3.11	0.94	0.210	0.000254	22	620	0
West Pakistan (Chop) Canal	-	351.12	112.17	2.13	1.47	0.130	0.000124	18	706	0
West Pakistan (Chop) Canal	-	359.61	111.25	2.10	1.54	0.120	0.000116	23	531	0
West Pakistan (Chop) Canal	-	362.44	99.06	3.08	1.19	0.120	0.000118	29	464	0
West Pakistan (Chop) Canal	-	362.44	118.26	2.99	1.03	0.200	0.000161	18	663	0
West Pakistan (Chop) Canal	-	376.60	115.82	2.35	1.39	0.210	0.000141	21	702	0
West Pakistan (Chop) Canal	-	393.59	99.67	3.38	1.17	0.200	0.000181	17	299	0
West Pakistan (Chop) Canal	-	399.26	112.78	3.41	1.04	0.311	0.000178	17	1,317	0
West Pakistan (Chop) Canal	-	413.41	110.64	2.44	1.53	0.200	0.000115	18	1,297	0
West Pakistan (Chop) Canal	-	424.74	111.86	2.38	1.60	0.140	0.000155	19	1,153	0
West Pakistan (Chop) Canal	-	427.57	121.62	3.17	1.11	0.210	0.000202	16	1,217	0
Wisconsin River	05/08/78	195	299	1.2	0.5	0.400	0.00033	13.5	56	0
Wisconsin River	07/11/78	714	310	2.6	0.9	0.400	0.00037	22	49	0
Wisconsin River	06/06/78	368	306	1.6	0.8	0.425	0.00035	22.5	50	0
Wisconsin River	10/18/77	289	302	1.3	0.7	0.430	0.00031	10	83	0
Wisconsin River	04/17/78	456	309	2	0.8	0.430	0.00031	9	22	0
Wisconsin River	08/15/78	145	292	1	0.5	0.430	0.00029	26	75	0
Wisconsin River	03/24/77	149	283	0.88	0.6	0.440	0.00032	7.5	110	0
Wisconsin River	08/24/77	86.9	219	0.85	0.5	0.440	0.00028	22	29	0
Wisconsin River	05/16/77	118	278	0.82	0.5	0.490	0.00041	25	27	0
Yampa River	06/10/83	425	91	3.5	1.3	0.450	0.00073	13	832	0
Yampa River	05/23/83	244	92	2.4	1.1	0.460	0.0006	14.5	1,524	0
Yampa River	05/26/83	430	92	3.6	1.3	0.460	0.00087	14.5	2,342	0
Yampa River	06/08/83	408	92	3.4	1.3	0.460	0.00067	11.5	1,049	0
Yampa River	04/22/83	108	90	1.5	0.8	0.510	0.00047	9.5	2,649	0
Yampa River	06/21/83	447	9.1	3.7	1.3	0.570	0.00065	16.5	662	0
Yampa River	05/27/83	447	92	3.9	1.3	0.590	0.00078	14	2,080	0
Yampa River	04/07/83	26.3	69	0.65	0.6	0.620	0.00072	5.5	599	0
Yampa River	05/07/83	185	91	1.8	1.1	0.660	0.00071	5	1,465	0
Yampa River	07/12/83	203	92	2.1	1.0	0.660	0.0004	20	602	0
Yampa River	05/12/83	337	93	2.9	1.2	0.700	0.00085	9.5	2,933	0

Yangtze River 40 sets of data can be found in Hydrau-Tech, Inc., 1998

Yellow River 1112 sets of data can be found in Hydrau-Tech, Inc., 1998

APPENDIX B. DETAILS OF LABORATORY DATA

(14 pages)

<i>Data Source</i>	<i>Date of measurement</i>	<i>Water Discharge</i> m^3/s	<i>Channel width</i> m	<i>Flow Depth</i> m	<i>Flow velocity</i> m/s	<i>Mean bed diameter</i> d_s mm	<i>W/S Slope</i> S_w m/m	<i>Water temp</i> $^{\circ}C$	<i>Transported Sediment Concent.</i> ppm	<i>Bed Form</i>
1	2	3	4	5	6	7	8	9	10	11
<i>Barton 1m</i>	-	0.126	1.219	0.238	0.435	0.18	0.000880	14.3	551	3
<i>Barton 1m</i>	-	0.085	1.219	0.171	0.408	0.18	0.000860	23.3	27	3
<i>Barton 1m</i>	-	0.099	1.219	0.192	0.423	0.18	0.000866	20.4	480	3
<i>Barton 1m</i>	-	0.113	1.219	0.210	0.442	0.18	0.000880	17.9	544	3
<i>Barton 1m</i>	-	0.156	1.219	0.256	0.499	0.18	0.000880	22.9	629	3
<i>Barton 1m</i>	-	0.088	1.219	0.198	0.363	0.18	0.000810	21.3	233	3
<i>Barton 1m</i>	-	0.057	1.219	0.155	0.299	0.18	0.000880	19.0	256	3
<i>Barton 1m</i>	-	0.042	1.219	0.140	0.249	0.18	0.000870	20.3	65	3
<i>Barton 1m</i>	-	0.056	1.219	0.201	0.226	0.18	0.000440	22.3	19	3
<i>Barton 1m</i>	-	0.043	1.219	0.165	0.216	0.18	0.000450	22.4	279	3
<i>Barton 1m</i>	-	0.076	1.219	0.137	0.457	0.18	0.001500	20.8	1,221	3
<i>Barton 1m</i>	-	0.054	1.219	0.122	0.362	0.18	0.001580	21.6	573	3
<i>Barton 1m</i>	-	0.038	1.219	0.110	0.284	0.18	0.001610	19.3	304	3
<i>Barton 1m</i>	-	0.025	1.219	0.091	0.229	0.18	0.001600	22.9	112	3
<i>Barton 1m</i>	-	0.059	1.219	0.122	0.400	0.18	0.001350	24.3	1,006	3
<i>Barton 1m</i>	-	0.075	1.219	0.146	0.419	0.18	0.001160	23.4	904	3
<i>Barton 1m</i>	-	0.118	1.219	0.223	0.433	0.18	0.000820	26.0	559	3
<i>Barton 1m</i>	-	0.204	1.219	0.314	0.533	0.18	0.000610	26.5	560	3
<i>Barton 1m</i>	-	0.251	1.219	0.421	0.489	0.18	0.000650	25.4	333	3
<i>Barton 1m</i>	-	0.210	1.219	0.210	0.817	0.18	0.001560	22.8	1,939	5
<i>Barton 1m</i>	-	0.255	1.219	0.229	0.915	0.18	0.001670	21.8	1,826	5
<i>Barton 1m</i>	-	0.190	1.219	0.186	0.837	0.18	0.001660	22.5	1,922	5
<i>Barton 1m</i>	-	0.258	1.219	0.232	0.912	0.18	0.001700	20.2	1,741	5
<i>Barton 1m</i>	-	0.210	1.219	0.198	0.868	0.18	0.001830	26.2	1,704	5
<i>Barton 1m</i>	-	0.229	1.219	0.238	0.791	0.18	0.001240	24.6	1,606	5
<i>Barton 1m</i>	-	0.201	1.219	0.210	0.784	0.18	0.001250	24.7	1,409	5
<i>Barton 1m</i>	-	0.164	1.219	0.183	0.737	0.18	0.001210	25.3	1,060	5
<i>Barton 1m</i>	-	0.119	1.219	0.125	0.781	0.18	0.001290	26.4	1,638	5
<i>Barton 1m</i>	-	0.204	1.219	0.171	0.980	0.18	0.001600	25.7	2,472	5
<i>Barton 1m</i>	-	0.215	1.219	0.162	1.093	0.18	0.002100	26.1	3,764	5
<i>Brooks 1957</i>	-	0.008	0.267	0.075	0.405	0.145	0.002600	27.5	1,099	3
<i>Brooks 1957</i>	-	0.006	0.267	0.076	0.279	0.145	0.002000	24.0	200	3
<i>Brooks 1957</i>	-	0.010	0.267	0.091	0.430	0.145	0.002200	26.0	720	3
<i>Brooks 1957</i>	-	0.006	0.267	0.060	0.380	0.145	0.003500	26.5	1,199	3
<i>Brooks 1957</i>	-	0.008	0.267	0.069	0.409	0.088	0.002800	25.0	3,990	3
<i>Brooks 1957</i>	-	0.006	0.267	0.057	0.373	0.088	0.003300	25.0	5,283	3
<i>Brooks 1957</i>	-	0.006	0.267	0.085	0.250	0.088	0.001300	25.0	190	3
<i>Brooks 1957</i>	-	0.006	0.267	0.070	0.302	0.088	0.002350	25.0	1,349	3
<i>Brooks 1957</i>	-	0.009	0.267	0.087	0.405	0.088	0.002400	25.0	3,592	3
<i>Brooks 1957</i>	-	0.008	0.267	0.086	0.329	0.088	0.002150	25.0	1,748	3
<i>Brooks 1957</i>	-	0.008	0.267	0.055	0.542	0.145	0.003100	26.0	1,898	4
<i>Brooks 1957</i>	-	0.011	0.267	0.073	0.544	0.145	0.002300	27.5	1,499	4
<i>Brooks 1957</i>	-	0.006	0.267	0.047	0.461	0.145	0.003300	26.0	2,696	4
<i>Brooks 1957</i>	-	0.012	0.267	0.074	0.624	0.145	0.002500	22.0	1,948	5
<i>Brooks 1957</i>	-	0.012	0.267	0.072	0.635	0.145	0.002400	12.5	2,446	5
<i>Brooks 1957</i>	-	0.010	0.267	0.059	0.616	0.145	0.002400	21.0	2,446	5
<i>Brooks 1957</i>	-	0.012	0.267	0.074	0.624	0.145	0.002100	31.5	2,147	5
<i>Brooks 1957</i>	-	0.012	0.267	0.072	0.642	0.088	0.002250	25.0	4,835	5
<i>Brooks 1957</i>	-	0.012	0.267	0.072	0.642	0.088	0.002200	25.0	4,885	5
<i>Brooks 1957</i>	-	0.009	0.267	0.058	0.599	0.088	0.002450	25.0	5,084	5
<i>Brooks 1957</i>	-	0.015	0.267	0.085	0.647	0.088	0.001850	25.0	3,443	5
<i>Franco 1968</i>	-	0.053	0.914	0.159	0.365	0.23	0.001196	4.4	40	2
<i>Franco 1968</i>	-	0.053	0.914	0.161	0.361	0.23	0.001109	4.4	40	2

