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Sedimentation Survey of Highland Silver Lake, Madison County, Illinois

by

William C. Bogner

Prepared for
The City of Highland

March 2001

Illinois State Water Survey
Watershed Science Section
Champaign, Illinois

A Division of the Illinois Department of Natural Resources

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Abstract

Sedimentation detracts from the use of any water supply lake by reducing lake depth and volume, with a reduction of reserve water supply capacity and possible burying of intake structures. Sedimentation of a reservoir is a natural process that can be accelerated or slowed by human activities in the watershed.

Silver Lake is located in Madison County, one mile northwest of Highland, Illinois. The location of the dam is 38° 46’ 00” north latitude and 89° 42’ 05” west longitude in Section 30, T.4N., R.5W., Madison County, Illinois. The dam impounds the East Fork of Silver Creek, a tributary of Silver Creek in the Kaskaskia River basin. The watershed is a portion of Hydrologic Unit 07140204 as defined by the U.S. Geological Survey. Construction of the lake was completed in 1962. The Silver Lake watershed consists of the 47.1-square-mile area drained by the East Fork of Silver Creek above the dam site.

Land use in the watershed of the lake is mainly agricultural. Average annual precipitation in the area is 38.98 inches as measured at Greenville (1961-1990), and the average runoff (1912-1998) is approximately 10.0 inches (Shoal Creek near Breese). The average annual lake evaporation rate is 35.2 inches per year at St. Louis, Missouri.

The Illinois State Water Survey conducted sedimentation surveys of Silver Lake in 1981 and 1984. In 1981, cross sections were laid out at 14 lines across the lake and surveyed. Sedimentation surveys of Silver Lake in 1984 and 1999 repeated as closely as possible the series of survey lines established during the 1981 survey.

Sedimentation has reduced the capacity of Silver Lake from 7,322 acre-feet or ac-ft (2,386 million gallons) in 1962 to 5,832 ac-ft (1,900 million gallons) in 1999. The sediment accumulation rates in the lake have averaged 40.3 ac-ft per year from 1962-1999. Annual sedimentation rates for three separate periods, 1962-1981, 1981-1984, and 1984-1999, were 51.2, 63.0, and 21.9 ac-ft, respectively.

Density analyses of the sediment samples indicate that sediment in the northern (upstream) portions of the lake has greater unit weight than sediment in the southern end of the lake. In general, coarser sediments are expected to be deposited in the upstream portion of a lake where the entrainment velocity of the stream is reduced to the much slower velocities of a lake environment. These coarser sediments tend to be denser when settled and are subject to drying and higher compaction rates as a result of more frequent drawdown exposure in the shallow water environment. As the remaining sediment load of the stream is transported through the lake, increasingly finer particle sizes and decreasing unit weight are observed.

The sedimentation rate for Highland Silver Lake is similar to the rates for other Illinois lakes of similar size and character. The sedimentation rate for Silver Lake is in the low to average range compared to other Illinois lakes.

Sedimentation Survey of Highland Silver Lake, Madison County, Illinois

Introduction

The Illinois State Water Survey (ISWS), in cooperation with the City of Highland, Illinois, conducted a sedimentation survey of Highland Silver Lake during the fall of 1999. The survey was undertaken to provide information on the storage and sedimentation conditions of the lake. Highland Silver Lake is owned and operated by the city. The city withdraws water from the lake as the sole raw water source of the public water supply for the community.

Sedimentation detracts from the use of any water supply lake by reducing lake depth and volume, with a reduction of reserve water supply capacity and possible burying of intake structures. Sedimentation of a reservoir is a natural process that can be accelerated or slowed by human activities in the watershed. In general, sedimentation of a lake is presumed to be accelerated unintentionally as a secondary impact of other developments within the watershed. For example, construction and agricultural activities in a lake watershed generally are found to increase sediment delivery to the lake due to increased exposure of soil material to erosive forces.

Reductions of the sedimentation rate in a lake due to human impacts almost always are the result of programs intentionally designed to reduce soil and streambank erosion, and they are often the result of implementing lake remediation programs. These programs might include, but are not limited to, the implementation of watershed erosion control practices (such as reduced tillage and other farming or development practices), streambank and lakeshore stabilization, stream energy dissipaters, and lake dredging.

Sedimentation of a reservoir is the final stage of a three-step sediment transport process. The three steps are watershed erosion by sheet, rill, gully, and/or streambank erosion; sediment transport in a defined stream system; and deposition of the sediment, which reduces stream energy such that the sediment can no longer be transported either in suspension or as bed load. Sediment deposition can occur throughout the stream system.

Lake sedimentation occurs when sediment-laden water in a stream enters the reduced flow velocity regime of a lake. As water velocity is reduced, suspended sediment is deposited in patterns related to the size and fall velocity of each particle. During this process, soil particles are partially sorted by size along the longitudinal axis of the lake. Larger and heavier sand and coarse silt particles are deposited in the upper end of the lake; finer silts and clay particles tend to be carried further into the lake.

Several empirical methods for estimating sedimentation rates in Illinois have been developed (ISWS, 1967; Upper Mississippi River Basin Commission, 1970; Singh and Durgunoglu, 1990). These methods use regionalized relationships between watershed size and lake sedimentation rates. As estimates, they serve well, within limits. A more precise measure of the sedimentation rate is provided by conducting a sedimentation survey of the reservoir. A sedimentation survey provides detailed information on distribution patterns within the lake and defines temporal changes in overall sedimentation rates.

Acknowledgments

The project was funded by the City of Highland. Dick Aten was project manager. Steve Shultz and Kevin Kehrer assisted with monument recovery.

This project was conducted by the author as part of his regular duties at the Illinois State Water Survey under the administrative guidance of Derek Winstanley, Chief, and Manoutchehr Heidari, Acting Head, and Mike Demissie, Head of the Watershed Science Section. Richard Allgire and K. Erin Hessler Bauer assisted with the field data collection. Yi Han analyzed the sediment samples. Don Roseboom and Shun Dar Lin provided technical review. Eva Kingston edited the report. Linda Hascall reviewed the graphics.

Lake Information

Silver Lake (figure 1) is located in Madison County, one mile northwest of Highland, Illinois. The location of the dam is 38° 46’ 00” north latitude and 89° 42’ 05” west longitude in Section 30, T.4N., R.5W., Madison County, Illinois. The dam impounds the East Fork of Silver Creek, a tributary of Silver Creek in the Kaskaskia River basin. The watershed is a portion of Hydrologic Unit 07140204 as defined by the U.S. Geological Survey (USGS, 1988).

Reservoir and Water Supply History

The earliest Water Survey file report on water supply or sewerage conditions in Highland is dated March 31, 1912. This report was prepared by Ralph Hilscher on the basis of a town visit on February 6, 1912. The following history has been prepared using Mr. Hilscher’s and later reports. Mr. Hilscher’s observations were that the town had no public water supply or sewage system. Household water was obtained from private, dug wells generally in the range of 20 to 40 feet deep. Mr. Hilscher considered these wells to be highly susceptible to contamination but noted that there had been no major outbreaks of typhoid although 12 cases had been diagnosed during the period 1907 to 1912 and resulted in three deaths. In about 1910 (two years prior to the 1912 visit) the city had contracted with an engineering firm to evaluate potential public water supply options for the community. The engineer’s report recommended the construction of an impounding reservoir north of town, a water works, and distribution system. This plan was not approved by the voters.

Water for fire fighting was available from a series of cisterns located every few blocks in town. Water for street sprinkling was collected in a cistern and distributed through town by a piping system. These systems were not used for household purposes.

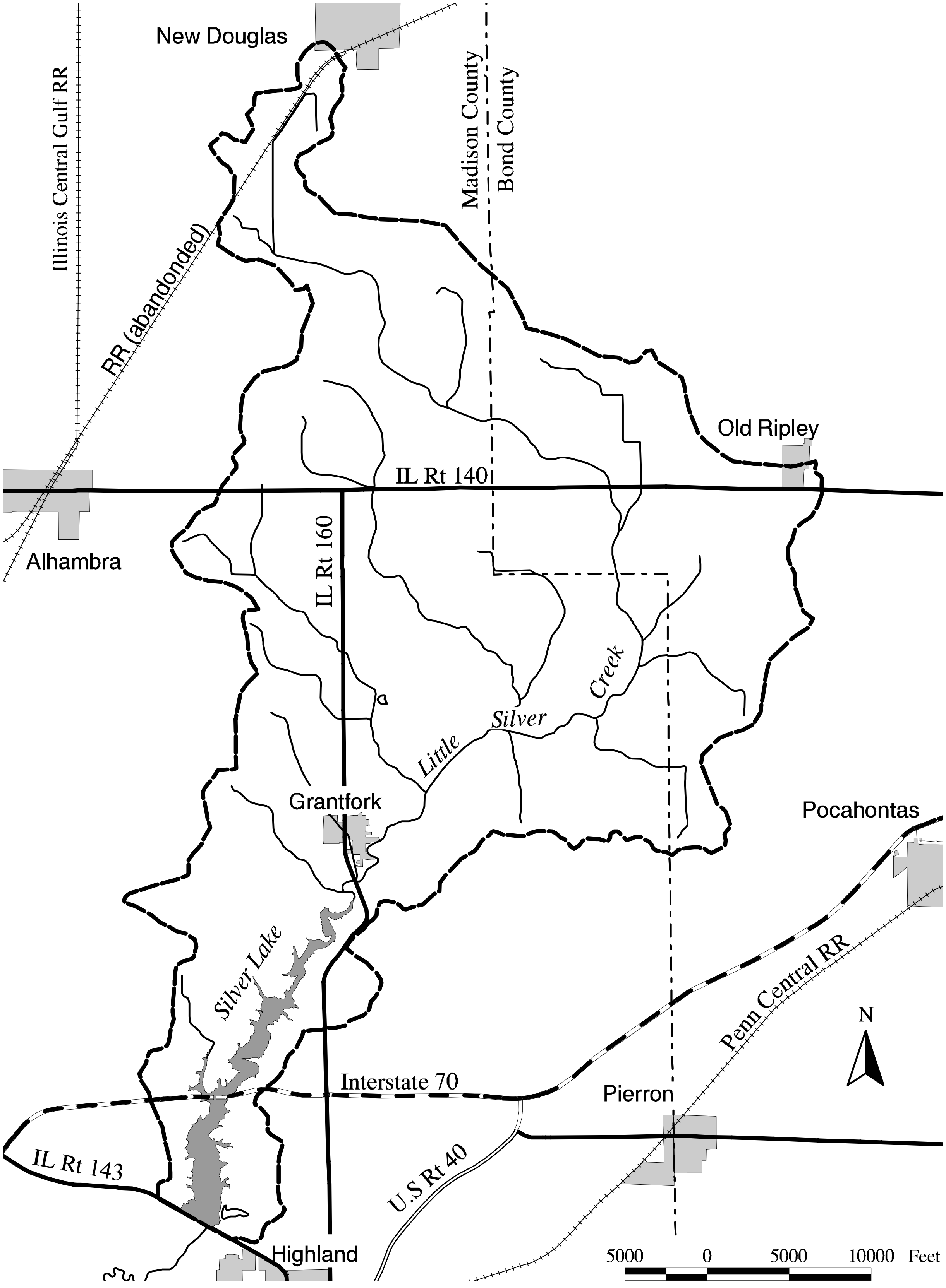


Figure 1. Location and watershed delineation for Silver Lake

The two major industries in town were a brewery and a condensed milk factory. In about 1902, these companies combined forces to build two small ponds north of town. Following the defeat of the public water supply initiative, these two companies again combined resources and constructed an impoundment at the site of the old city reservoir. This lake was partially fed by springs in the watershed. This lake with the previously constructed ponds and occasional withdrawals from the East Branch of Silver Creek provided sufficient water for the operation of both businesses.

