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Bank Erosion Survey of the Illinois River
Volume 1

by

Nani Bhowmik and David Soong

December 2000

Illinois State Water Survey
Watershed Science Section
Champaign, Illinois

A Division of the Illinois Department of Natural Resources

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Abstract

This report summarizes the research and surveying that were conducted in 1995 to determine the amount and severity of bank erosion that existed on the entire length of the Illinois River. The study reach extended from Grafton, River Mile (RM) 0 to Joliet, RM 286. A multi-disciplinary team of scientists traveled the entire length of the river, mapped bank conditions and erosion sites, and selected 29 reaches for detailed data collection and two sites as observation sites. Bank erosion types were developed by studying and analyzing the erosion features. The team also used fluvial and bank failure processes to guide detailed data collection at the 29 sites.

Color-coded bank feature maps were developed for the entire 286 miles of the river. These maps depict both sides of the river. Field data sheets were used at the 29 sites to record features such as bank conditions, severity of erosion, land use on the bank, and vegetation cover, surrounding features that could relate to the bank erosion. Data collection included a minimum of three bank profiles where slopes were measured, two to six bank material samples, one core sample, and at least one river cross section. All bank profiles were subsequently correlated with stage frequencies at those selected sites. Causative factors for possible bank erosion at the site were also identified by the multi-disciplinary team. All the collected data and the available flow-related data were subsequently used to classify bank erosion processes on the Illinois River.

Analysis of the data indicated:

- The median particle size diameter d_{50} of the bank materials varied from 0.002 millimeters (mm) to 0.7 mm.
- Erosion at many bank sections occurred within the normal range of stage fluctuations (between normal pool stages and ordinary high water).
- Twenty-seven percent of the bank sections showed erosion features at elevations above ordinary high water.
- Sixty-three percent of the sections had erosion at stages within normal range of stage fluctuations. Waves and currents have significant effects during these stages.
- Seventy-four percent of the bank sections had evidence of seepage; 26 percent had piping holes or springs.
- Twenty-eight percent of the bank sections had small scarps or benches that could have been formed by waves, seepage, or combinations of the two.
- Twenty-four percent of the bank sections showed traffic-induced disturbances.
- Ten percent of the bank sections showed eddy included erosion, and 11 percent had evidence of surface drainage.
- All measured bank profiles were divided into six categories that qualitatively identified the severity of bank erosion.

- Field mapping of the bank erosion indicated that about 117 riverbank miles are severely eroded, corresponding to approximately 20 percent of the total bank length (both banks). There are also about 90 miles of riverbank that have visible erosion features but are not considered severely eroded. On the other hand, about 189 bank miles are stable, and 88 miles are either rock or protected by riprap or other structures. Several other types of bank descriptions were also used in the mapping.
- Riverbank erosion is caused by a variety of factors. The report contains the best expert opinions on the causes of erosion at each site as was identified by the team making the field trips.

This is the first time a field study on the detailed bank erosion features of the Illinois River has been completed. The study included development of maps, collection of field data, and correlation of the approximate causative factors for bank erosion. Future site-specific or systemwide investigations will certainly benefit from this investigation.

Keywords:

Illinois River, Bank Erosion, Mapping, Waves, Seepage, River Traffic, Bank Materials, Hydraulics, Bank Slopes, Scarp, Berm, Bench.

Introduction

In 1995-1997, the Illinois State Water Survey with support from the U.S. Army Corps of Engineers (USACOE), Rock Island District, and in close cooperation with the University of Iowa and several districts of the USACOE, completed a bank erosion survey of the Upper Mississippi and Illinois Rivers. The USACOE, Rock Island District, has published a joint report for the Upper Mississippi and Illinois Rivers in CD-ROM (USACOE, 1997). That report contains detailed information on the work done for both the rivers. The present report contains materials that are pertinent to the Illinois River. For a detailed description of the bank erosion conditions on the Upper Mississippi River, readers are referred to the original publication.

Banklines and channel geometry are intimately related, and many factors can affect the stability of a bank. Magnitudes of flow, secondary circulation, turbulence characteristics, tow manipulation, increased commercial and recreational traffic, channel modifications, vessel and wind-generated waves, human activities, and geotechnical processes (piping, rapid recessional loading, cleft pressures, and slaking) may all result in increased bank erosion or migration of existing bank erosion sites. Bank erosion, in turn, can result in the loss of cropland, forest, pasture, and residential, municipal, wetland, and riparian zones. This affects plant and animal uses of aquatic and terrestrial bankline areas, cultural resources and historic properties located along bankline areas, and human uses of bankline areas. In addition to direct erosion impacts to the bankline, eroded soils, fills, and recently deposited alluvium from the banks may increase sedimentation of the backwater areas and side channels, increase the dredging maintenance requirement, increase water treatment costs, and adversely affect the operating life of machinery, shellfish quality, and recreational uses and aesthetic qualities of the river ecosystem.

Once a bank is eroded, rivers transport and deposit sediments to other channel areas. If banks are protected, related impacts could include channel bed degradation and incision.

Streambank erosion is an extremely complex process, but there are primarily three types of causative mechanisms in the bank erosion process (USACOE, 1981). These are: 1) mechanisms that displace soil particles from the bank surface; 2) mechanisms that destabilize the internal structure of the bank, resulting in failure of soil blocks or entire segments of the bank; and 3) mechanisms that transport the displaced soil particles or failed soil blocks away from the bank. Unless the stream can remove the displaced soil particles or the failed soil blocks through transport processes, the bank will tend toward a stable or aggrading condition. Soil displacement mechanisms include abrasion by ice and debris, biological processes, chemical processes, flow velocity, freeze-thaw, gravity, human activities, precipitation, waves, and wetting/drying processes. Internal soil failure mechanisms include slope instability, piping, liquefaction, tension cracks, swelling and shrinking, stresses from rapid recessional loading, cleft pressure, and surcharge. Transport mechanisms include gravity, human action, and water flow.

Changes in bankline as a result of bank erosion could affect the riparian habitat of fish and wildlife and cultural resources along the bankline. It is also important to understand these processes as they relate to the potential loss of land and its effect on property ownership, structural integrity, etc.

The study results reported in the present report address two areas: 1) a systemwide inspection of the Illinois River with a multi-disciplinary team to quantify the present extent of bank erosion and to attempt to discern the most probable causes of that erosion, and 2) a qualitative assessment of the relative significance of commercial navigation to existing bank erosion, based on pertinent literature, expertise of the investigators and the field data that were collected and subsequently analyzed.

Study Design

This study was designed to identify and describe riverbank conditions and bank erosion sites on the Illinois River. It was designed also to identify the major erosion sites, inventory those bank sites, identify bank soils and sediments, and provide opinions as to the erosion and failure mechanisms at each location.

The literature review completed by Maynord and Martin (1996) was available for reference throughout the design and completion of this study. Also, an aerial reconnaissance survey of bank conditions was completed by the USACOE prior to initiation of this study. During the aerial reconnaissance survey, oblique color video imagery and color still photos of every bank-mile adjacent to the navigation channel on the Illinois River were obtained. The video imagery and still photos were indexed to ground-coordinated positions using Global Positioning System (GPS) equipment onboard an aircraft. This information also was available for review at the onset of this study. These data are available from the USACOE, Rock Island District.

Scope of Work, Tasks, and Past Studies

The scope of work for this study identified the following work tasks:

1. Review the bank erosion study literature review conducted by the USACOE Waterways Experiment Station (Maynord and Martin, 1996).

2. Develop a classification system for all significant bank erosion sites.

3. Review the aerial video imagery and available mapping for preliminary selection of at least 60 sites for detailed study and data collection during the boat reconnaissance survey.

4. Conduct a boat reconnaissance survey of the Illinois River with a multi-disciplinary study team to document existing bank conditions. Field data will be collected from selected sites, and the team will provide opinions as to the erosion and failure mechanisms at each site.

5. Select five sites for detailed traffic impact studies — these studies were not done.

6. Prepare a report that includes a review of historical and technical information; a review of video photography and mapping, a detailed description of the classification system and resulting attribute database development; a report of the boat reconnaissance, including detailed descriptions of each of the selected sites for detailed investigations, opinions as to what initiated bank failure mechanisms and processes, a description of the sites selected for detailed traffic impact studies and reasons why these sites were selected; opinions regarding the relative significance of bank failure and erosion mechanisms and navigation effects on bank erosion and failure; and complete mapping of all recorded eroding banks and photographs taken during the boat reconnaissance.

7. Prepare an electronic database file containing all bank erosion classification system attribute data collected for the selected sites for detailed investigations.

The scope of work required the study team to identify and describe riverbank conditions and bank erosion sites on the entire Illinois River. The original study focused on the Upper Mississippi from the confluence with the Ohio River (River Mile or RM 0) to the Upper St. Anthony Falls Lock (RM 854), and on the Illinois River from Grafton, Illinois (RM 0), to Joliet, Illinois (RM 286). The present report only covers the Illinois River. For the entire study, readers are referred to the main report (USACOE, 1997).

Several studies have been conducted on the Upper Mississippi River and the Illinois River specifically to address commercial and recreational navigation impacts on bank erosion. Most notable of these are: Bhowmik and Schicht (1980); Bhowmik et al. (1982); Hagerty (1988, unpublished); Spoor and Hagerty (1989); and Johnson (1994). These authors present a variety of opinions on the subject of bank erosion and the relative significance of navigation traffic-generated waves as an erosion mechanism.

The report has been divided into two volumes. This volume, Volume I, contains all the background information, site-specific analyses, and the generalized analyses for all the selected erosion sites. Volume II contains all the appendices, which are available in limited quantities from the Illinois State Water Survey.

Acknowledgments

The authors are extremely grateful to many professional staff from the Illinois State Water Survey, four districts of the U.S. Army Corps of Engineers (USACOE), and many others who worked on this project. Several personnel assisted in the field data collection and review of the original report on the Upper Mississippi and Illinois Rivers bank erosion investigations: Dan

Johnson, Rock Island District Corps of Engineers, Mike Spoor, Huntington District Corps of Engineers, and Jeff Anderson, Anderson Environmental Services.

Professor Tatsuaki Nakato from the University of Iowa traveled the entire length of the Illinois River with other team members. Several Illinois State Water Survey professionals assisted in the field data collection and the analysis of the data: Bill Bogner, Jim Slowikowski, Maitreyee Bera, Dan Meyer, George Roadcap, Gana Ramamurthy, and Scott Maddux.

Linda Hascall provided the graphics, and Eva Kingston, Agnes Dillon, and Sarah Hibbeler edited the report. Lacie Jeffers typed the initial report and Becky Howard, Taryn Kelly, and Dawn Amrein assisted in the preparation of the present report. The authors express their sincere thanks and appreciation to all of them.

Any opinions, findings, and conclusions or recommendations presented in this report are those of the authors and do not necessarily reflect the views of the sponsor or the Illinois State Water Survey.

Data Collection

Basic data collection followed the procedures outlined by Bhowmik et al. (1990), Bhowmik and Schicht (1980), and Hagerty (1988). All the data collected and/or measured have been entered in a database.

During 1995, the project principals formed a multi-disciplinary study team to conduct the reconnaissance boat trip with members from the Illinois State Water Survey, the University of Iowa - Iowa Institute of Hydraulic Research, and the USACOE, Rock Island and Huntington Districts. The intent was to conduct a survey by boat and occasional shore expeditions along the Illinois River from Dresden Island Lock and Dam or L&D (RM 271.4) to Grafton (RM 0).

Several objectives were accomplished during the boat trips: documenting bank conditions along both sides of the river on navigation charts, selecting representative sites, collecting data on each site, and forming opinions about the causes of erosion at each site. Originally, it was proposed to select and collect data from 20 sites along the Illinois River. The total number of sites where field data were collected exceeded these numbers. Moreover, data also were collected from several observation sites.

Boat Trip

This section describes the boat trips conducted on the Illinois River. It was not possible to conduct the boat trips in a continuous fashion without any breaks because of the logistical and personnel needs. Thus the field trips were in two segments. Field trip participants included staff and personnel from the Illinois State Water Survey; the USACOE, Rock Island, Huntington, St. Paul, and St. Louis Districts; the University of Iowa — Iowa Institute of Hydraulic Research; and the Illinois Natural History Survey.

A team was assigned to each boat to conduct one or more specific tasks. All daily activities were planned and coordinated in advance. The daily activity normally started with pre-selecting the potential sites for field data collection based on an evaluation of the aerial photographs and video prior to arriving at the boat docks, checking equipment and supplies, and then starting field work.

Communication among boats was maintained through the use of cellular phones and marine radios. A chase vehicle on the shore provided logistical support throughout the day.

The entire team normally was divided into three or four subteams, and each subteam was assigned a specific task. Subteam 1 was assigned to the main boat where all the necessary supplies were stored. The main boat was used also as the mapping boat where judgments were made as to the severity of the erosion along both sides of the river, and these judgments were recorded on navigation charts. Subteam 1 partially was responsible for identifying potential field sites for additional data collection. Subteam 1 also was responsible for coordinating overall data collection and providing the necessary support on the river.

Subteam 2 was responsible for locating the latitude and longitude of each site by using a Global Positioning System (GPS). This team also measured the river cross section at the midsection of the selected site. Occasionally, cross sections of the channel, including eroding banks, were measured at the upstream and downstream ends of the site.

Subteams 3 and 4 were responsible for surveying at least three bank sections at each selected site. Bank section measurements were taken near the upstream and downstream ends of the reach and at the midsection. The team was responsible also for collecting bank soil samples, which included core samples and sediment samples from the river within wading depths. These two teams took shore-based photographs of the sites.

All boat trips on the Illinois River were coordinated with the waterway operation personnel of the USACOE. Figure 1 photographs depict the field data collection activities.

The study team completed the Illinois River survey on two different trips. From August 24-31, 1995, the team completed reconnaissance and site surveys from Ottawa (RM 240) to Grafton, Illinois (RM 0). From September 18-20, 1995, the team completed the remaining upper section from downstream of Brandon Road L&D (RM 282.5) to Ottawa (RM 240).

The August 24-31, 1995 trip was the first reconnaissance boat trip for the team. As planned, the team divided into four groups, each traveling by boat, to conduct the survey. A 36-foot field boat, the *Richardson,* owned by the State of Illinois, was the home base for the study team. This boat was used to map bank conditions, store camp supplies and miscellaneous equipment, and provide shelter during inclement weather. Normally, the *Richardson* moved slowly and kept moving while faster boats collected data from specific sites, and then caught up with the *Richardson.*

The second trip on the Illinois River was completed September 18-20, 1995, when the field crew traveled from Brandon Road L&D (RM 286) to Ottawa (RM 240). During these two trips, 29 sites were selected, and these sites were located on the Illinois Waterway Navigation Chart shown in figure 2. Table 1 provides the dates when these sites were selected and their locations.

Site Selection

One primary goal for the boat trip was to collect detailed information from representative sites for further testing and evaluation. A total of 29 sites on the Illinois River were selected for the detailed data collection and analysis. Information available to the team members selecting representative sites included an aerial oblique videotape, photographs, and information from the operation and maintenance personnel from the USACOE. Personnel from the USACOE Huntington District reviewed the videotape and all aerial photographs and tentatively selected

Figure 1. Field data collection on the Illinois River

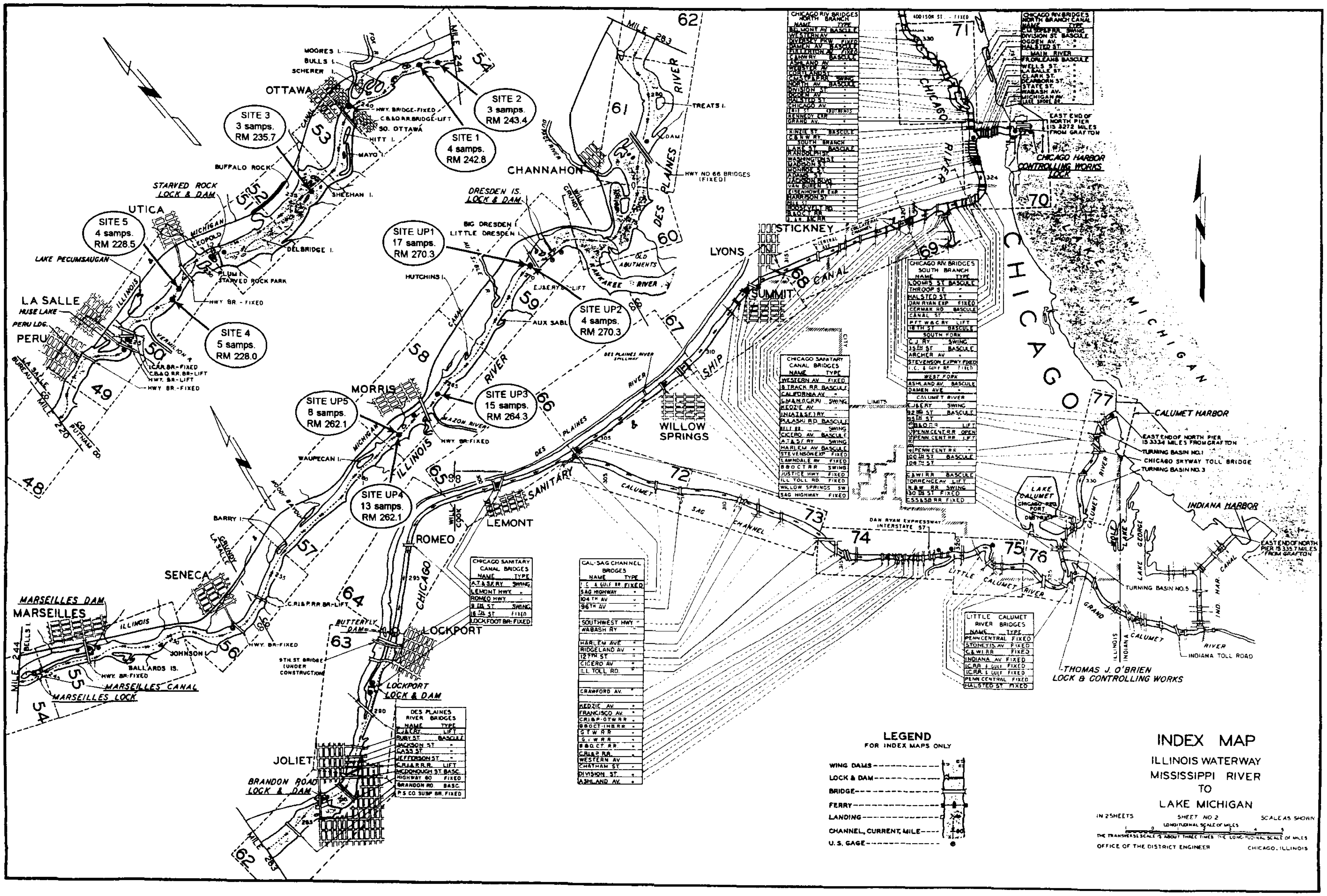


Figure 2. Location of field sites on the Illinois River

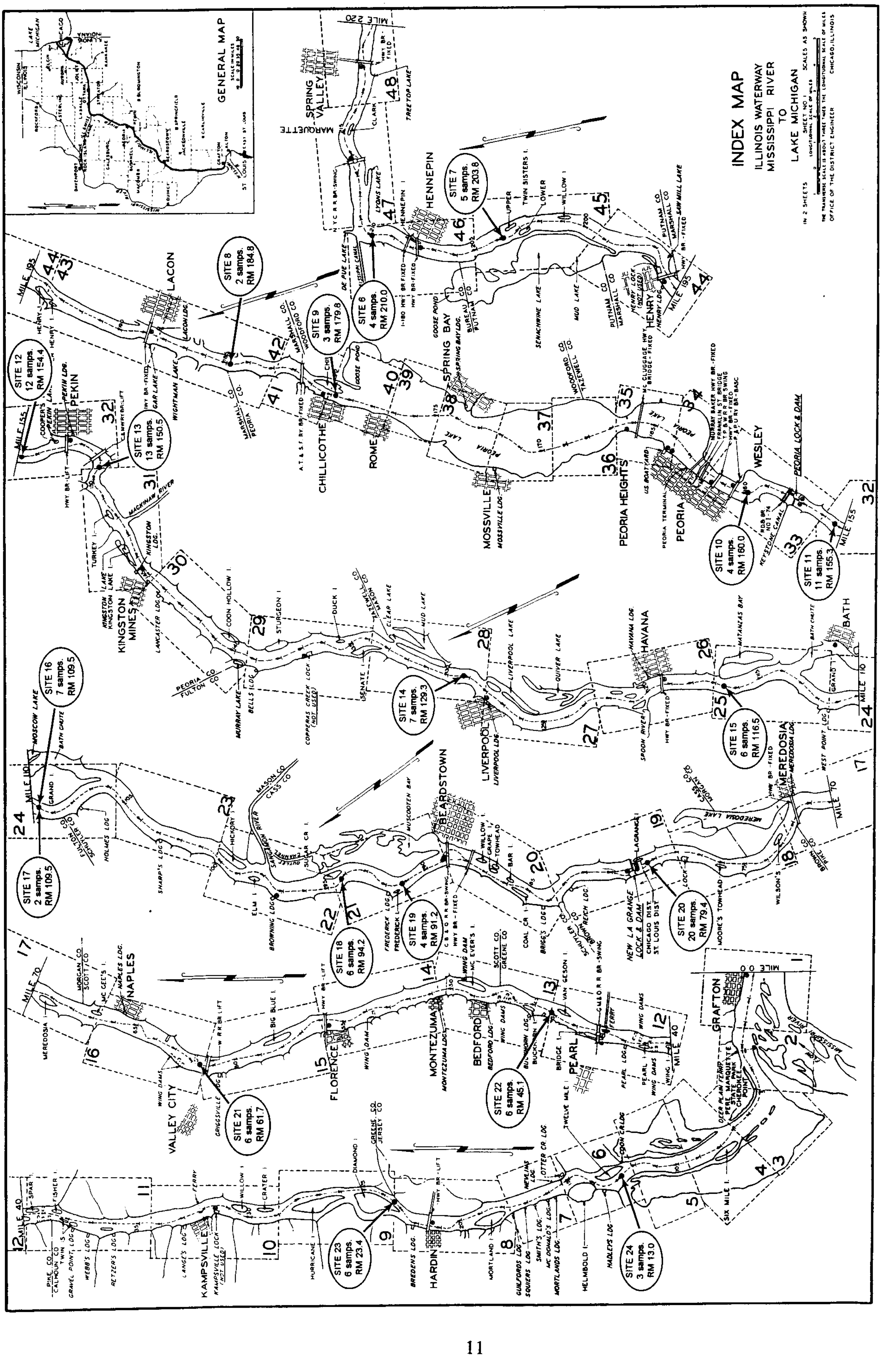


Figure 2. (concluded)

Table 1. Field Sites on the Illinois River. Date of Selection and River Miles

Date	*River miles traveled*	*Sites selected*
9/18/95	RM 263 – RM 282.5 – RM 263	UP1, UP2
9/19/95	RM263–RM264.3–RM263	UP3
9/19/95	RM263–RM244	UP4, UP5
8/28/95	RM240–RM244–RM225.6	Sites 1,2,3,4,5
8/29/95	RM 225.6 – RM 160	Sites 6,7, 8,9, 10
8/30/95	RM 160–RM 116.5	Sites 11, 12, 13, 14, 15
8/31/95	RM 116.5 – RM 79.4	Sites 16, 17, 18, 19,20
9/1/95	RM 79.4 – RM 0.	Sites 21,22,23,24

sites for detailed data collection from the river. This information and the input from the USACOE Operation and Maintenance personnel guided the selection of the sites before the field trip was initiated.

During the field reconnaissance trip, many sites were found to be suitable for further data collection. The number of sites suggested by the USACOE generally exceeded the sites that the study team could examine each day. Moreover, the videotape did not reveal actual field conditions, especially at sites covered by vegetation. In some instances, dredge disposal sites appeared in the aerial photographs and videotape to be sites with severe erosion. Consequently, the team used two approaches to select a site for detailed data collection. First, the team prepared a list of potential sites based on aerial photographs and videotape review, indicating geomorphic characteristics of the sites (straight reach, crossover, inside or outside bends, etc.). The team then determined the sites that would be visited that day. At significantly eroded sites where the team could not obtain complete data, personnel recorded the main features and called those sites "observation" sites. An observation site was a site that either had features similar to those measured at other sites, or the site was not sufficiently representative to conduct a full-scale survey. A limited amount of data was collected at observation sites.

Erosion Site Mapping

Subteam 1 was responsible for indicating on navigation charts the various degrees of erosion on both sides of the river by means of a color scheme to indicate the severity of erosion. Evaluations noted on the charts are all approximate, not based on measurements. In spite of these shortcomings, the navigation charts with erosion sites marked still will provide extremely valuable information about the current bank erosion of the Illinois River.

Navigation charts were colored to indicate the severity of erosion at various locations; ultimately only four major colors were included:

red	severe erosion, clear scarp with approximate height 4 feet or higher
orange	medium erosion, scarp with approximate height less than 4 feet
blue	minor erosion, moderate scarp bare bench
green	stable, almost no erosion

Notes were also written on any navigation features discernible from the boat. Figure 3 shows one page from the navigation charts (USACOE, 1974) with field notes inscribed. Marked and colored navigation charts were a separate product of this study, and these may be obtained from the USACOE, Rock Island District.

Field Data Sheets

The study team developed standard field data sheets that were used for the trips on the Illinois River. Figure 4 shows a sample data sheet used to record information in the field from the selected site.

Data collected from the observation sites were recorded on an "Observation Data Sheet Form" (figure 5). Again, the main information included the location of the observation site, and a description of the surrounding areas, including vegetation, soil types, and in some cases one or more sketches of the bank section. Information collected can be divided into four categories, including bank sections extended from bank crest to a near channel depth of 2 or 3 feet; soil samples – surficial samples from the bank crest, failure faces, berm, or bench, and core samples from nearshore areas (at depths of 1 or 2 feet); and vegetation, land use, exposed root, and adjacent appearance. Protocols for data collection have been prepared and appear in the section that describes sampling activities.

In many instances, three bank sections were chosen at the main site and three data sheets were prepared. For observation sites, normally only one sheet was completed.

Sampling

The field team was divided into two to four subteams. Subteam 1 was responsible for marking the upstream and downstream limits of each site reach and for collecting data at upstream and downstream quartile points. Subteam 2 was responsible for the bulk of the data collection effort, concentrated at the midpoint section: a detailed bank section, a river cross section, surficial bank sampling (including core sampling of shallow water soils and sediment), photographing bank soils at each sampling point, and drawing site sketches.

Data collection from the upstream and downstream ends essentially consisted of measuring bank sections, occasionally measuring river cross sections, and in a few instances, bank soil and sediment core sampling. Figure 6 shows photographs of typical data collection activities at a site on the Illinois River.

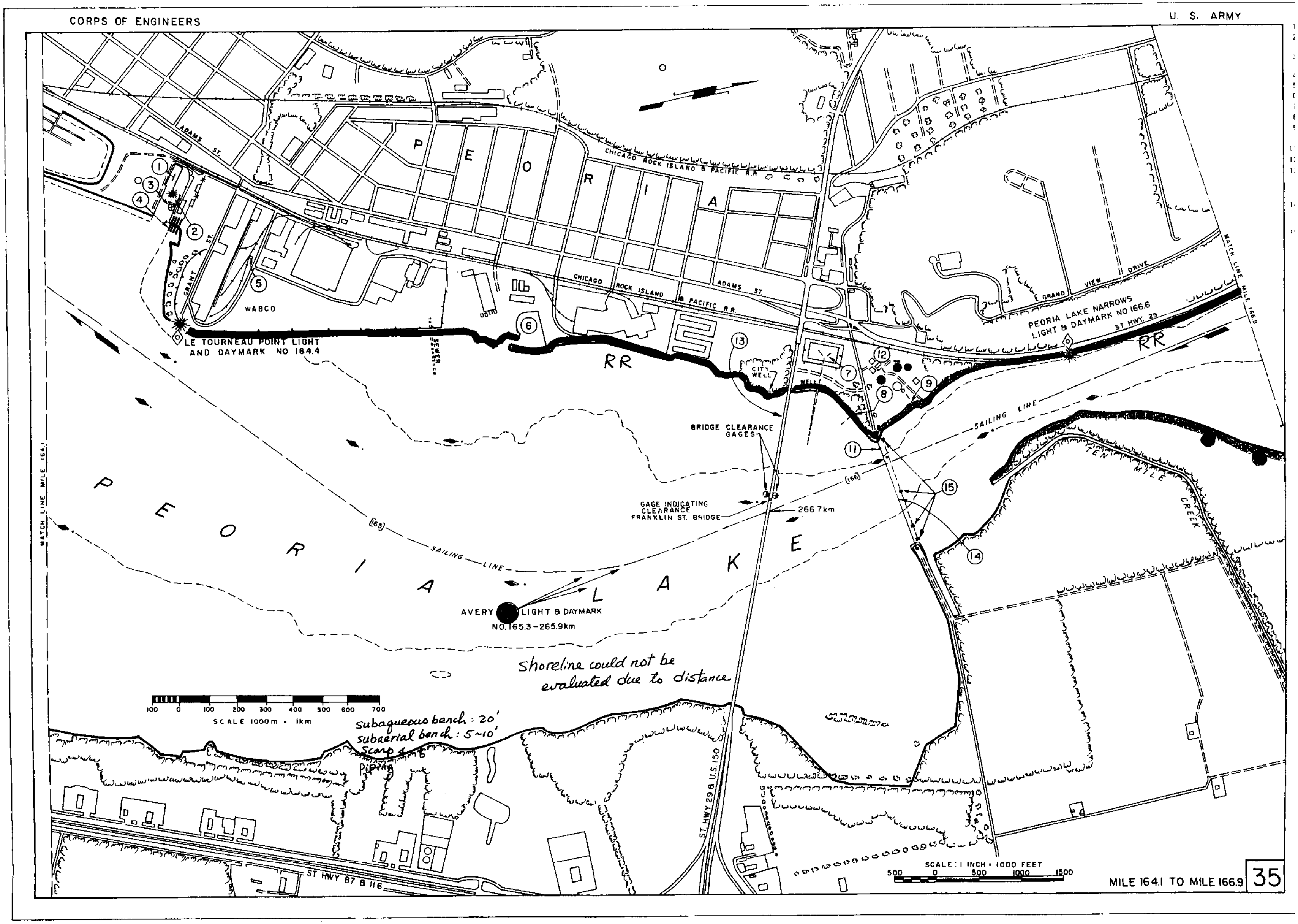


Figure 3. Field notation on the Illinois River navigation chart from approximately RM 144.8 to RM 150.6

0	Recorder's Name(s) -- First/Last	
1	Date & Time (e.g., 8/16/95 13:30)	
2	Weather	
3	River (ILWW/UMR)/Discharge (cfs)	
4	Navigation Pool No. for UMR/Name for ILWW	
5	Flat Pool Elevation (ft)	
6	Local Pool Elevation (ft) (Rising/Falling?)	
7	Site #: (RM @ Midpoint)	
8	Bank profile (UP/MP/DN?)	
9	Right Bank/Left Bank/Island (Tip/LT/RT/End?)	
10	Approx. RM of Erosion Site (miles)	
11	U/S RM of Erosion Reach (miles)	
12	D/S RM of Erosion Reach (miles)	
13	U/S UTM (x,y)	
14	D/S UTM (x,y)	
15	Natural or Revetted Bank (N/R)	
16	Geomorphic Charscteristics (see Codes)*	
17	Surrounding Structures (see Codes)**	
18	Archaeological Site (Y/N)	
19	Recreational Boat Traffic (L/M/H)	
20	Commercial Boat Traffic (Mean Daily Traffic?)	
21	Distance from Edge of Navigation Channel (ft)	
22	Land Use on Bank Crest (see Codes)***	
23	Vegetation at Bank Ledge (see Codes)****	
24	Vegetation on Bank Face (see Codes)****	
25	Assessment of Root Exposure on Bank Face	
26	Alongshore Vegetation (see Codes)*****	
27	Bank Failure Face Height (ft)	
28	Bank Failure Face Slope (ft/ft)	
29	Basal Berm Height (ft)	
30	Basal Berm Width (ft)	
31	Nearshore Underwater Slope (ft/ft)	
32	Bench Description	

Page 1: @ RM ________ on (ILWW/UMR: Pool #________)

Figure 4. Sample data sheet for bank erosion reconnaissance work group Upper Mississippi River/Illinois Waterway navigation impact study: streambank erosion

*Code for #16	**Code for #17	***Code for #22
C: Crossover **I:** Inside bend **L:** Island **O:** Outside bend **S:** Straight reach	**C:** Side-channels closure structure **D:** Boat Docks **F:** Fleeting area **M:** Mooring area **W:** Wingdams (I.D. #) & Conditions	**A:** Agriculture (Type?) **G:** Grass/Weeds (Species?) **H:** Highway **I:** Industrial **L:** Levee **R:** Railroad embankment **U:** Urban **W:** Wooded (Species?)

****Code for #23 & #24	*****Code for #26
A: Agricultural rows (Type?) **G:** Grass/Weeds (Type?) **W:** Wooded (Species?)	**N:** Nonsubmerged vegetation (Type?) **S:** Submerged vegetation (Type?)

33	Stage Variability (High, Moderate, Low)	
34	Erosional/Failure Features(Y/N); Description and Location Relative to Measured Profiles	
35	Overbank/Bank Drainage (Y/N); Extent and Location Relative to Measured Profiles	
36	Bank Erosion/Failure Type, Structure, Geometry & Causative Factors (see Code*#)	
37	Bank Failure Face Soil Type (see USC Sheet)	
38	Basal Berm Soil Type (see USC Sheet)	
39	Nearshore Soil Type (see USC Sheet)	
40	Channel Profiles Taken (Y/N?) If Y, how many?	
41	Soil Samples Taken (Y/N?) If Y, how many?	
42	Photographs Taken (Y/N?) If Y, how many?	
43	Video with Naration Taken (Y/N?)	
44	Potential for Future Field Investigations?	
45	Additional General Remarks:	

*#Code for #36	*# Code for #36	
F: Fall **RS:** Rotational Slump **PG:** Planar Glide **LS:** Lateral Spreading **DS:** Debris Slide	**C:** Cantilevers **S:** Slabs **B:** Blocks **L:** Loose	**SL:** Slaking **P:** Piping **W:** Wave&Prop Rework&Transport

Page 2: @ RM ________ on (ILWW/UMR: Pool #________)

Figure 4. (continued)

<Bank-Erosion Site Sketches>

[Page: 3/3]

A)

B)

Page 3: @ RM ________ on (ILWW/UMR: Pool # ________)

Figure 4. (concluded)

1	Date/Time	
2	River Mile (Left/Right)	
3	Navigation Pool Number	
4	UTM Coordinates	
5	Bank Type	
6	Geomorphic Characteristics (see codes)	
7	Surrounding Features	
8	Land Use	
9	Vegetation	
10	Bank Description	
11	Soil Type and Description	
12	Photographs	
13	Geologic Context LSA (see Anderson)	
14	Additional Comments	
15	Bank Sketch - on back (Y/N)	

Figure 5. Sample observation site data sheet for bank erosion reconnaissance work group Upper Mississippi River/Illinois Waterway navigation impact study: streambank erosion

<Bank-Erosion Site Sketches>

A)

B)

@ RM ________ on (IL WW/UMR: Pool #________)

Figure 5. (concluded)

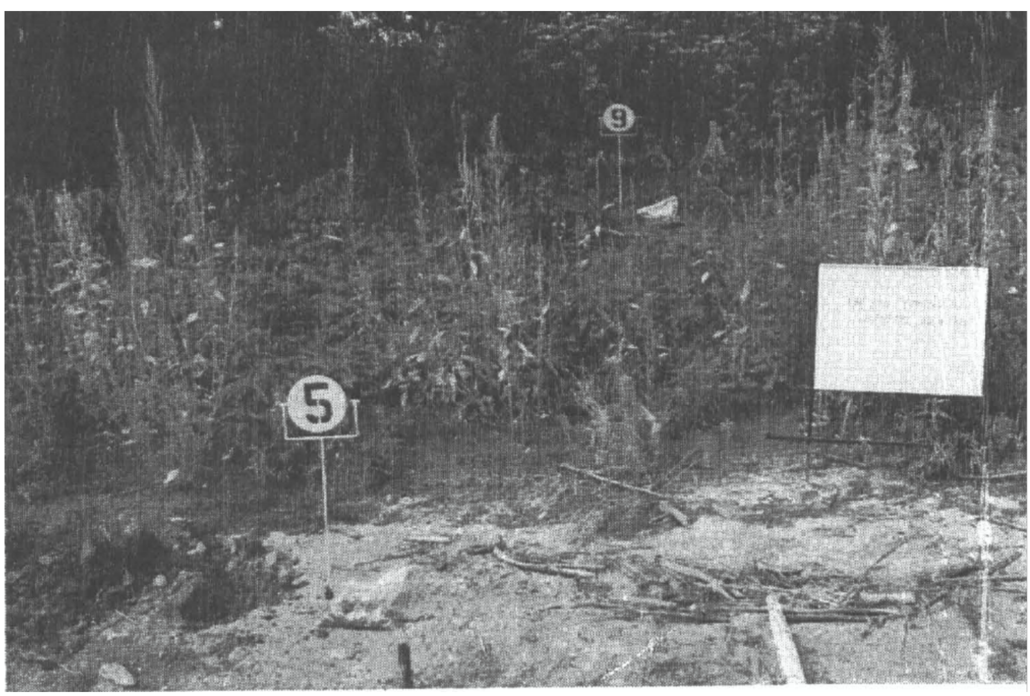


Figure 6.Typical data collection activities at a bank erosion site.

Bank Sections

Bank sections at most sites were measured using standard surveying equipment and procedures:

- A temporary benchmark on the bank was established.
- A standard level, leveling rod, and measuring tapes were used to measure the elevations of the bank at various locations on a transit starting from the top of the bank.
- Bank elevation measurements extended from the top of the bank to the water's edge and beyond, into 2-4 feet of water depth.
- All the measurement points, including distances and elevations, were recorded on field notes.
- A sketch of the bank section was also made on the field note pad.
- Similar measurements were occasionally repeated at the upstream or the downstream measuring section.

Bank Soils

Procedures used to collect bank soil samples follow:

- At least three surficial samples were collected at all the midsection measuring sections.
- These samples were collected by using either an ordinary garden shovel or a scraper.
- All the samples were preserved in zip-lock bags and clearly identified with time and date, river, location, river mile, and sample location relative to the bank section.
- Specific sample locations were measured and noted in field notes. Numbered posts in figure 6 were the locations where soil samples were taken.
- In general, three to nine samples were collected at each measuring section.
- When deemed necessary, core samples above the water's edge also were collected.

Subaqueous Core Samples

Subaqueous core sampling determined the composition and particle size distribution of these surficial soils and sediment. The sampling procedures were as follows:

- Sampling was done at l- and 2-foot depths along each profile line.
- A WILDCO core sampler was used with a graduated sample tube.
- The sampler was inserted as far as manually possible, then removed.
- The sampler was kept upright (vertical) after the sample was taken and while the contents of the tube were removed.
- For each sample, the total core length and the length of each separate horizon (with zero at the surface) were recorded on the appropriate sampling bag.

- After the length measurements were made, the sample was removed from the inner graduated tube and placed on a wooden sampling board. The core was divided into horizon samples, which were placed in labeled sample bags.
- After each sample was taken, the sample tube, corer tip, and corer threads were cleaned thoroughly.

Global Positioning System

A GPS was used to locate the midsection, upstream and downstream limits, and positions of any other important points on each site, to an accuracy of ± 3 meters (m). Figure 7 shows a photograph of the boat and clearly marked antennas used to measure the cross section.

River Cross-Sectional Profile

Procedures used to measure the cross section of the river are as follows:

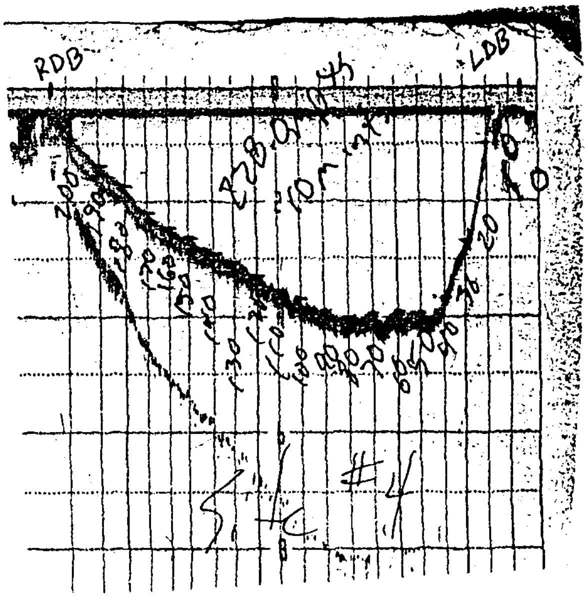
- A boat equipped with a sonar depth sounder with an accuracy of ± 0.3 m and a GPS unit were used.
- Once the midsection was located, two endpoints defining the cross section where depths were to be measured were identified, and the sounding boat was brought as close to the shore as possible.
- Tick marks with distances were noted on the sounding chart, and the exact distance from the starting point was noted on the strip chart. Figure 8 shows such two strip charts for sites 4 and 5 on the Illinois River at RM 228.1 and RM 228.5, respectively.
- Strip charts and associated data were subsequently used to develop cross sections of the rivers.

Island Sites

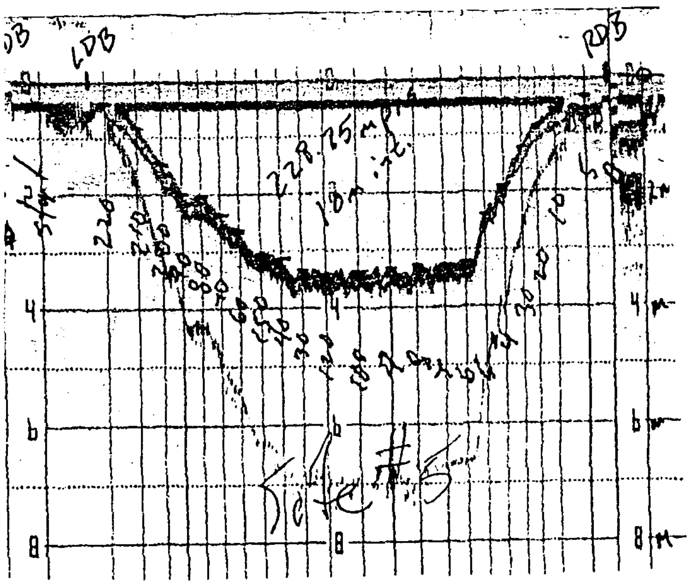
Many island erosion sites displayed similar patterns of bank morphology, erosion, and deposition. The following procedures were used when island sites were sampled:

- Island sites were chosen by consensus of the study team from reaches adjacent to the navigation channel.
- In addition to the three bank sections sampled for bank erosion sites, bank sections were taken at the upstream (head) and downstream (tail) ends of the island. Bank sections were also taken on the back of the island (side away from the navigation channel).
- Bank soil and core samples were collected at the midpoint section, and at the upstream and downstream limits.

Figure 7. River cross-section measurement by
an ISWS boat equipped with GPS and sonar



RM 228.1
Site 4



RM 228.5
Site 5

Figure 8. Strip chart showing river cross sections on the Illinois River

- At the upstream and downstream limits of a reach, a minimum of one bank sample and one core sample at a 2-foot depth were collected. Additional samples were collected at these locations as necessary.
- At island sites,bank core samples were collected at the midpoint section. Additional bank cores were collected at the upstream and downstream ends of the island.
- A cross channel section was measured along the line of the midpoint bank section. Additional cross-channel sectional were measured,provided there was sufficient evidence to suggest changes in the channel section along the length of the island.
- Longitudinal profile at several locations along the length of the island approximately 20-30 feet from the edge of water were also measured.

Other Information

The data sheets developed to collect various data from each of the erosion sites also contained information on vegetation, presence of bank revetments, wing dams, tributary mouths, general appearance of banks, dredge material disposal site close by (if any), land use on bank crest, exposed roots, bench description, bank drainage, presence of seepage, and other related data. This information was contained in the field notes (figure 4).

Classification Parameters and Database Structure

This section shows the set of parameters used in the field to classify the bank erosion sites from the Illinois River and the organization of a database.

Site Location

- River
- Navigation pool
- Right or left descending bank
- Upstream river mile
- Downstream river mile
- Upstream Universal Transverse Mercator (UTM) coordinates
- Downstream UTM coordinates

Site Attributes (limited to selected erosion sites)

Anthropic Characteristics

These data were developed prior to boat reconnaissance.

- Natural or revetted bank
- Presence/absence of wing dam(s) (as noted)
- Presence/absence of archaeological sites
- Recreational or commercial traffic levels
- Distance from center of navigation channel as shown on the navigation charts
- Land use on bank crest
  - Urban
  - Industrial
  - Agricultural
  - Wooded
  - Grasses and weeds
  - Levees
  - Railroad tracks

Geomorphic Characteristics

- Inside bend
- Outside bend
- Straight reach
- Transition reach
- Island

Erosion Attributes (limited to the sites selected for detailed investigations)

The study team adapted a nearshore bank failure model in bank assessment. A typical bank section consists of three features, i.e., scarp, berm, and bench (figure 9). This portion of the data was recorded at each site or developed shortly after field survey:

- Failure scarp height
- Failure scarp slope
- Basal berm height
- Basal berm width
- Failure scarp soil type
- Basal berm soil type
- Underwater slope
- Nearshore sediment type
- Vegetation at top of failure scarp
    - Wooded
    - Grasses and weeds
    - Agricultural row crops

Additional parameters that were measured whenever possible include the height and extent of exposed tree roots and heights of seepage and/or wave-wash created scarps.

Database Development

To organize the parameters described above, a database system was developed for the Illinois River. Each database contains information summarized from the field notes or calculated from measured data, as shown in table 2.

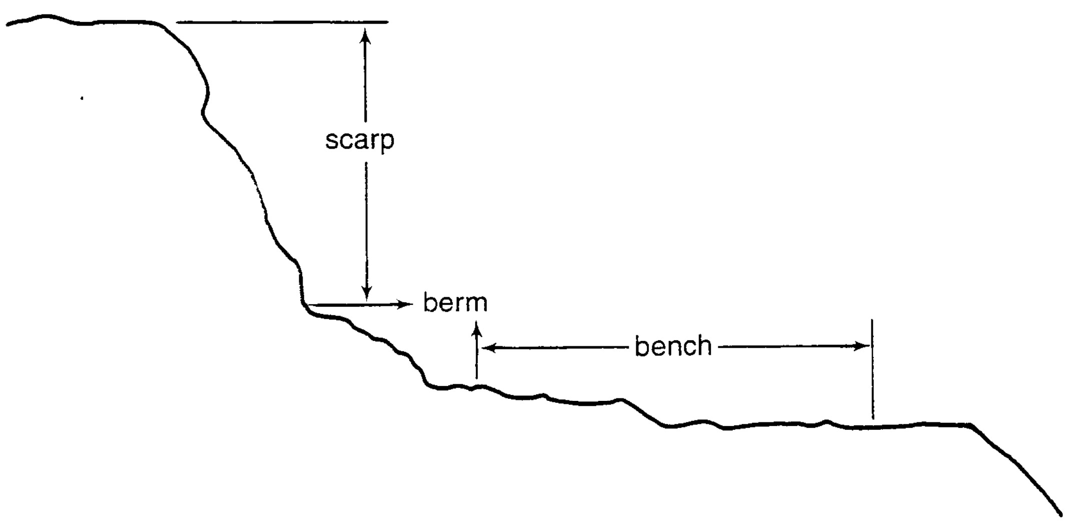


Figure 9. Definition sketch for scarp, berm, and bench

Table 2. Information Organized in the Database

Site #
  Date
  Time
River
  River mile at midpoint
Bank Section
RDB or LDB
Location Name
  Geomorphic characteristics
Bank Type

Bank Section
Bank Type
Wing Dam
Archeological Site
Surrounding Structures
Commercial Traffic Level
Recreation Traffic Level
Distance to the Sailing Line
Land Use on Bank Crest
Bank Crest Vegetation Type
Scarp/berm Vegetation Type
Alongshore Vegetation
Assessment of Root Exposure on Bank Scarp/Berm

Bank Section
Failure Feature
Bank Drainage
Bank Crest Type
Failure Scarp Height
Failure Scarp Slope
Failure Scarp Soil Type
Berm Height
Berm Width
Berm Soil Type
Underwater Slope
Nearshore Sediment Type

River Mile at Midpoint
Bank Section
Channel Profile Taken (Y/N)
Soil Sample Taken (Y/N)
Photographs Taken
Potential for Future Field Investigation
Bench Description

Characterization of Bank Erosion and Failure Mechanisms

This section will describe in general terms some of the characteristics of the riverbanks and near-bank benches (e.g., soils, slopes, depositional features, failure, and erosion mechanisms). Stage histograms were also developed to facilitate the evaluation of the bank failure and erosion processes (appendix A).

Soil Classification

The soil classification system used for this project was based on the Unified Soil Classification System as shown in table 3 (WES, 1982). In this system, the soils are classified according to their texture, consistency, particle size distribution, and a combination of these parameters. This system was used as a guide in the field to classify surficial bank soils.

Bank Erosion and Failure Mechanisms

Bank failure and erosion on any stream can result from instability of bed and/or banks. Therefore, causes and extent of bank failure and erosion are different in natural rivers and those modified by human actions. Channelization or other stream modifications often change the stream gradient and can cause erosion. Hydraulic and geotechnical evaluations should be conducted to determine the causes of bank retreat, and enable the resource agencies to address major mechanisms of streambank failure and erosion. Several interrelated processes define failure and erosion extent, severity, and resultant topography. These can be described as velocity and turbulence of flowing water, wave action, and tow transiting and mooring effects, including physical impacts, runout and runup, bank recharge and discharge, rapid recessional loading, cleft pressures, piping, slaking, ice wedging, plucking, and gorging.

Within river systems with permanently retained navigation pools (where water levels are no longer allowed to drop below certain elevations, as opposed to natural fluctuations in open rivers), the relative significance and occurrence of some of the referenced mechanisms can be modified by increased channel cross-sectional area for discharge of low and moderate flows, limited extents of recession from high stages, reductions in cleft pressures and seepage velocities, and restriction of areas subject to slaking and ice wedging. The effects of persistent seepage and wave action, within near normal pool elevations, have most probably resulted in the formation of benches. Lower bank benches found on controlled-stage waterways are locations of failed soil and recently deposited sediment reworking and erosion. Scarp and failed soil berms are affected by precipitation freezing-thaw, wetting and drying, seepage, stage, and flood flows. Scarp and bench areas somewhat remote from the normal pool land/water contact were not directly affected by persistent erosion processes within bench areas. Extensive erosion of banks, berms, and benches can occur during flood events.

Table 3. Unified Soil Classification System

Major Division		*Type*	*Letter symbol*	*Typical names*
COARSE-GRAIN SOILS >50 percent of material is retained on #200 sieve	GRAVELS (>50 percent of coarse fraction is retained on #4 sieve)	Clean gravels	GW	gravel, well graded, gravel-sand mixtures, little or no fines
			GP	gravel, poorly graded, gravel-sand mixtures, little or no fines
		Gravels with fines	GM	silty gravel, gravel-sand-silt, mixtures
			GC	clayey gravel, gravel-sand-clay mixtures
	SAND >50 percent of coarse fraction passes #4 sieve	Clean sands	SW	sand, well graded, gravelly sands
			SP	sand, poorly graded, gravelly sands
		Sands with fines	SM	silty sand, sand-silt mixtures
			SC	clayey sand, sand-clay mixtures
FINE-GRAINED SOILS >50 percent of material passes a #200 sieve		Silts and clays LL <50	ML	silt and very fine sand, silty or clayey find sand or clayey silt
			CL	lean clay, sandy clay, silty clay, of low to medium plasticity
			OL	organic silts and organic silty clays of low plasticity
		Silts and clays LL >50	MH	silt, fine sandy or silty soil with high plasticity
			CH	fat clay, inorganic clay of high plasticity
			OH	organic clays of medium to high plasticity, organic silts
HIGHLY ORGANIC SOILS			PT	peat and high organic soil

Notes:
#4 sieve: particles with diameter of 4.75 mm or less can go through.
#200 sieve: particles with diameter of 0.075 mm or less can go through.
LL: Liquidation limit.

A study of streambank erosion in the United States by the USACOE (1981) determined that 575,000 bank miles were eroded, of which 142,000 river miles were eroded seriously. In the Upper Mississippi River basin, about 14,800 bank miles were eroded along 198,200 stream miles (USACOE, 1981).

Keown et al. (1977) identified six types of streambank erosion:

1. Attack at the toe of the underwater slope, leading to bank failure and erosion: bank failure normally occurs in a falling river at a medium stage or lower.
2. Erosion of soil along the bank caused by current action.
3. Sloughing of saturated cohesive banks, i.e., banks incapable of free drainage due to rapid drawdown.
4. Flow slides (liquefaction) in saturated silty and sandy soil banks.
5. Erosion of the soil by seepage out of the bank at relatively low channel velocities.
6. Erosion of the upper bank or river bottom, or both, due to wave action caused by wind or passing boats.

A more detailed list of streambank failure mechanisms was compiled in a final report to Congress (USACOE, 1981), as shown in table 4.

More recently, Neill and Yaremko (1989) compiled a list of 14 causes of bank erosion, seven in natural environments and seven in disturbed environments. In watersheds undisturbed by human actions, the causes were: 1) the geological (geomorphic) process of valley widening, 2) meandering in alluvial floodplains, 3) extreme floods, 4) debris and vegetation, 5) coarse sediment, 6) ice and frozen banks, and 7) geotechnically unstable banks. Vegetation is usually considered a stabilizing factor, but protruding trees can cause erosion, and fallen trees may become debris and cause rapid local scour. Neil1 and Yaremko's list of causes in disturbed watersheds includes: 1) development and land-use change, 2) removal of bank vegetation, 3) boat-generated waves, 4) constructed bridge crossings, 5) bank protection and river training works, 6) mining of sand and gravel from streambeds, and 7) stream straightening and channelization.

Streambank erosion contributes to the total sediment load in a stream. It was estimated that about 7 percent of the total sediment yield in the nation was from streambank erosion. Many Midwestern streams and rivers contribute heavily to this total volume of eroded sediment (USDA, 1975; USDS-SCS, 1973).

Bank erosion processes can be divided into two broad classes: those closely related to the geotechnical aspect of the soils and those related to the fluvial activities of the stream. Erosion itself, however, is the result of the dynamic interactions between these two broad divisions. Each is dependent on the other within any stream ecosystem (Bhowmik, 1983).

Table 4. Streambank Failure Mechanisms

A. Surficial	Stresses within a streambank are changed by particular actions at the bank surface. Examples of surficial actions that affect bank stability are: 1. Severe surface deterioration caused by a number of physical, chemical, biological, and human actions may result in an unstable bank configuration. Erosion at the toe of the bank slope due to streamflow, erosion at the water surface due to waves, and erosion along the bank surface due to overbank and seepage flows are three common occurrences. 2b. Deep tension cracks due to excessive drying of a cohesive soil or similar structural change may cause the streambank to weaken and become unstable. Slaking may occur if excessive drying is followed by submergence. 3c. Overburden placed along top-of-bank may cause an otherwise stable streambank configuration to become unstable.
B . Moisture	Stresses and the ability of the bank material to withstand stress without failing are both affected by moisture variation within the bank. Examples of these moisture-induced effects are: 1. The slope of a cohesionless bank may be temporarily steeper than the angle of repose of the bank material due to capillarity or other nonpermanent stabilizing effect; when the nonpermanent effect is removed (usually by submergence and saturation of the bank material) the bank becomes unstable. 2. During piping, cohesionless material is eroded from a location on the bank surface by seepage flow; a cavity develops and extends rapidly into the bank along a dominant seepage path. 3. Liquefacation relates to fine-grained and loosely structured materials subject to a rapid increase in pore pressure (such as occurs during rapid drawdown or earthquake loading) and results in a large segment of bank material flowing downslope as a fluid-like mixture. 4. During periods of high water table and low stream levels an added hydraulic loading is placed on the bank structure; this added load may directly cause failure unless relieved otherwise (say by seepage or piping). 5. Swelling and shrinking during wetting and drying, respectively, affect the stability of clay soils. Substantial hydraulic pressures may result from water flowing freely into deep tension cracks (see Surficial, above) and into openings between different bank materials. 6. The shear strength of clay soils is highly dependent on pore pressure (slow versus quick shear) and by degree of saturation.
C. Miscellaneous	Because of the nonhomogeneous (heterogeneous, interbedded, stratified, etc.) character of most streambanks, combinations of failure mechanisms are common. Examples are: 1. Artesian or gravity flow within a cohesionless or porous layer that evacuates sediment particles by piping can result in shear failures of layers higher in the bank. 2. A think clay layer that weakens and compresses during saturated bank conditions can also cause shear failures in the upper bank. 3. Lubrication by water and high hydrostatic pressures along interfaces between bank materials that cause low resistance to sliding may result in a massive bank failure.

Source: After U.S. Army Corps of Engineers (1981)

Streambanks can be of cohesive or noncohesive materials. Most natural banks are actually composite materials, and some are presented in layered structures. Channel morphology often is also indicative of bank erosion. Bank erosion occurs often on the outside bank of a bend where water velocities and depths increase greatly. During floods, bed scours may occur at the outside bank and make bank slopes much steeper, in many cases almost vertical, thus increasing bank and bank slope instability.

Cohesive bank soils may be subject to a variety of failure mechanisms. Slip failures in cohesive bank soils are often brought about by rapid drawdown or rapid fluctuations of water levels. Figure 10 shows other typical bank failure mechanisms in streams, rivers, and lakes. In some instances, when a bank is saturated, a tension crack may develop on a horizontal surface due to hydrostatic pressure, which then exerts tensile forces on the bank soil. Rapid drying of the saturated bank can also produce vertical desiccation cracks accompanied by bank failure. Flood-flow-initiated erosional undercutting is a common type of failure for many cohesive and composite banks and can result in shear, beam, or tensional failure of the overhanging portion of the bank mass.

Bank Slopes

The slopes of riverbanks vary widely and from place to place. If a riverbank is composed of noncohesive materials without vegetation and tree roots, then the slope would tend to have a shape very close to the angle of repose of these soils. Because a natural riverbank is seldom composed of homogeneous soils, the bank slopes will vary. Figure 11 shows a nine-unit land-surface model proposed by Dalrymple et al. (1968) to illustrate the various slope patterns that could be present in a land surface environment.

Figure 12 shows another theoretical erosion pattern at and below the extremely high watermark in a free flowing system. This type of block failure was observed at several locations on the open river portion of the Upper Mississippi River (UMR) shown by two sets of photographs in figures 13 and 14 for two water levels. Figure 13 shows a set of five photographs at RM 605, tip of the Sweezy Island on the UMR, taken when the water level was quite high and the bank eroded by waves overtopping. Figure 14 shows a riverbank at RM 52.3, site 42 on the UMR where bank failure occurred due to failure of a sandy layer. Similar failure mechanisms were observed on the Illinois River. Again, riverbank failure and erosion can be interrelated with the dominant erosional process and have been categorized in following these concepts. The following sections describe exactly what was done for the Illinois River.

Bank Soils

All the bank soil and core samples collected for this project were analyzed to determine particle size distribution, Standard Deviation, σ, and uniformity coefficient, U. These parameters are defined as follows:

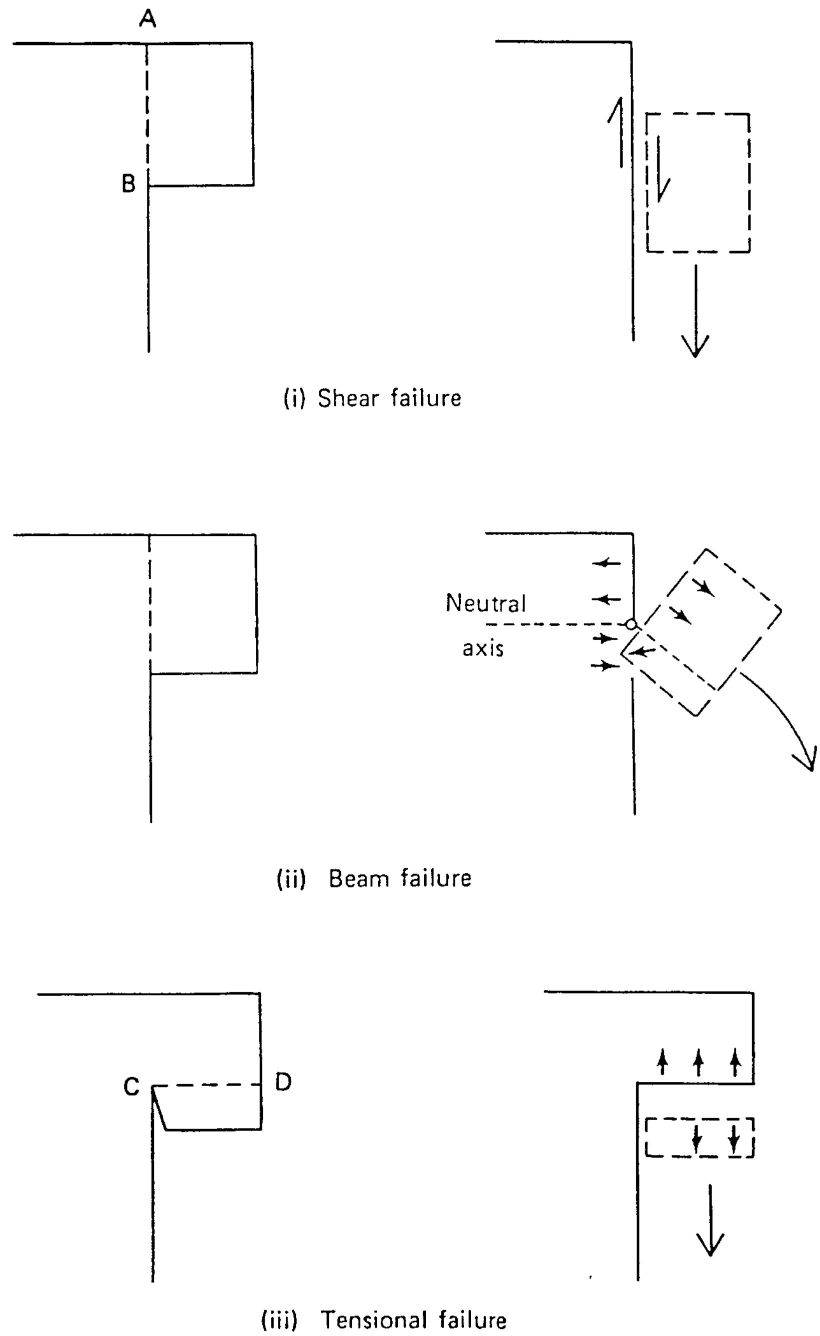


Figure 10. Modes of failure for cantilever overhang banks (from Bhowmik et al., 1983)

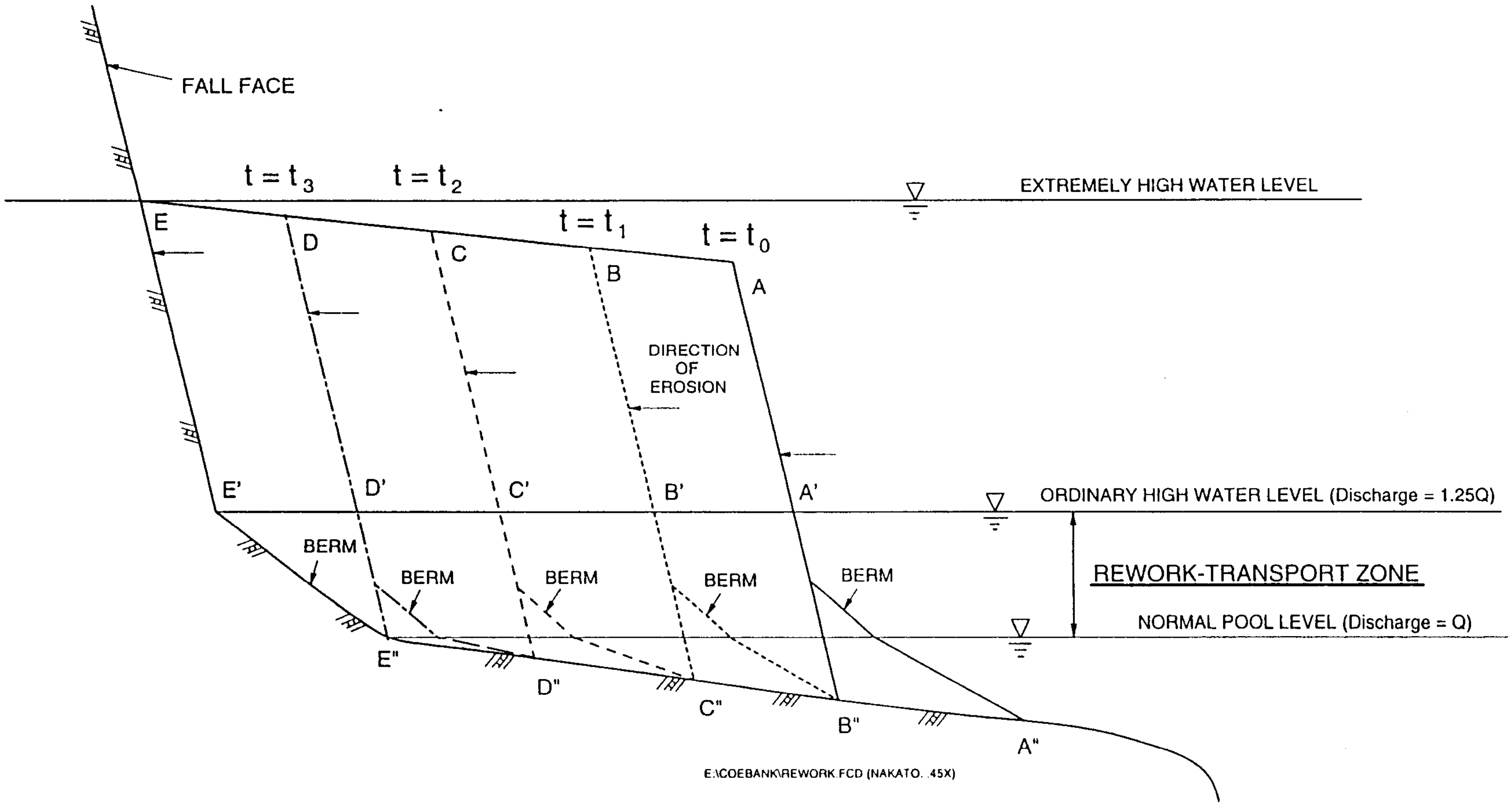
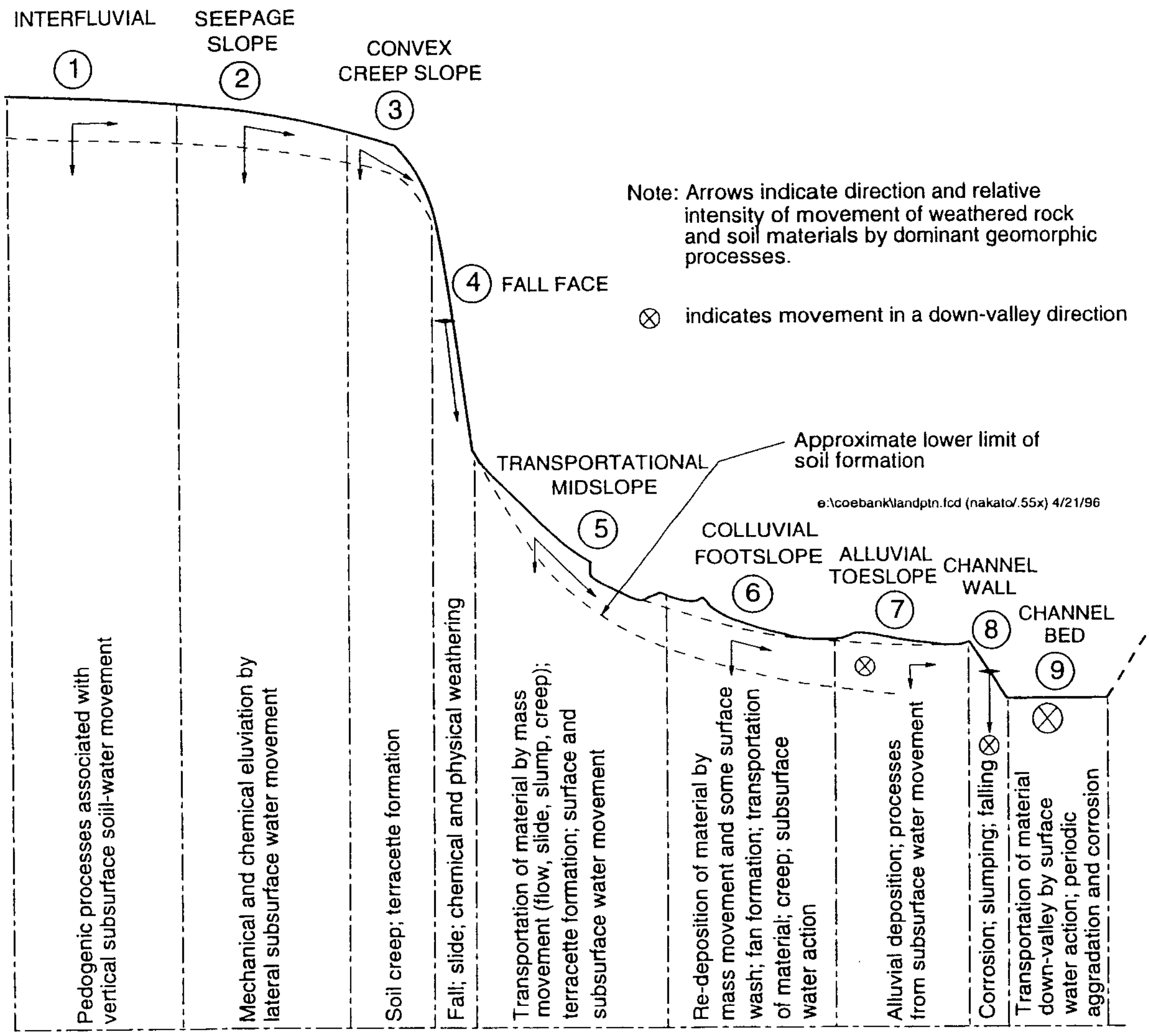


Figure 11. A hypothetical nine-unit land-surface model proposed by Dalrymple et al. (1968)



Re-drawn after Dalrymple et al., "A hypothetical nine-unit land surface model," Zeitschrift fur Geomorphologie, vol.12, 1968.