1	2	3	4	5	6	7	8	9	10	11
Franco 1968	-	0.053	0.914	0.159	0.363	0.23	0.001090	15.6	40	2
Franco 1968	-	0.053	0.914	0.159	0.365	0.23	0.000938	26.7	40	2
Franco 1968	-	0.053	0.914	0.147	0.394	0.23	0.001497	4.4	95	2
Franco 1968	-	0.053	0.914	0.144	0.403	0.23	0.001322	15.6	95	2
Franco 1968	-	0.053	0.914	0.141	0.412	0.23	0.001175	26.7	95	2
Franco 1968	-	0.053	0.914	0.139	0.417	0.23	0.001693	4.4	166	2
Franco 1968	-	0.053	0.914	0.135	0.429	0.23	0.001527	15.6	166	2
Franco 1968	-	0.053	0.914	0.134	0.434	0.23	0.001258	26.7	166	2
Franco 1968	-	0.053	0.914	0.129	0.450	0.23	0.001308	26.7	166	2
Franco 1968	-	0.036	0.914	0.141	0.280	2.2	0.000308	4.4	58	5
Franco 1968	-	0.036	0.914	0.142	0.278	2.2	0.000342	26.7	58	5
Franco 1968	-	0.036	0.914	0.134	0.293	2.2	0.000341	4.4	101	5
Franco 1968	-	0.036	0.914	0.135	0.291	2.2	0.000444	26.7	101	5
Franco 1968	-	0.036	0.914	0.150	0.263	2.2	0.000241	4.4	24	5
Franco 1968	-	0.036	0.914	0.146	0.270	2.2	0.000230	26.7	24	5
Franco 1968	-	0.036	0.914	0.131	0.301	2.2	0.000481	4.4	193	5
Franco 1968	-	0.036	0.914	0.126	0.313	2.2	0.000604	26.7	193	5
Guy Simons Richardson	-	0.189	2.438	0.323	0.240	0.1999488	0.000150	12.3	0	2
Guy Simons Richardson	-	0.183	2.438	0.283	0.264	0.1868424	0.000180	19.2	0	2
Guy Simons Richardson	-	0.252	2.438	0.305	0.339	0.1908048	0.000280	17.0	4	2
Guy Simons Richardson	-	0.097	2.438	0.177	0.225	0.1959864	0.000340	13.6	1	2
Guy Simons Richardson	-	0.301	2.438	0.311	0.397	0.1898904	0.000430	18.1	29	2
Guy Simons Richardson	-	0.116	2.438	0.168	0.283	0.1898904	0.000570	18.1	4	2
Guy Simons Richardson	-	0.359	2.438	0.314	0.469	0.195072	0.000580	16.4	120	2
Guy Simons Richardson	-	0.085	2.438	0.134	0.259	0.1819656	0.000620	18.1	2	2
Guy Simons Richardson	-	0.127	2.438	0.165	0.317	0.1898904	0.000790	18.0	34	2
Guy Simons Richardson	-	0.144	2.438	0.171	0.346	0.1959864	0.000840	19.1	58	2
Guy Simons Richardson	-	0.147	2.438	0.168	0.360	0.2008632	0.000920	12.3	84	2
Guy Simons Richardson	-	0.172	2.438	0.277	0.255	0.2609088	0.000180	15.8	1	2
Guy Simons Richardson	-	0.279	2.438	0.302	0.380	0.2709672	0.000460	16.0	12	2
Guy Simons Richardson	-	0.347	2.438	0.287	0.497	0.249936	0.000650	16.0	98	2
Guy Simons Richardson	-	0.145	2.438	0.146	0.406	0.2898648	0.001260	13.9	93	2
Guy Simons Richardson	-	0.220	2.438	0.308	0.293	0.300228	0.000230	10.9	3	2
Guy Simons Richardson	-	0.118	2.438	0.180	0.269	0.2639568	0.000410	15.1	1	2
Guy Simons Richardson	-	0.304	2.438	0.305	0.409	0.300228	0.000450	16.5	12	2
Guy Simons Richardson	-	0.381	2.438	0.305	0.513	0.2892552	0.000630	16.4	75	2
Guy Simons Richardson	-	0.304	2.438	0.262	0.475	0.2749296	0.000690	14.6	31	2
Guy Simons Richardson	-	0.139	2.438	0.180	0.318	0.2898648	0.000730	14.9	20	2
Guy Simons Richardson	-	0.204	2.438	0.174	0.481	0.2700528	0.001080	16.0	150	2
Guy Simons Richardson	-	0.144	2.438	0.244	0.241	0.438912	0.000230	11.0	1	2
Guy Simons Richardson	-	0.224	2.438	0.250	0.367	0.41148	0.000360	11.0	9	2
Guy Simons Richardson	-	0.224	2.438	0.259	0.354	0.451104	0.000390	11.5	10	2
Guy Simons Richardson	-	0.109	2.438	0.168	0.266	0.469392	0.000400	12.0	1	2
Guy Simons Richardson	-	0.222	2.438	0.244	0.374	0.438912	0.000420	9.0	23	2
Guy Simons Richardson	-	0.225	2.438	0.229	0.403	0.463296	0.000470	11.0	27	2
Guy Simons Richardson	-	0.055	2.438	0.107	0.212	0.445008	0.000490	11.5	5	2
Guy Simons Richardson	-	0.108	2.438	0.155	0.286	0.423672	0.000600	12.0	8	2
Guy Simons Richardson	-	0.110	2.438	0.140	0.323	0.499872	0.000880	9.5	42	2
Guy Simons Richardson	-	0.055	2.438	0.101	0.225	0.469392	0.000880	10.5	16	2
Guy Simons Richardson	-	0.055	2.438	0.088	0.256	0.469392	0.001060	11.7	1	2
Guy Simons Richardson	-	0.197	2.438	0.229	0.354	0.4636008	0.000460	19.1	2	2
Guy Simons Richardson	-	0.196	2.438	0.232	0.347	0.4379976	0.000460	17.0	2	2
Guy Simons Richardson	-	0.201	2.438	0.238	0.347	0.4578096	0.000470	12.7	6	2
Guy Simons Richardson	-	0.201	2.438	0.226	0.366	0.499872	0.000490	18.3	3	2
Guy Simons Richardson	-	0.197	2.438	0.183	0.443	0.413004	0.000530	17.1	37	2
Guy Simons Richardson	-	0.201	2.438	0.183	0.450	0.4599432	0.000650	18.5	31	2
Guy Simons Richardson	-	0.037	0.610	0.165	0.370	0.260292	0.000860	27.8	61	2
Guy Simons Richardson	-	0.044	0.610	0.174	0.417	0.3112008	0.001100	14.5	91	2
Guy Simons Richardson	-	0.028	0.610	0.152	0.305	0.3197352	0.000870	20.0	-	2
Guy Simons Richardson	-	0.032	0.610	0.149	0.348	0.32766	0.000880	20.0	47	2
Guy Simons Richardson	-	0.030	0.610	0.152	0.320	0.309372	0.000290	20.5	4	2
Guy Simons Richardson	-	0.030	0.610	0.155	0.317	0.28956	0.000470	22.5	12	2
Guy Simons Richardson	-	0.041	0.610	0.158	0.428	0.33528	0.000630	22.6	85	2
Guy Simons Richardson	-	0.034	0.610	0.189	0.297	0.483108	0.000260	16.9	1	2
Guy Simons Richardson	-	0.045	0.610	0.180	0.411	0.4651248	0.000380	18.0	17	2

1	2	3	4	5	6	7	8	9	10	11
Guy Simons Richardson	-	0.386	2.438	0.290	0.547	0.1978152	0.000660	18.2	281	3
Guy Simons Richardson	-	0.419	2.438	0.283	0.607	0.192024	0.000700	18.3	319	3
Guy Simons Richardson	-	0.472	2.438	0.323	0.599	0.1999488	0.000830	17.4	836	3
Guy Simons Richardson	-	0.580	2.438	0.332	0.716	0.1776984	0.000990	18.9	1300	3
Guy Simons Richardson	-	0.198	2.438	0.158	0.513	0.1990344	0.001270	16.6	503	3
Guy Simons Richardson	-	0.622	2.438	0.311	0.820	0.1807464	0.001300	19.7	1270	3
Guy Simons Richardson	-	0.231	2.438	0.186	0.508	0.188976	0.001300	15.3	861	3
Guy Simons Richardson	-	0.274	2.438	0.207	0.541	0.1871472	0.001400	18.0	1240	3
Guy Simons Richardson	-	0.213	2.438	0.158	0.551	0.1999488	0.001470	18.5	999	3
Guy Simons Richardson	-	0.233	2.438	0.149	0.639	0.1898904	0.001940	18.6	1210	3
Guy Simons Richardson	-	0.386	2.438	0.283	0.558	0.284988	0.000840	18.3	200	3
Guy Simons Richardson	-	0.441	2.438	0.311	0.582	0.2749296	0.001080	16.9	358	3
Guy Simons Richardson	-	0.314	2.438	0.229	0.563	0.2508504	0.001260	15.3	550	3
Guy Simons Richardson	-	0.504	2.438	0.329	0.628	0.2700528	0.001300	18.1	639	3
Guy Simons Richardson	-	0.545	2.438	0.344	0.648	0.2779776	0.001400	17.4	931	3
Guy Simons Richardson	-	0.610	2.438	0.314	0.797	0.2609088	0.001630	16.8	833	3
Guy Simons Richardson	-	0.444	2.438	0.287	0.636	0.2551176	0.001670	14.8	704	3
Guy Simons Richardson	-	0.191	2.438	0.140	0.559	0.2749296	0.001850	14.2	753	3
Guy Simons Richardson	-	0.446	2.438	0.323	0.566	0.2599944	0.000900	17.6	330	3
Guy Simons Richardson	-	0.360	2.438	0.268	0.550	0.3243072	0.001000	16.7	405	3
Guy Simons Richardson	-	0.244	2.438	0.189	0.529	0.2599944	0.001160	15.6	298	3
Guy Simons Richardson	-	0.514	2.438	0.320	0.658	0.2828544	0.001200	15.6	506	3
Guy Simons Richardson	-	0.430	2.438	0.280	0.629	0.2798064	0.001310	15.8	664	3
Guy Simons Richardson	-	0.577	2.438	0.326	0.726	0.2639568	0.001310	16.5	732	3
Guy Simons Richardson	-	0.280	2.438	0.198	0.580	0.265176	0.001340	14.9	563	3
Guy Simons Richardson	-	0.488	2.438	0.311	0.644	0.249936	0.001340	15.8	549	3
Guy Simons Richardson	-	0.283	2.438	0.198	0.587	0.2718816	0.001360	14.7	505	3
Guy Simons Richardson	-	0.433	2.438	0.268	0.662	0.2569464	0.001360	15.2	733	3
Guy Simons Richardson	-	0.339	2.438	0.186	0.747	0.2481072	0.001410	14.7	1040	3
Guy Simons Richardson	-	0.156	2.438	0.134	0.476	0.2898648	0.001500	14.1	480	3
Guy Simons Richardson	-	0.364	2.438	0.229	0.654	0.2551176	0.001580	13.0	789	3
Guy Simons Richardson	-	0.225	2.438	0.210	0.438	0.460248	0.000570	10.0	92	3
Guy Simons Richardson	-	0.226	2.438	0.213	0.434	0.445008	0.000780	11.5	268	3
Guy Simons Richardson	-	0.120	2.438	0.125	0.394	0.4785336	0.001120	18.0	208	3
Guy Simons Richardson	-	0.343	2.438	0.293	0.481	0.414528	0.001140	16.0	380	3
Guy Simons Richardson	-	0.383	2.438	0.305	0.516	0.381	0.001240	15.7	554	3
Guy Simons Richardson	-	0.139	2.438	0.128	0.445	0.4572	0.001890	17.0	378	3
Guy Simons Richardson	-	0.231	2.438	0.186	0.508	0.490728	0.001930	16.4	508	3
Guy Simons Richardson	-	0.378	2.438	0.198	0.782	0.42672	0.002470	16.0	856	3
Guy Simons Richardson	-	0.247	2.438	0.189	0.537	0.374904	0.002890	17.0	917	3
Guy Simons Richardson	-	0.606	2.438	0.247	1.007	0.429768	0.003010	19.0	2460	3
Guy Simons Richardson	-	0.129	2.438	0.091	0.577	0.451104	0.003690	17.4	1850	3
Guy Simons Richardson	-	0.204	2.438	0.189	0.443	0.5309616	0.000720	14.7	99	3
Guy Simons Richardson	-	0.202	2.438	0.192	0.432	0.4934712	0.000900	18.5	106	3
Guy Simons Richardson	-	0.202	2.438	0.177	0.468	0.490728	0.001170	18.0	195	3
Guy Simons Richardson	-	0.436	2.438	0.244	0.733	0.5398008	0.001800	18.7	1640	3
Guy Simons Richardson	-	0.248	2.438	0.198	0.514	0.4818888	0.001990	19.1	639	3
Guy Simons Richardson	-	0.441	2.438	0.277	0.652	0.4977384	0.002000	16.2	588	3
Guy Simons Richardson	-	0.235	2.438	0.162	0.597	0.4840224	0.002010	18.6	761	3
Guy Simons Richardson	-	0.240	2.438	0.192	0.514	0.4437888	0.002030	20.0	463	3
Guy Simons Richardson	-	0.233	2.438	0.195	0.491	0.4398264	0.002040	21.2	625	3
Guy Simons Richardson	-	0.232	2.438	0.198	0.480	0.4959096	0.002150	21.0	534	3
Guy Simons Richardson	-	0.227	2.438	0.168	0.555	0.4319016	0.002220	16.0	578	3
Guy Simons Richardson	-	0.232	2.438	0.186	0.512	0.477012	0.002220	20.7	662	3
Guy Simons Richardson	-	0.433	2.438	0.274	0.647	0.467868	0.002330	20.1	807	3
Guy Simons Richardson	-	0.227	2.438	0.174	0.535	0.4767072	0.002350	17.2	571	3
Guy Simons Richardson	-	0.435	2.438	0.287	0.623	0.5157216	0.002370	18.5	765	3
Guy Simons Richardson	-	0.320	2.438	0.247	0.532	0.4949952	0.002370	13.5	480	3
Guy Simons Richardson	-	0.435	2.438	0.280	0.636	0.4477312	0.002400	16.6	657	3
Guy Simons Richardson	-	0.231	2.438	0.195	0.486	0.5117592	0.002480	23.2	429	3
Guy Simons Richardson	-	0.436	2.438	0.265	0.674	0.4626864	0.002590	21.3	761	3
Guy Simons Richardson	-	0.326	2.438	0.219	0.610	0.4428744	0.003200	20.3	1510	3
Guy Simons Richardson	-	0.411	2.438	0.317	0.532	0.920496	0.000370	20.7	28	3
Guy Simons Richardson	-	0.380	2.438	0.308	0.506	0.96012	0.000370	18.0	21	3
Guy Simons Richardson	-	0.460	2.438	0.320	0.590	0.999744	0.000590	19.7	65	3