Over the next 20 years, several other potential reservoir sites and ground-water supplies were investigated. The reservoir sites generally were not well suited to construction of an adequate reservoir. Local ground-water conditions were not conducive to development as a source of supply. Any aquifers potentially having adequate water to develop were too highly mineralized to treat economically.

A 1923 ISWS file report notes that the brewery was then a soft drink manufacturer, and the condensed milk company was shipping whole milk. There had been no change in public water supply conditions. The pump station for withdrawing water from the creek had silted in, and sewerage was becoming a significant concern.

The Highland public water supply system was installed in 1925. No direct information about this system was available in ISWS file reports It appears that the city purchased the brewery/milk plant reservoir and installed a water works plant and distribution system.

At the time of a May 11, 1944 file report, the city was providing water using the old lake as a pump storage reservoir for water taken from the creek. The report estimated that only one-third of the water supply came from the direct watershed of the lake and two-thirds were taken from the creek.

During the early 1950s, southern Illinois experienced a severe and prolonged period of drought. Several file reports available from this period indicate that the lake level was being maintained by pumping water from the creek. Several emergency measures were implemented:

- Hauling 726 truckloads or 3.25 million gallons of water (August 1954).
- Installing a pump from what remained of the lake to the intake structure.
- Bringing in additional pump capacity to move water from the creek to the lake.
- Excavating a channel to intercept spring flow from sites south of Route 143.

In September 1954, with one Hammond, Indiana Civil Defense 1,500-gallon-per-minute (gpm) pump, a used 1,500 gpm pump from Breese, and existing pumping capacity, 6,800 gpm of pump capacity was available to intercept water from the creek and divert it into the reservoir. Water use had been reduced to about one-half of the pre-drought conditions.

The first indication of action to construct the new lake is in a 1954 water plant inspection report. Review of aerial photography taken in Spring 1962 indicates that the lake was just starting to fill. Inspection reports indicate that the lake was in use in September 1962.

Highland became a regional water supplier when bulk water connections were made to Pierron in Bond County (1972), Grant Fork (1975), and St. Jacob's (about 1980). An automatic pressure valve controls the St. Jacob's connection which supplements an existing well supply.

From 1981 to 1986, the Silver Lake watershed was selected as one of 13 experimental Rural Clean Water Program sites. The watershed was also selected as one of five of the 13 watersheds for a comprehensive monitoring and evaluation program under the direction of the Agricultural Stabilization and Conservation Service of the U.S. Department of Agriculture. As part of the monitoring program, sedimentation surveys were conducted for the lake in 1981 and 1984.

Watershed

The Silver Lake watershed consists of the 47.1-square-mile area drained by the East Fork of Silver Creek above the dam site (figure 1). The highest point in the watershed is at an elevation of 640 feet National Geodetic Vertical Datum or NGVD (southeast of New Douglas), and the normal pool elevation of the lake is 500.0 feet NGVD.

Land use in the watershed of the lake is mainly agricultural. Average annual precipitation in the area is 38.98 inches as measured at Greenville (1961-1990), and the average runoff (1912-1998) is approximately 10.0 inches (Shoal Creek near Breese). The average annual lake evaporation rate is 35.2 inches per year at St. Louis, Missouri, the closest available station (Roberts and Stall, 1967).

The upland soils in the watershed are in the Virden-Piasa-Darmstadt Association (USDA-SCS, 1986). These soils are nearly level to moderately sloping and may have some drainage problems due in part to the poor permeability of the subsoil. This association is usually formed in loess on broad, upland plains originally covered by prairie grasses. Slopes range from 0 to 8 percent.

Soils in stream depressions are in the Hickory-Elco-Rosetta Association (USDA-SCS, 1986). These soils are moderately sloping to steep and generally well drained. Subsoils have moderately slow permeability. These soils formed in glacial till, loess, and loess over an older buried soil on valley side slopes and in narrow upland ridges. The original soils formed mainly under deciduous forest cover. Slopes range from 5 to 30 percent.

Lake Sedimentation Surveys

The ISWS conducted sedimentation surveys of Silver Lake in 1981 (Bogner, 1982) and 1984 (Makowski et al., 1986). In 1981, cross sections were laid out at 14 lines across the lake and surveyed. During the 1984 and 1999 surveys, these survey lines were resurveyed to define temporal changes in lakebed topography. During the 1984 survey, the range ends were monumented by installing 4-inch by 4-inch concrete posts to mark the transect ends. The 1999 sedimentation survey of Silver Lake (figure 2) repeated as closely as possible the series of survey lines established during the 1981 survey.

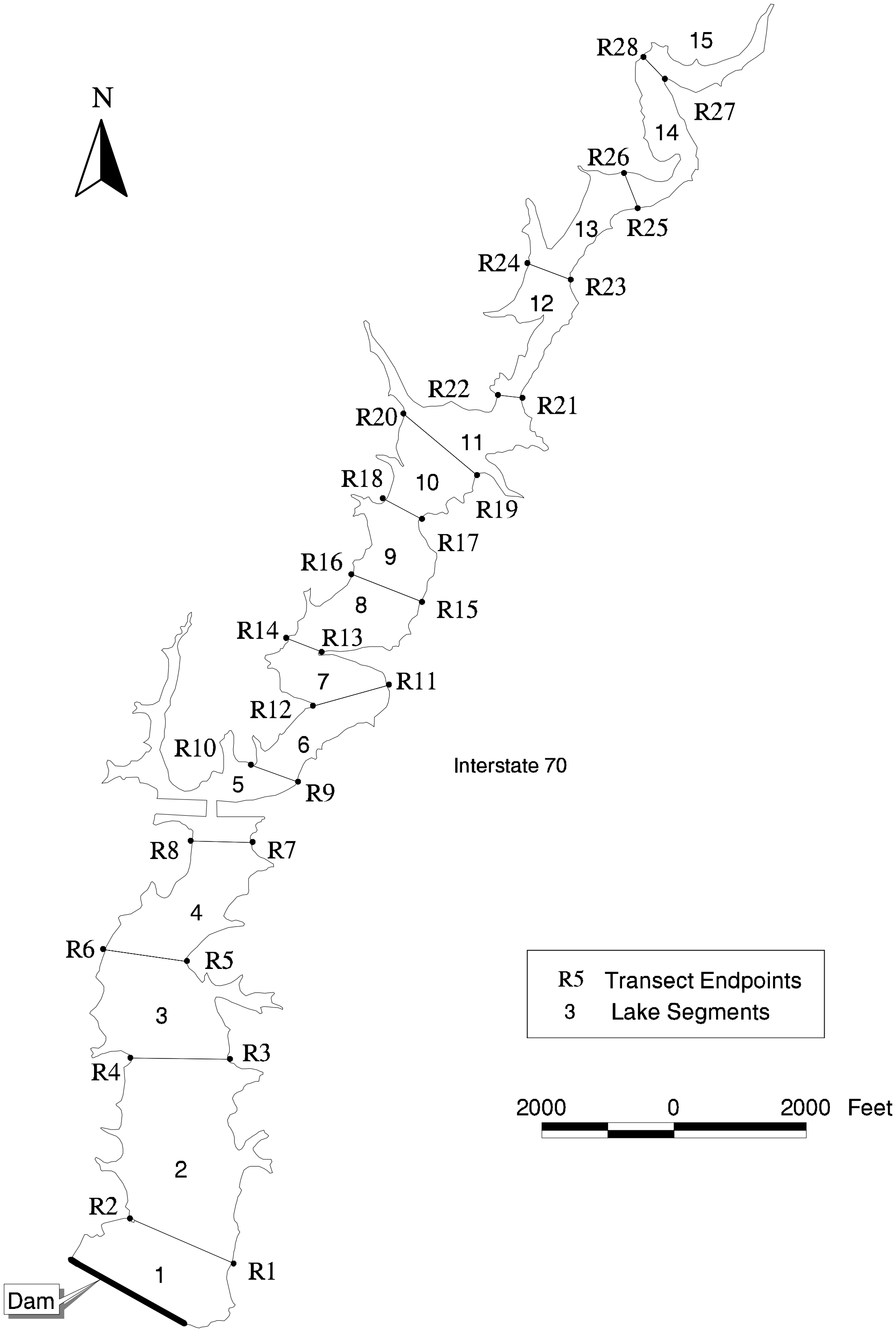


Figure 2. Survey plan for Silver Lake, 1999

For the 1981 and 1984 sedimentation surveys, horizontal distances along the cross-sectional transects were measured by stretching a marked polyethylene cable between corresponding range end monuments. Water depth (vertical control) was referenced to the water surface, and all depth data were adjusted to the spillway crest elevation. Depth measurements were made using an aluminum sounding pole lowered to the top of the sediment surface to measure the existing water depth. The pole was then used to probe to the original bottom as determined by the initial point of resistance to the sediment probe.

The 1999 survey was conducted using an Odom Hydrographic Systems MK II fathometer for depth measurement and a differentially corrected Leica 9600 System Geodetic Position System (GPS) for horizontal control across the transect. All navigation and data logging functions were controlled using Hypack, a hydrographic survey software. The GPS positions were differentially corrected using Radio Technical Commission for Maritime Services (RTCM) correction signals broadcast by the U.S. Coast Guard from St. Louis, Missouri.

The fathometer was calibrated daily prior to initiating measurements. Calibration checks at the end of most work days showed daily variations of 0.1-0.2 feet in a profile at one-foot depth intervals. For each main lake cross section, three to seven physical measurements of the water depth and sediment thickness were made with an aluminum sounding pole. The three upstream cross sections in the lake were resurveyed in 1999 with the traditional cable and pole method due to shallow depths.

Plots of all cross sections surveyed from 1981, 1984, and 1999 are presented in appendix I. For comparison, the 1999 pole measurements also are plotted in appendix I as point data. These water-depth measurements with the pole show a close correspondence with the 1999 depth sounder readings. Comparison of the original lake depth for the 1999 pole readings to the full cross-sectional data collected for the 1981 and 1984 surveys shows a good match for most measurements made.

Lake Basin Volumes

Calculations of the lake capacities were made using methods described in *the National Engineering Handbook* of the U.S. Soil Conservation Service (USDA-SCS, 1968). This method requires the surface area of the lake segments, the cross-sectional area and widths of their bounding segments, and a shape factor to determine the original and present volume of each segment. These volumes are then summed to determine the total lake volume. The reference elevation used for the lake was the top of the spillway, 500.0 feet NGVD. Table 1 presents the volume calculation results of the three surveys.

