HYDROLOGIC, SEDIMENTOLOGIC, AND CHEMICAL DATA DESCRIBING SURFICIAL BED SEDIMENTS IN THE NAVIGATION POOLS OF THE UPPER MISSISSIPPI RIVER, AFTER THE FLOOD OF 1993

Edited by John A. Moody

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BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY

Gordon P. Eaton, Director

For additional information write to:

Chief, Branch of Regional Research
U.S. Geological Survey
Box 25046, MS 418
Denver Federal Center
Denver, CO 80225

Copies of this report can be purchased from:

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OVERVIEW

Surficial bed-sediment samples were collected from the navigation pools (Pools 1-26) in the Upper Mississippi River between July 1991 and April 1992 before the flood of 1993. The purpose was to assess the longitudinal distribution of inorganic and organic compounds in the surficial sediments. This study assesses the longitudinal distribution of inorganic and organic compounds in surficial bed sediments collected after the flood of 1993, using the same procedures. In both studies a single composite sample was collected from each pool by combining samples from 12 to 23 individual sampling sites. Subsamples were taken from this composite sample for sediment characteristics and for organic chemical analyses of sterols, polynuclear aromatic hydrocarbons, linear alkylbenzene sulfonates, organochlorines, and polychlorinated biphenyls. Bed-sediment cores were also collected from the 12 to 23 individual sampling sites, composited in the laboratory, and then analyzed for major and trace elements. This was a cooperative study with the National Biological Service, which collected samples for bioaccumulation tests, biotoxicity tests, and additional chemical analyses. Their results are published in other reports.

Concentration of chemical compounds in the surficial bed sediments was greatest in fine-grain sediments. The median particle diameter of the sediment ranged from 0.002 millimeter (Pool 4, Lake Pepin) to 0.419 millimeter (Pool 20). Fine-grain sediment (median diameter less than 0.063 millimeter) was found generally in the upstream pools (2, 4, 9, 11, 12, and 13) but some was found in downstream pools (19, 25, and 26). Thus, generally, the maximum concentration of chemical compounds and elements was greatest in upstream pools: organic carbon was 3.79 percent in Pool 4, coprostanol was 4.41 milligrams per kilogram (mg/kg) in Pool 9, total polynuclear aromatic hydrocarbons were 5.28 mg/kg in Pool 1, linear alkylbenzene sulfonates were 1.07 mg/kg in Pool 13, technical chlordane was 2 nanogram per gram (ng/g) in Pools 4 and 21, polychlorinated biphenyls were 92.8 ng/g in Pool 4 (Lake Pepin), lead was 32 and 48 micrograms per gram (μg/g) in Pools 4 and 12, and mercury was 0.191 μg/g in Pool 2. However, the maximum concentration of dieldrin was 0.7 ng/g in Pool 26, the pool that is farthest downstream.

ACKNOWLEDGMENTS

Collecting surficial bed-sediment samples from all the navigation pools of the Upper Mississippi River after the flood is definitely a job which involved many people. The captains, Craig LeBoeuf and Wayne Simoneaux, and the crew of the research vessel *Acadiana* from the Louisiana University Marine Consortium, Cheryl Blanchard, Wilton Delaune, Mike Detraz, Derral Dupre, Chuck Guidry, and Jonathan Landry, provided excellent field support for other members of the sampling crews, Ron Antweiler, LaDonna Bishop, Terry Brinton, John Garbarino, Gary Johnson, Deborah Martin, Bob Meade, Ted Noyes, Dale Peart, Dave Roth, and Jeff Writer. Harold Wiegner from the Minnesota Pollution Control Agency designed and built the sediment corer used for collecting samples for inorganic analyses. Theodore Young of Sandwich, Massachusetts, designed and built the van Veen sampler. The research vessel itself served as a floating laboratory, and more than once, as an excellent refuge from severe and violent weather. Eric Brunson, from the Biologic Resources Division, was extremely cooperative in helping to plan and execute the field sampling after the flood and in providing the biological information. Funding for field collection and some chemical analyses was provided by the U.S. Environmental Protection Agency's Office of Water.

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CONVERSION FACTORS AND ABBREVIATIONS

Multiply	*By*	*To obtain*
	Length	
angstrom (Å)	3.937×10^{-9}	inch
centimeter (cm)	0.3937	inch
micrometer (µm)	0.00003937	inch
millimeter (mm)	0.03937	inch
meter (m)	3.281	foot
kilometer (km)	0.6214	mile
	Area	
square meter (m^2)	10.76	square foot
square kilometer (km^2)	0.3861	square mile
	Volume	
milliliter (mL)	0.03382	ounces, fluid
liter (L)	0.2642	gallon
cubic meter (m^3)	35.31	cubic foot
	Flow	
centimeter per second (cm/s)	0.03281	foot per second
meter per second (m/s)	3.281	foot per second
cubic meter per second (m^3/s)	35.31	cubic foot per second
cubic meter per year (m^3/yr)	35.31	cubic foot per year
hour per kilometer (h/km)	0.6214	hour per mile
	Mass	
milligram (mg)	0.00003527	ounce, avoirdupois
gram (g)	0.002205	pound, avoirdupois
metric ton	2,205	pound, avoirdupois

Degree Celsius (°C) may be converted to degree Fahrenheit (°F) by using the following equation:

$$F = 1.8\ (°C) + 32$$

The following terms and abbreviations also were used in these chapters:

atomic mass unit (amu)
electron volts (eV)
gram per milliliter (g/mL)
megohms per centimeter (Mohm/cm)
microangstrom (µA)
microgram (µg)
microliter (µL)
microgram per liter (µg/L)
microgram per gram (µg/g)
micrometer (µm)
microsiemens per centimeter (µS/cm)
milligrams per liter (mg/L)
milligram per kilogram (mg/kg)
nanogram per liter (ng/L)
nanogram per gram (ng/g)
normal (N)
parts per million (ppm)
parts per billion (ppb)
picogram (pg)
revolutions per minute (rpm)
torr

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)--a geodetic datum derived from a general adjustment of the first-order level nets of both the Unied States and Canada, formerly called Sea Level Datum of 1929.

CHAPTER 1 - Sampling Strategy, Hydrology, and Sediment Characteristics

By John A. Moody

ABSTRACT

Twenty-nine navigation pools are present along the reach of the Mississippi River from Minneapolis, Minnesota, to St. Louis, Missouri. A representative composite surficial bed-sediment sample was collected from the downstream one-third of 24 of the 29 navigation pools during a research cruise to assess the distribution of sewage-derived contaminants, selected organic contaminants, and major and trace elements after the flood of 1993 on the Upper Mississippi River. The particle-size distribution of a subsample of surficial bed sediment from each pool was determined by sieve, visual-accumulation tube, and SediGraph methods. Bulk chemistry (percent nitrogen, carbonate carbon, total carbon, total organic carbon, and total volatile solids) was determined for a second subsample of the surficial bed sediment.

The hydraulic conditions present at the time the surficial bed-sediment samples were collected were measured, and about 40 percent of the water discharge was measured outside the navigation channel in backwater areas ranging from 0.3 to 3.0 meters deep. The water velocities in the backwater areas were about 60 percent of the velocities in the navigation channel. Flushing rates ranged from 0.3 hour per kilometer to about 1.7 hours per kilometer. The median particle diameter of the surficial bed sediments ranged from 0.002 millimeter to 0.419 millimeter, and the organic carbon associated with these sediments ranged from 0.12 to 3.79 percent.

INTRODUCTION

The major hydraulic characteristic of the Upper Mississippi River is the series of locks and dams that create pools along its reach. Because the navigation pools are known to trap and store sediments and their associated pollutants, the U.S. Geological Survey (USGS) has undertaken studies of the Upper Mississippi River as part of a larger assessment of the environmental status of the entire Mississippi River. Twenty-nine locks and dams form 29 navigation pools on the Mississippi River between Minneapolis, Minn., and St. Louis, Mo. The first navigation pool (Pool 19, see table 1.1 and fig. 1.1) was formed behind a lock and dam built across the Mississippi River at Keokuk, Iowa, for electrical power generation in 1913 (Tweet, 1984; Whitacre, 1992). The second and third pools were formed by the construction of Lock and Dam 1 in 1917 at Minneapolis, Minn., and by Lock and Dam 2 in 1930 at Hastings, Minn., which provided 4.5- and 6-ft navigation channels (U.S. Army Corps of Engineers, 1988a).

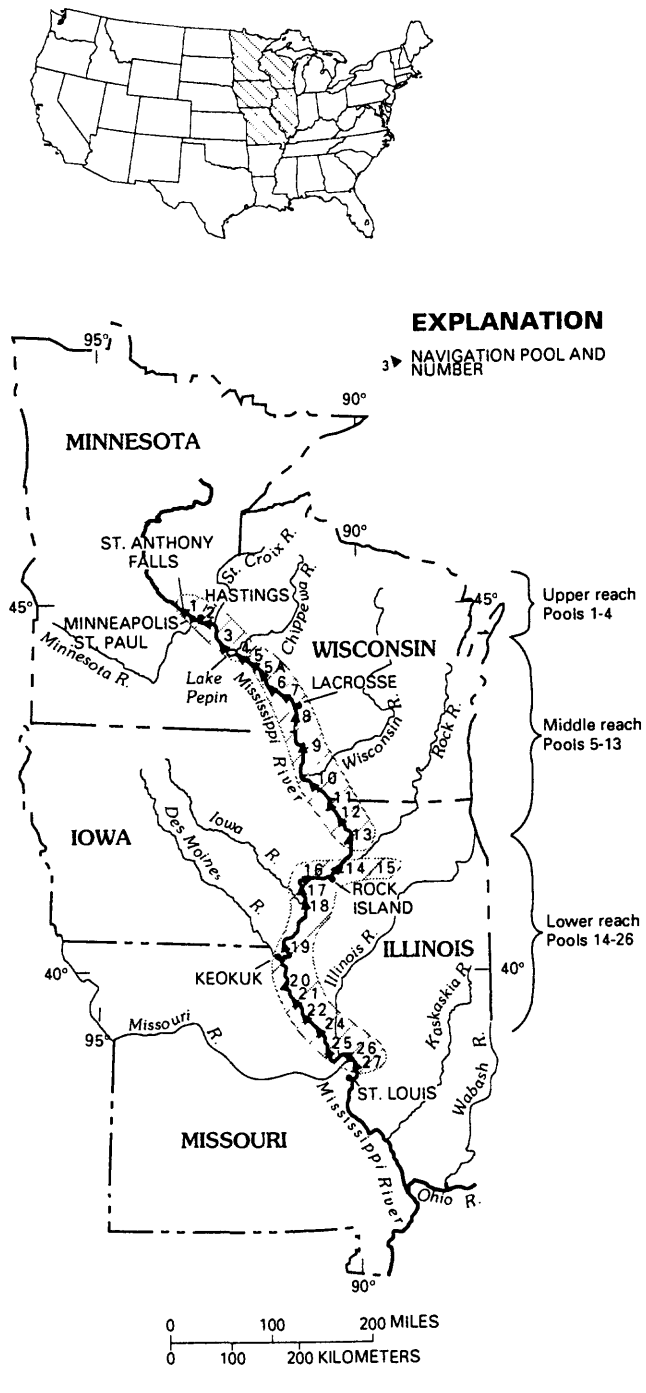


Figure 1.1--Location of navigation pools upstream from dams on the Upper Mississippi River. Cities are shown are solid circles and lock and dams as solid triangles.

Twenty-three additional pools (there is no Pool 23, but there is a Pool 5A) were formed by construction of locks and dams for the 9-foot channel project between Minneapolis, Minn., and St. Louis, Mo., in the 1930's. The 9-foot channel was extended upstream in Minneapolis, and two small pools (1.0 and 19 km long) were formed when the Lower and Upper St. Anthony Falls Lock and Dams were finished in 1963, making navigation possible around the 23-m-high St. Anthony Falls. The last lock and dam downstream, near St. Louis, Mo. (Lock and Dam 27), was completed in 1964, just downstream from the confluence of the Mississippi and Missouri Rivers. Lock and Dam 26, downstream from the confluence of the Mississippi and Illinois Rivers, was demolished and replaced in 1990 by the larger Melvin Price Lock and Dam, completing the series of 29 pools (Whitacre, 1992).

The system of navigation pools covers 36 percent of the reach of the Mississippi River from Minneapolis, Minn., to the Gulf of Mexico. The mean annual water discharge increases about twenty-fold from Minneapolis (230 m^3/s), at the beginning of the pool reach, to St. Louis (5,100 m^3/s), at the end of the pool reach.

The average length of the navigation pools is about 40 km, and approximately 8 percent of the surface area of the pools is maintained as a 9-foot navigation channel, leaving about 92 percent of the pool area as backwater areas with typical depths between 0.5 and 1.5 m. The average width-to-length ratio of the upper pools (Pools 1–15) is about twice the ratio of the lower pools (Pools 16–26), reflecting the general narrowing of the Mississippi River Valley in the downstream direction.

A navigation pool can be divided into three morphologically distinct regions (fig . 1.2). The first region (riverine) is immediately downstream from the preceding dam, where the flow is confined in a relatively narrow channel. The second region (deltaic) is characterized by several channels or sloughs that branch off from the navigation channel and return to the channel farther downstream. This deltaic region consists of numerous islands, which often bifurcate in the downstream direction, sheltering quiescent bays that face downstream out of the main current velocity. The third region (lacustrine) is characterized by the broad open water just upstream from the dam. These three types of regions produce a complex, heterogeneous benthic environment within each pool in contrast to the homogeneous (mostly medium to fine sand) benthic environment of the free-flowing lower Mississippi River downstream from St. Louis. These regions also may have different retention times for contaminants associated with the water.

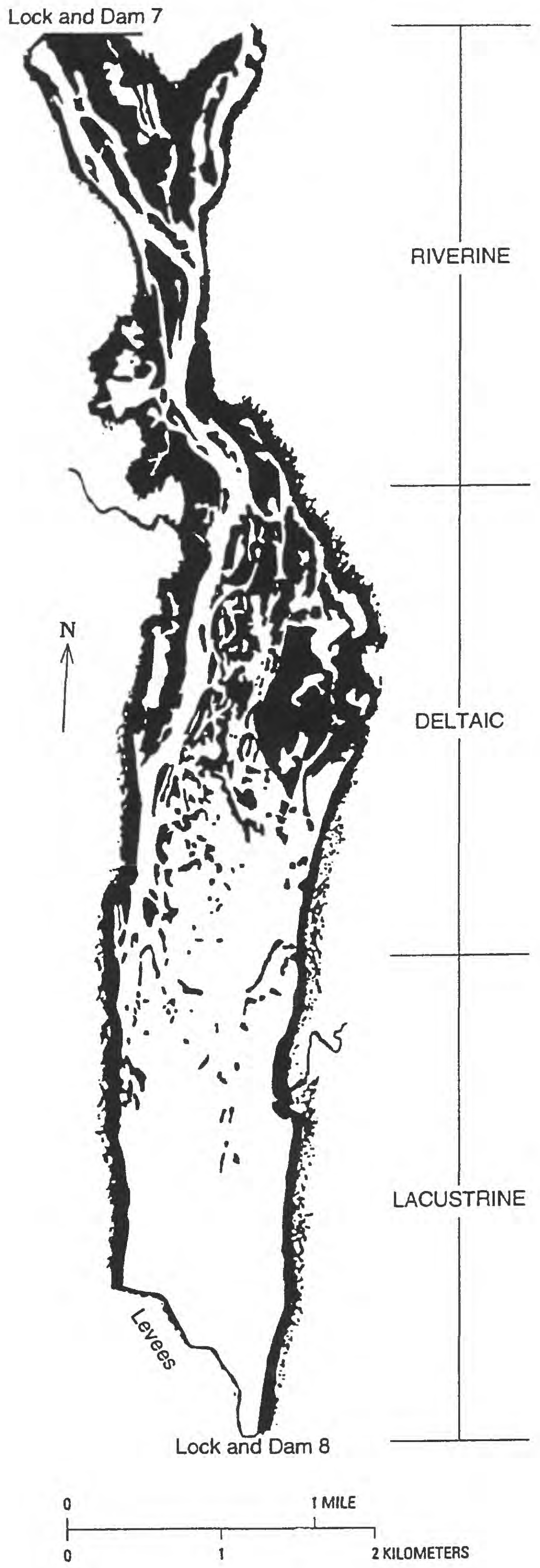


Figure 1.2--Typical navigation pool divided into three regions.

Table 1.1.--Physical and hydrologic characteristics of navigation pools in the Upper Mississippi River

[NGVD National Geodetic Vertical Datum of 1929; km, kilometers; m, meters, %, percent; m^3/s, cubic meter per second; T, tributaries that contribute less than 2 percent of the discharge of the Mississippi River are not listed; there is no Pool 23; NA, data not available; <, less than; --, not measured]

Pool	Length (km)	Project pool elevation above sea level	Surface area[1] (km^2)	Navigation channel area[2] (%)	Storage volume[3] ($10^6 m^3$)	Mean depth (m)	Mean annual discharge[4] (m^3/s)	Percentage of time at open river[5]	Tributary	
									Name	Percentage of discharge of Mississippi River down-stream from mouth of tributary[4]
1	10	221.0	2	50	NA	NA	230	NA		
2	53	209.5	48	11	85	1.8	340	1	Minnesota	34
3	29	205.7	[6]36	4	35	0.5	480	14	St. Croix	25
4	71	203.3	157	5	515	3.3	710	4	Chippewa	28
5	24	201.2	51	5	73	1.4	800	1	T	--
5A	14	198.4	28	5	35	1.3	800	13	T	--
6	24	196.7	36	7	51	1.4	850	7	T	--
7	19	194.8	54	4	92	1.7	850	5	Black	5
8	39	192.3	84	5	134	1.6	1,020	4	T	--
9	50	189.0	118	4	226	1.9	1,020	15	T	--
10	53	186.2	69	8	145	2.1	1,300	18	Wisconsin	18
11	51	183.8	[8]75	7	191	2.5	1,300	3	Turkey	2
12	42	180.4	[8]47	11	46	1.0	1,300	4	T	--
13	55	177.7	120	5	NA	NA	1,400	4	Maquoketa	2
14	48	174.3	42	11	NA	NA	1,400	<1	Wapsipinicon	3
15	16	171.0	15	11	NA	NA	NA	1	T	--
16	42	166.1	51	8	131	2.6	1,530	12	Rock	11
17	32	163.4	32	10	86	2.7	1,530	22	T	--
18	42	160.9	55	8	NA	NA	1,560	7	Iowa	11
19	76	157.9	125	6	360	2.9	1,800	0	Skunk	3
20	34	146.3	31	11	108	3.5	2,000	21	Des Moines	8

Table 1.1.--Physical and hydrologic characteristics of navigation pools in the Upper Mississippi River--Continued

									Tributary	
Pool	Length (km)	Project pool elevation above sea level	Surface area[1] (km^2)	Navigation channel area[2] (%)	Storage volume[3] ($10^6 m^3$)	Mean depth (m)	Mean annual discharge[4] (m^3/s)	Percentage of time at open river[5]	Name	Percentage discharge c Mississipp River down-strea from moutl of tributary
21	29	143.3	26	11	86	3.3	2,000	15	T	--
22	39	140.1	36	11	105	2.9	2,000	12	T	--
24	45	136.9	[8]51	9	NA	NA	2,040	NA	Salt	2
25	51	132.2	[8]69	7	192	2.8	2,040	NA	T	
26	61	127.7	121	8	424	3.5	2,600	NA	Illinois	24
27	17	NA	NA	50	NA	NA	5,100	NA	Missouri	43

[1]References for surface area are: Pools 2–10, U.S. Army Corps of Engineers, St. Paul District, Gordon Heitzman, oral commun., 1991; Pools 11–22, U.S. Army C of Engineers, Rock Island District, Harry Bottorff, oral commun., 1991; Nakato, Tatsuaki, 1980; Bhowmik and others, 1987; and Pools 24–26, St. Louis District, Ray psky, oral commun., 1991, Bhowmik and others, 1987.

[2]Navigation channel area was computed by assuming a 100-meter-wide channel in all pools. The values in the table are about 3–4 percent lower than some give Gilbertson and Kelly (1981).

[3]References for storage volume are: Pools 2–10, U.S. Army Corps of Engineers, St. Paul District reservoir regulation manuals; Pools 11, 16, 17, 20, 21, 22, 25 26, Nord, R.C., 1966:; Pool 19; Union Electric Co., Keokuk, Iowa, oral commun., 1991.

[4]Discharges were taken from USGS Water Resources Data published annually by each State.

[5]References for percent of time at open river are: Pools 2–10, U.S. Army Corps of Engineers, St. Paul District, Gordon Heitzman, oral commun., 1991; Pools 11- U.S. Army Corps of Engineers, Rock Island District, Harry Bottorff, oral commun., 1991; and Pools 24–26, U.S. Army Corps of Engineers, St. Louis District, Don Coler oral commun., 1991.

[6]Lake St. Croix is not included so that the original value of 73 km^2 (which includes Lake St. Croix) was reduced (Gordon Heitzman, U.S. Army Corps of Engineers, St. Louis District, oral commun., 1991).

[7]Where two or three different values were obtained, the average value is reported in this table.

These pools do not have sufficient storage capacity to be operated as flood-control structures; they are maintained at a nearly constant elevation (table 1.1), creating an environment conducive to the deposition and storage of sediment. In Pools 1-10, the St. Paul District of the U.S. Army Corps of Engineers used a primary control point that is approximately at midpool and maintains the pool elevation within a range of about 0.1 m (U.S. Army Corps of Engineers, 1988b). In Pools 11-22, the Rock Island District uses a primary control point at the dam, and the range of the pool elevation fluctuates between 0.03 m above to 0.12 m below project pool elevation (Bryan Goodrum, U.S. Army Corps of Engineers Rock Island District, oral commun., 1992). In Pools 24-26, the St. Louis District uses a primary control point located about one-third of the distance upstream to the next dam and maintains pool elevations within a range of 0.2 to 0.6 m. During times when the water discharge is high, all the gates in the dams are opened (referred to as "open river" in table 1.1) and the increased water velocity in the pools inhibits the settling of suspended sediment. As the inflow to the pools decreases, the gates are partially closed to maintain the 9-foot channel for navigation; this decreases the water velocities and decreases the flushing rate of water in the pools, creating conditions favorable for the deposition of sediment.

Between 1987 and 1990, the U.S. Geological Survey investigated the transport of contaminants by suspended sediment in the free-flowing Mississippi River between St. Louis, Mo., and New Orleans, La. (Leenheer and others, 1989, 1995; Meade and Stevens, 1990; Pereira and others, 1990, 1992, 1995; Taylor and others, 1990; Moody and Meade 1992, 1993). In 1991, the investigations were expanded to include a study of the transport of contaminants by suspended sediment (Moody and Meade, 1995) and a study of the storage of contaminants in the surficial bed sediments in the navigation-pool reach of the Upper Mississippi River before the flood of 1993 (Moody, 1997; Meade and others, 1995).

The navigation pools are known to trap and store sediments with associated contaminants during normal flow conditions. Dredging activities, commercial navigation, recreational boating, and natural resuspension processes can result in the remobilization of contaminated sediments. What is not known is how large flood events affect contaminants stored with the bed sediments in impounded river systems.

The primary objective of this study was to assess the effects of the flood of 1993 on the contaminants stored in the bed sediments of the navigation pools of the Upper Mississippi River by comparing post-flood contaminant levels with those that had been measured just prior to the flood in 1991-92. This primary objective evolved into the following components:

1. To locate the original sampling sites by using a Global Positioning System (GPS) so that the future sampling would be easier.

2. To collect samples of surficial bed sediments during the summer of 1994, following previously established bed-sampling methods at the sites used by the U.S. Geological Survey in 1991-92 in the navigation pools of the Upper Mississippi River.

3. To repeat chemical analyses of these surficial bed sediments so that the chemical characteristics before and after the flood of 1993 could be compared.

4. To collect additional hydraulic data to estimate the remobilization of sediment during flood conditions.

PURPOSE AND SCOPE

The purposes of this chapter are to provide a general introduction to this study of the effects of the flood of 1993 on the surficial sediments in the navigation pools of the Upper Mississippi River and to discuss the sampling strategy and the data-collection methods. The navigation pools were resampled during June and July of 1994. Some hydraulic characteristics related to flushing rates are discussed and listed in tables. The particle-size characteristics and bulk chemical characteristics of the surficial bed sediments necessary for normalizing chemical data in succeeding chapters are listed in this chapter.

Sterols, polynuclear aromatic hydrocarbons (PAH), and linear alkylbenzene sulfonates (LAS) are discussed in Chapter 2; polychlorinated biphenyls (PCB) in Chapter 3; organochlorines in Chapter 4; and major and trace elements in Chapter 5. The location of each sample combined to make the composite sample and ancillary data at each sampling site in each pool are listed and shown on maps in Chapter 6.

SAMPLING STRATEGY

The same sampling strategy was used to collect surficial bed sediments from the navigation pools after the flood of 1993 as was used to collect samples in 1991 and 1992. This strategy recognizes that the navigation-pool reach of the Upper Mississippi River is a complex aquatic system. Wilcox (1993) lists at least 26 different aquatic habitats associated with the navigation channel and backwater areas of a pool. This diversity makes it difficult to obtain a bed-sediment sample that is representative of a pool. The number of habitats is reduced significantly if only the lacustrine region, which usually occupies the downstream one-third of a pool just upstream from the lock and dam structure, is considered. This region is generally shallow, has weak currents, and also is morphologically simpler; thus, the bed sediment may be more homogeneous. The rate of deposition of fine particulate matter in this region is probably more rapid than in the higher energy environment downstream from the dams or in the deltaic regions. The association of nonionic, nonpolar contaminants with fine particulate matter has been addressed by several researchers (Leenheer, 1991). A correlation of clay-size sediment with trace-metal concentrations in Upper Mississippi River pools was shown by Bailey and Rada (1984). For these reasons, the bed-sediment sampling focused on the downstream one-third of each pool.

To obtain a representative sample within this region of the pool, one to five transects (consisting of 2–13 sampling sites each) were sampled across the pool, approximately perpendicular to the flow direction, so that a variety of different shallow benthic habitats was sampled. These gave 12-23 individual samples that were combined to form one composite representative sample. The number of individual samples was based on a study of standard error as a function of number of individual samples in a composite sample for polychlorinated biphenyl data collected from Pool 7 (Sullivan, 1988). The results showed that the relative standard error decreased 37 percent from 5 to 20 samples but only 3 percent from 20 to 30 samples.

The pools upstream from the Lower and Upper St. Anthony Locks and Dams and the last pool (Pool 27) were not sampled because they were predominantly riverine and were assumed to have little stored sediment. Most of the surface area and volume of Pool 4 is Lake Pepin—a lake formed by a natural dam consisting of sediment transported across the Mississippi River by the Chippewa River. Lake Pepin is deep; consequently, water velocities are less than 10 cm/s (Randy Burkhardt, U.S. Fish and Wildlife Service, oral commun., 1991), allowing sediment to be deposited. Since Lake Pepin is essentially a long sediment trap, the upper (Upper Mississippi River Mile 773–785) and lower (Upper Mississippi River Mile 765–773) parts of Lake Pepin were sampled separately.

The sampling strategy after the flood of 1993 differed in two ways from the sampling done before the flood of 1993. All the navigation pools were sampled during one research cruise in June-July 1994 rather than during three separate cruises as was done before the flood (table 1.2). Also, more field replicate samples were collected after the flood to determine the field-sampling uncertainty.

Table1.2--Location of pool transects in the Upper Mississippi River between Minneapolis, Minnesota, and St. Louis, Missouri

[X, single composite sample was collected; XX, duplicate composite samples were collected; SC, St. Croix River mile]

Pool	Transect number	Location in river miles upstream from mouth of Ohio River	Maximum number of samples along transect	Cruise			
				July-August 1991	October-November 1991	April-May 1992	June-July 1994
1	1	848.0	4	X			X
	2	848.5	4	X			X
	3	849.2	4	X			X
2	1	816.1	7	X	X	X	XX
	2	818.1	7	X	X	X	XX
	3	821.1	4	X	X	X	XX
St. Croix River	1	SC1.3	3				X
	2	SC1.9	3				X
	3	SC2.5	3				X
	4	SC3.3	3				X
	5	SC4.2	3				X
3	[1]1	798.1	8		X		
	[1]2	798.1	6		X		X
	3	797.3	2		X		X
[2]4	4	774.0	6		X		X
	5	776.0	5		X		X
	6	778.0	4		X		X
[3]4	1	772.0	7		X		X
	2	770.0	7		X		X
	3	768.0	7		X		X
5	1	744.7	9	X			X
	2	741.0	6	X			X

Table1.2--Location of pool transects in the Upper Mississippi River between Minneapolis, Minnesota, and St. Louis, Missouri--Continued

[X, single composite sample was collected; XX, duplicate composite samples were collected; SC, St. Croix River mile]

Pool	Transect number	Location in river miles upstream from mouth of Ohio River	Maximum number of samples along transect	Cruise: July-August 1991	Cruise: October-November 1991	Cruise: April-May 1992	Cruise: June-July 1994
	3	739.8	3	X			X
5A	[1]1	729.8	7	X			not sampled
	[1]2	729.8	7	X			
6	1	721.1	7			X	X
	[1]2	714.9	7			X	X
	[1]3	714.9	6			X	X
7	[1]1	702.7	13	X			X
	[1]2	702.7	7	X			X
8	1	684.7	7	X	Only two samples	X	XX
	2	683.3	7	X	X	X	XX
	3	682.1	6	X	X	X	XX
9	1	648.0	7		X		X
	[1]2	655.0	8		X		X
	[1]3	655.0	3				X
10	[1]1	615.0	3	X			X
	[1]2	615.0	6	X			X
	3	616.1	6	X			X
	4	617.2	5	X			X
11	1	591.9	7		X		X
	2	587.4	8		X		X
	3	585.1	5		X		X
12	[1]1	558.2	8			X	X
	[1]2	558.2	7			X	X
	3	560.7	5			X	X
13	1	526.0	10		X		X
	2	523.7	10		X		X
14	[1]1	499.8	3	X			X
	[1]2	499.8	3	X			X
	[1]3	494.8	7	X			X
	[1]4	494.8	3	X			X
15	1	484.0	2			X	X
	2	485.8	10			X	X
	3	487.8	6			X	X
16	[1]1	458.7	8		X		X
	[1]2	458.7	6		X		X
	3	457.0	5		X		X

Table1.2--Location of pool transects in the Upper Mississippi River between Minneapolis, Minnesota, and St. Louis, Missouri--Continued

[X, single composite sample was collected; XX, duplicate composite samples were collected; SC, St. Croix River mile]

Pool	Transect number	Location in river miles upstream from mouth of Ohio River	Maximum number of samples along transect	Cruise			
				July-August 1991	October-November 1991	April-May 1992	June-July 1994
18	1	414.5	9			X	X
	2	411.8	9			X	X
19	1	371.6	4		X		XX
	2	370.2	5		X		XX
	3	368.9	5		X		XX
	4	367.5	5		X		XX
	5	366.3	4		X		XX
20	1	346.6	6	X			X
	2	344.2	6	X			X
21	1	331.4	7			X	X
	[1]2	326.6	9			X	X
	[1]3	326.6	3			X	X
22	1	306.0	7	X			X
	[1]2	303.0	7	X			X
	[1]3	303.0	7	X			X
24	1	273.4	4		X		X
	2	274.4	7		X		X
	3	275.3	7		X		X
25	[1]1	243.1	8			X	XX
	[1]2	243.1	7			X	XX
	3	241.5	4			X	XX
26	1	206.1	13		X		XX

[1]Transects were in different directions.
[2]Upper Lake Pepin.
[3]Lower Lake Pepin.

SAMPLING PROCEDURE

In this section, the procedures are described for relocating the original 1991-92 sampling sites, for collecting samples from shallow and deep water, and for estimating the field-sampling uncertainty.

Locating the Original 1991-92 Sampling Sites

Two variations of the differential Global Positioning System (GPS) were used to locate the original sampling sites. A differential GPS system with a local reference station was used to locate the sampling sites in the upper pools (1-14) and in the St. Croix River. The latitude and longitude of the original sampling sites were scaled from U.S. Geological Survey's 7.5-minute quadrangles (accuracy ±0.005° or about ±8 m) and were based on the North American Datum for 1927 (NAD27). A local reference GPS station (Trimble model 4000 SSE 18-channel receiver, GPS antenna, modem, Motorola radio, and radio antenna) was set up at a prominent landmark, and the reference station's latitude and longitude were scaled from the 7.5-minute quadrangle (accuracy ±8 m). Corrections (RTCM-104 format) for the reference station were then generated by the GPS unit and transmitted by radio to a second GPS station (Trimble model 4000 SE 9-channel receiver, radio antenna, radio, and modem) in the small boat used for collecting the samples. The sites were relocated to within ±5 m (differential GPS error) plus the accuracy of the location of the reference station. The present accuracy of the reference station is ± 8 m, but this can be improved by reoccupying the site of the reference station (see description of the location of the reference station in Chapter 6) at a later date and averaging GPS fixes for 1 to 2 hours.

A differential GPS system using the navigation beacon near St. Louis, Mo., as the reference station was used to relocate the sites in the lower pools (15-26). The accuracy of the resampled sites is about ±0.001° latitude or longitude because the navigation beacon location is known more precisely. Because the navigation beacon was used to locate sampling sites in the lower pools, the latitude and longitude for these sites are based on the North American Datum for 1983 (NAD83). The differential GPS was checked twice. At Dam 16, the GPS-derived coordinates for the tip of the guidewall closest to the dam were 41°25.588 N., 021°00.456 W. , (NAD83) and the coordinates scaled from the Muscatine, Iowa-Ill. quadrangle were 41°25.580 N., 091°00.460 W., (NAD27). The difference was 14.4 m in latitude and 5.6 m in longitude. Similarly, the GPS coordinates for the southwest corner of the Union Electric Powerplant house at Dam 19, Keokuk, Iowa, were 40°23.851 N., 091°22.309 W. (NAD83) and coordinates scaled from the 7.5-minute quadrangle were 40°23.845 N., 091°22.315 W. (NAD27). The difference was 10.8 m in latitude and 8.4 m in longitude. Most of the difference is a result of scaling from a 1:24,000 map.

Shallow-Water Sampling

The backwater regions of the pools generally are less than 3 m deep, allowing all the bed samples to be collected from a small, 4.3-m-long boat (fig. 1.3) launched from the research vessel *Acadiana* (owned and operated by Louisiana Universities Marine Consortium). At each sampling site, the small boat was anchored on a short anchor line to prevent swinging, and three people measured surface temperature, specific conductance, water depth, and water velocity and collected two bed-sediment samples. The surface temperature and specific conductance (listed in Chapter 6) were measured with a LabComp model SCT-100 meter in a bucket after allowing about 30 seconds for the sensors to come to equilibrium. The accuracy of the unit was listed by the manufacturer as ±10 μS/cm for the 0–2,000 μS/cm range with resolutions of 1 μS/cm and 0.1°C. This was checked before and after the cruise, and the specific conductance was within ±5 μS/cm of a laboratory standard. The resolution of this meter was ±1 μS/cm and ±0.1°C. The depth was measured with a Lowrance Model X-16 analog recorder, and depths were recorded to the nearest 0.1 m. For depths less than about 1.3 m, a pole marked at 0.1-m intervals was used to measure the depth. The mean velocity was measured at 0.6 of the depth by using a standard Price AA current meter (Rantz and others, 1982), and the direction was determined by noting the direction, relative to a compass in the small boat, of the current meter and sounding weight after they were quickly raised a short distance (usually 1–3 m) to the surface. Depth, temperature, specific conductance, mean velocity, and direction are listed in Chapter 6.

The two bed-sediment samples were collected using a modified van Veen grab sampler and a gravity corer (fig. 1.4). The modified van Veen grab (fig. 1.4, Theodore E. Young, Sandwich, Mass., written commun., 1990) was operated from a small davit (fig. 1. 3) with a hand winch. The sampler collects a 20-cm by 20-cm sample of the bed sediments (0.04 m^2), which had a maximum thickness of 10 cm. The sampler consistently collected a full sample if the bed was mud without debris. In fine and medium sand, the sampler was usually 50 to 80 percent full. The only problem was clam shells, bark, sticks, or cobbles, which got caught between the jaws and allowed the sample to wash out. From the small boat, this sampler collected samples in water velocities as great as 90 cm/s and in water depths as great as 6 m.

After the sampler was brought aboard, subsamples were taken for particle size determination; carbon and nitrogen; sterols, PAH, and LAS; PCB; and organochlorine analyses. The subsamples were collected by using cores of various diameters made from Teflon cylinders (about 12–25-mm diameter) fitted with a Teflon-covered syringe plunger. The individual subsamples were added to glass or plastic jars as they were collected, then refrigerated and shipped to the laboratory for analysis (see this Chapter, and Chapters 2, 3, 4, and 5). The subsample for particle-size determination was collected by inserting a piece of U-shaped brass (0.4 cm wide, 0.2 cm deep, and 10 cm long) straight down into the sample, rotating the bottom of the U-shaped brass sampler, scraping off any excess sediment protruding above the sides of the sampler with a spatula, and then washing the sample into a plastic bottle with river water.

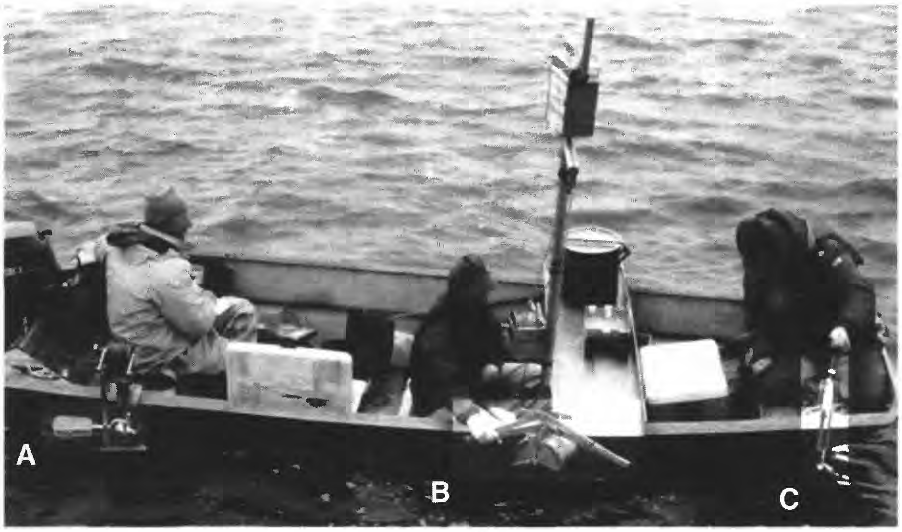
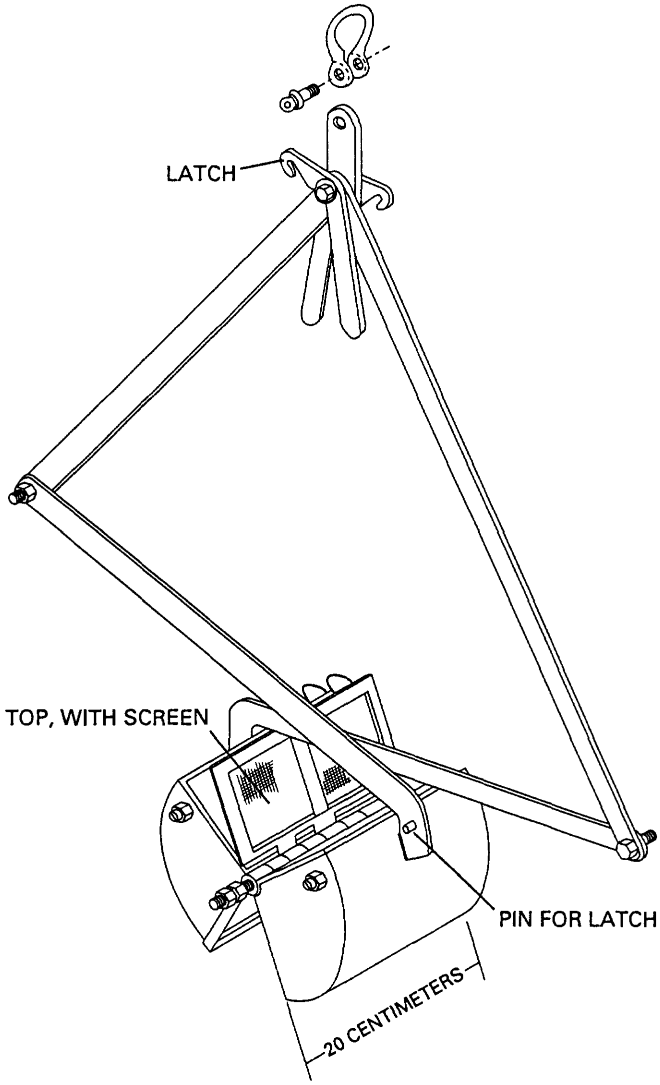
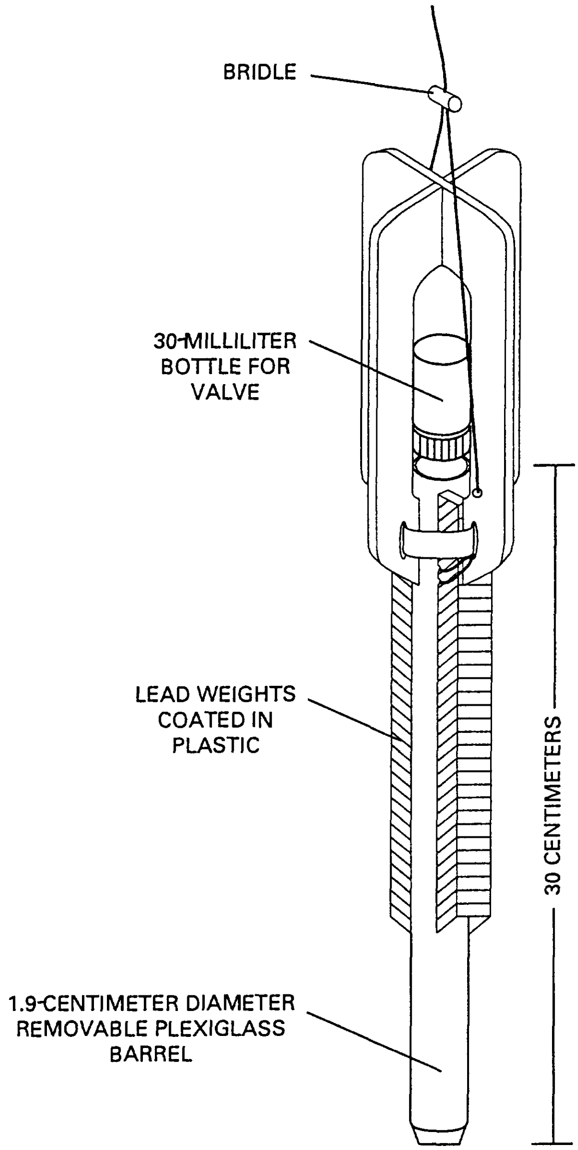


Figure 1.3--Shallow-water sampling equipment. At the bow of the 4.3-m-long boat, the small gravity corer (C) is being held over the side on a handline. Forward of the middle of the small boat, the modified van Veen grab sample (B) is hanging from a davit and boom assembly in the open position. On top of the davit is a microwave receiver/transmitter. Hanging over the side, just forward of the stern of the small boat, is a Price AA current meter (A). Photograph by R.H. Meade.



MODIFIED VAN VEEN GRAB



GRAVITY CORER

Figure 1.4--Details of the modified van Veen grab and gravity corer.

The second sampler was a gravity corer (designed and built by Harold Wiegner, Minnesota Pollution Control Agency, St. Paul, Minn.). T he core tube was made of plexiglass (methyl methacrylate polymer) and other parts were plastic coated (fig. 1.4). The corer was designed to collect a maximum 30-cm-long core, 1.9 cm in diameter, for major and trace-element analysis (Chapter 5). The plastic core barrel was removed, the ends capped with a plastic cap, and each individual core sample was put in a plastic bag, sealed, and frozen. After being shipped to the laboratory, the cores were subsampled and combined to form a composite sample. It was difficult to obtain a gravity core if the water velocities were greater than about 40 cm/s or if the bed sediment was sand. Some samples for major and trace elements were collected from the modified van Veen grab sampler if the gravity corer failed to get a sample after three to six attempts.

Deep-Water Sampling

In Lake Pepin (Pool 4) and in Pool 19, the water depths were great enough to permit sampling from the *Acadiana*. This sampling procedure was similar to the shallow-water procedure because the bed-sediment samples were collected with the same equipment. The depth was determined with the same depth recorder mounted on the research vessel, and the surface temperature and specific conductance were measured in the same manner, but no velocity measurements were made. Since the research vessel was the sampling platform, it had to be positioned at the sampling site. The vessel's operator positioned the vessel upwind of the sampling site by using the GPS unit, which displayed latitude and longitude. As the vessel drifted downwind, samples were collected when the latitude and longitude scaled from the map agreed with the display on the GPS unit.

Field-Sampling Uncertainty

Samples were collected from the downstream one-third of each pool in order to reduce the inhomogeneity of the surficial sediments. However, it was assumed that there was still some inhomogeneity and, consequently, corresponding field-sampling uncertainty. For this reason, field duplicates were collected from five different pools and in a different manner from each pool as listed below:

Pool 2--A duplicate composite sample was taken at the same sampling site along each transect.

Pool 4--A duplicate composite sample was collected from sampling sites along three separate transects (upper Lake Pepin) separated by about 5 km from sampling sites along three other transects (lower Lake Pepin).

Pool 8--A duplicate composite sample was collected from a sampling site on each transect that was about 2-20 meters from the original sampling site.

Pool 19--A duplicate composite sample was collected at distances ranging from 70 to 800 meters (average 280 meters) from the original sampling site along each transect.

Pool 25--A duplicate composite sample was obtained by collecting twice as much material from one-half the sampling sites (every other sampling site) along the transects such that the final volume of the duplicate composite was approximately the same size as the first composite sample.

Because all laboratory measurements are a function of both the field and laboratory analytical uncertainty, the estimate of the field-sampling uncertainty for each duplicate sample was based on six parameters (measured for the duplicate samples above) that had the smallest laboratory analytical uncertainty. The estimate of the field-sampling uncertainty was the relative percent difference (difference of the duplicate values divided by the average of the two values times 100) for each duplicate described above (see table 1.3). Because each pool varies in the character of the sediment, the five individual estimates of the field-sampling uncertainty were averaged for each parameter, and then the six values for each parameter were averaged to give a field sampling uncertainty of 25 percent.

Table 1.3--Estimates of field-sampling uncertainty for surficial bed sediments collected from the downstream one-third of 25 sampled navigation pools of the Upper Mississippi River, June-July 1994

Parameter	Uncertainty (relative percent difference)					Average
	Pool 2	Pool 4	Pool 8	Pool 19	Pool 25	
Median particle diameter	10	40	2	78	12	28
Percent finer than 0.062 millimeter	4	14	2	16	1	7
Total volatile solids	2	5	32	28	28	19
Total organic carbon	24	4	56	12	141	47
Copper	82	16	12	46	13	34
Lead	14	10	10	11	13	12
Average	23	15	19	32	35	25

HYDROLOGY

Cross-sectional profiles of rivers are commonly plotted with a vertical exaggeration to make variations in depth look more pronounced. It should be kept in mind that the Mississippi River is a very thin, ribbonlike layer of water. The width-to-depth ratio in the riverine reach of the pools just downstream from dams averages about 100:1. This ratio is about one-tenth that in the lacustrine reach (table 1.4) of the pools where the dams cause water to back up over wide, flat valleys. If the Upper Mississippi River were as wide as this page, its maximum depth (about 8 m in the navigation channel) would be represented by a line less than 2 mm thick, and a line representing the depths of the shallow, off-channel, backwater areas would be less than 0.5 mm thick.

Discharge

The water discharge was computed from velocity measurements made at 0.6 of the depth at each sampling site along the sampling transect and at an additional three to six locations across the navigation and secondary channels. The standard error in the water discharge for triplicate measurements was 12 and 2 percent in Pools 8 and 11, respectively and was 39 and 7 percent for duplicates in Pools 2 and 5, respectively. Standard error averaged 4 percent for duplicates in Pools 13, 18, and 20. The discharges in the pools were compared to the discharges reported by the U.S. Army Corps of Engineers at the dam downstream and ranged from 24 percent less to 22 percent greater (and averaged about 6 percent less) than the Corps of Engineers measurements.

Sixty-three percent of the water discharge in the lacustrine regions of the pools was in the navigation channel (table 1.4). In the regions of the pool occupied by the navigation or secondary channels, the current direction was the same as in the navigation channels. In areas outside the channels, the current direction was variable and affected by wind direction and topography but generally was downriver (see Chapter 6 for current magnitudes and directions). The mean velocity in these areas averaged 60 percent of the velocity in the navigation channel (table 1.4).

Table 1.4--Measured hydraulic parameters for the lacustrine regions of some navigation pools in the Upper Mississippi River between Minneapolis, Minnesota, and St. Louis, Missouri, June-July 1994

[m, meters; m^3/s, cubic meter per second; cm/s, centimeter per second]

			Cross section			Water discharge			Mean velocities		
Pool and transect number	Location in river miles upstream from mouth of Ohio River	Date	Mean depth (m)	Width-to-depth ratio	Area (m^2)	Measured (m^3/s)	Ratio of discharge to mean annual discharge[1]	Percentage of total discharge in channels (%)	In channel (cm/s)	Outside channel (cm/s)	Cross section (cm/s)
2-2	818.1	06-12-94	2.0	670	2,740	700	2.1	52	29	23	26
2-1	816.1		1.7	840	2,410	470	1.4	66	26	13	19
5-2	741.0	06-16-94	1.7	1,500	4,520	860	1.1	65	31	11	19
5-3	739.8		2.7	440	3,150	920	1.1	68	34	22	29
6-1	721.0	06-17-94	3.1	500	4,860	1,210	1.5	80	54	9	26
8-1	684.7	06-19-94	1.4	2,400	5,250	1,130	1.1	34	33	18	21
8-2	683.3		1.4	2,800	5,480	900	0.9	49	28	12	16
8-3	682.1		1.8	1,700	5,530	940	0.9	48	25	13	17
9-2	655.0	06-20-94	1.6	2,100	5,340	870	0.9	52	22	13	16
11-1	591.9	06-21-94	2.1	1,200	5,430	1,540	1.2	86	38	11	28
11-2	587.4		2.1	1,400	6,260	1,510	1.2	42	32	20	24
11-3	585.1		2.9	730	6,110	1,580	1.2	79	30	17	26
13-1	526.0	06-23-94	1.3	3,800	6,450	1,250	0.9	64	36	11	19
13-2	523.7		1.7	2,800	7,860	1,290	0.9	43	22	14	16
18-1	414.5	06-28-94	2.4	770	4,370	2,720	1.7	73	68	51	62
18-2	411.8		2.3	890	4,700	2,530	1.6	[1]78	62	37	54
20-1	346.6	06-30-94	2.5	600	3,840	2,980	1.5	[1]93	78	75	78
20-2	344.2		4.2	240	4,240	3,080	1.5	85	78	53	73
21-1	331.4	07-01-94	3.2	360	3,730	2,780	1.4	44	88	66	74
22-1	306.0	07-02-94	3.3	320	3,580	2,910	1.5	42	87	77	81
24-2	274.4	07-03-94	2.8	720	5,620	2,880	1.4	[1]74	52	48	51

[1]Ratio of discharge is the measured discharge divided by the discharge listed in table 1.1 for the dam closest to the sampling transect unless a major tributary was between the sampling transect and the dam.

[2]Includes flow in secondary channels.

Mixing

Lateral gradients of specific conductance greater than 10 µS/cm (twice the precision of the conductivity meter) were measured in 13 pools (table 1.5). Some of these pools have tributaries that contribute 2 percent or more of the discharge of the Mississippi River (Pool 2-Minnesota River; Pool 11-Turkey River; Pool 13-Maquoketa;, Pool 14-Wapsipinicon; Pool 16-Rock River; Pool 18-Iowa River; and Pool 20-Des Moines River) while other pools (5, 6, 8, 15, and 22) have smaller tributaries contributing less than 2 percent of the discharge. Pools 2, 5, 8, 11, 14, 16, 18, 20 and 22 had lateral gradients with difference across the pool that were greater than 10 µS/cm before and after the flood of 1993.

Table 1.5 --Magnitude of specific-conductance difference between the ends of cross-pool sampling transects in some navigation pools of the Upper Mississippi River between Minneapolis, Minnesota, and St. Louis, Missouri, July 1991-April 1992 and June-July 1994

[Only differences greater than 10 μS/cm across the pool are listed; μS/cm, microsiemens per centimeter at 25 degrees Celsius; --, does not apply]

Pool	Transect number	Specific-conductance differences (μS/cm)	
		July 1991-April 1992	June-July 1994
2	1	[1]17	20
	2	[2]13	16
4	5	16	--
	1	--	27
	2	--	25
5	2	80	17
	3	90	22
6	1	50	--
	2	56	--
8	1	[1]12	35
	2	[1]32	13
	3	[1]16	17
8	2	[3]20	--
	3	[3]17	--
8	1	[2]99	--
	2	[2]78	--
11	1	20	--
	2	19	25
	3	12	--
13	1	--	17
	2	--	--
14	3	16	13
	4	18	32
15	1	27	--
	2	32	--
16	1,2	141	76
18	1	83	27
20	1	52	53
	2	59	61
22	1	50	47
	2	37	--

[1]July-August 1991 cruise.
[2]April-May 1992 cruise.
[3]October-November 1991 cruise.

Flushing Rates

Governing officials of cities and towns along a river are concerned about pollution and the length of time that contaminated water may remain in their area (Ketchum, 1951; Ketchum and Keen, 1953; Rutherford and others, 1980). The Upper Mississippi River presents a difficult problem because the navigation pools are not water storage reservoirs nor are they like a free-flowing river, so standard methods for estimating retention times may not be applicable. The simplest standard method of computing an average retention time is to divide the volume of the pool by the mean annual discharge. Using data in table 1.1, this method gives a retention time for each pool that is a function of the length and changing cross-sectional area of the pool (table 1.6). This simple method is based on a conceptual model in which the water velocities are the same throughout the length of the pool, and the retention time is the time it takes for the water to flow from the upstream end to the downstream end of the pool. For a given discharge, the changing cross-sectional area of the pools in the riverine, deltaic, and lacustrine regions (table 1.4) will affect the water velocities in the longitudinal direction, and changes in depth and the presence or absence of islands will affect the water velocities in the lateral direction. Thus, the flushing rate, in hours per kilometer (h/km) of river, is perhaps a more applicable measure to use in constructing models that include downstream variations of the flushing rate. Different rates can be applied to the appropriate regions in the pool. By multiplying the flushing rate by the length of each appropriate region and summing over the length of the pool, an improved estimate for the retention time can be obtained that includes the effects of the downstream variation due to changes in morphology of the pool. The flushing rate is the reciprocal of the mean cross-sectional velocity for a specific cross section. The estimated flushing rates, equivalent to the retention times in table 1.6, were calculated by dividing the retention time by the length of the pool.

Flushing-rate measurements were made at 21 transects on the Upper Mississippi River during June-July 1994. The discharges ranged from one to two times the mean annual discharge, and the measured flushing rates are listed in table 1.6. The measured flushing rates ranged from 1.1 to 1.7 hr/km in the more lacustrine pools (2-13) and from 0.3 to 0.5 hour/km in the more riverine pools (14-24). The measured flushing rates were generally greater than or equal to the estimated flushing rates (see table 1.6).

Table 1.6--Estimated retention time, predicted flushing rates, and measured flushing rates in some navigation pools of the Upper Mississippi River between Minneapolis, Minnesota, and St. Louis, Missouri, June-July 1994

[Measured flushing rate is the reciprocal of the average cross-sectional velocities listed in table 1.4 for June-July 1994; Q is the average of the measured discharges in the pool divided by the mean annual discharge in table 1.1; NA, data not available; h, hour, and km, kilometer]

Pool	Estimated retention time[1] (h)	Estimated flushing rate (h/km)	Measured flushing rate (h/km)	Q	Normalized distance[2]
1	NA	NA	NA	NA	NA
2	69	1.3	1.2	1.8	0.06
3	20	0.7	NA	NA	NA
[3]4	200	2.8	NA	NA	NA
5	25	1.0	1.2	1.1	0.16
5A	12	0.9	NA	NA	NA
6	17	0.7	1.1	1.5	0.46
7	30	1.6	NA	NA	NA
8	36	0.9	1.5	1.0	0.18
9	62	1.2	1.7	0.9	0.22
10	31	0.6	NA	NA	NA
11	41	0.8	1.1	1.2	0.16
12	10	0.2	NA	NA	NA
13	NA	NA	1.5	0.9	0.06
14	NA	NA	NA	NA	NA
15	NA	NA	NA	NA	NA
16	24	0.6	NA	NA	NA
17	16	0.5	NA	NA	NA
18	NA	NA	0.5	1.6	0.08
19	56	0.7	NA	NA	NA
20	15	0.4	0.4	1.5	0.11
21	12	0.4	0.4	1.4	0.36
22	15	0.4	0.3	1.5	0.21
24	NA	NA	0.5	1.4	0.05
25	26	0.5	NA	NA	NA
26	45	0.7	NA	NA	NA

[1]Based on estimates of storage volumes and mean annual discharges from table 1.1.
[2]Normalized distance is the average distance of the transect(s) upstream from the dam divided by the length of the pool.
[3]Based on volume of Lake Pepin.

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- PAGE 25 FOLLOWS -

SEDIMENT CHARACTERISTICS

The surficial bed sediment was subsampled and analyzed for physical (particle-size) and bulk chemical (nitrogen, carbonate carbon, total carbon, and total organic carbon) characteristics. These characteristics have been used in some of the other chapters to normalize chemical data.

Particle Size

The composite samples for particle-size analysis were between 40 and 150 g and were sent to the U.S. Geological Survey Sediment Laboratory in Iowa City, Iowa. Each composite sample was first sieved to separate the fine fraction (less than 63 µm) from the coarse fraction (greater than 63 µm). The size distribution of the coarse fraction was determined by the sieve method for particle diameters greater than 1 mm and by the visual-accumulation tube method for particle diameters greater than 63 µm but less than 1 mm (Guy, 1969). Particle size of the fine fraction less than 63 µm was determined by the SediGraph method described by Lara and Matthes (1986). The U.S. Geological Survey is working with the American Society for Testing and Materials to develop standard reference samples for determining the accuracy of the sieve and visual accumulation-tube methods. At the present time, only a garnet reference sample is used to determine the accuracy of the SediGraph analysis, which is ±1.5 percent (Matthes and others, 1992). The precision is determined by laboratory splits or by reanalyzing a sample. For the sieve analysis, one sample in 20 is reanalyzed; for the visual-accumulation-tube analysis, one sample each day is reanalyzed; and for the SediGraph analysis, one sample in 10 is reanalyzed. The reanalyzed sample must be within 5 percent for all analyses (Matthes and others, 1992).

The median diameter (table 1.7) was computed by linearly interpolating between particle diameters that bracket the value of "50 percent finer than." Surficial bed sediments in Lake Pepin in Pool 4 were predominantly clay sized and had the smallest median diameters ranging from 0.002 to 0.003 mm. Downstream from Lake Pepin and the Chippewa River, the median diameter increased to 0.22 mm in Pool 6. Other pools with sediment of relatively large median particle diameter are Pools 1, 14, 15, 16, 18, 20, 21, 22, and 24. Some pools have relatively large tributaries such as the Wisconsin River (Pool 10) and the Des Moines River (Pool 20); some pools (for example Pools 1, 2, 10, 14, and 19) are relatively narrow with a width-to-length ratio (Surface area/Length^2 from table 1.1) less than or equal to 0.03; and some (for example, Pool 10) have essentially no lacustrine region, and sampling transects were nearly parallel to the flow, reducing the heterogeneity of the samples and biasing the samples toward sand. The percentage of clay in the surficial bed sediments is shown in figure 1.5.

Table 1.7--Particle size of the surficial bed sediment collected from the downstream one-third of the 25 sampled navigation pools of the Upper Mississippi River between Minneapolis, Minnesota, and St. Louis, Missouri, June-July 1994

[Analyses by U.S. Geological Survey Sediment Laboratory in Iowa City, Iowa; mm, millimeters; ns, not sampled]

Pool and duplicate	Date 1994	Number of samples in composite		Percent finer than indicated size in millimeters														Median diameter[1] (mm)
				SediGraph							Visual accumulation			Sieve				
				Clay (mm)			Silt (mm)				Sand (mm)					Grave (mm)		
		1994	1991-1992	0.001	0.002	0.004	0.008	0.016	0.031	0.063	0.125	0.250	0.500	1.0	2.0	4.0	8.0	
1	06-11	12	12	1.3	1.8	2.3	2.7	3.1	3.3	3.4	6.3	33.8	88.7	97.4	99.5	100.0		0.324
2-1	06-12	18	18	9.4	12.8	16.2	20.5	26.6	37.2	48.3	74.6	90.2	94.1	95.3	97.5	100.0		0.066
2-2	06-12	18	18	1.8	5.1	9.2	14.2	21.1	33.9	50.8	77.3	90.6	95.1	96.2	98.3	100.0		0.060
St. Croix	06-13	ns	15	7.9	13.5	20.0	26.5	33.0	58.6	60.5	66.0	79.6	93.1	98.2	99.5	100.0		0.027
3	06-14	15	16	0.5	1.7	3.3	5.6	8.3	12.9	17.6	45.0	60.8	82.0	97.2	100.0			0.165
[2]4	06-15	14	15	27.2	42.0	62.8	82.0	92.9	97.8	98.8	99.0	99.3	99.9	100.0				0.003
[3]4	06-15	20	21	34.2	48.8	65.5	77.5	83.5	84.7	85.6	85.7	89.3	98.7	100.0				0.002
5	06-16	18	18	0.9	3.4	6.8	11.2	15.5	27.4	45.6	60.7	73.1	88.2	100.0				0.080
6	06-17	20	20	4.0	5.2	6.2	6.9	7.5	7.9	8.0	23.0	56.8	87.8	93.5	99.8	100.0		0.220
7	06-18	20	20	0.6	2.6	5.4	8.7	11.7	20.7	40.3	63.6	85.2	98.5	99.4	100.0			0.088
8-1	06-19	19	20	1.1	2.6	4.8	7.1	9.7	17.9	30.9	54.0	86.7	95.2	96.9	99.0	100.0		0.113
8-2	06-19	19	20	3.6	5.9	8.3	11.2	14.2	21.0	30.2	55.3	86.2	94.9	98.7	100.0			0.111
9	06-20	18	18	3.1	9.2	16.6	24.9	36.7	67.3	87.4	96.7	99.3	99.6	99.6	100.0			0.023
10	06-21	20	20	3.9	7.0	11.3	16.2	20.5	30.3	40.9	50.1	76.5	93.1	98.5	100.0			0.125
11	06-21 06-22	20	20	1.3	4.6	8.4	13.56	20.47	37.1	51.2	69.1	87.0	98.2	99.7	100.0			0.059
12	06-22	20	20	0.5	4.5	10.3	18.3	30.0	56.8	89.4	95.8	99.3	99.9	99.9	100.0			0.028
13	06-23	20	20	2.1	5.8	11.9	18.5	26.7	50.1	78.1	87.5	96.2	99.5	99.5	100.0			0.031
14	06-23 06-24	16	16	2.7	5.3	10.4	16.2	22.9	31.8	33.8	35.5	58.6	97.9	99.3	100.0			0.203
15	06-26	15	18	5.7	8.1	11.3	15.1	22.2	34.9	40.4	42.8	50.2	78.9	93.7	98.4	100.0		0.250
16	06-27	[4]19	19	1.2	2.9	5.7	9.6	14.6	24.7	33.5	37.1	54.3	90.5	99.4	100.0			0.219

Table 1.7--Particle size of the surficial bed sediment collected from the downstream one-third of the 25 sampled navigation pools of the Upper Mississippi River between Minneapolis, Minnesota, and St. Louis, Missouri, June-July 1994--Continued

Pool and dupli-cate	Date 1994	Number of samples in composite		Percent finer than indicated size in millimeters														Median diameter[1] (mm)
				SediGraph							Visual accumulation			Sieve				
				Clay (mm)			Silt (mm)				Sand (mm)					Grave (mm)		
		1994	1991-1992	0.001	0.002	0.004	0.008	0.016	0.031	0.063	0.125	0.250	0.500	1.0	2.0	4.0	8.0	
18	06-28	[5]18	18	0.4	2.6	6.0	10.1	15.9	28.4	39.8	45.5	62.3	92.3	97.4	99.8	100.0		0.158
19-1	06-29	23	23	9.2	14.9	22.2	32.0	44.4	59.9	63.4	64.2	66.2	84.2	96.4	99.0	100.0		0.022
19-2	06-29	22	23	2.2	6.7	12.4	20.2	29.1	44.2	53.8	54.0	55.0	85.0	96.3	99.3	100.0		0.050
20	06-30	[6]12	12	3.3	3.8	4.4	4.8	5.4	6.5	8.2	12.0	19.7	64.4	91.8	97.6	100.0		0.419
21	07-01	16	19	3.2	5.2	7.5	10.3	14.1	23.0	28.2	33.7	47.2	90.2	97.2	99.2	100.0		0.266
22	07-02	20	20	2.6	4.8	8.2	12.5	18.8	27.6	32.0	34.8	52.2	93.9	98.9	100.0			0.234
24	07-03	18	18	2.7	5.6	10.6	16.2	24.3	34.4	36.0	38.3	49.9	79.3	95.5	98.8	100.0		0.250
25-1	07-04	18	19	4.1	9.2	16.8	26.7	41.6	59.6	63.4	67.3	72.0	88.1	96.7	99.5	100.0		0.023
25-2	07-04	9	19	6.6	11.3	16.6	24.8	38.0	57.5	62.8	65.1	70.0	90.5	97.0	98.9	99.6	100.0	0.026
26	07-05	11	13	7.6	13.6	23.0	33.6	49.1	71.0	75.5	82.4	95.9	99.2	99.5	100.0			0.017

[1]Median diameter determined by straight-line interpolation.
[2]Upper Lake Pepin.
[3]Lower Lake Pepin.
[4]Eight sites were not resampled in the same locations.
[5]Five sites were not resampled in the same locations.
[6]Two sites were sampled out of the water.

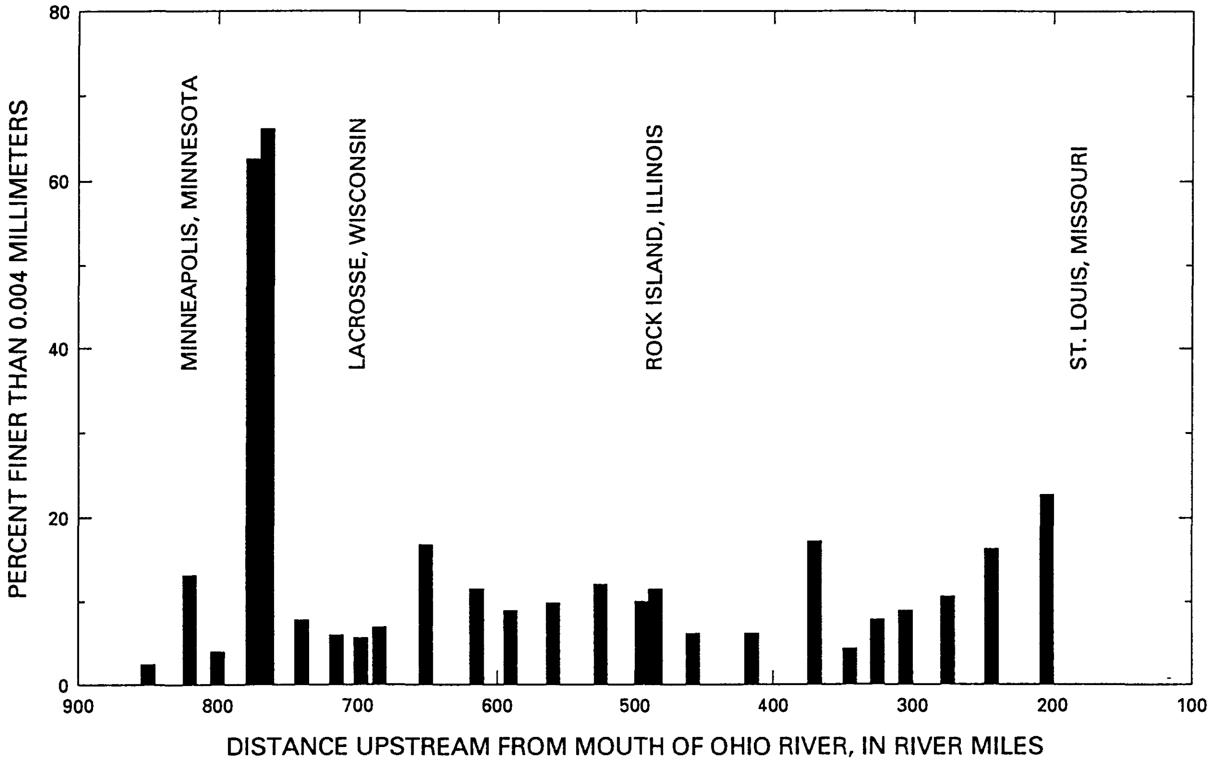

Figure 1.5--Percentage of surficial bed sediments finer than 0.004 millimeter collected from the downstream one-third of the 25 sampled navigation pools of the Upper Mississippi River between Minneapolis, Minnesota, and St. Louis, Missouri, June-July 1994. See table 1.2 for location of pools.

Bulk Chemistry

Subsamples were analyzed for the bulk chemical composition of percent nitrogen, percent carbonate carbon, percent total carbon, and percent organic carbon. Percentage values are based on dry weight. All samples were dried at a temperature of 105°C until a constant weight was obtained. Nitrogen was determined by high-temperature combustion on a Carlo Erba nitrogen detector. Total organic carbon was determined by combustion and infrared detection (total carbon samples collected before the flood of 1993 were analyzed by combustion and coulometric detection; Moody and Anderson, 1997). Carbonate carbon was determined by acidification and coulometric detection. Organic carbon was determined by difference between the percentages of carbonate carbon and total carbon and is plotted in figure 1.6. Total volatile solids was measured as 100 percent minus the loss of mass (percent) on ignition at 750°C. Huffman Laboratories, Inc., Golden, Colo., performed all the analyses, and the laboratory accuracy and precision uncertainty were determined by multiple measurements of the standard homogeneous reference material of total carbon ($CaCO_3$, triphenyl methane, steric acid, and National Institute for Standards and Technology Buffalo River Sediment), carbonate carbon ($CaCO_3$ and Na_2CO_3), and nitrogen (acetanilide, atropine, sulfanilamide, and nicotinic acid p-toluene sulfonate). The accuracy is the average percent difference from the "true" value, and the precision is the average of the relative standard deviations (table 1.8).

The precision uncertainty for measurements of field samples (which may be inhomogeneous) was also determined by multiple laboratory replicates (four or more) taken from samples from pools which were known (Moody and Anderson, 1997) to have high and low values of nitrogen (0.14 and 0.02 percent), carbonate carbon (0.55 and 0.03 percent), total carbon (4.34 and 0.15), and total volatile solids (13.93 and 0.91). The precision is measured as the relative standard deviations of these replicates (table 1.8). The bulk chemistry data are listed in table 1.9.

Table 1.8--Accuracy and precision estimates for total carbon, carbonate carbon, nitrogen measurements, and total volatile solids

[%, percent; and na, not available]

Analysis	Accuracy	Precision		
			Field sample	
	Reference standard (%)	Reference standard (%)	Low value (%)	High value (%)
Total carbon	0.6	1.0	15	6
Carbonate carbon	0.2	0.4	30	22
Nitrogen	0.4	0.8	50	27
Total volatile solids	4	na	13	6

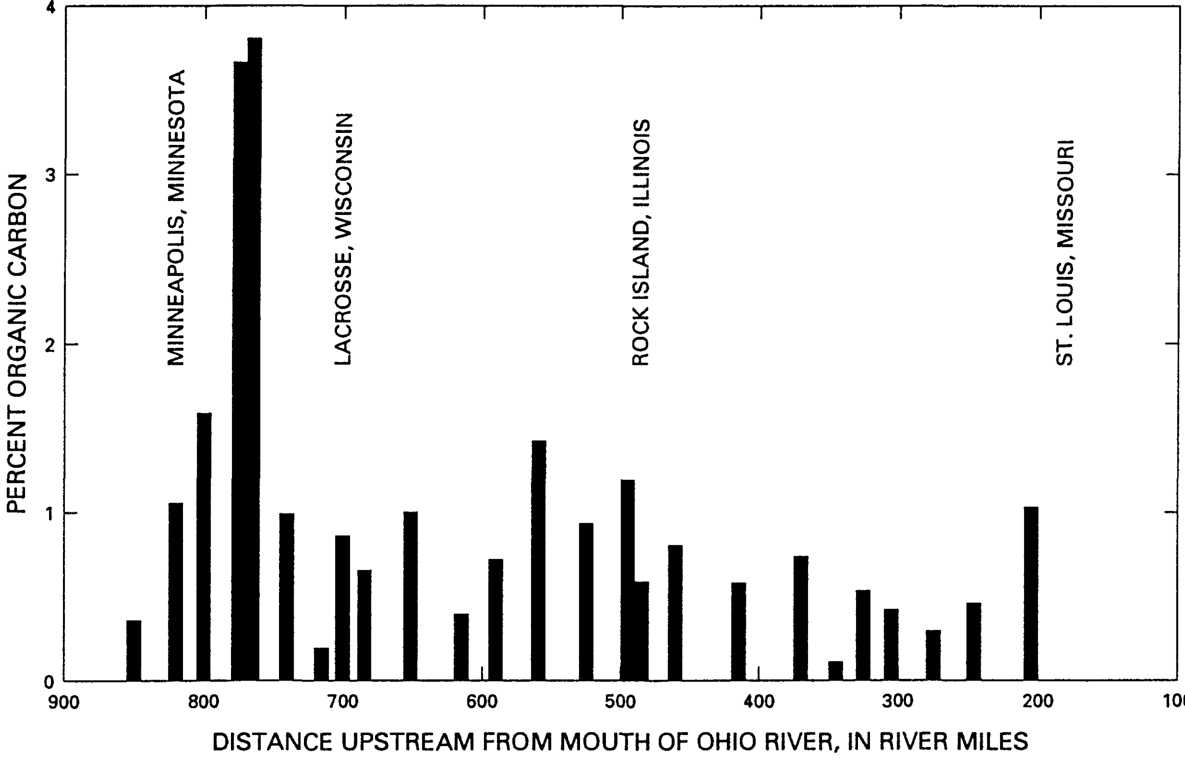

Figure 1.6--Percent organic carbon in surficial bed sediments collected from the downstream one-third of the 25 sampled navigation pools of the Upper Mississippi River between Minneapolis, Minnesota, and St. Louis, Missouri, June-July 1994. See table 1.2 for location of pools.

