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

Illinois Department of
Energy and Natural Resources

**SWS Contract Report 303**

# SEDIMENTATION SURVEY OF VIRGINIA RESERVOIR VIRGINIA, ILLINOIS

*by*
*William C. Bogner*
*Assistant Hydrologist*

**Prepared for**
**the City of Virginia, Illinois**

**January 1983**
**Champaign, Illinois**

CONTENTS

# SEDIMENTATION SURVEY OF VIRGINIA RESERVOIR
# VIRGINIA, ILLINOIS

by William C. Bogner, Assistant Hydrologist

## Introduction

The Illinois State Water Survey in cooperation with the City of Virginia, Illinois, has completed a sedimentation survey of the city's water supply reservoir. Previously (in May 1950) the lake was the subject of a reconnaissance survey performed by the U.S. Department of Agriculture, Soil Conservation Service, in cooperation with the Water Survey. The results of both surveys are summarized in this report.

Field data for the current survey were collected by the Water Survey with the assistance of city employees. Laboratory analyses of the accumulated sediments were made by the Water Survey Sediment Laboratory. Illustrations for the report were prepared by William Motherway and Linda Riggin under the supervision of John Brother. The report was edited by Gail Taylor; and Pamela Lovett, Kathleen Brown, and Lynn Weiss prepared the camera ready copy.

This work was accomplished by the author as part of his regular work at the Water Survey under the administrative guidance of Stanley A. Changnon, Jr., Chief; Michael L. Terstriep, Head of the Surface Water Section; and Nani G. Bhowmik, Assistant Head.

## Reservoir Location

The reservoir is located on Job's Creek, a tributary to the Sangamon River, 1 mile north of the City of Virginia. The dam is located in Section 34, T. 18N., R. 10W., in Cass County.

## Historical Background

Movements towards developing a water supply for the City of Virginia began in the early 1900s. In 1907, a consulting engineer was hired to plan the development of the water supply including source, treatment, and distribution. This study resulted in plans and specifications which were not implemented but did recommend construction of a reservoir at the site of the present reservoir.

In 1929, another study was commissioned for the planning of a complete water supply system. This system was implemented in 1933 with the construction of a reservoir, treatment plant, elevated tank, and distribution system (Stall, 1950).

In 1950, a reconnaissance sedimentation survey was made of the existing reservoir. As summarized by Stall (1950) this survey showed the reservoir to have an original capacity of 154 acre-feet and a capacity of 116 acre-feet in 1950. This indicates a sedimentation rate of 1.5% per year over the 17 years from 1933 to 1950.

During the period of 1952-1954, drought conditions forced the water level in the reservoir to be drawn down by as much as 7.5 feet. This most probably resulted in the exposure, drying, and compaction of a large portion of the accumulated sediments in the reservoir.

The water level was again drawn down in 1964, this time by approximately 5 feet, in order to raise the dam and spillway elevation and thus increase the capacity of the lake. At that time, the spillway was raised by 5 feet to its current elevation of 575 feet above MSL.

In 1954, the city drilled two wells about 1.5 miles east of the reservoir. These wells were used to supplement the reservoir supply during

dry periods and were constructed of 12-inch well casing and pumps with a capacity of 60 gallons per minute.

In 1977, these wells were replaced by a third well located in the Sangamon River Bottoms. This well has a 12-inch well casing and a 400-gallon-per-minute pump. The water from this well is pumped directly into the reservoir to maintain the water level.

## Watershed

The watershed of the Virginia reservoir is primarily agricultural in nature. However, large areas in the immediate vicinity of the reservoir and the tributaries are covered with trees. Land slopes are fairly flat with few developed creeks and tributaries. The drainage area of the lake at the spillway is 530 acres. The watershed of the reservoir is shown in figure 1.

## Sedimentation Survey

Sounding data were collected from 10 cross sections of the reservoir established for the 1982 survey. Figure 2 shows the locations of these 1982 cross sections. The range ends were monumented using steel fence posts.