Figure 12. Near bank rework-transport zone

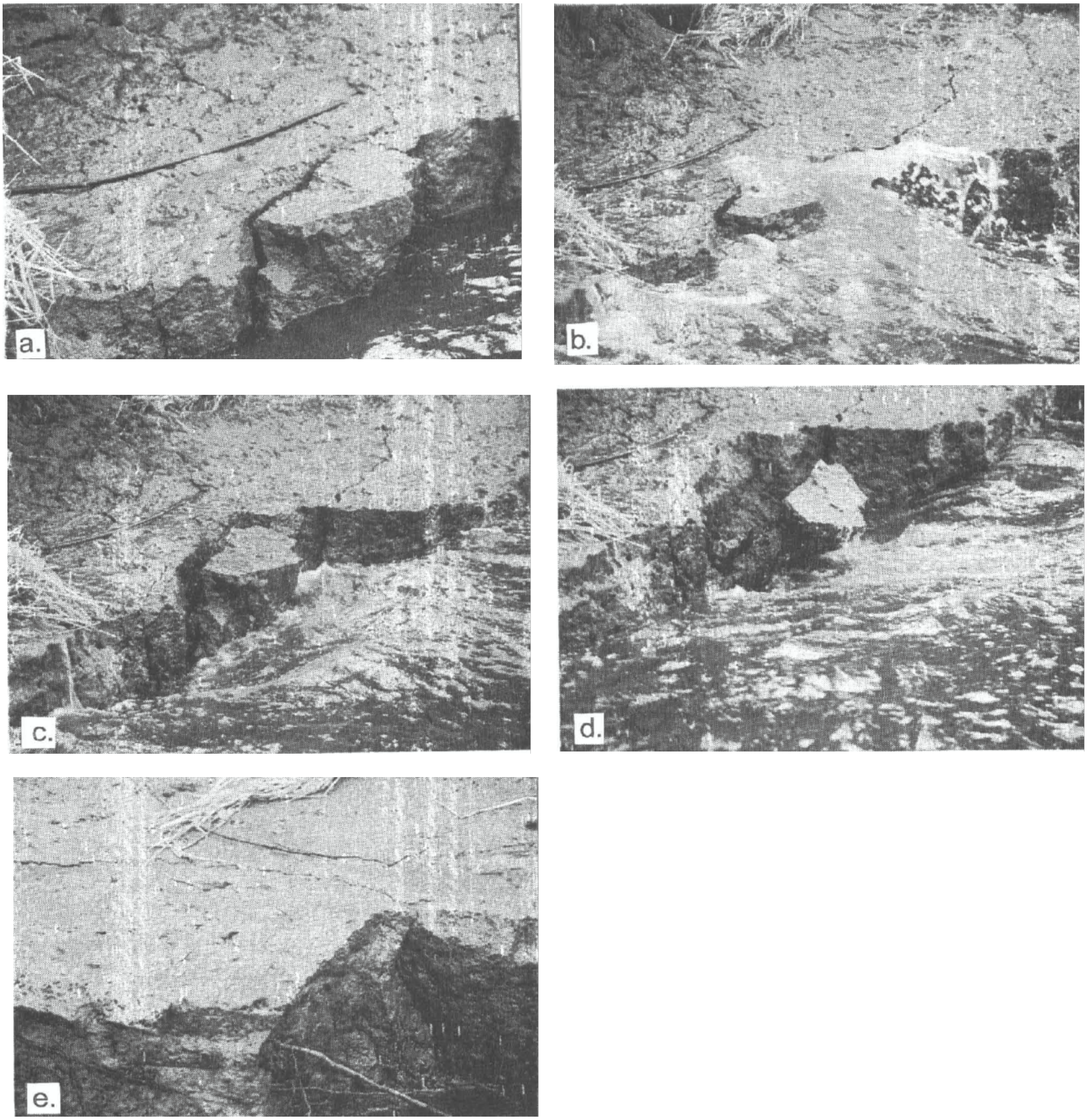


Figure 13. Bank erosion due to overtopping, RM 605, UMR

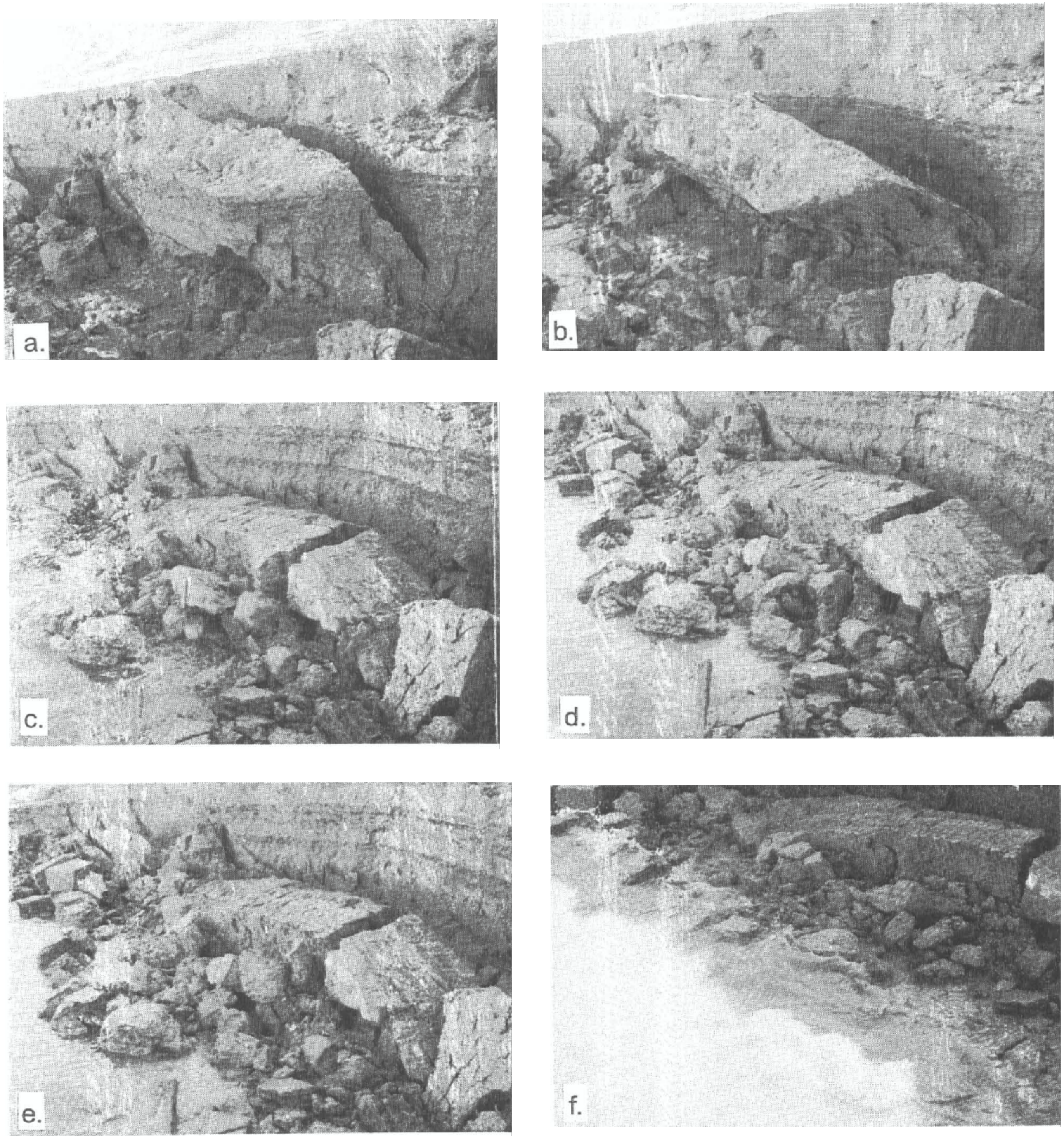


Figure 14. Bank erosion due to undercutting, RM 52.3, UMR

Standard Deviation, $\sigma = 1/2 \left[\frac{d84.5}{d50} + \frac{d50}{d15.9} \right]$ (1)

and

uniformity coefficient, $U = \frac{d60}{d10}$ (2)

The size distribution of the bank and core samples and the values of σ and U are described with the analyses of the data.

Stage Histograms

During and after the field trip on the Illinois River, study teams found evidence that erosion patterns, bank slopes, and other features could be related to stage-duration data. It was decided that an analysis of stages at various locations would be done to compare with bank section features. Consequently, data on daily water stages at stations close to the selected erosion sites on the river were gathered for 1985-1994, from USACOE records and were statistically analyzed to determine the histograms of water stages at the selected locations.

When stage data at each selected site were not available, the nearest available stage gage site within two miles was used in this analysis. Table 5 shows the stage gaging sites used to develop the stage histograms in connection with this study.

Data collected for the streambank sections at all the bank erosion study sites were plotted, including information such as the ordinary high water elevation (OHWE) and low operating pool elevation (LOPE). Note that LOPE and NP (normal pool) are used interchangeably in the text. Each plot of the bank section collected at each site was plotted with the stage histograms on the same sheet. Figure 15 shows such a plot for site No. UP1 on the Illinois River. Similar plots have been developed for all selected sites (appendix A).

It should be noted here that figure 15 and all other similar plots were prepared to show the general orientation of the erosion sites. For example, site UP1 on the Illinois River is on the right descending bank (RDB) of the river. Thus, the bank sections were plotted on the right side of the figure looking from the top of the illustration to the bottom.

Table 5. Stage Gaging Locations Used for Illinois River Study Sites

Site	*River mile*	*Gage used*	*Gage location, RM*
UP1	270.8	tail water gage of Dresden Island	271.5
UP2	270.8	tail water gage of Dresden Island	271.5
UP3	264.3	Illinois River near Morris, IL	263.1
UP4	262.1	Illinois River near Morris, IL	263.1
UP5	262.1	Illinois River near Morris, IL	263.1
1	242.8	tail water gage of Marseilles Pool	244.6
2	243.4	tail water gage of Marseilles Pool	244.6
3	235.7	Pool gage of Starved Rock Pool	231.0
4	228.0	tail water gage of Starved Rock Pool	231.0
5	228.5	tail water gage of Starved Rock Pool	231.0
6	210.0	Illinois River near Henry, IL	196.0
7	203.8	Illinois River near Henry, IL	196.0
8	184.8	Illinois River near Henry, IL	196.0
9	179.8	Illinois River near Henry, IL	196.0
10	160.0	gage of Peoria Pool	157.7
11	155.3	tail water gage of Peoria Pool	157.7
12	154.4	tail water gage of Peoria Pool	157.7
13	150.5	Illinois River near Kingston Mines, IL	145.4
14	129.3	Illinois River near Copperas Creek, IL	139.9
15	116.5	Illinois River near Havana, IL	119.6
16	109.5	Illinois River near Havana, IL	119.6
17	109.5	Illinois River near Havana, IL	119.6
18	94.2	Illinois River at Beardstown, IL	88.3
19	91.2	Illinois River at Beardstown, IL	88.3
20	79.4	tail water gage of La Grange Pool	80.2
21	61.7	Illinois River near Valley City, IL	61.3
22	45.1	Illinois River at Pearl, IL	43.2
23	23.4	Illinois River at Hardin, IL	21.6
24	13.0	Illinois River at Hardin, IL	21.6

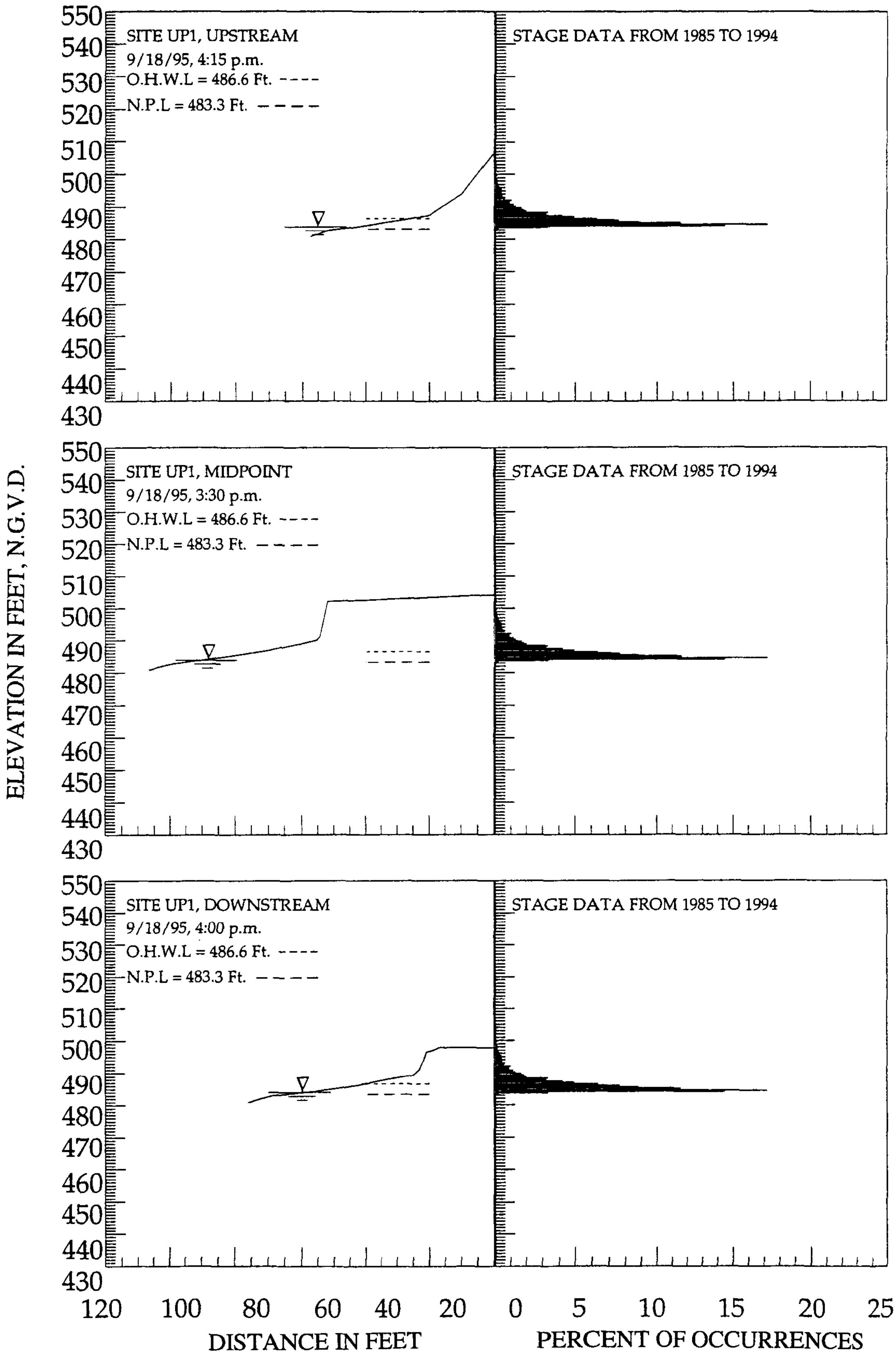


Figure 15. Bank profile at site UP1 in Marseilles Pool of the Illinois River, RM 270.8, RBD stage histogram at tail gage of Dresden Island Pool, RM 271.5

Data Analysis

This section describes the data collected from the Illinois River and the analyses that were performed. Some of the background materials are taken from Bhowmik and Schicht (1980).

The Illinois River and its main tributaries form one of the main waterways in Illinois and stretch from Milwaukee; Wisconsin, and South Bend, Indiana, to Grafton, Illinois. The tributaries of this river basically drain farmlands. Figure 16 shows the drainage basin of the Illinois River, which has a drainage area of 28,906 square miles.

The upper part of the Illinois River basically flows east to west and has a narrow channel. The riverbed has steeper slopes, and the drop between Lockport and Starved Rock (upstream of Hennepin, figure 16) is about 2.3 feet per mile. The river turns a southwesterly direction after passing De Pue. Below Starved Rock and until the mouth of the Illinois River, the channel becomes wider and meandering. The average slope is only about 1.6 inches per mile. Lubinski (1993) divides the Illinois River into the following two reaches:

- From confluence of the Kankakee and Des Plaines Rivers to Hennepin, Illinois. The river passes through a young geologic valley and has a relatively high gradient, narrow floodplain, and three navigation dams.

- From Hennepin, Illinois, to the Mississippi River. This section of the Illinois River is geologically older and wider than the upper reach. It was used by the Mississippi River before recent glacial activity redirected the Mississippi River westward. It has a very shallow gradient, extensive levees, and two navigation dams.

Physiographically, the river basin is located in the till plains section of the central United States (Fenneman, 1928). Large-scale relief features are absent within Illinois; however, some local relief features effectively change the physiography of the basin from one location to another.

Leighton et al. (1948) divided the State of Illinois into a number of physiographic divisions on the basis of the topography of the bedrock surface, glaciations, area of the drift, and other factors. The Illinois River flows through about five of these physiographic divisions characterized by broad till plains in the youthful stages of erosion. The alluvial soils near the river are most often layered and lensing alluvium.

The upper part of the river above the big bend near De Pue has a broad, flat bottom valley with steep walls. Between De Pue and Peoria, the floodplains are rather narrow; downstream from Meredosia, the floodplain gradually narrows until the Illinois River meets the Mississippi River near Grafton.

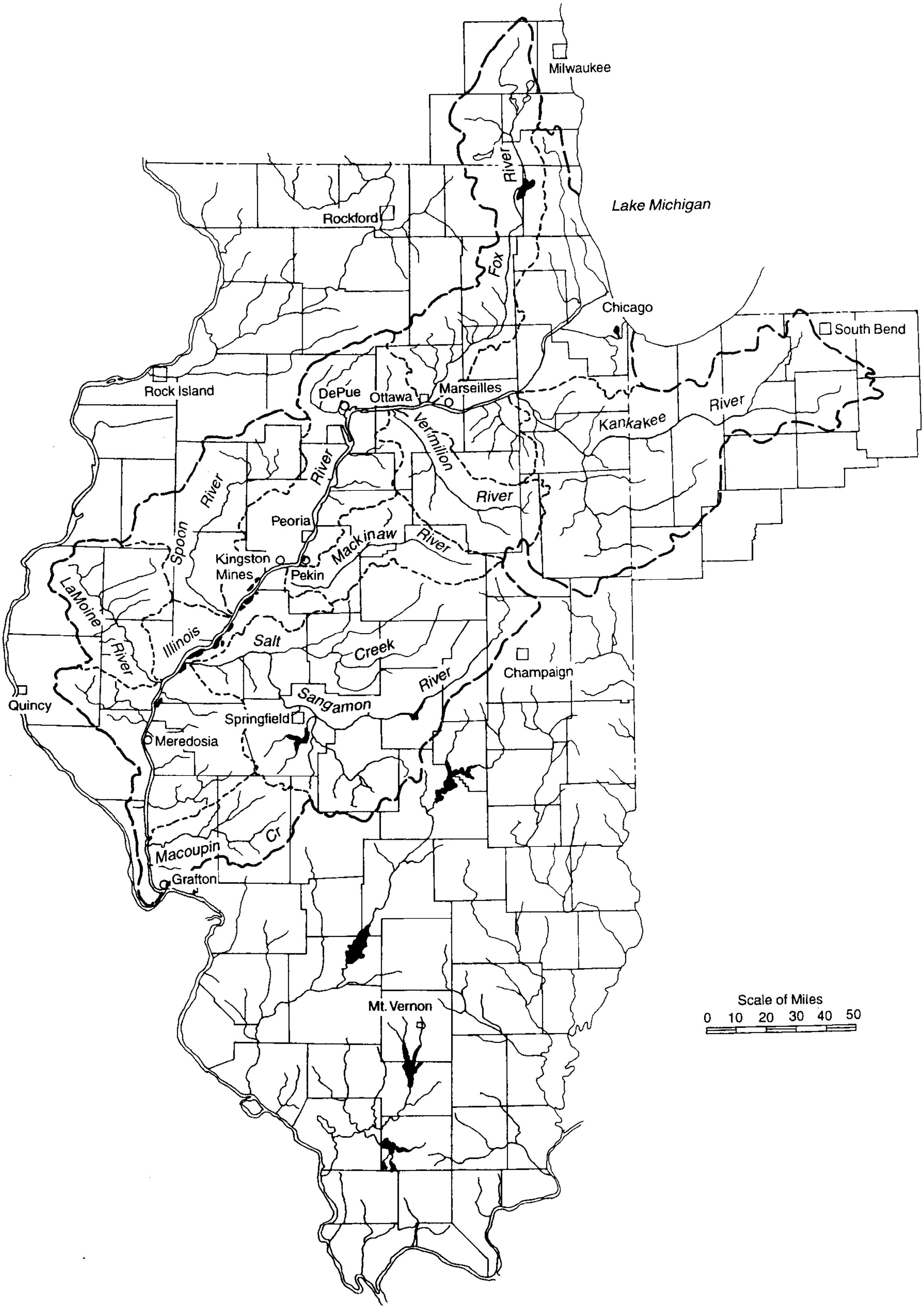


Figure 16. Drainage basin of the Illinios River

The Illinois River in its present form consists of a series of pools created by eight locks and dams. These locks and dams control the water surface profiles and the average depths of flow.

The USACOE maintains a 9-foot navigational channel along the length of the river for vessels that draw 9 feet of water. This major waterway has carried a large amount of barge traffic since the opening of the locks and dams in 1933. More than 46 million tons (1990 data in IPMP, 1994) of traffic traverse the river in a year. Tows operating on the river may have as many as 15 barges (each capable of carrying 1,500 tons) pushed by a 5,000 horsepower tow boat. A tow and barge configuration (nearly 105 feet wide and 1,100 feet long) can move at a speed in excess of 8 miles per hour with a draft of 9 feet and could move 1,100 cubic feet of water per second through its propeller (Adams, 1991).

Past Studies

Three prior studies of bank erosion on the Illinois River have been done: Bhowmik and Schicht (1980), Warren (1987), and Hagerty (1988).

Bhowmik and Schicht (1980) Study

This study was conducted with the following objectives:

- To document present bank erosion areas.
- To develop a present plan view of severely eroded banks at about 20 selected reaches.
- To make bank stability analyses for each reach.
- To attempt to assess the effect of the increase in the Lake Michigan diversion on bank erosion.
- To propose a monitoring system to document any future changes in bank conditions.
- To suggest future research areas that should be undertaken to better identify the causes of the bank erosion of the Illinois River.

A five-day boat trip on the Illinois River was taken from July 17-21, 1978, to document the severity of bank erosion. The trip started at Joliet and ended at Pere Marquette State Park near Grafton.

During the trip, severely eroded banks were photographed, and surficial soil samples from the eroded banks and the riverbed were collected at intervals of 3 to 4 miles. During this trip a total of 24 river reaches from one side of the river were selected for detailed plan form and collection of bank profile and bank material samples. These data indicated that the bank slopes varied from 1V:3.5H to 1V:9H. Here V indicates vertical displacement and H indicates horizontal displacements. The median diameter of bank materials were in general less than 0.3 mm with a majority less than 0.1 mm, indicating that these materials were in the silty to clayey ranges. The majority of the samples had d_{95} values less than 1 mm with most in the range of 0.1 to 0.6 mm, indicting that these were mostly sand. All these materials were also well graded.

Based on their investigation, Bhowmik and Schicht (1980, page 1) made the following observations. “Banks of the Illinois River have been eroding because of natural and man-made acts. In many places the erosion is very severe; in other places the banks are stable. The bank erosion of the river was investigated in detail to ascertain the probable effects of increased Lake Michigan diversion on bank stability or erosion. Hydraulic parameters were either computed or estimated, and the stability of the banks at all 20 locations was tested following accepted methods and techniques in hydraulics.

“The stability analysis based on hydraulic and gravity forces assuming noncohesive bank materials was done for discharges with and without additional Lake Michigan diversions for three typical water years. In general, the silty, sandy, and clayey materials of these severely eroded banks should be stable against the action of tractive force and flow velocity. However, preliminary computations indicated that the banks are unstable as far as the wind-generated wave action is concerned. It is possible that river-traffic-generated wave action also has a similar effect. A monitoring program is outlined, and a future research project related to the wave action on the banks is suggested.” It should be noted that no geotechnical analysis was performed for this study.

Warren (1987) Study

Warren (1987), based on historical observations, found the Illinois River had been geologically stable until the early 20th century. His summary stated: “Although it is difficult to judge the amount of bank erosion that occurred along the Illinois River under natural conditions, there is little question that erosion rates are much higher today. The modern channel is still straight, but a variety of artificial changes in the regime of the Illinois have both reinforced old causes and introduced new causes of erosion... some of the more important of these changes include the heightened water-surface elevation of the river; the increased frequency and magnitude of flooding along the river; the increase in wave action generated by vessel traffic and, perhaps, by wind; the introduction of drawdown as a new erosive force; and probably also the feedback between these various factors and the modem characteristics of cutbanks along the river. Together, these man-made causes and conditions have helped to create a severe erosion problem along many stretches of the Illinois River.

“A field study was conducted at five archaeologically important sites on the Illinois River. Rates of erosion were measured both horizontally and vertically over a period of approximately 6 months. At all but one site, banks were generally eroding. A statistical analysis using multi-regression of 14 variables related to site characteristics and erosion measurements was conducted. (None of the variables related to processes such as wind energy, or vessel waves, etc.) The average horizontal erosion rate at the five sites was 1 mm/day, with a high of 2.5 mm/day at one site and a low of -1 mm/day at another. Extrapolation of these rates indicates a

35-cm loss of bank deposits per year along the lower Illinois River. The author concluded that since erosion occurred on both sides of the river in both convex and concave channel areas, natural phenomena could not have caused the erosion; therefore, much of the erosion must be due to vessel traffic" (Maynord and Martin, 1996, page 50, on Warren's report).

Hagerty (1988) Study

Hagerty (1988) conducted an investigation on the conditions of banks along the Illinois River during June 1988. The purpose of this investigation was to observe bank conditions of the river, determine significant failure and erosion mechanisms on those banks, and describe the relative significance of each mechanism. Riverbanks were inspected by helicopter on a reconnaissance trip from St. Louis to Joliet (RM 286) and a bank inspection trip by boat from Joliet to Grafton. Hagerty (1988) summarized his observations about the channel morphology and surrounding structures after the helicopter overflight in his 1988 report and concluded (Hagerty,1988, page 11):

- Significant bank erosion was not present along the Illinois River.
- Extensive reaches of high bare bank were not seen.
- Many long reaches with apparent bank stability were observed.
- Large bodies of water were noted adjacent to low bare banks with seepage marks.

Based on observed bank conditions, sites with potential for erosion were divided into five categories. A description of each of these specific categories with an explanation could be found in Hagerty (1988).

The bank conditions described by Hagerty (1988) can be summarized as:

Condition	*Left Descending Bank (%)*	*Right Descending Bank (%)*
Severely eroded	1.84	2.35
Moderately eroded	16.27	14.46
Artificial	17.47	21.09
Apparently stable	63.58	60.76
Bedrock outcrop	0.84	1.34

In a later report, Spoor and Hagerty (1989) stated: "Investigations conducted in 1988 along the Illinois Waterway indicated that bank failure and erosion are initiated by the flow of water out of the banks and removal of soil particles by piping/sapping.... Wave swash did not appear to be a significant mechanism for removal of inplace soils, although levee notching indicated erosion by a combination of waves and tractive forces during floods. Propeller turbulence was a cause of only very localized bed/bench scour.... Waterway bank erosion was not severe or widespread; even within the pools where erosion was most extensive, only 6 percent of the total bank length was severely eroded" (Maynord and Martin, 1996, page 51).

Historical Navigation Traffic

The locations of lock and dams on the Illinois River are also shown in figure 17. The USACOE Rock Island District provided data on the navigation traffic in terms of empty and loaded barges moving either upstream or downstream from 1980-1995 (USACOE, 1997). In general, the number of barges per year (either empty or fully loaded) increases in the downstream direction. Traffic associated with the Mississippi River should increase as one moves from the headwaters of the Illinois River toward its confluence with the Mississippi River.

Data showed a significant increase in the navigation traffic in 1993. During the 1993 flood, traffic on the Mississippi River was completely halted for more than a month (July 11-August 22). High water stages on the Mississippi River may have diverted many barges to the Illinois River. On the other hand, the traffic level in 1995 was lower than that in 1994. The Illinois River was closed 60 days for river rehabilitation work, and near record flooding on the mid to lower Illinois River may have contributed to the decrease in traffic volume in 1995. Traffic in recent years appears to be increasing (USACOE, 1997). Figure 18 shows the average annual navigation traffic for 1980-1994 for empty and loaded barges for all locks on the Illinois River.

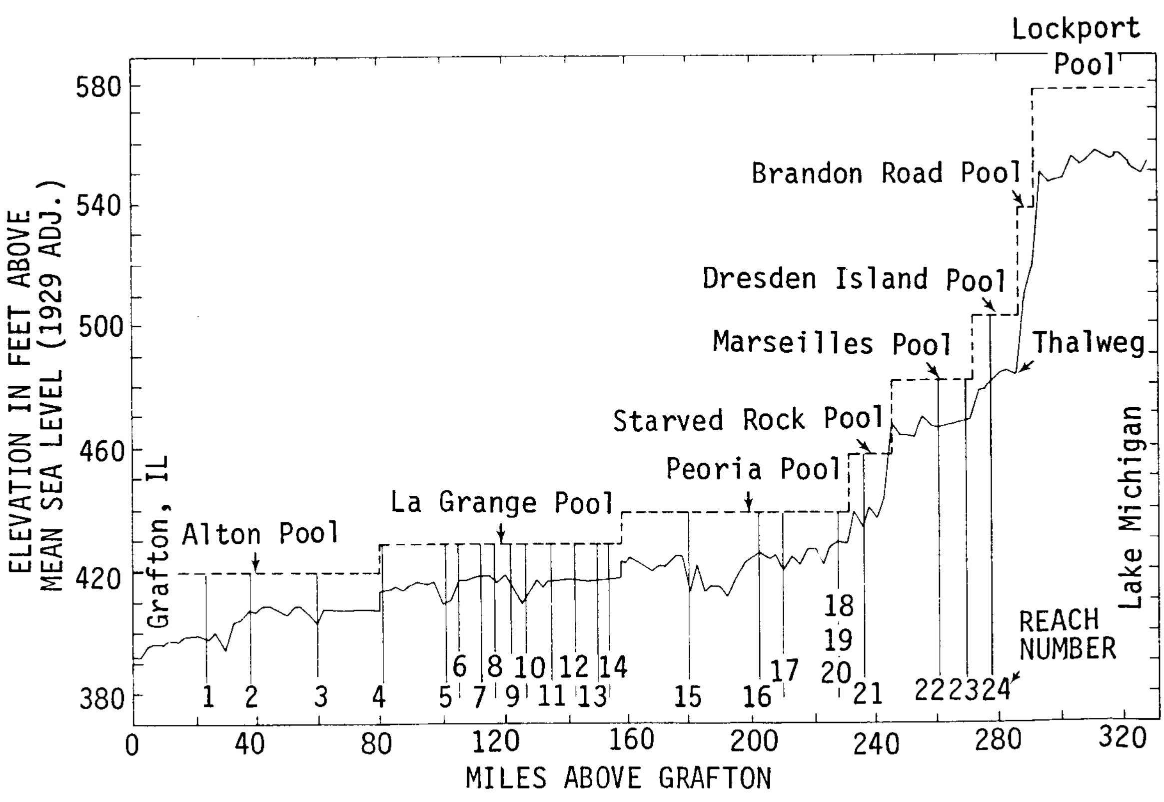


Figure 17. Profile of the Illinois River and the locations of the reaches selected for further bank erosion investigations by Bhowmik and Schicht (1980)

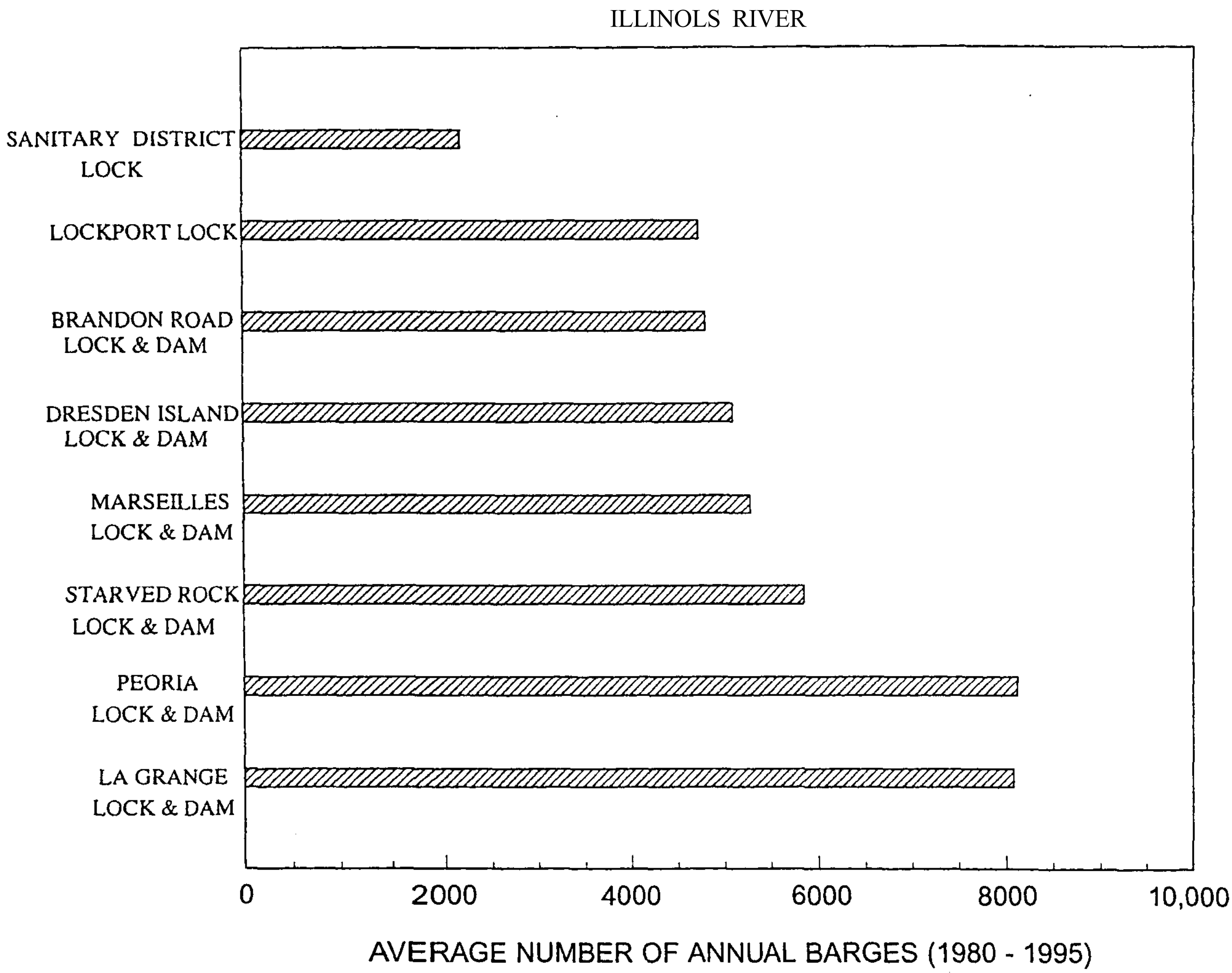


Figure 18. Average number of annual barges (empty, loaded, upstream bound and downstream bound) at various Lock and Dams on the Illinois River, 1980-1985 (data for Alton Pool were not available)

Site Characteristics

Site Locations

Twenty-nine sites were selected for the present study. Figure 19 shows the locations of the present study sites and those selected by Bhowmik and Schicht (1980) and Hagerty (1988). Sites selected in 1995 are fairly equally distributed along the entire length of the river, except in the Marseilles Pool and close to the Peoria L&D.

Sampling at Sites

After a site was selected, the limits of the site were delineated by placing temporary stakes on the bank. Then quarter points and midsection were located visually for further data

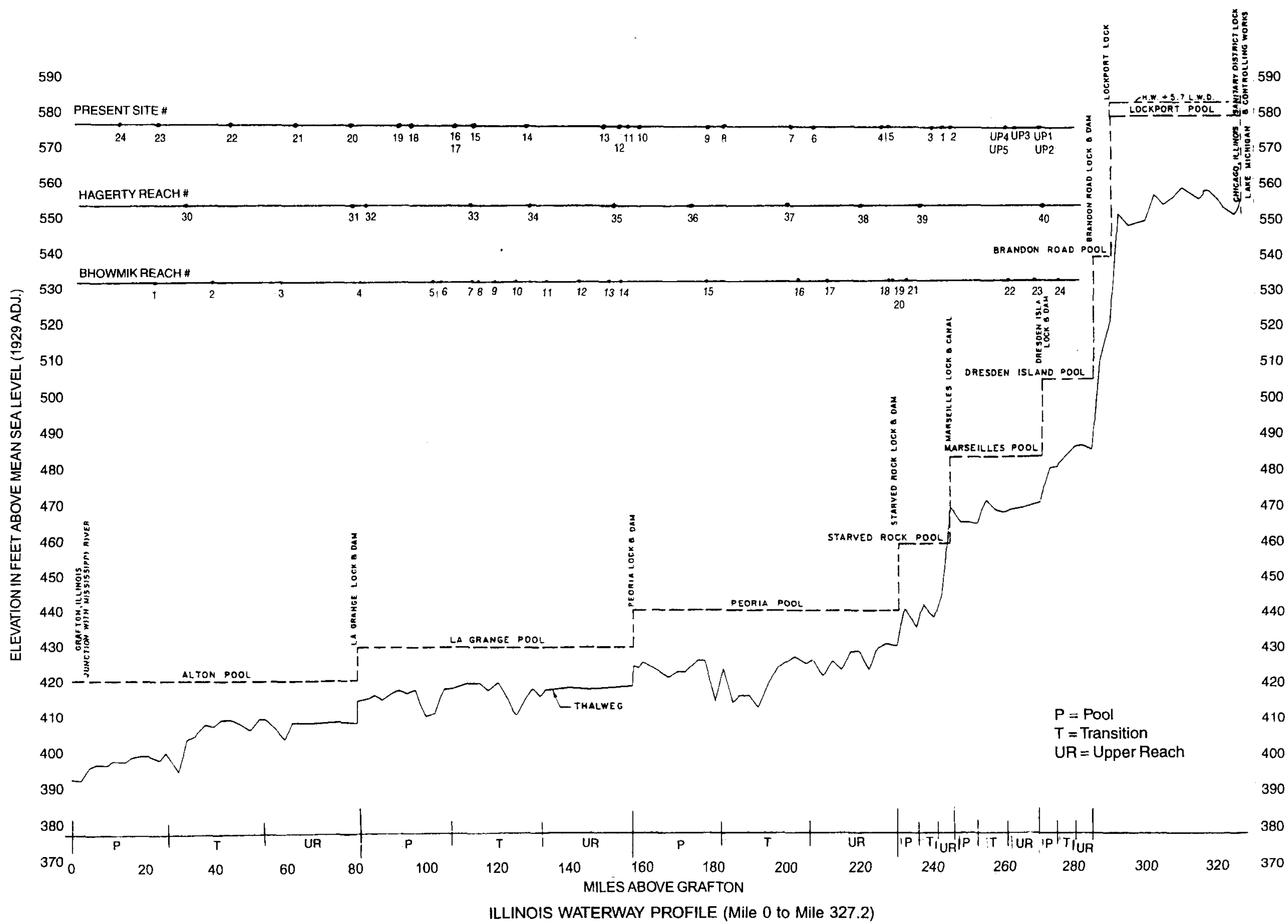


Figure 19. Relative location of sites selected for the present study and those selected by Bhowmik and Schicht (1980) and Hagerty (1988)

collection. Figure 20 shows the sampling locations selected for site UP4 on the Illinois River. The primary section is the place where a detailed bank section was measured and surficial and core samples were collected; a river cross section was also measured. At the two quarter points, normally the bank sections were surveyed, some bank and core material samples were collected, and occasionally, a river cross section was measured.

Site Parameters

After the field trip, the team organized the field information and determined the length of each site based on the GPS coordinates measured in the field. Table 6 shows various parameters associated with all 29 sites on the Illinois River, including the site number, date and time when data were collected, river mile, location of the midpoint, upstream and downstream points, right or left descending bank of the river where the site is located, site length in miles, water surface stage when the data were collected, recurrence frequency corresponding to the stage, and ordinary high water level and normal pool level.

Generalized Bank Types

After examining the field data associated with these 29 sites, and comparing them in conjunction with failure mechanisms, six "bank types" were grouped to facilitate the description of individual sites on the Illinois River (see Figures 21-26). It should be understood that the

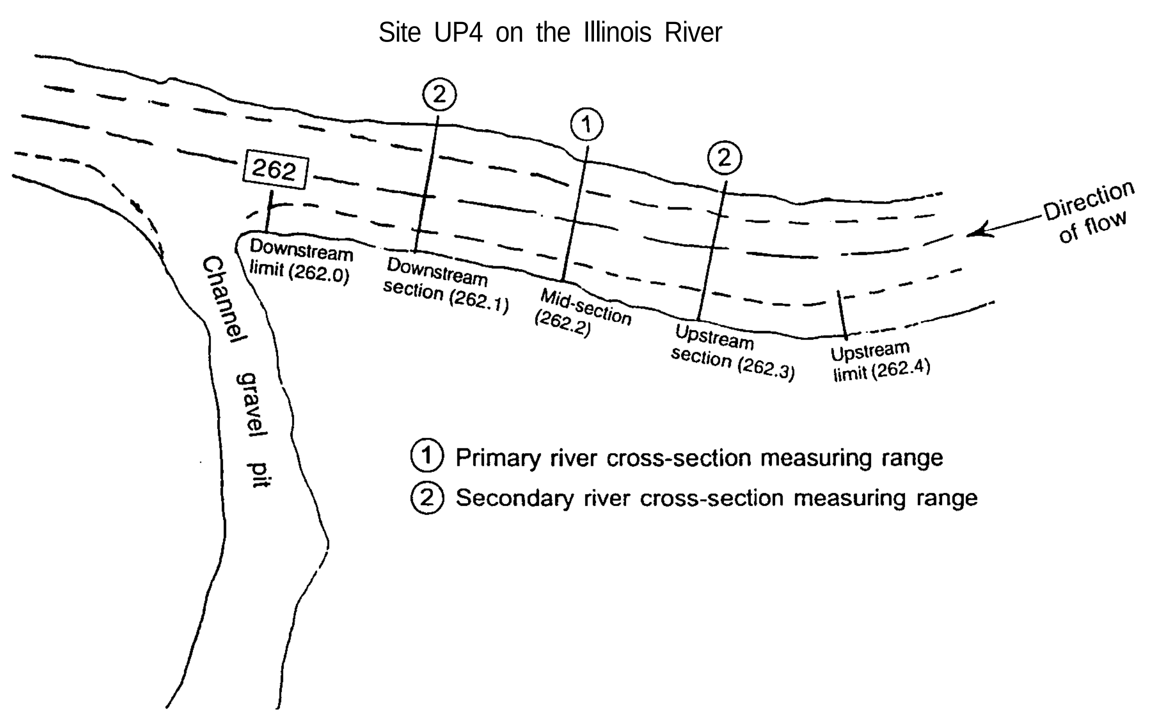


Figure 20. Typical sampling locations at a site: Site UP4 on the Illinois River

Table 6. Erosion Sites Selected on the Illinois River for Detailed Data Collection

Site	*Date*	*Time*	*RM*	*Location*	*Bank*	*Pool*	*Length (miles)*	*Stage (ft-msl)*	*Stage recurrence frequency (%)*	*OHW (ft-msl)*	*NP (ft-msl)*
UP1	18-Sep-95	04:15 PM	270.8*	up	RDB	Marseilles Pool		483.9	90	486.6	483.3
UP1	18-Sep-95	03:30 PM	270.8	mp	RDB	Marseilles Pool		483.9	90	486.6	483.3
UP1	18-Sep-95	04:00 PM	270.8	dn	RDB	Marseilles Pool		483.9	90	486.6	483.3
UP2	18-Sep-95	04:30 PM	270.8	mp	LDB	Marseilles Pool		483.9	90	486.6	483.3
UP3	19-Sep-95	08:20 AM	264.3	up	LDB	Marseilles Pool		483.7	80	485.7	483.3
UP3	20-Sep-95	07:30 AM	264.3	mp	LDB	Marseilles Pool	0.15	483.7	80	485.7	483.3
UP3	20-Sep-95	08:00 AM	264.3	dn	LDB	Marseilles Pool		483.7	80	485.7	483.3
UP4	20-Sep-95	10:30 AM	262.2	up	LDB	Marseilles Pool		483.7	90	485.5	483.3
UP4	20-Sep-95	10:00 AM	262.1	mp	LDB	Marseilles Pool	0.34	483.7	90	485.5	483.3
UP4	20-Sep-95	10:20 AM	262.0	dn	LDB	Marseilles Pool		483.7	90	485.5	483.3
UP5	20-Sep-95	11:00 AM	262.1	mp	RDB	Marseilles Pool		483.7	90	485.5	483.3
1	28-Aug-95	12:45 PM	242.9	up	LDB	Starved Rock Pool		458.6	90	460.0	458.5
1	28-Aug-95	10:45 AM	242.8	mp	LDB	Starved Rock Pool	0.24	458.8	90	460.1	458.5
2	28-Aug-95	11:45 AM	243.4	mp	LDB	Starved Rock Pool		459.4	50	460.3	458.5
3	28-Aug-95	04:00 PM	235.7	up	RDB	Starved Rock Pool		459.0	75	459.5	458.5
3	28-Aug-95	04:13 PM	235.7	mp	RDB	Starved Rock Pool	0.14	459.0	75	459.3	458.5
3	28-Aug-95	03:20 PM	235.7	dn	RDB	Starved Rock Pool		459.0	75	459.3	458.5
4	28-Aug-95	06:25 PM	228.1	up	LDB	Peoria Pool		441.6	75	446.1	440.0
4	28-Aug-95	06:40 PM	228.0	mp	LDB	Peoria Pool	0.24	441.6	75	446.0	440.0
4	28-Aug-95	07:00 PM	228.0	dn	LDB	Peoria Pool		441.6	75	446.0	440.0
5	28-Aug-95	07:40 PM	229.0	up	RDB	Peoria Pool		441.6	75	446.4	440.0
5	28-Aug-95	07:25 PM	228.75	mp	RDB	Peoria Pool	0.21	441.6	75	446.2	440.0
5	28-Aug-95	07:30 PM	228.5	dn	RDB	Peoria Pool		441.6	75	446.3	440.0
6	29-Aug-95	10:35 AM	210.0	up	RDB	Peoria Pool		441.1	75	444.3	440.0
6	29-Aug-95	10:40 AM	210.0	mp	RDB	Peoria Pool	0.34	441.1	75	444.3	440.0
6	29-Aug-95	11:15 AM	209.7	dn	RDB	Peoria Pool		441.1	75	444.2	440.0

Note: * River mile (RM) at the midpoint (mp) of a reach was used if the river miles at the upstream (up) or downstream (dn) points were unknown.

Table 6. (continued)

Site	*Date*	*Time*	*RM*	*Location*	*Bank*	*Pool*	*Length (miles)*	*Stage (ft-msl)*	*Stage recurrence frequency (%)*	*OHW (ft-msl)*	*NP (ft-msl)*
7	29-Aug-95	12:15 PM	203.8	up	LDB	Peoria Pool		441.1	75	443.9	440.0
7	29-Aug-95	12:00 PM	203.8	mp	LDB	Peoria Pool	0.20	441.1	75	443.9	440.0
7	29-Aug-95	12:45 PM	203.5	dn	LDB	Peoria Pool		441.1	75	443.9	440.0
8	29-Aug-95	02:45 PM	184.9	up	LDB	Peoria Pool		441.1	73	442.6	440.0
8	29-Aug-95	02:30 PM	184.8	mp	LDB	Peoria Pool	0.26	441.1	73	442.6	440.0
8	29-Aug-95	03:05 PM	184.7	dn	LDB	Peoria Pool		441.1	73	442.6	440.0
9	29-Aug-95	03:50 PM	179.9	up	LDB	Peoria Pool		440.6	90	442.4	440.0
9	29-Aug-95	03:45 PM	179.8	mp	LDB	Peoria Pool	0.21	440.6	90	442.4	440.0
9	29-Aug-95	04:05 PM	179.7	dn	LDB	Peoria Pool		440.6	90	442.4	440.0
10	29-Aug-95	06:25 PM	160.0	up	RDB	Peoria Pool		440.5	50	441.4	440.0
10	29-Aug-95	06:20 PM	160.0	mp	RDB	Peoria Pool	0.11	440.5	50	441.4	440.0
10	29-Aug-95	06:45 PM	160.0	dn	RDB	Peoria Pool		440.5	50	441.4	440.0
11	30-Aug-95	11:00 AM	155.5	up	RDB	La Grange Pool		432.8	70	440.8	429.5
11	30-Aug-95	08:15 AM	155.3	mp	RDB	La Grange Pool	0.54	432.8	70	440.8	429.5
11	30-Aug-95	11:30 AM	155.1	dn	RDB	La Grange Pool		432.8	70	440.8	429.5
12	30-Aug-95	08:45 AM	154.6	up	LDB	La Grange Pool		432.8	70	440.7	429.5
12	30-Aug-95	09:40 AM	154.4	mp	LDB	La Grange Pool	0.62	432.8	70	440.7	429.5
12	30-Aug-95	10:40 AM	154.2	dn	LDB	La Grange Pool		432.8	70	440.7	429.5
13	30-Aug-95	12:15 PM	150.6	up	LDB	La Grange Pool		432.3	75	440.5	429.5
13	30-Aug-95	12:10 PM	150.5	mp	LDB	La Grange Pool	0.18	432.3	75	440.5	429.5
13	30-Aug-95	12:45 PM	150.5	dn	LDB	La Grange Pool		432.3	75	440.5	429.5
14	30-Aug-95	04:15 PM	129.4	up	RDB	La Grange Pool		431.2	80	438.5	429.5
14	30-Aug-95	04:15 PM	129.3	mp	RDB	La Grange Pool	0.28	431.2	80	438.5	429.5
14	30-Aug-95	04:45 PM	129.2	dn	RDB	La Grange Pool		431.2	80	438.5	429.5
15	30-Aug-95	06:35 PM	116.7	up	RDB	La Grange Pool		430.8	75	437.0	429.5
15	30-Aug-95	06:45 PM	116.5	mp	RDB	La Grange Pool	0.95	430.8	75	437.0	429.5
15	30-Aug-95	07:10 PM	116.3	dn	RDB	La Grange Pool		430.8	75	437.0	429.5
16	31-Aug-95	11:05 AM	109.5	up	LDB	La Grange Pool		430.6	75	435.8	429.9
16	31-Aug-95	10:25 AM	109.5	mp	LDB	La Grange Pool	0.18	430.6	75	435.7	429.9

Table 6. (concluded)

Site	*Date*	*Time*	*RM*	*Location*	*Bank*	*Pool*	*Length (miles)*	*Stage (msl)*	*Stage recurrence frequency (%)*	*OHW (ft-msl)*	*NP (ft-msl)*
16	31-Aug-95	10:38 AM	109.5	dn	LDB	La Grange Pool		430.6	75	435.6	429.9
17	31-Aug-95	10:00 AM	109.6	up	RDB	La Grange Pool		430.6	75	435.7	429.9
17	31-Aug-95	09:15 AM	109.5	mp	RDB	La Grange Pool	0.18	430.6	75	435.7	429.9
17	31-Aug-95	10:30 AM	109.4	dn	RDB	La Grange Pool		430.6	75	435.7	429.9
18	31-Aug-95	02:40 AM	94.2	up	RDB	La Grange Pool		429.9	75	433.7	429.9
18	31-Aug-95	02:15 PM	94.2	mp	RDB	La Grange Pool	0.09	429.9	75	433.7	429.9
18	31-Aug-95	02:20 PM	94.2	dn	RDB	La Grange Pool		429.9	75	433.7	429.9
19	31-Aug-95	03:05 PM	91.2	up	RDB	La Grange Pool		429.9	65	433.3	429.9
19	31-Aug-95	04:00 PM	91.2	mp	RDB	La Grange Pool	0.22	429.9	65	433.3	429.9
19	31-Aug-95	04:30 PM	91.1	dn	RDB	La Grange Pool		429.9	65	433.3	429.9
20	31-Aug-95	07:40 PM	79.6	up	RDB	Alton Pool		420.6	90	NA	NA
20	31-Aug-95	07:15 PM	79.4	mp	RDB	Alton Pool	0.67	420.6	90	NA	NA
20	31-Aug-95	07:20 PM	79.2	dn	RDB	Alton Pool		420.6	90	NA	NA
21	01-Sep-95	11:00 AM	61.8	up	RDB	Alton Pool		420.6	80	NA	NA
21	01-Sep-95	10:45 AM	61.7	mp	RDB	Alton Pool	0.23	420.6	80	NA	NA
21	Ol-Sep-95	10:40 AM	61.6	dn	RDB	Alton Pool		420.6	80	NA	NA
22	Ol-Sep-95	01:00 PM	45.1	up	RDB	Alton Pool		419.9	85	NA	NA
22	Ol-Sep-95	12:50 PM	45.1	mp	RDB	Alton Pool	0.14	419.9	85	NA	NA
22	Ol-Sep-95	01:30 PM	45.1	dn	RDB	Alton Pool		419.9	85	NA	NA
23	Ol-Sep-95	04:30 PM	23.5	up	RDB	Alton Pool		419.3	90	NA	NA
23	Ol-Sep-95	04:20 PM	23.4	mp	RDB	Alton Pool	0.18	419.3	90	NA	NA
23	Ol-Sep-95	04:45 PM	23.3	dn	RDB	Alton Pool		419.3	90	NA	NA
24	Ol-Sep-95	06:30 PM	13.1	up	RDB	Alton Pool		419.3	90	NA	NA
24	Ol-Sep-95	06:00 PM	13.0	mp	RDB	Alton Pool	0.24	419.3	90	NA	NA
24	Ol-Sep-95	06:15 PM	12.9	dn	RDB	Alton Pool		419.3	90	NA	NA

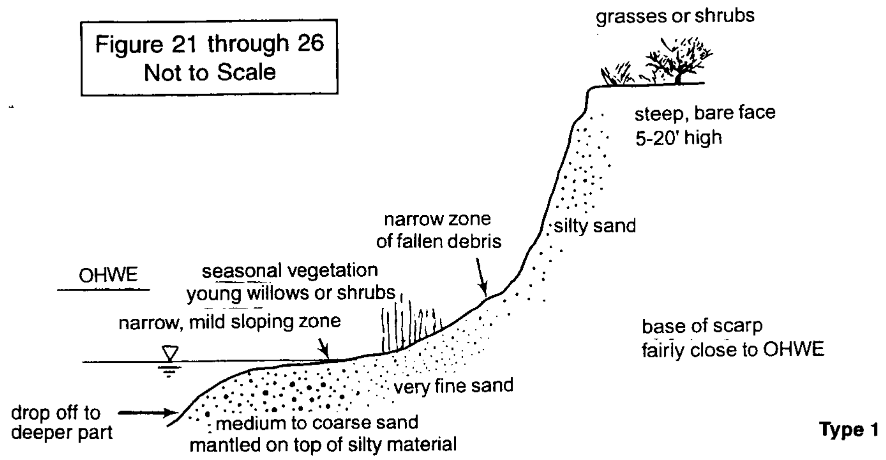


Figure 21. Type 1 bank on the Illinois River: steep bank with high bare face (ordinary high water elevation is low as compared to the bank elevation)

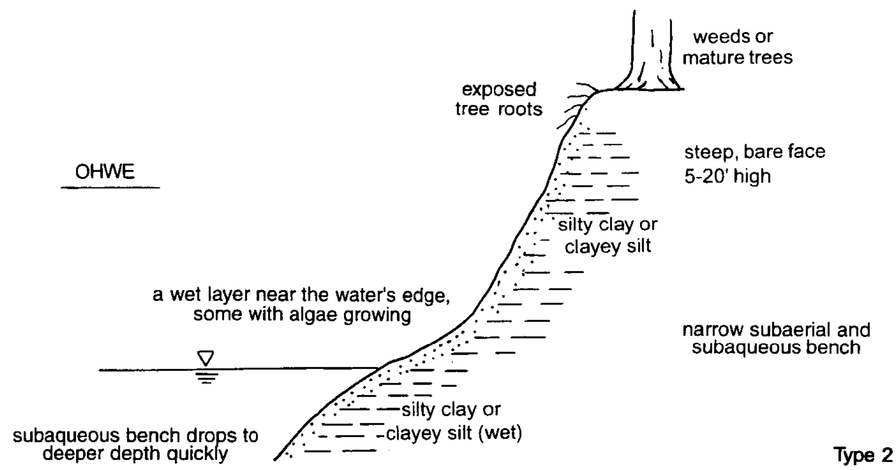


Figure 22. Type 2 bank on the Illinois River: steep bank with high bare face (ordinary high water elevation is comparable to the elevation at top of the bank)

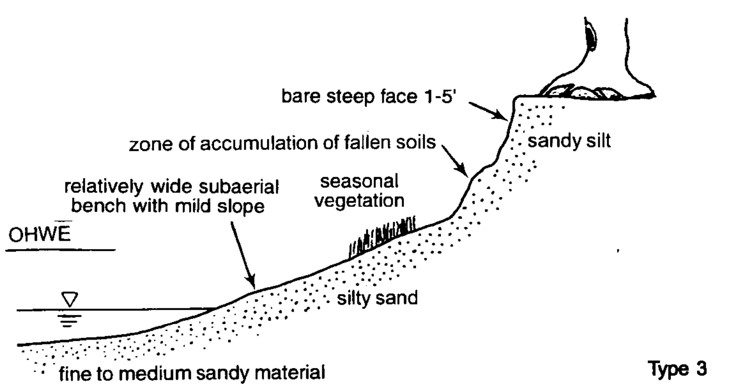


Figure 23. Type 3 bank on the Illinois River: short scarp face and fairly long bench (ordinary high water elevation is low as compared to the bank elevation)

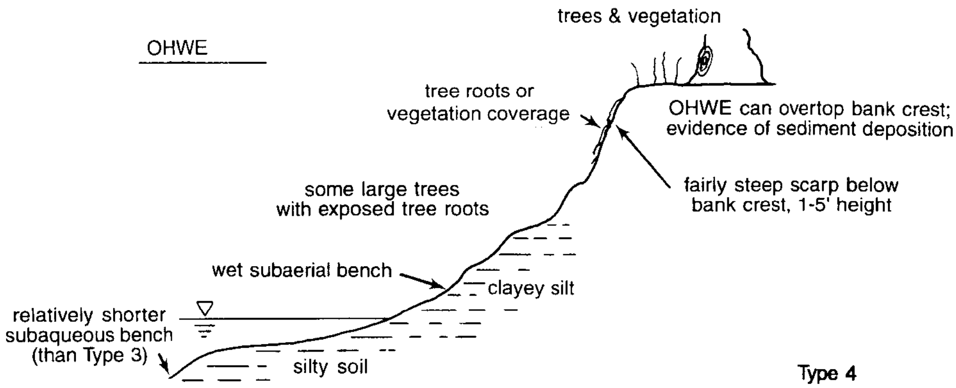


Figure 24. Type 4 bank on the Illinois River: small scarp face with bare bank (ordinary high water elevation can overtop bank crest or reach the face of scarp)

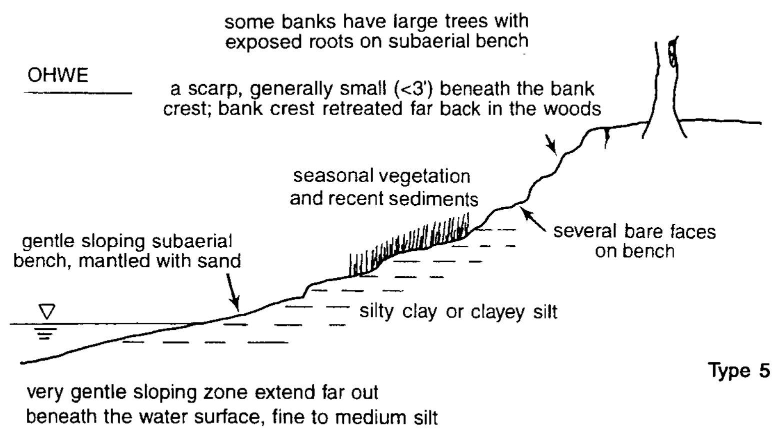


Figure 25. Type 5 bank on the Illinois River: small scarp face and fairly long bench (subaqueous bench has a gentle slope and extends far out)

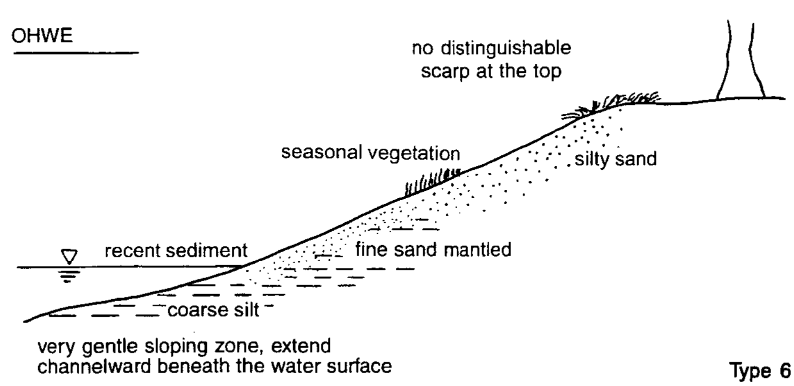


Figure 26. Type 6 bank on the Illinois River: a gently sloped bench with extended subaqueous bench

degree of failure mechanisms acting upon a bank will vary with the bank's size, geometry, and soil structure; and with the extent and slope of the corresponding bench. These mechanisms are subjected to the fluctuating water levels at that site. Therefore the most likely erosion processes are identified for each bank type and called "erosion potentials." Table 7 shows the corresponding main features and erosion potential with these bank types.

General Characteristics of Selected Erosion Sites

River Widths and Maximum Depths

River cross sections were measured at the 29 sites. The top width, W_T, at the midpoint, during the field data collection period, varied from 525 to 919 feet. The maximum depths, D_{max}, also at the midpoint, varied from 12 to 21 feet. Figures 27 and 28 show the histograms of W_T and D_{max} measured at the midpoints at all the sites.

Bank Slopes

Three bank slopes were determined at each one of the bank sections measured at all the sites: scarp slope, berm slope, and bench slope. Figure 29 shows a definition sketch for these parameters. These slopes are best approximations to the field conditions. After the field data were checked and bank sections were plotted, the study team selected the representative portion for each of these three features; and the slopes were determined.

Figure 30 shows plots of histograms for these three parameters. The scarp slope varied from 1V:3.2H to 1V:0.04H, with a median value of 1V:95H. Similarly, the berm slope varied from 1V:8.33H to 1V:0.83H, with a median value of 1V:2.84H and a Standard Deviation of 0.23. The bench slope varied from 1V:81 .00H to 1V:1H with a median value of 1V: 11.1H.

Scarp and bench slopes did not vary as much as the berm slopes. The majority of the scarp slopes were close to 1V:0.71H or 1V:0.48H, and most bench slopes were between 1V:20H and 1V:10H. However, most berm slopes were between 1V:3.33H and 1V:2.5H.

Bank Soils

A total of 174 surficial bank samples, including 81 core samples, were analyzed. Figure 31 shows histograms of d_{50} and d_{85} sizes of the bank soils and core samples collected from the Illinois River. For 141 of the samples, the d_{50} was in the range of 0.002 mm to 0.696 mm. The median value was 0.024 mm, and the Standard Deviation was 0.133. The surficial soils and sediments at the eroded sites are well graded.

For about 151 samples, the d_{85} values range from 0.014 mm to 5.073 mm. The median value is equal to 0.169 mm, with a standard deviation of 0.802 mm. From the figures, it is safe to state that the most frequent occurrence of d_{50} values is less than 0.015 mm.

