DISSERTATION

WATER TEMPERATURE EFFECT ON SAND TRANSPORT

BY SIZE FRACTION IN THE LOWER MISSISSIPPI RIVER

Submitted by

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WE HEREBY RECOMMEND THAT THE DISSERTATION PREPARED UNDER OUR SUPERVISION BY SULEYMAN AKALIN ENTITLED "WATER TEMPERATURE EFFECT ON SAND TRANSPORT BY SIZE FRACTION IN THE LOWER MISSISSIPPI RIVER" BE ACCEPTED AS FULFILLING IN PART REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY.

Committee on Graduate Work

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Advisor

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Department Head

For my family members

Ibrahim, Karanfil, Adem, Ali, Ayhan and Aysel AKALIN

And my wife

Catherine Elizabeth Burns-Akalin

In consideration of love & affection

"Research is formalized curiosity. It is poking and prying with a purpose."

Zora Neale Hurston,

Novelist and folklore researcher

"You know when you think about writing a book, you think it is overwhelming. But, actually, you break it down into tiny little tasks any moron could do."

Annie Dillard,

Naturalist

"The Mississippi River is a wonderful book with a new story to tell every day."

Mark Twain,

Novelist

ABSTRACT OF DISSERTATION

"WATER TEMPERATURE EFFECT ON SAND TRANSPORT

BY SIZE FRACTION IN THE LOWER MISSISSIPPI RIVER"

Sediment transport characteristics in large alluvial rivers are influenced by many variables. In this study, the effects of water temperature on sediment transport by size fraction are investigated in the Lower Mississippi River. The flow and sediment data for this study were collected near the Old River Control Structures Complex (ORCC) on the Lower Mississippi River at water temperatures ranging from 9 ^{o}C to 31 ^{o}C in 1998. Velocity magnitude and direction data were obtained using an Acoustic Doppler Current Profiler (ADCP), which is an accurate, reliable and easy-to-use high-performance current profiler. The suspended sediment concentrations were measured using a U.S. P-63 suspended sediment sampler, which is a common depth-integrating, discharge-weighted sampler. Bed material gradation samples were obtained using a drag bucket, which collects samples from the top layer of the bed material.

First, the analysis of the effect of water temperature on the transport of sediment is investigated by considering the water temperature effect on both the vertical distribution of velocity profiles and the vertical distribution of suspended sediment concentrations. The analysis of the effect of water temperature on the vertical distribution of velocity profiles was based on the fact that water temperature changes both the viscosity of water, ν, and possibly the von Karman parameter, κ. The analysis of the effect of water temperature on the movement of sediment is made both directly and indirectly. In the direct analysis, the sediment concentration and transport values at

different water temperatures are compared. In the indirect analysis, the effect of water temperature on the main parameters affecting the sediment transport characteristics such as the von Karman parameter (κ), Rouse number (R_o), and reference sediment concentration (C_a) are observed first, then these effects are deployed into effects of water temperature on sediment transport.

Second, sediment transport was analyzed based on the comparison of the measured and calculated suspended sediment concentration profiles by size fractions. Rouse's suspended sediment distribution equation was used to calculate concentration values for comparison with the field measurements by size fractions.

Finally, the analysis of the effect of the Coriolis force on the flow direction was accomplished by investigating the relationship between the ratio of the Coriolis acceleration to the gravitational acceleration and the flow direction measurements.

The following conclusions were obtained:

1. A change in water temperature somewhat changes the vertical velocity profiles and definitely the vertical distribution of suspended sediment concentration; thus, the suspended sediment transport amount in the Lower Mississippi River. On average, a water temperature increase of 1 ^{o}C causes approximately a 3.09 percent decrease in the suspended sand transport. When the individual sand size fractions are considered, there are about a 2.79, 3.40, 1.42 and 1.49 percent decrease in the suspended very fine, fine, medium and coarse sand transport, respectively.
2. The average sediment concentration decreases with water temperature regardless of sediment size, but the sand concentration decreases more than the silt and clay concentration with the same range of water temperature change. While, on average,

suspended sand concentration decreases by approximately 2.00 percent, suspended silt and clay concentration drops off by only 0.35 percent with a 1 ^{o}C increase in water temperature. As far as the individual sand fractions are concerned, a change in water temperature influences the fine and very fine sand fractions the most. There is about 2.48 and 1.40 percent decrease in the suspended fine and very fine sand concentration, respectively, with a water temperature rise of 1 ^{o}C.

3. The reference sediment concentration near the riverbed is also affected by water temperature change. This conclusion mainly results from the analysis of the fine and very fine sand concentrations because the amounts of both the coarse and medium sand near the riverbed are relatively low. With a water temperature increase of 1 ^{o}C, there is about a 1.69 and 0.90 percent decrease in the fine and very fine sand concentrations near the riverbed, respectively.
4. Both the calculated and measured Rouse numbers are the same for very fine sand. As the sand size increases however, there is a difference between the calculated and measured Rouse numbers; the calculated Rouse number values being a lot higher than the measured ones for coarse sand. For example, the calculated Rouse number for coarse sand is approximately 6.5 times higher in February and 3.5 times higher in August than the measured Rouse number.
5. There is a water temperature effect on the flow characteristics, also. Flow velocity and the von Karman parameter decrease slightly with water temperature. While the flow velocity drops off by about 0.66 percent when the water temperature is increased by 1 ^{o}C, there is approximately a 2.17 percent rise in the von Karman parameter value in the main flow region as a result of the same range of water temperature increase.

6. There is no clear indication of whether the flow direction in the Lower Mississippi River is influenced by the Coriolis force or not. Although a theoretical analysis indicates that the Coriolis acceleration is not negligible compared to the downstream gravitational acceleration, the variability in the field measurements does not allow substantiating the theoretical results.

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LIST OF SYMBOLS

Symbol	Definition
α:	Coefficient with a value of 4 to 5
a:	Reference elevation or height
A:	Integration constant
A_f :	Cross-sectional area of the flow
a':	$\left[\dfrac{9.5\, u_*}{z_0^{1/6}}\right]$
a_C :	Coriolis acceleration
$a_{C,x}$:	Component of Coriolis acceleration in x direction
$a_{C,y}$:	Component of Coriolis acceleration in y direction
$a_{C,z}$:	Component of Coriolis acceleration in z direction
B:	Integration constant
β:	Turbulent Schmidt number
c:	Integration constant
C:	Suspended sediment concentration at an arbitrary elevation z
$\overline{C}$:	Mean sediment discharge concentration
C':	$18 \log(12\, h / 3\, d_{90})$
$\dfrac{dC}{dz}$:	Concentration gradient in the z direction
C_0 :	Maximum volumetric sediment concentration near the bed

$\overline{C_0}$: $[C(d_1)/2]\ [d_1/h_s]$

$C(d_i)$: Measured sediment concentration at the sampling points

c_1, c_2 : Constants

C_a : Reference concentration at $z = a$

C_{ae} : Equilibrium reference volumetric sediment concentration

C_D : Drag coefficient

$C_{h/2}$: Suspended sediment concentration at mid-depth

$C_{\max}$: Maximum suspended sediment concentration at a vertical

$\overline{C_{ss}}$: Average suspended sand concentration

C_V : Volumetric suspended sediment concentration

^{o}C : Temperature in Degrees Celcius

δ : Laminar sublayer thickness, $11.6\,\nu / u_*$

Δ : Dune height

d_{50} : Median particle diameter

d_{65} : Particle size by which 65 percent by weight of sediment is finer

d_{90} : Particle size by which 90 percent by weight of sediment is finer

d_s : Particle diameter or size

d_* : Dimensionless particle diameter, $d_{50}\left((\rho_s - \rho)g / \rho\,\nu^2\right)^{1/3}$

ε_m : Momentum exchange coefficient

ε_s : Sediment mixing coefficient

exp :	Base of the natural logarithm
e_Q :	Discharge exponent
e_T :	Temperature exponent
f :	Coriolis parameter
F :	Longitudinal force
F_C :	Coriolis force
f_f :	Friction factor
F_g :	Gravitational force
Φ :	Latitude
^{o}F :	Temperature in Degrees Fahrenheit
g :	Gravitational acceleration
G :	Specific gravity, $\frac{\gamma_s}{\gamma}$
γ :	Specific weight of water
γ_s :	Specific weight of sediment particles
Γ :	$(\tau_b' - \tau_{b,cr}) / \tau_{b,cr}$
h :	Flow depth
h_s :	Maximum sampling depth
i :	$\frac{\omega}{\varepsilon_s}(z-a)$
i, j, k :	Direction vectors in the x, y, and z directions, respectively
k :	Parabola constant

κ : von Karman parameter

κ_0 : Universal von Karman constant (= 0.4)

k_s : Characteristic bed roughness height

ℓ_m : Prandtl's mixing length

m : Slope of the semi-logarithmic velocity profiles

μ : Dynamic viscosity of water

n_v : $0.1198+0.00048T$, where T is the water temperature in ^{o}F

ν : Kinematic viscosity of water

ν_m : Kinematic viscosity of sediment-water mixture

ω : Fall velocity of sediment particles

ω_0 : Fall velocity of sediment particles in a clear water

Ω : Angular velocity due to the Earth's rotation

P : Wetted perimeter of the river cross-section

π : 'Pi' constant (= 3.141592654)

Π : Wake strength coefficient

Q : Water discharge

q_s : Unit suspended sediment discharge

q_{ss} : Unit suspended sand discharge

r : Radius

R_h : Hydraulic radius

ρ : Density of water

ρ_s : Density of sediment particles

Re_p : Particle Reynolds number, $\dfrac{\omega\, d_s}{\nu}$

Re_* : Boundary Reynolds number, $\dfrac{u_*\, d_s}{\nu_m}$

R_o : Rouse number, $\dfrac{\omega_0}{\kappa_0\, u_*}$

R_{om} : Measured Rouse number

R_{oc} : Calculated Rouse number

R_o': Corrected Rouse number

S_0 : Riverbed slope

$\overline{S_0}$: Average riverbed slope

S_p : Shape factor of sediment particles

T : Water temperature

τ : Shear stress at an elevation z

τ_0 : Bed shear stress

$\tau_{b,cr}$: Critical bed shear stress

τ_b': $\rho\, g(\overline{V}/C')^2$

u_* : Shear velocity

u_{*c} : Critical shear velocity

V_s : Velocity at the water surface

V_x : x-component of the flow velocity at an arbitrary elevation z

V_y : y -component of the flow velocity at an arbitrary elevation z

V_z : z -component of the flow velocity at an arbitrary elevation z

$\overline{V_x}$: Average flow velocity in the x direction

V_x': Turbulent velocity fluctuation in the x direction

V_z': Turbulent velocity fluctuation in the z direction

$\frac{dV_x}{dz}$: Velocity gradient in the z direction

V_{xm} : Maximum velocity over the flow depth in the x direction

x : Distance in the flow direction

X : Ratio of the Coriolis acceleration to the gravitational acceleration

ψ : Factor representing both the hindered settling effect and the turbulence damping effect

ξ Power constant for the suspended sediment distribution profile

z : Distance from the riverbed

z_0 : Distance from the boundary where the velocity is zero

ABBREVIATIONS

ADCP	Acoustic Doppler Current Profiler
CS	Coarse Sand
Eq.	Equation
FS	Fine Sand
LMR	Lower Mississippi River
MRC	Mississippi River Commission
MR&T	Mississippi River and Tributaries
MS	Medium Sand
NOD	New Orleans District
ORCC	Old River Control Complex
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey
VCS	Very Coarse Sand
VFS	Very Fine Sand
WES	Waterways Experiment Station

Chapter 1. INTRODUCTION

Historical records of ancient civilizations, such as China, Egypt, and Mesopotamia, show that people have always been subjected to both the beneficial and harmful influences of sedimentation. Seasonal floods provide rich silt deposits, moisture and soil nutrients necessary for agricultural productivity, but erosion may cause damages to agricultural land by reducing the fertility and productivity of soils. The quality of water and its suitability for consumption may be seriously affected by the presence of sediment in water. The deposition of sediment in stream channels and hydraulic and general-purpose structures reduces the flood-carrying capacity of stream channels, damaging the structures or increasing the maintenance cost for these structures.

In spite of the fact that sediment flow has always significantly affected the development of civilizations, the process of sediment flow was not investigated until relatively recent times. Although much progress has been made, many of the variables and parameters governing the transport and deposition characteristics of sediment are in need of research. The knowledge of the sediment flow process is necessary to understand the underlying causes and effects of fluvial sediment, and to find feasible solutions to the sediment problems. There is also a need for a well-organized data collection program and a good river engineer who should have a broad understanding of river morphology to estimate the long-term effects of natural or man-made changes to a river.

Any change, whether natural or human-induced, in the hydrologic, hydraulic, climatic, vegetative, geologic, or topographic characteristics of a drainage basin can cause rivers (or some reaches of rivers) to lose equilibrium. In most alluvial rivers, such changes occur continually; therefore, to transport sediment with maximum efficiency, the channel always tries to adjust itself to these changes by changing its position, shape, dimension, and pattern (i.e., degradation, aggradation, meandering, or braiding). By means of such adjustments, a stream tends toward a certain hydraulic geometry and slope.

The vertical distribution of the suspended sediment concentration takes much attention of the scientists in the world because of its importance in estimating the river sediment load, in modeling natural channels, and in improving the sampling procedure. The study of flow direction change in rivers is also important to understand the rivers' morphologic changes. The problem of the vertical distribution of suspended sediment concentration, like many other engineering problems, has been studied by empirical methods in order to develop working formulas for field measurements. However, it is not appropriate to expect that such formulas will be universally applicable, considering that it is almost impossible to study enough field data to establish a truly general law. In recent years great progress has been made in studying the problem of suspended sediment transportation by using the knowledge of turbulent transport mechanism. A good suspended sediment transport theory should use the knowledge of the mutual interaction of suspended particles and the turbulence required to agitate the particle motion.

Variables affecting the suspended sediment concentration or transport and the flow direction are numerous and interrelated. The major factors affecting the suspended sediment transport and flow direction are stream discharge, vertical distribution of the velocity profile, flow depth, sediment and fluid characteristics, sediment load, longitudinal riverbed slope, bank and bed resistance to flow, vegetation, climate, geology, and man-made works.

Other variables affecting the suspended sediment concentration or transport, and flow direction are water temperature, particle size fraction, and Coriolis force. It is very well known that a change in one characteristic of water brings about changes in other characteristics. Because the flow in natural channels includes both water and sediment, any change in water or sediment characteristics will probably cause some changes in water and sediment flows in rivers.

It is proved by many theoretical and experimental investigations that a change in water temperature affects some characteristics of water such as viscosity and density, thereby affecting some sediment characteristics such as the settling velocity of sediment particles. Of course, any change in sediment properties finally brings about changes on the suspended sediment concentration and transport. It was known that the original path of any mass (i.e., oceanic currents and air flow in atmosphere) moving at the surface of the Earth is deflected due to the Coriolis effect resulted from the rotation. Therefore, one would expect that the Coriolis force would deflect the path of water flows in large rivers.

The water temperature influence on some characteristics of alluvial rivers such as sediment transport rate, bed configuration, and stage-discharge relations, has been studied by various investigators (see section 2.4 in Chapter 2). The studies were done in both experimental streams and natural rivers, more specifically the Lower Mississippi, the Lower Colorado, and the Missouri Rivers. In most of these studies, large changes in sediment discharge have been observed with water temperature changes. Even though there is a common understanding of the effect of the water temperature, we still don't have complete knowledge about how the water temperature affects suspended sediment concentration and transport and what the degree of the effect is.

The main objective of this study is two-fold: to examine the water temperature effect on the vertical distribution of suspended sediment concentration and suspended sediment transport by size fraction, and to explore the Coriolis effect on flow direction. More specifically, the effect of water temperature on the parameters affecting the vertical velocity profile (i.e., the von Karman constant) and the vertical distribution of suspended sediment concentration (i.e., the von Karman constant and Rouse number) are investigated.

To achieve the afore-mentioned objectives, the field sediment and flow data collected on the Lower Mississippi River at a reach near the Old River Control Structures Complex (see Figure 1.1) in 1998 were used. Only four locations (or cross-sections), namely Union Point, Line 13, Line 6, and Tarbert Landing, are considered because of the appropriateness of the data for this study. In each cross-section there are four equally spaced verticals, at which the data collection was performed. Seven flow events in the time period of about seven months (February through August) were observed.

The following main features about the study area and the nature of the data make this study unique. These features also indicate that the study conducted herein is a good representation of the effect of water temperature on the suspended sediment concentration and transport.

- Acoustic Doppler Current Profiler (ADCP) is used to collect velocity profile data. The quality, quantity, accuracy, and reliability of data collected using ADCP are much better than those obtained by traditional or conventional techniques. Because high resolution and accuracy are important in sediment transport as a result of the complex nature of the transport phenomena, it is important to use acoustic methods to collect flow data. Obviously, increased quality and quantity of data lead to better conclusions in analyses related to sediment transport.

- The data come directly from a large natural river, instead of a laboratory flume. Flow conditions in a natural stream may be considerably different from those in a flume. Natural streams are generally unsteady and non-uniform. Most of the time, laboratory experiments are performed by restricting the flow conditions, and may poorly represent some natural conditions. Therefore, the results obtained examining the natural river data may be a better representation of the natural conditions and may produce more reliable and accurate results.
- The effort spent on collection of data is also very crucial. The river reach studied has been investigated thoroughly because of the importance of the site. This condition creates more thorough data collection procedure, which leads to better data.
- One of the data collection stations (Tarbert Landing) in the study reach is considered to be the one of the best stations throughout the Lower Mississippi River. This has also increased the quality of the data.
- Short-term changes in suspended sediment concentrations in the study reach are the result of the deposition of sediment during low flows and re-suspension during high flows. There are no dams or other structures obstructing the reach, no tributaries bringing in sediment to the reach, and no uncontrolled outlets draining sediment away from the reach.

The analysis will indicate that water temperature can have a significant effect on the vertical distribution of suspended sediment concentration and suspended sediment transport. Large changes in the suspended fine sand (0.125-0.25 mm in size) discharges have been observed with a water temperature. However, the analysis shows inconsistent effect of the Coriolis force on flow direction. Although some findings demonstrate directly proportional effect, some others show the opposite or inverse proportional effect.

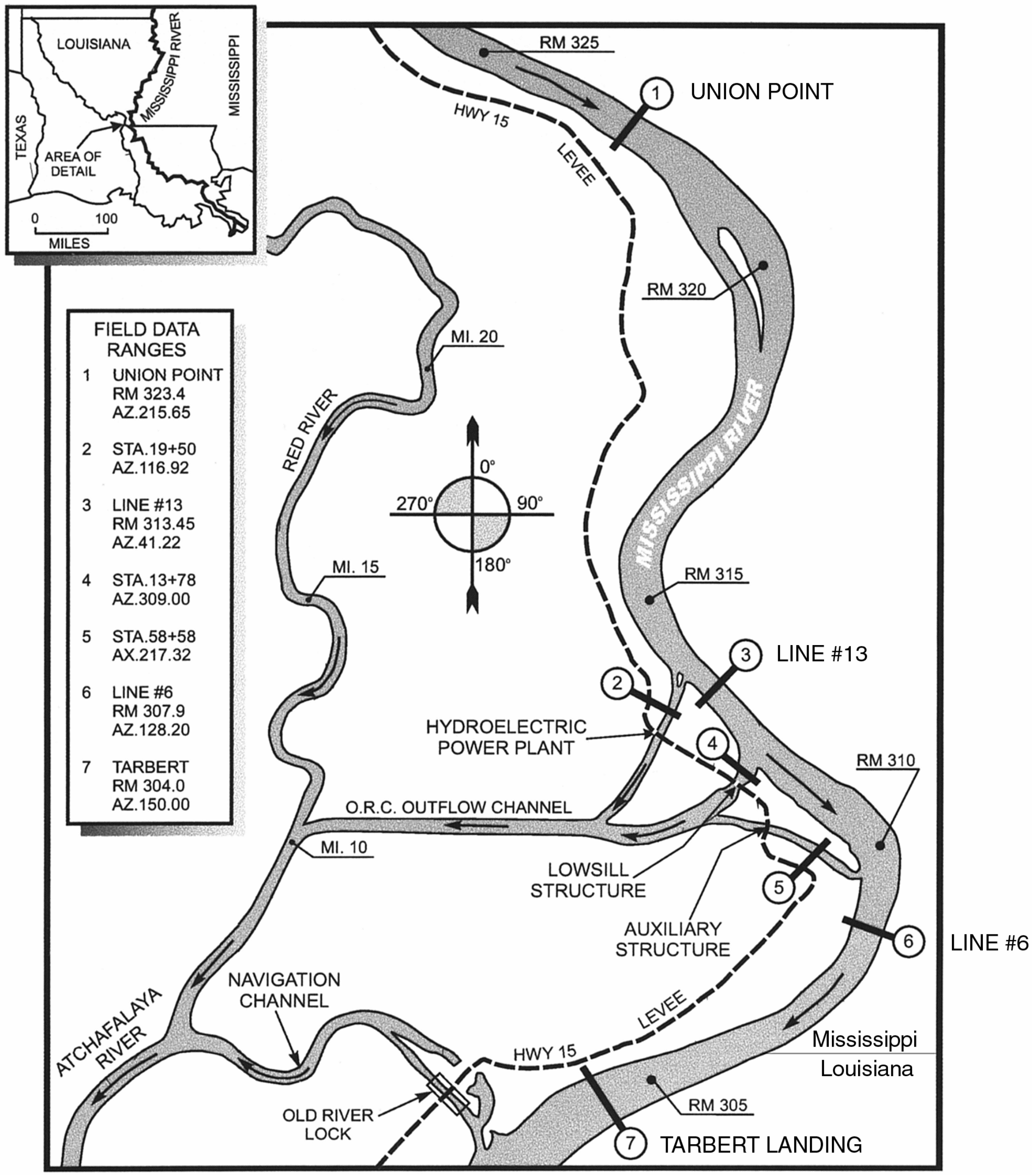

Figure 1.1. Plan view of the study reach on the Lower Mississippi River.

Chapter 2. LITERATURE REVIEW

This chapter provides the literature review of the studies on the turbulent velocity profiles in section 2.1; studies on the vertical distribution of suspended sediment concentration in section 2.2; studies on the water temperature effect on the suspended sediment concentration and transport in section 2.3; and studies on the Coriolis effect on flow direction in section 2.4. All studies are presented in chronological order with occasional exceptions.

2.1. STUDIES ON TURBULENT FLOW VELOCITY

Many equations for the velocity profiles for turbulent flows in pipes and open channels have been proposed. There have been different forms of the velocity profile, such as logarithmic, exponential, elliptical, and parabolic. In general, velocity profile equations were classified into three categories. The first was the group of equations that are based on the logarithmic law. For example, the equations derived by Prandtl and von Karman in the 1920s and 1930s, and Einstein and Chien in 1954 are in this first category. The second one was the group of equations that are purely based on empiricism. The power law was included in this second category. The third one was the group of equations involving the wake flow function above the turbulent boundary layer, such as the equations derived by Coles in 1956 and Coleman in 1981, whose derivations were based on the fact that the entire flow region in a turbulent open channel flow is composed of the turbulent boundary layer near the bed where the flow is influenced by the boundary, and the outer flow region in which the wake flow dominates with the negligible boundary effect.

2.1.1. Flow Velocity Equations Based on the Logarithmic Law

The Prandtl mixing length theory in 1925 and the von Karman similarity hypothesis in 1930 set the origin of the logarithmic velocity distribution laws in open channels and pipes.

Ludwig Prandtl was the first to come up with a satisfactory theory explaining turbulent characteristics in fluid flow. Prandtl in 1925 assumed that the motion of fluid particles in a turbulent flow is similar to the molecular motion of a gas; that is, fluid particles travel through a distance perpendicular to the mean flow velocity, which corresponds to the 'mean free path' of a gas molecule, and thus he established the mixing length theory for turbulent flows (Kundu, 1990).

Prandtl in 1926 assumed that the turbulent velocity fluctuations can be expressed in the following manner (Umeyama and Gerritsen, 1992):

$$V_x' = V_z' = \ell_m \frac{dV_x}{dz} \qquad \text{(Eq.2.1)}$$

where V_x' and V_z' are turbulent velocity fluctuations in the x and z directions, respectively, ℓ_m is the Prandtl mixing length, and $\frac{dV_x}{dz}$ is the velocity gradient in the z direction.

To find the velocity distribution near the wall, Prandtl derived an expression for the turbulent shear stress, τ, in a fluid moving past a solid wall as following:

$$\sqrt{\tau / \rho} = \ell_m \frac{dV_x}{dz} \qquad \text{or} \qquad \tau = \rho\, \ell_m^2 \left(\frac{dV_x}{dz} \right)^2 \qquad \text{(Eq.2.2)}$$

in which ρ is the density of the fluid.

By assuming $\tau = \tau_0$, $\ell_m = \kappa_0\, z$ and $u_* = \sqrt{\tau_0 / \rho}$, Prandtl in 1926 derived the following logarithmic velocity distribution near the wall (Coles, 1956).

$$\frac{dV_x}{dz} = \frac{u_*}{\kappa_0\, z} \qquad \text{(Eq.2.3)}$$

where $\tau_0 = \gamma\, h\, S_0$ is the turbulent shear stress at the riverbed, γ is the specific weight of the fluid, h is the flow depth, S_0 is the riverbed slope, and κ_0 is the universal von Karman constant in clear water with a value experimentally determined to be about 0.4.

H. Krey in 1927 proposed the following logarithmic velocity distribution relation for a moving fluid under the influence of gravity in a turbulent condition (Vanoni, 1975):

$$\frac{V_x}{V_{xm}} = \frac{\ln\left(1+\frac{z}{a}\right)}{\ln\left(1+\frac{h}{a}\right)} \quad \text{(Eq.2.4)}$$

where V_{xm} is the maximum velocity over the flow depth, and a is a small distance from the channel bottom.

Theodor von Karman in 1930 introduced his famous similarity hypothesis, which stated that turbulence phenomena are not affected by viscosity except in a region near the pipe wall, and the turbulence patterns at different positions are similar. Based on his similarity hypothesis, von Karman derived the following expression for the mixing length (Chien and Wan, 1999):

$$\ell_m = \kappa_0 \frac{dV_x / dz}{d^2V_x / dz^2} \quad \text{(Eq.2.5)}$$

in which κ_0 is the universal von Karman constant, which doesn't vary with discharge, velocity or boundary conditions, and is equal to 0.4 based on von Karman's observations in pipe flows. Von Karman discovered that κ_0 is independent of the nature of the wall, whether smooth or rough.

By utilizing Eq.2.5 and assuming the constant shear stress distribution ($\tau = \tau_0$), von Karman obtained the same equation derived by Prandtl in 1926 (Eq.2.3), but when the linear shear distribution ($\tau = \tau_0 \, (1 - z/h)$) was assumed, he obtained the following logarithmic velocity distribution (known as the von Karman's velocity defect law):

$$\frac{V_{xm} - V_x}{u_*} = -\frac{1}{\kappa_0}\left\{\left(1-\frac{z}{h}\right)^{1/2} + \ln\left[1-\left(1-\frac{z}{h}\right)^{1/2}\right]\right\} \qquad \text{(Eq.2.6)}$$

in which V_{xm} is the maximum velocity value attained at a vertical, which was obtained at the water surface, $z = h$.

In 1932, Prandtl and von Karman obtained the following famous relationship for the velocity distribution in the neighborhood of a solid wall (Bakhmeteff, 1941):

$$\frac{V_x}{u_*} = \frac{1}{\kappa_0}\ln\left(\frac{z}{z_0}\right) \qquad \text{(Eq.2.7)}$$

where $u_* = g\ h\ S_0$ is the friction velocity, and z_0 is the integration constant and depends on the bottom roughness scale.

Nikuradse (1933) gave the following expressions for hydrodynamically smooth and fully rough turbulent flows:

$$\frac{V_x}{u_*} = A\ln\frac{u_*\ z}{\nu} + B \quad \text{(hydrodynamically smooth)} \qquad \text{(Eq.2.8)}$$

$$\frac{V_x}{u_*} = A\ln\frac{z}{k_s} + B \quad \text{(hydrodynamically rough)} \qquad \text{(Eq.2.9)}$$

in which A and B are the integration constants, and k_s is the Nikuradse's original uniform sand grain roughness, which represents the equivalent sand roughness for any type of rough surface and is equal to the mean fall diameter, d_{50}, for a plane non-moving sand bed. After performing some experiments using sand-coated circular pipes, Nikuradse has shown that $A = 2.5$ (being independent of the form of the roughness), and $B = 5.5$ for hydraulically "smooth" pipe flow and $B = 8.5$ for hydraulically "rough" pipe flow.

Prandtl and von Karman in 1934 independently obtained their velocity defect relation in the following form (Prandtl-von Karman velocity defect law), considering that Eq.2.7 is sufficiently accurate for large values of z (Bakhmeteff, 1941):

$$\frac{V_x - V_{xm}}{u_*} = \frac{1}{\kappa_0} \ln\left(\frac{z}{h}\right) \tag{Eq.2.10}$$

Keulegan (1938) assumed that in the plane normal to the boundary of any open channel shape, the velocity distribution for fully developed turbulent flow derived by Nikuradse could be used.

An equation was developed by Einstein and Chien (1954) for vertical velocity distribution over alluvial beds by including the sediment particles in the exchange mechanism. Einstein's equation based on experimental approximation is given as follows:

$$\frac{V_x}{u_*} = 17.4 + \frac{2.3}{\kappa_0} \ln\left(\frac{z}{35.45\, k_s}\right) \tag{Eq.2.11}$$

where k_s is the characteristic bed roughness height and defined by Einstein as: $k_s = d_{65}$

in which d_{65} corresponds to the particle size for which 65 percent by weight of sediment is finer. Eq.2.11 is valid only in the main flow zone (light fluid zone).

Experimental evidence presented by Vanoni and Nomicos (1960) illustrated that, for the same discharge, the average velocity for sediment-laden flow is larger and the velocity distribution is less uniform than for the clear-water flow, as shown in Figure 2.1.

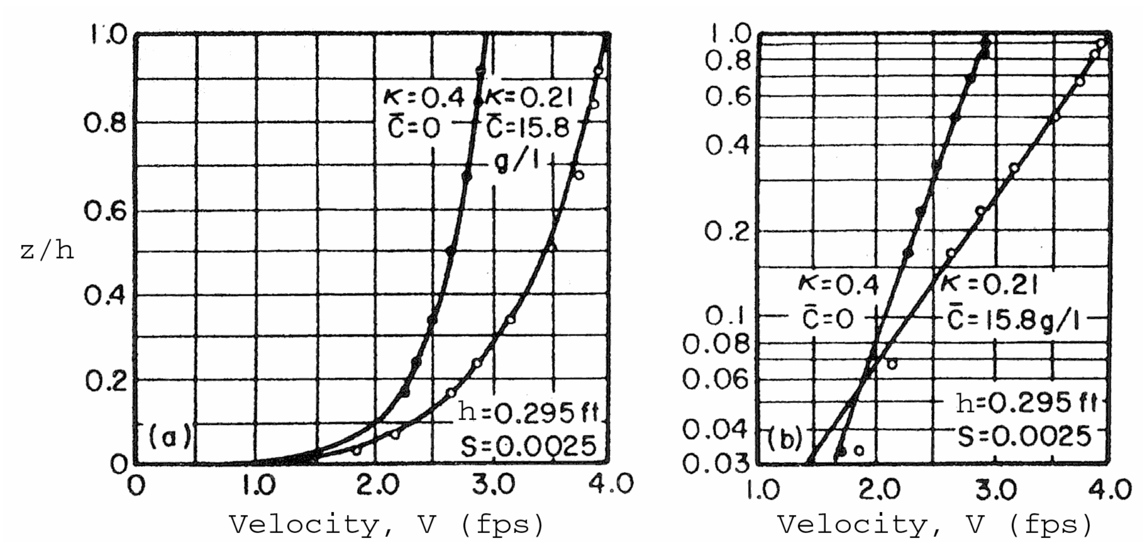

Figure 2.1. Comparison of velocity profiles for clear-water flow and sediment-laden flow (Vanoni and Nomicos, 1960).

After some experiments, Elata and Ippen (1961) showed that the velocity profile follows the logarithmic formula for clear-water flow, whereas in flow with uniformly distributed suspended particles, the velocity profiles deviate from the logarithmic formula near the bed. They also realized that the range in which the velocity profiles deviate from the logarithmic formula became bigger with higher concentration.

2.1.2. Flow Velocity Equations Based on the Power Law

Dobbins (1944) derived the following velocity equation by assuming that the velocity distribution follows a parabolic law:

$$V_x = V_s - k\,(h - z)^2 \qquad \text{(Eq.2.12)}$$

in which V_s is the velocity at the surface and k is the constant of the parabola.

Dobbins further explained that although both the logarithmic and power laws fit equally well to the velocity distribution in sediment-laden flow, the power law avoids the singularity at the boundary obtained by the logarithmic law and is more convenient for mathematical treatment.

In a procedure for an analytic determination of sand transport, Toffaleti (1968) derived the following power relation for the velocity profile:

$$V_x = (1 + n_v)\,\overline{V_x}\left(\frac{z}{R_h}\right)^{n_v} \qquad \text{(Eq.2.13)}$$

where $\overline{V_x}$ is the mean stream velocity, in feet per second, $R_h = A_f / P$ is the hydraulic radius and defined as the ratio of the flow area of stream (A_f) to the wetted perimeter of the stream cross-section (P), and $n_v = 0.1198 + 0.00048\,T$ in which T is the water temperature in degrees Fahrenheit.

After a theoretical study of the difference between the logarithmic velocity distribution and the power velocity distribution, Wooding et al. in 1973 found that the power law with a small exponent could not be distinguished experimentally from the logarithmic law. This finding in fact restates Schlichting's conclusion in 1968 that the logarithmic velocity distribution is applicable for large Reynolds numbers, whereas the power velocity distribution is applicable for small Reynolds numbers (Chen, 1991).

Cheng-lung Chen in 1988 showed that the power-law equivalent of Manning's formula for open channels of steady, uniform turbulent flow could be written in the following form (Chen, 1989):

$$\frac{V_x}{u_*} = 9.5\left(\frac{z}{z_0}\right)^{1/6} = a'\,z^{1/6} \qquad \text{(Eq.2.14)}$$

where $a' = \left[\frac{9.5\,u_*}{z_0^{1/6}}\right]$, and z_0 is the characteristic distance from the wall and can be determined empirically.

2.1.3. Flow Velocity Equations Based on the Wake Flow Function

After some measurements in the wholly turbulent flow region some scientists, such as Clark B. Millikan in 1939, and Hans A. Einstein and Ning Chien in 1954, have proved that the stream flow was composed of two regions in the vertical: an inner region near the wall and an outer region away from the wall (Umeyama and Gerritsen, 1992).

Millikan (1939) realized that the logarithmic velocity equation described the actual velocity distribution well in the inner region near the wall, whereas the experimental data deviated from the logarithmic equation in the outer region. Millikan suggested in a discussion on turbulent flows that the actual velocity distribution in the outer region might consist of two parts: namely, a logarithmic part and a correction part.

Sediment-laden flow was divided into two zones by Einstein and Chien (1954): a heavy fluid zone near the bed where the sediment is highly concentrated, and a light fluid zone away from the bed where the sediment concentration is so small that the fluid density remains unchanged. They stated that in the heavy fluid zone the work required to keep sediment grains in suspension must be gained from the vertical components of turbulent fluctuations, which leads to the dampening of turbulence. Moreover, Einstein and Chien (1955) discovered that the sediment-laden flow has steeper average velocity gradients than the clear-water flow for the same depth, slope and bed composition.

By utilizing Millikan's idea in 1939, Coles (1956) proposed that the velocity profile could be represented by the combination of the law of the wall and the law of the wake. Coles developed the following semi-empirical equation for the velocity distribution applicable to turbulent boundary layer flows, and suggested that the following equation is useful for practical applications:

$$\frac{V_x}{u_*} = \frac{1}{\kappa_0} \ln \frac{u_* z}{\nu} + c + \frac{\Pi}{\kappa_0} f\left(\frac{z}{\delta}\right) \qquad \text{(Eq.2.15)}$$

where c is the integration constant which was assumed to be 5.1, Π is a profile parameter related to a local friction coefficient and was found to be 0.55 with $\kappa_0 = 0.4$ and $c = 5.1$, and $f\left(\frac{z}{\delta}\right)$ is the wake function, the values of which was given according to some experimental data, and δ is the thickness of the shear flow (or laminar sublayer thickness) and was first formulated by von Karman as: $\delta = \frac{11.6\, \nu_m}{u_*}$. Coles empirically defined the wake function for zero pressure gradient or equilibrium boundary layers as: $f\left(\frac{z}{\delta}\right) = 2\sin^2\left(\frac{\pi}{2}\frac{z}{\delta}\right)$.

By applying the law of the wall to the inner region of the boundary layer on a rough surface, J. Rotta in 1962 derived the following velocity distribution, assuming that there is a velocity reduction across the viscous sublayer because of the rough surface (Kirkgoz, 1989):

$$\frac{V_x}{u_*} = \frac{1}{\kappa_0} \ln \frac{u_*\,(z + \Delta z)}{\nu} + B - \frac{\Delta V_x}{u_*} \qquad \text{(Eq.2.16)}$$

in which ΔV_x is the change in the velocity in the viscous sublayer corresponding to the Δz reference shift from the top of average roughness height, and B is a constant whose value depends on the nature of the wall surface.

Coleman (1981) proposed that the velocity equation for a sediment-laden flow also consists of a logarithmic velocity distribution extended by an additive term, as originally discussed by Coles in 1956 for clear-water flow. By combining and rearranging the equations derived by Coles in 1956 and Rotta in 1962, Coleman obtained the following expression for the velocity defect law:

$$\frac{V_{xm}-V_x}{u_*}=\left\{\left[-\frac{1}{\kappa_0}\ln\frac{z}{\delta}\right]+2\frac{\Pi}{\kappa_0}\right\}-\frac{2\,\Pi}{\kappa_0}\sin^2\left(\frac{\pi}{2}\frac{z}{\delta}\right) \qquad \text{(Eq.2.17)}$$

Eq.2.17 represents the entire velocity profile up to $z=\delta$, except for the viscous sublayer. In Eq.2.17 the part in square brackets is the original form of the Prandtl-von Karman velocity defect law. Coleman suggested that the von Karman constant, κ_0, must be evaluated from a straight line fit to the experimental velocity profiles only at low values of z/δ (lower 15 percent of the flow), and the values for Π can be evaluated from the intercept of the projected line fit at $z/\delta=1$ as following:

$$\Pi=\frac{\kappa_0}{2}\left[\frac{V_{xm}-V_x}{u_*}\right]_{z/\delta=1} \qquad \text{(Eq.2.18)}$$

In his investigation, Coleman came up with the result that κ_0 is essentially equal to 0.4, and is independent from the suspended sediment concentration, by knowing that other influences such as bedforms are more significant. Figure 2.2 shows clearly how to evaluate κ_0 and Π from the experimental velocity distributions.

Lau (1983) confirmed Coleman's finding on the basis of the flow-resistance concept, showing that the velocity is lower near the bed and higher near the water surface for sediment-laden flow than for clear-water flow for a given discharge and slope.

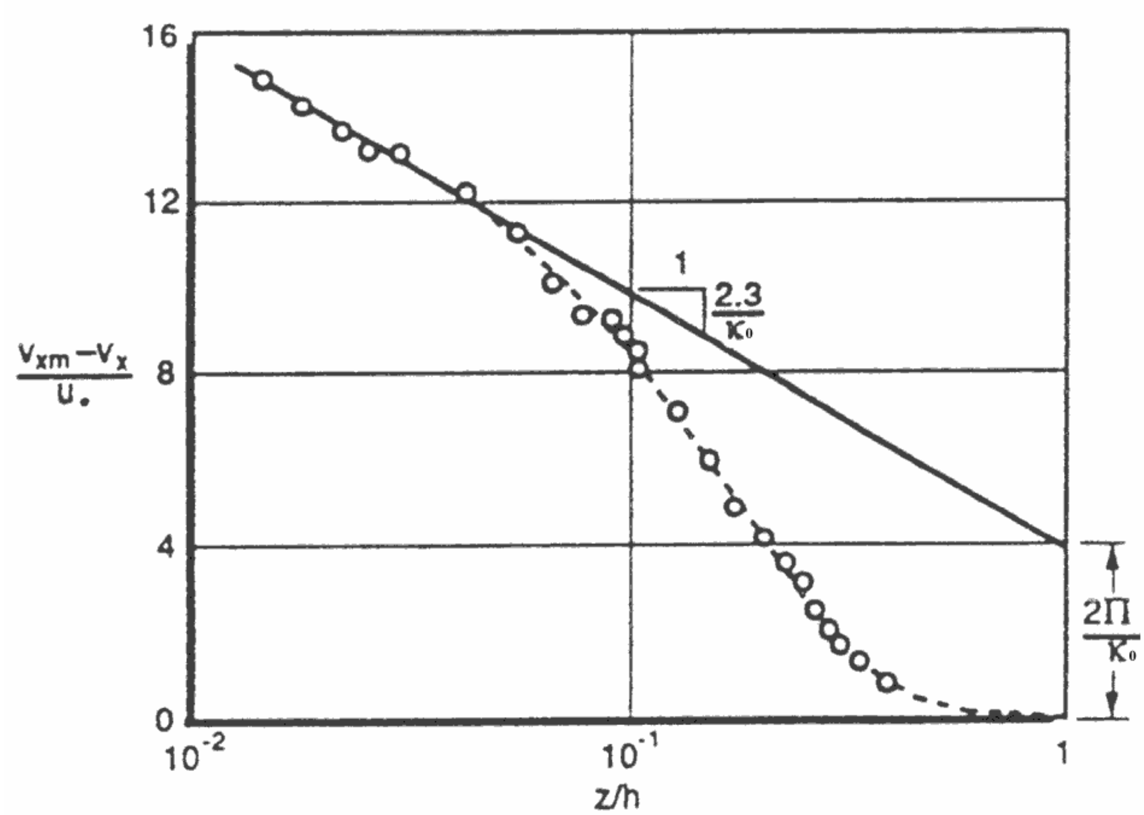

Figure 2.2. Evaluation of κ_0 and Π from the velocity defect law (Julien, 1995).

2.2. STUDIES ON VERTICAL DISTRIBUTION OF SUSPENDED SEDIMENT CONCENTRATION

In 1851, C. G. Forshey showed in his field measurements on the Mississippi River that more suspended sediment load moves closer to the bottom than to the top. About 14 years after Forshey, in 1865, Dupuit constructed the first physical model to explain why flowing water was able to carry solid particles in suspension. He believed that the reason for suspension of particles was the magnitude differences in the velocities of adjacent layers, and the reason for sediment settlement was the fall velocity of the sediment particles. He also discovered that the power of suspension depended on solid-liquid concentration, and the velocity. However, Dupuit failed to explain the interdependence of the velocity gradient and the suspension capacity of a stream. According to P. Jakuschoff in 1932, H. L. Partiot and C. Lechalas in 1871 were the first to explain that velocity fluctuations and bed roughness create vortices and eddies in the river, and thus the sediment particles become suspended (Graf, 1984).

The first quantitative study on the suspended load was done by R. G. Kennedy in 1895, who made observations at irrigation canals in India. In this study, Kennedy discovered that sediment in a flowing canal was kept in suspension because of the vertical components of eddies or vortices created at the bottom of the canal (Burke, 1966).

In 1925, Wilhelm Schmidt introduced a basic concept of turbulent suspension by developing a formula for the vertical transfer of dust particles in the atmosphere by atmospheric turbulence as follows (Taggart et al., 1972):

$$\omega C = -\varepsilon_s \frac{dC}{dz} \qquad \text{(Eq.2.19)}$$

where ω is the fall velocity of dust particles, C is the volumetric concentration of dust particles at a given elevation z, ε_s is the mixing coefficient for dust particles, which has the dimension of velocity times length, and dC/dz is the concentration gradient of dust particles in the z (vertical) direction.

The first term in Eq.2.19 indicates the mass rate of settling of the particles under the force of gravity, and the second one shows the rate of upward movement resulting from turbulence mixing. Schmidt derived Eq.2.19 for the equilibrium condition of the dust particles in the atmosphere; that is, the net convection resulting from turbulence is equal to the settling rate of the dust particles resulting from gravity (Taggart et al., 1972). Schmidt's concept of turbulent suspension in 1925 set the fundamentals of the diffusion theory.

Schmidt was also apparently the first to give the sediment distribution equation, which was applied to the suspension of dust particles in the atmosphere. Schmidt derived the following equation by assuming that the mixing coefficient is constant in the vertical direction in the atmosphere (Vanoni, 1946):

$$\frac{C}{C_a} = \exp[-i] \qquad \text{(Eq.2.20)}$$

in which C_a is the reference concentration at some reference depth, $z = a$, "exp" is the base of the natural logarithm, and $i = \frac{\omega}{\varepsilon_s}(z - a)$.

Makkaveev (1931) and O'Brien (1933) applied Schmidt's theory to the distribution of suspended sediment load in flowing water. O'Brien was the first to apply Schmidt's theory to suspended sediment in streams by integrating Eq.2.19 (Kalinske and Hsia, 1945). O'Brien (1933) also wrote a paper stating that there is a certain ratio of the mean amount of the substance transferred and the gradient of its content in turbulent flows.

Rouse (1937) was the first to derive and publish a theoretical formula for the suspended sediment distribution in turbulent streams based on Schmidt's diffusion theory, as given below:

$$\frac{C}{C_a} = \left[\frac{h-z}{z}\frac{a}{h-a}\right]^{R_o} \qquad \text{(Eq.2.21)}$$

in which C_a is the concentration at the reference level, $z = a$, R_o is the Rouse number and expressed as: $R_o = \dfrac{\omega_0}{\kappa_0\ u_*}$ in which ω_0 is the settling velocity of sediment particles in clear-water, κ_0 is the universal von Karman constant and equal to 0.4 for clear-water flow, and u_* is the shear (or friction) velocity and defined as: $u_* = \sqrt{g\ h\ S_0}$ where g is the gravitational acceleration, h is the flow depth, and S_0 is the riverbed slope.

To derive Eq.2.21, Rouse assumed that the coefficients for sediment mixing, ε_s, and momentum diffusion, ε_m, are the same with parabolic distribution assumption, and the shear stress distribution, τ, decreases linearly with distance z as given below:

$$\varepsilon_s = \varepsilon_m = \kappa_0\ u_*\ z\left(1-\frac{z}{h}\right) \qquad \text{(Eq.2.22)}$$

$$\tau = \tau_0\left(1-\frac{z}{h}\right) \qquad \text{(Eq.2.23)}$$

in which τ_0 is the boundary shear stress and expressed as: $\tau_0 = \rho\, u_*^2$ in which ρ is the density of water.

It was observed by Y. F. Richardson in 1937 that the suspended sediment concentration near the bed of a channel is inversely proportional to the distance from the bed, whereas the concentration in the main body varies exponentially with distance from the bed (Vanoni, 1946).

Vanoni (1941) and Anderson (1942) found that the exponential form of the sediment concentration profile given by Rouse (Eq.2.21) is satisfactory and could be used for practical purposes provided that an appropriate value of the exponent R_o is chosen. They concluded that R_o should be determined from measured data, not from the expression, $\dfrac{\omega_0}{\kappa_0\, u_*}$. Anderson also pointed out the need for further study into the mechanism of transfer in natural streams to predict R_o accurately.

Kline et al. (1967) gave a detailed description of the streaky nature of the flow structure in the viscous sublayer on a smooth wall with its alternating narrow, elongated zones of high and low velocity occurring randomly in time and space. This sublayer flow pattern appears to result from counter rotating streamwise vortex pairs. They linked the sublayer structure to the bursting process, which they described as a randomly occurring event comprising gradual local lift up of the low speed streaks, sudden oscillation, bursting, and ejection. This event is followed by an inrush or sweep event described by Grass (1971) based on observations from similar visualization studies of the boundary layer flow structure. Grass also observed that the bursting phenomenon appeared to influence the entire depth of the boundary layer (Grass, 1982).

Data from laboratory flumes, irrigation canals, and natural streams were analyzed by Paintal and Garde (1964) to compare Rouse's suspended sediment concentration equation (Eq.2.21) with others. They reached the conclusion that although some equations fitted the data equally well, Rouse's equation was preferable because of its simpler form.

Coleman (1969) suggested that a flow with suspended sediment could be divided into two regions: an inner suspension region near the bed and an outer suspension region in the free stream. After an extensive analysis of both flume and stream data, Coleman discovered that the ratio ε_s / ω_0 in the inner region is different from that in the outer region. Based on his analysis, Coleman assumed the ratio ε_s / ω_0 varies linearly with z in the inner region and is constant in the outer region, and derived the following concentration distribution equations for both regions:

$$\frac{C}{C_a} = \frac{a}{z} \qquad \text{(in the inner region, } z < a\text{)} \qquad \text{(Eq.2.24-a)}$$

$$\frac{C}{C_a} = \exp\left[-\frac{\omega_0}{\varepsilon_s}(z-a)\right] \qquad \text{(in the outer region, } z > a\text{)} \qquad \text{(Eq.2.24-b)}$$

Coleman recommended that these equations are supposedly universal relative concentration functions for the inner and outer suspension regions.

The experiments of Ikeda (1980) provided some information on the influence of bedforms on the mixing processes. In his experiments, Ikeda found that there is more intensive mixing as a result of the presence of bedforms. Another remarkable phenomenon observed by Ikeda was the increase of the sediment concentrations by a factor of 10, as the bedforms became 3-dimensional, whereas the bed-shear velocity remained nearly constant.

Different theories for the vertical distribution of suspended sediment concentration with measurements from the Rhine River were compared by Vetter (1986). He realized that Rouse's classical solution of the diffusion theory agrees well with measurements for fine size fractions ($d_s \leq 0.125\, mm$), but gets progressively worse for coarser particles.

Van Rijn (1986) concluded that there is a large influence of the bedforms on the mixing process, yielding more uniform concentration profiles for a rippled bed than for a flat bed at the same ratio of the particle fall velocity and bed shear velocity, and the magnitude of the concentration was largely increased in the presence of bedforms.

Cao et al. (1996) explained that the bursting process is responsible for the suspension of sediment particles; therefore, a physically more appealing approach to suspended sediment transport is to formulate the diffusion coefficient of sediment, ε_s, based on this mechanism.

Now, it is obvious that most researchers agreed on Rouse's equation being a close representation of the form of the real suspended sediment distribution profiles; however, certain modifications to Rouse's equation were needed to evaluate the suspended sediment discharge accurately. From this general idea many scientists have tried to find different methods to calculate or estimate the parameters involved in Rouse's equation. The most common parameters subject to investigation or modification included the reference suspended sediment concentration, C_a; the Rouse number, R_o; the fall (settling) velocity, ω_0; the Schmidt's parameter, β; and the von Karman constant, κ_0. The following sections provide studies on the afore-mentioned parameters briefly.

2.2.1. Studies on Reference Suspended Sediment Concentration, C_a

Most of the suspended sediment distribution equations derived were written in terms of the concentration at an arbitrary level near the bed, C_a. To calculate the suspended sediment discharge it was necessary to obtain this reference concentration. The idea of using a reference sediment concentration as a boundary condition occurred just after the introduction of the diffusion theory by Wilhelm Schmidt in 1925. The solution of the diffusion theory with certain assumptions resulted in a suspended sediment distribution equation, which depended on a reference concentration, C_a, at a reference height, a, close to the riverbed.

Von Karman (1934) was the first to speculate about the parameters influencing the reference concentration, C_a. He stated in his paper that the magnitude of C_a depends on the sediment size and the magnitude of the shear stress acting on the bed.

Various reference heights were suggested phenomenologically rather than physically by Brooks (1965) and Willis (1979). They explained that the value of a is rather arbitrary, and none of the values explicitly explains satisfactorily the fact that a is different for a plane bed than for a dune bed.

Itakura and Kishi (1980) suggested an equation for the concentration of suspended sediment in which the reference concentration C_a is calculated from the flow data alone. M. F. Karim and J. F. Kennedy in 1983 implied that $a = d_{50}\, u_* / u_{*c}$, in which u_{*c} is the critical shear velocity (Bechteler, 1986).

Based on an analysis of sediment concentration profiles, van Rijn (1984) proposed a simple function, which can be used to specify an effective boundary concentration, C_{ae}, as the following:

$$C_{ae} = 0.015\, \frac{d_{50}}{a}\, \frac{\Gamma^{1.5}}{d_*^{0.3}} \qquad \text{(Eq.2.25)}$$

in which $\Gamma = (\tau_b^{'} - \tau_{b,cr}) / \tau_{b,cr}$, where $\tau_b^{'} = \rho\, g (\overline{V_x} / C^{'})^2$ with $\overline{V_x}$ being the depth-averaged velocity and $C^{'} = 18 \log(12\, h / 3\, d_{90})$, $\tau_{b,cr}$ is the critical bed-shear stress according to Shields, and $d_* = d_{50} \left((\rho_s - \rho) g / \rho\, \nu^2 \right)^{1/3}$. Van Rijn used a rough criterion $a = \Delta / 2$ or $a = k_s$ with a minimum value of $a = 0.01\, d_s$, in which Δ is the dune height, and k_s is the characteristic bed roughness height.

Furthermore, van Rijn stated that the location at which the bed boundary condition is specified depends on the bed characteristics, and the most logical assumption for the location of the boundary for sediment concentrations is the upper edge of the bedload layer. He also found that for a perfectly flat bed, a good estimate of the thickness of the bedload layer could be obtained by taking the maximum saltation height of the bedload particles. This led to a value on the order of 10 d_{50} for the bedload layer on flat bed in the upper flow regime.

2.2.2. Studies on Rouse Number, R_o

Rouse (1937) was the first to introduce an expression for the exponent in the suspended sediment concentration profile equation. He discovered that the exponent was a function of the ratio of sediment properties to the hydraulic characteristics of the flow, and derived the following expression for the exponent, which is known as the Rouse number:

$$R_o = \frac{\omega_0}{\kappa_0 \; u_*} \qquad \text{(Eq.2.26)}$$

in which ω_0 is the settling velocity of particles in clear water flows, κ_0 is the universal von Karman constant and equal to 0.4 in clear-water flows, and u_* is the shear velocity.

Einstein and Chien (1954) collected data on the Missouri and Mississippi rivers, and determined the values of the exponent R_o. They deduced that for low values of R_o the experimental and theoretical findings agreed closely, but as R_o increased, the theoretical values (the values calculated by using Eq.2.26) exceeded the measured ones, which indicated a continuous increase in the turbulent Schmidt number, β, with increase in sediment size.

The analysis by Bruce R. Colby and C. H. Hembree in 1955 gave a practical empirical solution to the evaluation of the exponent R_o. They related values of R_o to the fall velocities of sediment raised to the power 0.7 (Richardson and Julien, 1986).

Weerappuli (1980) observed that the Rouse number, R_o, found by statistical regression using observed data, showed dependence not only on fall velocity ω, shear velocity u_*, and von Karman parameter κ, but also on average velocity $\overline{V_x}$, water temperature T, concentration of suspended sediment at mid-depth $C_{h/2}$, flow depth h, and particle size of sediment in suspension d_s. Weerappuli performed a multiple regression analysis on the data collected at the Omaha station and derived the following expression for R_o:

$$R_o = \omega^{0.52597} \, \overline{V_x}^{\,0.55999} \, \kappa^{-0.27420} \, u_*^{-1.06709} \, T^{-0.55875} \, C_{h/2}^{-0.02702} \, d_s^{0.27613} \qquad \text{(Eq.2.27)}$$

It was found that the R_o calculated from this expression seemed to be a better estimate than that from Eq.2.26.

Vetter (1986) observed that measured Rouse numbers (R_{om}) are generally smaller than the theoretical or calculated Rouse numbers ($R_{oc} = \dfrac{\omega_0}{\kappa_0 \, u_*}$) and the difference becomes greater for coarser size fractions.

For more practical calculations of the sediment concentration, a simplified method has been proposed based on the application of Rouse equation in combination with a corrected Rouse number $R_o^{'} = R_{oc} + \psi$, in which ψ was determined by computer calibration resulting in the following expression (van Rijn, 1986):

$$\psi = 2.5 \left(\frac{\omega}{u_*} \right)^{0.8} \left(\frac{C_a}{C_{max}} \right)^{0.4} \qquad \text{for} \quad 0.01 \le \frac{\omega}{u_*} \le 1 \qquad \text{(Eq.2.28)}$$

In Eq.2.28 the ψ-factor represents both the hindered settling effect and the turbulence damping effect, and C_{max} corresponds to the maximum value of suspended sediment concentration at a vertical.

2.2.2.1. Studies on Fall Velocity of Sediment Particles, ω

Sir George Stokes was one of the earliest scientists interested in fall velocity. Horace Lamb in 1945 gave the Stokes formulation (known as the Stokes Law) for viscous flow conditions as follows (Alger, 1964):

$$F = 3\,\pi\, d_s\, \mu\, \omega \qquad \text{(Eq.2.29)}$$

where F is the longitudinal force exerted by a slowly moving viscous fluid upon a small sphere, d_s is the diameter of the sphere particles, μ is the dynamic viscosity of the fluid, and ω is the fall velocity of the sphere particles.

McNown and Lin (1952) prepared a diagram showing the influence of sediment concentration on fall velocity, and came up with the conclusion that the fall velocity of particles is hindered by increasing amounts of material in suspension. The usefulness of this chart is limited because only uniform quartz particles were considered.

Brooks (1954) showed that the settling velocity differs along a vertical, being decreased with increasing distance from the bed.

It was found by H. W. Ho in 1964 that the fall velocity of an individual particle in a vertically oscillating fluid was less than that observed in a quiescent fluid, indicating that the fall velocity would be decreased by turbulence (Coleman, 1970).

In his report on water temperature effect on the flow discharge and bed configuration Burke (1966) stated that the fall velocity of a sediment particle is proportional to water viscosity, and in turn, proportional to water temperature.

Loyacano (1967) produced evidence indicating that a group of fall velocity existed in suspensions, and therefore particle fall velocity was increased by increasing amounts of material in suspension.

The effect of turbulence on fall velocity was investigated experimentally and theoretically by simulating turbulence in oscillating fluid by Houghton (1968) and Hwang (1985). According to Houghton and Hwang's results, turbulence seems to reduce the fall velocity. A similar conclusion was obtained by Bechteler et al. (1983) by using high-speed camera and digitized particle trajectories.

Bouvard and Petkovic (1985) measured the fall velocity of particles in turbulent open channel flow and found that the measured fall velocities are nearly 30 percent less than the settling velocities in quiescent water.

X. Zhang and X. Xi in 1993 obtained the following equation for the settling velocity of a single sediment particle in tranquil water (Cao, 1999):

$$\omega_0 = \left[(13.95\, \nu / d_{50})^2 + 1.09\, (G-1)\; g\; d_{50} \right]^{0.5} - 13.95\, \nu / d_{50} \qquad \text{(Eq.2.30)}$$

The following theoretical equation for the fall velocity of natural sand and gravel particles was derived based on the following drag coefficient relations for natural sand and gravel particles (Julien, 1995):

$$C_D = \frac{24}{\mathrm{Re}_p} + 1.5 \qquad \text{(Eq.2.31)}$$

$$\omega = \frac{8\nu}{d_s} \left\{ \left[1 + 0.0139\, d_*^3 \right]^{0.5} - 1 \right\} \qquad \text{(Eq.2.32)}$$

where C_D is the drag coefficient, $\mathrm{Re}_p = \frac{\omega\, d_s}{\nu}$ is the particle Reynolds number, ω is the fall velocity of sediment particles, ν is the kinematic viscosity of water, d_s is the particle diameter, and d_* is the dimensionless particle diameter and defined as follows:

$$d_* = d_s \left[\frac{(G-1)\, g}{\nu^2} \right]^{1/3} \qquad \text{(Eq.2.33)}$$

in which G is the specific gravity defined as the ratio of the specific weight of sediment, γ_s, to that of water, γ, and g is the gravitational acceleration.

2.2.2.2. Studies on Turbulent Schmidt Number, β

The turbulent Schmidt number, β, describes the difference in the diffusion of a fluid particle and a discrete sediment particle and is usually derived from theoretical relationships between dispersion coefficients of fluids and solids. It is the ratio of the sediment-mixing coefficient, ε_s, to the momentum exchange coefficient of the water, ε_m:

$$\beta = \frac{\varepsilon_s}{\varepsilon_m} \qquad \text{(Eq.2.34)}$$

The parameter β varies somewhat with the relative size of the particles in suspension. In spite of much research, the value of β, which is frequently measured by analyzing concentration profiles, is not quite clear. Studies of the evaluation of β in sediment-laden flow have led to opposite results.

Some theoretical considerations have indicated that the momentum exchange coefficient, ε_m, and the sediment-mixing coefficient, ε_s, are not the same. Ismail (1951) found that ε_s was greater than ε_m, but Vanoni (1953) concluded that the ratio $\varepsilon_s / \varepsilon_m$

could be greater or less than unity, and that the coefficients are reduced with increase of sediment concentration. Most of the findings were based on laboratory studies and there were very few investigations pertaining to field data.

Carstens (1952) showed that β decreases from unity as the inertia of suspended particles increase. His results were based on the assumption that turbulence may be simulated by a simple oscillating motion of fluid.

Singamsetti (1966) speculated that turbulence is composed of eddies of circulatory motion in nature. Moreover, he added that the centrifugal force acting on sediment particles would be greater than that acting on fluid particles, thereby causing the sediment to be thrown to the outside of the eddies, with a consequent increase in effective mixing length and diffusion rate.

R. L. Soulsby et al. in 1985 showed that β is less than unity whereas L. C. van Rijn in 1984 presented quantitative relations suggesting a relation between the value of β and the characteristics of flow, and suspended sediment particles. These relations suggested that β is always greater than unity (Schrimpf, 1986).

From a study carried out by Coleman (1970), β can be represented by the following function:

$$\beta = 1 + 2\left(\frac{\omega}{u_*}\right)^2 \quad \text{for} \quad 0.1 < \frac{\omega}{u_*} < 1 \qquad \text{(Eq.2.35)}$$

Eq.2.35 satisfies a value larger than unity, indicating a dominant influence of the centrifugal forces which cause the particles to be thrown outside of the eddies, with a consequent increase of the effective mixing length. According to Coleman, ε_s is 1.5 times more than ε_m for 0.1 mm sand and 1.3 times for 0.16 mm sand. This indicates that β varies between 1 and 2 and the sediment-mixing coefficient, ε_s, is always bigger than the momentum exchange coefficient, ε_m, (van Rijn, 1986).

Cellino and Graf (2000) experimentally researched the influence of bedforms in open channel flow on the suspended sediment concentration distribution. They concluded that Rouse's concentration distribution is altered because of the presence of bedforms because they found that the value of β for suspension flow over bedform, being larger than unity, is larger than that over a plane bed, which is less than unity.

Finally, Tsai and Tsai (2000) performed a stepwise multiple regression analysis for four sets of experimental data produced by Coleman in 1986, Einstein and Chien in 1955, Wang and Qian in 1989, and Vanoni in 1946, and numerical results from the developed mathematical model, and obtained the following equation for the estimation of β by a simple trial-and-error procedure:

$$\log \beta = 3.87 \log\left(\frac{C_a}{\overline{C}}\right) - 2.60 \log\left(\frac{\omega_0}{u_*}\right) + 1.89 \log\left(\frac{a}{h}\right) - 1.20 \qquad \text{(Eq.2.36)}$$

where $\overline{C}$ is the mean sediment discharge concentration.

2.2.2.3. Studies on von Karman Constant, κ_0

It was shown that both the velocity and suspended sediment profiles depend on the value of the von Karman constant, κ_0. Therefore, a vast amount of research has been done by different researchers on the study of this constant.

The trend in κ_0 to decrease as the concentration of suspended sediment increases has been observed in numerous flume experiments (Vito A. Vanoni in 1946 and 1953, and N. H. Brooks in 1954), and in the experiments carried out by H. M. Ismail in 1952 in a rectangular pipe. L. C. Fowler in 1953 made some measurements on the Missouri River, and showed that κ_0 values for sediment-laden Missouri River are appreciably less than for clear streams, thus confirming the results obtained in flume and pipe flow studies (Vanoni, 1975).

From his investigations, Vanoni (1946) obtained the von Karman constant, κ_0, values less than 0.4 for sediment-laden flows. After some more observations, Vanoni (1948) proposed that increased suspended sediment concentration increases the velocity gradient and the mean velocity, and thus decreases κ_0. He explained this reduction in κ_0 as a result of dampening of turbulence by suspended material.

Since Vanoni's investigations, many researchers have tried to analyze the variation of κ_0 with sediment concentration. The influence of ripples and dunes on the form of the velocity profile and the value of κ_0 was investigated with the help of measurements from a tilting flume at Colorado State University (Vetter, 1986). There was a gradual contraction of the section upstream of the dune crest, which caused an increase in velocity, and therefore a steeper velocity distribution with corresponding high κ_0 values. Downstream of the dune crest there was a comparatively sudden expansion of the section involving a decrease in velocity, and thus a decrease in the slope of the logarithmic velocity profile with lower κ_0 values. It was shown also that the bedforms must have a certain height to yield a significant effect on the velocity distribution.

Studies by Einstein and Chien (1955) also indicated that the value of the von Karman constant, κ_0, becomes smaller with the increase of sediment concentration. On the contrary, Coleman (1981) reanalyzed the data obtained from Vanoni in 1946 and Einstein and Chien in 1955 along with his data, and discovered that κ_0 is independent of the presence of sediment in water and equal to 0.4.

Vanoni and Brooks (1957) found that nearly uniformly distributed suspensions did not affect the logarithmic form of velocity profile; they only changed the gradient or value of κ_0, which increases with increasing concentration. Moreover, Elata and Ippen (1961) reported that suspended particles affect the flow directly only in a narrow region near the boundary. They concluded that suspensions cause a change in the structure of turbulence rather than damping of the turbulence. Elata and Ippen used neutrally buoyant plastic spheres as suspensions to study the variation of the von Karman parameter, κ, with increasing concentration. They came up with the following relation:

$$\kappa = \kappa_0 (1 - 0.15\, C_V) \qquad \text{(Eq.2.37)}$$

where κ_0 is the von Karman constant for clear-water and equal to 0.4, and C_V is the linear volumetric suspended sediment concentration at a specified elevation z.

A complete theoretical treatment of the effect of suspended particles in turbulent flows was presented by Hino (1963). The theory predicts that the von Karman constant diminishes as concentration of suspended particles increases for neutrally buoyant as well as for heavier particles.

The following expression for the von Karman parameter, κ, was developed by Ippen (1971) to account for the effect of suspended sediment on the flow:

$$\frac{1}{\kappa} = \frac{1}{\kappa_0}\left[\frac{1 + 2.5\, C_0}{1 + \overline{C}\,(G - 1)}\right] \qquad \text{(Eq.2.38)}$$

in which κ_0 is the von Karman constant, C_0 is the maximum sediment concentration near the bed in fraction by volume, $\overline{C}$ is the mean value of volume concentration in the entire flow, and $G = \gamma_s / \gamma$ is the specific gravity of the sediment. Because the term in parentheses exceeds unity, κ is always less than κ_0 and decreases with an increase in C_0. The theory agrees remarkably well with the κ observed by Elata and Ippen (1961) with suspensions of neutrally buoyant particles as well as with those with suspended sands by Vanoni (1946), and Vanoni and Nomicos (1960).

Itakura and Kishi (1980) analyzed the velocity distribution based on the theory for the Monin-Obukhov length, and found that the value of the von Karman constant is indisputable and equal to 0.4.

Coleman (1981) also proved in his experiment that κ_0 remained essentially constant over a range of Richardson numbers from zero (for clear-water) to about 100 (capacity sediment suspension). This conclusion was based on the fact that the existence of wake flow terms in addition to the original Prandtl-von Karman velocity defect law emphasizes the need for evaluating κ_0 from straight line fits to experimental velocity profiles in the lower 15 percent of the flow. Furthermore, Coleman (1986) explained that the findings of the variation of the value of the von Karman constant is a misapplication of a curve-fitting method because the logarithmic velocity distribution with the various values of κ_0 fits only the lower 15 percent of the total water depth.

2.3. STUDIES OF WATER TEMPERATURE EFFECT ON SUSPENDED SEDIMENT CONCENTRATION AND TRANSPORT

More than a century ago, in 1876, Andrew A. Humphreys and Henry L. Abbot were the first to realize the need for recording the temperature of both water and air among their routine data gathering observations (Dardeau and Causey, 1990).

The importance of the measurement of water temperature was not understood well until about the late 1930s. The laboratory and field investigations of the time gave conflicting and confusing statements with respect to the water temperature effect.

For instance, Ho (1939) found that bed material discharges increased as the water temperature increased and Mostafa (1949) concluded that a high-viscosity fluid would in most cases transport a smaller amount of bed material than a fluid having a low viscosity.

According to the data collected by the Bureau of Reclamation on the Lower Colorado River during the period 1943-1947, a much larger sediment load was carried during the winter than summer for approximately the same flow. Because the only apparent explanation for the difference in sediment discharge at these two periods of the year was the variation of the water temperature, this phenomenon initiated a general inquiry into the probable effect of temperature on the transportation of sediment in flowing streams (Lane et al., 1949).

Lane et al. (1948) observed in the Lower Colorado River that the major changes in sediment load resulted from the changes in the water discharge, water temperature, bed material size (coarsening of the bed), and possibly some other unknown cause. By eliminating the effect of the variation of stream flow and streambed coarsening, an attempt was made to compute the magnitude of the fluctuations assumed to result from the change in water temperature. They discovered, after some observations, that the sediment load varied roughly as the square of the discharge. Furthermore, Lane et al. (1949), after some observations at two locations in the Lower Colorado River, one just upstream of the Hoover Dam and the other just upstream of the Parker Dam, realized that the average sediment load in winter (50 ^{o}F) was as much as 2.5 times greater than that in summer (85 ^{o}F). They suggested that most of the effect of water temperature observed in the study reach resulted from the rate of picking up material from the riverbed.

Einstein and Barbarossa (1952) showed the effect of the water temperature on flow resistance for the Missouri River by developing a form resistance curve. For low temperatures, they showed that the bedform becomes plane; thus the sediment transport increases.

Some experiments in a re-circulating channel performed by Straub (1954) described the transport characteristics of the Missouri River sediment. The sediment used in his experiments was obtained from the Missouri River in the vicinity of Garrison Dam. His experiments indicated that when the water temperature was reduced by 40 ^{o}F the suspended sediment concentration, and thus the suspended load, was approximately doubled. In all of these experiments the Reynolds number was kept in a short range so that there would not be any appreciable change in turbulence patterns. Moreover, Straub (1955) carried out some experiments in a re-circulating flume with sediment (mostly fine sand size ranging from 0.125 mm to 0.25 mm) collected from the bed of the Missouri River. These experiments indicated that a 40 ^{o}F decrease in the water temperature produced an increase in suspended sediment concentration, and thus the suspended sediment load, by a factor of between 2 and 4. It was also found that cold-water flows supported 35 percent greater sediment in size compared to warm-water flows.

Vanoni and Brooks (1957) performed two experiments in a re-circulating flume with fine sand (0.125-0.25 mm), and found that with an increase in temperature there was a decrease in resistance to flow; thus, an increase in suspended sediment transport. In both experiments the velocity and depth were nearly the same, but the water temperature in one of the experiments was 15 ^{o}C and near 37 ^{o}C in the other.

Straub et al. (1958) performed further experiments in a re-circulating flume using bed material (mostly fine sand size ranging from 0.125 mm to 0.25 mm) from the Missouri River. The only difference in these experiments from those performed by Straub (1954) was the consideration of the total sediment load instead of the suspended load only. Based on these experiments, Straub et al. (1958) reached the following conclusions:

- The sediment transportation ability of the river was higher during cold-water flows because decreasing water temperature increased the viscosity of the flow, and thus decreased the fall velocity of the sediment.
- There was a strong degradation tendency of the streambed during the prolonged periods of cold-water flow, and the process was reversed during the prolonged periods of warm water flow.
- The total sediment load transported under essentially constant water discharge conditions increased parabolically as the temperature of the water decreased (e.g., the total sediment load rate was nearly tripled with a water temperature decrease of 50 ^{o}F).
- The sediment transported in suspension was similarly increased with the same amount of water temperature decrease.
- The riverbed slope increased with a decrease in water temperature, whereas the depth and velocity remained essentially constant.

Hubbell and al-Shaikh (1961) briefly summarized the conflicting results obtained from several laboratory and field investigations to indicate that increasing water temperatures could either increase or decrease sediment transport rate under various bed conditions. After conducting some experiments in a re-circulating flume using bed material (mostly fine sand size ranging from 0.125 mm to 0.25 mm) from the Elkhorn River near Waterloo, Nebraska, they came up with the following conclusions:

- The concentration of the total bed sediment discharge was greatest in the case of high temperatures in the presence of ripples or dunes with superposed ripples on the bed.

- The concentration of the total bed sediment discharge was greatest in the case of low temperatures in the presence of antidunes on the bed.
- No general trend was apparent in the case of dunes or plane bed.
- The change in effective sediment size with the water temperature, and the changes in the concentration of total bed sediment discharge and the flow resistance with shear, provided the basis for an explanation of the effect of temperature change on flow phenomena.

On the basis of field and laboratory studies, Carey (1963) concluded that with lower temperature the amplitudes of dunes or sand waves were reduced and the stage in both crossings and bends was lower.

Colby and Scott (1965) found that an increase in viscosity as a result of a decrease in water temperature (other factors remaining constant) caused an increase in sediment discharge because the particle fall velocity was decreased with viscosity. Moreover, they provided a diagram to select a correlation factor for the estimation of sediment discharge rate as a function of flow depth and temperature.

Likewise, Toffaleti (1968) found that the water temperature has a significant influence on the total sediment discharge rate in large rivers and proposed a new procedure for the calculation of sediment discharge in rivers. In this procedure, the suspended sediment transport rate decreased significantly while the water temperature increased, and sediment bed load transport first increased rapidly with temperatures up to about 80 ^{o}F and then reduced slightly for higher temperatures.

Burke (1966) studied the effect of water temperature on discharge and bed configuration in the Mississippi River at Red River Landing, Louisiana. On the basis of this study, he concluded that there was a significant effect on riverbed configuration and stage-discharge relation resulting from the change in water temperature. A statistical analysis was made of the discharge-temperature relationship for a given stage, and it was determined that:

$$Q = 945 - 2.8\,T \qquad \text{(Eq.2.39)}$$

in which Q is the river discharge in 1000 cfs, and T is the water temperature in ^{o}F.

Franco (1968) performed a series of tests in a feed-type flume with fine sand bed, and reached the conclusion that the bed load transport rate was increased with increase in water temperature. In all experiments the bed was covered with ripples. Franco also discovered that the roughness of the bed increased with a decrease in the water temperature. He presumed that the effect of water temperature change on bed load transport was mostly because of the formation of the bed roughness.

After an extensive analysis of data obtained from some large alluvial rivers such as the Mississippi, Missouri and Arkansas rivers, Fenwick (1969) concluded that increased water temperature caused significant increase in bed resistance.

Taylor (1971) performed some experiments in two re-circulating rectangular flumes with nine different sediments. The experiments were divided into three groups; namely, the low-transport flat bed experiments, high-transport flat bed experiments with fine sands, and constant-discharge experiments. Based on these experiments, Taylor concluded that:

- In both the low-transport and high-transport flat bed flows, the water temperature effect on sediment discharge depended on the roughness condition of the bed. When the bed was in the lower transition range, there was an increase in bed sediment discharge with an increase in water temperature, whereas there was a reduction in the sediment discharge in the upper transition range. In the case of rough bed condition, the change in water temperature did not affect the bed sediment discharge.
- In constant-discharge experiments, an increase in water temperature might result in either an increase or decrease in sediment transport and bed roughness depending on the magnitude of the boundary Reynolds number, $\mathrm{Re}_* = \dfrac{u_* \, d_s}{\nu_m}$. In flows where $\mathrm{Re}_* < 13$, it was observed that the bed-load discharge in a warm-water flow was larger than that in a cold-water flow at the same velocity and depth.

Taylor and Vanoni (1972) performed experiments similar to those of Taylor's in 1971 and obtained similar results with the exception that, for the boundary Reynolds number, Re_*, between 20 and 30, an increase in water temperature resulted in a reduction in bedload discharge, and when the riverbed was hydraulically rough, sediment discharge did not change with water temperature. They speculated that this was perhaps caused by the change in turbulence intensity.

According to measurements made by Blinco and Partheniades (1971), turbulence intensity increased with an increase in water temperature, and thus a decrease in water viscosity, for $\mathrm{Re}_* < 13$, but it decreased with an increase in water temperature for $\mathrm{Re}_* > 13$.

Based on data collected from the Mississippi River, Robbins (1973) showed that as the water temperature was decreased, the discharge, average velocity and suspended sand concentration increased, and the percent sand increased in the suspended samples and decreased in the bed samples. This suggested that as the water temperature decreased, the finer sand particles were picked up from the bed and carried in suspension. The entrainment of sand from the bed was also indicated by the fact that the mean diameter, d_{50}, of the bed material increased with decreasing water temperatures. He also showed that for the same stage, a difference in water temperature from 30 ^{o}F to 40 ^{o}F was accompanied by a 9 to 19 percent difference in sediment discharge. He assumed that these differences in sediment discharge resulted from the complex interrelationships between the variables affecting the hydraulic transport phenomena. It was suspected that other factors such as the seasonal variations in runoff and sediment supply might also play a role in the change in d_{50} and the percent sand contained in the samples.

Engelund and Fredsoe (1974) developed the stability theory that showed qualitatively the effect of water temperature on the flow characteristics in alluvial channels. The procedure for stability analysis was to introduce a small perturbation to the flow and investigate how the amplitude of the perturbation increased or decreased with time. Usually, the perturbation took the form of a sinusoid so that its amplitude could be described in a complex form. If the imaginary part grew with time, the flow was unstable, whereas if the imaginary part was dampened, the flow was stable. For flow over a sand bed, the stability analysis was complicated because both the flow and sediment transport equations must be coupled.

By examining the relationship between the friction factor, f_f, and the shear velocity, u_*, da Cunha in 1974 physically explained the effect of the water temperature on resistance to flow (see Figure 2.3). Da Cunha suggested that the effect of water temperature depended on the conditions at the bed and the size of the bed sediment (Chien and Wan, 1999). Figure 2.3 can be understood better by knowing that a decrease in water temperature causes an increase in the water viscosity.

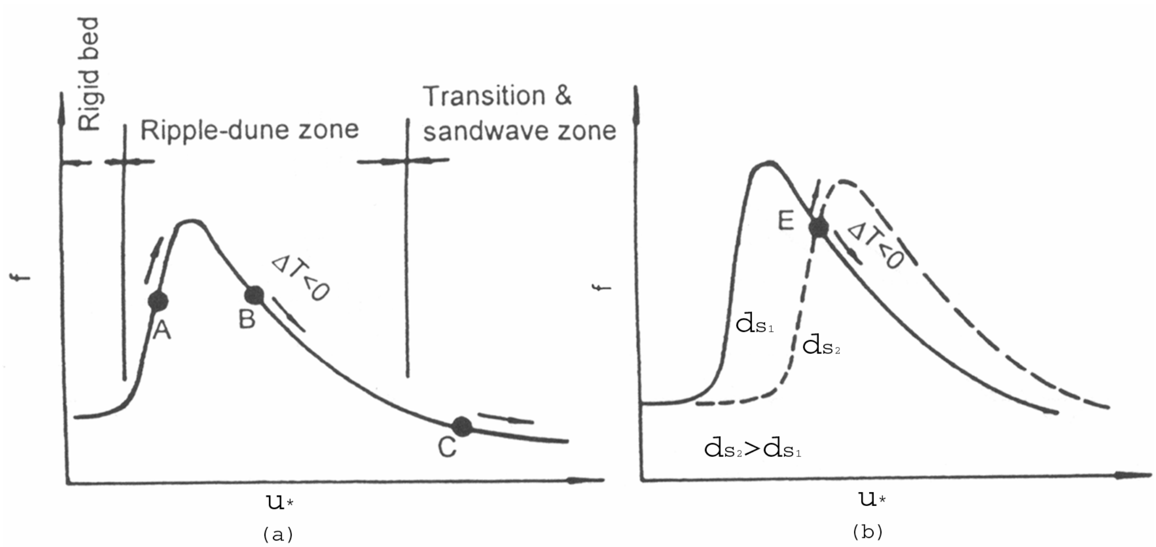

Figure 2.3. Effect of water temperature on resistance (Chien and Wan, 1999).

The U. S. Geological Survey (USGS) (1976), in collaboration with the U.S. Army Corps of Engineers (USACE), established some graphical relations for the Missouri River based on the 1974 stability analysis of Engelund and Fredsoe. The USGS and the USACE stated that the stability analysis could predict the bed configuration changes theoretically, and proved that water temperature change affected the sediment transport rate, bed configuration, and resistance to flow. This study showed in many cases that a decrease in temperature removed dunes from the sand bed when the flow regime was close to the transition zone, and therefore decreased the flow resistance and depth, and increased the flow velocity, which resulted in the increased sediment transport rate.

It has been well known that the bed-form configuration of the Missouri River changes with the water temperature at a constant flow discharge (Shen et al., 1981). When $\mathrm{Re}_* = 11.6$, a slight change in water temperature, and thus in kinematic viscosity of water, changes the bed condition from hydraulically smooth to hydraulically rough. When $3 < d_* < 6$, slight water temperature change, and thus in kinematic viscosity of water, may switch the values of Re_* below or above the threshold value of $\mathrm{Re}_* = 11.6$ (Julien and Raslan, 1998).

After an analysis of the major floods on the Lower Mississippi River, Tuttle and Pinner (1982) concluded that water temperature affected water viscosity and thus sediment transport capability (cold water resulting in high transport and warm water leading to a low transport). They came up with the above conclusion by observing the average temperatures corresponding to the month in which the floods peaked.

The Lower Mississippi River sediment study in the 1990s indicated that there is a direct correlation between temperature and stage. Measurements at Red River Landing showed that stages are higher for higher temperatures. It was also found that long-term trends were not affected even though temperature does affect stage (Catalyst-Old River, 1999).

In summary, previous studies have revealed some consistent and some conflicting statements about the effect of water temperature on the behavior and characteristics of flows in rivers. Therefore, there is a need for further research on this topic.

2.4. STUDIES OF CORIOLIS EFFECT ON RIVERS

In 1844 the French mathematical physicist Gustav G. Coriolis first showed that a body moving on a rotating surface would be deflected from its original path by the rotation of this surface (Williams, 1962).

The fact that the right bank of the Volga River was more elevated and eroded than the left bank was observed by von Baer (1860). In later years, he studied some other rivers around the world and found changes similar to those on the Volga River. Based on his observations, von Baer concluded that the rotation of the Earth causes the right banks of rivers to be more elevated and eroded than the left banks.

Einstein (1926) explained qualitatively that the initiation of river meandering might result from the Coriolis-driven secondary currents in rivers.

The effects of the rotation of the Earth on laminar flows in pipes was analyzed by Benton (1956), and he found that there is a Coriolis effect on the longitudinal velocity profile for a certain range of Reynolds and Rossby numbers.

Gehrig (1980) did some experiments with a fixed bed and a moveable bed model of the Elbe River, and observed asymmetric behavior of the bed because of the Coriolis effects. The asymmetric behavior of the bed was more distinct in the experiments with movable beds.

Winkley (1989) performed a geometrical analysis of the Lower Mississippi River bends and found that the Coriolis force has an effect on channel geometry. His analysis was based on survey data from 1911 to 1915 and from 1973 to 1975.

The influence of the Coriolis force has been studied for a number of large-scale flows in the oceans and atmosphere. However, the Coriolis effect on smaller-scale flows in natural rivers has been mentioned only in a limited number of articles in the literature, which indicates the need for further studies on this topic.

Chapter 3. LOWER MISSISSIPPI RIVER AND STUDY REACH

Although the study area includes only a small reach of the Lower Mississippi River, it is very important to know the history and characteristics of the valley as a whole. First, the description and history of the Lower Mississippi River will be given, and then the study reach will be described in the following sections.

3.1. THE LOWER MISSISSIPPI RIVER

The channel of the Mississippi River first takes its definite form as it emerges from Lake Itasca, Minnesota. At Cairo, Illinois, the Mississippi and Ohio rivers join each other and take a new name, “the Lower Mississippi River”. The Lower Mississippi River is the largest river in North America. The river flows through great alluvial plains, bounded by mountains on the west and east sides.

At Cairo, Illinois, the Lower Mississippi River begins a long journey to the Gulf of Mexico, meandering between deep bends and shallow crossings. Even though the straight distance from Cairo to the Gulf is only about 500 miles, the river's meandering course is more than 1100 miles long (Ellet, 1970). The Lower Mississippi River flows in the southwest direction between Cairo and the Old River Control Structures complex near the border of the Louisiana and Mississippi, and to the southeast thereafter, reaching the "Head of the Passes" where small channels branch into the Gulf. The Head of Passes is at the zero river mile, being the reference point to the river mile measurements. In the past, the Lower Mississippi River has diverted many times, forming new routes to the Gulf.

The main tributaries of the Lower Mississippi River are the Upper Mississippi, Missouri, Ohio, White, Arkansas, Ouachita and Red rivers. These tributaries and some other small tributary streams provide the major part of the water and sediment flow in the river.

3.1.1. Physical Characteristics

Along the Lower Mississippi River floodplain, most of the area is flat. The natural banks and bed of the Lower Mississippi River are alluvial deposits, which are mainly sand and various kinds of silt and clays, carried down by the stream. Managing this great river is difficult because of the alluvial nature of the valley. Because the sediment brought into the river is constantly subjected to deposition and erosion, as a result of the turbulence of flow, and because the slope of the river becomes progressively flatter downstream, the velocity and turbulence also progressively decrease. Hence, coarse particles are deposited in the upper reaches and fine particles in the lower (Biedenharn, 1995). The Lower Mississippi valley is subject to high flows from February through June because of the snowmelt and early spring rains, and low flows particularly from September through November because of the decrease of the underground water level during the hot summer weather (Robbins, 1977).

The climate of the Mississippi River watershed is as varied as its topography. The average monthly temperatures, in general, increase from north to south over the entire watershed. In winter, the average temperatures for the southernmost and northernmost parts of the basin are about 12.8 ^{o}C and -15 ^{o}C, respectively, but in summer, they are about 26.7 ^{o}C and 18.3 ^{o}C, respectively, (Elliott, 1932).

