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DISSERTATION

WATER TEMPERATURE EFFECT ON SAND TRANSPORT BY SIZE FRACTION IN THE LOWER MISSISSIPPI RIVER

Submitted by

SULEYMAN AKALIN

In partial fulfillment of the requirements
for the Degree of Doctor of Philosophy

Colorado State University

Fort Collins, Colorado

Fall, 2002

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COLORADO STATE UNIVERSITY

July 16, 2002

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.

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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 °C to 31 °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_{*}), and reference sediment concentration (C_r) 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 °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 °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 °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 °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 °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

<u>Symbol</u>	<u>Definition</u>
$\alpha :$	Coefficient with a value of 4 to 5
$a :$	Reference elevation or height
$A :$	Integration constant
$A_f :$	Cross-sectional area of the flow
$a' :$	$\left[\frac{9.5 u_*}{z_0^{1.6}} \right]$
$a_c :$	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
$\beta :$	Turbulent Schmidt number
$c :$	Integration constant
$C :$	Suspended sediment concentration at an arbitrary elevation z
$\bar{C} :$	Mean sediment discharge concentration
$C'' :$	$18 \log(12 h / 3 d_{90})$
$\frac{dC}{dz} :$	Concentration gradient in the z direction
$C_0 :$	Maximum volumetric sediment concentration near the bed

$\overline{C_0}$:	$[C(d_1)/2] [d_1/h_1]$
$C(d_i)$:	Measured sediment concentration at the sampling points
c_1, c_2 :	Constants
C_a :	Reference concentration at $z = a$
C_{ac} :	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_t :	Volumetric suspended sediment concentration
$^{\circ}C$:	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_s^* :	Dimensionless particle diameter, $d_{s0} \left((\rho_s - \rho)g / \rho \nu^2 \right)^{1/3}$
ε_m :	Momentum exchange coefficient
ε_s :	Sediment mixing coefficient

$\exp :$	Base of the natural logarithm
$e_D :$	Discharge exponent
$e_T :$	Temperature exponent
$f :$	Coriolis parameter
$F :$	Longitudinal force
$F_c :$	Coriolis force
$f_r :$	Friction factor
$F_g :$	Gravitational force
$\Phi :$	Latitude
$^{\circ}\text{F} :$	Temperature in Degrees Fahrenheit
$g :$	Gravitational acceleration
$G :$	Specific gravity, $\frac{\gamma_s}{\gamma}$
$\gamma :$	Specific weight of water
$\gamma_s :$	Specific weight of sediment particles
$\Gamma :$	$(\tau_b' - \tau_{b,cr}) / \tau_{b,cr}$
$h :$	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_s :	$0.1198+0.00048 T$, where T is the water temperature in °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. $\frac{\omega d_s}{\nu}$
Re_s :	Boundary Reynolds number. $\frac{u_* d_s}{\nu_m}$
R_o :	Rouse number. $\frac{\omega_0}{K_o u_*}$
$R_{o,m}$:	Measured Rouse number
$R_{o,c}$:	Calculated Rouse number
$R_{o,c}'$:	Corrected Rouse number
S_o :	Riverbed slope
$\overline{S_o}$:	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
$\tau_{b,c}$:	Critical bed shear stress
$\tau_{b,c}'$:	$\rho g(\overline{V}/C)^2$
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.

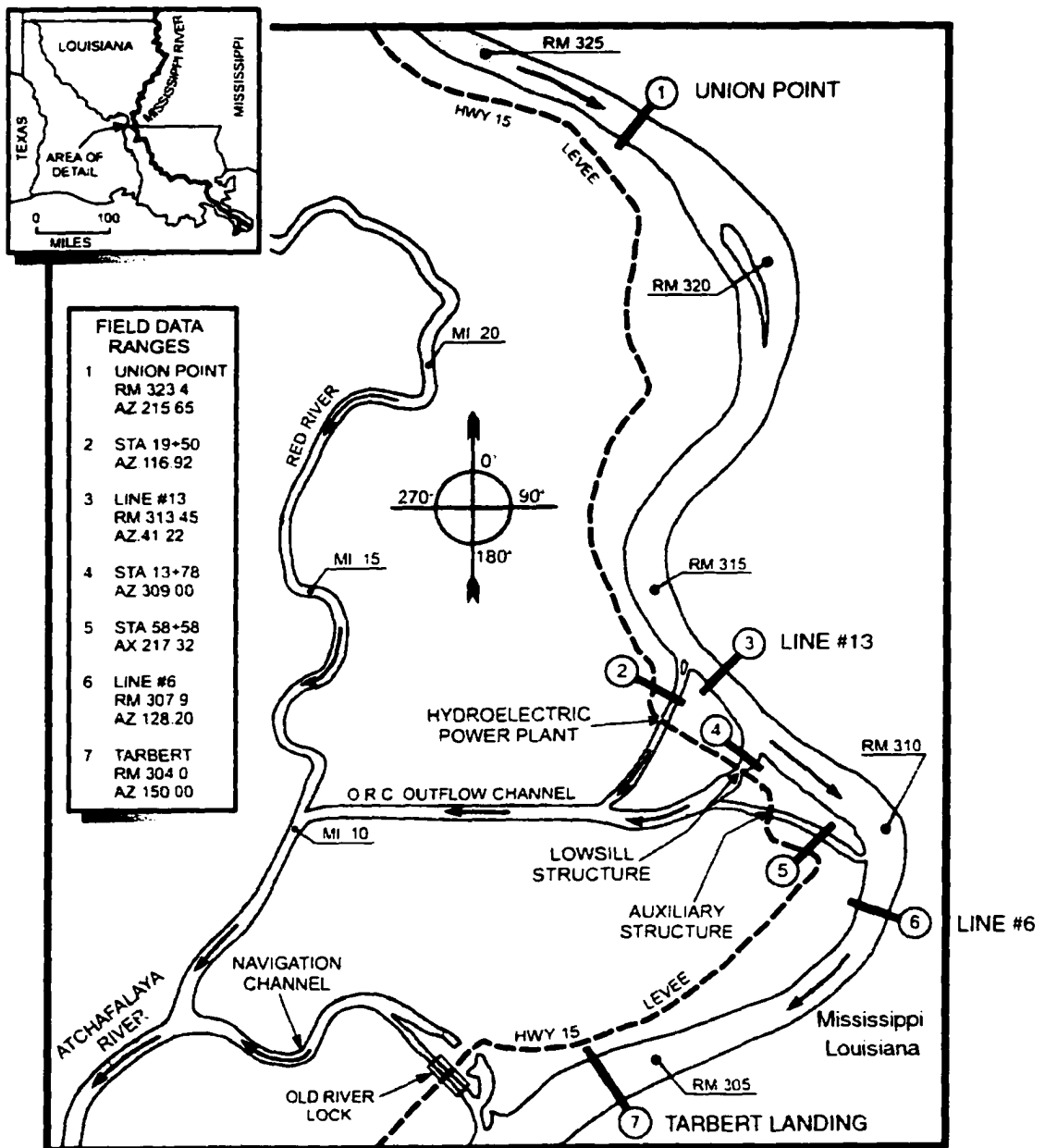


Figure 1.1. Plan view of the study reach on the Lower Mississippi River.

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):

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

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:

$$\sqrt{\tau/\rho} = l_m \frac{dV'_x}{dz} \quad \text{or} \quad \tau = \rho l_m^2 \left(\frac{dV'_x}{dz} \right)^2 \quad (\text{Eq.2.2})$$

in which ρ is the density of the fluid.

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

$$\frac{dV'_x}{dz} = \frac{u_*}{\kappa_0 z} \quad (\text{Eq.2.3})$$

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):

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

where V_m 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):

$$l_m = \kappa_0 \frac{dV_z / dz}{d^2V_z / dz^2} \quad (\text{Eq.2.5})$$

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):

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

in which V_{vm} 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):

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

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:

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

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

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):

$$\frac{V_z - V_m}{u_*} = \frac{1}{\kappa_0} \ln\left(\frac{z}{h}\right) \quad (\text{Eq.2.10})$$

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:

$$\frac{V_z}{u_*} = 17.4 + \frac{2.3}{\kappa_0} \ln\left(\frac{z}{35.45 k_s}\right) \quad (\text{Eq.2.11})$$

where k_s is the characteristic bed roughness height and defined by Einstein as: $k_s = d_{95}$

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.

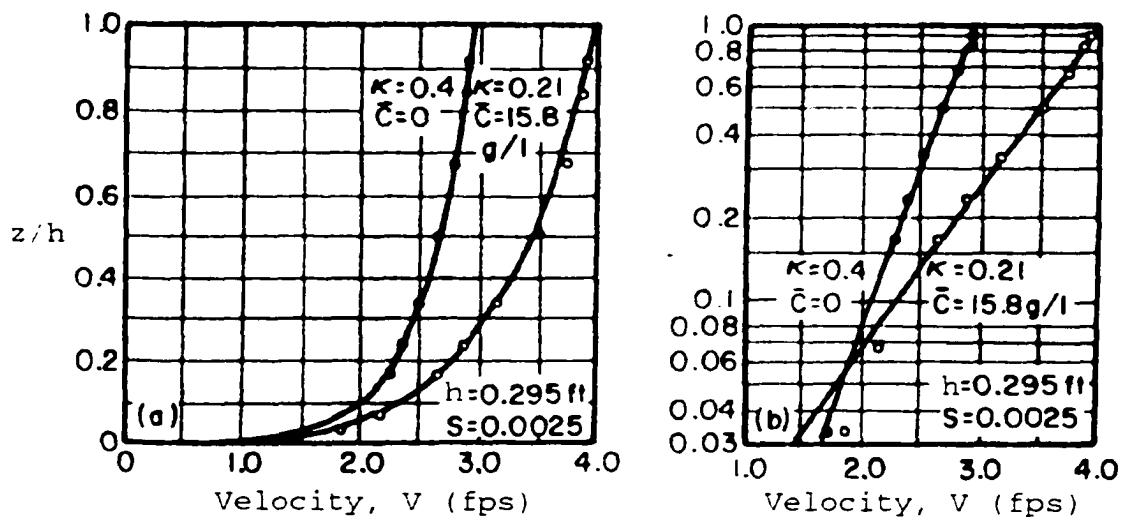


Figure 2.1. Comparison of velocity profiles for clear-water flow and sediment-laden flow (Vanoni and Nomicos, 1960).

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:

$$V_z = V_s - k (h - z)^2 \quad (\text{Eq.2.12})$$

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:

$$V_z = (1 + n_v) \bar{V}_v \left(\frac{z}{R_h} \right)^{n_v} \quad (\text{Eq.2.13})$$

where $\bar{V}_v$ is the mean stream velocity, in feet per second, $R_h = A_v / P$ is the hydraulic radius and defined as the ratio of the flow area of stream (A_v) 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):

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

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:

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

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):

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

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:

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

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:

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

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.

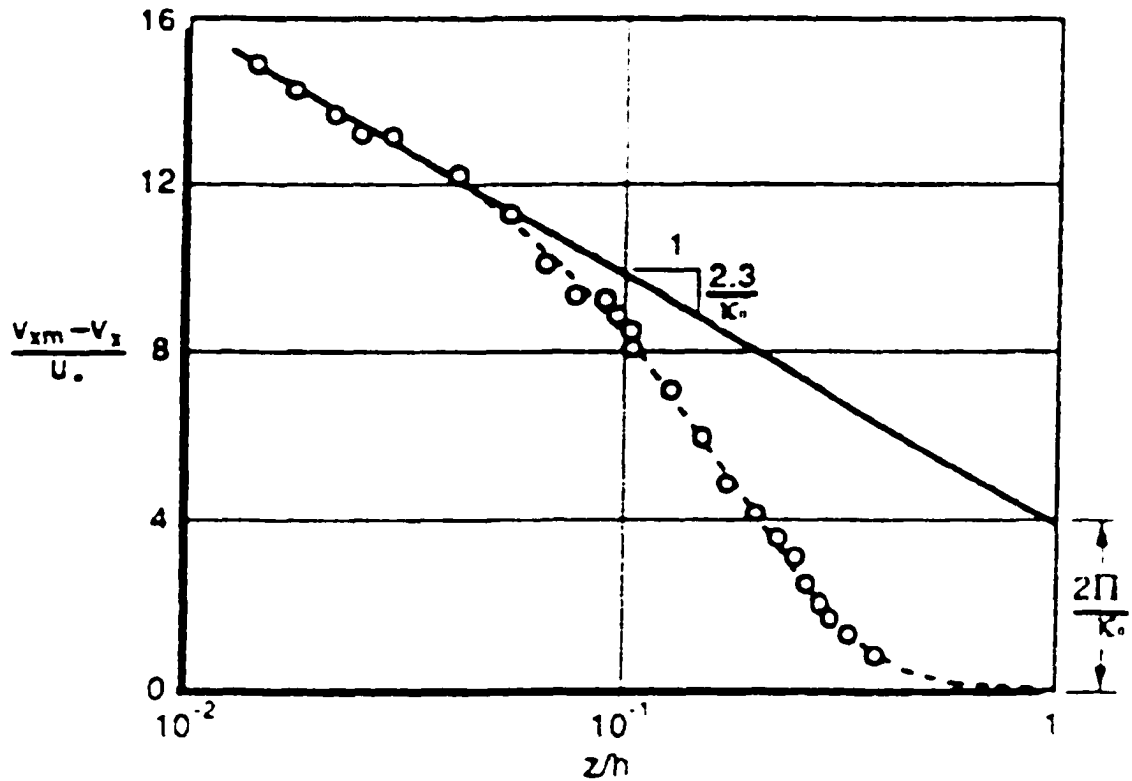


Figure 2.2. Evaluation of κ_0 and Π from the velocity defect law (Julien, 1995).

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. Lechallas 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):

$$\omega C' = -\varepsilon_z \frac{dC'}{dz} \quad (\text{Eq.2.19})$$

where ω is the fall velocity of dust particles, C' is the volumetric concentration of dust particles at a given elevation z , ε_z 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):

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

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

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:

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

in which C_a is the concentration at the reference level, $z = a$, R_s is the Rouse number and expressed as: $R_s = \frac{\omega_0}{\kappa_0 u_*}$ 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:

$$\epsilon_s = \epsilon_m = \kappa_0 u_* z \left(1 - \frac{z}{h} \right) \quad (\text{Eq.2.22})$$

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

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_s is chosen. They concluded that R_s should be determined from measured data, not from the expression, $\frac{\omega_0}{\kappa_0 u_*}$. Anderson also pointed out the need for further study into the mechanism of transfer in natural streams to predict R_s 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 intrush 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:

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

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

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 ($d_s \leq 0.125 \text{ mm}$), 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_{r0} ; the Rouse number, R_{*0} ; 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'_{uc} is calculated from the flow data alone. M. F. Karim and J. F. Kennedy in 1983 implied that $a = d_{s0} u_* / u_{*c}$, 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'_{uc} , as the following:

$$C'_{uc} = 0.015 \frac{d_{s0}}{a} \frac{\Gamma^{1.5}}{d_*^{0.3}} \quad (\text{Eq.2.25})$$

in which $\Gamma = (\tau_b - \tau_{b,c}) / \tau_{b,c}$, where $\tau_b = \rho g (\bar{V}_r / C')^2$ with $\bar{V}_r$ being the depth-averaged velocity and $C' = 18 \log(12 h / 3 d_{s0})$, $\tau_{b,c}$ is the critical bed-shear stress according to Shields, and $d_* = d_{s0} \left((\rho_s - \rho) g / \rho v_*^2 \right)^{1/3}$. Van Rijn used a rough criterion $a = \Delta / 2$ or $a = k_s$ with a minimum value of $a = 0.01 d_{s0}$, 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 $10 d_{s0}$ for the bedload layer on flat bed in the upper flow regime.

2.2.2. Studies on Rouse Number, R_{*}

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:

$$R_{*} = \frac{\omega_0}{\kappa_0 u_*} \quad (\text{Eq.2.26})$$

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_{*} . They deduced that for low values of R_{*} , the experimental and theoretical findings agreed closely, but as R_{*} 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_{ω} . They related values of R_{ω} to the fall velocities of sediment raised to the power 0.7 (Richardson and Julien, 1986).

Weerappuli (1980) observed that the Rouse number, R_{ω} , 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 $\bar{V}_r$, 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_{ω} :

$$R_{\omega} = \omega^{0.52597} \bar{V}_r^{-0.55909} \kappa^{-0.27426} u_*^{1.06709} T^{-0.55875} C'_{h/2}^{-0.02702} d_s^{0.27613} \quad (\text{Eq.2.27})$$

It was found that the R_{ω} calculated from this expression seemed to be a better estimate than that from Eq.2.26.

Vetter (1986) observed that measured Rouse numbers ($R_{\omega m}$) are generally smaller than the theoretical or calculated Rouse numbers ($R_{\omega} = \frac{\omega_0}{\kappa_{\omega} u_*}$) 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 $R''_n = R_{n\infty} + \psi$, in which ψ was determined by computer calibration resulting in the following expression (van Rijn, 1986):

$$\psi = 2.5 \left(\frac{\omega}{u_*} \right)^{0.8} \left(\frac{C'_s}{C'_{\max}} \right)^{0.4} \quad \text{for } 0.01 \leq \frac{\omega}{u_*} \leq 1 \quad (\text{Eq.2.28})$$

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):

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

where F is the longitudinal force exerted by a slowly moving viscous fluid upon a small

sphere. d , 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):

$$\omega_0 = \left[(13.95 \nu / d_{s0})^2 + 1.09 (G - 1) g d_{s0} \right]^{0.5} - 13.95 \nu / d_{s0} \quad (\text{Eq.2.30})$$

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):

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

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

where C_D is the drag coefficient, $\text{Re}_p = \frac{\omega d_s}{\nu}$ 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:

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

in which G is the specific gravity defined as the ratio of the specific weight of sediment, γ_s , to that of water, γ_w , 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 :

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

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:

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

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:

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

where $\bar{C}$ 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:

$$\kappa = \kappa_0 (1 - 0.15 C'_t) \quad (\text{Eq.2.37})$$

where κ_0 is the von Karman constant for clear-water and equal to 0.4, and C'_t 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:

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

in which κ_0 is the von Karman constant, C_0 is the maximum sediment concentration near the bed in fraction by volume, $\bar{C}$ 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 °F) was as much as 2.5 times greater than that in summer (85 °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 °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 °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 °C and near 37 °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 °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 °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:

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

in which Q is the river discharge in 1000 cfs, and T is the water temperature in °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, $Re_b = \frac{u_* d_s}{\nu_m}$. In flows where $Re_b < 13$, 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_b , 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 $Re_b < 13$, but it decreased with an increase in water temperature for $Re_b > 13$.

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 °F to 40 °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' , 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.

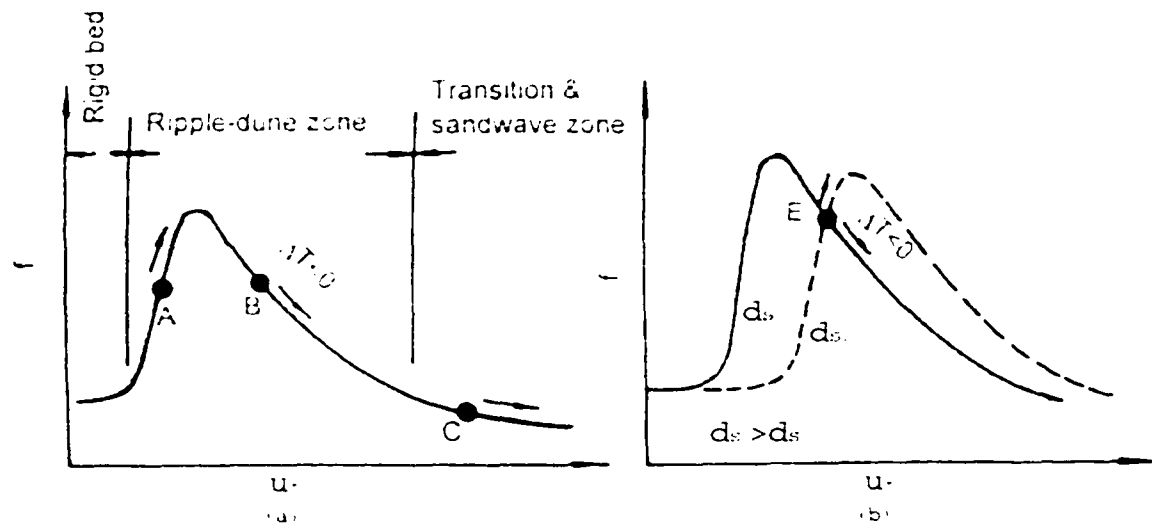


Figure 2.3. Effect of water temperature on resistance (Chien and Wan, 1999).

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 $Re_* = 11.6$, 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 $Re_* = 11.6$ (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 °C and -15 °C, respectively, but in summer, they are about 26.7 °C and 18.3 °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 $15.631 \text{ m}^3/\text{s}$ (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. $\overline{S_0} = 5.2 \times 10^{-4}$ (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 (Biedenham 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), Biedenham and Watson (1997), Biedenham (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 (Biedenham, 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 (Biedenham 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.

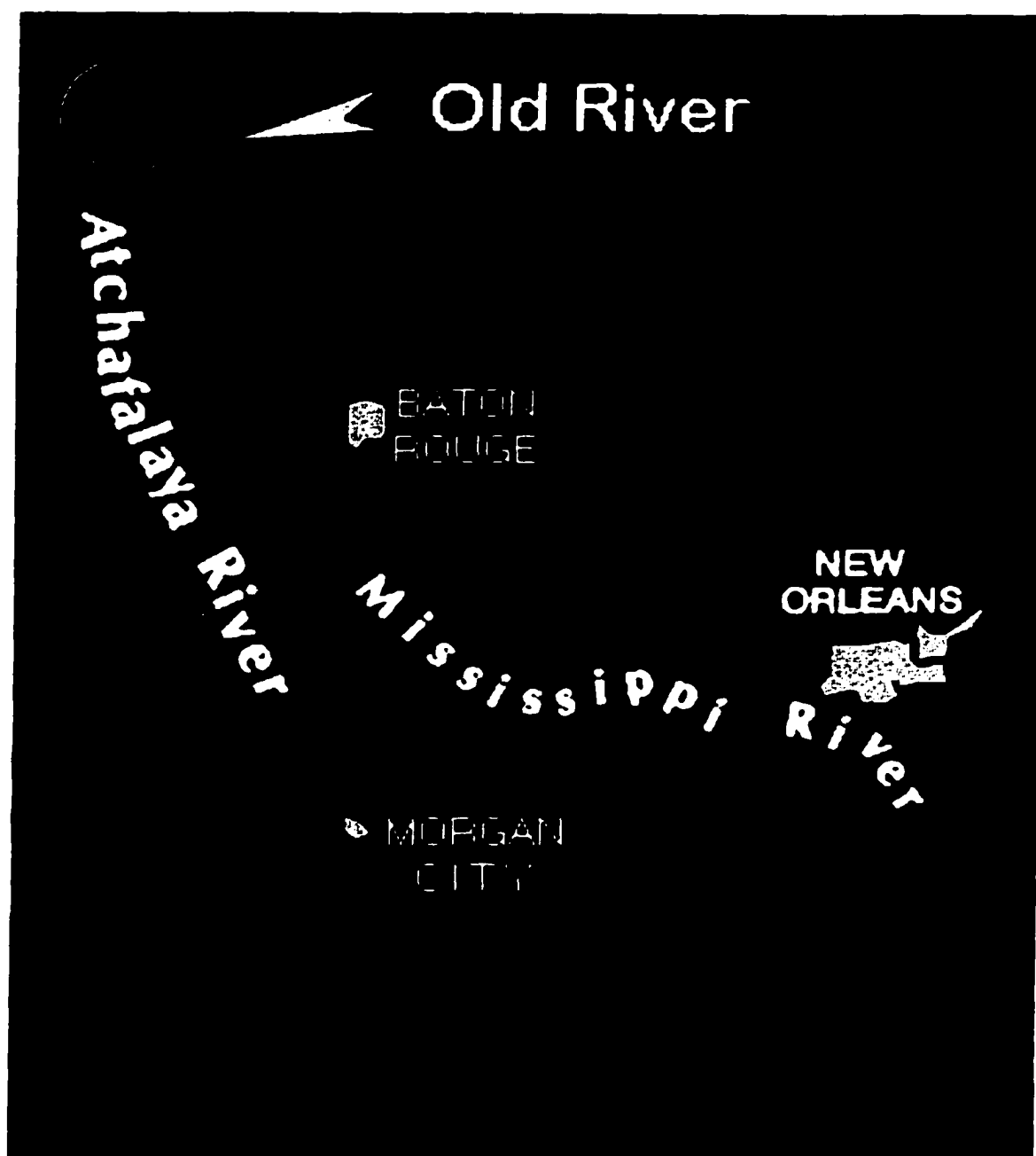


Figure 3.1. Comparison of the distances to the Gulf of Mexico via the Lower Mississippi and Atchafalaya Rivers.

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 $35.396 \text{ m}^3/\text{s}$ (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° apart horizontally and directed downward into the water column at an angle of 30° 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).

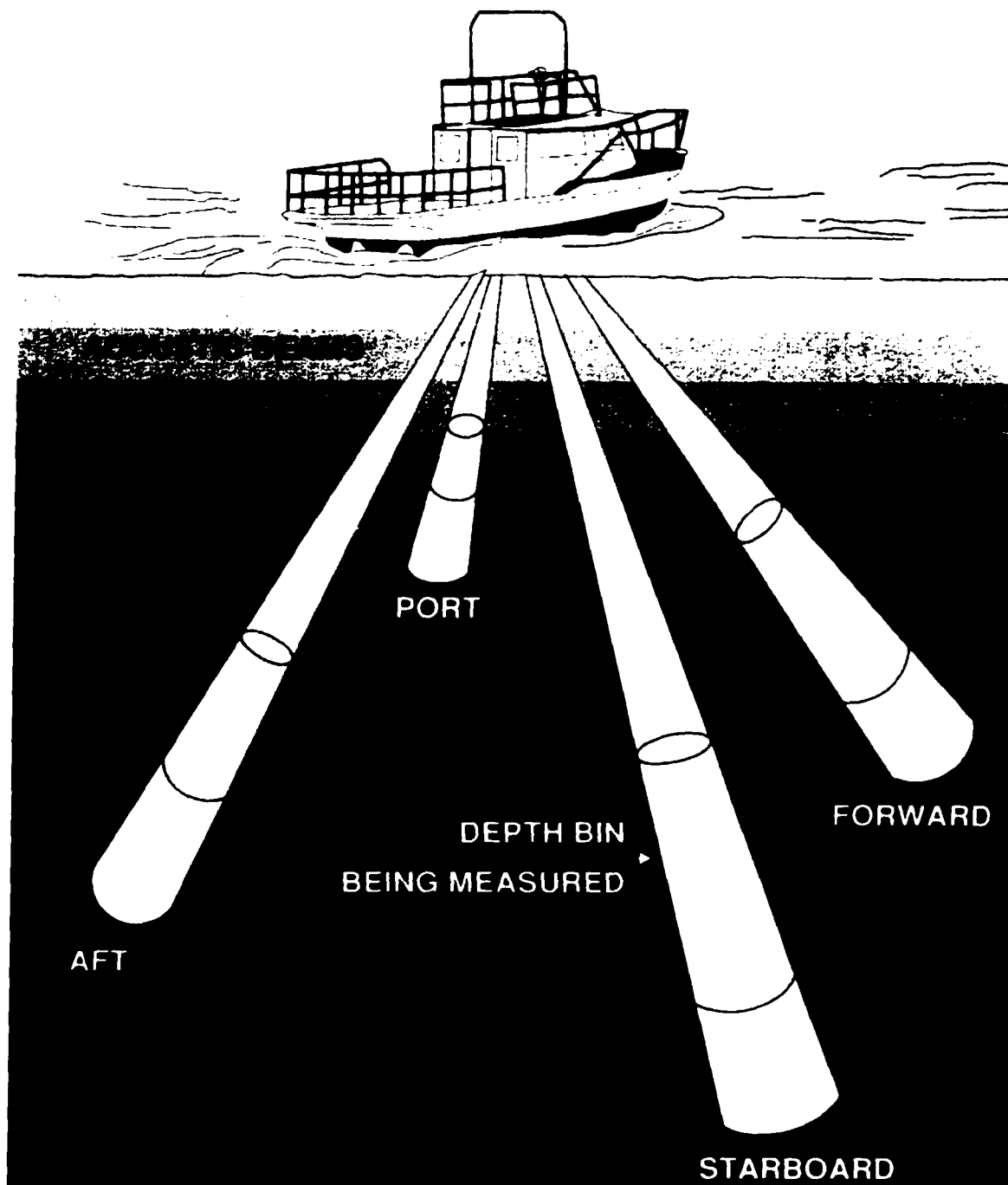


Figure 4.1. Beam configuration of the ADCP (Simpson and Oltmann, 1993).

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

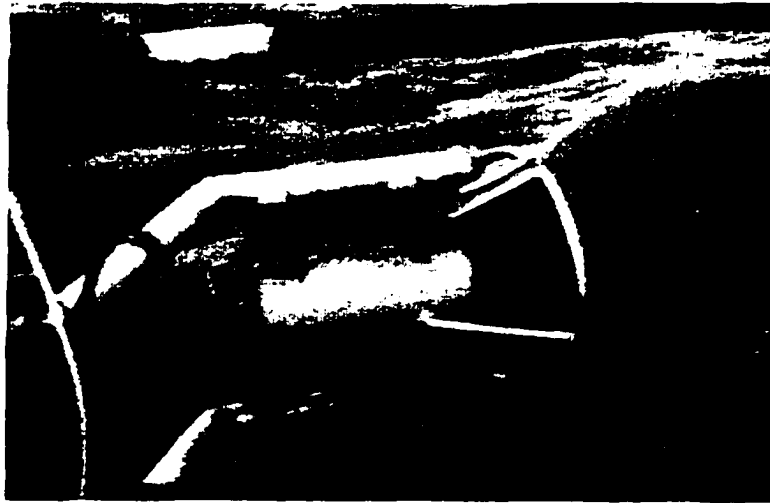


Figure 4.2. Acoustic Doppler Current Profiler (ADCP) mounted to the boat.



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.

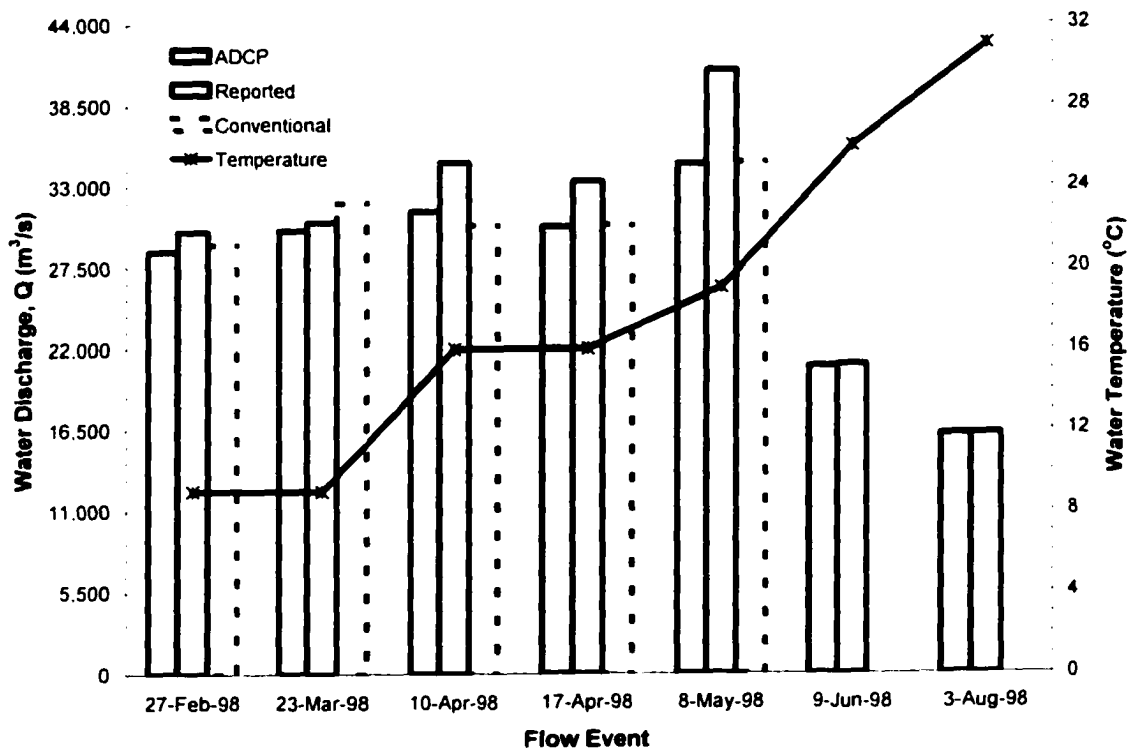


Figure 4.4. Comparison of the ADCP, conventional and reported discharges at Union Point.

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

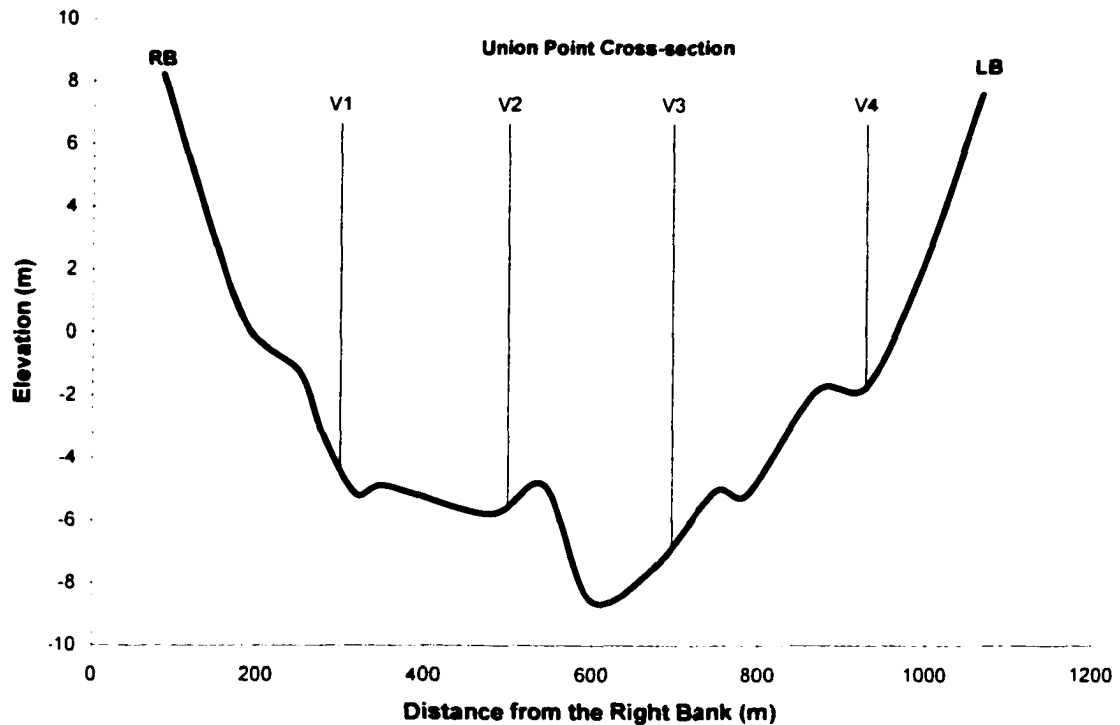


Figure 4.5. Locations of the four sampling verticals at Union Point.

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

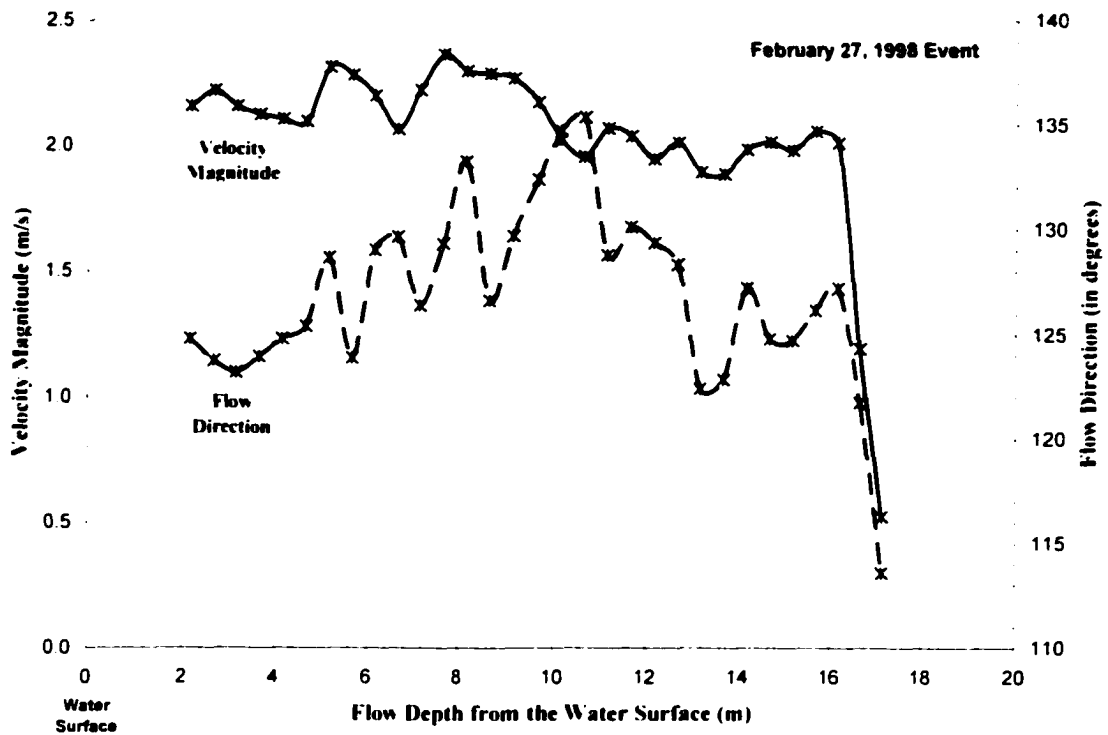


Figure 4.6. Flow velocity intensities and directions at the 4th vertical at Line 13.

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.

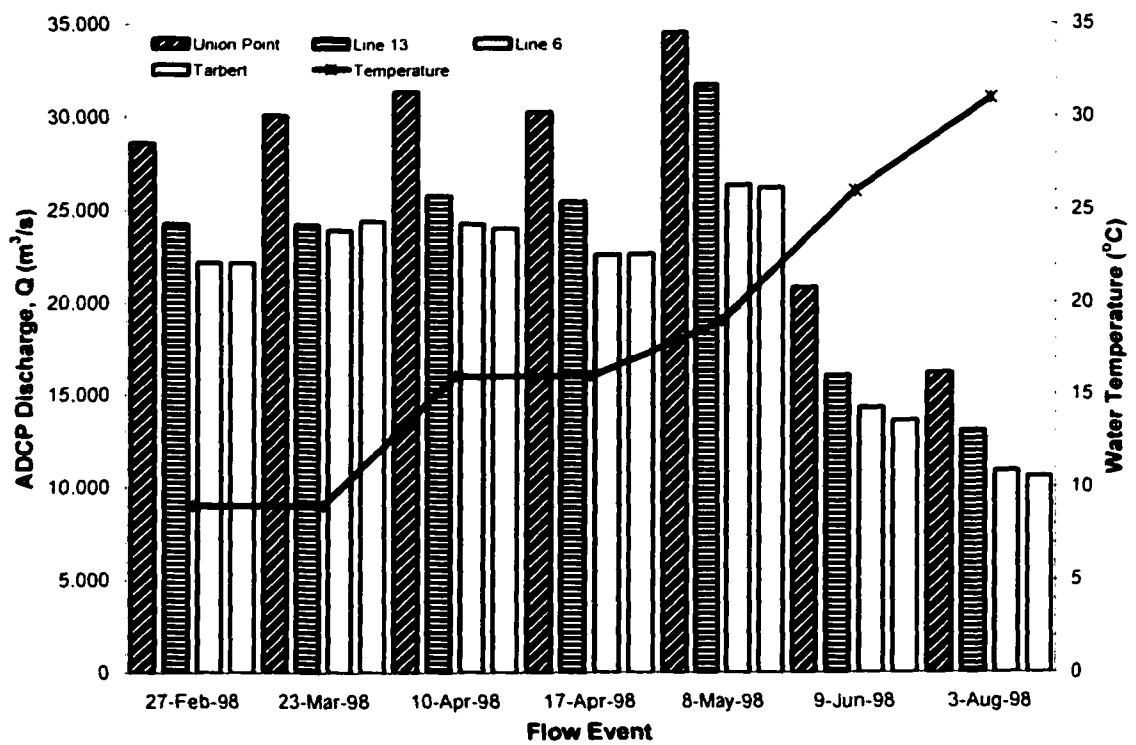


Figure 4.7. The ADCP discharges for all flow events at all locations.

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.

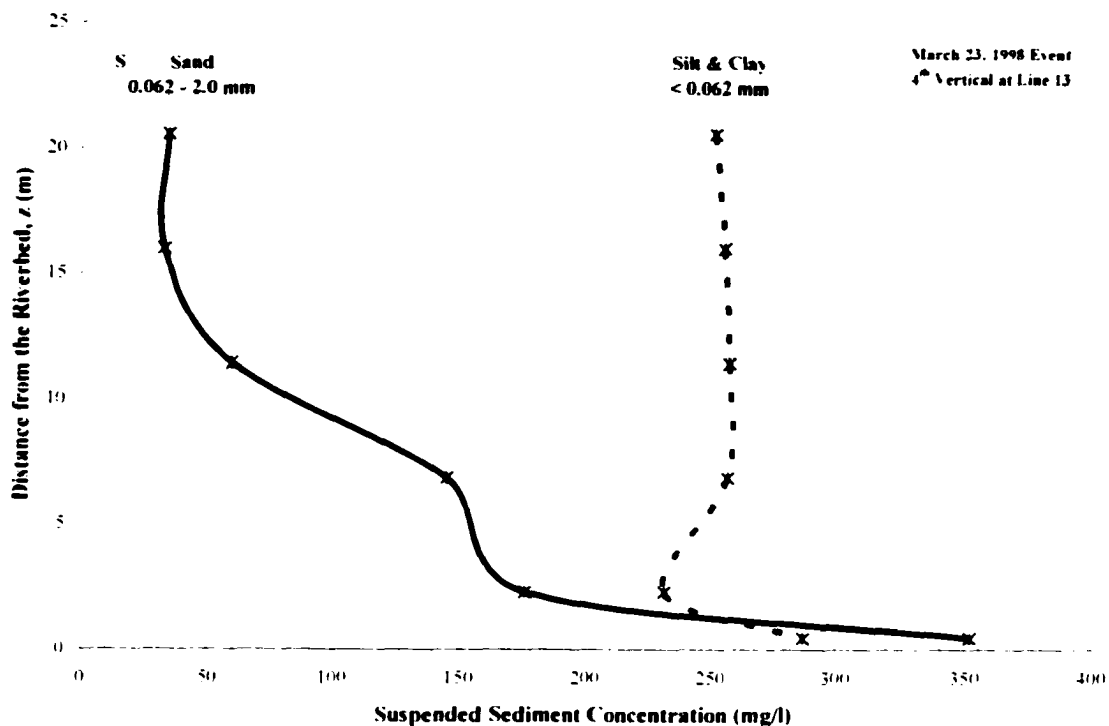


Figure 4.9. Suspended sediment concentration profile at a vertical at Line 13.

