Contract Report 2001-09

River Geometry, Bank Erosion, and Sand Bars within the Main Stem of the Kankakee River in Illinois and Indiana

by

Principal Investigators
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Prepared for the
Illinois Department of Natural Resources
Office of Realty and Environmental Planning

June 2001

Illinois State Water Survey
Watershed Science Section
Champaign, Illinois

A Division of the Illinois Department of Natural Resources

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Report Prepared for the:
Illinois Department of Natural Resources
Office of Realty and Environmental Planning

Conservation 2000 Ecosystem Project

This report was printed on recycled and recyclable papers.

River Geometry, Bank Erosion, and Sand Bars within the Main Stem of the Kankakee River in Illinois and Indiana

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Abstract

This is the third and final report on the Kankakee River in Illinois supported by the Conservation 2000 Program of the Illinois Department of Natural Resources. For this project, the Illinois State Water Survey mapped the bank erosion of the main stem of the Kankakee River from the Route 30 bridge in Indiana to the mouth of the Kankakee River with the Illinois River near Wilmington, collected about 100 bed and bank material samples, resurveyed all the previously surveyed river cross sections, surveyed four sand bars, and analyzed all historical and new data.

This research has shown that of 223.6 river bank miles (includes both sides of the river), about 10.4 river bank miles have severe erosion, 39.4 river bank miles have moderate erosion, 70.8 river bank miles have minor erosion, and the remainder are either protected or stabilized or data are not available. The median diameter of the bed materials varied from 0.27 millimeters (mm) to 0.52 mm. The median diameter of bank materials varied from 0.07 mm to 0.41 mm. Analyses of the long-term flows from six gaging stations in Illinois showed an increasing trend in flows through the 1960s with no discernible increase since that time.

Cross-sectional analyses of the river from the Kankakee Dam to the State Line Bridge did show some trends. The river reach from the Kankakee Dam to Aroma Park called Six- Mile Pool has lost 13.4 percent of its capacity due to sediment deposition since 1980. Similarly, Momence Wetland also has lost about 10.2 percent of its capacity since 1980. The section of the river between Aroma Park and Singleton Ditch showed both scour and sediment deposition. In general areas close to Aroma Park exhibited sediment deposition and the middle reach experienced scour. The recurring sand bar at the State Line Bridge area contains about 8,500 cubic yards of additional sediment in 1999 than were measured in 1980. The volumetric measurement of three additional sand bars showed some changes since 1980. The river is accumulating sediments within Six-Mile Pool and Momence Wetland. The middle reach is in semi-equilibrium with some sediment accumulation at several areas. Several management alternatives, both in-channel and watershed-based also are included to assist in the reduction of sedimentation problems of the Kankakee River.

Keywords: *Kankakee River, Sedimentation, Bank Erosion, River Geometry, Bed Materials, Hydraulics, Geomorphology*

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Background

The present report is the third one in a series of reports prepared for this project. This final report summarizes all the work completed for this project. The two previously published reports cited subsequently within this report.

The following descriptions are after Bhowmik and Demissie (2000).

The Kankakee River flows westward from Indiana into Illinois. The headwaters are near South Bend, Indiana, and the mouth is at the confluence of the Kankakee with the Des Plaines River where those two rivers join to become the Illinois River.

Of the 5,165 square miles in the Kankakee River drainage basin, 2,169 miles are in Illinois and 2,996 miles are in Indiana. The river has a total length of about 150 miles, with 59 miles in Illinois. Figure 1 shows the drainage basin of the Kankakee River.

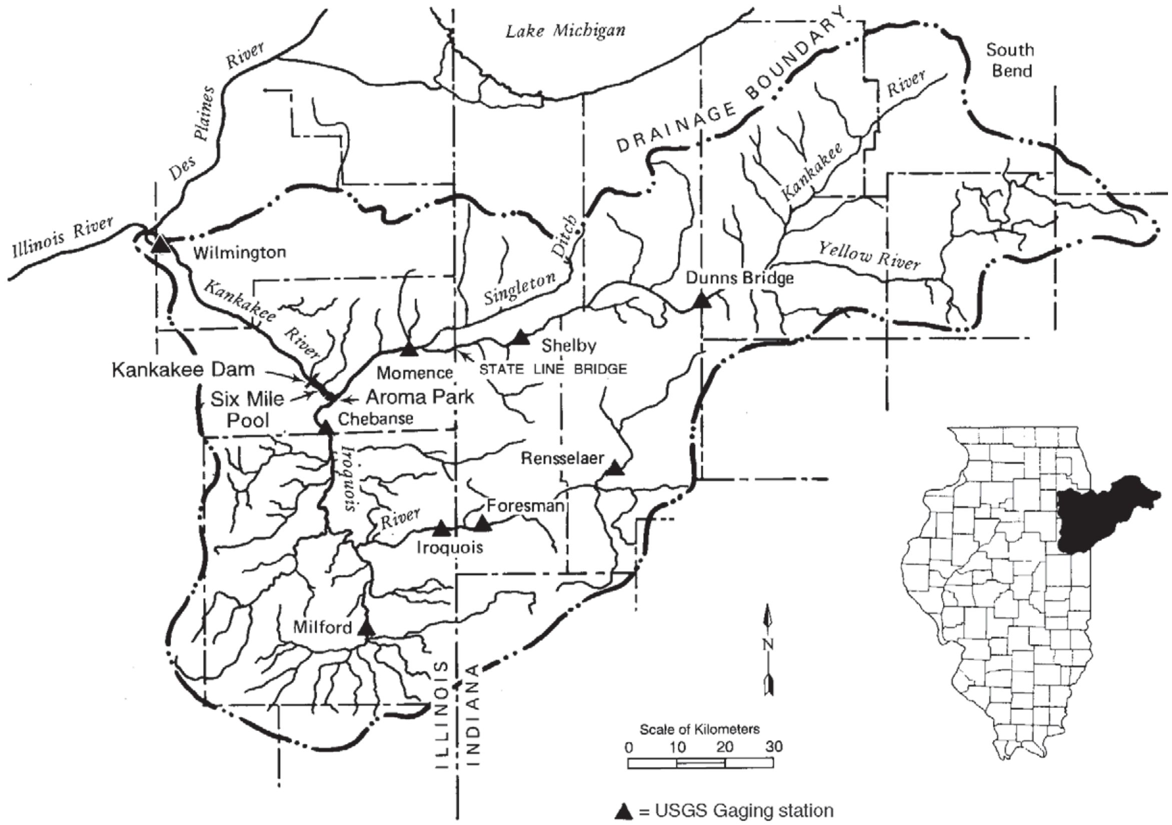

Figure 1. Drainage basin of the Kankakee River in Illinois and Indiana

Almost the entire main channel of the Kankakee River in Indiana was channelized by drainage improvement work beginning in the late nineteenth century and essentially completed by 1918. Today, that channel is essentially human-made, extending straight for many miles between small bends. All of the natural meanders were bypassed, although many remain today as oxbow lakes or marsh areas.

In Illinois, a small side channel dam exists at Momence, a larger dam at Kankakee, and an overflow dam at Wilmington, but most of the river remains a naturally meandering stream. A major tributary to the Kankakee River in Illinois is the Iroquois River, which joins the Kankakee River just below Aroma Park. Most of the Iroquois drainage basin also is in Indiana. Singleton Ditch, a channelized tributary in Indiana, joins the Kankakee River just above Illiana Heights in Illinois.

Before channelization, much of the drainage area of the river in Indiana was wetland swamps and marshes called the "Kankakee/Grand Marsh". The Grand Marsh encompassed approximately 400,000 acres and ranged from 3 to 5 miles in width with a water depth of 1 to 4 feet for eight or nine months of the year (Bhowmik et al., 1980). The marshplain was only about 85 miles long, but the river course was about 250 miles long with an average slope of 5 to 6 inches per mile. The nature of the marsh caused the Kankakee River to alter its course continuously, resulting in the formation of a variety of meanders, oxbow lakes, sloughs, and bayous.

In Illinois, especially in Kankakee County, the river continues to be a scenic, cultural, and recreational resource. The reach between the state line and Singleton Ditch is a naturally meandering stream with a sandy bottom, traversing an area of timber and relatively undisturbed wetlands, commonly called the "Momence Wetlands."

The reach between the mouth of Singleton Ditch and Aroma Park is also a natural stream that traverses an area of alternating bedrock and sandy bottom. Between Aroma Park and the city of Kankakee, a deepwater area called Six-Mile Pool (actually 4.7 miles long) was formed by the construction of Kankakee Dam. The deeper water has long been used for water supply and recreational boating. Fine homes have been built adjacent to the river. The entire river in Kankakee County is noted for high-quality water, excellent sport fishing, and scenic beauty.

Although river basin management practices differ significantly between the two states, some important geological differences occur near the state line. The wetlands, a result of continental glaciation, occur mainly on the Indiana side of the state line except for the small area east of Momence. Areas of bedrock outcrops, where the glacial deposits are thin or absent, occur mainly on the Illinois side of the line. These bedrock outcrops in Kankakee County have long been an important factor in the hydraulic control of the river.

The present project was initiated in response to a letter from Mr. J.R. Black of the "Kankakee River Basin Partnership," which has received three grants from the Conservation 2000 (C-2000) program of the Illinois Department of Natural Resources (IDNR). This project was conducted to address those three grants. In order to formulate a comprehensive work plan, all three projects were combined into a single project, and an overall plan was developed.

Related Research

Over the last 20 to 25 years, several reports have been prepared by researchers from Illinois and Indiana about the entire Kankakee River basin. Bhowmik and Demissie (2000) provide a thorough listing of the available research reports, publications, etc. Some other important past research reports include Bhowmik et al. (1980), Demissie et al. (1983), Brigham et al. (1981), Gross and Berg (1981), Terrio and Nazimek (1997), Ivens et al. (1981), Knapp (1992a,b), Mitsch et al. (1979), Phipps et al. (1995), and the Kankakee River Basin Commission (1989). There are many other reports and publications about the Kankakee River in Illinois and Indiana. Again, readers are referred to the past reports by Bhowmik et al. (1980) and Bhowmik and Demissie (2000) for a detailed list of related publications.

Objectives and Scope

The present project had several objectives:

a) To summarize most of the existing data on hydraulics, hydrology, and sediment transport and make those available on a CD.
b) To survey the bank erosion of the main stem of the Kankakee River from the Route 30 Bridge in Indiana to Wilmington, Illinois, up to the confluence of the Des Plaines River with the Kankakee River.
c) To measure all the original river cross sections from Kankakee Dam in Kankakee to the Illinois-Indiana State Line Bridge.
d) To resurvey four sand bars along the main stem of the Kankakee River, including the sand bar at the Stateline Bridge.
e) To analyze the data to determine the relative changes over approximately the last 30 years.

Acknowledgments

The authors would like to extend their sincere thanks to the Illinois Department of Natural Resources (IDNR) and the Kankakee River Basin Partnership (KRBP) for supporting this project under a C-2000 grant. J.R. Black from the KRBP, Bill White, Paul Vehlow, and Jim Mick from IDNR were extremely helpful throughout this study. Sincere appreciation is also extended to Gary Clark of the IDNR Office of Water Resources for providing many historical data sets on river geometry and to the U.S. Geological Survey for providing the river geometry data collected from the Momence Wetland area in 1994. Many Water Survey staff actively participated in this project and made significant contributions; their names appear on the title page of this report. Jennifer Tester and Dawn Amrein typed the camera-ready copy of the report. Eva Kingston edited the report, and Linda Hascall provided the graphic support and prepared the final layout of the report.

Previously Collected and Available Data

It has already been pointed out that a number of research projects about the Kankakee River were completed during the last several decades. A significant amount of hydraulic, hydrologic, sediment transport, and bed and bank material data also were collected. An attempt has been made to digitize all these data from various sources and make them available to all researchers, managers, and others. A CD provided with this report contains the following digitized data:

Hydrologic Data

- Compilation of daily, average, peak, and low flows for the Kankakee River at Momence, Illinois; Wilmington, Illinois; and Shelby, Indiana; for the Iroquois River at Chebanse, Illinois and Foresman, Indiana; and for Sugar Creek at Milford, Illinois

Bed Materials

- Compilation of the bed material data collected in 1980 by Bhowmik et al. (1980) and Bhowmik and Demissie (2000)

Suspended Sediment Data

- United States Geological Survey (USGS): Wilmington (1979-1982, 1994-1995); Momence (1979-1981, 1994-1995); Iroquois (1979-1980, 1993-1995); and Chebanse (1979-1981, 1993-1995)
- Illinois State Water Survey (ISWS): Wilmington (1983-1993); Momence (1982-1988, 1991-1993); Iroquois (1981-1982); Chebanse (1982-1983); Milford (1981-1982)

River Cross Sections

- Six-Mile Pool
    i. Office of Water Resources (OWR), Illinois Department of Natural Resources: 1959, 1968, and 1978
    ii. ISWS: 1980 and 1999
- Aroma Park to Momence
    i. OWR: 1966 and 1977
    ii. ISWS: 1999
- Momence Wetlands
    i. ISWS: 1980 and 1999
    ii. USGS: 1994

Sand Bars

- Compilation of sand bar survey data from the 1980 and 1999 surveys by the ISWS of the following sand bars: State Line, Sand bars 3 and 4, and Sand bar 2

Reports Completed for the Present Project

Water Survey researchers already have completed two reports for the present project. Materials contained in those reports will not be repeated here. However, the results contained in those reports will be summarized here so that all the results are included within this final report.

The Interim Report *Kankakee River Basin in Illinois: Hydraulics, Hydrology, River Geometry, and Sand Bars* by Bhowmik and Demissie (2000) summarizes the extensive literature survey conducted for the project, historical streamflow analysis for all the gaging stations in

Illinois, field data collection for the bank erosion survey, bed materials, bank materials, and provides a detailed description of the bank conditions for the main stem of the Kankakee River in Indiana and Illinois. Several illustrations and tables contained in that report are included in the final report.

Streamflows

Detailed streamflow analyses from several existing and old streamgaging stations were conducted to determine the variability in low, average, and peak flows. The gaging stations for which streamflows were analyzed are shown in Figure 2.

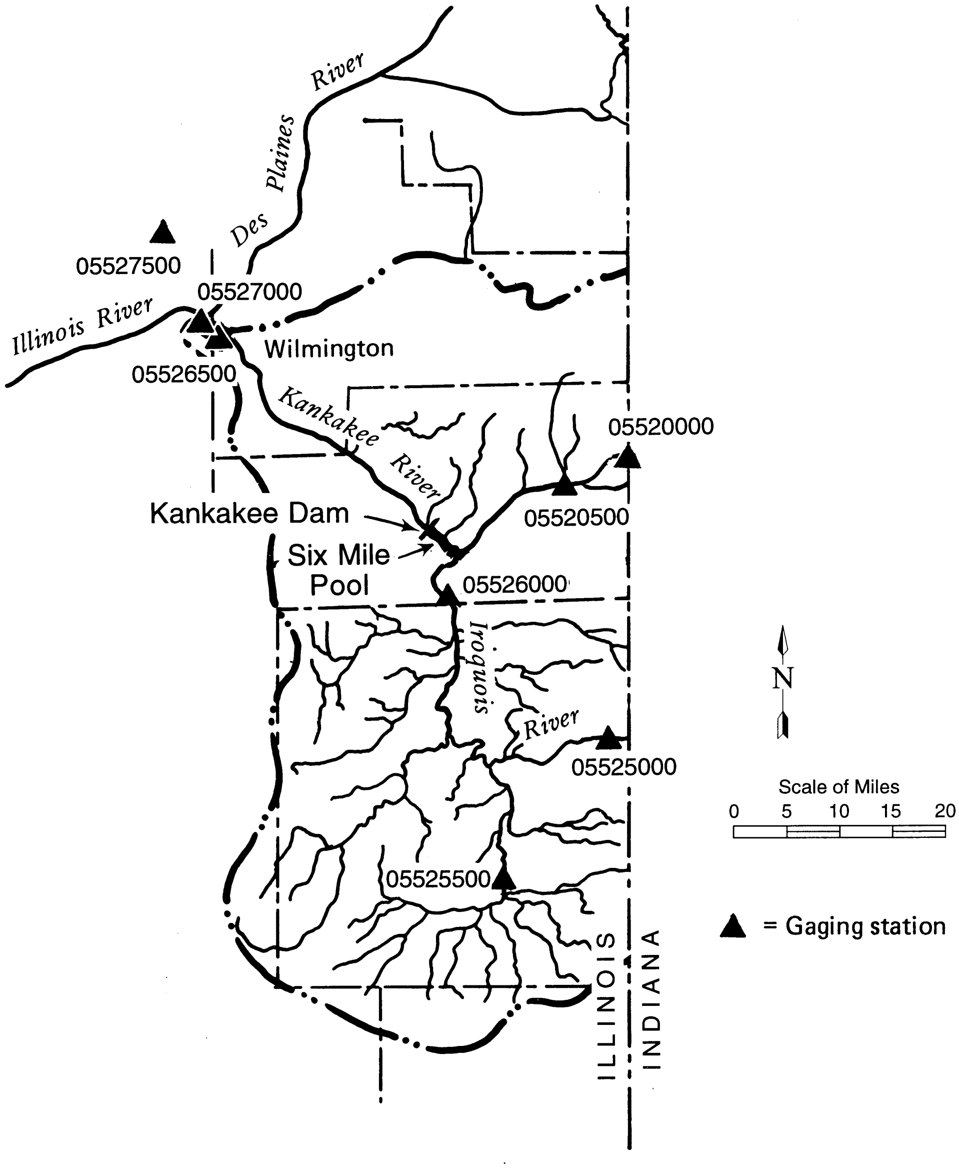

Figure 2. Streamgaging stations in the Kankakee River basin where streamflow analyses were completed (from Bhowmik and Demissie, 2000)

Streamflows vary from year to year. Average streamflow varies greatly from year to year and between decades. Figure 3 shows the annual series of average streamflow in cubic feet per second (cfs) for the streamgage records in the Kankakee River basin. As seen in this figure, the variation in annual flows is similar for most stations. Over the 82 years of record, the annual flows on the Kankakee River near Wilmington range from a low of 1450 cfs in the drought years of 1931 and 1964 to a high of more than 10,380 cfs in 1993. Annual flows in the Kankakee River at Momence are less variable, ranging from 850 to 3,740 cfs, while the variability of annual flows in the Iroquois River at Chebanse is greater, ranging from 425 to 5,160 cfs.

The long-term average flow in the Kankakee River basin at Wilmington is approximately 4,360 cfs per year. Prior to 1966, the average annual flow at Wilmington was less than 3,650 cfs, but it has averaged 5,590 cfs since then. Analyses of the regional precipitation records across northwestern Indiana and Kankakee, Will, and Iroquois Counties in Illinois indicated a correlation (r=0.89) between regional average precipitation and streamflows and a coincident increase in precipitation over the same period. This does not necessarily indicate a long-term trend. Periods of high precipitation occurred in the late 1800s, and it is likely that high average streamflow also occurred at this time.

Figure 4 plots the flow duration curves for seven gages in the Kankakee River basin from Illinois. The flow duration curve provides an estimate of the frequency with which the given flows are exceeded. As can be seen in this figure, the flows for all streams vary significantly and generally range from one-tenth to ten times the stream's average flow.

Variations in the general shapes of the flow duration curves often can point to significant differences in the hydrology of each stream. The Kankakee River at Momence and the Iroquois River near Chebanse drain watersheds of similar size and have similar average flow rates. However, the variability in flows for the Kankakee River at Momence is considerably smaller than that for the Iroquois River, as seen in Figure 4. This reduced range in flows for the upper Kankakee River basin is caused by 1) its coarse-grained soils, which have increased infiltration and less direct surface runoff, and 2) the direct connection of the river and its tributaries with shallow sand-and-gravel aquifers. Much of the streamflow in this region originates from the ground water and, as a result, the upper Kankakee River has substantial low flow even during the most severe droughts.

The variability of flows in the Iroquois River watershed is significantly greater than that for the upper Kankakee River and is more typical of streams throughout much of central Illinois. The Iroquois River watershed is the source of much of the direct surface runoff in the Kankakee River basin, and high flows on the Iroquois River are often more than twice as great as those on the upper Kankakee River. The lower Kankakee River, downstream of the confluence of the Iroquois and Kankakee Rivers, has flow characteristics that combine the high flood discharges from the Iroquois River with the sustained low flows contributed from the upper Kankakee River.

Figure 5 shows the annual series of peak flood discharges for the Kankakee River and tributaries in Illinois. Examination of this figure indicates a distinct increasing trend in peak discharges for the Momence and Wilmington gages on the Kankakee River. On the Iroquois River, the magnitude of the high flood levels has not changed substantially; however, the frequency of moderate flood events has increased, and there are fewer years with little or no flooding. Part of this increase in flood frequency is related to the corresponding increase in average flows and average precipitaion that have occurred since the 1960s.

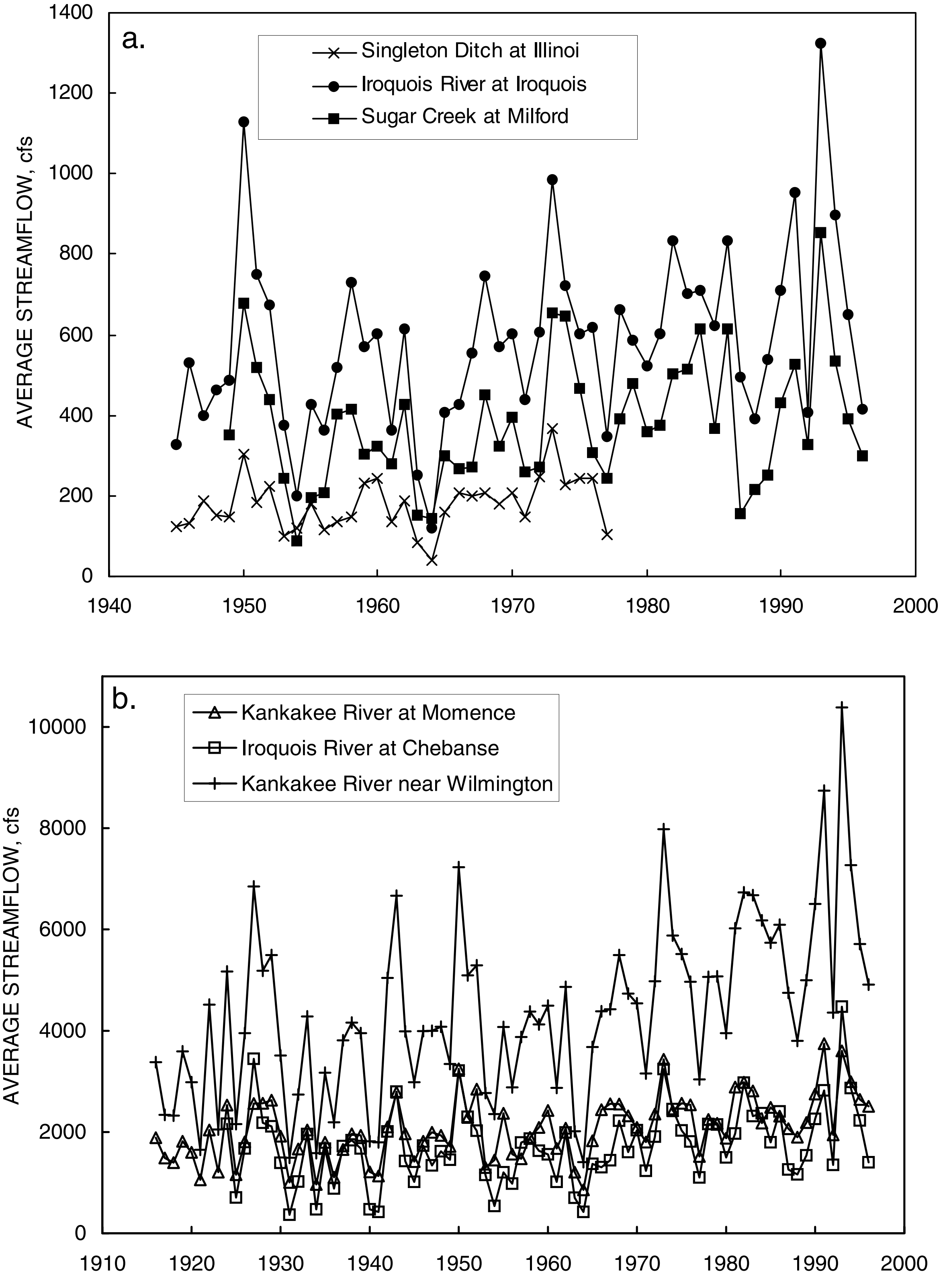

Figure 3. Average annual streamflows for gaging stations
in the Kankakee River basin in Illinois

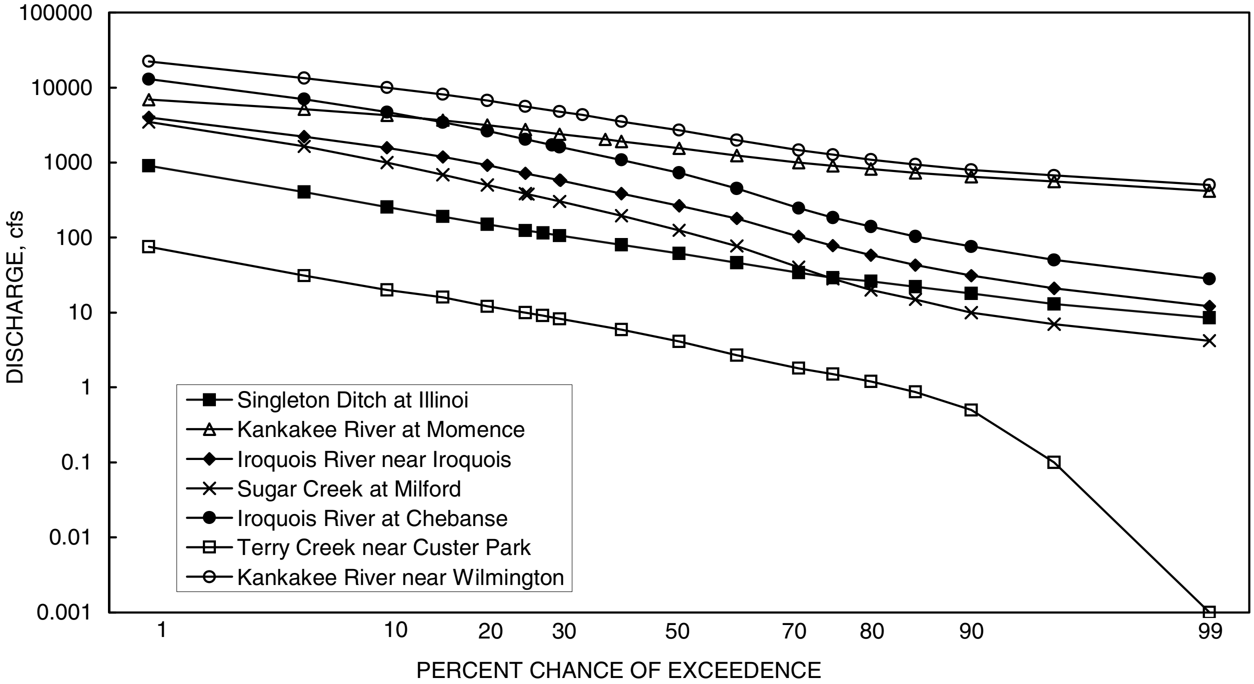

Figure 4. Flow duration curves (discharge vs. probability) for gaging stations in the Kankakee River basin in Illinois

Low-flow characteristics are a direct reflection of shallow ground-water storage and its connection to the streams in the basin. The upper Kankakee River has the greatest connection with shallow ground water and has substantial low flow even during the most severe droughts. The Iroquois River has a much lower but sustained flow during drought years. Almost all of the low flows on the Kankakee River and more than half of those on the Iroquois River originate from the shallow ground waters in the Indiana portion of the basin.

The 7-day, 10-year low flow (Q7, 10) for the Kankakee River ranges from 400 cfs at the Indiana border to 480 cfs at its confluence with the Illinois River (Singh et al., 1988). Two tributaries provide much of the increase in low flows over the distance: Singleton Ditch (near the Indiana border) and the Iroquois River. The Q7, 10 for the Iroquois River ranges from 14 cfs at the Indiana border to 31 cfs at its confluence with the Kankakee River. Sugar Creek is the only other tributary in the basin that has a Q7, 10 in excess of 1 cfs, and most tributaries have no flow during most dry years.

