# SEDIMENTATION SURVEY OF LAKE ELLSWORTH, CADDO AND COMANCHE COUNTIES, OKLAHOMA

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SEDIMENTATION SURVEY OF LAKE ELLSWORTH,

CADDO AND COMANCHE COUNTIES,

OKLAHOMA

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## PREFACE

The objectives of this study were to: (1) evaluate the loss of storage capacity of the reservoir due to sedimentation; (2) analyze the distribution of sediment based on particle size; (3) offer some constructive suggestions as to controls that will combat sedimentation in municipal reservoirs.

The samples were taken both in winter and summer months in order to observe any changes in sedimentation which might occur due to seasonal influences.

I wish to express my deep gratitude to Dr. Alex Ross for the encouragement, guidance and assistance which he provided during the preparation of this thesis. I also wish to thank Dr. Kenneth Wiggins for serving as committee chairman; Dr. Henry Johnston, Dr. J. W. Blankenship, and Dr. H. L. Bruneau for serving on my advisory committee. In addition, I wish to extend my thanks to Dr. John Naff for his suggestions and Dr. Richard Burch for his help.

Last but not least, I wish to express my gratitude to my wife, Shirley Jo, and my children, Jo Ann and Bradley Gene, for the sacrifices they made while assisting in the completion of my program of study.

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# CHAPTER I

## INTRODUCTION

Precipitation gives us our surface water supplies, in that a portion of it finds its way to the lakes and streams. Since streams sometimes dry up or have a low flow due to lack of precipitation, man has constructed impounding reservoirs, the purpose being the equalization of water supply by storing the large flows of wet seasons for release during periods of drought and low run-off (Brown, 1949).

The south-western one-third of the State of Oklahoma depends primarily on surface water for its supply for municipal usage. Ground water in this area is generally not adequate for municipal supplies. Therefore, any future water supply developments would normally include the construction of impounding reservoirs.

In the design of reservoirs, engineers usually select the most favorable sites for these reservoirs considering such factors as distance from the city, dam foundation conditions, water yield from the watershed, peak rates of run-off, population trends, cost of furnished water, and quantity of supply required.

In the design of a reservoir to be used as a source of supply for municipal use, an allowance of reserve storage space is usually provided for increased consumption due to population increases, changes in requirements of existing industrial users, and to meet the demands of probable new industries. The sedimentation factor was not considered because it was not generally recognized, or, if so, data on rates of sediment production necessary for design purposes were lacking (ISWS, 1949).

The menace of sediment, although always present, has not been well understood. It had been thought that erosion occurred primarily on steep lands; however, studies indicate that this is not necessarily true. As more land has become "improved" and used for grazing, tillage, grass, and cultivation, more erosion has taken place, and a greater amount of sediment has found its way to the streams. Due to erosion the top soil is removed from the land; the lands become less productive and eventually become almost worthless. Some of this sediment enters streams on which water supply reservoirs have been built to furnish a municipal supply. If erosion of the land is great, the sediment load carried by the stream is large. A portion of the sediment is deposited in the stream channel and impounding reservoirs. As the reservoirs become filled with the sediment, the ability to store water is reduced, and if the loss of capacity due to sedimentation is high, the reservoir may rapidly approach uselessness.

Reservoir sites must be considered as natural resources and everything should be done to prevent the waste of these sites due to high rates of sedimentation. It is desirable to establish information on all factors that affect sedimentation. There is definitely a need for a more complete understanding of the sedimentation problem by everyone concerned; by the public who will authorize funds for the construction of future reservoirs, by the engineer who will be designing and building them, and by the farmer who will profit by having his top soil retained on the land.

## Purpose and Scope of Investigation

The purpose of this investigation was to determine the amount and rate of sedimentation and the distribution of sediment in the lake. It was also desired to establish the relationship between the types of sediments and rate of sedimentation to the geology of the watershed. An additional problem, that of shoreline erosion, was recognized during the survey.

Most of the field investigations were confined to the lake and shoreline area and consisted primarily of mapping the shorelines and measuring water depth and sediment thickness along 27 ranges. From the data provided the original and the 1968 capacity of the reservoir were determined, as well as the volume of sediment deposited within the lake since its completion. Numerous reconnaissance trips were also made of the watershed to observe erosion and sedimentation processes, rocks, soils, slope angles, vegetative cover, and conservation practices.

## CHAPTER II

## LITERATURE REVIEW

Since the turn of the century, there have been many studies directed at the substrate as an integral part of the aquatic environment. Early studies, such as Baker (1918), were based on the visual appearance of the substrate rather than an analysis of characteristics such as particle size, organic content, or hydrogen ion concentration. Well defined analytical methods in sediment studies were not widely used until later investigations, such as Henson (1962).

The lack of standardization in sediment descriptors in early works make comparison of published works difficult. This difficulty was compounded by a lack of discrimination between the effects of the substrate on distribution patterns and the effects of other variables such as wave action, temperature, and dissolved oxygen concentration. More recent works, like those of Sublette (1957), have followed well defined methods of analysis and have included consideration of other environmental variables.

Prior to World War II the United States Department of Agriculture conducted many reservoir surveys. However, most of the studies were directed at conservation of surface water as it related to the groundwater table, and to the erosional aspects of farming lands. One of the main things accomplished by these studies was the development of some standard methods of collecting samples, such as that developed by Eakin (1936).

After World War II, with the great migration of people from rural to urban areas, it became apparent that existing municipal water supplies were insufficient. It was pointed out by the United States Department of Agriculture (1945) that water consumption, by cities, would double by 1955. There followed a period of reservoir construction that cost the American public millions of dollars. It seems that almost every city of any size, especially in the Southwest, began constructing reservoirs (Mann, 1952). Many of these were constructed with little or no regard to the length of time they would serve the purpose for which they were constructed (USDA, 1935). Also, during this period, the United States Department of Agriculture was involved with the construction of farm ponds as they related to the conservation of farming lands. Therefore, most of their sedimentation studies were studies concerning these ponds (AGT, 1947).

During this period, from the end of World War II until the late fifties, many reservoir studies were of the Limnological type such as those by Welch (1959). Of those which were not Limnological many were concerned with the geological aspects of the drainage basin like the study by Anderson (1957). However, some states recognized the need for agencies of the state to collect and report on municipal water supplies of their state. It is from these states, such as the State of Illinois, that we have some insight into the problems connected with silting in municipal water supplies (Illinois State Water Survey, 1949).

Agencies, such as the Illinois State Water Survey, could save cities, and in turn taxpayer, several million dollars by showing them how to receive maximum usage from their storage lakes (Larson, et al., 1951).

In the early sixties The American Public Health Association (1965) began publishing information regarding water, including bottom sediments and sludges. This may have initiated renewed interest in reservoir problems for, during the next few years, many new methods were devised for sampling sedimentation. These methods ranged from "Gamma Probe Analysis" developed by Heinemann (1962) to "Volumetric" surveys of Dovorak (1965). However, in all of these studies there is little if any method offered for controlling the rate of sedimentation.

# CHAPTER III

## DESCRIPTION OF LAKE ELLSWORTH

### Location

Lake Ellsworth is located in sections 3-5, 8-12, 14-17, 19-23 and 26-29, T. 4 N., R., 11 W.; sections 20-21, 27-29 and 33-34, T. 5 N., R., 11 W., Caddo and Comanche Counties, Oklahoma. It is 10 miles North-West of Lawton and just north of Federal Highway 277 (Figure 1).

### Purpose Served

The Lake Ellsworth dam impounds water on Tony Creek, Chandler Creek and East Cache Creek. The principal purpose of the dam and reservoir is to store water for present uses and for a future supply for the Lawton and Fort Sill areas. It helps to regulate flood waters, provides a site for various kinds of outdoor recreation, and serves as a sanctuary and feeding ground for migratory water fowl.

### Description of Dam

The dam is of the rolled earth-fill type with a crest length of 4,000 feet and a concrete spillway 300 feet long and 20 feet deep. The crest elevation of the spillway is 1,225 feet and during flood stage the spillway delivers water to the floodplain of East Cache Creek. The spillway is constructed to allow the addition of 10 feet flood gates and this would then make the elevation of the spillway 1,235 feet.