In the 1982 survey, sounding data were collected at 20-foot intervals on each cross section to measure both the original and current depths of water in the lake with reference to the current spillway elevation. All depth measurements were made with a 2-inch-diameter aluminum pole marked in tenths of feet. The pole was first lowered until it touched the current lake bottom and a depth measurement was made. The pole was then pushed through the accumulated sediment until it hit the solid original lake bed

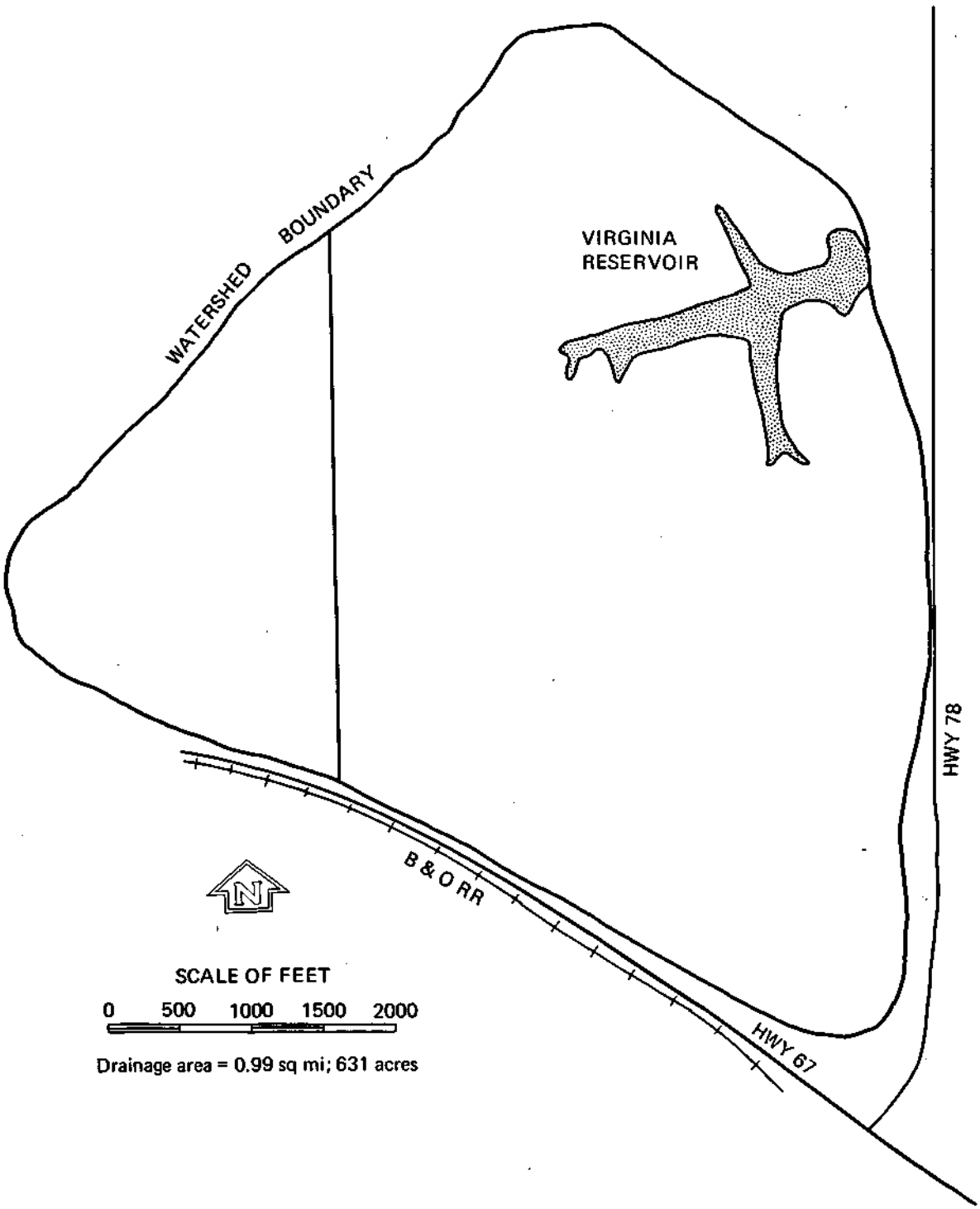


*Figure 1. Watershed of the Virginia Reservoir*

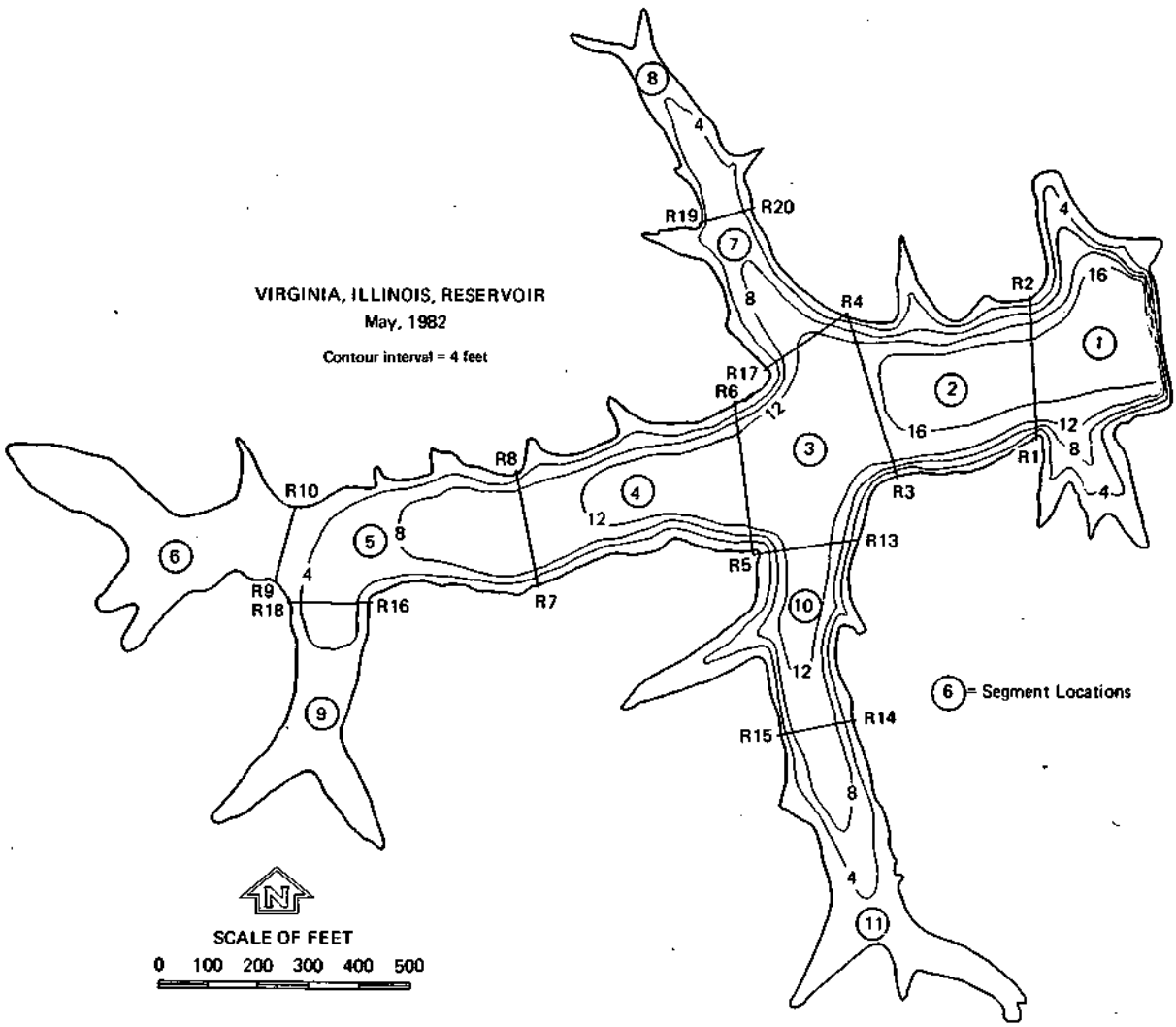


*Figure 2. Cross section locations and 1982 depth contours, Virginia Reservoir*

where another depth measurement was made. Horizontal control on each cross section was maintained with a marked plastic cable.