In general, the annual rate of precipitation may be said to increase from the western to the eastern divide, and from the northern divide to the Gulf of Mexico. The southerly portion of the watershed has an average annual rainfall approximating 1270 millimeters. In the northeast area the annual precipitation approximates 1143 millimeters, whereas in the north central and northwest areas the annual precipitation is 762 millimeters and 508 millimeters, respectively, while it is about 889 millimeters in the southwest area. The average rainfall over the entire watershed approximates 762 millimeters per year (Elliott, 1932).

Average relative humidity in the eastern portion of the watershed varies from about 65 to 80 percent. In the western areas the humidity is from 10 to 20 percent lower than in the eastern areas. The highest humidity is found in the southern portion where it approximates 80 percent (Elliott, 1932).

The average yearly evaporation from exposed water surfaces varies from a minimum of 508 millimeters in the northwestern portion to about 1270 millimeters in the states of Mississippi and Arkansas.

The number of days during which snow covers the ground annually varies from an average of less than 1 day in lower Louisiana to more than 120 days in upper North Dakota, Minnesota, and Wisconsin.

Average annual rainfall over the reach is about 1232 millimeters, and runoff is 162 millimeters. Average annual discharge is 15,631 m^3/s (Tuttle and Pinner, 1982).

3.1.2. Hydraulic Characteristics

The hydraulic parameters affecting the pattern and regime of the Lower Mississippi River include the channel geometry and alignment, the amount of water and sediment flow, and channel resistance to flow.

While the Lower Mississippi River has mild bed slopes, and subcritical flow regime, the channel geometry and alignment of the Lower Mississippi River are extremely variable, and channel widths and depths fluctuate considerably over time. Throughout the river, channel depth and width range from narrow, deep channels to very wide, shallow channels with middle bars. The channel cross-sectional area generally increases with downstream distance. Overall, the average width of the river is about 1 kilometers, and the flood-plain elevations range from about 84 meters at the Mississippi-Ohio rivers confluence to sea level at the Gulf of Mexico.

Alignment of the channel varies from extremely sinuous reaches to straight reaches of negligible sinuosity and these variations in geometry and alignment influence the river's ability to effectively transport flow and sediment, causing conditions that can affect flood flows and navigation condition. The effect of the variations in channel alignment and geometry on the sediment transport can be deduced from the variations of the sediment transport capacity of the river from one reach to another (Tuttle and Pinner, 1982).

Total mean depth of flow varies from a minimum of approximately 6 meters at some crossings to a maximum bend depth of about 60 meters. The average channel bottom slope is about 8.3 centimeters per mile, $\overline{S_0} = 5.2 \times 10^{-5}$ (Ellet, 1970) and the width of the alluvial valley varies between 48 and 200 kilometers. However, levees limit the flood flows to a floodplain having an average width of 4.8 kilometers (Biedenharn and Watson, 1997).

The magnitude of water and sediment discharge also varies substantially. From the confluence of the Mississippi and Ohio rivers, the river discharge increases with the addition of flows from the tributaries. After the inclusion of the Arkansas River flow, the river discharge decreases progressively, and the average annual discharge of water is about 15,574 cubic meters per second (m^3/s). Large water discharge variations cause variations in channel width and depth, sediment aggradation and degradation patterns, and hydraulic roughness characteristics of the riverbed. The variations in channel width and depth can be observed from the annual fluctuations of stage-discharge relationships, and these overall variations are sometimes such that different stages can be observed for the same magnitude of discharge.

Suspended sediment concentration in the Lower Mississippi River increases in the downstream direction at above average water discharge. In the short term, this indicates that sediment settles to the riverbed during low flows, and re-suspends and flushes out to the Gulf of Mexico during high flows (Curwick, 1986). The suspended sediment in the river moves by a series of alternating deposition and suspension events.

Many scales or sizes of bedforms exist along the Lower Mississippi River. These dynamic bedforms can reach wavelengths of 500 meters and heights of 10 meters. Bedforms are proportional to stage, and they have a dynamic interaction with the spatial pattern of flow. Dunes contribute to bed roughness, and tend to grow larger with increasing flow strength, thus size and roughness characteristics of dunes cannot be predicted well by experimental and theoretical relations in spite of intensive measurements and studies along the river (Harbor, 1998).

3.1.3. A Brief History of the Natural and Human-induced Activities

This section is based on a couple of references and readers are encouraged to read the following for further information: Catalyst-Old River (1999), Biedenharn and Watson (1997), Biedenharn (1995), Keown et al. (1981), Winkley (1977), and Elliott (1932).

Looking back we see that the Lower Mississippi River has undergone modifications from both natural and human activities throughout the centuries. The morphologic response of the Lower Mississippi River reflects the integration of each of these modifications. Trying to assess the individual effects of each of these features is extremely difficult because the response of the river to any specific feature is generally subtle or almost imperceptible.

Most of the modifications were natural before the start of the settlements around the 17th century. Attempts to restrain the Lower Mississippi began with the first settlements in the lower Alluvial Valley. The first major human-induced modification to the river was in the form of controlled overbank flow by earthen embankments called levees. Levees were initially built in 1717 to protect New Orleans, Louisiana, from overflow (Elliott, 1932). The extension of levees was carried on with the establishment and growth of settlements because all settlers were required to build levees along their property's river front for flood protection. By the turn of the century, thousands of new settlers were clearing lands and building levees where once the spring overflow had spread unhindered across the lowlands. However, the higher and more continuous the levees were, the higher the river rose in its narrowing flow-way.

As early as 1726 efforts were made to deepen the channel at the river mouth for sea-going commerce by dragging iron harrows over the bars. Navigation on the river grew and developed with the settlement in the lower valley though on the river itself it suffered difficulties. The introduction of steamboats on the Mississippi River system between 1811 and 1817 accelerated navigation, and thus increased demand for river improvement.

Beginning on December 16, 1811, and continuing through February 1812, a series of earthquake shocks with an epicenter near New Madrid, Missouri, which was referred to as the New Madrid Earthquake, introduced a great amount of sediment into the upper reaches of the river combined with a severe disturbance of the channel bottom, causing bar growth and navigation problems. During high flows this sediment was carried downstream, and settled during low flows increasing the river bed elevation, thus causing flooding.

By 1820 the period of discovery and settlement had come to an end. The

Mississippi River was then entirely within the territorial limits of the United States. From then on, national attention was directed to the improvement of the river. Federal operations on the Mississippi River date from 1820. With the Act of Congress in 1824 the improvement of the Ohio and Mississippi rivers for navigation was authorized. Later, navigation improvements were extended under the direction of the Chief of Engineers of the United States Army.

In the year 1831 an artificial cutoff, which was proposed by Captain Shreve and named after him, was constructed to improve navigation conditions at the mouth of Red River. This cutoff was followed by a second artificial cutoff made at Raccourci Bend several miles below the State of Louisiana in 1848.

Humphreys and Abbot of the Corps of Engineers in 1861 surveyed the Lower Mississippi, commonly known as the "Delta Survey", and published their great study of the Lower Mississippi under a book titled "Report upon the Physics and Hydraulics of the Mississippi River; Upon the Protection of the Alluvial Region against Overflow and Upon the Deepening of the Mouths". The report discusses river hydraulics and the effects of cutoffs, overflow basins, tributaries, outlets, levees, and crevasses. From the study of results of field observations and measurements, a new formula was developed for the determination of the flow of water in natural channels. An analysis was made of three distinct methods for protection against overflow; first, by the cutting bends in the river; second, by the diversion of tributaries and by artificial reservoirs and outlets; and third, by confining the river to its channel thus forcing it to regulate its own discharge (the levee system). Their scientific report stated that "levees only" was the solution to valley flooding and suggested that other approaches were not feasible. A system of levees from the mouth of the Ohio River to Fort St. Philip, Louisiana, was recommended. The Humphreys and Abbot Report remained as a guide to the Lower Mississippi River improvements for about six decades, but subsequent events would reveal its shortcomings.

The Civil War period was attended by a cessation of work on the river. Levees were allowed to fall into disrepair and the floods of 1862, 1865 and 1867 did great damage to the levee system. No navigation improvement was attempted. The year 1867 marks the resumption of dredging operations at the mouth of the river. Perhaps the greatest contributing reasons for the comparative lack of improvement were the scarcity of funds and the Civil War.

The year 1879 marks the end of the period of Federal operations. The need for improvement for navigation and flood control was generally recognized by the year 1879. The necessity for coordination of engineering operations through a centralized organization was also apparent. In 1879, the Mississippi River Commission (MRC) was created to examine and improve the river to protect its banks, improve navigation, and prevent destructive floods. The commission did some considerable channel improvement, navigation, and flood control works.

After the disastrous flood of 1927, the "levees only" approach was abandoned. In 1928, Congress directed the Corps of Engineers to develop a flood control system, which would prevent such massive flooding from ever occurring in the future. More than 300 flood control plans were put forth, but Congress adopted the Jadwin plan, which was proposed by General Edgar Jadwin, then Chief of Engineers. This plan suggested floodways to divert peak flows and hold down stages in the main channel, and designing all works on a "project flood", a hypothetical flood derived from examining historic rainfall and runoff patterns. The Jadwin Plan and its comprehensive approach to the river's management resulted in the Mississippi River and Tributaries (MR&T) Project authorized by the 1928 Flood Control Act.

The MR&T Project is one of the most complex and comprehensive water resources projects in the world. The primary elements of the MR&T Project include levees, channel improvement features (cutoffs, bank stabilization, dikes, revetment, dredging, floodways, and diversion structures), and tributary basin improvements (Biedenharn, 1995).

Levees were built to contain flood flows, extending from Cape Girardeau, Missouri, nearly to the Gulf of Mexico. The levee protection was continuous except where major tributaries enter the Lower Mississippi or where natural high ground makes them unnecessary. The current construction program also consisted of strengthening and raising, and in some cases extending the existing levees.

Cutoffs, constructed by the Corps of Engineers between 1929 and 1942, shortened the river by about 150 miles in the reach between Memphis and Old River, and reduced flood stages (Winkley, 1977). Fifteen artificial cutoffs were constructed above the mouth of the Red and Atchafalaya Rivers, which is upstream of the study reach. The primary purpose of the cutoff program was to improve the flood-carrying capacity of the river and thereby significantly reduce the required levee heights. In this respect, the cutoff program was a tremendous success in that it lowered stages to the lowest levels experienced in modern time. However, there is still considerable controversy about the long-term impacts of the cutoffs on the overall morphology of the system. A system of outlets was installed below the Red River to prevent overtopping of levees in this reach of the river. There are advantages and disadvantages of the cutoffs on the lower Mississippi River. The advantages are: (1) major reduction in flood profiles (flood-carrying capacity increases), (2) lower frequency and shorter flood duration, (3) shortening the navigation time and deepening the channel for easy navigation, and (4) reducing the length of channel to be stabilized. The disadvantages are: (1) a major dredging effort because of the increased stream velocities through the cutoff, (2) structures located upstream may be adversely affected by the lowering of both the high-water and low-water planes, and (3) excessive bank caving either in the reach or near it because of the increased velocities.

The tendency of the river to regain the pre-cutoff length was curtailed by the bank stabilization and channel improvement works. The banks of the Lower Mississippi River and its tributaries were stabilized to a desirable alignment, obtaining efficient flow characteristics from the standpoints of flood control and navigation. Dikes were constructed to confine the river to a single low-water channel, reducing excessive widths and developing desired alignments for navigation. Revetments, consisting of huge sections of concrete blocks joined together with wires, were built to help fix the channel and protect nearby levees by preventing bank caving. Improvement dredging was employed to adjust river flow patterns and maintenance dredging was employed to deepen shallow channel crossings that tend to form during low water. Foreshore protection was used primarily in the lower part of the river to laterally protect the riverbanks from wave wash attack and other erosion. The MR&T also incorporates four floodways that divert excess flows past critical reaches so the levee system will not be excessively loaded. For example, the Bonnet Carre' spillway diverts Mississippi River water into Lake Pontchartrain to keep stages down in the vicinity of New Orleans.

One of the Corps' greatest challenges has been building the Old River Control Structures to regulate the diversion of the Mississippi River flow into the Atchafalaya Basin. The initial Old River Structures were completed in 1963. The Auxiliary Structure was added in 1986 to provide greater control and flexibility of operations. A low-head hydroelectric power station slightly upstream of the Old River Structures came on line in 1990 (Biedenharn, 1995). Since the construction of these river control structures sediment yield has been on the decline.

Dams, reservoirs, control structures, canals, and pumping plants on the tributaries were constructed between 1953 and 1970 for flood control and drainage. These structures on the tributaries and navigation locks on the upper Mississippi River have served as sediment-retention structures, and resulted in a 64 percent decrease in suspended sediment delivery to the Lower Mississippi River as compared to the period prior to such construction (Keown et al., 1981).

The channel improvement work on the Lower Mississippi River and its tributaries is approximately 85 percent complete and the scheduled completion date is March of 2010 (Biedenharn and Watson, 1997).

3.2. DESCRIPTION OF THE STUDY REACH

The study area is located just upstream of the Mississippi and Louisiana state border line on the Lower Mississippi River (LMR), which is between the Tarbert and Union Point stations and is about 20 miles in length (see Figure 1.1 on page 7). The river in this section has an average slope of 3.78×10^{-5}, and the depth of the River in this section ranges approximately between 10 and 34 meters.

Flow in the studied reach of the LMR is mainly regulated by the Old River Control Complex (ORCC), which became operational in 1963. The construction of the ORCC is one of the primary elements of the Mississippi River and Tributaries (MR&T) Flood Control Project, which was initiated by the Flood Control Act of 1928 to provide flood control and navigation improvement for the LMR.

The main components of the Old River Complex include the Low Sill Structure (1963), the Auxiliary Structure (1986), and the Hydroelectric Power Station that came on line in 1990 (Biedenharn, 1995) (see Figure 1.1 on page 7). The primary reason to construct these structures is to control and regulate the flows from the Mississippi River into the Atchafalaya River, thereby preventing the capture of the Mississippi River by the Atchafalaya River. Prior to construction of these structures, the percentage of flow from the Mississippi into the Atchafalaya had been steadily increasing because the distance to the Gulf of Mexico via the Atchafalaya route is about one half the distance to the Gulf via the Mississippi route, which gives a definite hydraulic advantage to the Atchafalaya route (see Figure 3.1). Therefore, there was a big concern about the capture of the Mississippi River by the Atchafalaya River.

To maintain stability on both rivers the distribution of water and sediment into the Lower Mississippi and Atchafalaya Rivers is controlled by allowing 30 percent of the combined flow from the Mississippi and Red Rivers to flow into the Atchafalaya River.

Figure 3.1. Comparison of the distances to the Gulf of Mexico via the Lower Mississippi and Atchafalaya Rivers.

In addition to controlling the flow split at this location, these structures play an important role in determining the sediment distribution to both rivers. The complex also provides a navigation connection between the Mississippi River and the Atchafalaya and Red rivers (Catalyst-Old River, 1999).

The primary water and sediment discharge monitoring station for this reach of the Mississippi River is the Tarbert Landing station, which is located just downstream from the Old River Control Structures at river mile 306. The U.S. Army Engineer District, New Orleans, computes daily sediment and water discharge at this station. The Old River Structures are operated as necessary to ensure that the discharge at New Orleans does not exceed 35,396 m^3/s (Catalyst-Old River, 1999).

Any down-river changes that are observed in the discharges of suspended sediment represent deposition of material onto the riverbed or re-suspension of material from the riverbed. On a net basis, sediment is neither stored nor re-suspended at the average water discharge. At less-than-average water discharge, the suspended load decreases down the reach; sediment is being dropped by the flowing river and stored on the riverbed. At greater-than-average water discharge, the sediment load increases down the reach; at least part of the previously stored sediment is being re-suspended from the riverbed. The short-term pattern, therefore, shows sediment being deposited and stored on the riverbed at lower flows and being re-suspended and flushed out on higher flows (Meade and Parker, 1985).

Chapter 4. FIELD DATA COLLECTION

This chapter provides the sources of the field data used for the current study and describes the equipment and procedure used to collect the field data. First, in section 4.1, the sources of the field data used in the current study will be provided, and then in section 4.2 a brief description of the methods used to collect the field data, the data collection procedure, and the description and capabilities of the equipment used will be explained.

4.1. FIELD DATA SOURCE

The data in this study come from a comprehensive study at the Old River Control Complex (ORCC) by the U.S. Army Engineer Waterways Experiment Station (WES) and the New Orleans District of the U.S. Army Corps of Engineers (NOD) in 1998. The WES and the NOD were provided with funding by Louisiana Hydroelectric Power to provide an engineering analysis of the hydraulics and sediment transport characteristics associated with the diversion structures and the adjacent Mississippi and Atchafalaya rivers. To achieve this goal, the WES and the NOD started a data collection program. This program was initiated to provide a database for studies leading to a better understanding of the basic principles controlling water and sediment transport. The major study assignments and components were specific gage and slope analysis, sediment and flow analysis, channel geometry analysis, and integration of the above (Catalyst-Old

River, 1999).

The data collection program included 2 boats, each of which contained an Acoustic Doppler Current Profiler (ADCP), US P-63 suspended sediment sampler, drag bucket, electric winch, Price meter, and recording fathometer (depth sounder). The boat provided by WES could not be outfitted to deploy a P-63 sediment sampler and Price current meter; therefore, it could only obtain velocity profile data with the ADCP (Catalyst-Old River, 1999). The ADCP was used to obtain the velocity magnitudes and directions, and river discharges at the specified cross-sections. The suspended sediment concentrations were measured using U.S. P-63, and drag buckets were used to obtain bed material gradation samples.

Field sediment and flow data were collected at a couple of stations on the Lower Mississippi, Red, and Atchafalaya rivers, seven of which were on the Mississippi River. However, in this study only four out of the seven stations on the Lower Mississippi River will be used; namely, Union Point, Line 13, Line 6, and Tarbert Landing (see Figure 1.1 on page 7). Besides velocity intensities and directions data and sediment data, the following conditions and quantities are reported for each of these four locations: the river condition, the time of the measurement, the weather condition, the river discharge and water temperature measurements, and water elevation readings. All data used in this study are detailed in Appendix B (see Table B.1 through Table B.12). All suspended sediment data are provided in Table B.1 through Table B.4, all velocity and flow direction data in Table B.5 through Table B.8, and all bed material data in Table B.9 through Table B.12.

4.2. DATA COLLECTION METHODS

4.2.1. Flow Data Sampling Method

Accurate velocity and discharge measurements of large rivers have been a problem for many years. These measurements were difficult, time consuming, and sometimes dangerous. To eliminate the problems mentioned above, a new measurement technique and equipment was necessary; therefore, the U.S. Geological Survey has developed a technique which uses an Acoustic Doppler Current Profiler (ADCP). This technique was first used to make discharge measurements from a moving boat on the Lower Mississippi River at Baton Rouge, Louisiana, in 1982. The ADCP-measured discharges differed less than 5 percent from the simultaneous conventional discharge measurements, which was encouraging (Simpson and Oltmann, 1993). Over the past two decades, Acoustic Doppler Current Profilers have greatly expanded the ability to make detailed flow measurements in challenging field applications.

4.2.1.1. Description of the ADCP

The ADCP is an electronic instrument which is used in combination with some other instruments, such as sensors and data-processing equipment, to make flow measurements. The ADCP is an accurate, reliable and easy-to-use high-performance current profiler. It has an acoustic frequency of 600 kHz (kilohertz), profiling range of $3-67$ meters, and velocity range of ± 10 meters per second. The profiling range of an ADCP is determined by the acoustic frequency and the conditions in the water; specifically, the amount of suspended material present (RD Instruments, 1989).

The ADCP includes four transducers, each of which is 17.1 centimeters in diameter, and a thermistor. Transducers are positioned 90^0 apart horizontally and directed downward into the water column at an angle of 30^0 from the vertical. The thermistor is used to calculate the speed of sound in water (Simpson and Oltmann, 1993).

The ADCP uses a Doppler effect to measure vertical profiles of water velocities from a moving boat. The transducers transmit pulses of high frequency sound into the water. Transducers are constructed to generate a narrow beam of sound where the majority of energy is concentrated in a cone only a few degrees wide (see Figure 4.1).

As the sound travels through the water, it is reflected in all directions by particulate matter (sediment, biological matter, bubbles, etc.). Some portion of the reflected energy travels back along the transducer axis toward the transducers where the processing electronics measure the change in frequency. If the particles are moving toward the instrument the reflected sound pulse will have a higher frequency than the originally transmitted pulse. Conversely, if the particles are moving away from the instrument the reflected pulse will have a lower frequency. This is known as the Doppler shift, and it allows the determination of flow velocity along the acoustic beam path (Oberg and Mueller, 1994).

The ADCP has a region immediately in front of the transducers, which is called the blanking region, where no measurements can be made. This region is required for the transducers and electronics to recover from the high energy transmit pulse. The blanking distance is a function of the acoustic frequency (Simpson and Oltmann, 1993).

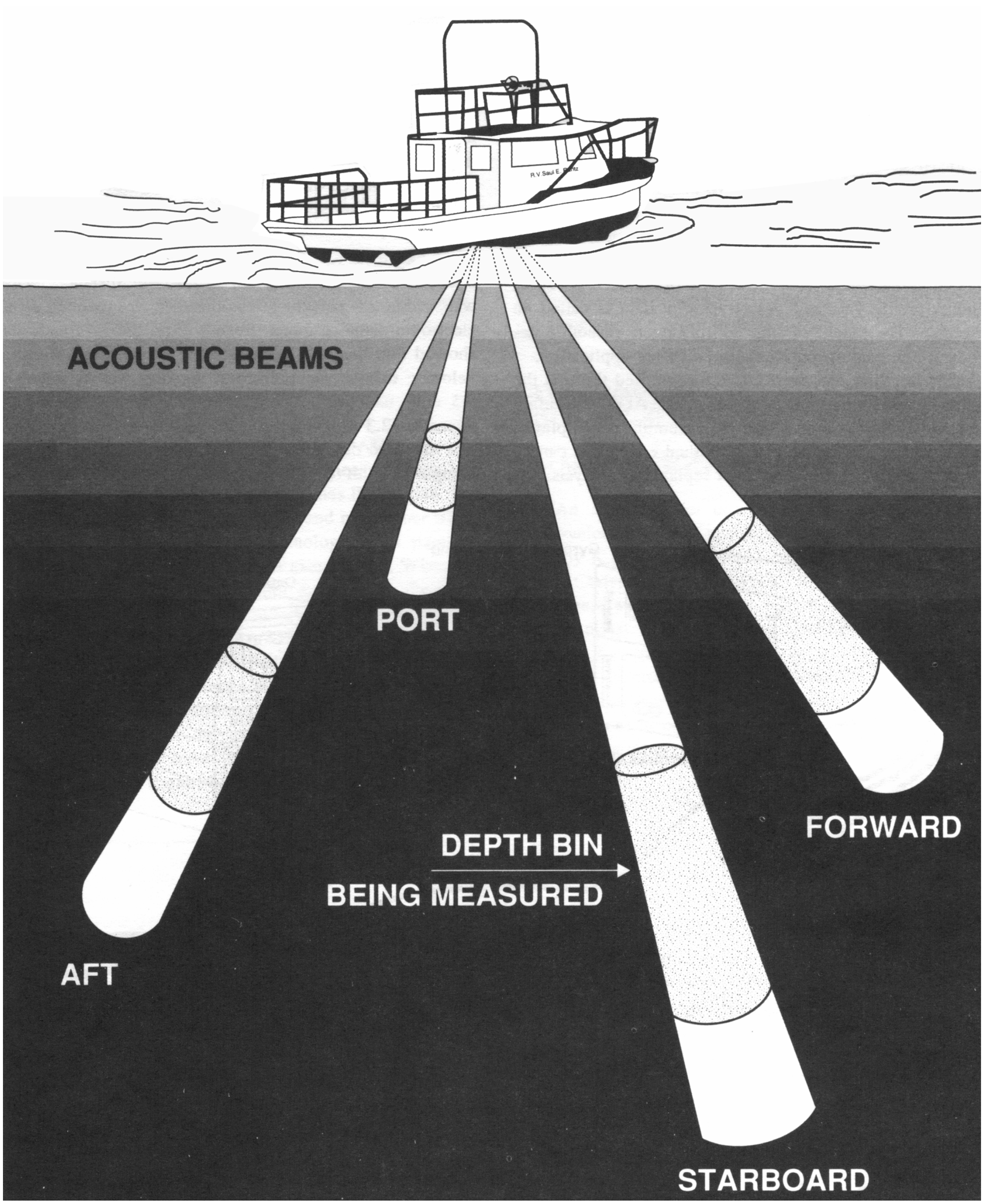

Figure 4.1. Beam configuration of the ADCP (Simpson and Oltmann, 1993).

The best characteristics of making a discharge measurement with an ADCP are high speed, high accuracy, and simple operation. With an ADCP mounted on a boat, a large number of velocity and discharge measurements can be achieved in a couple of minutes with an accuracy of about 98 percent. The ADCP can be used to make flow measurements wherever a boat can travel, provided the water is not too shallow.

4.2.1.2. Comparison of ADCP Techniques with Conventional Methods

Comparison of the ADCP techniques with the conventional methods such as a Price or other point-current meter can be made by considering the time required to complete a measurement, quality and quantity of data collected, functionality, and cost. There are advantages and disadvantages of making flow measurements using the ADCP compared with conventional methods, the advantages being greater than the disadvantages (Lipscomb, 1995).

The primary advantages follow:

- The time required to complete a measurement is reduced. Because traditional discharge measuring techniques with standard current meters would have taken such a long time to complete measurements at one transect, it would have been difficult to measure velocities and discharges at several transects with extensive floodplains during the peak of the flood. With an ADCP these measurements are done in a very short amount of time.

- Data can be collected throughout the water column and cross-section rather than at discrete points. The ADCP gathers far more velocities than conventional discharge measurement devices in the same amount of time; this considerably increases the resolution of the velocity profiles.
- Taglines or other stationing devices are unnecessary because the instrument keeps track of the distance traveled, provided the bed is stable. Frequently, velocity and discharge measurements cannot be made in tide-affected rivers using conventional measurement techniques because of dynamic conditions in the river. If a suitable bridge is not available from which to make conventional current-meter measurements, a tagline is suspended across the river and a small boat is attached to the tagline (use of a tagline is generally restricted to channels with widths of 250 meters or less). The boat then traverses the river cross-section, stopping at 25 or more positions where depth and two or more velocity measurements are made. Measurements of this type usually take 1 hour or longer, while the tagline poses a significant navigation hazard. The tagline often must be dropped to permit passage of boat traffic, thereby increasing the duration of the measurements and increasing the chance for accidents.
- The ADCP can be boat-mounted, thus eliminating the installation, maintenance, and liability of costly cableways.

The primary disadvantages follow:

- The ADCP instrument has a high initial cost.
- The ADCP doesn’t function well in shallow water conditions.
- Because of its complexity, the ADCP measurement requires an in-depth

understanding of the physics, electronics, and software of the system prior to use.

- Because the ADCP is a new technology, frequent revisions to hardware, firmware, and software are required to improve the accuracy.

The final result is that in the time required for one conventional discharge measurement, one could take 5 to 20 times as many discharge measurements with the ADCP. Now you can observe the variability of the discharge over short time scales or, if the flow is steady, average a few ADCP discharge measurements together to achieve even higher accuracy. The freedom from taglines or other fixed positioning equipment allows one to measure in locations that were previously impractical or impossible.

In brief, acoustic techniques to measure the suspended sediment transport parameters are a much better method than traditional techniques. The acoustic method has a high resolution and accuracy (Adams et al., 1998). Because the high resolution and accuracy are important in sediment transport because of the complex nature of the transport phenomena, it is essential to use acoustic methods to collect stream velocity data.

4.2.1.3. ADCP Data Collection Procedure

Flow data for all flow events were obtained by using the Acoustic Doppler Current Profiler (ADCP) (see Figure 4.2 and Figure 4.3).

The ADCP made measurements at 20-23 verticals across each of the four cross-sections. It took about 10 minutes for the ADCP to gather data at each vertical. The

Figure 4.2. Acoustic Doppler Current Profiler (ADCP) mounted to the boat.

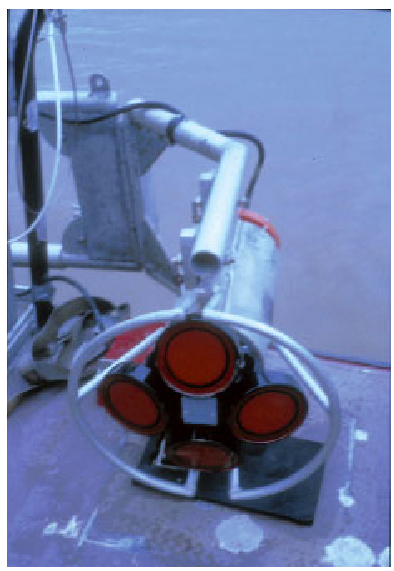

Figure 4.3. Perspective view of the Acoustic Doppler Current Profiler (ADCP).

ADCP and Price meter were operated at the same time only every 4 verticals, which makes Price meter measurements only at 5 verticals. Price meter readings were obtained at 5 depths (20, 40, 60, 80, and 98 percent) of the overall depth. Fathometer depth readings were done at the same verticals as the Price meter readings over the same time period (Catalyst-Old River, 1999).

The ADCP and Price meter were operated at the same time to obtain data values proper to make comparisons of the variables. The comparison of both methods was done only at Union Point station for five flow events from February to May. Figure 4.4 illustrates discharges both obtained by the ADCP and Price meter at different water temperatures. For comparison purposes the reported discharges are also shown in the same graph.

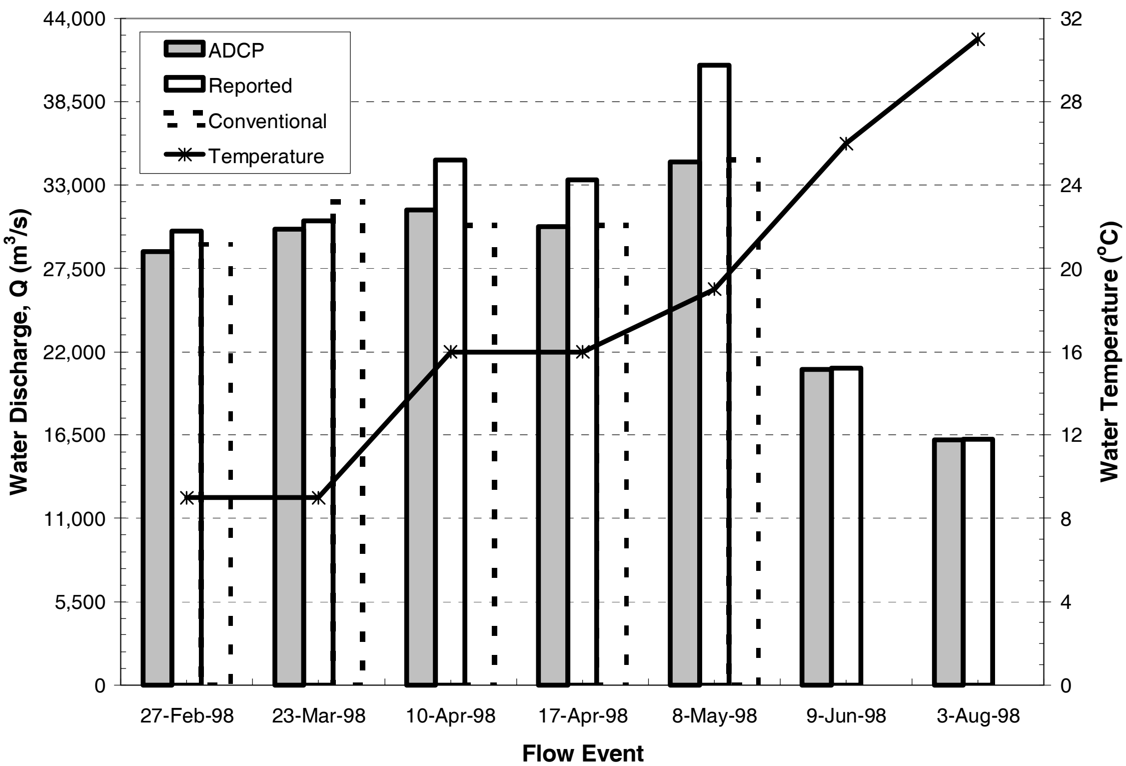

Figure 4.4. Comparison of the ADCP, conventional and reported discharges at Union Point.

Price meter velocities represent a single point velocity value at a particular depth and averaged over a 120-second time period. The ADCP data were recorded continuously during the time required to complete the Price meter vertical profile at 5 different depths (Catalyst-Old River, 1999).

The ADCP measures the velocities over a short period of time, so velocity fluctuations could be expected (Admiraal and Demissie, 1995). To make sure that the ADCP readings are not biased, a complete circuit of the river (crossing the river twice) was performed (Catalyst-Old River, 1999).

The water velocity at each depth of a velocity profile was determined with respect to the boat velocity; therefore, the accuracy of the measured boat velocity is important. The ADCP measured the boat velocity relative to the river bottom by using a flux-gate compass and the results of measurements of the Doppler shift of acoustic pulses reflected from the river bottom. In order for measurement of the boat velocity to be correct, the ADCP signal must penetrate through the channel bed load to the fixed river bottom. In addition to measuring boat velocity, the ADCP measured the depth of the river by measuring how long it took for an acoustic signal to be reflected off the channel bottom (Gordon, 1989).

The ADCP cannot measure water velocities near the top and bottom of the water column. The velocity measurements near the top cannot be made because of the physical characteristics of the ADCP, such as the transducer draft and blanking distance. The reason for not being able to measure water velocities accurately near the bottom is the contamination of the acoustic signals in the lower part of the water column because of the interference of vertical side lobes. Although the ADCP transducers concentrate most of the acoustic energy in a narrow beam, some energy is transmitted in all directions. A portion of this energy takes a direct path to the boundary; this is called side lobe energy and the reflections are called side lobe interference. Although side lobe energy levels are much lower than the main beam, the boundary reflection is much stronger than the reflection from particles in the water and can potentially bias velocity measurements. Side lobe interference may affect the bottom 10-15 percent of the velocity profile. The extent to which the side lobe reflection may contaminate the velocity measurements is a function of the boundary conditions, the scattering return strength from the water, and the acoustic properties of the transducers. There is always a potential for side lobe interference, and any near-boundary data should be analyzed carefully (Simpson and Oltmann, 1993).

A power law was used to construct a curve fit of the data, and velocities outside of the measurement range were extrapolated. Data does not always take on a power law form, so estimates of top and bottom discharge can be erroneous. However, velocity profiles of this type are not common in the main channel of the river, and most velocity profiles are well presented by the power law (Oberg and Mueller, 1994).

To be consistent with the suspended sediment data, the distribution of the horizontal velocity vector intensities and directions were reported only along four chosen verticals; the same ones that were used for collecting suspended-sediment samples (see Figure 4.5).

Each velocity vector intensity and direction value, reported for a particular point on a particular vertical, is the average of the value at the particular point and five or eight surrounding points. The ensemble averaging, instead of time averaging, was introduced

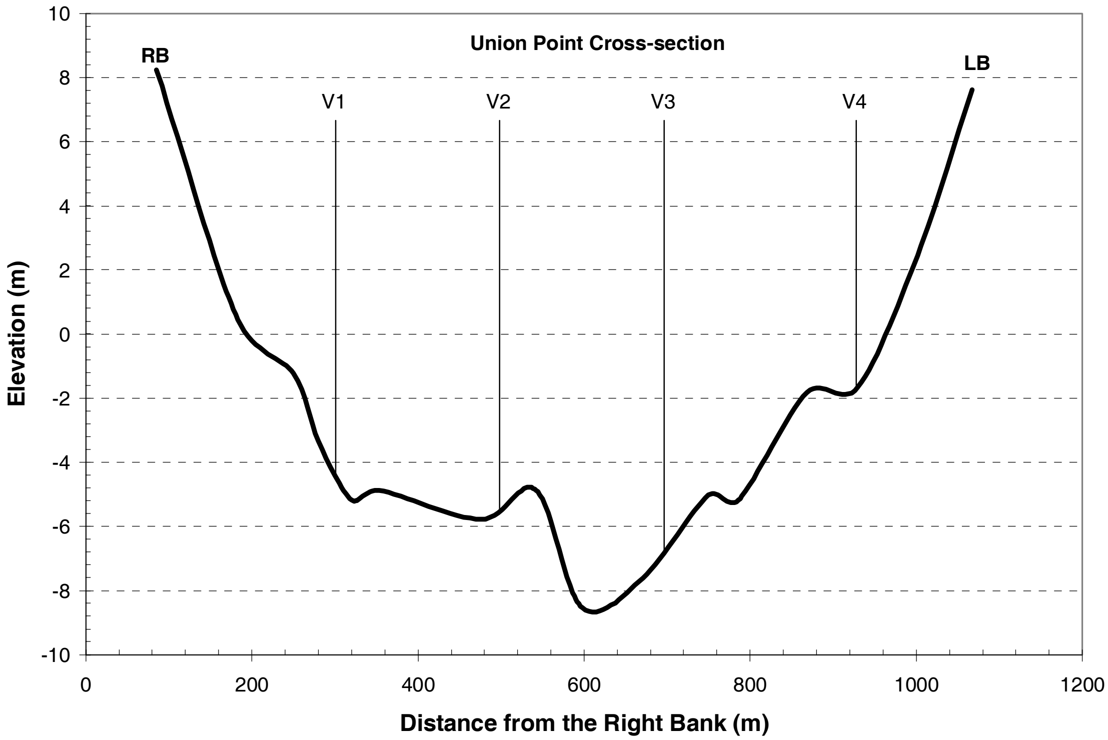

Figure 4.5. Locations of the four sampling verticals at Union Point.

to eliminate significant randomness in measured velocities caused by the ADCP high frequency sampling ($1-3$ seconds per vertical). The profile of water velocity is divided into range cells, where each cell represents the average of the return signal for a given period of time. The velocity intensity and direction data are provided with about 0.5 m increments along each vertical (see Figure 4.6).

Figure 4.6 is obtained using Table B.6 in Appendix B. Similar graphs at different verticals of all cross-sections can be attained using the flow data in Table B.5 through Table B.8 in Appendix B. Velocity and depth data were used to compute the individual subsection discharges. Finally, the ADCP software with a discharge computation

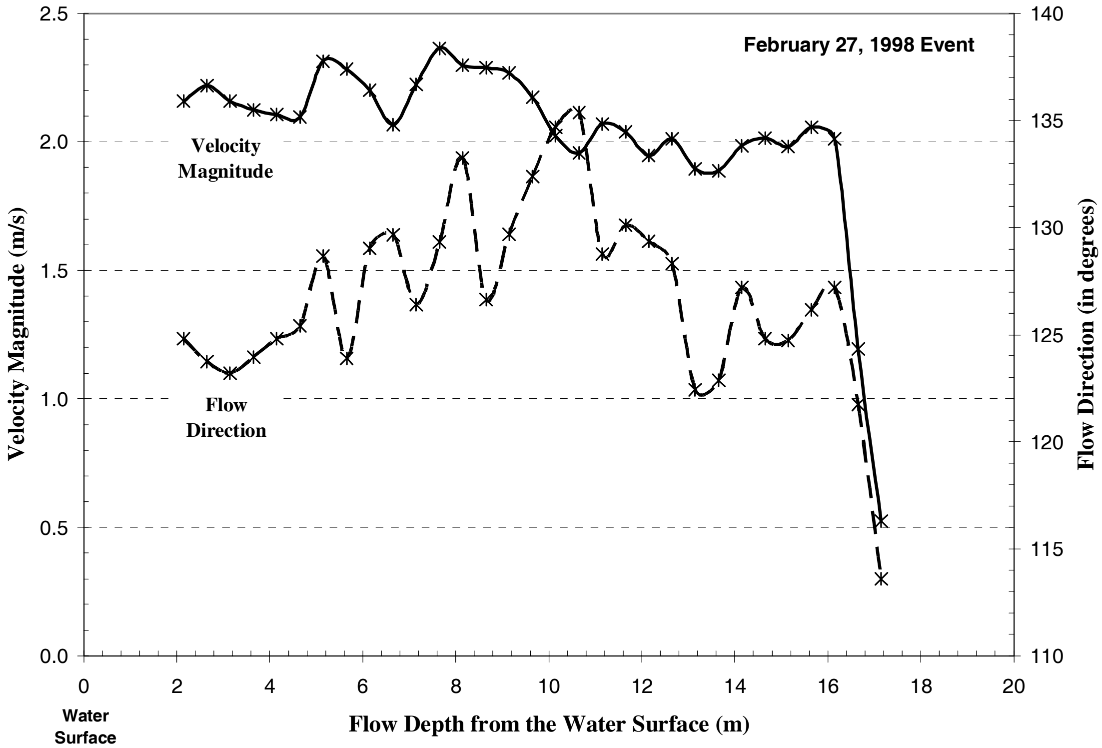

Figure 4.6. Flow velocity intensities and directions at the 4th vertical at Line 13.

algorithm was used to estimate discharges in the shallow regions that could not be measured, then total river discharge was computed by adding all the measured and estimated (unmeasured) discharges. Velocity, depth and discharge measurements were done simultaneously (Lipscomb, 1995). Figure 4.7 demonstrates the total water discharges at all cross-sections for all flow events. According to the figure below, the ADCP discharges for the individual locations are almost same for flow events between February 27 and April 17, 1998, but there is a drastic decrease in ADCP discharges after May 8, 1998 event. Due to the existence of control structures in the study reach, the ADCP discharges decrease by approximately 15 to 20 percent between the Union Point and Line 13 locations and by approximately 5 to 10 percent between the Line 13 and Line

6 locations, and stay almost the same thereafter. These changes in the Lower Mississippi River flow discharges in the study reach confirm the earlier statement that about 30 percent of the Lower Mississippi water flows into the Atchafalaya River through the outflow channel. Moreover, water temperatures are equal at all locations, and increase between the February 27 and August 3, 1998 flow events.

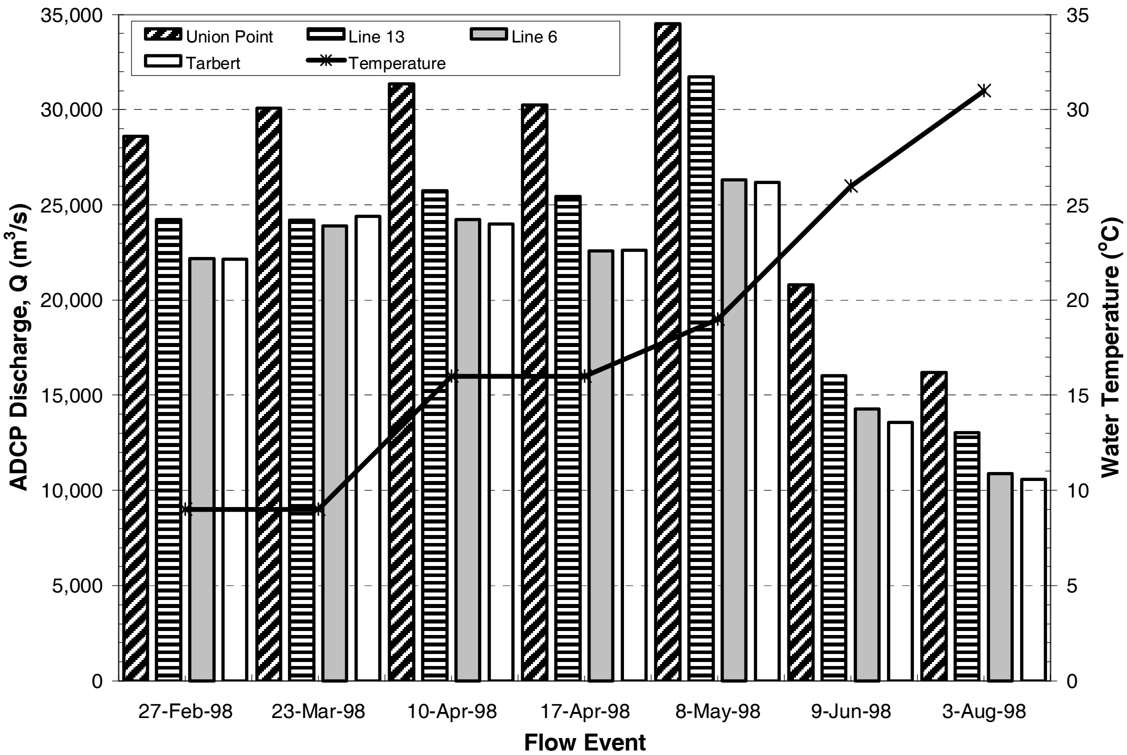

Figure 4.7. The ADCP discharges for all flow events at all locations.

4.2.2. Suspended Sediment Sampling Method

The measurement of suspended sediment, particularly in field settings, is important in the documentation of sediment transport and deposition to cope with the problems originating from the existence of sediment in streams. Many measurement techniques to measure sediment transport parameters, such as suspended sediment concentration, have been used with varying degrees of success. Some of the sediment concentration measurement methods include suspended sediment samplers, suction pumps, siphons, grab samplers, and optical measuring systems (Adams et al., 1998). Suspended sediment concentrations in this study were determined with a common depth-integrating discharge-weighted sampler, the US P-63 (see Figure 4.8).

Figure 4.8. The US P-63 (Point-integrating suspended sediment sampler).

Even though the operating mechanism in the US P-63 is the same as the US P-61, they differ mainly in size and weight. Because the US P-63 is larger and heavier than the

US P-61, it is better in large river environments with greater depths and higher velocities (Federal Inter-Agency Committee, 1963).

The US P-63 is an electrically operated cast bronze suspended sediment sampler. It weighs about 90.7 kilograms, and is 86.4 centimeters in length. The US P-63 can be used both as a point- and a depth-integrating sampler because the sampler head contains an electrically operated sampling mechanism. The sampling is controlled by an electrically operated, two-position rotary valve. The sample container is either a 1-pint or 1-quart round milk bottle. The maximum sampling depth is 55 meters with a pint sample container and 37 meters with a quart container (Federal Inter-Agency Committee, 1963).

The US P-63 has a specifically designed intake nozzle, which is 4.8 millimeters in diameter. The nozzle is cut and shaped so as to ensure that the velocity in the nozzle is the same as the stream-flow velocity, provided that the nozzle is oriented parallel to the flow direction with the help of tail vanes, in order to collect a sample representative of the mean discharge-weighted sediment concentration. Because of the design of the sampler, the US P-63 samples the water-sediment mixture from the water surface to within a zone close to the riverbed, which is about 8-9 centimeters apart from the riverbed (Edwards and Glysson, 1988).

Because of the extreme difficulty of calibration, suspended-load samplers generally are assumed to have a sampling efficiency of 1.0, that is, perfect efficiency. Sampling efficiency is the ratio of quantity of sediment trapped in the sampler to the quantity of sediment the stream actually would transport at the same time and place had the sampler not been there. Inaccuracy in the measured suspended sediment load can arise from sampler inefficiency, improper sampling in the vertical, and errors in measuring water discharge. Possibly a more serious problem arises in determining the average transport rate for the entire cross-section from a group of verticals. This problem results from hydraulic causes and natural fluctuations in sediment concentrations, both spatially and temporally. These fluctuations can vary by several orders of magnitude (Guy and Norman, 1970).

As mentioned earlier, four cross-sections, namely Union Point, Line 13, Line 6, and Tarbert Landing, are analyzed in this study. To obtain suspended sediment data, four verticals at each cross-section were chosen. The verticals in most cases were equally spaced across the stream, using a method known as the equal transit rate or equal width increment. For each vertical, samples were taken at six locations representing 10, 30, 50, 70, 90, and 98 percent of the total depth. Therefore, there are twenty-four point suspended sediment samples at each cross-section. Suspended sediment samples generally contained a significant amount of silt and clay and fine sand, some amount of very fine and medium sand, and very little coarse sand. Suspended sediment samples were processed to obtain vertical suspended sediment concentration profiles by size class for each of the chosen verticals. Suspended sediment concentration results are published in milligrams per liter (mg/l). Measured suspended silt and clay concentration is nearly uniform at each location, averaging approximately 250 mg/l. Measured suspended sand concentration, however, indicates significant variation in both the vertical and lateral directions. Figure 4.9 shows a sample suspended sediment concentration profile.

Each zone has a respective area, average concentration, and velocity. The unit suspended sediment discharges for each zone are computed by using the modified Einstein procedure, and then summed over all the zones to compute total unit suspended sediment discharge for each cross-section.

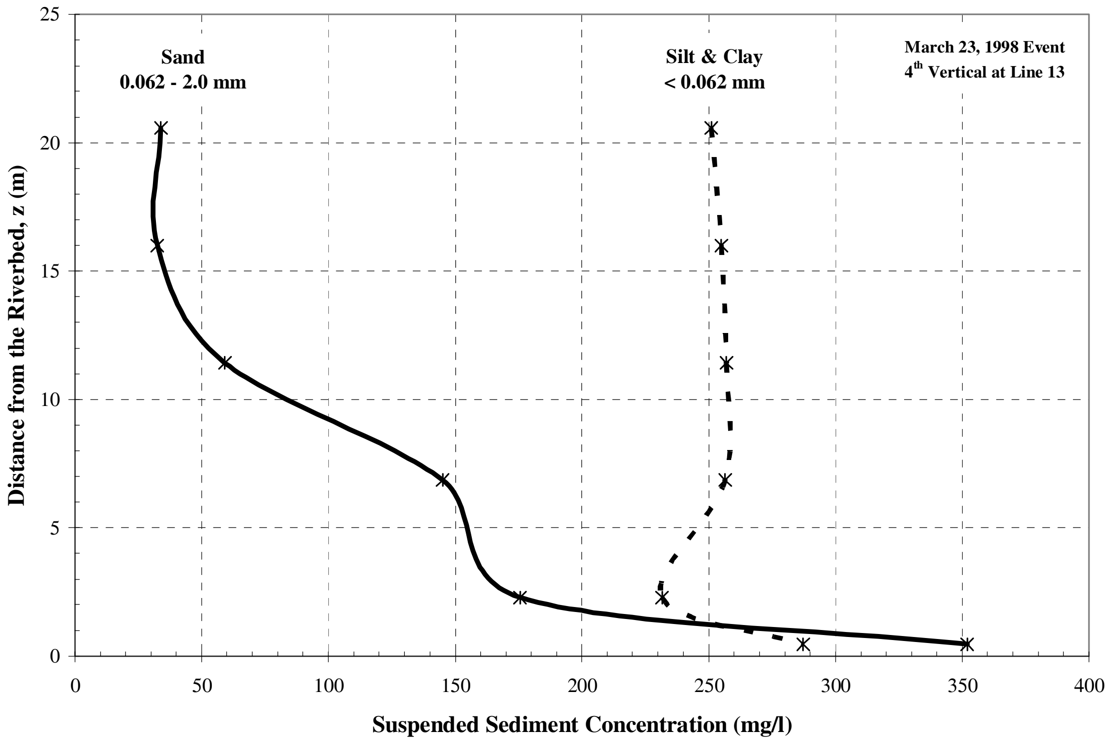

Figure 4.9. Suspended sediment concentration profile at a vertical at Line 13.

The suspended load being transported was computed as the product of the concentration and the local velocity based upon the individual measurements of concentration and velocity at the sampling point (see Figure 4.10). In the figures below, it seems like the suspended sediment concentration profile and the turbulent velocity profile are mirror images of each other. That is, the turbulent flow velocities are low at points of high suspended sediment concentrations, and high at points of low suspended sediment concentrations along a vertical. For example, the turbulent flow velocity is low near the riverbed, where the suspended sediment concentration is high, and is high near the water surface, where the suspended sediment concentration is low.

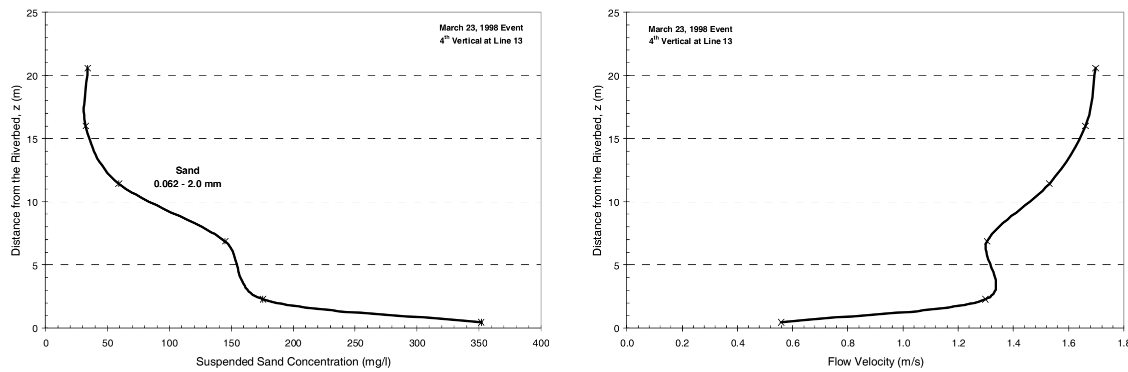

Figure 4.10. Calculation of the suspended sand discharge from the product of the sand concentration and flow velocity profiles.

4.2.3. Bed Material Sampling Method

Bed material samplers, as first developed, may be divided into three types: the drag bucket, grab bucket, and vertical pipe (Vanoni, 1975). Samples of bed material in this study were collected with a drag bucket. Figure 4.11 illustrates a drag bucket (bed material sampler) and a US P-63 (suspended sediment sampler) mounted on a boat. The drag bucket sampler consists of a weighted section of a cylinder with an open mouth and a cutting edge. As the sampler is dragged along the bed, it collects samples from the top layer of the bed material.

One disadvantage of using a drag bucket is that it is likely to permit fine material to be washed out as the sample is taken and then raised through the water column. Using a drag bucket can give a good result for gravel-size material gradation.

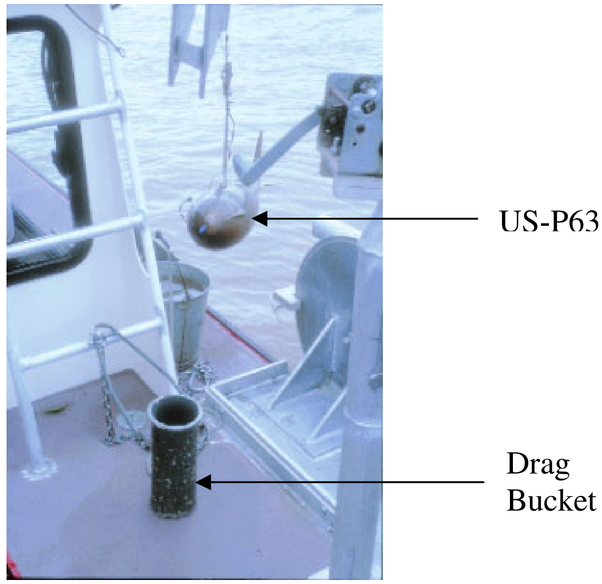

Figure 4.11. Drag bucket and US P-63 in the field.

Bed material samples are generally collected in conjunction with a set of suspended sediment samples. Four bed material samples were collected at bed surface locations corresponding to the same four chosen verticals for suspended sediment samples. Bed material samples generally contained a significant amount of sediment with a diameter smaller than 1mm (predominantly grain diameters varying between 0.125 and 0.5 millimeters), and only a small percentage of sediment with a diameter larger than 1 millimeters. Table 4.1 provides the percent average amount of bed material for all flow events at all locations. This table shows that the bed material is mostly composed of medium and fine sand fractions, medium sand fraction being the most. It also shows that there is only little coarse and very fine sand fraction, and almost negligible amount of very coarse sand fraction at the riverbed.

Table 4.1. Average percent bed material by sand size fraction at all locations.

Location	Percent Bed Material				
	VCS	CS	MS	FS	VFS
UP	1.1	5.2	47.0	42.3	1.9
L13	1.1	8.6	47.7	37.6	2.4
L6	0.2	4.0	57.0	36.2	2.4
T	0.2	4.7	56.9	37.1	1.0

Bed material samples were processed to obtain the bed sediment size distribution at the bed surface location of each vertical (see Figure 4.12).

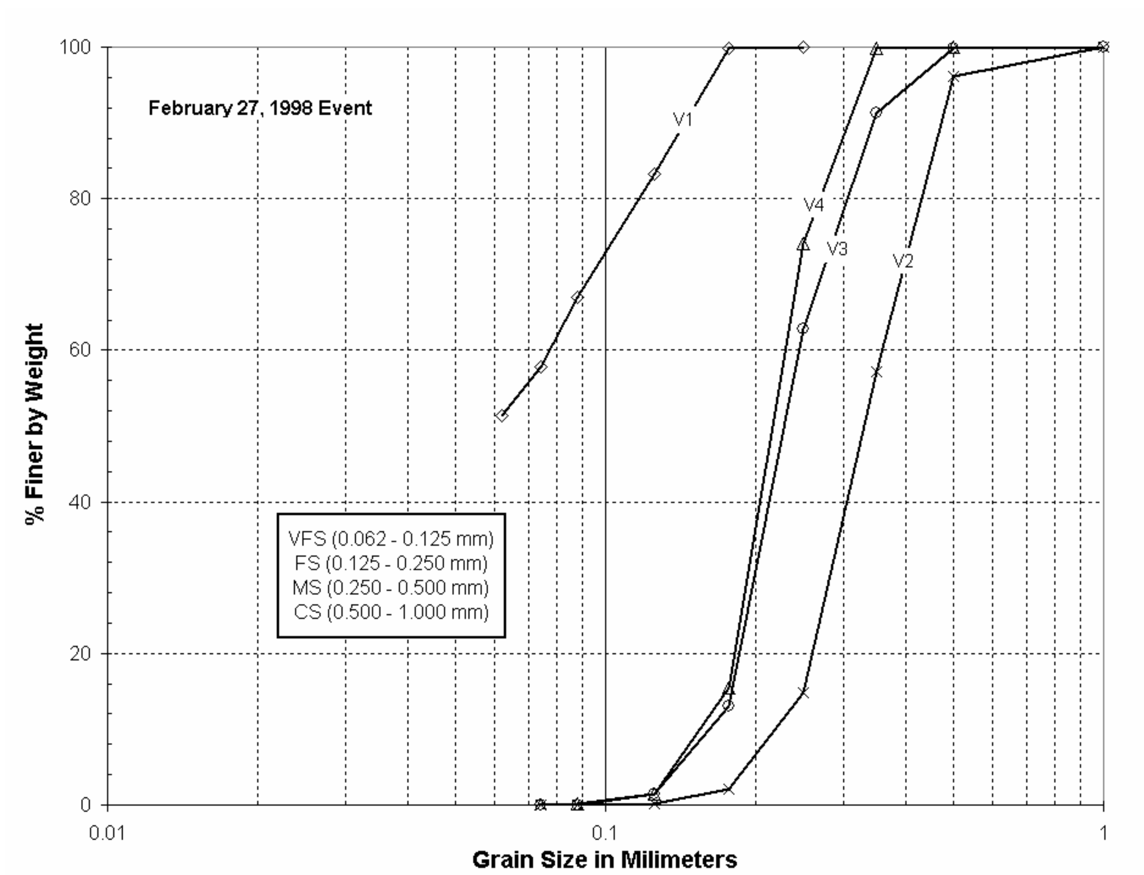

Figure 4.12. Bed material size distribution for February 27, 1998 event at Line 13.

Chapter 5. DATA ANALYSIS

This chapter provides an extensive analysis of the field data collected by the U.S. Army Engineer Waterways Experiment Station (WES) and the New Orleans District of the U.S. Army Corps of Engineers (NOD) at a reach near the Old River Control Structures Complex on the Lower Mississippi River in 1998. The purpose of the analysis was to determine whether the water temperature has any effect on the sediment movement processes, and the Coriolis effect on the flow direction in the Lower Mississippi River.

To understand how the water temperature affects the sediment distribution and transport by flowing water, and how the flow direction is affected by the Coriolis force, it is important to know the effects of water temperature, and the Coriolis force on parameters affecting both the water and sediment movement characteristics. There are many factors affecting the water and sediment transport characteristics in the Lower Mississippi River, which include all effective geometric, flow and fluid characteristics, and the properties of the sediment itself. As the sediment transport rate is the product of the vertical flow velocity and sediment concentration distributions, it is necessary to have reliable information on how the water temperature affects the vertical distributions of both the flow velocity and sediment concentration in the Lower Mississippi River.

The effect of water temperature on the vertical distribution of suspended sediment concentration and the transport of suspended sediment was sought in both direct and indirect ways. In the direct analysis, both the suspended sediment concentration and transport values were compared at different water temperature values. In the indirect analysis, on the other hand, first the effect of water temperature on the main parameters (i.e., the fall velocity of sediment particles, the kinematic viscosity of water, and the von Karman parameter) affecting the suspended sediment concentration and transport was searched, and then these effects were employed (i.e., by evaluating the change in Rouse number) to investigate the water temperature effect on the suspended sediment concentration and transport. The Coriolis effect on the flow direction was investigated by comparing the calculated and measured flow direction angles.

This chapter is mainly divided into four sections. The analysis of the effect of water temperature on the flow velocity in section 5.1 and on the sediment flow in section 5.2 is made. In section 5.3, a sample application is provided to demonstrate the difference between the measured and calculated sediment concentrations by size fraction. Finally, in section 5.4, the analysis of the Coriolis effect on flow direction is accomplished.

5.1. EFFECT OF WATER TEMPERATURE ON FLOW VELOCITY, V_x

Flow velocity depends highly on the fluid properties such as viscosity, bed roughness characteristics such as type of bedforms on the riverbed, and turbulence characteristics such as the von Karman parameter. Therefore, the effect of water temperature on afore-mentioned properties is the main reason for velocity profile change with water temperature. Because of the lack of bedform data in the study area, only the analysis of the effect of water temperature on water viscosity and the von Karman parameter was made first, and then the effect of water temperature on the vertical distribution of velocity profiles was analyzed based on the changes in water viscosity and the von Karman parameter with water temperature. Afterwards, a visual representation of the difference between velocity profiles at different water temperatures is demonstrated.

5.1.1. Water Temperature Effect on Kinematic Viscosity of Water, ν

Water viscosity results fundamentally from the cohesion and interaction between the water molecules. It opposes flow motion. Any pressure and temperature change affect the water viscosity, the pressure effect being to a negligible extent only.

Figure 5.1 based on Vanoni's 1970s experimental data clearly shows how the water temperature affects the kinematic viscosity of water. Figure 5.1 illustrates that the kinematic viscosity of water decreases considerably as the water temperature increases. However, there is an exponential decay of the effect of water temperature on the water viscosity towards the high water temperatures.

The existence of suspended sediment in the flow is also expected to change the viscosity of water. Because of the negligible suspended sediment concentrations in the study area of interest, it was assumed that the viscosity of sediment-water mixture is approximately equal to the viscosity of water, $\nu_m = \nu$.

Based on Eq.2.8, which is the velocity distribution equation in a turbulent flow, one can conclude that a decrease in kinematic viscosity with an increase in water temperature causes an increase in flow velocity. This means an increase in water temperature results in an increase in flow velocity. In the range of water temperature in the study reach, on average, there is approximately 1.9 percent decrease in the kinematic viscosity of water with a 1 ^{o}C increase in water temperature.

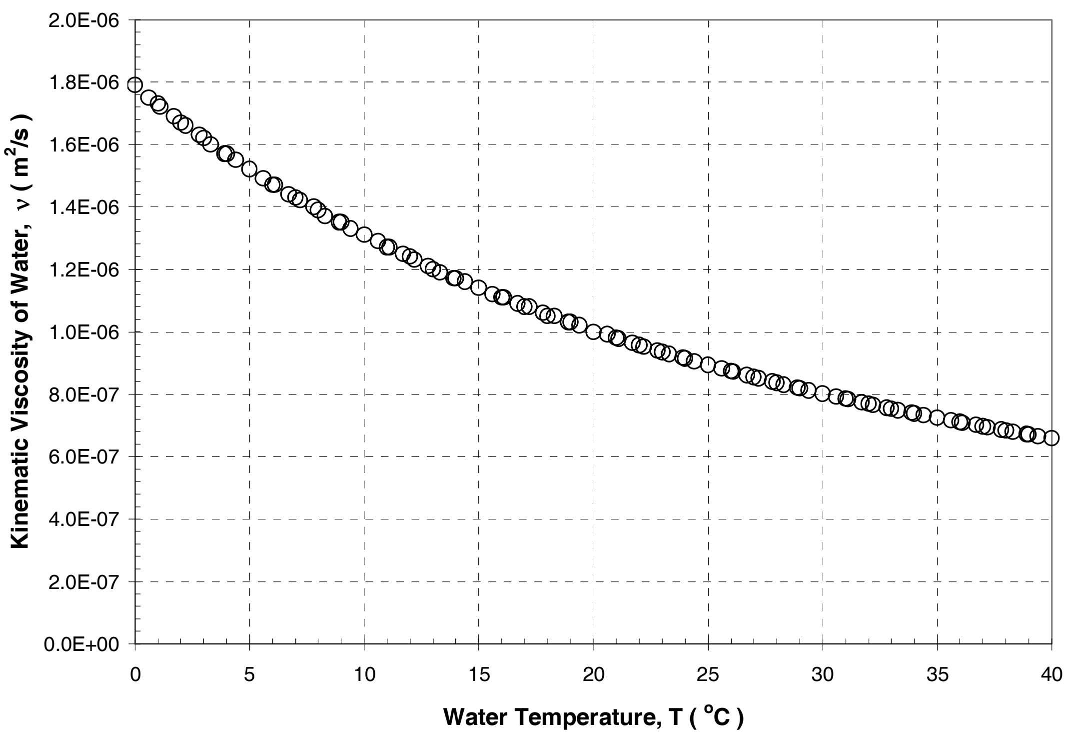

Figure 5.1. Water temperature effect on the kinematic viscosity of water.

5.1.2. Water Temperature Effect on von Karman Parameter, κ

The von Karman parameter, κ, is a measure of the slope of the local velocity profile (see Figure 2.2 on page 20). To investigate the behavior of the von Karman parameter, κ, under real conditions it is necessary to calculate the value of κ from measured velocity distributions. When measured velocity profiles are plotted as a straight line on semi-logarithmic paper, the average slope of the line represents the value of the von Karman parameter for a sediment-laden flow (see Figure 5.2).

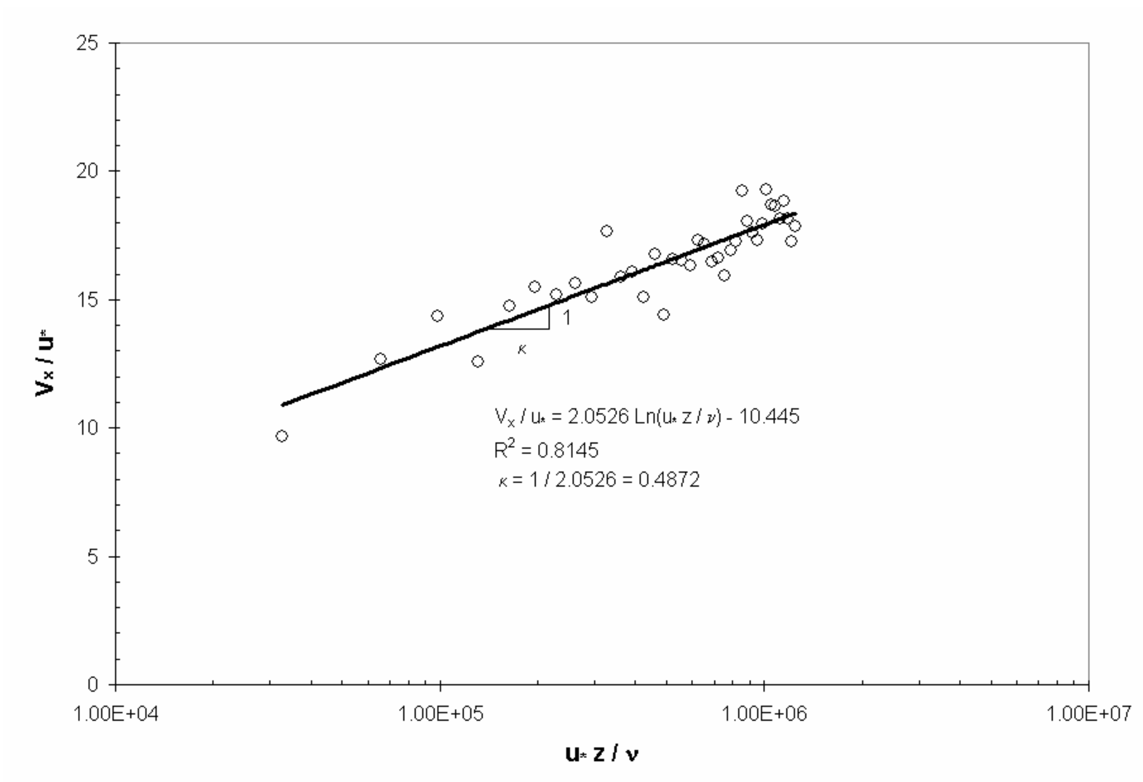

Figure 5.2. Obtaining the von Karman parameter from a velocity profile.

In analyzing the suspended sediment data, the von Karman parameter, κ, is determined from the velocity distribution according to the following equation:

$$\kappa = 1/m \qquad \text{(Eq.5.1)}$$

where m is the slope of the semi-logarithmic velocity profile, and expressed as follows:

$$m = \frac{d(V_x / u_*)}{d \ln(u_* \, z / \nu)} \qquad \text{(Eq.5.2)}$$

in which u_* is the shear velocity and ν is the viscosity of water. The shear velocity, u_*, is obtained using the following equation:

$$u_* = \sqrt{g \, h \, S_0} \qquad \text{(Eq.5.3)}$$

where g is the gravitational acceleration, h is the flow depth, and S_0 is the riverbed slope.

In clear-water flows, the value of κ is commonly assumed to be a constant and equal to 0.4. In the presence of sediment in the flow, κ is not really a constant and its value can be influenced by factors such as sediment concentration, C, and characteristic bed roughness height, k_s. However, there have been some conflicting ideas about how the changes in C and k_s affect the value of κ. Besides the effect of C and k_s, water temperature also has an influence on the value of κ.

In this study, the effect of water temperature on the value of κ is sought by observing the changes in the value of κ for different flow events with different water temperature values from the field data. The values of the von Karman parameter at all verticals at all locations are obtained from the slope of the logarithmic velocity profiles and are provided in Table 5.1. The majority of the κ values given in Table 5.1 are positive and there are only a few negative κ values. Therefore, it is assumed that the von Karman parameter, κ, takes positive values, and negative values of κ are disregarded in this study.

Table 5.1. Values of the von Karman parameter at all locations.

CROSS SECTION	VERTICAL	FLOW EVENT						
		27-Feb	23-Mar	10-Apr	17-Apr	8-May	9-Jun	3-Aug
Union Point	V1	0.8184	0.4247	0.9555	0.8349	0.4749	0.5748	0.2827
	V2	0.3288	0.6125	0.4397	0.2602	0.3119	0.2381	0.7301
	V3	0.2874	0.2070	0.2651	0.4445	0.5966	0.2928	0.4266
	V4	0.4267	0.4165	0.5001	0.2481	0.3639	0.4822	0.3375
Line 13	V1	0.6809	-0.7537	0.8295	0.5397	0.5018	0.5696	3.2613
	V2	0.2117	0.2996	0.2720	0.2018	0.2064	0.5651	0.5382
	V3	0.2782	0.2905	5.0665	0.6220	3.3953	0.3535	0.5180
	V4	0.4872	0.2967	1.4419	0.5164	1.1145	0.5253	0.5090
Line 6	V1	0.3868	0.3181	0.3751	0.2788	N/A	0.2562	0.5007
	V2	0.3244	0.3293	0.8891	0.2779	N/A	0.4236	0.5062
	V3	0.3821	0.5140	0.2824	0.5704	N/A	0.4374	0.4680
	V4	0.5046	-2.2182	0.7064	1.2714	N/A	-24.4309	0.6208
Tarbert	V1	0.4547	0.8524	0.8033	1.1037	0.7734	0.5703	0.5169
	V2	1.5453	0.6690	0.3065	0.3490	0.2887	0.3486	0.3599
	V3	0.4848	0.1708	0.2768	1.8484	0.7595	0.3931	0.3059
	V4	0.8073	0.2264	0.5698	0.3178	0.2600	0.4353	0.4473

To obtain the effect of water temperature on the von Karman parameter, first the von Karman parameter values at specific cross-sections at different flow events, which have approximately the same flow discharges, were compared by using the multiple regression analysis. In the multiple regression analysis, the von Karman parameter, κ, depends on both the water discharge, Q, and water temperature, T, as following:

$$\kappa = c\,Q^{e_Q}\,T^{e_T} \qquad \text{(Eq.5.4)}$$

in which c is a constant, and e_Q and e_T are the exponents of the water discharge and water temperature, respectively.

Table 5.2 below provides the values of the exponents e_Q and e_T at Union Point, Line 6, and Tarbert locations.

Table 5.2. The values of e_Q and e_T showing the relationship between the von Karman parameter, κ, and water temperature, T.

Location	Union Point		Line 6				Tarbert		
Flow Event	23-Mar	17-Apr	27-Feb	17-Apr	23-Mar	10-Apr	23-Mar	10-Apr	
Temperature (°C)	9	16	9	16	9	16	9	16	
ADCP Q (m^3/s)	30,092	30,265	22,174	22,571	23,900	24,239	24,388	23,989	Average
e_Q	-0.033		-0.024		-0.129		-0.048		-0.058
e_T	0.029		0.367		0.518		0.245		0.290

Since the purpose of the analysis herein is to figure out the water temperature effect on the von Karman parameter, the effect of water discharge on the von Karman parameter is eliminated by choosing the flow events that have approximately the same ADCP flow discharges (see Table 5.2). Based on Table 5.2, on average, the von Karman parameter, κ, is directly proportional to the water temperature, T. In other words, when the water temperature is increased, the value of the von Karman parameter increases. For instance, when the water temperature is increased from 9 to 16 ^oC (water discharge being constant), there is approximately 15 percent increase in the von Karman parameter.

Moreover, the effect of water temperature on the von Karman parameter is sought graphically (see Figure 5.3). Figure 5.3 is obtained from the von Karman parameter values calculated for February 27, March 23, April 10 and April 17 events at Union Point station because the flow discharges for these events are approximately equal, eliminating the flow discharge effect on the von Karman parameter.

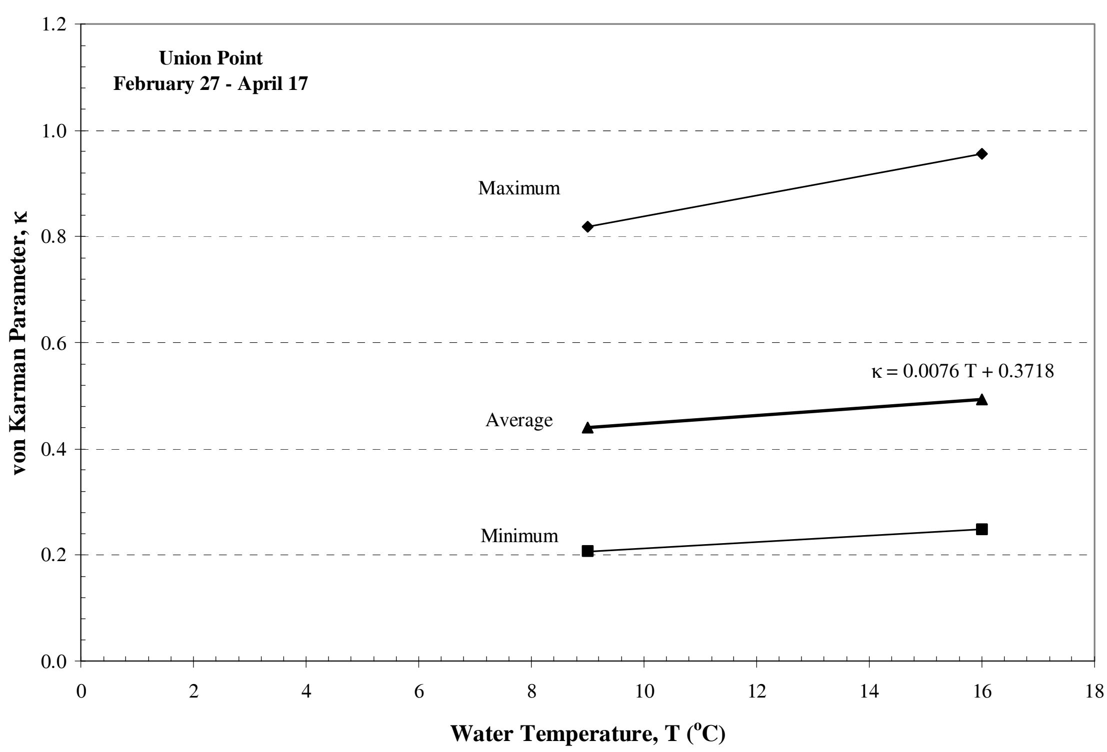

Figure 5.3. The effect of water temperature on the von Karman parameter for approximately same discharge events at Union Point.

As it is obvious from the above figure, the average value of the von Karman parameter increases with water temperature. Similar trends are obtained for other stations (Line 13, Line 6 and Tarbert) also (see Figure C.1 through Figure C.3 in Appendix C). In all of these figures the average value of the von Karman parameter is higher than the clear-water value of 0.4, averaging about 0.53 at 9 ^{o}C and 0.61 at 16 ^{o}C.

The von Karman parameter versus the water temperature for all events at all locations are also plotted and are shown in Figure 5.4. In Figure 5.4, the trendlines show that the average value of the von Karman parameter tends to decrease with increasing water temperature at Union Point and Tarbert stations, and increase with increasing water temperature at Line 13 and Line 6 stations. The difference in trendlines at different locations in Figure 5.4 indicates that there might exist other flow parameters (i.e. flow discharge, bedforms and secondary currents) that might affect the von Karman parameter.

The analysis herein shows that the von Karman parameter, κ, is not a constant and slightly increases with an increase in water temperature, T. On average, there is about 2.14 percent increase in the von Karman parameter for every 1 ^{o}C increase in water temperature. Also, the value of the von Karman parameter is always higher than its value of 0.4 in clear-water flows.

Another obvious conclusion that can be deduced from the Figure 5.4 is that in flows with low temperatures the von Karman parameter has a higher variability than that in flows with warmer water temperatures. To demonstrate this more clearly, the standard deviations of the von Karman parameter for all water temperatures are calculated first. Then, the average values of the standard deviations of the von Karman parameter for

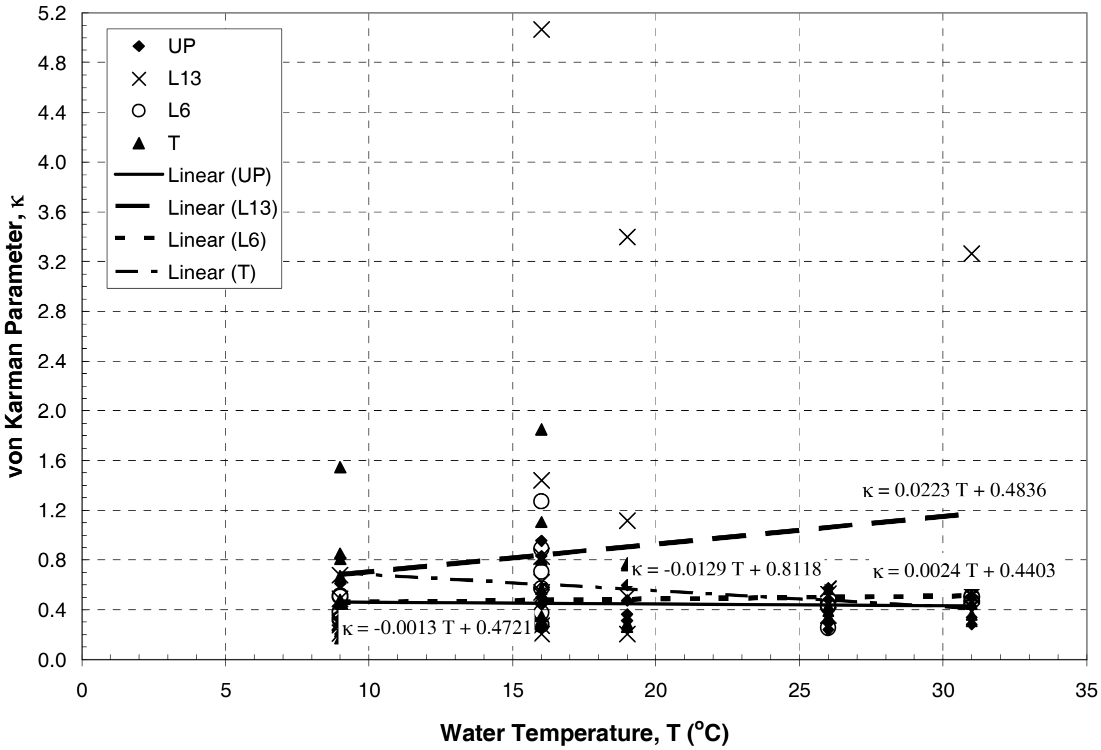

Figure 5.4. The effect of water temperature on the measured von Karman parameter for all locations.

each water temperature are determined (see Figure 5.5). Figure 5.5 indicates that the deviation of the von Karman parameter from an average value is small in warm temperatures, which tells us that the von Karman parameter can be defined more accurately in flows with higher water temperatures. More specifically, during the summer season the value of the von Karman parameter does not fluctuate as much as that during the winter season. Moreover, the value of the von Karman parameter is more accurately predictable in warm water flow than that in the cold one. This might be because of the fact that the turbulent velocity profiles during the winter are more uniform than those during the summer.

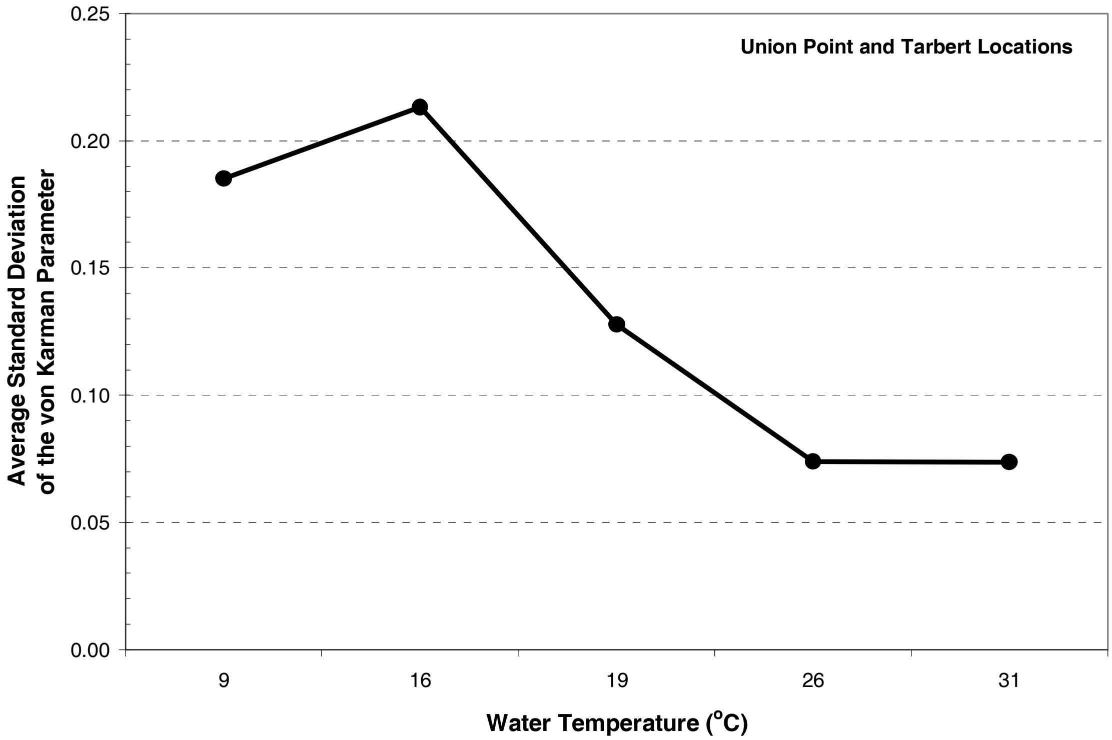

Figure 5.5. Average standard deviation of the von Karman parameter with water temperature at Union Point and Tarbert locations.

5.1.3. Comparison of Velocity Profiles at Different Water Temperatures

To visualize the effect of water temperature on velocity profiles, only the flow events that have almost the same flow discharges are selected for comparison. For example, March 23 & April 17 flow events at Union Point, February 27 & April 17 and March 23 & April 10 flow events at Line 6, and March 23 & April 10 flow events at Tarbert have approximately the same flow discharges (see Figure 5.6 through Figure 5.9). Comparison of the velocity profiles at different water temperatures at all verticals for the

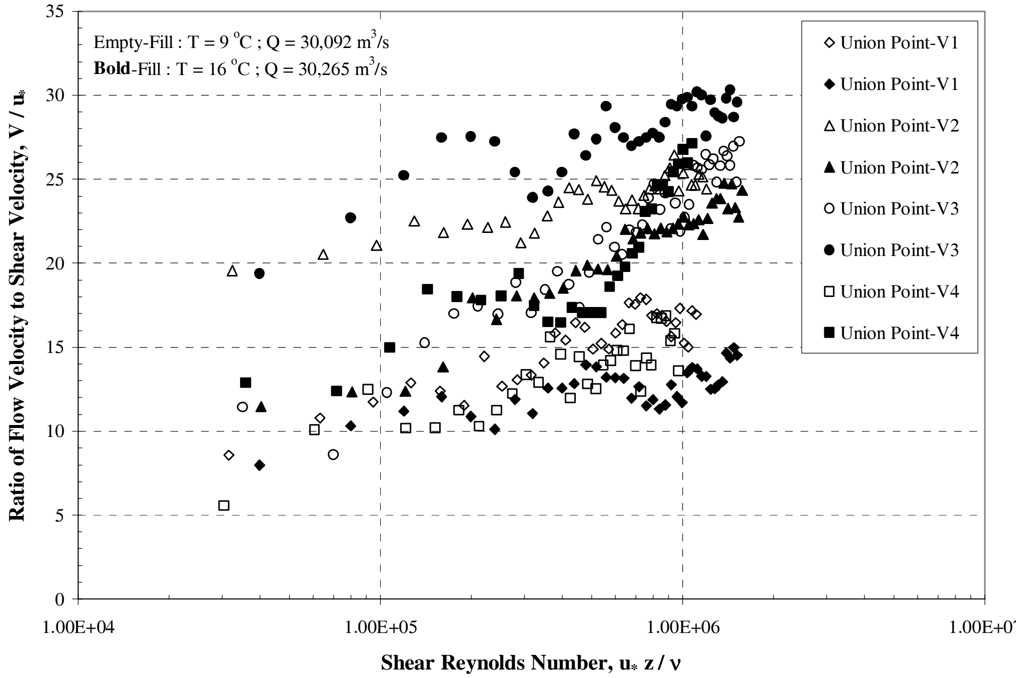

Figure 5.6. Water temperature effect on flow velocity profiles at Union Point.

