State Water Survey Division
SURFACE WATER SECTION
AT THE
UNIVERSITY OF ILLINOIS

Illinois Department of
Energy and Natural Resources

SWS Contract Report 342

SEDIMENTATION SURVEY OF LAKE DECATUR
DECATUR, ILLINOIS

by William C. Bogner, William P. Fitzpatrick,
and Nani G. Bhowmik

Prepared for
the City of Decatur, Illinois

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Addenda and Errata for CR 342, Sedimentation Survey of Lake Decatur, Illinois

page	change
36	"...one are described." The results presented in this section are those reported in the original survey reports. Where discrepancies exist with the presentation of the 1983 results, they represent either minor computational differences or errors in the presentation of the earlier results. In all cases, the 1983 results supercede earlier reports.
67	Equation (1) should read: $V = L/3\ (A_L + \sqrt{A_L \times Au} + Au)$ (1) .
71	In paragraph 2, 35.5% should read 32.6% and 0.58% per year should read 0.53% per year.
72	In table 5, the 1956 volume should read 22,200. There is an extra zero in the report.
73	In table 6, the values should be: 1956-1966 5.02 0.50 1922-1983 . 32.62 0.53
74-75	The following values should be corrected: segment 42 in 1946 452 segment 8 in 1936 88 segment 34-35 in 1983 181 segment 12, 1983 tonnage 322
79	Equation (3) should read: $T = 21.78\ [M_t A + M_b\ (V - A)]$ (3) Also, in the last paragraph, delete: "and "V" was then set equal to zero"
82	In table 9, the second column heading should read "Acre-feet of sediment deposited".

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INTRODUCTION

Background

The Illinois State Water Survey (ISWS), in cooperation with the City of Decatur, Illinois, has conducted a sedimentation survey of Lake Decatur, the water supply reservoir for the city.

The purpose of this survey was to determine the current volume of Lake Decatur and to calculate the past rates of volume loss and sediment accumulation. Lake Decatur is the sole source of water for the city's industries and 100,000 citizens. Lake sedimentation surveys provide the means for determining the available water supply and for projecting the useful life of the reservoir. The lake has been surveyed five times: in 1931-1932, 1936, 1946, 1956, and 1966. The current survey was conducted during the period June through August 1983.

Previous surveys of Lake Decatur have provided some of the most complete documentation of lake sedimentation processes in Illinois. This report presents the results of the 1983 survey as well as an analysis of the data from the earlier surveys.

Scope

This project report presents information regarding the following four areas:

1) History, geology, hydrology, and climatology of the Upper Sangamon River basin watershed.
2) Past surveys of Lake Decatur.

3) The 1983 lake survey.

4) Lake bed sediment characteristics

Acknowledgments

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Partial funding for this study was provided by the City of Decatur. Particular appreciation is expressed to Don Gibson, City of Decatur; Ron Lewis, Lake Maintenance; Brad Brown, Decatur Lake Police; and the citizens of the City of Decatur.

DAM AND RESERVOIR

History of Decatur Waterworks

The first public water supply for the residents of Decatur, built in the early 1830s, was a shallow public well near what is now Lincoln Square. Several other wells were finished in the following years, but their water capacity was insufficient for the growing population and industries of Decatur. The city population grew from less than 100 in 1830 to over 7,000 by 1870; in 1871 the city council voted $30,000 in bonds for the construction of a pumping station and related equipment on the Sangamon River. The new installation provided a capacity of one million gallons a day (1 MGD). The raw waters of the Sangamon proved to be too turbid, so an infiltration gallery was constructed in the bed of the river to filter the river water through sand and gravel. To keep up with the demands of the growing city a wood dam was built in 1878 across the river near the present low dam (a few hundred feet downstream of the current city dam).

By 1884 the city's pumpage capacity had increased to 7 MGD. A new pumping station was built in 1909 at a cost of $225,000, and in 1913 a new filter plant was under construction.

The old wood low dam was replaced in 1910 by a new low dam of concrete with a spillway elevation of 595 feet msl (mean sea level). Later, in 1920, the A. E. Staley Co. built its own dam 100 feet downstream of the Staley Bridge, constructed to alleviate periodic shutdowns at the Staley Company's corn processing plant due to water shortages at the city's water works. The Staley dam was used to augment the municipal water supply as well as to supply the Staley plant until the new city dam was completed in 1922, at which time the Staley dam was removed. The location of the Decatur city dam and its watershed is shown in figure 1.

The new city dam and reservoir cost approximately $2 million. Of this amount, the city paid $725,000 and the rest was financed by the Decatur Water Supply Company, a quasi-public company established to issue bonds to cover the remaining costs, and to administer the new lake and dam. The Decatur Water Supply Company was dissolved in 1932 when the last of the bonds were retired, and the ownership of the lake was turned over to the City of Decatur.

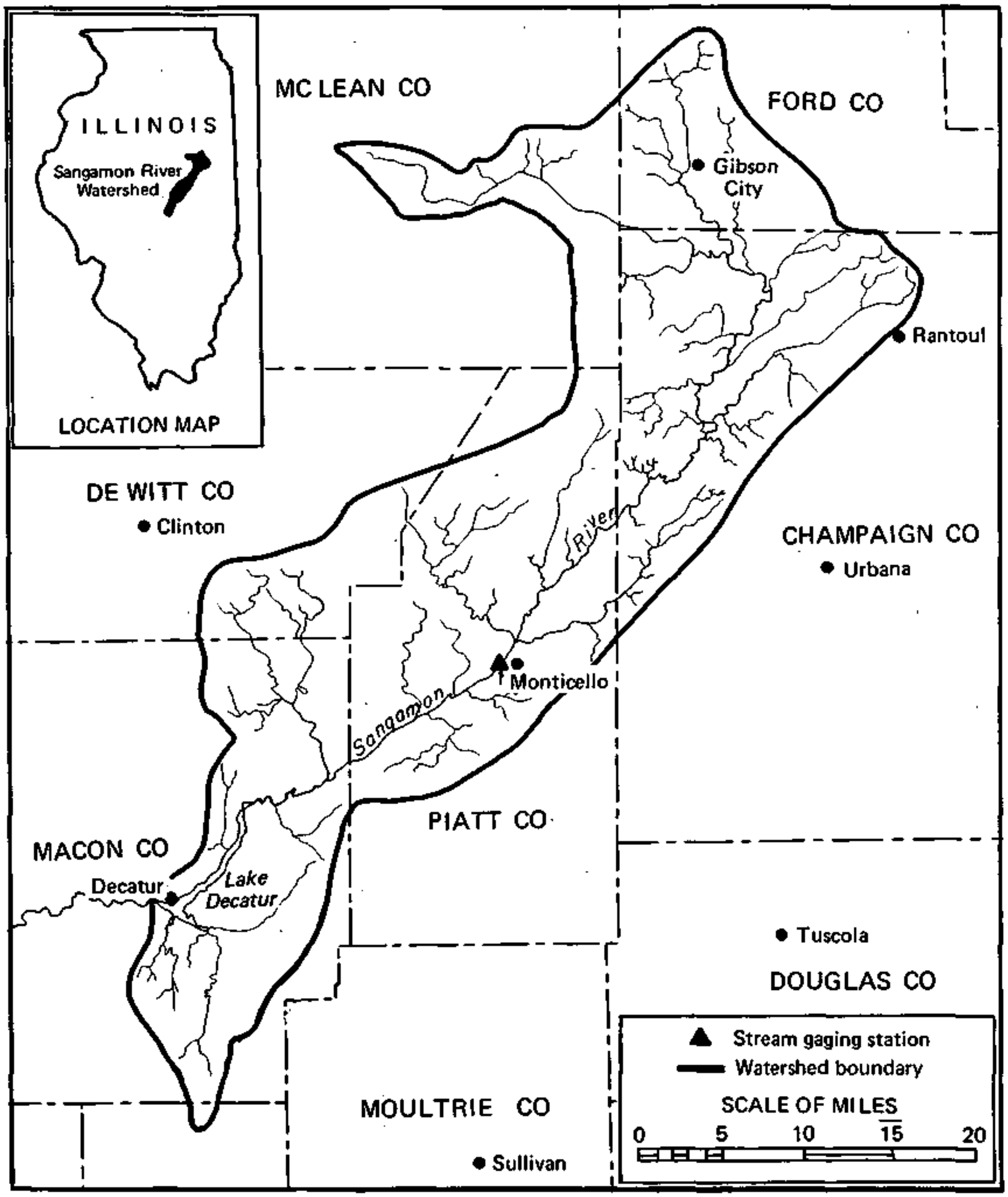

Figure 1. Location of Lake Decatur, showing watershed boundary and Monticello gaging station

At the same time the population and industries of Decatur continued to grow and place new demands on the city water works, Lake Decatur was being reduced in capacity by sedimentation. By 1956, the lake had lost approximately 30$ of its volume and the city's water reserve, built to guard against times of drought, was at an all-time low. In 1956 a set of hydraulically controlled bascule gates was installed on top of the spillway segment of the city dam to raise the storage capacity of the lake by providing a means of varying the spillway elevation between 610 and 615 feet msl.

The city's water treatment capabilities have been expanded over the years. The main water treatment plant, just north, of the city dam, has been enlarged several times and has a capacity of 28 MGD. A new plant was built in 1975, near Rea's Bridge, at a cost of $8 million. The new North Water Treatment Plant has an installed capacity of 12 MGD, which can be expanded to 2k MGD.

The North Water Treatment Plant was situated near the upper end of the lake in anticipation of the construction of a new flood control and water supply reservoir, the Oakley/Springer project, proposed by the U.S. Army Corps of Engineers. The Oakley/Springer dam was to be built just north of Rea's Bridge and would have provided several tens of thousands of acre feet of storage that would have supplied the city's needs well into the next century. In the late 1970's, however, Congress ceased appropriating money to the project and it was deauthorized.

Several reservoir projects have been proposed over the years to increase the municipal water supply of Decatur: Big Creek, Sand Creek, Friends Creek, and others. For one reason or another these projects were not built and Lake Decatur remains the sole source of potable water for the city.

Decatur Dam and Reservoir

The city dam at Lake Decatur has a total length of approximately 1900 feet extending north and south across the Sangamon River Valley. The dam consists of three segments: the concrete spillway segment in the middle, which is 480 feet long, 28 feet in height above the bottom of the original river channel, 4 feet thick at the top, and 14 feet thick at the base; and two earth-filled sections on either end of the spillway, each having a length of about 675 feet and providing a freeboard of approximately 22 feet between the spillway crest and the top of the end sections (Brown et al., 1947).

The original spillway elevation was 610 feet msl. The set of moveable gates installed atop the spillway section in 1956. is capable of raising the pool elevation to 615 feet; however, the pool is normally maintained at 613.5 feet. The upstream end segments of the dam have slopes of 2.5 to 1 and are faced with concrete slabs. The upstream face of the spillway section is vertical.

A flushing conduit of 3 by 4 feet was built into the spillway section at a depth of 15 feet below the crest. The total cost of the dam construction was $940,000. Other costs, including land purchase and clearing, road and bridge relocation, and riprapping, brought the original cost up to $2,013,840 (Brown et al., 1947).

Lake Decatur covers the entire floodplain of the Sangamon River and encroaches on the bluffs and slopes of the valley. The old floodplain is approximately 1/2-mile wide and was occupied by a winding river channel 100-200 feet across and about 5 to 10 feet deep. The submerged river channel has been completely buried in much of the lake as the fine silts washed into the lake have settled out in the deeper, quiet portions of the lake. The original maximum depth of the lake at the dam was about 28 feet in the old river channel and about 16 feet over the old floodplain. Currently the maximum depth is 17 feet at the dam and over 20 feet deep at a scour hole in the lake bed below Staley Bridge (below elevation 613).

The lake forms an inverted "T" shape (see figure 1) where the valley of the Sangamon River takes a right angle turn from a southwest orientation to a northwest direction at the junction of the major tributary, Big Creek, about 1-1/2 miles upstream of the dam. The only other major tributary of the lake is Sand Creek, which joins the lake at the "T" from the southwest. The lake is bounded by bluffs of up to 70 feet and steep slopes which are most noticeable along the southern shore of the Big Creek tributary and along the shoreline of the main lake on its upper part.

Pre-Dam Valley Topography. Before the construction of the city dam, the valley of the Sangamon River at Decatur was occupied by the meandering course of the river. Parcels of farmland on the floodplain are bordered by the river and the valley walls, as shown in figure 2. The map of the valley shown in figure 2 was obtained from the Water Survey's files. It was undated and drawn sometime prior to 1918 as indicated by a handwritten note on the original.

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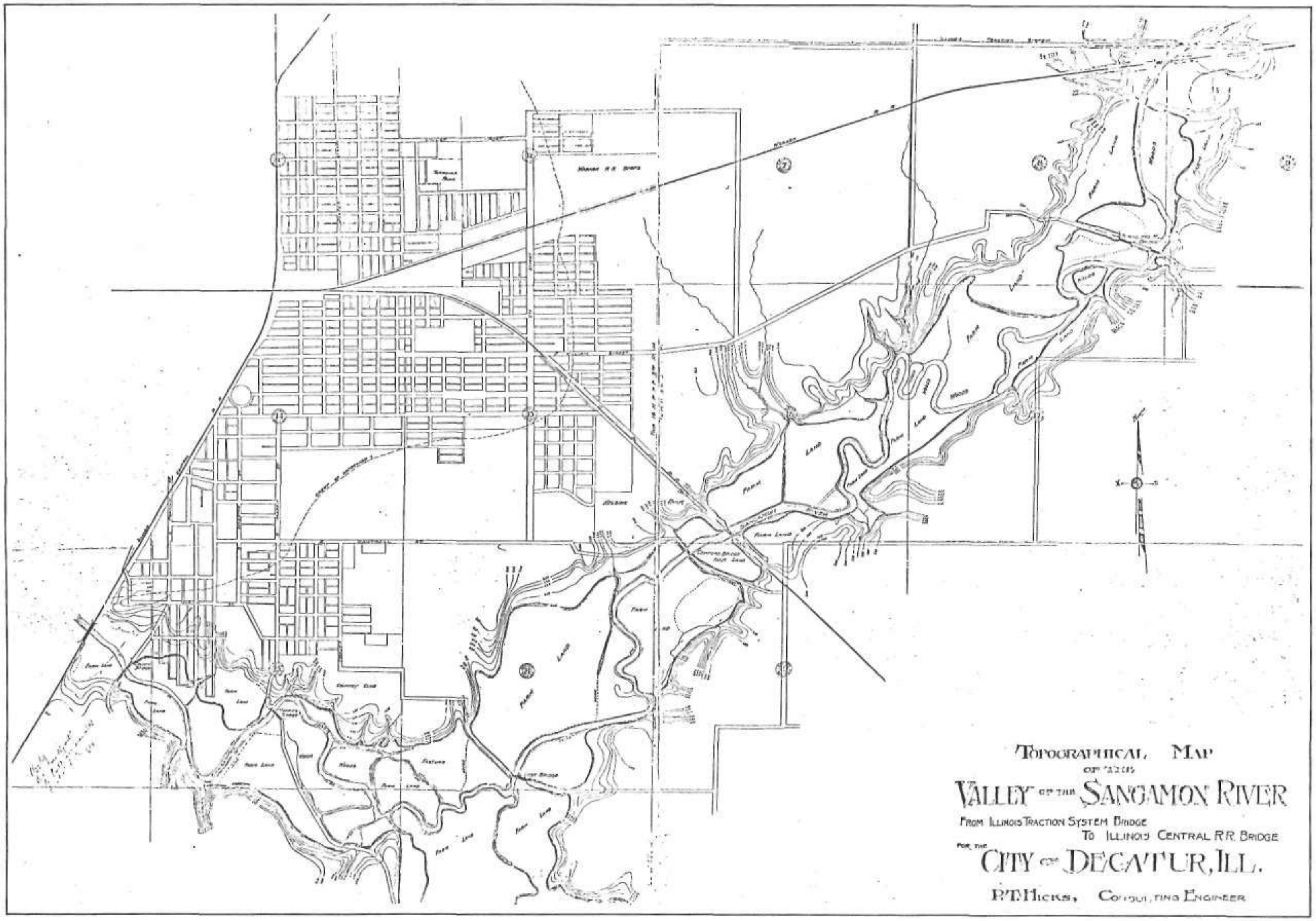


Figure 2. Valley of the Sangamon River before construction of Lake Decatur

The floodplain of the Sangamon River occupied the entire valley floor and averaged about 1/2 mile wide. The valley walls are composed of Illinoian and Wisconsinan glacial till and are capable of holding near vertical bluffs, as can be seen in the southwestern portion of the map in figure 2.

The twisting course of the river shown in figure 2 is a result of the low gradient and high sediment load of the river. In this figure one can see the cut-off meanders and side channels which are typical of the Sangamon River. In the area shown by the pre-dam map, the river traveled 8.7 miles from the north railroad bridge to the county bridge in the southwest, a valley distance of 5.8 miles.

In figure 2 the old bridges and levees of the pre-dam valley can be seen. Of the six highway bridges shown in this figure which crossed the valley, four were maintained in service when the valley was inundated. The Maffit and Cowford Bridges were abandoned.

Shoreline Usage and Recreation. Land use along the shore of Lake Decatur varies from highly developed urban areas, to public parks and clubs, to undeveloped woodlands. Developed areas including parks and clubs encompass over 90% of the total shoreline. The southern shore is dominated by single family housing, while the northern shores are generally wooded and less developed.

Lake Decatur provides a focal point for recreation in the area. Nine city parks are on the lake shore, of which the largest are Nelson, Faries, and Big Creek Parks. Approximately 10 private/semi-private clubs also occupy the lakeshore. These clubs cover a wide range of interests ranging from Boy Scout and Girl Scout camps to the Decatur Country Club and the Yacht Club.

Major recreational activities on the lake are boating, water-skiing, sailing, and fishing. In 1983 approximately 2600 boat licenses were issued by the city for Lake Decatur. The number of boat licenses averages about one per 40 people for the city population of 100,000. In 1983, 420 dock permits (individual and multiple) were issued by the city for the lake front property owners and tenants.

Water Quality. The water quality of Lake Decatur is considered fair to moderate. The lake has high concentrations of nitrates and total dissolved solids, and it has had periodic problems with turbidity and bacterial contamination (IEPA, 1978).

Thirty-one Illinois lakes were sampled in 1973 for the USEPA national eutrophication survey. Lake Decatur ranked 28 out of 31 in overall trophic quality (USEPA, 1975), and was classified as eutrophic by the USEPA. A eutrophic lake is one that exhibits any of the following characteristics: algal blooms, excessive aquatic weeds, oxygen deficiencies, or a shift in species composition of aquatic fauna to forms that can tolerate low concentrations of dissolved oxygen. Most of these problems have been seen in Lake Decatur.

PHYSICAL AND GEOLOGICAL CHARACTERISTICS OF THE WATERSHED

Climate

The climate of the Decatur region is classified as humid continental. Typical features of the climate are the great variations in temperature and precipitation between months and years (Changnon, 1964; and N0AA, 1982).

The seasons of the year in the watershed range from warm to hot summers and cool to cold winters. On the average, weather fronts move through the region 25 to 30 times a year, causing abrupt changes in weather conditions.

Average annual precipitation from 1951 to 1980 was 39.12 inches; it has been as high as 60.58 inches (in 1927) and as low as 25.10 inches (in 1914). Thunderstorms account for approximately 41% of the average annual precipitation, and snowfall is 5% of the total. Precipitation during the months of April to September is normally 60% of the annual total. June is the wettest month and February the driest. The heaviest 24-hour rainfall on record is 4.76 inches on June 2, 1975. Thunderstorms occur on the average of 45 days of the year with hail occurring on 2 to 3 days, sleet on 6 days, and freezing rain on 4 days. Snowfalls of 1 inch or more in 24 hours normally occur 6 times a year. July is normally the warmest month and January the coldest. Temperature extremes on record are 113 degrees Fahrenheit on July 14, 1954, and -24 degrees Fahrenheit on February 13, 1905. The average growing season is 173 days from the last frost in late April to the first frost in mid-October. The average annual number of degree-days from 1951 to 1980 was 5453. The average annual number of cooling degree days over the same period was 1175.

Physiography and Geology

The Upper Sangamon River and Lake Decatur are situated in the Till Plains section of the Central Lowland physiographic province, as shown in figure 3. The Till Plains section covers approximately 80% of Illinois and is generally characterized by broad till plains which are mostly in a youthful erosion stage in contrast with the Dissected Till Plains on the older drift-sheets to the west as in Iowa and extreme western Illinois. The Upper

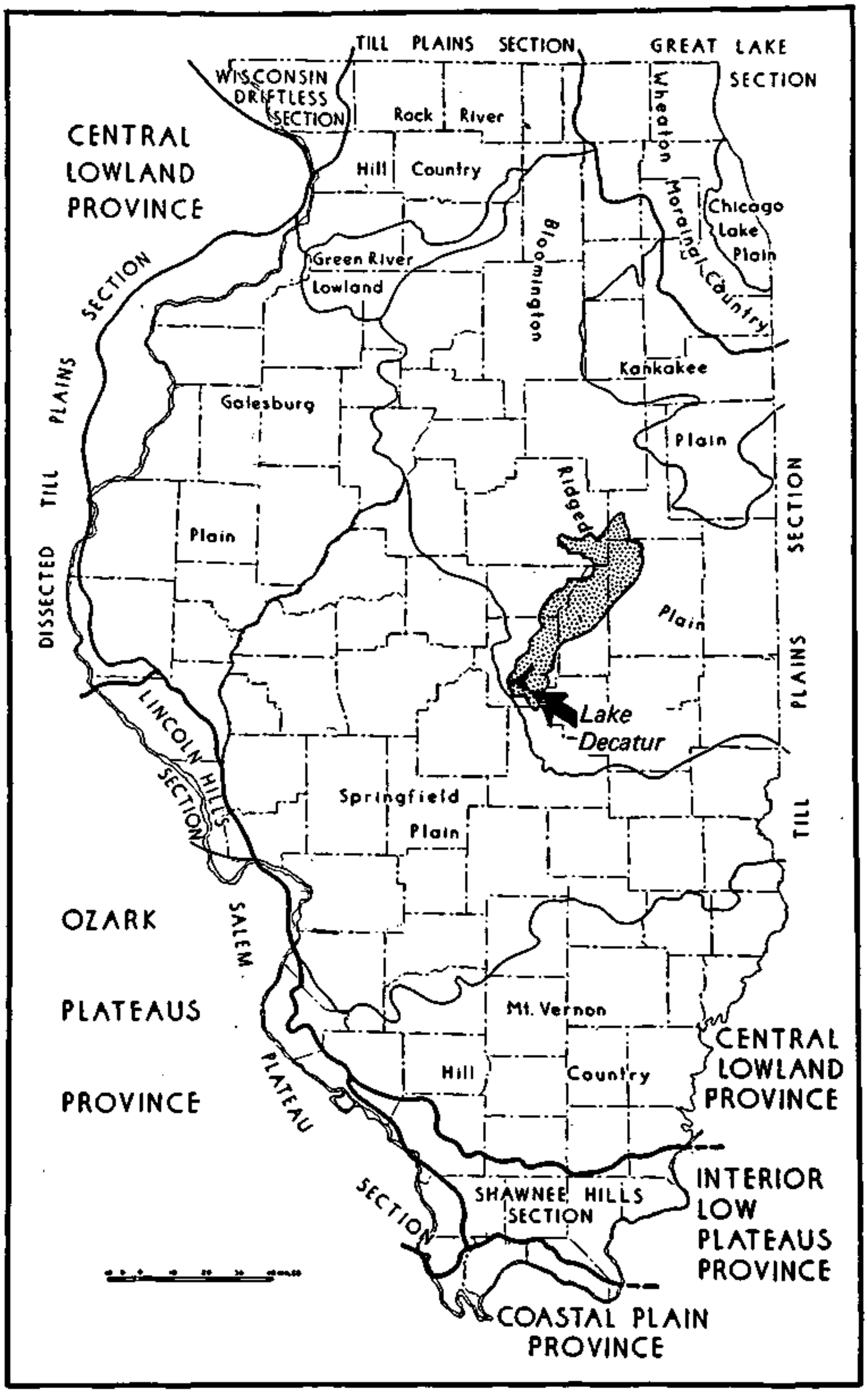


Figure 3. Physiographic divisions of Illinois

Sangamon Watershed is located on the Bloomington Ridged Plain subdivision of the Till Plains section. The Bloomington Ridged Plain is characterized by low broad morainic ridges with intervening wide stretches of relatively flat or gently undulatory ground moraine (Leighton et al., 1948).