Samples of the accumulated sediment were not collected during the 1950 sedimentation survey. However, unit weight sediment samples were collected in 1955, after the drawdown of the reservoir due to the drought.

During the 1982 survey, the lake sediments were sampled for unit weight and particle size analyses. The locations where samples were collected are given in table 1.

## Sedimentation Calculations

The sounding data from the surveys were used to calculate the original storage capacity of the reservoir and the corresponding capacities at the time of the surveys. The differences between these storage capacities is the volume of the lake that has been lost to sedimentation from the date of construction of the reservoir in 1933 until the time of the surveys in 1950 and 1982.

The calculations for volume were made using the Dobson prismoidal formula as described in the National Engineering Handbook of the Soil Conservation Service, Section 3 (SCS, 1968). The volumes were also determined using the contour method calculation described in the same handbook.

In determining the sedimentation rate of the reservoir, the sedimentation rate found in the 1950 survey was extrapolated to determine the 1964 capacity of the lake. This is the year when the spillway was raised by 5 feet. The sedimentation rate for the period 1964 to 1982 was then determined based on this estimated 1964 capacity and the capacity measured in 1982.

Table 1. Locations, Sampling Depths and Unit Weight of Sediment Samples from the Virginia Reservoir

| Sample | Location* | Sample depth | Unit weight (pounds per cubic foot) | |
|---|---|---|---|---|
| | | | Top layer | Bottom layer |
| 1 | R3-R4 | Surface | 25.7 | 44.7 |
| 2 | R9-R10 | Surface | 52.7 | 66.4 |
| 3 | R7-R8 | 1.0-1.4 ft below present bed | 33.8 | 61.0 |
| 4 | R7-R8 | Surface | | |
| 5 | R19-R20 | Surface | | 72.6 |
| | R13-R5 | No sample | 40.8 | 61.2 |

*See figure 2

Results and Analysis

Table 2 is a summary of the results of the 1950 and 1982 surveys of the reservoir. These results indicate a significant reduction in the volumetric sedimentation rate from 2.2 acre-feet per year in the period 1933-1950 to 0.83 acre-feet per year in the period 1964-1982. This reduction in the sedimentation rate could result from one of a number of factors or a combination of several of these factors. These factors might include changes in erosion rates from the watershed, changes in the hydraulics of the lake-tributary system, compaction of the sediments, changes in trap efficiency, or many others. The fact that the volumetric sedimentation rate changed significantly while the actual weight of sediment input stayed relatively constant, as indicated by the average annual accumulation in tons/acre (table 2), indicates that compaction of the sediments may have been a major factor in the variation of the sedimentation rates.

The periods of water level drawdown in the early 1950s and again in 1964 may have had a significant impact on the nature of the sediments which had deposited at those times.

As sediments accumulate naturally in a reservoir, they collect into a very soft, unconsolidated mass with water contents in some cases greater than 150% by weight. In their submerged condition, the sediment particles tend to be buoyed up by interstitial water and therefore are exposed to very little consolidating weight.

When a lake is dewatered or dries up due to natural causes, as was the case for large portions of the Virginia reservoir in the 1950s and again in 1964, the weight of the deposited sediment is no longer buoyed by water, and the sediments begin to consolidate. This consolidation can be

Table 2. Summary of Sedimentation Data for the Virginia Reservoir, Illinois

(Values in parentheses indicate an adjustment of the 1933-1964 sedimentation rate to 1% per year)