	1	2	3	4	5	6	7	8	9	10	11
Guy Simons Richardson	-		0.210	2.438	0.177	0.487	0.9906	0.000710	17.4	63	3
Guy Simons Richardson	-		0.201	2.438	0.165	0.500	0.859536	0.000800	19.5	73	3
Guy Simons Richardson	-		0.477	2.438	0.317	0.617	0.969264	0.001120	19.4	140	3
Guy Simons Richardson	-		0.216	2.438	0.162	0.549	0.920496	0.001300	17.1	201	3
Guy Simons Richardson	-		0.477	2.438	0.305	0.641	0.938784	0.001360	19.2	211	3
Guy Simons Richardson	-		0.232	2.438	0.171	0.557	0.911352	0.001450	19.0	253	3
Guy Simons Richardson	-		0.465	2.438	0.283	0.672	0.908304	0.001830	17.5	308	3
Guy Simons Richardson	-		0.195	2.438	0.140	0.572	0.981456	0.001920	19.0	450	3
Guy Simons Richardson	-		0.639	2.438	0.338	0.775	0.740664	0.002750	18.0	601	3
Guy Simons Richardson	-		0.254	2.438	0.168	0.621	0.935736	0.003040	17.3	519	3
Guy Simons Richardson	-		0.632	2.438	0.317	0.817	0.890016	0.003130	19.1	537	3
Guy Simons Richardson	-		0.286	2.438	0.180	0.652	1.030224	0.003390	18.3	822	3
Guy Simons Richardson	-		0.643	2.438	0.311	0.848	0.755904	0.003560	18.9	1,080	3
Guy Simons Richardson	-		0.629	2.438	0.280	0.920	0.96012	0.003930	18.3	1,180	3
Guy Simons Richardson	-		0.628	2.438	0.271	0.950	0.920496	0.004370	18.5	1,900	3
Guy Simons Richardson	-		0.044	0.610	0.171	0.427	0.3105912	0.001030	33.8	117	3
Guy Simons Richardson	-		0.053	0.610	0.180	0.486	0.2602992	0.001180	27.2	168	3
Guy Simons Richardson	-		0.053	0.610	0.171	0.512	0.2551176	0.001390	10.2	226	3
Guy Simons Richardson	-		0.065	0.610	0.177	0.599	0.3163824	0.001470	14.3	455	3
Guy Simons Richardson	-		0.076	0.610	0.216	0.573	0.3264408	0.002010	13.1	854	3
Guy Simons Richardson	-		0.075	0.610	0.201	0.610	0.3105912	0.002100	33.1	719	3
Guy Simons Richardson	-		0.065	0.610	0.192	0.554	0.315468	0.002140	34.3	787	3
Guy Simons Richardson	-		0.040	0.610	0.158	0.413	0.3544824	0.001020	20.1	142	3
Guy Simons Richardson	-		0.048	0.610	0.149	0.526	0.3544824	0.002130	20.0	460	3
Guy Simons Richardson	-		0.056	0.610	0.158	0.574	0.3096768	0.002400	20.0	732	3
Guy Simons Richardson	-		0.074	0.610	0.158	0.768	0.3297936	0.003200	19.8	1,960	3
Guy Simons Richardson	-		0.055	0.610	0.152	0.594	0.32004	0.000970	22.1	507	3
Guy Simons Richardson	-		0.048	0.610	0.146	0.537	0.356616	0.001170	23.4	452	3
Guy Simons Richardson	-		0.060	0.610	0.155	0.631	0.440436	0.001200	24.1	1,030	3
Guy Simons Richardson	-		0.066	0.610	0.162	0.667	0.4291584	0.001630	23.2	1,220	3
Guy Simons Richardson	-		0.069	0.610	0.219	0.519	0.499872	0.001700	18.6	387	3
Guy Simons Richardson	-		0.088	0.610	0.247	0.587	0.48006	0.002010	19.2	408	3
Guy Simons Richardson	-		0.105	0.610	0.268	0.639	0.5998464	0.002480	23.3	720	3
Guy Simons Richardson	-		0.109	0.610	0.259	0.689	0.5940552	0.002930	21.5	904	3
Guy Simons Richardson	-		0.108	0.610	0.262	0.679	0.5401056	0.002940	22.4	1,100	3
Guy Simons Richardson	-		0.108	0.610	0.256	0.693	0.5178552	0.003310	18.7	1,050	3
Guy Simons Richardson	-		0.108	0.610	0.238	0.746	0.5800344	0.003510	18.9	1,200	3
Guy Simons Richardson	-		0.097	0.610	0.219	0.724	0.5498592	0.003880	20.6	1,250	3
Guy Simons Richardson	-		0.622	2.438	0.271	0.941	0.179832	0.001000	19.3	1,240	4
Guy Simons Richardson	-		0.626	2.438	0.262	0.980	0.1719072	0.001060	19.4	1,490	4
Guy Simons Richardson	-		0.619	2.438	0.256	0.991	0.2898648	0.001380	17.8	1,270	4
Guy Simons Richardson	-		0.624	2.438	0.277	0.922	0.3038856	0.001340	15.6	1,230	4
Guy Simons Richardson	-		0.444	2.438	0.195	0.934	0.29718	0.001420	14.5	1,370	4
Guy Simons Richardson	-		0.622	2.438	0.250	1.021	0.2740152	0.001720	15.7	2,350	4
Guy Simons Richardson	-		0.224	2.438	0.101	0.913	0.505968	0.004360	18.0	4,100	4
Guy Simons Richardson	-		0.089	2.438	0.058	0.632	0.4572	0.004460	19.0	1,370	4
Guy Simons Richardson	-		0.151	2.438	0.082	0.752	0.478536	0.004920	17.2	3,550	4
Guy Simons Richardson	-		0.158	2.438	0.076	0.850	0.521208	0.004940	17.0	4,610	4
Guy Simons Richardson	-		0.534	2.438	0.131	1.672	0.50292	0.006200	18.5	5,570	4
Guy Simons Richardson	-		0.435	2.438	0.198	0.900	0.467868	0.003260	21.7	2,920	4
Guy Simons Richardson	-		0.626	2.438	0.250	1.026	0.920496	0.005870	18.4	2,750	4
Guy Simons Richardson	-		0.321	2.438	0.149	0.880	0.966216	0.006000	18.3	2,620	4
Guy Simons Richardson	-		0.466	2.438	0.183	1.045	0.938784	0.006500	17.3	3,110	4
Guy Simons Richardson	-		0.632	2.438	0.207	1.251	0.999744	0.007100	19.3	4,020	4
Guy Simons Richardson	-		0.625	2.438	0.162	1.587	0.920496	0.009200	18.2	6,140	4
Guy Simons Richardson	-		0.443	2.438	0.155	1.169	0.938784	0.009400	18.0	5,090	4
Guy Simons Richardson	-		0.444	2.438	0.134	1.357	1.039368	0.011200	21.7	9,480	4
Guy Simons Richardson	-		0.089	0.610	0.195	0.745	0.3203448	0.001660	33.9	1,150	4
Guy Simons Richardson	-		0.099	0.610	0.226	0.717	0.2953512	0.001720	12.1	706	4
Guy Simons Richardson	-		0.089	0.610	0.177	0.823	0.315468	0.001840	12.4	907	4
Guy Simons Richardson	-		0.099	0.610	0.183	0.884	0.28956	0.001890	11.9	1,410	4
Guy Simons Richardson	-		0.099	0.610	0.219	0.741	0.3057144	0.001940	26.9	1,820	4
Guy Simons Richardson	-		0.099	0.610	0.223	0.727	0.2791968	0.002610	32.8	1,150	4
Guy Simons Richardson	-		0.093	0.610	0.149	1.023	0.310896	0.002700	20.0	2,210	4
Guy Simons Richardson	-		0.074	0.610	0.158	0.768	0.338328	0.001880	22.1	2,790	4

1	2	3	4	5	6	7	8	9	10	11
Guy Simons Richardson	-	0.095	0.610	0.158	0.979	0.3096768	0.003430	21.9	4.320	4
Guy Simons Richardson	-	0.107	0.610	0.219	0.798	0.5199888	0.001980	25.0	5.21	4
Guy Simons Richardson	-	0.135	0.610	0.250	0.888	0.5599176	0.003660	24.3	1.970	4
Guy Simons Richardson	-	0.136	0.610	0.265	0.841	0.5599176	0.003770	22.2	1.950	4
Guy Simons Richardson	-	0.135	0.610	0.271	0.817	0.5800344	0.003990	19.3	1.790	4
Guy Simons Richardson	-	0.108	0.610	0.232	0.766	0.5449824	0.004080	21.5	1.200	4
Guy Simons Richardson	-	0.118	0.610	0.219	0.881	0.4721352	0.004330	17.7	1.520	4
Guy Simons Richardson	-	0.619	2.438	0.241	1.053	0.1780032	0.001120	19.3	2.000	5
Guy Simons Richardson	-	0.331	2.438	0.155	0.873	0.1789176	0.001700	19.1	2.480	5
Guy Simons Richardson	-	0.616	2.438	0.226	1.120	0.2520696	0.001670	18.5	1.670	5
Guy Simons Richardson	-	0.423	2.438	0.183	0.948	0.2898648	0.001530	12.7	1.540	5
Guy Simons Richardson	-	0.619	2.438	0.219	1.156	0.3142488	0.001990	14.7	2.710	5
Guy Simons Richardson	-	0.445	2.438	0.168	1.089	0.2660904	0.002290	15.1	2.760	5
Guy Simons Richardson	-	0.445	2.438	0.158	1.150	0.2831392	0.002780	15.4	3.120	5
Guy Simons Richardson	-	0.605	2.438	0.189	1.312	0.499872	0.003420	21.1	3.290	5
Guy Simons Richardson	-	0.604	2.438	0.186	1.332	0.5248656	0.003550	23.2	3.390	5
Guy Simons Richardson	-	0.233	2.438	0.098	0.979	0.5099304	0.005310	21.4	5.250	5
Guy Simons Richardson	-	0.234	2.438	0.098	0.984	0.4840224	0.005500	20.2	5.680	5
Guy Simons Richardson	-	0.231	2.438	0.091	1.034	0.461772	0.006400	20.2	6.310	5
Guy Simons Richardson	-	0.607	2.438	0.155	1.600	0.4757928	0.007900	13.3	8.440	5
Guy Simons Richardson	-	0.336	2.438	0.308	0.447	0.850392	0.000280	22.7	3	5
Guy Simons Richardson	-	0.154	2.438	0.152	0.415	0.981456	0.000540	16.8	4	5
Guy Simons Richardson	-	0.177	2.438	0.158	0.458	0.908304	0.000640	16.7	26	5
Guy Simons Richardson	-	0.129	0.610	0.171	1.238	0.2983992	0.004170	28.4	4.340	5
Guy Simons Richardson	-	0.151	0.610	0.204	1.210	0.3203448	0.004560	7.9	3.960	5
Guy Simons Richardson	-	0.114	0.610	0.155	1.198	0.339852	0.002900	20.0	3.090	5
Guy Simons Richardson	-	0.063	0.610	0.155	0.669	0.359664	0.003500	20.0	3.280	5
Guy Simons Richardson	-	0.113	0.610	0.155	1.195	0.28956	0.004330	21.8	5.100	5
Guy Simons Richardson	-	0.151	0.610	0.195	1.269	0.5539552	0.004860	20.3	2.690	5
Guy Simons Richardson	-	0.421	2.438	0.134	1.286	0.481584	0.004320	17.5	4.750	6
Guy Simons Richardson	-	0.612	2.438	0.165	1.526	0.347472	0.004660	18.7	4.340	6
Guy Simons Richardson	-	0.239	2.438	0.085	1.149	0.399258	0.005460	17.5	5.960	6
Guy Simons Richardson	-	0.284	2.438	0.082	1.414	0.384048	0.006070	16.0	6.810	6
Guy Simons Richardson	-	0.605	2.438	0.152	1.629	0.414528	0.006190	19.0	6.230	6
Guy Simons Richardson	-	0.605	2.438	0.168	1.479	0.4828032	0.006340	10.7	4.480	6
Guy Simons Richardson	-	0.601	2.438	0.165	1.498	0.5020056	0.006220	24.5	4.490	6
Guy Simons Richardson	-	0.591	2.438	0.162	1.500	0.493776	0.006460	22.7	4.390	6
Guy Simons Richardson	-	0.603	2.438	0.168	1.476	0.413004	0.006510	21.0	5.760	6
Guy Simons Richardson	-	0.593	2.438	0.162	1.505	0.5297424	0.007400	23.5	6.760	6
Guy Simons Richardson	-	0.579	2.438	0.134	1.770	0.810768	0.011600	20.4	7.320	6
Guy Simons Richardson	-	0.440	2.438	0.116	1.557	0.829056	0.012300	19.6	10.200	6
Guy Simons Richardson	-	0.584	2.438	0.134	1.787	0.758952	0.012600	21.0	7.000	6
Guy Simons Richardson	-	0.591	2.438	0.131	1.850	1.02108	0.012800	20.5	7.010	6
Guy Simons Richardson	-	0.130	0.610	0.149	1.431	0.300228	0.004470	21.6	7.900	6
Guy Simons Richardson	-	0.197	0.610	0.226	1.429	0.5279136	0.005510	21.7	3.330	6
Guy Simons Richardson	-	0.198	0.610	0.229	1.421	0.5650992	0.005500	22.5	4.350	6
Guy Simons Richardson	-	0.197	0.610	0.229	1.414	0.5599176	0.005370	23.7	4.710	6
Guy Simons Richardson	-	0.198	0.610	0.223	1.459	0.5248656	0.006280	24.0	7.640	6
Guy Simons Richardson	-	0.180	0.610	0.219	1.348	0.5221224	0.005650	18.1	3.350	6
Guy Simons Richardson	-	0.212	0.610	0.201	1.727	0.4599432	0.007680	19.9	5.690	6
Guy Simons Richardson	-	0.216	0.610	0.216	1.636	0.569976	0.005200	22.6	3.330	6
Guy Simons Richardson	-	0.214	0.610	0.232	1.518	0.5599176	0.005080	22.5	3.400	6
Guy Simons Richardson	-	0.215	0.610	0.210	1.677	0.5599176	0.007900	23.3	9.730	6
Guy Simons Richardson	-	0.628	2.438	0.204	1.262	0.1709928	0.001960	19.1	4.650	-
Guy Simons Richardson	-	0.628	2.438	0.195	1.319	0.1819656	0.003000	18.9	9.240	-
Guy Simons Richardson	-	0.628	2.438	0.195	1.321	0.1719072	0.003500	18.7	12.900	-
Guy Simons Richardson	-	0.632	2.438	0.186	1.395	0.150876	0.003900	18.8	16.200	-
Guy Simons Richardson	-	0.628	2.438	0.183	1.408	0.179832	0.004600	18.5	23.900	-
Guy Simons Richardson	-	0.617	2.438	0.192	1.318	0.2630424	0.002800	13.6	4.760	-
Guy Simons Richardson	-	0.614	2.438	0.180	1.401	0.2609088	0.004930	15.9	9.080	-
Guy Simons Richardson	-	0.615	2.438	0.168	1.504	0.2398776	0.008130	10.2	28.700	-
Guy Simons Richardson	-	0.439	2.438	0.152	1.182	0.2700528	0.003280	15.0	5.060	-
Guy Simons Richardson	-	0.616	2.438	0.177	1.430	0.2578608	0.004700	10.8	10.500	-
Guy Simons Richardson	-	0.438	2.438	0.131	1.371	0.2791968	0.005330	15.1	11.500	-
Guy Simons Richardson	-	0.604	2.438	0.171	1.452	0.2761488	0.005930	10.2	13.000	-

