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# THE 1967 ALTUS RESERVOIR SEDIMENT SURVEY

Joe M. Lara
Engineering and Research Center
Bureau of Reclamation

March 1971

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16. ABSTRACT

Altus Reservoir was surveyed in 1967 to gather the data needed in computing the latest reservoir capacity. The data were also used to compute the quantity of sediments accumulating in the reservoir since the dam was closed in 1940. Capacity of the reservoir is 134,000 acre-ft and the surface area 6,260 acres at spillway crest elevation 1559 ft. Sediments accumulated in the reservoir at an annual rate of 838 acre-ft between 1940 and 1947. Thirty sediment samples of reservoir deposits were collected from 23 reservoir range sites. An average unit weight of 70 lb/cu ft was determined from analyses of samples collected during the 1948, 1953, and 1967 surveys. Particle size analyses of these samples indicated an average breakdown of 29% clay, 32% silt, and 39% sand. Sonic depth recording mechanism was used to run the hydrographic survey. Reservoir capacity was computed based on areas determined by a width ratio method. Sediments have deposited longitudinally to depths of 1 to 9 ft throughout the reservoir length. Depths ranged from 1 to 6 ft for the laterally deposited sediments.

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by

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March 1971

Hydrology Branch
Division of Planning Coordination
Engineering and Research Center
Denver, Colorado

UNITED STATES DEPARTMENT OF THE INTERIOR
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Secretary

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BUREAU OF RECLAMATION
Ellis L. Armstrong
Commissioner

## ACKNOWLEDGMENT

The hydrographic survey was run by Joe M. Lara, Engineering and Research Center, Denver, Colorado. Survey personnel included H. T. Daniel, R. Carey, and W. Vanhosser under the supervision of the Regional Office, Amarillo, Texas. They ran the required land surveys and assisted in running the hydrographic survey and taking the sediment samples. Transcription of the field notes for computer processing was done by R. L. Ochs and W. A. Seth under the supervision of R. Weimer, Regional Office, Amarillo. This report was prepared under the supervision of Ernest L. Pemberton, Head, Sedimentation Section, Engineering and Research Center, Denver, Colorado. Mr. Pemberton also reviewed the report and the data and information used in its preparation.

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## GENERAL INFORMATION

### Location and Ownership

Altus Dam is located on the North Fork of the Red River about 18 miles north of Altus, Oklahoma. The reservoir is situated in Greer and Kiowa Counties. The dam and reservoir are owned by the U.S. Government and operated by the Bureau of Reclamation, Department of the Interior.

### Description of the Dam

Altus Dam is a concrete gravity type, partially curved structure faced with granite masonry on both faces except the downstream face of the overflow section. It rises 110 feet above its foundation and is 1,112 feet long. Incorporated within the dam section are both controlled and uncontrolled overflow-type spillways and an outlet works that delivers water into the project canal system. The spillway capacity is 58,000 cubic feet per second regulated by nine radial gates. A drawing of the general plan and sections is shown in Figure 1.

### Description of the Reservoir

The present capacity of the reservoir is 134,549 acre-feet at the spillway crest elevation 1559 feet. This shows a loss of 22,119 acre-feet since the dam was closed in 1940. The present reservoir surface area is 6,260 acres at elevation 1559 feet. The reservoir is 13.1 miles long from the dam to the head of the reservoir. It has an average width of 1 mile. Figures 2 and 3 are plan maps of the reservoir.

The reservoir was designed to provide water for irrigation, flood control, an augmented municipal water supply for the city of Altus, fish and wildlife benefits, and recreational facilities.

### Drainage Area Description

The drainage area above Altus Dam is 2,515 square miles of which 399 square miles is probably noncontributing. It originates in the Panhandle of Texas about 15 miles west of Amarillo, Texas, and extends eastwardly into western Oklahoma. The area is drained by the North Fork of the Red River, whose principal tributaries are McClellan and Sweetwater Creeks.

There are no major structures in the watershed that would reduce the sediment contribution to Altus Reservoir. However, the restriction of the lake imposed by the approaches to Granite Bridge and another restriction existing naturally about 3000 feet above the dam do affect the distribution of sediment after it enters the lake.

Further description of the drainage area regarding geology, topography, soils, land use, and other features is given in a Bureau of Reclamation report published in 1949.[1]

### Hydrographic Records

Streamflow records of the North Fork of Red River near Carter, Oklahoma, were used to estimate the inflow to Altus Reservoir. These records, adjusted for drainage area, showed an annual average inflow of 104,400 acre-feet for 20 years of record (1944-62, 1964-66). Outflow from the reservoir was based upon records of the river at the gaging station below the dam. These showed an outflow of 36,340 acre-feet per year for a 14-year period (1950-62, 1964-66). The outflow is controlled by releases from the dam. Altus Reservoir operation ranged from a minimum elevation of 1523.20 feet in 1945 to a maximum of 1562.10 feet in 1951.

## SURVEYS, SAMPLING, AND EQUIPMENT

Two surveys of Altus Reservoir were previously run in 1948 and 1953 using a combination contour and range method. The range method was used for the 1967 survey that began in February 1967 and completed April 14, 1967. Results of each survey are summarized in Table 2 (pages 12 and 13).

### Surveying Methods

Field survey work was begun by locating and flagging all 25 reservoir sedimentation range ends (Figures 2 and 3) that had been permanently monumented during previous surveys. In some cases it was necessary to relocate the range and monuments that had been removed or possibly destroyed for one reason or another. The ranges were profiled across their full length. Standard land surveying procedures and equipment were used to run levels along each range line from the permanent range end monuments down to the water surface from each side of the reservoir. Stations were temporarily established at the terminal land points near water's edge for use in the hydrographic survey.

[1] Seavy, L. M., "Sedimentation survey of Altus Reservoir—W. C. Austin Project, Oklahoma," Bureau of Reclamation, U.S. Department of the Interior, December 1949.

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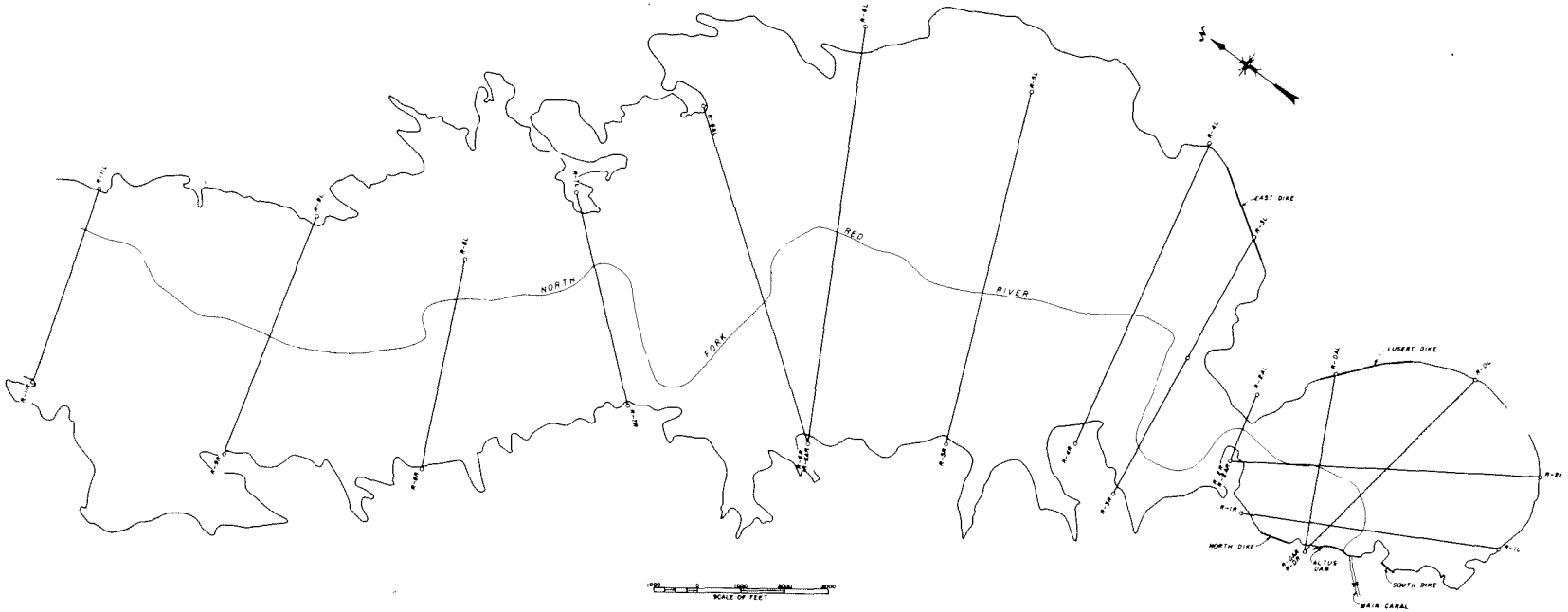



Figure 2. Reservoir sedimentation range system.

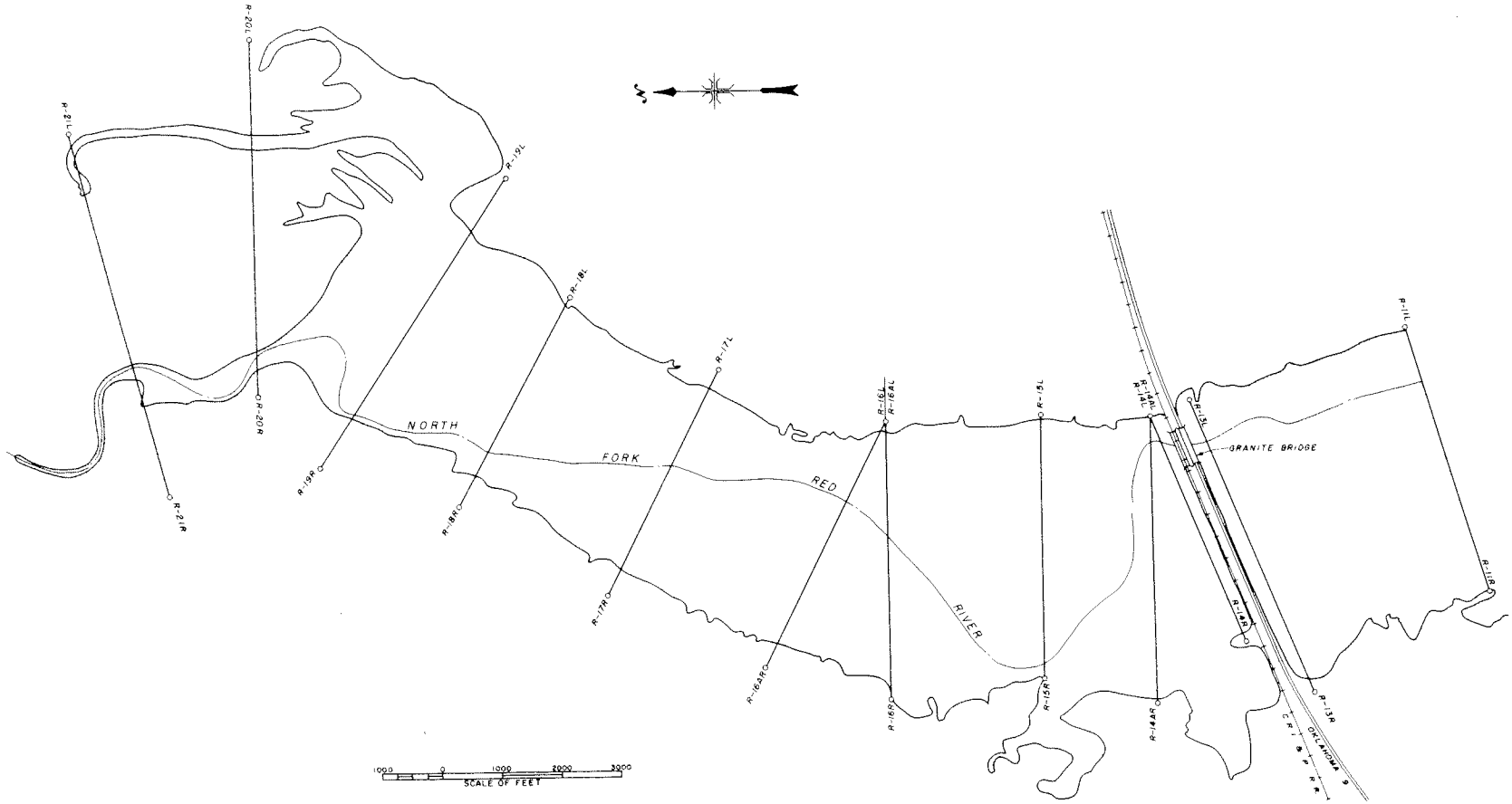



Figure 3. Reservoir sedimentation range system.

The hydrographic survey was run in April 1967 using sonic depth recording equipment (Figure 4) to sound the submerged portion of the ranges. The equipment is installed in a sounding boat as shown in Figure 5. The boat is first positioned on range line as near to the shore as possible. Then the line is profiled from the water's edge station using a level rod and stadia or tape to measure the distance to the center point of the transducer. The depth recorder is started up and the boat is propelled across the range at speeds of about 3 to 5 feet per second (Figure 6). A man on shore keeps the boat on line through radio communication with the boat operator (Figure 7). The distance measuring machine shown in Figure 8 is used to measure horizontal distances across the reservoir. The machine provides a way of noting "fix" lines on the sonar chart that is contained in the recorder cabinet shown in Figure 9. Vertical control was maintained by referencing the recorded soundings to the reservoir water surface indicated by gage at the dam which was read each day of the survey operation.

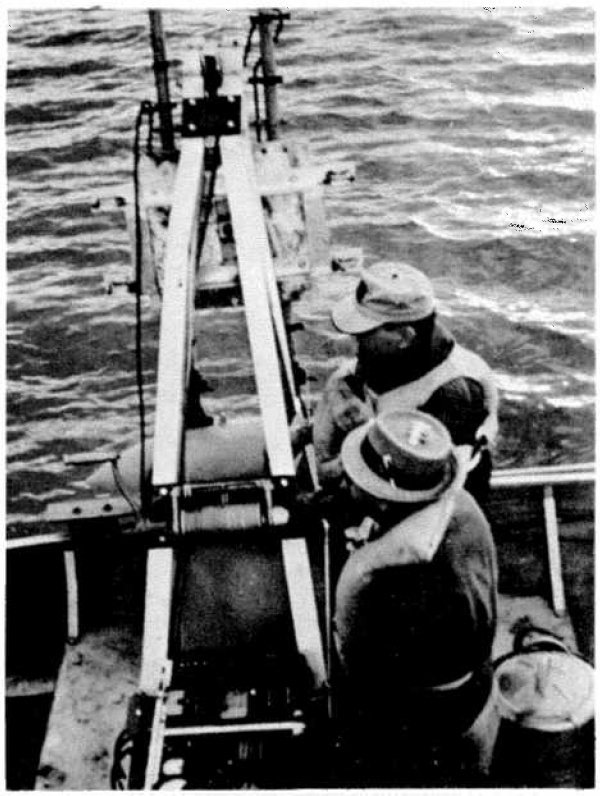


Figure 4. Sonic depth recording equipment. Transducer is out of water. Photo P258-D-57761

Figure 5. Sounding boat used in the hydrographic survey. Photo P258-D-57701

**Sampling Methods and Equipment**

Ten samples of the underwater reservoir sediment deposits were collected with a gravity core sampler that is suspended from a frame mounted on a raft (Figure 10). The sampler is operated with a power winch using a 0.25-inch cable. It is allowed to fall free into the sediment deposits to the greatest possible penetration. After the sampler is raised it is brought onto the raft, the cutting shoe at the bottom is removed, and the plastic tube containing the sediment sample is withdrawn. A hacksaw is used to cut that part of the tube holding the sample and each end of the tube is capped and identified for analysis.

Samples were collected from 13 of the upstream ranges using a 2-inch diameter plastic tube that was pounded into the sediment deposits with a rubber mallet (Figure 11).

The field density apparatus was used to take samples at seven of the upstream ranges in the manner prescribed by a Bureau of Reclamation manual.[2] Figure 12 shows one of these samples being taken.

[2] Bureau of Reclamation, *Earth Manual,* U.S. Dept. of the Interior, pp 582-91, 1963.

Figure 6. Sounding Range 1. Photograph was taken from atop the dam looking towards the narrows in the background. Photo P258-D-57705

Figure 7. Transit set up on range point in line with R7L at water's edge. During the sounding operation the man on shore keeps the boat on line through the transit. Radios are used for communication between the transit man and the boat operator. Photo P258-D-57711

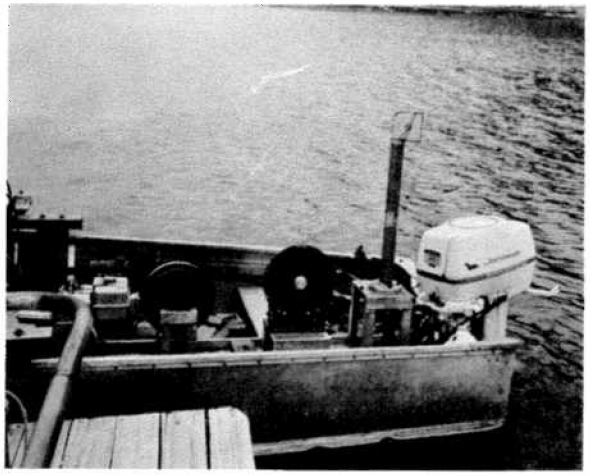


Figure 8. Distance measuring machine mounted in back of the boat. Fair lead for piano wire guidance can be seen at right. It has a periscope appearance. Photo P258-D-57703

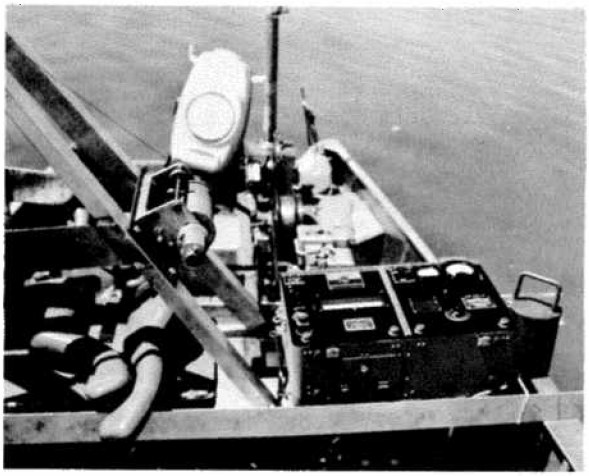


Figure 9. View of sonic depth recorder cabinet (in right foreground). Photo P258-D-57706

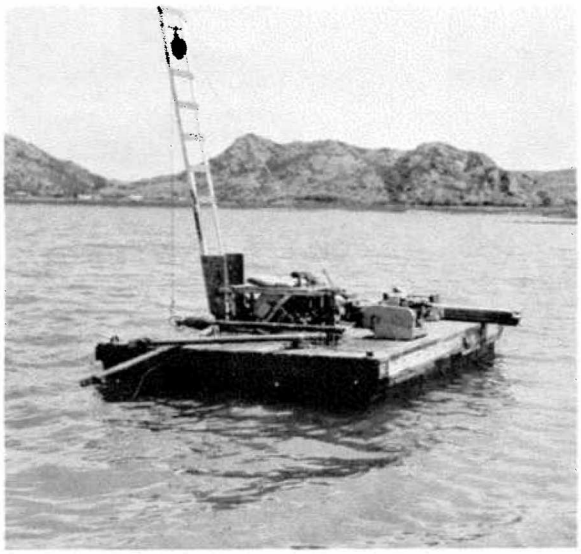


Figure 10. Gravity core sampler shown suspended from a cable and lying on the platform of the raft. Photo P258-D-57699

Figure 11. Sediment sample being taken by pounding a plastic tube into the sediment deposits with a rubber mallet. Photo P258-D-57702

Figure 12. Taking a sediment sample with field density apparatus. Photo P258-D-57697

## RESERVOIR SEDIMENT DISTRIBUTION

### Longitudinal Distribution

A summary of the sediment distribution computations for Altus Reservoir is contained in Table 1. In Column 6 of the table are the actual accumulated sediment volumes determined from the 1967 survey. Total sediments accumulated in the reservoir since the original survey of 1940 amounted to 22,119 acre-feet at spillway crest elevation 1559 feet. Column 7 lists the volume of sediment accumulated at corresponding reservoir elevations expressed as percentage of the actual total sediment volume, 22,119 acre-feet. To check the theoretical distribution, the Empirical Area-Reduction Method was used to compute the sediment distribution of 22,119 acre-feet in the reservoir. The reservoir depth-capacity relation plotted for the 1940 (original) data in Figure 13 showed the reservoir to be a Type II. A plot of the curves to determine the depth of sediment at the dam is shown in Figure 14. Results of the sediment distribution computations are listed in Columns 8, 9, and 10 of Table 1. The theoretical computations showed the sediment would reach an elevation of 1512.6 feet compared to the actual elevation of 1509 feet. The sediment disposition curves plotted in Figure 15 show a comparison of the actual with the theoretical distribution. The curves graphically show the percentages of reservoir depth plotted against the sediment deposited. Inspecting the curves shows that