| Age | Years | | |
|---|---|---|---|
| Filled December 1933 | | | |
| Surveyed May 1950 | 17 | | |
| Spillway Raised 1964 | 31 | | |
| Surveyed May 1982 | 49 | | |
| **Watershed** | **Sq mi** | **Acres** | |
| Total area | 0.83 | 530 | |
| Area excluding lake | 0.80 | 509 | |
| **Reservoir** | **Acres** | | |
| Surface area at spillway level | | | |
| 1933 | 18.7 | | |
| 1982 | 22.3 | | |
| Storage capacity at 1933 spillway level | Acre-feet | | Mil gal |
| 1933 | 154 | | 50.2 |
| 1950 | 116 | | 37.8 |
| 1964* | 82 | (106) | 26.9 |
| Storage capacity at 1982 spillway level | | | |
| 1964* | 194 | (218) | 63.-2 |
| 1982 | 179 | | 58.3 |
| 1933 | 266 | | 86.7 |
| Capacity per square mile of drainage area** | Acre-feet | | |
| 1933 | 186 | | |
| 1950 | 140 | | |
| 1964* (pre-construction) | 99 | (128) | |
| 1964* (post-construction) | 234 | (263) | |
| 1982 | 216 | | |
| Sedimentation | Acre-feet | | |
| 1933-1950 | 38 | | |
| 1950-1964* | 34 | (22) | |
| 1964-1982* | 15 | (39) | |
| 1933-1982 | 87 | | |

*Continued on next page*

Table 2 (Concluded)

| Average annual accumulation*** | | | |
|---|---|---|---|
| | Acre-feet from entire watershed | | |
| 1933-1950 | 2.2 | | |
| 1964-1982 | 0.83 | (2.17) | |
| 1933-1982 | 1.78 | | |
| | Acre-feet per square mile | | |
| 1933-1950 | 2.79 | | |
| 1964-1982 | 1.04 | (2.71) | |
| 1933-1982 | 2.22 | | |
| | Cubic feet per acre | | |
| 1933-1950 | 190 | | |
| 1964-1982 | 71 | (184) | |
| 1933-1982 | 151 | | |
| | Tons per acre | | |
| 1933-1950 | 3.8**** | | |
| 1964-1982 | | | |
| 1933-1982 | 3.8 | | |

| Depletion of original storage | Percent of original storage | | Percent per year | |
|---|---|---|---|---|
| 1933-1950 (based on 1933 volume) | 24.7 | (17.0) | 1.5 | (1.0) |
| 1964-1982 (based on 1964 post-construction volume) | 7.7 | (17.9) | 0.43 | (0.99) |
| 1933-1982 (based on 1933 volume at 1982 spillway elevation) | 32.7 | | 0.67 | |

*Estimated
**Includes area of lake
***Excludes area of lake
****Based on an estimated unit weight of 40 pounds per cubic foot

considerable, with a shrinkage of as much as 50% (Stall and Gibb, 1966; Peterson, 1981). It is most probable that this process of consolidation did occur in the Virginia reservoir in the 1950s and again in 1964.

When the 1950 survey was made the sediments were not sampled to determine particle size distributions and unit weights. However, the unit weight of sediments was estimated as 40 lbs/cu ft, which is a reasonable value for undisturbed lake sediment samples. When the sediments were sampled for unit weight determination in 1955, after the water level in the reservoir had recovered, the unit weights of the samples were found to average about 65 lbs/cu ft. This would indicate that the sediments had consolidated to about two-thirds of their 1950 volume as a result of the drought. If this is assumed, then the sedimentation rate for the period 1933-1964 should be reduced from 1.5% per year to approximately 1.0% per year.

In table 2, the values in parentheses reflect this adjustment. This adjustment results in a 0.99%-per-year sedimentation rate for the existing reservoir based on the 1964 post-construction volume.

This hypothesis is further supported by the unit weights of samples taken during the 1982 survey. The analysis of these samples, as shown in table 1, indicates that the more recent sediments in the top layer of the sediment column have much lower unit weights than the sediment near the original bed. These sediments near the bed are probably representative of the sediments deposited prior to 1964 and reflect the effects of consolidation. The unit weight of 52.7 pounds per cubic foot for the top sediments at R9-R10 (see figure 2) indicates that the lake level is regularly lowered at this location, exposing the sediments to drying.

Table 3 shows the distribution of accumulated sediments by segment. These segments are identified in figure 2. The rate of volume loss in percent per year cannot be evaluated on a segment-by-segment basis due to the sediment shrinkage and spillway level increases.

The results given in tables 2 and 3 were developed using the Dobson prismoidal formula (SCS, 1968). The depth contours shown in figure 2 and the stage volume curves shown in figure 3 were developed to determine the reservoir volume using the contour method of volume determination (SCS, 1968). The volumes calculated using these two methods, the contour method and Dobson's formula, agree to within 7%, with the contour method giving slightly lower volumes. Thus, figure 3 can be used to estimate the reservoir capacity for a given water level below the spillway elevation.