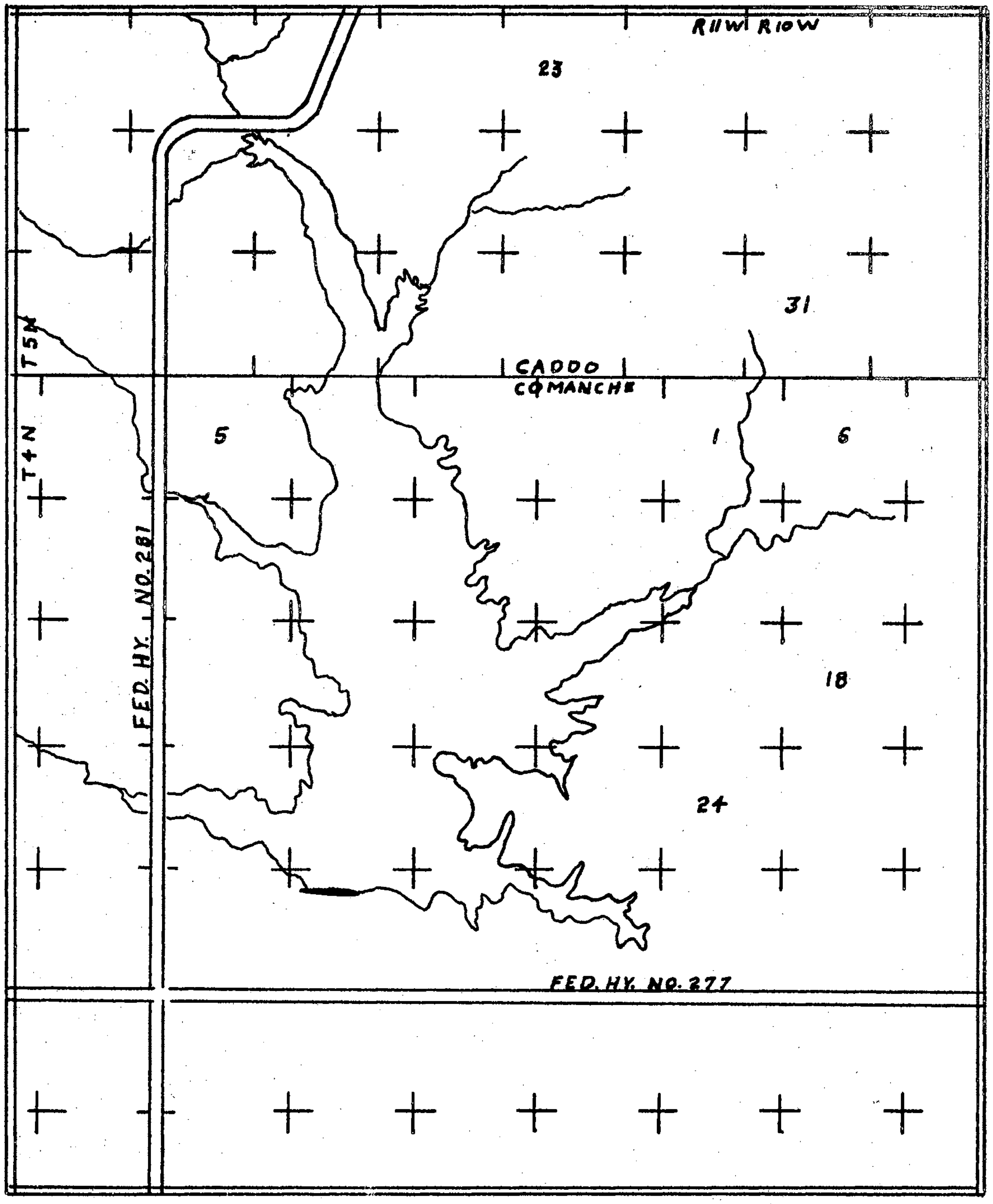


Figure 1. Map Showing Location of Lake Ellsworth

The dam is equipped with a 42 inch pipeline and pumping facility which carries water to the municipal filter plant located at Medicine Park.

## Description of Lake

Lake Ellsworth consists of a main body and six smaller arms (Figure 1). The length of the main body, above the dam, is 6.31 miles; the head of the backwater extends an additional mile to the north. Maximum width of the lake near the dam is 4.1 miles and to the north it narrows. The width opposite arms 3 and 4 is approximately 1.54 miles which is also an average width for the lake.

The area of the lake at the spillway crest elevation (1,225 feet) is 5,389 acres. Its original capacity was 94,805 acre-feet and its present capacity is 93,356 acre-feet. The loss of capacity due to sedimentation is 1,449 acre-feet.

## Description of Watershed

The area of the watershed is 250 square miles, of which about 80 percent lies to the north and west of the lake (Figure 2). Some of the area does not contribute sediment to the lake since there are natural and artificial obstructions to cause deposition before reaching the lake. An estimate of the net sediment contributing area is not feasible at this time.

The watershed and lake are located in the Central Redbed Plains physiographic province (Curtis and Ham, 1957). This name is derived from the sequence of red sediments of Permian age which underlie the area. Mobley and Brinlee (1967) has mapped in detail the surface geology

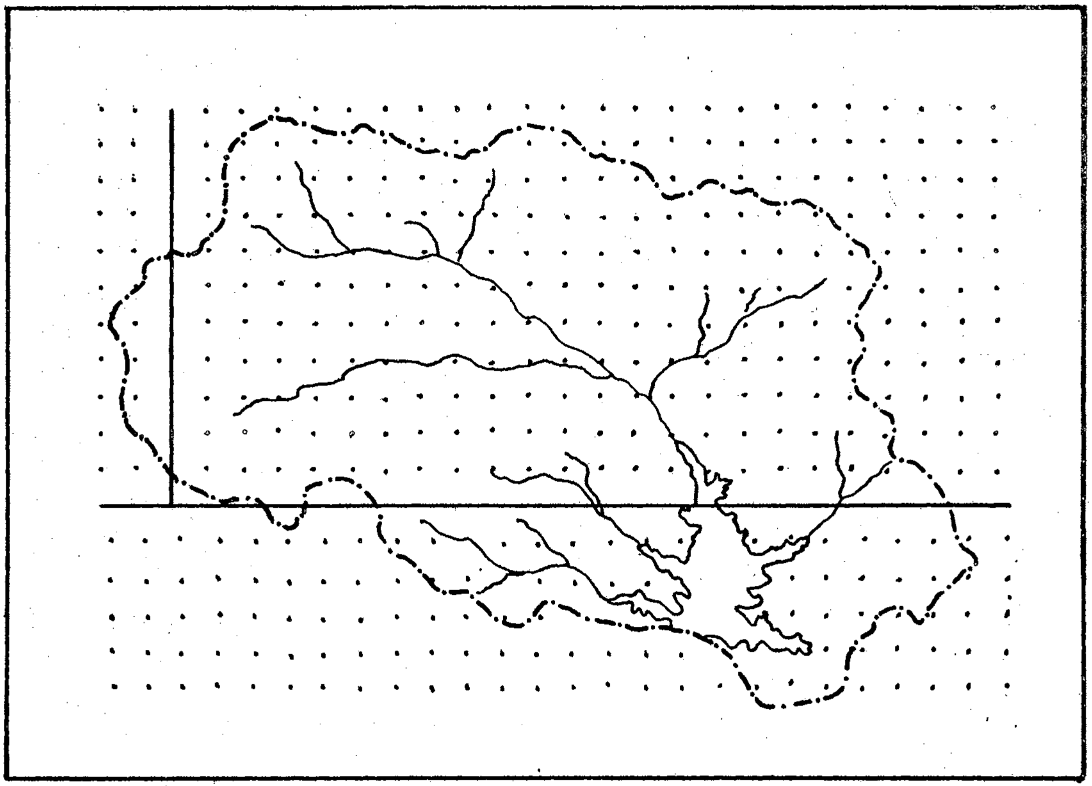

Figure 2. Drainage Basin of Lake Ellsworth

of northern Comanche County which includes the area immediately west and east of Lake Ellsworth. They assign the sediments to the Wichita formation which in this area is made up of red clay shales interbedded with various thin blue-gray shales and includes six fine-grained quartz sandstones which vary from light yellow to buff to brown to red-brown in color. The regional dip is to the north (Figure 3).

The watershed is an undulating to rolling prairie area. Valleys have developed in the soft shales while sandstones underlie or cap hills and form small escarpments. The sandstone outcrops are usually identified by thick stands of blackjack oak and post oak. Slopes bordering the lake range from 3 to 7 percent.

The three main creeks entering the lake have an average gradient of 9 feet per mile. The tributaries are intermittent streams which average 40 feet per mile although they start as high as 70 to 90 feet per mile. East Cache Creek and its tributaries form a dendritic drainage pattern. Drainage is into the Red River which lies to the south.

The soils of the watershed area divide into a number of catenas. One important catena consists of the Lawton, Foard and Tillman soil series. These developed in a subhumid climate, in noncalcerous granitic outwash from the Wichita Mountains under a cover of grass. The Tarrant soils developed from sandstones and sandy shales under a cover of grass. The Port and Windhorst soils have developed from alluvium on high bottoms or low stream terraces and on floodplains.