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.

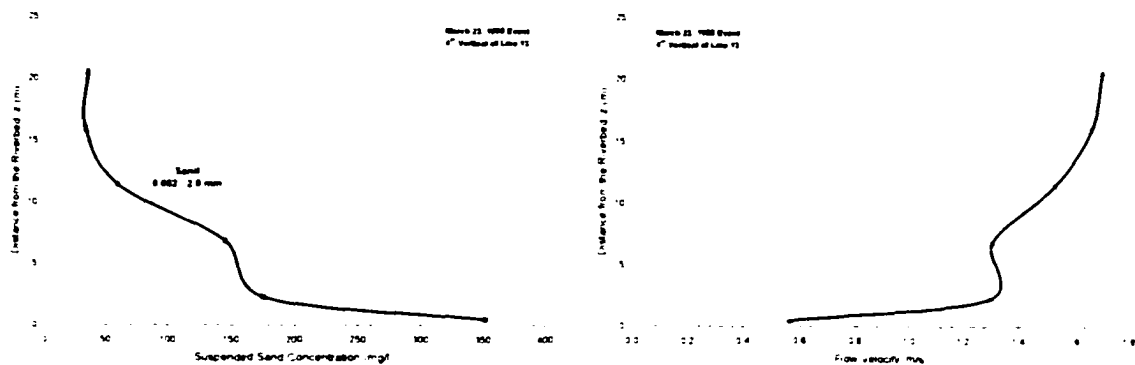


Figure 4.10. Calculation of the suspended sand discharge from the product of the sand concentration and flow velocity profiles.

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.

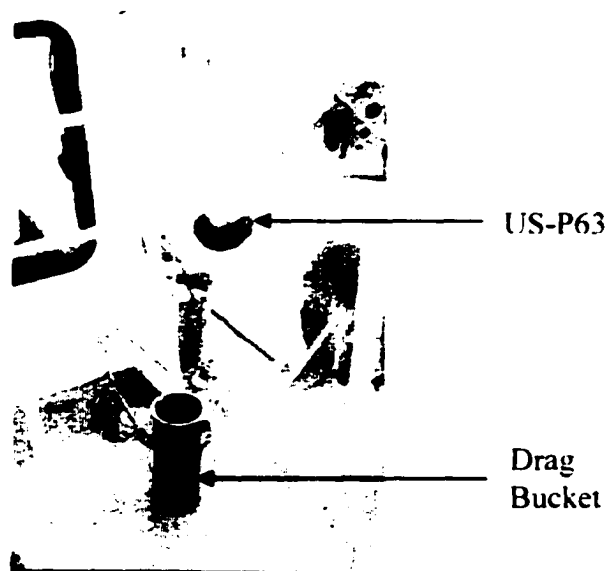


Figure 4.11. Drag bucket and US P-63 in the field.

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).

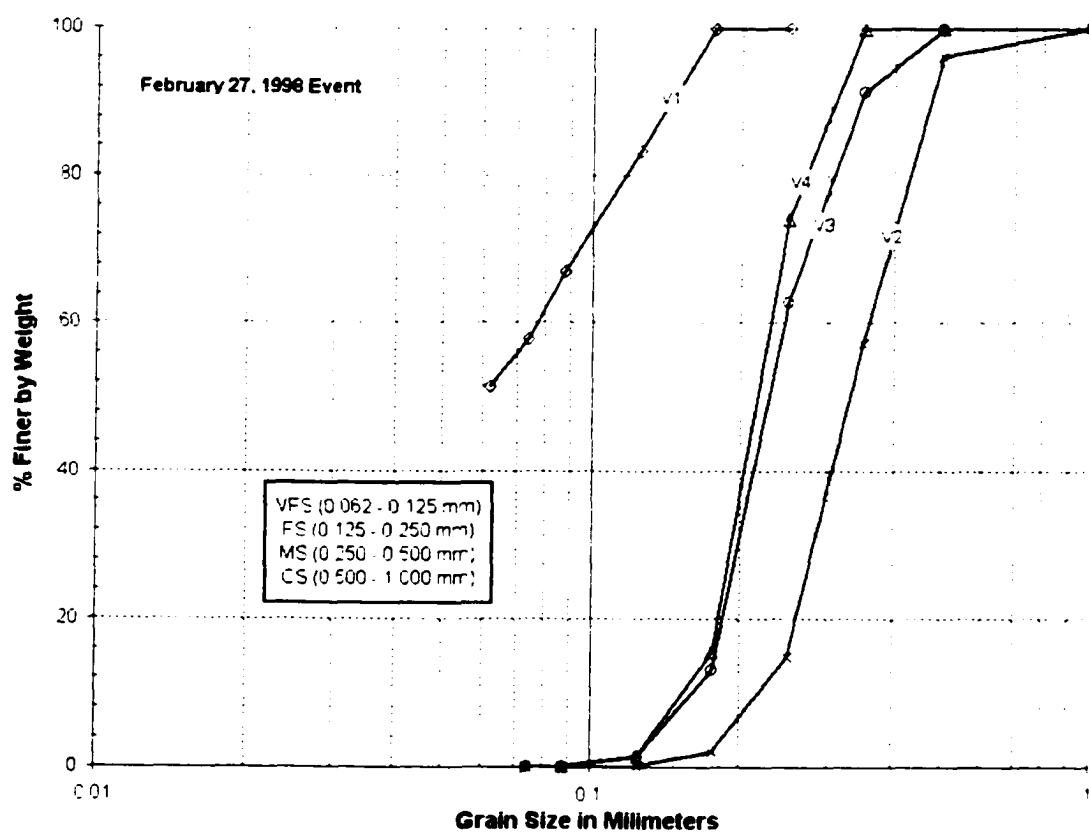


Figure 4.12. Bed material size distribution for February 27, 1998 event at Line 13.

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_r

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,

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 °C increase in water temperature.

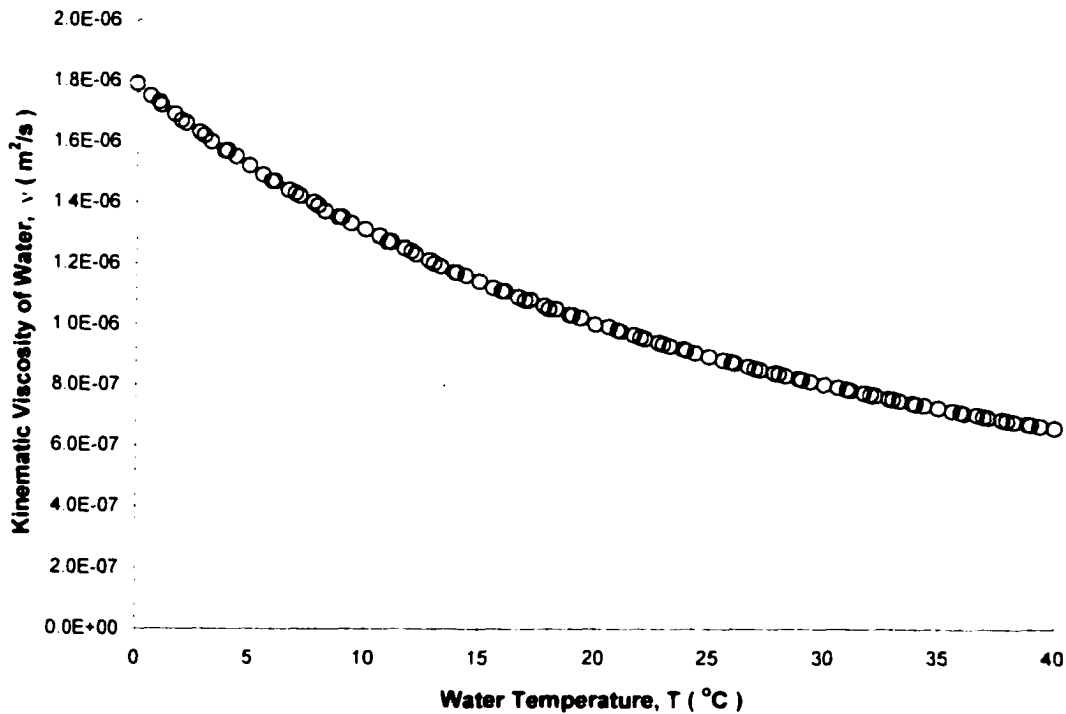


Figure 5.1. Water temperature effect on the kinematic viscosity of water.

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).

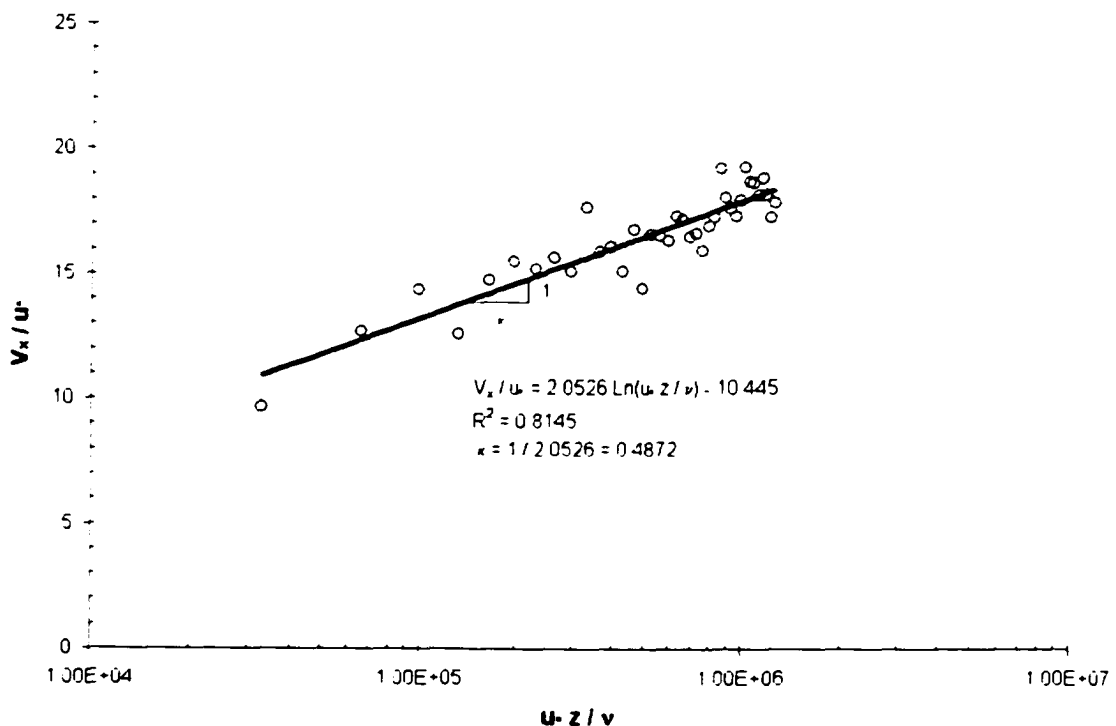


Figure 5.2. Obtaining the von Karman parameter from a velocity profile.

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

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

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

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

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

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

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:

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

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		Average
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	
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 °C (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.

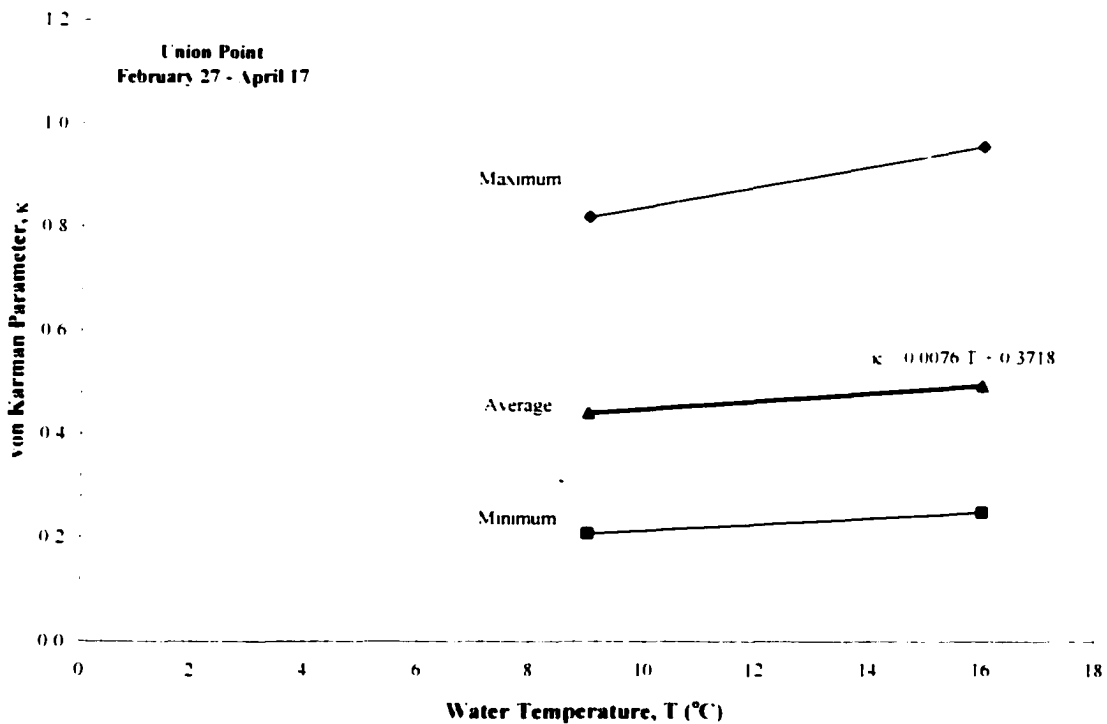


Figure 5.3. The effect of water temperature on the von Karman parameter for approximately same discharge events at Union Point.

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 °C and 0.61 at 16 °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 °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

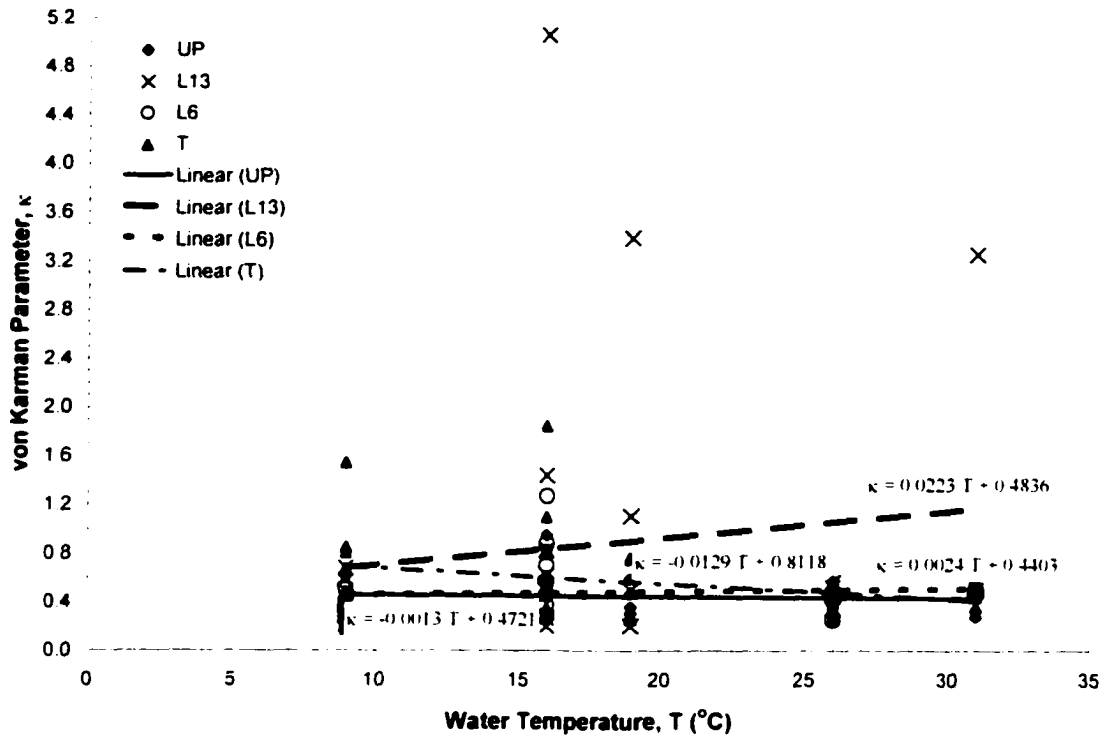


Figure 5.4. The effect of water temperature on the measured von Karman parameter for all locations.

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.

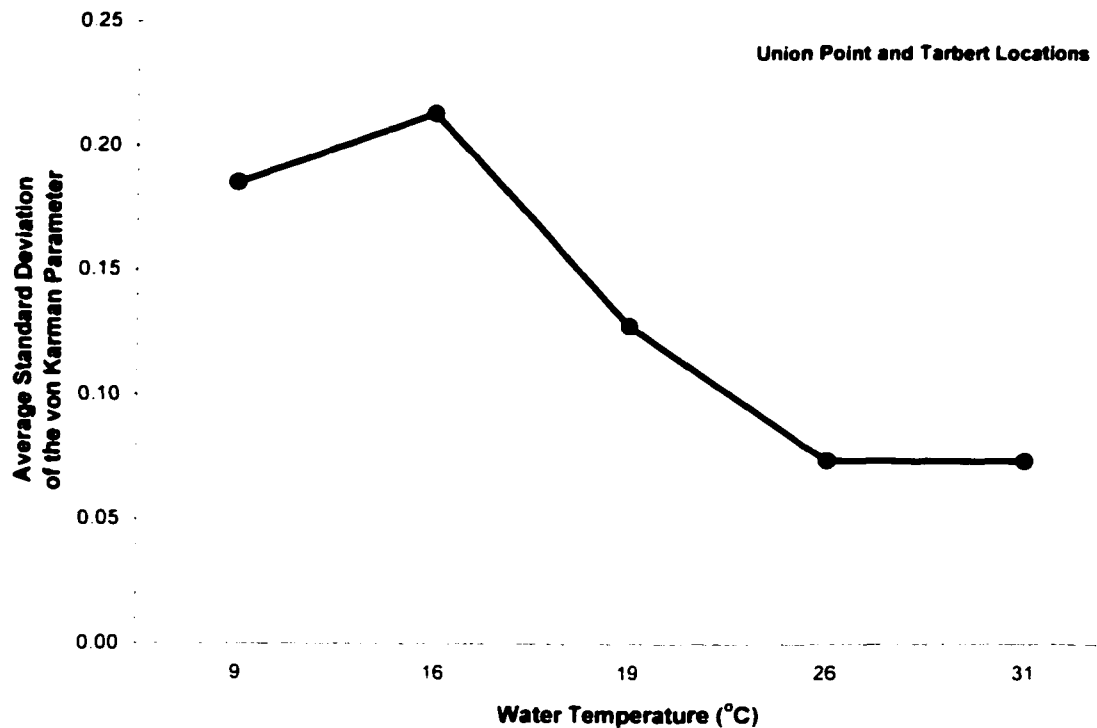


Figure 5.5. Average standard deviation of the von Karman parameter with water temperature at Union Point and Tarbert locations.

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

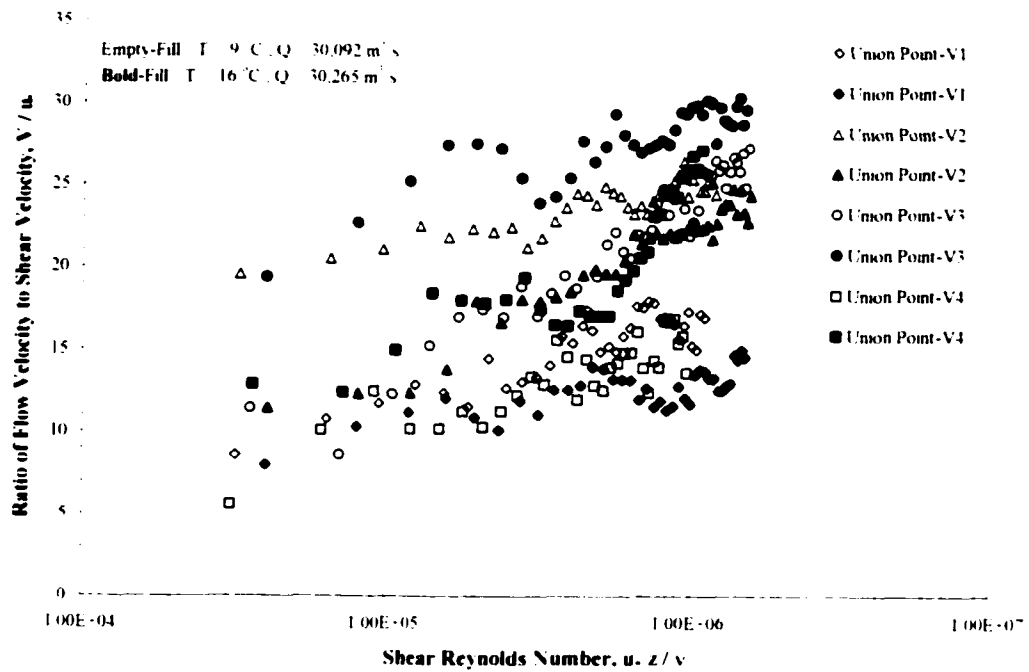


Figure 5.6. Water temperature effect on flow velocity profiles at Union Point.

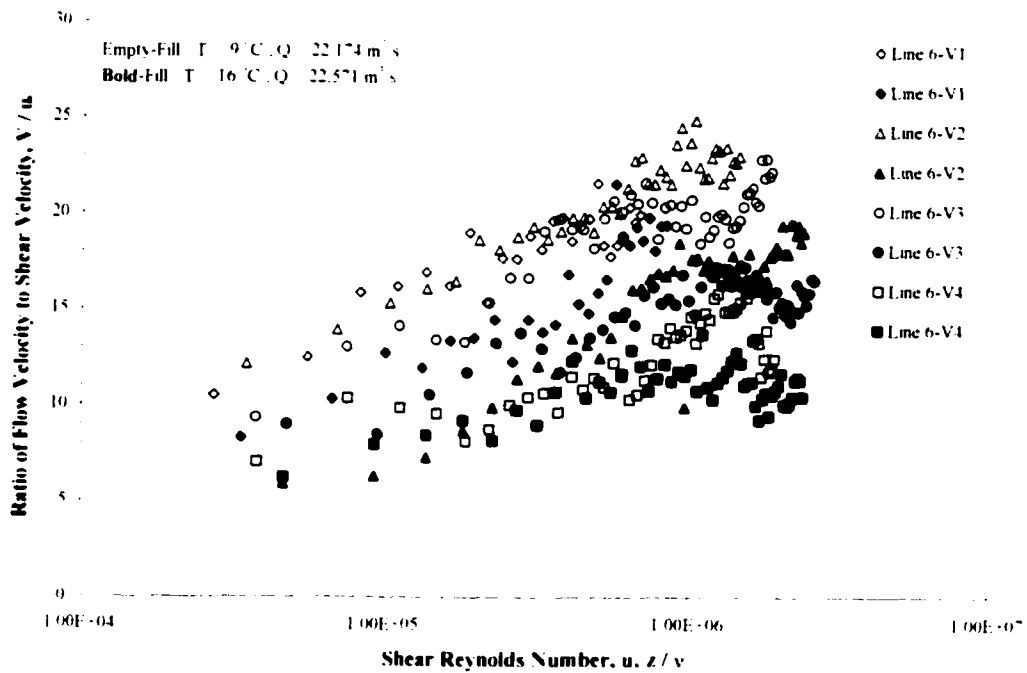


Figure 5.7. Water temperature effect on flow velocity profiles at Line 6.

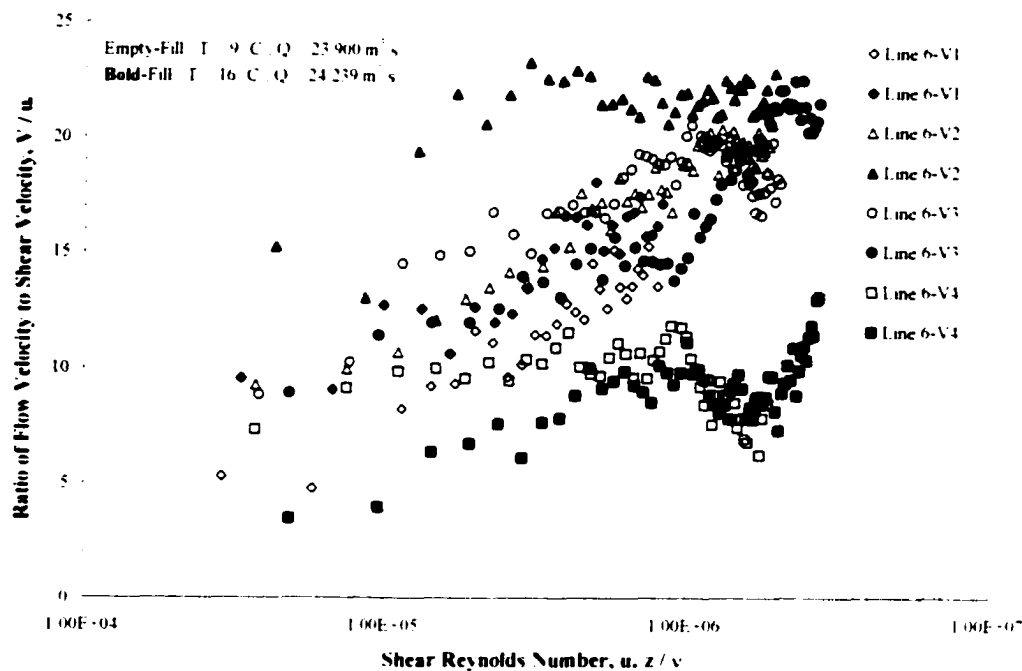


Figure 5.8. Water temperature effect on flow velocity profiles at Line 6.

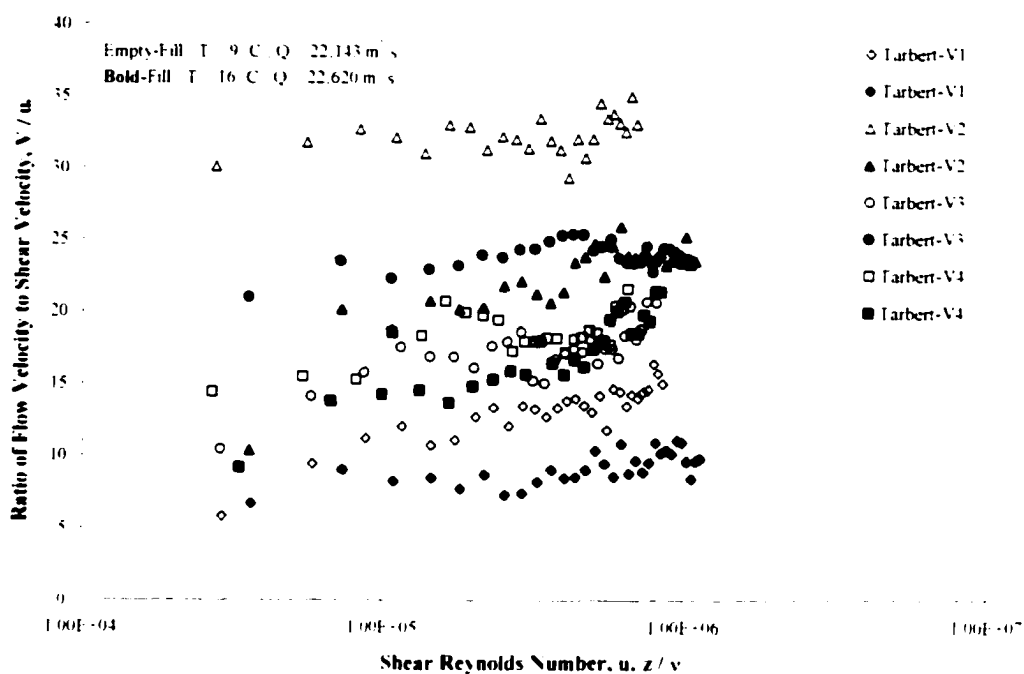


Figure 5.9. Water temperature effect on flow velocity profiles at Tarbert.

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.

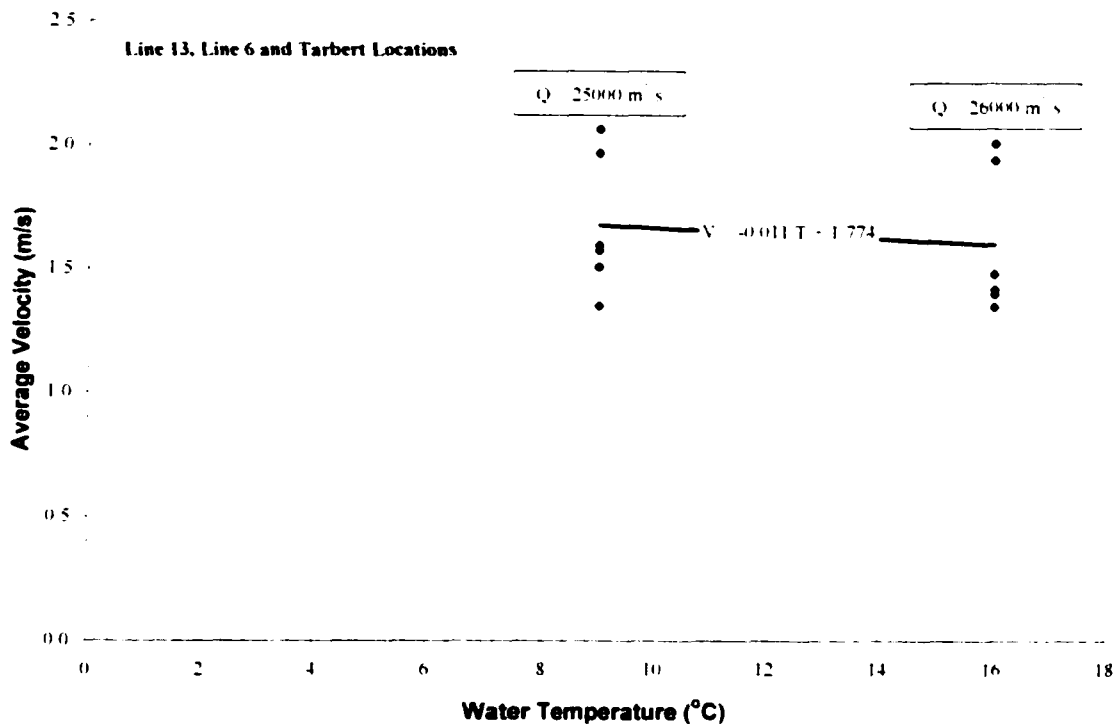


Figure 5.10. The effect of water temperature on average flow velocity for about the same flow discharges at all locations.

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 °C to 16 °C, flow velocity drops off by about 4.6 percent. In other words, the flow velocity decreases by approximately 0.66 percent for every 1 °C 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.

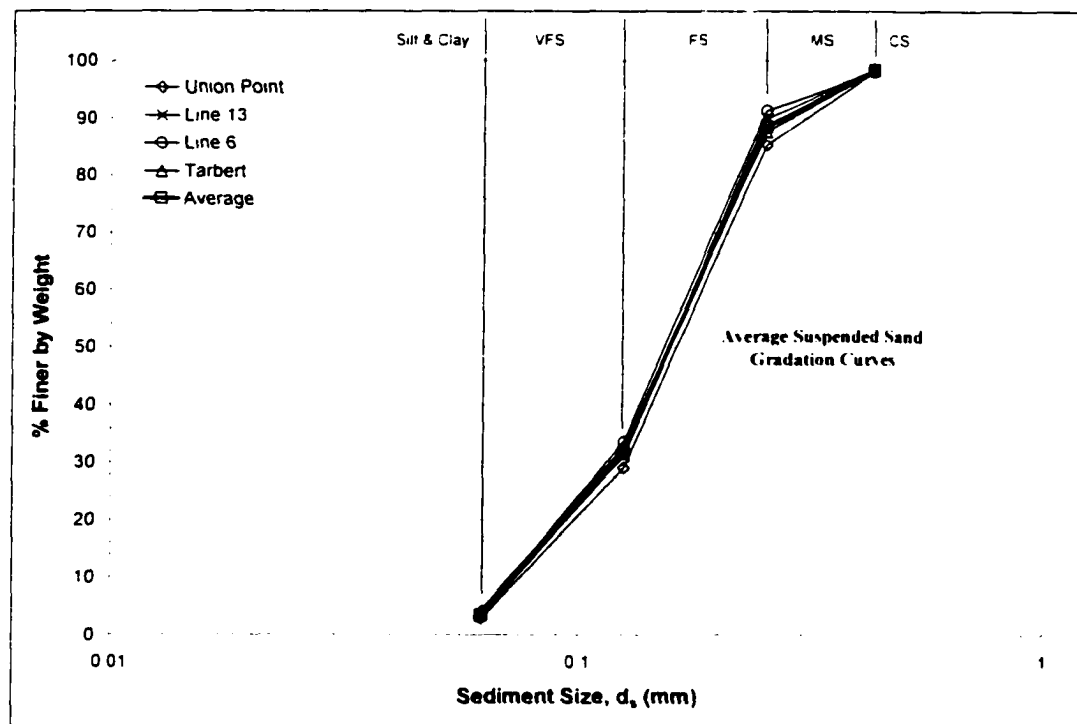


Figure 5.11. Average suspended sand gradation curves at all locations.

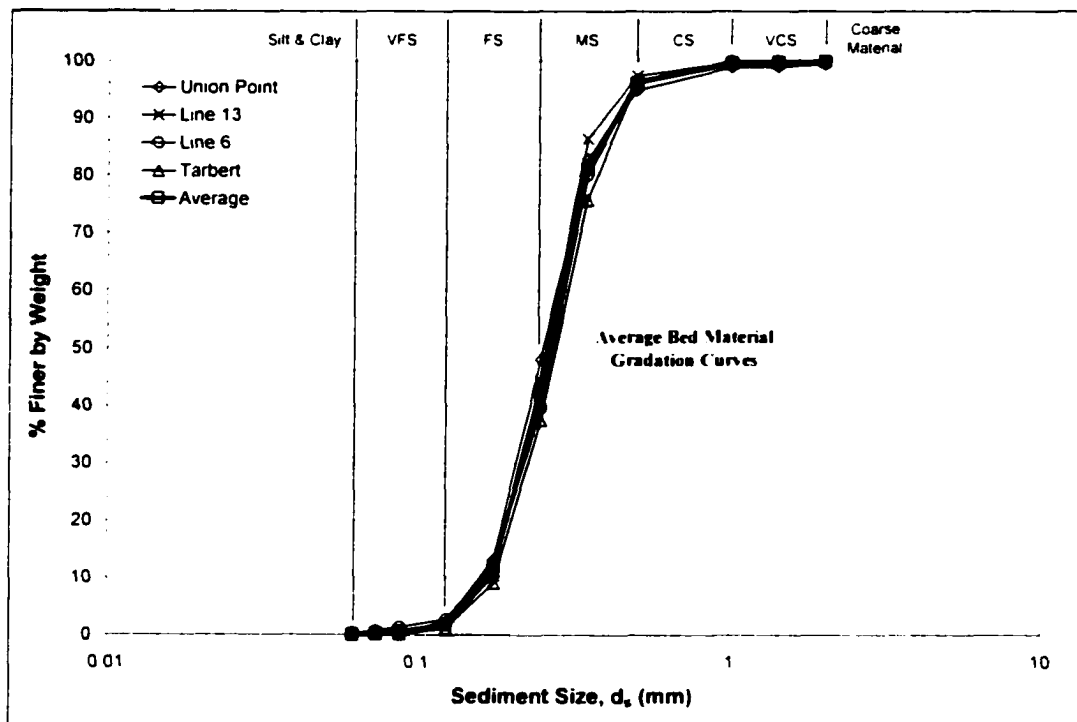


Figure 5.12. Average bed material gradation curves at all locations.

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:

$$\bar{C} = \bar{C}_0 + \frac{\sum_{i=1}^6 \left[\frac{(C(d_i) + C(d_{i+1})) \Delta d}{2} \right]}{h_1} \quad (\text{Eq.5.4})$$

in which $\bar{C}$ is the depth-averaged suspended sediment concentration at a vertical. $\bar{C}_0$ is the depth-averaged concentration at the region between the water surface and the first sampling point and expressed as: $[C(d_1)/2] [d_1/h_1]$, 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 $i = 1 \dots 6$ because there are 6 sampling points at each vertical, and h_1 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 °C. 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 °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.

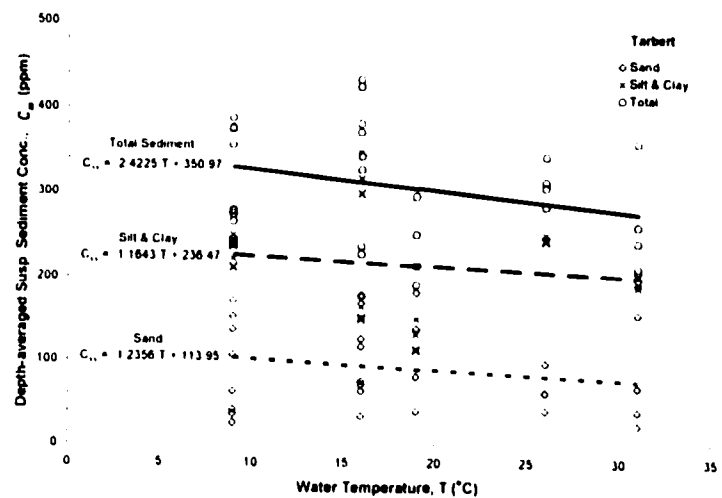
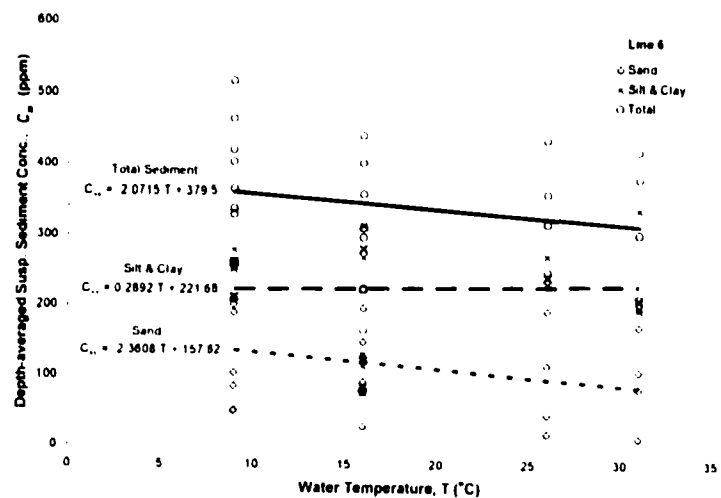
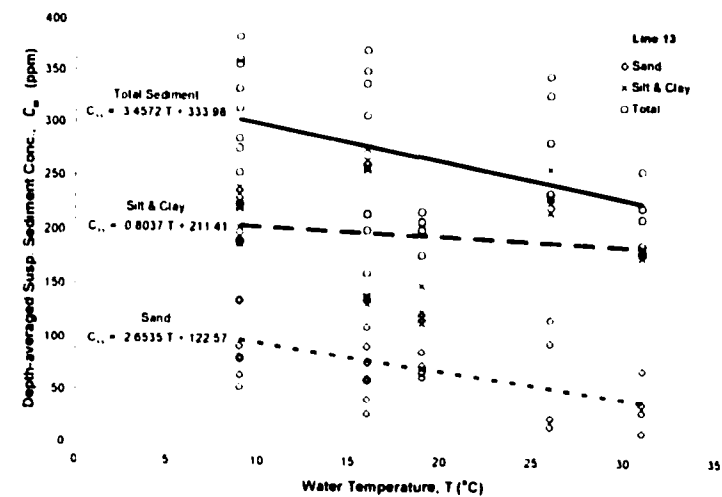
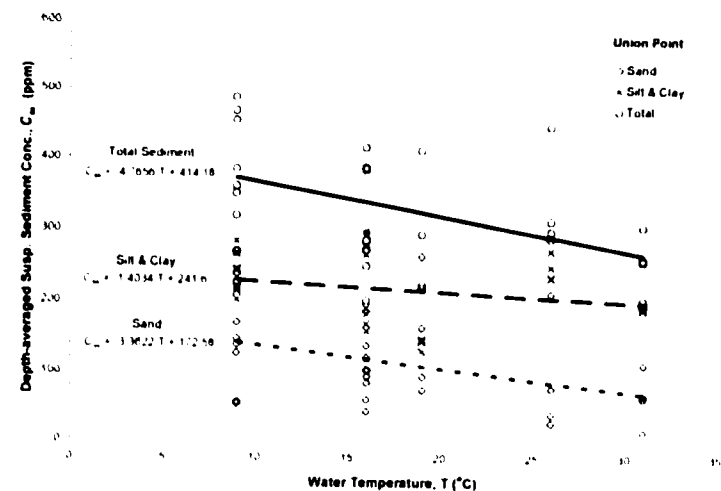


Figure 5.13. Depth-averaged suspended sediment concentration change with water temperature at all locations.