Table 1

SUMMARY OF RESERVOIR SEDIMENT DISTRIBUTION COMPUTATIONS

| (1) Elevation (feet) | (2) 1940 area (acres) | (3) 1940 capacity (acre-feet) | (4) 1967 area (acres) | (5) 1967 capacity (acre-feet) | (6) Measured sediment volume (acre-feet) | (7) Percent of measured sediment | (8) Type II computations: 1967 capacity (acre-feet) | (9) Type II computations: Sediment volume (acre-feet) | (10) Type II computations: Percent |
|---|---|---|---|---|---|---|---|---|---|
| 1559 | 6,772 | 156,668 | 6,260 | 134,549 | 22,119 | 100.0 | 134,557 | 22,111 | 100.0 |
| 1555 | 6,007 | 131,132 | 5,534 | 110,963 | 20,169 | 91.2 | 109,653 | 21,479 | 97.2 |
| 1550 | 5,302 | 102,872 | 4,626 | 85,565 | 17,307 | 78.2 | 83,236 | 19,636 | 88.9 |
| 1547 | 4,777 | 87,670 | 4,081 | 72,504 | 15,166 | 68.6 | 69,353 | 18,317 | 82.9 |
| 1545 | 4,279 | 78,704 | 3,823 | 64,167 | 14,537 | 65.7 | 61,324 | 17,380 | 78.6 |
| 1540 | 3,720 | 58,718 | 3,219 | 46,560 | 12,158 | 55.0 | 43,811 | 14,907 | 67.5 |
| 1535 | 3,103 | 41,678 | 2,616 | 31,972 | 9,706 | 43.9 | 29,359 | 12,319 | 55.7 |
| 1530 | 2,510 | 27,668 | 2,165 | 20,276 | 7,392 | 33.4 | 17,967 | 9,701 | 43.9 |
| 1525 | 1,991 | 16,302 | 1,645 | 10,752 | 5,550 | 25.1 | 9,179 | 7,123 | 32.2 |
| 1520 | 1,445 | 7,732 | 1,103 | 3,844 | 3,888 | 17.6 | 3,087 | 4,645 | 21.0 |
| 1517.5 | 1,073 | 4,608 | 643 | 1,663 | 2,945 | 13.3 | 1,144 | 3,464 | 15.7 |
| 1515 | 678 | 2,448 | 182 | 632 | 1,816 | 8.2 | 114 | 2,334 | 10.6 |
| 1510 | 135 | 586 | 59 | 30 | 586 | 2.7 | **0 | 0 | 2.7 |
| 1505 | 58 | 116 | *0 | 0 | 116 | 0.5 | — | — | 0.5 |
| 1500 | 1 | 2 | — | — | 2 | 0 | — | — | 0 |
| 1496.7 | 0 | 0 | — | — | 0 | 0 | — | — | 0 |

*El. 1509

**El. 1512.6

EXPLANATION OF COLUMNS

(1) Elevation of reservoir.
(2) Original reservoir surface area surveyed in 1940.
(3) Original reservoir capacity from 1940 survey.
(4) Reservoir surface area surveyed in 1967.
(5) Reservoir capacity from 1967 survey.
(6) Accumulated sediment volume = Column (3) minus Column (5).
(7) Measured sediment expressed as percentage of total sediment (22,119 acre-feet).
(8) Computed 1967 reservoir capacity using Emperical Area-Reduction Method.
(9) Computed sediment volume to date = Column (3) minus Column (8).
(10) Computed sediment expressed as percentage of total sediment (22,111 acre-feet).

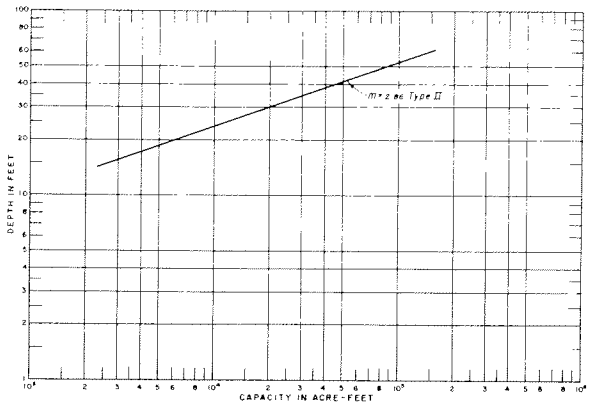



Figure 13. Reservoir depth-capacity relation.

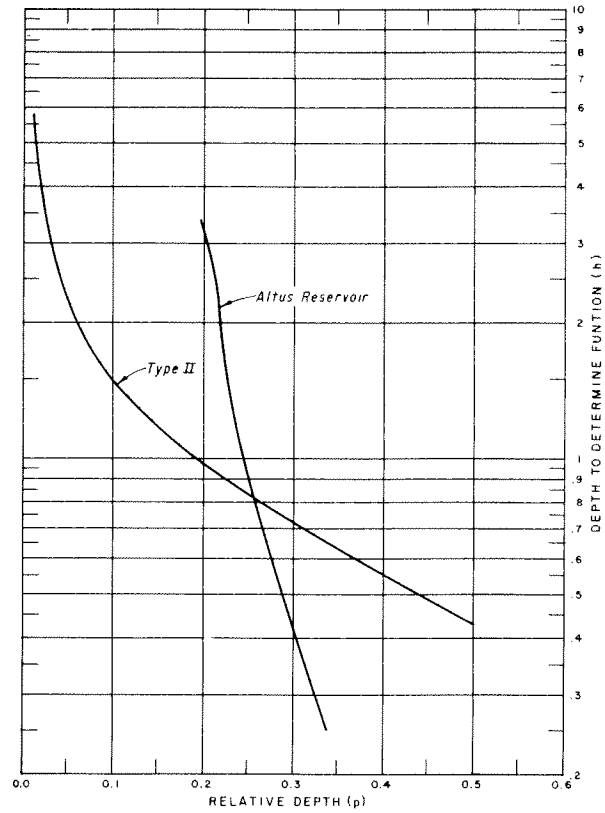



Figure 14. Curves to determine depth of sediment at dam.

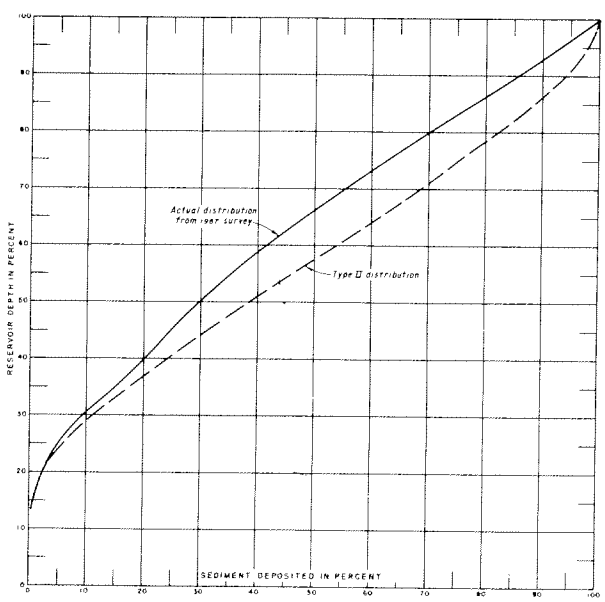



Figure 15. Sediment disposition curves.

the actual and Type II distribution compare favorably throughout the depth range. Deviations of the sediment deposited do not exceed 13 percent for reservoir depths ranging from 60 to 80 percent. In an actual project planning study, results of the Type II computations would have been used which show about a 3-1/2-foot difference in the elevation of sediment at the dam when compared to the observed data. A sediment accumulation curve covering the 1940-67 period is plotted in Figure 16 using the values in Columns 1 and 6 of Table 1.

A further idea of how the sediment was distributed longitudinally through the reservoir can be obtained by studying the profiles in Figure 17. The points plotted to define these profiles are not, in every case, the valley thalweg; i.e., the minimum point of the range line cross section. The thalweg elevation of the old floodplain

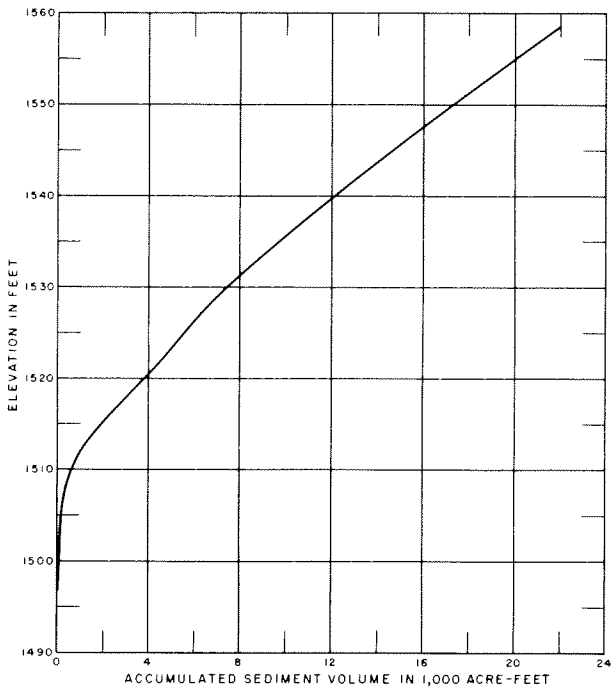



Figure 16. Sediment accumulation curve.

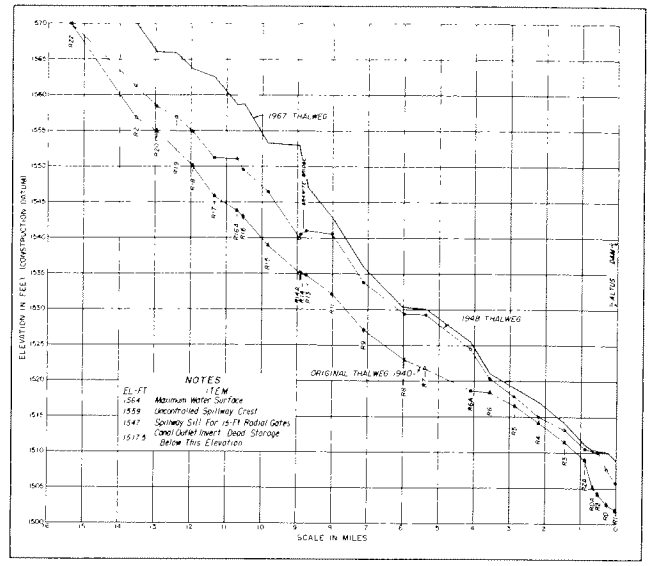



Figure 17. Longitudinal profiles.

was plotted in some instances. The table below summarizes the depths to which the sediments had accumulated between the 1940-67 and 1948-67 periods.

| Distance above dam (miles) | Depth of sediment (feet) | |
|---|---|---|
| | Between 1940-67 survey | Between 1948-67 survey |
| 0-8 | | range <1 to 2 |
| 8-12 | | 8.5 average* |
| 0-1 | 6.5 average | |
| 1-3.5 | 2.5 average | |
| 3.5-7 | 7.5 average | |
| 7-12 | 14 average** | |

*Excludes maximum of 13 feet at Range 14A.
**Excludes maximum of 18 feet at Range 14A.

The extreme rise in the depths of sediment at Range 14A results from the influence of Granite Bridge downstream. However, the narrows area occurring naturally at Range 2A had little influence on the sediment depositional pattern immediately upstream (Range 3).

### Lateral Distribution

Profiles of all 25 sedimentation ranges surveyed in 1948 and 1967 were plotted in Figures 28 through 52 in the appendix. These profiles show generally how sediments were laterally distributed in the reservoir. Sediments are shown depositing laterally to depths of 1 to 4 feet from sedimentation Ranges 1 to 11, 8 miles above the dam. From sedimentation Range 13 on upstream to Range 19, the laterally deposited sediments averaged about 6 feet except at Range 15 that showed an average depth of about 11 feet. The cross sectional plottings show that Ranges 20 and 21 were essentially filled laterally with sediment to maximum water surface, 1564 feet.

## SEDIMENT ANALYSES

### Sediment Accumulations

The total volume of sediments that has accumulated in Altus Reservoir amounted to 22,120 acre-feet at spillway crest elevation 1559 feet (Item 38a, Table 2) as computed by subtracting the 1967 from the 1940 capacity. An average annual sediment accumulation rate of 838 acre-feet was determined for the 26.4 years since the dam was built. Sediments deposited at a rate

of 0.398 acre-foot per square mile per year for this period.

**Reservoir Sedimentation Summary**

Table 2 gives a comprehensive summary of the reservoir sediment data relative to each survey that has been run. The data include tabulating incremental sediment inflow volumes as well as sediment yield rates computed for periods between surveys. Both of these values are considered important for practical and research use.

**Unit Weight Analyses**

During the 1948, 1953, and 1967 surveys, 69 physical samples of the reservoir sediment deposits were collected. A summary of the results of each sample taken during these surveys is contained in Table 3. Unit weights, median diameters, and percentages of clay, silt, and sand are tabulated.

Analyses were made of the sample data collected to determine a unit weight for the inflowing deposited sediments. A weighting process was used to do this by computing the unit weight averages of the sediments sampled within individual segmented reservoir areas. These averages were multiplied by the incremental sediment volumes and the resulting products summed. The sum was divided by the total sediment volume giving a weighted unit weight of 70.2 pounds per cubic foot. This compares with unit weights of 66.9 and 52.3 pounds per cubic foot determined for the 1953 and 1948 surveys, respectively.

An empirical method[3] was used to compute the unit weight applying the representative clay, silt, and sand size gradations subsequently described. Assuming a Type II reservoir operation,[4] an initial unit weight of 70.5 pounds per cubic foot was computed which compares favorably with the 70.2 weighted value described above. However, by considering a compaction correction using the method of Miller,[5] a unit weight of 73.4 pounds per cubic foot was determined for a 26-year period.

**Particle Size Analyses**

A study was made of the particle size analysis tests run on 62 of the samples collected in the 1948, 1953, and 1967 surveys. The graphs in Figures 18 through 24 contain the particle size analysis curves for each sample. Representative particle sizes in the clay, silt, and sand ranges were determined by the weighting process as was used in the unit weight analyses. The data in Figures 18 through 24 were used to determine the percentages of clay, silt, and sand of each range sample taken within the same segmented areas used in the unit weight analyses. The representative size was computed to be 29 percent clay, 32 percent silt, and 39 percent sand.

**Estimated Sediment Inflow to Reservoir**

An attempt was made to estimate the sediment inflow to the reservoir for comparison with the inflow determined from the 1967 survey. The estimate is based on a sediment rating curve that was developed from records available for the period March 1, 1948 to September 30, 1953, shown in Figure 25. Records of the North Fork Red River near Carter, Oklahoma, were used. The sediment rating curve was used in conjunction with the flow duration curve (Figure 26) for the period covering water years 1941-1965. The results of this analysis in Table 4 show an average total sediment discharge of 1,475,000 tons per year assuming 15 percent for the bedload discharge. This value was adjusted further to take into account the drainage area (149 square miles) between the Carter gaging station and Altus Dam. Assuming an annual sediment yield rate of 0.4 acre-foot per square mile for this area and assuming a unit weight of 70.2 pounds per cubic foot as determined by the 1967 survey, a sediment discharge of 91,100 tons per year was computed. Adding this to the total in Table 4 (1,475,000) gives an estimated 1,566,100 tons per year total sediment inflow to the reservoir. This compares to the total sediment inflow of 1,430,720 tons per year measured by the 1967 survey. A difference of about 9.5 percent is indicated between estimated and measured sediment inflow rates. This indicates a reasonable check from a practical standpoint. However, it should be pointed out that several factors have been determined by judgment in the course of the computations. Included in these are the major factors of the assumption for bedload (15 percent) the assumed annual sediment yield rate of 0.4 acre-foot per square mile as well as the assumed unit weight of 70 pounds per cubic foot.

[3] Lara, J. M., and Pemberton, E. L., "Initial Unit Weight of Deposited Sediments," Paper No. 82, Proc. of the Federal Inter-Agency Sedimentation Conference, Misc. Publ. No. 970, U.S. Department of Agriculture, 1963.
[4] Ibid, p 845.
[5] Miller, C. R., "Determination of the Unit Weight of Sediment for Use in Sediment Volume Computations," U.S. Dept. of the Interior, Bureau of Reclamation, Feb. 1953.

Table 2

RESERVOIR SEDIMENT DATA SUMMARY

Altus Reservoir
NAME OF RESERVOIR

DATA SHEET NO.

**DAM**

| | | |
|---|---|---|
| 1. OWNER U.S. Dept. of Int., Bur. of Recl. | 2. STREAM North Fork, Red River | 3. STATE Oklahoma |
| 4. SEC. 22 TWP. 5N RANGE 20W | 5. NEAREST P.O. Altus 18NE | 6. COUNTY Greer-Kiowa |
| 7. LAT. 34 ° 53 ′ " LONG. 99 ° 18 ′ " | 8. TOP OF DAM ELEVATION 1567 | 9. SPILLWAY CREST ELEV. [1]1559 |

**RESERVOIR**

| 10. STORAGE ALLOCATION | 11. ELEVATION TOP OF POOL | 12. ORIGINAL SURFACE AREA, ACRES | 13. ORIGINAL CAPACITY, ACRE-FEET | 14. GROSS STORAGE, ACRE-FEET | 15. DATE STORAGE BEGAN |
|---|---|---|---|---|---|
| a. FLOOD CONTROL | | | | | |
| b. MULTIPLE USE | [2]1564 | 7,705 | 36,174 | [4]192,842 | Dec 1940[5] |
| c. POWER | | | | | |
| d. WATER SUPPLY | | | | | 16. DATE NORMAL OPER. BEGAN |
| e. IRRIGATION | 1559 | 6,772 | [3]152,060 | 156,668 | |
| f. CONSERVATION | | | | | |
| g. INACTIVE | 1517.5 | 1,073 | 4,608 | 4,608 | June 19, 1946 |

| | | | |
|---|---|---|---|
| 17. LENGTH OF RESERVOIR | 13.1 MILES | AV. WIDTH OF RESERVOIR | 1 MILES |

**WATERSHED**

| | | | |
|---|---|---|---|
| 18. TOTAL DRAINAGE AREA | 2,515 SQ. MI. | 22. MEAN ANNUAL PRECIPITATION | 24.2 (14-39) INCHES |
| 19. NET SEDIMENT CONTRIBUTING AREA | 2,104 SQ. MI. | 23. MEAN ANNUAL RUNOFF | 0.78 INCHES |
| 20. LENGTH 146.5 MILES | AV. WIDTH 17.2 MILES | 24. MEAN ANNUAL RUNOFF | [6]104,400 AC.-FT. |
| 21. MAX. ELEV. 3,500+ | MIN. ELEV. 1496.7 | 25. ANNUAL TEMP.: MEAN 63.1 | RANGE 65.9-62.3 |