Table 7. Bank Erosion Types, Main Features, and Erosion Potential on the Illinois River

Type	*Main features*	*Erosion potential*
Type 1	• Steep to fairly steep scarp face, 5'–20' height • Roots drape or exposed roots on upper portion of the bank • A narrow, mild sloping subaerial bench, some seasonal vegetation growing • Limited extend of subaqueous bench, drop-off at deeper part • Primarily silty sand to sandy materials • Near bank and underwater materials have similar characteristics • OHWE is close or falls below the base of scarp	• Rework, transport of failed soils or recent sediment by waves and currents; basal failure induces further bank slips • Piping or seepage sluice out coarse material, weakens basal support • Overland drainage • Human disturbance • Debris-induced flow disturbance • Freeze/thaw cycles, weathering processes • Removal of surficial bank materials by waves and currents during high water or floods
Type 2	• Steep to fairly steep scarp face, 5'–20' height • Exposed roots or vegetation cover on scarp • Narrow subaerial and subaqueous bench • Subaquesous bench drop to deeper depth quickly • Primarily silty clay or clayey silt materials • A persistent wet layer near the water's edge, some with algae growing • OHWE is on the scarp	• Piping or seepage-processes weaken the basal support or strength of the bank • Scour by waves and currents; bank slips follow the failure of basal support • Surficial block failures by waves or high water after the formation of tension cracks • Freeze - thaw - desiccation cycles, weathering processes • Debris-induced local flow disturbances • Overland drainage • Human impact
Type 3	• Steep scarp face below bank crest, 1'–5' height • A fairly extended subaerial bench with mild slope • Berm section is relatively wide • Extended subaqueous bench with gentle slope • Subaerial bench has recent sediment, some with desiccation cracks, seasonal vegetation growing • Primarily silty sand or sandy silt materials • OHWE is close to or fall below base of scarp	• Transport of bench materials by waves and currents • Removal of surficial bank materials during high stages or floods • Overland drainage-induced rill erosion on bench • Freeze - thaw - desiccation cycles, weathering • Piping- or seepage-induced failure • Wet and dry cycle-induced tension cracks

Table 7. (concluded)

Type	*Main features*	*Erosion potential*
Type 4	• Fairly steep scarp below bank crest, 1'–5' height • Tree roots exposed on scarp • Sediment deposition on top of bank • Subaerial bench has a mild slope • Smaller scarps on subaerial bench • Generally subaerial bench is wet or has springs • Trees with exposed roots on bench zone • Shorter subaqueous bench than type 3 • Primarily silt or silty clay materials • OHWE is on the scarp or higher than bank top	• Transport bench material or recent sediment by waves and current • Piping-and seepage-related process Removal of surficial bank materials during high water or floods • Overland drainage. • Wave wash and seepage creates scarps on bench area. • Freeze-thaw-desiccation cycles, weathering processes.
Type 5	• A small scarp (< 3') remains on top of bank section, some with several bare scarps on the upper bank. • Sediment deposition on top of bank, buried tree roots • No clear division of berm and bench • Gentle sloping bench, mantled with sand (recent sediment) • Gentle sloping subaqueous bench, extends far out • Primarily fine to medium silt materials • OHWE may submerge bank crest	• Transport bench materials by waves and currents • Removal of surficial bank materials during high water or floods. • Overland drainage • Seepage-related process
Type 6	• Seldom has distinguishable scarp or bare faces • Sediment deposition on bank crest, deposition around trees. • No distinguishable berm and bench • Recent sediment on bench area • Gentle sloping bench zone • Very gentle bench slope, subaqueous bench extends far into channel • Primarily fine to medium silt materials • OHWE may overtop the bank	• Rework and transport of bench materials by waves and current • Removal of surficial bank materials during high water or floods • Seepage-related process (wet/dry, poor drainage, piping) • Overland drainage

Note: OHWE = Ordinary High Water Elevation

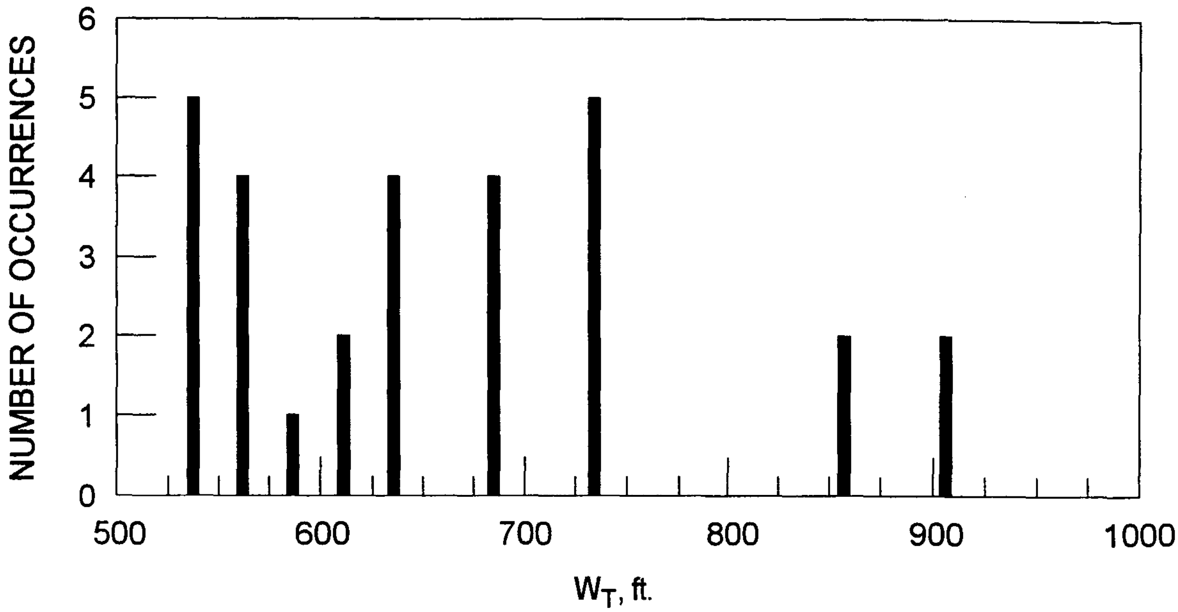


Figure 27. Histogram of the top widths, W_T, at the midsection measuring station of the Illinois River

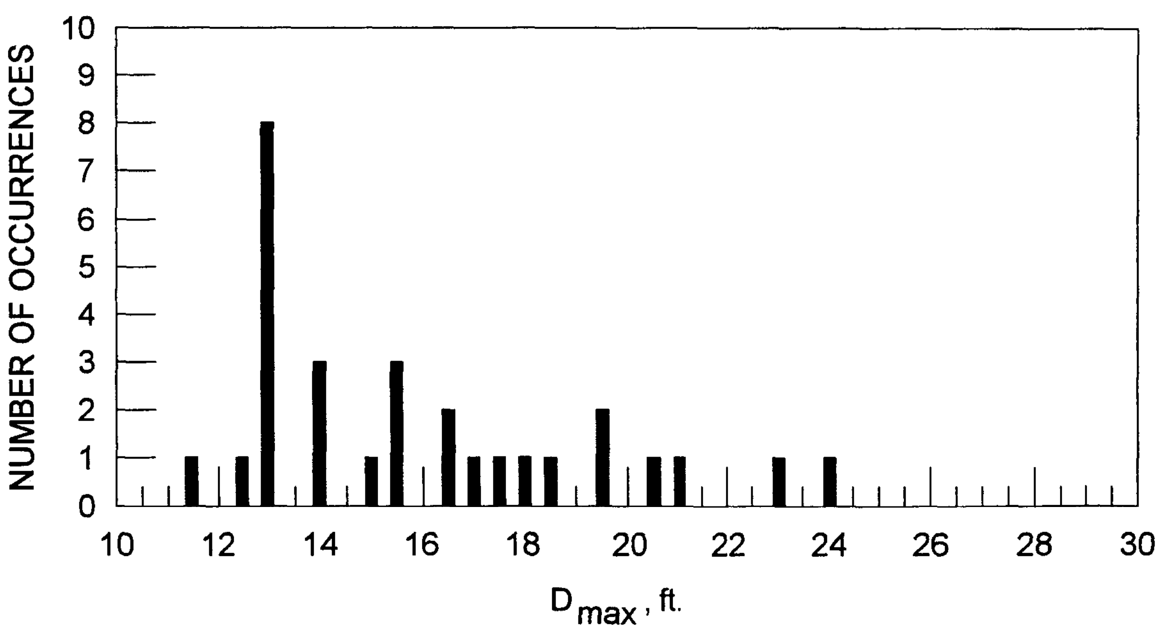


Figure 28. Histogram of the maximum depths, D_{max}, at the midsection measuring station of the Illinois River

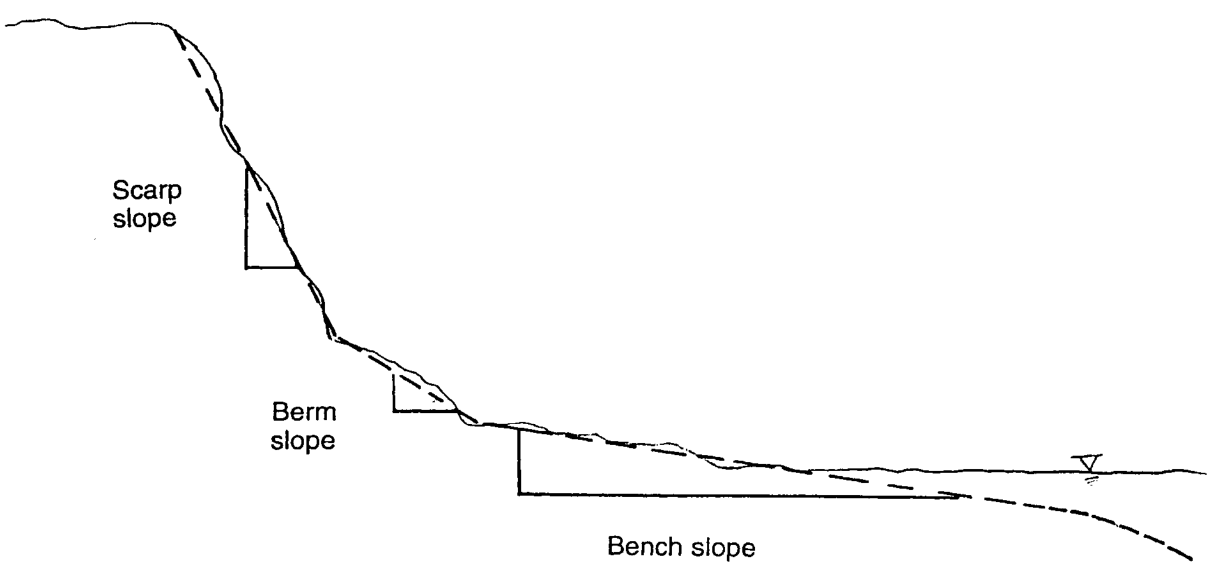


Figure 29. Definition sketch for scarp, berm, and bench slopes

The uniformity of the bank soils is examined by the value and spread of standard deviation, σ, and uniformity coefficient, U. Figure 32 provides histograms for these two values for all the samples. Whenever the particles are quite uniform, the values of σ and U approach "1". Significant deviations from the value of 1 indicate the presence of graded materials. Figure 32 indicates that the values of σ and U are close to 2 or more, showing that the surficial soils and sediments at the eroded sites are well graded.

Site Lengths

These length limits were accurately determined using a portable GPS, which was mentioned earlier. Figure 33 shows the distribution of these measured site lengths varies from a minimum of 0.09 mile to about 0.95 mile. The median value is 0.22 mile, with a Standard Deviation of 0.21 mile. Most of the sites clustered around values of 0.15 to 0.25 mile (figure 33).

Geomorphic and Land Cover Characteristics

For the sites at which field data were collected, geomorphic characteristics were listed as RDB, left descending bank (LDB), straight or curve reaches, inside or outside of a bend, crossover position, and island sites. Land covers on the bank crests were recorded as urban, agriculture, grass/weeds, and wooded.

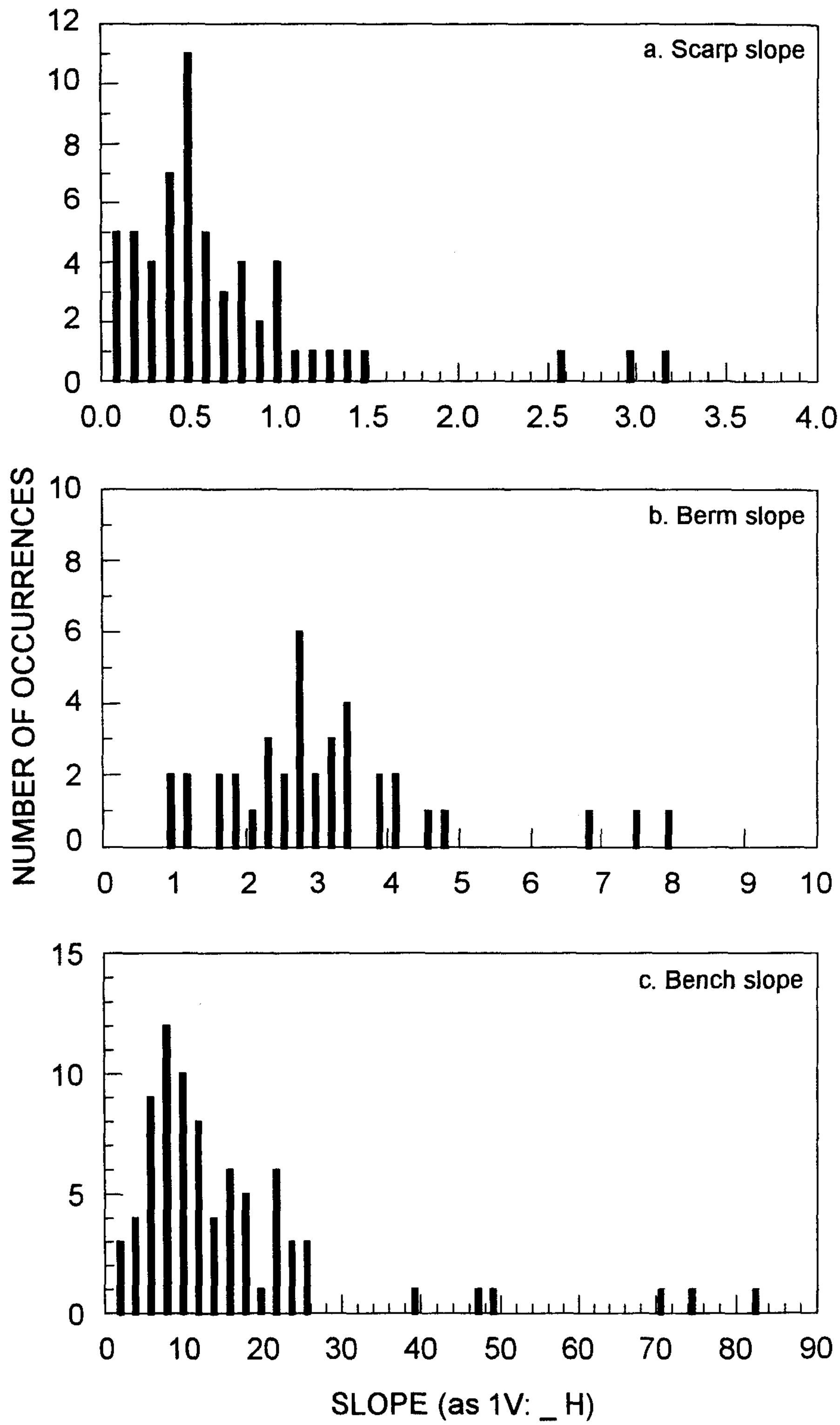


Figure 30. Histograms of scarp, berm, and bench slopes for the Illinois River

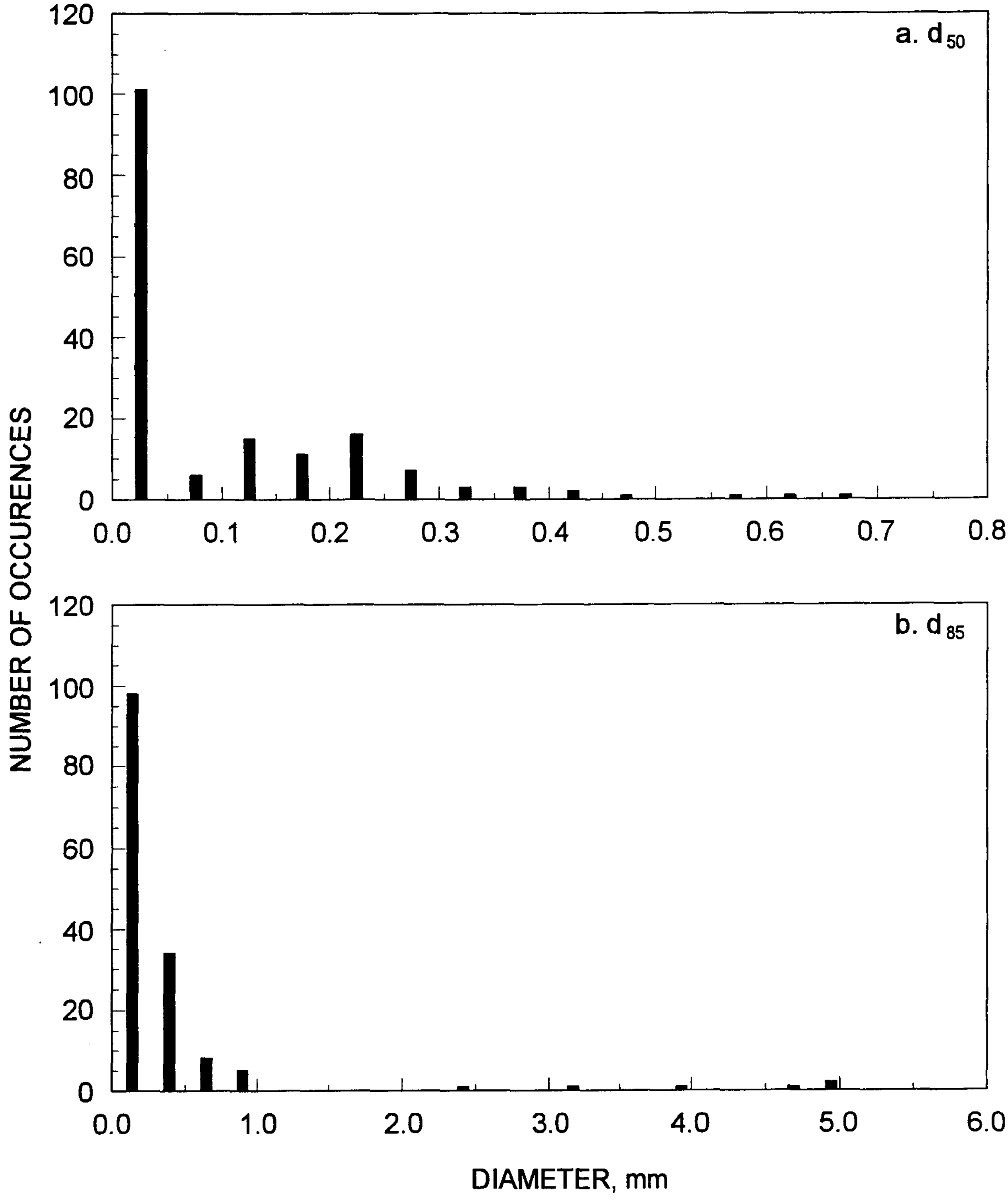


Figure 31. Histograms of d_{50} and D_{85} sizes of bank materials on the Illinois River

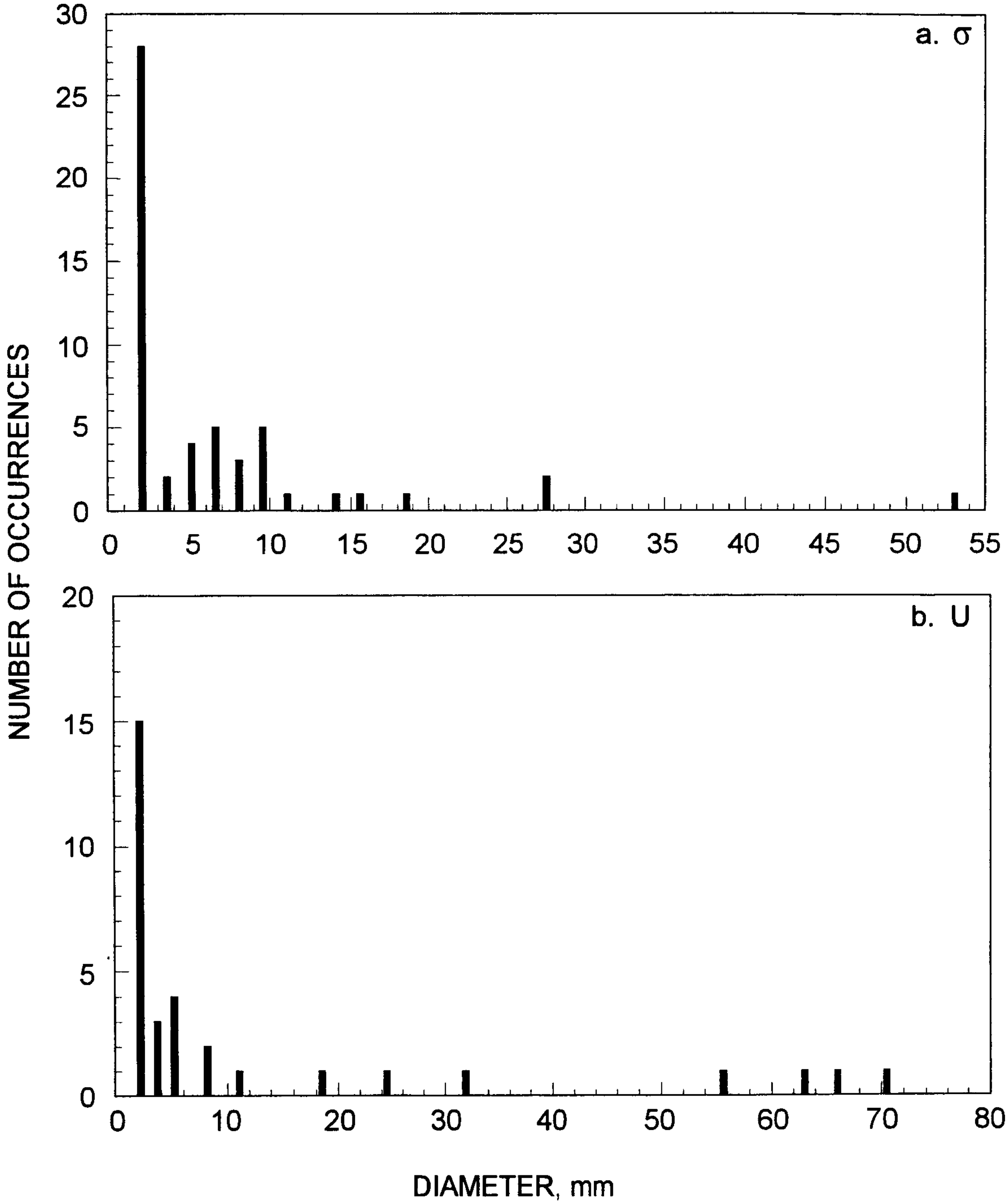


Figure 32. Histograms of σ and U for all bank materials from the Illinois River

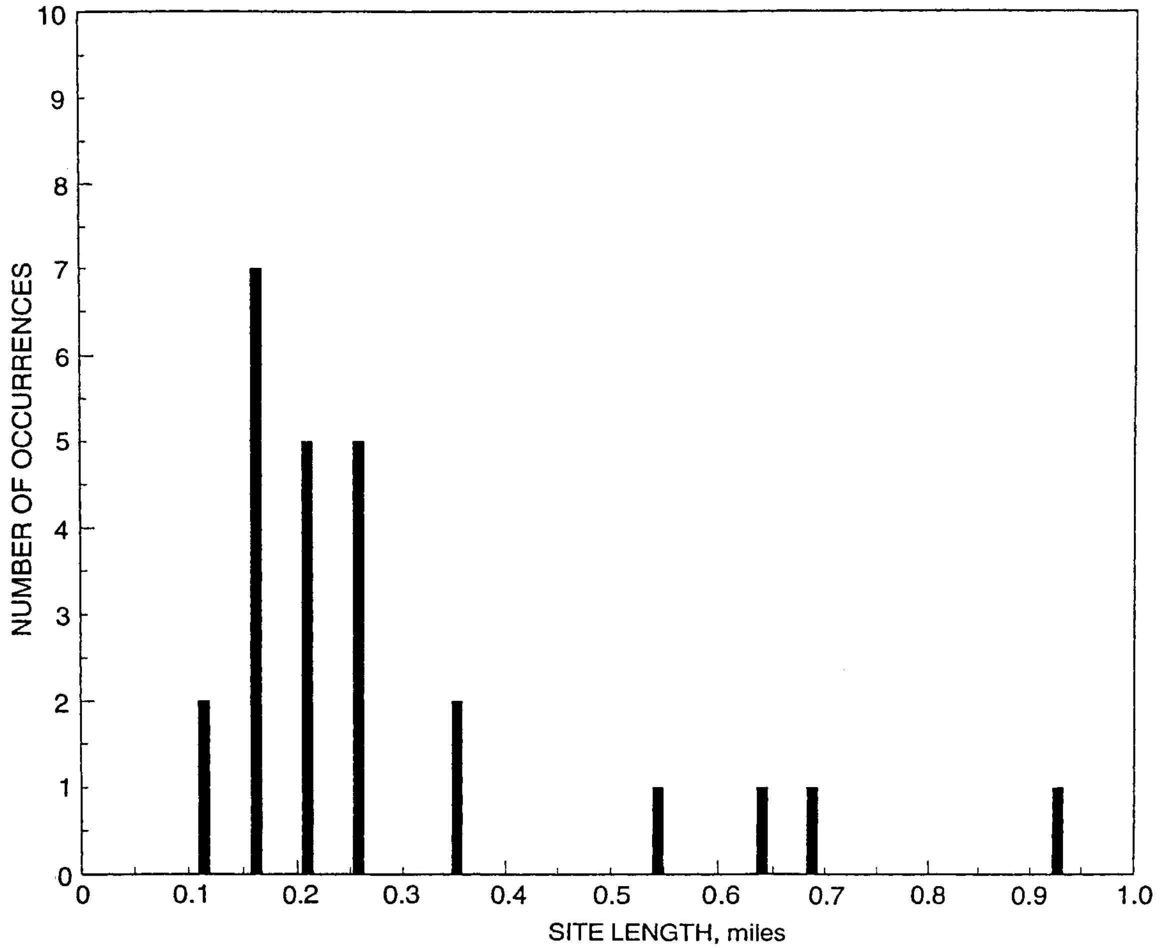


Figure 33. Histograms of site lengths for the Illinois River bank erosion study

Figure 34 shows geomorphic characteristics and land cover. Examination of this illustration shows 17 sites on the RDB, 12 sites on the LDB, 13 sites on the straight reaches, 11 sites on the outside of the bank, 3 sites on the inside of the bank, and only two sites on the crossover. The dominant land covers on the bank crest were wooded followed by agricultural crops, grasses, or weeds. Furthermore, most of the selected sites were natural banks, with the remaining belonging to levees and railroad embankment.

Figure 35 shows the geomorphic parameters, which are also indicated on the Illinois River profiles map. Most of the straight-reach sites selected for the present study were from the upper- and lowermost portions of the waterway, whereas erosion sites selected from the outside bank were distributed over the entire river length. Three inside-bend sites were all located in La Grange Pool. Only one site was located on a crossover in Peoria Pool.

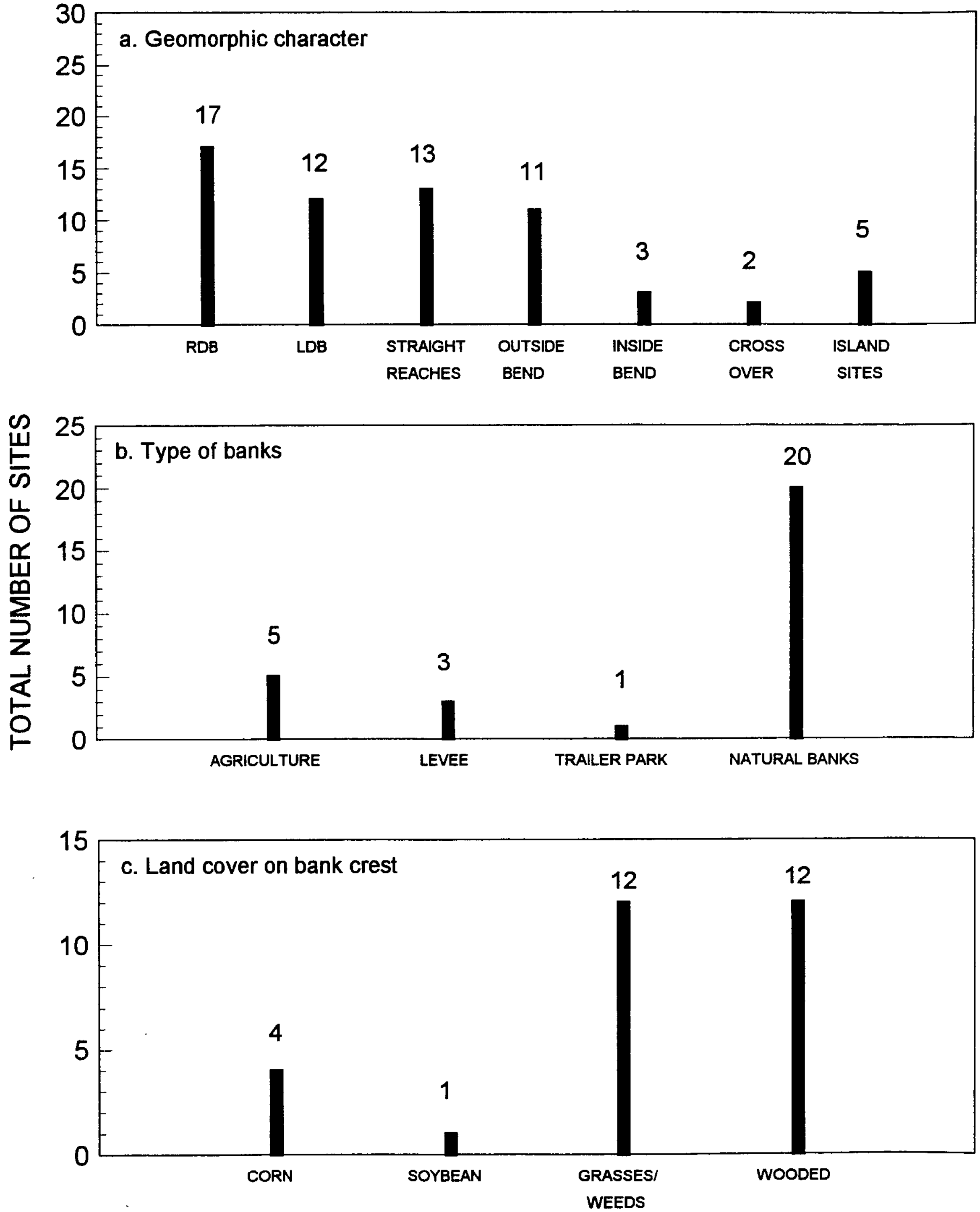


Figure 34. Histograms of geomorphic and land use characteristics of erosion sites on the Illinois River

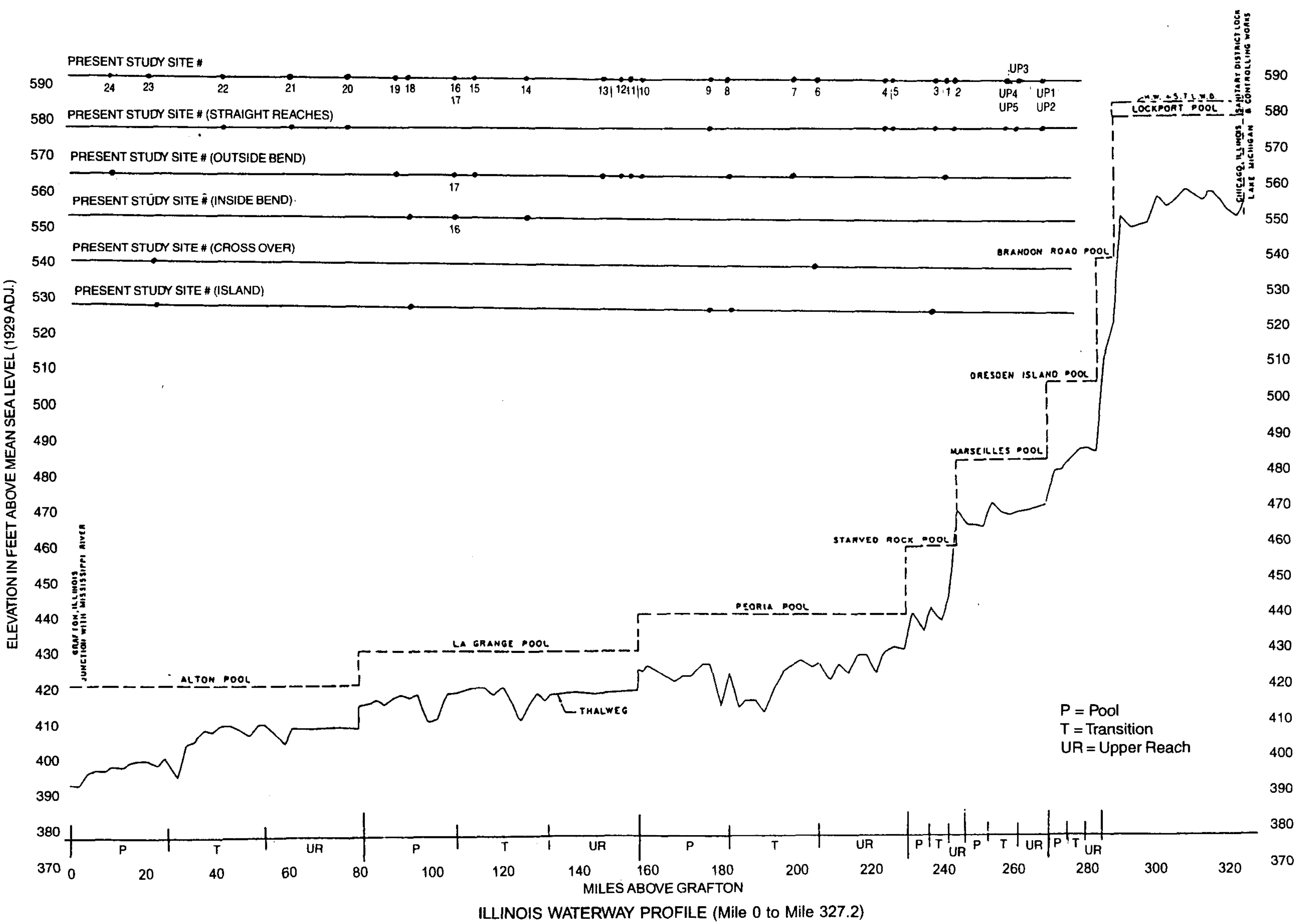


Figure 35. Relative locations of selected sites on the Illinois River

Table 8 shows the relative positions of these sites with respect to portions of the pools.

Table 9 provides additional parameters associated with the erosion sites. Table 10 summarizes bank characteristics, which can serve as the basis for selecting future study sites.

Site-Specific Descriptions

Overall, 80 bank sections at 29 sites were measured during the field trip, 183 bank soil samples were collected, and 174 samples were analyzed. River cross sections were also measured at 29 locations.

For each site the following are given: a site location map, a representative site photograph, and all the bank sections and channel cross sections measured for the site. In the bank section plots, d_{50} values (in mm) at surficial sampling locations, the OHWE and the NP elevation, noted soil classifications (see table 3 for acronyms), and other observations are noted. Readers are referred to figure 19 and table 6 for specific locations. All the sites are described starting at the upstream end of the river. Types of erosion at each site will be cross referenced with the "types" shown in figures 21-26 and described in table 7. In order to reduce the number of illustrations within the main body of the report, all the plots associated with the determination of the bank soil size distributions and the river cross sections are included in appendices C and D, respectively.

Site UP1, Marseilles Pool, 9/18/95

This site is located on the RDB of the Illinois River at RM 270.8, a straight reach approximately 0.8 miles downstream of the Dresden Island Lock and Dam (RM 271.5). Figure 36 shows the position of the site on a Geographic Information System (GIS)-based map of the Illinois navigation chart, and figure 37 is a photograph of the site.

Table 8. Location of Surveyed Site in Navigation Pool, Illinois River

Pool	*Upper 1/3*	*Middle 1/3*	*Lower 1/3*
Marseilles	UP1,UP2,UP3,UP4,UP5		
Starved Rock	1,2	3	
Peoria	4,5,6	7,8	9, 10
La Grange	11,12,13	14, 15, 16, 17	18, 19
Alton	20,21	22	23, 24

Summary: 13 sites are in the upper 1/3 of a pool; 8 sites are in the middle 1/3 of a pool; 8 sites are in the lower 1/3 of a pool.

Table 9. Selected Parameters Associated with Erosion Sites

Site	Date in 1995	Time	RM	Location	Side	Pool	Length (miles)	Stage (ft-msl)	f (%)	OHWE (ft-msl)	NP (ft-msl)	Type	Remarks
UP1	18/09	04:15 PM	270.8	up	RDB	Marseilles		483.9	90	486.6	483.3	1&3	
UP1	18/09	03:30 PM	270.8	mp	RDB	Marseilles		483.9	90	486.6	483.3	1&3	
UP1	18/09	04:00 PM	270.8	dn	RDB	Marseilles		483.9	90	486.6	483.3	1&3	
UP2	18/09	04:30 PM	270.8	mp	LDB	Marseilles		483.9	90	486.6	483.3	5	
UP3	19/09	08:20 AM	264.3	up	LDB	Marseilles		483.7	80	485.7	483.3	3	
UP3	20/09	07:30 AM	264.3	mp	LDB	Marseilles	0.15	483.7	80	485.7	483.3	3	
UP3	20/09	08:00 AM	264.3	dn	LDB	Marseilles		483.7	80	485.7	483.3	3	
UP4	20/09	10:30 AM	262.2	up	LDB	Marseilles		483.7	90	485.5	483.3	2&3	Fleeting area
UP4	20/09	10:00 AM	262.1	mp	LDB	Marseilles	0.34	483.7	90	485.5	483.3	2&3	Silty clay bank, sandy bench
UP4	20/09	10:20 AM	262.0	dn	LDB	Marseilles		483.7	90	485.5	483.3	2&3	
UP5	20/09	11:00 AM	262.1	mp	RDB	Marseilles		483.7	90	485.5	483.3	4&5	Silty clay bank, subaqueous scour
1	28/08	12:45 PM	242.9	up	LDB	Starved Rock		458.6	90	460.0	458.5	1	Aggregated silt blocks
1	28/08	10:45 AM	242.8	mp	LDB	Starved Rock	0.24	458.8	90	460.1	458.5	1	
2	28/08	11:45 AM	243.4	mp	LDB	Starved Rock		459.4	50	460.3	458.5	2&6	Extended shallow bench
3	28/08	04:00 PM	235.7	up	RDB	Starved Rock		459.0	75	459.5	458.5	1&6	Extended shallow bench
3	28/08	04:13 PM	235.7	mp	RDB	Starved Rock	0.14	459.0	75	459.3	458.5	1&6	
3	28/08	03:20 PM	235.7	dn	RDB	Starved Rock		459.0	75	459.3	458.5	1&6	
4	28/08	06:25 PM	228.1	up	LDB	Peoria		441.6	75	446.1	440.0	5	
4	28/08	06:40 PM	228.0	mp	LDB	Peoria	0.24	441.6	75	446.0	440.0	5	
4	28/08	07:00 PM	228.0	dn	LDB	Peoria		441.6	75	446.0	440.0	5	
5	28/08	07:40 PM	229.0	up	RDB	Peoria		441.6	75	446.4	440.0	3&5	Downstream of a barge terminal
5	28/08	07:25 PM	228.75	mp	RDB	Peoria	0.21	441.6	75	446.2	440.0	3&5	piping at lower bank,
5	28/08	07:30 PM	228.75	dn	RDB	Peoria		441.6	75	446.3	440.0	3&5	wave wash on bench area
6	29/08	10:35 AM	210.0	up	RDB	Peoria		441.1	75	444.3	440.0	4	subaqueous scour
6	29/08	10:40 AM	210.0	mp	RDB	Peoria	0.34	441.1	75	444.3	440.0	5	
6	29/08	11:15 AM	209.7	dn	RDB	Peoria		441.1	75	444.2	440.0	6	
7	29/08	12:15 PM	203.8	up	LDB	Peoria		441.1	75	443.9	440.0	5	
7	29/08	12:00 PM	203.8	mp	LDB	Peoria	0.20	441.1	75	443.9	440.0	5	Levee
7	29/08	12:45 PM	203.5	dn	LDB	Peoria		441.1	75	443.9	440.0	5	

Note: River mile (RM) at the midpoint (mp) of a reach was used if the river miles at the upstream (up) or downstream (dn) points were unknown. OHWE = ordinary high water elevation. NP = normal pool level.

Table 9. (continued)

Site	*Date in 1995*	*Time*	*RM*	*Location*	*Side*	*Pool*	*Length (miles)*	*Stage (ft-msl)*	*f (%)*	*OHWE (ft-msl)*	*NP (ft-msl)*	*Type*	*Remarks*
8	29/08	02:45 PM	184.9	up	LDB	Peoria		441.1	73	442.6	440.0	4&5	Piping at lower scarp, extended
8	29/08	02:30 PM	184.8	mp	LDB	Peoria	0.26	441.1	73	442.6	440.0	4&5	subaqueous bench
8	29/08	03:05 PM	184.7	dn	LDB	Peoria		441.1	73	442.6	440.0	4&5	
9	29/08	03:50 PM	179.8	up	LDB	Peoria		440.6	90	442.4	440.0	6	
9	29/08	03:45 PM	179.9	mp	LDB	Peoria	0.21	440.6	90	442.4	440.0	6	
9	29/08	04:05 PM	179.7	dn	LDB	Peoria		440.6	90	442.4	440.0	6	
10	29/08	06:25 PM	160.0	up	RDB	Peoria		440.5	50	441.4	440.0	4&5	
10	29/08	06:20 PM	160.0	mp	RDB	Peoria	0.11	440.5	50	441.4	440.0	4&5	Extended subaqueous bench
10	29/08	06:45 PM	160.0	dn	RDB	Peoria		440.5	50	441.4	440.0	4&5	
11	30/08	11:00 AM	155.5	up	RDB	La Grange		432.8	70	440.8	429.5	6	
11	30/08	08:15 AM	155.3	mp	RDB	La Grange	0.54	432.8	70	440.8	429.5	6	
11	30/08	11:30 AM	155.1	dn	RDB	La Grange		432.8	70	440.8	429.5	6	
12	30/08	08:45 AM	154.6	up	LDB	La Grange		432.8	70	440.7	429.5	5	
12	30/08	09:40 AM	154.4	mp	LDB	La Grange	0.62	432.8	70	440.7	429.5	5	
12	30/08	10:40 AM	154.2	dn	LDB	La Grange		432.8	70	440.7	429.5	5	
13	30/08	12:15 PM	150.6	up	LDB	La Grange		432.3	75	440.5	429.5	4	Water surface on scarp face
13	30/08	12:10 PM	150.5	mp	LDB	La Grange	0.18	432.3	75	440.5	429.5	4	may be scraped by traffic
13	30/08	12:45 PM	150.5	dn	LDB	La Grange		432.3	75	440.5	429.5	4	
14	30/08	04:15 PM	129.4	up	RDB	La Grange		431.2	80	438.5	429.5	4	
14	30/08	04:15 PM	129.3	mp	RDB	La Grange	0.28	431.2	80	438.5	429.5	4	Levee
14	30/08	04:45 PM	129.2	dn	RDB	La Grange		431.2	80	438.5	429.5	4	Subaqueous scour
15	30/08	06:35 PM	116.7	up	RDB	La Grange		430.8	75	437.0	429.5	3&5	
15	30/08	06:45 PM	116.5	mp	RDB	La Grange	0.95	430.8	75	437.0	429.5	3&5	Levee
15	30/08	07:10 PM	116.3	dn	RDB	La Grange		430.8	75	437.0	429.5	3&5	
16	31/08	11:05 AM	109.5	up	LDB	La Grange		430.6	75	435.8	429.9	2	
16	31/08	10:25 AM	109.5	mp	LDB	La Grange	0.18	430.6	75	435.7	429.9	2	
16	31/08	10:38 AM	109.5	dn	LDB	La Grange		430.6	75	435.6	429.9	3	Near Anderson Lake
17	31/08	10:00 AM	109.6	up	RDB	La Grange		430.6	75	435.7	429.9	5	
17	31/08	09:15 AM	109.5	mp	RDB	La Grange	0.18	430.6	75	435.7	429.9	5	
17	31/08	10:30 AM	109.4	dn	RDB	La Grange		430.6	75	435.7	429.9	4	

Table 9. (concluded)

Site	Date in 1995	Time	RM	Location	Side	Pool	Length (miles)	Stage (ft-msl)	f (%)	OHWE (ft-msl)	NP (ft-msl)	Type	Remarks
18	31/08	02:40 AM	94.2	up	RDB	La Grange		429.9	75	433.7	429.9	4	
18	31/08	02:15 PM	94.2	mp	RDB	La Grange	0.09	429.9	75	433.7	429.9	2&4	
18	31/08	02:20 PM	94.2	dn	RDB	La Grange		429.9	75	433.7	429.9	4	
19	31/08	03:05 PM	91.2	up	RDB	La Grange		429.9	65	433.3	429.9	2&4	Downstream of barge terminals
19	31/08	04:00 PM	91.2	mp	RDB	La Grange	0.22	429.9	65	433.3	429.9	2&4	
19	31/08	04:30 PM	91.1	dn	RDB	La Grange		429.9	65	433.3	429.9	2&4	
20	31/08	07:40 PM	79.6	up	RDB	Alton		420.6	90	NA	NA	2	d/s La Grange L & D
20	31/08	07:15 PM	79.4	mp	RDB	Alton	0.67	420.6	90	NA	NA	2	
20	31/08	07:20 PM	79.2	dn	RDB	Alton		420.6	90	NA	NA	2	
21	01/09	11:00 AM	61.8	up	RDB	Alton		420.6	80	NA	NA	5	Wet bench
21	01/09	10:45 AM	61.7	mp	RDB	Alton	0.23	420.6	80	NA	NA	4	small scarp on top of bank, wet
21	01/09	10:40 AM	61.6	dn	RDB	Alton		420.6	80	NA	NA	5	bench, shorter subaqueous bench
22	01/09	01:00 PM	45.1	up	RDB	Alton		419.9	85	NA	NA	4&5	
22	01/09	12:50 PM	45.1	mp	RDB	Alton	0.14	419.9	85	NA	NA	4&5	
22	01/09	01:30 PM	45.1	dn	RDB	Alton		419.9	85	NA	NA	4&5	
23	01/09	04:30 PM	23.5	up	RDB	Alton		419.3	90	NA	NA	4	
23	01/09	04:20 PM	23.4	mp	RDB	Alton	0.18	419.3	90	NA	NA	4	
23	01/09	04:45 PM	23.3	dn	RDB	Alton		419.3	90	NA	NA	2	
24	01/09	06:30 PM	13.1	up	RDB	Alton		419.3	90	NA	NA	2&5	
24	01/09	06:00 PM	13.0	mp	RDB	Alton	0.24	419.3	90	NA	NA	2&5	
24	01/09	06:15 PM	12.9	dn	RDB	Alton		419.3	90	NA	NA	2&5	

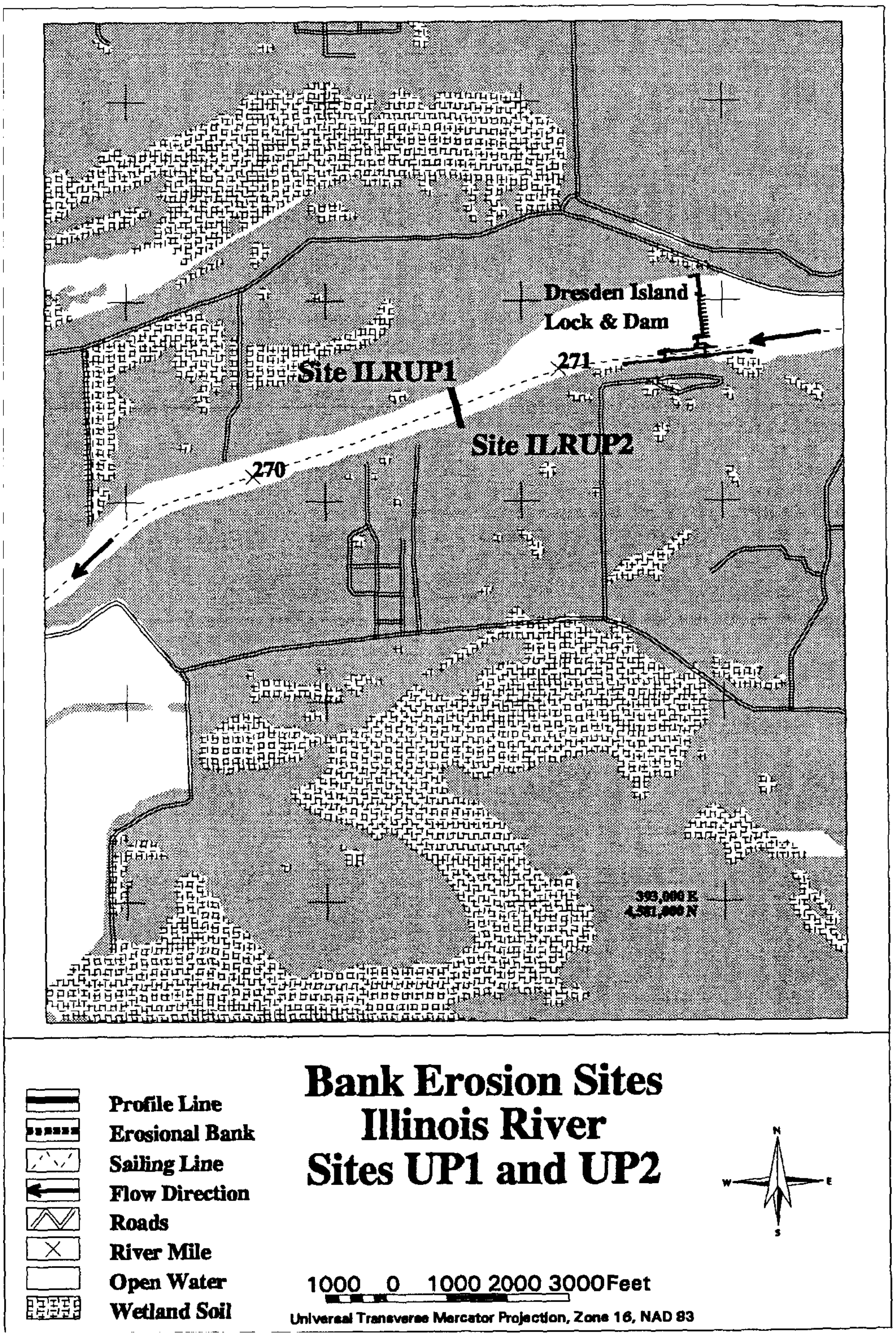


Figure 36. Locations of sites UP1 and UP2 on the Illinois River

Table 10. Classification of Erosion Sites on the Illinois River

Parameters	*Most frequent values*	*Second most frequent values*
Bench Slopes	18 (0.025-0.05)	15 (0.1-0.125)*
Berm Slopes	4 (3 ranges)	3 (3 ranges)
Scarp Slopes	16 (1.4-2.1)	13 (0.7-1.4)
d_{50}	101 (0.0-0.05)	16 (0.1 8-0.23)
d_{85}	98 (0.0-0.14)	34 (0.14-0.39)
O	28 (2-3)	5 (6-7; 9-10) (2 ranges)
U	15 (2-3)	4 (5-6)
Site Lengths (miles)	7 (0.l5-0.2)	5 (0.2-0.25) (2 ranges)
Sites with Natural Banks	28	
Top Width (ft)	5 (525-550) (2 ranges)	4 (550-575) (3 ranges)
Max. Depth (ft)	8 (12.5-13.0)	3 (14-14.5) (2 ranges)

Sunmary: 17 Sites on the RDB, 12 on the LDB, 13 sites on straight reach, 11 sites on outside bend, 3 sites on inside bend, and 2 sites on crossover; 5 sites were located on islands

Note: * This value occurred 15 times and the range was 0.1 to 0.125.

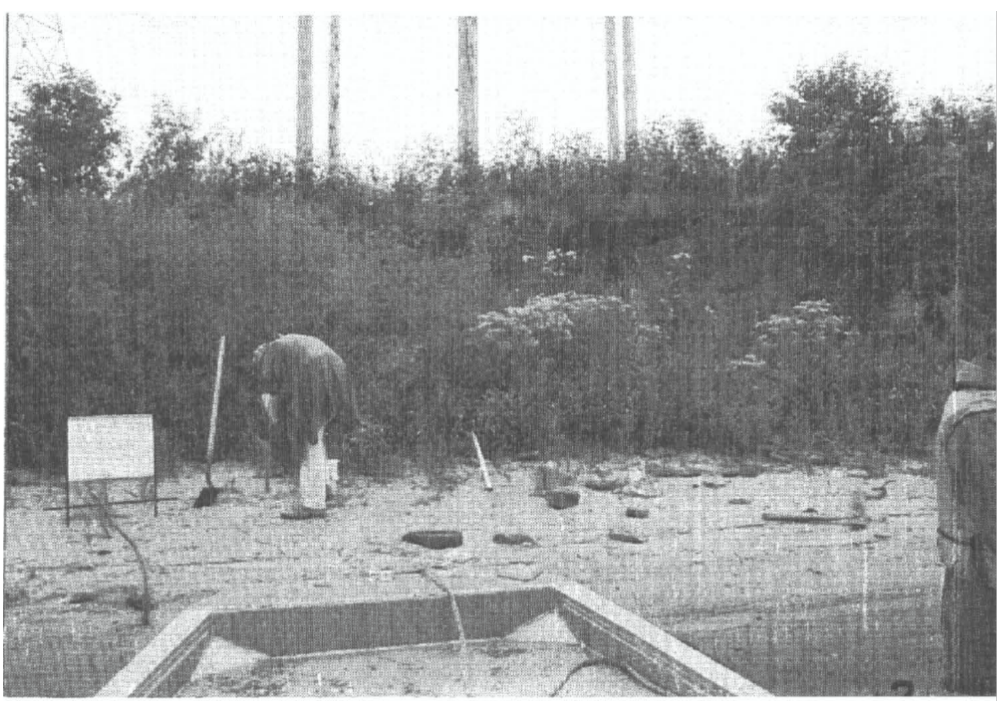


Figure 37. Site UP1 on the Illinois River

The site is about 180 feet from the sailing line, and no major tributary enters the river at this location. An Elgin-Joliet and Eastern Railroad bridge is located at RM 270.6. In two earlier studies Bhowmik and Schicht (1980) indicated erosion on the RDB and Hagerty (1988) indicated erosion on both banks.

An almost vertical failure face approximately 15-20 feet high is present at this site. Recession of the bank line is close to the support of a nearby powerline frame. One of the four legs of a nearby powerline support was only 3 feet from the bank face.

Only one river cross section was measured at this site, and the detailed cross section and coordinates are shown in appendix D. Three bank sections were measured at this site, as given in figure 38 with the computed values of bench slopes and median diameters of the bank soils. For site UP1, the OHWE is at 486.6 and NP is at 483.3 feet above mean sea level (ft-msl), respectively. The NP elevation corresponds to a break in the subaqueous bench slope. There were weeds growing on the bench near the base of the scarp. The bank above the OHWE line is relatively high as compared to local stage fluctuations. According to 10-year stage data (see table 11), the OHWE reaches the base of the scarp and only high stages (less than 10 percent exceedence frequency, or approximately at 489.9 feet) can reach the existing scarp face. Otherwise, normal stage fluctuations (the range between OHWE and NP) occur mostly on the bench area.

The gradation plots of bank soils and nearshore sediment are presented in appendix C. At the midsection, the d_{50} varies from 0.009 mm at the top surface of the bank to 0.379 mm at the upper part of a core sample at a depth of about 2 feet of water.

The bench slope varied from lV:6.8H to 1V:9.H. The bank at this site can be classified as a combination of types 1 and 3 (figure 21 and 23 and table 9). Floods and high water stages could be the major cause of bank erosion. There was a collapsed bank section. Failure could be due to erosional oversteeping. Several holes were observed on the bank face, indicating that piping could also be a factor in bank failure.

Site UP2, Marseilles Pool, 9/18/95

This site is located on the LDB at RM 270.8, opposite site UPl. Figure 36 shows the position of the site on a GIS-based map of the Illinois navigation chart, and figure 39 is a photograph of the site.

The site is about 280 feet from the sailing line, and no major tributary enters the river at this location. In Bhowmik and Schicht's (1980) note, this side was marked as a dredge material displacement site. Trees and grass covered an obvious scarp approximately 3 feet in height and 100 feet from the water's edge. The bench was composed of coarse sand, gravel, and boulders. More boulders were encountered between the scarp face and the bench.

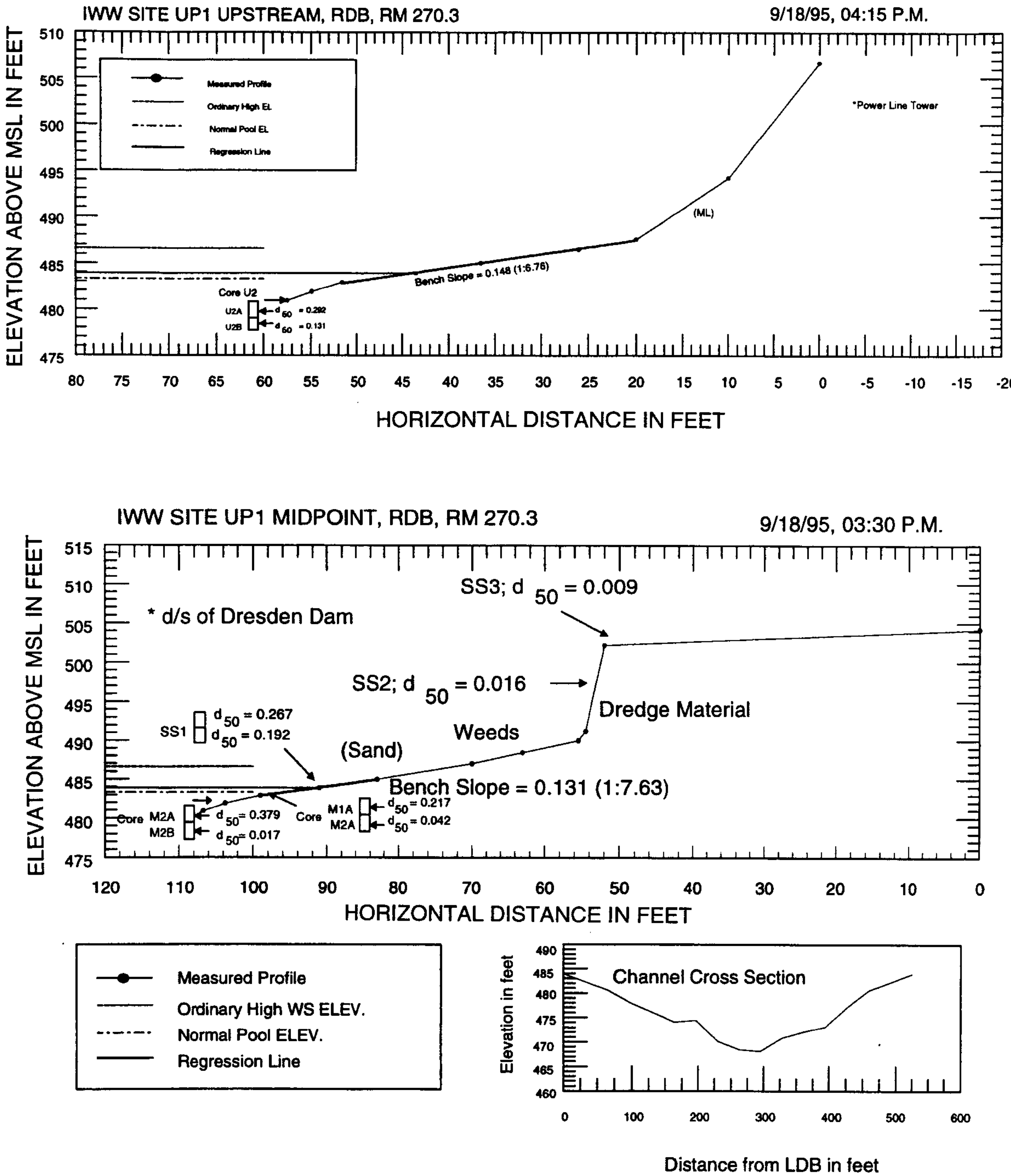


Figure 38. Bank sections at site UP1

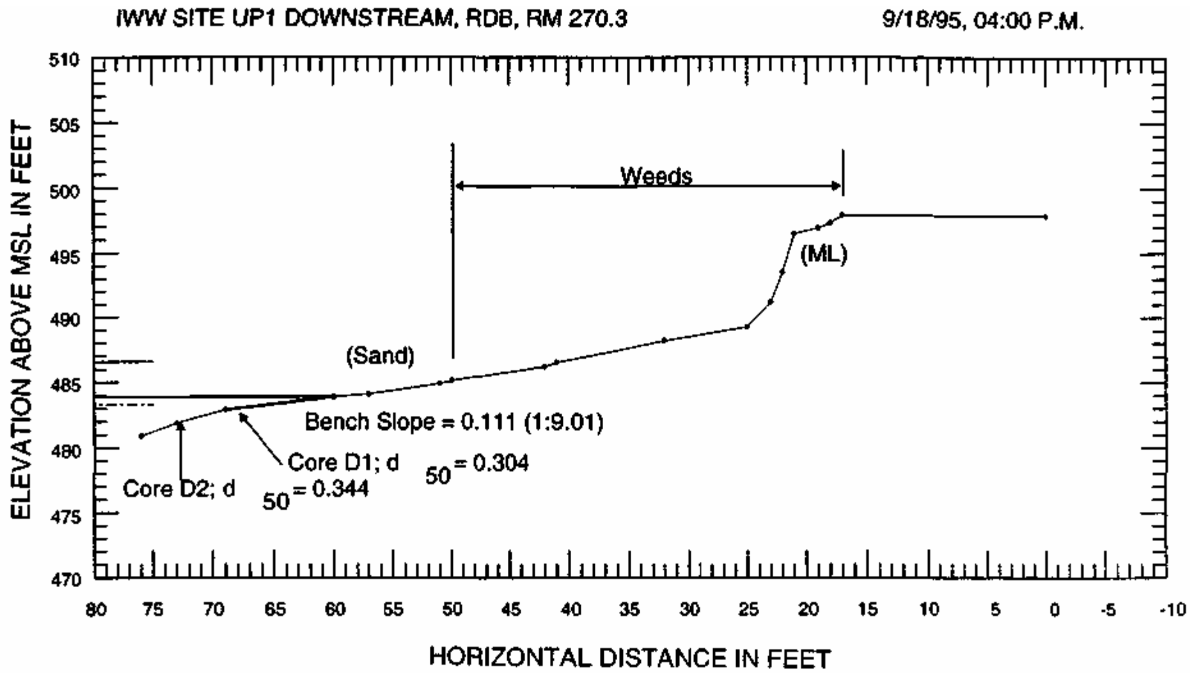


Figure 38. Bank sections at site UP1 (concluded)

Table 11. Site UP1 Characteristics

Percentage of occurrence	*Stage above msl.ft*	*Topographical features*	*Bank/bed material, mm*
90	484.2	• Bench (slope varied from 1V:9H to 1V:6.8H)	• d_{50} (core) @ 2 feet of water varied (0.017-0.379)
75	484.6	• Bench	• d_{50} @ 1 foot of water varied (0.042-0.304)
50	485.5	• Bench	
25	487.3	• Toe of berm	
10	489.9	• Berm • Berm (slopes varied from 1V:1.05H to 1V:5H)	• d_{50} = 0.016
0-9	>490.0	• Toe of scarp • Scarp (slope varied from 1V:1.05H to 1V:0.38H)	• d_{50} = 0.009

Note: Tail water gage of Dresden Island @ RM 271.5 was used for stage histogram; WSE = 483.9 feet; OHWE = 486.6 feet; and NP = 483.3 feet.

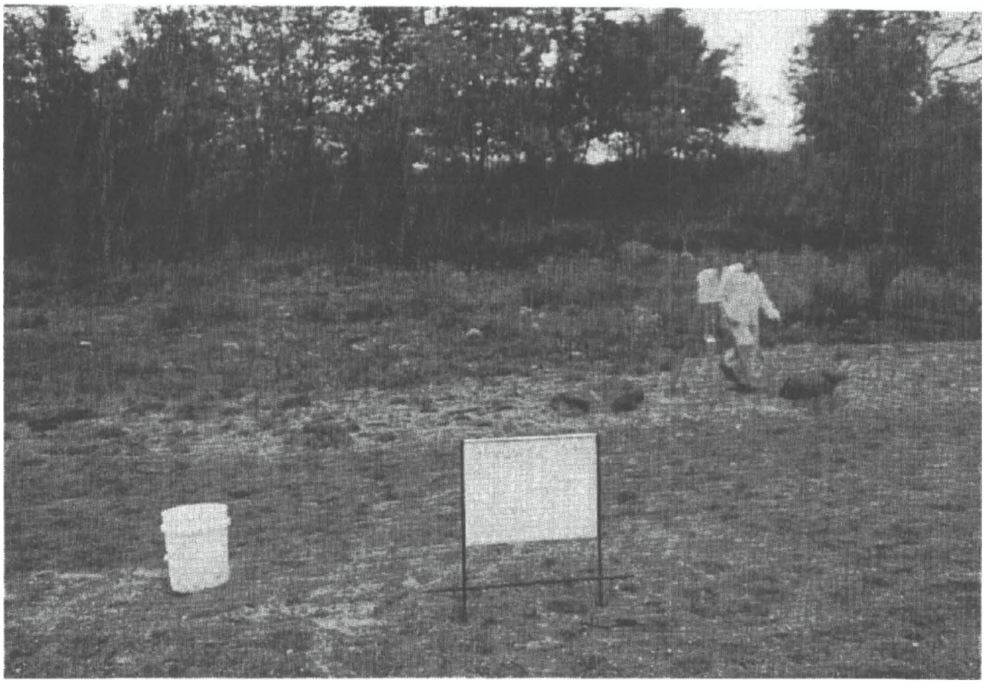


Figure 39. Site UP2 on the Illinois River

Figure 40 shows the plot of the bank sections and a cross section. Only one river cross section and one bank section were measured at this site. The OHWE is the same as site UP1 at 486.6 ft-msl and NP at 483.3 ft-msl. On this side of the river, the OHWE is on the bench area and only stages exceeding 10 percent occurrence level (table 12) can reach to the base of the minor scarp face at about 494 ft-msl.

The d_{50} varied from 0.138 mm at the top surface of the bank to 0.429 mm for a core sample at a depth of about 2 feet of water. Another core sample at 1 foot of water showed coarse sand (d_{50}= 0.589 mm) on top and fine sand (d_{50}= 0.239) at the bottom. Gradation plots of bank soils and nearshore sediment are presented in appendix C. The detailed cross section and coordinates are shown in appendix D.

The bench slope was 1V:11H, and the bench was covered with noncohesive sandy soil. This site can be classified as type 5 (see figure 25 and table 9). The scarp was above OHWE stage. Erosion could have occurred during flood stages. The base of the scarp showed sand deposits indicating that seepage at the base could weaken the bank. Waves and currents could remove/transport failed soils that mantle the bench.

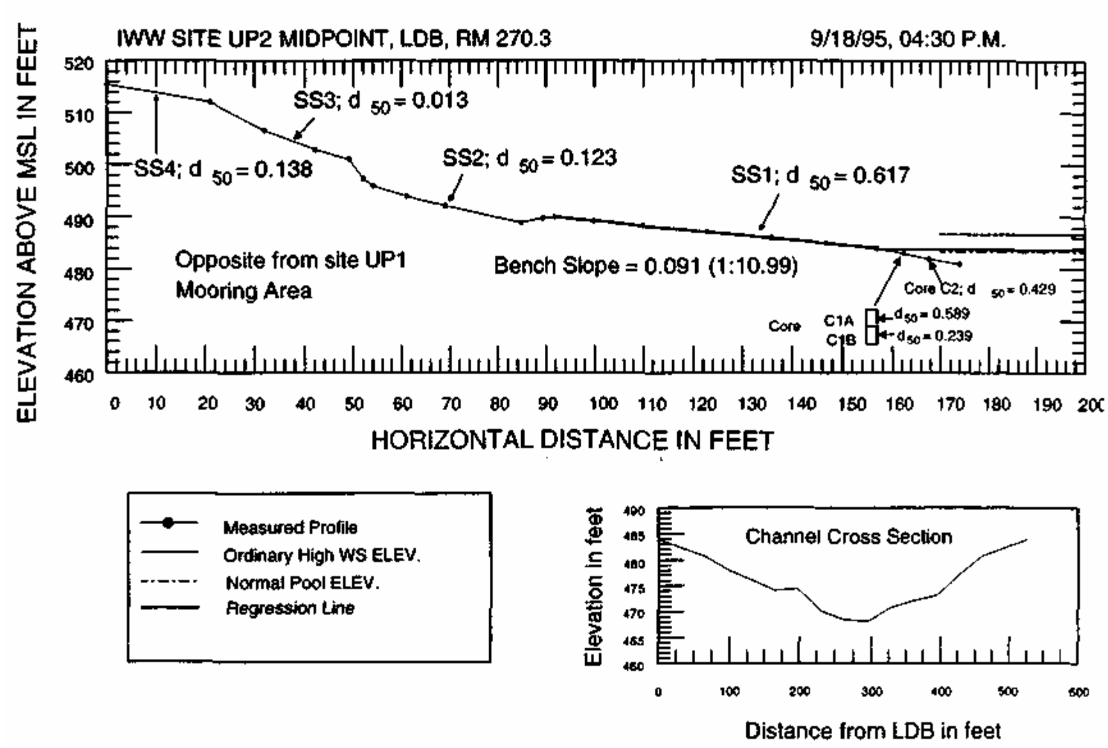


Figure 40. Bank section at site UP2, midsection

Table 12. Site UP2 Characteristics

Percentage of occurrence	*Stage above msl, ft*	*Topographical features*	*Bank/bed material, mm*
90	484.2	• Bench	• d_{50} = 0.617
75	484.6	• Bench	• d_{50} (core) @ 1 foot of water varied (0.239-0.589)
50	485.5	• Bench	• d_{50} (core) @ 2 feet of water = 0.429
25	487.3	• Bench	
10	489.9	• Bench (slope = IV: 11H)	
0-9	>490.0	• Scarp (slope = 1V:9.2H)	• d_{50} varied (0.013-0.138)

Note: Tail water gage of Dresden Island @ RM 271.5 was used for stage histogram; WSE = 483.9 feet; OHWE = 486.6 feet; and NP = 483.3 feet.