Sedimentation has reduced the basin capacity from 7,322 acre-feet (ac-ft) in 1962 to 5,832 ac-ft in 1999. The 1999 basin capacity was 79.4 percent of the 1962 potential basin capacity. For water supply purposes, these volumes convert to capacities of 2,386 million gallons in 1962 and 1,900 million gallons in 1999. The capacity of the lake in 1981 was 6,349 ac-ft (2,069 million gallons), and 6,160 ac-ft (2,007 million gallons) in 1984.

Table 1. Reservoir Capacity and Capacity Loss Analysis

Period	*Capacity*	*Capacity loss for period*	*Cumulative capacity loss*	*Period annual capacity loss rate*	*Cumulative annual capacity loss rate*
a) Analysis in units of acre-feet					
1962	7,322				
1962-1981	6,349	973	973	51.2	51.2
1981-1984	6,160	189	1,162	63.0	52.8
1984-1999	5,832	328	1,491	21.9	40.3
b) Analysis in units of million gallons					
1962	2,386				
1962-1981	2,069	317	317	17	17
1981-1984	2,007	62	379	21	17
1984-1999	1,900	107	486	7	13

Note: Lake surface area was 600 acres for 1999.
Capacity shown is for the sedimentation survey conducted at the end of the period.

The 1999 water depths for the lake were used to generate the bathymetric map in figure 3 and the volume distribution curve data in figure 4. Figure 4 can be used to determine the capacity of the reservoir below a given stage elevation. For example, the water volume below the 4-foot depth contour (shown by the dashed line in figure 4) is 3,869 ac-ft. With time and continued sedimentation, the relationships shown in figure 4 will become obsolete. Alteration of the spillway elevation, or the implementation of a dredging program would likewise alter these relationships.

Sedimentation Rates

Sedimentation rates for Silver Lake were analyzed in terms of delivery rates from the watershed and accumulation rates in the reservoir. The watershed delivery processes and rates are the link between soil erosion processes in the watershed, sediment transport processes, and water supply quantity impacts in the reservoir. These delivery rates measure the actual sediment yield from the watershed, including reduced sediment transport due to field and in-stream redeposition. The delivery rate is determined by dividing the volume or mass of sediment deposited in the lake over a period of time by the length of the time period. This value is then divided by the area of the watershed and presented in a range of unit values.

The in-lake accumulation rate provides a means of extrapolating future lake conditions from past and present lake conditions in order to evaluate the integrity of the lake as a water supply source as well as a recreational resource. To determine the accumulation rate, the sediment deposition

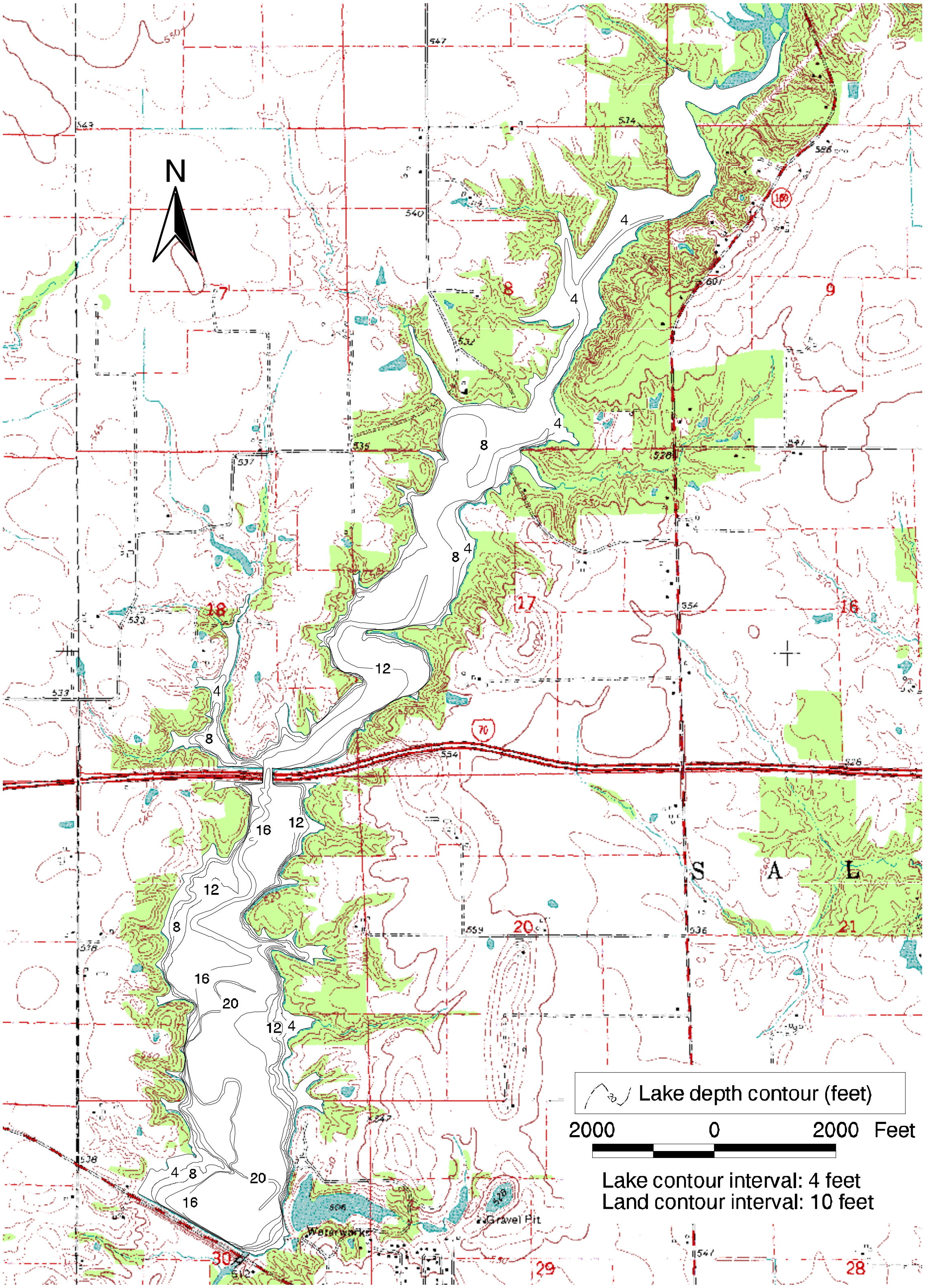
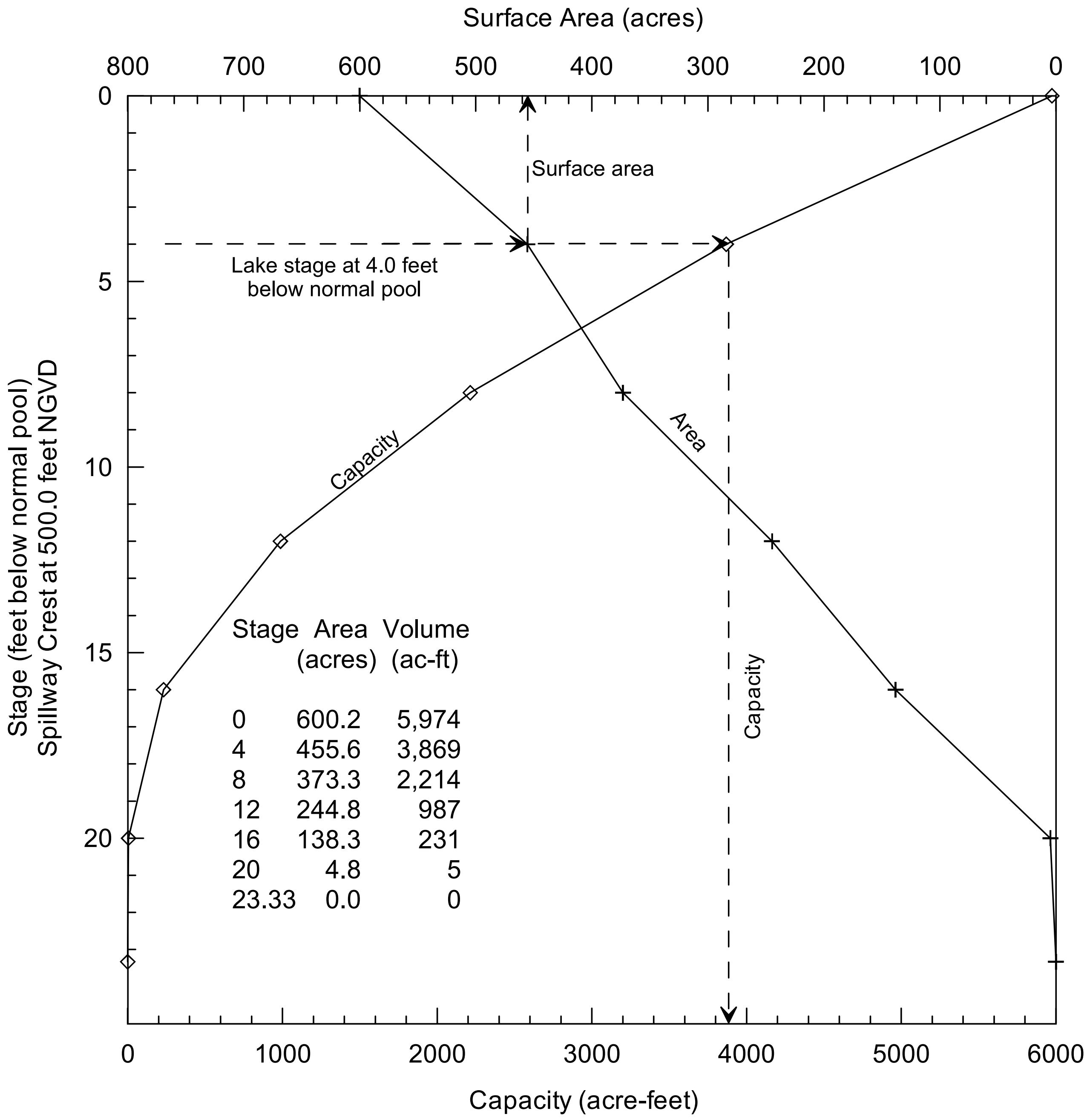


Figure 3. Bathymetric map of Silver Lake



Stage	Area (acres)	Volume (ac-ft)
0	600.2	5,974
4	455.6	3,869
8	373.3	2,214
12	244.8	987
16	138.3	231
20	4.8	5
23.33	0.0	0

Figure 4. Stage vs. volume vs. area relationship for Silver Lake, 1999

volume is divided by the original capacity of the reservoir and converted to a percent. This value is then divided by the time between surveys to convert it to a rate of capacity loss per year. This sedimentation rate is determined for each sedimentation period as well as cumulatively for the life of the reservoir.