Different types of dry periods cause extreme low flows on the Kankakee and Iroquois Rivers. The lowest flows on the Kankakee River are most common during intensely hot and dry summers when there is a relatively quick reduction in ground-water storage near the streams. Lowest flows on the Iroquois River tend to occur more often during extended droughts when there is a sustained reduction in ground-water storage throughout the watershed. In some cases, but not all, the intense and sustained dry periods occur during the same year. On the Kankakee River, the lowest 7-day low flows occurred in the drought years of 1934, 1964, and 1988, as well as several times in the period 1917-1925. For the Iroquois River, the lowest 7-day low flows occurred during the drought years of 1934, 1941, and 1956.

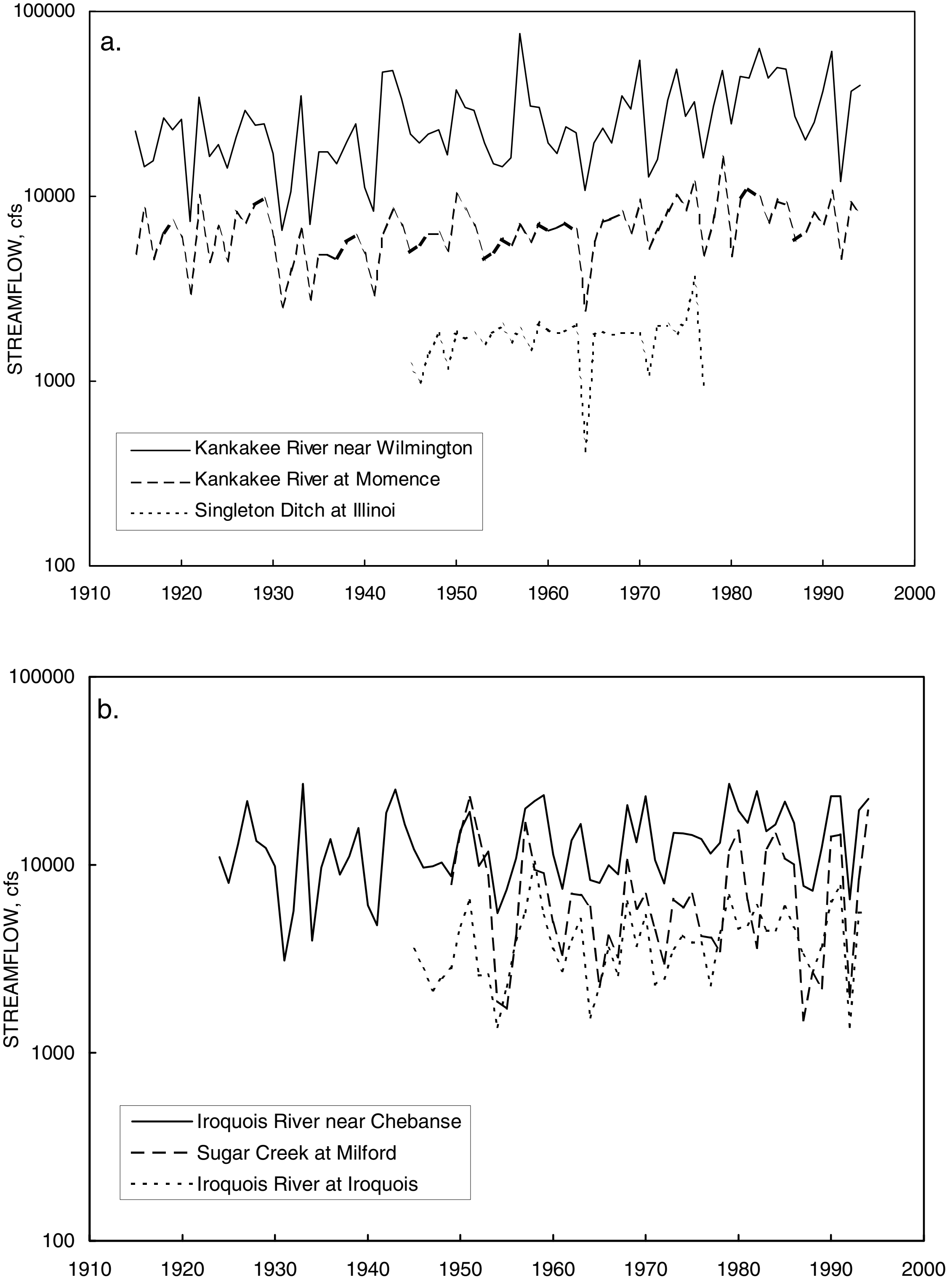

Figure 5. Annual peak discharges for gaging stations in the Kankakee River basin in Illinois

The Kankakee River, more than any other river in the State, shows definite increasing trends of high, medium, and low streamflows. Streamflow records on the Kankakee River show that a major jump in the flow amounts occurred in the mid- to late 1960s. All trends appear to be related to a coincident increase in average annual precipitation. Examination of land use in the watershed has not identified a direct cause for the increase in average flow conditions, but such changes may play a secondary role in high and low trends. Irrigation withdrawals from streams have some impact on reducing low flows during drought years. Trend analysis does not identify any continued increases in high or low flows over the past 30 years.

Flows in the remainder of the basin also have increased, but to a much smaller degree. These increases also appear to be related to precipitation changes. Flow records for the southern portion of the Iroquois River basin on Sugar Creek do not show any trends in flow.

Bank Erosion

Recently the Water Survey completed another research report entitled *Bank Erosion Survey of the Main Stem of the Kankakee River in Illinois and Indiana* (Bhowmik et al., 2001). Some of the important findings from that report are summarized here.

Bank conditions for the Kankakee River were qualitatively assessed during the field reconnaissance survey from the Route 30 Bridge in Starke County, Indiana, to the confluence of the Kankakee, Des Plaines, and Illinois Rivers (Bhowmik et al., 2001). A total of 111.8 River Miles were evaluated between November 19 and December 1, 1998. The bank conditions described during the reconnaissance survey refer only to nearshore bank conditions that could be associated with hydraulic forces of river flow and that also were visible from a boat.

Observations of bank features were recorded on USGS quadrangle maps with a survey system previously developed and used on the upper Mississippi and Illinois Rivers (Bhowmik et al., 1997). The survey details bank features, erosion and deposition features, causative processes, and bed features. The causative factors include hydraulic forces, such as potential of high velocity, secondary circulation, inside or outside of a bend, wave forces, potential of seepage, and others. Attributes of the riverbank describe and identify the severity of erosion along the bank and regions of the bank that are considered stable or are protected by rock or other structures. In addition to these records, the location of pump stations, USGS streamgages, boat ramps, bed material sample sites, established stands of trees, and regions of relatively new accumulations of sand above water level also were marked on the map for reference. Survey data have been transferred into a Geographical Information System (GIS) database. Figures 6 and 7 show some typical erosion in Indiana and Illinois. These photographs are from Bhowmik and Demissie (2000).

All the bank erosion maps have been color coded to identify the severity of erosion and/or stability of the bank conditions on both sides of the river. These color-coded maps in CD format are available on request from the Illinois State Water Survey. This is the first time in the history of the Kankakee River investigation that such detailed bank condition maps have been prepared. For a detailed description of bank conditions along each segment, readers are referred to the original publication (Bhowmik and Demissie, 2000).

Channel features in Illinois were much more variable, including long pool-riffle sequences, rock ledges and sand bars, broad and sharp meanders, and islands. General bank features in Illinois ranged from sand-and-gravel deposits along the water's edge to mild bank

Figure 6a. A typical view of the Kankakee River channelization and bank vegetation in Indiana (from Bhowmik and Demissie, 2000)

Figure 6b. An example of a 5-foot scarp with underlying piping above a steep sandy bench on the Kankakee River in Indiana (from Bhowmik and Demissie, 2000)

Figure 7a. An example of a riffle formed by the edge of a bedrock section and gravel deposits on the Kankakee River in Illinois (from Bhowmik and Demissie, 2000)

Figure 7b. An example of the installation of bank protection residential sheet-piling on the Kankakee River in Kankakee, Illinois (from Bhowmik and Demissie, 2000)

slopes and human-made graded slopes to natural rock cliffs and human-made bank protection structures. Dwellings located within 100 feet of the riverbank were common. This segment of the river is 60 miles long starting at the mouth of the river with the Des Plaines and Illinois Rivers. All the individual maps, including a legend and other descriptive information, are given in Bhowmik et al. (2001).

Channelization of the river in Indiana by public and private groups was completed by 1918 (Bhowmik et al., 1980). The channel is generally trapezoidal in shape. High water marks were generally visible at the top of the scarps. Eddies induced by the presence of trees on bank slopes and on the top of the bank were observed. Bhowmik and Demissie (2000) have described the bank conditions for each of the surveyed quad maps.

The field survey data were used to estimate the relative magnitudes of the bank erosion on the main stem of the Kankakee River for 111.8 River Miles from its mouth with the DesPlaines and Illinois Rivers to Route 30 Bridge in Indiana. This information is given in Table 1. The bank erosion was categorized as severe, moderate, minor, stable, rock or protected, and areas where information could not be gathered because of some obstructions.

A total of 223.6 River Bank Miles were evaluated on a stretch of river extending 111.8 miles. Out of this total, 103 River Bank Miles are located in Indiana and 120.6 River Bank Miles are located in Illinois. About 10.4 River Bank Miles in Indiana and Illinois showed severe bank erosion (Table 1). This is about 4.6 percent of the total. Relatively, there is more severe bank erosion in Indiana than in Illinois.

About 39.4 River Bank Miles showed moderate bank erosion in Illinois and Indiana. This translates into 17.6 percent of the total River Bank Miles investigated. Again, about 70 percent of the River Bank Miles exhibiting moderate bank erosion are located in Indiana and another 30 percent in Illinois.

This analysis also showed that about 31.7 percent of the total River Bank Miles exhibited minor erosion (about 21 percent in Indiana and 10.7 percent in Illinois). This translates into 46.9 River Bank Miles in Indiana and 23.9 River Bank Miles in Illinois exhibiting minor bank erosion.

In general, about 82 River Bank Miles in Indiana exhibited some form of erosion from minor to severe, and 38.6 River Bank Miles in Illinois exhibited minor to severe erosion. About

Table 1. Bank Erosion Conditions of the Main Stem of the Kankakee River in Indiana and Illinois (After Bhowmik and Demissie, 2001)

Bank erosion conditions	*Bank miles*		*Bank miles for each state (%)*		*Total*
	Indiana	*Illinois*	*Indiana*	*Illinois*	*bank miles (%)*
Severe	7.4	3.0	7.2	2.5	4.6
Moderate	27.7	11.7	26.9	9.7	17.6
Minor	46.9	23.9	45.6	9.8	31.7
Stable	5.6	40.7	5.4	33.7	20.7
Rock or protected	13.4	33.3	13.0	27.7	20.9
Data could not be collected	2.0	8.0	1.9	6.6	4.5
Total	103.0	120.6	100.0	100.0	100.0

80 percent of the Indiana River Bank Miles exhibited minor to severe erosion, and 20 percent of the Indiana River Bank Miles are either stable or protected by structural means or at locations where data could not be collected. There were reaches of the river where the river banks were either obscured by snags or behind islands that were inaccessible from the boat.

Similar analyses for Illinois showed that 38.6 River Bank Miles exhibited minor to severe erosion, and 82 River Bank Miles are either stable, protected by structural means, or at locations where data could not be collected due to the presence of obstructions to the bank such as islands, etc. Thus, 32 percent of the River Bank Miles in Illinois had some type of erosion, and 68 percent are essentially stable because of natural conditions, protection by artificial means, or at locations where data could not be collected.

Bed and Bank Materials

For the present project, bed and bank material samples were collected to characterize the particle size distributions of these materials. Bhowmik and Demissie (2000) provide detailed results from these analyses. For the research conducted in 1978-1980 (Bhowmik et al., 1980), many more bed material samples were collected and analyzed. Some of those results will be repeated here. For detailed explanations, readers are referred to the original publications (Bhowmik et al., 1980; Bhowmik and Demissie, 2000).

For the present project, bed samples were collected at approximately every mile by scaling distances from 7.5-minute quad maps, and a bank sample was taken on alternating sides of the channel at every fifth site. Bank samples were generally taken at the toe of the bank after removing approximately 1 inch of surface material to ensure samples contained undisturbed bank materials. A total of 82 mid-channel samples and 19 bank samples were collected.

Laboratory analyses of the samples consisted of dry sieving the samples using standard techniques. A particle size of 0.062 mm was used as the break between the sand and silt/clay fractions. Bed material samples from every fifth mile and all bank material samples were analyzed for particle size distribution. A total of 21 bed material and 19 bank samples were analyzed by the Water Survey Sediment Laboratory. Figure 8 shows the variations of d_{50} sizes of the bed materials as one moves from upstream in Indiana from Illinois. Table 2 shows the particle size characteristics of the bed materials collected for the present project.

Bed material samples consisted primarily of sand. In general, bed materials become finer in the downstream direction. Bhowmik et al. (1980) collected 375 bed material samples. They developed frequency distributions for 281 bed material samples, which excluded samples from Six-Mile Pool and the sand bars. Figure 9 is a reproduction of that frequency distribution plot. This illustration indicates that the median diameters are between 0.3 and 0.4 mm (136 samples), between 0.2 and 0.4 mm (221 samples), and between 0.1 and 0.4 mm (almost all bed materials). This range of median diameters places all these materials in the range of fine to medium sand. Thus, for all practical purposes, it can be assumed that the bed materials of the Kankakee River, except in areas of rocky bed, are composed of fine to medium sand. This point is further amplified in the next illustration, Figure 10.

The changing patterns of the d_{50} sizes of the bed materials along the centerline of the Kankakee River are shown in Figure 10 (after Bhowmik et al., 1980). As can be seen, the d_{50} sizes of the majority of the bed materials are close to 0.35 mm. Bhowmik et al. (1980) also have shown that there is not much variability between the patterns of particle size distributions from

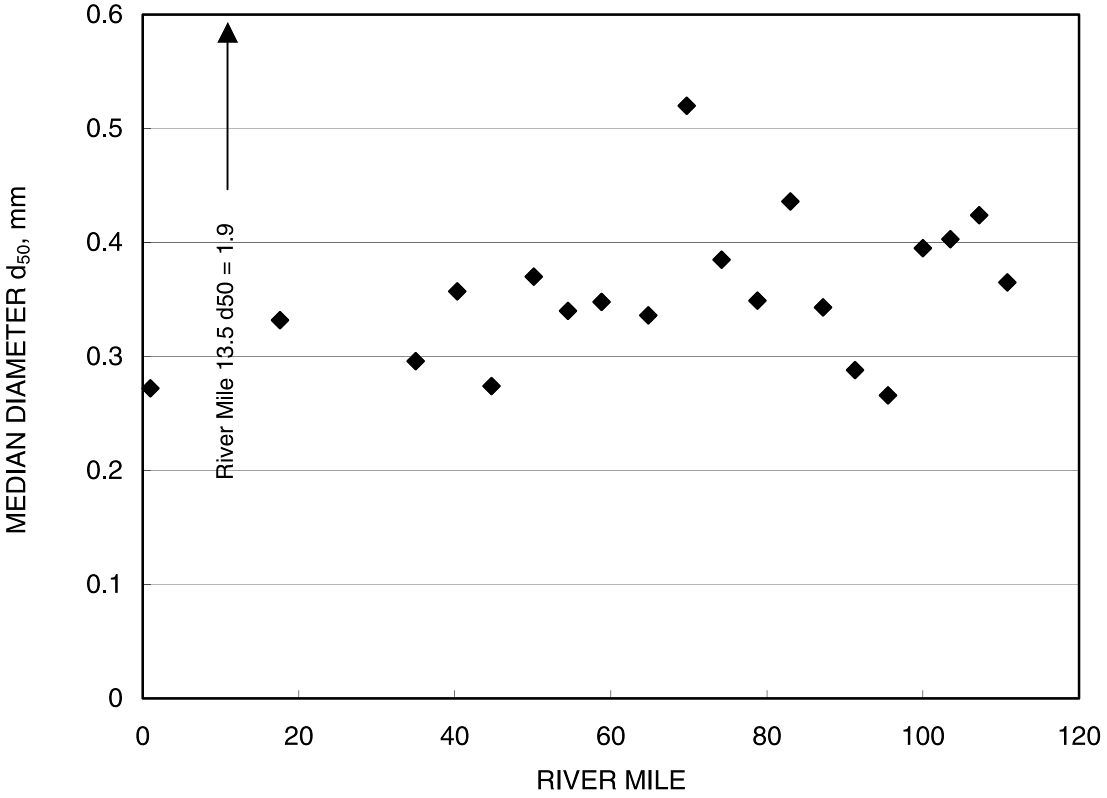

Figure 8. Median diameter d_{50} of the bed material at the mid-channel of the Kankakee River

Indiana to Illinois. The shapes of the plots are similar, and the particles are basically uniform, ranging in size from medium to fine sands. This was also found to be true for the bed of the river from Six-Mile Pool, and from sand bars. This shows that the bed of the Kankakee River is composed of sand, except in some segments in Illinois where the bed is covered with rocky materials.

Bhowmik et al. (1980) also analyzed the sand deposited from sand bars in Illinois for particle size distribution. Core samples extending up to 2 feet in length were collected. Particle size distributions of samples from different depths were made. Figure 11 shows the particle size distribution of four samples (0 to 0.5 feet or ft., 0.5 to 1.0 ft., 1.0 to 1.5 ft., and 1.5 to 1.9 ft.) from the sand bar in Six-Mile Pool. This illustration indicates that even with depth, the particle size distributions of the deposited sediments are nearly identical. Medium-sized sand constituted the bulk of the sand bars. The d_{50} size varied between 0.3 and 0.4 mm (Figure 11).

Bhowmik et al. (1980) also collected similar core samples from the centerline and near the left and right sides of the river at the sand bar near the State Line Bridge. Figure 12 shows the particle size distributions of the materials. Here again, the sediment deposited in this sand bar consists of medium-sized sands. The d_{50} size varied from 0.25 to 0.35 mm.

The analyses presented thus far indicate that the bed materials of the Kankakee River essentially consist of fine to medium sand. This is an important indicator that must be considered in the further hydraulic analyses of the main stem of the river. A sand bed channel behaves in a

Table 2. Bed Material Characteristics of Mid-Channel Samples (After Bhowmik and Demissie, 2000)

Sample ID	*Particle diameter (mm)*			*Uniformity coefficient, U*
	d_{35}	d_{50}	d_{85}	
KKRIN01	0.312	0.365	0.615	1.82
KKRIN05	0.374	0.424	0.647	1.71
KKRIN09	0.348	0.430	0.644	1.72
KKRIN13	0.326	0.395	0.717	2.68
KKRIN17	0.235	0.266	0.349	1.52
KKRIN21	0.245	0.288	0.462	1.68
KKRIN25	0.297	0.343	0.558	1.78
KKRIN29	0.372	0.436	0.841	1.84
KKRIN33	0.295	0.349	0.752	1.97
KKRIN37	0.312	0.385	1.120	2.15
KKRIN41	0.419	0.520	1.120	2.36
KKRIN45	0.294	0.336	0.521	1.72
KKRIN49	0.302	0.348	0.542	1.74
KKRIL53	0.300	0.340	0.478	1.60
KKRIL57	0.321	0.370	0.523	1.59
KKRIL65	0.242	0.274	0.363	1.58
KKRIL69	0.311	0.357	0.565	1.64
KKRIL74	0.262	0.296	0.431	1.69
KKRIL89	0.253	0.332	0.676	2.41
KKRIL93	0.478	1.900	>8.000	17.99
KKRIL104	0.238	0.272	0.353	NA

Note: NA = not applicable.

particular fashion as far as the hydraulics of flow is concerned. Some of these basic concepts are given in numerous textbooks, including a summary provided by Bhowmik et al. (1980).

Bank materials also were analyzed for the present project and the previous research by Bhowmik et al. (1980). In general, the d_{50} size of the bank materials varies from 0.16 mm to 0.4 mm. Again, all the particles are essentially in the sandy fraction except for a few samples where finer bank materials were evident. Bank material samples collected by Bhowmik et al. (1980) between River Mile (RM) 67.0 and RM 80.0 in Indiana showed that the d_{50} sizes ranged from 0.14 mm to 0.35 mm. Thus, all data collected and analyzed until now from the main stem of the Kankakee River indicate that the main stem essentially flows on a sand bed and should be treated as an alluvial river with sand beds.

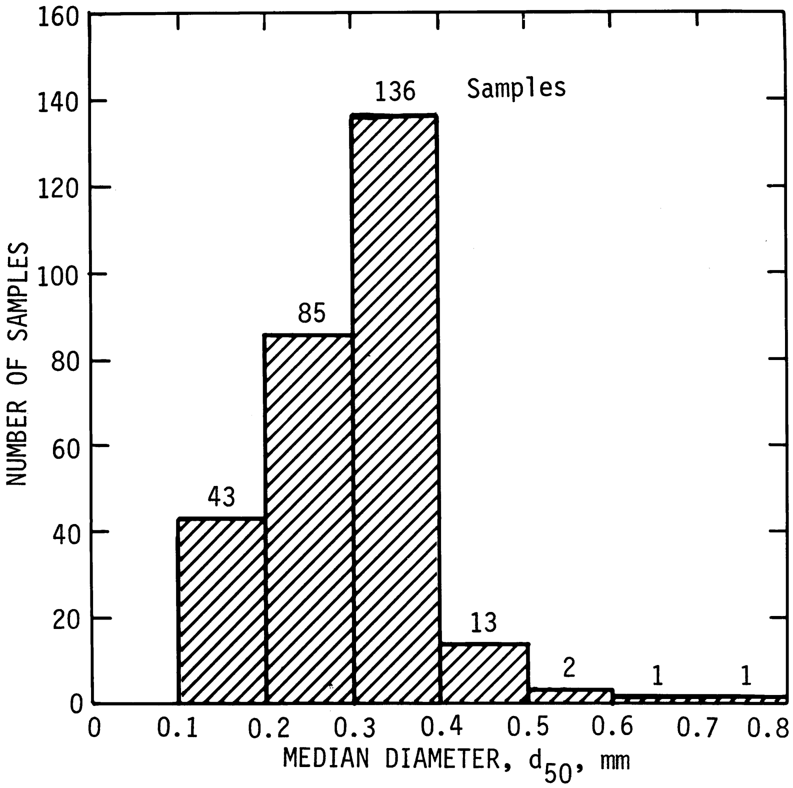

Figure 9. Frequency distribution of the d_{50} sizes of the bed materials (from Bhowmik et al., 1980)

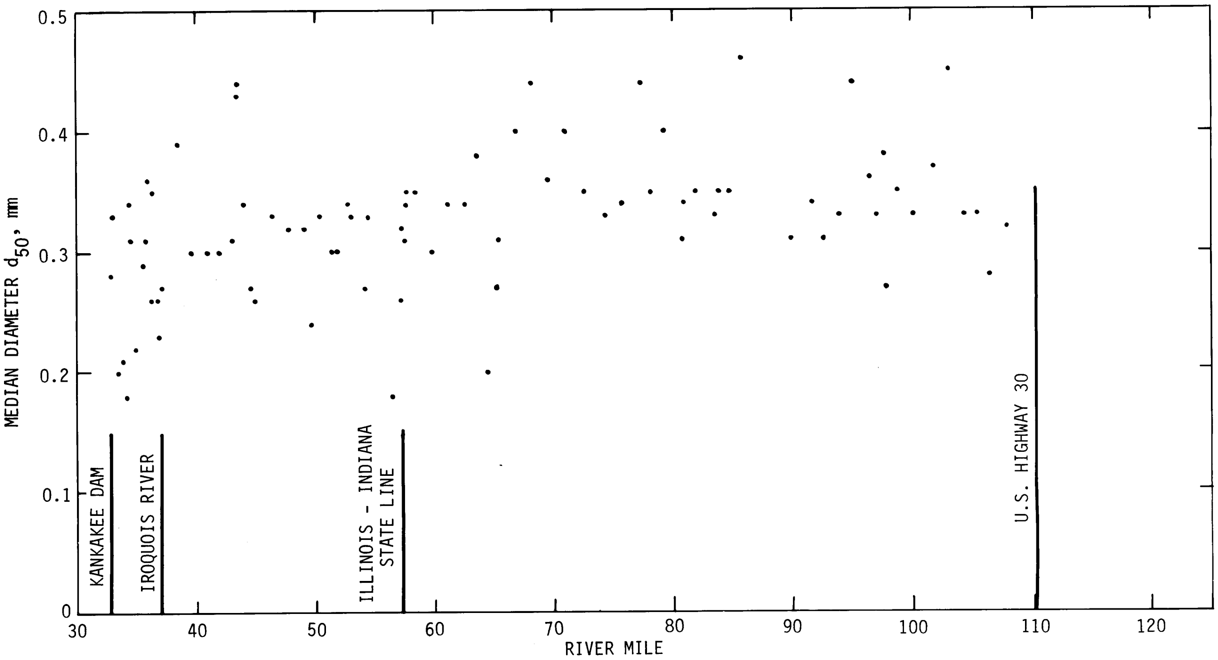

Figure 10. Median diameter d_{50} of the bed material versus distance along the centerline of the Kankakee River (from Bhowmik et al., 1980)

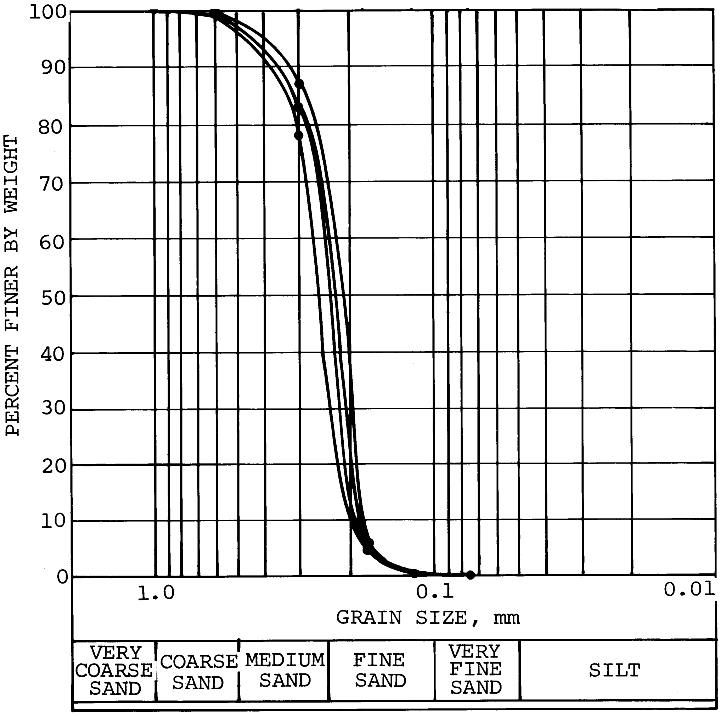

Figure 11. Particle size distributions of a sand deposit in Six-Mile Pool (depth of sampling: 0 to 2 feet) (from Bhowmik et al., 1980)

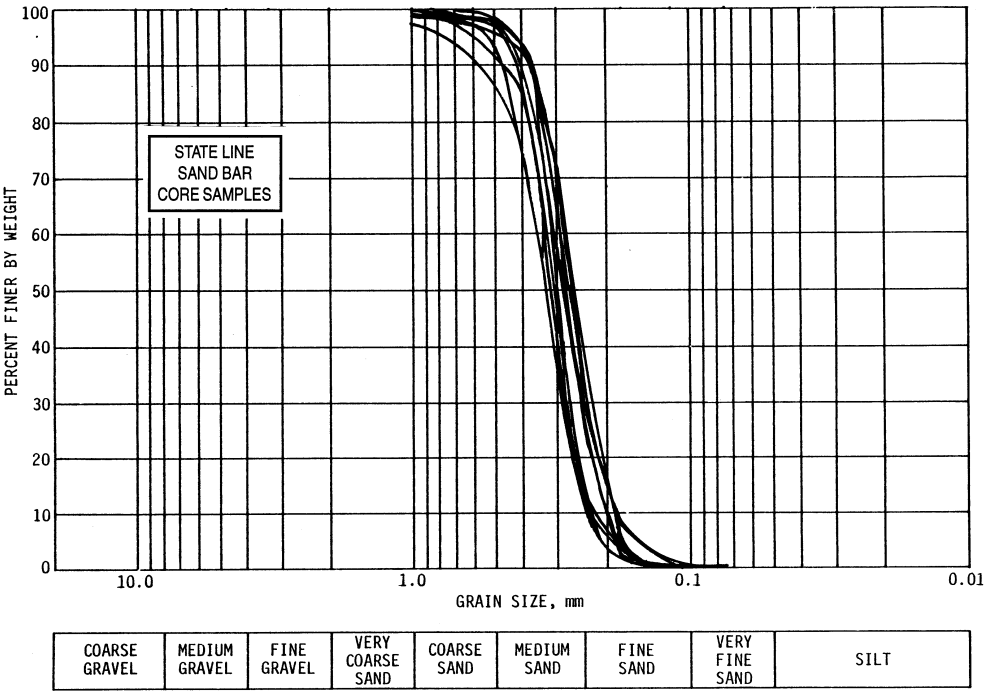

Figure 12. Particle size distributions of core samples from the sand bar near the State Line Bridge (from Bhowmik et al., 1980)

River Geometry

Historical Data

River geometry data from the Kankakee River in Illinois have been collected since 1959. Some data extended only a few miles, and other data extended from near the Kankakee Dam in Kankakee, RM 32.75, to the State Line Bridge, RM 58.19. Historical data were collected by several agencies and organizations. For this report, all the old data and new data collected in 1999-2000 were compiled to compare the relative changes over the last 20 to 40 years. All the surveying for the 1999 data was completed by the Illinois State Water Survey. Each data set will be described briefly, including their extent and limitations.