**SURVEY DATA**

| 26. DATE OF SURVEY | 27. PERIOD YEARS | 28. ACCL. YEARS | 29. TYPE OF SURVEY | 30. NO. OF RANGES OR CONTOUR INT. | 31. SURFACE AREA, ACRES | 32. CAPACITY, ACRE-FEET | 33. C/I. RATIO, AC.-FT. PER AC.-FT. |
|---|---|---|---|---|---|---|---|
| Dec 1940 | | | Contour | 2 to 5 ft | 6,772 | 156,668 [7](192,842) | |
| Jun 1948 | 7.5 | 7.5 | Contour and range (S) | 26 (R) 5 ft (CI) | 6,793 | 148,640 (185,035) | |
| Jul 1953 | 5.1 | 12.6 | Contour and range (S) | 25 (R) 5 ft (CI) | 6,575 | 142,862 (178,610) | 1.74 |
| Apr 14, 1967 | 13.8 | 26.4 | Range (R) | 25 (R) | 6,260 | 134,549 (168,117) | 1.61 |

| 26. DATE OF SURVEY | 34. PERIOD ANNUAL PRECIPITATION | 35. PERIOD WATER INFLOW, ACRE-FEET | | | 36. WATER INFL. TO DATE, AC.-FT. | |
|---|---|---|---|---|---|---|
| | | a. MEAN ANNUAL | b. MAX. ANNUAL | c. PERIOD TOTAL | a. MEAN ANNUAL | b. TOTAL TO DATE |
| Dec 1940 | | | | | | |
| Jun 1948 | [8]27.0 | 126,980 | 256,700 | 952,320 | 126,980 | 952,320 |
| Jul 1953 | [8]20.3 | 107,940 | 213,400 | 550,473 | 119,270 | 1,502,793 |
| Apr 14, 1967 | [9]24.4 | 89,000 | 188,800 | 1,227,897 | 103,440 | 2,730,690 |

| 26. DATE OF SURVEY | 37. PERIOD CAPACITY LOSS, ACRE-FEET | | | 38. TOTAL SED. DEPOSITS TO DATE, ACRE-FEET | | |
|---|---|---|---|---|---|---|
| | a. PERIOD TOTAL | b. AV. ANNUAL | c. PER SQ. MI.-YEAR | a. TOTAL TO DATE | b. AV. ANNUAL | c. PER SQ. MI.-YEAR |
| Dec 1940 | | | | | | |
| Jun 1948 | 8,028 [7](7,807) | 1,070 [7](1,041) | 0.506 [7](0.495) | 8,028 [7](7,807) | 1,070 [7](1,041) | 0.509 [7](0.495) |
| Jul 1953 | 5,778 (6,425) | 1,133 (1,260) | 0.535 (0.599) | 13,806 (14,232) | 1,096 (1,130) | 0.521 (0.537) |
| Apr 14, 1967 | 8,313 (10,493) | 602 (760) | 0.286 (0.361) | 22,119 (24,725) | 838 (937) | 0.398 (0.445) |

| 26. DATE OF SURVEY | 39. AV. DRY WGT., LBS. PER CU. FT. | 40. SED. DEP., TONS PER SQ. MI.-YR. | | 41. STORAGE LOSS, PCT. | | 42. SED. INFLOW, PPM | |
|---|---|---|---|---|---|---|---|
| | | a. PERIOD | b. TOTAL TO DATE | a. AV. ANN. | b. TOT. TO DATE | a. PERIOD | b. TOT. TO DATE |
| Dec 1940 | | | | | | | |
| Jun 1948 | 52.3 | 580 [7](564) | 580 [7](564) | 0.683 [7](0.540) | 5.12 [7](4.05) | 7,072 [7](6,877) | 7,065 [7](6,871) |
| Jul 1953 | 66.9 | 1,023 (1,104) | 759 (782) | 0.700 (0.586) | 8.81 (7.38) | 14,673 (15,835) | 9,849 (10,153) |
| Apr 14, 1967 | 70.2 | 472 (588) | 609 (680) | 0.535 (0.486) | 14.12 (12.82) | 8,213 (10,231) | 9,113 (10,187) |

Table 2—Continued

| 26. DATE OF SURVEY | 43. DEPTH DESIGNATION RANGE IN FEET BELOW, AND ABOVE, CREST ELEVATION | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 62.3-60 | 60-50 | 50-40 | 40-30 | 30-20 | 20-10 | 10-C | C-5 | | | | |
| | PERCENT OF TOTAL SEDIMENT LOCATED WITHIN DEPTH DESIGNATION | | | | | | | | | | | |
| Dec 1940 | | | | | | | | | | | | |
| Jun 1948 | 0.01 | 5.26 | 8.22 | 28.31 | 25.96 | 22.62 | 12.44 | -2.83 | | | | |
| Jul 1953 | 0.01 | 3.24 | 16.48 | 26.61 | 16.47 | 14.85 | 19.35 | 2.99 | | | | |
| Apr 14, 1967 | 0.01 | 1.99 | 13.54 | 13.71 | 18.92 | 20.62 | 20.67 | 10.54 | | | | |

| 26. DATE OF SURVEY | 44. REACH DESIGNATION PERCENT OF TOTAL ORIGINAL LENGTH OF RESERVOIR | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0-10 | 10-20 | 20-30 | 30-40 | 40-50 | 50-60 | 60-70 | 70-80 | 80-90 | 90-100 | -105 | -110 | -115 | -120 | -125 |
| | PERCENT OF TOTAL SEDIMENT LOCATED WITHIN REACH DESIGNATION | | | | | | | | | | | | | | |
| Dec 1940 | | | | | | | | | | | | | | | |
| Jun 1948 | 14.26 | 4.48 | 11.83 | 11.10 | 14.42 | 12.31 | 7.97 | 11.93 | 7.93 | 3.78 | | | | | |
| Jul 1953 | Not computed | | | | | | | | | | | | | | |
| Apr 14, 1967 | 6.07 | 3.03 | 6.67 | 8.50 | 11.12 | 12.74 | 25.88 | 4.05 | 7.28 | 7.68 | 4.86 | 2.12 | | | |

45. RANGE IN RESERVOIR OPERATION

| WATER YEAR | MAX. ELEV. | MIN. ELEV. | INFLOW, AC.-FT. | WATER YEAR | MAX. ELEV. | MIN. ELEV. | INFLOW, AC.-FT. |
|---|---|---|---|---|---|---|---|
| 1940-44 | – | – | – | 1956 | 1544.99 | 1525.80 | 49,620 |
| 1945 | 1536.90 | 1523.20 | [10]59,000 | 1957 | 1559.53 | 1525.02 | 122,900 |
| 1946 | 1531.20 | 1526.90 | 12,920 | 1958 | 1557.93 | 1549.43 | 64,190 |
| 1947 | 1550.50 | 1528.23 | 160,200 | 1959 | 1559.85 | 1548.62 | 120,600 |
| 1948 | 1548.01 | 1541.95 | 51,180 | 1960 | 1560.04 | 1552.47 | 136,700 |
| 1949 | 1560.20 | 1540.80 | 139,900 | 1961 | 1561.96 | 1552.69 | 188,800 |
| 1950 | 1560.39 | 1553.47 | 158,600 | 1962 | 1560.06 | 1551.83 | 122,800 |
| 1951 | 1562.10 | 1551.59 | 213,400 | 1963 | 1559.31 | 1554.06 | 62,800 |
| 1952 | 1551.82 | 1530.82 | 22,960 | 1964 | 1548.24 | 1529.30 | 31,300 |
| 1953 | 1531.40 | 1525.63 | 15,750 | 1965 | 1547.70 | 1528.48 | 79,660 |
| 1954 | 1549.63 | 1525.60 | 99,630 | 1966 | 1551.70 | 1537.65 | 68,740 |
| 1955 | 1543.90 | 1525.60 | 57,150 | 1967 | 1542.02 | 1530.03 | 42,340 |

46. ELEVATION-AREA-CAPACITY DATA

| ELEVATION | AREA | CAPACITY | ELEVATION | AREA | CAPACITY | ELEVATION | AREA | CAPACITY |
|---|---|---|---|---|---|---|---|---|
| | 1940 Survey | | 1540 | 3,720 | 58,718 | 1517.5 | 643 | 1,663 |
| 1496.7 | 0 | 0 | 1545 | 4,279 | 78,704 | 1520 | 1,103 | 3,844 |
| 1500 | 1 | 2 | 1550 | 5,302 | 102,872 | 1525 | 1,645 | 10,752 |
| 1505 | 58 | 116 | 1555 | 6,007 | 131,132 | 1530 | 2,165 | 20,276 |
| 1510 | 135 | 586 | 1559 | 6,772 | 156,668 | 1535 | 2,616 | 31,972 |
| 1515 | 678 | 2,448 | 1564 | 7,705 | 192,842 | 1540 | 3,219 | 46,560 |
| 1517.5 | 1,073 | 4,608 | | | | 1545 | 3,823 | 64,167 |
| 1520 | 1,445 | 7,732 | | 1967 Survey | | 1550 | 4,626 | 85,565 |
| 1525 | 1,991 | 16,302 | 1509 | 0 | 0 | 1555 | 5,534 | 110,963 |
| 1530 | 2,510 | 27,668 | 1510 | 59 | 30 | 1559 | 6,260 | 134,549 |
| 1535 | 3,103 | 41,678 | 1515 | 182 | 632 | 1564 | 7,168 | 168,117 |

47. REMARKS AND REFERENCES

[1] Uncontrolled spillway crest.
[2] Maximum water surface—includes surcharge.
[3] Includes 4,800 acre-feet of storage for municipal use.
[4] Includes flood control between elevations 1559 and 1562 and surcharge between elevations 1562 and 1564.
[5] Date of original survey for new dam over deposits placed behind old dam.
[6] North Fork Red River near Carter, Oklahoma, 20-year average adjusted for drainage area.
[7] Values in parentheses are for maximum water surface elevation 1564 feet.
[8] Recorded at Sayre and Erick, Oklahoma.
[9] Record at Altus Dam.
[10] From records at Carter gage except 1963 and 1964 are from Project records.

48. AGENCY MAKING SURVEY Bureau of Reclamation
49. AGENCY SUPPLYING DATA Bureau of Reclamation
50. DATE January 29, 1971

April 1966

Table 3

SUMMARY OF SEDIMENT SAMPLE DATA ANALYSES

| Range location | Sample No. | In percent Clay | Silt | Sand | Unit weight pcf | Median diameter ($D_{50}$) mm |
|---|---|---|---|---|---|---|
| **1948-49 Survey Data** | | | | | | |
| Gravity Core Samples | | | | | | |
| 1 | 6 | 21 | 64 | 15 | 26.3 | 0.0245 |
| 2 | 8 | 27 | 59 | 14 | 53.6 | .0215 |
| D | 1 | 43 | 55 | 2 | 26.7 | .0054 |
| DA | 4 | 39 | 50 | 11 | 36.5 | .0120 |
| 2A | 11 | 22 | 19 | 59 | 91.6 | .1490 |
| 3 | A1 | 1 | 11 | 88 | 106.6 | .1270 |
| 5 | A3 | 40 | 59 | 1 | 45.8 | .0058 |
| 6 | A6 | 3 | 47 | 50 | 65.4 | .0610 |
| 6A | 12 | 24 | 42 | 34 | 80.8 | .0355 |
| 7 | 10 | 55 | 42 | 3 | 54.3 | .0032 |
| 8 | A4 | 22 | 55 | 23 | 57.9 | .0250 |
| 9 | A2 | 33 | 51 | 16 | 32.8 | .0072 |
| 11 | A10 | 51 | 47 | 2 | 39.6 | .0037 |
| 13 | 3 | 50 | 47 | 3 | 43.1 | .0036 |
| 14 | A8 | 55 | 44 | 1 | 49.3 | .0034 |
| **1953 Survey Data** | | | | | | |
| D | 384 | 44 | 53 | 3 | 36.1 | 0.0056 |
| DA | 385 | 18 | 51 | 31 | 58.6 | .0395 |
| 1 | 386 | 16 | 65 | 19 | 51.9 | .0440 |
| 2 | 388 | 27 | 45 | 28 | 56.3 | .0348 |
| 2A | 389 | 18 | 70 | 12 | 38.3 | .0322 |
| 3 | 390 | 21 | 36 | 43 | 49.8 | .0440 |
| 4 | 391 | 53 | 43 | 4 | 19.9 | .0033 |
| 5 | 392 | 47 | 46 | 7 | 19.3 | .0045 |
| 6 | 393 | 6 | 49 | 45 | 79.8 | .0560 |
| 6A | 394 | 37 | 24 | 39 | 62.2 | .0320 |
| 7 | 395 | 9 | 62 | 29 | 82.6 | .0430 |
| 8 | 397 | 17 | 17 | 66 | 63.2 | .1400 |
| 9 | 398 | 15 | 30 | 55 | 88.1 | .0770 |
| 11 | 399 | 53 | 41 | 6 | c63.5 | .0035 |
| 13 | 400 | 59 | 35 | 6 | 61.5 | .0027 |
| 14A | 401 | 4 | 15 | 81 | 101.7 | .1550 |
| 14 | 404 | 36 | 51 | 13 | 69.9 | .0104 |
| 15 | 407 | 32 | 36 | 32 | 78.4 | .0320 |
| 16 | 410 | 51 | 37 | 12 | 82.3 | .0039 |
| 16A | 412 | 13 | 14 | 73 | 97.8 | .1390 |
| 17 | 415 | 0 | 3 | 97 | 95.1 | .1520 |
| 18 | 416 | 13 | 35 | 52 | 82.3 | .0650 |
| 19 | 417 | 4 | 20 | 76 | 88.5 | .1270 |
| 20 | 418 | 6 | 19 | 75 | 88.5 | .6200 |

Table 3—Continued

1967 Survey Data

| Range location | Sample No. | In percent Clay | Silt | Sand | Unit weight pcf | Median diameter ($D_{50}$) mm |
|---|---|---|---|---|---|---|
| | | Gravity Core Samples* | | | | |
| 1 | 16 | 9 | 25 | 66 | – | 0.1050 |
| 2 | 15 | 3 | 95 | 2 | – | .0019 |
| D | 24 | 2 | 95 | 3 | – | .0020 |
| DA | 14 | 34 | 45 | 21 | – | .0190 |
| 2A | 20 | 41 | 53 | 6 | – | .0081 |
| 3 | 19 | 13 | 43 | 44 | – | .0520 |
| 4 | 26 | 71 | 27 | 2 | – | .0013 |
| 5 | 11 | 65 | 24 | 11 | – | .0016 |
| 6/6A | 18 | 56 | 43 | 1 | – | .0027 |
| 7 | 23 | 14 | 59 | 27 | – | .0410 |
| | | Plastic Tube Samples* | | | | |
| 8 | 21 | 53 | 40 | 7 | – | 0.0032 |
| 8/9 | 22 | 63 | 30 | 7 | – | .0020 |
| 11 | 33 | 18 | 27 | 55 | – | .0850 |
| 13 | 12 | 41 | 45 | 14 | – | .0044 |
| 14 | 29 | 28 | 32 | 40 | – | .0310 |
| 14 | 30 | 0 | 1 | 99 | – | .2400 |
| 14A | 27 | 43 | 38 | 19 | – | .0076 |
| 14A | 28 | 0 | 1 | 99 | – | .1570 |
| 15 | 17 | 19 | 10 | 71 | – | .2000 |
| 16A | 31 | 37 | 25 | 38 | – | .0240 |
| 16A | 32 | 0 | 1 | 99 | – | .1900 |
| 17 | 10 | 55 | 42 | 3 | – | .0028 |
| 19 | 13 | 18 | 18 | 64 | – | .0950 |
| 20 | 9 | 6 | 24 | 70 | – | .1200 |
| 21 | 25 | 0 | 1 | 99 | – | .2140 |
| 22 | 34 | 0 | 1 | 99 | – | .2690 |
| | | Field Density Samples** | | | | |
| 13 | 1 | – | – | – | 49.6 | – |
| 14 | 2 | – | – | – | 96.2 | – |
| 14A | 3 | – | – | – | 88.4 | – |
| 16A | 4 | – | – | – | 77.9 | – |
| 19 | 5 | – | – | – | 90.4 | – |
| 20 | 6 | – | – | – | 87.9 | – |
| 21 | 7 | – | – | – | 121.5 | – |

*Unit weights not determined for gravity core and plastic tube samples.
**Gradation tests not run for field density samples.

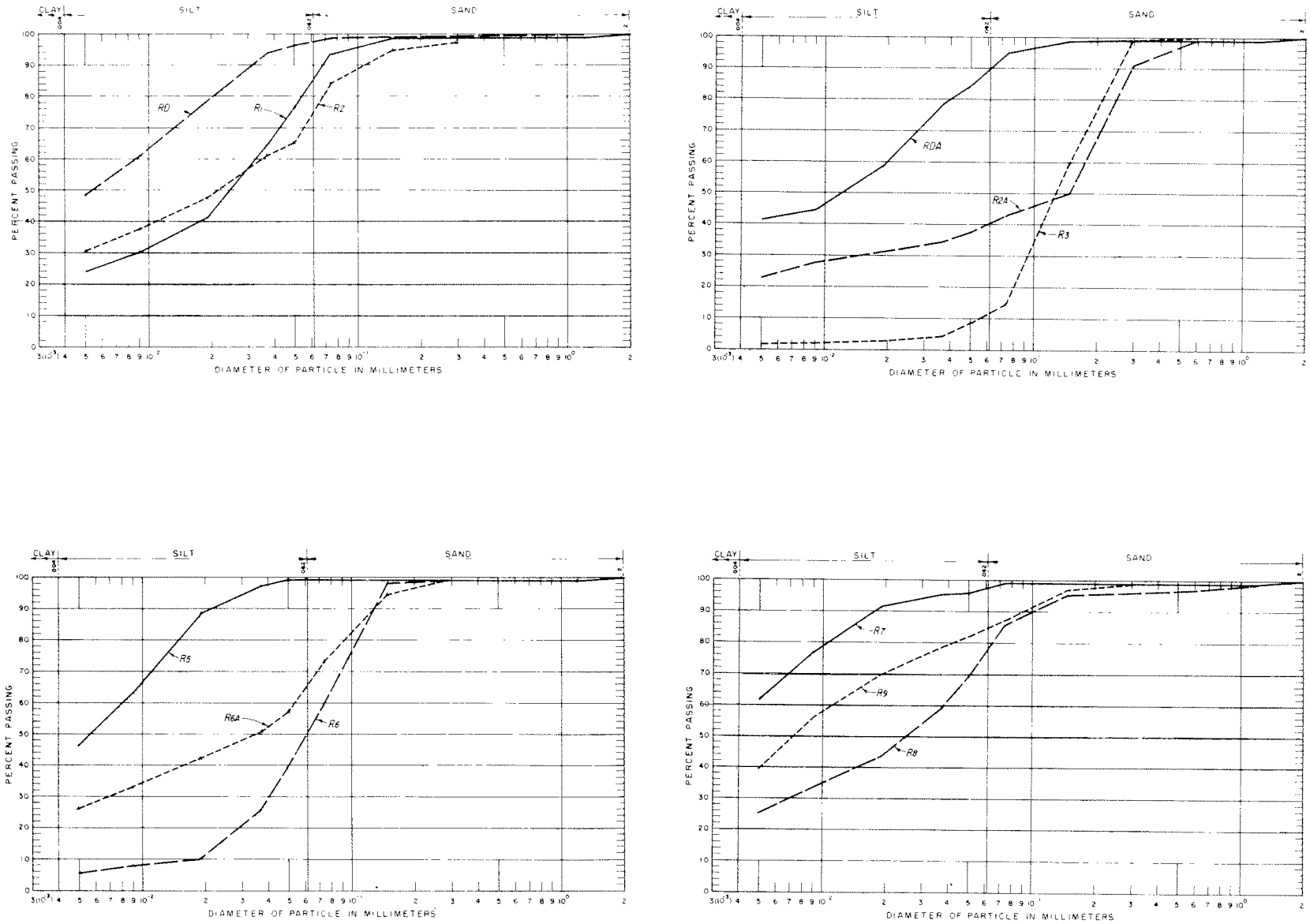



Figure 18. Particle size analysis curves. Ranges 1, D, 2, DA, 2A, 3, 5, 6, 6A, 7, 8, and 9—1948 survey.