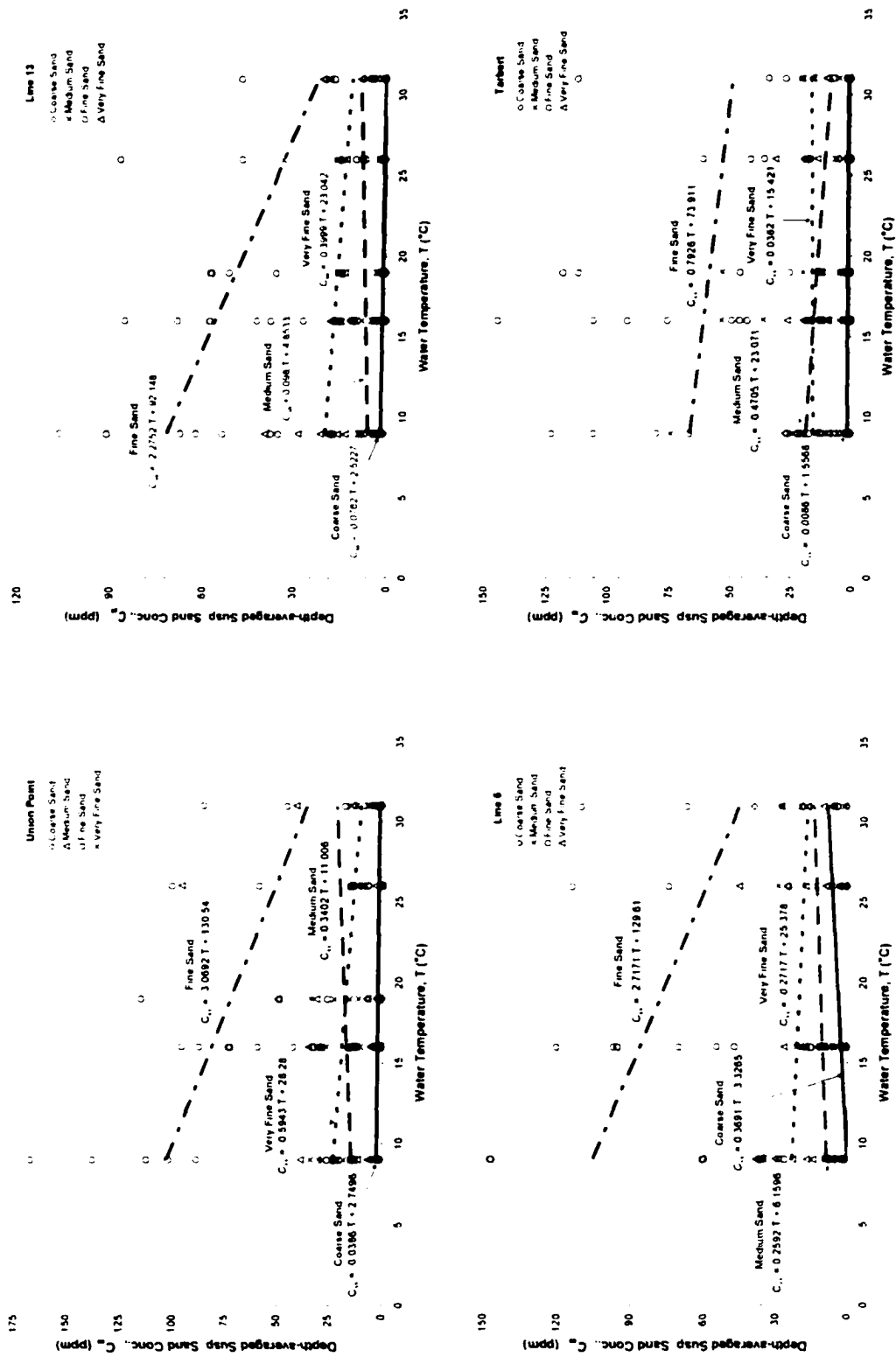


Figure 5.14. Depth-averaged suspended sand concentration change with water temperature at all locations

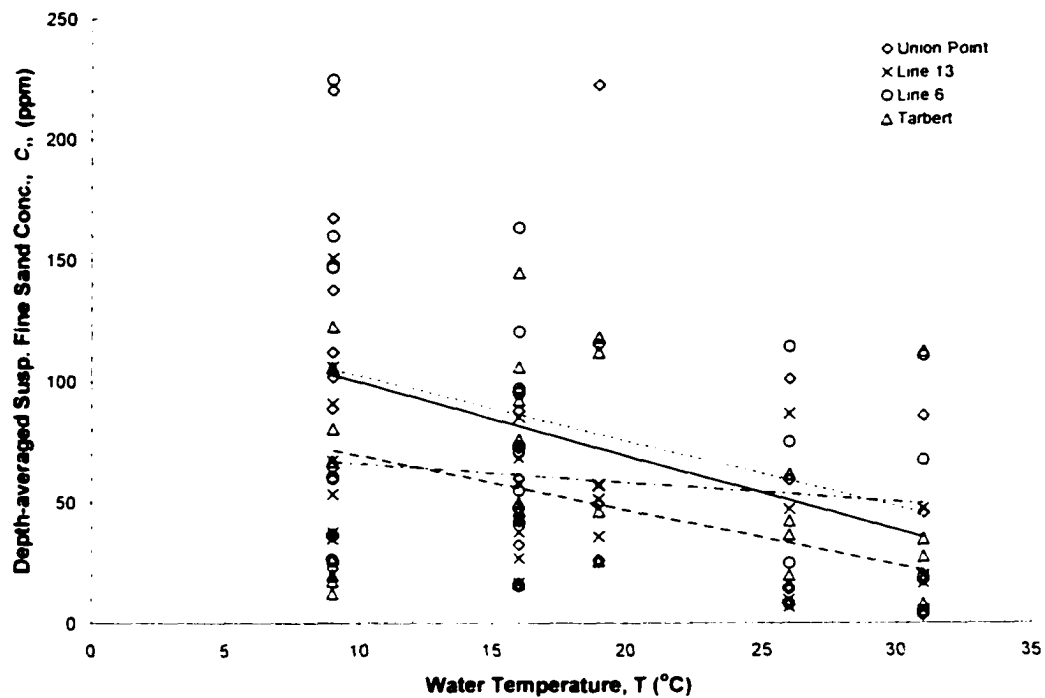


Figure 5.15. Depth-averaged suspended fine sand concentration change with water temperature for all events at all locations.

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 °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 °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:

$$q_{ss} = \int_0^h C_{ss} V_x dz \quad (\text{Eq.5.5})$$

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).

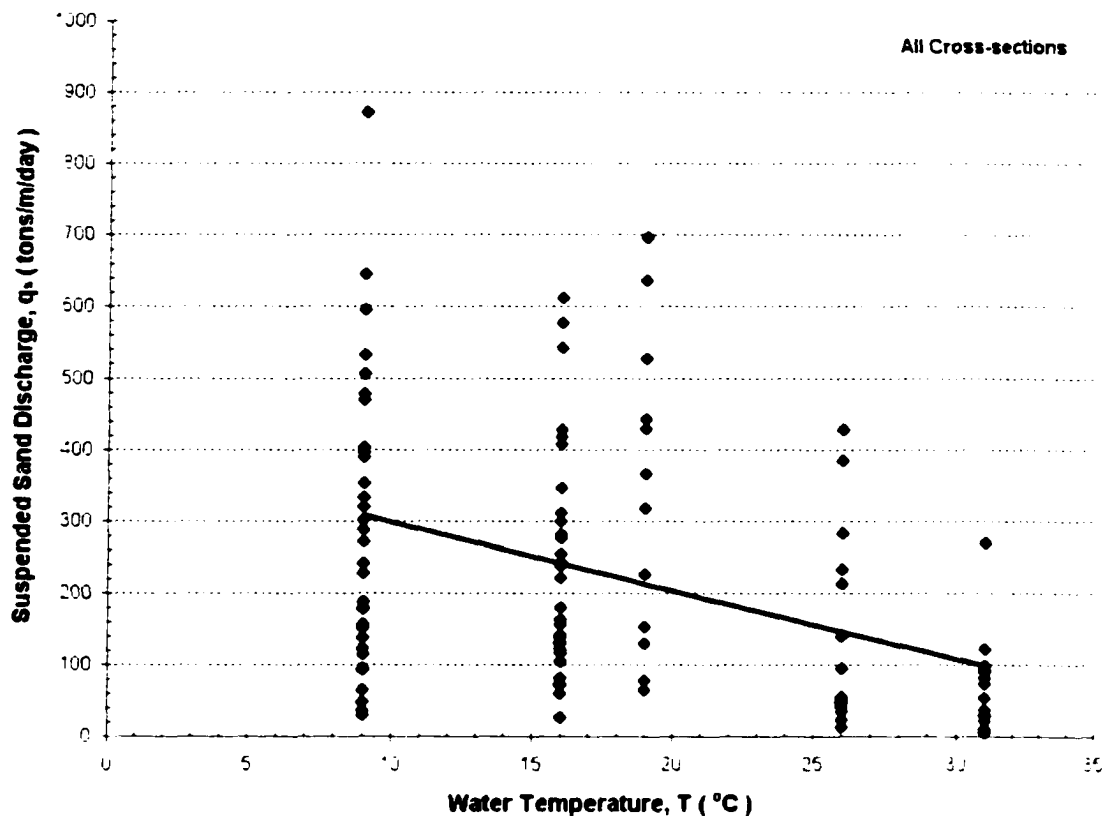


Figure 5.16. Effect of water temperature on suspended sand discharge for all events at all locations.

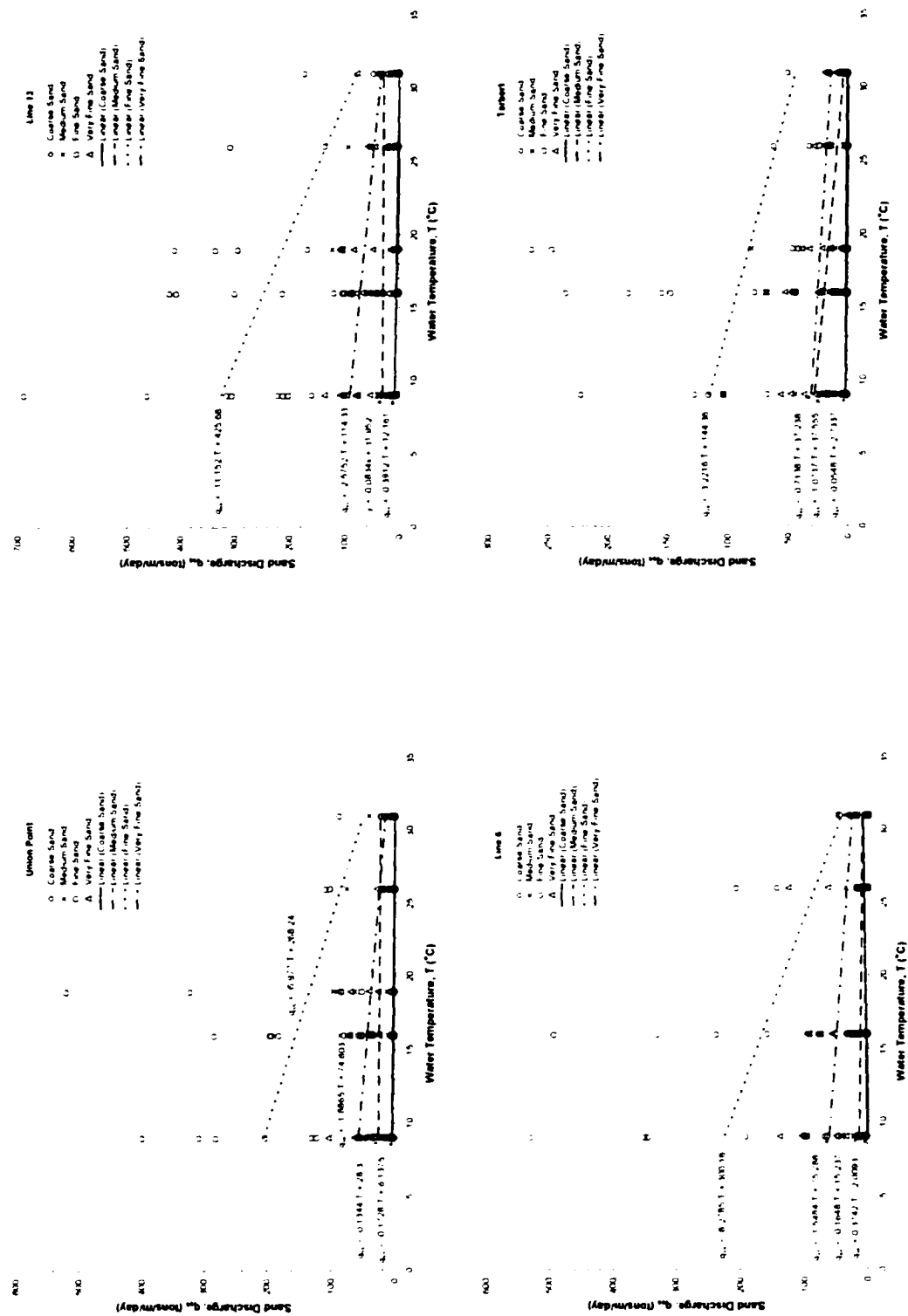


Figure 5.17. Effect of water temperature on discharges of different size fractions at all locations

To obtain a better picture of the effect of the water temperature change on the suspended sand concentrations, the ratio of $\Delta\bar{C}/\Delta T$ 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. $\Delta\bar{C}/\Delta T$ 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 $\Delta\bar{C}/\Delta T$ for each size fraction are obtained from the arithmetic averages of the $\Delta\bar{C}/\Delta T$ 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 $\Delta\bar{C}/\Delta T$ 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 $\Delta\bar{C}/\Delta T$ 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.

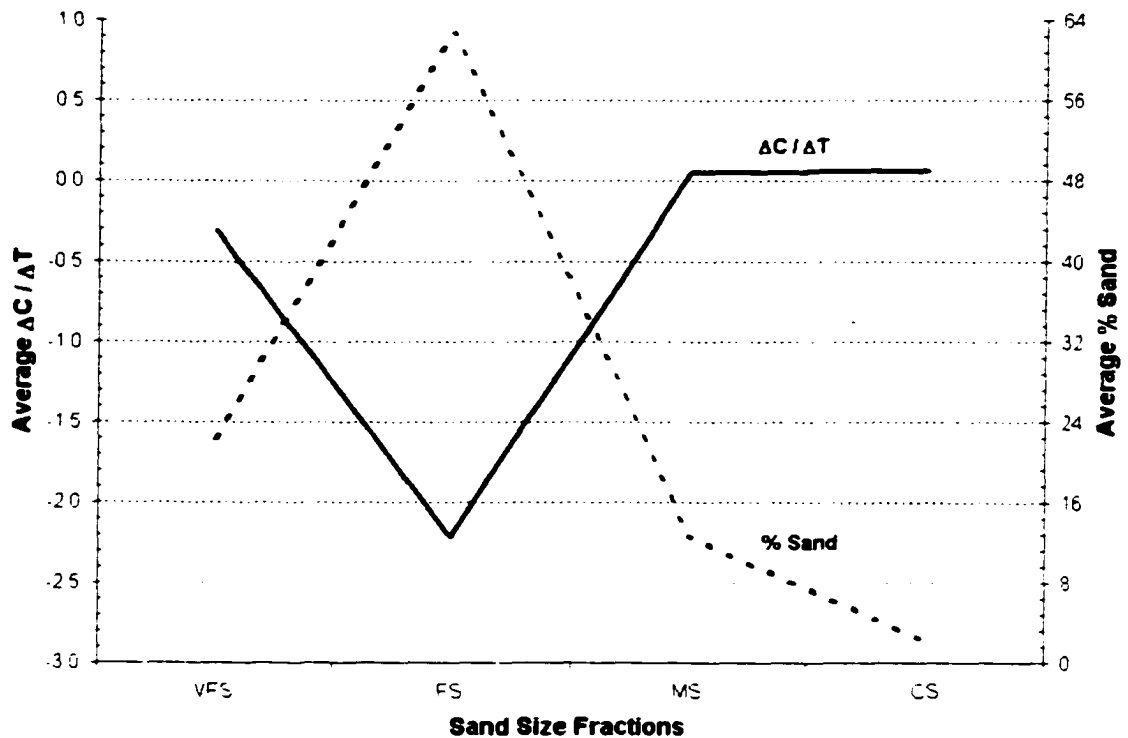


Figure 5.18. Comparison of $\Delta C / \Delta T$ values for different sand fractions, and average percent amount of each fraction for all flow events at all locations.

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_s , 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:

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

$$C_s = c_2 Q^{e_Q} T^{e_T} \quad (\text{Eq.5.7})$$

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.

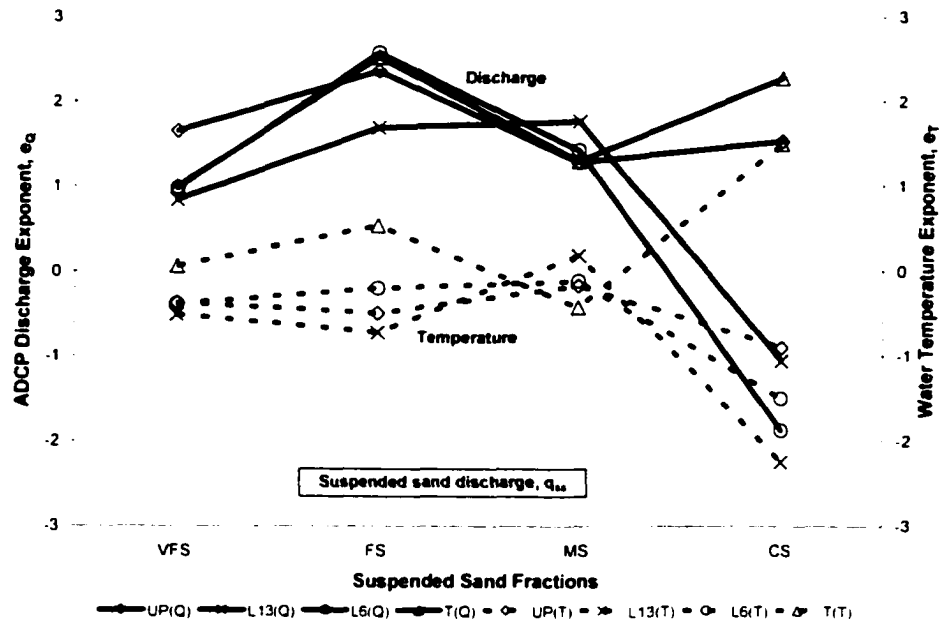


Figure 5.19. Water discharge and temperature exponents versus the suspended sand fractions by means of the calculated suspended sand discharge values.

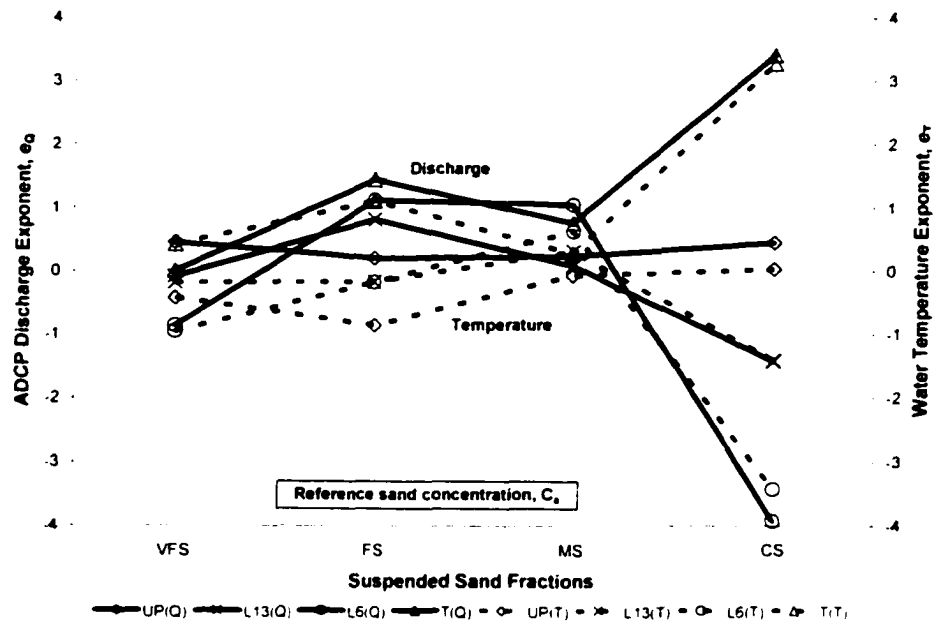


Figure 5.20. Water discharge and temperature exponents versus the suspended sand fractions by means of measured reference sand concentration values.

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_r , fall velocity of sediment particles, ω , Rouse number, R_v) 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_a , 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).

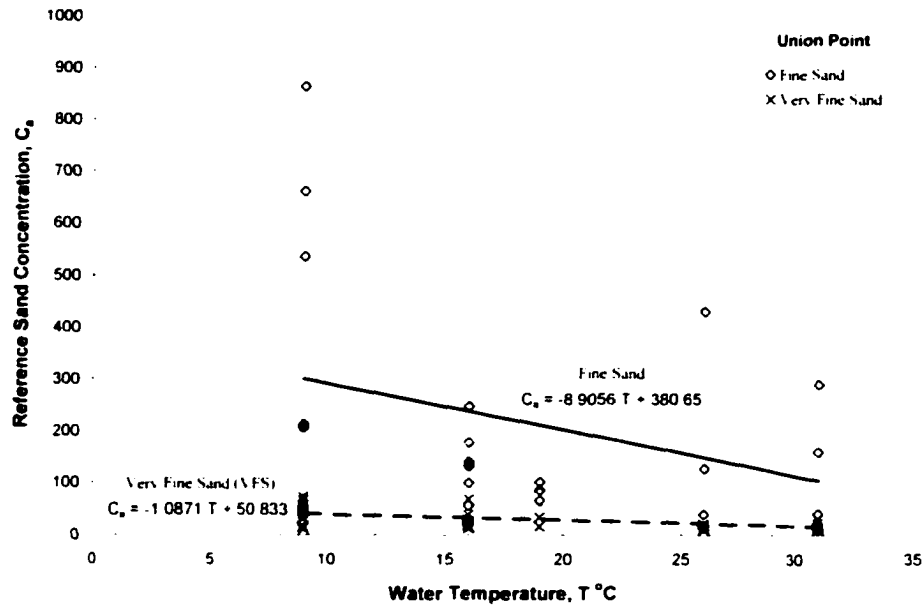


Figure 5.21. Water temperature effect on the reference suspended very fine and fine sand concentrations by size fraction at Union Point.

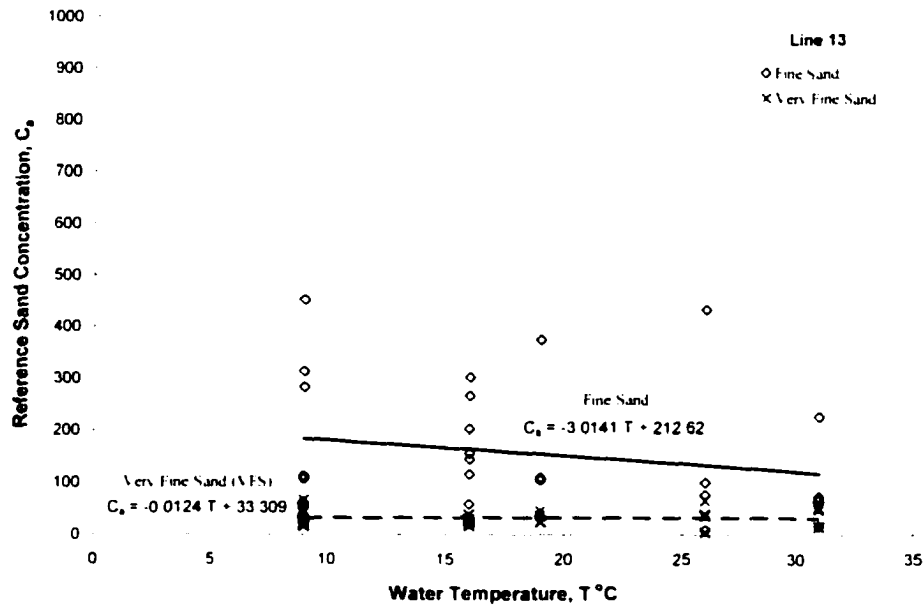


Figure 5.22. Water temperature effect on the reference suspended very fine and fine sand concentrations by size fraction at Line 13.

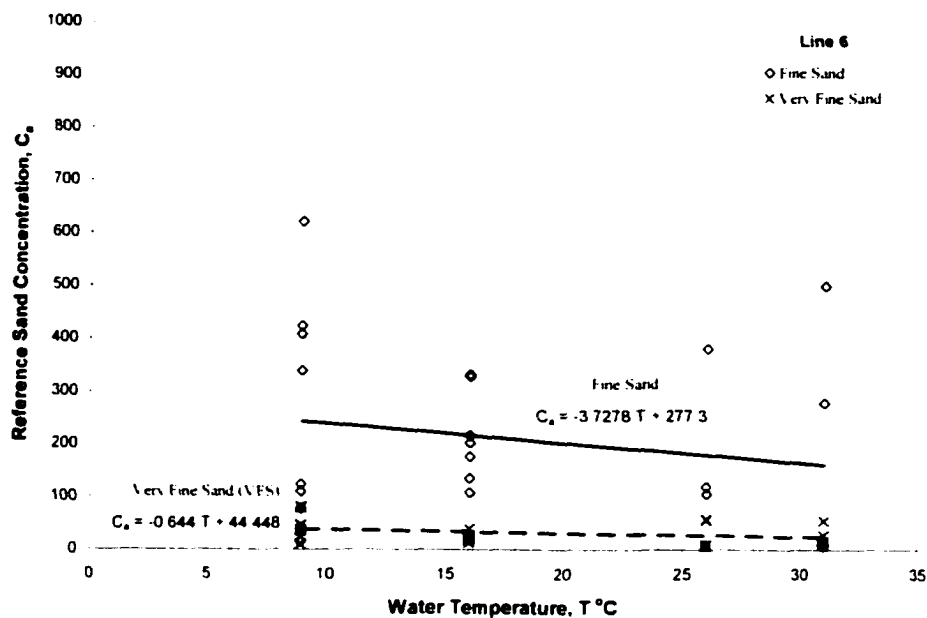


Figure 5.23. Water temperature effect on the reference suspended very fine and fine sand concentrations by size fraction at Line 6.

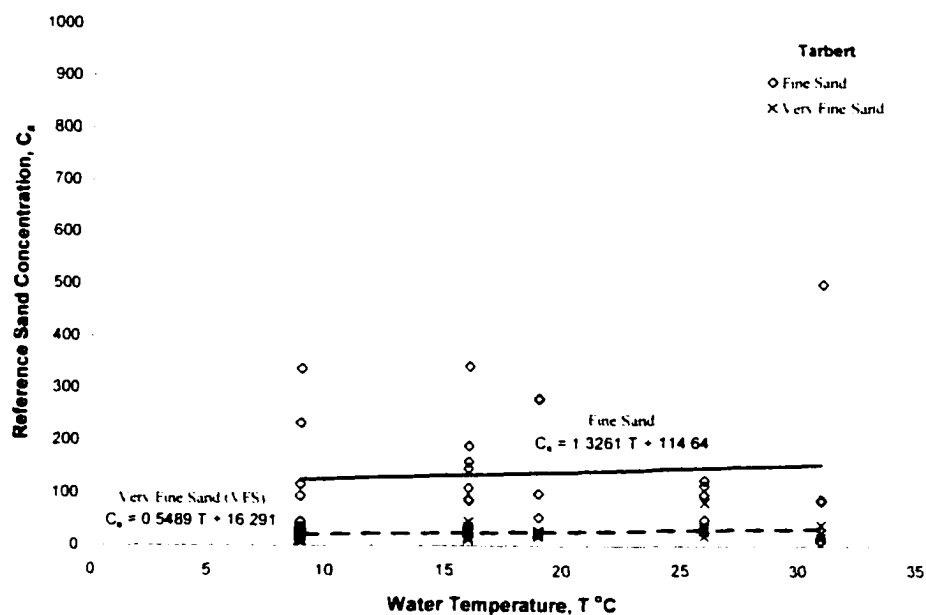


Figure 5.24. Water temperature effect on the reference suspended very fine and fine sand concentrations by size fraction at Tarbert.

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 °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, $C_{r,s}$, decrease being higher for highly-concentrated sand sizes (in this case fine sand (FS)). In Figure 5.25, an increase of 1 °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.

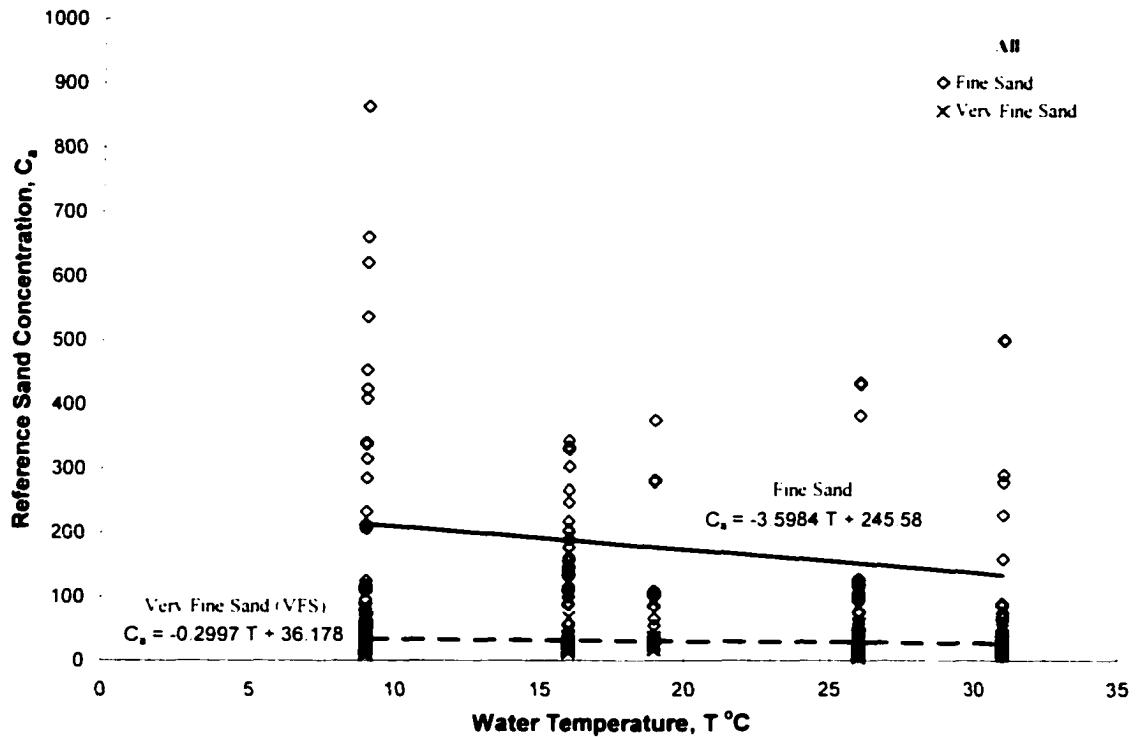


Figure 5.25. Water temperature effect on the reference suspended very fine and fine sand concentrations at all locations.

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 , shape factor of particles, s_p , suspended sediment concentration, C , and water temperature, T .

The particle diameter, d , 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):

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

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

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

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 $Re_p = \frac{\omega d_p}{\nu}$.

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.

		Fall Velocity of Sediment Particles in Sediment-Water Mixture, w (mm/s)							
Class Name	Particle Diameter (mm)	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 °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.

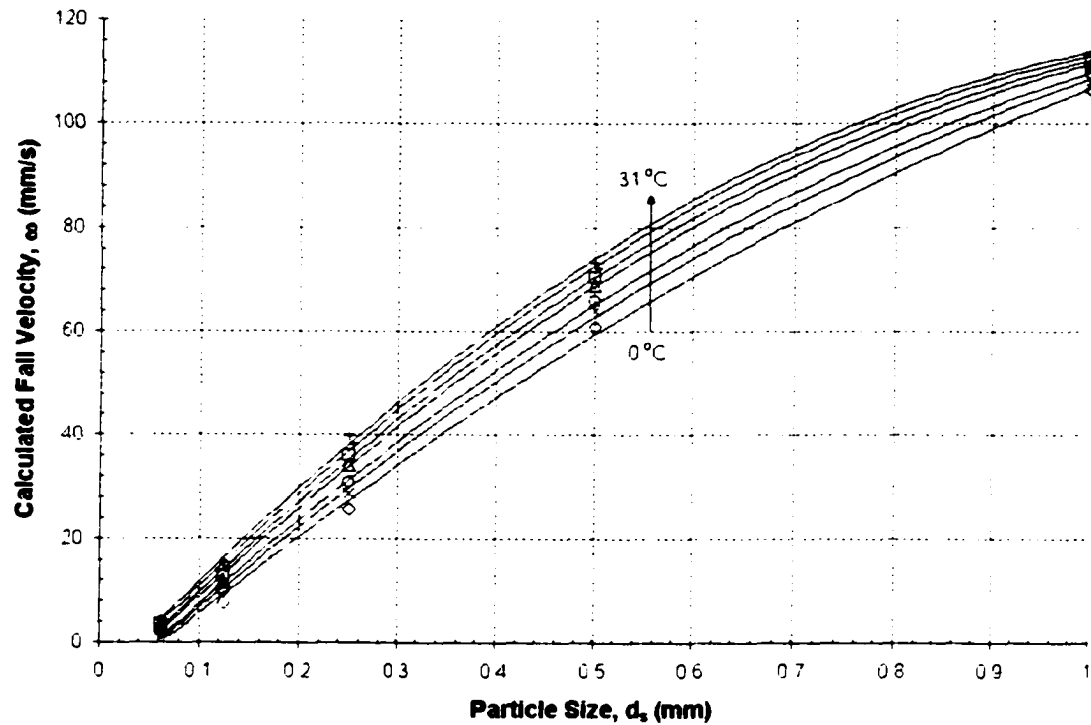


Figure 5.26. Effect of water temperature on the fall velocity of sand particles.

5.2.2.3. Analysis of the Water Temperature Effect on Rouse Number, R_{*}

The Rouse number, R_{*} , 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:

$$R_{*} = \frac{\omega}{\beta \kappa u_*} \quad (\text{Eq.5.10})$$

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_{*} , definitely has a big effect on the vertical distribution of suspended sediment, and thus on the suspended sediment transport. Because R_{*} is a function of ω, β, κ , and u_* (see Eq.5.10), any changes to these parameters cause a change in R_{*} . 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_{*} . 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_{*} , 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_{*} .

Experimentally, in this study, R_{*} 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_{om} value is the exponent value of the power function, which is shown in Figure 5.27 below.

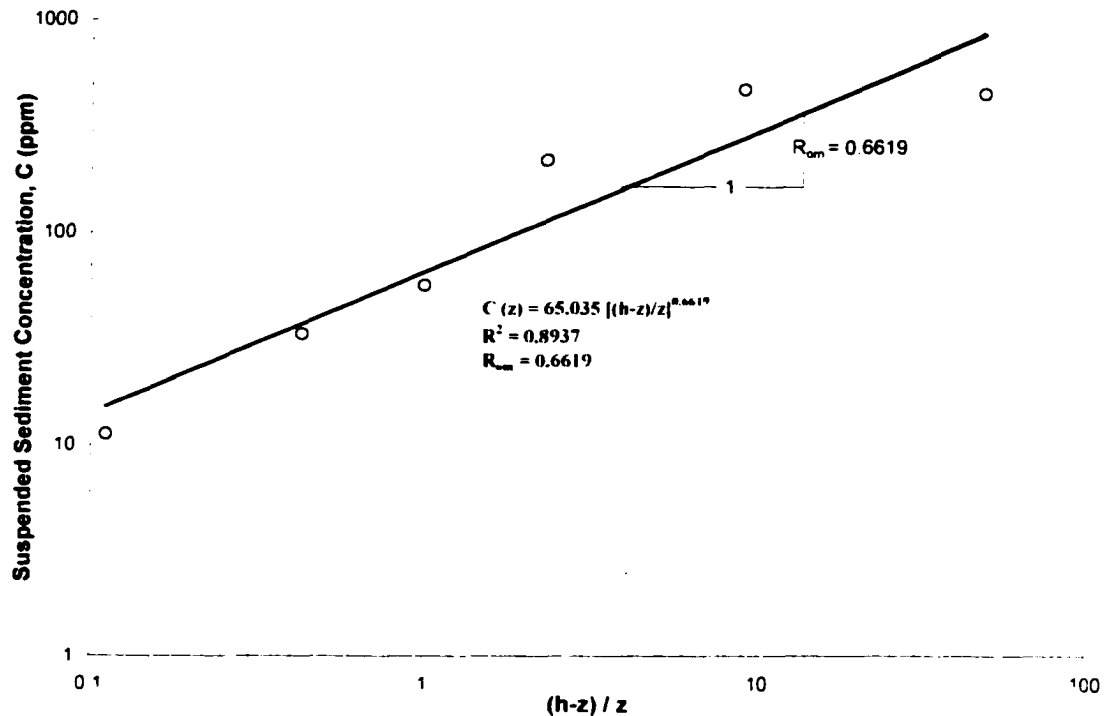


Figure 5.27. Obtaining Rouse number from the slope of a suspended sediment concentration profile.

To find out how a change in the water temperature affects Rouse number, R_{om} , first the average Rouse number values, $\overline{R_{om}}$, for the specified cross-sections are obtained (see Table B.15 in Appendix B). To obtain the average R_{om} 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_{om} values are the exponent values of the

power functions. After obtaining the average R_{om} values for all flow events at all locations, a graph of the average R_{om} values for all sand fractions versus the water temperature in degrees Celsius is plotted (see Figure 5.28).

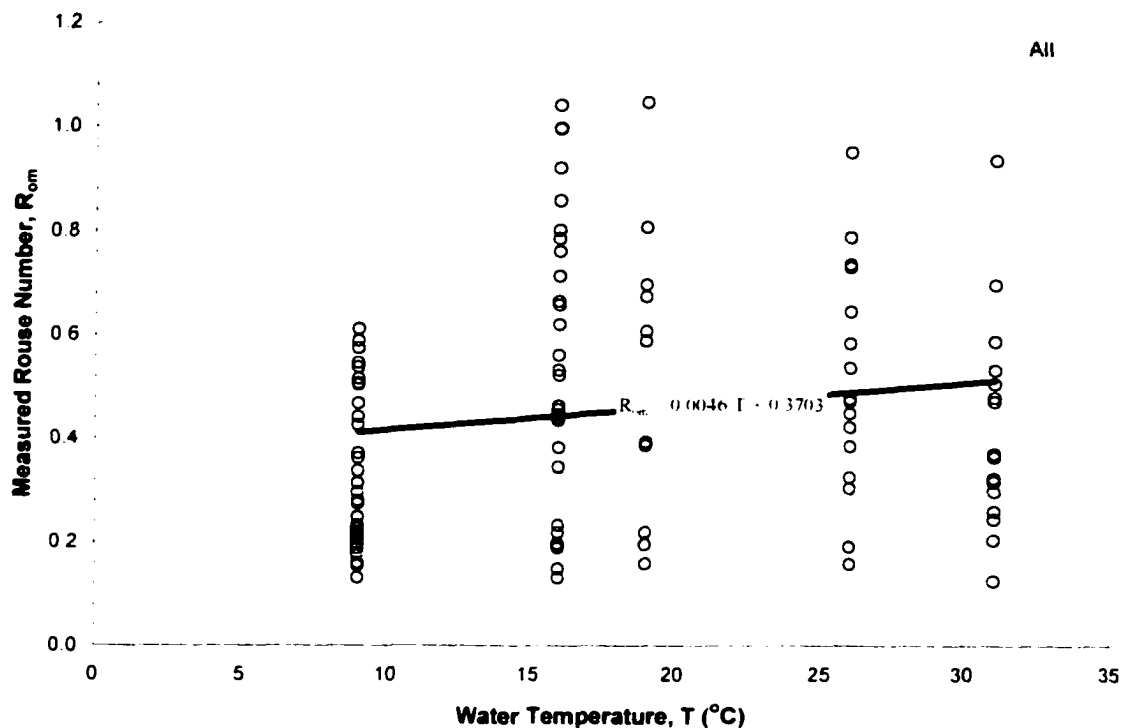


Figure 5.28. Average measured Rouse number change with water temperature.

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_{om}) is accurate and the main reason for R_{om} 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 °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_{00} , in this equation should be determined by considering the water temperature effect on the parameters affecting the Rouse's parameter, R_{00} , (see Eq.2.21). The difference between the measured and calculated R_{00} numbers is shown in the following sample figure (Figure 5.29).

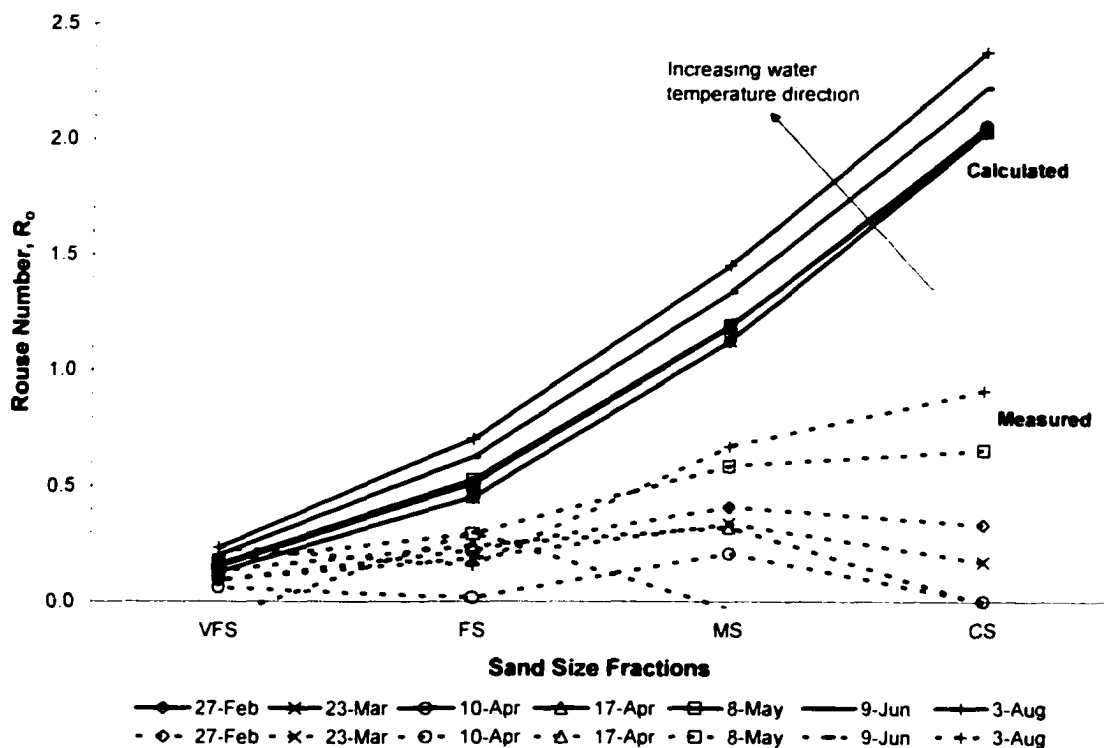


Figure 5.29. Comparison of the calculated and measured Rouse number for all flow events at a vertical at Line 13.

