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THE 1969 ELEPHANT BUTTE RESERVOIR SEDIMENT SURVEY

Joe M. Lara
Engineering and Research Center
Bureau of Reclamation

March 1972

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16. ABSTRACT

The Elephant Butte Reservoir was surveyed in 1969 to gather data needed in computing the present reservoir capacity. The data were also used to compute the volume of sediments that accumulated in the reservoir since the dam was closed in 1915. Reservoir capacity is 2,137,200 acre-feet and the surface area 36,600 acres at spillway crest elevation 4407 feet. Sediments accumulated at an annual rate of 9,164 acre-feet between 1915 and 1969. Seventeen sediment samples of reservoir deposits were collected from sites of the reservoir ranges immediately above the dam during the 1969 survey. An average unit weight of 62 lb/cu ft was determined from analyses of samples collected during 1952, 1957, and 1969. Particle size analyses of these samples indicated an average breakdown of 60 percent clay, 31 percent silt, and 9 percent sand. Sonic depth recording apparatus 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 8 to 42 feet throughout the reservoir length. Depths ranged from 10 to 44 feet for the laterally deposited sediments.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. *DESCRIPTORS*-- / *reservoir silting/ sedimentation/ *reservoir surveys/ range lines/ *sediment distribution/ contours/ fluvial hydraulics/ sediment production/ sonar/ *sediment sampling/ field investigations/ *unit weight/ sediment deposits/ sediment yield/ *reservoir storage/ *reservoir capacity/ Texas/ New Mexico

b. *IDENTIFIERS*-- / Elephant Butte Reservoir, N Mex/ width ratio method

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by

Joe M. Lara

March 1972

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

UNITED STATES DEPARTMENT OF THE INTERIOR
Rogers C. B. Morton
Secretary

*

BUREAU OF RECLAMATION
Ellis L. Armstrong
Commissioner

ACKNOWLEDGMENT

The hydrographic survey was run by Joe M. Lara, Hydraulic Engineer, Engineering and Research Center, Denver, Colorado. Survey personnel included Mike Tracy and Emery Goertz on detail from the Navajo Indian Irrigation Project Office, Farmington, New Mexico, and H. T. Daniel and other members of the Power Field Branch Office, Elephant Butte, New Mexico. 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 Sam Bock and others under the supervision of James W. Kirby, Project Superintendent, El Paso, Texas. 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

Elephant Butte Reservoir is in Sierra and Socorro Counties of New Mexico. The dam is on the Rio Grande about 4 miles east of Truth or Consequences, New Mexico, and 125 miles north of El Paso, Texas. The dam and reservoir are owned and operated by the Bureau of Reclamation, U.S. Department of the Interior.

Description of the Dam

Elephant Butte was originally named Engle Dam. It is a gravity dam (Figure 1), 301 feet (ft) high and 1,674 ft long including the spillway. A drawing of the general plan and sections of the dam is shown in Figure 2. The dam was completed in 1916, but storage operation began in 1915.

The power system consists of the 24,300-kilowatt (kw) hydroelectric powerplant at the dam, 490 miles of 115-kilovolt (kv) transmission lines radiating from it, and 11 substations totaling 81,750 kilovolt-amperes (kva) in transformer capacity. More details on the description of the dam are contained in two previously published Bureau of Reclamation reports.[1] [2]

Description of the Reservoir

The original (1915) surface area of Elephant Butte Reservoir was 40,060 acres at spillway crest elevation (el) 4407 ft. This compares to a surface of area of 36,600 acres at the same elevation determined from the 1969 survey. The present capacity at this elevation is 2,137,200 acre-feet (acre-ft) showing a loss of 497,600 acre-ft since the dam was originally built. The length of the reservoir is about 41 miles and its average width is 1.39 miles.

Drainage Area Description

The drainage area of the Rio Grande above Elephant Butte Dam is 25,923 square miles of which 25,866 square miles is considered as the net sediment contributing area.

The Rio Grande rises in the San Juan Mountains of Colorado and flows between the Conejos Mountains and La Garita Hills. Water surface slopes are steep in the mountainous headwater regions. Most of the rocks in these regions are igneous or metamorphic and are not easily eroded. Just above the New Mexico state line the river enters a deep canyon flowing through a stretch of low sediment contribution until it enters Espanola Valley near the confluence with Rio Chama. Upon leaving this valley, it enters White Rock Canyon in the vicinity of Otowi Bridge. The unconsolidated sediments of the Santa Fe formation (Miocene and Pliocene continental deposits) have been eroded to form the valley of the Rio Grande from the lower end of White Rock Canyon near Cochiti Diversion Dam to near San Acacia. The flood plains and terraces of the valley are composed of alluvium that is available for transport and contributes substantial quantities of sediment to the Rio Grande. From the mouth of Rio Salado, just upstream from San Acacia, to the headwaters of Elephant Butte Reservoir, the Palomas formation of the Quaternary period has been eroded to form the river valley. The major geologic formations of the Rio Grande Valley are of the Cenozoic Era.