Table 1.9--Bulk chemical characteristics of surficial bed sediments collected from the downstream one-third of the 25 sampled navigation pools of the Upper Mississippi River between Minneapolis, Minnesota, and St. Louis, Missouri, June-July 1994

[Samples were analyzed by Huffman Laboratories, Inc., Golden, Colorado; Reference, Lake Pepin reference standard; --, not measured]

Pool and duplicate	Date	Number of samples in composite		Percentage of dry weight				
		1994	1991-1992	Nitrogen	Carbonate carbon	Total carbon	Total organic carbon	Total volatile solids
Reference	05-15-91			0.53	0.73	5.39	4.66	16.33
1	06-11-94	12	12	0.02	0.17	0.54	0.37	1.90
2-1	06-12-94	18	18	0.12	1.22	2.15	0.93	7.79
2-2	06-12-94	18	18	0.11	1.15	2.33	1.18	7.60
St. Croix River	06-13-84	15	15	0.24	0.25	2.79	2.54	9.16
3	06-14-94	15	16	0.20	1.07	2.67	1.60	8.07
[1]4	06-15-94	14	15	0.43	1.23	4.88	3.65	14.70
[2]4	06-15-94	20	21	0.14	0.55	4.34	3.79	13.93
5	06-16-94	18	18	0.15	0.30	1.29	0.99	3.90
6	06-17-94	20	20	0.01	0.06	0.26	0.20	1.22
7	06-18-94	20	20	0.10	0.25	1.13	0.88	3.58
8-1	06-19-94	19	20	0.05	0.32	1.17	0.85	4.34
8-2		19	20	0.05	0.39	0.87	0.48	3.13
9	06-20-94	18	18	0.14	0.71	1.71	1.00	5.90
10	06-21-94	20	20	0.05	0.61	1.00	0.39	4.37
11	06-21 and 06-22-94	20	20	0.06	0.73	1.46	0.73	5.08
12	06-22-94	20	20	0.12	0.51	1.94	1.43	4.98
13	06-23-94	20	20	0.12	0.65	1.60	0.95	5.00
14	06-23 and 06-24-94	16	16	0.06	0.14	1.35	1.21	5.47
15	06-26-94	15	18	0.06	0.20	0.78	0.58	2.80
16	06-27-94	[3]19	19	0.07	0.33	1.16	0.83	3.85
18	06-28-94	[4]18	18	0.06	0.32	0.91	0.59	3.55

Table 1.9--Bulk chemical characteristics of surficial bed sediments collected from the downstream one-third of the 25 sampled navigation pools of the Upper Mississippi River between Minneapolis, Minnesota, and St. Louis, Missouri, June-July 1994--Continued

Pool and duplicate	Date	Number of samples in composite		Percentage of dry weight				
		1994	1991-1992	Nitrogen	Carbonate carbon	Total carbon	Total organic carbon	Total volatile solids
19-1	06-29-94	23	23	0.09	0.23	1.03	0.80	4.07
19-2		22	23	0.08	0.52	1.23	0.71	5.40
20	06-30-94	[5]12	12	[6]0.02	0.03	0.15	0.12	0.91
21	07-01-94	16	19	0.05	0.11	0.66	0.55	3.07
22	07-02-94	20	20	0.04	0.13	0.58	0.45	2.16
24	07-03-94	18	18	0.03	0.10	0.41	0.31	2.03
25-1	07-04-94	18	19	0.11	0.19	1.00	0.81	5.18
25-2		9	19	0.09	0.60	0.74	0.14	3.90
26	07-05-94	11	13	0.12	0.15	1.20	1.05	5.52

[1]Upper Lake Pepin.
[2]Lower Lake Pepin.
[3]Eight sites were not resampled in the same locations.
[4]Five sites were not resampled in the same locations.
[5]Two sites were sampled out of the water.
[6]Two laboratory replicate analyses were reported as less than 0.01 and were not included in the values listed here.

SUMMARY

A representative, composite, surficial bed-sediment sample was collected from the downstream one-third of 24 navigation pools by compositing 12 to 23 individual samples from 1 to 5 transects across the pools. These individual samples were collected away from the main navigation channel in backwater regions where the water depths ranged from about 0.3 m to about 3.0 m and where the water velocities were about 60 percent of the velocity in the main navigation channel. Estimates of flushing rates varied from 0.3 hr/km to about 1.7 hr/km. The median particle diameter of the surficial bed sediments ranged from 0.002 mm in lower Lake Pepin (or Pool 4) to 0.42 mm in Pool 20. The organic carbon associated with the surficial bed sediments ranged from 0.12 percent in Pool 20 to 3.8 percent in Lower Lake Pepin (or Pool 4). Nitrogen was lowest in Pool 6 (0.01 percent) and highest (0.43 percent) in Upper Lake Pepin (or Pool 4).

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– PAGE 37 FOLLOWS –

CHAPTER 2 - Sterols, Polynuclear Aromatic Hydrocarbons, and Linear Alkylbenzene Sulfonates

By Larry B. Barber, II, and Jeffrey H. Writer

ABSTRACT

Fecal sterols, polynuclear aromatic hydrocarbons, and linear alkylbenzene sulfonates were measured in surficial bed-sediment samples collected from 24 of the navigation pools on the Upper Mississippi River in June and July 1994. These samples were collected 1 year after the flood of 1993. Fecal sterols, polynuclear aromatic hydrocarbons, and linear alkylbenzene sulfonates are relatively biorefractory compounds that accumulate in the bed sediments and are indicative of sewage and industrial contamination. The rates of biodegradation vary; fecal sterols are the most stable, polynuclear aromatic hydrocarbons show a range of degradation rates, and linear alkylbenzene sulfonates are the most degradable. Coprostanol concentrations ranged from 0.23 to 4.41 milligrams per kilogram in the postflood samples, total polynuclear aromatic hydrocarbons concentrations ranged from 0.10 to 5.28 milligrams per kilogram, and linear alkylbenzene sulfonate concentrations ranged from 0.03 to 1.07 milligrams per kilogram.

INTRODUCTION

The Upper Mississippi River between Minneapolis, Minn., and St. Louis, Mo., contains a series of 29 pools formed by navigation locks and dams which trap sediment and sediment-bound organic contaminants at accumulation rates of 1 to 4 cm/yr (McHenry and others, 1984). The Mississippi River receives many organic contaminants from a variety of both point and nonpoint sources; of particular interest to this study was the effect of municipal wastewater discharge on the bed sediments of the Upper Mississippi River.

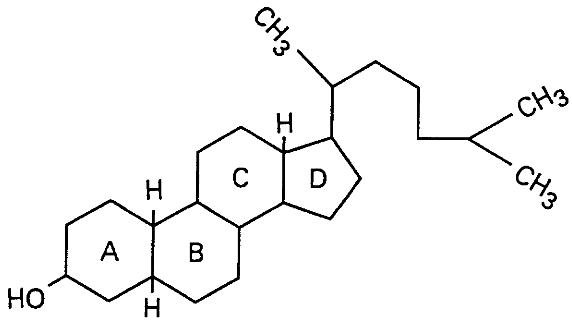


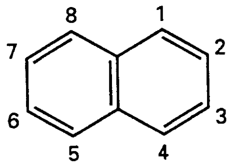
Figure 2.1--Chemical structure of coprostanol. A, B, C, and D are ring labels for the molecule; HO is the hydroxyl group; H is the point of reductive hydrogenation of the molecule; CH_3 are methyl groups.

Fecal sterols are present in the feces of humans, livestock, and birds (Walker and others, 1982; Subbiah and others, 1972; Nishimura and Koyama, 1977), are associated primarily with particulate matter, and accumulate in the bed sediments (Hatcher and McGillvary, 1979; Brown and Wade, 1984). Routinely monitored parameters such as nutrients, oxygen demand, and fecal coliform bacteria are fairly transient in the river environment in contrast to nonionic-organic contaminants such as coprostanol (fig. 2.1) Because coprostanol is biodegraded slowly, it can be used as a molecular indicator of long-term sewage effects on the environment (Hatcher and McGillvary, 1979; Brown and Wade, 1984; Venkattsen and Kaplan, 1990). Tabak and others (1977) conducted a limited analysis of coprostanol in the Mississippi River around the Burlington, Iowa, wastewater-treatment plant and found that the sediments in that reach of the river had been contaminated by fecal sterols.

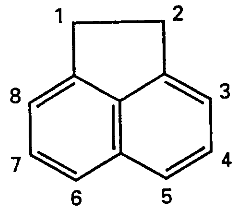
Polynuclear aromatic hydrocarbons (PAH) are an important class of organic contaminants that include many individual compounds (fig. 2.2). PAH come primarily from the combustion of plant material and fossil fuels such as coal and petroleum. Because of their many natural and anthropogenic sources and their widespread occurrence (Jones and Leber, 1979; Hoffman and others, 1984; Boehm and Farrington, 1984; Barrick and others, 1984), PAH are general indicators of sediment contamination. These compounds have a wide range of molecular structures and consequently have a wide range of environmental behaviors such as sorption, volatilization, and biodegradation.

Linear alkylbenzene sulfonates (LAS) are the most common anionic surfactants used in the United States for detergent formulations. Their annual consumption is about 4×10^5 metric tons (Modler and others, 1993). Most LAS are consumed in domestic and commercial applications and disposed of in wastewater. LAS formulations are a mixture of homologies and isomers (fig. 2.3). The alkyl-chain length varies from C_{10} to C_{14}, and the point of attachment for the alkyl chain varies from the 2-phenyl to the 7-phenyl position. LAS are readily biodegraded under aerobic conditions, and sewage treatment is effective in removing more than 90 percent of LAS (Rapaport and Eckhoff, 1990). However, LAS slowly biodegrade under anaerobic conditions (Larson and Payne, 1981; Federle and Schwab, 1992). Because of their high water solubility and anionic character, LAS are not as strongly sorbed to sediments as compounds such as sterols and PAH (Hand and Williams, 1987).

The sorption of organic contaminants to sediments depends primarily on the water solubility of the compounds and the characteristics of the sediment (Chiou and others, 1983; Karickhoff, 1984; Leenheer, 1991). As the water solubility of a compound decreases, its sorption to sediments typically increases. The most important sediment variables for sorption of organic contaminants are sediment-organic-matter concentrations and clay content. Smaller particles have a higher percentage of organic coatings because of the large surface area:volume ratio, and an inverse relation between particle size and percentage of organic carbon commonly exists in natural sediments (Barber, 1994).



NAPHTHALENE



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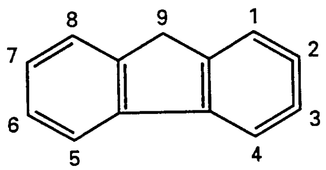
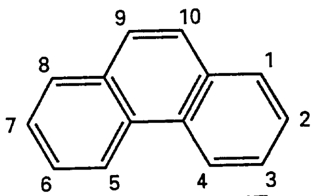


FLUORENE



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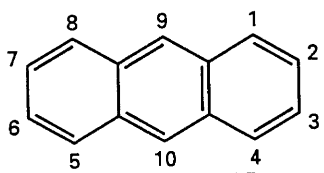

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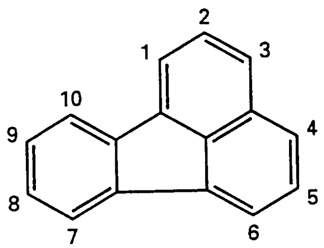

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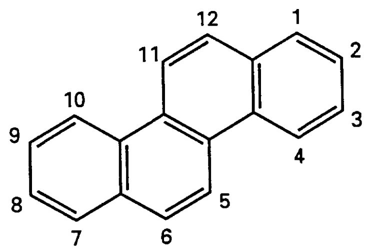

CHRYSENE

Figure 2.2--Chemical structure of some polynuclear aromatic hydrocarbons.

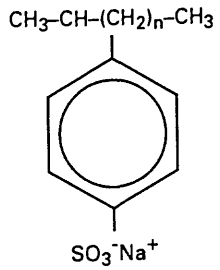

Figure 2.3--Chemical structure of linear alkylbenzene sulfonate. This example shows a 2-phenyl isomer where n ranges from 7 to 11.

PURPOSE AND SCOPE

In the summer of 1993, the Upper Mississippi River flooded extensively. The purpose of this chapter is to (1) report the concentrations of fecal sterols, PAH, and LAS in surficial bed sediments collected from the navigation pools of the Upper Mississippi River after the flood, and (2) describe the analytical methods. Tables and graphs of the data are presented to show the longitudinal distribution of the concentrations of these compounds. These data and data obtained prior to the flood (Barber and others, 1997; Writer and others, 1995; Tabor and Barber, 1996) can be used to evaluate changes caused by the flood.

METHODS

Sample Collection and Preservation

Samples were collected in the Upper Mississippi River from the lower one-third of 24 of the 29 navigation pools. A composite sample also was collected from the St. Croix River upstream from the confluence with the Upper Mississippi River. Locations of the pools are shown in figure.1.1, and the method for collecting a representative composite sample is described in Chapter 1. All composite samples were preserved with 10 mL of chloroform and stored at 4°C.

Sterols and Polynuclear Aromatic Hydrocarbons

The sterols were extracted from the bed sediments and measured by gas chromatography-mass spectroscopy (GC-MS). The analytical procedures were similar to those used for analyzing samples collected in 1991-92 (Barber and others, in press) with a few minor exceptions that are discussed herein. The extraction procedure (Brown and Wade, 1984) entailed saponification/extraction of 50 g of wet sediment for 2.5 hours with a 100-mL solution of 0.5 N potassium hydroxide in methanol and 10 mL benzene. The extract was filtered to remove sediment, the potassium hydroxide was neutralized with hydrochloric acid, and the extract was partitioned between water and methylene chloride. The methylene chloride extract was evaporated under nitrogen gas to dryness, and the residue was taken up in 10 mL of hexane. The hexane extract was evaporated under nitrogen gas to 2 mL and applied to a column using a Waters 1A Millilab robotics system. The preflood analytical procedures utilized a column of neutral silica (0.35 g) over neutral alumina (0.75 g), while the postflood analytical procedure utilized only neutral silica (690 g). Evaluation of the two columns indicated little difference in compound separation. The extract was then fractionated using a sequential elution procedure of hexane (5 mL), benzene (5 mL), and methanol (5 mL). The PAH were eluted from the column in the initial hexane fraction because of residual benzene in the robotics system. The methanol fraction was derivatized using Tri-Sil 'Z' (Pierce, Rockford, Ill.) to convert the free sterols to their trimethyl silyl ethers. Sterols were quantified by comparison with the surrogate deuterated standard d_7-cholesterol added at the beginning of the analytical procedure. PAH were quantified by comparison with five deuterated PAH added at the beginning of the analytical procedure (d_8-naphthalene, d_{10}-cenaphthalene, d_{12}-phenanthrene, d_{12}-chrysene, and d_{12}-perylene).

Gas Chromatography-Mass Spectrometry Analysis

Gas chromatography-mass spectrometry analysis was performed on a Hewlett-Packard 5890 gas chromatograph with a Hewlett-Packard Ultra II column (25-m $\times$ 0.2-mm inside diameter and 20-µm film thickness), a splitless injection port, ultrahigh-purity helium as the carrier gas (27 cm/s liner flow velocity), and a mass spectrometer interface temperature of 280°C. A Hewlett-Packard 5970 mass selective detector (MSD) was used with a source temperature of 250°C, a source pressure of 1.5×10^{-5} torr, and an ionization energy of 70 eV. Additional GC-MS operating conditions are listed in table 2.1. The sample extracts were analyzed in full-scan mode [mass-to-charge ratios (m/z) range from 45 to 550 atomic mass units/electron unit (amu/eu)] at a rate of one scan per second and in selected-ion monitoring (SIM) mode with a dwell time of 50 milliseconds. Identification was achieved by comparison of full-scan mass spectra and retention times with authentic standards and library searches. Quantitation was based on the SIM data. Sterols were determined by analysis of the methanol fraction of the sediment extract, and PAH were determined in the hexane/benzene extracts. Because of the similar chemical characteristics between the target compounds and the deuterated surrogate standards, concentrations were not corrected for recovery.

Table 2.1--Gas chromatograph operating conditions for sterol, polynuclear aromatic hydrocarbon, and linear alkylbenzene sulfonate analyses

[°C, degree Celsius; min, minute]

Condition	Sterol	Polynuclear aromatic hydrocarbon	Linear alkylbenzene sulfonate
Injection port temperature (°C)	290	290	280
Initial temperature (°C)	60	60	110
Initial time (min)	2	2	1
Ramp rate °C/min	10	10	8
Final temperature (°C)	300	300	300
Final time (min)	20	20	5

Linear Alkylbenzene Sulfonates

Linear alkylbenzene sulfonates were extracted from the bed sediments by placing 15-30 g of wet sediment in a centrifuge tube, removing pore water by centrifuging at 3,500 rpm for 20 minutes, and pipetting off the supernatant for later analysis. Ten mL of methanol was added to the sediment and the sediment was extracted on a rotary mixer for 1 hour. Each sample was then centrifuged at 3,500 rpm for 20 minutes and the supernatant liquid transferred to a holding vial. The extraction process was repeated two more times, using an extraction time of 12 hours. The extracts were combined, quantitatively transferred to a 5-mL reaction vial, and evaporated to dryness under nitrogen gas.

The extract residues were derivatized with phosphorus pentachloride and 2,2,2-trifluoroethanol to form the trifluoroethyl esters of LAS (Trehy and others, 1990). All samples were analyzed using a Hewlett-Packard 5890 GC coupled to a Hewlett-Packard 5970 MSD mass spectrometer (table 2.1). Linear alkylbenzene sulfonates were quantified by comparison with the surrogate standard C_9-LAS (provided by the Procter Gamble Company, Cincinnati, Ohio) added to the sediment before extraction. A C_8-LAS (Aldrich) derivatization standard was added to the sample residue after extraction but before derivatization. Further discussion on LAS analytical methodology is presented by Barber and others (1997).

Accuracy and Precision

Estimates of accuracy were determined from the standard deviation of the percent recovery of deuterated compounds added to the extracts (tables 2.2 and 2.3). The LAS accuracy is the percent recovery of C_9 -LAS normalized to the C_8 -LAS derivatization standard (each added in equal concentrations). The precision is the relative standard deviation from multiple analyses of a surrogate compound for each class of compounds (sterols, d_7 -cholesterol; LAS, C_9-LAS; and PAH, average of d_8-naphthalene, d_{10}-acenaphthalene, d_{10}-phenanthrene, d_{12}-chrysene, and d_{12}-perylene).

Table 2.2--Accuracy and precision estimates for sterol, polynuclear aromatic hydrocarbon, and linear alkylbenzene sulfonate measurements

[%, percent; >, greater than]

Class	Accuracy (%)	Precision (%)
Sterols	>95[1]	20
Polynuclear aromatic hydrocarbons	>95[1]	22
Linear alkylbenzene sulfonates	34	40

[1]Quantified by comparison against a surrogate standard added at the beginning of the analytical procedure; thus, the accuracy is assumed to be greater than 95 percent.

Table 2.3--Variability of cholestanol, cholesterol, coprostanol, and polynuclear aromatic hydrocarbons in duplicate samples collected from Pools 2, 8, and 19, and triplicate extraction of surficial sediment from Pool 3

[S, sample; mg, milligram; kg, kilogram; %, percent; RPD, relative percent difference; STD, standard deviation; RSTD, relative standard deviation; nd, not detected; na, not applicable; PAH, polynuclear aromatic hydrocarbons]

	Extractions									Triplicate extraction		
	Pool 2			Pool 8			Pool 19			Pool 3		
	S 1 (mg/kg)	S 2 (mg/kg)	RPD (%)	S 1 (mg/kg)	S 2 (mg/kg)	RPD (%)	S 1 (mg/kg)	S 2 (mg/kg)	RPD (%)	Average (mg/kg)	STD (mg/kg)	RSTD (%)
Sterols												
Cholestanol	0.89	1.11	21.7	0.46	0.47	2.55	1.12	1.16	2.91	1.11	0.02	1.55
Cholesterol	2.70	2.55	5.71	1.63	1.58	2.86	4.08	3.24	22.9	2.37	0.10	4.06
Coprostanol	0.78	1.01	26.1	0.18	0.15	18.0	0.31	0.27	12.7	0.38	0.04	10.7
Polynuclear aromatic hydrocarbons												
Corrected Naphthalene	0.034	0.029	17.0	nd	nd	na	nd	nd	na	1.03	0.05	5.28
Acenaphtha lene	0.017	0.014	16.6	0.080	0.002	188	0.319	0.041	154	0.38	0.44	115
Acenaphthene	0.015	0.016	3.48	nd	0.002	na	nd	0.009	na	0.00	0.00	141
Fluorene	0.019	0.023	18.2	nd	0.003	na	nd	0.022	na	0.05	0.03	51.3
Phenanthrene	0.248	0.205	19.1	0.010	0.024	79.3	0.026	0.028	8.76	0.09	0.01	8.75
Anthracene	0.027	0.015	55.8	0.001	0.004	134	0.008	0.009	10.9	0.01	0.00	21.7
Fluoranthene	0.539	0.359	39.9	0.030	0.041	29.5	0.068	0.053	23.9	0.21	0.02	10.8
Pyrene	0.606	0.329	59.3	0.027	0.034	24.9	0.075	0.058	25.7	0.19	0.02	11.3
Benzo[a] anthracene	0.178	0.106	50.9	0.005	0.010	63.3	0.023	0.023	3.46	0.06	0.00	1.71
Chrysene	0.332	0.216	42.3	0.016	0.020	22.9	0.035	0.038	8.47	0.14	0.00	1.05
Benzo[b] fluoranthene	0.357	0.293	19.6	0.015	0.025	48.2	0.051	0.061	16.7	0.21	0.01	4.20
Benzo[k] fluoranthene	nd	nd	na	nd	nd	na	nd	nd	na	0.00	0.00	0.00
Benzo[a]pyrene	0.142	0.076	61.1	nd	0.005	na	0.021	0.023	7.94	0.04	0.00	2.72
Benzo[ghi] perylene	0.176	0.115	41.8	nd	nd	na	0.008	0.015	55.2	0.04	0.01	19.4
Indeno [1,2,3-cd] pryene	0.259	0.155	50.4	nd	nd	na	0.010	0.017	53.7	0.05	0.01	21.5
Dibenzo- [a,h] anthracene	0.076	0.046	48.9	nd	nd	na	0.004	0.008	53.3	0.01	0.01	75.6
Total PAH	3.025	1.997	41.0	0.185	0.171	7.95	0.647	0.404	46.3	2.53	0.55	21.6

RESULTS

Concentrations of coprostanol and polynuclear aromatic hydrocarbons were greatest just downstream from the Minneapolis-St. Paul metropolitan area and then decreased with increasing distance downstream. Concentrations of linear alkylbenzene sulfonates, however, did not have any distinct longitudinal distribution pattern.

Sterols

Coprostanol concentrations measured in the surficial bed sediments ranged from 0.23 mg/kg to 4.41 mg/kg (table 2.4). Sterol ratios ranged from 0.02 to 0.28. Analysis of duplicate samples collected from Pools 2, 8, and 19 indicated an average relative percent difference in coprostanol concentrations of 18.9 percent. Triplicate extractions on the Pool 3 sample indicated a relative standard deviation in coprostanol concentrations of 10.7 percent (see table 2.3). Triplicate extractions on preflood samples collected from Pools 1, 10, and 13 showed a relative standard deviation in coprostanol concentrations of 22.8 percent (Barber and others, 1997).

The longitudinal distribution pattern of sterols in the postflood sampling indicated an increased sterol concentration downstream from Minneapolis-St. Paul to Lake Pepin (Pool 4) (fig. 2.4). Sediment-bound contaminants are deposited in the large sediment trap formed by Lake Pepin, and sterol concentrations in pools downstream from pool 4 were less than those in pool 4.

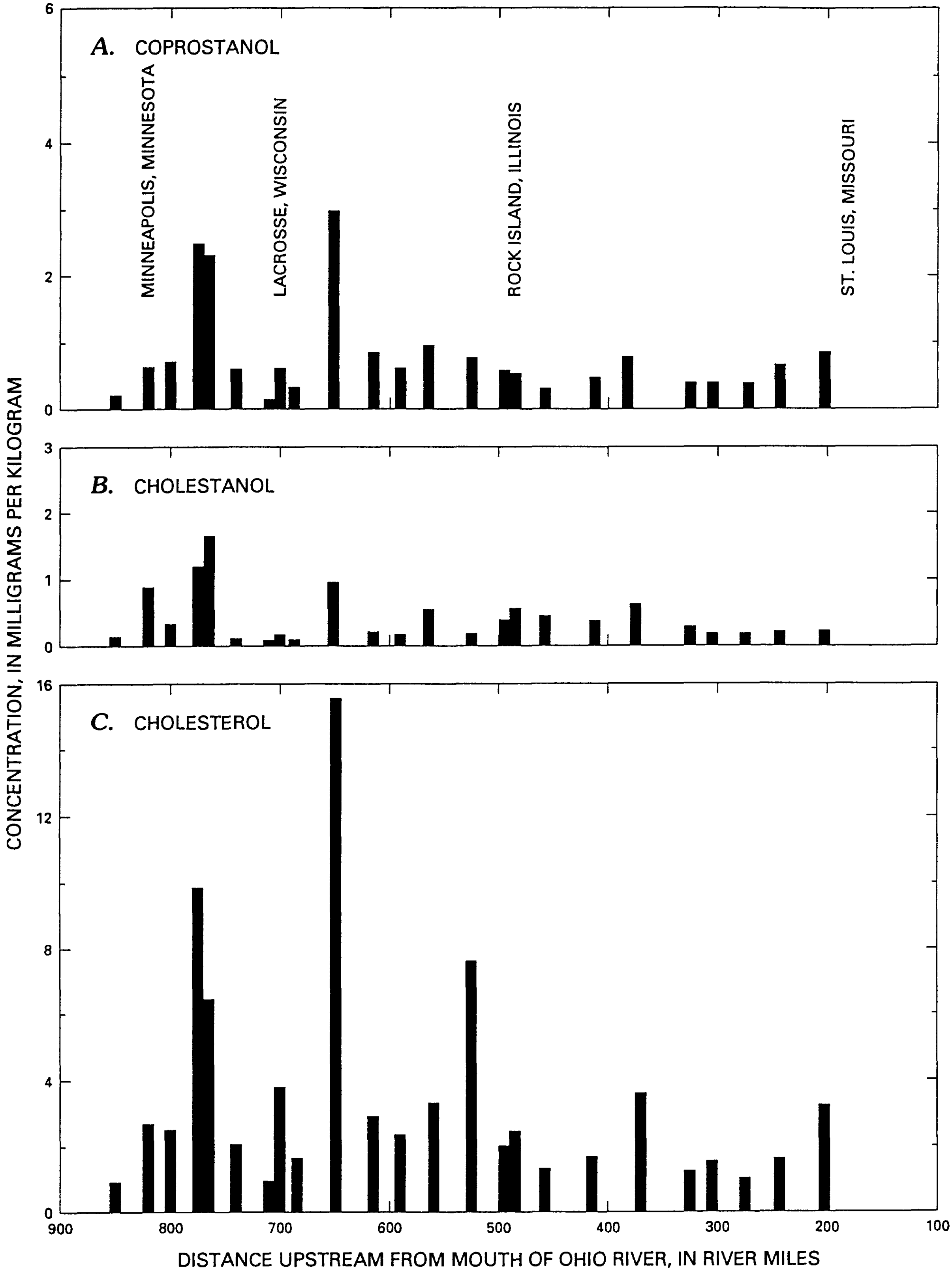

Figure 2.4--Sterol concentrations in surficial bed sediments from the downstream one-third of the 25 sampled navigation pools of the Upper Mississippi River, June-July 1994. See table 1.2 for location of pools.

Table 2.4--Fecal sterol concentrations in surficial bed sediments collected from the downstream one-third of the 25 sampled navigation pools of the Upper Mississippi River, June-July, 1994

[mg, milligram; kg, kilogram]

Pool-duplicate	Date	Coprostanol (mg/kg)	Cholesterol (mg/kg)	Cholestanol (mg/kg)	Sterol ratio[1]
1	06-11-94	0.27	0.88	0.18	0.15
[2]2-1	06-12-94	0.89	2.70	0.78	0.22
[2]2-2		1.11	2.55	1.01	0.28
St. Croix River	06-13-94	2.26	5.38	0.75	0.10
[3]3	06-14-94	1.12	2.34	0.33	0.10
		1.13	2.50	0.43	0.12
		1.09	2.27	0.38	0.11
[4]4	06-15-94	3.76	9.83	1.22	0.09
[5]4		3.54	7.43	1.64	0.15
5	06-16-94	0.89	1.97	0.11	0.04
6	06-17-94	0.23	0.94	0.07	0.06
7	06-18-94	0.92	3.76	0.18	0.04
[2]8-1	06-19-94	0.46	1.63	0.18	0.09
[2]8-2		0.47	1.58	0.15	0.08
9	06-20-94	4.41	15.63	0.96	0.05
10	06-21-94	1.27	3.07	0.19	0.04
11	06-21-94	0.89	2.34	0.19	0.06
12	06-22-94	1.39	3.31	0.56	0.12
13	06-23-94	1.09	7.60	0.20	0.02
14	06-23-94	0.82	2.03	0.35	0.12
15	06-26-94	0.76	2.40	0.52	0.16
16	06-27-94	0.44	1.29	0.39	0.23
18	06-28-94	0.65	1.69	0.35	0.15
[2]19-1	06-29-94	1.12	4.08	0.31	0.06
[2]19-2		1.16	3.24	0.27	0.06
20	06-30-94	0.21	0.44	0.04	0.06
21	07-01-94	0.51	1.22	0.24	0.14
22	07-02-94	0.52	1.48	0.13	0.07
24	07-03-94	0.53	1.09	0.12	0.07
25	07-04-94	0.88	1.78	0.17	0.07
26	07-05-94	1.20	3.28	0.29	0.06

[1]Sterol ratio is equal to concentrations of coprostanol/(cholestanol + cholesterol).
[2]Duplicate sample collected in the field.
[3]Analysis performed in triplicate to assess analytical variability.
[4]Upper Lake Pepin.
[5]Lower Lake Pepin.

Polynuclear Aromatic Hydrocarbons

Preflood concentrations of polynuclear aromatic hydrocarbons were determined using an external standard, whereas postflood concentrations were based on comparison with surrogate standards added at the beginning of the analytical procedure. The preflood sample collected from upper Lake Pepin was reanalyzed with a surrogate standard added at the beginning of the analytical procedure to assess the variability between these two techniques; total PAH concentrations were 2.18 mg/kg for the preflood and 2.05 mg/kg for the postflood analyses. Total PAH concentrations of postflood samples ranged from 0.10 to 5.28 mg/kg (table 2.5). Analysis of duplicate samples collected from Pools 2, 8, and 19 indicated that the average relative percent difference was about 32 percent (table 2.3). Analytical variability as indicated by triplicate extractions of Pool 3 indicated a relative standard deviation of 21.6 percent (table 2.3). The greatest PAH concentrations were measured at Pool 1 and decreased downstream (fig. 2.5).

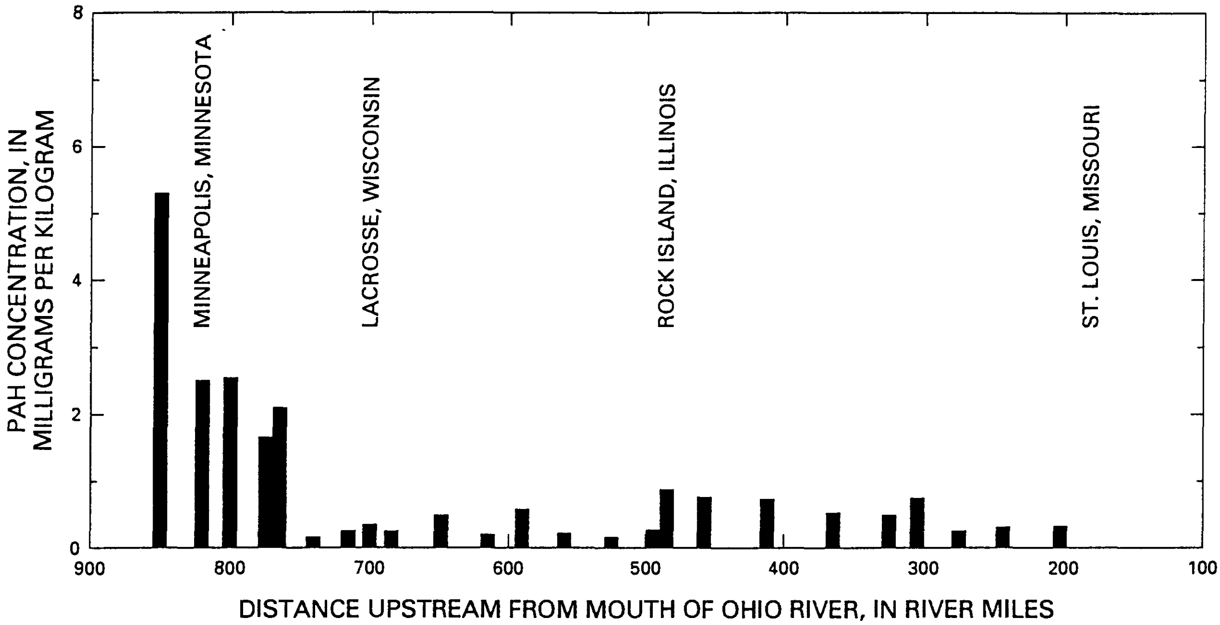

Figure 2.5--Total polynuclear aromatic hydrocarbon concentrations in surficial bed sediments from the downstream one-third of the 25 sampled navigation pools of the Upper Mississippi River, June-July 1994. See table 1.2 for location of pools.

Table 2.5--Polynuclear aromatic hydrocarbon concentrations in surficial bed sediments of the Upper Mississippi

[All units are milligrams per kilogram;

Pool-duplicate	Date	Corrected naph-thalene[1]	Ace-naphthalene	Ace-naphthene	Fluorene	Phen-anthrene	Anthracene	Fluor-anthene	Pyrene
1	06-11-94	<1.08	0.23	0.04	0.20	0.30	0.04	0.60	0.58
[2]2-1	06-12-94	0.03	0.02	0.02	0.02	0.25	0.03	0.54	0.61
[2]2-2		0.03	0.01	0.02	0.02	0.21	0.02	0.36	0.33
St. Croix River	06-13-94	0.00	0.61	0.07	0.00	0.05	0.01	0.23	0.21
[3]3	06-14-94	1.06	0.99	0.00	0.08	0.10	0.01	0.24	0.22
		1.08	0.13	0.00	0.06	0.10	0.01	0.21	0.19
		0.96	0.02	0.01	0.02	0.08	0.01	0.19	0.17
[4]4	06-15-94	0.00	0.02	0.01	0.02	0.10	0.01	0.30	0.31
[5]4		0.00	0.59	0.00	0.00	0.05	0.01	0.35	0.42
5	06-16-94	0.00	0.05	0.00	0.00	0.01	0.00	0.03	0.03
6	06-17-94	0.00	0.00	0.00	0.00	0.01	0.00	0.09	0.10
7	06-18-94	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.13
[2]8-1	06-19-94	0.00	0.08	0.00	0.00	0.01	0.00	0.03	0.03
[2]8-2		0.00	0.00	0.00	0.00	0.02	0.00	0.04	0.03
9	06-20-94	0.01	0.00	0.00	0.01	0.04	0.00	0.08	0.07
10	06-21-94	0.00	0.00	0.00	0.00	0.01	0.00	0.02	0.02
11	06-21-94	0.00	0.23	0.00	0.00	0.02	0.00	0.09	0.08
12	06-22-94	0.00	0.00	0.00	0.00	0.01	0.00	0.06	0.05
13	06-23-94	0.00	0.02	0.00	0.00	0.01	0.00	0.03	0.03
14	06-23-94	0.00	0.03	0.00	0.04	0.02	0.00	0.03	0.03
15	06-26-94	0.00	0.14	0.00	0.00	0.07	0.00	0.21	0.17
16	06-27-94	0.00	0.05	0.00	0.05	0.07	0.07	0.14	0.12
18	06-28-94	0.00	0.33	0.00	0.00	0.02	0.00	0.08	0.09
[2]19-1	06-29-94	0.00	0.32	0.00	0.00	0.03	0.01	0.07	0.07
[2]19-2		0.00	0.04	0.01	0.02	0.03	0.01	0.05	0.06
20	06-30-94	0.00	0.03	0.00	0.00	0.01	0.00	0.03	0.03
21	07-01-94	0.00	0.03	0.00	0.00	0.07	0.01	0.22	0.19
22	07-02-94	0.00	0.26	0.00	0.00	0.02	0.00	0.07	0.08
24	07-03-94	0.00	0.00	0.00	0.00	0.01	0.00	0.06	0.07
25	07-04-94	0.00	0.01	0.00	0.00	0.02	0.00	0.05	0.05
26	07-05-94	0.00	0.01	0.00	0.00	0.02	0.00	0.05	0.05

[1]Naphthalene concentration based on comparison with surrogate standard (d_8-naphthalene) added at the beginning of analytical procedure. Concentration was assumed to be greater than surrogate standard if naphthalene, but not d_8-naphthalene was recovered.
[2]Average of duplicate samples.
[3]Average of triplicate analysis.
[4]Upper Lake Pepin.
[5] Lower Lake Pepin.

collected from the downstream one-third of the 25 sampled navigation pools River, June-July 1994

and PAH, polynuclear aromatic hydrocarbons]

Pool-duplicate	Benzo[a] anthracene	Chrysene	Benzo[b] fluoranthene	Benzo[k] fluoranthene	Benzo[a] pyrene	Benzo-[ghi] perylene	Indeno [123-cd] pyrene	Dibenzo-[a,h] anthracene	Total PAH
1	0.19	0.28	0.39	0.00	0.13	0.06	0.08	0.00	5.28
[2]2-1	0.18	0.33	0.36	0.00	0.14	0.18	0.26	0.08	3.03
[2]2-2	0.11	0.22	0.29	0.00	0.08	0.12	0.15	0.05	2.00
St. Croix River	0.04	0.13	0.14	0.00	0.02	0.05	0.08	0.02	1.66
3[3]	0.06	0.14	0.20	0.00	0.04	0.05	0.06	0.02	3.28
	0.06	0.14	0.21	0.00	0.04	0.04	0.05	0.00	2.31
	0.06	0.14	0.22	0.00	0.05	0.03	0.04	0.01	1.99
[4]4	0.07	0.19	0.29	0.00	0.06	0.09	0.13	0.03	1.63
[5]4	0.05	0.14	0.23	0.00	0.05	0.08	0.12	0.02	2.13
5	0.00	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.15
6	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.21
7	0.00	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.27
[2]8-1	0.01	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.19
[2]8-2	0.01	0.02	0.03	0.00	0.01	0.00	0.00	0.00	0.17
9	0.00	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.42
10	0.01	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.10
11	0.02	0.03	0.04	0.00	0.01	0.00	0.00	0.00	0.52
12	0.01	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.16
13	0.01	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.12
14	0.01	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.20
15	0.04	0.07	0.10	0.02	0.02	0.00	0.00	0.00	0.85
16	0.03	0.07	0.09	0.00	0.02	0.00	0.00	0.00	0.71
18	0.02	0.04	0.05	0.00	0.02	0.00	0.00	0.00	0.65
[2]19-1	0.02	0.03	0.05	0.00	0.02	0.01	0.01	0.00	0.65
[2]19-2	0.02	0.04	0.06	0.00	0.02	0.01	0.02	0.01	0.40
20	0.01	0.01	0.00	0.00	0.06	0.00	0.00	0.00	0.18
21	0.04	0.06	0.09	0.00	0.03	0.00	0.00	0.00	0.73
22	0.01	0.02	0.03	0.00	0.01	0.00	0.00	0.00	0.52
24	0.01	0.02	0.02	0.00	0.01	0.00	0.00	0.00	0.22
25	0.02	0.03	0.04	0.00	0.01	0.00	0.00	0.00	0.22
26	0.02	0.03	0.05	0.00	0.02	0.00	0.00	0.00	0.25

Linear Alkylbenzene Sulfonates

Linear alkylbenzene sulfonate concentrations in the postflood samples ranged from 0.03 to 1.07 mg/kg (table 2.6). Field-and-analytical variability for LAS was 47 percent based on multiple extractions of Pool 2 and Pool 8 samples (4 and 5 extractions, respectively). The longitudinal distribution pattern of LAS (fig. 2.6) in the Upper Mississippi River bed sediments is more variable than the patterns for sterols and PAH.

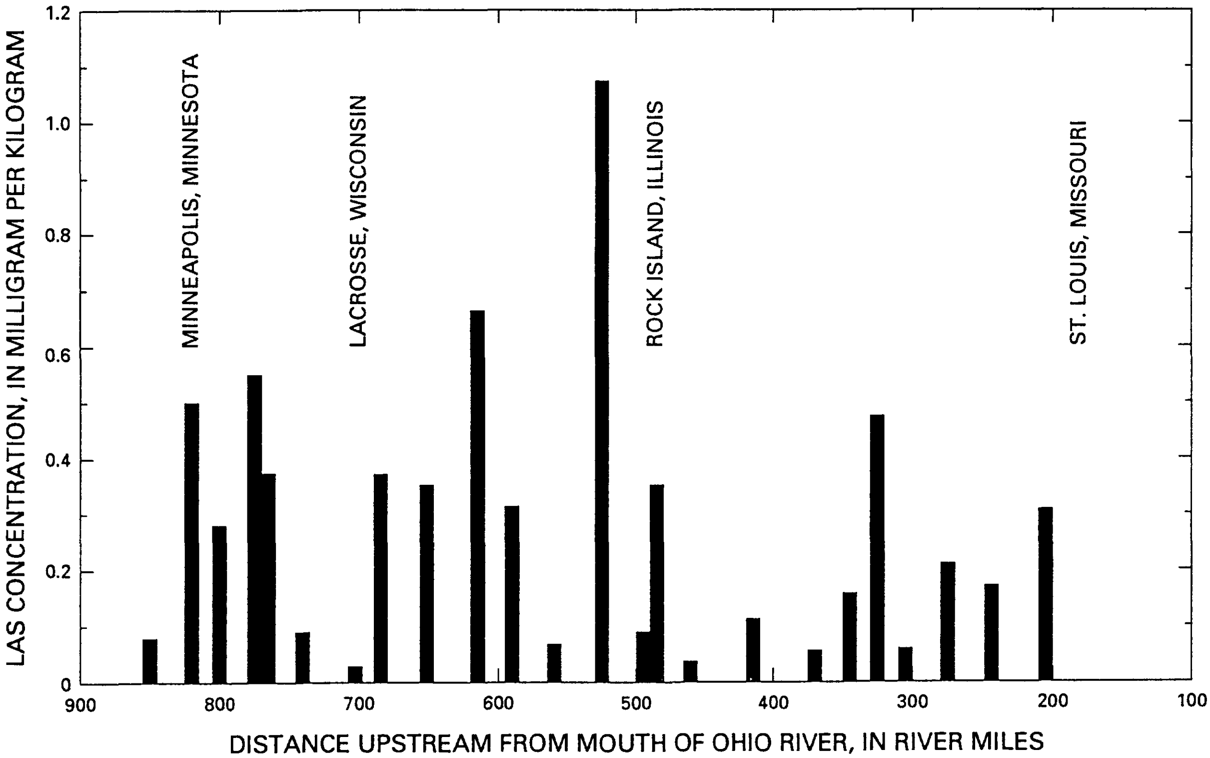

Figure 2.6--Total linear alkylbenzene sulfonate concentrations in surficial bed sediments from the downstream one-third of the 25 sampled navigation pools of the Upper Mississippi River, June-July 1994. See table 1.2 for location of pools.

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Table 2.6--Linear alkylbenzene sulfonate concentrations in surficial bed sediments, of the Upper Mississippi River, June-July 1994

[Data are the average from duplicate analyses; g, gram; mg, milligram; kg, kilogram; LAS, linear alkylbenzene

Pool-duplicate	Date	Dry weight (g)	LAS concentration (mg/kg)	Average chain length	Homologues (percent of total LAS)				Isomers (as percent of total LAS)				
					C_{10}	C_{11}	C_{12}	C_{13}	C_{10}-5	C_{10}-4	C_{10}-3	C_{10}-2	C_{11}-5&6
1	06-11-94	20.25	0.08	10.7	50	28	22	0	24	0	26	0	0
[1]2-1	06-12-94	17.54	0.52	10.9	26	58	15	0	8	6	9	3	20
2-1		18.37	0.37	11.3	22	20	59	0	5	0	8	9	7
2-2		15.00	0.26	10.6	44	46	9	0	15	0	22	7	10
[2]2-2		20.39	0.78	11.0	34	33	28	5	9	14	7	5	6
[2]2-2		20.61	0.38	10.6	67	14	9	10	17	33	17	0	0
[2]2-2		22.63	0.68	11.3	24	34	32	11	7	6	7	5	5
St. Croix River	06-13-94	5.61	0.14	10.2	77	23	0	0	45	0	32	0	0
3	06-14-94	15.62	0.28	10.1	90	10	0	0	30	22	38	0	0
[3]4	06-15-94	5.73	0.55	10.1	90	10	0	0	40	21	30	0	0
[4]4		4.68	0.37	10.0	100	0	0	0	44	24	32	0	0
5	06-16-94	17.07	0.09	10.0	100	0	0	0	0	60	40	0	0
6	06-17-94	31.64	0.03	10.9	28	51	21	0	10	0	18	0	0
7	06-18-94	19.04	0.16	11.2	22	31	47	0	0	0	17	5	6
[1]8-1	06-19-94	21.40	0.14	11.1	21	46	32	0	5	0	8	8	12
[1]8-1		21.98	0.19	10.9	29	50	20	0	10	0	10	10	10
[1]8-1		21.98	0.77	11.1	20	45	35	0	4	2	4	10	9
[1]8-2		21.64	0.38	11.2	10	58	32	0	0	0	10	0	12
[1]8-2		21.75	0.39	11.2	15	45	40	0	3	0	6	6	8
9	06-20-94	6.45	0.35	10.6	54	30	16	0	18	0	22	15	14
10	06-21-94	14.33	0.66	11.2	27	26	47	0	0	12	12	4	5
11	06-21-94	17.56	0.31	10.9	25	59	16	0	0	0	16	8	11
12	06-22-94	18.99	0.07	11.0	38	23	39	0	20	0	18	0	0
13	06-23-94	18.92	1.07	11.5	21	29	34	16	4.7	4	9	4	5
14	06-23-94	23.85	0.09	10.0	100	0	0	0	32	30	38	0	0
15	06-26-94	20.99	0.35	11.7	11	26	46	17	3	2	4	2	5
16	06-27-94	19.85	0.04	10.7	34	66	0	0	0	14	21	0	0
18	06-28-94	23.06	0.11	10.9	44	31	20	5	13	13	13	5	8
[1]19-1	06-29-94	16.74	0.16	10.3	77	16	7	0	25	21	32	0	0
[1]19-1		16.41	0.00	0.0	nd	nd	nd	nd	nd	nd	nd	nd	nd
[1]19-2		18.34	0.08	10.3	71	29	0	0	27	44	0	0	0
[1]19-2		17.26	0.00	0.0	nd	nd	nd	nd	nd	nd	nd	nd	nd
20	06-30-94	31.25	0.16	11.0	32	34	34	0	6	12	8	6	8
21	07-01-94	22.45	0.47	11.6	18	28	32	21	4	4	5	6	9
22	07-02-94	19.87	0.06	10.2	83	17	0	0	30	33	19	0	0
24	07-03-94	26.80	0.21	10.9	43	43	0	14	15	13	15	0	43
25	07-04-94	21.30	0.17	10.5	68	16	11	5	24	23	19	2	3
26	07-05-94	17.57	0.31	10.9	40	33	22	5	15	12	14	0	9

[1]Analysis performed in duplicate to assess analytical variability.
[2]Analysis performed in triplicate to assess analytical variability.
[3]Upper Lake Pepin.
[4]Lower Lake Pepin.

collected from the downstream one-third of the 25 sampled navigation pools

sulfonate; I/E, internal/external isomer ratio; c_{ii}-k, ii is the homologue and k is the phenyl position; nd, not detected]

Pool-duplicate	Isomers (as percent of total LAS)												
	C_{11}-4	C_{11}-3	C_{11}-2	C_{12}-6	C_{12}-5	C_{12}-4	C_{12}-3	C_{12}-2	C_{13}-6&7	C_{13}-5	C_{13}-4	C_{13}-3	C_{13}-2
1	0	0	28	0	0	0	0	22	0	0	0	0	0
[1]2-1	32	3	4	2	2	4	2	4	0	0	0	0	0
[1]2-1	0	0	13	10	10	7	11	20	0	0	0	0	0
2-2	6	16	15	0	0	4	0	5	0	0	0	0	0
[2]2-2	7	8	11	6	5	6	4	7	0	0	5	0	0
[2]2-2	0	8	5	0	0	0	9	0	0	0	10	0	0
[2]2-2	8	10	10	4	6	5	6	11	0	0	7	0	0
St. Croix River	0	16	6	0	0	0	0	0	0	0	0	0	0
3	0	10	0	0	0	0	0	0	0	0	0	0	0
[3]4	0	10	0	0	0	0	0	0	0	0	0	0	0
[4]4	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0
6	16	12	23	0	0	0	0	21	0	0	0	0	0
7	6	7	13	8	9	11	7	12	0	0	0	0	0
[1]8-1	8	13	13	5	5	5	7	11	0	0	0	0	0
[1]8-1	13	11	17	4	4	3	3	7	0	0	0	0	0
[1]8-1	10	10	17	7	7	5	6	11	0	0	0	0	0
[1]8-2	15	11	20	5	5	5	8	10	0	0	0	0	0
[1]8-2	13	9	14	5	6	6	8	15	0	0	0	0	0
9	0	7	9	3	3	0	4	6	0	0	0	0	0
10	4	6	11	7	8	7	11	14	0	0	0	0	0
11	8	14	26	5	0	11	0	0	0	0	0	0	0
12	0	0	23	18	21	0	0	0	0	0	0	0	0
13	6	6	12	7	5	5	7	9	6	10	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0
15	4	5	12	5	5	7	9	20	4	3	3	2	4
16	0	66	0	0	0	0	0	0	0	0	0	0	0
18	4	12	7	2	4	8	2	5	0	0	5	0	0
[1]19-1	0	16	0	0	0	7	0	0	0	0	0	0	0
[1]19-1	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
[1]19-2	0	0	29	0	0	0	0	0	0	0	0	0	0
[1]19-2	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
20	6	8	13	6	5	6	8	8	0	0	0	0	0
21	4	6	8	4	6	7	6	9	5	4	4	3	4
22	0	7	10	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	14	0	0	0
25	0	8	4	1	2	1	3	4	1	1	2	1	0
26	7	9	9	0	8	7	0	7	0	0	5	0	0

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Chapter 3 - Polychlorinated Biphenyl Congeners

By John F. Sullivan *and* Keith B. Lodge

ABSTRACT

Representative subsamples of surficial bed sediments were collected from the Mississippi River and analyzed for polychlorinated biphenyl congeners by two different laboratories. Samples from the upstream navigation pools (mainly above Lock and Dam 11) were analyzed by the Wisconsin State Laboratory of Hygiene in Madison, Wisconsin. Samples from the downstream navigation pools were analyzed by the University of Minnesota Trace Organic Laboratory in Duluth, Minnesota. The maximum total polychlorinated biphenyl concentration (92.8 nanograms per gram) was from Pool 4 (Lake Pepin), but the highest total polychlorinated biphenyls normalized by the amount of organic carbon was calculated for Pool 20 (6,500 nanograms per gram organic carbon). Spatial evaluation of these data are complicated by method differences and low total organic-carbon content in some samples from the downstream navigation pools.

INTRODUCTION

Polychlorinated biphenyls (PCB) are a group of organic compounds that were produced commercially by the chlorination of biphenyl with anhydrous chlorine (Eisler, 1986; Alford-Stevens, 1986). This process yielded a complex array of individual PCB molecules (congeners) with various chlorine contents. In the United States, PCB mixtures were commonly sold under the trade name of Aroclor. There are 209 potential PCB congeners (Mullin and Pochini, 1984), but not all congeners are found in the original formulations (Alford-Stevens, 1986). The actual number of congeners present in environmental samples is substantially less (McFarland and Clarke, 1989) as a result of differential partitioning and degradation.

PCB have been widely used since the 1930's, especially in electrical equipment, lubricants, and fire retardants (Eisler, 1986; Alford-Stevens, 1986). State and Federal regulations were enacted in the mid-1970's to restrict the production, use, and disposal of these compounds. The input of PCB to the Upper Mississippi River has been a water-quality problem for more than 20 years and has been especially apparent in the river reach extending from the Twin Cities metropolitan area to Lake Pepin (Sullivan, 1988; Steingraeber and others, 1994).

Like other organochlorine compounds, PCB generally have low solubility in water and have a strong affinity to adsorb to soil and sediment particles, especially those high in organic content (Karickhoff and others, 1979). As a result, contaminated sediment presents a major source of exposure of aquatic organisms to PCB (Lyman and others, 1987; Baudo and others, 1990). Volatilization of PCB from contaminated aquatic and terrestrial systems contributes to the transport of these compounds to the atmosphere (Hornbuckle and others, 1993).

PURPOSE AND SCOPE

One purpose of the bed-sediment sampling was to provide the concentrations of PCB congeners in surficial bed sediments collected in the downstream one-third of each navigation pool of the Upper Mississippi River after the flood of 1993. Congener PCB analysis provides a lower level of detection and is generally less subjective than older Aroclor-based methods. Congener data provide more specific information on the longitudinal distribution of PCB in Upper Mississippi River surficial bed sediments and allows for a more accurate assessment of their fate and partitioning to other environmental matrices. Two analytical laboratories were utilized as a result of laboratory work loads and a need to ensure consistency with previous congener PCB analysis of suspended sediment samples from the Mississippi River. The results from the two different methods are listed in two tables and the spatial distribution of total PCB (congener sums) and selected congeners are shown graphically.

ANALYTICAL METHODS

The subsamples collected for PCB congener analysis were kept refrigerated at about 4°C in glass jars with Teflon-lined lids until they were analyzed by either the Wisconsin State Laboratory of Hygiene in Madison, Wis. (hereinafter referred to as the WSLOH), or the University of Minnesota Trace Organic Analytical Laboratory in Duluth, Minn. (hereinafter referred to as the TOAL). The WSLOH analyzed bed-sediment samples from Pools 1-11, except 5A and 10, and the TOAL analyzed Pools 10 and 12-26, except 17. A reference sediment, collected from lower Lake Pepin in May 1991 by State and Federal agencies, was analyzed by both laboratories for comparison purposes.

Wisconsin State Laboratory of Hygiene Method

The WSLOH method identified 85 PCB congeners (some co-eluting) in surficial bed sediments using capillary column gas chromatography and electron-capture detection (Wisconsin State Laboratory of Hygiene, 1993). The sum of the individual congener concentrations provided an estimate of total PCB.

Sample Preparation

The sediment sample was air-dried at room temperature to about 10-30 percent moisture for about 2 to 5 days and then passed through a #10 sieve. Remaining material that did not pass through the sieve was discarded. A 10- to 25-g subsample of the homogenized sample was dried at 103°C for at least 10 hours in order to determine the percent moisture. If the moisture content exceeded 30 percent, the sample was redried. A 40- to 50-g subsample of air-dried sediment was then weighed into an acetone-washed paper extraction thimble and placed in an acetone-washed Soxhlet extraction apparatus. Each dry sample was spiked with a surrogate mixture (consisting of PCB congeners #14, #65, and #166 at concentrations of 100, 75, and 25 ng/mL, respectively) at two to five times the detection level to measure analytical recoveries for establishing upper and lower warning limits (equal to two standard deviations either side of the average analytical recovery). The average analytical recoveries (± the standard deviation) for 321 sediment samples for PCB congeners #14, #65, and # 166 were 87 ± 13, 91 ± 12, and 102 ± 11 percent, respectively. This information is from laboratory quality-assurance information reported by the WSLOH on August 18, 1993, and includes several years of data.

A few glass beads or boiling chips were placed in the Soxhlet flask with 300 mL of 50:50 (v : v) acetone : hexane mixture. Granular activated copper was added to the flask to minimize sulfur interferences. The Soxhlet extraction apparatus was placed on a hot plate and the sample was extracted for approximately 8 hours. The temperature was adjusted so that the Soxhlet cycled 5-8 times per hour. The acetone-hexane mixture was then concentrated under a gentle stream of filtered air or in a rotary evaporation apparatus to about 10 mL. Anhydrous sodium sulfate was added to aid in the removal of water.

Extract cleanup was performed using florisil and silica-gel fractionation. The PCB were eluted from the florisil column with 200 mL of a 94:6 (v : v) hexane-ethyl ether mixture. The extract was concentrated to approximately 5 mL and added to a silica-gel column. The silica-gel column was eluted with 50 mL of hexane at a rate of 1-2 mL/min. The final extract volume was reduced under a gentle stream of filtered air to 10 mL.

Sample Analysis

Sample analysis was performed with a gas chromatograph (HP 5880 Gas Chromatograph) using a capillary column (60-meter DB-5 column, 0.2-mm inside diameter, and 0.1-µm film; and an electron-capture detector. The calibration standard included a mixture of Aroclors 1232, 1248, and 1262 at concentrations of 0.250, 0.180, and 0.180 mg/L, respectively. The concentration of each congener in this mixture was provided by Mullin (1985). This standard also contained PCB congeners #30 (12 ng/mL) and #204 (13.8 ng/mL), which were used as retention-time reference peaks and as internal standards for quantitation. Internal standards were added to sample extracts just prior to gas chromatographic analysis.

Precision estimates (average absolute difference of duplicate sediment samples) and accuracy measurements (based on percent recoveries of spiked sediment samples) were conducted over a period of several years. One matrix spike sediment sample was analyzed for every 10 unknown sediment samples. Matrix spike solutions consisted of the same PCB Aroclor mixture used as the calibration standard above. Average and standard deviation values for precision and accuracy measurements are utilized to establish warning limits (average ± 2 SD) and control limits (average ± 3 SD) for PCB congener determinations. Sample results falling outside the control limits were reanalyzed or flagged for further evaluation. The method detection limit, limit of quantification, average precision, and average percent recovery for PCB congeners are listed in table 3.1. This table represents typical laboratory performance for several years ending in August 1993. The method detection limit is defined as the minimum concentration of a substance which can be measured and reported with 99-percent confidence that the analyte concentration is greater than zero and is determined from an analysis of a sample in a given matrix containing the analyte (U.S. Environmental Protection Agency, 1991). The limit of quantification is approximately 3.3 times the method detection limit (American Chemical Society, 1983).

Table 3.1--Method detection limit, limit of quantification, precision, and accuracy information for polychlorinated biphenyl congener analysis at the Wisconsin State Laboratory of Hygiene, Madison, Wisconsin

[Congeners are listed in order as reported by the laboratory; IUPAC, International Union of Pure and Applied Chemistry; ng/g, nanogram per gram of dry weight; N, number of replicate analyses; and %, percent]

IUPAC number	Structure	Method detection limit (ng/g)	Limit of quanti-fication (ng/g)	Precision[1]		Accuracy[2]	
				N	%	N	%
7	2,4	0.20	0.70	30	6.7	45	85.9
6	2,3′	0.45	1.5	36	8.5	44	89.7
5/8	2,3/2,4′	1.3	4.3	42	8.3	45	87.3
19	2,2′,6	0.30	1.0	30	10.0	42	69.0
18	2,2′5	0.35	1.2	41	5.8	45	87.3
17	2,2′,4	0.30	1.0	41	5.1	45	87.4
24/27	2,3,6/2,3′,6	0.30	1.0	36	5.9	44	85.5
16/32	2,2′,3/2,4′,6	0.40	1.5	42	7.4	44	85.9
26	2,3′,5	0.35	1.2	40	9.6	44	90.0
28/31	2,4,4′/2,4′,5	1.4	4.6	43	7.0	44	90.7
33	2′,3,4	0.45	1.5	36	8.8	45	89.8
22	2,3,4′	0.60	2.0	39	8.4	45	91.7
45	2,2′,3,6	0.30	1.0	38	7.0	45	83.0
46	2,2′,3,6′	0.35	1.2	35	6.3	45	82.7
52	2,2′,5,5′	0.30	1.0	44	4.8	45	92.3
49	2,2′,4,5′	0.30	1.0	42	5.0	45	91.1
47/48	2,2′,4,4′/2,2′,4,5	0.50	1.6	38	5.1	45	89.0
44	2,2′,3,5′	0.30	1.0	42	5.3	45	91.2
37/42	3,4,4′/2,2′,3,4′	0.40	1.3	40	7.4	45	91.1
41/64/71	2,2′,3,4/2,3,4′,6/2,3′,4′,6	0.50	1.6	39	7.4	45	88.1
40	2,2′,3,3′	0.30	1.0	37	6.1	45	87.7
74	2,4,4′,5	0.30	1.0	43	8.0	45	94.8
70/76	2,3′,4′,5/2′,3,4,5	0.45	1.5	45	7.6	45	96.4
66/95	2,3′,4,4′/2,2′,3,5′,6	0.60	2.0	43	6.1	45	93.2
91	2,2′,3,4′,6	0.40	1.3	39	5.5	45	96.1
56/60	2,3,3′,4′/2,3,4,4′	0.80	2.6	43	7.8	45	94.3
84/92	2,2′,3,3′,6/2,2′,3,5,5′	0.70	2.3	39	6.2	44	93.8
101	2,2′,4,5,5′	0.30	1.0	45	7.0	44	97.1
99	2,2′,4,4′,5	0.30	1.0	42	6.5	44	94.8
97	2,2′,3′,4,5	0.30	1.0	40	4.9	44	96.1
87	2,2′,3,4,5′	0.35	1.2	42	8.7	44	98.0
85	2,2′,3,4,4′	0.35	1.0	32	5.4	45	98.4
136	2,2′,3,3′,6,6′	0.20	0.70	21	6.1	45	94.6
77/110	3,3′,4,4′/2,3,3′,4′,6	0.40	1.3	45	7.4	44	96.1

Table 3.1--Method detection limit, limit of quantification, precision, and accuracy information for polychlorinated biphenyl congener analysis at the Wisconsin State Laboratory of Hygiene, Madison, Wisconsin--Continued

IUPAC number	Structure	Method detection limit (ng/g)	Limit of quanti-fication (ng/g)	Precision[1]		Accuracy[2]	
				N	%	N	%
82	2,2′,3,3′,4	0.30	1.0	36	7.8	44	93.8
151	2,2′,3,5,5′,6	0.30	1.0	40	9.8	45	93.4
135/144	2,2′,3,3′,5,6′/2,2′,3,4,5′,6	0.30	1.0	36	9.1	45	92.5
149	2,2′,3,4′,5′,6	0.30	1.0	41	7.0	45	93.6
118	2,3′,4,4′,5	0.45	1.5	44	8.5	44	95.6
146	2,2′,3,4′,5,5′	0.35	1.2	33	6.2	44	102.0
132/153	2,2′,3,3′,4,6′/2,2′,4,4′,5,5′	0.45	1.5	44	8.8	45	95.4
141	2,2′,3,4,5,5′	0.30	1.0	31	7.1	45	93.0
137/176	2,2′,3,4,4′,5/2,2′,3,3′,4,6,6′	0.30	1.0	45	10.0	45	95.5
138/163	2,2′,3,4,4′,5′/2,3,3′,4′,5,6	0.40	1.3	45	10.0	45	96.8
178	2,2′,3,3′,5,5′,6	0.40	1.3	22	13.0	45	94.6
182/187	2,2′,3,4,4′,5,6′/2,2′,3,4′,5,5′,6	0.40	1.3	40	9.8	45	94.3
183	2,2′,3,4,4′,5′,6	0.40	1.3	32	12.0	45	95.4
185	2,2′,3,4,5,5′,6	0.30	1.0	13	7.6	45	94.9
174	2,2′,3,3′,4,5,6′	0.30	1.0	39	8.3	45	93.7
177	2,2′,3,3′,4′,5,6	0.35	1.2	34	8.2	45	95.5
171/202	2,2′,3,3′,4,4′,6/2,2′,3,3′,5,5′,6,6′	0.30	1.0	27	11.0	45	96.2
172/197	2,2′,3,3′,4,5,5′/2,2′,3,3′,4,4′,6,6′	0.50	1.6	14	14.0	45	93.9
180	2,2′,3,4,4′,5,5′	0.35	1.2	41	8.4	45	96.0
199	2,2′,3,3′,4,5,6,6′	0.30	1.0	5	7.6	45	92.6
170/190	2,2′,3,3′,4,4′,5/2,3,3′,4,4′,5,6	0.70	2.3	32	9.0	45	95.4
201	2,2′,3,3′4,5,5′,6	0.50	1.6	39	11.0	45	95.3
196/203	2,2′,3,3′,4,4′,5,6′/2,2′,3,4,4′,5,5′,6	0.70	2.3	38	10.0	45	94.8
195/208	2,2′,3,3′,4,4′5,6/2,2′,3,3′,4,5,5′,6,6′	0.70	2.3	30	13.0	45	93.8
194	2,2′,3,3′,4,4′,5,5′	0.50	1.6	36	12.0	45	96.5
206	2,2′,3,3′,4,4′,5,5′,6	0.40	1.3	39	17.0	45	93.8
128	2,2′3,3′4,4′	0.50	1.6	---------------------no data--------------			
167	2,3′,4,4′,5,5′	0.50	1.6	---------------------no data--------------			

[1]Precision-average absolute difference between duplicate analyses over several years ending August 18, 1993.
[2]Accuracy-average percent recoveries of sediment samples spiked with standard solutions analyzed under similar test conditions over several years ending August 18, 1993.

Trace Organic Analytical Laboratory Method

The TOAL determined 117 PCB congeners (some co-eluting) by appropriate sample preparation, extraction, and cleanup, followed by analysis using capillary-column gas chromatography with electron-capture detection. Total PCB represented a sum of detected congeners.

Sample Preparation

The wet sediment was air-dried for several days under ambient laboratory conditions, then ground to a fine powder and stored in a freezer until the extraction step. Representative laboratory subsamples were collected from two samples, and simple grab samples were collected from the remaining samples.

Five representative subsamples each for Pool 19-1 and Lake Pepin reference sediment were utilized for laboratory replicates. Representative subsamples were prepared using a Sieving Riffler (Quantachrome, Model SRR-2). This consisted of eight stainless-steel collector bins placed upon a rotating platform. The dried and ground sediment sample was placed in a bowl attached to a vibrator. A chute with a gate delivered the dried sediment from the bowl to the collector bins. The amplitude of the vibrator, the speed of rotation of the platform, and the gate opening were adjusted to obtain a rotation speed that was faster than the delivery rate. A number of passes were required using combinations of representative subsamples in order to prepare final representative subsamples of about 10 g for analysis.

The subsamples obtained from the other sediments were grab samples. The samples were run in three sets with the extractions starting on October 12, 17, and 19, 1994. Approximately 10 g of the dried and ground sediment was mixed with sodium sulfate; the mixture was transferred to a Soxhlet thimble and spiked with 1,000 ng each of surrogate congeners #14 and #166 (recovery standards). The thimble was placed in a Soxhlet apparatus and extracted overnight with 250 mL 1:1 (v : v) acetone : hexane solution. Copper beads were added to the extraction flask to remove sulfur. The extract was reduced to 1 mL, using a Kuderna-Danish evaporative concentrator, and transferred to a florisil column for adsorption cleanup. PCB were eluted from the column using 75 mL of 20 percent (v:v) dichloromethane: hexane. This extract was again reduced to 1 mL, transferred to a 4-mL vial with three rinses of iso-octane, and spiked with 500 ng each of instrument internal standard consisting of congeners #30 and #204.

Sample Analysis

Sample analysis was performed using a Hewlett-Packard gas chromatograph (HP5890II) equipped with an autosampler (HP7672A) and an electron-capture detector. The column was a DB-5 (30 m by 0.25-mm inside diameter) with 0.25-μm film. Quantitation of individual congeners was accomplished by the determination of average response factors, relative to congeners #30 and #204 (15 ng/mL in the standards), from running a series of three calibration standards. The concentrations of total PCB Aroclors in these standards were 100, 200 and 400 ng/mL. The proportion of Aroclors was 1:1:1:1 (v:v) of 1242, 1248, 1254, and 1260 (Schwartz and others, 1990). The mixed Aroclor calibration standards were run with each sample set, which contains three quality-assurance samples (see below) and nine sediment extracts for analysis. A summary of PCB congener precision and accuracy data for a fortified sediment sample (West Bearskin Lake) is provided in table 3.2.

Five replicates of the Lake Pepin reference sediment and Pool 19-1 sample were analyzed by the TOAL. Generally, the standard deviation decreases with the mean concentration; this is observed by plotting the standard deviation against mean concentrations for congeners within each homologue group (plots not shown). Extrapolation of the mean concentration to zero provides an estimate of the limit of detection, as the t-estimator at the 99-percent confidence interval multiplied by the standard deviation. The estimates are 0.2 ng/g for tri- and tetra-chlorinated biphenyls, 0.02 ng/g for penta-chlorinated biphenyls, 0.01 ng/g for hexa-chlorinated biphenyls, and 0.008 ng/g for hepta- and octa-chlorinated biphenyls. Values below 0.01 ng/g are not reported here, although a satisfactory peak may be present.

Quality-assurance samples consisted of a method blank, containing only reagents to test for laboratory-derived contamination; a sediment spiked with PCB (West Bearskin Lake sediment fortified with 200 ng each of Aroclors 1242, 1248, 1254, and 1260) or a standard reference sediment (HS-1, National Research Council of Canada); and a duplicate sediment sample to test for precision (two replicates in table 3.4). The five replicate samples, each for Pool 19-1 and Lake Pepin, were not considered as quality-assurance samples in the composition of the sample sets. Samples not meeting the accepted requirements for recovery (40-120 percent of the surrogates), precision (relative difference ≤ 50 percent), and accuracy (relative difference ≤ 50 percent) were reanalyzed or flagged.

Table 3.2--Precision and accuracy data for polychlorinated biphenyl congeners analyzed by University of Minnesota Total Organic Analytical Laboratory, June-July 1994

[Five replicates were analyzed from a sample with a high concentration (Reference, 290 ng/g) and from a sample with a low concentration (Pool 19, 15.3 ng/g) to determine Precision, which is measured as the percent relative standard deviation; Accuracy is the percent spike recovery of a fortified sediment sample (West Bearskin Lake measured twice); IUPAC, International Union of Pure and Applied Chemistry; i, interference in the peak; d, detected congener but expected concentration was zero; and --, not detected; <, less than]

Con-gener IUPAC number	Precision		Accuracy	Con-gener IUPAC	Precision		Accuracy	Con-gener IUPAC	Precision		Accuracy
	Reference sample	Pool 19	West Bearskin Lake		Reference sample	Pool 19	West Bearskin Lake		Reference sample	Pool 19	West Bearskin Lake
4/10	--	38	80	89	14	--	[1]79	174	12	14	58
7	12	8	64	101	4	20	110	177	6	14	86
6	17	9	62	99	4	--	70	202/171	10	33	85
5/8	31	7	80	119	8	40	[1]190	156	6	29	77
19	--	--	63	83	5	33	[1]93	173	15	33	--
18	33	34	127	97	4	15	103	172/197	6	50	[1]86
17	5	16	108	87	3	10	84	180	5	36	75
24/27	42	33	[1]90	85	4	11	96	193	25	0	84
16/32	16	24	51	136	--	--	--	191	14	50	[1]220
29	--	50	[1]280	77/110	4	30	94	199	7	50	[1]100
26	42	--	130	82	5	25	63	170/190	5	17	[1]66
25	29	25	68	151	5	8	185	198	45	--	d
28/31	10	25	101	135/144	4	0	58	201	6	57	88
21/33/53	11	27	91	124	5	33	[1]51	203/196	3	75	84
51	43	50	[1]150	147	3	33	[1]99	189	35	--	d
22	--	--	80	107	2	25	[1]87	208/195	3	25	[1]79
45	21	47	130	123/149	4	5	66	207	5	100	d
46	23	25	51	118	3	10	110	194	15	50	84
52	3	8	68	134	3	33	87	205	27	--	d
43	--	20	[1]220	114	3	10	[1]420				
49	4	11	72	131/122	6	25	[1]55				
47/48	3	14	90	146	4	20	67				
44	4	12	68	132/153/105	5	9	69				
42	i	--	i	141	4	6	86				
41/71	4	11	72	137/176	4	17	150				
64	9	7	73	130	5	25	[1]580				
40	14	--	--	163/138	4	6	67				
100	18	28	[1]420	158	5	0	68				
63	56	--	[1]310	126/129	--	12	[1]49				
74	7	15	79	178	14	50	[1]56				
70/76	3	24	85	187/182	7	12	29				
95/66	3	29	86	183	4	20	76				
91	3	27	130	128	5	10	54				
56/60	6	0	65	167	13	--	[1]330				
84/92	4	9	117	185	18	50	[1]170				

[1]Poor accuracy may be associated with low expected concentrations (less than 0.2 ng/g) of these congeners.

RESULTS

The concentrations of PCB congeners reported in bed sediments by the WSLOH and TOAL are provided in tables 3.3 and 3.4, respectively. The Lake Pepin reference sediment was analyzed by both laboratories. The WSLOH method identified 67 of 89 assayed congeners in this sample. The TOAL method detected 110 of 117 measured congeners. The total PCB (congener sum) concentration reported by the WSLOH and TOAL in this reference sample was very similar and averaged 280 and 290 ng/g, respectively. There were no reference sediment comparisons between the two laboratories at lower PCB concentrations.