It is estimated that 60 percent of the watershed is in pasture with some timber. The remainder is under cultivation chiefly for small grains, hay and row crops.

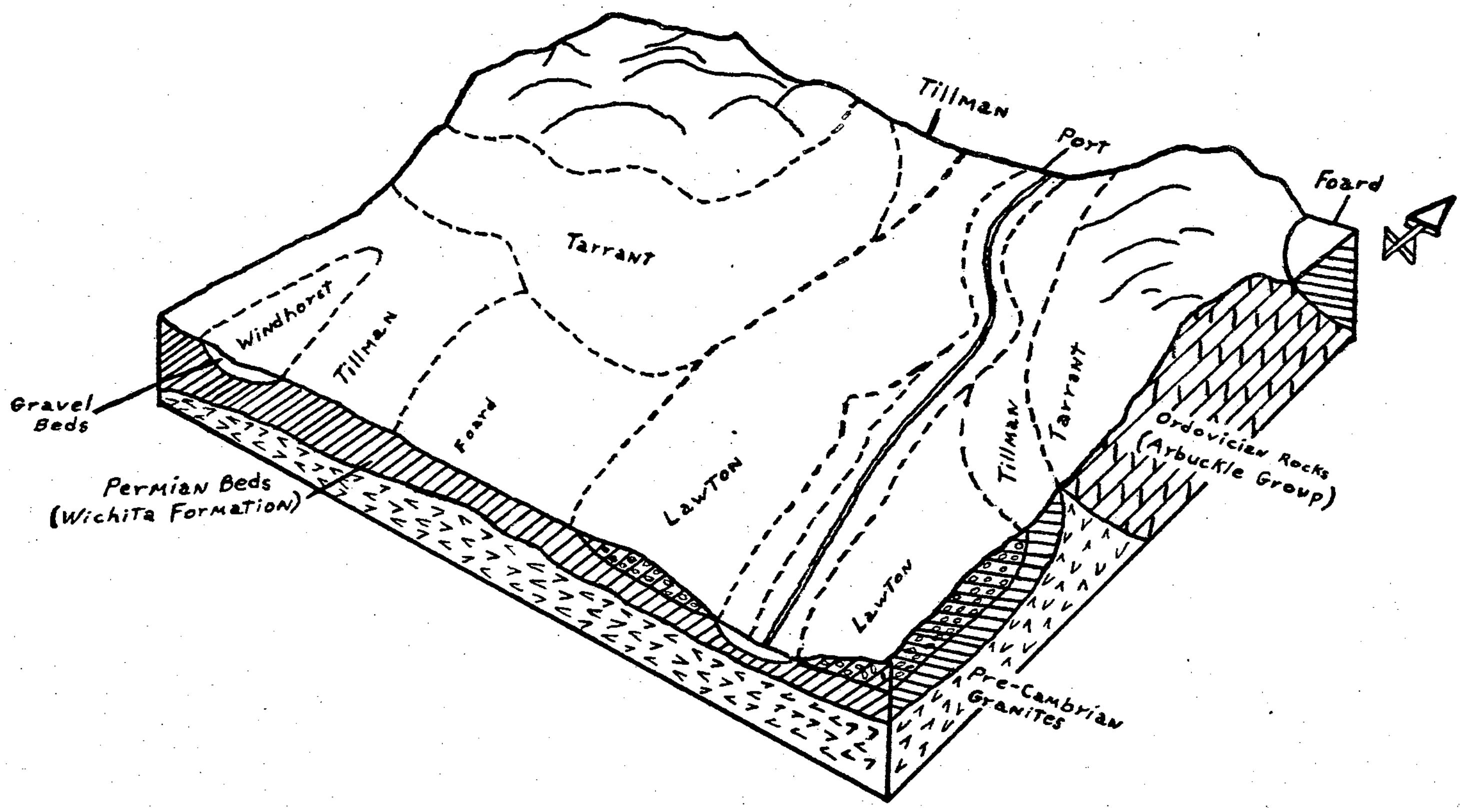


Figure 3. Topography and Underlying Material of Lawton and Other Extensive Soils in Northeast Comanche County

Erosion could become a serious problem for the land around the lake. Many miles of graded and unmaintained "tire tracks" surround the lake and are prime sites for accelerated erosion unless corrective steps are taken soon. After a heavy downpour many sandy roads are washed out in place and made impassable. The "tire tracks" act as collecting channels for the sediment-laden sheet flow. Present road grading practice is to cut the roadbed deeper pushing more loose sediment into the drainage ditch where it can be carried off by the next rain.

The remainder of the drainage area shows similar conditions. North and east of the lake are more tilled areas subject to sheet and rill erosion. Along the steeper stream banks and at the heads of streams gullying is more common.

The mean annual rainfall for this area is approximately 30 inches. Rainfall records over a 28-year period kept at the USDA Hydraulics Laboratory show a low of 17.78 inches for 1944 and a high of 42.38 inches for 1957.

## CHAPTER IV

## GENERAL PLAN OF SURVEY

Survey operations were designed to establish accurate basic data and field layout to facilitate future resurveys, as well as to check present survey and indicate past rates of silting.

The field work included primary triangulation control, topographic mapping, range location, leveling range cross-sections, and direct measurements of silt deposits.

Primary control was established by plane table triangulation, starting from a chained and rechecked 4,000 foot base line laid out along the dam. A plane table triangulation net was established around the shores of the main body of the lake. It was also extended into the arms where ranges measuring over 1,200 feet were to be encountered. Scales of primary triangulation was adjusted to the size of the reservoir with a view to facilitating progress and keeping the number of field sheets within practical limits. A scale of 500 feet to the inch was used.

Secondary control was tied to primary triangulation stations where they had been established or otherwise to well referenced features shown on the map. The shoreline was mapped on aerial photographs at a time when the lake stood at or very near to spillway crest elevation. Range ends were also marked on the photos. The scale of the aerial photographs was determined by chaining between easily recognized points; scale was 3.13 inches to the mile.

The main body of the lake and its principal arms was subdivided by cross ranges so that each subdivision would present about the same silted conditions as occurs on the bordering ranges.

The ranges were extended rather directly across the lake from shore to shore where it was practicable. Also, the upstream and downstream ranges were approximately parallel, a divergence of not more than 15 degrees was tolerated.

Where a tributary enters or an arm of the lake is cut off, a new series of ranges was started without regard to the direction of the two main ranges of the segment. The first range was across the mouth of the tributary and perpendicular to its general direction or as near to this position as practical considerations would permit.

The elevation of each end point of a range was established. Where the end point of the range was not more than 500 feet from the water's edge, the plane table was used as a level in establishing this elevation. Most of the range ends were established at or near the 1,240 foot contour. The elevation of the range end on the far side of the lake was established by plane table on the near side provided the shots to the end point and the water level were neither more than 2,000 feet long and the difference in the length of these two shots is not more than 200 feet. The difference between the two rod readings was added to the lake level to give the elevation of the range ends.

To locate stations along a range the plane table was set up so as to have a clear view of the range ends. The range was divided into intervals of 25 to 200 feet, depending upon the length of the range; these points were designated "drop stations." The plane table operator cut in each station as the motor boat moved slowly across the range.

Upon a signal from the plane table the boat operator dropped a buoy at each station. The team then occupied each station to measure water depth and sediment thickness.

Direct measurement of silt with a sampling spud (Figure 4) to the nearest tenth of a foot was made at intervals on all ranges.

Water depths were measured and recorded by sounding at each point of direct silt measurement. The elevation of old soil surface was computed from this depth and determined silt thickness. Spacing of spudding depended on silt conditions, and no set of rigid rules were followed. The main object being to obtain a measurement with each appreciable change of silt depth.

Range profiles were plotted on cross-section paper ruled 10 squares to the inch. For most ranges a horizontal scale of 50 feet to the inch and a vertical scale of 5 feet to the inch were used.

The elevations calculated for each sounding were plotted as a profile cross-section of the range. Distances of soundings from one end of the range were scaled from the planetable sheet. With distances and elevations recorded, the points were plotted, and was joined by straight line segments to form the range cross-section.

The elevation of the old soil at each point of spudding was plotted after the silt surface cross-section was completed by plotting a point directly below the sounding equal to the silt thickness recorded. The thickness of silt between spud measurements were interpolated by plotting half the difference in silt depth at a point halfway between spuddings.