The topography of the drainage area is varied. In the extreme upper portion it is mountainous and rugged. South of Santa Fe, New Mexico, the topography is less rugged consisting of isolated mountains separated by desert plains and the Rio Grande Valley. The ranges of the drainage area elevation vary from 12,000 ft mean sea level (msl) at the Continental Divide in the upper portion to 4,450 ft msl in the Elephant Butte Reservoir headwaters area.

Figure 1. Elephant Butte Dam. Photo P24-D-24996

[1] Seavy, L. M., "Sedimentation Surveys of Elephant Butte Reservoir," Bureau of Reclamation, U.S. Department of the Interior, Denver, Colorado, February 1949.

[2] Lara, J. M., "The 1957 Sedimentation Survey of Elephant Butte Reservoir," Bureau of Reclamation, U.S. Department of the Interior, Denver, Colorado, November 1960.

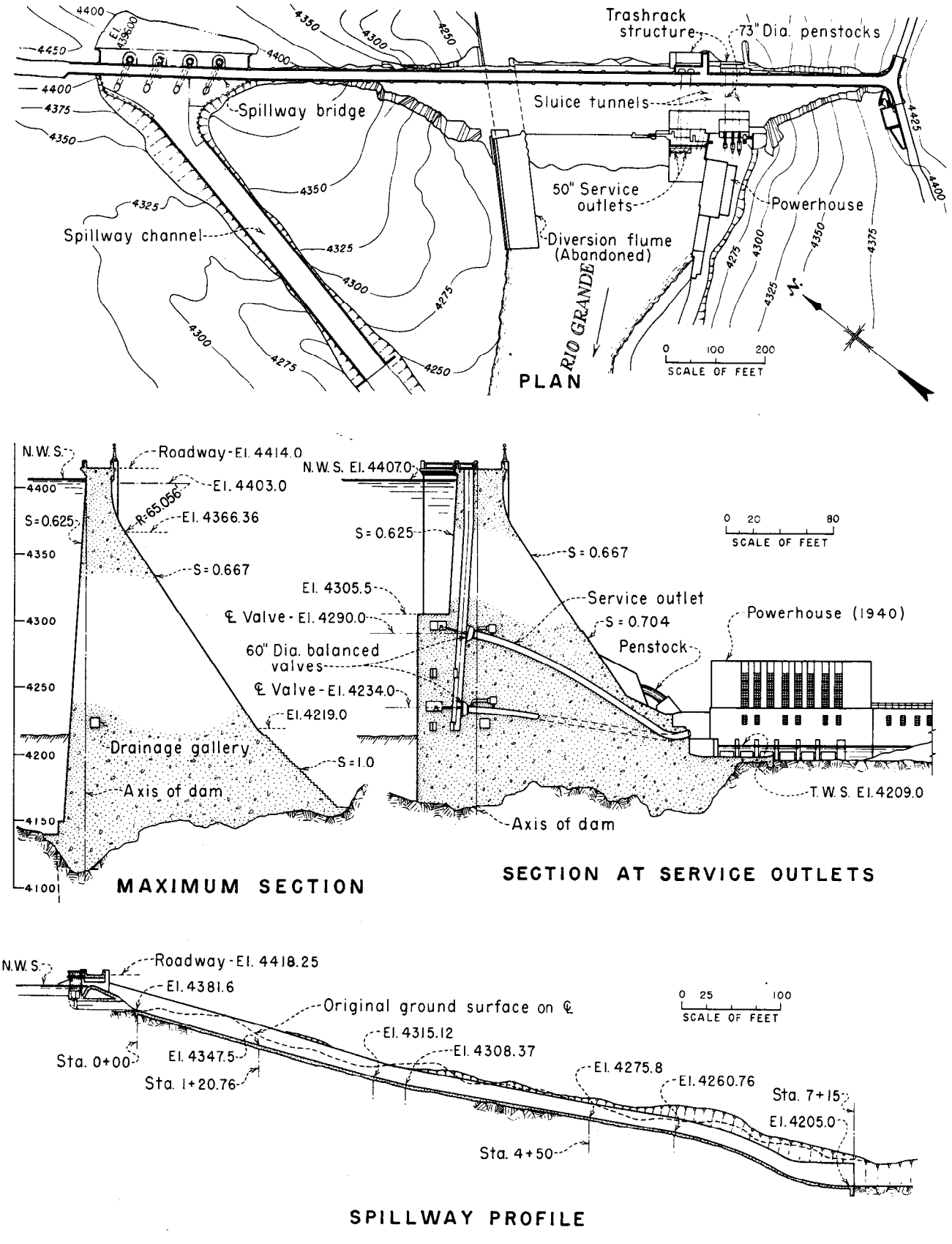


Figure 2. General plan and sections--Elephant Butte Dam.

The higher elevations are forested with pine and fir trees and the slopes are sprinkled with cedars along the foothills. Natural cover of the plains consists chiefly of creosote bush, sagebrush, greasewood, cactus, and natural grasses. Thick stands of salt cedars, willows, and cottonwoods grow along the riverbanks above the reservoir.

The previously cited reports[1] [2] contain further descriptions of the drainage area.

Datum

All elevations quoted in this report are based on the project datum. To adjust these elevations to mean-sea-level datum, 43.3 ft should be added.

Hydrographic Records

Records of the inflow to Elephant Butte Reservoir show an average of 866,000 acre-ft per year for 53 years (1915-1968, no record in 1957). The 11-year average (1958-1968), covering about the period since the last survey (1957), is 603,000 acre-ft per year. This 11-year average is about 70 percent of the average computed for 53 years.

Based on 53 years of record (1915-1968), the average annual discharge of the Rio Grande below Elephant Butte Dam is 732,700 acre-ft giving an indication of the outflow.

Elephant Butte Reservoir operation ranged from a minimum elevation of 4258.03 ft in 1954 to a maximum of 4409.15 ft in 1942.