Figure 5.29 illustrates clearly that the calculated Rouse number values, R_{ck} , 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_{ck} . R_{om} and R_{ck} values are approximately equal to each other for very fine sand, but the difference between R_{om} and R_{ck} 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_{ck} , 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_{κ} 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.

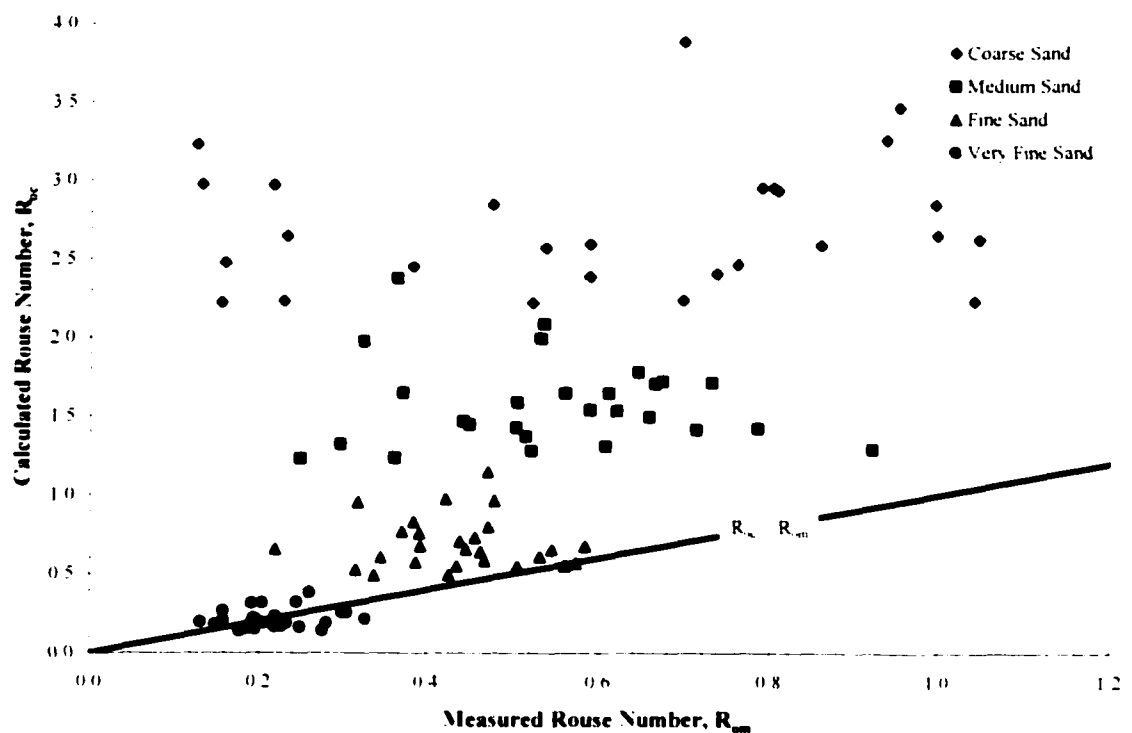


Figure 5.30. Comparison of the measured and calculated Rouse numbers.

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.

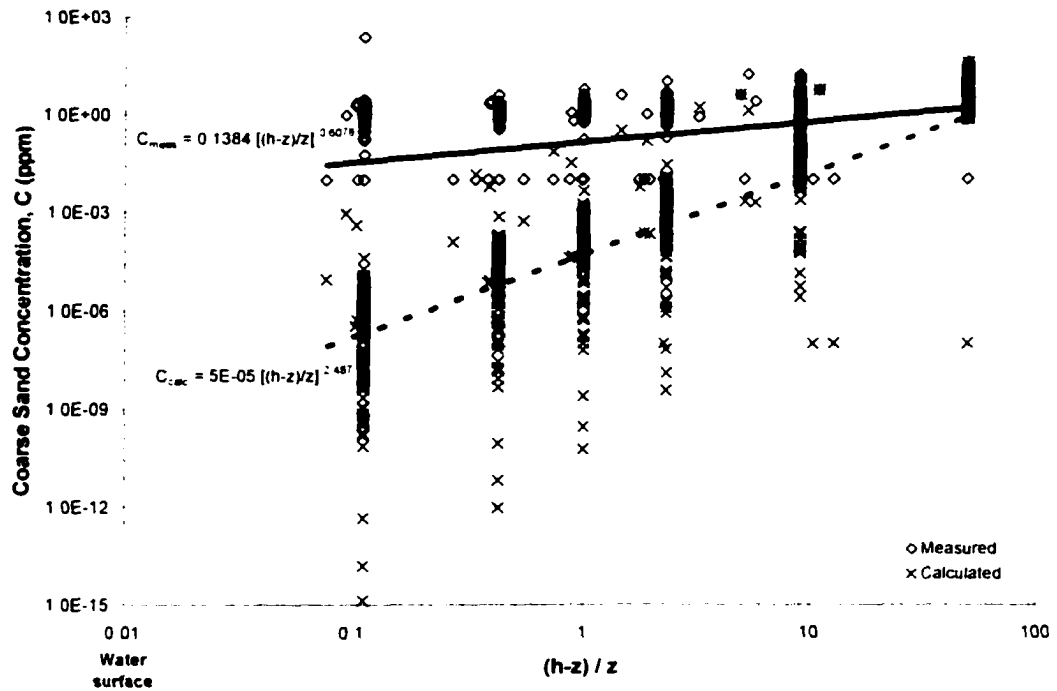


Figure 5.31. Measured and calculated Rouse numbers for coarse sand fraction.

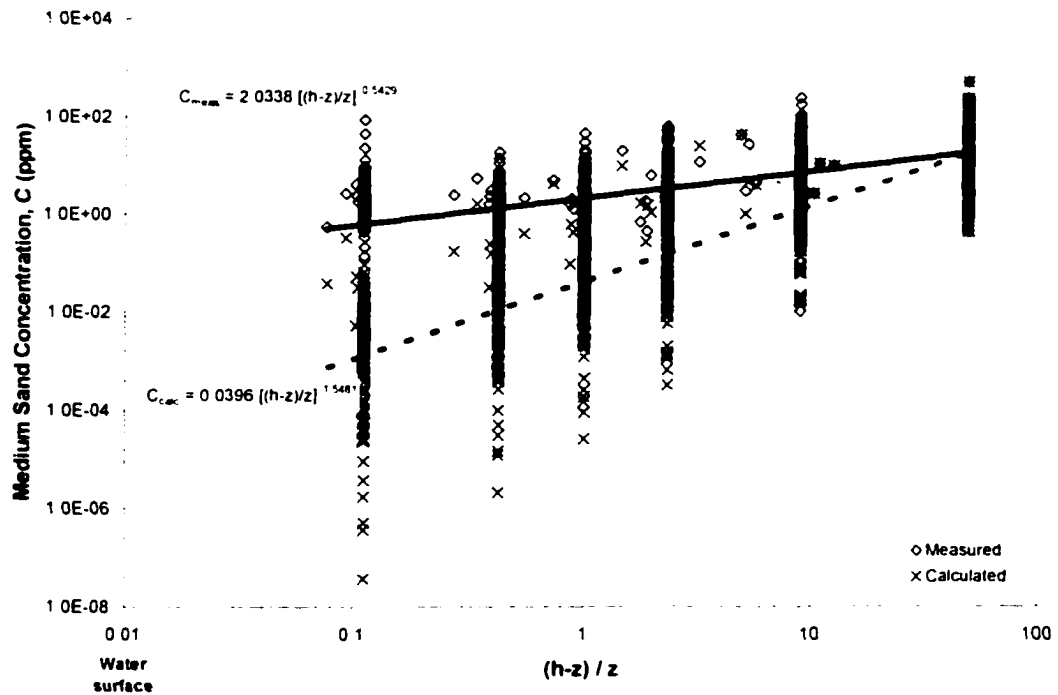


Figure 5.32. Measured and calculated Rouse numbers for medium sand fraction.

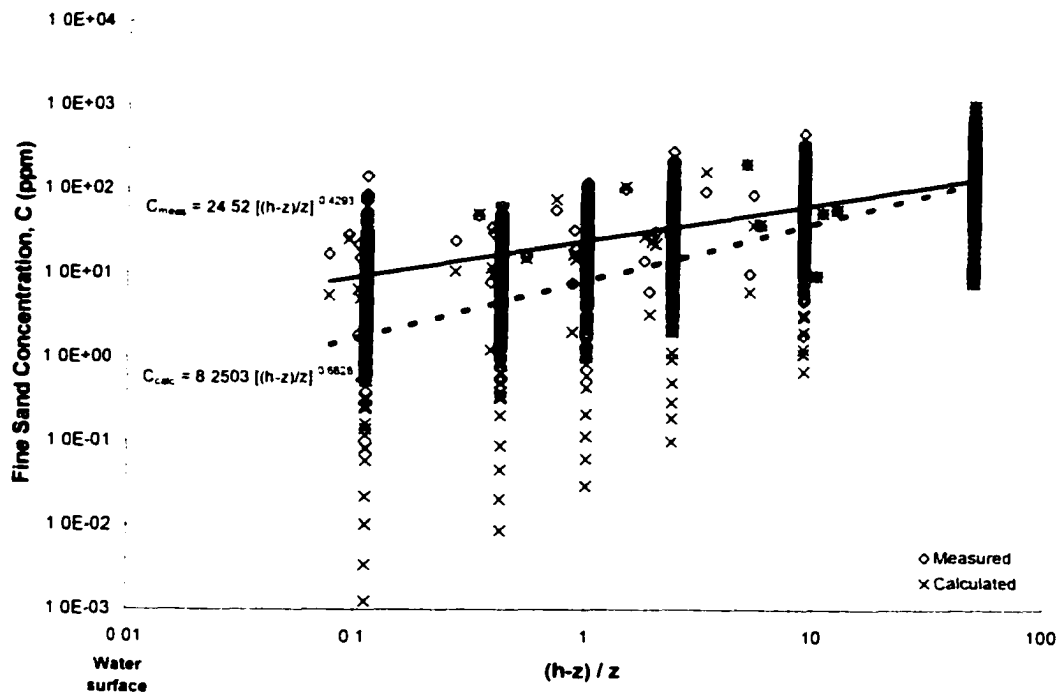


Figure 5.33. Measured and calculated Rouse numbers for fine sand fraction.

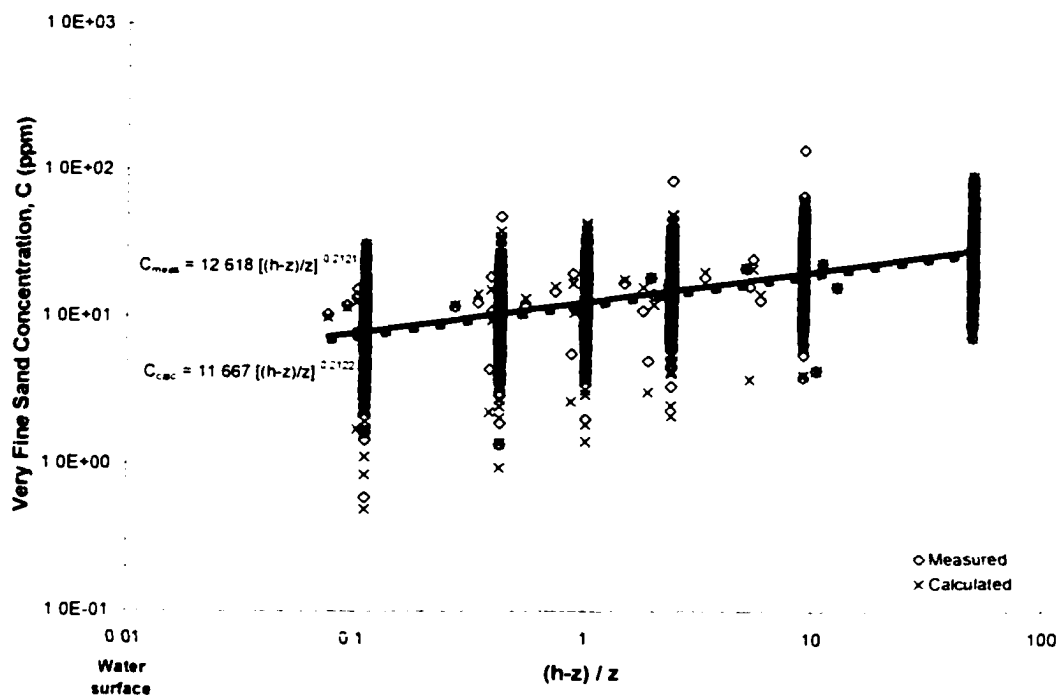


Figure 5.34. Measured and calculated Rouse numbers for very fine sand fraction.

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 °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_{*} , 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_{*} 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 °C. These results would lead to an increase or decrease in the suspended sand concentration depending on whether the value of ratio C'/C_u is bigger or smaller than unity. In general, the change of suspended sediment concentration can be shown with the following relation:

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

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_u 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 °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 °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 °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:

$$F_c = 2 V_r \Omega \sin \Phi \quad (\text{Eq.5.12})$$

where V_r is the horizontal particle velocity, Ω is the angular velocity of the earth's rotation and approximately equals to $7.3 \times 10^{-5} \text{ s}^{-1}$, 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:

$$X = \frac{\text{Coriolis acceleration}}{\text{Gravitational acceleration}} = \frac{\Omega V_r}{g S_0} \quad (\text{Eq.5.13})$$

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 $2V_r \Omega \sin \Phi$. However, the latitude of the study reach is about 31° ; 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.

$\text{Arc sin } X$ 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.

Verticals	Slope of the Trendline						
	Flow Events						
	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

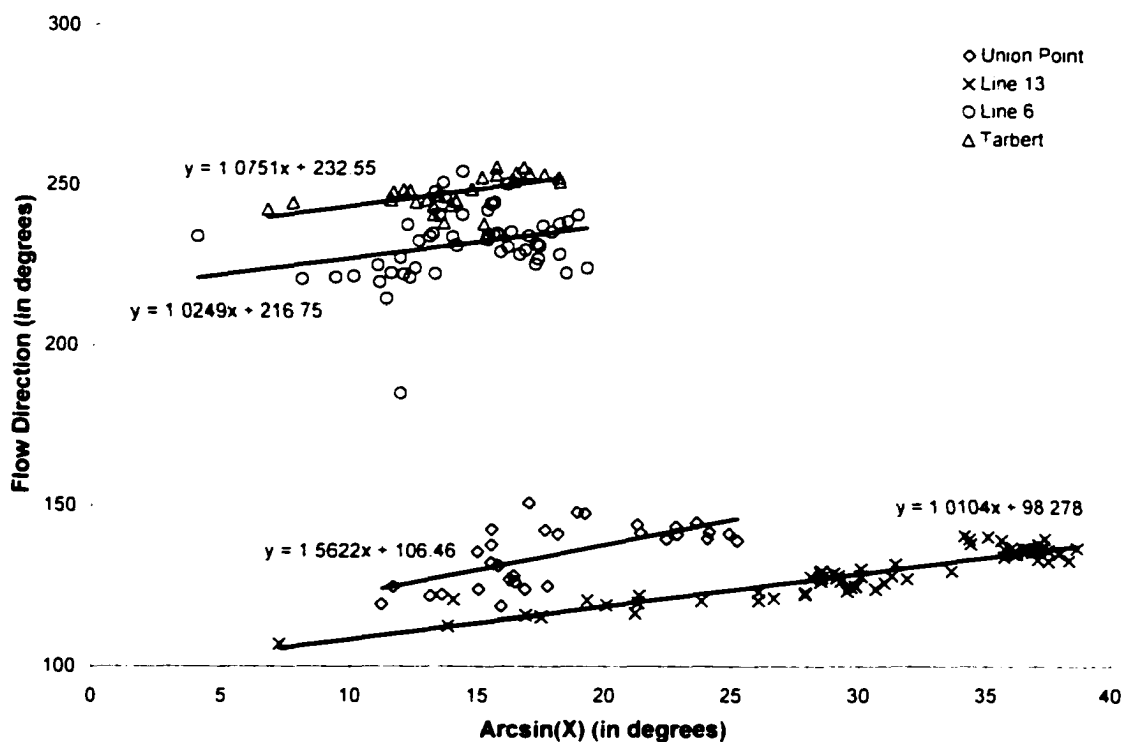


Figure 5.35. Direct proportionality of Arcsin(X) versus Flow Direction for sample verticals at each location.

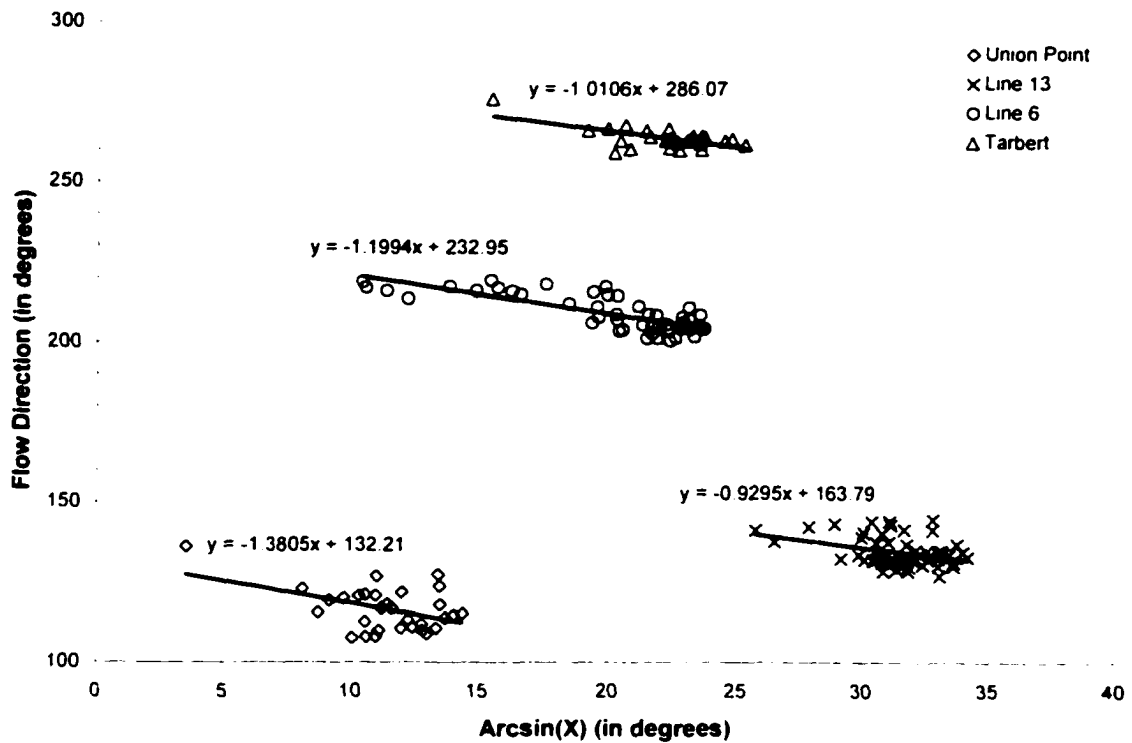


Figure 5.36. Inverse proportionality of Arcsin(X) versus Flow Direction for sample verticals at each location.

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.

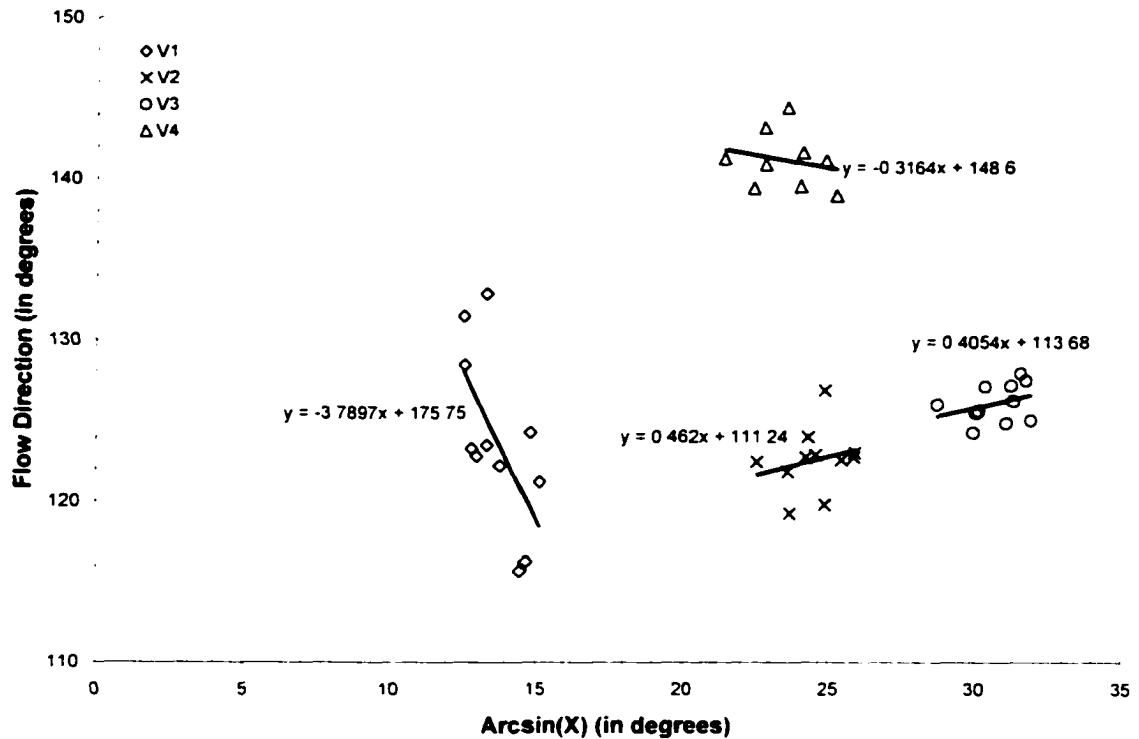


Figure 5.37. Relationship of measured flow directions to the Coriolis force deflections at the upper 33 percent of all verticals for the April 17, 1998 event at Union Point.

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 °C increase in water temperature. As far as the individual sand fractions are concerned, a water temperature increase of 1 °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 °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 °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 °C when the data for all cross-sections are considered.
- Although the change in the measured Rouse number, R_{*m} , with size fraction doesn't

have an obvious trend like the calculated Rouse number, R_{κ} . On average, R_{m} 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_{m} , value goes up slightly with a water temperature increase (see Figure 5.28). The value of R_{m} increases by approximately 1.12 percent with a water temperature increase of every 1 °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 °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 °C to 16 °C, the von Karman parameter increases by about 15 percent, which corresponds to a 2.17 percent increase for every 1 °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 °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).

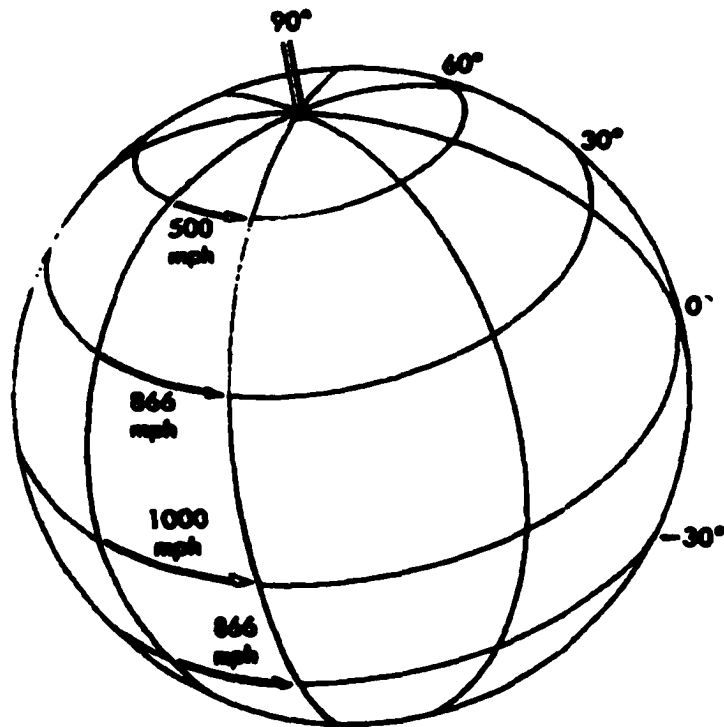


Figure A.1. Points at different latitudes on the earth's surface rotate at different velocities.

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.

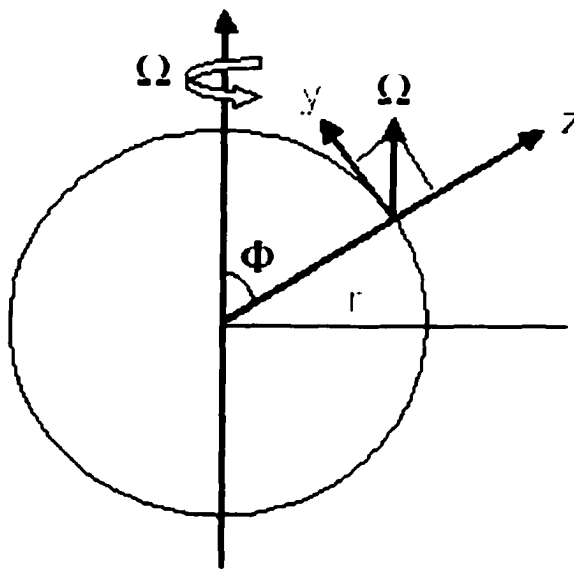


Figure A.2. Local Cartesian coordinates. The x axis is into the plane of the paper.

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 $\Omega \times V$, 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 (Egleson, 1970).

The earth rotates at a rate $\Omega = 2\pi \text{ rad/day} = 7.3 \times 10^{-5} \text{ s}^{-1}$ 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):

$$a_c = 2\Omega \times V = \begin{vmatrix} i & j & k \\ 0 & 2\Omega \cos \Phi & 2\Omega \sin \Phi \\ V_x & V_y & V_z \end{vmatrix} \quad (\text{Eq.A.1})$$

$$a_c = 2\Omega [i(V_z \cos \Phi - V_y \sin \Phi) + jV_x \sin \Phi - kV_x \cos \Phi]$$

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

$$a_{c_x} = -2\Omega V_y \sin \Phi = -f V_y \quad (\text{Eq.A.2a})$$

$$a_{c_y} = 2\Omega V_x \sin \Phi = f V_x \quad (\text{Eq.A.2b})$$

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

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 $\pm 1.45 \times 10^{-4} \text{ s}^{-1}$ 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 ($V_y \ll V_x$), 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:

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

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										DIVER CONDITION: GOOD										TYPE SAMPLER: #3											
OCEAN WINDSPEED: 0 KTS										TIME: 06:00 TO 06:07										TYPE SAMPLER: 105P											
LOCATION: UNCLIP										TEMP: 9.0 C/48 F										NO VERTICALS: 0											
GAGE: WADY LANDING										WEATHER: 100%										NO. EVENTS: 4											
DEPTH: 10.0 METERS (33 FT)										GAZE READING: 48.80 FT																					
CONVENTIONAL METHOD: 100.00 FT																															
										Suspended Sediment Grain Size Analysis																				Sediment	
										Sand Sieve Analysis: Cumulative Area Retained																				Concentration	
										US 60 425 MIC 60 250 MIC 60 150 MIC 60 75 MIC 60 42 MIC 60 25 MIC 60 15 MIC 60 7.5 MIC 60 4.75 MIC 60 2.5 MIC 60 1.5 MIC 60 .84 MIC 60 .42 MIC 60 .25 MIC 60 .15 MIC 60 .075 MIC 60 .042 MIC 60 .025 MIC 60 .015 MIC 60 .0075 MIC 60 .0042 MIC 60 .0025 MIC 60 .0015 MIC 60 .00075 MIC 60 .00042 MIC 60 .00025 MIC 60 .00015 MIC 60 .000075 MIC 60 .000042 MIC 60 .000025 MIC 60 .000015 MIC 60 .0000075 MIC 60 .0000042 MIC 60 .0000025 MIC 60 .0000015 MIC 60 .00000075 MIC 60 .00000042 MIC 60 .00000025 MIC 60 .00000015 MIC 60 .000000075 MIC 60 .000000042 MIC 60 .000000025 MIC 60 .000000015 MIC 60 .0000000075 MIC 60 .0000000042 MIC 60 .0000000025 MIC 60 .0000000015 MIC 60 .00000000075 MIC 60 .00000000042 MIC 60 .00000000025 MIC 60 .00000000015 MIC 60 .000000000075 MIC 60 .000000000042 MIC 60 .000000000025 MIC 60 .000000000015 MIC 60 .0000000000075 MIC 60 .0000000000042 MIC 60 .0000000000025 MIC 60 .0000000000015 MIC 60 .00000000000075 MIC 60 .00000000000042 MIC 60 .00000000000025 MIC 60 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[illegible][illegible]

Table B.1 (continued)

DATE: 17 APR 88
STREAM: MISSISSIPPI RIVER
LOCATION: UNION POINT
GAGE: UNION POINT
DISCHARGE: 1069.427 CFS (ADP)
CONVENTIONAL METHOD: 77.37 FFS

RIVER CONDITION: GOOD
TIME: 10:10:30
TEMP: 60.5 F
WEATHER: CLOUDY AND RAIN
GAGE READING: 42.80 FT

TYPE SAMPLER: P-63
TYPE SAMPLES: 7 SP
NO. VERTICALS: 4
NO. POINTS: 6

Distance from Face of Reference Pile (ft)	Station Depth ft	Sampling Depth ft	Samp Velocity ft/s	Flow Direction at 1 Deg	Sediment Grain Size Analysis												Sediment Concentration	
					U.S. 40 to 425 mm				U.S. 40 to 250 mm				U.S. 250 to 125 mm				U.S. 125 to 60 mm	
ft	ft	ft	ft/s	ft/s	mm	% Ret	% Finer	mm	% Ret	% Finer	mm	% Ret	% Finer	mm	% Ret	% Finer	g	%
73	1040	69	6.4	4.32	116.84	100.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	1.23	1.23
74	1040	69	20.7	3.85	132.07	100.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	47.4	278.4
75	1040	69	34.5	3.29	135.249	100.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	55.3	261.2
76	1040	69	48.3	4.02	113.321	100.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	62.2	297.0
77	1040	69	62.1	3.50	114.546	100.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	56.9	307.6
78	1040	69	67.6	2.30	126.676	100.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	58.4	300.0
79	1648	77	1.1	7.16	122.584	100.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	44.3	258.9
80	1648	77	1.2	5.67	121.844	100.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	43.4	241.4
81	1648	77	35.5	6.43	124.331	100.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	38.9	230.8
82	1648	77	49.7	5.19	124.529	100.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	38.9	230.8
83	1648	77	63.9	4.07	116.916	100.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	38.9	230.8
84	1648	77	69.6	2.37	126.740	100.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	38.9	230.8
85	2247	89	4.4	5.60	124.973	100.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	49.1	262.1
86	2247	89	30.7	5.01	126.015	100.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	49.1	262.1
87	2247	89	34.5	7.99	130.230	100.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	49.1	262.1
88	2247	89	48.3	7.86	130.156	100.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	49.1	262.1
89	2247	89	62.1	5.80	124.461	100.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	49.1	262.1
90	2247	89	67.6	5.63	126.134	100.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	49.1	262.1
91	2866	97	5.7	7.10	136.974	100.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	49.1	262.1
92	2866	97	35.5	6.40	146.917	100.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	49.1	262.1
93	2866	97	38.5	5.04	142.272	100.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	49.1	262.1
94	2866	97	39.4	4.32	127.688	100.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	49.1	262.1
95	2866	97	51.3	3.92	130.856	100.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	49.1	262.1
96	2866	97	55.9	2.74	146.470	100.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	49.1	262.1

DATE: 08 MAY 88
STREAM: MISSISSIPPI RIVER
LOCATION: UNION POINT
GAGE: UNION POINT
DISCHARGE: 122.937 CFS (ADP)
CONVENTIONAL METHOD: 24.84 FFS

RIVER CONDITION: GOOD
TIME: 10:10:30
TEMP: 59.0 F
WEATHER: CLEAR AND WARM
GAGE READING: 56.10 FT

TYPE SAMPLER: P-63
TYPE SAMPLES: 5 SP
NO. VERTICALS: 4
NO. POINTS: 6

Distance from Face of Reference Pile (ft)	Station Depth ft	Sampling Depth ft	Samp Velocity ft/s	Flow Direction at 1 Deg	Sediment Grain Size Analysis												Sediment Concentration					
					U.S. 40 to 425 mm				U.S. 40 to 250 mm				U.S. 250 to 125 mm				U.S. 125 to 60 mm				Grain g	Total %
					mm	% Ret	% Finer	mm	% Ret	% Finer	mm	% Ret	% Finer	mm	% Ret	% Finer	mm	% Ret	% Finer			
97	1054	73	1.3	4.32	127.650	100.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	31.5	162.1	74.1			
98	1054	73	21.3	4.24	126.140	100.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	31.5	162.1	74.1			
99	1054	73	36.5	3.65	126.900	100.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	31.5	162.1	74.1			
100	1054	73	41.1	3.45	127.120	100.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	31.5	162.1	74.1			
101	1054	73	65.7	3.02	140.990	100.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	31.5	162.1	74.1			
102	1054	73	71.4	2.36	137.130	100.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	31.5	162.1	74.1			
103	1652	73	1.0	7.61	126.780	100.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	31.5	162.1	74.1			
104	1652	73	21.3	7.44	127.750	100.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	31.5	162.1	74.1			
105	1652	73	36.5	7.43	126.137	100.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	31.5	162.1	74.1			
106	1652	73	50.4	6.70	130.207	100.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	31.5	162.1	74.1			
107	1652	73	64.8	5.74	121.444	100.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	31.5	162.1	74.1			
108	1652	73	70.6	4.35	126.255	100.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	31.5	162.1	74.1			
109	2276	73	1.0	5.49	121.075	100.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	31.5	162.1	74.1			
110	2276	73	21.3	5.73	120.463	100.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	31.5	162.1	74.1			
111	2276	73	36.5	5.42	123.436	100.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	31.5	162.1	74.1			
112	2276	73	47.4	5.11	124.958	100.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	31.5	162.1	74.1			
113	2276	73	64.8	3.02	126.970	100.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	31.5	162.1	74.1			
114	2276	73	70.6	2.36	121.652	100.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	31.5	162.1	74.1			
115	2869	86	4.8	4.47	131.814	100.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	31.5	162.1	74.1			
116	2869	86	17.4	7.07	130.136	100.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	31.5	162.1	74.1			
117	2869	86	39.4	7.00	136.653	100.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	31.5	162.1	74.1			
118	2869	86	40.6	5.84	141.039	100.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	31.5	162.1	74.1			
119	2869	86	42.2	4.66	134.498	100.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	31.5	162.1	74.1			
120	2869	86	56.9	4.78	134.139	100.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	31.5	162.1	74.1			

DATE: 09 JUN 88

STREAM: MISSISSIPPI RIVER

LOCATION: UNION POINT

GAGE: UNION POINT

DISCHARGE: 135.771 CFS (ADP)

CONVENTIONAL METHOD: 42.70 FFS

RIVER CONDITION: MODERATE

TIME: 05:50:10

TEMP: 55.0 F

WEATHER: CLEAR AND HOT

GAGE READING: 47.10 FT

TYPE SAMPLER: P-63

TYPE SAMPLES: 7 SP

NO. VERTICALS: 4

NO. POINTS: 6

Distance from Face of Reference Pile (ft)	Station Depth ft	Sampling Depth ft	Samp Velocity ft/s	Flow Direction at 1 Deg	Sediment Grain Size Analysis												Sediment Concentration					
					U.S. 40 to 425 mm				U.S. 40 to 250 mm				U.S. 250 to 125 mm				U.S. 125 to 60 mm				Grain	Total
					mm	% Ret	% Finer	mm	% Ret	% Finer	mm	% Ret	% Finer	mm	% Ret	% Finer						
121	1047	67	1.7	4.15	115.055	100.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	13.4	220.0	136.4			
122	1047	67	21.3	2.19	126.754	100.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	16.8	256.1	151.6			
123	1047	67	36.5	3.11	129.860	100.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	16.8	256.1	151.6			
124	1047	67	54.4	2.88	116.649	100.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	14.9	238.1	144.4			
125	1047	67	67.3	2.53	116.607	100.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	16.8	256.1	151.6			
126	1047	67	65.4	2.44	118.019	100.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	16.8	256.1	151.6			
127	1013	60	1.2	1.04	119.830	100.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	15.1	241.1	144.4			
128	1013	60	16.0	5.92	113.516	100.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	14.0	231.6	136.4			
129	1013	60	60.0	2.70	116.086	100.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	16.8	256.1	151.6			
130	1013	60	42.0	4.86	115.051	100.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	16.8	256.1	151.6			
131	1013	60	24.0	5.40	124.745	100.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	16.8	256.1	151.6			
132	1013	60	59.3	2.30	111.718	100.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	16.8	256.1	151.6			
133	2913	67	67.3	2.53	116.607	100.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	16.8	256.1	151.6			
134	2913	67	19.4	2.41	116.607	100.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	16.8	256.1	151.6			
135	2913	67	11.6	5.62	134.557	100.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	16.8	256.1	151.6			
136	2913	67	44.0	5.17	115.055	100.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	16.8	256.1	151.6			
137	2913	67	66.6	4.07	129.749	100.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	16.8	256.1	151.6			
138	2913	67	11.7	5.17	124.609	100.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	16.8	256.1	151.6			
139	2913	67	43.0	4.81	124.751	100.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	16.8	256.1	151.6			
140	2913	67	19.4	5.94	124.751	100.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	16.8	256.1	151.6			
141	2913	67	41.0	4.94	124.751	100.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	16.8	256.1	151.6			
142	2913	67	12.2	4.32	134.066	100.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	16.8	256.1	151.6			
143	2913	67	41.4	4.40	124.751	100.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	16.8	256.1	151.6			
144	2913	67	65.7	5.11	124.751	100.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	100.00	0.00	0.00	16.8	256.1	151.6			

Table B.1 (continued)

DATE: 03 AUG 88						RIVER CONDITION: CHOPPY						TYPE SAMPLER: P-63							
STREAM: MISSISSIPPI RIVER						TIME: 09:30 TO 10:30						TYPE SAMPLES: 30/SP							
LOCATION: UNION POINT						TEMP: 31.0 @ 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																			
Field No.	Distance from the Reference Point (ft.)	Station Depth (ft.)	Sampling Depth (ft.)	Samp. Velocity (ft/s)	Flow Direction (Deg.)	Suspended Sediment Grain Size Analysis												Sediment Concentration (ppm)	
						Sand Size Analysis (Cumulative Weight Retained)													
						U.S. #40 (0.425 mm)			U.S. #60 (0.250 mm)			U.S. #100 (0.150 mm)			U.S. #200 (0.075 mm)			Pan	Total
						Wt (g)	% Ret.	% Finer	Wt (g)	% Ret.	% Finer	Wt (g)	% Ret.	% Finer	Wt (g)	% Ret.	% Finer		
145	1030	47	4.7	4.40	117.424	0.0000	0.0	100.0	0.0006	15.4	94.6	0.0029	14.4	35.6	0.0039	10.7	216.5	226.2	
146	1030	47	14.1	4.52	120.885	0.0000	0.0	100.0	0.0003	3.9	96.1	0.0039	49.4	50.6	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	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	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	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	0.0889	197.0	198.2	395.2	
151	1625	50	5.0	6.03	126.423	0.0000	0.0	100.0	0.0004	2.9	97.1	0.0098	62.4	37.6	0.0141	19.0	193.6	212.6	
152	1625	50	15.0	5.48	125.231	0.0005	2.7	97.3	0.0017	7.1	92.9	0.0156	70.1	29.9	0.0214	30.4	185.5	216.9	
153	1625	50	25.0	5.75	127.634	0.0000	0.0	100.0	0.0013	6.1	93.9	0.0144	74.2	25.8	0.0192	30.7	192.6	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	102.9	173.8	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	99.9	0.1	0.0367	99.7	33.7	147.7	
156	1625	50	49.0	2.29	122.893	0.0012	0.6	99.4	0.0295	13.8	86.2	0.1999	93.3	6.7	0.2134	99.6	214.2	571.0	
157	2229	50	5.0	6.12	123.307	0.0000	0.0	100.0	0.0009	11.9	88.1	0.0247	61.8	38.2	0.0073	96.1	12.6	171.5	184.1
158	2229	50	15.0	6.95	119.913	0.0000	0.0	100.0	0.0017	29.3	70.7	0.0334	58.6	41.4	0.0057	96.3	1.7	225.0	
159	2229	50	25.0	6.31	123.798	0.0000	0.0	100.0	0.0032	33.0	67.0	0.0065	67.0	33.0	0.0095	57.5	2.1	100.2	
160	2229	50	35.0	4.68	124.938	0.0000	0.0	100.0	0.0075	36.2	63.8	0.0162	77.1	22.9	0.0206	98.1	1.9	100.2	
161	2229	50	45.0	4.81	120.448	0.0003	3.7	96.3	0.0637	71.7	28.3	0.0832	33.7	66.3	0.0886	99.8	0.2	100.2	
162	2229	50	49.0	2.47	121.212	0.0027	3.2	96.8	0.0813	70.0	30.0	0.1084	93.4	6.6	0.1154	99.4	0.6	100.2	
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	100.2	
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	100.2	
165	2901	41	20.5	4.27	137.919	0.0000	0.0	100.0	0.0005	9.7	90.3	0.0019	30.6	69.4	0.0060	96.9	3.1	100.2	
166	2901	41	28.7	4.28	135.424	0.0003	4.5	95.5	0.0005	7.6	92.4	0.0019	29.9	70.1	0.0063	95.5	4.5	100.2	
167	2901	41	36.9	2.65	135.836	0.0000	0.0	100.0	0.0010	21.3	78.7	0.0021	44.7	55.3	0.0044	93.6	6.4	100.2	
168	2901	41	45.0	2.39	159.426	0.0024	1.5	98.5	0.0063	39.6	60.4	0.0105	66.0	34.0	0.0165	37.5	2.5	100.2	