Tables 2 and 3 provide the sedimentation rates for Silver Lake and its watershed for the periods 1962-1981, 1981-1984, 1984-1999, and 1962-1999. These rates indicate a decline in net sediment yield from the watershed from 51 ac-ft from 1962-1981 to 22 ac-ft annually from 1984-1999. The long-term average annual sediment yield from 1962-1999 was 40 ac-ft. These delivery rates show the need for continuing efforts to control watershed erosion, thereby reducing reservoir sedimentation rates.

Factors Affecting Lake Sedimentation Rates

Sedimentation rates in a lake can vary over time due to changes in either watershed or in-lake conditions. Changes in watershed conditions, such as altered precipitation patterns, land-use patterns, and streamflow variability, also affect the sediment delivery rates to the lake. In-lake conditions that also affect sedimentation rates involve the variation of trap efficiency (due to reduced storage capacity) and sediment consolidation.

Figure 5 shows representative streamflow values for the East Fork Shoal Creek near Coffeen from October 1963-September 1997 (USGS web page, 2000). The most important of these plots for analysis of lake sedimentation are the maximum flows and the average flows. High sediment transport rates are closely related to peak water discharge periods (Demissie et al., 1983; Bhowmik et al., 1993). The plots in figure 5 indicate that average flows for most months were higher during the 1981-1984 sedimentation study period for Silver Lake. Average flows for the 1962-1981 and 1984-1999 sedimentation periods were very similar on both a monthly and annual basis. This suggests that sediment delivery to the lake should be somewhat higher during the 1981-1984 survey period with the other two periods being very similar.

In contrast to the observations of the average flow characteristics, the monthly and annual peak discharges tend to be lower during the 1981 to 1984 period. In the case of peak flows, the 1984 to 1999 period shows a tendency to higher peak flows. This is particularly true for the late Spring and late Fall periods when row cropped fields would be most exposed. These higher peak flows would also be expected to indicate a higher potential soil loss rate.

Instead, sedimentation rates for the middle sedimentation period are somewhat higher, but the sedimentation rate for the latter (1984 to 1999) period is significantly less than the rate for either of the earlier periods. This suggests that other watershed conditions have been larger factors in determining Silver Lake sedimentation rates after 1984. This may indicate that the watershed treatment program implemented under the Rural Clean Water Program (1981-1986) was a positive influence on sediment delivery to the lake.

The results of this flow analysis should be treated cautiously due to the short time periods involved. This is particularly true of the 3-year time period for the 1981 to 1984 period. For the peak flow analysis for this period, three short-time frame values are included in this data set.

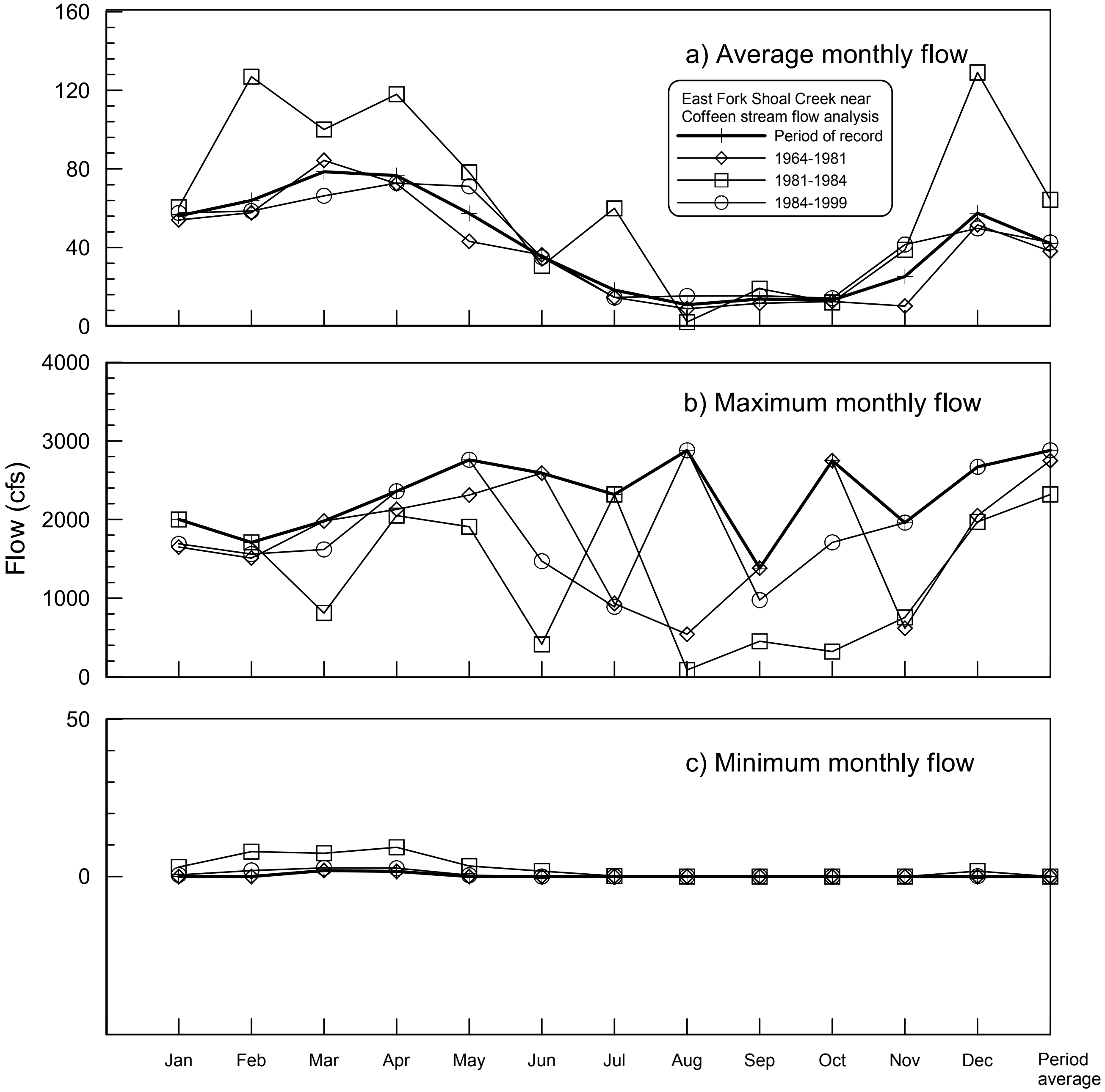
Table 2. Computed Sediment Delivery Rates from the Watershed for Each Sedimentation Period

	Annual deposition rates			
Period	*Acre-feet*	*Acre-feet per square mile*	*Cubic feet per acre*	*Tons per acre*
1962-1981	51	1.09	74.0	
1981-1984	63	1.34	91.0	
1984-1999	22	0.46	31.6	
1962-1999	40	0.86	58.2	1.19

Note: Total watershed area is 47.1 square miles.

Table 3. Capacity Loss Rates (percent) Relative to Original Lake Capacity

Period	*Per period*	*Cumulative*	*Period annual loss*	*Cumulative annual loss*
1962-1981	13.29	13.29	0.70	0.70
1981-1984	2.58	15.87	0.86	0.72
1984-1999	4.49	20.36	0.30	0.55
1962-1999	20.36	20.36	0.55	0.55



Note: Maximum and minimum lines and symbols for sub-periods are hidden when they are coincident with the period of record (heavier line) in the figure.

Figure 5. Comparison of a) average, b) maximum, and c) minimum monthly flow for the East Fork Shoal Creek near Coffeen for the three sedimentation periods (1964-1981, 1981-1984, and 1984-1999) and the full record of the station (1964-1999)

The trap efficiency (percentage portion of sediment captured by the reservoir) of the lake was determined using a predictive equation developed by Dendy (1974) based on the relationship between the annual capacity to inflow ratio and sediment-holding capacity. The trap efficiency of Silver Lake was 92.7 percent in 1962, meaning that 92.7 percent of all sediment entering the lake was trapped in the lake basin. In general, as sediment accumulation reduces the volume of the lake basin, the holding time for water entering the lake is reduced. This reduction in holding time means less time for sediment to drop out of suspension and a reduction in trap efficiency. Due to the large capacity of Silver Lake relative to the size of its watershed, the trap efficiency of the lake has not been significantly reduced. In 1999, the trap efficiency was 91.5 percent.

Gradual consolidation of lake sediments affects the calculated sedimentation rate of the lake by reducing the volume of accumulated sediments. Sediments accumulate on the bottom of the lake in a very loose, fluid mass. As these sediments are covered by continued sedimentation or are exposed by occasional lake drawdown, they are subject to compaction. This process reduces the volume of the sediments while increasing the weight per unit volume. Thus, the tonnage of the sediments accumulated during a period of time will not change, but the volume of the sediments may be reduced over time by up to 50 percent. This is also consistent with a reduced volumetric sedimentation rate over time. Consolidation of sediments would be most pronounced in the north end of Silver Lake. Some portions of the upper end of the lake are being exposed even at normal pool level. The exposure of sediment in these terrestrial deposits and the shallow water deposits that are subject to frequent exposure due to lake level drawdown would be consolidated on an annual basis.

Overall, sedimentation rates for Silver Lake were high for the initial periods (1962-1984) with a range of 74 to 91 cubic feet per acre per year. Sedimentation rates for the period 1984-1999 have been considerably lower.

Sediment Distribution

Table 4 shows the distribution of sediment in the lake. This table lists the average sediment thickness and mass distribution for the lake and for each lake calculation segment as shown in figure 2. Sediment thickness ranges from 1.9 to 4.1 feet. The most significant accumulation by either measure, depth or mass, is in segments 12 and 13 in the northern portion of the lake.

Density analyses of the sediment samples (appendix II) indicate that sediment in the northern (upstream) portions of the lake has greater unit weight than sediment in the southern end of the lake. In general, coarser sediments are expected to be deposited in the upstream portion of a lake where the entrainment velocity of the stream is reduced to the much slower velocities of a lake environment. These coarser sediments tend to be denser when settled and are subject to drying and higher compaction rates as a result of more frequent drawdown exposure in the shallow water environment. As the remaining sediment load of the stream is transported through the lake, increasingly finer particle sizes and decreasing unit weight are observed.