SURVEYS, SAMPLING, AND EQUIPMENT

Seven surveys of varying degrees of accuracy have been previously run, beginning in 1916. Results of these surveys are documented later in the report. All surveys, except the one in 1947, were run using the contour method. The 1947 and 1969 surveys were run using the range method. Fieldwork for the last survey began February 3 and ended April 1, 1969.

Surveying Methods

Field survey work consisted initially of locating 60 of the reservoir sediment range ends permanently monumented during previous surveys. Ranges 90 to 65 were profiled across their full length. Above Range 65, only the main channel section was profiled; for the remainder of the range line in the floodway on each side of the main channel, the 1957 profile data were used. This was done for each range in the upper reservoir area because the water had never reached floodway levels since the 1957 survey. Standard land surveying procedures and equipment were used to run levels on each range line. For those ranges that are partly submerged underwater, levels were run on line down to water's edge from both sides of the reservoir. Stations were established at the edge of the water for the hydrographic survey.

The hydrographic survey was run in March and April 1969 using sonic depth recording equipment (Figures 3 and 4) to sound the submerged portion of the ranges. The equipment was installed on the deck of a pontoon boat as shown in Figure 5. First, the boat was positioned on range line near to the shore as possible. Then the line was profiled from the station at water's edge using stadia or tape to measure the distance to the center point of the transducer. The depth recorder was turned on and the boat was propelled (Figure 6) across the range at speeds of about 3 to 5 feet per second (fps). A man on shore (Figure 7) kept the boat on line through radio communication with the boat operator. A distance measuring machine was used to measure horizontal distances across the reservoir. The machine provided a way of marking the "fix" lines on the sonar