The Sangamon River Valley dates back to the Sangamon interglacial period which followed the Illinoian glaciers approximately 100,000 years ago. When the ice sheets of the Illinoian glacial epoch melted, they left behind a relatively flat ground moraine composed of clay till with scattered pebble and sand lenses. A relatively broad and shallow valley was carved into the ground moraine by the waters draining from the retreating ice and the newly exposed land surface (Leighton, 1923).

Figure 4 shows the valley strata as compiled from well borings and test pits made as part of engineering studies carried out before the Decatur dam was built. In this figure the bedding of glacial till, sand, and gravel can be seen. The strata shown in figure 4 are the end products of countless erosion and deposition cycles which alternately cut into and filled the valley. The major cycles were the result of glacial processes which destroyed old drainage systems and reworked the regional topography.

The upper surface of the Illinoian till was shaped by the newly created Sangamon River. The river drained the retreating Illinoian ice front and carved the valley down into the till. Leighton (1923) found an old soil surface (6-8 inches deep) on top of Illinoian till, as well as oxidated and leached zones of till below. The soil surfaces indicate a relatively long period of exposure before burial by deposits from the next glacial period. Leighton interpreted the sand and gravel layers between the two tills, seen in figure 4, as the outwash deposits from the advancing ice front of the Wisconsinan glaciers.

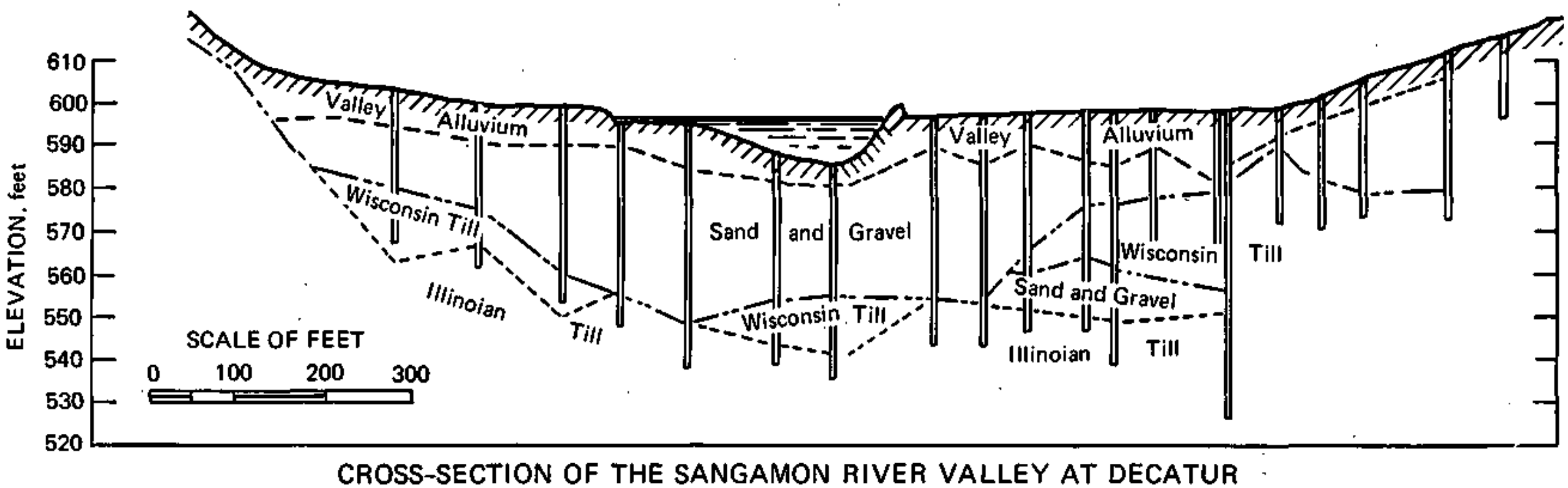


Figure 4. Stratigraphic cross section of the Sangamon River near Decatur

The Wisconsinan period followed the Sangamon interglacial period. The ice sheets of the Wisconsinan glacier advanced out of the northeast as a result of climatic changes which cooled the region. The outwash deposits of the early Wisconsinan were overridden by the ice sheet. Later melting cycles eroded the outwash deposits and laid down unsorted till composed mostly of clay with some pebbles and boulders. The glacial till was deposited over most of the area that the ice sheet had occupied, leaving a flattened topography with the river valleys smoothed over. The Sangamon Valley was almost buried by the till of the Wisconsinan glaciers. As the ice front retreated to the northeast, meltwaters recarved the valley (Leighton, 1923).

The discontinuous layers of Wisconsinan Till shown in figure 4 are the result of the erosion and downcutting of the post-Wisconsinan Sangamon River. The river cut the valley bottom to an elevation of approximately 540 feet, which was 50 feet deeper than the pre-dam valley. The extensive erosion and downcutting carved the valley to the level of the top of the till surface shown in figure 4. When the Wisconsinan glaciers retreated out of the watershed, the flow carried by the Sangamon River decreased; the river adjusted to the reduced flow by aggrading the valley floor. It deposited a large sand and gravel layer on top of the Wisconsinan till as shown in figure 4. Recent deposits of silt and clay were laid by the river on the floodplain between the valley walls, as indicated by the valley alluvium shown in figure 4.

At the end of the Wisconsinan period, approximately 10,000 years ago, the valley took on its present appearance. The valley averaged 1-1/2 miles wide between the bluffs, and the floodplain was divided by the meandering course of the river. As can be seen in figure 5, the valley walls are

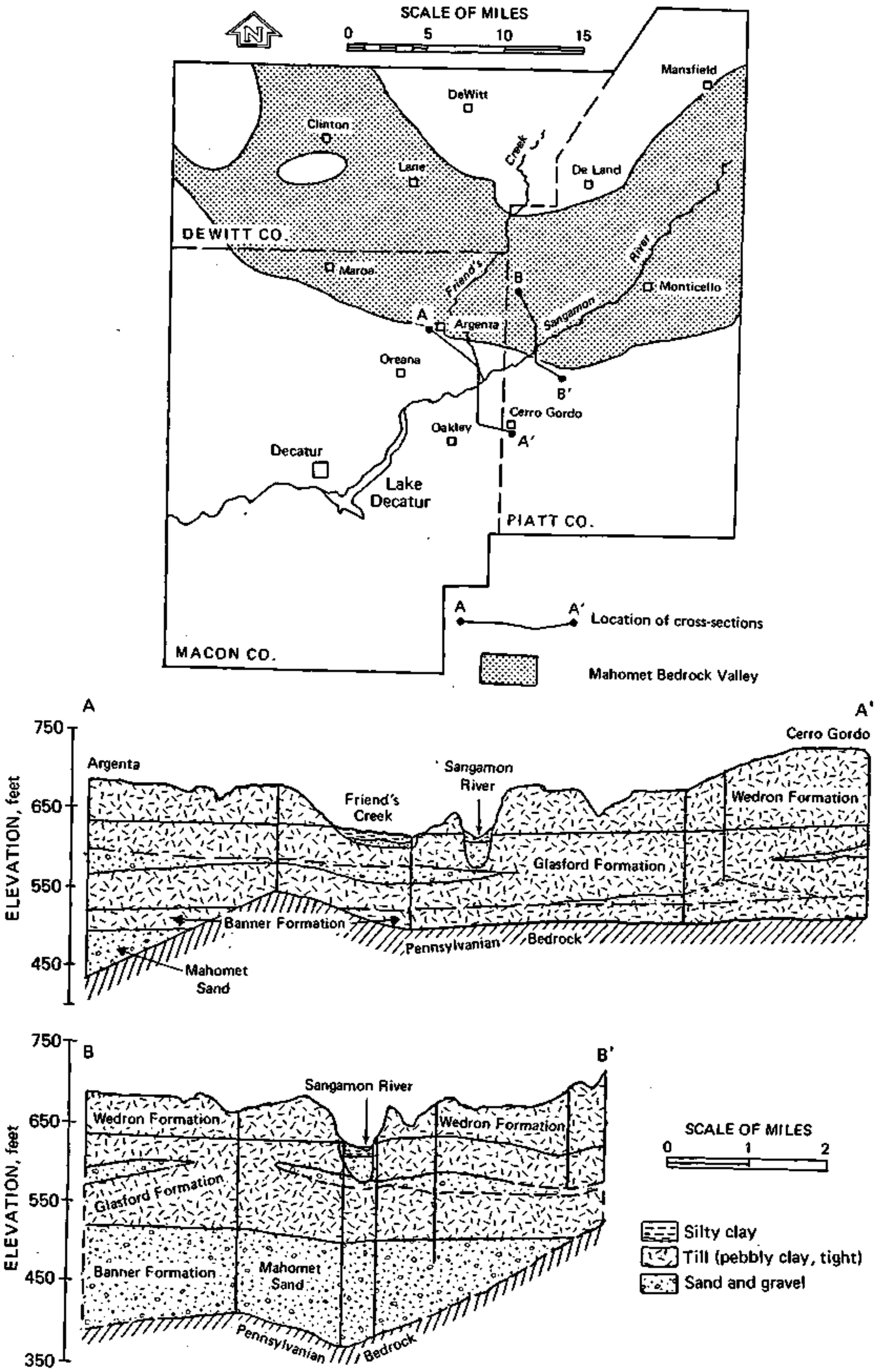


Figure 5. Geologic components of the Upper Sangamon River showing the Mahomet Valley Aquifer

composed of till of the Wedron and Glasford Formations (Bergstrom and Piskin, 1974. These tills are pebbly clay and were laid down by the Wisconsinan and Illinoian glaciers, respectively.

Pleistocene deposits above the bedrock range up to 300 feet thick and consist of till, sand, and gravel. Figure 5 shows the major Pleistocene formations: the Banner, Glasford, and Wedron, which resulted from the Kansan, Illinoian, and Wisconsinan glacial stages, respectively. These formations of pebbly clay till are interbedded with discontinuous layers of sand and gravel.

The major feature of the bedrock surface is an old valley which drained east-central Illinois prior to the glacial epochs. This valley is known as the Mahomet Valley and is located 200 - 300 feet below the current ground surface. The main valley lies in an east-west orientation, is approximately 8 miles wide, and passes under the central portion of the watershed, as shown in figure 5. The Mahomet Valley stretches across eastern Illinois from approximately Hoopeston in the east to Havana in the west. It was the course of a major river that had laid sand and gravel deposits across the floor of the old valley and is now buried beneath glacial till (Stephenson, 1966). The valley was filled and destroyed by glacial deposits starting with the Kansan glaciers approximately 1/2 million years ago. These sands and gravels are now an important source of groundwater for the communities that overlie the valley.

The regional topography was also shaped by the glacial activity of the Pleistocene ice ages and by the streams that developed on the glacially-deposited materials after the retreat of the ice sheets. Pleistocene and recent deposits consist of glacial till, wind-blown loess, and river deposits. Prominent large-scale features of the area are the roughly concentric moraines, shown in figure 6, which lie in a northwest to southeast orientation and include the Shelbyville, Cerro Gordo, Champaign, Leroy, Bloomington, and Normal Moraines.

The western boundary of the Lake Decatur/Upper Sangamon River watershed is the Shelbyville moraine, which lies in a north-south orientation through DeWitt, Macon, and Shelby Counties. This moraine separates the surficial glacial deposits of the older Illinoian deposits to the south and west and the younger Wisconsinan deposits to the north and east.

Glacial deposits are relatively thick and completely conceal the underlying bedrock topography. Fluvial processes are responsible for the higher reliefs of the watershed. Steep slopes are found along the major streams of the watershed such as the Sangamon, Friends Creek, and Big Creek. These slopes are in contrast to the generally flat areas which comprise the majority of the land surfaces.

The bedrock under the watershed is of Pennsylvanian age (310 - 280 million years old) through Macon, Piatt, and McLean Counties. Older strata lie beneath the glacial deposits in Champaign and Ford Counties in the eastern portion of the watershed. The bedrock of the western portion is the Pennsylvanian system which is characterized by thin layers of sandstone, limestone, shale, and coal of the Bond and Modesto formations (Willman et al., 1967). These rocks were deposited in shallow continental seas which repeatedly inundated the region, and in the coastal swamps which occupied the area between the periods of inundation.

The bedrock of the eastern portion of the watershed ranges in age from Silurian to Pennsylvanian (approximately 435 to 280 million years old). The LaSalle anticline trending in a north-south direction has uplifted rocks as

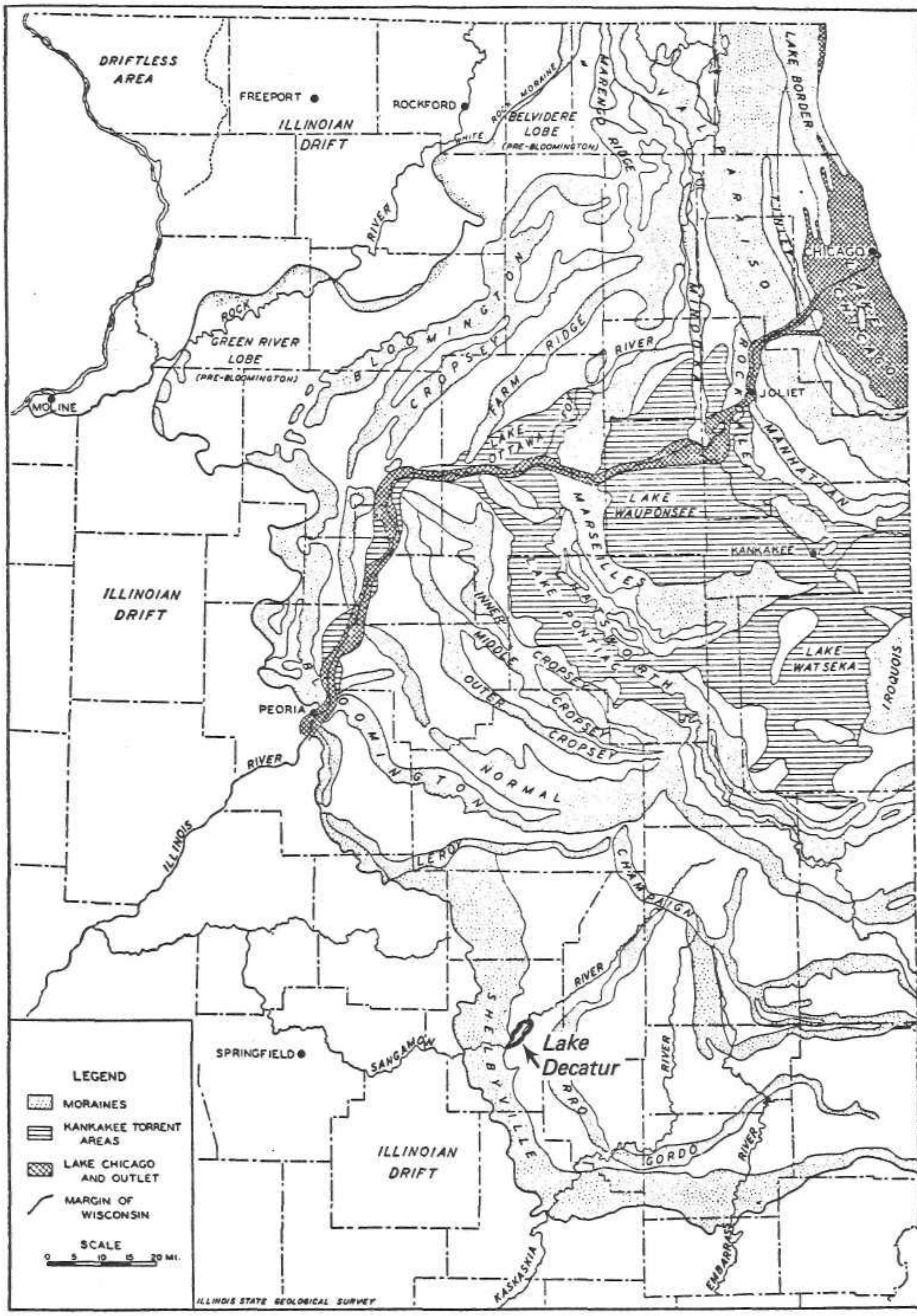


Figure 6. Surficial deposits of Northern Illinois

old as the Silurian in Champaign and Ford Counties. Under the thick blanket of Wisconsinan glacial till and moraines the dominant rock types are the Silurian dolomites and Devonian limestones in southern Ford and northwestern Champaign Counties. Younger formations that contribute to the bedrock surface in the two counties are the Mississippian limestones and shales of the Kinderhookian and Valmeyerian Formations, and the Pennsylvanian limestone, shale, and coal measures of the Spoon, Carbondale, and Modesto Formations (Willman et al., 1967).

Soils

The soils of the Upper Sangamon watershed have been divided into five soil type slope areas by the Soil Conservation Service (1983) to delineate the major soil environments. The areal distribution of the major soil types is shown in figure 7. These soil areas are described as follows:

Area 1 - This area, which is the largest of the areas, covers 59% of the watershed and contains the most productive soils of the watershed. This area groups together the nearly level prairie soils that formed in 40 to greater than 60 inches of loess and the loam of glacial till on the uplands. Major soils are the poorly drained Drummer and Sable silty clay loams and the somewhat poorly drained Flanagan and Ipava silt loams. These soils have a high organic content and a high resistance to drought. They are very fertile and are the highest producing soils of the watershed. For this reason area 1 is used mostly for row crops.

Area 2- This area encompasses 12$ of the watershed and consists of nearly level to sloping prairie soils that were formed in less than 20 inches of loess and the silty clay loam glacial till on the uplands. Soil groups of this area are the Vanna silt loam on the slopes up to 12% and the Elliott

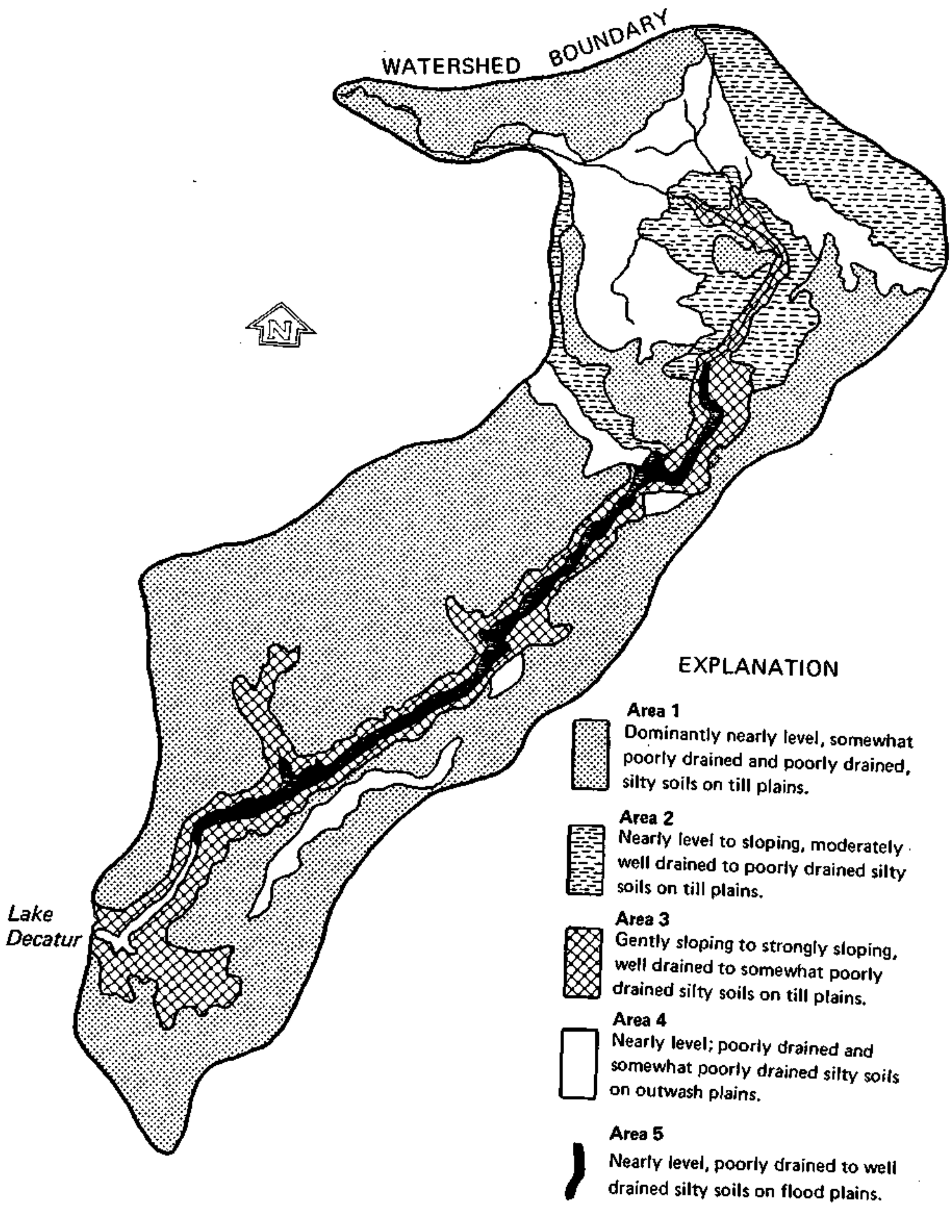


Figure 7. Major soil types of the Upper Sangamon River watershed

silt loam and Ashkura silty clay loam on the flat areas. Most of the area is devoted to cultivated crops although the productivity is not as high as in area 1.