Sediment Particle Size Distribution

A total of 16 lakebed sediment samples were collected for particle size distribution analysis. Appendix III presents the laboratory analyses for these samples. Figure 6 A-C shows particle

Table 4. Sediment Distribution in Silver Lake

Segment from figure 2	*1962 volume (ac-ft)*	*1981 volume (ac-ft)*	*1984 volume (ac-ft)*	*1999 volume (ac-ft)*	*1999 sediment accumulation (ac-ft)*	*1999 sediment weight (tons)*	*1999 sediment thickness (feet)*	*1999 sediment per segment acre (tons)*
1	795	728	709	690	105	84,553	2.0	1,584
2	1,771	1,623	1,609	1,531	240	193,260	2.1	1,683
3	956	869	862	829	127	80,440	1.9	1,205
4	730	652	638	626	103	93,016	2.0	1,813
5	524	460	454	436	87	66,860	1.9	1,489
6	345	306	294	280	65	45,341	2.5	1,746
7	314	267	242	232	82	56,779	3.5	2,392
8	399	323	302	290	109	104,455	3.2	3,096
9	300	247	246	231	69	66,452	2.4	2,291
10	292	240	232	217	75	68,033	2.7	2,408
11	323	257	245	221	102	119,356	2.8	3,292
12	213	156	142	112	100	112,906	4.0	4,499
13	174	119	101	68	105	94,256	4.1	3,673
14	137	78	64	48	89	103,252	3.4	3,904
15	50	24	19	20	31	35,694	2.1	2,408
Totals	7,322	6,349	6,160	5,832				
Averages					1,491	1,324,652	2.5	2,207

Notes: Averages are whole lake averages, not column averages.

size distribution plots for samples collected from the top surface of the accumulated sediments. These samples show the tendency for sediment particle size to decrease from upstream to downstream in the lake. This reduction in deposited sediment particle sizes is consistent with all other Illinois impoundment lakes for which particle size distribution data are available. This trend in particle-size distribution is a result of the natural sorting of suspended sediments in the lake environment. Coarser sediments are deposited as the inflowing stream water is first slowed upon entering the lake. As water moves through the lake, the suspended sediments become finer as the coarser-sized fractions fall out of suspension. At the dam, the suspended sediments are predominantly composed of colloidal and organic materials.

All samples were composed of clay and silt sediment materials. This would be consistent with general observations concerning sediment distribution in Illinois lakes (Fitzpatrick et al., 1987; Bogner, 1986). These and other sources indicate that the occurrences of sand exceeding 10 percent are unusual for samples collected from lake sediment.

Two sets of samples (shown in figure 6D) were collected to analyze vertical variations in particle size distribution. These samples show a temporal trend toward coarser sediments in the surface layer at each sample site. This observation is also consistent with general trends in lake sediments. Surficial sediment, the most recently deposited sediment, tends to be coarser with time at a given point. This is due to the downlake shift in the initial depositional environment of the lake due to the loss of trap efficiency of the upper end of the lake. With time, the initial depositional zone in the lake will move further down the lake because of water volume loss to sedimentation.

Evaluation and Comparison to Other Illinois Lakes

The sedimentation rate for Highland Silver Lake is similar to the rates for other Illinois lakes of similar size and character. Table 5 presents comparative data for other selected Illinois lakes from ISWS lake sedimentation files and for Silver Lake. The sedimentation rate for Silver Lake is in the low to average range compared to the other lakes. The drainage areas of all of the other lakes in this list are also from rural watersheds.

Maintaining the water supply storage capacity of Silver Lake is essential for the maintenance of an adequate water supply for Highland. In addition to water supply, Silver Lake also provides a much needed water-based recreational resource for the Madison County area.

Capacity loss rate (0.55 percent per year) and watershed sediment yield rate (1.19 tons per acre) of the lake and its watershed over the 1962-1999 period are about average for Illinois impoundment lakes.

The capacity loss rate of 0.55 percent per year determined by this study is considerably lower than the values in the 1981 (0.70 percent per year) and 1984 (0.86 percent per year) reports.

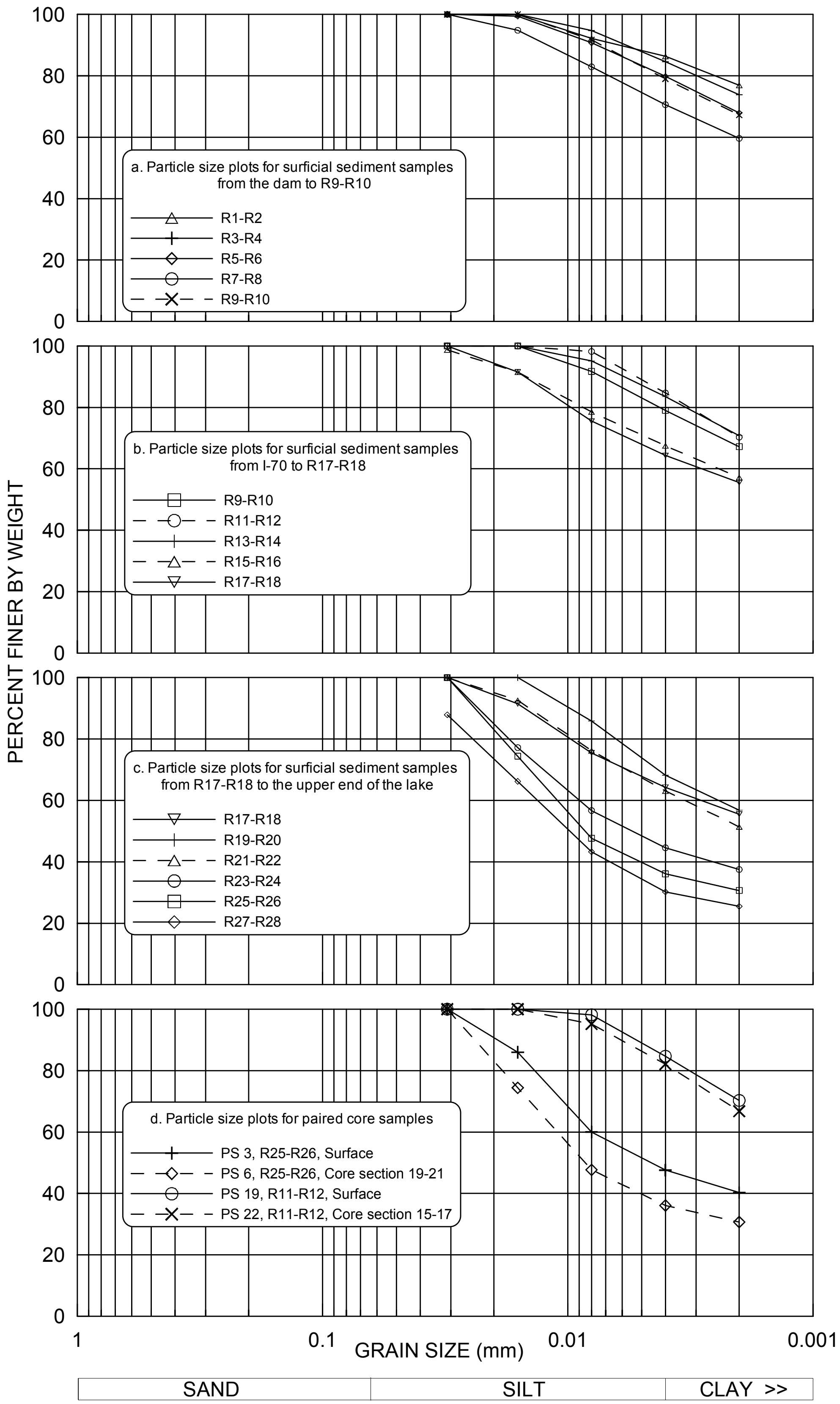


Figure 6. Particle size (PS) distributions for Silver Lake sediment samples

Table 5. Comparison of Highland Silver Lake and Other Illinois Lakes

Lake	*County*	*Survey year*	*Lake age (years)*	*Watershed area (sq. mi.)*	*As-built capacity (ac-ft)*	*Surveyed capacity (ac-ft)*	*Annual volume loss (percent)*
Otter Lake	Macoupin	1998	30	20.3	16,140	15,040	0.23
Lake Pittsfield	Pike	1992	31	11.1	3,563	2,679	0.80
Lake Taylorville	Christian	1977	15	131.3	9,410	7,920	1.06
Raccoon Lake	Marion	1993	50	48.6	5,580	4,090	0.53
Lake Springfield	Sangamon	1984	50	265	59,900	52,200	0.26
Lake Lou Yeager	Montgomery	1977	11	115	15,800	13,900	1.09
Silver Lake	Madison	1999	37	47.1	7,320	5,830	0.55

Notes: sq. mi. = square miles; ac-ft = acre-feet

Summary

The Illinois State Water Survey has conducted a sedimentation survey of Silver Lake in Highland, Illinois. The lake, originally constructed in 1962, is the raw water source for the Highland public water supply. Previous lake sedimentation surveys were conducted in 1981 and 1984. The operating elevation for the reservoir is 500.0 feet NGVD.

Sedimentation has reduced the capacity of Silver Lake from 7,322 ac-ft (2,386 million gallons) in 1962 to 5,832 ac-ft (1,900 million gallons) in 1999. The sediment accumulation rates in the lake have averaged 40.3 ac-ft per year from 1962-1999. Annual sedimentation rates for three separate periods, 1962-1981, 1981-1984, and 1984-1999 were 51.2, 63.0, and 21.9 ac-ft, respectively.