Site UP3, Marseilles Pool, 9/19/95

This site is located on the LDB at RM 264.3; the reach is fairly straight. The Morris Boat Club Dock and Vogler Gravel Company are located across the river at RM 264.5. No major tributary enters this site. Figure 41 shows the position of the site on a GIS-based map of the Illinois navigation chart, and figure 42 is a photograph of the site.

The site is about 250 feet from the sailing line as measured from the navigation chart. Both Bhowmik and Schicht (1980) and Hagerty (1988) indicated the existence of a significantly long stretch of bank erosion on the LDB. The site is currently used as a trailer park located at the top of the bank, and boat docks were installed. An abandoned boat ramp was found at the upstream end of the site. Quite a few boulders were found in the nearshore area. When taking core samples, the crew noted that sediments showed a very high level of oil staining, and oil emerged when the crew split samples.

An obvious scarp approximately 5-10 feet high was at this site. Erosion of the bench area, if not retreat of the bank line, could be described as significant when compared with a 1988 photo. Figure 43 shows the three measured bank sections and a reduced cross section. At all subsequent figures, w.e. indicates water surface elevation. At the downstream section, a concave bank face was observed. The OHWE is 485.7 feet and NP is 483.3 ft-msl. The NP elevation corresponds to a break in the subaqueous bench slope. The OHWE reaches to the upper part of the bench and corresponded well with the lower end of the weed zone. The bank top is relatively high and only high, stages exceeding the 10 percent occurrence frequency (at 488 feet, see table 13) can reach the berm or the scarp.

Table 13. Site UP3 Characteristics

Percentage of occurrence	*Stage above msl,ft*	*Topographical features*	*Bank/bed material, mm*
90	483.7	• Bench (slopes varied from 1V:21.7H to 1V:20.8H)	• d_{50} (core) @ 1 foot of water varied (0.095-0.152)
75	484.0	• Bench	• d_{50} (core) @ 2 feet of water varied (0.023-0.419)
50	484.6	• Bench	
25	486.0	• Bench	
10	488.0	• Bench	
0-9	>488.0	• Berm	• d_{50} varied (0.059-0.062)
		• Berm (slopes varied from 1V:3.8H to 1V:1.6H)	• d_{50} (top of bank) = 0.023
		• Scarp (slopes varied from 1V:0.85H to 1V:0.17H)	

Note: Gage on the Illinois River near Morris, IL @ RM 263.1 was used for stage histogram. WSE = 483.7 feet; OHWE = 485.7 feet; and NP = 483.3 feet.

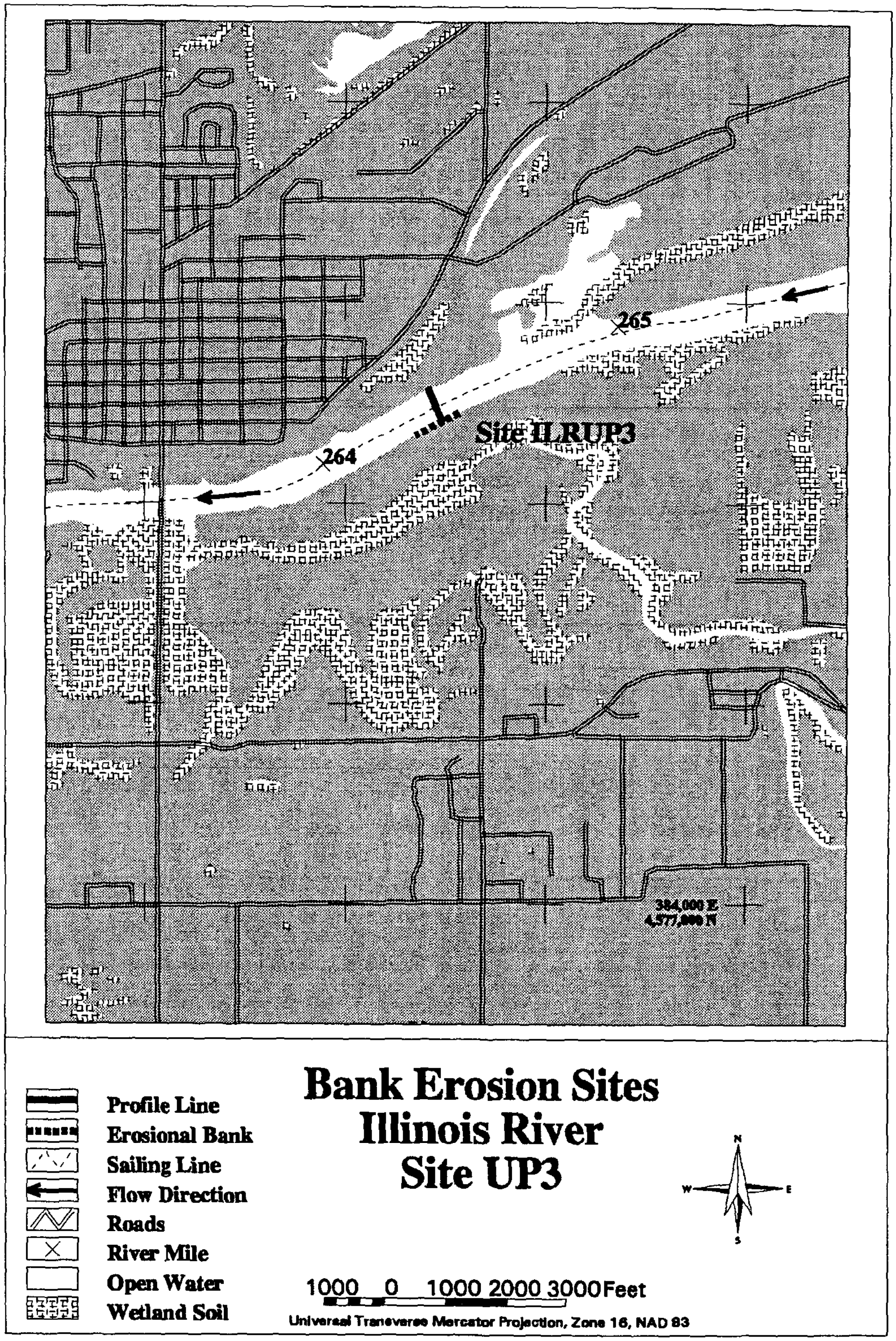


Figure 41. Location of site UP3 on the Illinsois River

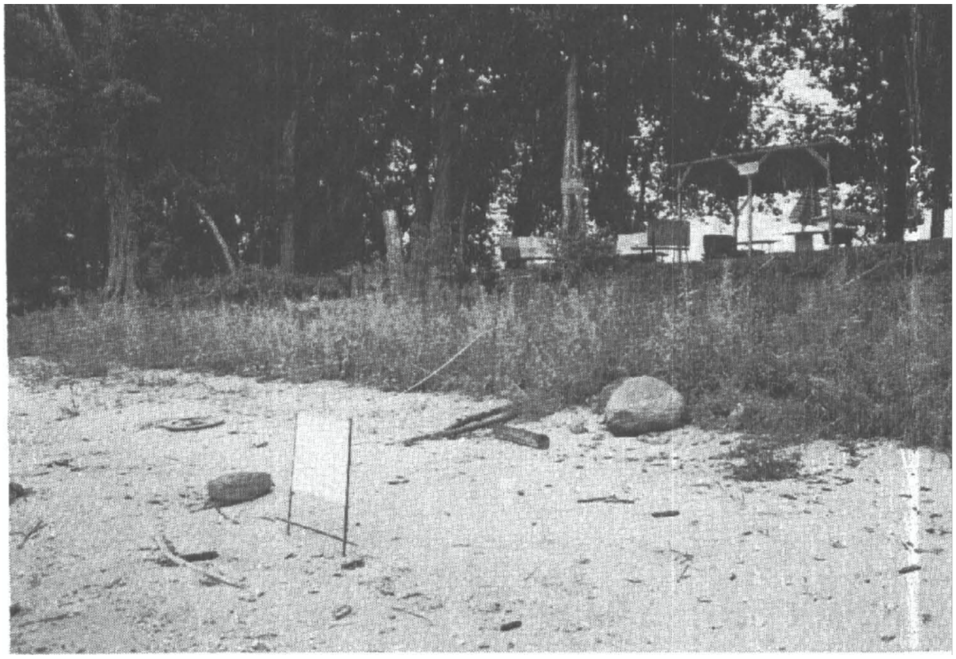


Figure 42. Site UP3 on the Illinois River

At the midsection, the d_{50} varies from 0.023 mm at the top surface of the bank to 0.419 mm for a core sample at a depth of about 2 feet of water. Gradation plots of bank soils and nearshore sediment cores are presented in appendix C. The detailed cross section and coordinates are shown in appendix D.

Bench slopes varied only slightly from 1V:21.7H, and the bench was covered with noncohesive sandy materials. This site can be classified as type 3 (see figure 23 and table 9). Erosional undercutting, rework, and transport by waves and currents at high stages or during floods could be major causes of erosion at this site. After a flood recedes, the bank soil may slip and fall as blocks, as shown in the downstream section. Land use as a trailer park can be a factor at this site too. Seepage at the recession stage of a flood also could play a significant role in bank failure. Waves and disturbances created by local boating activities can cause entrainment of recently deposited sediments from bench areas.

Site UP4, Marseilles Pool, 9/20/95

This site is located on the LDB at RM 262.1. Figure 44 shows the position of the site on a GIS-based map of the Illinois navigation chart, and figure 45 is a photograph of the site. Higher velocity can be expected on this side as it is in a straight reach downstream from a mild bend. Hagerty (1988) indicated erosion on the LDB but also marked a long stretch of erosion on the opposite bank. Bhowmik and Schicht (1980) marked this as an erosion site.

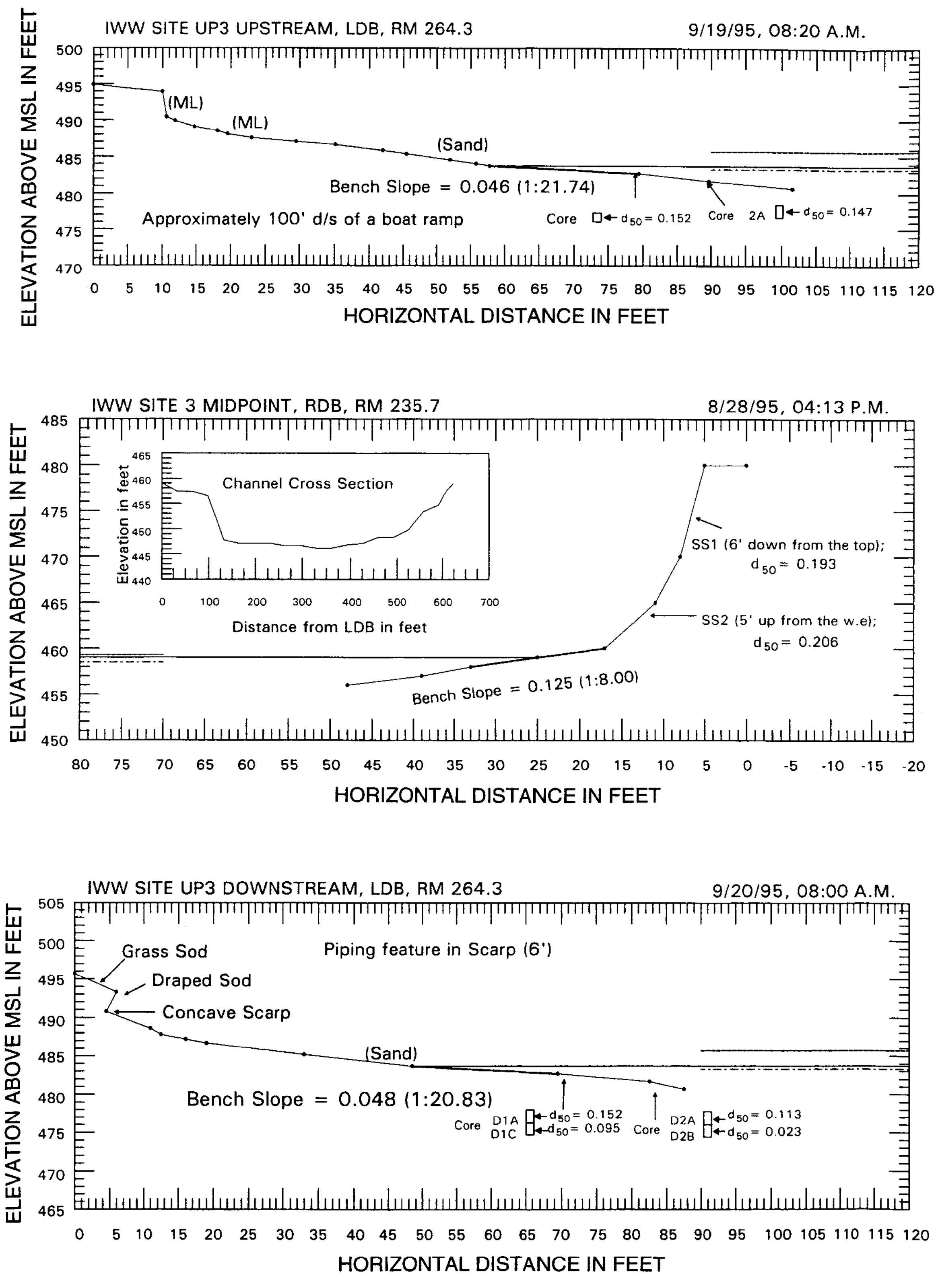


Figure 43. Bank sections at site UP3

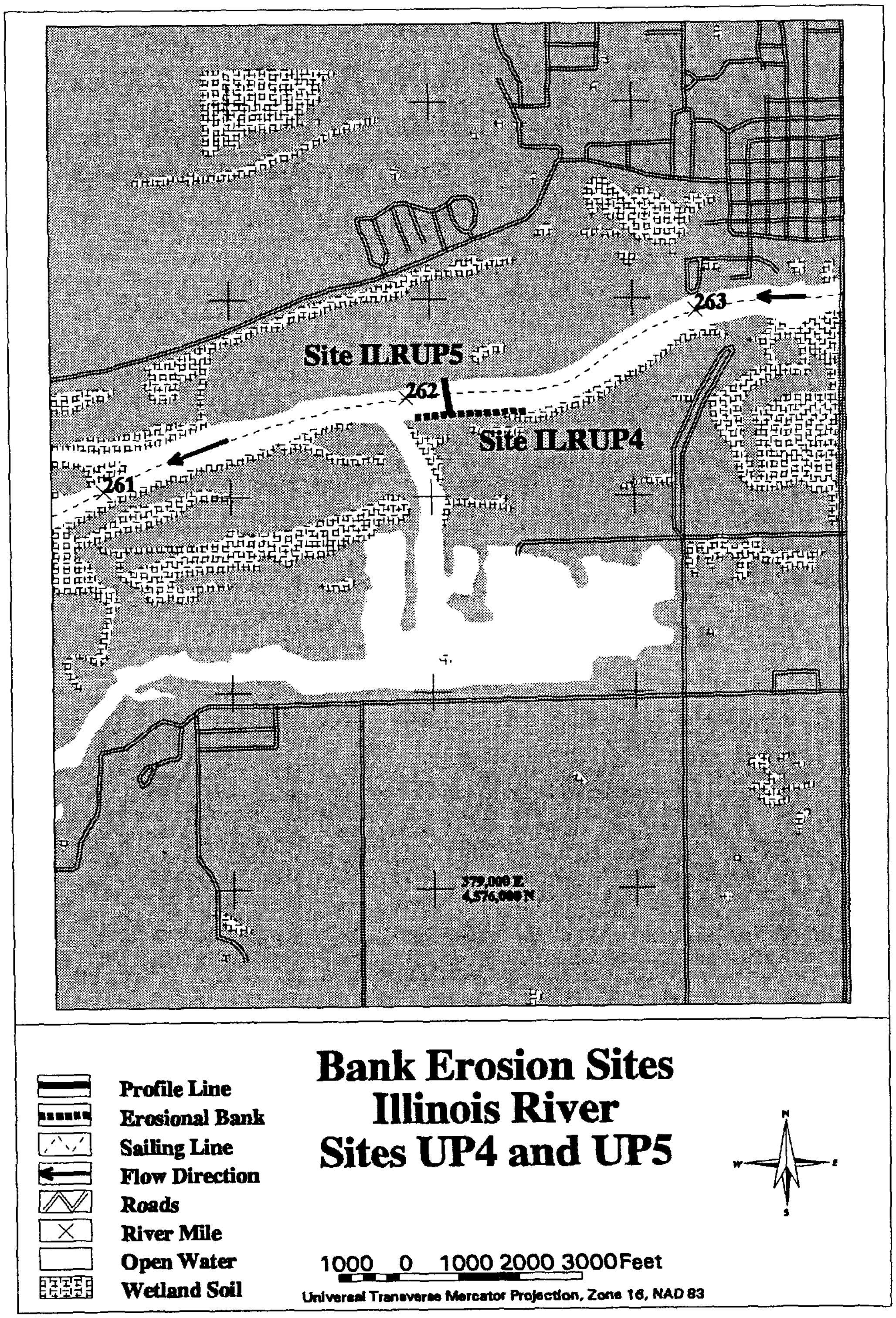


Figure 44. Locations of sites UP4 and UP5 on the Illinois River

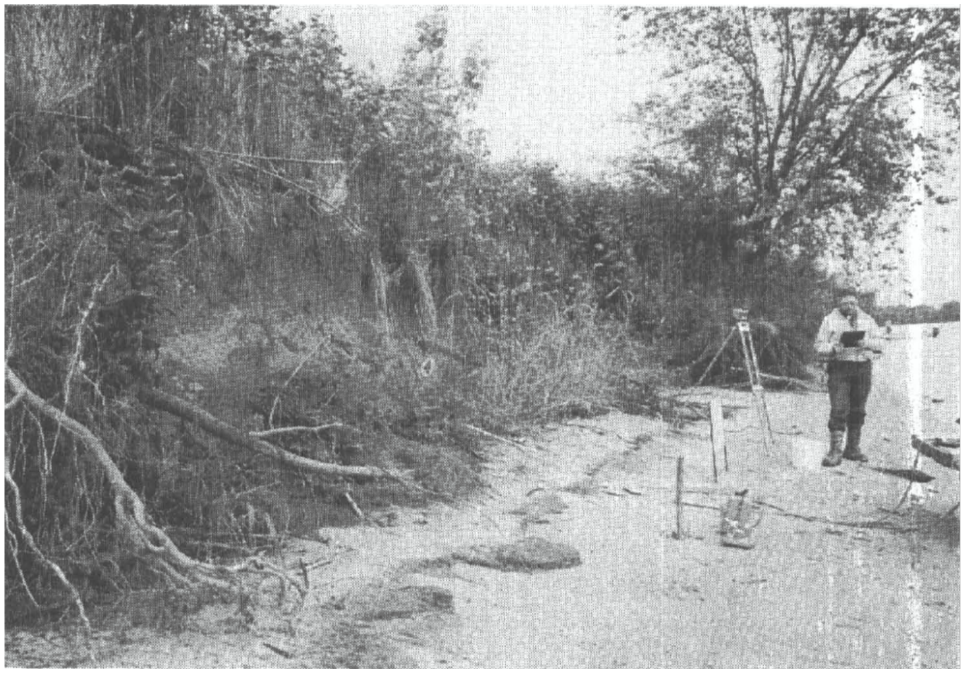
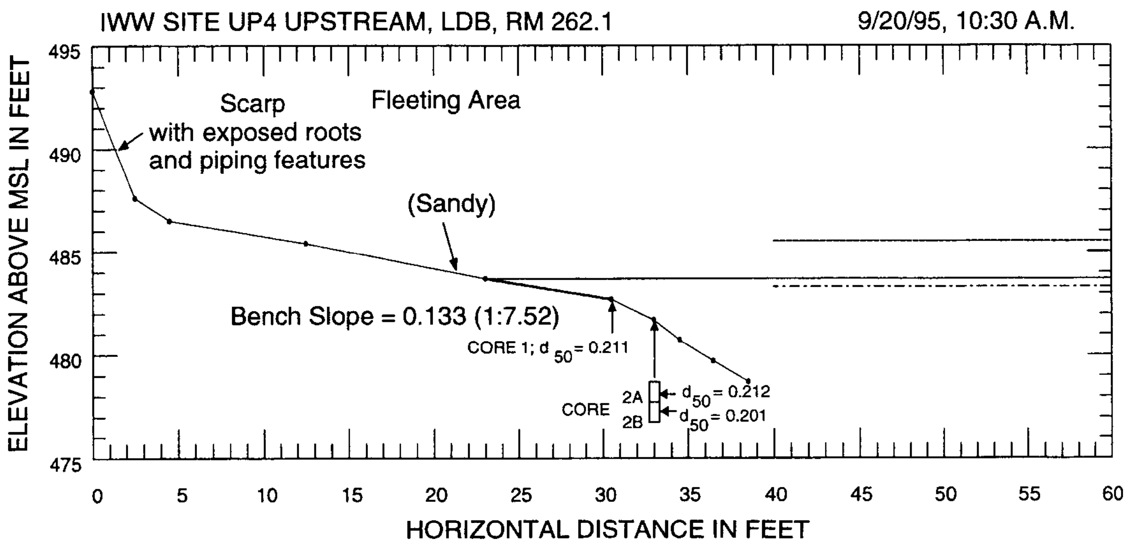
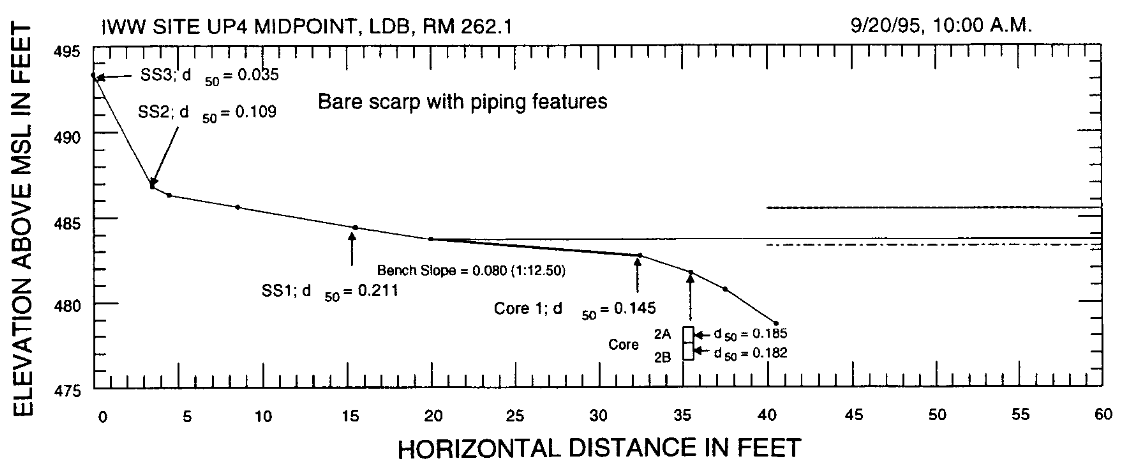


Figure 45. Site UP4 on the Illinois River

Site UP4 is in a fleeting area in which the distance to a red buoy marking the navigation channel was less than 50 feet from shore. Land use on top of the bank was agriculture (corn), and tall weeds were encountered on the bank crest. The top portion of scarp 5 to 10 feet high was covered with exposed roots, and the lower portion had piping holes. The lower bank was a narrow sand bench. Failed riprap existed downstream of the site at an entrance channel to a gravel pit. Local tow traffic at this reach can be very frequent. Figure 46 shows the three measured bank sections and a reduced cross section. A slumped bank face was observed at the downstream section. The OHWE is 485.5 feet, and NP is 483.3 ft-msl. Except at the downstream section, the base of the scarp is slightly higher than the OHW level. At higher stages (10 percent occurrence frequency, 488 feet, see table 14) wave and current can have a direct contact on the scarp.

At the midsection, the d_{50} varied from 0.035 mm at the top of the bank to 0.185 mm for the top portion of a core sample at a water depth of about 2 feet. The bank scarp consisted of cohesive materials, and the sediments were of fine sand fairly consistently at three sections. Gradation plots of bank soils and nearshore sediment are presented in appendix C. The detailed cross section and coordinates are shown in appendix D.





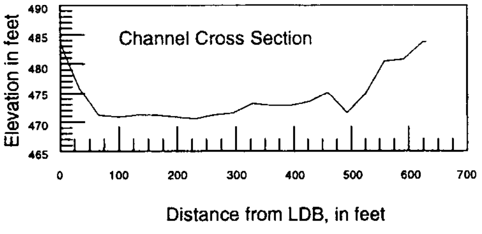


Figure 46. Bank sections at site UP4

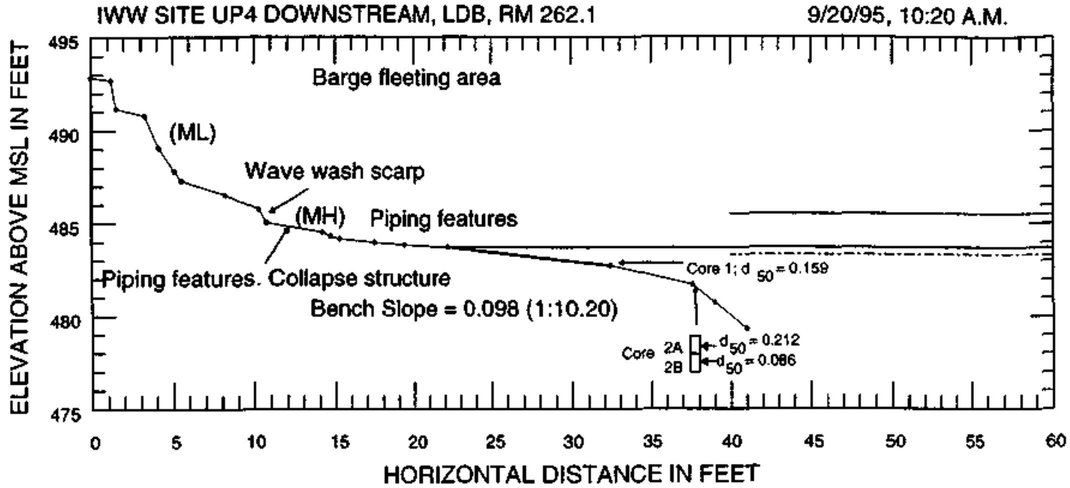


Figure 46. Bank sections at site UP4 (concluded)

Table 14. Site UP4 Characteristics

Percentage of occurrence	*Stage above msl, ft*	*Topographical features*	*Bank/bed material, mm*
90	483.7	• Bench (slopes varied from 1V:12.5H to 1V:7.5H)	• d_{50} (core) @ 1 foot of water varied (0.145-0.211)
75	484.0	• Bench	• d_{50} (core) @ 2 feet of water varied (0.086-0.212)
50	484.6	• Bench	• d_{50} =0.211
25	486.0	• Berm/bench • Berm (slopes varied from 1V:3H to 1V:1.8H)	• d_{50} = 0.109
10	488.0	• Scarp base	
0-9	>488.0	• Scarp • Scarp (slopes varied from 1V:0.8H to 1V:0.5H)	• d_{50} = 0.035 (T.O.B.)

Note: Gage on the Illinois River near Morris, IL @ RM 263.1 was used for stage histogram. WSE = 483.7 feet; OHWE = 485.7 feet; NP = 483.3 feet; and T.O.B. = Top of Bank.

Bench slopes varied from 1V: 12.5H to 1V:7.5H, and the subaqueous bench becomes steeper. Piping holes at the scarp and moist soils on the lower portion of the bank were noted. This site can be classified as a combination of types 2 and 3 (see figures 22 and 23 and table 9). The bank soils appeared to be cohesive, but the bench was sandy with several clay outcrops. Seepage could weaken the base support and cause the bank to slip, as shown at the downstream section. Failed soils and/or recently deposited sediment on the bench were reworked and transported by wind or tow-generated waves. The steep dropoff in subaqueous benches is indicative of effects of direct vessel contact or traffic-induced velocities.

Site UP5, Marseilles Pool, 9/20/95

This is at the bank opposite site UP4. Figure 44 shows the position of the site on a GIS-based map of the Illinois navigation chart, and figure 47 is a photograph of the site. Site UP5 is in a straight reach downstream from a mild bend. Bhowmik and Schicht (1980) marked this site as an erosion site and indicated dredge material displacement on this bank. A one by one loaded barge passed in the upstream direction while the team was on the bank. Although the barge slowed down at the site, the drawdown induced by this traffic event was approximately 1.5 feet vertically. Four or five large waves with crests approximately 0.9 feet higher than pool level came in after the drawdown.

Figure 47. Site UP5 on the Illinois River

The site is about 300 feet from the sailing line, and there is no major tributary at this location. The bank section has a scarp with exposed roots and piping holes. However, the bench was wet and did not have heavy sand deposition as on the opposite bank. A subaqueous scarp was found at the water's edge. Figure 48 shows one measured bank section and a reduced cross section. The OHWE is 485.5 ft-msl, and NP is 483.3 ft-msl. The subaqueous bench extends at least 100 feet from the water's edge. A l0-year stage data analysis (table 15) shows that stages higher than 25 percent recurrence frequency (the OHWE) would submerge the base of the scarp; those higher than 10 percent recurrence frequency (above 490 feet) will overtop the bank.

At the midsection, the d_{50} varies from 0.129 mm at the top surface of the bank to 0.279 mm for the top portion of a core sample at a water depth of about 2 feet. Core samples were similar to those at site UP4. Gradation plots of bank soils and nearshore sediment are presented in appendix C. The detailed river cross section and coordinates are shown in appendix D.

The bench slope was lV:26H. Some algae were observed on the subaerial bench. This site is classified as a combination of types 4 and 5 (see figures 24 and 25, and table 9). Banks are susceptible to erosion by tractive forces from flows at OHWE or during floods. Piping, seepage, and weathering could loosen the bank soils, which are then subject to removal by currents and waves. At this site, traffic-induced currents and waves can erode failed soils and recently deposited sediments within bench areas during periods of NP stages.

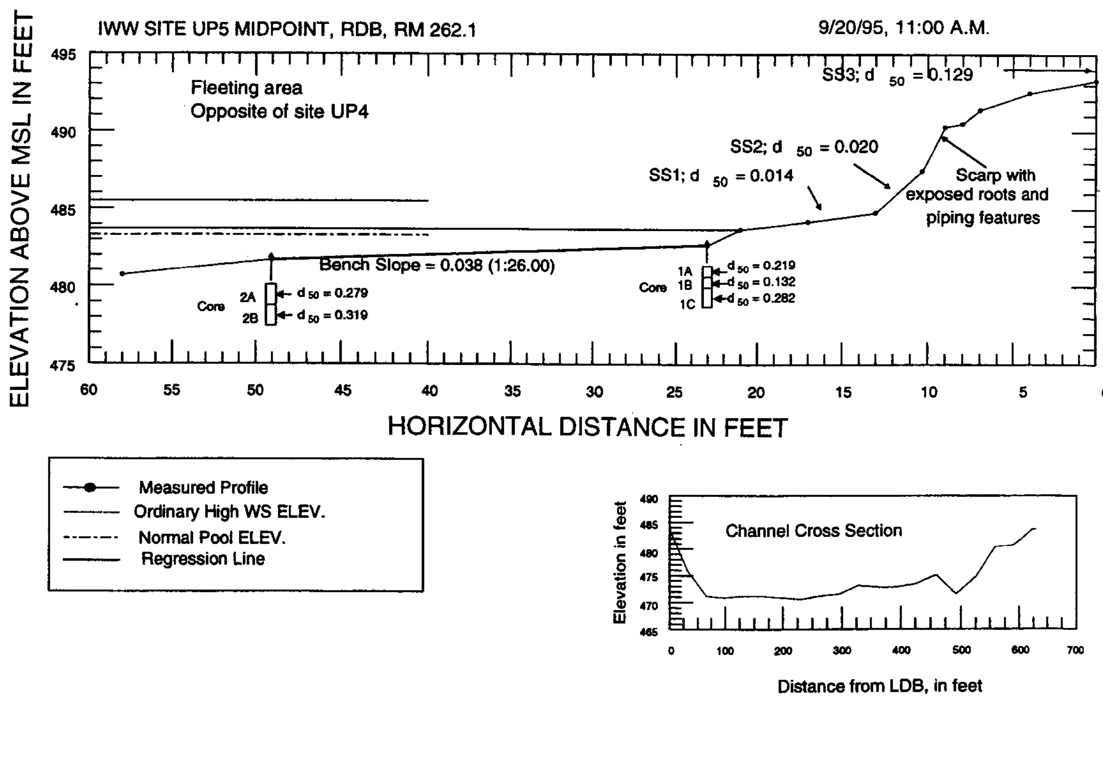


Figure 48. Bank section at site UP5

Table 15. Site UP5 Characteristics

Percentage of occurrence	*Stage above msl,ft*	*Topographical features*	*Bank/bed material, mm*
>90	<483.7	• Bench (underwater) • Slope = 0.038	• d_{50} (core) @ 2 feet of water varied (0.28-0.32)
90	483.7	• Berm • Slope = 1V:2.6H	• d_{50} = 0.014
75	484.0	• Berm	
50	484.6	• Toe of scarp	
25	486.0	• Scarp • Slope = 1V:2.6H	• d_{50} = 0.020
10	488.0	• Scarp	
0-9	>490.0	• Top of the bank	• d_{50} = 0.129 • d_{50} (core) @ 1 foot of water varied (0.132-0.282)

Note: Gage on the Illinois River near Morris, IL @ RM 263.1 was used for stage histogram. WSE = 483.7 feet; OHWE = 485.7 feet; and NP = 483.3 feet.

Site 1, Starved Rock Pool, 8/28/95

This site is located on the LDB at RM 242.9, on the outside of a sharp bend. Figure 49 shows the position of the site on a GIS-based map of the Illinois navigation chart, and figure 50 is a photograph of the site. The site is about 400 feet from the sailing line, and Moores Creek enters the Illinois River downstream of this site.

Neither Bhowmik and Schicht (1980) nor Hagerty (1988) observed erosion at this site. Hagerty (1988) noted rock instead. During this survey a near vertical scarp about 8 feet high was encountered. Exposed tree and grass roots covered the top of the scarp, and some leaning tall trees were found on the scarp. Flat slabs or rocks approximately 1-2 inches in length and only about a quarter inch in thickness were found on the bench at the foot of the scarp. Rocks increased in size to about 4 or 5 inches long near the water's edge. Rock crops out along the Moores Creek. Figure 51 shows the two measured bank sections and a reduced cross section. Available stage data from the Marseilles L & D is used for interpolating stage information at this site (table 16). The OHWE is 460 ft-msl and NP is 458.5 ft-msl. Stages higher than 461.8 feet will submerge the scarp.

At the midsection, the d_{50} varies from 0.010 mm at the surface of the bank to 0.696 mm at the edge of water to 0.025 mm for a core sample at a depth of about 1 foot of water. Gradation plots of bank soils and nearshore sediment are presented in appendix C. The detailed cross section and coordinates are shown in appendix D.

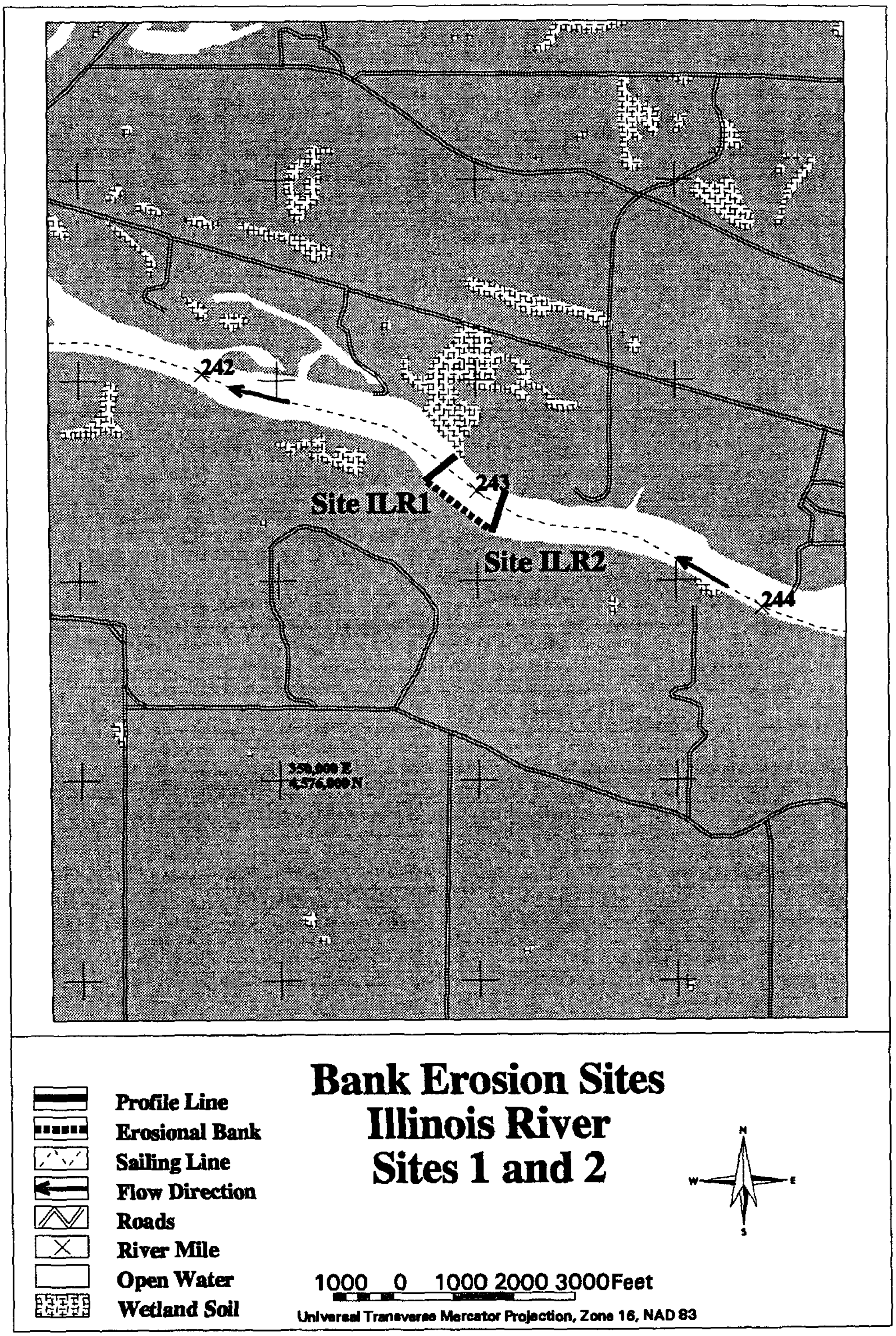


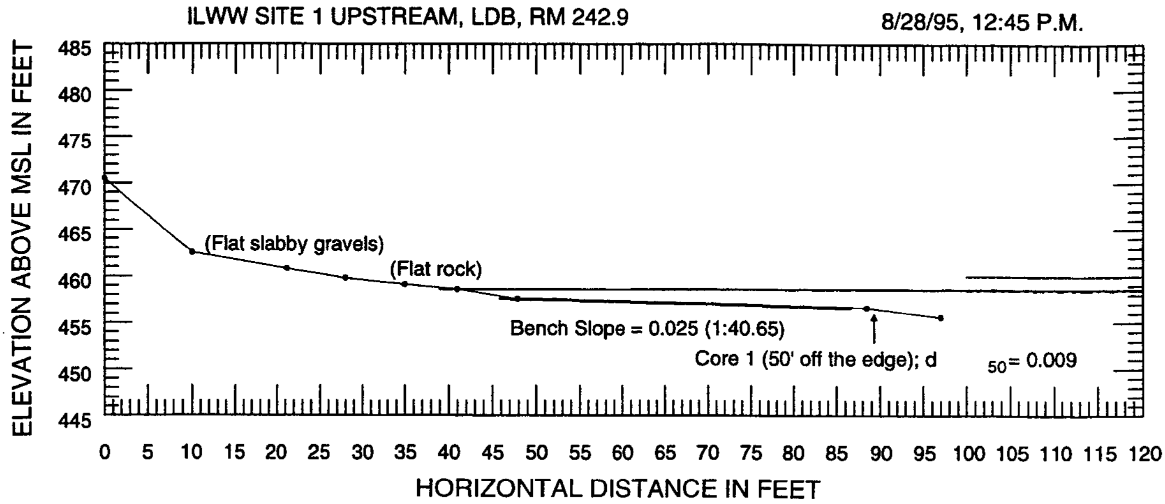
Figure 49. Locations of sites 1 and 2 on the Illinois River

Figure 50. Site 1 on the Illinois River

Table 16. Site 1 Characteristics

Percentage of occurrence	*Stage above msl,ft*	*Topographical features*	*Bank/bed material, mm*
90	459.0	• Bench (slopes varied from 1V:40H to 1V:6 . 1H)	
75	459.2	• Bench	
50	459.6	• Bench	
25	460.4	• Bench	
10	461.8	• Bench/toe of scarp	. d_{50} varied (0.014-0.696)
0-9	>461.8	• Scarp (slopes varied from 1V:0.8H to 1V:0.53H)	. d_{50}= 0.010

Note: Tail water gage of Marseilles Pool @ RM 244.6 was used for stage histogram. WSE = 458.8 feet; OHWE = 460.1 feet; and NP = 458.5 feet.



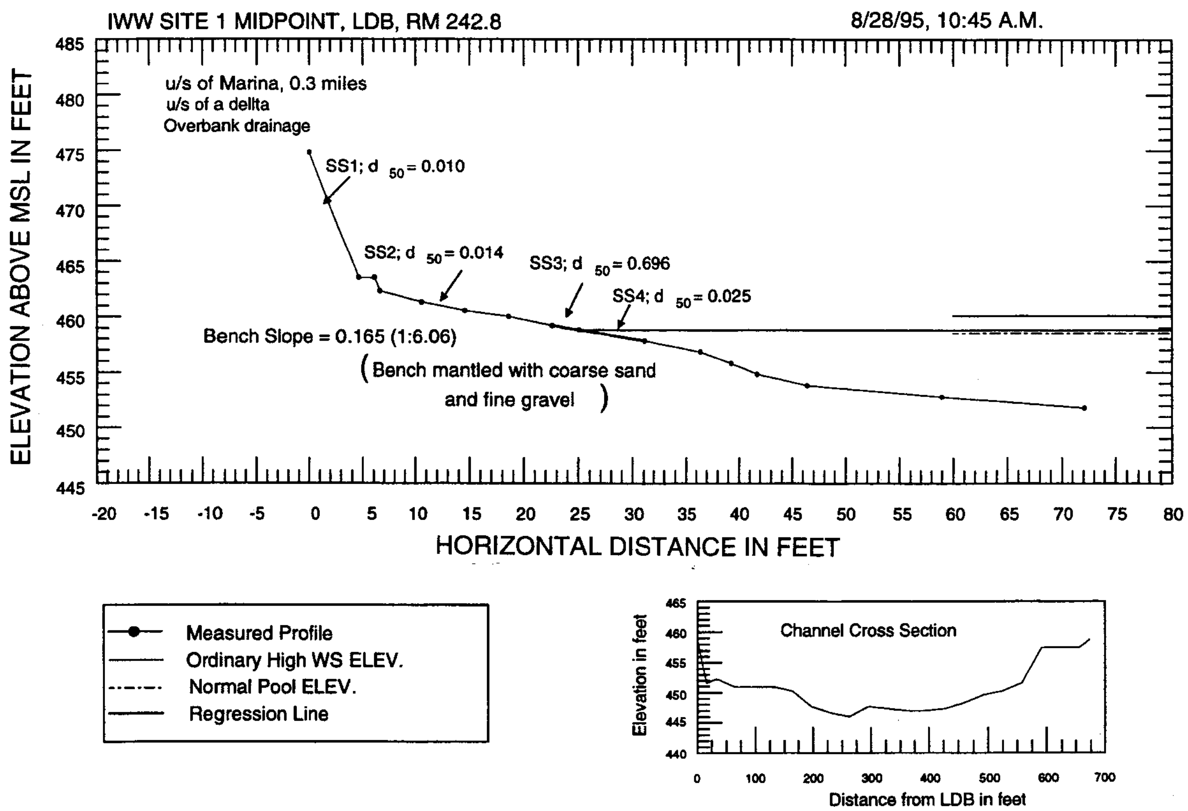


Figure 51. Bank sections at site 1

Bench slopes varied from 1V:6.1H to 1V:17.2H. This site can be classified as type 1 (figure 21 and table 9). Surficial bank materials slake and are loosened by weathering with subsequent collapse. Reworking and transport of failed materials and recently deposited sediments occurs within bench areas during high flows.

Site 2, Starved Rock Pool, 8/28/95

This site is located on the LDB at RM 243.4 upstream of site 1. The entrance to the Marseilles Canal is at RM 244.6. Figure 49 shows the position of the site on a GIS-based map of the Illinois navigation chart, and figure 52 is a photograph of the site. The bank at this site is about 250 feet from the sailing line. No tributary enters the river at this location.

Hagerty (1988) noted erosion, but Bhowmik and Schicht (1980) indicated riprap at this site. During this survey, there was a fairly long stretch of eroded bank with a nearly vertical scarp about 6-7 feet in height. Trees of 6-inch diameter stood at the edge of the scarp, some with extensive root exposure on the bank face, and some downed trees were lying on the bench. The relatively narrow bench was covered with fine sand. Nearshore materials were mostly fine sand on soft silt.

Figure 53 shows the measured bank section and a reduced cross section. The OHWE is 459.5 ft-msl and NP is 458.5 ft-msl. According to l0-year stage data (table 17), stages with 25 percent or less exceedence frequencies will reach the base of the scarp, and any stage higher than OHWE elevation will be on the scarp.

Figure 52. Site 2 on the Illinois River

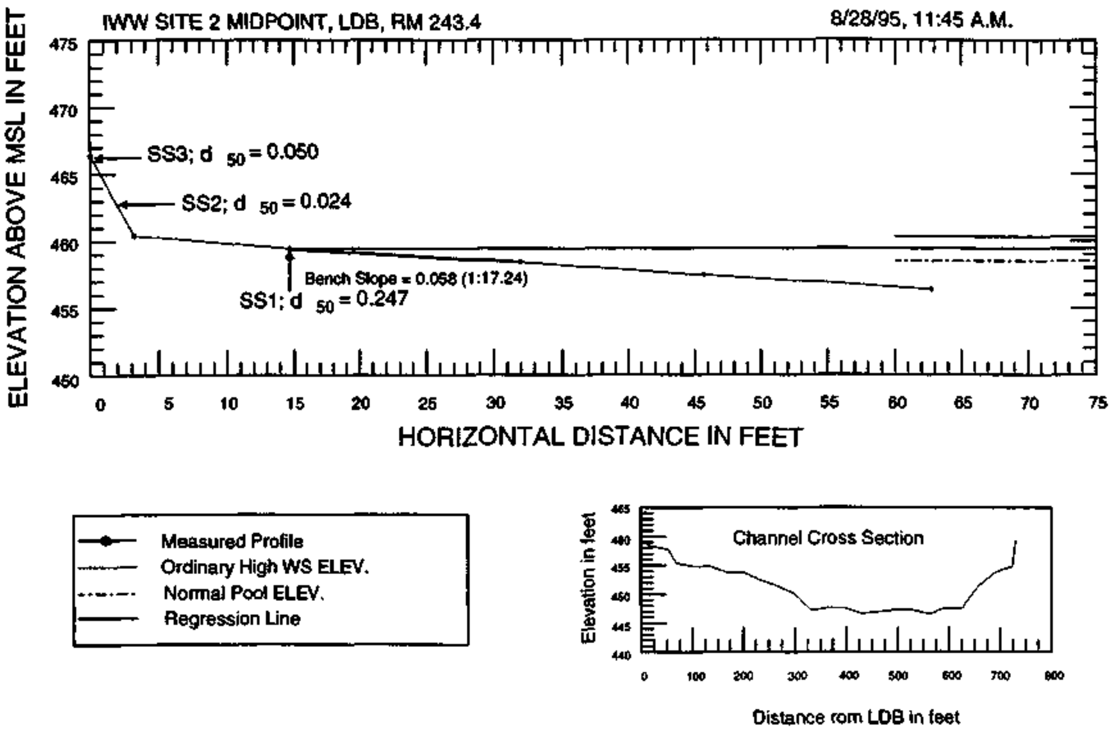


Figure 53. Bank section at site 2

Table 17. Site 2 Characteristics

Percentage of occurrence	*Stage above msl, ft*	*Topographical features*	*Bank/bed material, mm*
90	459.0	• Bench (underwater)	• d_{50} = 0.247
75	459.2	• Bench	
50	459.6	• Bench	
25	460.4	• Scarp toe	
10	461.8	• Scarp	• d_{50} varied (0.024-0.050)
0-9	>462.0	• Scarp	

Note: Tail water gage of Marseilles Pool @ RM 244.6 was used for stage histogram. WSE = 459.4 feet; OHWE = 460.3 feet; and NP = 458.5 feet.

The d_{50} varied from 0.050 mm at the top of the bank face to 0.247 mm for a core sample at the edge of water. Gradation plots of bank soils and nearshore sediment are presented in appendix C. The detailed cross section and coordinates are shown in appendix D.

The bench slope was 1V:17.2H, and the bench was covered with noncohesive sandy materials. This site was considered as the combination of types 2 and 6 (figures 21 and 26 and table 9). The scarp was nearly vertical and covered with fine roots. There was a moist layer at the base of the scarp and the subaerial bench was narrow and covered with sand. Several factors contribute to bank failure: tractive forces during floods, wave and current actions at stages above OHWE, and seepage at the base of scarp could all contribute to the rework and erosion of failed bank soils and recently deposited sediment.

Site 3, Starved Rock Pool, 8/28/95

This site is located on the RDB at RM 235.8. The reach is fairly straight, and the site is on Sheehan Island. Behind this bank is a lake, and the top width of the levee is only 5 to 6 feet. The levee appeared to be wider on the navigation chart that Bhowmik and Schicht (1980) used. However, the navigation chart that Hagerty (1988) used in 1988 showed a very thin levee. Figure 54 shows the position of the site on a GIS-based map of the Illinois navigation chart, and figure 55 is a photograph of the site.

Site 3 is about 550 feet from the sailing line, and no major tributary enters the river at this location. Bhowmik and Schicht (1980) noted erosion along RM 235.4 of the LDB, and Hagerty (1988) noted erosion at RM 235.8.

The bank consisted of a bare face approximately 15-20 feet high. Toppled trees halfway up the bank face supported stems regrown to upright directions. Fine sand and gravel were found at the water's edge. Although the reach is straight, the three sections surveyed all were measured from locally concave banklines. These concavities were about 50 feet wide, and all had either gravel or trees at the water's edge at the upstream end. Several mass failures had occurred at the downstream ends; which indicated the concave sections were widening.

Figure 56 shows the three measured bank sections and a reduced cross section. The bank slopes were steeper toward the downstream limit. The OHWE is 459.3 ft-msl and NP is 458.5 ft-msl. This range of fluctuation is within the bench area. Ten-year stage data (table 18) shows that only stages with less than 10 percent recurrence frequency can reach the base of the bank face.

At the midsection, the d_{50} varied from 0.193 mm at the upper part of the bank surface to 0.206 mm at the base of the bank. A core sample at 2 feet of depth on the upstream section had d_{50} of 0.202 mm. Gradation plots of bank soils and nearshore sediment are presented in appendix C. The detailed cross section and coordinates are shown in appendix D.

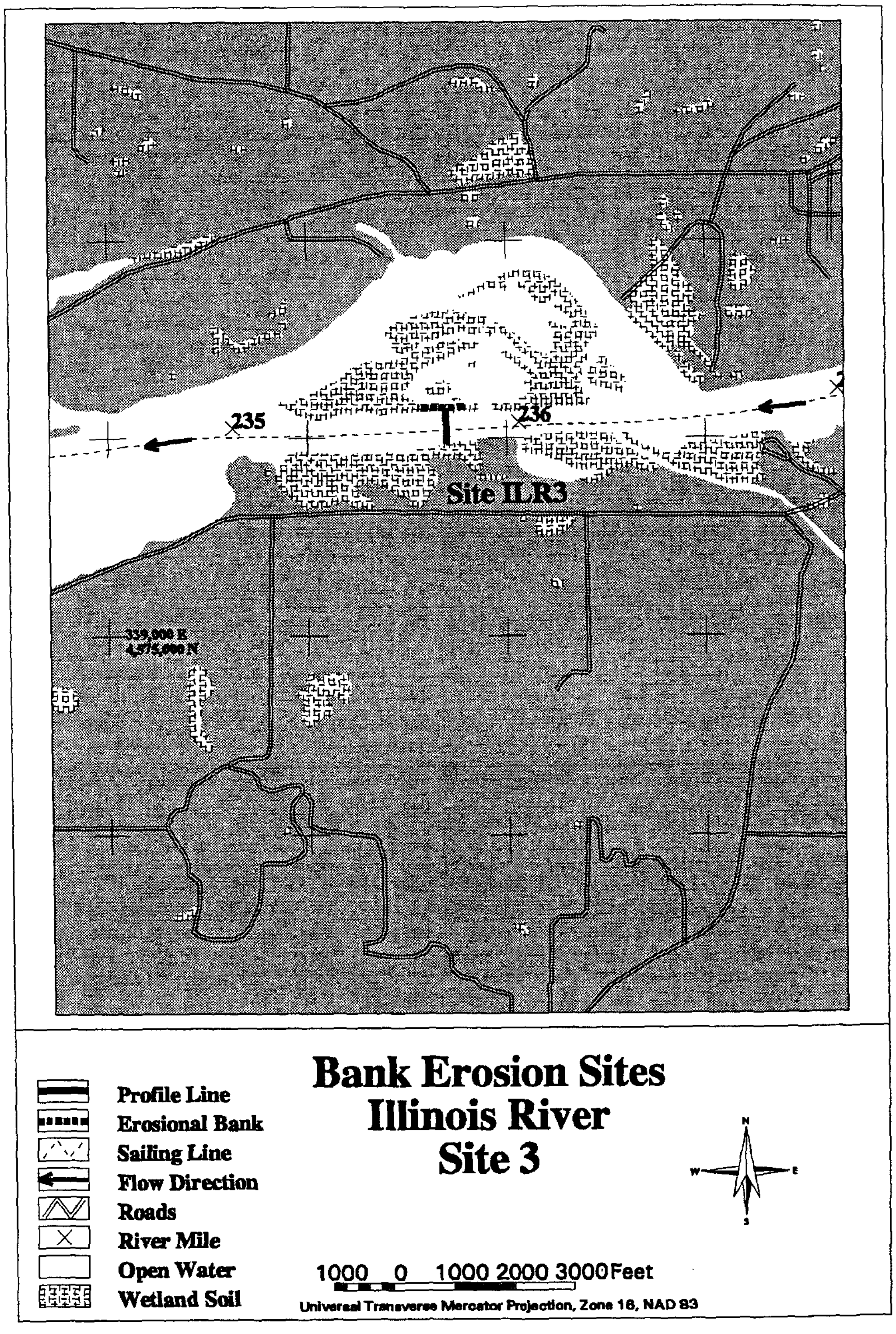


Figure 54. Location of site 3 on the Illinois River

Figure 55. Site 3 on the Illinois River

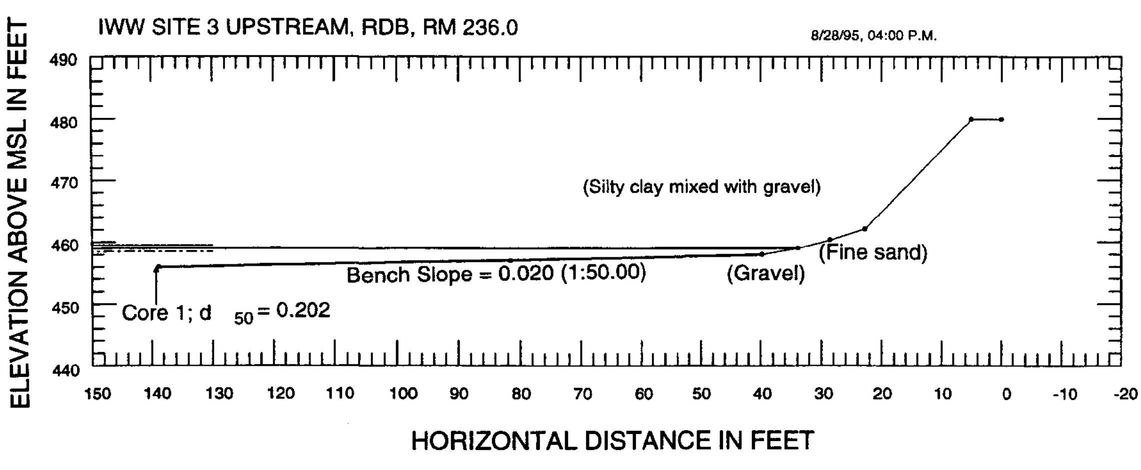


Figure 56. Bank sections at site 3

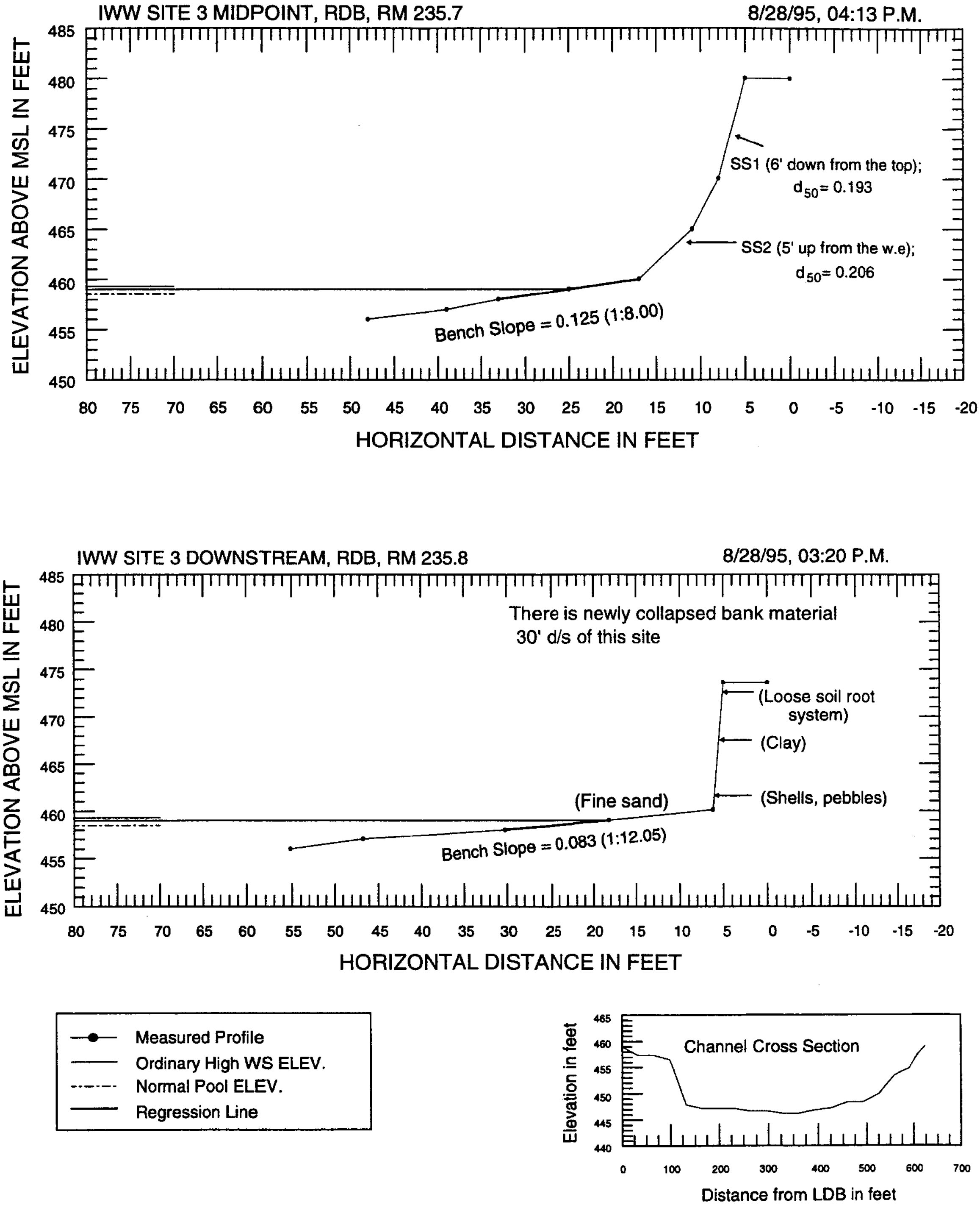


Figure 56. Bank sections at site 3 (concluded)

Table 18. Site 3 Characteristics

Percentage of occurrence	*Stage above msl, ft*	*Topographical features*	*Bank/bed material, mm*
90	458.7	• Bench (underwater) • Bench (slopes varied from 1V:5H to 1V:8H)	• d_{50} (core) @ 1 foot of water = 0.202
75	458.8	• Bench (underwater)	
50	458.8	• Bench (underwater)	
25	458.9	• Bench (underwater)	
10	458.9	• Berm/bench(1V:1.2H) • Berm slope	• d_{50} = 0.206
0-9	>459.0	• Scarp	• d_{50} = 0.193

Note: Pool gage of Starved Rock Pool @ RM 231.0 was used for stage histogram. WSE = 459.0 feet; OHWE = 459.3 feet; and NP = 458.8 feet.

Bench slopes varied from 1V:50H at the upstream section to 1V:8H at the midsection. The bank consisted mostly of noncohesive sandy materials. The three sections can be classified as a combination of types 1 and 6 because of the extended subaqueous bench width (figures 21 and 26 and table 9). Rework and transport of failed soils and recently deposited sediment occur during floods. Eddy currents induced by the trees or gravel upstream of concave sections can cause bank failure, and eddies are generated at stages when the flows are disturbed by trees or gravel.

Site 4, Peoria Pool, 8/28/95

This site is located on the LDB at RM 228.1 in a long, straight reach downstream from the Starved Rock L&D (RM 231). Figure 57 shows the position of the site on a GIS-based map of the Illinois navigation chart, and figure 58 is a photograph of the site.

Site 4 is about 360 feet from the sailing line. No major tributary enters the river at this location, but a state highway bridge crosses the river at RM 229.6. Bhowmik and Schicht (1980) selected both banks as erosion sites (sites 18 and 19) with surveys completed on the RDB and one survey on the LDB (site 20). Erosion of these two sites was indicated on Hagerty's (1988) chart also. At site 4, a mildly sloped bench lies under a small scarp, and mature trees grow behind the scarp. The bench was very wide, sandy, and mostly covered with tall weeds. Tall trees with roots exposed to the air survive in an area between the weed zone and scarps. The root crown is approximately at the same level as the top of the bank. The bench is clay mantled with sand mixed with shells.

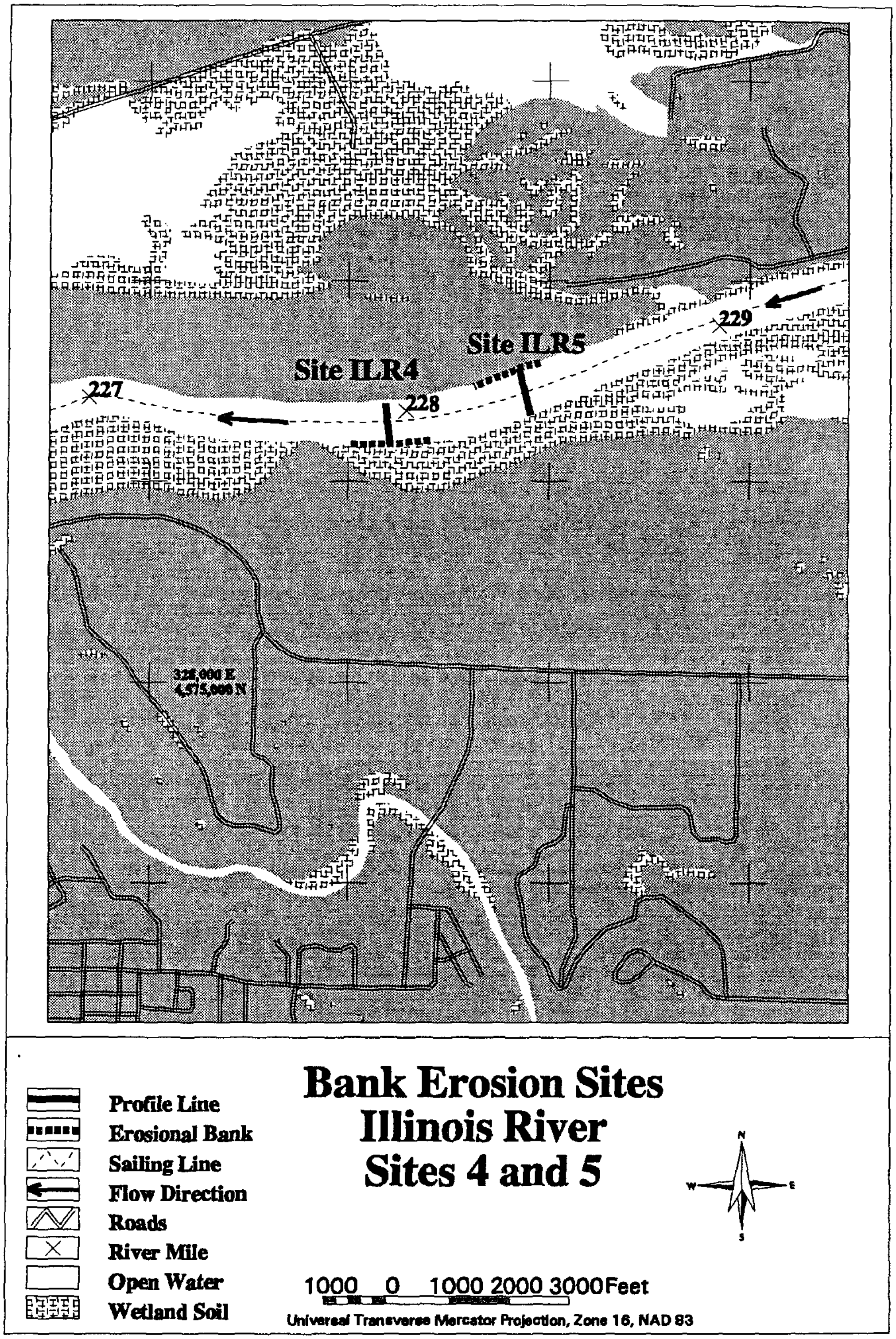


Figure 57. Locations of sites 4 and 5 on the Illinois River

Figure 58. Site 4 on the Illinois River

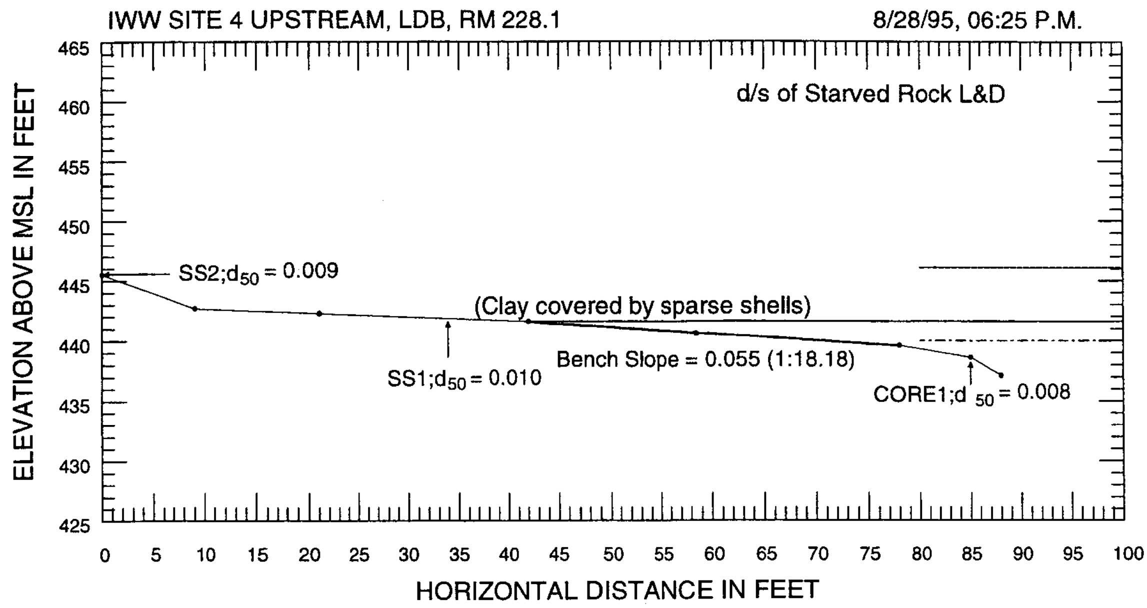
Figure 59 shows the three measured bank sections and a reduced cross section. Bank sections were fairly uniform at this site. The OHWE is 446 ft-msl and NP is 440 ft-msl. The range of fluctuation between the OHWE and NP covers the entire bench.