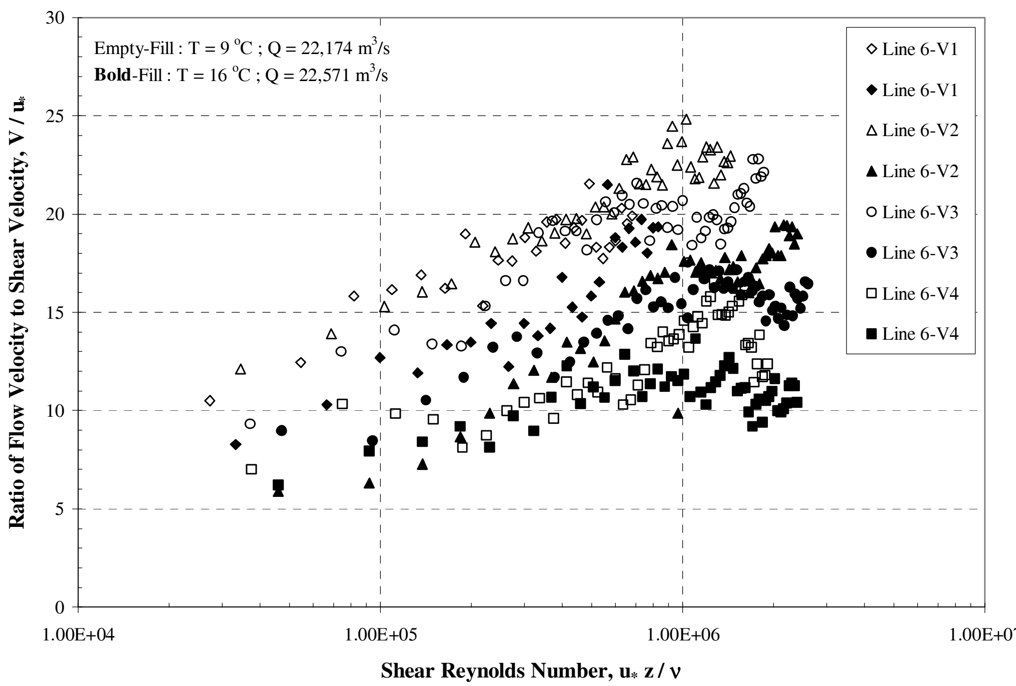

Figure 5.7. Water temperature effect on flow velocity profiles at Line 6.

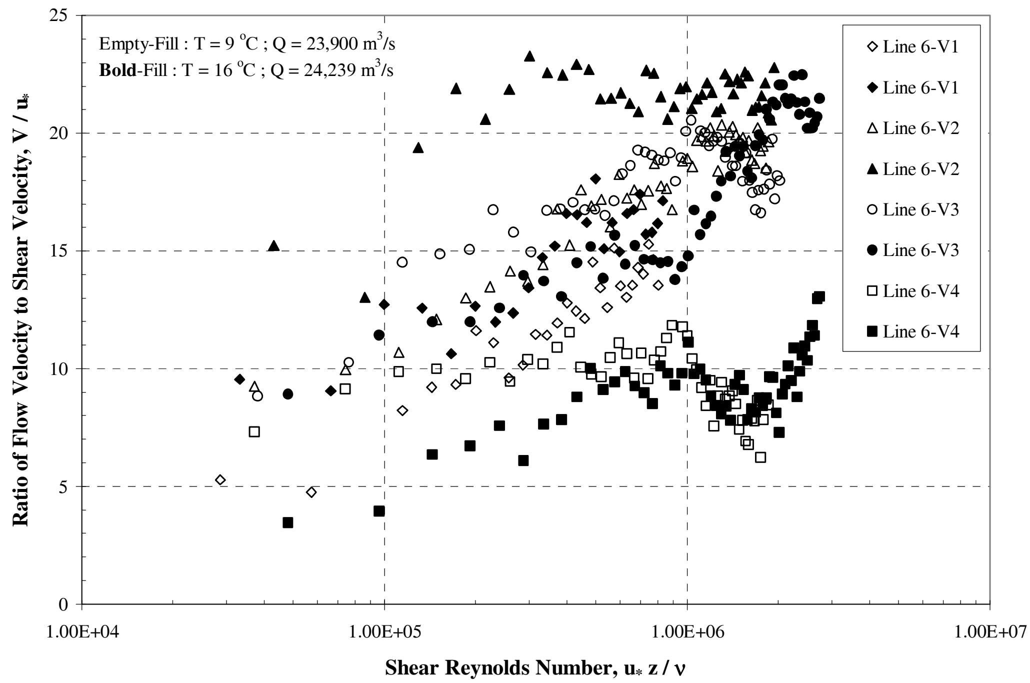

Figure 5.8. Water temperature effect on flow velocity profiles at Line 6.

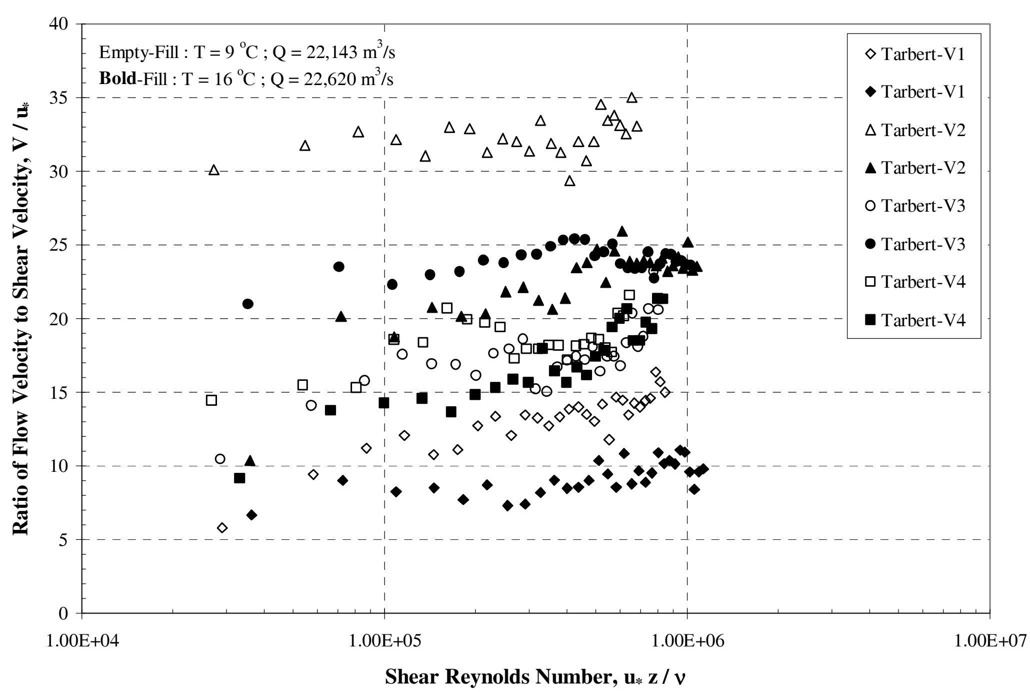

Figure 5.9. Water temperature effect on flow velocity profiles at Tarbert.

above specified flow events and locations indicate that the flow velocity increases, decreases or stays almost the same at different verticals (see Figure 5.6 through Figure 5.9). However, in general, the flow velocity decreases with water temperature at most verticals. In the above graphs the flow velocities at warmer water temperature are indicated by bold-filled marker styles.

The relationship between the turbulent flow velocity and water temperature is shown in Figure 5.10.

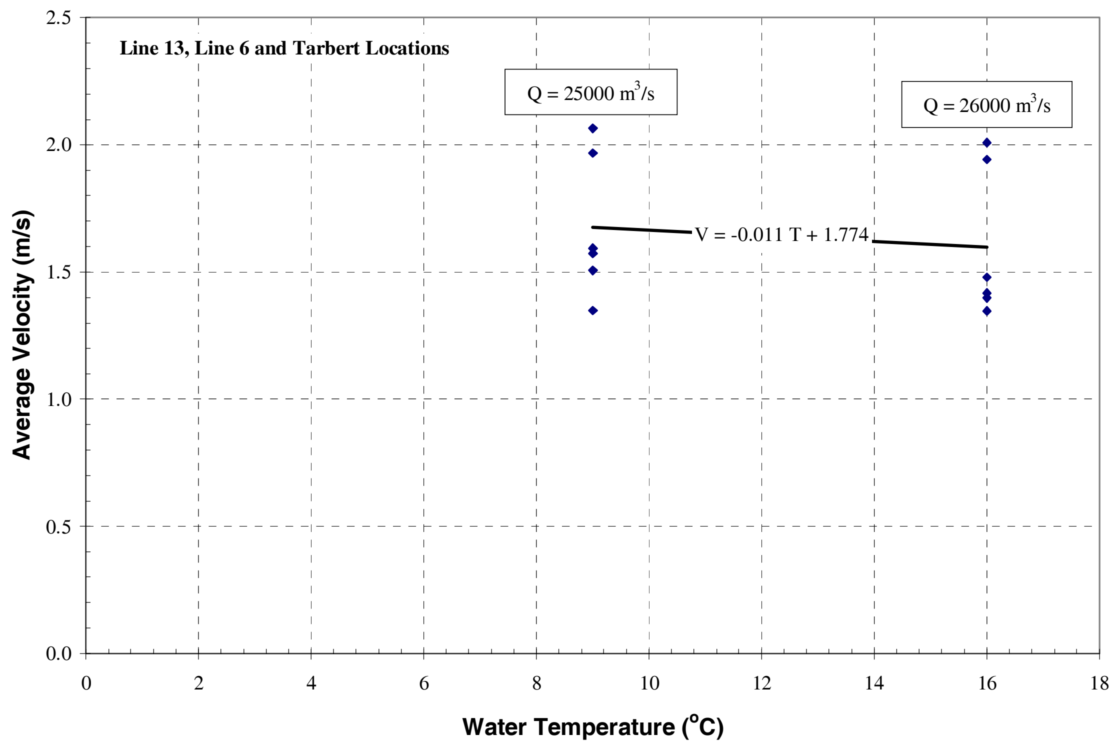

Figure 5.10. The effect of water temperature on average flow velocity for about the same flow discharges at all locations.

This graph is produced based on the data at Line 13, Line 6 and Tarbert locations since these locations have almost the same discharges for February 27 through April 17, 1998, flow events. The figure below clearly indicates that, for almost the same discharge events, the flow velocity decrease with water temperature. For example, when the water temperature is increased from 9 ^oC to 16 ^oC, flow velocity drops off by about 4.6 percent. In other words, the flow velocity decreases by approximately 0.66 percent for every 1 ^oC increase in water temperature.

5.1.4. Concluding Remarks about the Effect of Water Temperature on Flow Velocity

On average, the flow velocity decreases with water temperature. The main reason for the flow velocity to decrease with water temperature is an increase in the von Karman parameter, κ, and a decrease in the kinematic viscosity of water, ν, with water temperature. Eq.2.8 shows clearly the relationship between the flow velocity, the von Karman parameter, and the kinematic viscosity of water.

5.2. WATER TEMPERATURE EFFECT ON SEDIMENT FLOW

The suspended sediment and bed material in the study reach are mainly composed of fine material (clay and silt), sand, and little gravel (see Figure 5.11 and Figure 5.12). The analysis mainly focuses on certain sand fractions; namely, very fine sand (VFS), fine sand (FS), medium sand (MS), and coarse sand (CS). Fine materials (clay and silt) are excluded in this study because large changes in the flow can bring about only minor changes in the transport of fine sediment. Also, very coarse sand (VCS) and gravel are not accounted for in this study because their volume in the flow is so minor that the analysis would produce incorrect results. After an examination of the all suspended and bed material gradation curves at all locations, it was realized that the bed material is mostly composed of the medium sand (MS) fraction, and the suspended sediment is mostly made up of the fine sand (FS) fraction.

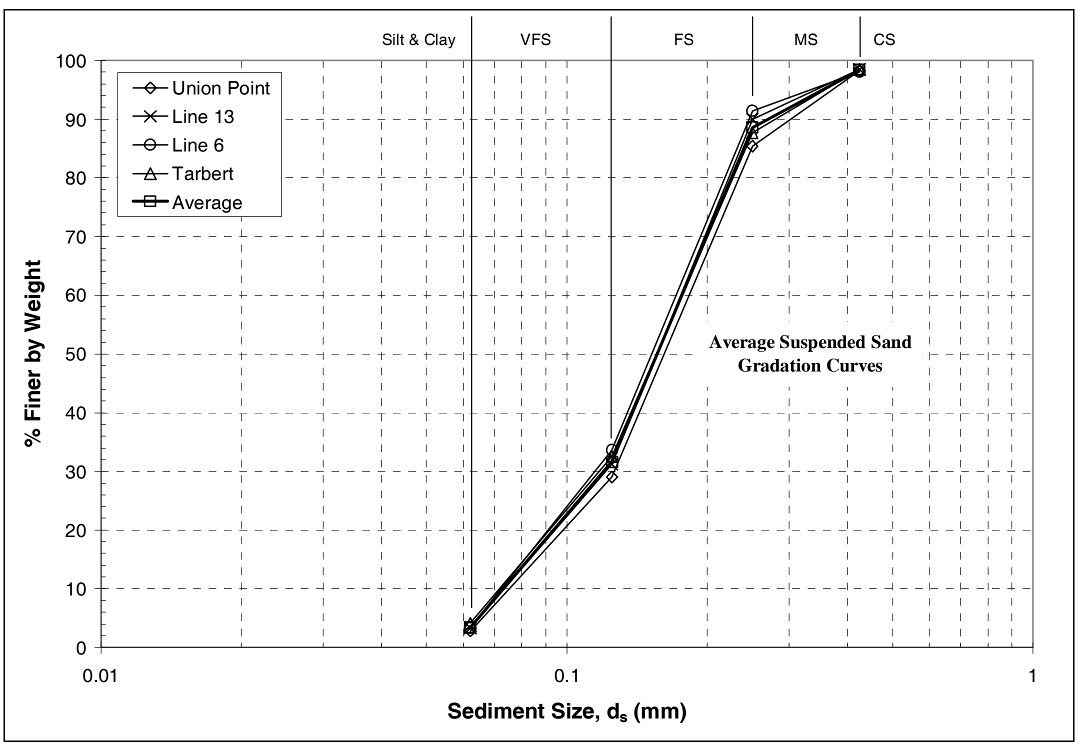

Figure 5.11. Average suspended sand gradation curves at all locations.

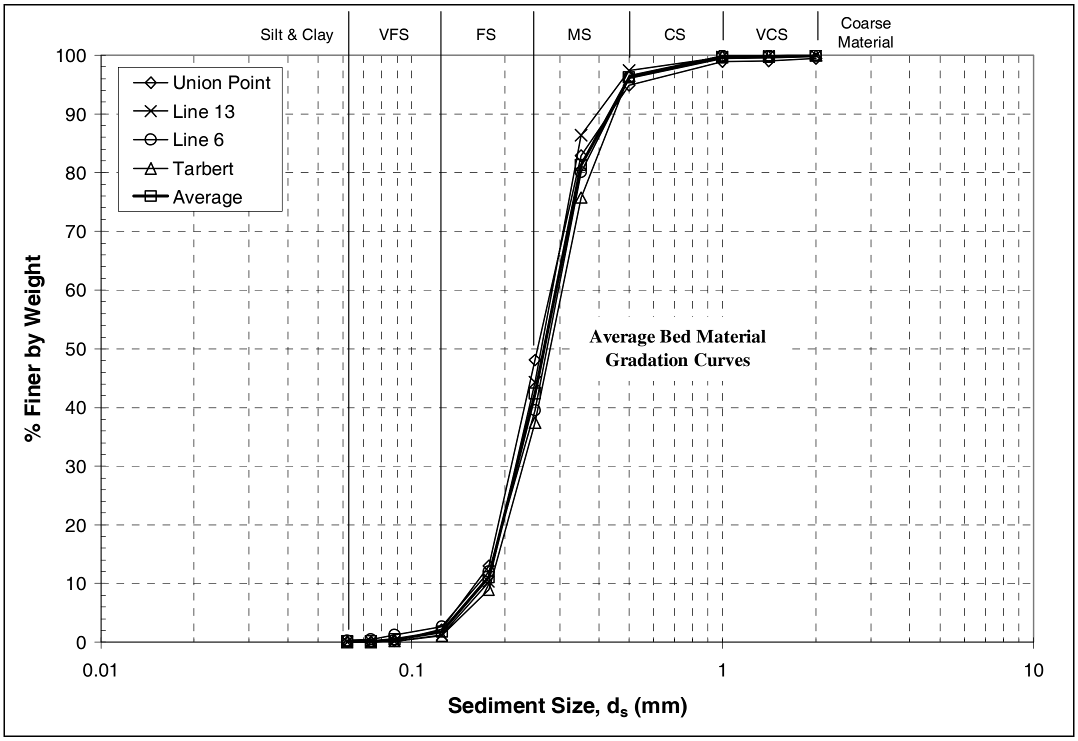

Figure 5.12. Average bed material gradation curves at all locations.

Water temperature affects the sediment flow mainly by changing the vertical distribution of velocity profiles and sediment concentration. The effect of water temperature on velocity profiles was discussed in detail in the previous section (section 5.2). In this section the water temperature effect on the vertical distribution of the suspended sediment concentration and transport will be sought.

The effect of water temperature on sediment concentration and transport was sought in both direct and indirect ways. In the direct analysis, both the suspended sediment concentration and transport values were compared at different water temperature values. In the indirect analysis, on the other hand, first the effect of water temperature on the main parameters (i.e., kinematic viscosity of water, von Karman parameter, fall velocity, turbulent Schmidt number, shear velocity, and Rouse number) affecting the suspended sediment concentration and transport was searched, and then these effects were employed to investigate the water temperature effect on the suspended sediment concentration and transport. In previous sections it was already mentioned that both the kinematic viscosity of water and the von Karman parameter are influenced by water temperature. Also, because of the lack of data on the turbulent Schmidt number and shear velocity, only the analysis of the effect of water temperature on the fall velocity of sediment particles and the Rouse number is included in the indirect analysis subsection (section 5.2.2).

5.2.1. Direct Analysis of Water Temperature Effect on the Vertical Distribution and Transport of Suspended Sediment

In this section, the effect of water temperature on the Mississippi River sediment is analyzed by calculating the depth-averaged sediment concentrations and unit suspended sediment discharges at different water temperatures, and applying the multiple regression analysis method to relate both the suspended sediment discharge and bed sediment concentration to water temperature.

To explore the direct effects of the water temperature on the vertical distribution of suspended sediment concentration, depth-averaged suspended sediment concentrations were obtained first. Depth-average suspended sediment concentrations at each vertical for each flow event were calculated by using the following equation:

$$\overline{C} = \overline{C_0} + \frac{\sum_{i=1}^{6}\left[\frac{\left(C(d_i) + C(d_{i+1})\right)\Delta d}{2}\right]}{h_s} \qquad \text{(Eq.5.4)}$$

in which $\overline{C}$ is the depth-averaged suspended sediment concentration at a vertical, $\overline{C_0}$ is the depth-averaged concentration at the region between the water surface and the first sampling point and expressed as: $\left[C(d_1)/2\right]\left[d_1/h_s\right]$, where $C(d_1)$ is the measured sediment concentration at the first (or minimum) sampling depth from the water surface (d_1), $C(d_i)$ and $C(d_{i+1})$ are the suspended sediment concentrations at consecutive sampling points, where $i = 1...6$ because there are 6 sampling points at each vertical, and h_s is the maximum sampling depth.

Table 5.3 on the following page shows the depth-averaged suspended sediment concentration values for each vertical at all locations. Because the water temperatures for all flow events are known at the specified locations, a graph of the depth-averaged suspended sediment concentrations versus the water temperature for all flow events can be plotted (see Figure 5.13).

Figure 5.13 shows that the depth-averaged suspended sediment concentration values decrease when the water temperature is increased. It is also obvious from these graphs in Figure 5.13 that the effect of water temperature on sand particles is greater than that on fine particles (silt and clay) because the trendlines for sand particles in the above graphs have higher negative slopes than those for silt and clay particles. The higher the negative slope of the trendline, the more change occurs in the depth-averaged suspended sediment concentration with an increase in water temperature. Although the average suspended silt and clay concentration decreases by about 0.35 percent with a water temperature increase of 1°C, the average suspended sand concentration decreases by about 2.0 percent with the same range of water temperature increase.

Table 5.3. Depth-averaged suspended sediment concentrations for each vertical at all locations.

Vertical	Date	Water Temp. (°C)	Depth-averaged Suspended Sediment Concentration (mg/l)											
			Union Point			Line 13			Line 6			Tarbert		
			Sand	Fine	Total	Sand	Fine	Total	Sand	Fine	Total	Sand	Fine	Total
V-1	27-Feb	9	90.72	218.68	309.40	65.25	188.32	253.57	77.53	246.99	324.52	137.26	221.30	340.16
	23-Mar	9	94.36	271.78	366.14	53.16	222.84	276.00	143.72	241.41	385.13	27.02	228.61	255.63
	10-Apr	16	42.12	179.37	221.50	28.74	133.29	162.03	66.15	128.64	194.79	61.63	142.27	203.90
	17-Apr	16	73.49	275.01	348.49	42.20	265.77	307.97	100.04	302.28	402.32	26.18	320.47	346.65
	8-May	19	62.69	138.98	201.68	63.43	115.06	178.49	N/A	N/A	N/A	31.52	147.65	179.17
	9-Jun	26	18.69	249.32	268.02	16.61	218.56	235.16	16.61	218.55	235.15	43.66	231.63	275.30
	3-Aug	31	37.24	187.46	224.69	11.18	177.73	188.90	9.97	186.19	196.16	26.66	189.99	216.66
V-2	27-Feb	9	147.89	200.70	348.60	82.15	203.12	285.26	144.83	200.90	345.73	52.46	194.59	247.05
	23-Mar	9	111.09	228.25	339.34	135.04	226.34	361.38	181.06	237.82	418.88	107.75	210.37	318.12
	10-Apr	16	77.38	159.50	236.87	60.55	140.66	201.21	153.43	107.93	261.37	143.43	141.84	285.26
	17-Apr	16	95.28	252.61	347.89	93.44	257.43	350.87	91.68	273.21	364.89	99.28	301.57	400.85
	8-May	19	125.16	131.92	257.08	88.20	120.33	208.53	N/A	N/A	N/A	99.73	105.48	205.20
	9-Jun	26	64.27	221.32	285.59	96.84	231.75	328.59	96.84	231.75	328.59	73.90	231.60	305.50
	3-Aug	31	68.81	180.67	249.48	30.94	181.76	212.71	56.33	184.36	240.68	75.14	192.00	267.15
V-3	27-Feb	9	116.07	190.89	306.95	189.29	194.43	383.73	135.26	202.98	338.23	19.60	225.75	245.36
	23-Mar	9	117.75	230.87	348.62	80.68	233.41	314.09	65.54	224.41	289.95	125.95	228.56	354.51
	10-Apr	16	77.99	156.43	234.42	78.17	138.29	216.47	103.88	72.29	176.17	133.96	155.24	289.20
	17-Apr	16	100.37	266.22	366.59	112.04	259.18	371.22	59.11	268.70	327.81	99.39	287.98	387.38
	8-May	19	134.28	124.68	258.96	75.14	125.60	200.74	N/A	N/A	N/A	122.60	105.62	228.22
	9-Jun	26	95.65	221.92	317.57	119.10	227.24	346.34	119.10	227.24	346.34	43.95	229.64	273.58
	3-Aug	31	43.53	183.23	226.77	71.50	185.39	256.89	83.11	196.03	279.14	44.43	183.11	227.54
V-4	27-Feb	9	42.88	200.41	243.30	135.95	220.55	356.50	42.66	199.14	241.80	31.50	222.72	254.21
	23-Mar	9	41.13	248.95	290.07	92.98	240.03	333.01	44.79	277.82	322.61	78.05	237.41	315.46
	10-Apr	16	37.12	153.66	190.77	77.90	138.30	216.20	51.71	75.81	127.53	45.81	162.54	208.35
	17-Apr	16	62.04	287.92	349.97	62.19	276.38	338.57	23.40	252.85	276.25	51.70	289.34	341.04
	8-May	19	57.43	127.27	184.70	68.37	149.71	218.08	N/A	N/A	N/A	59.58	110.31	169.89
	9-Jun	26	31.81	236.56	268.37	24.83	258.31	283.14	24.83	258.31	283.14	29.02	229.63	258.65
	3-Aug	31	8.46	175.08	183.53	38.59	184.63	223.23	75.71	357.50	433.21	19.27	176.26	195.53

It was also observed that the effect of water temperature is different for different sand size fractions (see Figure 5.14). Figure 5.14 shows that the general trend is toward a decrease in the depth-averaged suspended sand concentration with an increase in water temperature. From the graphs in Figure 5.14, it was noticed that the fine sand size is influenced the most from water temperature changes. While, on average, the suspended fine sand concentration decreases by approximately 2.48 percent, the suspended coarse, medium and very fine sand concentrations reduce less than 1.40 percent with a water temperature increase of 1 oC. Figure 5.15 shows the water temperature effect on the suspended fine sand concentrations at all four locations. As it is clear from Figure 5.15, on average, fine sand concentration decreases when the water temperature is increased. That is, suspended fine sand concentration is inversely proportional to water temperature. This is true for other sediment sizes, too, but the effect is less pronounced for other sand size fractions. A 1.19 to 3.17 percent decrease in the depth-averaged suspended fine sand concentration was determined with an increase in water temperature of 1 ^{o}C.

Why is there more pronounced effect of water temperature on fine sand (FS) than other sediment sizes? This question can be answered by determining the sediment size that is in transition between the hydraulically smooth and rough flows. More specifically, the sediment particle in question is so unstable in the flow that even little changes in the flow can influence the state (suspended or settled) of that sediment size. One of the methods to determine whether a particle will be suspended or settled is by comparing the size of that particle, d_s, with the thickness of the laminar sublayer, $\delta = 11.6\,\nu / u_*$ (Julien, 1995). Table 5.4 on page 111 provides the values of δ at different verticals at all locations. The laminar sublayer thickness (δ) values in Table 5.4 are mainly in the fine sand (FS) size range, which indicates that a slight change in the water temperature changes behavior between the hydrodynamically rough and smooth.

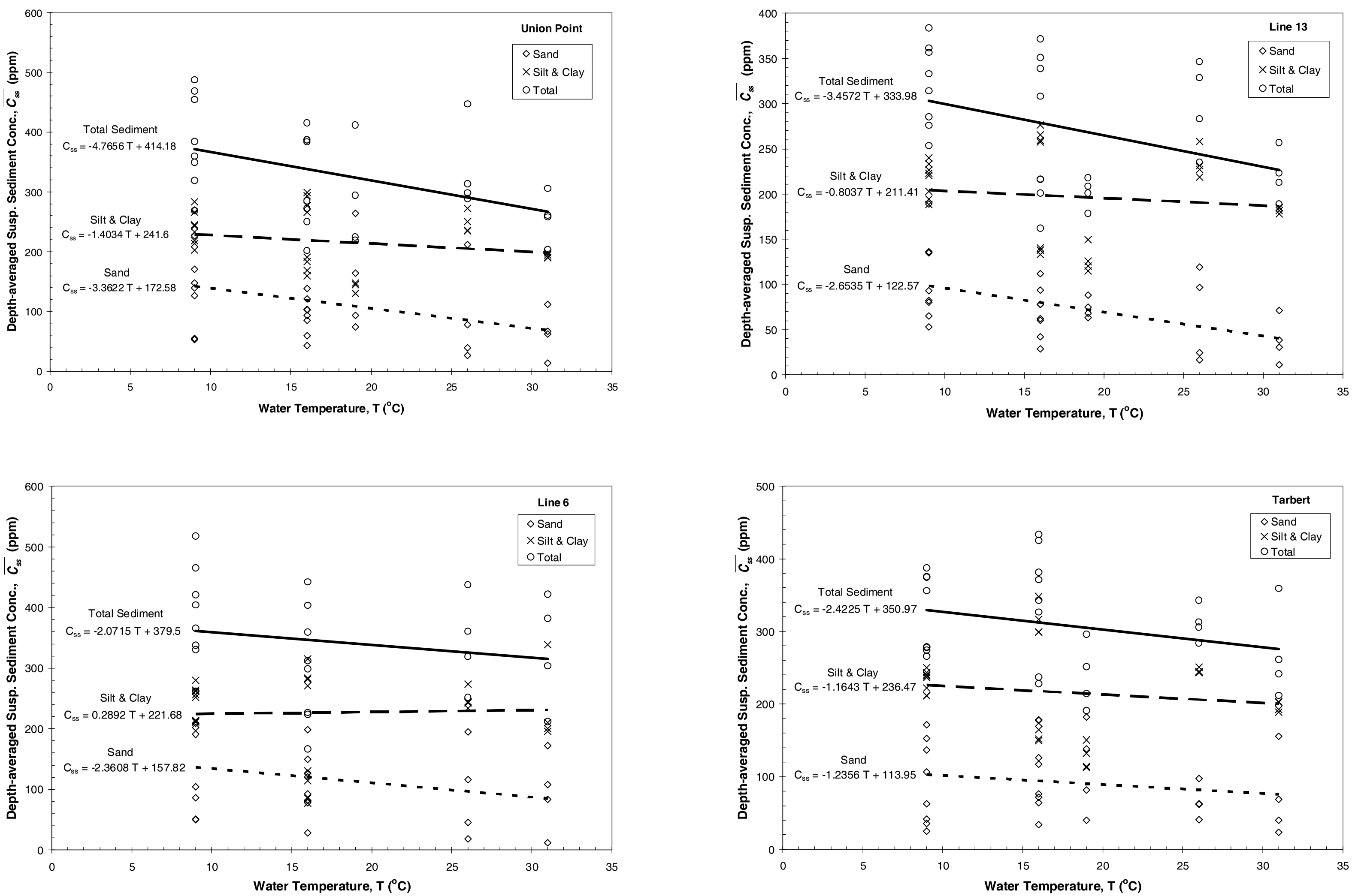

Figure 5.13. Depth-averaged suspended sediment concentration change with water temperature at all locations.

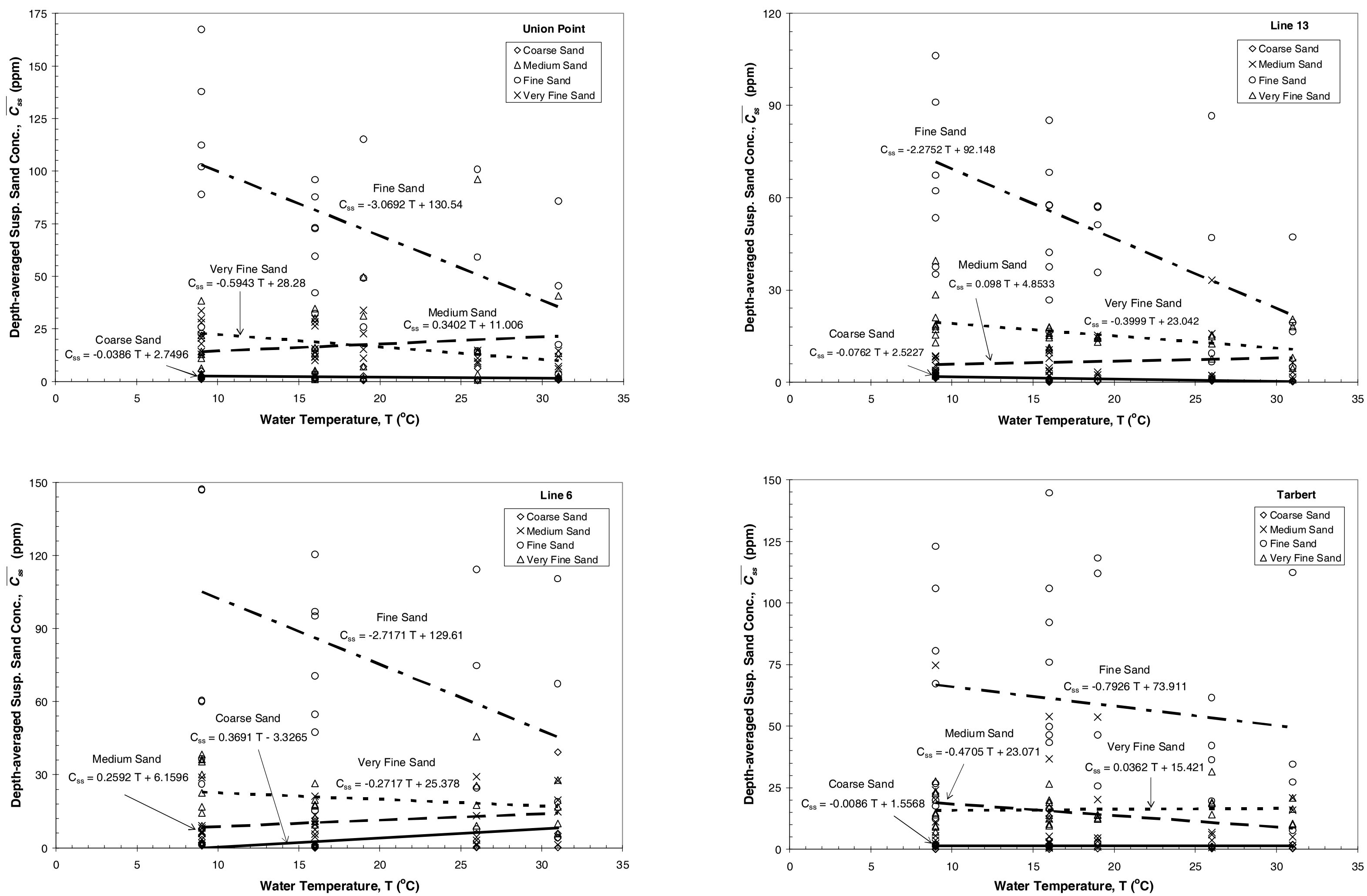

Figure 5.14. Depth-averaged suspended sand concentration change with water temperature at all locations

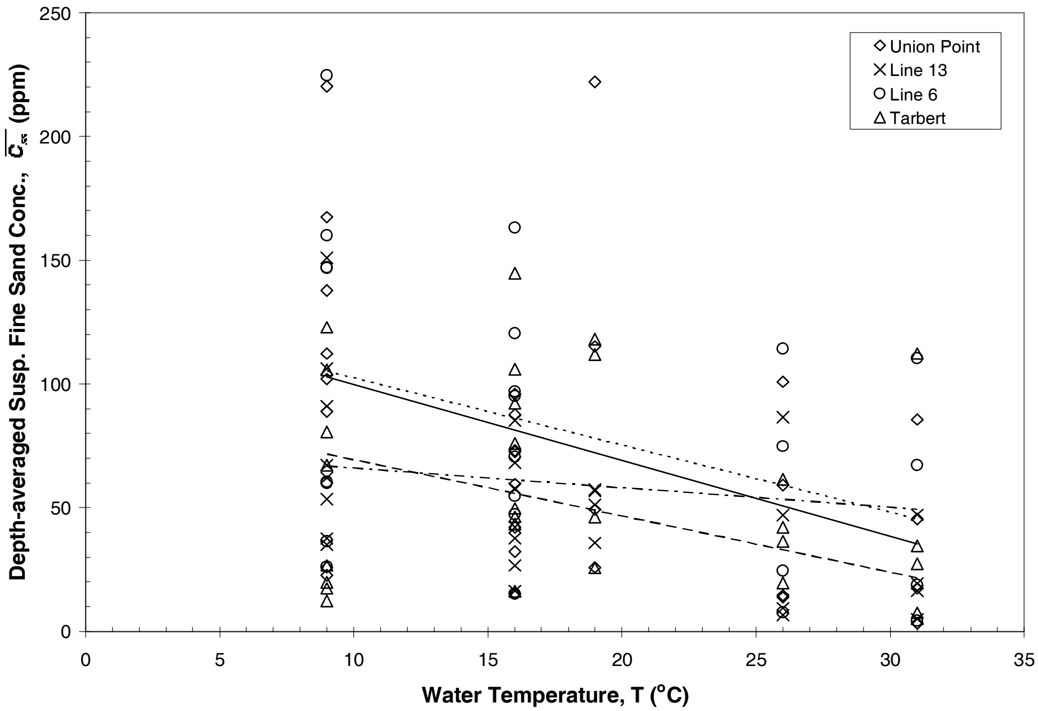

Figure 5.15. Depth-averaged suspended fine sand concentration change with water temperature for all events at all locations.

Table 5.4. Laminar sublayer thickness values at all locations.

Location	Vertical	δ Values in Millimeter Flow Events 27-Feb	23-Mar	10-Apr	17-Apr	8-May	9-Jun	3-Aug
Union Point	V1	0.179	0.184	0.144	0.144	0.130	0.125	0.124
	V2	0.179	0.178	0.143	0.142	0.131	0.122	0.120
	V3	0.179	0.163	0.133	0.144	0.131	0.119	0.120
	V4	0.195	0.188	0.155	0.159	0.146	0.139	0.132
Line 13	V1	0.141	0.141	0.114	0.114	0.104	0.095	0.090
	V2	0.148	0.150	0.120	0.117	0.110	0.097	0.093
	V3	0.154	0.156	0.125	0.126	0.119	0.105	0.099
	V4	0.174	0.168	0.137	0.137	0.124	0.113	0.112
Line 6	V1	0.210	0.202	0.171	0.173	N/A	0.167	0.185
	V2	0.167	0.154	0.134	0.125	N/A	0.113	0.113
	V3	0.154	0.150	0.120	0.122	N/A	0.103	0.097
	V4	0.154	0.154	0.122	0.125	N/A	0.103	0.095
Tarbert	V1	0.198	0.193	0.152	0.157	0.142	0.136	0.132
	V2	0.210	0.213	0.151	0.163	0.153	0.147	0.141
	V3	0.200	0.204	0.159	0.163	0.149	0.149	0.148
	V4	0.215	0.213	0.171	0.173	0.157	0.159	0.169

Similar trends were obtained for the suspended sand discharges. Suspended sand discharge decreases when the water temperature is increased (see Figure 5.16). Figure 5.16 shows that there is approximately a 3.09 percent drop in the suspended sand transport with a water temperature increase of 1 ^{o}C. As for sand size fractions, the fine sand fraction shows the highest sensitivity to a change in water temperature. Figure 5.17 illustrates clearly the sensitivity of the fine sand discharge to a change in water temperature. Because the slope of the trendline for fine sand has the highest negative value compared to the other sizes, the suspended fine sand discharge change in the given water temperature range is also the highest. There is approximately 3.4 percent decrease in the suspended fine sand discharge with a 1 ^{o}C increase in water temperature while it is about 1.49, 1.42 and 2.79 percent decrease for coarse, medium and very fine sand discharge, respectively, for the same range of increase in water temperature.

The suspended sand discharge values were calculated using the measured suspended sand concentrations and velocity intensities. The suspended sand discharges are calculated using the following relationship:

$$q_{ss} = \int_a^h C_{ss} \; V_x \; dz \qquad \text{(Eq.5.5)}$$

in which C_{ss} is the suspended sand concentration, and V_x is the flow velocity in the x direction.

First, at every sampling point, the product of sand concentration and flow velocity values was obtained, and then sand discharge values for every individual incremental depth were determined. To calculate the unit sand discharge at the section between the water surface and first sampling point, it was assumed that the suspended sand concentration at the water surface is zero. Then, unit suspended sand discharge at each vertical is obtained from the summation of all individual sand discharge values for every incremental section. By using proper unit conversion factors (see Table B.13 in Appendix B), the unit of the suspended sand discharge is obtained as tons per meter per day (tons/m/day).

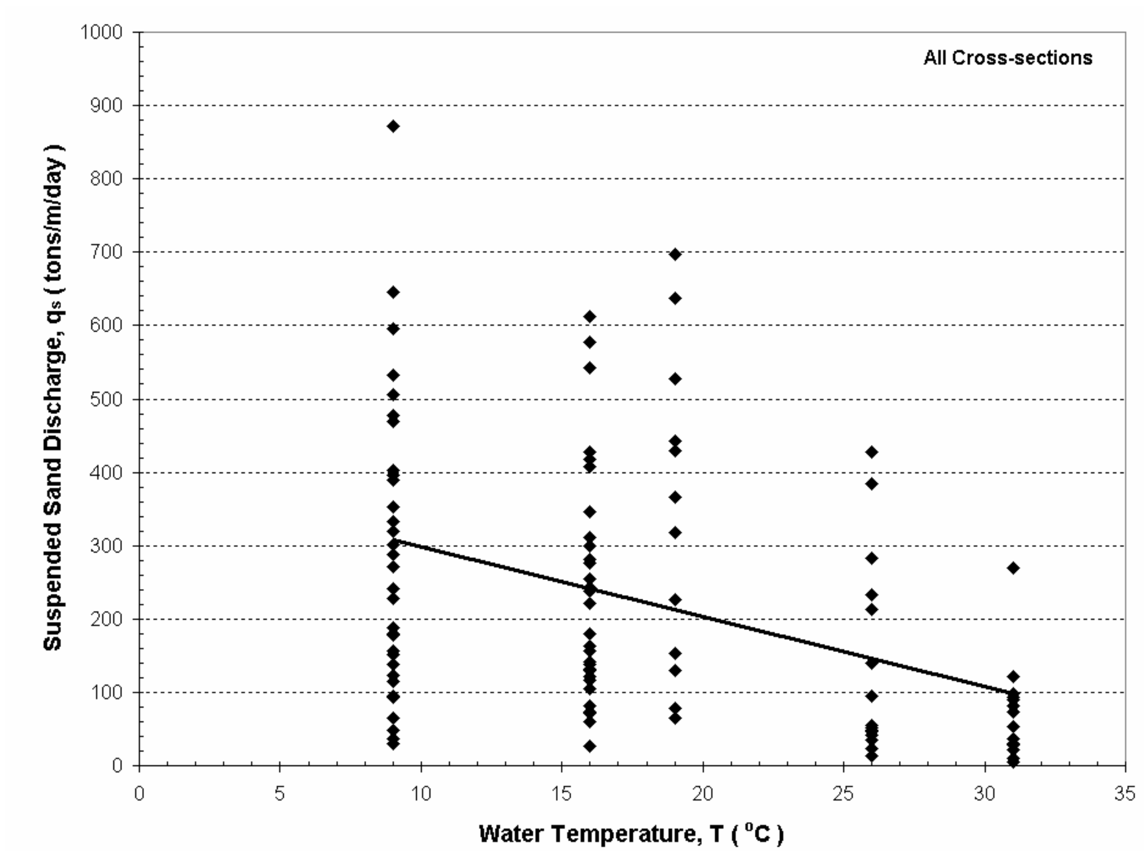

Figure 5.16. Effect of water temperature on suspended sand discharge for all events at all locations.

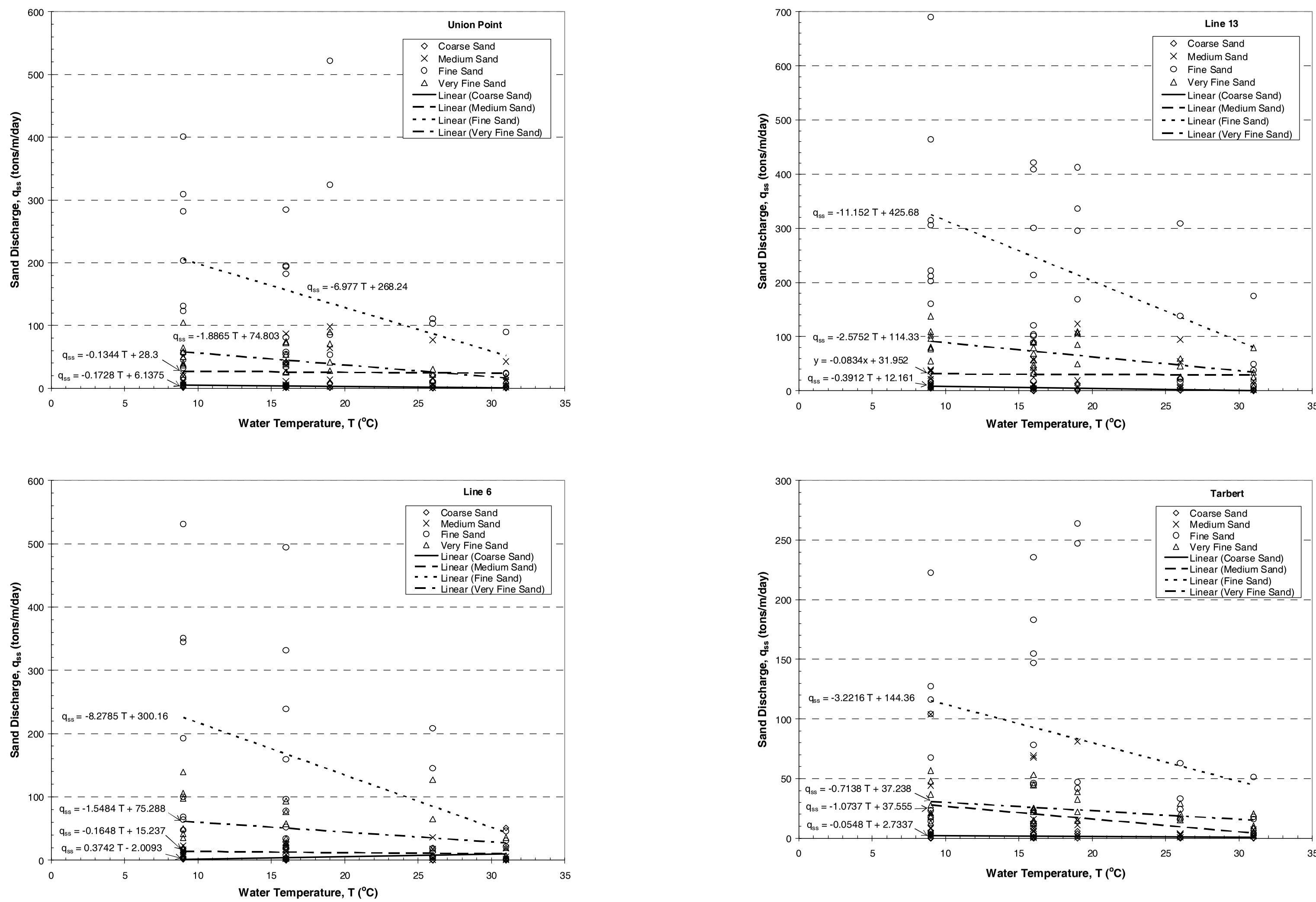

Figure 5.17. Effect of water temperature on discharges of different size fractions at all locations

To obtain a better picture of the effect of the water temperature change on the suspended sand concentrations, the ratio of $\Delta\overline{C}/\Delta T$ is calculated for different sand size fractions at all locations (see Figure 5.18). Percent amount of each sand size fraction is also calculated and shown in Figure 5.18. $\Delta\overline{C}/\Delta T$ values are obtained from the slopes of graphs of the depth-averaged suspended sediment concentrations against the water temperatures at each vertical. The average values of $\Delta\overline{C}/\Delta T$ for each size fraction are obtained from the arithmetic averages of the $\Delta\overline{C}/\Delta T$ values for all verticals at all cross-sections. Figure 5.18 indicates that fine sand has the highest percentage compared to the other sand fractions, and the average value of the ratio $\Delta\overline{C}/\Delta T$ is the minimum for fine sand size, which confirms that water temperature change affects the suspended fine sand concentration the most.

There is only a minor decrease in the suspended very fine sand concentration with an increase in water temperature. Suspended medium and coarse sand concentrations, on the other hand, don't change with the change in water temperature. Also, it can be deduced from Figure 5.18 that the amount of change in suspended sand concentration with water temperature change is influenced by the amount of the sand present in the flow. The higher the concentration of a sand size fraction, the higher the effect of water temperature on the concentration of that size fraction. It was also observed at some verticals that the value of the ratio $\Delta\overline{C}/\Delta T$ can reach up to about -6 (see Table B.14 in Appendix B), which is an indication of the pronounced effect of the water temperature on the average suspended sediment concentrations.

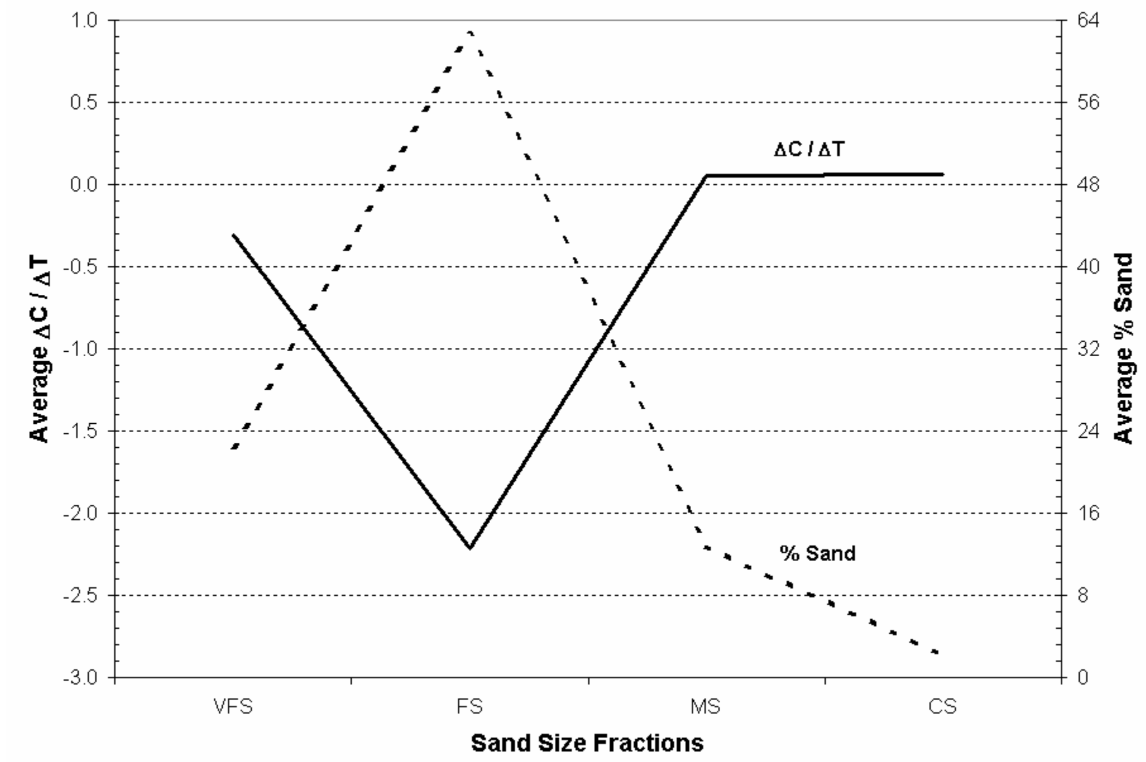

Figure 5.18. Comparison of DC/DT values for different sand fractions, and average percent amount of each fraction for all flow events at all locations.

5.2.1.1. Multiple Regression Analysis

Multiple regression analysis is one way of showing how different parameters are related to each other. With this kind of analysis, it is possible to find a relationship between the dependent and independent parameters (or variables). In this study, the dependent parameter is the depth-averaged sediment concentration or transport and the independent parameters are water temperature and water discharge.

The following two models were considered for the analysis. In the first model, the unit suspended sediment discharges, q_s, and, in the second one, reference sediment concentrations, C_a, which are the concentrations measured at the lowest points of the suspended sediment concentration profiles, were written as functions of water discharge and water temperature in the following manners:

$$q_s = c_1 \, Q^{e_Q} \, T^{e_T} \qquad \text{(Eq.5.6)}$$

$$C_a = c_2 \, Q^{e_Q} \, T^{e_T} \qquad \text{(Eq.5.7)}$$

in which c_1 and c_2 are constants, and e_Q and e_T are the exponents of water discharge and water temperature, respectively.

To estimate the exponents e_Q and e_T, the logarithm of both Eq.5.6 and Eq.5.7 were taken to make linear transformations, and then Microsoft Excel was used to perform the multiple linear regression analysis. The average values of the exponents e_Q and e_T for all sand fractions at each observed cross-section are given in Table 5.5 for both suspended sand discharge and reference sand concentration.

According to Table 5.5, most of the values of e_T have negative signs, which indicates that, on average, suspended sand discharge and reference sand concentration are inversely related to water temperature. That is, when the water temperature is raised both the suspended sand discharge and reference sand concentration decrease.

Table 5.5. The average values of the exponents e_Q and e_T for different sand size fractions at all locations for suspended sand discharge and reference concentration.

		Water Discharge Exponent, e_Q				Water Temperature Exponent, e_T			
		Sand Size Fractions				Sand Size Fractions			
		VFS	FS	MS	CS	VFS	FS	MS	CS
q_s	UP	1.654	2.364	1.287	1.536	-0.365	-0.488	-0.166	-0.894
	L13	0.843	1.694	1.770	-1.052	-0.506	-0.718	0.191	-2.245
	L6	0.976	2.577	1.427	-1.876	-0.382	-0.195	-0.110	-1.496
	T	0.998	2.529	1.299	2.279	0.067	0.536	-0.419	1.503
C_a	UP	0.456	0.203	0.241	0.448	-0.423	-0.854	-0.063	0.026
	L13	-0.079	0.815	0.089	-1.426	-0.118	-0.165	0.316	-1.410
	L6	-0.851	1.123	1.053	-3.929	-0.948	-0.175	0.630	-3.430
	T	0.009	1.447	0.769	3.406	0.427	1.112	0.280	3.266

The following graphs based on Table 5.5 are plotted to understand or see the effect of the water temperature on both the suspended sand discharges and reference sand concentrations visually. As it can be seen from Figure 5.19 and Figure 5.20, both the suspended sand discharge and the reference suspended sand concentration are inversely proportional to water temperature, and the effect of water temperature on both the suspended sand discharge and the reference suspended sand concentration is about the same. Because the amount of coarse sand (CS) both near the riverbed and in suspension in the flow is relatively low, it can be misleading to draw a conclusion about how the CS is influenced by the change in water temperature. Therefore, the conclusion drawn based on both Figure 5.19 and Figure 5.20 is valid only for very fine sand (VFS), fine sand (FS), and medium sand (MS) fractions.

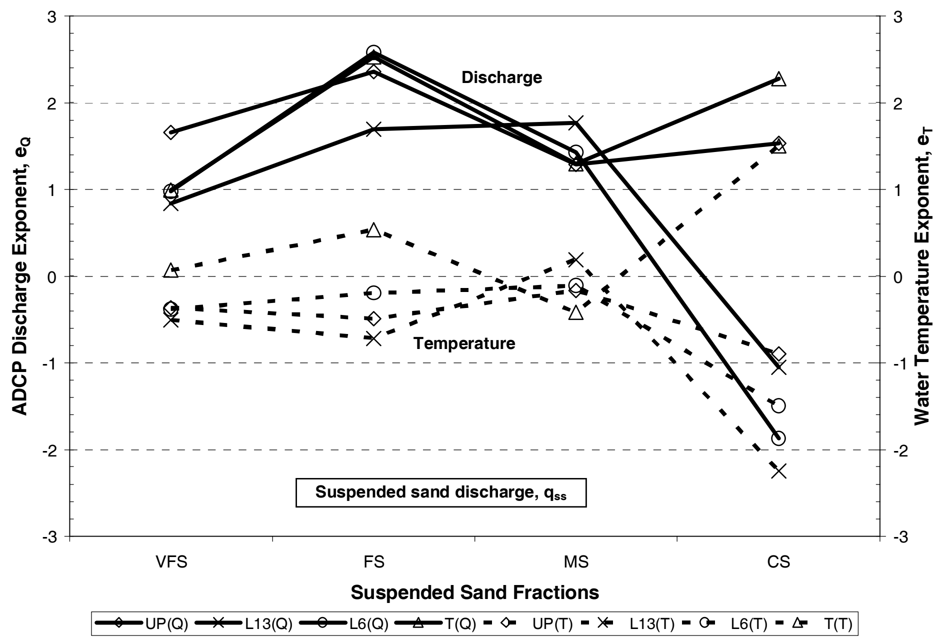

Figure 5.19. Water discharge and temperature exponents versus the suspended sand fractions by means of the calculated suspended sand discharge values.

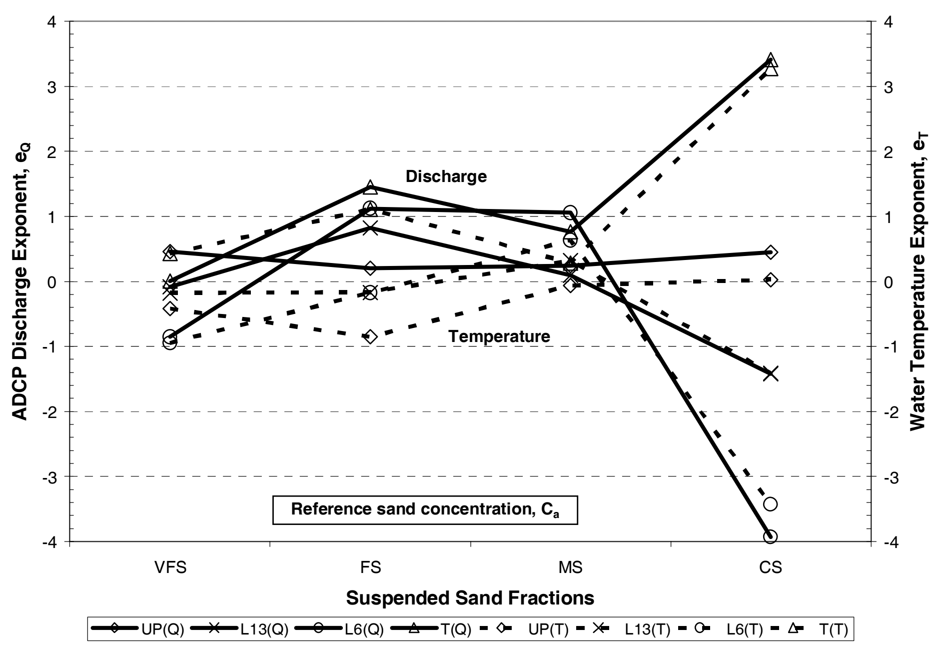

Figure 5.20. Water discharge and temperature exponents versus the suspended sand fractions by means of measured reference sand concentration values.

5.2.2. Indirect Analysis of Water Temperature Effect on Suspended Sediment Distribution and Transport

The effect of water temperature on the vertical distribution and transport of suspended sediment mostly depends on the parameters influencing the vertical distributions of velocity profiles and suspended sediment concentration profiles. In section 5.1, the effect of water temperature on the parameters influencing the vertical velocity profiles (i.e., kinematic viscosity of water, ν, von Karman parameter, κ) was analyzed in detail. In this section, the effect of the water temperature on the parameters influencing the vertical distribution of suspended sediment concentration (i.e., reference suspended sediment concentration, C_a, fall velocity of sediment particles, ω, Rouse number, R_o) is analyzed.

Although there may be a water temperature effect on the turbulent Schmidt number and riverbed configuration, the effect of water temperature on these parameters is not analyzed in this study because of the lack of data on these parameters. Whether or not water temperature has an effect on the turbulent Schmidt number, β, can be determined from a close study of sediment mixing, ε_s, and momentum exchange, ε_m, coefficients. Because there are not enough data on both coefficients, and knowing that both coefficients are approximately the same in the case of the existence of low sediment concentration in streams, which is the case for the study reach, β is assumed to be unity. Finally, because of the lack of data, an analysis of the effect of water temperature on the riverbed configuration and roughness is not possible at this time.

This section is subdivided into three sections. In section 5.2.2.1, the effect of water temperature on the reference suspended sediment concentration, C_a, is analyzed first. Then, in section 5.2.2.2, water temperature effect on the fall velocity of sediment particles is determined. Finally, in section 5.2.2.3, an analysis of the effect of water temperature on the Rouse number, R_o, is accomplished.

5.2.2.1. Analysis of the Water Temperature Effect on Reference Suspended Sediment Concentration, C_a

Most of the suspended sediment distribution equations (i.e., Rouse's equation and Einstein's equation) do not apply right at the bed where most of the sediment moves as bedload. There exists a height from the riverbed, above which the full suspension of sediment is possible and the suspended sediment distribution equation is applicable. This height is called the reference height, which is located a distance apart from the riverbed. The reference suspended sediment concentration C_a is the sediment concentration at the reference height, a, above the riverbed. The value of C_a depends on the reference height, a, and maybe some other unknown variables. Because the value of a is arbitrary one could say that C_a also has an arbitrary value.

It must also be pointed out that the sediment distribution equation gives only the relative concentration and cannot be used to determine the suspended sediment load unless the reference suspended sediment concentration, C_a, is known. To get the real concentration, C, the reference concentration C_a must either be known from measurements or calculated from special relations, such as theoretical, empirical or statistic relations.

It is clear, for example, from Eq.2.21, that a change in the reference suspended sediment concentration, C_a, and reference height, a, affect sediment concentration distribution drastically; therefore, an accurate determination of C_a and a is crucial. There have been a variety of studies on determining the value of reference height, a, and reference suspended sediment concentration, C_a. To estimate a and C_a many researchers have used simple models, the validity of which is very limited because of the complex processes near the riverbed.

The location at which the specified bed boundary condition depends on the bed characteristics, and the most logical assumption for the location of the boundary (or reference level) for suspended sediment concentrations, is the upper edge of the bedload layer. The reference suspended sediment concentration, C_a, in this study is equal to the concentration measured at the lowest elevation, a, for each vertical at the specified cross-sections.

In this section, the effect of water temperature on the reference suspended sediment concentration, C_a, is determined by graphing the suspended sediment concentration values measured at the lowest elevations of each vertical for each individual cross-section as a function of the water temperature values, which were measured in the study area for all flow events (see Figure 5.21 through Figure 5.24).

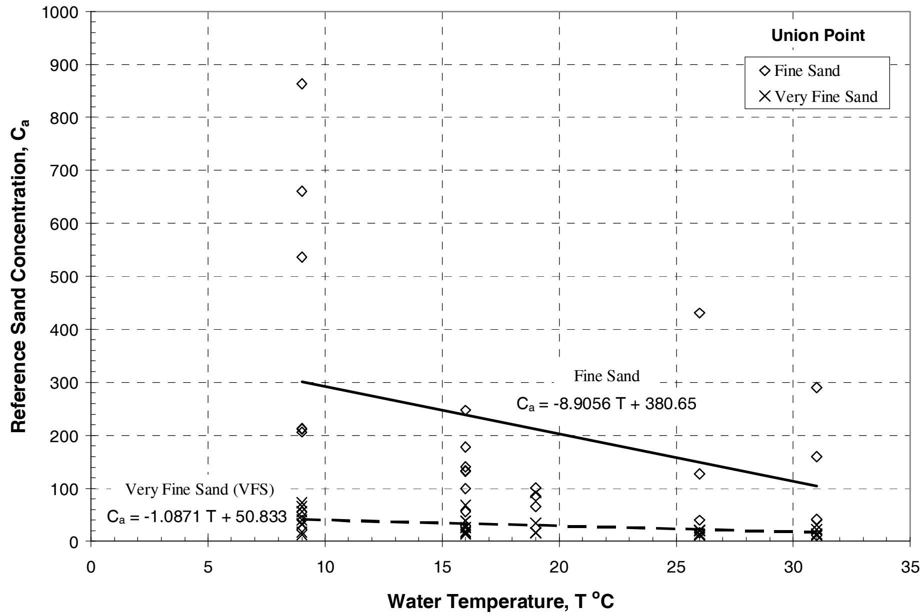

Figure 5.21. Water temperature effect on the reference suspended very fine and fine sand concentrations by size fraction at Union Point.

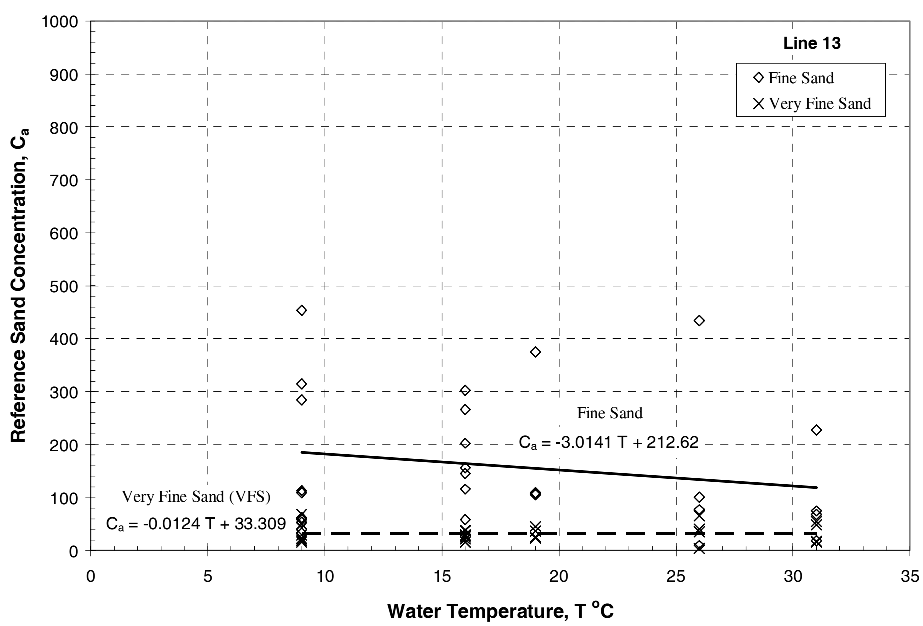

Figure 5.22. Water temperature effect on the reference suspended very fine and fine sand concentrations by size fraction at Line 13.

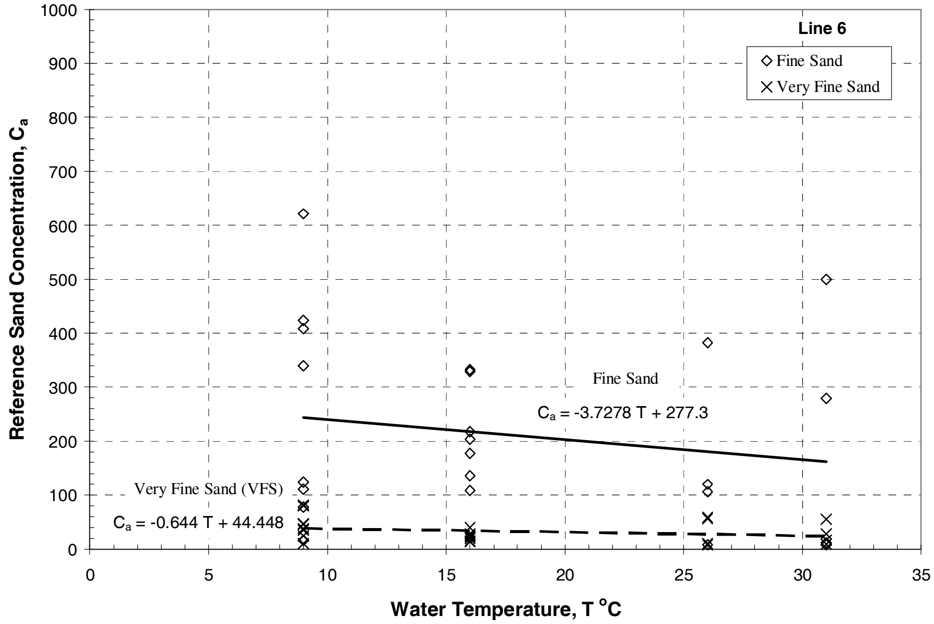

Figure 5.23. Water temperature effect on the reference suspended very fine and fine sand concentrations by size fraction at Line 6.

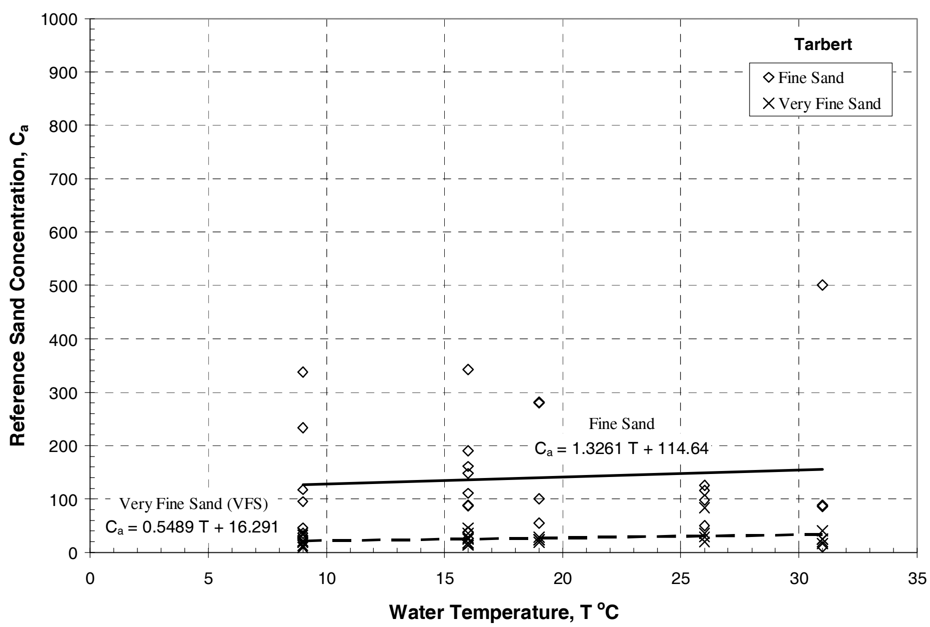

Figure 5.24. Water temperature effect on the reference suspended very fine and fine sand concentrations by size fraction at Tarbert.

These figures (Figure 5.21 through Figure 5.24) include only the fine sand (FS) and very fine sand (VFS) fractions because of the fact that there is an insufficient amount of coarse sand (CS) and medium sand (MS) fractions in the flow, and therefore, there would be an inaccurate representation of the temperature effect on these sand fractions (CS and MS).

Figure 5.21 through Figure 5.24 show clearly that both the suspended fine sand (FS) and the very fine sand (VFS) concentrations near the riverbed decrease with the increase of water temperature for Union Point, Line 13 and Line 6, and increase with the increase of water temperature for Tarbert. The trend of the water temperature effect on the reference suspended sediment concentration at Tarbert may be misleading because of a high reference concentration measurement during the summer (high water temperature), which is unusual (see Figure 5.24). While the decrease in the reference suspended fine sand concentration with a temperature increase of 1 ^{o}C is approximately 1.53 to 2.96 percent, it is about 0.04 to 2.65 percent for the reference suspended very fine sand concentration. These results explain that the reference concentration of fine sand is affected the most from the water temperature changes.

When all of the reference suspended sediment concentrations are plotted against the water temperature for all locations (see Figure 5.25), the trends are toward a decrease when the water temperature is increased. In a general sense, this means there is an inverse relationship between the reference suspended sand concentration and the water temperature. In other words, an increase in water temperature decreases the reference suspended sand concentration, C_a, decrease being higher for highly-concentrated sand sizes (in this case fine sand (FS)). In Figure 5.25, an increase of 1 ^{o}C in the water temperature, on average, results in a 1.69 percent decrease in the reference fine sand concentration and 0.90 percent reduction in the very fine sand reference concentration. These results are also an indication of the effect of water temperature change being higher for the reference suspended fine sand concentration.

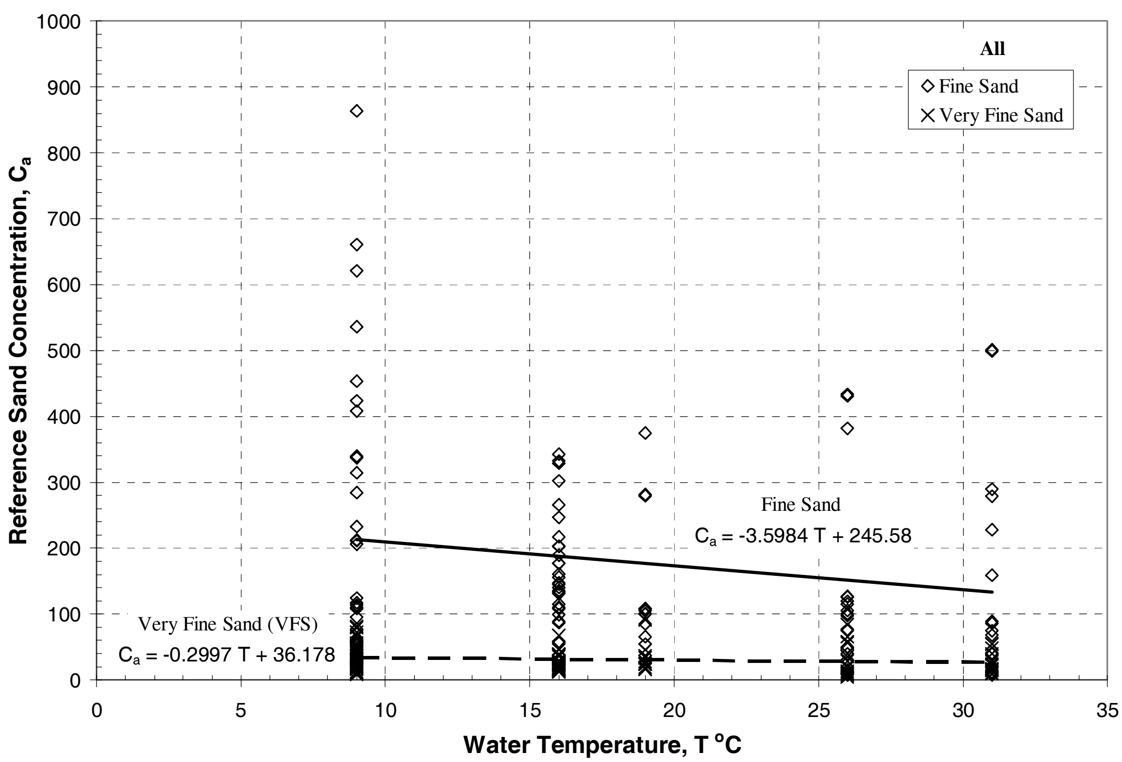

Figure 5.25. Water temperature effect on the reference suspended very fine and fine sand concentrations at all locations.

5.2.2.2. Analysis of the Water Temperature Effect on Fall Velocity of Sediment Particles, ω

The fall velocity of a sediment particle, ω, is the terminal velocity attained when the sediment particle is settling in an extended fluid under the action of gravity. The fall velocity of sediment particles in sediment-laden flows is an important factor governing the concentration distribution of suspended sediment. It is the primary variable defining the interaction of sediment transport with the riverbed, banks or suspended in the fluid. It is an important variable used to estimate resistance to flow and the rate of sediment transport. Thus, it is important to understand the physical process that establishes the fall velocity of sediment particles and the parameters affecting this variable.

The fall velocity of sediment particles depends on several parameters, the most important of which are the density of water, ρ, density of the sediment particles, ρ_s, kinematic viscosity of water, ν, particle diameter, d_s, shape factor of particles, s_p, suspended sediment concentration, C, and water temperature, T.

The particle diameter, d_s, and the shape factor of particles, s_p are not affected by the change in water temperature. The effect of water temperature on the density of water, ρ, and the density of the sediment particles, ρ_s is so small that it can be neglected. The effect of suspended sediment concentration on the fall velocity of sediment particles is so small that even if the suspended sediment concentration is changed by the change in water temperature, there is not sufficient change in the fall velocity of sediment particles because of the change in suspended sediment concentration with water temperature. Therefore, the fall velocity of sediment particle is influenced drastically by only a change in the kinematic viscosity of water. The analysis of the water temperature effect on the kinematic viscosity of water was accomplished in section 5.1.1.

In this section, the effect of water temperature on fall velocity of sediment particles is examined based on the following equation, which was derived for sand and gravel sediment sizes based on some intensive experiments (Julien, 1995):

$$\omega = \frac{8\nu}{d_s}\left\{\left[1 + 0.0139 d_*^3\right]^{0.5} - 1\right\} \qquad \text{(Eq.5.8)}$$

where ν is the kinematic viscosity water, d_s is the particle diameter, and d_* is the dimensionless particle diameter defined as follows:

$$d_* = d_s\left[\frac{(G-1)g}{\nu^2}\right]^{1/3} \qquad \text{(Eq.5.9)}$$

in which G is the specific gravity and defined as the ratio of the specific weight of sediment, γ_s, to that of water, γ, $G = \frac{\gamma_s}{\gamma} = \frac{\rho_s}{\rho}$, and g is the gravitational acceleration. Eq.5.8 estimates the fall velocity of particles under a wide range of particle Reynolds numbers $\mathrm{Re}_p = \frac{\omega\, d_s}{\nu}$.

Approximate values of the fall velocity of sediment particles for different water temperatures based on Eq.5.8 are given on the following page (see Table 5.6).

Table 5.6 indicates that the water temperature effect on fall velocities of sediment particles is different for different sizes. The fall velocities of the particles larger than sand stay the same regardless of what the water temperature may be. The effect of water temperature on the silt and clay size sediment is not considerable because of the fact that

Table 5.6. Fall velocities of sediment particles at different water temperatures.

Class Name		Particle Diameter (mm)	Fall Velocity of Sediment Particles in Sediment-Water Mixture, ω (mm/s) Near 0 °C	At 5 °C	At 9 °C	At 16 °C	At 20 °C	At 26 °C	At 31 °C	At 35 °C
Gravel										
Very coarse	>	32	678.36	678.43	678.47	678.53	678.56	678.59	678.61	678.63
Coarse	>	16	479.10	479.23	479.32	479.44	479.49	479.56	479.60	479.63
Medium	>	8	337.62	337.89	338.06	338.30	338.41	338.53	338.62	338.68
Fine	>	4	236.44	236.98	237.31	237.79	238.00	238.26	238.43	238.55
Very fine	>	2	162.69	163.73	164.39	165.32	165.75	166.25	166.59	166.83
Sand										
Very coarse	>	1	106.53	108.45	109.68	111.45	112.26	113.22	113.88	114.35
Coarse	>	0.5	60.91	63.95	65.96	68.93	70.35	72.03	73.22	74.05
Medium	>	0.25	25.67	28.60	30.73	34.20	36.00	38.25	39.93	41.15
Fine	>	0.125	7.60	8.85	9.85	11.70	12.79	14.28	15.52	16.49
Very fine	>	0.0625	1.96	2.30	2.58	3.13	3.47	3.96	4.38	4.73
Silt										
Coarse	>	0.031	0.49	0.578	0.650	0.791	0.877	1.004	1.116	1.210
Medium	>	0.016	0.12	0.145	0.163	0.198	0.220	0.252	0.280	0.303
Fine	>	0.008	0.03	0.036	0.041	0.049	0.055	0.063	0.070	0.076
Very fine	>	0.004	0.01	0.009	0.010	0.012	0.014	0.016	0.017	0.019
Clay										
Coarse	>	0.002	0.00	0.0023	0.0025	0.0031	0.0034	0.0039	0.0044	0.0047
Medium	>	0.001	0.00	0.0006	0.0006	0.0008	0.0009	0.0010	0.0011	0.0012
Fine	>	0.0005	0.00	0.0001	0.0002	0.0002	0.0002	0.0002	0.0003	0.0003
Very fine	>	0.00024	0.00	0.0000	0.0000	0.0000	0.0001	0.0001	0.0001	0.0001

the fall velocity of particles finer than sand is low no matter what the water temperature may be, and a large percentage change in the low fall velocities may not affect the carrying ability of the stream for these sizes to a significant degree. The greatest absolute increase in fall velocity for the same temperature change is for quartz particles whose median diameters are about 0.125 - 1 millimeters. The change in fall velocity of sand particles is demonstrated in Figure 5.26 below.

Figure 5.26 shows that as the particle size increases the fall velocity also increases, the increase being higher for higher water temperature. The main reason for a change in the fall velocity of sand particles with water temperature can be attributed to the change in the kinematic viscosity of water with water temperature. An increase in water temperature causes a decrease in viscosity, and thus causes an increase in the fall velocity of sand particles. The increase rate of the fall velocity decreases as the temperature increases (see Figure 5.26). From Table 5.6 and Figure 5.26, it is observed that with a water temperature increase of 1 ^{o}C, there is approximately 0.50, 1.36, 2.62, and 3.17 percent increase in the fall velocity of coarse, medium, fine, and very fine sand particles, respectively.

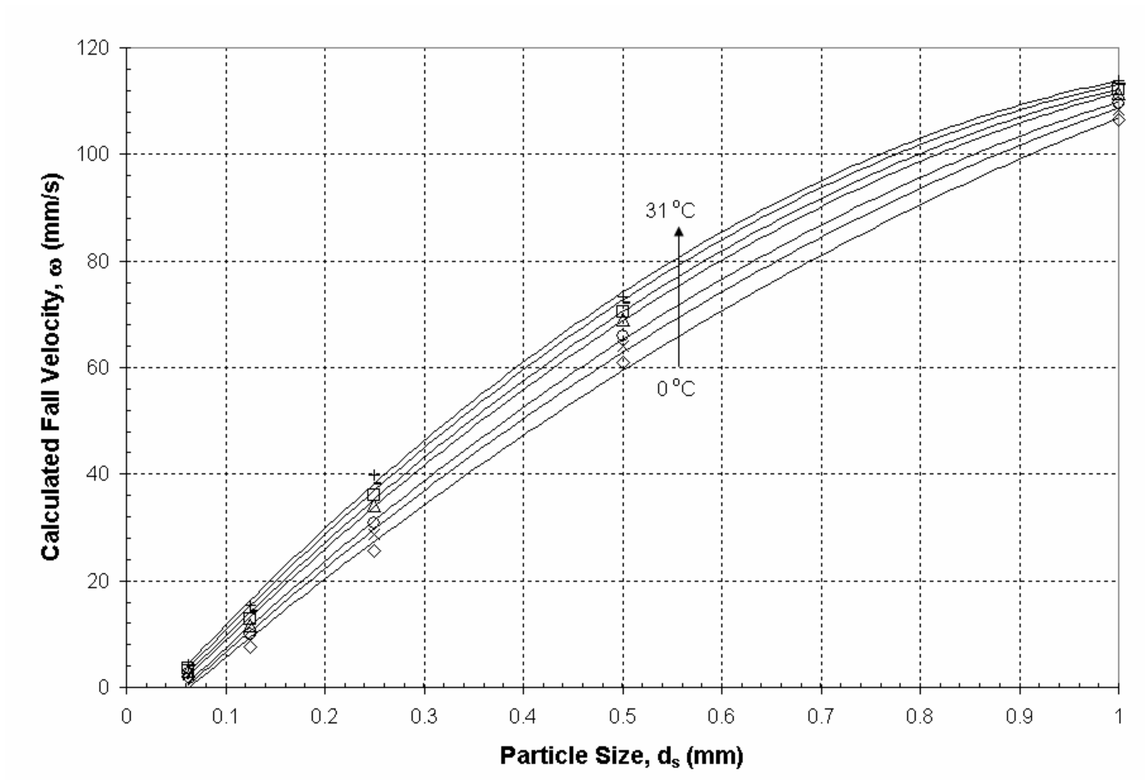

Figure 5.26. Effect of water temperature on the fall velocity of sand particles.

5.2.2.3. Analysis of the Water Temperature Effect on Rouse Number, R_o

The Rouse number, R_o, has an important role in describing the vertical profile of suspended sediment in stream flow. It reflects the ratio of sediment properties to the hydraulic characteristics of the flow and is defined as:

$$R_o = \frac{\omega}{\beta \, \kappa \, u_*} \qquad \text{(Eq.5.10)}$$

The parameters $\omega, \beta, \kappa, u_*$ are particle fall velocity, turbulent Schmidt number, von Karman parameter and particle shear velocity, respectively, and are uncertain.

It is clear from Eq.2.21 that the Rouse number, R_o, definitely has a big effect on the vertical distribution of suspended sediment, and thus on the suspended sediment transport. Because R_o is a function of $\omega, \beta, \kappa,$ and u_* (see Eq.5.10), any changes to these parameters cause a change in R_o. As mentioned before, water temperature has an effect on both ω and κ. Therefore, a change in the water temperature also brings about a change in R_o. Because both the particle fall velocity, ω and the von Karman parameter, κ, and water temperature are directly proportional, the relationship between the Rouse number, R_o, and water temperature depends on the ratio of the particle fall velocity to the von Karman parameter. Since, on average, the particle fall velocity increases more than the von Karman parameter with water temperature, the Rouse number is definitely directly proportional with water temperature. This means an increase in water temperature causes an increase in R_o.

Experimentally, in this study, R_o values are obtained by first plotting suspended sediment concentration, C, versus $(h-z)/z$ in a logarithmic scale and fitting a power function to the data points. The R_o value is the exponent value of the power function, which is shown in Figure 5.27 below.

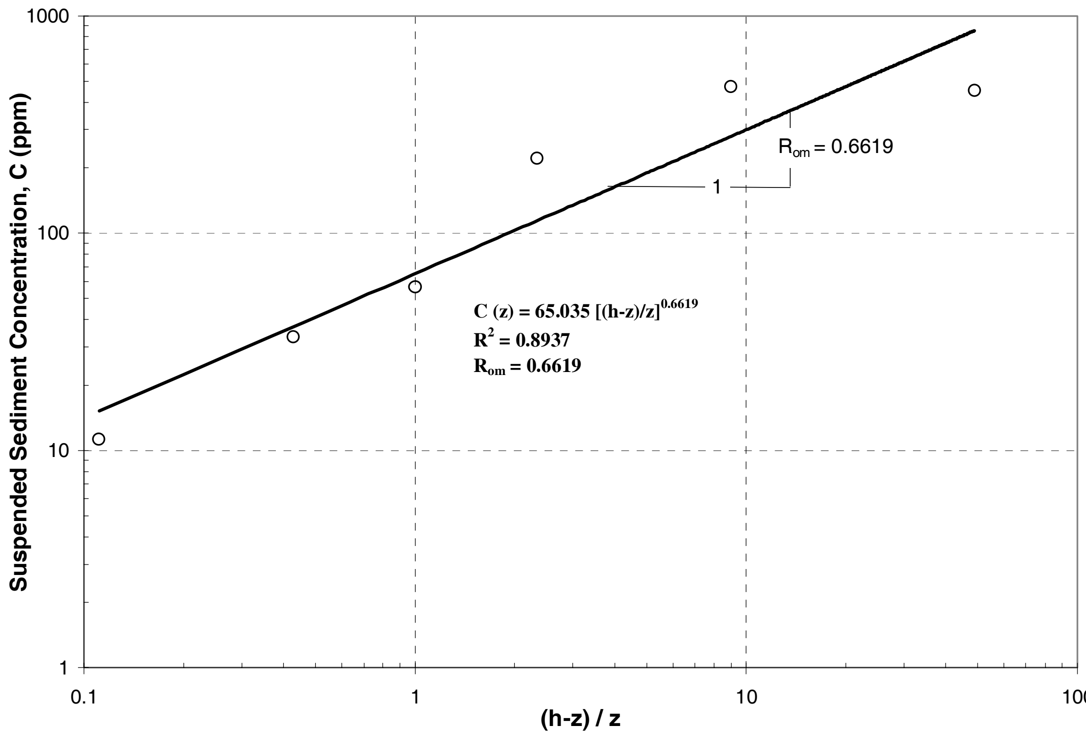

Figure 5.27. Obtaining Rouse number from the slope of a suspended sediment concentration profile.