The area enclosed by the old soil or bottom curve up to crest level was obtained by planimeter in square feet. The area enclosed by the silt or upper curve up to crest level was measured in the same way. The

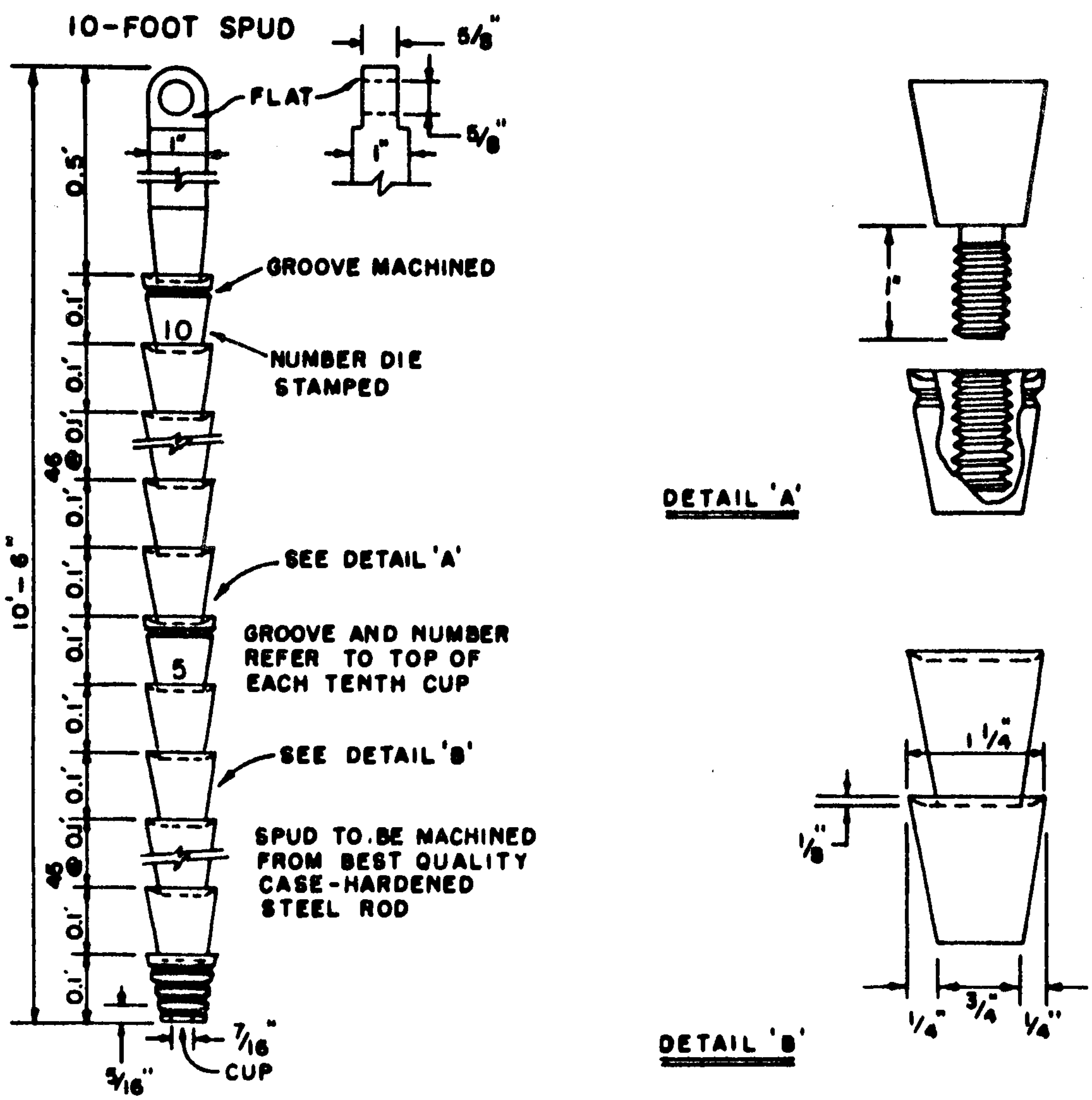


Figure 4. Diagrammatic Representation of the Spud Bar Used for Measuring Depth of Reservoir Sediment

difference in area represents area of silt.

The area enclosed by all ranges and intervening shore line bounding each segment of the lake was planimetered. The quadrilateral area, which was formed by the two main ranges and straight lines connecting the points where they intersect the shore lines, was then obtained by planimetering, or by scaling and computing. These areas were then converted into acres to the second decimal place and recorded on the base map, labeled A and A' respectively.

The original capacity and silt volume for all segments except the one next to the dam was computed by the following general formula (Eakin, 1936).

$$V = \frac{A'}{3}\left(\frac{E_1 + E_2}{W_1 + W_2}\right) + \frac{A}{3}\left(\frac{E_1 + E_2}{W_1 + W_2}\right) + \frac{h_3E_3 + h_4E_4}{130,680} \; . \; . \; . \; .$$

where: V = Original capacity or silt volume in acre-feet

A' = The quadrilateral area.

A = The lake area of the segment in acre-feet.

E = The cross-sectional area, in square feet, of original capacity or silt volume cut by bounding range.

W = Width of bounding range at crest elevation in feet.

h = The perpendicular distance from the range on a tributary to the junction of the tributary with the main stream.

The formula used for the segment next to the dam was:

$$V = \frac{A'}{3}\left(\frac{E_1}{W_1}\right) + \frac{A}{3}\left(\frac{E_1}{W_1}\right)$$

## Particle Size Diameter of Sediment

The hydrometer method (Bouyoucos, 1927) was used to determine the particle size distribution of the samples. The density of a suspension is a function of the amount of suspended matter. Therefore, measurements of the density of suspension at intervals following mixing allows calculation of the percentage by weight of soil particles remaining in suspension at the measured depth. The diameter of the particles that have reached the measured depth in their fall from the surface of the suspension were computed from Stoke's formula. Particles of greater diameter, or particles not starting at the surface of the suspension, are below the measured depth at the time the reading is taken. Since Stoke's law is stated in terms of a single spherical particle, the diameters calculated by use of the formula are those of spheres which will have the same settling velocity as the sediment particles.

The procedure used to determine particle size diameter is modified from that given by ASTM (1958). A 10-50 gm sample was thoroughly mixed with distilled water and a dispersing agent (sodium carbonate) to form a suspension totaling 1,000 ml. Particles began to settle immediately after mixing ceased and the first hydrometer reading was made after 30 seconds. The second reading was made at the end of 1 minute and subsequent readings were taken 3, 10, 30, and 90 minutes, 4, 8, 12, and 24 hours. The grams per liter of sediment remaining in suspension was read directly from the hydrometer, and the effective diameter calculated from the formula (Bauer, 1937):

$$D = \sqrt{\frac{30}{980} \cdot \frac{N}{G-G_1} \cdot \frac{L}{T}}$$

In the formula, D equals the diameter of the particles in millimeters, G equals the specific gravity of the sediment, $G_1$ equals the specific gravity of the liquid, N equals the viscosity of the liquid, and L equals the distance in centimeters through which the particles of diameter D have fallen. T is the time in minutes from the start to the time the observation was made.

As Bouyoucos (1929) pointed out, the results of the hydrometer method agree with those obtained by the pipette method, though the latter is still considered as the only standard method by investigators in some fields.

## Specific Gravity

Specific gravity was measured by the procedure modified from ASTM (1959). A known weight of dry sediment, approximately 0.5 gm, which passed a #20 sieve was placed in a 50 ml volumetric flask and covered with about 40 ml of distilled water. The sample was aspirated to remove air entrapped in the sample and distilled water was used to fill the flask. The bottle was weighed on an analytical balance.

# CHAPTER V

# SEDIMENT CHARACTERISTICS

The lake, as stated before, was divided into 27 ranges for the purpose of taking samples (Figure 5). Most of the samples taken, along the ranges, were for the purpose of determining the depth of the silt. However, on each sample visual inspection was made and recorded as to the color, texture, and general appearance.

Visual inspection revealed that the sediment deposits consist chiefly of reddish-brown silt and clay with some fine-grained and very fine-grained sand. Over most of the areas of the bottom, the upper 5 to 6 inches of the deposit has a watery consistency but with depth becomes better compacted.

Size analyses were made of 15 lake sediment samples, taken from locations both on and between ranges, and 4 soils from the watershed (see Figure 6 for sample location). Results are given in Table I; representative analyses are presented graphically as cumulative curves in Figure 7.