Area 3- This area encompasses the forest soils formed on the uplands in loess and loam glacial till of less than 40 inches. Area 3 covers 13% of the watershed. Major soil types are the Birkbeck and Xenia silt loams on 2 to 5% slopes and the Russell and Miami silt loam on the 2 to 25% slopes. Most of this area is used for cultivated crops although these are the least productive soils of the watershed.

Area 4- Major soils of this area are the Brenton and Elburn silt loams and the Drummer silty clay loam. These soils formed in 24 to 60 inches of loess and underlying sand and gravel on stream terraces. Most of the area is level and is used for cultivated crops. Productivity is high and similar to that of area 1. Area 4 covers 13% of the total watershed.

Area 5- This area consists of level, dark colored soils on floodplains. Major soils are the Sawmill and Colo silty clay loam and the Lawson and Ross silt loam. These soils were formed in the alluvial deposits of floodplains and are very fertile and productive. Most of this area is used for pasture, hay, and woodlands, with smaller areas used for cultivated crops. This area covers less than 3% of the watershed.

Land Use

Row crops are the largest land use in the Upper Sangamon/Lake Decatur watershed, covering approximately 87% of the total area in 1982 (Soil Conservation Service, 1983). Historically the watershed has shown a trend towards increasing row crop acreage, as can be seen in figure 8 which shows the acreage devoted to corn and soybeans in the six major counties of the

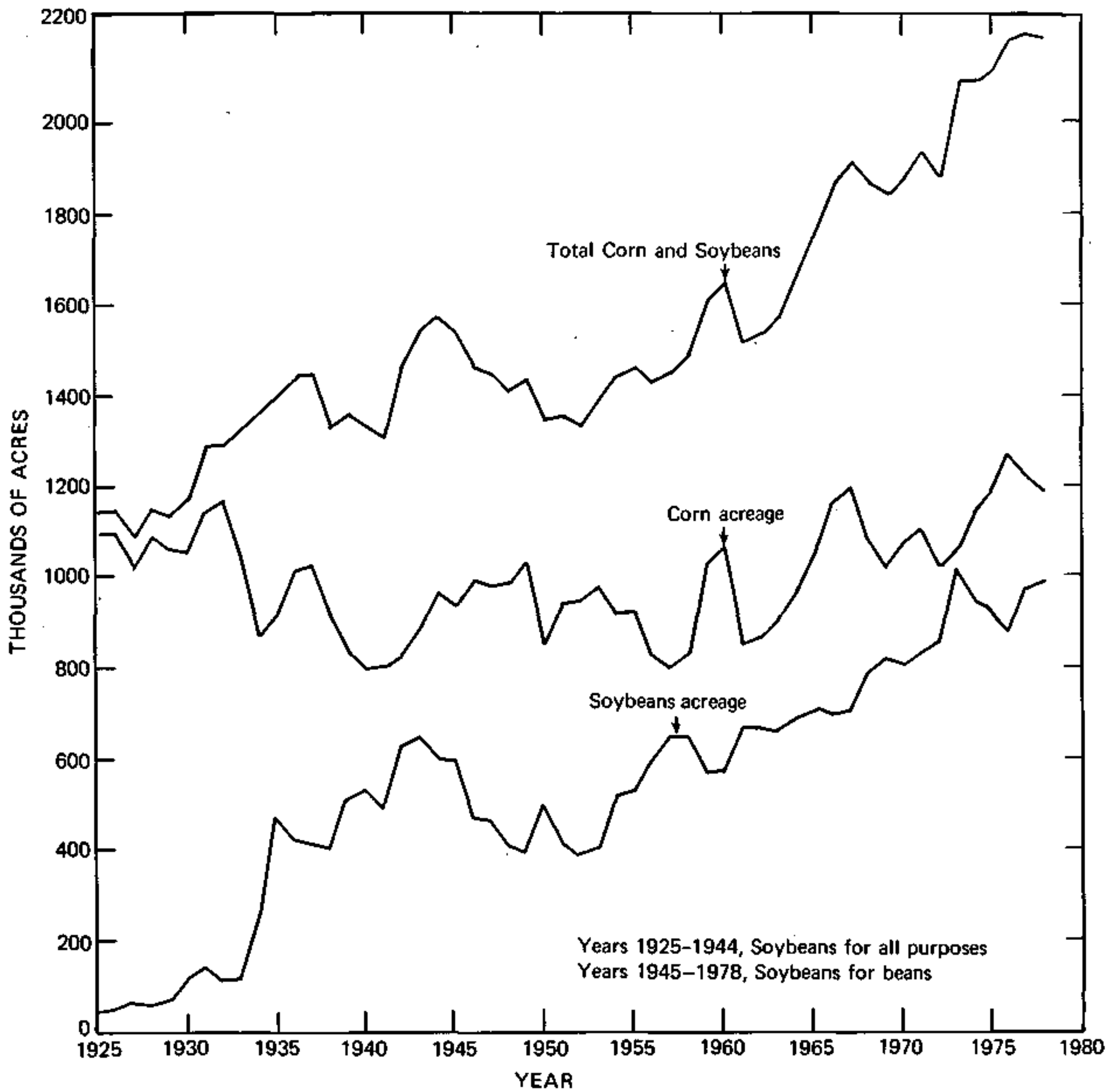


Figure 8. Row crop production (corn and soybeans) in the Upper Sangamon River watershed

watershed. Row crops covered over one million more acres in 1978 than they did in 1925, a total increase of over 91$ or an average annual increase of 1.7%. Major increases in total corn and soybean acreage occurred in the years 1927-1937, 1941-1944, 1952-1960, 1961-1967, and 1972-1978. Soybeans showed a relatively consistent trend overall towards increasing acreage with the exception of a 200,000-acre decline in the late 1940's and early 1950's. The early 1930's showed an abrupt increase in soybean acreage of 350,000 acres in the years 1933-1935. Corn plantings peaked in 1932 at 1,174,000 acres, a number not reached again until 1967. The largest rates of increase in the total acreage given to corn and soybeans occurred in the early 1940s, the mid-1960s, and the early 1970s. The rates of increase in total corn and soybean acreage for selected years are presented in table 1; it can be seen in table 1 that the largest rate of increase in corn and soybean acreage occurred in the years 1941-1944.

To assess the effects of land use trends on the sedimentation of Lake Decatur, the yearly total acreage in corn and soybeans was computed for each time period between the sedimentation surveys of the lake. The totals are presented in table 2; the lake sedimentation surveys will be described later.

Table 1. Major Increases in Corn and Soybean Acreage*

Years	Total increase	$ increase	Average % increase per year
1941-1944	269,500/ 3 years	20.6%	6.8%
1961-1967	397,500/ 6 years	26.1%	4.4%
1972-1978	311 ,600/ 6 years	16.5%	2.7%

* for the six counties: Champaign, Macon, DeWitt, McLean, Ford, and Piatt

Table 2. Six County Acreage in Corn and Soybeans Averaged per Year over Survey Period

Sedimentation Survey period	Years	Average Yearly Total Corn and Soybeans (acres/year)	Percent Increase over previous period
1	1925-1936	1,215,600	+5.7*
2	1937-1946	1,444,290	+18.8
3	1947-1956	1,413,360	-2.1
4	1957-1966	1,620,430	+14.7
5	-1967-1978	2,026,675	+25.1

* compared with 1925 total of 1,149,700 acres.

From table 2 it is seen that the largest increase in corn and soybean acreage occurred during lake survey period 5 (1967-1983) as represented by the acreage values for this period up to 1978, the last available data. Period 2 (1937-1946) showed the second largest percentage increase in total acreage for corn and soybeans. The only period with a decrease in the total acreage given to these crops was period 3 (1947-1956), which showed a slight, decrease of about 30,000 acres.

Historical events help to explain the overall changes in land use in the watershed. Period 1 (1925-1936) showed an increase of nearly 6% in corn and soybean acreage, which was expected considering that soybeans had recently been introduced to the area and provided an attractive new cash crop during the depression era. Period 2 (1937-1946) included the years of World War II and the resulting demands on farm operators to increase production of food, fiber, and oil crops. An examination of figure 8 shows an increase in both corn and soybean acreage between the years 1941-1944. Following 1944, acreage of both crops decreased, more dramatically for soybeans than for corn. Period 3 (1947-1956) shows a decrease in total acreage for the first six years and an increase in the last four years, primarily due to increased soybean plantings. Period 4 (1957-1966) and period 5 (1967-1978) both show an overall trend toward increased plantings in both crops. These years were not only periods of increasing row crop acreage but also periods of dramatic increases in yields for both crops. Average yields for corn and soybeans were 73 and 31 bushels per acre respectively in 1957. Yields in 1978 averaged 126 and 39 bushels per acre for corn and soybeans respectively (Illinois Cooperative Crop Reporting Service).

Gross Erosion Rates

The most significant source of sediment delivered to Lake Decatur is sheet and rill erosion. It has been estimated that 93% of the total erosion in the watershed is from this source (Soil Conservation Service, 1983). The areas of highest erosion are located along the outer boundaries of the watershed and along the streams where the steepest slopes are found. Croplands make up 88% of the land area and contribute 98% of the sheet and rill erosion (table 3). Critical areas, those having annual gross erosion greater than 10 tons/acre, make up only 6% of the watershed area but contribute 23% of the total sheet and rill erosion. In contrast, the areas devoted to pasture, woodland, and miscellaneous uses comprise 12? of the watershed area and contribute less than 2? of the total sheet and rill erosion. It has been estimated that 166,200 acres of cropland (28? of the total) are eroding at rates in excess of the soil tolerance level of 5 tons/acre/year (Soil Conservation Service, 1983). Channel and gully erosion have been estimated at 185,000 tons of sediment per year. Total gross erosion including channel, gully, sheet, and rill erosion from this watershed amounts to 2,646,000 tons per year.

Table 3. Sheet and Rill Erosion Sources by Land Use for the Upper Sangamon River Watershed (Soil Conservation Service, 1983)

	Total acres	Total tons	% of tonnage	Average tons/acre	% of total acreage
Cropland 0-5 tons/acre/yr	349,600	966,100	39	2.76	60
Cropland 5-10 tons/acre/yr	128,900	879,300	36	6.82	22
Cropland 10+ tons/acre/yr	37,300	576,300	23	15.45	6
Pasture	23,100	16,300	0.6.	0.71	4
Woodland	20,800	15,800	0.6	0.76	3
Miscellaneous	27,800	6,800	0.3	0.25	5
TOTAL		2,460,600			

Table 4 shows the estimated gross erosion and percentage of sediment yield to Lake Decatur by regional source area for 1983 as compiled by the Soil Conservation Service (1983). From this table it is seen that the source area with the highest sediment yield to the lake represents only 25% of the total watershed yet contribut es over 40% of the in-lake sediment. This area is the last 20 miles of the Sangamon River and its tributaries, below Monticello and above the lake. The USDA estimates that currently 28% of the in-lake sediment is contributed by the direct tributaries of the lake, i.e., Big Creek, Sand Creek, and the bluff watersheds. These combined sources represent 15% of the total watershed area.

Conservation Efforts

It is impossible to document all the conservation efforts of the past or present, since the individual efforts of landowners and operators have not usually been recorded over the years. However, this section outlines some of the large-scale efforts undertaken towards soil conservation.

Soil and water conservation districts were first organized in the 1930s. One of the first efforts was the Erosion Control Demonstration Project in McLean County, established in 1933 by the Soil Conservation Service in cooperation with the University of Illinois. This project was successful in demonstrating effective methods of soil conservation and became a forerunner of future conservation districts. The information presented here on the conservation districts of the 1930s and 1940s is summarized from Brown et al. (1947).

In the early 1940s conservation districts were established in all the counties of the watershed. By 1946, 87% of the watershed was included in organized districts. These districts were formed to provide technical,

Table 4. Erosion Source and Sediment Yield to Lake Decatur by Watersheds

Source	Area in acres	% total area	Gross erosion (tons)	Average gross erosion (tons/acre/yr)	Estimated % of total yield to Lake Decatur
Total watershed	593,400	100.0	2,645,840	4.5	100.0
Sangamon River above Monticello	352,000	59.3	1,540,740	4.4	29.4
Sangamon River below Monticello	241,514	40.7	1,105,100	4.6	70.6
Main stem*	149,244	25.2	690,250	4.6	42.5
Bluff watersheds	37,960	6.4	155,510	4.1	9.3
Big and Sand Creeks	54,400	9.2	259,250	4.8	18.8

*Main stem of Sangamon River between Monticello and 15.5 miles above city dam, including Friends Creek educational and financial assistance to local landowners for the purpose of maintaining the productivity of the soil and reducing the denudation of farmland. Assistance to the districts in the watershed was provided by a variety of sources including the City of Decatur, the University of Illinois, the USDA, and others. Initially, progress was slow. In 1946 307 farms had formulated complete conservation plans with about one-half of the plans implemented. The new practices covered approximately 2% of the watershed and included activities such as contour plowing, terracing, waterways, and diversions.

The Soil Conservation Service (1983) reported that in 1982 conservation practices were needed on 47% of the watershed in order to reduce all gross erosion values to below 5 tons per acre per year. This acreage included 19% of the watershed area on which gross erosion values were already below the 5 tons per acre standard but were interspersed with acreage that did not meet the standards. This indicates that a great deal of work remains to be done in soil conservation activities.

If all the proposed conservation practices were implemented, the USDA estimates that the gross erosion in the watershed would be reduced by 35% (Soil Conservation Service, 1983). Fields planted in continuous corn and managed with conservation tillage showed soil losses 58? less than fields with conventional tillage in Missouri claypan soil (Burwell and Kramer, 1983).

General statistics on conservation tillage compiled from No-Till Farmer magazine's annual acreage survey show that in the years 1973 through 1981 there was a 133% increase in acreage planted with minimum tillage, a 6% increase for no-till, and an 11% decrease in conventional tillage for the "corn belt" states of Illinois, Indiana, Iowa, Missouri, and Ohio

(Christensen and Magleby, 1983). In 1981 conservation tillage methods were used on 1/3 of the harvested cropland in the "corn belt" (Moldenhauer et al., 1983). These statistics indicate that farm operations are accepting and applying new technologies and methods for the reduction of soil erosion.

Flow Analysis

The U.S. Geological Survey has collected discharge records for the Sangamon River at Monti cello since 1915. These records have been used in the analysis of flow in the Sangamon River.

The 550-square-mile drainage area of the Monticello station represents only 59% of the drainage area upstream of the Lake Decatur dam. The values determined for discharges at Monticello will provide only a qualitative evaluation of discharges at the Decatur dam.

Discharge records are generally developed on a water year basis. Water years are defined as the period from October 1 to September 30 and are listed according to the calendar year in which they end (i.e., the period October 1, 1952, to September 30, 1953, would be considered Water Year 1953). The exception to this is low flow analysis, which is based on the climatic year April 1 to March 31 with a listing according to the calendar year in which it starts (April 1, 1953, to March 31, 1954, is climatic year 1953).

Average Discharges. Average annual discharge is defined as the discharge past a point in one year in cubic feet per second. Figure 9 is a graph of the annual discharges of the Sangamon River at Monticello since 1922 (the date of construction of the dam). These annual discharges varied considerably over this period (from 1105 cfs in 1927 to 68 cfs in 1934) and have averaged 405.9 cfs since 1915. A discharge of 405.9 cfs is the

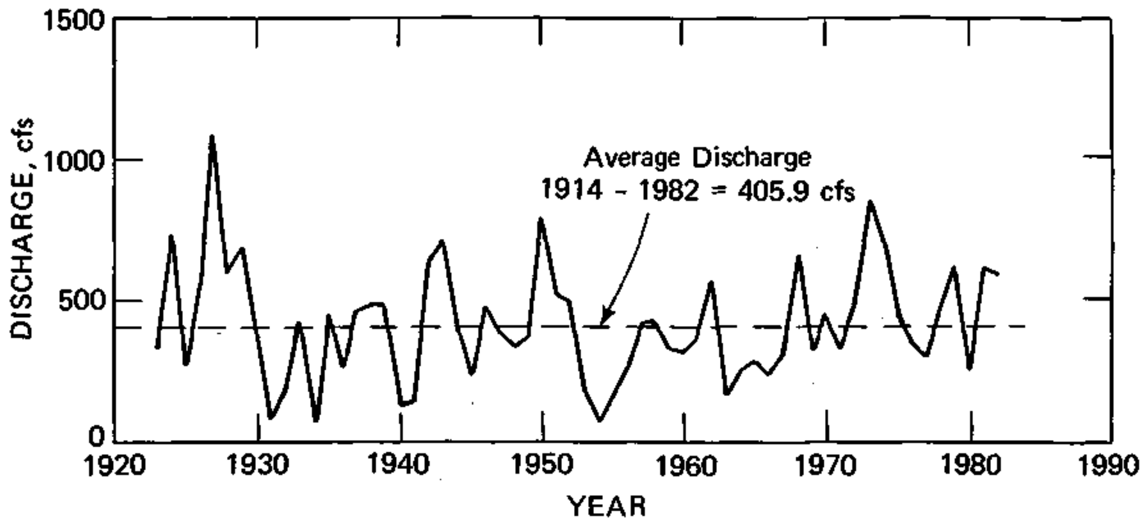


Figure 9. Average annual discharge of the Sangamon River at Monticello

equivalent of 9.98 inches of water per unit watershed area. This is equivalent to 26% of the long-term average precipitation of 39.12 inches measured at Decatur.

This average annual discharge can be extended to the whole watershed of Lake Decatur by applying 9.98 inches of runoff to the 925-square-mile watershed of Lake Decatur. This yields an average inflow to the lake of 680 cfs (492,000 acre-feet per year) or 160 billion gallons per year.

High and Low Flows. High and low daily flows are defined as the highest and lowest daily flows occurring during a one-year period. High and low flows for the Sangamon River at Monticello are given in figure 10 for the period 1922-1982. The highest flow for the period of record was 18,700 cfs in 1927 (1926 calendar year). The lowest flow for the period of record was

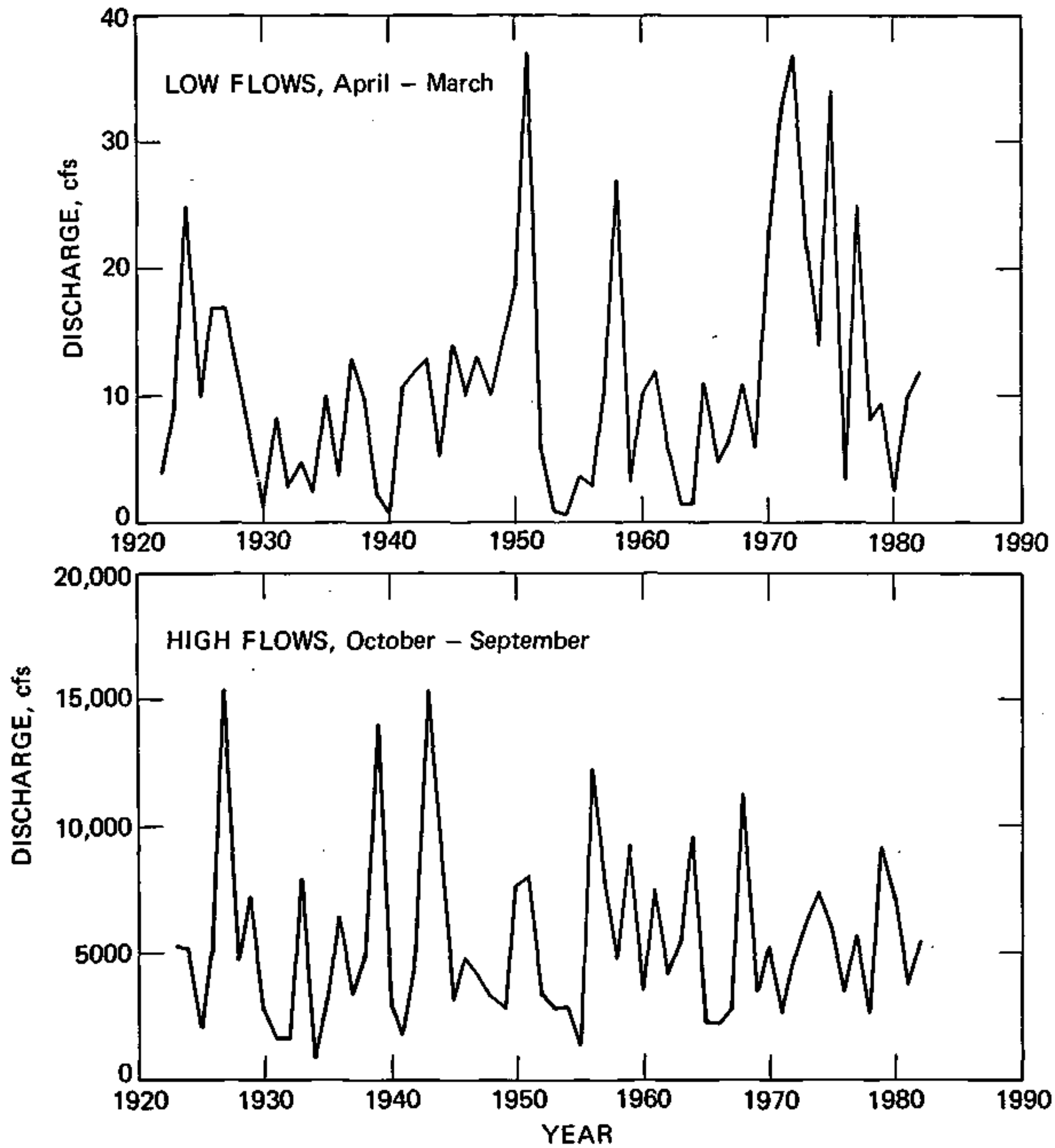


Figure 10. High and low flows for the Sangamon River at Monticello

0.2 cfs in 1954. These high and low flows at Monticello cannot be readily translated into high and low flows at Decatur. However, they provide a qualitative basis for analyzing trends in discharge at Decatur.

As an example, the high discharges in figure 10 indicate much higher peak discharges with more annual fluctuation during the period 1922-1945 than during the period 1960-1982. These high discharges may have had considerable impact on sediment inflow to the lake since high flows are capable of carrying much larger quantities of sediment than lower discharges. Thus the extreme high discharges indicated by the spikes in the high flow chart might indicate periods of extremely high sediment input to the lake as well.

Likewise, the low flows in figure 10 indicate a period of relatively high low flows during the 1970s. The low flows will not influence sediment inflow rates as much as the high flows. However, very low flows indicate periods when the lake level may have been drawn down and sediment deposits exposed to drying and compaction as in the early 1930s and the early 1950s.

Flow Duration. Flow duration analysis classifies the daily flows during the period of record and ranks them according to the portion of the record during which that discharge was exceeded. The flow duration curve for the Sangamon River at Monticello is given in figure 11. This graph can be used to make a rough estimate of the number of days each year that the City of Decatur actually uses the storage of Lake Decatur.