This figure should give a conservative estimate of the reservoir capacity. Although the 1982 curve in figure 3 is recommended for future use, it must be remembered that as the lake ages, the sedimentation process will continue and adjustments must be made in this graph to reflect the altered condition.

The results of particle size analyses for the accumulated sediments are shown in figure 4. These samples indicate that the lake sediments are composed primarily of silt- and clay-sized materials and show an almost complete absence of materials of sand size or larger.

These samples also show a general variation in particle sizes from the primarily silt composition in the headwater areas (samples 2, and 5) to the primarily clay composition near the dam (sample 1).

A reservoir yield analysis was made with the aid of the procedures prescribed by Water Survey Bulletin 67 (Terstriep et al., 1982). This analysis was made by reducing the 1982 volume to an estimated volume for

Table 3. Virginia Reservoir Volumes and Percent Lost by Segments

| Segment* | 1933 volume | 1982 volume | % of vol. lost, 1933-1982 | 1982 weight of sediment (tons) |
|---|---|---|---|---|
| 1 | 52.5 | 37.9 | 27.8 | 12,900 |
| 2 | 43.5 | 30.9 | 29.0 | 11,300 |
| 3 | 43.0 | 30.9 | 28.1 | 10,800 |
| 4 | 36.5 | 26.0 | 28.8 | 12,500 |
| 5 | 26.5 | 13.7 | 48.3 | 16,700 |
| 6 | 9.4 | 2.4 | 74.5 | 9,500 |
| 8 | 12.0 | 8.7 | 27.5 | 3,600 |
| 9 | 5.0 | 3.4 | 32.0 | 2,500 |
| 10 | 4.3 | 1.9 | 55.8 | 3,200 |
| 11 | 21.4 | 14.9 | 30.4 | 7,900 |
| 12 | 11.8 | 8.3 | 29.7 | 3,700 |
| Total | 265.9 | 179.0 | | 94,600 |
| Percentage of total volume lost | | | 32.7 | |