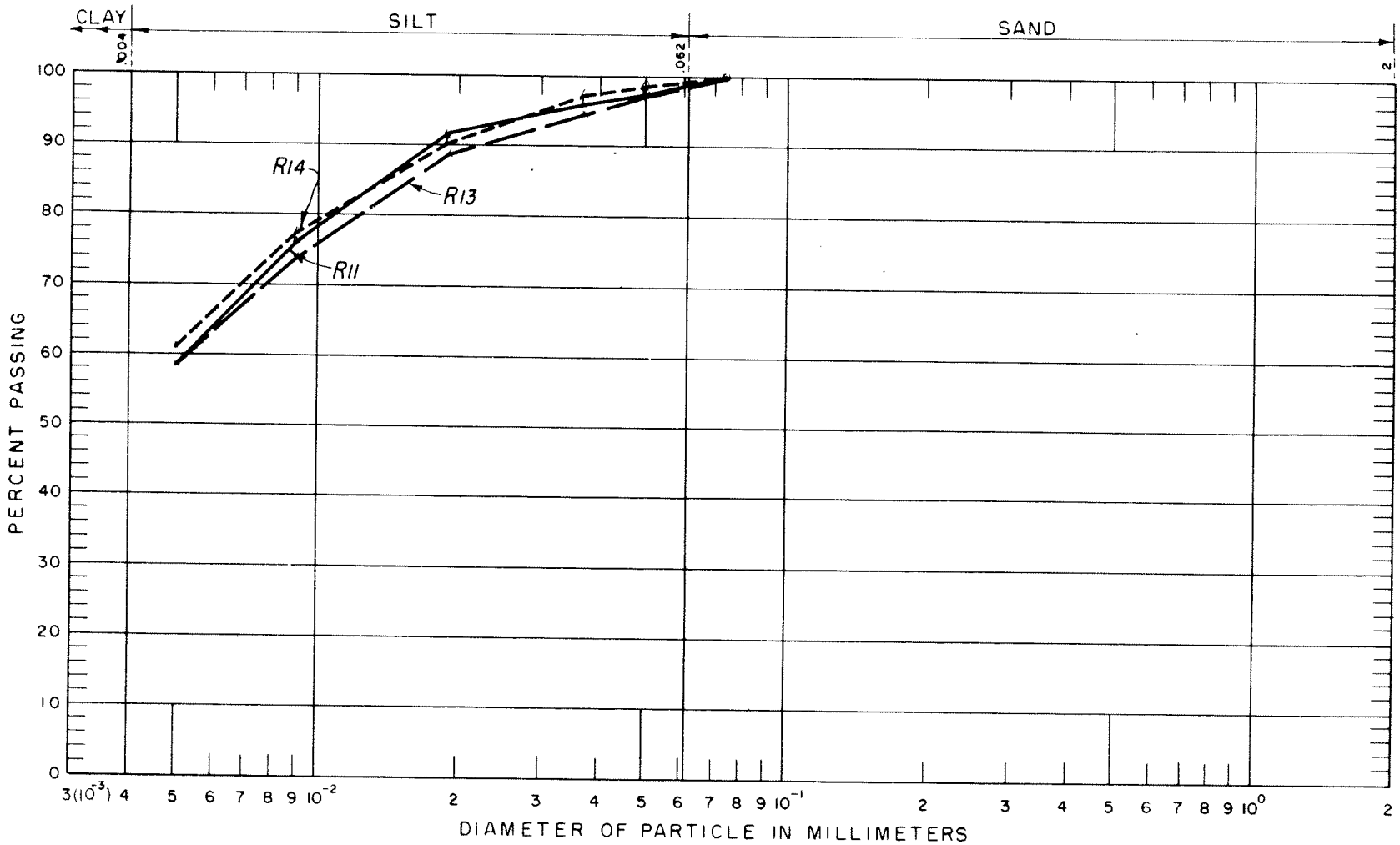



Figure 19. Particle size analysis curves. Ranges 11, 13, and 14—1948 survey.

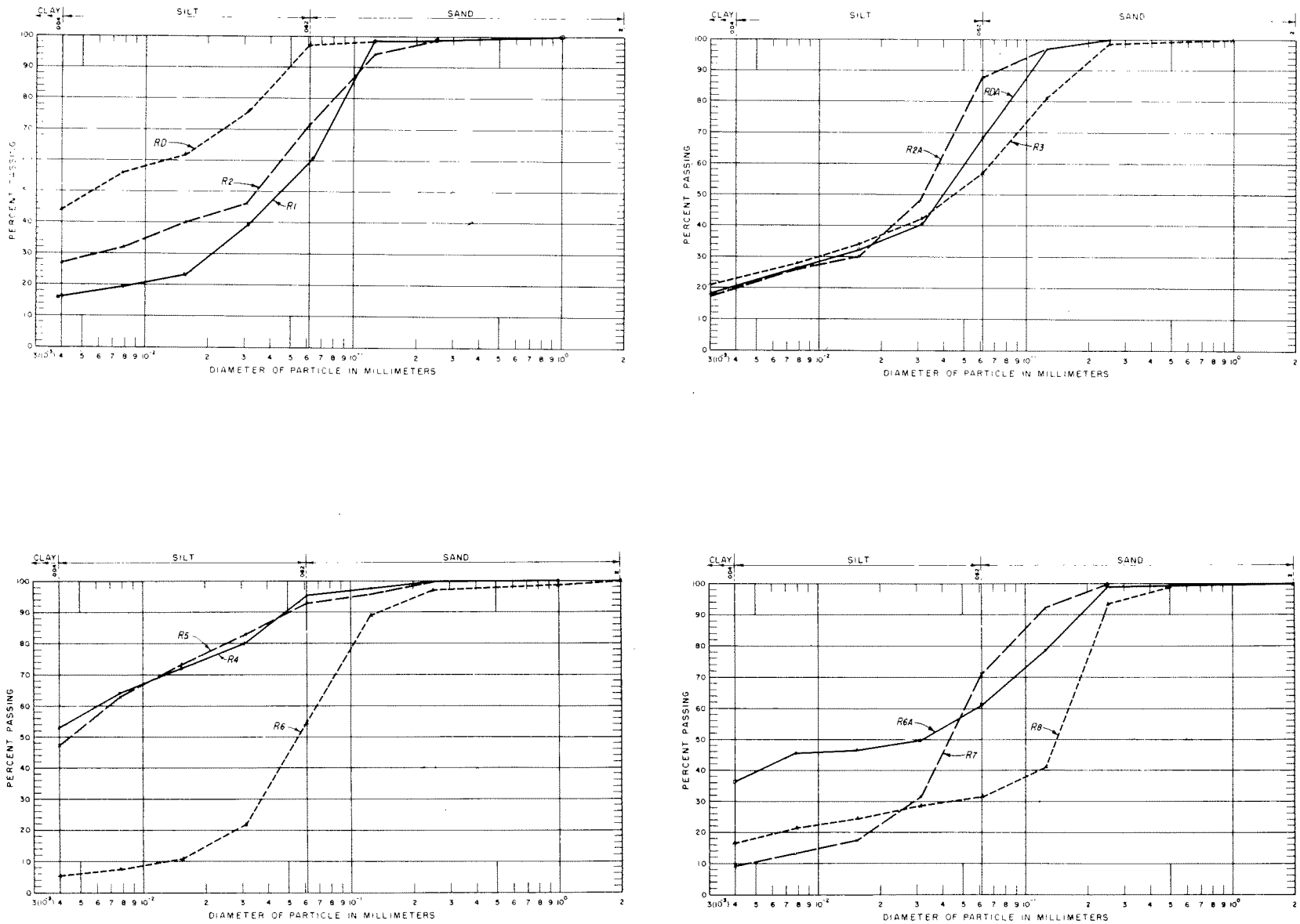



Figure 20. Particle size analysis curves. Ranges 1, D, 2, DA, 2A, 3, 4, 5, 6, 6A, 7, and 8—1953 survey.

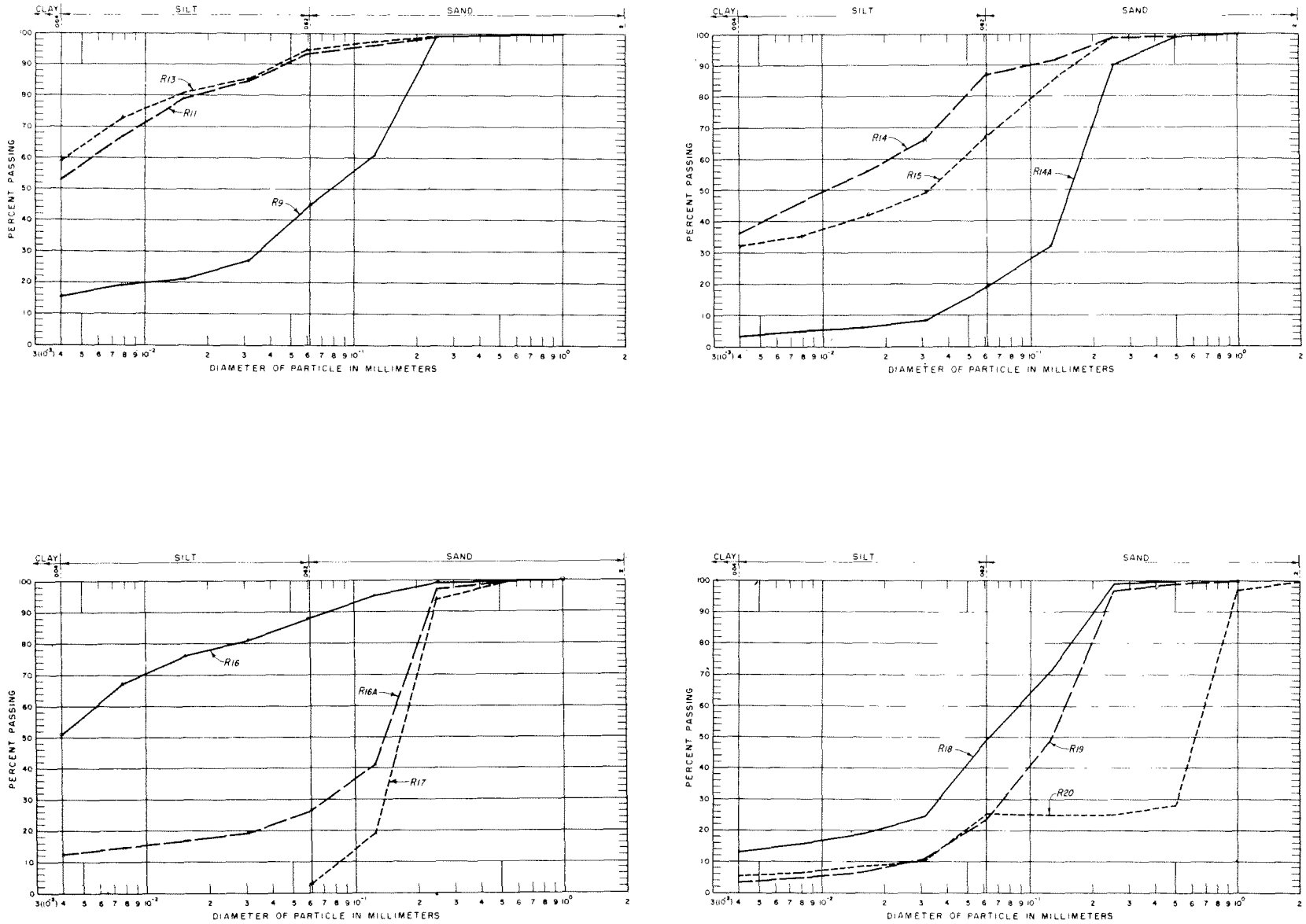



Figure 21. Particle size analysis curves. Ranges 9, 11, 13, 14, 14A, 15, 16, 17, 18, 19, and 20—1953 survey.

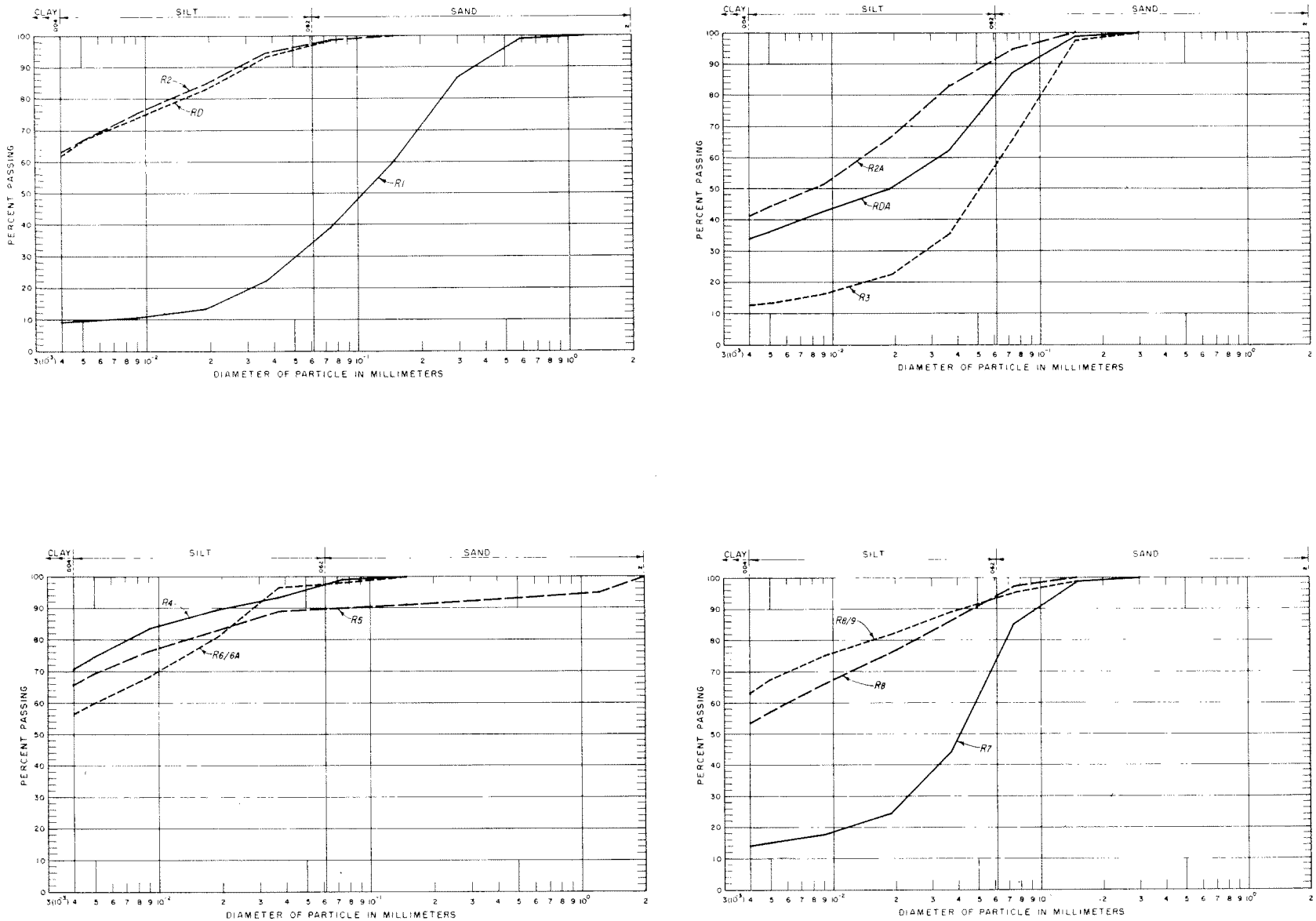



Figure 22. Particle size analysis curves. Ranges 1, D, 2, DA, 2A, 3, 4, 5, 6/6A, 7, 8, and 8/9—1967 survey.

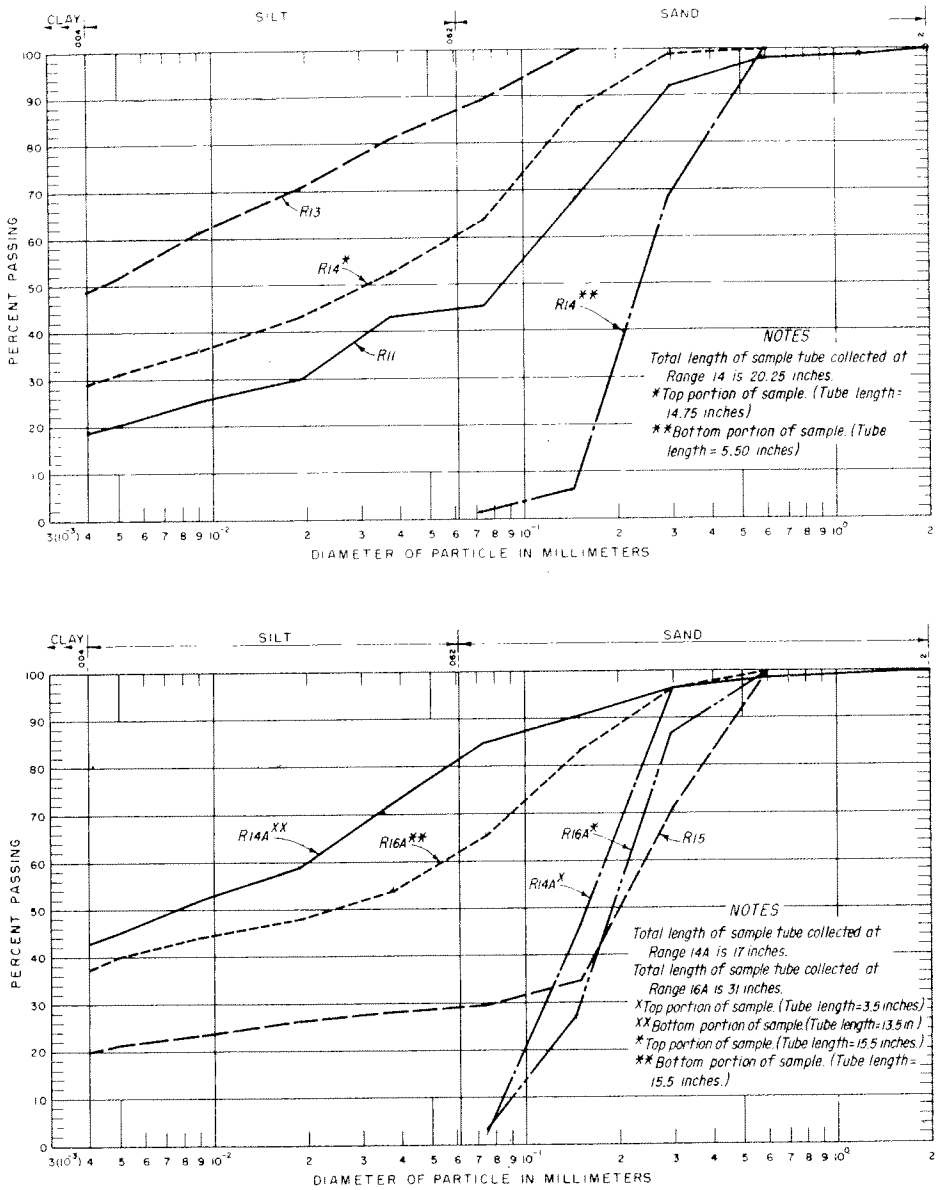



Figure 23. Particle size analysis curves. Ranges 11, 13, 14, 14A, 15, and 16A—1967 survey.

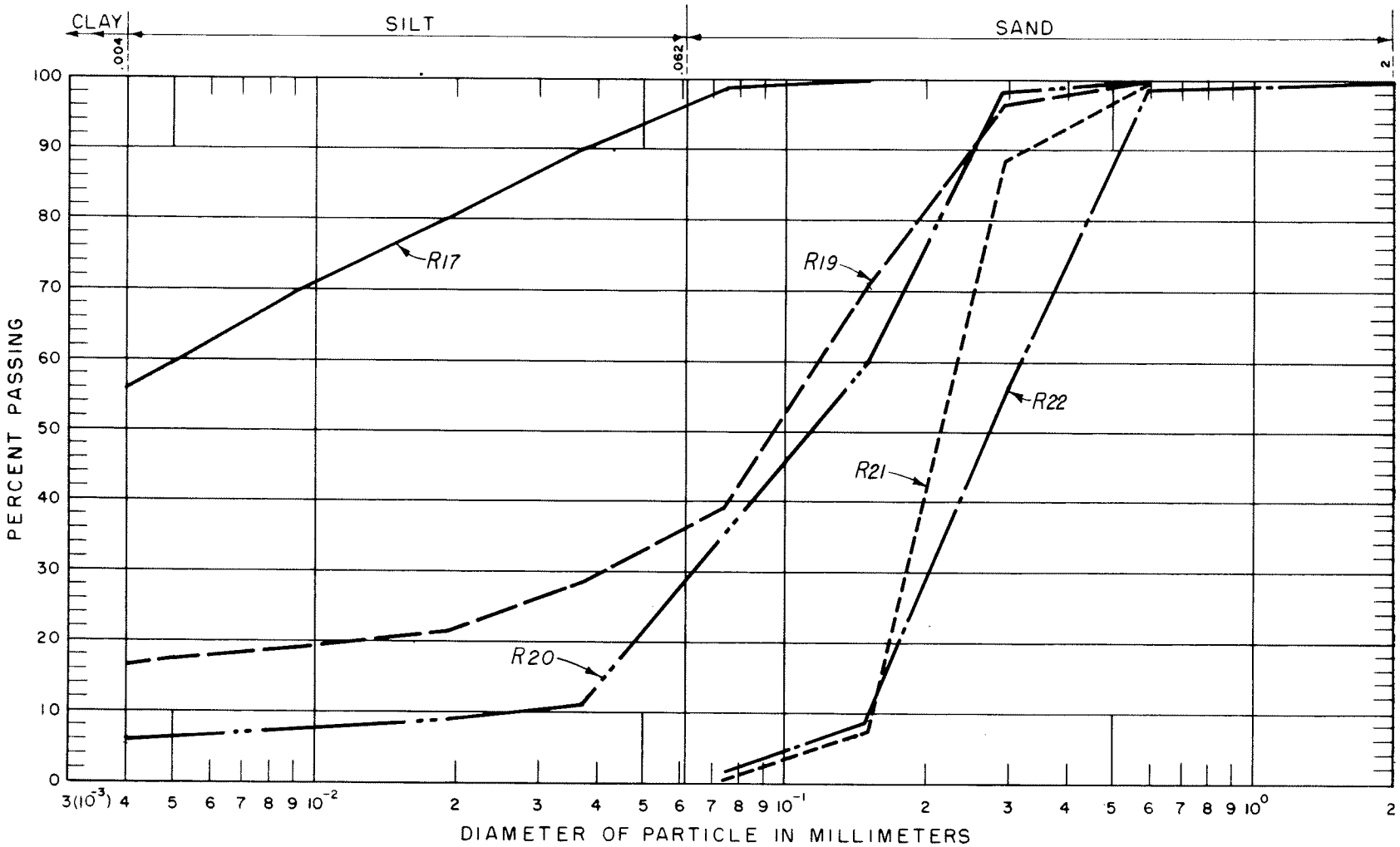



Figure 24. Particle size analysis curves. Ranges 17, 19, 21, and 22—1967 survey.