1959 Data

This set of data was collected by the old Division of Water Resources (DWR), presently called the Office of Water Resources (OWR) of Illinois Department of Natural Resources (IDNR). Data were collected from within the lower reach of Six-Mile Pool from ten cross sections extending from RM 34.01 to RM 34.84 and shown in Figure 13.

1966 Data

This set of data was collected by DWR, presently called OWR of IDNR. Data were collected for the reach of the river from Aroma Park to upstream of Momence to the confluence of the Kankakee River with Singleton Ditch. Figure 14 shows the locations of these cross sections. In 1966, 60 cross sections were measured from RM 37.15 to RM 50.80. No data were collected from Six-Mile Pool nor from the Momence Wetland area.

1968 Data

River cross-sectional data were collected by DWR, presently called OWR of IDNR. Data were collected from the upper reach of Six-Mile Pool from RM 35.90 to RM 36.96. Ten river cross sections were measured in 1968, and their locations are shown in Figure 15.

1977 Data

Data were collected by DWR, presently called OWR of IDNR. Data were collected for the reach of the river from Aroma Park to upstream of Momence extending to Singleton Ditch, from RM 37.15 to RM 50.80. Data for 52 river cross sections were collected in 1977, and their locations are shown in Figure 16.

1978 Data

Data were again collected by DWR, presently called OWR of IDNR. For this period a total of 32 cross sections were measured within the Six-Mile Pool area. The extent of the mea-

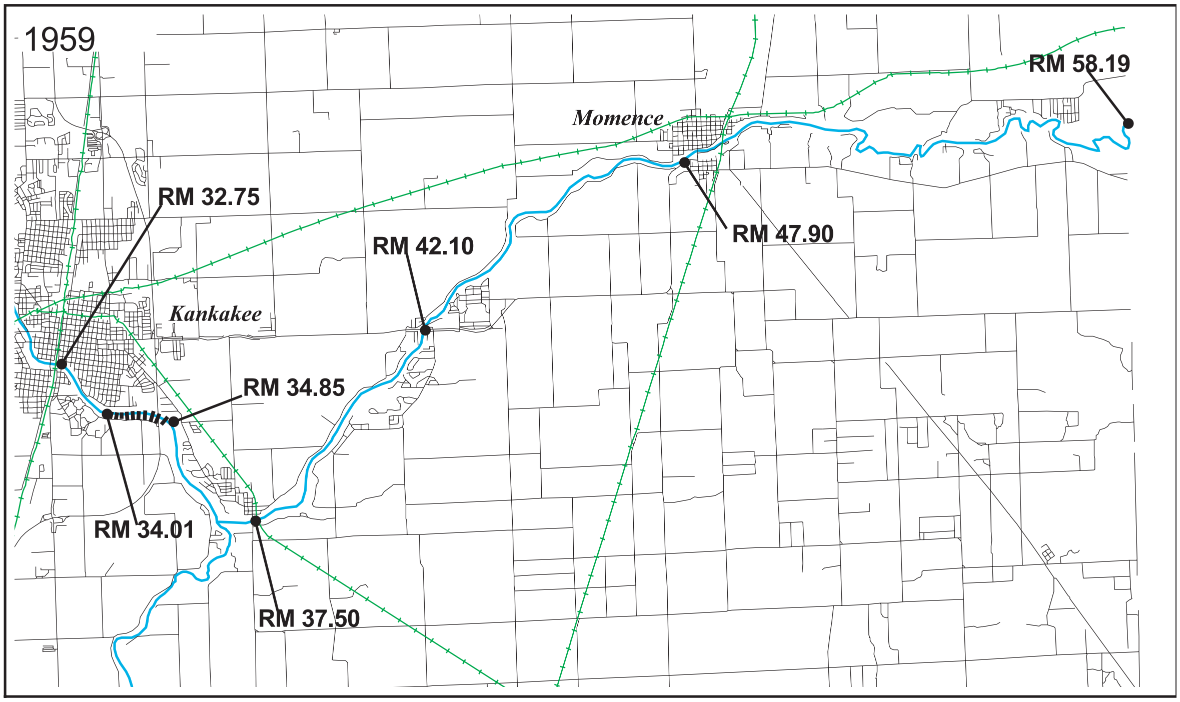

Figure 13. Kankakee River cross-section locations within Six-Mile Pool, 1959

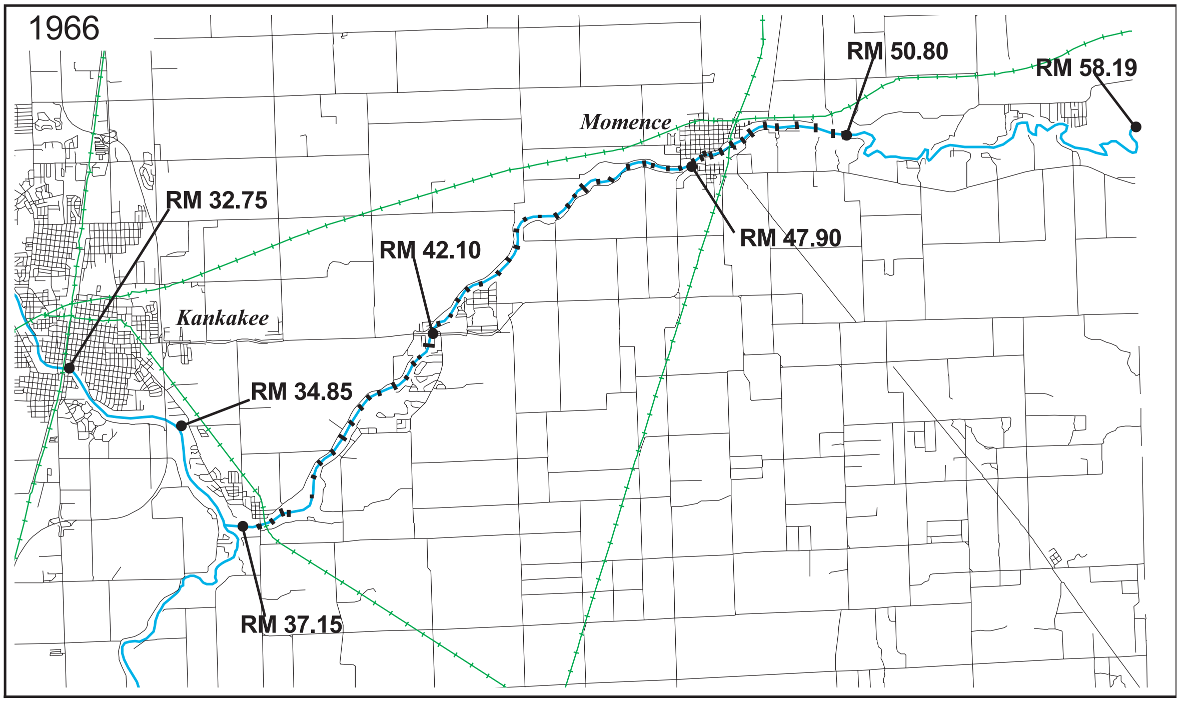

Figure 14. Kankakee River cross-section locations between Aroma Park and Singleton Ditch, 1966

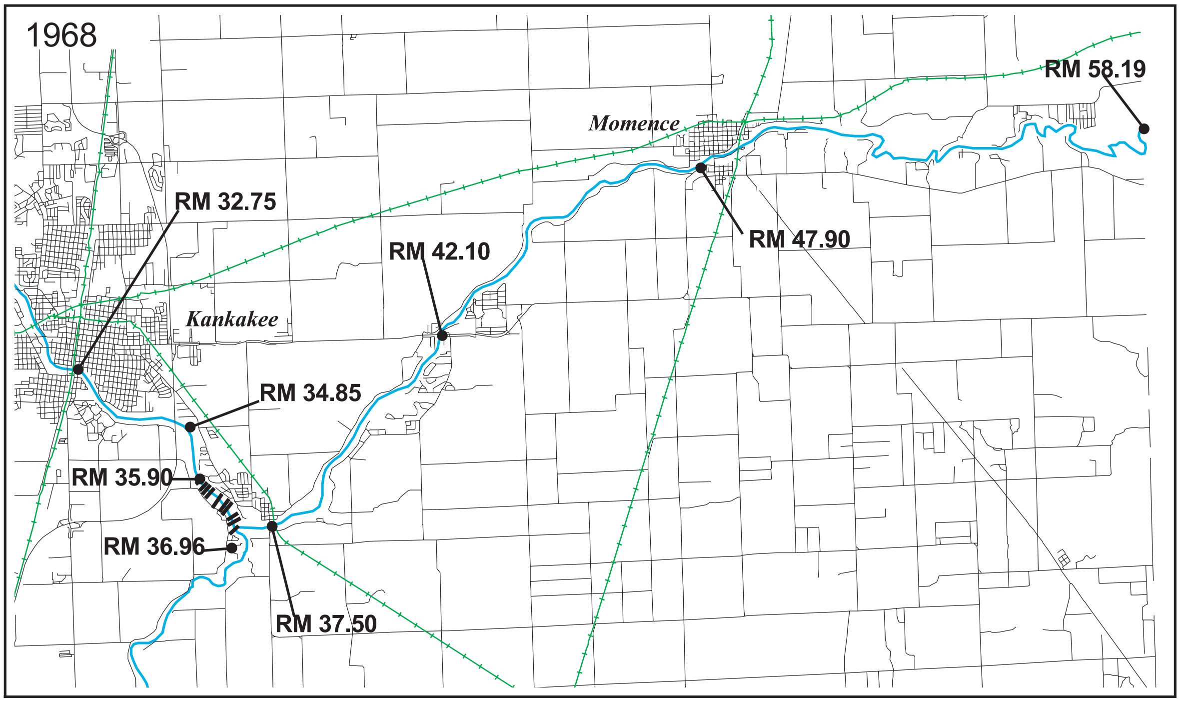

Figure 15. Kankakee River cross-section locations within Six-Mile Pool, 1968

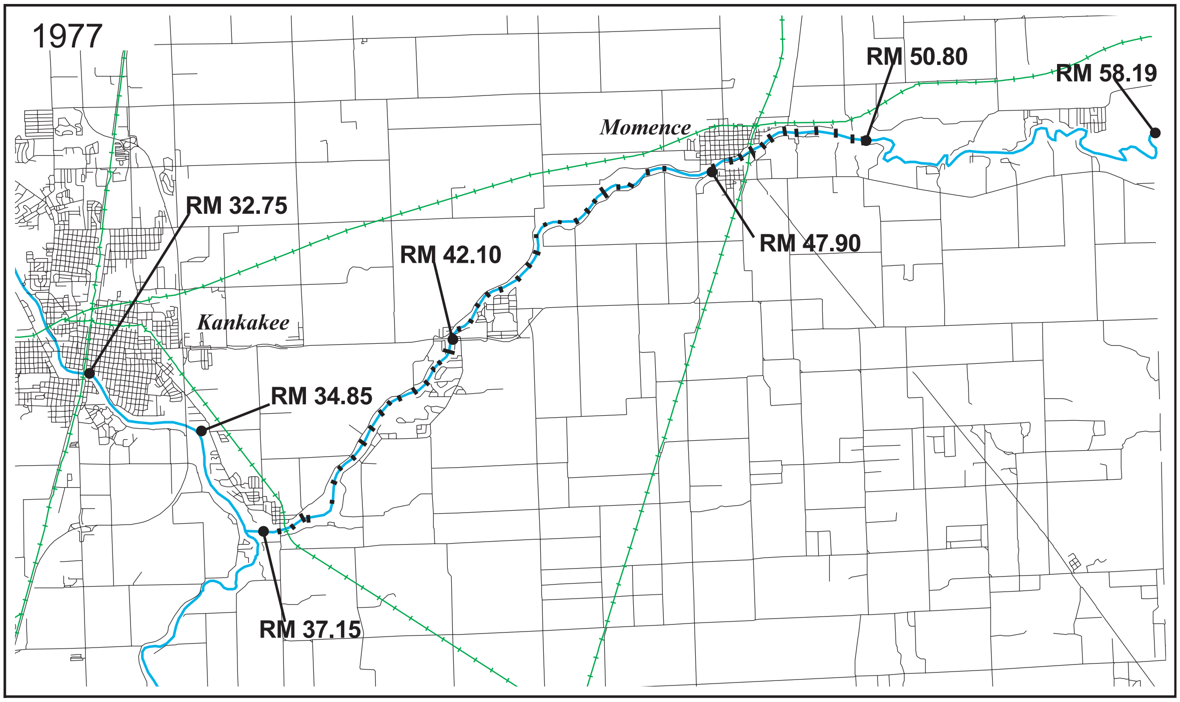

Figure 16. Kankakee River cross-section locations between Aroma Park and Singleton Ditch, 1977

sured cross sections was from RM 32.75 to RM 36.86. Note that for this surveying, most of the cross sections measured in 1959 and 1968 within Six-Mile Pool were resurveyed in 1978. Figure 17 indicates the locations of these cross sections.

1980 Data

This data set was collected by the Illinois State Water Survey (Bhowmik et al., 1980) for a major investigation on the hydraulics and hydrology of the Kankakee River basin. The extent of the data included Six-Mile Pool and the Momence Wetland area. The cross-sectional data from the Six-Mile Pool area covered those areas surveyed by the OWR of IDNR in 1959, 1968, and 1978. This is the first complete set of data from Six-Mile Pool. A total of 34 river cross sections were measured from RM 32.75 to RM 36.96.

The 1980 data on river cross sections collected by the Water Survey for the Momence Wetland were the first complete data on this area ever collected. A total of 36 river cross sections were collected from RM 50.77 to the Illinois-Indiana State Line Bridge (RM 58.19). Figure 18 shows the locations of these cross sections.

1994 Data

The United States Geological Survey or USGS (Terrio and Nazimek, 1997) collected a complete set of river cross-section data from the Momence Wetland area. The USGS repeated most of the original cross sections where 1980 data were collected by the Illinois State Water Survey (Bhowmik et al., 1980). The USGS measured 36 cross sections extending from RM 50.77 to RM 58.19, and locations are shown in Figure 19.

New Data

1999 Data

River Cross Sections. The latest set of river cross-section data are those collected by the Illinois State Water Survey from late 1998 through early 2000 and designated as 1999 data. Note that almost all the surveying was done in 1999 with some additional surveying in 2000. For the first time, this is the complete set of 134 cross sections from the Kankakee River in Illinois extending from near the Kankakee Dam, RM 32.75, to the State Line Bridge, RM 58.19. An attempt also was made to repeat the survey at all the old cross sections completed through 1994 by OWR (DWR), ISWS, and USGS. Figure 20 shows the locations of all of these cross sections.

Sand Bars. Bhowmik et al. (1980) identified eight sand bars (Figure 21) within the main stem of the Kankakee River from Aroma Park to the State Line Bridge. Detailed topographic surveys of four of these sand bars were done in 1979 as reported in that report. The sand bar at the State Line Bridge area was also monitored in 1979 (Bhowmik et al., 1980) to show its progression over a period of 10 weeks from July 16, 1979 through September 24, 1979. Figure 22 shows the progressive movement of this sand bar based on Bhowmik et al. (1980).

During 1999 surveying, four of the same sand bars were surveyed in detail to determine their volume and extent in 1999. Figure 21 shows the locations of these four sand bars: State Line, and sand bars 2, 3, and 4.

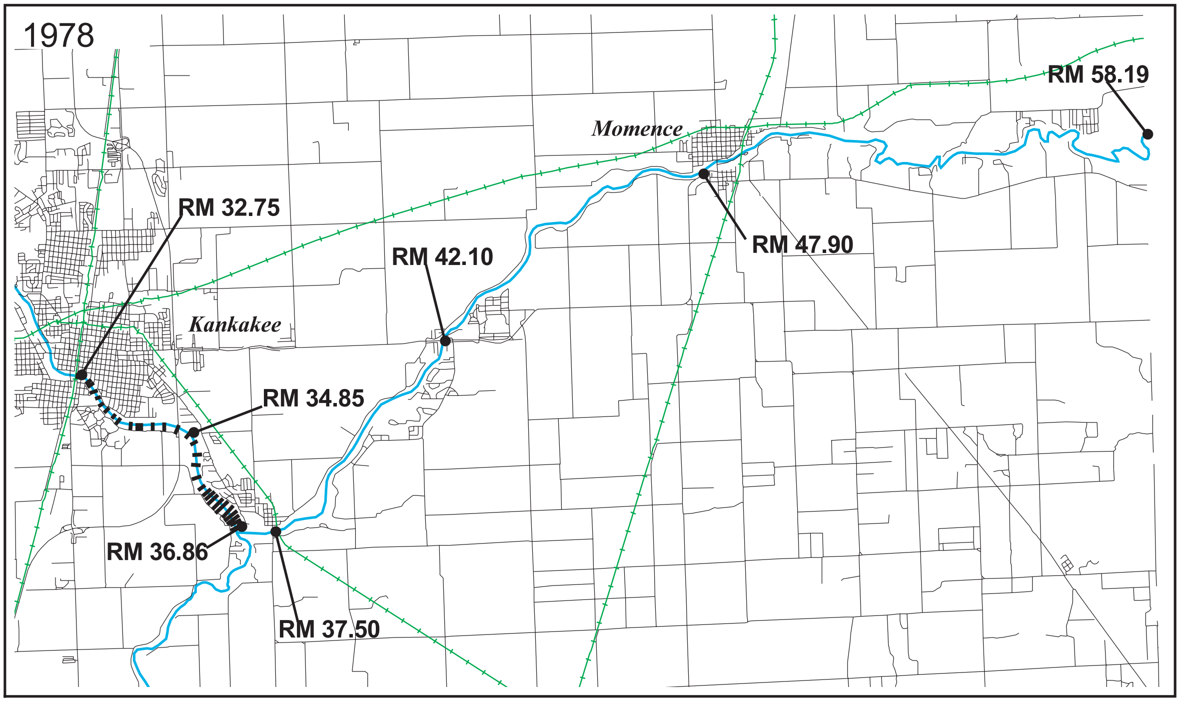

Figure 17. Kankakee River cross-section locations within Six-Mile Pool, 1978

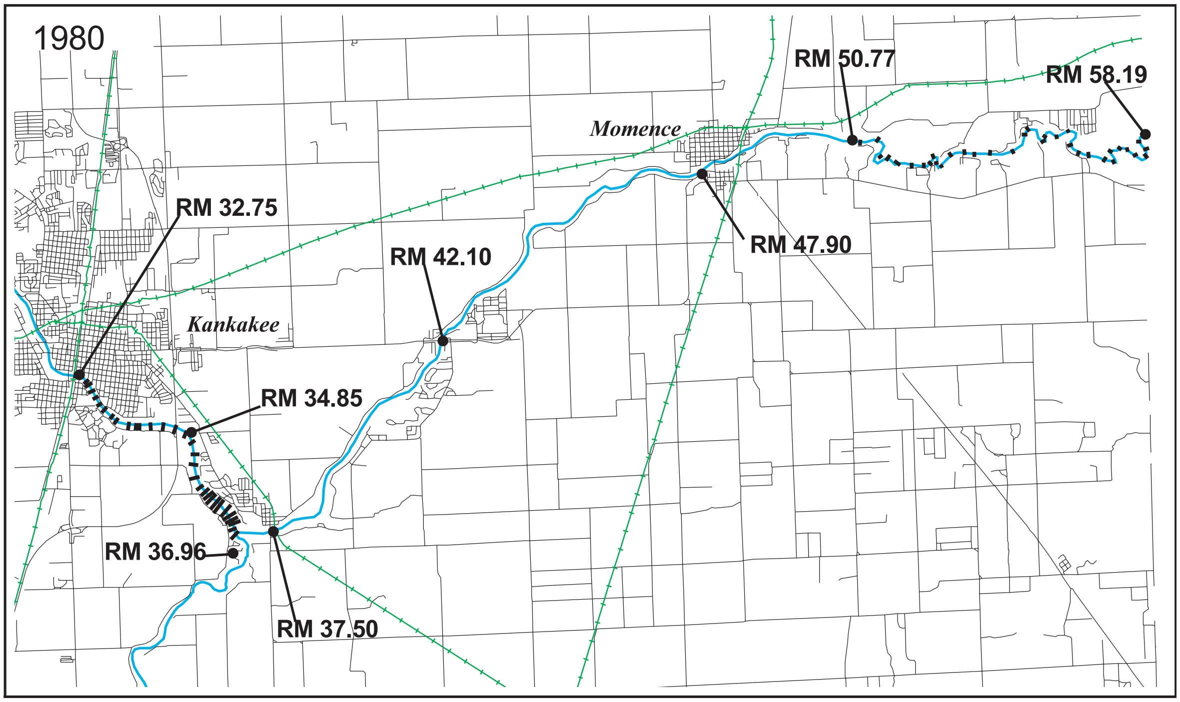

Figure 18. Kankakee River cross-section locations within Six-Mile Pool and the Momence Wetland area, 1980

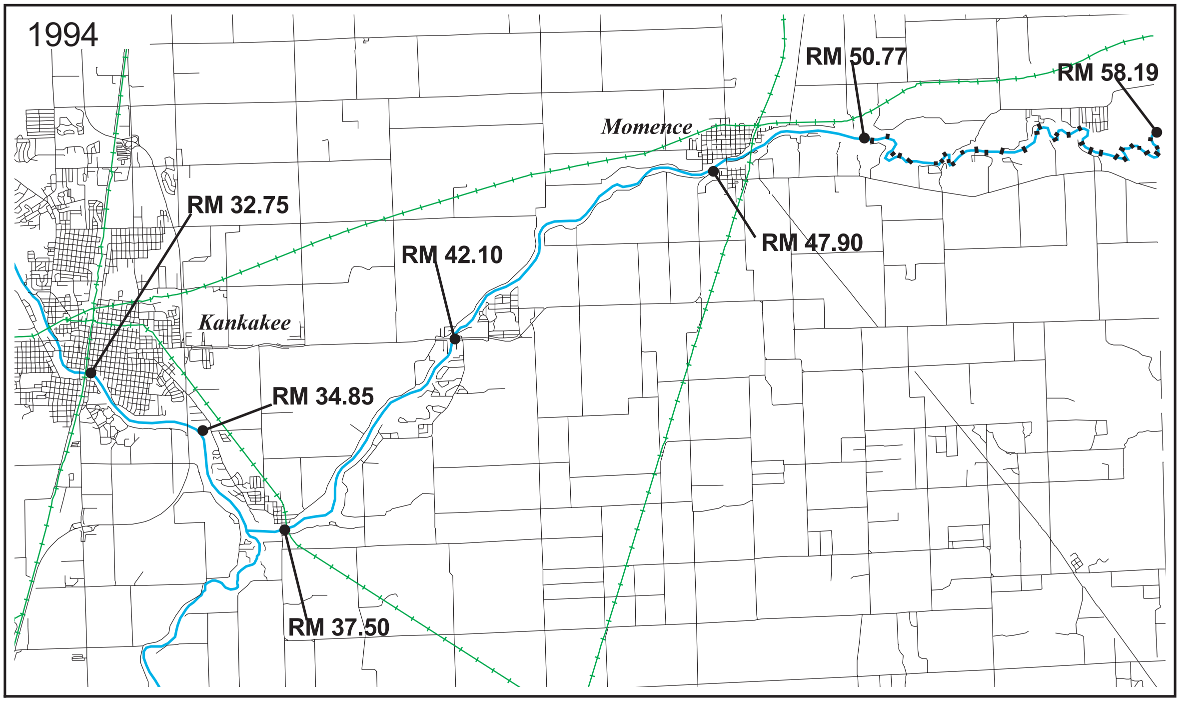

Figure 19. Kankakee River cross-section locations within the Momence Wetland area, 1994

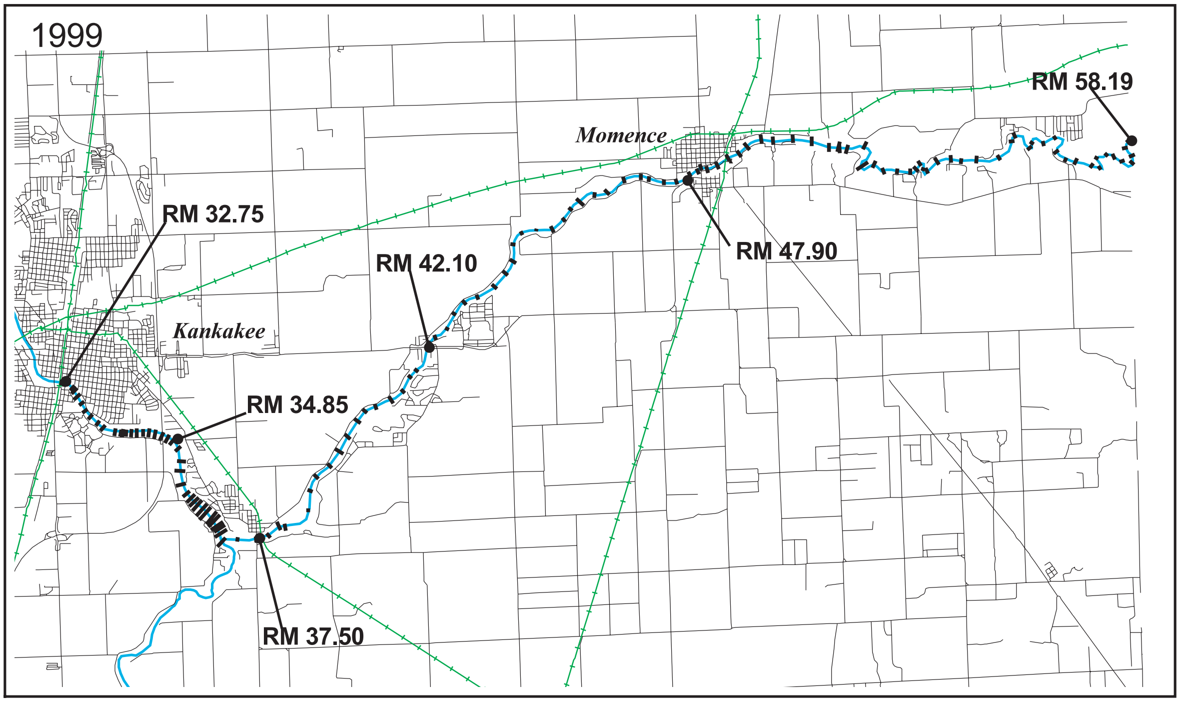

Figure 20. Kankakee River cross-section locations for the Kankakee Dam to the Illinois-Indiana State Line Bridge, 1999

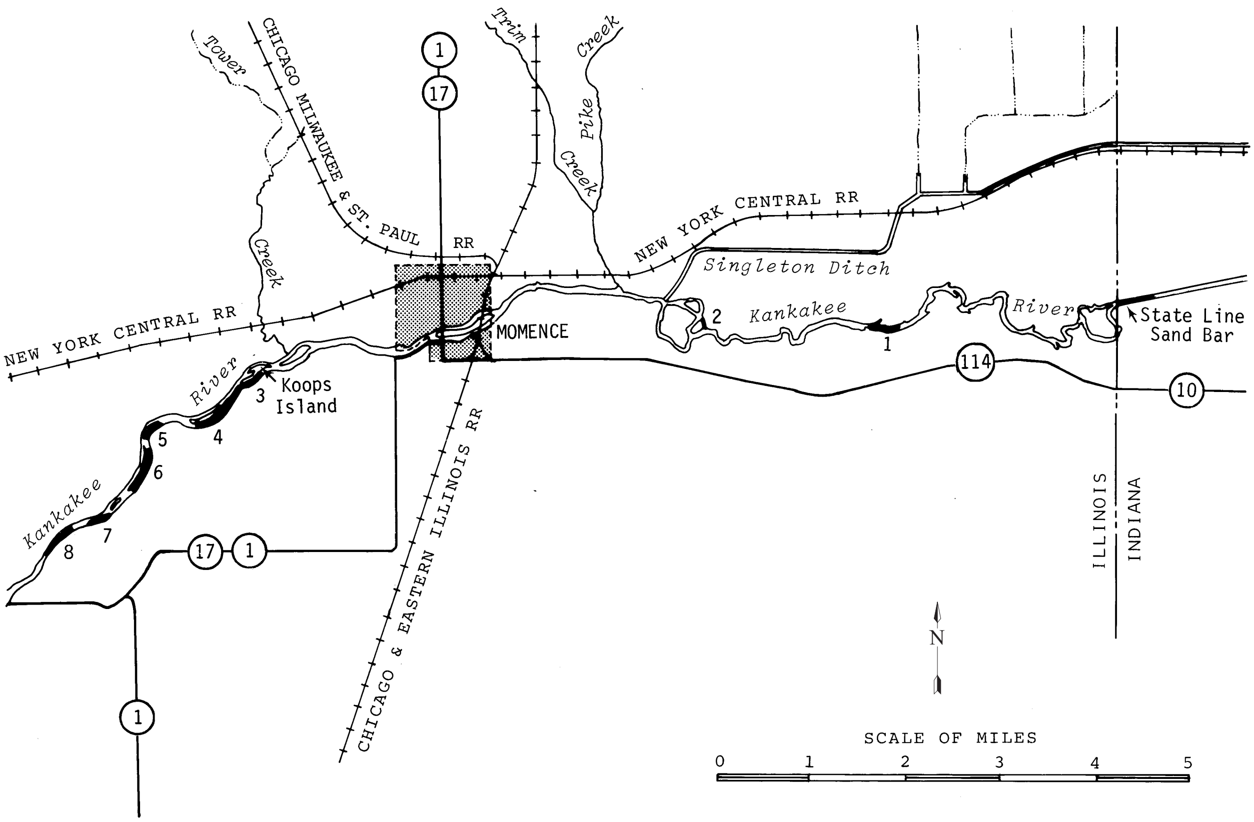

Figure 21. Locations of major open river sand bars in Illinois (from Bhowmik et al., 1980)

The above section has briefly summarized the historical and present river cross-sectional surveying completed through 1999. The next section presents a comprehensive analysis of all the river cross-sectional and sand bar data.