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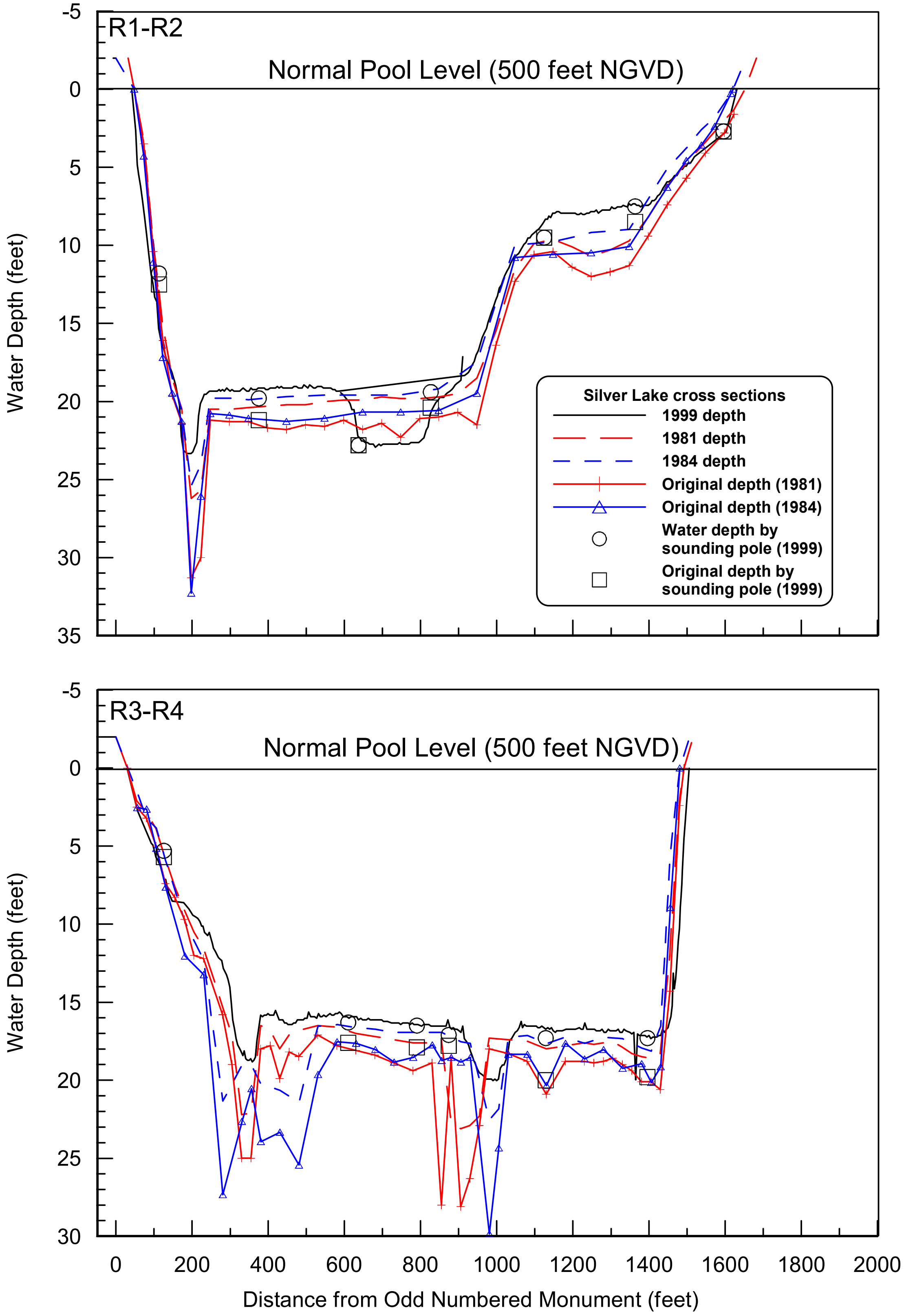
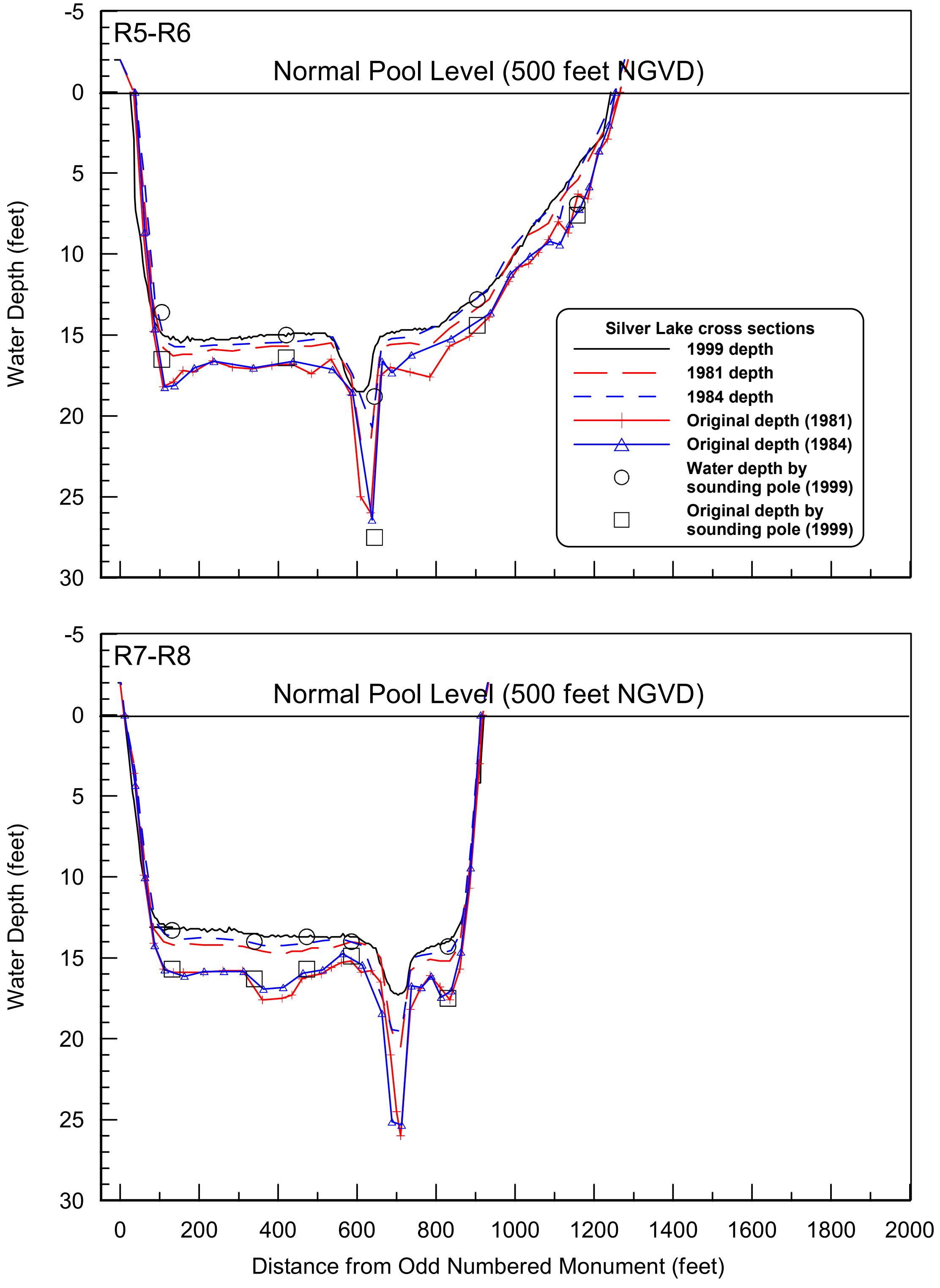
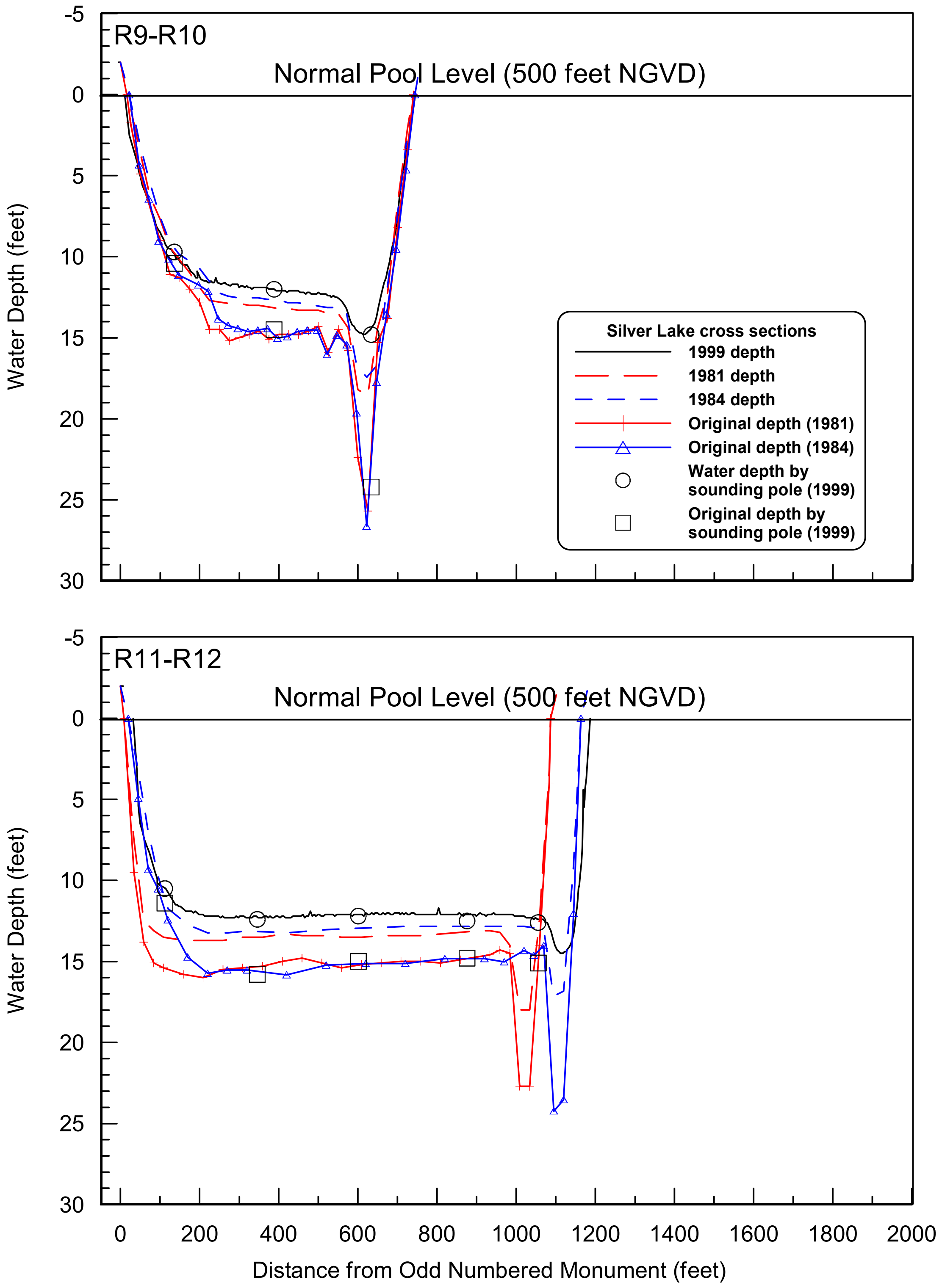
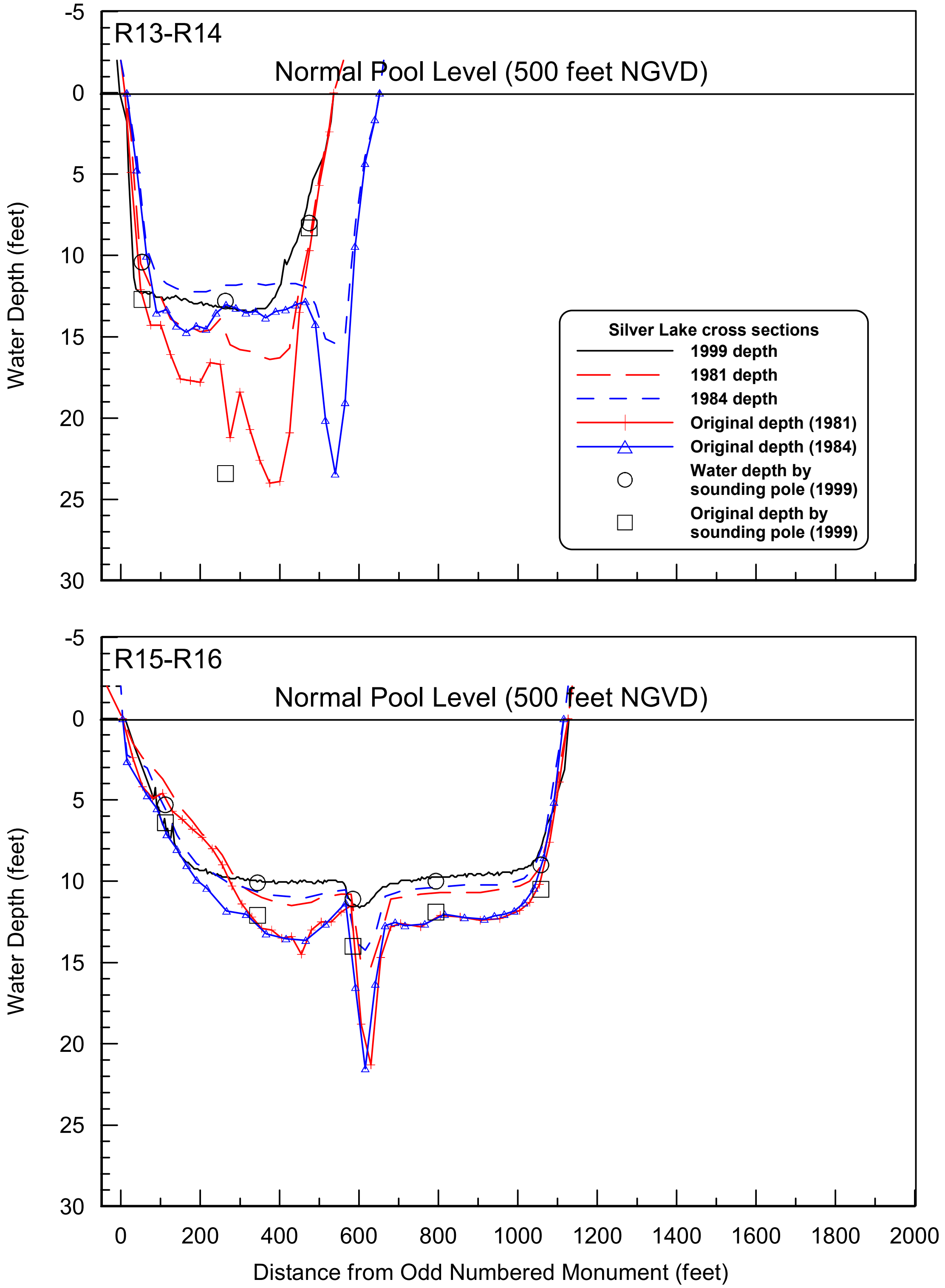
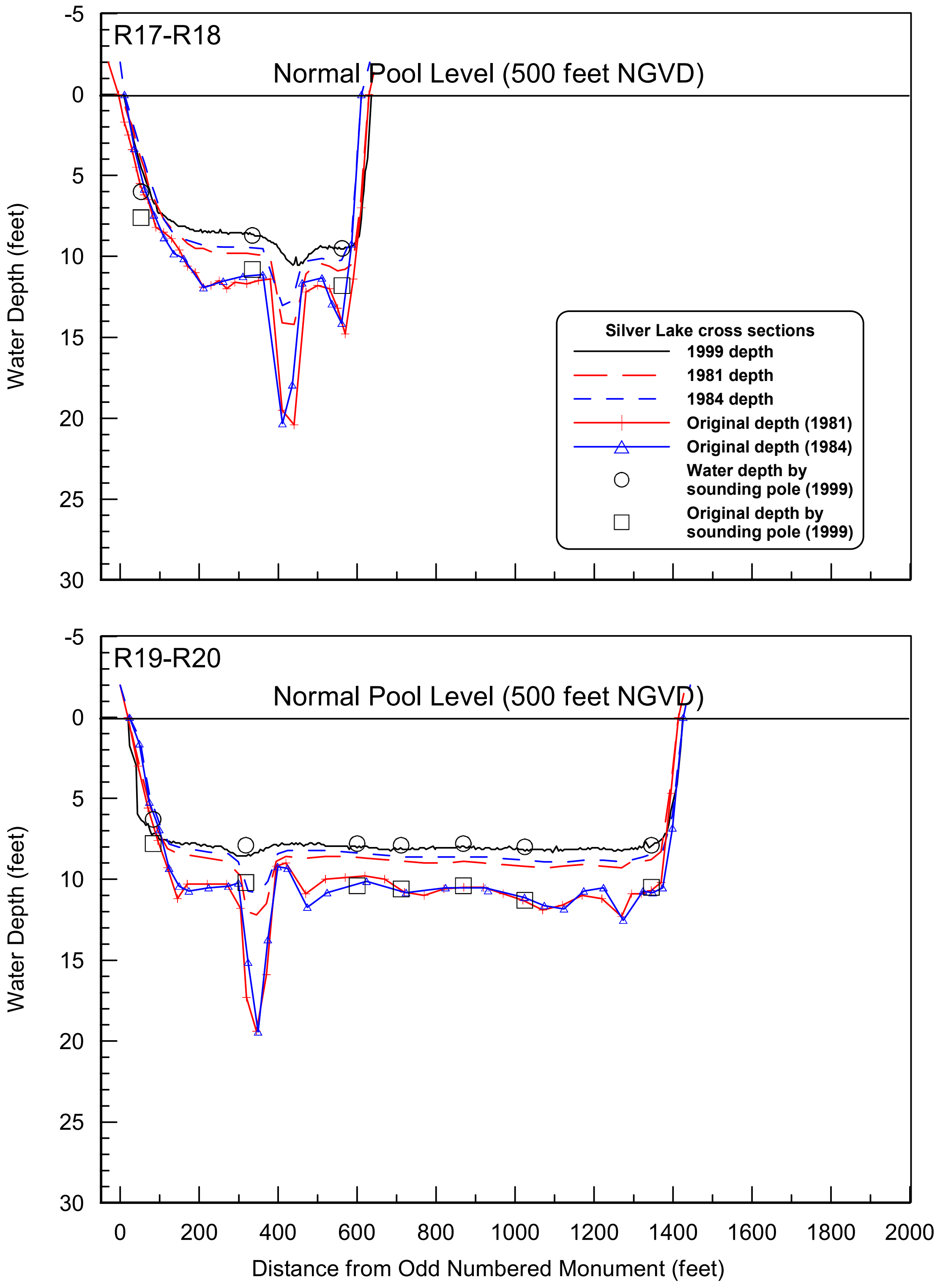
Appendix I. Cross Sections of Silver Lake Transects