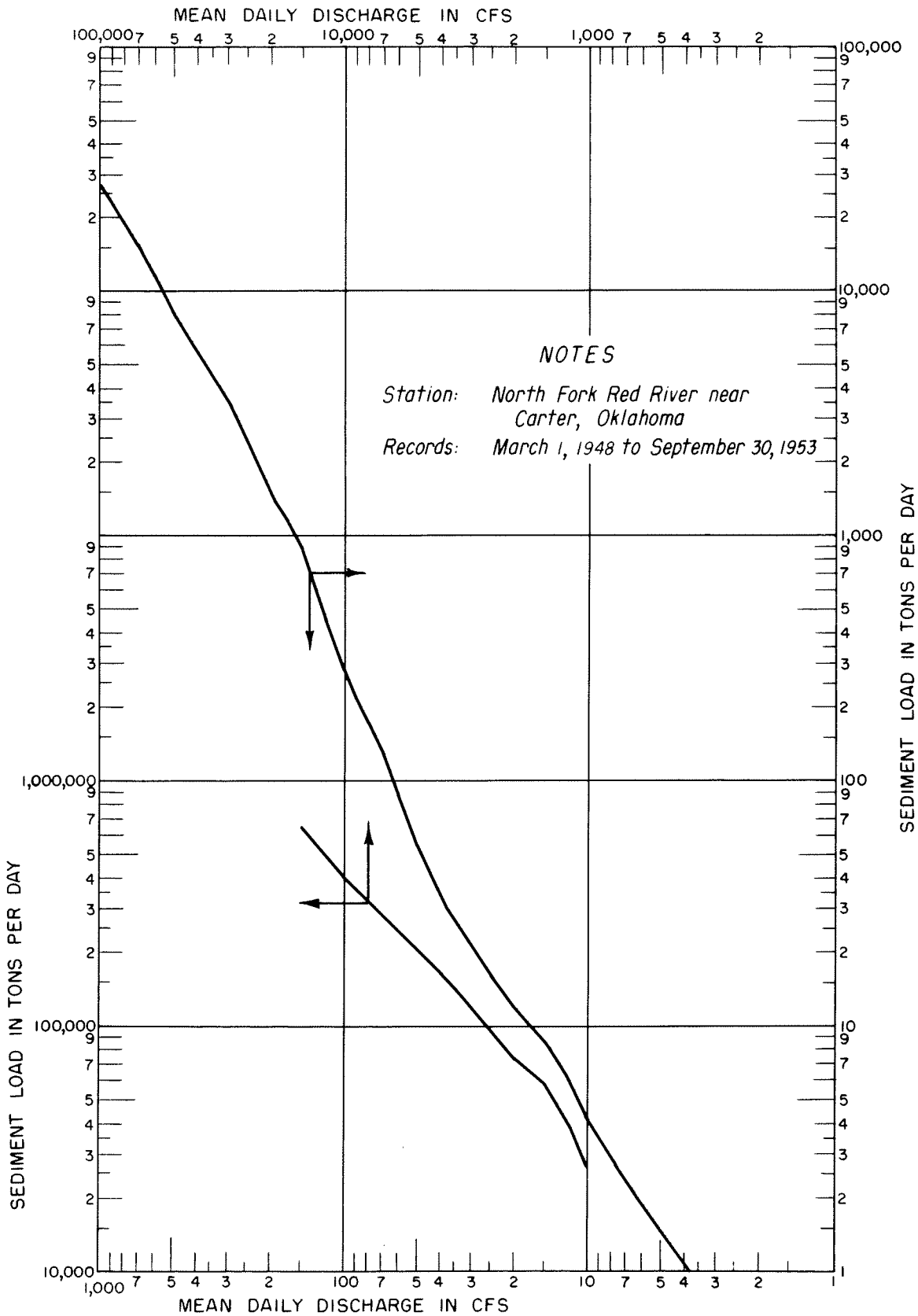



Figure 25. Sediment rating curve.

Table 4

TOTAL SEDIMENT DISCHARGE COMPUTATIONS

| SECTION | PERIOD | RIVER |
|---|---|---|
| Near Carter, Oklahoma | WY 1941–1965 | North Fork Red River |
| **COMPUTED BY** | **CHECKED BY** | **DATE** |
| JML | | 5-5-70 |

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| % LIMITS | % INTERVAL | % MID. ORD. | Qw | Qs | 2x4 Qw. DISCH. | 2x5 Qs. DISCH. |
| 0.00-0.02 | 0.02 | 0.01 | 17,500 | 750,000 | 3.5 | 150 |
| 0.02-0.1 | 0.08 | 0.06 | 10,000 | 420,000 | 8.0 | 336 |
| 0.1 -0.5 | 0.4 | 0.3 | 6,000 | 250,000 | 24.0 | 1,000 |
| 0.5 -1.5 | 1.0 | 1.0 | 2,500 | 96,000 | 25.0 | 960 |
| 1.5 -5.0 | 3.5 | 3.25 | 860 | 21,000 | 30.1 | 735 |
| 5-15 | 10 | 10 | 260 | 2,600 | 26.0 | 260 |
| 15-25 | 10 | 20 | 127 | 520 | 12.7 | 52 |
| 25-35 | 10 | 30 | 75 | 150 | 7.5 | 15 |
| 35-45 | 10 | 40 | 41.5 | 37.5 | 4.2 | 3.8 |
| 45-55 | 10 | 50 | 22 | 13.5 | 2.2 | 1.4 |
| 55-65 | 10 | 60 | 8.7 | 3.2 | 0.9 | 0.3 |
| 65-75 | 10 | 70 | 0.5 | – | | |
| 75-85 | 10 | 80 | | | | |
| 85-95 | 10 | 90 | | | | |
| 95-98.5 | 3.5 | 96.75 | | | | |
| 98.5-99.5 | 1.0 | 99.0 | | | | |
| 99.5-99.9 | 0.4 | 99.7 | | | | |
| 99.9-99.98 | 0.08 | 99.94 | | | | |
| 99.98-100 | 0.02 | 99.99 | | | | |
| | | | | TOTAL | 144.1 | 3,513.5 |

Qw.A.D. = 144 D.D.x365x1.9835 = 104,253 (AF)/yr.

Qs.A.D. = 3,514 D.D.x365 = 1,282,610 Tons/yr.

15 Percent Correction for Bedload = 192,391 Tons/yr.

Total Sediment Discharge = 1,475,001 Tons/yr.

Sediment

A.D. = _____ Tons/yr. / Tons/(AF) _____ = (AF)/yr.

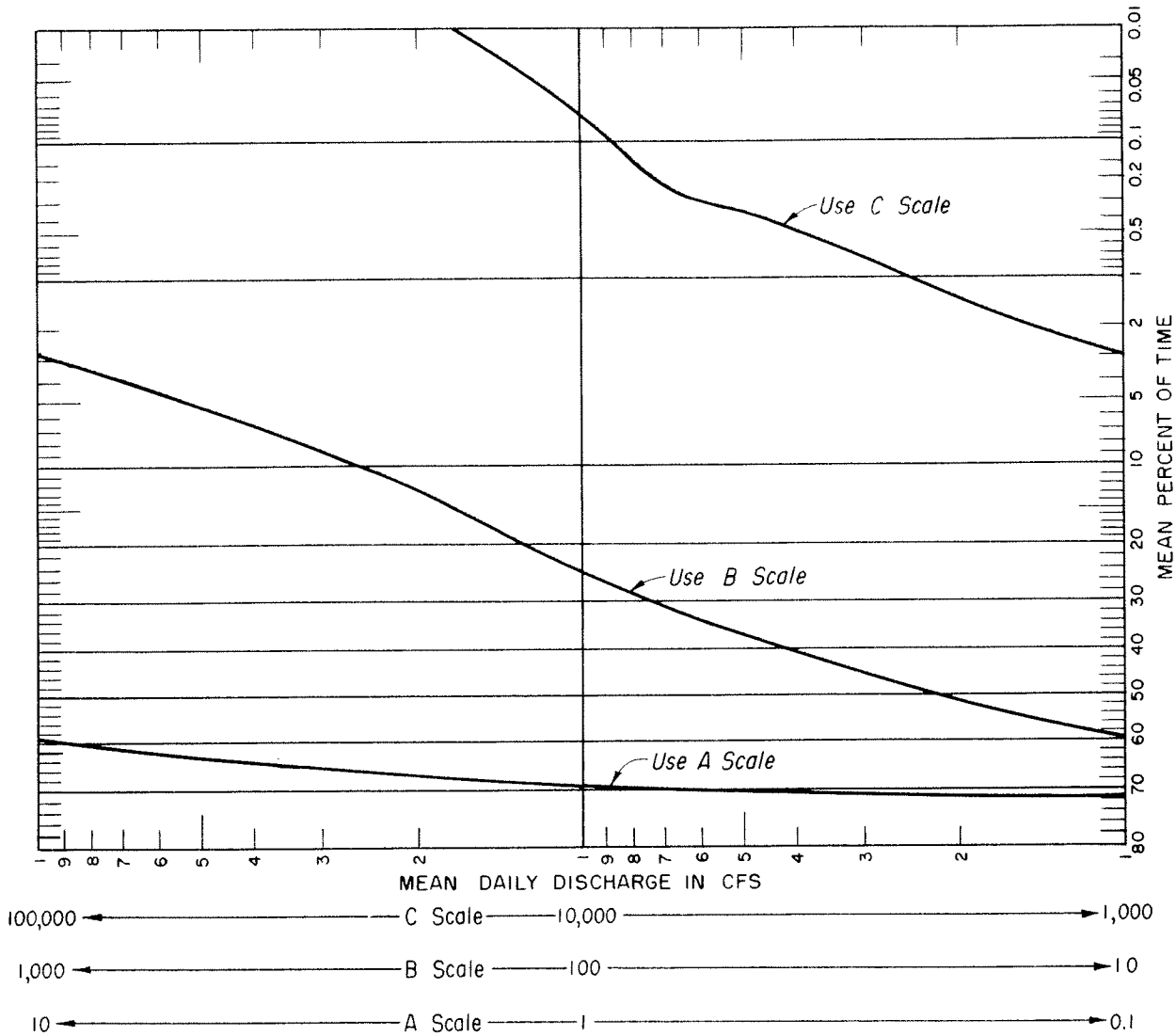
Yield = _____ Tons/yr. / Tons/(AF)xD.A. _____ = (AF)/sq.mi.

Concentration = 1,282,610 x 100 / 104,253 x 1,361 Qs A.D.x100 / Qw A.D.x1361 = 0.904 Percent

Runoff

Rate = _____ Qw A.D. / D.A. _____ = (AF)/sq.mi.

D.D. = Daily Discharge
A.D. = Annual Discharge
D.A. = Drainage Area
67.5 = lbs./cubic foot
1,470 = Tons/ acre foot




NOTES

Station: North Fork Red River
near Carter, Oklahoma.

Records: Water Years 1941 to 1965

Figure 26. Flow duration curve.

## RESERVOIR AND AREA AND CAPACITY

The 1967 Altus Reservoir surface areas were determined by a method using reservoir sedimentation range width ratios. Briefly, this method entails comparing the 1967 range widths with the 1948 widths at corresponding elevation intervals. The results are tabulated in the ratio form 1967/1948. To facilitate the computations the reservoir is divided into segments using the sedimentation range lines to delineate the segmental boundaries. The 1948 reservoir topographic maps were used to planimeter the surface areas at 5-foot contour intervals. For corresponding elevations, these areas were multiplied by the width ratios obtained and the 1967 surface areas were determined.

The 1967 surface areas were the control parameters for computing the reservoir capacities with the electronic computer. The computer program computes 1-foot area increments by linear interpolation between the 5-foot contour intervals. Respective capacities and capacity equations are then obtained by integration of the area equations. The initial capacity equation is tested over successive intervals to check whether it fits within an allowable error limit (0.01). This one equation is then used over the whole range that fits within the allowable error limit. For the next interval beginning at the elevation where the initial allowable error limit has been exceeded, a new capacity equation (integrated from the basic area equation over that interval) begins testing the fit until it too exceeds the error limit. Thus, the capacity curve is defined by a series of curves, each falling within a specific elevation interval as constrained by the limiting error. The final area equations are subsequently derived by differentiation of the capacity equations. Capacity equations are of second order polynominal form, $y = a_1 + a_2x + a_3x^2$, where y is the capacity, x is the elevation above an elevation base, $a_1$ is the intercept, and $a_2$ and $a_3$ are coefficients. Results of the 1967 reservoir area and capacity computations are listed in Columns 4 and 5 of Table 1 (page 8). Listed also in this table in Columns 2 and 3 are the original area and capacity values for comparison purposes. Both the original and 1967 area and capacity curves are plotted in Figure 27. At elevation 1559 feet (uncontrollable spillway crest), the present capacity of Altus Reservoir is 134,550 acre-feet and the surface area is 6,260 acres.

## SUMMARY AND CONCLUSIONS

The 1967 sediment survey report of Altus Reservoir briefly describes the field surveying and sediment sampling procedures and equipment. Also discussed are the analytical methods used to measure and study the nearly 26.5 years of reservoir sediment accumulation. The survey was primarily run to gather the necessary data for use in computing the latest capacity of Altus Reservoir.

Standard land surveying methods were used to run levels from the permanent range end monuments to stations that were temporarily established at the reservoir water's edge. The hydrographic survey was run using sonic depth recording equipment operated from a boat. This system continuously recorded reservoir depths on charts as the boat was propelled across the range line. Five men were required to run the hydrographic survey. A distance measuring machine was used to maintain horizontal control and the water surface elevations determined from the gage at the dam were used as a reference for vertical control.

Ten sediment samples of the reservoir deposits were collected with a gravity core sampler and 13 more using a 2-inch diameter plastic tube driven by hand into the deposits with a rubber mallet. Field density apparatus was used to take seven additional samples at upstream range locations. Analyzing these samples and others collected during the 1948 and 1953 surveys resulted in determining a unit weight of 70.2 pounds per cubic foot and a representative size of 29 percent clay, 32 percent silt, and 39 percent sand.

The longitudinal and lateral deposition of sediments in the reservoir generally followed the usual pattern. Longitudinally, the sediments deposited between the 1940 and 1967 surveys to average depths of 6.5 feet for a distance from the dam to a mile above the dam, 2.5 feet from 1 to 3-1/2 miles above the dam, 7.5 feet from 3-1/2 to 7 miles above dam, and 14 feet from 7 to 12 miles above the dam. Between the 1948 and 1967 surveys, these deposited depths varied from less than 1 to 2 feet for a distance from the dam to 8 miles above the dam and averaged about 8.5 feet from 8 to 12 miles above the dam. Laterally, the reservoir range cross sectional profiles for the 1948 and 1967 surveys show sediments deposited to depths of 1 to 4 feet for the area 8 miles above the dam. For the area from 8 to 12 miles above the dam the laterally deposited sediments averaged about 6 feet with the greatest average depth of about 11 feet at 10 miles above the dam. For all practical purposes sediments have essentially deposited to maximum water surface, 1564 feet, in the reservoir area beginning at 12 miles above the dam.

The capacity of Altus Reservoir as determined by the 1967 survey is 134,550 acre-feet and the surface area 6,260 acres at spillway crest elevation 1559 feet (see

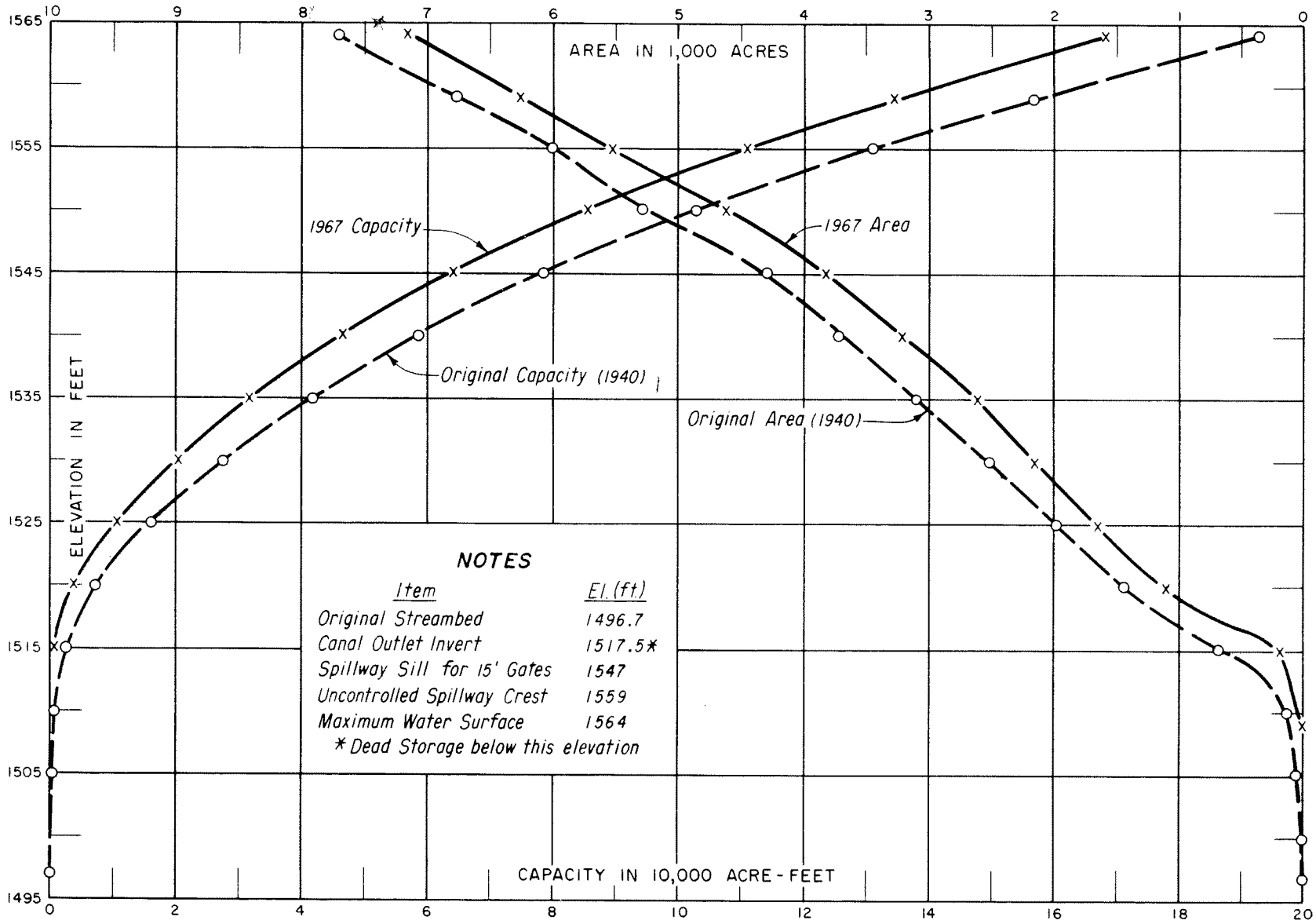



Figure 27. Reservoir area-capacity curves.

area-capacity curves in Figure 27). The 1967 reservoir surface areas were determined by a width ratio method described on page 26. The electronic computer was used to compute areas at 1-foot increments by linear interpolation. The computer was also used to compute the reservoir capacity which is defined by a series of curves obtained by integrating the area equations over an elevation interval within a restricted error limit. The capacity data were also compiled at 1-foot intervals.

A comprehensive summary of the reservoir sediment data for the 1967 survey is contained in Table 2. Sediments have accumulated to a volume of 22,120 acre-feet at elevation 1559 feet since the dam was closed in 1940. This indicates a loss in reservoir capacity of about 14 percent. The average annual sediment accumulation rate of 838 acre-feet was found for the 1940-67 period. Sediments deposited at a rate of 0.398 acre-feet per square mile annually during this period.