Lake Decatur serves to protect the city's water supply during periods of low flow in the Sangamon River. Thus when the city is using more water than is flowing into Lake Decatur, the lake is actually being used. Average daily water withdrawals from the lake are approximately 18 million gallons or 27.9 cfs. When this number is adjusted for the Monticello gaging station, it

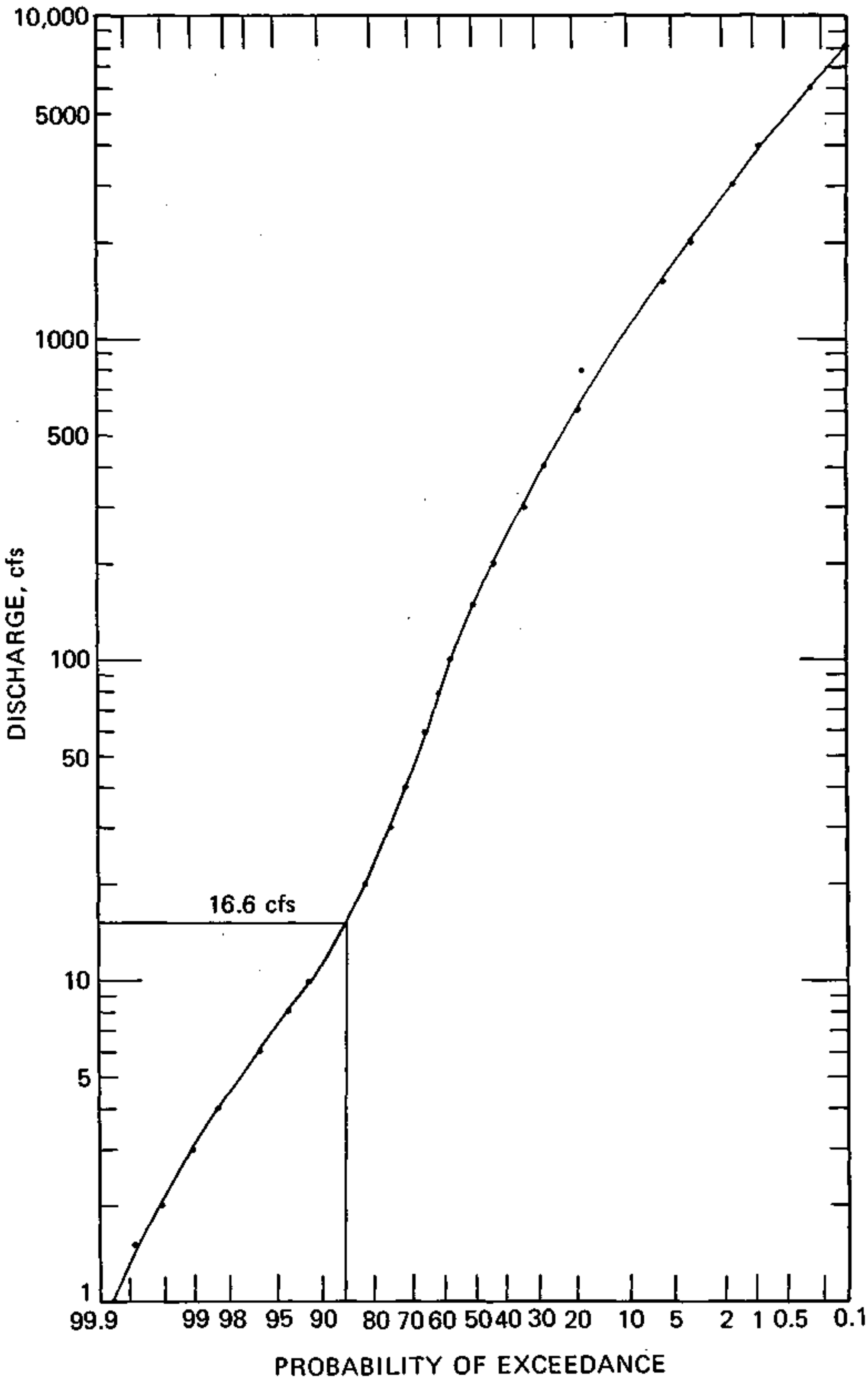


Figure 11. Flow duration curve for the Sangamon River at Monticello

becomes 16.6 cfs. On the basis of the flow duration curve, the lake storage is necessary to meet daily withdrawal demands 14% of the time or 51 days per year. This analysis does not include summer increases in water usage or the effects of evaporation which will also be greater during the summer.

Flood Frequency. The frequency of flooding does not have a direct impact on the water supply potential of the city. It can, however, be a significant factor in sedimentation of a reservoir because of the large amounts of sediment carried by the river during flood discharges.

A flood frequency analysis was performed for the Sangamon River at Monticello using methods prescribed by the U.S. Water Resources Council (USWRC, 1976). The results of this analysis, presented in figure 12, indicate that the 100-year recurrence interval discharge is 20,200 cfs. The maximum recorded discharge for the Sangamon River at Monticello was 18,700 cfs on October 4, 1926. This value corresponds to a recurrence interval of 65 years.

PRE-1983 SURVEYS, METHODS, AND RESULTS

The study of reservoir sedimentation is an examination of the changes over time in the accumulation of sediment and aggradation of the lake bed. An important factor in this study is a comparison of past survey results with results of the present survey to assess the quantitative change in the sedimentation rates of the lake. A total of six lake sedimentation surveys including the present one are described.

1930 Reconnaissance Survey

The City of Decatur recognized in the late 1920s that their new lake was being reduced in size due to sedimentation. A preliminary study of the rate of sedimentation and bank erosion was carried out in 1930, under the

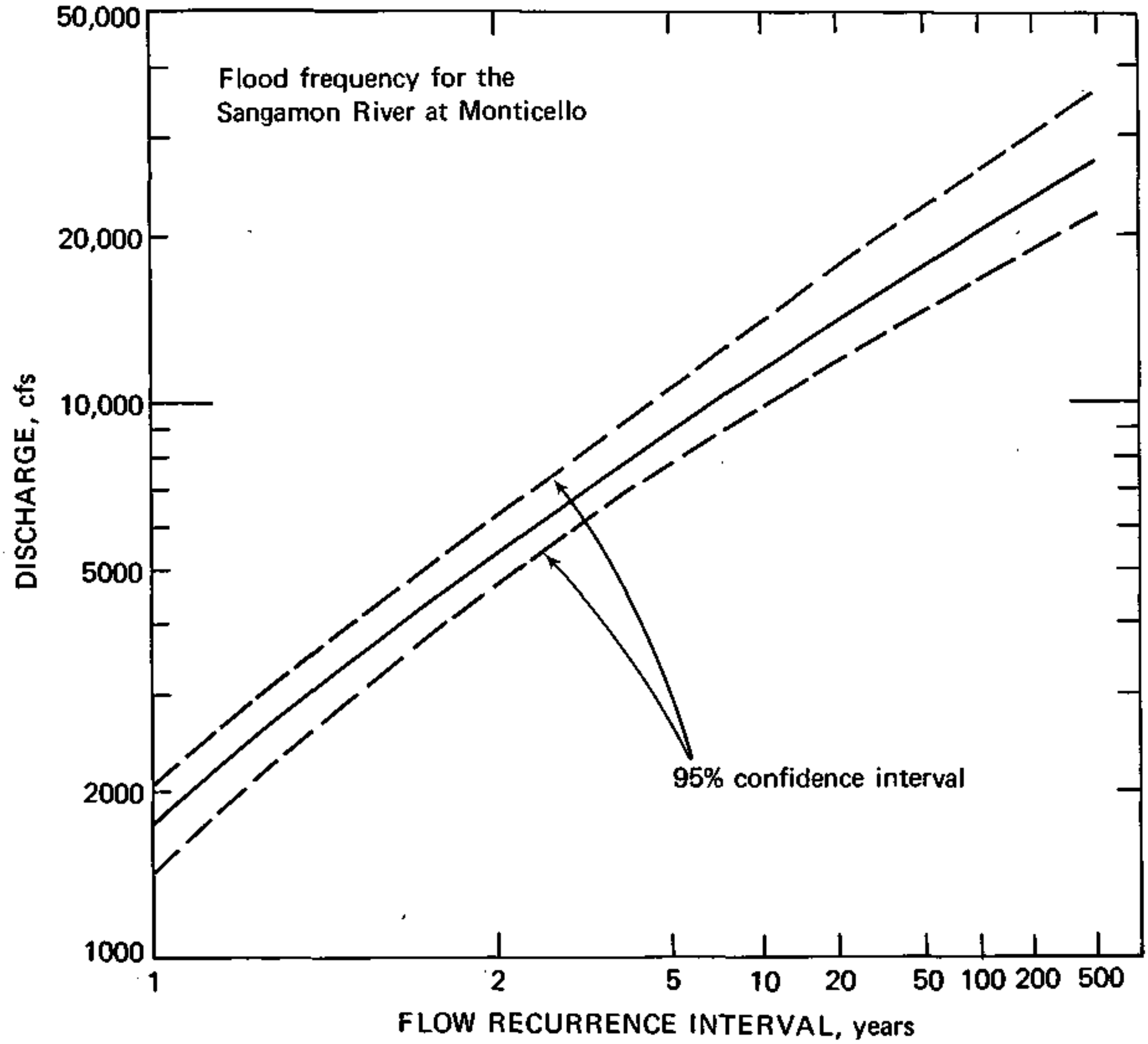


Figure 12. Flood recurrence interval for the Sangamon River at Monticello

direction of F. L. Washburn, Engineer for Macon County. The results showed sedimentation averaging 1-2 feet in Sand Creek and the upper reaches of the main lake above Rea's Bridge. Several small bays and inlets had been filled with sediment, and bank erosion had removed up to 35 feet of shoreline in some areas.

1931-1932 Survey

The findings of the 1930 survey led the Illinois State Water Survey in cooperation with the Decatur Water Supply Company to begin a more thorough study of sedimentation in the lake in 1931-1932. The purpose of this new study was to determine the 1931-1932 elevations of the lake bed and then to resurvey in a few years to determine the rate of sedimentation based on the changes in elevation and volume over the time interval. Prior to 1931 no topographic map or cross sections of sufficient precision were available to allow the direct determination of the sedimentation rates in the flooded valley. The largest scale map made of the river valley prior to lake construction was the 1918 "Topographical Map of the Valley of the Sangamon River from Illinois Traction System Bridge to Illinois Central Railroad Bridge for the City of Decatur, Illinois" by P. T. Hicks, Consulting Engineer, shown in figure 2. The contour interval of 5 feet and the scale of 1 inch to 600 feet were not of sufficient precision to allow direct calculation of sedimentation rates. As a result, during the 1931-1932 survey, benchmark ranges were established that could be used in the future for comparison of the changes in lake bed elevations.

In the 1931-1932 survey, 55 ranges were established across the lake for the measurement of sediment accumulations and water depths. The range ends on shore were marked with concrete monuments or iron pipes for the purpose of accurate relocation for future surveys. One emphasis of the 1931~1932 survey was to assess the effects of the bridge crossings on the hydraulics of flow and the sedimentation pattern within the lake. Twenty ranges were established within a distance of 1/2 mile around the railroad bridges south of Faries Park. Fifteen ranges were located within a distance of 1/3 mile near Rea's Bridge. Other areas of emphasis were the Staley and Sand Creek Bridges. In areas away from the bridge crossings the ranges were spaced at intervals of 3/4 to 1-1/4 miles.

In the 1931-1932 survey, the sounding boat was positioned along the range line using a cable. A steel cable was fastened on shore at both ends of the range line, and the horizontal distance across the lake was measured using floats attached to the cable at 5-foot intervals. Soundings were made using a 1-pound sounding lead 5 inches in diameter, which was suspended on a wire.

Sediment measurement procedures for the 1931-1932 survey were described as follows by Glymph and Jones (1937):

> Silt depths were determined with a special silt sampler, consisting of a 3-foot length of thin iron tubing, 4 inches in diameter, and closed at the upper end. This was lowered to the lake bottom by attaching successive sections of threaded iron pipe. Samples were obtained by forcing the tube solidly into the bottom sediment. If the silt was penetrated and the subsilt material was sufficiently coherent to seal the bottom of the tube, a complete section or core of the sediment was

obtained. A number of slots one-half inch wide and five inches long in the walls of the tube permitted inspection of the sample at any level.

In the 1931-1932 survey, silt measurements were made only in the upper part of the lake above the William Street Bridge and near the mouths of Sand and Big Creeks. Silt measurements were not made in the old river channel because the sediment depth exceeded the length of the sampler.

The results of the 1931-1932 survey showed no unusual delta deposits on the upper end of the lake; however, both Sand and Big Creeks had small deltas. The absence of a delta on the Sangamon was attributed to the fine silts and clay carried by that river which are held in suspension by the incoming water well into the lake. The maximum sediment deposits of 4 feet were found in the old river channel above Rea's Bridge. Deposits in the lake averaged approximately 1-2 feet on the old floodplain above Rea's Bridge. Below Rea's Bridge, the deposits were difficult to measure due to the depth limitations of the core sampler. Since the sampler operated in water depths of less than 12 feet, no estimate of the sediment depth below Rea's Bridge was made (Gerber, 1932).

The results of the 1931-1932 survey were not published; however, the findings of the investigators did help to outline the need for a more intensive assessment of the problem.

1936 Survey

A resurvey of the lake was performed in 1936. The emphasis of this survey was to map the total sediment in the lake by determining the original valley depth and the 1936 lake bed depth across each range line.

The 1936 survey was performed under a cooperative agreement between the Water Survey and the Illinois Agricultural Experiment Station under the direction of Louis M. Glymph, Jr., and Victor H. Jones.

A spud bar was used to measure the depth of the deposited sediment below the current lake bed. The spud bar is a steel rod with triangular grooves machined at 0.1-foot intervals, forming a series of cups opening upward along the length of the bar. The cups open to the top of the bar, allowing the bar to easily penetrate the sediment. The bar is dropped vertically through the water and into the sediment and old soil of the valley. Each cup on the spud bar retains a sample of the sediment at the point of maximum penetration, i.e., the cups grab a sample when the direction of travel of the bar is reversed and the sampler is pulled out of the lake bed.

When the spud bar is retrieved from the lake bed, the sample cups are examined for texture differences which indicate the old soil of the valley. Root zones, coarser particles, and color differences identify the old valley bottom. The depth and elevation of the old soil is determined by measuring the distance along the spud bar between the top of the current lake bed and the first sample of the old soil. The depth measured by the spud bar is subtracted from the lake bed elevation to determine the elevation of the old valley.

The 1936 survey established 14 special shore-line ranges to study the importance of bank erosion in reservoir sedimentation. In addition, 13 end sections of regular ranges were measured in detail to establish the shore profile. This survey also used the range-line method. Forty-nine ranges were used, of which 24 had been established previously for the survey of 1931-1932 (Glymph and Jones, 1937).

In 1936 the sounding boat was positioned in the lake using a cut-in method of range-line intersection employing a plane table and alidade. Where it was impractical to establish plane table stations for positioning the boat, the cable method was used. Soundings were made using a 5-pound aluminum bell-shaped sounding weight with a base diameter of 5 inches and a height of approximately 6 inches. This sounding bell was developed by the Soil Conservation Service and was calibrated with the sounding weight used in the 1931-1932 survey.

Sounding stations along the range lines were generally 50 feet apart. At every third station, sediment depth was measured using the spud bar or core sampler. The core sampler used in 1931-1932 was used for this survey in areas. where the water depth was less than 12 feet and the sediment thickness was less than 3 feet. In areas of deep water and/or thick sediment a spud bar was used to sample the lake bed and determine the original valley elevation.

Cross sections of the lake were plotted showing the original valley elevations, the 1931-1932 lake bed, and the 1936 lake bed. The plotted cross sections were planimetered to determine the cross-sectional areas of the water and sediment for each survey. The cross-sectional areas were combined with planimetered segment surface areas and entered into the prismoidal formula (as will be described in the analysis of the 1983 survey) to yield segment volumes of the lake for the original, 1931-1932, and 1936 conditions. No estimate of the weight of sediment was made in 1936.

The preliminary results of the 1936 survey were published by the USDA, Soil Conservation Service (Glymph and Jones, 1937). The authors determined a rate of volume loss in the reservoir of 1.0% per year. The sediment tended to accumulate in the deeper and quieter portions of the lake, especially in the old river channel through the main lake. The upstream portion of the lake showed no typical delta deposits and the river channel was free of accumulated sediment. The authors attributed this to the uniformly fine sediment washed into the lake by the Sangamon River. Smaller side channels and backwater areas on the upstream end of the lake were noted to have accumulated as much as 4 feet of sediment.

Bank erosion was recognized to be a contributing factor in reservoir sedimentation, but estimates of the amount of sediment from bank erosion were not made.

1946 Survey

In 1946, 39 of the 49 sedimentation ranges established during the 1936 survey were resurveyed by the Water Survey. The ranges omitted in 1946 were the extreme upstream ranges on the Sangamon River, the Big Creek tributary, and the Sand Creek tributary. An examination of these ranges in 1946 indicated that no sediment deposition had occurred due to the scouring action of the inflowing streams. In these upper reaches, the lake is confined to the old stream channel with no overbank floodplain flow.

The 1946 survey used the same survey methods as the 1936 survey. The sounding boat was positioned in the cross section using a cut-in method of positioning by employing a plane table - alidade system. Depth measurements were made using a cast aluminum sounding weight.

Lake sedimentation rates are determined by comparing the original lake bed elevations with the present sediment surface. During the 1946 survey, selected points were measured for comparison with the original elevations as measured in 1936. It was found that these measurements were generally within 0.1 to 0.2 feet of the 1936 elevations.

The 1946 lake and sediment volumes were calculated using methods developed by the Soil Conservation Service (Eakin,1936). The lake bed elevations were plotted for the years 1922, 1936, and 1946, and these plots were used to determine cross-sectional areas of water and sediment for each year. The volume of each segment of the lake was calculated using the prismoidal formula.

The unit weight analysis of the deposited sediment for the 1916 survey as well as that for the 1936 survey were of limited use. In both surveys, lake sediment samples were collected using the spud sampler and the pipe sampler from the 1936 survey. Samples were collected by combining material contained in the spud cups or by scooping material from the pipe sampler. These samples were placed in jars of known volume and heated to remove all moisture. The weight of the sample was then divided by the jar volume to determine a volume weight or unit weight. These samples were easily biased by the degree of packing used when the sediment material was placed in the sampling jar. Unit weight of deposited sediment is best determined by using undisturbed sediment samples.

The results of the 1946 survey were published by ISWS (Brown et al., 1947). This report documented a 25% loss in volume of the lake from 1922 to 1946. The average annual capacity loss from 1936 to 1946 was 1.2% compared to the 1.0% rate determined for the period 1922-1936. This was a 20% increase in the sedimentation rate. The authors found a tentative correlation between the increases in row crop production in the watershed and the increase in the rate of sedimentation in Lake Decatur.

The lake sediment samples collected in 1936 and 1946 were analyzed during the 1946 study to determine particle size distribution, organic carbon, total nitrogen content, and apparent unit weights. These samples showed similar particle size characteristics, organic carbon, and total nitrogen content to the typical prairie soils and it was concluded that the source of the lake sediment was sheet erosion from the upland prairie soils.

The authors estimated the trap efficiency of the reservoir to be 78% based on turbidity records, flow records at Monticello, and the weight of the deposited sediment in the years 1936 to 1946.

Bank erosion along the shore of the lake was estimated to be 35.5 acre-feet or 1.5% of the total deposited sediment within the lake.

The total weight of sediment was estimated to be 2,650,000 tons for the period 1936 to 1946 with an average unit weight of 51.5 pounds per cubic foot. This value was recognized to represent only a very gross estimate of the total sediment weight due to the limitations of the sediment sampling methods.

1956 Survey

The 1956 survey was conducted by the Water Survey at the same time that the new bascule spillway gates, which allowed the pool elevation to vary from 610 to 615 msl, were being positioned on the spillway. During this survey, seven new cross sections were established upstream from the previously established cross sections to provide full coverage of the lake area at the new spillway elevation. The sedimentation survey was conducted using a sounding pole for depth measurements and a plane table - alidade method for horizontal locations.

During the 1956 survey, no measurements of the original bed elevations were taken. The 1956 measured bottom elevations were compared to the elevations of the original bed surveyed in 1936. The lake capacity was determined using the Soil Conservation Service methods (Soil Conservation Service, 1939). The original (1922) volume of the lake as determined in the 1936 survey was used for comparative purposes.

The 1956 survey was the first survey of the lake in which undisturbed samples of the accumulated sediment were collected. A 3- and 9-foot long, 2.875-inch diameter barrel sampler was used. A total of 93 samples were taken varying in length from 4 to 4.2 inches. Depth of sampling was as much as 7 feet.

Results of the 1956 survey were published in a Letter Report by ISWS (1957). This report noted a considerable reduction in the volumetric sedimentation rate from the two earlier periods, which was attributed primarily to the drought of the early 1950s. The impact of the drought was two-fold. Initially, the lake bed was exposed to prolonged dry periods which compacted the deposited sediment due to dehydration. Second, during the drought, the inflow to the lake was very low which contributed toward a substantial reduction in sediment brought to the lake. The authors hypothesized that the reduction of the sedimentation rate was also due to increased erosion control measures in the watershed.

Total sediment deposition during the period 1946 to 1956 was estimated to be 771 acre-feet. This was about 77 acre-feet per year for ten years. Sedimentation rates of 198 acre-feet per year and 236 acre-feet per year were observed for the 1922-1936 and 1936-1946 periods, respectively.

1966 Survey

The 1966 sedimentation survey was conducted by the Water Survey using a sounding pole for water depth measurement and a plane table and alidade for horizontal control. No measurements of sediment thickness were made.

Water and sediment volumes were recalculated for all previous surveys, but no adjustments in the results were made. The 1966 water volume of the lake was determined for both the 610 msl spillway elevation and the 613 msl normal pool elevation maintained by the moveable spillway gates.

The sediment unit weight analysis for the 1966 survey report (Stall and Gibb, 1966) was the most thorough up to that time. Although no analysis of these unit weights was published, a thorough review of all survey results was made based on unit weight sampling for the 1956 and 1966 surveys. The results of these analyses indicated that the average unit weights for each survey year were as follows:

1936	40.5 pounds per cubic foot
1946	40.5 pounds per cubic foot
1956	44.9 pounds per cubic foot
1966	46.9 pounds per cubic foot

These results were based on estimates for the 1936 and 1946 surveys, and on sediment sampling for the 1956 and 1966 surveys.

The results of the 1966 survey showed that sedimentation during the period 1956 to 1966 was 1031 acre-feet for an average annual rate of 103 acre-feet per year. This rate was above the drought-affected rate determined for the period 1946 to 1956 but was still considerably lower than the rates of the 1922-1936 and 1936-1946 periods.

1983 RESERVOIR SEDIMENTATION SURVEY

The 1983 hydrographic survey of Lake Decatur began in the spring of 1983. Past reports on the lake, old survey field books, maps, newspaper clippings, and other related material were obtained from the Water Survey files and the University of Illinois library during this survey. These sources as well as field reconnaissances of the lake and watershed were used to develop the methodology used in the 1983 survey.