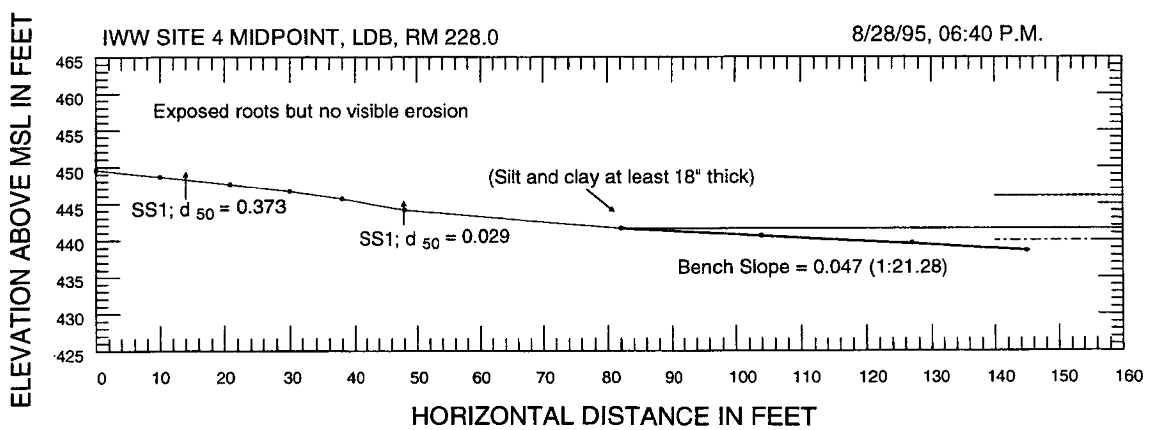
At the midsection, the d_{50} varied from 0.373 mm for materials on the scarp under the exposed tree roots of a mature tree to 0.029 mm on the bench (table 19). Mean particle size at the upstream section varied from 0.009 mm at the top surface of the bank to 0.008 mm for a core sample at a water depth of about 1 foot. Gradation plots of bank soils and nearshore sediment are presented in appendix C. The detailed cross section and coordinates are shown in appendix D.

Bench slopes varied slightly from 1V: 18.2H at the upstream section to 1V:25.6H at the downstream section. This site can be classified as type 5 (figure 25 and table 9). The bank seemed to be stable in 1995 but was eroded in 1978 (Bhowmik and Schicht, 1980). The elevation of the scarp was fairly high compared to NP or OHWE stages at which piping was noted. Erosion of bench soils or recently deposited sediments can occur during flow at stages higher than OHWE.

Site 5, Peoria Pool, 8/28/95

This site is located on the RDB at RM 228.5, slightly upstream from site 4 on the LDB. Figure 57 shows the position of the site on a GIS-based map of the Illinois navigation chart.





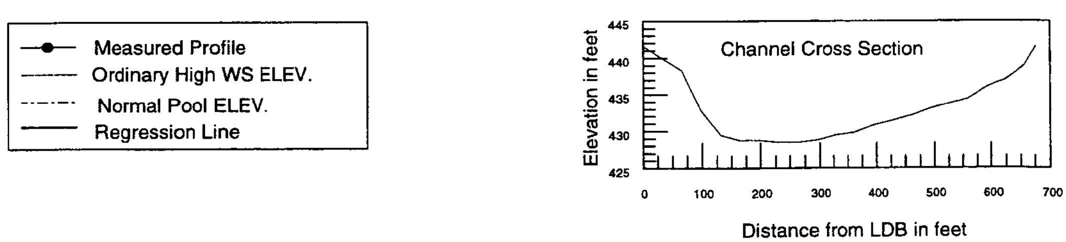


Figure 59. Bank sections at site 4

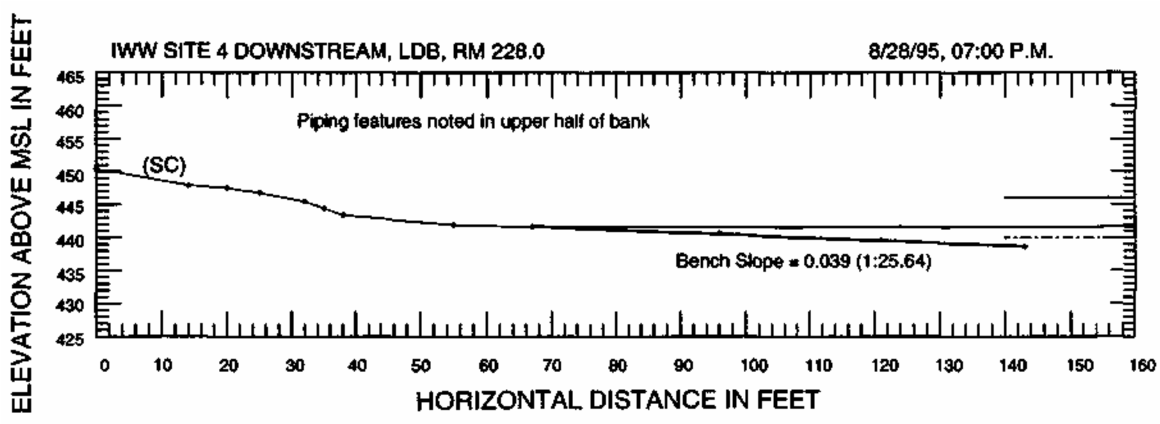


Figure 59. Bank sections at site 4 (concluded)

Table 19. Site 4 Characteristics

Percentage of occurrence	*Stage above msl, ft*	*Topographical features*	*Bank/bed material, mm*
90	441.2	• Bench (underwater) • Slope varied from 1V:25.6H to 1V:18.2H	• d_{50} varied (0.010-0.029)
75	441.9	• Bench	
50	443.8	• Scarp/bench	
25	447.1	• Bank with gentle slope	• d_{50} = 0.373
10	450.6	• Bank with gentle slope	
0-9	>450.6	• Top of the bank	• d_{50} = 0.009

Note: Tail water gage of Starved Rock Pool @ RM 231.0 was used for stage histogram. WSE = 441.6 feet; OHWE = 446.0 feet; and NP = 440.0 feet.

Site 5 is about 375 feet from the sailing line. No major tributary enters the river at this location, but there is a state highway bridge at RM 229.6. The upstream end of this reach is about 150 feet downstream from a barge terminal. Bank sections were similar to those for site 4, but the scarp at the upper part of the bank was higher and contained piping holes. Agriculture (corn) was the land use on top of the bank. Tall weeds were growing below the scarp on the sand-covered bench. The team dug a trench on the bench, and seepage water filled the hole very quickly. Subaqueous sediment near the shore was mostly sand, and the bench slope was mild.

Figure 60 shows the three measured bank sections and a reduced cross section. The OHWE is 446.2 ft-msl and NP is 440.0 ft-msl. The OHWE elevation was at the base of the scarp at all three sections, and the NP was at a break in the subaqueous slope at the upstream section.

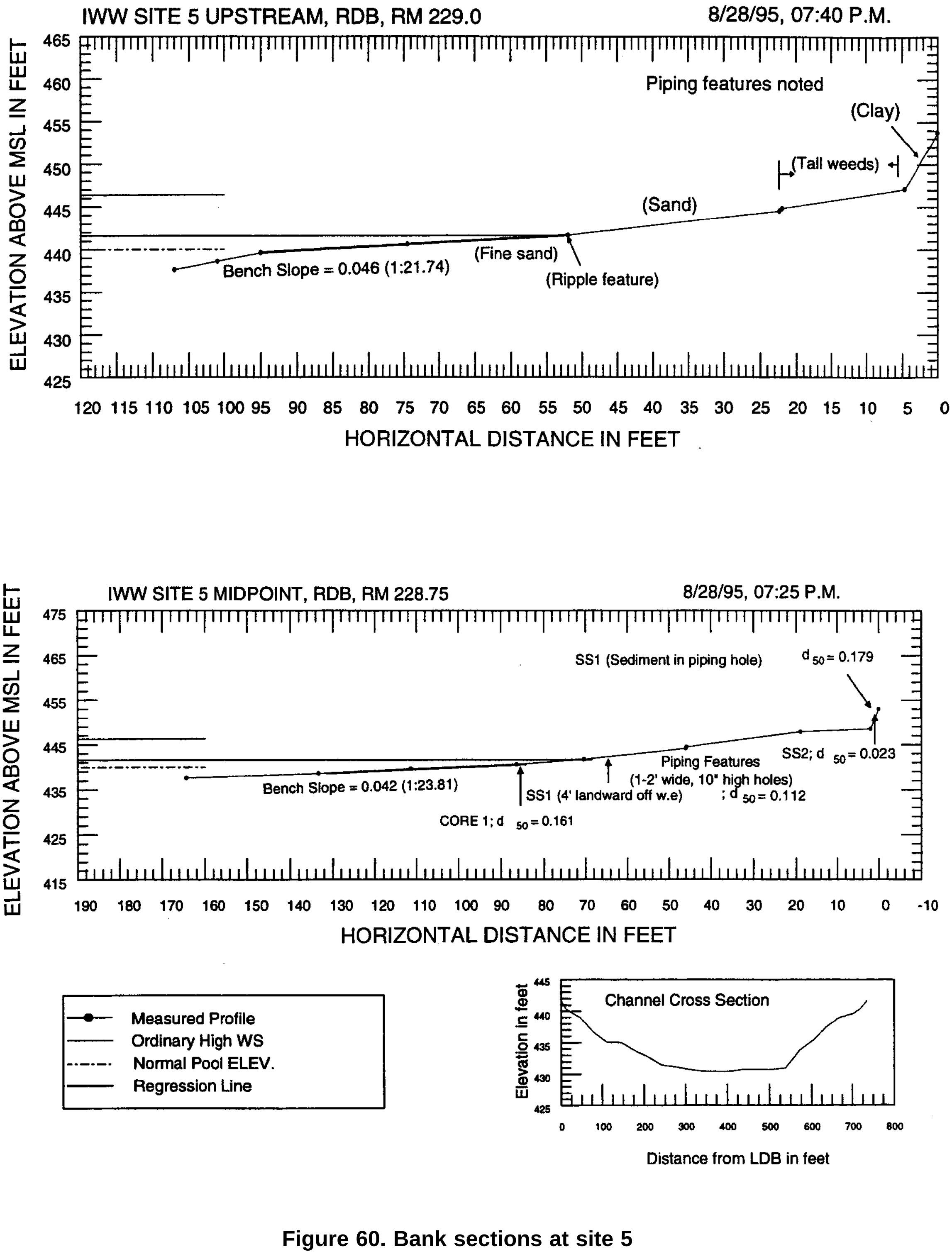


Figure 60. Bank sections at site 5

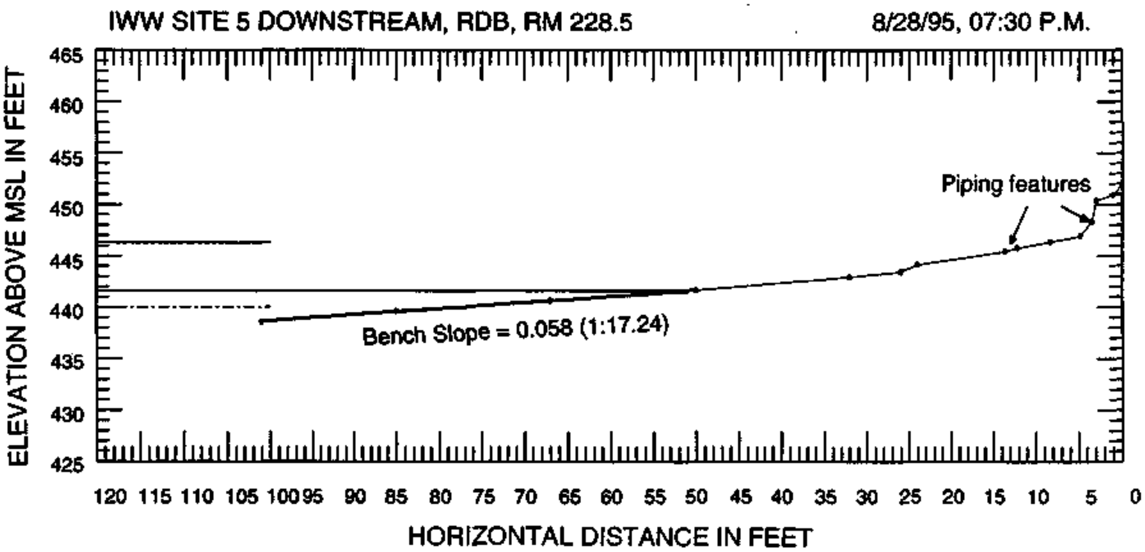


Figure 60. Bank sections at site 5 (concluded)

According to the stage analysis using 10-year data (table 20), river stages with 25 percent or less occurrence frequency reach the scarp, and stages with 10 percent or less occurrence frequency top the bank.

Table 20. Site 5 Characteristics

Percentage of occurrence	*Stage above msl, ft*	*Topographical features*	*Bank/bed material, mm*
90	441.2	• Bench (underwater)	• d_{50} (core) = 0.161 • d_{50} = 0.112
75	441.9	• Bench (slopes varied between 1V:23.8H and 17.2H)	
50	443.8	• Berm/bench slope = 1V:6.7H	
25	447.1	• Toe of scarp	
10	450.6	• Scarp slope (1V:0.69H) • Piping feature	
0-9	>450.6	• Scarp/Top of the bank	• d_{50} = 0.179

Note: Tail water gage of Starved Rock Pool @ RM 231.0 was used for stage histogram. WSE = 441.6 feet; OHWE = 446.2 feet; and NP = 440.0 feet.

At the midsection, the d_{50} varied from 0.023 mm at the top surface of the bank to 0.161 mm for a core sample at a water depth of about 1 foot. Gradation plots of bank soils and nearshore sediment are presented in appendix C. The detailed cross section and coordinates are shown in appendix D.

Bench slopes varied slightly between 1V:23.8H and 1V: 17.2H. With a scarp over a gentle bench slope, this site is classified as a combination of types 3 and 5 (figures 23 and 25 and table 9). The scarps have layered failure features and were initiated by piping and surface drainage. Waves and currents at OHWE cause erosion of failed soil or recent sediments on the bench area.

Site 6, Peoria Pool, 8/29/95

This site is located on the RDB at RM 210.0, immediately downstream of the outlet of Spring Lake. Figure 61 shows the position of the site on a GIS-based map of the Illinois navigation chart, and figure 62 is a photograph of the site.

The site is about 310 feet from the sailing line. In plan form it is on the outer side of a bend. Bhowmik and Schicht (1980) observed erosion on both banks. Hagerty (1988) noted erosion only on the RDB, but his site extended further upstream and downstream from the entrance of the lake. The bank contains small scarps, and the top of the bank is covered with some fine tree roots. Agriculture (corn) is the land use for the upstream section, and woods cover the bank for the other two sections. At the most upstream end point of this reach (immediately downstream from the lake outlet), the subaqueous bench dropped more than 11 feet right off the water's edge, a feature not observed at the remaining sections. Judging from the plan form, this truncation could be caused by tow-induced current passing through the bend. Small worm holes existed on the truncated bench face near the water's edge.

Figure 63 shows the three measured bank sections and two reduced cross sections. The thalweg was farther away from the water's edge downstream. The OHWE is 443.2 ft-msl and NP is 440.0 ft-msl. Mature trees were growing at the water's edge; the midsection and downstream section were measured between trees. Banks between the trees were eroded. The crown of the tree roots appeared to be higher than the bank top. A flood stage higher than 10 percent recurrence frequency will overtop the bank (see table 21). Standing (but dead) trees were in place in water at the NP level.

At the midsection, the d_{50} varied from 0.003 mm at the top surface of the bank to 0.012 mm on the bench. A core sample at a depth of about 1 foot of water on the downstream section had d_{50} equal to 0.025 mm. Gradation plots of bank soils and nearshore sediment are presented in appendix C. The detailed river cross section and coordinates are shown in appendix D.

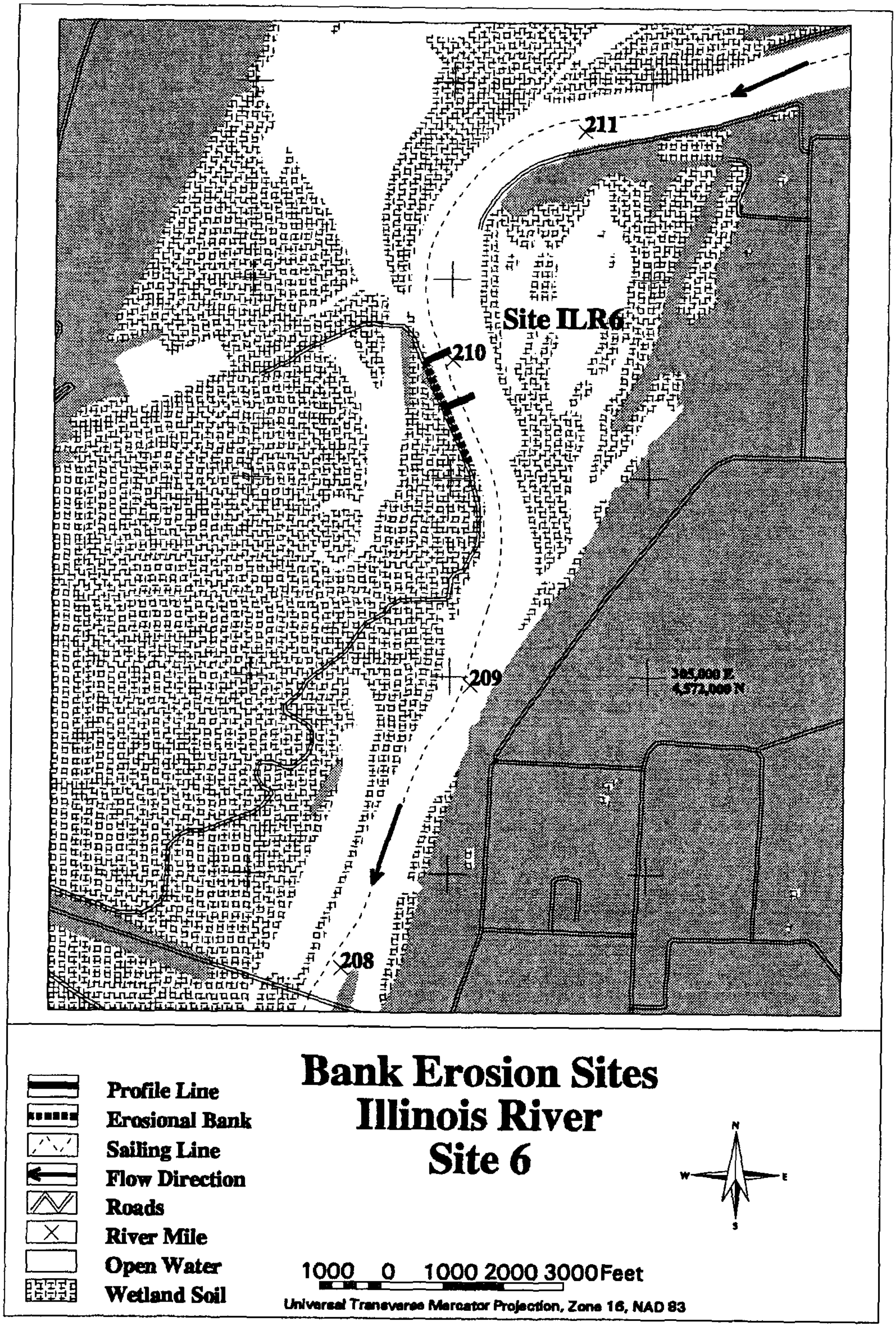


Figure 61. Location of site 6 on the Illinois River

Figure 62. Site 6 on the Illinois River

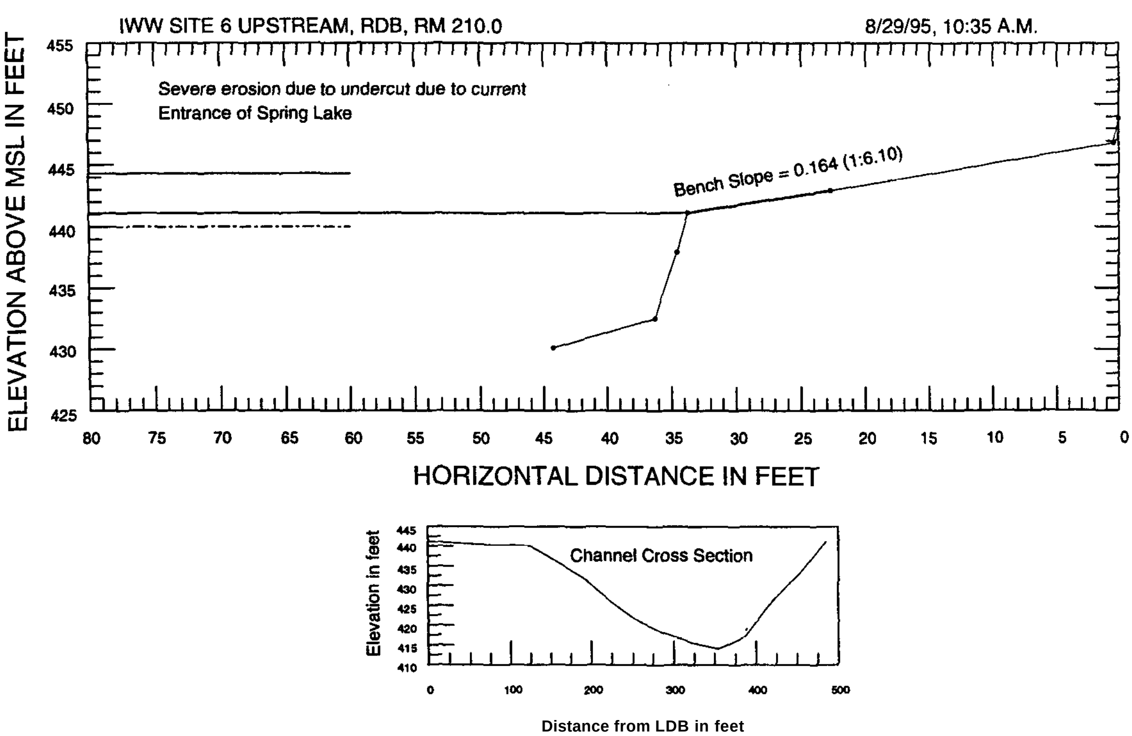
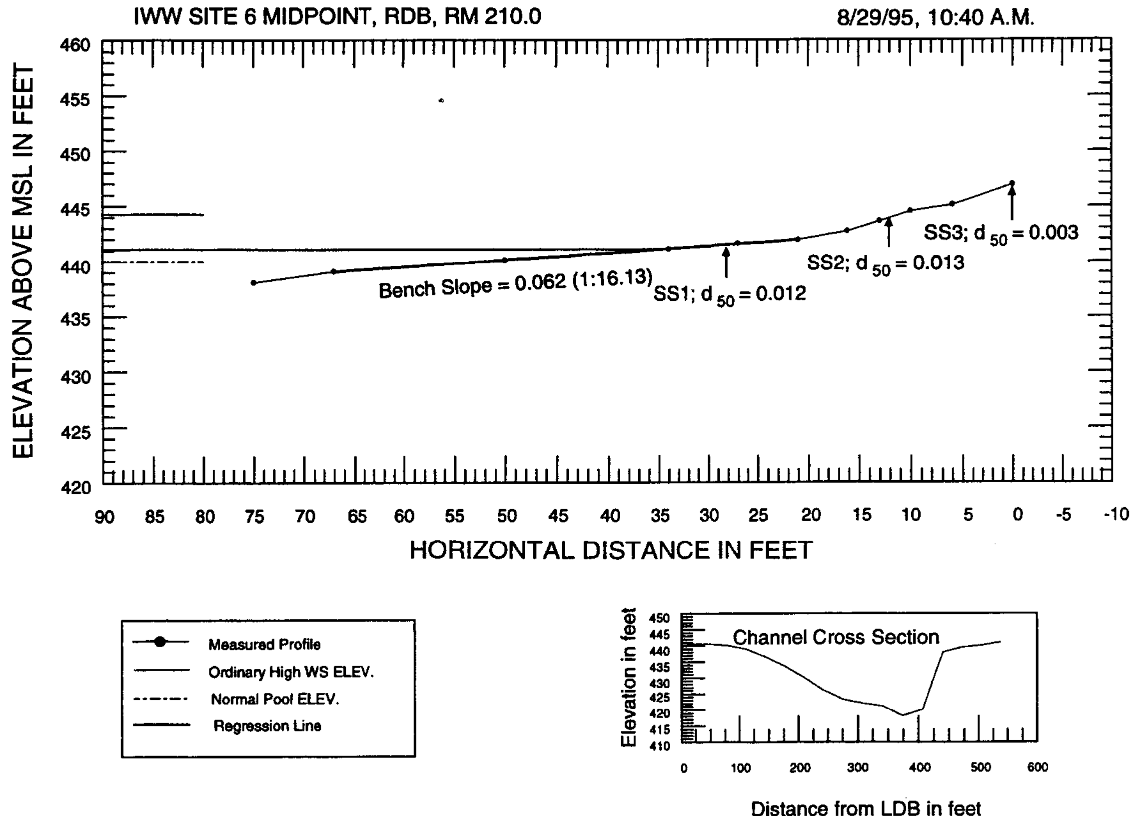


Figure 63. Bank sections at site 6



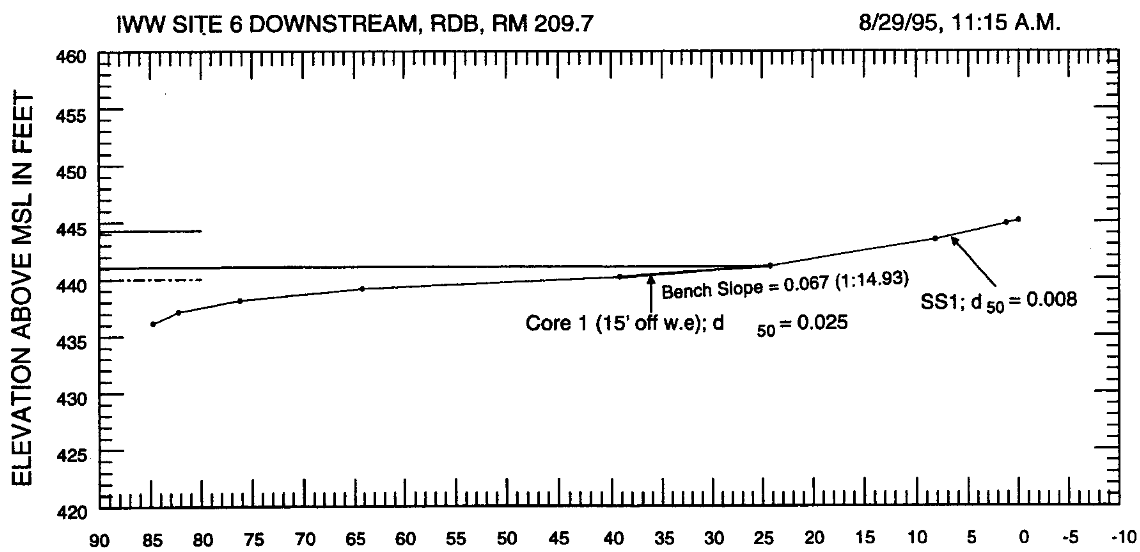


Figure 63. Bank sections at site 6 (concluded)

Table 21. Site 6 Characteristics

Percentage of occurrence	*Stage above msl, ft*	*Topographical features*	*Bank/bed material, mm*
90	440.5	• Steep subaqueous drop at upstream section • Bench (underwater)	• d_{50} = 0.025
75	440.8	• Bench (underwater) slope Varied between 1V:16.1H and 1V:6.1H	
50	441.6	• Bench	• d_{50} = 0.012
25	444.1	• Bench/scarp	• d_{50} = 0.008
10	447.5	• Scarp	• d_{50} = 0.013
0-9	>447.5	• Top of the bank	• d_{50} = 0.003

Note: Gage on the Illinois River near Henry, IL @ RM 186.0 was used for stage histogram. Gage is 14 miles away from the site. WSE = 441.1 feet; OHWE = 444.3 feet; and NP = 440.0 feet.

Bench slopes varied only slightly from 1V:16.1H at the midsection and downstream section. The three sections, from upstream to downstream, are classified as types 4, 5, and 6 (figures 24-26 and table 9). Traffic-induced currents appear to be a significant factor for the subaqueous scarp at the upstream section. Small worms nesting in the bank soils also will weaken the bank strength. Eddy currents, induced by fallen trees or nearshore land features, exist at the midsection and downstream section. These eddy currents can cause local scours. Other erosion mechanisms include surface drainage for the upstream section, piping, and floods for the whole reach.

Site 7, Peoria Pool, 8/29/95

This site is located on the LDB at RM 203.8 in a straight reach just downstream from a small bend. Upper Twin Sister Island is located at the downstream end between RM 203.1 and 203.3. Figure 64 shows the position of the site on a GIS-based map of the Illinois navigation chart, and figure 65 is a photograph of the site.

Site 7 is at the Hennepin Levee System, about 400 feet from the sailing line, and no tributaries enter the site. Bhowmik and Schicht (1980) noted almost the entire riverbank from the Upper Twin Sister Island to site 6 as eroding bank. Hagerty's observation (1988) was similar to that of Bhowmik and Schicht (1980), but the erosion reaches indicated by Hagerty (1988) were shorter and were shown mostly on the RDB. Hagerty (1988) also noted erosion on both the Upper and Lower Twin Sister Islands on the sides facing the channel. The back side (facing the levee) of Upper Twin Sister Island also had a long reach of overhanging matted roots as noted by Hagerty (1988).

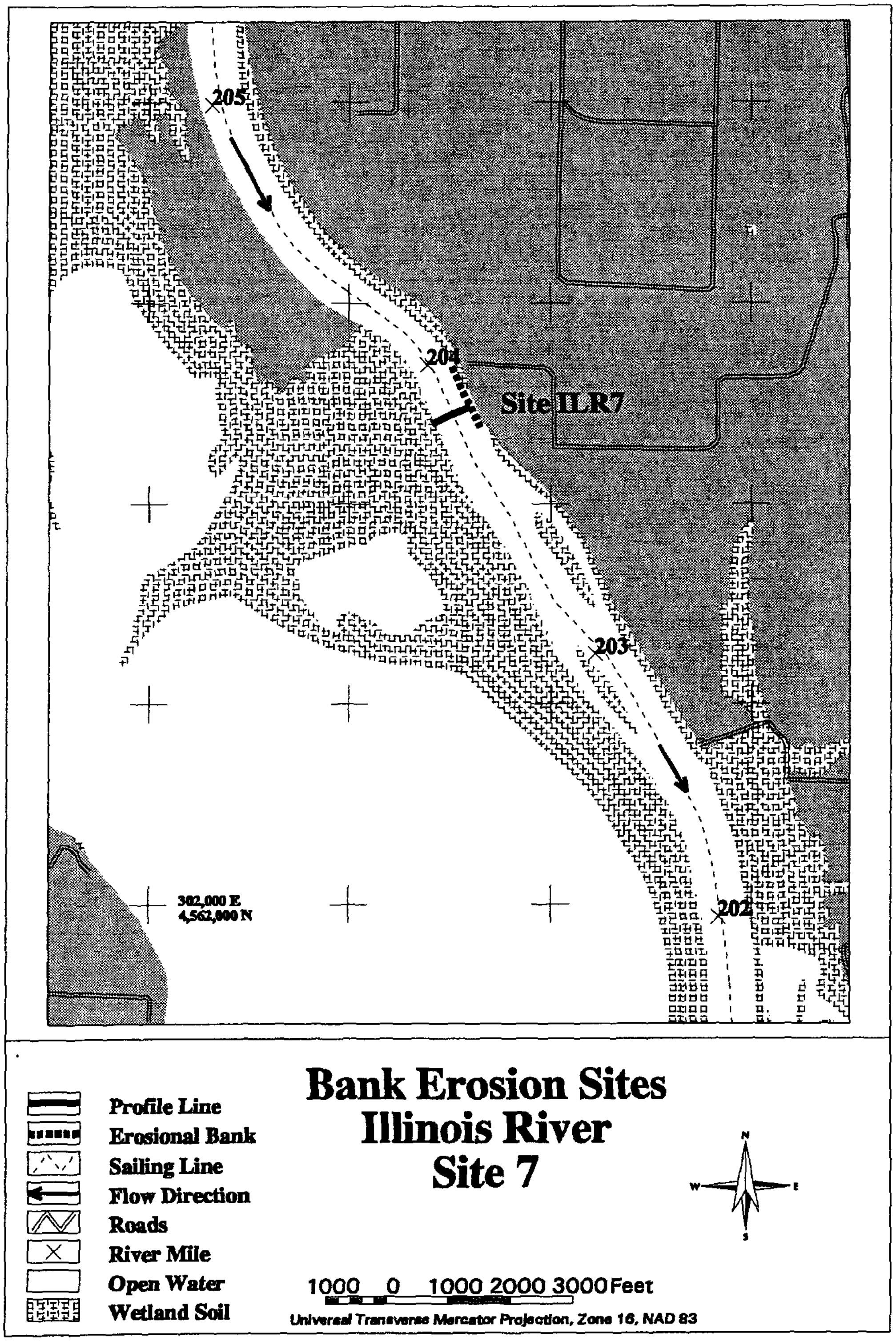


Figure 64. Location of site 7 on the Illinois River

Figure 65. Site 7 on the Illinois River

At the site, a scarp 3-5 feet high was located about 2-4 feet below the levee crown. Tall weeds were growing on the berm, and many small scarps were observed on the bench. Figure 66 shows the three measured bank sections and a reduced cross section. The OHWE is 443.9 ft-msl and NP is 440.0 ft-msl. The OHWE corresponded well with the lower edge of the weed zone on the shore, where debris was found, in the bench area. Stages above 447.5 feet (about 10 percent recurrence frequency, see table 22), reach the base of the scarp near the top of the levee.

At the upstream section, the d_{50} varied from 0.018 mm at the surface of the scarp to 0.021 mm for a core sample at a water depth of about 1 foot. Gradation plots of bank soils and nearshore sediment are presented in appendix C. The detailed cross section and coordinates are shown in appendix D.

Bench slopes varied only slightly from 1V:23.3H. This site can be classified as type 5 (figure 25 and table 9). The scarp was located above most flood stages. Rework and transport by wave and currents are major factors in removing failed soil or recent sediments from the bench.

Site 8, Peoria Pool, 8/29/95

This site is located on the LDB at RM 184.8 on the lower end of Woodyard Island and upstream from the opening into Babbs Slough, in an inner bend reach. The slough opening was completely closed by historical deposits. Figure 67 shows the position of the site on a GIS-based map of the Illinois navigation chart, and figure 68 is a photograph of the site.

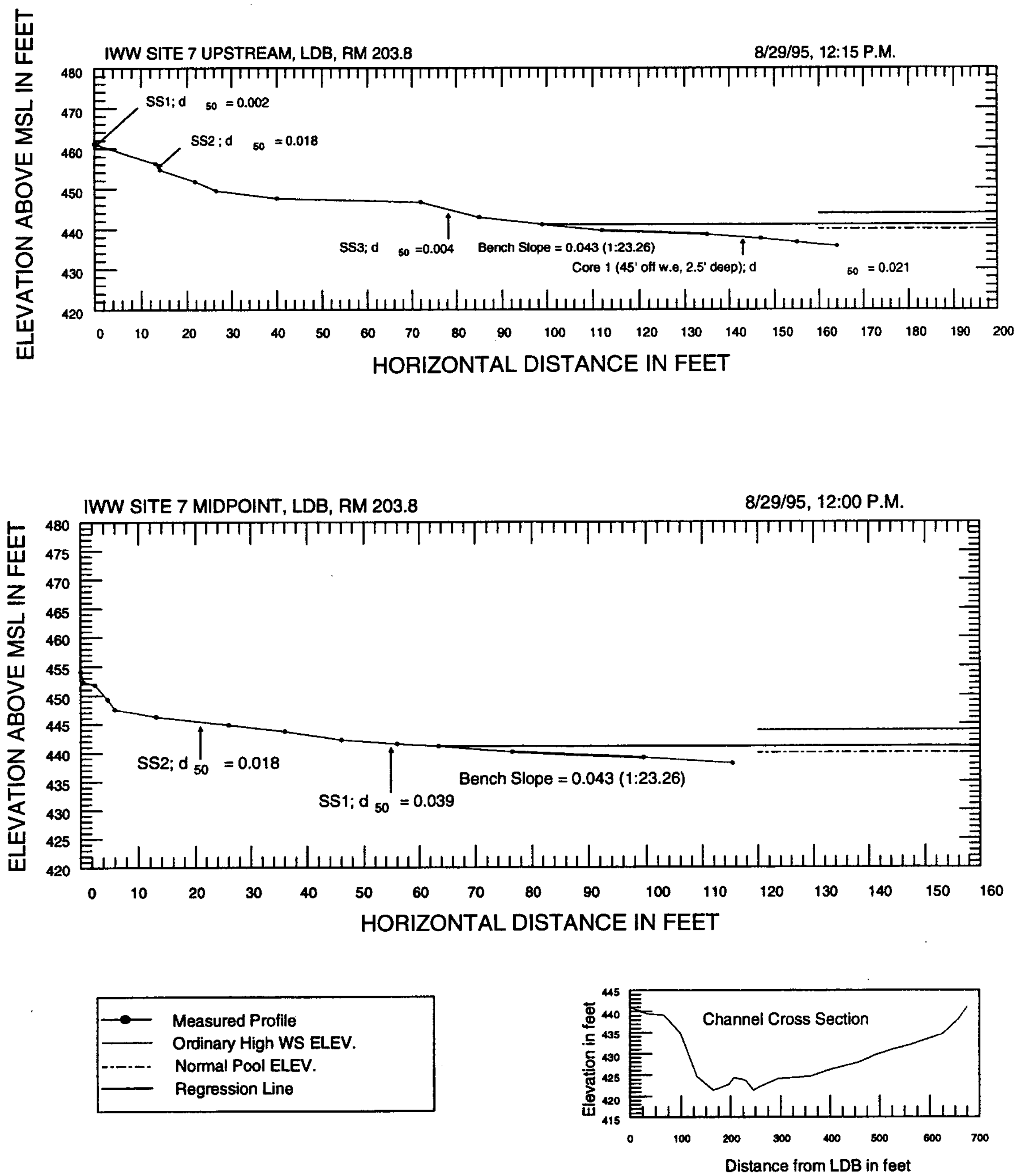


Figure 66. Bank sections at site 7

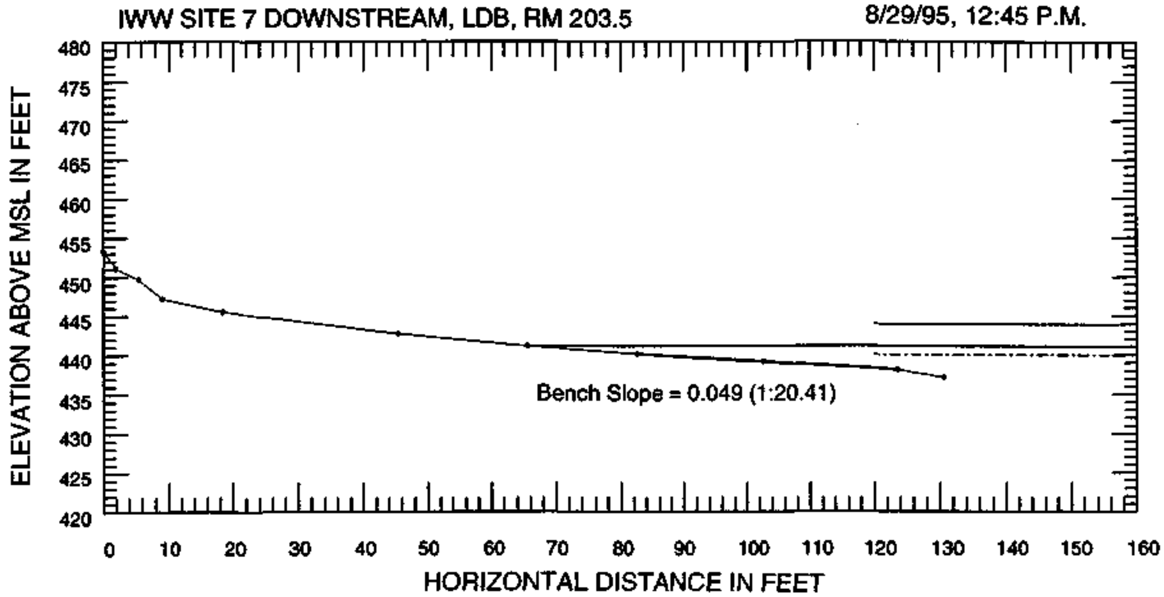


Figure 66. Bank sections at site 7 (concluded)

Table 22. Site 7 Characteristics

Percentage of occurrence	*Stage above msl,ft*	*Topographical features*	*Bank/bed material, mm*
90	440.5	• Bench (underwater) (slope Varied between 1V:23.2H and 1V:20.4H)	• d_{50} (core) = 0.021
75	440.8	• Bench (underwater)	
50	441.6	• Berm/bench	• d_{50} varied (0.039-0.004)
25	444.1	• Berm (slope varied between 1V:8.3H and 1V:7.7H)	
10	447.5	• Scarp (slope varied between 1V:1.4Hand 1V:0.63H)	• d_{50} = 0.018
0-9	>447.5	• Top of the bank	• d_{50} = 0.002

Note: Gage on the Dlinois River near Henry, IL @ RM 196.0 was used for stage histogram. Gage is 7.8 miles away from site. WSE = 441.1 feet; OHWE = 443.9 feet; and NP = 440.0 feet.

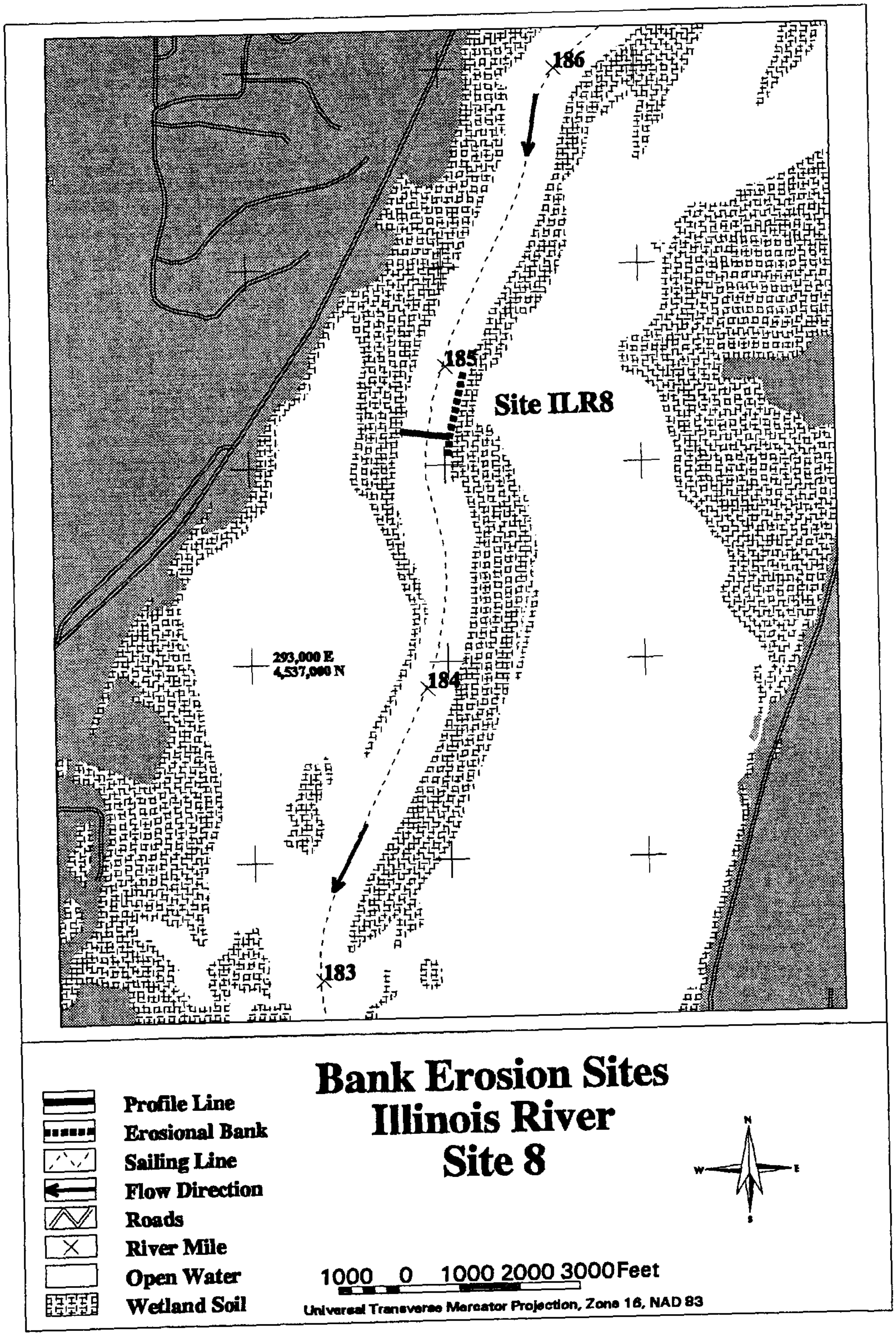


Figure 67. Location of site 8 on the Illinois River

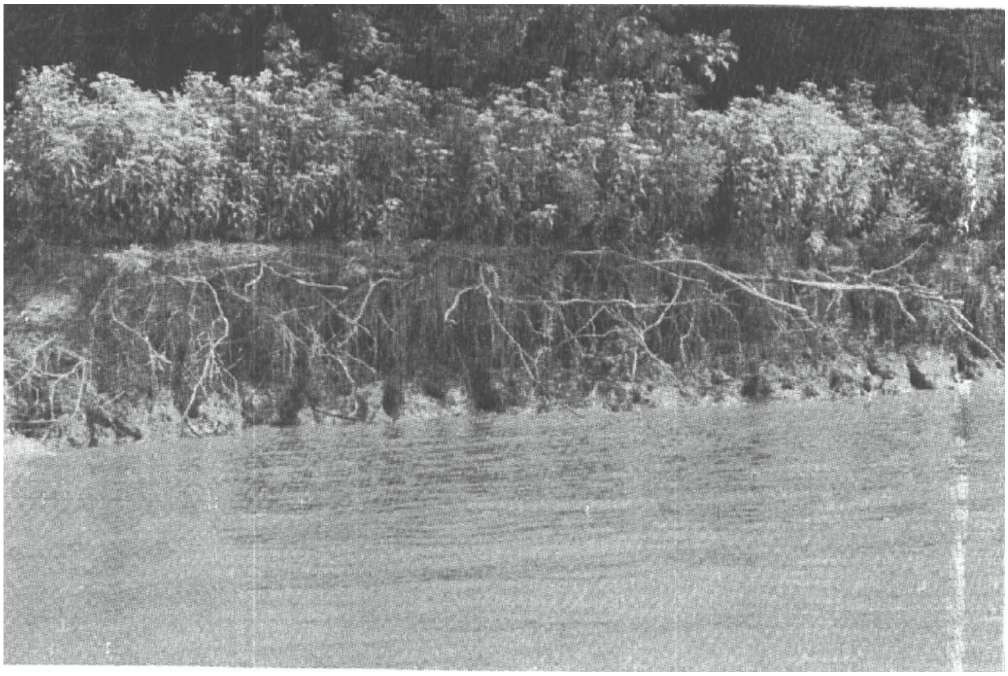


Figure 68. Site 8 on the Illinois River

The site is about 330 feet from the sailing line. Hagerty (1988) recorded this site as severely eroded, and Bhowmik and Schicht (1980) noted erosion at the opposite bank. The opposite bank had several moored barges at the time of the survey. The site had a steep scarp right on the edge of the water. The scarp is about 3-5 feet high and covered with fine roots on the top. These roots were from the mature trees inside the bank area; the top of the bank was covered with tall seasonal vegetation. The scarp was composed of cohesive soil and contained piping holes or holes that riverine animals use, generally with a diameter of l-4 inches. The subaqueous bench was gently sloping, extended far out, and was covered with silt and clay.

At the midsection, the d_{50} varied from 0.005 mm at the surface of the top of the bank to 0.018 mm for a core sample at a water depth of about 1 foot. Gradation plots of bank soils and nearshore sediment are presented in appendix C. The detailed cross section and coordinates are shown in appendix D.

Figure 69 shows the three measured bank sections and a reduced cross section. The OHWE is 442.6 ft-msl and NP is 440.0 ft-msl. The OHWE corresponds to the base of the scarp. Floods with stage higher than 447.5 feet (about 10 percent recurrence frequency) overtop the bank (table 23).

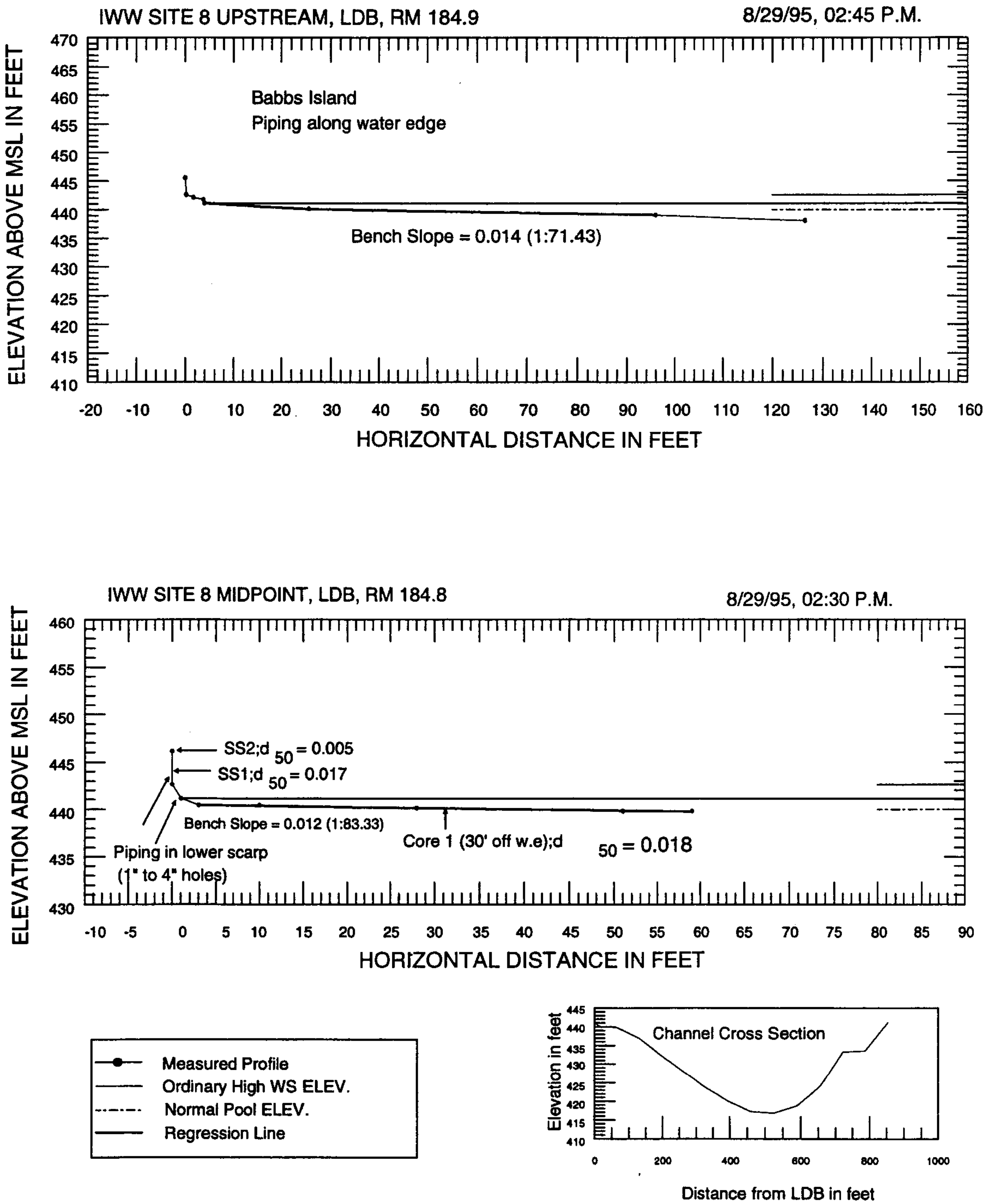


Figure 69. Bank sections at site 8

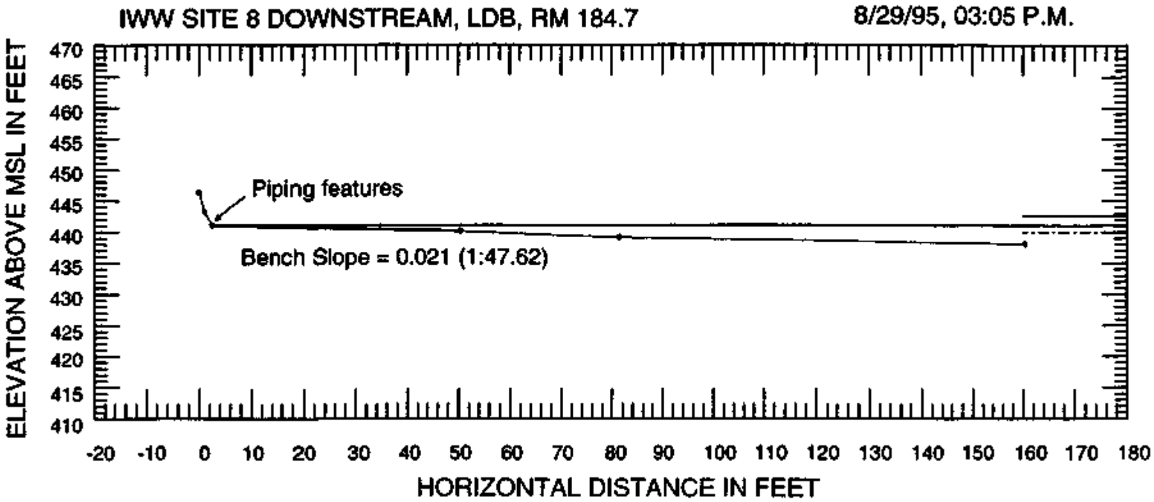


Figure 69. Bank sections at site 8 (concluded)

Table 23. Site 8 Characteristics

Percentage of occurrence	*Stage above msl, ft*	*Topographical features*	*Bank/bed material, mm*
90	440.5	• Subaqueous bend (slope varied between 1V:83.3H and 1V:47.6H	• d_{50} (core) = 0.018
75	440.8	• Subaqueous bench	
50	441.6	• Berm (slope varied between 1V:2.8H and 1V:2.5H)	
25	444.1	• Scarp (slope varied between 1V:O.48H and 1V:0.07H)	• d_{50} = 0.017
10	447.5	• Top of the bank	• d_{50} = 0.005
0-9	>447.5		

Note: Illinois River near Henry, IL gage @ RM 196.0 was used for stage histogram. Gage is 11.2 miles away from the site. WSE = 441.1 feet; OHWE = 442.6 feet; and NP = 440.0 feet.

Bench slopes varied from 1 V:83.3H to 1V:47.6H. This site is classified as a combination of types 4 and 5 (figures 24 and 25 and table 9). Bank failures are initiated by piping or burrowing activities from riverine animals. Rework and transport of failed bank soils by wave action at NP appeared to be significant. Wave action probably was responsible for an erosion scarp at water's edge.

Site 9, Peoria Pool, 8/29/95

This site is located on the LDB at RM 179.8 on Chillicothe Island, immediately upstream of the opening into Peoria Lake. Figure 70 shows the position of the site on a GIS-based map of the Illinois navigation chart, and figure 71 is a photograph of the site.

The site is about 310 feet from the sailing line, and the Chillicothe Sports & Marine Small Boat Harbor is located across the river. Bhowmik and Schicht (1980) and Hagerty (1988) marked this as an erosion site. The bank was mildly sloped and covered with weeds of medium density. The foundation of an old monument installed by Bhowmik and Schicht (1980) on shore was exposed for about a foot. A scarp about 0.3 foot high existed on the lower bank where the weed zone ends above a sandy bench. A scarp also existed at the water's edge. The wet bench did not support large weights. Submerged nearshore material, however, was hard clay mantled with sand.

Figure 72 shows the three measured bank sections and a reduced cross section. The OHWE is 442.4 ft-msl and NP is 440.0 ft-msl. The OHWE corresponds well to the lower edge of the weed zone. High water of a stage exceeding 447.5 feet (10 percent recurrence frequency, table 24) submerges the entire bank.

The d_{50} on the bench varied from 0.208 mm at the upstream section to 0.035 mm at the downstream section. Gradation plots of bank soils and nearshore sediment are presented in appendix C. The detailed cross section and coordinates are shown in appendix D.

Bench slopes varied from 1V:21.3H at the upstream section to 1V:14.1H at the downstream section. This site is classified as types 4 and 6 (figures 21 and 26 and table 9). The combinations of wave actions and seepage within the bench near NP elevations could be the major causes of erosion at this site. Recreational and commercial traffic volumes are high at site 9. Traffic-induced waves and current can also be the cause of erosion at this site.

Table 24. Site 9 Characteristics

Percentage of occurrence	*Stage above msl, ft*	*Topographical features*	*Bank/bed material, mm*
90	440.5	• Bench (underwater)	• d_{50} (core) = 0.35
75	440.8	• Bench (slope varied between 1V:21.3H and 1V:14.1H)	• d_{50} = 0.208
50	441.6	• Bench/berm	
25	444.1	• Scarp with gentle slope	
10	447.5	• Top of the bank	• d_{50} = NA
0-9	>447.5		

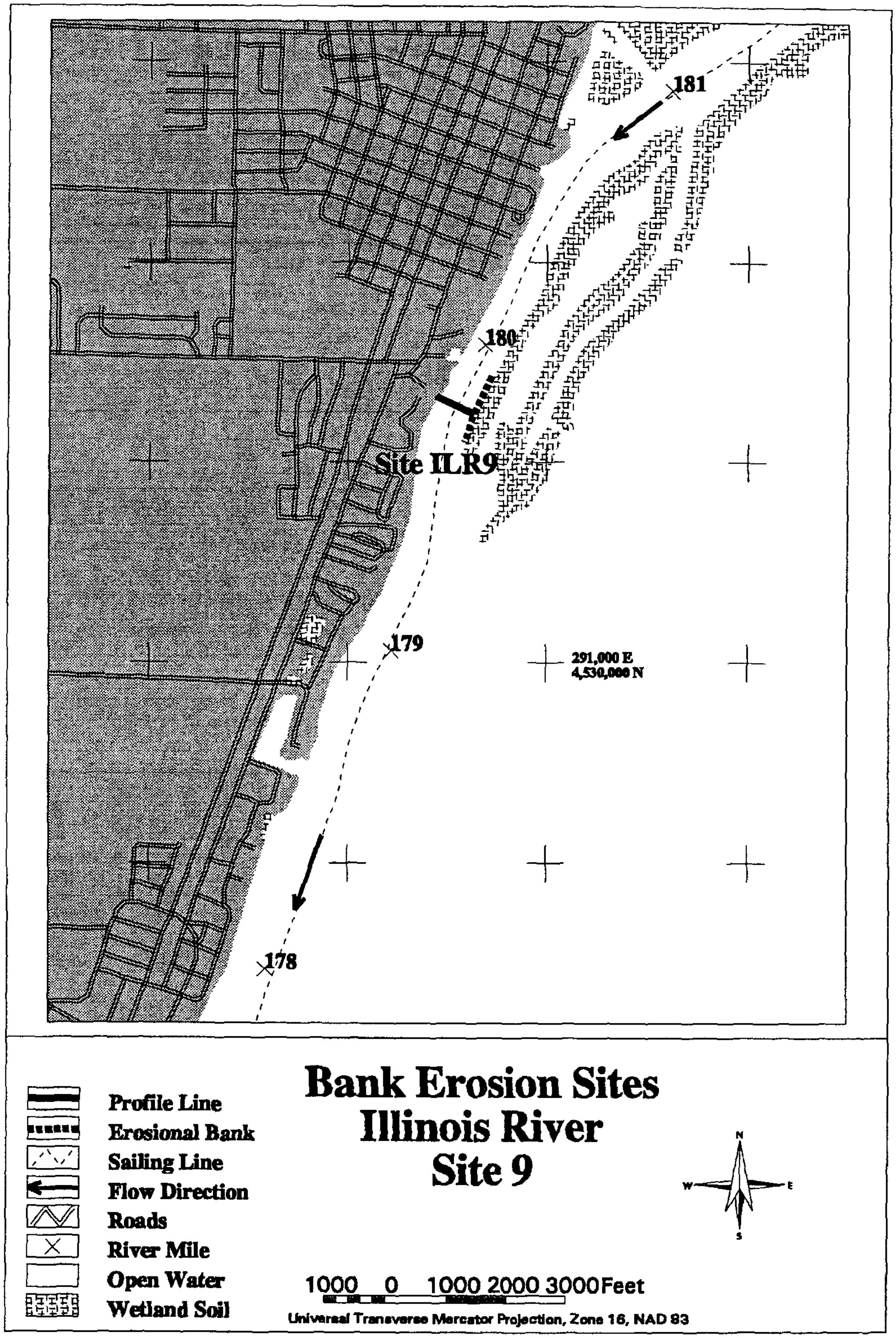


Figure 70. Location of site 9 on the Illinois River

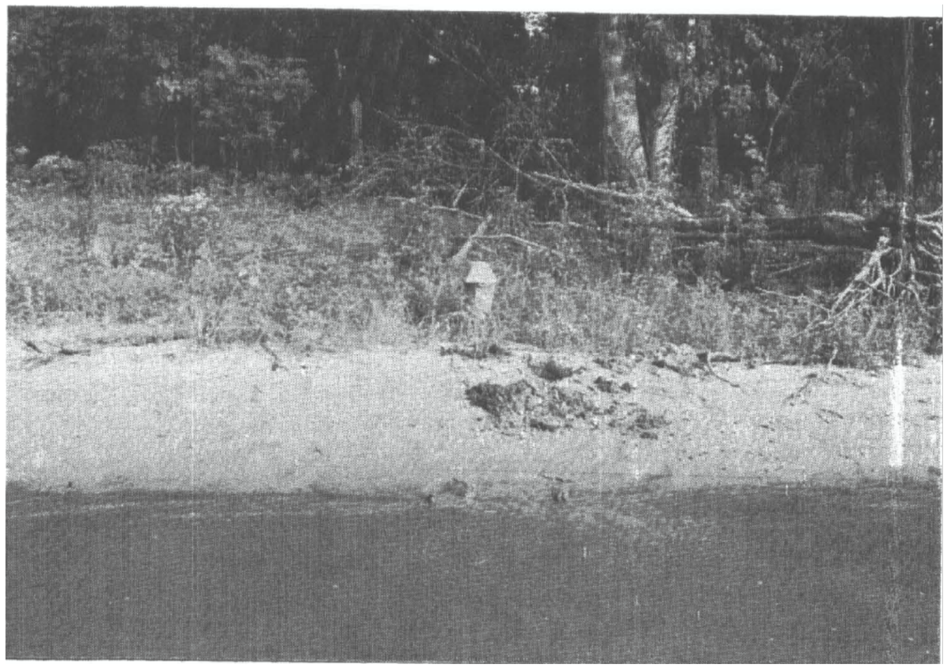


Figure 71. Site 9 on the Illinois River

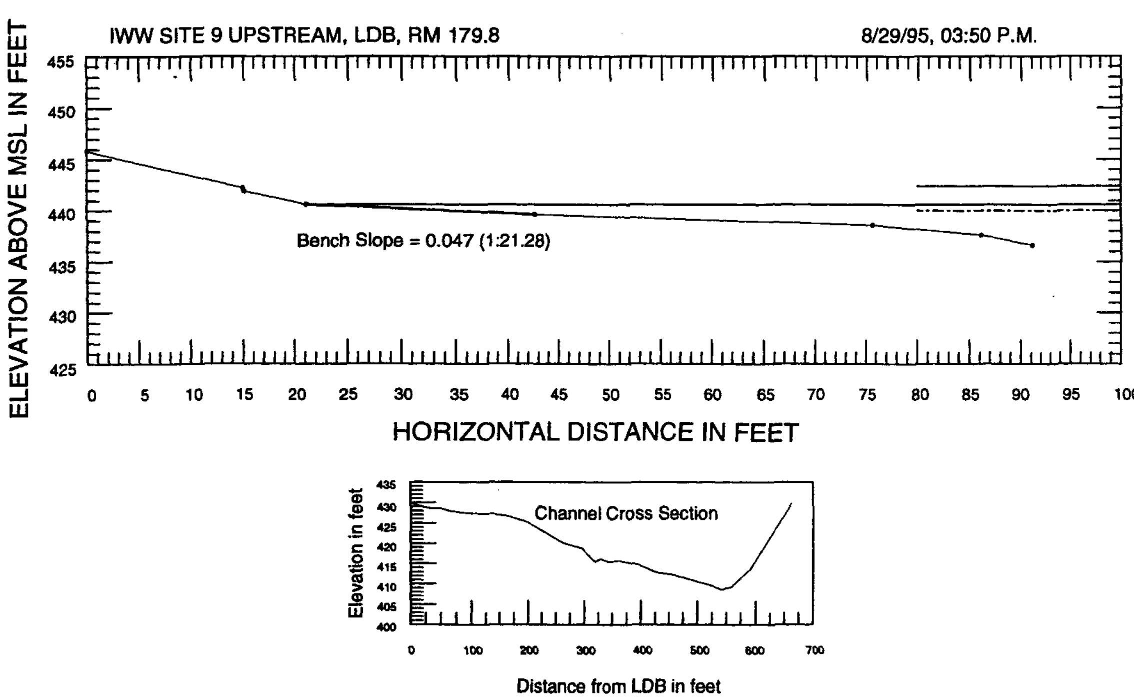
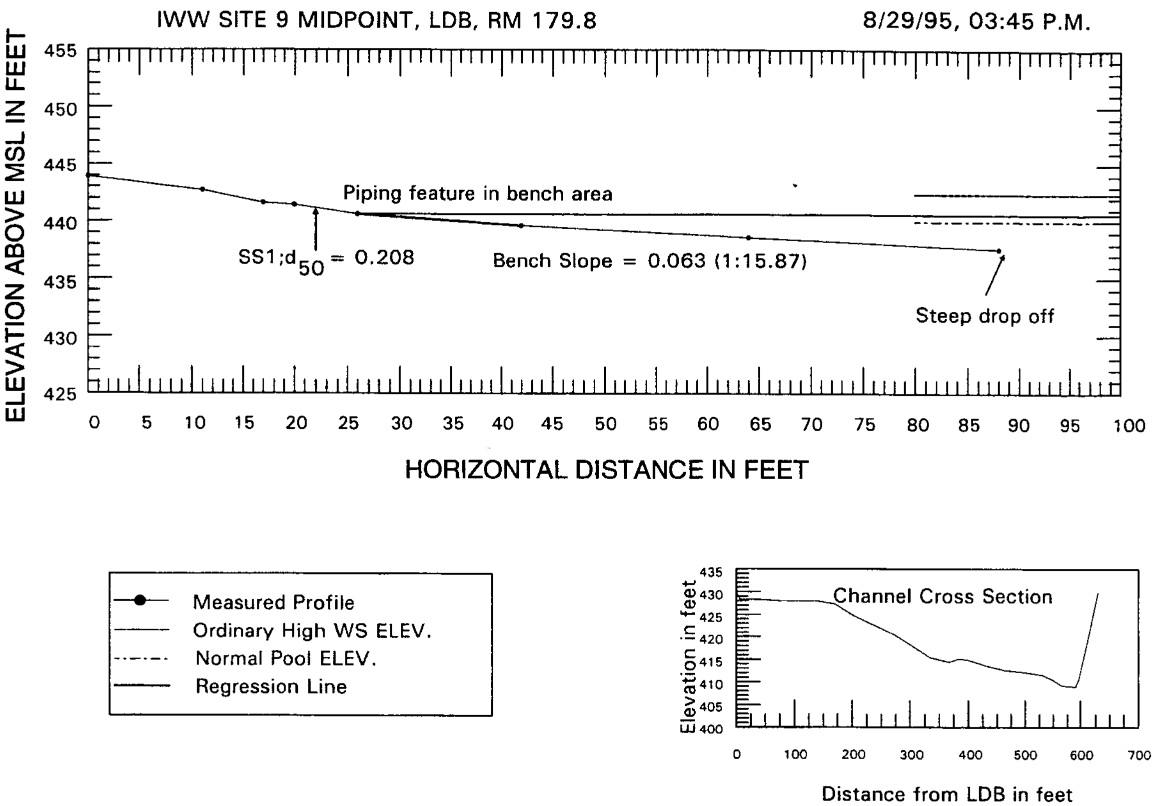


Figure 72. Bank sections at site 9



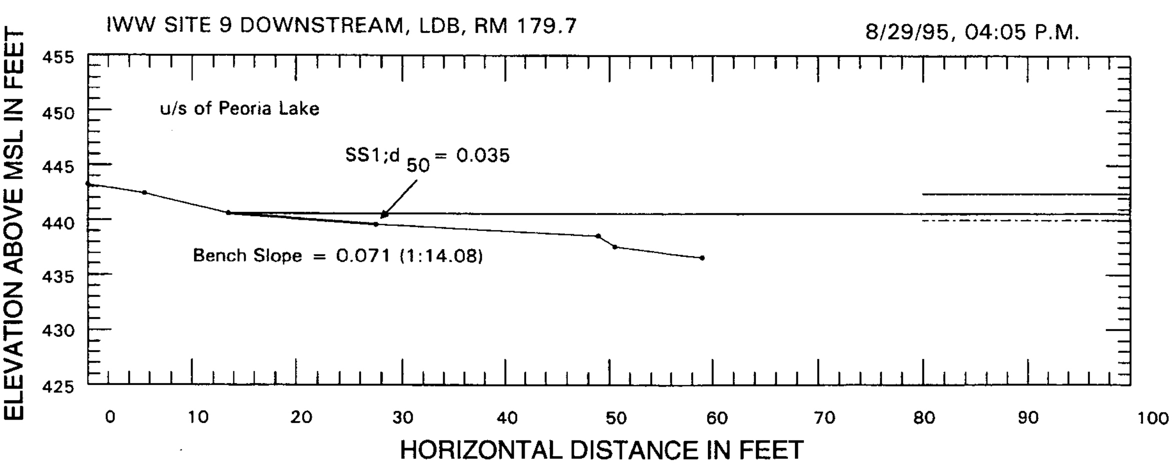


Figure 72. Bank sections at site 9 (concluded)

Site 10, Peoria Pool, 8/29/95

This site is located on the RDB and at the outside of a sharp bend at RM 160.0. Peoria L&D is located downstream at RM 157.8. Figure 73 shows the position of the site on a GIS-based map of the Illinois navigation chart, and figure 74 is a photograph of the site.