## Similarity of Sediment to Watershed Soils

The similarity of sediments to watershed soils is not too definite. Particle size fractions were not made on a sufficient number of sediment samples to permit a detailed comparison of the sediments to the principal soil types of the watershed. The Lawton silt loam and its eroded phase

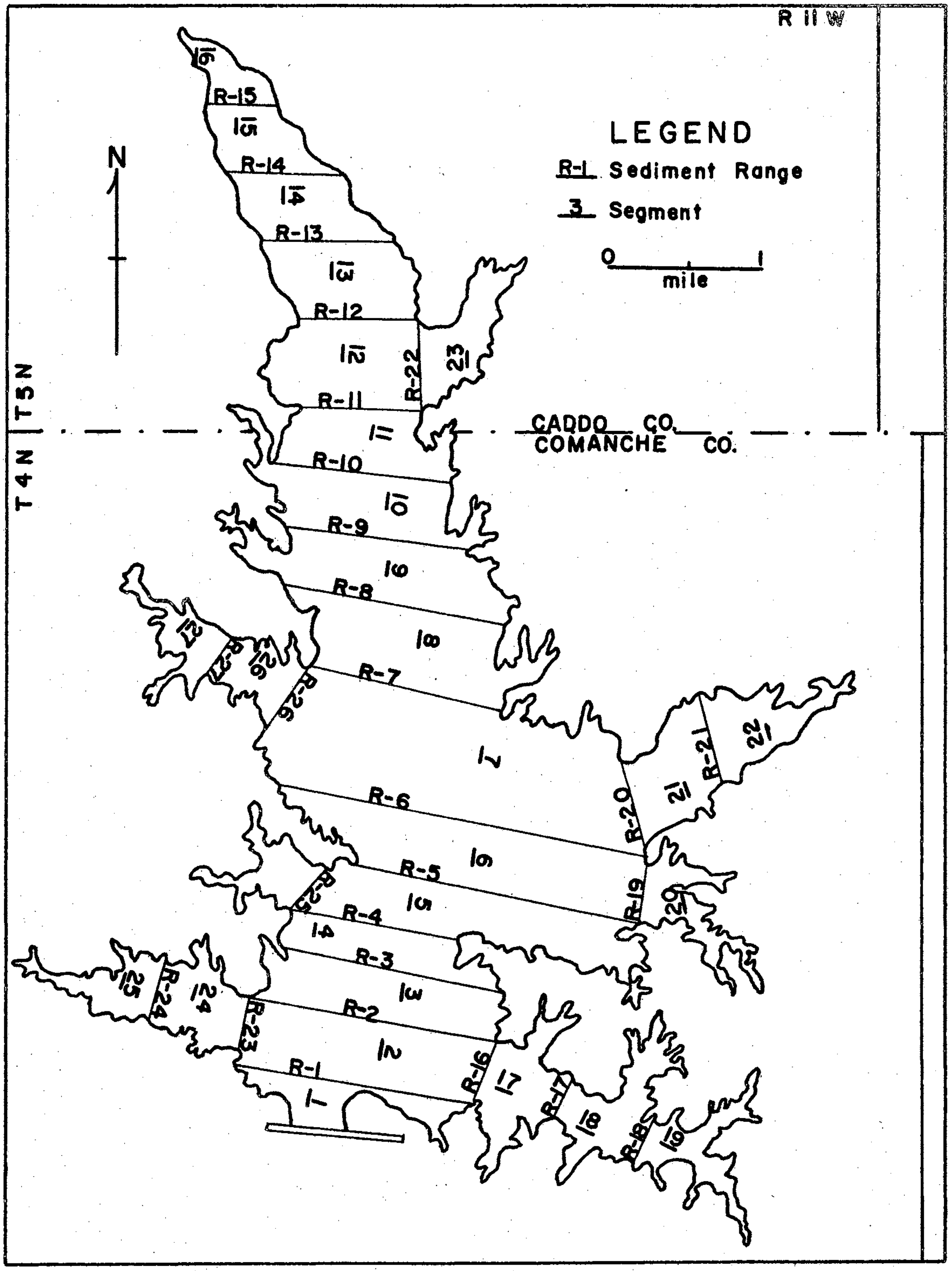


Figure 5. Lake Ellsworth with Range and Segment Location

TABLE I

SIZE ANALYSIS OF SEDIMENTS (PERCENT BY WEIGHT)

| Sample No. | Fine* Sand | Very Fine Sand | Coarse Silt | Medium Silt | Fine Silt | Very Fine Silt | Coarse Clay | Medium Clay | Fine Clay | "Finer Clay" |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ----- | 2.12 | 16.86 | 11.50 | 8.75 | 8.75 | 10.00 | 5.50 | 4.00 | 32.52 |
| 2 | 29.94 | 44.80 | 0.89 | 14.75 | 0.88 | 1.38 | 0.50 | 1.00 | 0.75 | 5.11 |
| 3 | 2.76 | 21.44 | 37.53 | 10.25 | 7.25 | 3.25 | 1.50 | 2.75 | 0.13 | 13.14 |
| 4 | 2.57 | 14.59 | 27.51 | 12.25 | 6.00 | 8.50 | 0.25 | 8.25 | 1.50 | 18.58 |
| 5 | 5.06 | 63.35 | 14.79 | 4.75 | 1.00 | 1.75 | 1.00 | 1.25 | ---- | 8.05 |
| 6 | ---- | 0.48 | 13.02 | 5.00 | 10.25 | 11.75 | 7.00 | 6.50 | 3.50 | 42.50 |
| 7 | 7.16 | 17.34 | 26.26 | 11.25 | 8.00 | 4.00 | 4.00 | 3.50 | 1.75 | 15.74 |
| 8 | ---- | 26.20 | 23.30 | 11.25 | 8.50 | 5.00 | 4.75 | 4.75 | 1.50 | 14.75 |
| 9 | ---- | 15.74 | 37.01 | 10.50 | 3.50 | 6.50 | 7.25 | 0.00 | 1.75 | 17.75 |
| 10 | 3.54 | 19.87 | 17.84 | 4.75 | 0.50 | 5.50 | 7.00 | 6.00 | 2.75 | 32.25 |
| 11 | ---- | 4.65 | 11.10 | 7.00 | 4.00 | 1.75 | 8.25 | 11.00 | 3.50 | 48.75 |
| 12 | ---- | 0.77 | 8.73 | 3.50 | 1.75 | 7.75 | 12.25 | 5.25 | 9.25 | 50.75 |
| 13 | ---- | 0.67 | 9.30 | 3.25 | 1.75 | 6.75 | 10.50 | 5.00 | 10.50 | 52.28 |
| 14 | ---- | 8.44 | 28.31 | 16.50 | 8.75 | 9.50 | 6.00 | 5.75 | 4.25 | 12.50 |
| 15 | ---- | 0.79 | 10.72 | 8.50 | 12.75 | 16.75 | 7.50 | 19.25 | 3.00 | 20.74 |
| 16 | ---- | 2.82 | 24.68 | 12.75 | 11.25 | 13.50 | 4.00 | 7.75 | 3.50 | 19.75 |
| 17 | ---- | 0.82 | 26.68 | 11.75 | 11.25 | 14.50 | 4.00 | 6.50 | 4.75 | 19.75 |
| 18 | ---- | 6.44 | 29.31 | 16.75 | 9.50 | 9.50 | 5.25 | 6.25 | 4.50 | 12.50 |
| 19 | ---- | 0.48 | 12.02 | 6.00 | 11.75 | 10.25 | 5.00 | 7.50 | 3.50 | 42.50 |

*See Figure 7 for grade size in millimeters.