## APPENDIX

Profiles run for the 25 sedimentation ranges surveyed in 1948 and 1967 are plotted in Figures 28 through 52.

NOTE (applicable to Figures 28 through 52)

1948 profile

1967 profile

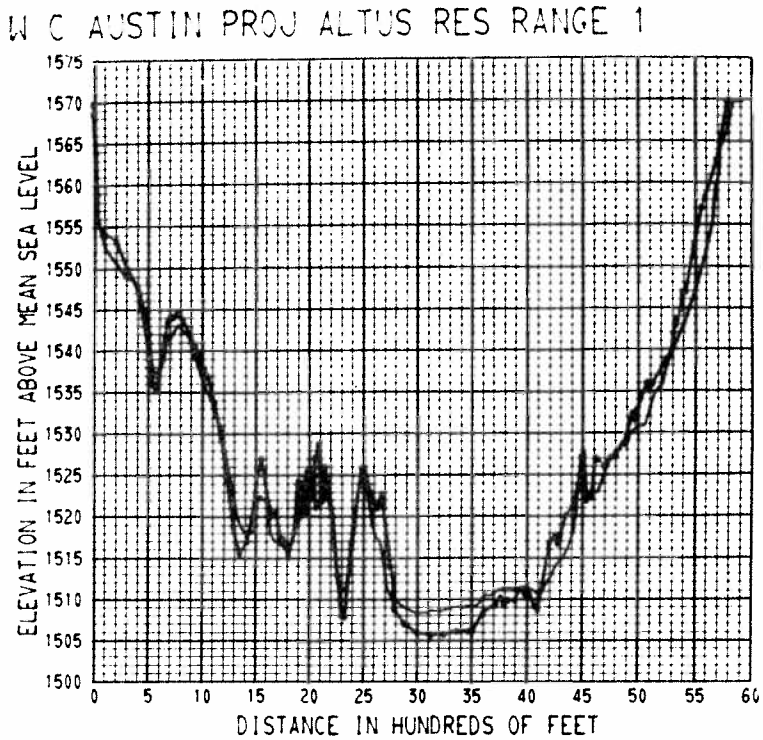



Figure 28. 1948 and 1967 sedimentation range profiles—Range 1.

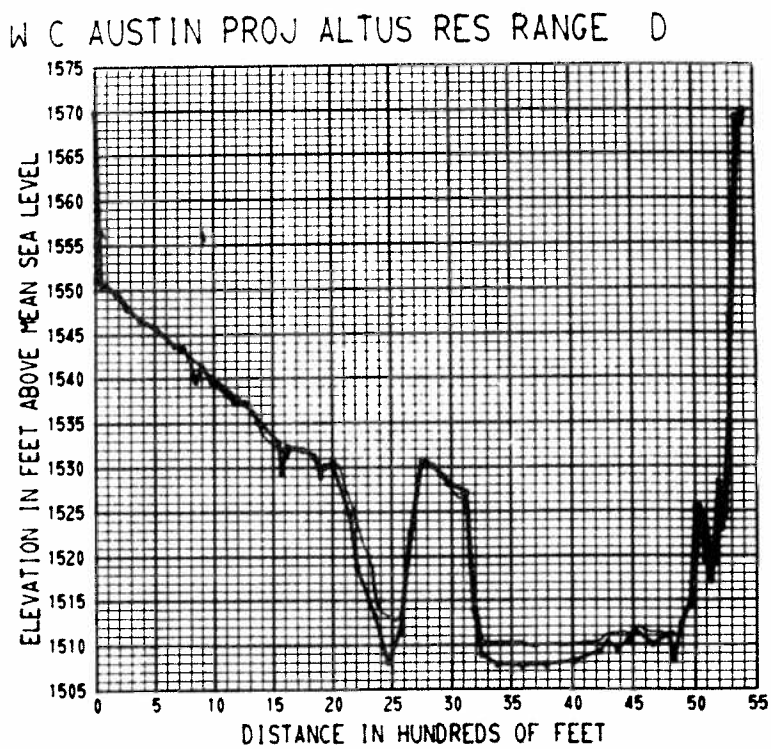



Figure 29. 1948 and 1967 sedimentation range profiles—Range D.

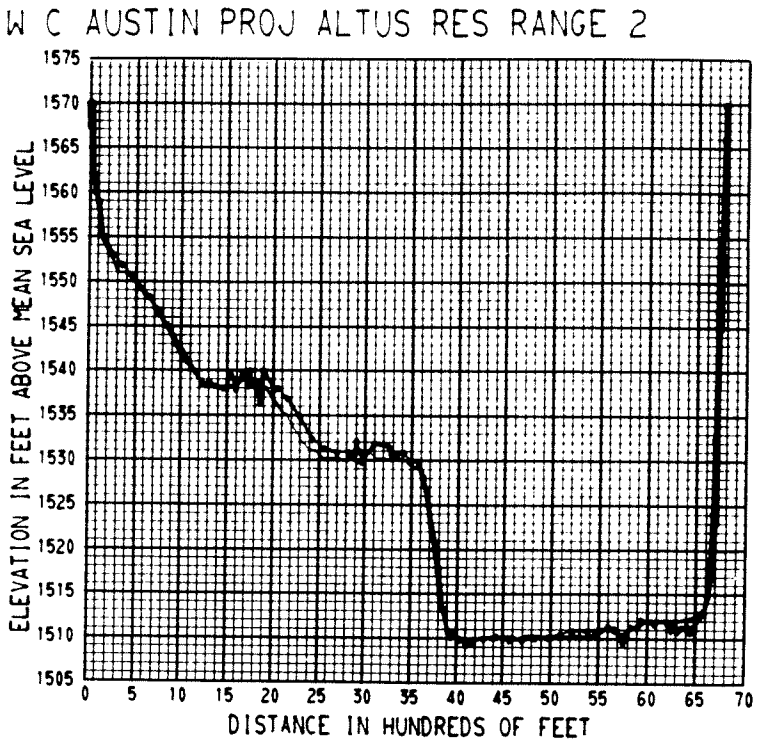



Figure 30. 1948 and 1967 sedimentation range profiles—Range 2.

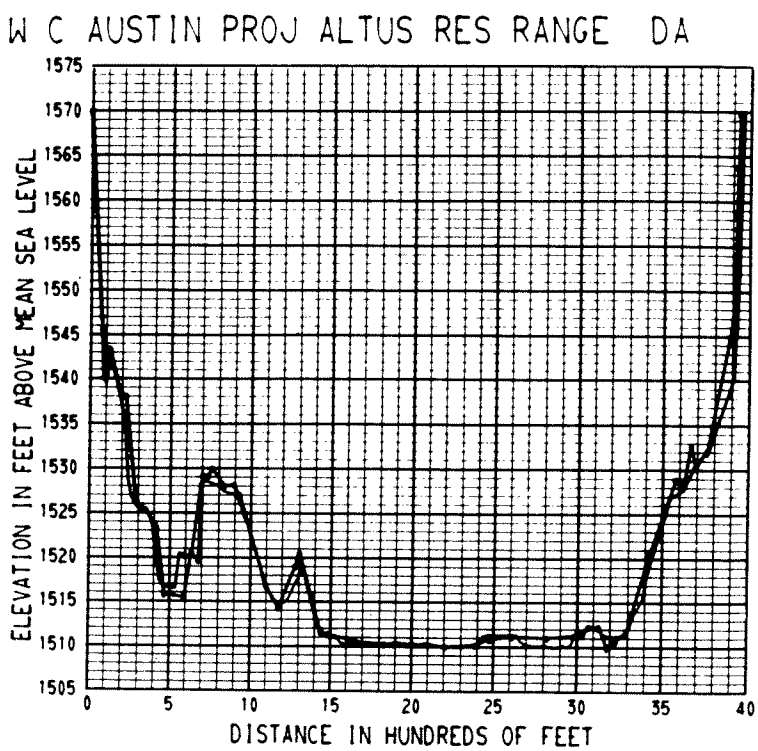



Figure 31. 1948 and 1967 sedimentation range profiles—Range DA.

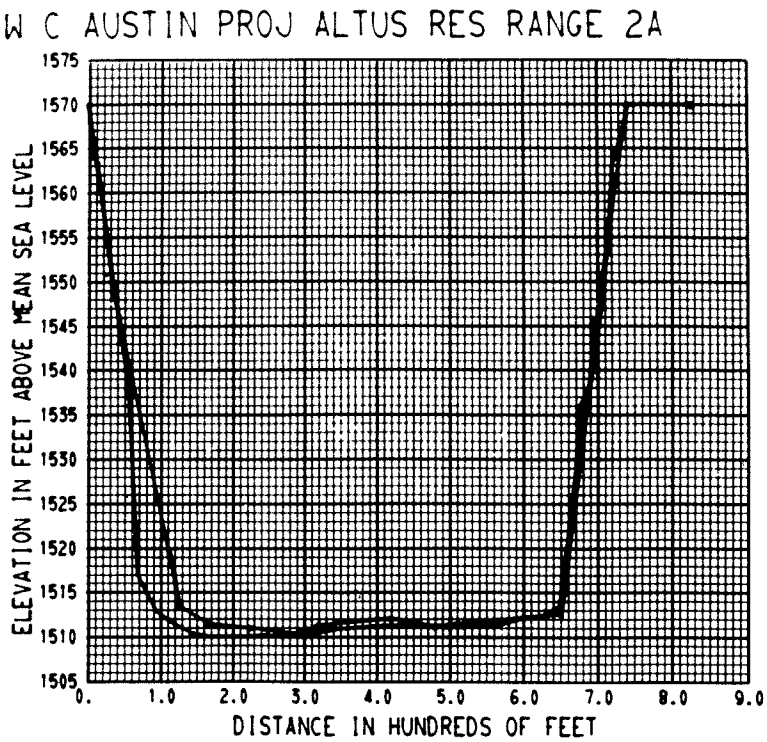



Figure 32. 1948 and 1967 sedimentation range profiles—Range 2A.

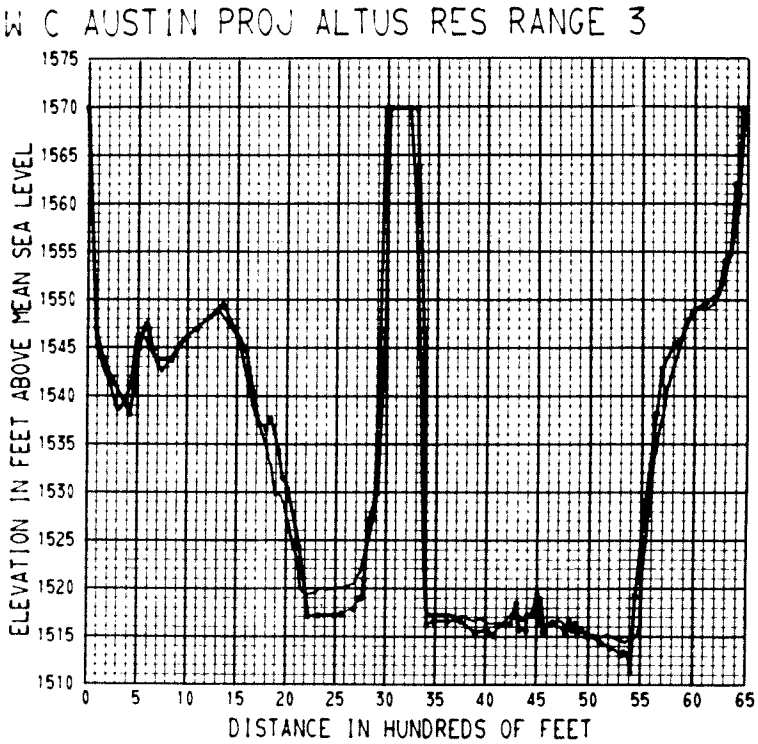



Figure 33. 1948 and 1967 sedimentation range profiles—Range 3.

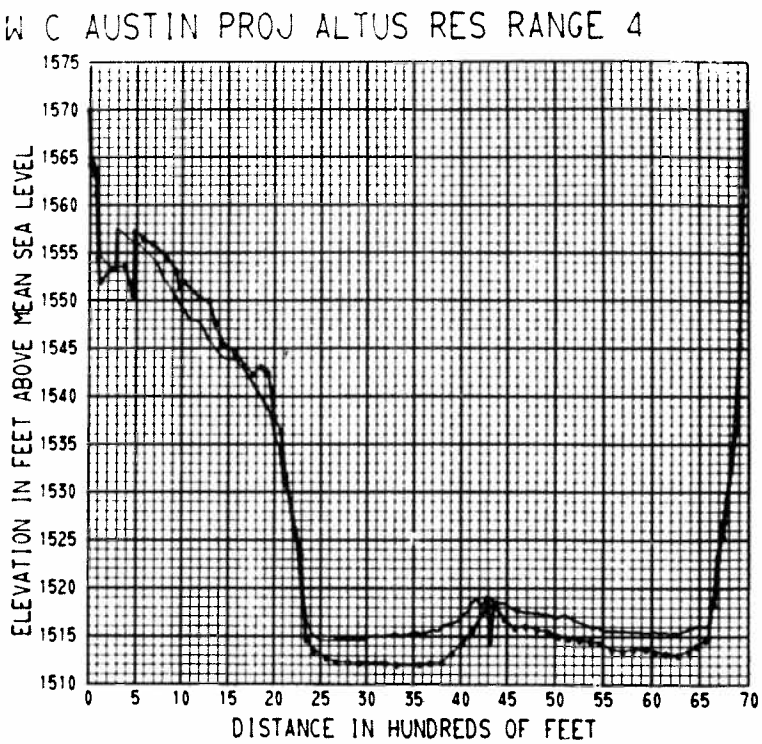



Figure 34. 1948 and 1967 sedimentation range profiles—Range 4.

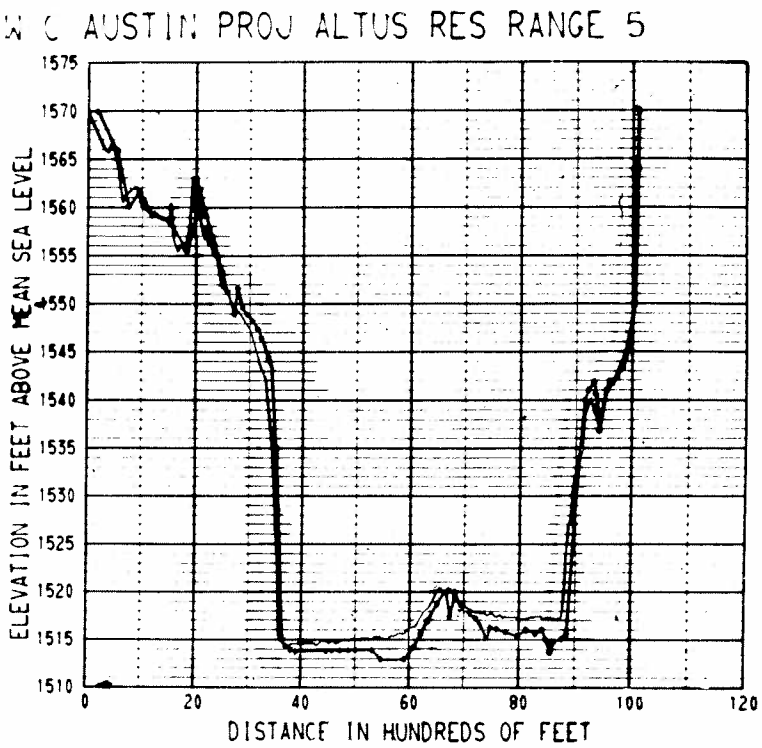



Figure 35. 1948 and 1967 sedimentation range profiles—Range 5.

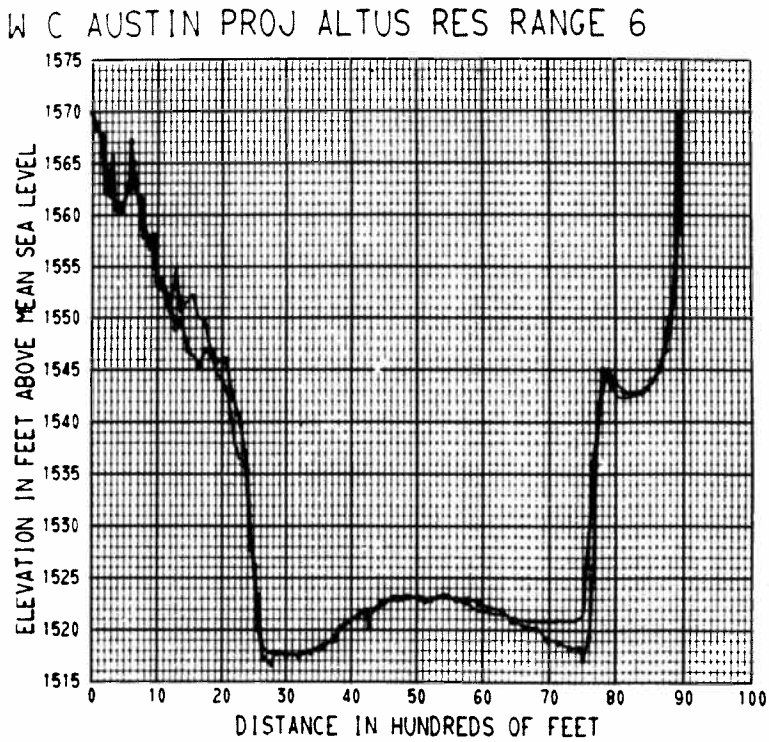



Figure 36. 1948 and 1967 sedimentation range profiles—Range 6.

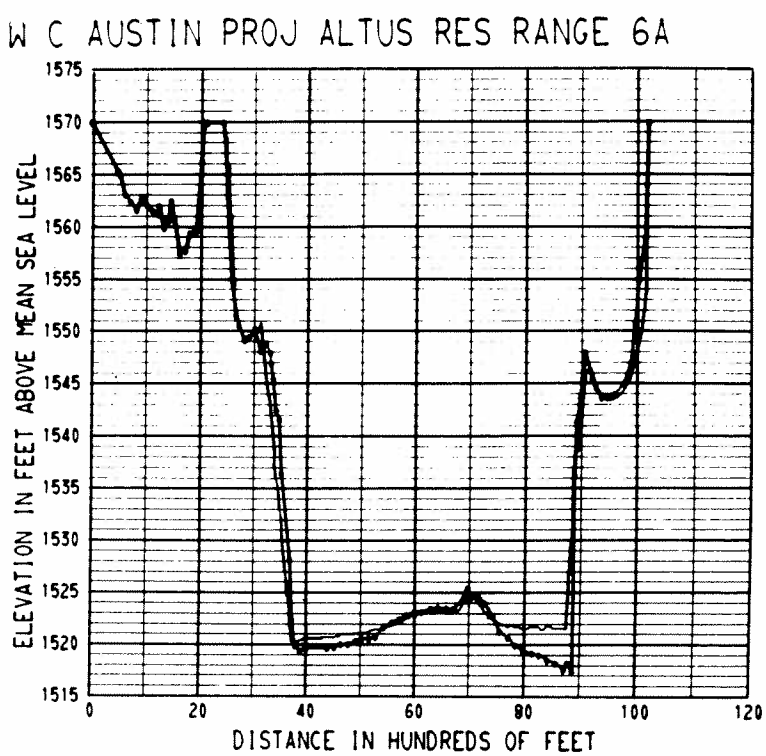



Figure 37. 1948 and 1967 sedimentation range profiles—Range 6A.

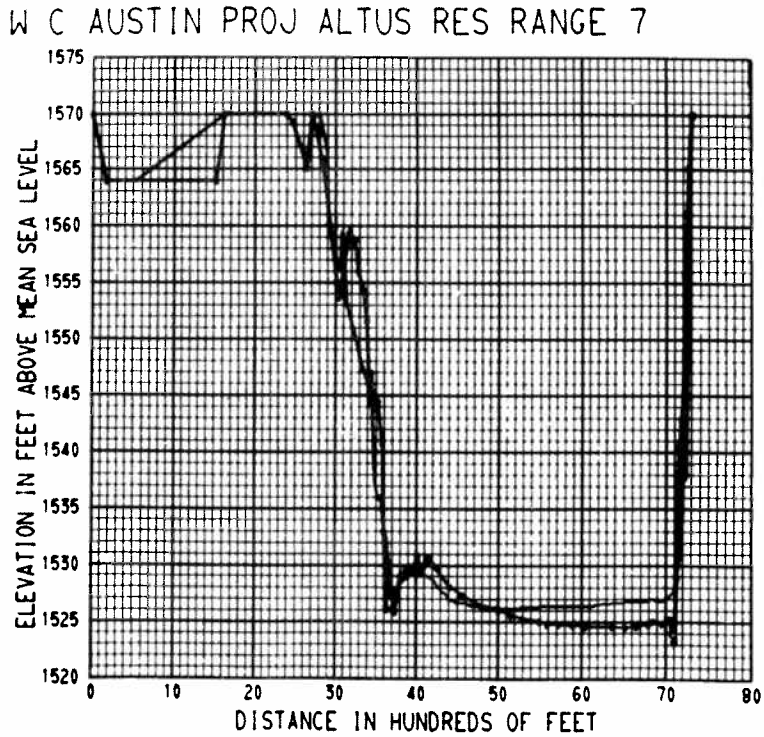



Figure 38. 1948 and 1967 sedimentation range profiles—Range 7.