Surveying and Sampling Techniques

The equipment used for the 1983 survey field data collection was selected on the basis of the precision and accuracy needs of this type of hydrographic survey. Preference was given to equipment of simple and reliable design.

The workboats were chosen for their shallow draft and stability. A 14-foot tri-hull ABS plastic boat was used for sounding and sampling. This boat was mated with a 10- or 20-horsepower outboard motor depending on the water depth in the work area and distance from the launch site. A 12-foot flat bottom jon-boat, coupled with a 10-horsepower motor, was used for the very shallow upper reaches of the lake.

The basic data collection equipment used in this survey was as follows:

1) 2-inch diameter aluminum sounding pole in 8-foot sections with marked 0.1-foot graduations
2) Sediment shoe for the sounding pole
3) Hewlett-Packard model electronic distance measuring device (EDM)
4) Polypropylene cable of 1/4-inch diameter
5) Cable meter to measure distance along the cable
6) Automatic level and theodite
7) Stadia rod and range poles
8) 2-inch-diameter by 3~foot-long core sampler
9) Eckman "clam-shell" type dredge
10) Measuring and examination board for sediment cores

11) Two-way Citizen Band radios

12) Electric trolling motor and marine battery

13) Sample storage jars and plastic bags

14) Miscellaneous items: field books, pencils, camera, spatula, ice hole cutter, concrete survey monuments, post hole diggers, machetes, survey ribbon, etc.

Some of the above equipment will be described in more detail in the next section.

The hydrographic survey of the lake was accomplished using 37 range sections which were sounded using a 2-inch aluminum pole with an 8-inch sediment shoe. These ranges were among the 49 used during the 1936 survey, which were sounded in 1936 and 1946. Due to the fairly uniform distribution of sediment within a given area the number of ranges was reduced to 37 for the 1956, 1966, and 1983 surveys. The 1936 survey plan segment locations and range lines are shown in figure 13. Cross sections which were not surveyed in 1983 are marked but not identified by number.

Depth measurements were made over the side of the workboat by lowering the sounding pole with a sediment shoe at its end. The sediment shoe is constructed so that it "floats" on the water/sediment interface and is free to slide up and down the sounding pole as the pole is pushed into the top of the lake bed. When the pole is raised up from the bottom, limiting guides at its base catch the sediment shoe, resulting in a distinct clicking sound. When this sound is heard, the depth of the pole in the water is measured by means of marked graduations in tenths of a foot along the pole. Depth

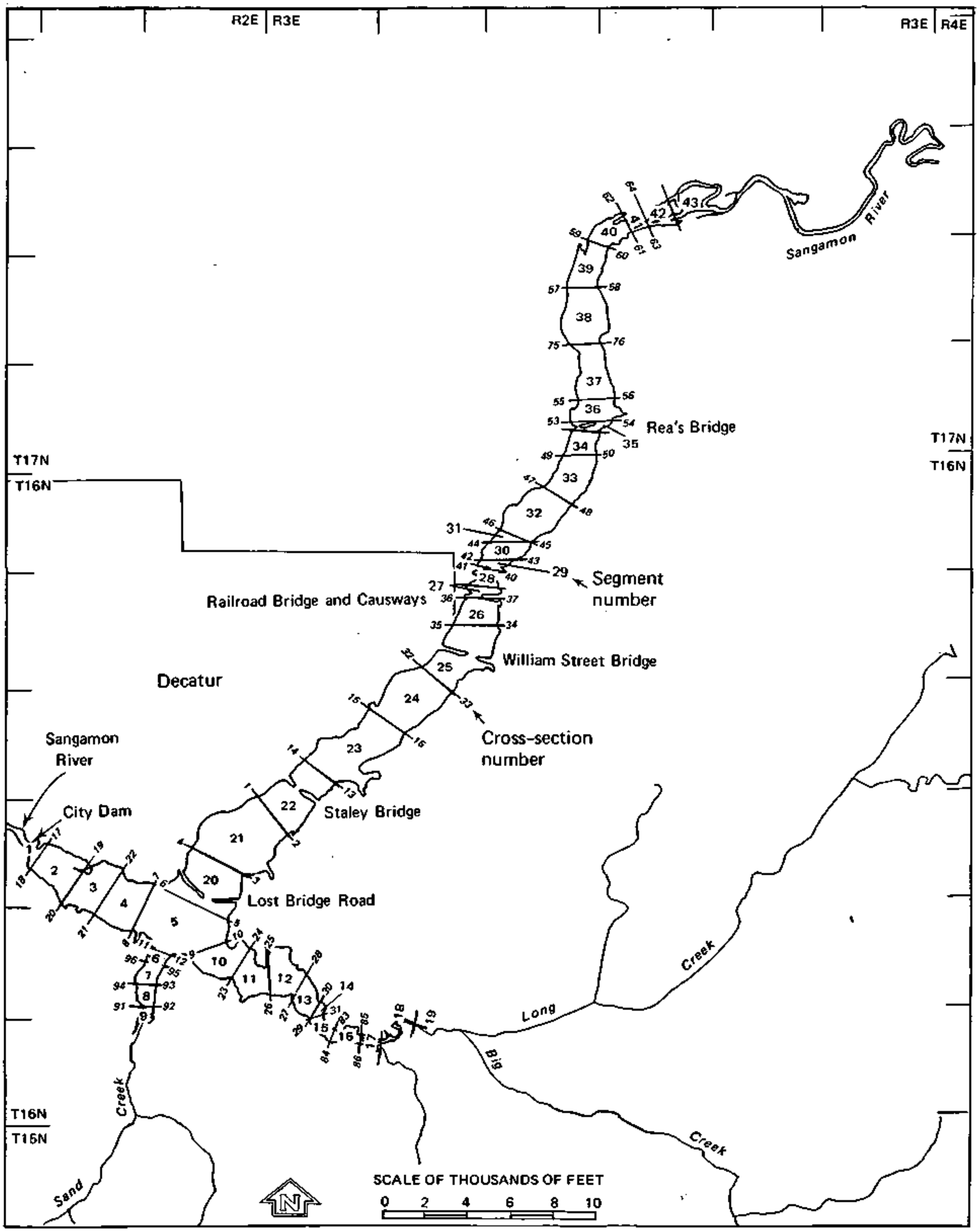


Figure 13. Plan view of Lake Decatur showing cross section and segment locations

readings use the water surface as a temporary datum and these readings are later converted into lake bed elevations by subtracting the depth readings from the lake surface elevations.

Two methods of sounding were used in the 1983 survey: the cable and the shore station methods. Both methods required that the sounding boat be positioned in the lake along the range line at a known distance from the range markers.

The cable method was used to sound approximately half of the ranges. This method involved stretching a 1/4-inch polypropylene cable across the lake and measuring the horizontal distance between the range markers using a cable meter. Soundings of the current lake bottom were made at 25-to 100-foot intervals. Two factors limited the use of this method: the range length was limited to less than 1500 feet due to the cable length; and areas of high boat traffic precluded the use of the cable due to the possible danger of accidents.

The second survey method (shore station method) employed a Hewlett-Packard electronic distance measuring device (EDM) which uses an infrared light beam reflected off a mirrored prism to measure the boat distance from the shore station. Using this method, lines of sight were cleared between range stations on opposite lake shores, and the shore station equipment operator used the EDM to determine the sounding boat's position while sampling. Soundings were obtained using the same aluminum pole and sediment shoe used in the cable method. Sounding intervals were 25 to 150 feet and usually were more widely spaced than in the cable method owing to the much larger distances across the lake.

The sounding crew consisted of three persons: the boat operator/data recorder, the sounding man, and the reflector/cable handler. This last individual would switch between duties depending on the type of survey method used. An additional person was required on shore for the shore station method to operate the EDM and communicate with the rest of the crew via two-way radio.

Following the sounding of all lake cross sections, samples of the lake bed sediments were collected to determine 1) particle size distribution, 2) unit weights, and 3) changes in the sediment over the length of the core samples. During this survey, bottom sediments were collected from 38 sites.

Two types of samplers were used for lake sediment sampling, an Eckman "clam-shell" type dredge and a core sampler. Surface samples were obtained using the dredge sampler, which scooped up the top 2 to 1 inches of the lake bed sediment. Core samples were taken using a 3-foot-long, 2-inch-diameter sampler which was lowered to the lake bed from the workboat using ropes and then driven into the sediment by means of a sliding lead weight built into the top of the core sampler and operated by ropes from the workboat. The sampler was withdrawn from the lake bed after penetrating 30 inches into the sediment. Further penetration could compact the sample. The cores were extruded onto a core measuring board in the workboat and examined for sand content, organics, compaction, and changes in color and texture over the length of the sample. Portions of the sample were then removed for later analyses to determine the unit weight and particle size distributions.

Generally three unit weight samples were cut from the core (one each) at the upper, middle, and lower third of the core. Multiple unit weight analyses for each core allowed the calculation of accumulated sediment weights for lake sediments whose density could vary with depth.

Particle size samples were also taken from the core samples and from the dredged samples for determination of the areal distribution of particle sizes of the older sediments. These samples were collected less frequently than the unit weights.

Following the sampling of lake bed sediment, the efforts of field data collection were directed towards depth sounding the Sangamon River at six cross sections upstream of the lake up to the Oakley Bridge, which is 15 miles upstream of the city dam (figure 13). The bridge sections within the lake were also measured to determine the impacts of the bridge causeways on the areal distribution of sediment deposition. A shoreline and bluff reconnaissance survey was also undertaken to determine areas of high bank erosion.

Concurrent with the latter field data collection, related data necessary for a generalized analysis were gathered. Data on lake water level records, rainfall records, stream discharge, stream sediment discharge, watershed land use, and soils were among the types of data assembled from various sources to aid in the analysis of the 1983 survey.

Analyses of Data

Data collected during the 1983 sedimentation survey were analyzed to determine the variations within the cross-sectional areas of the lakes, to develop a 1983 hydrographic map, to develop the stage-volume and stage-area relationships, and to determine the lake bed sediment characteristics including textures, unit weights, and particle size distributions. Other analyses consisted of the determination of the sedimentation rates both volumetrically and on the basis of the weight of the deposited sediment. A brief analysis was also made on the interrelationship between the delivery rate of sediment with sediment yield and trap efficiency.

Cross-Sectional Profiles. A total of 37 cross sections were surveyed in 1983 (figure 13), and the data collected from these cross sections were compared with the cross-sectional data collected in previous surveys. Some of the typical cross-sectional plots are described here.

Range 07-08: Range 07-08 is located 1.2 miles above the city dam, as shown in figure 13. The cross-sectional plot is shown in figure 14. At this cross section it can be seen how the old river channel is completely covered by the accumulated sediment. An old side channel of the Sangamon River shown on the left of the plot is also completely covered with deposited sediment. Variations in the original lake bed were as much as 12 feet, whereas presently it has been smoothed over and varies by only about 2 feet across most of the range line. The 4-foot peak in the lake bed near the shore at Monument 07 is the result of dredging and fill for a private harbor construction. The 1922 lake bed surface shows an old natural levee approximately 1 foot above the floodplain. This levee is the result of overbank flows of the pre-dam Sangamon River, when the river would overflow its channel and the overbank flow would diminish in velocity and drop out some of the sediment it carried. The result of this process is the development of a natural levee along the river bank.

Range 015-016: This cross section is located 4.1 miles upstream of the dam on the main body of the lake (figure 13). Figure 15 shows a plot of this cross section for various surveys. The most noticeable feature of the cross-sectional plot shown in figure 15 is the five old river channels

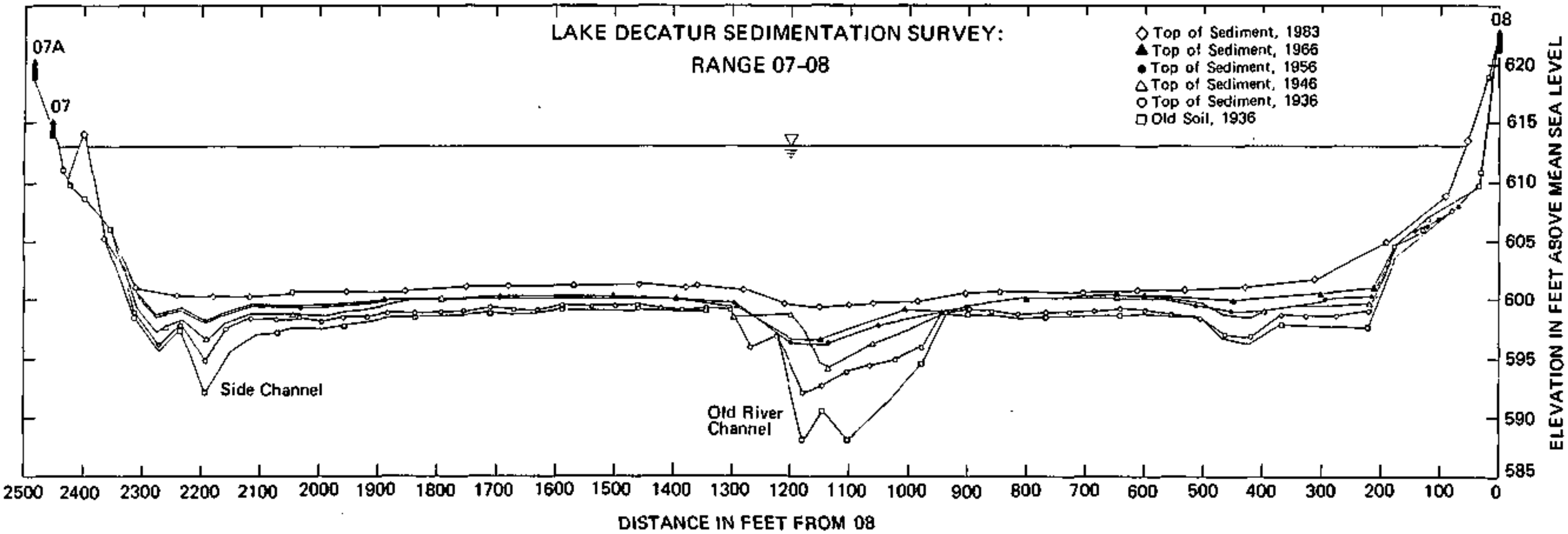


Figure 14. Lake Decatur cross section 07-08

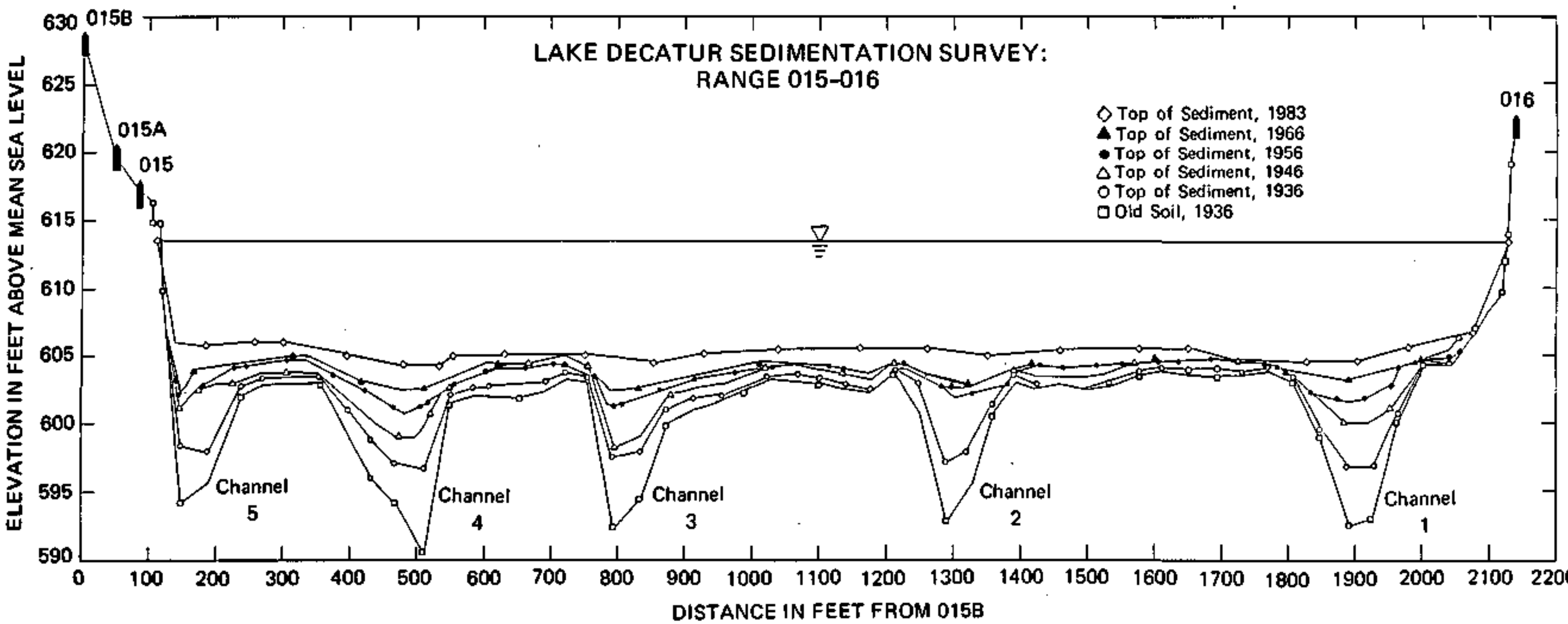


Figure 15. Lake Decatur cross section 15-16

(numbered in the figure from upstream to downstream), which are the result of four tight meander bends of the old river. The meander pattern at this location can be seen in the pre-dam valley map of figure 2. The old flow pattern of the pre-dam river at this cross section was as follows: at channel 1, the flow came from upstream and hence as the cross section is orientated "came out of the graph." After channel 1, the river flowed south and west a few hundred feet, took a sharp bend to the left, and flowed back through channel 2. After channel 2, the river flowed north and east before turning left again and flowing back through the cross section in channel 3. Similarly, for channel 4, the river flowed though channel 3, took a turn to the left, flowed through channel 4, and after another turn flowed back through channel 5.

Between 1922 and 1983 the maximum depth decreased 14 feet from 22.5 feet to 8.5 feet. The highest sedimentation rates occurred within the old channels; the floodplain valley experienced a relatively low sedimentation rate. It is apparent that the 1983 topography is much more subdued than the 1922 topography at this cross section. Other features of this location are the relatively low near shore bluffs of the valley in contrast with the next cross section at range 044-045, discussed below.

Range 044-045: This cross section is located 6.1 valley miles from the city dam (figure 13). The original channel of this cross section (figure 16) is located against the valley bluff near the right shoreline. Natural overbank levee deposits are seen on the left side of the channel. The maximum depth below 613 msl decreased from 19 feet in 1922 to approximately 5

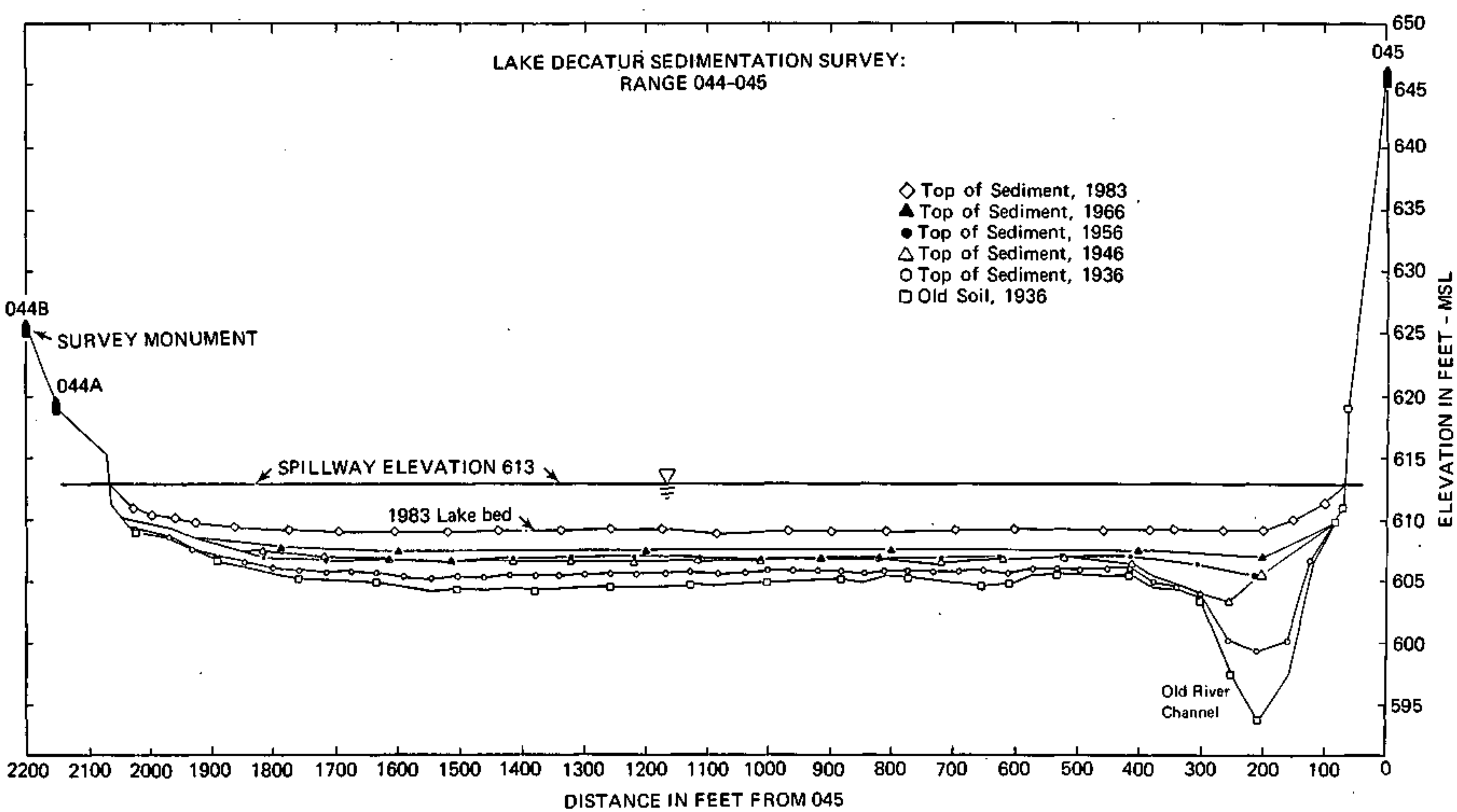


Figure 16. Lake Decatur cross section 44-45

feet in 1983. The bulk of the sediment at this cross section was deposited in the old channel during the period 1922-1946, whereas sediment deposition in the period 1966-1983 was more evenly distributed across the range line.

Range 075-076: This is one of the upstream cross sections located 8.2 miles from the city dam (figure 13). Cross-sectional plots for this range are shown in figure 17. A noticeable feature of this cross section is the high bluff on the left shore which rises 50 feet above the lake with a near vertical face. This bluff has eroded back *HO* feet since 1936 and is the most severe area of lakeshore erosion. By contrast the shore on the other side has filled in approximately 30 feet over the same period.