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

DATE: 27 FEB 88
 STREAM: MISSISSIPPI RIVER
 LOCATION: LINE #3 D/S OF HYDRO STAKE 14
 GAGE: WINN LAKE
 DISCHARGE: 652 CFS (2.5 ACP)

RIVER CONDITION: GOOD
 TIME: 10:10 TO 10:15
 TEMP: 50.0 TO 51.0 F
 WEATHER: WINDY AND MILD
 GAGE READING: 48.6 FT

TYPE SAMPLER: P-3
 TYPE SAMPLES: SUSP
 NO VERTICALS: 4
 NO POINTS: 6

Field No.	Distance from the Reference Point (ft)	Station	Depth (ft)	Sampling Depth (ft)	Temp (°C)	Flow (cfs)	Suspended Sediment Grain Size Analysis												Sediment Concentration (ppm)			
							Sand Size Analysis (Cumulative Weight Percent)												Sand	Total		
							U.S. 40 (0.425 mm)															
							Wt. (%)	% Ret.	% Finer	Wt. (%)	% Ret.	% Finer	Wt. (%)	% Ret.	% Finer	Wt. (%)	% Ret.	% Finer			Wt. (%)	% Ret.
1	1793	17	10.0	7.19	1.29	1.93	0.000	0.0	100.0	0.000	0.0	100.0	0.011	0.1	99.9	0.017	0.2	99.8	0.018	42.3	271.1	253.4
2	1793	17	30.0	5.88	1.30	4.96	0.001	0.1	99.9	0.023	2.3	97.7	0.007	0.7	99.3	0.005	0.5	99.5	0.013	58.4	199.4	257.8
3	1793	17	50.0	4.75	1.31	8.28	0.005	0.5	99.5	0.014	1.4	98.6	0.006	0.6	99.4	0.004	0.4	99.6	0.012	56.7	188.4	245.1
4	1793	17	70.0	7.20	1.38	6.46	0.007	0.7	99.3	0.010	1.0	99.0	0.003	0.3	99.7	0.004	0.4	99.6	0.007	47.4	185.5	232.9
5	1793	17	90.0	5.28	1.39	6.67	0.009	0.9	99.1	0.006	0.6	99.4	0.006	0.6	99.4	0.004	0.4	99.6	0.010	154.4	194.3	348.7
6	1793	17	110.0	5.09	1.41	5.98	0.010	1.0	99.0	0.005	0.5	99.5	0.006	0.6	99.4	0.004	0.4	99.6	0.007	92.0	185.1	277.1
7	2115	97	9.7	9.95	1.13	2.77	0.000	0.0	100.0	0.004	0.4	99.6	0.004	0.4	99.6	0.010	1.0	99.0	0.015	30.5	199.3	229.8
8	2115	97	29.7	9.21	1.16	1.40	0.010	1.0	99.0	0.003	0.3	99.7	0.001	0.1	99.9	0.004	0.4	99.6	0.011	43.8	179.1	222.9
9	2115	97	49.7	4.09	1.17	4.41	0.012	1.2	98.8	0.004	0.4	99.6	0.002	0.2	99.8	0.004	0.4	99.6	0.008	122.0	243.3	365.3
10	2115	97	69.7	3.35	1.20	4.87	0.013	1.3	98.7	0.004	0.4	99.6	0.002	0.2	99.8	0.004	0.4	99.6	0.010	103.4	232.9	336.3
11	2115	97	89.7	5.78	1.21	4.82	0.010	1.0	99.0	0.004	0.4	99.6	0.002	0.2	99.8	0.004	0.4	99.6	0.015	107.6	305.0	412.6
12	2115	97	109.7	3.10	1.22	5.98	0.008	0.8	99.2	0.002	0.2	99.8	0.002	0.2	99.8	0.004	0.4	99.6	0.008	27.31	242.0	453.3
13	2449	89	8.9	7.52	1.12	1.29	0.014	1.4	98.6	0.003	0.3	99.7	0.000	0.0	100.0	0.006	0.6	99.4	0.010	24.5	196.0	220.5
14	2449	89	28.9	3.72	1.12	1.27	0.010	1.0	99.0	0.004	0.4	99.6	0.000	0.0	100.0	0.006	0.6	99.4	0.007	49.1	188.1	237.2
15	2449	89	48.9	4.44	1.16	1.67	0.000	0.0	100.0	0.002	0.2	99.8	0.007	0.7	99.3	0.004	0.4	99.6	0.006	94.5	204.9	299.4
16	2449	89	68.9	6.23	1.16	1.84	0.012	1.2	98.8	0.002	0.2	99.8	0.007	0.7	99.3	0.004	0.4	99.6	0.009	265.6	187.5	453.1
17	2449	89	88.9	5.08	1.17	1.26	0.011	1.1	98.9	0.006	0.6	99.4	0.008	0.8	99.2	0.004	0.4	99.6	0.006	563.3	256.2	819.5
18	2449	89	108.9	3.17	1.16	6.60	0.006	0.6	99.4	0.004	0.4	99.6	0.001	0.1	99.9	0.004	0.4	99.6	0.007	557.2	219.2	776.4
19	2916	70	7.0	5.19	1.29	6.43	0.012	1.2	98.8	0.002	0.2	99.8	0.000	0.0	100.0	0.006	0.6	99.4	0.013	36.9	209.1	246.0
20	2916	70	27.0	5.21	1.28	4.29	0.007	0.7	99.3	0.002	0.2	99.8	0.000	0.0	100.0	0.006	0.6	99.4	0.005	54.3	187.2	241.5
21	2916	70	47.0	4.79	1.27	4.98	0.008	0.8	99.2	0.004	0.4	99.6	0.000	0.0	100.0	0.006	0.6	99.4	0.007	115.5	225.2	340.7
22	2916	70	67.0	4.67	1.27	7.05	0.009	0.9	99.1	0.004	0.4	99.6	0.000	0.0	100.0	0.006	0.6	99.4	0.008	303.8	309.3	613.1
23	2916	70	87.0	3.86	1.29	6.78	0.009	0.9	99.1	0.002	0.2	99.8	0.000	0.0	100.0	0.006	0.6	99.4	0.009	199.0	215.3	414.3
24	2916	70	107.0	6.86	1.29	4.00	0.011	1.1	98.9	0.004	0.4	99.6	0.001	0.1	99.9	0.006	0.6	99.4	0.007	164.8	362.8	527.6

DATE: 23 MAR 88
 STREAM: MISSISSIPPI RIVER
 LOCATION: LINE #3 D/S OF HYDRO STAKE 14
 GAGE: WINN LAKE
 DISCHARGE: 664 CFS (2.5 ACP)

RIVER CONDITION: CHOPPY
 TIME: 12:30 TO 12:45
 TEMP: 54.0 TO 55.0 F
 WEATHER: WINDY AND MILD
 GAGE READING: 50.6 FT

TYPE SAMPLER: P-3
 TYPE SAMPLES: SUSP
 NO VERTICALS: 4
 NO POINTS: 6

Field No.	Distance from the Reference Point (ft)	Station	Sampling Depth (ft)	Temp (°C)	Flow (cfs)	Suspended Sediment Grain Size Analysis												Sediment Concentration (ppm)				
						Sand Size Analysis (Cumulative Weight Percent)												Sand	Fine	Total		
						U.S. 40 (0.425 mm)				U.S. 60 (0.25 mm)				U.S. 200 (0.075 mm)								
						Wt. (%)	% Ret.	% Finer	Wt. (%)	% Ret.	% Finer	Wt. (%)	% Ret.	% Finer	Wt. (%)	% Ret.	% Finer	Wt. (%)	% Ret.	% Finer		
25	1795	17	10.0	5.98	1.33	4.44	0.004	0.4	99.6	0.004	0.4	99.6	0.009	0.9	99.1	0.007	0.7	99.3	0.016	31.1	224.0	255.1
26	1795	17	30.0	4.40	1.33	4.12	0.007	0.7	99.3	0.004	0.4	99.6	0.009	0.9	99.1	0.007	0.7	99.3	0.012	42.2	213.9	256.1
27	1795	17	50.0	3.29	1.41	7.70	0.007	0.7	99.3	0.002	0.2	99.8	0.004	0.4	99.6	0.007	0.7	99.3	0.008	62.7	243.6	306.3
28	1795	17	70.0	4.19	1.43	4.13	0.005	0.5	99.5	0.002	0.2	99.8	0.004	0.4	99.6	0.007	0.7	99.3	0.006	156.1	227.6	383.7
29	1795	17	90.0	5.68	1.43	3.00	0.016	1.6	98.4	0.007	0.7	99.3	0.008	0.8	99.2	0.004	0.4	99.6	0.008	194.4	240.6	435.0
30	1795	17	110.0	5.14	1.43	4.12	0.009	0.9	99.1	0.007	0.7	99.3	0.008	0.8	99.2	0.004	0.4	99.6	0.009	47.7	254.1	301.8
31	3068	96	9.6	9.9	1.16	1.11	0.006	0.6	99.4	0.007	0.7	99.3	0.004	0.4	99.6	0.006	0.6	99.4	0.012	67.1	229.4	296.5
32	3068	96	29.6	3.85	1.17	1.40	0.005	0.5	99.5	0.003	0.3	99.7	0.000	0.0	100.0	0.006	0.6	99.4	0.014	237.2	280.6	517.8
33	3068	96	49.6	5.15	1.17	1.57	0.006	0.6	99.4	0.006	0.6	99.4	0.000	0.0	100.0	0.006	0.6	99.4	0.007	132.4	241.1	373.5
34	3068	96	69.6	5.24	1.19	4.68	0.005	0.5	99.5	0.005	0.5	99.5	0.000	0.0	100.0	0.006	0.6	99.4	0.008	334.1	217.6	551.7
35	3068	96	89.6	5.43	1.14	4.45	0.005	0.5	99.5	0.002	0.2	99.8	0.000	0.0	100.0	0.006	0.6	99.4	0.010	103.4	277.4	380.8
36	3068	96	109.6	4.39	1.14	4.78	0.007	0.7	99.3	0.008	0.8	99.2	0.004	0.4	99.6	0.006	0.6	99.4	0.009	85.7	240.1	325.8
37	2459	97	8.7	9.89	1.16	1.11	0.003	0.3	99.7	0.006	0.6	99.4	0.006	0.6	99.4	0.006	0.6	99.4	0.009	19.7	251.9	271.6
38	2459	97	28.7	3.61	1.16	1.24	0.003	0.3	99.7	0.004	0.4	99.6	0.000	0.0	100.0	0.006	0.6	99.4	0.005	59.8	184.3	244.1
39	2459	97	48.7	3.08	1.19	1.17	0.005	0.5	99.5	0.006	0.6	99.4	0.000	0.0	100.0	0.006	0.6	99.4	0.005	24.1	234.8	258.9
40	2459	97	68.7	6.04	1.19	1.17	0.004	0.4	99.6	0.004	0.4	99.6	0.000	0.0	100.0	0.006	0.6	99.4	0.005	47.1	233.9	281.0
41	2459	97	88.7	9.87	1.17	4.96	0.005	0.5	99.5	0.006	0.6	99.4	0.000	0.0	100.0	0.006	0.6	99.4	0.008	260.8	235.5	496.3
42	2459	97	108.7	5.27	1.17	1.11	0.010	1.0	99.0	0.002	0.2	99.8	0.000	0.0	100.0	0.006	0.6	99.4	0.010	185.0	181.1	366.1
43	2990	75	7.5	5.57	1.29	7.79	0.007	0.7	99.3	0.007	0.7	99.3	0.000	0.0	100.0	0.006	0.6	99.4	0.014	31.0	251.0	282.0
44	2990	75	27.5	5.45	1.30	4.97	0.005	0.5	99.5	0.004	0.4	99.6	0.000	0.0	100.0	0.006	0.6	99.4	0.014	32.6	256.0	288.6
45	2990	75	47.5	5.10	1.30	5.11	0.008	0.8	99.2	0.004	0.4	99.6	0.000	0.0	100.0	0.006	0.6	99.4	0.014	59.2	256.9	316.1
46	2990	75	67.5	4.26	1.32	5.99	0.007	0.7	99.3	0.002	0.2	99.8	0.004	0.4	99.6	0.006	0.6	99.4	0.011	145.1	256.5	401.6
47	2990	75	87.5	4.35	1.34	7.10	0.007	0.7	99.3	0.004	0.4	99.6	0.000	0.0	100.0	0.006	0.6	99.4	0.015	175.6	231.5	407.1
48	2990	75	107.5	1.81	1.33	6.17	0.016	1.6	98.4	0												

Table B.2 (continued)

DATE: 17 APR 88
 STREAM: MISSISSIPPI RIVER
 LOCATION: LINE #3 OF HYDRO INTAKE CH
 GAGE: WINO LANDING
 DISCHARGE: 680.752 CFS (ADCP)

RIVER CONDITION: GOOD
 TIME: 11:30 TO 12:15
 TEMP: 15.0 @ 1.5 FT
 WEATHER: CLOUDY AND RAIN
 GAGE READING: 50.52 FT

TYPE SAMPLER: P&S
 TYPE SAMPLES: SLURP
 NO VERTICALS: 4
 NO POINTS: 5

Field No.	Distance from the Reference Point (ft)	Station Depth (ft)	Sampling Depth (ft)	Samp. Velocity (ft/s)	Flow Direction (ft)	Suspend. Sediment Grain Size Analysis												Sediment Concentration (gpm)			
						Sand Size Analysis (Cumulative Weight Retained)															
						U.S. #40 (0.425 mm)				U.S. #60 (0.250 mm)				U.S. #100 (0.150 mm)						U.S. #200 (0.075 mm)	
Wt. (g)	% Ret.	% Finer	% Pass	Wt. (g)	% Ret.	% Finer	% Pass	Wt. (g)	% Ret.	% Finer	% Pass	Wt. (g)	% Ret.	% Finer	% Pass	Plan	Field				
72	1786	10	10	0.8	6.4	195.40	0.000	0.0	100.0	0.0010	0.0	99.9	0.009	0.0	100.0	0.0	0.0143	25.1	259.7		
74	1786	10	31.2	5.16	140.913	0.000	0.0	100.0	0.0010	0.0	99.9	0.009	0.0	100.0	0.0	0.0143	25.1	259.7			
75	1786	10	52.0	4.44	134.791	0.000	0.0	100.0	0.0010	0.0	99.9	0.009	0.0	100.0	0.0	0.0143	25.1	259.7			
76	1786	10	72.8	3.92	124.541	0.000	0.0	100.0	0.0010	0.0	99.9	0.009	0.0	100.0	0.0	0.0143	25.1	259.7			
77	1786	10	93.6	3.40	114.291	0.000	0.0	100.0	0.0010	0.0	99.9	0.009	0.0	100.0	0.0	0.0143	25.1	259.7			
78	1786	10	104.4	2.88	104.041	0.000	0.0	100.0	0.0010	0.0	99.9	0.009	0.0	100.0	0.0	0.0143	25.1	259.7			
79	2086	15	8.9	9.73	136.257	0.000	0.0	100.0	0.0010	0.0	99.9	0.009	0.0	100.0	0.0	0.0143	25.1	259.7			
80	2086	15	26.7	9.80	136.673	0.000	0.0	100.0	0.0010	0.0	99.9	0.009	0.0	100.0	0.0	0.0143	25.1	259.7			
81	2086	15	44.5	9.82	136.108	0.000	0.0	100.0	0.0010	0.0	99.9	0.009	0.0	100.0	0.0	0.0143	25.1	259.7			
82	2086	15	62.3	8.60	136.985	0.000	0.0	100.0	0.0010	0.0	99.9	0.009	0.0	100.0	0.0	0.0143	25.1	259.7			
83	2086	15	80.1	7.80	122.674	0.000	0.0	100.0	0.0010	0.0	99.9	0.009	0.0	100.0	0.0	0.0143	25.1	259.7			
84	2086	15	97.9	7.88	127.002	0.000	0.0	100.0	0.0010	0.0	99.9	0.009	0.0	100.0	0.0	0.0143	25.1	259.7			
85	2454	31	9.1	7.22	129.651	0.000	0.0	100.0	0.0010	0.0	99.9	0.009	0.0	100.0	0.0	0.0143	25.1	259.7			
86	2454	31	27.3	7.22	130.493	0.000	0.0	100.0	0.0010	0.0	99.9	0.009	0.0	100.0	0.0	0.0143	25.1	259.7			
87	2454	31	45.5	7.22	125.391	0.000	0.0	100.0	0.0010	0.0	99.9	0.009	0.0	100.0	0.0	0.0143	25.1	259.7			
88	2454	31	63.7	7.34	125.564	0.000	0.0	100.0	0.0010	0.0	99.9	0.009	0.0	100.0	0.0	0.0143	25.1	259.7			
89	2454	31	81.9	6.55	123.180	0.000	0.0	100.0	0.0010	0.0	99.9	0.009	0.0	100.0	0.0	0.0143	25.1	259.7			
90	2454	31	99.2	4.70	126.913	0.000	0.0	100.0	0.0010	0.0	99.9	0.009	0.0	100.0	0.0	0.0143	25.1	259.7			
91	2834	77	7.7	5.89	127.809	0.000	0.0	100.0	0.0010	0.0	99.9	0.009	0.0	100.0	0.0	0.0143	25.1	259.7			
92	2834	77	22.1	5.74	127.633	0.000	0.0	100.0	0.0010	0.0	99.9	0.009	0.0	100.0	0.0	0.0143	25.1	259.7			
93	2834	77	36.5	5.21	127.637	0.000	0.0	100.0	0.0010	0.0	99.9	0.009	0.0	100.0	0.0	0.0143	25.1	259.7			
94	2834	77	50.9	5.16	124.439	0.000	0.0	100.0	0.0010	0.0	99.9	0.009	0.0	100.0	0.0	0.0143	25.1	259.7			
95	2834	77	65.3	3.89	123.341	0.000	0.0	100.0	0.0010	0.0	99.9	0.009	0.0	100.0	0.0	0.0143	25.1	259.7			
96	2834	77	79.7	2.59	100.111	0.000	0.0	100.0	0.0010	0.0	99.9	0.009	0.0	100.0	0.0	0.0143	25.1	259.7			

DATE: 05 MAY 88
 STREAM: MISSISSIPPI RIVER
 LOCATION: LINE #3 OF HYDRO INTAKE CH
 GAGE: WINO LANDING
 DISCHARGE: 1120.82 CFS (ADCP)

RIVER CONDITION: GOOD
 TIME: 10:45 TO 11:15
 TEMP: 13.0 @ 1.5 FT
 WEATHER: CLEAR AND WARM
 GAGE READING: 54.25 FT

TYPE SAMPLER: P&S
 TYPE SAMPLES: SLURP
 NO VERTICALS: 4
 NO POINTS: 5

Field No.	Distance from Reference Point (ft)	Station Depth (ft)	Sampling Depth (ft)	Samp. Velocity (ft/s)	Flow Direction (ft)	Suspend. Sediment Grain Size Analysis												Sediment Concentration (gpm)			
						Sand Size Analysis (Cumulative Weight Retained)															
						U.S. #40 (0.425 mm)				U.S. #60 (0.250 mm)				U.S. #100 (0.150 mm)							
Wt. (g)	% Ret.	% Finer	% Pass	Wt. (g)	% Ret.	% Finer	% Pass	Wt. (g)	% Ret.	% Finer	% Pass	Wt. (g)	% Ret.	% Finer	% Pass	Plan	Field				
97	1787	14	11.4	9.21	129.387	0.000	0.0	100.0	0.0010	0.0	99.9	0.011	37.1	25.9	0.0167	96.4	3.0	0.0167	27.4	117.1	157.1
98	1787	14	34.2	8.67	130.191	0.000	0.0	100.0	0.0010	0.0	99.9	0.011	37.1	25.9	0.0167	96.4	3.0	0.0167	19.1	144.4	173.5
99	1787	14	57.0	8.86	136.902	0.000	0.0	98.1	0.0021	6.5	93.5	0.022	70.0	29.9	0.0006	99.4	0.6	0.0008	44.4	106.7	151.1
100	1787	14	79.8	10.06	139.922	0.000	0.0	100.0	0.0011	7.4	92.6	0.015	34.9	24.9	0.0001	96.1	3.9	0.0611	14.4	143.4	157.8
101	1787	14	102.6	7.11	147.743	0.000	0.0	100.0	0.0043	10.9	89.1	0.028	31.1	28.7	0.0002	99.5	0.5	0.0094	64.1	111.1	175.1
102	1787	14	111.7	7.14	147.244	0.000	0.0	98.3	0.0059	23.6	76.5	0.017	36.0	24.1	0.0001	99.5	0.5	0.0091	17.1	122.5	139.6
103	2032	12	10.2	11.16	137.795	0.000	0.0	97.9	0.0029	8.3	89.7	0.022	76.4	21.6	0.0005	98.1	1.7	0.0002	27.9	133.9	161.8
104	2032	12	30.6	10.78	130.563	0.000	0.0	100.0	0.0019	10.9	89.1	0.025	9.9	22.1	0.0006	98.5	1.5	0.0031	63.0	107.1	169.9
105	2032	12	51.0	10.16	124.990	0.000	0.0	100.0	0.0167	12.1	87.9	0.016	32.1	27.9	0.0001	98.1	1.9	0.0001	22.1	137.9	160.0
106	2032	12	71.4	9.81	130.635	0.000	0.0	97.9	0.0087	2.1	97.9	0.033	32.6	17.4	0.0011	98.5	1.5	0.0013	54.1	126.1	180.2
107	2032	12	91.8	8.52	127.179	0.000	0.0	97.9	0.0054	20.1	79.9	0.008	49.1	10.9	0.0006	98.5	1.5	0.0009	20.6	151.1	171.7
108	2032	12	112.0	5.70	136.562	0.000	0.0	99.5	0.0006	3.5	96.5	0.012	82.7	17.3	0.0001	99.7	0.3	0.0033	143.5	16.1	159.6
109	2456	47	8.1	8.73	138.220	0.000	0.0	100.0	0.0009	1.1	98.9	0.012	86.2	33.9	0.0007	98.5	1.5	0.0002	42.1	119.5	161.4
110	2456	47	26.5	8.60	137.264	0.000	0.0	100.0	0.0022	2.3	97.7	0.023	13.9	66.2	0.0001	97.5	2.4	0.0004	46.1	136.1	182.1
111	2456	47	43.9	8.74	136.886	0.000	0.0	100.0	0.0012	4.7	95.3	0.0187	73.0	27.0	0.0006	100.0	0.0	0.0006	62.1	113.1	175.1
112	2456	47	61.3	9.37	140.129	0.000	0.0	100.0	0.0019	12.5	87.5	0.002	16.1	63.9	0.0004	98.5	1.5	0.0004	11.6	126.1	137.7
113	2456	47	78.7	9.22	137.258	0.000	0.0	98.9	0.0038	5.3	94.7	0.0043	38.9	41.1	0.0006	99.3	0.7	0.0022	22.7	163.1	185.8
114	2456	47	96.1	7.41	131.609	0.000	0.0	99.5	0.0051	15.1	84.9	0.007	49.1	11.1	0.0001	99.9	0.1	0.0009	24.9	147.1	172.0
115	2856	81	9.1	5.23	149.141	0.000	0.0	100.0	0.0010	0.0	100.0	0.0004	44.6	46.4	0.0009	99.4	0.6	0.0011	16.1	157.1	173.1
116	2856	81	24.3	5.16	139.047	0.000	0.0	100.0	0.0000	0.0	100.0	0.0002	52.4	47.6	0.0005	99.9	0.1	0.0002	15.0	167.1	182.1
117	2856	81	40.5	5.80	134.862	0.000	0.0	100.0	0.0006	0.0	100.0	0.0001	51.6	48.4	0.0001	99.9	0.1	0.0001	16.1	162.1	178.1
118	2856	81	56.7	6.21	133.362	0.000	0.0	100.0	0.0018	7.4	92.6	0.0002	51.1	48.9	0.0005	99.6	0.4	0.0003	62.7	160.1	172.7
119	2856	81	72.9	5.22	130.813	0.000	0.0	100.0	0.0011	1.1	98.9	0.0006	41.9	58.1	0.0009	99.6	0.4	0.0001	21.9	145.1	167.0
120	2856	81	89.1	3.31	127.645	0.000	0.0	99.3	0.0029	3.3	96.7	0.0002	59.7	40.3	0.0002	97.4	2.6	0.0002	10.1	126.1	136.1

DATE: 05 JUN 88
 STREAM: MISSISSIPPI RIVER
 LOCATION: LINE #3 OF HYDRO INTAKE CH
 GAGE: WINO LANDING
 DISCHARGE: 666.70 CFS (ADCP)

RIVER CONDITION: TURBID
 TIME: 12:30 TO 13:15
 TEMP: 15.0 @ 1.5 FT
 WEATHER: CLOUDY AND HOT
 GAGE READING: 46.1 FT

TYPE SAMPLER: P&S
 TYPE SAMPLES: SLURP
 NO VERTICALS: 4
 NO POINTS: 5

Field No.	Distance from the Reference Point (ft)	Station Depth (ft)	Sampling Depth (ft)	Samp. Velocity (ft/s)	Flow Direction (ft/deg)	Suspend. Sediment Grain Size Analysis																		Sediment Concentration (gpm)	
						Sand Size Analysis (Cumulative Weight Retained)																			
						U.S. #40 (0.425 mm)				U.S. #60 (0.250 mm)				U.S. #100 (0.150 mm)				U.S. #200 (0.075 mm)							
						Wt. (g)	% Ret.	% Finer	% Pass	Wt. (g)	% Ret.	% Finer	% Pass	Wt. (g)	% Ret.	% Finer	% Pass	Wt. (g)	% Ret.	Plan	Field				
121	1771	99	9.2	4.71	119.213	0.000	0.0	91.8	0.0019	26.2	74.0	0.0025	34.2	65.8	0.0086	64.5	35.5	0.0073	21.4	237.8					
122	1771	99	27.6	4.76	115.662	0.000	0.0	100.0	0.0010	10.7	89.3	0.0034	34.9	64.1	0.0086	66.7	33.3	0.0041	11.8	217.1					
123	1771	99	46.0	4.95	120.281	0.000	0.0	100.0	0.0019	9.9	90.1	0.0062	59.4	40.6	0.0086	95.0	5.0	0.0101	14.9	239.6					
124	1771	99	54.4	5.12	127.283	0.000	0.0	100.0	0.0039	12.7	87.3	0.0041	57.1	42.9	0.0077	84.4	15.6	0.0073	12.9	227.4					
125	1771	99	82.8	4.38	119.140	0.000	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	229.2					
126	1771	99	90.2	3.99	118.454	0.000	0.0	100.0	0.0011	14.5	85.5	0.0051	59.9	40.1	0.0127	84.7	15.3	0.0076	16.4	232.0					
127	1089	94	9.4	5.12	144.251	0.000	0.0	100.0	0.0006	6.9	93.1	0.0044	49.4	50.6	0.0086	94.3	5.7	0.0091	14.3	237.7					
128	1089	94	26.2	5.98	140.747	0.000	0.0	100.0	0.0063	25.3	74.7	0.0179	74.9	25.1	0.0244	98.0	2.0	0.0249	41.3	229.7					
129	1089	94	47.6	6.04	147.404	0.000	0.0	100.0	0.0012	10.2	89.8	0.0034	34.9	65.1	0.0077	90.1	9.9	0.0023	11.8	237.4					
130	1089	94	66.8	4.43	130.821	0.000	0.0	99.7	0.0033	35.6	64.4	0.0076	36.6	63.4	0.0096	48.6	51.4	0.0091	16.4	252.5					
131	1089	94	94.6	3.48	117.881	0.000	0.0	99.7	0.0010	44.6	55.4	0.0076	36.6	63.4	0.0116	99.7	0.3	0.0116	25.4	238.6					
132	1089	94	95.2	3.33	120.615	0.000	0.0	99.7	0.0046	62.4	37.6	0.0096	79.9	20.1	0.0168	99.6	0.4	0.0193	130.5	244.6					
133	1476	81	8.1	7.27	139.624	0.000	0.0	100.0	0.0015	19.7	80.3	0.0054	37.1	62.9	0.0086	98.7	1.3	0.0076	18.8	246.1					
134	1476	81	24.3	7.11	127.336	0.000	0.0	99.7	0.0014	9.1	90.9	0.0081	53.6	46.4	0.0121	94.4	5.6	0.0121	19.8	244.2					
135	1476	81	40.5	6.22	138.027	0.004	1.1	99.3	0.0017	4.4	95.6	0.0072	37.3	62.7	0.0076	57.7	42.3	0.0087	52.9	222.5					
136	1476	81	56.7	6.30	146.444	0.000	0.0	99.7	0.0065	9.4	90.6	0.0046	30.5	69.5	0.0081	61.0	39.0	0.0040	14.0	241.1					
137	1476	81	72.9	6.05	132.286	0.000	0.0	99.7	0.0041	16.2	83.8	0.0076	32.6	67.4	0.0082	99.6	0.4	0.0040	37.0	246.3					
138	1476	81	95.4	4.21	139.686	0.000	0.0	99.7	0.0034	14.5	85.5	0.0043	33.3	66.7	0.0086	89.3	10.7	0.0086	29.6	244.3					
139	1089	65	6.3	4.21	129.881	0.000	0.0	100.0	0.0012	8.0	92.0	0.0046	32.0	68.0	0.0086	100.0	0.0	0.0086	19.9	248.4					
140	1089	65	26.2	4.21	132.640	0.000	0.0	100.0	0.0006	15.6	84.4	0.0046	36.6	63.4	0.0086	93.3	6.7	0.0046	19.9	245.3					
141	1089	65	47.6	4.21	131.401	0.000	0.0	100.0	0.0006	15.6	84.4	0.0046	36.6	63.4	0.0086	93.3	6.7	0.0046	19.9	245.3					
142	1089	65	48.3	4.24	131.280	0.000	0.0	100.0	0.0009	15.9	84.1	0.0023	36.7	63.3	0.0086	96.7	3.3	0.0086	23.5	246.1					
143	1089	65	62.1	3.40	130.121	0.000	0.0	94.3	0.0014	9.1	90.9	0.0046	36.6	63.4	0.0076	100.0	0.0	0.0076	4.4	245.1					
144	1089	65	67.6	2.47	142.352	0.000	0.0	97.7	0.0009	2.9	97.1	0.0034	41.4	58.6	0.0029	99.6	0.4	0.0034	17.6	249.1					

Table B.2 (continued)

[illegible]

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

DATE: 27 FEB 88
 STREAM: MISSISSIPPI RIVER
 LOCATION: LINE 60 S/D OF HYDRO INTAKE CH
 GAGE: WIND LANDING
 DISCHARGE: 193,520 CFS (ACCP)

RIVER CONDITION: SMOOTH
 TIME: 14:10 TO 14:15
 TEMP: 50.0 C/F
 WEATHER: CLOUDY AND MILD
 GAGE READING: 45.62 FT

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

Field No.	Distance from Reference Point (ft)	Station Depth (ft)	Sampling Depth (ft)	Camp Velocity (ft/s)	Flow Direction (deg)	Suspended Sediment Grain Size Analysis														Sediment Concentration (ppm)	
						Sand Size Analysis (Cumulative Weight Retained)															
						U.S. 40 (0.425 mm)	U.S. 60 (0.250 mm)	U.S. 100 (0.150 mm)	U.S. 200 (0.075 mm)	U.S. 400 (0.045 mm)	U.S. 600 (0.030 mm)	U.S. 840 (0.020 mm)	U.S. 1060 (0.015 mm)	U.S. 1490 (0.010 mm)	U.S. 2000 (0.0075 mm)	U.S. 2500 (0.006 mm)	U.S. 3000 (0.005 mm)	Sand	Fine		
1	211	48	4.8	4.82	157.745	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	
2	211	48	4.4	4.43	157.530	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	
3	211	48	24.0	4.48	211.227	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	
4	211	48	33.6	4.27	229.543	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
5	211	48	43.2	3.93	231.575	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
6	211	48	47.0	2.54	184.246	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	
7	301	76	7.6	5.98	229.389	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	
8	301	76	22.8	4.63	236.286	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	
9	301	76	38.0	6.77	208.850	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	
10	301	76	52.2	5.78	225.255	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	
11	301	76	56.4	5.00	210.132	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	
12	301	76	74.5	3.69	197.510	0.0019	0.0019	0.0019	0.0019	0.0019	0.0019	0.0019	0.0019	0.0019	0.0019	0.0019	0.0019	0.0019	0.0019	0.0019	
13	4090	89	8.9	7.21	231.688	0.0007	0.0007	0.0007	0.0007	0.0007	0.0007	0.0007	0.0007	0.0007	0.0007	0.0007	0.0007	0.0007	0.0007	0.0007	
14	4090	89	26.7	6.35	223.382	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	
15	4090	89	44.5	6.81	212.381	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
16	4090	89	62.3	5.61	227.570	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	
17	4090	89	80.1	4.37	217.430	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	0.0014	
18	4090	89	87.2	3.07	187.558	0.0022	0.0022	0.0022	0.0022	0.0022	0.0022	0.0022	0.0022	0.0022	0.0022	0.0022	0.0022	0.0022	0.0022	0.0022	
19	4718	90	9.0	3.92	245.521	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	
20	4718	90	27.0	4.09	225.132	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	
21	4718	90	45.0	4.39	232.745	0.0007	0.0007	0.0007	0.0007	0.0007	0.0007	0.0007	0.0007	0.0007	0.0007	0.0007	0.0007	0.0007	0.0007	0.0007	
22	4718	90	63.0	3.42	227.258	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	
23	4718	90	81.0	1.90	211.241	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	
24	4718	90	86.2	2.33	220.212	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	

DATE: 23 MAR 88
 STREAM: MISSISSIPPI RIVER
 LOCATION: LINE 60 S/D OF AUXILIARY INTAKE CH
 GAGE: WIND LANDING
 DISCHARGE: 844,513 CFS (ACCP)

RIVER CONDITION: UNIFORM
 TIME: 16:00 TO 16:15
 TEMP: 50.0 C/F
 WEATHER: CLOUDY AND MILD
 GAGE READING: 52.62 FT

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

Field No.	Distance from Station (ft)	Depth (ft)	Sampling Depth (ft)	Camp Velocity (ft/s)	Flow Direction (deg)	Suspended Sediment Grain Size Analysis														Sediment Concentration (ppm)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																							
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25	3218	62	6.2	3.44	212.550	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004

DATE: 18 APR 88
 STREAM: MISSISSIPPI RIVER
 LOCATION: LINE 60 S/D OF AUXILIARY INTAKE CH
 GAGE: WIND LANDING
 DISCHARGE: 196,512 CFS (ACCP)

RIVER CONDITION: SMOOTH

Table B.3 (continued)

DATE: 17 APR 88 STREAM: MISSISSIPPI RIVER LOCATION: LINE 46 DIS OF AUXILIARY INTAKE CH GAGE: KNOX LANDING DISCHARGE: 793,350 CFS (ADCP)										RIVER CONDITION: CLOUDY TIME: 14:30 TO 14:45 TEMP: 16.0 @ 15 FT WEATHER: CLOUDY AND RAIN GAGE READING: 56.50 FT										TYPE SAMPLER: P-63 TYPE SAMPLES: SLSP NO. VERTICALS: 4 NO. POINTS: 6									
Field No.	Distance from Reference Point (ft)	Station Depth (ft)	Sampling Depth (ft)	Samp Velocity (ft/s)	Flow Direction (° Deg)	Suspend Sediment Grain Size Analysis												Pan	Sediment Concentration (ppm)										
						Sand Size Analysis (Cumulative Weight Retained)													Total	Sand	Fines								
						U.S. #10 (0.425 mm)	U.S. #20 (0.850 mm)	U.S. #40 (0.425 mm)	U.S. #60 (0.250 mm)	U.S. #100 (0.150 mm)	U.S. #200 (0.075 mm)	U.S. #400 (0.0375 mm)	U.S. #600 (0.025 mm)	U.S. #840 (0.0175 mm)	U.S. #1060 (0.01375 mm)	U.S. #1490 (0.0100 mm)	U.S. #2000 (0.0075 mm)												
73	3159	40	4.8	4.86	230.622	0.0000	0.0	100.0	0.0000	0.0	100.0	0.0000	0.0	100.0	0.0000	0.0	0.0125	99.7	2.3	0.0138	29.2	238.9	372.1						
74	3159	40	14.4	4.85	195.917	0.0000	0.0	100.0	0.0003	3.7	96.9	0.0094	64.6	35.4	0.0119	91.5	8.5	0.0130	44.2	34.8	392.3								
75	3159	40	24.0	4.83	195.689	0.0000	0.0	100.0	0.0029	6.6	93.4	0.0356	61.3	38.7	0.0480	98.2	1.8	0.0480	111.5	30.7	411.2								
76	3159	40	33.6	3.49	199.509	0.0005	1.0	99.0	0.0046	9.0	91.0	0.0432	64.5	35.5	0.0510	99.8	0.2	0.0511	132.2	310.8	443.0								
77	3159	40	43.2	3.07	206.966	0.0016	2.2	97.8	0.0073	10.2	89.8	0.0512	65.2	34.8	0.0711	99.0	1.0	0.0716	171.8	299.9	677.7								
78	3159	40	47.0	2.00	203.491	0.0014	1.2	98.8	0.0060	13.3	86.7	0.0880	80.1	19.9	0.1192	99.4	0.6	0.1199	263.2	294.8	598.0								
79	3026	92	9.2	6.20	227.134	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	3026	92	17.6	5.79	200.590	0.0000	0.0	100.0	0.0008	2.9	97.1	0.0216	71.7	28.3	0.0273	98.2	1.8	0.0278	67.7	320.7	402.4								
81	3026	92	26.0	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	3026	92	34.4	5.66	206.298	0.0004	1.0	99.0	0.0024	6.0	94.0	0.0333	62.6	37.4	0.0430	99.3	0.7	0.0433	48.9	301.1	450.0								
83	3026	92	42.8	3.81	208.152	0.0005	0.5	99.5	0.0069	8.5	91.5	0.0500	69.5	30.5	0.0680	99.8	0.2	0.0682	112.3	283.9	496.2								
84	3026	92	50.2	1.96	207.438	0.0006	0.4	99.6	0.0064	9.1	90.9	0.0599	80.2	19.8	0.0962	99.5	0.5	0.0962	244.3	361.4	515.7								
85	4131	92	9.2	5.44	229.177	0.0000	0.0	100.0	0.0000	0.0	100.0	0.0007	64.3	35.7	0.0075	95.4	4.6	0.0089	19.5	295.9	315.4								
86	4131	92	17.6	5.19	208.306	0.0000	0.0	100.0	0.0015	3.4	96.6	0.0261	76.4	23.6	0.0281	99.2	0.8	0.0283	49.2	381.1	430.3								
87	4131	92	26.0	5.12	206.624	0.0000	0.0	100.0	0.0005	2.4	97.6	0.0194	77.5	22.5	0.0239	99.6	0.4	0.0250	47.7	386.1	433.8								
88	4131	92	34.4	5.34	202.325	0.0000	0.0	100.0	0.0009	3.3	96.7	0.0295	74.5	25.5	0.0368	97.5	2.5	0.0375	45.0	367.7	412.7								
89	4131	92	42.8	4.73	210.860	0.0000	0.0	100.0	0.0006	2.5	97.5	0.0348	91.3	8.7	0.0368	99.6	0.4	0.0381	150.9	304.8	455.7								
90	4131	92	50.2	3.09	222.786	0.0000	0.0	100.0	0.0024	22.4	77.6	0.1111	90.9	9.1	0.1218	99.5	0.5	0.1224	158.3	362.3	520.6								
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	0.0062	96.8	3.2	0.0062	18.1	266.5	283.6								
92	4695	92	17.6	3.52	211.618	0.0000	0.0	100.0	0.0000	0.0	100.0	0.0006	75.9	24.1	0.0110	91.2	8.8	0.0118	19.4	246.7	266.1								
93	4695	92	26.0	3.84	207.353	0.0000	0.0	100.0	0.0007	7.9	92.1	0.0056	62.9	37.1	0.0086	96.4	3.6	0.0089	25.0	293.3	318.3								
94	4695	92	34.4	3.81	213.940	0.0000	0.0	100.0	0.0000	0.0	100.0	0.0044	69.7	30.3	0.0074	98.7	1.3	0.0075	17.2	289.1	306.3								
95	4695	92	42.8	3.26	213.319	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	37.5	210.5	248.0								
96	4695	92	50.2	2.06	222.506	0.0000	0.0	100.0	0.0009	6.2	93.8	0.0071	49.5	50.5	0.0131	93.8	6.2	0.0146	47.3	317.0	364.3								
DATE: 09 JUN 88										RIVER CONDITION: CLOUDY										TYPE SAMPLER: P-63									
STREAM: MISSISSIPPI RIVER										TIME: 15:30 TO 16:15										TYPE SAMPLES: SLSP									
LOCATION: LINE 46 DIS OF AUXILIARY INTAKE CH										TEMP: 26.0 @ 10 FT										NO. VERTICALS: 4									
GAGE: KNOX LANDING										WEATHER: CLOUDY AND HOT										NO. POINTS: 6									
DISCHARGE: 504,517 CFS (ADCP)										GAGE READING: 46.10 FT																			
Field No.	Distance from Reference Point (ft)	Station Depth (ft)	Sampling Depth (ft)	Samp Velocity (ft/s)	Flow Direction (° Deg)	Suspend Sediment Grain Size Analysis												Pan	Sediment Concentration (ppm)										
						Sand Size Analysis (Cumulative Weight Retained)													Total	Sand	Fines								
						U.S. #10 (0.425 mm)	U.S. #20 (0.850 mm)	U.S. #40 (0.425 mm)	U.S. #60 (0.250 mm)	U.S. #100 (0.150 mm)	U.S. #200 (0.075 mm)	U.S. #400 (0.0375 mm)	U.S. #600 (0.025 mm)	U.S. #840 (0.0175 mm)	U.S. #1060 (0.01375 mm)	U.S. #1490 (0.0100 mm)	U.S. #2000 (0.0075 mm)												
97	3197	32	3.2	3.64	212.287	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	211.121	0.0000	0.0	100.0	0.0000	0.0	100.0	0.0028	43.1	56.9	0.0090	92.9	7.1	0.0094	19.8	218.0	237.8								
99	3197	32	16.0	3.45	212.271	0.0005	4.8	95.2	0.0010	9.5	90.5	0.0051	69.5	30.5	0.0123	98.7	1.3	0.0105	14.9	219.6	234.5								
100	3197	32	22.4	3.06	214.407	0.0000	0.0	100.0	0.0009	4.4	95.6	0.0091	48.4	51.6	0.0146	93.4	6.6	0.0162	12.9	227.6	240.5								
101	3197	32	28.8	2.53	219.425	0.0000	0.0	100.0	0.0000	0.0	100.0	0.0028	52.9	47.1	0.0052	98.1	1.9	0.0053	29.2	235.0	264.2								
102	3197	32	35.2	1.64	204.254	0.0000	0.0	100.0	0.0010	4.5	95.5	0.0110	49.1	50.9	0.0138	89.4	1.6	0.0124	16.4	242.0	258.4								
103	3786	32	3.2	5.46	202.761	0.0006	6.7	93.3	0.0008	8.9	91.1	0.0046	61.1	38.9	0.0095	94.4	5.6	0.0090	14.5	203.7	218.2								
104	3786	32	9.6	5.27	202.894	0.0000	0.0	100.0	0.0009	6.6	94.4	0.0076	47.2	52.8	0.0153	95.0	5.0	0.0161	47.3	229.7	277.0								
105	3786	32	16.0	4.85	205.242	0.0013	5.6	94.4	0.0019	6.2	93.8	0.0134	48.1	51.9	0.0230	94.6	5.4	0.0231	46.1	267.7	313.8								
106	3786	32	22.4	4.15	206.444	0.0012	2.2	97.8	0.0055	5.3	94.7	0.0420	71.2	28.8	0.0564	95.6	4.4	0.0590	162.4	252.5	414.9								
107	3786	32	28.8	4.36	213.952	0.0009	1.9	98.1	0.0041	8.8	91.2	0.0193	77.4	22.6	0.0499	99.7	0.3	0.0484	154.1	266.6	420.7								
108	3786	32	35.2	3.22	203.423	0.0060	2.9	97.1	0.0050	28.1	71.9	0.0076	54.3	45.7	0.0091	99.5	0.5	0.0102	180.5	244.8	425.3								
109	4093	60	6.0	6.37	206.670	0.0004	1.6	98.4	0.0019	6.3	93.7	0.0138	45.3	54.7	0.0243	96.8	3.2	0.0251	115.8	305.1	420.9								
110	4093	60	12.0	6.02	211.948	0.0000	0.0	100.0	0.0000	0.0	100.0	0.0014	49.4	50.6	0.0091	99.4	0.6	0.0093	19.8	234.2	254.0								
111	4093	60	18.0	5.93	200.743	0.0018	2.7	97.3	0.0022	15.1	84.9	0.0372	55.3	44.7	0.0568	98.8	1.2	0.0575	52.9	222.5	275.4								
112	4093	60	24.0	4.93	211.964	0.0006	0.8	99.2	0.0047	4.0	96.0	0.0523	67.1	32.9	0.0754	98.1	1.9	0.0779	124.0	361.9	586.9								
113	4093	60	30.0	4.75	202.352	0.0002	3.3	96.7	0.0033	5.9	93.1	0.0391	61.2	38.8	0.0636	98.0	2.0	0.0639	370.0	270.7	543.1								
114	4093	60	36.0	3.71	211.987	0.0012	2.7	97.3	0.0123	25.6	74.4	0.0576	70.2	29.8	0.0749	99.8	0.2	0.0561	586.6	305.9	489.5								
115	4703	64	8.4	7.24	166.781	0.0009	2.4	99.5	0.0045	20.9	79.1	0.0193	43.7	56.3	0.0695	99.1	0.9	0.0695	10.9	129.4	140.3								
116	4703	64	16.8	6.50	165.348	0.0000	0.0	100.0	0.0005	3.9	96.1	0.0042	37.1	62.9	0.0124	96.1	3.9	0.0109	7.3	231.3	238.6								
117	4703	64	25.2	5.38	174.731	0.0000	0.0	100.0	0.0007	6.5	93.5	0.0040	79.1	20.9	0.0070	96.8	3.2	0.0087	18.1	226.3	244.4								
118	4703	64	33.6	2.88	212.427	0.0000	0.0	100.0	0.0005	4.4	95.6	0.0038	27.2	72.8	0.0124	91.2	8.8	0.0135	23.5	315.0	338.5								
119	4703	64	42.0	1.67	206.311	0.0006	3.5	96.5	0.0031	18.1	81.9	0.0096	46.1	53.9	0.0149	87.1	12.9	0.0155	42.7	275.6	318.3								
120	4703	64	50.4	1.12	213.548	0.0004	0.7	99.3	0.0026	4.3	95.7	0.0286	64.3	35.7	0.0599	98.0	2.0	0.0611	121.5	255.5	437.7								
DATE: 03 AUG 88										RIVER CONDITION: CLOUDY										TYPE SAMPLER: P-63									
STREAM: MISSISSIPPI RIVER										TIME: 15:00 TO 16:30										TYPE SAMPLES: SLSP									
LOCATION: LINE 46 DIS OF AUXILIARY INTAKE CH										TEMP: 31.0 @ 10 FT										NO. VERTICALS: 4									
GAGE: KNOX LANDING										WEATHER: CLOUDY AND HOT										NO. POINTS: 6									
DISCHARGE: 364,364 CFS (ADCP)										GAGE READING: 33.0 FT																			
Field No.	Distance from Reference Point (ft)	Station Depth (ft)	Sampling Depth (ft)	Samp Velocity (ft/s)	Flow Direction (° Deg)	Suspend Sediment Grain Size Analysis												Pan	Sediment Concentration (ppm)										
						Sand Size Analysis (Cumulative Weight Retained)													Total	Sand	Fines								
						U.S. #10 (0.425 mm)	U.S. #20 (0.850 mm)	U.S. #40 (0.425 mm)	U.S. #60 (0.250 mm)																				

Table B.4. Suspended sediment data at Tarbert.