The concentration of total PCB and selected congeners (IUPAC #28/31, #118, and #180) are shown in figs. 3.1 and 3.2. Greatest PCB concentrations (about 30-90 ng/g) were in samples collected from Pools 2 through 4. Individual congener concentrations (#118 and #180) were distinctly greater in Pools 2 through 4. In general sample results for Pools 9 through 12 revealed a greater number of detected congeners (about 100 more) and greater PCB concentrations (about 17 ng/g) with the TOAL method (tables 3.3 and 3.4). Organic carbon-normalized total PCB concentrations (fig. 3.1) exhibited the largest values (3,900-6,500 ng/g of carbon) in Pools 10, 15, and 20. Differences in PCB congener methods and low total organic-carbon concentrations (Chapter 1) makes the interpretation of the spatial trends difficult.

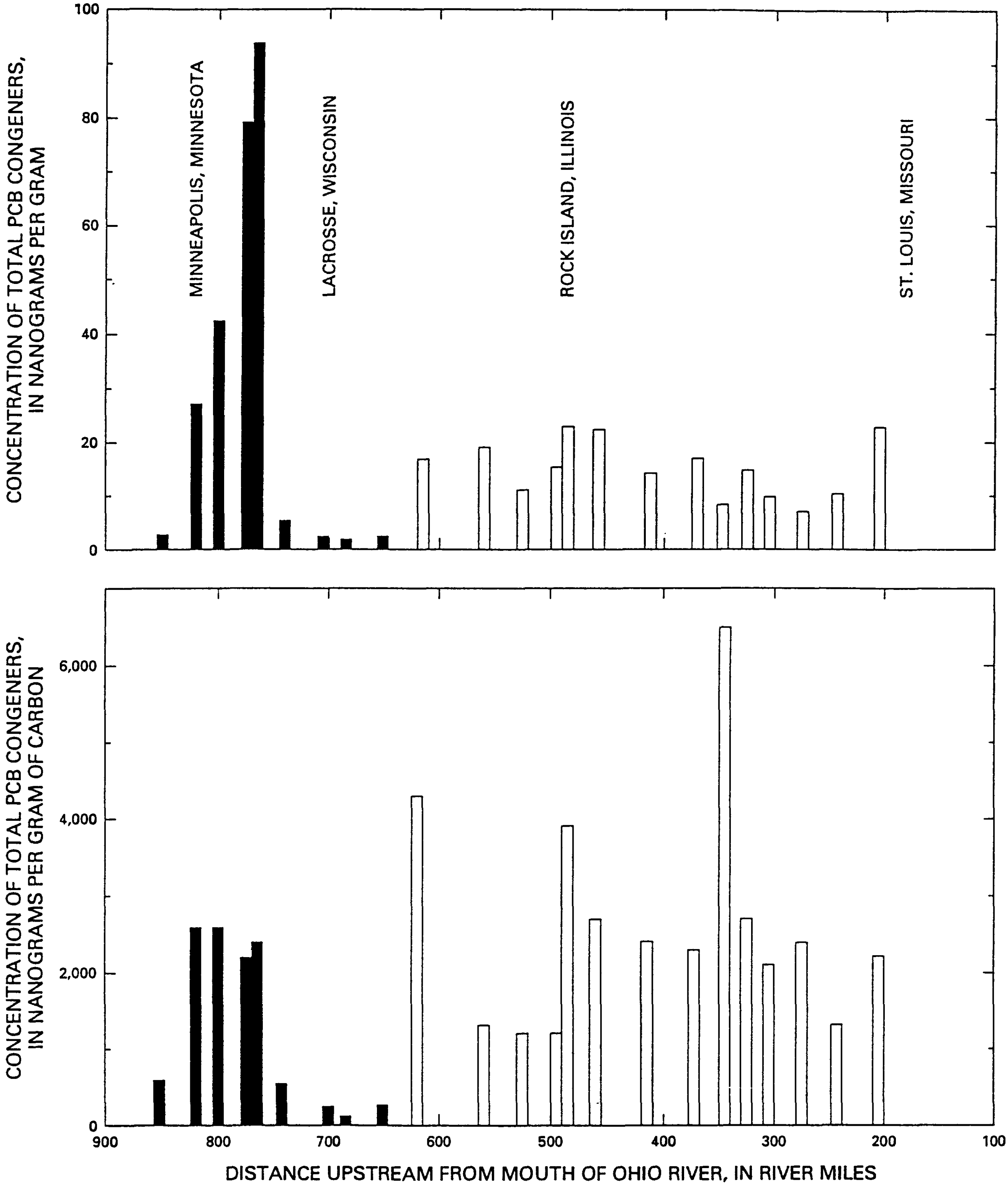

Figure 3.1--Concentration of total polychlorinated biphenyl congeners (upper panel) and concentration of total polychlorinated biphenyl congeners per gram of organic carbon (lower panel) in surficial sediment from the downstream one-third of the 25 sampled navigation pools of the Upper Mississippi River, June-July 1994. Solid black bars are data from Wisconsin State Laboratory of Hygiene, Madison, Wisconsin, and the white bars are data from the University of Minnesota Total Organics Analytical Laboratory. See table 1.2 for location of pools.

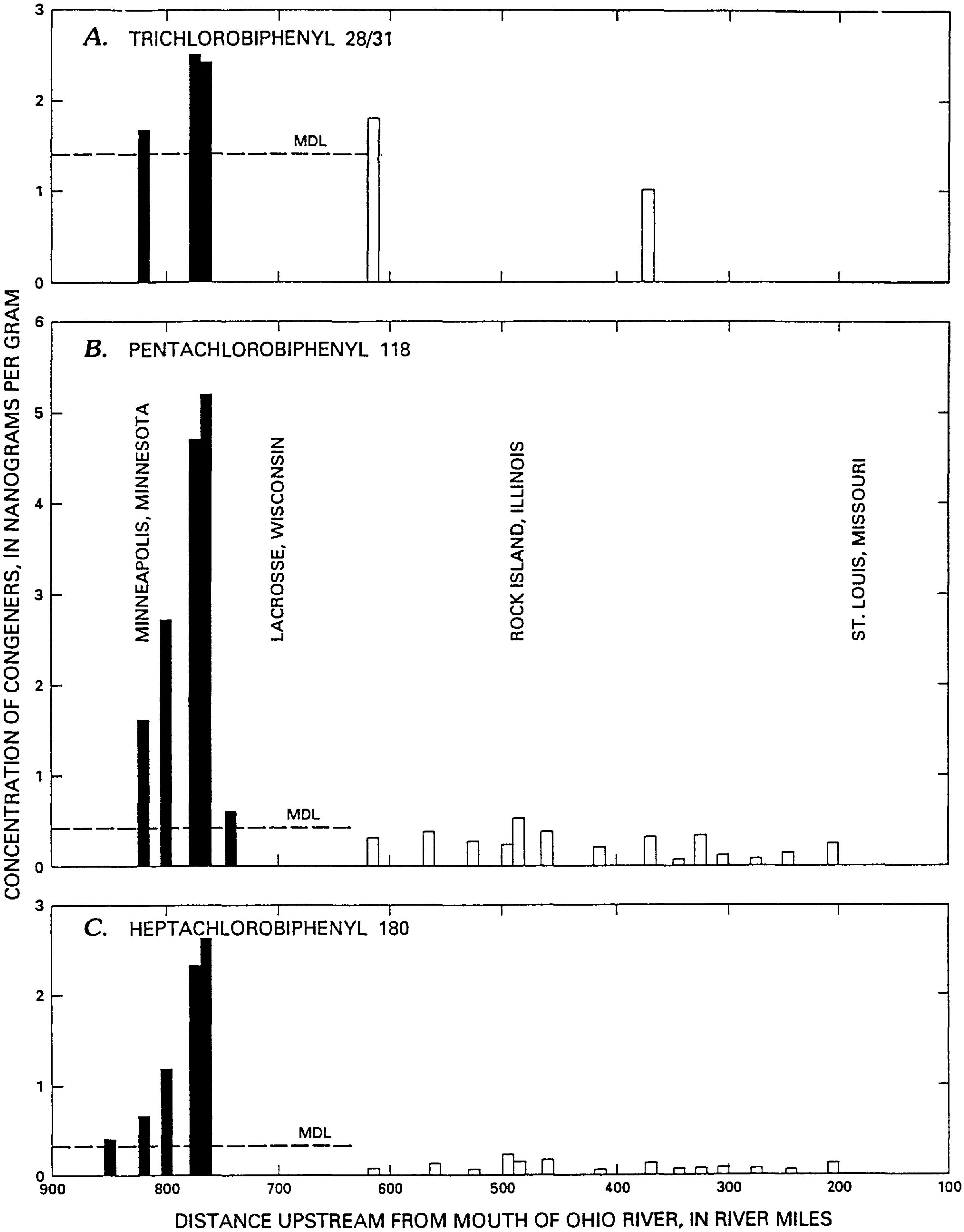

Figure 3.2--Concentration of three selected congeners in surficial sediment from downstream one-third of the 25 sampled navigation pools of the Upper Mississippi River, June-July 1994.
A. Trichlorobiphenyl pair numbers 28 and 31.
B. Pentachlorobiphenyl number 118.
C. Heptachlorobiphenyl number 180.
Solid black bars are data from Wisconsin State Laboratory of Hygiene, Madison, Wisconsin. The white bars are data from the University of Minnesota Total Organics Analytical Laboratory, and MDL is the method detection limit. See table 1.2 for location of pools.

Table 3.3--Concentration of polychlorinated biphenyl congeners in surficial bed sediment collected from the downstream one-third of the 25 sampled navigation pools of the Upper Mississippi River and analyzed by Wisconsin State Laboratory of Hygiene method, June-July 1994

[Concentrations are in nanograms per gram, ng/g IUPAC, International Union of Pure and Applied Chemistry; Reference, Lake Pepin reference sample; U, Upper Lake Pepin; L, Lower Lake Pepin; --, no congener detected; and gTOC, gram of total organic carbon in table 1.9 in Chapter 1]

Congener IUPAC number	Reference[1]	Pool and date collected in 1994													Lake St. Croix
		1	2-1	2-2	3	4U	4L	5	6	7	8-1	8-2	9	11	
	5-15-91	6-11	6-12		6-14	6-15		6-16	6-17	6-18	6-19		6-20	6-21	6-13
7	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
6	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
5/8	1.4	--	--	--	--	--	--	--	--	--	--	--	--	--	--
19	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
18	0.45	--	--	--	--	--	--	--	--	--	--	--	--	--	--
17	0.61	--	--	--	--	--	0.32	--	--	--	--	--	--	--	--
24/27	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
16/32	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
26	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
28/31	5.5	--	1.6	1.8	--	2.5	2.4	--	--	--	--	--	--	--	--
33	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
22	0.80	--	--	--	--	--	--	--	--	--	--	--	--	--	--
45	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
46	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
52	4.6	--	1	1.2	1.2	1.8	1.8	--	--	--	--	--	--	--	0.86
49	3.4	--	1.2	1.2	0.93	1.5	1.5	--	--	--	--	--	--	--	0.34
47/48	2.8	--	1.5	1.7	0.97	1.8	1.5	--	--	--	--	--	--	--	0.57
44	3.2	--	0.69	0.73	0.89	1.4	1.3	--	--	--	--	--	--	--	--
37/42	2.9	--	0.59	0.65	0.54	1.0	1.1	--	--	--	--	--	--	--	--
41/64/71	2.9	--	--	0.58	0.65	1.1	1.1	--	--	--	--	--	--	--	--
40	0.52	--	--	--	--	--	--	--	--	--	--	--	--	--	--
74	2.3	--	--	--	--	--	0.95	--	--	--	--	--	--	--	--
70/76	8.0	--	1.6	1.8	2.3	3.5	3.2	--	--	--	--	--	--	--	1.2
66/95	22	0.60	2.7	3.1	4.6	7.2	8.1	1.2	--	--	--	0.74	--	--	2.9
91	3.2	--	0.58	0.93	0.70	1.2	1.3	--	--	--	--	--	--	--	0.40
56/60	4.3	--	--	--	0.81	1.6	1.7	--	--	--	--	--	--	--	0.86
84/92	7.5	--	0.97	0.93	1.6	2.3	2.6	--	--	--	--	--	--	--	1.1
101	12	--	1.3	1.5	2.2	3.4	4.1	0.50	--	0.34	--	--	0.35	--	1.4
99	7.5	--	0.70	0.77	1.2	2.1	2.5	--	--	--	--	--	--	--	0.79
97	5.3	--	0.46	0.49	0.82	1.4	1.7	--	--	--	--	--	--	--	0.54
87	8.3	--	0.70	--	1.4	2.3	2.7	--	--	--	--	--	--	--	1.2
85	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
136	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Table 3.3--Concentration of polychlorinated biphenyl congeners in surficial bed sediment collected from the downstream one-third of the 25 sampled navigation pools of the Upper Mississippi River and analyzed by Wisconsin State Laboratory of Hygiene method, June-July 1994--Continued

Congener IUPAC number	Reference[1]	Pool and date collected in 1994													Lake St. Croix
		1	2-1	2-2	3	4U	4L	5	6	7	8-1	8-2	9	11	
	5-15-91	6-11	6-12		6-14	6-15		6-16	6-17	6-18	6-19		6-20	6-21	6-13
77/110	28	0.40	2.7	3.4	4.6	7.8	9.5	1.1	--	0.83	0.43	0.47	0.83	--	2.7
82	2.2	--	--	--	0.31	0.56	0.64	--	--	--	--	--	--	--	--
151	3.0	--	--	--	0.42	0.77	0.96	--	--	--	--	--	--	--	--
135/144	2.4	--	--	--	0.35	0.68	0.82	--	--	--	--	--	--	--	--
149	10	--	0.98	1.0	1.6	2.7	3.3	0.37	--	--	--	--	--	--	1.0
118	18	--	1.6	1.6	2.7	4.7	5.2	0.60	--	--	--	--	--	--	1.3
146	4.1	--	--	--	0.48	0.98	1.3	--	--	--	--	--	--	--	--
132/153	24	0.47	2.2	2.2	3.6	6.5	7.8	0.84	--	0.60	--	--	0.64	--	2.2
141	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
137/176	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
138	28	0.42	2.3	2.5	3.9	7.3	9.0	0.88	--	0.66	0.42	--	0.62	--	2.1
178	0.81	--	--	--	--	--	--	--	--	--	--	--	--	--	--
182/187	2.7	--	--	--	--	0.66	0.69	--	--	--	--	--	--	--	--
183	2.5	--	--	--	--	0.72	0.75	--	--	--	--	--	--	--	0.42
185	0.6	--	--	--	--	--	--	--	--	--	--	--	--	--	--
174	2.9	--	--	--	0.42	0.81	0.96	--	--	--	--	--	--	--	--
177	2.5	--	--	--	--	0.71	0.87	--	--	--	--	--	--	--	--
171/202	1.2	--	--	--	--	--	--	--	--	--	--	--	--	--	--
172/197	1.1	--	--	--	--	--	--	--	--	--	--	--	--	--	--
180	8.0	0.39	0.67	0.68	1.2	2.3	2.6	--	--	--	--	--	--	--	0.73
199	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
170/190	9.4	--	--	0.76	1.1	2.4	2.8	--	--	--	--	--	--	--	--
201	2.8	--	--	--	--	0.83	0.96	--	--	--	--	--	--	--	--
196/203	3.4	--	--	--	--	1.0	1.1	--	--	--	--	--	--	--	--
195/208	2.2	--	--	--	--	--	0.78	--	--	--	--	--	--	--	--
194	1.8	--	--	--	--	--	0.56	--	--	--	--	--	--	--	--
206	1.6	--	--	--	--	0.52	0.55	--	--	--	--	--	--	--	--
128	6.2	--	--	--	0.75	1.4	1.8	--	--	--	--	--	--	--	--
167	1.2	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Sum	280.1	2.3	26.0	29.5	42.2	79.4	92.8	5.5	--	2.4	0.8	1.2	2.4	--	22.6
Sum/gTOC	5,600	620	2,800	2,500	2,600	2,200	2,400	560	--	270	110	250	240	--	890

[1]Values are the average of two separate samples.

Table 3.4--Concentration of polychlorinated biphenyl congeners in surficial bed sediment collected from the downstream one-third of the 25 sampled navigation pools of the Upper Mississippi River and analyzed by University of Minnesota Total Organics Analytical Laboratory, June-July 1994

[Concentrations are in nanograms per gram, ng/g; IUPAC, International Union of Pure and Applied Chemistry; Reference, Lake Pepin reference sample; i, interference present in the peak; ic, interference present in the peak as determined by the software program COMSTAR; --, below reporting limit (0.01 ng/g); and gTOC, gram of total organic carbon in table 1.9 in Chapter 1]

Congener IUPAC number	Reference[1]	Pool and date collected in 1994														
		10	12	13	14	15	16	18	19-1[1]	19-2	20[2]	21	22	24	25[2]	26[2]
	5-15-91	6-21	6-22	6-23	6-23	6-26	6-27	6-28	6-29		6-30	7-01	7-02	7-03	7-04	7-05
4/10	--	0.09	2.5	1.8	2.5	i	i	i	0.29	0.30	--	i	0.89	i	--	--
7	0.43	0.06	0.15	0.27	0.40	0.51	1.02	0.33	0.12	0.14	0.40	0.75	0.09	0.13	0.22	0.34
6	0.35	0.04	0.07	0.04	0.03	0.08	--	0.06	0.11	0.15	--	0.05	0.03	0.01	0.05	0.20
5/8	1.01	0.04	0.13	0.05	0.04	0.20	0.22	0.04	0.14	0.13	0.06	0.12	0.05	0.04	0.06	0.26
19	--	0.15	0.10	0.17	0.17	0.10	0.19	0.22	--	--	0.24	0.16	--	--	--	0.10
18	3.9	1.97	i	i	i	i	i	i	1.1	1.7	--	ic	ic	ic	--	--
17	3.3	0.23	--	--	--	--	--	--	0.45	0.69	--	--	--	--	--	--
24/27	0.12	0.01	0.01	--	--	0.02	--	--	0.06	0.06	[3]0.01	0.01	0.07	0.02	[3]0.03	0.06
16/32	0.32	0.32	i	ic	ic	ic	ic	ic	0.21	0.18	--	ic	ic	ic	--	1.56
29	--	0.08	0.01	--	--	0.09	0.09	--	0.14	0.23	[3]0.01	0.04	--	0.03	--	0.06
26	0.19	--	--	--	--	0.06	--	--	--	--	--	--	0.15	--	--	[3]0.14
25	0.14	0.04	0.09	--	0.05	--	0.16	--	0.08	0.12	[3]0.04	0.05	0.19	0.06	0.06	--
28/31	4.1	1.6	i	ic	ic	ic	i	i	0.92	1.1	--	ic	ic	i	--	--
21/33/53	2.2	0.23	0.73	i	1.3	2.6	5.3	2.0	0.30	0.35	2.9	4.0	0.79	0.58	0.84	1.58
51	0.28	0.13	0.24	0.09	0.21	1.10	1.4	0.55	0.14	0.18	0.10	0.91	0.03	0.04	0.10	0.30
22	--	--	--	--	--	--	--	--	--	--	0.09	--	0.08	--	--	--
45	0.68	0.31	1.4	1.8	2.8	3.9	i	3.5	0.17	0.19	--	i	--	0.77	1.2	3.1
46	0.30	0.08	0.18	--	--	--	--	--	0.08	0.08	--	--	0.25	0.19	--	0.53
52	7.9	0.20	0.67	0.41	0.40	0.98	0.76	0.41	0.76	0.82	0.28	0.47	0.48	0.34	0.54	0.76
43	--	0.08	0.19	--	0.22	0.19	0.54	0.10	0.10	0.12	0.32	0.57	0.06	0.04	0.12	0.16
49	6.0	0.39	0.65	0.36	0.41	0.90	0.71	0.29	0.47	0.59	0.08	0.24	0.23	0.13	0.34	0.56
47/48	4.3	0.46	0.94	0.60	0.58	1.22	1.10	0.54	0.63	0.80	0.48	0.70	0.43	0.45	0.64	[3]0.89
44	3.4	0.16	0.19	0.26	0.12	0.48	0.39	0.21	0.34	0.44	0.06	0.18	0.16	0.19	0.24	0.36
42	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
41/71	1.1	0.12	0.09	0.05	0.03	0.16	0.10	0.04	0.09	0.17	0.02	0.06	0.04	0.04	0.04	0.08
64	7.4	1.2	1.3	1.0	0.74	0.83	0.68	1.0	0.88	1.1	0.74	1.11	0.59	0.74	0.62	0.60
40	0.28	0.03	--	--	--	--	--	--	[3]0.02	--	--	--	--	--	--	--
100	0.50	0.15	0.20	0.15	0.13	0.24	0.29	0.16	0.26	0.28	0.09	0.25	0.29	0.18	0.18	0.52
63	0.36	0.05	--	0.01	0.01	--	--	--	--	0.04	0.01	--	--	--	0.01	--
74	2.1	0.17	0.26	0.11	0.06	0.25	0.20	0.13	0.27	0.24	0.04	0.07	0.31	0.05	0.16	0.40
70/76	4.6	0.20	0.74	0.16	0.11	0.59	0.65	0.21	0.34	0.37	0.07	0.19	0.33	0.16	0.21	0.57
95/66	6.9	0.21	0.17	0.11	0.09	0.43	0.39	0.07	0.17	0.09	0.07	0.16	0.13	0.12	0.16	0.34
91	1.8	0.38	0.56	0.10	0.20	0.32	0.33	0.09	0.15	0.10	0.06	0.13	0.29	0.18	0.10	0.46

Table 3.4--Concentration of polychlorinated biphenyl congeners in surficial bed sediment collected from the downstream one-third of the 25 sampled navigation pools of the Upper Mississippi River and analyzed by University of Minnesota Total Organics Analytical Laboratory, June-July 1994--Continued

Con-gener IUPAC number	Refer-ence[1]	Pool and date collected in 1994														
		10	12	13	14	15	16	18	19-1[1]	19-2	20[2]	21	22	24	25[2]	26[2]
	5-15-91	6-21	6-22	6-23	6-23	6-26	6-27	6-28	6-29		6-30	7-01	7-02	7-03	7-04	7-05
56/60	1.1	--	--	--	--	0.27	0.08	0.05	0.06	0.08	0.02	0.07	0.04	--	0.02	0.26
84/92	6.4	0.73	ic	ic	ic	ic	0.61	ic	0.43	0.62	0.12	ic	ic	0.19	0.32	1.1
89	0.21	0.05	--	0.02	0.04	0.12	0.08	0.07	--	--	0.04	0.09	0.03	--	--	0.27
101	13.6	0.27	0.34	0.24	0.28	ic	0.74	0.21	0.61	0.42	0.24	ic	0.36	0.23	0.42	1.4
99	8.1	0.64	0.45	ic	ic	ic	0.61	ic	0.68	0.89	0.19	ic	ic	ic	--	1.5
119	0.71	--	--	--	--	0.08	0.06	0.07	0.05	0.06	[3]0.01	0.04	0.04	0.02	0.02	0.05
83	1.41	--	0.09	0.03	0.02	0.06	0.13	0.02	0.09	0.14	0.01	0.03	0.01	0.05	0.07	0.14
97	4.8	0.12	0.22	0.13	0.10	0.26	0.17	0.04	0.27	0.28	0.02	0.17	0.06	0.02	0.18	0.28
87	5.1	0.16	0.23	0.12	0.10	0.27	0.22	0.11	0.21	0.25	0.06	0.17	0.09	0.08	0.12	0.23
85	1.9	0.10	0.13	0.04	0.03	0.09	0.07	0.04	0.09	0.11	0.01	0.06	0.03	0.01	0.06	0.13
136	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1.2
77/110	20.5	0.54	0.59	0.35	0.28	0.72	0.59	0.28	0.45	0.54	0.10	0.38	0.22	0.18	0.26	0.42
82	2.4	0.05	0.06	0.03	0.05	0.07	0.17	0.07	0.07	0.12	0.04	0.06	0.04	0.04	0.04	0.17
151	5.3	0.35	0.40	0.18	0.22	0.24	0.32	0.28	0.12	0.12	0.12	0.21	0.09	0.07	0.08	0.16
135/144	4.2	0.08	0.10	0.06	0.06	0.09	0.06	0.06	0.09	0.10	0.04	0.07	0.08	0.07	0.08	0.16
124	0.57	--	--	0.02	0.01	0.06	--	0.02	0.03	0.04	[3]0.01	--	0.02	0.03	0.02	--
147	1.1	0.03	0.04	0.03	0.03	0.11	0.05	0.03	0.03	0.05	0.02	0.06	0.03	0.02	0.03	0.13
107	2.6	0.05	0.05	0.05	0.05	0.21	0.08	0.07	0.04	0.06	0.02	0.10	0.02	0.03	0.03	[3]0.08
123/149	16.7	0.26	0.31	0.22	0.20	0.37	0.25	0.17	0.38	0.41	0.08	0.28	0.18	0.19	0.24	0.50
118	12.9	0.30	0.37	0.25	0.19	0.50	0.38	0.19	0.29	0.34	0.06	0.33	0.11	0.09	0.14	0.23
134	1.9	0.02	--	0.01	0.01	0.03	--	0.01	0.03	0.03	0.01	0.02	0.01	0.01	0.01	0.04
114	1.8	0.07	0.11	0.07	0.14	0.24	0.14	0.08	0.20	0.22	0.03	0.36	0.08	0.07	0.18	0.30
131/122	1.6	0.04	0.08	--	--	0.05	--	--	[3]0.04	0.05	--	0.01	--	0.01	[3]0.02	--
146	4.7	0.09	0.11	0.04	0.04	0.09	0.05	0.05	0.10	0.10	0.01	0.06	0.04	0.03	0.04	0.10
132/153/105	31.0	0.54	0.64	0.42	0.37	0.71	0.60	0.36	0.64	0.74	0.10	0.44	0.29	0.28	0.38	0.75
141	6.4	0.21	0.24	0.08	0.13	0.21	0.20	0.15	0.16	0.18	0.03	0.13	0.14	0.11	0.10	0.18
137/176	2.9	0.24	0.35	0.09	0.12	0.14	0.11	0.21	0.12	0.09	0.04	0.10	0.17	0.07	0.08	0.16
130	3.2	0.62	0.90	0.18	0.19	0.22	0.21	0.36	0.08	0.10	0.05	0.15	0.09	0.02	0.07	0.20
163/138	19.5	0.19	0.17	0.15	0.12	0.26	0.26	0.13	0.32	0.37	0.05	0.22	0.23	ic	0.20	0.46
158	2.2	0.06	0.07	0.02	0.02	0.03	0.04	0.04	[3]0.03	0.04	[3]0.01	0.02	0.04	0.01	0.02	0.06
126/129	0.4[3]	0.28	0.22	0.14	0.10	0.08	0.16	0.18	0.41	0.37	0.10	0.11	0.38	0.39	0.41	0.60
178	1.6	--	0.11	--	--	--	0.06	--	[3]0.06	0.09	--	--	--	--	[3]0.02	--
187/182	3.2	0.08	0.05	0.09	0.14	0.10	0.10	0.12	0.17	0.18	0.08	0.11	0.05	0.13	0.10	0.15
183	1.9	0.12	0.14	0.03	0.07	0.12	0.05	0.03	0.05	0.06	[3]0.01	0.03	0.03	0.03	0.03	0.06
128	5.8	0.20	0.23	0.08	0.05	0.09	0.13	0.04	0.10	0.13	[3]0.01	0.06	0.05	0.03	0.06	0.11

Table 3.4--Concentration of polychlorinated biphenyl congeners in surficial bed sediment collected from the downstream one-third of the 25 sampled navigation pools of the Upper Mississippi River and analyzed by University of Minnesota Total Organics Analytical Laboratory, June-July 1994--Continued

Congener IUPAC number	Reference[1]	Pool and date collected in 1994														
		10	12	13	14	15	16	18	19-1[1]	19-2	20[2]	21	22	24	25[2]	26[2]
	5-15-91	6-21	6-22	6-23	6-23	6-26	6-27	6-28	6-29		6-30	7-01	7-02	7-03	7-04	7-05
167	2.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
185	0.4	0.05	0.04	0.04	0.04	0.18	0.08	0.03	0.02	0.03	[3]0.01	0.03	0.03	0.02	0.02	0.04
174	2.4	0.03	0.06	0.03	0.07	0.17	0.05	0.06	0.07	0.06	0.02	0.07	0.03	0.03	0.04	0.15
177	2.1	0.08	0.11	0.07	0.10	0.28	0.08	0.10	0.07	0.07	0.04	0.07	0.06	0.04	0.05	0.12
202/171	1.2	0.05	0.04	0.01	0.05	0.13	0.04	0.04	0.03	0.03	0.05	0.03	0.02	0.02	0.02	0.05
156	3.7	0.08	0.16	0.02	0.03	0.20	0.13	0.06	0.07	0.10	[3]0.02	0.02	0.02	0.06	0.03	0.12
173	0.19	0.03	0.04	0.01	0.01	0.03	0.03	0.02	0.033	0.04	--	0.02	--	0.01	0.02	0.06
172/197	0.68	0.06	--	0.03	--	0.07	0.03	0.03	0.02	0.03	--	0.04	0.02	0.02	0.02	0.02
180	5.2	0.05	0.13	0.05	0.22	0.12	0.13	0.04	0.11	0.15	0.03	0.10	0.05	0.08	0.06	0.12
193	0.2	0.01	0.02	--	0.02	0.01	0.01	0.01	0.01	0.02	--	0.02	--	0.01	--	0.01
191	0.67	--	0.01	0.03	0.03	0.04	0.06	--	0.02	0.05	--	0.04	0.03	0.01	0.02	0.04
199	0.3	0.03	0.03	0.02	0.04	0.01	0.02	0.02	0.02	0.02	--	0.02	0.01	--	0.01	0.02
170/190	3.2	0.08	0.05	0.06	0.05	0.03	0.07	0.03	0.06	0.05	0.01	0.04	0.03	0.03	0.03	0.08
198	0.17	0.25	i	i	i	i	i	i	--	i	--	i	i	i	--	--
201	1.3	0.04	0.07	--	0.12	0.03	0.08	0.04	0.07	0.06	0.02	0.02	0.04	0.06	0.03	0.08
203/196	1.2	0.02	0.02	0.01	0.12	--	0.03	--	0.04	0.03	0.01	--	0.01	0.02	0.01	0.04
189	0.21	--	0.00	--	--	0.06	0.03	0.03	--	--	--	--	0.04	--	--	0.03
208/195	0.68	0.03	0.03	0.02	0.05	0.03	0.03	0.02	0.03	0.02	0.01	0.02	0.03	0.01	0.01	0.03
207	0.22	0.01	0.03	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01
194	1.6	0.02	0.09	--	0.10	0.04	0.07	0.03	0.06	0.05	0.01	0.04	0.05	0.03	0.02	0.04
205	0.72	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.03
Sum	290	17	19	11	15	23	22	14	15	19	8	15	10	7	10	23
Sum/gTOC	6,200	4,300	1,300	1,200	1,200	3,900	2,700	2,400	1,900	2,700	6,500	2,700	2,100	2,400	1,300	2,200

[1]Five replicate samples.
[2]Two replicate samples.
[3]There is at least one nondetection not included in the average.

SUMMARY

Surficial bed-sediment samples from the navigation pools of the Upper Mississippi River were analyzed for PCB congeners at two laboratories. The Wisconsin State Laboratory of Hygiene in Madison, Wis., analyzed samples from Pools 1 to 11, except 5A and 10. The University of Minnesota Trace Organic Analytical Laboratory in Duluth, Minn., was used for Pools 10, and 12 through 26, except 17.

Maximum total PCB concentrations in surficial bed sediments were found in Pools 2 through 4 immediately downstream from the Twin Cities metropolitan area. This was consistent with previous PCB data in environmental samples for the Upper Mississippi River. Total organic carbon-normalized PCB values were largest in samples collected from the downstream portion of the study area (Pools 10, 15, and 20). PCB method differences and lower total organic carbon contents in bed sediments collected from the lower navigation pools influenced the spatial results.

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CHAPTER 4 - Organochlorine Compounds

By Dawn E. Hrinko and John A. Moody

ABSTRACT

Representative subsamples of surficial bed sediment were collected from 24 navigation pools on the Upper Mississippi River and analyzed for organochlorine compounds (aldrin; *p,p'*-DDD; *p,p'*-DDE; *p,p'*-DDT; dieldrin; endosulfan I; endrin; heptachlor; heptachlor epoxide; lindane; *p,p'*-methoxychlor; mirex; perthane; gross polychlorinated biphenyls; gross polychlorinated naphthalenes; technical chlordane; and toxaphene). The samples were analyzed at the U.S. Geological Survey National Water Quality Laboratory in Arvada, Colorado, using an analytical method that uses shake-extraction with acetone-hexane and analysis of the extract by capillary gas chromatography with electron-capture detection.

The concentrations of most organochlorine compounds in the surficial bed sediments were below reporting levels. However, the maximum concentration of *p,p'*-DDT [1.8 nanograms per gram (ng/g)] was in Pool 15, dieldrin (0.7 ng/g) was in Pool 26 , gross polychlorinated biphenyls (33 ng/g) was in Pool 3 , and technical chlordane (2ng/g) was in Pools 4 (Lake Pepin) and 21.

INTRODUCTION

Organochlorine compounds are widespread in the environment and are derived both from manufactured and natural sources. The manufacture, distribution, and use of insecticides, pesticides, and industrial chemicals [like polychlorinated biphenyls (PCB) and polychlorinated naphthalenes (PCN)] have contributed to a large array of organic contaminants and their degradation products in the environment. Anthropogenic activities such as incineration of manufactured organic compounds and combustion of fossil fuels have contributed to the production and airborne release of contaminants such as dioxins, furans, and polynuclear aromatic hydrocarbons (Voldner and Li, 1995). The organochlorine contaminants associated with surficial bed sediments determined in this study are aldrin, *p,p'*-DDD; *p,p'*-DDE; *p,p'*-DDT; dieldrin; endosulfan I; endrin; heptachlor; heptachlor epoxide; lindane; *p,p'*-methoxychlor; mirex; perthane; gross polychlorinated biphenyls; gross polychlorinated naphthalenes; technical chlordane; and toxaphene.

Organochlorine compounds have been released to the air, water, and land over many years through their use and disposal. As a result of their chemical structure, organochlorine compounds are often highly persistent contaminants in aquatic and terrestrial ecosystems. This is true even though the production and use of some of these compounds such as DDT and PCB have been eliminated or greatly restricted since 1977. Their solubility in water is generally low; as a result, in aquatic systems they are mainly found adsorbed to suspended particulate matter and in bed sediments, especially silt-sized and clay-sized sediment (less than 63 μm) with high organic carbon content. Thus, contaminated sediments provide a major source of present-day exposure of these chemicals to aquatic organisms (Lyman and others, 1987; Baudo and others, 1990).

Runoff from contaminated soils or improper disposal are important pathways that have led to serious contamination problems in both riverine and lacustrine systems. Volatilization of organochlorine compounds to the atmosphere has resulted in their global distribution. When present at acute concentrations these organochlorine compounds can directly affect the distribution and abundance of aquatic organisms. Furthermore, long-term exposure at low concentrations may contribute to carcinogenic, teratogenic, and mutagenic effects. The transfer of organochlorine contaminants through the aquatic food chain contributes to contamination problems in fish, piscivorous mammals and birds, and eventually humans. In some instances, PCB and chlordane contamination in fish from the Mississippi River resulted in certain States issuing consumption advisories for the commercial and sport fishery.

PURPOSE AND SCOPE

The purpose of this chapter is to describe the method used to determine the concentration of organochlorine compounds in the surficial bed sediments collected during June 1994 from the downstream one-third of 24 navigation pools of the Upper Mississippi River after the flood of 1993 and to list the results in tables. The spatial distribution of some of the more abundant compounds in the Upper Mississippi River are shown graphically.

ANALYTICAL METHOD

After the composite samples were collected in the field (see Chapter 1), they were kept refrigerated at about 4°C in glass jars with Teflon-lined lids until they were analyzed by the U.S. Geological Survey National Water Quality Laboratory's Schedule 1325 method (hereinafter referred to as the Schedule 1325 method).

A large volume (240 L) of surficial bed sediment was collected from lower Lake Pepin in May 1991 and prepared as a reference sample by personnel from the U.S. Army Corps of Engineers (St. Paul and Rock Island Districts), the Minnesota Pollution Control Agency, the Wisconsin Department of Natural Resources, and the U.S. Fish and Wildlife Service. The wet sediment was mixed in three batches (approximately 80 L each) using a large Hobart blender and then portioned into individual glass containers and frozen. Samples of the Lake Pepin reference sample were analyzed by the Schedule 1325 method, and the results are listed in the data tables as "Reference."

The Schedule 1325 method is used for the determination of organochlorines in sediment in the following order: lindane; heptachlor; aldrin; heptachlor epoxide; technical chlordane; endosulfan I; dieldrin; *p,p'*-DDE; endrin; perthane; *p,p'*-DDD; *p,p'*-DDT; *p,p'*-methoxychlor; mirex; toxaphene; gross polychlorinated biphenyls (PCB); and gross polychlorinated naphthalenes (PCN) (Wershaw and others, 1987). Gross PCB are the sum of Aroclors 1242, 1254, and 1260.

Sample Preparation

The sample preparation consisted of three steps: extraction, concentration, and cleanup. Organochlorine compounds were extracted from 50 g of equivalent dry sediment. The homogenized wet sediment was shaken on a wrist-action shaker for 20 minutes with 20 mL of acetone, then shaken for 10 minutes with 80 mL of hexane. The solvent was decanted and the process repeated two additional times. The combined extracts were gently rolled in a separatory funnel containing 500 mL of distilled water to remove the acetone. The hexane layer was removed and concentrated to approximately 4 mL in a 500-mL Kuderna-Danish apparatus. It was concentrated to exactly 4 mL by using a gentle stream of nitrogen.

The first step in the cleanup procedure was to fractionate the sample on an 8.5-percent deactivated alumina column using 2 mL of the 4-mL Kuderna-Danish extract. The sample was eluted with 43 mL of hexane to obtain the A1 fraction (18 mL) and the A2 fraction (25 mL). The A3 fraction (20 mL) was collected by eluting with 20 mL of benzene. The A1 fraction was evaporated to exactly 1 mL under a gentle stream of nitrogen. Sulfur was removed by shaking the A1 fraction with elemental mercury. The A1 fraction was further fractionated on a 3.0-percent deactivated silica column that was prerinsed with hexane and eluted with 19 mL of hexane to obtain the S1 fraction (20 mL). The S2 fraction (20 mL) was collected by eluting the column with 20 mL of benzene. A portion of the final extract from the A2 and A3 fractions was archived and a portion used for analysis.

Sample Analysis

Organochlorine analytes are confirmed on a dual-column capillary gas chromatograph (Hewlett-Packard 5890) with dual electron-capture detectors. Rtx-5 and Rtx-1701 columns (30-m by 0.25-mm, Restek Corporation) were preceded with an uncoated guard column connected to the injector by a glass Y union and a splitless deactivated liner. The oven temperature ramp was from 60°C (held for 2 minutes) to 180° at 30°C per minute (held for 2 minutes at 180°C), to 210°C at 1°C per minute and finally to 280°C at 4°C per minute, and held for 5 to 25 minutes. The injector port temperature was 220°C and the detector temperature was 350°C. The carrier gas was helium and the make-up gas was nitrogen.

A solution containing *p,p'*-DDT and endrin was used to evaluate the percent breakdown of these analytes in the injection port. This solution was followed by standards containing aldrin; *p,p'*-DDD; *p,p'*-DDE; *p,p'*-DDT; dieldrin; endosulfan I; endrin; heptachlor; heptachlor epoxide; lindane; *p,p'*-methoxychlor; mirex; and perthane at 1, 5, 10, 20, 50, and 100 pg/µL; Aroclors 1242, 1254, and 1260 at 50 and 100 pg/µL; toxaphene at 400 and 800 pg/µL; technical chlordane at 40, 80, and 160 pg/µL; and a third-party standard containing at least six of the organochlorine analytes at 20 pg/µL. Standards were measured to within 20 percent of their acceptable value. A method blank was analyzed for every 10 samples, and a reagent spike containing all of the individual organochlorine analytes was used to monitor method accuracy.

The method detection limits were determined using the procedure outlined in the Code of Federal Regulations (U.S. Environmental Protection Agency, 1991) and were rounded up to the reporting levels. The reporting levels (see table 4.1) are listed for the analytes in the order that they elute from the Rtx-5 column. Each sample was spiked with a surrogate, isodrin, at 0.200 ng/g. The accuracy data (table 4.1) are the mean percent recovery of 20 samples for each spike analyte. The precision data (table 4.1) are the mean relative percent differences for each analyte calculated from 10 sets of sample duplicates. A midrange standard (20 pg/µL) was run every 10 samples to monitor analytical performance.

A minimum 5-point calibration curve bracketing the targeted concentration range (generally 1 to 100 pg/µL) must requantitate within 20 percent of the expected values based on a linear regression coefficient (r^2) greater than 0.995. Continuing calibration checks (± 20 percent) and performance check standards (breakdown less than or equal to 20 percent) were run every 8 to 10 samples. One blank was run for every 10 samples, and analyte concentrations in the blanks were all less than the reporting level. A third-party check standard was run at the beginning of each batch (± 30 percent) to ensure the standards were accurate. Surrogates were added to all samples, blanks, and spikes; the surrogates had to measure within three standard deviations of the mean. Two compounds, tetrachloro-m-xylene and decachloro-biphenyl, were added to all samples as retention-time markers (Hrinko, 1994).

Table 4.1--Accuracy estimates, precision estimates, and reporting levels of organochlorine measurements made using the U.S. Geological Survey National Water Quality Laboratory Schedule 1325 method

[These values reflect the analytical laboratory uncertainty and do not include the field sampling uncertainty; accuracy is given as the mean percent recovery (%) for 20 samples; precision is given as the mean relative percent difference (RPD) for each analyte calculated from 10 sets of sample duplicates; ng/g, nanograms per gram; na, not available]

Analyte	Reporting level[1] (ng/g)	Accuracy (%)	Precision (RPD)
Lindane	0.1	78	11
Heptachlor	0.1	73	10
Aldrin	0.1	75	1.1
Heptachlor epoxide	0.1	74	2.5
Technical chlordane	1.	70	5.7
Endosulfan I	0.1	67	2.6
Dieldrin	0.1	79	2.2
p,p'-DDE	0.1	82	5.3
Endrin	0.1	63	na
Perthane	1.	103	na
p,p'-DDD	0.1	91	5.8
p,p'-DDT	0.1	77	5.8
p,p'-methoxychlor	0.1	103	na
Mirex	0.1	68	32
Toxaphene	10	71	na
Gross PCB	1	99	3.1
Gross PCN	1	na	na

[1]Reporting level for ideal matrix; if there are interferences, the reporting level is raised.

RESULTS

The concentrations of organochlorine compounds associated with the reference sample and the surficial sediments from the navigation pools are listed in table 4.2. Two samples of the Lake Pepin reference sample were analyzed separately, and one sample was split into two duplicates. Most organochlorine compounds in the reference sample were below the reporting level. Organochlorine compounds in the reference sample that were above the reporting level were technical chlordane, *p,p'*-DDE, *p,p'*-DDD, and gross PCB; the relative standard deviations of the three analyses were 0, 26, 36, and 17 percent, respectively.

Most of the organochlorines compounds in the surficial bed sediments were less than the reporting level; however, *p,p'*-DDE, *p,p'*-DDD, and gross PCB were found in all composite samples. Dieldrin, *p,p'*-DDT, and technical chlordane were found in some composite samples, generally with highest concentrations in samples collected from the upper one-half of the navigation pool reach. The concentrations of *p,p'*-DDE and dieldrin are shown in figures 4.1 and 4.2.

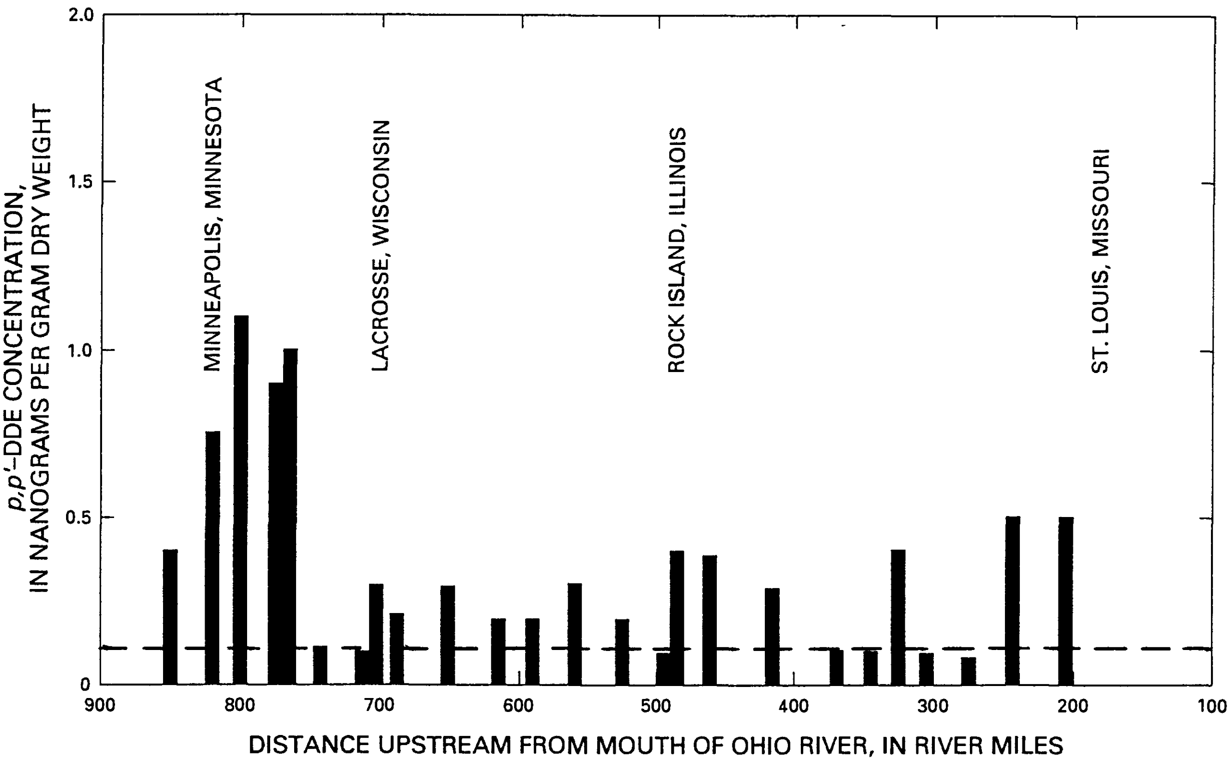

Figure 4.1--Concentration of *p,p'*-DDE in surficial bed sediment in the downstream one-third of the 25 sampled navigation pools of the Upper Mississippi River, June-July 1994. No composite samples were collected from pools 5A and 17. The dashed line is at the reporting level equal to 0.1 nanogram per gram. See table 1.2 for location of pools.

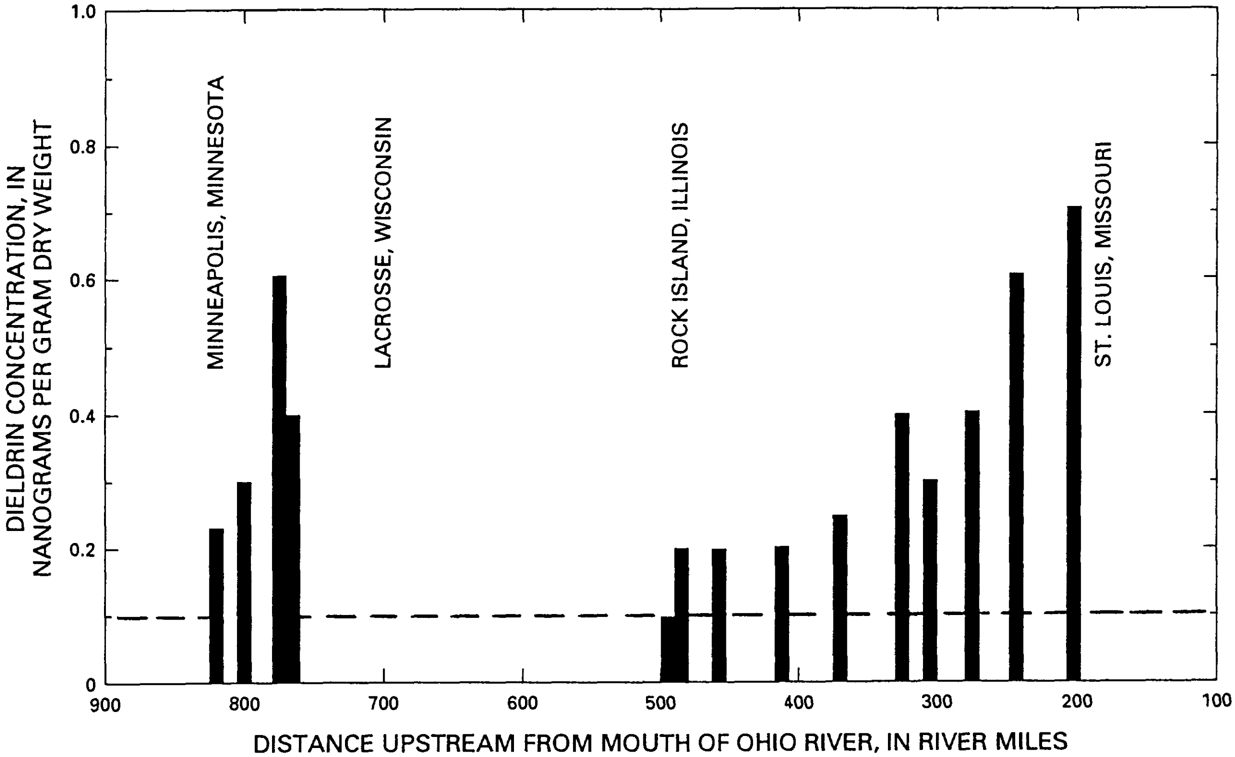

Figure 4.2--Concentration of dieldrin in bed sediments in the downstream one-third of the 25 sampled navigation pools of the Upper Mississippi River, June-July 1994. No composite samples were collected from pools 5A and 17. Dieldrin was detected in pools 5-13 (between river miles 500 and 750) but it was below the reporting limit so no bar is drawn. The dashed line is at the reporting level equal to 0.1 nanogram per gram. See table 1.2 for location of pools.

SUMMARY

Composite surficial bed-sediment samples were collected from the downstream one-third of 24 navigation pools of the Upper Mississippi River and were analyzed for organochlorine compounds by the U.S. Geological Survey National Water Quality Laboratory Schedule 1325 method.

The concentration of most organochlorine compounds in the surficial bed sediments was below the reporting level; however, concentrations of *p,p'*-DDE, *p,p'*-DDD and gross PCB were above the reporting level in all pools. Maximum concentration of *p,p'*-DDD [3.8 nanogram per gram , ng/g)]; *p,p'*-DDE (1.1 ng/g); and PCB (33 ng/g) were all in Pool 3. Concentration of *p,p'*-DDT was a maximum in Pool 15 (1.8 ng/g), but in most other pools it was less than the reporting level. The concentration of dieldrin was a maximum in Pool 26 (0.7 ng/g).

Table 4.2--Concentration of organochlorine compounds on surficial bed sediments collected from based on the Schedule 1325 method,

[Analyzed by gas chromatography/electron-capture detector; one blank was run for every 10 samples and all blanks had analyte PCB, polychlorinated biphenyls; PCN, polychlorinated naphthalenes; Ref., Lake Pepin reference sample;

Pool duplicate	Date	Number of samples in composite		Lindane	Hepta-chlor	Aldrin	Hepta-chlor epoxide	Technical chlordane	Endo-sulfan I	Dieldrin	p-p'-DDE	Endrin
		1994	1991-1992									
Ref. 1-1	05-15-91	--	--	<0.1	<0.1	<0.1	<0.1	2.	<0.3	0.4	2.9	<0.1
Ref. 2-1		--	--	<0.1	<0.1	<0.1	<0.1	2.	<0.1	<0.4	1.9	<0.1
Ref. 2-2		--	--	<0.1	<0.1	<0.1	<0.1	2.	<0.1	<0.4	1.9	<0.1
1	06-11-94	12	12	<0.1	<0.1	<0.1	<0.1	1.	<0.1	<0.2	0.4	<0.1
2-1	06-12-94	18	18	<0.1	<0.1	<0.1	<0.1	1.	<0.1	0.2	0.6	<0.1
2-2	06-12-94	18	18	<0.1	<0.1	<0.1	<0.1	1.	<0.1	0.3	0.9	<0.1
St. Croix River	06-13-84	15	ns	<0.1	<0.1	<0.1	<0.1	<1.	<0.1	<0.2	0.7	<0.1
3	06-14-94	15	16	<0.1	<0.1	<0.1	<0.1	<1.	<0.1	0.3	1.1	<0.1
[1]4	06-15-94	14	15	<0.3	<0.3	<0.3	<0.3	2.	<0.3	0.6	0.9	<0.3
[2]4	06-15-94	20	21	<0.1	<0.1	<0.1	<0.1	2.	<0.1	0.4	1.0	<0.1
5	06-16-94	18	18	<0.1	<0.1	<0.1	<0.1	<1.	<0.1	<0.2	0.1	<0.1
6	06-17-94	20	20	<0.1	<0.1	<0.1	<0.1	<1.	<0.1	<0.2	0.1	<0.1
7	06-18-94	20	20	<0.1	<0.1	<0.1	<0.1	<1.	<0.1	<0.2	0.3	<0.1
8-1	06-19-94	19	20	<0.1	<0.1	<0.1	<0.1	<1.	<0.1	<0.2	0.3	<0.1
8-2		19	20	<0.1	<0.1	<0.1	<0.1	<1.	<0.1	<0.2	0.1	<0.1
9	06-20-94	18	18	<0.1	<0.1	<0.1	<0.1	<1.	<0.1	<0.2	0.3	<0.1
10	06-21-94	20	20	<0.1	<0.1	<0.1	<0.1	<1.	<0.1	<0.2	0.2	<0.1
11	06-21 and 06-22-94	20	20	<0.1	ns	<0.1	<0.2	<1.	<0.1	<0.2	0.2	<0.1
12	06-22-94	20	20	<0.1	<0.1	<0.1	<0.1	<1.	<0.1	<0.2	0.3	<0.1
13	06-23-94	20	20	<0.1	<0.1	<0.1	<0.1	<1.	<0.1	<0.2	0.2	<0.1
14	06-23 and 06-24-94	16	16	<0.1	<0.1	<0.1	<0.1	<1.	<0.1	0.1	0.1	<0.1
15	06-26-94	15	18	<0.1	<0.1	<0.1	<0.1	1.	<0.1	0.2	0.4	<0.1
16	06-27-94	[3]19	19	<0.1	<0.1	<0.1	<0.1	<1.	<0.1	0.2	0.4	<0.1
18	06-28-94	[4]18	18	<0.1	<0.1	<0.1	<0.1	<1.	<0.1	0.2	0.3	<0.1
19-1	06-29-94	23	23	<0.1	<0.1	<0.1	<0.1	<1.	<0.1	0.3	0.1	<0.1
19-2		22	23	<0.1	<0.1	<0.1	<0.1	<1.	<0.1	0.2	0.1	<0.1

the downstream one-third of the 25 sampled navigation pools of the Upper Mississippi River, June-July 1994

concentrations which were less than the reporting level; concentrations are nanogram per gram of dry weight; ns, not sampled, and <, less than the reporting limit]

Pool duplicate	Perthane	*p-p'*-DDD	*p-p'*-DDT	*p-p'*-Meth-oxychlor	Mirex	Toxaphene	Gross PCB	Gross PCN	Percent isodrin recovery
Ref. 1-1	<1.	1.7	0.2	<0.1	<0.1	<10.	92.	<1.	72
Ref. 2-1	<1.	1.0	<0.1	<4.	<0.1	<10.	130	<1.	42
Ref. 2-2	<1.	0.9	<0.1	<4	<0.1	<10.	113	<1.	38
1	<1.	0.5	<0.1	<0.2	<0.1	<10.	5.	<1.	52
2-1	<1.	0.6	<0.1	<0.2	<0.2	<10.	12.	<1.	39
2-2	<1.	2.6	0.2	<0.2	<0.1	<10.	16.	<1.	70
St. Croix River	<1.	0.4	0.1	<0.2	<0.1	<10.	6.	<1.	74
3	<1.	3.8	0.2	<0.2	<0.1	<10.	33.	<1.	64
[1]4	<3.	0.9	<0.3	<0.5	<0.3	<30.	21.	<3.	79
[2]4	<1.	1.	<0.1	<0.2	<0.1	<10.	20.	<1.	
5	<1.	0.1	<0.1	<0.2	<0.1	<10.	4.	<1.	40
6	<1.	0.3	<0.1	<0.2	<0.1	<10.	3.	<1.	66
7	<1.	1.	0.1	<0.2	<0.1	<10.	7.	<1.	82
8-1	<1.	0.6	<1.0	<0.2	<0.1	<10.	4.	<1.	76
8-2	<1.	0.1	<0.1	<0.2	<0.1	<10.	4.	<1.	82
9	<1.	1.	0.1	<0.2	<0.1	<10.	6.	<1.	71
10	<1.	0.1	<0.1	<0.2	<0.1	<10.	3.	<1.	66
11	<1.	0.4	<0.1	<0.2	<0.1	<10.	3.	<1.	86
12	<1.	0.6	<0.1	<0.2	<0.1	<10.	4.	<1.	77
13	<1.	0.4	<0.1	<0.2	<0.1	<10.	3.	<1.	71
14	<1.	0.2	<0.1	<0.2	<0.1	<10.	2.	<1.	39
15	<1.	0.5	1.8	<0.2	<0.1	<10.	5.	<1.	40
16	<1.	0.4	<0.1	<0.2	<0.1	<10.	10.	<1.	71
18	<1.	0.6	<0.1	<0.2	<0.1	<10.	5.	<1.	75
19-1	<1.	0.2	<0.1	<0.2	<0.1	<10.	2.	<1.	44
19-2	<1.	0.2	<0.1	<0.2	<0.1	<10.	3.	<1.	22

Table 4.2--Concentration of organochlorine compounds on surficial bed sediments collected from based on the Schedule 1325 method,

Pool duplicate	Date	Number of samples in composite		Lindane	Hepta-chlor	Aldrin	Hepta-chlor epoxide	Technical chlordane	Endo-sulfan I	Dieldrin	*p-p'*-DDE	Endrin
		1994	1991-1992									
20	06-30-94	[5]12	12	<0.1	<0.1	<0.1	<0.1	<1.	<0.1	<0.2	0.1	<0.1
21	07-01-94	16	19	<0.1	<0.1	<0.1	<0.1	2.	<0.1	0.4	0.4	<0.1
22	07-02-94	20	20	<0.1	<0.1	<0.1	<0.1	<1.	<0.1	0.3	0.1	<0.1
24	07-03-94	18	18	<0.1	<0.1	<0.1	<0.1	1.	<0.1	0.4	0.1	<0.1
25	07-04-94	18	19	<0.1	<0.1	<0.1	<0.1	1.	<0.1	0.6	0.5	<0.1
26	07-05-94	11	13	<0.1	<0.1	<0.1	<0.2	<2.	<0.1	0.7	0.5	<0.1

[1]Upper Lake Pepin.
[2]Lower Lake Pepin.
[3]Eight sites were not resampled in the same locations.
[4]Five sites were not resampled in the same locations.
[5]Two sites were sampled out of the water.

the downstream one-third of the 25 sampled navigation pools of the Upper Mississippi River, June-July 1994--Continued

Pool duplicate	Perthane	*p-p'*-DDD	*p-p'*-DDT	*p-p'*-Meth-oxychlor	Mirex	Toxaphene	Gross PCB	Gross PCN	Percent isodrin recovery
20	<1.	0.2	<0.1	<0.2	<0.1	<10.	1.	<1.	83
21	<1.	0.8	0.3	<0.2	<0.1	<10.	4.	<1.	45
22	<1.	0.1	<0.1	<0.2	<0.1	<10.	2.	<1.	46
24	<1.	0.1	<0.1	<0.2	<0.1	<10.	2.	<1.	46
25	<1.	0.5	<0.1	<0.2	<0.1	<10.	3.	<1.	35
26	<1.	1.0	<0.1	<0.2	<0.1	<10.	6.	<1.	46

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CHAPTER 5 - Major and Trace Elements

By David A. Roth, Ronald C. Antweiler, Terry I. Brinton, and Howard E. Taylor

ABSTRACT

Bed-sediment cores were collected in the backwater areas of the navigation pools of the Upper Mississippi River. The bed-sediment cores from each pool were composited and subsampled; sediment fraction with diameter of less than 2 millimeters was chemically digested and analyzed for major and trace elements.

Digestion methods include a three-part sequential extraction, for which only the values of the sums are reported, and a total digestion using aqua regia and hydrofluoric acid. Methods of analysis for the major and trace elements were inductively coupled plasma-atomic emission spectrometry for the major elements and high-concentration trace elements, inductively coupled plasma-mass spectrometry for the low-concentration trace elements, and cold vapor-atomic fluorescence spectrometry for mercury. For elements in which the detection limit was similar, the analytical results from the two methods were in good agreement. For 30 samples, the ratio of the concentration of calcium (major element) based on the sequential-extraction method to the concentration based on the total digestion method ranged from 0.75 to 1.61 with a mean and standard deviation of 0.9 ± 0.17, and the ratio for lead (trace element) ranged from 0.50 to 1.14 with a mean and standard deviation of 0.85 ± 0.19.

INTRODUCTION

The Mississippi River from Minneapolis, Minn., to St. Louis, Mo., is characterized by a series of 29 locks and dams that make 29 navigation pools, which creates a very different hydrological system compared to the free-flowing Lower Mississippi River and hinders the transport and deposition of major and trace elements. The navigation pools of the Upper Mississippi act as sediment traps. Large proportions of the major and trace elements are associated with these sediments; thus, these elements can be stored in the pools for long periods of time.

Major and trace elements in the Mississippi River come from both natural and anthropogenic sources. Naturally introduced elements are primarily from rock weathering, soil erosion, or the dissolution of water-soluble salts. Other elements are introduced as a result of anthropogenic activities such as mining, sewage outfalls, and industrial discharge. The Upper Mississippi River flows through two major lead-zinc mining districts located along Pools 9, 10, 11, and 12. Numerous industries and several major metropolitan areas are located along this reach of the river: Minneapolis near Pools 1 and 2, Quad Cities area near Pools 15 and 16, and St. Louis, Mo., downstream from Pool 26.

Many of the metallic elements categorized as lighter metals, or those with a specific gravity of less than 5, which include sodium, magnesium, and potassium, are found in the tissue of living organisms and are essential to life. The heavy elements have a specific gravity of greater than 5 and include copper, iron, and lead. Some of these heavy elements in very small amounts are also essential to human life, but in larger amounts are toxic. Several of these elements such as cadmium, lead, and mercury are not needed in any amount, are toxic at extremely low concentrations, and can accumulate in body tissues to toxic levels over long periods of exposure.

PURPOSE AND SCOPE

The purpose of the bed-sediment sampling was to determine the concentrations of major and trace elements in representative samples from each navigation pool. Samples were collected during June and July of 1994, from 24 of the 29 navigation pools between Minneapolis, Minn., and St. Louis, Mo. The results are listed in tables, and the spatial distribution of some elements are shown graphically. Sampling locations are shown in figure 1.1 of this report (Chapter 1).

METHODS

The core collection method and the gravity corer used to collect the bed sediment cores are described in Chapter 1. After the core was collected, the water column above the core in the plastic core cylinder was decanted and the ends capped. The core cylinder was put in plastic whirl-pak bags, then placed in a cooler and frozen no more than 3 hours after collection. The integrity of the vertical layering in the core sample was maintained through all aspects of sample collection and preservation. The cores were shipped to the laboratory frozen and stored, still frozen, until they were subsampled and composited.

Subsampling

Each of the individual cores collected from the same pool were thawed around the edges only and extruded from the core tube. Only the top 2 cm were subsampled by cutting the measured core with a perpendicular cut in order to sample a consistent section of the core. The core was divided longitudinally into two equal sections, one for analysis and the other for archiving. The core sections for each transect were combined and sieved through a 2-mm nylon mesh screen to produce a transect composite sample. The transect composite sample was representatively subsampled through a Jones-type splitter made of Teflon, and the correct amount from each transect was combined proportionally, according to the number of cores collected per transect, producing a pool composite.

Dewatering of the pool composite sample was accomplished by centrifugation at 35,800 times the force of gravity. The resulting paste was mixed by coning (a mixing technique that requires the paste to be folded over on itself by alternating the fold axis by 90 degrees until the sample is homogeneous), and subsampled with Teflon utensils. Two or more subsamples were taken from the pool composite sample and weighed wet. One was used for chemical analysis, and the other was used to determine the percent moisture to obtain a final dry weight for the sample that was used in the chemical analysis.

Sequential Extraction and Total Digestion

The data from a sediment sequential extraction listed in this chapter represent a sum of three different phase extractions of a single sample. The purpose of the first two extractions were to leach the various coatings found on the particles. The third was a total digestion of the leftover residual. Therefore, the final sum of this extraction/digestion process represents a complete digestion of the sediment sample; however, the additional handling involved in this multistep extraction process has the potential to increase the error in the final sum value. A comparison between the sum of the extraction phase concentrations and total digestion concentrations for the Standard Reference Material NIST (National Institute of Technology) no. 2704 Buffalo River is found in table 5.1. Additional information regarding the sequential-extraction method is described by Hayes (1993).

The total digestion was identical to the final step of the extraction procedure. It entailed a one-step aqua-regia/hydrofluoric microwave digestion of the sample. Reagent amounts were adjusted to account for the additional material to be digested because of the absence of previous leaching treatments in this step. The entire procedure is outlined in detail by Hayes (1993).

Table 5.1--Comparison of certified values, total digestion, and the sum of the sequential extraction concentrations for National Institute of Standards and Technology Standard reference material

[Reference material was Standard Reference Material NIST no. 2704 Buffalo River sediment; ±, the uncertainty represents 1 standard deviation of the analysis of 10 samples for the total digestion and 4 samples for the sum of sequential extraction; NA, data not available]

Element	Concentration (micrograms of analyte per gram of dry sediment)		
	Certified value	Total digestion	Sum of sequential extraction
Aluminum	61,000 ± 1,600	48,000 ± 3,000	44,000 ± 7,000
Barium	414 ± 12	330 ± 30	420 ± 80
Cadmium	3.45 ± 0.22	3.9 ± 0.3	3.19 ± 0.10
Calcium	26,000 ± 300	25,500 ± 1,100	25,700 ± 2,000
Chromium	135 ± 5	130 ± 6.4	130 ± 9
Copper	99 ± 5	125 ± 7.5	105 ± 7
Iron	41,100 ± 1,000	40,500 ± 900	39,200 ± 2,500
Lead	161 ± 17	166 ± 14	180 ± 7
Magnesium	12,000 ± 200	6,300 ± 1,400	6,700 ± 300
Manganese	555 ± 19	610 ± 10	550 ± 40
Mercury	1.47 ± 0.07	NA ± NA	1.52 ± 0.12
Silicon	291,000 ± 1,300	280,000 ± 20,000	270,000 ± 10,000
Vanadium	95 ± 4	96 ± 3	125 ± 16
Zinc	438 ± 12	440 ± 11	420 ± 16

Analysis of Bed-Sediment Digestion Extracts

Analytical methods used for the analysis of the extract of the digestion included inductively coupled plasma-atomic emission spectrometry, inductively coupled plasma-mass spectrometry, and cold vapor-atomic fluorescence spectrometry. Elements determined by the inductively coupled plasma-atomic emission spectrometry method (Garbarino and Taylor, 1979) included aluminum, barium, calcium, chromium, iron, magnesium, manganese, silicon (as silica), strontium, vanadium, and zinc. Cadmium, chromium, copper, and lead were determined using an inductively coupled plasma-mass spectrometry method described by Garbarino and Taylor (1993) and Hayes (1993). Mercury was determined using cold vapor-atomic fluorescence spectrometry following the method outlined by Roth (1994).

Accuracy and Precision

Accuracy and precision data for the sum of the sequential extractions and the total digestions (based on the analysis of Standard Reference Material NIST no. 2704 Buffalo River sediment) for selected major and trace elements are in table 5.1. All samples were analyzed in a random fashion, background corrected, and reagent blank subtracted.

To ensure that a mass balance of the extracted elements was obtained during the sequential extraction procedure, elemental concentrations in the total digestion were compared to the concentrations of the sum of the sequential extraction for 15 Mississippi River sediment samples. The sum of the sequential extractions divided by the total digestion concentrations yields a value of 96 to 120 percent for all the elements analyzed with the exception of silicon. The results are listed in table 5.2. In addition, the Standard Reference Material NIST no. 2704 Buffalo River sediment sum of extracted element concentrations were compared to the total digestion concentrations as well as to the certified values. The results, tabulated in table 5.1, show comparisons between values of the total digestion concentrations, sum of sequential extract concentrations, and the certified concentrations

To evaluate the precision of the sequential extraction and total digestion, a Standard Reference Material NIST no. 2704 Buffalo River sediment sample was extracted along with each set of sample extractions or digestions. These reference samples were analyzed in the same manner as the samples and distributed periodically throughout the analysis run sequence. The resulting precision represents the variability associated with the entire process, from subsampling and extracting the sediment to the analysis of the sample digestion extracts. The calculated relative standard deviations for the total digestions are 9.1 percent or less for all elements reported except for magnesium (which is 22 percent). All reported element results from the sums of the sequential digests have relative standard deviations less than 7.9 percent except for vanadium, aluminum, and barium, which are 13, 16, and 19 percent, respectively.

Table 5.2 --Mass balance results of sequential extractions

[Sum is the summation of the concentrations in the hydroxylamine, persulfate, and residual extracts; total is the concentration in the total digestion of the sample; ±, the uncertainty represents 1 standard deviation of 15 Mississippi River samples; %, percent]

Element	Sum/Total (%)
Aluminum	98 ± 2
Barium	96 ± 2
Calcium	103 ± 5
Chromium	107 ± 6
Copper	120 ± 11
Iron	104 ± 1
Lead	112 ± 3
Magnesium	99 ± 1
Manganese	98 ± 2
Silicon	135 ± 4
Vanadium	99 ± 2
Zinc	115 ± 10

Quality Control and Quality Assurance

In all sampling methods, extreme care was used to minimize possible contamination by using Teflon, high-density polyethylene, and, where necessary, Teflon-coated stainless-steel sample-processing equipment. The use of Teflon or non-talc, polyvinyl chloride gloves was required for all sample-handling and processing procedures. All processing devices used to collect the sample were cleaned with deionized water with a resistivity of 17.0 megohms/cm prior to sampling.

Reference standards were used to monitor the accuracy of the analyses. Multiple analyses of the same samples were used to check analytical precision. The accuracy of the sample data was ensured by analyzing two to three standard reference materials periodically within each set of unknown samples. Reference standards routinely composed about 30 to 50 percent of the suite of samples for analysis, or about two or three in every six. Calibration of the instruments varied, depending on the particular instrument, and the appropriate reference should be consulted for further information. Sample unknowns were reanalyzed whenever the duplicates deviated from one another by an amount that depended on the particular instrument and analyte (see the reference for the applicable method) or when standard reference water samples deviated more than 1.5 standard deviations from the certified value. Quality-control data from the standard reference sediment used in the analysis of the extracts from the sediment digests for metals are listed in table 5.1.

RESULTS

Results for the sum of sequential extractions of surficial bed sediment are listed in table 5.3, and those for the total digestions are in table 5.4. They are the mean of two or more replicate analyses from a single sequential extraction or total digestion. These numbers represent the total amount of analyte found in the sediment sample. The results of the two methods are compared in figure 5.1. When sample concentrations are less than or equal to the detection limit, the results are identified as "less than" values with < preceding the detection limit value. Detection limits were calculated on an individual analysis set basis and were dependent on the dry weight of each individual sample.

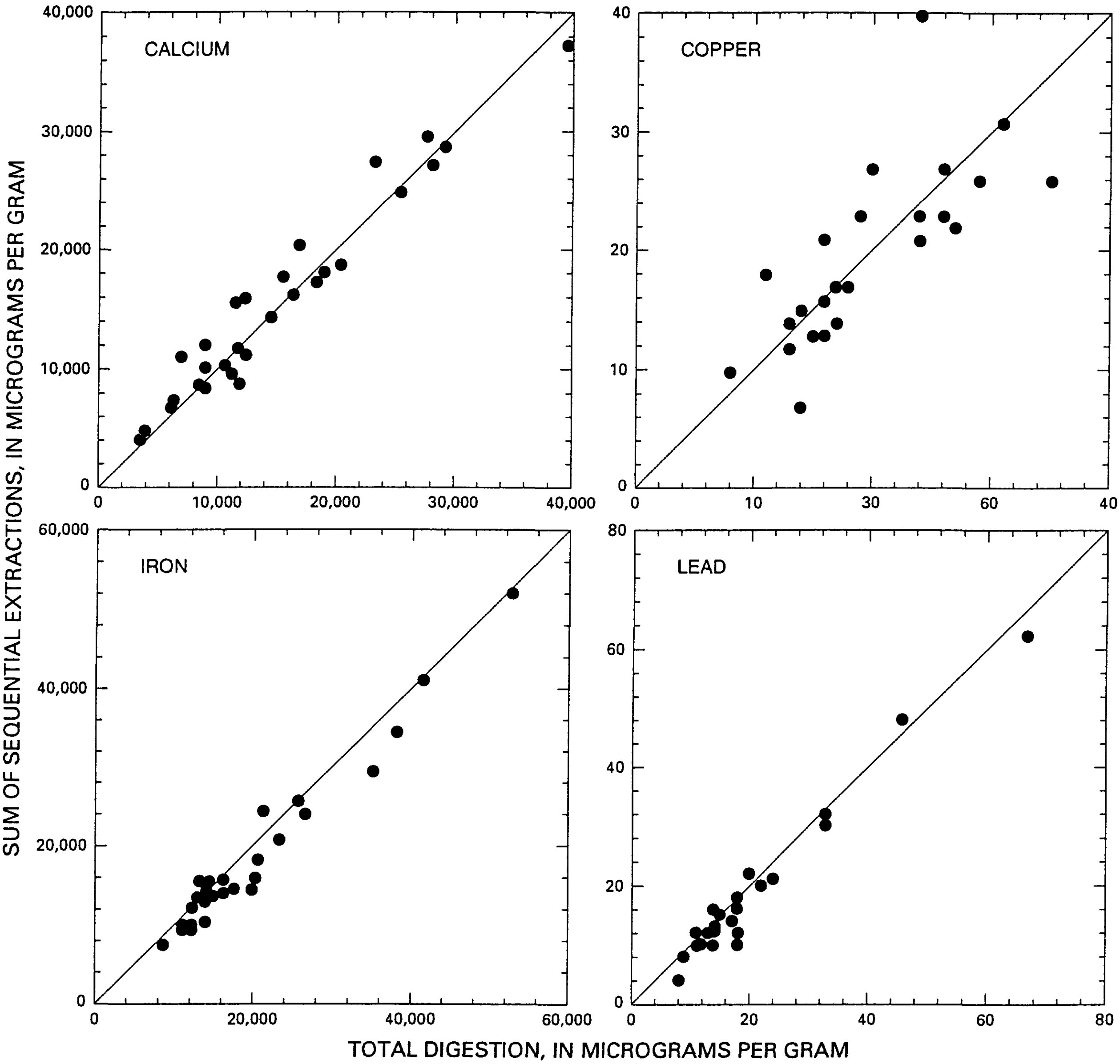

Figure 5.1--Comparison of the sum of sequential extraction with total digestion for calcium, copper, iron, and lead.