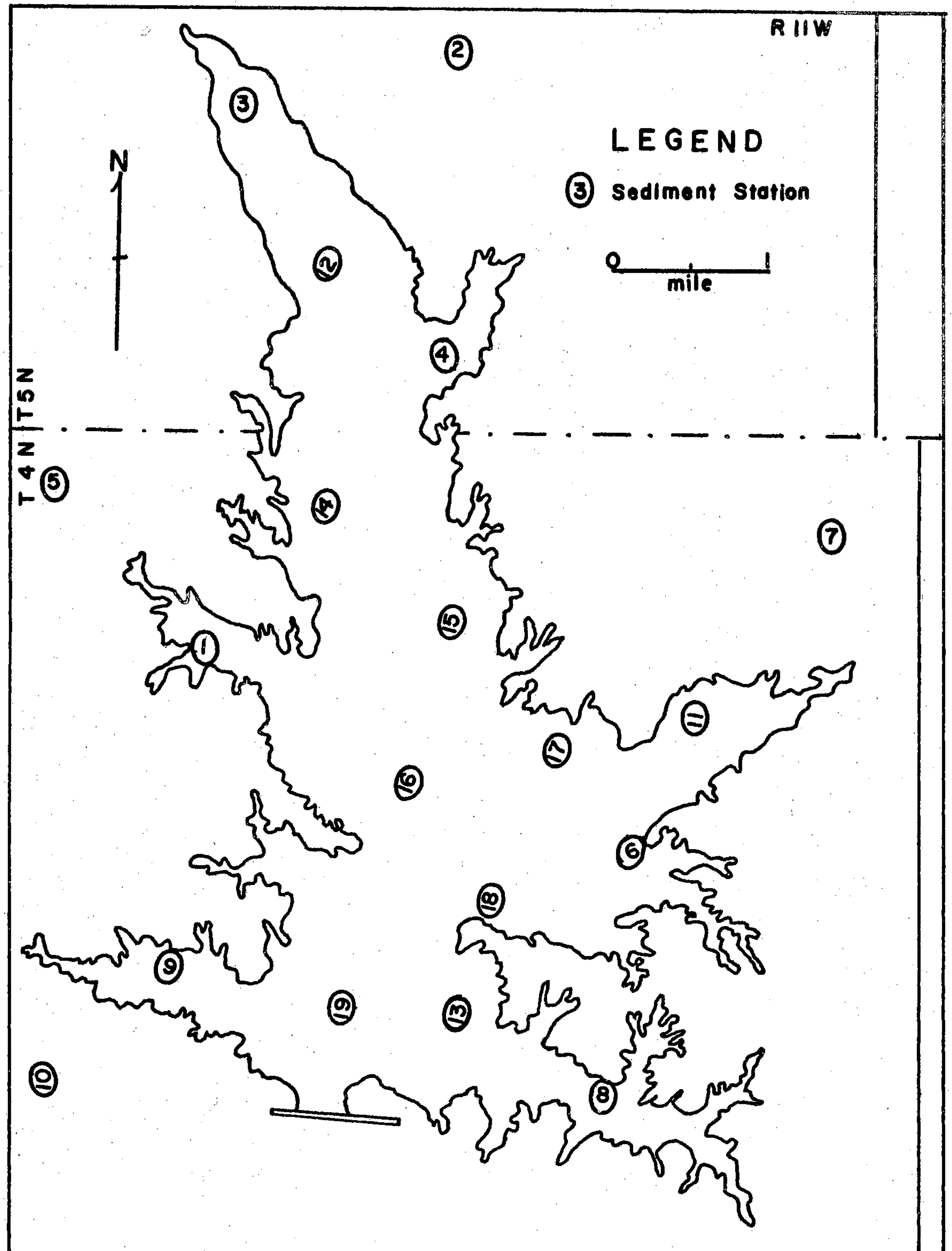


Figure 6. Locations for Size Analysis Stations


Figure 7. Cumulative Curves of Size Analysis of Sediments

are probably the main source of sediment since they occupy the most extensive area. However, it is difficult to relate the sediment in the reservoir to any single soil type because the predominant types are so similar in their physical characteristics. This similarity in physical composition of the watershed soil types, and the sediments of the lake (Figure 8), makes it impossible to ascribe, on the basis of these analyses, the sediment accumulations in the reservoir to erosion of a specific soil type within the watershed.

## Distribution of Sediments

The sediment in Lake Ellsworth has been deposited entirely as bottom set muds with East Cache Creek supplying the most sediment (Figure 9). Coarser particles are deposited soon after they enter the reservoir whether they are transported by stream or slope runoff, while the finer particles which tend to remain in suspension longer are deposited in deeper water.

During the sampling period, which extended from February to June, wave action appeared to cause suspension of near shore sediments and deposition in deeper water. The waters at the north end of the lake are turbid much of the year, while the south end clears in a few days to a week after heavy runoff from the watershed. It is very probable that some sediment has been transported to the south end of the lake along the old stream channel by a turbidity current. Turbidity and depth of sediment measurements support this conclusion. For example, on Range 5, several inches of near shore sediments present in February were absent in June. There was, however, a significant increase in the depth of