1	2	3	4	5	6	7	8	9	10	11
Guy Simons Richardson	-	0.604	2.438	0.165	1.505	0.2752344	0.008150	10.9	27.600	-
Guy Simons Richardson	-	0.236	2.438	0.091	1.059	0.284988	0.008200	11.6	19.900	-
Guy Simons Richardson	-	0.424	2.438	0.113	1.541	0.41148	0.006560	18.0	6.180	-
Guy Simons Richardson	-	0.158	2.438	0.085	0.759	0.405384	0.008620	18.9	9.630	-
Guy Simons Richardson	-	0.307	2.438	0.085	1.474	0.530352	0.008980	19.4	4.160	-
Guy Simons Richardson	-	0.380	2.438	0.094	1.651	0.39624	0.009860	20.0	11.400	-
Guy Simons Richardson	-	0.607	2.438	0.131	1.898	0.478536	0.010100	18.5	11.500	-
Guy Simons Richardson	-	0.439	2.438	0.131	1.374	0.467868	0.005700	21.2	5.360	-
Guy Simons Richardson	-	0.442	2.438	0.125	1.451	0.4879848	0.005780	21.2	5.480	-
Guy Simons Richardson	-	0.442	2.438	0.128	1.415	0.4590288	0.005710	21.6	5.160	-
Guy Simons Richardson	-	0.440	2.438	0.137	1.314	0.4651248	0.005750	23.0	5.130	-
Guy Simons Richardson	-	0.432	2.438	0.119	1.492	0.4858512	0.006430	21.8	7.140	-
Guy Simons Richardson	-	0.435	2.438	0.125	1.428	0.499872	0.007400	15.0	7.100	-
Guy Simons Richardson	-	0.440	2.438	0.131	1.377	0.435864	0.007340	22.4	8.280	-
Guy Simons Richardson	-	0.447	2.438	0.134	1.368	0.458912	0.008210	19.0	17.700	-
Guy Simons Richardson	-	0.602	2.438	0.152	1.621	0.4547616	0.008060	19.6	16.100	-
Guy Simons Richardson	-	0.340	2.438	0.113	1.237	0.4867656	0.009600	19.5	8.960	-
Guy Simons Richardson	-	0.129	0.610	0.168	1.261	0.3051048	0.005660	12.7	5.600	-
Guy Simons Richardson	-	0.135	0.610	0.180	1.255	0.3051048	0.007100	7.0	5.180	-
Guy Simons Richardson	-	0.135	0.610	0.171	1.301	0.284988	0.004930	23.5	5.530	-
Guy Simons Richardson	-	0.150	0.610	0.183	1.346	0.3203448	0.004080	23.8	5.250	-
Guy Simons Richardson	-	0.161	0.610	0.183	1.448	0.370332	0.008650	12.5	12.300	-
Guy Simons Richardson	-	0.161	0.610	0.183	1.448	0.3197352	0.007300	31.7	8.780	-
Guy Simons Richardson	-	0.188	0.610	0.192	1.604	0.353568	0.008350	11.4	26.100	-
Guy Simons Richardson	-	0.188	0.610	0.189	1.632	0.4654296	0.006350	26.7	21.000	-
Guy Simons Richardson	-	0.192	0.610	0.189	1.669	0.3361944	0.009700	12.9	29.600	-
Guy Simons Richardson	-	0.193	0.610	0.186	1.704	0.3752088	0.006560	27.9	20.800	-
Guy Simons Richardson	-	0.125	0.610	0.152	1.347	0.341376	0.006200	20.3	4.990	-
Guy Simons Richardson	-	0.132	0.610	0.152	1.421	0.3096768	0.008000	20.0	7.110	-
Guy Simons Richardson	-	0.153	0.610	0.158	1.583	0.3197352	0.009100	20.3	18.400	-
Guy Simons Richardson	-	0.171	0.610	0.158	1.770	0.3297936	0.011400	19.9	18.400	-
Guy Simons Richardson	-	0.152	0.610	0.149	1.673	0.2801112	0.006950	19.6	15.100	-
Guy Simons Richardson	-	0.183	0.610	0.158	1.893	0.3297936	0.009100	19.6	22.500	-
Guy Simons Richardson	-	0.171	0.610	0.155	1.805	0.3496056	0.009800	19.6	14.600	-
Guy Simons Richardson	-	0.215	0.610	0.213	1.653	0.5849112	0.009000	23.7	22.300	-
Guy Simons Richardson	-	0.222	0.610	0.201	1.811	0.5221224	0.010750	25.0	10.300	-
Guy Simons Richardson	-	0.223	0.610	0.198	1.843	0.5599176	0.013050	25.1	15.800	-
Guy Simons Richardson	-	0.223	0.610	0.198	1.850	0.515112	0.011750	22.5	9.180	-
Guy Simons Richardson	-	0.222	0.610	0.198	1.836	0.5599176	0.013650	22.3	21.800	-
Guy Simons Richardson	-	0.223	0.610	0.207	1.762	0.64008	0.019280	24.0	50.000	-
Guy Simons Richardson	-	0.222	0.610	0.195	1.867	0.5629656	0.014380	16.9	26.000	-
Guy Simons Richardson	-	0.440	2.438	0.155	1.161	0.2060448	0.008450	16.8	35.500	8
Guy Simons Richardson	-	0.619	2.438	0.198	1.280	0.2100072	0.009500	17.3	47.300	8
Guy Simons Richardson	-	0.436	2.438	0.137	1.305	0.291084	0.009520	11.0	7.920	8
Guy Simons Richardson	-	0.605	2.438	0.183	1.356	0.3148384	0.010220	10.8	35.800	8
Guy Simons Richardson	-	0.432	2.438	0.122	1.454	0.2779776	0.009300	11.1	36.100	8
Guy Simons Richardson	-	0.605	2.438	0.174	1.429	0.2999232	0.010070	11.5	42.400	8
Kalmske Hsia	-	0.020	0.686	0.113	0.256	0.011	0.000250	15.0	6.404	2
Kalmske Hsia	-	0.036	0.686	0.149	0.348	0.011	0.000250	15.0	12.895	2
Kalmske Hsia	-	0.055	0.686	0.201	0.400	0.011	0.000250	15.0	16.704	2
Kalmske Hsia	-	0.029	0.686	0.110	0.380	0.011	0.000500	15.0	19.499	4
Kalmske Hsia	-	0.051	0.686	0.158	0.472	0.011	0.000500	15.0	22.402	4
Kalmske Hsia	-	0.074	0.686	0.195	0.550	0.011	0.000500	15.0	22.703	4
Kalmske Hsia	-	0.037	0.686	0.107	0.511	0.011	0.001000	15.0	33.599	4
Kalmske Hsia	-	0.076	0.686	0.171	0.653	0.011	0.001000	15.0	68.100	4
Kalmske Hsia	-	0.091	0.686	0.158	0.834	0.011	0.001300	15.0	110.999	5
Kennedy Brooks	-	0.040	0.851	0.168	0.277	0.142	0.000560	19.5	14	3
Kennedy Brooks	-	0.040	0.851	0.134	0.348	0.142	0.001450	18.4	390	3
Kennedy Brooks	-	0.040	0.851	0.114	0.412	0.142	0.002060	18.4	1.419	3
Kennedy Brooks	-	0.040	0.851	0.105	0.442	0.142	0.001980	25.1	1.129	3
Kennedy Brooks	-	0.040	0.851	0.104	0.448	0.142	0.001600	25.3	979	3
Kennedy Brooks	-	0.040	0.851	0.077	0.600	0.142	0.002500	25.3	1.708	5
Kennedy Brooks	-	0.040	0.851	0.072	0.650	0.142	0.001980	25.7	1.568	5
Kennedy Brooks	-	0.040	0.851	0.071	0.655	0.142	0.002070	25.2	1.409	5
Kennedy Brooks	-	0.040	0.851	0.069	0.674	0.142	0.002100	25.4	1.738	5

1	2	3	4	5	6	7	8	9	10	11
Laurson 1958	-	0.081	0.914	0.171	0.515	0.11	0.001220	20.6	2.247	2
Laurson 1958	-	0.087	0.914	0.229	0.415	0.11	0.000550	21.8	290	2
Laurson 1958	-	0.105	0.914	0.283	0.405	0.11	0.000430	22.8	140	2
Laurson 1958	-	0.182	0.914	0.283	0.704	0.11	0.001010	24.0	2,696	2
Laurson 1958	-	0.084	0.914	0.157	0.585	0.11	0.001520	21.3	4,239	2
Laurson 1958	-	0.075	0.914	0.158	0.518	0.11	0.001440	21.6	3,134	2
Laurson 1958	-	0.060	0.914	0.162	0.402	0.11	0.001060	23.3	660	2
Laurson 1958	-	0.111	0.914	0.230	0.527	0.11	0.000920	21.6	1,559	2
Laurson 1958	-	0.134	0.914	0.303	0.485	0.11	0.000580	26.5	610	2
Laurson 1958	-	0.050	0.914	0.116	0.472	0.11	0.001860	24.9	2,715	2
Laurson 1958	-	0.028	0.914	0.095	0.326	0.11	0.001600	26.4	550	2
Laurson 1958	-	0.042	0.914	0.116	0.390	0.11	0.001500	21.5	1,029	2
Laurson 1958	-	0.104	0.914	0.221	0.515	0.11	0.000800	23.7	1,309	2
Laurson 1958	-	0.024	0.914	0.076	0.351	0.11	0.002100	19.8	1,429	2
Laurson 1958	-	0.135	0.914	0.144	1.024	0.11	0.001200	22.8	5,153	2
Laurson 1958	-	0.133	0.914	0.216	0.671	0.11	0.001070	23.2	3,054	2
Laurson 1958	-	0.090	0.914	0.173	0.570	0.04	0.001000	22.9	83,402	2
Laurson 1958	-	0.068	0.914	0.141	0.530	0.04	0.001170	22.9	81,998	2
Laurson 1958	-	0.109	0.914	0.205	0.582	0.04	0.000860	22.9	58,397	2
Laurson 1958	-	0.057	0.914	0.165	0.375	0.04	0.000810	22.9	30,298	2
Laurson 1958	-	0.027	0.914	0.116	0.259	0.04	0.000780	22.9	7,297	2
Laurson 1958	-	0.087	0.914	0.146	0.649	0.04	0.001070	22.9	97,004	4
Laurson 1958	-	0.125	0.914	0.172	0.796	0.04	0.001140	22.9	83,402	4
Laurson 1958	-	0.136	0.914	0.202	0.738	0.04	0.001000	22.9	98,098	4
Meyer, Peter & Muller	-	1.641	1.999	0.387	2.121	28.65	0.010700	20.0	1,106	
Meyer, Peter & Muller	-	1.641	1.999	0.444	1.849	28.65	0.006538	13.0	28	
Meyer, Peter & Muller	-	1.641	1.999	0.397	2.066	28.65	0.009199	13.0	604	
Meyer, Peter & Muller	-	1.641	1.999	0.399	2.058	28.65	0.009278	13.0	599	
Meyer, Peter & Muller	-	1.641	1.999	0.399	2.057	28.65	0.009148	13.0	617	
Meyer, Peter & Muller	-	1.641	1.999	0.398	2.065	28.65	0.009157	13.0	603	
Meyer, Peter & Muller	-	1.641	1.999	0.368	2.228	28.65	0.013730	13.0	2,332	
Meyer, Peter & Muller	-	1.641	1.999	0.413	1.989	28.65	0.008204	13.0	302	
Meyer, Peter & Muller	-	1.641	1.999	0.418	1.963	28.65	0.007607	13.0	195	
Meyer, Peter & Muller	-	1.641	1.999	0.455	1.805	28.65	0.005613	13.0	19	
Meyer, Peter & Muller	-	1.641	1.999	0.342	2.398	28.65	0.017690	13.0	5,102	
Meyer, Peter & Muller	-	3.271	1.999	0.597	2.740	28.65	0.012190	13.0	2,589	
Meyer, Peter & Muller	-	3.271	1.999	0.653	2.506	28.65	0.008483	13.0	1,175	
Meyer, Peter & Muller	-	3.271	1.999	0.694	2.357	28.65	0.007070	13.0	586	
Meyer, Peter & Muller	-	3.271	1.999	0.722	2.266	28.65	0.005915	13.0	295	
Meyer, Peter & Muller	-	3.271	1.999	0.729	2.245	28.65	0.005783	13.0	294	
Meyer, Peter & Muller	-	3.271	1.999	0.835	1.960	28.65	0.003520	13.0	10	
Meyer, Peter & Muller	-	3.271	1.999	0.853	1.918	28.65	0.003446	13.0	8	
Meyer, Peter & Muller	-	3.271	1.999	0.600	2.727	28.65	0.012410	13.0	2,589	
Meyer, Peter & Muller	-	4.614	1.999	0.801	2.879	28.65	0.010870	13.0	1,828	
Meyer, Peter & Muller	-	4.483	1.999	0.781	2.870	28.65	0.010670	13.0	1,896	
Meyer, Peter & Muller	-	4.578	1.999	0.861	2.660	28.65	0.007385	13.0	834	
Meyer, Peter & Muller	-	4.554	1.999	0.852	2.672	28.65	0.007369	13.0	833	
Meyer, Peter & Muller	-	4.583	1.999	0.908	2.524	28.65	0.005782	13.0	421	
Meyer, Peter & Muller	-	4.609	1.999	0.925	2.491	28.65	0.005747	13.0	416	
Meyer, Peter & Muller	-	4.600	1.999	0.973	2.363	28.65	0.004790	13.0	209	
Meyer, Peter & Muller	-	4.600	1.999	0.961	2.395	28.65	0.005021	13.0	208	
Meyer, Peter & Muller	-	4.600	1.999	1.018	2.261	28.65	0.003955	13.0	565	
Meyer, Peter & Muller	-	4.600	1.999	1.026	2.242	28.65	0.003996	13.0	577	
Meyer, Peter & Muller	-	4.600	1.999	1.092	2.106	28.65	0.003171	13.0	6	
Meyer, Peter & Muller	-	4.600	1.999	1.092	2.107	28.65	0.003247	13.0	-	
Meyer, Peter & Muller	-	1.641	1.999	0.351	2.340	28.65	0.017672	13.0	5,170	
Meyer, Peter & Muller	-	3.271	1.999	0.823	1.988	28.65	0.003895	13.0	10	
Meyer, Peter & Muller	-	0.022	0.354	0.060	1.022	5.21	0.022700	13.0	6,896	
Meyer, Peter & Muller	-	0.022	0.354	0.071	0.864	5.21	0.009640	13.0	598	
Meyer, Peter & Muller	-	0.022	0.354	0.077	0.793	5.21	0.006940	13.0	54	
Meyer, Peter & Muller	-	0.022	0.354	0.067	0.919	5.21	0.012670	13.0	1,744	
Meyer, Peter & Muller	-	0.022	0.354	0.061	1.006	5.21	0.017600	13.0	4,085	
Meyer, Peter & Muller	-	0.022	0.354	0.058	1.065	5.21	0.022260	13.0	7,000	
Meyer, Peter & Muller	-	0.061	0.354	0.136	1.262	5.21	0.011200	13.0	2,536	