This cross section is located approximately 1-1/2 miles downstream from the junction of the Sangamon River and the upstream section of the lake. Figure 17 shows how the Sangamon River flow has continued to follow the old river channel in the lake, as evidenced by the presence of the channel in 1983 on the left side of the figure. Except for this depression on the old channel, the bed elevations of this cross section have become fairly flat over the last 61 years. An old natural levee approximately 2 feet above the floodplain is present near the right bank of the river channel.

Range 027-028: This cross section is shown in figure 18. It is located 2.9 miles upstream of the dam in the Big Creek arm of the lake. From figure 18, it can be seen that the bed topography has flattened over the years; the old channel has been filled and the sediment has feathered out near the shore. The channel shown in this plot was formerly occupied by the Big Creek tributary of the Sangamon River (figure 13). It can be seen that the deepest part of the cross section is still close to the old river channel and is about 1 foot deeper than the surrounding river bed. The channel has not yet

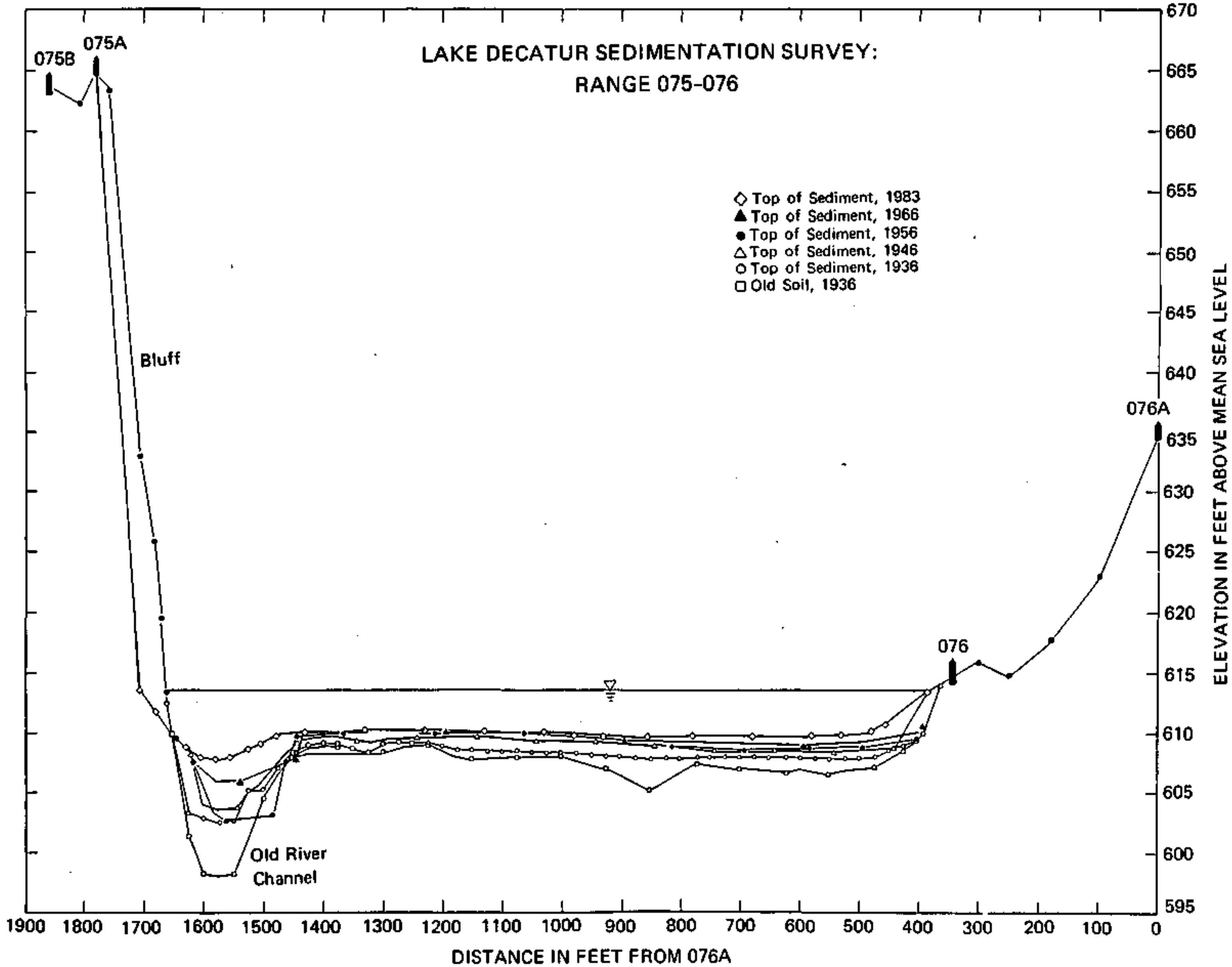


Figure 17. Lake Decatur cross section 75-76

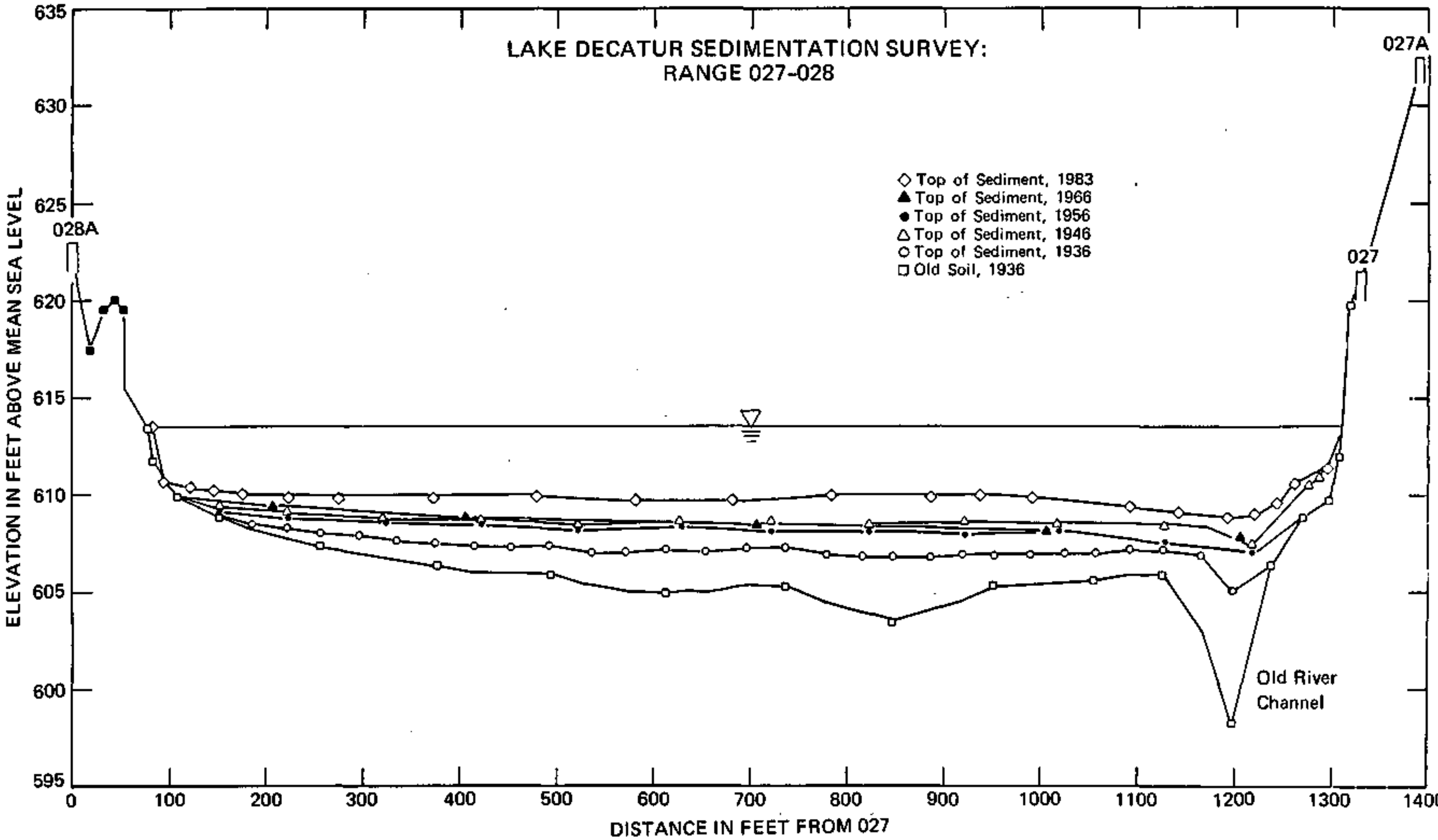


Figure 18. Lake Decatur cross section 27-28

been completely obliterated by the deposited sediments because of the high velocity of the incoming flow from Big Creek, which has kept this area relatively deep by eroding the deposited sediment. Lake bed aggradation has reduced the maximum depth below 613 msl from 14.5 feet in 1922 to 1.0 feet in 1983. An old natural levee and side channel can be seen to the left of the old channel in figure 18.

Range 095-096: This cross section is located on the Sand Creek arm of the lake 1.7 miles upstream of the city dam (figure 13). Figure 19 shows that this cross section had no well developed channel in 1922. Sand Creek, which flowed through this cross section, had a high sediment load and relatively low average discharge, and as a result the stream wandered back and forth across the width of the valley with no defined channel. In 1922, the maximum depth was over 10 feet; currently it is less than 5 feet. This range lost an average of 3 feet of depth during the first 24 years after the dam was constructed and has lost approximately 2-1/2 feet of depth in the last 37 years.

Some general observations can be made concerning these cross-sectional plots.

1) Lake deposited sediment tends to smooth over the old river valley topography.
2) Sediment thickness is greatest in the old river channel.
3) The sediment thickness tends to feather out near shore.
4) Over time the maximum depth of water at each cross section decreases faster than the average depth.

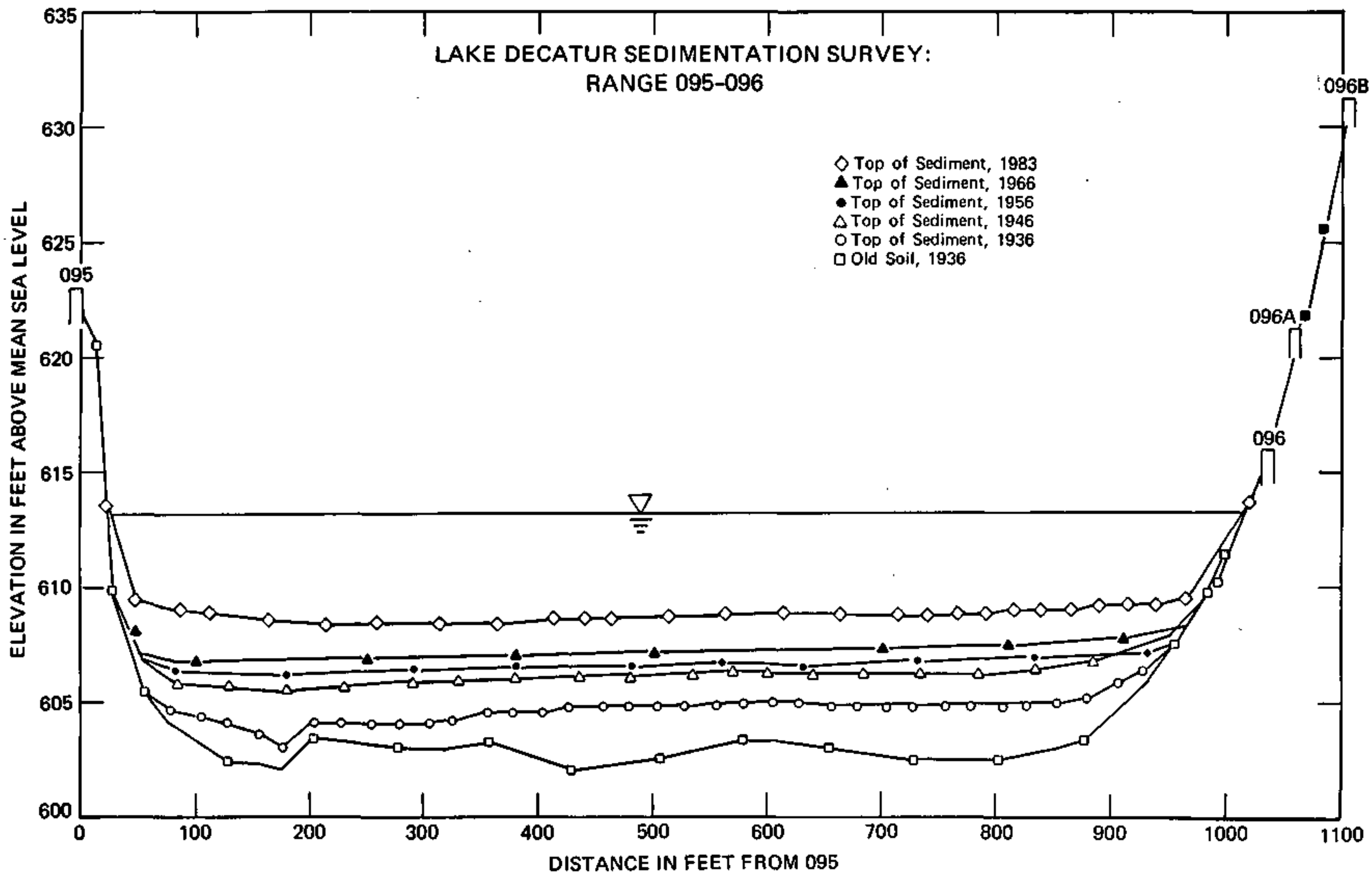
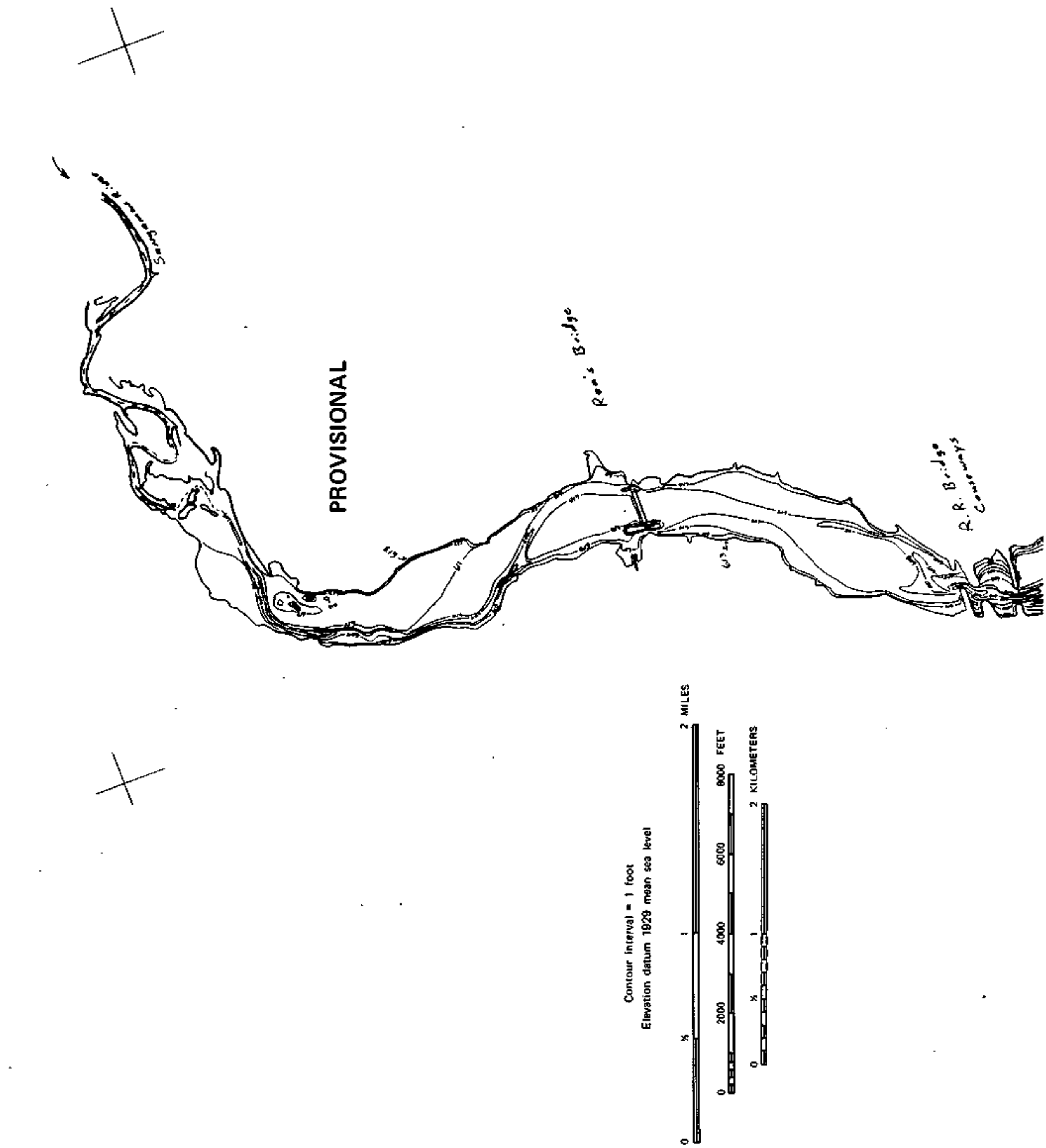


Figure 19. Lake Decatur cross section 95-96


PROVISIONAL
R. R. Bridge
Causeways
Contour interval = 1 foot
Elevation datum 1929 mean sea level
0
½
1
2 MILES
0
2000
4000
6000
8000 FEET
0
½
1
2 KILOMETERS

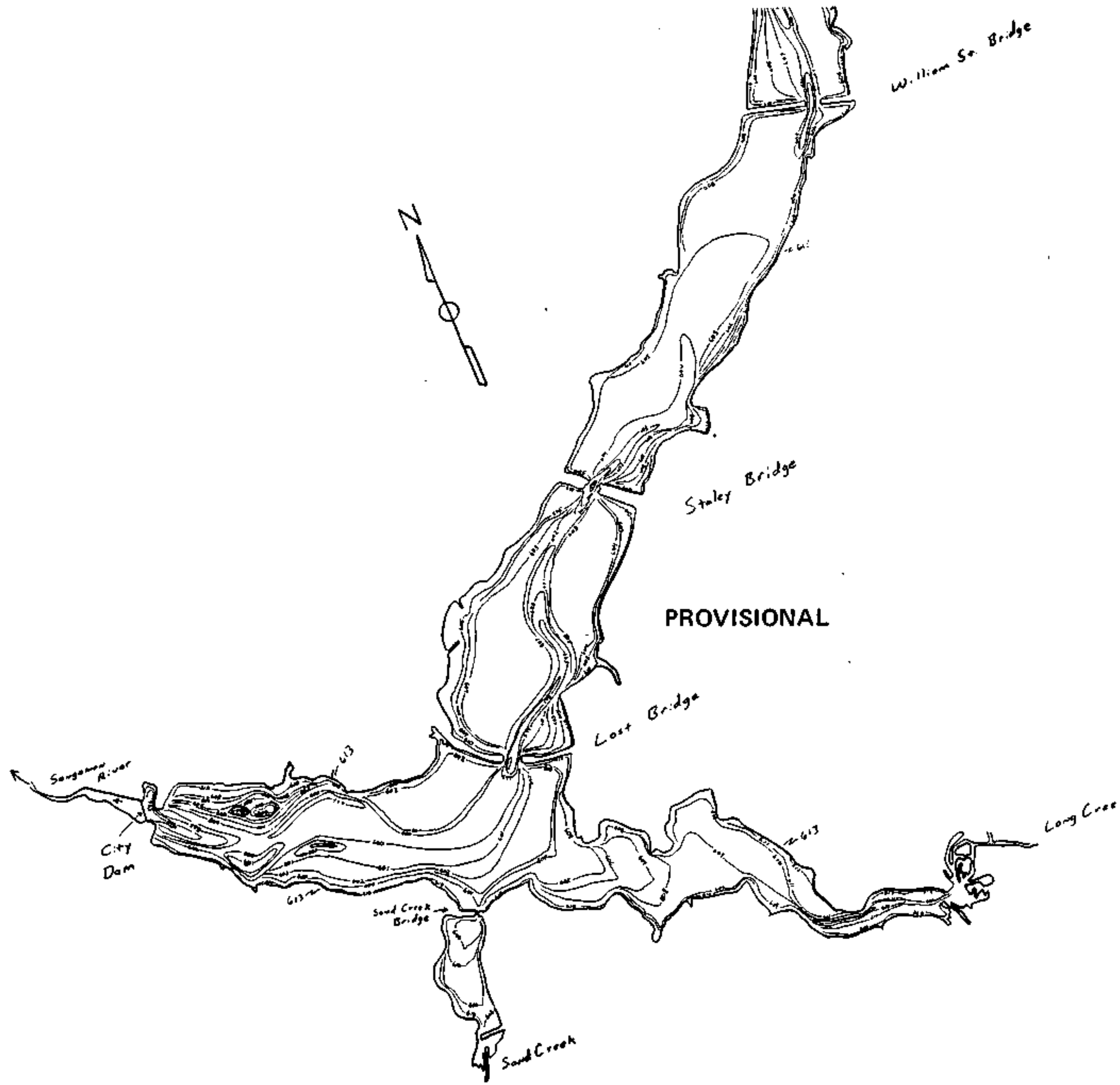


Figure 20. Hydrographic map of Lake Decatur, 1983 (Provisional)

5) The lake bed elevations from the years 1946 and 1956 are coincident across most of the cross sections. This results from the relatively low sedimentation rate of the time period between the two surveys.

Hydrographic Map. The cross-sectional depth soundings obtained during the 1983 lake survey were used to generate a hydrographic map of the lake. This map is presented in figure 20 and represents the bed topography as can - be inferred from the 1983 data. The map was drawn with a contour interval of 1 foot; however, many contours have been omitted because of space constraints.

From this map, it is seen that the deepest part of the lake is the downstream region near the dam. This area represents a great deal of the total lake volume and therefore a high percentage of the water storage. In figure 20, it is seen that the old river channel portion of the lake bed has been filled in throughout much of the lake. The river channel bottom was originally at 582 feet msl at the dam in 1922. Currently the bed elevation is 596 feet msl near the dam. A bed elevation of 590 feet was measured beneath the Staley Bridge. This is interpreted to be the result of localized scour produced by water moving through the causeway openings.

A noticeable feature of the map is the deep portions of the lake beneath the bridges. These deep areas are scour holes which were carved by the flow of water through the openings between the bridge causeways.

Stage Area and Stage Capacity Relationships. The hydrographic map developed using the 1983 survey data was used to analyze the relationship between water level or stage in the lake and the capacity and area of the lake.