Site 10 is about 430 feet from the sailing line. Kickapoo Creek enters the river at RM 159.6 on the RDB. At the upstream end of the site a drawbridge is located at RM 160.8. Neither Bhowmik and Schicht (1980) nor Hagerty (1988) recorded the site as an erosion site. Parked barge fleets were noted on the LDB about 1,000 feet upstream from this site. This bank bore some resemblance to site 8, but trees were growing at the water's edge, and there was not much seasonal vegetation on top of the bank. A scarp 3-5 feet high and some piping holes were observed near the water's edge. The underwater bench extended toward the channel, and a thick layer of fine materials was noted on the subaqueous bench. Strong currents were encountered near the bank.

Figure 75 shows the three measured bank sections and a reduced cross section. The OHWE is 441.4 ft-msl and NP is 440.0 ft-msl. Water surface elevation was at the base of the scarp. At stages corresponding to OHWE, the scarp is mostly submerged. Floods of a stage higher than 445.4 ft-msl (10 percent recurrence frequency, table 25) overtop the bank crest. There was sediment deposition on top of the bank.

At the midsection, the d_{50} varied from 0.015 mm at the top surface of the bank to 0.013 mm at the upper portion of the scarp. Gradation plots of bank soils and nearshore sediment are presented in appendix C. The detailed cross section and coordinates are shown in appendix D.

Table 25. Site 10 Characteristics

Percentage of occurrence	*Stage above msl, ft*	*Topographical features*	*Bank/bed material, mm*
90	439.7	• Bench (underwater) (slopes varied between 1V:14.9H and 1V:5.6H)	• d_{50} (core) @ 2 feet of water = 0.025
75	440.1	• Bench (underwater)	
50	440.4	• Bench (underwater)	
25	441.8	• Scarp/berm • Berm slope = 1V:2.7H	
10	445.4	• Scarp (slope varied between 1V:0.8H and 1V:0.56H)	• d_{50} varied (0.013-0.015)
0-9	>445.4	• Top of the bank	• d_{50} = 0.018

Note: Pool level gage of Peoria Pool @ RM 157.7 was used for stage histogram. WSE = 440.5 feet; OHWE = 441.4 feet; and NP = 440.0 feet.

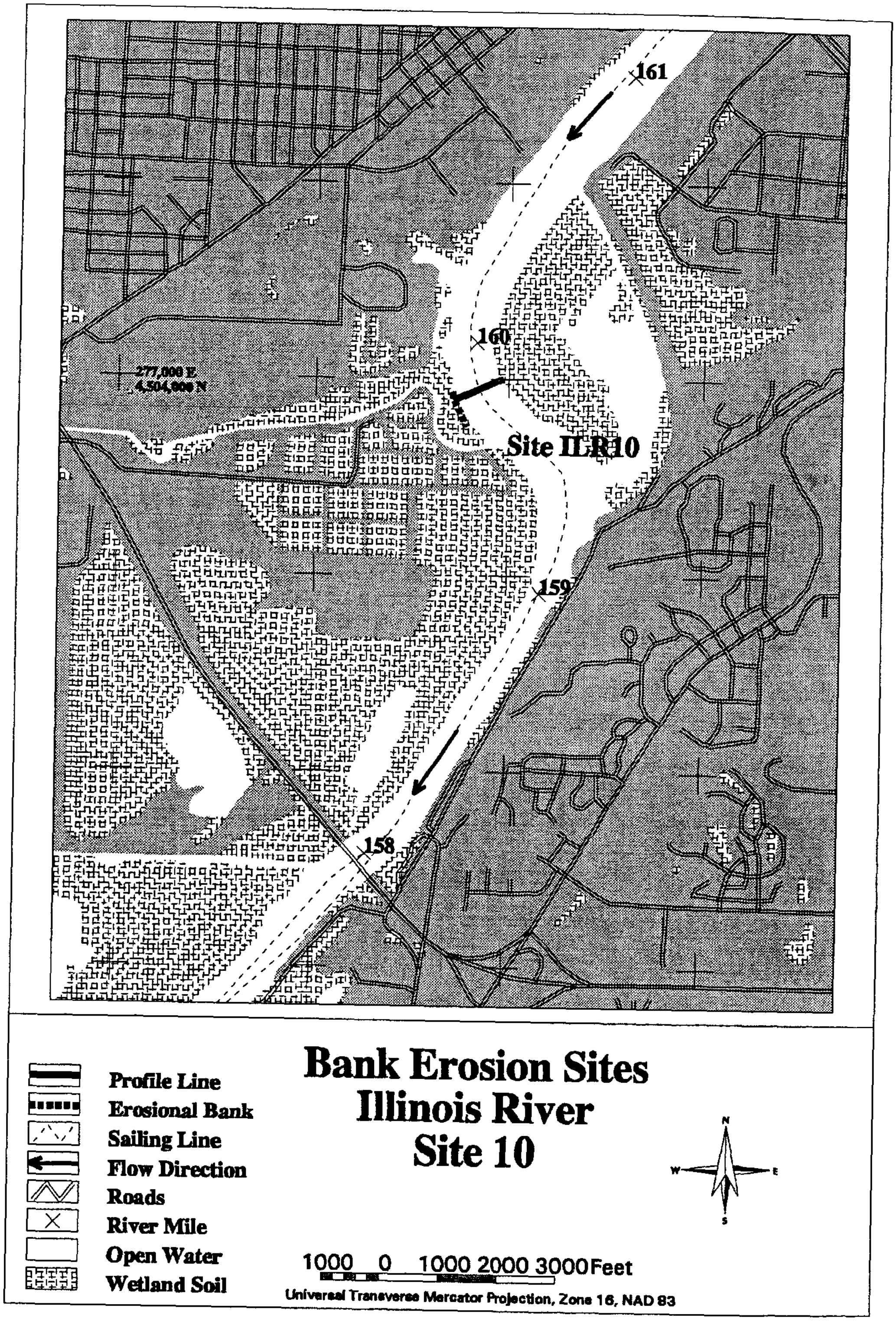


Figure 73. Location of site 10 on the Illinois River

Figure 74. Site 10 on the Illinois River

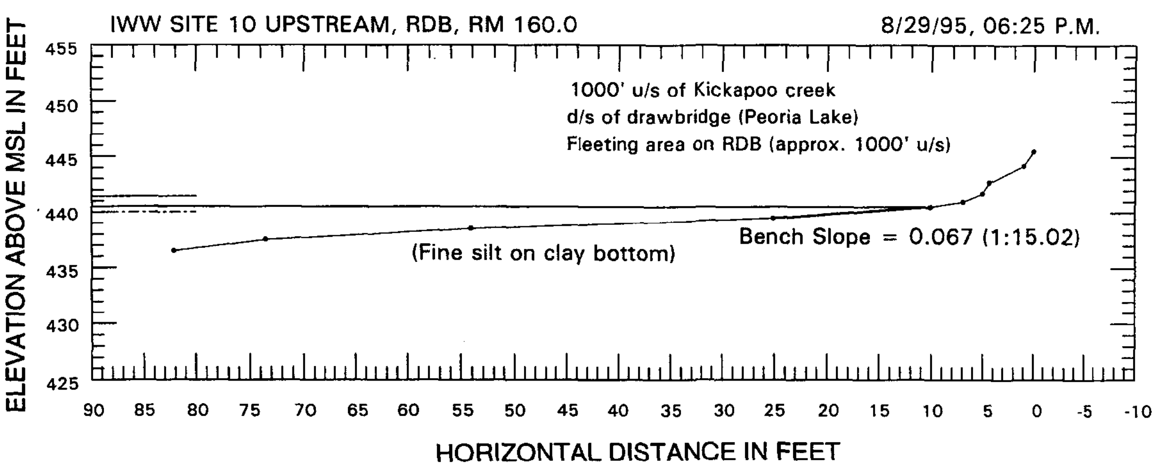


Figure 75. Bank sections at site 10

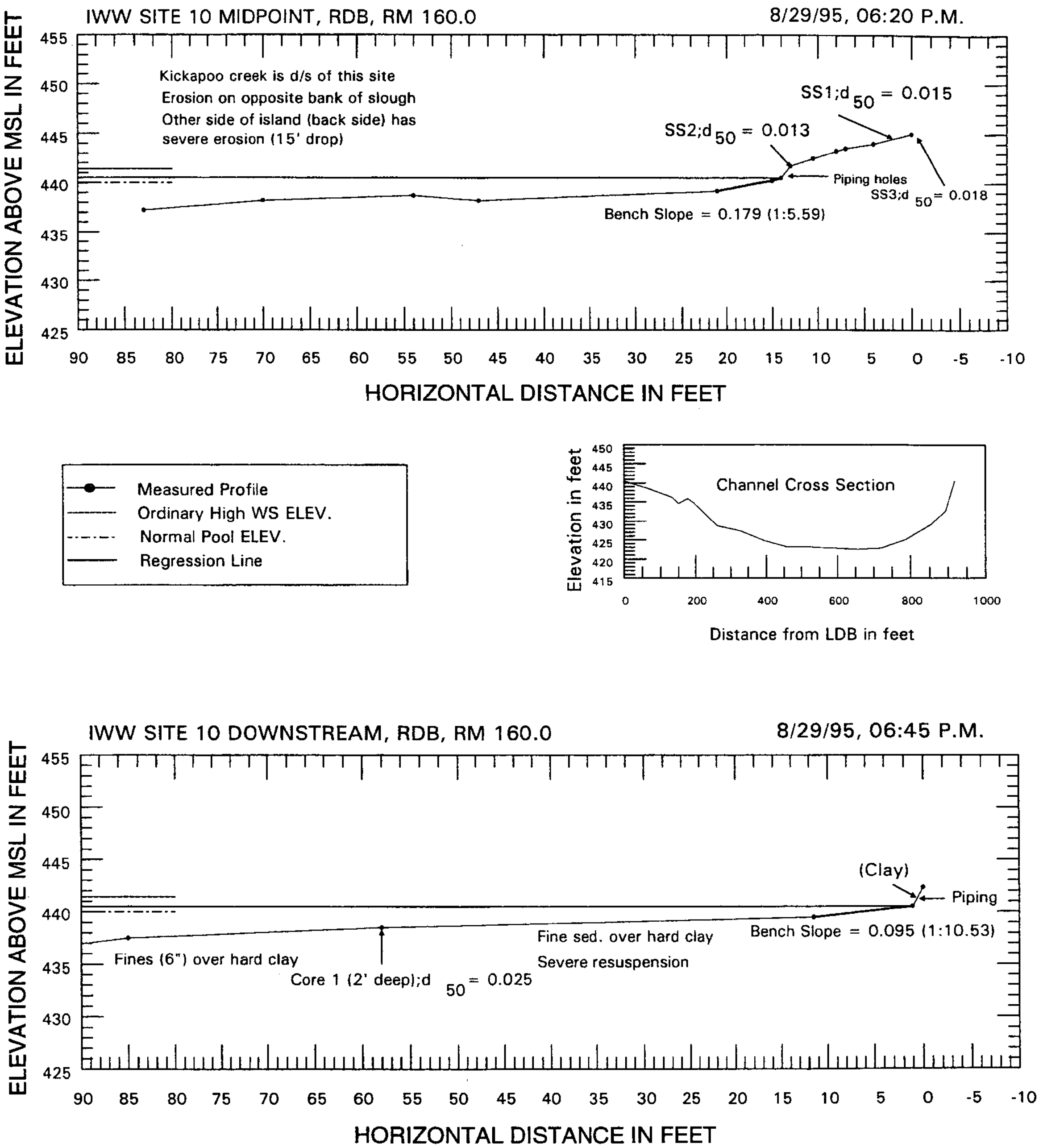


Figure 75. Bank sections at site 10 (concluded)

Bench slopes varied between 1V:15.0H and lV:5.6H, and the subaqueous bench extended more than 70 feet. Soils on the scarp were cohesive. The site can be classified as a combination of types 4 and 5 (figures 24 and 25 and table 9). Piping-related internal erosion weakens the bank. Soils exposed and displaced by bank failures are susceptible to removal by wave and current actions during normal stages. Traffic is heavy at this site and could add to the tractive forces by waves and currents.

Site 11, La Grange Pool, 8/30/95

This site is located on the RDB at RM 155.3. The reach is fairly straight, but the site is at the entrance to a sharp bend between RM 154.5 and 149. Other surrounding structures include the Peoria Lock and Dam upstream at RM 157.8 and a docking facility approximately 500 feet downstream. Figure 76 shows the position of the site on a GIS-based map of the Illinois navigation chart, and figure 77 is a photograph of the site.

The navigation sailing line is near the RDB at site 11 (the distance from the navigation chart is about 250 feet). Lick Creek enters the Illinois River from the LDB at RM 156.5. Bhowmik and Schicht (1980) noted some erosion on both banks around RM 156, and Hagerty (1988) noted dredged material cited on the navigation chart for both banks.

Figure 78 shows the three measured bank sections and a reduced cross section. The entire bank was mildly sloped, with a small scarp remote from the water at the top of the bank. Trees with exposed roots were at the crest of the bank, above a weed zone and a bare bench with several small wave scarps covered with recent sediments. The OHWE is 440.8 ft-msl and NP is 429.5 ft-msl. Stage fluctuations at the upper part of the pool are generally large, and banks often have mildly sloped benches. The OHWE can reach the upper part of the bank close to the base of a small scarp at the downstream section. Table 26 shows the recurrence frequencies for various stages at this site.

At the midsection, the d_{50} varied from 0.235 mm at the top of the bank to 0.158 mm from the upper part of a core sample at a water depth of about 2 feet. Gradation plots of bank soils and nearshore sediment are presented in appendix C. The detailed cross section and coordinates are shown in appendix D.

Bench slopes varied slightly between 1V: 11.2H and lV:9.0H. This site is classified as type 6 (figure 26 and table 9). Wave actions are primarily responsible for rework and transport of failed soil or recently deposited sediments on the bench at various stages within the normal range of pool level fluctuations.

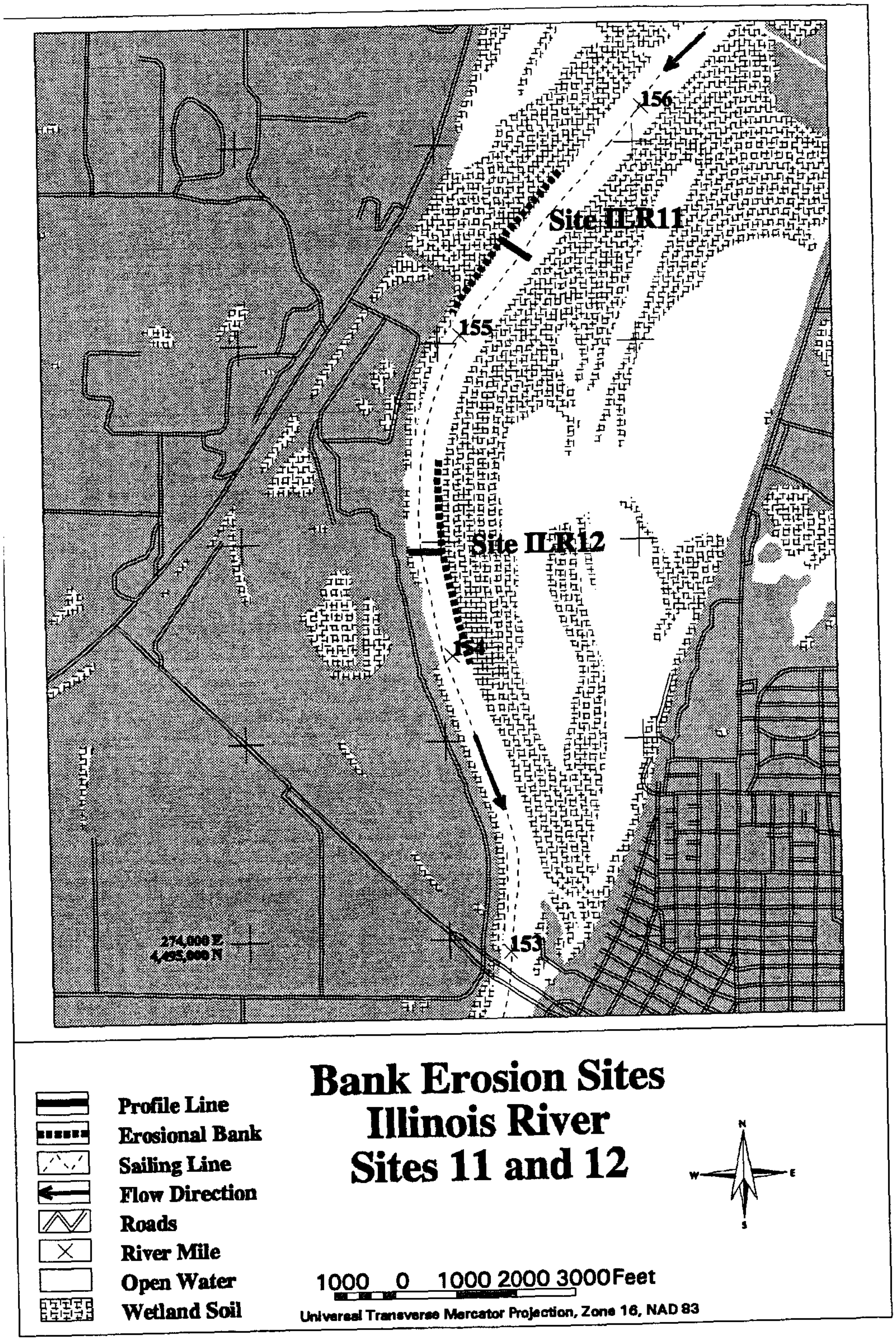


Figure 76. Locations of sites 11 and 12 on the Illinois River

Figure 77. Site 11 on the Illinois River

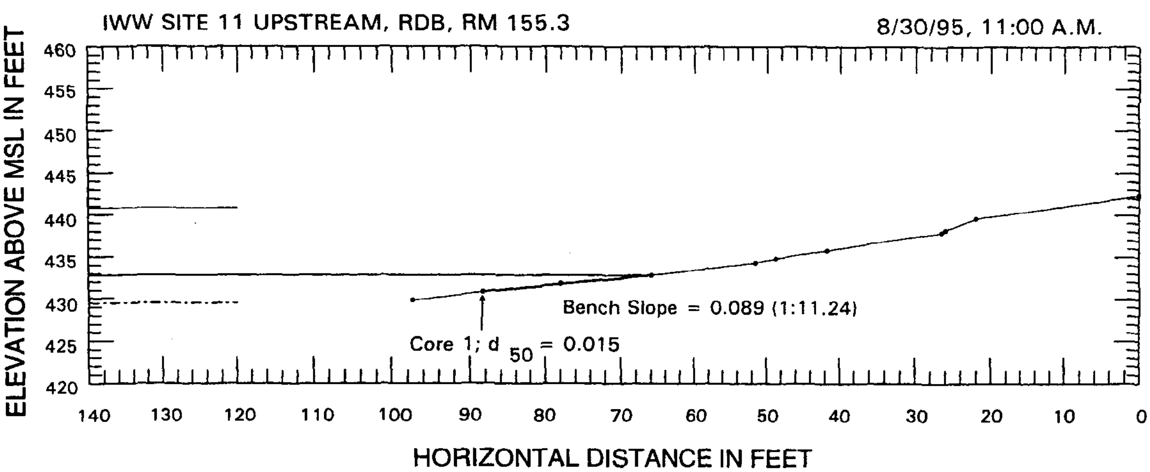


Figure 78. Bank sections at site 11

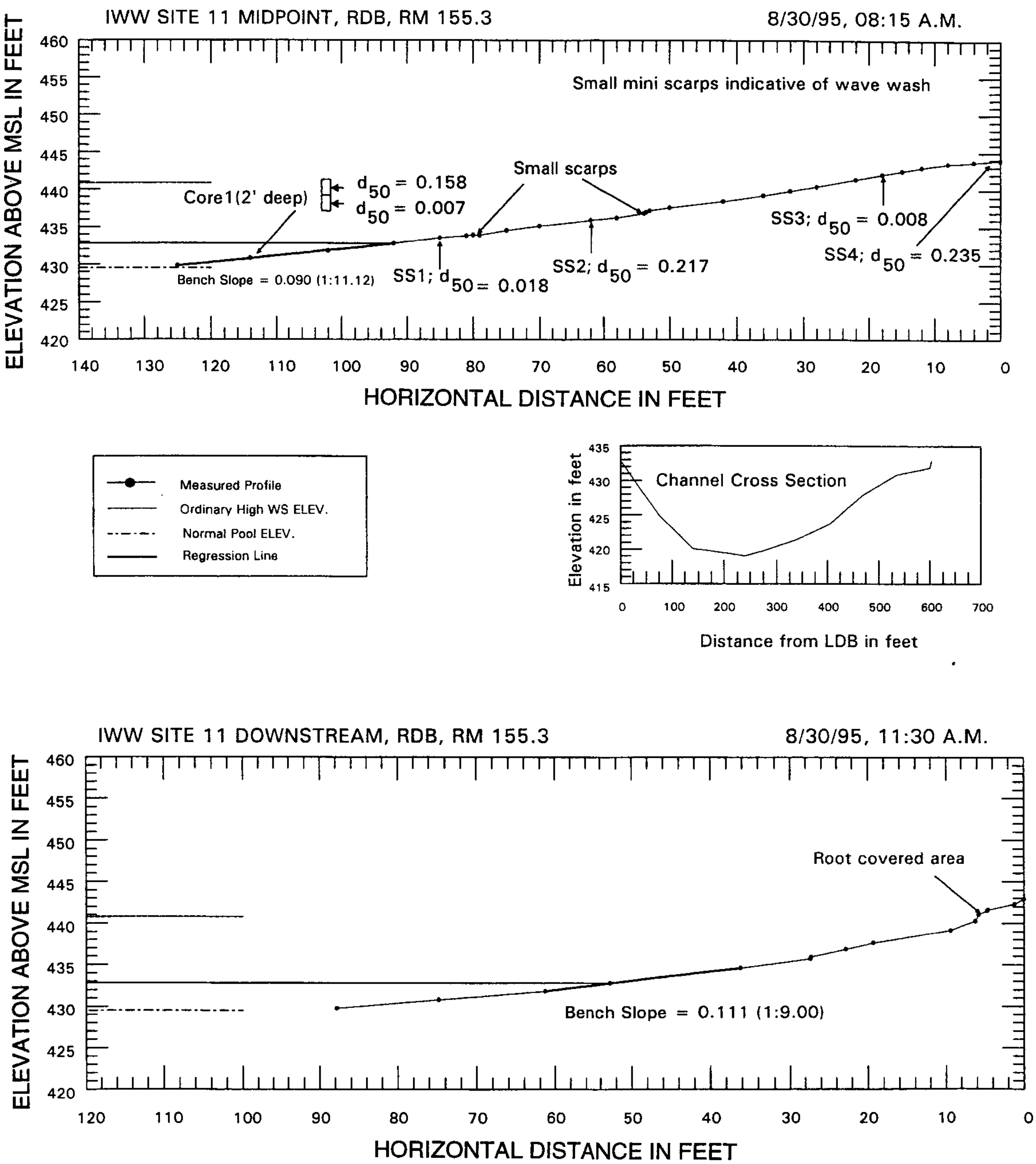


Figure 78. Bank sections at site 11 (concluded)

Table 26. Site 11 Characteristics

Percentage of occurrence	*Stage above msl,ft*	*Topographical features*	*Bank/bed material, mm*
90	431.65	Bench (underwater), slopes varied between 1V: 11.2H and lV:9.0H	d_{50}(core) @ 1 foot of water = 0.015 d_{50} (core) 2 feet of water varied (0.007-0.158)
75	432.95	Bench Small scarps	d_{50} varied (0.018-0.217)
50	436.0	Small scarps Berm	
25	441.1	Scarp	d_{50}= 0.008
10	444.25	Top of the bank	d_{50}= 0.235
0-9	>444.3		

Note: Tail water gage of Peoria Pool @ RM 157.7 was used for stage histogram. WSE = 432.8 feet; OHWE = 440.8 feet; and NP = 429.5 feet.

Site 12, La Grange Pool, 8/30/95

This site is located on the LDB at RM 154.4 on the inside of a mild bend; a sharp bend is downstream from the site. A power plant across the river has docking facilities for barges. The Lake of the Woods is located approximately 1,000 feet behind this bank. Figure 76 shows the position of the site on a GIS-based map of the Illinois navigation chart, and figure 79 is a photograph of the site.

Figure 79. Site 12 on the Illinois River

Site 12 is about 320 feet from the sailing line, and no major tributary enters the river at this location. Bhowmik and Schicht (1980) and Hagerty (1988) noted erosion on both sides of this reach of the waterway.

An obvious scarp was present at the water's edge. Figure 80 shows the three measured bank sections and a reduced cross section. The wide bench has a mild slope. At the top of the bank, tall trees and a scarp were hidden behind a belt of tall weeds and young willows. Vegetation formed a band approximately 90-100 feet wide on the bank. A berm was present inside the vegetation zone, and its soils were desiccated. The open bench area was wet and clayey and had piping features. The OHWE is 440.7 ft-msl, and NP is 429.5 ft-msl. At OHWE, the water would submerge some of the vegetation on the bank. Small scarps in the vegetation zone were below the OHWE, and the scarp at the upstream section was at the water's edge. Table 27 gives the recurrence frequencies for various stages at this site.

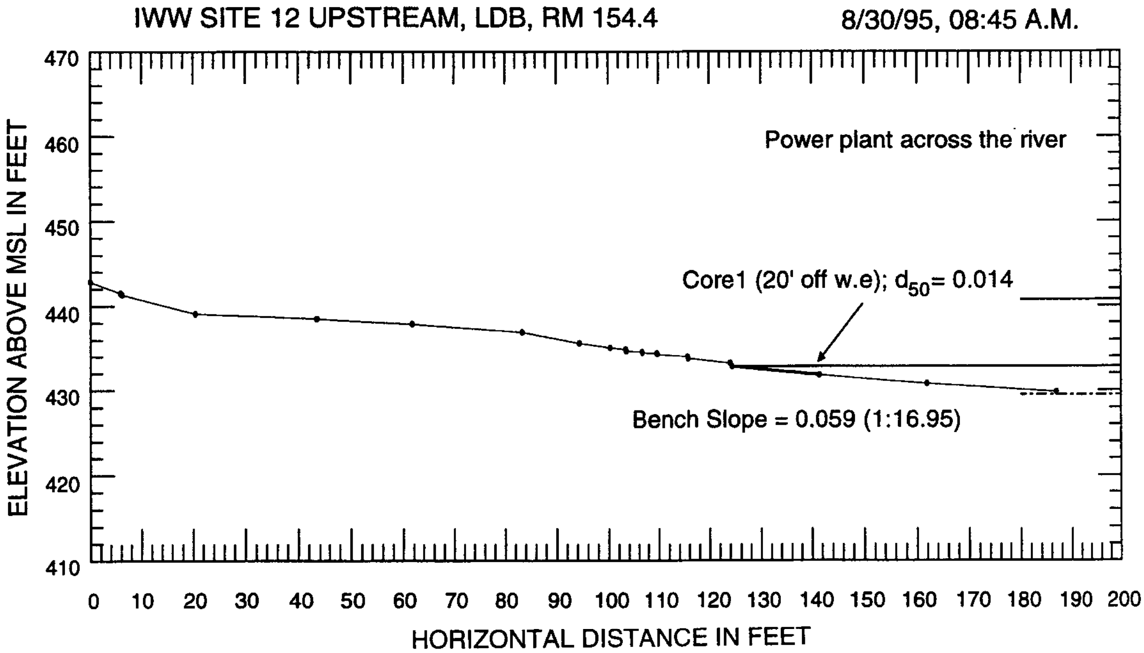
At the midsection, the d_{50} varied from 0.046 mm at the top surface of the bank to 0.022 mm at the top portion of a core sample at a water depth of about 1 foot. Gradation plots of bank soils and nearshore sediment are presented in appendix C. The detailed cross section and coordinates are shown in appendix D.

Bench slopes varied between 1V:16.9H and 1V:9.0H. This site is classified as type 5 (figure 25 and table 9). Wave action was suspected to be one of the main mechanisms for erosion because of the scarps on the sloping bank. Piping also was noted at the lower subaerial bench. Rework and transport could be significant at various stages within the normal range of pool-level fluctuations at this site.

Table 27. Site 12 Characteristics

Percentage of occurrence	*Stage above msl,ft*	*Topographical features*	*Bank/bed material, mm*
90	431.65	• Bench (underwater)	• d_{50} (core) varied (0.014-0.022)
75	432.95	• Bench (slope varied between lV:16.9H and lV: 9.0H	• d_{50} varied (0.046-0.077)
50	436.0	• Bench	
25	441.1	• Scarp	
10	444.25	• Top of the bank	• d_{50} = 0.046
0-9	>444.3	• Top of the bank	

Note: Tail water gage of Peoria Pool @ RM 157.7 was used for stage histogram. WSE = 432.8 feet; OHWE = 440.7 feet; and NP = 429.5 feet.



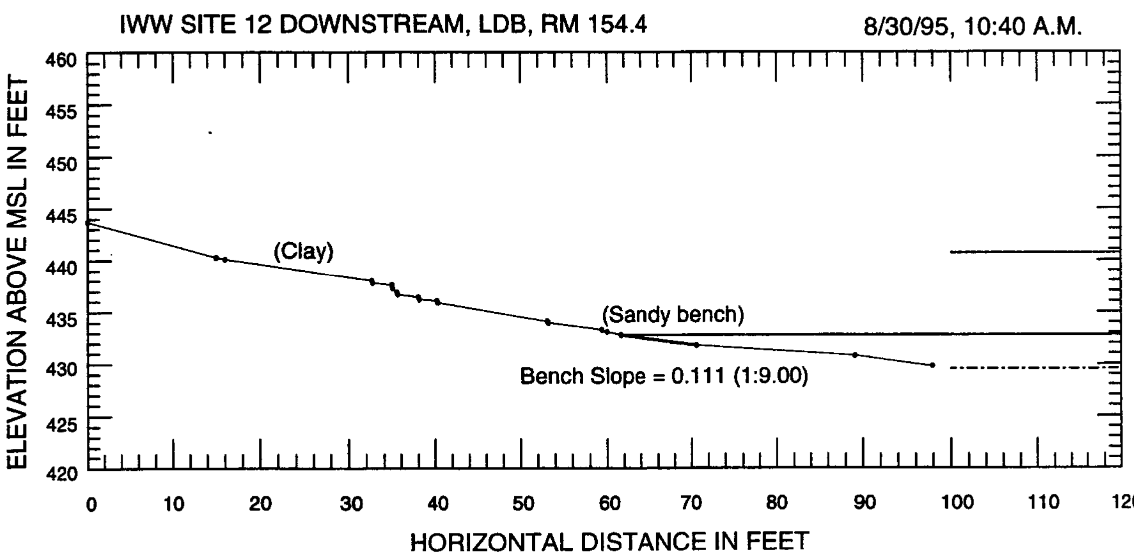


Figure 80. Bank sections at site 12

Site 13, La Grange Pool, 8/30/95

This site is located on the LDB at RM 150.6 on the outside of a sharp bend. A 3 by 5 foot barge tow would have considerable difficulty in maneuvering through this sharp bend. A delta at the upstream end (RM 150.9) near the mouth of a small creek further reduces the maneuvering space for barge tows and increased flow velocity. The Chicago and Northwestern Railway bridge crosses the river at RM 151.2. All these factors may be responsible for changes in bank sections from upstream to downstream. Figure 81 shows the position of the site on a GIS-based map of the Illinois navigation chart, and figure 82 is a photograph of the site.

The site is about 370 feet from the sailing line, and there are two barge canals for a coal pit on the LDB at RM 150.9. Hagerty (1988) found this site severely eroded and included it as a study site. Bhowmik and Schicht (1980) did not specify this site but cited a reach at the downstream end at RM 149.5-150.0. A vertical scarp was present at the water's edge. When tows pass near this bank reach, direct impact is likely, especially when water stages are low. There were multiple scarps on the upper bank. Dredged materials had been deposited here, and two layers of different soils were observed on the bank. There were dense small holes on the bank surface, which may have been created by worms. Bhowmik and Schicht (1980) and Hagerty (1988) referenced erosion on both banks at this river mile.

At the midsection, the d_{50} varied from 0.117 mm at the top surface of the bank to 0.005 mm at the upper portion of a core sample at a water depth of about 2 feet. Gradation plots of bank soils and nearshore sediment are presented in appendix C. The detailed cross section and coordinates are shown in appendix D.

Materials on the scarp were cohesive. This site can be classified as type 4 (figure 24 and table 9). Under normal stages, waves and turbulence created by traffic are causes for bank erosion. Rework and transport by current at stages within the normal range of pool level fluctuation can be significant. Seepage and nesting worms can also weaken bank strength.

Figure 83 shows the three measured bank sections and a reduced cross section. The OHWE is 440.5 ft-msl, and NP is 429.5 ft-msl. The NP elevation is about at the base of the berm, and the OHWE reaches the upper part of the bank. Table 28 gives the stages for various recurrence frequencies at this site.

Site 14, La Grange Pool, 8/30/95

This site is located on the RDB at RM 129.3, at the beginning of an inside bend. The river is fairly straight upstream from RM 129.9. Figure 84 shows the position of the site on a GIS-based map of the Illinois navigation chart, and figure 85 is a photograph of the site.

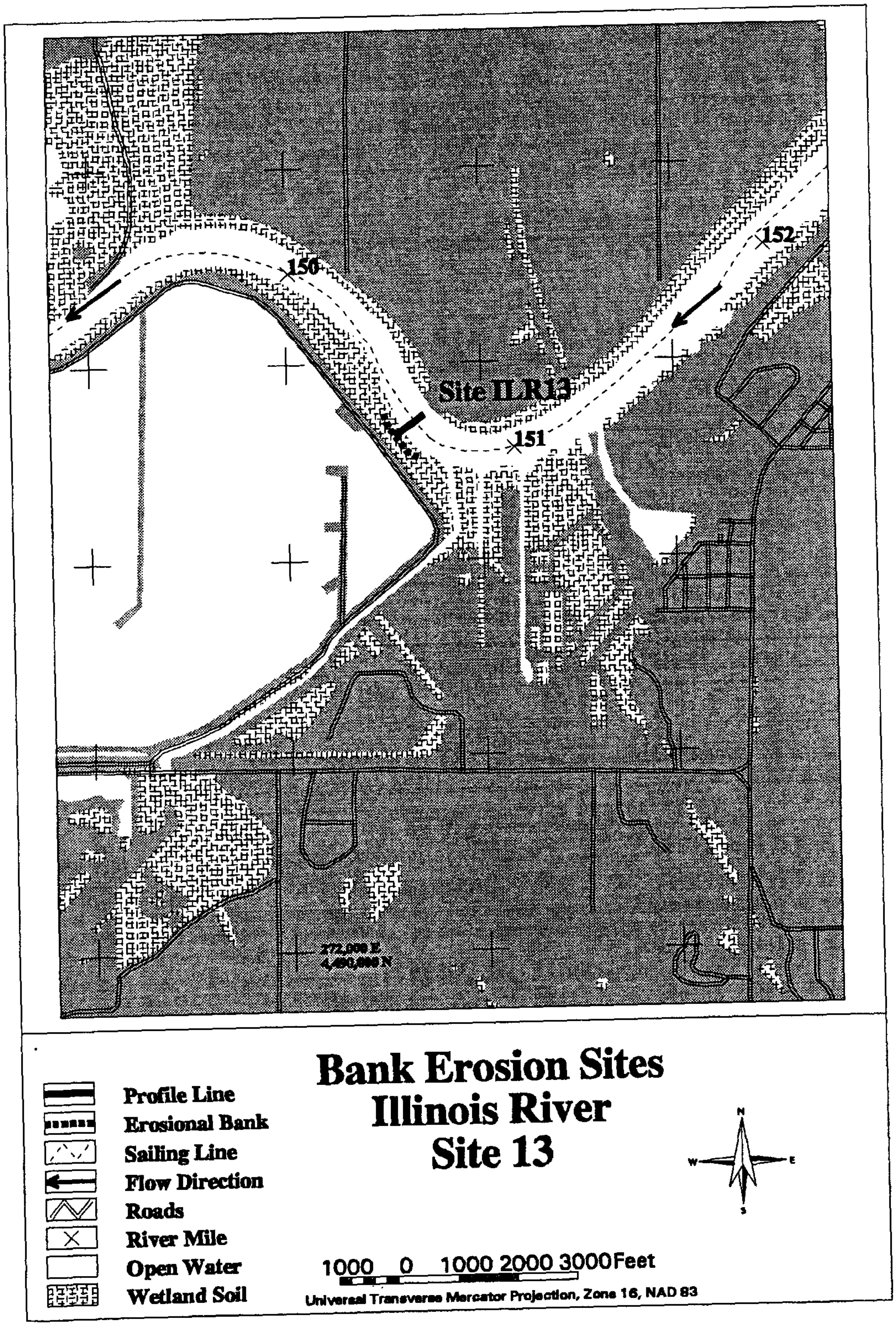


Figure 81. Location of site 13 on the Illinois River

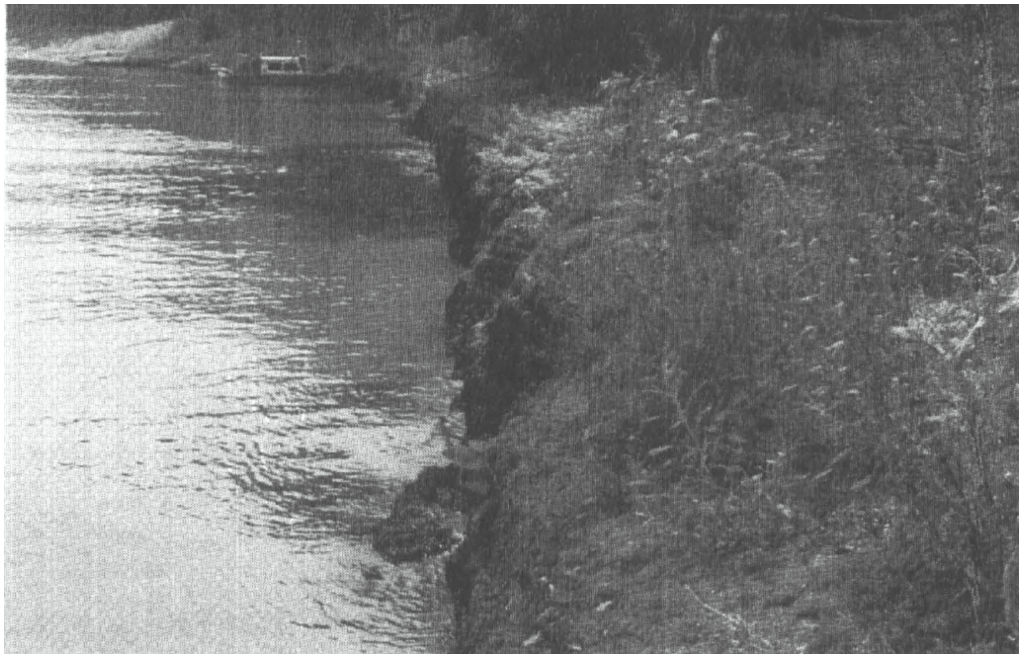


Figure 82. Site 13 on the Illinois River

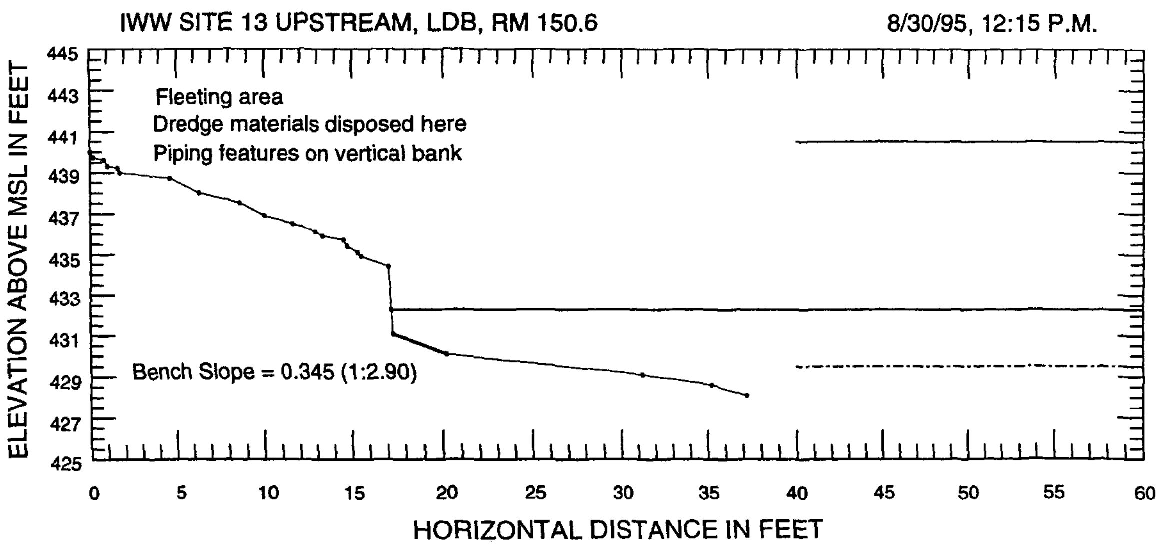


Figure 83. Bank sections at site 13

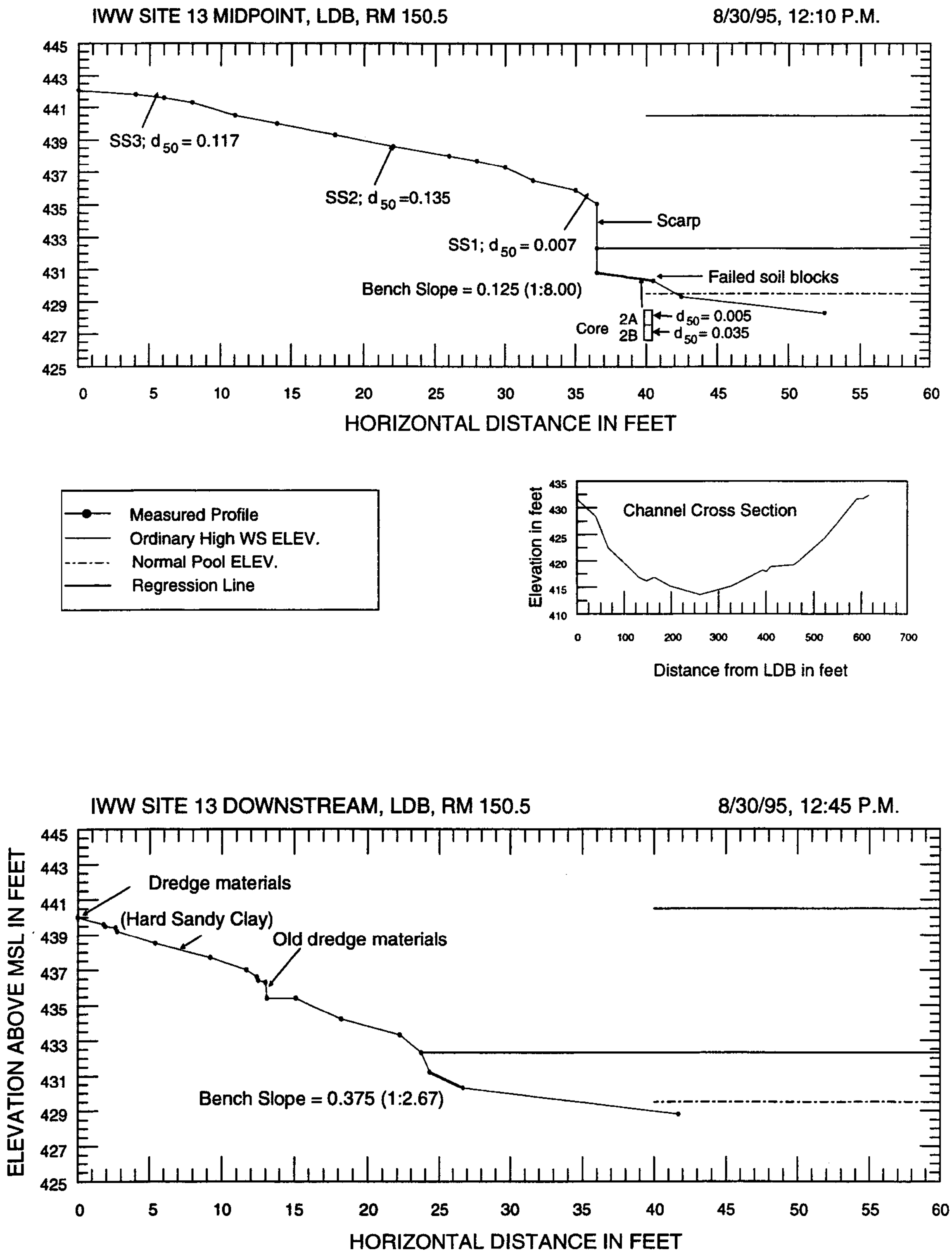


Figure 83. Bank sections at site 13 (concluded)

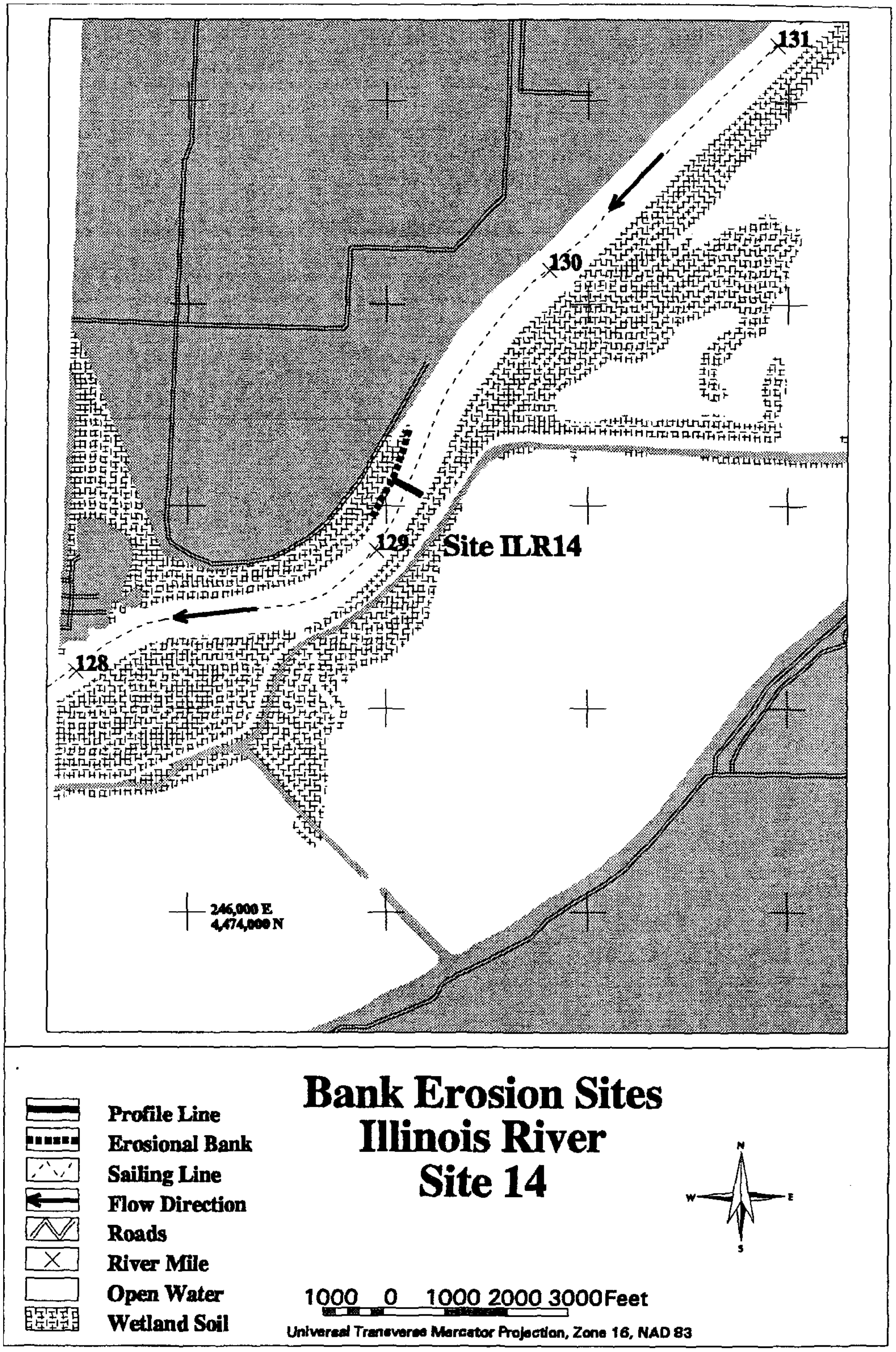


Figure 84. Location of site 14 on the Illinois River

Figure 85. Site 14 on the Illinois River

Table 28. Site 13 Characteristics

Percentage of occurrence	*Stage above msl, ft*		*Topographical features*	*Bank/bed material, mm*
90	<430.0	*	Bench (underwater), slopes varied between 1V:10HandlV:8.5H	d_{50} (core) 2 feet of water varied (0.005-0.035)
90	431.3	*	Scarp/berm, slopes of scarp: lV:0.58H to lV:0.09H	
75	432.5	•	Scarp/berm	
		®	Berm slopes vary between lV:4HandlV:2.6H	
50	435.8	•	Top of the bank/scarp	
25	440.7			d_{50} varied (0.117-0.135)
10	443.99			
0-9	444.0			

Note: Gage on the Illinois River near Kingston Mines, IL @ RM 145.4 was used for stage histogram. WSE = 432.3 feet; OHWE = 440.5 feet; and NP = 429.5 feet.

Site 14 is about 270 feet from the sailing line, and no major tributary enters the river at this location. Approximately 600 feet behind this site is the East Liverpool Levee System. Bhowmik and Schicht (1980) found erosion on the opposite bank on an island. Hagerty (1988) observed erosion on this bank but not on the opposite bank. Trees are close to the bank crest at many locations at this site, and some roots extended beyond the bank face. A scarp about 1.5 feet high was located on the upper part of the bank, which was covered by seasonal grasses. Several breaks in the bank sections appeared to correspond to different erosion mechanisms at this site. Dislodged peds and some micro-scale piping existed on a bare bench area. The bench between the scarp and the water's edge was covered with moist, soft clay.

Figure 86 shows the three measured bank sections and a reduced cross section. The OHWE is 438.5 ft-msl, and NP is 429.5 ft-msl. A scarp was noted at the downstream section, where the NP elevation matched the base of the scarp. The OHWE elevation- is about the same height as the short scarp at the midsection, and any stages higher than the OHWE elevation will top the bank (see table 29 for the recurrence frequencies for various stages).

At the midsection, the d50 varied from 0.026 mm at the top surface of the bank to 0.012 mm at the upper part of a core sample at a depth of about 1 foot of water. Gradation plots of bank soils and nearshore sediment are presented in appendix C. The detailed cross section and coordinates are shown in appendix D.

Bench slopes varied from 1V:10.1H at the upstream section to 1V:7.9H at the midsection. The slope for the subaqueous bench was 1V:14.5H below a water's edge scarp at the downstream section. The site is classified as type 4 (figure 24 and table 9). The subaerial bench was wet due to poor drainage. Wave wash, in combination with piping, appeared to have created the downstream small scarp on the bench. Rework and transport of failed soils and recently deposited sediments at stages within the normal range of pool-level fluctuations could be significant.

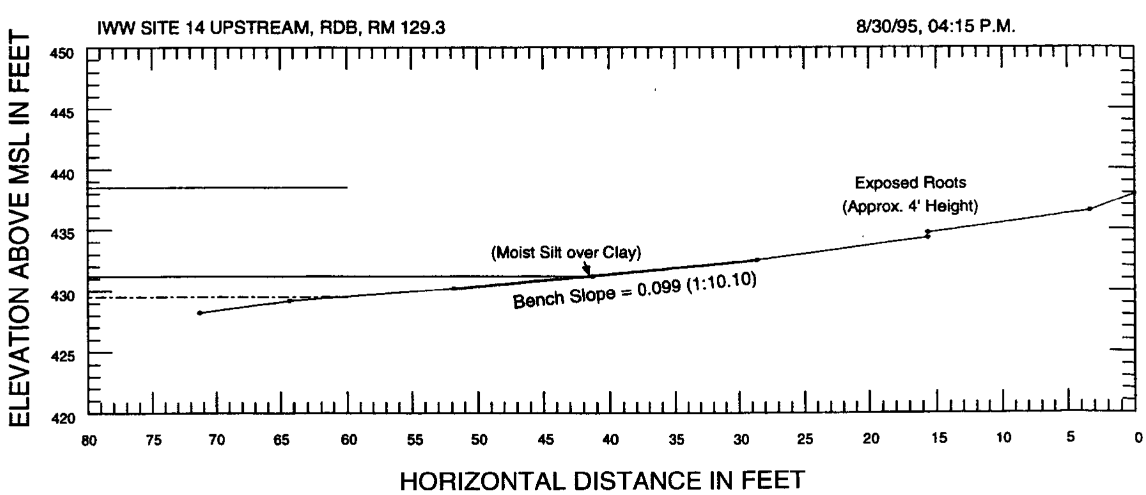
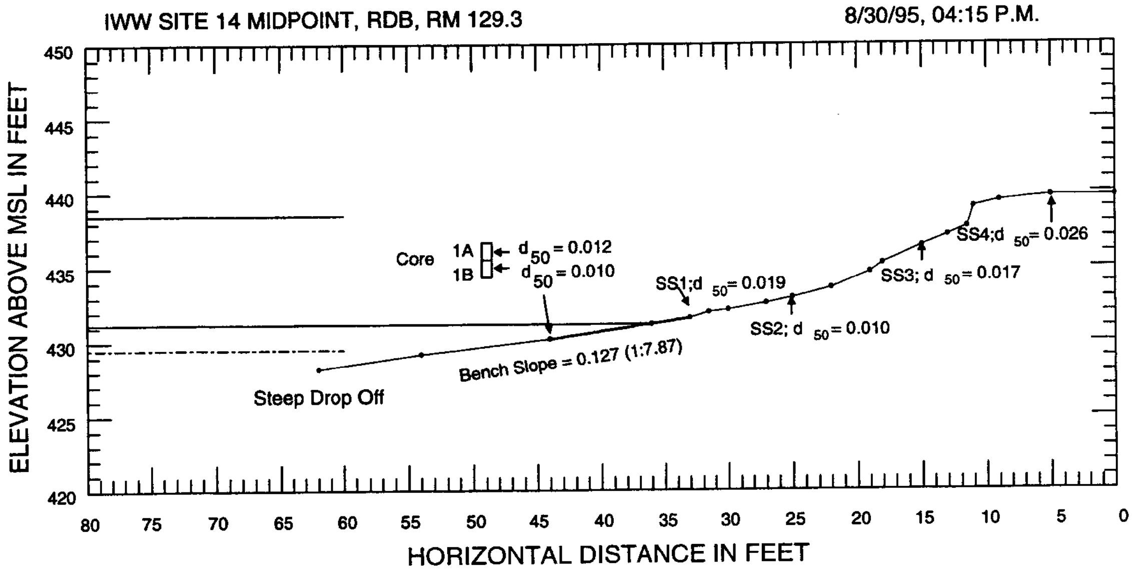
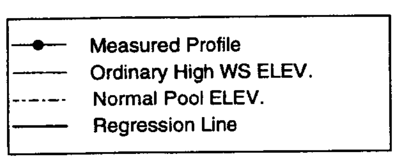
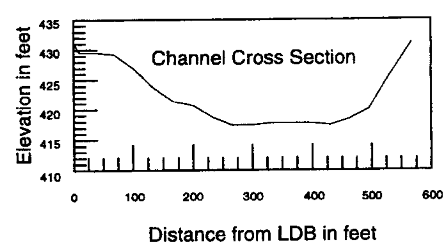


Figure 86. Bank sections at site 14







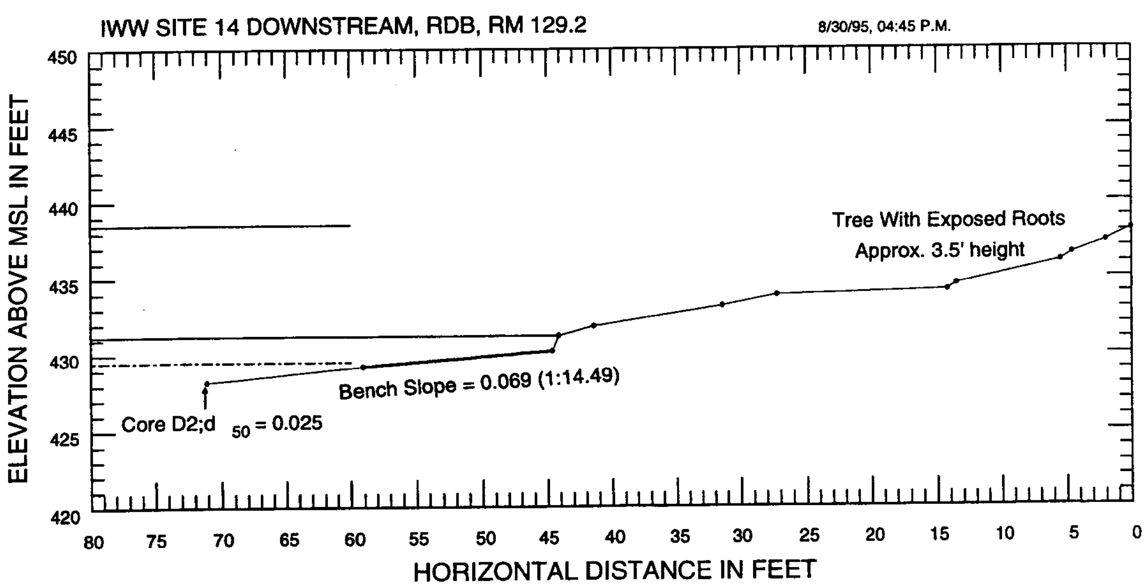


Figure 86. Bank sections at site 14 (concluded)

Table 29. Site 14 Characteristics

Percentage of occurrence	*Stage above msl.ft*	*Topographical features*	*Bank/bed material, mm*
90	430.9	• Bench (underwater), slopes vary between 1V:14.5H and 1V:7.9H	• d_{50} (core) varied (0.010-0.012)
75	432.3	• Bench	• d_{50} varied (0.010-0.019)
50	435.3	• Berm (slopes varied between 1V:4.6H and 1V:2.6H)	• d_{50} = 0.017
25	440.0	• Top of the bank	• d_{50} = 0.026
10	443.1		
0-9	>443.1		

Note: Gage on the Illinois River near Copperas Creek @ RM 139.9 was used for stage histogram. WSE = 431.2 feet; OHWE = 438.5 feet; and NP = 429.5 feet.

Site 15, La Grange Pool, 8/30/95

This site is located at the RDB at RM 116.5, where an embankment lies on the outside of a gentle bend. The embankment is part of the Lacey, Langellier, West Matanzas & Drainage Levee System. Figure 87 shows the position of the site on a GIS-based map of the Illinois navigation chart, and figure 88 is a photograph of the site.

The site is about 310 feet from the sailing line. No major tributary enters the river at this location. Bhowmik and Schicht (1980) noted erosion along a long stretch of this side of the river, and Hagerty (1988) noted dredged material at the site as well as some old dredged material on the opposite bank. Tall grass covered the bank face, with scarps inside the grass zone. The bench below the grass zone contained a series of small scarps.

Figure 89 shows the three measured bank sections and a reduced cross section. The OHWE is 437.0 ft-msl, and NP is 430.8 ft-msl. The NP elevation corresponds to a break in the subaqueous slope. From figure 89, the OHWE elevation corresponds to the base of a small scarp Table 30 shows the recurrence frequencies for various stages.

At the midsection, the dso varied from 0.008 mm at the top surface of the bank to 0.265 mm at the upper part of a core sample at a water depth of about 2 feet. The nearshore sediment was stratified. Gradation plots of bank soils and nearshore sediment are presented in appendix C. A detailed cross section is shown in appendix D.