Table 5.3 --Concentration of major and trace elements as the sum of sequential extractions of navigation pools of the Upper

[Ref., Lake Pepin reference sample; <, less than the detection limit; units in

Pool	Date	Aluminum	Barium	Cad-mium	Calcium	Chromium	Copper	Iron
Ref.	05-15-91	55,000	660	3.5	29,700	110	70	51,700
1	06-11-94	24,000	380	0.3	8,800	<44	18	9,100
2-1	06-12-94	34,000	560	<0.3	27,200	<44	40	13,700
2-2	06-12-94	33,000	540	<0.3	28,700	<63	21	14,100
St. Croix R.	06-13-94	34,000	490	<0.3	10,100	40	26	28,900
3	06-14-94	32,000	460	<0.3	27,600	50	23	14,300
[1]4	06-15-94	43,000	520	<0.3	24,900	70	38	34,000
[2]4	06-15-94	39,000	480	1.2	37,300	70	43	40,500
5	06-16-94	31,000	510	0.5	15,600	<61	21	15,300
6	06-17-94	14,000	220	<0.3	4,100	<52	7	9,800
7	06-18-94	27,000	530	0.4	8,600	50	21	13,500
8-1	06-19-94	29,000	470	<0.3	14,400	<57	17	12,600
8-2	06-19-94	27,000	440	<0.3	11,900	<49	13	12,600
9	06-20-94	38,000	560	<0.3	16,300	<64	23	20,400
10	06-21-94	28,000	450	<0.3	10,400	60	16	15,100
11	06-21-94	29,000	460	<0.3	17,800	<50	17	13,400
12	06-22-94	45,000	690	<0.3	20,400	70	27	24,100
13	06-23-94	33,000	580	0.4	18,700	50	23	14,100
14	06-23-94	24,000	380	0.3	8,800	<58	15	9,200
15	06-26-94	27,000	370	<0.3	12,100	<60	13	13,100
16	06-27-94	26,000	450	<0.3	11,300	<61	14	10,200
18	06-28-94	32,000	410	<0.3	16,000	50	17	13,200
19-1	06-29-94	40,000	590	<0.3	18,200	40	23	17,800
19-2	06-29-94	29,000	290	<0.3	17,300	50	26	23,500
20	06-30-94	24,000	510	<0.3	4,900	<58	10	7,100
21	07-01-94	25,000	360	<0.3	7,600	<93	12	9,800
22	07-02-94	28,000	420	0.3	6,900	<67	14	11,900
24	07-03-94	35,000	520	<0.3	11,100	<114	15	15,200
25-1	07-04-94	36,000	470	<0.3	9,700	<60	22	15,500
25-2	07-04-94	34,000	470	<0.3	8,600	<70	27	15,300
26-2	07-05-94	47,000	640	<0.3	10,400	70	31	25,200

[1]Upper Lake Pepin.
[2]Lower Lake Pepin.

surficial bed-sediment samples collected from the downstream one-third of the 25 sampled Mississippi River, June–July 1994

micrograms per gram dry sediment weight]

Pool	Date	Lead	Magnesium	Manganese	Mercury	Silica	Strontium	Vanadium	Zinc
Ref.	05-15-91	62	10,000	2,750	0.384	490,000	110	156	210
1	06-11-94	10	2,000	190	0.032	620,000	140	10	<41
2-1	06-12-94	13	8,900	550	0.191	560,000	170	50	<56
2-2	06-12-94	12	9,900	530	0.175	540,000	160	44	<48
St. Croix R.	06-13-94	21	4,400	1,240	0.100	590,000	100	61	60
3	06-14-94	12	10,300	690	0.095	420,000	140	49	<46
[1]4	06-15-94	30	6,600	1,690	0.167	480,000	130	98	110
[2]4	06-15-94	32	8,900	2,100	0.137	500,000	120	135	130
5	06-16-94	12	4,300	640	0.052	550,000	100	47	<45
6	06-17-94	4	1,700	240	0.017	610,000	60	3	<39
7	06-18-94	10	2,500	460	0.030	650,000	100	36	<44
8-1	06-19-94	11	3,800	420	0.050	740,000	100	5	<41
8-2	06-19-94	10	3,800	450	0.048	660,000	90	25	<40
9	06-20-94	16	4,700	800	0.071	560,000	120	60	60
10	06-21-94	10	4,100	560	0.046	740,000	80	37	<62
11	06-21-94	12	7,800	580	0.064	620,000	100	109	<39
12	06-22-94	48	6,500	810	0.044	750,000	150	51	330
13	06-23-94	15	6,300	580	0.027	620,000	120	27	<49
14	06-23-94	10	3,000	310	0.046	700,000	80	6	<50
15	06-26-94	12	3,600	450	0.049	620,000	90	27	<45
16	06-27-94	12	4,100	350	0.089	630,000	90	52	<46
18	06-28-94	12	4,300	450	0.054	600,000	110	33	<40
19-1	06-29-94	18	3,900	670	0.085	610,000	120	66	25
19-2	06-29-94	20	3,000	910	0.071	550,000	50	49	80
20	06-30-94	8	1,200	170	0.017	640,000	160	17	<39
21	07-01-94	12	2,300	310	0.056	520,000	90	6	<66
22	07-02-94	10	1,900	290	0.046	640,000	100	14	<46
24	07-03-94	10	3,500	410	0.097	590,000	110	13	<79
25-1	07-04-94	14	3,300	450	0.087	540,000	110	66	<44
25-2	07-04-94	16	2,900	420	0.130	590,000	100	58	<55
26	07-05-94	22	3,600	900	0.042	620,000	120	88	50

Table 5.4--Concentration of major and trace elements from total digestions of surficial bed-pools of the Upper

[Ref., Lake Pepin reference sample, total mercury concentrations are not listed due to

Pool	Date	Aluminum	Barium	Cadmium	Calcium	Chromium	Copper	Iron
Ref.	05-15-91	47,000	530	4.1	27,600	110	72	52,700
1	06-11-94	27,000	320	0.3	11,800	20	11	11,700
2-1	06-12-94	35,000	460	0.7	28,000	40	24	16,000
2-2	06-12-94	35,000	500	1.0	29,100	40	24	19,500
St. Croix R.	06-13-94	33,000	380	0.6	8,900	50	29	34,900
3	06-14-94	30,000	390	0.8	23,200	40	24	17,200
[1]4	06-15-94	42,000	450	1.3	25,300	60	41	37,800
[2]4	06-15-94	52,000	500	1.6	39,400	80	53	41,600
5	06-16-94	22,000	330	0.4	11,500	20	16	14,100
6	06-17-94	15,000	300	0.2	3,400	10	14	11,700
7	06-18-94	22,000	390	0.4	8,900	20	16	14,400
8-1	06-19-94	23,000	420	0.4	14,500	26	17	13,600
8-2	06-19-94	21,000	400	0.3	11,600	25	16	13,600
9	06-20-94	31,000	440	0.6	16,300	60	26	23,100
10	06-21-94	22,000	320	0.4	10,800	20	16	14,300
11	06-21-94	21,000	380	0.3	15,500	20	18	14,700
12	06-22-94	29,000	430	1.0	16,800	50	26	21,000
13	06-23-94	26,000	450	0.4	20,300	40	19	13,800
14	06-23-94	25,000	340	0.1	8,600	20	14	10,500
15	06-26-94	21,000	290	0.3	8,900	20	15	12,500
16	06-27-94	25,000	350	0.8	12,300	30	17	13,500
18	06-28-94	25,000	400	0.4	12,300	30	18	13,900
19-1	06-29-94	32,000	420	0.6	19,000	40	24	20,300
19-2	06-29-94	50,000	520	0.8	18,200	50	35	26,300
20	06-30-94	19,000	310	0.1	3,800	10	8	8,200
21	07-01-94	22,000	290	0.3	6,200	20	13	10,700
22	07-02-94	22,000	310	0.3	6,000	30	13	11,800
24	07-03-94	27,000	330	0.3	6,900	20	14	13,000
25-1	07-04-94	31,000	400	0.6	11,200	40	27	20,000
25-2	07-04-94	29,000	330	0.5	8,200	30	20	16,000
26	07-05-94	33,000	290	0.8	8,900	60	31	25,400

[1]Upper Lake Pepin.
[2]Lower Lake Pepin.

sediment samples collected from the downstream one-third of the 25 sampled navigation Mississippi River, June-July, 1994

the instability of mercury in the digested sample; units in micrograms per gram dry sediment weight]

Pool	Date	Lead	Magnesium	Manganese	Silica	Strontium	Vanadium	Zinc
Ref.	05-15-91	67	4,600	2,910	510,000	110	132	210
1	06-11-94	12	2,700	280	810,000	150	30	24
2-1	06-12-94	14	8,700	740	700,000	170	56	48
2-2	06-12-94	18	10,000	760	670,000	170	56	55
St. Croix R.	06-13-94	24	2,300	1,520	770,000	100	66	69
3	06-14-94	18	6,300	730	740,000	150	52	52
[1]4	06-15-94	33	5,600	2,050	570,000	110	104	140
[2]4	06-15-94	33	1,600	2,400	590,000	140	124	150
5	06-16-94	11	1,600	590	740,000	90	34	38
6	06-17-94	8	900	360	820,000	60	28	14
7	06-18-94	11	700	540	740,000	90	34	30
8-1	06-19-94	11	2,500	500	790,000	100	35	25
8-2	06-19-94	18	1,600	530	740,000	90	32	31
9	06-20-94	18	1,100	1,000	660,000	120	58	65
10	06-21-94	11	1,600	550	810,000	80	40	37
11	06-21-94	14	2,600	630	730,000	90	37	47
12	06-22-94	46	1,400	780	670,000	120	54	280
13	06-23-94	15	2,800	610	770,000	120	39	48
14	06-23-94	11	2,500	450	840,000	90	32	39
15	06-26-94	13	1,300	490	700,000	90	30	46
16	06-27-94	14	1,800	510	790,000	100	39	42
18	06-28-94	14	1,300	490	740,000	120	38	48
19-1	06-29-94	18	1,100	780	710,000	110	55	66
19-2	06-29-94	22	4,800	1,030	730,000	110	82	100
20	06-30-94	9	900	250	690,000	90	16	13
21	07-01-94	14	800	360	790,000	90	31	31
22	07-02-94	12	700	330	720,000	80	31	31
24	07-03-94	14	800	360	830,000	90	35	38
25-1	07-04-94	17	1,000	650	740,000	90	58	53
25-2	07-04-94	14	800	440	820,000	100	46	41
26	07-05-94	20	800	880	700,000	70	78	62

SUMMARY

The bed-sediment data listed in this report represents a complete digestion of the <2-mm fraction of surficial bed sediment. These samples were composited from a number of individual cores collected from the downstream one-third of the 25 sampled navigation pools on the Upper Mississippi River. For 30 samples, the ratio of the concentration of calcium (major element) based on the sequential-extraction method to the concentration based on the total digestion method ranged from 0.75 to 1.61 with a mean and standard deviation of 0.9±0.17, and the ratio for lead (trace element) ranged from 0.50 to 1.14 with a mean and standard deviation of 0.85±0.19. Results summarizing the spatial distribution of calcium, lead, mercury, and strontium as sums of sequential extraction in the bed sediments of the Upper Mississippi River pools are shown in figures 5.2 to 5.5. The concentration of samples that were sequentially extracted and summed is compared to the concentration of samples that were totally digested in a single step in figure 5.1.

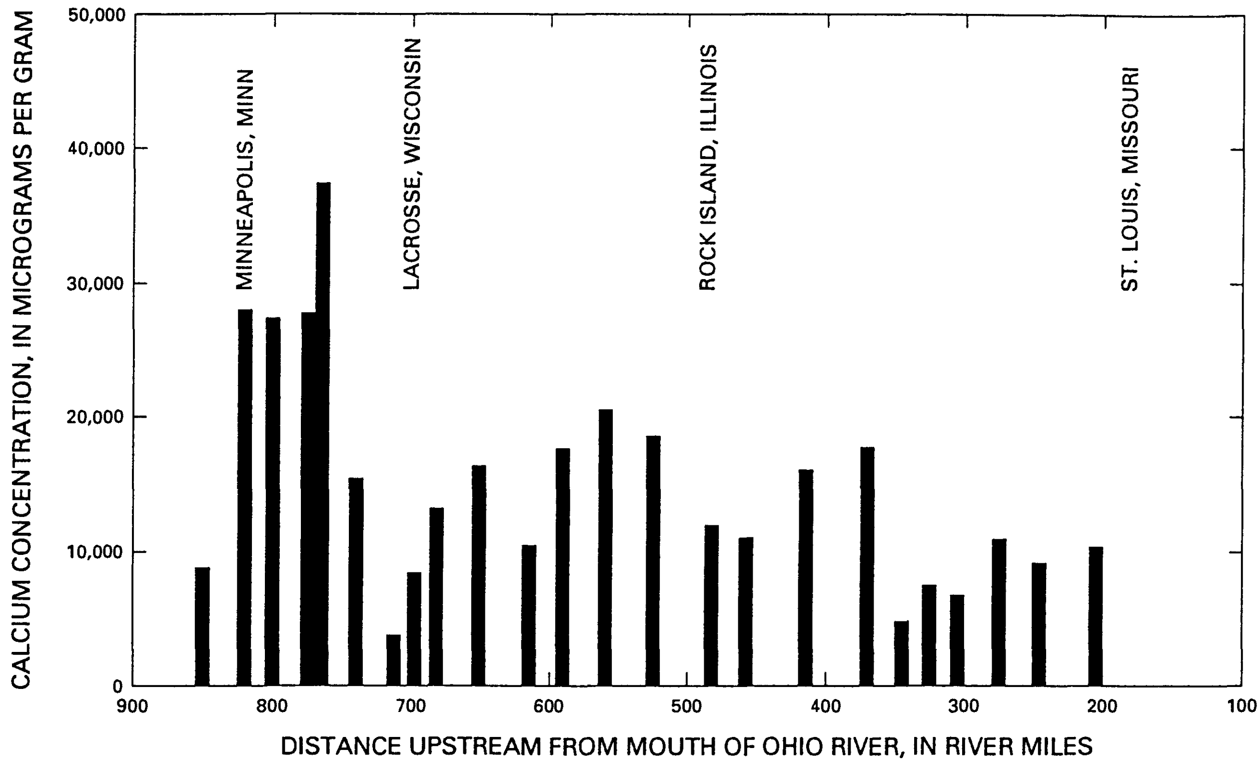

Figure 5.2--Concentration of calcium (sum of sequential extractions) in the surficial bed sediments collected from the downstream one-third of the 25 sampled navigation pools of the Upper Mississippi River, June-July 1994.. See table 1.2 for location of pools.

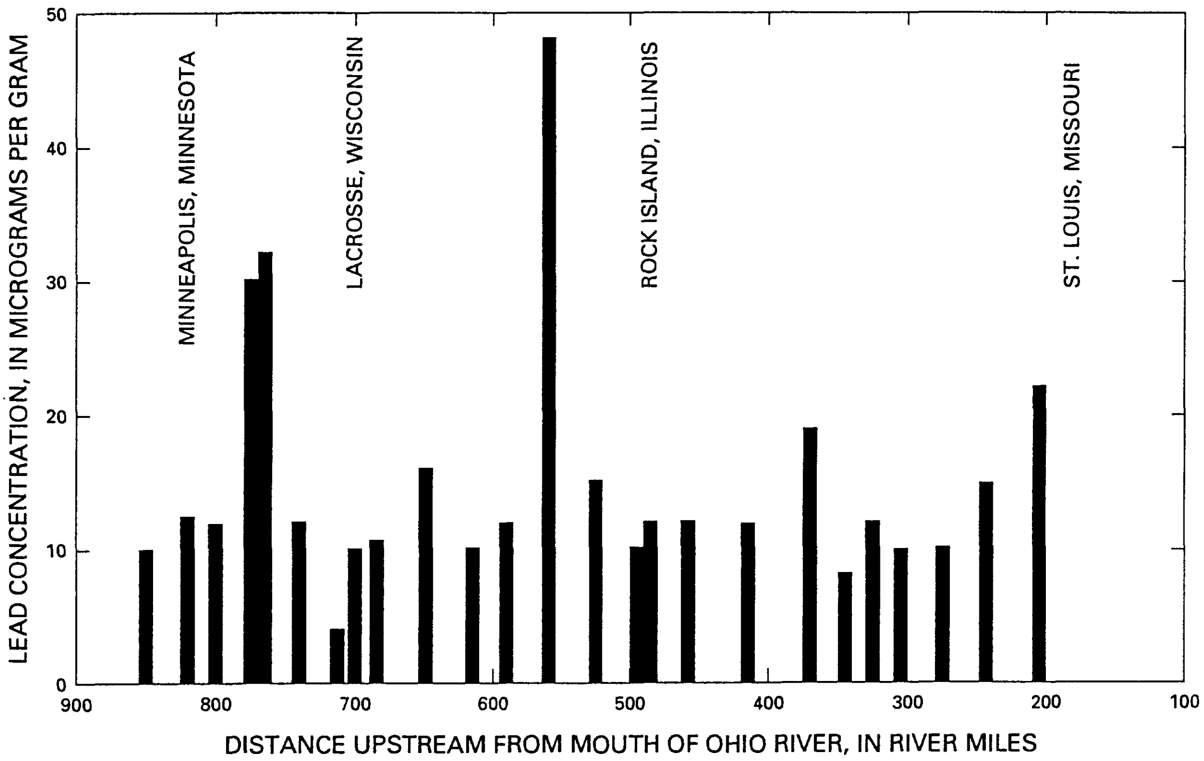

Figure 5.3--Concentration of lead (sum of sequential extractions) in the surficial bed sediments collected from the downstream one-third of the 25 sampled navigation pools of the Upper Mississippi River, June-July 1994. See table 1.2 for location of pools.

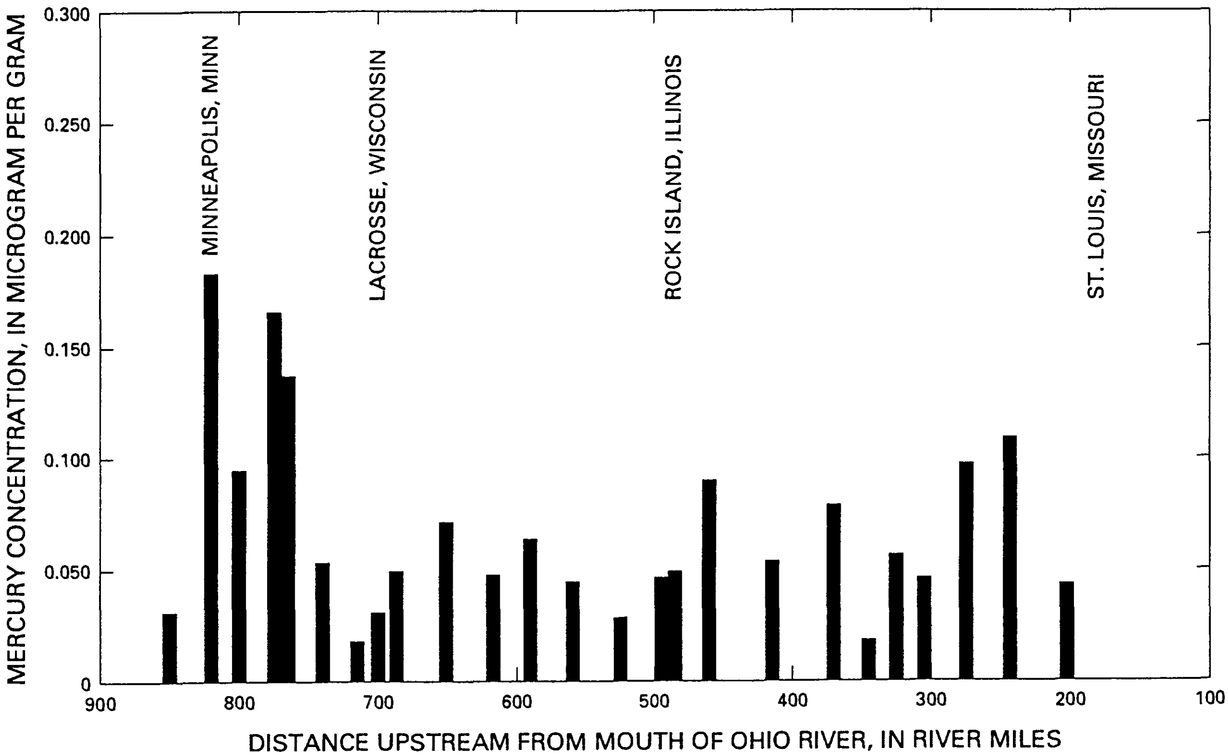

Figure 5.4--Concentration of mercury (sum of sequential extractions) in the surficial bed sediments collected from the downstream one-third of the 25 sampled navigation pools of the Upper Mississippi River, June-July 1994. See table 1.2 for location of pools.

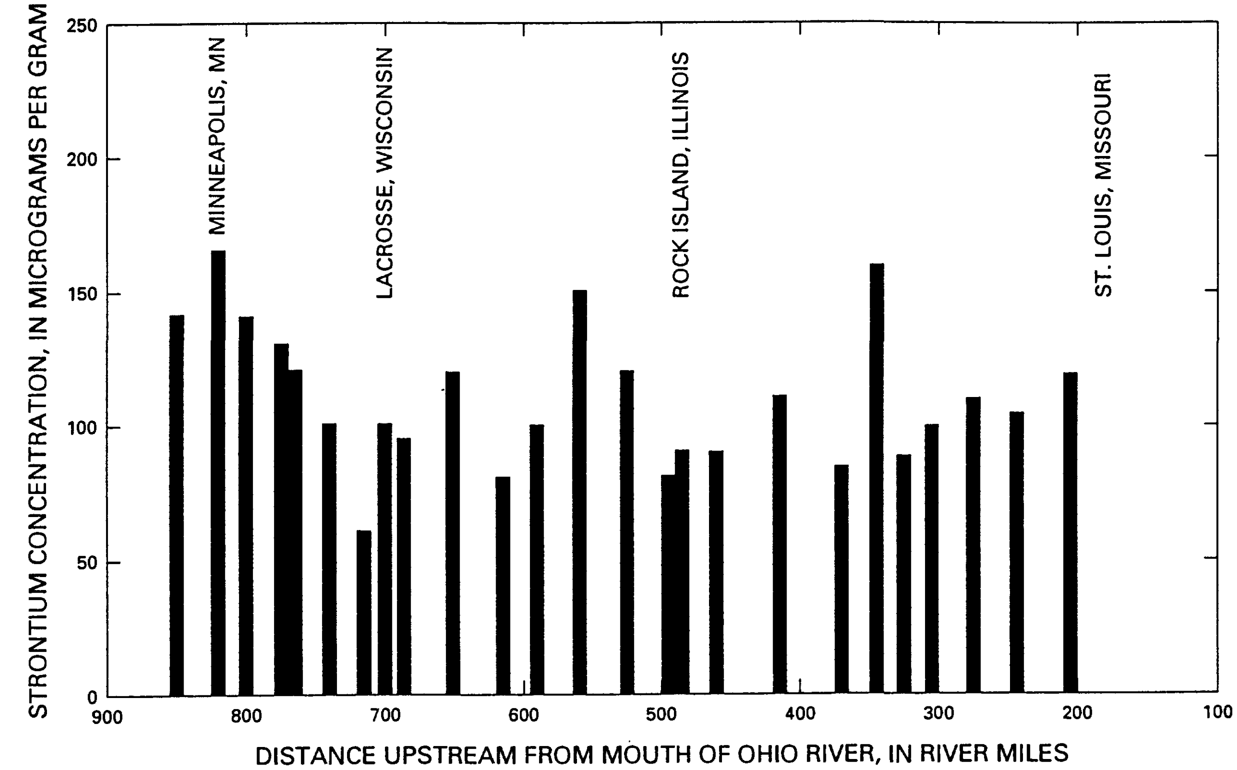

Figure 5.5--Concentration of strontium (sum of sequential extractions) in the surficial bed sediments collected from the downstream one-third of the 25 sampled navigation pools of the Upper Mississippi River, June-July 1994. See table 1.2 for location of pools.

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Chapter 6 - Sampling-Site Information

By John A. Moody *and* Deborah A. Martin

ABSTRACT

One purpose of this study was to locate the individual sampling sites so that the sampling could be repeated at a future time. With this in mind, sampling-site information is presented in three ways: (1) a map showing the location of sampling sites in each pool, (2) a vertical profile of each transect in each pool showing the water depth at each sampling site, and (3) a table that lists the latitude and longitude of each sampling site and field data collected at each site.

EXPLANATION

The sampling-site information consists of three parts for each pool:

A map, adapted from U.S. Geological Survey 7.5-minute quadrangle maps, shows the transects and location of each individual sampling site (a solid circle) where a sample was collected and combined to make a composite sample for each pool. The navigation lights and daymarks are shown as open circles and their locations are approximate. Island locations and shapes are approximate because they are constantly changing. The navigation channel is also approximate and is shown as two dashed lines.

A profile of each transect in each pool shows the location of each sampling site and the water depth. Profiles with dashed lines are based on depths measured in 1991 or 1992 (see Moody, 1997).

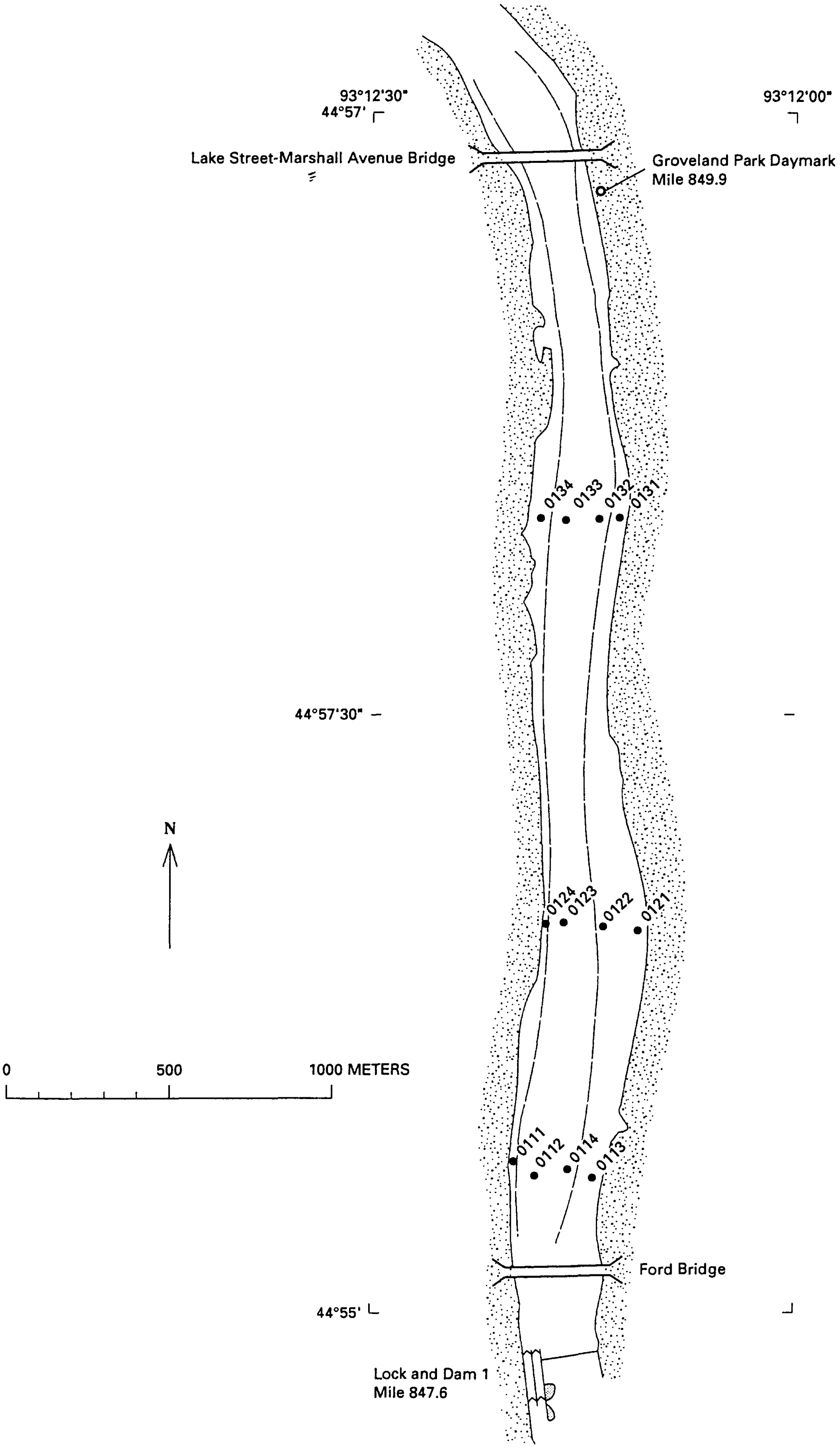
A table for each transect in a pool lists the sampling sites and field data collected at each site. Each individual sampling site is identified by an identifier under the column labeled "Site." The first two characters are the pool number, the third digit is the transect number, and the last digit (or two digits) is the sample number. Single-digit numbers identify additional sites where only velocity measurements were made. The field data are: latitude and longitude, depth, surface specific conductance, surface-water temperature, dissolved oxygen (Pools 1-11), mean velocity measured at 0.6 of the water depth, the estimated magnetic direction of the velocity, and surficial bed-sediment type. Gage heights are listed in feet for ease of comparison with data published by the U.S. Army Corps of Engineers.

REFERENCES

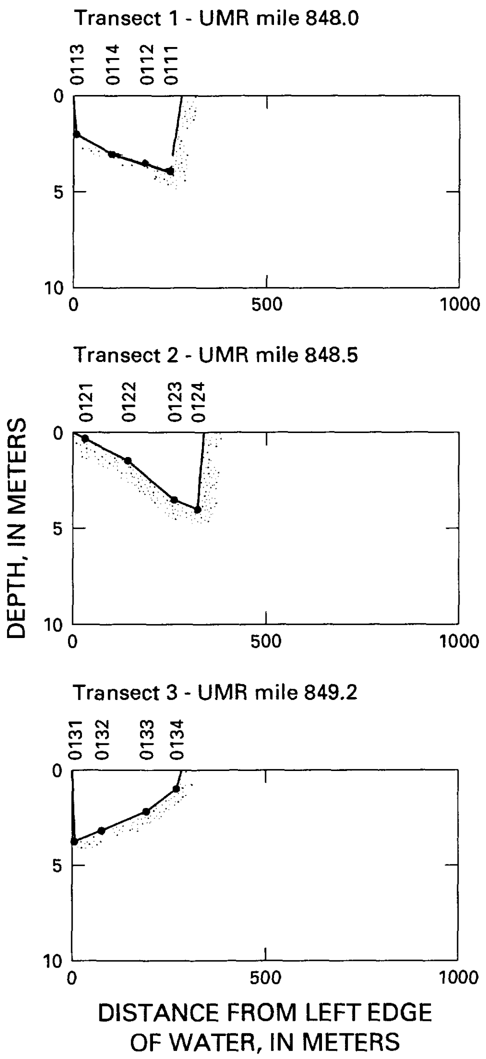
Moody, J.A., 1997, editor, Hydrologic, sedimentologic, and chemical data describing surficial bed sediments and water in the navigation pools of the Upper Mississippi River, July 1991-April 1992: U.S. Geological Survey Open-File Report 95-708, 276 p.

The following additional abbreviations are used:

- BM = benchmark
- cm = centimeters
- °C = degrees Celsius
- ft = foot
- GPS = Global Positioning System
- m = meters
- m/s = meters per second
- m^3/s = cubic meters per second
- LEW = left edge of water
- N = North
- na = not applicable
- NAD27 = North American Datum 1927
- NAD83 = North American Datum 1983
- rev/s = revolutions per second
- S = South
- SAFL = St. Anthony Falls Lower
- SC = St. Croix River
- T = Township
- TW = Tailwater
- UMR = Upper Mississippi River
- USGS = United States Geological Survey
- W = West
- ~ = approximate
- -- = no measurement taken
- µS/cm - microsiemens per centimeter at 25 degrees Celsius



93°12'30"
44°57'
93°12'00"
Lake Street-Marshall Avenue Bridge
Groveland Park Daymark
Mile 849.9
0134
0133
0132
0131
44°57'30"
N
0124
0123
0122
0121
0
500
1000 METERS
0111
0112
0114
0113
Ford Bridge
44°55'
Lock and Dam 1
Mile 847.6



Transect 1 - UMR mile 848.0
0113
0114
0112
0111
Transect 2 - UMR mile 848.5
0121
0122
0123
0124
Transect 3 - UMR mile 849.2
0131
0132
0133
0134
DEPTH, IN METERS
0
5
10
0
500
1000
DISTANCE FROM LEFT EDGE OF WATER, IN METERS

STATION: Mississippi River in Pool 1, Transect 1--UMR mile 848.0
PARTY: Moody, Sullivan, and Writer
DATE: June 11, 1994
GAGE HEIGHT at SAFL TW: na
GAGE HEIGHT at Dam 1: 724.25 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: na
CURRENT METER No: W-223906
DATE RATED: 06-25-92
MAP: USGS 7.5-minute quadrangle is St. Paul West, Minn.
REMARKS:

Resampled sites within ±5 m by using differential GPS. The GPS reference station was at end of center guidewall (44°54.945 N, 093°12.130 W, NAD27, accuracy ±25 m). Velocity was not measured at 0.6 depth but at the surface. Oxygen was measured by using the Yellow Springs Instrument (Model 57). Surface specific conductance and temperature were measured by using a LabComp meter. Biological Resources Division collected a sample from site 0114.

CURRENT METER EQUATION: V(m/s)=0.666*rev/s + 0.006

BEARING OF TRANSECT: 096° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Depth (m)	Surface Conductance (μS/cm)	Surface Temperature (°C)	Dissolved oxygen (mg/L)	Velocity (m/s)	Direction (°magnetic)	Surficial bed sediment
LEW			0.0						
0113	44°55.221	093°11.977	2.0	399	22.4	11.2	--	--	sand
0114	55.221	12.049	2.8	401	21.8	10.4	--	--	sand
0112	55.211	12.117	3.3	404	21.8	10.3	--	--	sand
0111	44°55.234	093°12.160	4.0	392	23.2	--	--	--	sand
REW			0.0						

STATION: Mississippi River in Pool 1, Transect 2--UMR mile 848.5
PARTY: Moody, Sullivan, and Writer
DATE: June 11, 1994
GAGE HEIGHT at SAFL TW: na
GAGE HEIGHT at Dam 1: 724.25 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: na
CURRENT METER No: W-223906
DATE RATED: 06-25-92
MAP: USGS 7.5-minute quadrangle is St. Paul West, Minn.
REMARKS:

Resampled sites within ±5 m by using differential GPS. The GPS reference station was at end of center guidewall (44°54.945 N, 093°12.130 W, NAD27, accuracy ±25 m). Velocity was not measured at 0.6 depth but at the surface. Oxygen was measured by using the Yellow Springs Instrument (Model 57). Surface specific conductance and temperature were measured by using a LabComp meter. New sandbar at old site 0121.

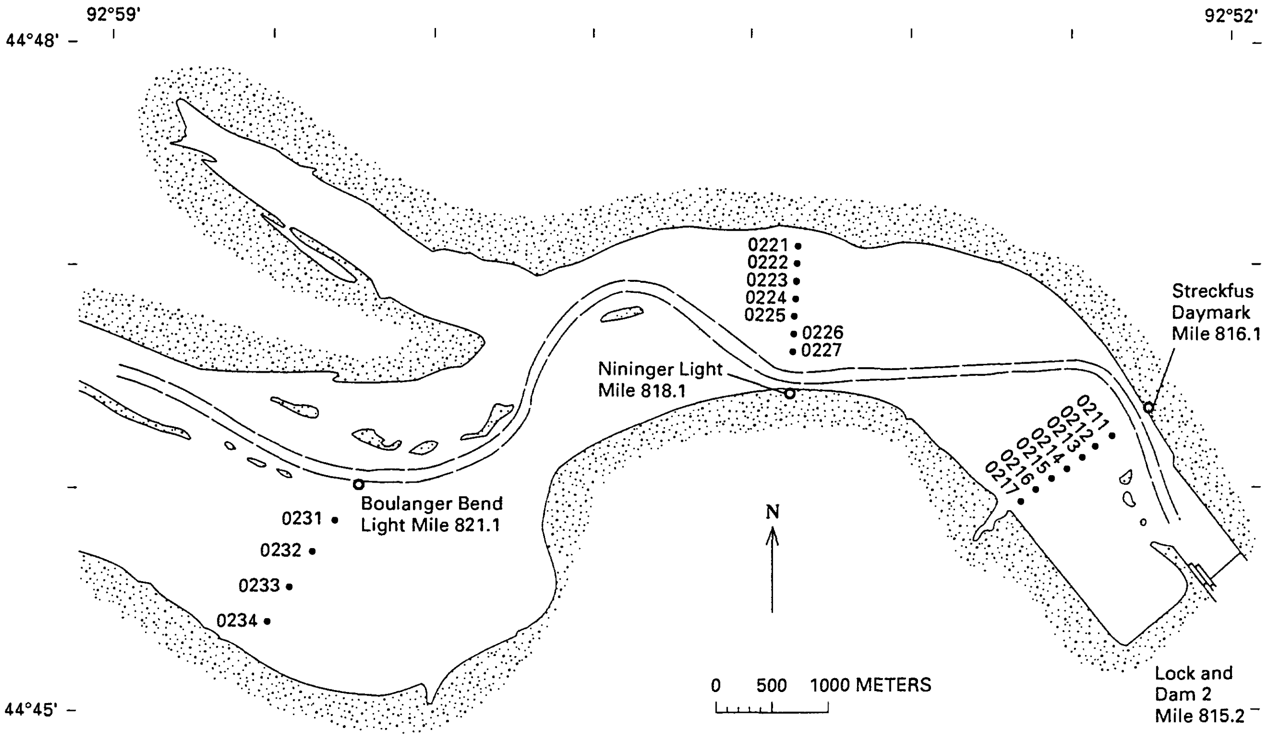
CURRENT METER EQUATION: V(m/s)=0.668*rev/s + 0.006

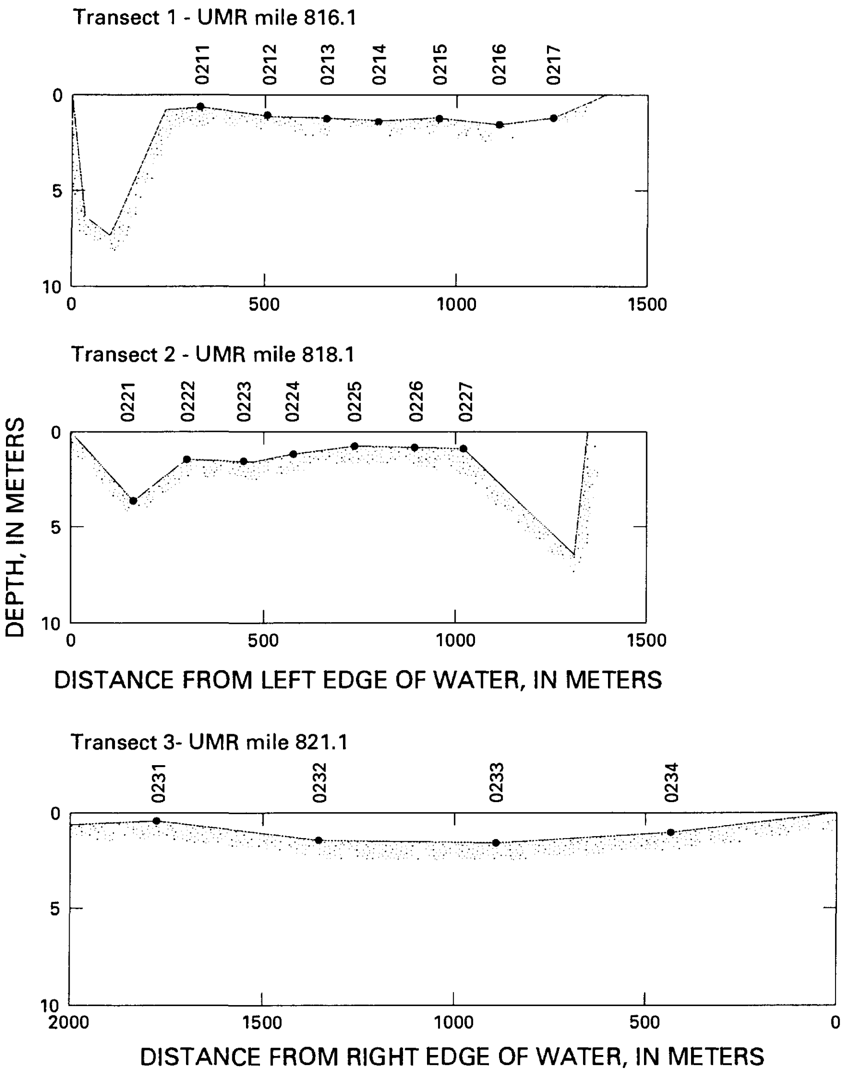
BEARING OF TRANSECT: 104° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Depth (m)	Surface Conductance (μS/cm)	Surface Temperature (°C)	Dissolved oxygen (mg/L)	Velocity (m/s)	Direction (°magnetic)	Surficial bed sediment
LEW			0.0						
0121	44°55.627	093°11.900	0.3	402	22.3	10.8	0.11	~180	sand
0122	55.627	11.954	1.4	404	21.8	11.0	0.29	~180	sand
0123	55.626	12.032	3.7	406	21.2	10.6	0.40	180	sand
0124	44°55.636	093°12.079	4.0	403	21.8	11.0	0.48	170	sand
REW			0.0						

STATION: Mississippi River in Pool 1, Transect 3--UMR mile 849.2
PARTY: Moody, Sullivan, and Writer
GAGE HEIGHT at SAFL TW: na
SUSPENSION: 15-pound weight
CURRENT METER No: W-223906
DATE: June 11, 1994
GAGE HEIGHT at Dam 1: 724.25 ft
RIVER SLOPE: na
DATE RATED: 06-25-92
MAP: USGS 7.5-minute quadrangle is St. Paul West, Minn.
REMARKS:
Resampled sites within ±5 m by using differential GPS. The GPS reference station was at end of center guidewall (44°54.945 N, 093°12.130 W, NAD27, accuracy ±25 m). Velocity was not measured at 0.6 depth but at the surface. Oxygen was measured by using the Yellow Springs Instrument (Model 57). Surface specific conductance and temperature were measured by using a LabComp meter.
CURRENT METER EQUATION: V(m/s)=0.668*rev/s + 0.006
BEARING OF TRANSECT: 100° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Depth (m)	Surface Conductance (µS/cm)	Surface Temperature (°C)	Dissolved oxygen (mg/L)	Velocity (m/s)	Direction (°magnetic)	Surficial bed sediment
LEW			0.0						
0131	44°56.307	093°11.913	3.6	405	21.5	10.2	0.21	160	sand
0132	56.301	11.973	3.2	404	21.7	10.2	0.44	150	sand
0133	56.303	12.069	2.2	405	22.2	10.6	0.20	190	sand
0134	44°56.315	093°12.104	1.0	404	22.7	10.5	0.11	--	mud
REW			0.0						


92°59'
92°52'
44°48'
44°45'
0221
0222
0223
0224
0225
0226
0227
Streckfus
Daymark
Mile 816.1
Nininger Light
Mile 818.1
0211
0212
0213
0214
0215
0216
0217
Boulanger Bend
Light Mile 821.1
0231
0232
0233
0234
N
0 500 1000 METERS
Lock and
Dam 2
Mile 815.2



Transect 1 - UMR mile 816.1
0211
0212
0213
0214
0215
0216
0217
0
5
10
0
500
1000
1500
Transect 2 - UMR mile 818.1
0221
0222
0223
0224
0225
0226
0227
DEPTH, IN METERS
0
5
10
0
500
1000
1500
DISTANCE FROM LEFT EDGE OF WATER, IN METERS
Transect 3- UMR mile 821.1
0231
0232
0233
0234
0
5
10
2000
1500
1000
500
0
DISTANCE FROM RIGHT EDGE OF WATER, IN METERS

STATION: Mississippi River in Pool 2, Transect 1--UMR mile 816.1
PARTY: Moody, Sullivan, and Writer
DATE: June 11, 1994
GAGE HEIGHT at Dam 1 TW: 690.53 ft
GAGE HEIGHT at Dam 1: 686.64 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 22.3 x 10^{-6}
CURRENT METER No: W-223906
DATE RATED: 06-25-92
MAP: USGS 7.5-minute quadrangle is St. Paul Park, Minn.
REMARKS:

Resampled sites within ±5 m by using differential GPS. The GPS reference station was at a box culvert which drained a pond on the left bank opposite mile 818.1 (44°47.110 N, 092°55.040 W, NAD27, accuracy ±25 m). Oxygen was measured by using the Yellow Springs Instrument (Model 57). Surface specific conductance and temperature were measured by using a LabComp meter. Measured discharge was 470 m^3/s and the discharge at Dam 2 (provided by the U.S. Army Corps of Engineers) was 575 m^3/s.

CURRENT METER EQUATION: V(m/s)=0.668*rev/s + 0.006
BEARING OF TRANSECT: 035° magnetic

Site	NAD27		Depth (m)	Surface		Dissolved oxygen (mg/L)	Velocity (m/s)	Direction (°magnetic)	Surficial bed sediment
	Latitude N	Longitude W		Conductance (µS/cm)	Temperature (°C)				
LEW			0.0						
04	44°46.325	092°52.549	6.5	674	23.0	8.0	0.20	110	--
05	~46.300	~52.600	7.3	657	23.1	8.0	0.37	130	--
06	46.281	52.646	4.6	661	23.2	8.5	0.32	090	--
07	46.239	52.714	0.9	652	21.7	7.5	0.15	120	--
0211	46.241	52.759	0.5	656	21.7	7.5	0.13	140	sand
0212	46.185	52.841	1.0	654	23.1	7.5	0.18	110	mud
0213	46.139	52.950	1.1	648	22.9	7.8	0.15	110	mud
0214	46.093	53.040	1.4	645	22.7	8.0	0.13	120	mud
0215	46.044	53.132	1.2	657	21.9	8.0	0.15	090	mud
0216	45.974	53.232	1.6	656	22.2	8.0	0.19	110	mud
0217	44°45.931	093°53.327	1.2	654	22.1	7.7	0.17	090	mud
REW			0.0						

STATION: Mississippi River in Pool 2, Transect 2--UMR mile 818.1
PARTY: Moody, Sullivan, and Writer
GAGE HEIGHT at Dam 1 TW: 690.53 ft
SUSPENSION: 15-pound weight
CURRENT METER No: W-223906
MAP: USGS 7.5-minute quadrangle is St. Paul West, Minn.

DATE: June 12, 1994
GAGE HEIGHT at Dam 2: 686.64 ft
RIVER SLOPE: 22.3×10^{-6}
DATE RATED: 06-25-92

REMARKS:

Resampled sites within ±5 m by using differential GPS. The GPS reference station was at a box culvert which drained a pond on the left bank opposite mile 818.1 (44°47.110 N, 092°55.040 W, NAD27, accuracy ±25 m). Oxygen was measured by using the Yellow Springs Instrument (Model 57), and the surface specific conductance and temperature were measured by using a LabComp meter. Measured discharge was 700 m^3/s and the discharge at Dam 2 (provided by the U.S. Army Corps of Engineers) was 575 m^3/s.

CURRENT METER EQUATION: V(m/s)=0.668*rev/s + 0.006
BEARING OF TRANSECT: 000° magnetic

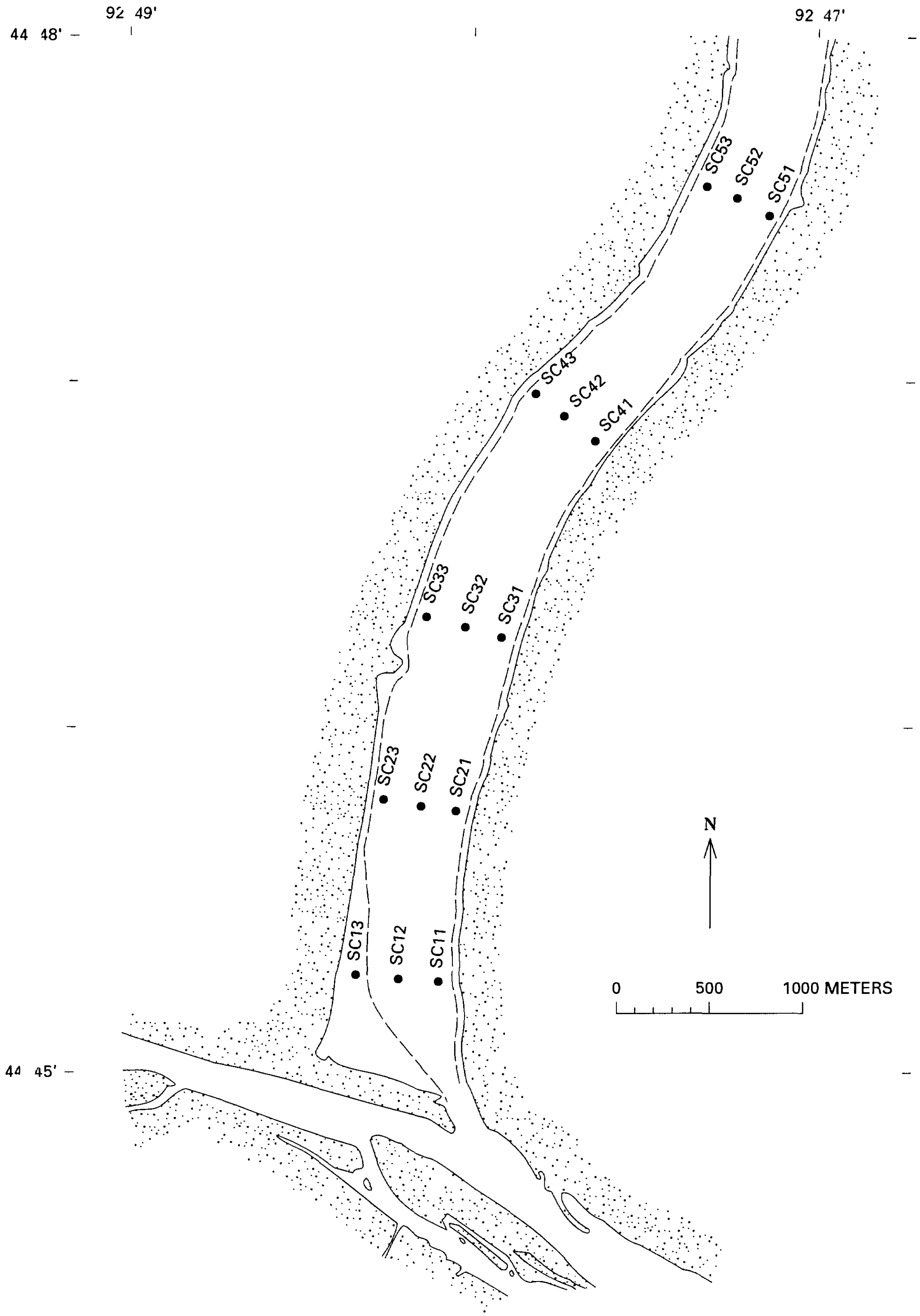
	NAD27			Surface					
Site	Latitude N	Longitude W	Depth (m)	Conductance (µS/cm)	Temperature (°C)	Dissolved oxygen (mg/L)	Velocity (m/s)	Direction (°magnetic)	Surficial bed sediment
LEW			0.0						
0221	44°47.049	092°54.747	3.5	660	21.4	8.0	0.30	080	sand
0222	46.970	54.749	1.1	665	21.5	7.6	0.15	090	mud
0223	46.885	54.756	1.5	659	21.5	7.8	0.21	080	mud
0224	46.821	54.764	1.4	660	21.5	7.7	0.20	080	mud
0225	46.745	54.770	1.1	661	21.5	7.8	0.20	090	mud
0226	46.660	54.780	0.8	661	21.9	7.9	0.14	090	mud
0227	46.589	54.774	1.0	661	21.8	8.0	0.23	090	mud
01	46.521	54.778	3.3	660	22.9	8.0	0.28	100	--
02	46.456	54.772	6.0	662	22.6	7.8	0.29	070	--
03	44°46.413	092°54.773	6.5	644	22.1	7.3	0.36	080	--
REW			0.0						

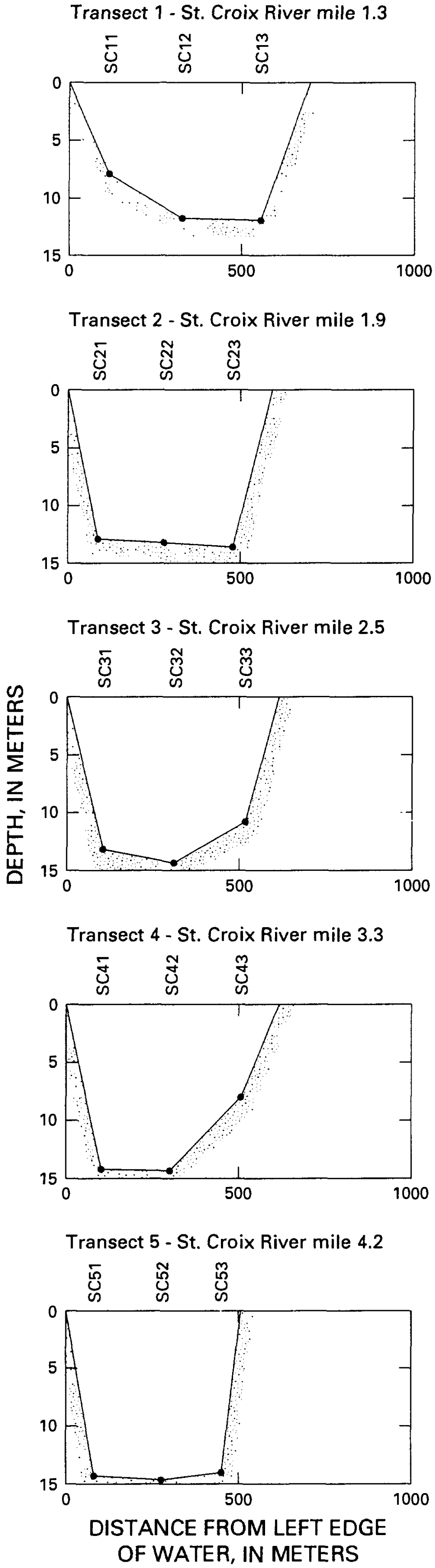
STATION: Mississippi River in Pool 2, Transect 3--UMR mile 821.1
PARTY: Moody, Sullivan, and Writer
DATE: June 12, 1994
GAGE HEIGHT at Dam 1 TW: 690.53 ft
GAGE HEIGHT at Dam 1: 686.64 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 22.3×10^{-6}
CURRENT METER No: W-223906
DATE RATED: 06-25-92
MAP: USGS 7.5-minute quadrangle is St. Paul West, Minn.
REMARKS:

Resampled sites within ±5 m by using differential GPS. The GPS reference station was at a box culvert which drained a pond on the left bank opposite mile 818.1 (44°47.110 N, 092°55.040 W, NAD27, accuracy ±25 m). Oxygen was measured by using the Yellow Springs Instrument (Model 57), and the surface specific conductance and temperature were measured by using a LabComp meter. Biological Resources Division collected a sample from site 0232.

CURRENT METER EQUATION: V(m/s)=0.668*rev/s + 0.006
BEARING OF TRANSECT: 019° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Depth (m)	Surface Conductance (µS/cm)	Surface Temperature (°C)	Dissolved oxygen (mg/L)	Velocity (m/s)	Direction (°magnetic)	Surficial bed sediment
0231	44°45.804	092°57.699	0.6	660	20.7	7.8	0.07	040	mud
0232	45.662	57.820	1.4	660	20.7	7.6	0.12	090	mud
0233	45.511	57.947	1.4	661	20.8	7.7	0.12	120	mud
0234	45.350	58.096	1.3	662	20.9	7.8	0.10	110	mud
REW			0.0						


92 49'
92 47'
44 48'
44 45'
SC53
SC52
SC51
SC43
SC42
SC41
SC33
SC32
SC31
SC23
SC22
SC21
SC13
SC12
SC11
N
0
500
1000 METERS



Transect 1 - St. Croix River mile 1.3
SC11
SC12
SC13
Transect 2 - St. Croix River mile 1.9
SC21
SC22
SC23
Transect 3 - St. Croix River mile 2.5
SC31
SC32
SC33
Transect 4 - St. Croix River mile 3.3
SC41
SC42
SC43
Transect 5 - St. Croix River mile 4.2
SC51
SC52
SC53
DEPTH, IN METERS
0
5
10
15
0
500
1000
DISTANCE FROM LEFT EDGE OF WATER, IN METERS

STATION: St. Croix River, Transect 1, St. Croix River mile 1.3
PARTY: Moody, Sullivan, and Writer
GAGE HEIGHT: na
SUSPENSION: no velocity measurements
CURRENT METER No: na
MAP: USGS 7.5-minute quadrangle is Prescott, Minn.-Wis.

DATE: June 13, 1994
GAGE HEIGHT: na
RIVER SLOPE: na
DATE RATED: na

REMARKS:

Sampled 15 new sites using differential GPS. The GPS reference station was on the right bank just south of a small inlet near the lettering "BR 697" on the quadrangle (1967) (44°46.985 N, 092°48.015 W, NAD 27, accuracy ±25 m). Oxygen and temperature were measured at three depths by using the Yellow Springs Instrument (Model 57), and the surface specific conductance and temperature were measured by using a LabComp meter. No velocity measurements were made because the speeds were estimated to be less than 0.05 m/s. Samples were collected from the *ACADIANA* and estimated to be within ±20 m of the locations listed below, which were recorded when the van Veen grab hit bottom. Site SC11 had lots of pieces of bark on the bottom and no van Veen grab was collected but a core sample was collected.

BEARING OF TRANSECT: 093° magnetic

Site	NAD27		Depth (m)	Surface		Depth of sensor (m)	Dissolved oxygen (mg/L)	Temperature (°C)
	Latitude N	Longitude W		Conductance (µS/cm)	Temperature (°C)			
LEW			0.0					
SC11	44°45.278	092°48.328	8.0	189	22.7	0.1	10.1	22.0
						4.0	9.7	21.3
						7.5	9.1	21.0
SC12	45.285	48.508	11.7	187	23.4	0.1	9.9	21.9
						6.0	9.4	21.2
						11.0	2.0	14.3
SC13	44°45.313	092°48.698	12.0	190	25.2	0.1	10.1	24.6
						6.0	9.1	21.2
						11.5	1.0	14.0
REW			0.0					

STATION: St. Croix River, Transect 2, St. Croix River mile 1.9
PARTY: Moody, Sullivan, and Writer — DATE: June 13, 1994
GAGE HEIGHT: na — GAGE HEIGHT: na
SUSPENSION: no velocity measurements — RIVER SLOPE: na
CURRENT METER No: na — DATE RATED: na
MAP: USGS 7.5-minute quadrangle is Prescott, Minn.-Wis.
REMARKS:

Sampled 15 new sites using differential GPS. The GPS reference station was on the right bank just south of a small inlet near the lettering "BR 697" on the quadrangle (1967) (44°46.985 N, 092°48.015 W, NAD 27, accuracy ±25 m). Oxygen and temperature were measured at three depths by using the Yellow Springs Instrument (Model 57), and the surface specific conductance and temperature were measured by using a LabComp meter. No velocity measurements were made because the speeds were estimated to be less than 0.05 m/s. Samples were collected from the *ACADIANA* and estimated to be within ±20 m of the locations listed below, which were recorded when the van Veen grab hit bottom.

BEARING OF TRANSECT: 100° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Depth (m)	Surface Conductance (µS/cm)	Surface Temperature (°C)	Depth of sensor (m)	Dissolved oxygen (mg/L)	Temperature (°C)
LEW			0.0					
SC21	44°45.752	092°48.272	12.9	190	24.5	0.1	10.1	22.7
						6.5	9.2	21.0
						12.0	1.5	14.0
SC22	45.770	48.401	13.2	192	23.2	0.1	10.4	22.6
						6.5	9.2	21.0
						12.0	2.1	13.4
SC23	44°45.805	092°48.552	13.4	190	23.0	0.1	10.1	22.5
						6.5	9.3	21.1
						12.0	1.2	13.2
REW			0.0					

STATION: St. Croix River, Transect 3, St. Croix River mile 2.5
PARTY: Moody, Sullivan, and Writer
GAGE HEIGHT: na
SUSPENSION: no velocity measurements
CURRENT METER No: na
MAP: USGS 7.5-minute quadrangle is Prescott, Minn.-Wis.

DATE: June 13, 1994
GAGE HEIGHT: na
RIVER SLOPE: na
DATE RATED: na

REMARKS:
Sampled 15 new sites using differential GPS. The GPS reference station was on the right bank just south of a small inlet near the lettering "BR 697" on the quadrangle (1967) (44°46.985 N, 092°48.015 W, NAD 27, accuracy ±25 m). Oxygen and temperature were measured at three depths by using the Yellow Springs Instrument (Model 57), and the surface specific conductance and temperature were measured by using a LabComp meter. No velocity measurements were made because the speeds were estimated to be less than 0.05 m/s. Samples were collected from the *ACADIANA* and estimated to be within ±20 m of the locations listed below, which were recorded when the van Veen grab hit bottom.

BEARING OF TRANSECT: 101° magnetic

Site	NAD27		Depth (m)	Surface		Depth of sensor (m)	Dissolved oxygen (mg/L)	Temperature (°C)
	Latitude N	Longitude W		Conductance (µS/cm)	Temperature (°C)			
LEW			0.0					
SC31	44°46.267	092°48.083	13.3	193	24.1	0.1	10.1	23.3
						7.0	9.0	21.0
						12.0	2.6	14.5
SC32	46.288	48.245	14.4	191	23.3	0.1	10.2	22.6
						7.0	8.7	20.8
						12.0	3.1	14.8
SC33	44°46.325	092°48.370	10.7	191	23.7	0.1	10.1	23.4
						7.0	8.3	21.0
REW			0.0					

STATION: St. Croix River, Transect 4, St. Croix River mile 3.3
PARTY: Moody, Sullivan, and Writer
DATE: June 13, 1994
GAGE HEIGHT: na
GAGE HEIGHT: na
SUSPENSION: no velocity measurements
RIVER SLOPE: na
CURRENT METER No: na
DATE RATED: na
MAP: USGS 7.5-minute quadrangle is Prescott, Minn.-Wis.
REMARKS:

Sampled 15 new sites using differential GPS. The GPS reference station was on the right bank just south of a small inlet near the lettering "BR 697" on the quadrangle (1967) (44°46.985 N, 092°48.015 W, NAD 27, accuracy ±25 m). Oxygen and temperature were measured at three depths by using the Yellow Springs Instrument (Model 57), and the surface specific conductance and temperature were measured by using a LabComp meter. No velocity measurements were made because the speeds were estimated to be less than 0.05 m/s. Samples were collected from the *ACADIANA* and estimated to be within ±20 m of the locations listed below, which were recorded when the van Veen grab hit bottom. Biological Resources Division collected a sample from site SC42.

BEARING OF TRANSECT: 123° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Depth (m)	Surface Conductance (µS/cm)	Surface Temperature (°C)	Depth of sensor (m)	Dissolved oxygen (mg/L)	Temperature (°C)
LEW			0.0					
SC41	44°46.841	092°47.694	13.9	192	22.2	0.1	10.0	21.6
						7.0	8.5	20.7
						12.0	4.0	16.4
SC42	46.880	47.816	14.2	194	22.2	0.1	9.6	22.3
						7.0	8.0	20.4
						12.0	3.1	14.2
SC43	44°46.980	092°47.941	7.8	193	23.0	0.1	9.8	23.2
						4.0	9.3	21.2
						7.5	8.5	20.5
REW			0.0					

STATION: St. Croix River, Transect 5, St. Croix River mile 4.2
PARTY: Moody, Sullivan, and Writer
GAGE HEIGHT: na
SUSPENSION: no velocity measurements
CURRENT METER No: na
MAP: USGS 7.5-minute quadrangle is Prescott, Minn.-Wis.

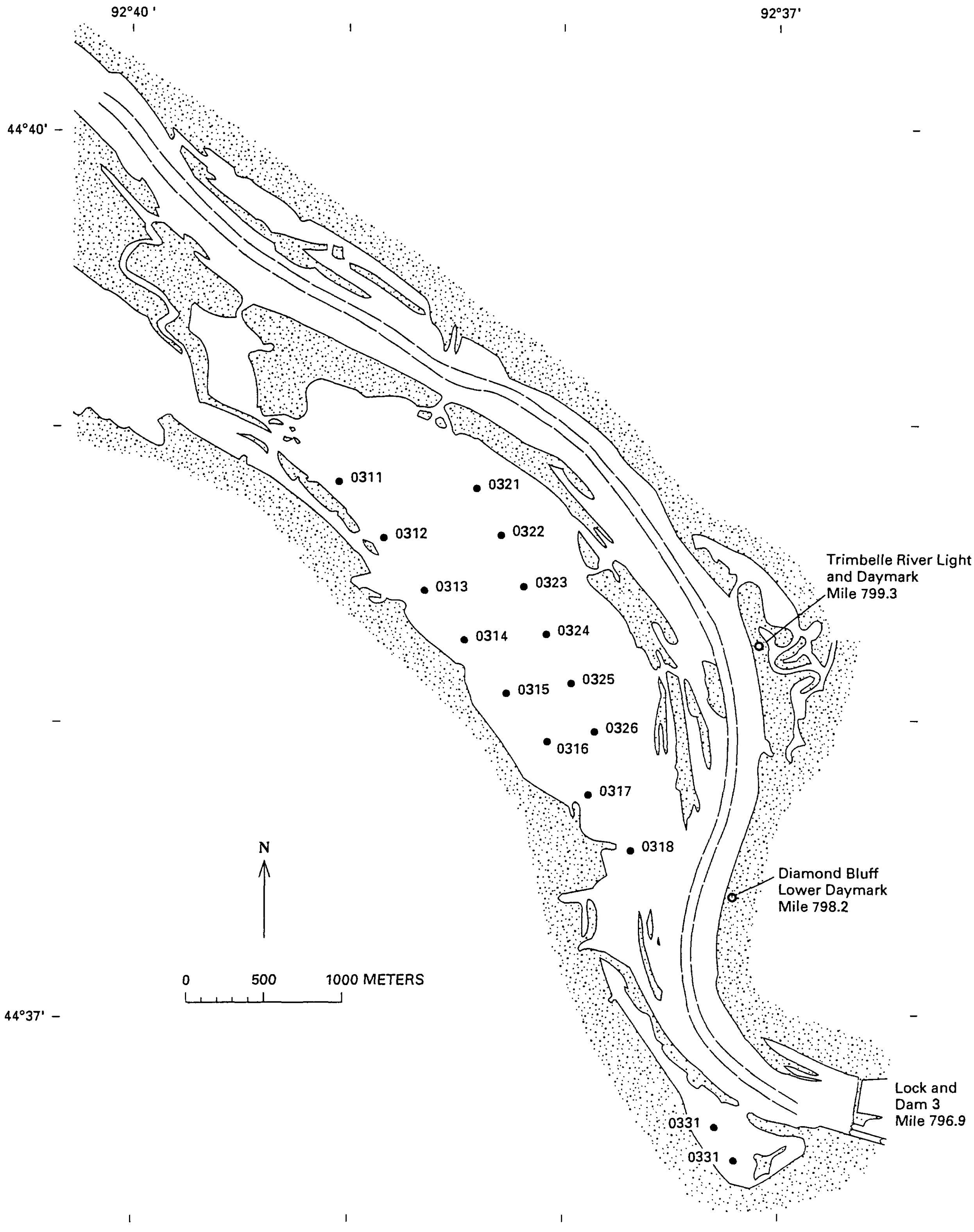
DATE: June 13, 1994
GAGE HEIGHT: na
RIVER SLOPE: na
DATE RATED: na

REMARKS:

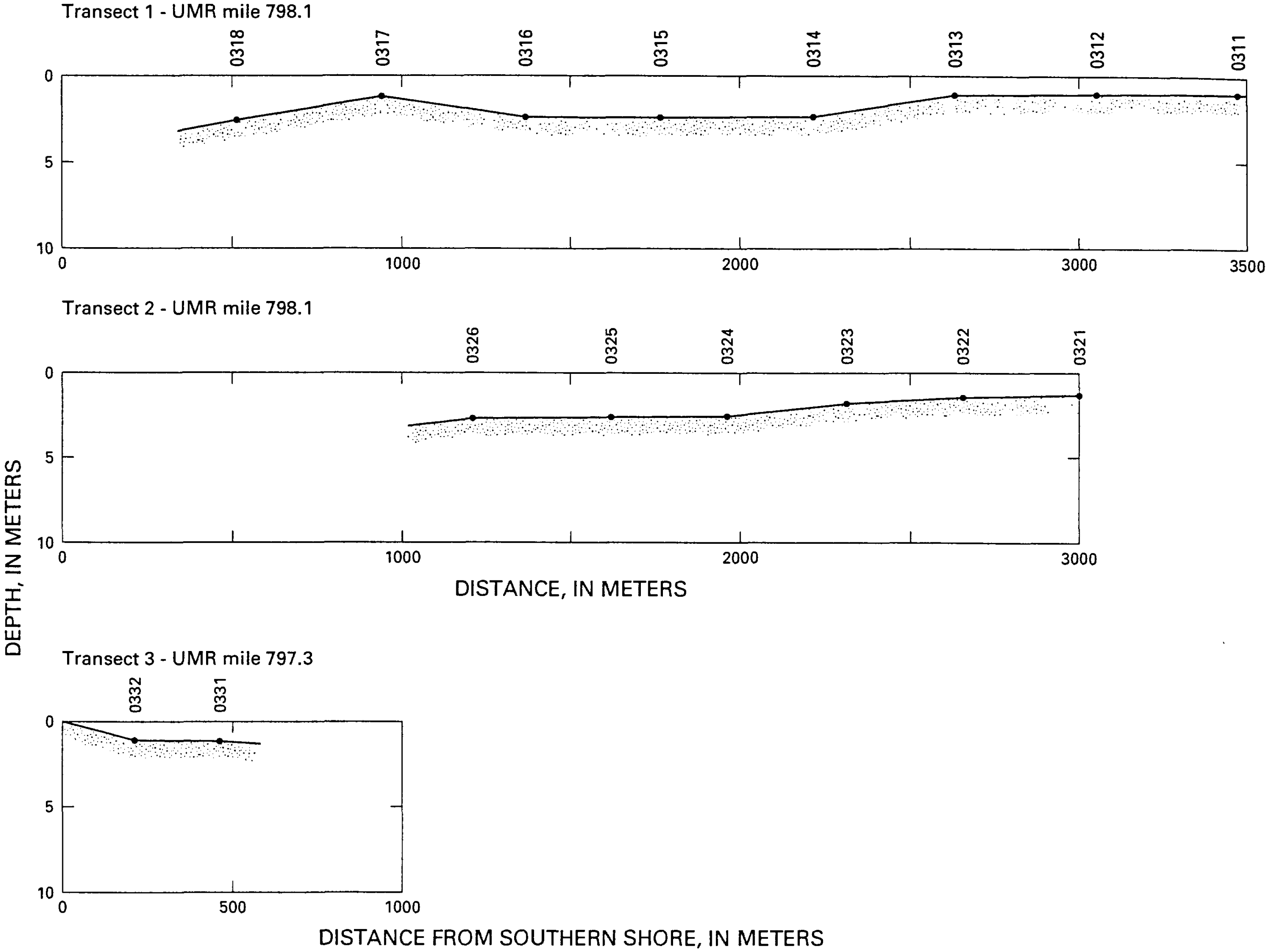
Sampled 15 new sites using differential GPS. The GPS reference station was on the right bank just south of a small inlet near the lettering "BR 697" on the quadrangle (1967) (44°46.985 N, 092°48.015 W, NAD 27, accuracy ±25 m). Oxygen and temperature were measured at three depths by using the Yellow Springs Instrument (Model 57), and the surface specific conductance and temperature were measured by using a LabComp meter. No velocity measurements were made because the speeds were estimated to be less than 0.05 m/s. Samples were collected from the *ACADIANA* and estimated to be within ±20 m of the locations listed below, which were recorded when the van Veen grab hit bottom.