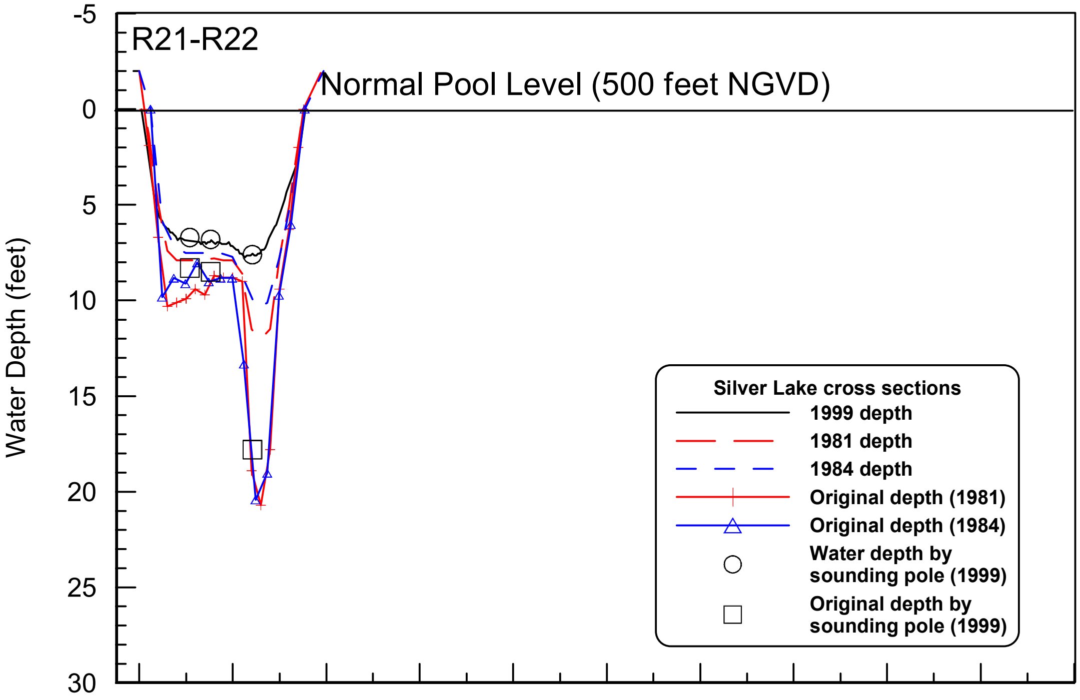

R1-R2
Normal Pool Level (500 feet NGVD)
Water Depth (feet)
-5
0
5
10
15
20
25
30
35
Silver Lake cross sections
1999 depth
1981 depth
1984 depth
Original depth (1981)
Original depth (1984)
Water depth by sounding pole (1999)
Original depth by sounding pole (1999)
R3-R4
Normal Pool Level (500 feet NGVD)
Water Depth (feet)
-5
0
5
10
15
20
25
30
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Distance from Odd Numbered Monument (feet)

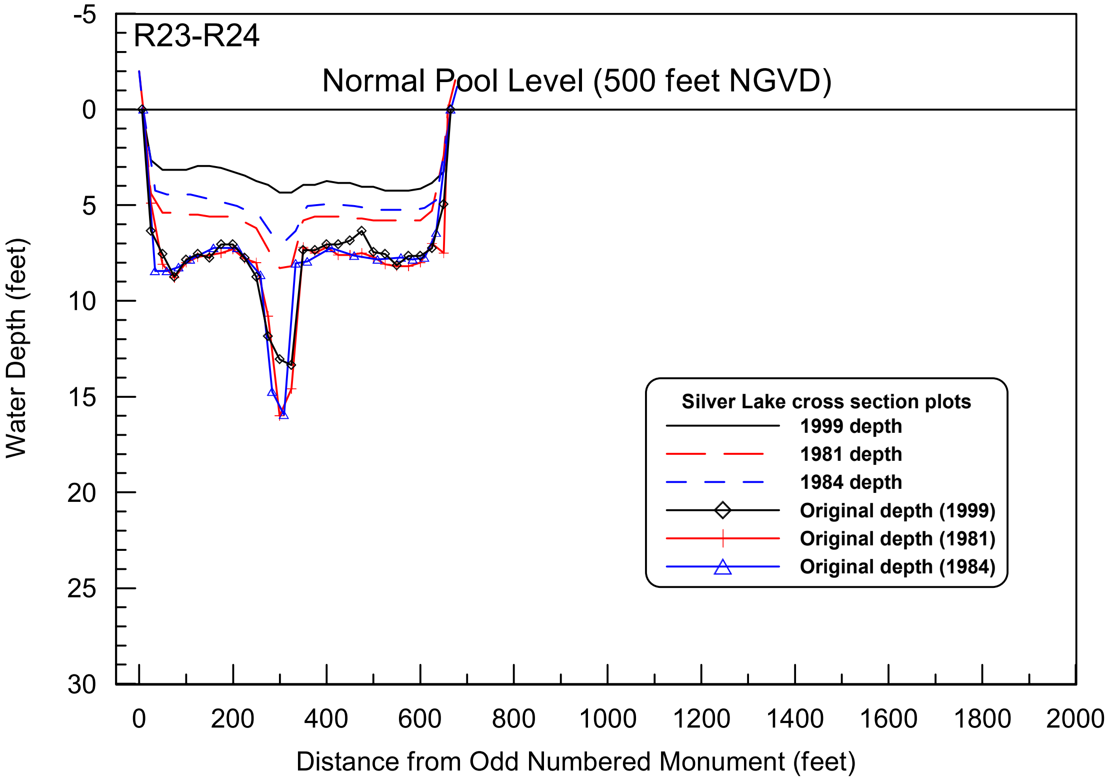

R5-R6
Normal Pool Level (500 feet NGVD)
Water Depth (feet)
-5
0
5
10
15
20
25
30
Silver Lake cross sections
1999 depth
1981 depth
1984 depth
Original depth (1981)
Original depth (1984)
Water depth by sounding pole (1999)
Original depth by sounding pole (1999)
R7-R8
Normal Pool Level (500 feet NGVD)
Water Depth (feet)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Distance from Odd Numbered Monument (feet)