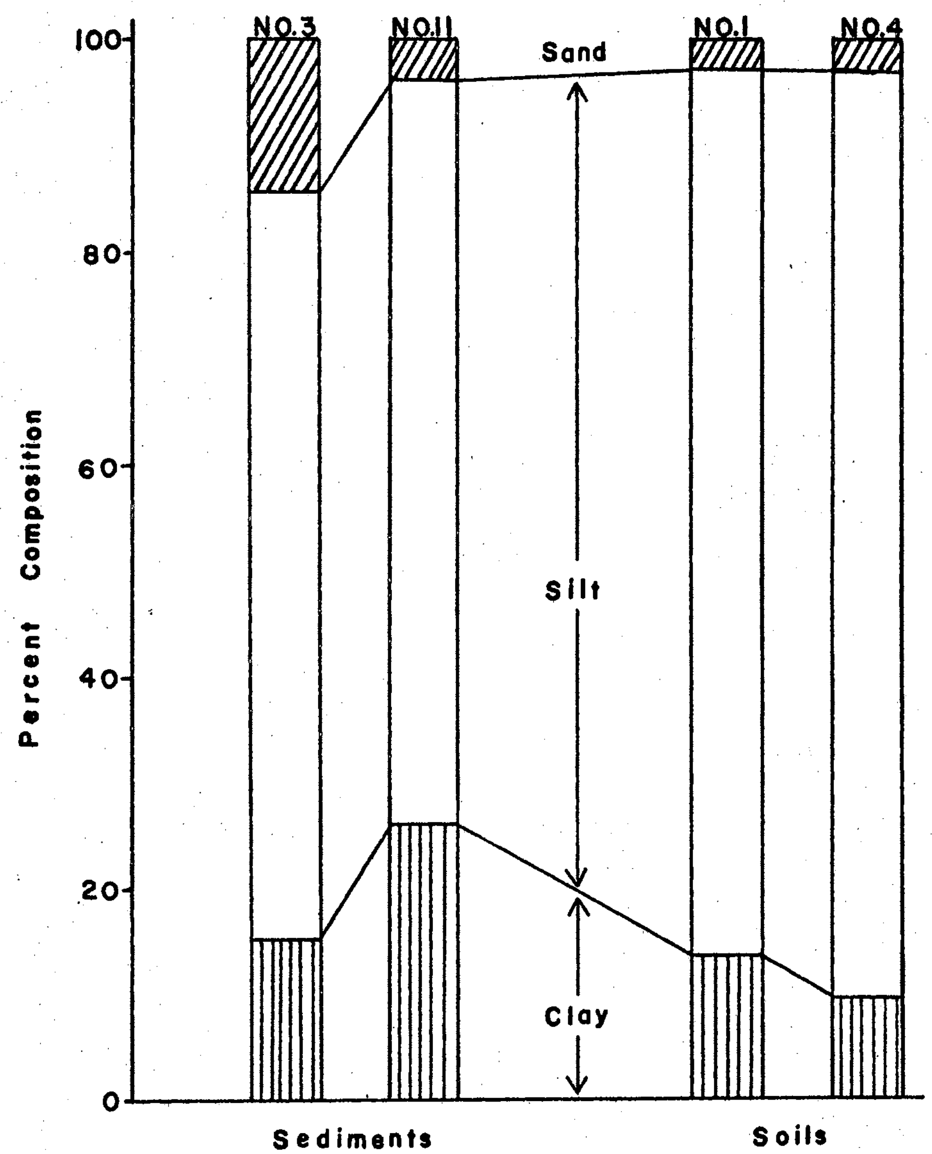


Figure 8. Size Distribution of Sediment Samples
Compared to Watershed Soils

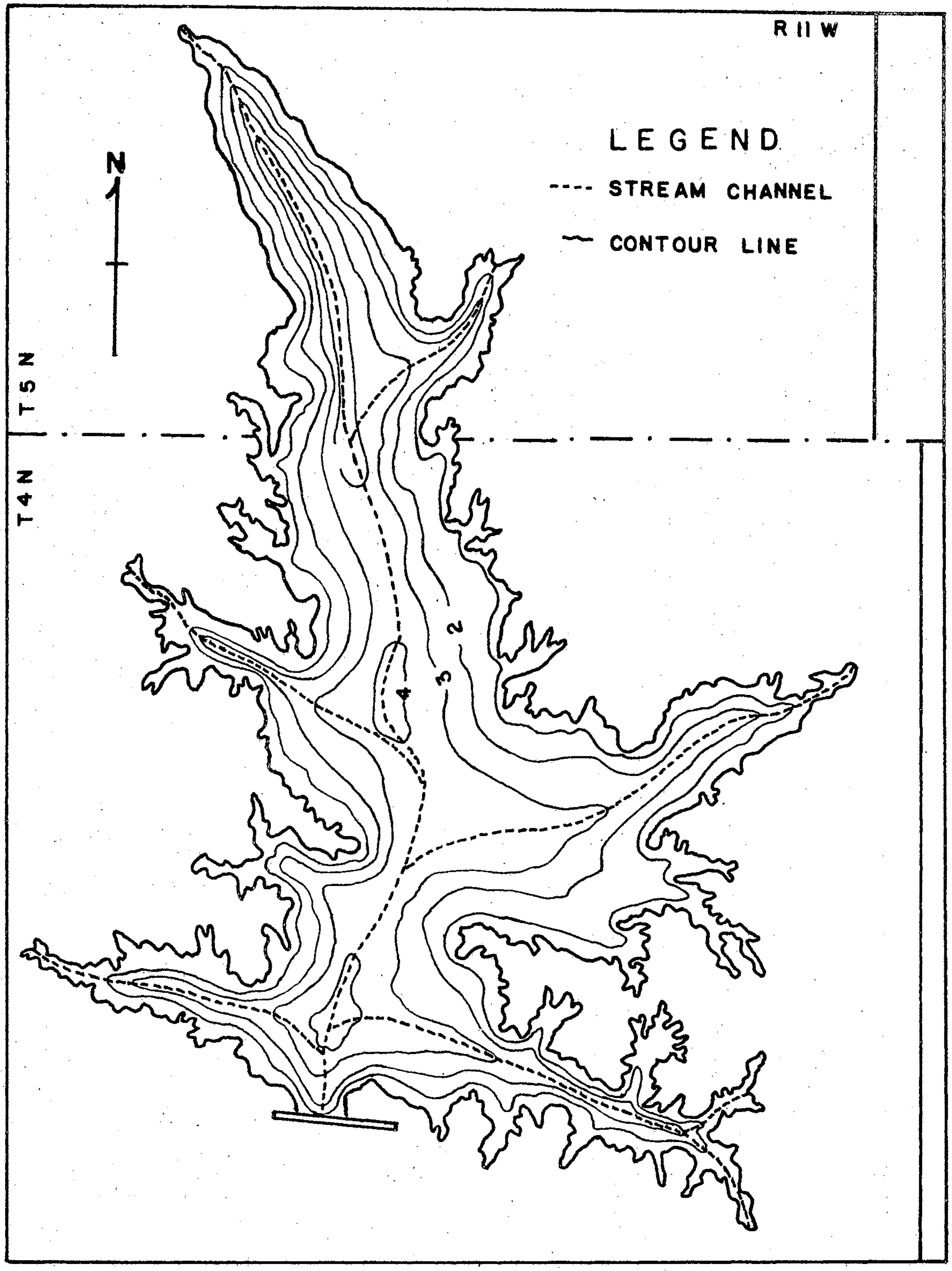


Figure 9. Lake Ellsworth Sediment Depth Contours (Feet)
During February, 1968

sediment at some distance from shore (Figure 10). The first sample site was always on the east side of the lake and was therefore exposed to wide expanses of open water resulting in heavy wave action from the prevailing southwest winds. Reid (1961) described a similar phenomenon causing formation of a littoral shelf by suspension of small particles from beaches by wave action in a period of high wave activity and disposition offshore in areas of less turbulence.

A second type of sediment redistribution may occur when flocculent sediments suspended by wave action at the western side of the reservoir are moved by wind-created currents toward the eastern side of the reservoir. Sediment resuspension was described by Jackson and Starrett (1959) for Lake Chautauqua, Illinois. Return currents, moving from east to west along the bottom of the reservoir, may be strong enough to resuspend light flocculent material from the sediment-water interface. Further investigation would be necessary to determine the actual resuspension mechanisms.

The thickest deposits are found at the northern end. A thickness of 4 feet and 7 inches was measured in the old channel of East Cache Creek on range 12. One mile south on range 9 the sediment had a maximum thickness of 3.6 feet and averaged 1.2 feet. To the south the thickness decreases irregularly.

Segments 11, 12, 13, 14, 15, and 16 have lost the most storage capacity. The heads of the arms have also lost considerable storage capacity, especially in segments 20, 21, and 22. See Table II for segment data. Figure 11 shows typical range cross-sections.

Sediment samples from the arms contained more abundant sand and coarse silt than did samples from the main body. This distribution is

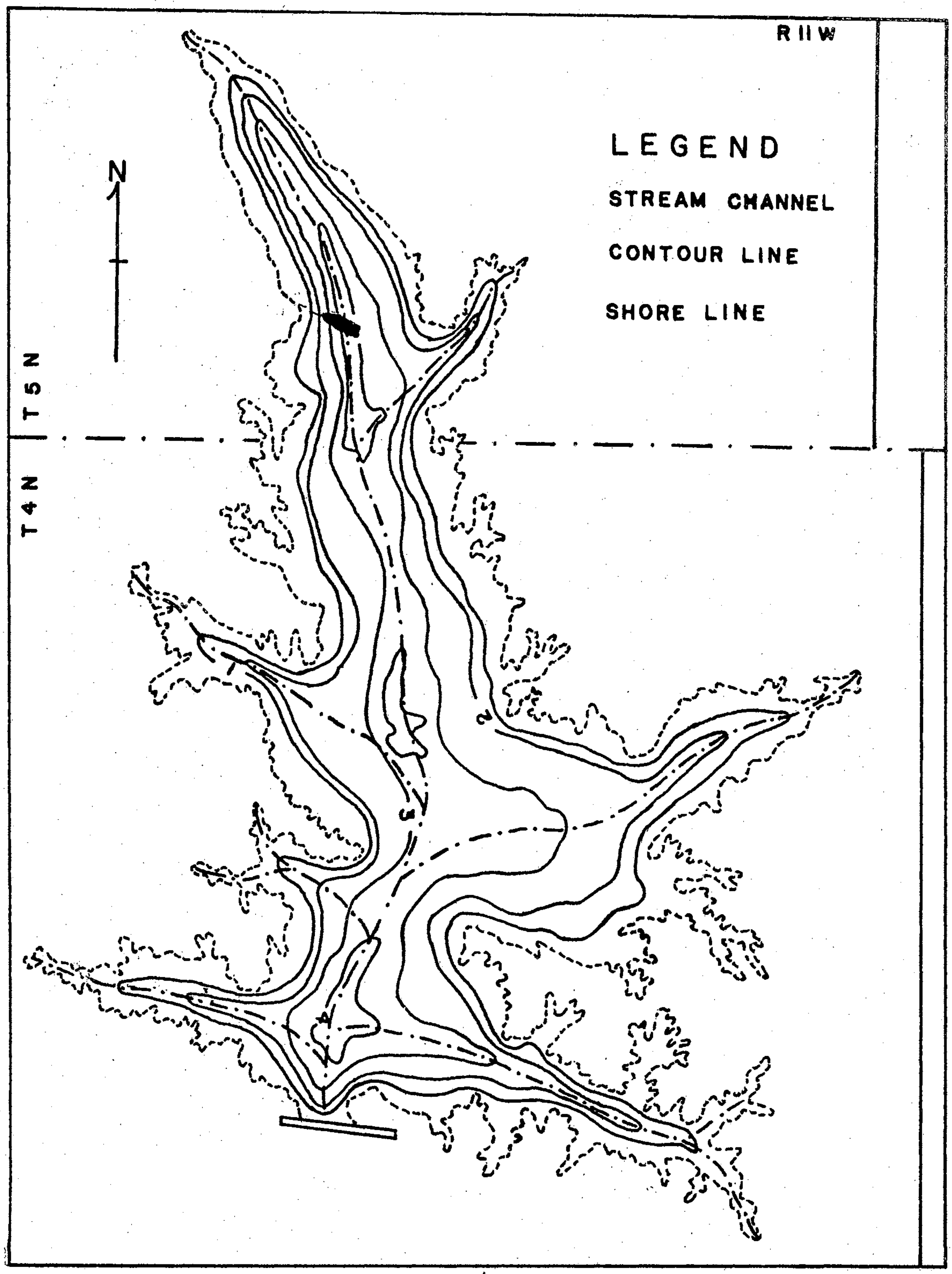


Figure 10. Lake Ellsworth Sediment Depth Contours (Feet) During June, 1968.