BEARING OF TRANSECT: 106° magnetic

	NAD27			Surface				
Site	Latitude N	Longitude W	Depth (m)	Conductance (µS/cm)	Temperature (°C)	Depth of sensor (m)	Dissolved oxygen (mg/L)	Temperature (°C)
LEW			0.0					
SC51	44°47.486	092°46.998	14.3	195	22.3	0.1	9.5	21.8
						7.0	7.8	20.2
						12.0	4.6	16.5
SC52	47.532	47.131	14.8	192	22.1	0.1	10.0	21.5
						7.0	7.8	20.2
						12.0	3.7	15.8
SC53	44°47.557	092°47.255	14.0	193	22.6	0.1	10.1	22.8
						7.0	8.4	20.6
						12.0	3.0	14.9
REW			0.0					



92°40'
92°37'
44°40'
44°37'
0311
0312
0313
0314
0315
0316
0317
0318
0321
0322
0323
0324
0325
0326
0331
0331
Trimbelle River Light and Daymark Mile 799.3
Diamond Bluff Lower Daymark Mile 798.2
Lock and Dam 3 Mile 796.9
N
0 500 1000 METERS



Transect 1 - UMR mile 798.1
0318
0317
0316
0315
0314
0313
0312
0311
Transect 2 - UMR mile 798.1
0326
0325
0324
0323
0322
0321
Transect 3 - UMR mile 797.3
0332
0331
DEPTH, IN METERS
DISTANCE, IN METERS
DISTANCE FROM SOUTHERN SHORE, IN METERS
0
5
10
500
1000
2000
3000
3500

STATION: Mississippi River in Pool 3, Transect 1--UMR mile 798.1
PARTY: Moody, Sullivan, and Writer
DATE: June 14, 1994
GAGE HEIGHT at Dam 1 TW: 677.30 ft
GAGE HEIGHT at Dam 3: 673.98 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 34.6 x 10^{-6}
CURRENT METER No: W-223906
DATE RATED: 06-25-92
MAP: USGS 7.5-minute quadrangle is Diamond Bluff West, Wis.-Minn.
REMARKS:

Resampled sites within ±5 m by using differential GPS. The error is estimated to be about ±5 m because of the choppy water conditions. The GPS reference station was located on a small dock at the end of a peninsula extending westward from the longest guidewall for Lock 3 at UMR mile 797.3 (44°36.690 N, 092°37.080 W, NAD27, accuracy ±25 m). Oxygen was measured by using the Yellow Springs Instrument (Model 57), and the surface specific conductance and temperature were measured by using a LabComp meter. Location of site 0318 was not recorded at the time the measurements were made so that the target location was used which is within ±5 m. Discharge at Dam 3 (provided by the U.S. Army Corps of Engineers) was about 650 m^3/s.

CURRENT METER EQUATION: V(m/s)=0.668*rev/s + 0.006
BEARING OF TRANSECT: 140° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Depth (m)	Surface Conductance (µS/cm)	Surface Temperature (°C)	Dissolved oxygen (mg/L)	Velocity (m/s)	Direction (°magnetic)	Surficial bed sediment
REW			0.0						
0311	44°38.774	092°39.052	0.8	633	23.3	7.7	0.29	120	sand
0312	38.602	38.856	0.6	641	23.4	7.4	0.18	090	mud
0313	38.425	38.652	0.8	630	23.7	7.6	0.35	120	sand
0314	38.270	38.475	2.0	- - - - - - - - - - - no measurements at new marina. - - - - - - - - -					--
0315	38.079	38.254	2.2	623	23.9	7.5	0.24	170	mud
0316	37.913	38.065	2.3	630	24.0	7.5	0.21	170	mud
0317	37.736	37.862	1.0	620	24.0	7.4	0.37	120	sand
0318	44°37.560	092°37.665	2.4	602	25.1	7.3	0.23	180	--

STATION: Mississippi River in Pool 3, Transect 2--UMR mile 798.1
PARTY: Moody, Sullivan, and Writer
DATE: June 14, 1994
GAGE HEIGHT at Dam 1 TW: 677.30 ft
GAGE HEIGHT at Dam 3: 673.98 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 34.6 x 10^{-6}
CURRENT METER No: W-223906
DATE RATED: 06-25-92
MAP: USGS 7.5-minute quadrangle is Diamond Bluff West, Wis.-Minn.
REMARKS:

Resampled sites using differential GPS. The error is estimated to be about ±5 m because of the choppy water conditions. The GPS reference station was located on a small dock at the end of a peninsula extending westward from the longest guidewall for Lock 3 at UMR mile 797.3 (44°36.690 N, 092°37.080 W, NAD27, accuracy ±25 m). Oxygen was measured by using the Yellow Springs Instrument (Model 57), and the surface specific conductance and temperature were measured by using a LabComp meter. Steep waves were encountered at site 0323. Discharge at Dam 3 (provided by the U.S. Army Corps of Engineers) was about 650 m^3/s. Biological Resources Division collected a sample from site 0324.

CURRENT METER EQUATION: V(m/s)=0.668*rev/s + 0.006
BEARING OF TRANSECT: 153° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Depth (m)	Surface Conductance (μS/cm)	Surface Temperature (°C)	Dissolved oxygen (mg/L)	Velocity (m/s)	Direction (°magnetic)	Surficial bed sediment
REW			0.0						
0321	44°38.783	092°38.413	1.1	630	23.3	7.0	0.15	120	mud
0322	38.613	38.287	1.3	633	23.1	7.4	0.34	090	mud
0323	38.474	38.171	1.7	650	22.6	7.6	0.31	--	mud
0324	38.319	38.042	2.4	646	22.4	7.4	0.25	170	mud
0325	38.108	37.944	2.2	650	22.2	7.3	0.16	160	mud
0326	44°37.974	092°37.824	2.4	644	22.1	7.2	0.18	150	mud

STATION: Mississippi River in Pool 3, Transect 3--UMR mile 797.3

PARTY: Moody, Sullivan, and Writer

DATE: June 14, 1994

GAGE HEIGHT at Dam 1 TW: 677.30 ft

GAGE HEIGHT at Dam 3: 673.98 ft

SUSPENSION: 15-pound weight

RIVER SLOPE: 34.6×10^{-6}

CURRENT METER No: W-223906

DATE RATED: 06-25-92

MAP: USGS 7.5-minute quadrangle is Diamond Bluff West, Wis.-Minn.

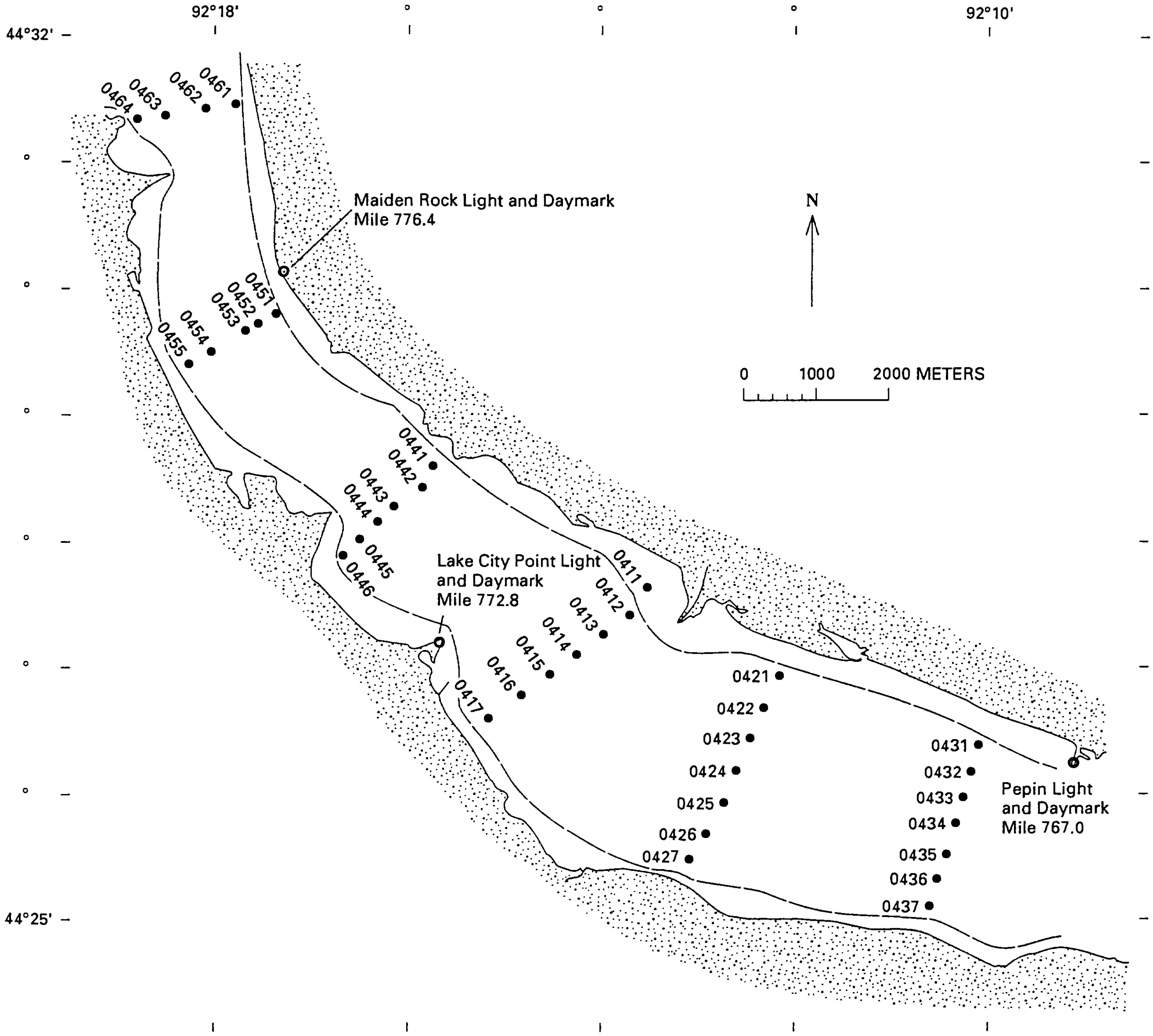
REMARKS:

Resampled sites using differential GPS. The error is estimated to be about ±3 m. The GPS reference station was located on a small dock at the end of a peninsula extending westward from the longest guidewall for Lock 3 at UMR mile 797.3 (44°36.690 N, 092°37.080 W, NAD27, accuracy ±25 m). Oxygen was measured by using the Yellow Springs Instrument (Model 57), and the surface specific conductance and temperature were measured by using a LabComp meter. Discharge at Dam 3 (provided by the U.S. Army Corps of Engineers) was about 650 m^3/s.

CURRENT METER EQUATION: V(m/s)=0.668*rev/s + 0.006

BEARING OF TRANSECT: 148° magnetic

	NAD27			Surface					
Site	Latitude N	Longitude W	Depth (m)	Conductance (µS/cm)	Temperature (°C)	Dissolved oxygen (mg/L)	Velocity (m/s)	Direction (°magnetic)	Surficial bed sediment
0331	44°36.631	092°37.235	1.0	623	25.7	7.4	0.06	320	mud
0332	44°36.525	092°37.158	1.0	625	25.8	7.4	0.09	270	mud
REW			0.0						


92°18'
92°10'
44°32'
44°25'
Maiden Rock Light and Daymark
Mile 776.4
N
0 1000 2000 METERS
Lake City Point Light
and Daymark
Mile 772.8
Pepin Light
and Daymark
Mile 767.0
0461
0462
0463
0464
0451
0452
0453
0454
0455
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0442
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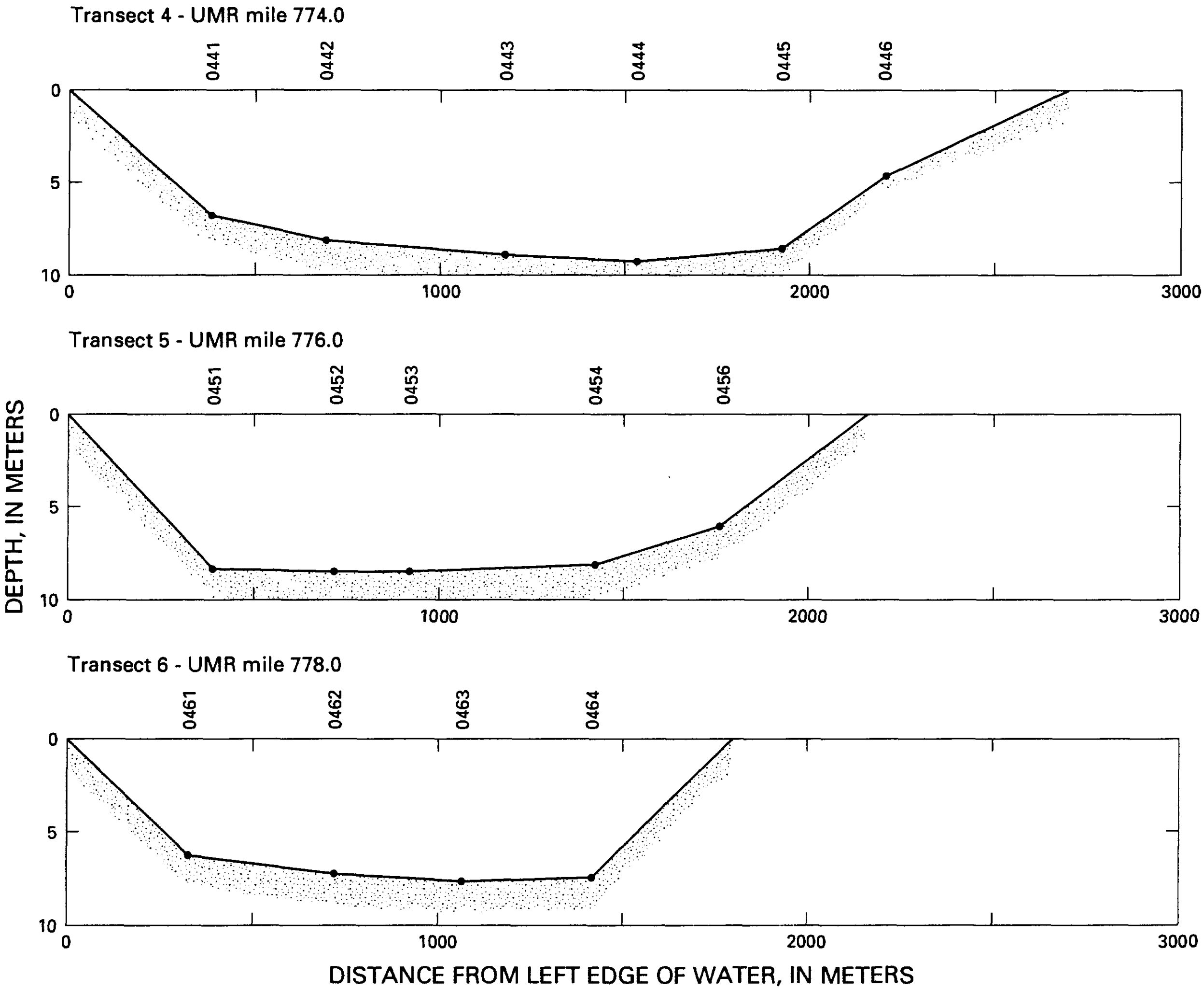
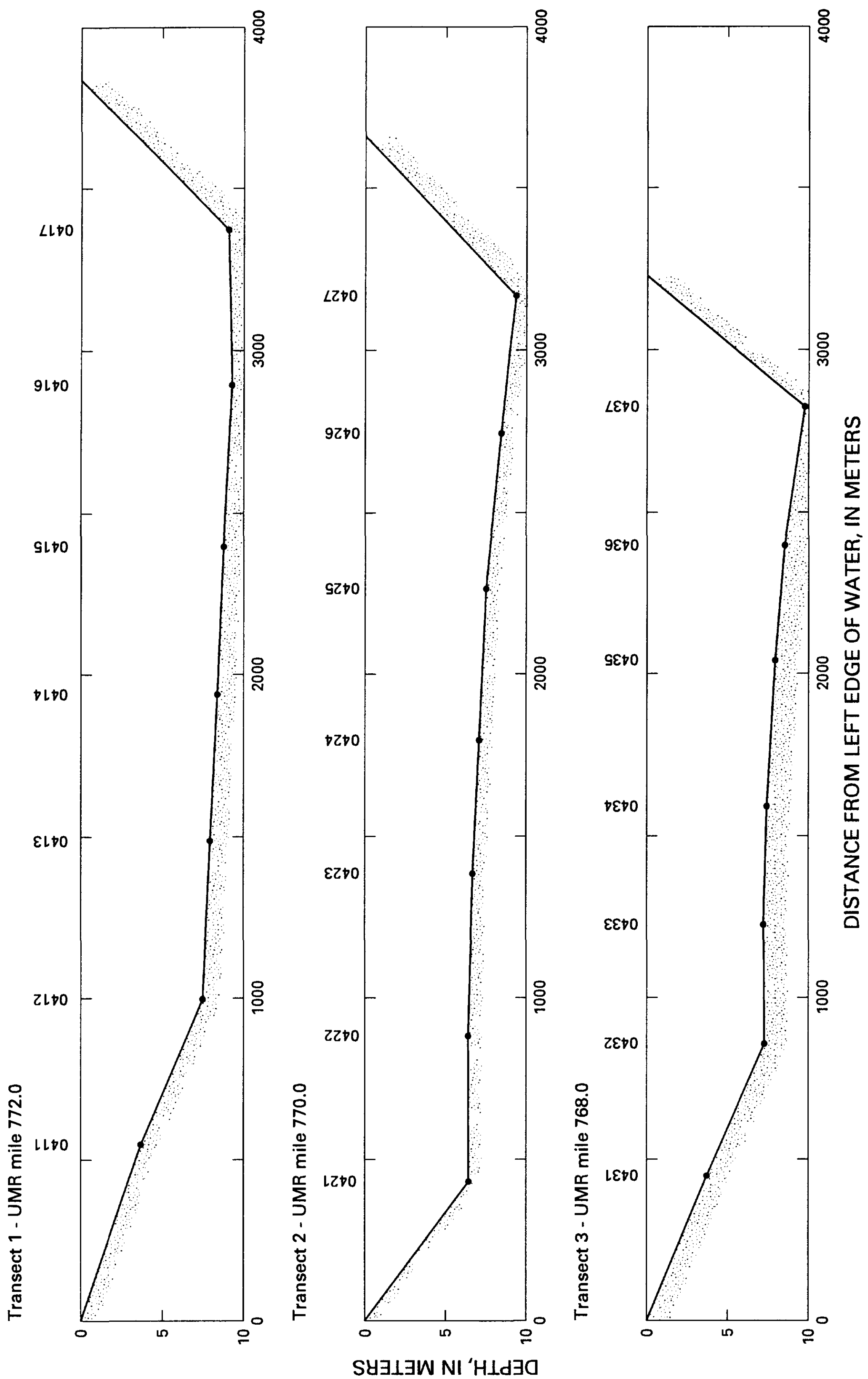
0437


Transect 4 - UMR mile 774.0
0441
0442
0443
0444
0445
0446
Transect 5 - UMR mile 776.0
0451
0452
0453
0454
0456
Transect 6 - UMR mile 778.0
0461
0462
0463
0464
0
5
10
0
1000
2000
3000
DEPTH, IN METERS
DISTANCE FROM LEFT EDGE OF WATER, IN METERS



Transect 1 - UMR mile 772.0
Transect 2 - UMR mile 770.0
Transect 3 - UMR mile 768.0
0411
0412
0413
0414
0415
0416
0417
0421
0422
0423
0424
0425
0426
0427
0431
0432
0433
0434
0435
0436
0437
0
5
10
0
1000
2000
3000
4000
DEPTH, IN METERS
DISTANCE FROM LEFT EDGE OF WATER, IN METERS

STATION: Mississippi River in Pool 4, Transect 6--UMR mile 778.0
PARTY: Moody, Sullivan, and Writer — DATE: June 15, 1994
GAGE HEIGHT at Dam 3 TW: 670.4 ft — GAGE HEIGHT at Dam 4: 666.87 ft
SUSPENSION: no velocity measurements — RIVER SLOPE: 15.2 x 10^{-6}
CURRENT METER No: na — DATE RATED: na
MAP: USGS 7.5-minute quadrangle is Maiden Rock, Wis.-Minn.
REMARKS:

Resampled four sites using autonomous GPS because of the necessity of drifting over the target site when sampling from *ACADIANA*, because of the homogenous bed sediments, and trying to collect both upper and lower Lake Pepin sites in one day. Resampled sites were within ±60 m. Locations listed below were recorded when the van Veen grab hit bottom. The core sample was collected immediately after the grab. Oxygen and temperature were measured at two depths by using the Yellow Springs Instrument (Model 57), and the surface specific conductance and temperature were measured by using a LabComp meter. No velocity measurements were made because the speeds were estimated to be less than 0.05 m/s. Discharge was 1,050 m^3/s at Dam 4 (provided by the U.S. Army Corps of Engineers). The blue-green alga, *Aphanizomenon flos-aquae*, was beginning a bloom according to John Sullivan.

BEARING OF TRANSECT: 084° magnetic

	NAD27			Surface				
Site	**Latitude N**	**Longitude W**	**Depth (m)**	**Conductance (µS/cm)**	**Temperature (°C)**	**Depth of sensor (m)**	**Dissolved oxygen (mg/L)**	**Temperature (°C)**
LEW			0.0					
0461	44°31.23	092°17.82	6.7	582	24.7	0.1	7.4	24.4
						6.0	6.2	23.8
0462	31.21	18.15	7.4	586	24.9	0.1	7.3	24.8
						6.0	6.1	23.6
0463	31.24	18.39	7.8	588	25.1	0.1	7.0	24.7
						7.0	3.5	23.4
0464	44°31.19	092°18.67	7.8	588	24.9	0.1	6.3	24.2
						7.0	5.5	23.6
REW			0.0					

STATION: Mississippi River in Pool 4, Transect 5--UMR mile 776.0
PARTY: Moody, Sullivan, and Writer — DATE: June 15, 1994
GAGE HEIGHT at Dam 3 TW: 670.4 ft — GAGE HEIGHT at Dam 4: 666.87 ft
SUSPENSION: no velocity measurements — RIVER SLOPE: 15.2 x 10^{-6}
CURRENT METER No: na — DATE RATED: na
MAP: USGS 7.5-minute quadrangle is Lake City, Minn.-Wis.
REMARKS:

Resampled five sites using autonomous GPS because of the necessity of drifting over the target site when sampling from *ACADIANA*, because of the homogenous bed sediments, and trying to collect both upper and lower Lake Pepin sites in one day. Resampled sites were within ±70 m. Locations listed below were recorded when the van Veen grab hit bottom. The core sample was collected immediately after the grab. Oxygen and temperature were measured at two depths by using the Yellow Springs Instrument (Model 57), and the surface specific conductance and temperature were measured by using a LabComp meter. No velocity measurements were made because the speeds were estimated to be less than 0.05 m/s. Discharge was 1,050 m^3/s at Dam 4 (provided by the U.S. Army Corps of Engineers). The blue-green alga, *Aphanizomenon flos-aquae*, was beginning a bloom according to John Sullivan.

BEARING OF TRANSECT: 056° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Depth (m)	Surface Conductance (µS/cm)	Surface Temperature (°C)	Depth of sensor (m)	Dissolved oxygen (mg/L)	Temperature (°C)
LEW			0.0					
0451	44°29.74	092°17.41	8.4	576	24.8	0.1	7.2	24.2
						7.0	4.7	23.1
0452	29.62	17.60	8.4	577	24.6	0.1	6.9	24.1
						7.5	5.7	23.1
0453	29.56	17.73	8.6	576	24.7	0.1	6.9	24.2
						7.0	5.8	23.5
0454	29.43	18.08	8.3	578	24.6	0.1	6.8	24.0
						7.5	6.0	23.2
0455	44°29.36	092°18.30	6.3	579	24.3	0.1	6.8	23.8
						5.5	6.3	23.3
REW			0.0					

STATION: Mississippi River in Pool 4, Transect 4--UMR mile 774.0
PARTY: Moody, Sullivan, and Writer
GAGE HEIGHT at Dam 3 TW: 670.4 ft
SUSPENSION: no velocity measurements
CURRENT METER No: na
MAP: USGS 7.5-minute quadrangle is Lake City, Minn.-Wis.

DATE: June 15, 1994
GAGE HEIGHT at Dam 4: 666.87 ft
RIVER SLOPE: 15.2×10^{-6}
DATE RATED: na

REMARKS:

Resampled six sites using autonomous GPS because of the necessity of drifting over the target site when sampling from *ACADIANA*, because of the homogenous bed sediments, and trying to collect both upper and lower Lake Pepin sites in one day. Resampled sites were within ±80 m. Locations listed below were recorded when the van Veen grab hit bottom. The core sample was collected immediately after the grab. No grab sample was obtained at site 0446 because of sand and shells. Oxygen and temperature were measured at two depths by using the Yellow Springs Instrument (Model 57), and the surface specific conductance and temperature were measured by using a LabComp meter. No velocity measurements were made because the speeds were estimated to be less than 0.05 m/s. Discharge was 1,050 m^3/s at Dam 4 (provided by the U.S. Army Corps of Engineers). The blue-green alga, *Aphanizomenon flos-aquae*, was beginning a bloom according to John Sullivan.

BEARING OF TRANSECT: 041° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Depth (m)	Surface Conductance (µS/cm)	Surface Temperature (°C)	Depth of sensor (m)	Dissolved oxygen (mg/L)	Temperature (°C)
LEW			0.0					
0441	44°28.56	092°15.75	6.6	570	24.5	0.1	7.0	24.3
						5.0	6.9	24.2
0442	28.42	15.83	8.1	573	24.3	0.1	6.7	24.0
						7.5	5.6	23.0
0443	28.25	16.15	9.1	579	23.9	0.1	6.3	23.7
						8.0	5.0	22.9
0444	28.11	16.33	9.5	580	23.8	0.1	6.1	23.3
						8.5	5.5	23.0
0445	27.95	16.58	8.8	580	23.7	0.1	6.4	23.2
						8.0	5.8	22.8
0446	44°27.88	092°16.74	4.7	578	24.1	0.1	6.3	23.2
						4.0	5.7	22.7
REW			0.0					

STATION: Mississippi River in Pool 4, Transect 1--UMR mile 772.0
PARTY: Moody, Sullivan, and Writer | DATE: June 15, 1994
GAGE HEIGHT at Dam 3 TW: 670.4 ft | GAGE HEIGHT at Dam 4: 666.87 ft
SUSPENSION: no velocity measurements | RIVER SLOPE: 15.2×10^{-6}
CURRENT METER No: -- | DATE RATED: na
MAP: USGS 7.5-minute quadrangle are Lake City, Minn.-Wis., and Pepin, Wis.-Minn.
REMARKS:

Resampled seven sites using autonomous GPS because of the necessity of drifting over the target site when sampling from *ACADIANA*, because of the homogenous bed sediments, and trying to collect both upper and lower Lake Pepin sites in one day. Resampled sites were within ±150 m. Locations listed below were recorded when the van Veen grab hit bottom. The core sample was collected immediately after the grab. No grab sample was obtained at site 0446 because of sand and shells. Oxygen and temperature were measured at two depths by using the Yellow Springs Instrument (Model 57), and the surface specific conductance and temperature were measured by using a LabComp meter. No velocity measurements were made because the speeds were estimated to be less than 0.05 m/s. Discharge was 1,050 m^3/s at Dam 4 (provided by the U.S. Army Corps of Engineers). The blue-green alga, *Aphanizomenon flos-aquae*, was beginning a bloom according to John Sullivan.

BEARING OF TRANSECT: 047° magnetic

	NAD27			Surface				
Site	Latitude N	Longitude W	Depth (m)	Conductance (µS/cm)	Temperature (°C)	Depth of sensor (m)	Dissolved oxygen (mg/L)	Temperature (°C)
LEW			0.0					
0411	44°27.59	092°13.38	3.7	554	24.9	0.1	8.9	23.9
						3.0	7.6	23.7
0412	27.41	13.58	7.4	568	24.5	0.1	6.8	23.7
						7.0	6.7	23.3
0413	27.24	13.98	8.0	570	24.3	0.1	6.5	23.1
						7.0	6.0	23.1
0414	27.11	14.24	8.3	577	24.0	0.1	7.2	23.8
						7.0	6.2	22.8
0415	26.94	14.42	8.8	579	24.1	0.1	7.1	23.8
						8.0	5.6	22.7
0416	26.79	14.78	9.3	580	24.1	0.1	7.2	23.7
						9.0	5.8	22.7
0417	44°26.63	092°15.11	9.0	581	24.1	0.1	6.9	23.5
						8.5	6.1	22.8
REW			0.0					

STATION: Mississippi River in Pool 4, Transect 2--UMR mile 770.0

PARTY: Moody, Sullivan, and Writer

DATE: June 15, 1994

GAGE HEIGHT at Dam 3 TW: 670.4 ft

GAGE HEIGHT at Dam 4: 666.87 ft

SUSPENSION: no velocity measurements

RIVER SLOPE: 15.2×10^{-6}

CURRENT METER No: na

DATE RATED: na

MAP: USGS 7.5-minute quadrangle is Pepin, Wis.-Minn.

REMARKS:

Resampled seven sites using autonomous GPS because of the necessity of drifting over the target site when sampling from *ACADIANA*, because of the homogenous bed sediments, and trying to collect both upper and lower Lake Pepin sites in one day. Resampled sites were within ±110 m. Locations listed below were recorded when the van Veen grab hit bottom. The core sample was collected immediately after the grab. Oxygen and temperature were measured at two depths by using the Yellow Springs Instrument (Model 57), and the surface specific conductance and temperature were measured by using a LabComp meter. No velocity measurements were made because the speeds were estimated to be less than 0.05 m/s. Discharge was 1,050 m^3/s at Dam 4 (provided by the U.S. Army Corps of Engineers). The blue-green alga, *Aphanizomenon flos-aquae*, was beginning a bloom according to John Sullivan.

BEARING OF TRANSECT: 021° magnetic

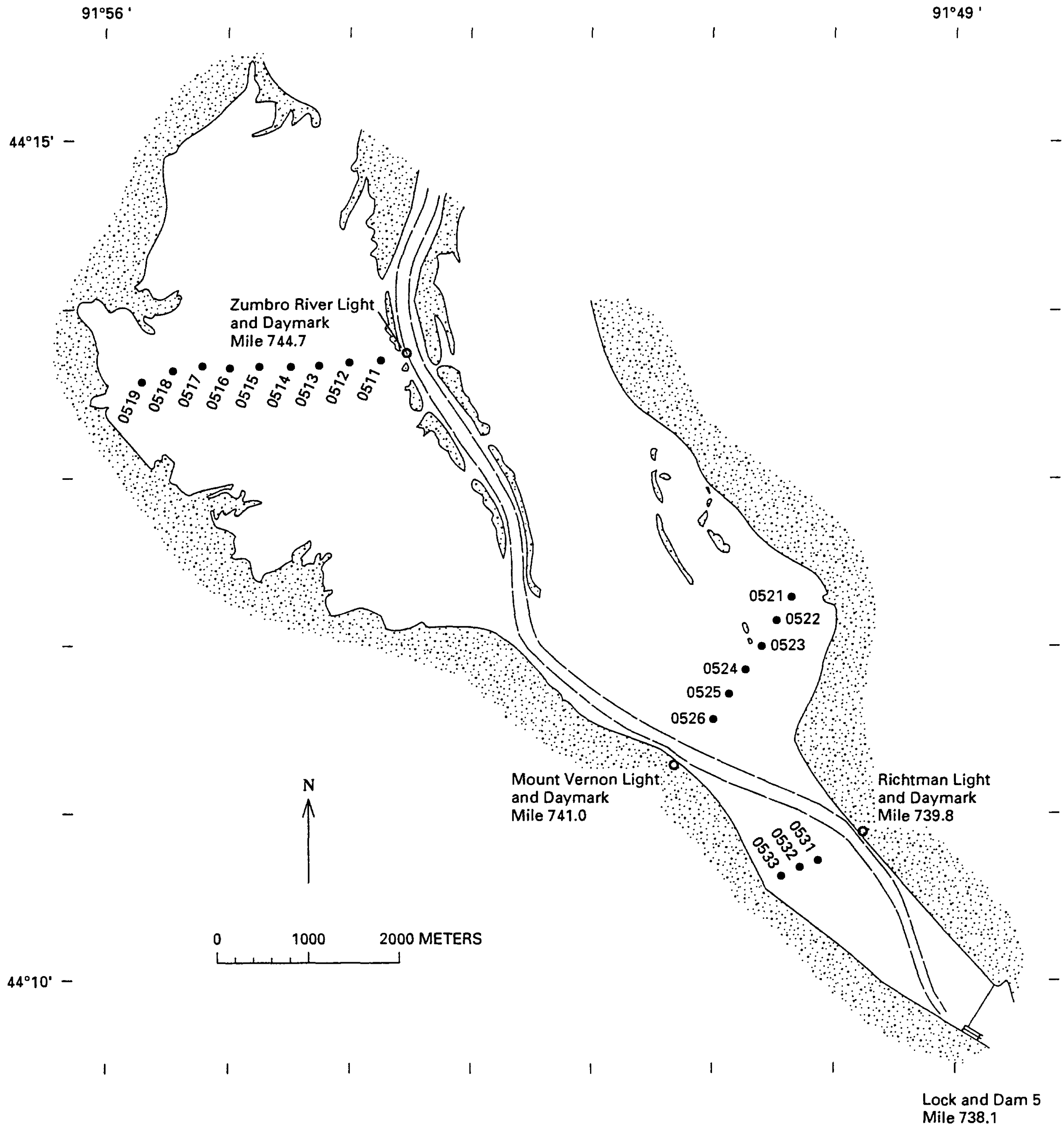
Site	NAD27 Latitude N	NAD27 Longitude W	Depth (m)	Surface Conductance (µS/cm)	Surface Temperature (°C)	Depth of sensor (m)	Dissolved oxygen (mg/L)	Temperature (°C)
LEW			0.0					
0421	44°26.89	092°12.03	6.6	552	24.1	0.1	7.7	24.0
						5.0	6.7	23.0
0422	26.68	12.18	7.6	564	23.7	0.1	7.3	23.2
						7.0	6.2	22.8
0423	26.47	12.32	7.7	569	23.5	0.1	6.9	23.1
						7.0	6.2	22.7
0424	26.22	12.46	8.2	572	23.5	0.1	6.6	23.1
						7.5	6.4	--
0425	25.95	12.59	8.4	579	23.7	0.1	6.6	23.1
						7.0	6.2	22.8
0426	25.78	12.73	8.9	578	23.9	0.1	6.5	23.3
						8.0	5.6	22.7
0427	44°25.52	092°12.95	9.6	577	24.2	0.1	6.7	23.2
						8.0	5.8	22.7
REW			0.0					

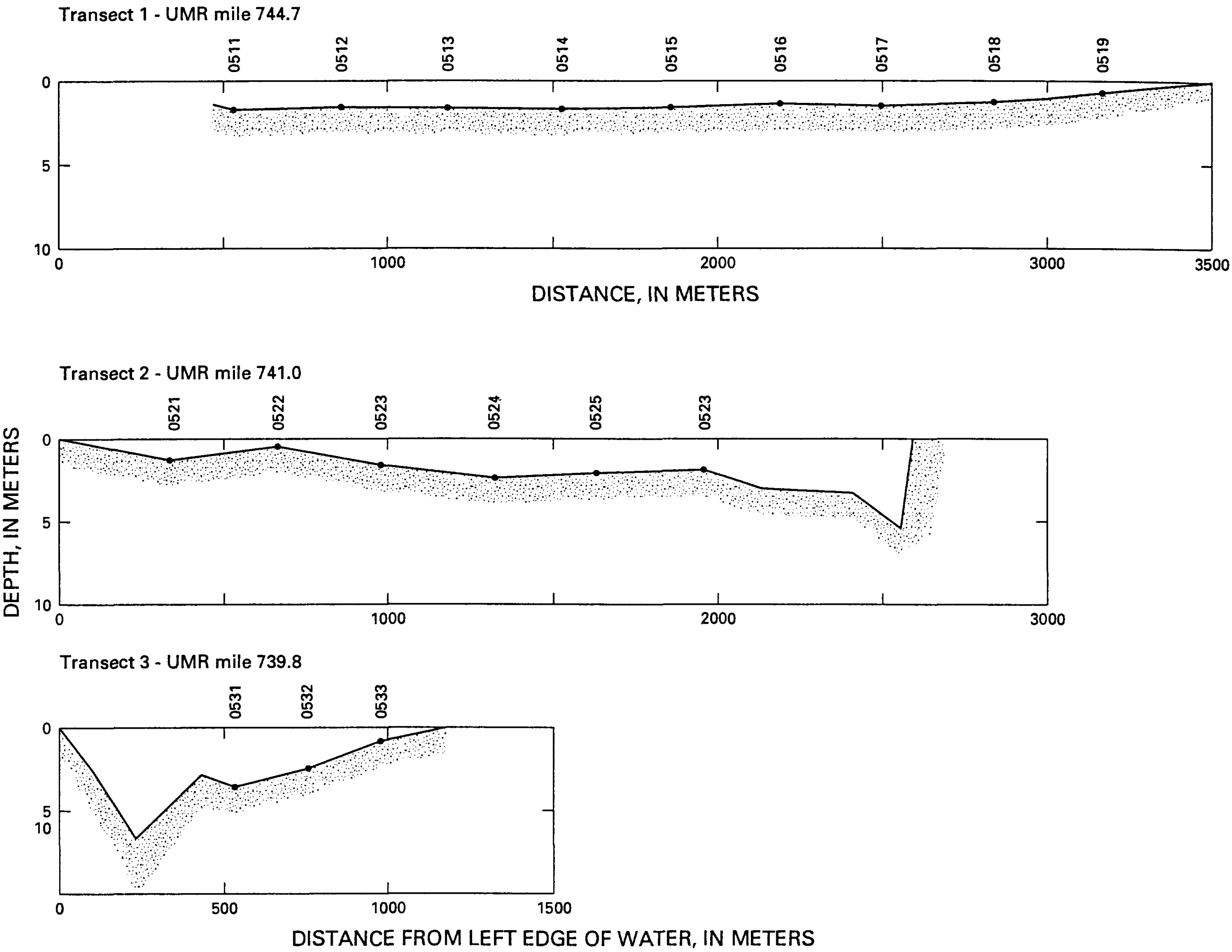
STATION: Mississippi River in Pool 4, Transect 3--UMR mile 768.0
PARTY: Moody, Sullivan, and Writer
DATE: June 15, 1994
GAGE HEIGHT at Dam 3 TW: 670.4 ft
GAGE HEIGHT at Dam 4: 666.87 ft
SUSPENSION: no velocity measurements
RIVER SLOPE: 15.2×10^{-6}
CURRENT METER No: na
DATE RATED: na
MAP: USGS 7.5-minute quadrangle is Pepin, Wis.-Minn.
REMARKS:

Resampled 7 sites using autonomous GPS because of the necessity of drifting over the target site when sampling from *ACADIANA*, because of the homogenous bed sediments, and trying to collect both upper and lower Lake Pepin sites in one day. Resampled sites were within ±80 m. Locations listed below were recorded when the van Veen grab hit bottom. The core sample was collected immediately after the grab. Oxygen and temperature were measured at two depths by using the Yellow Springs Instrument (Model 57), and the surface specific conductance and temperature were measured by using a LabComp meter. No velocity measurements were made because the speeds were estimated to be less than 0.05 m/s. Discharge was 1,050 m^3/s at Dam 4 (provided by the U.S. Army Corps of Engineers). The blue-green alga, *Aphanizomenon flos-aquae*, was beginning a bloom according to John Sullivan. Biological Resources Division collected a sample from site 0437.

BEARING OF TRANSECT: 013° magnetic

	NAD27			Surface				
Site	Latitude N	Longitude W	Depth (m)	Conductance (µS/cm)	Temperature (°C)	Depth of sensor (m)	Dissolved oxygen (mg/L)	Temperature (°C)
LEW			0.0					
0431	44°26.39	092°09.99	5.0	565	23.1	0.1	6.3	22.8
						2.0	6.3	22.8
0432	26.21	10.06	7.6	580	23.1	0.1	6.0	22.8
						6.0	5.9	22.7
0433	25.98	10.13	7.7	583	23.1	0.1	5.7	22.8
						7.0	5.6	22.7
0434	25.80	10.23	7.7	580	23.2	0.1	5.8	22.8
						7.0	5.5	22.8
0435	25.54	10.28	8.2	580	23.4	0.1	5.8	22.9
						7.0	5.5	22.7
0436	25.35	10.39	8.9	583	23.4	0.1	5.8	22.9
						4.0	5.5	22.8
						8.0	5.1	22.6
0437	44°25.12	092°10.52	9.9	581	23.7	--	--	--
REW			0.0					


91°56'
91°49'
44°15'
44°10'
Zumbro River Light
and Daymark
Mile 744.7
0511
0512
0513
0514
0515
0516
0517
0518
0519
0521
0522
0523
0524
0525
0526
0531
0532
0533
Mount Vernon Light
and Daymark
Mile 741.0
Richtman Light
and Daymark
Mile 739.8
N
0
1000
2000 METERS
Lock and Dam 5
Mile 738.1


Transect 1 - UMR mile 744.7
0511
0512
0513
0514
0515
0516
0517
0518
0519
0
5
10
0
1000
2000
3000
3500
DISTANCE, IN METERS
Transect 2 - UMR mile 741.0
0521
0522
0523
0524
0525
0523
DEPTH, IN METERS
0
5
10
0
1000
2000
3000
Transect 3 - UMR mile 739.8
0531
0532
0533
0
5
10
0
500
1000
1500
DISTANCE FROM LEFT EDGE OF WATER, IN METERS

STATION: Mississippi River in Pool 5, Transect 1--UMR mile 744.7
PARTY: Moody, Sullivan, and Writer
DATE: June 16, 1994
GAGE HEIGHT at Dam 4 TW: 661.51 ft
GAGE HEIGHT at Dam 5: 659.80 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 34.6×10^{-6}
CURRENT METER No: W-223906
DATE RATED: 06-25-92
MAP: USGS 7.5-minute quadrangle is Weaver, Minn.-Wis.
REMARKS:

Resampled sites using differential GPS. The error is estimated to be about ±5 m. The GPS reference station was located at the 120° corner of the levee (UMR mile 740.6) opposite the lookout tower on the Cochrane, Wis.-Minn. quadrangle (44°11.380 N, 091°50.180 W, NAD27, accuracy ±25 m). Biological Resources Division collected a sample at site 0515. Oxygen was measured by using the Yellow Springs Instrument (Model 57), and the surface specific conductance and temperature were measured by using a LabComp meter. Discharge at Dam 5 (provided by the U.S. Army Corps of Engineers) was about 1,060 m^3/s.

CURRENT METER EQUATION: V(m/s)=0.668*rev/s + 0.006
BEARING OF TRANSECT: 082° magnetic

	NAD27			Surface					
Site	**Latitude N**	**Longitude W**	**Depth (m)**	**Conductance (µS/cm)**	**Temperature (°C)**	**Dissolved oxygen (mg/L)**	**Velocity (m/s)**	**Direction (°magnetic)**	**Surficial bed sediment**
0511	44°13.662	091°53.799	0.9	497	24.2	8.0	0.07	300	hard mud
0512	13.649	54.046	1.4	497	24.3	8.2	0.06	280	hard mud
0513	13.640	54.293	1.5	498	24.5	8.2	0.07	280	hard mud
0514	13.636	54.530	1.3	495	25.6	8.2	0.08	280	mud
0515	13.641	54.773	1.3	496	25.9	8.4	0.07	330	mud
0516	13.626	55.022	1.0	464	26.6	7.5	0.07	010	mud
0517	13.667	55.254	0.9	477	27.0	8.1	0.09	330	mud
0518	13.621	55.504	0.8	482	27.3	8.9	0.07	310	mud
0519	44°13.571	091°55.790	0.6	473	27.6	12.6	0.06	290	
REW			0.0						

STATION: Mississippi River in Pool 5, Transect 2--UMR mile 741.0
PARTY: Moody, Sullivan, and Writer
GAGE HEIGHT at Dam 4 TW: 661.51 ft
SUSPENSION: 15-pound weight
CURRENT METER No: W-223906
MAP: USGS 7.5-minute quadrangle is Cochrane, Wis.-Minn.

DATE: June 16, 1994
GAGE HEIGHT at Dam 5: 659.80 ft
RIVER SLOPE: 34.6 x 10^{-6}
DATE RATED: 06-25-92

REMARKS:
Resampled sites using differential GPS. The error is estimated to be about ±5 m. The GPS reference station was located at the 120° corner of the levee (UMR mile 740.6) opposite the lookout tower on the Cochrane, Wis.-Minn. quadrangle (44°11.380 N, 091°50.180 W, NAD27, accuracy ±25 m). Oxygen was measured by using the Yellow Springs Instrument (Model 57), and the surface specific conductance and temperature were measured by using a LabComp meter. Measured discharge was 860 m^3/s, and the discharge at Dam 5 (provided by the U.S. Army Corps of Engineers) was 1,060 m^3/s.

CURRENT METER EQUATION: V(m/s)=0.668*rev/s + 0.006
BEARING OF TRANSECT: 032° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Depth (m)	Surface Conductance (µS/cm)	Surface Temperature (°C)	Dissolved oxygen (mg/L)	Velocity (m/s)	Direction (°magnetic)	Surficial bed sediment
LEW			0.0						
0521	44°12.223	091°50.229	1.2	470	26.2	9.0	0.09	310	mud
0522	12.084	50.368	0.8	467	26.7	10.4	0.07	290	sand
0523	11.951	50.433	1.3	467	26.6	10.4	0.09	270	mud, sand
0524	11.798	50.624	2.2	469	26.3	9.4	0.23	140	sand, mud
0525	11.658	50.756	1.9	470	26.7	9.5	0.24	110	sand
0526	11.518	50.885	1.5	466	26.9	9.6	0.25	120	sand
01	11.452	50.910	2.7	469	26.8	9.5	0.28	120	--
02	11.309	50.992	2.9	480	26.2	8.7	0.32	110	--
03	44°11.224	091°51.033	5.5	487	25.8	8.5	0.36	110	--
REW			0.0						

STATION: Mississippi River in Pool 5, Transect 3--UMR mile 739.8

PARTY: Moody, Sullivan, and Writer

DATE: June 16, 1994

GAGE HEIGHT at Dam 4 TW: 661.51 ft

GAGE HEIGHT at Dam 5: 659.80 ft

SUSPENSION: 15-pound weight

RIVER SLOPE: 34.6 x 10^{-6}

CURRENT METER No: W-223906

DATE RATED: 06-25-92

MAP: USGS 7.5-minute quadrangle is Cochrane, Wis.-Minn.

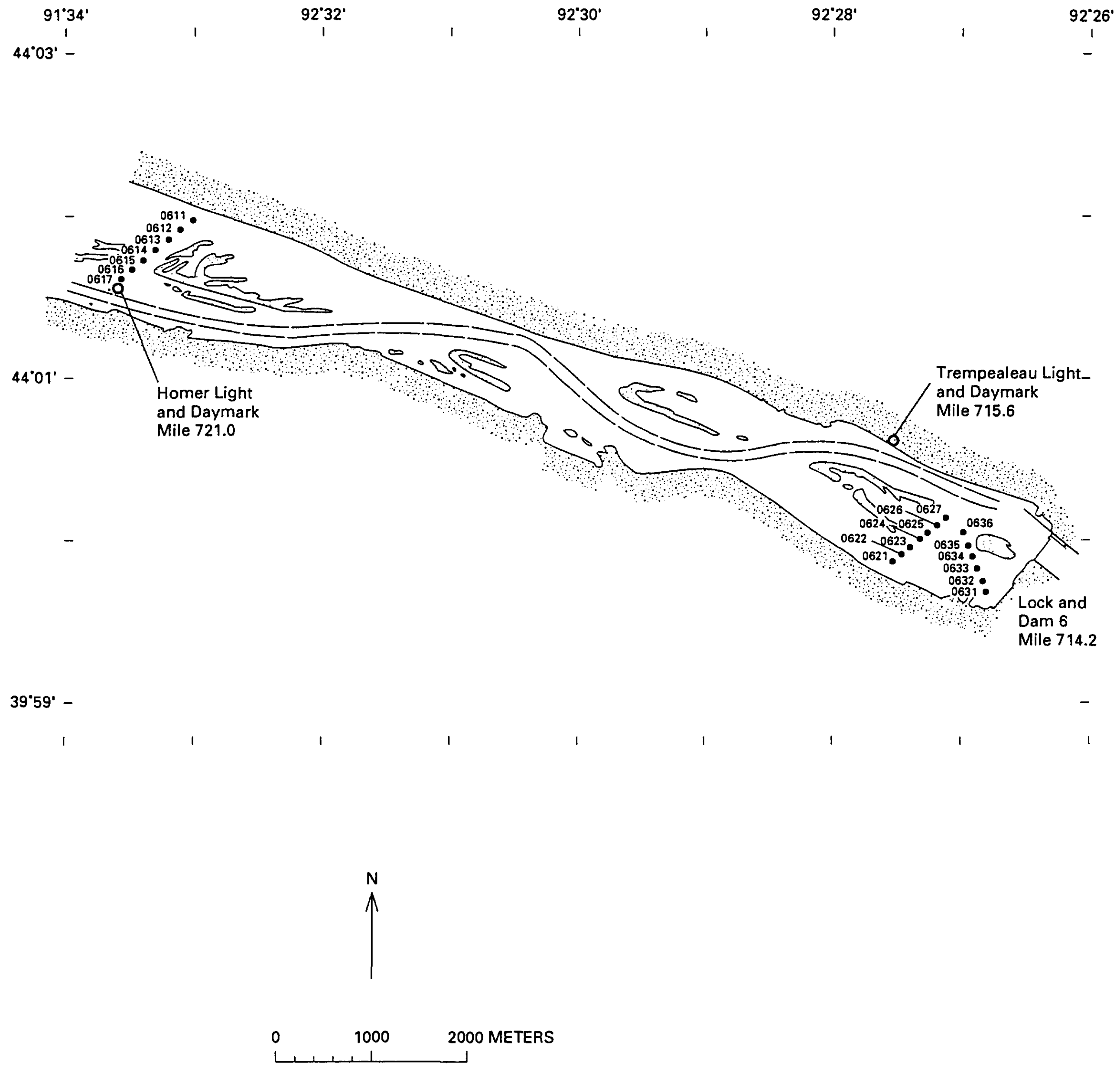
REMARKS:

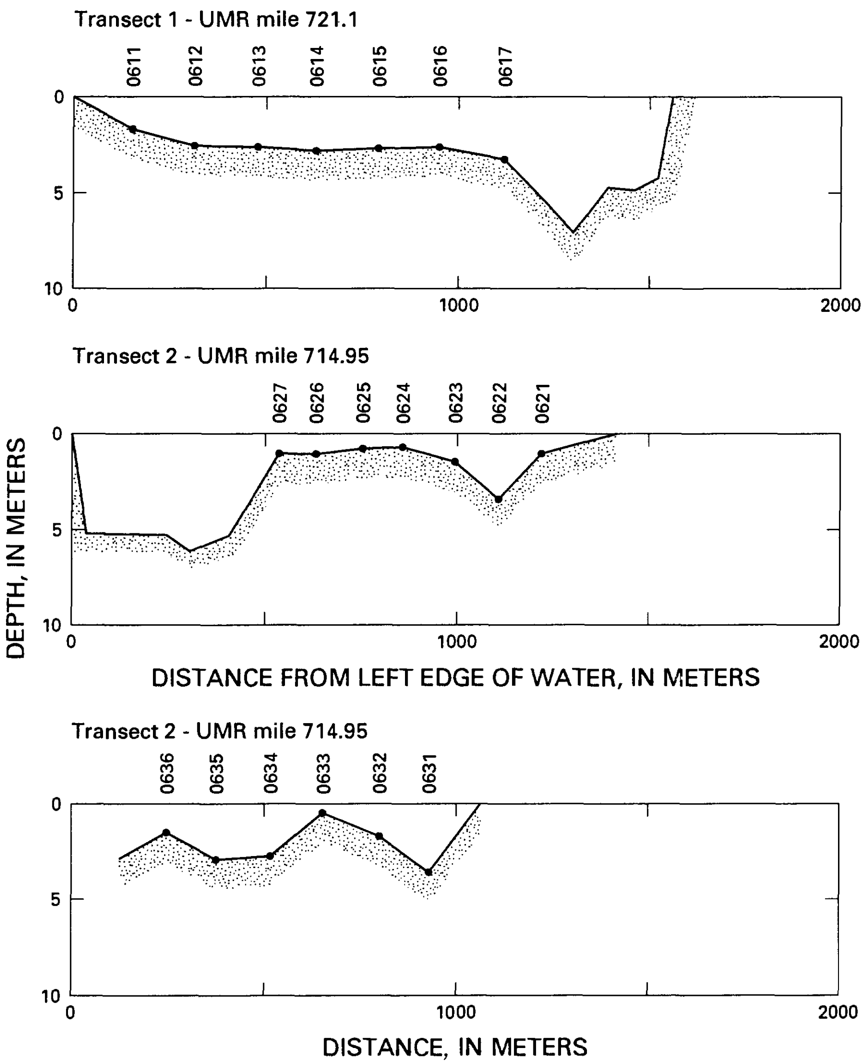
Resampled sites using differential GPS. The error is estimated to be about ±5 m. The GPS reference station was located at the 120° corner of the levee (UMR mile 740.6) opposite the lookout tower on the Cochrane, Wis.-Minn. quadrangle (44°11.380 N, 091°50.180 W, NAD27, accuracy ±25 m). Oxygen was measured by using the Yellow Springs Instrument (Model 57), and the surface specific conductance and temperature were measured by using a LabComp meter. Measured discharge was 920 m^3/s, and the discharge at Dam 5 (provided by the U.S. Army Corps of Engineers) was 1,060 m^3/s.

CURRENT METER EQUATION: V(m/s)=0.668*rev/s + 0.006

BEARING OF TRANSECT: 060° magnetic

	NAD27			Surface					
Site	Latitude N	Longitude W	Depth (m)	Conductance (μS/cm)	Temperature (°C)	Dissolved oxygen (mg/L)	Velocity (m/s)	Direction (°magnetic)	Surficial bed sediment
LEW			0.0						
07	44°10.805	091°49.757	3.3	471	26.6	10.1	0.16	130	--
06	10.771	49.799	6.4	480	25.6	10.0	0.43	120	--
05	10.745	49.839	3.6	476	25.7	9.9	0.40	120	--
04	10.703	49.904	2.8	484	25.5	9.1	0.48	120	--
0531	10.666	49.960	3.5	492	25.1	8.5	0.29	120	sand
0532	10.614	50.125	2.4	494	25.2	8.6	0.25	120	sand
0533	44°10.560	091°50.279	1.0	493	26.4	9.0	0.14	120	sand
REW			0.0						


91°34'
92°32'
92°30'
92°28'
92°26'
44°03'
44°01'
39°59'
0611
0612
0613
0614
0615
0616
0617
Homer Light
and Daymark
Mile 721.0
Trempealeau Light
and Daymark
Mile 715.6
0626
0627
0624
0625
0636
0622
0623
0635
0621
0634
0633
0632
0631
Lock and
Dam 6
Mile 714.2
N
0
1000
2000 METERS


Transect 1 - UMR mile 721.1
0611
0612
0613
0614
0615
0616
0617
Transect 2 - UMR mile 714.95
0627
0626
0625
0624
0623
0622
0621
DEPTH, IN METERS
DISTANCE FROM LEFT EDGE OF WATER, IN METERS
Transect 2 - UMR mile 714.95
0636
0635
0634
0633
0632
0631
0
5
10
0
1000
2000
DISTANCE, IN METERS

STATION: Mississippi River in Pool 6, Transect 1--UMR mile 721.1
PARTY: Moody, Sullivan, and Writer
DATE: June 16, 1994
GAGE HEIGHT at Dam 5A TW: 647.04 ft
GAGE HEIGHT at Dam 6: 644.69 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 29.7 x 10^{-6}
CURRENT METER No: W-223906
DATE RATED: 06-25-92
MAP: USGS 7.5-minute quadrangle is Winona East, Wis.-Minn.
REMARKS:

Resampled sites using differential GPS. The error is estimated to be about ±5 m. The GPS reference station was located 240 m upstream from a railroad bridge over a small creek which enters the Mississippi River west of Homer, Minn., and east of BM 679 on the Winona East quadrangle (44°01.460 N, 091°33.830 W, NAD27, accuracy ±25 m). Oxygen was measured by using the Yellow Springs Instrument (Model 57), and the surface specific conductance and temperature were measured by using a LabComp meter. Measured discharge was 1,280 m^3/s, and the discharge at Dam 6 (provided by the U.S. Army Corps of Engineers) was 1,060 m^3/s.

CURRENT METER EQUATION: V(m/s)=0.668*rev/s + 0.006

BEARING OF TRANSECT: 047° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Depth (m)	Surface Conductance (µS/cm)	Surface Temperature (°C)	Dissolved oxygen (mg/L)	Velocity (m/s)	Direction (°magnetic)	Surficial bed sediment
LEW			0.0						
0611	44°01.956	091°33.017	1.5	483	25.4	8.5	0.27	080	sand
0612	01.879	33.108	4.4	482	25.3	8.5	0.40	070	sand
0613	01.847	33.192	2.2	484	25.3	8.4	0.57	060	sand
0614	01.787	33.298	2.7	483	25.2	8.3	0.53	040	sand
0615	01.737	33.393	2.5	487	25.2	8.3	0.53	040	sand
0616	01.681	33.477	2.5	485	25.2	8.3	0.51	040	sand
0617	01.632	33.568	2.7	486	25.2	8.2	0.36	070	sand
04	01.556	33.679	7.3	488	25.2	--	--	--	--
03	01.529	33.726	4.4	490	25.2	--	--	--	--
02	01.500	33.771	4.5	489	25.2	--	--	--	--
01	44°01.470	091°33.850	4.0	490	25.1	--	--	--	--
REW			0.0	483	24.8				

STATION: Mississippi River in Pool 6, Transect 2--UMR mile 714.95

PARTY: Moody, Sullivan, and Writer

DATE: June 17, 1994

GAGE HEIGHT at Dam 5A TW: 647.04 ft

GAGE HEIGHT at Dam 6: 644.69 ft

SUSPENSION: 15-pound weight

RIVER SLOPE: 29.7×10^{-6}

CURRENT METER No: W-223906

DATE RATED: 06-25-92

MAP: USGS 7.5-minute quadrangle is Trempealeau, Wis.

REMARKS:

Resampled sites using differential GPS. The error is estimated to be about ±5 m. The GPS reference station was located on the dam side wall of the auxiliary lock (43°59.980 N, 091°26.320 W, NAD27, accuracy ±25 m). Oxygen was measured by using the Yellow Springs Instrument (Model 57), and the surface specific conductance and temperature were measured by using a LabComp meter. Discharge at Dam 6 (provided by the U.S. Army Corps of Engineers) was about 1,060 m^3/s.

CURRENT METER EQUATION: V(m/s)=0.668*rev/s + 0.006

BEARING OF TRANSECT: 049° magnetic

	NAD27			Surface					
Site	Latitude N	Longitude W	Depth (m)	Conductance (µS/cm)	Temperature (°C)	Dissolved oxygen (mg/L)	Velocity (m/s)	Direction (°magnetic)	Surficial bed sediment
0621	43°59.868	091°27.494	1.2	473	27.3	10.1	0.32	070	sand
0622	59.902	27.429	1.5	478	27.3	10.2	0.29	090	sand
0623	59.934	27.358	2.6	465	28.5	10.4	0.28	070	sand
0624	59.977	27.284	0.1	461	29.2	11.5	<0.05	--	sand
0625	44°00.010	27.222	1.0	480	28.6	11.7	0.06	270	sand, mud
0626	00.047	27.147	1.1	477	28.3	12.2	0.14	110	sand, mud
0627	44°00.087	091°27.081	0.8	473	27.4	10.9	0.14	110	sand
REW			0.0						

STATION: Mississippi River in Pool 6, Transect 3--UMR mile 714.95

PARTY: Moody, Sullivan, and Writer

DATE: June 17, 1994

GAGE HEIGHT at Dam 5A TW: 647.04 ft

GAGE HEIGHT at Dam 6: 644.69 ft

SUSPENSION: 15-pound weight

RIVER SLOPE: 29.7 x 10^{-6}

CURRENT METER No: W-223906

DATE RATED: 06-25-92

MAP: USGS 7.5-minute quadrangle is Trempealeau, Wis.

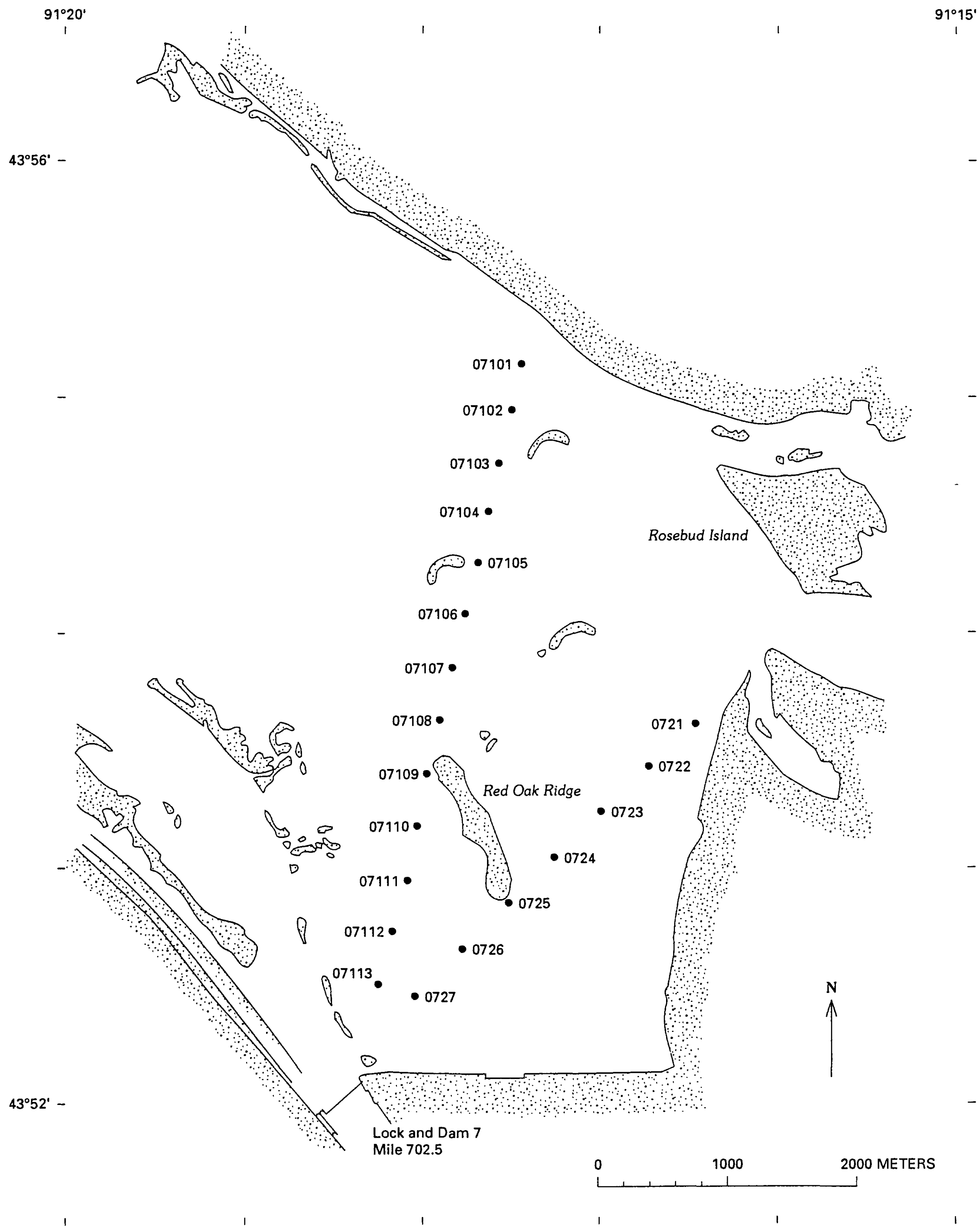
REMARKS:

Resampled sites using differential GPS. The error is estimated to be about ±5 m. The GPS reference station was located on the dam side wall of the auxiliary lock (43°59.980 N, 091°26.320 W, NAD27, accuracy ±25 m). Biological Resources Division collected a sample from site 0632. Oxygen was measured by using the Yellow Springs Instrument (Model 57), and the surface specific conductance and temperature were measured by using a LabComp meter. Discharge at Dam 6 (provided by the U.S. Army Corps of Engineers) was about 1,060 m^3/s.

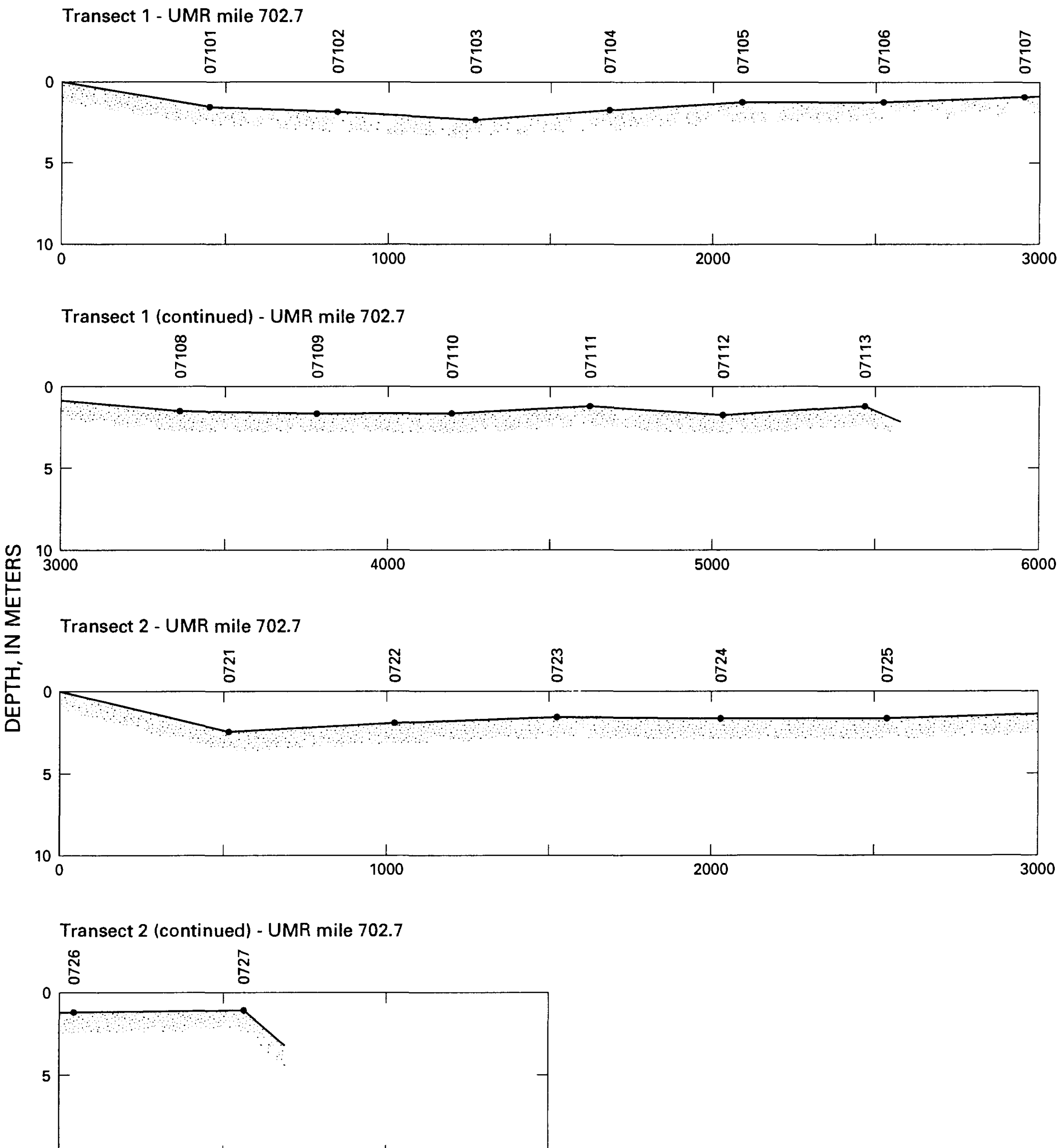
CURRENT METER EQUATION: V(m/s)=0.668*rev/s + 0.006

BEARING OF TRANSECT: 150° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Depth (m)	Surface Conductance (µS/cm)	Surface Temperature (°C)	Dissolved oxygen (mg/L)	Velocity (m/s)	Direction (°magnetic)	Surficial bed sediment
0631	43°59.660	091°26.755	3.1	478	26.8	10.2	0.29	090	sand
0632	59.728	26.803	1.6	483	26.5	10.2	0.10	290	mud, sand
0633	59.796	26.828	0.4	493	27.6	10.8	<0.05	050	sand
0634	59.872	26.873	2.2	476	27.2	10.9	0.07	060	mud
0635	59.935	26.904	2.9	474	27.5	11.6	0.07	090	sand, mud
0636	44°00.001	091°26.947	1.1	471	27.8	11.8	0.14	120	sand
REW			0.0						



91°20'
91°15'
43°56'
43°52'
07101
07102
07103
07104
07105
07106
07107
07108
07109
07110
07111
07112
07113
0721
0722
0723
0724
0725
0726
0727
Rosebud Island
Red Oak Ridge
Lock and Dam 7
Mile 702.5
N
0
1000
2000 METERS



Transect 1 - UMR mile 702.7
07101
07102
07103
07104
07105
07106
07107
Transect 1 (continued) - UMR mile 702.7
07108
07109
07110
07111
07112
07113
Transect 2 - UMR mile 702.7
0721
0722
0723
0724
0725
Transect 2 (continued) - UMR mile 702.7
0726
0727
DEPTH, IN METERS
0
5
10
0
1000
2000
3000
4000
4500
5000
6000
DISTANCE FROM LEFT EDGE OF WATER, IN METERS

STATION: Mississippi River in Pool 7, Transect 1--UMR mile 702.7
PARTY: Moody, Sullivan, and Writer — DATE: June 18, 1994
GAGE HEIGHT at Dam 6 TW: 640.78 ft — GAGE HEIGHT at Dam 7: 639.17 ft
SUSPENSION: 15-pound weight — RIVER SLOPE: 27.7×10^{-6}
CURRENT METER No: W-223906 — DATE RATED: 06-25-92
MAP: USGS 7.5-minute quadrangles are Holmen, Wis., and LaCrescent, Minn.-Wis.
REMARKS:

Resampled sites using differential GPS. The error is estimated to be about ±5 m. The GPS reference station was located on the dam side wall of the auxiliary lock (43°51.995 N, 091°18.550 W, NAD27, accuracy ±25 m). Biological Resources Division collected a sample from site 07103. Oxygen was measured by using the Yellow Springs Instrument (Model 57), and the surface specific conductance and temperature were measured by using a LabComp meter. Discharge at Dam 7 (provided by the U.S. Army Corps of Engineers) was about 1,090 m^3/s.

CURRENT METER EQUATION: V(m/s)=0.668*rev/s + 0.006
BEARING OF TRANSECT: 013° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Depth (m)	Surface Conductance (µS/cm)	Surface Temperature (°C)	Dissolved oxygen (mg/L)	Velocity (m/s)	Direction (°magnetic)	Surficial bed sediment
LEW			0.0						
07101	43°55.054	091°17.449	1.6	300	28.2	12.0	0.06	040	sand, mud
07102	54.908	17.494	1.7	400	27.5	11.2	0.06	070	mud
07103	54.689	17.564	2.0	475	26.5	10.3	0.08	090	mud
07104	54.476	17.621	1.8	477	26.3	9.8	0.09	090	mud, sand
07105	54.266	17.692	1.1	474	25.9	8.9	0.11	100	sand
07106	54.030	17.757	0.9	475	25.8	8.5	<0.05	120	mud
07107	53.810	17.832	0.8	478	25.6	8.6	0.05	100	sand
07108	53.599	17.890	1.2	477	25.7	8.4	0.08	130	mud, sand
07109	53.376	17.958	1.7	476	26.0	8.4	0.14	130	mud
07110	53.150	18.027	1.5	478	25.7	8.2	0.08	140	mud, roots
07111	52.925	18.099	1.2	478	26.2	8.4	0.10	150	sand
07112	52.712	18.168	1.8	477	26.1	8.7	0.11	180	sand, mud
07113	43°52.486	091°18.233	1.2	475	26.4	9.1	0.15	170	sand

STATION: Mississippi River in Pool 7, Transect 2--UMR mile 702.7

PARTY: Moody, Sullivan, and Writer | DATE: June 18, 1994

GAGE HEIGHT at Dam 6 TW: 640.78 ft | GAGE HEIGHT at Dam 7: 639.17 ft

SUSPENSION: 15-pound weight | RIVER SLOPE: 27.7 x 10^{-6}

CURRENT METER No: W-223906 | DATE RATED: 06-25-92

MAP: USGS 7.5-minute quadrangles are Holmen, Wis., and LaCrescent, Minn.-Wis.