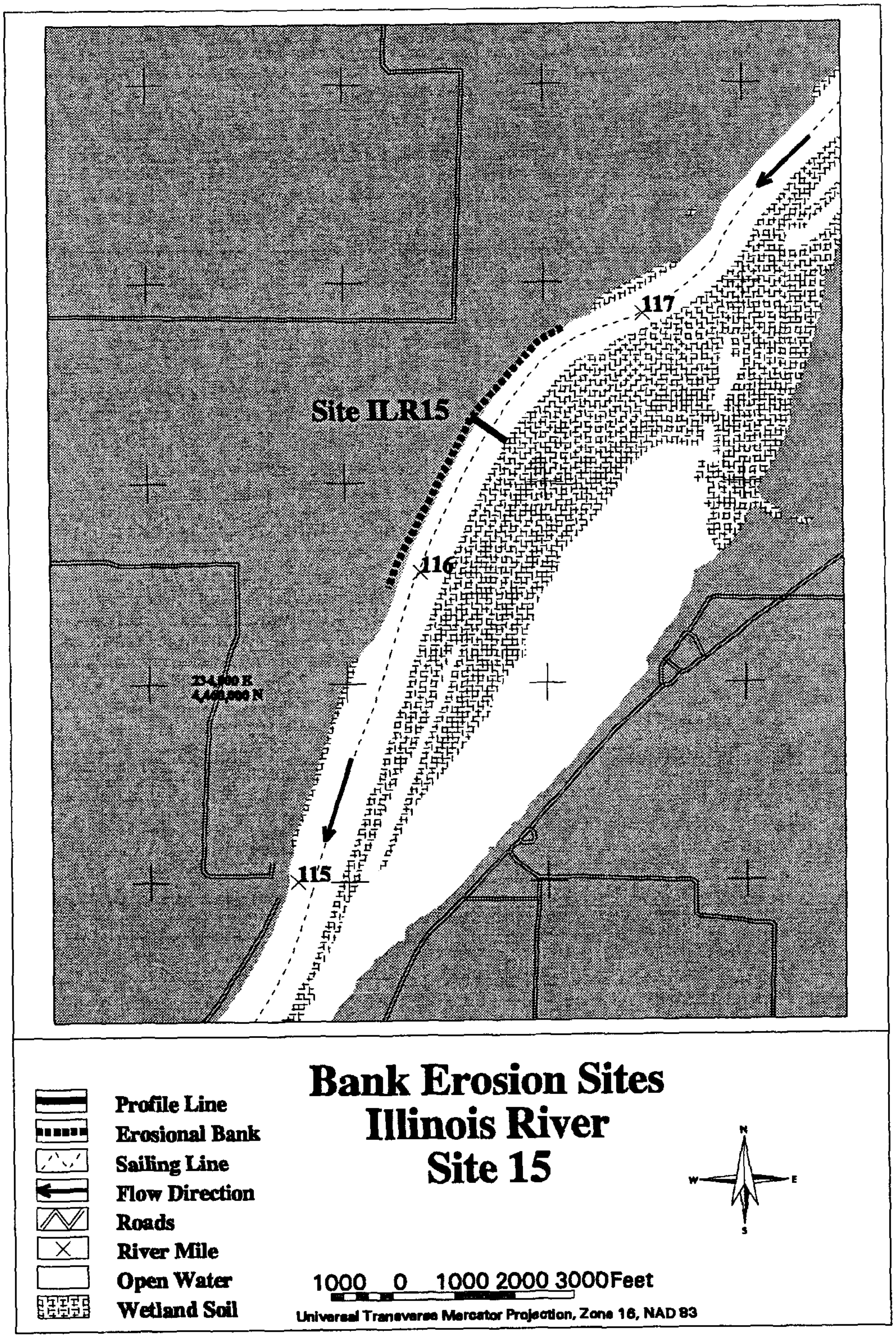


Figure 87. Location of site 15 on the Illinois River

Figure 88. Site 15 on the Illinois River

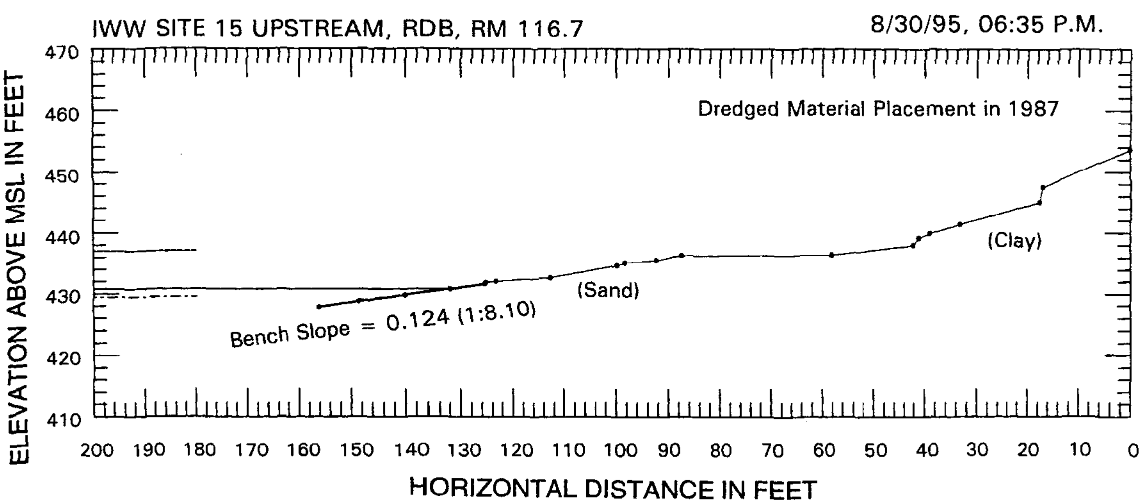
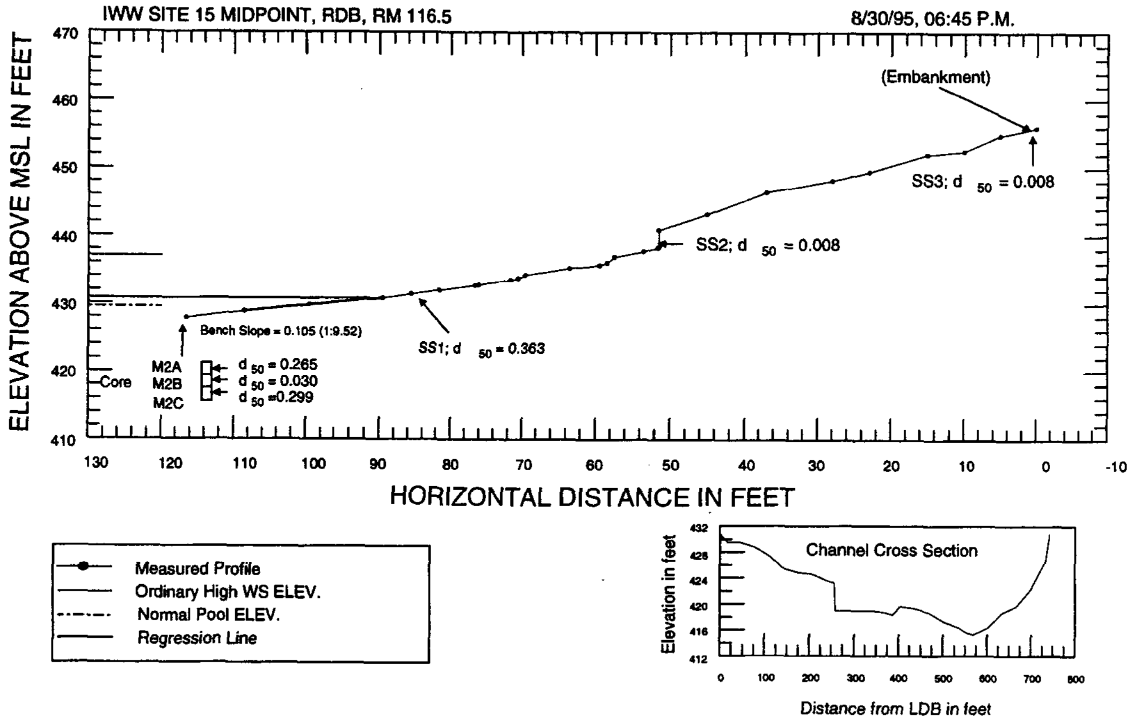


Figure 89. Bank sections at site 15



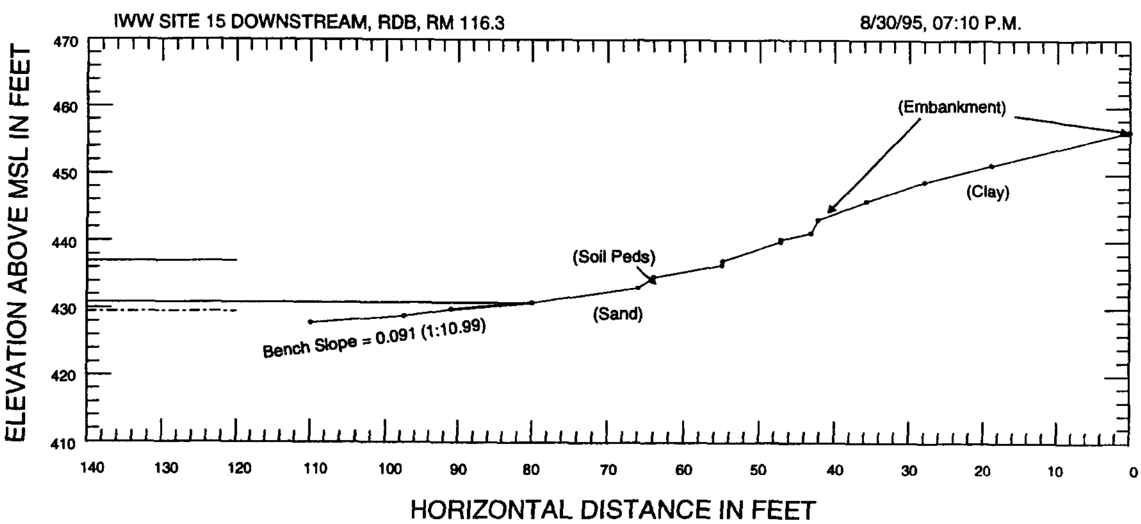


Figure 89. Bank sections at site 15 (concluded)

Table 30. Site 15 Characteristics

Percentage of occurrence	*Stage above msl, ft*	*Topographical features*	*Bank/bed material, mm*
90	430.1	• Bench (underwater) (slopes varied between 1V:11H and 1V:8.1H)	• d_{50} (core) varied (0.03-0.299)
75	431.1	• Bench	• d_{50} = 0.363
50	433.7	• Bench	
25	438.1	• Berm/bench (slopes varied between 1V:3.5H and 1V:2.8H)	• d_{50} = 0.008
10	441.5	• Scarp/berm (scarp slopes varied between 1V:0.45H and 1V:0.04H)	
0-9	>441.5	• Top of the bank	• d_{50} = 0.008

Note: Gage on the Illinois River near Havana, IL @ RM 119.6 was used for stage histogram. WSE = 430.8 feet; OHWE = 437.0 feet; and NP = 429.5 feet.

Bench slopes varied from 1V:8.1H at the upstream section to 1V:11H at the downstream section. This site is classified as a combination of types 3 and 5 (figures 23 and 25 and table 9). The existing scarp was located at higher elevations that could be caused by floods. The peds indicated seepage activities. Rework and transport by waves and currents on failed soils or recent sediments could also be important at this site.

Site 16, La Grange Pool, 8/31/95

This site is located on the LDB of RM 109.5 at a crossover of a bend within the Anderson Lake Conservation Area. Figure 90 shows the position of the site on a GIS-based map of the Illinois navigation chart, and figure 91 is a photograph of the site.

Site 16 is about 250 feet from the sailing line, and large lakes are located on both sides of the river. No tributary enters the Illinois River at this location. According to Bhowmik and Schicht (1980), erosion was occurring at an upstream reach above RM 110.2 on both sides of the river, but approximately between RM 109.5 and 109.8; only an LDB reach was eroded. Hagerty (1988) indicated both banks were eroded. The present study also observed that both banks were eroded. Large debris (dead trees) crowded the bank. There also was a steep scarp near the upstream section, and the opposite side was designated as site 17.

Trees were present at the bank crest, and the bank had an almost vertical scarp. Fine roots extended over the upper portion of the bank. At the bottom of the scarp, sparse vegetation had grown on the berm. A bare bench with a series of small scarps extended to the water's edge. The bench is covered with desiccated clay and holes dug by microorganisms. A passing barge generated fairly large bow-push and drawdown, stranding some juvenile fish on the bench.

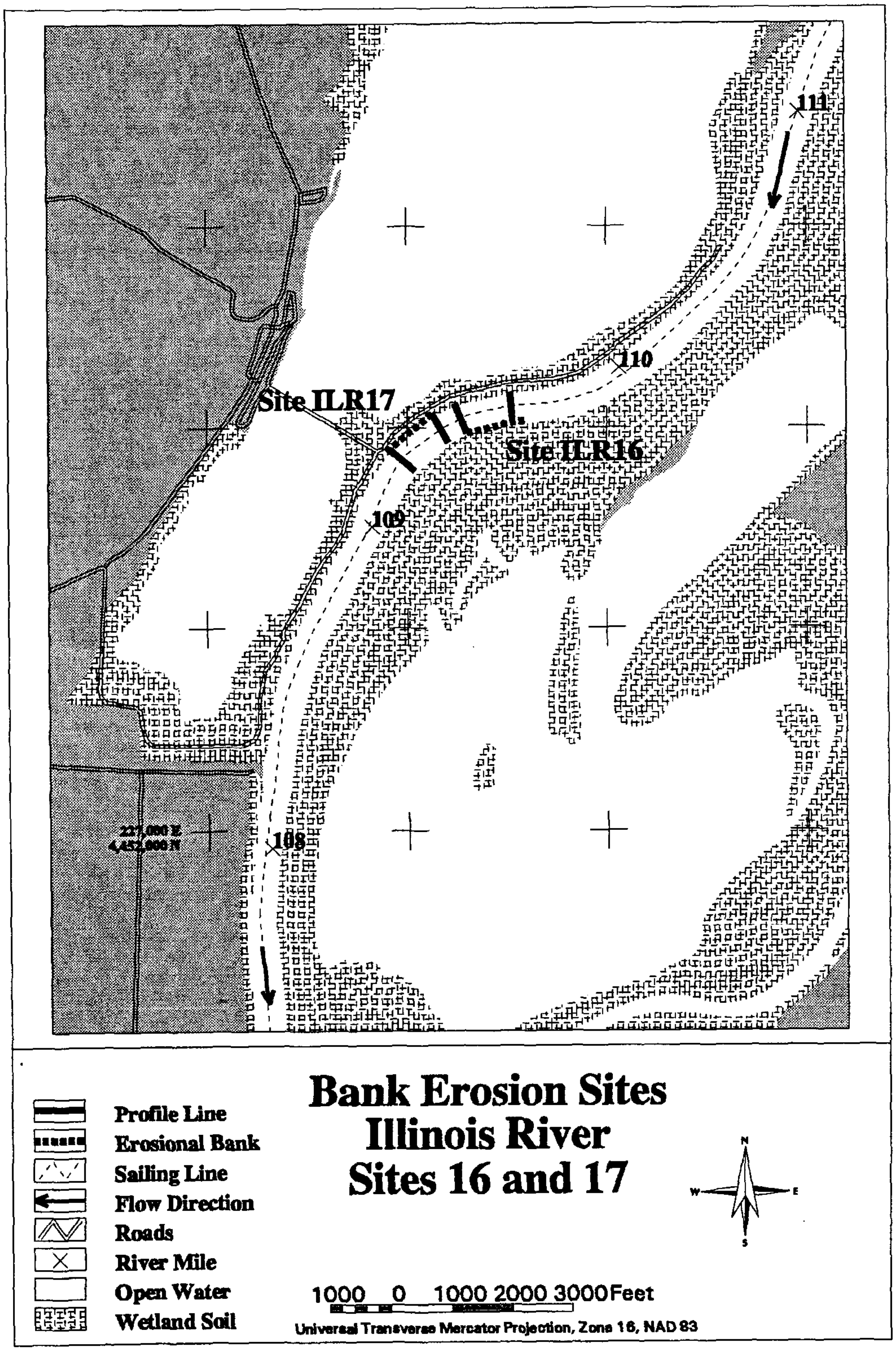


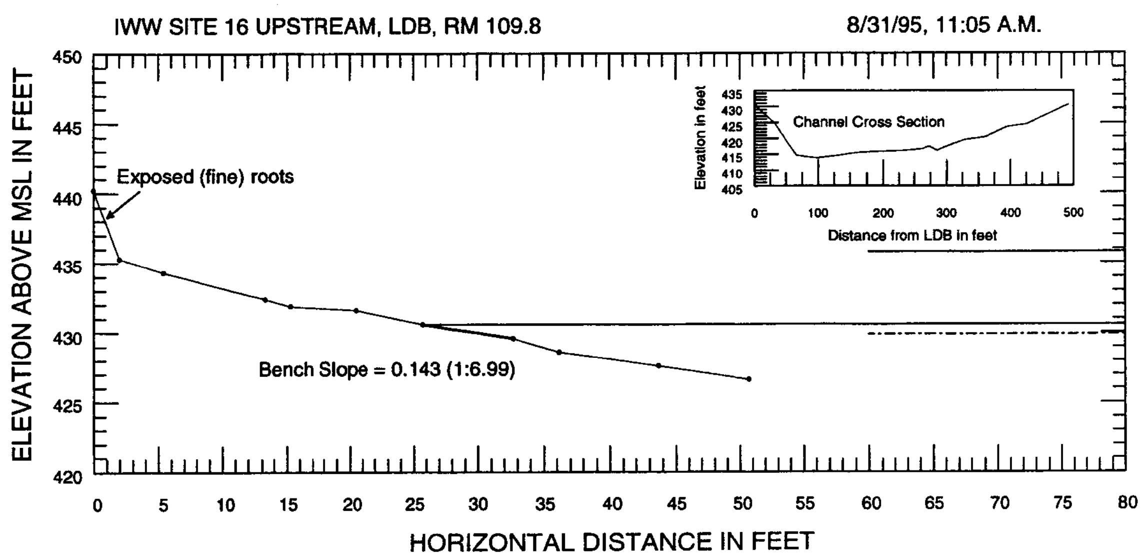
Figure 90. Locations of sites 16 and 17 on the Illinois River

Figure 91. Site 16 on the Illinois River

Figure 92 shows the three measured bank sections and two reduced cross sections. The OHWE is 435.7 ft-msl, and NP is 429.9 ft-msl. The NP elevation corresponds well to a break in the subaqueous bench slope. Water at the OHWE elevation generally reached the base of the scarp or submerged part of the scarp; higher stages (table 31) overtop the bank. Most of the lower scarp and recent sedimentation were observed between NP and OHWE.

At the midsection, the d_{50} varied from 0.011 mm at the top surface of the bank to 0.005 mm at the upper portion of a core sample at a water depth of about 2 feet. The d_{50} of the lower portion of this core sample, 0.015 mm, is similar to that of other materials found on the bank Gradation plots of bank soils and nearshore sediment are presented in appendix C. The detailed cross section and coordinates are shown in appendix D.

Bench slopes varied from lV:7.0H at the upstream section to lV:14.5H at the downstream section. The upstream section and midsections are classified as type 2, and the downstream section is classified as type 3 (figures 22 and 23 and table 9). Rework and transport of bench materials occur at stages within the normal range of pool-level fluctuations. Erosion of in-place soils occurs at stages above OHWE. Seepage and piping affect the extent of failure during recession periods when the river stages can drain.



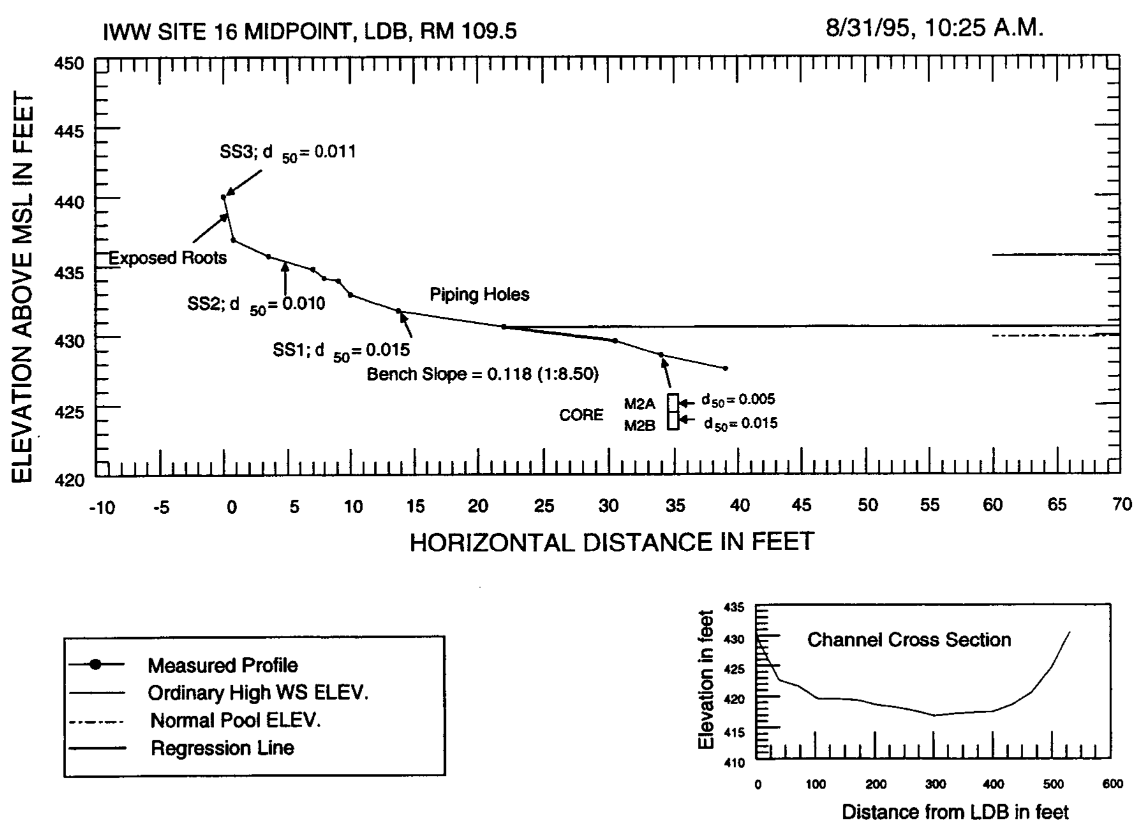


Figure 92. Bank sections at site 16

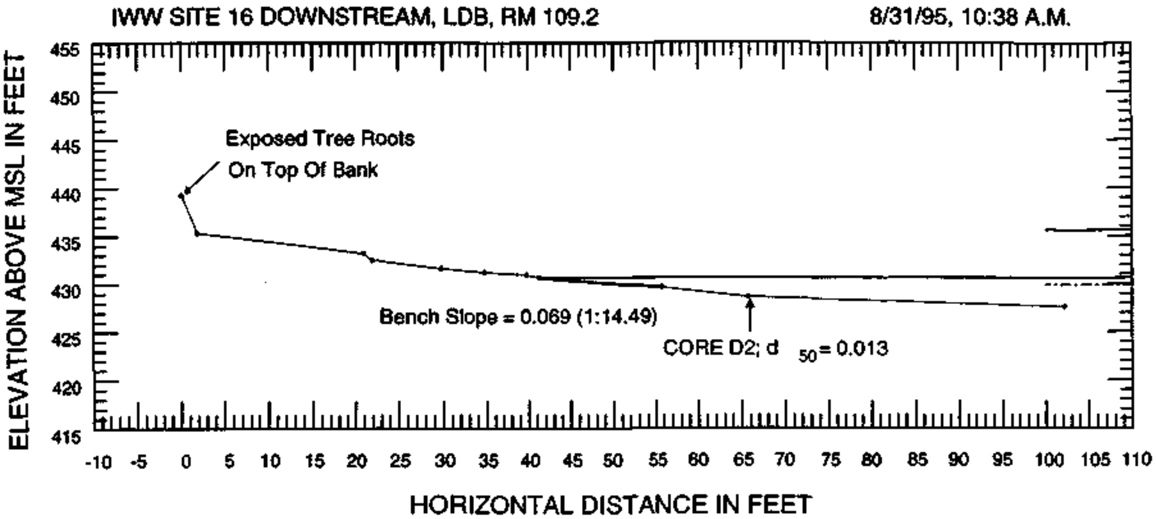


Figure 92. Bank sections at site 16 (concluded)

Table 31. Site 16 Characteristics

Percentage of occurrence	*Stage above msl, ft*	*Topographical features*	*Bank/bed material, mm*
90	430.1	• Bench (underwater) (slopes varied between 1V:14.5H and 1V:7.0H)	• d_{50} (core) varied (0.005-0.015)
75	431.1	• Bench	• d_{50} = 0.015
50	433.7	• Berm/bench (slopes varied between 1V:3.9H and 1V:2.3H)	• d_{50} = 0.010
25	438.1	• Scarp (slopes varied between 1V:0.48H and 1V: 0.26H)	
10	441.5	• Top of the bank	• d_{50} = 0.011
0-9	>441.5		

Note: Gage on the Illinois River near Havana, IL @ RM 119.6 was used for stage histogram. Gage is 10.1 miles away from the site. WSE = 430.6 feet; OHWE = 435.7 feet; and NP = 429.9 feet.

Site 17, La Grange Pool, 8/31/95

This site is located at the outside of the bend across the river from site 16. The whole area s within Anderson Lake Conservation Area. Figure 90 shows the position of the site on a GIS-based map of the Illinois navigation chart, and figure 93 is a photograph of the site.

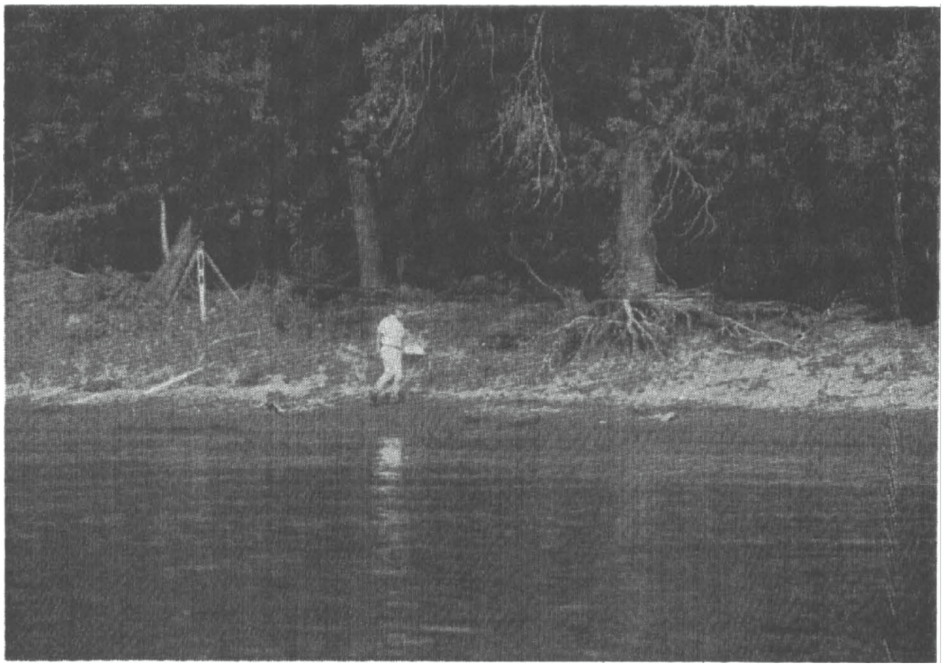
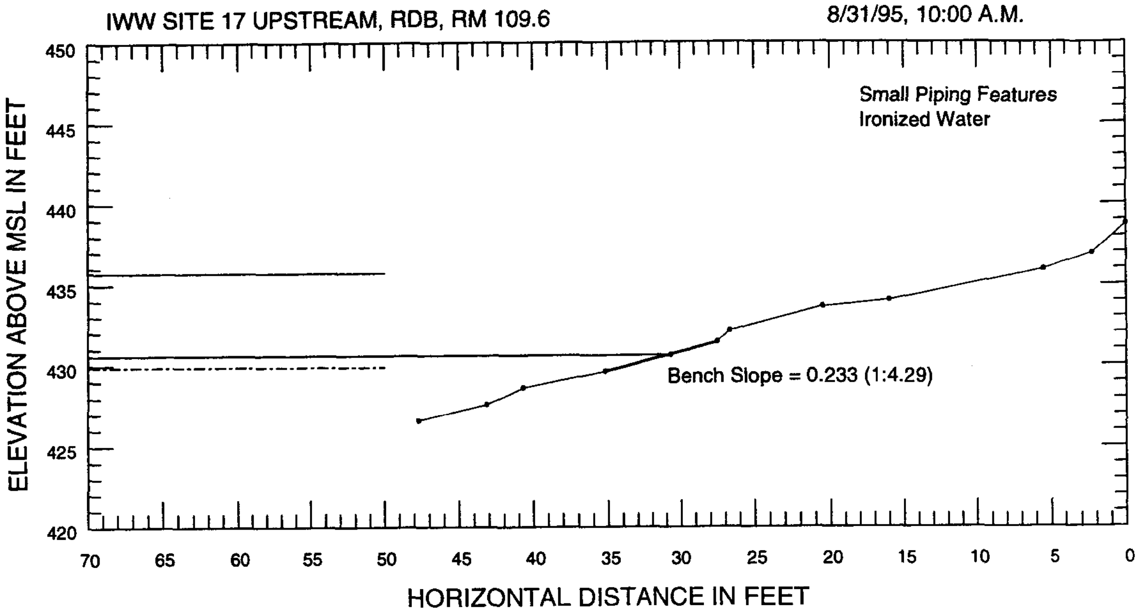


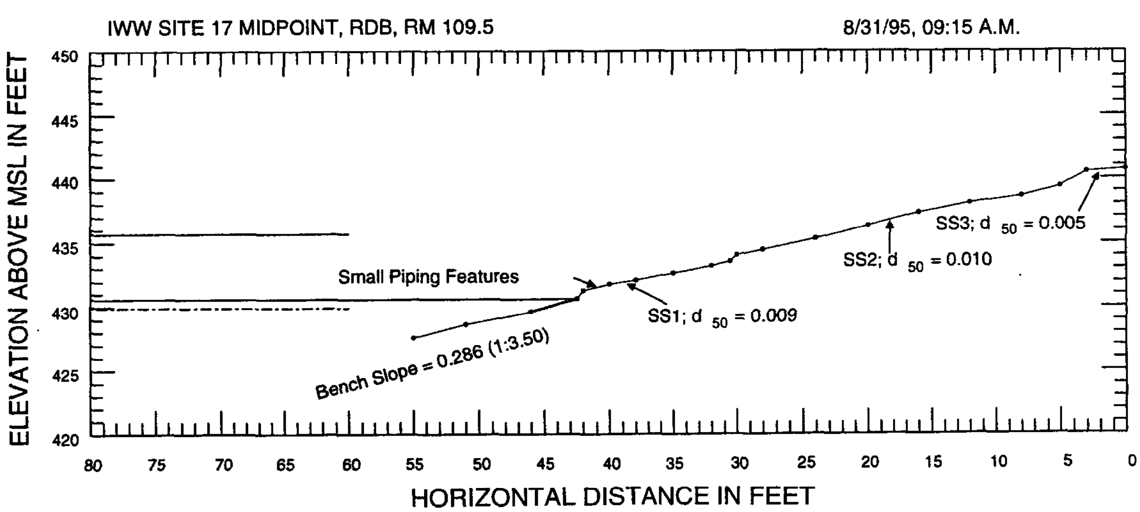
Figure 93. Site 17 on the Illinois River

The site is about 280 feet from the sailing line. This site was described as severely eroded by Hagerty (1988). According to USACOE personnel, this was formerly a dredged material placement site, containing about 8 feet of dredged materials. However, floods apparently have removed all the dredged materials. Seepage flows containing oxidized iron (brownish color) were observed along the bank. Seepage may be attributed to the presence of adjacent Anderson Lake behind this site.

Figure 94 shows the three measured bank sections and two reduced cross sections. The OHWE is 435.7 ft-msl, and NP is 429.9 ft-msl. There is a scarp near the water's edge and downslope from areas of seepage flows; the OHWE elevation is above a zone of seasonal grasses and the OHWE elevation corresponds well to the base of a scarp on the upper portion of the bank. Other stages and corresponding features are given in table 32.

At the midsection, the d_{50} varied from 0.005 mm at the top surface of the bank to 0.009 mm near the water's edge. Bank materials are similar. Gradation plots of bank soils and nearshore sediment are presented in appendix C. The detailed cross section and coordinates are shown in appendix D.





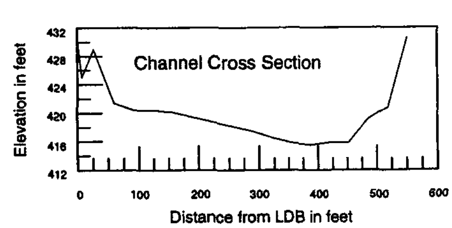


Figure 94. Bank sections at site 17

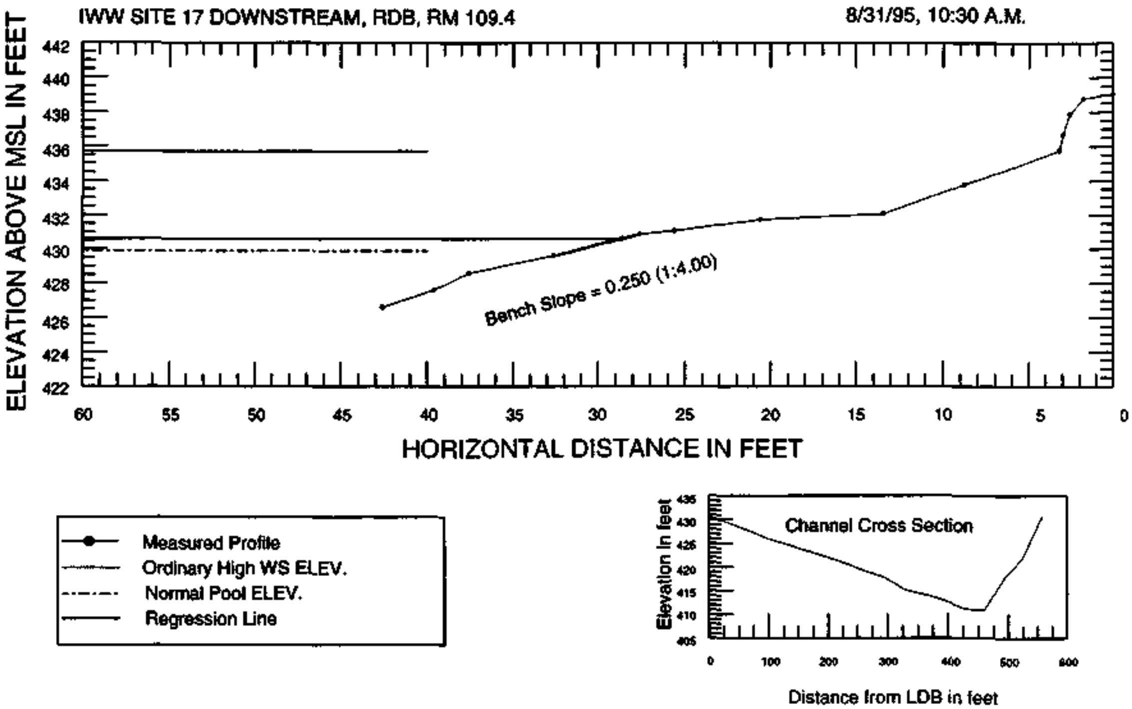


Figure 94. Bank sections at site 17 (concluded)

Table 32. Site 17 Characteristics

Percentage of occurrence	*Stage above msl, ft*	*Topographical features*	*Bank/bed material, mm*
90	430.1	• Bench (underwater) (slopes varied between 1V:4.3H and 1V:3.4H)	
75	431.1	• Bench	• d_{50} = 0.009
50	433.7	• Berm/bench (slopes = 1V:2.8H)	• d_{50} = 0.010
25	438.1	• Scarp (slopes = 1V:O.47H	
10	441.5	• Top of the bank	• d_{50} = 0.005
0-9	>441.5		

Note: Gage on the Illinois River near Havana, IL @ RM 119.6 was used for stage histogram. Gauge is 10.1 miles away from the site. WSE = 430.6 feet; OHWE = 435.7 feet; and NP = 429.9 feet.

Bench slopes varied around 1V:4.0H. Both the upstream section and midsection are classified as type 5, and the downstream section is classified as type 4 (figures 24 and 25 and table 9). Seepage at NP stages could weaken the bench materials, and wave wash could create scarps on the bench. As at site 16, the subaerial bench was moist. Waves and currents at stages within the normal range of pool fluctuations caused erosion on the bench and berm. These forces moved failed soil or recent sediment away from the bank sections also.

Site 18, La Grange Pool, 8/31/95

This site is located on the RDB at RM 94.3. Sugar Creek Island is located on the other side of the river. The mouth of Sugar Creek is located at RM 94.5. The site is located in a crossover between bends. Figure 95 shows the position of the site on a GIS-based map of the Illinois navigation chart, and figure 96 is a photograph of the site.

The site is about 250 feet from the sailing line. Both Bhowmik and Schicht (1980) and Hagerty (1988) observed erosion immediately upstream and downstream from the mouth of Sugar Creek, but these did not indicate erosion at this location. However, scarps and displaced trees were found on the bank in our study. The bank had a thick cover of sand over exposed clay in several places. Dredged material was placed here in the 196Os, according to USACOE personnel. In this 1995 trip, the previously eroded section was covered with sand, shells, and gravel at the water's edge. For comparison purposes, the upstream section was taken from that previously eroded section.

Figure 97 shows the three measured bank sections and a reduced cross section. All three sections were cut by a scarp, but scarp elevations were different. At this site, the OHWE is 433.7 ft-msl, and the NP is 429.9 ft-msl. The scarp was above the OHWE elevation at the upstream section, but the scarp elevations were lower for the midsection and downstream sections. The midsection and downstream section had small scarps in the stage range between the OHWE and NP, but the upstream section did not have such scarps. Table 33 lists the stages with corresponding recurrence frequencies at this site.

At the midsection, the d_{50} varied from 0.016 mm at the top surface of the bank to 0.015 mm at the upper part of a core sample at a water depth of about 2 feet. Gradation plots of bank soils and nearshore sediment are presented in appendix C. The detailed river cross section and coordinates are shown in appendix D.

The bench slopes varied from lV:7.4H at the upstream section to lV:13.0 at the downstream sections. The subaqueous bench dropped off quickly at the midsection at this site. Both the upstream and downstream sections are classified as type 4, but the midsection is classified as a combination of types 2 and 4 (figures 2 and 4 and table 9). The bank crest was

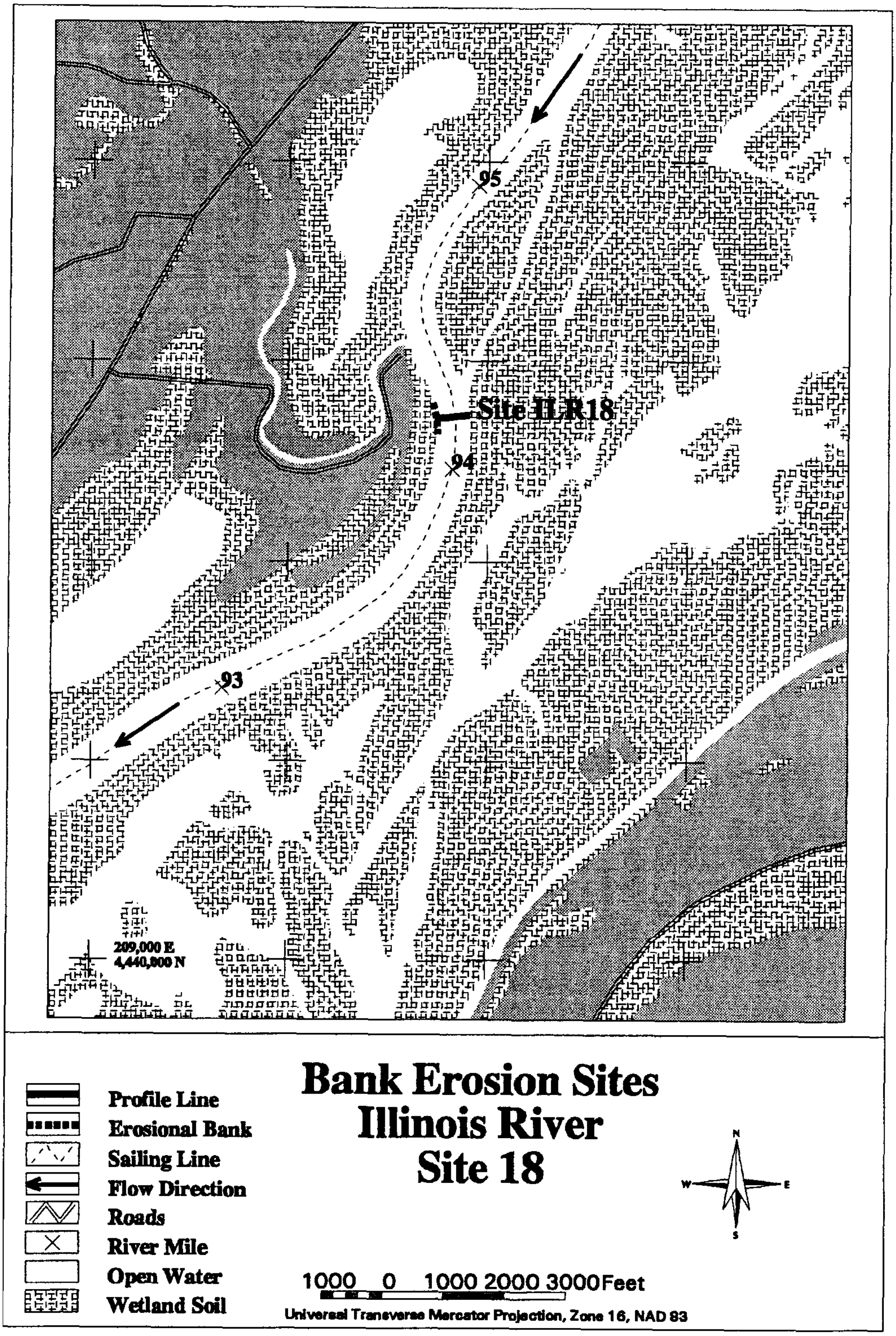


Figure 95. Location of site 18 on the Illinois River

Figure 96. Site 18 on the Illinois River

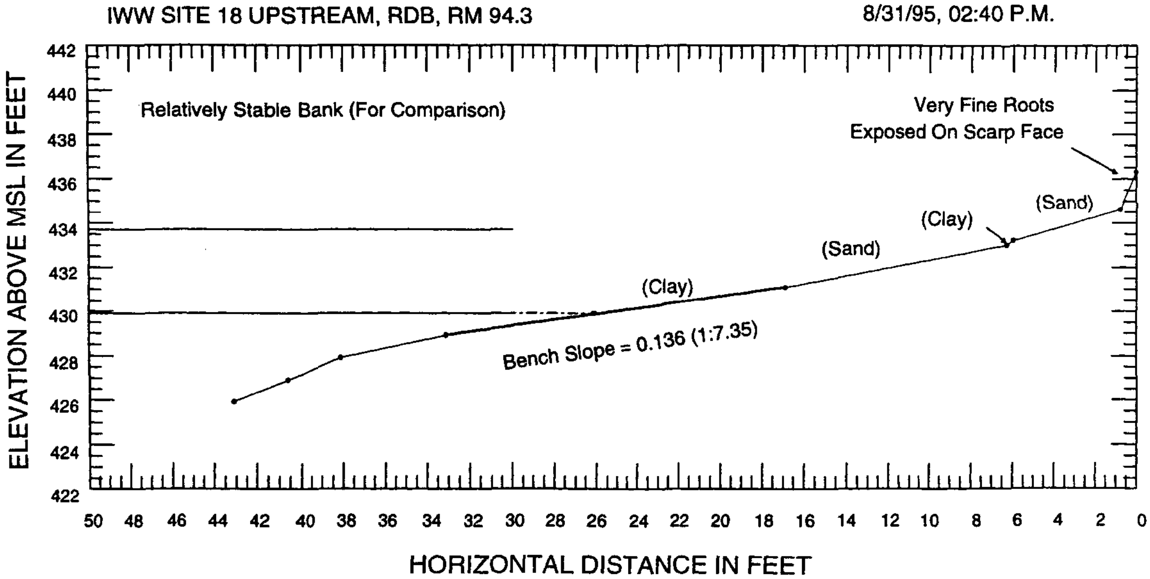


Figure 97. Bank sections at site 18

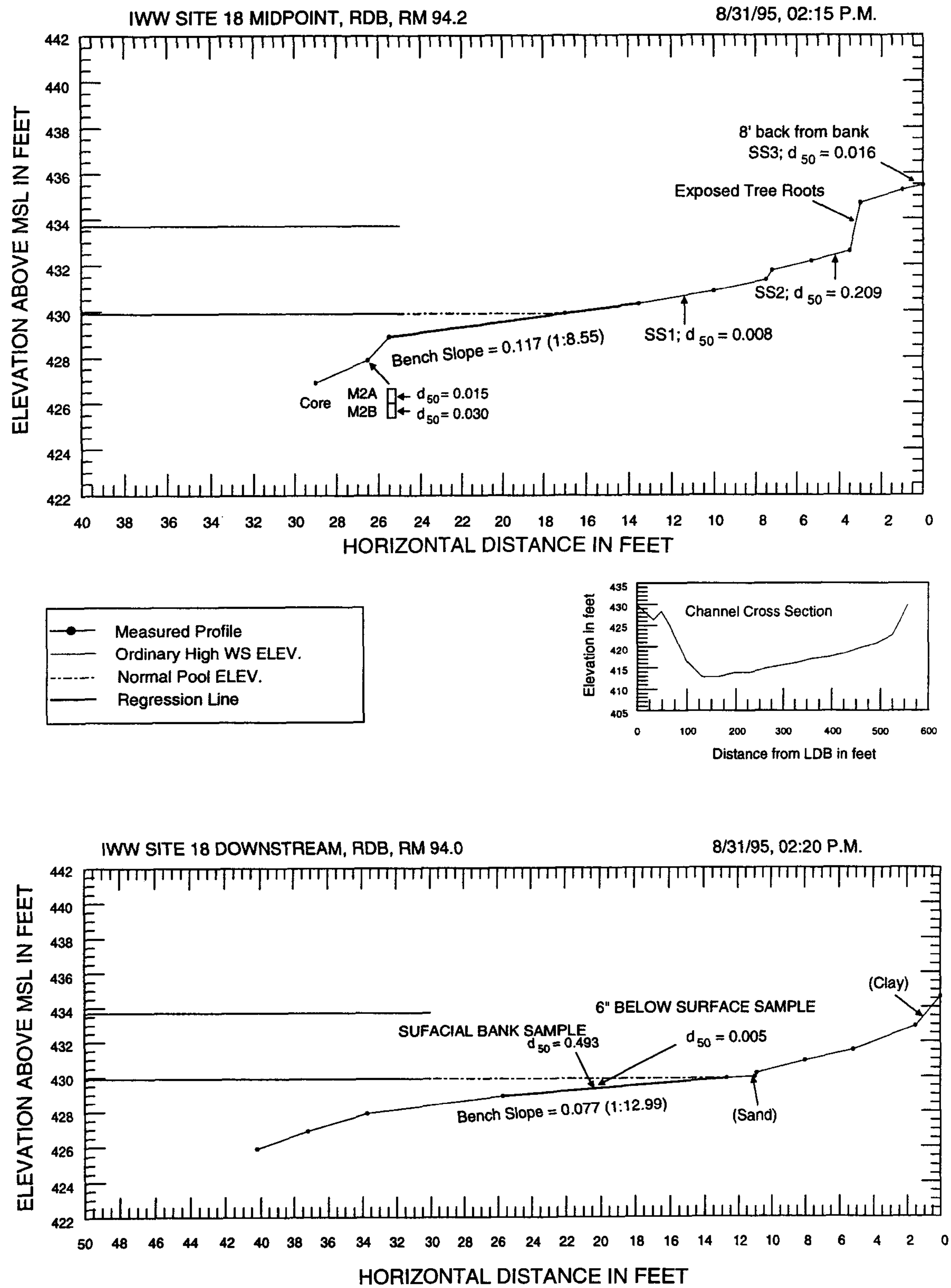


Figure 97. Bank sections at site 18 (concluded)

Table 33. Site 18 Characteristics

Percentage of occurrence	*Stage above msl, ft*	*Topographical features*	*Bank/bed material, mm*
90	429.4	• Bench (underwater) (slopes varied between IV: 13.0H and 1V:7.4H)	• d_{50} (core) varied (0.015-0.030) • d_{50} varied (0.005-0.493)
75	429.6	• Bench (underwater)	
50	430.2	• Bench	
25	433.6	• Bench/berm (slope varied between 1V:3.4H and 1V:3.3H)	• d_{50} = 0.209
10	438.15	• Top of the bank • Scarp (slopes varied between 1V:0.88H and 1V:0.24H)	• d_{50} = 0.016
0-9	>438.15		

Note: Gage on the Illinois River near Beardstown, IL @ RM 88.3 was used for stage histogram. WSE = 429.9 feet; OHWE = 433.7 feet; and NP = 429.9 feet.

covered by dense vegetation, and roots from that vegetation provided additional bonds to bank materials. The bank showed vertical cracks, which apparently were caused by basal scour. Sandy materials underneath the scarp seeped out after rapid stage recession. Waves and currents can rework and transport failed soils or recent sediments at stages within the normal range of pool-level fluctuations.

Site 19, La Grange Pool, 8/31/95

This site is located on the RDB at RM 91.2 outside a gentle bend. The Peabody Coal Company barge terminal is at RM 91.7, and the Farmers Grain Company barge terminal is at RM 91.1. Both terminals are on the RDB. Figure 98 shows the position of the site on a GIS-based map of the Illinois navigation chart, and figure 99 is a photograph of the site.

The site is about 310 feet from the sailing line. A Chicago Burlington & Quincy railroad line is located just behind the site. Hagerty (1988) noted this site as an erosion site, but it appeared to be stable when Bhowmik and Schicht (1980) surveyed. A depression between the bank and the railroad embankment will retain floodwater or rainwater and cause seepage to the bank. The depression was a borrow pit for the construction of the railroad embankment. Some large, dead trees and exposed roots were observed. Velocities were relatively high at a close distance from the shore.

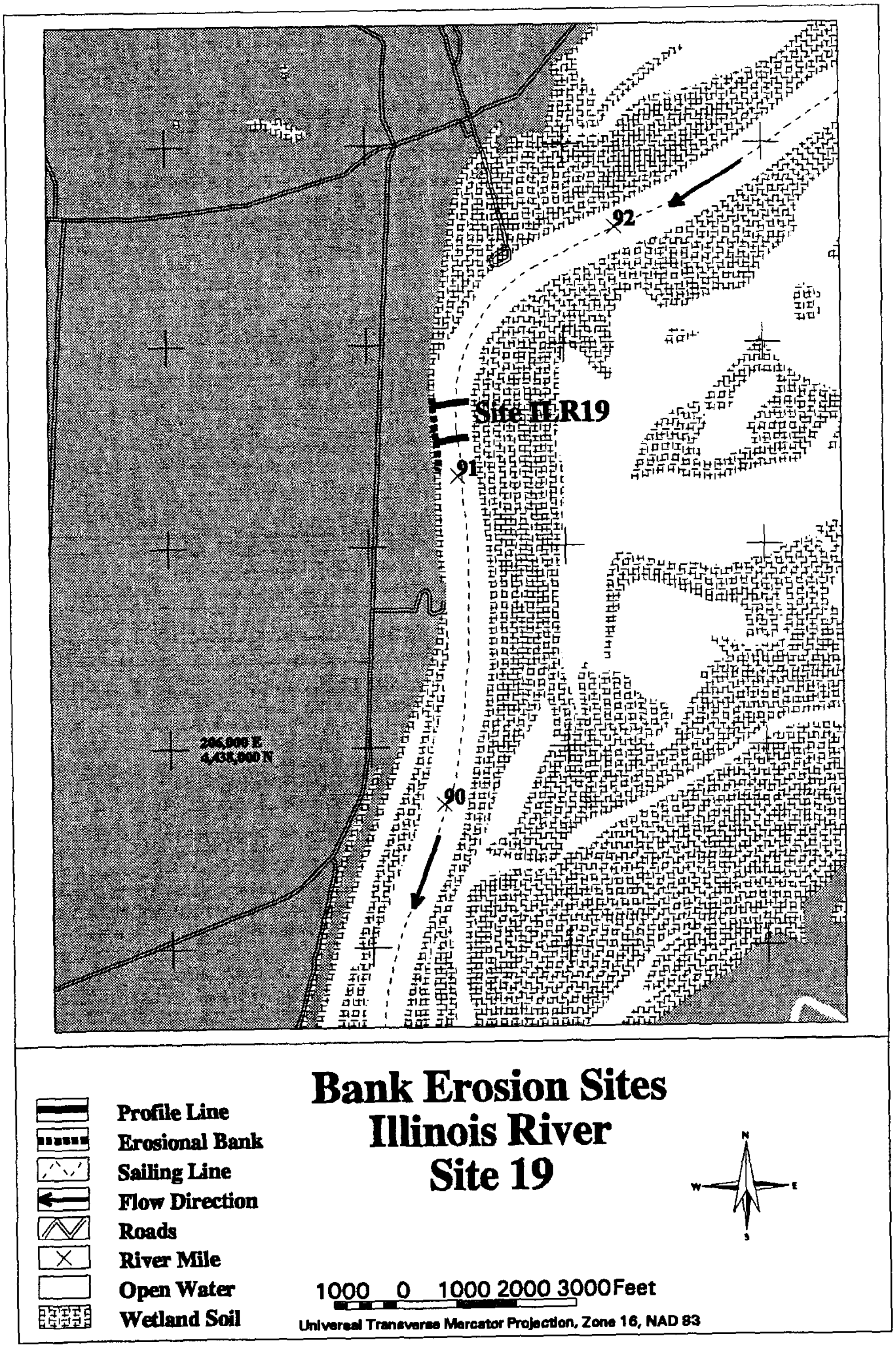


Figure 98. Location of site 19 on the Illinois River

Figure 99. Site 19 on the Illinois River

A scarp approximately 4-6 feet high was present. The lower bank and berm area contained several scarps and a moist soil layer at the toe. Some sand deposition was found on the narrow bench area. Figure 100 shows the three measured bank sections and a reduced cross section. The upstream bank section was extended approximately 160 feet to include the top of the embankment for the Chicago Burlington & Quincy Railroad. The OHWE is 433.3 ft-msl, and NP is 429.9 ft-msl. The OHWE elevation is at the base of the large scarp. The stage at the time of the field visit was at NP level.

At the midsection, the d_{50} varied from 0.027 mm at the top surface of the bank to 0.014 mm at the upper part of a core sample at a water depth of about 2 feet (table 34). Gradation plots of bank soils and nearshore sediment are presented in appendix C. The detailed river cross section and coordinates are shown in appendix D.

Bench slopes varied from 1V:4.8H at the upstream section to 1V:10H at the downstream section. This site is classified as a combination of types 2 and 4 (figures 22 and 24 and table 9). Seepage initiated bank failure; rework and transport of failed soils occurred at stages within the normal pool-level fluctuations. Traffic-induced disturbances should be considered because of the closeness to the barge terminal. Rapid drop of depth at mid- and downstream sections may reflect such a factor.

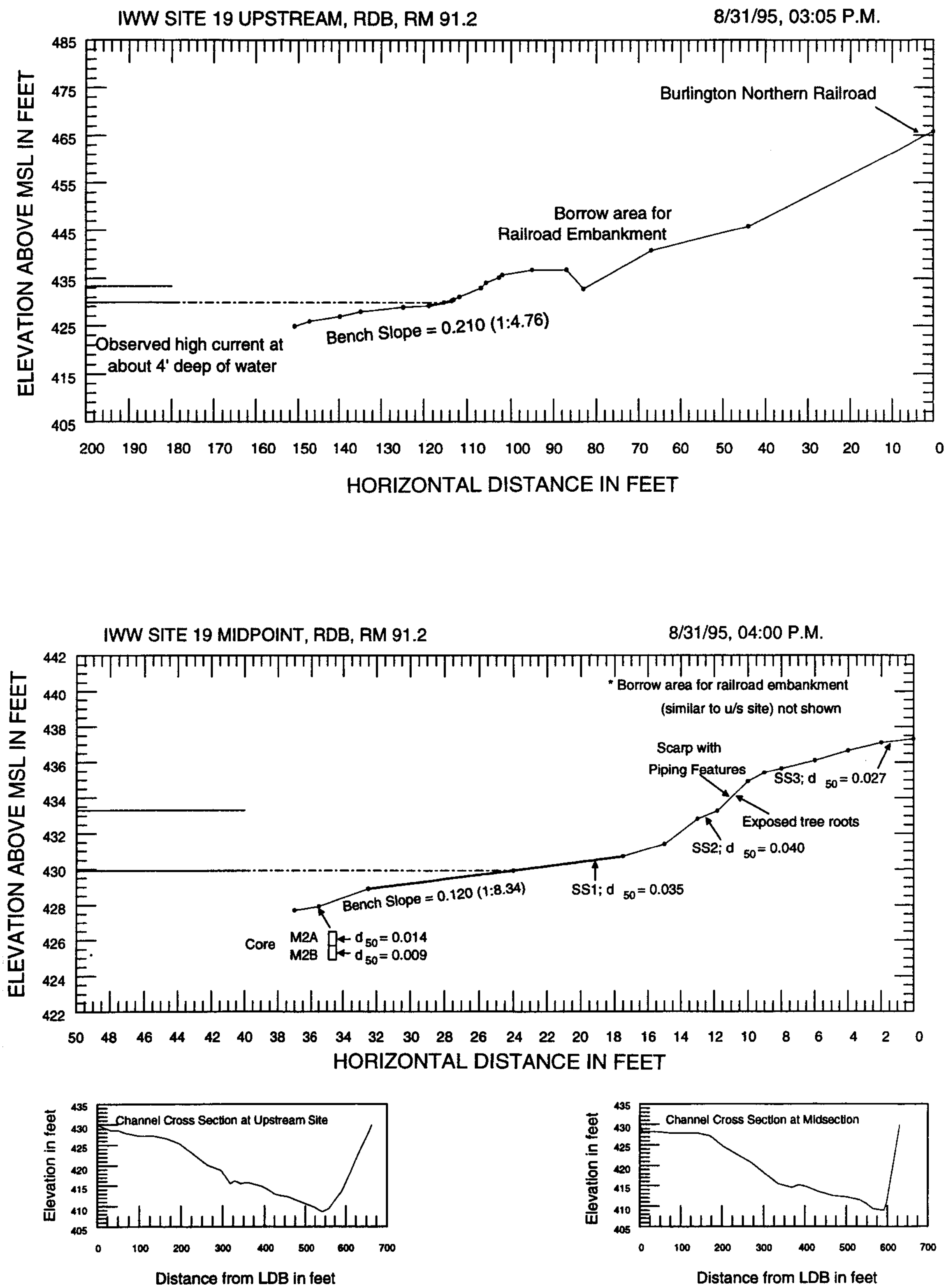


Figure 100. Bank sections at site 19

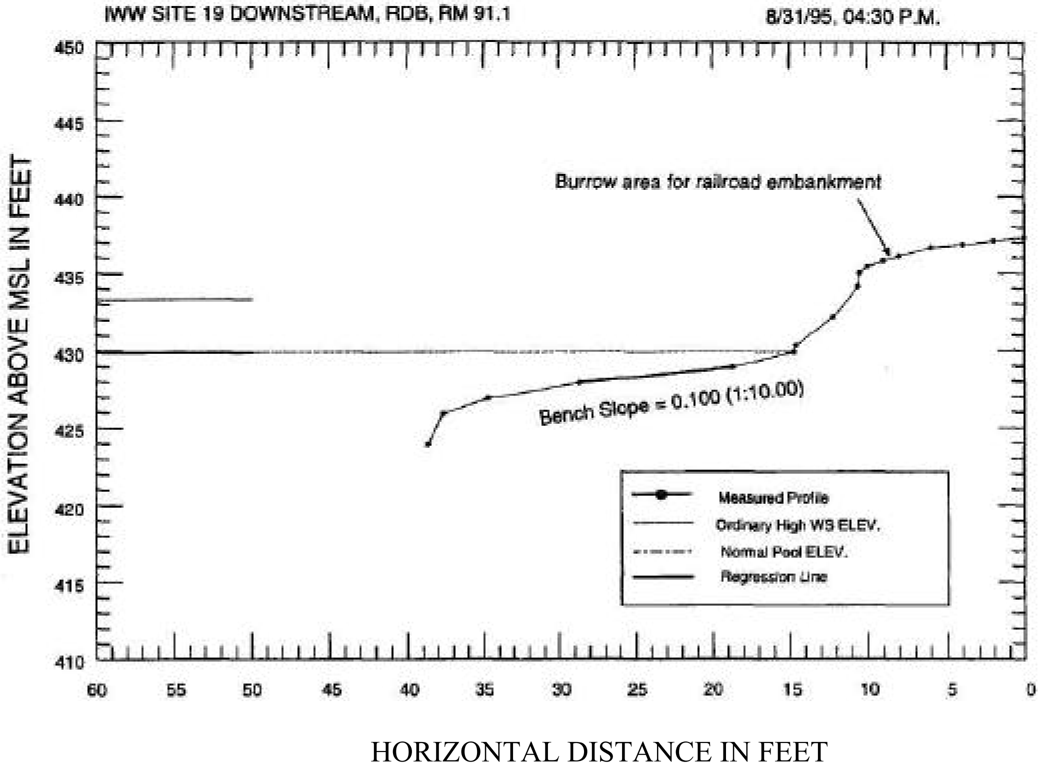


Figure 100. Bank sections at site 19 (concluded)

Table 34. Site 19 Characteristics

Percentage of occurrence	*Stage above msl,ft*	*Topographical features*	*Bank/bed material, mm*
90	429.4	• Bench (underwater) (slopes varied between 1V:10H and 1V:4.8H)	• d_{50} (core) varied (0.009-0.014)
75	429.6	• Bench (underwater)	
50	430.2	• Bench	• d_{50} = 0.035
25	433.6	• Bench/berm/scarp • Berm slope = 1V:2.2H • Scarp slope = 1V: 1.1H	• d_{50} = 0.040
10	438.15	• Top of the bank	• d_{50} = 0.027
0-9	>438.15		

Note: Gage on the Illinois River near Beardstown, IL @ RM 88.3 was used for stage histogram. WSE = 429.9 feet; OHWE = 433.3 feet; and NP = 429.9 feet.

Site 20, Alton Pool, 8/31/95

This site is located on the RDB at RM 79.4 just downstream of La Grange Lock and Dam at RM 80.2. The lock is on the RDB. The site is in a straight reach. Figure 101 shows the position of the site on a GIS-based map of the Illinois navigation chart, and figure 102 is a photograph of the site.

The navigation channel is fairly close to site 20; the bank is about 230 feet from the sailing line. No major tributary enters the river at this location. The opposite side of the river is used as a mooring area as barges wait for lockage. Bhowmik and Schicht (1980) noted erosion on both sides of the river downstream from the lock and dam. Hagerty (1988) selected this site for further survey and indicated scarps about 12-14 feet high. In 1995, the face of the bank was bare, and the upper bank was covered with short grasses. A fairly clear wet/dry line was present at the lower portion of the bank. The subaqueous bench dropped very quickly toward the channel. The land use on the top of the bank was agriculture (corn).

Figure 103 shows the three measured bank sections and two reduced cross sections. The bench narrowed at the downstream section. The OHWE and NP elevations were not available for the Alton Pool, but analysis of the historical data indicated that the river stage at the time of the survey had a recurrence frequency of about 90 percent. As shown in table 35, the bare bank area lies between the NP level and the 50 percent recurrence frequency stage (425.7 ft-msl).

At the midsection, the d50 varied from 0.023 mm at the top surface of the bank to 0.004 mm near the water's edge. Seepage water quickly filled a trench dug on the bank (figure 102) even though the bank material was hard and cohesive. Gradation plots of bank soils and nearshore sediment are presented in appendix C. The detailed river cross section and coordinates are shown in appendix D.

Table 35. Site 20 Characteristics

Percentage of occurrence	*Stage above msl, ft*	*Topographical features*	*Bank/bed material, mm*
90	420.8	• Bench (slopes varied between 1V: 15.9H and 1V:5.4H)	• d_{50} = 0.004
75	422.2	• Bench/berm	
50	425.7	• Scarp/bench	• d_{50}= 0.11
25	430.7	• Berm	
10	435.2	• Scarp	
0-9	>435.2	• Top of the bank/Scarp	• d_{50} = 0.023

Note: Tail water gage of La Grange Pool @ RM 80.2 was used for stage histogram. WSE = 420.6 feet; OHWE, NA; and NP, NA.

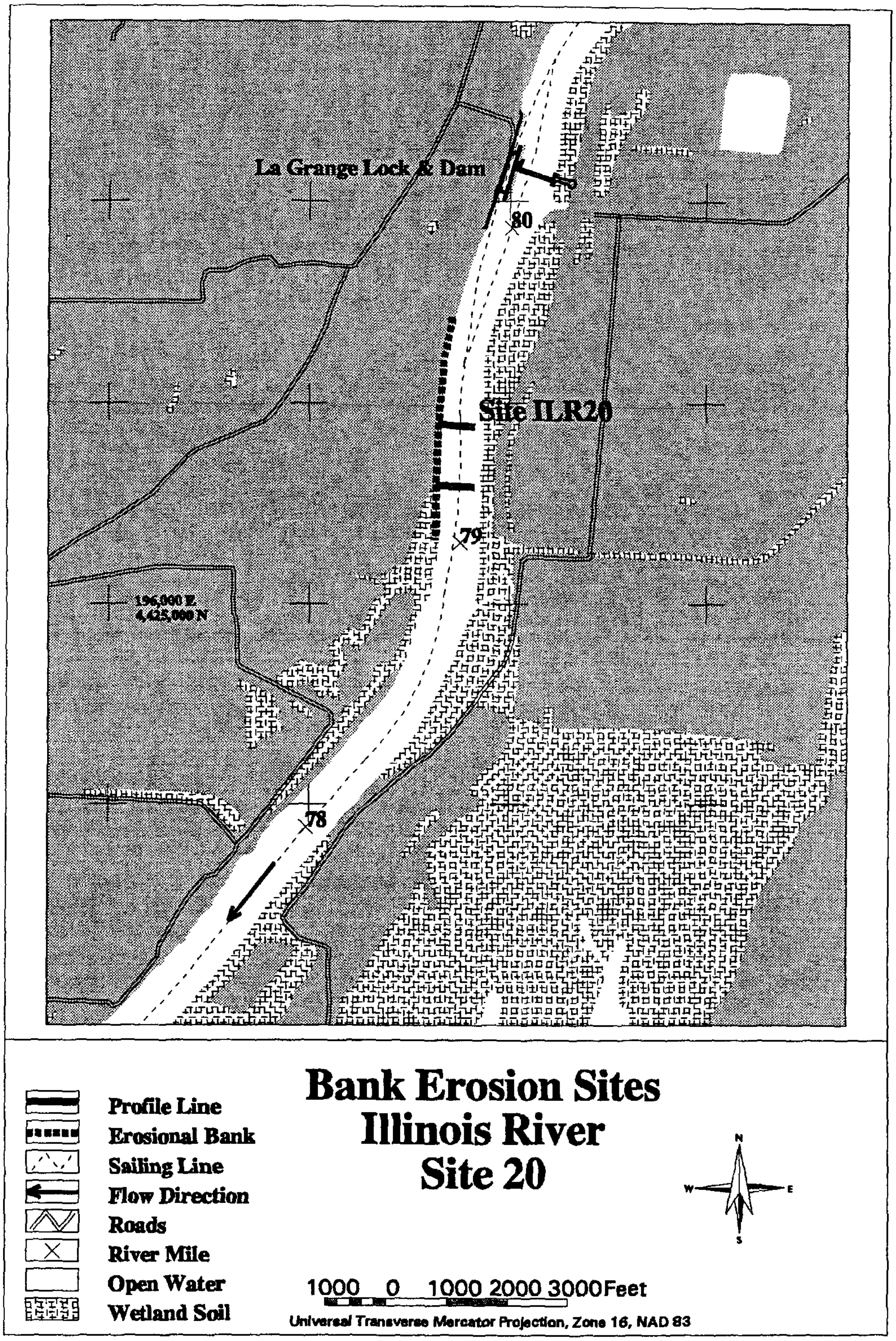


Figure 101. Location of site 20 on the Illinois River

Figure 102. Site 20 on the Illinois River

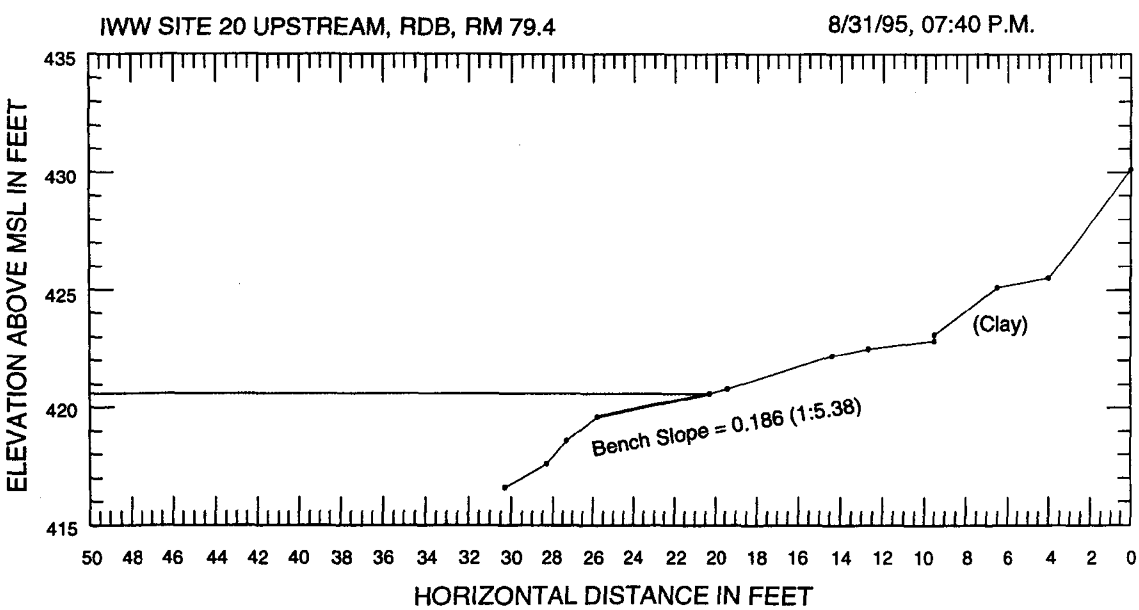
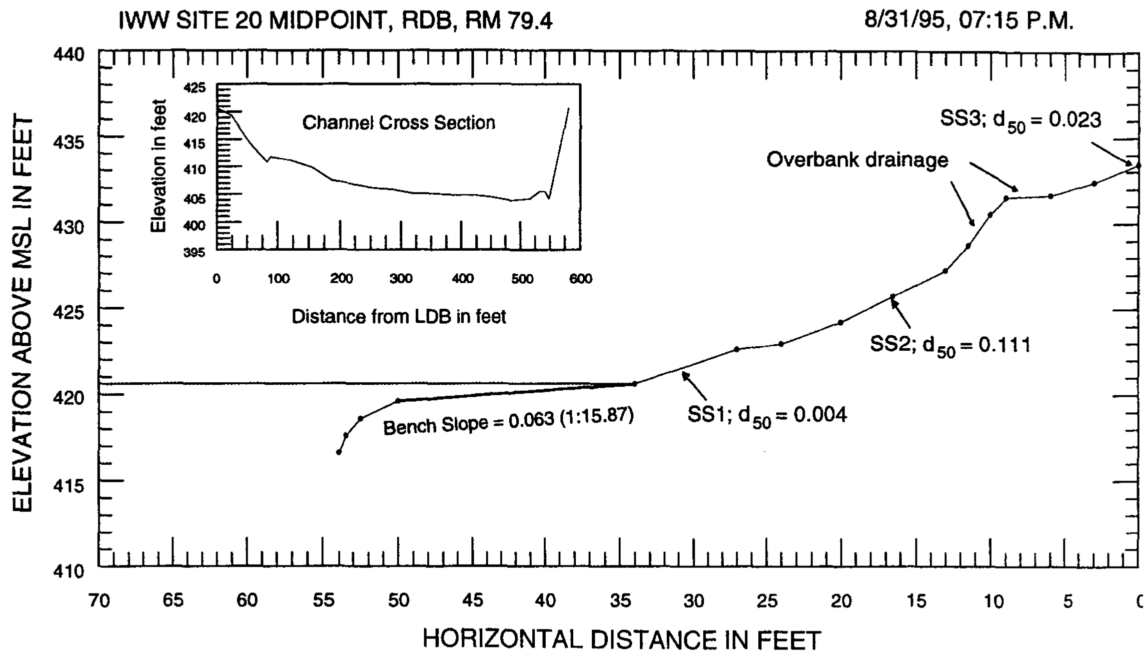


Figure 103. Bank sections at site 20



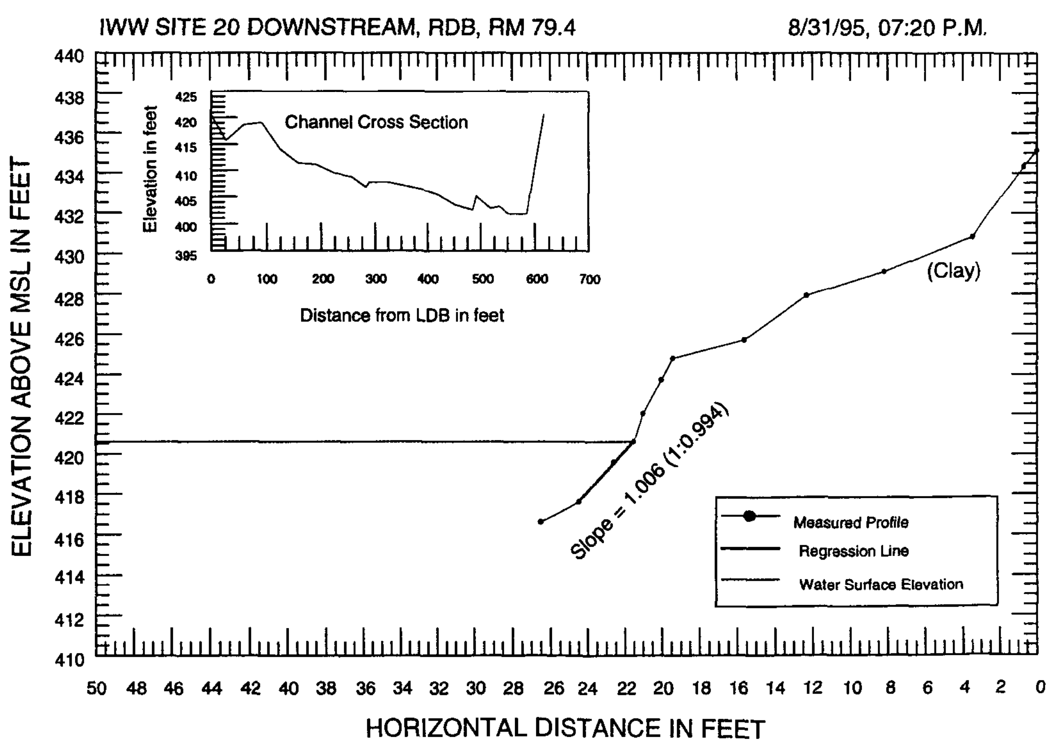


Figure 103. Bank sections at site 20 (concluded)

Bench slopes varied from lV:5.4H to lV:15.9H to lV:0.99H from upstream to downstream sections. This site can be classified as type 2 (figure 22 and table 9). Traffic approaching the La Grange Lock and Dam gets close to this site. High velocity flows released from the lock of the La Grange Lock and Dam, and turbulence induced by navigation traffic appeared to be the major causes of erosion at this site, but seepage effects also appeared to be significant.