To find out how a change in the water temperature affects Rouse number, R_o, first the average Rouse number values, $\overline{R_o}$, for the specified cross-sections are obtained (see Table B.15 in Appendix B). To obtain the average R_o values for all size fractions at all verticals, graphs of suspended sediment concentrations for each size fraction, C versus $(h-z)/z$, are plotted and a power function fit for the data set for each size fraction is drawn (see Figure 5.27). Average R_o values are the exponent values of the power functions. After obtaining the average R_o values for all flow events at all locations, a graph of the average R_o values for all sand fractions versus the water temperature in degrees Celsius is plotted (see Figure 5.28).

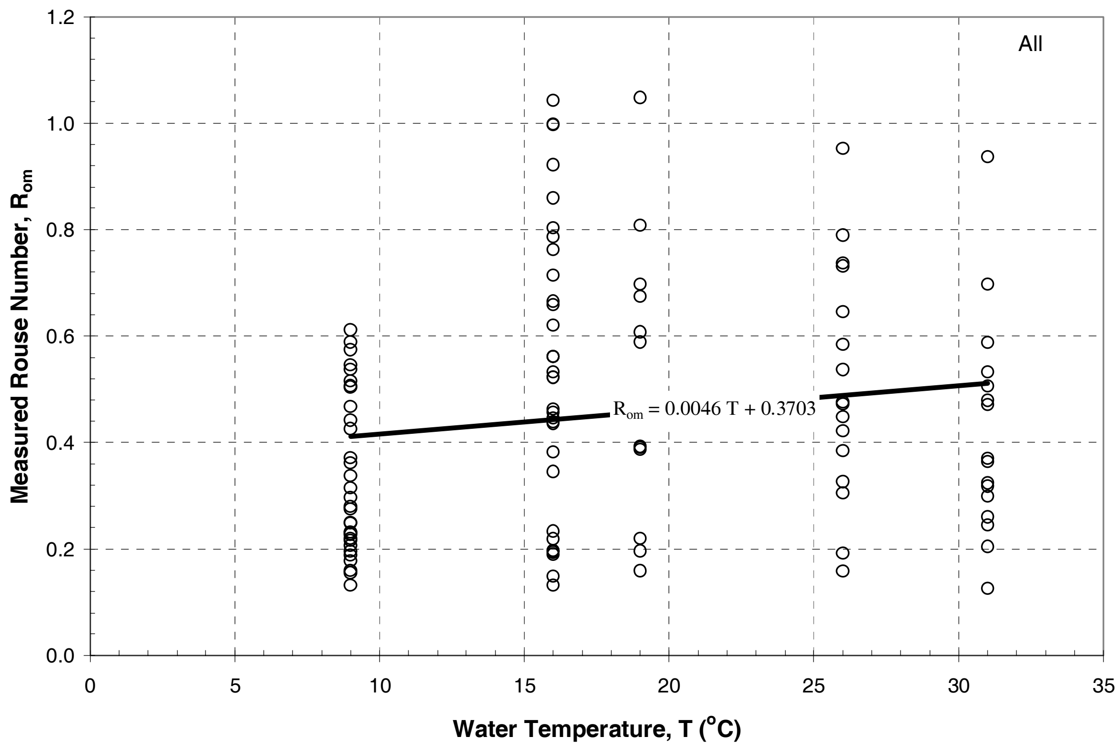

Figure 5.28. Average measured Rouse number change with water temperature.

It is clear from Figure 5.28 that the average R_{om} values increase as the water temperature increases. This also proves that the form of the expression for the Rouse number (R_o) is accurate and the main reason for R_o to increase with an increase in water temperature is the increase in fall velocity, ω and the von Karman parameter, κ, with an increase in water temperature. Based on Figure 5.28, it is found that the average value of the Rouse number goes up approximately 1.14 percent with a water temperature increase of 1 ^{o}C.

Furthermore, it is proven that the form of the Rouse's suspended sediment concentration equation (Eq.2.21) is correct, but the value of the exponent parameter, R_o, in this equation should be determined by considering the water temperature effect on the parameters affecting the Rouse's parameter, R_o, (see Eq.2.21). The difference between the measured and calculated R_o numbers is shown in the following sample figure (Figure 5.29).

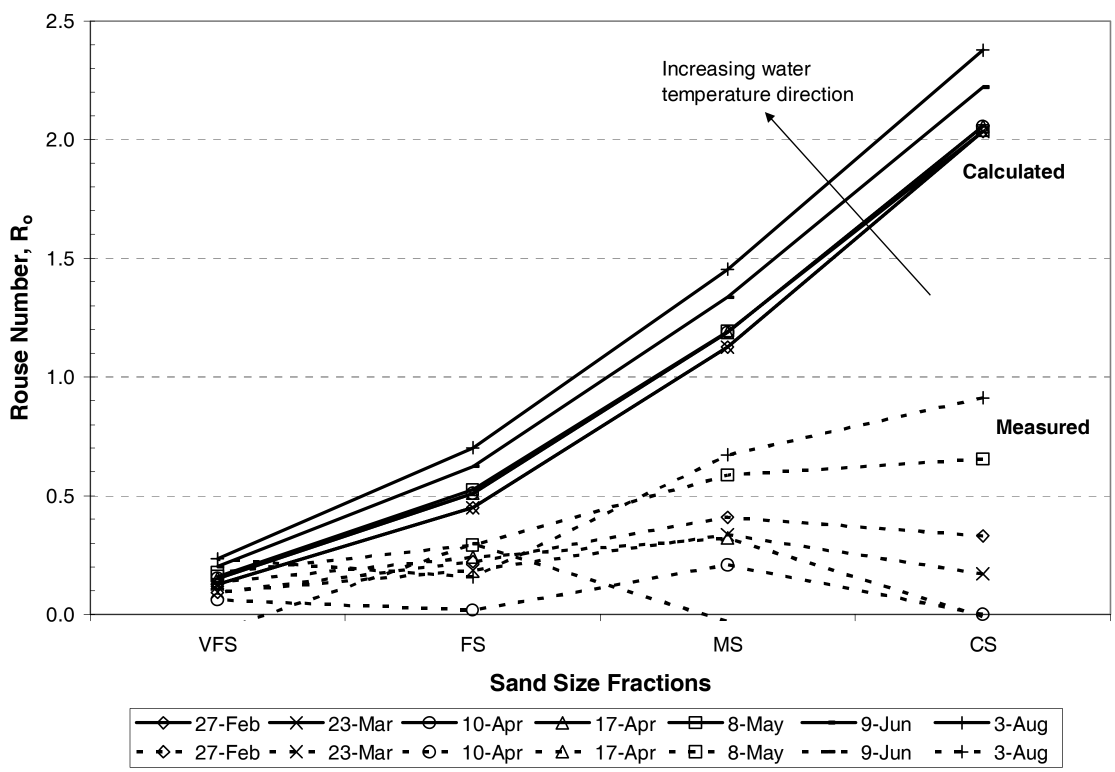

Figure 5.29. Comparison of the calculated and measured Rouse number for all flow events at a vertical at Line 13.

Figure 5.29 illustrates clearly that the calculated Rouse number values, R_{oc}, increase parabolically with an increase in sand size from very fine sand to coarse sand. The measured Rouse number values, R_{om}, also increase with an increase in sand size, but the percent increase in R_{om} is less than that in R_{oc}. R_{om} and R_{oc} values are approximately equal to each other for very fine sand, but the difference between R_{om} and R_{oc} gets larger toward coarse sand. Examination of every vertical for all locations indicated that the measured Rouse number values take the maximum value of approximately unity for coarse sand (see Figure 5.29 in previous page and Table B.15 in Appendix B). The most likely reason for the measured Rouse numbers for medium and coarse sand fractions to be a lot less than the ones calculated using Eq.5.10 is the inability of the suspended sediment samplers to measure sediment concentrations lower than a certain value (i.e., less than 1 mg/l or 1 ppm). When the sediment concentration in the flow is less than 1 ppm, the suspended sediment samplers cannot measure the concentration, which leads to a zero value for the low concentrations. This concept will be clearer after the following sample applications are studied in section 5.3.

5.2.2.4. Comparison of the Measured and Calculated Rouse Number

The measured Rouse number, R_{om}, and the calculated Rouse number, R_{oc}, are compared for all verticals at all locations (see Figure 5.30). While the R_{om} values are obtained from the slopes of the suspended sand concentration profiles (see Figure 5.27), the R_{oc} values are calculated from Eq.5.10, assuming $\beta = 1$ and $\kappa = 0.4$. The solid line in Figure 5.30 represents the line of equal measured and calculated Rouse number values. That is, measured and calculated Rouse numbers are equal at point along this solid line. According to Figure 5.30, the difference between the measured and calculated Rouse number gets larger with increase in sand size because most of the points are located above the solid line. For instance, the measured and calculated Rouse numbers are equal to each other for very fine sand fraction, and the difference between these two numbers grows exponentially with an increase in sand size. Therefore, one should not use Eq.5.10 to calculate the Rouse number unless the suspended sediment in the river is in the very fine sand range.

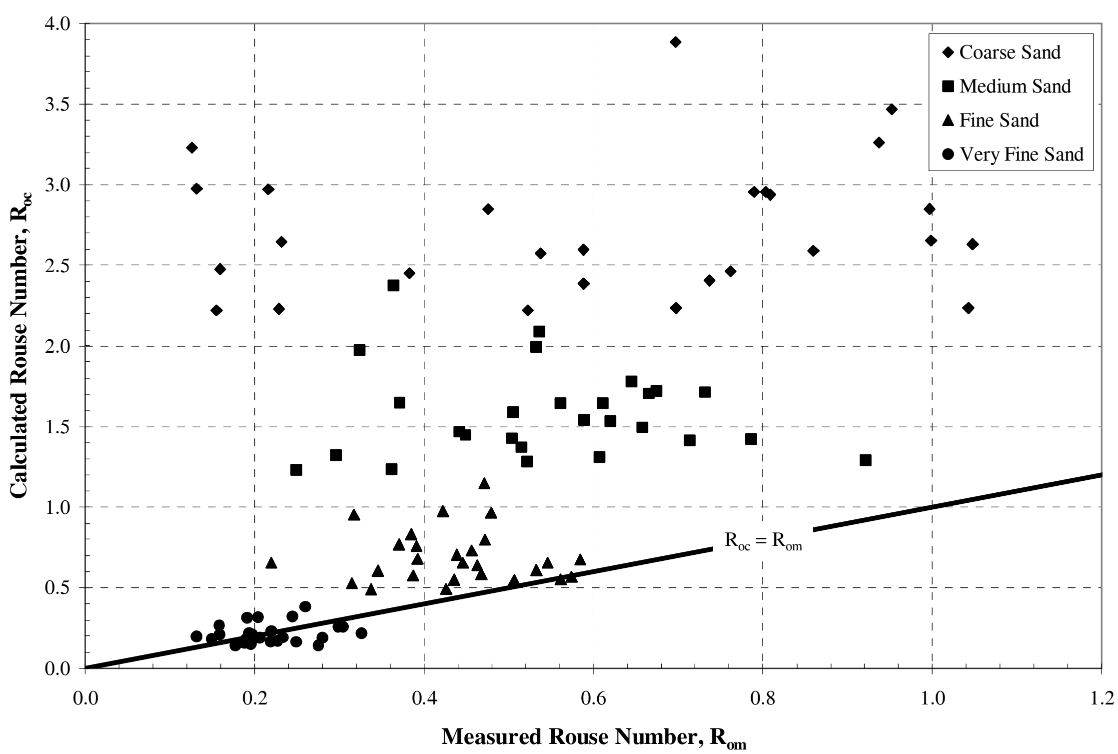

Figure 5.30. Comparson of the meausred and calculated Rouse numbers.

The difference between the measured and calculated Rouse numbers can be also observed by plotting both the measured and calculated suspended sand concentrations in the same graph (see Figure 5.31 through Figure 5.34). As it is obvious from Figure 5.31 through Figure 5.34 that there is a difference between the measured Rouse number obtained from the observation of field data and the calculated Rouse number obtained from the expression $\omega_0 / 0.4\, u_*$. More specifically, the trendlines for calculated suspended sand concentration values for all sand fractions are lower than those for measured ones. This proves that the suspended sand concentration would be underestimated when the calculated Rouse numbers are used instead of the real (or measured) Rouse number values. However, when the sand size gets smaller, the difference between the measured and calculated Rouse numbers disappears. For example, both the measured and calculated Rouse numbers for very fine sand are approximately the same (see Figure 5.34). The percent deviation of the calculated Rouse number values from the measured ones for coarse, medium, fine and very fine sand fractions are 75.56, 64.93, 37.13 and 0.05 percent, respectively.

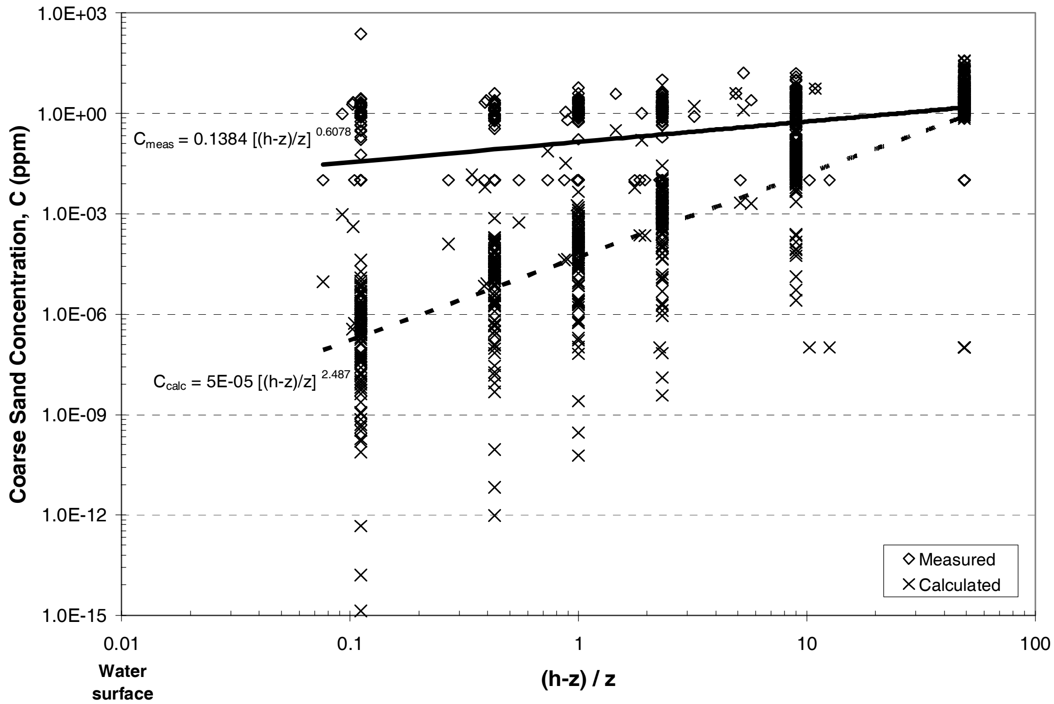

Figure 5.31. Measured and calculated Rouse numbers for coarse sand fraction.

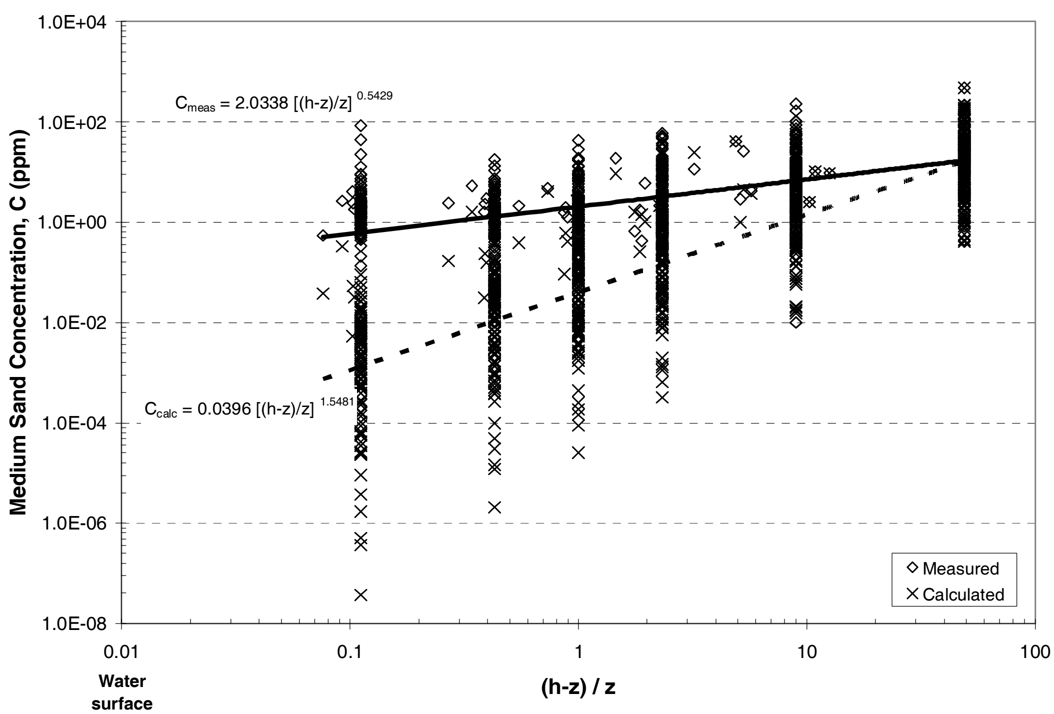

Figure 5.32. Measured and calculated Rouse numbers for medium sand fraction.

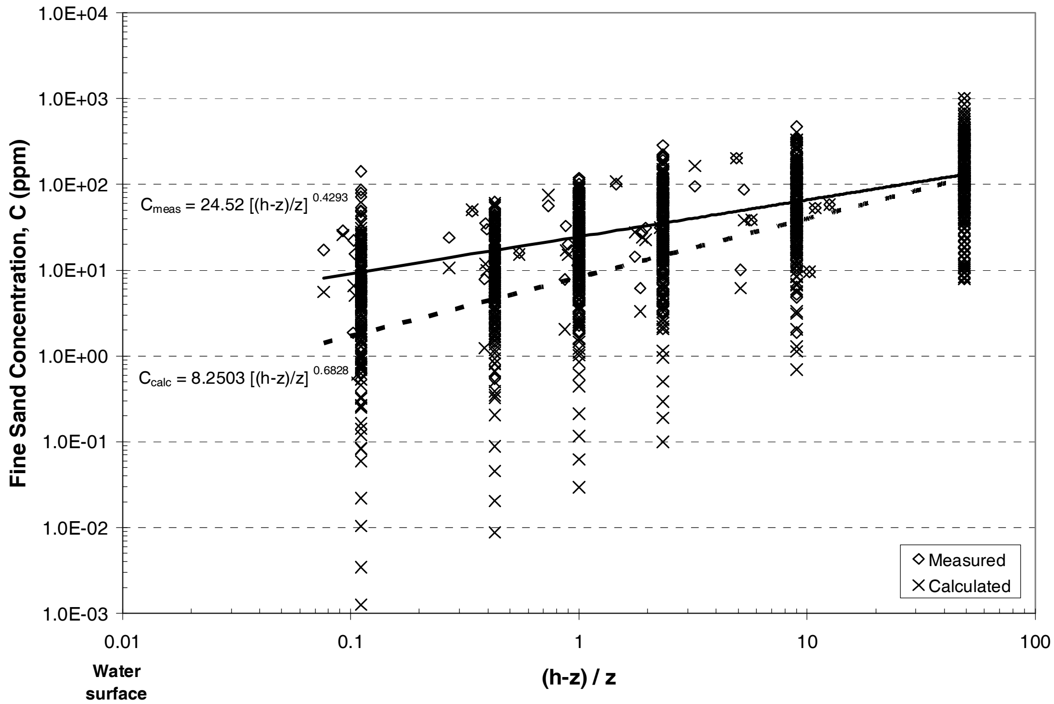

Figure 5.33. Measured and calculated Rouse numbers for fine sand fraction.

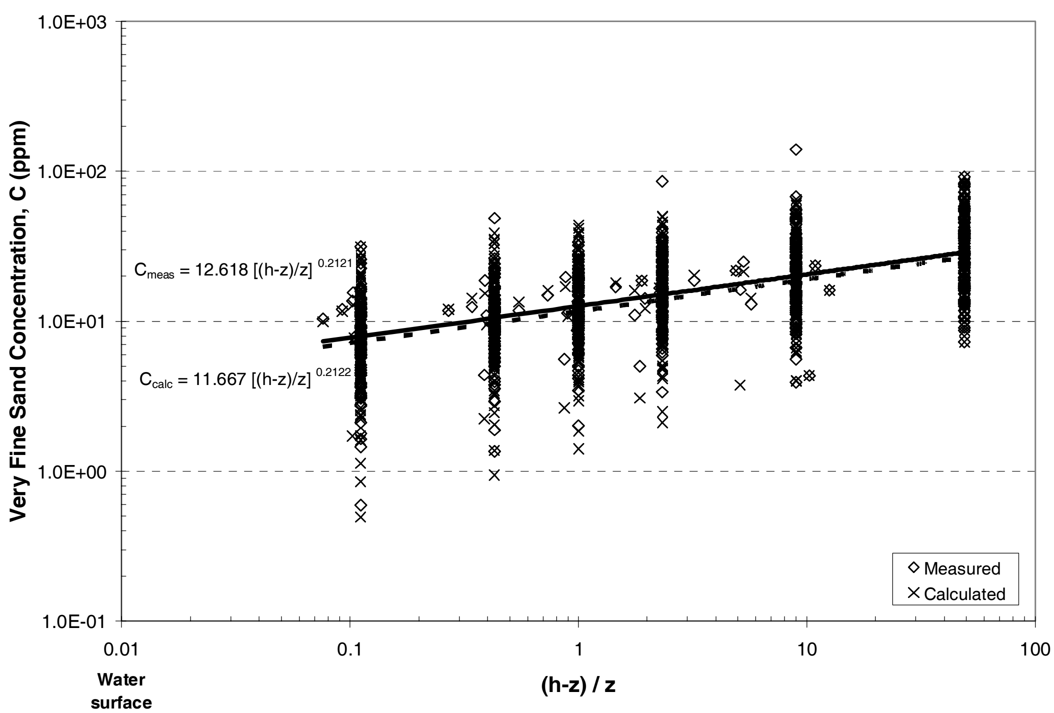

Figure 5.34. Measured and calculated Rouse numbers for very fine sand fraction.

5.3. SAMPLE APPLICATION

The analysis in the previous sections proved that there is a water temperature effect on the vertical distribution of suspended sediment concentration and transport of suspended sediment, and that the measured Rouse number is different than the one calculated from the expression, $\omega_0/(0.4\,u_*)$.

In this section, the degree of the water temperature effect difference between the measured and calculated suspended sand concentration and transport will be sought numerically.

The effect of water temperature change on the von Karman parameter, κ, was analyzed in the previous sections, and it was found that κ increases with an increase in water temperature. A further analysis of the data used to obtain Figure 5.6 showed that κ almost always takes a value more than 0.4, and the value of κ increases about 2.17 percent with a 1 ^{o}C increase in water temperature.

Moreover, as mentioned earlier, the fall velocity of sediment particles, ω, is affected by a change in water temperature. On average, ω for coarse, medium, fine and very fine sand decreases by approximately 0.5, 1.36, 2.62 and 3.17 percent, respectively.

Because the Rouse number, which is the exponent parameter, R_o, in Rouse's suspended sediment concentration equation, is inversely proportional to κ and directly proportional to ω, an increase in the value of κ and ω with an increase in water temperature causes the value of R_o to increase or decrease depending on the size fraction. It decreases by approximately 1.63 and 0.79 percent for coarse and medium sand, respectively, and increases by about 0.44 and 0.98 percent for fine and very fine sand, respectively, with a water temperature increase of 1 ^{o}C. These results would lead to an increase or decrease in the suspended sand concentration depending on weather the value of ratio C/C_a is bigger or smaller than unity. In general, the change of suspended sediment concentration can be shown with the following relation:

$$\left(\frac{C}{C_a}\right)_2 = \left[\left(\frac{C}{C_a}\right)_1\right]^{\xi} \qquad \text{(Eq.5.11)}$$

where the subscripts 1 and 2 indicate the conditions before and after the temperature change, respectively, and the exponent value, ξ, differs based on the size fraction of concern. The value of ξ is 0.9837, 0.9921, 1.0044 and 1.0098 for coarse, medium, fine and very fine sand fraction, respectively.

An analysis of the available data shows that at almost all verticals the value of the ratio C/C_a is smaller than unity, which indicates that an increase in water temperature would result in an increase in the suspended coarse and medium sand concentration, and decrease in the suspended fine and very fine sand concentration. Since there is mainly fine and very fine sand fractions suspended in the main flow region, and coarse and medium sand fractions near the riverbed, the quantity of fine and very fine sand decreases in the main flow region, and that of coarse and medium sand increases near the riverbed because of an increase in water temperature. This condition creates a less uniform suspended sediment concentration profile along a vertical in the river. The increase in coarse and medium sand and decrease in fine and very fine sand reveals that there exists a sand fraction between the medium and fine sand that would be in equilibrium along a vertical in the river.

From the analysis of the suspended sediment data in Appendix B, it was found that the suspended sand discharge, on average, decreases about 3.09 percent with an increase in water temperature by 1 ^{o}C. Based on a trendline fit to the suspended sand discharge data in Figure 5.16, the rate of decrease in the suspended sand discharge is about 9.51 ton/m/day for every 1 ^{o}C increase in water temperature. It was assumed that the suspended sand is composed of four main sand fractions, namely, coarse (CS), medium (MS), fine (FS), and very fine sand (VFS). A further analysis showed that fine sand was particularly influenced by the water temperature change. The rates of decrease in the suspended coarse, medium, fine, and very fine sand discharges are about 0.06, 0.36, 7.41, and 1.68 tons/m/day, respectively, for every 1 ^{o}C increase in water temperature.

5.4. CORIOLIS EFFECT ON FLOW DIRECTION

The Coriolis effect is a result of the Coriolis force which is defined as the deflecting force of the Earth's rotation. It is an apparent force that appears when coordinate axes are rotated. Coriolis effects occur widely in nature, and often play an important role in the dynamics of fluid flows. Normally, it is far weaker than gravity, so its vertical effect is rarely dealt with, whereas its horizontal effect is essential to the dynamics of the atmosphere and the oceans. However, this effect is very weak for small-scale fluid motions, such as bathtubs and small channels. The Coriolis force is directed normal to the velocity and to the right in the Northern Hemisphere, and to the left in the Southern Hemisphere.

The magnitude of the horizontal component of the force is given by the following equation:

$$F_c = 2\, V_x\, \Omega \sin \Phi \qquad \text{(Eq.5.12)}$$

where V_x is the horizontal particle velocity, Ω is the angular velocity of the earth's rotation and approximately equals to $7.3x10^{-5}\, s^{-1}$, and Φ is the latitude.

Eq.5.12 reveals that the Coriolis force exists only when there is velocity relative to the Earth surface. There is no horizontal component at the equator because $\sin \Phi = 0$. Because the Coriolis force always acts perpendicular to the direction of motion of a particle, it can only deflect the particle direction, not change its speed.

As for the analysis of the field data, the following equation is used to test whether the Coriolis force has an effect on the direction of the Lower Mississippi River flows or not:

$$X = \frac{\textit{Coriolis acceleration}}{\textit{Gravitational acceleration}} = \frac{\Omega\, V_x}{g\, S_0} \qquad \text{(Eq.5.13)}$$

where X is a dimensionless parameter and defined as the ratio of the Coriolis force to the gravitational force, and S_0 is the riverbed slope. In fact, the Coriolis force term in

Eq.5.13 is equal to $2 V_x \Omega \sin\Phi$. However, the latitude of the study reach is about 31^0; thus $\sin\Phi$ is approximately equal to 0.5. That is why one would obtain the above simplified form of the equation.

By using the flow data in Appendix A, the value of the parameter X at every measured velocity point is calculated. Because the rotational speed of the Earth, Ω, the gravitational acceleration, g, and the riverbed slope, S_0, are constant, only the relative velocity of particles have an effect on the value of the parameter X. Therefore, the parameter X changes directly proportional with the changes in the intensity of the velocity vectors. That is, the higher the flow velocity, the greater the parameter X would be, and thus the greater the effect of the Coriolis force.

$Arc\sin X$ versus the flow direction at all verticals for each cross-section is graphed to compare the measured flow directions with the calculated flow deflections because of the Coriolis effect. After the examination of all the graphs at all cross-sections, it was noticed that the measured flow direction and the calculated flow deflections are directly proportional at some verticals and inversely proportional at some other verticals (see Table 5.7, Figure 5.35 and Figure 5.36).

In general, if there is an effect on the flow direction resulting from the Coriolis force, the trendlines of the data in the above graphs should have tendencies to increase, not decrease, from left to right on the plots. Also, in Table 5.7 the slope values of the trendlines should be close to unity. As seen in Figure 5.36, the trendlines have a tendency to decrease, and slopes in Table 5.7 have high negative values. Therefore, these results lead to the conclusion that there exists a random relationship between the measured flow direction and the flow direction deflections because of the Coriolis effect.

Table 5.7. Slope values of the trendlines for ArcsinX versus Flow Direction data at all verticals at Union Point.

	Slope of the Trendline						
	Flow Events						
Verticals	27-Feb	23-Mar	10-Apr	17-Apr	8-May	9-Jun	3-Aug
V1	-2.0997	-1.1713	-1.8743	0.5769	-0.5338	-0.4649	-1.1445
V2	-0.3958	0.5422	-0.2025	0.5367	0.2991	-1.2807	-1.4316
V3	0.0877	0.5418	-0.1228	0.5550	-0.0815	-0.6264	0.2560
V4	0.1397	0.9566	0.5453	1.5998	0.4217	-0.2094	0.6317
All	-0.1582	-0.1751	-0.0831	0.1827	0.1181	0.2744	0.4237

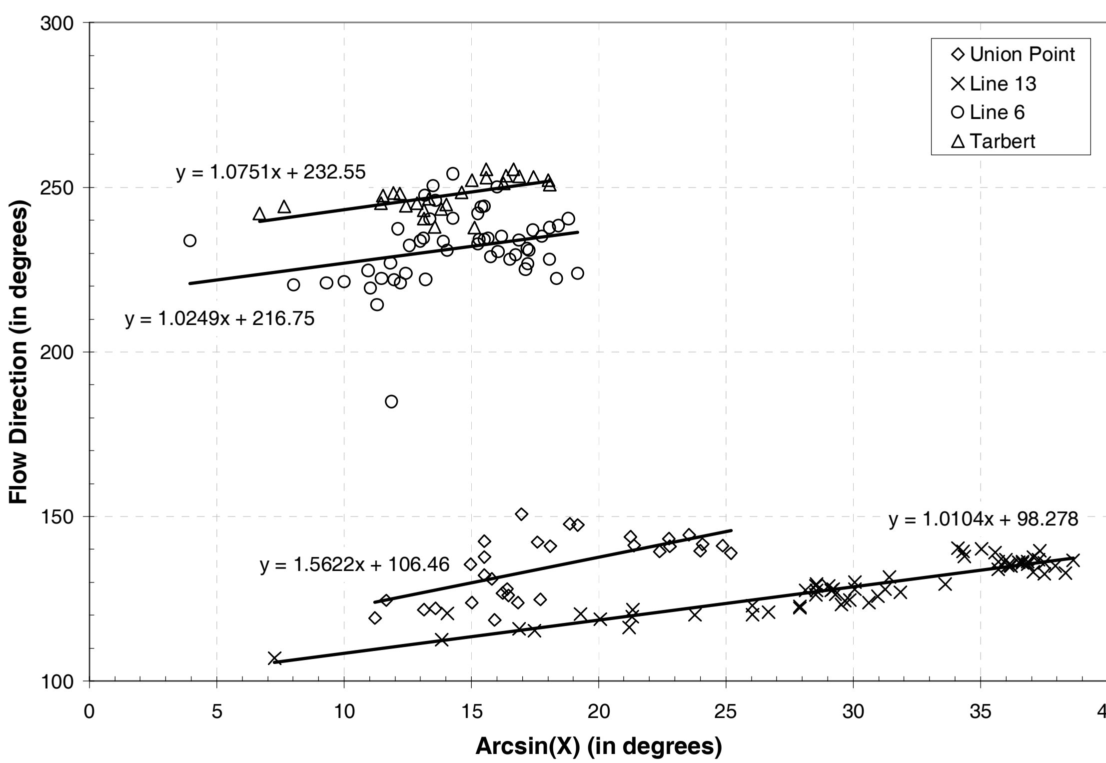

Figure 5.35. Direct proportionality of Arcsin(X) versus Flow Direction for sample verticals at each location.

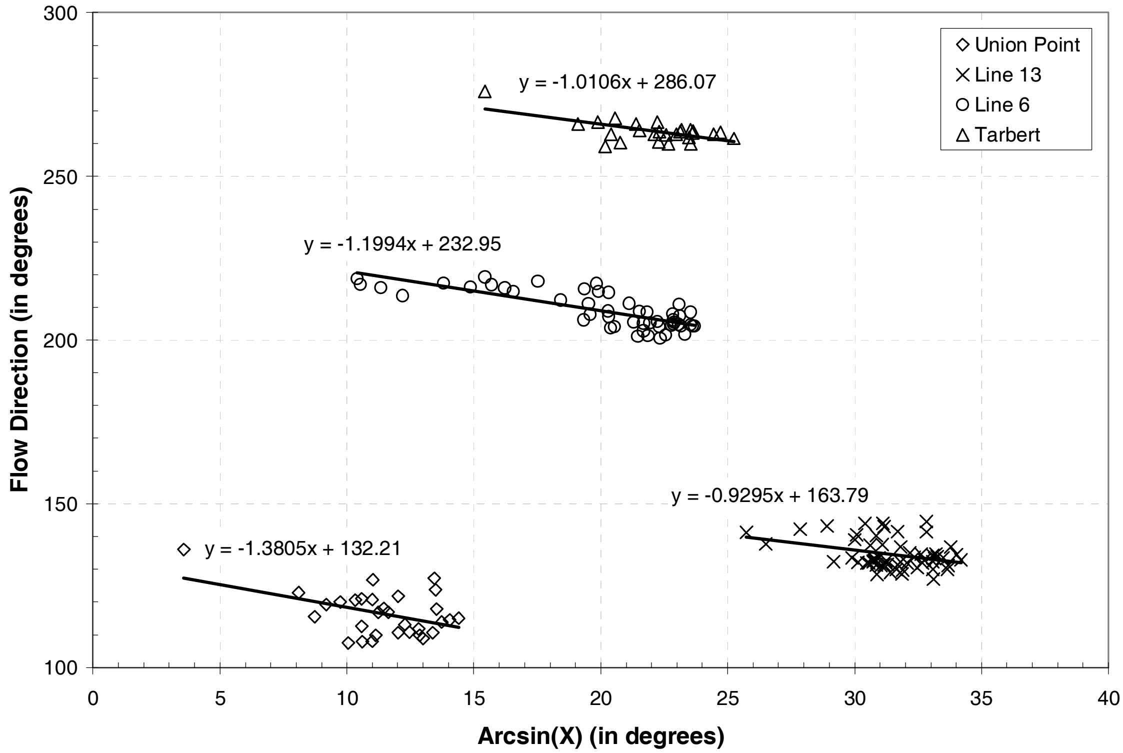

Figure 5.36. Inverse proportionality of Arcsin(X) versus Flow Direction for sample verticals at each location.

Moreover, because the velocity intensities are higher close to the water surface, the $\arcsin X$ versus the flow direction graphs for the upper 33 percent data of all verticals at all locations were plotted. Figure 5.37 below shows one of these graphs for the February 27, 1998 event at Union Point. As is obvious from Figure 5.37, the relationship of the flow direction with the Coriolis force is vague because the trends in the figure have both increasing and decreasing tendencies.

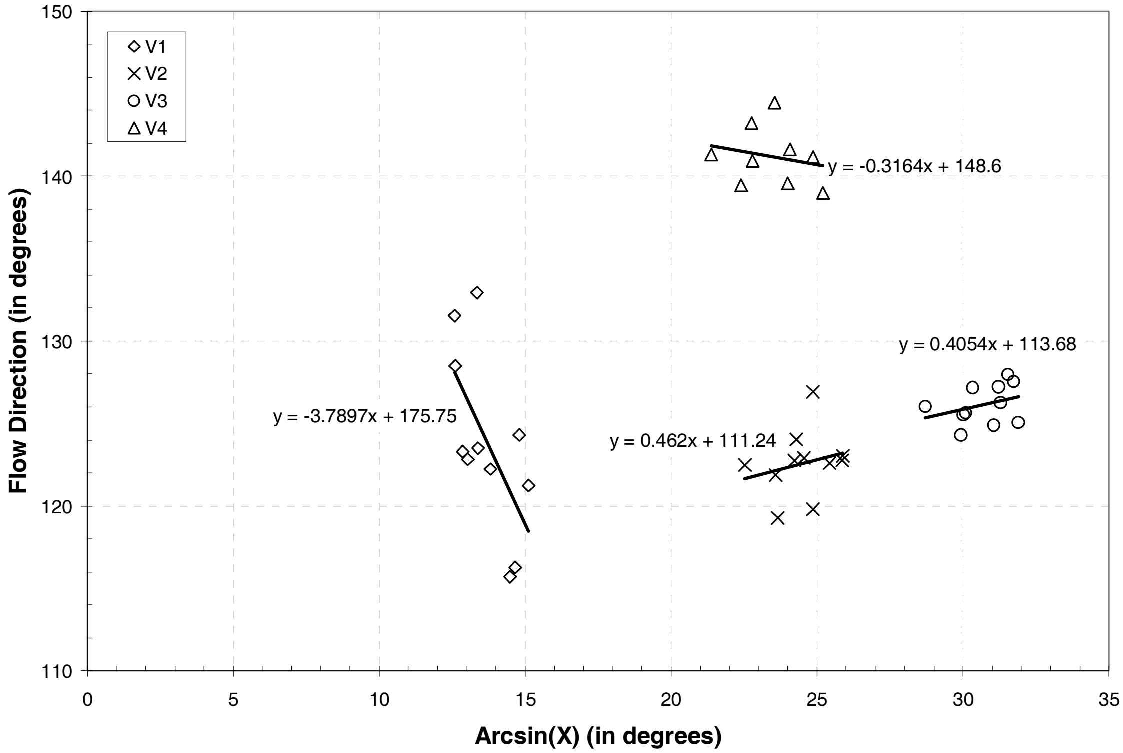

Figure 5.37. Relationship of measured flow directions to the Coriolis force deflections at the upper 33 percent of all verticals for the April 17, 1998 event at Union Point.

In theory, because the study area is located at the North Pole, if there exists such an effect as the Coriolis force, the flow direction in the river should be diverted towards the West, which means the measured flow direction angles should increase when the velocity intensity is increased. However, the analysis herein fails to validate the theory because the measured flow direction angles don't relate to the velocity intensity. Maybe the river flow direction doesn't respond to the Coriolis effect in the short period covered in this study, but the flow direction is responsive to the Coriolis effect in the long period.

Chapter 6. SUMMARY AND CONCLUSIONS

This study defines the effects of the water temperature on sediment transport by size fraction, and the Coriolis effect on the flow direction in the Lower Mississippi River. The data collected at a reach near the Old River Control Structures complex in the Lower Mississippi River were used for the analysis.

First, the water temperature effect on the transport of sediment was examined by observing the changes in both the vertical velocity profiles and the suspended sediment concentration distributions. Changes in vertical velocity profiles were linked to the changes in the viscosity of water and the von Karman parameter. Changes in the vertical sediment concentration distributions, on the other hand, were correlated to the changes in the Rouse number and the von Karman parameter. Moreover, the general trends of the suspended sediment concentration and discharge values with water temperature change were observed by means of graphs and statistical tools.

Next, the measured Rouse number and suspended sediment concentration values by size fraction were compared with those calculated with Rouse's equation for the vertical distribution of the suspended sediment concentration.

Finally, the effect of the Coriolis force on flow directions in the Lower Mississippi River was investigated by comparing the measured flow directions with those calculated by utilizing the ratio of the Coriolis acceleration to the gravitational acceleration. A direct one-to-one relationship between the measured and calculated flow directions would indicate the existence of the Coriolis effect on the flow direction.

The analysis of the field data led to the following major conclusions:

- Sediment transport is sensitive to the changes in water temperature. An increase in water temperature definitely decreases the suspended sediment discharge (see Figure 5.16). The amount of sand transported by the river falls down by approximately 3.09 percent for every 1 ^{o}C increase in water temperature. As far as the individual sand fractions are concerned, a water temperature increase of 1 ^{o}C results in approximately 2.79, 3.40, 1.42 and 1.49 percent decrease in the suspended very fine, fine, medium and coarse sand transport, respectively. The biggest effect is on the transport of fine sand size fraction (see Figure 5.17).
- On average, sediment concentration decreases with the increase of the water temperature regardless of the sediment size. The decrease in sand concentration is higher than that for silt and clay concentration (see Figure 5.13). A water temperature increase of 1 ^{o}C results in about 1.20 to 2.69 percent decrease in the suspended sand concentration. Fine sand size is influenced the most from the water temperature change. There is up to a 3.17 percent decrease in the suspended fine sand concentration with every 1 ^{o}C rise in water temperature rise.
- Because of the negligible amount of medium and coarse sand sizes in the flow, the effect of water temperature on the reference sand concentration is obtained by considering only the fine and very fine sand sizes (see Figure 5.25). There is about a 1.69 percent decrease in the reference fine sand concentration and about a 0.90 percent decrease in the reference very fine sand concentration with a water temperature increase of 1 ^{o}C when the data for all cross-sections are considered.
- Although the change in the measured Rouse number, R_{om}, with size fraction doesn't

have an obvious trend like the calculated Rouse number, R_{oc}, on average, R_{om} decreases with sediment size (see Figure 5.28 and Figure 5.29). For example, Rouse number values for coarse sand fraction, on average, are higher than those for medium, fine, and very fine sand sizes. Both the measured and calculated Rouse numbers are higher in warmer water temperatures. For fine and very fine sand fractions both the measured and calculated Rouse number values are similar, but for medium and coarse sand sizes, the difference between the calculated and measured Rouse number values increases. For coarse sand size, the calculated Rouse number exceeds the measured Rouse number by approximately 76 percent.

- The average measured Rouse number, R_{om}, value goes up slightly with a water temperature increase (see Figure 5.28). The value of R_{om} increases by approximately 1.12 percent with a water temperature increase of every 1 ^{o}C. Fine and very fine sand fractions are influenced the most. The measured Rouse number for fine and very fine sand fractions increases by approximately 0.76 and 1.61 percent due to a 1 ^{o}C increase in water temperature.
- The average measured von Karman parameter, κ, value for all cross-sections increases slightly with an increase in the water temperature (see Figure 5.3, and Figure C.1 through Figure C.3). When the water temperature increases from 9 ^{o}C to 16 ^{o}C, the von Karman parameter increases by about 15 percent, which corresponds to a 2.17 percent increase for every 1 ^{o}C increase in water temperature. An increase in the von Karman parameter along with a decrease in the kinematic viscosity of water with water temperature brings about a little decrease in the turbulent flow

velocity (see Figure 5.10). On average, there is about a 0.66 percent reduction in the turbulent flow velocity with a water temperature rise of 1 ^{o}C.

- Although the theory shows that the Coriolis force influences the direction of any object moving on the Earth surface, it is not obvious that the Coriolis force has an apparent effect on the flow direction in the Lower Mississippi River. Figure 5.37 shows clearly the conflicting effect of the Coriolis force on the Lower Mississippi River flow direction. Even though some verticals (see Figure 5.35) show a directly proportional relationship between the Coriolis force and the flow direction, the relationship is inversely proportional for other verticals (see Figure 5.36). Other factors such as turbulence, thermal currents, and centrifugal, pressure gradient and friction forces also affect the flow direction, thus masking the Coriolis effect.

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APPENDIX A – CORIOLIS FORCE

The Coriolis force, which was first introduced in 1835 by the French mathematical physicist G. G. Coriolis, is created by the rotation of the Earth about its axis and has an effect on any object that is not firmly attached to the Earth's surface. The air in the atmosphere, the water in lakes, rivers, seas, and oceans is in a continuous motion, and therefore, is subject to the deflecting Coriolis force (Stommel and Moore, 1989).

Some examples indicating the effect of the Coriolis force are as follows: A projectile fired towards the South from the North Pole will miss its target unless the earth's rotation is taken into account when aiming; railroad tracks wear out faster on one side than the other, and riverbeds are dug deeper on one side than the other depending on which hemisphere the railroads or rivers are in.

To an observer in space the Coriolis force does not exist. It is an apparent force. However, to an observer on the moving system, that is, to someone on the surface of the Earth, the force exerted on a particle as it moves along the surface of the Earth is real. There is a deviation from the original direction of motion due to this force, which can be measured by the observer on the surface of the Earth. It acts at right angles to the direction of motion, and deflects toward the right in the Northern Hemisphere and toward the left in the Southern Hemisphere (Williams, 1962).

The Coriolis effect is zero at the equator and maximum at the poles. A particle at rest is not affected, nor is a particle moving exactly East-West along the equator. As soon as the particle moves over the Earth, however, the poleward component of gravitational force and the horizontal component of the centrifugal force accompanying the Earth's rotation are no longer in balance. If a particle moves eastward over the earth, it will have a centrifugal reaction toward the equator, which is slightly greater than that of the earth beneath, and will tend to move toward the equator. If the particle moves westward over the Earth, gravitation will tend to move it poleward, since its centrifugal reaction is less than the reaction of the Earth (von Arx, 1962).

The Coriolis force is proportional to the relative velocity of the particle moving on the Earth and the sine of the latitude. The Earth rotates in the east-west, anti-clockwise direction around its tilted axis with the speed of the rotation zero at the poles and increasing towards the equator, being maximum at the equator (see Figure A.1).

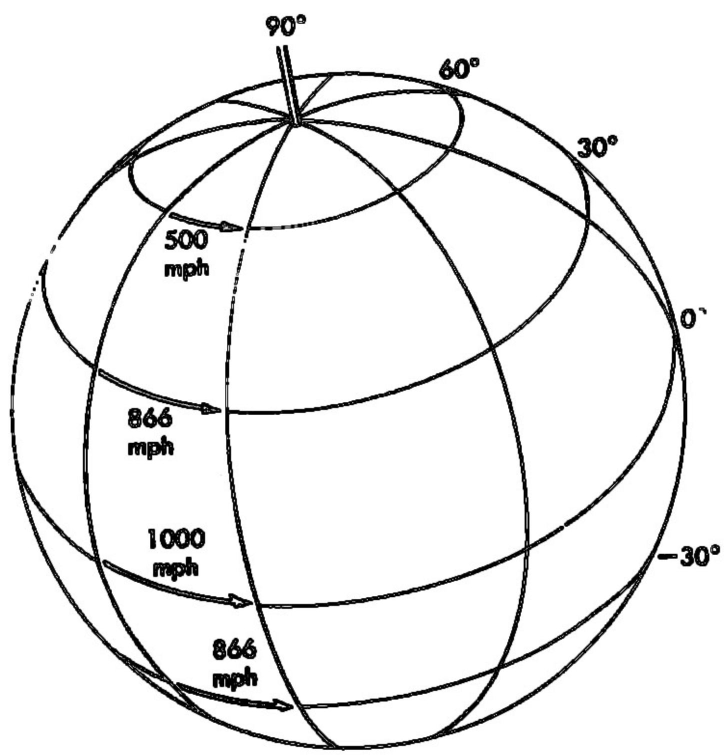

Figure A.1. Points at different latitudes on the earth's surface rotate at different velocities.

Normally, the Coriolis force is far weaker than gravity, so its vertical effects are rarely dealt with, whereas its horizontal effect is essential to the dynamics of the air and water flows. The Coriolis force exists only when there is velocity relative to the earth's surface.

The atmosphere, the ocean, and the river are very thin layers in which the depth scale of flow is smaller than the length scale in the order of hundreds or even thousands. The trajectories of fluid elements are very shallow, and the vertical velocities are much smaller than the horizontal velocities. Stratification and Coriolis effects usually constrain the vertical velocity (Kundu, 1990). Large-scale geophysical flow problems should be solved using spherical polar coordinates. If, however, the horizontal length scales are smaller than the radius of the earth (= 6371 km), then the curvature of the earth can be ignored, and the motion can be studied by adopting a local Cartesian system on a tangent plane (see Figure A.2). On this plane we take a x, y, z coordinate system, with x increasing eastward, y northward, and z upward.

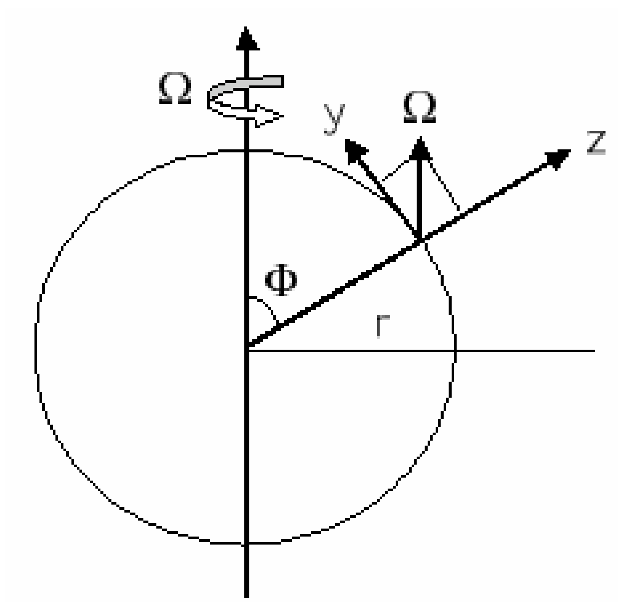

Figure A.2. Local Cartesian coordinates. The x axis is into the plane of the paper.

The time rate of change of any vector due solely to rotation of the coordinate system, in which it is defined, is given by the vector product Ω x V, in which Ω is the vector (in a right-handed system) the angular velocity of the moving coordinate frame and V is the vector of fluid velocity with respect to the moving coordinate frame (Eagleson, 1970).

The earth rotates at a rate $\Omega = 2\pi\ rad/day = 7.3\times10^{-5}\ s^{-1}$ around the polar axis, in an anti-clockwise sense looking from above the North Pole. From Table B.1, the components of angular velocity of Earth in the local Cartesian system are $\Omega_x = 0$, $\Omega_y = \Omega\cos\Phi$, $\Omega_z = \Omega\sin\Phi$, where Φ is the latitude. The Coriolis force, F_C, per unit mass, which is also called the Coriolis acceleration, a_C, can be defined as the following (Kundu, 1990):

$$a_C = 2\Omega\times V = \begin{vmatrix} i & j & k \\ 0 & 2\Omega\cos\Phi & 2\Omega\sin\Phi \\ V_x & V_y & V_z \end{vmatrix}$$

$$a_C = 2\Omega\left[i(V_z\cos\Phi - V_y\sin\Phi) + jV_x\sin\Phi - kV_x\cos\Phi\right] \qquad \text{(Eq.A.1)}$$

Thin sheet approximation requires that $V_z << V_x, V_y$. The three components of the Coriolis acceleration are, therefore,

$$a_{C,x} = -2\,\Omega\,V_y\,\sin\Phi = -f\,V_y \qquad \text{(Eq.A.2a)}$$

$$a_{C,y} = -2\,\Omega\,V_x\,\sin\Phi = -f\,V_x \qquad \text{(Eq.A.2b)}$$

$$a_{C,z} = -2\,\Omega\,V_x\,\cos\Phi = -f\,V_x\cot\Phi \qquad \text{(Eq.A.2c)}$$

where $f = 2\,\Omega\sin\Phi$ is more commonly called the Coriolis parameter (less commonly, the planetary vorticity or the Coriolis frequency). It is positive in the Northern Hemisphere and negative in the Southern Hemisphere, varying from $\pm 1.45\times10^{-4}\ s^{-1}$ at the poles to zero at the equator. This makes sense, since a person standing at the North Pole would spin around himself in an anti-clockwise sense at a rate Ω, whereas a person standing at the equator would not spin around himself, but simply translate.

Since the component of the flow velocity in the y direction is small compared to that in the x direction ($V_y << V_x$), and the pole-ward component (z component) of the gravitational acceleration counterbalances that of the Coriolis acceleration accompanying the earth's rotation, only the component of the Coriolis acceleration in the y direction is of concern in this study. The component of the Coriolis acceleration in the y direction is written as:

$$a_{C,y} = 2\,V_x\ \Omega\sin\Phi \qquad \text{(Eq.A.3)}$$

where Ω is the angular velocity of the earth's rotation, Φ is the latitude, and V_x is the component of the flow velocity in the x direction.

As it can be seen clearly from Eq.A.3, there is no horizontal component of the Coriolis force at the equator because $\Phi = 0$, thus $\sin\Phi = 0$. This force is directed normal to the flow velocity, and performs no work because it is always directed at right angles to the direction of the flow. Because the Coriolis force always acts perpendicular to the direction of the flow, it can only deflect the particle's direction, not change its speed. Eq.A.3 also states that the faster the flow is, the stronger the Coriolis force acting on it will be. Therefore, it can be concluded that the Coriolis force is only significant (relative to other forces acting) on large scale flows such as flows in the atmosphere and oceans, and it is not so effective on small scale flows such as flows in rivers and bathtubs.

Experiments have been done in both Northern and Southern hemispheres to verify that under carefully controlled conditions, bathtubs drain in opposite directions due to the Coriolis acceleration from the Earth's rotation. This effect is so small that you would have to get out and wait until the motion in the water is far less than one rotation per day to detect it. This would require removing thermal currents, vibration, and any other sources of noise (Feinstein, 1993).

Gravitational force, F_g, which is assumed to be a constant due to the negligible effects of other forces, such as friction force, influences the relative effect of the Coriolis force, F_C, on the air and water flows. Therefore, the effect of the Coriolis force on flows should be examined with respect to the gravitational force.

APPENDIX B – TABLES

Table B.1. Suspended sediment data at Union Point.

DATE: 27-FEB-98
STREAM: MISSISSIPPI RIVER
LOCATION: UNION POINT
GAGE: KNOX LANDING
DISCHARGE: 1,010,854 CFS (ADCP)

RIVER CONDITION: GOOD
TIME: 08:00 TO 09:00
TEMP: 9 C @10 FT.
WEATHER: CLOUDY
GAGE READING: 48.60 FT.

TYPE SAMPLER: P-63
TYPE SAMPLES: SUSP.
NO. VERTICALS: 4
NO. POINTS: 6

CONVENTIONAL METHOD: 1,028,013 CFS

Suspended Sediment Grain Size Analysis — Sand Sieve Analysis (Cumulative Weight Retained)

Field No.	Distance from the Reference Point (ft)	Station Depth h (ft)	Sampling Depth h - z (ft)	Samp. Velocity V (ft/s)	Flow Direction ϕ (Deg.)	U.S. 40 (0.425 mm)			U.S. 60 (0.250 mm)			U.S. 120 (0.125 mm)			U.S. 230 (0.062 mm)			Pan	Sediment Concentration (ppm)		
						Wt. (g)	% Ret.	% Finer	Wt. (g)	% Ret.	% Finer	Wt. (g)	% Ret.	% Finer	Wt. (g)	% Ret.	% Finer		Sand	Fine	Total
1	1066	66	6.6	4.43	118.898	0.0008	1.2	98.8	0.0112	17.3	82.7	0.0516	79.6	20.4	0.0638	98.5	1.5	0.0648	135.9	213.1	349.0
2	1066	66	19.8	4.06	122.202	0.0003	6.8	93.2	0.0005	11.4	88.6	0.0016	36.4	63.6	0.0039	88.6	11.4	0.0044	11.5	236.2	247.7
3	1066	66	33.0	4.46	122.859	0.0011	3.6	96.4	0.0016	5.2	94.8	0.0173	56.0	44.0	0.0304	98.4	1.6	0.0309	68.6	212.5	281.1
4	1066	66	46.2	4.18	117.028	0.0000	0.0	100.0	0.0000	0.0	100.0	0.0086	55.1	44.9	0.0149	95.5	4.5	0.0156	58.2	263.9	322.1
5	1066	66	59.4	3.88	122.267	0.0007	0.6	99.4	0.0052	4.7	95.3	0.0905	82.6	17.4	0.1083	98.9	1.1	0.1095	214.7	209.1	423.8
6	1066	66	64.7	2.59	148.750	0.0008	1.0	99.0	0.0022	2.8	97.2	0.0622	78.0	22.0	0.0786	98.6	1.4	0.0797	270.0	263.8	533.8
7	1658	66	6.6	8.67	118.562	0.0002	2.2	97.8	0.0027	29.7	70.3	0.0061	67.0	33.0	0.0087	95.6	4.4	0.0091	19.2	208.8	228.0
8	1658	66	19.8	8.40	118.778	0.0007	2.7	97.3	0.0014	5.4	94.6	0.0134	51.9	48.1	0.0246	95.3	4.7	0.0258	48.1	203.4	251.5
9	1658	66	33.0	8.65	120.308	0.0007	1.2	98.8	0.0017	2.8	97.2	0.0430	71.3	28.7	0.0586	97.2	2.8	0.0603	103.3	197.7	301.0
10	1658	66	46.2	7.25	123.006	0.0008	1.0	99.0	0.0028	3.6	96.4	0.0617	78.4	21.6	0.0770	97.8	2.2	0.0787	147.0	202.3	349.3
11	1658	66	59.4	6.68	121.394	0.0013	1.4	98.6	0.0031	3.4	96.6	0.0747	82.0	18.0	0.0901	98.9	1.1	0.0911	304.0	249.0	553.0
12	1658	66	64.7	5.57	112.622	0.0026	0.8	99.2	0.0230	6.7	93.3	0.3224	93.2	6.8	0.3451	99.8	0.2	0.3458	995.4	245.7	1241.1
13	2256	66	6.6	6.93	121.703	0.0012	6.8	93.2	0.0017	9.6	90.4	0.0095	53.7	46.3	0.0167	94.4	5.6	0.0177	25.6	185.0	210.6
14	2256	66	19.8	6.49	124.750	0.0009	7.4	92.6	0.0014	11.5	88.5	0.0091	74.6	25.4	0.0114	93.4	6.6	0.0122	26.7	215.5	242.2
15	2256	66	33.0	6.52	127.060	0.0028	6.4	93.6	0.0078	17.8	82.2	0.0331	75.7	24.3	0.0425	97.3	2.7	0.0437	88.1	207.9	296.0
16	2256	66	46.2	5.05	126.996	0.0015	1.3	98.7	0.0102	8.5	91.5	0.1004	83.8	16.2	0.1179	98.4	1.6	0.1198	195.3	196.5	391.8
17	2256	66	59.4	4.25	126.578	0.0007	0.4	99.6	0.0473	24.5	75.5	0.1705	88.3	11.7	0.1908	98.9	1.1	0.1930	259.6	190.5	450.1
18	2256	66	64.7	3.43	121.245	0.0013	1.0	99.0	0.0193	15.3	84.7	0.1119	88.5	11.5	0.1257	99.4	0.6	0.1264	288.5	216.7	505.2
19	2941	56	5.6	7.08	124.794	0.0007	7.4	92.6	0.0012	12.6	87.4	0.0061	64.2	35.8	0.0089	93.7	6.3	0.0095	22.3	206.0	228.3
20	2941	56	16.8	7.59	128.664	0.0004	2.4	97.6	0.0020	12.2	87.8	0.0097	59.1	40.9	0.0152	92.7	7.3	0.0164	31.8	207.5	239.3
21	2941	56	28.0	7.51	126.629	0.0003	1.9	98.1	0.0017	11.0	89.0	0.0095	61.7	38.3	0.0151	98.1	1.9	0.0154	29.0	194.7	223.7
22	2941	56	39.2	6.39	129.349	0.0015	6.3	93.8	0.0081	33.8	66.3	0.0170	70.8	29.2	0.0234	97.5	2.5	0.0240	65.9	223.3	289.2
23	2941	56	50.4	6.50	124.717	0.0013	5.8	94.2	0.0053	23.6	76.4	0.0152	67.6	32.4	0.0215	95.6	4.4	0.0225	61.5	223.8	285.3
24	2941	56	54.9	3.92	121.736	0.0064	15.1	84.9	0.0233	55.1	44.9	0.0373	88.2	11.8	0.0414	97.9	2.1	0.0423	118.3	226.8	345.1

DATE :23-MAR-98
STREAM: MISSISSIPPI RIVER
LOCATION: UNION POINT
GAGE: UNION POINT
DISCHARGE: 1,063,325 CFS (ADCP)

RIVER CONDITION :CHOPPY
TIME: 09:00 TO 11:00
TEMP:9 ^{0}C @1.5 FT.
WEATHER: WINDY AND MILD
GAGE READING: 52.90 FT.

TYPE SAMPLER: P-63
TYPE SAMPLES: SUSP.
NO. VERTICALS: 4
NO. POINTS: 6

CONVENTIONAL METHOD: 1,127,296 CFS

Suspende Sediment Grain Size Analysis — Sand Sieve Analysis (Cumulative Weight Retained)

Field No.	Distance from the Reference Point (ft)	Station Depth h (ft)	Sampling Depth h - z (ft)	Samp. Velocity V (ft/s)	Flow Direction ϕ (Deg.)	U.S. 40 (0.425 mm)			U.S. 60 (0.250 mm)			U.S. 120 (0.125 mm)			U.S. 230 (0.062 mm)			Pan	Sediment Concentration (ppm)		
						Wt. (g)	% Ret.	% Finer	Wt. (g)	% Ret.	% Finer	Wt. (g)	% Ret.	% Finer	Wt. (g)	% Ret.	% Finer		Sand	Fine	Total
25	1020	63	6.3	4.75	105.760	0.0000	0.0	100.0	0.0010	14.9	85.1	0.0039	58.2	41.8	0.0063	94.0	6.0	0.0067	15.9	262.9	278.8
26	1020	63	18.9	4.63	112.350	0.0000	0.0	100.0	0.0004	3.3	96.7	0.0059	48.8	51.2	0.0112	92.6	7.4	0.0121	29.1	279.1	308.2
27	1020	63	31.5	4.58	109.230	0.0002	1.7	98.3	0.0006	5.0	95.0	0.0061	50.4	49.6	0.0114	94.2	5.8	0.0121	31.6	277.4	309.0
28	1020	63	44.1	4.44	106.600	0.0004	1.1	98.9	0.0013	3.4	96.6	0.0295	78.2	21.8	0.0369	97.9	2.1	0.0377	128.8	318.0	446.8
29	1020	63	56.7	3.47	114.960	0.0004	0.7	99.3	0.0020	3.3	96.7	0.0494	81.1	18.9	0.0598	98.2	1.8	0.0609	195.4	294.0	489.4
30	1020	63	61.7	3.02	123.550	0.0011	0.5	99.5	0.0044	1.9	98.1	0.2056	87.6	12.4	0.2329	99.2	0.8	0.2347	620.7	271.3	892.0
31	1755	67	6.7	7.01	126.220	0.0006	7.2	92.8	0.0009	10.8	89.2	0.0034	41.0	59.0	0.0075	90.4	9.6	0.0083	14.6	245.7	260.3
32	1755	67	20.1	7.59	129.040	0.0004	2.0	98.0	0.0012	5.9	94.1	0.0097	47.8	52.2	0.0181	89.2	10.8	0.0203	26.6	221.7	248.3
33	1755	67	33.5	6.82	131.746	0.0003	2.4	97.6	0.0006	4.8	95.2	0.0063	50.8	49.2	0.0119	96.0	4.0	0.0124	22.1	245.8	267.9
34	1755	67	46.9	7.03	128.020	0.0009	0.6	99.4	0.0057	3.9	96.1	0.1254	86.8	13.2	0.1426	98.8	1.2	0.1444	242.1	240.1	482.2
35	1755	67	60.3	6.27	123.391	0.0013	0.8	99.2	0.0053	3.3	96.7	0.1405	87.3	12.7	0.1596	99.1	0.9	0.1610	273.3	245.9	519.2
36	1755	67	65.7	5.62	122.836	0.0009	0.7	99.3	0.0023	1.9	98.1	0.1003	83.0	17.0	0.1191	98.6	1.4	0.1208	256.5	272.0	528.5
37	2274	80	8.0	7.71	119.554	0.0003	1.0	99.0	0.0014	4.5	95.5	0.0214	69.5	30.5	0.0295	95.8	4.2	0.0308	42.4	230.0	272.4
38	2274	80	24.0	8.22	114.120	0.0004	1.2	98.8	0.0040	12.1	87.9	0.0248	74.9	25.1	0.0317	95.8	4.2	0.0331	55.6	260.1	315.7
39	2274	80	40.0	7.20	114.872	0.0006	2.2	97.8	0.0032	12.0	88.0	0.0195	73.0	27.0	0.0253	94.8	5.2	0.0267	55.2	254.1	309.3
40	2274	80	56.0	6.04	115.771	0.0008	1.0	99.0	0.0109	14.2	85.8	0.0625	81.6	18.4	0.0746	97.4	2.6	0.0766	104.5	219.5	324.0
41	2274	80	72.0	4.74	114.775	0.0009	0.9	99.1	0.0129	12.7	87.3	0.0905	89.1	10.9	0.1004	98.8	1.2	0.1016	220.4	253.5	473.9
42	2274	80	78.4	3.55	106.963	0.0057	0.9	99.1	0.1308	20.9	79.1	0.6005	95.9	4.1	0.6239	99.6	0.4	0.6263	878.0	238.0	1116.0
43	3091	60	6.0	3.66	130.752	0.0002	1.6	98.4	0.0005	4.1	95.9	0.0060	48.8	51.2	0.0114	92.7	7.3	0.0123	16.7	226.7	243.4
44	3091	60	18.0	3.86	135.654	0.0006	4.1	95.9	0.0023	15.9	84.1	0.0085	58.6	41.4	0.0131	90.3	9.7	0.0145	27.6	247.5	275.1
45	3091	60	30.0	3.75	140.323	0.0000	0.0	100.0	0.0036	18.9	81.1	0.0132	69.5	30.5	0.0176	92.6	7.4	0.0190	43.7	265.6	309.3
46	3091	60	42.0	3.47	129.472	0.0006	2.8	97.2	0.0017	8.1	91.9	0.0107	50.7	49.3	0.0201	95.3	4.7	0.0211	53.1	273.6	326.7
47	3091	60	54.0	3.36	132.782	0.0002	1.0	99.0	0.0037	19.1	80.9	0.0135	69.6	30.4	0.0180	92.8	7.2	0.0194	58.3	293.6	351.9
48	3091	60	58.8	1.50	135.000	0.0021	5.8	94.2	0.0139	38.2	61.8	0.0304	83.5	16.5	0.0356	97.8	2.2	0.0364	118.9	288.0	406.9

DATE: 10-APR-98
STREAM: MISSISSIPPI RIVER
LOCATION: UNION POINT
GAGE: UNION POINT
DISCHARGE: 1,107,752 CFS (ADCP)

RIVER CONDITION: GOOD
TIME: 09:00 TO 11:00
TEMP: 16 C @1.5 FT.
WEATHER: CLEAR AND WARM
GAGE READING: 54.55 FT.

TYPE SAMPLER: P-63
TYPE SAMPLES: SUSP.
NO. VERTICALS: 4
NO. POINTS: 6

CONVENTIONAL METHOD: 1,072,507 CFS

Suspende Sediment Grain Size Analysis — Sand Sieve Analysis (Cumulative Weight Retained)

Field No.	Distance from the Reference Point (ft)	Station Depth h (ft)	Sampling Depth h - z (ft)	Samp. Velocity V (ft/s)	Flow Direction ϕ (Deg.)	U.S. 40 (0.425 mm)			U.S. 60 (0.250 mm)			U.S. 120 (0.125 mm)			U.S. 230 (0.062 mm)			Pan	Sediment Concentration (ppm)		
						Wt. (g)	% Ret.	% Finer	Wt. (g)	% Ret.	% Finer	Wt. (g)	% Ret.	% Finer	Wt. (g)	% Ret.	% Finer		Sand	Fine	Total
49	1075	69	6.9	4.62	119.987	0.0008	6.8	93.2	0.0009	7.6	92.4	0.0062	52.5	47.5	0.0116	98.3	1.7	0.0118	23.9	156.7	180.6
50	1075	69	20.7	4.07	110.204	0.0000	0.0	100.0	0.0000	0.0	100.0	0.0023	48.9	51.1	0.0046	97.9	2.1	0.0047	10.0	179.7	189.7
51	1075	69	34.5	3.43	110.518	0.0000	0.0	100.0	0.0000	0.0	100.0	0.0030	46.2	53.8	0.0062	95.4	4.6	0.0065	25.6	252.7	278.3
52	1075	69	48.3	3.91	122.810	0.0000	0.0	100.0	0.0004	1.7	98.3	0.0123	52.3	47.7	0.0228	97.0	3.0	0.0235	34.9	157.8	192.7
53	1075	69	62.1	3.49	126.795	0.0000	0.0	100.0	0.0013	2.1	97.9	0.0510	83.2	16.8	0.0610	99.5	0.5	0.0613	131.1	183.5	314.6
54	1075	69	67.6	2.72	134.365	0.0012	2.7	97.3	0.0019	4.3	95.7	0.0353	79.5	20.5	0.0441	99.3	0.7	0.0444	131.0	213.8	344.8
55	1643	70	7.0	7.44	122.051	0.0000	0.0	100.0	0.0004	2.7	97.3	0.0074	50.7	49.3	0.0140	95.9	4.1	0.0146	18.9	155.7	174.6
56	1643	70	21.0	7.93	123.197	0.0000	0.0	100.0	0.0000	0.0	100.0	0.0030	33.0	67.0	0.0082	90.1	9.9	0.0091	14.1	169.2	183.3
57	1643	70	35.0	7.31	121.586	0.0000	0.0	100.0	0.0000	0.0	100.0	0.0066	55.9	44.1	0.0116	98.3	1.7	0.0118	24.4	185.6	210.0
58	1643	70	49.0	7.31	120.019	0.0012	1.5	98.5	0.0019	2.4	97.6	0.0595	74.3	25.7	0.0796	99.4	0.6	0.0801	109.9	158.3	268.2
59	1643	70	63.0	5.98	119.928	0.0028	1.5	98.5	0.0070	3.8	96.2	0.1497	81.4	18.6	0.1835	99.8	0.2	0.1839	251.3	166.4	417.7
60	1643	70	68.6	4.92	111.128	0.0005	0.5	99.5	0.0023	2.1	97.9	0.0730	66.6	33.4	0.1092	99.6	0.4	0.1096	203.3	175.9	379.2
61	2224	81	8.1	7.10	122.508	0.0000	0.0	100.0	0.0005	6.9	93.1	0.0034	47.2	52.8	0.0062	86.1	13.9	0.0072	8.2	137.7	145.9
62	2224	81	24.3	6.98	127.667	0.0011	2.7	97.3	0.0051	12.4	87.6	0.0340	82.5	17.5	0.0411	99.8	0.2	0.0412	67.5	150.8	218.3
63	2224	81	40.5	6.58	126.281	0.0000	0.0	100.0	0.0031	10.7	89.3	0.0210	72.2	27.8	0.0283	97.3	2.7	0.0291	37.6	143.8	181.4
64	2224	81	56.7	5.58	129.060	0.0005	1.5	98.5	0.0033	10.1	89.9	0.0269	82.0	18.0	0.0324	98.8	1.2	0.0328	85.1	189.6	274.7
65	2224	81	72.9	4.11	131.732	0.0011	1.0	99.0	0.0157	13.8	86.2	0.1045	91.8	8.2	0.1133	99.6	0.4	0.1138	205.7	167.8	373.5
66	2224	81	79.4	3.04	119.860	0.0030	8.2	91.8	0.0092	25.1	74.9	0.0338	92.3	7.7	0.0366	100.0	0.0	0.0366	209.0	307.8	516.8
67	2943	60	6.0	6.40	137.661	0.0000	0.0	100.0	0.0009	9.9	90.1	0.0049	53.8	46.2	0.0087	95.6	4.4	0.0091	11.3	140.9	152.2
68	2943	60	18.0	6.16	137.765	0.0000	0.0	100.0	0.0016	17.2	82.8	0.0056	60.2	39.8	0.0093	100.0	0.0	0.0093	22.0	177.8	199.8
69	2943	60	30.0	6.23	137.197	0.0000	0.0	100.0	0.0134	45.7	54.3	0.0239	81.6	18.4	0.0291	99.3	0.7	0.0293	60.7	170.9	231.6
70	2943	60	42.0	6.99	138.275	0.0012	4.5	95.5	0.0099	36.9	63.1	0.0201	75.0	25.0	0.0264	98.5	1.5	0.0268	48.8	159.7	208.5
71	2943	60	54.0	5.15	148.942	0.0001	0.4	99.6	0.0080	34.6	65.4	0.0169	73.2	26.8	0.0226	97.8	2.2	0.0231	38.2	155.8	194.0
72	2943	60	58.8	3.11	131.453	0.0048	8.6	91.4	0.0298	53.6	46.4	0.0453	81.5	18.5	0.0548	98.6	1.4	0.0556	75.8	148.9	224.7

Table B.1 (continued)

DATE: 17-APR-98
STREAM: MISSISSIPPI RIVER
LOCATION: UNION POINT
GAGE: UNION POINT
DISCHARGE: 1,069,422 CFS (ADCP)

RIVER CONDITION: GOOD
TIME: 08:30 TO 09:30
TEMP: 16 C @1.5 FT.
WEATHER: CLOUDY AND RAIN
GAGE READING: 52.60 FT.

TYPE SAMPLER: P-63
TYPE SAMPLES: SUSP.
NO. VERTICALS: 4
NO. POINTS: 6

CONVENTIONAL METHOD: 1,072,377 CFS

						Suspende Sediment Grain Size Analysis													Sediment		
						Sand Sieve Analysis (Cumulative Weight Retained)													Concentration (ppm)		
Field No.	Distance from the Reference Point (ft)	Station Depth h (ft)	Sampling Depth h - z (ft)	Samp. Velocity V (ft/s)	Flow Direction φ (Deg.)	U.S. 40 (0.425 mm) Wt. (g)	U.S. 40 % Ret.	U.S. 40 % Finer	U.S. 60 (0.250 mm) Wt. (g)	U.S. 60 % Ret.	U.S. 60 % Finer	U.S. 120 (0.125 mm) Wt. (g)	U.S. 120 % Ret.	U.S. 120 % Finer	U.S. 230 (0.062 mm) Wt. (g)	U.S. 230 % Ret.	U.S. 230 % Finer	Pan	Sand	Fine	Total
73	1040	69	6.9	4.22	116.260	0.0000	0.0	100.0	0.0008	4.0	96.0	0.0101	50.2	49.8	0.0190	94.5	5.5	0.0201	52.1	314.1	366.2
74	1040	69	20.7	3.85	132.927	0.0004	1.4	98.6	0.0008	2.9	97.1	0.0133	47.5	52.5	0.0272	97.1	2.9	0.0280	47.4	278.4	325.8
75	1040	69	34.5	3.29	129.249	0.0017	4.3	95.7	0.0034	8.6	91.4	0.0187	47.2	52.8	0.0382	96.5	3.5	0.0396	65.9	261.2	327.1
76	1040	69	48.3	4.02	113.321	0.0006	1.9	98.1	0.0016	5.1	94.9	0.0164	52.7	47.3	0.0305	98.1	1.9	0.0311	62.2	297.0	359.2
77	1040	69	62.1	3.50	114.546	0.0002	0.3	99.7	0.0031	4.7	95.3	0.0530	80.1	19.9	0.0656	99.1	0.9	0.0662	156.9	307.6	464.5
78	1040	69	67.6	2.32	126.676	0.0008	1.0	99.0	0.0028	3.3	96.7	0.0645	77.2	22.8	0.0823	98.4	1.6	0.0836	178.4	300.2	478.6
79	1648	71	7.1	7.16	122.584	0.0000	0.0	100.0	0.0010	4.2	95.8	0.0067	28.0	72.0	0.0231	96.7	3.3	0.0239	44.3	258.9	303.2
80	1648	71	21.3	6.67	121.844	0.0000	0.0	100.0	0.0010	5.7	94.3	0.0076	43.4	56.6	0.0146	83.4	16.6	0.0175	18.7	222.7	241.4
81	1648	71	35.5	6.43	124.331	0.0004	0.8	99.2	0.0019	3.8	96.2	0.0403	79.2	20.8	0.0503	98.8	1.2	0.0509	111.3	293.8	405.1
82	1648	71	49.7	5.78	124.529	0.0010	1.4	98.6	0.0044	6.2	93.8	0.0534	75.2	24.8	0.0688	96.9	3.1	0.0710	112.5	268.1	380.6
83	1648	71	63.9	4.07	116.916	0.0022	2.4	97.6	0.0049	5.3	94.7	0.0775	83.3	16.7	0.0914	98.3	1.7	0.0930	207.0	297.2	504.2
84	1648	71	69.6	3.37	120.140	0.0021	1.3	98.7	0.0102	6.5	93.5	0.1300	82.8	17.2	0.1560	99.4	0.6	0.1570	231.2	254.9	486.1
85	2247	69	6.9	8.60	124.872	0.0000	0.0	100.0	0.0000	0.0	100.0	0.0028	49.1	50.9	0.0051	89.5	10.5	0.0057	13.1	290.6	303.7
86	2247	69	20.7	8.01	126.015	0.0000	0.0	100.0	0.0024	14.0	86.0	0.0108	63.2	36.8	0.0161	94.2	5.8	0.0171	26.0	245.4	271.4
87	2247	69	34.5	7.99	130.200	0.0000	0.0	100.0	0.0083	18.1	81.9	0.0398	86.9	13.1	0.0451	98.5	1.5	0.0458	99.4	272.7	372.1
88	2247	69	48.3	7.96	130.166	0.0004	0.8	99.2	0.0109	22.5	77.5	0.0443	91.5	8.5	0.0476	98.3	1.7	0.0484	151.6	325.3	476.9
89	2247	69	62.1	7.98	124.481	0.0011	1.1	98.9	0.0254	24.3	75.7	0.0957	91.6	8.4	0.1032	98.8	1.2	0.1045	193.5	275.1	468.6
90	2247	69	67.6	5.63	125.134	0.0015	0.8	99.2	0.0424	23.5	76.5	0.1705	94.3	5.7	0.1802	99.7	0.3	0.1808	347.7	252.9	600.6
91	2966	57	5.7	7.10	138.974	0.0000	0.0	100.0	0.0014	14.0	86.0	0.0054	54.0	46.0	0.0096	96.0	4.0	0.0100	18.6	280.4	299.0
92	2966	57	17.1	6.46	140.917	0.0008	4.6	95.4	0.0032	18.5	81.5	0.0108	62.4	37.6	0.0165	95.4	4.6	0.0173	38.8	299.5	338.3
93	2966	57	28.5	5.04	142.272	0.0000	0.0	100.0	0.0025	18.1	81.9	0.0095	68.8	31.2	0.0125	90.6	9.4	0.0138	42.7	331.5	374.2
94	2966	57	39.9	4.32	127.688	0.0007	2.1	97.9	0.0120	36.8	63.2	0.0285	87.4	12.6	0.0315	96.6	3.4	0.0326	85.0	306.6	391.6
95	2966	57	51.3	3.92	130.856	0.0023	4.9	95.1	0.0230	48.8	51.2	0.0401	85.1	14.9	0.0462	98.1	1.9	0.0471	117.3	296.5	413.8
96	2966	57	55.9	3.79	140.410	0.0072	8.0	92.0	0.0536	59.4	40.6	0.0780	86.5	13.5	0.0894	99.1	0.9	0.0902	207.3	276.9	484.2

DATE: 08-MAY-98
STREAM: MISSISSIPPI RIVER
LOCATION: UNION POINT
GAGE: UNION POINT
DISCHARGE: 1,219,937 CFS (ADCP)

RIVER CONDITION: GOOD
TIME: 08:15 TO 10:15
TEMP: 19 C @10 FT.
WEATHER: CLEAR AND WARM
GAGE READING: 56.10 FT.

TYPE SAMPLER: P-63
TYPE SAMPLES: SUSP.
NO. VERTICALS: 4
NO. POINTS: 6

CONVENTIONAL METHOD: 1,224,614 CFS

						Suspende Sediment Grain Size Analysis													Sediment		
						Sand Sieve Analysis (Cumulative Weight Retained)													Concentration (ppm)		
Field No.	Distance from the Reference Point (ft)	Station Depth h (ft)	Sampling Depth h - z (ft)	Samp. Velocity V (ft/s)	Flow Direction φ (Deg.)	U.S. 40 (0.425 mm) Wt. (g)	U.S. 40 % Ret.	U.S. 40 % Finer	U.S. 60 (0.250 mm) Wt. (g)	U.S. 60 % Ret.	U.S. 60 % Finer	U.S. 120 (0.125 mm) Wt. (g)	U.S. 120 % Ret.	U.S. 120 % Finer	U.S. 230 (0.062 mm) Wt. (g)	U.S. 230 % Ret.	U.S. 230 % Finer	Pan	Sand	Fine	Total
97	1094	73	7.3	5.20	121.650	0.0000	0.0	100.0	0.0000	0.0	100.0	0.0094	53.4	46.6	0.0169	96.0	4.0	0.0176	27.5	120.9	148.4
98	1094	73	21.9	4.24	125.740	0.0000	0.0	100.0	0.0009	2.5	97.5	0.0245	69.4	30.6	0.0350	99.2	0.8	0.0353	76.0	138.5	214.5
99	1094	73	36.5	3.65	125.900	0.0000	0.0	100.0	0.0007	2.7	97.3	0.0156	59.8	40.2	0.0256	98.1	1.9	0.0261	53.1	134.3	187.4
100	1094	73	51.1	3.26	120.720	0.0003	1.7	98.3	0.0006	3.3	96.7	0.0130	71.8	28.2	0.0181	100.0	0.0	0.0181	60.2	184.1	244.3
101	1094	73	65.7	3.22	140.990	0.0003	0.7	99.3	0.0012	2.9	97.1	0.0301	71.8	28.2	0.0418	99.8	0.2	0.0419	103.2	151.1	254.3
102	1094	73	71.5	2.38	137.130	0.0007	1.1	98.9	0.0030	4.5	95.5	0.0480	72.1	27.9	0.0661	99.2	0.8	0.0666	125.1	138.4	263.5
103	1652	72	7.2	7.61	129.730	0.0000	0.0	100.0	0.0006	4.4	95.6	0.0044	32.6	67.4	0.0129	95.6	4.4	0.0135	16.4	103.1	119.5
104	1652	72	21.6	7.44	127.750	0.0000	0.0	100.0	0.0019	5.5	94.5	0.0247	71.4	28.6	0.0340	98.3	1.7	0.0346	71.7	128.0	199.7
105	1652	72	36.0	7.49	126.197	0.0000	0.0	100.0	0.0007	2.5	97.5	0.0197	70.1	29.9	0.0280	99.6	0.4	0.0281	68.5	157.0	225.5
106	1652	72	50.4	6.72	130.207	0.0000	0.0	100.0	0.0014	3.4	96.6	0.0301	72.2	27.8	0.0412	98.8	1.2	0.0417	91.3	143.8	235.1
107	1652	72	64.8	6.79	123.544	0.0011	1.1	98.9	0.0038	3.9	96.1	0.0801	81.7	18.3	0.0972	99.2	0.8	0.0980	204.6	139.1	343.7
108	1652	72	70.6	4.35	126.205	0.0009	0.3	99.7	0.0073	2.7	97.3	0.2501	91.4	8.6	0.2721	99.5	0.5	0.2736	1131.4	214.6	1346.0
109	2276	72	7.2	9.89	121.075	0.0000	0.0	100.0	0.0065	11.4	88.6	0.0472	83.1	16.9	0.0563	99.1	0.9	0.0568	109.9	136.4	246.3
110	2276	72	21.6	9.23	120.583	0.0000	0.0	100.0	0.0021	12.6	87.4	0.0109	65.3	34.7	0.0161	96.4	3.6	0.0167	28.5	116.4	144.9
111	2276	72	36.0	9.42	123.496	0.0006	2.8	97.2	0.0049	22.8	77.2	0.0169	78.6	21.4	0.0209	97.2	2.8	0.0215	46.8	141.0	187.8
112	2276	72	50.4	9.77	126.358	0.0009	1.1	98.9	0.0087	11.0	89.0	0.0732	92.4	7.6	0.0790	99.7	0.3	0.0792	158.3	130.1	288.4
113	2276	72	64.8	9.02	126.970	0.0012	0.8	99.2	0.0221	14.4	85.6	0.1433	93.3	6.7	0.1532	99.7	0.3	0.1536	427.9	139.9	567.8
114	2276	72	70.6	6.36	121.582	0.0049	4.0	96.0	0.0542	44.6	55.4	0.1120	92.1	7.9	0.1215	99.9	0.1	0.1216	212.2	115.9	328.1
115	2959	58	5.8	6.80	130.814	0.0000	0.0	100.0	0.0012	11.8	88.2	0.0056	54.9	45.1	0.0099	97.1	2.9	0.0102	18.0	121.3	139.3
116	2959	58	17.4	7.07	133.196	0.0013	4.6	95.4	0.0111	38.9	61.1	0.0216	75.8	24.2	0.0281	98.6	1.4	0.0285	51.0	115.9	166.9
117	2959	58	29.0	7.00	136.653	0.0000	0.0	100.0	0.0021	21.4	78.6	0.0070	71.4	28.6	0.0095	96.9	3.1	0.0098	29.7	175.1	204.8
118	2959	58	40.6	5.84	141.039	0.0021	5.2	94.8	0.0197	49.0	51.0	0.0331	82.3	17.7	0.0393	97.8	2.2	0.0402	82.3	127.4	209.7
119	2959	58	52.2	4.66	134.486	0.0000	0.0	100.0	0.0115	48.7	51.3	0.0193	81.8	18.2	0.0229	97.0	3.0	0.0236	57.1	131.7	188.8
120	2959	58	56.8	4.78	134.109	0.0208	10.9	89.1	0.1426	74.5	25.5	0.1811	94.6	5.4	0.1909	99.7	0.3	0.1914	324.7	110.2	434.9

DATE: 09-JUN-98
STREAM: MISSISSIPPI RIVER
LOCATION: UNION POINT
GAGE: UNION POINT
DISCHARGE: 735,773 CFS (ADCP)

RIVER CONDITION: CHOPPY
TIME: 09:50 TO 10:50
TEMP: 26 C @10 FT.
WEATHER: CLEAR AND HOT
GAGE READING: 42.30 FT.