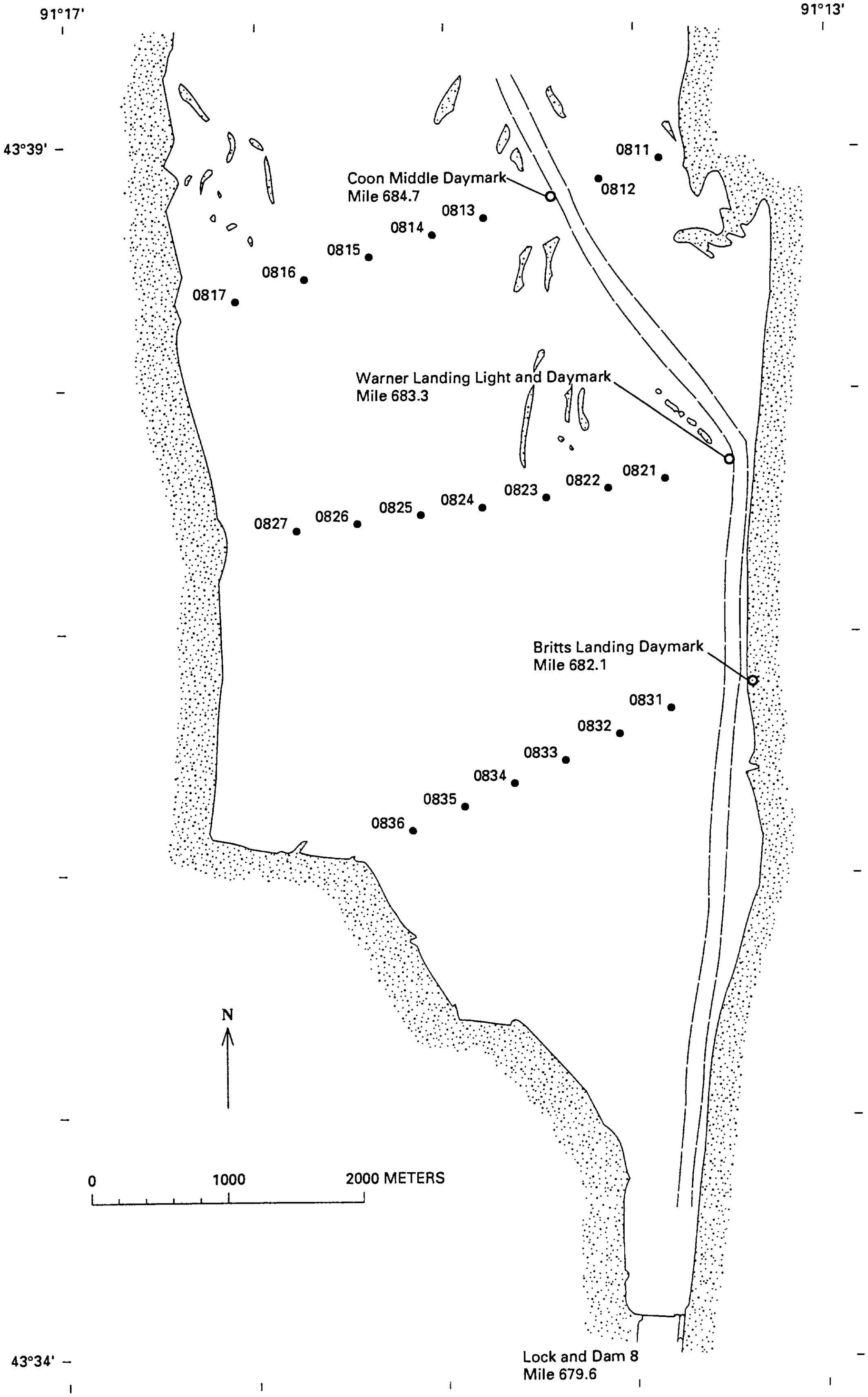
REMARKS:

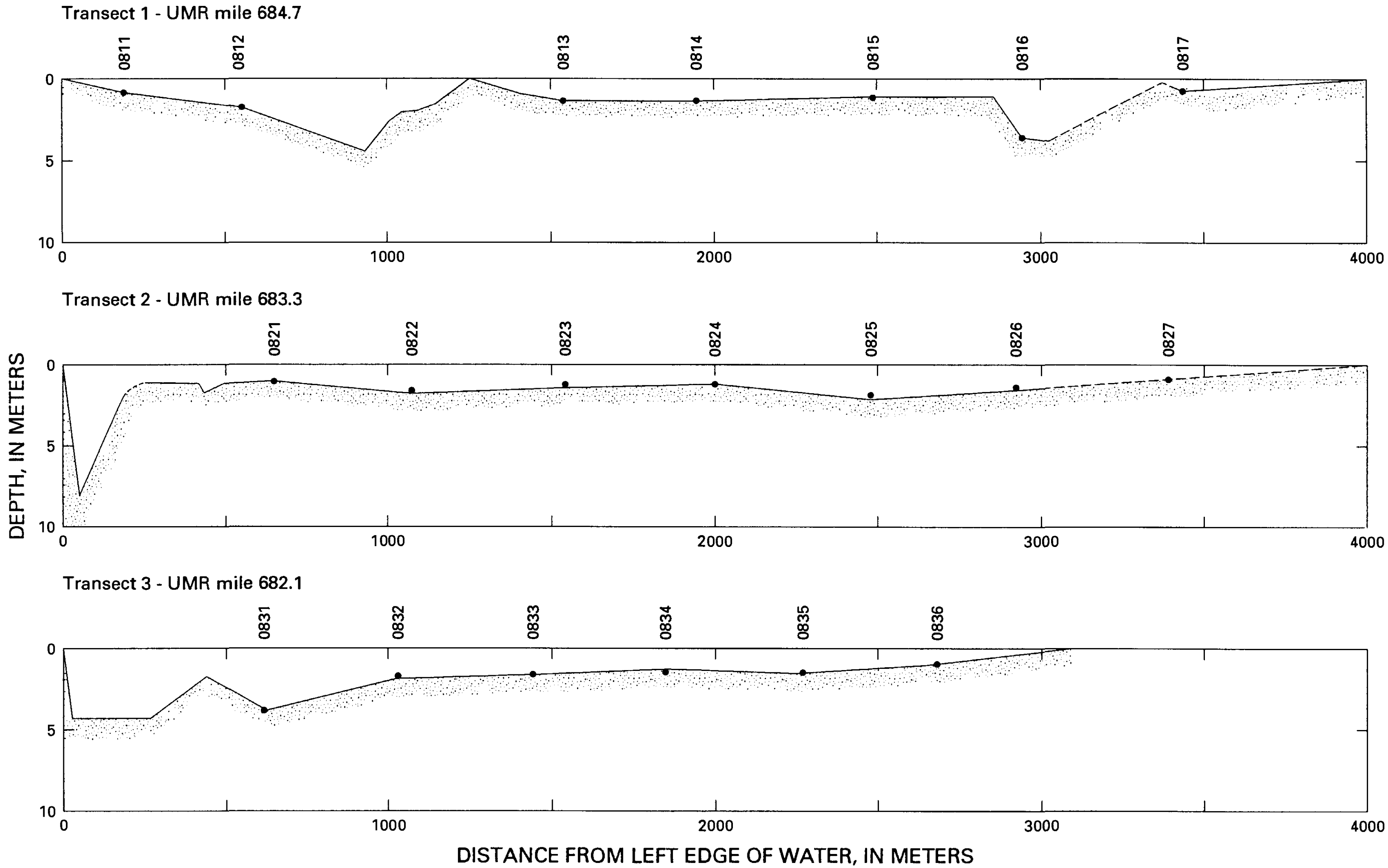
Resampled sites using differential GPS. The error is estimated to be about ±5 m. The GPS reference station was located on the dam side of the wall of the auxiliary lock (43°51.995 N, 091°18.550 W, NAD27, accuracy ±25 m). Oxygen was measured by using the Yellow Springs Instrument (Model 57), and the surface specific conductance and temperature were measured by using a LabComp meter. Discharge at Dam 7 (provided by the U.S. Army Corps of Engineers) was about 1,090 m^3/s.

CURRENT METER EQUATION: V(m/s)=0.668*rev/s + 0.006

BEARING OF TRANSECT: 046° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Depth (m)	Surface Conductance (µS/cm)	Surface Temperature (°C)	Dissolved oxygen (mg/L)	Velocity (m/s)	Direction (°magnetic)	Surficial bed sediment
LEW			0.0						
0721	43°53.609	091°16.420	2.2	441	28.1	11.9	0.07	140	mud
0722	53.423	16.692	1.9	458	28.1	12.6	0.12	150	mud,shells
0723	53.238	16.946	1.7	469	27.9	10.0	0.09	130	mud
0724	53.035	17.224	1.4	470	27.9	10.0	0.12	160	mud
0725	52.849	17.481	1.5	462	28.6	10.0	0.16	180	sand
0726	52.664	17.749	1.6	465	28.6	11.0	0.14	170	--
0727	43°52.466	091°18.024	1.1	464	28.4	10.8	0.14	200	--


91°17'
91°13'
43°39'
43°34'
0811
0812
Coon Middle Daymark
Mile 684.7
0813
0814
0815
0816
0817
Warner Landing Light and Daymark
Mile 683.3
0821
0822
0823
0824
0825
0826
0827
Britts Landing Daymark
Mile 682.1
0831
0832
0833
0834
0835
0836
N
0
1000
2000 METERS
Lock and Dam 8
Mile 679.6



Transect 1 - UMR mile 684.7
0811
0812
0813
0814
0815
0816
0817
Transect 2 - UMR mile 683.3
0821
0822
0823
0824
0825
0826
0827
Transect 3 - UMR mile 682.1
0831
0832
0833
0834
0835
0836
DEPTH, IN METERS
0
5
10
0
1000
2000
3000
4000
DISTANCE FROM LEFT EDGE OF WATER, IN METERS

STATION: Mississippi River in Pool 8, Transect 1--UMR mile 684.7

PARTY: Moody, Sullivan, and Writer — DATE: June 19, 1994

GAGE HEIGHT at Dam 7 TW: 632.86 ft — GAGE HEIGHT at Dam 8: 630.14 ft

SUSPENSION: 15-pound weight — RIVER SLOPE: 21.5×10^{-6}

CURRENT METER No: W-223906 — DATE RATED: 06-25-92

MAP: USGS 7.5-minute quadrangles are Brownsville, Minn.-Wis., and Stoddard, Wis.

REMARKS:

Resampled sites using differential GPS. The error is estimated to be about ±5 m. The GPS reference station was located on a dogleg of the earth dam next to a dirt road with an elevation of 640 ft (43°36.040 N, 091°15.470 W, NAD27, accuracy ±25 m). Biological Resources Division collected a sample from site 0817. Oxygen was measured by using the Yellow Springs Instrument (Model 57), and the surface specific conductance and temperature were measured by using a LabComp meter. Measured discharge was 1,340 m^3/s, and the discharge at Dam 8 (provided by the U.S. Army Corps of Engineers) was 1,190 m^3/s.

CURRENT METER EQUATION: V(m/s)=0.668*rev/s + 0.006

BEARING OF TRANSECT: 067° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Depth (m)	Surface Conductance (µS/cm)	Surface Temperature (°C)	Dissolved oxygen (mg/L)	Velocity (m/s)	Direction (°magnetic)	Surficial bed sediment
LEW			0.0						
0811	43°38.839	091°13.794	1.0	450	29.6	8.6	0.22	170	--
0812	38.759	14.120	2.0	466	27.8	8.8	0.20	160	sand
09	38.736	14.233	3.4	466	28.0	8.5	0.14	110	--
08	38.725	14.300	4.3	476	27.2	9.5	0.51	140	--
07	38.706	14.365	2.2	468	27.9	9.2	0.40	120	--
06	38.682	14.470	1.3	463	28.6	9.2	0.42	170	--
05	38.622	14.695	0.3	463	29.2	9.3	0.21	180	--
0813	38.615	14.747	1.4	464	28.5	9.2	0.35	190	sand
0814	38.544	15.032	1.1	471	28.1	9.9	0.14	140	mud, sand
0815	38.466	15.395	1.2	478	29.6	10.2	0.10	170	sand
0816	38.377	15.743	3.5	484	27.4	9.5	0.31	150	sand
0817	43°38.300	091°16.101	1.3	485	26.9	10.1	0.06	350	mud
REW			0.0						

STATION: Mississippi River in Pool 8, Transect 2--UMR mile 683.3

PARTY: Moody, Sullivan, and Writer | DATE:June 19, 1994

GAGE HEIGHT at Dam 7 TW: 632.86 ft | GAGE HEIGHT at Dam 8: 630.14 ft

SUSPENSION: 15-pound weight | RIVER SLOPE: 21.5×10^{-6}

CURRENT METER No: W-223906 | DATE RATED: 06-25-92

MAP: USGS 7.5-minute quadrangles are Brownsville, Minn.-Wis.; Stoddard, Wis.; Genoa, Wis.; and Reno, Minn.

REMARKS:

Resampled sites using differential GPS. The error is estimated to be about ±5 m. The GPS reference station was located on a dogleg of the earth dam next to a dirt road with an elevation of 640 ft (43°36.040 N, 091°15.470 W, NAD27, accuracy ±25 m). Oxygen was measured by using the Yellow Springs Instrument (Model 57), and the surface specific conductance and temperature were measured by using a LabComp meter. Measured discharge was 900 m^3/s, and the discharge at Dam 8 (provided by the U.S. Army Corps of Engineers) was 1,190 m^3/s.

CURRENT METER EQUATION: V(m/s)=0.668*rev/s + 0.006

BEARING OF TRANSECT: 078° magnetic

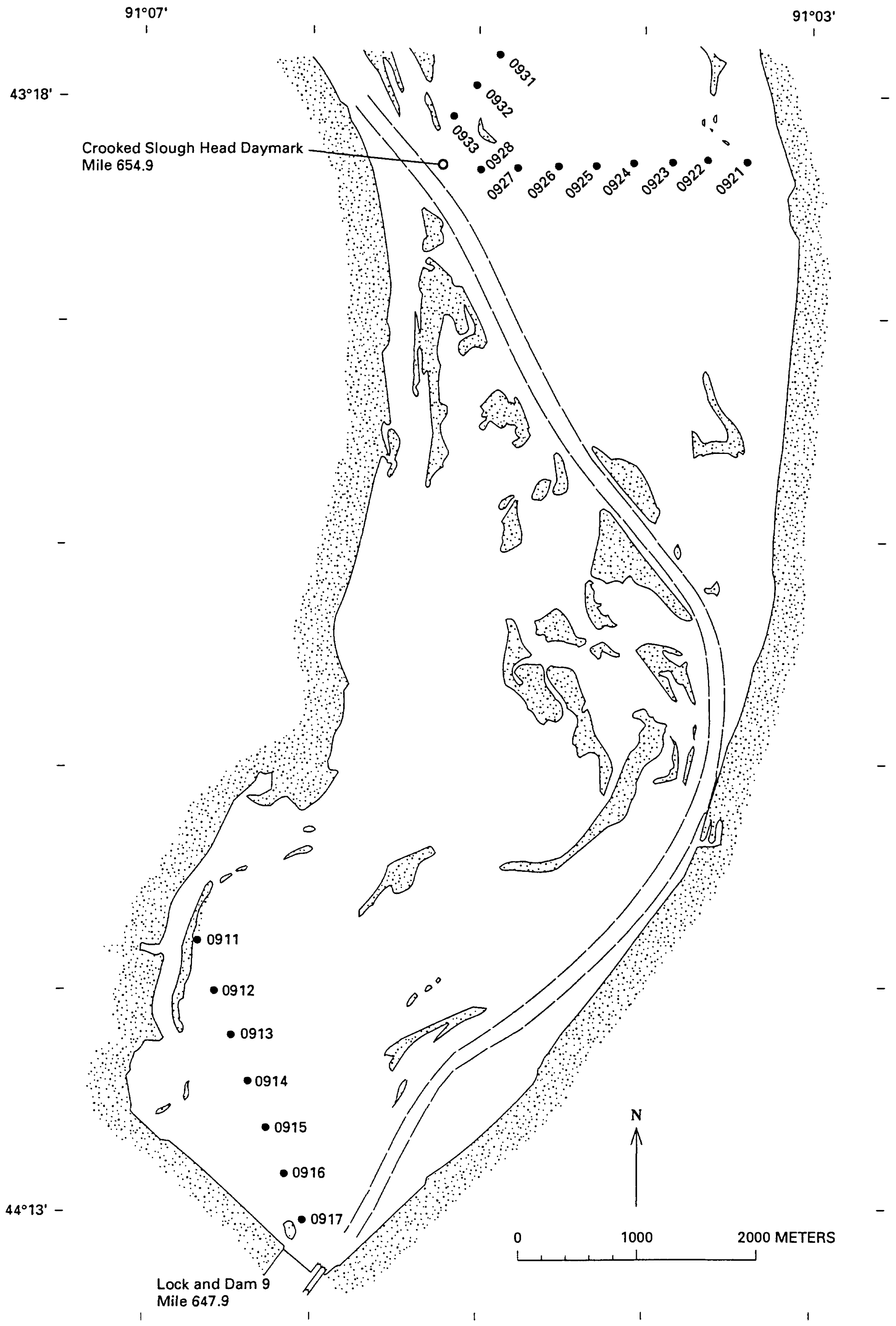
	NAD27			Surface					
Site	Latitude N	Longitude W	Depth (m)	Conduct-ance (µS/cm)	Tem-perature (°C)	Dissolved oxygen (mg/L)	Velocity (m/s)	Direction (°magnetic)	Surficial bed sediment
LEW			0.0						
10	43°37.608	091°13.312	4.2	462	29.5	9.8	0.15	150	--
11	37.600	13.366	7.4	458	29.7	10.0	0.33	150	--
12	37.589	13.408	3.6	461	28.3	9.3	0.31	140	--
13	37.550	13.628	1.4	460	29.0	10.0	0.38	150	--
0821	37.555	13.799	1.0	466	29.1	10.4	0.11	160	sand
0822	37.527	14.105	1.7	460	30.3	11.0	0.15	160	sand
0823	37.499	14.447	0.9	444	31.3	11.5	0.14	150	sand
0824	37.467	14.787	1.0	464	30.6	12.0	0.13	150	sand
0825	37.432	15.122	2.0	462	30.3	12.4	0.14	130	mud,shells
0826	37.410	15.461	1.5	460	31.2	14.0	0.13	140	mud
0827	43°37.379	091°15.798	0.8	475	29.5	12.8	0.11	110	mud
REW			0.0						

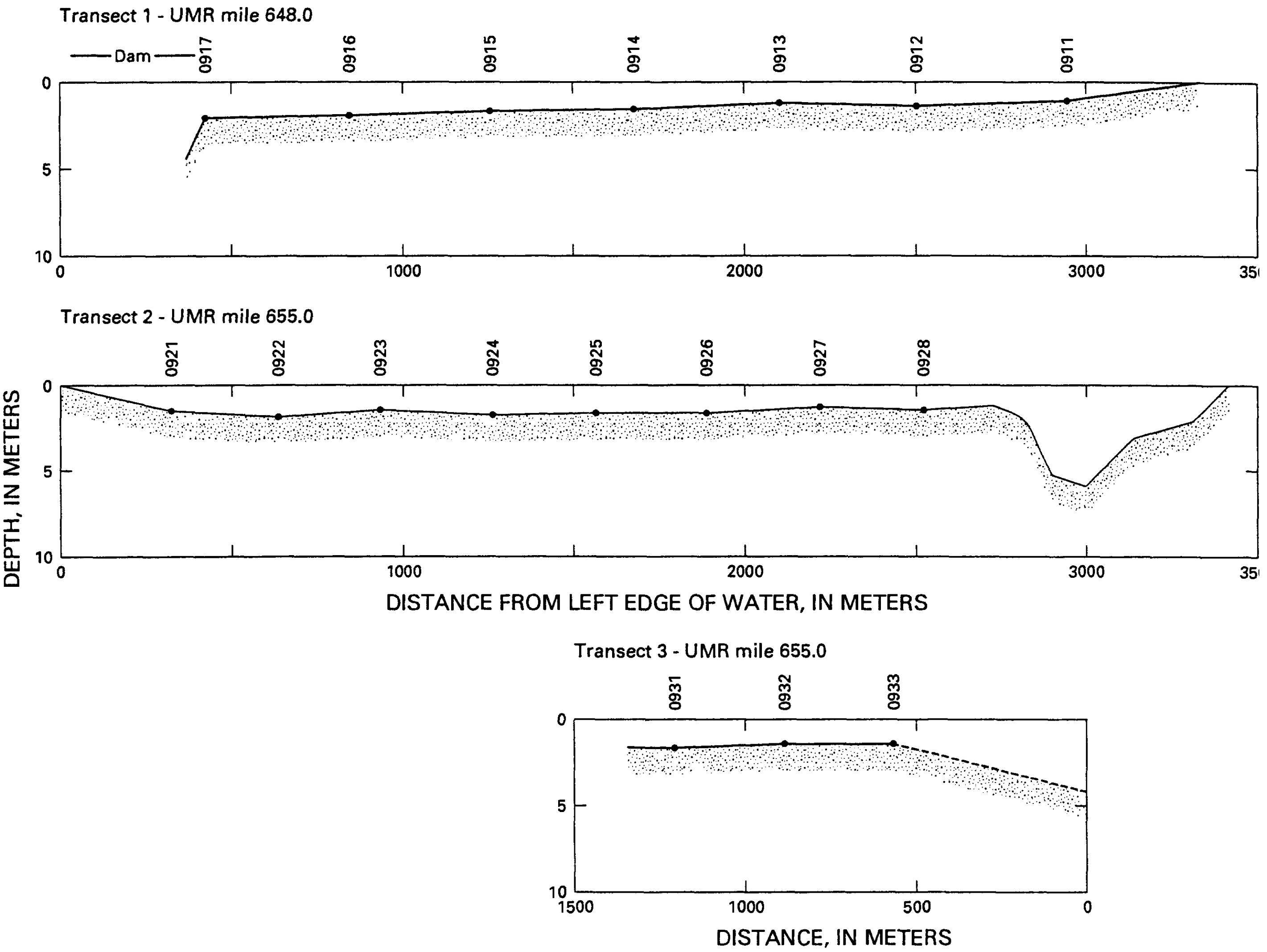
STATION: Mississippi River in Pool 8, Transect 3--UMR mile 682.1
PARTY: Moody, Sullivan, and Writer
GAGE HEIGHT at Dam 7 TW: 632.86 ft
SUSPENSION: 15-pound weight
CURRENT METER No: W-223906
DATE: June 19, 1994
GAGE HEIGHT at Dam 8: 630.14 ft
RIVER SLOPE: 21.5 x 10^{-6}
DATE RATED: 06-25-92
MAP: USGS 7.5-minute quadrangles are Genoa, Wis., and Reno, Minn.
REMARKS:

Resampled sites using differential GPS. The error is estimated to be about ±5 m. The GPS reference station was located on a dogleg of the earth dam next to a dirt road with an elevation of 640 ft (43°36.040 N, 091°15.470 W, NAD27, accuracy ±25 m). No grab sample was collected from site 0834. Oxygen was measured by using the Yellow Springs Instrument (Model 57), and the surface specific conductance and temperature were measured by using a LabComp meter. Measured discharge was 940 m^3/s and the discharge at Dam 8 (provided by the U.S. Army Corps of Engineers) was about 1,190 m^3/s.

CURRENT METER EQUATION: V(m/s)=0.668*rev/s + 0.006
BEARING OF TRANSECT: 064° magnetic

	NAD27			Surface					
Site	Latitude N	Longitude W	Depth (m)	Conductance (µS/cm)	Temperature (°C)	Dissolved oxygen (mg/L)	Velocity (m/s)	Direction (°magnetic)	Surficial bed sediment
LEW			0.0						
04	43°36.741	091°13.383	4.1	469	26.9	8.0	0.30	140	--
03	36.729	13.431	4.8	471	26.8	8.1	0.32	150	--
02	36.705	13.517	4.0	472	26.6	8.4	0.25	140	--
01	36.660	13.655	1.7	474	26.7	9.5	0.13	140	--
0831	36.623	13.787	3.4	473	26.6	8.9	0.14	120	mud
0832	36.528	14.068	1.6	473	26.5	8.8	0.21	140	mud, sand
0833	36.425	14.362	1.5	478	26.4	8.9	0.17	120	clay
0834	36.329	14.627	1.2	475	26.7	8.8	0.14	120	clay
0835	36.245	14.879	1.4	474	26.5	9.0	0.13	120	mud, sand
0836	43°36.146	091°15.163	1.0	486	26.2	8.5	0.13	150	sand
REW			0.0						


91°07'
91°03'
43°18'
44°13'
Crooked Slough Head Daymark
Mile 654.9
0931
0932
0933
0928
0927
0926
0925
0924
0923
0922
0921
0911
0912
0913
0914
0915
0916
0917
N
0
1000
2000 METERS
Lock and Dam 9
Mile 647.9


Transect 1 - UMR mile 648.0
Dam
0917
0916
0915
0914
0913
0912
0911
0
5
10
0
1000
2000
3000
Transect 2 - UMR mile 655.0
0921
0922
0923
0924
0925
0926
0927
0928
0
5
10
0
1000
2000
3000
DEPTH, IN METERS
DISTANCE FROM LEFT EDGE OF WATER, IN METERS
Transect 3 - UMR mile 655.0
0931
0932
0933
0
5
10
1500
1000
500
0
DISTANCE, IN METERS

STATION: Mississippi River in Pool 9, Transect 1--UMR mile 648.0

PARTY: Moody, Sullivan, and Writer

DATE: June 20, 1994

GAGE HEIGHT at Dam 8 TW: 623.59 ft

GAGE HEIGHT at Dam 9: 619.19 ft

SUSPENSION: 15-pound weight

RIVER SLOPE: 26.9 x 10^{-6}

CURRENT METER No: W-223906

DATE RATED: 06-25-92

MAP: USGS 7.5-minute quadrangle is Eastman, Wis.-Iowa

REMARKS:

Resampled sites using differential GPS. The error is estimated to be about ±5 m. The GPS reference station was located at the tip of the dam side wall of the auxiliary lock (43°12.740 N, 091°05.955 W, NAD27, accuracy ±25 m). Biological Resources Division collected a sample from site 0915. Oxygen was measured by using the Yellow Springs Instrument (Model 57), and the surface specific conductance and temperature were measured by using a LabComp meter. Discharge at Dam 9 (provided by the U.S. Army Corps of Engineers) was about 1,070 m^3/s.

CURRENT METER EQUATION: V(m/s)=0.668*rev/s + 0.006

BEARING OF TRANSECT: 159° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Depth (m)	Surface Conductance (µS/cm)	Surface Temperature (°C)	Dissolved oxygen (mg/L)	Velocity (m/s)	Direction (°magnetic)	Surficial bed sediment
REW			0.0						
0911	43°14.203	091°06.665	0.7	485	26.5	2.8	<0.05	--	mud
0912	13.988	06.547	1.1	484	26.8	4.0	0.05	150	mud
0913	13.795	06.452	1.0	480	27.1	4.2	0.09	120	mud
0914	13.583	06.350	1.2	483	26.8	3.7	0.12	130	mud
0915	13.367	06.242	1.3	483	27.0	3.5	0.14	130	mud
0916	13.154	06.133	1.7	484	27.0	3.6	0.20	140	mud, clay
0917	43°12.938	091°06.031	1.8	484	27.1	3.4	0.40	130	clay

STATION: Mississippi River in Pool 9, Transect 2--UMR mile 655.0
PARTY: Moody, Sullivan, and Writer
DATE: June 20, 1994
GAGE HEIGHT at Dam 8 TW: 623.59 ft
GAGE HEIGHT at Dam 9: 619.19 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 26.9×10^{-6}
CURRENT METER No: W-223906
DATE RATED: 06-25-92
MAP: USGS 7.5-minute quadrangle is Ferryville, Iowa-Wis.
REMARKS:

Resampled sites using differential GPS. The error is estimated to be about ±5 m. The GPS reference station was located at the tip of the dam side wall of the auxiliary lock (43°12.740 N, 091°05.955 W, NAD27, accuracy ±25 m). Oxygen was measured by using the Yellow Springs Instrument (Model 57), and the surface specific conductance and temperature were measured by using a LabComp meter. Measured discharge was 860 m^3/s, and the discharge at Dam 9 (provided by the U.S. Army Corps of Engineers) was 1,070 m^3/s.

CURRENT METER EQUATION: V(m/s)=0.668*rev/s + 0.006
BEARING OF TRANSECT: 089° magnetic

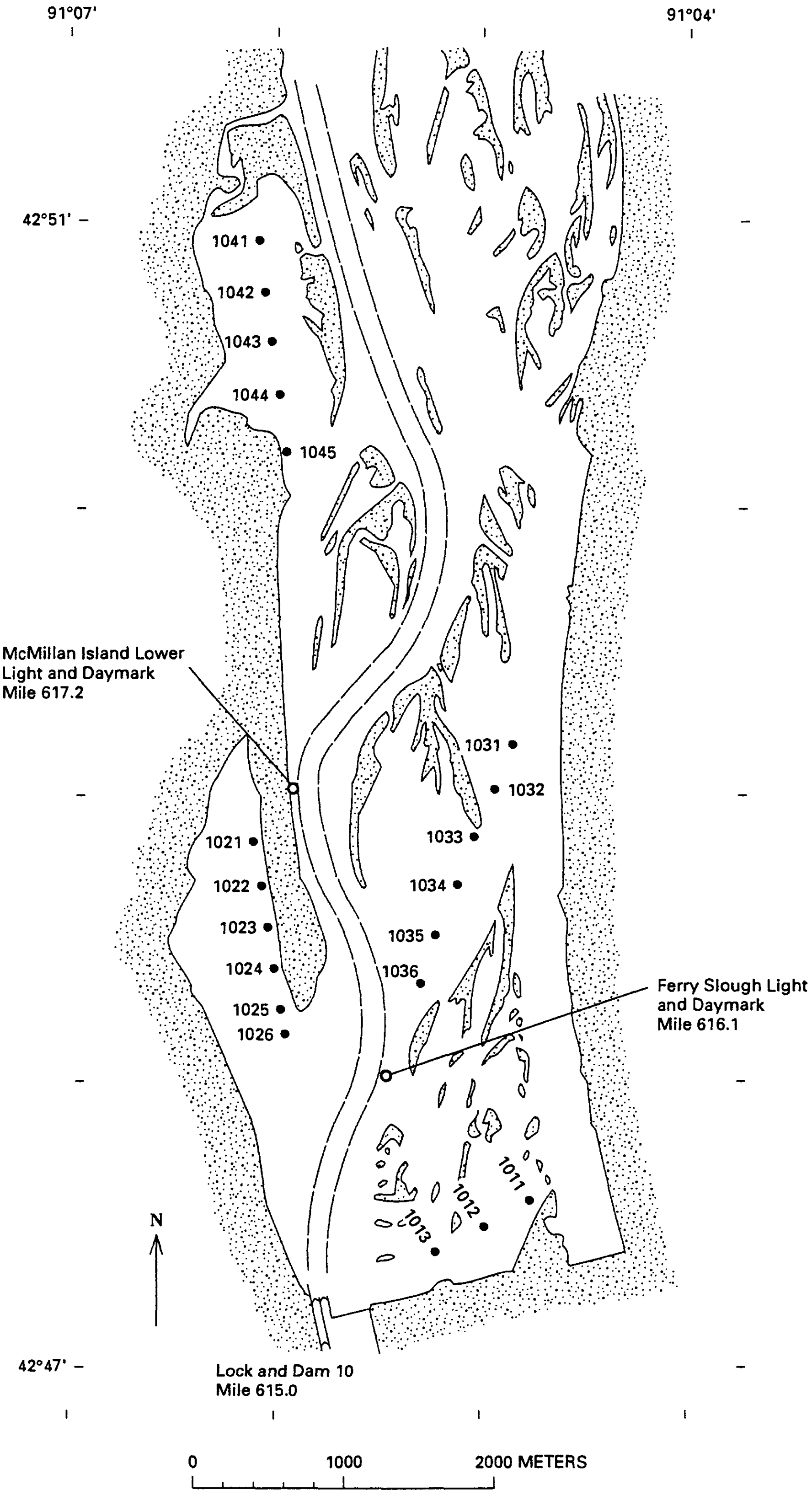
Site	NAD27 Latitude N	NAD27 Longitude W	Depth (m)	Surface Conductance (µS/cm)	Surface Temperature (°C)	Dissolved oxygen (mg/L)	Velocity (m/s)	Direction (°magnetic)	Surficial bed sediment
LEW			0.0						
0921	43°17.761	091°03.322	1.2	459	27.4	4.5	0.18	150	mud
0922	17.758	03.564	1.8	456	27.7	4.9	0.17	140	mud
0923	17.747	03.792	1.3	455	27.9	5.2	0.17	150	mud
0924	17.735	04.033	1.4	455	27.4	5.2	0.23	140	mud
0925	17.730	04.248	1.4	455	27.3	5.1	0.16	140	mud
0926	17.724	04.487	1.2	455	27.1	4.9	0.06	130	mud
0927	17.713	04.728	1.0	469	27.3	4.8	0.14	150	mud
0928	17.705	04.964	1.3	464	27.1	4.9	0.14	160	mud
01	17.694	05.106	0.9	469	27.2	5.4	0.17	090	--
02	17.691	05.187	1.9	473	27.6	7.0	0.18	150	--
03	17.689	05.245	5.3	472	27.6	7.5	0.39	130	--
04	17.688	05.310	6.0	470	27.6	7.1	0.33	120	--
05	17.687	05.408	2.8	472	27.6	6.8	0.39	120	--
06	43°17.682	091°05.541	2.1	470	27.8	6.5	0.30	170	--
REW			0.0						

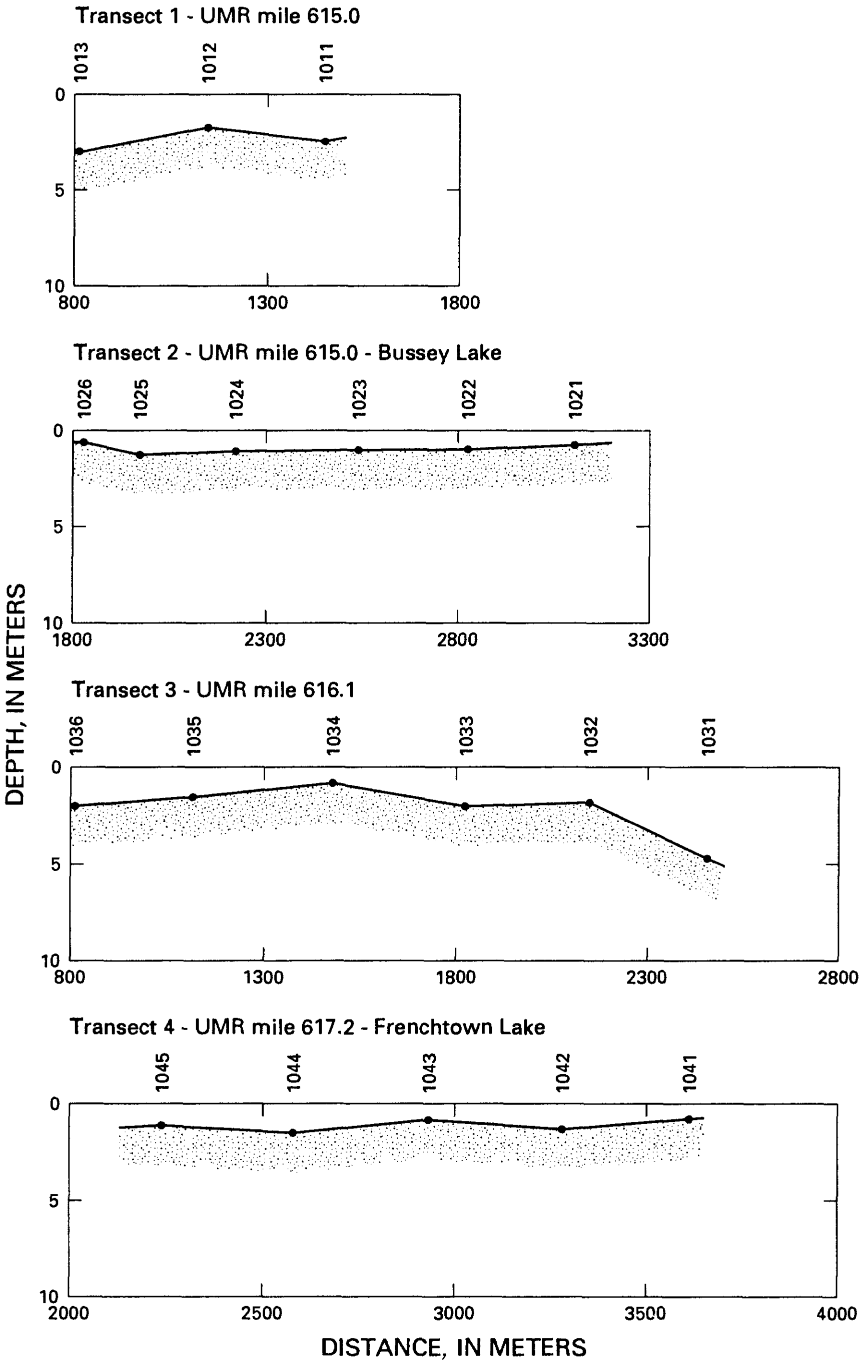
STATION: Mississippi River in Pool 9, Transect 3--UMR mile 655.0
PARTY: Moody, Sullivan, and Writer
DATE: June 20, 1994
GAGE HEIGHT at Dam 8 TW: 623.59 ft
GAGE HEIGHT at Dam 9: 619.19 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 26.9×10^{-6}
CURRENT METER No: W-223906
DATE RATED: 06-25-92
MAP: USGS 7.5-minute quadrangle is Ferryville, Iowa-Wis.
REMARKS:

Resampled sites using differential GPS. The error is estimated to be about ±5 m. The GPS reference station was located at the tip of the dam side wall of the auxiliary lock (43°12.740 N, 091°05.955 W, NAD27, accuracy ±25 m). Oxygen was measured by using the Yellow Springs Instrument (Model 57), and the surface specific conductance and temperature were measured by using a LabComp meter. Discharge at Dam 9 (provided by the U.S. Army Corps of Engineers) was about 1,070 m^3/s.

CURRENT METER EQUATION: V(m/s)=0.668*rev/s + 0.006
BEARING OF TRANSECT: 037° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Depth (m)	Surface Conductance (µS/cm)	Surface Temperature (°C)	Dissolved oxygen (mg/L)	Velocity (m/s)	Direction (°magnetic)	Surficial bed sediment
LEW			0.0						
0931	43°18.223	091°04.850	1.3	474	26.8	5.6	0.13	150	mud
0932	18.074	04.993	1.0	473	27.0	5.2	0.11	140	mud
0933	43°17.941	05.135	1.1	471	27.0	5.9	0.11	110	mud


91°07'
91°04'
42°51' –
42°47' –
1041
1042
1043
1044
1045
McMillan Island Lower
Light and Daymark
Mile 617.2
1031
1032
1033
1034
1035
1036
1021
1022
1023
1024
1025
1026
Ferry Slough Light
and Daymark
Mile 616.1
1011
1012
1013
N
Lock and Dam 10
Mile 615.0
0
1000
2000 METERS



Transect 1 - UMR mile 615.0
1013
1012
1011
Transect 2 - UMR mile 615.0 - Bussey Lake
1026
1025
1024
1023
1022
1021
Transect 3 - UMR mile 616.1
1036
1035
1034
1033
1032
1031
Transect 4 - UMR mile 617.2 - Frenchtown Lake
1045
1044
1043
1042
1041
DEPTH, IN METERS
DISTANCE, IN METERS

STATION: Mississippi River in Pool 10, Transect 1--UMR mile 615.0

PARTY: Moody, Sullivan, and Writer

DATE: June 20, 1994

GAGE HEIGHT at Dam 9 TW: 615.62 ft

GAGE HEIGHT at Dam 10: 611.13 ft

SUSPENSION: 15-pound weight

RIVER SLOPE: 25.8 x 10^{-6}

CURRENT METER No: W-223906

DATE RATED: 06-25-92

MAP: USGS 7.5-minute quadrangle is Guttenberg, Iowa-Wis.

REMARKS:

Resampled sites using differential GPS. The error is estimated to be about ±5 m. The GPS reference station was located at the tip of the dam side wall of the auxiliary lock (42°47.165 N, 091°05.675 W, NAD27, accuracy ±25 m). John Sullivan got a navigation beacon fix at this location of 42°47.1705 N, 091°05.6856 W, NAD27, the average of 100 fixes over 4 minutes. Oxygen was measured by using the Yellow Springs Instrument (Model 57), and the surface specific conductance and temperature were measured by using a LabComp meter. Discharge at Dam 10 (provided by the U.S. Army Corps of Engineers) was about 1,360 m^3/s. The discharge, gage heights, and river slopes are for June 21, 1994.

CURRENT METER EQUATION: V(m/s)=0.668*rev/s + 0.006

BEARING OF TRANSECT: 057° magnetic

	NAD27			Surface					
Site	Latitude N	Longitude W	Depth (m)	Conduct-ance (µS/cm)	Tem-perature (°C)	Dissolved oxygen (mg/L)	Velocity (m/s)	Direction (°magnetic)	Surficial bed sediment
LEW			0.0						
1011	42°47.553	091°04.725	2.2	429	28.1	5.6	0.24	200	sand
1012	47.458	04.946	1.4	423	28.3	5.9	0.18	220	sand
1013	42°47.372	05.154	2.9	424	28.1	5.8	0.35	200	sand

STATION: Mississippi River in Pool 10, Transect 2--UMR mile 615.0

PARTY: Moody, Sullivan, and Writer

DATE: June 20, 1994

GAGE HEIGHT at Dam 9 TW: 615.62 ft

GAGE HEIGHT at Dam 10: 611.13 ft

SUSPENSION: 15-pound weight

RIVER SLOPE: 25.8 x 10^{-6}

CURRENT METER No: W-223906

DATE RATED: 06-25-92

MAP: USGS 7.5-minute quadrangle is Guttenberg, Iowa-Wis.

REMARKS:

Resampled sites using differential GPS. The error is estimated to be about ±5 m. The GPS reference station was located at the tip of the dam side wall of the auxiliary lock (42°47.165 N, 091°05.675 W, NAD27, accuracy ±25 m). John Sullivan got a navigation beacon fix at this location of 42°47.1705 N, 091°05.6856 W, NAD27, the average of 100 fixes over 4 minutes. Biological Resources Division collected a sample at site 1023. Oxygen was measured by using the Yellow Springs Instrument (Model 57), and the surface specific conductance and temperature were measured by using a LabComp meter. Discharge at Dam 10 (provided by the U.S. Army Corps of Engineers) was about 1,360 m^3/s. The discharge, gage heights, and river slopes are for June 21, 1994.

CURRENT METER EQUATION: V(m/s)=0.668*rev/s + 0.006

BEARING OF TRANSECT: 164° magnetic

	NAD27			Surface					
Site	Latitude N	Longitude W	Depth (m)	Conductance (µS/cm)	Temperature (°C)	Dissolved oxygen (mg/L)	Velocity (m/s)	Direction (°magnetic)	Surficial bed sediment
1021	42°48.839	091°06.079	0.6	362	24.8	2.9	<0.05	--	mud, roots
1022	48.674	06.041	0.9	383	24.9	2.4	<0.05	--	mud
1023	48.518	05.999	1.1	450	25.9	5.2	<0.05	--	mud
1024	48.373	05.968	1.0	462	26.3	3.8	0.07	150	mud
1025	48.212	05.920	1.1	476	26.7	3.7	0.09	240	mud
1026	42°48.135	091°05.901	0.7	477	27.0	3.8	0.25	210	sand, clay

STATION: Mississippi River in Pool 10, Transect 3--UMR mile 616.1

PARTY: Moody, Sullivan, and Writer — DATE: June 21, 1994

GAGE HEIGHT at Dam 9 TW: 615.62 ft — GAGE HEIGHT at Dam 10: 611.13 ft

SUSPENSION: 15-pound weight — RIVER SLOPE: 25.8 x 10^{-6}

CURRENT METER No: W-223906 — DATE RATED: 06-25-92

MAP: USGS 7.5-minute quadrangle is Guttenberg, Iowa--Wis.

REMARKS:

Resampled sites using differential GPS. The error is estimated to be about ±5 m. The GPS reference station was located at the tip of the dam side wall of the auxiliary lock (42°47.165 N, 091°05.675 W, NAD27, accuracy ±25 m). John Sullivan got a navigation beacon fix at this location of 42°47.1705 N, 091°05.6856 W, NAD27, the average of 100 fixes over 4 minutes. Oxygen was measured by using the Yellow Springs Instrument (Model 57), and the surface specific conductance and temperature were measured by using a LabComp meter. Discharge at Dam 10 (provided by the U.S. Army Corps of Engineers) was about 1,360 m^3/s.

CURRENT METER EQUATION: V(m/s)=0.668*rev/s + 0.006

BEARING OF TRANSECT: 015° magnetic

	NAD27			Surface					
Site	Latitude N	Longitude W	Depth (m)	Conductance (µS/cm)	Temperature (°C)	Dissolved oxygen (mg/L)	Velocity (m/s)	Direction (°magnetic)	Surficial bed sediment
LEW			0.0						
1031	42°49.156	091°04.854	4.7	439	27.5	4.9	0.36	170	mud
1032	48.999	04.929	1.8	454	27.5	4.9	0.41	210	sand
1033	48.788	05.031	2.0	451	27.6	4.9	0.28	190	sand
1034	48.650	05.095	0.6	449	27.3	5.0	0.37	190	sand
1035	48.471	05.175	1.2	447	27.7	5.2	0.22	190	mud, sand
1036	42°48.310	091°05.252	1.8	442	28.1	5.3	0.16	190	mud

STATION: Mississippi River in Pool 10, Transect 4--UMR mile 617.2

PARTY: Moody, Sullivan, and Writer

DATE: June 21, 1994

GAGE HEIGHT at Dam 9 TW: 615.62 ft

GAGE HEIGHT at Dam 10: 611.13 ft

SUSPENSION: 15-pound weight

RIVER SLOPE: 25.8 x 10^{-6}

CURRENT METER No: W-223906

DATE RATED: 06-25-92

MAP: USGS 7.5-minute quadrangle is Guttenberg, Iowa-Wis.

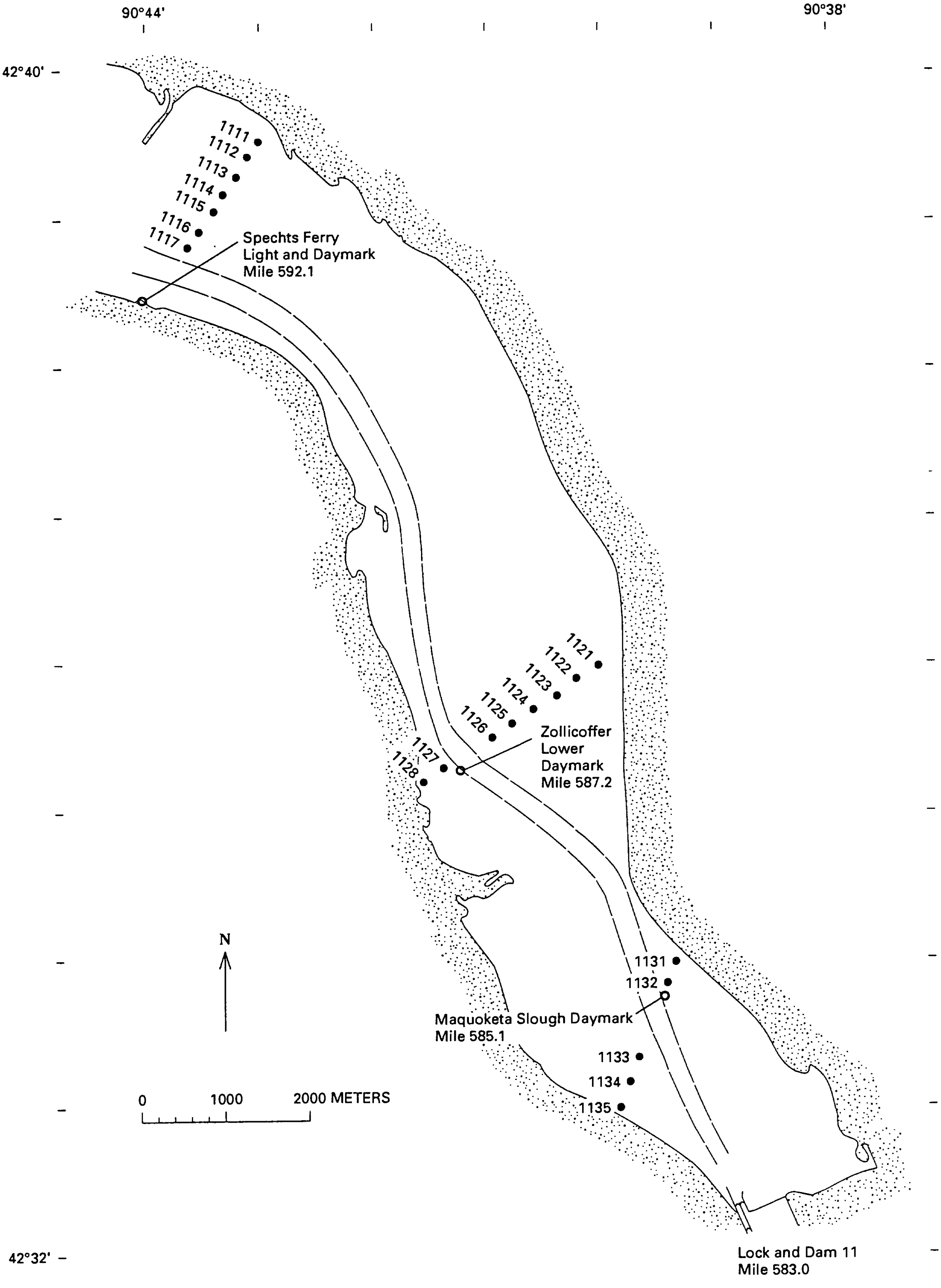
REMARKS:

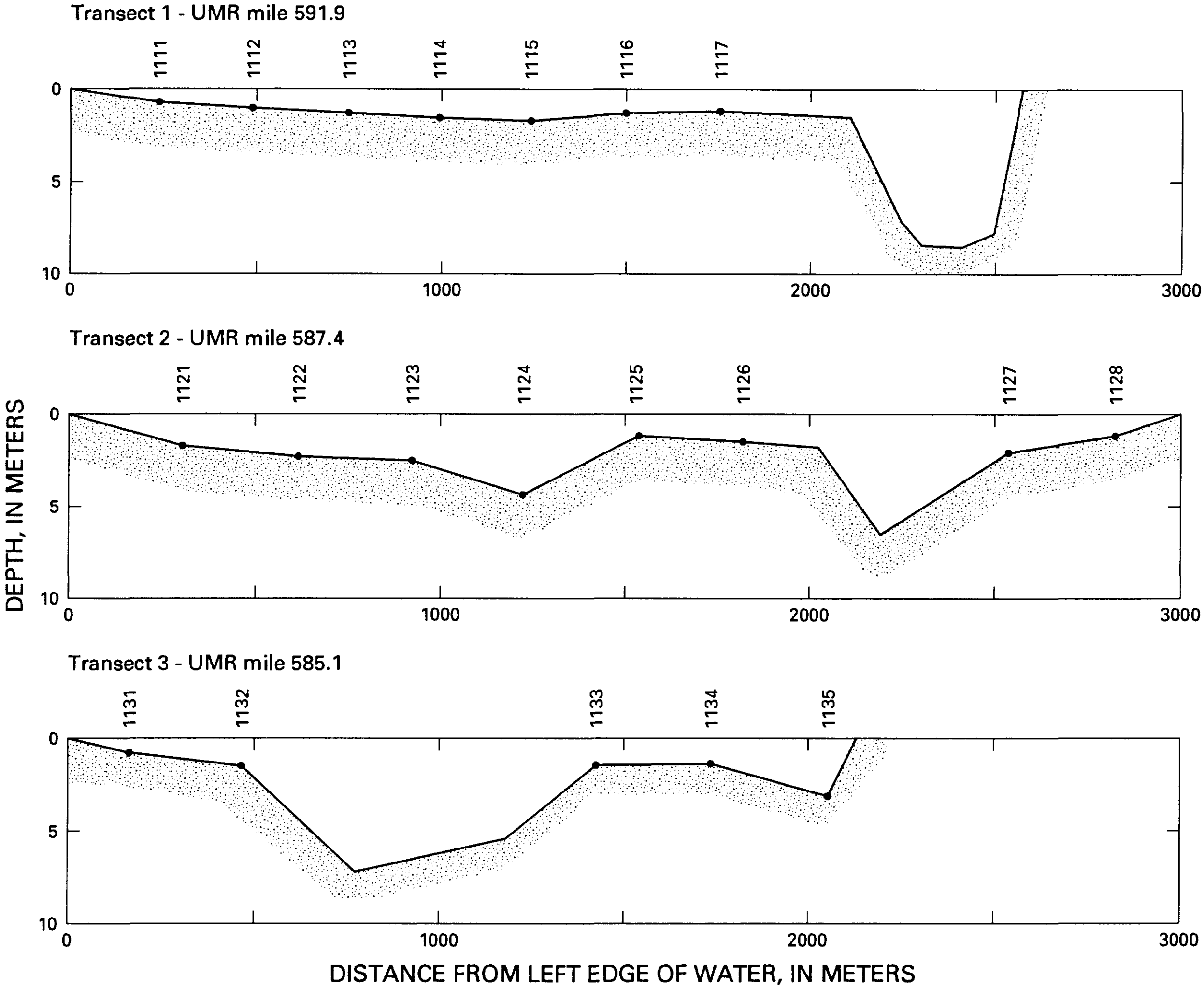
Resampled sites using differential GPS. The error is estimated to be about ±5 m. The GPS reference station was located at the tip of the dam side wall of the auxiliary lock (42°47.165 N, 091°05.675 W, NAD27, accuracy ±25 m). John Sullivan got a navigation beacon fix at this location of 42°47.1705 N, 091°05.6856 W, NAD27, the average of 100 fixes over 4 minutes. Oxygen was measured by using the Yellow Springs Instrument (Model 57), and the surface specific conductance and temperature were measured by using a LabComp meter. Discharge at Dam 10 (provided by the U.S. Army Corps of Engineers) was about 1,360 m^3/s.

CURRENT METER EQUATION: V(m/s)=0.668*rev/s + 0.006

BEARING OF TRANSECT: 168° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Depth (m)	Surface Conductance (µS/cm)	Surface Temperature (°C)	Dissolved oxygen (mg/L)	Velocity (m/s)	Direction (°magnetic)	Surficial bed sediment
1041	42°50.940	091°06.101	0.8	477	26.2	3.5	<0.05	--	mud
1042	50.770	06.062	1.2	476	27.3	4.2	0.17	170	sand
1043	50.582	06.021	0.8	476	27.2	4.1	0.10	160	mud
1044	50.394	05.975	1.1	476	27.2	4.1	0.17	--	mud
1045	42°50.211	091°05.956	0.9	483	25.5	3.6	0.20	130	mud


90°44'
90°38'
42°40'
42°32'
1111
1112
1113
1114
1115
1116
1117
Spechts Ferry
Light and Daymark
Mile 592.1
1121
1122
1123
1124
1125
1126
1127
1128
Zollicoffer
Lower
Daymark
Mile 587.2
N
1131
1132
Maquoketa Slough Daymark
Mile 585.1
1133
1134
1135
0
1000
2000 METERS
Lock and Dam 11
Mile 583.0



Transect 1 - UMR mile 591.9
1111
1112
1113
1114
1115
1116
1117
Transect 2 - UMR mile 587.4
1121
1122
1123
1124
1125
1126
1127
1128
Transect 3 - UMR mile 585.1
1131
1132
1133
1134
1135
0
5
10
0
1000
2000
3000
DEPTH, IN METERS
DISTANCE FROM LEFT EDGE OF WATER, IN METERS

STATION: Mississippi River in Pool 11, Transect 1--UMR mile 591.9

PARTY: Moody, Sullivan, and Writer

DATE: June 21, 1994

GAGE HEIGHT at Dam 10 TW: 606.82 ft

GAGE HEIGHT at Dam 11: 603.11 ft

SUSPENSION: 15-pound weight

RIVER SLOPE: 22.0 x 10^{-6}

CURRENT METER No: W-223906

DATE RATED: 06-25-92

MAP: USGS 7.5-minute quadrangle is Potosi, Wis.-Iowa

REMARKS:

Resampled sites using differential GPS. The error is estimated to be about ±5 m. The GPS reference station was located at the tip of a small delta at Spechts Ferry, Iowa (42°38.510 N, 090°44.000 W, NAD27, accuracy ±25 m). Oxygen was measured by using the Yellow Springs Instrument (Model 57), and the surface specific conductance and temperature were measured by using a LabComp meter. Measured discharge was 1,540 m^3/s.

CURRENT METER EQUATION: V(m/s)=0.668*rev/s + 0.006

BEARING OF TRANSECT: 034° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Depth (m)	Surface Conductance (µS/cm)	Surface Temperature (°C)	Dissolved oxygen (mg/L)	Velocity (m/s)	Direction (°magnetic)	Surficial bed sediment
LEW			0.0						
1111	42°39.522	090°42.999	0.4	540	30.3	8.5	0.05	090	mud
1112	39.430	43.098	0.6	431	30.8	8.8	0.12	090	mud
1113	39.300	43.197	1.2	423	30.2	7.7	0.13	100	mud,shells
1114	39.177	43.308	1.5	421	30.1	6.8	0.15	090	mud
1115	39.062	43.404	1.7	422	29.9	6.2	0.17	090	mud,shells
1116	38.946	43.502	1.2	424	30.1	7.4	0.08	070	mud, sand
1117	38.832	43.602	1.1	428	29.8	7.2	0.16	090	sand
05	38.709	43.830	1.8	433	29.9	5.8	0.20	100	--
04	38.630	43.863	6.7	443	29.0	6.1	0.41	080	--
03	38.575	43.871	8.0	444	28.8	6.0	0.52	100	--
02	38.541	43.900	8.3	447	28.7	5.5	0.60	100	--
01	42°38.507	090°43.928	7.8	441	29.2	5.1	0.28	110	--
REW			0.0						

STATION: Mississippi River in Pool 11, Transect 2--UMR mile 587.4
PARTY: Moody, Sullivan, and Writer
DATE: June 22, 1994
GAGE HEIGHT at Dam 10 TW: 606.82 ft
GAGE HEIGHT at Dam 11: 603.11 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 22.0 x 10^{-6}
CURRENT METER No: W-223906
DATE RATED: 06-25-92
MAP: USGS 7.5-minute quadrangle is Dubuque, Iowa-Wis.-Ill.
REMARKS:

Resampled sites using differential GPS. The error is estimated to be about ±5 m. The GPS reference station was located on the outer auxiliary lockwall (42°32.435 N, 090°38.705 W, NAD27, accuracy ±25 m) at the dam side corner where the wall is widest (upstream from the auxiliary lock gate and downstream from the opening in the lockwall at water level). Biological Resources Division collected a sample at site 1122. Oxygen was measured by using the Yellow Springs Instrument (Model 57), and the surface specific conductance and temperature were measured by using a LabComp meter. Tailwater (TW) measured at Dam 10 is for June 21, 1994, so that river slope is not for June 22, but is approximate. Measured discharge was 1,510 m^3/s.

CURRENT METER EQUATION: V(m/s)=0.668*rev/s + 0.006
BEARING OF TRANSECT: 057° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Depth (m)	Surface Conductance (µS/cm)	Surface Temperature (°C)	Dissolved oxygen (mg/L)	Velocity (m/s)	Direction (°magnetic)	Surficial bed sediment
LEW			0.0						
1121	42°36.013	090°40.020	1.4	435	27.3	6.7	0.19	160	mud, clay
1122	35.922	40.207	2.0	443	26.7	6.2	0.17	170	mud,shells
1123	35.831	40.388	2.1	449	27.3	5.3	0.22	150	mud,shells
1124	35.735	40.581	4.5	449	27.3	5.2	0.28	150	sand
1125	35.639	40.772	0.9	453	27.6	5.5	0.10	150	mud, sand
1126	35.559	40.932	1.2	455	27.2	5.8	0.12	140	mud
08	35.485	41.060	1.5	458	27.0	5.2	0.22	160	--
09	35.435	41.149	6.5	464	27.2	5.1	0.44	170	--
10	35.397	41.253	4.1	470	26.8	5.0	0.26	140	--
1127	35.338	41.364	1.9	459	26.8	4.4	0.23	130	mud
1128	42°35.275	090°41.529	0.9	457	25.7	4.1	0.07	150	mud
REW			0.0						

STATION: Mississippi River in Pool 11, Transect 3--UMR mile 585.1

PARTY: Moody, Sullivan, and Writer

DATE: June 22, 1994

GAGE HEIGHT at Dam 10 TW: 606.82 ft

GAGE HEIGHT at Dam 11: 603.11 ft

SUSPENSION: 15-pound weight

RIVER SLOPE: 22.0×10^{-6}

CURRENT METER No: W-223906

DATE RATED: 06-25-92

MAP: USGS 7.5-minute quadrangle is Dubuque, Iowa-Wis.-Ill.

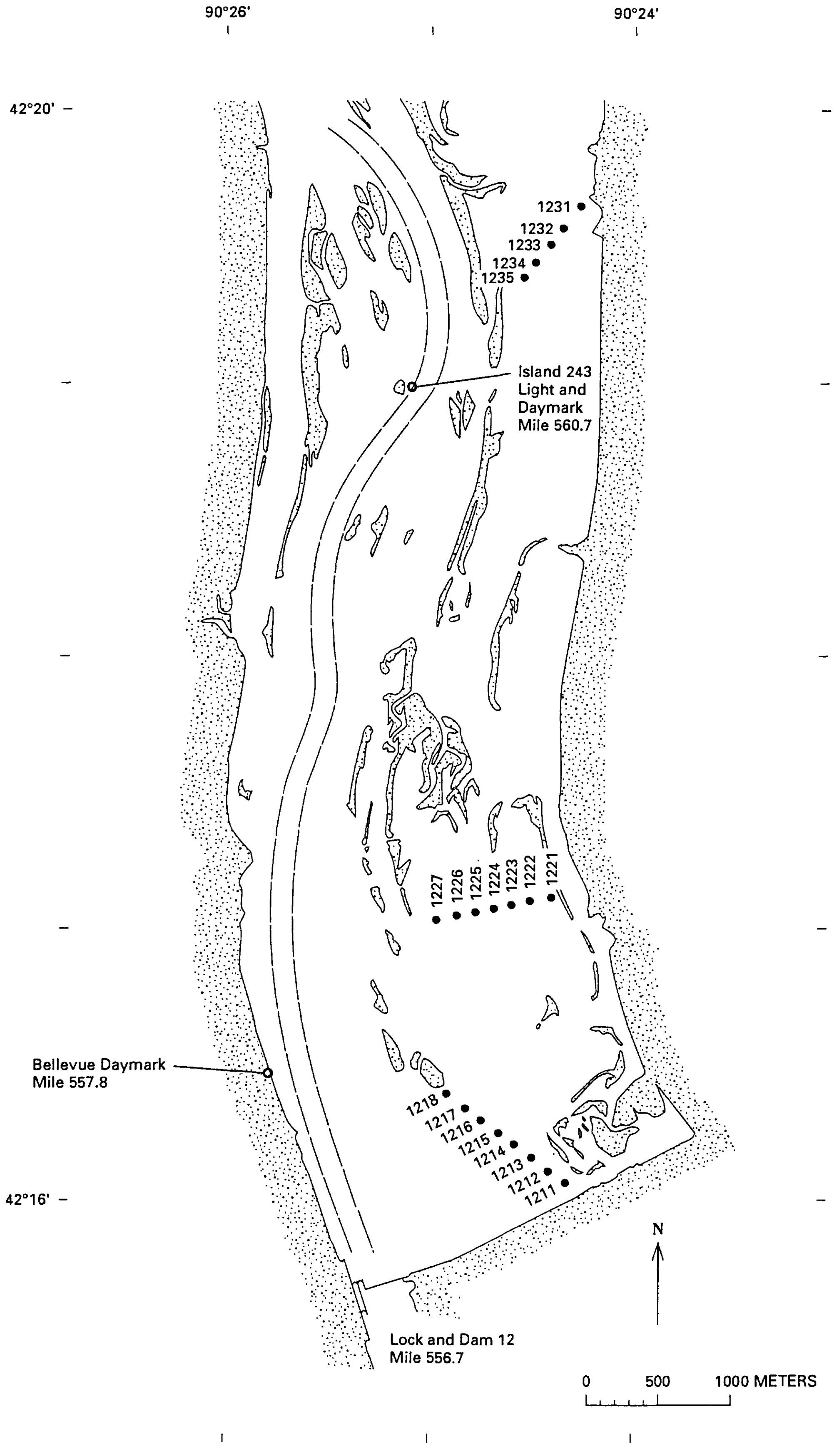
REMARKS:

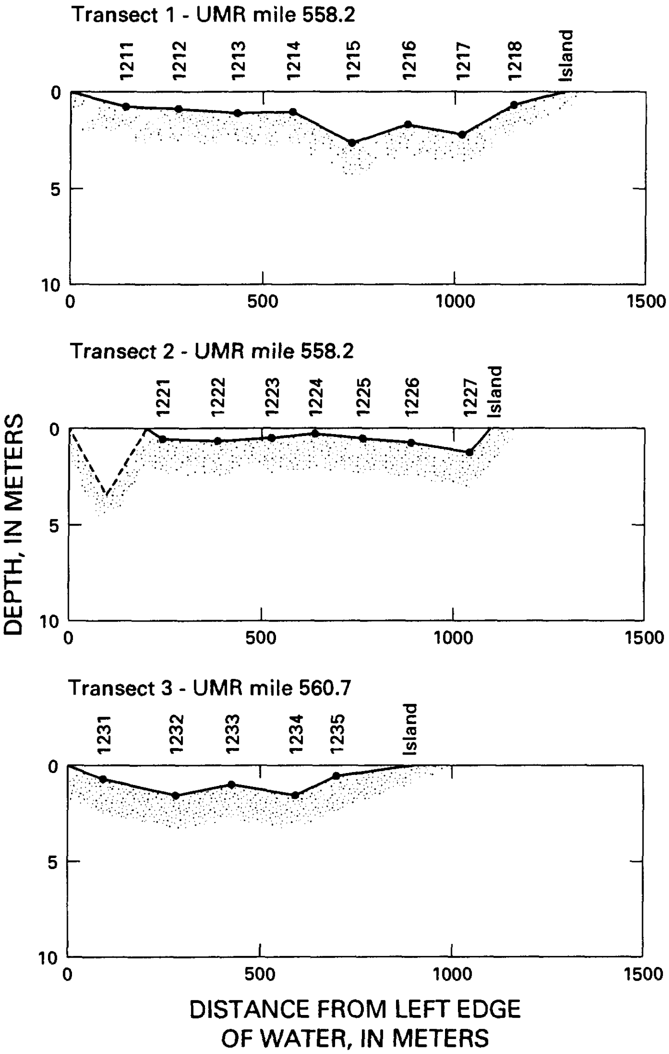
Resampled sites using differential GPS. The error is estimated to be about ±5 m. The GPS reference station was located on the outer auxiliary lockwall (42°32.435 N, 090°38.705 W, NAD27, accuracy ±25 m) at the dam side corner where the wall is widest (upstream from the auxiliary lock gate and downstream from the opening in the lockwall at water level). Oxygen was measured by using the Yellow Springs Instrument (Model 57), and the surface specific conductance and temperature were measured by using a LabComp meter. Measured discharge was 1,580 m^3/s.

CURRENT METER EQUATION: V(m/s)=0.668*rev/s + 0.006

BEARING OF TRANSECT: 021° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Depth (m)	Surface Conductance (µS/cm)	Surface Temperature (°C)	Dissolved oxygen (mg/L)	Velocity (m/s)	Direction (°magnetic)	Surficial bed sediment
LEW			0.0						
1131	42°34.059	090°39.343	0.7	452	28.5	8.0	0.14	130	sand
1132	33.907	39.416	1.4	453	28.4	7.6	0.19	130	mud, sand
06	33.754	39.473	7.0	441	28.4	--	0.38	140	--
07	33.542	39.518	5.0	443	28.5	--	0.44	160	--
1133	33.421	39.660	1.4	446	28.5	6.0	0.27	150	sand
1134	33.267	39.734	1.2	444	28.4	6.2	0.16	140	mud
1135	42°33.102	090°39.815	3.0	445	28.4	6.4	0.20	120	mud
REW			0.0						


90°26'
90°24'
42°20'
42°16'
1231
1232
1233
1234
1235
Island 243
Light and
Daymark
Mile 560.7
1221
1222
1223
1224
1225
1226
1227
1211
1212
1213
1214
1215
1216
1217
1218
Bellevue Daymark
Mile 557.8
Lock and Dam 12
Mile 556.7
N
0
500
1000 METERS


Transect 1 - UMR mile 558.2
1211
1212
1213
1214
1215
1216
1217
1218
Island
0
5
10
0
500
1000
1500
Transect 2 - UMR mile 558.2
1221
1222
1223
1224
1225
1226
1227
Island
DEPTH, IN METERS
0
5
10
0
500
1000
1500
Transect 3 - UMR mile 560.7
1231
1232
1233
1234
1235
Island
0
5
10
0
500
1000
1500
DISTANCE FROM LEFT EDGE
OF WATER, IN METERS

STATION: Mississippi River in Pool 12, Transect 1--UMR mile 558.2
PARTY: Moody, Sullivan, and Writer
DATE: June 22, 1994
GAGE HEIGHT at Dam 11 TW: 595.10 ft
GAGE HEIGHT at Dam 12: 592.08 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 21.8×10^{-6}
CURRENT METER No: W-223906
DATE RATED: 06-25-92
MAP: USGS 7.5-minute quadrangle is Bellevue, Iowa-Ill.
REMARKS:

Resampled sites using differential GPS. The error is estimated to be about ±5 m. The GPS reference station was located at the tip of the outer auxiliary lockwall (42°15.695 N, 090°25.350 W, NAD27, accuracy ±25 m). Autonomous GPS was used to navigate to sites 1211, 1212, and 1213 and used to determine the latitude and longitude at sites 1211 and 1212. Differential/fixed height mode was used to determine the latitude and longitude at site 1213. The surface specific conductance and temperature were measured by using a LabComp meter. Biological Resources Division collected a sample at site 1215.

CURRENT METER EQUATION: V(m/s)=0.668*rev/s + 0.006
BEARING OF TRANSECT: 126° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Depth (m)	Surface Conductance (µS/cm)	Surface Temperature (°C)	Velocity (m/s)	Direction (°magnetic)	Surficial bed sediment
LEW			0.0					
1211	42°16.07	090°24.33	0.9	450	31.7	<0.05	--	mud
1212	16.10	24.10	0.9	444	30.9	0.07	130	mud
1213	16.126	24.486	1.1	447	30.3	--	--	mud
1214	16.201	24.578	1.0	455	29.3	0.08	210	mud
1215	16.239	24.667	2.1	457	30.5	0.10	210	mud
1216	16.288	24.754	1.7	435	31.4	0.10	170	mud
1217	16.329	24.822	2.0	443	31.6	0.15	180	mud
1218	42°16.381	090°24.914	0.6	430	33.5	0.10	190	mud
REW			0.0					

STATION: Mississippi River in Pool 12, Transect 2--UMR mile 558.2

PARTY: Moody, Sullivan, and Writer — DATE: June 22, 1994

GAGE HEIGHT at Dam 11 TW: 595.10 ft — GAGE HEIGHT at Dam 12: 592.08 ft

SUSPENSION: 15-pound weight — RIVER SLOPE: 21.8×10^{-6}

CURRENT METER No: W-223906 — DATE RATED: 06-25-92

MAP: USGS 7.5-minute quadrangle is Bellevue, Iowa-Ill.

REMARKS:

Resampled sites using differential GPS. The error is estimated to be about ±5 m. The GPS reference station was located at the tip of the outer auxiliary lockwall (42°15.695 N, 090°25.350 W, NAD27, accuracy ±25 m). The surface specific conductance and temperature were measured by using a LabComp meter. No measurements were made of the velocity at sites 1223 through 1227 because of the shallow water and lack of time.