*Refer to figure 2 for locations of segments

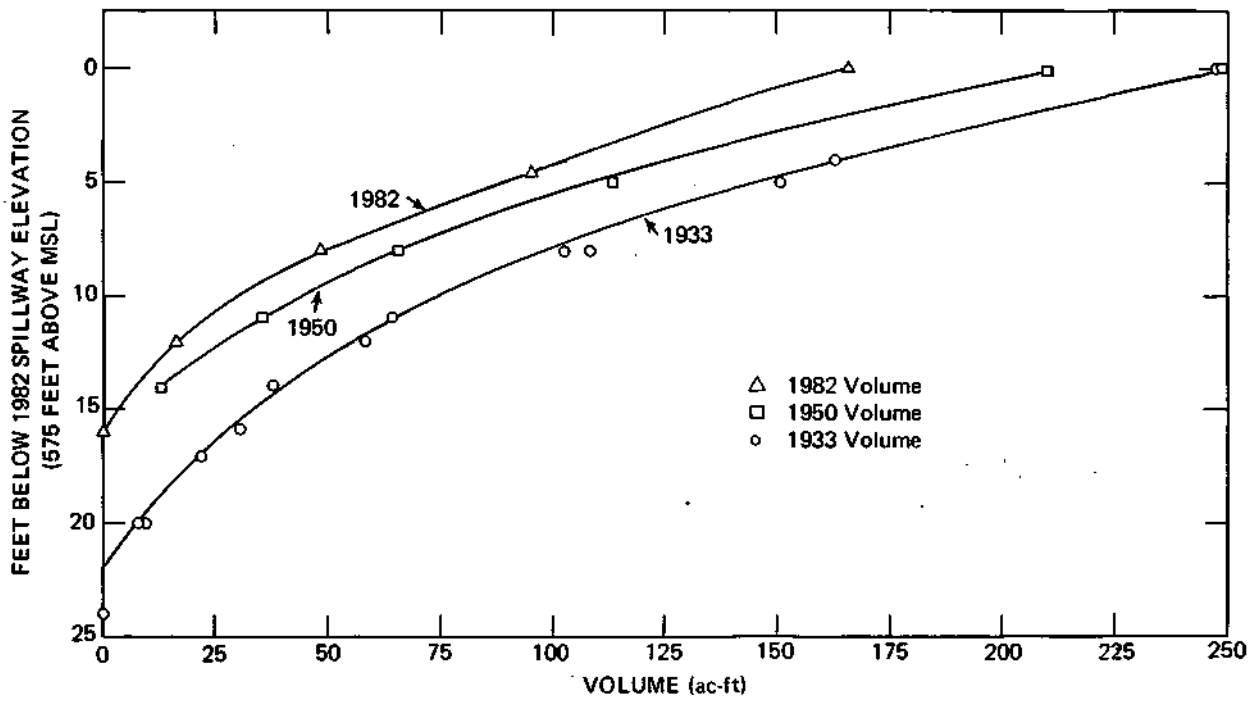


*Figure 3. Stage volume curves for 1933, 1950, and 1982*

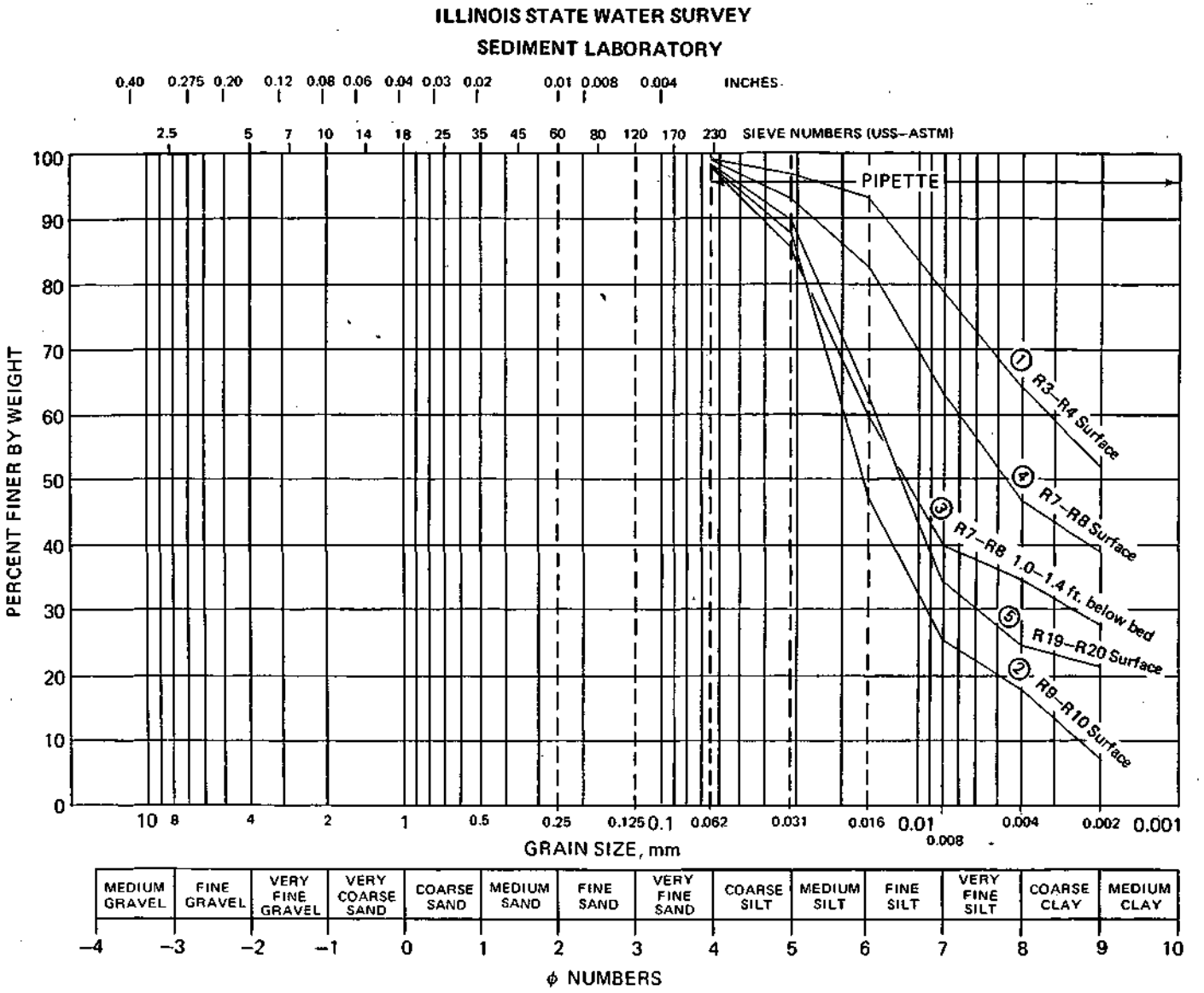


*Figure 4. Particle size analyses for Virginia Reservoir (See figure 2 for locations of samples)*

the year 2000, assuming that sedimentation from 1982 to 2000 will continue at the rate of 0.99% per year. The results of the yield analysis are shown in table 4.

Table 4. Results of Reservoir Yield Analysis for Virginia Reservoir

| Recurrence interval | Net yield (gallons/day) |
|---|---|
| 5 | 212,000 |
| 10 | 185,000 |
| 20 | 103,000 |
| 40 | 63,000 |

A projection of population and water use for the City of Virginia was made for the city and is summarized in table 5. The population figures in table 5 are based on data and projections given by the Illinois Bureau of the Budget (1981), and the water use data on figures given by the Illinois Environmental Protection Agency in its Public Water Supply Inventory Reports.

Table 5. Population and Water Use Projections for Virginia, Illinois

| | Cass County | | |
|---|---|---|---|
| | Population | Estimated water use (gallons per capita per day) | Estimated water use (gallons per day) |
| 1980 | 15,090 | | |
| 2000 | 16,173 | | |
| | Virginia | | |
| 1980 | 1,825 | 85 | 155,000 |
| 2000 | 1,956 | 90 | 176,000 |

The yield analysis in table 4 and the water use projection in table 5 indicate that the capacity of this reservoir will be sufficient to meet the city's water needs through the year 2000 up to droughts of 10-year recur-

rence intervals. With the additional supply of 576,000 gallons per day available from the city's well, there should not be any water supply problem for the city through the year 2000 up to droughts of 40-year recurrence intervals.