TYPE SAMPLER: P-63
TYPE SAMPLES: SUSP.
NO. VERTICALS: 4
NO. POINTS: 6

CONVENTIONAL METHOD: DID NOT DO

						Suspende Sediment Grain Size Analysis													Sediment		
						Sand Sieve Analysis (Cumulative Weight Retained)													Concentration (ppm)		
Field No.	Distance from the Reference Point (ft)	Station Depth h (ft)	Sampling Depth h - z (ft)	Samp. Velocity V (ft/s)	Flow Direction φ (Deg.)	U.S. 40 (0.425 mm) Wt. (g)	U.S. 40 % Ret.	U.S. 40 % Finer	U.S. 60 (0.250 mm) Wt. (g)	U.S. 60 % Ret.	U.S. 60 % Finer	U.S. 120 (0.125 mm) Wt. (g)	U.S. 120 % Ret.	U.S. 120 % Finer	U.S. 230 (0.062 mm) Wt. (g)	U.S. 230 % Ret.	U.S. 230 % Finer	Pan	Sand	Fine	Total
121	1047	57	5.7	4.15	115.085	0.0000	0.0	100.0	0.0000	0.0	100.0	0.0035	40.2	59.8	0.0080	92.0	8.0	0.0087	13.4	223.0	236.4
122	1047	57	17.1	3.19	126.764	0.0000	0.0	100.0	0.0005	8.9	91.1	0.0029	51.8	48.2	0.0056	100.0	0.0	0.0056	18.9	296.7	315.6
123	1047	57	28.5	3.71	109.862	0.0000	0.0	100.0	0.0000	0.0	100.0	0.0015	27.8	72.2	0.0054	100.0	0.0	0.0054	9.8	246.3	256.1
124	1047	57	39.9	3.25	116.849	0.0000	0.0	100.0	0.0000	0.0	100.0	0.0029	31.2	68.8	0.0090	96.8	3.2	0.0093	14.6	238.3	252.9
125	1047	57	51.3	2.53	115.601	0.0002	1.5	98.5	0.0008	6.2	93.8	0.0082	63.1	36.9	0.0122	93.8	6.2	0.0130	36.1	295.0	331.1
126	1047	57	55.9	1.04	136.018	0.0009	5.7	94.3	0.0010	6.4	93.6	0.0106	67.5	32.5	0.0157	100.0	0.0	0.0157	64.9	333.2	398.1
127	1613	60	6.0	5.89	119.963	0.0000	0.0	100.0	0.0009	4.1	95.9	0.0143	65.9	34.1	0.0213	98.2	1.8	0.0217	28.0	216.5	244.5
128	1613	60	18.0	5.30	113.516	0.0000	0.0	100.0	0.0004	2.3	97.7	0.0101	58.7	41.3	0.0171	99.4	0.6	0.0172	24.0	201.6	225.6
129	1613	60	30.0	5.27	120.382	0.0006	1.4	98.6	0.0023	5.4	94.6	0.0322	75.6	24.4	0.0415	97.4	2.6	0.0426	77.1	240.3	317.4
130	1613	60	42.0	4.86	119.092	0.0000	0.0	100.0	0.0026	5.0	95.0	0.0442	84.7	15.3	0.0520	99.6	0.4	0.0522	114.1	257.3	371.4
131	1613	60	54.0	3.56	124.745	0.0002	0.5	99.5	0.0019	5.1	94.9	0.0282	75.6	24.4	0.0366	98.1	1.9	0.0373	68.6	246.4	315.0
132	1613	60	58.8	2.39	132.718	0.0009	0.9	99.1	0.0044	4.6	95.4	0.0824	86.9	13.1	0.0943	99.5	0.5	0.0948	153.4	252.1	405.5
133	2235	63	6.3	6.30	129.439	0.0000	0.0	100.0	0.0000	0.0	100.0	0.0010	33.3	66.7	0.0026	86.7	13.3	0.0030	5.1	226.3	231.4
134	2235	63	18.9	6.00	135.421	0.0000	0.0	100.0	0.0005	6.3	93.8	0.0034	42.5	57.5	0.0075	93.8	6.3	0.0080	12.6	227.5	240.1
135	2235	63	31.5	5.52	134.157	0.0000	0.0	100.0	0.0009	12.0	88.0	0.0050	66.7	33.3	0.0073	97.3	2.7	0.0075	19.3	252.0	271.3
136	2235	63	44.1	5.57	122.885	0.0008	0.9	99.1	0.0306	32.6	67.4	0.0842	89.8	10.2	0.0936	99.8	0.2	0.0938	156.6	232.2	388.8
137	2235	63	56.7	4.07	129.729	0.0000	0.0	100.0	0.0267	36.6	63.4	0.0669	91.6	8.4	0.0728	99.7	0.3	0.0730	121.0	224.1	345.1
138	2235	63	61.7	3.55	140.968	0.0150	3.8	96.2	0.2100	53.9	46.1	0.3852	98.8	1.2	0.3896	99.9	0.1	0.3898	958.4	245.5	1203.9
139	2923	46	4.6	4.70	140.053	0.0005	1.8	98.2	0.0139	48.9	51.1	0.0260	91.5	8.5	0.0280	98.6	1.4	0.0284	91.7	270.6	362.3
140	2923	46	13.8	5.04	142.272	0.0000	0.0	100.0	0.0009	19.6	80.4	0.0026	56.5	43.5	0.0043	93.5	6.5	0.0046	9.5	242.6	252.1
141	2923	46	23.0	4.89	145.222	0.0000	0.0	100.0	0.0011	9.4	90.6	0.0060	51.3	48.7	0.0115	98.3	1.7	0.0117	21.8	233.4	255.2
142	2923	46	32.2	4.32	134.846	0.0000	0.0	100.0	0.0007	6.2	93.8	0.0050	44.2	55.8	0.0111	98.2	1.8	0.0113	21.2	239.8	261.0
143	2923	46	41.4	3.91	142.496	0.0000	0.0	100.0	0.0042	34.1	65.9	0.0081	65.9	34.1	0.0123	100.0	0.0	0.0123	33.6	275.1	308.7
144	2923	46	45.1	3.11	141.878	0.0012	3.9	96.1	0.0143	47.0	53.0	0.0227	74.7	25.3	0.0299	98.4	1.6	0.0304	55.4	239.1	294.5

Table B.1 (continued)

DATE: 03-AUG-98	RIVER CONDITION: CHOPPY	TYPE SAMPLER: P-63
STREAM: MISSISSIPPI RIVER	TIME: 09:30 TO 10:30	TYPE SAMPLES: SUSP.
LOCATION: UNION POINT	TEMP: 31 C @10 FT.	NO. VERTICALS: 4
GAGE: UNION POINT	WEATHER: CLOUDY	NO. POINTS: 6
DISCHARGE: 571,934 CFS (ADCP)	GAGE READING: 35.3 FT.	

CONVENTIONAL METHOD: DID NOT DO

						Suspende Sediment Grain Size Analysis													Sediment Concentration (ppm)		
						Sand Sieve Analysis (Cumulative Weight Retained)															
Field	Distance from the Reference	Station Depth	Sampling Depth	Samp. Velocity	Flow Direction	U.S. 40 (0.425 mm)			U.S. 60 (0.250 mm)			U.S. 120 (0.125 mm)			U.S. 230 (0.062 mm)						
No.	Point (ft)	h (ft)	h - z (ft)	V (ft/s)	ϕ (Deg.)	Wt. (g)	% Ret.	% Finer	Wt. (g)	% Ret.	% Finer	Wt. (g)	% Ret.	% Finer	Wt. (g)	% Ret.	% Finer	Pan	Sand	Fine	Total
145	1030	47	4.7	4.40	117.424	0.0000	0.0	100.0	0.0006	15.4	84.6	0.0029	74.4	25.6	0.0039	100.0	0.0	0.0039	10.7	215.5	226.2
146	1030	47	14.1	4.52	120.885	0.0000	0.0	100.0	0.0003	3.8	96.2	0.0039	49.4	50.6	0.0079	100.0	0.0	0.0079	13.5	193.2	206.7
147	1030	47	23.5	3.39	111.873	0.0000	0.0	100.0	0.0005	6.4	93.6	0.0036	46.2	53.8	0.0078	100.0	0.0	0.0078	17.0	202.9	219.9
148	1030	47	32.9	3.58	126.155	0.0000	0.0	100.0	0.0007	4.1	95.9	0.0098	57.6	42.4	0.0170	100.0	0.0	0.0170	30.4	188.8	219.2
149	1030	47	42.3	2.46	117.694	0.0009	1.4	98.6	0.0024	3.7	96.3	0.0503	77.1	22.9	0.0652	100.0	0.0	0.0652	105.9	189.1	295.0
150	1030	47	46.1	1.20	154.489	0.0011	1.1	98.9	0.0035	3.5	96.5	0.0835	84.3	15.7	0.0989	99.8	0.2	0.0991	197.0	198.2	395.2
151	1625	50	5.0	6.03	126.433	0.0000	0.0	100.0	0.0004	2.8	97.2	0.0088	62.4	37.6	0.0141	100.0	0.0	0.0141	19.0	183.6	202.6
152	1625	50	15.0	5.48	125.031	0.0006	2.7	97.3	0.0017	7.7	92.3	0.0155	70.1	29.9	0.0214	96.8	3.2	0.0221	30.4	186.5	216.9
153	1625	50	25.0	5.75	127.634	0.0000	0.0	100.0	0.0013	6.7	93.3	0.0144	74.2	25.8	0.0192	99.0	1.0	0.0194	30.7	182.6	213.3
154	1625	50	35.0	5.11	122.434	0.0007	1.0	99.0	0.0097	13.8	86.2	0.0614	87.5	12.5	0.0700	99.7	0.3	0.0702	102.9	179.8	282.7
155	1625	50	45.0	4.66	125.716	0.0000	0.0	100.0	0.0045	12.2	87.8	0.0331	89.9	10.1	0.0367	99.7	0.3	0.0368	123.2	224.5	347.7
156	1625	50	49.0	2.29	122.893	0.0012	0.6	99.4	0.0296	13.8	86.2	0.1999	93.3	6.7	0.2134	99.6	0.4	0.2142	363.4	207.6	571.0
157	2229	50	5.0	6.12	123.307	0.0000	0.0	100.0	0.0009	11.8	88.2	0.0047	61.8	38.2	0.0073	96.1	3.9	0.0076	12.6	171.5	184.1
158	2229	50	15.0	5.95	119.913	0.0000	0.0	100.0	0.0017	29.3	70.7	0.0034	58.6	41.4	0.0057	98.3	1.7	0.0058	13.9	221.1	235.0
159	2229	50	25.0	5.31	123.798	0.0000	0.0	100.0	0.0032	33.0	67.0	0.0065	67.0	33.0	0.0095	97.9	2.1	0.0097	14.8	185.4	200.2
160	2229	50	35.0	5.68	124.938	0.0000	0.0	100.0	0.0076	36.2	63.8	0.0162	77.1	22.9	0.0206	98.1	1.9	0.0210	35.7	200.0	235.7
161	2229	50	45.0	4.81	120.448	0.0033	3.7	96.3	0.0637	71.7	28.3	0.0832	93.7	6.3	0.0886	99.8	0.2	0.0888	149.1	178.6	327.7
162	2229	50	49.0	2.47	79.212	0.0037	3.2	96.8	0.0813	70.0	30.0	0.1084	93.4	6.6	0.1154	99.4	0.6	0.1161	175.5	188.5	364.0
163	2901	41	4.1	4.54	129.488	0.0000	0.0	100.0	0.0009	33.3	66.7	0.0014	51.9	48.1	0.0027	100.0	0.0	0.0027	4.4	185.4	189.8
164	2901	41	12.3	4.55	134.679	0.0000	0.0	100.0	0.0004	10.5	89.5	0.0014	36.8	63.2	0.0035	92.1	7.9	0.0038	5.9	184.0	189.9
165	2901	41	20.5	4.27	137.928	0.0000	0.0	100.0	0.0006	9.7	90.3	0.0019	30.6	69.4	0.0060	96.8	3.2	0.0062	9.0	183.8	192.8
166	2901	41	28.7	4.28	135.404	0.0003	4.5	95.5	0.0005	7.6	92.4	0.0019	28.8	71.2	0.0063	95.5	4.5	0.0066	9.4	178.4	187.8
167	2901	41	36.9	2.69	139.835	0.0000	0.0	100.0	0.0010	21.3	78.7	0.0021	44.7	55.3	0.0044	93.6	6.4	0.0047	7.5	182.0	189.5
168	2901	41	40.2	2.39	159.426	0.0024	15.1	84.9	0.0063	39.6	60.4	0.0105	66.0	34.0	0.0155	97.5	2.5	0.0159	42.9	226.1	269.0

Table B.2. Suspended sediment data at Line 13.

DATE: 27-FEB-98	RIVER CONDITION: GOOD	TYPE SAMPLER: P-63
STREAM: MISSISSIPPI RIVER	TIME: 09:30 TO 10:30	TYPE SAMPLES: SUSP.
LOCATION: LINE #13 D/S OF HYDRO INTAKE CH.	TEMP: 9 C @10 FT.	NO. VERTICALS: 4
GAGE: KNOX LANDING	WEATHER: CLOUDY AND MILD	NO. POINTS: 6
DISCHARGE: 857,119 CFS (ADCP)	GAGE READING: 48.60 FT.	

						Suspended Sediment Grain Size Analysis													Sediment		
	Distance from	Station	Sampling	Samp.	Flow	Sand Sieve Analysis (Cumulative Weight Retained)													Concentration		
Field	the Reference	Depth	Depth	Velocity	Direction	U.S. 40 (0.425 mm)			U.S. 60 (0.250 mm)			U.S. 120 (0.125 mm)			U.S. 230 (0.062 mm)				(ppm)		
No.	Point (ft)	h (ft)	h - z (ft)	V (ft/s)	ϕ (Deg.)	Wt. (g)	% Ret.	% Finer	Wt. (g)	% Ret.	% Finer	Wt. (g)	% Ret.	% Finer	Wt. (g)	% Ret.	% Finer	Pan	Sand	Fine	Total
1	1793	107	10.0	7.19	129.983	0.0009	4.7	95.3	0.0019	10.0	90.0	0.0112	58.9	41.1	0.0177	93.2	6.8	0.0190	42.3	211.1	253.4
2	1793	107	30.0	6.88	130.456	0.0011	3.5	96.5	0.0023	7.3	92.7	0.0207	66.1	33.9	0.0305	97.4	2.6	0.0313	58.4	199.4	257.8
3	1793	107	50.0	7.75	139.828	0.0005	1.9	98.1	0.0014	5.2	94.8	0.0164	61.4	38.6	0.0254	95.1	4.9	0.0267	55.7	206.4	262.1
4	1793	107	70.0	7.20	138.046	0.0007	2.0	98.0	0.0010	2.8	97.2	0.0203	56.9	43.1	0.0334	93.6	6.4	0.0357	47.4	185.5	232.9
5	1793	107	90.0	6.28	139.665	0.0095	10.2	89.8	0.0250	26.9	73.1	0.0766	82.4	17.6	0.0914	98.3	1.7	0.0930	154.4	194.3	348.7
6	1793	107	98.0	6.09	141.258	0.0040	5.7	94.3	0.0115	16.5	83.5	0.0505	72.5	27.5	0.0678	97.3	2.7	0.0697	92.0	185.7	277.7
7	2115	97	9.7	8.95	133.277	0.0006	5.2	94.8	0.0014	12.2	87.8	0.0084	73.0	27.0	0.0109	94.8	5.2	0.0115	20.5	199.3	219.8
8	2115	97	29.1	9.21	136.140	0.0010	3.2	96.8	0.0021	6.8	93.2	0.0201	64.6	35.4	0.0304	97.7	2.3	0.0311	43.8	178.1	221.9
9	2115	97	48.5	9.09	131.941	0.0012	3.1	96.9	0.0040	10.5	89.5	0.0292	76.4	23.6	0.0376	98.4	1.6	0.0382	122.0	243.3	365.3
10	2115	97	67.9	8.26	128.987	0.0013	3.4	96.6	0.0042	10.9	89.1	0.0299	77.9	22.1	0.0375	97.7	2.3	0.0384	103.4	232.9	336.3
11	2115	97	87.3	5.78	133.482	0.0010	2.7	97.3	0.0040	10.7	89.3	0.0289	77.1	22.9	0.0369	98.4	1.6	0.0375	107.6	205.0	312.6
12	2115	97	95.1	3.10	132.596	0.0058	8.4	91.6	0.0222	32.3	67.7	0.0580	84.3	15.7	0.0673	97.8	2.2	0.0688	213.1	240.0	453.1
13	2449	89	8.9	7.52	132.329	0.0014	10.1	89.9	0.0028	20.3	79.7	0.0085	61.6	38.4	0.0124	89.9	10.1	0.0138	24.5	199.0	223.5
14	2449	89	26.7	8.02	133.275	0.0010	2.7	97.3	0.0042	11.4	88.6	0.0285	77.7	22.3	0.0359	97.8	2.2	0.0367	49.1	188.1	237.2
15	2449	89	44.5	8.67	135.031	0.0000	0.0	100.0	0.0012	2.6	97.4	0.0307	66.2	33.8	0.0442	95.3	4.7	0.0464	84.5	204.9	289.4
16	2449	89	62.3	7.55	133.891	0.0012	0.6	99.4	0.0062	3.3	96.7	0.1618	85.5	14.5	0.1876	99.1	0.9	0.1893	265.6	187.5	453.1
17	2449	89	80.1	6.08	137.626	0.0017	1.0	99.0	0.0086	5.2	94.8	0.1448	87.7	12.3	0.1644	99.6	0.4	0.1651	569.3	256.2	825.5
18	2449	89	87.2	3.72	146.660	0.0006	0.3	99.7	0.0149	6.5	93.5	0.2011	87.2	12.8	0.2288	99.2	0.8	0.2306	557.2	218.2	775.4
19	2916	70	7.0	5.19	129.643	0.0012	8.8	91.2	0.0029	21.2	78.8	0.0082	59.9	40.1	0.0125	91.2	8.8	0.0137	26.9	209.1	236.0
20	2916	70	21.0	5.21	128.429	0.0007	2.2	97.8	0.0029	8.9	91.1	0.0197	60.6	39.4	0.0309	95.1	4.9	0.0325	54.3	187.2	241.5
21	2916	70	35.0	4.79	127.459	0.0008	1.5	98.5	0.0014	2.6	97.4	0.0381	70.9	29.1	0.0528	98.3	1.7	0.0537	115.5	225.1	340.6
22	2916	70	49.0	4.67	137.905	0.0008	1.5	98.5	0.0015	2.7	97.3	0.0387	70.6	29.4	0.0539	98.4	1.6	0.0548	303.8	308.3	612.1
23	2916	70	63.0	3.66	129.076	0.0008	0.9	99.1	0.0025	2.8	97.2	0.0632	70.7	29.3	0.0879	98.3	1.7	0.0894	199.2	215.3	414.5
24	2916	70	68.6	2.81	140.400	0.0011	2.3	97.7	0.0019	4.0	96.0	0.0315	66.9	33.1	0.0449	95.3	4.7	0.0471	164.8	262.8	427.6

DATE: 23-MAR-98	RIVER CONDITION: CHOPPY	TYPE SAMPLER: P-63
STREAM: MISSISSIPPI RIVER	TIME: 12:30 TO 14:15	TYPE SAMPLES: SUSP.
LOCATION: LINE #13 D/S OF HYDRO INTAKE CH.	TEMP: 9 ^{0}C @10 FT.	NO. VERTICALS: 4
GAGE: KNOX LANDING	WEATHER: WINDY AND MILD	NO. POINTS: 6
DISCHARGE: 855,124 CFS (ADCP)	GAGE READING: 50.60 FT.	

						Suspende Sediment Grain Size Analysis													Sediment		
	Distance from	Station	Sampling	Samp.	Flow	Sand Sieve Analysis (Cumulative Weight Retained)													Concentration		
Field	the Reference	Depth	Depth	Velocity	Direction	U.S. 40 (0.425 mm)			U.S. 60 (0.250 mm)			U.S. 120 (0.125 mm)			U.S. 230 (0.062 mm)				(ppm)		
No.	Point (ft)	h (ft)	h - z (ft)	V (ft/s)	ϕ (Deg.)	Wt. (g)	% Ret.	% Finer	Wt. (g)	% Ret.	% Finer	Wt. (g)	% Ret.	% Finer	Wt. (g)	% Ret.	% Finer	Pan	Sand	Fine	Total
25	1785	107	10.7	6.56	133.844	0.0004	2.2	97.8	0.0014	7.7	92.3	0.0109	59.9	40.1	0.0167	91.8	8.2	0.0182	31.0	224.0	255.0
26	1785	107	32.1	6.90	133.902	0.0007	3.0	97.0	0.0012	5.2	94.8	0.0158	68.4	31.6	0.0221	95.7	4.3	0.0231	42.2	233.5	275.7
27	1785	107	53.5	8.29	141.170	0.0007	1.9	98.1	0.0021	5.8	94.2	0.0264	72.9	27.1	0.0345	95.3	4.7	0.0362	62.7	243.6	306.3
28	1785	107	74.9	7.19	133.243	0.0005	1.3	98.7	0.0027	7.0	93.0	0.0282	72.9	27.1	0.0366	94.6	5.4	0.0387	59.2	227.6	286.8
29	1785	107	96.3	6.58	139.730	0.0016	4.2	95.8	0.0074	19.3	80.7	0.0298	77.6	22.4	0.0373	97.1	2.9	0.0384	79.4	240.6	320.0
30	1785	107	104.9	5.74	129.202	0.0008	2.0	98.0	0.0037	9.0	91.0	0.0301	73.6	26.4	0.0387	94.6	5.4	0.0409	87.7	254.1	341.8
31	2068	95	9.5	7.99	135.932	0.0006	1.2	98.8	0.0037	7.7	92.3	0.0374	77.6	22.4	0.0463	96.1	3.9	0.0482	67.7	225.4	293.1
32	2068	95	28.5	7.07	137.481	0.0005	1.6	98.4	0.0030	9.6	90.4	0.0220	70.1	29.9	0.0298	94.9	5.1	0.0314	53.4	237.2	290.6
33	2068	95	47.5	6.75	137.897	0.0006	0.9	99.1	0.0068	10.1	89.9	0.0565	84.2	15.8	0.0659	98.2	1.8	0.0671	133.9	241.7	375.6
34	2068	95	66.5	5.24	129.668	0.0076	3.0	97.0	0.0205	8.2	91.8	0.2331	93.2	6.8	0.2491	99.6	0.4	0.2502	334.1	217.6	551.7
35	2068	95	85.5	5.43	134.045	0.0005	1.4	98.6	0.0020	5.6	94.4	0.0260	72.2	27.8	0.0341	94.7	5.3	0.0360	103.4	279.3	382.7
36	2068	95	93.1	4.38	144.288	0.0007	1.4	98.6	0.0038	7.6	92.4	0.0380	76.5	23.5	0.0471	94.8	5.2	0.0497	85.7	240.1	325.8
37	2459	87	8.7	8.89	136.017	0.0003	3.3	96.7	0.0006	6.6	93.4	0.0056	61.5	38.5	0.0080	87.9	12.1	0.0091	19.7	251.9	271.6
38	2459	87	26.1	8.62	132.454	0.0008	3.3	96.7	0.0019	7.8	92.2	0.0178	73.3	26.7	0.0232	95.5	4.5	0.0243	59.8	262.3	322.1
39	2459	87	43.5	8.08	129.317	0.0005	3.3	96.7	0.0009	6.0	94.0	0.0075	49.7	50.3	0.0138	91.4	8.6	0.0151	24.1	234.8	258.9
40	2459	87	60.9	7.90	128.017	0.0000	0.0	100.0	0.0004	1.8	98.2	0.0137	60.9	39.1	0.0217	96.4	3.6	0.0225	41.1	233.8	274.9
41	2459	87	78.3	6.87	131.456	0.0009	0.6	99.4	0.0039	2.7	97.3	0.1248	86.5	13.5	0.1425	98.8	1.2	0.1442	260.8	233.5	494.3
42	2459	87	85.3	6.27	137.013	0.0010	1.0	99.0	0.0023	2.2	97.8	0.0908	87.5	12.5	0.1027	98.9	1.1	0.1038	365.0	302.1	667.1
43	2890	75	7.5	5.57	129.719	0.0007	4.5	95.5	0.0014	9.1	90.9	0.0077	50.0	50.0	0.0144	93.5	6.5	0.0154	34.0	251.0	285.0
44	2890	75	22.5	5.45	130.897	0.0005	3.5	96.5	0.0010	7.1	92.9	0.0082	58.2	41.8	0.0131	92.9	7.1	0.0141	32.5	255.0	287.5
45	2890	75	37.5	5.02	130.151	0.0008	3.3	96.7	0.0020	8.1	91.9	0.0181	73.6	26.4	0.0235	95.5	4.5	0.0246	59.2	256.9	316.1
46	2890	75	52.5	4.28	132.359	0.0007	1.0	99.0	0.0023	3.2	96.8	0.0547	76.9	23.1	0.0692	97.3	2.7	0.0711	145.1	256.5	401.6
47	2890	75	67.5	4.26	134.190	0.0007	1.0	99.0	0.0024	3.4	96.6	0.0558	78.0	22.0	0.0703	98.3	1.7	0.0715	175.6	231.5	407.1
48	2890	75	73.5	1.83	133.837	0.0016	1.4	98.6	0.0058	5.1	94.9	0.0975	85.2	14.8	0.1135	99.2	0.8	0.1144	352.0	287.2	639.2

DATE: 10-APR-98	RIVER CONDITION: GOOD	TYPE SAMPLER: P-63
STREAM: MISSISSIPPI RIVER	TIME: 13:15 TO 14:15	TYPE SAMPLES: SUSP.
LOCATION: LINE #13 D/S OF HYDRO INTAKE CH.	TEMP: 16 C @1.5 FT.	NO. VERTICALS: 4
GAGE: KNOX LANDING	WEATHER: CLEAR AND WARM	NO. POINTS: 6
DISCHARGE: 910,249 CFS (ADCP)	GAGE READING: 52.35 FT.	

						Suspende Sediment Grain Size Analysis													Sediment		
	Distance from	Station	Sampling	Samp.	Flow	Sand Sieve Analysis (Cumulative Weight Retained)													Concentration		
Field	the Reference	Depth	Depth	Velocity	Direction	U.S. 40 (0.425 mm)			U.S. 60 (0.250 mm)			U.S. 120 (0.125 mm)			U.S. 230 (0.062 mm)				(ppm)		
No.	Point (ft)	h (ft)	h - z (ft)	V (ft/s)	ϕ (Deg.)	Wt. (g)	% Ret.	% Finer	Wt. (g)	% Ret.	% Finer	Wt. (g)	% Ret.	% Finer	Wt. (g)	% Ret.	% Finer	Pan	Sand	Fine	Total
49	1801	110	7.8	9.24	130.076	0.0000	0.0	100.0	0.0003	1.8	98.2	0.0099	60.7	39.3	0.0157	96.3	3.7	0.0163	28.2	147.1	175.3
50	1801	110	23.4	8.95	130.553	0.0000	0.0	100.0	0.0015	6.1	93.9	0.0167	67.6	32.4	0.0242	98.0	2.0	0.0247	38.2	132.3	170.5
51	1801	110	39.0	9.12	133.353	0.0000	0.0	100.0	0.0015	6.9	93.1	0.0128	59.3	40.7	0.0212	98.1	1.9	0.0216	29.9	119.8	149.7
52	1801	110	54.6	8.31	133.512	0.0000	0.0	100.0	0.0019	14.1	85.9	0.0083	61.5	38.5	0.0132	97.8	2.2	0.0135	23.4	155.6	179.0
53	1801	110	70.2	8.92	133.689	0.0000	0.0	100.0	0.0003	2.5	97.5	0.0069	57.0	43.0	0.0120	99.2	0.8	0.0121	26.0	148.6	174.6
54	1801	110	76.4	8.13	132.398	0.0000	0.0	100.0	0.0016	4.2	95.8	0.0253	66.2	33.8	0.0379	99.2	0.8	0.0382	50.1	155.5	205.6
55	2072	100	10.0	10.03	131.472	0.0000	0.0	100.0	0.0000	0.0	100.0	0.0099	54.1	45.9	0.0179	97.8	2.2	0.0183	25.4	130.0	155.4
56	2072	100	30.0	8.95	131.150	0.0000	0.0	100.0	0.0013	5.7	94.3	0.0146	64.0	36.0	0.0226	99.1	0.9	0.0228	33.0	153.5	186.5
57	2072	100	50.0	8.74	132.946	0.0006	5.0	95.0	0.0025	20.8	79.2	0.0099	82.5	17.5	0.0119	99.2	0.8	0.0120	20.6	189.6	210.2
58	2072	100	70.0	6.97	132.368	0.0003	0.8	99.2	0.0034	9.2	90.8	0.0284	76.8	23.2	0.0367	99.2	0.8	0.0370	52.1	141.3	193.4
59	2072	100	90.0	6.73	123.752	0.0041	2.7	97.3	0.0460	30.4	69.6	0.1359	89.8	10.2	0.1510	99.8	0.2	0.1513	198.2	112.4	310.6
60	2072	100	98.0	5.84	119.242	0.0026	2.1	97.9	0.0158	12.7	87.3	0.1021	81.9	18.1	0.1239	99.4	0.6	0.1246	166.0	143.3	309.3
61	2433	92	9.2	7.00	133.727	0.0000	0.0	100.0	0.0000	0.0	100.0	0.0013	25.5	74.5	0.0048	94.1	5.9	0.0051	9.5	133.8	143.3
62	2433	92	27.6	7.29	134.161	0.0000	0.0	100.0	0.0006	7.7	92.3	0.0028	35.9	64.1	0.0075	96.2	3.8	0.0078	11.2	140.7	151.9
63	2433	92	46.0	7.26	131.739	0.0000	0.0	100.0	0.0006	2.2	97.8	0.0145	54.1	45.9	0.0265	98.9	1.1	0.0268	37.5	155.4	192.9
64	2433	92	64.4	7.69	137.991	0.0016	1.4	98.6	0.0099	8.4	91.6	0.1007	85.6	14.4	0.1172	99.6	0.4	0.1177	155.3	148.9	304.2
65	2433	92	82.8	7.28	142.401	0.0006	0.4	99.6	0.0093	6.6	93.4	0.1220	86.1	13.9	0.1412	99.6	0.4	0.1417	193.9	152.0	345.9
66	2433	92	90.2	4.80	156.961	0.0010	0.7	99.3	0.0071	5.2	94.8	0.1163	85.1	14.9	0.1360	99.5	0.5	0.1367	181.0	129.4	310.4
67	2869	76	7.6	3.30	139.355	0.0000	0.0	100.0	0.0000	0.0	100.0	0.0036	42.9	57.1	0.0082	97.6	2.4	0.0084	16.7	172.8	189.5
68	2869	76	22.8	3.43	134.690	0.0000	0.0	100.0	0.0003	2.4	97.6	0.0047	37.3	62.7	0.0119	94.4	5.6	0.0126	16.1	150.3	166.4
69	2869	76	38.0	2.95	145.071	0.0000	0.0	100.0	0.0006	1.6	98.4	0.0245	66.8	33.2	0.0367	100.0	0.0	0.0367	50.2	152.0	202.2
70	2869	76	53.2	3.12	129.328	0.0009	1.0	99.0	0.0040	4.5	95.5	0.0692	77.2	22.8	0.0886	98.9	1.1	0.0896	116.4	131.5	247.9
71	2869	76	68.4	2.82	151.081	0.0007	0.5	99.5	0.0036	2.7	97.3	0.1092	83.1	16.9	0.1310	99.7	0.3	0.1314	175.1	117.6	292.7
72	2869	76	74.5	2.81	139.697	0.0011	0.5	99.5	0.0106	4.6	95.4	0.2004	87.6	12.4	0.2279	99.6	0.4	0.2288	319.5	159.8	479.3

Table B.2 (continued)

DATE: 17-APR-98	RIVER CONDITION: GOOD	TYPE SAMPLER: P-63
STREAM: MISSISSIPPI RIVER	TIME: 11:00 TO 12:15	TYPE SAMPLES: SUSP.
LOCATION: LINE #13 D/S OF HYDRO INTAKE CH.	TEMP: 16 C @1.5 FT.	NO. VERTICALS: 4
GAGE: KNOX LANDING	WEATHER: CLOUDY AND RAIN	NO. POINTS: 6
DISCHARGE: 898,752 CFS (ADCP)	GAGE READING: 50.50 FT.	

Field No.	Distance from the Reference Point (ft)	Station Depth h (ft)	Sampling Depth h - z (ft)	Samp. Velocity V (ft/s)	Flow Direction φ (Deg.)	Suspende Sediment Grain Size Analysis, Sand Sieve Analysis (Cumulative Weight Retained), U.S. 40 (0.425 mm) Wt. (g)	% Ret.	% Finer	U.S. 60 (0.250 mm) Wt. (g)	% Ret.	% Finer	U.S. 120 (0.125 mm) Wt. (g)	% Ret.	% Finer	U.S. 230 (0.062 mm) Wt. (g)	% Ret.	% Finer	Pan	Sediment Concentration (ppm) Sand	Fine	Total
73	1786	110	10.4	6.24	145.240	0.0000	0.0	100.0	0.0010	7.0	93.0	0.0095	66.4	33.6	0.0138	96.5	3.5	0.0143	25.1	269.6	294.7
74	1786	110	31.2	5.16	140.913	0.0014	5.2	94.8	0.0031	11.5	88.5	0.0203	75.2	24.8	0.0266	98.5	1.5	0.0270	46.2	266.2	312.4
75	1786	110	52.0	4.44	134.791	0.0003	1.8	98.2	0.0009	5.5	94.5	0.0106	64.6	35.4	0.0161	98.2	1.8	0.0164	33.3	288.2	321.5
76	1786	110	72.8	3.92	124.541	0.0000	0.0	100.0	0.0022	11.4	88.6	0.0138	71.5	28.5	0.0191	99.0	1.0	0.0193	51.3	303.6	354.9
77	1786	110	93.6	5.13	146.787	0.0014	4.2	95.8	0.0038	11.4	88.6	0.0257	76.9	23.1	0.0332	99.4	0.6	0.0334	57.8	267.2	325.0
78	1786	110	101.9	4.00	139.500	0.0000	0.0	100.0	0.0053	11.2	88.8	0.0381	80.2	19.8	0.0472	99.4	0.6	0.0475	83.6	275.3	358.9
79	2098	105	8.9	9.73	136.257	0.0006	2.1	97.9	0.0023	7.9	92.1	0.0207	71.4	28.6	0.0284	97.9	2.1	0.0290	44.3	260.9	305.2
80	2098	105	26.7	9.80	136.873	0.0000	0.0	100.0	0.0034	7.8	92.2	0.0349	80.4	19.6	0.0430	99.1	0.9	0.0434	66.1	264.0	330.1
81	2098	105	44.5	9.82	135.108	0.0000	0.0	100.0	0.0020	6.2	93.8	0.0258	80.1	19.9	0.0321	99.7	0.3	0.0322	75.8	297.9	373.7
82	2098	105	62.3	8.80	126.985	0.0018	2.7	97.3	0.0107	15.9	84.1	0.0585	87.1	12.9	0.0665	99.0	1.0	0.0672	141.1	256.9	398.0
83	2098	105	80.1	7.80	122.674	0.0005	0.6	99.4	0.0075	9.6	90.4	0.0661	84.6	15.4	0.0776	99.4	0.6	0.0781	125.6	271.0	396.6
84	2098	105	87.2	7.48	121.007	0.0023	1.5	98.5	0.0261	16.5	83.5	0.1449	91.7	8.3	0.1576	99.7	0.3	0.1581	269.2	286.3	555.5
85	2454	91	9.1	7.32	129.651	0.0000	0.0	100.0	0.0012	16.4	83.6	0.0031	42.5	57.5	0.0065	89.0	11.0	0.0073	13.6	271.3	284.9
86	2454	91	27.3	7.32	130.493	0.0010	3.2	96.8	0.0021	6.8	93.2	0.0210	68.0	32.0	0.0254	82.2	17.8	0.0309	51.7	259.5	311.2
87	2454	91	45.5	7.32	125.391	0.0013	3.5	96.5	0.0032	8.5	91.5	0.0224	59.7	40.3	0.0358	95.5	4.5	0.0375	74.7	267.8	342.5
88	2454	91	63.7	7.34	125.564	0.0000	0.0	100.0	0.0019	5.1	94.9	0.0287	77.4	22.6	0.0359	96.8	3.2	0.0371	82.5	287.4	369.9
89	2454	91	81.9	6.85	123.180	0.0006	0.4	99.6	0.0129	8.8	91.2	0.1349	91.6	8.4	0.1471	99.9	0.1	0.1472	368.1	283.0	651.1
90	2454	91	89.2	4.70	126.910	0.0015	0.5	99.5	0.0163	5.9	94.1	0.2448	89.1	10.9	0.2731	99.4	0.6	0.2748	361.1	268.6	629.7
91	2834	77	7.7	5.49	127.809	0.0000	0.0	100.0	0.0000	0.0	100.0	0.0024	45.3	54.7	0.0045	84.9	15.1	0.0053	12.9	293.8	306.7
92	2834	77	23.1	5.74	127.263	0.0000	0.0	100.0	0.0034	11.4	88.6	0.0218	73.4	26.6	0.0293	98.7	1.3	0.0297	54.7	251.6	306.3
93	2834	77	38.5	5.21	121.837	0.0000	0.0	100.0	0.0011	4.1	95.9	0.0197	73.2	26.8	0.0263	97.8	2.2	0.0269	74.0	295.4	369.4
94	2834	77	53.9	5.16	124.529	0.0000	0.0	100.0	0.0022	4.0	96.0	0.0377	68.4	31.6	0.0534	96.9	3.1	0.0551	93.1	275.2	368.3
95	2834	77	69.3	3.88	123.341	0.0000	0.0	100.0	0.0004	3.3	96.7	0.0084	69.4	30.6	0.0113	93.4	6.6	0.0121	43.5	366.1	409.6
96	2834	77	75.5	2.39	108.111	0.0038	3.6	96.4	0.0142	13.6	86.4	0.0890	85.3	14.7	0.1025	98.3	1.7	0.1043	214.0	277.3	491.3

DATE: 08-MAY-98	RIVER CONDITION: GOOD	TYPE SAMPLER: P-63
STREAM: MISSISSIPPI RIVER	TIME: 10:45 TO 12:30	TYPE SAMPLES: SUSP.
LOCATION: LINE #13 D/S OF HYDRO INTAKE CH.	TEMP: 19 C @10 FT.	NO. VERTICALS: 4
GAGE: KNOX LANDING	WEATHER: CLEAR AND WARM	NO. POINTS: 6
DISCHARGE: 1,120,828 CFS (ADCP)	GAGE READING: 54.25 FT.	

Field No.	Distance from the Reference Point (ft)	Station Depth h (ft)	Sampling Depth h - z (ft)	Samp. Velocity V (ft/s)	Flow Direction φ (Deg.)	Suspende Sediment Grain Size Analysis, Sand Sieve Analysis (Cumulative Weight Retained), U.S. 40 (0.425 mm) Wt. (g)	% Ret.	% Finer	U.S. 60 (0.250 mm) Wt. (g)	% Ret.	% Finer	U.S. 120 (0.125 mm) Wt. (g)	% Ret.	% Finer	U.S. 230 (0.062 mm) Wt. (g)	% Ret.	% Finer	Pan	Sediment Concentration (ppm) Sand	Fine	Total
97	1787	114	11.4	9.21	129.087	0.0000	0.0	100.0	0.0005	3.0	97.0	0.0112	67.1	32.9	0.0161	96.4	3.6	0.0167	27.4	111.3	138.7
98	1787	114	34.2	9.67	130.199	0.0000	0.0	100.0	0.0014	9.3	90.7	0.0102	67.5	32.5	0.0150	99.3	0.7	0.0151	31.8	144.4	176.2
99	1787	114	57.0	9.86	136.902	0.0006	1.9	98.1	0.0021	6.8	93.2	0.0216	70.1	29.9	0.0306	99.4	0.6	0.0308	44.6	108.7	153.3
100	1787	114	79.8	10.06	139.972	0.0000	0.0	100.0	0.0231	37.8	62.2	0.0519	84.9	15.1	0.0592	96.9	3.1	0.0611	134.1	124.8	258.9
101	1787	114	102.6	7.81	141.743	0.0000	0.0	100.0	0.0043	10.9	89.1	0.0281	71.3	28.7	0.0392	99.5	0.5	0.0394	64.7	111.3	176.0
102	1787	114	111.7	7.14	147.244	0.0014	1.7	98.3	0.0195	23.5	76.5	0.0714	85.9	14.1	0.0828	99.6	0.4	0.0831	172.3	122.6	294.9
103	2032	102	10.2	11.15	131.205	0.0006	2.1	97.9	0.0029	10.3	89.7	0.0221	78.4	21.6	0.0280	99.3	0.7	0.0282	77.9	133.9	211.8
104	2032	102	30.6	10.78	130.569	0.0000	0.0	100.0	0.0029	8.8	91.2	0.0258	77.9	22.1	0.0326	98.5	1.5	0.0331	63.0	121.8	184.8
105	2032	102	51.0	10.16	124.090	0.0000	0.0	100.0	0.0029	12.8	87.2	0.0163	72.1	27.9	0.0217	96.0	4.0	0.0226	43.1	121.3	164.4
106	2032	102	71.4	8.81	130.535	0.0009	2.2	97.8	0.0087	21.1	78.9	0.0341	82.6	17.4	0.0411	99.5	0.5	0.0413	95.8	128.2	224.0
107	2032	102	91.8	7.82	132.178	0.0026	3.0	97.0	0.0254	28.9	71.1	0.0783	89.1	10.9	0.0866	98.5	1.5	0.0879	204.5	132.3	336.8
108	2032	102	100.0	5.70	136.562	0.0003	0.5	99.5	0.0060	9.5	90.5	0.0521	82.3	17.7	0.0631	99.7	0.3	0.0633	143.5	126.4	269.9
109	2456	87	8.7	8.73	138.320	0.0000	0.0	100.0	0.0008	3.1	96.9	0.0172	66.2	33.8	0.0257	98.8	1.2	0.0260	42.1	119.5	161.6
110	2456	87	26.1	8.50	133.264	0.0000	0.0	100.0	0.0002	2.9	97.1	0.0023	33.8	66.2	0.0063	92.6	7.4	0.0068	16.0	136.1	152.1
111	2456	87	43.5	8.74	136.886	0.0000	0.0	100.0	0.0012	4.7	95.3	0.0187	73.0	27.0	0.0256	100.0	0.0	0.0256	62.1	131.2	193.3
112	2456	87	60.9	9.37	140.128	0.0000	0.0	100.0	0.0009	12.5	87.5	0.0026	36.1	63.9	0.0069	95.8	4.2	0.0072	13.6	125.1	138.7
113	2456	87	78.3	9.02	137.358	0.0008	1.1	98.9	0.0038	5.3	94.7	0.0643	88.9	11.1	0.0718	99.3	0.7	0.0723	227.7	153.2	380.9
114	2456	87	85.3	7.61	131.609	0.0010	0.4	99.6	0.0093	3.6	96.4	0.2267	88.9	11.1	0.2481	97.3	2.7	0.2549	427.6	130.8	558.4
115	2855	81	8.1	5.23	149.141	0.0000	0.0	100.0	0.0000	0.0	100.0	0.0054	44.6	55.4	0.0099	81.8	18.2	0.0121	16.1	121.0	137.1
116	2855	81	24.3	5.16	139.047	0.0000	0.0	100.0	0.0000	0.0	100.0	0.0022	52.4	47.6	0.0039	92.9	7.1	0.0042	15.0	183.7	198.7
117	2855	81	40.5	5.80	134.862	0.0000	0.0	100.0	0.0008	4.8	95.2	0.0126	75.9	24.1	0.0164	98.8	1.2	0.0166	57.1	152.1	209.2
118	2855	81	56.7	6.01	133.362	0.0000	0.0	100.0	0.0018	7.4	92.6	0.0150	61.7	38.3	0.0209	86.0	14.0	0.0243	67.7	180.0	247.7
119	2855	81	72.9	5.02	130.813	0.0000	0.0	100.0	0.0011	1.1	98.9	0.0786	81.8	18.2	0.0899	93.5	6.5	0.0961	215.9	145.5	361.4
120	2855	81	79.4	3.31	121.645	0.0006	0.7	99.3	0.0029	3.3	96.7	0.0622	69.7	30.3	0.0872	97.8	2.2	0.0892	160.1	125.8	285.9

DATE: 09-JUN-98	RIVER CONDITION: CHOPPY	TYPE SAMPLER: P-63
STREAM: MISSISSIPPI RIVER	TIME: 12:30 TO 13:35	TYPE SAMPLES: SUSP.
LOCATION: LINE #13 D/S OF HYDRO INTAKE CH.	TEMP: 26 C @10 FT.	NO. VERTICALS: 4
GAGE: KNOX LANDING	WEATHER: CLOUDY AND HOT	NO. POINTS: 6
DISCHARGE: 566,002 CFS (ADCP)	GAGE READING: 40.30 FT.	

Field No.	Distance from the Reference Point (ft)	Station Depth h (ft)	Sampling Depth h - z (ft)	Samp. Velocity V (ft/s)	Flow Direction φ (Deg.)	Suspende Sediment Grain Size Analysis, Sand Sieve Analysis (Cumulative Weight Retained), U.S. 40 (0.425 mm) Wt. (g)	% Ret.	% Finer	U.S. 60 (0.250 mm) Wt. (g)	% Ret.	% Finer	U.S. 120 (0.125 mm) Wt. (g)	% Ret.	% Finer	U.S. 230 (0.062 mm) Wt. (g)	% Ret.	% Finer	Pan	Sediment Concentration (ppm) Sand	Fine	Total
121	1771	99	9.2	4.71	119.210	0.0006	8.2	91.8	0.0019	26.0	74.0	0.0025	34.2	65.8	0.0069	94.5	5.5	0.0073	21.4	253.3	274.7
122	1771	99	27.6	4.78	115.862	0.0000	0.0	100.0	0.0010	11.0	89.0	0.0060	65.9	34.1	0.0088	96.7	3.3	0.0091	13.8	218.0	231.8
123	1771	99	46.0	4.95	133.281	0.0000	0.0	100.0	0.0010	9.9	90.1	0.0060	59.4	40.6	0.0096	95.0	5.0	0.0101	14.9	219.6	234.5
124	1771	99	64.4	5.17	127.343	0.0000	0.0	100.0	0.0009	12.7	87.3	0.0041	57.7	42.3	0.0067	94.4	5.6	0.0071	12.9	227.6	240.5
125	1771	99	82.8	4.08	119.140	0.0000	0.0	100.0	0.0016	9.5	90.5	0.0073	43.2	56.8	0.0164	97.0	3.0	0.0169	29.2	239.0	268.2
126	1771	99	90.2	3.09	114.494	0.0000	0.0	100.0	0.0011	14.5	85.5	0.0053	69.7	30.3	0.0072	94.7	5.3	0.0076	16.4	242.0	258.4
127	2089	94	9.4	5.12	144.253	0.0000	0.0	100.0	0.0006	6.6	93.4	0.0044	48.4	51.6	0.0086	94.5	5.5	0.0091	14.3	223.7	238.0
128	2089	94	28.2	3.68	140.247	0.0000	0.0	100.0	0.0063	25.3	74.7	0.0179	71.9	28.1	0.0244	98.0	2.0	0.0249	41.3	229.1	270.4
129	2089	94	47.0	4.85	137.604	0.0000	0.0	100.0	0.0036	16.1	83.9	0.0146	65.5	34.5	0.0221	99.1	0.9	0.0223	46.1	257.7	303.8
130	2089	94	65.8	4.43	133.831	0.0012	1.3	98.7	0.0333	36.6	63.4	0.0790	86.7	13.3	0.0898	98.6	1.4	0.0911	162.4	252.5	414.9
131	2089	94	84.6	3.40	117.380	0.0042	3.7	96.3	0.0510	44.4	55.6	0.1056	91.9	8.1	0.1146	99.7	0.3	0.1149	254.1	256.5	510.6
132	2089	94	92.1	3.37	130.615	0.0012	1.0	99.0	0.0446	37.4	62.6	0.0953	79.9	20.1	0.1188	99.6	0.4	0.1193	180.5	244.8	425.3
133	2476	81	8.1	7.33	128.824	0.0000	0.0	100.0	0.0015	19.7	80.3	0.0054	71.1	28.9	0.0075	98.7	1.3	0.0076	11.8	205.1	216.9
134	2476	81	24.3	7.31	127.636	0.0005	3.3	96.7	0.0014	9.3	90.7	0.0081	53.6	46.4	0.0120	79.5	20.5	0.0151	18.8	234.2	253.0
135	2476	81	40.5	6.82	128.027	0.0004	1.0	99.0	0.0017	4.4	95.6	0.0272	70.3	29.7	0.0378	97.7	2.3	0.0387	52.9	222.5	275.4
136	2476	81	56.7	6.00	126.444	0.0013	1.9	98.1	0.0065	9.4	90.6	0.0540	78.3	21.7	0.0681	98.7	1.3	0.0690	124.0	261.9	385.9
137	2476	81	72.9	5.65	132.386	0.0013	0.9	99.1	0.0241	16.2	83.8	0.1378	92.5	7.5	0.1483	99.5	0.5	0.1490	373.0	270.1	643.1
138	2476	81	79.4	4.31	139.866	0.0027	0.8	99.2	0.0704	19.6	80.4	0.3343	93.1	6.9	0.3586	99.9	0.1	0.3589	589.6	259.9	849.5
139	2855	69	6.9	4.03	129.381	0.0000	0.0	100.0	0.0012	48.0	52.0	0.0018	72.0	28.0	0.0025	100.0	0.0	0.0025	10.9	328.4	339.3
140	2855	69	20.7	4.40	133.640	0.0000	0.0	100.0	0.0007	15.6	84.4	0.0021	46.7	53.3	0.0042	93.3	6.7	0.0045	7.9	231.3	239.2
141	2855	69	34.5	4.31	136.140	0.0010	7.6	92.4	0.0010	7.6	92.4	0.0039	29.8	70.2	0.0120	91.6	8.4	0.0131	18.1	228.3	246.4
142	2855	69	48.3	4.04	131.282	0.0000	0.0	100.0	0.0009	15.0	85.0	0.0023	38.3	61.7	0.0058	96.7	3.3	0.0060	23.5	315.0	338.5
143	2855	69	62.1	3.60	130.822	0.0008	5.2	94.8	0.0014	9.0	91.0	0.0072	46.5	53.5	0.0155	100.0	0.0	0.0155	42.4	275.6	318.0
144	2855	69	67.6	2.47	142.352	0.0013	1.3	98.7	0.0029	2.8	97.2	0.0634	61.4	38.6	0.1028	99.6	0.4	0.1032	171.5	259.5	431.0

Table B.2 (continued)

DATE: 03-AUG-98	RIVER CONDITION: CHOPPY	TYPE SAMPLER: P-63
STREAM: MISSISSIPPI RIVER	TIME: 12:30 TO 13:40	TYPE SAMPLES: SUSP.
LOCATION: LINE #13 D/S OF HYDRO INTAKE CH.	TEMP: 31 C @10 FT.	NO. VERTICALS: 4
GAGE: KNOX LANDING	WEATHER: CLOUDY AND HOT	NO. POINTS: 6
DISCHARGE: 459,967 CFS (ADCP)	GAGE READING: 33.0 FT.	

						Suspende Sediment Grain Size Analysis													Sediment		
	Distance from	Station	Sampling	Samp.	Flow	Sand Sieve Analysis (Cumulative Weight Retained)													Concentration		
Field	the Reference	Depth	Depth	Velocity	Direction	U.S. 40 (0.425 mm)			U.S. 60 (0.250 mm)			U.S. 120 (0.125 mm)			U.S. 230 (0.062 mm)				(ppm)		
No.	Point (ft)	h (ft)	h - z (ft)	V (ft/s)	ϕ (Deg.)	Wt. (g)	% Ret.	% Finer	Wt. (g)	% Ret.	% Finer	Wt. (g)	% Ret.	% Finer	Wt. (g)	% Ret.	% Finer	Pan	Sand	Fine	Total
145	1791	88	8.8	2.49	148.338	0.0000	0.0	100.0	0.0002	4.9	95.1	0.0026	63.4	36.6	0.0037	90.2	9.8	0.0041	10.9	208.1	219.0
146	1791	88	26.4	3.16	145.286	0.0000	0.0	100.0	0.0001	1.2	98.8	0.0028	34.6	65.4	0.0076	93.8	6.2	0.0081	10.8	181.0	191.8
147	1791	88	44.0	3.18	148.570	0.0000	0.0	100.0	0.0003	6.1	93.9	0.0029	59.2	40.8	0.0042	85.7	14.3	0.0049	6.5	179.4	185.9
148	1791	88	61.6	2.91	161.933	0.0000	0.0	100.0	0.0006	9.8	90.2	0.0033	54.1	45.9	0.0056	91.8	8.2	0.0061	8.2	181.0	189.2
149	1791	88	79.2	3.37	148.396	0.0002	2.5	97.5	0.0011	13.8	86.3	0.0041	51.3	48.8	0.0076	95.0	5.0	0.0080	12.1	189.5	201.6
150	1791	88	86.2	1.56	140.040	0.0009	2.4	97.6	0.0161	42.3	57.7	0.0273	71.7	28.3	0.0379	99.5	0.5	0.0381	63.1	203.7	266.8
151	2076	83	8.3	5.69	123.617	0.0000	0.0	100.0	0.0005	7.4	92.6	0.0030	44.1	55.9	0.0066	97.1	2.9	0.0068	14.1	203.8	217.9
152	2076	83	24.9	5.20	125.365	0.0002	1.8	98.2	0.0016	14.3	85.7	0.0060	53.6	46.4	0.0105	93.8	6.2	0.0112	18.0	186.1	204.1
153	2076	83	41.5	5.28	127.632	0.0001	0.5	99.5	0.0027	14.1	85.9	0.0139	72.4	27.6	0.0184	95.8	4.2	0.0192	31.0	196.8	227.8
154	2076	83	58.1	4.67	126.347	0.0000	0.0	100.0	0.0023	11.4	88.6	0.0142	70.6	29.4	0.0196	97.5	2.5	0.0201	27.3	180.0	207.3
155	2076	83	74.7	4.16	131.126	0.0000	0.0	100.0	0.0089	31.6	68.4	0.0228	80.9	19.1	0.0282	100.0	0.0	0.0282	53.3	191.2	244.5
156	2076	83	81.3	3.54	127.082	0.0006	0.9	99.1	0.0213	33.1	66.9	0.0561	87.2	12.8	0.0639	99.4	0.6	0.0643	137.2	205.2	342.4
157	2474	73	7.3	8.17	129.034	0.0000	0.0	100.0	0.0008	5.8	94.2	0.0066	48.2	51.8	0.0135	98.5	1.5	0.0137	22.7	195.3	218.0
158	2474	73	21.9	7.71	129.403	0.0004	2.4	97.6	0.0007	4.3	95.7	0.0070	42.7	57.3	0.0160	97.6	2.4	0.0164	24.9	188.2	213.1
159	2474	73	36.5	7.63	124.380	0.0006	1.4	98.6	0.0025	5.8	94.2	0.0306	71.0	29.0	0.0428	99.3	0.7	0.0431	63.0	190.6	253.6
160	2474	73	51.1	6.44	125.790	0.0000	0.0	100.0	0.0028	4.3	95.7	0.0473	72.2	27.8	0.0652	99.5	0.5	0.0655	101.2	198.3	299.5
161	2474	73	65.7	5.89	132.179	0.0003	0.5	99.5	0.0024	4.2	95.8	0.0421	74.3	25.7	0.0565	99.6	0.4	0.0567	117.8	200.9	318.7
162	2474	73	71.5	5.65	123.579	0.0024	1.4	98.6	0.0152	8.6	91.4	0.1460	82.4	17.6	0.1772	100.0	0.0	0.1772	308.8	221.1	529.9
163	2881	57	5.7	4.87	133.362	0.0001	1.2	98.8	0.0004	4.7	95.3	0.0060	70.6	29.4	0.0082	96.5	3.5	0.0085	13.5	177.6	191.1
164	2881	57	17.1	5.41	133.501	0.0000	0.0	100.0	0.0002	2.8	97.2	0.0056	78.9	21.1	0.0068	95.8	4.2	0.0071	10.7	184.8	195.5
165	2881	57	28.5	4.93	131.871	0.0003	3.4	96.6	0.0006	6.7	93.3	0.0068	76.4	23.6	0.0087	97.8	2.2	0.0089	20.0	202.4	222.4
166	2881	57	39.9	4.71	133.194	0.0004	1.0	99.0	0.0009	2.3	97.7	0.0171	44.3	55.7	0.0378	97.9	2.1	0.0386	66.3	200.5	266.8
167	2881	57	51.3	3.72	133.927	0.0000	0.0	100.0	0.0008	1.5	98.5	0.0226	41.2	58.8	0.0544	99.1	0.9	0.0549	82.5	198.1	280.6
168	2881	57	55.9	3.12	116.188	0.0011	2.5	97.5	0.0016	3.6	96.4	0.0264	59.5	40.5	0.0442	99.5	0.5	0.0444	121.2	225.7	346.9

Table B.3. Suspended sediment data at Line 6.

DATE: 27-FEB-98	RIVER CONDITION: SMOOTH	TYPE SAMPLER: P-63
STREAM: MISSISSIPPI RIVER	TIME: 14:30 TO 15:30	TYPE SAMPLES: SUSP.
LOCATION: LINE #6 D/S OF HYDRO INTAKE CH.	TEMP: 9 C @10 FT.	NO. VERTICALS: 4
GAGE: KNOX LANDING	WEATHER: CLOUDY AND MILD	NO. POINTS: 6
DISCHARGE: 783,520 CFS (ADCP)	GAGE READING: 48.60 FT.	

						Suspended Sediment Grain Size Analysis — Sand Sieve Analysis (Cumulative Weight Retained)													Sediment Concentration (ppm)		
						U.S. 40 (0.425 mm)			U.S. 60 (0.250 mm)			U.S. 120 (0.125 mm)			U.S. 230 (0.062 mm)						
Field No.	Distance from the Reference Point (ft)	Station Depth h (ft)	Sampling Depth h - z (ft)	Samp. Velocity V (ft/s)	Flow Direction φ (Deg.)	Wt. (g)	% Ret.	% Finer	Wt. (g)	% Ret.	% Finer	Wt. (g)	% Ret.	% Finer	Wt. (g)	% Ret.	% Finer	Pan	Sand	Fine	Total
1	3211	48	4.8	4.82	197.745	0.0003	5.2	94.8	0.0006	10.3	89.7	0.0020	34.5	65.5	0.0056	96.6	3.4	0.0058	22.3	270.7	293.0
2	3211	48	14.4	4.43	197.630	0.0007	1.5	98.5	0.0020	4.3	95.7	0.0257	55.7	44.3	0.0450	97.6	2.4	0.0461	61.3	185.8	247.1
3	3211	48	24.0	4.48	211.827	0.0004	2.2	97.8	0.0017	9.4	90.6	0.0118	65.6	34.4	0.0176	97.8	2.2	0.0180	58.2	247.3	305.5
4	3211	48	33.6	4.27	209.543	0.0000	0.0	100.0	0.0002	4.3	95.7	0.0015	31.9	68.1	0.0045	95.7	4.3	0.0047	40.6	338.1	378.7
5	3211	48	43.2	3.83	201.975	0.0000	0.0	100.0	0.0061	10.7	89.3	0.0444	77.9	22.1	0.0566	99.3	0.7	0.0570	225.1	268.1	493.2
6	3211	48	47.0	2.54	194.646	0.0010	1.8	98.2	0.0028	5.1	94.9	0.0341	61.9	38.1	0.0547	99.3	0.7	0.0551	217.6	257.8	475.4
7	3811	76	7.6	6.98	209.989	0.0006	3.3	96.7	0.0020	10.9	89.1	0.0121	65.8	34.2	0.0181	98.4	1.6	0.0184	30.9	190.6	221.5
8	3811	76	22.8	6.63	206.286	0.0003	0.8	99.2	0.0008	2.1	97.9	0.0200	53.3	46.7	0.0357	95.2	4.8	0.0375	51.4	188.8	240.2
9	3811	76	38.0	6.77	208.850	0.0010	1.3	98.7	0.0023	3.0	97.0	0.0531	69.9	30.1	0.0747	98.3	1.7	0.0760	117.1	191.3	308.4
10	3811	76	53.2	5.78	205.255	0.0004	0.7	99.3	0.0024	4.2	95.8	0.0442	76.6	23.4	0.0569	98.6	1.4	0.0577	155.1	233.6	388.7
11	3811	76	68.4	5.00	210.132	0.0011	0.8	99.2	0.0050	3.8	96.2	0.1140	85.9	14.1	0.1322	99.6	0.4	0.1327	360.6	239.2	599.8
12	3811	76	74.5	3.69	187.510	0.0019	0.9	99.1	0.0133	6.1	93.9	0.1844	84.7	15.3	0.2165	99.4	0.6	0.2177	536.3	231.6	767.9
13	4090	89	8.9	7.21	201.588	0.0007	2.2	97.8	0.0016	5.1	94.9	0.0143	45.4	54.6	0.0307	97.5	2.5	0.0315	42.1	180.3	222.4
14	4090	89	26.7	6.35	203.082	0.0010	2.4	97.6	0.0021	5.1	94.9	0.0109	26.5	73.5	0.0387	94.2	5.8	0.0411	67.8	202.3	270.1
15	4090	89	44.5	6.81	212.081	0.0000	0.0	100.0	0.0000	0.0	100.0	0.0395	78.4	21.6	0.0487	96.6	3.4	0.0504	145.8	245.7	391.5
16	4090	89	62.3	6.61	207.570	0.0011	1.9	98.1	0.0022	3.8	96.2	0.0398	67.9	32.1	0.0572	97.6	2.4	0.0586	93.8	199.2	293.0
17	4090	89	80.1	4.37	207.430	0.0014	1.0	99.0	0.0055	4.0	96.0	0.1156	84.4	15.6	0.1355	98.9	1.1	0.1370	322.2	219.0	541.2
18	4090	89	87.2	3.07	187.558	0.0022	1.0	99.0	0.0113	5.0	95.0	0.1980	88.1	11.9	0.2154	95.8	4.2	0.2248	471.1	234.3	705.4
19	4718	90	9.0	3.92	245.921	0.0003	5.0	95.0	0.0006	10.0	90.0	0.0021	35.0	65.0	0.0057	95.0	5.0	0.0060	14.4	210.0	224.4
20	4718	90	27.0	5.09	235.132	0.0004	1.9	98.1	0.0023	11.1	88.9	0.0129	62.0	38.0	0.0198	95.2	4.8	0.0208	42.6	202.9	245.5
21	4718	90	45.0	4.39	232.745	0.0007	2.8	97.2	0.0012	4.8	95.2	0.0130	51.6	48.4	0.0241	95.6	4.4	0.0252	32.8	171.3	204.1
22	4718	90	63.0	3.42	227.058	0.0005	3.6	96.4	0.0009	6.5	93.5	0.0070	50.4	49.6	0.0129	92.8	7.2	0.0139	29.9	203.0	232.9
23	4718	90	81.0	2.90	221.241	0.0006	5.8	94.2	0.0011	10.6	89.4	0.0068	65.4	34.6	0.0089	85.6	14.4	0.0104	36.0	274.1	310.1
24	4718	90	88.2	2.33	220.312	0.0004	0.6	99.4	0.0209	31.4	68.6	0.0550	82.6	17.4	0.0658	98.8	1.2	0.0666	149.4	206.0	355.4

DATE: 23-MAR-98	RIVER CONDITION: CHOPPY	TYPE SAMPLER: P-63
STREAM: MISSISSIPPI RIVER	TIME: 16:00 TO 17:15	TYPE SAMPLES: SUSP.
LOCATION: LINE #6 D/S OF AUXILIARY INTAKE CH.	TEMP: 9 C @10 FT.	NO. VERTICALS: 4
GAGE: KNOX LANDING	WEATHER: WINDY AND MILD	NO. POINTS: 6
DISCHARGE: 844,513 CFS (ADCP)	GAGE READING: 50.60 FT.	

						Suspende Sediment Grain Size Analysis — Sand Sieve Analysis (Cumulative Weight Retained)													Sediment Concentration (ppm)		
						U.S. 40 (0.425 mm)			U.S. 60 (0.250 mm)			U.S. 120 (0.125 mm)			U.S. 230 (0.062 mm)						
Field No.	Distance from the Reference Point (ft)	Station Depth h (ft)	Sampling Depth h - z (ft)	Samp. Velocity V (ft/s)	Flow Direction φ (Deg.)	Wt. (g)	% Ret.	% Finer	Wt. (g)	% Ret.	% Finer	Wt. (g)	% Ret.	% Finer	Wt. (g)	% Ret.	% Finer	Pan	Sand	Fine	Total
25	3218	52	5.2	3.44	212.660	0.0004	3.2	96.8	0.0009	7.1	92.9	0.0075	59.5	40.5	0.0116	92.1	7.9	0.0126	30.3	257.8	288.1
26	3218	52	15.6	3.44	203.779	0.0000	0.0	100.0	0.0009	4.7	95.3	0.0120	63.2	36.8	0.0178	93.7	6.3	0.0190	37.9	231.9	269.8
27	3218	52	26.0	3.08	212.115	0.0006	1.1	98.9	0.0047	8.8	91.2	0.0429	80.6	19.4	0.0517	97.2	2.8	0.0532	109.4	239.4	348.8
28	3218	52	36.4	2.58	227.060	0.0006	0.8	99.2	0.0068	9.0	91.0	0.0615	81.7	18.3	0.0737	97.9	2.1	0.0753	137.3	227.3	364.6
29	3218	52	46.8	2.09	218.989	0.0020	2.3	97.7	0.0165	18.7	81.3	0.0802	90.9	9.1	0.0872	98.9	1.1	0.0882	435.6	332.7	768.3
30	3218	52	51.0	1.34	294.677	0.0021	1.5	98.5	0.0259	18.3	81.7	0.1298	91.6	8.4	0.1407	99.3	0.7	0.1417	460.0	290.3	750.3
31	3825	89	8.9	6.46	204.468	0.0000	0.0	100.0	0.0007	3.2	96.8	0.0149	67.7	32.3	0.0207	94.1	5.9	0.0220	43.7	246.6	290.3
32	3825	89	26.7	6.68	204.286	0.0008	2.7	97.3	0.0015	5.2	94.8	0.0214	73.5	26.5	0.0280	96.2	3.8	0.0291	71.7	253.4	325.1
33	3825	89	44.5	6.23	205.296	0.0006	0.7	99.3	0.0021	2.6	97.4	0.0625	77.6	22.4	0.0778	96.6	3.4	0.0805	107.9	219.9	327.8
34	3825	89	62.3	6.01	211.184	0.0000	0.0	100.0	0.0013	1.6	98.4	0.0704	84.8	15.2	0.0815	98.2	1.8	0.0830	252.5	271.7	524.2
35	3825	89	80.1	4.28	216.061	0.0010	0.5	99.5	0.0045	2.4	97.6	0.1661	87.3	12.7	0.1884	99.0	1.0	0.1903	406.0	253.4	659.4
36	3825	89	87.2	3.05	217.008	0.0008	0.4	99.6	0.0062	3.2	96.8	0.1814	92.6	7.4	0.1948	99.4	0.6	0.1959	690.5	290.0	980.5
37	4010	95	9.5	5.82	204.081	0.0005	1.6	98.4	0.0017	5.6	94.4	0.0231	75.7	24.3	0.0292	95.7	4.3	0.0305	58.2	228.3	286.5
38	4010	95	28.5	6.07	209.073	0.0000	0.0	100.0	0.0010	8.7	91.3	0.0065	56.5	43.5	0.0101	87.8	12.2	0.0115	21.8	232.6	254.4
39	4010	95	47.5	6.78	209.442	0.0005	1.6	98.4	0.0019	6.1	93.9	0.0233	75.4	24.6	0.0297	96.1	3.9	0.0309	51.7	229.7	281.4
40	4010	95	66.5	6.30	211.256	0.0006	2.1	97.9	0.0014	5.0	95.0	0.0211	75.4	24.6	0.0270	96.4	3.6	0.0280	57.1	237.5	294.6
41	4010	95	85.5	5.09	203.262	0.0021	2.4	97.6	0.0169	19.0	81.0	0.0812	91.1	8.9	0.0883	99.1	0.9	0.0891	163.4	223.7	387.1
42	4010	95	93.1	2.99	210.662	0.0005	2.2	97.8	0.0009	3.9	96.1	0.0156	68.1	31.9	0.0216	94.3	5.7	0.0229	162.7	359.9	522.6
43	4743	89	8.9	2.86	218.537	0.0003	0.5	99.5	0.0036	5.9	94.1	0.0554	90.7	9.3	0.0605	99.0	1.0	0.0611	165.8	242.0	407.8
44	4743	89	26.7	2.98	213.077	0.0000	0.0	100.0	0.0005	18.5	81.5	0.0017	63.0	37.0	0.0024	88.9	11.1	0.0027	14.2	340.0	354.2
45	4743	89	44.5	3.75	206.139	0.0000	0.0	100.0	0.0004	15.4	84.6	0.0015	57.7	42.3	0.0023	88.5	11.5	0.0026	12.0	324.3	336.3
46	4743	89	62.3	3.65	199.706	0.0006	10.9	89.1	0.0009	16.4	83.6	0.0034	61.8	38.2	0.0052	94.5	5.5	0.0055	24.7	319.4	344.1
47	4743	89	80.1	3.15	210.001	0.0007	2.0	98.0	0.0033	9.6	90.4	0.0253	73.3	26.7	0.0333	96.5	3.5	0.0345	55.1	210.3	265.4
48	4743	89	87.2	2.41	200.188	0.0003	2.7	97.3	0.0007	6.3	93.8	0.0067	59.8	40.2	0.0107	95.5	4.5	0.0112	28.3	244.5	272.8

DATE: 10-APR-98	RIVER CONDITION: SMOOTH	TYPE SAMPLER: P-63
STREAM: MISSISSIPPI RIVER	TIME: 15:45 TO 17:15	TYPE SAMPLES: SUSP.
LOCATION: LINE #6 D/S OF AUXILIARY INTAKE CH.	TEMP: 16 C @1.5 FT.	NO. VERTICALS: 4
GAGE: KNOX LANDING	WEATHER: CLEAR AND MILD	NO. POINTS: 6
DISCHARGE: 856,512 CFS (ADCP)	GAGE READING: 52.35 FT.	

						Suspende Sediment Grain Size Analysis — Sand Sieve Analysis (Cumulative Weight Retained)													Sediment Concentration (ppm)		
						U.S. 40 (0.425 mm)			U.S. 60 (0.250 mm)			U.S. 120 (0.125 mm)			U.S. 230 (0.062 mm)						
Field No.	Distance from the Reference Point (ft)	Station Depth h (ft)	Sampling Depth h - z (ft)	Samp. Velocity V (ft/s)	Flow Direction φ (Deg.)	Wt. (g)	% Ret.	% Finer	Wt. (g)	% Ret.	% Finer	Wt. (g)	% Ret.	% Finer	Wt. (g)	% Ret.	% Finer	Pan	Sand	Fine	Total
49	3203	49	4.9	4.14	214.710	0.0000	0.0	100.0	0.0008	5.9	94.1	0.0084	61.8	38.2	0.0136	100.0	0.0	0.0136	34.3	78.5	112.8
50	3203	49	14.7	4.05	215.478	0.0000	0.0	100.0	0.0009	5.2	94.8	0.0110	63.6	36.4	0.0167	96.5	3.5	0.0173	25.1	149.9	175.0
51	3203	49	24.5	3.92	223.238	0.0006	2.5	97.5	0.0014	5.9	94.1	0.0173	73.3	26.7	0.0236	100.0	0.0	0.0236	43.0	157.1	200.1
52	3203	49	34.3	2.99	228.731	0.0004	0.7	99.3	0.0015	2.8	97.2	0.0403	74.1	25.9	0.0533	98.0	2.0	0.0544	73.3	150.9	224.2
53	3203	49	44.1	2.19	234.931	0.0010	0.8	99.2	0.0051	4.3	95.7	0.0995	84.1	15.9	0.1177	99.5	0.5	0.1183	161.3	128.0	289.3
54	3203	49	48.0	1.98	233.062	0.0009	0.6	99.4	0.0102	7.0	93.0	0.1267	87.2	12.8	0.1450	99.8	0.2	0.1453	220.5	119.7	340.2
55	3778	80	8.0	6.45	202.375	0.0000	0.0	100.0	0.0006	5.9	94.1	0.0049	48.5	51.5	0.0096	95.0	5.0	0.0101	13.8	81.2	95.0
56	3778	80	24.0	6.94	207.958	0.0000	0.0	100.0	0.0012	2.9	97.1	0.0293	71.8	28.2	0.0386	94.6	5.4	0.0408	55.0	132.4	187.4
57	3778	80	40.0	6.73	213.341	0.0000	0.0	100.0	0.0013	2.2	97.8	0.0454	75.3	24.7	0.0597	99.0	1.0	0.0603	80.8	103.1	183.9
58	3778	80	56.0	6.67	211.713	0.0007	0.4	99.6	0.0074	4.1	95.9	0.1526	84.2	15.8	0.1797	99.2	0.8	0.1812	237.5	124.6	362.1
59	3778	80	72.0	6.46	215.642	0.0010	0.3	99.7	0.0154	5.0	95.0	0.2770	89.1	10.9	0.3100	99.7	0.3	0.3108	416.8	117.6	534.4
60	3778	80	78.4	4.09	208.229	0.0011	0.4	99.6	0.0088	3.5	96.5	0.2241	89.6	10.4	0.2499	99.9	0.1	0.2501	382.1	127.8	509.9
61	4095	100	10.0	7.15	202.660	0.0000	0.0	100.0	0.0001	0.3	99.7	0.0199	69.6	30.4	0.0281	98.3	1.7	0.0286	37.6	89.1	126.7
62	4095	100	30.0	7.71	204.710	0.0000	0.0	100.0	0.0000	0.0	100.0	0.0154	66.7	33.3	0.0229	99.1	0.9	0.0231	32.6	91.9	124.5
63	4095	100	50.0	6.66	209.304	0.0008	1.2	98.8	0.0019	2.8	97.2	0.0512	75.6	24.4	0.0669	98.8	1.2	0.0677	96.0	61.1	157.1
64	4095	100	70.0	4.82	217.861	0.0000	0.0	100.0	0.0060	6.1	93.9	0.0848	86.1	13.9	0.0970	98.5	1.5	0.0985	132.6	71.9	204.5
65	4095	100	90.0	4.88	214.042	0.0026	1.7	98.3	0.0079	5.3	94.7	0.1287	86.3	13.7	0.1484	99.5	0.5	0.1492	200.9	65.3	266.2
66	4095	100	98.0	3.12	237.982	0.0021	0.8	99.2	0.0276	10.9	89.1	0.2399	94.8	5.2	0.2525	99.8	0.2	0.2530	395.0	83.9	478.9
67	4676	96	9.6	3.99	205.869	0.0000	0.0	100.0	0.0005	7.0	93.0	0.0026	36.6	63.4	0.0069	97.2	2.8	0.0071	10.3	74.0	84.3
68	4676	96	28.8	3.27	204.791	0.0000	0.0	100.0	0.0000	0.0	100.0	0.0085	58.2	41.8	0.0140	95.9	4.1	0.0146	26.4	104.8	131.2
69	4676	96	48.0	3.19	201.758	0.0000	0.0	100.0	0.0016	5.3	94.7	0.0208	69.3	30.7	0.0295	98.3	1.7	0.0300	42.4	92.2	134.6
70	4676	96	67.2	3.43	212.580	0.0016	3.0	97.0	0.0046	8.5	91.5	0.0438	80.8	19.2	0.0537	99.1	0.9	0.0542	76.2	56.3	132.5
71	4676	96	86.4	3.08	222.968	0.0000	0.0	100.0	0.0041	8.3	91.7	0.0378	76.2	23.8	0.0492	99.2	0.8	0.0496	68.0	52.9	120.9
72	4676	96	94.1	2.35	199.826	0.0000	0.0	100.0	0.0836	42.9	57.1	0.1828	93.8	6.2	0.1939	99.5	0.5	0.1949	265.3	128.3	393.6

Table B.3 (continued)

DATE: 17-APR-98	RIVER CONDITION: GOOD	TYPE SAMPLER: P-63
STREAM: MISSISSIPPI RIVER	TIME: 14:00 TO 15:15	TYPE SAMPLES: SUSP.
LOCATION: LINE #6 D/S OF AUXILIARY INTAKE CH.	TEMP: 16 C @1.5 FT.	NO. VERTICALS: 4
GAGE: KNOX LANDING	WEATHER: CLOUDY AND RAIN	NO. POINTS: 6
DISCHARGE: 793,350 CFS (ADCP)	GAGE READING: 50.50 FT.	

Field No.	Distance from the Reference Point (ft)	Station Depth h (ft)	Sampling Depth h - z (ft)	Samp. Velocity V (ft/s)	Flow Direction φ (Deg.)	Suspende Sediment Grain Size Analysis – Sand Sieve Analysis (Cumulative Weight Retained): U.S. 40 (0.425 mm) Wt. (g)	U.S. 40 % Ret.	U.S. 40 % Finer	U.S. 60 (0.250 mm) Wt. (g)	U.S. 60 % Ret.	U.S. 60 % Finer	U.S. 120 (0.125 mm) Wt. (g)	U.S. 120 % Ret.	U.S. 120 % Finer	U.S. 230 (0.062 mm) Wt. (g)	U.S. 230 % Ret.	U.S. 230 % Finer	Pan	Sediment Concentration (ppm) Sand	Fine	Total
73	3159	48	4.8	4.68	200.622	0.0000	0.0	100.0	0.0000	0.0	100.0	0.0073	57.0	43.0	0.0125	97.7	2.3	0.0128	39.2	332.9	372.1
74	3159	48	14.4	4.49	195.917	0.0000	0.0	100.0	0.0004	3.1	96.9	0.0084	64.6	35.4	0.0119	91.5	8.5	0.0130	44.2	348.1	392.3
75	3159	48	24.0	3.83	195.669	0.0000	0.0	100.0	0.0029	6.6	93.4	0.0356	81.3	18.7	0.0430	98.2	1.8	0.0438	111.5	303.7	415.2
76	3159	48	33.6	3.49	199.509	0.0005	1.0	99.0	0.0046	9.0	91.0	0.0432	84.5	15.5	0.0510	99.8	0.2	0.0511	132.2	310.8	443.0
77	3159	48	43.2	3.07	206.565	0.0016	2.2	97.8	0.0073	10.2	89.8	0.0612	85.2	14.8	0.0711	99.0	1.0	0.0718	171.8	299.9	471.7
78	3159	48	47.0	2.00	203.491	0.0014	1.2	98.8	0.0160	13.3	86.7	0.1080	90.1	9.9	0.1192	99.4	0.6	0.1199	263.2	294.8	558.0
79	3826	92	9.2	6.20	207.134	0.0000	0.0	100.0	0.0003	1.8	98.2	0.0089	53.9	46.1	0.0159	96.4	3.6	0.0165	25.7	259.1	284.8
80	3826	92	27.6	5.79	200.590	0.0000	0.0	100.0	0.0008	2.9	97.1	0.0216	77.7	22.3	0.0273	98.2	1.8	0.0278	81.7	320.7	402.4
81	3826	92	46.0	5.74	210.301	0.0000	0.0	100.0	0.0009	2.8	97.2	0.0227	71.4	28.6	0.0310	97.5	2.5	0.0318	49.9	267.6	317.5
82	3826	92	64.4	5.66	206.298	0.0004	1.0	99.0	0.0024	6.0	94.0	0.0333	82.6	17.4	0.0400	99.3	0.7	0.0403	98.9	305.1	404.0
83	3826	92	82.8	3.81	208.752	0.0005	0.5	99.5	0.0069	6.5	93.5	0.0950	89.5	10.5	0.1060	99.8	0.2	0.1062	212.3	283.9	496.2
84	3826	92	90.2	1.98	207.438	0.0006	0.4	99.6	0.0084	5.1	94.9	0.1499	90.2	9.8	0.1653	99.5	0.5	0.1662	254.3	261.4	515.7
85	4131	97	9.7	5.44	209.377	0.0000	0.0	100.0	0.0000	0.0	100.0	0.0057	64.0	36.0	0.0076	85.4	14.6	0.0089	15.5	295.9	311.4
86	4131	97	29.1	5.19	208.006	0.0000	0.0	100.0	0.0015	5.7	94.3	0.0201	76.4	23.6	0.0261	99.2	0.8	0.0263	48.0	281.1	329.1
87	4131	97	48.5	5.70	206.624	0.0000	0.0	100.0	0.0006	2.4	97.6	0.0194	77.6	22.4	0.0239	95.6	4.4	0.0250	47.7	280.1	327.8
88	4131	97	67.9	5.34	202.325	0.0000	0.0	100.0	0.0009	3.3	96.7	0.0205	74.5	25.5	0.0268	97.5	2.5	0.0275	45.0	267.7	312.7
89	4131	97	87.3	4.73	220.360	0.0000	0.0	100.0	0.0096	25.2	74.8	0.0348	91.3	8.7	0.0368	96.6	3.4	0.0381	150.9	304.8	455.7
90	4131	97	95.1	3.09	222.796	0.0000	0.0	100.0	0.0274	22.4	77.6	0.1111	90.8	9.2	0.1218	99.5	0.5	0.1224	158.3	262.3	420.6
91	4695	92	9.2	3.78	209.190	0.0007	11.3	88.7	0.0017	27.4	72.6	0.0041	66.1	33.9	0.0060	96.8	3.2	0.0062	18.1	265.5	283.6
92	4695	92	27.6	3.55	211.618	0.0000	0.0	100.0	0.0000	0.0	100.0	0.0066	55.9	44.1	0.0110	93.2	6.8	0.0118	18.4	246.7	265.1
93	4695	92	46.0	3.84	207.353	0.0000	0.0	100.0	0.0007	7.9	92.1	0.0056	62.9	37.1	0.0086	96.6	3.4	0.0089	25.0	293.3	318.3
94	4695	92	64.4	3.81	213.950	0.0000	0.0	100.0	0.0000	0.0	100.0	0.0044	58.7	41.3	0.0074	98.7	1.3	0.0075	21.9	289.1	311.0
95	4695	92	82.8	3.26	213.019	0.0000	0.0	100.0	0.0000	0.0	100.0	0.0078	62.4	37.6	0.0117	93.6	6.4	0.0125	37.6	210.5	248.1
96	4695	92	90.2	2.08	202.606	0.0000	0.0	100.0	0.0009	6.2	93.8	0.0071	48.6	51.4	0.0137	93.8	6.2	0.0146	47.3	317.0	364.3

DATE: 09-JUN-98	RIVER CONDITION :CHOPPY	TYPE SAMPLER: P-63
STREAM: MISSISSIPPI RIVER	TIME: 15:05 TO 16:20	TYPE SAMPLES: SUSP.
LOCATION: LINE #6 D/S OF AUXILIARY INTAKE CH.	TEMP:26 C @10 FT.	NO. VERTICALS: 4
GAGE: KNOX LANDING	WEATHER: CLOUDY AND HOT	NO. POINTS: 6
DISCHARGE: 504,817 CFS (ADCP)	GAGE READING: 40.30 FT.	