1	2	3	4	5	6	7	8	9	10	11
Meyer, Peter & Muller	-	0.061	0.354	0.148	1.166	5.21	0.008880	13.0	1.468	
Meyer, Peter & Muller	-	0.061	0.354	0.160	1.073	5.21	0.006220	13.0	632	
Meyer, Peter & Muller	-	0.061	0.354	0.160	1.075	5.21	0.006330	13.0	632	
Meyer, Peter & Muller	-	0.043	0.354	0.119	1.026	5.21	0.007550	13.0	870	
Meyer, Peter & Muller	-	0.061	0.354	0.175	0.983	5.21	0.004670	13.0	223	
Meyer, Peter & Muller	-	0.061	0.354	0.198	0.868	5.21	0.003190	13.0	191	
Meyer, Peter & Muller	-	0.061	0.354	0.195	0.882	5.21	0.003290	13.0	191	
Meyer, Peter & Muller	-	0.043	0.354	0.145	0.843	5.21	0.003720	13.0	271	
Meyer, Peter & Muller	-	0.043	0.354	0.101	1.215	5.21	0.013070	13.0	3569	
Meyer, Peter & Muller	-	0.043	0.354	0.130	0.942	5.21	0.005620	13.0	313	
Meyer, Peter & Muller	-	0.082	0.354	0.182	1.278	5.21	0.009830	13.0	1,884	
Meyer, Peter & Muller	-	0.082	0.354	0.213	1.090	5.21	0.005380	13.0	467	
Meyer, Peter & Muller	-	0.082	0.354	0.248	0.935	5.21	0.003180	13.0	46	
Meyer, Peter & Muller	-	0.068	0.500	0.200	0.675	2.69	0.002680	13.0	69	
Meyer, Peter & Muller	-	0.061	0.500	0.185	4.359	2.69	0.002700	13.0	61	
Meyer, Peter & Muller	-	0.054	0.500	0.171	5.212	2.69	0.002750	13.0	45	
Meyer, Peter & Muller	-	0.044	0.500	0.149	5.547	2.69	0.002740	13.0	34	
Meyer, Peter & Muller	-	0.035	0.500	0.127	5.547	2.69	0.002750	13.0	5	
Meyer, Peter & Muller	-	0.028	0.500	0.113	5.547	2.69	0.002790	13.0	2	
Meyer, Peter & Muller	-	0.020	0.500	0.092	5.547	2.69	0.002750	13.0	0	
Meyer, Peter & Muller	-	0.015	0.500	0.078	5.547	2.69	0.002760	13.0	0	
Meyer, Peter & Muller	-	0.061	0.500	0.184	5.547	2.69	0.002770	13.0	54	
Meyer, Peter & Muller	-	0.091	0.500	0.243	5.547	2.69	0.002730	13.0	309	
Meyer, Peter & Muller	-	0.061	0.500	0.185	5.547	2.69	0.002750	13.0	115	
Meyer, Peter & Muller	-	0.091	0.500	0.242	5.547	2.69	0.002770	13.0	383	
Meyer, Peter & Muller	-	0.085	0.500	0.230	5.547	2.69	0.002820	13.0	384	
Meyer, Peter & Muller	-	0.075	0.500	0.211	5.547	2.69	0.002770	13.0	287	
Meyer, Peter & Muller	-	0.068	0.500	0.199	5.547	2.69	0.002760	13.0	219	
Meyer, Peter & Muller	-	0.061	0.500	0.185	5.547	2.69	0.002730	13.0	182	
Meyer, Peter & Muller	-	0.050	0.500	0.163	5.547	2.69	0.002720	13.0	88	
Meyer, Peter & Muller	-	0.040	0.500	0.141	5.547	2.69	0.002740	13.0	46	
Meyer, Peter & Muller	-	0.061	0.500	0.184	5.547	2.69	0.002710	13.0	161	
Meyer, Peter & Muller	-	0.062	0.500	0.188	5.547	3.33	0.002709	13.0	58	
Meyer, Peter & Muller	-	0.043	0.500	0.147	5.547	3.33	0.002659	13.0	-	
Meyer, Peter & Muller	-	0.093	0.500	0.244	5.547	3.33	0.002807	13.0	222	
Meyer, Peter & Muller	-	0.050	0.500	0.164	5.547	3.33	0.002668	13.0	11	
Meyer, Peter & Muller	-	0.020	0.649	0.063	5.547	1.11	0.002825	13.0	296	
Meyer, Peter & Muller	-	0.037	0.649	0.091	5.547	1.11	0.003250	13.0	770	
Meyer, Peter & Muller	-	0.015	0.649	0.052	5.547	1.11	0.002355	13.0	101	
Meyer, Peter & Muller	-	0.027	0.649	0.075	5.547	1.11	0.002672	13.0	525	
Meyer, Peter & Muller	-	0.029	0.649	0.077	5.547	1.11	0.003038	13.0	734	
Meyer, Peter & Muller	-	0.059	0.649	0.132	5.547	1.11	0.004066	13.0	1,090	
Meyer, Peter & Muller	-	0.003	0.649	0.010	5.547	1.11	0.016000	13.0	4,900	
Meyer, Peter & Muller	-	0.001	0.300	0.010	5.547	1.11	0.016500	13.0	6,031	
Meyer, Peter & Muller	-	0.001	0.149	0.010	5.547	1.11	0.019920	13.0	6,448	
Meyer, Peter & Muller	-	0.001	0.149	0.014	5.547	1.11	0.020700	13.0	9,511	
Meyer, Peter & Muller	-	0.150	1.999	0.112	5.547	1.5	0.002400	13.0	581	
Meyer, Peter & Muller	-	0.100	1.999	0.078	5.547	1.5	0.002500	13.0	246	
Meyer, Peter & Muller	-	0.100	1.999	0.079	5.547	1.5	0.002550	13.0	282	
Meyer, Peter & Muller	-	0.070	1.999	0.056	5.547	1.5	0.002590	13.0	129	
Meyer, Peter & Muller	-	0.120	1.999	0.094	5.547	1.5	0.002440	13.0	394	
Meyer, Peter & Muller	-	0.225	1.999	0.150	5.547	1.5	0.002420	13.0	696	
Meyer, Peter & Muller	-	0.180	1.999	0.123	5.547	1.5	0.002650	13.0	742	
Meyer, Peter & Muller	-	0.330	1.999	0.187	5.547	1.5	0.002940	13.0	89	
Meyer, Peter & Muller	-	0.330	1.999	0.204	5.547	1.5	0.002480	13.0	566	
Meyer, Peter & Muller	-	0.330	1.999	0.203	5.547	1.5	0.002410	13.0	640	
Meyer, Peter & Muller	-	0.330	1.999	0.207	5.547	1.5	0.002390	13.0	627	
Meyer, Peter & Muller	-	0.330	1.999	0.198	5.547	1.5	0.002750	13.0	775	
Meyer, Peter & Muller	-	0.330	1.999	0.198	5.547	1.5	0.002610	13.0	713	
Meyer, Peter & Muller	-	0.260	1.999	0.166	5.547	1.5	0.002450	13.0	731	
Meyer, Peter & Muller	-	0.260	1.999	0.170	5.547	1.5	0.002250	13.0	549	
Meyer, Peter & Muller	-	0.150	1.999	0.115	5.547	1.5	0.002400	13.0	381	
Meyer, Peter & Muller	-	0.190	1.999	0.135	5.547	1.5	0.002350	13.0	477	
Meyer, Peter & Muller	-	0.160	1.999	0.087	5.547	4	0.008270	13.0	2,252	
Meyer, Peter & Muller	-	0.220	1.999	0.108	5.547	4	0.008010	13.0	3,017	