The shoreline elevation of the lake at each stage was digitized and the area was calculated from these values. These areas were then used to calculate the incremental water capacity for each increase in stage as follows (SCS, 1968)

$$V = {}^{L}/3 \; (A_L + \sqrt{A_L \times A_u} + A_u) \qquad (1)$$

where

V = the capacity between two water surfaces in acre-feet

L = the distance between the two water surfaces in feet

A_L = the area of the lower surface in acres

A_u = the area of the upper surface in acres

The sum of all incremental volumes below a surface is the capacity for that stage. The stage vs. area and stage vs. capacity relationships are plotted in figure 21. This figure can be used to readily determine the capacity or area of the lake for a given stage below 613 msl. This relationship will change with time as sedimentation causes more volume loss in the lake but can be used to make a quick evaluation of the city's water supply situation.

Lake Bed Sediment Characteristics

Textures. Three types of textures were observed in the lake sediment: (1) the top very saturated light grey sediment, which was very loose and uncompacted; (2) the older and more compacted sediments, which grade from slightly compacted and loose in the upper portion of the column to consolidated and firm in the older and deeper portions (this is the most abundant part of the core, generally starting 0.3 to 0.4 feet below the lake bed and continuing down to the original valley soils); and (3) the original valley soils that formed prior to the lake construction, recognized by the old root zone layer, generally larger particle sizes, and usually a very

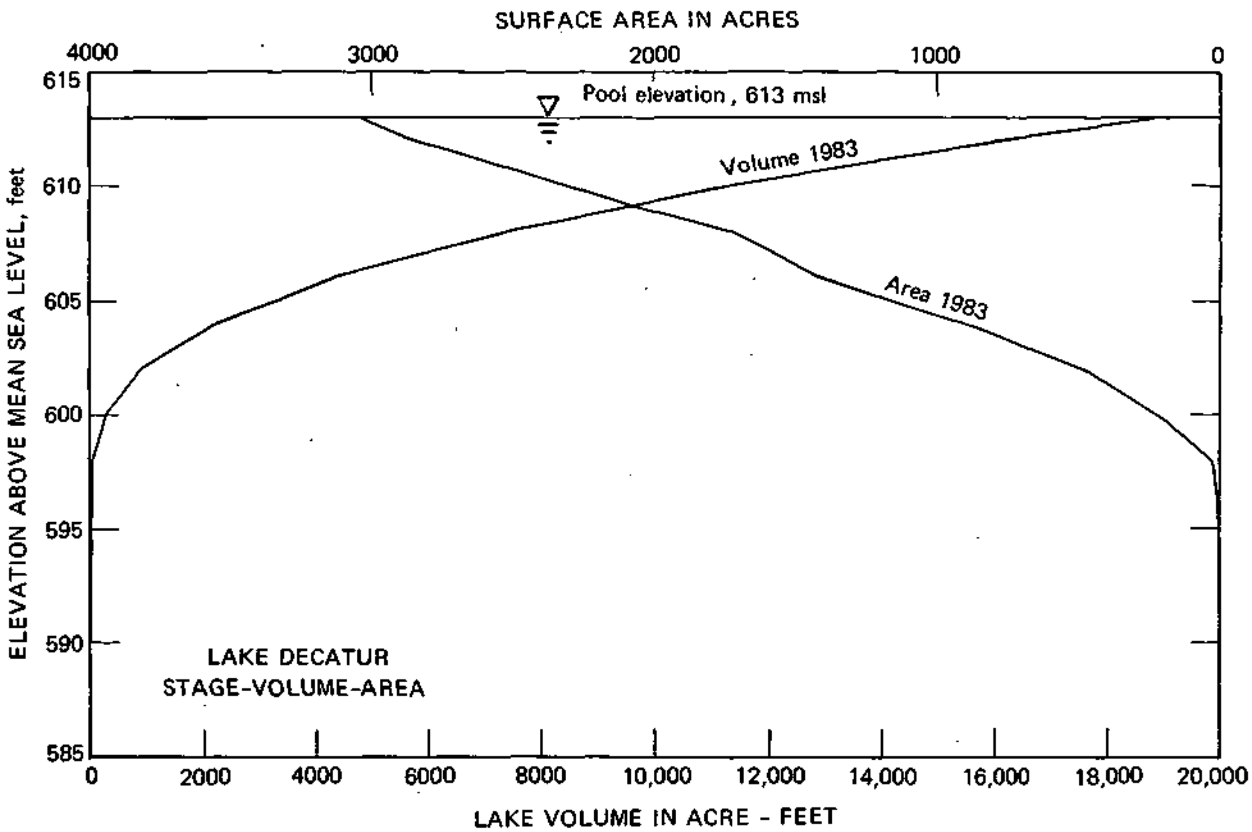


Figure 21. Stage-volume-area curves for Lake Decatur

consolidated texture. The old soil layer was usually absent from cores taken in the lake owing to the depth of the accumulated sediments which exceeded the sampling depth of the core sampler.

Unit Weight. The unit weights of Lake Decatur sediments show a general decreasing trend from the upper end of the lake to the dam. This is to be expected in lake sedimentation studies (Heineman, 1962; Bogner, 1983) and results from the progression of sediment particle deposition in the lake. As the moving water of the Sangamon River enters Lake Decatur, it slows drastically and can no longer maintain its sediment load. As the water enters the lake, the heavier sediment materials tend to drop from suspension first. As the water moves further down the lake it slows even more and the lower density sediments settle to the bottom. At the dam, only the least dense materials will still be carried by the water to either be settled out in the lake near the dam or pass over the spillway.

The unit weights in the upper segments of the lake are also affected by the periodic exposure to drying and compaction during times of low water levels. Lake Decatur is a public water supply lake and the pool level is frequently lowered by the demands of the water treatment plants during periods of low flow on the Sangamon River. As a result the aeration and resulting compaction of lake sediment occur more frequently in the shallow upstream lake segments.

Particle Size. The lake sediment in Lake Decatur is predominantly clay. The simple averages of all particle size samples are: 57% clay, 36% silt, and 1% sand. Appendix 1 lists the results of particle size analyses of 40 lake bed samples. In Appendix 1 a general trend is seen towards increasing silt and clay from downstream to upstream in the lake. This trend is seen in the main stem of the lake as well as the Big and Sand Creek tributary arms. A trend of increasing particle size towards the upstream has been observed in other reservoirs (Heinemann, 1962; Eakin and Brown, 1936, 1939).

Sedimentation Rates by Volume

The reservoir volumes for 1922, 1936, 1946, 1956, 1966, and 1983 were determined using the prismoidal formula as described in SCS (1968). Basically, the volume of the reservoir is determined as the sum of a series of segmental volumes derived from surface area, cross-sectional area, and cross section width of each segment and cross section.

The lake was divided into 38 segments as shown in figure 13, with each segment bounded by two range lines which are roughly parallel, and by the two shorelines. End ranges are used for segments which terminate at the mouth of a tributary of the lake. Segments which contain end ranges are generally triangular in shape where the apex represents a cross-sectional area of zero at the intersection of the lacustrine and riverine environment.

The ranges are measured cross sections with a known cross-sectional area for each year of survey. Using the cross-sectional areas of the ranges, the volume of each segment is calculated for each survey-year and the difference in volume from year to year represents the amount of accumulated sediments.

To facilitate the calculation of the volumes as well as the weight of the deposited sediment tonnages, the program Prismoid was developed on the CDC Cyber system at the University of Illinois. This program was written specifically for the Lake Decatur project but could be readily adapted for other lakes. The full text of Prismoid is given in Appendix 2.

The results of these calculations are given in table 5. As stated earlier, the effective spillway elevation of Lake Decatur was increased in 1956 from 610 to 615 msl. An elevation of 613 msl was chosen as a representative lake level based on prevailing conditions. All surveys, including the pre-1956 surveys, have been adjusted to this elevation for purposes of comparative analysis. Table 5 also gives the 610 msl volumes for the pre-1956 surveys. These results show that the storage capacity of the reservoir at an elevation of 613 msl was reduced from 27,900 acre-feet in 1922 to 18,800 acre-feet in 1983. This represents a total volumetric deposition of 9100 acre-feet.

Sediment accumulation rates in the lake based on the 1922 capacity at 613 msl are given in tables 6 and 7. The sediment accumulation from 1922 to 1983 amounted to 35.5% of the 1922 capacity (at 613 msl) or an average annual accumulation of 0.58* per year. This accumulation resulted in an average deposition of 2.96 feet of sediment on the reservoir bed or an average annual bed accretion of 0.05 feet per year.

Table 8 gives the volume of each segment of the reservoir for the 1922, 1936, 1946, 1956, 1966, and 1983 surveys. The differences between these volumes indicate the increased volume of sediment in a given segment and the corresponding decrease in water volume. In some cases, there is a net reduction of sediment in a segment over a period of time. This might result from consolidation of the sediment due to drying (as during the early 1950s) or from localized scour or dredging.

Figure 22 shows the percent volume loss by lake segments from 1922-1983. From this figure it can be seen that the segments which have lost more than half of their volumes are located in the upstream portions of the lake. Most

Table 5. Capacity of the Lake and the Volume of the Accumulated Sediment

Watershed area - 925 square miles
Reservoir area - 3072 acres @ 613 msl

Year of survey	Survey interval (years)	Reservoir storage capacity (acre-feet)	Capacity per sq mile (acre-feet)	Deposited sediment between surveys (acre-feet)
1922		27,900 (19,700)*	30.2 (21.3)*	
	14.2			2800
1936		25,100 (16,900)	27.1 (18.3)	
	10.0			2400
1946		22,700 (14,600)	24.5 (15.7)	
	10.0			500
1956		22,2000 (14,100)	24.0 (15.2)	
	10.0			1400
1966		20,800	22.5	
	17.0			2000
1983		18,800	20.3	
1922-1983	61.2			9100

*Capacity at spillway elevation of 610 msl

Table 6. Reservoir Capacity Loss* and Rates of Sediment Accumulation in Lake Decatur

Period	Percent loss per period	Percent loss per year
1922 - 1936	10.04	0.71
1936 - 1946	8.60	0.86
1946 - 1956	1.79	0.18
1956 - 1966	5.38	0.54
1966 - 1983	7.17	0.42
1922 - 1983	35.48	0.58

*In percent of original capacity at spillway elevation 613 msl

Table 7. Average Accumulation of Sedimentation on the Lake Bed

Period	Total accumulation (feet per period)	Annual accumulation (feet per year)
1922 - 1936	0.91 (1.00)*	0.07 (0.07)
1936 - 1946	0.78 (0.86)	0.08 (0.09)
1946 - 1956	0.16 (0.18)	0.02 (0.02)
1956 - 1966	0.46	0.05
1966 - 1983	0.65	0.04
1922 - 1983	2.96	0.05

*At spillway elevation 610 msl

Table 8. Lake Decatur Volume in Acre-Feet by Segments, 1922-1983, with 1983 Sediment Tonnages

Segment number	Volume in acre-feet						1983 sediment tonnage by one unit weight	1983 sediment tonnage by two unit weights
	1922	1936	1916	1956	1966	1983		
1	263	249	240	236	206	189	51	50
2	1120	1060	1020	1050	963	902	161	154
3	1250	1160	1110	1120	1080	1010	178	171
4	1700	1570	1190	1110	1100	1280	301	291
5	2830	2610	2130	2390	2300	2100	689	639
6	89	75	61	62	57	16	15	42
7	221	179	110	131	115	75	218	209
8	122	89	62	60	52	26	111	134
9	59	37	26	28	26	11	86	79
10	671	621	560	511	511	159	211	216
11	578	509	139	113	391	326	297	268
12	532	131	310	311	323	219	321	306
13	259	195	118	159	140	110	187	177
14	29	21	'16	17	13	11	26	21
15	101	63	52	19	12	10	90	83
16	100	60	52	16	39	38	96	93
17-19	120	79	72	65	15	11	127	129
20	2110	2020	1920	1890	1830	1710	331	312
21	2850	2700	2510	2520	2110	2300	510	115
22	1660	1560	1450	1450	1380	1290	392	332
23	2120	1930	1760	1690	1590	1110	603	550
21	1.580	1130	1300	1250	1180	1060	180	439
25	1280	1170	1050	1050	978	900	327	300
26	138	100	317	353	325	302	118	109
27-28	391	352	302	297	269	258	120	113
29	159	110	118	116	103	91	60	57
30	301	266	219	218	192	161	126	118
31	120	106	90	87	76	65	52	18
32	1020	862	712	666	595	178	576	532
33	589	188	395	351	321	256	398	389
31-35	125	317	277	253	225	131	310	323
36	359	289	221	211	190	152	317	277

Table 8. Concluded

Segment number	Volume in acre-feet 1922	1936	1946	1956	1966	1983	1983 sediment tonnage by one unit weight	1983 sediment tonnage by two unit weights
37	562	459	376	366	332	277	425	371
38	632	489	423	385	339	291	517	448
39	343	256	229	195	161	153	285	252
40	219	179	166	149	124	108	151	139
41	104	94	'87	81	68	56	68	64
42	530	492	542	433	355	297	344	313
Total	27900	25100	22700	22200	20800	18800	9830	8990

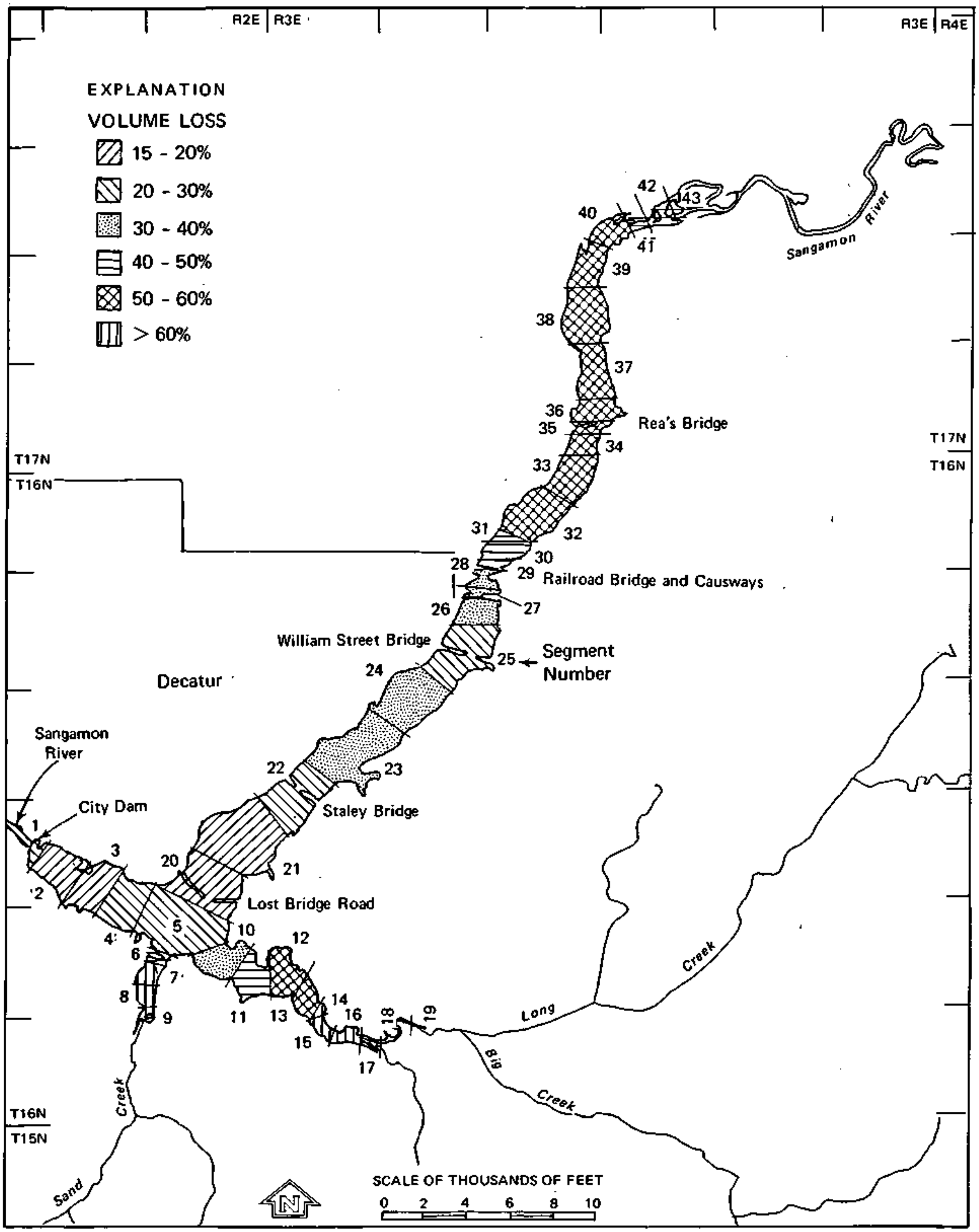


Figure 22. Percent loss of volume in Lake Decatur by segments

of the segments in the Sand and Big Creek reservoir arms have lost more than 50% of their volume. Segments with the least amount of percent volume loss are found in the deep portions of the lake near the dam.

Sedimentation Rates by Weight

The determination of the volume of sediment that has accumulated over time is useful in that it provides a general picture of the available water storage of the lake. The extrapolation of the previous volume loss rates is needed to estimate the future available storage. The application of previous lake volume analysis to predict future volume loss is limited by the fact that the density of sediment deposits changes with time and the newer deposits change the volume of the previously deposited sediment. In general the sedimentation rate over time will increase both the volume and mass of lake sediment and correspondingly decrease available water storage. The calculation of the sedimentation rates by weight provides the data necessary to determine the amount of material washed into the lake based on the dry weight of the sediments. This allows a better assessment of the changes in the rate of sediment inflow over time. Once the sedimentation rates by dry weight are determined, a more detailed analysis of watershed erosion and delivery ratios is possible. This section will delineate the methods used and the assumptions made for the calculation of the sedimentation rates by dry weight.

Unit weight analysis provides an estimate of the relative density of sediment. The unit weights of 85 samples collected from Lake Decatur are presented in Appendix 2. The dry density of the sediment varies from 28 to 89 pounds per cubic foot. In general the unit weights are lowest near the dam and highest at the upstream reaches of the lake. Table 8 presents the average unit weight density used for each lake segment to calculate the total sediment weight in the lake in 1983. The unit weight of the sediment in each lake segment was determined by averaging the density for the bounding cross sections of each segment.

Many factors can affect the density of lake sediment and its resulting volume: aeration of the lake bed due to low water levels can compact sediment, different particle sizes occupy different volumes, the weight of sediment above a given point can increase compaction, and other factors such as organic content and rate of sediment input may affect sediment density.

The weight of sediment accumulated in Lake Decatur from 1922 to 1983 was determined based on segmental sediment volumes as described earlier and unit weight of the sediment as determined by the 1983 sediment sampling program. Unit weights determined for sediment samples collected in 1983 were applied to the appropriate segmental sediment volumes. In general, the samples were collected at the midpoint of each cross section, and the unit weight for a segment was determined by averaging the unit weights of the two bounding cross sections.

Two techniques for applying the unit weights for the calculation of sedimentation rates by weight were tested. The first technique was the method that has been generally used for unit weight analysis in the previous surveys of Lake Decatur. In this method, one unit weight is used for each segment based on the field sampling. Thus, the tonnage of sediment in the reservoir will be the sum of the following segmental tonnages:

$$T = (21.78)\ MV \qquad (2)$$

where

T = the segmental sediment tonnage

21.78 = a unit conversion factor

M = the segmental unit weight in pounds per cubic foot

V = the segmental sediment volume

The second technique for sediment tonnage calculation was developed based on the field observation that the sediment deposits could generally be divided into two zones. These zones were an unconsolidated top layer of sediment which ranged from 0.2 - 1.0 feet in thickness, and the more consolidated lower sediment layer. Based on this observation, a system of two unit weights per segment was developed.

The first or top unit weight was used on a volume of sediment equal to the area of the segment to a depth of 1 foot. The second unit weight was used on the remaining volume of sediment. Symbolically this method is as follows:

$$T = 21.78\ [M_t{+}A + M_b\ (V - A)] \qquad (3)$$

where

T = the segmental sediment tonnage

21 .78 = a unit conversion factor

M_t = a top unit weight

M_b = a bottom unit weight

A = the segmental area in acres (times one foot)

V = the segmental sediment volume

A check was always made to ascertain that "A" was less than "V". If "A" was greater, "V" was substituted for "A" and "V" was then set equal to zero in equation 3.

The two sediment weight calculation techniques were used to determine the segmental and total sediment tonnages given in table 8. These results indicate that the two unit weight method gives significantly lower sediment tonnages than the single unit weight method.

Although the two unit weight method is believed to be the best estimate of sediment tonnages in the lake, the single unit weight tonnages are used in the remainder of this analysis in the interest of consistency. All previous surveys were analyzed using the single unit weight method and cannot be readily adjusted to the two weight method.

This sediment weight calculation was used to determine the segmental and total sediment tonnages presented in table 8 according to segment numbers as indicated in figure 13.

The tonnages in table 8 show that tonnages of sediment in all segments of the lake are roughly equivalent. Further analysis of these sediment volumes by particle size, unit weight, and water depth indicate very large variations in the materials in each segment.

Sediments near the dam are generally very fine silt and clay materials with low unit weight and high water content in depths of water to 10-12 feet. Sediments in the north (Sangamon River) lake area, Big Creek, or Sand Creek tend to contain coarser sand size materials, with much higher unit weights, in shallower water depths. These coarser, heavier materials occupy the most likely dredging areas. These areas are most reasonable for dredging based on both availability at reasonable dredging depths and provision of increased accessible water storage.

Rates of Accumulation from the Watershed

Table 9 summarizes the annual rates of accumulation of sediment from the watershed of Lake Decatur. Rates of accumulation of sediment have varied from 50 acre-feet per year from 1946 to 1956 to 240 acre-feet per year from 1936 to 1946. These values correspond to losses of 0.17 tons per acre of watershed and 0.36 tons per acre of watershed per year, respectively. These rates of accumulation are relatively low compared to other Illinois lakes, where rates of 0.5 to 1.0 tons per acre per year are common and can range as high as 4+ tons per acre.

The rates presented in table 9 are shown graphically in figure 23. Note that the use of tonnage analysis reduces the discrepancy of accumulation rates between survey periods.

SUMMARY

A sedimentation survey has been conducted on Lake Decatur, Decatur, Illinois. The June to August 1983 survey was conducted by the Illinois State Water Survey in cooperation with the City of Decatur.

Lake Decatur is a man-made impoundment on the Sangamon River and serves as the sole source of water for the City of Decatur. The watershed of Lake Decatur is characterized by low, glacial topography and is heavily utilized for agricultural production.

The climate of the area is classified as humid continental and averages 39.12 inches of rainfall per year. Average runoff in the Sangamon River is approximately 10 inches. This report summarizes the results of five detailed sedimentation surveys of Lake Decatur conducted in 1936, 1946, 1956, 1966, and 1983. Sedimentation rates have varied from 0.18% per year from 1946-1956 to 0.86% per year from 1936-1946. These rates represent deposits of 0.17 and 0.36 tons per acre of watershed per year, respectively.