Analyses of River Geometry and Sand Bar Data

All the river cross-sectional data and the sand bar surveying completed through 1999 were combined to make a comprehensive analysis of the river geometry and the sand bars over the last several decades. This analysis should provide an excellent glimpse of the changes that have occurred along the main stem of the Kankakee River from Kankakee Dam to the State Line Bridge. In order to make it relatively easy for overall understanding, this segment of the river has been divided into three sub-sections: Six-Mile Pool, RM 32.75 to RM 36.96; Aroma Park to Singleton Ditch, RM 36.96 to RM 50.80; and the Momence Wetland area extending from Singleton Ditch to the State Line Bridge, RM 50.80 to RM 58.19.

For the present analysis, the Momence Wetland was assumed to extend from the confluence of Singleton Ditch with the Kankakee River, RM 50.80, up to the State Line Bridge, RM 58.19. Figure 21 gives the location of Singleton Ditch.

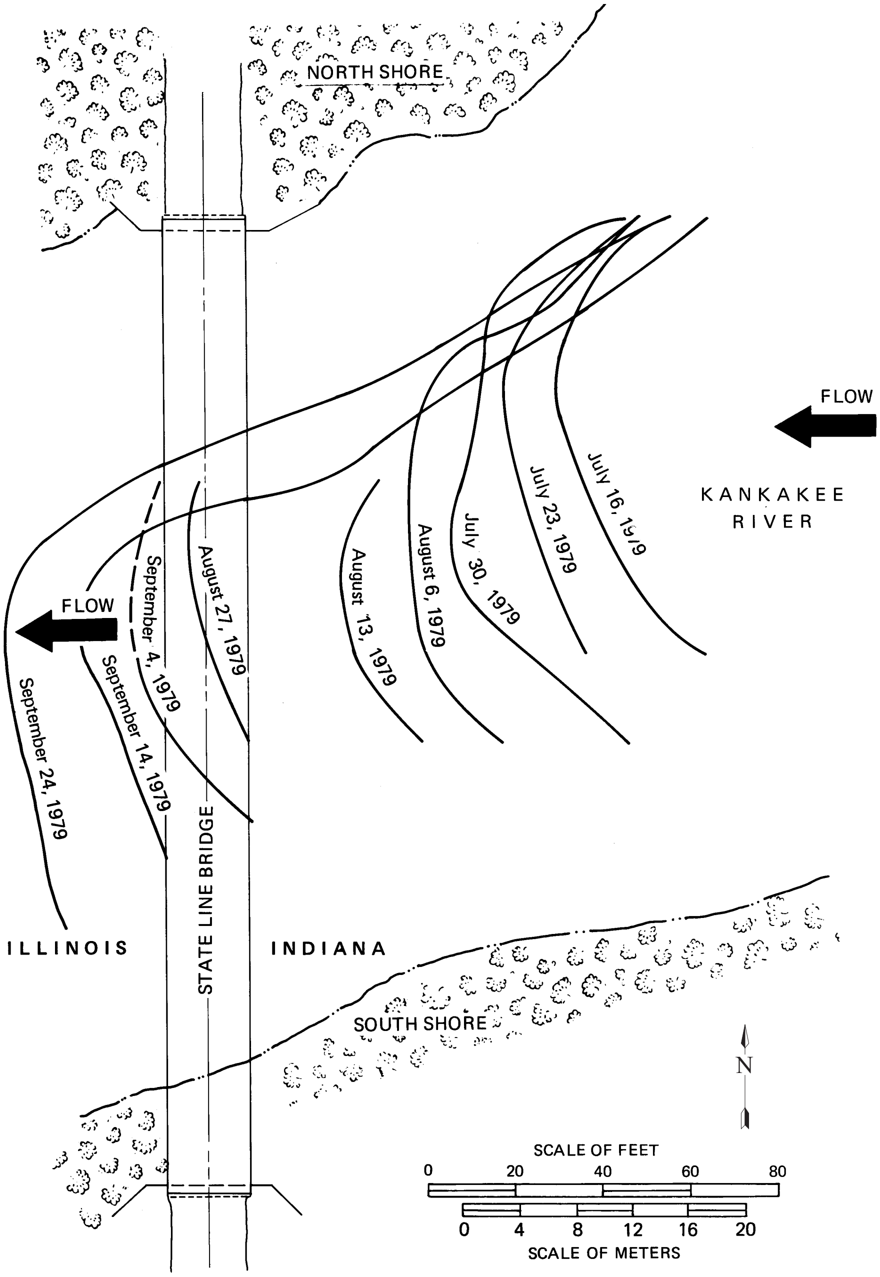

Figure 22. Successive movement of the sand bar at the State Line Bridge (from Bhowmik et al., 1980)

River Geometry

Six-Mile Pool

River cross-sectional data available through 1999 were plotted for all the cross sections (Appendix A- C). Cross-sectional areas at different time periods also were computed (Appendix D). These data were subsequently used to compute and compare the changes in cross-sectional areas and capacities below specified elevations along the main stem of the Kankakee River in Illinois.

A comparison of the variabilities of the cross sections for different time periods within Six-Mile Pool yields some very dramatic and important observations that need to be considered in the development of future management alternatives for this river in Illinois. Figures 23-25 show 12 cross sections within Six-Mile Pool. These illustrations show changes in the cross-sectional areas from 1968 through 1999. Examination of these 12 cross sections and all the cross-sectional data shown in Appendix A shows that the Six-Mile Pool area has been losing its cross-sectional areas and consequently volumes within the last 20 to 30 years. This important observation will be elaborated upon within the following paragraphs.

All the river cross-sectional data were used to determine an average bed elevation at each cross section for each time period when the data were collected. A plot of the average bed elevation or invert elevation, as it is normally called, with distance for Six-Mile Pool is shown (Figure 26). In general, this reach of the river has been aggrading since 1959. The aggradation is quite severe for the segment of the river downstream of RM 36.50. These changes are further amplified in the next two illustrations.

Figure 27 shows the differences in cross-sectional data between 1959, 1968, 1978, and 1980 with those observed in 1999. All cross-sectional areas were computed below an average water surface elevation of 595 feet above mean sea level (ft-msl). Whenever the cross-sectional area measured at any particular cross section in 1999 was less than that measured in the previous surveys, the difference is the area that has been filled by the deposition of sediment. Conversely, whenever the cross-sectional areas measured in 1999 at any particular cross section were more than those measured in any previous surveys, then those cross sections have shown the scouring activities.

A review of Figure 27 indicates that this pool has been accumulating sediments for about the last 40 years. This illustration is also a very illuminating example of how an in-channel dam probably acts as far as hydraulics and sediment deposition are concerned. The dam at Kankakee is an overflow dam, not controlled by gates, and flows over the spillway never completely stop. Within the last decade, steps were taken to increase the spillway elevation by installing wooden planks to increase the water depths upstream of the dams, especially during low flows. The impacts of these seasonal installations of wooden planks on the hydraulics and sediment deposition patterns above the dam are not known.

Figure 27 indicates that the pool is accumulating sediments from just upstream of the dam at RM 32.75 through RM 33.14, scour at or near RM 33.24 to RM 33.41, heavy sediment deposition from around RM 33.41 through RM 36.37, some scouring at or near RM 36.72 and RM 36.78, and deposition upstream of RM 36.86. The apparent scour zone around RM 33.24 and RM 33.41 could be explained in terms of the flow patterns that could generate upstream of an in-channel dam within a very confined channel. It appears that as the water

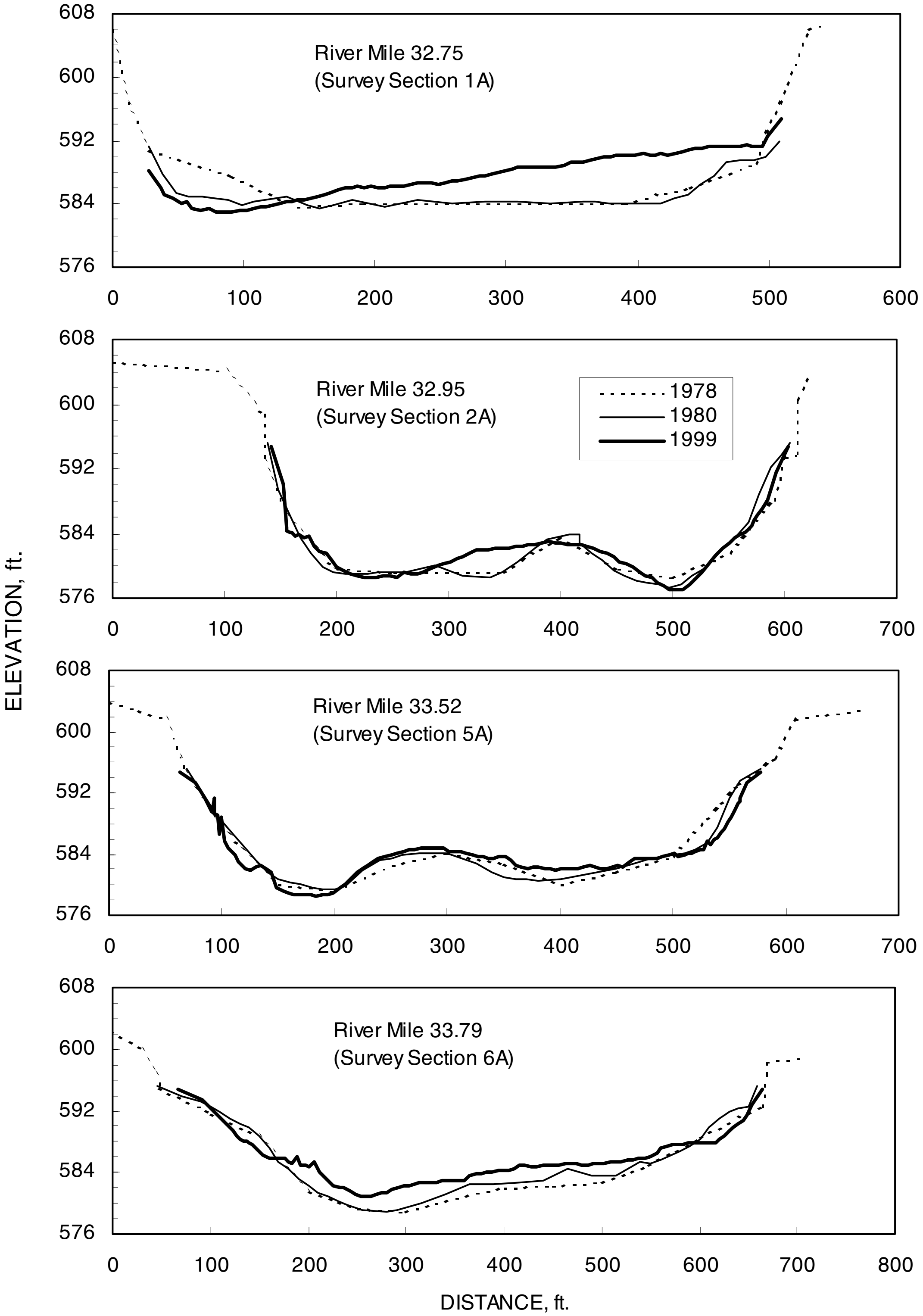

Figure 23. Typical river cross sections within Six-Mile Pool:
RM 32.75, RM 32.95, RM 33.52, and RM 33.79

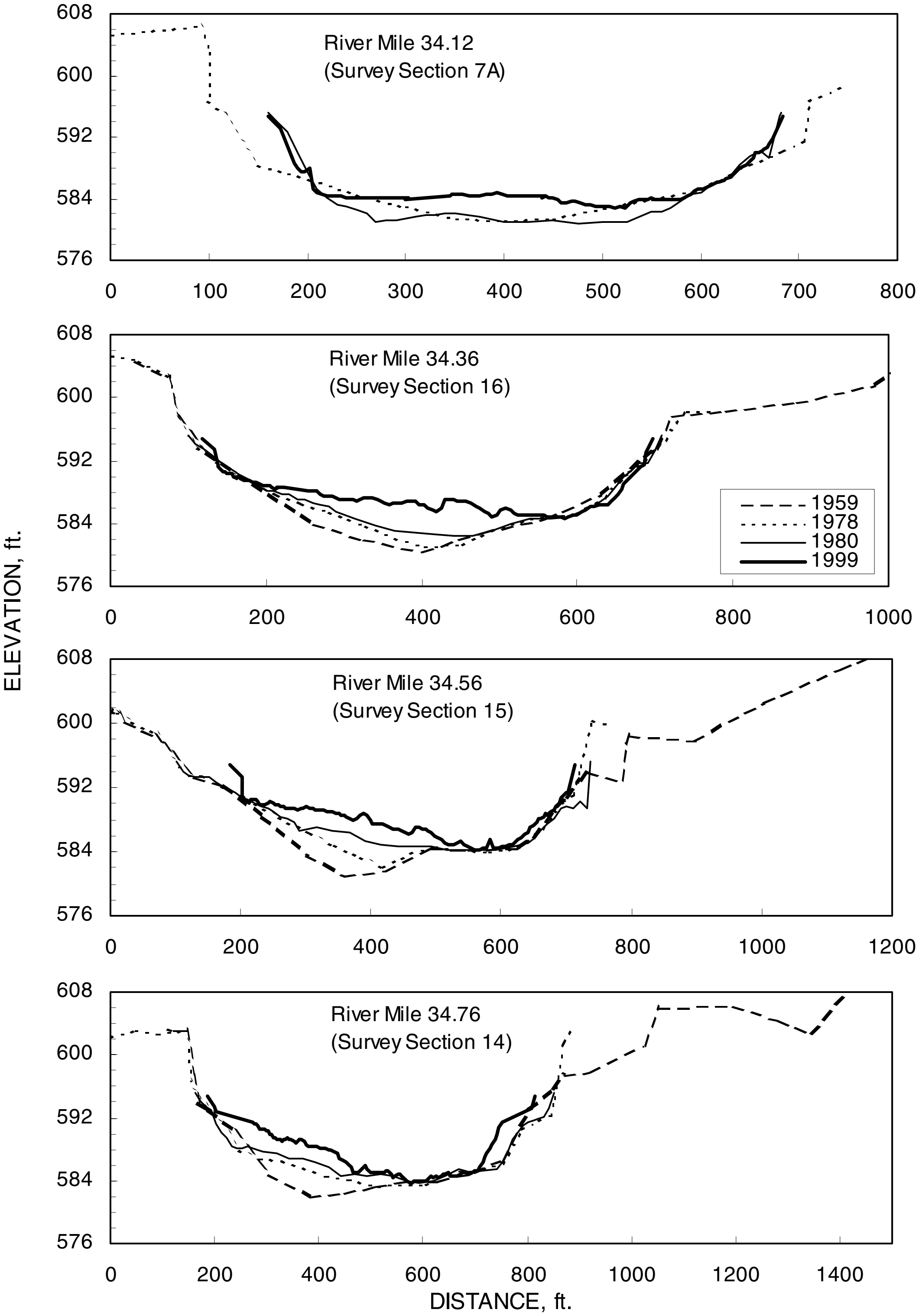

Figure 24. Typical river cross sections within Six-Mile Pool:
RM 34.12, RM 34.36, RM 34.56, and RM 34.76

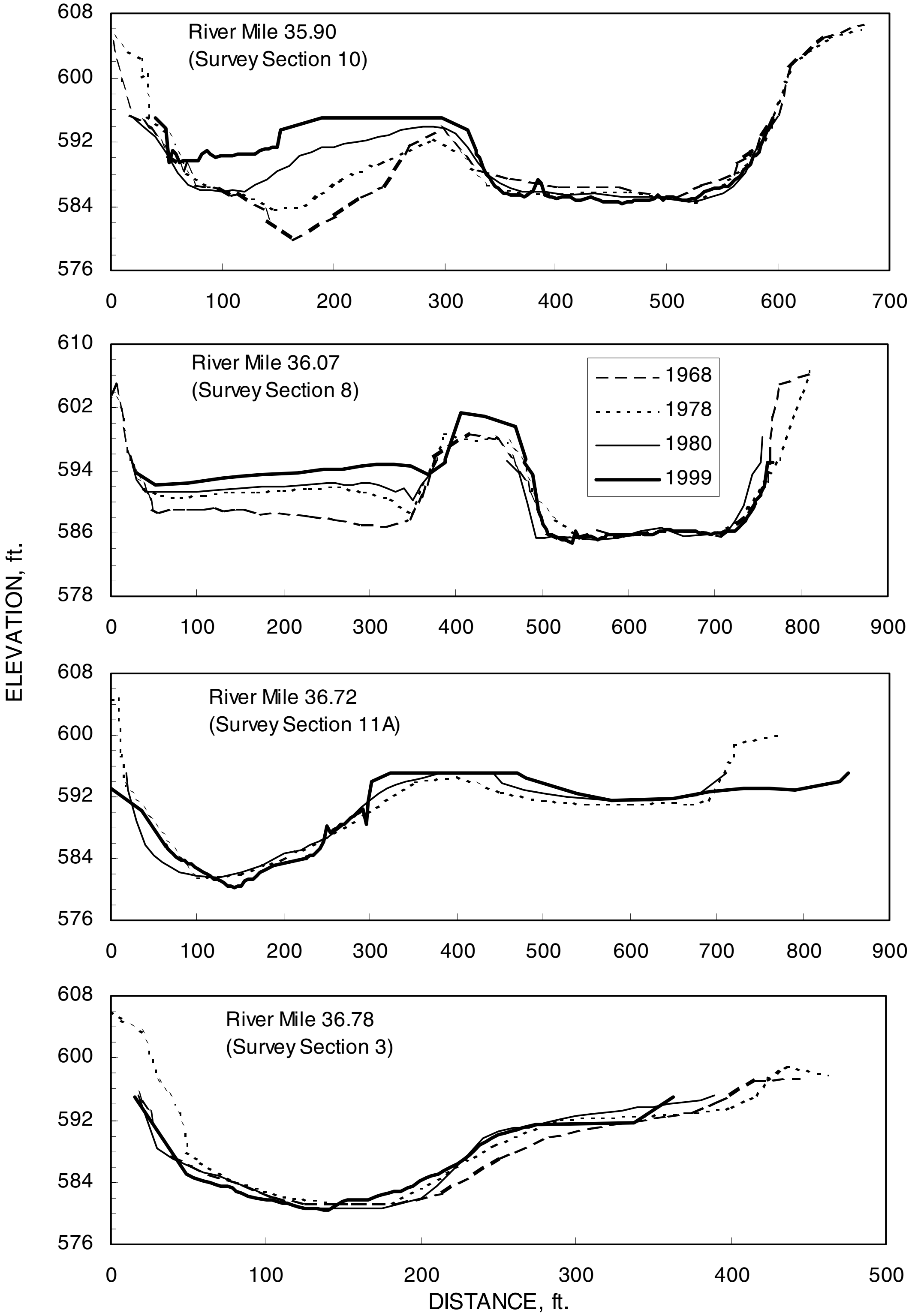

Figure 25. Typical river cross sections within Six-Mile Pool:
RM 35.90, RM 36.07, RM 36.72, and RM 36.78

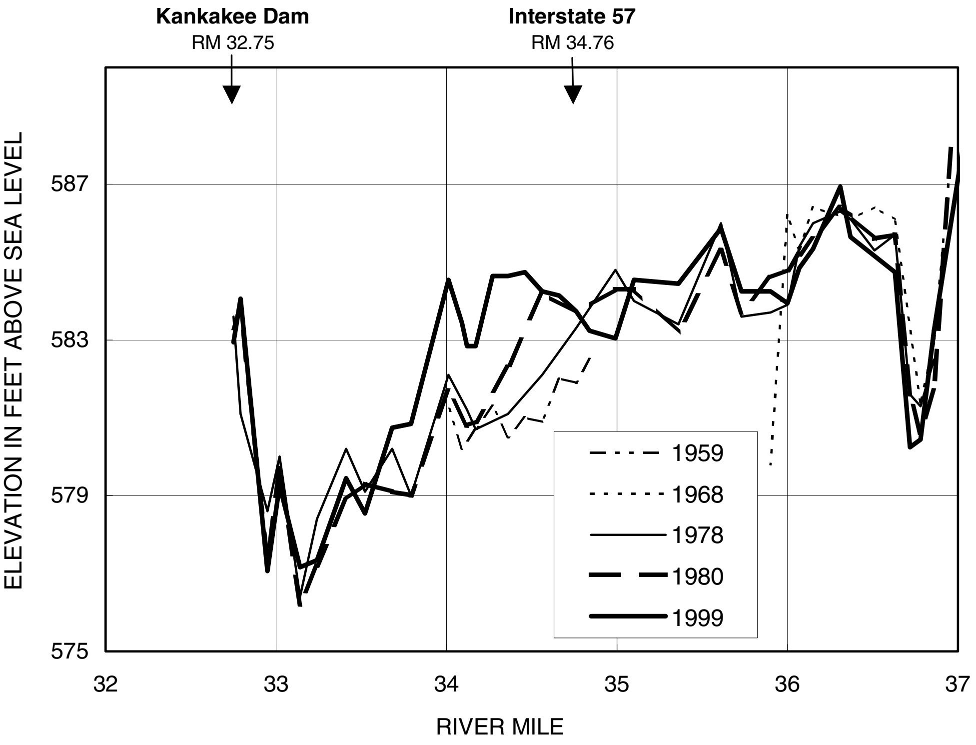

Figure 26. Invert elevations for various periods for Six-Mile Pool

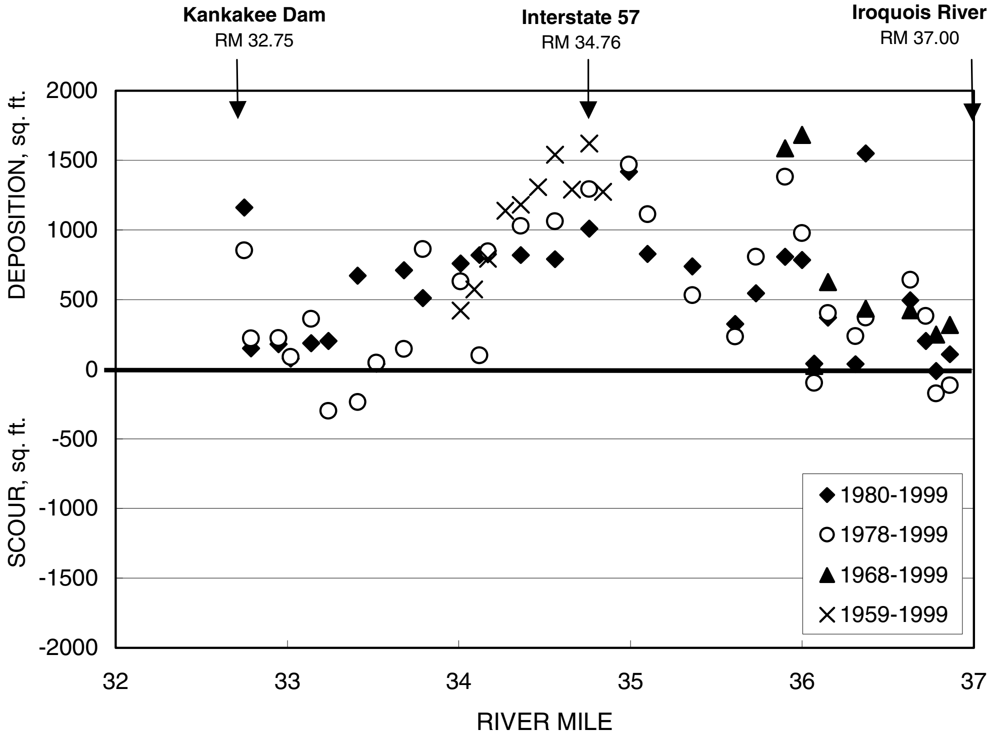

Figure 27. Changes in cross-sectional areas within Six-Mile Pool between 1959, 1968, 1978, and 1980, compared with those collected in 1999, in square feet

moves downstream after depositing its sediment loads from RM 33.68 through RM 36.37, it attempts to accelerate and takes a diving motion toward the bed. This diving motion with high velocity may scour the bed. But the water cannot continue its downstream movement near the bed with the same velocity and direction because of the effects of the solid obstruction by the dam and the dead zone upstream of the dam. Subsequently, the flow is forced to take an inclined path toward the surface to pass over the dam. With this inclined motion toward the top of the dam, the water is forced to drop a portion of its sediment loads upstream of the dam. This is why there is a sediment deposition zone just upstream of the Kankakee Dam. Hydrodynamically, this is an excellent example of how a sand bed channel would behave when the river flows in a well-defined channel: it is unidirectional in nature and a vertical obstruction is placed across the channel at a later time. The river is behaving in a way consistent with its flow, geometry, and hydraulic forces.

The reach of the river from RM 33.52 through RM 36.37 has been accumulating sediment at least since 1959 when the earliest data sets are available. However, this plot also indicates that at various time periods some scouring and deposition did take place. At no time did the river completely scour the bed, however.

Figure 28 further illustrates the accumulation of sediments within Six-Mile Pool. The total volume of Six-Mile Pool below a fixed water surface elevation of 595 ft-msl is plotted for three different years when such complete data are available. Figure 28 shows that the total volume of the pool was 3.83 million cubic yards in 1978, 3.81 million cubic yards in 1980, and 3.32 million cubic yards in 1999. Thus, for the period 1980-1999, the pool lost about 490,000 cubic yards of its volume to sediment deposition.