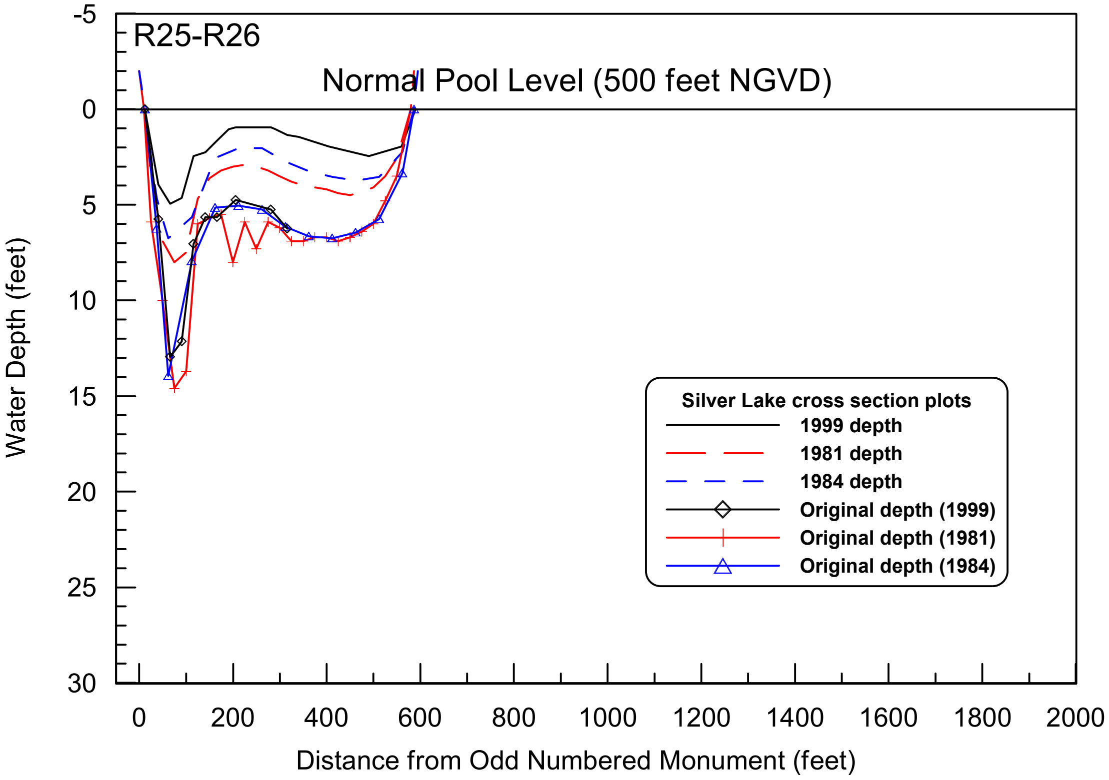
R9-R10
Normal Pool Level (500 feet NGVD)
R11-R12
Normal Pool Level (500 feet NGVD)
Water Depth (feet)
-5
0
5
10
15
20
25
30
Distance from Odd Numbered Monument (feet)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Silver Lake cross sections
1999 depth
1981 depth
1984 depth
Original depth (1981)
Original depth (1984)
Water depth by sounding pole (1999)
Original depth by sounding pole (1999)

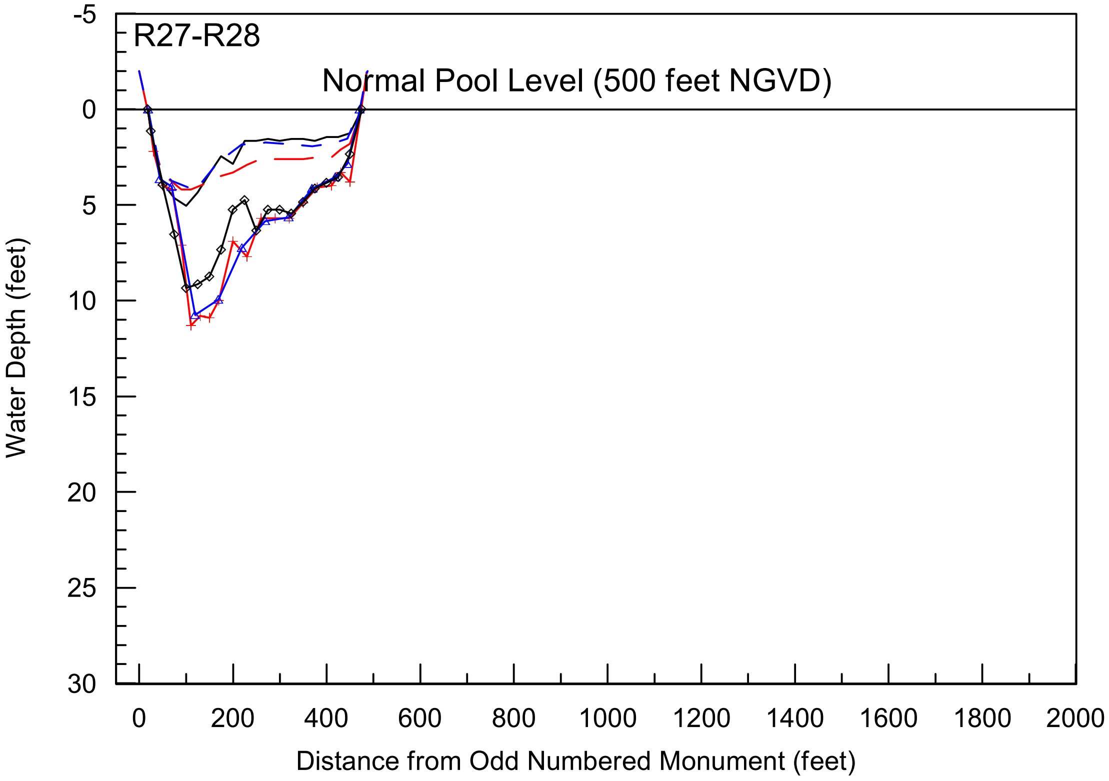

R13-R14
Normal Pool Level (500 feet NGVD)
Water Depth (feet)
-5
0
5
10
15
20
25
30
Silver Lake cross sections
1999 depth
1981 depth
1984 depth
Original depth (1981)
Original depth (1984)
Water depth by sounding pole (1999)
Original depth by sounding pole (1999)
R15-R16
Normal Pool Level (500 feet NGVD)
Water Depth (feet)
-5
0
5
10
15
20
25
30
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Distance from Odd Numbered Monument (feet)


R17-R18
Normal Pool Level (500 feet NGVD)
Water Depth (feet)
-5
0
5
10
15
20
25
30
Silver Lake cross sections
1999 depth
1981 depth
1984 depth
Original depth (1981)
Original depth (1984)
Water depth by sounding pole (1999)
Original depth by sounding pole (1999)
R19-R20
Normal Pool Level (500 feet NGVD)
Water Depth (feet)
-5
0
5
10
15
20
25
30
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Distance from Odd Numbered Monument (feet)


R21-R22
Normal Pool Level (500 feet NGVD)
Water Depth (feet)
-5
0
5
10
15
20
25
30
Silver Lake cross sections
1999 depth
1981 depth
1984 depth
Original depth (1981)
Original depth (1984)
Water depth by sounding pole (1999)
Original depth by sounding pole (1999)


R23-R24
Normal Pool Level (500 feet NGVD)
Water Depth (feet)
-5
0
5
10
15
20
25
30
Silver Lake cross section plots
1999 depth
1981 depth
1984 depth
Original depth (1999)
Original depth (1981)
Original depth (1984)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Distance from Odd Numbered Monument (feet)


R25-R26
Normal Pool Level (500 feet NGVD)
Water Depth (feet)
-5
0
5
10
15
20
25
30
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Distance from Odd Numbered Monument (feet)
Silver Lake cross section plots
1999 depth
1981 depth
1984 depth
Original depth (1999)
Original depth (1981)
Original depth (1984)


R27-R28
Normal Pool Level (500 feet NGVD)
Water Depth (feet)
-5
0
5
10
15
20
25
30
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Distance from Odd Numbered Monument (feet)

Appendix II. Sediment Core Sample Unit Weight Results

Sample number	*Location*	*Sediment layers*	*Unit weight (pounds per cubic foot)*
2	R27-R28	5-8	53.4
4	R25-R26	4-7	37.8
5	R25-R26	16-19	44.4
8	R23-R24	2-5	46.9
9	R23-R24	16-19	56.4
11	R21-R22	4-7	53.8
13	R19-R20	7-10	41.5
15	R17-R18	4-7	44.2
17	R15-R16	5-8	43.9
19	R13-R14	9-12	31.8
20	R11-R12	3-6	29.4
21	R11-R12	12-15	34.3
24	R9-R10	6-9	35.2
26	R7-R8	6-9	41.4
28	R5-R6	10-13	29.1
30	R3-R4	7-10	36.9

Appendix III. Sediment Particle Size Distribution Sample Results

	Sample number				
Particle size (millimeters)	*PS-1 R27-R28*	*PS-3 R25-R26*	*PS-6 R25-R26*	*PS-7 R23-R24*	*PS-10 R21-R22*
0.062					
0.031	87.9	100	100	100	100
0.016	66.2	86	74.4	77.2	92.6
0.008	43.3	60	47.7	56.7	76.2
0.004	30.2	47.6	36.1	44.6	63.1
0.002	25.5	40.3	30.7	37.5	51.4

	Sample number				
Particle size (millimeters)	*PS-12 R19-R20*	*PS-14 R17-R18*	*PS-16 R15-R16*	*PS-18 R13-R14*	*PS-19 R11-R12*
0.062					
0.031	100	100	98.7	100	100
0.016	100	91.5	91.5	100	100
0.008	85.9	75.5	78.5	95.1	98.2
0.004	68.2	64.3	67.5	83.5	84.7
0.002	56.8	55.5	57.2	70.8	70.3

	Sample number					
Particle size (millimeters)	*PS-22 R11-R12*	*PS-23 R9-R10*	*PS-25 R7-R8*	*PS-27 R5-R6*	*PS-29 R3-R4*	*PS-31 R1-R2*
0.062						
0.031	100	100	100	100	100	100
0.016	100	100	94.8	99.4	100	99.9
0.008	95.2	91.7	82.9	90.7	94.7	92.2
0.004	82.1	79	70.6	79.8	84.6	86.3
0.002	66.8	67.2	59.6	67.9	73.8	76.9

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