CURRENT METER EQUATION: V(m/s)=0.668*rev/s + 0.006

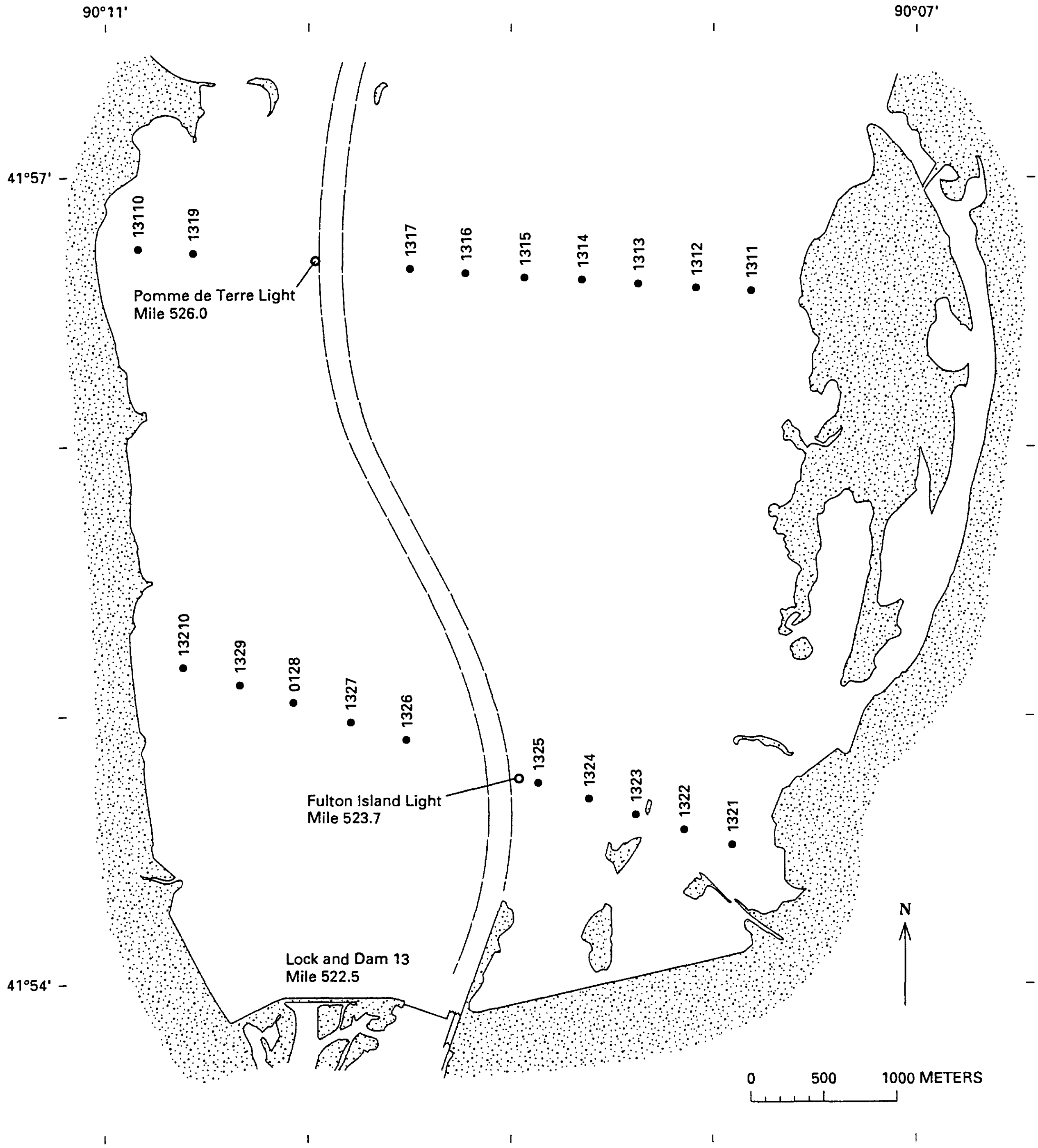
BEARING OF TRANSECT: 079° magnetic

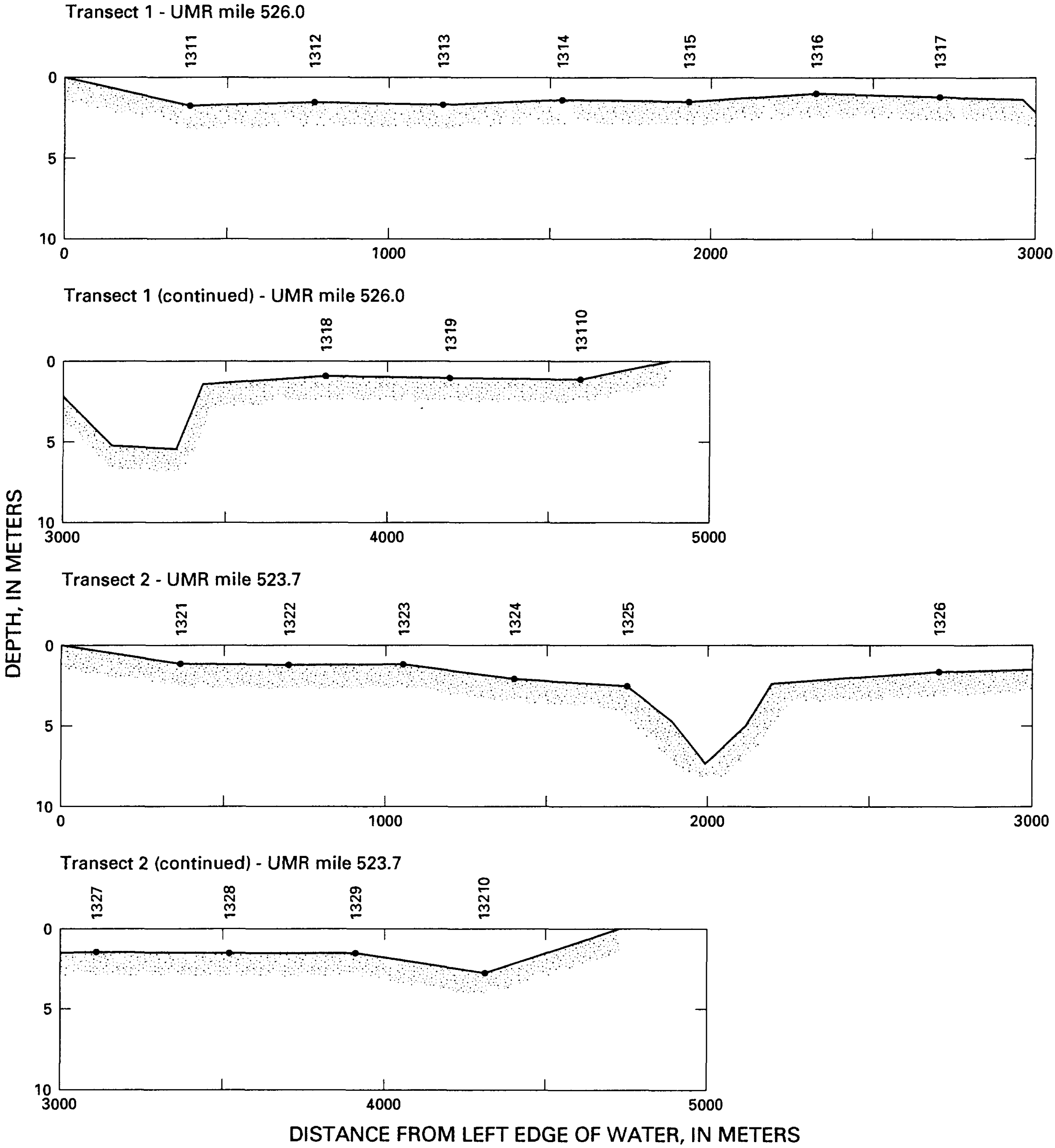
Site	NAD27 Latitude N	NAD27 Longitude W	Depth (m)	Surface Conductance (µS/cm)	Surface Temperature (°C)	Velocity (m/s)	Direction (°magnetic)	Surficial bed sediment
LEW			0.0					
1221	42°17.112	090°24.399	0.6	425	33.4	0.09	180	mud
1222	17.089	24.506	0.6	424	32.2	0.12	220	mud
1223	17.079	24.591	0.3	427	32.7	--	--	mud
1224	17.069	24.681	0.3	420	33.8	--	--	mud
1225	17.054	24.770	0.4	437	30.4	--	--	mud, lily pads
1226	17.044	24.868	0.5	438	29.5	--	--	--
1227	42°17.032	090°24.966	1.3	438	30.8	--	--	--
REW			0.0					

STATION: Mississippi River in Pool 12, Transect 3--UMR mile 560.7
PARTY: Moody, Sullivan, and Writer
DATE: June 22, 1994
GAGE HEIGHT at Dam 11 TW: 595.10 ft
GAGE HEIGHT at Dam 12: 592.08 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 21.8×10^{-6}
CURRENT METER No: W-223906
DATE RATED: 06-25-92
MAP: USGS 7.5-minute quadrangle is Bellevue, Iowa-Ill.
REMARKS:
Resampled sites using differential GPS. The error is estimated to be about ±5 m. The GPS reference station was located at the tip of the outer auxiliary lockwall (42°15.695 N, 090°25.350 W, NAD 27, accuracy ±25 m). The surface specific conductance and temperature were measured by using a LabComp meter.

CURRENT METER EQUATION: V(m/s)=0.668*rev/s + 0.006
BEARING OF TRANSECT: 039° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Depth (m)	Surface Conductance (μS/cm)	Surface Temperature (°C)	Velocity (m/s)	Direction (°magnetic)	Surficial bed sediment
LEW			0.0					
1231	42°19.64	090°24.25	0.6	496	30.5	<0.05	--	mud
1232	19.58	24.36	1.3	473	29.2	0.07	150	mud
1233	19.52	24.42	1.0	456	30.4	0.08	170	mud
1234	19.44	24.49	1.2	458	31.4	0.06	170	mud
1235	42°19.45	090°24.55	0.2	435	32.9	<0.05	--	mud
REW			0.0					


90°11'
90°07'
41°57'
41°54'
13110
1319
1317
1316
1315
1314
1313
1312
1311
Pomme de Terre Light
Mile 526.0
13210
1329
0128
1327
1326
1325
1324
1323
1322
1321
Fulton Island Light
Mile 523.7
Lock and Dam 13
Mile 522.5
N
0 500 1000 METERS


Transect 1 - UMR mile 526.0
1311
1312
1313
1314
1315
1316
1317
Transect 1 (continued) - UMR mile 526.0
1318
1319
13110
Transect 2 - UMR mile 523.7
1321
1322
1323
1324
1325
1326
Transect 2 (continued) - UMR mile 523.7
1327
1328
1329
13210
DEPTH, IN METERS
DISTANCE FROM LEFT EDGE OF WATER, IN METERS

STATION: Mississippi River in Pool 13, Transect 1--UMR mile 526.0
PARTY: Moody, Sullivan, and Writer
DATE: June 23, 1994
GAGE HEIGHT at Dam 12 TW: 587.42 ft
GAGE HEIGHT at Dam 13: 583.40 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 22.4×10^{-6}
CURRENT METER No: W-223906
DATE RATED: 06-25-92
MAP: USGS 7.5-minute quadrangle is Clinton NW, Iowa-Ill.
REMARKS:

Resampled sites using differential GPS. The error is estimated to be about ±10 m because of wind and waves. The GPS reference station was located at the tip of the center lockwall at Lock 13 (41°53.910 N, 090°09.265 W, NAD27, accuracy ±25 m). The surface specific conductance and temperature were measured by using a LabComp meter. Wind was from the southeast at 2-7 m/s. Measured discharge was 1,250 m^3/s.

CURRENT METER EQUATION: V(m/s)=0.668*rev/s + 0.006
BEARING OF TRANSECT: 095° magnetic

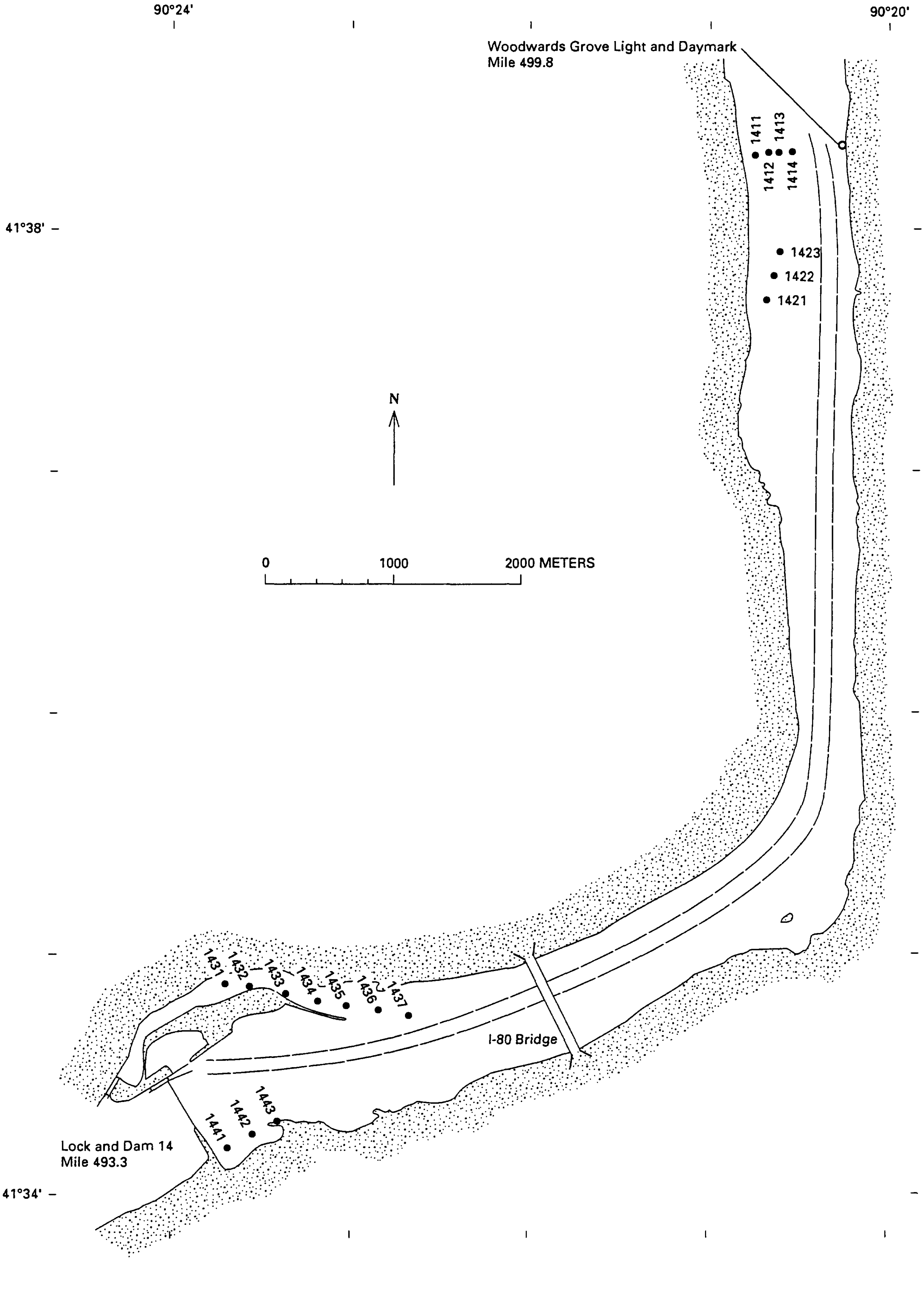
Site	NAD27		Depth (m)	Surface		Velocity (m/s)	Direction (°magnetic)	Surficial bed sediment
	Latitude N	Longitude W		Conductance (µS/cm)	Temperature (°C)			
LEW			0.0					
1311	41°56.575	090°07.808	1.7	447	25.1	0.23	230	mud
1312	56.589	08.073	1.3	436	24.6	0.13	230	mud
1313	56.599	08.363	1.5	443	25.4	0.18	220	mud
1314	56.615	08.650	1.3	434	24.8	0.18	240	mud
1315	56.624	08.930	1.1	435	25.1	0.17	200	sand
1316	56.641	09.223	0.9	442	26.2	0.14	260	sand
1317	56.656	09.504	1.0	451	25.4	0.20	210	sand, mud
09	56.660	09.701	1.9	438	26.7	0.34	160	--
08	56.660	09.843	5.0	448	25.8	0.42	170	--
07	56.676	09.955	5.2	449	25.6	0.42	170	--
06	56.687	10.044	1.2	450	25.4	0.22	210	--
1318	56.708	10.291	0.8	453	24.0	0.14	250	mud
1319	56.723	10.576	0.8	437	25.2	0.10	240	mud
13110	41°56.729	090°10.857	0.8	430	24.2	0.12	240	mud
REW			0.0					

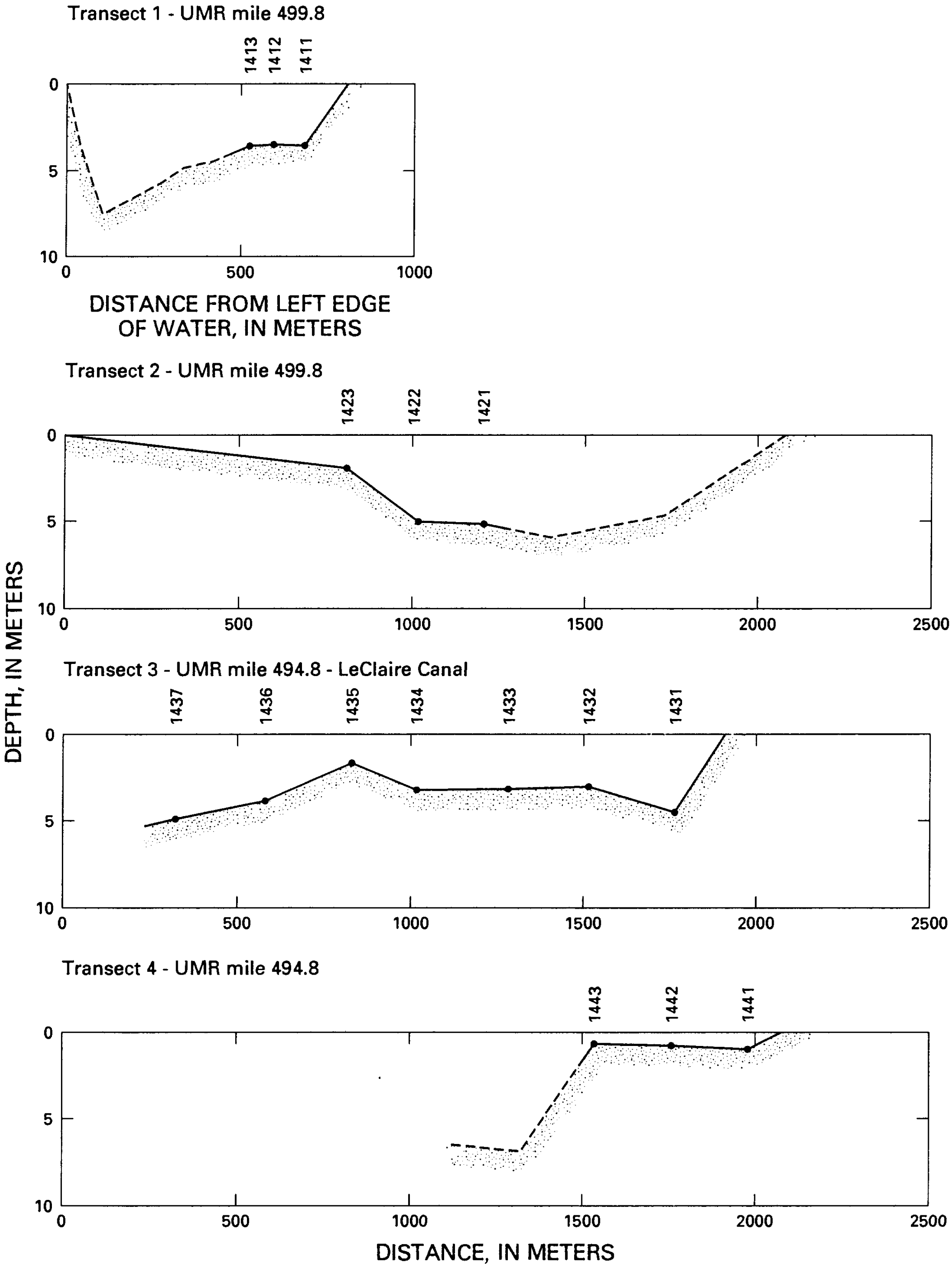
STATION: Mississippi River in Pool 13, Transect 2--UMR mile 523.7
PARTY: Moody, Sullivan, and Writer
DATE: June 23, 1994
GAGE HEIGHT at Dam 12 TW: 587.42 ft
GAGE HEIGHT at Dam 13: 583.40 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 22.4×10^{-6}
CURRENT METER No: W-223906
DATE RATED: 06-25-92
MAP: USGS 7.5-minute quadrangle is Clinton NW, Iowa-Ill.
REMARKS:

Resampled sites using differential GPS. The error is estimated to be about ±10 m because of wind and waves. The GPS reference station was located at the tip of the center lockwall at Lock 13 (41°53.910 N, 090°09.265 W, NAD27, accuracy ±25 m). Biological Resources Division collected a sample at site 1322. The surface specific conductance and temperature were measured by using a LabComp meter. Wind was from the southeast at 2-7 m/s. At sites 1324 and 1325 the boat drifted about 10 to 20 m (probably to the west) after the van Veen grab was collected and before the location was recorded. Measured discharge was 1,290 m^3/s.

CURRENT METER EQUATION: V(m/s)=0.668*rev/s + 0.006
BEARING OF TRANSECT: 107° magnetic

Site	NAD27		Depth (m)	Surface		Velocity (m/s)	Direction (°magnetic)	Surficial bed sediment
	Latitude N	Longitude W		Conductance (µS/cm)	Temperature (°C)			
LEW			0.0					
1321	41°54.512	090°07.897	1.0	339	24.8	<0.05	--	mud
1322	54.577	08.134	1.0	427	23.2	0.05	150	mud
1323	54.636	08.385	1.1	448	24.6	0.10	200	sand
1324	54.700	08.622	1.8	460	25.0	0.13	200	mud
1325	54.758	08.879	2.1	448	24.2	0.13	180	mud
04	54.774	08.908	1.9	443	24.8	0.16	220	--
05	54.754	08.967	4.2	445	24.4	0.22	180	--
03	54.763	09.031	7.7	450	25.6	0.29	150	--
02	54.794	09.112	5.1	446	26.2	0.31	170	--
01	54.825	09.178	2.1	451	25.7	0.28	160	--
1326	54.918	09.524	1.6	459	24.8	0.16	170	mud
1327	54.990	09.807	1.5	452	24.5	0.19	170	mud, shells
1328	55.059	10.084	1.3	448	24.8	0.22	150	mud
1329	55.129	10.346	1.3	448	25.0	0.21	150	mud
13210	41°55.201	090°10.637	2.3	437	25.3	0.23	160	mud
REW			0.0					


90°24'
90°20'
Woodwards Grove Light and Daymark
Mile 499.8
41°38'
41°34'
1411
1412
1413
1414
1421
1422
1423
N
0
1000
2000 METERS
1431
1432
1433
1434
1435
1436
1437
I-80 Bridge
1441
1442
1443
Lock and Dam 14
Mile 493.3



Transect 1 - UMR mile 499.8
1413
1412
1411
0
5
10
0
500
1000
DISTANCE FROM LEFT EDGE OF WATER, IN METERS
Transect 2 - UMR mile 499.8
1423
1422
1421
0
5
10
0
500
1000
1500
2000
2500
DEPTH, IN METERS
Transect 3 - UMR mile 494.8 - LeClaire Canal
1437
1436
1435
1434
1433
1432
1431
0
5
10
0
500
1000
1500
2000
2500
Transect 4 - UMR mile 494.8
1443
1442
1441
0
5
10
0
500
1000
1500
2000
2500
DISTANCE, IN METERS

STATION: Mississippi River in Pool 14, Transect 1 and 2--UMR mile 499.8
PARTY: Moody, Sullivan, and Writer
DATE: June 23, 1994
GAGE HEIGHT at Dam 13 TW: 575.80 ft
GAGE HEIGHT at Dam 14: 572.24 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 22.5 x 10^{-6}
CURRENT METER No: W-223906
DATE RATED: 06-25-92
MAP: USGS 7.5-minute quadrangle is Cordova, Ill.-Iowa
REMARKS:

Resampled sites using differential GPS. The error is estimated to be about ±50 m because of wind and waves. The surface specific conductance and temperature were measured by using a LabComp meter.

CURRENT METER EQUATION: V(m/s)=0.668*rev/s + 0.006
BEARING OF TRANSECT 1: 088° magnetic
BEARING OF TRANSECT 2: 191° magnetic

Site	NAD27 Latitude N	NAD27 Longitude W	Depth (m)	Surface Conductance (µS/cm)	Surface Temperature (°C)	Velocity (m/s)	Direction (°magnetic)	Surficial bed sediment
REW			0.0					
1411	41°38.30	090°20.78	3.6	462	25.8	0.29	160	mud
1412	38.31	20.70	3.5	440	27.5	0.34	150	sand
1413	38.31	20.65	3.2	443	27.6	0.27	160	sand
1421	37.71	20.71	5.0	457	26.2	0.38	190	sand
1422	37.79	20.68	5.0	446	27.3	0.36	180	mud, sand
1423	41°37.91	090°20.64	1.9	453	26.5	0.29	180	mud, sand

STATION: Mississippi River in Pool 14, Transect 3 and 4--UMR mile 494.8

PARTY: Moody, Sullivan, and Writer — DATE: June 24, 1994

GAGE HEIGHT at Dam 13 TW: 576.41 ft — GAGE HEIGHT at Dam 14: 572.45 ft

SUSPENSION: 15-pound weight — RIVER SLOPE: 25.0 x 10^{-6}

CURRENT METER No: W-223906 — DATE RATED: 06-25-92

MAP: USGS 7.5-minute quadrangle is Silvis, Iowa-Ill.

REMARKS:

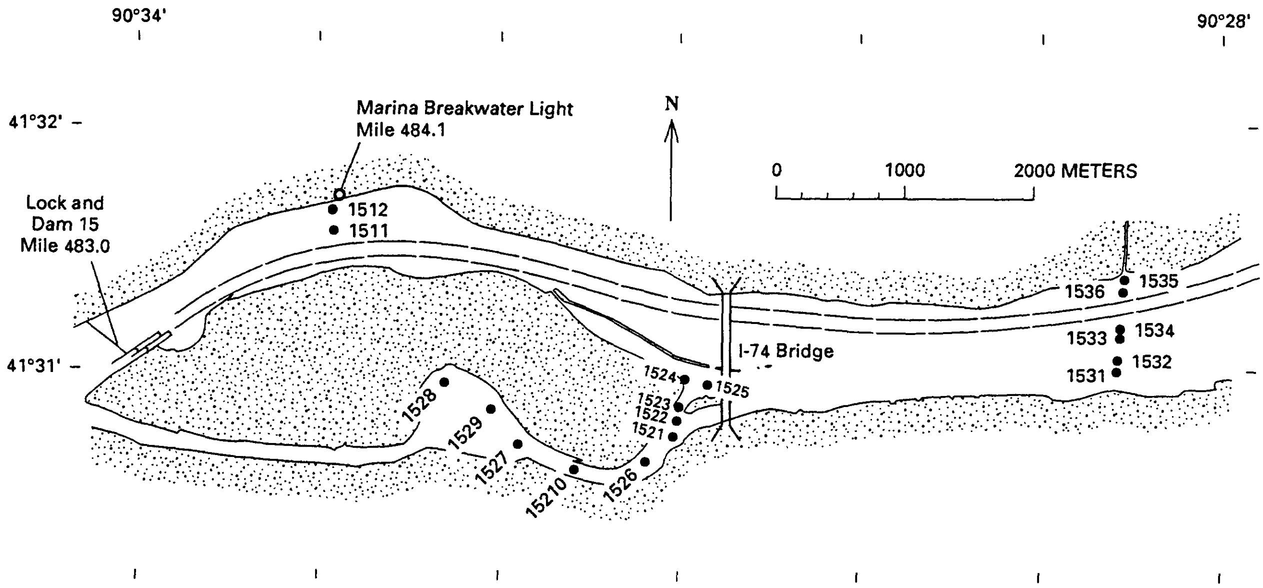
Resampled sites using differential GPS. The error is estimated to be about ±5 m. The GPS reference station was located at the upstream tip of the dam-side lockwall where the narrower guidewall begins (41°34.480 N, 090°23.955 W, NAD27, accuracy ±25 m). The surface specific conductance and temperature were measured by using a LabComp meter. Biological Resources Division collected a sample from site 1433.

CURRENT METER EQUATION: V(m/s)=0.668*rev/s + 0.006

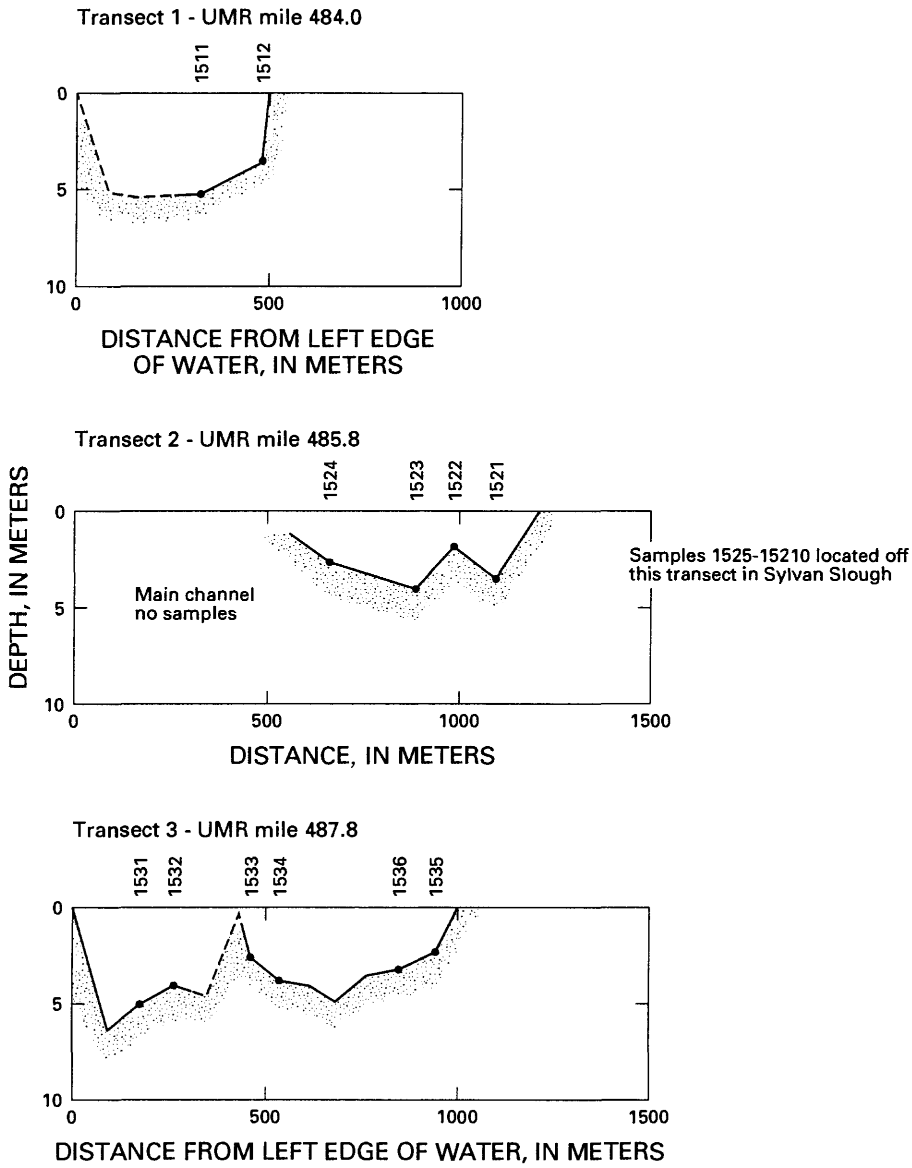
BEARING OF TRANSECT 1: 096° magnetic

BEARING OF TRANSECT 2: 056° magnetic

Site	NAD27		Depth (m)	Surface		Velocity (m/s)	Direction (°magnetic)	Surficial bed sediment
	Latitude N	Longitude W		Conductance (μS/cm)	Temperature (°C)			
1431	41°34.871	090°23.681	4.3	466	24.6	0.10	130	mud
1432	34.849	23.534	2.9	460	26.5	0.07	110	sand
1433	34.821	23.339	3.2	457	26.5	0.06	140	mud
1434	34.797	23.147	2.9	457	25.7	0.07	120	mud
1435	34.777	23.002	1.8	470	25.5	0.16	260	mud
1436	34.752	22.841	3.5	463	25.2	0.38	240	sand
1437	34.729	22.670	4.7	453	25.1	0.47	260	sand
1441	34.177	23.665	0.9	450	23.4	0.06	120	mud
1442	34.229	23.524	0.8	475	24.1	--	--	mud
1443	41°34.298	090°23.395	0.5	482	24.3	--	--	



90°34'
90°28'
41°32'
41°31'
Marina Breakwater Light
Mile 484.1
N
0
1000
2000 METERS
Lock and
Dam 15
Mile 483.0
1512
1511
1536
1535
1533
1534
1531
1532
I-74 Bridge
1524
1525
1523
1522
1521
1528
1529
1527
15210
1526



Transect 1 - UMR mile 484.0
1511
1512
0
5
10
0
500
1000
DISTANCE FROM LEFT EDGE
OF WATER, IN METERS
Transect 2 - UMR mile 485.8
1524
1523
1522
1521
DEPTH, IN METERS
Main channel
no samples
Samples 1525-15210 located off
this transect in Sylvan Slough
0
5
10
0
500
1000
1500
DISTANCE, IN METERS
Transect 3 - UMR mile 487.8
1531
1532
1533
1534
1536
1535
0
5
10
0
500
1000
1500
DISTANCE FROM LEFT EDGE OF WATER, IN METERS

STATION: Mississippi River in Pool 15, Transect 1--UMR mile 484.0
PARTY: Moody, Johnson, and Martin
DATE: June 26, 1994
GAGE HEIGHT at Dam 14 TW: 563.72 ft
GAGE HEIGHT at Dam 15: 561.20 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 47.8 x 10^{-6}
CURRENT METER No: W-223906
DATE RATED: 06-25-92
MAP: USGS 7.5-minute quadrangle is Davenport East, Iowa-Ill.
REMARKS:

Resampled sites using differential GPS navigation beacon located in East St. Louis, Ill. The estimated error in site location is about ±5 m. The surface specific conductance and temperature were measured by using a LabComp meter.

CURRENT METER EQUATION: V(m/s)=0.668*rev/s + 0.006
BEARING OF TRANSECT 1: 174° magnetic

Site	NAD83 Latitude N	NAD83 Longitude W	Depth (m)	Surface Conductance (µS/cm)	Surface Temperature (°C)	Velocity (m/s)	Direction (°magnetic)	Surficial bed sediment
1511	41°31.570	090°32.877	5.0	444	24.7	0.71	270	sand
1512	41°31.664	090°32.863	3.5	434	23.6	<0.05	--	mud

STATION: Mississippi River in Pool 15, Transect 2--UMR mile 485.8
PARTY: Moody, Johnson, and Martin
DATE: June 26, 1994
GAGE HEIGHT at Dam 14 TW: 563.72 ft
GAGE HEIGHT at Dam 15: 561.20 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 47.8×10^{-6}
CURRENT METER No: W-223906
DATE RATED: 06-25-92
MAP: USGS 7.5-minute quadrangle is Davenport East, Iowa-Ill.
REMARKS:

Resampled sites using differential GPS navigation beacon located in East St. Louis, Ill. The estimated error in site location is about ±5 m. The surface specific conductance and temperature were measured by using a LabComp meter. No grab sample was collected from sites 1522 and 1525. Biological Resources Division collected a sample from site 1529.

CURRENT METER EQUATION: V(m/s)=0.668*rev/s + 0.006
BEARING OF TRANSECT: 003° magnetic

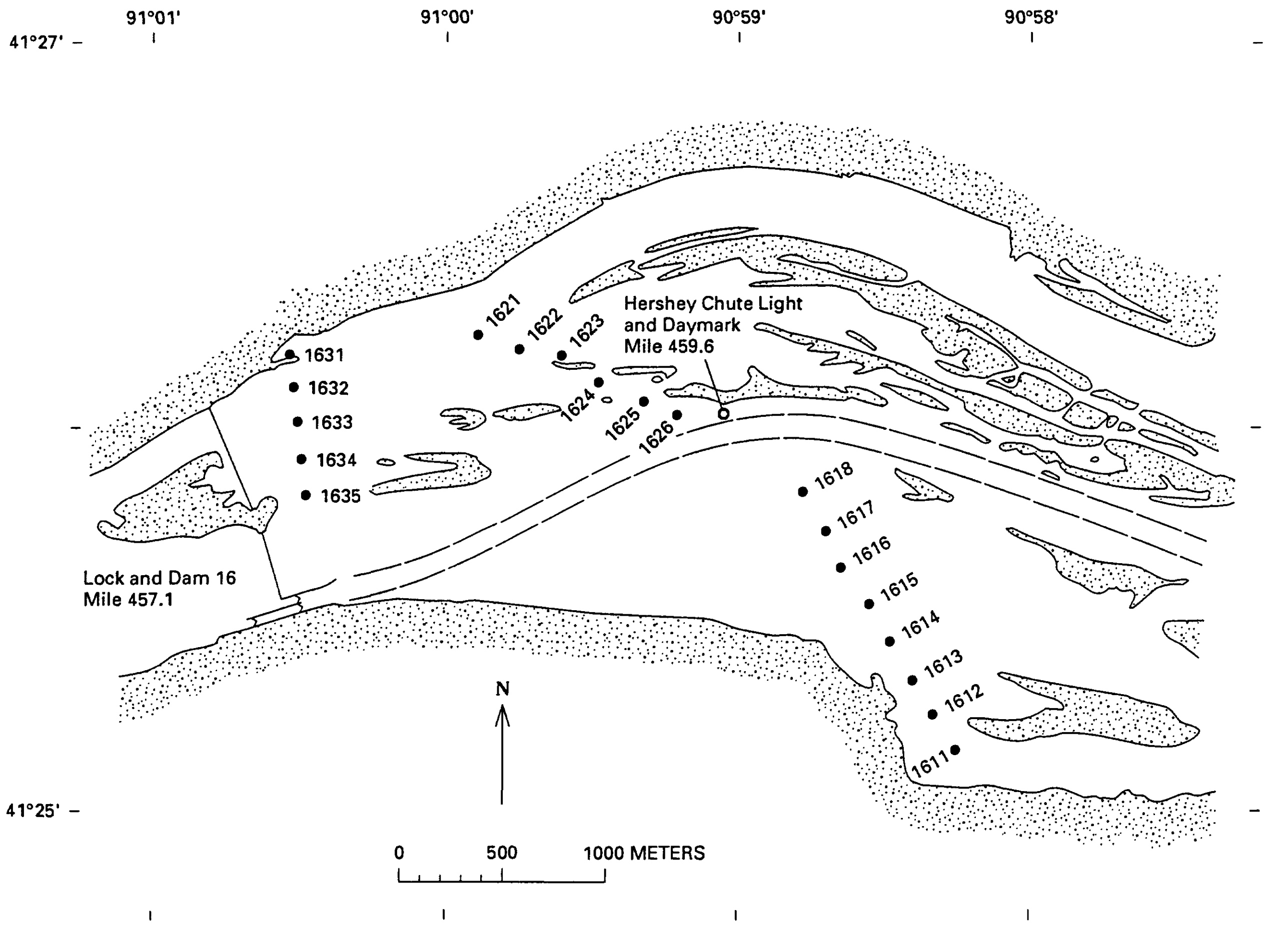
Site	NAD83		Depth	Surface		Velocity	Direction	Surficial
	Latitude N	Longitude W	(m)	Conductance (µS/cm)	Temperature (°C)	(m/s)	(°magnetic)	bed sediment
1521	41°30.738	090°30.982	3.2	452	24.7	0.42	210	mud
1522	30.798	30.964	1.6	445	25.1	0.27	230	shells
1523	30.853	30.949	3.9	445	25.1	0.29	200	mud
1524	30.977	30.920	2.7	446	25.0	0.31	280	mud
The following sites were not on the transect, but in the backwater area of Sylvan Slough upstream from Sylvan Island.								
1525	30.948	30.790	2.3	441	25.3	0.36	290	shells, sand
1526	30.633	31.112	3.5	453	24.8	0.20	180	mud
1527	30.702	31.837	0.8	450	24.4	0.13	310	mud
1528	30.946	32.249	1.1	447	24.5	0.11	250	mud
1529	30.837	31.989	0.5	443	23.7	--	--	mud
15210	41°30.595	090°31.526	2.0	451	24.7	0.31	300	mud

STATION: Mississippi River in Pool 15, Transect 3--UMR mile 487.8
PARTY: Moody, Johnson, and Martin
DATE: June 26, 1994
GAGE HEIGHT at Dam 14 TW: 563.72 ft
GAGE HEIGHT at Dam 15: 561.20 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 47.8×10^{-6}
CURRENT METER No: W-223906
DATE RATED: 06-25-92
MAP: USGS 7.5-minute quadrangle is Silvis, Ill.-Iowa
REMARKS:

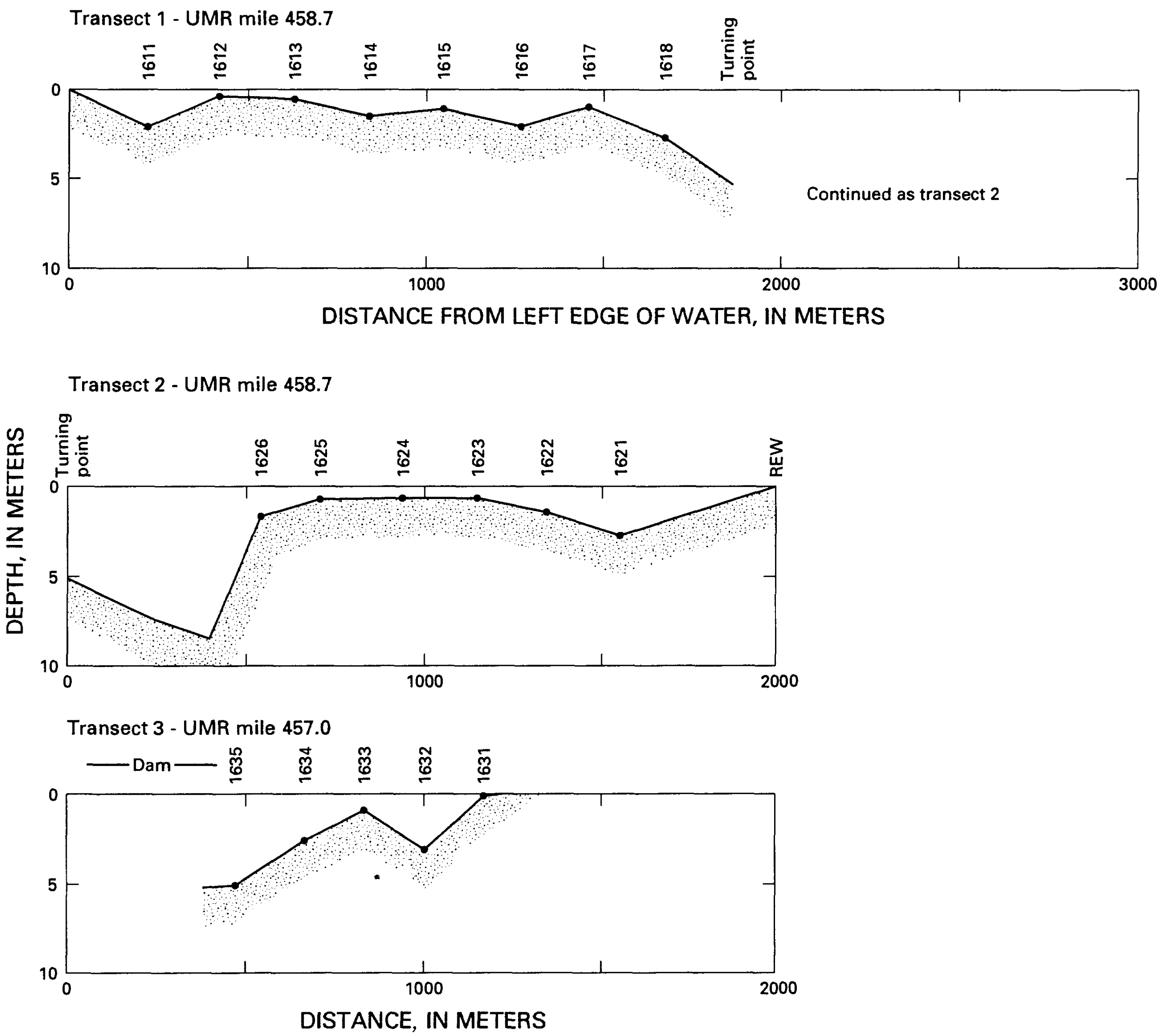
Resampled sites using differential GPS navigation beacon located in East St. Louis, Ill. The estimated error in site location is about ±5 m. The surface specific conductance and temperature were measured by using a LabComp meter. No grab sample was collected from sites 1532 and 1535.

CURRENT METER EQUATION: V(m/s)=0.668*rev/s + 0.006
BEARING OF TRANSECT: 003° magnetic

Site	NAD83 Latitude N	NAD83 Longitude W	Depth (m)	Surface Conductance (µS/cm)	Surface Temperature (°C)	Velocity (m/s)	Direction (°magnetic)	Surficial bed sediment
1531	41°31.010	090°28.537	4.7	446	25.2	0.52	290	mud, sand
1532	31.062	28.527	3.5	447	25.3	0.66	270	sand, rocks
1533	31.157	28.518	2.6	428	26.9	0.47	270	mud, sand
1534	31.145	28.516	3.5	443	25.5	0.71	260	sand
1535	31.392	28.499	2.3	429	27.0	0.55	240	sand, rocks
1536	41°31.339	090°28.496	3.3	430	26.6	0.65	270	sand



91°01'
91°00'
90°59'
90°58'
41°27'
41°25'
Hershey Chute Light
and Daymark
Mile 459.6
Lock and Dam 16
Mile 457.1
1611
1612
1613
1614
1615
1616
1617
1618
1621
1622
1623
1624
1625
1626
1631
1632
1633
1634
1635
N
0
500
1000 METERS


Transect 1 - UMR mile 458.7
1611
1612
1613
1614
1615
1616
1617
1618
Turning point
Continued as transect 2
DISTANCE FROM LEFT EDGE OF WATER, IN METERS
Transect 2 - UMR mile 458.7
Turning point
1626
1625
1624
1623
1622
1621
REW
DEPTH, IN METERS
Transect 3 - UMR mile 457.0
Dam
1635
1634
1633
1632
1631
DISTANCE, IN METERS

STATION: Mississippi River in Pool 16, Transect 1--UMR mile 458.7
PARTY: Moody, Johnson, and Martin
DATE: June 27, 1994
GAGE HEIGHT at Dam 15 TW: 551.02 ft
GAGE HEIGHT at Dam 16: 544.49 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 47.7×10^{-6}
CURRENT METER No: W-223906
DATE RATED: 06-25-92
MAP: USGS 7.5-minute quadrangle is Illinois City, Iowa-Ill.
REMARKS:
Resampled sites using differential GPS navigation beacon located in East St. Louis, Ill. The estimated error in site location is about ±5 m. Differential GPS was checked by comparing the GPS-derived coordinates for the tip of the guidewall closest to the dam (41°25.588 N, 091°00.456 W, NAD27) with coordinates taken from the Muscatine, Iowa-Ill., quadrangle (41°25.580 N, 091°00.460 W, NAD27). The difference is about 14 m in latitude and 6 m in longitude. The surface specific conductance and temperature were measured by using a LabComp meter. Some stratification was observed in the core samples, with coarser silt on top of finer silt and mud. Biological Resources Division collected a sample at site 1613.

CURRENT METER EQUATION: V(m/s)=0.668*rev/s + 0.006
BEARING OF TRANSECT: 149° magnetic

	NAD83			Surface				
Site	Latitude N	Longitude W	Depth (m)	Conductance (μS/cm)	Temperature (°C)	Velocity (m/s)	Direction (°magnetic)	Surficial bed sediment
LEW			0.0					
1611	41°25.151	090°58.279	1.8	508	23.9	0.51	300	sand
1612	25.233	58.377	0.2	507	23.8	0.16	270	mud
1613	25.350	58.397	0.4	496	24.5	0.45	220	mud, sand
1614	25.450	58.432	1.3	497	24.3	0.60	280	sand
1615	25.545	58.552	1.0	500	24.2	0.28	290	sand
1616	25.634	58.651	2.2	489	24.5	0.78	250	sand, peloids
1617	25.731	58.703	0.5	492	24.5	0.25	300	mud
1618	41°25.832	090°58.788	2.5	463	24.9	0.65	290	mud

STATION: Mississippi River in Pool 16, Transect 2--UMR mile 458.7
PARTY: Moody, Johnson, and Martin
DATE: June 27, 1994
GAGE HEIGHT at Dam 15 TW: 551.02 ft
GAGE HEIGHT at Dam 16: 544.49 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 47.7×10^{-6}
CURRENT METER No: W-223906
DATE RATED: 06-25-92
MAP: USGS 7.5-minute quadrangle is Illinois City, Iowa-Ill.
REMARKS:

Resampled sites using differential GPS navigation beacon located in East St. Louis, Ill. The estimated error in site location is about ±5 m. Differential GPS was checked by comparing the GPS-derived coordinates for the tip of the guidewall closest to the dam (41°25.588 N, 091°00.456 W, NAD83) with coordinates taken from the Muscatine, Iowa-Ill. quadrangle (41°25.580 N, 091°00.460 W, NAD27). The difference is about 14 m in latitude and 6 m in longitude.

Several sites could not be resampled because locations were on land, resulting from a 0.3-m lower pool elevation and perhaps deposition of sediment along the downstream edges of islands by the flood of 1993. Site 1621 was sampled 60 m south, site 1622 was sampled 39 m south and 31 m west; site 1623 was sampled 44 m south and 16 m east; and site 1624 was sampled 17 m south of the original sampling sites. In pools farther downstream, if the site was out of water, it was sampled out of water at the original location.

The surface specific conductance and temperature were measured by using a LabComp meter. A lot of mud was stirred up trying to reach site 1623, which may have affected the specific conductance. Some stratification was observed in the core samples, with coarser silt on top of finer silt and mud.

CURRENT METER EQUATION: V(m/s)=0.668*rev/s + 0.006
BEARING OF TRANSECT: 112° magnetic

	NAD83			Surface				
Site	Latitude N	Longitude W	Depth (m)	Conductance (μS/cm)	Temperature (°C)	Velocity (m/s)	Direction (°magnetic)	Surficial bed sediment
REW			0.0					
1621	41°26.202	090°59.898	2.3	432	27.0	0.49	220	mud
1622	26.174	59.792	1.3	437	27.1	0.35	240	mud
1623	26.131	59.636	0.2	504	27.4	0.11	280	mud
1624	26.106	59.490	0.2	439	26.5	--	--	mud
1625	26.066	59.329	0.3	443	25.6	0.18	270	mud
1626	41°26.048	090°59.218	1.3	445	25.6	0.24	270	mud

STATION: Mississippi River in Pool 16, Transect 3--UMR mile 457.0
PARTY: Moody, Johnson, and Martin
GAGE HEIGHT at Dam 15 TW: 551.02 ft
SUSPENSION: 15-pound weight
CURRENT METER No: W-223906
MAP: USGS 7.5-minute quadrangle is Muscatine, Iowa-Ill.
REMARKS:

DATE: June 27, 1994
GAGE HEIGHT at Dam 16: 544.49 ft
RIVER SLOPE: 47.7×10^{-6}
DATE RATED: 06-25-92

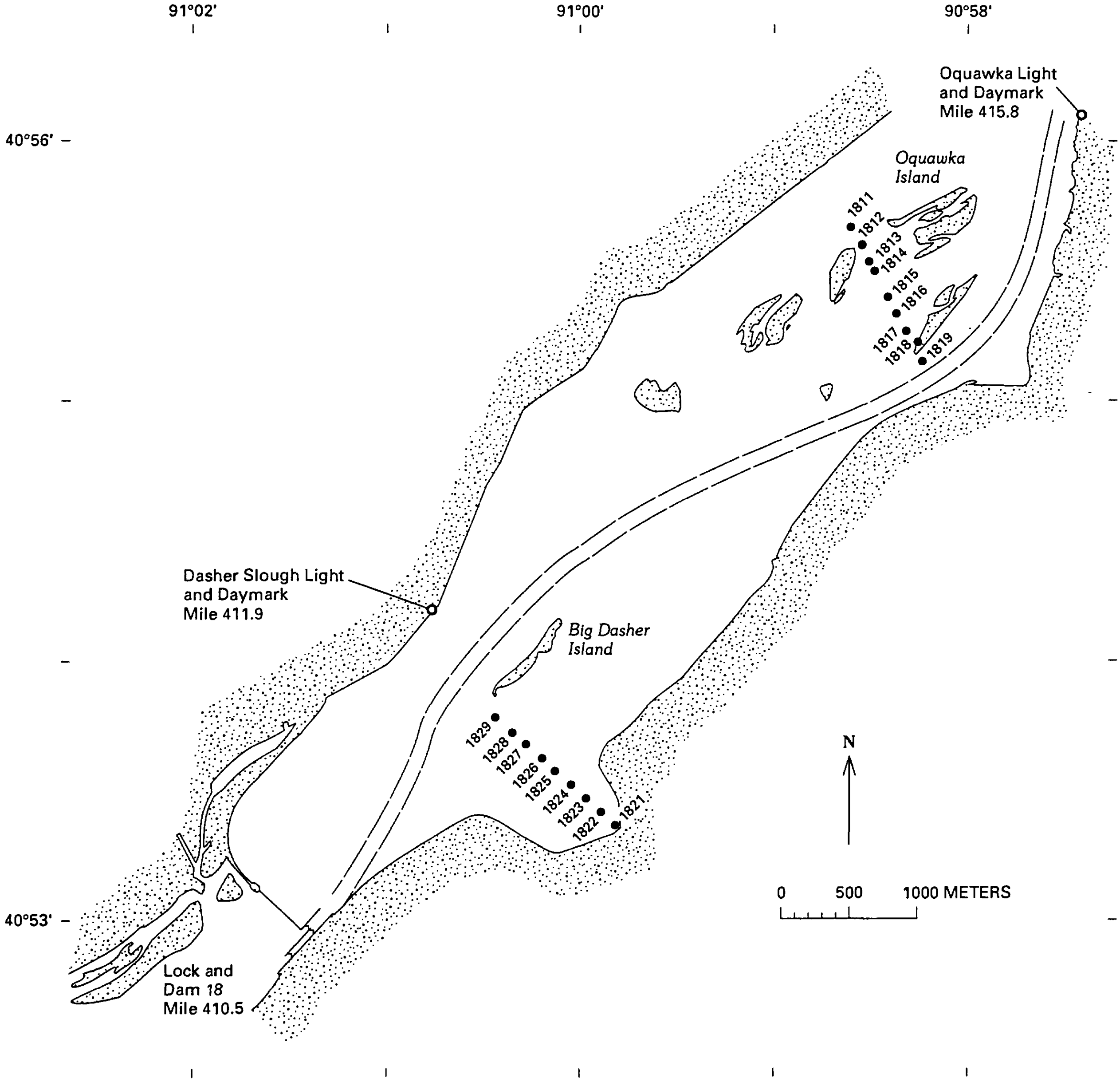
Resampled sites using differential GPS navigation beacon located in East St. Louis, Ill. The estimated error in site location is about ±5 m. Differential GPS was checked by comparing the GPS-derived coordinates for the tip of the guidewall closest to the dam (41°25.588 N, 091°00.456 W, NAD83) with coordinates taken from the Muscatine, Iowa-Ill., quadrangle (41°25.588 N, 091°00.460 W, NAD 83). The difference is about 14 m in latitude and 6 m in longitude.

Several sites could not be resampled because locations were on land, resulting from a 0.3 m-lower pool elevation and perhaps deposition of sediment along the downstream edges of islands by the flood of 1993. Site`1631 was sampled 44 m east of original sampling site.

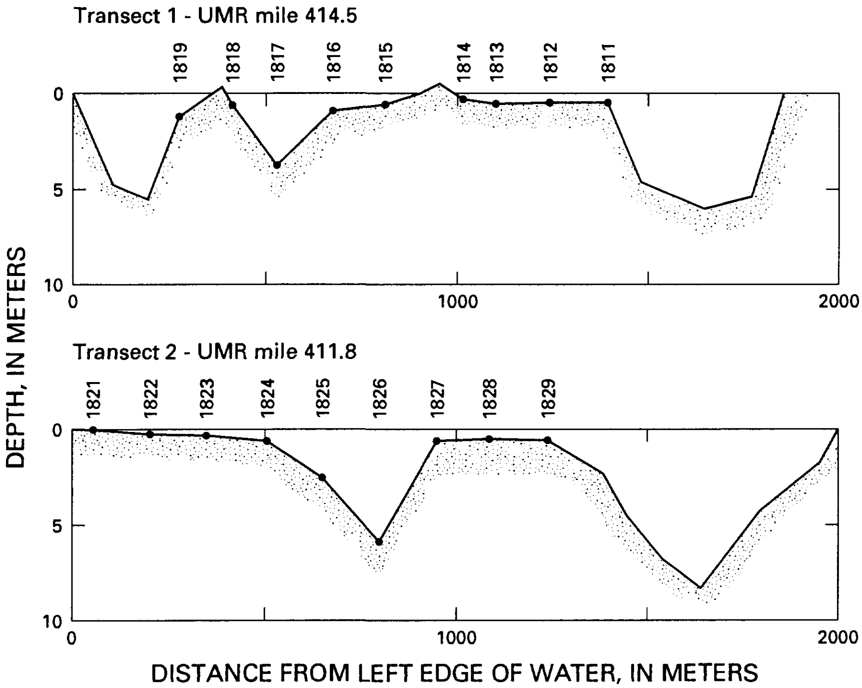
The surface specific conductance and temperature were measured by using a LabComp meter.

CURRENT METER EQUATION: V(m/s)=0.668*rev/s + 0.006
BEARING OF TRANSECT: 173° magnetic

Site	NAD83 Latitude N	NAD83 Longitude W	Depth (m)	Surface Conductance (μS/cm)	Surface Temperature (°C)	Velocity (m/s)	Direction (°magnetic)	Surficial bed sediment
REW			0.0					
1631	41°26.182	091°00.538	0.2	454	28.4	--	--	mud
1632	26.099	00.553	3.0	437	26.4	0.55	220	sand
1633	26.002	00.534	0.7	436	26.8	0.22	180	mud
1634	25.910	00.526	2.5	432	27.2	0.37	200	mud
1635	41°25.817	090°00.513	5.0	433	27.2	0.73	200	sand



91°02'
91°00'
90°58'
40°56'
40°53'
Oquawka Light and Daymark Mile 415.8
Oquawka Island
1811
1812
1813
1814
1815
1816
1817
1818
1819
Dasher Slough Light and Daymark Mile 411.9
Big Dasher Island
1821
1822
1823
1824
1825
1826
1827
1828
1829
N
0 500 1000 METERS
Lock and Dam 18 Mile 410.5



Transect 1 - UMR mile 414.5
1819
1818
1817
1816
1815
1814
1813
1812
1811
Transect 2 - UMR mile 411.8
1821
1822
1823
1824
1825
1826
1827
1828
1829
DEPTH, IN METERS
0
5
10
0
1000
2000
DISTANCE FROM LEFT EDGE OF WATER, IN METERS

STATION: Mississippi River in Pool 18, Transect 1--UMR mile 414.5
PARTY: Moody, Johnson, and Martin
GAGE HEIGHT at Dam 17 TW: 535.19 ft
SUSPENSION: 15-pound weight
CURRENT METER No: W-223906
MAP: USGS 7.5-minute quadrangle is Oquawka, Ill.-Iowa
DATE: June 28, 1994
GAGE HEIGHT at Dam 18: 527.75 ft
RIVER SLOPE: 54.2×10^{-6}
DATE RATED: 06-25-92

REMARKS:

Resampled sites using differential GPS navigation beacon located in East St. Louis, Ill. The estimated error in site location is about ±5 m. The surface specific conductance and temperature were measured by using a LabComp meter. Pool elevation was 0.1 m lower than on April 22, 1992, when the pool was first sampled, and 3.8 m lower than the maximum 1993 flood elevation. Some deposition may have occurred between sites 1811 and 1812 because there was land between the two sites in 1994 where there was water in 1992. Site 1812 was sampled 60 m south and 33 m east, site 1813 was sampled 10 m northwest, site 1814 was sampled 33 m east, and site 1818 was sampled 26 m east of the original sampling site. Measured discharge was 2,720 m^3/s.

CURRENT METER EQUATION: V(m/s)=0.668*rev/s + 0.006
BEARING OF TRANSECT: 149° magnetic

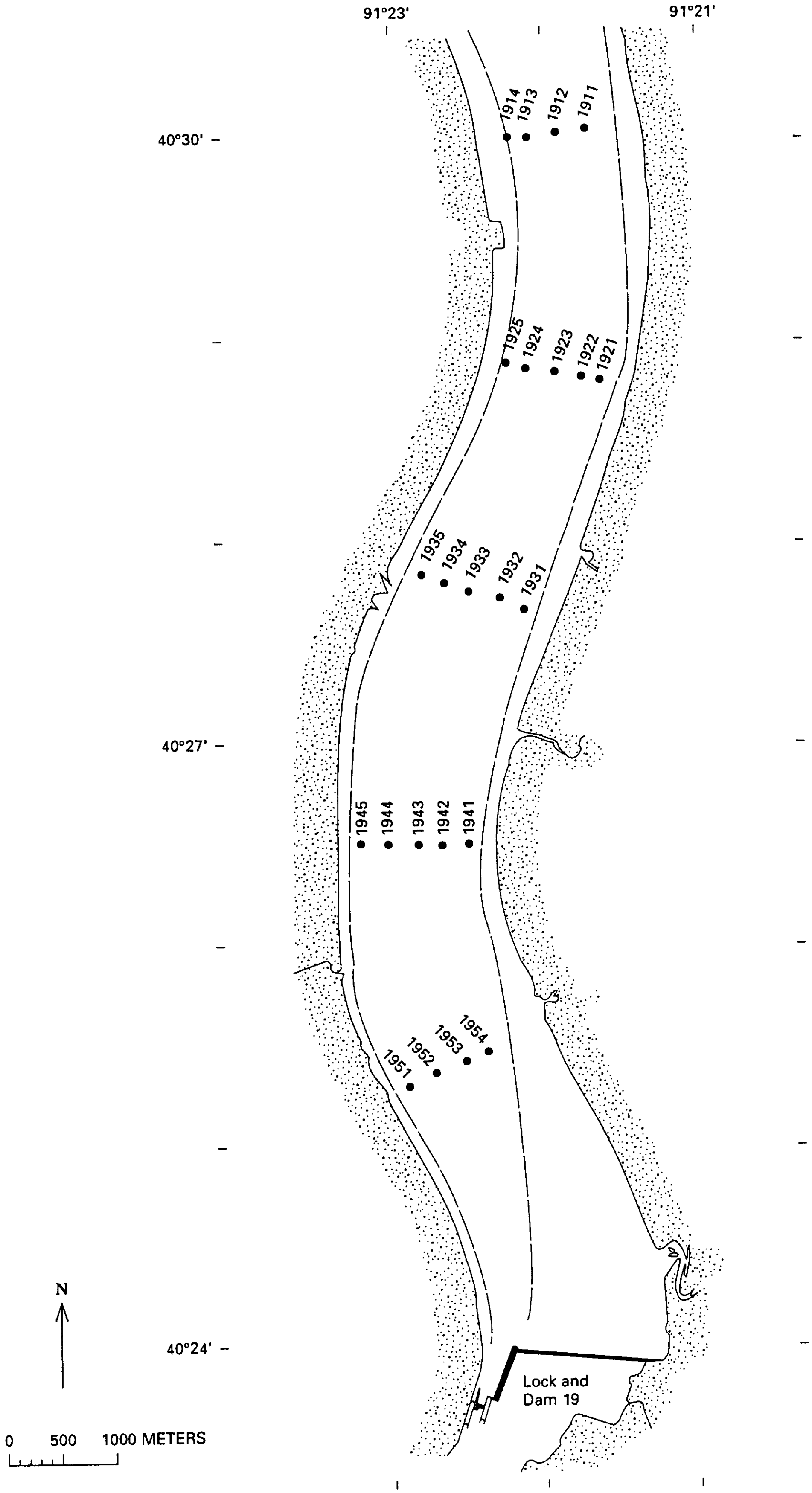
Site	NAD83 Latitude N	NAD83 Longitude W	Depth (m)	Surface Conductance (µS/cm)	Surface Temperature (°C)	Velocity (m/s)	Direction (°magnetic)	Surficial bed sediment
LEW	40°55.029	090°58.149	0.0	457	26.0	0.00	--	--
08	55.047	58.185	4.6	459	25.7	0.69	220	--
09	55.095	58.212	5.5	461	25.6	0.76	220	--
1819	55.148	58.240	2.0	460	25.9	0.40	210	sand
Island								
1818	55.201	58.298	0.3	455	27.4	0.08	270	mud
1817	55.269	58.331	2.5	456	26.0	0.68	210	sand
1816	55.333	58.376	4.3	444	26.9	0.71	210	sand
1815	55.399	58.423	0.8	446	26.8	0.31	200	muddy sand
Island								
1814	55.502	58.519	0.1	426	31.6	<0.05	--	mud
1813	55.545	58.527	0.2	445	29.6	<0.05	--	mud
1812	55.572	58.552	0.2	428	30.6	<0.05	--	sandy mud
Island								
1811	55.666	58.610	0.7	439	28.5	0.25	210	mud
10	55.711	58.683	4.4	420	29.0	0.64	230	--
11	55.781	58.750	6.0	434	--	0.76	230	--
12	40°55.843	090°58.799	5.3	430	28.5	0.54	230	--
REW			0.0					

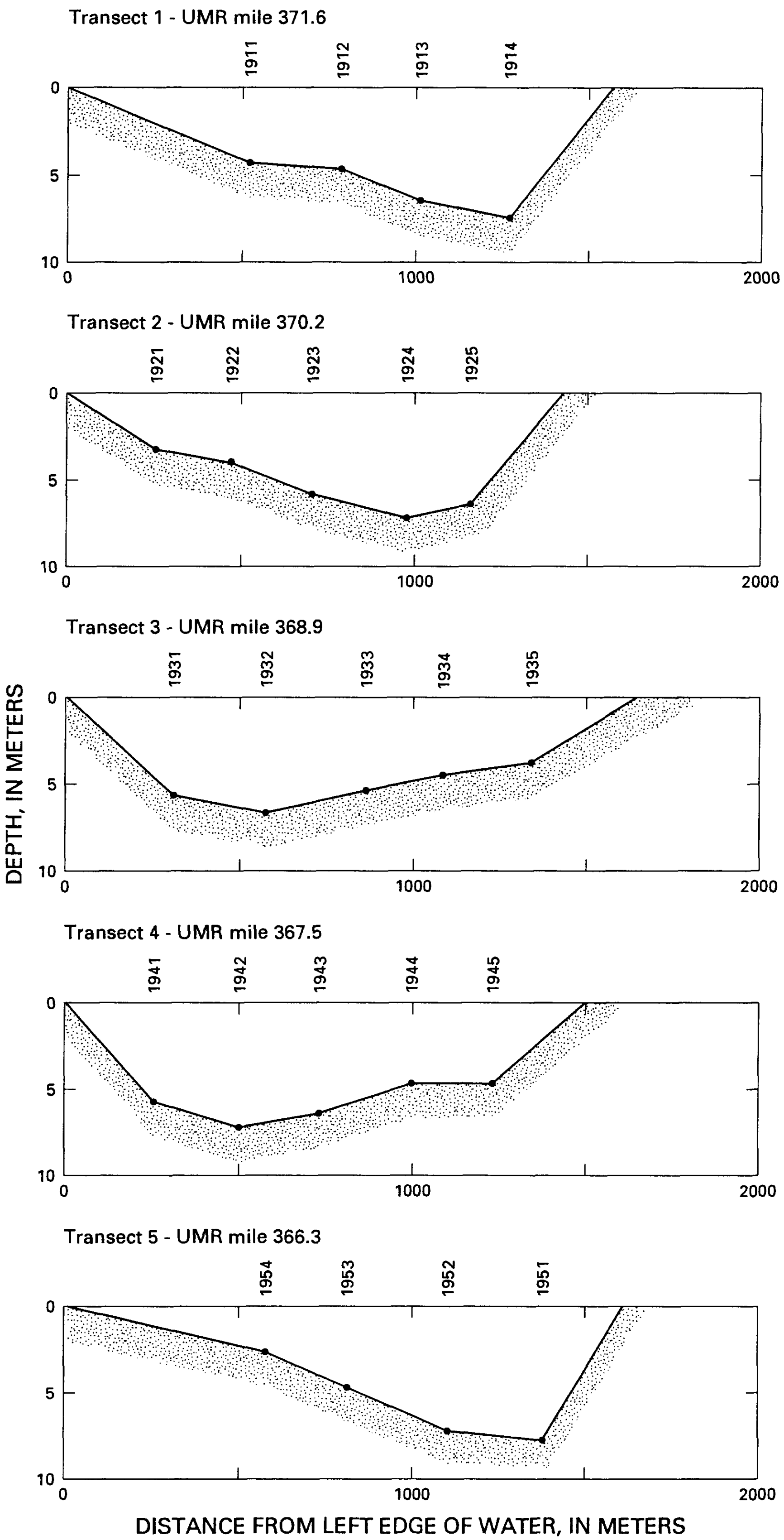
STATION: Mississippi River in Pool 18, Transect 2--UMR mile 411.8
PARTY: Moody, Johnson, and Martin
DATE: June 28, 1994
GAGE HEIGHT at Dam 17 TW: 535.19 ft
GAGE HEIGHT at Dam 18: 527.75 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 54.2×10^{-6}
CURRENT METER No: W-223906
DATE RATED: 06-25-92
MAP: USGS 7.5-minute quadrangle is Oquawka, Ill.-Iowa
REMARKS:

Resampled sites using differential GPS navigation beacon located in East St. Louis, Ill. The estimated error in site location is about ±5 m. The surface specific conductance and temperature were measured by using a LabComp meter. Pool elevation was 0.1 m lower than on April 22, 1992, when the pool was first sampled, and 3.8 m lower than the maximum 1993 flood elevation. Some deposition may have occurred between sites 1821 and 1823 because the water was too shallow to get to site 1821, and site 1822 was resampled 75 m north and 36 m west of the original site. Measured discharge was 2,720 m^3/s. Biological Resources Division collected a sample from site 1823.

CURRENT METER EQUATION: V(m/s)=0.668*rev/s + 0.006
BEARING OF TRANSECT: 129° magnetic

Site	NAD83 Latitude N	NAD83 Longitude W	Depth (m)	Surface Conductance (µS/cm)	Surface Temperature (°C)	Velocity (m/s)	Direction (°magnetic)	Surficial bed sediment
LEW			0.0					
1821	Could not reach this site because the water was less than 0.1 m deep							
1822	40°53.445	090°59.926	0.1	460	22.5	<0.05	--	mud
1823	53.458	59.972	0.2	462	23.7	<0.05	--	mud
1824	53.509	091°00.059	0.4	464	24.3	0.08	010	mud
1825	53.564	00.150	2.1	465	24.3	0.21	240	mud
1826	53.607	00.222	5.9	463	25.1	0.59	210	sand
1827	53.665	00.300	0.6	462	24.7	0.10	130	mud
1828	53.715	00.374	0.6	468	24.8	0.11	130	mud
1829	53.770	00.461	0.6	465	24.9	0.21	120	mud
01	53.824	00.535	1.7	467	24.8	0.31	180	mud
02	53.858	00.582	4.8	467	24.9	0.64	190	--
03	53.894	00.645	7.2	461	25.1	0.71	210	--
04	53.931	00.691	8.3	455	25.2	0.62	210	--
05	53.947	00.721	6.3	453	25.2	0.67	210	--
06	53.975	00.763	4.3	454	25.4	0.76	200	--
07	40°54.046	091°00.848	1.3	454	25.4	0.35	200	--
REW			0.0					


91°23'
91°21'
40°30'
40°27'
40°24'
1914
1913
1912
1911
1925
1924
1923
1922
1921
1935
1934
1933
1932
1931
1945
1944
1943
1942
1941
1954
1953
1952
1951
Lock and Dam 19
N
0 500 1000 METERS


Transect 1 - UMR mile 371.6
1911
1912
1913
1914
Transect 2 - UMR mile 370.2
1921
1922
1923
1924
1925
Transect 3 - UMR mile 368.9
1931
1932
1933
1934
1935
Transect 4 - UMR mile 367.5
1941
1942
1943
1944
1945
Transect 5 - UMR mile 366.3
1954
1953
1952
1951
0
5
10
0
1000
2000
DEPTH, IN METERS
DISTANCE FROM LEFT EDGE OF WATER, IN METERS

STATION: Mississippi River in Pool 19, Transect 1--UMR mile 371.6
PARTY: Moody, Johnson, and Martin
GAGE HEIGHT at Dam 18 TW: 523.52 ft
SUSPENSION: na
CURRENT METER No: na
MAP: USGS 7.5-minute quadrangle is Niota, Ill.-Iowa
REMARKS:

DATE: June 29, 1994
GAGE HEIGHT at Dam 19: 518.14 ft
RIVER SLOPE: 21.7 x 10^{-6}
DATE RATED: 06-25-92

Resampled sites using differential GPS navigation beacon located in East St. Louis, Ill. Sites were resampled within 50 m of the original locations. The surface specific conductance and temperature were measured by using a LabComp meter. No grab sample was collected at site 1914.

BEARING OF TRANSECT: 079° magnetic

Site	Replicate	NAD83 Latitude N	NAD83 Longitude W	Depth (m)	Surface Conductance (µS/cm)	Surface Temperature (°C)	Surficial bed sediment
LEW				0.0			--
1911	1	40°30.075	091°22.872	4.2	--	23.4	--
	2	29.889	22.639	4.1	453	23.9	--
1912	1	30.040	21.931	4.9	457	24.8	--
	2	29.950	22.843	4.0	455	25.1	--
1913	1	30.028	22.105	7.0	451	25.1	mud
	2	29.843	21.940	5.9	453	25.3	mud
1914	1	30.013	22.219	7.3	443	25.1	sand
	2	40°29.784	091°22.101	7.3	--	--	rocks
REW				0.0			

STATION: Mississippi River in Pool 19, Transect 2--UMR mile 370.2
PARTY: Moody, Johnson, and Martin
GAGE HEIGHT at Dam 18 TW: 523.52 ft
SUSPENSION: na
CURRENT METER No: na
MAP: USGS 7.5-minute quadrangle is Hamilton, Ill.-Iowa
DATE: June 29, 1994
GAGE HEIGHT at Dam 19: 518.14 ft
RIVER SLOPE: 21.7 x 10^{-6}
DATE RATED: 06-25-92
REMARKS:

Resampled sites using differential GPS navigation beacon located in East St. Louis, Ill. Sites were resampled within 60 m of the original locations. The surface specific conductance and temperature were measured by using a LabComp meter.

BEARING OF TRANSECT: 094° magnetic

Site	Replicate	NAD83		Depth	Surface		Surficial bed sediment
		Latitude N	Longitude W	(m)	Conductance (µS/cm)	Temperature (°C)	
LEW				0.0			--
1921	1	40°28.835	091°21.594	3.1	453	25.4	--
	2	28.765	21.628	3.4	453	25.7	--
1922	1	28.837	21.763	4.2	455	25.3	--
	2	28.738	21.730	3.7	453	25.4	--
1923	1	28.870	21.901	6.6	452	25.5	--
	2	28.683	21.811	4.5	452	25.7	--
1924	1	28.889	22.153	6.8	447	25.3	--
	2	28.778	22.110	6.9	446	25.6	--
1925	1	28.908	22.213	6.3	440	25.6	mud, sand
	2	40°28.704	091°22.197	6.4	445	25.4	mud, sand
REW				0.0			

STATION: Mississippi River in Pool 19, Transect 3--UMR mile 368.9
PARTY: Moody, Johnson, and Martin
DATE: June 29, 1994
GAGE HEIGHT at Dam 18 TW: 523.52 ft
GAGE HEIGHT at Dam 19: 518.14 ft
SUSPENSION: na
RIVER SLOPE: 21.7 x 10^{-6}
CURRENT METER No: na
DATE RATED: 06-25-92
MAP: USGS 7.5-minute quadrangles are Keokuk, Iowa-Mo.-Ill. and Hamilton, Ill.-Iowa
REMARKS:

Resampled sites using differential GPS navigation beacon located in East St. Louis, Ill. Sites were resampled within 60 m of the original locations. The surface specific conductance and temperature were measured by using a LabComp meter.

BEARING OF TRANSECT: 102° magnetic

Site	Replicate	NAD83		Depth	Surface		Surficial bed sediment
		Latitude N	Longitude W	(m)	Conductance (µS/cm)	Temperature (°C)	
LEW				0.0			--
1931	1	40°27.719	091°22.108	5.1	454	25.9	mud
	2	27.706	22.143	5.5	454	25.6	--
1932	1	27.758	22.285	7.0	453	25.7	--
	2	27.598	22.241	6.3	454	25.4	--
1933	1	27.752	22.476	5.3	448	25.5	sand
	2	27.650	22.438	5.9	451	25.3	sand
1934	1	27.829	22.656	4.5	444	25.1	mud
	2	27.745	22.603	4.9	--	--	--
1935	1	27.870	22.794	3.6	442	25.3	--
	2	40°27.782	091°22.751	4.3	--	--	--
REW				0.0			

STATION: Mississippi River in Pool 19, Transect 4--UMR mile 367.5
PARTY: Moody, Johnson, and Martin
DATE: June 29, 1994
GAGE HEIGHT at Dam 18 TW: 523.52 ft
GAGE HEIGHT at Dam 19: 518.14 ft
SUSPENSION: na
RIVER SLOPE: 21.7 x 10^{-6}
CURRENT METER No: na
DATE RATED: 06-25-92
MAP: USGS 7.5-minute quadrangles are Keokuk, Iowa-Mo.-Ill., and Hamilton, Ill.-Iowa
REMARKS:

Resampled sites using differential GPS navigation beacon located in East St. Louis, Ill. Sites were resampled within 30 m of the original locations. The surface specific conductance and temperature were measured by using a LabComp meter.