Most sediments in the Kankakee River are essentially in the sandy fraction ranges. By assuming a unit weight of these sediments to be 93 pounds per cubic foot (Terrio and Nazimek,

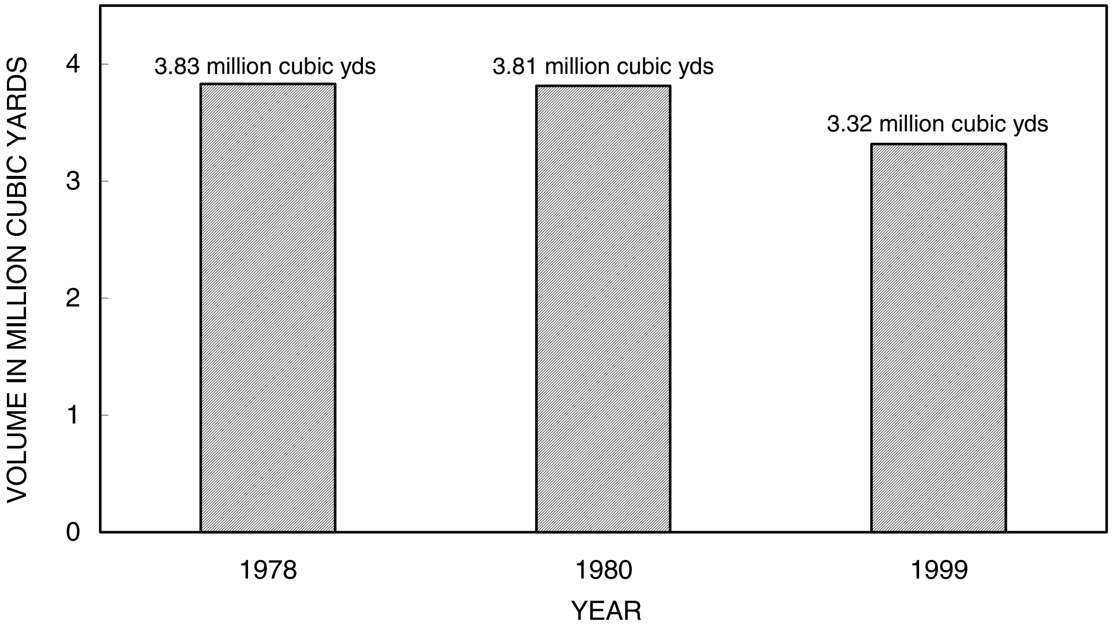

Figure 28. Volume of Six-Mile Pool below 595 ft-msl in 1978, 1980, and 1999

1997), the 1980-1999 net accumulation of sediments becomes 615,195 tons. Assuming a constant rate of sedimentation over this 20-year period, then the average annual sediment deposition for Six-Mile Pool becomes 30,760 tons.

The same data also can be used to determine the loss of capacity in percent of Six-Mile Pool since 1980. Again, the water surface elevation is assumed to be constant at 595 ft-msl. With this assumption, Six-Mile Pool lost about 13.4 percent of its 1980 capacity by 1999. This translates into an annual capacity loss of 0.67 percent per year since 1980.

It is not certain if this rate of capacity loss for Six-Mile Pool will continue in the future. The Six-Mile Pool area of the Kankakee River is similar to a deep wide channel that happened to have a dam with an overflow spillway extending from one side of the river to the other side. Hydraulically, the river should scour the sediment during flood events. However, it appears that insufficient scouring is taking place, and that the pool is filling up with sediments. Research conducted on Peoria Lake, a main stem lake along the Illinois River, shows that the lake has been losing capacity at the rate of 1.44 percent per year between 1965 and 1985 (Demissie and Bhowmik, 1986). Most other major lakes in Illinois have been losing capacity at a lower rate than was observed for Peoria Lake and Six-Mile Pool, except for the Keokuk Pool on the Mississippi River (Demissie and Bhowmik, 1986). Table 3 is a partial reproduction of a table from Demissie and Bhowmik (1986) with the addition of two new data sets from the Kankakee River.

It is quite interesting to note that Six-Mile Pool had a very high capacity loss similar to that for Peoria Lake and a little less than for Keokuk Pool on the Mississippi River. Keokuk Pool was created by construction of a lock and dam on the Mississippi River for navigation. Water stored behind Lock and Dam No. 19 is allowed to pass unobstructed during extreme flooding events such as the one in 1993. Peoria Lake also was partially created by a lock and dam in Peoria that becomes inoperable during high flows when open river conditions exist. Peoria Lake also has a major constriction due to the delta formed by Ten-Mile Creek. The

Table 3. Sedimentation Rates for Large Reservoirs in Illinois
(adapted from Demissie and Bhowmik, 1986)

Reservoir	*Sedimentation period*	*Annual volume loss (percent)*
Keokuk Pool	1913-1979	0.83
Lake Carlyle	1967-1976	0.53
Lake Shelbyville	1969-1980	0.37
Rend Lake	1970-1980	0.41
Peoria Lake	1903-1965	0.63
Peoria Lake	1965-1985	1.44
Crab Orchard Lake	1940-1951	0.44
Lake Springfield	1934-1984	0.26
Lake Decatur	1921-1983	0.53
Six-Mile Pool on Kankakee River	1980-1999	0.67
Momence Wetland along Kankakee River	1980-1999	0.51

Illinois River also has a sharp gradient change within Peoria Pool where a relatively steeper river changes to a very flat gradient. All these changes and natural constrictions are partially responsible for the high sedimentation rates of Peoria Lake. On the other hand, the Kankakee Dam on the Kankakee River is an overflow dam, and flows never stop completely. In spite of these differences, the capacity loss of Six-Mile Pool is quite high compared to other dams constructed in Illinois.

Bhowmik et al. (1980) have shown that the main stem of the Kankakee River carries mostly sand as bed load and also a significant component of the suspended load. Even though the Iroquois River carries more sediment load in absolute numbers compared to the main stem of the Kankakee River (Bhowmik et al., 1980), still most of the sediment load on the Iroquois River is fine-grained and is transported as wash load and/or suspended load. Thus, if it is assumed that the Iroquois River contributes very little bed load to Six-Mile Pool, then the main stem of the Kankakee River probably transports and deposits most of its bed load within the Six-Mile Pool area.

Bhowmik et al. (1980) used the so-called Brune's curve to estimate the trapping capacity of Six-Mile Pool. That analysis has shown that the trapping capacity of Six-Mile Pool should be zero based on relationships between the trapping ratio and the capacity-inflow ratio. However, field data indicate that this is not true. Thus, if it is assumed that about 50 percent of the bed load is deposited within Six-Mile Pool and most of the suspended load goes over the dam, then it appears that the Kankakee River probably transports about 61,520 tons of bed load per year. Caution must be exercised before these data are extensively used. The authors estimate that Six-Mile Pool traps about 50 percent of the bed load and that most, if not all, of the bed load to Six-Mile Pool is contributed by the main stem of the Kankakee River. Overall hydraulics of flow and an intimate knowledge of the Kankakee River indicate that this assumption may not be too far off. It is extremely difficult to collect meaningful bed load data from a sand bed channel. However, long-term changes in the river geometry can provide a window of opportunity to estimate the long-term bed load transport in sand bed channels.

Aroma Park to Singleton Ditch

This reach extends from RM 36.96 through RM 50.80 to the confluence of Singleton Ditch with the Kankakee River. At many locations within this reach, especially close to Momence, the river flows on a rocky substrate. The river gradient is also relatively steep, except close to the Iroquois River. The steep gradient and rocky substrate help to keep some portion of this river relatively free of excessive sediment deposition. However, at several locations, major sand bars are still present, and the river is accumulating sediment at a relatively slower rate.

Fairly complete river cross-sectional data for this reach are available for three time periods: 1966, 1977, and 1999. All data were used to determine the relative changes on this part of the river from 1966 through 1999. All cross-sectional data collected previously and for the present project were used to develop cross-sectional plots (Appendix B). Appendix E shows the cross-sectional areas and cumulative volumes for this reach of the river.

Figure 29 shows the average invert elevations of the river from Aroma Park to Momence. A review of this illustration shows the river aggrading at a few locations, some scour at other locations, and no change in river bed elevations since 1966 at other locations. These conditions are further illustrated with the aid of several river cross-sectional plots (Figures 30 and 31).

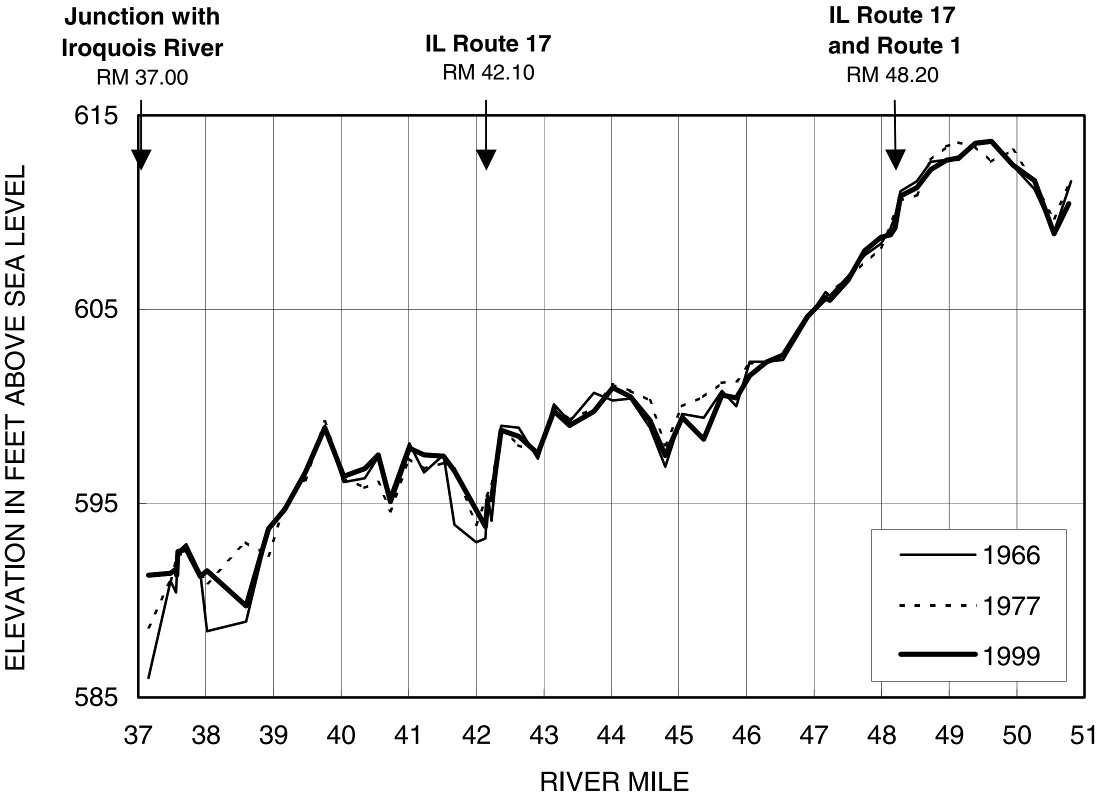

Figure 29. Invert elevations for various periods from Aroma Park to Singleton Ditch

Computations also were made to determine the changes in the cross-sectional areas between 1966, 1977, and 1999. In order to determine the cross-sectional areas at various locations with respect to the same reference elevations, the bankful elevation at each cross section with distance was plotted to determine the reference elevation for each cross section. Then a line or lines were drawn for the entire reach from the Kankakee Dam to the State Line Bridge so that the lowest bank elevations at each cross section will be at or above this reference elevation (Figure 32). The reference elevation was kept constant at 595 ft-msl for Six-Mile Pool, and the reference elevations for the Momence Wetland area from Singleton Ditch to the State Line Bridge were kept at the same levels as those used by Terio and Nazimek (1997). Then the elevation at each cross section referring to this line or lines was used as the base elevation below which the cross-sectional areas and capacities between any two adjacent cross sections were computed.

Figure 33 shows the relative changes that have occurred between 1966 and 1999, and 1977 and 1999 for the entire reach. The deposition area of the river is shown above the zero axis, and the scour is shown below the zero axis. All cross-sectional areas were compared with the 1999 cross-sectional areas. This reach was divided into four sub-reaches. Examination of the cross-sectional areas at each cross section for the two periods, 1966-1999 and 1977-1999, indicated that this reach did in fact experience both deposition and scour within these intervening years. Table 4 summarizes the relative changes in volumes for each sub-reach identified in Figure 33. It appears that at RM 38.60 (Figure 33a) a scour hole developed between 1977 and 1999 with

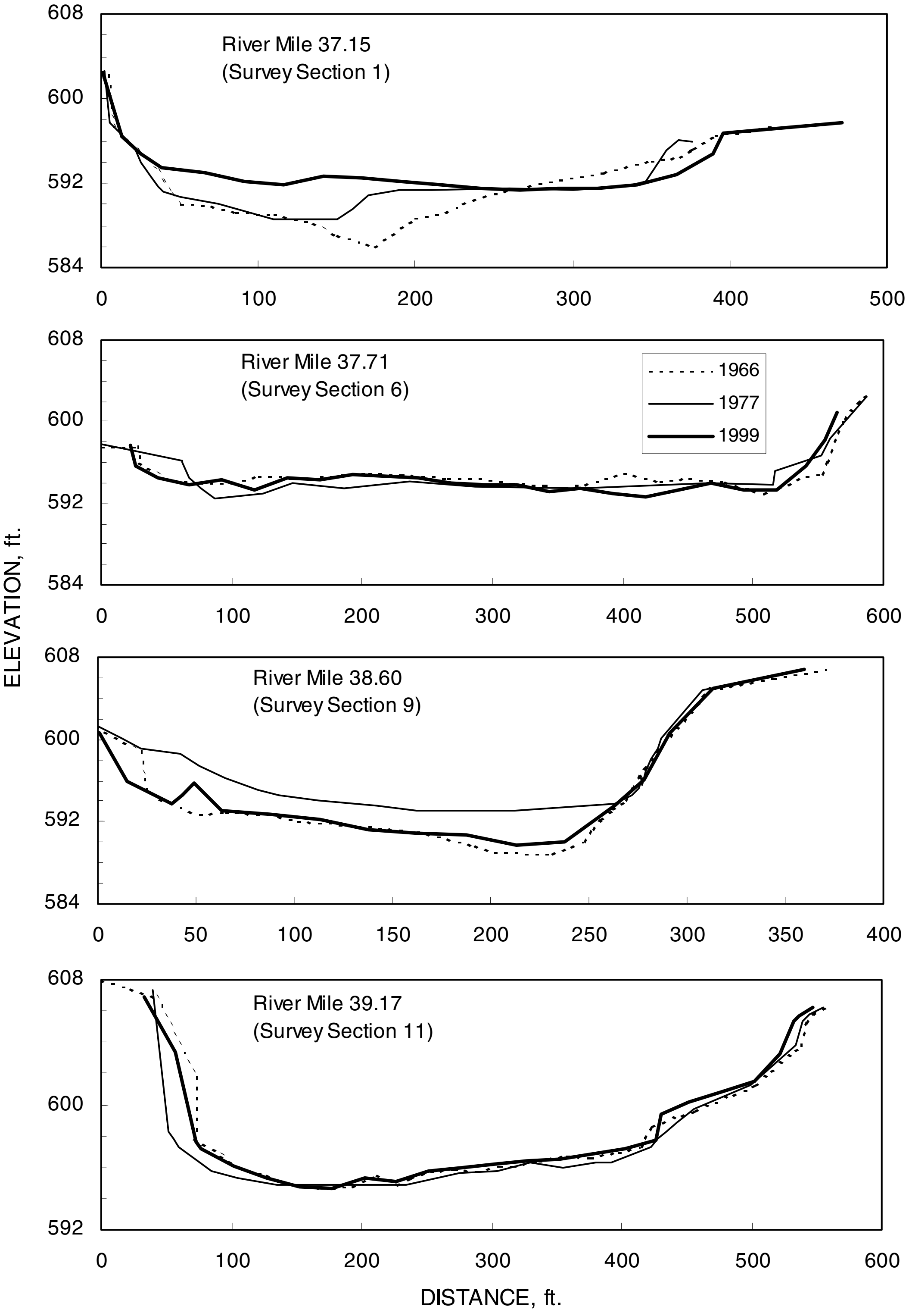

Figure 30. Typical river cross sections from Aroma Park to Singleton Ditch: RM 37.15, RM 37.71, RM 38.60, and RM 39.17

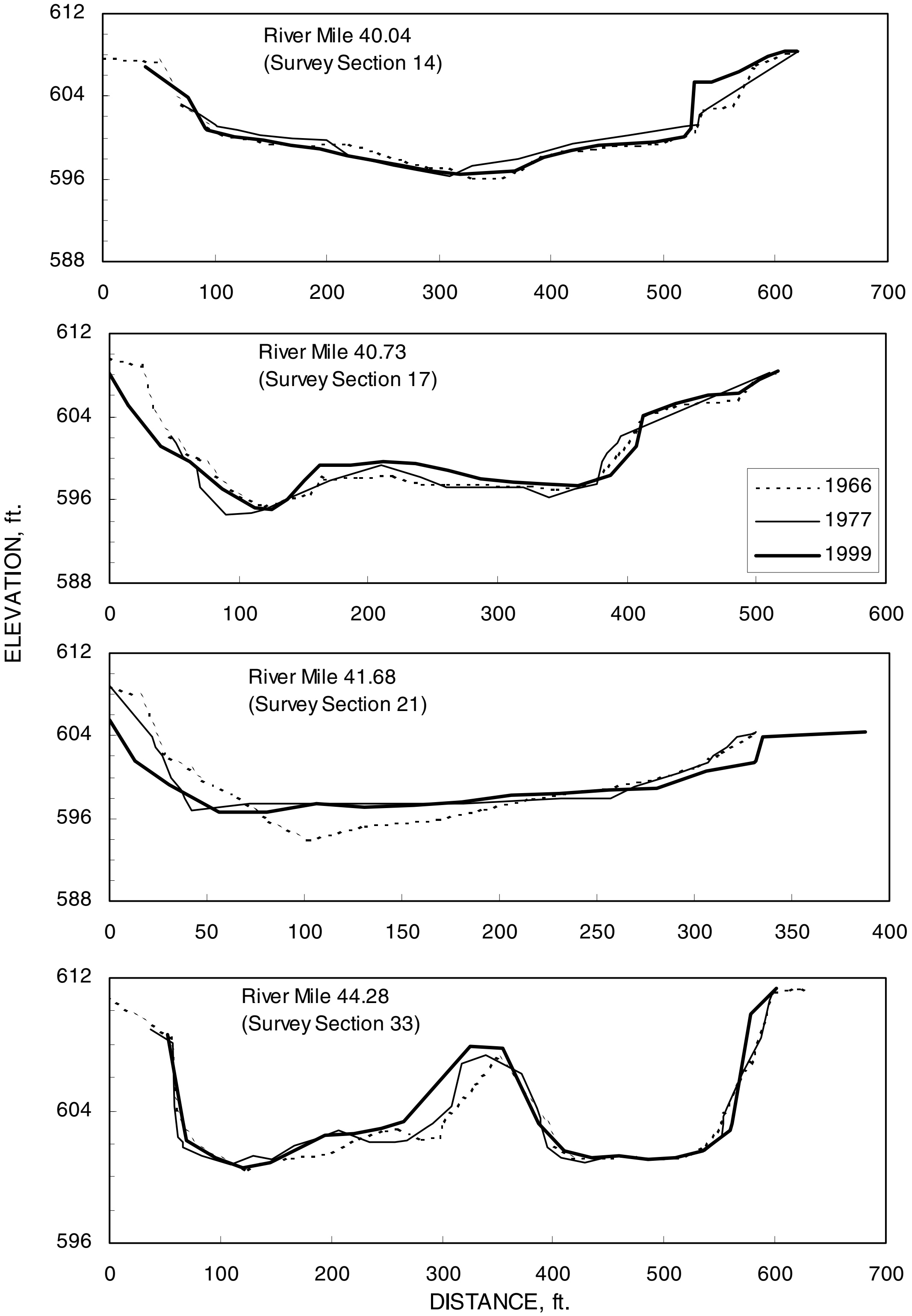

Figure 31. Typical river cross sections from Aroma Park to Singleton Ditch: RM 40.04, RM 40.73, RM 41.68, and RM 44.28

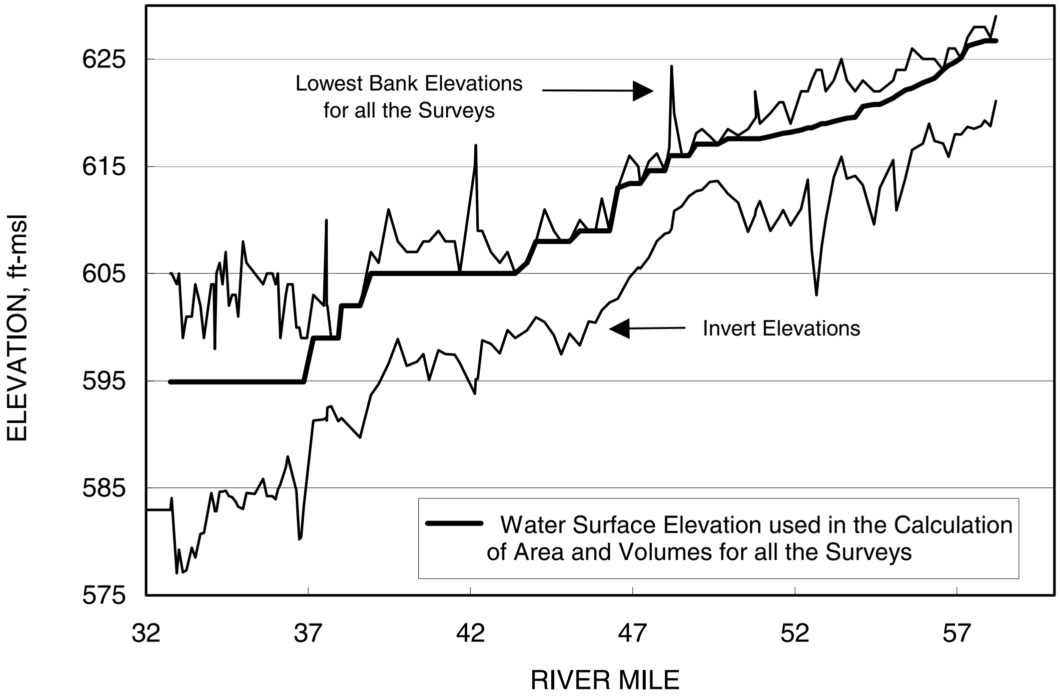

Figure 32. Water surface elevations used in the calculation of areas and volumes for the entire reach of the Kankakee River in Illinois from the Kankakee Dam to the State Line Bridge

sediment deposition near RM 38.93 and onward. In general, most deposition was confined between RM 37.0 and RM 38.5, scour at RM 38.60, and deposition for about the next mile. The next area near RM 40 indicated some scour, but sediment deposition was significant between RM 40.35 and RM 41.23.

Summary data shown in Table 4 indicate that for this entire sub-reach, RM 37.0 to RM 41.5, there was a net loss of capacity by 1.26 percent between 1966 and 1997, 3.94 percent between 1966 and 1999, and 2.71 percent between 1977 and 1999. Thus, between 1966 and 1999, i.e., for the last 33 years, this sub-reach lost 0.12 percent of its capacity per year on average.

Figure 33b shows the changes in cross-sectional areas between 1966 and 1999, and 1977 and 1999 for RM 41.5 through RM 45.0. In general, scour and deposition are taking place along this entire sub-reach. However, on the average and for this 3.5-mile reach, there was more scour than deposition. Table 4 shows that deposition exceeded scour between 1966 and 1977, but scour exceeded deposition between 1977 and 1999. It appears that this sub-reach is passing through some type of dynamic changes where deposition and scour are alternating as one moves from the upstream end of the sub-reach to the downstream end. Similar types of alternating deposition and scour are also observed for the sub-reach from RM 41.5 to RM 37.0 (Figure 33a).

Figure 33c shows the river from RM 45.0 to RM 47.5. For this sub-reach and also between 1966, 1977, and 1999, scour certainly exceeded deposition. Table 4 indicates that even though sediment deposition exceeded scour between 1966 and 1977, the reach definitely experienced more scour than sediment deposition between 1977 and 1999. This reach gained

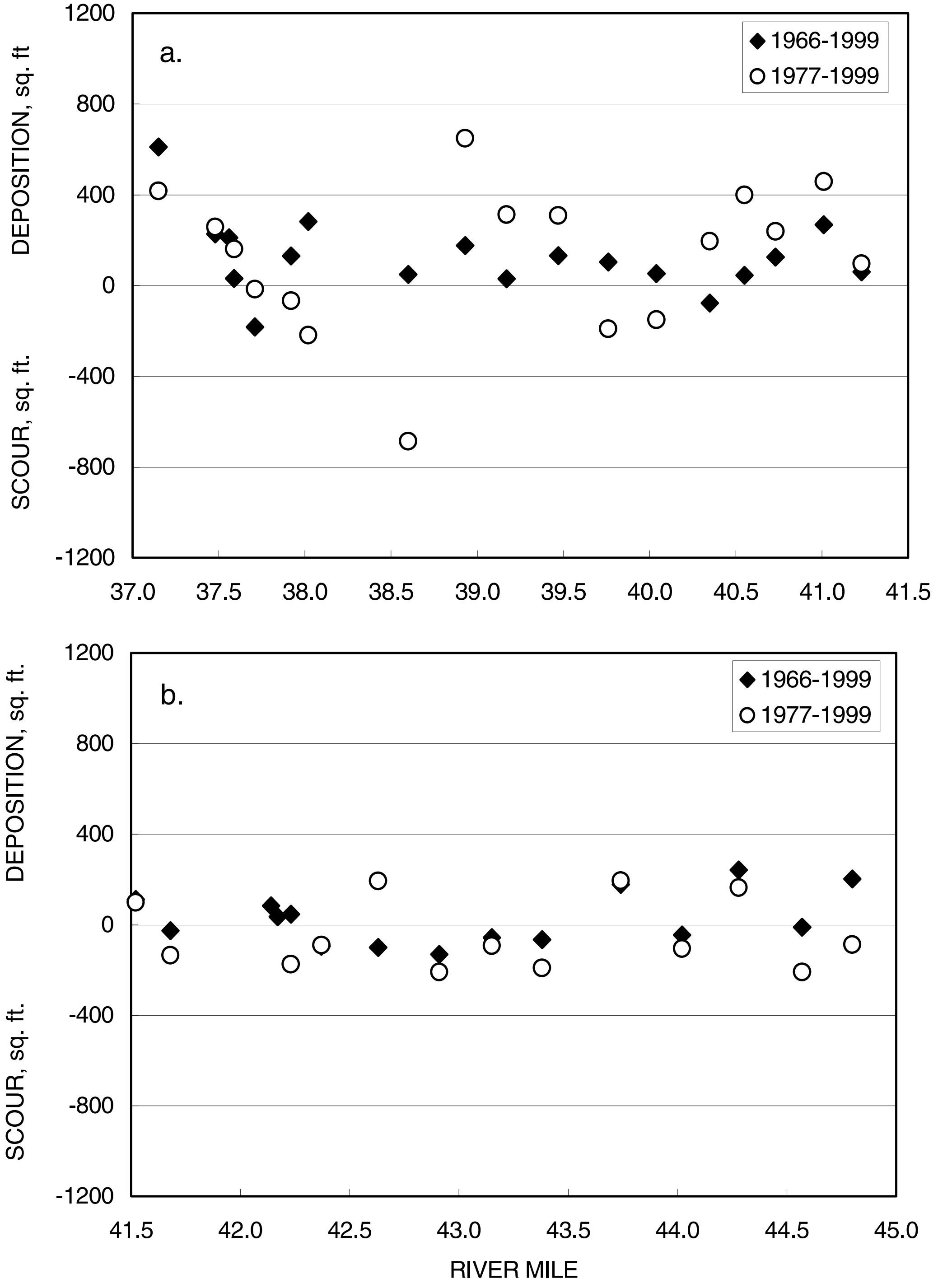

Figure 33. Changes in cross-sectional area in the reach from Aroma Park to Singleton Ditch between 1966 and 1977 compared with those collected in 1999, in square feet

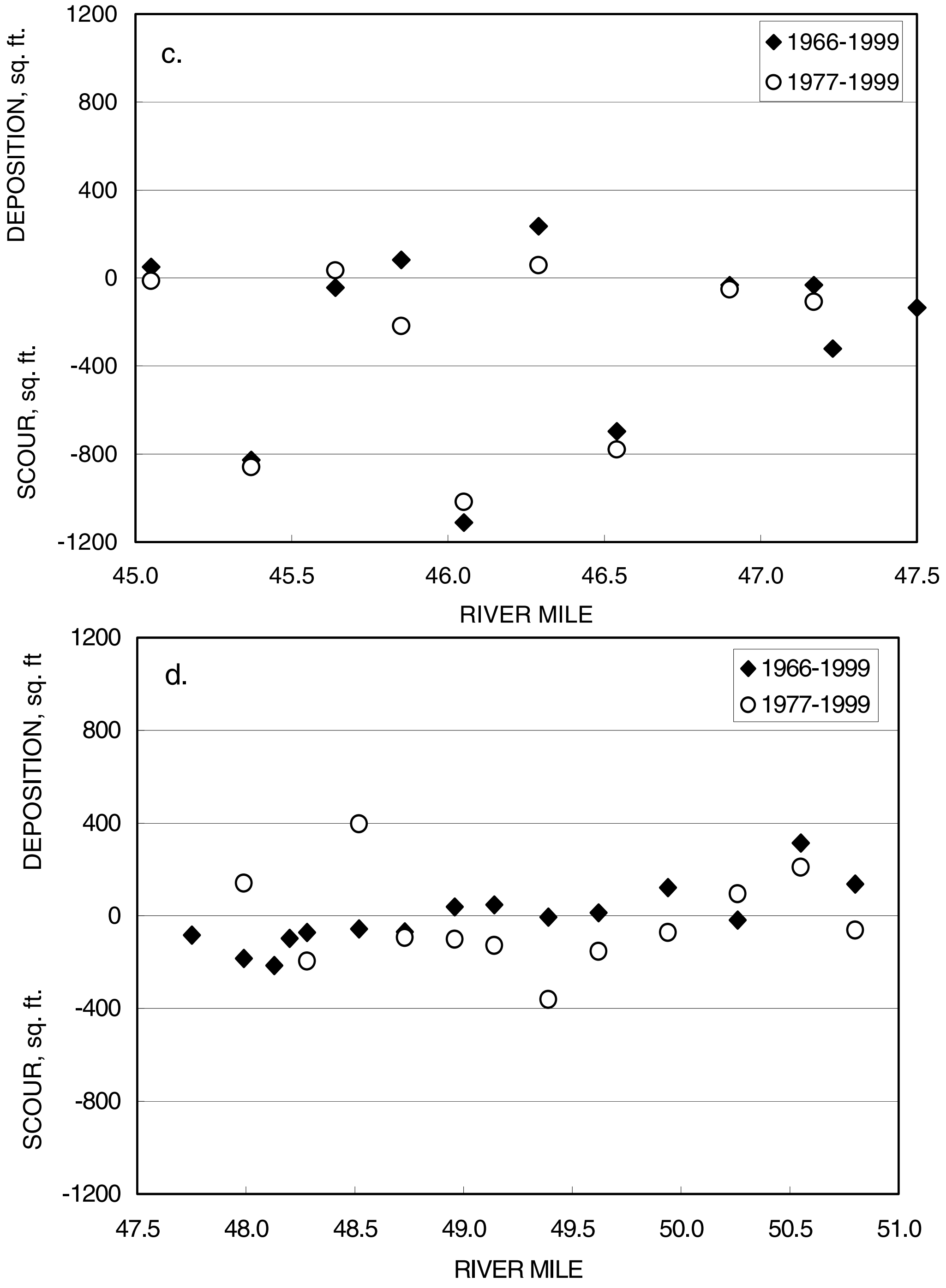

Figure 33. Concluded

approximately 29 percent of its 1977 capacity by 1999. Obviously, scour is taking place in this 2.5-mile reach of the river.