	1	2	3	4	5	6	7	8	9	10	11
Meyer, Peter & Muller			0.220	1.999	0.106	5.547	4	0.008110	13.0	2.929	
Meyer, Peter & Muller			0.250	1.999	0.106	5.547	4	0.008100	13.0	3.178	
Meyer, Peter & Muller			0.195	1.999	0.099	5.547	4	0.008130	13.0	2.651	
Meyer, Peter & Muller			0.140	1.999	0.086	5.547	4	0.008190	13.0	1.937	
Meyer, Peter & Muller			0.100	1.999	0.068	5.547	4	0.008120	13.0	1.187	
Meyer, Peter & Muller			0.550	1.999	0.490	5.547	0.34	0.000500	13.0	32	
Meyer, Peter & Muller			0.300	1.999	0.352	5.547	0.34	0.000420	13.0	14	
Meyer, Peter & Muller			0.400	1.999	0.400	5.547	0.34	0.000480	13.0	35	
Meyer, Peter & Muller			0.200	1.999	0.285	5.547	0.34	0.000400	13.0	7	
Meyer, Peter & Muller			0.350	1.999	0.372	5.547	0.34	0.000450	13.0	26	
Meyer, Peter & Muller			0.180	1.999	0.191	5.547	1	0.001003	13.0	94	
Meyer, Peter & Muller			0.140	1.999	0.152	5.547	1	0.001043	13.0	95	
Meyer, Peter & Muller			0.100	1.999	0.112	5.547	1	0.001074	13.0	109	
Meyer, Peter & Muller			0.010	0.354	0.077	5.547	5.21	0.001750	13.0	424	
Meyer, Peter & Muller			0.010	0.354	0.063	5.547	5.21	0.003260	13.0	2.722	
Meyer, Peter & Muller			0.010	0.354	0.058	5.547	5.21	0.004270	13.0	4.809	
Meyer, Peter & Muller			0.005	0.354	0.033	5.547	5.21	0.006970	13.0	9.688	
Meyer, Peter & Muller			0.022	0.354	0.117	5.547	5.21	0.002800	13.0	2.282	
Meyer, Peter & Muller			0.005	0.354	0.046	5.547	5.21	0.002170	13.0	212	
Meyer, Peter & Muller			0.010	0.354	0.082	5.547	5.21	0.001280	13.0	106	
Meyer, Peter & Muller			0.010	0.354	0.051	5.547	5.21	0.006380	13.0	10.660	
Meyer, Peter & Muller			0.022	0.354	0.098	5.547	5.21	0.003910	13.0	5.039	
Meyer, Peter & Muller			0.002	0.354	0.024	5.547	5.21	0.005720	13.0	2.125	
Meyer, Peter & Muller			0.001	0.354	0.013	5.547	5.21	0.007910	13.0	4.092	
Meyer, Peter & Muller			0.001	0.354	0.008	5.547	5.21	0.010630	13.0	5.666	
Meyer, Peter & Muller			0.002	0.354	0.055	5.547	5.21	0.018400	13.0	2.945	
Meyer, Peter & Muller			0.002	0.354	0.058	5.547	5.21	0.016010	13.0	758	
Meyer, Peter & Muller			0.002	0.354	0.053	5.547	5.21	0.022700	13.0	9.441	
Meyer, Peter & Muller			0.006	0.354	0.142	5.547	5.21	0.008230	13.0	1.120	
Meyer, Peter & Muller			0.006	0.354	0.117	5.547	5.21	0.016540	13.0	18.596	
Meyer, Peter & Muller			0.006	0.354	0.124	5.547	5.21	0.012680	13.0	9.374	
Meyer, Peter & Muller			0.008	0.354	0.198	5.547	5.21	0.005780	13.0	220	
Meyer, Peter & Muller			0.008	0.354	0.166	5.547	5.21	0.011020	13.0	7.055	
Nomicos1	-	-	0.005	0.267	0.073	0.246	0.152	0.002000	25.0	183	3
Nomicos1	-	-	0.005	0.267	0.073	0.260	0.152	0.002100	25.0	348	3
Nomicos1	-	-	0.005	0.267	0.073	0.279	0.152	0.002400	25.0	459	3
Nomicos1	-	-	0.006	0.267	0.073	0.299	0.152	0.002600	25.0	662	3
Nomicos1	-	-	0.006	0.267	0.073	0.317	0.152	0.002750	25.0	882	3
Nomicos1	-	-	0.007	0.267	0.073	0.366	0.152	0.002700	25.0	1.249	3
Nomicos1	-	-	0.008	0.267	0.073	0.422	0.152	0.002400	25.0	1.766	3
Nomicos1	-	-	0.011	0.267	0.073	0.539	0.152	0.002000	25.0	1.918	5
Nomicos1	-	-	0.012	0.267	0.073	0.629	0.152	0.002250	25.0	2.173	5
Nomicos1	-	-	0.016	0.267	0.073	0.811	0.152	0.003900	25.0	5.386	5
Nomicos1	-	-	0.009	0.267	0.073	0.473	0.152	0.002250	25.0	1.565	6
Nomicos1	-	-	0.010	0.267	0.073	0.518	0.152	0.002100	25.0	1.945	6
Nomicos2	-	-	0.008	0.267	0.074	0.387	0.145	0.002700	25.0	1.199	3
Nomicos2	-	-	0.005	0.267	0.073	0.279	0.145	0.002100	25.0	230	3
Nomicos2	-	-	0.005	0.267	0.073	0.246	0.152	0.002000	26.0	300	3
Nomicos2	-	-	0.005	0.267	0.073	0.260	0.152	0.002100	25.0	590	3
Nomicos2	-	-	0.005	0.267	0.073	0.279	0.152	0.002400	25.0	820	3
Nomicos2	-	-	0.006	0.267	0.073	0.299	0.152	0.002600	25.0	1.149	3
Nomicos2	-	-	0.006	0.267	0.073	0.317	0.152	0.002750	25.0	1.798	3
Nomicos2	-	-	0.007	0.267	0.073	0.366	0.152	0.002700	25.0	2.496	3
Nomicos2	-	-	0.008	0.267	0.073	0.422	0.152	0.002400	25.0	3.393	3
Nomicos2	-	-	0.005	0.267	0.074	0.278	0.152	0.002350	15.0	310	3
Nomicos2	-	-	0.005	0.267	0.073	0.279	0.152	0.002100	25.0	230	3
Nomicos2	-	-	0.005	0.267	0.073	0.279	0.152	0.002100	25.0	220	3
Nomicos2	-	-	0.005	0.267	0.073	0.280	0.152	0.001900	35.0	110	3
Nomicos2	-	-	0.012	0.267	0.073	0.629	0.145	0.002100	25.0	1.848	5
Nomicos2	-	-	0.012	0.267	0.071	0.652	0.137	0.002500	24.0	2.297	5
Nomicos2	-	-	0.011	0.267	0.068	0.605	0.137	0.002250	24.0	3.293	5
Nomicos2	-	-	0.011	0.267	0.073	0.539	0.152	0.002000	25.0	3.194	5
Nomicos2	-	-	0.012	0.267	0.073	0.629	0.152	0.002250	25.0	3.393	5
Nomicos2	-	-	0.016	0.267	0.073	0.811	0.152	0.003900	25.0	5.381	5
Nomicos2	-	-	0.012	0.267	0.073	0.631	0.152	0.002400	15.0	3.233	5

	1	2	3	4	5	6	7	8	9	10	11
Nomcos2	-		0.012	0.267	0.073	0.629	0.152	0.002100	25.0	1.868	5
Nomcos2	-		0.012	0.267	0.073	0.629	0.152	0.002300	25.0	2.137	5
Nomcos2	-		0.012	0.267	0.074	0.626	0.152	0.002200	38.0	1.658	5
Nomcos2	-		0.008	0.267	0.072	0.431	0.137	0.002750	24.1	1.998	6
Nomcos2	-		0.009	0.267	0.073	0.473	0.152	0.002250	25.0	2.895	6
Nomcos2	-		0.010	0.267	0.073	0.518	0.152	0.002100	25.0	3.293	6
Onishi Jam Kennedy	-		0.034	0.914	0.102	0.369	0.25	0.001540	28.4	67	3
Onishi Jam Kennedy	-		0.046	0.914	0.101	0.495	0.25	0.001935	20.0	744	3
Onishi Jam Kennedy	-		0.040	0.914	0.108	0.402	0.25	0.001630	25.5	196	3
Onishi Jam Kennedy	-		0.039	0.914	0.100	0.430	0.25	0.001840	21.0	485	3
Onishi Jam Kennedy	-		0.030	0.914	0.081	0.405	0.25	0.002540	21.0	311	3
Onishi Jam Kennedy	-		0.030	0.914	0.075	0.439	0.25	0.002560	21.0	524	3
Onishi Jam Kennedy	-		0.027	0.914	0.077	0.384	0.25	0.002670	21.0	314	3
Onishi Jam Kennedy	-		0.024	0.914	0.076	0.349	0.25	0.002560	24.0	282	3
Onishi Jam Kennedy	-		0.053	0.914	0.123	0.476	0.25	0.001465	24.0	406	3
Onishi Jam Kennedy	-		0.050	0.914	0.133	0.412	0.25	0.001220	26.0	98	3
Onishi Jam Kennedy	-		0.039	0.914	0.127	0.338	0.25	0.001090	25.0	66	3
Onishi Jam Kennedy	-		0.065	0.914	0.135	0.527	0.25	0.001560	25.0	688	3
Onishi Jam Kennedy	-		0.052	0.914	0.096	0.585	0.25	0.001650	21.8	1.063	4
Onishi Jam Kennedy	-		0.052	0.914	0.096	0.585	0.25	0.001650	21.8	3.348	4
Stem 1965	-		0.152	1.219	0.183	0.681	0.4	0.003520	21.1	2.089	3
Stem 1965	-		0.115	1.219	0.183	0.514	0.4	0.002850	20.6	1.028	3
Stem 1965	-		0.200	1.219	0.183	0.897	0.4	0.003210	22.2	3.034	3
Stem 1965	-		0.156	1.219	0.305	0.421	0.4	0.000610	22.8	93	3
Stem 1965	-		0.198	1.219	0.305	0.533	0.4	0.001680	21.7	476	3
Stem 1965	-		0.240	1.219	0.305	0.647	0.4	0.002600	22.8	943	3
Stem 1965	-		0.282	1.219	0.305	0.759	0.4	0.002900	20.0	1.767	3
Stem 1965	-		0.283	1.219	0.305	0.761	0.4	0.002980	20.6	1.506	3
Stem 1965	-		0.326	1.219	0.299	0.894	0.4	0.003000	24.4	1.881	3
Stem 1965	-		0.329	1.219	0.311	0.867	0.4	0.003010	21.1	1.958	3
Stem 1965	-		0.368	1.219	0.305	0.991	0.4	0.003270	22.2	2.254	3
Stem 1965	-		0.411	1.219	0.302	1.116	0.4	0.003280	22.2	2.823	3
Stem 1965	-		0.283	1.219	0.302	0.768	0.4	0.002900	22.2	1.552	3
Stem 1965	-		0.156	1.219	0.244	0.526	0.4	0.002010	21.1	638	3
Stem 1965	-		0.199	1.219	0.244	0.668	0.4	0.002980	21.1	1.461	3
Stem 1965	-		0.241	1.219	0.244	0.811	0.4	0.002970	21.1	1.955	3
Stem 1965	-		0.283	1.219	0.244	0.952	0.4	0.002850	21.1	2.165	3
Stem 1965	-		0.326	1.219	0.244	1.095	0.4	0.002690	24.4	2.792	3
Stem 1965	-		0.303	1.219	0.244	1.019	0.4	0.002860	22.2	2.702	3
Stem 1965	-		0.264	1.219	0.247	0.877	0.4	0.002490	22.2	2.231	3
Stem 1965	-		0.178	1.219	0.244	0.598	0.4	0.002670	22.2	1.040	3
Stem 1965	-		0.084	1.219	0.122	0.568	0.4	0.003470	23.3	479	3
Stem 1965	-		0.115	1.219	0.125	0.753	0.4	0.003870	22.2	2.527	3
Stem 1965	-		0.312	1.219	0.366	0.699	0.4	0.002540	26.7	943	3
Stem 1965	-		0.286	1.219	0.335	0.700	0.4	0.002560	26.7	1.014	3
Stem 1965	-		0.234	1.219	0.274	0.699	0.4	0.003100	26.1	1.457	3
Stem 1965	-		0.182	1.219	0.210	0.709	0.4	0.003480	26.7	1.894	3
Stem 1965	-		0.156	1.219	0.180	0.713	0.4	0.003950	28.3	2.202	3
Stem 1965	-		0.131	1.219	0.152	0.703	0.4	0.003870	25.6	2.387	3
Stem 1965	-		0.078	1.219	0.091	0.701	0.4	0.004030	25.6	2.549	3
Stem 1965	-		0.240	1.219	0.183	1.078	0.4	0.003310	23.3	3.990	5
Stem 1965	-		0.453	1.219	0.305	1.219	0.4	0.002260	22.2	2.686	5
Stem 1965	-		0.481	1.219	0.305	1.296	0.4	0.002510	23.3	2.934	5
Stem 1965	-		0.368	1.219	0.244	1.238	0.4	0.002610	23.3	3.344	5
Stem 1965	-		0.141	1.219	0.122	0.947	0.4	0.003700	22.2	3.499	5
Stem 1965	-		0.111	1.219	0.098	0.936	0.4	0.003980	26.7	4.227	5
Stem 1965	-		0.430	1.219	0.210	1.679	0.4	0.007050	25.0	16.932	5
Stem 1965	-		0.320	1.219	0.216	1.213	0.4	0.003040	26.7	3.733	5
Stem 1965	-		0.453	1.219	0.305	1.219	0.4	0.002590	28.9	3.037	5
Stem 1965	-		0.284	1.219	0.183	1.274	0.4	0.005080	23.9	7.059	-
Stem 1965	-		0.329	1.219	0.183	1.473	0.4	0.007360	23.3	13.364	-
Stem 1965	-		0.368	1.219	0.183	1.651	0.4	0.010790	22.8	23.887	-
Stem 1965	-		0.411	1.219	0.247	1.364	0.4	0.003270	22.8	4.406	-
Stem 1965	-		0.453	1.219	0.244	1.524	0.4	0.004170	22.2	7.294	-
Stem 1965	-		0.481	1.219	0.247	1.599	0.4	0.005240	22.2	9.553	-