BEARING OF TRANSECT: 086° magnetic

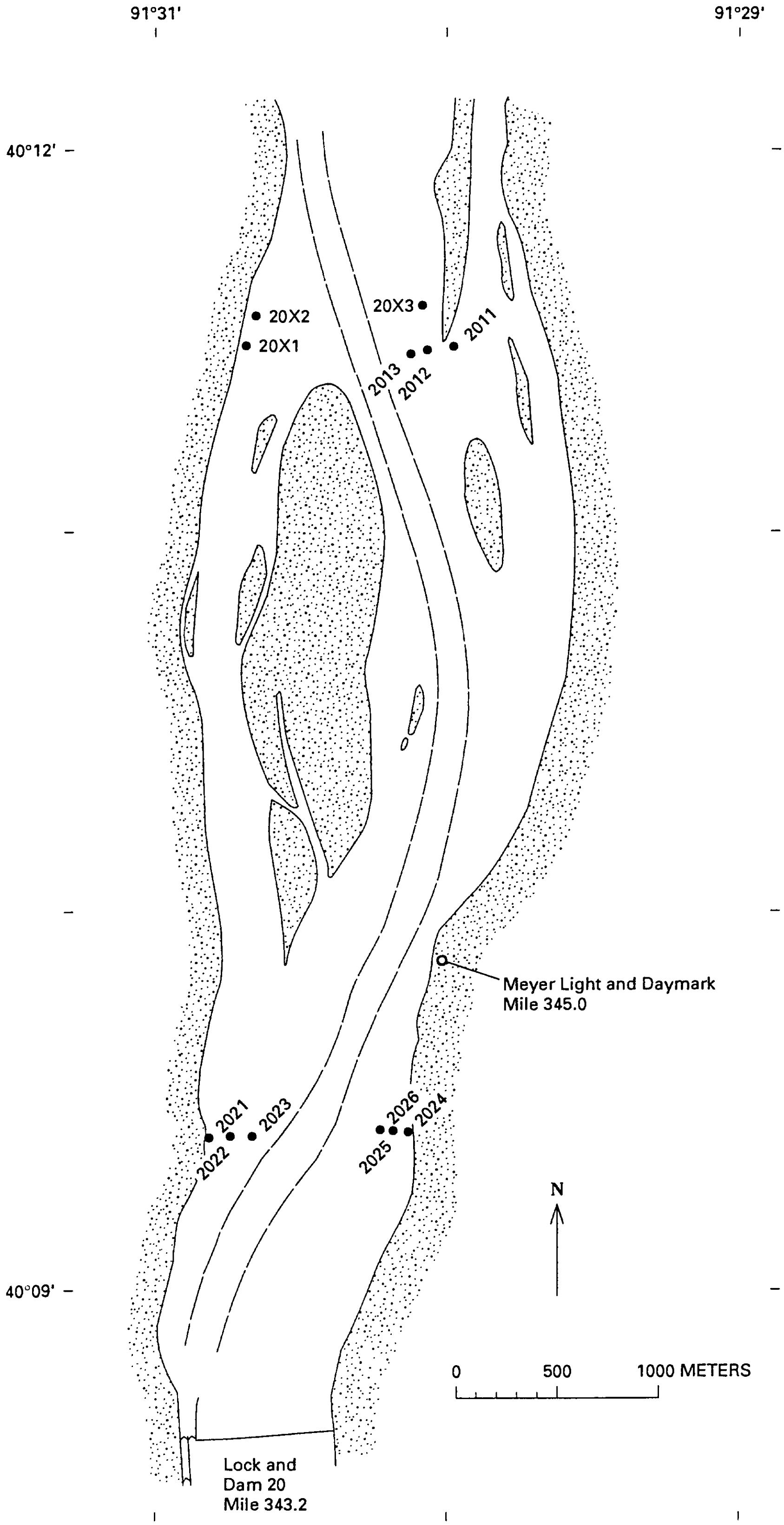
Site	Replicate	NAD83 Latitude N	NAD83 Longitude W	Depth (m)	Surface Conductance (µS/cm)	Surface Temperature (°C)	Surficial bed sediment
LEW				0.0			--
1941	1	40°26.528	091°22.491	5.5	455	25.3	--
	2	26.415	22.541	6.0	453	25.3	--
1942	1	26.522	22.649	7.0	455	25.4	--
	2	26.418	22.666	6.9	454	25.3	--
1943	1	26.510	22.810	5.2	449	25.3	--
	2	26.318	22.739	7.5	453	25.3	--
1944	1	26.514	23.000	3.8	449	25.2	--
	2	26.382	22.901	4.7	--	--	--
1945	1	26.524	23.179	4.9	445	25.4	--
	2	40°26.410	091°23.130	3.9	--	--	--
REW				0.0			

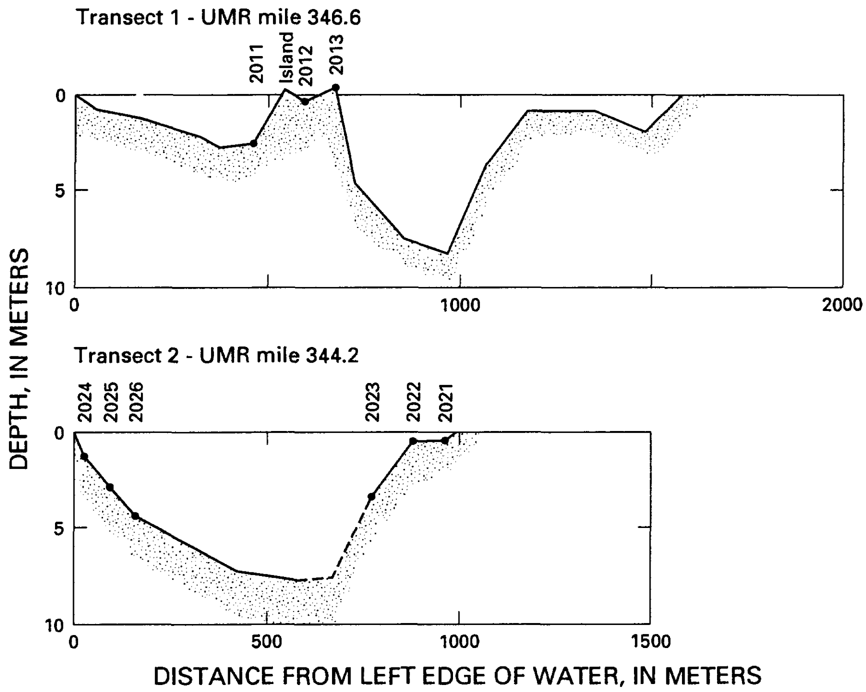
STATION: Mississippi River in Pool 19, Transect 5--UMR mile 366.3
PARTY: Moody, Johnson, and Martin
DATE: June 29, 1994
GAGE HEIGHT at Dam 18 TW: 523.52 ft
GAGE HEIGHT at Dam 19: 518.14 ft
SUSPENSION: na
RIVER SLOPE: 21.7 x 10^{-6}
CURRENT METER No: na
DATE RATED: 06-25-92
MAP: USGS 7.5-minute quadrangles are Keokuk, Iowa-Mo.-Ill., and Hamilton, Ill.-Iowa
REMARKS:

Resampled sites using differential GPS navigation beacon located in East St. Louis, Ill. Sites were resampled within 30 m of the original locations. The surface specific conductance and temperature were measured by using a LabComp meter. Biological Resources Division collected a sample from site 1951.

BEARING OF TRANSECT: 063° magnetic

Site	Replicate	NAD83 Latitude N	NAD83 Longitude W	Depth (m)	Surface Conductance (µS/cm)	Surface Temperature (°C)	Surficial bed sediment
LEW				0.0			--
1951	1	40°25.291	091°22.872	8.4	457	--	--
	2	24.998	22.517	8.6	453	24.3	--
1952	1	25.310	22.651	7.8	453	24.0	--
	2	25.179	22.495	6.2	455	24.5	--
1953	1	25.412	22.524	5.1	451	24.2	--
	2	25.162	22.361	4.0	455	24.5	--
1954	1	25.429	22.328	2.0	457	24.1	--
	2	40°25.385	091°22.324	2.0	454	24.3	--
REW				0.0			


91°31'
91°29'
40°12'
40°09'
20X2
20X1
20X3
2011
2012
2013
Meyer Light and Daymark
Mile 345.0
2021
2022
2023
2024
2025
2026
N
0
500
1000 METERS
Lock and
Dam 20
Mile 343.2


Transect 1 - UMR mile 346.6
2011
Island
2012
2013
DEPTH, IN METERS
0
5
10
0
1000
2000
Transect 2 - UMR mile 344.2
2024
2025
2026
2023
2022
2021
0
5
10
0
500
1000
1500
DISTANCE FROM LEFT EDGE OF WATER, IN METERS

STATION: Mississippi River in Pool 20, Transect 1--UMR mile 346.6
PARTY: Moody, Johnson, and Martin — DATE: June 30, 1994
GAGE HEIGHT at Dam 19 TW: 485.39 ft — GAGE HEIGHT at Dam 20: 478.40 ft
SUSPENSION: 15-pound weight — RIVER SLOPE: 63.0×10^{-6}
CURRENT METER No: W-223906 — DATE RATED: 06-25-92
MAP: USGS 7.5-minute quadrangles are Lima, Ill.-Mo., and Canton, Mo.-Ill.
REMARKS:

Resampled sites using differential GPS navigation beacon located in East St. Louis, Ill. The estimated error in site location is about ±5 m. The surface specific conductance and temperature were measured by using a LabComp meter. Pool elevation was 0.1 m lower than on July 22, 1991, when the pool was first sampled, and 5.4 m lower than the maximum 1993 flood elevation. Some deposition may have occurred between sites 20X3, 2013, and 2012 because the first two sites were out of water on an apparently new sandbar to the west of Blue Goose Island. Sites with negative depths are out of the water. Sites with only hundredths of a degree are ones that could not be reached by boat but were located by measuring the remaining distance from the GPS antenna in the boat to the site using a tape measure. Measured discharge was 2,980 m^3/s.

CURRENT METER EQUATION: V(m/s)=0.668*rev/s + 0.006
BEARING OF TRANSECT: 077° magnetic

Site	NAD83 Latitude N	NAD83 Longitude W	Depth (m)	Surface Conductance (µS/cm)	Surface Temperature (°C)	Velocity (m/s)	Direction (°magnetic)	Surficial bed sediment
LEW	40°11.552	091°29.676	0.0	458	25.6	--	--	--
04	11.539	29.705	0.9	446	25.9	0.52	130	--
03	11.530	29.769	1.1	452	25.4	0.57	130	--
02	11.514	29.835	1.8	455	25.1	0.59	170	--
01	11.502	29.909	2.5	455	25.0	0.78	180	--
2011	11.492	29.980	2.8	451	25.6	0.83	190	sand
2012	11.48	30.07	0.3	436	24.7	<0.05	--	sand
2013	11.47	30.12	-0.1	--	--	--	--	sand
05	11.463	30.171	4.3	445	26.3	0.65	150	--
06	11.443	30.261	7.2	451	25.5	1.00	150	--
07	11.430	30.346	8.4	490	25.6	0.99	150	--
08	11.426	30.409	3.7	511	25.8	0.55	130	--
09	11.416	30.482	0.8	513	25.9	0.64	160	--
10	11.399	30.594	0.7	505	26.6	0.56	210	--
11	11.379	30.717	1.7	516	26.1	0.80	190	--
REW	40°11.375	091°30.755	0.0	511	26.6	0.00	--	--
These sites are not on the transect but nearby.								
20X1	40°11.510	091°30.667	1.8	511	26.6	0.68	190	sand
20X2	11.586	30.640	2.0	506	26.8	0.57	200	sand
20X3	40°11.61	091°30.06	-0.3	--	--	--	--	sand

STATION: Mississippi River in Pool 20, Transect 2--UMR mile 344.2
PARTY: Moody, Johnson, and Martin
GAGE HEIGHT at Dam 19 TW: 485.39 ft
SUSPENSION: 15-pound weight
CURRENT METER No: W-223906
MAP: USGS 7.5-minute quadrangle is Canton, Mo.-Ill.

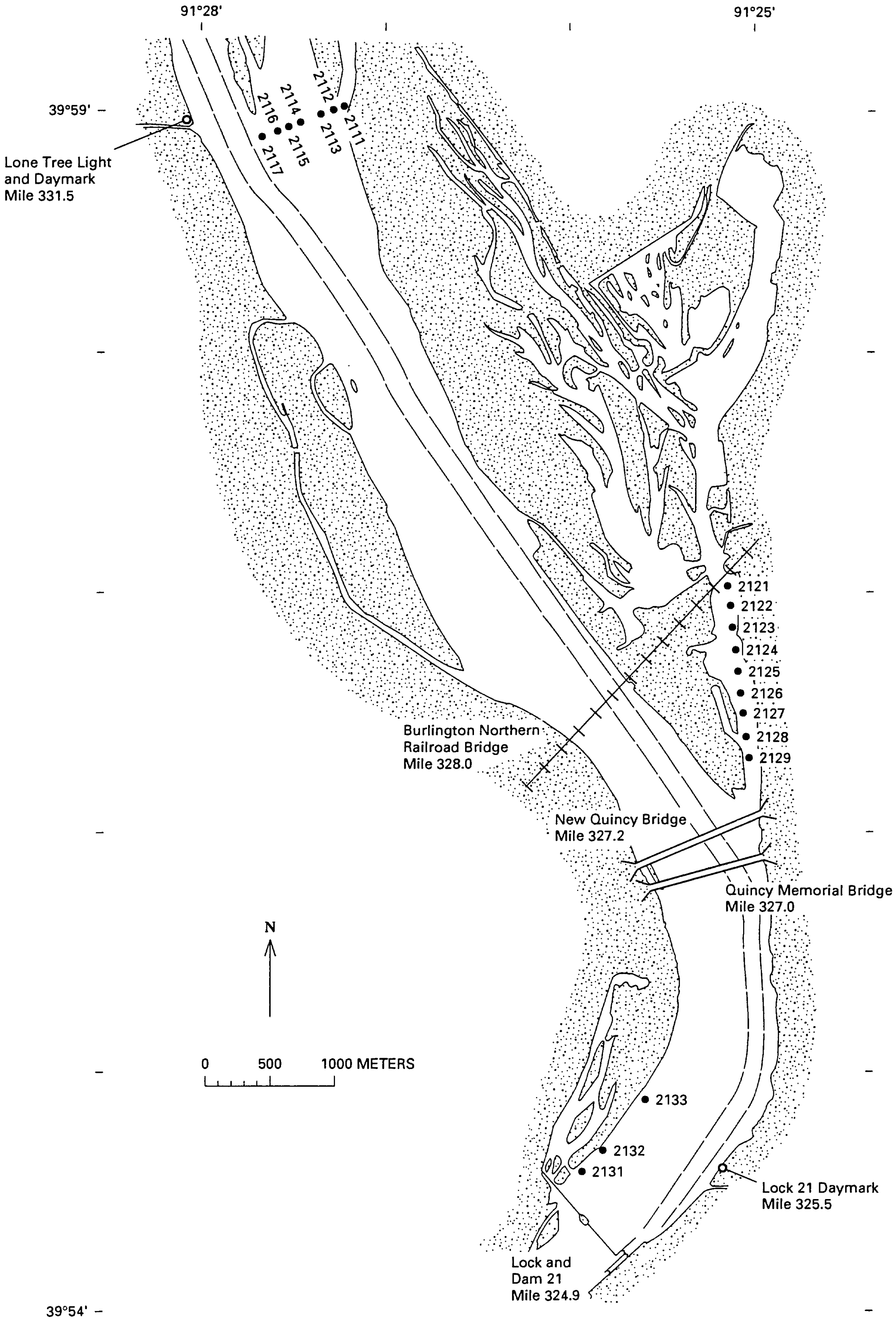
DATE:June 30, 1994
GAGE HEIGHT at Dam 20: 478.40 ft
RIVER SLOPE: 63.0 x 10^{-6}
DATE RATED: 06-25-92

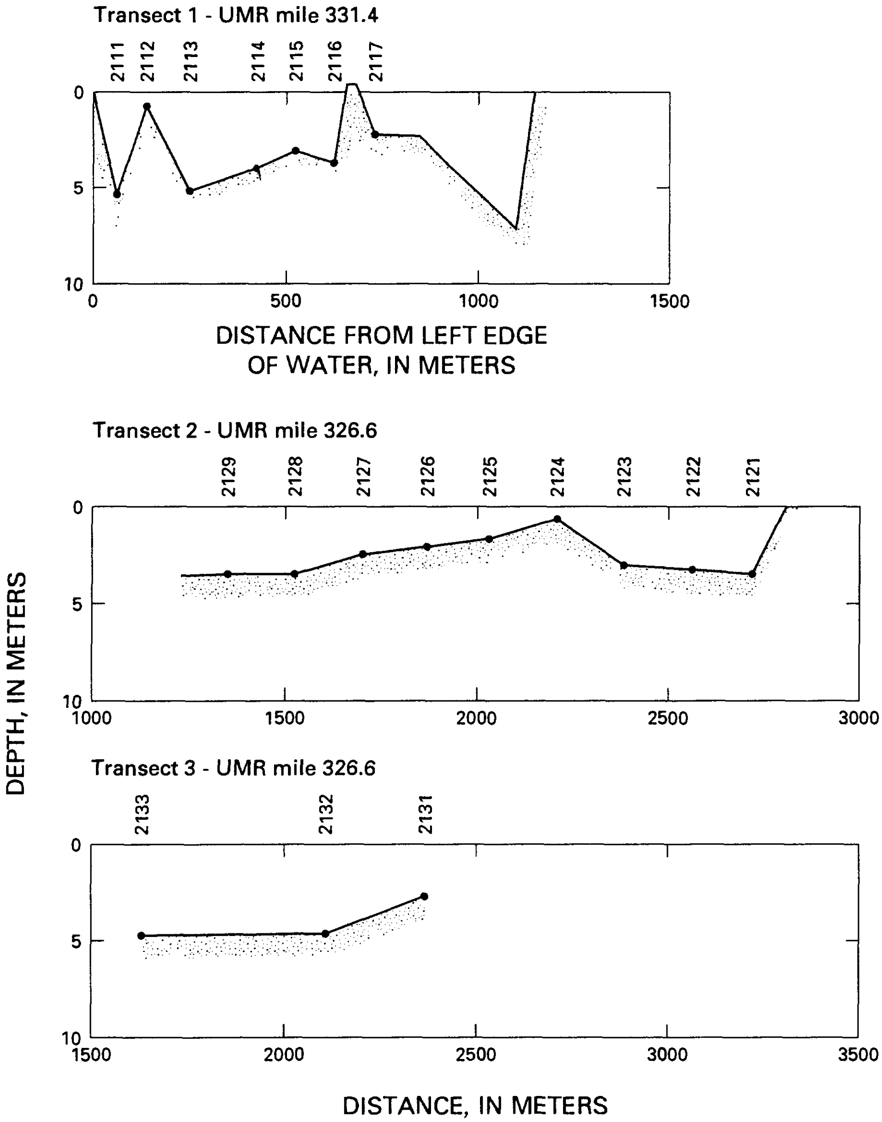
REMARKS:

Resampled sites using differential GPS navigation beacon located in East St. Louis, Ill. The estimated error in site location is about ±5 m. The surface specific conductance and temperature were measured by using a LabComp meter. Pool elevation was 0.1 m lower than on July 22, 1991, when the pool was first sampled, and 5.4 m lower than the maximum 1993 flood elevation. Some deposition may have occurred near site 2021 because it could not be reached by boat. This site was located by measuring the remaining distance from the GPS antenna in the boat to the site using a tape measure--location is given in hundredths of a degree. Several pictures were taken of the Lima levee break just downstream from Dam 20 on the left bank. Measured discharge was 3,080 m^3/s. Biological Resources Division collected a sample at site 2024.

CURRENT METER EQUATION: V(m/s)=0.668*rev/s + 0.006
BEARING OF TRANSECT: 086° magnetic

Site	NAD83 Latitude N	NAD83 Longitude W	Depth (m)	Surface Conductance (µS/cm)	Surface Temperature (°C)	Velocity (m/s)	Direction (°magnetic)	Surficial bed sediment
LEW			0.0					
2024	40°09.436	091°30.131	0.8	445	26.8	0.32	180	sticky mud
2025	09.445	30.189	3.6	429	28.3	0.56	180	sand
2026	09.443	30.221	4.5	413	29.5	0.62	180	sand
12	09.434	30.313	6.0	427	28.5	0.80	180	--
13	09.429	30.405	7.2	437	27.7	0.85	190	--
14	09.433	30.489	7.7	471	27.2	0.84	190	--
15	09.438	30.563	6.5	480	29.9	0.71	180	--
2023	09.434	30.658	1.0	495	28.8	0.51	140	sand
2022	09.428	30.722	0.4	493	30.3	0.08	130	sand
2021	40°09.43	091°30.80	0.3	506	28.5	~0.07	--	sand
REW			0.0					


91°28'
91°25'
39°59'
39°54'
2111
2112
2113
2114
2115
2116
2117
Lone Tree Light
and Daymark
Mile 331.5
2121
2122
2123
2124
2125
2126
2127
2128
2129
Burlington Northern
Railroad Bridge
Mile 328.0
New Quincy Bridge
Mile 327.2
Quincy Memorial Bridge
Mile 327.0
N
0
500
1000 METERS
2133
2132
2131
Lock 21 Daymark
Mile 325.5
Lock and
Dam 21
Mile 324.9



Transect 1 - UMR mile 331.4
2111
2112
2113
2114
2115
2116
2117
0
5
10
0
500
1000
1500
DISTANCE FROM LEFT EDGE OF WATER, IN METERS
Transect 2 - UMR mile 326.6
2129
2128
2127
2126
2125
2124
2123
2122
2121
0
5
10
1000
1500
2000
2500
3000
DEPTH, IN METERS
Transect 3 - UMR mile 326.6
2133
2132
2131
0
5
10
1500
2000
2500
3000
3500
DISTANCE, IN METERS

STATION: Mississippi River in Pool 21, Transect 1--UMR mile 331.4
PARTY: Moody, Johnson, and Martin
DATE: July 1, 1994
GAGE HEIGHT at Dam 20 TW: 476.98 ft
GAGE HEIGHT at Dam 21: 470.30 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 70.3×10^{-6}
CURRENT METER No: W-223906
DATE RATED: 06-25-92
MAP: USGS 7.5-minute quadrangle is Quincy West, Ill.-Mo.
REMARKS:
Resampled sites using differential GPS navigation beacon located in East St. Louis, Ill. The estimated error in site location is about ±5 m. The surface specific conductance and temperature were measured by using a LabComp meter. Pool elevation was 0.6 m lower than on April 24, 1992, when the pool was first sampled, and 6.0 m lower than the maximum 1993 flood elevation. Measured discharge was 2,780 m^3/s. No grab sample was collected at site 2114.

CURRENT METER EQUATION: V(m/s)=0.668*rev/s + 0.006
BEARING OF TRANSECT: 068° magnetic

	NAD83			Surface				
Site	**Latitude N**	**Longitude W**	**Depth (m)**	**Conductance (µS/cm)**	**Temperature (°C)**	**Velocity (m/s)**	**Direction (°magnetic)**	**Surficial bed sediment**
LEW	39°59.013	091°27.200	0.0	457	26.0	0.00	--	
2111	59.011	27.225	5.3	460	25.7	0.69	190	sand
2112	59.001	27.287	0.7	457	26.2	0.21	210	mud
2113	58.976	27.350	5.0	450	26.6	0.64	160	sand
2114	58.947	27.465	3.8	459	25.9	0.88	170	gravel
2115	58.930	27.532	2.9	454	26.6	0.80	180	sand
2116	58.909	27.587	3.5	455	26.7	0.71	160	sand
2117	58.885	27.668	1.9	454	27.5	0.64	190	sand, gravel
01	58.870	27.750	2.0	457	27.6	0.85	150	--
02	58.847	27.806	3.3	467	27.5	0.90	150	--
03	58.827	27.864	5.6	478	27.9	0.80	150	--
04	58.806	27.907	6.5	490	27.8	0.99	150	--
05	58.800	27.938	1.4	491	28.0	0.74	140	--
REW	39°58.795	091°27.946	0.0	497	28.0	0.00	--	--

STATION: Mississippi River in Pool 21, Transect 2--UMR mile 326.6
PARTY: Moody, Johnson, and Martin
DATE: July 1, 1994
GAGE HEIGHT at Dam 20 TW: 476.98 ft
GAGE HEIGHT at Dam 21: 470.30 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 70.3×10^{-6}
CURRENT METER No: W-223906
DATE RATED: 06-25-92
MAP: USGS 7.5-minute quadrangle is Quincy West, Ill.-Mo.
REMARKS:

Resampled sites using differential GPS navigation beacon located in East St. Louis, Ill. The estimated error in site location is about ±5 m. The surface specific conductance and temperature were measured by using a LabComp meter. Pool elevation was 0.6 m lower than on April 24, 1992, when the pool was first sampled, and 6.0 m lower than the maximum 1993 flood elevation. No grab sample was collected at sites 2123 and 2125.

CURRENT METER EQUATION: V(m/s)=0.668*rev/s + 0.006
BEARING OF TRANSECT: 168° magnetic

Site	NAD83 Latitude N	NAD83 Longitude W	Depth (m)	Surface Conductance (µS/cm)	Surface Temperature (°C)	Velocity (m/s)	Direction (°magnetic)	Surficial bed sediment
REW			0.0					
2121	39°57.022	091°25.125	3.2	465	25.2	0.22	100	mud
2122	56.934	25.117	3.0	466	25.1	0.37	150	mud
2123	56.846	25.107	2.9	463	25.4	0.39	160	mud, roots
2124	56.572	25.094	0.6	467	25.3	0.21	150	mud
2125	56.662	25.073	1.5	464	25.1	0.32	140	debris
2126	56.575	25.057	1.7	463	25.4	0.39	150	mud
2127	56.490	25.044	2.1	463	25.1	0.38	150	sandy mud
2128	56.383	25.030	3.5	460	25.3	0.40	140	mud
2129	39°56.299	091°25.027	3.5	462	25.2	0.36	150	mud

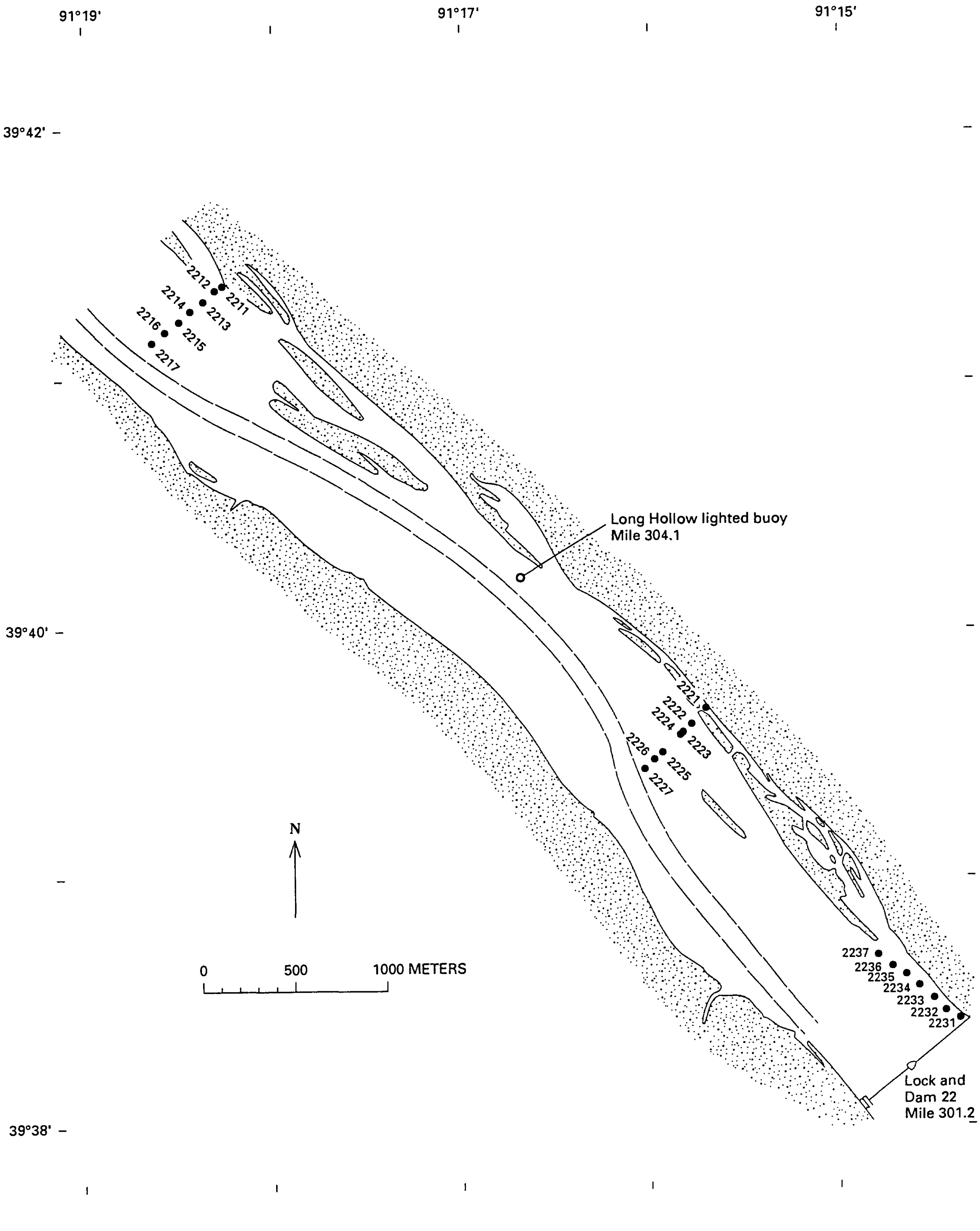
STATION: Mississippi River in Pool 21, Transect 3--UMR mile 326.6
PARTY: Moody, Johnson, and Martin
GAGE HEIGHT at Dam 20 TW: 476.98 ft
SUSPENSION: 15-pound weight
CURRENT METER No: W-223906
MAP: USGS 7.5-minute quadrangle is Quincy West, Ill.-Mo.

DATE: July 1, 1994
GAGE HEIGHT at Dam 21: 470.30 ft
RIVER SLOPE: 70.6×10^{-6}
DATE RATED: 06-25-92

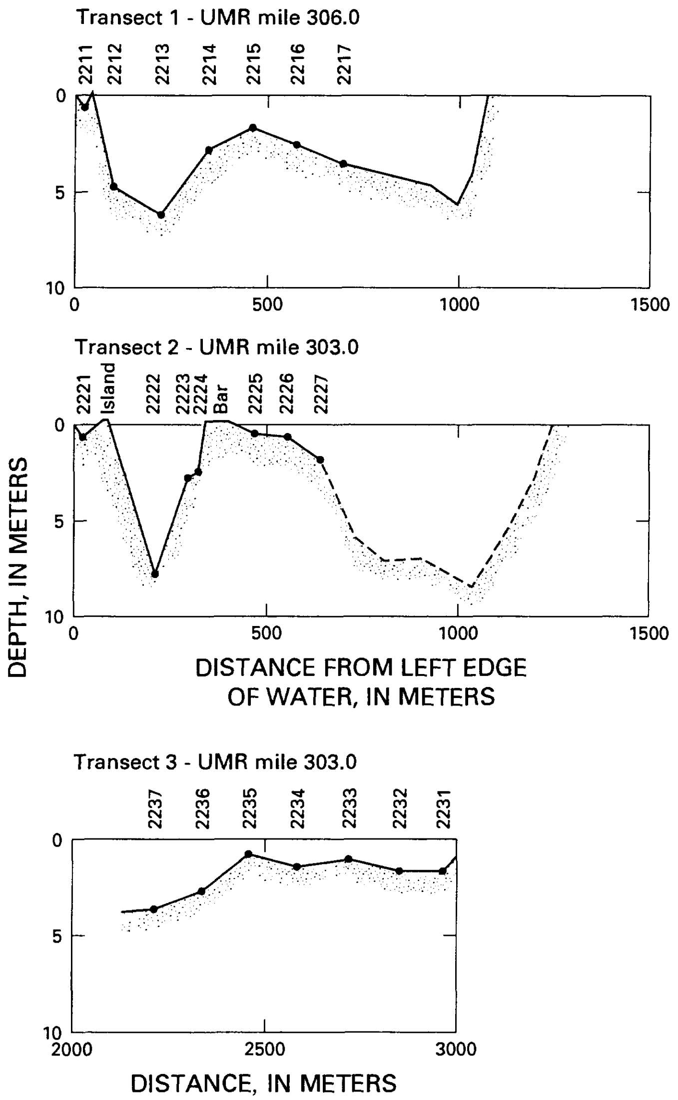
REMARKS:
Resampled sites using the differential GPS navigation beacon located in East St. Louis, Ill. The estimated error in site location is about ±5 m. The surface specific conductance and temperature were measured by using a LabComp meter. Pool elevation was 0.6 m lower than on April 24, 1992, when the pool was first sampled, and 6.0 m lower than the maximum 1993 flood elevation. Biological Resources Division collected a sample at site 2131.

CURRENT METER EQUATION: V(m/s)=0.668*rev/s + 0.006
BEARING OF TRANSECT: 034° magnetic

	NAD83			Surface				
Site	Latitude N	Longitude W	Depth (m)	Conductance (µS/cm)	Temperature (°C)	Velocity (m/s)	Direction (°magnetic)	Surficial bed sediment
REW			0.0					
2131	39°54.585	091°25.927	2.6	507	25.7	0.34	200	mud
2132	54.675	25.823	4.4	507	25.7	0.46	200	sand
2133	39°54.885	091°25.574	4.4	508	25.6	0.71	200	coarse sand



91°19'
91°17'
91°15'
39°42'
39°40'
39°38'
2211
2212
2213
2214
2215
2216
2217
Long Hollow lighted buoy
Mile 304.1
2221
2222
2223
2224
2225
2226
2227
N
0
500
1000 METERS
2231
2232
2233
2234
2235
2236
2237
Lock and
Dam 22
Mile 301.2



Transect 1 - UMR mile 306.0
2211
2212
2213
2214
2215
2216
2217
Transect 2 - UMR mile 303.0
2221
Island
2222
2223
2224
Bar
2225
2226
2227
DEPTH, IN METERS
DISTANCE FROM LEFT EDGE OF WATER, IN METERS
Transect 3 - UMR mile 303.0
2237
2236
2235
2234
2233
2232
2231
DISTANCE, IN METERS

STATION: Mississippi River in Pool 22, Transect 1--UMR mile 306.0
PARTY: Moody, Johnson, and Martin
DATE: July 2, 1994
GAGE HEIGHT at Dam 21 TW: 466.87 ft
GAGE HEIGHT at Dam 22: 459.40 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 59.0×10^{-6}
CURRENT METER No: W-223906
DATE RATED: 06-25-92
MAP: USGS 7.5-minute quadrangle is Hannibal East, Mo.-Ill.
REMARKS:

Resampled sites using differential GPS navigation beacon located in East St. Louis, Ill. The estimated error in site location is about ±5 m. The surface specific conductance and temperature were measured by using a LabComp meter. Pool elevation was 0.1 m lower than on July 23, 1991, when the pool was first sampled. Measured discharge was 2,900 m^3/s.

CURRENT METER EQUATION: V(m/s)=0.668*rev/s + 0.006
BEARING OF TRANSECT: 048° magnetic

	NAD83			Surface				
Site	Latitude N	Longitude W	Depth (m)	Conductance (μS/cm)	Temperature (°C)	Velocity (m/s)	Direction (°magnetic)	Surficial bed sediment
LEW			0.0					
2211	39°41.353	091°18.189	0.7	455	25.8	<0.05	110	fine mud
2212	41.321	18.227	5.0	462	26.1	0.93	120	sand
2213	41.285	18.292	5.7	466	26.1	0.78	130	sand
2214	41.223	18.363	2.7	470	26.0	0.76	120	sand
Island	41.22	18.40	0.0	--	--	--	--	--
2215	41.212	18.421	1.5	473	25.9	0.64	110	sand
2216	41.168	18.443	2.3	476	25.9	0.70	120	sand
2217	41.124	18.556	3.5	489	25.6	0.81	120	sand
01	41.084	18.616	3.8	491	25.7	0.83	130	--
02	41.056	18.668	4.5	497	25.8	0.87	120	--
03	41.031	18.719	5.2	501	25.9	1.03	120	--
04	41.015	18.750	3.9	502	25.8	0.72	120	--
REW	39°41.003	091°18.764	0.0					

STATION: Mississippi River in Pool 22, Transect 2--UMR mile 303.0
PARTY: Moody, Johnson, and Martin
GAGE HEIGHT at Dam 21 TW: 466.87 ft
SUSPENSION: 15-pound weight
CURRENT METER No: W-223906
MAP: USGS 7.5-minute quadrangle is Hannibal East, Mo.-Ill.

DATE: July 2, 1994
GAGE HEIGHT at Dam 22: 459.40 ft
RIVER SLOPE: 59.0×10^{-6}
DATE RATED: 06-25-92

REMARKS:
Resampled sites using differential GPS navigation beacon located in East St. Louis, Ill. The estimated error in site location is about ±5 m. The surface specific conductance and temperature were measured by using a LabComp meter. Pool elevation was 0.1 m lower than on July 23, 1991, when the pool was first sampled.

CURRENT METER EQUATION: V(m/s)=0.668*rev/s + 0.006
BEARING OF TRANSECT: 041° magnetic

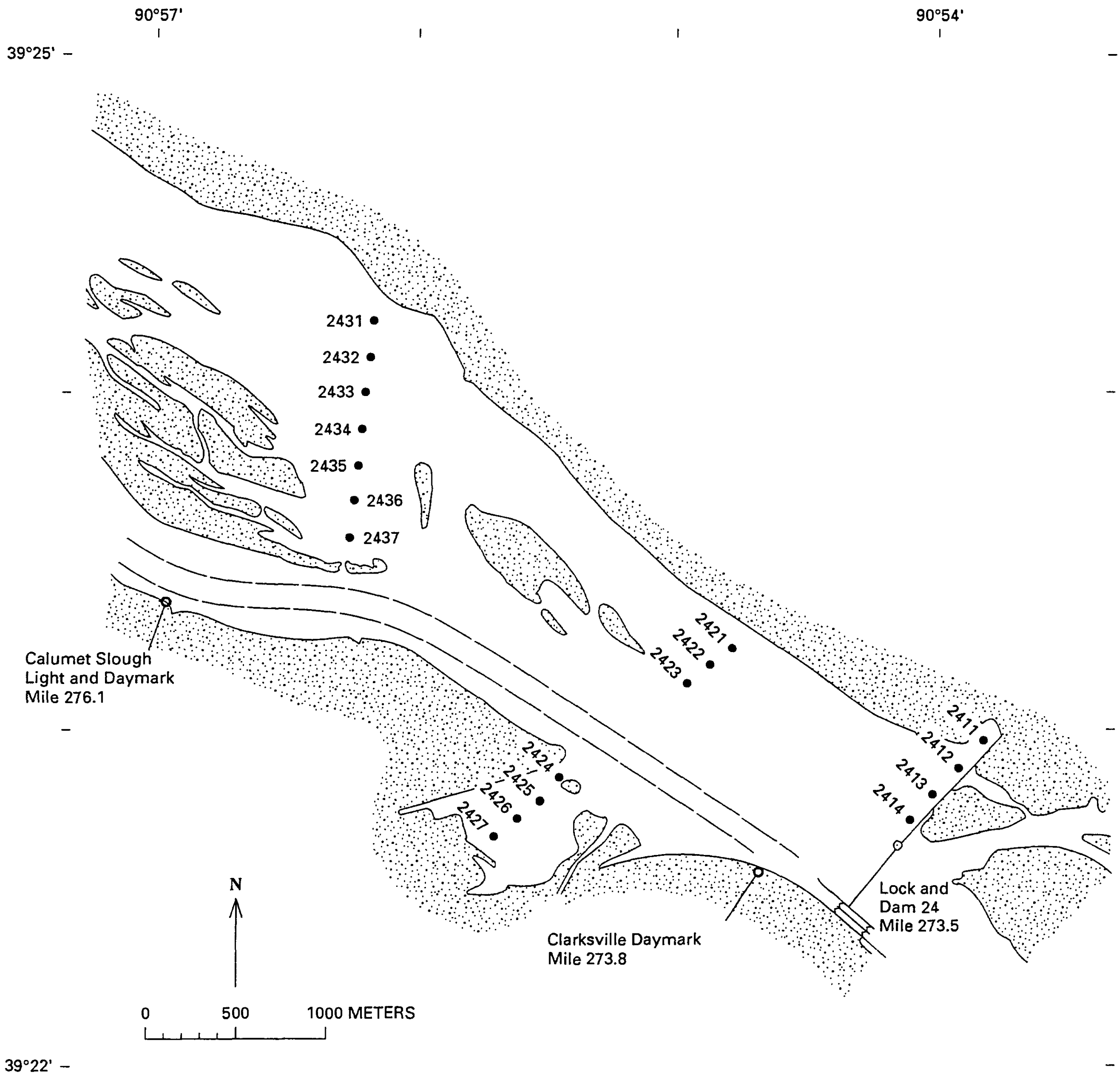
Site	NAD83 Latitude N	NAD83 Longitude W	Depth (m)	Surface Conductance (µS/cm)	Surface Temperature (°C)	Velocity (m/s)	Direction (°magnetic)	Surficial bed sediment
LEW			0.0					
2221	39°39.705	091°15.745	0.8	469	24.8	0.14	140	mud
2222	39.635	15.828	7.4	474	25.1	0.56	130	sand
2223	39.602	15.867	2.7	478	25.0	0.47	130	mud
2224	39.592	15.881	2.4	475	25.1	0.26	120	sand
2225	39.530	15.968	0.3	468	24.0	<0.05	--	mud, leaves
2226	39.513	16.010	0.4	468	24.4	0.11	090	mud
2227	39°39.470	091°16.046	0.9	479	25.0	0.42	120	sand

STATION: Mississippi River in Pool 22, Transect 3--UMR mile 303.0
PARTY: Moody, Johnson, and Martin
DATE: July 2, 1994
GAGE HEIGHT at Dam 21 TW: 466.87 ft
GAGE HEIGHT at Dam 22: 459.40 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 59.0×10^{-6}
CURRENT METER No: W-223906
DATE RATED: 06-25-92
MAP: USGS 7.5-minute quadrangle is Hannibal East, Mo.-Ill.
REMARKS:

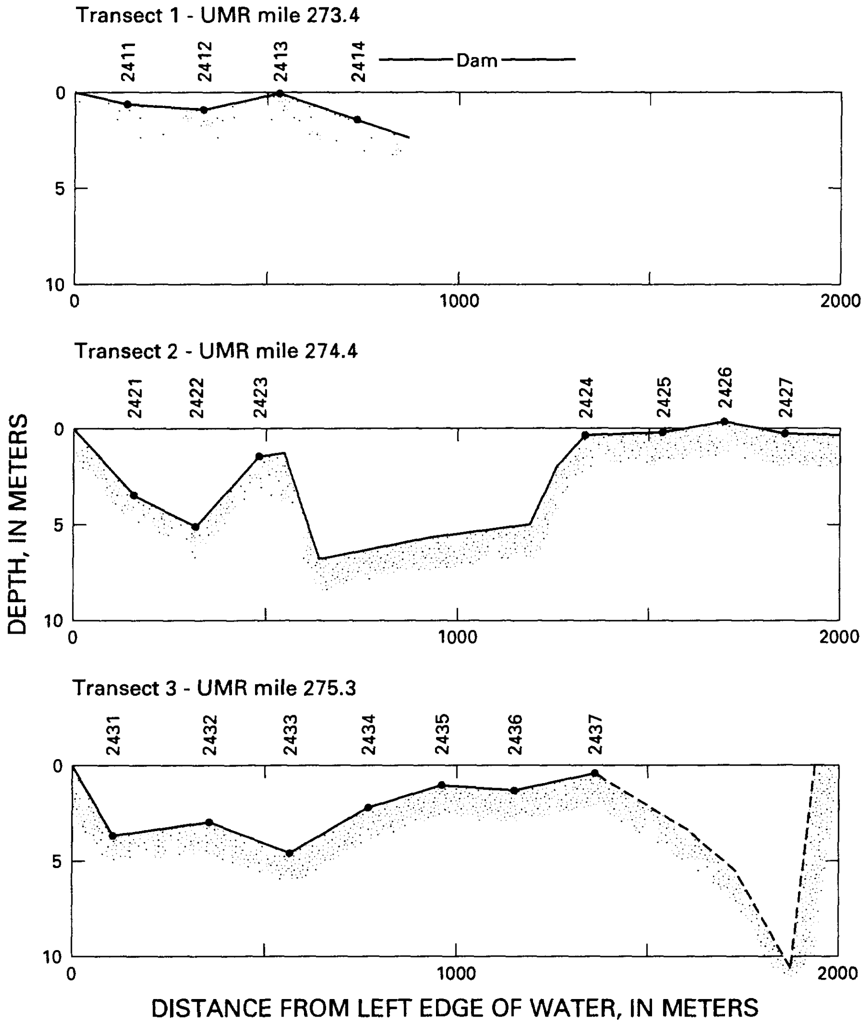
Resampled sites using differential GPS navigation beacon located in East St. Louis, Ill. The estimated error in site location is about ±5 m. The surface specific conductance and temperature were measured by using a LabComp meter. Pool elevation was 0.1 m lower than on July 23, 1991, when the pool was first sampled. Biological Resources Division collected a sample from site 2231.

CURRENT METER EQUATION: V(m/s)=0.668*rev/s + 0.006
BEARING OF TRANSECT: 126° magnetic

Site	NAD83 Latitude N	NAD83 Longitude W	Depth (m)	Surface Conduct-ance (µS/cm)	Surface Tem-perature (°C)	Velocity (m/s)	Direction (°magnetic)	Surficial bed sediment
LEW			0.0					
2231	39°38.496	091°14.463	1.5	461	24.8	0.05	170	sticky mud
2232	38.529	14.518	1.3	468	24.4	<0.05	--	sticky mud
2233	38.569	14.587	1.1	474	24.8	0.11	100	mud
2234	38.616	14.655	1.2	474	25.0	0.22	120	mud
2235	38.660	14.724	0.8	472	25.1	0.25	110	mud
2236	38.698	14.794	2.5	474	25.5	0.36	120	mud, clay
2237	39°38.737	091°14.862	3.4	468	25.7	0.69	110	clay, sand



90°57'
90°54'
39°25'
39°22'
2431
2432
2433
2434
2435
2436
2437
2421
2422
2423
2424
2425
2426
2427
2411
2412
2413
2414
Calumet Slough
Light and Daymark
Mile 276.1
Clarksville Daymark
Mile 273.8
Lock and
Dam 24
Mile 273.5
N
0
500
1000 METERS



Transect 1 - UMR mile 273.4
2411
2412
2413
2414
Dam
Transect 2 - UMR mile 274.4
2421
2422
2423
2424
2425
2426
2427
Transect 3 - UMR mile 275.3
2431
2432
2433
2434
2435
2436
2437
DEPTH, IN METERS
0
5
10
1000
2000
DISTANCE FROM LEFT EDGE OF WATER, IN METERS

STATION: Mississippi River in Pool 24, Transect 1--UMR mile 273.4
PARTY: Moody, Johnson, and Martin
DATE: July 3, 1994
GAGE HEIGHT at Dam 22 TW: 455.69 ft
GAGE HEIGHT at Dam 24: 447.32 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 56.6 x 10^{-6}
CURRENT METER No: W-223906
DATE RATED: 06-25-92
MAP: USGS 7.5-minute quadrangle is Pleasant Hill, Ill.-Mo.
REMARKS:

Resampled sites using differential GPS navigation beacon located in East St. Louis, Ill. The estimated error in site location is about ±5 m. The surface specific conductance and temperature were measured by using a LabComp meter. Pool elevation was 0.5 m lower than on October 29, 1991, when the pool was first sampled. Site 2411 was cut off from the pool by a sandbar; we walked until the water was too deep and the mud too soft to walk farther--so location is given to the nearest hundredth of a degree. Biological Resources Division collected a sample from site 2412.

CURRENT METER EQUATION: V(m/s)=0.668*rev/s + 0.006
BEARING OF TRANSECT: 045° magnetic

Site	NAD83 Latitude N	NAD83 Longitude W	Depth (m)	Surface Conductance (µS/cm)	Surface Temperature (°C)	Velocity (m/s)	Direction (°magnetic)	Surficial bed sediment
LEW			0.0					
2411	39°22.97	090°53.83	0.6	470	24.0	0.00	--	mud
2412	22.887	53.917	0.7	465	23.7	<0.05	--	mud
2413	22.805	54.025	0.01	--	--	--	--	sand
2414	39°22.735	090°54.107	1.3	463	24.3	<0.05	--	mud

STATION: Mississippi River in Pool 24, Transect 2--UMR mile 274.4
PARTY: Moody, Johnson, and Martin
GAGE HEIGHT at Dam 22 TW: 455.69 ft
SUSPENSION: 15-pound weight
CURRENT METER No: W-223906
MAP: USGS 7.5-minute quadrangle is Pleasant Hill, Ill.-Mo.

DATE: July 3, 1994
GAGE HEIGHT at Dam 24: 447.32 ft
RIVER SLOPE: 56.6 x 10^{-6}
DATE RATED: 06-25-92

REMARKS:

Resampled sites using differential GPS navigation beacon located in East St. Louis, Ill. The estimated error in site location is about ±5 m. The surface specific conductance and temperature were measured by using a LabComp meter. Pool elevation was 0.5 m lower than on October 29, 1991, when the pool was first sampled. Sites 2424 (within 30 m of original sample site), 2425 (out of water), 2426, and 2427 (within 30 m of original sampling site) were difficult to get to because of low water. Location of sites 2425 and 2426 are given to the nearest hundredth of a degree. Negative depth is elevation above pool level. Measured discharge was 2,880 m^3/s..

CURRENT METER EQUATION: V(m/s)=0.668*rev/s + 0.006
BEARING OF TRANSECT: 053° magnetic

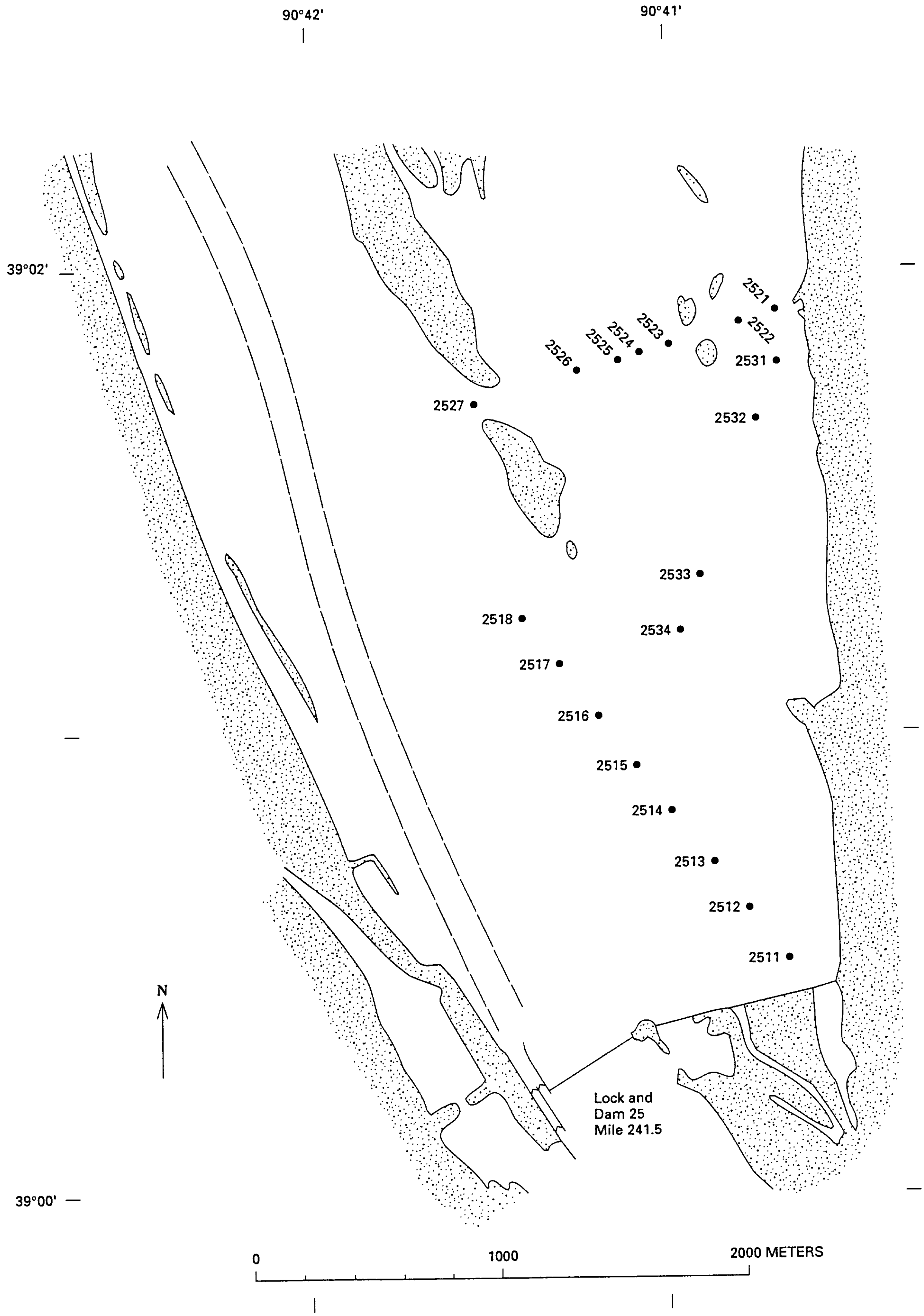
Site	NAD83 Latitude N	NAD83 Longitude W	Depth (m)	Surface Conductance (μS/cm)	Surface Temperature (°C)	Velocity (m/s)	Direction (°magnetic)	Surficial bed sediment
LEW	39°23.296	090°54.705	0.0	465	25.3			
01	23.273	54.725	2.8	473	24.6	0.54	120	--
2421	23.238	54.791	3.2	480	24.5	0.61	120	sand
2422	23.181	54.879	5.0	480	24.7	0.62	100	sand
2423	23.130	54.967	1.5	488	24.5	0.54	150	clay
02	23.084	55.048	6.0	484	24.5	0.31	130	--
03	23.035	55.137	6.0	481	25.7	0.65	110	--
04	22.990	55.195	5.9	492	24.9	0.70	110	--
05	22.929	55.325	5.3	475	24.8	0.62	120	--
2424	22.862	55.447	0.3	472	24.2	<0.05	--	mud
2425	22.79	55.40	-0.2	--	--	--	--	mud
2426	22.74	55.63	0.05	--	--	--	--	mud
2427	39°22.695	090°55.715	0.2	585	21.8	0.00	--	mud
REW			0.0					

STATION: Mississippi River in Pool 24, Transect 3--UMR mile 275.3
PARTY: Moody, Johnson, and Martin
DATE: July 3, 1994
GAGE HEIGHT at Dam 22 TW: 455.69 ft
GAGE HEIGHT at Dam 24: 447.32 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 56.6 x 10^{-6}
CURRENT METER No: W-223906
DATE RATED: 06-25-92
MAP: USGS 7.5-minute quadrangle is Pleasant Hill, Ill.-Mo.
REMARKS:

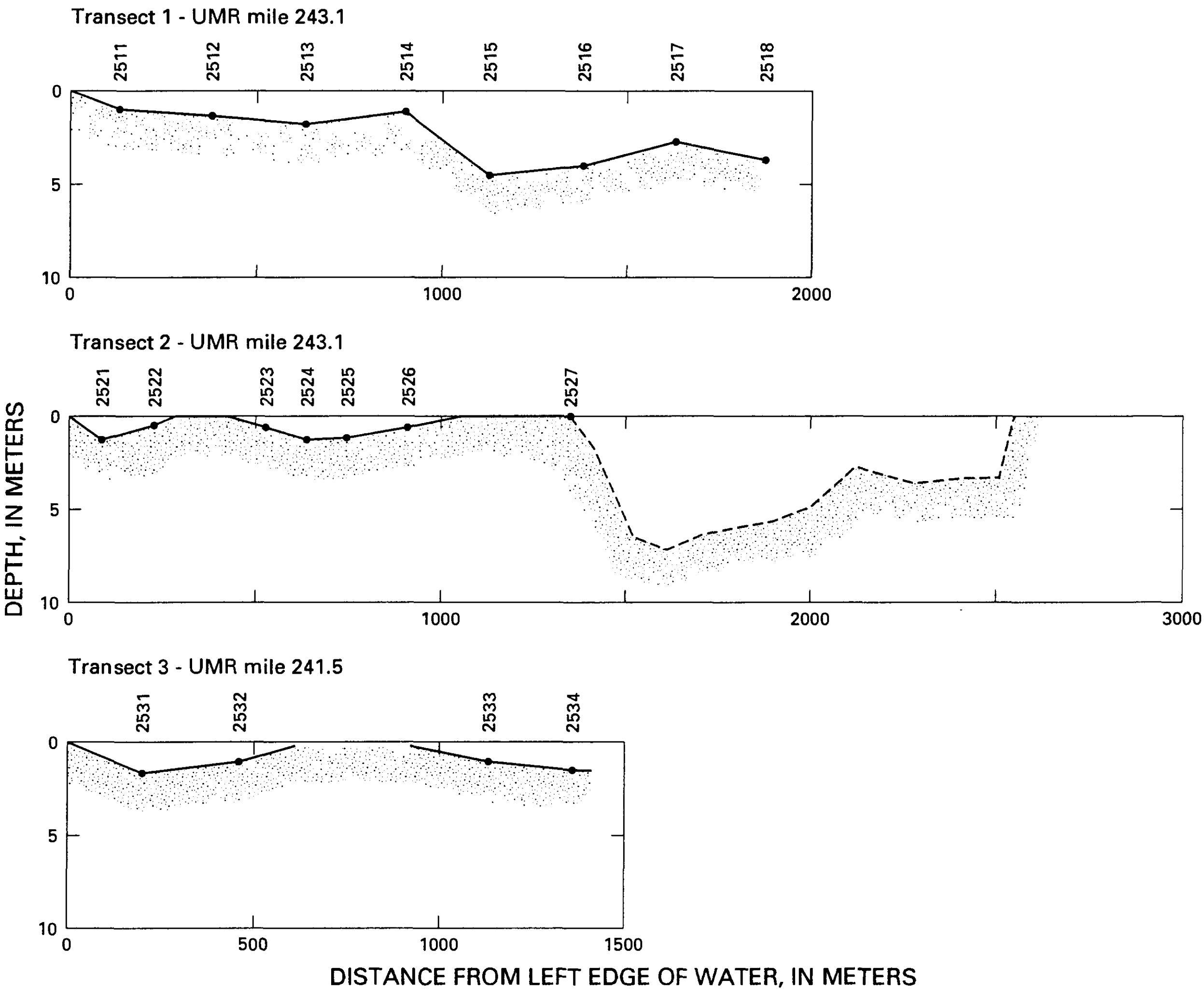
Resampled sites using differential GPS navigation beacon located in East St. Louis, Ill. The estimated error in site location is about ±5 m. The surface specific conductance and temperature were measured by using a LabComp meter. Pool elevation was 0.5 m lower than on October 29, 1991, when the pool was first sampled.

CURRENT METER EQUATION: V(m/s)=0.668*rev/s + 0.006
BEARING OF TRANSECT: 007° magnetic

	NAD83			Surface				
Site	Latitude N	Longitude W	Depth (m)	Conductance (µS/cm)	Temperature (°C)	Velocity (m/s)	Direction (°magnetic)	Surficial bed sediment
LEW			0.0					
2431	39°24.208	090°56.171	3.6	468	25.8	0.70	090	sand
2432	24.099	56.192	2.9	472	25.6	0.76	120	sand
2433	23.996	56.207	4.3	474	25.5	0.68	100	sand
2434	23.889	56.231	2.0	469	25.5	<0.05	140	mud, sand
2435	23.777	56.250	0.9	472	25.2	<0.05	120	mud, sand
2436	23.682	56.259	1.2	479	25.3	0.14	140	mud, sand
2437	39°23.571	090°56.281	0.3	484	23.8	0.06	170	mud



90°42'
90°41'
39°02'
39°00'
2521
2522
2523
2524
2525
2526
2531
2527
2532
2533
2518
2534
2517
2516
2515
2514
2513
2512
2511
N
Lock and
Dam 25
Mile 241.5
0
1000
2000 METERS



Transect 1 - UMR mile 243.1
2511
2512
2513
2514
2515
2516
2517
2518
Transect 2 - UMR mile 243.1
2521
2522
2523
2524
2525
2526
2527
Transect 3 - UMR mile 241.5
2531
2532
2533
2534
DEPTH, IN METERS
DISTANCE FROM LEFT EDGE OF WATER, IN METERS

STATION: Mississippi River in Pool 25, Transect 1--UMR mile 275.3
PARTY: Moody, Johnson, and Martin
DATE: July 4, 1994
GAGE HEIGHT at Dam 24 TW: 440.76 ft
GAGE HEIGHT at Dam 25: 432.20 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 50.7×10^{-6}
CURRENT METER No: W-223906
DATE RATED: 06-25-92
MAP: USGS 7.5-minute quadrangle is Foley, Mo.-Ill.
REMARKS:

Resampled sites using differential GPS navigation beacon located in East St. Louis, Ill. The estimated error in site location is about ±5 m. The surface specific conductance and temperature were measured by using a LabComp meter. Pool elevation was the same elevation as on April 22, 1991, when the pool was first sampled. The "R" indicates sites where a replicate sample for sediment size, total organic carbon, and total volatile solids was collected. No grab sample was collected from site 2517. Biological Resources Division collected a sample from site 2511.

CURRENT METER EQUATION: V(m/s)=0.668*rev/s + 0.006
BEARING OF TRANSECT: 139° magnetic

	NAD83			Surface				
Site	**Latitude N**	**Longitude W**	**Depth (m)**	**Conductance (μS/cm)**	**Temperature (°C)**	**Velocity (m/s)**	**Direction (°magnetic)**	**Surficial bed sediment**
LEW			0.0					
2511	39°00.509	090°40.660	1.0	471	24.7	0.13	210	mud
2512-R	00.621	40.768	1.0	472	25.9	0.23	210	clay
2513	00.721	40.867	1.5	474	25.9	0.32	170	mud
2514-R	00.839	40.107	1.3	463	24.3	0.50	150	mud
2515	00.927	40.090	4.1	474	25.9	0.61	140	sand, gravel
2516-R	01.038	41.197	3.4	471	26.0	0.63	130	sand
2517	01.154	41.303	2.5	474	26.0	0.77	140	rock
2518-R	39°01.253	090°41.403	3.8	473	26.1	0.65	140	sand

STATION: Mississippi River in Pool 25, Transect 2--UMR mile 243.1

PARTY: Moody, Johnson, and Martin

DATE: July 4, 1994

GAGE HEIGHT at Dam 24 TW: 440.76 ft

GAGE HEIGHT at Dam 25: 432.20 ft

SUSPENSION: 15-pound weight

RIVER SLOPE: 50.7×10^{-6}

CURRENT METER No: W-223906

DATE RATED: 06-25-92

MAP: USGS 7.5-minute quadrangle is Foley, Mo.-Ill.

REMARKS:

Resampled sites using differential GPS navigation beacon located in East St. Louis, Ill. The estimated error in site location is about ±5 m. The surface specific conductance and temperature were measured by using a LabComp meter. Pool elevation was the same elevation as on April 22, 1991, when the pool was first sampled. Site 2527 was in water less than 0.1 m deep. The last 41 m were measured with a tape measure while walking to the site, so the location is listed below to the nearest hundredth of a degree. The "R" indicates sites where a replicate sample for sediment size, total organic carbon, and total volatile solids was collected.

CURRENT METER EQUATION: V(m/s)=0.668*rev/s + 0.006

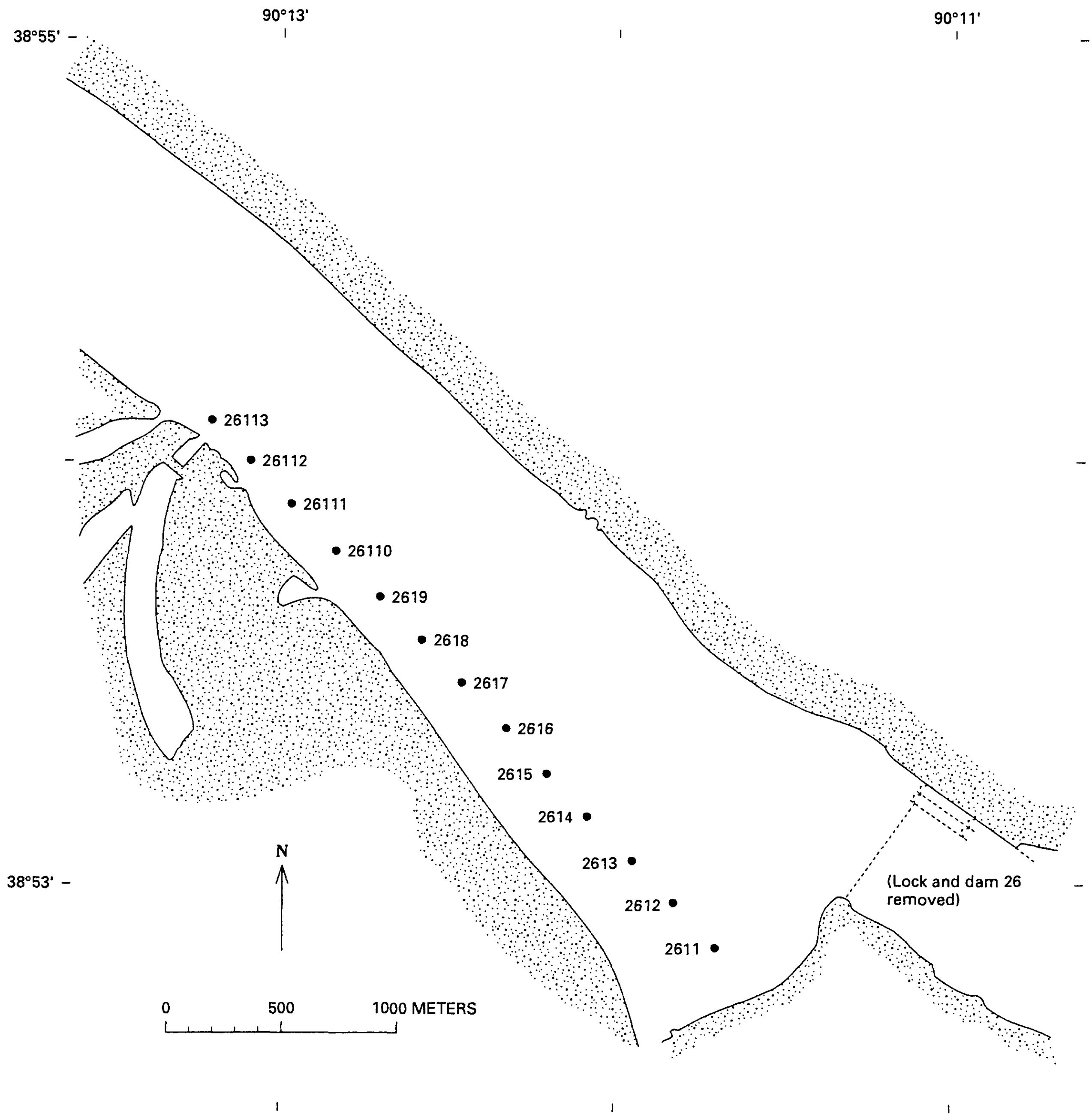
BEARING OF TRANSECT: 071° magnetic

Site	NAD83 Latitude N	NAD83 Longitude W	Depth (m)	Surface Conductance (µS/cm)	Surface Temperature (°C)	Velocity (m/s)	Direction (°magnetic)	Surficial bed sediment
LEW			0.0					
2521	39°01.915	090°40.701	1.1	447	30.1	0.14	210	mud
2522-R	01.887	40.805	0.5	455	29.7	0.05	290	mud
2523	01.846	40.999	0.3	457	28.4	0.14	320	mud
2524-R	01.831	41.077	1.0	455	28.2	0.13	270	mud
2525	01.816	41.144	1.0	455	28.1	0.06	250	mud
2526-R	01.787	41.252	0.7	453	27.6	<0.05	330	mud
2527	39°01.72	090°41.55	0.05	471	26.2	--	--	sticky mud

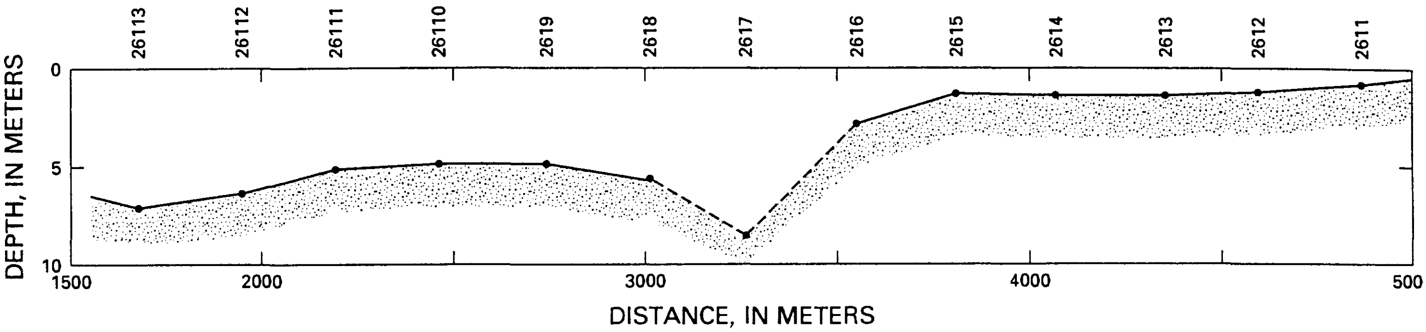
STATION: Mississippi River in Pool 25, Transect 3--UMR mile 241.5
PARTY: Moody, Johnson, and Martin
DATE: July 4, 1994
GAGE HEIGHT at Dam 24 TW: 440.76 ft
GAGE HEIGHT at Dam 25: 432.20 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 50.7×10^{-6}
CURRENT METER No: W-223906
DATE RATED: 06-25-92
MAP: USGS 7.5-minute quadrangle is Foley, Mo.-Ill.
REMARKS:
Resampled sites using differential GPS navigation beacon located in East St. Louis, Ill. The estimated error in site location is about ±5 m. The surface specific conductance and temperature were measured by using a LabComp meter. Pool elevation was the same elevation as on April 22, 1991, when the pool was first sampled. The "R" indicates sites where a replicate sample for sediment size, total organic carbon, and total volatile solids was collected.

CURRENT METER EQUATION: V(m/s)=0.668*rev/s + 0.006
BEARING OF TRANSECT: 016° magnetic

	NAD83			Surface				
Site	Latitude N	Longitude W	Depth (m)	Conductance (µS/cm)	Temperature (°C)	Velocity (m/s)	Direction (°magnetic)	Surficial bed sediment
LEW			0.0					
2531	39°01.810	090°40.705	1.3	454	29.2	0.36	200	mud
2532-R	01.679	40.762	0.9	457	28.7	0.08	230	mud
2533	01.341	40.917	1.0	466	26.5	0.11	260	mud
2534-R	39°01.223	090°40.967	1.2	461	26.6	0.05	240	mud



90°13'
90°11'
38°55'
38°53'
26113
26112
26111
26110
2619
2618
2617
2616
2615
2614
2613
2612
2611
N
0
500
1000 METERS
(Lock and dam 26 removed)


26113
26112
26111
26110
2619
2618
2617
2616
2615
2614
2613
2612
2611
DEPTH, IN METERS
0
5
10
1500
2000
3000
4000
500
DISTANCE, IN METERS

STATION: Mississippi River in Pool 26, Transect 1--UMR mile 206.1
PARTY: Moody, Johnson, and Martin
DATE: July 4, 1994
GAGE HEIGHT at Dam 25 TW: 425.37 ft
GAGE HEIGHT at Dam 25: 432.20 ft
SUSPENSION: 15-pound weight
RIVER SLOPE: 42.3×10^{-6}
CURRENT METER No: W-223906
DATE RATED: 06-25-92
MAP: USGS 7.5-minute quadrangle is Alton, Ill.-Mo.
REMARKS:

Resampled sites using differential GPS navigation beacon located in East St. Louis, Ill. The estimated error in site location is about ±5 m. The surface specific conductance and temperature were measured by using a LabComp meter. Site 2617 was 5.3 m deeper than on November 2, 1991, when it was originally sampled. It was too deep to get a van Veen grab, and when we moved toward the right bank, it only got deeper. Site 2618 was about 2 m deeper. No grab sample was collected from sites 2616. Biological Resources Division collected a sample from site 2612.

CURRENT METER EQUATION: V(m/s)=0.668*rev/s + 0.006
BEARING OF TRANSECT: 137° magnetic

Site	NAD83		Depth (m)	Surface		Velocity (m/s)	Direction (°magnetic)	Surficial bed sediment
	Latitude N	Longitude W		Conductance (µS/cm)	Temperature (°C)			
REW			0.0					
2611	38°52.850	090°11.695	0.4	472	26.7	0.08	270	mud
2612	52.948	11.820	0.9	476	26.9	0.25	060	mud
2613	53.050	11.936	1.0	474	27.2	0.09	080	mud
2614	53.162	12.081	1.0	476	27.2	0.14	080	mud
2615	53.266	12.197	1.0	476	27.2	0.26	100	mud
2616	53.364	12.323	2.3	474	27.2	0.37	100	clay
2617	53.475	12.460	8.8	--	--	--	--	--
2618	53.583	12.579	5.2	474	27.3	0.43	120	mud
2619	53.677	12.708	4.8	475	27.3	0.40	110	mud
26110	53.784	12.840	4.7	475	27.3	0.45	120	mud
26111	53.898	12.971	5.1	473	27.5	0.46	120	mud
26112	53.994	13.082	6.1	473	27.5	0.47	120	mud
26113	38°54.095	090°13.213	7.0	473	27.5	0.42	100	mud

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