## Summary and Conclusions

A sedimentation survey of the Virginia reservoir was made in 1982. Data from this survey and a 1950 survey have been analyzed. The results of these surveys indicate that 32.7% of the available water volume has been lost to sedimentation since 1933.

The sedimentation rate since 1950 has been affected by two periods of severe drawdown as well as the reconstruction of the dam to a higher spillway elevation. The sedimentation rate as surveyed for the period 1933-1950 was 1.5% per year. This value was adjusted to account for compaction of the sediment during periods of drawdown.

The reservoir and available well should be sufficient to supply needed water to the city up to the year 2000 through at least a 40-year recurrence interval drought. However, it is recommended that another sedimentation survey of the reservoir be made in the 1990s in order to better define the changing sedimentation rate.

## References

Illinois Bureau of the Budget. 1981. Illinois population projections; Revised 1981.

Peterson, Spencer A. 1981. Sediment removal as a lake restoration technique. U.S. Environmental Protection Agency EPA-600/3-81-013, February.

Soil Conservation Service. 1968. National engineering handbook, Section 3, Sedimentation, Chapters 1, 2, and 7.

Stall, John B. 1950. Report on the water supply situation at Virginia, Illinois. Illinois State Water Survey Letter Report, September.

Stall, John B., and James P. Gibb. 1966. Report on the sedimentation of Lake Decatur, Decatur, Illinois. Illinois State Water Survey Letter Report, December.

Terstriep, Michael L., Misganaw Demissie, Douglas C. Noel, and H. Vernon Knapp. 1982. Hydrologic design of impounding reservoirs in Illinois. Illinois State Water Survey Bulletin 67.