The last sub-reach shown here is for the river between RM 47.5 and RM 51.0 (Figure 33d and Table 4). For this sub-reach, the river gained its 1966 capacity by about 18.4 percent but lost its 1977 capacity to sediment deposition by about 15.6 percent through 1999. Again, alternating deposition and scour are evident (Figure 33d) as one moves from upstream to downstream.

Figure 34 summarizes four plots already shown in Figure 33.

The next four illustrations show the changes in volumes or capacities of the channel at three different time periods (Figure 35). The volumetric capacity was 6,383,828 cubic yards (3,957 ac-feet) in 1966, which was reduced to 6,245,084 cubic yards (3,871 ac-feet) in 1977 and 6,401,574 cubic yards (3,968 ac-feet) in 1999. The total capacity loss from 1966 to 1977 was 2.17 percent, and from 1977 to 1999 it was a gain of 2.51 percent.

These illustrations for the reach of the river between RM 37.0 and RM 51.0 are quite descriptive in terms of the geomorphological changes that take place on a sand bed river with intermittent rocky substrate. It is obvious that the changes in morphometry are varied both in time and space. Not only are there changes in the morphometry as one moves from upstream to downstream, but also the patterns of scour and deposition change with time. It is quite rare to have river cross-sectional data available for 33-34 years. These data not only show that the river is constantly changing, but they also show that the zones of scour and deposition are relatively semi-constant, affording an opportunity to develop management alternatives consistent with the flow, gradient, sediment particle size distribution, and overall sediment loads.

Table 4. Changes in River Cross-Sectional Areas and Volumes for the Reach from Aroma Park to Singleton Ditch

Location	*Year*	*Volume, acre-ft*	*Volume, 1000 cu/yd*	*1966-1977, %*	*1966-1999, %*	*1977-1999, %*
Sub-Reach a	1966	1554	2507.9			
(RM 35.15 - RM 41.50)	1977	1535	2476.3	1.26		
	1999	1493	2409.1		3.94	2.71
Sub-Reach b	1966	947	1527.4			
(RM 41.50 - RM 45.00)	1977	912	1470.9	3.70		
	1999	936	1510.7		1.10	-2.70
Sub-Reach c	1966	887	1431.6			
(RM 45.00 - RM 47.50)	1977	752	1212.5	15.30		
	1999	970	1565.3		-9.34	-29.10
Sub-Reach d	1966	569	917.5			
(RM 47.50 - RM 50.80)	1977	673	1086.4	-18.40		
	1999	568	916.6		0.10	15.63

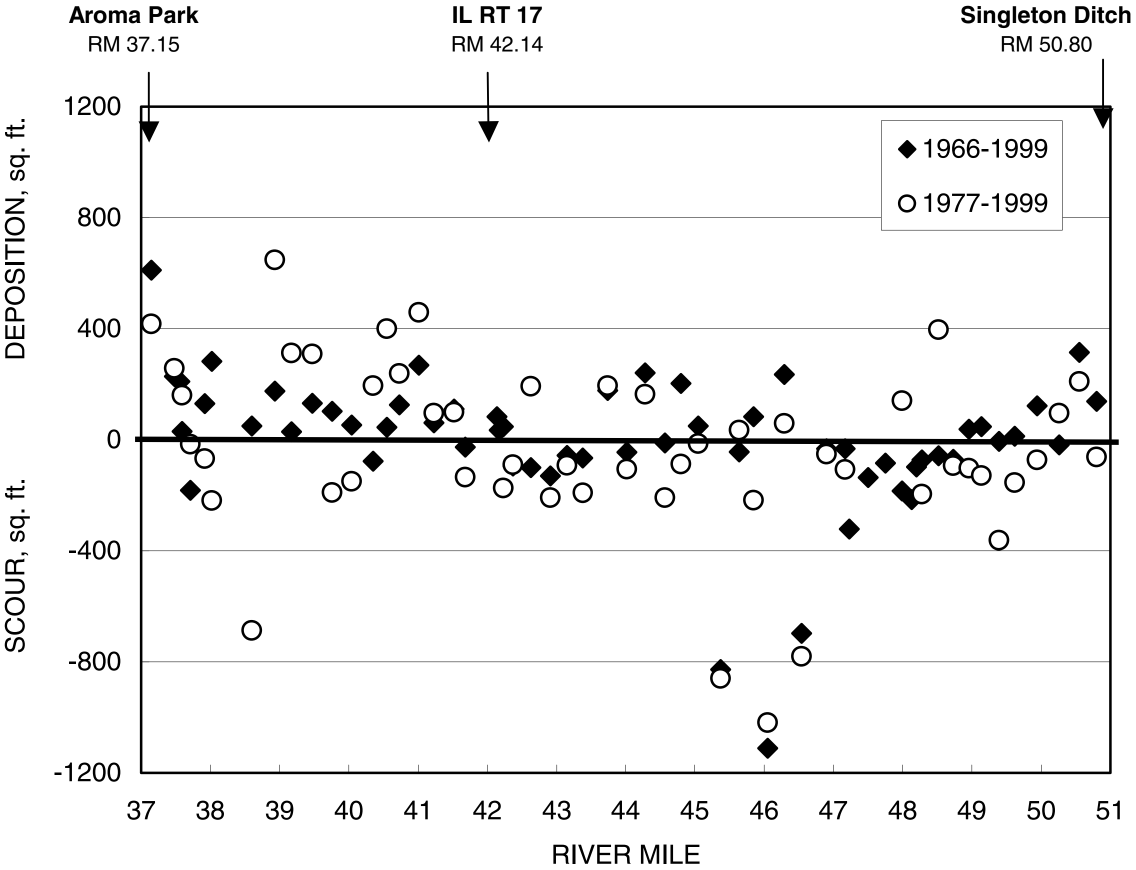

Figure 34. Changes in cross-sectional area in the reach from Aroma Park to Singleton Ditch between 1966 and 1977 compared with those collected in 1999, in square feet

Momence Wetland

For the present analysis, the river extending from Singleton Ditch, RM 50.80 to the State Line Bridge, RM 58.19, was considered to be the Momence Wetland. Similar analyses shown previously for Six-Mile Pool and the reach between Aroma Park and Momence also were done for this part of the river. All cross-sectional data collected previously and for the present project were used to develop cross-sectional plots (Appendix C). Appendix F shows the cross-sectional areas and cumulative volumes for this reach of the river.

A cautionary note must be included with this analysis before further discussion on sedimentation patterns. River cross-sectional data were collected only from the channel segment of the river. Major portions of the Momence Wetland area have very low floodplains, and they are flooded quite frequently. No historical floodplain data on sediment deposition or scour are available for this reach, and no comparative analyses can be made. Moreover, when the volumetric changes are compared, it must be understood that the volume of the sediments that may have deposited within the floodplain are neither included nor considered in this analysis. In all probability, the amount of sediment deposited within the entire Momence Wetland area is probably much higher than the amount estimated based on the river cross-sectional data.

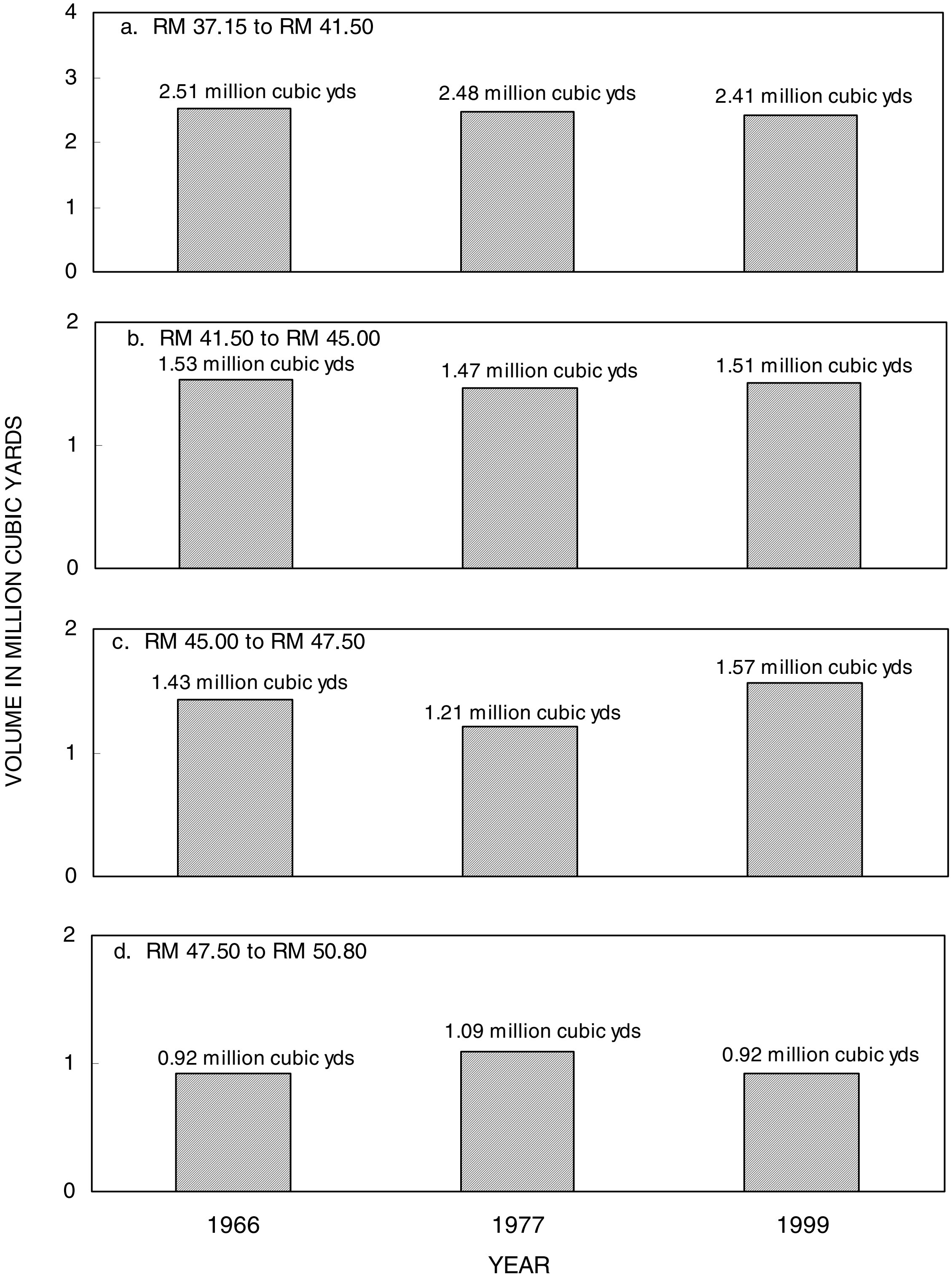

Figure 35. Historic volumetric change for RM 37.15 to RM 41.50, RM 41.50 to RM 45.00, RM 45.00 to RM 47.50, and RM 47.50 to RM 50.80 in the reach from Aroma Park to Singleton Ditch

The three sets of data available for this reach of the river were used to compute an average invert elevation at each cross section (Bhowmik et al., 1980; Terio and Nazimek, 1997; present data). The average invert elevations thus computed were plotted against river miles (Figure 36). Close examination of this figure shows that the river on average is depositing sediment even though scour holes did develop at a few locations. In general, the upper part of the river within one and one-half to two miles from the State Line Bridge is experiencing more capacity loss than at other locations. There is also a deep scour hole in the river at or near RM 52.52 through RM 52.82 (Appendix C).

Figures 37, 38 and 39 show 12 typical river cross sections within the Momence Wetland area. All three sets of data are shown. A close review of these figures shows that, in general, the 1999 river cross-sectional areas are less than those present in the other two periods. Thus, this reach of the river is also aggrading as more and more sediments are trapped and deposited. Again, floodplain sediment deposition is not included in this analysis.

Cross-sectional areas for each section in 1999 were compared with cross-sectional areas measured in 1994 and 1980. Figure 40 shows the changes that have occurred within the last 20 years since 1980, and the 5 years since 1994, respectively. In general, this reach of the river within stream cross section has been aggrading since 1980. River cross-sectional data are not available before 1980. Thus, no postulation could be made on what may have happened before 1980. As mentioned previously, floodplains of the Momence Wetland area probably are also accumulating sediments at a rate not known presently.

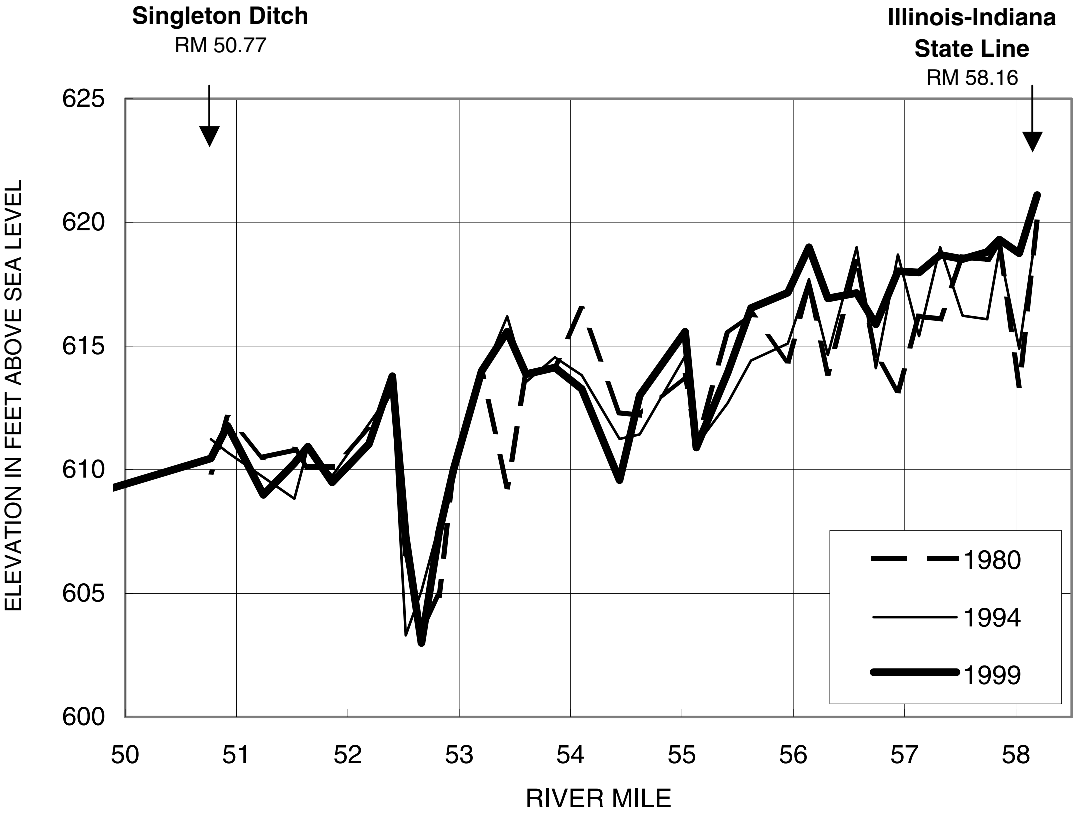

Figure 36. Invert elevations for various periods for the Momence Wetland

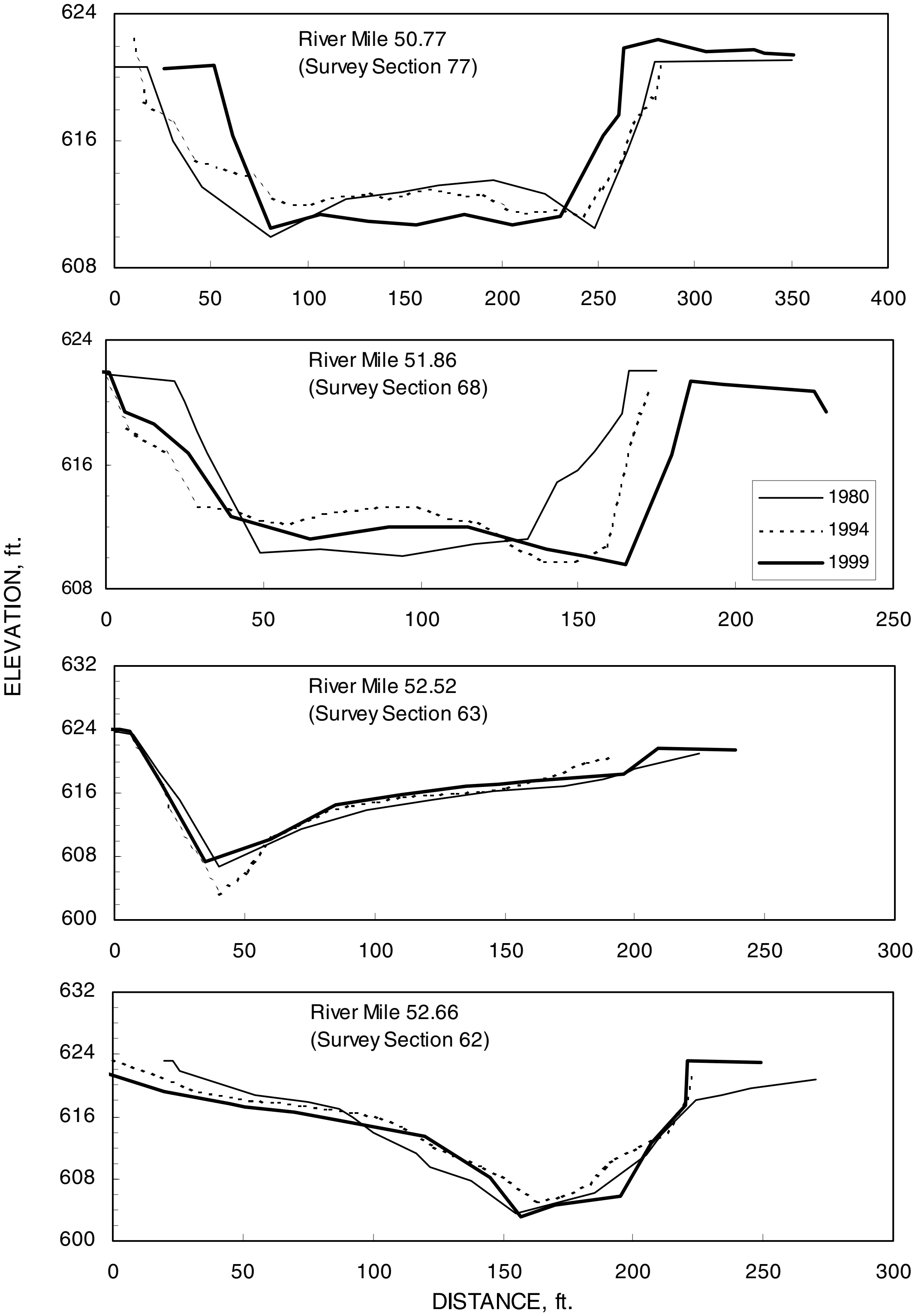

Figure 37. Typical river cross-sections within Momence Wetland area (Singleton Ditch to State Line Bridge): RM 50.77, RM 51.86, RM 52.52, and RM 52.66

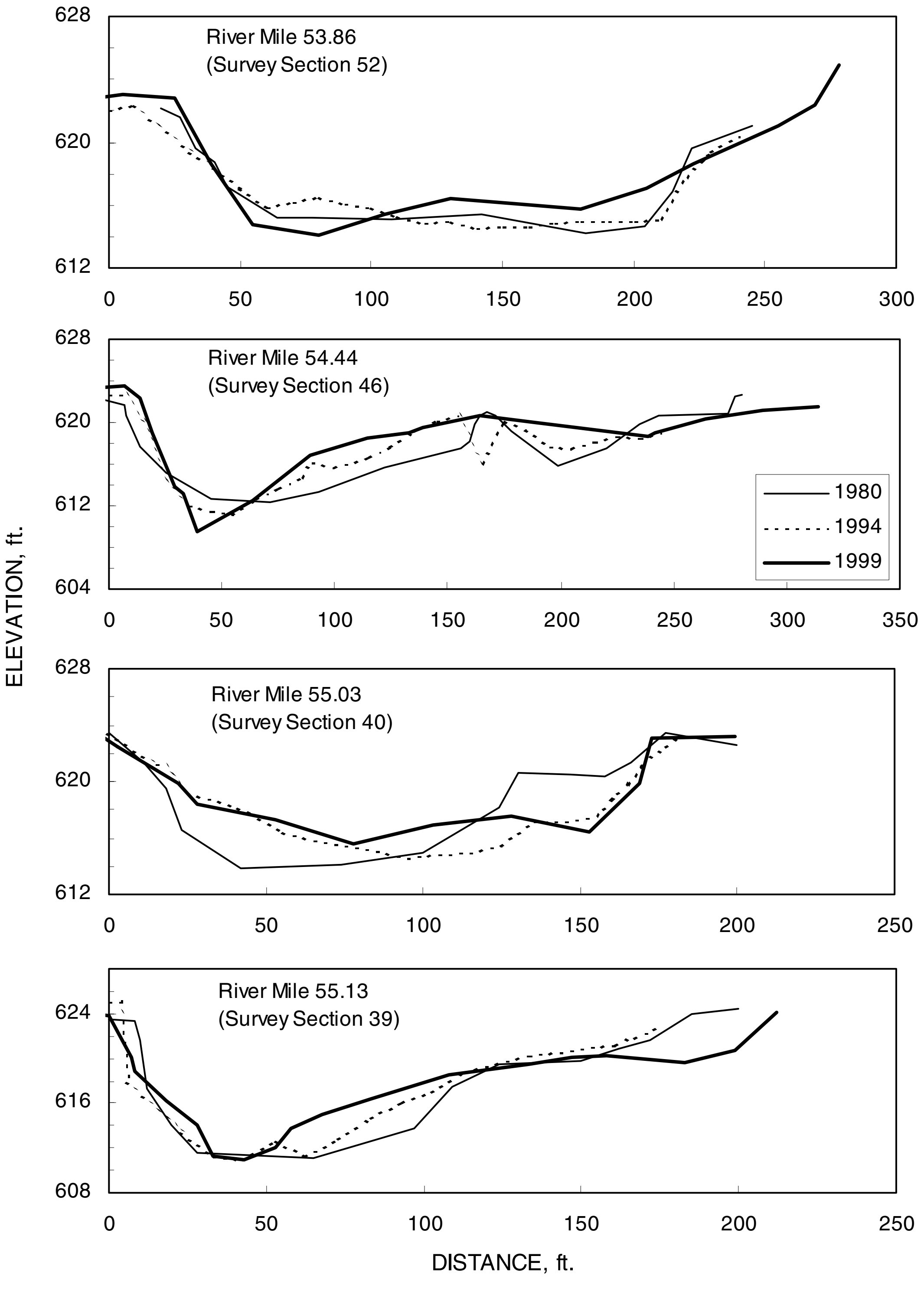

Figure 38. Typical river cross sections within Momence Wetland area (Singleton Ditch to State Line Bridge): RM 53.86, RM 54.44, RM 55.03, and RM 55.13

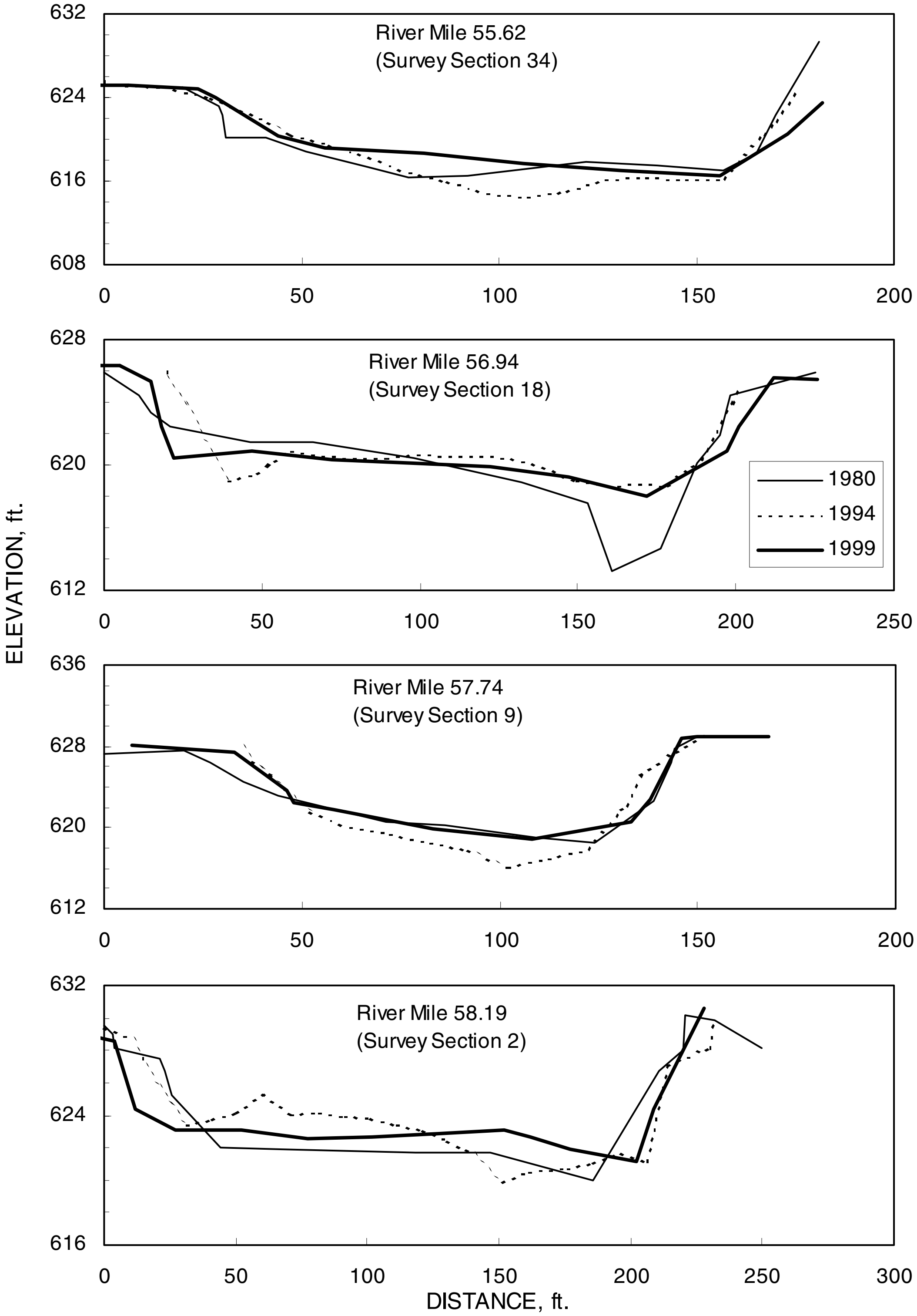

Figure 39. Typical river cross sections within Momence Wetland Area (Singleton Ditch to State Line Bridge): RM 55.62, RM 56.94, RM 57.74, and RM 58.19