DATE: 27 FEB 88 STREAM: MISSISSIPPI RIVER LOCATION: TARBERT GAGE: RED RIVER (ANR) DISCHARGE: 782.440 CFS (ACCP)										RIVER CONDITION: SMOOTH TIME: 16:00 TO 17:00 TEMP: 9.0 @ 1 FT WEATHER: CLOUDY AND MILD GAGE READING: 46.50 FT										TYPE SAMPLER: P-3 TYPE SAMPLES: 2, 5, 10 NO VERTICALS: 4 NO POINTS: 6											
Field No.	Distance from the Reference Point (ft)	Station Depth (ft)	Sampling Depth (ft)	Samp. Velocity (ft/s)	Flow Direction (°)	Suspended Sediment Grain Size Analysis														Sediment Concentration (ppm)											
						Sand Sine Analysis (Cumulative Weight Retained)																									
						U.S. 10 (0.075 mm)	U.S. 20 (0.075 mm)	U.S. 40 (0.075 mm)	U.S. 60 (0.075 mm)	U.S. 80 (0.075 mm)	U.S. 100 (0.075 mm)	U.S. 150 (0.075 mm)	U.S. 200 (0.075 mm)	U.S. 250 (0.075 mm)	U.S. 300 (0.075 mm)	U.S. 350 (0.075 mm)	U.S. 400 (0.075 mm)	U.S. 450 (0.075 mm)	U.S. 500 (0.075 mm)												
1	1417	54	5.4	1.07	258.109	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	191.5	191.5									
2	1417	54	15.2	1.09	260.152	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	200.6	200.6									
3	1417	54	25.0	1.36	251.370	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	0.0011	190.9	190.9									
4	1417	54	37.8	1.47	252.534	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	190.9	190.9									
5	1417	54	48.6	1.11	256.100	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	191.5	191.5									
6	1417	54	52.9	1.50	242.280	LOST	N/A	N/A	LOST	N/A	N/A	LOST	N/A	N/A	LOST	N/A	N/A	LOST	N/A	N/A	191.5	191.5									
7	2264	46	4.6	1.00	249.297	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	202.1	202.1									
8	2264	46	14.4	1.17	249.493	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	202.1	202.1									
9	2264	46	24.2	1.10	246.457	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	202.1	202.1									
10	2264	46	33.6	1.04	245.586	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	202.1	202.1									
11	2264	46	43.2	0.91	247.367	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	202.1	202.1									
12	2264	46	47.0	1.29	244.489	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	202.1	202.1									
13	2797	52	5.2	1.23	250.220	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	224.1	224.1									
14	2797	52	15.9	1.17	241.517	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	224.1	224.1									
15	2797	52	26.5	1.31	251.416	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	224.1	224.1									
16	2797	52	37.1	1.43	253.466	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	224.1	224.1									
17	2797	52	47.7	1.07	253.135	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	224.1	224.1									
18	2797	52	51.9	1.06	277.230	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	0.0010	224.1	224.1									
19	3409	46	4.6	1.13	256.262	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	224.1	224.1									
20	3409	46	14.4	1.21	242.571	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	224.1	224.1									
21	3409	46	23.0	1.32	257.793	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	0.0009	224.1	224.1									
22	3409	46	32.4	1.24	249.748	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	224.1	224.1									
23	3409	46	41.8	1.64	243.986	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	224.1	224.1									
24	3409	46	49.1	1.43	230.588	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	0.0013	224.1	224.1									
DATE: 23 MAR 88										RIVER CONDITION: CHOPPY										TYPE SAMPLER: P-3											
STREAM: MISSISSIPPI RIVER										TIME: 17:00 TO 19:00										TYPE SAMPLES: 5, 10											
LOCATION: TARBERT										TEMP: 9.0 @ 1 FT										NO VERTICALS: 4											
GAGE: TARBERT (ANR)										WEATHER: WINDY AND MILD										NO POINTS: 6											
DISCHARGE: 851.783 CFS (ACCP)										GAGE READING: 49.00 FT																					
Field No.	Distance from the Reference Point (ft)	Station Depth (ft)	Sampling Depth (ft)	Samp. Velocity (ft/s)	Flow Direction (°)	Suspended Sediment Grain Size Analysis														Sediment Concentration (ppm)											
						Sand Sine Analysis (Cumulative Weight Retained)																									
						U.S. 10 (0.075 mm)	U.S. 20 (0.075 mm)	U.S. 40 (0.075 mm)	U.S. 60 (0.075 mm)	U.S. 80 (0.075 mm)	U.S. 100 (0.075 mm)	U.S. 150 (0.075 mm)	U.S. 200 (0.075 mm)	U.S. 250 (0.075 mm)	U.S. 300 (0.075 mm)	U.S. 350 (0.075 mm)	U.S. 400 (0.075 mm)	U.S. 450 (0.075 mm)	U.S. 500 (0.075 mm)												
25	1368	57	5.7	1.02	247.447	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	190.9	190.9									
26	1368	57	15.5	1.10	247.198	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	190.9	190.9									
27	1368	57	25.5	1.04	243.250	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	190.9	190.9									
28	1368	57	35.5	1.10	244.514	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	190.9	190.9									
29	1368	57	45.5	1.27	253.296	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	190.9	190.9									
30	1368	57	55.5	1.11	256.112	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	190.9	190.9									
31	2169	47	4.7	1.04	262.492	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	224.1	224.1									
32	2169	47	14.7	1.06	260.218	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	224.1	224.1									
33	2169	47	24.7	1.12	264.788	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	224.1	224.1									
34	2169	47	34.7	1.25	266.560	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	224.1	224.1									
35	2169	47	44.7	1.06	267.786	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	224.1	224.1									
36	2169	47	54.7	1.09	266.337	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	224.1	224.1									
37	3023	51	5.1	1.07	244.134	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	190.9	190.9									
38	3023	51	15.1	1.09	248.236	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	190.9	190.9									
39	3023	51	25.1	1.06	240.525	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	190.9	190.9									
40	3023	51	35.1	1.																											

Table B.4 (continued)

DATE: 17 APR 88
 STREAM: MISSISSIPPI RIVER
 LOCATION: "ARBERT"
 GAGE: "ARBERT" DISCHG. GNG
 DISCHARGE: 199.300 CFS (ADCP)
 RIVER CONDITION: GOOD
 TIME: 15:30 TO 16:30
 TEMP: 16.0 C @ 1.5 FT
 WEATHER: CLOUDY AND RAIN
 GAGE READING: 49.00 FT
 TYPE SAMPLER: P-63
 TYPE SAMPLES: S-15P
 NO VERTICALS: 4
 NO POINTS: 6

Sediment Grain Size Analysis															Sediment Concentration			
Sand Sieve Analysis (Cumulative Weight Retained)															Pan	Sand	Fines	Total
Field No.	Distance from Reference Point (ft)	Station Depth (ft)	Sampling Depth (ft)	Samp. Velocity (ft/s)	Flow Direction (ft/s)	U.S. #4 (0.425 mm)	U.S. #10 (0.25 mm)	U.S. #20 (0.85 mm)	U.S. #40 (0.425 mm)	U.S. #60 (0.25 mm)	U.S. #100 (0.15 mm)	U.S. #200 (0.075 mm)	U.S. #400 (0.0375 mm)	U.S. #600 (0.025 mm)				
73	1.82	54	5.4	2.60	240.591	0.000	0.0	100.0	0.0000	0.0	100.0	0.000	0.0	0.000	14.4	130.1	344.5	
74	1.85	54	7.4	2.59	254.219	0.000	0.0	100.0	0.0000	0.0	100.0	0.000	0.0	0.000	19.8	370.3	380.1	
75	1.86	54	25.0	2.53	246.177	0.000	0.0	100.0	0.0000	0.0	100.0	0.000	0.0	0.000	14.5	306.4	322.7	
76	1.86	54	40.6	2.25	251.724	0.000	0.0	100.0	0.0000	0.0	100.0	0.000	0.0	0.000	32.3	304.2	336.3	
77	1.86	54	52.2	2.19	248.629	0.000	0.0	100.0	0.0000	0.0	100.0	0.000	0.0	0.000	53.7	273.5	327.3	
78	1.86	54	56.8	2.77	239.873	0.000	0.0	100.0	0.0000	0.0	100.0	0.000	0.0	0.000	65.5	403.6	427.1	
79	1.86	54	5.4	6.16	254.373	0.000	0.0	100.0	0.0000	0.0	100.0	0.000	0.0	0.000	16.9	279.6	296.5	
80	1.86	54	7.4	6.20	252.956	0.000	0.0	100.0	0.0000	0.0	100.0	0.000	0.0	0.000	27.3	267.1	294.3	
81	1.86	54	27.0	6.25	249.463	0.000	2.8	97.2	0.0000	4.3	95.7	0.000	0.0	0.000	73.2	351.1	424.3	
82	1.86	54	37.8	5.50	247.707	0.000	1.6	98.4	0.0000	4.2	95.7	0.000	0.0	0.000	146.8	363.1	510.1	
83	1.86	54	46.6	5.28	247.114	0.000	1.3	98.7	0.0000	3.8	96.2	0.000	0.0	0.000	188.0	317.3	505.3	
84	1.86	54	54.4	5.27	257.021	0.000	2.0	98.0	0.0000	4.5	95.5	0.000	0.0	0.000	134.4	319.4	513.8	
85	1.86	54	5.4	6.29	258.660	0.000	0.0	100.0	0.0000	6.1	93.5	0.000	0.0	0.000	116.6	248.9	375.5	
86	1.86	54	7.4	6.11	252.450	0.000	3.8	96.4	0.0000	3.6	96.4	0.000	0.0	0.000	38.2	349.2	387.4	
87	1.86	54	27.0	6.72	257.215	0.000	0.0	100.0	0.0000	0.0	100.0	0.000	0.0	0.000	136.5	318.9	455.3	
88	1.86	54	37.8	6.42	249.677	0.000	0.0	99.1	0.0000	37.4	72.6	0.000	0.0	0.000	138.0	300.4	438.5	
89	1.86	54	46.6	5.72	252.443	0.000	6.9	93.1	0.0000	12.1	87.9	0.000	0.0	0.000	221.7	270.4	492.1	
90	1.86	54	52.2	5.41	240.057	0.000	0.8	99.2	0.0000	36.0	64.3	0.000	0.0	0.000	251.7	296.3	548.0	
91	2.80	46	4.8	5.16	252.061	0.000	0.0	100.0	0.0000	10.3	89.7	0.000	0.0	0.000	19.4	265.1	275.1	
92	2.80	46	14.4	4.88	252.959	0.000	0.0	100.0	0.0000	4.2	95.8	0.000	0.0	0.000	24.4	363.7	408.1	
93	2.80	46	24.0	4.21	248.497	0.000	0.0	100.0	0.0000	9.0	91.0	0.000	0.0	0.000	31.0	276.7	307.7	
94	2.80	46	33.6	3.79	243.169	0.000	0.0	100.0	0.0000	13.1	86.9	0.000	0.0	0.000	61.8	363.1	424.9	
95	2.80	46	43.2	3.45	248.259	0.000	2.3	97.7	0.0000	27.9	72.1	0.000	0.0	0.000	122.4	294.5	416.9	
96	2.80	46	47.0	2.22	244.231	0.000	2.5	97.5	0.0000	35.5	73.5	0.000	0.0	0.000	159.5	262.1	421.7	

DATE: 20 MAY 88
 STREAM: MISSISSIPPI RIVER
 LOCATION: "ARBERT"
 GAGE: "ARBERT" DISCHG. GNG
 DISCHARGE: 935.210 CFS (ADCP)
 RIVER CONDITION: GOOD
 TIME: 15:00 TO 17:00
 TEMP: 19.0 C @ 1.0 FT
 WEATHER: CLOUDY
 GAGE READING: 52.50 FT
 TYPE SAMPLER: P-63
 TYPE SAMPLES: S-15P
 NO VERTICALS: 4
 NO POINTS: 6

Field No.	Distance from Reference Point (ft)	Station Depth (ft)	Sampling Depth (ft)	Samp. Velocity (ft/s)	Flow Direction (ft/s)	Sediment Grain Size Analysis												Sediment Concentration (gpm)				
						Sand Sieve Analysis (Cumulative Weight Retained)												Pan	Sand	Fines		
						U.S. #4 (0.425 mm)	U.S. #10 (0.25 mm)	U.S. #20 (0.85 mm)	U.S. #40 (0.425 mm)	U.S. #60 (0.25 mm)	U.S. #100 (0.15 mm)	U.S. #200 (0.075 mm)	U.S. #400 (0.0375 mm)	U.S. #600 (0.025 mm)	U.S. #840 (0.0175 mm)	U.S. #1060 (0.015 mm)	U.S. #1490 (0.0106 mm)					
97	1.82	61	6.1	4.21	240.071	0.000	0.0	100.0	0.0000	0.0	0.000	0.0	0.000	0.0	0.000	0.0	0.000	0.0	0.000	13.8	165.3	169.1
98	1.82	61	11.7	4.54	236.519	0.000	0.0	100.0	0.0000	0.0	0.000	0.0	0.000	0.0	0.000	0.0	0.000	0.0	0.000	24.6	198.1	142.7
99	1.82	61	15.5	4.50	237.251	0.000	0.0	100.0	0.0000	0.0	0.000	0.0	0.000	0.0	0.000	0.0	0.000	0.0	0.000	23.5	185.5	105.0
100	1.82	61	41.7	4.43	212.999	0.000	0.0	100.0	0.0000	0.0	0.000	0.0	0.000	0.0	0.000	0.0	0.000	0.0	0.000	42.8	163.1	205.9
101	1.82	61	54.9	3.37	245.023	0.000	0.0	100.0	0.0000	6.4	93.6	0.000	0.0	0.000	0.0	0.000	0.0	0.000	0.0	51.4	174.2	226.7
102	1.82	61	62.8	3.51	229.795	0.000	1.4	99.6	0.0000	17.1	82.9	0.000	0.0	0.000	0.0	0.000	0.0	0.000	0.0	86.1	110.4	196.6
103	2.82	43	4.3	4.10	249.264	0.000	2.1	97.8	0.0000	3.2	96.8	0.000	0.0	0.000	0.0	0.000	0.0	0.000	0.0	36.5	130.2	166.7
104	2.82	43	16.3	4.27	255.866	0.000	4.0	96.0	0.0000	9.4	91.6	0.000	0.0	0.000	0.0	0.000	0.0	0.000	0.0	49.4	114.8	164.2
105	2.82	43	26.4	4.12	255.154	0.000	0.0	100.0	0.0000	1.6	98.4	0.000	0.0	0.000	0.0	0.000	0.0	0.000	0.0	59.6	105.1	144.9
106	2.82	43	37.1	4.21	251.036	0.000	0.7	99.3	0.0000	3.9	96.1	0.000	0.0	0.000	0.0	0.000	0.0	0.000	0.0	123.7	105.5	209.3
107	2.82	43	47.1	2.11	254.957	0.000	1.7	99.4	0.0000	4.4	95.6	0.000	0.0	0.000	0.0	0.000	0.0	0.000	0.0	153.4	110.4	174.1
108	2.82	43	47.9	2.10	255.521	0.000	1.1	99.8	0.0000	4.2	95.8	0.000	0.0	0.000	0.0	0.000	0.0	0.000	0.0	318.9	119.2	248.2
109	2.82	43	5.5	4.57	252.947	0.000	0.0	100.0	0.0000	6.8	93.2	0.000	0.0	0.000	0.0	0.000	0.0	0.000	0.0	31.6	110.4	142.0
110	2.82	43	16.8	3.77	249.636	0.000	0.0	100.0	0.0000	4.3	95.7	0.000	0.0	0.000	0.0	0.000	0.0	0.000	0.0	29.5	119.1	145.4
111	2.82	43	25.0	4.38	250.351	0.000	0.9	99.1	0.0000	12.7	87.3	0.000	0.0	0.000	0.0	0.000	0.0	0.000	0.0	111.9	107.3	214.1
112	2.82	43	35.0	4.29	245.951	0.000	1.4	99.1	0.0000	15.0	85.0	0.000	0.0	0.000	0.0	0.000	0.0	0.000	0.0	136.1	115.7	211.8
113	2.82	43	52.4	4.57	252.858	0.000	1.3	99.2	0.0000	23.7	76.3	0.000	0.0	0.000	0.0	0.000	0.0	0.000	0.0	149.5	105.4	254.9
114	2.82	43	54.3	4.33	259.902	0.000	1.6	99.1	0.0000	44.1	55.9	0.000	0.0	0.000	0.0	0.000	0.0	0.000	0.0	154.7	133.4	268.1
115	3.82	47	5.0	4.48	254.082	0.000	0.0	100.0	0.0000	22.4	77.6	0.000	0.0	0.000	0.0	0.000	0.0	0.000	0.0	75.3	116.2	176.0
116	3.82	47	15.0	4.45	250.685	0.000	1.9	98.1	0.0000	27.8	72.2	0.000	0.0	0.000	0.0	0.000	0.0	0.000	0.0	39.8	103.5	143.6
117	3.82	47	26.0	4.46	246.636	0.000	2.0	99.0	0.0000	16.1	83.9	0.000	0.0	0.000	0.0	0.000	0.0	0.000	0.0	52.4	90.1	132.5
118	3.82	47	35.0	3.57	249.648	0.000	0.0	100.0	0.0000	14.0	86.0	0.000	0.0	0.000	0.0	0.000	0.0	0.000	0.0	111.6	116.3	269.4
119	3.82	47	45.0	2.79	259.902	0.000	4.3	95.7	0.0000	32.2	67.8	0.000	0.0	0.000	0.0	0.000	0.0	0.000	0.0	134.9	146.1	289.9
120	3.82	47	49.0	2.36	236.949	0.000	4.1	95.9	0.0000	34.6	65.4	0.000	0.0	0.000	0.0	0.000	0.0	0.000	0.0	132.0	221.3	353.3

DATE: 20 JUN 88
 STREAM: MISSISSIPPI RIVER
 LOCATION: "ARBERT"
 GAGE: "ARBERT" DISCHG. GNG
 DISCHARGE: 479.779 CFS (ADCP)
 RIVER CONDITION: IMPROV
 TIME: 15:50 TO 17:50
 TEMP: 26.0 C @ 1.0 FT
 WEATHER: CLOUDY AND HOT
 GAGE READING: 49.00 FT
 TYPE SAMPLER: P-63
 TYPE SAMPLES: S-15P
 NO VERTICALS: 4

Table B.4 (continued)

DATE: 03 AUG 98										RIVER CONDITION: CHOPPY										TYPE SAMPLER: P-3											
STREAM: MISSISSIPPI RIVER										TIME: 16 40 TO 17 50										TYPE SAMPLES: SUSP											
LOCATION: TARBERT										TEMP: 31.0 @ 10 FT										NO VERTICALS: 4											
GAUGE: TARBERT DISCHARGE RING										WEATHER: CLOUDY AND HOT										NO POINTS: 6											
DISCHARGE: 374.327 CFS (ADCP)										GAUGE READING: 31.4 FT																					
Field No	Distance from the Reference Point (ft)	Station	Depth (ft)	Sampling Depth (ft)	Samp Velocity (ft/s)	Flow Direction (° Deg)	Suspend Sediment Grain Size Analysis																Sediment Concentration (ppm)								
							Sand Sieve Analysis (Cumulative Weight Retained)																								
							U.S. #40 (0.425 mm)				U.S. #60 (0.250 mm)				U.S. #100 (0.150 mm)				U.S. #200 (0.075 mm)												
Wt. (g)	% Ret.	% Finer	Wt. (g)	% Ret.	% Finer	Wt. (g)	% Ret.	% Finer	Wt. (g)	% Ret.	% Finer	Wt. (g)	% Ret.	% Finer	Pan	Coarse	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	94.4	203.7	210.0										
146	1380	41	12.3	4.08	253.998	0.0000	0.0	100.0	0.0008	6.3	93.7	0.0091	64.3	35.7	0.0121	96.0	4.0	0.0136	35.7	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	0.0086	96.0	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	30.6	199.7	230.3										
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	98.6	1.4	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	93.7	0.0013	11.6	88.4	0.0047	42.0	58.0	0.0109	97.3	2.7	0.0112	18.4	196.9	215.3										
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	97.3	2.7	0.0281	46.5	151.3	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	99.3	0.8	0.0370	62.1	204.5	266.6										
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	250.993	0.0007	3.2	96.8	0.0001	16.6	83.4	0.3392	93.6	6.4	0.3616	99.8	0.2	0.3624	649.1	205.0	1854.3										
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	68.5	193.7	262.2										
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	259.679	0.0000	0.0	100.0	0.0006	3.8	96.2	0.0065	35.9	64.1	0.0149	95.5	4.5	0.0156	25.9	203.3	229.2										
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	198.3	230.2										
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	32.7	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	198.5	185.6	384.1										
163	3390	25	2.5	3.15	252.282	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	252.282	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	9.2	165.1	174.3										
165	3390	25	12.5	3.44	252.845	0.0000	0.0	100.0	0.0006	6.1	93.9	0.0021	29.4	70.6	0.0069	93.2	6.8	0.0074	10.4	188.7	199.1										
166	3390	25	17.5	3.14	247.932	0.0001	0.0	100.0	0.0017	10.5	89.5	0.0072	44.4	55.6	0.0151	93.2	6.8	0.0162	26.4	197.4	223.8										
167	3390	25	22.5	2.51	235.395	0.0010	3.3	96.7	0.0109	36.3	63.7	0.0205	68.7	31.3	0.0291	97.0	3.0	0.0300	46.5	151.1	237.6										
168	3390	25	24.5	BC	BC	0.0000	0.0	100.0	0.0033	17.5	82.5	0.0092	48.7	51.3	0.0183	96.9	3.1	0.0195	32.7	206.2	238.9										

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

February 27, 1998

March 23, 1998

Distance from the Right Bank (ft)

Distance from the Right Bank (ft)

1066				2256				2941			
Depth	Vel	Q	Dir	Depth	Vel	Q	Dir	Depth	Vel	Q	Dir
7.35	4.43	110.888	7.05	8.57	118.952	7.05	6.93	121.733	7.05	7.08	124.794
8.89	4.43	122.914	8.65	8.69	121.836	8.65	6.61	121.554	8.65	7.25	123.740
10.34	4.03	117.483	10.34	8.10	119.244	10.34	6.71	123.993	10.34	7.05	123.130
11.98	4.31	116.467	11.98	7.35	118.829	11.98	6.36	126.397	11.98	6.97	123.950
13.62	3.91	121.954	13.62	6.40	120.108	13.62	6.44	127.565	13.62	6.91	124.807
15.35	4.43	115.050	15.35	6.15	118.537	15.35	6.79	124.711	15.35	6.85	125.411
16.90	4.17	123.253	16.90	6.39	119.712	16.90	6.93	122.998	16.90	7.59	128.664
18.54	4.28	118.744	18.54	6.19	116.985	18.54	6.42	122.681	18.54	7.43	123.899
20.18	4.05	125.302	20.18	6.40	118.778	20.18	6.49	124.750	20.18	7.72	129.027
21.82	4.01	125.669	21.82	6.21	123.156	21.82	6.91	125.330	21.82	8.78	139.656
23.46	3.74	121.851	23.46	6.35	120.748	23.46	6.62	125.084	23.46	7.29	126.401
25.10	3.99	118.734	25.10	6.34	119.974	25.10	6.54	124.620	25.10	7.75	129.322
26.74	4.16	125.365	26.74	6.68	122.375	26.74	6.51	125.793	26.74	7.54	133.254
28.38	4.25	127.413	28.38	6.95	121.202	28.38	6.91	128.325	28.38	7.51	126.629
30.02	4.18	125.386	30.02	6.58	121.851	30.02	6.45	128.496	30.02	7.44	129.636
31.66	4.05	122.527	31.66	6.60	119.087	31.66	6.30	128.441	31.66	7.13	132.391
33.30	4.46	122.859	33.30	6.65	120.308	33.30	6.52	127.050	33.30	6.64	134.680
34.94	4.35	127.345	34.94	6.87	120.484	34.94	6.41	128.207	34.94	6.42	135.373
36.58	4.75	127.764	36.58	6.91	121.698	36.58	6.81	127.459	36.58	6.79	128.754
38.22	4.35	125.633	38.22	6.35	120.037	38.22	6.21	127.681	38.22	6.69	130.104
39.86	4.18	127.165	39.86	6.31	121.990	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	6.61	132.480	41.50	6.62	128.317
43.14	4.28	125.985	43.14	7.74	121.534	43.14	6.22	129.638	43.14	6.15	122.425
44.78	4.32	127.696	44.78	7.70	121.891	44.78	6.84	127.095	44.78	6.79	127.856
46.42	4.18	127.036	46.42	7.25	123.006	46.42	6.43	126.995	46.42	6.51	127.211
48.06	4.37	125.795	48.06	7.55	122.198	48.06	6.64	127.734	48.06	6.61	124.803
49.70	4.53	122.127	49.70	7.19	123.719	49.70	6.50	127.121	49.70	6.50	124.711
51.34	4.04	126.626	51.34	6.54	122.079	51.34	6.05	125.085	51.34	6.75	126.156
52.98	4.11	127.771	52.98	6.36	121.698	52.98	6.23	126.674	52.98	6.67	127.700
54.62	3.62	115.323	54.62	6.99	121.877	54.62	6.93	135.296	54.62	6.83	121.736
56.26	3.75	126.456	56.26	6.33	120.474	56.26	6.73	134.456	56.26	6.77	113.506
57.90	3.58	115.748	57.90	7.11	120.492	57.90	6.81	130.473			
59.54	3.88	122.267	59.54	6.58	121.394	59.54	6.25	135.578			
61.18	3.56	125.270	61.18	6.49	127.299	61.18	6.70	131.979			
62.82	3.38	134.959	62.82	6.57	120.100	62.82	6.67	117.273			
64.46	3.52	145.760	64.46	5.57	121.622	64.46	6.43	121.245			
66.10	3.77	144.431	66.10	3.35	114.563	66.10	5.54	121.144			

1320				1755				2274				3091					
Depth	Vel	Q	Dir	Depth	Vel	Q	Dir	Depth	Vel	Q	Dir	Depth	Vel	Q	Dir		
7.05	4.75	105.752	7.05	7.01	26.221	7.05	8.46	116.973	7.05	7.35	130.752	7.05	7.35	130.752	7.05	7.35	130.752
8.69	4.81	107.388	8.69	7.22	29.262	8.69	7.71	119.554	8.69	8.46	134.470	8.69	8.46	134.470	8.69	8.46	134.470
10.34	4.20	102.767	10.34	7.25	28.688	10.34	8.37	117.439	10.34	8.44	131.468	10.34	8.44	131.468	10.34	8.44	131.468
11.98	4.27	101.741	11.98	7.09	31.508	11.98	8.02	115.191	11.98	8.54	138.721	11.98	8.54	138.721	11.98	8.54	138.721
13.62	4.85	103.367	13.62	7.04	29.812	13.62	8.19	116.319	13.62	8.40	140.955	13.62	8.40	140.955	13.62	8.40	140.955
15.26	4.61	108.503	15.26	7.43	34.624	15.26	8.28	118.250	15.26	8.51	145.353	15.26	8.51	145.353	15.26	8.51	145.353
16.90	4.35	107.360	16.90	7.29	33.122	16.90	8.01	116.198	16.90	8.75	143.471	16.90	8.75	143.471	16.90	8.75	143.471
18.54	4.63	112.345	18.54	6.98	27.242	18.54	7.71	115.148	18.54	8.86	136.654	18.54	8.86	136.654	18.54	8.86	136.654
20.18	4.77	108.134	20.18	7.49	29.035	20.18	8.12	114.281	20.18	9.31	129.277	20.18	9.31	129.277	20.18	9.31	129.277
21.82	4.76	106.622	21.82	7.37	29.070	21.82	8.13	114.866	21.82	9.74	128.950	21.82	9.74	128.950	21.82	9.74	128.950
23.46	4.73	104.470	23.46	7.24	28.895	23.46	8.22	114.100	23.46	8.43	131.623	23.46	8.43	131.623	23.46	8.43	131.623
25.10	5.00	107.388	25.10	7.02	29.802	25.10	7.94	116.756	25.10	9.88	131.657	25.10	9.88	131.657	25.10	9.88	131.657
26.74	5.03	103.782	26.74	7.07	38.955	26.74	7.98	116.249	26.74	9.39	133.900	26.74	9.39	133.900	26.74	9.39	133.900
28.38	4.92	106.974	28.38	7.01	31.997	28.38	8.02	114.381	28.38	8.62	136.254	28.38	8.62	136.254	28.38	8.62	136.254
30.02	4.94	108.483	30.02	6.90	30.853	30.02	7.79	114.569	30.02	8.75	140.323	30.02	8.75	140.323	30.02	8.75	140.323
31.66	4.56	108.226	31.66	6.60	30.241	31.66	7.05	114.536	31.66	9.31	133.918	31.66	9.31	133.918	31.66	9.31	133.918
33.30	4.44	114.272	33.30	6.82	31.746	33.30	6.80	114.277	33.30	9.45	126.772	33.30	9.45	126.772	33.30	9.45	126.772
34.94	4.77	106.981	34.94	6.67	31.910	34.94	7.32	111.172	34.94	9.88	125.571	34.94	9.88	125.571	34.94	9.88	125.571
36.58	4.26	115.520	36.58	6.80	32.778	36.58	6.84	111.628	36.58	9.41	126.179	36.58	9.41	126.179	36.58	9.41	126.179
38.22	4.77	116.223	38.22	6.99	31.785	38.22	7.51	115.960	38.22	9.92	127.972	38.22	9.92	127.972	38.22	9.92	127.972
39.86	4.52	108.347	39.86	7.05	28.144	39.86	7.20	114.972	39.86	8.40	129.269	39.86	8.40	129.269	39.86	8.40	129.269
41.50	4.61	109.354	41.50	7.15	29.958	41.50	7.68	114.555	41.50	8.47	129.472	41.50	8.47	129.472	41.50	8.47	129.472
43.14	4.35	110.500	43.14	6.84	25.589	43.14	7.42	114.287	43.14	9.15	136.480	43.14	9.15	136.480	43.14	9.15	136.480
44.78	4.44	106.602	44.78	7.01	28.039	44.78	6.92	116.371	44.78	9.43	131.052	44.78	9.43	131.052	44.78	9.43	131.052
46.42	3.94	104.454	46.42	7.03	28.020	46.42	6.75	114.258	46.42	8.43	133.267	46.42	8.43	133.267	46.42	8.43	133.267
48.06	3.74	110.356	48.06	6.79	25.142	48.06	6.83	112.205	48.06	8.77	127.527	48.06	8.77	127.527	48.06	8.77	127.527
49.70	3.66	105.332	49.70	6.55	25.004	49.70	6.37	112.326	49.70	8.71	133.265	49.70	8.71	133.265	49.70	8.71	133.265
51.34	3.25	105.351	51.34	6.25	27.638	51.34	6.51	113.233	51.34	9.15	134.141	51.34	9.15	134.141	51.34	9.15	134.141
52.98	4.76	106.245	52.98	6.09	29.113	52.98	6.88	111.795	52.98	9.29	127.762	52.98	9.29	127.762	52.98	9.29	127.762
54.62	3.23	102.588	54.62	6.35	25.429	54.62	6.65	110.232	54.62	9.36	127.762	54.62	9.36	127.762	54.62	9.36	127.762
56.26	3.47	114.364	56.26	6.45	27.953	56.26	6.04	115.771	56.26	9.27	127.762	56.26	9.27	127.762	56.26	9.27	127.762
57.90	3.61	112.140	57.90	6.41	27.526	57.90	6.11	114.789	57.90	9.41	116.761	57.90	9.41	116.761	57.90	9.41	116.761
59.54	3.25	119.315	59.54	6.27	23.391	59.54	6.82	115.637	59.54	9.11							

Table B.5 (continued)

May 8 1998											
Distance from the Right Bank (ft)											
1094				2279				2959			
Depth	Vel	Q Dr	Depth	Vel	Q Dr	Depth	Vel	Q Dr	Depth	Vel	Q Dr
7.05	5.3	121.645	7.05	7.61	129.73	7.05	9.89	121.075	7.05	6.80	130.814
8.69	4.91	130.452	8.69	7.48	127.03	8.69	9.92	130.883	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	122.303	23.46	6.36	134.362
25.1	4.34	120.733	25.1	7.80	129.36	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	125.363	26.74	6.80	132.104
28.38	3.71	134.536	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	132.936
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	122.567	44.79	7.53	125.96	44.79	9.02	124.136	44.79	5.92	141.395
46.43	2.55	117.522	46.43	8.36	128.55	46.43	9.18	121.132	46.43	5.31	139.913
48.07	2.91	117.606	48.07	6.61	125.86	48.07	9.53	121.945	48.07	4.98	137.244
49.71	3.13	118.254	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	6.79	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	125.295	57.91	4.67	131.754
59.55	3.49	125.306	59.55	6.36	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	127.586	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	137.126	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	126.65						

June 9 1998											
Distance from the Right Bank (ft)											
1047				1613				2276			
Depth	Vel	Q Dr	Depth	Vel	Q Dr	Depth	Vel	Q Dr	Depth	Vel	Q Dr
7.05	4.15	115.085	7.05	5.89	119.963	7.05	6.30	119.439	7.05	4.70	140.053
8.69	3.46	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	6.29	131.932	11.98	4.80	138.526
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	112.668	15.26	5.46	121.867	15.26	6.00	134.448	15.26	4.41	136.300
16.90	3.19	126.764	16.90	5.70	122.831	16.90	6.36	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	117.946	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	5.64	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	136.125
28.38	3.71	109.852	28.38	4.87	116.151	28.38	5.86	139.884	28.38	4.13	136.597
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	106.024	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	136.617
39.86	3.25	116.649	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	3.66	142.369
44.79	3.22	109.858	44.79	3.62	126.226	44.79	5.57	122.885	44.79	3.11	141.879
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	127.455			
49.71	3.18	120.757	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	1.54	136.018	56.27	2.53	132.949	56.27	4.07	129.729			
						57.91	2.39	132.718	57.91	3.75	129.982
						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			
Depth	Vel	Q Dr	Depth	Vel	Q Dr	Depth	Vel	Q Dr	Depth	Vel	Q Dr
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	5.56	128.332	21.82	5.80	122.023	21.82	4.36	129.264
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	123.786	25.10	3.68	129.723
26.74	3.90	117.622	26.74	5.61	126.931	26.74	5				