Table 9. Annual Sediment Accumulation Rates from the Lake Decatur Watershed

Period	Acre-feet of deposited sedimentation sediment	Acre-feet of sediment deposited per square mile of watershed	Acre-feet of sediment deposited per acre of watershed	Tons of deposited sediment per acre of watershed
1922-1936	200	0.22	15.0	0.29
1936-1946	240	0.26	17.7	0.36
1946-1956	50	0.054	3.7	0.17
1956-1966	140	0.15	10.2	0.28
1966-1983	120	0.13	8.8	0.26
1922-1983	150	0.16	10.9	0.27

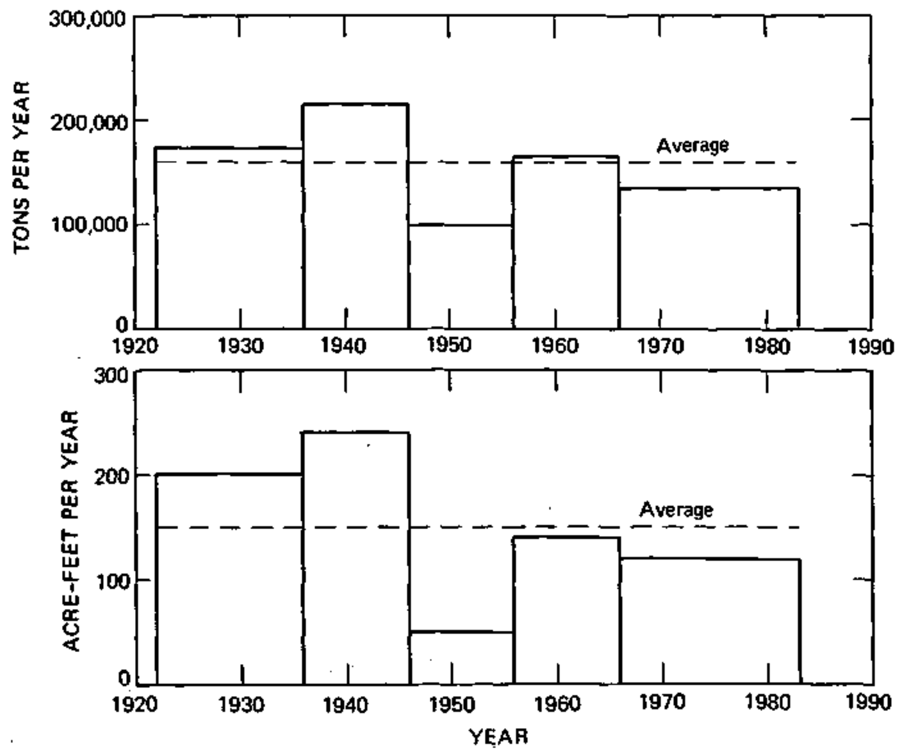


Figure 23. Sediment accumulation rates in Lake Decatur

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Appendix I. Lake Decatur particle size and unit weight analysis

Appendix I. Lake Decatur particle size and unit weight analysis

X-Section	Depth below lakebed to mid-pt. of sample (ft)	% clay	% silt	% sand	Density $\frac{lb}{ft^3}$
17-18	. 0.1	78.78	20.83	0.39	
	0.25				28.53
	0.95				28.29
	1.2	80.05	19.45	0.50	
	1.65				31.33
19-20	0.1	76.95	22.65	0.40	
	0.25				31.56
	1.25				32.20
	2.25				36.18
21-22	0.1	73.29	26.51	0.20	
	0.35				29.98
	1.35				32.17
07-08	0.1	72.44.	27.47	0.09	
	0.35				26.54
	1.25				32.67
	*2.15				30.28
11-12	0.1	65.53	34.26	0.21	
	0.35				31.29
	1.35				33.58
	2.55				44.33
95-96	0.1	48.41	51.48	0.11	
	0.35				36.28
	2.35				51.77
93-94					
91-92	0.1	25.75	44.01	30.24	
	4.5				66.32
	1.75				82.73
09-10	0.1	66.95	32.92	0.13	
	0.35				33.96
	0.65				42.84
	0.85				51.17
23-24	0.45				34.09
	1.25				46.01
	1.95				52.65
25-26	0.75				55.44
27-28	0.1	37.38	62.11	0.51	
	0.55				42.11
	0.85				43.96
27-28	1.55				48.96
	1.6	43.22	56.36	0.42	
29-30	0.45				49.72
	1.25				64.13
	1.55				66.63
83-84	0.1	57.68	40.50	1.82	
	0.15				49.47
	0.65				69.09
	1.15				65.41

Appendix I. Continued

X-Section	Depth below lakebed to mid-pt. of sample (ft)	% clay	% silt	% sand	Density lb/ft^3
85-86	0.1	17.87	48.19	3.94	
	0.45				76.83
	0.75				74.37
05-06	0.1	73.94	24.12	1.94	
	0.35				39.41
	0.85				46.28
	1.35				65.01
03-04	0.1	79.36	20.59	0.05	
	0.45	87.12	12.37	0.51	25.33
	1.4				
	1.75				31.23
01-02	0.1	77.70	20.21	2.09	
	0.45				29.31
	1.35				59.28
	1.8	7.06	7.87	85.07	
	2.45				75.52
13-14	0.1	70.67	29.15	0.18	
	0.25				28.23
	1.15				37.86
15-16	0.1	69.32	30.57	0.11	
	0.25				28.19
	1.05				31.63
	1.75				43.69
32-33	0.1	65.56	33.76	0.68	
	0.45				31.33
	1.2	64.24	34.26	1.50	
	1.65				39.92
34-35	0.1	48.10	21.21	30.69	
	0.25				32.40
	1.05				89.20
	1.2	44.08	54.88	1.04	
40-41	0.1	75.15	24.63	0.22	
	0.45				33.08
	1.25				34.36
	1.6	71.18	28.48	0.34	
	2.05				40.56
42-43	0.1	61.71	38.06	0.23	
	0.45				32.64
	1.55				40.25
	2.0	66.76	33.06	0.18	
	2.35				43.39
44-45	0.1	58.49	41.36	0.15	
	0.25				31.80
	1.15				37.86
	1.8	61.86	37.81	0.33	
	2.05				40.86

Appendix I. Concluded

X-Section	Depth below lakebed to mid-pt. of sample (ft)	% clay	% silt	% sand	Density $\frac{lb}{ft^3}$
45-46	0.25				31.46
	1.05				40.08
	1.75				45.44
47-48	0.35				36.01
	1.15				52.55
49-50	0.1	49.95	42.18	7.87	
	0.1	26.97	23.17	49.86	
	0.25				62.72
	0.35				64.67
	1.65				57.36
55-56	0.1	49.64	49.93	0.43	
	0.35				39.78
	1.4	34.93	42.72	22.35	
	1.75				70.53
75-76	0.1	44.83	54.97	0.20	
	0.35				41.87
	0.95				46.85
	1.65				66.12
57-58	0.1	45.78	50.56	3.66	
	0.25				44.13
	1.05				62.72
	1.4	33.43	63.51	3.06	
	1.75				73.50
59-60	0.1	33.74	41.75	24.51	
	0.15				49.75
	1.35				64.17
61-62	0.1	44.42	47.99	7.59	
	0.25				54.87
	1.05				53.52
	1.6	54.44	45.31	0.25	
	1.85				61.61
63-64	0.45				61.51
	1.75				67.71

Appendix 2. Primoid — A FORTRAN program for the calculation of lake volumes using the Dobson Prismoidal Formula

```
      PROGRAM PRIMOID (INPUT,OUTPUT)
      INTEGER TOTSEG,TOTYR
      DIMENSION A(101),W(101),APRIME(101),VOL(101,6),TOTVOL(6),
     $TPUW(101),BTMUW(101),SEDVL(101,6),WGT(101,6),TOTWGT(6),TOTSD(6)
      DATA TOTVOL/6*0.0/,TOTWGT/6*0.0/
      IN=5
      I0UT=6
C
C
C          PRIMOID— A FORTRAN PROGRAM FOR THE CALCULATION OF LAKE
C             VOLUMES USING THE DOBSON PRISMOIDAL FORMULA
C
C
C                                  BY
C                             KURT JOHNSON
C                                AND
C                             BILL BOGNER
C
C
C     PRIMOID CALCULATES THE VOLUME OF A LAKE FOR A GIVEN NUMBER OF
C     SURVEY YEARS. FOLLOWING THE VOLUME CALCULATION, PRIMOID
C     DETERMINES THE VOLUME AND TONNAGE OF SEDIMENT ACCUMULATION IN THE
C     LAKE BETWEEN SURVEY YEARS AND FOR THE TOTAL PERIOD OF EXISTENCE OF
C     THE LAKE.
C
C     THE CALCULATION IN THIS PROGRAM IS BASED ON THE DOBSON PRISMOIDAL
C     FORMULA FROM SOIL CONSERVATION SERVICE(1968):
C
C                 V=(A'/3)*((E1+E2)/(W1+W2))+(A/3)*(E1/W1+E2/W2)+
C                    (H3*E3+H4*E4+..........)/130680
C
C     THESE SYMBOLS ARE REPRESENTED BY THE FOLLOWING VARIABLE ARRAYS
C.    AND ARE DESCRIBED AS FOLLOWS:
C
C
C
C         SYMBOL   VARIABLE   DESCRIPTION
C           V          VOL        THE TOTAL SEGMENT VOLUME,ACRE-FEET
C
C           A'         APRIME     THE QUADRILATERAL AREA OF THE SEGMENT
C                                 FORMED ON TWO SIDES BY THE RANGE ENDS
C                                 AND ON THE OTHER TWO SIDES BY LINES
C                                 DRAWN FROM THE INTERSECTION OF THE
C                                 RANGE LINES AND CREST CONTOUR, ACRES
C
C           A          A          THE MEASURED SEGMENT AREA OF THE
C                                 RESERVOIR, ACRES
C
C           El         E2         THE CROSS-SECTIONAL AREA OF WATER
                                  ALONG THE DOWNSTREAM RANGE OF THE
```

```
C                                      SEGMENT FOR A SURVEY YEAR, SQ. FEET
C
C         E2         E1               THE CROSS-SECTIONAL AREA OF WATER
C                                      ALONG THE UPSTREAM RANGE OF THE
C                                      SEGMENT FOR A SURVEY YEAR, SQ. FEET
C
C         W1          W2              THE WIDTH OF THE DOWNSTREAM CROSS
C                                      SECTION, FEET
C
C         W2          Wl              THE WIDTH OF THE UPSTREAM CROSS
C                                      SECTION, FEET
C
C      H3,H4,...      H3              THE PERPENDICULAR DISTANCE FROM THE
C                                      RANGE ON A TRIBUTARY TO THE JUNCTION
C                                      OF THE TRIBUTARY ON THE MAIN STREAM;
C                                      OR IF THIS JUNCTION IS OUTSIDE THE
C                                      SEGMENT, TO THE POINT WHERE THE
C                                      THALWEG OF THE TRIBUTARY INTERSECTS
C                                      THE DOWNSTREAM RANGE, FEET
C
C
C
C
C     THE HISTORY OF THE LAKE SURVEYS IS DESCRIBED BY THE FOLLOWING
C     VARIABLES WHICH SERVE AS THE BASIC PROGRAM PARAMETERS:
C
C        TOTSEG— THE TOTAL NUMBER OF SEGMENTS USED IN THE VOLUME
C                CALCULATION
C
C        TOTYR— THE NUMBER OF YEARS FOR WHICH SURVEY DATA WILL BE
C               SUPPLIED
C
C
      READ(IN,106)TOTSEG
      READ(IN,106)TOTYR
C
C
C
C     BASIC PHYSICAL PARAMETERS ARE READ IN TO DESCRIBE THE LAKE CROSS
C     SECTIONS AND SEGMENTS. THESE PARAMETERS ARE CONSIDERED TO BE
C     NON-VARIABLE IN THIS PROGRAM. CONDITIONS IN OTHER LAKES MAY
C     INVALIDATE THIS ASSUMPTION. THESE PARAMETERS ARE, W, A, APRIME,
C     TPUW, AND BTMUW. TPUW AND BTMUW ARE THE UNIT WEIGHTS FOR THE TOP
C     ONE FOOT OF SEDIMENT AND THE REMAINING BOTTOM LAYER OF SEDIMENT
C     RESPECTIVELY.
C
C
C
      READ(IN,108) W(l)
```

```
      DO 5 NSEG=2,T0TSEG
         READ(IN,107)A(NSEG),APRIME(NSEG),W(NSEG),TPUW(NSEG),BTMUW(NSEG)
    5 CONTINUE
C
C
C
C     FOR EACH SURVEY YEAR(NYR) DATA ARE INPUT FOR CALCULATING EACH
C     SEGMENT VOLUME AND THE CALCULATION IS MADE.
C
C
C
      DO 10 IYR=l,TOTYR
         READ(IN,106)NYR
         READ(IN,100)ISEG,E1,ICOMP,H3
         DO 11 NSEG=2,T0TSEG
            E2=E1
C
C
C
C     ICOMP IS USED TO DESCRIBE COMPLICATED SEGMENTS WHICH ARE EITHER THE
C     FIRST SEGMENT OF A TRIBUTARY BRANCH OR AN END SEGMENT WHICH IS
C     DEFINED BY ONLY ONE CROSS SECTION. IN THIS CASE, CALCULATIONS TAKE
C     PLACE IN THE SECOND AND THIRD IF STATEMENTS. SINCE RESERVOIRS END
C     WITH A TRIBUTARY, THERE WILL BE NO UPSTREAM CROSS SECTION FOR THE
C     FINAL SEGMENT. THE PROGRAM INSERTS A NEGATIVE NUMBER IN ICOMP.
C
C
C
            IF(NSEG.EQ.TOTSEG)THEN
              ICOMP=(-l)
              ISEG=NSEG
              NSEGM1=ISEG-1
              GO TO 8
            ENDIF
C
C
C
C     THE SEGMENT NUMBER, CROSS-SECTIONAL AREA, ICOMP, AND H3 ARE READ IN.
C
C
C
            READ(IN,100)ISEG,E1,ICOMP,H3
            ISEG=ISEG+1
            NSEGP1=ISEG+1
            NSEGM1=ISEG-1
C
C
C
C     ICOMP CAN HAVE THREE TYPES OF VALUES:
C     ______IF ICOMP IS GREATER THAN OR EQUAL TO ZERO,THE SEGMENT VOLUME
```

```
C          IS CALCULATED USING THE STANDARD TWO CROSS SECTION FORMULA
C          PRESENTED ABOVE.
C
C
C
    8        IF(ICOMP.GE.O) THEN
               V0L(ISEG,IYR)=((APRIME(ISEG)/3.)*(E1+E2
     $        )/(W(ISEG)+W(NSEGMl)))+((A(ISEG)/3.)*(El/W(ISEG)+
     $       E2/W(NSEGM1)))
C
C
C
C     ----IF ICOMP IS NEGATIVE,THE SEGMENT OCCURS AT THE UPSTREAM END OF
C         THE MAIN BODY OF THE LAKE OR OF A TRIBUTARY BRANCH. THIS VOLUME
C         WILL BE CALCULATED USING ONLY ONE CROSS SECTION.
C
C
C
             ELSE IF(ICOMP.LT.O) THEN
               VOL(ISEG,IYR)=((APRIME(ISEG)+A(ISEG))/3.0)*E2/W(NSEGM1)
            ICOMP=ICOMP*(-l)
            ENDIF
C
C
C
C     ----IF ICOMP IS NON-ZERO AND AN H3 VALUE IS GIVEN, THE SEGMENT IS
C         THE FIRST SEGMENT OF A TRIBUTARY BRANCH AND THE VOLUME:
C
C               H3* E2/130680
C
C         IS ADDED INTO THE SEGMENT REPRESENTED BY THE ABSOLUTE VALUE
C         OF ICOMP.
C
C
C
            IF(ICOMP.NE.0)THEN
            IC0MP=IC0MP+1
            VOL(ICOMP,IYR)=VOL(ICOMP,IYR)+H3*E2/1306 80
            ENDIF
   11       CONTINUE
   10       CONTINUE
C
C
C
C     FOR EACH SURVEY YEAR,THE TOTAL VOLUME OF THE RESERVOIR IS
C     DETERMINED BY SUMMING THE SEGMENTAL VOLUMES FOR THAT SURVEY YEAR.
C             TOTVOL - AN ARRAY WHICH WILL RECIEVE THE TOTAL
C                VOLUME OF WATER CONTAINED IN THE RESERVOIR
C                FOR EACH YEAR A SURVEY WAS CONDUCTED.
C
```

```
C
C
      DO 14 IYR=l,TOTYR
      DO 15 NSEG=2,TOTSEG
            TOTVOL(IYR)=TOTVOL(IYR)+VOL(NSEG,IYR)
   15 CONTINUE
   14 CONTINUE
C
C
C
C     THE SUBROUTINE WGHT WILL CALCULATE THE VOLUME AND WEIGHT OF SEDIMENT
C     IN EACH SEGMENT AS WELL AS THE TOTAL WEIGHT ACCUMULATED IN THE
C     RESERVOIR.TO CALCULATE THE WEIGHT USING ONLY ONE UNIT WEIGHT, TPUW
C     SHOULD BE REPLACED BY BTMUW IN THE CALL STATEMENT.
C
C
C
      DO 12 IYR=2,TOTYR
      DO 13 NSEG=2,TOTSEG
         CALL WGHT (VOL(NSEG,l),VOL(NSEG,IYR),A(NSEG),BTMUW(NSEG),
     $TPUW(NSEG),NSEGM1,SEDVL,WGT,NSEG,IYR,TOTWGT(IYR))
C
C
C
C
  13     CONTINUE
           TOTSD(IYR)=TOTVOL(1)-TOTVOL(IYR)
  12  CONTINUE
C
C
C
C     OUTPUT AND FORMAT STATEMENTS
C
C
C
      WRITE(IOUT,215)
      WRITE(IOUT,216)
      WRITE(IOUT,217)
      WRITE(IOUT,218)
      DO 22 NSEG=2,TOTSEG
         NSEGM1=NSEG-1
         WRITE(IOUT,214)NSEGMl,(VOL(NSEG,IYR),IYR=l,TOTYR)
   22 CONTINUE
      WRITE(IOUT,223)
      WRITE(I0UT,221)(T0TV0L(IYR),IYR=1,T0TYR)
      WRITE(I0UT,224)
C
C
C
      WRITE(I0UT,219)
```

```
     $NSEG,IYR,TOTWGT)
      DIMENSION SEDVL(101,6),WGT(101,6)
C
C           OLDVL -IS THE VOLUME OF WATER IN THE SEG
C              MENT NSEG DURING 1922.
C
C
C           PRESVL - IS THE VOLUME OF WATER IN THE SEG-
C              NSEG DURING IYR.
C
C
C           AREA - IS THE SURFACE AREA OF NSEG.
C
C
C           BTMUW - IS THE DEEPER UNIT WEIGHT OF SEDI-
C              MENT IN NSEG.
C
C
C           TPUW - IS THE UPPER UNIT WEIGHT OF SEDI-
C              MENT IN NSEG.
C
C
C
C
C              THE SEDIMENT VOLUME IS CALCULATED.
C
C
C
C
         SEDVL(NSEG,IYR)=OLDVL-PRESVL
C
C
C
C              IF THE SEDIMENT VOLUME IS LESS THAN
C           THE SEGMENT'S AREA THEN THE SEDIMENT
C           VOLUME IS MULTIPLIED BY THE TOP UNIT
C           IN ORDER TO CALCULATE THE SEGMENT'S
C           SEDIMENT WEIGHT.
C
C
C
         IF(SEDVL(NSEG,IYR).GT.AREA)THEN
            WGT(NSEG,IYR)=(SEDVL(NSEG,IYR)-AREA)*BTMUW
            WGT(NSEG,IYR)=(TPUW*AREA)+WGT(NSEG,IYR)
         ELSE
            WGT(NSEG,IYR)=SEDVL(NSEG,IYR)*BTMUW
         ENDIF
            WGT(NSEG,IYR)=(WGT(NSEG,IYR)*43560.0/2000.0)/1000.0
      TOTWGT=TOTWGT+WGT(NSEG,IYR)
      RETURN
      END
```

```
      WRITE(I0UT,225)
      WRITE(I0UT,213)
      WRITE(IOUT,210)
      WRITE(I0UT,212)
      DO 17 NSEG=2,TOTSEG
         NSEGM1=NSEG-1
         WRITE(IOUT,211)NSEGMl,(SEDVLCNSEG,IYR),WGT(NSEG,IYR),IYR=2,
     $TOTYR)
   17 CONTINUE
      WRITE(I0UT,223)
      WRITE(IOUT,222)(TOTSD(IYR),TOTWGT(IYR),IYR=2,TOTYR)
      WRITE(I0UT,224)
C
C
C
C
  211 FORMAT(/2X,I3,6X,F8.2,2X,F8.2,4C4X,F8.2,2X,F8.2))
  213 FORMATC                    1936                  1946
     $    1956                   1966                  1983')
  210 FORMATC SEGMENT   SEDIMENT  SEDIMENT    SEDIMENT  SEDIMENT    SED
     $IMENT  SEDIMENT    SEDIMENT  SEDIMENT    SEDIMENT  SEDIMENT')
  219 FORMAT('1'//)
  212 FORMAT(NUMBER     VOLUME    WEIGHT      VOLUME    WEIGHT      VO
     $LUME    WEIGHT      VOLUME    WEIGHT      VOLUME    WEIGHT')
  214 FORMAT(/2X,I3,8X,F8.2,5(5X,F8.2))
  215 FORMAT('l'//36X,'LAKE DECATUR'//42X,'WATER VOLUME IN ACRE FEET.'/)
  216 FORMAT(//8X,6(5X,'********'))
  217 FORMATC/' SEGMENT',7X,'1922',9X,'1936',9X,'1946',9X,'1956',9X,'196
     $6',9X,'1983')
  218 FORMAT(' NUMBER ' ,6(5X, '********'))
  221 FORMAT(/' SUBTOTAL',4X,F8.2,5(5X.F8.2))
  222 FORMAT(/'  SUBTOTAL',1X,F8.2,2X,F8.2,4(4X,F8.2,2X,F8.2))
  223 FORMAT(/' *************')
  224 FORMAT(/'          *****************************************************
     $**********************************************************')
  225 FORMAT(/36X,'ACCUMULATED SEDIMENT'//42X,'WEIGHT IN KILOTONS'/42X,'
     $VOLUME IN ACRE FEET'//)
  106 FORMAT(I4)
  100 F0RMAT(2X,I2,40X,F13.2,I4,F5.0)
  107 FORMAT(43X,F7.2/43X,F7.2/20X,F8.2/20X,F8.2,14X,F8.2)
  108 FORMAT(20X,F7.2)
      END
C
C
C
C
C
C
C
C
      SUBROUTINE WGHT (0LDVL,PRESVL,AREA,BTMUW,TPUW,NSEGM1,SEDVL,WGT,
```