Field No.	Distance from the Reference Point (ft)	Station Depth h (ft)	Sampling Depth h - z (ft)	Samp. Velocity V (ft/s)	Flow Direction φ (Deg.)	Suspende Sediment Grain Size Analysis – Sand Sieve Analysis (Cumulative Weight Retained): U.S. 40 (0.425 mm) Wt. (g)	U.S. 40 % Ret.	U.S. 40 % Finer	U.S. 60 (0.250 mm) Wt. (g)	U.S. 60 % Ret.	U.S. 60 % Finer	U.S. 120 (0.125 mm) Wt. (g)	U.S. 120 % Ret.	U.S. 120 % Finer	U.S. 230 (0.062 mm) Wt. (g)	U.S. 230 % Ret.	U.S. 230 % Finer	Pan	Sediment Concentration (ppm) Sand	Fine	Total
97	3197	32	3.2	3.64	212.087	0.0000	0.0	100.0	0.0000	0.0	100.0	0.0031	37.3	62.7	0.0078	94.0	6.0	0.0083	21.4	253.3	274.7
98	3197	32	9.6	3.49	217.021	0.0000	0.0	100.0	0.0000	0.0	100.0	0.0028	43.1	56.9	0.0060	92.3	7.7	0.0065	13.8	218.0	231.8
99	3197	32	16.0	3.45	212.271	0.0005	4.8	95.2	0.0010	9.5	90.5	0.0051	48.6	51.4	0.0103	98.1	1.9	0.0105	14.9	219.6	234.5
100	3197	32	22.4	3.05	224.607	0.0000	0.0	100.0	0.0009	5.4	94.6	0.0081	48.5	51.5	0.0156	93.4	6.6	0.0167	12.9	227.6	240.5
101	3197	32	28.8	2.53	219.425	0.0000	0.0	100.0	0.0008	15.1	84.9	0.0028	52.8	47.2	0.0052	98.1	1.9	0.0053	29.2	239.0	268.2
102	3197	32	31.4	1.64	204.254	0.0000	0.0	100.0	0.0010	4.5	95.5	0.0110	49.1	50.9	0.0198	88.4	11.6	0.0224	16.4	242.0	258.4
103	3786	70	7.0	5.46	202.051	0.0006	6.7	93.3	0.0008	8.9	91.1	0.0046	51.1	48.9	0.0085	94.4	5.6	0.0090	14.3	223.7	238.0
104	3786	70	21.0	5.27	202.894	0.0000	0.0	100.0	0.0009	5.6	94.4	0.0076	47.2	52.8	0.0153	95.0	5.0	0.0161	41.3	229.1	270.4
105	3786	70	35.0	4.89	205.242	0.0013	5.6	94.4	0.0019	8.2	91.8	0.0134	58.0	42.0	0.0230	99.6	0.4	0.0231	46.1	257.7	303.8
106	3786	70	49.0	4.18	206.444	0.0013	2.2	97.8	0.0055	9.3	90.7	0.0420	71.2	28.8	0.0564	95.6	4.4	0.0590	162.4	252.5	414.9
107	3786	70	63.0	4.38	213.357	0.0009	1.9	98.1	0.0041	8.8	91.2	0.0359	77.4	22.6	0.0458	98.7	1.3	0.0464	254.1	256.5	510.6
108	3786	70	68.6	3.22	193.923	0.0060	2.9	97.1	0.0590	28.1	71.9	0.1976	94.0	6.0	0.2091	99.5	0.5	0.2102	180.5	244.8	425.3
109	4093	83	8.3	6.37	198.670	0.0004	1.6	98.4	0.0019	7.6	92.4	0.0138	55.0	45.0	0.0243	96.8	3.2	0.0251	11.8	205.1	216.9
110	4093	83	24.9	6.00	201.348	0.0072	20.4	79.6	0.0096	27.2	72.8	0.0175	49.6	50.4	0.0351	99.4	0.6	0.0353	18.8	234.2	253.0
111	4093	83	41.5	5.70	200.743	0.0018	2.7	97.3	0.0102	15.1	84.9	0.0372	55.0	45.0	0.0668	98.8	1.2	0.0676	52.9	222.5	275.4
112	4093	83	58.1	5.93	201.854	0.0006	0.8	99.2	0.0047	6.0	94.0	0.0523	67.1	32.9	0.0764	98.1	1.9	0.0779	124.0	261.9	385.9
113	4093	83	74.7	4.75	202.352	0.0021	3.3	96.7	0.0063	9.9	90.1	0.0391	61.2	38.8	0.0626	98.0	2.0	0.0639	373.0	270.1	643.1
114	4093	83	81.3	3.70	211.687	0.0152	2.7	97.3	0.1423	25.6	74.4	0.5016	90.2	9.8	0.5549	99.8	0.2	0.5561	589.6	259.9	849.5
115	4703	84	8.4	2.74	196.181	0.0009	0.5	99.5	0.0355	20.9	79.1	0.1593	93.7	6.3	0.1685	99.1	0.9	0.1701	10.9	328.4	339.3
116	4703	84	25.2	2.59	205.948	0.0000	0.0	100.0	0.0005	3.9	96.1	0.0040	31.0	69.0	0.0124	96.1	3.9	0.0129	7.9	231.3	239.2
117	4703	84	42.0	2.38	204.731	0.0000	0.0	100.0	0.0007	6.5	93.5	0.0032	29.6	70.4	0.0070	64.8	35.2	0.0108	18.1	228.3	246.4
118	4703	84	58.8	2.88	212.421	0.0000	0.0	100.0	0.0006	4.4	95.6	0.0038	27.9	72.1	0.0124	91.2	8.8	0.0136	23.5	315.0	338.5
119	4703	84	75.6	2.87	206.331	0.0006	3.5	96.5	0.0031	18.1	81.9	0.0096	56.1	43.9	0.0149	87.1	12.9	0.0171	42.4	275.6	318.0
120	4703	84	82.3	2.12	193.548	0.0004	0.7	99.3	0.0026	4.3	95.7	0.0396	64.8	35.2	0.0599	98.0	2.0	0.0611	171.5	259.5	431.0

DATE: 03-AUG-98	RIVER CONDITION: CHOPPY	TYPE SAMPLER: P-63
STREAM: MISSISSIPPI RIVER	TIME: 15:20 TO 16:30	TYPE SAMPLES: SUSP.
LOCATION: LINE #6 D/S OF AUXILIARY INTAKE CH.	TEMP: 31 C @10 FT.	NO. VERTICALS: 4
GAGE: KNOX LANDING	WEATHER: CLOUDY AND HOT	NO. POINTS: 6
DISCHARGE: 384,264 CFS (ADCP)	GAGE READING: 33.0 FT.	

Field No.	Distance from the Reference Point (ft)	Station Depth h (ft)	Sampling Depth h - z (ft)	Samp. Velocity V (ft/s)	Flow Direction φ (Deg.)	Suspende Sediment Grain Size Analysis – Sand Sieve Analysis (Cumulative Weight Retained): U.S. 40 (0.425 mm) Wt. (g)	U.S. 40 % Ret.	U.S. 40 % Finer	U.S. 60 (0.250 mm) Wt. (g)	U.S. 60 % Ret.	U.S. 60 % Finer	U.S. 120 (0.125 mm) Wt. (g)	U.S. 120 % Ret.	U.S. 120 % Finer	U.S. 230 (0.062 mm) Wt. (g)	U.S. 230 % Ret.	U.S. 230 % Finer	Pan	Sediment Concentration (ppm) Sand	Fine	Total
121	3204	21	2.1	3.65	202.232	0.0000	0.0	100.0	0.0000	0.0	100.0	0.0004	26.7	73.3	0.0013	86.7	13.3	0.0015	2.1	184.9	187.0
122	3204	21	6.3	3.65	202.232	0.0007	9.1	90.9	0.0010	13.0	87.0	0.0038	49.4	50.6	0.0075	97.4	2.6	0.0077	13.1	191.5	204.6
123	3204	21	10.5	2.97	202.542	0.0000	0.0	100.0	0.0004	8.5	91.5	0.0020	42.6	57.4	0.0046	97.9	2.1	0.0047	8.9	197.2	206.1
124	3204	21	14.7	2.73	201.161	0.0000	0.0	100.0	0.0009	11.7	88.3	0.0029	37.7	62.3	0.0072	93.5	6.5	0.0077	11.8	191.9	203.7
125	3204	21	18.9	2.82	199.892	0.0000	0.0	100.0	0.0006	12.2	87.8	0.0024	49.0	51.0	0.0047	95.9	4.1	0.0049	13.6	212.1	225.7
126	3204	21	20.6	3.57	194.483	0.0000	0.0	100.0	0.0010	13.5	86.5	0.0039	52.7	47.3	0.0072	97.3	2.7	0.0074	19.8	223.0	242.8
127	3785	56	5.6	4.52	208.481	0.0000	0.0	100.0	0.0009	9.1	90.9	0.0046	46.5	53.5	0.0096	97.0	3.0	0.0099	15.1	194.7	209.8
128	3785	56	16.8	4.20	195.373	0.0000	0.0	100.0	0.0004	2.4	97.6	0.0072	42.9	57.1	0.0162	96.4	3.6	0.0168	25.3	192.8	218.1
129	3785	56	28.0	2.92	205.729	0.0012	6.6	93.4	0.0012	6.6	93.4	0.0106	58.6	41.4	0.0179	98.9	1.1	0.0181	28.7	191.4	220.1
130	3785	56	39.2	3.07	204.484	0.0007	1.3	98.7	0.0023	4.4	95.6	0.0371	71.5	28.5	0.0516	99.4	0.6	0.0519	82.5	193.0	275.5
131	3785	56	50.4	3.05	205.296	0.0008	2.4	97.6	0.0028	8.3	91.7	0.0242	71.4	28.6	0.0332	97.9	2.1	0.0339	58.5	199.2	257.7
132	3785	56	54.9	BD	BD	0.0104	4.4	95.6	0.0696	29.5	70.5	0.2201	93.2	6.8	0.2352	99.6	0.4	0.2361	436.1	203.4	639.5
133	4108	76	7.6	3.79	210.292	0.0009	5.0	95.0	0.0037	20.6	79.4	0.0122	67.8	32.2	0.0179	99.4	0.6	0.0180	34.5	200.6	235.1
134	4108	76	22.8	3.17	220.672	0.0000	0.0	100.0	0.0008	4.8	95.2	0.0068	40.7	59.3	0.0166	99.4	0.6	0.0167	27.9	199.6	227.5
135	4108	76	38.0	3.70	224.569	0.0010	3.5	96.5	0.0023	8.1	91.9	0.0156	54.9	45.1	0.0283	99.6	0.4	0.0284	44.2	190.1	234.3
136	4108	76	53.2	3.07	221.491	0.0011	2.2	97.8	0.0028	5.7	94.3	0.0303	61.7	38.3	0.0490	99.8	0.2	0.0491	88.0	214.8	302.8
137	4108	76	68.4	2.12	210.690	0.0015	4.0	96.0	0.0036	9.5	90.5	0.0268	70.9	29.1	0.0376	99.5	0.5	0.0378	107.9	228.9	336.8
138	4108	76	74.5	BD	BD	0.0112	3.6	96.4	0.0742	23.8	76.2	0.2874	92.2	7.8	0.3110	99.8	0.2	0.3116	728.7	226.8	955.5
139	4669	79	7.9	2.27	209.488	0.0952	58.9	41.1	0.1289	79.8	20.2	0.1578	97.7	2.3	0.1602	99.2	0.8	0.1615	396.7	213.0	609.7
140	4669	79	23.7	1.94	208.781	0.0000	0.0	100.0	0.0008	9.3	90.7	0.0051	59.3	40.7	0.0079	91.9	8.1	0.0086	24.2	234.8	259.0
141	4669	79	39.5	1.70	213.260	0.0000	0.0	100.0	0.0007	5.8	94.2	0.0048	39.7	60.3	0.0117	96.7	3.3	0.0121	20.4	982.9	1003.3
142	4669	79	55.3	0.98	231.221	0.0000	0.0	100.0	0.0004	4.9	95.1	0.0030	37.0	63.0	0.0081	100.0	0.0	0.0081	12.3	193.4	205.7
143	4669	79	71.1	0.93	233.211	0.0000	0.0	100.0	0.0000	0.0	100.0	0.0034	39.5	60.5	0.0083	96.5	3.5	0.0086	15.5	198.9	214.4
144	4669	79	77.4	BD	BD	0.0000	0.0	100.0	0.0006	3.3	96.7	0.0073	40.6	59.4	0.0174	96.7	3.3	0.0180	28.5	208.4	236.9

Table B.4. Suspended sediment data at Tarbert.

DATE: 27-FEB-98	RIVER CONDITION: SMOOTH	TYPE SAMPLER: P-63
STREAM: MISSISSIPPI RIVER	TIME: 16:00 TO 17:00	TYPE SAMPLES: SUSP.
LOCATION: TARBERT	TEMP: 9 C @10 FT.	NO. VERTICALS: 4
GAGE: RED RIVER LANDING	WEATHER: CLOUDY AND MILD	NO. POINTS: 6
DISCHARGE: 782,440 CFS (ADCP)	GAGE READING: 46.50 FT.	

Field No.	Distance from the Reference Point (ft)	Station Depth h (ft)	Sampling Depth h - z (ft)	Samp. Velocity V (ft/s)	Flow Direction ϕ (Deg.)	Suspended Sediment Grain Size Analysis, Sand Sieve Analysis (Cumulative Weight Retained): U.S. 40 (0.425 mm)			U.S. 60 (0.250 mm)			U.S. 120 (0.125 mm)			U.S. 230 (0.062 mm)			Pan	Sediment Concentration (ppm)		
						Wt. (g)	% Ret.	% Finer	Wt. (g)	% Ret.	% Finer	Wt. (g)	% Ret.	% Finer	Wt. (g)	% Ret.	% Finer		Sand	Fine	Total
1	1417	54	5.4	3.87	258.109	0.0010	5.2	94.8	0.0020	10.5	89.5	0.0116	60.7	39.3	0.0176	92.1	7.9	0.0191	35.3	221.8	257.1
2	1417	54	16.2	3.68	260.152	0.0005	2.1	97.9	0.0013	5.5	94.5	0.0170	71.4	28.6	0.0236	99.2	0.8	0.0238	59.5	230.6	290.1
3	1417	54	27.0	3.36	251.370	0.0011	1.5	98.5	0.0096	13.0	87.0	0.0603	81.6	18.4	0.0729	98.6	1.4	0.0739	161.7	213.9	375.6
4	1417	54	37.8	3.47	252.834	0.0010	1.1	98.9	0.0079	8.5	91.5	0.0783	84.6	15.4	0.0924	99.8	0.2	0.0926	139.1	190.9	330.0
5	1417	54	48.6	3.11	255.100	0.0010	0.5	99.5	0.0379	19.1	80.9	0.1823	91.7	8.3	0.1977	99.4	0.6	0.1988	461.8	222.6	684.4
6	1417	54	52.9	1.50	242.090	LOST	N/A	N/A	LOST	N/A	N/A	LOST	N/A	N/A	LOST	N/A	N/A	N/A	N/A	191.5	N/A
7	2204	48	4.8	8.00	249.097	0.0009	5.5	94.5	0.0021	12.7	87.3	0.0118	71.5	28.5	0.0161	97.6	2.4	0.0165	33.9	202.1	236.0
8	2204	48	14.4	8.17	248.493	0.0003	3.2	96.8	0.0012	12.8	87.2	0.0044	46.8	53.2	0.0088	93.6	6.4	0.0094	19.5	212.6	232.1
9	2204	48	24.0	7.10	246.457	0.0004	1.6	98.4	0.0073	29.9	70.1	0.0185	75.8	24.2	0.0235	96.3	3.7	0.0244	58.5	219.5	278.0
10	2204	48	33.6	7.79	245.886	0.0006	1.5	98.5	0.0135	33.5	66.5	0.0315	78.2	21.8	0.0396	98.3	1.7	0.0403	62.6	162.1	224.7
11	2204	48	43.2	7.91	247.351	0.0008	2.1	97.9	0.0139	37.2	62.8	0.0289	77.3	22.7	0.0370	98.9	1.1	0.0374	101.2	227.2	328.4
12	2204	48	47.0	7.28	244.289	0.0005	1.6	98.4	0.0136	43.6	56.4	0.0243	77.9	22.1	0.0309	99.0	1.0	0.0312	101.0	243.3	344.3
13	2797	53	5.3	5.23	250.020	0.0003	6.1	93.9	0.0010	20.4	79.6	0.0037	75.5	24.5	0.0047	95.9	4.1	0.0049	13.0	226.1	239.1
14	2797	53	15.9	5.17	241.517	0.0005	9.6	90.4	0.0011	21.2	78.8	0.0039	75.0	25.0	0.0049	94.2	5.8	0.0052	14.3	229.2	243.5
15	2797	53	26.5	4.37	253.416	0.0009	11.4	88.6	0.0009	11.4	88.6	0.0042	53.2	46.8	0.0072	91.1	8.9	0.0079	17.2	217.0	234.2
16	2797	53	37.1	4.73	253.465	0.0005	6.2	93.8	0.0010	12.3	87.7	0.0042	51.9	48.1	0.0073	90.1	9.9	0.0081	20.1	233.1	253.2
17	2797	53	47.7	4.01	253.135	0.0008	10.3	89.7	0.0010	12.8	87.2	0.0040	51.3	48.7	0.0071	91.0	9.0	0.0078	35.5	299.4	334.9
18	2797	53	51.9	2.66	277.230	0.0010	6.1	93.9	0.0017	10.4	89.6	0.0099	60.7	39.3	0.0156	95.7	4.3	0.0163	49.3	238.7	288.0
19	3409	46	4.6	5.13	255.262	0.0005	6.3	93.7	0.0012	15.2	84.8	0.0046	58.2	41.8	0.0077	97.5	2.5	0.0079	22.4	228.7	251.1
20	3409	46	13.8	4.28	252.357	0.0003	3.2	96.8	0.0011	11.8	88.2	0.0045	48.4	51.6	0.0087	93.5	6.5	0.0093	21.3	214.8	236.1
21	3409	46	23.0	4.32	257.093	0.0009	5.8	94.2	0.0020	13.0	87.0	0.0110	71.4	28.6	0.0147	95.5	4.5	0.0154	37.3	223.9	261.2
22	3409	46	32.2	4.62	249.958	0.0006	5.2	94.8	0.0009	7.8	92.2	0.0063	54.3	45.7	0.0108	93.1	6.9	0.0116	26.4	217.7	244.1
23	3409	46	41.4	3.64	243.366	0.0003	3.2	96.8	0.0011	11.8	88.2	0.0045	48.4	51.6	0.0089	95.7	4.3	0.0093	49.3	313.2	362.5
24	3409	46	45.1	3.43	230.398	0.0013	3.7	96.3	0.0095	27.1	72.9	0.0273	77.8	22.2	0.0348	99.1	0.9	0.0351	90.1	220.7	310.8

DATE: 23-MAR-98	RIVER CONDITION: CHOPPY	TYPE SAMPLER: P-63
STREAM: MISSISSIPPI RIVER	TIME: 17:30 TO 18:30	TYPE SAMPLES: SUSP.
LOCATION: TARBERT	TEMP: 9 C @10 FT.	NO. VERTICALS: 4
GAGE: TARBERT DSCHG. RNG.	WEATHER: WINDY AND MILD	NO. POINTS: 6
DISCHARGE: 861,783 CFS (ADCP)	GAGE READING: 49.00 FT.	

Field No.	Distance from the Reference Point (ft)	Station Depth h (ft)	Sampling Depth h - z (ft)	Samp. Velocity V (ft/s)	Flow Direction ϕ (Deg.)	Suspende Sediment Grain Size Analysis, Sand Sieve Analysis (Cumulative Weight Retained): U.S. 40 (0.425 mm)			U.S. 60 (0.250 mm)			U.S. 120 (0.125 mm)			U.S. 230 (0.062 mm)			Pan	Sediment Concentration (ppm)		
						Wt. (g)	% Ret.	% Finer	Wt. (g)	% Ret.	% Finer	Wt. (g)	% Ret.	% Finer	Wt. (g)	% Ret.	% Finer		Sand	Fine	Total
25	1368	57	5.7	3.48	247.447	0.0000	0.0	100.0	0.0000	0.0	100.0	0.0007	18.4	81.6	0.0024	63.2	36.8	0.0038	4.4	196.1	200.5
26	1368	57	17.1	3.10	242.188	0.0000	0.0	100.0	0.0000	0.0	100.0	0.0002	11.8	88.2	0.0007	41.2	58.8	0.0017	1.9	252.3	254.2
27	1368	57	28.5	2.84	243.050	0.0000	0.0	100.0	0.0014	9.8	90.2	0.0084	58.7	41.3	0.0113	79.0	21.0	0.0143	25.3	218.7	244.0
28	1368	57	39.9	2.92	254.514	0.0000	0.0	100.0	0.0020	35.7	64.3	0.0032	57.1	42.9	0.0049	87.5	12.5	0.0056	17.1	275.0	292.1
29	1368	57	51.3	2.27	253.396	0.0000	0.0	100.0	0.0123	36.0	64.0	0.0290	84.8	15.2	0.0332	97.1	2.9	0.0342	103.4	248.5	351.9
30	1368	57	55.9	1.71	256.017	0.0000	0.0	100.0	0.0054	28.9	71.1	0.0145	77.5	22.5	0.0182	97.3	2.7	0.0187	62.1	265.9	328.0
31	2169	47	4.7	6.51	262.997	0.0000	0.0	100.0	0.0014	32.6	67.4	0.0031	72.1	27.9	0.0037	86.0	14.0	0.0043	10.1	231.9	242.0
32	2169	47	14.1	6.66	260.018	0.0000	0.0	100.0	0.0089	18.5	81.5	0.0380	79.2	20.8	0.0464	96.7	3.3	0.0480	68.8	202.5	271.3
33	2169	47	23.5	6.12	264.088	0.0000	0.0	100.0	0.0029	15.7	84.3	0.0109	58.9	41.1	0.0142	76.8	23.2	0.0185	35.2	181.8	217.0
34	2169	47	32.9	6.31	266.660	0.0000	0.0	100.0	0.0037	21.5	78.5	0.0141	82.0	18.0	0.0169	98.3	1.7	0.0172	52.5	272.8	325.3
35	2169	47	42.3	5.86	267.785	0.0000	0.0	100.0	0.1095	52.1	47.9	0.1997	95.0	5.0	0.2085	99.2	0.8	0.2101	428.8	222.1	650.9
36	2169	47	46.1	6.08	266.007	0.0029	1.7	98.3	0.1004	60.3	39.7	0.1615	97.0	3.0	0.1660	99.7	0.3	0.1665	318.7	221.5	540.2
37	3023	51	5.1	6.77	244.044	0.0000	0.0	100.0	0.0036	8.6	91.4	0.0231	55.0	45.0	0.0287	68.3	31.7	0.0420	59.0	211.7	270.7
38	3023	51	15.3	6.09	248.026	0.0000	0.0	100.0	0.0014	2.3	97.7	0.0319	52.3	47.7	0.0464	76.1	23.9	0.0610	66.4	189.4	255.8
39	3023	51	25.5	6.06	240.505	0.0000	0.0	100.0	0.0002	0.8	99.2	0.0169	67.3	32.7	0.0232	92.4	7.6	0.0251	81.8	275.3	357.1
40	3023	51	35.7	5.80	239.970	0.0000	0.0	100.0	0.0008	1.4	98.6	0.0480	83.2	16.8	0.0563	97.6	2.4	0.0577	199.6	286.1	485.7
41	3023	51	45.9	5.39	241.470	0.0000	0.0	100.0	0.0029	2.3	97.7	0.1042	81.6	18.4	0.1254	98.2	1.8	0.1277	284.4	233.3	517.7
42	3023	51	50.0	2.99	255.705	0.0000	0.0	100.0	0.0010	1.6	98.4	0.0457	71.7	28.3	0.0612	96.1	3.9	0.0637	130.2	235.3	365.5
43	3378	47	4.7	6.50	248.177	0.0000	0.0	100.0	0.0009	6.5	93.5	0.0054	38.8	61.2	0.0105	75.5	24.5	0.0139	22.5	205.8	228.3
44	3378	47	14.1	6.21	249.621	0.0000	0.0	100.0	0.0003	2.2	97.8	0.0058	43.3	56.7	0.0104	77.6	22.4	0.0134	32.0	277.0	309.0
45	3378	47	23.5	6.46	240.233	0.0000	0.0	100.0	0.0004	1.4	98.6	0.0172	61.4	38.6	0.0249	88.9	11.1	0.0280	80.7	224.6	305.3
46	3378	47	32.9	6.22	243.746	0.0000	0.0	100.0	0.0007	2.4	97.6	0.0195	66.6	33.4	0.0279	95.2	4.8	0.0293	103.1	263.2	366.3
47	3378	47	42.3	4.92	228.109	0.0000	0.0	100.0	0.0005	1.5	98.5	0.0235	70.4	29.6	0.0323	96.7	3.3	0.0334	140.3	277.0	417.3
48	3378	47	46.1	2.13	224.875	0.0000	0.0	100.0	0.0015	1.6	98.4	0.0835	89.5	10.5	0.0908	97.3	2.7	0.0933	257.9	251.3	509.2

DATE: 10-APR-98	RIVER CONDITION: SMOOTH	TYPE SAMPLER: P-63
STREAM: MISSISSIPPI RIVER	TIME: 17:30 TO 18:30	TYPE SAMPLES: SUSP.
LOCATION: TARBERT DISCHARGE RANGE	TEMP: 16 C @1.5 FT.	NO. VERTICALS: 4
GAGE: TARBERT DSCHG. RNG.	WEATHER: CLEAR AND MILD	NO. POINTS: 6
DISCHARGE: 847,658 CFS (ADCP)	GAGE READING: 50.80 FT.	

Field No.	Distance from the Reference Point (ft)	Station Depth h (ft)	Sampling Depth h - z (ft)	Samp. Velocity V (ft/s)	Flow Direction ϕ (Deg.)	Suspende Sediment Grain Size Analysis, Sand Sieve Analysis (Cumulative Weight Retained): U.S. 40 (0.425 mm)			U.S. 60 (0.250 mm)			U.S. 120 (0.125 mm)			U.S. 230 (0.062 mm)			Pan	Sediment Concentration (ppm)		
						Wt. (g)	% Ret.	% Finer	Wt. (g)	% Ret.	% Finer	Wt. (g)	% Ret.	% Finer	Wt. (g)	% Ret.	% Finer		Sand	Fine	Total
49	1371	62	6.2	4.85	255.737	0.0000	0.0	100.0	0.0016	8.6	91.4	0.0127	68.3	31.7	0.0178	95.7	4.3	0.0186	29.0	162.0	191.0
50	1371	62	18.6	4.11	252.288	0.0000	0.0	100.0	0.0037	10.0	90.0	0.0283	76.3	23.7	0.0362	97.6	2.4	0.0371	49.3	150.9	200.2
51	1371	62	31.0	4.04	255.434	0.0000	0.0	100.0	0.0022	7.3	92.7	0.0207	68.5	31.5	0.0290	96.0	4.0	0.0302	39.5	135.0	174.5
52	1371	62	43.4	4.25	252.419	0.0000	0.0	100.0	0.0096	15.0	85.0	0.0535	83.7	16.3	0.0628	98.3	1.7	0.0639	87.8	147.7	235.5
53	1371	62	55.8	3.57	250.782	0.0017	2.3	97.7	0.0144	19.6	80.4	0.0627	85.2	14.8	0.0727	98.8	1.2	0.0736	107.5	158.0	265.5
54	1371	62	60.8	2.36	231.999	0.0044	4.3	95.7	0.0256	25.1	74.9	0.0887	87.0	13.0	0.1008	98.8	1.2	0.1020	141.9	157.1	299.0
55	2129	63	6.3	5.99	256.086	0.0000	0.0	100.0	0.0026	10.0	90.0	0.0194	74.6	25.4	0.0254	97.7	2.3	0.0260	33.7	153.5	187.2
56	2129	63	18.9	4.94	263.824	0.0000	0.0	100.0	0.0052	12.7	87.3	0.0332	80.8	19.2	0.0405	98.5	1.5	0.0411	56.3	138.4	194.7
57	2129	63	31.5	3.90	272.460	0.0011	1.6	98.4	0.0132	19.4	80.6	0.0576	84.7	15.3	0.0672	98.8	1.2	0.0680	95.3	153.4	248.7
58	2129	63	44.1	3.50	252.380	0.0026	1.8	98.2	0.0396	27.7	72.3	0.1300	90.9	9.1	0.1421	99.4	0.6	0.1430	194.4	159.0	353.4
59	2129	63	56.7	2.90	251.606	0.0046	1.6	98.4	0.1276	44.6	55.4	0.2731	95.4	4.6	0.2860	99.9	0.1	0.2862	389.2	141.3	530.5
60	2129	63	61.7	2.14	245.592	0.0084	3.8	96.2	0.0658	29.9	70.1	0.2064	93.8	6.2	0.2191	99.5	0.5	0.2201	295.4	150.8	446.2
61	2730	57	5.7	6.42	249.204	0.0002	0.8	99.2	0.0008	3.1	96.9	0.0156	60.7	39.3	0.0243	94.6	5.4	0.0257	37.3	161.4	198.7
62	2730	57	17.1	6.47	250.076	0.0000	0.0	100.0	0.0007	1.5	98.5	0.0303	65.4	34.6	0.0454	98.1	1.9	0.0463	62.1	154.3	216.4
63	2730	57	28.5	5.88	250.645	0.0009	1.0	99.0	0.0027	3.1	96.9	0.0700	81.3	18.7	0.0856	99.4	0.6	0.0861	115.5	162.1	277.6
64	2730	57	39.9	4.75	241.149	0.0016	1.2	98.8	0.0059	4.5	95.5	0.1133	85.8	14.2	0.1311	99.2	0.8	0.1321	184.7	171.6	356.3
65	2730	57	51.3	4.71	236.122	0.0019	1.0	99.0	0.0077	4.0	96.0	0.1687	87.0	13.0	0.1930	99.5	0.5	0.1940	263.8	167.8	431.6
66	2730	57	55.9	3.28	235.515	0.0040	1.5	98.5	0.0121	4.6	95.4	0.2340	88.5	11.5	0.2637	99.8	0.2	0.2643	407.3	170.8	578.1
67	3369	49	4.9	5.56	251.042	0.0000	0.0	100.0	0.0000	0.0	100.0	0.0018	37.5	62.5	0.0047	97.9	2.1	0.0048	10.4	193.3	203.7
68	3369	49	14.7	5.30	240.260	0.0006	4.1	95.9	0.0008	5.5	94.5	0.0060	41.4	58.6	0.0132	91.0	9.0	0.0145	18.1	159.5	177.6
69	3369	49	24.5	5.74	237.092	0.0000	0.0	100.0	0.0010	7.5	92.5	0.0056	42.1	57.9	0.0120	90.2	9.8	0.0133	17.6	157.8	175.4
70	3369	49	34.3	4.84	245.173	0.0000	0.0	100.0	0.0000	0.0	100.0	0.0086	47.8	52.2	0.0179	99.4	0.6	0.0180	27.6	174.7	202.3
71	3369	49	44.1	3.72	251.789	0.0010	0.9	99.1	0.0020	1.8	98.2	0.0850	78.2	21.8	0.1074	98.8	1.2	0.1087	183.1	177.3	360.4
72	3369	49	48.0	2.60	241.787	0.0007	0.9	99.1	0.0018	2.2	97.8	0.0566	70.5	29.5	0.0793	98.8	1.2	0.0803	125.9	176.9	302.8

Table B.4 (continued)

DATE: 17-APR-98	RIVER CONDITION: GOOD	TYPE SAMPLER: P-63
STREAM: MISSISSIPPI RIVER	TIME: 15:30 TO 16:30	TYPE SAMPLES: SUSP.
LOCATION: TARBERT	TEMP: 16 C @1.5 FT.	NO. VERTICALS: 4
GAGE: TARBERT DSCHG. RNG.	WEATHER: CLOUDY AND RAIN	NO. POINTS: 6
DISCHARGE: 799,303 CFS (ADCP)	GAGE READING: 49.00 FT.	

Suspende Sediment Grain Size Analysis — Sand Sieve Analysis (Cumulative Weight Retained)

Field No.	Distance from the Reference Point (ft)	Station Depth h (ft)	Sampling Depth h - z (ft)	Samp. Velocity V (ft/s)	Flow Direction ϕ (Deg.)	U.S. 40 (0.425 mm)			U.S. 60 (0.250 mm)			U.S. 120 (0.125 mm)			U.S. 230 (0.062 mm)				Sediment Concentration (ppm)		
						Wt. (g)	% Ret.	% Finer	Wt. (g)	% Ret.	% Finer	Wt. (g)	% Ret.	% Finer	Wt. (g)	% Ret.	% Finer	Pan	Sand	Fine	Total
73	1365	58	5.8	2.60	249.393	0.0000	0.0	100.0	0.0000	0.0	100.0	0.0021	39.6	60.4	0.0051	96.2	3.8	0.0053	14.4	330.1	344.5
74	1365	58	17.4	2.69	254.218	0.0000	0.0	100.0	0.0000	0.0	100.0	0.0025	45.5	54.5	0.0053	96.4	3.6	0.0055	19.8	370.3	390.1
75	1365	58	29.0	2.33	246.177	0.0000	0.0	100.0	0.0000	0.0	100.0	0.0022	29.7	70.3	0.0070	94.6	5.4	0.0074	14.5	306.2	320.7
76	1365	58	40.6	2.25	251.724	0.0000	0.0	100.0	0.0004	2.6	97.4	0.0063	41.7	58.3	0.0149	98.7	1.3	0.0151	32.3	304.0	336.3
77	1365	58	52.2	2.19	248.629	0.0000	0.0	100.0	0.0001	0.7	99.3	0.0070	49.6	50.4	0.0139	98.6	1.4	0.0141	53.7	373.6	427.3
78	1365	58	56.8	1.77	239.873	0.0000	0.0	100.0	0.0003	1.8	98.2	0.0099	57.9	42.1	0.0168	98.2	1.8	0.0171	66.5	403.6	470.1
79	2180	54	5.4	6.16	254.373	0.0000	0.0	100.0	0.0005	5.0	95.0	0.0051	50.5	49.5	0.0097	96.0	4.0	0.0101	16.9	279.6	296.5
80	2180	54	16.2	6.08	252.856	0.0000	0.0	100.0	0.0007	3.6	96.4	0.0108	55.1	44.9	0.0192	98.0	2.0	0.0196	27.3	267.0	294.3
81	2180	54	27.0	6.25	249.463	0.0009	2.8	97.2	0.0014	4.3	95.7	0.0236	72.6	27.4	0.0302	92.9	7.1	0.0325	79.2	331.1	410.3
82	2180	54	37.8	5.60	247.707	0.0008	1.6	98.4	0.0022	4.3	95.7	0.0435	85.5	14.5	0.0507	99.6	0.4	0.0509	196.8	383.9	580.7
83	2180	54	48.6	5.28	247.114	0.0010	1.3	98.7	0.0030	3.8	96.2	0.0663	83.3	16.7	0.0791	99.4	0.6	0.0796	188.0	317.3	505.3
84	2180	54	52.9	5.27	257.021	0.0021	2.0	98.0	0.0047	4.5	95.5	0.0916	87.0	13.0	0.1048	99.5	0.5	0.1053	194.4	319.4	513.8
85	2780	54	5.4	6.09	258.660	0.0000	0.0	100.0	0.0006	6.5	93.5	0.0053	57.6	42.4	0.0079	85.9	14.1	0.0092	11.6	258.9	270.5
86	2780	54	16.2	6.11	252.450	0.0004	3.6	96.4	0.0015	13.6	86.4	0.0082	74.5	25.5	0.0104	94.5	5.5	0.0110	38.2	349.2	387.4
87	2780	54	27.0	6.12	251.216	0.0000	0.0	100.0	0.0149	33.0	67.0	0.0407	90.0	10.0	0.0443	98.0	2.0	0.0452	126.5	318.8	445.3
88	2780	54	37.8	6.42	249.677	0.0010	1.9	98.1	0.0143	27.4	72.6	0.0465	89.3	10.7	0.0514	98.7	1.3	0.0521	108.1	300.4	408.5
89	2780	54	48.6	5.92	252.443	0.0104	6.9	93.1	0.0481	32.1	67.9	0.1387	92.7	7.3	0.1488	99.4	0.6	0.1497	221.7	270.4	492.1
90	2780	54	52.9	5.41	240.057	0.0010	0.8	99.2	0.0432	36.0	64.0	0.1133	94.3	5.7	0.1197	99.7	0.3	0.1201	251.7	296.3	548.0
91	3382	48	4.8	5.16	252.061	0.0000	0.0	100.0	0.0014	10.3	89.7	0.0083	61.0	39.0	0.0122	89.7	10.3	0.0136	19.4	255.7	275.1
92	3382	48	14.4	4.48	252.959	0.0000	0.0	100.0	0.0002	4.2	95.8	0.0031	64.6	35.4	0.0048	100.0	0.0	0.0048	24.4	383.7	408.1
93	3382	48	24.0	4.21	248.497	0.0000	0.0	100.0	0.0016	9.0	91.0	0.0117	65.7	34.3	0.0157	88.2	11.8	0.0178	31.0	276.7	307.7
94	3382	48	33.6	3.79	243.169	0.0000	0.0	100.0	0.0033	13.1	86.9	0.0206	81.7	18.3	0.0249	98.8	1.2	0.0252	63.8	303.0	366.8
95	3382	48	43.2	3.45	248.259	0.0012	2.3	97.7	0.0147	27.9	72.1	0.0475	90.3	9.7	0.0515	97.9	2.1	0.0526	122.4	294.5	416.9
96	3382	48	47.0	2.22	244.231	0.0019	2.5	97.5	0.0198	26.5	73.5	0.0674	90.1	9.9	0.0730	97.6	2.4	0.0748	169.5	282.2	451.7

DATE: 08-MAY-98	RIVER CONDITION: GOOD	TYPE SAMPLER: P-63
STREAM: MISSISSIPPI RIVER	TIME: 16:00 TO 17:00	TYPE SAMPLES: SUSP.
LOCATION: TARBERT	TEMP:19 C @10 FT.	NO. VERTICALS: 4
GAGE: TARBERT DSCHG. RNG.	WEATHER: CLOUDY	NO. POINTS: 6
DISCHARGE: 925,212 CFS (ADCP)	GAGE READING: 52.50 FT.	

Suspende Sediment Grain Size Analysis — Sand Sieve Analysis (Cumulative Weight Retained)

Field No.	Distance from the Reference Point (ft)	Station Depth h (ft)	Sampling Depth h - z (ft)	Samp. Velocity V (ft/s)	Flow Direction ϕ (Deg.)	U.S. 40 (0.425 mm)			U.S. 60 (0.250 mm)			U.S. 120 (0.125 mm)			U.S. 230 (0.062 mm)				Sediment Concentration (ppm)		
						Wt. (g)	% Ret.	% Finer	Wt. (g)	% Ret.	% Finer	Wt. (g)	% Ret.	% Finer	Wt. (g)	% Ret.	% Finer	Pan	Sand	Fine	Total
97	1357	61	6.1	4.31	240.077	0.0000	0.0	100.0	0.0000	0.0	100.0	0.0028	66.7	33.3	0.0041	97.6	2.4	0.0042	13.8	155.3	169.1
98	1357	61	18.3	4.54	236.919	0.0000	0.0	100.0	0.0000	0.0	100.0	0.0062	50.8	49.2	0.0122	100.0	0.0	0.0122	24.6	118.1	142.7
99	1357	61	30.5	4.50	237.051	0.0000	0.0	100.0	0.0000	0.0	100.0	0.0041	71.9	28.1	0.0055	96.5	3.5	0.0057	23.5	181.5	205.0
100	1357	61	42.7	4.43	232.799	0.0000	0.0	100.0	0.0000	0.0	100.0	0.0082	72.6	27.4	0.0112	99.1	0.9	0.0113	42.8	163.0	205.8
101	1357	61	54.9	3.97	245.023	0.0000	0.0	100.0	0.0009	6.4	93.6	0.0085	60.7	39.3	0.0140	100.0	0.0	0.0140	51.4	174.7	226.1
102	1357	61	59.8	3.91	229.795	0.0008	1.4	98.6	0.0017	3.0	97.0	0.0379	66.0	34.0	0.0567	98.8	1.2	0.0574	86.1	110.5	196.6
103	2152	53	5.3	8.30	249.266	0.0004	2.2	97.8	0.0013	7.2	92.8	0.0135	74.6	25.4	0.0181	100.0	0.0	0.0181	36.6	120.0	156.6
104	2152	53	15.9	8.27	255.666	0.0010	4.0	96.0	0.0021	8.4	91.6	0.0197	78.8	21.2	0.0248	99.2	0.8	0.0250	49.4	114.8	164.2
105	2152	53	26.5	8.12	255.155	0.0000	0.0	100.0	0.0012	3.6	96.4	0.0271	82.4	17.6	0.0326	99.1	0.9	0.0329	59.6	105.3	164.9
106	2152	53	37.1	8.21	251.036	0.0004	0.7	99.3	0.0021	3.9	96.1	0.0472	87.1	12.9	0.0542	100.0	0.0	0.0542	103.7	105.6	209.3
107	2152	53	47.7	7.11	254.367	0.0014	1.1	98.9	0.0055	4.4	95.6	0.1168	93.0	7.0	0.1253	99.8	0.2	0.1256	263.9	110.4	374.3
108	2152	53	51.9	7.10	255.521	0.0013	1.2	98.8	0.0047	4.2	95.8	0.1040	92.2	7.8	0.1125	99.7	0.3	0.1128	318.9	119.3	438.2
109	2769	56	5.6	7.57	252.947	0.0000	0.0	100.0	0.0013	6.8	93.2	0.0142	74.3	25.7	0.0184	96.3	3.7	0.0191	31.6	110.4	142.0
110	2769	56	16.8	7.73	249.535	0.0000	0.0	100.0	0.0005	4.3	95.7	0.0083	70.9	29.1	0.0117	100.0	0.0	0.0117	29.5	111.3	140.8
111	2769	56	28.0	6.88	250.061	0.0005	0.9	99.1	0.0074	12.7	87.3	0.0525	89.9	10.1	0.0581	99.5	0.5	0.0584	111.8	107.3	219.1
112	2769	56	39.2	6.89	255.951	0.0018	1.9	98.1	0.0238	25.0	75.0	0.0885	93.1	6.9	0.0947	99.6	0.4	0.0951	196.1	115.7	311.8
113	2769	56	50.4	6.57	252.868	0.0010	0.8	99.2	0.0313	23.7	76.3	0.1216	92.1	7.9	0.1320	99.9	0.1	0.1321	189.5	105.4	294.9
114	2769	56	54.9	6.33	259.902	0.0085	3.9	96.1	0.0964	44.1	55.9	0.2105	96.2	3.8	0.2182	99.7	0.3	0.2188	534.9	133.4	668.3
115	3367	50	5.0	4.68	254.082	0.0000	0.0	100.0	0.0021	22.6	77.4	0.0070	75.3	24.7	0.0093	100.0	0.0	0.0093	18.4	116.6	135.0
116	3367	50	15.0	4.59	250.685	0.0005	1.9	98.1	0.0034	12.6	87.4	0.0210	77.8	22.2	0.0267	98.9	1.1	0.0270	39.8	103.8	143.6
117	3367	50	25.0	4.46	246.696	0.0006	2.0	98.0	0.0049	16.1	83.9	0.0225	73.8	26.2	0.0292	95.7	4.3	0.0305	52.4	80.1	132.5
118	3367	50	35.0	3.57	249.648	0.0000	0.0	100.0	0.0028	14.0	86.0	0.0152	76.0	24.0	0.0195	97.5	2.5	0.0200	53.1	116.3	169.4
119	3367	50	45.0	2.09	258.302	0.0016	4.3	95.7	0.0119	32.2	67.8	0.0328	88.6	11.4	0.0370	100.0	0.0	0.0370	134.9	155.0	289.9
120	3367	50	49.0	2.86	236.949	0.0011	4.1	95.9	0.0093	34.8	65.2	0.0230	86.1	13.9	0.0263	98.5	1.5	0.0267	192.0	221.9	413.9

DATE: 09-JUN-98	RIVER CONDITION :CHOPPY	TYPE SAMPLER: P-63
STREAM: MISSISSIPPI RIVER	TIME: 16:50 TO 17:50	TYPE SAMPLES: SUSP.
LOCATION: TARBERT	TEMP:26 C @10 FT.	NO. VERTICALS: 4
GAGE: TARBERT DISCHARGE RNG.	WEATHER: CLOUDY AND HOT	NO. POINTS: 6
DISCHARGE: 479,979 CFS (ADCP)	GAGE READING: 38.90 FT.	

Suspende Sediment Grain Size Analysis — Sand Sieve Analysis (Cumulative Weight Retained)

Field No.	Distance from the Reference Point (ft)	Station Depth h (ft)	Sampling Depth h - z (ft)	Samp. Velocity V (ft/s)	Flow Direction ϕ (Deg.)	U.S. 40 (0.425 mm)			U.S. 60 (0.250 mm)			U.S. 120 (0.125 mm)			U.S. 230 (0.062 mm)				Sediment Concentration (ppm)		
						Wt. (g)	% Ret.	% Finer	Wt. (g)	% Ret.	% Finer	Wt. (g)	% Ret.	% Finer	Wt. (g)	% Ret.	% Finer	Pan	Sand	Fine	Total
121	1377	48	4.8	4.39	252.391	0.0000	0.0	100.0	0.0000	0.0	100.0	0.0023	25.8	74.2	0.0086	96.6	3.4	0.0089	17.0	220.2	237.2
122	1377	48	14.4	3.94	255.548	0.0000	0.0	100.0	0.0000	0.0	100.0	0.0021	31.8	68.2	0.0060	90.9	9.1	0.0066	13.5	244.7	258.2
123	1377	48	24.0	3.50	251.905	0.0000	0.0	100.0	0.0006	2.8	97.2	0.0129	59.7	40.3	0.0211	97.7	2.3	0.0216	38.8	241.4	280.2
124	1377	48	33.6	3.71	241.260	0.0000	0.0	100.0	0.0005	1.4	98.6	0.0233	64.5	35.5	0.0355	98.3	1.7	0.0361	60.1	248.8	308.9
125	1377	48	43.2	2.78	248.312	0.0000	0.0	100.0	0.0007	1.6	98.4	0.0304	71.5	28.5	0.0422	99.3	0.7	0.0425	80.2	249.5	329.7
126	1377	48	47.0	2.55	246.850	0.0004	1.1	98.9	0.0005	1.3	98.7	0.0289	77.9	22.1	0.0369	99.5	0.5	0.0371	163.3	301.5	464.8
127	2188	41	4.1	4.89	255.693	0.0000	0.0	100.0	0.0005	2.5	97.5	0.0115	57.8	42.2	0.0196	98.5	1.5	0.0199	34.4	234.3	268.7
128	2188	41	12.3	4.85	253.868	0.0000	0.0	100.0	0.0004	4.2	95.8	0.0046	48.4	51.6	0.0091	95.8	4.2	0.0095	21.2	248.8	270.0
129	2188	41	20.5	4.28	246.853	0.0007	1.8	98.2	0.0014	3.6	96.4	0.0260	66.2	33.8	0.0389	99.0	1.0	0.0393	59.6	233.2	292.8
130	2188	41	28.7	4.26	257.260	0.0009	1.4	98.6	0.0027	4.1	95.9	0.0470	70.7	29.3	0.0656	98.6	1.4	0.0665	111.6	252.5	364.1
131	2188	41	36.9	3.79	257.971	0.0004	0.6	99.4	0.0020	2.9	97.1	0.0546	78.7	21.3	0.0683	98.4	1.6	0.0694	144.4	248.4	392.8
132	2188	41	40.2	2.48	259.180	0.0009	0.7	99.3	0.0084	6.8	93.2	0.0749	60.6	39.4	0.1231	99.6	0.4	0.1236	214.2	253.6	467.8
133	2768	40	4.0	4.27	252.039	0.0000	0.0	100.0	0.0010	4.6	95.4	0.0119	54.3	45.7	0.0216	98.6	1.4	0.0219	37.5	246.7	284.2
134	2768	40	12.0	4.43	253.792	0.0000	0.0	100.0	0.0009	6.3	93.7	0.0063	44.4	55.6	0.0133	93.7	6.3	0.0142	22.7	238.4	261.1
135	2768	40	20.0	3.75	253.214	0.0000	0.0	100.0	0.0010	5.4	94.6	0.0104	56.5	43.5	0.0184	100.0	0.0	0.0184	30.4	231.9	262.3
136	2768	40	28.0	3.82	259.395	0.0005	2.4	97.6	0.0020	9.7	90.3	0.0118	57.0	43.0	0.0202	97.6	2.4	0.0207	36.4	242.7	279.1
137	2768	40	36.0	3.06	263.567	0.0007	1.2	98.8	0.0077	13.1	86.9	0.0429	73.2	26.8	0.0579	98.8	1.2	0.0586	96.6	253.7	350.3
138	2768	40	39.2	1.16	268.480	0.0011	1.2	98.8	0.0140	15.7	84.3	0.0714	80.2	19.8	0.0882	99.1	0.9	0.0890	150.5	248.0	398.5
139	3373	35	3.5	4.85	239.356	0.0000	0.0	100.0	0.0008	7.8	92.2	0.0050	48.5	51.5	0.0099	96.1	3.9	0.0103	23.1	264.5	287.6
140	3373	35	10.5	4.93	242.071	0.0000	0.0	100.0	0.0008	7.0	93.0	0.0053	46.5	53.5	0.0111	97.4	2.6	0.0114	20.0	233.4	253.4
141	3373	35	17.5	4.37	239.177	0.0000	0.0	100.0	0.0007	7.3	92.7	0.0033	34.4	65.6	0.0096	100.0	0.0	0.0096	17.6	227.3	244.9
142	3373	35	24.5	4.99	236.362	0.0000	0.0	100.0	0.0011	7.8	92.2	0.0074	52.5	47.5	0.0140	99.3	0.7	0.0141	27.9	243.6	271.5
143	3373	35	31.5	4.14	242.237	0.0004	1.3	98.7	0.0039	13.0	87.0	0.0206	68.7	31.3	0.0300	100.0	0.0	0.0300	57.0	247.8	304.8
144	3373	35	34.3	2.93	239.894	0.0030	5.6	94.4	0.0148	27.7	72.3	0.0421	78.8	21.2	0.0528	98.9	1.1	0.0534	97.3	245.3	342.6

Table B.4 (continued)

DATE: 03-AUG-98	RIVER CONDITION :CHOPPY	TYPE SAMPLER: P-63
STREAM: MISSISSIPPI RIVER	TIME: 16:40 TO 17:50	TYPE SAMPLES: SUSP.
LOCATION: TARBERT	TEMP:31 C @10 FT.	NO. VERTICALS: 4
GAGE: TARBERT DISCHARGE RNG.	WEATHER: CLOUDY AND HOT	NO. POINTS: 6
DISCHARGE: 374,327 CFS (ADCP)	GAGE READING: 31.4 FT.	

						Suspende Sediment Grain Size Analysis													Sediment Concentration (ppm)		
						Sand Sieve Analysis (Cumulative Weight Retained)															
Field No.	Distance from the Reference Point (ft)	Station Depth h (ft)	Sampling Depth h - z (ft)	Samp. Velocity V (ft/s)	Flow Direction ϕ (Deg.)	U.S. 40 (0.425 mm) Wt. (g)	% Ret.	% Finer	U.S. 60 (0.250 mm) Wt. (g)	% Ret.	% Finer	U.S. 120 (0.125 mm) Wt. (g)	% Ret.	% Finer	U.S. 230 (0.062 mm) Wt. (g)	% Ret.	% Finer	Pan	Sand	Fine	Total
145	1380	41	4.1	4.21	255.661	0.0000	0.0	100.0	0.0008	29.6	70.4	0.0018	66.7	33.3	0.0025	92.6	7.4	0.0027	6.4	203.7	210.1
146	1380	41	12.3	4.08	253.998	0.0000	0.0	100.0	0.0008	6.3	93.7	0.0081	64.3	35.7	0.0121	96.0	4.0	0.0126	20.7	200.9	221.6
147	1380	41	20.5	3.56	242.657	0.0000	0.0	100.0	0.0014	13.9	86.1	0.0065	64.4	35.6	0.0096	95.0	5.0	0.0101	15.3	191.4	206.7
148	1380	41	28.7	3.59	254.479	0.0000	0.0	100.0	0.0011	6.8	93.2	0.0102	63.4	36.6	0.0158	98.1	1.9	0.0161	30.5	199.7	230.2
149	1380	41	36.9	3.00	245.199	0.0005	1.9	98.1	0.0010	3.8	96.2	0.0192	72.7	27.3	0.0260	98.5	1.5	0.0264	52.4	205.8	258.2
150	1380	41	40.2	2.57	243.500	0.0010	1.6	98.4	0.0014	2.2	97.8	0.0482	77.4	22.6	0.0615	98.7	1.3	0.0623	113.3	210.7	324.0
151	2186	36	3.6	4.81	253.705	0.0003	3.7	96.3	0.0008	9.8	90.2	0.0034	41.5	58.5	0.0080	97.6	2.4	0.0082	15.0	194.4	209.4
152	2186	36	10.8	4.94	255.853	0.0007	6.3	93.8	0.0013	11.6	88.4	0.0047	42.0	58.0	0.0109	97.3	2.7	0.0112	18.4	195.9	214.3
153	2186	36	18.0	4.15	248.409	0.0012	4.3	95.7	0.0017	6.0	94.0	0.0160	56.9	43.1	0.0275	97.9	2.1	0.0281	46.5	197.9	244.4
154	2186	36	25.2	4.58	253.745	0.0017	4.6	95.4	0.0034	9.2	90.8	0.0230	62.2	37.8	0.0367	99.2	0.8	0.0370	62.7	204.5	267.2
155	2186	36	32.4	3.32	254.000	0.0011	2.0	98.0	0.0057	10.2	89.8	0.0460	82.1	17.9	0.0548	97.9	2.1	0.0560	142.2	222.4	364.6
156	2186	36	35.3	3.46	260.993	0.0007	0.2	99.8	0.0601	16.6	83.4	0.3392	93.6	6.4	0.3616	99.8	0.2	0.3624	649.1	205.2	854.3
157	2783	33	3.3	3.52	250.029	0.0000	0.0	100.0	0.0052	12.5	87.5	0.0338	81.4	18.6	0.0410	98.8	1.2	0.0415	68.6	193.7	262.3
158	2783	33	9.9	3.56	248.739	0.0000	0.0	100.0	0.0005	5.9	94.1	0.0026	30.6	69.4	0.0079	92.9	7.1	0.0085	12.2	187.2	199.4
159	2783	33	16.5	3.29	258.679	0.0000	0.0	100.0	0.0006	3.8	96.2	0.0056	35.9	64.1	0.0149	95.5	4.5	0.0156	25.8	203.3	229.1
160	2783	33	23.1	2.30	245.448	0.0004	1.7	98.3	0.0012	5.2	94.8	0.0106	45.9	54.1	0.0222	96.1	3.9	0.0231	31.9	188.3	220.2
161	2783	33	29.7	2.51	271.645	0.0011	1.9	98.1	0.0125	21.3	78.7	0.0436	74.4	25.6	0.0578	98.6	1.4	0.0586	83.8	193.2	277.0
162	2783	33	32.3	1.26	242.769	0.0066	4.8	95.2	0.0543	39.7	60.3	0.1183	86.5	13.5	0.1358	99.3	0.7	0.1367	188.5	189.6	378.1
163	3390	25	2.5	3.15	252.283	0.0000	0.0	100.0	0.0023	26.4	73.6	0.0061	70.1	29.9	0.0086	98.9	1.1	0.0087	15.1	182.6	197.7
164	3390	25	7.5	3.15	252.283	0.0000	0.0	100.0	0.0006	11.5	88.5	0.0015	28.8	71.2	0.0050	96.2	3.8	0.0052	8.2	165.7	173.9
165	3390	25	12.5	3.44	252.845	0.0000	0.0	100.0	0.0006	8.1	91.9	0.0021	28.4	71.6	0.0069	93.2	6.8	0.0074	10.4	188.7	199.1
166	3390	25	17.5	3.14	247.932	0.0000	0.0	100.0	0.0017	10.5	89.5	0.0072	44.4	55.6	0.0151	93.2	6.8	0.0162	25.4	197.4	222.8
167	3390	25	22.5	2.51	235.395	0.0010	3.3	96.7	0.0109	36.3	63.7	0.0206	68.7	31.3	0.0291	97.0	3.0	0.0300	46.5	191.0	237.5
168	3390	25	24.5	BD	BD	0.0000	0.0	100.0	0.0033	17.5	82.5	0.0092	48.7	51.3	0.0183	96.8	3.2	0.0189	32.7	206.2	238.9

Table B.5. ADCP flow velocity and direction data at Union Point.

February 27,1998

Distance from the Right Bank (ft)											
1066			1658			2256			2941		
Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.
7.05	4.43	118.898	7.05	8.67	118.562	7.05	6.93	121.703	7.05	7.08	124.794
8.69	4.43	122.914	8.69	8.69	121.836	8.69	6.61	121.554	8.69	7.28	123.740
10.34	4.03	117.483	10.34	8.10	119.244	10.34	6.71	123.993	10.34	7.08	123.190
11.98	4.31	116.467	11.98	7.95	118.829	11.98	6.36	126.397	11.98	6.97	123.960
13.62	3.91	121.954	13.62	8.40	120.108	13.62	6.44	127.565	13.62	6.91	124.807
15.26	4.43	119.050	15.26	8.15	118.537	15.26	6.79	124.711	15.26	6.88	125.411
16.90	4.17	123.353	16.90	8.39	119.712	16.90	6.93	122.998	16.90	7.59	128.664
18.54	4.28	118.744	18.54	8.19	116.986	18.54	6.40	122.681	18.54	7.49	123.899
20.18	4.06	122.202	20.18	8.40	118.778	20.18	6.49	124.750	20.18	7.22	129.022
21.82	4.01	125.669	21.82	8.21	123.156	21.82	6.91	125.320	21.82	6.78	129.656
23.46	3.74	121.851	23.46	8.35	120.748	23.46	6.65	126.084	23.46	7.29	126.401
25.10	3.99	118.734	25.10	8.34	119.974	25.10	6.54	124.622	25.10	7.76	129.322
26.74	4.16	120.126	26.74	8.68	122.375	26.74	6.51	126.783	26.74	7.54	133.254
28.38	4.25	122.413	28.38	8.95	121.202	28.38	6.93	128.325	28.38	7.51	126.629
30.02	4.18	125.386	30.02	8.58	121.861	30.02	6.45	128.496	30.02	7.44	129.686
31.66	4.05	122.507	31.66	8.60	119.097	31.66	6.30	128.441	31.66	7.13	132.391
33.30	4.46	122.859	33.30	8.65	120.308	33.30	6.52	127.060	33.30	6.64	134.680
34.94	4.35	127.345	34.94	8.87	120.484	34.94	6.41	128.207	34.94	6.42	135.373
36.58	4.75	127.764	36.58	8.53	122.688	36.58	5.81	127.569	36.58	6.79	128.764
38.22	4.35	129.833	38.22	8.36	120.027	38.22	6.21	127.681	38.22	6.69	130.104
39.86	4.18	127.185	39.86	8.01	121.998	39.86	6.41	129.329	39.86	6.39	129.349
41.50	4.27	123.873	41.50	7.77	120.039	41.50	6.01	132.480	41.50	6.60	128.317
43.15	4.28	119.985	43.15	7.74	121.534	43.15	6.22	129.608	43.15	6.22	122.425
44.79	4.32	121.696	44.79	7.70	121.881	44.79	5.84	127.095	44.79	6.19	122.856
46.43	4.18	117.028	46.43	7.25	123.006	46.43	5.05	126.996	46.43	6.51	127.211
48.07	4.37	129.795	48.07	7.55	122.198	48.07	4.64	127.704	48.07	6.61	124.803
49.71	4.53	122.137	49.71	7.19	123.719	49.71	4.50	127.171	49.71	6.50	124.717
51.35	4.04	128.696	51.35	5.64	122.079	51.35	5.08	125.086	51.35	6.75	126.156
52.99	4.11	123.233	52.99	6.36	121.658	52.99	4.23	126.674	52.99	6.60	127.200
54.63	3.42	119.322	54.63	6.99	121.877	54.63	4.93	135.296	54.63	3.92	121.736
56.27	3.72	126.466	56.27	6.93	120.424	56.27	4.73	134.466	56.27	1.72	113.586
57.91	3.54	116.708	57.91	7.11	120.492	57.91	4.61	130.473			
59.55	3.88	122.267	59.55	6.68	121.394	59.55	4.25	126.578			
61.19	3.55	129.230	61.19	6.98	117.239	61.19	5.02	131.979			
62.83	3.28	134.959	62.83	6.57	120.100	62.83	4.87	117.273			
64.47	2.59	148.750	64.47	5.57	112.622	64.47	3.43	121.245			
66.11	1.17	138.420	66.11	3.05	114.663	66.11	1.54	138.194			

March 23,1998

Distance from the Right Bank (ft)											
1020			1755			2274			3091		
Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.
7.05	4.75	105.755	7.05	7.01	126.221	7.05	8.46	116.973	7.05	3.66	130.752
8.69	4.81	107.088	8.69	7.22	129.262	8.69	7.71	119.554	8.69	4.26	134.470
10.34	4.20	102.767	10.34	7.26	128.668	10.34	8.37	117.439	10.34	4.14	131.468
11.98	4.27	101.741	11.98	7.08	131.506	11.98	8.02	115.191	11.98	4.54	138.721
13.62	4.85	103.067	13.62	7.08	129.812	13.62	8.19	116.319	13.62	4.50	140.655
15.26	4.61	108.603	15.26	7.43	134.624	15.26	8.28	118.250	15.26	4.51	145.063
16.90	4.38	107.960	16.90	7.29	133.122	16.90	8.01	116.198	16.90	3.75	143.471
18.54	4.63	112.345	18.54	6.98	127.242	18.54	7.71	115.148	18.54	3.86	135.654
20.18	4.73	108.134	20.18	7.59	129.035	20.18	8.14	114.281	20.18	3.33	129.277
21.82	4.76	108.822	21.82	7.37	129.070	21.82	8.03	114.366	21.82	3.74	128.950
23.46	4.73	104.470	23.46	7.24	128.895	23.46	8.22	114.120	23.46	4.33	131.623
25.10	5.00	107.888	25.10	7.02	129.802	25.10	7.94	116.756	25.10	3.98	131.657
26.74	5.03	103.782	26.74	7.07	128.955	26.74	7.98	116.249	26.74	3.99	133.900
28.38	4.92	106.974	28.38	7.01	131.587	28.38	8.02	114.081	28.38	3.82	136.254
30.02	4.94	108.483	30.02	6.90	130.853	30.02	7.29	114.269	30.02	3.75	140.323
31.66	4.58	109.226	31.66	6.68	130.241	31.66	7.06	114.636	31.66	3.37	133.818
33.30	4.44	114.272	33.30	6.82	131.746	33.30	6.80	114.277	33.30	3.45	126.772
34.94	4.17	106.881	34.94	6.67	131.910	34.94	7.32	111.172	34.94	3.88	125.571
36.58	4.26	115.520	36.58	6.80	132.378	36.58	6.84	111.628	36.58	3.22	126.379
38.22	4.17	116.223	38.22	6.99	131.785	38.22	7.51	115.860	38.22	3.92	127.972
39.86	4.53	108.947	39.86	7.05	128.144	39.86	7.20	114.872	39.86	4.20	129.289
41.50	4.61	109.054	41.50	7.15	129.058	41.50	7.68	114.551	41.50	3.47	129.472
43.15	4.32	110.500	43.15	6.84	125.589	43.15	7.42	114.287	43.15	3.60	135.480
44.79	4.44	106.602	44.79	7.00	128.009	44.79	6.92	116.371	44.79	3.29	143.062
46.43	3.94	104.464	46.43	7.03	128.020	46.43	6.78	114.258	46.43	3.03	126.857
48.07	3.74	110.356	48.07	6.79	125.142	48.07	6.83	112.205	48.07	2.77	135.527
49.71	3.66	105.332	49.71	6.55	125.004	49.71	6.37	112.826	49.71	3.03	126.957
51.35	3.55	105.051	51.35	6.26	127.638	51.35	6.51	113.233	51.35	2.75	134.324
52.99	4.05	106.245	52.99	6.09	129.113	52.99	6.88	111.705	52.99	2.74	133.062
54.63	3.23	102.668	54.63	6.45	125.429	54.63	6.65	110.232	54.63	3.36	132.782
56.27	3.47	114.964	56.27	6.36	127.963	56.27	6.04	115.771	56.27	2.72	141.761
57.91	3.61	112.140	57.91	6.41	127.826	57.91	5.39	113.789	57.91	1.50	135.000
59.55	3.29	119.915	59.55	6.27	123.391	59.55	5.82	112.647	59.55	0.96	137.000
61.19	3.02	123.552	61.19	6.46	116.968	61.19	6.06	110.425			
62.83	2.40	119.862	62.83	6.05	117.426	62.83	5.72	110.098			
64.47	2.57	126.797	64.47	5.89	117.279	64.47	5.29	111.326			
			66.11	5.62	122.836	66.11	5.85	113.604			
			67.75	4.93	124.717	67.75	5.27	108.119			
						69.39	5.42	113.117			
						71.03	5.28	114.559			
						72.67	4.74	114.775			
						74.31	3.82	108.777			
						75.96	2.67	90.422			
						77.60	3.55	106.963			
						79.24	1.07	99.549			

April 10,1998

Distance from the Right Bank (ft)											
1075			1643			2224			2943		
Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.
7.05	4.62	119.987	7.05	7.44	122.051	7.05	6.96	120.927	7.05	6.25	138.062
8.69	4.49	120.949	8.69	7.14	121.821	8.69	7.10	122.508	8.69	6.17	139.590
10.34	4.16	116.908	10.34	7.56	124.104	10.34	7.58	122.287	10.34	6.47	139.134
11.98	4.23	117.181	11.98	7.45	125.306	11.98	7.19	119.242	11.98	6.22	139.749
13.62	4.52	110.697	13.62	7.29	124.162	13.62	6.91	121.584	13.62	6.21	141.440
15.26	4.66	110.080	15.26	7.89	125.851	15.26	7.36	124.760	15.26	6.22	140.458
16.90	4.07	107.164	16.90	7.11	126.309	16.90	7.03	125.892	16.90	6.43	140.277
18.54	4.09	112.510	18.54	7.45	126.037	18.54	7.01	121.667	18.54	6.16	137.765
20.18	4.07	110.204	20.18	7.49	127.136	20.18	6.94	124.637	20.18	6.12	140.304
21.82	4.17	112.387	21.82	7.93	123.197	21.82	6.76	129.781	21.82	5.76	140.132
23.46	4.62	109.065	23.46	7.44	124.313	23.46	6.98	127.667	23.46	6.50	140.609
25.10	3.71	104.353	25.10	7.53	126.481	25.10	7.41	129.500	25.10	6.50	140.698
26.74	3.90	107.978	26.74	7.34	121.012	26.74	6.86	130.536	26.74	6.15	140.300
28.38	4.06	109.738	28.38	7.16	123.428	28.38	7.29	129.304	28.38	6.10	140.234
30.02	3.78	112.735	30.02	6.73	125.015	30.02	6.64	129.729	30.02	6.23	137.197
31.66	3.96	117.606	31.66	6.92	120.065	31.66	6.74	129.609	31.66	5.64	139.601
33.30	3.73	116.678	33.30	7.13	121.036	33.30	6.63	129.094	33.30	5.66	138.620
34.94	3.43	110.518	34.94	7.31	121.586	34.94	6.19	128.195	34.94	5.83	138.602
36.58	3.53	111.129	36.58	7.58	122.252	36.58	6.51	127.799	36.58	6.20	143.482
38.22	3.82	121.901	38.22	7.22	117.950	38.22	6.62	127.631	38.22	6.51	142.148
39.86	3.51	117.283	39.86	7.51	117.013	39.86	6.58	126.281	39.86	6.49	140.395
41.50	4.10	130.914	41.50	6.88	117.653	41.50	6.60	125.770	41.50	6.99	138.275
43.15	3.44	129.266	43.15	7.14	118.367	43.15	6.36	128.946	43.15	6.51	134.305
44.79	3.56	134.542	44.79	7.47	121.931	44.79	6.35	130.855	44.79	6.10	134.913
46.43	3.95	136.793	46.43	7.07	118.148	46.43	6.47	127.422	46.43	5.90	137.231
48.07	3.91	134.284	48.07	7.34	117.402	48.07	6.41	127.322	48.07	5.66	135.376
49.71	4.01	132.232	49.71	7.31	120.019	49.71	6.19	129.020	49.71	5.07	138.671
51.35	4.09	131.956	51.35	7.24	119.842	51.35	5.61	127.640	51.35	5.29	141.551
52.99	4.65	131.357	52.99	6.93	123.171	52.99	5.80	126.332	52.99	5.40	143.346
54.63	4.05	133.512	54.63	6.69	118.929	54.63	5.60	131.079	54.63	5.15	148.942
56.27	4.11	131.301	56.27	6.54	124.943	56.27	5.58	129.060	56.27	4.56	148.095
57.91	3.87	131.147	57.91	6.60	121.731	57.91	5.17	133.637	57.91	4.36	144.157
59.55	3.89	132.379	59.55	6.45	119.814	59.55	5.52	132.446	59.55	3.11	131.453
61.19	3.90	133.379	61.19	5.63	124.450	61.19	5.86	131.458			
62.83	3.49	131.966	62.83	5.98	119.928	62.83	5.90	138.089			
64.47	3.12	132.770	64.47	5.73	118.401	64.47	5.50	137.202			
66.11	3.53	131.267	66.11	5.80	116.362	66.11	5.39	134.852			
67.75	2.72	131.942	67.75	5.07	118.673	67.75	5.12	136.610			
69.39	2.21	133.689	69.39	4.92	111.128	69.39	4.97	134.786			
						71.03	4.73	132.694			
						72.67	4.11	131.732			
						74.31	3.31	122.510			
						75.96	4.16	129.944			
						77.60	4.24	119.162			
						79.24	3.04	119.860			
						80.88	2.61	119.977			

April 17,1998

Distance from the Right Bank (ft)											
1040			1648			2247			2966		
Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.
7.05	4.22	116.260	7.05	7.16	122.584	7.05	8.60	124.872	7.05	7.10	138.974
8.69	4.35	121.208	8.69	6.69	119.254	8.69	8.34	125.517	8.69	6.80	141.642
10.34	4.17	115.698	10.34	6.86	124.002	10.34	8.81	125.039	10.34	7.01	141.152
11.98	4.26	124.290	11.98	7.27	122.772	11.98	8.66	126.249	11.98	6.78	139.534
13.62	3.76	122.801	13.62	6.84	122.745	13.62	8.32	124.285	13.62	6.66	144.462
15.26	3.71	123.268	15.26	7.28	123.024	15.26	8.36	125.637	15.26	6.35	139.444
16.90	3.64	128.482	16.90	7.01	119.781	16.90	8.42	127.142	16.90	6.46	140.917
18.54	3.63	131.517	18.54	7.01	126.918	18.54	8.64	127.192	18.54	6.45	143.206
20.18	3.85	132.927	20.18	6.93	122.877	20.18	8.01	126.015	20.18	6.08	141.287
21.82	3.86	123.487	21.82	6.67	121.844	21.82	8.72	127.970	21.82	6.04	143.877
23.46	3.98	122.211	23.46	6.39	122.473	23.46	8.77	127.522	23.46	5.48	147.395
25.10	4.01	126.654	25.10	6.64	120.978	25.10	8.53	129.176	25.10	5.39	147.839
26.74	3.92	124.022	26.74	6.58	119.135	26.74	8.68	130.185	26.74	5.18	140.994
28.38	3.40	122.357	28.38	6.56	125.191	28.38	8.65	128.300	28.38	5.04	142.272
30.02	3.50	117.429	30.02	6.69	121.865	30.02	8.53	131.008	30.02	4.87	150.686
31.66	3.71	122.988	31.66	6.57	121.047	31.66	8.56	130.213	31.66	4.46	142.465
33.30	3.36	128.852	33.30	6.49	122.758	33.30	8.25	130.759	33.30	4.46	137.712
34.94	3.29	129.249	34.94	6.43	124.331	34.94	7.99	130.200	34.94	4.46	132.138
36.58	3.45	116.760	36.58	6.49	123.706	36.58	8.06	130.508	36.58	4.54	131.104
38.22	3.35	119.731	38.22	6.40	121.962	38.22	7.98	132.316	38.22	4.31	135.494
39.86	3.68	122.189	39.86	6.49	122.107	39.86	7.92	131.963	39.86	4.32	123.797
41.50	3.48	117.290	41.50	6.41	124.675	41.50	7.84	131.894	41.50	4.57	118.600
43.15	3.82	118.964	43.15	6.31	124.318	43.15	7.98	127.600	43.15	5.07	124.778
44.79	3.83	121.485	44.79	6.47	124.359	44.79	8.16	125.792	44.79	4.72	125.989
46.43	3.84	118.427	46.43	6.01	125.192	46.43	8.53	125.353	46.43	4.66	126.826
48.07	4.02	113.321	48.07	5.77	125.072	48.07	7.96	130.166	48.07	4.71	128.031
49.71	4.05	117.395	49.71	5.78	124.529	49.71	7.67	130.088	49.71	4.83	123.792
51.35	3.73	122.139	51.35	5.85	125.373	51.35	8.05	128.094	51.35	3.92	122.100
52.99	3.65	122.376	52.99	5.75	121.905	52.99	7.39	126.102	52.99	3.24	119.119
54.63	3.65	117.372	54.63	5.45	118.371	54.63	7.06	123.343	54.63	3.37	124.529
56.27	3.21	120.572	56.27	5.35	120.548	56.27	6.95	123.683	56.27	3.79	121.762
57.91	3.46	122.305	57.91	5.28	113.171	57.91	7.39	125.638			
59.55	2.94	111.873	59.55	5.31	117.198	59.55	7.92	126.172			
61.19	3.16	110.375	61.19	4.90	115.604	61.19	8.00	130.127			
62.83	3.50	114.546	62.83	5.28	113.746	62.83	7.98	124.481			
64.47	3.25	103.489	64.47	4.07	116.916	64.47	7.33	121.883			
66.11	3.00	112.407	66.11	3.64	114.230	66.11	6.60	118.961			
67.75	2.32	126.676	67.75	3.63	110.302	67.75	5.63	125.134			
69.39	2.14	119.433	69.39	3.37	120.140	69.39	4.60	122.976			
			71.03	2.74	115.183						

Table B.5 (continued)

May 8,1998

Distance from the Right Bank (ft)											
1094			1652			2279			2959		
Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.
7.05	5.2	121.645	7.05	7.61	129.73	7.05	9.89	121.075	7.05	6.80	130.814
8.69	4.91	120.452	8.69	7.48	127.03	8.69	9.92	120.883	8.69	6.57	133.686
10.34	4.71	126.391	10.34	7.72	131.23	10.34	9.95	122.013	10.34	6.79	136.939
11.98	4.72	125.459	11.98	7.42	127.78	11.98	9.69	121.423	11.98	6.48	131.265
13.62	4.33	124.256	13.62	7.81	128.09	13.62	9.73	123.101	13.62	6.54	132.601
15.26	4.49	124.317	15.26	7.59	127.3	15.26	9.63	123.257	15.26	6.76	129.877
16.9	4.59	121.393	16.9	7.82	126.25	16.9	9.27	122.397	16.9	7.07	133.196
18.54	4.65	127.080	18.54	7.74	128.82	18.54	9.78	123.109	18.54	6.58	135.182
20.18	4.46	124.999	20.18	7.84	126.75	20.18	9.77	121.544	20.18	6.42	132.431
21.82	4.24	125.744	21.82	7.44	127.75	21.82	9.23	120.583	21.82	6.81	132.502
23.46	3.95	134.529	23.46	7.74	130.91	23.46	9.41	122.903	23.46	6.36	134.352
25.1	4.34	120.733	25.1	7.80	129.35	25.1	9.49	122.998	25.1	6.78	133.137
26.74	3.97	128.896	26.74	7.27	129.47	26.74	9.37	125.353	26.74	6.80	132.104
28.38	3.71	134.535	28.38	7.59	125.81	28.38	9.69	124.358	28.38	7.00	136.653
30.02	3.84	134.654	30.02	7.70	130.72	30.02	9.48	124.708	30.02	6.28	132.926
31.66	3.69	130.601	31.66	7.55	129.96	31.66	9.70	126.455	31.66	6.51	133.489
33.3	3.58	124.011	33.3	7.49	128.150	33.3	9.34	125.807	33.3	6.63	130.829
34.94	3.52	127.468	34.94	7.36	124.56	34.94	9.31	122.721	34.94	6.12	136.848
36.58	3.65	125.903	36.58	7.49	126.2	36.58	9.42	123.496	36.58	6.04	140.402
38.22	3.41	127.289	38.22	7.47	125.92	38.22	9.19	123.815	38.22	5.78	139.836
39.86	3.39	127.768	39.86	7.43	126.29	39.86	9.47	124.571	39.86	5.84	141.039
41.50	3.65	123.119	41.5	7.42	125.64	41.50	9.25	124.203	41.5	6.23	136.409
43.15	3.56	123.910	43.15	7.94	127.49	43.15	8.90	123.924	43.15	5.87	137.173
44.79	3.04	122.557	44.79	7.53	125.96	44.79	9.02	124.135	44.79	5.92	141.395
46.43	2.55	117.522	46.43	6.96	128.55	46.43	9.18	121.132	46.43	5.31	139.913
48.07	2.99	117.606	48.07	6.61	125.86	48.07	9.53	121.945	48.07	4.98	137.244
49.71	3.13	118.394	49.71	6.72	130.21	49.71	9.77	126.358	49.71	4.91	132.510
51.35	3.26	120.717	51.35	6.75	126.73	51.35	9.56	127.102	51.35	4.66	134.486
52.99	3.55	120.737	52.99	6.54	126.62	52.99	9.31	125.358	52.99	5.36	130.403
54.63	3.34	128.941	54.63	6.69	124.97	54.63	9.29	128.533	54.63	5.18	130.991
56.27	3.32	127.731	56.27	6.78	125.94	56.27	9.30	128.019	56.27	4.78	134.109
57.91	3.28	128.955	57.91	6.82	128.26	57.91	9.68	125.285	57.91	4.67	131.754
59.55	3.49	125.306	59.55	6.96	126.52	59.55	9.32	124.853			
61.19	2.92	119.849	61.19	6.76	123.61	61.19	9.25	123.355			
62.83	2.47	125.316	62.83	6.44	128.49	62.83	9.28	125.347			
64.47	2.97	133.476	64.47	6.79	123.54	64.47	9.02	126.970			
66.11	3.22	140.994	66.11	6.53	124.78	66.11	9.10	126.498			
67.75	2.78	137.585	67.75	5.96	127.87	67.75	8.71	129.546			
69.39	3.14	140.164	69.39	6.06	128.32	69.39	8.58	125.222			
71.03	2.38	137.125	71.03	4.35	126.21	71.03	6.36	121.582			
72.67	0.95	132.486	72.67	3.14	102.82	72.67	2.92	116.882			
			74.31	1.23	126.66						

June 9,1998

Distance from the Right Bank (ft)											
1047			1613			2235			2923		
Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.
7.05	4.15	115.085	7.05	5.89	119.963	7.05	6.30	129.439	7.05	4.70	140.053
8.69	3.96	113.784	8.69	5.72	118.681	8.69	6.49	130.036	8.69	4.97	138.348
10.34	4.05	114.632	10.34	5.79	119.745	10.34	6.29	134.155	10.34	5.29	140.946
11.98	3.75	108.847	11.98	5.87	123.166	11.98	6.28	131.932	11.98	4.80	138.825
13.62	3.86	110.625	13.62	5.49	122.437	13.62	6.43	135.248	13.62	5.04	142.272
15.26	3.06	112.658	15.26	5.46	121.867	15.26	6.02	134.448	15.26	4.41	136.900
16.90	3.19	126.764	16.90	5.70	122.831	16.90	6.06	132.630	16.90	4.49	140.012
18.54	3.88	127.306	18.54	5.30	113.516	18.54	6.00	135.421	18.54	4.38	142.890
20.18	3.89	123.744	20.18	5.34	114.456	20.18	5.81	135.641	20.18	4.59	138.421
21.82	3.90	117.945	21.82	5.42	117.295	21.82	6.14	134.437	21.82	4.92	141.095
23.46	3.31	118.012	23.46	5.11	118.176	23.46	6.07	135.789	23.46	4.89	145.222
25.10	3.47	121.753	25.10	5.54	120.498	25.10	6.39	136.913	25.10	4.71	143.705
26.74	3.55	113.039	26.74	5.39	117.892	26.74	5.78	138.499	26.74	4.56	136.225
28.38	3.71	109.862	28.38	4.87	116.151	28.38	5.86	138.884	28.38	4.13	136.897
30.02	3.60	110.813	30.02	5.27	120.382	30.02	5.86	136.839	30.02	4.22	139.447
31.66	3.70	111.905	31.66	4.86	118.123	31.66	5.52	134.157	31.66	4.32	134.846
33.30	3.07	107.892	33.30	4.81	130.301	33.30	6.07	136.643	33.30	4.40	134.336
34.94	3.18	108.024	34.94	4.82	125.302	34.94	5.75	133.612	34.94	4.66	136.425
36.58	3.47	110.594	36.58	4.77	121.437	36.58	5.84	136.547	36.58	4.55	133.482
38.22	3.36	116.890	38.22	4.68	125.594	38.22	5.49	132.988	38.22	4.09	135.617
39.86	3.25	116.849	39.86	4.50	125.334	39.86	5.28	130.061	39.86	4.19	141.515
41.50	2.82	120.026	41.50	4.86	119.092	41.50	5.52	127.851	41.50	3.91	142.496
43.15	2.91	107.496	43.15	4.31	123.013	43.15	5.68	125.757	43.15	3.65	142.369
44.79	3.22	109.858	44.79	3.62	126.226	44.79	5.57	122.885	44.79	3.11	141.878
46.43	3.06	120.995	46.43	3.96	126.139	46.43	5.25	129.549	46.43	2.61	140.381
48.07	2.99	120.651	48.07	3.47	126.664	48.07	5.03	132.465			
49.71	3.18	120.751	49.71	3.57	129.293	49.71	4.74	134.412			
51.35	2.53	115.601	51.35	3.04	139.949	51.35	5.01	138.289			
52.99	2.66	119.219	52.99	3.12	140.032	52.99	4.71	138.191			
54.63	2.35	122.803	54.63	3.56	124.745	54.63	4.48	139.221			
56.27	1.04	136.018	56.27	2.53	132.949	56.27	4.07	129.729			
			57.91	2.39	132.718	57.91	3.75	129.992			
			59.55	1.93	152.042	59.55	3.36	138.645			
						61.19	3.55	140.968			
						62.83	2.99	143.922			

August 3,1998

Distance from the Right Bank (ft)											
1030			1625			2229			2901		
Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.
7.05	4.40	117.424	7.05	6.03	126.433	7.05	6.12	123.307	7.05	4.54	129.643
8.69	4.10	124.249	8.69	5.42	126.551	8.69	5.96	122.544	8.69	4.31	130.276
10.34	3.96	119.068	10.34	5.93	131.344	10.34	6.14	120.538	10.34	4.54	130.284
11.98	4.09	118.270	11.98	5.78	126.317	11.98	5.93	117.854	11.98	4.55	130.531
13.62	4.52	120.885	13.62	5.38	126.597	13.62	6.07	123.759	13.62	4.52	129.262
15.26	4.29	118.310	15.26	5.48	125.031	15.26	5.95	119.913	15.26	4.41	127.939
16.90	4.29	120.430	16.90	5.68	124.461	16.90	5.89	123.964	16.90	4.31	130.098
18.54	4.36	120.690	18.54	5.54	126.422	18.54	5.93	121.448	18.54	4.69	128.801
20.18	4.28	123.800	20.18	5.39	125.432	20.18	5.61	116.715	20.18	4.27	128.429
21.82	3.95	119.142	21.82	5.55	128.332	21.82	5.60	122.023	21.82	4.36	129.284
23.46	3.39	111.873	23.46	5.31	128.201	23.46	5.21	121.830	23.46	3.87	127.943
25.10	3.65	112.786	25.10	5.75	127.634	25.10	5.31	123.798	25.10	3.68	129.723
26.74	3.90	117.622	26.74	5.61	125.931	26.74	5.19	121.710	26.74	3.95	131.550
28.38	3.18	114.209	28.38	5.36	122.318	28.38	5.49	118.802	28.38	4.28	130.707
30.02	3.08	115.991	30.02	5.59	122.187	30.02	5.17	115.362	30.02	4.01	133.893
31.66	2.94	121.063	31.66	5.49	123.662	31.66	5.64	119.741	31.66	4.38	131.354
33.30	3.58	126.155	33.30	4.92	123.870	33.30	5.78	124.024	33.30	4.05	129.317
34.94	3.42	125.001	34.94	5.11	122.434	34.94	5.68	124.938	34.94	3.66	127.459
36.58	3.58	119.361	36.58	5.05	123.556	36.58	5.49	126.206	36.58	3.69	124.850
38.22	2.99	116.368	38.22	5.47	124.062	38.22	5.68	123.387	38.22	2.49	131.615
39.86	2.62	127.358	39.86	5.47	120.704	39.86	5.84	121.439	39.86	2.39	134.328
41.50	2.46	117.694	41.50	5.03	120.074	41.50	5.23	120.262	41.50	0.22	132.232
43.15	2.41	129.536	43.15	4.48	125.133	43.15	5.27	120.939			
44.79	1.63	143.107	44.79	4.66	125.716	44.79	4.81	120.448			
46.43	1.20	154.489	46.43	5.47	123.385	46.43	4.21	116.086			
			48.07	4.56	117.229	48.07	3.74	115.485			
			49.71	2.29	122.893	49.71	2.47	79.212			

Table B.6. ADCP flow velocity and direction data at Line 13.