	1	2	3	4	5	6	7	8	9	10	11
Stem 1965	-		0.169	1.219	0.122	1.139	0.4	0.004270	25.0	4.892	-
Stem 1965	-		0.200	1.219	0.122	1.347	0.4	0.006610	24.4	7.145	-
Stem 1965	-		0.226	1.219	0.122	1.522	0.4	0.010150	23.9	18.155	-
Stem 1965	-		0.255	1.219	0.122	1.713	0.4	0.013050	23.9	28.628	-
Stem 1965	-		0.281	1.219	0.125	1.842	0.4	0.016950	25.6	38.368	-
Stem 1965	-		0.394	1.219	0.213	1.513	0.4	0.005530	26.7	8.619	-
Stem 1965	-		0.314	1.219	0.183	1.410	0.4	0.005240	27.2	7.983	-
Stem 1965	-		0.238	1.219	0.149	1.310	0.4	0.005290	27.2	7.535	-
Stem 1965	-		0.134	1.219	0.091	1.199	0.4	0.004910	26.7	6.112	-
Stem 1965	-		0.282	1.219	0.149	1.551	0.4	0.009800	26.7	19.175	-
Stem 1965	-		0.262	1.219	0.149	1.437	0.4	0.006790	25.6	12.248	-
Stem 1965	-		0.357	1.219	0.216	1.352	0.4	0.003650	26.7	4.604	-
Straub 1954&1958	-		0.008	0.305	0.063	0.417	0.191	0.002980	20.0	7.45	2
Straub 1954&1958	-		0.008	0.305	0.074	0.356	0.191	0.002536	20.0	423	2
Straub 1954&1958	-		0.008	0.305	0.076	0.345	0.191	0.002642	20.0	417	2
Straub 1954&1958	-		0.008	0.305	0.077	0.560	0.191	0.003439	20.0	1.743	2
Straub 1954&1958	-		0.014	0.305	0.075	0.622	0.163	0.002350	30.0	1.408	2
Straub 1954&1958	-		0.014	0.305	0.073	0.640	0.163	0.002560	23.9	2.003	2
Straub 1954&1958	-		0.014	0.305	0.071	0.657	0.163	0.002820	17.2	2.297	2
Straub 1954&1958	-		0.014	0.305	0.070	0.660	0.163	0.003240	11.1	2.817	2
Straub 1954&1958	-		0.014	0.305	0.069	0.677	0.163	0.003260	5.8	3.612	2
Straub 1954&1958	-		0.014	0.305	0.068	0.683	0.163	0.003620	1.7	4.784	2
Straub 1954&1958	-		0.008	0.305	0.043	0.612	0.191	0.004043	20.0	3.138	-
Straub 1954&1958	-		0.008	0.305	0.040	0.664	0.191	0.005890	20.0	4.937	-
Straub 1954&1958	-		0.008	0.305	0.037	0.713	0.191	0.006309	20.0	6.950	-
Straub 1954&1958	-		0.008	0.305	0.035	0.757	0.191	0.007347	20.0	8.740	-
Straub 1954&1958	-		0.008	0.305	0.043	0.616	0.191	0.006574	20.0	12.479	-
Straub 1954&1958	-		0.024	0.914	0.048	0.546	0.191	0.004620	20.0	6.264	-
Straub 1954&1958	-		0.057	0.914	0.088	0.701	0.191	0.002370	20.0	2.664	-
Straub 1954&1958	-		0.113	0.914	0.169	0.732	0.191	0.001080	20.0	1.337	-
Straub 1954&1958	-		0.142	0.914	0.203	0.764	0.191	0.000950	20.0	1.065	-
Straub 1954&1958	-		0.170	0.914	0.235	0.790	0.191	0.000560	20.0	889	-
Straub 1954&1958	-		0.170	0.914	0.223	0.835	0.191	0.001024	20.0	889	-
Straub 1954&1958	-		0.024	0.914	0.042	0.630	0.191	0.004440	20.0	6.264	-
Straub 1954&1958	-		0.113	0.914	0.172	0.720	0.191	0.001160	20.0	1.337	-
Straub 1954&1958	-		0.170	0.914	0.239	0.779	0.191	0.000780	20.0	889	-
Taylor Vanoni	-		0.048	0.852	0.081	0.692	0.228	0.002050	23.0	1.211	5
Taylor Vanoni	-		0.047	0.852	0.079	0.707	0.228	0.002080	38.0	1.250	5
Taylor Vanoni	-		0.084	0.852	0.114	0.866	0.228	0.001980	24.5	2.001	5
Taylor Vanoni	-		0.084	0.852	0.112	0.878	0.228	0.001990	38.9	2.151	5
Taylor Vanoni	-		0.012	0.267	0.078	0.585	0.138	0.001870	48.0	2.892	5
Taylor Vanoni	-		0.012	0.267	0.078	0.585	0.138	0.001910	33.0	2.772	5
Vanoni Brooks	-		0.014	0.851	0.073	0.234	0.137	0.001410	23.4	3.7	3
Vanoni Brooks	-		0.017	0.851	0.074	0.276	0.137	0.002040	24.5	240	3
Vanoni Brooks	-		0.020	0.851	0.073	0.325	0.137	0.002800	25.2	1.149	3
Vanoni Brooks	-		0.024	0.851	0.073	0.389	0.137	0.002780	25.5	1.898	3
Vanoni Brooks	-		0.026	0.851	0.072	0.428	0.137	0.002770	22.4	2.197	3
Vanoni Brooks	-		0.028	0.851	0.076	0.439	0.137	0.002460	27.4	1.399	3
Vanoni Brooks	-		0.033	0.851	0.092	0.423	0.137	0.002010	18.9	2.197	3
Vanoni Brooks	-		0.034	0.851	0.165	0.244	0.137	0.000390	24.6	3	3
Vanoni Brooks	-		0.044	0.851	0.161	0.318	0.137	0.000700	23.4	68	3
Vanoni Brooks	-		0.053	0.851	0.167	0.372	0.137	0.001050	21.9	210	3
Vanoni Brooks	-		0.063	0.851	0.163	0.454	0.137	0.001220	25.2	670	3
Vanoni Brooks	-		0.075	0.851	0.169	0.523	0.137	0.001020	20.7	1.449	3
Vanoni Brooks	-		0.033	0.851	0.062	0.629	0.137	0.002760	18.9	2.994	5
Vanoni Brooks	-		0.039	0.851	0.071	0.647	0.137	0.002050	23.5	2.496	5
Vanoni Brooks	-		0.109	0.851	0.166	0.771	0.137	0.001070	24.9	1.149	5
Vanoni Hwang	-		0.006	0.267	0.076	0.274	0.23	0.002300	22.0	120	2
Vanoni Hwang	-		0.005	0.267	0.074	0.246	0.23	0.002000	21.2	62	2
Vanoni Hwang	-		0.004	0.267	0.073	0.188	0.23	0.001200	22.0	1	2
Vanoni Hwang	-		0.007	0.267	0.073	0.376	0.23	0.002800	22.6	488	2
Vanoni Hwang	-		0.006	0.267	0.074	0.291	0.23	0.000700	25.5	265	2
Vanoni Hwang	-		0.007	0.267	0.073	0.335	0.23	0.002900	21.7	417	2
Vanoni Hwang	-		0.008	0.267	0.071	0.426	0.23	0.002700	21.9	619	2
Vanoni Hwang	-		0.004	0.267	0.070	0.229	0.23	0.001590	21.0	-	2

1	2	3	4	5	6	7	8	9	10	11
Yanoni Hwang	-	0.007	0.267	0.073	0.380	0.23	0.002860	20.9	448	2
Yanoni Hwang	-	0.064	1.100	0.182	0.319	0.206	0.000642	19.8	31	2
Yanoni Hwang	-	0.088	1.100	0.180	0.443	0.206	0.001055	20.1	180	2
Yanoni Hwang	-	0.108	1.100	0.176	0.538	0.206	0.001303	20.7	1489	2
Yanoni Hwang	-	0.091	1.100	0.180	0.462	0.206	0.001116	21.0	380	2
Yanoni Hwang	-	0.095	1.100	0.184	0.472	0.206	0.001100	19.2	410	2
Yanoni Hwang	-	0.122	1.100	0.238	0.466	0.206	0.000809	18.8	261	2
Yanoni Hwang	-	0.185	1.100	0.371	0.455	0.206	0.000455	20.0	61	2
Wilcock Southard	-	0.031	0.600	0.114	0.447	1.86	0.000960	25.1	0	1
Williams	-	0.012	0.305	0.096	0.425	1.35	0.001210	22.8	11	3
Williams	-	0.012	0.305	0.090	0.451	1.35	0.001620	18.6	39	3
Williams	-	0.013	0.305	0.090	0.467	1.35	0.001820	16.6	60	3
Williams	-	0.013	0.305	0.091	0.479	1.35	0.002000	18.4	87	3
Williams	-	0.014	0.305	0.092	0.502	1.35	0.002100	17.2	116	3
Williams	-	0.014	0.305	0.093	0.503	1.35	0.002110	17.8	119	3
Williams	-	0.015	0.305	0.090	0.529	1.35	0.002360	17.2	183	3
Williams	-	0.015	0.305	0.090	0.547	1.35	0.002720	17.8	280	3
Williams	-	0.016	0.305	0.088	0.582	1.35	0.003180	16.2	316	3
Williams	-	0.016	0.305	0.088	0.602	1.35	0.003970	16.2	449	3
Williams	-	0.018	0.305	0.088	0.686	1.35	0.005090	15.8	778	3
Williams	-	0.021	0.305	0.090	0.764	1.35	0.005570	12.4	828	3
Williams	-	0.023	0.305	0.095	0.777	1.35	0.006430	15.6	967	3
Williams	-	0.022	0.305	0.153	0.467	1.35	0.001060	19.0	9	3
Williams	-	0.024	0.305	0.155	0.507	1.35	0.001370	21.0	38	3
Williams	-	0.023	0.305	0.148	0.499	1.35	0.001530	26.0	42	3
Williams	-	0.025	0.305	0.154	0.522	1.35	0.001440	22.8	53	3
Williams	-	0.026	0.305	0.158	0.532	1.35	0.001720	23.6	85	3
Williams	-	0.027	0.305	0.156	0.572	1.35	0.001840	23.2	102	3
Williams	-	0.027	0.305	0.154	0.578	1.35	0.002160	17.8	120	3
Williams	-	0.030	0.305	0.158	0.618	1.35	0.002510	18.8	172	3
Williams	-	0.031	0.305	0.154	0.664	1.35	0.003140	20.8	287	3
Williams	-	0.037	0.305	0.155	0.791	1.35	0.004160	20.8	404	3
Williams	-	0.033	0.305	0.212	0.512	1.35	0.000810	22.0	6	3
Williams	-	0.035	0.305	0.217	0.531	1.35	0.000790	16.0	18	3
Williams	-	0.037	0.305	0.214	0.573	1.35	0.001310	21.6	39	3
Williams	-	0.040	0.305	0.218	0.606	1.35	0.001780	20.6	66	3
Williams	-	0.046	0.305	0.216	0.706	1.35	0.002720	19.0	196	3
Williams	-	0.007	0.610	0.030	0.373	1.35	0.004890	26.6	226	3
Williams	-	0.008	0.610	0.028	0.486	1.35	0.005690	25.6	387	3
Williams	-	0.010	0.610	0.028	0.579	1.35	0.008160	25.0	1092	3
Williams	-	0.024	0.610	0.087	0.457	1.35	0.001180	24.0	25	3
Williams	-	0.025	0.610	0.090	0.464	1.35	0.001540	25.6	45	3
Williams	-	0.028	0.610	0.088	0.527	1.35	0.002100	28.2	135	3
Williams	-	0.033	0.610	0.088	0.623	1.35	0.003300	28.2	338	3
Williams	-	0.044	0.610	0.146	0.496	1.35	0.001060	23.6	15	3
Williams	-	0.048	0.610	0.150	0.529	1.35	0.000970	26.4	25	3
Williams	-	0.050	0.610	0.152	0.538	1.35	0.001370	26.8	55	3
Williams	-	0.063	0.610	0.152	0.679	1.35	0.002810	24.8	203	3
Williams	-	0.073	0.610	0.148	0.809	1.35	0.004450	26.0	450	3
Williams	-	0.063	0.610	0.211	0.493	1.35	0.000600	22.4	84	3
Williams	-	0.073	0.610	0.208	0.574	1.35	0.000800	26.6	19	3
Williams	-	0.078	0.610	0.216	0.589	1.35	0.001470	25.2	48	3
Williams	-	0.080	0.610	0.215	0.607	1.35	0.001720	27.8	83	3
Williams	-	0.102	0.610	0.215	0.778	1.35	0.002800	27.8	263	3
Williams	-	0.143	1.190	0.225	0.532	1.35	0.000960	28.0	19	3
Williams	-	0.142	1.190	0.215	0.553	1.35	0.000910	25.0	26	3
Williams	-	0.150	1.190	0.215	0.588	1.35	0.001150	28.6	43	3
Williams	-	0.158	1.190	0.210	0.632	1.35	0.001910	27.6	93	3
Williams	-	0.163	1.190	0.205	0.666	1.35	0.002140	26.2	122	3
Williams	-	0.003	0.305	0.028	0.379	1.35	0.004070	13.8	76	5
Williams	-	0.004	0.305	0.030	0.393	1.35	0.004110	18.6	183	5
Williams	-	0.004	0.305	0.030	0.440	1.35	0.004950	19.2	328	5
Williams	-	0.004	0.305	0.032	0.456	1.35	0.005900	21.0	604	5
Williams	-	0.011	0.305	0.030	1.240	1.35	0.033100	19.2	19753	5
Williams	-	0.011	0.305	0.091	0.413	1.35	0.001100	21.4	10	5