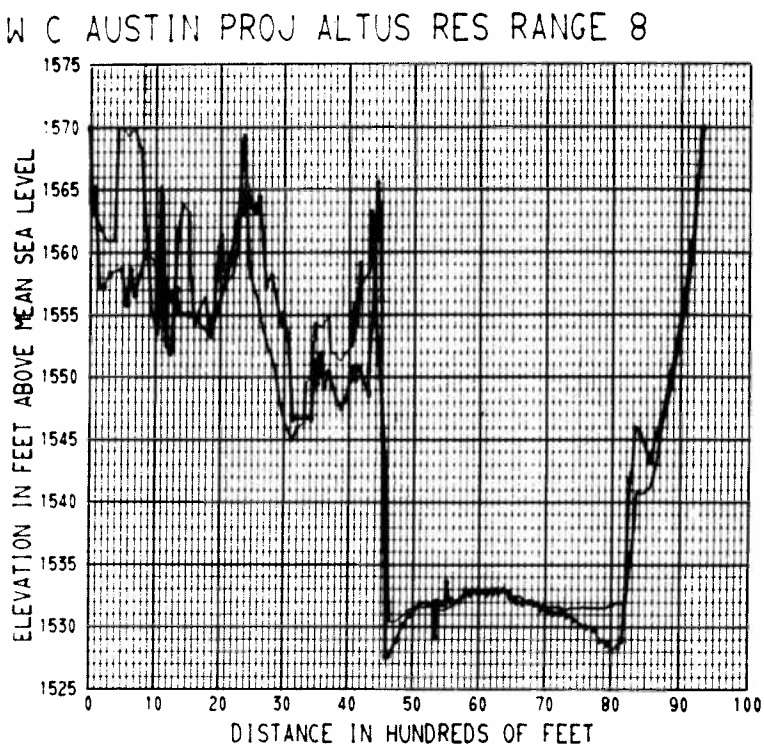



Figure 39. 1948 and 1967 sedimentation range profiles—Range 8.

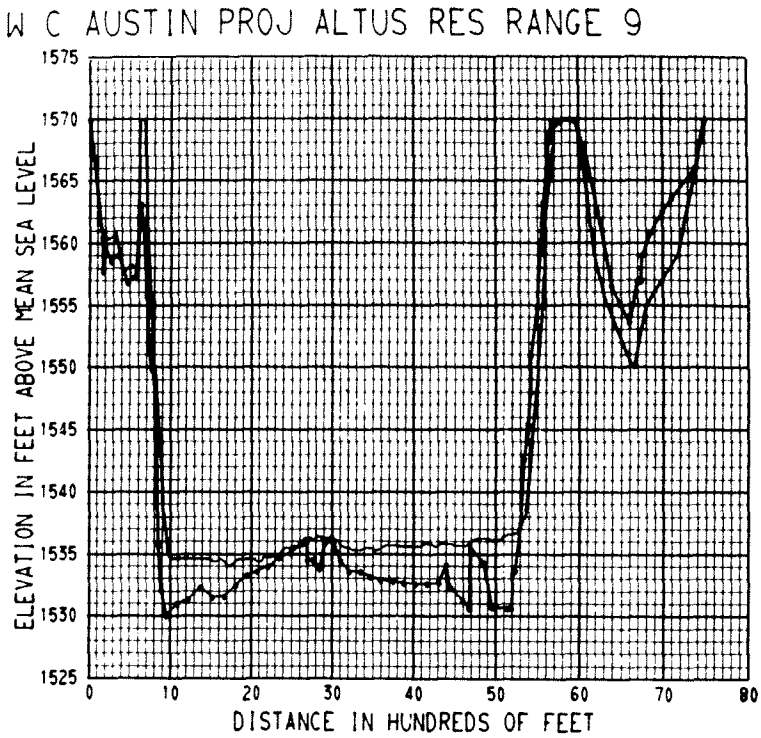



Figure 40. 1948 and 1967 sedimentation range profiles—Range 9.

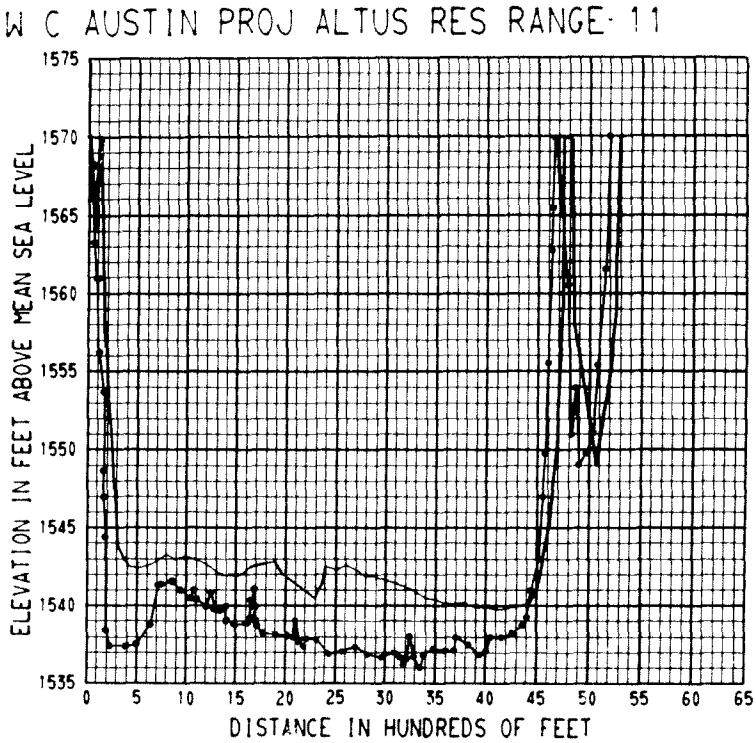



Figure 41. 1948 and 1967 sedimentation range profiles—Range 11.

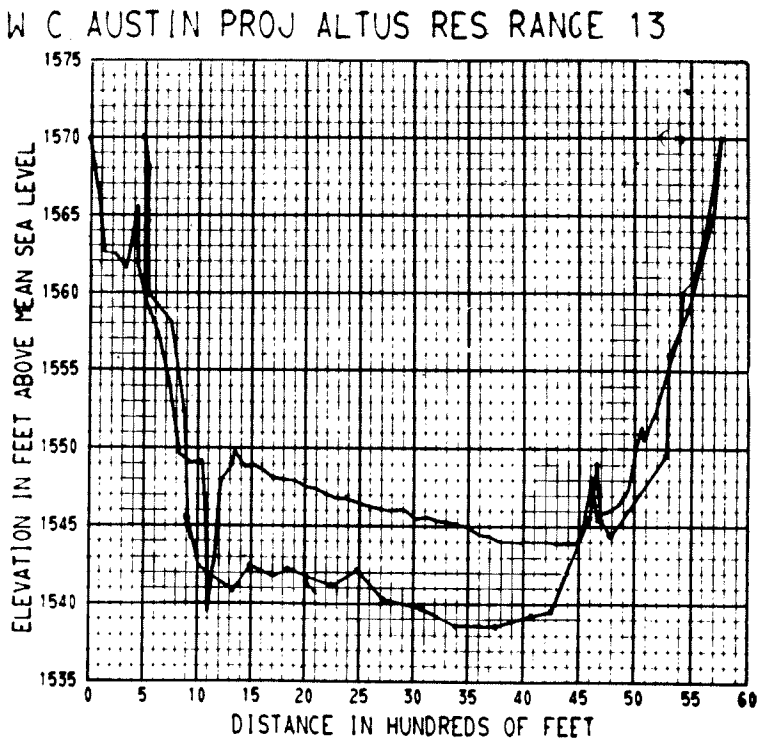



Figure 42. 1948 and 1967 sedimentation range profiles—Range 13.

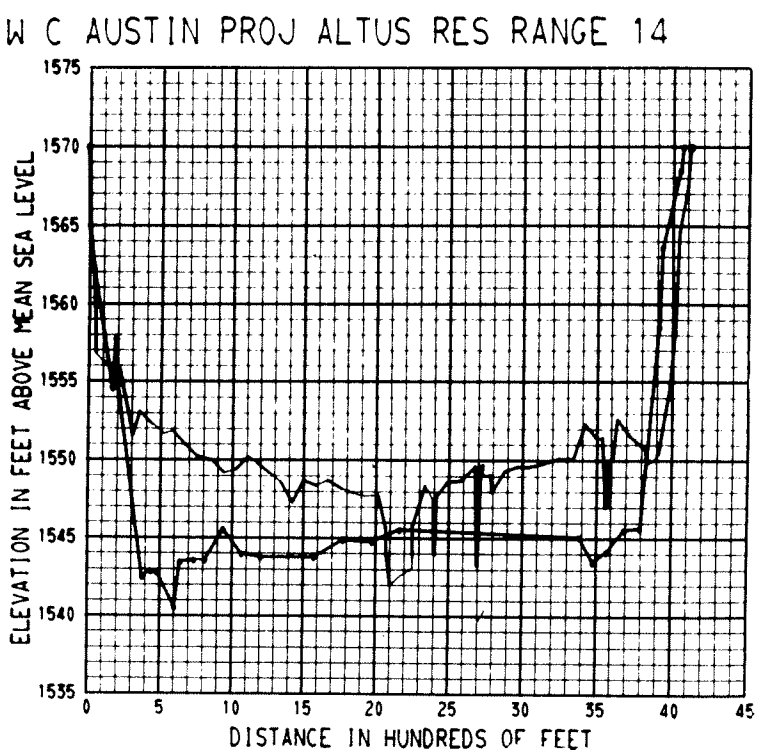



Figure 43. 1948 and 1967 sedimentation range profiles—Range 14.

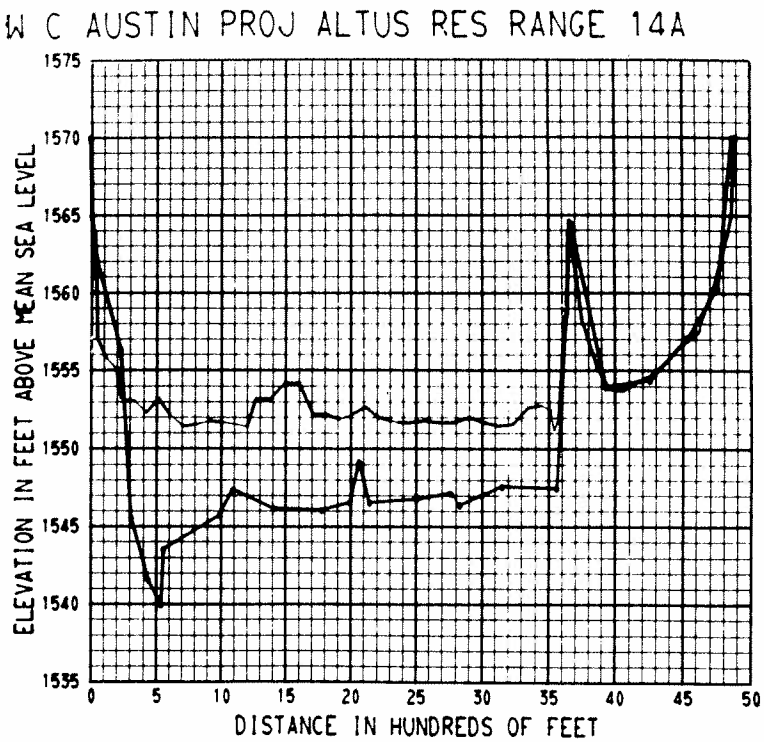



Figure 44. 1948 and 1967 sedimentation range profiles—Range 14A.

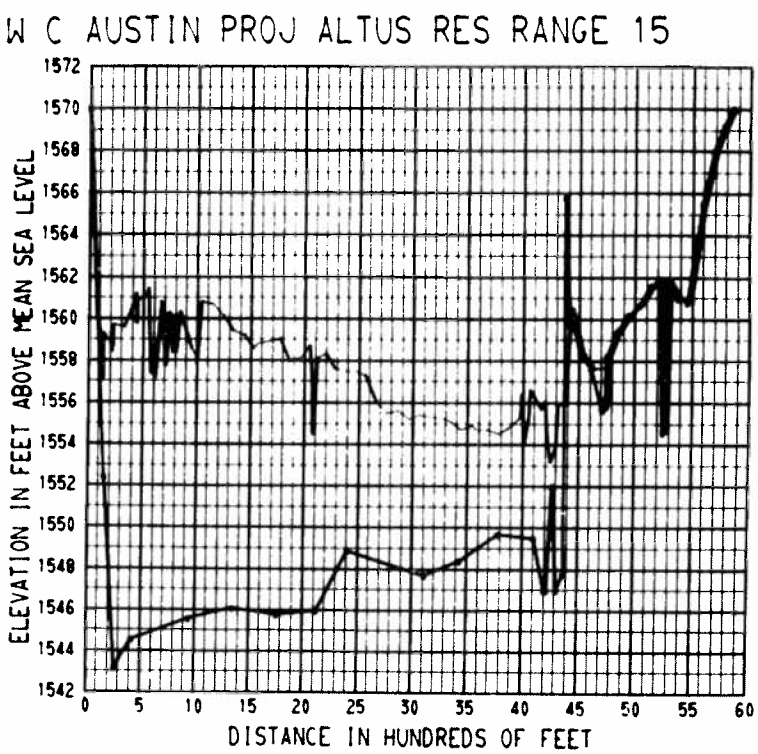



Figure 45. 1948 and 1967 sedimentation range profiles—Range 15.

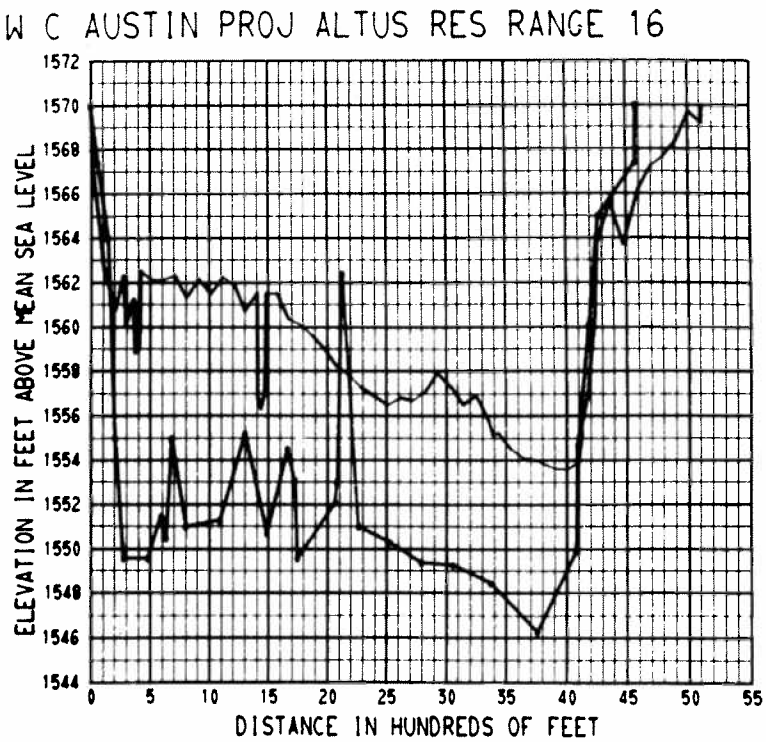



Figure 46. 1948 and 1967 sedimentation range profiles—Range 16.

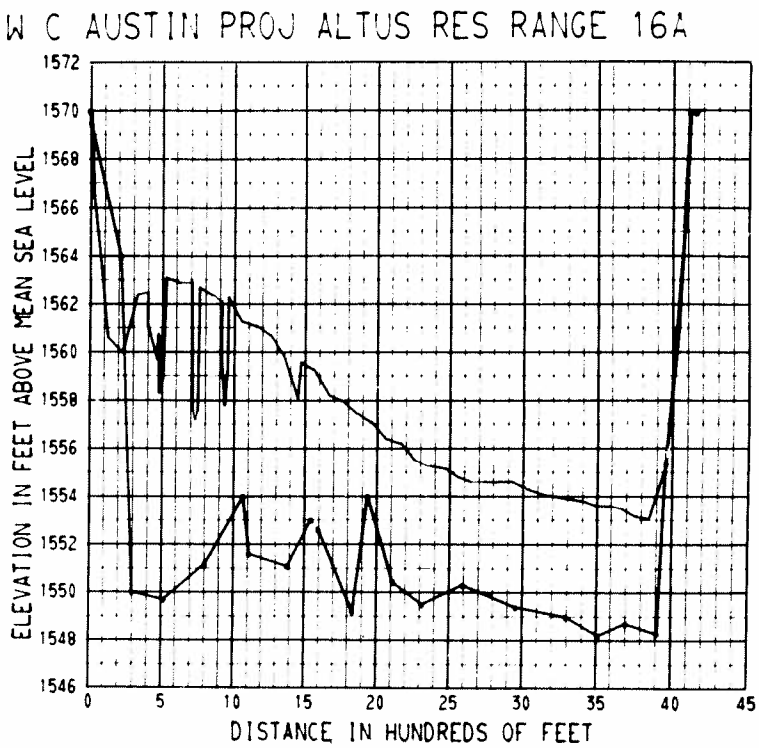



Figure 47. 1948 and 1967 sedimentation range profiles—Range 16A.

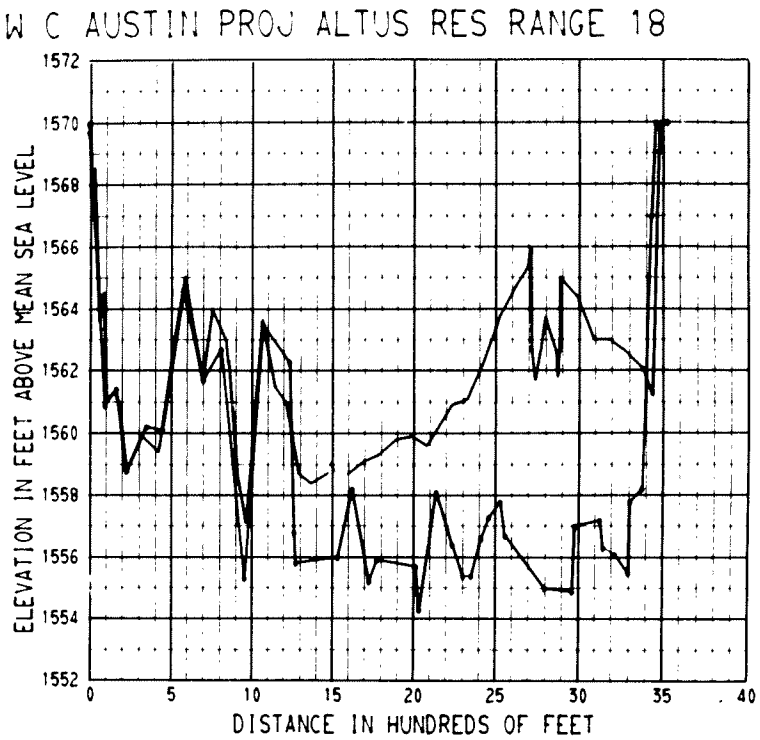



Figure 48. 1948 and 1967 sedimentation range profiles—Range 17.