February 27,1998

Distance from the Right Bank (ft)											
1793			2115			2449			2916		
Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.
7.05	6.87	127.450	7.05	8.95	133.277	7.05	7.91	131.671	7.05	5.19	129.643
8.69	7.18	130.610	8.69	9.32	129.000	8.69	7.52	132.329	8.69	5.01	130.276
10.34	7.19	129.983	10.34	9.12	134.417	10.34	8.14	134.559	10.34	5.28	130.284
11.98	6.72	132.012	11.98	9.09	133.100	11.98	8.14	132.174	11.98	5.48	130.531
13.62	7.11	125.955	13.62	9.13	132.292	13.62	7.70	130.956	13.62	5.27	129.262
15.26	6.60	131.373	15.26	9.50	131.221	15.26	7.68	128.671	15.26	5.42	127.939
16.90	6.36	128.189	16.90	9.11	130.545	16.90	8.10	130.435	16.90	5.43	130.098
18.54	6.79	126.249	18.54	8.79	130.898	18.54	8.20	133.006	18.54	5.61	128.801
20.18	5.91	127.035	20.18	8.82	131.773	20.18	7.93	131.342	20.18	5.21	128.429
21.82	6.91	125.108	21.82	8.42	131.304	21.82	8.02	133.840	21.82	5.03	129.284
23.46	6.43	128.975	23.46	8.65	129.444	23.46	8.25	130.453	23.46	5.12	127.943
25.10	6.81	131.796	25.10	8.41	131.266	25.10	8.37	131.249	25.10	5.25	129.723
26.74	6.93	131.125	26.74	9.00	133.508	26.74	8.02	133.275	26.74	5.59	131.550
28.38	6.58	130.939	28.38	9.21	136.140	28.38	8.56	134.488	28.38	5.02	130.707
30.02	6.88	130.456	30.02	9.00	131.333	30.02	8.77	134.727	30.02	4.92	133.893
31.66	6.73	130.271	31.66	9.24	133.373	31.66	8.05	131.713	31.66	4.63	131.354
33.30	6.88	132.818	33.30	9.05	133.810	33.30	8.48	131.987	33.30	4.83	129.317
34.94	6.89	129.069	34.94	9.05	133.648	34.94	8.66	129.280	34.94	4.79	127.459
36.58	7.30	130.956	36.58	9.28	134.900	36.58	9.07	132.184	36.58	4.99	124.850
38.22	7.01	130.901	38.22	9.25	134.209	38.22	8.75	132.492	38.22	5.03	131.615
39.86	7.42	134.283	39.86	8.73	130.671	39.86	9.28	129.606	39.86	4.75	134.328
41.50	7.69	129.042	41.50	9.06	131.816	41.50	8.84	131.884	41.50	4.80	132.232
43.15	7.49	135.035	43.15	9.08	135.337	43.15	8.88	131.510	43.15	4.81	135.525
44.79	7.41	139.181	44.79	8.91	133.090	44.79	8.67	135.031	44.79	4.18	138.979
46.43	7.63	133.676	46.43	9.22	127.539	46.43	8.53	133.894	46.43	4.87	134.918
48.07	7.09	136.669	48.07	9.09	131.941	48.07	8.26	132.182	48.07	4.38	136.547
49.71	7.75	139.828	49.71	8.85	130.219	49.71	7.95	132.759	49.71	4.67	137.905
51.35	7.26	134.341	51.35	8.88	132.274	51.35	7.90	134.680	51.35	4.62	127.318
52.99	7.34	133.026	52.99	9.07	130.981	52.99	8.32	133.945	52.99	5.13	134.741
54.63	7.21	135.074	54.63	8.56	130.430	54.63	8.50	132.826	54.63	4.39	127.229
56.27	7.43	134.982	56.27	8.67	130.472	56.27	8.34	130.997	56.27	4.54	134.737
57.91	7.39	134.910	57.91	8.67	133.359	57.91	8.11	129.319	57.91	4.42	127.882
59.55	7.45	131.430	59.55	8.35	132.979	59.55	7.82	128.634	59.55	4.50	129.313
61.19	7.50	131.575	61.19	8.87	130.633	61.19	7.46	131.577	61.19	4.28	136.429
62.83	7.37	130.073	62.83	8.09	130.097	62.83	7.55	133.891	62.83	3.66	129.076
64.47	7.13	134.496	64.47	7.92	130.277	64.47	7.60	133.164	64.47	4.17	131.555
66.11	6.99	138.366	66.11	8.20	130.487	66.11	7.50	131.719	66.11	3.69	129.232
67.75	6.97	135.858	67.75	8.26	128.987	67.75	7.18	132.427	67.75	2.81	140.400
69.39	7.20	138.046	69.39	7.82	130.169	69.39	7.53	132.951	69.39	1.83	153.711
71.03	7.08	137.253	71.03	8.43	129.154	71.03	7.84	133.966			
72.67	6.96	133.816	72.67	7.99	127.378	72.67	7.06	134.812			
74.31	7.09	134.062	74.31	7.76	131.193	74.31	6.90	135.154			
75.96	6.95	132.532	75.96	7.48	129.272	75.96	6.94	133.065			
77.60	7.08	133.198	77.60	7.05	129.560	77.60	6.52	134.184			
79.24	6.90	136.098	79.24	6.87	129.728	79.24	6.55	135.446			
80.88	6.14	140.030	80.88	6.39	126.917	80.88	6.08	137.626			
82.52	5.79	140.631	82.52	6.07	129.008	82.52	5.96	133.929			
84.16	5.70	148.431	84.16	5.98	128.134	84.16	4.24	132.649			
85.80	5.50	142.029	85.80	5.42	126.058	85.80	3.77	142.602			
87.44	6.09	140.950	87.44	5.78	133.482	87.44	3.72	146.660			
89.08	6.32	138.072	89.08	6.05	127.131	89.08	3.69	122.312			
90.72	6.28	139.665	90.72	4.90	133.453						
92.36	6.15	137.724	92.36	4.86	139.907						
94.00	6.17	140.218	94.00	3.66	144.659						
95.64	6.27	139.415	95.64	3.10	132.596						
97.28	6.09	141.258	97.28	2.02	151.523						
98.92	5.43	137.079									
100.56	5.74	126.615									
102.20	5.60	130.962									
103.84	5.37	119.758									
105.48	4.79	125.529									
107.12	3.86	140.594									

March 23,1998

Distance from the Right Bank (ft)											
1785			2068			2459			2890		
Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.
7.05	6.13	135.975	7.05	7.71	137.726	7.05	8.83	135.557	7.05	5.57	129.719
8.69	6.18	134.268	8.69	7.99	135.932	8.69	8.89	136.017	8.69	5.47	129.792
10.34	6.56	133.844	10.34	7.64	136.601	10.34	8.63	135.801	10.34	5.71	129.704
11.98	6.43	133.388	11.98	8.04	135.446	11.98	9.01	136.018	11.98	5.57	129.836
13.62	7.13	135.112	13.62	8.14	138.610	13.62	8.64	136.447	13.62	5.17	127.932
15.26	6.97	137.443	15.26	7.60	136.889	15.26	8.27	136.833	15.26	5.47	126.636
16.90	8.03	135.795	16.90	7.96	138.341	16.90	8.41	135.126	16.90	5.40	127.301
18.54	8.05	134.075	18.54	8.46	136.902	18.54	8.04	136.307	18.54	5.75	130.023
20.18	7.41	138.337	20.18	8.40	133.987	20.18	8.49	135.767	20.18	5.34	129.463
21.82	7.44	136.502	21.82	8.45	136.574	21.82	8.54	134.735	21.82	5.45	130.897
23.46	7.42	137.851	23.46	8.46	138.664	23.46	8.31	135.064	23.46	5.57	130.030
25.10	6.91	139.293	25.10	7.70	138.125	25.10	8.74	135.989	25.10	5.57	133.951
26.74	6.55	130.654	26.74	7.23	136.857	26.74	8.62	132.454	26.74	5.81	128.923
28.38	6.75	127.316	28.38	7.07	137.481	28.38	8.26	133.697	28.38	5.54	128.893
30.02	6.91	132.614	30.02	7.20	140.790	30.02	8.32	133.562	30.02	5.69	128.943
31.66	6.90	133.902	31.66	6.93	140.857	31.66	8.74	133.312	31.66	5.12	133.104
33.30	6.78	140.752	33.30	6.47	138.415	33.30	8.21	133.915	33.30	5.26	129.000
34.94	7.19	142.848	34.94	6.40	138.262	34.94	8.25	133.808	34.94	5.44	125.916
36.58	6.78	143.856	36.58	6.49	144.173	36.58	7.90	132.761	36.58	4.95	135.027
38.22	7.38	142.346	38.22	7.01	143.318	38.22	8.31	134.616	38.22	5.02	130.151
39.86	7.37	142.528	39.86	6.56	140.884	39.86	8.42	130.732	39.86	4.94	132.496
41.50	7.60	139.409	41.50	6.79	142.920	41.50	8.58	129.629	41.50	5.18	131.763
43.15	7.38	143.426	43.15	6.51	143.592	43.15	8.08	129.317	43.15	5.55	131.451
44.79	8.03	143.102	44.79	6.30	144.365	44.79	8.47	133.163	44.79	4.75	133.907
46.43	7.98	140.571	46.43	6.86	143.838	46.43	8.03	131.404	46.43	4.23	133.367
48.07	7.98	139.706	48.07	6.75	137.897	48.07	8.09	132.353	48.07	4.54	126.928
49.71	8.28	143.829	49.71	6.09	135.393	49.71	7.89	133.687	49.71	4.37	135.456
51.35	8.06	142.510	51.35	6.37	133.831	51.35	8.04	130.617	51.35	4.38	131.359
52.99	8.29	141.170	52.99	5.76	139.434	52.99	8.27	129.541	52.99	4.28	132.359
54.63	8.28	139.968	54.63	5.46	141.932	54.63	7.99	131.704	54.63	4.64	129.977
56.27	7.65	141.286	56.27	5.52	136.444	56.27	7.58	131.664	56.27	4.57	127.290
57.91	7.25	145.943	57.91	5.86	138.518	57.91	7.91	134.210	57.91	4.36	135.549
59.55	7.62	142.168	59.55	5.38	138.189	59.55	8.25	132.614	59.55	4.43	132.717
61.19	7.80	136.500	61.19	5.88	128.675	61.19	7.90	128.017	61.19	4.29	130.725
62.83	7.62	132.853	62.83	5.64	128.998	62.83	8.18	129.403	62.83	4.51	135.648
64.47	7.29	130.473	64.47	5.52	128.415	64.47	7.78	132.812	64.47	4.32	133.553
66.11	7.45	129.282	66.11	5.24	129.668	66.11	7.79	132.542	66.11	4.35	133.686
67.75	7.28	128.926	67.75	5.13	122.064	67.75	7.94	131.366	67.75	4.26	134.190
69.39	6.91	127.627	69.39	4.84	125.628	69.39	7.61	130.714	69.39	3.93	137.540
71.03	7.33	130.367	71.03	4.88	123.423	71.03	7.65	132.723	71.03	3.63	140.758
72.67	7.28	133.211	72.67	5.05	121.269	72.67	7.57	135.053	72.67	1.83	133.837
74.31	7.19	133.243	74.31	4.82	121.592	74.31	7.46	134.893	74.31	0.87	111.038
75.96	7.42	137.525	75.96	5.05	123.587	75.96	6.70	134.028	75.96	1.86	121.984
77.60	7.40	136.760	77.60	4.84	121.396	77.60	6.87	131.456			
79.24	7.27	136.482	79.24	4.61	127.661	79.24	7.05	130.922			
80.88	7.40	135.611	80.88	5.41	128.101	80.88	6.35	132.885			
82.52	6.85	135.427	82.52	4.99	135.053	82.52	6.26	134.512			
84.16	7.20	136.182	84.16	5.35	128.206	84.16	6.35	134.728			
85.80	6.73	137.172	85.80	5.43	134.045	85.80	6.27	137.013			
87.44	6.69	138.499	87.44	5.13	137.282	87.44	5.53	133.438			
89.08	6.46	137.389	89.08	4.74	135.926	89.08	5.04	138.404			
90.72	6.81	135.801	90.72	4.26	139.337	90.72	4.28	138.388			
92.36	6.61	134.920	92.36	4.38	144.288	92.36	4.49	132.958			
94.00	6.64	136.543	94.00	3.43	147.436	94.00	3.38	109.227			
95.64	6.58	139.730									
97.28	6.65	134.520									
98.92	6.79	138.527									
100.56	6.27	139.838									
102.20	6.11	138.093									
103.84	7.00	140.627									
105.48	5.74	129.202									
107.12	6.99	134.266									

Table B.6 (continued)

April 10,1998

Distance from the Right Bank (ft)											
1801			2072			2433			2869		
Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.
7.05	9.24	130.076	7.05	9.37	132.730	7.05	6.97	134.905	7.05	3.30	139.355
8.69	8.69	128.981	8.69	9.55	133.845	8.69	7.00	133.727	8.69	3.21	134.420
10.34	9.11	126.886	10.34	10.03	131.472	10.34	6.79	134.491	10.34	2.99	125.699
11.98	9.10	129.999	11.98	9.60	132.508	11.98	6.74	133.363	11.98	3.15	130.012
13.62	8.75	129.962	13.62	9.46	135.225	13.62	6.65	131.521	13.62	3.19	131.751
15.26	8.56	128.358	15.26	9.42	132.770	15.26	7.30	131.905	15.26	3.18	128.752
16.90	8.80	128.596	16.90	9.53	133.758	16.90	7.41	131.499	16.90	3.20	135.290
18.54	8.66	131.468	18.54	9.44	131.223	18.54	6.66	137.937	18.54	3.29	136.374
20.18	8.81	129.713	20.18	9.52	133.584	20.18	6.93	128.931	20.18	3.50	132.910
21.82	8.65	132.525	21.82	9.51	134.958	21.82	7.32	131.113	21.82	3.47	135.344
23.46	8.95	130.553	23.46	9.09	134.678	23.46	7.46	132.308	23.46	3.43	134.690
25.10	9.20	133.467	25.10	9.05	132.810	25.10	6.74	130.994	25.10	3.23	131.866
26.74	9.13	134.738	26.74	9.17	130.750	26.74	7.57	133.665	26.74	3.03	130.877
28.38	8.85	131.994	28.38	9.03	132.733	28.38	7.29	134.161	28.38	3.72	136.822
30.02	8.52	132.489	30.02	8.95	131.150	30.02	7.20	133.745	30.02	3.29	134.111
31.66	8.58	133.420	31.66	8.81	131.027	31.66	7.40	138.290	31.66	3.33	133.841
33.30	9.37	132.815	33.30	9.17	131.504	33.30	7.37	133.215	33.30	3.45	139.978
34.94	9.33	134.459	34.94	9.29	133.683	34.94	7.12	135.317	34.94	2.73	137.045
36.58	9.10	132.385	36.58	9.04	129.478	36.58	7.18	138.166	36.58	2.95	146.733
38.22	9.25	131.075	38.22	8.88	131.692	38.22	7.45	135.000	38.22	2.95	145.071
39.86	9.12	133.353	39.86	8.89	133.206	39.86	7.45	133.020	39.86	3.02	140.330
41.50	9.02	132.832	41.50	9.38	132.208	41.50	7.21	136.660	41.50	3.31	143.062
43.15	8.88	135.000	43.15	9.06	132.564	43.15	7.29	137.244	43.15	3.28	135.162
44.79	8.99	134.542	44.79	8.82	131.653	44.79	7.19	132.429	44.79	3.33	136.158
46.43	9.27	136.793	46.43	8.81	132.964	46.43	7.26	131.739	46.43	2.54	134.215
48.07	9.10	134.284	48.07	8.56	132.778	48.07	7.23	138.917	48.07	2.59	139.525
49.71	8.79	132.232	49.71	8.74	132.946	49.71	7.06	139.127	49.71	2.86	132.955
51.35	8.48	131.956	51.35	8.42	136.310	51.35	7.34	137.792	51.35	3.23	130.721
52.99	8.76	131.357	52.99	8.24	133.452	52.99	7.62	137.950	52.99	3.12	129.328
54.63	8.31	133.512	54.63	8.51	134.094	54.63	7.57	141.457	54.63	2.98	137.718
56.27	8.63	131.301	56.27	8.59	134.102	56.27	7.40	137.624	56.27	3.16	141.906
57.91	8.60	131.147	57.91	8.92	132.570	57.91	7.48	138.112	57.91	2.80	135.759
59.55	8.52	132.379	59.55	8.47	133.666	59.55	7.70	139.560	59.55	2.81	136.088
61.19	8.53	133.379	61.19	8.06	134.456	61.19	7.78	139.619	61.19	3.15	139.988
62.83	8.46	131.966	62.83	7.49	134.113	62.83	7.86	138.416	62.83	2.87	137.176
64.47	8.53	132.770	64.47	7.57	133.613	64.47	7.69	137.991	64.47	2.79	130.133
66.11	8.55	131.267	66.11	7.37	133.322	66.11	7.66	138.422	66.11	2.63	133.837
67.75	9.00	131.942	67.75	7.47	133.576	67.75	7.74	138.540	67.75	2.82	151.081
69.39	8.92	133.689	69.39	6.97	132.368	69.39	8.09	138.751	69.39	2.24	144.287
71.03	9.14	133.793	71.03	7.06	128.248	71.03	7.55	139.177	71.03	2.51	150.822
72.67	8.79	136.814	72.67	6.98	126.972	72.67	7.70	140.063	72.67	2.99	139.767
74.31	8.37	132.107	74.31	7.14	128.660	74.31	7.25	140.234	74.31	2.81	139.697
75.96	8.13	132.398	75.96	7.23	136.986	75.96	7.57	138.849	75.96	1.01	150.348
77.60	8.49	137.286	77.60	7.14	130.436	77.60	7.65	139.351			
79.24	8.34	139.083	79.24	6.89	127.028	79.24	7.77	144.867			
80.88	8.61	137.547	80.88	6.87	130.548	80.88	7.32	141.661			
82.52	8.36	140.462	82.52	7.22	126.391	82.52	7.28	142.401			
84.16	8.55	140.228	84.16	7.14	125.342	84.16	7.38	143.828			
85.80	9.04	141.363	85.80	7.08	125.377	85.80	6.90	146.506			
87.44	8.63	142.960	87.44	6.95	127.752	87.44	9.30	145.681			
89.08	8.76	141.555	89.08	6.54	129.342	89.08	5.89	149.895			
90.72	9.04	144.557	90.72	6.73	123.752	90.72	4.80	156.961			
92.36	8.62	144.120	92.36	6.60	125.981	92.36	3.42	139.907			
94.00	8.06	143.228	94.00	6.52	127.089						
95.64	8.44	143.919	95.64	6.02	126.670						
97.28	7.79	142.253	97.28	6.02	123.690						
98.92	7.24	141.288	98.92	5.84	119.242						
100.56	7.44	137.682	100.56	4.51	118.431						
102.20	BD	BD	102.20	3.88	126.308						
103.84	BD	BD									
105.48	BD	BD									
107.12	BD	BD									
108.76	BD	BD									
110.40	BD	BD									

April 17,1998

Distance from the Right Bank (ft)											
1786			2098			2454			2834		
Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.
7.05	5.67	148.655	7.05	10.41	136.725	7.05	6.74	132.319	7.05	5.49	127.809
8.69	6.23	149.207	8.69	9.73	136.257	8.69	7.32	129.651	8.69	5.71	126.119
10.34	6.24	145.240	10.34	9.85	135.054	10.34	7.14	131.572	10.34	5.77	122.181
11.98	6.82	141.409	11.98	10.00	135.531	11.98	7.30	131.210	11.98	6.04	122.144
13.62	6.38	146.457	13.62	10.05	133.161	13.62	7.11	129.924	13.62	5.86	127.608
15.26	6.77	146.973	15.26	10.15	132.616	15.26	7.12	128.280	15.26	5.80	122.242
16.90	6.39	147.779	16.90	10.25	135.013	16.90	7.35	125.877	16.90	6.12	123.247
18.54	6.53	143.585	18.54	10.10	136.855	18.54	6.96	131.714	18.54	5.93	123.145
20.18	5.94	141.820	20.18	10.34	132.942	20.18	6.91	130.318	20.18	5.99	122.358
21.82	6.18	140.708	21.82	9.95	136.309	21.82	7.01	128.618	21.82	5.54	122.872
23.46	6.24	139.928	23.46	10.05	137.738	23.46	6.92	129.670	23.46	5.74	127.263
25.10	6.11	141.850	25.10	9.92	136.112	25.10	7.53	127.529	25.10	6.04	126.533
26.74	5.70	147.627	26.74	9.80	136.873	26.74	7.32	130.493	26.74	5.93	121.377
28.38	5.38	136.038	28.38	10.11	139.540	28.38	7.67	134.411	28.38	5.73	123.581
30.02	5.45	141.717	30.02	10.00	136.249	30.02	7.94	133.308	30.02	5.74	122.946
31.66	5.16	140.913	31.66	9.95	135.895	31.66	7.45	130.787	31.66	5.53	122.106
33.30	5.99	140.761	33.30	10.15	136.022	33.30	7.85	127.631	33.30	5.43	123.239
34.94	5.46	135.365	34.94	9.70	139.048	34.94	7.72	130.261	34.94	5.26	122.540
36.58	5.72	137.068	36.58	9.40	139.485	36.58	7.82	129.879	36.58	5.03	119.138
38.22	5.98	139.450	38.22	9.57	140.202	38.22	7.68	129.069	38.22	5.21	121.837
39.86	5.62	132.870	39.86	9.35	140.426	39.86	7.77	128.758	39.86	5.37	123.797
41.50	5.26	135.632	41.50	9.41	137.983	41.50	7.58	128.939	41.50	5.50	118.600
43.15	5.39	134.013	43.15	9.84	135.122	43.15	7.35	129.950	43.15	5.32	124.778
44.79	5.39	141.373	44.79	9.82	135.108	44.79	7.32	125.391	44.79	5.42	125.989
46.43	5.14	136.707	46.43	9.73	133.921	46.43	7.63	128.525	46.43	5.19	126.826
48.07	4.87	135.027	48.07	9.23	129.461	48.07	7.84	130.841	48.07	5.28	128.031
49.71	4.99	139.881	49.71	8.69	131.619	49.71	7.46	129.089	49.71	5.61	123.792
51.35	4.44	134.791	51.35	8.35	130.105	51.35	7.67	130.213	51.35	5.25	122.100
52.99	4.05	132.371	52.99	7.97	127.474	52.99	7.14	129.388	52.99	5.14	119.119
54.63	4.25	129.137	54.63	7.97	129.470	54.63	7.74	132.509	54.63	5.16	124.529
56.27	4.35	133.257	56.27	8.12	127.578	56.27	8.11	129.405	56.27	5.09	121.762
57.91	4.48	128.968	57.91	8.25	124.430	57.91	7.84	127.761	57.91	4.71	122.771
59.55	4.28	124.920	59.55	7.86	127.659	59.55	7.93	130.316	59.55	5.07	119.055
61.19	4.41	130.962	61.19	8.22	123.215	61.19	7.23	127.499	61.19	4.89	118.009
62.83	4.61	130.522	62.83	8.80	126.985	62.83	7.34	125.564	62.83	5.15	126.140
64.47	4.70	127.262	64.47	8.58	125.836	64.47	7.98	125.814	64.47	4.87	123.679
66.11	4.58	124.794	66.11	8.49	123.856	66.11	7.48	129.233	66.11	5.13	126.262
67.75	4.10	119.864	67.75	8.09	128.841	67.75	7.18	127.540	67.75	4.30	115.860
69.39	3.98	114.726	69.39	8.16	126.368	69.39	7.51	127.776	69.39	3.88	123.341
71.03	3.98	116.523	71.03	7.96	126.284	71.03	6.94	127.374	71.03	4.05	120.701
72.67	3.92	124.541	72.67	8.14	128.039	72.67	6.59	126.271	72.67	3.90	126.205
74.31	3.60	112.355	74.31	7.96	128.947	74.31	6.77	126.309	74.31	4.26	120.139
75.96	3.56	125.845	75.96	8.65	127.865	75.96	7.06	127.919	75.96	2.39	108.111
77.60	3.69	136.945	77.60	8.35	127.932	77.60	6.77	127.453			
79.24	4.38	148.536	79.24	8.30	124.658	79.24	6.96	123.825			
80.88	4.36	145.460	80.88	7.80	122.674	80.88	6.76	126.013			
82.52	4.97	145.922	82.52	7.32	122.928	82.52	6.85	123.180			
84.16	5.55	153.980	84.16	7.80	122.233	84.16	5.97	123.620			
85.80	5.23	158.526	85.80	7.32	120.268	85.80	5.45	126.628			
87.44	4.55	154.526	87.44	7.48	121.007	87.44	5.50	134.493			
89.08	4.68	153.130	89.08	6.72	120.144	89.08	4.70	126.910			
90.72	5.18	151.861	90.72	6.03	116.328	90.72	2.33	120.035			
92.36	5.20	145.206	92.36	6.07	121.792						
94.00	5.13	146.787	94.00	6.06	119.491						
95.64	5.37	138.096	95.64	5.72	118.889						
97.28	4.94	137.097	97.28	5.51	120.350						
98.92	5.22	153.065	98.92	5.01	115.373						
100.56	4.67	166.374	100.56	4.84	115.853						
102.20	BD	BD	102.20	3.99	112.580						
103.84	BD	BD	103.84	4.05	120.650						
105.48	BD	BD	105.48	2.11	106.970						
107.12	BD	BD									
108.76	BD	BD									
110.40	BD	BD									

Table B.6 (continued)

May 8,1998

Distance from the Right Bank (ft)											
1787			2032			2456			2855		
Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.
7.05	9.70	130.336	7.05	11.00	131.554	7.05	8.76	137.931	7.05	4.89	145.777
8.69	9.14	129.784	8.69	11.00	130.959	8.69	8.73	138.320	8.69	5.23	149.141
10.34	9.11	129.549	10.34	11.15	131.205	10.34	8.61	140.952	10.34	5.37	144.727
11.98	9.21	129.087	11.98	11.29	131.830	11.98	8.22	136.472	11.98	5.33	152.046
13.62	9.63	131.671	13.62	11.29	131.255	13.62	8.46	138.536	13.62	5.75	152.791
15.26	9.20	131.297	15.26	10.80	132.353	15.26	8.56	137.174	15.26	5.15	146.482
16.90	9.76	131.825	16.90	11.22	133.744	16.90	8.55	137.332	16.90	5.28	146.113
18.54	9.37	130.841	18.54	10.84	132.633	18.54	8.87	136.364	18.54	5.49	142.521
20.18	9.45	133.382	20.18	11.09	131.534	20.18	8.54	137.568	20.18	5.01	141.387
21.82	9.49	130.681	21.82	11.06	135.060	21.82	8.51	134.281	21.82	4.81	141.920
23.46	9.32	129.341	23.46	11.28	130.778	23.46	8.57	137.389	23.46	5.16	139.047
25.10	9.80	129.855	25.10	11.22	130.147	25.10	8.43	135.994	25.10	5.01	137.363
26.74	9.15	127.832	26.74	11.10	131.573	26.74	8.50	133.264	26.74	5.41	139.798
28.38	9.38	130.845	28.38	11.05	132.123	28.38	8.61	139.987	28.38	5.60	136.402
30.02	8.56	133.182	30.02	10.78	130.569	30.02	9.01	138.751	30.02	5.87	136.947
31.66	8.83	131.460	31.66	10.84	128.966	31.66	8.70	137.567	31.66	5.78	133.734
33.30	9.03	127.216	33.30	11.00	129.309	33.30	8.78	135.711	33.30	5.51	137.316
34.94	9.67	130.199	34.94	10.95	126.592	34.94	8.74	135.061	34.94	5.75	136.873
36.58	9.06	131.596	36.58	10.95	128.258	36.58	8.59	139.816	36.58	5.64	137.785
38.22	8.44	127.021	38.22	10.77	131.048	38.22	8.44	137.048	38.22	5.45	136.511
39.86	9.20	126.106	39.86	10.64	127.523	39.86	8.98	136.110	39.86	5.80	134.862
41.50	9.72	127.729	41.50	10.34	126.768	41.50	9.04	136.236	41.50	5.74	136.806
43.15	10.19	130.601	43.15	10.52	125.351	43.15	8.74	136.886	43.15	5.54	133.681
44.79	10.10	130.731	44.79	10.30	126.329	44.79	8.62	134.198	44.79	6.02	138.512
46.43	10.25	131.326	46.43	10.45	126.381	46.43	9.22	135.692	46.43	6.12	135.782
48.07	9.33	135.228	48.07	10.49	126.648	48.07	9.24	137.188	48.07	5.94	135.447
49.71	10.19	133.878	49.71	10.32	125.114	49.71	8.99	137.898	49.71	5.92	136.168
51.35	10.24	136.039	51.35	10.16	124.090	51.35	8.75	138.632	51.35	6.13	139.668
52.99	9.36	137.075	52.99	9.57	122.230	52.99	9.22	136.485	52.99	6.25	136.894
54.63	9.39	139.579	54.63	9.35	121.212	54.63	8.97	134.155	54.63	6.11	137.110
56.27	9.86	136.902	56.27	9.32	122.980	56.27	9.18	136.550	56.27	6.01	133.362
57.91	10.36	136.913	57.91	9.41	128.813	57.91	9.28	138.297	57.91	6.15	132.340
59.55	9.65	137.315	59.55	9.45	125.135	59.55	9.04	138.577	59.55	6.21	131.510
61.19	9.35	135.128	61.19	9.06	125.480	61.19	9.37	140.128	61.19	5.87	132.917
62.83	9.50	132.621	62.83	9.28	123.477	62.83	9.46	138.446	62.83	5.92	131.138
64.47	9.20	133.020	64.47	9.02	122.655	64.47	9.89	137.607	64.47	6.04	130.304
66.11	10.04	132.111	66.11	8.64	128.014	66.11	8.89	136.914	66.11	5.41	131.241
67.75	9.97	131.851	67.75	8.80	126.109	67.75	9.28	135.215	67.75	5.58	129.391
69.39	9.96	131.728	69.39	8.58	127.168	69.39	9.14	136.309	69.39	5.57	131.754
71.03	10.17	132.961	71.03	8.31	130.535	71.03	8.86	137.146	71.03	5.50	133.090
72.67	9.80	132.760	72.67	8.07	129.239	72.67	8.98	136.406	72.67	5.02	130.813
74.31	10.09	132.627	74.31	7.76	128.928	74.31	8.99	133.965	74.31	5.07	127.582
75.96	10.33	134.730	75.96	7.95	130.196	75.96	9.29	134.156	75.96	5.01	125.189
77.60	10.09	137.174	77.60	8.06	127.308	77.60	9.02	137.358	77.60	4.86	125.268
79.24	10.06	139.972	79.24	8.33	129.681	79.24	8.85	133.303	79.24	3.31	121.645
80.88	9.45	141.144	80.88	7.86	128.817	80.88	8.74	135.395	80.88	3.82	130.815
82.52	9.32	144.603	82.52	7.95	127.334	82.52	7.63	131.844	82.52	4.49	123.226
84.16	9.30	146.276	84.16	8.43	130.425	84.16	7.67	134.775			
85.80	9.29	139.840	85.80	8.47	130.053	85.80	7.61	131.609			
87.44	8.94	142.739	87.44	8.36	131.275	87.44	6.92	135.346			
89.08	8.78	141.635	89.08	8.48	131.941						
90.72	8.91	138.884	90.72	8.20	126.379						
92.36	9.09	140.962	92.36	7.82	132.178						
94.00	9.32	144.151	94.00	7.48	131.087						
95.64	9.68	143.588	95.64	7.86	130.464						
97.28	9.21	142.530	97.28	8.02	135.414						
98.92	9.31	142.932	98.92	7.14	135.633						
100.56	8.69	143.771	100.56	5.70	136.562						
102.20	7.81	141.743	102.20	2.59	126.870						
103.84	7.63	140.598	103.84	1.84	114.647						
105.48	7.49	143.376									
107.12	8.43	142.100									
108.77	8.17	146.048									
110.41	7.95	146.074									
112.05	7.14	147.244									
113.69	6.75	152.326									
115.33	5.00	152.038									
116.97	2.36	154.255									

June 9,1998

Distance from the Right Bank (ft)											
1771			2089			2476			2855		
Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.
7.05	4.30	121.444	7.05	5.16	141.426	7.05	6.76	132.008	7.05	4.03	129.381
8.69	4.71	119.210	8.69	5.12	144.253	8.69	7.33	128.824	8.69	4.39	132.366
10.34	4.49	122.574	10.34	5.52	147.500	10.34	6.68	132.332	10.34	4.68	133.550
11.98	4.24	118.052	11.98	5.04	139.569	11.98	6.52	132.000	11.98	4.75	130.859
13.62	4.17	119.935	13.62	5.05	141.880	13.62	6.73	129.755	13.62	4.66	135.827
15.26	4.38	118.504	15.26	5.04	138.196	15.26	6.54	125.635	15.26	4.73	135.506
16.90	4.15	118.936	16.90	4.72	141.402	16.90	6.67	129.632	16.90	4.70	131.886
18.54	4.32	122.144	18.54	4.87	141.919	18.54	6.85	126.612	18.54	4.64	136.576
20.18	4.45	125.916	20.18	5.05	140.648	20.18	6.71	127.565	20.18	4.40	133.640
21.82	4.88	124.011	21.82	5.08	145.766	21.82	7.46	129.412	21.82	4.78	132.858
23.46	4.80	123.864	23.46	4.81	144.154	23.46	7.31	127.636	23.46	4.54	136.757
25.10	4.62	122.010	25.10	4.15	147.240	25.10	6.85	130.997	25.10	4.76	135.056
26.74	5.13	120.172	26.74	4.31	144.072	26.74	6.62	130.318	26.74	4.71	134.548
28.38	4.78	115.862	28.38	3.68	140.247	28.38	6.91	133.037	28.38	4.61	130.906
30.02	5.15	118.605	30.02	4.26	141.622	30.02	6.51	129.291	30.02	4.56	132.290
31.66	5.34	120.662	31.66	4.04	148.670	31.66	6.56	132.710	31.66	4.93	132.949
33.30	5.30	122.137	33.30	3.89	148.266	33.30	6.34	135.042	33.30	4.47	138.035
34.94	5.12	122.601	34.94	4.25	148.285	34.94	6.79	130.868	34.94	4.31	136.140
36.58	4.93	126.283	36.58	4.14	147.644	36.58	6.65	131.138	36.58	4.25	133.844
38.22	4.96	124.194	38.22	4.03	150.012	38.22	6.32	129.836	38.22	4.65	127.492
39.86	5.00	121.093	39.86	4.24	146.617	39.86	6.82	128.027	39.86	4.41	129.238
41.50	4.62	131.144	41.50	4.70	146.310	41.50	6.77	129.041	41.50	4.26	136.842
43.15	4.39	128.988	43.15	4.20	145.801	43.15	6.55	127.938	43.15	5.00	130.186
44.79	5.02	130.601	44.79	4.60	139.749	44.79	6.57	124.483	44.79	4.29	131.779
46.43	4.95	133.281	46.43	4.85	137.604	46.43	6.06	127.410	46.43	4.34	131.781
48.07	4.82	140.359	48.07	4.98	142.851	48.07	6.66	124.481	48.07	4.04	131.282
49.71	5.14	133.681	49.71	4.99	142.670	49.71	6.44	122.135	49.71	4.06	124.332
51.35	4.87	132.378	51.35	4.90	127.814	51.35	7.10	127.002	51.35	4.18	129.967
52.99	4.82	131.520	52.99	4.34	134.296	52.99	6.60	127.735	52.99	4.37	127.652
54.63	5.28	126.585	54.63	4.45	136.375	54.63	5.85	129.292	54.63	4.22	130.210
56.27	5.54	132.575	56.27	4.29	132.271	56.27	6.00	126.444	56.27	4.14	138.117
57.91	5.23	134.084	57.91	4.43	128.348	57.91	6.38	129.662	57.91	3.70	130.482
59.55	5.06	130.763	59.55	4.63	137.268	59.55	5.99	128.591	59.55	3.54	129.928
61.19	5.17	126.354	61.19	4.12	135.000	61.19	5.41	131.804	61.19	3.76	130.466
62.83	5.37	131.927	62.83	4.25	135.814	62.83	5.53	133.894	62.83	3.60	130.822
64.47	5.17	127.343	64.47	3.93	139.373	64.47	5.27	133.614	64.47	3.44	137.087
66.11	4.89	128.576	66.11	4.43	133.831	66.11	5.28	134.647	66.11	2.95	137.980
67.75	4.84	127.895	67.75	4.34	143.476	67.75	5.31	138.331	67.75	2.47	142.352
69.39	4.35	126.853	69.39	4.21	134.589	69.39	5.17	144.382	69.39	2.11	140.266
71.03	4.30	125.035	71.03	3.90	133.093	71.03	5.50	131.418			
72.67	4.42	127.483	72.67	3.42	133.989	72.67	5.65	132.386			
74.31	4.26	130.999	74.31	3.47	125.884	74.31	5.18	131.971			
75.96	4.18	130.007	75.96	3.46	122.951	75.96	5.20	133.670			
77.60	4.01	127.517	77.60	3.54	126.020	77.60	4.61	143.856			
79.24	4.39	128.566	79.24	3.58	118.937	79.24	4.31	139.866			
80.88	3.89	123.730	80.88	3.29	127.133	80.88	4.00	141.755			
82.52	4.08	119.140	82.52	3.12	125.096	82.52	3.87	148.567			
84.16	3.72	120.816	84.16	3.40	117.380	84.16	3.94	145.161			
85.80	3.74	126.759	85.80	3.46	114.624						
87.44	3.21	116.696	87.44	3.42	120.898						
89.08	3.25	105.676	89.08	2.69	125.708						
90.72	3.09	114.494	90.72	2.25	125.382						
92.36	3.56	108.251	92.36	3.37	130.615						
94.00	3.43	111.238	94.00	3.48	123.960						
95.64	3.48	108.332	95.64	3.91	135.000						
97.28	4.21	105.694	97.28	2.72	139.054						
98.92	4.10	106.582	98.92	2.68	140.838						
100.56	2.94	103.397									
102.20	2.47	100.020									
103.84	2.25	97.765									
105.48	2.05	89.730									

Table B.6 (continued)

August 3,1998

Distance from the Right Bank (ft)											
1791			2076			2474			2881		
Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.
7.05	2.73	156.205	7.05	5.58	126.277	7.05	8.17	129.034	7.05	4.87	133.362
8.69	2.49	148.338	8.69	5.69	123.617	8.69	7.72	127.683	8.69	4.63	133.047
10.34	2.84	154.767	10.34	5.57	124.289	10.34	7.82	126.466	10.34	5.30	128.333
11.98	3.27	146.677	11.98	4.89	123.968	11.98	7.83	126.356	11.98	5.06	129.611
13.62	2.85	150.984	13.62	5.34	124.882	13.62	7.16	126.655	13.62	5.15	135.826
15.26	2.53	149.942	15.26	5.29	122.201	15.26	7.16	126.371	15.26	5.02	131.341
16.90	2.86	145.580	16.90	5.34	124.695	16.90	7.38	125.147	16.90	5.41	133.501
18.54	2.95	143.551	18.54	5.14	124.522	18.54	7.29	124.605	18.54	4.89	127.332
20.18	3.18	149.513	20.18	5.07	122.795	20.18	7.82	127.692	20.18	4.83	130.618
21.82	2.46	143.680	21.82	5.11	122.005	21.82	7.71	129.403	21.82	4.53	130.655
23.46	2.56	143.379	23.46	5.08	126.337	23.46	7.53	129.786	23.46	4.89	131.081
25.10	2.40	136.608	25.10	5.20	125.365	25.10	7.21	129.886	25.10	4.99	127.465
26.74	3.16	145.286	26.74	5.42	126.315	26.74	7.40	129.188	26.74	4.98	132.279
28.38	3.50	144.550	28.38	5.70	124.413	28.38	7.23	125.356	28.38	4.93	131.871
30.02	3.35	145.905	30.02	5.02	124.593	30.02	7.06	122.449	30.02	4.48	129.768
31.66	3.23	144.740	31.66	5.81	125.575	31.66	7.67	127.032	31.66	4.25	134.374
33.30	3.80	145.652	33.30	5.69	124.340	33.30	7.38	130.366	33.30	4.45	127.816
34.94	3.74	143.633	34.94	5.61	123.188	34.94	7.26	128.854	34.94	4.59	126.124
36.58	3.54	145.396	36.58	5.61	129.282	36.58	7.63	124.380	36.58	4.52	131.616
38.22	4.10	145.458	38.22	5.24	130.687	38.22	7.52	129.300	38.22	5.08	133.404
39.86	3.63	149.605	39.86	5.08	131.468	39.86	7.21	125.483	39.86	4.71	133.194
41.50	3.93	147.609	41.50	5.28	127.632	41.50	7.39	134.118	41.50	4.15	132.791
43.15	3.18	148.570	43.15	5.26	130.373	43.15	7.49	127.126	43.15	4.04	135.033
44.79	3.82	142.864	44.79	5.18	130.735	44.79	7.32	126.141	44.79	3.66	134.818
46.43	3.45	150.654	46.43	4.65	128.382	46.43	7.06	127.120	46.43	3.85	134.551
48.07	4.15	144.626	48.07	5.16	128.073	48.07	6.97	127.889	48.07	3.95	142.768
49.71	3.81	149.900	49.71	4.67	129.445	49.71	6.87	129.515	49.71	4.06	137.782
51.35	3.46	149.865	51.35	4.98	128.660	51.35	6.44	125.790	51.35	3.72	133.927
52.99	3.82	150.926	52.99	4.45	132.373	52.99	7.09	125.374	52.99	3.76	136.097
54.63	3.34	148.042	54.63	4.71	126.726	54.63	6.48	128.053	54.63	3.68	137.348
56.27	3.62	156.549	56.27	4.26	124.327	56.27	7.10	128.221	56.27	3.12	116.188
57.91	3.32	156.325	57.91	4.67	126.347	57.91	6.66	129.422			
59.55	3.70	165.698	59.55	4.51	121.271	59.55	6.35	131.019			
61.19	2.91	161.933	61.19	4.56	124.250	61.19	6.42	129.633			
62.83	3.22	162.636	62.83	4.83	124.392	62.83	6.74	128.337			
64.47	3.08	166.260	64.47	5.08	124.840	64.47	6.29	129.132			
66.11	3.13	161.186	66.11	4.27	133.536	66.11	5.89	132.179			
67.75	3.11	163.399	67.75	3.99	135.600	67.75	6.14	129.315			
69.39	3.20	157.087	69.39	4.03	129.782	69.39	6.51	126.616			
71.03	3.46	141.510	71.03	4.56	132.202	71.03	5.65	123.579			
72.67	3.48	151.718	72.67	4.28	133.883	72.67	4.05	125.700			
74.31	3.44	153.826	74.31	4.16	131.126						
75.96	3.41	146.295	75.96	4.03	131.234						
77.60	3.45	154.776	77.60	3.56	126.427						
79.24	3.37	148.396	79.24	3.80	126.603						
80.88	3.16	147.711	80.88	3.54	127.082						
82.52	2.76	142.722	82.52	2.44	135.273						
84.16	2.77	142.220									
85.80	1.56	140.040									
87.44	1.07	350.854									

Table B.7. ADCP flow velocity and direction data at Line 6.

February 27,1998

Distance from the Right Bank (ft)											
3211			3811			4090			4718		
Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.
7.05	4.82	197.745	7.05	6.98	209.989	7.05	7.29	205.562	7.05	4.11	240.590
8.69	4.72	200.528	8.69	6.88	206.858	8.69	7.21	201.588	8.69	3.92	245.921
10.34	4.91	203.877	10.34	6.90	205.200	10.34	7.51	207.561	10.34	3.89	250.525
11.98	4.51	205.186	11.98	6.69	210.463	11.98	7.18	206.940	11.98	4.60	250.080
13.62	4.43	197.630	13.62	7.12	208.585	13.62	7.50	205.432	13.62	4.11	254.023
15.26	4.29	203.388	15.26	6.56	207.835	15.26	6.71	204.509	15.26	3.80	247.601
16.90	4.43	200.919	16.90	7.08	209.000	16.90	6.77	205.112	16.90	4.39	241.980
18.54	5.21	203.545	18.54	7.12	208.265	18.54	7.01	206.325	18.54	4.46	244.227
20.18	4.76	204.215	20.18	6.96	208.390	20.18	6.93	210.206	20.18	4.43	244.004
21.82	4.67	203.394	21.82	6.65	210.222	21.82	6.91	207.137	21.82	5.27	238.388
23.46	4.48	211.827	23.46	6.63	206.286	23.46	6.69	206.829	23.46	5.17	237.752
25.10	4.77	205.401	25.10	6.81	208.441	25.10	6.46	207.385	25.10	5.38	240.402
26.74	4.74	209.651	26.74	7.55	206.253	26.74	6.35	203.082	26.74	5.09	235.132
28.38	4.38	198.258	28.38	7.20	210.454	28.38	6.33	204.599	28.38	4.99	236.948
30.02	4.55	203.258	30.02	6.84	211.982	30.02	6.08	203.966	30.02	4.93	231.352
31.66	4.26	204.590	31.66	7.44	209.491	31.66	6.49	206.552	31.66	4.95	230.836
33.30	4.27	209.543	33.30	7.17	205.170	33.30	6.57	208.946	33.30	4.94	226.829
34.94	3.71	204.910	34.94	6.53	202.711	34.94	6.53	207.608	34.94	5.48	223.883
36.58	4.59	202.015	36.58	6.66	205.530	36.58	6.30	214.071	36.58	5.25	222.216
38.22	3.92	197.571	38.22	6.77	208.850	38.22	6.18	216.139	38.22	5.17	228.089
39.86	4.09	205.186	39.86	6.54	207.863	39.86	6.53	213.355	39.86	4.80	229.433
41.50	3.91	199.379	41.50	6.55	208.748	41.50	6.06	212.554	41.50	4.91	225.000
43.15	3.83	201.975	43.15	6.97	210.899	43.15	5.77	212.371	43.15	4.74	228.116
44.79	3.01	187.450	44.79	6.92	206.954	44.79	6.81	212.081	44.79	4.39	232.745
46.43	2.54	194.646	46.43	6.48	205.476	46.43	6.32	211.229	46.43	4.84	233.907
48.07	2.03	153.834	48.07	6.08	207.767	48.07	6.71	213.985	48.07	4.61	230.518
			49.71	6.19	201.203	49.71	6.36	210.943	49.71	4.53	228.908
			51.35	6.19	207.177	51.35	6.73	213.938	51.35	4.50	234.516
			52.99	5.78	205.255	52.99	6.68	215.181	52.99	4.65	235.167
			54.63	6.01	203.121	54.63	6.14	213.002	54.63	4.40	234.139
			56.27	6.00	208.373	56.27	6.76	212.556	56.27	4.46	234.183
			57.91	5.79	206.652	57.91	7.10	208.082	57.91	4.01	233.552
			59.55	5.67	207.188	59.55	6.75	207.873	59.55	3.75	233.671
			61.19	5.87	210.794	61.19	6.90	208.040	61.19	3.50	237.294
			62.83	5.70	210.252	62.83	6.61	207.570	62.83	3.42	227.058
			64.47	5.50	212.875	64.47	6.79	205.030	64.47	3.86	240.297
			66.11	5.65	211.078	66.11	6.49	207.912	66.11	4.05	230.890
			67.75	5.00	210.132	67.75	5.98	201.696	67.75	3.63	232.261
			69.39	4.88	203.962	69.39	6.30	207.099	69.39	3.79	234.468
			71.03	4.65	201.591	71.03	6.30	202.650	71.03	3.59	223.814
			72.67	4.23	197.521	72.67	6.47	203.252	72.67	3.81	222.035
			74.31	3.69	187.510	74.31	6.27	205.613	74.31	3.19	219.443
			75.96	2.79	176.020	75.96	5.47	207.979	75.96	3.53	220.925
						77.60	5.47	207.287	77.60	3.46	221.850
						79.24	5.04	207.166	79.24	3.32	222.198
						80.88	4.37	207.430	80.88	2.90	221.241
						82.52	4.41	202.656	82.52	2.70	220.911
						84.16	4.64	210.686	84.16	3.17	224.664
						85.80	4.28	212.959	85.80	3.27	214.200
						87.44	3.07	187.558	87.44	3.43	184.932
						89.08	1.46	194.349	89.08	2.33	220.312
									90.72	1.15	233.816

March 23,1998

Distance from the Right Bank (ft)											
3218			3825			4010			4743		
Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.
7.05	3.44	212.660	7.05	6.46	204.468	7.05	6.08	206.745	7.05	2.78	223.467
8.69	3.72	209.776	8.69	6.10	201.126	8.69	6.15	209.218	8.69	2.86	218.537
10.34	3.88	204.938	10.34	6.40	201.518	10.34	5.82	204.081	10.34	2.58	217.862
11.98	3.56	210.801	11.98	6.34	200.612	11.98	6.68	201.838	11.98	2.05	220.204
13.62	3.63	209.205	13.62	6.66	204.671	13.62	6.03	206.286	13.62	2.85	224.814
15.26	3.44	203.779	15.26	6.16	202.766	15.26	6.23	206.012	15.26	2.56	229.526
16.90	3.31	210.935	16.90	6.21	201.329	16.90	5.96	203.431	16.90	2.60	214.832
18.54	3.43	209.854	18.54	6.48	204.866	18.54	5.62	207.746	18.54	2.23	221.122
20.18	3.84	216.625	20.18	6.31	205.618	20.18	5.94	205.644	20.18	2.28	214.011
21.82	3.20	207.326	21.82	6.53	204.725	21.82	5.66	206.387	21.82	2.57	230.129
23.46	3.41	210.680	23.46	6.49	205.399	23.46	5.91	206.466	23.46	2.44	226.089
25.10	3.69	206.998	25.10	6.56	204.230	25.10	6.08	207.256	25.10	2.80	218.576
26.74	3.08	212.115	26.74	6.68	204.286	26.74	6.48	211.212	26.74	2.98	213.077
28.38	3.16	209.361	28.38	6.60	201.759	28.38	6.07	209.073	28.38	2.91	218.720
30.02	3.25	207.834	30.02	6.33	204.189	30.02	6.62	209.361	30.02	2.87	222.587
31.66	3.03	217.478	31.66	6.70	204.230	31.66	6.29	208.062	31.66	3.10	218.944
33.30	2.90	223.120	33.30	6.06	205.330	33.30	6.29	212.588	33.30	2.91	211.274
34.94	2.91	218.811	34.94	6.55	207.361	34.94	6.55	213.340	34.94	2.49	214.380
36.58	2.58	227.060	36.58	6.66	208.408	36.58	6.41	214.064	36.58	3.13	213.374
38.22	2.44	226.091	38.22	6.47	207.931	38.22	6.64	212.441	38.22	2.77	210.661
39.86	2.82	223.259	39.86	6.54	210.914	39.86	6.70	210.030	39.86	3.03	213.398
41.50	2.95	229.509	41.50	6.48	206.124	41.50	6.65	209.296	41.50	3.28	218.910
43.15	2.37	217.298	43.15	6.12	208.667	43.15	6.58	208.111	43.15	3.43	211.518
44.79	2.34	223.464	44.79	6.23	205.296	44.79	6.77	210.606	44.79	3.75	206.139
46.43	2.09	218.998	46.43	6.20	208.477	46.43	6.80	205.476	46.43	3.88	202.098
48.07	N/A	N/A	48.07	N/A	N/A	48.07	N/A	N/A	48.07	N/A	N/A
49.71	1.21	143.829	49.71	5.52	206.154	49.71	6.95	206.190	49.71	3.90	203.287
51.35	1.34	142.510	51.35	5.81	203.683	51.35	6.79	210.185	51.35	3.72	203.424
52.99	0.44	141.170	52.99	5.85	204.047	52.99	6.41	213.348	52.99	3.53	206.994
			54.63	6.16	205.131	54.63	6.07	211.532	54.63	3.41	205.999
			56.27	5.78	208.849	56.27	6.48	208.421	56.27	3.15	205.096
			57.91	5.59	207.813	57.91	6.37	211.242	57.91	3.51	203.642
			59.55	5.79	207.160	59.55	6.38	210.721	59.55	3.16	208.107
			61.19	5.68	214.710	61.19	6.45	214.328	61.19	3.50	197.959
			62.83	6.01	211.184	62.83	6.49	215.137	62.83	3.65	199.706
			64.47	5.27	212.176	64.47	6.52	211.819	64.47	3.45	198.108
			66.11	5.66	217.275	66.11	6.30	211.256	66.11	3.18	204.082
			67.75	5.57	211.097	67.75	6.18	210.265	67.75	3.21	204.075
			69.39	5.79	214.492	69.39	5.79	211.548	69.39	3.31	202.139
			71.03	5.02	218.016	71.03	5.58	210.548	71.03	3.80	204.886
			72.67	5.53	215.613	72.67	5.67	211.657	72.67	3.59	208.159
			74.31	4.75	214.710	74.31	5.66	205.272	74.31	3.36	207.667
			75.96	4.51	216.844	75.96	5.77	202.424	75.96	3.42	209.008
			77.60	4.66	215.888	77.60	5.68	203.411	77.60	3.11	206.553
			79.24	4.44	219.211	79.24	5.65	205.256	79.24	3.38	208.881
			80.88	4.28	216.061	80.88	5.06	200.552	80.88	3.15	210.001
			82.52	3.98	217.328	82.52	5.34	198.802	82.52	3.29	212.339
			84.16	3.52	213.551	84.16	5.66	200.758	84.16	3.25	207.334
			85.80	3.28	215.953	85.80	5.09	203.262	85.80	3.01	203.442
			87.44	3.05	217.008	87.44	5.03	208.975	87.44	2.41	200.188
			89.08	3.01	218.773	89.08	4.91	214.370	89.08	2.08	206.997
						90.72	3.47	222.128			
						92.36	2.99	210.662			
						94.00	2.48	215.038			

Table B.7 (continued)

April 10,1998

Distance from the Right Bank (ft)											
3203			3778			4095			4676		
Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.
7.05	4.14	214.710	7.05	7.15	204.072	7.05	7.51	204.090	7.05	4.57	202.923
8.69	3.91	215.437	8.69	6.45	202.375	8.69	7.24	204.975	8.69	4.54	204.211
10.34	3.82	220.748	10.34	6.54	205.163	10.34	7.15	202.660	10.34	3.99	205.869
11.98	3.80	219.571	11.98	6.94	205.620	11.98	7.07	206.173	11.98	4.14	207.845
13.62	4.21	221.270	13.62	6.77	205.386	13.62	7.30	205.378	13.62	3.97	209.170
15.26	4.05	215.478	15.26	6.63	205.918	15.26	7.07	203.544	15.26	3.62	208.681
16.90	4.01	214.562	16.90	6.62	203.706	16.90	7.46	204.152	16.90	3.83	207.356
18.54	3.62	216.849	18.54	6.58	206.872	18.54	7.86	203.557	18.54	3.70	208.132
20.18	3.92	213.225	20.18	7.04	207.449	20.18	7.27	205.293	20.18	3.46	204.475
21.82	3.65	214.747	21.82	7.09	208.225	21.82	7.45	204.024	21.82	3.08	213.589
23.46	4.37	226.064	23.46	6.94	207.958	23.46	7.85	203.221	23.46	3.80	207.560
25.10	3.92	223.238	25.10	6.99	206.565	25.10	7.50	204.334	25.10	3.32	210.566
26.74	4.00	224.435	26.74	6.80	209.594	26.74	7.43	207.809	26.74	3.54	209.080
28.38	4.01	227.357	28.38	6.96	206.529	28.38	7.51	205.053	28.38	3.27	204.791
30.02	3.68	224.892	30.02	7.06	202.563	30.02	7.71	204.710	30.02	3.12	201.757
31.66	3.56	222.536	31.66	6.60	209.190	31.66	7.71	204.101	31.66	2.55	202.540
33.30	3.25	225.000	33.30	6.56	212.188	33.30	7.41	207.779	33.30	2.84	195.354
34.94	2.99	228.731	34.94	6.82	208.525	34.94	7.46	206.667	34.94	3.37	196.267
36.58	2.90	239.147	36.58	6.94	211.827	36.58	7.20	208.304	36.58	3.38	195.938
38.22	3.06	228.912	38.22	6.79	209.525	38.22	7.35	207.686	38.22	3.06	200.088
39.86	2.57	230.494	39.86	6.73	213.341	39.86	6.89	204.478	39.86	2.95	199.383
41.50	3.04	235.074	41.50	6.60	207.291	41.50	6.97	203.464	41.50	3.06	200.844
43.15	3.08	243.462	43.15	6.89	206.650	43.15	6.81	206.824	43.15	2.85	202.869
44.79	2.19	234.931	44.79	6.87	209.015	44.79	6.33	207.295	44.79	2.90	201.717
46.43	2.31	234.462	46.43	6.63	211.188	46.43	6.43	205.819	46.43	2.74	204.722
48.07	1.98	233.062	48.07	6.46	211.009	48.07	6.80	208.112	48.07	3.19	201.758
			49.71	6.76	212.079	49.71	6.66	209.304	49.71	3.40	197.998
			51.35	7.07	212.798	51.35	6.80	211.229	51.35	3.26	205.869
			52.99	7.11	212.070	52.99	6.36	207.834	52.99	2.73	208.259
			54.63	6.56	213.714	54.63	6.72	212.465	54.63	2.94	207.336
			56.27	6.67	211.713	56.27	6.28	215.051	56.27	2.82	202.333
			57.91	6.81	217.008	57.91	6.06	216.442	57.91	2.95	208.076
			59.55	6.74	215.168	59.55	5.76	215.302	59.55	3.09	205.204
			61.19	6.73	211.730	61.19	5.65	218.000	61.19	3.33	205.808
			62.83	7.12	213.214	62.83	5.49	217.521	62.83	3.49	207.023
			64.47	7.19	213.560	64.47	5.85	213.654	64.47	3.42	208.089
			66.11	7.05	211.398	66.11	5.17	215.060	66.11	3.89	205.549
			67.75	7.08	216.217	67.75	5.01	218.115	67.75	3.43	212.580
			69.39	7.30	218.431	69.39	4.82	217.861	69.39	3.25	208.841
			71.03	6.86	214.139	71.03	5.09	219.300	71.03	3.43	210.126
			72.67	6.46	215.642	72.67	5.07	220.167	72.67	3.54	216.222
			74.31	6.87	210.152	74.31	5.11	221.747	74.31	2.98	212.974
			75.96	6.08	210.232	75.96	5.12	220.896	75.96	3.14	213.806
			77.60	4.09	208.229	77.60	5.33	219.476	77.60	3.24	218.759
			79.24	4.78	212.534	79.24	5.05	217.793	79.24	3.45	212.889
			80.88	3.98	210.337	80.88	5.48	222.066	80.88	3.30	224.395
						82.52	4.84	214.820	82.52	3.19	225.793
						84.16	5.31	216.657	84.16	3.50	226.517
						85.80	5.07	214.594	85.80	3.08	222.968
						87.44	4.57	217.240	87.44	2.74	224.806
						89.08	4.80	217.607	89.08	2.67	214.784
						90.72	4.88	214.042	90.72	2.13	217.294
						92.36	4.40	214.684	92.36	2.65	211.037
						94.00	4.19	218.548	94.00	2.35	199.826
						95.64	4.19	220.971	95.64	2.22	207.132
						97.28	4.00	216.522	97.28	1.38	254.017
						98.92	3.12	237.982	98.92	1.21	232.880
						100.56	1.88	259.141	100.56	1.03	241.118

April 17,1998

Distance from the Right Bank (ft)											
3159			3826			4131			4695		
Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.
7.05	4.68	200.622	7.05	6.37	202.590	7.05	5.66	205.035	7.05	3.49	209.384
8.69	4.67	199.429	8.69	6.20	207.134	8.69	5.70	205.739	8.69	3.78	209.190
10.34	4.36	203.612	10.34	6.49	203.168	10.34	5.44	209.377	10.34	3.82	219.006
11.98	4.77	198.572	11.98	6.34	203.448	11.98	5.23	211.518	11.98	3.77	212.391
13.62	4.49	195.917	13.62	6.51	204.226	13.62	5.40	207.640	13.62	3.48	218.719
15.26	4.66	198.511	15.26	6.52	205.470	15.26	5.48	207.655	15.26	3.38	212.088
16.90	4.43	203.182	16.90	6.00	206.607	16.90	5.10	210.148	16.90	3.33	213.862
18.54	4.55	202.054	18.54	6.00	204.478	18.54	5.60	210.860	18.54	3.35	209.724
20.18	5.20	199.406	20.18	6.49	205.897	20.18	5.11	208.801	20.18	3.89	211.569
21.82	4.00	205.641	21.82	6.04	205.451	21.82	4.93	207.008	21.82	3.68	215.704
23.46	3.83	195.669	23.46	6.12	208.152	23.46	5.24	208.089	23.46	3.59	210.038
25.10	3.57	194.215	25.10	5.99	206.636	25.10	5.05	214.578	25.10	3.52	211.247
26.74	3.69	197.582	26.74	5.94	202.649	26.74	5.27	212.780	26.74	3.15	220.601
28.38	4.06	202.257	28.38	5.52	200.590	28.38	5.19	208.006	28.38	3.55	211.618
30.02	3.43	197.707	30.02	5.79	203.616	30.02	5.47	204.444	30.02	3.46	211.625
31.66	3.34	201.215	31.66	5.56	205.593	31.66	5.01	207.320	31.66	3.08	208.202
33.30	3.49	199.509	33.30	5.36	205.845	33.30	5.44	207.973	33.30	3.33	205.706
34.94	2.96	199.902	34.94	5.61	203.577	34.94	5.34	205.605	34.94	3.74	214.206
36.58	3.49	198.878	36.58	6.00	209.173	36.58	5.61	211.998	36.58	3.73	214.753
38.22	3.26	198.945	38.22	5.55	208.445	38.22	5.53	209.121	38.22	3.68	215.847
39.86	3.23	194.699	39.86	5.81	206.405	39.86	5.77	205.078	39.86	4.07	213.728
41.50	2.88	198.167	41.50	5.76	204.825	41.50	5.70	202.463	41.50	4.26	207.551
43.15	3.07	206.565	43.15	5.97	202.170	43.15	5.47	207.763	43.15	4.12	210.995
44.79	2.49	200.229	44.79	5.60	204.715	44.79	5.90	209.788	44.79	3.95	214.509
46.43	2.00	203.491	46.43	5.74	210.301	46.43	5.57	206.490	46.43	3.84	207.353
48.07	1.92	205.668	48.07	5.72	208.005	48.07	5.70	206.624	48.07	3.74	210.506
			49.71	5.72	207.520	49.71	5.57	206.942	49.71	3.45	206.760
			51.35	5.88	206.336	51.35	5.88	212.148	51.35	3.66	205.119
			52.99	5.72	205.859	52.99	5.59	213.307	52.99	4.58	210.020
			54.63	5.92	207.914	54.63	5.91	206.437	54.63	3.59	208.907
			56.27	5.90	211.603	56.27	5.74	204.455	56.27	3.97	209.592
			57.91	3.31	207.182	57.91	5.88	209.499	57.91	3.86	211.039
			59.55	6.18	204.850	59.55	5.56	207.140	59.55	3.93	212.056
			61.19	5.71	204.812	61.19	5.06	206.881	61.19	3.76	212.969
			62.83	5.61	209.762	62.83	5.31	207.024	62.83	4.06	206.958
			64.47	5.66	206.298	64.47	5.77	203.827	64.47	3.81	213.950
			66.11	5.56	210.424	66.11	5.24	204.607	66.11	3.59	204.552
			67.75	5.40	207.702	67.75	5.34	202.325	67.75	4.03	208.234
			69.39	5.37	212.855	69.39	5.26	207.061	69.39	4.31	211.442
			71.03	4.91	209.393	71.03	5.55	207.353	71.03	3.86	211.949
			72.67	4.54	211.106	72.67	5.40	208.466	72.67	3.57	200.383
			74.31	4.18	212.730	74.31	4.87	210.951	74.31	3.75	204.008
			75.96	4.41	213.324	75.96	5.10	211.931	75.96	3.47	202.395
			77.60	4.52	210.721	77.60	5.02	215.351	77.60	4.11	203.967
			79.24	3.92	205.043	79.24	4.79	218.635	79.24	3.58	207.832
			80.88	4.04	204.671	80.88	4.64	218.831	80.88	3.00	206.958
			82.52	3.81	208.752	82.52	4.29	219.474	82.52	3.26	213.019
			84.16	3.31	205.651	84.16	4.02	215.728	84.16	2.73	211.720
			85.80	2.91	208.183	85.80	4.45	214.476	85.80	3.08	213.385
			87.44	2.44	206.738	87.44	4.73	220.360	87.44	2.82	212.563
			89.08	2.11	205.228	89.08	4.55	216.462	89.08	2.66	196.645
			90.72	1.98	207.438	90.72	4.02	218.371	90.72	2.08	202.606
			92.36	1.91	208.632	92.36	3.62	220.881	92.36	2.01	225.993
						94.00	2.91	221.070			
						95.64	3.09	222.796			
						97.28	2.21	219.678			

Table B.7 (continued)

June 9,1998

Distance from the Right Bank (ft)											
3197			3786			4093			4703		
Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.
7.05	3.64	212.087	7.05	5.46	202.051	7.05	6.33	196.839	7.05	2.30	203.489
8.69	3.85	211.534	8.69	5.81	205.148	8.69	6.37	198.670	8.69	2.74	196.181
10.34	3.49	217.021	10.34	6.01	199.038	10.34	6.50	200.238	10.34	2.76	198.349
11.98	4.02	214.858	11.98	5.06	204.121	11.98	5.76	203.134	11.98	2.71	200.013
13.62	3.60	211.895	13.62	5.65	203.854	13.62	6.04	196.031	13.62	2.79	205.782
15.26	3.45	212.271	15.26	5.96	207.876	15.26	6.34	196.963	15.26	2.23	199.370
16.90	3.65	221.099	16.90	5.95	205.760	16.90	5.94	202.172	16.90	2.04	209.242
18.54	3.59	219.208	18.54	5.39	201.944	18.54	5.65	201.542	18.54	2.82	211.124
20.18	3.20	218.431	20.18	5.27	202.894	20.18	6.28	204.811	20.18	2.54	209.019
21.82	3.05	224.607	21.82	5.46	203.917	21.82	6.26	203.636	21.82	2.74	208.621
23.46	2.75	218.031	23.46	5.27	206.788	23.46	6.25	196.933	23.46	2.48	212.826
25.10	2.78	222.560	25.10	5.02	198.187	25.10	6.00	201.348	25.10	2.59	205.948
26.74	2.92	208.898	26.74	4.96	199.825	26.74	5.73	196.724	26.74	2.90	211.086
28.38	2.53	219.425	28.38	5.71	201.759	28.38	5.54	195.997	28.38	2.83	207.366
30.02	2.21	222.474	30.02	4.89	200.731	30.02	5.93	195.444	30.02	2.24	204.201
31.66	1.64	204.254	31.66	5.20	206.872	31.66	6.03	198.346	31.66	2.73	210.668
33.30	1.53	214.564	33.30	5.23	207.481	33.30	6.03	198.918	33.30	2.56	210.863
			34.94	4.89	205.242	34.94	5.62	202.460	34.94	2.52	211.681
			36.58	4.80	208.298	36.58	6.09	203.446	36.58	2.80	203.472
			38.22	4.31	206.624	38.22	6.34	196.316	38.22	2.87	212.311
			39.86	4.66	204.344	39.86	6.14	201.420	39.86	2.75	207.147
			41.50	4.81	204.658	41.50	5.70	200.743	41.50	2.38	204.731
			43.15	4.92	210.859	43.15	6.28	200.139	43.15	2.84	204.965
			44.79	4.56	204.905	44.79	6.44	198.361	44.79	3.18	204.767
			46.43	4.68	199.681	46.43	6.19	198.550	46.43	3.23	206.201
			48.07	4.70	207.548	48.07	6.01	201.848	48.07	3.05	212.064
			49.71	4.18	206.444	49.71	5.92	200.252	49.71	2.95	207.735
			51.35	4.30	209.555	51.35	5.89	201.452	51.35	2.66	202.772
			52.99	4.42	209.402	52.99	5.81	197.667	52.99	2.77	200.755
			54.63	4.61	214.651	54.63	5.37	202.620	54.63	2.48	213.249
			56.27	4.17	200.318	56.27	5.70	202.630	56.27	2.92	203.917
			57.91	4.18	204.172	57.91	5.93	201.854	57.91	3.19	202.842
			59.55	4.26	211.055	59.55	5.60	197.224	59.55	2.88	212.421
			61.19	4.56	213.484	61.19	5.39	198.578	61.19	2.83	208.854
			62.83	4.38	213.357	62.83	5.55	197.053	62.83	2.85	207.154
			64.47	3.71	212.973	64.47	5.85	197.408	64.47	2.92	211.603
			66.11	3.63	210.137	66.11	5.47	196.870	66.11	3.34	208.305
			67.75	3.80	196.808	67.75	5.55	195.499	67.75	2.81	219.403
			69.39	3.22	193.923	69.39	5.00	202.429	69.39	2.98	212.379
			71.03	3.59	193.642	71.03	5.33	202.666	71.03	3.10	204.720
			72.67	2.78	220.213	72.67	5.32	197.339	72.67	3.30	211.238
						74.31	4.75	202.352	74.31	3.21	210.261
						75.96	4.78	203.395	75.96	2.87	206.331
						77.60	4.78	200.837	77.60	2.75	210.483
						79.24	4.21	204.370	79.24	2.61	198.754
						80.88	3.70	211.687	80.88	2.03	212.379
						82.52	2.90	203.369	82.52	2.12	193.548
						84.16	1.51	208.528	84.16	1.45	202.369

August 3,1998

Distance from the Right Bank (ft)											
3204			3785			4108			4669		
Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.
7.05	3.65	202.232	7.05	4.52	208.481	7.05	3.79	210.292	7.05	2.04	211.185
8.69	3.78	200.731	8.69	4.67	204.871	8.69	3.33	208.435	8.69	2.27	209.488
10.34	2.97	202.542	10.34	4.17	204.627	10.34	4.01	209.919	10.34	2.44	211.109
11.98	3.06	197.405	11.98	4.39	205.283	11.98	3.63	206.774	11.98	2.07	221.536
13.62	2.74	210.281	13.62	4.33	200.124	13.62	3.80	214.705	13.62	1.76	209.294
15.26	2.73	201.161	15.26	4.50	200.840	15.26	3.67	213.335	15.26	1.63	217.653
16.90	3.07	199.831	16.90	4.20	195.373	16.90	3.04	225.219	16.90	2.61	210.692
18.54	2.82	199.892	18.54	4.24	202.896	18.54	3.60	229.552	18.54	2.36	206.708
20.18	3.57	194.483	20.18	3.82	193.678	20.18	3.55	221.295	20.18	1.96	217.282
21.82	2.29	164.190	21.82	3.74	196.083	21.82	3.14	216.045	21.82	2.04	210.077
23.46	2.03	116.026	23.46	3.93	199.644	23.46	3.17	220.672	23.46	1.94	208.781
			25.10	4.14	195.821	25.10	3.05	230.754	25.10	1.69	216.870
			26.74	3.33	199.453	26.74	3.19	226.125	26.74	2.23	219.676
			28.38	2.92	205.729	28.38	2.72	243.960	28.38	2.04	212.719
			30.02	3.67	198.419	30.02	2.92	229.469	30.02	1.56	217.833
			31.66	3.13	202.214	31.66	2.96	230.626	31.66	1.72	221.453
			33.30	3.22	200.631	33.30	3.57	226.005	33.30	1.54	224.222
			34.94	3.00	194.234	34.94	3.46	224.308	34.94	1.88	240.205
			36.58	3.13	195.608	36.58	3.32	221.234	36.58	1.42	237.630
			38.22	3.22	198.214	38.22	3.70	224.569	38.22	1.93	228.997
			39.86	3.07	204.484	39.86	4.05	222.143	39.86	1.70	213.260
			41.50	2.95	200.690	41.50	3.48	219.183	41.50	1.66	239.776
			43.15	3.08	211.487	43.15	3.94	225.304	43.15	1.16	231.290
			44.79	3.02	209.382	44.79	3.85	224.689	44.79	1.54	233.667
			46.43	2.84	204.641	46.43	4.12	223.032	46.43	1.70	233.832
			48.07	2.99	202.455	48.07	3.68	217.391	48.07	1.16	242.347
			49.71	3.05	205.296	49.71	3.72	217.052	49.71	1.43	236.783
			51.35	3.37	206.515	51.35	3.00	219.276	51.35	1.64	245.433
			52.99	2.94	203.048	52.99	3.07	221.491	52.99	2.12	238.004
			54.63	0.93	192.813	54.63	3.27	217.754	54.63	0.98	231.221
						56.27	3.11	214.042	56.27	1.25	225.000
						57.91	3.00	203.737	57.91	1.57	249.976
						59.55	3.12	217.642	59.55	1.55	264.784
						61.19	2.84	213.819	61.19	1.18	261.218
						62.83	2.62	221.699	62.83	1.15	242.043
						64.47	2.47	214.936	64.47	1.37	264.793
						66.11	2.67	221.616	66.11	1.42	263.894
						67.75	2.12	210.690	67.75	0.97	264.386
						69.39	2.01	212.989	69.39	0.86	264.964
						71.03	2.01	208.819	71.03	0.93	233.211
						72.67	1.55	224.743	72.67	0.49	237.913
						74.31	0.87	205.305	74.31	0.50	250.372
						75.96	0.64	235.735	75.96	0.55	356.594
									77.60	1.28	99.559

Table B.8. ADCP flow velocity and direction data at Tarbert.

February 27,1998

Distance from the Right Bank (ft)												
1417			2204			2797			3409			
Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.	
7.05	3.87	258.109	7.05	8.00	249.097	7.05	5.23	250.020	7.05	5.13	255.262	
8.69	4.05	259.127	8.69	8.47	247.737	8.69	5.90	248.057	8.69	4.80	251.070	
10.34	4.22	252.904	10.34	7.87	246.481	10.34	5.25	246.557	10.34	4.84	255.446	
11.98	3.76	257.054	11.98	8.01	244.789	11.98	4.77	248.696	11.98	4.21	249.773	
13.62	3.72	258.650	13.62	8.17	248.493	13.62	4.60	246.361	13.62	4.28	252.357	
15.26	3.61	257.556	15.26	8.09	248.867	15.26	5.17	241.517	15.26	4.41	254.113	
16.90	3.68	260.152	16.90	8.35	246.819	16.90	4.66	243.922	16.90	4.44	247.829	
18.54	3.47	264.187	18.54	7.75	247.496	18.54	4.27	245.129	18.54	4.34	247.290	
20.18	3.73	256.208	20.18	7.43	245.416	20.18	4.43	246.969	20.18	4.31	252.407	
21.82	3.78	258.895	21.82	7.75	247.856	21.82	4.43	245.616	21.82	4.09	255.015	
23.46	3.04	261.564	23.46	7.10	246.457	23.46	4.17	249.898	23.46	4.32	257.093	
25.10	3.66	252.394	25.10	7.57	248.139	25.10	4.59	257.396	25.10	4.33	257.217	
26.74	3.36	251.370	26.74	7.72	249.401	26.74	4.37	253.416	26.74	4.27	248.084	
28.38	3.48	251.548	28.38	8.09	248.130	28.38	4.43	250.144	28.38	4.27	249.629	
30.02	3.61	257.974	30.02	7.59	245.640	30.02	4.36	256.142	30.02	4.11	249.947	
31.66	3.57	248.736	31.66	7.74	246.741	31.66	4.25	253.356	31.66	4.62	249.958	
33.30	3.44	248.837	33.30	7.79	245.886	33.30	3.82	250.803	33.30	4.69	248.942	
34.94	3.28	248.699	34.94	7.57	247.701	34.94	3.87	253.040	34.94	4.74	247.572	
36.58	3.42	266.424	36.58	7.95	245.720	36.58	4.73	253.465	36.58	4.92	246.395	
38.22	3.47	252.834	38.22	7.98	250.448	38.22	4.56	246.937	38.22	4.37	246.417	
39.86	3.11	254.337	39.86	7.51	247.357	39.86	4.48	246.779	39.86	4.41	247.272	
41.50	3.45	254.429	41.50	7.77	247.767	41.50	4.10	252.392	41.50	3.64	243.366	
43.15	3.28	256.422	43.15	7.91	247.351	43.15	4.29	247.262	43.15	3.68	244.897	
44.79	2.86	254.370	44.79	7.68	243.172	44.79	4.30	246.446	44.79	3.43	230.398	
46.43	2.78	251.309	46.43	7.28	244.289	46.43	4.46	249.567	46.43	3.08	261.353	
48.07	3.11	255.100	48.07	5.08	239.011	48.07	4.01	253.135				
49.71	2.89	250.968				49.71	3.58	259.554				
51.35	2.43	265.037				51.35	2.66	277.230				
52.99	1.50	242.090				52.99	2.11	236.359				
54.63	1.57	245.258										

March 23,1998

Distance from the Right Bank (ft)												
1368			2169			3023			3378			
Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.	
7.05	3.48	247.447	7.05	6.51	262.997	7.05	6.77	244.044	7.05	6.50	248.177	
8.69	3.57	247.182	8.69	6.64	261.962	8.69	6.93	244.649	8.69	6.65	247.421	
10.34	3.08	245.783	10.34	6.97	263.404	10.34	6.57	244.779	10.34	6.60	246.506	
11.98	3.23	239.966	11.98	7.11	261.586	11.98	6.78	244.538	11.98	6.01	246.428	
13.62	3.34	240.995	13.62	6.66	260.018	13.62	6.99	244.915	13.62	6.21	249.621	
15.26	3.36	239.478	15.26	6.90	262.875	15.26	6.09	248.026	15.26	6.02	247.532	
16.90	3.10	242.188	16.90	6.28	262.920	16.90	6.79	248.034	16.90	6.67	244.682	
18.54	2.72	249.121	18.54	6.55	263.558	18.54	6.71	248.162	18.54	6.90	242.972	
20.18	2.90	249.353	20.18	6.32	260.626	20.18	6.65	247.243	20.18	6.59	239.902	
21.82	2.97	244.822	21.82	6.69	263.809	21.82	7.07	246.135	21.82	6.30	246.213	
23.46	3.04	249.784	23.46	6.12	264.088	23.46	6.75	243.883	23.46	6.46	240.233	
25.10	2.91	246.793	25.10	6.68	263.284	25.10	6.06	240.505	25.10	6.24	239.103	
26.74	2.90	238.325	26.74	6.56	264.321	26.74	6.12	243.806	26.74	6.22	242.462	
28.38	2.84	243.050	28.38	6.66	264.149	28.38	6.21	243.611	28.38	6.21	244.423	
30.02	3.21	246.555	30.02	6.40	262.514	30.02	6.17	242.971	30.02	6.39	240.657	
31.66	2.98	251.525	31.66	6.31	266.660	31.66	6.26	243.328	31.66	5.89	246.445	
33.30	2.72	247.672	33.30	5.81	262.955	33.30	6.26	241.541	33.30	6.22	243.746	
34.94	3.02	247.145	34.94	5.91	260.224	34.94	5.80	239.970	34.94	5.93	241.817	
36.58	2.61	249.216	36.58	5.75	259.075	36.58	5.90	238.042	36.58	5.65	235.793	
38.22	2.66	249.287	38.22	6.33	263.512	38.22	6.36	242.232	38.22	5.29	229.503	
39.86	2.92	254.514	39.86	6.43	259.985	39.86	5.88	245.493	39.86	5.08	227.908	
41.50	2.83	250.600	41.50	5.86	267.785	41.50	6.14	244.051	41.50	4.92	228.109	
43.15	2.39	244.912	43.15	5.46	266.003	43.15	5.91	238.862	43.15	4.74	227.414	
44.79	3.39	249.794	44.79	5.67	266.647	44.79	5.69	242.415	44.79	4.92	231.793	
46.43	2.91	248.763	46.43	6.08	266.007	46.43	5.39	241.470	46.43	2.13	224.875	
48.07	2.61	244.338	48.07	4.44	275.850	48.07	5.08	257.355	48.07	1.42	223.781	
49.71	2.30	253.684				49.71	2.99	255.705				
51.35	2.27	253.396				51.35	2.63	206.341				
52.99	2.39	249.104				52.99	2.39	217.122				
54.63	2.36	246.644				54.63	1.92	174.027				
56.27	1.71	256.017				56.27	1.88	188.463				

April 10,1998

Distance from the Right Bank (ft)												
1371			2129			2730			3369			
Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.	
7.05	4.85	255.738	7.05	5.99	256.086	7.05	6.42	249.204	7.05	5.56	251.042	
8.69	4.52	255.792	8.69	5.54	257.479	8.69	6.83	250.659	8.69	5.26	245.225	
10.34	4.29	260.288	10.34	5.29	253.508	10.34	6.16	248.737	10.34	5.47	246.386	
11.98	4.62	257.772	11.98	5.16	250.873	11.98	6.06	249.426	11.98	5.16	247.887	
13.62	4.18	255.822	13.62	5.04	255.955	13.62	6.47	246.439	13.62	4.84	244.495	
15.26	4.52	254.986	15.26	4.94	257.174	15.26	6.37	247.355	15.26	5.30	240.260	
16.90	4.18	258.320	16.90	5.06	258.894	16.90	6.47	250.076	16.90	5.24	245.954	
18.54	4.11	252.288	18.54	4.94	263.824	18.54	6.54	250.956	18.54	5.26	244.729	
20.18	4.40	253.661	20.18	4.61	260.035	20.18	6.50	250.541	20.18	5.34	240.190	
21.82	4.55	259.621	21.82	4.49	259.822	21.82	6.50	251.035	21.82	5.19	244.164	
23.46	4.34	254.263	23.46	4.22	264.205	23.46	6.19	247.172	23.46	5.52	239.153	
25.10	4.35	255.859	25.10	4.11	263.312	25.10	6.49	248.365	25.10	5.74	237.092	
26.74	4.17	256.237	26.74	4.22	258.646	26.74	5.53	248.684	26.74	5.14	242.749	
28.38	4.01	261.293	28.38	4.00	256.180	28.38	5.88	250.645	28.38	5.33	238.631	
30.02	4.36	255.765	30.02	4.04	265.576	30.02	5.77	248.955	30.02	5.43	240.478	
31.66	4.04	255.434	31.66	3.90	272.460	31.66	5.50	251.003	31.66	4.96	238.477	
33.30	4.29	251.330	33.30	4.11	267.160	33.30	5.61	248.024	33.30	5.31	240.822	
34.94	4.10	251.087	34.94	3.96	263.046	34.94	5.19	246.773	34.94	4.84	245.173	
36.58	4.32	257.084	36.58	3.76	262.372	36.58	5.10	243.880	36.58	4.60	249.200	
38.22	4.22	251.650	38.22	3.43	255.326	38.22	5.17	246.085	38.22	4.98	247.203	
39.86	4.42	254.002	39.86	4.16	258.060	39.86	4.75	241.149	39.86	5.05	248.406	
41.50	4.28	256.060	41.50	3.99	258.894	41.50	4.72	240.779	41.50	4.95	251.998	
43.15	4.25	252.419	43.15	3.98	251.132	43.15	4.71	242.007	43.15	4.50	252.661	
44.79	4.09	249.412	44.79	3.50	252.380	44.79	4.88	239.036	44.79	3.72	251.789	
46.43	4.12	250.454	46.43	3.35	259.725	46.43	4.80	241.596	46.43	4.23	253.109	
48.07	4.06	249.574	48.07	3.77	251.849	48.07	4.88	242.127	48.07	2.60	241.787	
49.71	3.90	248.557	49.71	2.90	234.636	49.71	4.78	242.555				
51.35	4.05	246.948	51.35	2.86	254.307	51.35	4.71	236.122				
52.99	3.88	251.335	52.99	3.52	243.077	52.99	4.77	243.118				
54.63	3.98	254.737	54.63	3.23	253.000	54.63	3.80	237.916				
56.27	3.57	250.782	56.27	2.90	251.606	56.27	3.28	235.515				
57.91	3.35	249.313	57.91	2.43	254.310	57.91	2.04	246.028				
59.55	3.19	252.534	59.55	2.51	258.778							
61.19	2.36	231.999	61.19	2.14	245.592							

April 17,1998

Distance from the Right Bank (ft)												
1365			2180			2780			3382			
Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.	
7.05	2.60	249.393	7.05	6.16	254.373	7.05	6.09	258.660	7.05	5.16	252.061	
8.69	2.55	258.111	8.69	6.10	254.626	8.69	6.10	251.497	8.69	5.17	250.725	
10.34	2.23	244.790	10.34	6.60	253.753	10.34	6.17	254.841	10.34	4.67	251.107	
11.98	2.55	250.633	11.98	6.13	252.021	11.98	6.15	250.636	11.98	4.78	255.439	
13.62	2.90	251.524	13.62	6.33	252.476	13.62	6.28	251.168	13.62	4.48	252.959	
15.26	2.94	247.807	15.26	6.17	253.038	15.26	6.29	246.389	15.26	4.48	255.353	
16.90	2.69	254.218	16.90	6.08	252.856	16.90	6.11	252.450	16.90	5.00	253.074	
18.54	2.76	241.575	18.54	6.31	250.717	18.54	5.86	251.301	18.54	4.84	253.334	
20.18	2.70	242.812	20.18	6.17	251.459	20.18	6.32	252.976	20.18	4.70	253.511	
21.82	2.89	246.348	21.82	6.23	251.384	21.82	6.05	252.587	21.82	4.32	252.197	
23.46	2.53	253.636	23.46	6.26	248.611	23.46	6.03	252.936	23.46	4.21	248.497	
25.10	2.36	250.180	25.10	6.22	251.728	25.10	6.04	251.496	25.10	3.91	237.939	
26.74	2.57	247.397	26.74	6.25	250.253	26.74	6.12	251.216	26.74	4.04	244.851	
28.38	2.33	246.177	28.38	6.79	249.463	28.38	6.46	249.781	28.38	3.79	240.372	
30.02	2.88	250.100	30.02	6.43	246.824	30.02	6.32	249.127	30.02	3.98	243.435	
31.66	2.27	257.588	31.66	5.88	247.242	31.66	6.25	254.104	31.66	4.35	237.665	
33.30	2.51	262.113	33.30	6.47	245.320	33.30	6.54	249.928	33.30	3.79	243.169	
34.94	2.75	243.221	34.94	6.23	250.125	34.94	6.55	250.485	34.94	3.84	246.460	
36.58	2.39	251.814	36.58	6.14	251.633	36.58	6.53	251.929	36.58	3.71	245.066	
38.22	2.27	249.230	38.22	5.60	247.750	38.22	6.42	249.677	38.22	3.59	244.417	
39.86	2.25	251.724	39.86	5.40	247.707	39.86	6.28	254.055	39.86	3.31	245.035	
41.50	2.40	245.258	41.50	5.56	248.462	41.50	6.27	253.577	41.50	3.52	248.079	
43.15	2.18	248.647	43.15	5.79	249.170	43.15	6.13	260.820	43.15	3.45	248.259	
44.79	1.97	238.187	44.79	5.71	250.118	44.79	6.18	256.775	44.79	3.33	247.558	
46.43	1.94	247.767	46.43	5.32	244.985	46.43	5.98	254.042	46.43	2.22	244.231	
48.07	2.31	239.217	48.07	5.28	244.518	48.07	5.92	257.103	48.07	1.94	242.115	
49.71	2.05	240.562	49.71	5.44	247.114	49.71	5.75	252.443				
51.35	2.26	255.641	51.35	4.91	253.818	51.35	6.06	251.085				
52.99	2.19	248.629	52.99	5.27	251.294	52.99	5.41	240.966				
54.63	2.39	245.934	54.63	2.72	257.021	54.63	2.24	240.057				
56.27	1.77	239.873	56.27	2.21	254.188							
57.91	1.25	228.630										

Table B.8 (continued)

May 8,1998

Distance from the Right Bank (ft)											
1357			2152			2769			3367		
Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.
7.05	4.31	240.077	7.05	8.30	249.266	7.05	7.57	252.947	7.05	4.68	254.082
8.69	4.38	240.537	8.69	8.72	251.735	8.69	7.45	248.517	8.69	4.23	252.802
10.34	4.33	232.045	10.34	8.38	250.345	10.34	7.63	248.547	10.34	4.84	251.012
11.98	4.29	231.340	11.98	7.85	250.201	11.98	7.45	245.500	11.98	4.75	246.781
13.62	4.56	239.171	13.62	8.29	253.933	13.62	7.31	247.267	13.62	4.86	248.810
15.26	4.18	242.791	15.26	8.27	255.666	15.26	7.48	251.176	15.26	4.59	250.685
16.90	4.38	242.303	16.90	8.31	251.129	16.90	7.73	249.535	16.90	4.58	251.189
18.54	4.54	236.919	18.54	8.72	253.255	18.54	6.78	252.029	18.54	4.33	256.732
20.18	4.16	239.308	20.18	7.75	251.059	20.18	7.17	250.463	20.18	4.05	252.344
21.82	4.19	240.889	21.82	8.42	252.828	21.82	7.12	251.857	21.82	3.97	248.823
23.46	4.50	241.546	23.46	8.10	252.336	23.46	7.28	250.478	23.46	4.22	251.847
25.10	4.14	238.452	25.10	8.43	253.010	25.10	7.15	251.881	25.10	4.46	246.696
26.74	4.27	234.575	26.74	8.12	255.155	26.74	7.26	251.147	26.74	4.96	250.402
28.38	4.46	237.749	28.38	8.51	253.478	28.38	6.88	250.061	28.38	4.39	245.350
30.02	4.50	237.051	30.02	8.37	253.761	30.02	6.96	251.966	30.02	4.21	249.925
31.66	4.18	239.753	31.66	7.94	253.407	31.66	7.07	249.329	31.66	3.87	260.937
33.30	4.55	235.783	33.30	8.01	254.638	33.30	6.94	250.126	33.30	3.34	255.363
34.94	4.34	235.505	34.94	7.72	253.837	34.94	6.70	250.926	34.94	3.57	249.648
36.58	3.90	239.359	36.58	8.21	251.036	36.58	6.95	251.232	36.58	2.75	241.171
38.22	3.99	236.532	38.22	7.63	256.621	38.22	7.41	252.696	38.22	3.39	247.900
39.86	4.12	242.150	39.86	7.98	252.429	39.86	6.89	255.951	39.86	2.34	253.955
41.50	4.15	240.255	41.50	7.59	253.054	41.50	7.00	256.993	41.50	2.57	259.538
43.15	4.43	232.799	43.15	8.13	257.434	43.15	6.78	252.117	43.15	2.02	259.604
44.79	4.21	239.059	44.79	7.11	257.752	44.79	7.72	255.332	44.79	2.09	258.302
46.43	4.32	242.306	46.43	7.41	253.933	46.43	7.21	256.052	46.43	2.51	253.387
48.07	4.67	246.987	48.07	7.11	254.367	48.07	6.95	252.430	48.07	2.19	253.465
49.71	4.11	239.365	49.71	6.87	253.487	49.71	6.57	252.868	49.71	2.86	236.949
51.35	4.00	248.277	51.35	7.10	255.521	51.35	6.24	251.898	51.35	2.11	245.207
52.99	4.33	252.677	52.99	3.98	263.754	52.99	6.29	253.870			
54.63	3.97	245.023	54.63	2.80	247.613	54.63	6.33	259.902			
56.27	3.84	246.615				56.27	4.27	255.409			
57.91	3.65	244.519									
59.55	3.91	229.795									
61.19	2.14	210.421									
62.83	1.67	211.755									

June 9,1998

Distance from the Right Bank (ft)											
1377			2188			2768			3373		
Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.
7.05	4.39	252.391	7.05	4.89	255.693	7.05	4.27	252.039	7.05	4.85	239.356
8.69	3.75	251.058	8.69	4.67	258.785	8.69	4.05	252.474	8.69	5.11	240.374
10.34	3.66	256.424	10.34	4.54	258.674	10.34	4.22	251.889	10.34	4.93	242.071
11.98	3.39	252.302	11.98	4.85	253.868	11.98	4.43	253.792	11.98	5.02	244.741
13.62	3.94	255.548	13.62	4.68	253.790	13.62	4.32	259.177	13.62	5.36	240.064
15.26	3.56	258.255	15.26	4.97	256.946	15.26	4.36	260.474	15.26	4.79	242.943
16.90	3.43	259.592	16.90	5.10	256.848	16.90	3.52	251.413	16.90	4.37	239.177
18.54	3.62	262.714	18.54	4.31	254.156	18.54	4.40	250.309	18.54	4.80	243.330
20.18	3.79	255.254	20.18	4.28	246.853	20.18	3.75	253.214	20.18	4.82	241.586
21.82	3.25	254.968	21.82	4.43	249.057	21.82	3.93	247.115	21.82	4.71	244.310
23.46	3.50	251.905	23.46	4.18	247.321	23.46	4.27	251.690	23.46	4.91	239.956
25.10	3.28	257.645	25.10	4.81	249.339	25.10	4.07	257.992	25.10	4.99	236.362
26.74	3.50	254.077	26.74	4.34	248.922	26.74	3.56	255.900	26.74	5.14	241.194
28.38	3.91	250.181	28.38	4.26	257.260	28.38	3.82	259.395	28.38	4.67	242.283
30.02	3.82	253.310	30.02	4.19	256.508	30.02	3.41	261.300	30.02	4.17	239.114
31.66	3.95	246.289	31.66	3.67	248.275	31.66	3.78	256.819	31.66	4.14	242.237
33.30	3.71	241.260	33.30	3.78	248.180	33.30	3.32	259.057	33.30	3.37	240.675
34.94	3.35	253.785	34.94	4.25	252.643	34.94	3.87	259.348	34.94	2.93	239.894
36.58	3.75	254.165	36.58	3.79	257.971	36.58	3.06	263.567			
38.22	2.75	256.975	38.22	3.65	264.838	38.22	2.27	267.786			
39.86	2.57	257.931	39.86	2.48	259.180	39.86	1.16	268.480			
41.50	2.99	256.223	41.50	1.98	281.086						
43.15	2.78	248.312									
44.79	2.85	239.059									
46.43	2.55	246.850									
48.07	1.47	225.361									

August 3,1998

Distance from the Right Bank (ft)											
1380			2186			2783			3390		
Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.	Depth	Vel.	Q Dir.
7.05	4.21	255.661	7.05	4.81	253.705	7.05	3.52	250.026	7.05	3.15	252.283
8.69	3.93	254.199	8.69	4.52	253.341	8.69	3.62	249.529	8.69	3.64	253.806
10.34	3.70	260.864	10.34	4.94	255.853	10.34	3.56	248.739	10.34	3.96	253.351
11.98	4.08	253.998	11.98	4.38	256.806	11.98	3.54	256.930	11.98	3.44	252.845
13.62	4.08	264.179	13.62	4.66	259.497	13.62	2.95	256.381	13.62	4.19	237.219
15.26	4.03	247.506	15.26	4.17	255.428	15.26	2.82	254.347	15.26	3.78	251.534
16.90	3.57	245.600	16.90	4.50	248.858	16.90	3.29	258.679	16.90	3.14	247.932
18.54	3.18	253.941	18.54	4.15	248.409	18.54	3.27	254.987	18.54	3.21	258.126
20.18	3.56	242.657	20.18	4.04	245.726	20.18	3.04	256.024	20.18	2.98	242.928
21.82	3.22	254.704	21.82	4.42	247.069	21.82	2.07	252.397	21.82	2.51	235.395
23.46	3.63	257.959	23.46	4.37	253.239	23.46	2.30	245.448	23.46	3.12	256.169
25.10	3.63	249.335	25.10	4.58	253.745	25.10	2.65	259.816	25.10	0.32	163.811
26.74	3.27	253.526	26.74	3.72	251.294	26.74	2.88	256.027			
28.38	3.59	254.479	28.38	3.94	249.997	28.38	2.74	260.970			
30.02	3.44	256.838	30.02	3.46	247.593	30.02	2.51	271.645			
31.66	3.14	252.532	31.66	3.32	254.000	31.66	1.26	242.769			
33.30	3.29	252.956	33.30	3.01	247.793	33.30	0.51	55.281			
34.94	3.20	248.684	34.94	3.46	260.993						
36.58	3.00	245.199	36.58	1.21	238.903						
38.22	3.06	243.627									
39.86	2.57	243.500									
41.50	0.57	233.658									

Table B.9. Bed material data at Union Point.