	1	2	3	4	5	6	7	8	9	10	11
Williams	-	0.012	0.305	0.096	0.425	1.35	0.001360	19.8	20	5	
Williams	-	0.056	0.305	0.098	1.867	1.35	0.016200	19.8	8,815	5	
Williams	-	0.018	0.610	0.030	0.993	1.35	0.023400	26.0	9,341	5	
Williams	-	0.004	0.305	0.030	0.480	1.35	0.007510	12.6	965	-	
Williams	-	0.005	0.305	0.030	0.513	1.35	0.010800	11.8	1,913	-	
Williams	-	0.005	0.305	0.030	0.593	1.35	0.012800	17.6	2,871	-	
Williams	-	0.006	0.305	0.030	0.680	1.35	0.015100	15.6	4,200	-	
Williams	-	0.007	0.305	0.030	0.720	1.35	0.019900	23.6	7,694	-	
Williams	-	0.008	0.305	0.030	0.907	1.35	0.022200	24.8	9,139	-	
Williams	-	0.022	0.305	0.090	0.784	1.35	0.003940	20.4	914	-	
Williams	-	0.022	0.305	0.090	0.784	1.35	0.003920	22.0	1,001	-	
Williams	-	0.024	0.305	0.095	0.840	1.35	0.007210	21.8	1,277	-	
Williams	-	0.030	0.305	0.100	0.976	1.35	0.008240	23.6	1,484	-	
Williams	-	0.032	0.305	0.100	1.040	1.35	0.010900	25.0	2,333	-	
Williams	-	0.037	0.305	0.100	1.208	1.35	0.012900	20.4	3,848	-	
Williams	-	0.046	0.305	0.150	1.016	1.35	0.008420	18.8	1,318	-	
Williams	-	0.053	0.305	0.145	1.199	1.35	0.011800	18.8	2,751	-	
Williams	-	0.071	0.305	0.145	1.596	1.35	0.011300	19.0	3,880	-	
Williams	-	0.064	0.305	0.210	1.000	1.35	0.004540	18.8	571	-	
Williams	-	0.079	0.305	0.200	1.296	1.35	0.009550	20.0	1,761	-	
Williams	-	0.010	0.610	0.027	0.622	1.35	0.011700	26.8	2,407	-	
Williams	-	0.015	0.610	0.028	0.864	1.35	0.017200	26.8	4,738	-	
Williams	-	0.048	0.610	0.090	0.873	1.35	0.007140	28.4	1,322	-	
Williams	-	0.063	0.610	0.090	1.140	1.35	0.011300	24.8	2,783	-	
Williams	-	0.091	0.610	0.150	0.995	1.35	0.006430	26.8	998	-	
Williams	-	0.097	0.610	0.140	1.134	1.35	0.008770	26.2	1,843	-	
Williams	-	0.130	0.610	0.200	1.064	1.35	0.005600	27.2	813	-	
Willis Coleman Ellis	-	0.197	1.219	0.274	0.589	0.1	0.000962	21.7	2,096	3	
Willis Coleman Ellis	-	0.197	1.219	0.335	0.482	0.1	0.000519	20.6	580	3	
Willis Coleman Ellis	-	0.170	1.219	0.335	0.416	0.1	0.000442	22.2	196	3	
Willis Coleman Ellis	-	0.227	1.219	0.320	0.581	0.1	0.000654	23.3	1,264	3	
Willis Coleman Ellis	-	0.255	1.219	0.305	0.686	0.1	0.000500	22.2	1,728	3	
Willis Coleman Ellis	-	0.283	1.219	0.320	0.726	0.1	0.000481	25.0	1,357	3	
Willis Coleman Ellis	-	0.255	1.219	0.366	0.572	0.1	0.000519	26.7	904	3	
Willis Coleman Ellis	-	0.228	1.219	0.375	0.498	0.1	0.000538	26.9	573	3	
Willis Coleman Ellis	-	0.194	1.219	0.378	0.420	0.1	0.000346	27.8	158	3	
Willis Coleman Ellis	-	0.142	1.219	0.305	0.381	0.1	0.000308	26.7	87	3	
Willis Coleman Ellis	-	0.170	1.219	0.317	0.440	0.1	0.000462	26.7	291	3	
Willis Coleman Ellis	-	0.194	1.219	0.314	0.506	0.1	0.000635	25.3	735	3	
Willis Coleman Ellis	-	0.198	1.219	0.314	0.518	0.1	0.000615	25.8	779	3	
Willis Coleman Ellis	-	0.227	1.219	0.299	0.622	0.1	0.000769	23.9	1,424	3	
Willis Coleman Ellis	-	0.254	1.219	0.262	0.794	0.1	0.000750	25.0	1,629	3	
Willis Coleman Ellis	-	0.227	1.219	0.238	0.782	0.1	0.000538	20.8	2,702	3	
Willis Coleman Ellis	-	0.170	1.219	0.287	0.486	0.1	0.000730	21.9	640	3	
Willis Coleman Ellis	-	0.199	1.219	0.287	0.571	0.1	0.000884	22.2	1,736	3	
Willis Coleman Ellis	-	0.227	1.219	0.247	0.753	0.1	0.000788	19.4	2,056	3	
Willis Coleman Ellis	-	0.142	1.219	0.290	0.401	0.1	0.000712	20.8	213	3	
Willis Coleman Ellis	-	0.114	1.219	0.262	0.358	0.1	0.000269	21.1	101	3	
Willis Coleman Ellis	-	0.142	1.219	0.259	0.448	0.1	0.000711	21.4	459	3	
Willis Coleman Ellis	-	0.170	1.219	0.259	0.538	0.1	0.001000	23.1	1,372	3	
Willis Coleman Ellis	-	0.227	1.219	0.229	0.813	0.1	0.000980	26.4	2,032	3	
Willis Coleman Ellis	-	0.213	1.219	0.229	0.764	0.1	0.000576	25.6	1,743	3	
Willis Coleman Ellis	-	0.113	1.219	0.198	0.469	0.1	0.000808	23.6	996	3	
Willis Coleman Ellis	-	0.127	1.219	0.195	0.533	0.1	0.000962	23.9	1,514	3	
Willis Coleman Ellis	-	0.078	1.219	0.146	0.438	0.1	0.001210	26.1	993	3	
Willis Coleman Ellis	-	0.084	1.219	0.143	0.480	0.1	0.001320	24.4	1,343	3	
Willis Coleman Ellis	-	0.085	1.219	0.143	0.486	0.1	0.001380	22.5	1,091	3	
Willis Coleman Ellis	-	0.085	1.219	0.168	0.416	0.1	0.000981	22.5	478	3	
Willis Coleman Ellis	-	0.113	1.219	0.232	0.401	0.1	0.000577	22.2	240	3	
Willis Coleman Ellis	-	0.142	1.219	0.232	0.501	0.1	0.000865	22.2	1,076	3	
Willis Coleman Ellis	-	0.156	1.219	0.229	0.561	0.1	0.000865	21.1	1,507	3	
Willis Coleman Ellis	-	0.198	1.219	0.207	0.784	0.1	0.000615	22.2	1,883	3	
Willis Coleman Ellis	-	0.227	1.219	0.213	0.871	0.1	0.000750	21.7	2,359	3	
Willis Coleman Ellis	-	0.340	1.219	0.256	1.089	0.1	0.001480	30.0	3,681	3	
Willis Coleman Ellis	-	0.340	1.219	0.302	0.924	0.1	0.000923	30.6	1,941	3	

1	2	3	4	5	6	7	8	9	10	11
Willis Coleman Ellis	-	0.340	1.219	0.305	0.915	0.1	0.000692	28.3	2.181	5
Willis Coleman Ellis	-	0.199	1.219	0.195	0.838	0.1	0.001020	28.3	2.807	5
Willis Coleman Ellis	-	0.283	1.219	0.283	0.819	0.1	0.000654	22.8	1.709	5
Willis Coleman Ellis	-	0.312	1.219	0.287	0.892	0.1	0.000692	24.2	2.013	5
Willis Coleman Ellis	-	0.368	1.219	0.290	1.043	0.1	0.000885	23.9	3.374	5
Willis Coleman Ellis	-	0.396	1.219	0.290	1.123	0.1	0.001150	23.1	4.973	5
Willis Coleman Ellis	-	0.425	1.219	0.280	1.243	0.1	0.001870	25.6	6.720	5
Willis Coleman Ellis	-	0.453	1.219	0.277	1.340	0.1	0.001100	26.1	8.286	5
Willis Coleman Ellis	-	0.453	1.219	0.305	1.219	0.1	0.001190	22.8	5.427	5
Willis Coleman Ellis	-	0.425	1.219	0.305	1.143	0.1	0.000827	25.8	3.945	5
Willis Coleman Ellis	-	0.396	1.219	0.317	1.026	0.1	0.000712	25.0	2.905	5
Willis Coleman Ellis	-	0.368	1.219	0.308	0.981	0.1	0.000442	24.4	2.239	5
Willis Coleman Ellis	-	0.340	1.219	0.308	0.905	0.1	0.000462	25.8	1.579	5
Willis Coleman Ellis	-	0.312	1.219	0.305	0.838	0.1	0.000538	26.1	1.286	5
Willis Coleman Ellis	-	0.283	1.219	0.271	0.856	0.1	0.000673	25.6	1.690	5
Willis Coleman Ellis	-	0.312	1.219	0.274	0.931	0.1	0.000788	26.4	3.075	5
Willis Coleman Ellis	-	0.340	1.219	0.274	1.016	0.1	0.000808	24.7	3.691	5
Willis Coleman Ellis	-	0.368	1.219	0.271	1.113	0.1	0.000981	23.3	4.859	5
Willis Coleman Ellis	-	0.396	1.219	0.274	1.185	0.1	0.001130	23.9	5.836	5
Willis Coleman Ellis	-	0.425	1.219	0.271	1.284	0.1	0.001980	24.2	6.551	5
Willis Coleman Ellis	-	0.453	1.219	0.268	1.386	0.1	0.001290	21.1	11.174	5
Willis Coleman Ellis	-	0.480	1.219	0.290	1.361	0.1	0.001500	22.2	11.626	5
Willis Coleman Ellis	-	0.479	1.219	0.250	1.572	0.1	0.001380	23.1	19.119	5
Willis Coleman Ellis	-	0.423	1.219	0.238	1.458	0.1	0.001210	24.4	13.962	5
Willis Coleman Ellis	-	0.396	1.219	0.241	1.331	0.1	0.001400	17.5	13.207	5
Willis Coleman Ellis	-	0.367	1.219	0.244	1.235	0.1	0.001130	21.9	8.067	5
Willis Coleman Ellis	-	0.339	1.219	0.247	1.125	0.1	0.001080	21.7	6.296	5
Willis Coleman Ellis	-	0.312	1.219	0.244	1.048	0.1	0.001120	22.2	4.634	5
Willis Coleman Ellis	-	0.283	1.219	0.244	0.933	0.1	0.000807	21.4	3.216	5
Willis Coleman Ellis	-	0.255	1.219	0.238	0.879	0.1	0.000538	21.7	2.353	5
Willis Coleman Ellis	-	0.255	1.219	0.241	0.868	0.1	0.000826	25.6	2.332	5
Willis Coleman Ellis	-	0.283	1.219	0.232	1.003	0.1	0.000846	26.1	3.120	5
Willis Coleman Ellis	-	0.312	1.219	0.235	1.089	0.1	0.001100	25.3	4.125	5
Willis Coleman Ellis	-	0.340	1.219	0.232	1.203	0.1	0.001290	21.1	5.798	5
Willis Coleman Ellis	-	0.170	1.219	0.177	0.788	0.1	0.000827	23.9	2.271	5
Willis Coleman Ellis	-	0.127	1.219	0.137	0.759	0.1	0.001270	24.2	3.154	5
Willis Coleman Ellis	-	0.100	1.219	0.119	0.688	0.1	0.001330	23.9	3.415	5
Willis Coleman Ellis	-	0.170	1.219	0.162	0.863	0.1	0.001080	21.1	3.261	5
Willis Coleman Ellis	-	0.212	1.219	0.189	0.919	0.1	0.001060	22.2	3.436	5
Willis Coleman Ellis	-	0.255	1.219	0.210	0.994	0.1	0.000808	22.5	3.459	5
Willis Coleman Ellis	-	0.283	1.219	0.210	1.104	0.1	0.000981	22.8	4.861	5
Willis Coleman Ellis	-	0.340	1.219	0.210	1.325	0.1	0.001440	30.0	13.867	-
Willis Coleman Ellis	-	0.447	1.219	0.244	1.505	0.1	0.001670	24.4	18.320	-
Willis Coleman Ellis	-	0.142	1.219	0.128	0.907	0.1	0.001020	24.2	4.358	-
Willis Coleman Ellis	-	0.170	1.219	0.131	1.063	0.1	0.001760	25.0	10.924	-
Willis Coleman Ellis	-	0.127	1.219	0.104	1.004	0.1	0.001750	25.6	10.513	-
Willis Coleman Ellis	-	0.113	1.219	0.110	0.847	0.1	0.001420	24.7	5.761	-
Willis Coleman Ellis	-	0.184	1.219	0.158	0.950	0.1	0.001120	21.1	4.447	-
Willis Coleman Ellis	-	0.198	1.219	0.149	1.089	0.1	0.001120	21.7	6.808	-
Willis Coleman Ellis	-	0.212	1.219	0.152	1.140	0.1	0.001120	21.7	9.070	-
Willis Coleman Ellis	-	0.227	1.219	0.183	1.016	0.1	0.001100	22.2	4.632	-
Willis Coleman Ellis	-	0.240	1.219	0.186	1.059	0.1	0.001190	22.2	5.564	-
Willis Coleman Ellis	-	0.255	1.219	0.183	1.143	0.1	0.001540	23.1	7.793	-
Willis Coleman Ellis	-	0.270	1.219	0.177	1.251	0.1	0.001230	21.7	10.032	-
Willis Coleman Ellis	-	0.283	1.219	0.180	1.292	0.1	0.001440	21.7	13.469	-
Willis Coleman Ellis	-	0.312	1.219	0.210	1.215	0.1	0.001810	22.8	9.898	-
Willis Coleman Ellis	-	0.312	1.219	0.204	1.251	0.1	0.001210	23.1	7.998	-
Willis Coleman Ellis	-	0.340	1.219	0.213	1.306	0.1	0.002040	24.2	12.344	-