Site 21, Alton Pool, 9/1/95

This site is on the RDB at RM 61.7, in a straight reach with the navigation channel close to this bank. According to the navigation chart, there is a wing dam field on the LDB at RM 61.9. Surrounding structures include a bridge at RM 61.4 and a slough about 200 feet behind the bank at this site. Figure 104 shows the position of the site on a GIS-based map of the Illinois navigation chart, and figure 105 is a photograph of the site.

The navigation channel is close to this site; the bank is about 230 feet from the sailing line. A pumping station is on the opposite bank, and there are several wing dams upstream in this reach. Bhowmik and Schicht (1980) did not note erosion in 1978, but Hagerty (1988) observed erosion around RM 61.9 on this bank. Silver maples are growing on the edge of the bank. Slaked blocks were mantled with grass and trees; tree roots extended out on the scarp.

Seasonal grasses were growing on the upper portion of the bank face. A bare bench with springs coming out of clay layers extended from the failed soil blocks to the water's edge. Dead trees were present on the upper part of the bench.

Figure 106 shows the three measured bank sections and a reduced cross section. The bank sections at the midsection differs from the up- or downstream sections. The stage at the time of the survey corresponded to approximately 90 percent recurrence frequency. The scarps observed in the upstream and downstream sections were present in the range of stage fluctuation between 50 percent and 25 percent (424.5 and 429.1 feet, respectively, see table 36); this was also the range of scarp in the midsection.

At the midsection, the d_{50} was 0.025 mm at the top surface of the bank. The d_{50} from the core samples at the downstream section was 0.046 at 1 foot and 0.032 at 2 feet of water depth. Gradation plots of bank soils and nearshore sediment are presented in appendix C. The detailed river cross section and coordinates are shown in appendix D.

Bench slopes varied from lV:10.5H to lV:7.4H. The upstream and downstream sections were classified as type 5, and the midsection was classified as Type 4 (figure 24 and 25 and table 9). Wave wash apparently produced some small scarps on the bench area. Springs and seepage weakened the bench soils and made them susceptible to wave erosion. Currents at high stages or during floods can erode in-place bank soils.

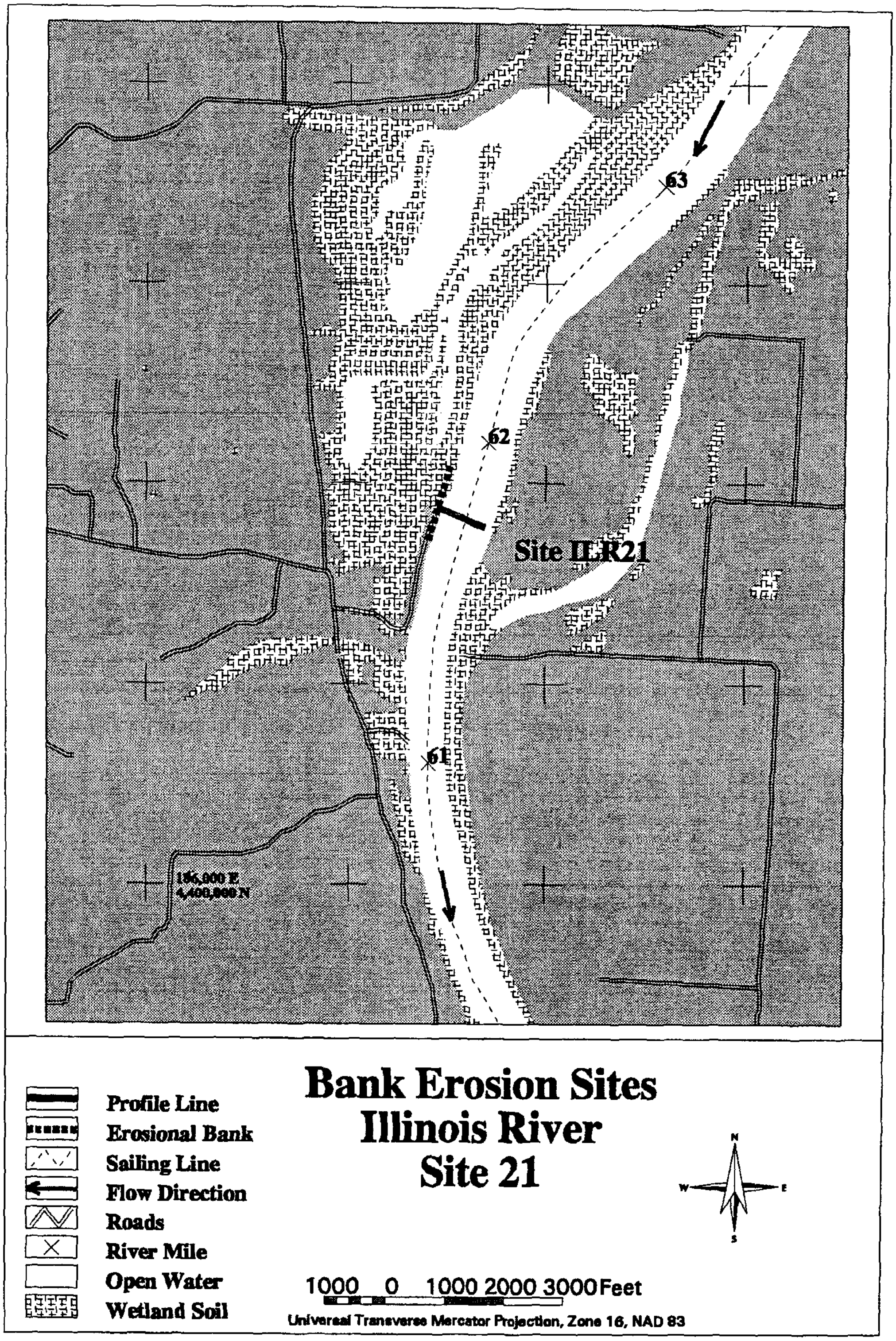


Figure 104. Location of site 21 on the Illinois River

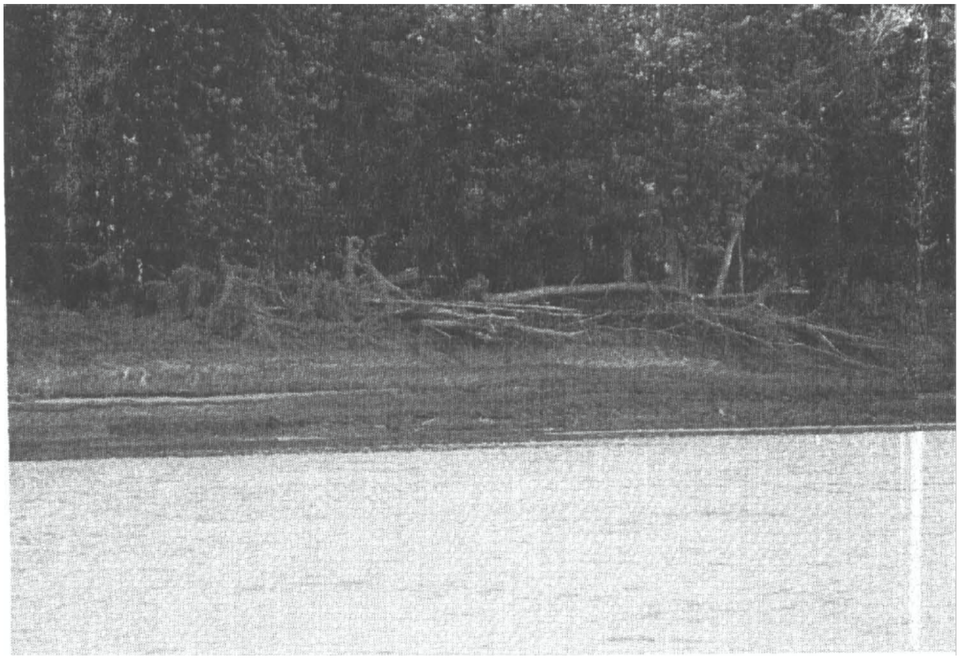


Figure 105. Site 21 on the Illinois River

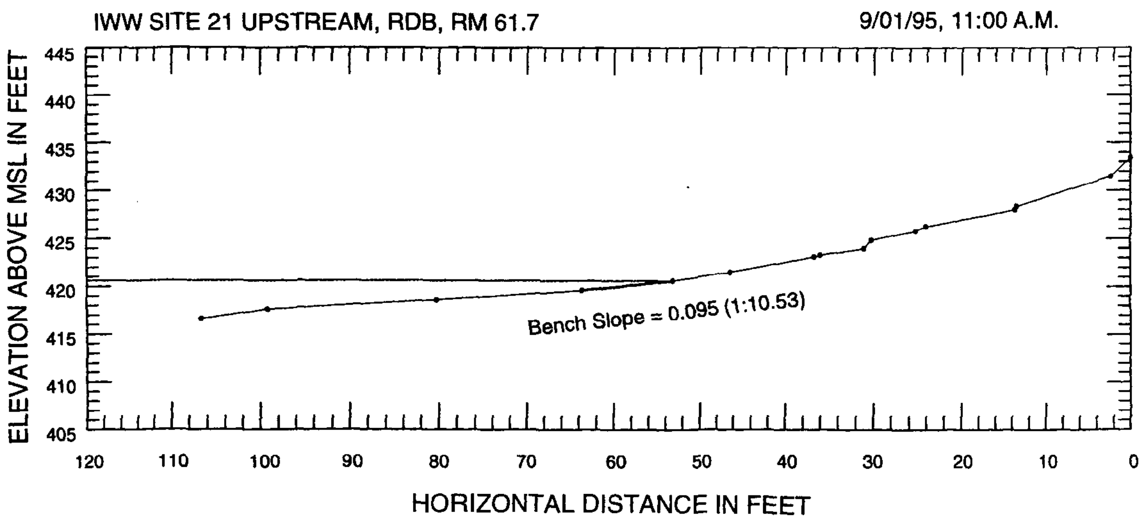
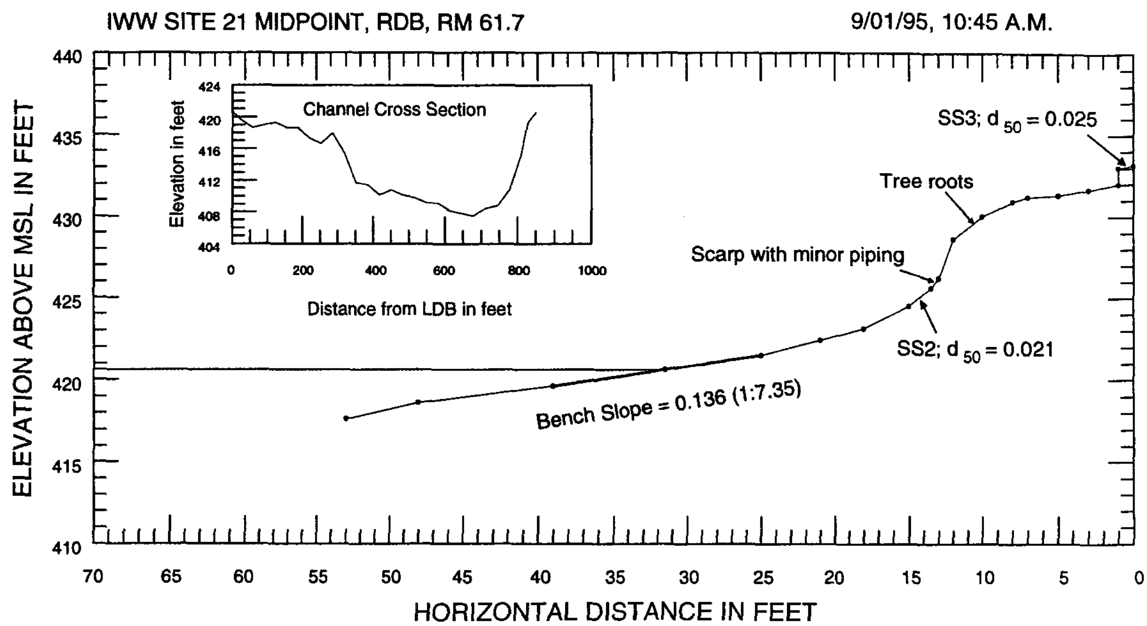


Figure 106. Bank sections at site 21



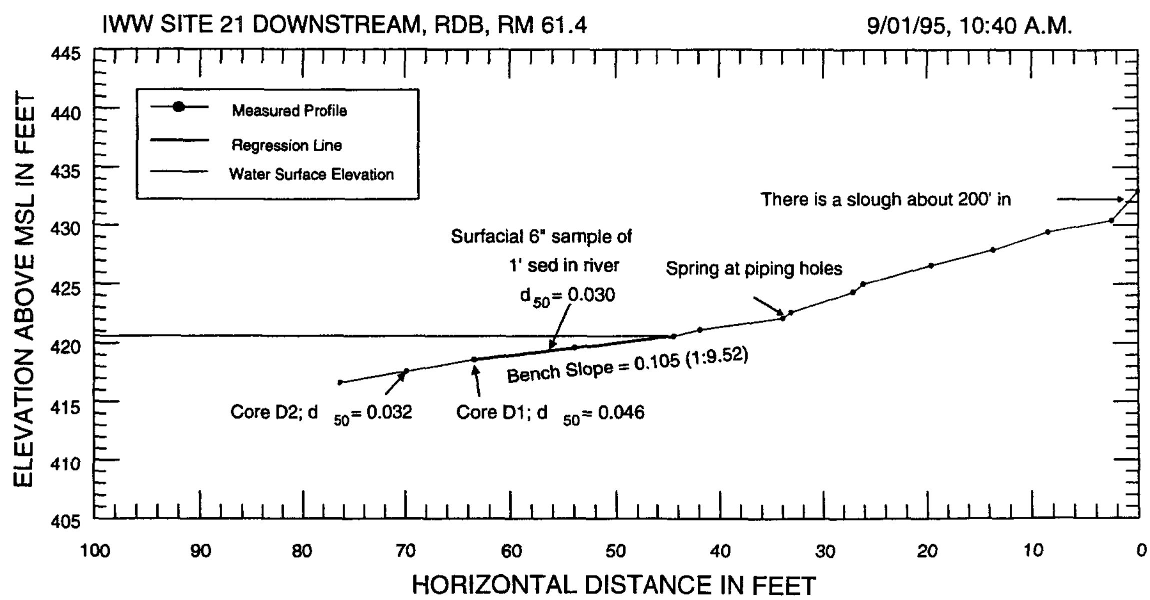


Figure 106. Bank sections at site 21 (concluded)

Table 36. Site 21 Characteristics

Percentage of occurrence	*Stage above msl,ft*	*Topographical features*	*Bank/bed material, mm*
90	420.2	• Bench (underwater) (slopes varied between 1V:1O.5H and 1V:7.4H)	• d_{50} (core) varied (0.032-0.046)
75	421.2	• Bench	• d_{50} = 0.030
50	424.5	• Bench/berm	• d_{50} = 0.021
		• Berm (slope = 1V: 1.6H)	
25	429.1	• Scarp (slope vary between 1V:lH and 1V:0.42H)	
10	433.7	• Top of the bank	• d_{50} = 0.025
0-9	>433.7		

Note: Gage on the Illinois River near Valley City, IL @ RM 61.3 was used for stage histogram. WSE = 420.6 feet; OHWE, NA; and NP; NA.

Site 22, Alton Pool, 9/1/95

This site is located on the RDB at RM 45.1. The reach from RM 44 to 47 can be considered a straight reach typical of the Illinois River. Buckhorn Island is located upstream at RM 46.1. Figure 107 shows the position of the site on a GIS-based map of the Illinois navigation chart, and figure 108 is a photograph of the site.

The navigation channel is close to site 22; the bank is about 300 feet from the sailing line. No major tributary enters the river at this location. Neither Bhowmik and Schicht (1980) nor Hagerty (1988) observed erosion at this location. A wing dam field exists, on the RDB at RM 45.5, where Hagerty (1988) noted erosion.

A soybean field was behind the top of the bank. The upper bank was covered by a zone of dense grasses with some tall matured trees. The grass zone ended at a scarp about 12-18 inches high. Below the scarp, a bench was composed of very soft, silty soil with many peds on the silt surface. The bench was fairly moist.

Figure 109 shows the three measured bank sections and a reduced cross section. The stage at the time of measurement corresponded approximately to the 85 percent recurrence frequency. The 50 and 25 percent recurrence stages (table 37) are 422.4 and 425.9 ft-msl, respectively. The base of the scarp at the end of the weed zone was about 422.4 ft-msl.

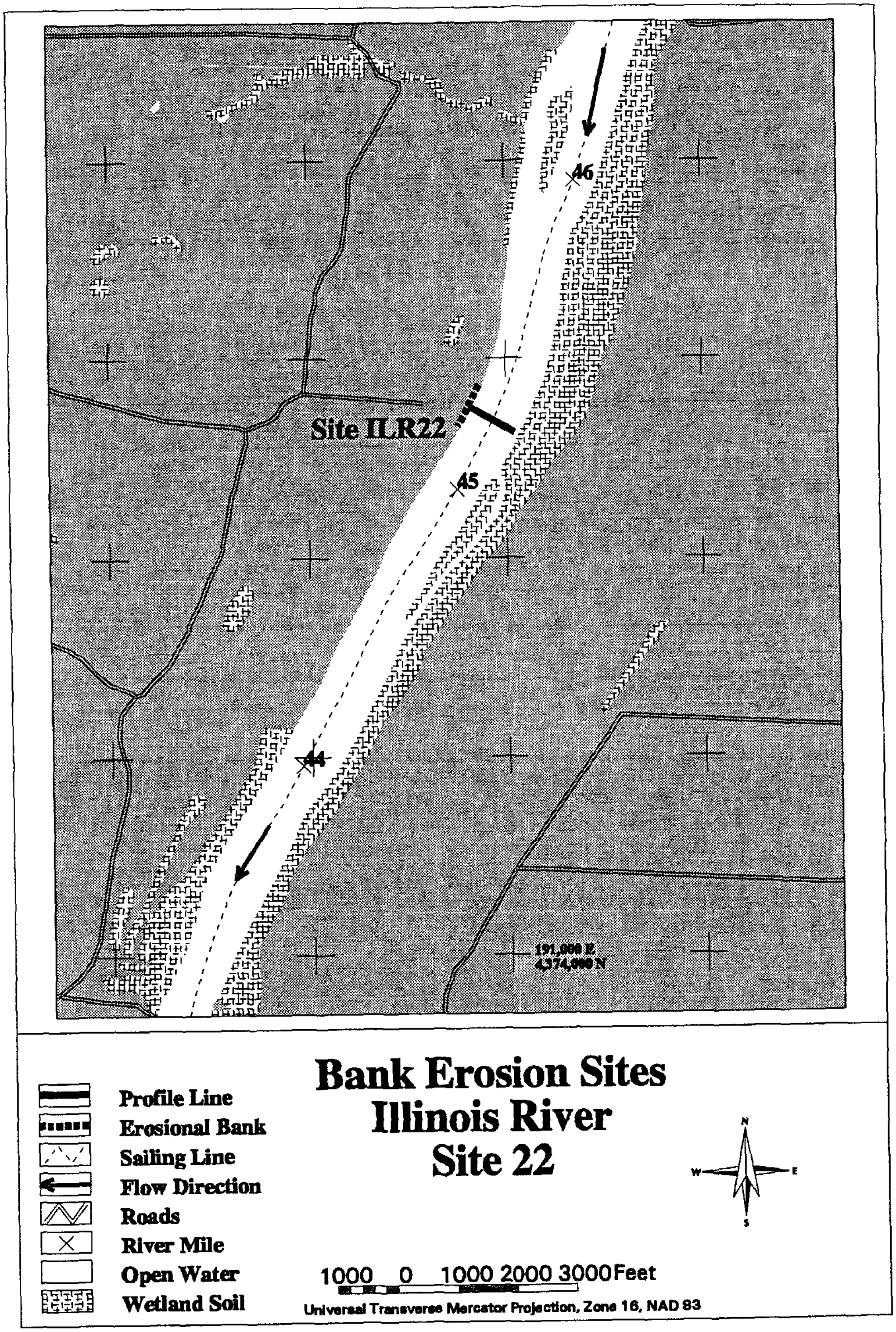


Figure 107. Location of site 22 on the Illinois River

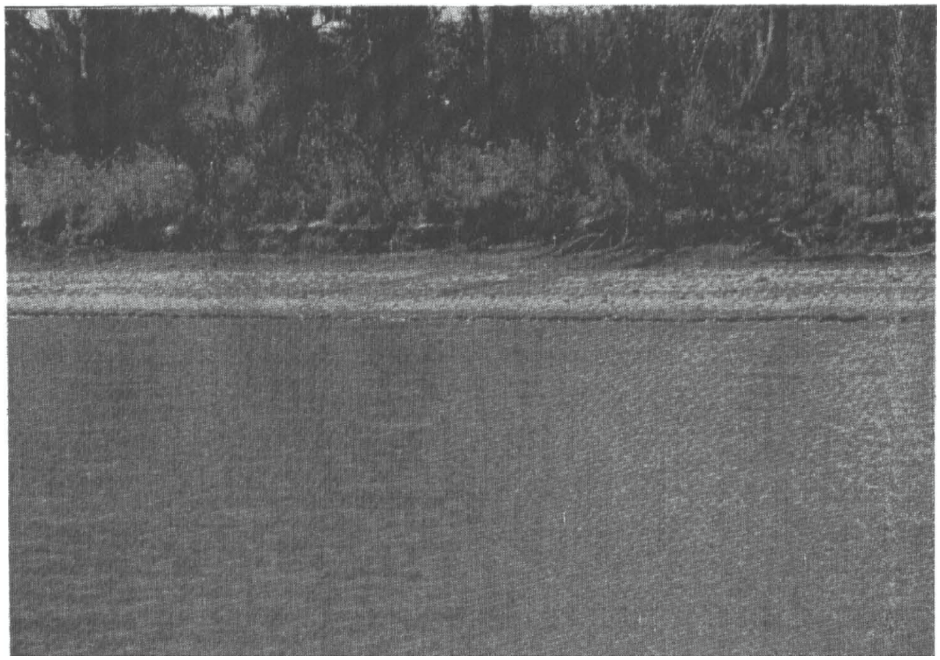


Figure 108. Site 22 on the Illinois River

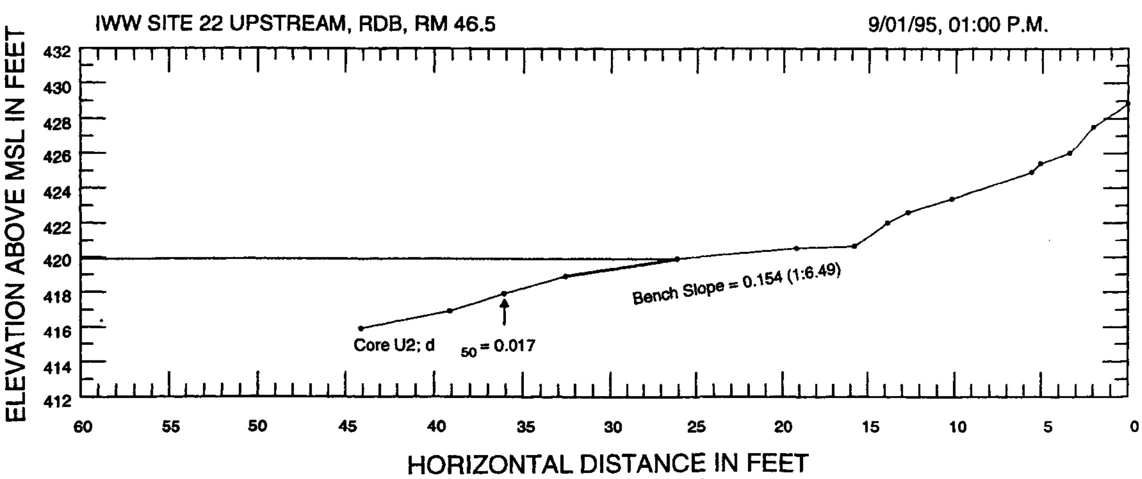
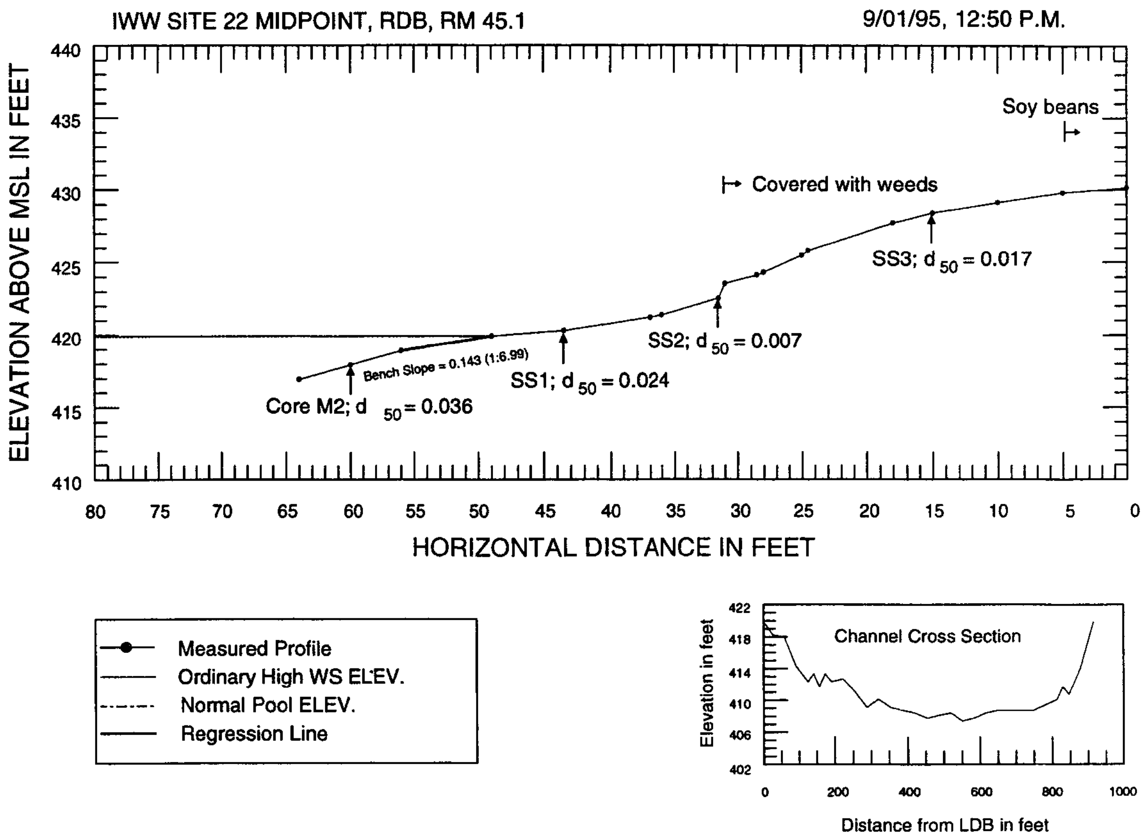


Figure 109. Bank sections at site 22



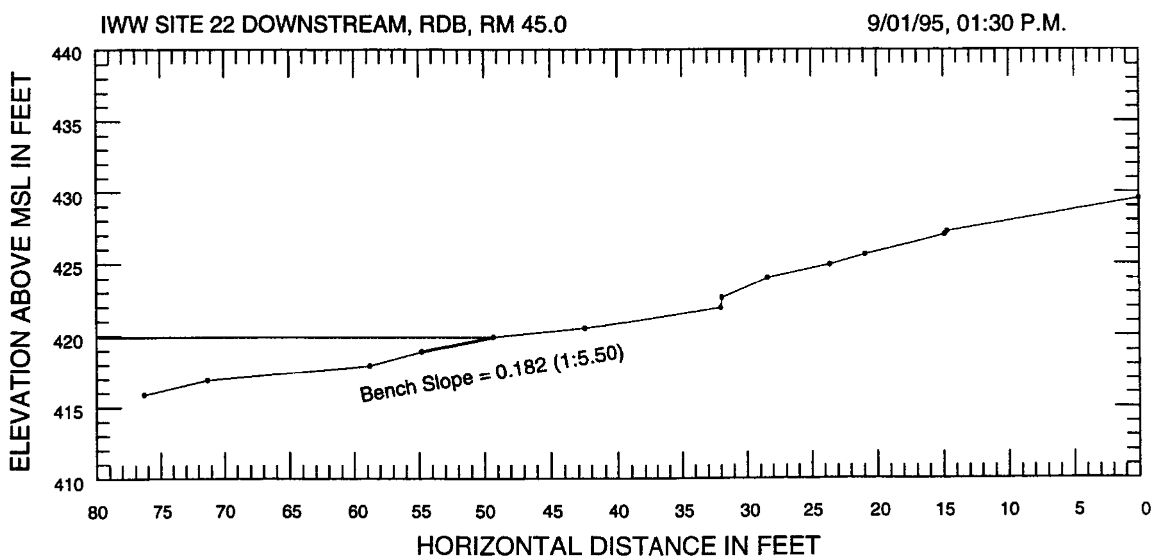


Figure 109. Bank sections at site 22 (concluded)

Table 37. Site 22 Characteristics

Percentage of occurrence	*Stage above msl, ft*	*Topographical features*	*Bank/bed material, mm*
90	419.7	• Bench (underwater) (slopes varied between 1V:7.0H and 1V:5.5H)	• d_{50} (core) varied (0.017-0.036)
75	420.2	• Bench	• d_{50} varied (0.007-0.024)
50	422.4	• Bench/berm/scarp • Scarp (slopes varied between lV:0.5H and 1V:0.14H) • Berm slope = 1V:4.2H	
25	425.9	• Top of the bank	
10	430.3		• d_{50} = 0.017
0-9	>430.3		

Note: Gage on the Illinois River at Pearl, IL @ RM 43.2 was used for stage histogram. WSE = 419.9 feet; OHWE, NA; and NP, NA.

At the midsection, the d_{50} varied from 0.017 mm at the top surface of the bank to 0.036 mm for a core sample at a water depth of about 2 feet. Gradation plots of bank soils and nearshore sediment are presented in appendix C. The detailed river cross section and coordinates are shown in appendix D.

Bench slopes varied from 0.143 1V:7.0H to 1V:5.5H. This site can be classified as a combination of types 5 and 4 (figure 25 and 24 and table 9). Apparent erosion mechanisms were emergent to seepage on the subaerial bench, rework, and transport by waves and currents at various stages between NP and OHWE.

Site 23, Alton Pool, 9/1/95

This site is on the RDB at RM 23.5 in a crossover from a gentle bend. This site is near the downstream tail of Diamond Island; Dark Chute runs from the back (west) side of the island to the confluence with the Illinois River at RM 22.7. Figure 110 shows the position of the site on a GIS-based map of the Illinois navigation chart, and figure 111 is a photograph of the site.

The navigation channel is close to this site; the bank is about 180 feet from the sailing line. Bhowmik and Schicht's (1980) Reach 1 was located at RM 24.0 on the opposite bank. Hagerty (1988) noted erosion on both bank sections, but eroded reaches were shown in several segments. For this site, Hagerty (1988) noted 6 feet of bare scarp.

Figure 112 shows the three measured bank sections and a reduced cross section. The stage at the time of survey was at about the 90 percent recurrence frequency stage. Dense seasonal vegetation covered the upper portion of the bank face, and the bank slope was steeper

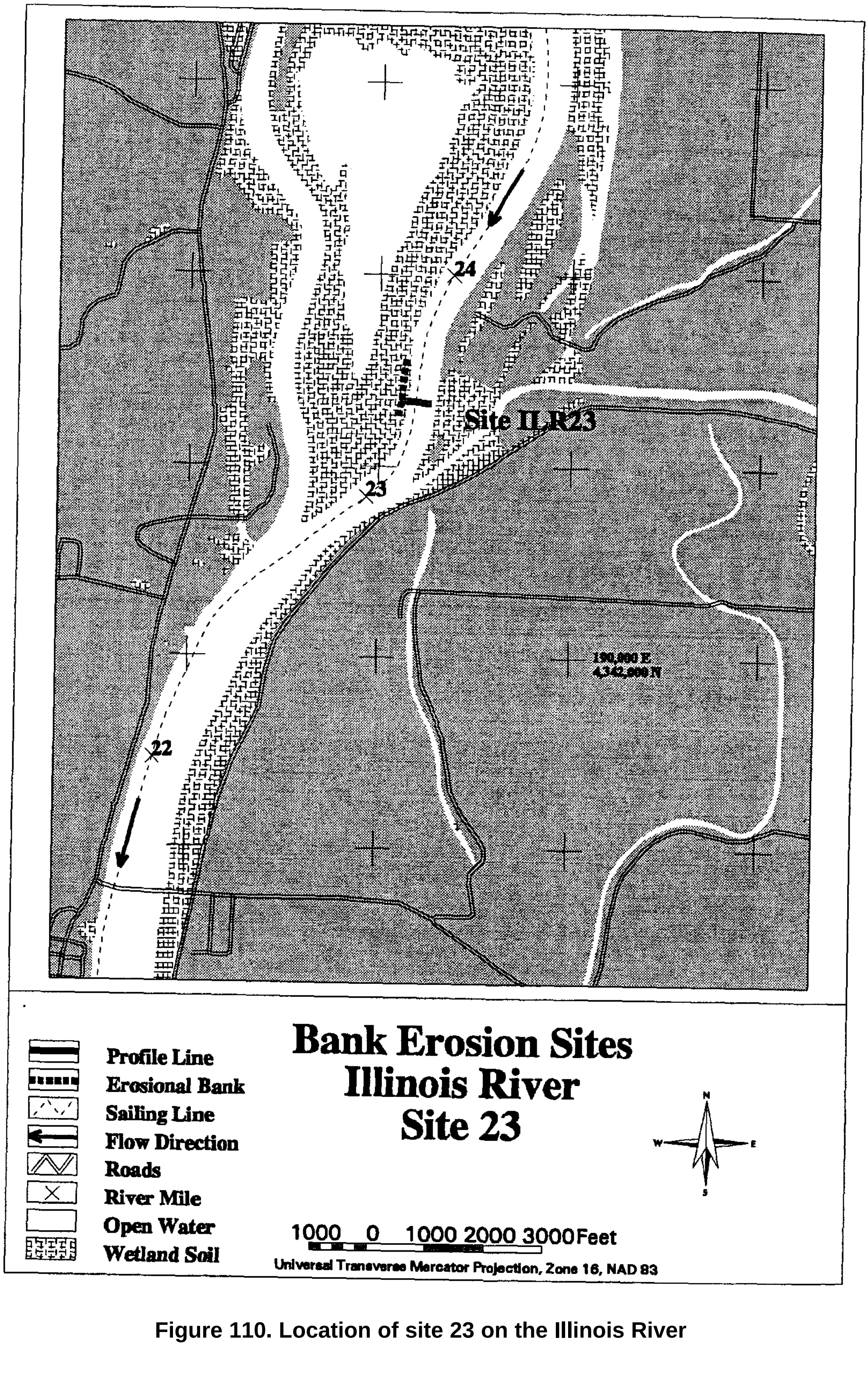


Figure 110. Location of site 23 on the Illinois River

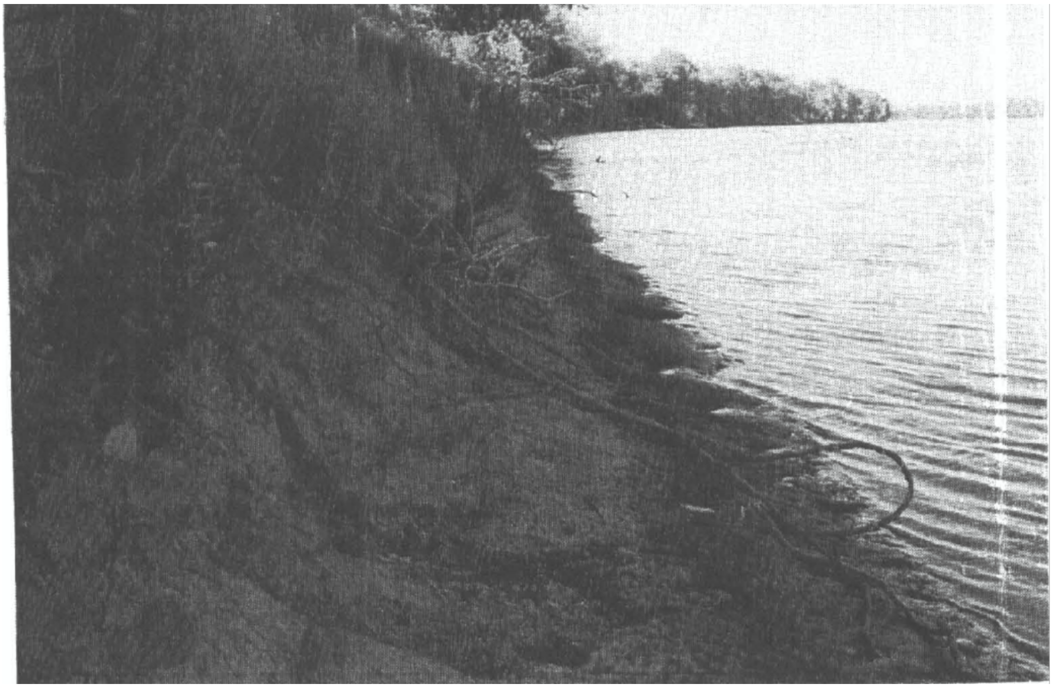


Figure 111. Site 23 on the Illinois River

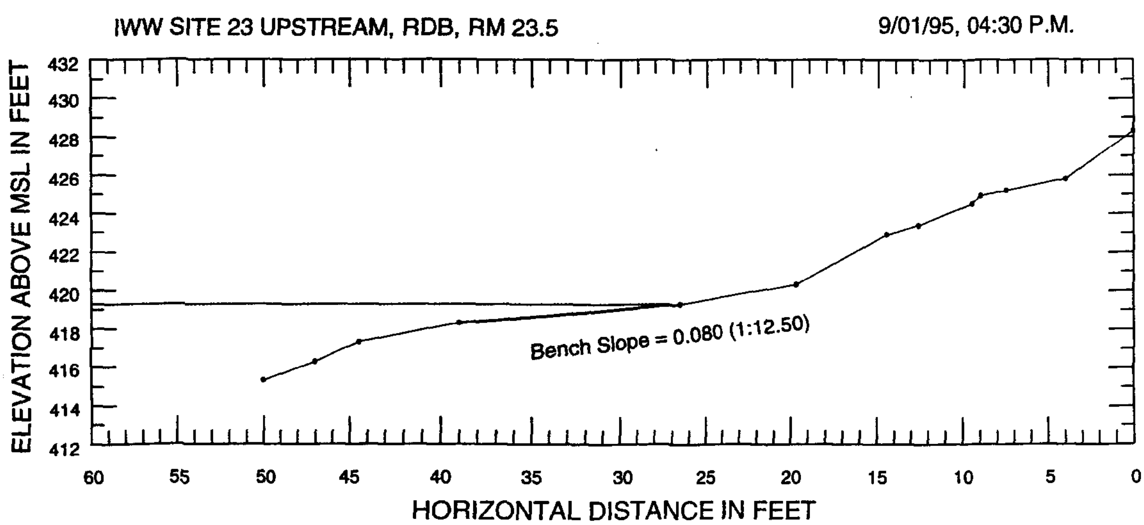


Figure 112. Bank sections at site 23

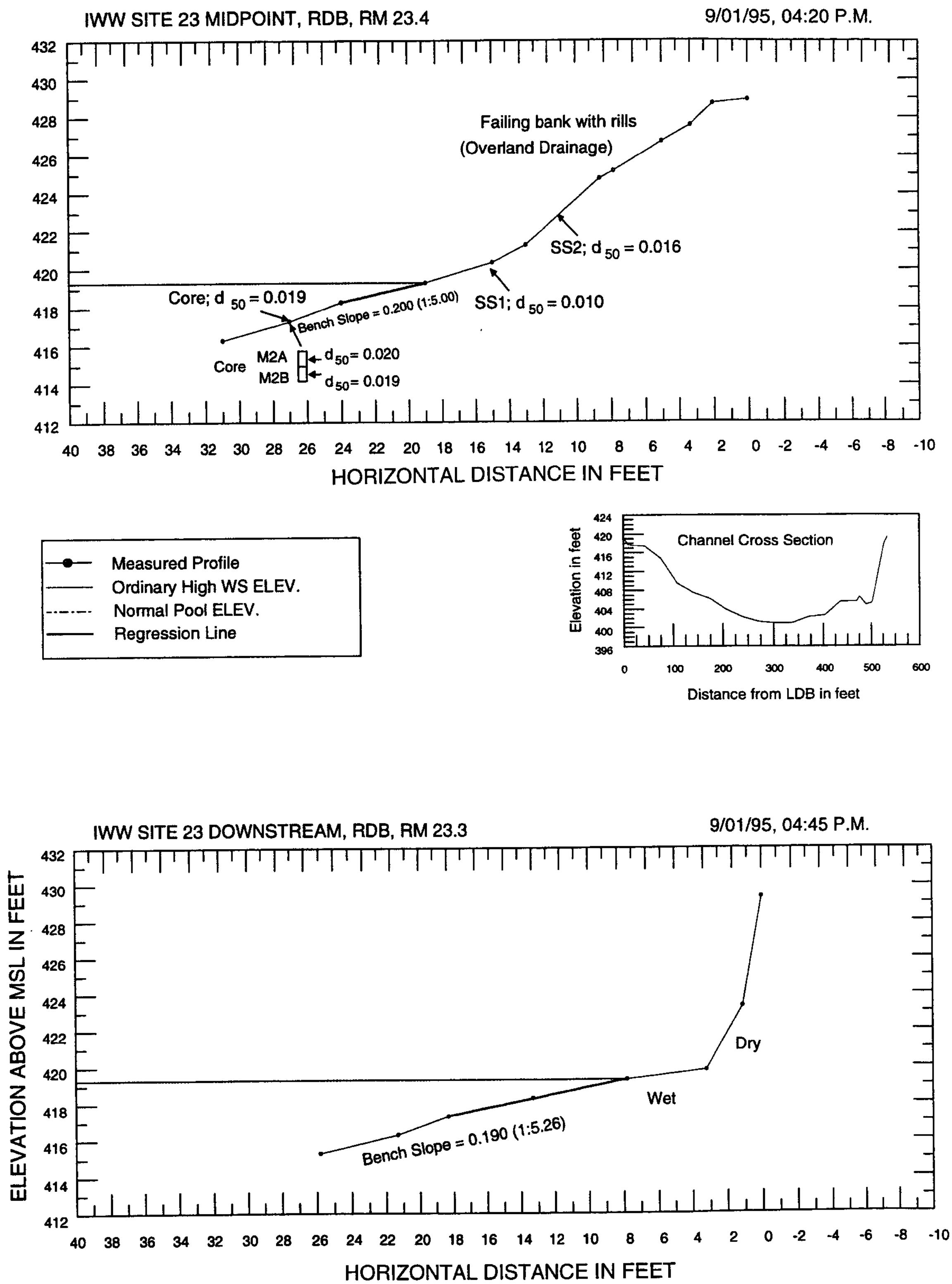


Figure 112. Bank sections at site 23 (concluded)

downstream. Bank materials were similar to those at other bank sections in the Alton Pool, with a hard clayey layer at the upper part of the bank, and a lower bank covered by moist, soft clayey soil. Algae were growing near the water's edge. As shown in table 38, the bare bank face corresponds well to the stage ranging between 50 and 25 percent recurrence frequencies. The 50 percent recurrence stage is about 420.3 feet at the base of the scarp.

At the midsection, the d_{50} varied from 0.016 mm at the surface of the bank to 0.020 mm at the upper part of a core sample at a water depth of about 2 feet. The d_{50} values were very uniform at the midsection. Gradation plots of bank soils and nearshore sediment are presented in appendix C. The detailed river cross section and coordinates are shown in appendix D.

Bench slopes varied from 1V:12.5H at the upstream section to about 1V:5.0H at the mid- and downstream sections. The upstream section and midsection were classified as type 4, and the downstream section was classified as type 2 (figures 24 and 22 and table 9). There was erosion due to surface drainage; other apparent causes are seepage, rework, and transport by levees and currents at various stages of pool-level fluctuations.

Site 24, Alton Pool, 9/l/95

This site is on the RDB at RM 13.1 on the outside of a bend. Upstream on the RDB is the (old) Hadley's Landing (RM 13.4), and across the river is Twelve Mile Island. Figure 113 shows the position of the site on a GIS-based map of the Illinois navigation chart, and figure 114 is a photograph of the site.

Table 38. Site 23 Characteristics

Percentage of occurrence	*Stage above msl, ft*	*Topographical features*	*Bank/bed material, mm*
90	419.2	• Bench (underwater) (slopes varied between 1V: 12.5H and 1V:5.0H)	• d_{50} (core) varied (0.019-0.020)
75	419.5	• Bench	• d_{50} =0.010
50	420.3	• Bench/berm (slope = 1V:2.2.H)	• d_{50} = 0.016
25	422.5	• Berm/scarp	
		• Scarp (slopes varied between 1V:1.3H and 1V:0.34H	
10	426.6	• Scarp/Top of the bank	
0-9	>426.6	• Top of the bank	

Note: Gage on the Illinois River at Hardin, IL @ RM 21.6 was used for stage histogram. WSE = 419.3 feet; OHWE, NA; and NP, NA.

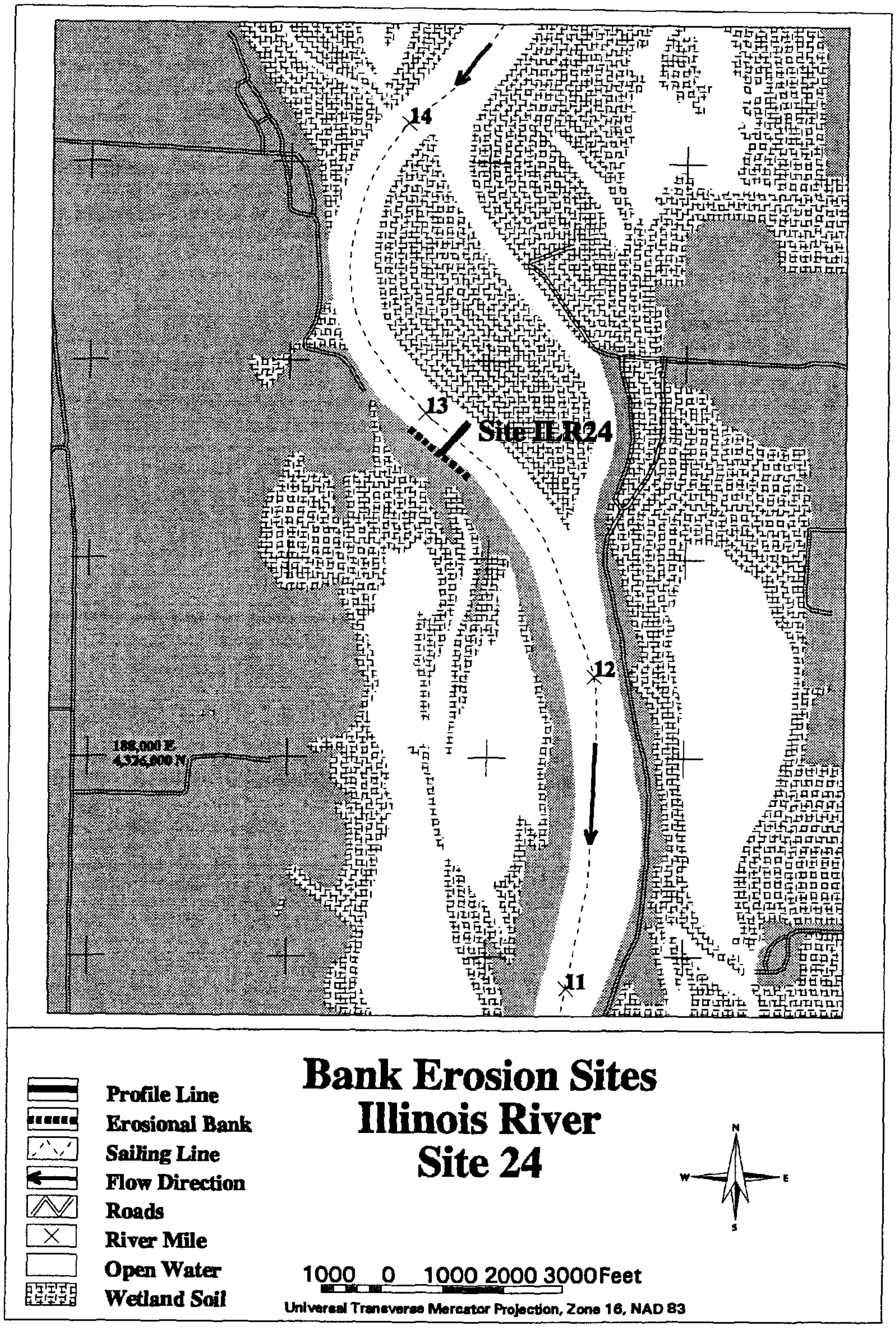


Figure 113. Location of site 24 on the Illinois River

Figure 114. Site 24 on the Illinois River

The site is about 430 feet from the sailing line, and no major tributary enters the river at this location. Bhowmik and Schicht (1980) marked the site as a "Wave Study" site. Hagerty's 1988 erosion site was at RM 13.4 immediately downstream from Hadley's Landing.

The bank characteristics are similar to those at other sites in the Alton Pool. Figure 115 shows the three measured bank sections and a reduced cross section. Land cover on the top and upper portion of the bank was dense seasonal vegetation, mostly above the water line. The sloping bank below the vegetation zone was bare. The base of the bare area was moist, and algae was growing near the water's edge. The stage at the time of the survey was at about the 90 percent recurrence frequency stage. The subaqueous bench at the site was broader and flatter than the bench at site 23. The bench was covered with a layer of thick sediment in the nearshore area, but farther riverward the bench surface was hard and closer to the river. The stage analysis (table 39) indicated that the bare bank face was between the 50 and 25 percent recurrence stages. The 50 percent recurrence stage, 420.3 feet, was at the base of the scarp.

At the midsection, the d_{50} varied from 0.019 mm at the surface of the bank to 0.020 mm at the upper portion of a core sample at a water depth of about 2 feet. The d_{50} for the lower core sample is 0.019 mm. A detailed river cross section is shown in appendix D. Gradation plots of bank soils and nearshore sediment are presented in appendix C.

Bench slopes varied slightly from 1V:25.OH to 1V:15.9H in this reach. The bank soils were cohesive. This site can be classified as a combination of types 2 and 5 (figures 22 and 25 and table 9). Erosion processes could be traced as initiated by piping; debris-induced local currents and wave wash extend the erosion; rework and transport by waves and currents at various stages of pool-level fluctuation then remove the failed soils or recently deposited sediment.

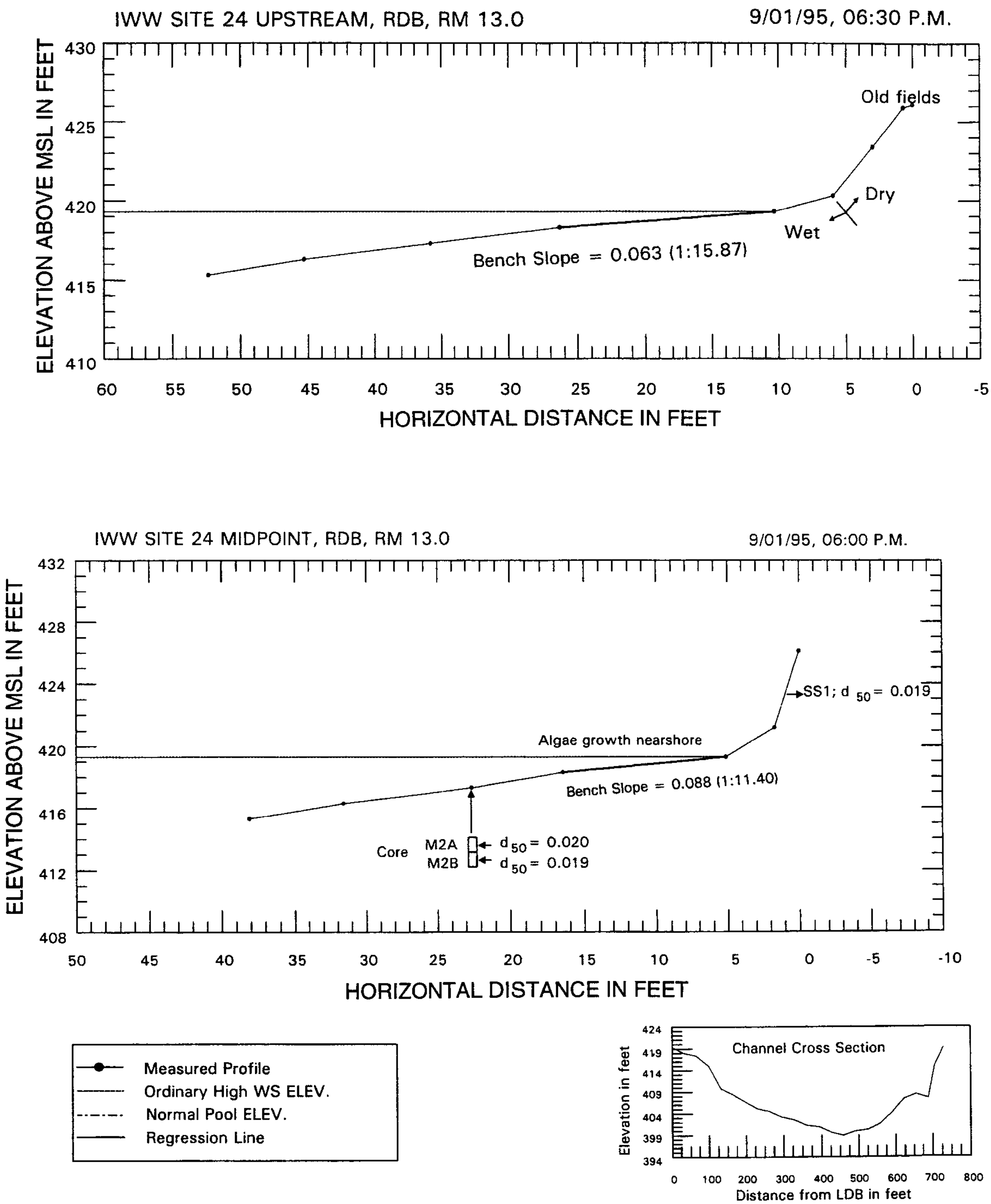


Figure 115. Bank sections at site 24

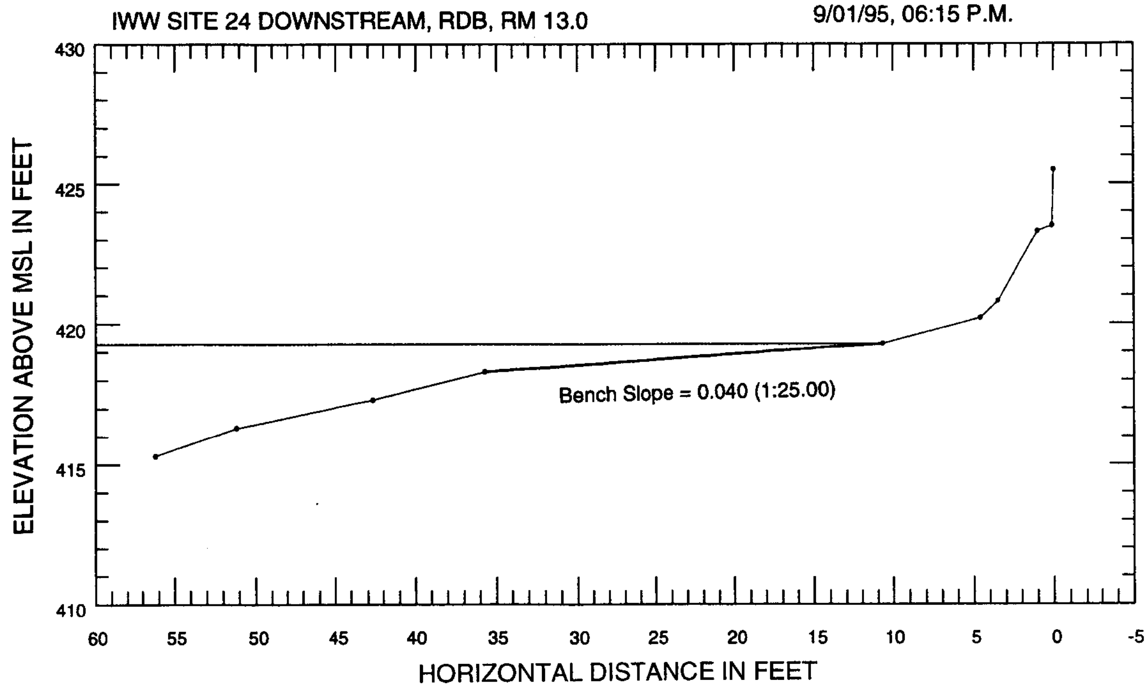


Figure 115. Bank sections at site 24 (concluded)

Table 39. Site 24 Characteristics

Percentage of occurrence	*Stage above msl, ft*	*Topographical features*	*Bank/bed material, mm*
90	419.2	• Bench (underwater) (slopes varied between 1V:25.0H and 1V:15.9H)	• d_{50} (core) varied (0.019-0.020)
75	419.5	• Bench	
50	420.3	• Bench/berm (slopes varied between 1V:1.8H and 1V:1.2H)	
25	422.5	• Scarp/berm • Scarp (slopes varied between 1V:0.34H and 1V:0.05H)	• d_{50} = 0.019
10	426.6	• Top of the bank	
0-9	>426.6		

Note: Gage on the Illinois River at Hardin, IL @ RM 21.6 was used for stage histogram. Gauge is 8.6 miles away from the site. WSE = 419.3 feet; OHWE, NA; and NP, NA.

Summary

This report presents the results of data collection and analysis performed on the Illinois River to survey the bank erosion of the river. The field visits and data collection were conducted from August 24-31, and from September 18-20, 1995. A summary of the study is as follows:

- Detailed field data were collected at 29 study sites and 3 observation sites.
- The distribution of sites with respect to various pools is:

Marseilles - 5 sites	(pool length = 24.5 miles)
Starved Rock - 3 sites	(pool length = 15.8 miles)
Peoria - 7 sites	(pool length = 73.3 miles)
La Grange - 9 sites	(pool length = 77.7 miles)
Alton - 5 sites	(pool length = 80.1 miles)

- Observation sites were located as follows: one in Dresden Pool and two in Marseilles Pool. The length of Dresden Pool is 14.3 miles.
- Both of the bank lines from RM 286 to RM 0 have been mapped on navigation charts of the river. Eroded and stable reaches were identified on these charts. These maps (colored) have been published in CD-ROM by the USACOE, Rock Island District.
- Field mapping of the bank erosion indicated that about 117 riverbank miles are severely eroded corresponding to approximately 20 percent of the total bank length (both banks). There are also about 90 miles of riverbank that have visible erosion features but are not considered severely eroded. On the other hand, about 189 bank miles are stable, and 88 miles are either rock or protected by riprap or other structures. Several other types of bank descriptions were also used in the mapping.
- At all the selected sites, bank sections, bank and core samples, and at least one river cross section at the midpoint were obtained. Photographs of the sites, including panoramic and feature specific, were taken. All the sites were located by using a portable GPS system.
- A total of 80 bank sections from 29 eroded sites were measured.
- The river widths varied from 529 to 919 feet, and the maximum depths varied from 12 to 21 feet.
- Bank sections were measured to determine the slopes of scarp, berm, and bench. Scarp slopes varied from about 1V:0.83H to 1V:0.04H, berm slopes varied from 1V:8H to 1V:0.83H, and bench slopes varied from 1V:83.3H to 1V:1H. Scarp and bench slopes did not show too much variation, whereas berm slopes showed quite a bit of variation.
- A total of 174 surficial bank and nearshore bed material samples were analyzed: 93 samples from the riverbanks and 81 core samples. For about 141 of the samples, d_{50} varied from 0.002 mm to 0.696 mm. Surficial bank materials consisted of fine sand and silt within the upper portion of the river and became silty and clayey within the lower reach of the river. Almost all the surficial bank material samples appeared to be well graded.

- Erosion reaches selected varied from a minimum length of 0.09 mile to a maximum length of 0.95 mile.
- All selected bank sections had natural coverings. Among the 29 study reaches, 17 were on the RDB and 12 were on the LDB; 13 were on the straight reaches of the river, 11 were on the outside bank, 3 were on the inside bank, and 2 were in crossover. The dominant land cover on the bank face was grass or weeds. The dominant land cover on the bank crest was woody vegetation.
- Most of the 1995 bank sections were within the straight portion of the river. Sites selected from the outside bank were distributed throughout the waterway.
- During field data collection, the field team identified the probable cause or causes of erosion at all the bank sections at which bank sections were measured. The probable causes were organized for evaluating the percentage of each cause in these 80 bank sections. The data from the 80 bank sections indicated that:
    - ♦ Although large floods could be the dominant cause of erosion on natural rivers, this study found erosion at many bank sections within the normal range of stage fluctuation (between the OHWE and NP stages) which cannot completely be attributed to large floods. Among these bank sections, 27 percent of them showed erosion occurring only at high stages, and 63 percent had erosion occurring at stages within the normal range of stage fluctuations. The rework and transport processes, as caused by waves and currents, are significant during these stages.
    - ♦ Seventy-four percent of the bank sections had evidence of seepage effects, About 26 percent of these bank sections had piping holes or springs, the remaining 48 percent had wet subaerial benches.
    - ♦ Twenty-eight percent of the bank sections had small scarps on bench that could have been formed by waves, seepage, or a combination of these causes.
    - ♦ Twenty-four percent of the bank sections showed evidence of traffic-induced disturbance. These included impact from direct contacts and undercut in submerged banklines near fleeting areas.
    - ♦ Ten percent of the bank sections showed erosion associated with eddy/disturbed flow induced by riparian trees or gravel.
    - ♦ Eleven percent of the bank sections had the presence of surface drainage; five bank sections were adjacent to water bodies (e.g., lakes or borrow pit).
    - ♦ Four percent of the sites showed erosion associated with weathering (freeze/thaw) of surficial soils.
- All the measured bank sections were divided into six erosion types on the basis of the height of scarp, types of soils, and widths of subaerial and subaqueous benches. Each measured bank section was subsequently analyzed to determine which type or types describe that particular profile. In this categorization, types 1 and 2 indicated high potential for erosion, types 3 and 4 indicated moderate potential for erosion, and types 5 and 6 indicated active but less severe erosion.

- Analyses of the erosion mechanisms at all the measured bank sections (80 cross section) indicated the following distribution:

  Type 1: 2 bank sections (i.e., 2.5 percent of the total measured bank sections)
  Type 2: 6 bank sections (7.5 percent)
  Type 3: 4 bank sections (5.0 percent)
  Type 4: 13 bank sections (16.25 percent)
  Type 5: 15 bank sections (18.75 percent)
  Type 6: 7 bank sections (8.75 percent)

  The remaining bank sections showed some deviation from the types as defined earlier. They are presented as a combination of different types:

  Types 1 and 2: 3 bank sections (3.75 percent)
  Types 1 and 6: 3 bank sections (3.75 percent)
  Types 2 and 3: 3 bank sections (3.75 percent)
  Types 2 and 4: 4 bank sections (5.0 percent)
  Types 2 and 5: 3 bank sections (3.75 percent)
  Types 2 and 6: 1 bank section (1.25 percent)
  Types 3 and 5: 6 bank sections (7.5 percent)
  Types 4 and 5: 10 bank sections (12.5 percent)

- Several erosion mechanisms were present at many bank sections, and this field survey was not designed to identify all the specific erosion mechanisms. However, the analysis for potential causes indicated that erosion at approximately 63 percent of the measured bank sections could be attributed partially to rework and transport processes (waves and currents) associated with stage variations within the normal range of pool fluctuations. The waves can be generated by winds or navigation traffic, and the currents also can be part of natural flows or turbulence from traffic or other causes. It is recommended that further studies be conducted to investigate the sources of these causes
- A classification of all the bank sections indicated that future site-specific field experimentation should include bank sections with the following characteristics: bench slopes: 1V:50H to 1V:20H; berm slopes about 1V:4H; scarp slopes about 1V:0.7H to 1V:0.5H; d_{50} about 0.05 mm; and standard deviations of about 2 to 3. It should be noted that bank sections with other similar characteristics would also be suitable for detailed field experimentation.
- Detailed descriptions of all individual bank sections and related photographs and other data are included in this report.
- Site-specific field experimentation should be conducted to estimate the rate of bank erosion due to the movement of river traffic at representative bank sections. On the basis of such scientific information, specific relationship or relationships could be developed that could be systematically applied to the entire river and cover the wide variety of bank conditions existing on the river.

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