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

February 27, 1998												March 23, 1998											
Distance from the Right Bank (ft)												Distance from the Right Bank (ft)											
1793				2449				2916				1795				2068				2459			
Depth	Vel	Q Dir	Depth	Vel	Q Dir	Depth	Vel	Q Dir	Depth	Vel	Q Dir	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	7.35	6.13	136.975	7.35	7.71	137.735	7.35	8.83	135.557	7.35	5.57	129.719
8.69	7.18	130.610	8.69	9.32	129.000	8.69	7.52	132.329	8.69	5.01	130.276	8.69	6.19	134.268	8.69	7.99	135.932	8.69	8.89	136.017	8.69	5.41	129.792
10.34	7.19	129.983	10.34	9.12	134.417	10.34	8.14	134.559	10.34	5.28	130.284	10.34	6.56	133.844	10.34	7.64	136.601	10.34	9.63	135.801	10.34	5.71	129.704
11.98	6.72	132.012	11.98	9.09	133.100	11.98	8.14	132.174	11.98	5.48	130.531	11.98	6.43	133.388	11.98	8.04	135.446	11.98	9.01	136.018	11.98	5.57	129.806
13.62	7.11	125.955	13.62	9.13	132.292	13.62	7.73	130.956	13.62	5.27	129.252	13.62	7.13	136.112	13.62	8.14	138.610	13.62	8.64	136.447	13.62	5.17	127.932
15.26	6.60	131.373	15.26	9.50	131.221	15.26	7.68	128.671	15.26	5.42	127.939	15.26	6.97	137.443	15.26	7.60	136.989	15.26	8.27	136.833	15.26	5.41	126.636
16.90	6.36	128.189	16.90	9.11	130.545	16.90	8.10	130.435	16.90	5.43	130.098	16.90	8.03	135.795	16.90	7.95	138.341	16.90	8.41	135.126	16.90	5.40	127.301
18.54	6.79	126.249	18.54	8.79	130.898	18.54	8.30	133.006	18.54	5.61	128.801	18.54	8.25	134.075	18.54	8.46	136.302	18.54	8.04	136.307	18.54	5.75	130.023
20.18	5.91	127.035	20.18	8.82	131.773	20.18	7.93	131.342	20.18	5.21	128.429	20.18	7.41	136.337	20.18	8.40	133.987	20.18	8.49	135.767	20.18	5.34	129.463
21.82	5.91	125.108	21.82	8.42	131.304	21.82	8.02	133.640	21.82	5.03	129.284	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	5.43	128.975	23.46	8.65	129.444	23.46	8.25	130.453	23.46	5.12	127.943	23.46	7.42	137.051	23.46	8.46	136.664	23.46	8.74	136.054	23.46	5.17	130.030
25.10	6.81	131.796	25.10	8.41	131.366	25.10	8.37	131.249	25.10	5.25	129.723	25.10	6.91	139.293	25.10	7.70	138.125	25.10	8.74	136.989	25.10	5.57	133.951
26.74	6.93	131.125	26.74	9.00	133.508	26.74	8.02	133.275	26.74	5.69	131.560	26.74	6.55	130.654	26.74	7.23	136.057	26.74	8.62	132.454	26.74	5.81	128.923
28.38	6.58	130.939	28.38	9.21	136.140	28.38	8.55	134.488	28.38	5.92	130.707	28.38	6.75	127.316	28.38	7.07	137.481	28.38	8.35	133.697	28.38	5.54	128.993
30.02	6.88	130.456	30.02	9.00	131.333	30.02	8.77	134.727	30.02	4.92	133.893	30.02	6.91	132.614	30.02	7.30	140.790	30.02	8.30	133.562	30.02	5.69	128.943
31.66	6.73	130.271	31.66	9.24	133.373	31.66	8.05	131.713	31.66	4.63	131.354	31.66	6.90	133.902	31.66	6.93	140.957	31.66	8.74	133.312	31.66	5.12	133.104
33.30	6.88	132.818	33.30	9.05	132.810	33.30	8.49	131.987	33.30	4.83	129.317	33.30	6.78	140.752	33.30	6.47	138.415	33.30	8.21	133.915	33.30	5.26	129.900
34.94	6.89	129.059	34.94	9.05	133.548	34.94	8.65	129.280	34.94	4.79	127.459	34.94	7.19	142.848	34.94	6.40	138.562	34.94	8.25	133.808	34.94	5.44	129.916
36.58	7.30	130.956	36.58	9.29	134.900	36.58	9.07	132.184	36.58	4.99	124.850	36.58	6.78	143.056	36.58	6.49	144.173	36.58	7.90	132.761	36.58	4.95	126.027
38.22	7.01	130.901	38.22	9.25	134.209	38.22	8.75	132.492	38.22	5.03	131.615	38.22	7.39	142.346	38.22	7.01	143.318	38.22	7.91	134.616	38.22	5.02	130.151
39.86	7.42	134.283	39.86	9.72	130.671	39.86	9.28	129.606	39.86	4.75	134.328	39.86	7.37	142.528	39.86	6.56	140.884	39.86	6.42	130.732	39.86	4.34	121.496
41.50	7.69	129.042	41.50	9.06	131.816	41.50	8.84	131.884	41.50	4.80	132.232	41.50	7.60	139.409	41.50	6.79	142.300	41.50	6.58	129.629	41.50	5.18	131.763
43.15	7.49	135.035	43.15	9.08	136.337	43.15	8.88	131.510	43.15	4.81	135.525	43.15	7.38	143.426	43.15	6.51	143.592	43.15	6.08	129.317	43.15	5.55	131.451
44.79	7.41	139.181	44.79	8.91	133.090	44.79	8.67	135.031	44.79	4.18	138.979	44.79	8.03	143.102	44.79	6.30	144.365	44.79	6.47	133.163	44.79	4.75	133.903
46.43	7.63	133.676	46.43	9.22	127.539	46.43	8.53	133.894	46.43	4.87	134.918	46.43	7.98	140.571	46.43	6.86	143.938	46.43	6.03	131.404	46.43	4.73	133.367
48.07	7.03	136.659	48.07	9.09	131.541	48.07	9.26	132.182	48.07	4.38	136.547	48.07	7.98	139.706	48.07	6.75	137.897	48.07	6.09	132.253	48.07	4.54	126.326
49.71	7.75	139.839	49.71	8.85	130.219	49.71	7.95	132.759	49.71	4.67	137.305	49.71	8.28	143.829	49.71	6.05	135.393	49.71	7.69	133.687	49.71	4.37	125.456
51.35	7.26	134.341	51.35	8.88	132.774	51.35	7.90	134.680	51.35	4.62	137.318	51.35	6.05	142.510	51.35	6.37	133.831	51.35	6.04	130.617	51.35	4.38	131.359
52.99	7.31	133.026	52.99	9.07	130.981	52.99	8.32	133.945	52.99	5.13	134.741	52.99	6.29	141.170	52.99	5.75	139.434	52.99	6.27	129.541	52.99	4.29	122.369
54.63	7.21	135.074	54.63	8.56	130.430	54.63	8.50	132.826	54.63	4.35	127.229	54.63	8.29	139.968	54.63	5.45	141.332	54.63	7.99	131.754	54.63	4.64	129.977
56.27	7.43	134.982	56.27	8.67	130.472	56.27	8.34	130.997	56.27	4.54	134.737	56.27	7.65	141.285	56.27	5.52	136.444	56.27	7.58	131.654	56.27	4.57	127.290
57.91	7.75	134.910	57.91	8.67	133.359	57.91	8.11	129.318	57.91	4.42	127.882	57.91	7.25	145.843	57.91	6.86	138.518	57.91	7.91	134.210	57.91	4.36	125.549
59.55	7.45	131.430	59.55	8.35	132.979	59.55	7.82	128.634	59.55	4.50	129.313	59.55	6.21	142.168	59.55	5.38	138.199	59.55	8.25	132.514	59.55	4.43	122.717
61.19	7.50	131.575	61.19	8.97	130.633	61.19	7.46	131.577	61.19	4.28	136.429	61.19	7.80	136.500	61.19	5.88	128.575	61.19	7.90	128.017	61.19	4.29	130.725
62.83	7.37	130.373	62.83	8.09	130.097	62.83	7.55	133.891	62.83	3.66	129.076	62.83	7.62	132.853	62.83	5.64	128.398	62.83	8.19	129.403	62.83	4.51	135.646
64.47	7.13	134.496	64.47	7.32	130.277	64.47	7.60	133.164	64.47	4.17	131.555	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	6.99	139.366	66.11	8.20	130.487	66.11	7.50	131.719	66.11	3.69	129.232	66.11	7.45	129.282	66.11	5.24	129.688	66.11	7.79	132.542	66.11	4.35	133.686
67.75	6.97	135.958	67.75	8.26	128.987	67.75	7.18	132.427	67.75	2.81	140.400	67.75	7.28	128.926	67.75	5.13	122.354	67.75	7.94	131.365	67.75	4.35	134.140
69.39	7.20	138.046	69.39	7.92	130.689	69.39	7.53	132.951	69.39	1.83	153.711	69.39	6.91	127.627	69.39	4.84	125.626	69.39	7.61	130.714	69.39	3.93	137.540
71.03	7.08	137.253	71.03	8.43	129.154	71.03	7.84	133.966	71.03			71.03	7.33	130.367	71.03	4.88	123.423	71.03	7.65	142.723	71.03	3.63	140.768
72.67	6.96	133.816	72.67	7.95	127.379	72.67	7.36	134.812	72.67			72.67	7.29	132.211	72.67	5.05	121.269	72.67	7.57	135.253	72.67	1.93	133.837
74.31	7.05	134.062	74.31	7.76	131.193	74.31	6.90	135.154	74.31			74.31	7.19	133.243	74.31	4.82	121.592	74.31	7.46	134.893	74.31	0.97	111.238
75.95	6.95	132.532	75.95	7.48	129.272	75.95	6.94	133.065	75.95			75.95	7.42	137.525	75.95	5.05	123.587	75.95	6.70	134.028	75.95	1.36	121.364
77.60	7.08	133.198	77.60	7.05	129.560	77.60	6.52	134.184	77.60			77.60	7.40	136.150	77.60	4.84	121.396	77.60	6.97	131.456	77.60		
79.24	6.90	136.098	79.24	6.87	129.725	79.24	6.55	135.446	79.24			79.24	7.27	136.482	79.24	4.61	127.661	79.24	7.35	130.322			

Table B.6 (continued)

April 10, 1998											
Distance from the Right Bank (ft)											
1801			2072			2433			2669		
Depth	Vel	G Dr	Depth	Vel	G Dr	Depth	Vel	G Dr	Depth	Vel	G Dr
7.35	9.24	130.076	7.05	9.37	132.730	7.05	6.57	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	6.74	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	134.998	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	133.457	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	8.95	131.994	28.38	9.03	132.733	28.38	7.29	134.151	28.38	3.12	135.822
30.02	8.62	132.469	30.02	8.95	131.150	30.02	7.20	133.745	30.02	3.29	134.111
31.66	8.98	133.420	31.66	8.81	131.027	31.66	7.40	136.280	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	139.378
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	8.99	133.206	39.86	7.45	133.030	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	135.300	43.15	9.36	132.564	43.15	7.29	137.244	43.15	3.38	135.162
44.79	8.95	134.542	44.79	9.82	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	131.735	46.43	2.54	134.215
48.07	9.10	134.284	48.07	8.66	132.778	48.07	7.23	136.917	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	8.74	133.452	52.99	7.62	137.950	52.99	3.12	129.328
54.63	8.31	133.512	54.63	8.24	134.054	54.63	7.57	141.457	54.63	3.98	137.718
56.27	8.63	131.301	56.27	8.69	134.122	56.27	7.40	137.624	56.27	3.16	141.306
57.91	8.40	131.47	57.91	8.92	132.570	57.91	7.48	136.112	57.91	3.80	135.759
59.55	8.52	132.379	59.55	8.47	133.656	59.55	7.72	139.560	59.55	3.81	136.386
61.19	8.53	133.379	61.19	8.36	134.456	61.19	7.76	135.619	61.19	3.15	139.380
62.83	8.46	131.966	62.83	7.49	134.113	62.83	7.96	139.416	62.83	2.87	137.776
64.47	8.53	132.770	64.47	7.57	133.613	64.47	7.69	137.991	64.47	2.79	130.123
66.11	8.55	131.257	66.11	7.37	133.322	66.11	7.56	136.422	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	2.62	151.381
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	7.56	139.177	71.03	2.51	150.822
72.67	8.79	136.814	72.67	6.98	126.972	72.67	7.73	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	139.667
75.95	8.13	132.398	75.95	7.23	136.366	75.95	7.57	138.849	75.95	2.81	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	127.328	79.24	7.71	144.867			
80.88	8.61	137.547	80.88	6.97	130.548	80.88	7.32	141.661			
82.52	8.36	140.462	82.52	7.23	125.391	82.52	7.28	142.401			
84.16	8.65	140.278	84.16	7.14	125.842	84.16	7.38	143.828			
85.80	9.04	141.363	85.80	7.08	125.377	85.80	6.90	145.506			
87.44	8.63	142.960	87.44	6.95	127.752	87.44	9.30	145.691			
89.08	8.76	141.555	89.08	6.54	129.342	89.08	6.99	149.695			
90.72	9.24	144.557	90.72	6.73	127.752	90.72	4.90	156.951			
92.36	8.62	144.120	92.36	6.60	125.981	92.36	3.42	139.907			
94.00	8.06	143.238	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	123.680						
98.92	7.24	141.288	98.92	5.84	119.242						
100.56	7.44	137.682	100.56	5.41	119.431						
102.20	8.00	80	102.20	3.88	126.308						
103.84	8.00	80									
105.48	8.00	80									
107.12	8.00	80									
108.76	8.00	80									
110.40	8.00	80									

April 17, 1998											
Distance from the Right Bank (ft)											
1786			2098			2454			2834		
Depth	Vel	G Dr	Depth	Vel	G Dr	Depth	Vel	G Dr	Depth	Vel	G Dr
7.35	5.67	148.655	7.05	10.41	136.725	7.05	5.74	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	126.191
10.34	6.24	145.240	10.34	9.85	135.054	10.34	7.14	131.672	10.34	5.77	122.781
11.98	6.82	141.409	11.98	10.30	135.531	11.98	7.30	131.210	11.98	5.04	122.144
13.62	6.38	146.457	13.62	10.05	133.161	13.62	7.11	129.524	13.62	5.86	122.608
15.26	6.77	146.373	15.26	10.15	132.616	15.26	7.12	128.290	15.26	5.80	122.242
16.90	6.39	147.779	16.90	10.25	135.013	16.90	7.35	125.977	16.90	6.12	123.247
18.54	6.53	143.585	18.54	10.10	136.856	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	128.518	21.82	5.54	122.872
23.46	6.24	139.328	23.46	10.05	137.738	23.46	6.92	129.670	23.46	5.74	122.363
25.10	6.11	141.950	25.10	9.92	136.112	25.10	7.53	127.529	25.10	6.04	125.533
26.74	5.71	147.627	26.74	9.80	136.873	26.74	7.32	127.493	26.74	5.33	121.377
28.38	5.38	136.038	28.38	10.11	139.540	28.38	7.67	134.411	28.38	5.73	123.582
30.02	5.45	141.717	30.02	10.00	136.149	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	140.781	33.30	10.15	136.022	33.30	7.65	127.631	33.30	5.43	122.239
34.94	5.46	135.365	34.94	9.70	139.348	34.94	7.72	130.251	34.94	5.26	122.540
36.58	5.72	137.368	36.58	9.40	139.495	36.58	7.92	129.979	36.58	5.03	121.138
38.22	5.98	139.450	38.22	9.57	140.202	38.22	7.66	129.069	38.22	5.21	121.837
39.86	5.62	132.970	39.86	9.35	140.426	39.86	7.77	129.758	39.86	5.37	123.797
41.50	5.26	135.632	41.50	9.41	137.983	41.50	7.58	128.938	41.50	5.50	122.600
43.15	5.39	140.013	43.15	9.84	135.122	43.15	7.35	129.950	43.15	5.72	124.778
44.79	5.39	141.373	44.79	9.82	135.108	44.79	7.32	125.951	44.79	5.42	125.968
46.43	5.14	136.707	46.43	9.73	133.921	46.43	7.63	128.525	46.43	5.13	126.026
48.07	4.87	135.027	48.07	9.23	129.461	48.07	7.54	130.941	48.07	5.28	128.031
49.71	4.39	139.881	49.71	9.69	131.619	49.71	7.46	129.989	49.71	5.61	123.792
51.35	4.44	134.791	51.35	9.35	130.105	51.35	7.67	130.213	51.35	5.35	125.100
52.99	4.05	132.371	52.99	7.97	127.474	52.99	7.14	129.388	52.99	5.14	126.119
54.63	4.25	129.137	54.63	7.97	129.475	54.63	7.14	131.529	54.63	5.16	124.549

Table B.6 (continued)

May 9 1998											
Distance from the Right Bank - 4											
1797			2031			2456			2656		
Depth	Vel	G.Dr	Depth	Vel	G.Dr	Depth	Vel	G.Dr	Depth	Vel	G.Dr
7.05	9.70	130.336	7.05	11.00	131.554	7.05	8.75	117.931	7.35	4.89	145.777
8.69	9.74	129.784	8.69	11.00	130.959	8.69	8.73	118.320	8.69	5.23	145.141
10.34	9.11	129.545	10.34	11.15	131.205	10.34	8.61	140.952	10.34	5.37	144.727
11.98	9.21	129.387	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	131.256	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	146.422
16.90	9.76	131.825	16.90	11.22	133.744	16.90	8.55	137.232	16.90	5.28	146.113
18.54	9.37	130.841	18.54	10.84	132.633	18.54	8.87	136.354	18.54	5.49	142.521
20.18	9.45	133.382	20.18	11.29	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	137.399	23.46	5.16	139.347
25.10	9.80	129.855	25.10	11.22	130.147	25.10	8.43	136.994	25.10	5.01	137.363
26.74	9.15	127.832	26.74	11.10	131.573	26.74	8.50	133.354	26.74	5.41	139.786
28.38	9.36	130.645	28.38	11.05	132.123	28.38	8.61	139.987	28.38	5.60	136.422
30.02	9.56	133.182	30.02	10.79	130.569	30.02	9.01	138.751	30.02	5.67	136.947
31.66	9.83	131.460	31.66	10.84	128.366	31.66	8.70	137.567	31.66	5.19	133.734
33.30	9.03	127.215	33.30	11.29	129.309	33.30	9.78	135.111	33.30	5.51	137.316
34.94	9.67	130.199	34.94	10.95	126.592	34.94	9.74	135.051	34.94	5.75	136.973
36.58	9.06	131.596	36.58	10.95	128.258	36.58	8.99	139.816	36.58	5.64	137.795
38.22	9.44	127.321	38.22	10.77	131.048	38.22	8.44	137.048	38.22	5.45	136.511
39.86	9.70	126.106	39.86	10.64	127.523	39.86	8.38	136.110	39.86	5.80	134.860
41.50	9.72	127.725	41.50	10.34	126.758	41.50	8.24	136.236	41.50	5.71	136.806
43.15	10.19	130.601	43.15	10.52	125.351	43.15	8.74	136.886	43.15	5.54	133.651
44.79	10.10	130.731	44.79	10.30	126.325	44.79	8.52	134.198	44.79	6.02	136.512
46.43	10.25	131.225	46.43	10.45	126.381	46.43	9.22	135.692	46.43	6.12	135.782
48.07	9.22	135.225	48.07	10.49	126.648	48.07	9.24	137.198	48.07	5.94	135.447
49.71	10.19	136.039	49.71	10.32	125.114	49.71	8.99	137.898	49.71	5.90	136.168
51.35	10.24	136.039	51.35	10.16	124.290	51.35	8.75	138.632	51.35	6.13	139.658
52.99	9.36	137.075	52.99	9.57	122.230	52.99	9.22	135.495	52.99	6.25	136.954
54.63	9.39	139.579	54.63	9.36	121.212	54.63	8.37	134.155	54.63	6.11	137.110
56.27	9.86	136.302	56.27	9.30	122.980	56.27	9.18	136.550	56.27	6.01	133.352
57.91	10.36	135.913	57.91	9.41	125.813	57.91	8.28	138.287	57.91	6.15	132.340
59.55	9.65	137.315	59.55	9.45	125.135	59.55	8.54	138.577	59.55	6.21	131.510
61.19	9.25	125.128	61.19	9.06	125.480	61.19	9.37	140.126	61.19	5.87	132.917
62.83	9.50	132.521	62.83	9.28	123.477	62.83	9.46	138.446	62.83	5.92	131.136
64.47	9.20	133.020	64.47	9.02	122.655	64.47	8.89	137.607	64.47	5.04	130.304
66.11	10.24	132.111	66.11	8.54	125.014	66.11	8.89	136.914	66.11	5.41	131.241
67.75	9.97	131.951	67.75	8.90	126.135	67.75	8.28	135.215	67.75	5.58	129.391
69.39	9.96	131.725	69.39	8.56	127.168	69.39	9.14	136.305	69.39	5.57	131.154
71.03	10.17	132.961	71.03	8.31	130.535	71.03	8.86	137.146	71.03	5.50	130.813
72.67	9.80	132.760	72.67	8.07	129.239	72.67	8.98	138.406	72.67	5.02	130.813
74.31	10.25	132.627	74.31	7.75	126.925	74.31	8.99	133.955	74.31	5.07	127.582
75.95	10.33	134.730	75.95	7.96	130.136	75.95	9.29	134.156	75.95	5.01	125.199
77.59	10.28	137.174	77.59	8.06	127.308	77.59	9.22	137.358	77.59	4.86	125.258
79.23	10.26	139.970	79.23	8.33	129.681	79.23	9.65	133.303	79.23	3.31	121.645
80.87	9.45	141.144	80.87	7.96	126.817	80.87	8.74	135.395	80.87	3.80	130.815
82.51	9.32	144.603	82.51	7.96	127.334	82.51	7.53	131.844	82.51	4.49	127.226
84.15	9.30	146.275	84.15	8.43	130.425	84.15	7.57	134.175			
85.79	9.29	149.940	85.79	8.47	130.352	85.79	7.61	131.609			
87.43	8.94	142.739	87.43	8.36	131.275	87.43	6.32	135.346			
89.07	8.78	141.635	89.07	8.48	131.941						
90.71	8.91	138.984	90.71	8.20	126.373						
92.35	9.09	140.962	92.35	7.32	132.175						
94.00	9.32	144.151	94.00	7.48	131.287						
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	142.332	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	125.870						
103.84	7.63	140.588	103.84	1.94	114.647						
105.48	7.45	143.375									
107.12	8.43	142.100									
108.76	8.17	146.048									
110.41	7.95	146.074									
112.05	7.14	147.244									
113.69	6.75	152.328									
115.33	5.00	152.338									
116.97	2.35	154.255									

June 9 1998											
Distance from the Right Bank - 8											
1777			2089			2476			2956		
Depth	Vel	G.Dr	Depth	Vel	G.Dr	Depth	Vel	G.Dr	Depth	Vel	G.Dr
7.05	4.30	121.444	7.05	5.15	141.426	7.05	6.76	132.008	7.05	4.03	129.361
8.69	4.71	119.210	8.69	5.12	144.253	8.69	7.33	139.824	8.69	4.39	132.366
10.34	4.49	122.524	10.34	5.52	147.500	10.34	6.66	132.132	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	125.827
15.26	4.38	118.504	15.26	5.04	138.196	15.26	6.54	125.635	15.26	4.73	125.505
16.90	4.15	118.936	16.90	4.72	141.402	16.90	6.67	129.632	16.90	4.70	121.886
18.54	4.32	122.144	18.54	4.87	141.919	18.54	6.85	126.612	18.54	4.64	126.576
20.18	4.45	125.916	20.18	5.05	140.548	20.18	6.71	127.555	20.18	4.40	123.640
21.82	4.88	124.011	21.82	5.08	145.756	21.82	7.46	129.412	21.82	4.79	122.858
23.46	4.80	123.864	23.46	4.81	144.154	23.46	7.31	127.536	23.46	4.54	126.757
25.10	4.62	122.010	25.10	4.15	147.240	25.10	6.85	130.997	25.10	4.76	125.056
26.74	5.13	120.172	26.74	4.31	144.272	26.74	6.62	130.218	26.74	4.71	124.548
28.38	4.78	115.852	28.38	3.68	140.247	28.38	6.91	123.037	28.38	4.61	120.900
30.02	5.15	118.605	30.02	4.26	141.622	30.02	6.51	129.291	30.02	4.56	123.295
31.66	5.34	120.662	31.66	4.04	148.670	31.66	6.56	132.710	31.66	4.92	123.905
33.30	5.30	122.137	33.30	3.89	148.285	33.30	6.34	135.042	33.30	4.47	128.025
34.94	5.12	122.601	34.94	4.25	148.285	34.94	6.79	130.968	34.94	4.31	126.140
36.58	4.93	126.283	36.58	4.14	147.644	36.58	6.55	131.138	36.58	4.25	123.844
38.22	4.36	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	146.517	39.86	6.82	128.221	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	126.842
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	5.22	130.521	44.79	4.60	139.759	44.79	6.57	124.483	44.79	4.29	121.779
46.43	4.35	132.251	46.43	4.85	137.524	46.43	6.35	127.410	46.43	4.34	

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	166 698	59 55	4 51	121 271	59 55	6 36	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	136 600	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			3211			4730			4730		
Depth	Vel	G Dr	Depth	Vel	G Dr	Depth	Vel	G Dr	Depth	Vel	G Dr
7.05	4.82	197.745	7.35	6.98	209.989	7.55	7.29	205.962	7.05	4.11	240.590
8.69	4.72	200.528	8.69	6.96	205.858	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	207.961	10.34	3.99	250.525
11.98	4.51	205.186	11.98	6.69	210.463	11.98	7.19	206.940	11.98	4.50	255.380
13.62	4.43	197.630	13.62	7.12	208.685	13.62	7.50	205.432	13.62	4.11	254.223
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	4.35	241.980
18.54	5.21	203.545	18.54	7.10	208.265	18.54	7.31	206.325	18.54	4.46	244.227
20.19	4.76	204.515	20.19	6.36	208.390	20.19	6.93	210.206	20.19	4.43	244.304
21.82	4.67	203.794	21.82	6.66	210.222	21.82	6.91	207.137	21.82	5.27	238.388
23.46	4.48	211.827	23.46	6.63	208.395	23.46	6.69	206.829	23.46	5.17	237.752
25.10	4.77	205.401	25.10	6.91	208.441	25.10	6.46	203.965	25.10	5.38	240.402
26.74	4.74	209.651	26.74	7.55	206.253	26.74	6.35	203.982	26.74	5.39	238.100
28.38	4.38	196.258	28.38	7.20	210.454	28.38	6.33	204.599	28.38	4.95	236.948
30.02	4.55	203.258	30.02	6.61	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	206.952	31.66	4.95	236.936
33.30	4.27	209.543	33.30	7.17	205.170	33.30	6.57	208.946	33.30	4.94	238.829
34.94	3.71	204.910	34.94	6.53	202.711	34.94	6.53	207.608	34.94	4.94	238.829
36.58	4.59	192.015	36.58	6.66	205.630	36.58	6.30	214.071	36.58	5.25	232.216
38.22	3.90	197.571	38.22	6.77	208.850	38.22	6.18	215.139	38.22	5.17	235.089
39.86	4.39	205.186	39.86	6.54	207.863	39.86	6.53	213.355	39.86	4.80	239.433
41.50	3.91	199.379	41.50	6.56	208.748	41.50	6.06	212.554	41.50	4.91	225.000
43.15	3.93	201.975	43.15	6.37	210.899	43.15	5.77	212.371	43.15	4.74	226.116
44.79	3.01	187.450	44.79	6.32	206.954	44.79	6.31	212.381	44.79	4.39	232.745
46.43	2.54	194.646	46.43	6.48	205.475	46.43	6.32	211.229	46.43	4.64	233.307
48.07	2.03	153.834	48.07	6.36	207.757	48.07	6.71	213.985	48.07	4.61	230.516
			49.71	6.19	201.203	49.71	6.36	210.943	49.71	4.53	238.908
			51.35	6.19	207.177	51.35	6.73	213.938	51.35	4.52	234.516
			52.99	5.78	205.256	52.99	6.68	215.181	52.99	4.55	235.167
			54.63	6.01	203.121	54.63	6.74	213.307	54.63	4.40	234.135
			56.27	6.00	208.373	56.27	6.75	212.656	56.27	4.48	234.183
			57.91	5.79	206.652	57.91	7.10	208.362	57.91	4.21	233.652
			59.55	5.97	207.198	59.55	6.75	207.873	59.55	3.75	233.671
			61.19	5.97	210.794	61.19	6.30	209.340	61.19	3.50	237.294
			62.83	5.72	210.252	62.83	6.61	207.572	62.83	3.42	237.258
			64.47	5.50	212.875	64.47	6.79	205.330	64.47	3.96	240.297
			66.11	5.65	211.078	66.11	6.49	207.912	66.11	4.35	230.990
			67.75	5.00	210.132	67.75	6.46	207.696	67.75	3.63	232.261
			69.39	4.98	203.962	69.39	6.30	207.395	69.39	3.75	234.466
			71.03	4.55	201.691	71.03	6.30	202.650	71.03	3.69	233.814
			72.67	4.33	197.531	72.67	6.41	203.252	72.67	3.81	232.036
			74.31	3.69	187.510	74.31	6.27	205.513	74.31	3.19	218.443
			75.95	2.75	176.020	75.95	5.47	207.979	75.95	3.53	220.925
						77.59	5.47	207.297	77.59	3.46	221.950
						79.23	5.44	207.156	79.23	3.30	222.198
						80.87	4.37	207.430	80.87	2.90	221.241
						82.51	4.41	200.656	82.51	2.70	220.911
						84.15	4.64	210.686	84.15	3.17	224.664
						85.79	4.29	212.958	85.79	3.27	214.200
						87.43	3.77	187.558	87.43	3.43	184.932
						89.07	4.46	194.349	89.07	2.33	220.310
										3.72	233.616

March 23, 1998											
Distance from the Right Bank (ft)											
3218			3225			4012			4743		
Depth	Vel	G Dr	Depth	Vel	G Dr	Depth	Vel	G Dr	Depth	Vel	G Dr
7.05	3.44	212.660	7.05	6.46	204.468	7.05	6.08	206.745	7.05	3.78	223.467
8.69	3.72	205.776	8.69	6.10	201.135	8.69	6.15	209.218	8.69	3.86	216.537
10.34	3.88	204.936	10.34	6.40	201.619	10.34	5.80	204.061	10.34	3.56	217.952
11.98	3.56	210.901	11.98	6.34	200.612	11.98	6.68	201.838	11.98	3.05	220.204
13.62	3.63	209.205	13.62	6.66	204.671	13.62	6.03	206.286	13.62	2.95	224.814
15.26	3.44	203.779	15.26	6.16	202.765	15.26	6.23	206.072	15.26	2.95	229.525
16.90	3.31	210.935	16.90	6.21	201.329	16.90	5.96	203.421	16.90	2.87	214.832
18.54	3.43	209.954	18.54	6.48	204.866	18.54	5.62	207.746	18.54	2.23	221.122
20.19	3.84	216.625	20.19	6.31	205.619	20.19	5.94	205.644	20.19	2.28	214.011
21.82	3.30	207.326	21.82	6.53	204.725	21.82	6.66	206.387	21.82	2.57	220.125
23.46	3.41	210.680	23.46	6.49	205.399	23.46	5.91	206.466	23.46	2.44	226.389
25.10	3.69	206.988	25.10	6.56	204.730	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	213.277
28.38	3.15	209.361	28.38	6.60	201.762	28.38	6.07	209.073	28.38	2.91	218.720
30.02	3.25	207.334	30.02	6.33	204.189	30.02	6.02	209.361	30.02	2.67	222.587
31.66	3.03	211.478	31.66	6.70	204.230	31.66	6.29	208.062	31.66	3.10	216.344
33.30	2.90	223.100	33.30	6.35	205.330	33.30	6.29	212.988	33.30	2.91	211.274
34.94	2.91	219.911	34.94	6.55	207.361	34.94	6.55	213.340	34.94	2.49	214.380
36.58	2.98	227.360	36.58	6.56	209.409	36.58	6.41	214.064	36.58	2.13	213.374
38.22	2.44	226.391	38.22	6.47	207.331	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	213.396
41.50	2.95	225.505	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	209.667	43.15	6.58	208.111	43.15	3.43	211.516
44.79	2.34	223.464	44.79	6.20	205.236	44.79	6.27	210.605	44.79	3.75	206.135
46.43	2.05	218.998	46.43	6.20	209.477	46.43	6.80	205.476	46.43	3.96	202.398
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	143.929	49.71	5.52	206.164	49.71	6.95	206.190	49.71	3.90	203.287
51.35	1.34	142.510	51.35	5.81	203.883	51.35	6.79	210.195	51.35	3.72	203.424
52.99	2.44	141.110	52.99	6.85	204.247	52.99	6.41	213.348	52.99	3.63	206.394
			54.63	6.15	205.131	54.63	6.07	211.532	54.63	3.41	205.399
			56.27	5.79	209.549	56.27	6.48	209.421	56.27	3.15	205.396
			57.91	5.59	207.813	57.91	6.37	211.242	57.91	3.51	202.642
			59.55	5.79	207.160	59.55	6.39	210.721	59.55	3.15	208.107
			61.19	5.68	214.710	61.19	6.45	214.328	61.19	3.50	197.959
			62.83	6.01	211.164	62.83	6.49	216.137	62.83	3.65	199.736
			64.47	5.77	212.115	64.47	6.52	211.819	64.47	3.45	198.138
			66.11	5.66	217.275	66.11	6.30	211.255	66.11	3.16	204.261
			67.75	5.57	211.287	67.75	6.19	210.255	67.75	3.21	204.075
			69.39	5.79	214.492	69.39	6.19	211.548	69.39	3.11	202.135
			71.03	6.02	219.216	71.03	5.68	210.548	71.03	3.80	204.896
			72.67	5.53	215.813	72.67	5.67	211.657	72.67	3.55	209.159
			74.31	4.75	214.110	74.31	5.66	206.272	74.31	3.36	207.567
			75.95	4.51	216.544	75.95	5.77	202.424	75.95	3.42	205.006
			77.59	4.56	216.388	77.59	5.62	202.411	77.59	3.11	206.553

Table B.7 (continued)

April 10, 1998											
Distance from the Right Bank (ft)											
4095											
Depth	Vel	G Dr	Depth	Vel	G Dr	Depth	Vel	G Dr	Depth	Vel	G Dr
7.95	4.14	214.710	7.95	1.15	204.072	7.95	7.51	204.090	7.05	4.52	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	205.969
11.98	3.80	219.571	11.98	6.94	205.620	11.98	7.07	206.173	11.98	4.14	207.945
13.62	4.21	221.270	13.62	6.77	205.396	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	208.661
16.90	4.01	214.562	16.90	6.62	203.706	16.90	7.46	204.152	16.90	3.92	207.356
18.54	3.62	216.849	18.54	6.58	206.872	18.54	7.86	203.567	18.54	3.75	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	213.599
23.46	4.37	226.064	23.46	6.94	207.968	23.46	7.85	203.221	23.46	3.80	207.560
25.10	3.92	223.238	25.10	6.99	206.965	25.10	7.50	204.334	25.10	3.30	210.956
26.74	4.01	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	2.56	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	211.627	36.58	7.20	208.304	36.58	3.30	195.938
38.22	3.06	228.912	38.22	6.73	209.525	38.22	7.35	207.686	38.22	3.06	200.089
39.86	2.57	230.494	39.86	6.73	213.341	39.86	6.89	204.478	39.86	2.95	199.363
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	3.38	243.452	43.15	6.99	206.650	43.15	6.81	206.824	43.15	2.95	202.869
44.79	2.19	234.931	44.79	6.87	209.015	44.79	6.33	207.295	44.79	2.30	201.717
46.43	2.31	234.452	46.43	6.63	211.198	46.43	6.43	205.819	46.43	2.74	204.722
48.07	1.96	233.062	48.07	6.46	211.009	48.07	6.60	208.112	48.07	3.19	201.758
			49.71	6.76	212.379	49.71	6.66	209.304	49.71	3.40	197.998
			51.35	7.37	212.798	51.35	6.80	211.229	51.35	3.36	205.869
			52.99	7.11	212.072	52.99	6.36	207.834	52.99	2.73	208.259
			54.63	6.56	213.114	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	202.337
			57.91	6.81	212.008	57.91	6.06	216.442	57.91	2.95	208.776
			59.55	6.74	215.168	59.55	5.76	216.302	59.55	3.09	205.204
			61.19	6.73	211.700	61.19	5.65	218.000	61.19	3.35	205.908
			62.83	7.12	213.214	62.83	5.49	217.521	62.83	3.49	207.323
			64.47	7.19	213.562	64.47	5.85	213.664	64.47	3.42	208.089
			66.11	7.05	211.394	66.11	5.11	215.260	66.11	3.95	205.543
			67.75	7.06	216.217	67.75	5.01	218.115	67.75	3.43	201.590
			69.39	7.30	219.431	69.39	4.82	217.861	69.39	3.25	208.941
			71.03	6.86	214.136	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	6.81	210.152	74.31	5.11	221.747	74.31	3.96	212.974
			75.95	6.38	210.132	75.95	5.12	220.996	75.95	3.14	211.906
			77.59	4.39	208.229	77.59	5.32	219.476	77.59	3.24	216.759
			79.24	4.78	211.534	79.24	5.35	217.793	79.24	3.45	212.989
			80.88	1.98	210.337	80.88	5.48	222.366	80.88	3.40	224.395
						82.52	4.94	214.920	82.52	3.19	225.793
						84.16	5.31	216.667	84.16	3.62	226.517
						85.80	5.07	214.594	85.80	3.09	222.868
						87.44	4.57	217.240	87.44	2.74	224.906
						89.08	4.90	217.607	89.08	2.67	214.794
						90.72	4.88	214.042	90.72	2.13	217.294
						92.36	4.40	214.684	92.36	2.65	211.727
						94.00	4.19	218.548	94.00	2.35	199.826
						95.64	4.19	220.371	95.64	2.22	207.132
						97.28	4.00	216.522	97.28	1.38	204.017
						98.92	3.12	237.382	98.92	1.21	232.880
						100.56	1.96	259.141	100.56	1.13	241.119

April 17, 1998											
Distance from the Right Bank (ft)											
3159			3626			4131			4695		
Depth	Vel	G Dr	Depth	Vel	G Dr	Depth	Vel	G Dr	Depth	Vel	G Dr
7.05	4.68	200.622	7.05	6.37	202.590	7.05	5.56	205.036	7.05	3.49	209.484
9.69	4.67	199.429	9.69	6.30	207.134	9.69	5.70	205.736	9.69	3.79	209.190
10.34	4.36	207.612	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	204.225	13.62	5.40	207.540	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	213.088
16.90	4.43	203.182	16.90	6.00	206.807	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	210.650	18.54	3.75	209.724
20.18	5.20	199.406	20.18	5.49	205.697	20.18	5.11	206.801	20.18	3.89	211.569
21.82	4.00	205.641	21.82	6.04	205.451	21.82	4.93	207.308	21.82	3.68	216.704
23.46	3.83	195.689	23.46	6.12	208.152	23.46	5.24	208.989	23.46	3.53	210.038
25.10	3.57	194.215	25.10	5.99	206.636	25.10	5.35	214.578	25.10	3.52	211.247
26.74	3.69	197.582	26.74	5.94	202.649	26.74	5.27	212.790	26.74	3.15	220.601
28.38	4.76	202.257	28.38	5.52	200.590	28.38	5.19	206.206	28.38	3.65	211.619
30.02	3.43	197.707	30.02	5.79	203.616	30.02	5.47	204.444	30.02	3.42	211.625
31.66	3.34	201.215	31.66	5.56	205.593	31.66	5.31	207.320	31.66	3.38	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	205.606	34.94	3.74	214.206
36.58	3.49	198.578	36.58	6.00	209.173	36.58	5.61	211.398	36.58	3.47	213.782
38.22	3.26	198.945	38.22	5.55	208.445	38.22	5.52	209.121	38.22	3.68	216.847
39.86	3.23	194.699	39.86	5.81	206.405	39.86	5.77	205.078	39.86	4.07	213.729
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	3.27	206.565	43.15	5.97	202.773	43.15	5.44	207.763	43.15	4.12	210.996
44.79	2.49	200.229	44.79	5.60	204.715	44.79	5.90	209.798	44.79	3.95	214.579
46.43	2.00	203.491	46.43	5.74	210.301	46.43	5.57	206.490	46.43	3.94	207.353
48.07	1.32	205.668	48.07	5.72	208.005	48.07	5.70	205.624	48.07	3.74	210.506
			49.71	5.72	207.520	49.71	5.57	206.342	49.71	3.45	206.760
			51.35	5.88	206.306	51.35	5.88	212.148	51.35	3.66	205.119
			52.99	5.72	205.869	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	1.31	207.182	57.91	5.86	209.439	57.91	3.86	211.036
			59.55	6.18	204.850	59.55	5.56	207.140	59.55	3.93	212.056
			61.19	5.71	204.612	61.19	5.36	206.981	61.19	3.76	212.969
			62.83	5.61	209.762	62.83	5.31	207.024	62.83	4.03	206.958
			64.47	5.66	206.298	64.47	5.77	203.827	64.47	3.91	213.950
			66.11	5.56	210.424	66.11	5.34	204.607	66.11	3.55	204.462
			67.75	5.40	207.702	67.75	5.34	207.226	67.75	4.22	209.174
			69.39	5.37	212.856	69.39	5.25	207.767	69.39	4.31	211.442
			71.03	4.91	209.593	71.03	5.56	207.353	71.03	3.96	211.949
			72.67	4.54	211.106	72.67	6.40	206.466	72.67	3.57	208.585
			74.31	4.6	212.730	74.31	4.87	210.961	74.31	3.15	204.008
			75.95	4.41	213.214	75.95	5.02	211.331	75.95	3.47	202.396
			77.60	4.52	210.771	77.60	5.32	215.351	77.60	4.11	203.967
			79.24	3.92	205.043	79.24	4.79	219.676	79.24	3.58	207.832
			80.88	4.04	204.671	80.88	4.54	219.421	80.88	3.90	206.590
			82.52	3.87	208.753	82.52	4.29	219.474	82.52	3.35	213.019
			84.16	3.37	206.651	84.16	4.31	216.726	84.16	2.73	211.730
			85.80	2.91	208.183	85.80	4.43	214.476	85.80	3.08	213.985
			87.44	2.44	206.739	87.44	4.73	220.360	87.44	2.82	217.563
			89.08	1.11	205.278	89.08	4.66	216.462	89.08	2.66	196.645
			90.72	1.98	207.438	90.72	4.02	219.371	90.72	2.99	202.606
			92.36	1.91	209.632	92.36	3.62	220.881	92.36	2.01	225.993
						94.00	2.31	221.370			
						95.64	3.39	220.736			
						97.28	2.21	219.679			

Table B.7 (continued)

June 9 1998											
Distance from the Right Bank (ft.)											
3197			3785			4093			4733		
Depth	Vel	Q Dr	Depth	Vel	Q Dr	Depth	Vel	Q Dr	Depth	Vel	Q Dr
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	2.75	198.349
11.98	4.02	214.858	11.98	5.06	204.121	11.98	5.75	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	205.182
15.26	3.45	212.271	15.26	5.95	207.876	15.26	6.34	196.963	15.26	2.23	199.370
16.90	3.65	221.099	16.90	5.95	205.780	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	198.933	23.46	2.46	212.926
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	208.899	26.74	4.96	199.825	26.74	5.73	196.724	26.74	2.30	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	2.74	204.201
31.66	1.64	204.254	31.66	5.20	206.872	31.66	6.03	198.346	31.66	2.73	210.688
33.30	1.53	214.564	33.30	5.23	207.481	33.30	6.03	198.918	33.30	2.66	210.853
			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	2.94	204.955
			44.79	4.56	204.905	44.79	6.44	198.361	44.79	3.18	204.757
			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	212.364
			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	5.77	202.620	54.63	2.48	213.249
			56.27	4.71	200.318	56.27	5.70	202.630	56.27	2.92	202.917
			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	4.36	213.357	62.83	5.55	197.053	62.83	2.85	207.154
			64.47	3.71	212.973	64.47	5.95	197.408	64.47	2.92	211.503
			66.11	3.63	210.137	66.11	5.47	196.970	66.11	3.34	208.305
			67.75	3.80	196.808	67.75	5.55	195.499	67.75	2.91	219.403
			69.39	3.22	193.923	69.39	5.00	202.429	69.39	2.98	212.379
			71.03	3.58	193.642	71.03	5.33	202.666	71.03	3.10	204.730
			72.67	2.78	200.213	72.67	5.32	197.339	72.67	3.30	211.238
						74.31	4.75	202.352	74.31	3.21	210.351
						75.95	4.78	203.395	75.95	2.97	206.331
						77.59	4.78	200.937	77.59	2.75	210.482
						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	2.30	203.365	82.52	2.12	197.548
						84.16	1.51	208.528	84.16	1.45	202.369