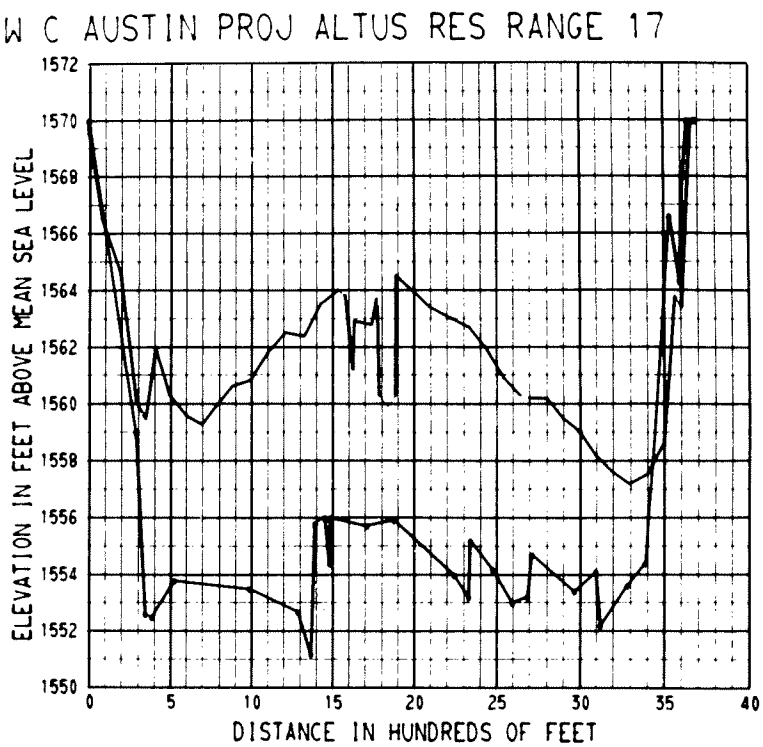



Figure 49. 1948 and 1967 sedimentation range profiles—Range 18.

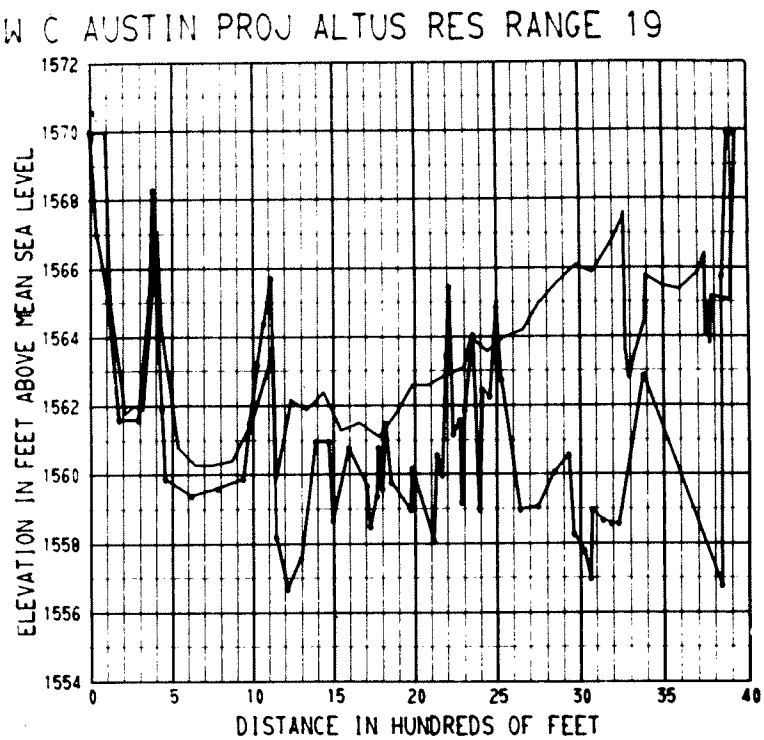



Figure 50. 1948 and 1967 sedimentation range profiles—Range 19.

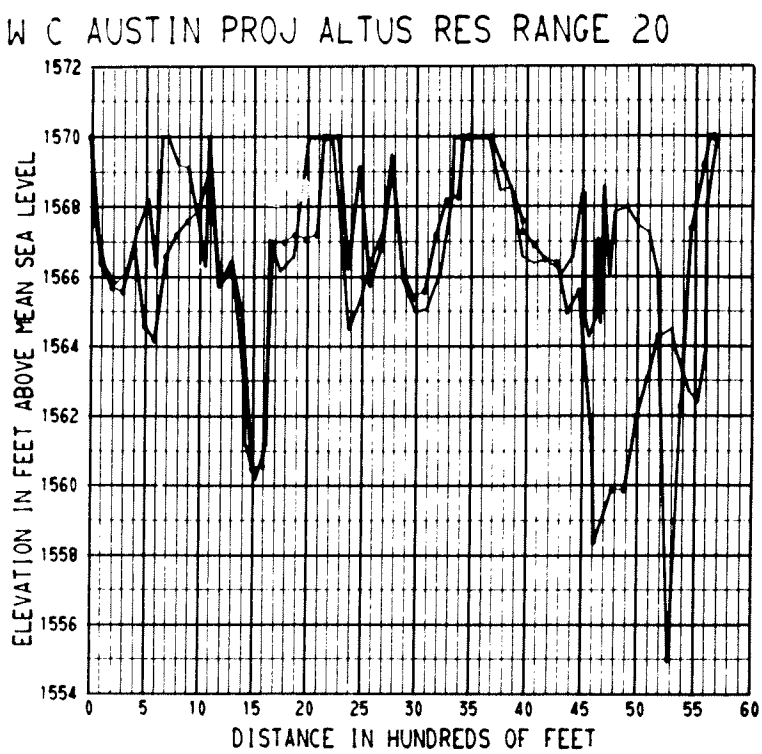



Figure 51. 1948 and 1967 sedimentation range profiles—Range 20.

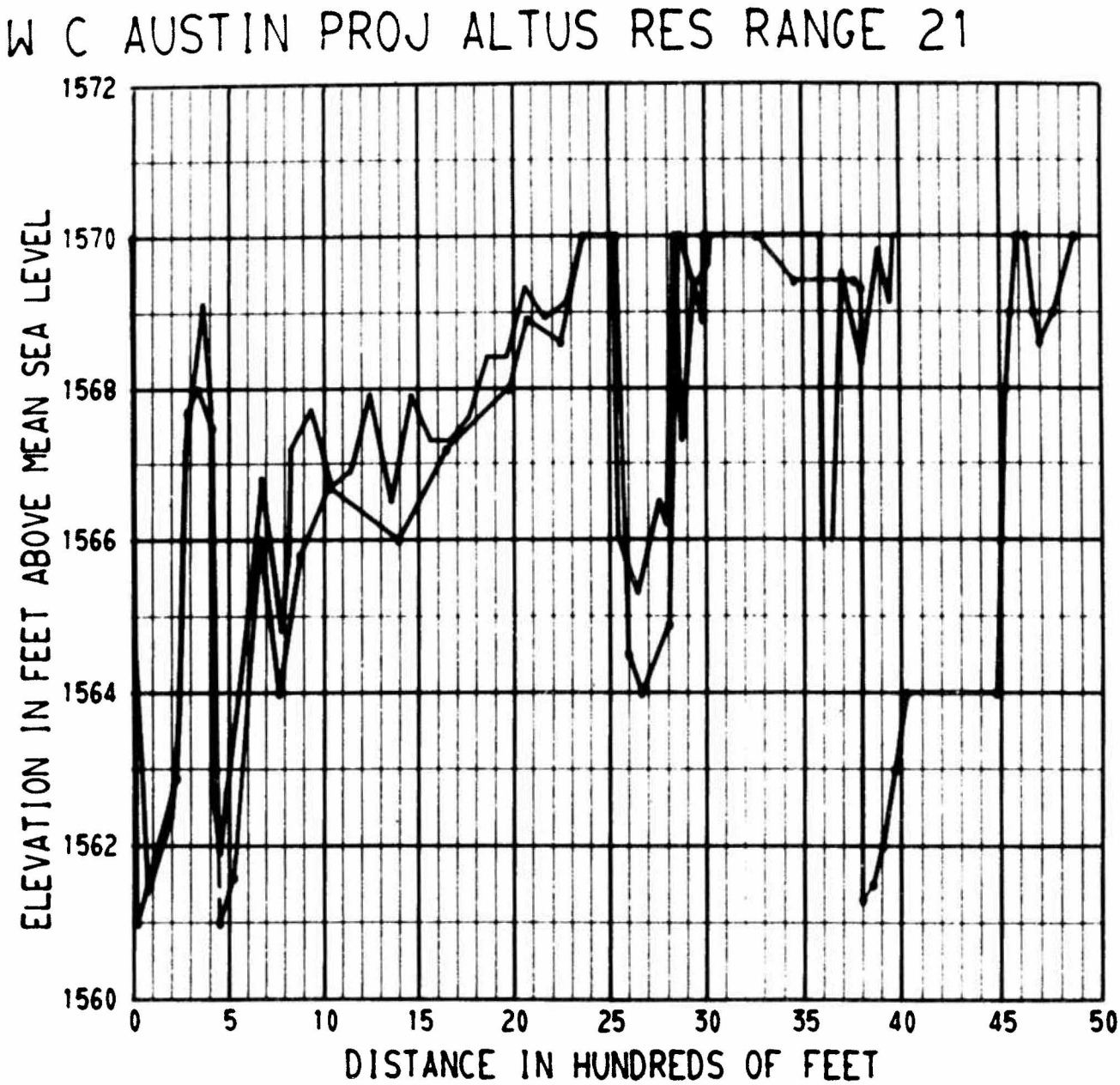



Figure 52. 1948 and 1967 sedimentation range profiles—Range 21.

7-1750 (3-71)
Bureau of Reclamation

# CONVERSION FACTORS—BRITISH TO METRIC UNITS OF MEASUREMENT

The following conversion factors adopted by the Bureau of Reclamation are those published by the American Society for Testing and Materials (ASTM Metric Practice Guide, E 380-68) except that additional factors (*) commonly used in the Bureau have been added. Further discussion of definitions of quantities and units is given in the ASTM Metric Practice Guide.

The metric units and conversion factors adopted by the ASTM are based on the "International System of Units" (designated SI for Systeme International d'Unites), fixed by the International Committee for Weights and Measures; this system is also known as the Giorgi or MKSA (meter-kilogram (mass)-second-ampere) system. This system has been adopted by the International Organization for Standardization in ISO Recommendation R-31.

The metric technical unit of force is the kilogram-force; this is the force which, when applied to a body having a mass of 1 kg, gives it an acceleration of 9.80665 m/sec/sec, the standard acceleration of free fall toward the earth's center for sea level at 45 deg latitude. The metric unit of force in SI units is the newton (N), which is defined as that force which, when applied to a body having a mass of 1 kg, gives it an acceleration of 1 m/sec/sec. These units must be distinguished from the (inconstant) local weight of a body having a mass of 1 kg, that is, the weight of a body is that force with which a body is attracted to the earth and is equal to the mass of a body multiplied by the acceleration due to gravity. However, because it is general practice to use "pound" rather than the technically correct term "pound-force," the term "kilogram" (or derived mass unit) has been used in this guide instead of "kilogram-force" in expressing the conversion factors for forces. The newton unit of force will find increasing use, and is essential in SI units.

Where approximate or nominal English units are used to express a value or range of values, the converted metric units in parentheses are also approximate or nominal. Where precise English units are used, the converted metric units are expressed as equally significant values.

Table I

QUANTITIES AND UNITS OF SPACE

| Multiply | By | To obtain |
|---|---|---|
| | LENGTH | |
| Mil | 25.4 (exactly) | Micron |
| Inches | 25.4 (exactly) | Millimeters |
| Inches | 2.54 (exactly)* | Centimeters |
| Feet | 30.48 (exactly) | Centimeters |
| Feet | 0.3048 (exactly)* | Meters |
| Feet | 0.0003048 (exactly)* | Kilometers |
| Yards | 0.9144 (exactly) | Meters |
| Miles (statute) | 1,609.344 (exactly)* | Meters |
| Miles | 1.609344 (exactly) | Kilometers |
| | AREA | |
| Square inches | 6.4516 (exactly) | Square centimeters |
| Square feet | *929.03 | Square centimeters |
| Square feet | 0.092903 | Square meters |
| Square yards | 0.836127 | Square meters |
| Acres | *0.40469 | Hectares |
| Acres | *4,046.9 | Square meters |
| Acres | *0.0040469 | Square kilometers |
| Square miles | 2.58999 | Square kilometers |
| | VOLUME | |
| Cubic inches | 16.3871 | Cubic centimeters |
| Cubic feet | 0.0283168 | Cubic meters |
| Cubic yards | 0.764555 | Cubic meters |
| | CAPACITY | |
| Fluid ounces (U.S.) | 29.5737 | Cubic centimeters |
| Fluid ounces (U.S.) | 29.5729 | Milliliters |
| Liquid pints (U.S.) | 0.473179 | Cubic decimeters |
| Liquid pints (U.S.) | 0.473166 | Liters |
| Quarts (U.S.) | *946.358 | Cubic centimeters |
| Quarts (U.S.) | *0.946331 | Liters |
| Gallons (U.S.) | *3,785.43 | Cubic centimeters |
| Gallons (U.S.) | 3.78543 | Cubic decimeters |
| Gallons (U.S.) | 3.78533 | Liters |
| Gallons (U.S.) | *0.00378543 | Cubic meters |
| Gallons (U.K.) | 4.54609 | Cubic decimeters |
| Gallons (U.K.) | 4.54596 | Liters |
| Cubic feet | 28.3160 | Liters |
| Cubic yards | *764.55 | Liters |
| Acre-feet | *1,233.5 | Cubic meters |
| Acre-feet | *1,233,500 | Liters |

Table II

QUANTITIES AND UNITS OF MECHANICS

| Multiply | By | To obtain |
|---|---|---|
| **MASS** | | |
| Grains (1/7,000 lb) | 64.79891 (exactly) | Milligrams |
| Troy ounces (480 grains) | 31.1035 | Grams |
| Ounces (avdp) | 28.3495 | Grams |
| Pounds (avdp) | 0.45359237 (exactly) | Kilograms |
| Short tons (2,000 lb) | 907.185 | Kilograms |
| Short tons (2,000 lb) | 0.907185 | Metric tons |
| Long tons (2,240 lb) | 1,016.05 | Kilograms |
| **FORCE/AREA** | | |
| Pounds per square inch | 0.070307 | Kilograms per square centimeter |
| Pounds per square inch | 0.689476 | Newtons per square centimeter |
| Pounds per square foot | 4.88243 | Kilograms per square meter |
| Pounds per square foot | 47.8803 | Newtons per square meter |
| **MASS/VOLUME (DENSITY)** | | |
| Ounces per cubic inch | 1.72999 | Grams per cubic centimeter |
| Pounds per cubic foot | 16.0185 | Kilograms per cubic meter |
| Pounds per cubic foot | 0.0160185 | Grams per cubic centimeter |
| Tons (long) per cubic yard | 1.32894 | Grams per cubic centimeter |
| **MASS/CAPACITY** | | |
| Ounces per gallon (U.S.) | 7.4893 | Grams per liter |
| Ounces per gallon (U.K.) | 6.2362 | Grams per liter |
| Pounds per gallon (U.S.) | 119.829 | Grams per liter |
| Pounds per gallon (U.K.) | 99.779 | Grams per liter |
| **BENDING MOMENT OR TORQUE** | | |
| Inch-pounds | 0.011521 | Meter-kilograms |
| Inch-pounds | $1.12985 \times 10^6$ | Centimeter-dynes |
| Foot-pounds | 0.138255 | Meter-kilograms |
| Foot-pounds | $1.35582 \times 10^7$ | Centimeter-dynes |
| Foot-pounds per inch | 5.4431 | Centimeter-kilograms per centimeter |
| Ounce-inches | 72.008 | Gram-centimeters |
| **VELOCITY** | | |
| Feet per second | 30.48 (exactly) | Centimeters per second |
| Feet per second | 0.3048 (exactly)* | Meters per second |
| Feet per year | $*0.965873 \times 10^{-6}$ | Centimeters per second |
| Miles per hour | 1.609344 (exactly) | Kilometers per hour |
| Miles per hour | 0.44704 (exactly) | Meters per second |
| **ACCELERATION*** | | |
| Feet per second$^2$ | *0.3048 | Meters per second$^2$ |
| **FLOW** | | |
| Cubic feet per second (second-feet) | *0.028317 | Cubic meters per second |
| Cubic feet per minute | 0.4719 | Liters per second |
| Gallons (U.S.) per minute | 0.06309 | Liters per second |
| **FORCE*** | | |
| Pounds | *0.453592 | Kilograms |
| Pounds | *4.4482 | Newtons |
| Pounds | $*4.4482 \times 10^5$ | Dynes |

Table II—Continued

| Multiply | By | To obtain |
|---|---|---|
| **WORK AND ENERGY*** | | |
| British thermal units (Btu) | *0.252 | Kilogram calories |
| British thermal units (Btu) | 1,055.06 | Joules |
| Btu per pound | 2.326 (exactly) | Joules per gram |
| Foot-pounds | *1.35582 | Joules |
| **POWER** | | |
| Horsepower | 745.700 | Watts |
| Btu per hour | 0.293071 | Watts |
| Foot-pounds per second | 1.35582 | Watts |
| **HEAT TRANSFER** | | |
| Btu in./hr ft$^2$ degree F (k, thermal conductivity) | 1.442 | Milliwatts/cm degree C |
| Btu in./hr ft$^2$ degree F (k, thermal conductivity) | 0.1240 | Kg cal/hr m degree C |
| Btu ft/hr ft$^2$ degree F | *1.4880 | Kg cal m/hr m$^2$ degree C |
| Btu/hr ft$^2$ degree F (C, thermal conductance) | 0.568 | Milliwatts/cm$^2$ degree C |
| Btu/hr ft$^2$ degree F (C, thermal conductance) | 4.882 | Kg cal/hr m$^2$ degree C |
| Degree F hr ft$^2$/Btu (R, thermal resistance) | 1.761 | Degree C cm$^2$/milliwatt |
| Btu/lb degree F (c, heat capacity) | 4.1868 | J/g degree C |
| Btu/lb degree F | *1.000 | Cal/gram degree C |
| Ft$^2$/hr (thermal diffusivity) | 0.2581 | Cm$^2$/sec |
| Ft$^2$/hr (thermal diffusivity) | *0.09290 | M$^2$/hr |
| **WATER VAPOR TRANSMISSION** | | |
| Grains/hr ft$^2$ (water vapor) transmission) | 16.7 | Grams/24 hr m$^2$ |
| Perms (permeance) | 0.659 | Metric perms |
| Perm-inches (permeability) | 1.67 | Metric perm-centimeters |

Table III

OTHER QUANTITIES AND UNITS

| Multiply | By | To obtain |
|---|---|---|
| Cubic feet per square foot per day (seepage) | *304.8 | Liters per square meter per day |
| Pound-seconds per square foot (viscosity) | *4.8824 | Kilogram second per square meter |
| Square feet per second (viscosity) | *0.092903 | Square meters per second |
| Fahrenheit degrees (change)* | 5/9 exactly | Celsius or Kelvin degrees (change)* |
| Volts per mil | 0.03937 | Kilovolts per millimeter |
| Lumens per square foot (foot-candles) | 10.764 | Lumens per square meter |
| Ohm-circular mils per foot | 0.001662 | Ohm-square millimeters per meter |
| Millicuries per cubic foot | *35.3147 | Millicuries per cubic meter |
| Milliamps per square foot | *10.7639 | Milliamps per square meter |
| Gallons per square yard | *4.527219 | Liters per square meter |
| Pounds per inch | *0.17858 | Kilograms per centimeter |

GPO 835-947

## ABSTRACT

Altus Reservoir was surveyed in 1967 to gather the data needed in computing the latest reservoir capacity. The data were also used to compute the quantity of sediments accumulating in the reservoir since the dam was closed in 1940. Capacity of the reservoir is 134,000 acre-ft and the surface area 6,260 acres at spillway crest elevation 1559 ft. Sediments accumulated in the reservoir at an annual rate of 838 acre-ft between 1940 and 1947. Thirty sediment samples of reservoir deposits were collected from 23 reservoir range sites. An average unit weight of 70 lb/cu ft was determined from analyses of samples collected during the 1948, 1953, and 1967 surveys. Particle size analyses of these samples indicated an average breakdown of 29% clay, 32% silt, and 39% sand. Sonic depth recording mechanism was used to run the hydrographic survey. Reservoir capacity was computed based on areas determined by a width ratio method. Sediments have deposited longitudinally to depths of 1 to 9 ft throughout the reservoir length. Depths ranged from 1 to 6 ft for the laterally deposited sediments.



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REC-ERC-71-21
Lara, Joe M.
THE 1967 ALTUS RESERVOIR SEDIMENT SURVEY
Bur Reclam Rep REC-ERC-71-21, March 1971. Bureau of Reclamation, Denver, 41 p, 52 fig, 4 tab, 5 ref

DESCRIPTORS– /*reservoir silting/ sedimentation/ *reservoir surveys/ sediment distribution/ range lines/ Oklahoma/ contours/ deltas/ fluvial hydraulics/ sediment production/ sonar/ *sediment sampling/ field investigations/ sediment transport/ unit weight/ *aggradation/ deposition (sediments)/ sediment yield
IDENTIFIERS–/*reservoir capacity/ Altus Reservoir, Okla/ width ratio method

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