DATE: 27-FEB-98	RIVER CONDITION: GOOD	TYPE SAMPLER: DRAG BUCKET
STREAM: MISSISSIPPI RIVER	TIME: 08:00 TO 09:00	TYPE SAMPLES: BED MATERIAL
LOCATION: UNION POINT	TEMP: 9 C @10 FT.	NO. VERTICALS: 4
GAGE: KNOX LANDING	WEATHER: CLOUDY AND MILD	NO. POINTS: 1
DISCHARGE: 1,010,854 CFS (DOPPLER)	GAGE READING: 48.60 FT.	
CONVENTIONAL METHOD: 1,028,013 CFS		

(SAMPLE)																		
FIELD NO.	1																	
DISTANCE (FT.)	1066																	
DEPTH (FT)	66																	
DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.5	31.5	123.6	147.9	149.7	149.9	149.9	150
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.3	21.0	82.4	98.6	99.8	99.9	99.9	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.9	99.7	79.0	17.6	1.4	0.2	0.1	0.1	0.0

(SAMPLE)																		
FIELD NO.	2																	
DISTANCE (FT.)	1658																	
DEPTH (FT)	66																	
DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	7.5	52.8	116.1	124.0	124.7	124.7	124.7	124.8
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	6.0	42.3	93.0	99.4	99.9	99.9	99.9	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.3	94.0	57.7	7.0	0.6	0.1	0.1	0.1	0.0

(SAMPLE)																		
FIELD NO.	3																	
DISTANCE (FT.)	2256																	
DEPTH (FT)	66																	
DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	6.5	6.5	6.5	6.5	6.5	6.5	9.1	22.6	97.7	144.8	149.3	149.8	149.8	149.8	149.8
% HELD	0.0	0.0	0.0	4.3	4.3	4.3	4.3	4.3	4.3	6.1	15.1	65.2	96.7	99.7	100.0	100.0	100.0	100.0
% FINER	100.0	100.0	100.0	95.7	95.7	95.7	95.7	95.7	95.7	93.9	84.9	34.8	3.3	0.3	0.0	0.0	0.0	0.0

(SAMPLE)																		
FIELD NO.	4																	
DISTANCE (FT.)	2941																	
DEPTH (FT)	56																	
DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	15.8	39.6	58.2	100.0	137.6	236.7	268.7	274.5	338.2	380.5	392.1	393.4	393.5	393.5	393.5	393.6	393.6
% HELD	0.0	4.0	10.1	14.8	25.4	35.0	60.1	68.3	69.7	85.9	96.7	99.6	99.9	100.0	100.0	100.0	100.0	100.0
% FINER	100.0	96.0	89.9	85.2	74.6	65.0	39.9	31.7	30.3	14.1	3.3	0.4	0.1	0.0	0.0	0.0	0.0	0.0

DATE: 23-MAR-98	RIVER CONDITION: CHOPPY	TYPE SAMPLER: DRAG BUCKET
STREAM: MISSISSIPPI RIVER	TIME: 09:00 TO 11:00	TYPE SAMPLES: BED MATERIAL
LOCATION: UNION POINT	TEMP: 9 C @10 FT.	NO. VERTICALS: 4
GAGE: UNION POINT	WEATHER: WINDY AND MILD	NO. POINTS: 1
DISCHARGE: 1,063,325 CFS (ADCP)	GAGE READING: 52.90 FT.	
CONVENTIONAL METHOD: 1,127,296 CFS		

(SAMPLE)																		
FIELD NO.	5																	
DISTANCE (FT.)	1020																	
DEPTH (FT)	63																	
DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	11.0	91.2	143.9	149.3	149.7	149.8	150
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	7.3	60.8	96.0	99.6	99.9	99.9	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.9	92.7	39.2	4.0	0.4	0.1	0.1	0.0

(SAMPLE)																		
FIELD NO.	6																	
DISTANCE (FT.)	1755																	
DEPTH (FT)	67																	
DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	37.7	123.3	147.6	149.7	149.9	149.9	149.9
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	25.2	82.3	98.5	99.9	100.0	100.0	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.7	74.8	17.7	1.5	0.1	0.0	0.0	0.0

(SAMPLE)																		
FIELD NO.	7																	
DISTANCE (FT.)	2274																	
DEPTH (FT)	80																	
DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.6	13.1	83.5	127.9	149.0	149.8	149.8	149.9
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.4	8.7	55.7	85.3	99.4	99.9	99.9	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.9	99.6	91.3	44.3	14.7	0.6	0.1	0.1	0.0

(SAMPLE)																		
FIELD NO.	8																	
DISTANCE (FT.)	3091																	
DEPTH (FT)	60																	
DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	3.2	9.7	14.9	78.6	133.7	148.3	150.1	150.5	150.6	150.6	150.6	150.7
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	2.1	6.4	9.9	52.2	88.7	98.4	99.6	99.9	99.9	99.9	99.9	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	97.9	93.6	90.1	47.8	11.3	1.6	0.4	0.1	0.1	0.1	0.1	0.0

Table B.9 (continued)

DATE: 10-APR-98	RIVER CONDITION: GOOD	TYPE SAMPLER: DRAG BUCKET
STREAM: MISSISSIPPI RIVER	TIME: 09:00 TO 11:00	TYPE SAMPLES: BED MATERIAL
LOCATION: UNION POINT	TEMP: 16 C @1.5 FT.	NO. VERTICALS: 4
GAGE: UNION POINT	WEATHER: CLEAR AND WARM	NO. POINTS: 1
DISCHARGE: 1,107,752 CFS (ADCP)	GAGE READING: 54.55 FT.	
CONVENTIONAL METHOD: 1,072,507 CFS		

(SAMPLE)	
FIELD NO.	9
DISTANCE (FT.)	1075
DEPTH (FT)	69

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.1	49.0	127.0	148.1	149.7	149.8	149.8	150
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.7	32.7	84.7	98.8	99.9	99.9	99.9	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.9	99.3	67.3	15.3	1.2	0.1	0.1	0.1	0.0

(SAMPLE)	
FIELD NO.	10
DISTANCE (FT.)	1643
DEPTH (FT)	70

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.2	14.0	92.9	132.4	149.2	149.9	149.9	150.0
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	9.3	61.9	88.3	99.5	99.9	99.9	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.9	99.9	90.7	38.1	11.7	0.5	0.1	0.1	0.0

(SAMPLE)	
FIELD NO.	11
DISTANCE (FT.)	2224
DEPTH (FT)	81

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.9	14.0	112.4	147.4	149.7	149.9	149.9	150.0	150.0
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.3	9.3	74.9	98.3	99.8	99.9	99.9	100.0	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.9	98.7	90.7	25.1	1.7	0.2	0.1	0.1	0.0	0.0

(SAMPLE)	
FIELD NO.	12
DISTANCE (FT.)	2943
DEPTH (FT)	60

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	1.2	9.8	52.3	130.8	147.9	149.7	149.9	150.0	150.0
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.8	6.5	34.9	87.2	98.6	99.8	99.9	100.0	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.7	99.2	93.5	65.1	12.8	1.4	0.2	0.1	0.0	0.0

DATE: 17-APR-98	RIVER CONDITION: GOOD	TYPE SAMPLER: DRAG BUCKET
STREAM: MISSISSIPPI RIVER	TIME: 08:30 TO 09:30	TYPE SAMPLES: BED MATERIAL
LOCATION: UNION POINT	TEMP: 16 C @1.5 FT.	NO. VERTICALS: 4
GAGE: UNION POINT	WEATHER: CLOUDY AND RAIN	NO. POINTS: 1
DISCHARGE: 1,069,422 CFS (ADCP)	GAGE READING: 52.60 FT.	
CONVENTIONAL METHOD: 1,072,377 CFS		

(SAMPLE)	
FIELD NO.	13
DISTANCE (FT.)	1040
DEPTH (FT)	69

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	3.1	3.7	12.1	61.7	116.5	140.5	143.3	149.9	149.9	150.0	150.0	150
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	2.1	2.5	8.1	41.1	77.7	93.7	95.5	99.9	99.9	100.0	100.0	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	97.9	97.5	91.9	58.9	22.3	6.3	4.5	0.1	0.1	0.0	0.0	0.0

(SAMPLE)	
FIELD NO.	14
DISTANCE (FT.)	1648
DEPTH (FT)	71

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.2	12.7	112.0	148.0	149.8	149.9	149.9	150.0	150.0
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.8	8.5	74.7	98.7	99.9	99.9	99.9	100.0	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.9	99.2	91.5	25.3	1.3	0.1	0.1	0.1	0.0	0.0

(SAMPLE)	
FIELD NO.	15
DISTANCE (FT.)	2247
DEPTH (FT)	69

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.7	37.7	128.7	148.9	149.9	149.9	149.9	150.0
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.1	25.1	85.8	99.3	99.9	99.9	99.9	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.9	98.9	74.9	14.2	0.7	0.1	0.1	0.1	0.0

(SAMPLE)	
FIELD NO.	16
DISTANCE (FT.)	2966
DEPTH (FT)	57

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4	13.2	114.0	148.9	149.7	149.9	149.9	150.0	150.0
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	8.8	76.0	99.3	99.8	99.9	99.9	100.0	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.1	91.2	24.0	0.7	0.2	0.1	0.1	0.0	0.0

Table B.9 (continued)

DATE: 08-MAY-98	RIVER CONDITION: GOOD	TYPE SAMPLER: DRAG BUCKET
STREAM: MISSISSIPPI RIVER	TIME: 08:15 TO 10:15	TYPE SAMPLES: BED MATERIAL
LOCATION: UNION POINT	TEMP: 19 C @10 FT.	NO. VERTICALS: 4
GAGE: UNION POINT	WEATHER: CLEAR AND WARM	NO. POINTS: 1
DISCHARGE: 1,219,937 CFS (ADCP)	GAGE READING: 56.10 FT.	

CONVENTIONAL METHOD: 1,224,614 CFS

(SAMPLE)	
FIELD NO.	17
DISTANCE (FT.)	1094
DEPTH (FT)	73

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	23.7	105.6	145.4	149.5	149.9	150.0	150
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	15.8	70.4	96.9	99.7	99.9	100.0	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.9	84.2	29.6	3.1	0.3	0.1	0.0	0.0

(SAMPLE)	
FIELD NO.	18
DISTANCE (FT.)	1652
DEPTH (FT)	72

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	25.4	117.6	147.9	149.9	149.9	150.0	150.0
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	16.9	78.4	98.6	99.9	99.9	100.0	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.8	83.1	21.6	1.4	0.1	0.1	0.0	0.0

(SAMPLE)	
FIELD NO.	19
DISTANCE (FT.)	2276
DEPTH (FT)	72

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.5	3.9	21.8	111.3	146.5	149.5	149.9	149.9	150.0	150.0
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.3	2.6	14.5	74.2	97.7	99.7	99.9	99.9	100.0	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.8	99.7	97.4	85.5	25.8	2.3	0.3	0.1	0.1	0.0	0.0

(SAMPLE)	
FIELD NO.	20
DISTANCE (FT.)	2959
DEPTH (FT)	58

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.5	1.5	2.6	3.5	5.2	38.2	114.8	148.2	149.6	149.8	149.9	149.9	149.9	150.0
% HELD	0.0	0.0	0.0	0.0	0.3	1.0	1.7	2.3	3.5	25.5	76.5	98.8	99.7	99.9	99.9	99.9	99.9	100.0
% FINER	100.0	100.0	100.0	100.0	99.7	99.0	98.3	97.7	96.5	74.5	23.5	1.2	0.3	0.1	0.1	0.1	0.1	0.0

DATE: 09-JUN-98	RIVER CONDITION: CHOPPY	TYPE SAMPLER: DRAG BUCKET
STREAM: MISSISSIPPI RIVER	TIME: 09:50 TO 10:45	TYPE SAMPLES: BED MATERIAL
LOCATION: UNION POINT	TEMP: 26 C @10 FT.	NO. VERTICALS: 4
GAGE: UNION POINT	WEATHER: CLOUDY AND HOT	NO. POINTS: 1
DISCHARGE: 735,773 CFS (ADCP)	GAGE READING: 42.30 FT.	

CONVENTIONAL METHOD: DID NOT DO

(SAMPLE)	
FIELD NO.	21
DISTANCE (FT.)	1047
DEPTH (FT)	57

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	18.6	103.7	126.8	145.4	149.2	149.7	149.9	150
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	12.4	69.1	84.5	96.9	99.5	99.8	99.9	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.8	87.6	30.9	15.5	3.1	0.5	0.2	0.1	0.0

(SAMPLE)	
FIELD NO.	22
DISTANCE (FT.)	1613
DEPTH (FT)	60

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	3.6	29.8	119.9	146.8	149.7	149.9	150.0	150.0
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	2.4	19.9	79.9	97.9	99.8	99.9	100.0	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.4	97.6	80.1	20.1	2.1	0.2	0.1	0.0	0.0

(SAMPLE)	
FIELD NO.	23
DISTANCE (FT.)	2235
DEPTH (FT)	63

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.7	4.5	24.9	113.0	139.8	145.8	147.3	149.8	149.9	150.0
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.5	3.0	16.6	75.3	93.2	97.2	98.2	99.9	99.9	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.9	99.5	97.0	83.4	24.7	6.8	2.8	1.8	0.1	0.1	0.0

(SAMPLE)	
FIELD NO.	24
DISTANCE (FT.)	2923
DEPTH (FT)	46

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	4.3	16.9	78.4	132.8	147.8	149.4	149.9	149.9	150.0	150.0
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	2.9	11.3	52.3	88.5	98.5	99.6	99.9	99.9	100.0	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.5	97.1	88.7	47.7	11.5	1.5	0.4	0.1	0.1	0.0	0.0

Table B.9 (continued)

DATE: 03-AUG-98	RIVER CONDITION: CHOPPY	TYPE SAMPLER: DRAG BUCKET
STREAM: MISSISSIPPI RIVER	TIME: 09:30 TO 10:30	TYPE SAMPLES: BED MATERIAL
LOCATION: UNION POINT	TEMP: 31 C @10 FT.	NO. VERTICALS: 4
GAGE: UNION POINT	WEATHER: CLOUDY	NO. POINTS: 1
DISCHARGE: 571,934 CFS (ADCP)	GAGE READING: 35.3 FT.	

CONVENTIONAL METHOD: DID NOT DO

(SAMPLE)																		
FIELD NO.	25																	
DISTANCE (FT.)	1030																	
DEPTH (FT)	47																	
DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.18	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.3	0.3	1.9	65.7	136.1	148.7	149.8	149.9	149.9	150
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.2	1.3	43.8	90.7	99.1	99.9	99.9	99.9	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.8	99.8	99.8	98.7	56.2	9.3	0.9	0.1	0.1	0.1	0.0

(SAMPLE)																		
FIELD NO.	26																	
DISTANCE (FT.)	1625																	
DEPTH (FT)	50																	
DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.18	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.4	31.0	119.4	147.6	149.7	149.8	149.9	149.9	150.0
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6	20.7	79.6	98.4	99.8	99.9	99.9	99.9	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	98.4	79.3	20.4	1.6	0.2	0.1	0.1	0.1	0.0

(SAMPLE)																		
FIELD NO.	27																	
DISTANCE (FT.)	2229																	
DEPTH (FT)	50																	
DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.18	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	8.0	73.6	146.9	147.6	148.9	149.7	149.9	149.9	150.0
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	5.3	49.1	97.9	98.4	99.3	99.8	99.9	99.9	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.9	99.9	94.7	50.9	2.1	1.6	0.7	0.2	0.1	0.1	0.0

(SAMPLE)																		
FIELD NO.	28																	
DISTANCE (FT.)	2901																	
DEPTH (FT)	41																	
DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.18	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.7	74.9	138.7	147.8	148.8	149.7	149.9	150.0	150.0
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.1	49.9	92.5	98.5	99.2	99.8	99.9	100.0	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	94.9	50.1	7.5	1.5	0.8	0.2	0.1	0.0	0.0

Table B.10. Bed material data at Line 13.

DATE: 27-FEB-98	RIVER CONDITION: GOOD	TYPE SAMPLER: DRAG BUCKET
STREAM: MISSISSIPPI RIVER	TIME: 09:30 TO 10:30	TYPE SAMPLES: BED MATERIAL
LOCATION: LINE #13 D/S OF HYDRO INTAKE CH.	TEMP: 9 C @10 FT.	NO. VERTICALS: 4
GAGE: KNOX LANDING	WEATHER: CLOUDY AND MILD	NO. POINTS: 1
DISCHARGE: 857,119 CFS (ADCP)	GAGE READING: 48.60 FT.	

(SAMPLE)	
FIELD NO.	1
DISTANCE (FT.)	1793
DEPTH (FT.)	107

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	16.7	33.0	42.1	48.6	99.9
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	16.7	33.0	42.1	48.6	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.8	83.3	67.0	57.9	51.4	0.0

(SAMPLE)	
FIELD NO.	2
DISTANCE (FT.)	2115
DEPTH (FT.)	97

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.8	64.3	127.8	146.9	149.7	149.9	150.0	150.0	150.0
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.9	42.9	85.2	97.9	99.8	99.9	100.0	100.0	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	96.1	57.1	14.8	2.1	0.2	0.1	0.0	0.0	0.0

(SAMPLE)	
FIELD NO.	3
DISTANCE (FT.)	2449
DEPTH (FT.)	89

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	10.8	46.5	108.6	123.1	124.9	125.0	125.0	125.0
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	8.6	37.2	86.9	98.5	99.9	100.0	100.0	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.8	91.4	62.8	13.1	1.5	0.1	0.0	0.0	0.0

(SAMPLE)	
FIELD NO.	4
DISTANCE (FT.)	2916
DEPTH (FT.)	70

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	38.8	126.7	147.8	149.8	150.0	150.0	150.0
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	25.9	84.5	98.5	99.9	100.0	100.0	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.8	74.1	15.5	1.5	0.1	0.0	0.0	0.0

DATE: 23-MAR-98	RIVER CONDITION: CHOPPY	TYPE SAMPLER: DRAG BUCKET
STREAM: MISSISSIPPI RIVER	TIME: 12:30 TO 14:15	TYPE SAMPLES: BED MATERIAL
LOCATION: LINE #13 D/S OF HYDRO INTAKE CH.	TEMP: 9 C @10 FT.	NO. VERTICALS: 4
GAGE: KNOX LANDING	WEATHER: WINDY AND MILD	NO. POINTS: 1
DISCHARGE: 855,124 CFS (ADCP)	GAGE READING: 50.60 FT.	

(SAMPLE)	
FIELD NO.	5
DISTANCE (FT.)	1785
DEPTH (FT.)	107

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	2.8	9.1	42.9	108.6	142.2	148.0	149.0	149.2	150
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.9	6.1	28.7	72.5	95.0	98.9	99.5	99.7	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.9	98.1	93.9	71.3	27.5	5.0	1.1	0.5	0.3	0.0

(SAMPLE)	
FIELD NO.	6
DISTANCE (FT.)	2068
DEPTH (FT.)	95

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	3.4	12.5	59.1	124.5	147.1	149.7	150.0	150.0	150.0
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	2.3	8.3	39.4	83.0	98.1	99.8	100.0	100.0	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.9	97.7	91.7	60.6	17.0	1.9	0.2	0.0	0.0	0.0

(SAMPLE)	
FIELD NO.	7
DISTANCE (FT.)	2459
DEPTH (FT.)	87

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.8	4.3	38.8	127.6	147.5	149.9	150.0	150.0	150.0
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.5	2.9	25.9	85.1	98.3	99.9	100.0	100.0	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.9	99.5	97.1	74.1	14.9	1.7	0.1	0.0	0.0	0.0

(SAMPLE)	
FIELD NO.	8
DISTANCE (FT.)	2890
DEPTH (FT.)	75

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	30.5	114.8	145.6	149.7	149.9	149.9	150.0
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	20.3	76.5	97.1	99.8	99.9	99.9	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.9	79.7	23.5	2.9	0.2	0.1	0.1	0.0

Table B.10 (continued)

DATE: 10-APR-98	RIVER CONDITION: GOOD	TYPE SAMPLER: DRAG BUCKET
STREAM: MISSISSIPPI RIVER	TIME: 13:15 TO 14:15	TYPE SAMPLES: BED MATERIAL
LOCATION: LINE #13 D/S OF HYDRO INTAKE CH.	TEMP: 16 C @1.5 FT.	NO. VERTICALS: 4
GAGE: KNOX LANDING	WEATHER: CLEAR AND WARM	NO. POINTS: 1
DISCHARGE: 910,249 CFS (ADCP)	GAGE READING: 52.35 FT.	
REPORTED: 1,056,000 CFS		

(SAMPLE)	
FIELD NO.	9
DISTANCE (FT.)	1801
DEPTH (FT.)	110

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	7.6	39.9	113.5	146.2	149.6	149.8	149.9	150.0	150
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	5.1	26.6	75.7	97.5	99.7	99.9	99.9	100.0	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.9	99.9	94.9	73.4	24.3	2.5	0.3	0.1	0.1	0.0	0.0

(SAMPLE)	
FIELD NO.	10
DISTANCE (FT.)	2072
DEPTH (FT.)	100

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.6	40.9	114.4	146.2	149.4	149.8	149.8	149.9	150.0
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.1	27.3	76.3	97.5	99.6	99.9	99.9	99.9	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	94.9	72.7	23.7	2.5	0.4	0.1	0.1	0.1	0.0

(SAMPLE)	
FIELD NO.	11
DISTANCE (FT.)	2433
DEPTH (FT.)	92

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.8	30.6	87.3	138.3	148.9	149.8	149.8	149.9	150.0
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.5	20.4	58.2	92.2	99.3	99.9	99.9	99.9	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	97.5	79.6	41.8	7.8	0.7	0.1	0.1	0.1	0.0

(SAMPLE)	
FIELD NO.	12
DISTANCE (FT.)	2869
DEPTH (FT.)	76

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	3.5	72.9	134.1	147.9	149.8	149.9	150.0	150.0
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	2.3	48.6	89.4	98.6	99.9	99.9	100.0	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.9	97.7	51.4	10.6	1.4	0.1	0.1	0.0	0.0

DATE: 17-APR-98	RIVER CONDITION: GOOD	TYPE SAMPLER: DRAG BUCKET
STREAM: MISSISSIPPI RIVER	TIME: 11:00 TO 12:15	TYPE SAMPLES: BED MATERIAL
LOCATION: LINE #13 D/S OF HYDRO INTAKE CH.	TEMP: 16 C @1.5 FT.	NO. VERTICALS: 4
GAGE: KNOX LANDING	WEATHER: CLOUDY AND RAIN	NO. POINTS: 1
DISCHARGE: 898,752 CFS (ADCP)	GAGE READING: 50.50 FT.	

(SAMPLE)	
FIELD NO.	13
DISTANCE (FT.)	1786
DEPTH (FT.)	110

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	4.7	4.7	13.5	120.9	136.6	139.9	142.0	143.8	147.3	149.6	150.0	150
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	3.1	3.1	9.0	80.6	91.1	93.3	94.7	95.9	98.2	99.7	100.0	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	96.9	96.9	91.0	19.4	8.9	6.7	5.3	4.1	1.8	0.3	0.0	0.0

(SAMPLE)	
FIELD NO.	14
DISTANCE (FT.)	2098
DEPTH (FT.)	105

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	3.1	17.5	100.1	144.3	149.4	149.9	149.9	149.9	150.0
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	2.1	11.7	66.7	96.2	99.6	99.9	99.9	99.9	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.9	97.9	88.3	33.3	3.8	0.4	0.1	0.1	0.1	0.0

(SAMPLE)	
FIELD NO.	15
DISTANCE (FT.)	2454
DEPTH (FT.)	91

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	4.6	19.2	102.4	124.6	148.9	149.6	149.9	149.9	150.0
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	3.1	12.8	68.3	83.1	99.3	99.7	99.9	99.9	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.9	96.9	87.2	31.7	16.9	0.7	0.3	0.1	0.1	0.0

(SAMPLE)	
FIELD NO.	16
DISTANCE (FT.)	2834
DEPTH (FT.)	77

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	5.1	21.6	112.9	138.6	147.9	149.4	149.9	150.0	150.0
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	3.4	14.4	75.3	92.4	98.6	99.6	99.9	100.0	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.8	96.6	85.6	24.7	7.6	1.4	0.4	0.1	0.0	0.0

Table B.10 (continued)

DATE: 08-MAY-98	RIVER CONDITION: GOOD	TYPE SAMPLER: DRAG BUCKET
STREAM: MISSISSIPPI RIVER	TIME: 10:45 TO 12:30	TYPE SAMPLES: BED MATERIAL
LOCATION: LINE #13 D/S OF HYDRO INTAKE CH.	TEMP: 19 C @10 FT.	NO. VERTICALS: 4
GAGE: KNOX LANDING	WEATHER: CLEAR AND WARM	NO. POINTS: 1
DISCHARGE: 1,120,828 CFS (ADCP)	GAGE READING: 54.25 FT.	

(SAMPLE)	
FIELD NO.	17
DISTANCE (FT.)	1787
DEPTH (FT.)	114

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	4.8	8.2	13.8	17.6	27.4	112.8	141.2	149.0	149.7	149.8	149.9	149.9	149.9	150
% HELD	0.0	0.0	0.0	0.0	3.2	5.5	9.2	11.7	18.3	75.2	94.1	99.3	99.8	99.9	99.9	99.9	99.9	100.0
% FINER	100.0	100.0	100.0	100.0	96.8	94.5	90.8	88.3	81.7	24.8	5.9	0.7	0.2	0.1	0.1	0.1	0.1	0.0

(SAMPLE)	
FIELD NO.	18
DISTANCE (FT.)	2032
DEPTH (FT.)	102

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.3	6.0	20.2	97.2	145.6	149.1	149.5	149.8	149.9	150.0
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	4.0	13.5	64.8	97.1	99.4	99.7	99.9	99.9	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.9	99.8	96.0	86.5	35.2	2.9	0.6	0.3	0.1	0.1	0.0

(SAMPLE)	
FIELD NO.	19
DISTANCE (FT.)	2456
DEPTH (FT.)	87

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4	11.3	64.8	138.2	149.2	149.8	149.9	149.9	150.0
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	7.5	43.2	92.1	99.5	99.9	99.9	99.9	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.1	92.5	56.8	7.9	0.5	0.1	0.1	0.1	0.0

(SAMPLE)	
FIELD NO.	20
DISTANCE (FT.)	2855
DEPTH (FT.)	81

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	1.0	100.6	131.8	147.3	149.6	149.9	149.9	150.0
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.7	67.1	87.9	98.2	99.7	99.9	99.9	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.9	99.9	99.3	32.9	12.1	1.8	0.3	0.1	0.1	0.0

DATE: 09-JUN-98	RIVER CONDITION: CHOPPY	TYPE SAMPLER: DRAG BUCKET
STREAM: MISSISSIPPI RIVER	TIME: 12:30 TO 13:35	TYPE SAMPLES: BED MATERIAL
LOCATION: LINE #13 D/S OF HYDRO INTAKE CH.	TEMP: 26 C @10 FT.	NO. VERTICALS: 4
GAGE: KNOX LANDING	WEATHER: CLOUDY AND HOT	NO. POINTS: 1
DISCHARGE: 566,002 CFS (ADCP)	GAGE READING: 40.30 FT.	

(SAMPLE)	
FIELD NO.	21
DISTANCE (FT.)	1771
DEPTH (FT.)	99

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	3.8	6.7	10.9	14.5	25.7	109.6	137.3	147.5	149.7	149.8	149.9	150.0	150.0	150
% HELD	0.0	0.0	0.0	0.0	2.5	4.5	7.3	9.7	17.1	73.1	91.5	98.3	99.8	99.9	99.9	100.0	100.0	100.0
% FINER	100.0	100.0	100.0	100.0	97.5	95.5	92.7	90.3	82.9	26.9	8.5	1.7	0.2	0.1	0.1	0.0	0.0	0.0

(SAMPLE)	
FIELD NO.	22
DISTANCE (FT.)	2089
DEPTH (FT.)	94

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.3	5.9	22.0	96.5	140.2	148.9	149.6	149.7	149.9	150.0
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	3.9	14.7	64.3	93.5	99.3	99.7	99.8	99.9	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.9	99.8	96.1	85.3	35.7	6.5	0.7	0.3	0.2	0.1	0.0

(SAMPLE)	
FIELD NO.	23
DISTANCE (FT.)	2476
DEPTH (FT.)	81

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.2	12.6	60.4	132.3	148.6	149.7	149.9	150.0	150.0
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.8	8.4	40.3	88.2	99.1	99.8	99.9	100.0	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.9	99.2	91.6	59.7	11.8	0.9	0.2	0.1	0.0	0.0

(SAMPLE)	
FIELD NO.	24
DISTANCE (FT.)	2855
DEPTH (FT.)	69

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	1.1	90.8	129.6	146.6	149.8	149.9	150.0	150.0
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.7	60.5	86.4	97.7	99.9	99.9	100.0	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.9	99.3	39.5	13.6	2.3	0.1	0.1	0.0	0.0

Table B.10 (continued)

DATE: 03-AUG-98	RIVER CONDITION: CHOPPY	TYPE SAMPLER: DRAG BUCKET
STREAM: MISSISSIPPI RIVER	TIME: 12:30 TO 13:40	TYPE SAMPLES: BED MATERIAL
LOCATION: LINE #13 D/S OF HYDRO INTAKE CH.	TEMP: 31 C @10 FT.	NO. VERTICALS: 4
GAGE: KNOX LANDING	WEATHER: CLOUDY AND HOT	NO. POINTS: 1
DISCHARGE: 459,967 CFS (ADCP)	GAGE READING: 33.0 FT.	

(SAMPLE)																		
FIELD NO.	25																	
DISTANCE (FT.)	1791																	
DEPTH (FT.)	88																	
DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.18	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	7.8	24.6	109.0	137.2	143.5	146.9	149.6	149.9	150.0	150
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	5.2	16.4	72.7	91.5	95.7	97.9	99.7	99.9	100.0	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.7	94.8	83.6	27.3	8.5	4.3	2.1	0.3	0.1	0.0	0.0
(SAMPLE)																		
FIELD NO.	26																	
DISTANCE (FT.)	2076																	
DEPTH (FT.)	83																	
DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.18	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.4	7.1	22.6	99.4	144.2	149.2	149.7	149.9	149.9	150.0
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.3	4.7	15.1	66.3	96.1	99.5	99.8	99.9	99.9	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.8	99.7	95.3	84.9	33.7	3.9	0.5	0.2	0.1	0.1	0.0
(SAMPLE)																		
FIELD NO.	27																	
DISTANCE (FT.)	2474																	
DEPTH (FT.)	73																	
DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.18	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.6	12.8	68.9	140.3	149.6	149.9	149.9	150.0	150.0
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.1	8.5	45.9	93.5	99.7	99.9	99.9	100.0	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.9	98.9	91.5	54.1	6.5	0.3	0.1	0.1	0.0	0.0
(SAMPLE)																		
FIELD NO.	28																	
DISTANCE (FT.)	2881																	
DEPTH (FT.)	57																	
DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.18	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.4	1.1	91.7	129.8	147.9	149.6	149.7	149.9	150.0
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.3	0.7	61.1	86.5	98.6	99.7	99.8	99.9	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.8	99.7	99.3	38.9	13.5	1.4	0.3	0.2	0.1	0.0

Table B.11. Bed material data at Line 6.

DATE: 27-FEB-98	RIVER CONDITION: GOOD	TYPE SAMPLER: DRAG BUCKET
STREAM: MISSISSIPPI RIVER	TIME: 14:30 TO 15:30	TYPE SAMPLES: BED MATERIAL
LOCATION: LINE #6 D/S OF AUX.	TEMP: 9 C @10 FT.	NO. VERTICALS: 4
GAGE: KNOX LANDING	WEATHER: CLOUDY AND MILD	NO. POINTS: 1
DISCHARGE: 783,520 CFS (ADCP)	GAGE READING: 48.60 FT.	

(SAMPLE)	
FIELD NO.	1
DISTANCE (FT.)	3211
DEPTH (FT.)	48

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	6.2	37.1	94.7	117.8	124.1	124.9	125.0	125.0	125
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	5.0	29.7	75.8	94.2	99.3	99.9	100.0	100.0	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.9	95.0	70.3	24.2	5.8	0.7	0.1	0.0	0.0	0.0

(SAMPLE)	
FIELD NO.	2
DISTANCE (FT.)	3811
DEPTH (FT.)	76

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	12.7	30.5	82.5	136.6	148.7	149.7	149.7	149.7	149.8
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	8.5	20.4	55.1	91.2	99.3	99.9	99.9	99.9	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.5	91.5	79.6	44.9	8.8	0.7	0.1	0.1	0.1	0.0

(SAMPLE)	
FIELD NO.	3
DISTANCE (FT.)	4090
DEPTH (FT.)	89

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9	21.7	91.6	141.5	146.6	150.0	150.0	150.0	150.0
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	14.5	61.1	94.3	97.7	100.0	100.0	100.0	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	98.7	85.5	38.9	5.7	2.3	0.0	0.0	0.0	0.0

(SAMPLE)	
FIELD NO.	4
DISTANCE (FT.)	4718
DEPTH (FT.)	90

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.3	28.3	92.8	112.1	138.1	143.4	149.8
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.9	18.9	61.9	74.8	92.2	95.7	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.9	99.1	81.1	38.1	25.2	7.8	4.3	0.0

DATE: 23-MAR-98	RIVER CONDITION: CHOPPY	TYPE SAMPLER: DRAG BUCKET
STREAM: MISSISSIPPI RIVER	TIME: 16:00 TO 17:10	TYPE SAMPLES: BED MATERIAL
LOCATION: LINE #6 D/S OF AUX.	TEMP: 9 C @10 FT.	NO. VERTICALS: 4
GAGE: KNOX LANDING	WEATHER: WINDY AND MILD	NO. POINTS: 1
DISCHARGE: 844,513 CFS (ADCP)	GAGE READING: 50.60 FT.	

(SAMPLE)	
FIELD NO.	5
DISTANCE (FT.)	3218
DEPTH (FT.)	52

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.9	19.1	95.6	140.7	149.4	150.0	150.0	150.0	150
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.6	12.7	63.7	93.8	99.6	100.0	100.0	100.0	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	97.4	87.3	36.3	6.2	0.4	0.0	0.0	0.0	0.0

(SAMPLE)	
FIELD NO.	6
DISTANCE (FT.)	3825
DEPTH (FT.)	89

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	3.1	49.1	128.7	148.1	149.7	149.8	149.8	149.9
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	2.1	32.8	85.9	98.8	99.9	99.9	99.9	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.9	97.9	67.2	14.1	1.2	0.1	0.1	0.1	0.0

(SAMPLE)	
FIELD NO.	7
DISTANCE (FT.)	4010
DEPTH (FT.)	95

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	1.9	25.9	102.2	145.8	149.5	149.7	149.8	149.8
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	1.3	17.3	68.2	97.3	99.8	99.9	100.0	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.8	98.7	82.7	31.8	2.7	0.2	0.1	0.0	0.0

(SAMPLE)	
FIELD NO.	8
DISTANCE (FT.)	4743
DEPTH (FT.)	89

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	1.3	19.7	99.1	145.0	149.4	149.9	149.9	150.0
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.9	13.1	66.1	96.7	99.6	99.9	99.9	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.9	99.1	86.9	33.9	3.3	0.4	0.1	0.1	0.0

Table B.11 (continued)

DATE: 10-APR-98	RIVER CONDITION: SMOOTH	TYPE SAMPLER: DRAG BUCKET
STREAM: MISSISSIPPI RIVER	TIME: 15:45 TO 17:15	TYPE SAMPLES: BED MATERIAL
LOCATION: LINE #6 D/S OF AUX.	TEMP: 16 C @1.5 FT.	NO. VERTICALS: 4
GAGE: KNOX LANDING	WEATHER: CLEAR AND MILD	NO. POINTS: 1
DISCHARGE: 856,512 CFS (ADCP)	GAGE READING: 52.35 FT.	
REPORTED: 964,000 CFS		

(SAMPLE)	
FIELD NO.	9
DISTANCE (FT.)	3203
DEPTH (FT.)	49

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.6	62.3	123.6	146.4	149.7	149.9	149.9	149.9	150.0
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.1	41.5	82.4	97.6	99.8	99.9	99.9	99.9	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	88.9	58.5	17.6	2.4	0.2	0.1	0.1	0.1	0.0

(SAMPLE)	
FIELD NO.	10
DISTANCE (FT.)	3778
DEPTH (FT.)	80

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.3	5.3	12.6	75.8	143.3	149.7	150.0	150.0	150.0	150.0
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	3.5	8.4	50.5	95.5	99.8	100.0	100.0	100.0	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.9	99.8	96.5	91.6	49.5	4.5	0.2	0.0	0.0	0.0	0.0

(SAMPLE)	
FIELD NO.	11
DISTANCE (FT.)	4095
DEPTH (FT.)	100

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	5.4	22.2	82.1	134.4	147.9	149.5	149.7	149.9	150.0
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	3.6	14.8	54.7	89.6	98.6	99.7	99.8	99.9	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.9	99.9	96.4	85.2	45.3	10.4	1.4	0.3	0.2	0.1	0.0

(SAMPLE)	
FIELD NO.	12
DISTANCE (FT.)	4676
DEPTH (FT.)	102

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	6.7	27.1	89.9	137.4	148.4	149.7	149.8	149.9	150.0
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	4.5	18.1	59.9	91.6	98.9	99.8	99.9	99.9	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.9	99.9	95.5	81.9	40.1	8.4	1.1	0.2	0.1	0.1	0.0

DATE: 17-APR-98	RIVER CONDITION: GOOD	TYPE SAMPLER: DRAG BUCKET
STREAM: MISSISSIPPI RIVER	TIME: 14:00 TO 15:15	TYPE SAMPLES: BED MATERIAL
LOCATION: LINE #6 D/S OF AUX.	TEMP: 16 C @1.5 FT.	NO. VERTICALS: 4
GAGE: KNOX LANDING	WEATHER: CLOUDY AND RAIN	NO. POINTS: 1
DISCHARGE: 793,350 CFS (ADCP)	GAGE READING: 50.50 FT.	

(SAMPLE)	
FIELD NO.	13
DISTANCE (FT.)	3159
DEPTH (FT.)	48

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.5	59.8	128.8	144.8	149.5	149.9	149.9	150.0	150.0
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.7	39.9	85.9	96.5	99.7	99.9	99.9	100.0	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	96.3	60.1	14.1	3.5	0.3	0.1	0.1	0.0	0.0

(SAMPLE)	
FIELD NO.	14
DISTANCE (FT.)	3826
DEPTH (FT.)	92

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.2	1.2	2.0	3.5	20.0	55.4	117.7	143.9	148.8	149.3	149.8	149.9	150.0
% HELD	0.0	0.0	0.0	0.0	0.0	0.1	0.8	1.3	2.3	13.3	36.9	78.5	95.9	99.2	99.5	99.9	99.9	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	99.9	99.2	98.7	97.7	86.7	63.1	21.5	4.1	0.8	0.5	0.1	0.1	0.0

(SAMPLE)	
FIELD NO.	15
DISTANCE (FT.)	4131
DEPTH (FT.)	97

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.1	16.0	53.1	122.8	146.2	149.3	149.7	149.7	149.9	150.0
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.7	10.7	35.4	81.9	97.5	99.5	99.8	99.8	99.9	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.9	99.3	89.3	64.6	18.1	2.5	0.5	0.2	0.2	0.1	0.0

(SAMPLE)	
FIELD NO.	16
DISTANCE (FT.)	4695
DEPTH (FT.)	92

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	1.4	8.8	27.5	92.5	139.6	149.0	149.8	149.8	149.9	150.0
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.9	5.9	18.3	61.7	93.1	99.3	99.9	99.9	99.9	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.5	99.1	94.1	81.7	38.3	6.9	0.7	0.1	0.1	0.1	0.0

Table B.11 (continued)

DATE: 09-JUN-98	RIVER CONDITION: CHOPPY	TYPE SAMPLER: DRAG BUCKET
STREAM: MISSISSIPPI RIVER	TIME: 15:05 TO 16:20	TYPE SAMPLES: BED MATERIAL
LOCATION: LINE #6 D/S OF AUX.	TEMP: 26 C @10 FT.	NO. VERTICALS: 4
GAGE: KNOX LANDING	WEATHER: CLOUDY AND HOT	NO. POINTS: 1
DISCHARGE: 504,817 CFS (ADCP)	GAGE READING: 40.30 FT.	

(SAMPLE)	
FIELD NO.	17
DISTANCE (FT.)	3197
DEPTH (FT.)	32

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	12.2	76.5	128.9	146.7	148.9	149.6	149.9	150.0
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	8.1	51.0	85.9	97.8	99.3	99.7	99.9	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.6	91.9	49.0	14.1	2.2	0.7	0.3	0.1	0.0

(SAMPLE)	
FIELD NO.	18
DISTANCE (FT.)	3786
DEPTH (FT.)	70

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	4.6	44.4	128.1	144.9	149.5	149.9	150.0	150.0	150.0
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	3.1	29.6	85.4	96.6	99.7	99.9	100.0	100.0	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.9	96.9	70.4	14.6	3.4	0.3	0.1	0.0	0.0	0.0

(SAMPLE)	
FIELD NO.	19
DISTANCE (FT.)	4093
DEPTH (FT.)	83

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	3.2	15.1	89.5	136.9	148.9	149.9	150.0	150.0	150.0
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	2.1	10.1	59.7	91.3	99.3	99.9	100.0	100.0	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.9	99.9	97.9	89.9	40.3	8.7	0.7	0.1	0.0	0.0	0.0

(SAMPLE)	
FIELD NO.	20
DISTANCE (FT.)	4703
DEPTH (FT.)	84

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.6	6.3	31.8	120.5	145.0	149.5	149.9	149.9	150.0	150.0
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.4	4.2	21.2	80.3	96.7	99.7	99.9	99.9	100.0	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.9	99.6	95.8	78.8	19.7	3.3	0.3	0.1	0.1	0.0	0.0

DATE: 03-AUG-98	RIVER CONDITION: CHOPPY	TYPE SAMPLER: DRAG BUCKET
STREAM: MISSISSIPPI RIVER	TIME: 15:20 TO 16:30	TYPE SAMPLES: BED MATERIAL
LOCATION: LINE #6 D/S OF AUX.	TEMP: 31 C @10 FT.	NO. VERTICALS: 4
GAGE: KNOX LANDING	WEATHER: CLOUDY AND HOT	NO. POINTS: 1
DISCHARGE: 384,264 CFS (ADCP)	GAGE READING: 33.0 FT.	

(SAMPLE)	
FIELD NO.	21
DISTANCE (FT.)	3204
DEPTH (FT.)	21

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.1	42.3	117.4	143.2	148.8	149.7	149.8	149.8	150.0
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.1	28.2	78.3	95.5	99.2	99.8	99.9	99.9	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	95.9	71.8	21.7	4.5	0.8	0.2	0.1	0.1	0.0

(SAMPLE)	
FIELD NO.	22
DISTANCE (FT.)	3785
DEPTH (FT.)	56

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	7.9	89.8	133.7	146.6	149.5	149.8	149.9	150.0
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	5.3	59.9	89.1	97.7	99.7	99.9	99.9	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.4	94.7	40.1	10.9	2.3	0.3	0.1	0.1	0.0

(SAMPLE)	
FIELD NO.	23
DISTANCE (FT.)	4108
DEPTH (FT.)	76

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	8.8	108.2	141.3	148.9	149.7	149.9	149.9	150.0	150.0
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	5.9	72.1	94.2	99.3	99.8	99.9	99.9	100.0	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.8	94.1	27.9	5.8	0.7	0.2	0.1	0.1	0.0	0.0

(SAMPLE)	
FIELD NO.	24
DISTANCE (FT.)	4669
DEPTH (FT.)	79

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.9	39.2	128.7	144.4	149.2	149.7	149.9	150.0	150.0
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.6	26.1	85.8	96.3	99.5	99.8	99.9	100.0	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	93.4	73.9	14.2	3.7	0.5	0.2	0.1	0.0	0.0

Table B.12. Bed material data at Tarbert.

DATE: 27-FEB-98	RIVER CONDITION: SMOOTH	TYPE SAMPLER: DRAG BUCKET
STREAM: MISSISSIPPI RIVER	TIME: 16:00 TO 17:00	TYPE SAMPLES: BED MATERIAL
LOCATION: TARBERT	TEMP: 9 C @1 FT.	NO. VERTICALS: 4
GAGE: RED RIVER LDG.	WEATHER: CLOUDY AND MILD	NO. POINTS: 1
DISCHARGE: 782,440 CFS (ADCP)	GAGE READING: 46.50 FT.	

(SAMPLE)																		
FIELD NO.	1																	
DISTANCE (FT.)	1417																	
DEPTH (FT.)	54																	
DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	8.4	85.9	119.9	124.3	124.6	124.7	124.8
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	6.7	68.8	96.1	99.6	99.8	99.9	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.9	93.3	31.2	3.9	0.4	0.2	0.1	0.0

(SAMPLE)																		
FIELD NO.	2																	
DISTANCE (FT.)	2204																	
DEPTH (FT.)	48																	
DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.3	34.8	133.0	149.1	149.9	149.9	149.9	149.9
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	23.2	88.7	99.5	100.0	100.0	100.0	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.9	99.8	76.8	11.3	0.5	0.0	0.0	0.0	0.0

(SAMPLE)																		
FIELD NO.	3																	
DISTANCE (FT.)	2797																	
DEPTH (FT.)	53																	
DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	13.1	121.5	147.1	149.8	150.0	150.0	150.0	150.0
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	8.7	81.0	98.1	99.9	100.0	100.0	100.0	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.6	91.3	19.0	1.9	0.1	0.0	0.0	0.0	0.0

(SAMPLE)																		
FIELD NO.	4																	
DISTANCE (FT.)	3409																	
DEPTH (FT.)	46																	
DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	2.1	28.1	107.9	148.6	149.7	150.0	150.0	150.0	150.0	150.0
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	1.4	18.7	71.9	99.1	99.8	100.0	100.0	100.0	100.0	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.1	98.6	81.3	28.1	0.9	0.2	0.0	0.0	0.0	0.0	0.0

DATE: 23-MAR-98	RIVER CONDITION: CHOPPY	TYPE SAMPLER: DRAG BUCKET
STREAM: MISSISSIPPI RIVER	TIME: 17:30 TO 18:30	TYPE SAMPLES: BED MATERIAL
LOCATION: TARBERT	TEMP: 9 C @10 FT.	NO. VERTICALS: 4
GAGE: TARBERT	WEATHER: WINDY AND MILD	NO. POINTS: 1
DISCHARGE: 861,783 CFS (ADCP)	GAGE READING: 49.00 FT.	

(SAMPLE)																		
FIELD NO.	5																	
DISTANCE (FT.)	1368																	
DEPTH (FT.)	57																	
DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	29.1	123.1	148.0	149.3	149.8	149.9	150.0
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	19.4	82.1	98.7	99.5	99.9	99.9	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.9	80.6	17.9	1.3	0.5	0.1	0.1	0.0

(SAMPLE)																		
FIELD NO.	6																	
DISTANCE (FT.)	2169																	
DEPTH (FT.)	47																	
DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	57.1	133.6	148.0	149.8	149.9	149.9	150.0
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	38.1	89.1	98.7	99.9	99.9	99.9	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.3	61.9	10.9	1.3	0.1	0.1	0.1	0.0

(SAMPLE)																		
FIELD NO.	7																	
DISTANCE (FT.)	3023																	
DEPTH (FT.)	51																	
DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9	27.7	133.5	147.8	149.7	149.8	149.9	150.0	150.0
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	18.5	89.0	98.5	99.8	99.9	99.9	100.0	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	98.7	81.5	11.0	1.5	0.2	0.1	0.1	0.0	0.0

(SAMPLE)																		
FIELD NO.	8																	
DISTANCE (FT.)	3378																	
DEPTH (FT.)	47																	
DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.4	24.6	113.1	146.0	149.1	149.8	149.8	149.9	149.9	149.9
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.3	16.4	75.5	97.4	99.5	99.9	99.9	100.0	100.0	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.8	99.7	83.6	24.5	2.6	0.5	0.1	0.1	0.0	0.0	0.0

Table B.12 (continued)

DATE: 10-APR-98	RIVER CONDITION: SMOOTH	TYPE SAMPLER: DRAG BUCKET
STREAM: MISSISSIPPI RIVER	TIME: 17:30 TO 18:30	TYPE SAMPLES: BED MATERIAL
LOCATION: TARBERT	TEMP: 16 C @1.5 FT.	NO. VERTICALS: 4
GAGE: TARBERT	WEATHER: CLEAR AND MILD	NO. POINTS: 1
DISCHARGE: 847,658 CFS (ADCP)	GAGE READING: 50.80 FT.	

REPORTED: 964,000 CFS

(SAMPLE)	
FIELD NO.	9
DISTANCE (FT.)	1371
DEPTH (FT.)	62

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	12.8	98.1	144.9	149.8	149.9	150.0	150.0
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	8.5	65.4	96.6	99.9	99.9	100.0	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.6	91.5	34.6	3.4	0.1	0.1	0.0	0.0

(SAMPLE)	
FIELD NO.	10
DISTANCE (FT.)	2129
DEPTH (FT.)	63

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	3.0	82.6	138.6	148.9	149.8	150.0	150.0	150.0
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	2.0	55.1	92.4	99.3	99.9	100.0	100.0	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.9	98.0	44.9	7.6	0.7	0.1	0.0	0.0	0.0

(SAMPLE)	
FIELD NO.	11
DISTANCE (FT.)	2730
DEPTH (FT.)	57

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.3	32.9	120.1	146.4	149.7	149.9	150.0	150.0	150.0
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	21.9	80.1	97.6	99.8	99.9	100.0	100.0	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	98.5	78.1	19.9	2.4	0.2	0.1	0.0	0.0	0.0

(SAMPLE)	
FIELD NO.	12
DISTANCE (FT.)	3369
DEPTH (FT.)	49

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	30.5	110.5	139.8	147.9	148.8	149.6	149.9	149.9	150.0
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	20.3	73.7	93.2	98.6	99.2	99.7	99.9	99.9	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.4	79.7	26.3	6.8	1.4	0.8	0.3	0.1	0.1	0.0

DATE: 17-APR-98	RIVER CONDITION: GOOD	TYPE SAMPLER: DRAG BUCKET
STREAM: MISSISSIPPI RIVER	TIME: 15:30 TO 16:30	TYPE SAMPLES: BED MATERIAL
LOCATION: TARBERT	TEMP: 16 C @1.5 FT.	NO. VERTICALS: 4
GAGE: TARBERT DISCHARGE RNG.	WEATHER: CLOUDY AND RAIN	NO. POINTS: 1
DISCHARGE: 799,303 CFS (ADCP)	GAGE READING: 49.00 FT.	

(SAMPLE)	
FIELD NO.	13
DISTANCE (FT.)	1365
DEPTH (FT.)	58

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	13.1	111.9	144.4	149.5	149.9	150.0	150.0
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	8.7	74.6	96.3	99.7	99.9	100.0	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.9	91.3	25.4	3.7	0.3	0.1	0.0	0.0

(SAMPLE)	
FIELD NO.	14
DISTANCE (FT.)	2180
DEPTH (FT.)	54

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	12.6	109.7	143.9	148.9	149.6	149.9	149.9	150.0
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	8.4	73.1	95.9	99.3	99.7	99.9	99.9	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.9	91.6	26.9	4.1	0.7	0.3	0.1	0.1	0.0

(SAMPLE)	
FIELD NO.	15
DISTANCE (FT.)	2780
DEPTH (FT.)	54

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.9	5.5	110.7	142.7	149.3	149.9	149.9	150.0	150.0
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.6	3.7	73.8	95.1	99.5	99.9	99.9	100.0	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.9	99.9	99.4	96.3	26.2	4.9	0.5	0.1	0.1	0.0	0.0

(SAMPLE)	
FIELD NO.	16
DISTANCE (FT.)	3382
DEPTH (FT.)	48

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.3	82.1	131.2	148.2	149.6	149.9	149.9	150.0	150.0
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.2	54.7	87.5	98.8	99.7	99.9	99.9	100.0	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	95.8	45.3	12.5	1.2	0.3	0.1	0.1	0.0	0.0

Table B.12 (continued)

DATE: 08-MAY-98	RIVER CONDITION: GOOD	TYPE SAMPLER: DRAG BUCKET
STREAM: MISSISSIPPI RIVER	TIME: 16:00 TO 17:00	TYPE SAMPLES: BED MATERIAL
LOCATION: TARBERT	TEMP: 19 C @10 FT.	NO. VERTICALS: 4
GAGE: TARBERT DISCHARGE RNG.	WEATHER: CLOUDY	NO. POINTS: 1
DISCHARGE: 925,212 CFS (ADCP)	GAGE READING: 52.50 FT.	

(SAMPLE)	
FIELD NO.	17
DISTANCE (FT.)	1357
DEPTH (FT.)	61

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	22.6	102.8	144.5	149.0	149.4	149.7	150.0
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	15.1	68.5	96.3	99.3	99.6	99.8	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.9	84.9	31.5	3.7	0.7	0.4	0.2	0.0

(SAMPLE)	
FIELD NO.	18
DISTANCE (FT.)	2152
DEPTH (FT.)	53

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.9	101.9	134.8	149.3	149.7	149.9	150.0	150.0
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.6	67.9	89.9	99.5	99.8	99.9	100.0	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.9	99.4	32.1	10.1	0.5	0.2	0.1	0.0	0.0

(SAMPLE)	
FIELD NO.	19
DISTANCE (FT.)	2769
DEPTH (FT.)	56

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	4.9	82.9	135.9	147.6	149.4	149.6	149.8	149.9	150.0
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	3.3	55.3	90.6	98.4	99.6	99.7	99.9	99.9	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.9	96.7	44.7	9.4	1.6	0.4	0.3	0.1	0.1	0.0

(SAMPLE)	
FIELD NO.	20
DISTANCE (FT.)	3367
DEPTH (FT.)	50

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	5.6	88.6	139.1	146.2	148.9	149.6	149.9	150.0	150.0
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	3.7	59.1	92.7	97.5	99.3	99.7	99.9	100.0	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.8	96.3	40.9	7.3	2.5	0.7	0.3	0.1	0.0	0.0

DATE: 09-JUN-98	RIVER CONDITION: CHOPPY	TYPE SAMPLER: DRAG BUCKET
STREAM: MISSISSIPPI RIVER	TIME: 16:50 TO 17:50	TYPE SAMPLES: BED MATERIAL
LOCATION: TARBERT	TEMP: 26 C @10 FT.	NO. VERTICALS: 4
GAGE: TARBERT DSCHG. RNG.	WEATHER: CLOUDY AND HOT	NO. POINTS: 1
DISCHARGE: 479,979 CFS (ADCP)	GAGE READING: 38.90 FT.	

(SAMPLE)	
FIELD NO.	21
DISTANCE (FT.)	1377
DEPTH (FT.)	48

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	21.9	101.0	146.6	149.3	149.6	149.9	150.0	150.0
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	14.6	67.3	97.7	99.5	99.7	99.9	100.0	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.5	85.4	32.7	2.3	0.5	0.3	0.1	0.0	0.0

(SAMPLE)	
FIELD NO.	22
DISTANCE (FT.)	2188
DEPTH (FT.)	41

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.8	78.9	122.4	146.6	149.2	149.8	150.0	150.0
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.5	52.6	81.6	97.7	99.5	99.9	100.0	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.9	99.9	99.5	47.4	18.4	2.3	0.5	0.1	0.0	0.0

(SAMPLE)	
FIELD NO.	23
DISTANCE (FT.)	2768
DEPTH (FT.)	40

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.9	83.7	133.8	149.7	149.8	149.9	149.9	150.0	150.0
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.6	55.8	89.2	99.8	99.9	99.9	99.9	100.0	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	97.4	44.2	10.8	0.2	0.1	0.1	0.1	0.0	0.0

(SAMPLE)	
FIELD NO.	24
DISTANCE (FT.)	3373
DEPTH (FT.)	35

DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.177	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	79.9	133.9	145.5	148.8	149.2	149.8	149.9	150.0
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	53.3	89.3	97.0	99.2	99.5	99.9	99.9	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.4	46.7	10.7	3.0	0.8	0.5	0.1	0.1	0.0

Table B.12 (continued)

DATE: 03-AUG-98	RIVER CONDITION: CHOPPY	TYPE SAMPLER: DRAG BUCKET
STREAM: MISSISSIPPI RIVER	TIME: 16:40 TO 17:50	TYPE SAMPLES: BED MATERIAL
LOCATION: TARBERT	TEMP: 31 C @10 FT.	NO. VERTICALS: 4
GAGE: TARBERT	WEATHER: CLOUDY AND HOT	NO. POINTS: 1
DISCHARGE: 374,327 CFS (ADCP)	GAGE READING: 31.40 FT.	

(SAMPLE)																		
FIELD NO.	25																	
DISTANCE (FT.)	1380																	
DEPTH (FT.)	41																	
DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.18	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.9	111.7	147.9	149.7	149.8	149.8	150.0
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.6	74.5	98.6	99.8	99.9	99.9	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	93.4	25.5	1.4	0.2	0.1	0.1	0.0
(SAMPLE)																		
FIELD NO.	26																	
DISTANCE (FT.)	2186																	
DEPTH (FT.)	36																	
DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.18	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	60.8	139.9	149.2	149.9	149.9	150.0	150.0
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	40.5	93.3	99.5	99.9	99.9	100.0	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.0	59.5	6.7	0.5	0.1	0.1	0.0	0.0
(SAMPLE)																		
FIELD NO.	27																	
DISTANCE (FT.)	2783																	
DEPTH (FT.)	33																	
DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.18	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.5	25.1	75.3	131.7	148.3	149.6	149.8	149.8	149.8	150.0
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.3	16.7	50.2	87.8	98.9	99.7	99.9	99.9	99.9	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.8	99.7	83.3	49.8	12.2	1.1	0.3	0.1	0.1	0.1	0.0
(SAMPLE)																		
FIELD NO.	28																	
DISTANCE (FT.)	3390																	
DEPTH (FT.)	25																	
DIA. (MM)	25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.35	0.25	0.18	0.125	0.088	0.074	0.062	PAN
CUM. WT.	0.0	0.0	0.0	0.0	0.0	1.2	3.0	4.7	7.9	72.3	127.5	147.4	149.4	149.5	149.7	149.9	150.0	150.0
% HELD	0.0	0.0	0.0	0.0	0.0	0.8	2.0	3.1	5.3	48.2	85.0	98.3	99.6	99.7	99.8	99.9	100.0	100.0
% FINER	100.0	100.0	100.0	100.0	100.0	99.2	98.0	96.9	94.7	51.8	15.0	1.7	0.4	0.3	0.2	0.1	0.0	0.0

Table B.13. Unit conversion table.

Amount	Unit	Amount	lb, ft, s	Amount	kg, m, s	Amount	N, Pa, W
1	day (d)			86400	second (s)		
1	degree Celsius (C = 5 (F - 32) / 9)			1	K		
1	degree Fahrenheit (F = 32 + 1.8 C)			0.5556	K		
1	foot (ft)			0.3048	meter (m)		
1	ft / s			0.3048	m / s		
1	ft^2			0.0929	m^2		
1	ft^2 / s			0.0929	m^2 / s		
1	ft^3 / s			0.0283	m^3 / s		
1	inch (in)			0.0254	m		
1	lb / ft^3			157.08	kg / m^2 * s^2	157.08	N / m^3
1	liter (l)			0.001	m^3		
1	metric ton			1000	kg		
1	mile (mi)	5280	ft	1609.34	m		
1	milligram/liter (mg/l)			1.0E-06	ton / m^3		
1	newton (N)			1	kg X m / s^2	1	N
1	pound - force (lb)			4.448	kg X m / s^2	4.448	N
1	slug			14.59	kg		
1	slug / ft^3			515.40	kg / m^3		
1	year			31536000	s		

Table B.14. $\Delta\overline{C} / \Delta T$ and percent sand values by size fraction at all locations.

Cross Section	Vertical	$\Delta C_{ave}/\Delta T$ (Slope)				Average % Sand			
		VFS	FS	MS	CS	VFS	FS	MS	CS
UP	V-1	-0.769	-3.694	-0.161	-0.032	27.68	68.17	2.88	1.28
L13	V-1	-0.481	-1.453	-0.101	-0.108	31.78	54.85	11.41	1.98
L6	V-1	-1.076	-4.997	-0.790	-0.102	30.32	60.01	8.48	1.22
T	V-1	-0.062	-1.679	-0.777	-0.028	27.33	62.04	9.90	0.76
UP	V-2	-0.309	-0.862	-0.327	-0.110	17.13	77.43	4.57	0.87
L13	V-2	-0.331	-2.483	0.446	-0.101	18.06	63.53	16.48	1.93
L6	V-2	-0.636	-5.901	0.539	0.111	15.86	75.36	7.39	1.40
T	V-2	0.621	2.056	-1.642	-0.002	15.77	63.61	19.21	1.41
UP	V-3	-0.541	-3.994	1.730	0.059	9.42	61.14	27.36	2.08
L13	V-3	-0.141	-2.080	0.141	-0.031	18.60	74.49	5.93	0.99
L6	V-3	0.562	0.577	1.120	0.222	17.02	70.33	10.89	1.76
T	V-3	-0.077	-1.613	0.457	0.009	19.99	62.52	14.79	2.71
UP	V-4	-0.758	-3.726	0.119	-0.071	24.45	36.37	33.58	5.60
L13	V-4	-0.647	-3.085	-0.094	-0.065	31.34	63.39	4.03	1.24
L6	V-4	0.063	-0.547	0.167	1.245	25.20	52.31	13.44	9.07
T	V-4	-0.337	-1.934	0.080	-0.014	27.52	56.38	14.10	2.02

Table B.15. Average measured Rouse number values at all locations.

Union Point

Distance	FEB. 27 Event				Distance	MAR. 23 Event				Distance	APR. 10 Event			
from the	Measured Rouse number values at 9 °C				from the	Measured Rouse number values at 9 °C				from the	Measured Rouse number values at 16 °C			
right bank	Sand size fractions				right bank	Sand size fractions				right bank	Sand size fractions			
(ft)	CS	MS	FS	VFS	(ft)	CS	MS	FS	VFS	(ft)	CS	MS	FS	VFS
1066	0.0400	-0.0227	0.3868	0.2066	1020	1.0267	0.2986	0.7461	0.3887	1075	0.1910	0.7692	0.5008	0.2087
1658	0.4483	0.4461	0.7644	0.3631	1755	0.1772	0.3645	0.7183	0.2903	1643	1.0514	0.7698	0.6036	0.3891
2256	-0.0143	0.7603	0.5208	0.2419	2274	0.4461	0.7243	0.5319	0.1814	2224	1.0773	0.6107	0.5513	0.2082
2941	0.4542	0.5836	0.1995	0.0967	3091	0.5004	0.6283	0.3014	0.1354	2943	1.1186	0.4833	0.1969	0.1271
Ave. R_{om}	0.2320	0.4418	0.4679	0.2271	Ave. R_{om}	0.5376	0.5039	0.5744	0.2490	Ave. R_{om}	0.8596	0.6583	0.4632	0.2333

Distance	APR. 17 Event				Distance	MAY 8 Event				Distance	JUN. 9 Event			
from the	Measured Rouse number values at 16 °C				from the	Measured Rouse number values at 19 °C				from the	Measured Rouse number values at 26 °C			
right bank	Sand size fractions				right bank	Sand size fractions				right bank	Sand size fractions			
(ft)	CS	MS	FS	VFS	(ft)	CS	MS	FS	VFS	(ft)	CS	MS	FS	VFS
1040	0.5748	0.2321	0.3378	0.0695	1094	0.9880	0.7535	0.2482	0.1462	1047	1.0760	0.5237	0.3463	0.1622
1648	1.1108	0.3454	0.5351	0.1148	1652	1.1659	0.5020	0.7742	0.3227	1613	0.7897	0.3129	0.3359	0.1206
2247	1.1638	1.2640	0.5942	0.1771	2276	1.2126	0.4483	0.2639	0.0762	2235	1.1643	1.6647	0.8958	0.1895
2966	1.1444	0.6396	0.3155	0.1653	2959	0.8239	0.6521	0.2835	0.0909	2923	0.1273	0.0807	-0.0385	0.1611
Ave. R_{om}	0.9984	0.6203	0.4457	0.1317	Ave. R_{om}	1.0476	0.5890	0.3925	0.1590	Ave. R_{om}	0.7893	0.6455	0.3849	0.1584

Distance	AUG. 3 Event			
from the	Measured Rouse number values at 31 °C			
right bank	Sand size fractions			
(ft)	CS	MS	FS	VFS
1030	1.0626	0.2540	0.6133	0.3948
1625	0.4860	0.7554	0.5477	0.1870
2229	1.2788	0.7894	0.3990	0.1535
2901	0.9206	0.3318	0.3561	0.2448
Ave. R_{om}	0.9370	0.5327	0.4790	0.2450

Line 13

Distance	FEB. 27 Event				Distance	MAR. 23 Event				Distance	APR. 10 Event			
from the	Measured Rouse number values at 9 °C				from the	Measured Rouse number values at 9 °C				from the	Measured Rouse number values at 16 °C			
right bank	Sand size fractions				right bank	Sand size fractions				right bank	Sand size fractions			
(ft)	CS	MS	FS	VFS	(ft)	CS	MS	FS	VFS	(ft)	CS	MS	FS	VFS
1793	0.3307	0.4087	0.2223	0.0920	1785	0.1705	0.3354	0.1851	0.0933	1801	0.0000	0.2073	0.0162	0.0606
2115	0.4039	0.5608	0.3273	0.2475	2068	0.0969	0.0141	0.0758	0.0636	2072	1.1156	1.1467	0.4171	0.1966
2449	0.1562	0.4713	0.6619	0.4016	2459	0.1865	0.2962	0.5638	0.3171	2433	1.0019	1.0326	0.7804	0.2536
2916	0.1001	-0.0015	0.3819	0.2830	2890	0.1657	0.3515	0.5246	0.2367	2869	1.0255	1.0693	0.6772	0.2577
Ave. R_{om}	0.2288	0.3619	0.4260	0.2756	Ave. R_{om}	0.1549	0.2493	0.3373	0.1777	Ave. R_{om}	1.0426	0.9214	0.5615	0.2192

Distance	APR. 17 Event				Distance	MAY 8 Event				Distance	JUN. 9 Event			
from the	Measured Rouse number values at 16 °C				from the	Measured Rouse number values at 19 °C				from the	Measured Rouse number values at 26 °C			
right bank	Sand size fractions				right bank	Sand size fractions				right bank	Sand size fractions			
(ft)	CS	MS	FS	VFS	(ft)	CS	MS	FS	VFS	(ft)	CS	MS	FS	VFS
1786	-0.0082	0.3215	0.2399	0.1345	1787	0.6538	0.5868	0.2907	0.1752	1771	-0.9042	-0.0312	0.2973	-0.0700
2098	0.7584	0.6105	0.4410	0.1514	2032	0.4274	0.2556	0.1795	0.0948	2089	1.2035	0.7059	0.4496	0.2496
2454	0.5622	0.4439	0.6924	0.2773	2456	1.0658	0.4969	0.5608	0.1789	2476	0.8724	0.7867	0.7735	0.4140
2834	0.9131	0.8656	0.3864	0.1801	2855	0.6431	1.0904	0.5171	0.3357	2855	0.9504	0.0875	0.6093	0.5095
Ave. R_{om}	0.5226	0.5223	0.4354	0.1960	Ave. R_{om}	0.6975	0.6074	0.3870	0.1961	Ave. R_{om}	0.7368	0.4490	0.5842	0.3266

Distance	AUG. 3 Event			
from the	Measured Rouse number values at 31 °C			
right bank	Sand size fractions			
(ft)	CS	MS	FS	VFS
1791	0.9111	0.6719	0.1561	0.2336
2076	0.3642	0.6095	0.4181	0.1249
2474	0.7124	0.5177	0.5472	0.2568
2881	0.3645	0.2224	0.3593	0.5801
Ave. R_{om}	0.5881	0.5054	0.3702	0.2989

Table B.15 (continued)

Line 6

Distance from the right bank	FEB. 27 Event				Distance from the right bank	MAR. 23 Event				Distance from the right bank	APR. 10 Event			
	Measured Rouse number values at 9 °C					Measured Rouse number values at 9 °C					Measured Rouse number values at 16 °C			
	Sand size fractions					Sand size fractions					Sand size fractions			
(ft)	CS	MS	FS	VFS	(ft)	CS	MS	FS	VFS	(ft)	CS	MS	FS	VFS
3211	-0.1765	0.3851	0.4873	0.2772	3218	0.6934	0.7635	0.5508	0.2239	3203	0.8992	0.3649	0.4408	0.1780
3811	0.3221	0.5222	0.5681	0.3109	3825	0.6666	0.4436	0.5296	0.2480	3778	1.0589	0.5175	0.6565	0.3069
4090	0.3938	0.6220	0.5743	0.0682	4010	0.5667	0.1939	0.2817	0.2155	4095	1.0457	1.1699	0.4615	0.1237
4718	0.0900	0.5256	0.3889	0.0898	4743	0.4267	-0.2469	-0.1326	0.0640	4676	0.0454	1.0765	0.5532	0.1345
Ave. R_{om}	0.1574	0.5137	0.5046	0.1865	Ave. R_{om}	0.5884	0.2885	0.3074	0.1878	Ave. R_{om}	0.7623	0.7822	0.5280	0.1858

Distance from the right bank	APR. 17 Event				Distance from the right bank	JUN. 9 Event				Distance from the right bank	AUG. 3 Event			
	Measured Rouse number values at 16 °C					Measured Rouse number values at 26 °C					Measured Rouse number values at 31 °C			
	Sand size fractions					Sand size fractions					Sand size fractions			
(ft)	CS	MS	FS	VFS	(ft)	CS	MS	FS	VFS	(ft)	CS	MS	FS	VFS
3159	1.2140	1.1386	0.3722	0.0936	3197	-0.1171	0.9219	0.0390	-0.0312	3204	-0.3032	0.7781	0.3231	0.2350
3826	0.9582	0.5415	0.4366	0.1173	3786	0.6042	0.8013	0.5401	0.1087	3785	1.2534	0.8466	0.6063	0.1810
4131	0.0000	1.2157	0.3571	0.1431	4093	0.6471	0.8674	0.8087	0.4822	4108	0.7601	0.5694	0.5923	0.2564
4695	-0.6424	-0.0457	0.1892	0.2163	4703	0.7726	0.3402	0.4920	0.6502	4669	-1.2083	-0.9003	-0.2691	0.1280
Ave. R_{om}	0.3825	0.7125	0.3388	0.1426	Ave. R_{om}	0.4767	0.7327	0.4699	0.3025	Ave. R_{om}	0.1255	0.3235	0.3131	0.2001

Tarbert

Distance from the right bank	FEB. 27 Event				Distance from the right bank	MAR. 23 Event				Distance from the right bank	APR. 10 Event			
	Measured Rouse number values at 9 °C					Measured Rouse number values at 9 °C					Measured Rouse number values at 16 °C			
	Sand size fractions					Sand size fractions					Sand size fractions			
(ft)	CS	MS	FS	VFS	(ft)	CS	MS	FS	VFS	(ft)	CS	MS	FS	VFS
1417	0.0437	0.8702	0.6424	0.2355	1368	0.0000	1.4648	0.6732	0.3228	1371	1.2402	0.4307	0.2697	0.1148
2204	0.0670	0.5402	0.1801	0.1667	2169	0.8647	0.7122	0.5185	0.2263	2129	1.2934	0.6109	0.3862	0.1325
2797	0.2282	0.1226	0.2099	0.3488	3023	0.0000	-0.0395	0.2282	0.1900	2730	0.7451	0.4842	0.4610	0.1936
3409	0.1543	0.3567	0.2429	0.1621	3378	0.0000	0.1760	0.5219	0.1392	3369	0.7016	0.6963	0.6139	0.3216
Ave. R_{om}	0.1281	0.3682	0.2160	0.2024	Ave. R_{om}	0.2162	0.5784	0.4855	0.2196	Ave. R_{om}	0.9951	0.5555	0.4327	0.1907

Distance from the right bank	APR. 17 Event				Distance from the right bank	MAY 8 Event				Distance from the right bank	JUN. 9 Event			
	Measured Rouse number values at 16 °C					Measured Rouse number values at 19 °C					Measured Rouse number values at 26 °C			
	Sand size fractions					Sand size fractions					Sand size fractions			
(ft)	CS	MS	FS	VFS	(ft)	CS	MS	FS	VFS	(ft)	CS	MS	FS	VFS
1365	0.0000	0.9294	0.3372	0.2239	1357	0.6564	1.0513	0.2874	0.2917	1377	0.7079	0.7462	0.5901	0.2024
2180	1.0717	0.3406	0.5360	0.2041	2152	0.3547	0.3177	0.4505	0.1683	2188	0.8952	0.4585	0.3952	0.3061
2780	0.9412	0.7290	0.4870	0.1958	2769	1.2942	0.8315	0.4474	0.1620	2768	1.0645	0.4846	0.3490	0.1260
3382	1.2020	0.6256	0.4207	0.1064	3367	0.9307	0.4943	0.3692	0.2491	3373	1.1465	0.4467	0.3342	0.1102
Ave. R_{om}	0.8037	0.6561	0.4452	0.1826	Ave. R_{om}	0.8090	0.6737	0.3886	0.2178	Ave. R_{om}	0.9536	0.5340	0.4171	0.1862

Distance from the right bank	AUG. 3 Event			
	Measured Rouse number values at 31 °C			
	Sand size fractions			
(ft)	CS	MS	FS	VFS
1380	1.0146	-0.1627	0.5394	0.3933
2186	0.1478	0.8210	0.7958	0.2480
2783	1.2979	0.5134	0.2867	0.1501
3390	0.3313	0.2681	0.2451	0.2316
Ave. R_{om}	0.6979	0.3599	0.4668	0.2558

APPENDIX C – FIGURES

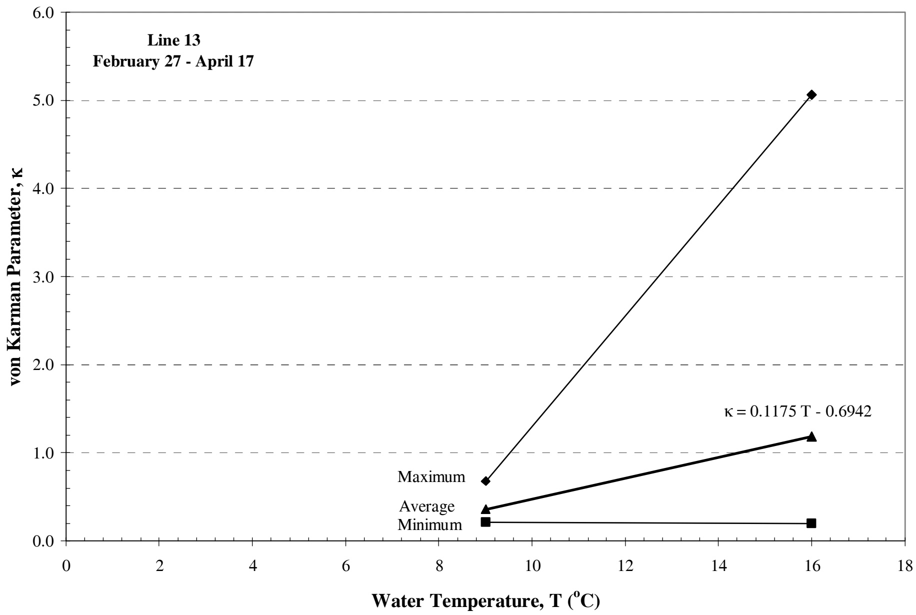

Figure C.1. The effect of water temperature on the von Karman parameter for approximately same discharge events at Line 13.

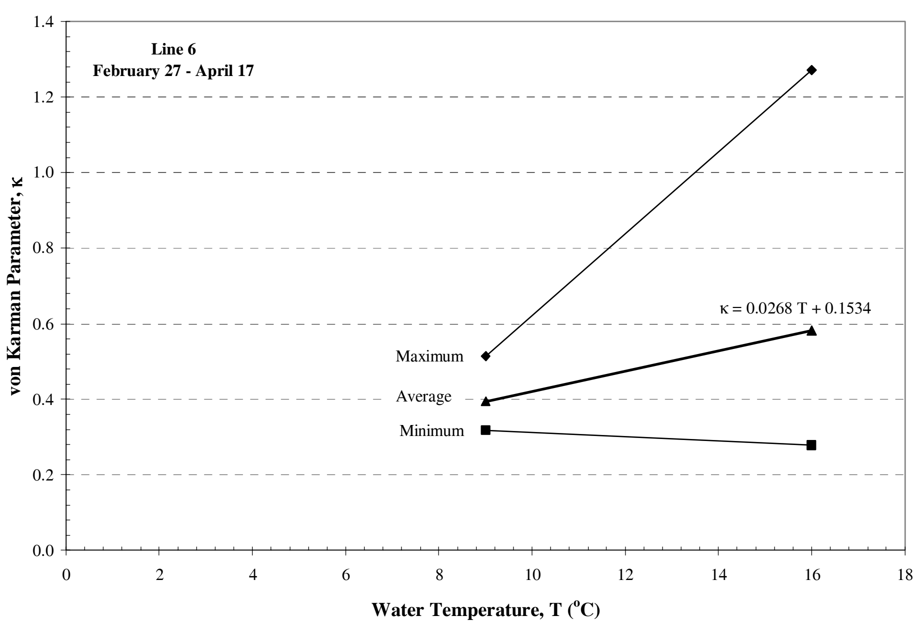

Figure C.2. The effect of water temperature on the von Karman parameter for approximately same discharge events at Line 6.

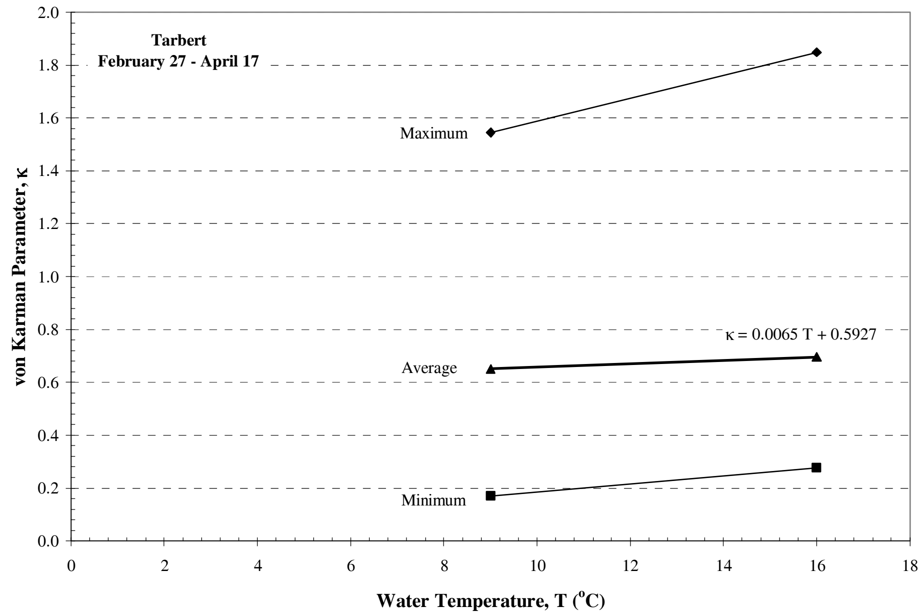

Figure C.3. The effect of water temperature on the von Karman parameter for approximately same discharge events at Tarbert.