August 3 1998											
Distance from the Right Bank (ft.)											
3204			3785			4108			4665		
Depth	Vel	Q Dr	Depth	Vel	Q Dr	Depth	Vel	Q Dr	Depth	Vel	Q Dr
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	2.77	209.498
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	3.05	197.405	11.98	4.39	205.283	11.98	3.63	206.774	11.98	2.07	221.526
13.62	2.74	210.381	13.62	4.33	200.124	13.62	3.80	214.705	13.62	1.76	209.394
15.26	2.72	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	202.895	18.54	3.60	229.552	18.54	2.35	206.708
20.18	3.57	194.483	20.18	3.82	193.678	20.18	3.55	221.295	20.18	1.95	217.282
21.82	2.29	164.190	21.82	3.74	196.383	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	216.970
			26.74	3.33	199.453	26.74	3.19	226.125	26.74	2.23	219.678
			28.38	2.92	205.729	28.38	2.72	243.950	28.38	2.04	212.719
			30.02	3.67	198.419	30.02	2.92	229.469	30.02	2.56	217.833
			31.66	3.13	202.214	31.66	2.95	230.625	31.66	3.16	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	240.305
			36.58	3.13	195.608	36.58	3.32	221.234	36.58	1.40	237.630
			38.22	3.22	198.214	38.22	3.70	224.589	38.22	1.93	228.997
			39.86	3.07	204.484	39.86	4.05	222.143	39.86	1.70	213.250
			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	233.657
			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	1.15	242.347
			49.71	3.05	205.296	49.71	3.72	217.052	49.71	1.43	236.193
			51.35	3.37	206.515	51.35	3.00	219.275	51.35	1.35	245.433
			52.99	2.94	203.248	52.99	3.07	221.497	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
									57.91	3.00	203.737
									59.55	3.12	217.642
									61.19	2.84	213.819
									62.83	2.62	221.699
									64.47	2.47	214.936
									66.11	2.67	221.615
									67.75	2.12	210.620
									69.39	2.01	212.989
									71.03	2.01	208.819
									72.67	1.55	224.143
									74.31	0.87	205.305
									75.95	0.64	205.125
									77.59	1.35	99.559

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

February 27 1998											
Distance from the Right Bank (ft)											
1417			2304			2797			3409		
Depth	Vel	Q Dr	Depth	Vel	Q Dr	Depth	Vel	Q Dr	Depth	Vel	Q Dr
7.05	3.87	258.109	7.05	8.00	249.997	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	7.97	246.481	10.34	5.25	246.957	10.34	4.84	255.486
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	257.555	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	258.896	21.82	7.75	247.956	21.82	4.43	246.616	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	262.394	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	3.52	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	3.67	253.040	34.94	4.74	247.572
36.58	3.42	266.424	36.58	7.95	245.720	36.58	4.73	253.466	36.58	4.92	246.356
38.22	3.47	262.804	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	247.362	43.15	3.68	244.897
44.79	2.96	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	253.136			
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 Dr	Depth	Vel	Q Dr	Depth	Vel	Q Dr	Depth	Vel	Q Dr
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	246.505
11.98	3.73	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	239.302
21.82	2.97	244.822	21.82	6.69	263.809	21.82	7.07	246.136	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	240.733
25.10	2.91	246.793	25.10	6.68	263.394	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	6.68	264.149	28.38	6.21	243.611	28.38	6.21	244.423
30.02	3.21	246.565	30.02	6.40	262.514	30.02	6.17	242.971	30.02	6.39	240.657
31.66	2.98	251.625	31.66	6.31	266.660	31.66	6.26	243.328	31.66	6.09	246.445
33.30	2.72	247.672	33.30	5.81	262.956	33.30	5.26	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	236.793
38.22	2.66	249.287	38.22	6.33	263.512	38.22	6.66	242.332	38.22	5.29	229.593
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	267.786	41.50	6.04	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	227.474
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	1.39	249.104				52.99	2.39	217.122			
54.63	1.36	246.644				54.63	1.92	174.027			
56.27	1.71	256.017				56.27	1.88	188.453			

April 10 1998											
Distance from the Right Bank (ft)											
1371			2129			2730			3368		
Depth	Vel	Q Dr	Depth	Vel	Q Dr	Depth	Vel	Q Dr	Depth	Vel	Q Dr
7.05	4.85	255.738	7.05	5.39	256.086	7.05	6.42	249.204	7.05	5.56	251.342
8.69	4.52	255.792	8.69	5.54	257.479	8.69	6.83	250.659	8.69	5.26	245.235
10.34	4.29	260.298	10.34	5.29	253.508	10.34	6.16	248.737	10.34	5.47	246.396
11.98	4.52	257.772	11.98	5.16	250.873	11.98	6.06	249.426	11.98	5.16	247.987
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	254.966	15.26	4.94	257.741	15.26	6.37	247.355	15.26	5.30	240.260
16.90	4.18	258.320	16.90	5.06	258.954	16.90	6.47	250.076	16.90	5.24	245.954
18.54	4.11	252.288	18.54	4.94	263.924	18.54	6.54	250.956	18.54	5.26	244.739
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	251.036	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	256.190	28.38	5.88	250.645	28.38	5.33	238.531
30.02	4.36	255.765	30.02	4.04	255.575	30.02	5.77	248.956	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	240.922
34.94	4.10	251.037	34.94	3.96	263.046	34.94	5.19	246.773	34.94	4.84	245.173
36.58	4.21	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	255.325	38.22	5.17	246.085	38.22	4.96	247.203
39.86	4.42	254.002	39.86	4.16	258.050	39.86	4.75	241.149	39.86	5.05	248.406
41.50	4.38	256.060	41.50	3.99	258.994	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	4.86	239.036	44.79	3.72	261.789
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	4.05	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	4.79	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			

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	252.902
10.34	4.33	232.045	10.34	8.38	250.345	10.34	7.63	248.547	10.34	4.84	251.312
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	7.38	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	246.686
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	8.27	253.761	30.02	6.86	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	250.937
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	235.532	38.22	7.63	256.621	38.22	7.41	252.686	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	2.32	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	6.67	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	259.302			
56.27	3.94	246.515				56.27	4.27	255.409			
57.91	3.65	244.519									
59.55	3.31	229.735									
61.19	2.14	210.421									
62.83	1.67	211.756									

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	255.683	7.05	4.21	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	238.177
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	249.052	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	256.900	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	256.509	30.02	3.41	261.300	30.02	4.17	238.114
31.66	3.95	246.389	31.66	3.67	248.275	31.66	3.78	256.819	31.66	4.14	242.237
33.30	3.71	241.360	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	239.884
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	254.838	38.22	2.27	257.786			
39.86	2.57	257.931	39.86	2.48	259.180	39.86	1.16	258.480			
41.50	2.98	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	250.036	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	248.729	10.34	3.36	253.351
11.98	4.08	253.998	11.98	4.38	256.806	11.98	3.54	256.330	11.98	3.44	252.845
13.62	4.08	254.179	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	253.341	18.54	4.15	248.409	18.54	3.21	254.987	18.54	3.21	258.126
20.18	3.56	242.657	20.18	4.04	245.726	20.18	3.04	255.024	20.18	2.98	242.328
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 LANCING	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 (F')	.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 31.5 123.6 147.9 149.7 149.9 150.0
% 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 99.9 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 0.0
(SAMPLE)		
FIELD NO.	2	
DISTANCE (FT.)	1658	
DEPTH (F')	.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 52.8 116.1 124.0 124.7 124.7 124.8
% 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 99.9 100.0
% FINER	100.0	100.0 100.0 100.0 100.0 100.0 100.0 100.0 99.3 94.0 57.7 7.0 6.6 3.1 0.1 0.1 0.0
(SAMPLE)		
FIELD NO.	3	
DISTANCE (FT.)	2256	
DEPTH (F')	.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 6.5 6.5 6.5 6.5 6.5 9.1 22.6 97.7 144.6 149.3 149.8 149.8 149.8
% HELD	0.0	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
% FINER	100.0	100.0 100.0 95.7 95.7 95.7 95.7 95.7 95.7 93.9 84.9 34.6 3.3 0.3 0.0 0.0 0.0
(SAMPLE)		
FIELD NO.	4	
DISTANCE (FT.)	2941	
DEPTH (F')	.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	5.9 39.6 58.2 100.0 137.6 236.7 268.7 274.5 338.2 380.5 395.1 393.4 393.5 393.5 393.6 393.6
% HELD	0.0	4.0 0.1 4.8 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
% FINER	100.0	95.0 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

[illegible]

Table B.9 (continued)

DATE: 16 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	150.0
% 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	98.6	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	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	0.0	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	0.0	0.1	9.3	61.3	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)			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	0.1	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	96.3	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	100.0	99.9	98.7	90.7	25.1	3.7	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	2.2	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	12.9	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	0.0	3.1	3.7	12.1	61.7	116.5	140.5	143.3	149.9	149.9	150.0	150.0
% HELD		0.0	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
% FINER		100.0	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
(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	0.0	0.1	1.2	12.7	112.0	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	0.1	0.8	6.5	74.7	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	99.9	99.2	91.5	25.3	1.3	0.1	0.1	0.1	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	149.9	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	86.8	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	99.6	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	99.1	91.2	24.0	3.7	0.2	0.1	0.1	0.0	0.0

Table B.9 (continued)

DATE: 08-MAY-98				RIVER CONDITION: 3000				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 0.36 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											
% 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											
% 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											
(SAMPLE)											
FIELD NO: 18											
DISTANCE (FT): 1662											
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 0.36 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											
% 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											
% 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											
(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 0.36 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											
% 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											
% 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											
(SAMPLE)											
FIELD NO: 20											
DISTANCE (FT): 2959											
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 0.36 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 38.2 114.8 148.2 149.6 149.8 149.9 149.9 150.0											
% 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 99.3 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 0.0											

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 HCT				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	0.3	18.6	103.7	126.8	145.4	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	0.2	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	99.8	87.6	30.9	15.5	3.1	0.5	0.2	0.1	0.0	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	0.9	3.6	29.8	113.9	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	0.6	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	99.4	97.6	80.1	20.1	2.1	0.2	0.1	0.0	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	145.6	147.3	149.6	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	15.6	75.3	93.2	97.5	99.2	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	0.4	0.1	0.1	0.0	0.0
(SAMPLE)																						
FIELD NO: 24																						
DISTANCE (FT): 2923																						
DEPTH (FT): 45																						
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	0.8	4.3	16.9	78.4	132.9	147.8	149.4	149.9	149.9	150.0	150.0	150.0	
% HELD:				0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	2.9	11.3	52.3	88.5	96.5	99.6	99.9	99.9	100.0	100.0	
% FINER:				100.0	100.0	100.0	100.0	100.0	100.0	99.5	97.1	86.7	47.7	11.5	3.5	0.4	0.1	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 BEC 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 957,119 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	3.2	16.7	33.0	42.1	48.6	99.9		
% MELD	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		
% MELD	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		
% MELD	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	0.3	36.8	126.7	147.6	149.6	150.0	150.0	150.0	150.0		
% MELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	3.2	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	99.8	74.1	15.5	1.5	0.1	0.0	0.0	0.0	0.0		

DATE: 23 MAR 98	RIVER COORDINATION CHIPPY	TYPE SAMPLER CRAG BUCKE*
STREAM MISSISSIPPI RIVER	TIME 12 30 TO 14 15	*TYPE SAMPLES BED MATERIAL
LOCATION LINE #13 DWS OF HYDRO INTAKE CH	TEMP 9 C @ 10 FT	NO VERTICALS 4
GAGE KNOX LANDING	WEATHER WINDY AND MILD	NO POINTS
DISCHARGE 865,124 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 0.36 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 42.9 108.6 142.2 148.0 149.3 149.2 150.0
% 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 .5 .3 0.0

(SAMPLE)	
FIELD NO	5
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 0.36 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 .2 .0 .0 0.0

(SAMPLE)	
FIELD NO	7
DISTANCE (FT)	2499
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 0.36 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 38.6 137.6 147.5 149.9 150.0 150.0 150.0
% 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 95.1 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 1.1 .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 0.36 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 0.5 3.0 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 0.1 0.3 2.3 26.5 97.1 98.8 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 99.7 97.7 23.5 2.9 .2 .0 .0 .0 0.0

Table B.10 (continued)

DATE: 16 APR 98		RIVER CONDITION: GOOD										TYPE SAMPLER: DRAG BUCKET									
STREAM: MISSISSIPPI RIVER		TIME: 13:5 TO 14:15										TYPE SAMPLES: BED MATERIAL									
LOCATION: LINE #13 D/S OF HYDRO NTAKE 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	0.0	0.1	0.1	7.6	39.9	113.5	146.2	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	0.1	5.1	26.6	75.7	97.5	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	99.9	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	0.0	7.6	40.9	114.4	146.2	149.4	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	5.1	27.3	76.3	97.5	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	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	0.0	3.8	30.6	87.3	136.3	148.9	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	2.5	20.4	58.2	92.2	99.3	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): 2669																					
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	22.9	134.1	147.9	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	0.1	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 NTAKE CH		TEMP: 16 C @ 1.5 FT										NO VERTICALS: 4									
GAGE: KNOX LANDING		WEATHER: CLOUDY AND RAIN										NO POINTS: 1									
DISCHARGE: 998,752 CFS (ADCP)		GAGE READING: 50.50 FT																			
(SAMPLE)																					
FIELD NO: 13																					
DISTANCE (FT): 1796																					
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	4.7	4.7	13.5	120.9	1136.6	139.9	142.0	143.8	147.3	149.6	150.0		
% HELD		0.0	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		
% FINER		100.0	100.0	100.0	100.0	100.0	100.0	96.9	96.9	91.0	19.4	9.9	6.7	5.3	4.1	1.8	0.3	0.0	0.0		
(SAMPLE)																					
FIELD NO: 14																					
DISTANCE (FT): 2038																					
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	0.0	0.3	5.7	21.6	112.9	136.6	147.9	149.4	149.9	150.0		
% HELD		0.0	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		
% FINER		100.0	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		
(SAMPLE)																					
FIELD NO: 16																					
DISTANCE (FT): 2634																					
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	0.0	0.3	5.7	21.6	112.9	136.6	147.9	149.4	149.9	150.0		
% HELD		0.0	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		
% FINER		100.0	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		

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 JUNE #13 D/S OF HYDRO INTAKE CH		TEMP 19.0 @ 10 FT										NO VERTICALS 4									
GAGE KNOX LANDING		WEATHER CLEAR AND WARM										NO POINTS 1									
DISCHARGE 1120.828 CFS (ADCP)		GAGE READING 54.25 FT																			
(SAMPLE)																					
FIELD NO 17																					
DISTANCE (FT) 1767																					
DEPTH (FT) 17.4																					
DIA (MM)		25.40	19.10	12.70	9.52	4.76	3.36	2.00	1.41	1.00	0.50	0.36	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	150.0		
% 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	0.36	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	0.36	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	54.8	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) 2866																					
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	0.36	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																					
STREAM MISSISSIPPI RIVER		RIVER CONDITION CHOPPY										TYPE SAMPLER DRAG BUCKET									
LOCATION JUNE #13 D/S OF HYDRO INTAKE CH		TIME 12 30 TO 13 35										TYPE SAMPLES BED MATERIAL									
GAGE KNOX LANDING		TEMP 26.0 @ 10 FT										NO VERTICALS 4									
DISCHARGE 566.002 CFS (ADCP)		WEATHER CLOUDY AND HOT										NO POINTS 1									
GAGE READING 40.30 FT																					
(SAMPLE)																					
FIELD NO 21																					
DISTANCE (FT) 771																					
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	0.36	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	150.0		
% HELD		0.0	0.0	0.0	0.0	2.5	4.5	7.3	9.7	17.1	73.1	81.5	86.3	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	18.5	13.7	0.2	0.1	0.1	0.0	0.0	0.0		
(SAMPLE)																					
FIELD NO 22																					
DISTANCE (FT) 2099																					
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	0.36	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	149.9	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	92.5	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	7.5	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	0.36	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	130.3	146.6	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	0.1	0.9	9.4	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	99.9	90.6	59.7	11.8	0.9	0.2	0.1	0.0	0.0		
(SAMPLE)																					
FIELD NO 24																					
DISTANCE (FT) 2866																					
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	0.36	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	30.8	129.6	146.6	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	0.1	0.7	60.5	96.4	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	3.6	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	150.0			
% 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	96.6	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	36.9	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: 9.0 @ 10 FT		NO VERTICALS: 4															
GAGE: KNOX LANDING		WEATHER: CLOUDY AND MILD		NO POINTS: *															
DISCHARGE: 793.520 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	0.0	6.2	37.1	94.7	117.9	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	0.0	5.0	29.7	75.9	94.2	99.1	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	95.0	70.3	24.2	5.8	0.7	0.1	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	0.0	0.8	12.7	30.5	82.5	136.9	148.7	149.7	149.7	149.9	
% HELD	0.0	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	100.0	
% FINER	100.0	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	0.0	
(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	0.0	1.9	2.7	9.6	14.5	146.8	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	1.3	1.5	6.1	94.3	97.7	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	98.7	98.5	93.9	5.7	2.3	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	0.0	0.0	1.3	26.3	92.8	112.1	136.1	143.4	
% 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	0.9	16.9	81.9	74.8	90.2	95.7	
% 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	99.1	83.1	18.1	25.2	7.8	4.3	
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: 9.0 @ 10 FT		NO VERTICALS: 4															
GAGE: KNOX LANDING		WEATHER: WINDY AND MILD		NO POINTS: *															
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	9.1	95.8	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	146.1	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	2.7	32.8	95.9	96.8	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	4.1	3.2	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	122.2	145.8	149.5	149.7	149.8	149.9	
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	1.3	12.3	66.2	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	99.9	98.7	87.7	33.8	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	0.0	0.0	

Table B.11 (continued)

DATE: 16 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 1/2 S OF AUA		TEMP: 16.0 @ 1.5 FT		NO VERTICALS: 4															
GAGE: #NOX LANDING		WEATHER: CLEAR AND MILD		NO POINTS: 1															
DISCHARGE: 956.51 CFS (ADCP)		GAGE READING: 52.35 FT																	
REPORTED: 964.000 CFS																			
(SAMPLE)																			
FIELD NO: 9																			
DISTANCE (FT): 3203																			
DEPTH (FT): 49																			
DA (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	0.086	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	16.6	62.3	123.5	146.4	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	11.1	41.5	52.4	37.5	99.6	99.3	99.9	100.0	
% FNER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	98.9	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																			
DA (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	0.086	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	5.3	12.6	25.8	143.3	149.7	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	3.5	9.4	50.5	95.5	99.6	100.0	100.0	
% FNER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.9	99.8	95.5	91.6	49.5	4.5	0.2	0.0	0.0	0.0	
(SAMPLE)																			
FIELD NO: 11																			
DISTANCE (FT): 4095																			
DEPTH (FT): 100																			
DA (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	0.086	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	5.4	22.2	52.1	134.4	147.9	149.5	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	3.6	14.6	54.7	95.5	99.6	99.7	100.0	
% FNER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.9	99.9	95.4	95.2	45.3	10.4	1.4	0.3	0.2	0.1	
(SAMPLE)																			
FIELD NO: 12																			
DISTANCE (FT): 4676																			
DEPTH (FT): 100																			
DA (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	0.086	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	6.1	27.1	99.9	137.4	149.4	149.5	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	4.5	18.1	53.9	91.5	98.9	99.9	100.0	
% FNER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.9	99.9	95.5	91.9	40.1	8.4	1.1	0.2	0.1	0.0	
(SAMPLE)																			
FIELD NO: 13																			
DISTANCE (FT): 3759																			
DEPTH (FT): 49																			
DA (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	0.086	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	5.5	59.6	126.9	144.8	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	3.1	39.9	55.9	96.5	99.7	99.3	99.9	100.0	
% FNER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	98.3	50.1	14.1	3.5	0.3	0.1	0.1	0.0	0.0	
(SAMPLE)																			
FIELD NO: 14																			
DISTANCE (FT): 3926																			
DEPTH (FT): 92																			
DA (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	0.086	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	1.2	2.0	3.5	29.0	55.4	117.7	143.9	148.6	
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	1.3	2.3	13.3	16.9	19.5	95.4	99.2	
% FNER	100.0	100.0	100.0	100.0	100.0	100.0	99.9	99.2	98.7	97.7	95.1	53.1	21.5	4.1	0.8	0.4	0.1	0.0	
(SAMPLE)																			
FIELD NO: 15																			
DISTANCE (FT): 4731																			
DEPTH (FT): 91																			
DA (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	0.086	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	1.4	6.6	17.5	30.5	136.6	149.0	149.9	
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	10.7	25.4	51.9	97.5	99.5	99.8	100.0	
% FNER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.9	99.3	99.3	54.6	19.1	2.5	0.5	0.2	0.2	0.1	0.0	
(SAMPLE)																			
FIELD NO: 16																			
DISTANCE (FT): 4636																			
DEPTH (FT): 92																			
DA (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	0.086	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	1.4	6.6	17.5	30.5	136.6	149.0	149.9	
% HELD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.9	5.9	15.3	51.7	93.1	99.3	99.9	
% FNER	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.9	99.1	99.1	54.1	51.7	38.3	5.9	0.7	0.1	0.1	0.0	

Table B.11 (continued)

DATE: 05 JUN 98		RIVER CONDITION: CHOPPY		TYPE SAMPLER: DRAG BUCKET															
STREAM: MISSISSIPPI RIVER		TIME: 15:25 TO 16:30		TYPE SAMPLES: BED MATERIAL															
LOCATION: LINE #6 D/S OF AUX		TEMP: 25.0 @ 10 FT		NO VERTICALS: 4															
GAGE: KNOX LANDING		WEATHER: CLOUDY AND HOT		NO POINTS: *															
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	4.75	3.36	2.00	1.41	1.00	0.50	0.36	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	65.9	97.9	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	41.1	2.2	0.7	0.3	0.1	0.0
(SAMPLE)																			
FIELD NO: 18																			
DISTANCE (FT): 3796																			
DEPTH (FT): 70																			
DIA (MM)		25.40	19.10	12.70	9.52	4.75	3.36	2.00	1.41	1.00	0.50	0.36	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	25.6	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	4.75	3.36	2.00	1.41	1.00	0.50	0.36	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	86.5	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	12.1	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): 4793																			
DEPTH (FT): 84																			
DIA (MM)		25.40	19.10	12.70	9.52	4.75	3.36	2.00	1.41	1.00	0.50	0.36	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	150.0	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
(SAMPLE)																			
FIELD NO: 21																			
DISTANCE (FT): 5204																			
DEPTH (FT): 21																			
DIA (MM)		25.40	19.10	12.70	9.52	4.75	3.36	2.00	1.41	1.00	0.50	0.36	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	149.9	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	76.3	95.5	99.2	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	95.9	71.8	23.7	4.5	0.8	0.2	0.1	0.1	0.0
(SAMPLE)																			
FIELD NO: 22																			
DISTANCE (FT): 5795																			
DEPTH (FT): 56																			
DIA (MM)		25.40	19.10	12.70	9.52	4.75	3.36	2.00	1.41	1.00	0.50	0.36	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	39.6	133.7	146.6	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	0.0	0.6	5.3	59.3	95.1	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): 6106																			
DEPTH (FT): 76																			
DIA (MM)		25.40	19.10	12.70	9.52	4.75	3.36	2.00	1.41	1.00	0.50	0.36	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	8.8	139.2	141.3	146.9	149.7	149.9	149.9	150.0
% HELD		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	5.9	72.1	84.2	95.1	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	99.8	94.1	27.9	14.8	4.7	0.4	0.1	0.1	0.0
(SAMPLE)																			
FIELD NO: 24																			
DISTANCE (FT): 6523																			
DEPTH (FT): 19																			
DIA (MM)		25.40	19.10	12.70	9.52	4.75	3.36	2.00	1.41	1.00	0.50	0.36	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	129.1	144.4	149.0	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	6.8	26.1	95.6	96.3	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	93.4	73.9	4.4	3.7	0.4	0.2	0.1	0.1	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 LG		WEATHER CLOUDY AND MILD										NO POINTS 1									
DISCHARGE 782 140 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	0.0	0.2	0.3	34.8	133.0	149.1	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	0.1	0.2	23.2	88.7	99.5	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	99.9	99.8	76.8	11.3	0.5	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	0.0	0.6	13.1	121.5	147.1	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	0.4	8.7	81.0	96.1	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	99.6	91.3	19.0	3.9	0.1	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	0.3	2.7	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	0.3	1.4	8.7	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																					
STREAM MISSISSIPPI RIVER		RIVER CONDITION CHOPPY										TYPE SAMPLER DRAG BUCKET									
LOCATION TARBERT		TIME 17 30 TO 18 00										TYPE SAMPLES BED MATERIAL									
GAGE TARBERT		TEMP 9 C @ 10 FT										NO VERTICALS 4									
DISCHARGE 981 783 CFS (ADCP)		WEATHER WINDY AND MILD										NO POINTS 1									
		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	29.7	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	57.7	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	0.0	1.9	27.7	133.5	147.8	149.7	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	1.3	8.5	69.0	96.5	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	100.0	98.7	81.5	11.0	1.5	0.2	0.1	0.1	0.0		
(SAMPLE)																					
FIELD NO		8																			
DISTANCE (FT)		3375																			
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	2.4	24.5	113.7	146.5	149.1	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	0.0	2.3	6.4	75.5	97.4	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	99.8	94.7	24.5	2.6	0.5	0.1	0.1	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 847 668 CFS (ADCP)			GAGE READING 50 90 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 0.0 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 0.0 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 0.0 0.0 0.1 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 0.0 0.0 0.1 2.0 56.1 92.4 99.3 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 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 0.0 0.0 0.3 32.9 120.1 146.4 149.7 149.9 150.0 150.0																			
% HELD 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 1.5 21.9 80.1 97.6 99.8 99.9 100.0 100.0																			
% FINER 100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0 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 0.0 0.0 0.0 0.9 30.5 110.5 139.8 147.3 148.8 149.6 150.0																			
% HELD 0.0 0.0 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 99.9 100.0																			
% FINER 100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0 100.0 99.4 79.7 26.3 6.9 1.4 0.8 0.3 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 PNG			WEATHER CLOUDY AND RAIN										NO POINTS 1						
DISCHARGE 799 303 CFS (ADCP)			GAGE READING 45 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 0.0 0.1 13.1 111.3 144.4 149.5 149.9 150.0 150.0																			
% HELD 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 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) 2190																			
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 0.0 0.2 12.6 109.7 143.9 148.9 149.6 149.9 150.0																			
% HELD 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.1 9.4 73.1 95.9 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 99.9 91.5 26.9 4.1 0.7 0.3 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 0.0 0.0 0.0 0.0 0.9 5.5 110.7 142.7 149.3 149.9 150.0 150.0																			
% HELD 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.6 3.7 73.8 95.1 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 99.4 36.3 26.2 4.9 0.5 0.1 0.1 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 0.0 0.0 0.7 92.1 131.2 148.2 149.6 149.9 150.0 150.0																			
% HELD 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.4 54.7 87.5 98.6 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 99.6 45.3 12.5 1.2 0.3 0.1 0.1 0.0 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: 19.1 @ 10 FT	NO VERTICALS: 4
GAGE: TARBERT DISCHRG PNG	WEATHER: CLOUDY	NO POINTS: 1
DISCHARGE: 925,212 CFS (ADCP)	GAGE READING: 52.50 FT	

(SAMPLE)	
FIELD NO	17
DISTANCE (FT)	1367
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 0.36 0.25 0.177 0.125 0.098 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 22.6 102.8 144.5 143.0 149.4 149.7 150.0
% 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 58.5 96.3 99.3 99.6 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 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 0.36 0.25 0.177 0.125 0.098 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 0.36 0.25 0.177 0.125 0.098 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 0.36 0.25 0.177 0.125 0.098 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 69.1 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: 26.0 @ 10 FT	NO VERTICALS: 4
GAGE: TARBERT DISCHRG PNG	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 0.36 0.25 0.177 0.125 0.098 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 0.2 0.1 0.0 0.0

(SAMPLE)	
FIELD NO	22
DISTANCE (FT)	2186
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 0.36 0.25 0.177 0.125 0.098 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 79.9 120.4 146.6 149.2 149.8 149.9 150.0
% HELD	0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.1 0.1 0.5 62.5 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 39.5 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 0.36 0.25 0.177 0.125 0.098 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 93.7 133.8 149.7 149.8 149.9 149.9 150.0 150.0
% HELD	0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.2 56.8 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 10.9 0.2 0.1 0.1 0.1 0.0 0.0

(SAMPLE)	
FIELD NO	24
DISTANCE (FT)	3373
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 0.36 0.25 0.177 0.125 0.098 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 79.9 133.9 145.6 148.9 149.3 149.8 149.9 150.0
% HELD	0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.2 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 3.1 0.8 0.5 0.1 0.0 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)		1360																		
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. $\Delta \bar{C} / \Delta T$ 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 from the right bank (ft.)	FEB 27 Event				Distance from the right bank (ft.)	MAR 23 Event				Distance from the right bank (ft.)	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					
	CS	MS	FS	VFS		CS	MS	FS	VFS		CS	MS	FS	VFS		
1066	0.0400	0.0227	0.3968	0.2066	1020	0.0267	0.2986	0.7461	0.3887	1075	0.1910	0.7692	0.5008	0.2087		
1658	0.4483	0.4461	0.7544	0.3631	1755	0.1772	0.3645	0.7183	0.2903	1643	0.0514	0.7698	0.6036	0.3691		
2256	0.0143	0.7603	0.5208	0.2419	2274	0.4461	0.7243	0.5319	0.1814	2224	0.0773	0.6107	0.5613	0.2082		
2941	0.4542	0.5836	0.1995	0.0967	3091	0.5004	0.6283	0.3014	0.1354	2943	0.1186	0.4833	0.1969	0.1271		
Ave R_{um}	0.2320	0.4418	0.4679	0.2271	Ave R_{um}	0.5376	0.5039	0.5744	0.2490	Ave R_{um}	0.0596	0.6583	0.4632	0.2333		

Distance from the right bank (ft.)	APR 17 Event				Distance from the right bank (ft.)	MAY 8 Event				Distance from the right bank (ft.)	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					
	CS	MS	FS	VFS		CS	MS	FS	VFS		CS	MS	FS	VFS		
1040	0.5748	0.2321	0.3378	0.0695	1094	0.9880	0.7535	0.2482	0.1462	1047	0.0760	0.5237	0.3463	0.1622		
1648	0.1108	0.3454	0.5351	0.1148	1652	0.1659	0.5020	0.7742	0.3227	1613	0.7897	0.3129	0.3369	0.1206		
2247	0.1638	0.2640	0.5942	0.1771	2276	0.2126	0.4483	0.2639	0.0762	2235	0.1643	0.6647	0.8958	0.1895		
2966	0.1444	0.6396	0.3155	0.1653	2959	0.8239	0.6521	0.2835	0.0909	2923	0.1273	0.0807	0.0365	0.1611		
Ave R_{um}	0.9984	0.6203	0.4457	0.1317	Ave R_{um}	1.0475	0.5890	0.3925	0.1590	Ave R_{um}	0.7893	0.6455	0.3849	0.1584		

Distance from the right bank (ft.)	AUG 3 Event			
	Measured Rouse number values at 31 °C			
	Sand size fractions			
	CS	MS	FS	VFS
1030	0.0626	0.2540	0.6133	0.3948
1625	0.4860	0.7554	0.5477	0.1870
2229	0.2788	0.7894	0.3990	0.1535
2901	0.9206	0.3318	0.3561	0.2446
Ave R_{um}	0.9370	0.5327	0.4790	0.2450

Line 13

Distance from the right bank (ft.)	FEB 27 Event				Distance from the right bank (ft.)	MAR 23 Event				Distance from the right bank (ft.)	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					
	CS	MS	FS	VFS		CS	MS	FS	VFS		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	0.1156	0.1467	0.4171	0.1966		
2449	0.1562	0.4713	0.6619	0.4016	2453	0.1865	0.2962	0.5638	0.3171	2433	0.0019	0.0326	0.7804	0.2536		
2916	0.1001	0.0015	0.3819	0.3830	2890	0.1657	0.3515	0.5245	0.2067	2869	0.0255	0.0653	0.6772	0.2577		
Ave R_{um}	0.2288	0.3619	0.4260	0.2756	Ave R_{um}	0.1549	0.2493	0.3373	0.1777	Ave R_{um}	0.0426	0.9214	0.5615	0.2192		

Distance from the right bank (ft.)	APR 17 Event				Distance from the right bank (ft.)	MAY 8 Event				Distance from the right bank (ft.)	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					
	CS	MS	FS	VFS		CS	MS	FS	VFS		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	0.2035	0.7059	0.4496	0.2496		
2454	0.5622	0.4439	0.6924	0.2773	2456	0.0658	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	0.0904	0.5171	0.3357	2855	0.9504	0.0875	0.6093	0.5095		
Ave R_{um}	0.5226	0.5223	0.4354	0.1960	Ave R_{um}	0.6975	0.6074	0.3870	0.1961	Ave R_{um}	0.7368	0.4490	0.5842	0.3266		

Distance from the right bank (ft.)	AUG 3 Event			
	Measured Rouse number values at 31 °C			
	Sand size fractions			
	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_{um}	0.5881	0.5054	0.3702	0.2989

Table B.15 (continued)

Line 6

Distance from the right bank (ft.)	FEB 27 Event				Distance from the right bank (ft.)	MAR 23 Event				Distance from the right bank (ft.)	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					
	CS	MS	FS	VFS		CS	MS	FS	VFS		CS	MS	FS	VFS		
3211	0.1765	0.3651	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	0.6665	0.3069		
4090	0.3936	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_{gm}	0.1574	0.5137	0.5046	0.1865	Ave R_{gm}	0.5884	0.2895	0.3074	0.1878	Ave R_{gm}	0.7623	0.7822	0.5280	0.1858		

Distance from the right bank (ft.)	APR 17 Event				Distance from the right bank (ft.)	JUN 9 Event				Distance from the right bank (ft.)	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					
	CS	MS	FS	VFS		CS	MS	FS	VFS		CS	MS	FS	VFS		
3159	1.2140	1.1366	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	0.5042	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	0.9674	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	0.6602	4669	1.2083	0.9003	0.3691	0.1290		
Ave R_{gm}	0.3825	0.7125	0.3388	0.1426	Ave R_{gm}	0.4767	0.7327	0.4699	0.3025	Ave R_{gm}	0.1255	0.3235	0.3131	0.2001		

Tarbert

Distance from the right bank (ft.)	FEB 27 Event				Distance from the right bank (ft.)	MAR 23 Event				Distance from the right bank (ft.)	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					
	CS	MS	FS	VFS		CS	MS	FS	VFS		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	0.2363	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_{gm}	0.1281	0.3682	0.2160	0.2024	Ave R_{gm}	0.2162	0.5784	0.4855	0.2196	Ave R_{gm}	0.9951	0.5555	0.4327	0.1907		

Distance from the right bank (ft.)	APR 17 Event				Distance from the right bank (ft.)	MAY 8 Event				Distance from the right bank (ft.)	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					
	CS	MS	FS	VFS		CS	MS	FS	VFS		CS	MS	FS	VFS		
1365	0.0000	0.9294	0.3372	0.2239	1367	0.6564	1.0513	0.2874	0.3917	1377	0.7079	0.7462	0.5901	0.2024		
2160	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		
3362	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_{gm}	0.8037	0.6561	0.4452	0.1826	Ave R_{gm}	0.9090	0.6737	0.3886	0.2178	Ave R_{gm}	0.9536	0.5340	0.4171	0.1862		

Distance from the right bank (ft.)	AUG 3 Event			
	Measured Rouse number values at 31 °C			
	Sand size fractions			
	CS	MS	FS	VFS
1380	1.0146	0.1627	0.5394	0.3833
2186	0.1479	0.8210	0.7958	0.2480
2783	1.2979	0.5134	0.2967	0.1501
3390	0.3313	0.2681	0.2451	0.2316
Ave R_{gm}	0.6979	0.3599	0.4668	0.2558

APPENDIX C – FIGURES

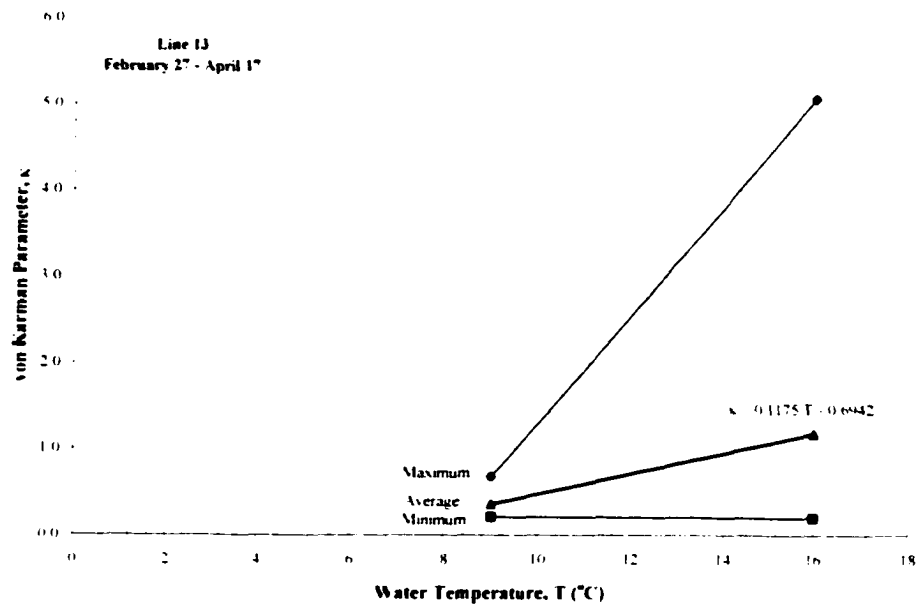


Figure C.1. The effect of water temperature on the von Karman parameter for approximately same discharge events at Line 13.

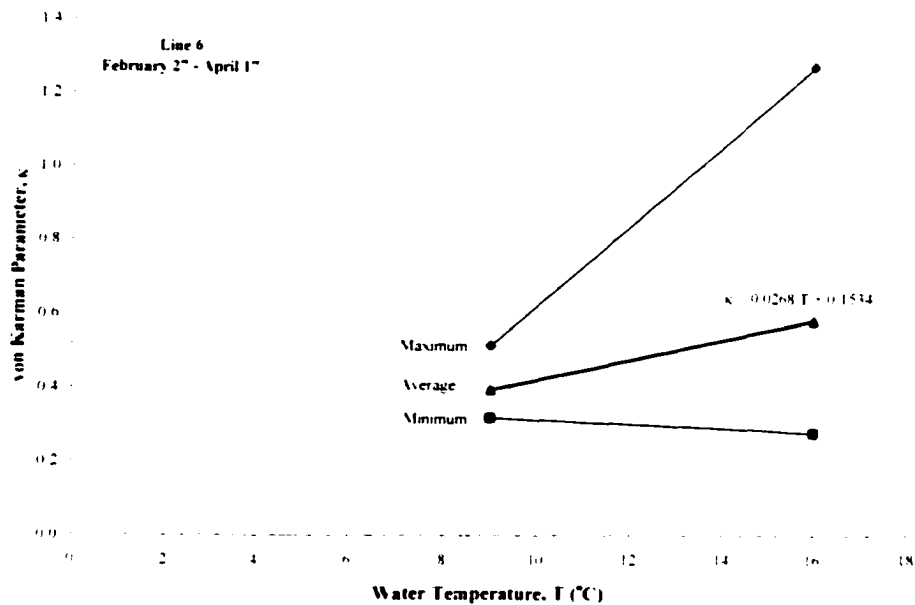


Figure C.2. The effect of water temperature on the von Karman parameter for approximately same discharge events at Line 6.

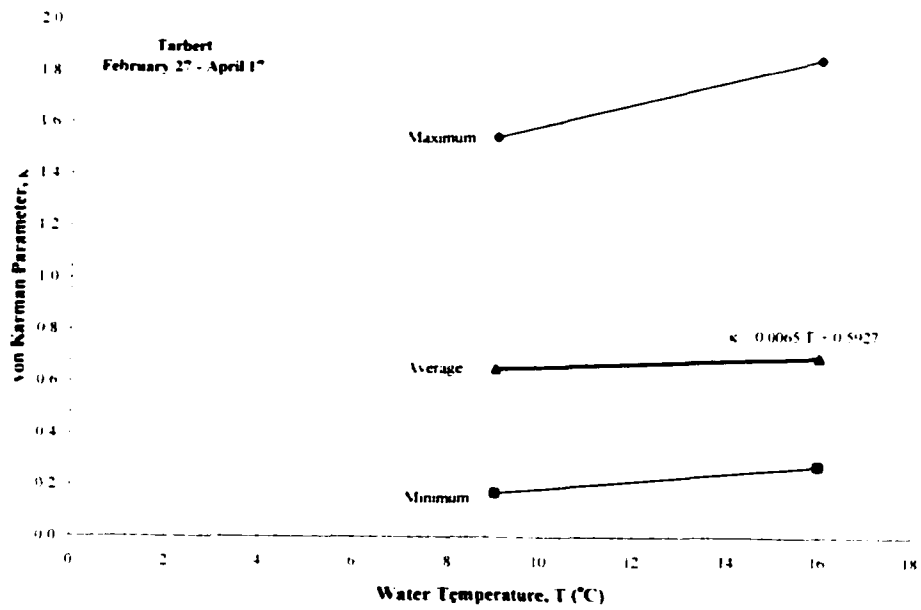


Figure C.3. The effect of water temperature on the von Karman parameter for approximately same discharge events at Tarbert.