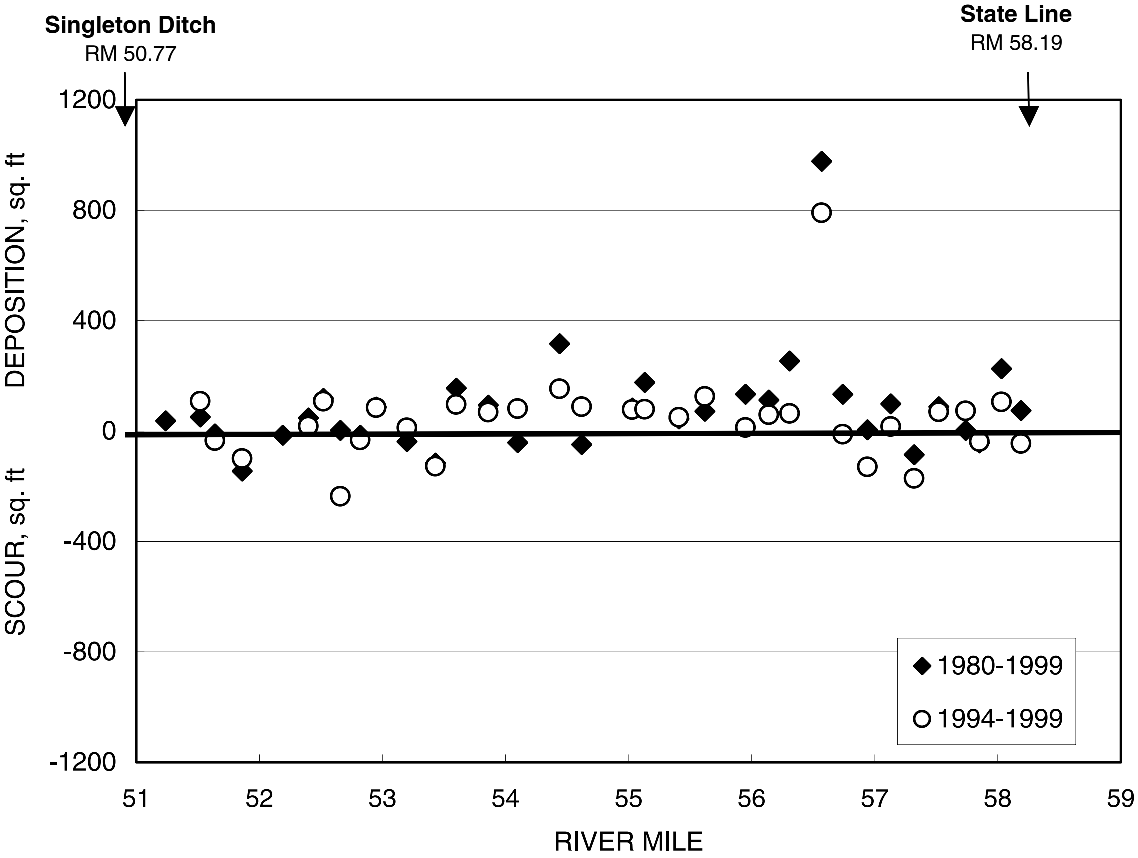

Figure 40. Changes in cross-sectional area within Momence Wetland between 1980 and 1994 compared with those collected in 1999, in square feet

Figure 41 shows the volumetric changes between 1980 and 1999. All volumes were computed below constant reference elevations for all the intervening years. This illustration indicates that in 1980, the Momence Wetland area below bankful elevation had a total volumetric capacity of 1,235,788 cubic yards (766 ac-feet), which has reduced to 1,185,776 cubic yards (735 ac-feet) in 1994 and 1,108,337 cubic yards (687 ac-feet) in 1999. This reduction in volumes is quite significant. The *river* within the Momence Wetland had a total deposition of sediment of about 50,000 cubic yards (31 ac-feet) between 1980 and 1994, and about 77,440 cubic yards (48 ac-feet) between 1994 and 1999.

These losses in capacities could be used as a surrogate to estimate the movement of coarse-grained materials from Indiana to Illinois through the main stem of the Kankakee River. Some of the coarse-grained material, which is presumed to be moving as bed loads, must have passed through the river to its downstream reaches. However, if it is assumed that most of the bed load stayed within the stream channel and probably in the Momence Wetland area, then it appears that the stream channel within the Momence Wetland and between the river banks had an accumulation of 127,440 cubic yards of sediment between 1980 and 1999.

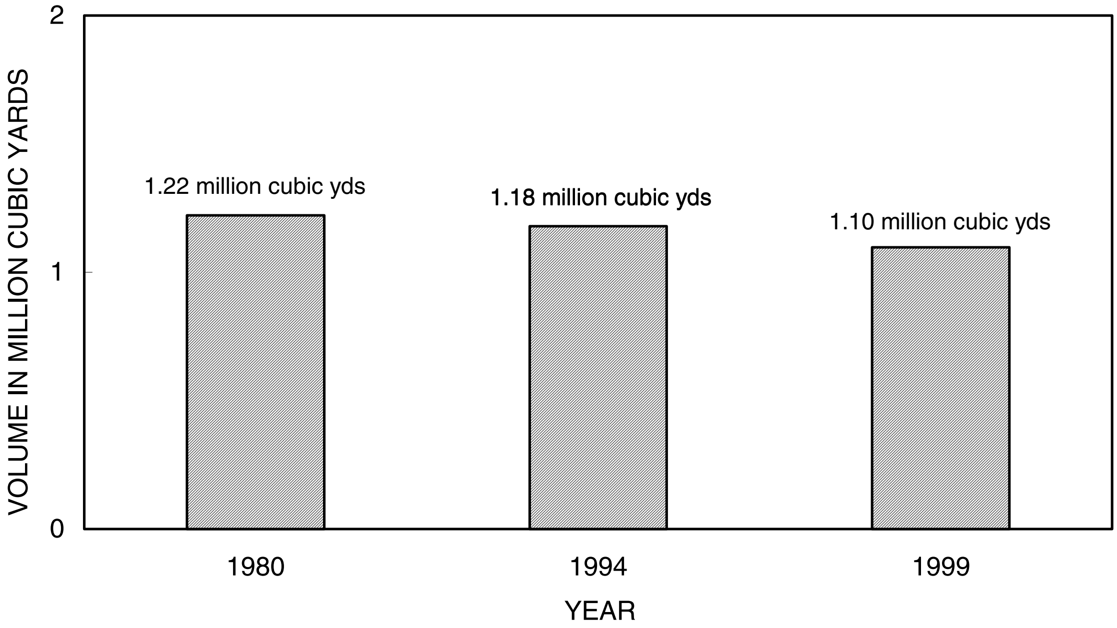

Figure 41. Volume of Momence Wetland (from Singleton Ditch to State Line Bridge) within river banks in 1980, 1994, and 1999

If it is assumed that about 30 percent of the bed load passed through the system and another 15 percent did in fact deposit within the floodplains within the Momence Wetland area, then the estimated volume of bed load that moved into the entire Momence Wetland area can be computed by assuming that 127,440 cubic yards is 55 percent of the total bed load. With this assumption, the total bed load becomes 231,700 cubic yards. Assuming a unit weight of 93 pounds per cubic foot, the total estimated weight of these sediments becomes 290,900 tons. Even though sediment does not move uniformly from year to year, still on the average about 14,545 tons of sediment moved to this area on an annual basis for the last 20 years. This estimated sediment volume or weight could be used as a surrogate to the bed load that may have been transported through this reach of the river. Table 5 shows the capacities and volume losses with time for these three reaches of the river.

Rate of Capacity Loss: Kankakee Dam to State Line Bridge

The capacity loss or changes in capacities at the two reaches i.e., Six-Mile Pool and Momence Wetland, were plotted with river/section within the time, and these are shown in Figure 42. Appendix G shows the capacities at various times for all reaches of the river.

Appendix H shows the surveyed cross-section locations with the state plane coordinate systems for all the cross sections. Figure 43 shows the nondimensional capacity loss with time for four sub-reaches within the river from Aroma Park to Singleton Ditch. Here nondimensional plots were developed relating present capacity with the original capacity as it varies with time. The original capacities are those when the original data sets were collected for any particular reach. For example, for Six-Mile Pool, the original complete data set was available in 1978. With this assumption, the capacity of Six-Mile Pool in 1980 becomes 99.6, and in 1999 it is 0.866 or

Table 5. Loss of Capacities of Three Reaches of the Kankakee River over Time

Reach	*Year*	*Capacity, million cubic yards*	*Capacity compared to original capacity, percent*
Six-Mile Pool	1978	3.83	100.0
	1980	3.81	99.6
	1999	3.32	86.6
Aroma Park to Singleton Ditch	1966	6.38	100.0
	1977	6.25	97.8
	1999	6.40	100.3
Momence Wetland	1980	1.22	100.0
	1994	1.18	96.6
	1999	1.10	89.8

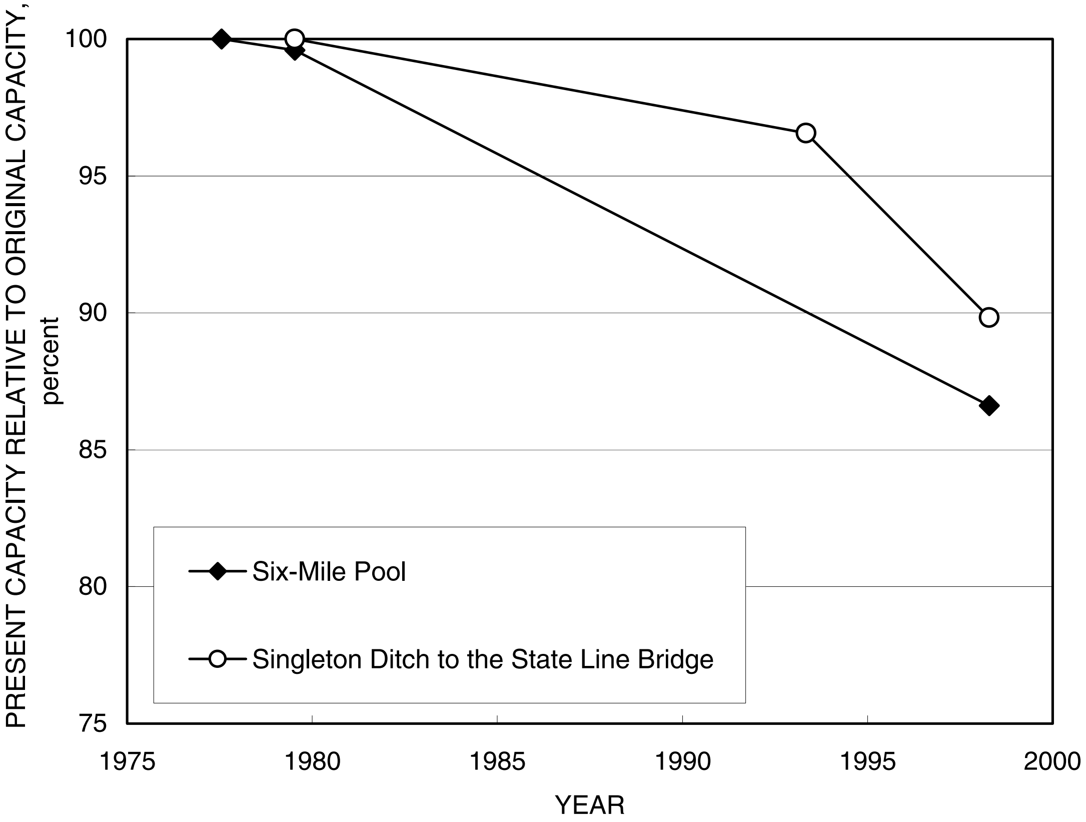

Figure 42. Nondimensional capacity loss for two reaches along the Kankakee River: Six-Mile Pool and river cross sections from the Singleton Ditch to State Line Bridge (Momence Wetland)

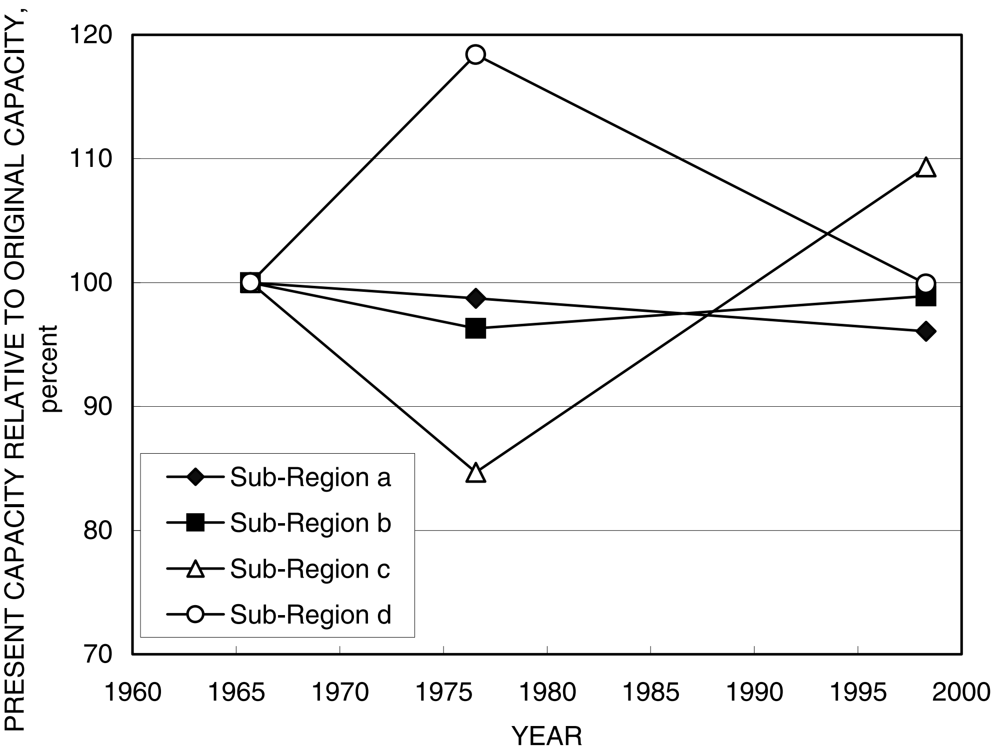

Figure 43. Nondimensional capacity loss for four sub-regions within the reach of the Kankakee River from Aroma Park to Singleton Ditch

86.6 percent of the 1978 volume. It appears that the overall capacity within the Aroma Park to Singleton Ditch area did not change between 1966 and 1999. However, as was mentioned previously (see Figures 33-35, Table 4) some of this overall reach did experience sediment deposition and area scour. However, when the entire reach is considered as a single unit, the scour and deposition essentially balanced out. This does not mean that there is no problem with scour and sediment deposition. It shows that there are still problems with localized sediment deposition and/or scour. The original data set for the reach of the river from Aroma Park to Singleton Ditch was collected in 1966. For the Momence Wetland area, the capacity loss from 1980 to 1994 was about 3.4 percent compared to a capacity loss of 6.8 percent between 1994 and 1999 (see Table 5). From Figure 42, it is quite clear that Six-Mile Pool is losing its capacity at a faster rate than that within the river cross sections within the Momence Wetland area.

At this point, it is very difficult to postulate what will happen in the future. However, based on these past records, it appears that these two reaches of the river, Six-Mile Pool and the stream reach within the Momence Wetland area, are experiencing a very high rate of sediment deposition. It is suspected that sometime in the future, the streams within the Momence Wetland area will lose additional capacity until this area reaches some type of dynamic equilibrium. On the other hand, Six-Mile Pool may never reach a complete dynamic equilibrium because of the shape and flow dynamics of the pool. However, right now it looks like the loss of capacity is very high.

In the future, the reach of the river between Aroma Park and Singleton Ditch may lose some capacity due to sediment deposition; however, the rate of loss of the capacity within this reach will be at a much much smaller rate than those within Six-Mile Pool and the Momence Wetland area.

Sand Bars

It was already mentioned that during 1999 sand bars 3 and 4, sand bar 2, and the sand bar at the State Line Bridge were resurveyed (Figure 21). Hydrographic data on these sand bars were used to develop contour plots and also to compute the total volumetric deposition of sediment at each sand bar.

Sand Bars 3 and 4

Sand Bars 3 and 4 are located near Koops Island (Figure 21). Figure 44 shows the contour shading of these two sand bars based on the surveying data collected in 1980 (Bhowmik et al., 1980) and the data collected in 1999 for the present project. Examination of this illustration will show that the patterns of sedimentation observed in 1999 are different than those observed in 1980. It cannot be inferred whether or not the original sand bars surveyed in 1980 are the same ones observed in 1999.

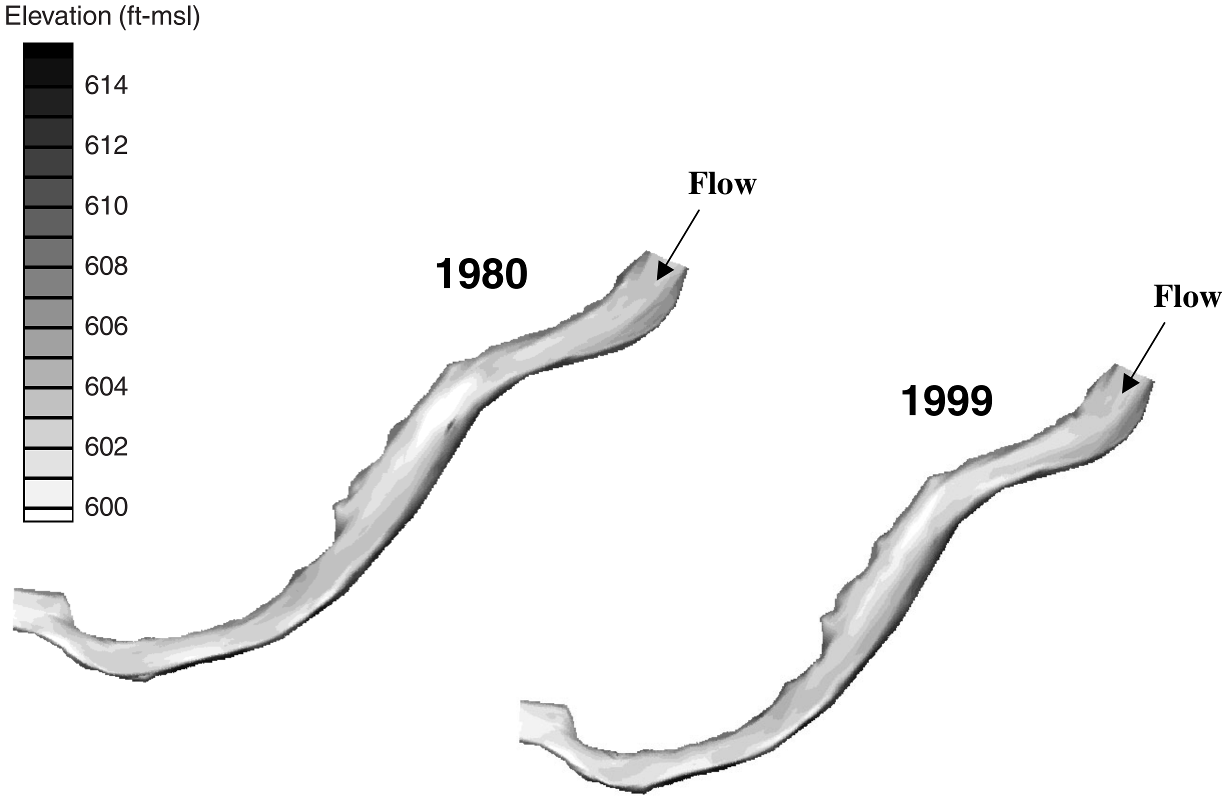

Figure 44. Planform and depth variations of sand bar 3 and 4, 1980 and 1999

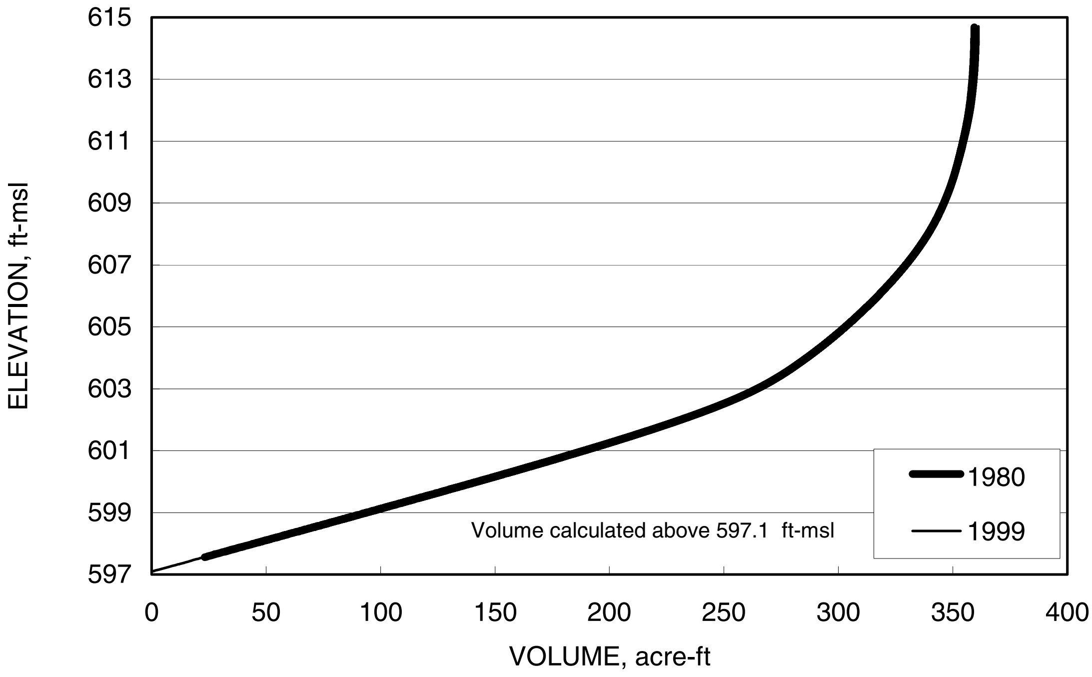

Figure 45. Elevation versus volumetric deposition of sediments in sand bar 3 and 4, 1980 and 1999

Surveyed data were further analyzed to compute the total volume of the sediments in these two sand bars for 1980 and 1999. For this computation, an absolute lowest bed elevation for both time periods was determined based on the surveyed data. This lowest elevation is 597.1 ft-msl. The volume of sediment above this elevation for various elevations up to the topmost elevation was then computed. These data were used to develop a plot for the elevation versus sediment volume for two periods. Figure 45 shows this relationship.

Clearly, the accumulative volumes of the sediments for both sand bars and also for both time periods are almost identical. The cumulative volumes are 359.31 ac-ft in 1980 compared to a volume of 361.19 ac-ft in 1999. Table 6 shows the computed volumes of all the sand bars for these two time periods. The difference in volume between 1980 and 1999 is only 1.88 ac-ft, which raises some interesting questions. The identical nature of these plots may show that the sand bars may have changed somewhat between 1980 and 1999, but overall they did not change too much in volume. On the other hand, it may also be possible that these sand bars are transient in nature, that they undergo erosion and deposition on a continuous basis, and that the measurements in 1980 and 1999 accidentally happened to occur when the volumes of the sediments within these two sand bars were almost same.

The most plausible explanation is that this reach of the river is at a location where sediment deposition should be expected. However, these deposited sediments may be changing during the high flows where scouring would take place, and sediments are deposited more or less at the same locations during the falling stages of the hydrographs. Thus, measurements during low flow stages would only show minor volumetric changes. It is also quite possible that the

Table 6. Computed Volumes of Sand Bars at Different Time Periods

Sand bar name	*Volume computation above lowest elevation, ft-msl*	*Year*	*Volume, acre-ft*
3 and 4	597.1	1980	359.31
	597.1	1999	361.19
2	613.0	1980	47.59
	613.0	1999	44.75
State Line	615.7	1980	42.62
	615.7	1999	47.92

river has attained some kind of hydraulic stability with the inflow and outflow hydrographs, sediment inputs and outputs within this reach, and that the overall hydraulic geometry at this reach will not change significantly in the future.

This semiconstant nature of these sand bars can also be used in the bed load management of the river. It may be feasible to use this reach as a sediment sink basin from which the sand could be mined frequently, consequently reducing the downstream movement of sand load.

Sand Bar 2

Sand bar 2 is located within the Momence Wetland area upstream of the confluence of Singleton Ditch with the Kankakee River (Figure 21). This sand bar was surveyed in 1980 and again in 1999. Figure 46 shows the planform and depth variations of this sand bar in 1980 and 1999. Examination of this figure shows that some of the shallower areas in 1980 became deeper, and other deeper areas became shallower. This shows that the sand bar is a dynamic entity that changes shape and size over time. This becomes more pronounced as one examines Figure 47, which shows the volumetric changes with elevation.

Data for Figure 47 were again developed by selecting the lowest bed elevation within and around the sand bar and determining the cumulative sediment deposition with height above this elevation. This plot indicates that at and above an elevation of 613 ft-msl, the volumetric deposition of sediments in 1980 was larger than those present in 1999. Thus, for this specific sand bar, absolute volume measured in 1999 is about 2.84 ac-feet less than that measured in 1980. This shows that this sand bar eroded between 1980 and 1999. This supports the postulation that the sand bars are quite dynamic.