TABLE II

SEGMENT DATA SHOWING ORIGINAL CAPACITY AND PRESENT CAPACITY OF RESERVOIR

| Segment | Original Surface Area (ac.) | Original Capacity (ac.-ft.) | Capacity at Date of Survey (ac.-ft.) | Sediment Volume (ac.-ft.) |
|---|---|---|---|---|
| 1 | 32.12 | 839 | 836 | 3 |
| 2 | 312.80 | 6,903 | 6,824 | 79 |
| 3 | 315.68 | 8,884 | 8,802 | 82 |
| 4 | 199.84 | 8,963 | 8,882 | 81 |
| 5 | 415.64 | 8,786 | 8,675 | 111 |
| 6 | 438.96 | 8,591 | 8,466 | 125 |
| 7 | 849.64 | 10,639 | 10,478 | 161 |
| 8 | 233.52 | 5,539 | 5,461 | 78 |
| 9 | 253.80 | 5,201 | 5,113 | 88 |
| 10 | 223.24 | 5,013 | 4,911 | 102 |
| 11 | 310.08 | 5,637 | 5,515 | 122 |
| 12 | 194.76 | 4,681 | 4,548 | 133 |
| 13 | 185.72 | 4,247 | 4,143 | 104 |
| 14 | 138.20 | 1,471 | 1,432 | 39 |
| 15 | 110.88 | 537 | 525 | 12 |
| 16 | 66.00 | 324 | 307 | 17 |
| 17 | 117.16 | 1,117 | 1,106 | 11 |
| 18 | 126.28 | 1,187 | 1,166 | 21 |
| 19 | 66.52 | 207 | 200 | 7 |
| 20 | 105.44 | 919 | 907 | 12 |
| 21 | 136.20 | 1,448 | 1,439 | 9 |
| 22 | 117.76 | 1,256 | 1,247 | 9 |
| 23 | 105.16 | 813 | 802 | 11 |
| 24 | 102.64 | 745 | 740 | 5 |
| 25 | 77.20 | 391 | 385 | 6 |
| 26 | 76.42 | 273 | 264 | 9 |
| 27 | 67.52 | 194 | 182 | 12 |
| Total or Average | 5,389.18 | 94,805 | 93,356 | 1,449 |

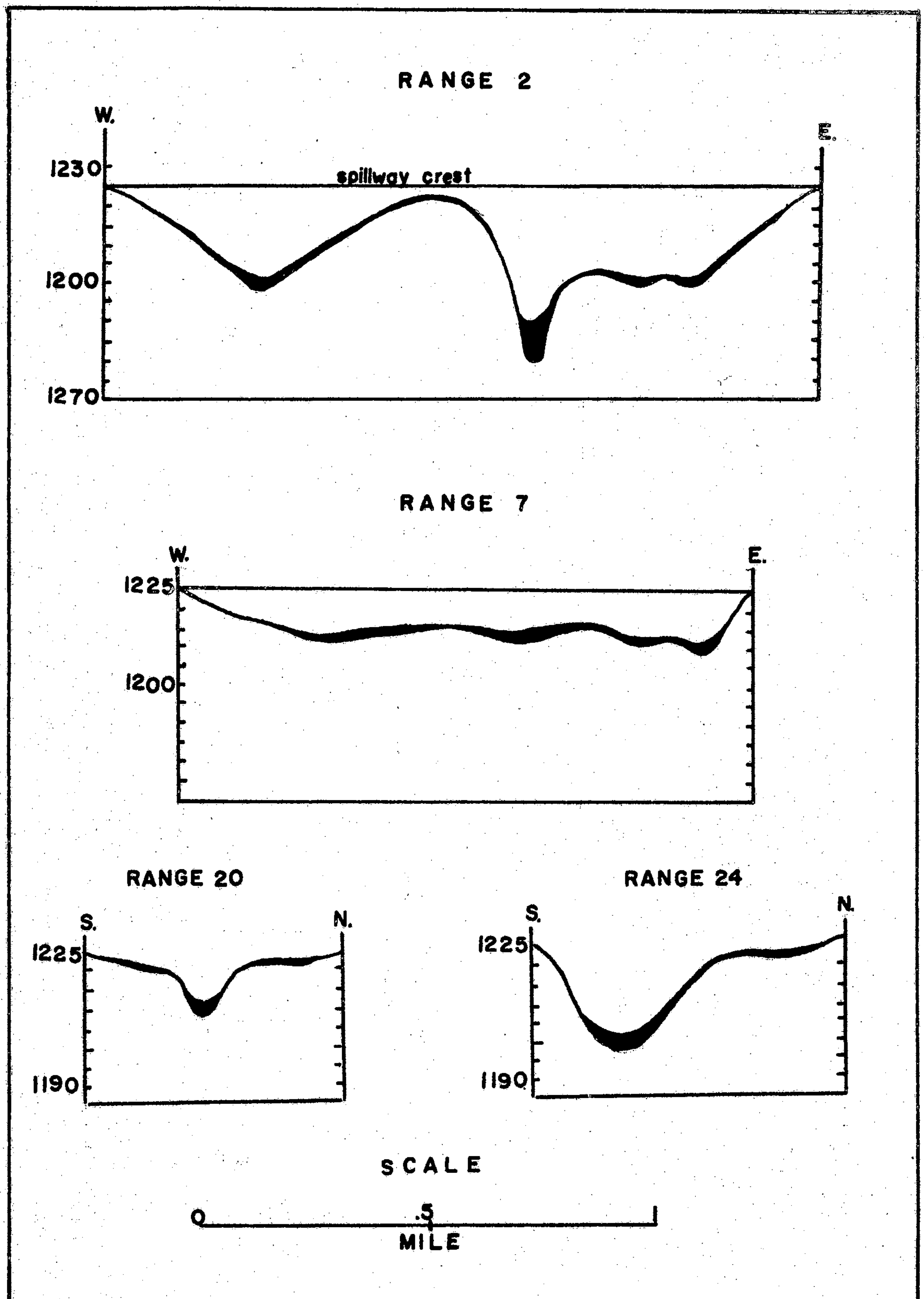


Figure 11. Typical Range Cross-Sections

to be expected since sand and coarse silt-size particles would settle out soon after reaching a standing body of water. Sediments in segments 15, 14, and 13 also contained significant amounts of sand, but in the segments to the south clays and silts dominated.

Although sand is available over the watershed, not much is transported into the lake. It takes a concentrated flow of water to move sand-size particles while clays and silts are easily transported by sheet flow. The loose sand is left on the slopes or deposited along the beds of the many small, temporary streams leading to the lake arms.

## Shoreline Erosion

As Lake Ellsworth filled up with water the surrounding land was flooded and shoreline erosion started. Today erosion is most common on the bold headlands of the main body and along certain shores of the larger arms. The results of shoreline erosion are most easily seen where a cliff has been carved. In areas where the sandstones alternate with clay shale beds a different problem exists. The clay shales are easily eroded, but this action causes slumping of sandstone blocks which then serve to break up the full force of the waves. The east shore of the main body north of the lake office has many hundreds of yards of 3 to 4 foot cliffs exposed.

# CHAPTER VI

## CONCLUSIONS

Lake Ellsworth, one of the municipal water supply reservoirs at Lawton, Oklahoma, was built in 1961. The Lake has a drainage area of 250 square miles; original reservoir surface area was 5,389.18 acres and volume was 94,805 acre feet.

This 1968 sedimentation survey of the reservoir shows a capacity loss of .2 percent per year. In 7.5 years the lake has lost 1.53 percent of original capacity.

Lake Ellsworth is connected, by a 42 inch pipeline, to the other city reservoir, Lake Lawtonka and the city tries to maintain the level of Lawtonka by pumping water from Lake Ellsworth. Lake Lawtonka is a much deeper lake than is Ellsworth and therefore is a much better holding basin than Ellsworth, because not nearly as much water is lost due to evaporation. Serious drawdowns have occurred on the Lake Ellsworth Reservoir in several years since construction. During the droughts of 1966 and 1967, the reservoir was almost emptied by the city pumpage.

A deficiency in rainfall of 10 inches or more from the average in any year will probably result in a water shortage at Lawton. Such deficiencies in 1966 and 1967 necessitated the city to look for other sources for future needs. Shortages of increasing severity can be expected in future years as the population of the city grows.

Even though the sedimentation problem at Lake Ellsworth is a serious one and needs much attention it is not the only problem that exists for the city of Lawton. The deficiency of supply at Lawton is not primarily due to loss of reservoir capacity to sediment but rather to inadequate total storage to meet the increasing water needs of the city.

The present Lake Ellsworth Reservoir, although inadequate, is worth preserving. It will probably continue to be one of the major sources of supply in conjunction with any other supply decided upon. For this reason, a watershed protection program is suggested. Such a program should also be included in plans for future reservoirs.

Of the total watershed area, 42.7 percent has a slope exceeding 7 percent and 29.7 percent of the area has a slope exceeding 12 percent. Erosion classified as "severe" and "very severe" is occurring on 43.6 percent of the watershed area, while 1.2 percent of the area is considered "destroyed land." Conservation measures needed to reduce soil losses on this watershed are profitable to the individual farmers by increasing income. Also, these same conservation measures would save the taxpayers' money already invested. Lake Ellsworth is reported to have cost the taxpayers a total of $6,182,840 in 1961 when it was built. Since this survey shows the original capacity of the reservoir to be 94,805 acre-feet, it is seen that this storage thus cost originally $6.52 per acre-foot. The present survey also shows that 193.2 acre-feet of storage capacity are being lost per year to sediments. At this rate, the loss amounts to $1,259.66 of the original investment lost per year. Replacements of this lost storage capacity as well as the building of additional facilities at present prices would be expensive. It is recommended that the City of Lawton immediately sponsor the development of a soil and water conservation program on the Ellsworth Reservoir watershed in order to prolong the ultimate life of this reservoir and the length of time it can be used as part of the public supply.

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VITA

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