State Line Bridge Sand Bar

Bhowmik et al. (1980) have explained the formation of a sand bar at the transition zone between the channelized river in Indiana and the natural river in Illinois. However, considering the fact that this is an important consideration in the development of management alternatives for

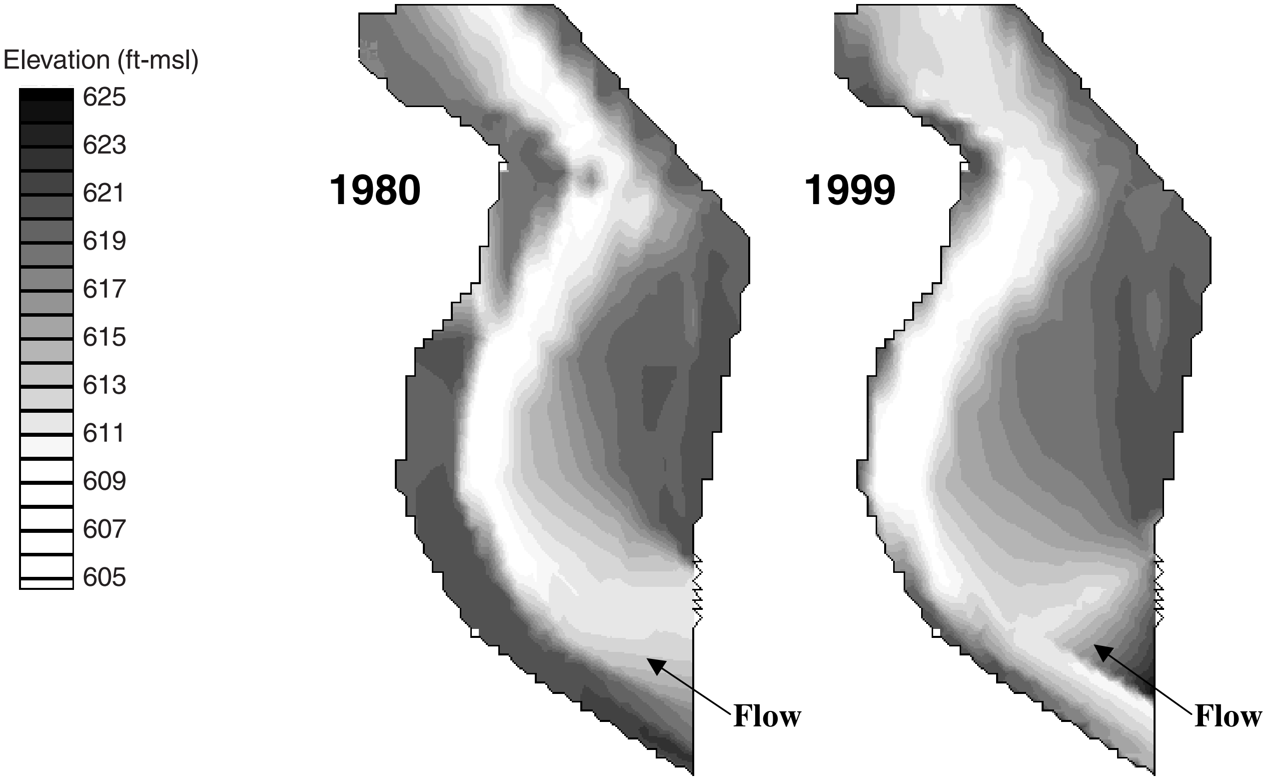

Figure 46. Planform and depth variations of sand bar 2, 1980 and 1999

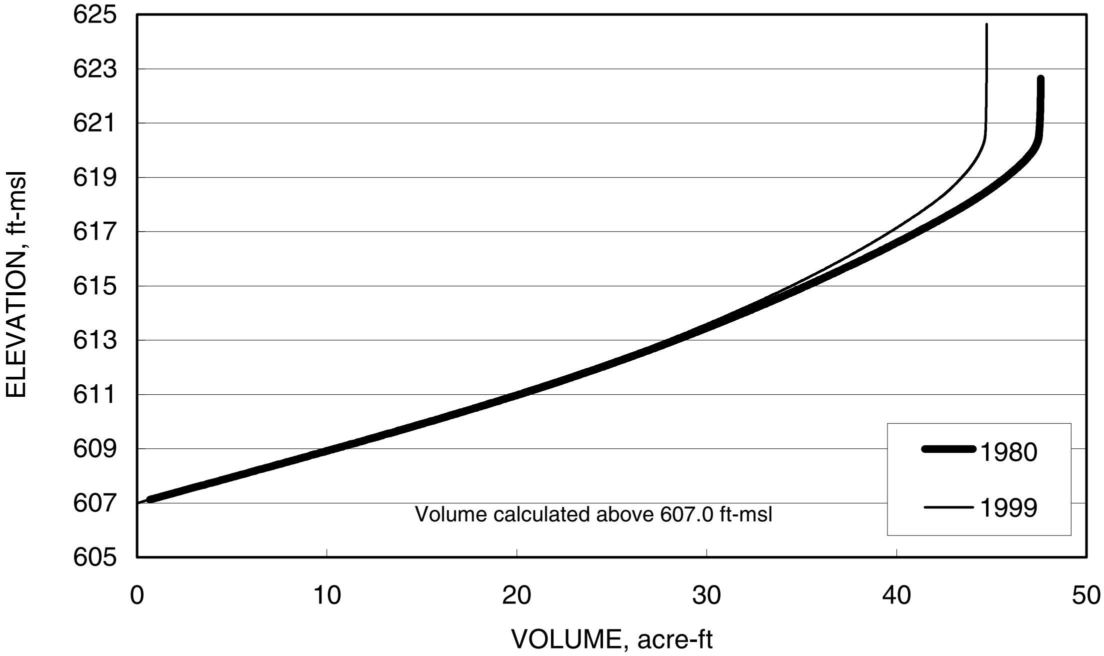

Figure 47. Elevation versus volumetric deposition of sediments in sand bar 2, 1980 and 1999

streams and rivers, and that many streams and rivers were channelized about 100 years ago, the authors felt it necessary to repeat some of the morphological conditions associated with river channelization before discussing the results on the State Line Bridge sand bar. The following materials are from Bhowmik et al. (1980) with minor revisions and changes.

Many different theories explain what happens when a river regime is changed. One explanation is that nature always tries to revert to its former appearance or to a new appearance or shape consistent with existing physical constraints. Throughout the world there are many examples of the effects of channelization on natural rivers. In almost all cases, the river tries to revert to its original shape and size. The river tries to expend minimum energy to move from one place to another; thus, when a stream is channelized, it will try to meander, which may initiate bank erosion, bed scour, or both. If a river has no meandering tendencies, it can be concluded that its present shape and size are geometrically correct for the type of flow and other antecedent conditions present in the river.

For any stable stream, a balance exists between the water discharge, gradient, sediment load, type of bed material through which the river flows, and other physical and meteorological variables. However, if a simple approach is taken, the following balancing relationship of a river seems to work out fairly well:

$$Q_w S \sim Q_s d_s$$

where Q_w is water discharge, S is the gradient of the river, Q_s is the sediment load, and d_s is the characteristic bed material size. Lane (1955) originally postulated this relationship. It can further be explained by the schematic diagram shown in figure 48, which indicates that a river will remain in balance as long as the product of Q_w and S is proportional to the product of Q_s and d_s. A change in any one of these parameters must be accompanied by a proportional change in other corresponding parameters. The equation is very useful for predicting the changes in a river that may occur because of human alterations. Some of these changes may not be noticeable immediately, and it may take years before they start to affect the river.

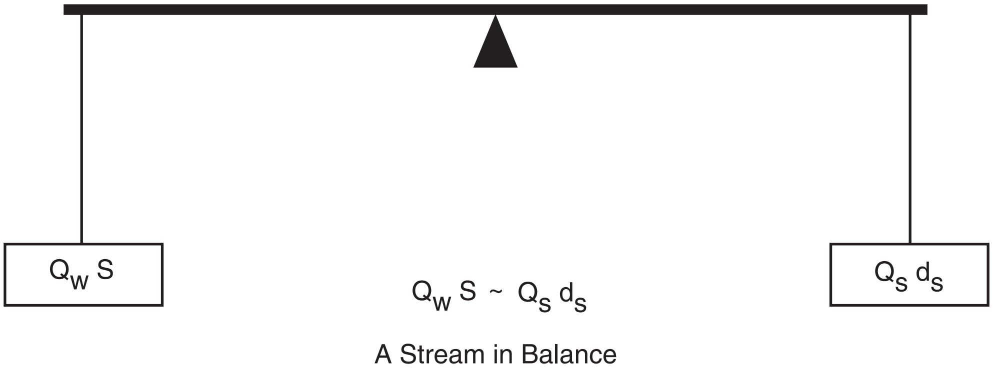

Figure 48. Schematic diagram of a river in balance

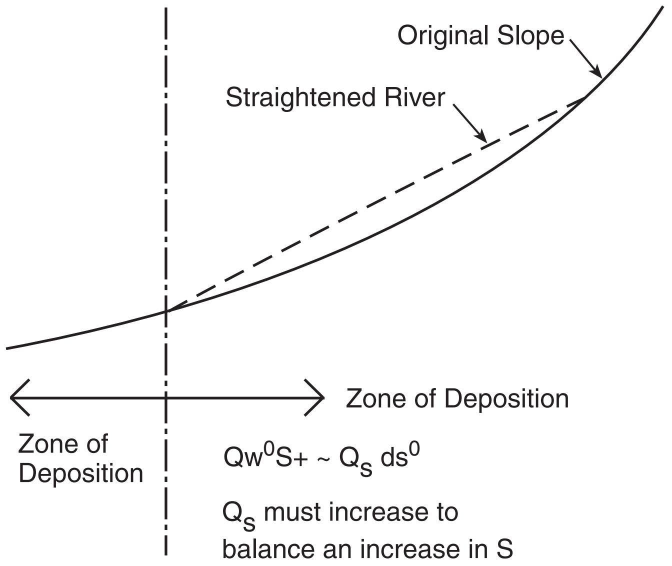

Figure 49. Effect of increased gradient in a river

One hypothetical case may be used to show what can happen in a river if changes are made by river users. Figure 49 shows the changes that a river may experience if the gradient of the river is increased, which may occur as the result of channelization. Channelization shortens the length of the river, but the bed elevations of the river at points upstream and downstream of the channelized reach remain at their natural elevations. Thus, the drop between those two points remains the same, although the length of the river has been shortened. Therefore, the S gradient must be increased as a consequence of straightening the river.

If it is assumed that the materials through which the river flows do not change and the water discharge remains more or less the same; that is, Q_w and d_s are unchanged, then Q_s must increase to compensate for increased S in the equation. In other words, the river will pick up relatively large quantities of sediment load from the channelized reaches for deposition in the downstream, unchannelized natural reaches of the river as shown schematically in Figure 49.

The observation made in connection with Figure 48 may be applied to the conditions of the Kankakee River in Indiana and Illinois. The river was channelized in Indiana 85 or 90 years ago, and the river is still picking up sediment in Indiana and depositing it at the transition zone as postulated in Figure 49. If it is assumed that the vertical dotted line in Figure 49 is the boundary line between the two states, then the river should be acquiring an additional load of sediment in Indiana and depositing the same load in Illinois. Before this hypothesis is carried too far, however, it must be cautioned that many other variables may be acting either to oppose or to support the situation shown in Figure 49.

Progression of the sand bar at the State Line Bridge in 1979 was already reported (Bhowmik et al., 1980), and an illustration has been reproduced (Figure 22). A detailed survey of this sand bar also was made in 1980. During 1999, another sand bar was noted at the State Line Bridge, and a detailed survey was again done. Figure 50 shows the depth shading of these two

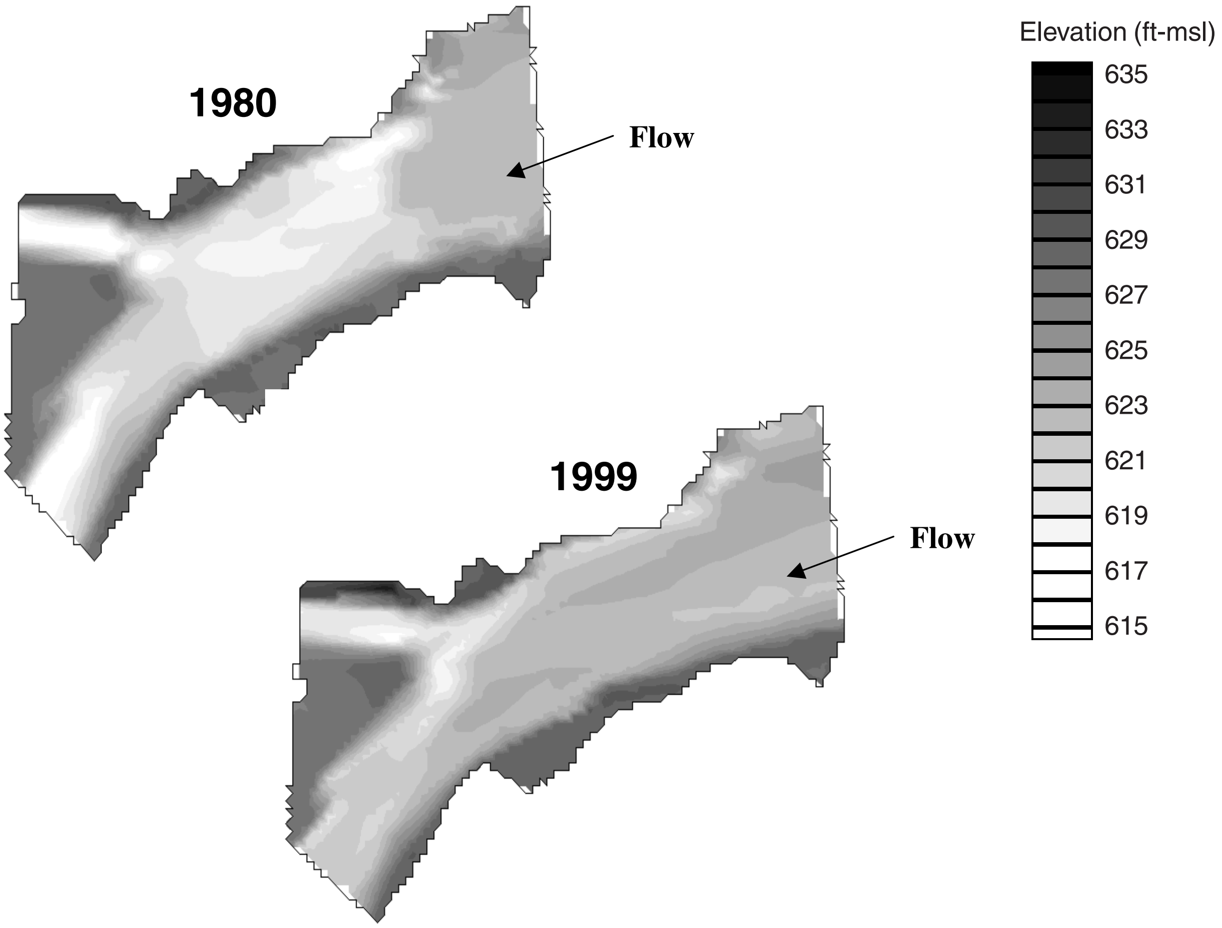

Figure 50. Planform and depth variations of the State Line sand bar, 1980 and 1999

surveys. This illustration indicates that the zones occupied by the 1980 sand bar are not exactly the same ones observed in 1999.

These changes in the relative movement of these sand bars at two time periods is expected. These are dynamic sand bars; the location, areal extent, and shapes at different time periods should be different. It should also be pointed out that the changes in the river gradient at this location, which was postulated to be the cause of the formation of this sand bar in 1980 (Bhowmik et al., 1980), is still true. This is the normal reaction of any sandbed or other similar alluvial river once the upstream reach is channelized.

When a river flowing on erodible bed and bank is straightened within the upper reach for any purpose, the normal reaction of the river is to erode the straightened reach due to its increased gradient and deposit the eroded materials within immediate downstream nonchannelized reach of the river. This is what has been occurring on the Kankakee River at this location on a regular basis, probably since the channelization many years back. Examples such as this one are evident in many channelized streams and rivers in Illinois, in the nation, and all over the world. The river is essentially trying to adjust to the imposed constraints.

The volumetric deposition of the sediments in 1980 and 1999 at this location were computed at different elevations with reference to a fixed low elevation. The lowest elevation selected here is 615.7 ft -msl, (table 6). Figure 51 shows the plots developed between elevation and volumetric deposition of the sediments.

The total accumulative volume of the sand bar measured in 1980 was 42.62 ac-feet compared to the total accumulative sediment deposition in 1999 at 47.92 ac-feet. Thus, assuming a unit weight of 93 pounds per cubic foot (Terio and Nazimek, 1997), the total weight of the sediment was about 86,300 tons in 1980 and about 97,000 tons in 1999. Thus the sand bar measured in 1999 had about 10,700 tons more sediment than the one measured in 1980.

The recurrence of the sand bar at the State Line Bridge also offers an opportunity for the overall management of the coarse-grained sediment within the Kankakee River. Since it is certain that sand bars do form on a regular basis at the State Line Bridge area, similar to the one measured in 1980 and 1999, and also move downstream to the Momence Wetland area and ultimately to Six-Mile Pool and beyond, then some type of sediment removal operation at or near the State Line Bridge could at least reduce the sedimentation problems within the downstream reaches. It would be desirable to perform some type of basic regular surveying at this location on an annual basis to determine the recurrence phenomenon of the sand bar.

Suggested Management Alternatives

Data collected over approximately the last 40 years, and the analyses presented in this report and the other previously published reports, offer an opportunity to suggest several

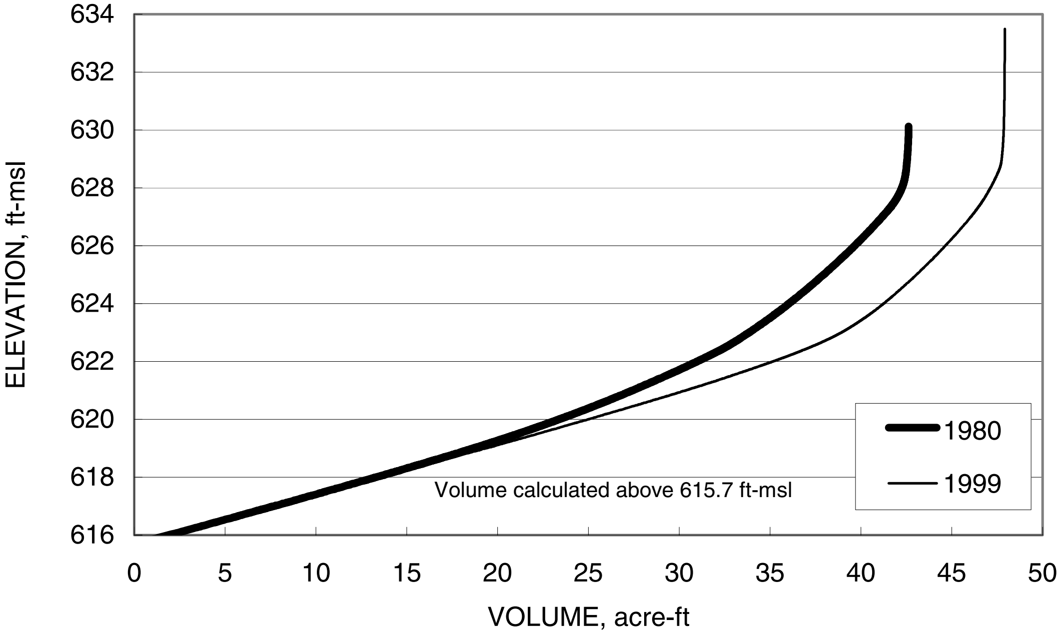

Figure 51. Elevation versus volumetric deposition of sediments in State Line sand bar, 1980 and 1999

management alternatives for the main stem of the Kankakee River that possibly could be implemented soon and also on a long-term basis. River bank erosion, excessive sediment deposition at critical points, and a possible and associated change in the channel conveyance appear to be the major hydraulic and hydrologic concerns within the main stem of the Kankakee River.

Any and all management alternatives must address the problem on two fronts: deposition and movement of sediment within the main channel, and the process of erosion from the watershed and the sediment delivery to the river. Implementation of management alternatives within the watershed without addressing the in-channel problem will not solve the problem. At the same time, implementing remedial measures to manage in-channel sedimentation problems without addressing watershedwide problems would not work either. Thus, any remedial measures must consider both in-channel sedimentation and the inflow of sediments from the watershed.

The following list of suggested alternatives could be evaluated and implemented to manage sediments now in the channel and also sediment that may be delivered to the river in the future from the watershed.

In-Channel Alternatives

Bank Erosion

In order to reduce further bank erosion and direct delivery of sediments to the river:

- Evaluate severe and moderate erosion sites for potential stabilization options.
- Stabilize some severe erosion sites with bioengineering techniques, if feasible; otherwise use structural means (riprap, stones, ajax, etc.). A combination of bioengineering techniques and structural toe protection also could be viable.
- Review some erosion-prone areas, especially in Indiana where the river has been channelized. Stabilization of those sites may require the establishment or recreation of mild meander bends to reduce the gradient and partially reestablish the natural mild stream gradient.
- Review sites of bank erosion caused by the skewed alignment of bridges. At those locations, consideration should be given either to realigning the bridges to reduce the obstruction of flow by the bridge piers and or abutments or to establishing some type of natural meandering patterns at that site so that the bridge crossing is not skewed to the normal flow direction.
- Examine those sites where river banks are stable because of the presence of mature tree stands with a solid root system. If possible, those trees should be left undisturbed. If the trees are removed, it may initiate a vicious circle of bank erosion, bed scour, or deposition that will be hard to remedy. Attempts should be made to establish vegetation as a means of bank protection.

Sediment Load

Previous analyses have shown that at several locations sand bars have been forming on a regular basis. Sediment has been depositing at least for the last 20 years at two reaches, Six-Mile

Pool and the Momence Wetland area. Actions or activities could be initiated to reduce these sediments from moving in the downstream direction. At other locations, sand bars were observed to be depositing at the mouth of tributary streams. Side channels at other areas are being choked with deposited sediments. Actions or activities could be initiated to address sedimentation problems at selected sites. Several options could be implemented:

- Create sediment detention basins at the mouths of several tributaries that carry excessive amounts of sand as sediment load. This is especially true for tributaries in Indiana. Once detention basins are constructed, sediments within these basins could be removed on a regular basis.
- The tributary mouths where sedimentation is a problem can be hydraulically modified by constructing slanted dikes. These dikes will concentrate flow and could wash out the deposited sediment. However, before such actions are implemented, detailed hydrodynamic and sediment transport modeling work should be completed to determine the impacts of such action on the tributary and the downstream reach of the river. Possible tributaries are Fall Creek, Tower Creek, Spring Creek, and others.
- Build side-channel sediment traps to trap sediments especially during high flows. Periodic removal of sediments from these traps will maintain their capacities for a longer period of time.
- Remove the sand from the sand bar at the State Line Bridge on a regular basis. Sand bars form frequently at this location, and removal will reduce the sediment that moves into the Momence Wetland and further downstream. This probably will be a semi-continuous operation, not a one-time solution or activity.
- Consider the removal of some of the other sand bars. Once these sandbars are removed, the area thus cleaned will probably fill up with sediment. Thus, this will also be a recurring phenomenon.
- Implement a plan to address the sedimentation problems of Six-Mile Pool, especially between RM 33.50 and RM 36.20. This area has been experiencing excessive sediment deposition since 1959. If the deposited sediment is removed, this area will probably be filled up with sediment requiring removal at 5-, 10-, or 20-year intervals based on the severity of the problem.
- Consider installing chevron type structures at the upstream end of in-channel island(s) to redirect partially flows around the island through the side channel. This type of action could force the scour of deposited sediment, thus enabling those side channels to become flowing channels. This type of action may be appropriate at several islands, such as Patrick Island, Eagle Island, Maple Island, Koops Island, Parish Island, Snake Island, Shannon Island, etc. However, before such actions are implemented, thorough hydrodynamic and sediment transport modeling must be completed to determine the potential impacts of such actions on the velocity structure, hydraulics, and sedimentation or scour patterns.

Watershed-Based Alternatives

Many watershed-based alternatives could be implemented to reduce the sediment flow to the river. A partial list follows.

- Erosion and sedimentation is a natural occurrence, which no amount of work can completely eliminate. However, methods and means are now available to reduce the excessive amount of sediment that moves into a water body.

Some of the readily available concepts and solutions that could be implemented are as given below. This is not an exhaustive list.

- Establish buffer zones along stream corridors.
- Construct detention ponds on tributary streams to reduce sediment loads to the main river. This could also reduce peak flows.
- Create wetlands to reduce sediment loads and decrease flood peaks.
- Stabilize unstable tributary banks.
- Install grade control structures on tributaries as needed to control head cutting.
- Implement best management practices (BMPs) on tributary streams. Implementation will depend on the available data on soil erosion, land-use patterns, geology, soils, and future impacts on the river and the watershed.
- Reestablish some old meander belts on a few tributary streams to reduce their tendencies to transport excessive sediment loads.

Implementation of any and all bank erosion control programs, in-channel sediment management alternatives, and watershed-based management will require extensive cooperation between the local landowners, local management authorities, cities if the river is within an urban area, and state and federal agencies. Moreover, it is neither practical nor feasible to collect field data from the entire watershed. Thus, in addition to collecting critical data such as river geometry, flows, sediment load, and bed and bank materials, additional mathematical modeling for the watershed, hydraulics, and hydrodynamics and sediment transport modeling for the main channel must be done to locate and determine the appropriate locations of the selected management alternative(s) and also to determine their impacts on the total system. Once models are calibrated and verified, remedial measures could be designed. Before implementing any remedial measures, the potential impacts must be evaluated based on the calibrated mathematical model or models. This exercise, if done properly, will enable managers to implement management alternatives that have a high degree of success.

Summary

The Kankakee River flows from east in Indiana to west in Illinois. Once the river joins the Des Plaines River, it forms the main stem of the Illinois River. The total drainage area of the Kankakee River is 5,165 square miles (2,169 square miles in Illinois and 2,996 square miles in Indiana). The main stem of the river is about 150 miles long.

Illinois State Water Survey (ISWS) engineers and scientists have been conducting research on the Kankakee River since 1978. The present project was undertaken to bring together all the available hydraulic, hydrologic, and sediment data; collect bank erosion data from the main stem of the river in Indiana and Illinois; resurvey all the old cross sections and resurvey four sand bars; and analyze all the recently collected data. This report summarizes all the analyses on bank erosion, bank and bed materials, river geometry, and sand bar surveys. All the new data were collected in late 1998 through early 2000 and designated as 1999 data.

Maps of the extent of the bank erosion on both sides of the main stem of the river have been developed, and a report has been published. This research (Bhowmik and Demissie, 2001) showed that out of 223.6 river bank miles on both sides of the river, about 10.4 river bank miles have severe erosion, 39.4 river bank miles have moderate erosion, 70.8 river bank miles have minor erosion, and the rest of the bank miles are either stabilized, protected, or in areas where data could not be collected.

The median diameter of the bed materials varies from 0.27 to 0.52 mm, similar to the data collected in 1980 by ISWS. Thus, the bed materials essentially range from fine to medium sand. The Kankakee River essentially flows on a sand bed channel except in some areas near Momence where rock outcrops are present. The median diameter of bank materials varies from 0.07 mm to 0.41 mm.

Analyses of the long-term flows at several gaging stations showed an increasing trend until the 1960s similar to an increase in precipitation. However, no statistically valid trends were observed since 1960.

The cross-sectional data did, in fact, show some alarming trends. Six-Mile Pool is trapping sediments at a rate of about 0.67 percent per year since 1980. The pool has lost about 13.4 percent of its 1980 capacity through 1999. This is a fairly high capacity loss compared to many human-made lakes in Illinois. The area between RM 33.50 and RM 36.5 has been a net accumulator of sediments since 1959 through 1999.

The reach of the river between Aroma Park and Singleton Ditch has been fairly stable since 1977. However, this reach also experienced some sediment deposition between 1966 and 1977. This reach has a steep slope, it flows on rocky substrates at several locations, and the channel geometry is fairly well defined. These hydraulic geometry factors are probably responsible for reduced sediment deposition within this reach. Even though the absolute values of the sediment deposition are small, still some areas of this reach have been accumulating sediments since 1966, and some scour is evident at other areas.

The next reach of the river from Singleton Ditch to State Line Bridge, the so-called Momence Wetland area, also has shown a similar trend to the Six-Mile Pool area of losing its capacity. This reach has lost about 10.2 percent of its 1980 capacity, which translates into 0.51 percent capacity loss per year. Since 1980, the river within its banks in the area has accumulated about 127,500 cubic yards of sediment.

Four sand bars surveyed in 1980 were resurveyed in 1999. Even though some of these sand bars are transient in nature, they are forming at somewhat the same locations. This offers an opportunity to remove some of the sand from these sand bars. Once removed, these coarse-grained bed materials moving as bed loads will not be entering and depositing within the Momence Wetland or Six-Mile Pool.

The sand bar measured at the State Line Bridge area in 1999 is a recurring phenomenon and has 5.3 ac-ft more sand in 1999 compared to the one measured in 1980. Sand bar 2 above the confluence of Singleton Ditch with the Kankakee River had a net degradation of 2.84 ac-ft in 1999 compared to the volume measured in 1980.

For the first time, the present research has attempted to compile all the hydraulic, sediment, and river cross-sectional data in one place, and a complete set of river geometry data has been collected. Analyses have been completed to put a historic perspective on the sedimentation problems of the Kankakee River. Analyses of the data also have shown that the Kankakee River flows on a sand bed channel except at a few locations where it flows on a rocky substrate, and that the sand is depositing at certain locations, which may facilitate the future management of the sand load of this river. For the first time, a set of bank erosion maps has been developed for the main stem of the Kankakee River that would be extremely useful in the future as a management tool.

Finally, several management alternatives to prevent further bank erosion and to decrease the capacity loss in Momence Wetland and Six-Mile Pool have been included in the report. These include stabilization of the banks with bioengineering and structural means, creation of sediment traps, removal of sediment from areas where sedimentation is a recurring problem, establishment of river meanders, and increased BMPs on selected and highly erosive sub-watersheds. Suggestions also have been incorporated on how to use the river flows to recreate or reestablish side channels along the main stem of the Kankakee that are being partially blocked by sediment deposition.

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