Figure 3. Recorder for sonic charting. Photo P24-500-1246 NA

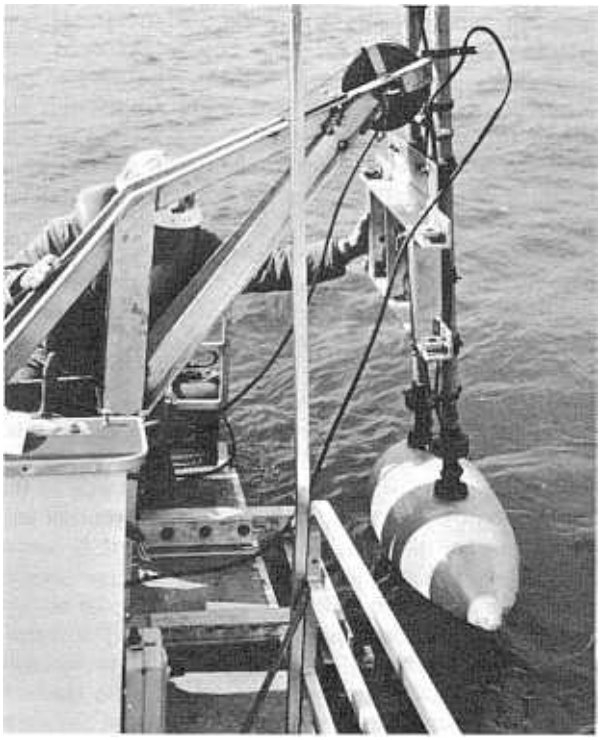


Figure 4. Transducer being readied for operation.

Figure 6. Launching the boat to sound a range line. Photo P24-500-1244 NA

Figure 5. Equipment installed on deck of pontoon boat to run hydrographic survey.

Figure 7. Man on shore keeps boat on line through radio communication with boat operator. Photo P24-500-1247 NA

chart. Vertical control was maintained by referencing the recorded soundings to the reservoir water surface indicated by the gage at the dam which was read each day of the survey operation.

A graphical reproduction of a sonar chart is shown in Figure 8 for the west portion of Range 90. The chart shows it was necessary to change the depth scale from the 0- to 60-ft scale to the 60- to 120-ft scale between 50 and 100 ft from the beginning station. Then, the scale was changed back to the 0- to 60-ft range just after passing a distance of 650 ft from the beginning station.

Sampling Method and Equipment

A gravity core sampler (Figure 9) was used to take 17 samples of the underwater reservoir sediment deposits. The sampler was suspended over the side of the boat from a 0.25-inch (in.) cable reeled off a power-operated winch. It was allowed to fall free into the sediment deposits to maximum possible penetration. When the sampler was retrieved on the boat deck, the cutterhead at the bottom was removed and the plastic liner containing the sediment sample was withdrawn from the coring pipe (Figure 10). A hacksaw was used to cut that part of the liner holding the sample. Plastic caps were put on each end of the liner which was identified for analysis.

RESERVOIR SEDIMENT DISTRIBUTION

Longitudinal Distribution

A study of how sediments were distributed in the reservoir can be made by plotting a longitudinal profile as shown in Figure 11. The thalweg elevation or lowest point on the range line is used to plot the profiles for the 1915 and 1969 conditions. The shaded area represents the sediment encroachment into the reservoir since the dam was closed in 1915. However, beginning about 28 miles above the dam, the conveyance channel (a manmade channel) thalweg was plotted indicating depths of the sediment deposits less than those that would be indicated by the main channel thalweg. The table below lists the depths to which sediments had longitudinally accumulated between the 1915 and 1969 period.

Interval distances above dam (miles)	Average depth of sediment (ft)
0 to 3	27
3 to 6	20
6 to 11	29
11 to 12	37
12 to 16	42
16 to 21	34
21 to 24	26
24 to 27	24
27 to 31	18
31 to 36	14
36 to 40	8

The greatest depths of longitudinal sediment deposits occur between 11 and 21 miles above the dam. It is likely that "The Narrows" area between 15 and 19.5 miles above the dam may have influenced the depositional pattern in this region of the reservoir. Another factor influencing the pattern is the lack of water inflow that was evidenced by a severe drought period since 1950. Average annual inflow for the 1950-1968 period (18 years) was 501,000 acre-ft or only 58 percent of the long-term annual average of 866,000 acre-ft for 1915-1968 (53 years).

Table 1 contains a summary of the sediment distribution computations for Elephant Butte Reservoir. Tabulated in column (6) are the accumulated sediment volumes as determined from the 1969 survey results. Total sediments accumulated in the reservoir (see top of column (6)) since the 1915 survey amounted to 497,581 acre-ft. Column (7) lists the volumes expressed in percentage of the total measured sediment volume.

As a matter of further practical interest, a theoretical distribution of the sediment was computed using the Empirical Area-Reduction Method. It was assumed that the sediment inflow volume to be distributed would be 497,600 acre-ft (equal to that measured by the 1969 survey). A plotting of the depth-capacity (Figure 12) relationship using the original (1915) data indicated the reservoir to be a Type II. The Elephant Butte Reservoir data are plotted in Figure 13 which shows it crossing the Type II curve to determine the depth of sediment at the dam. Results of the sediment distribution computations are listed in columns (8),

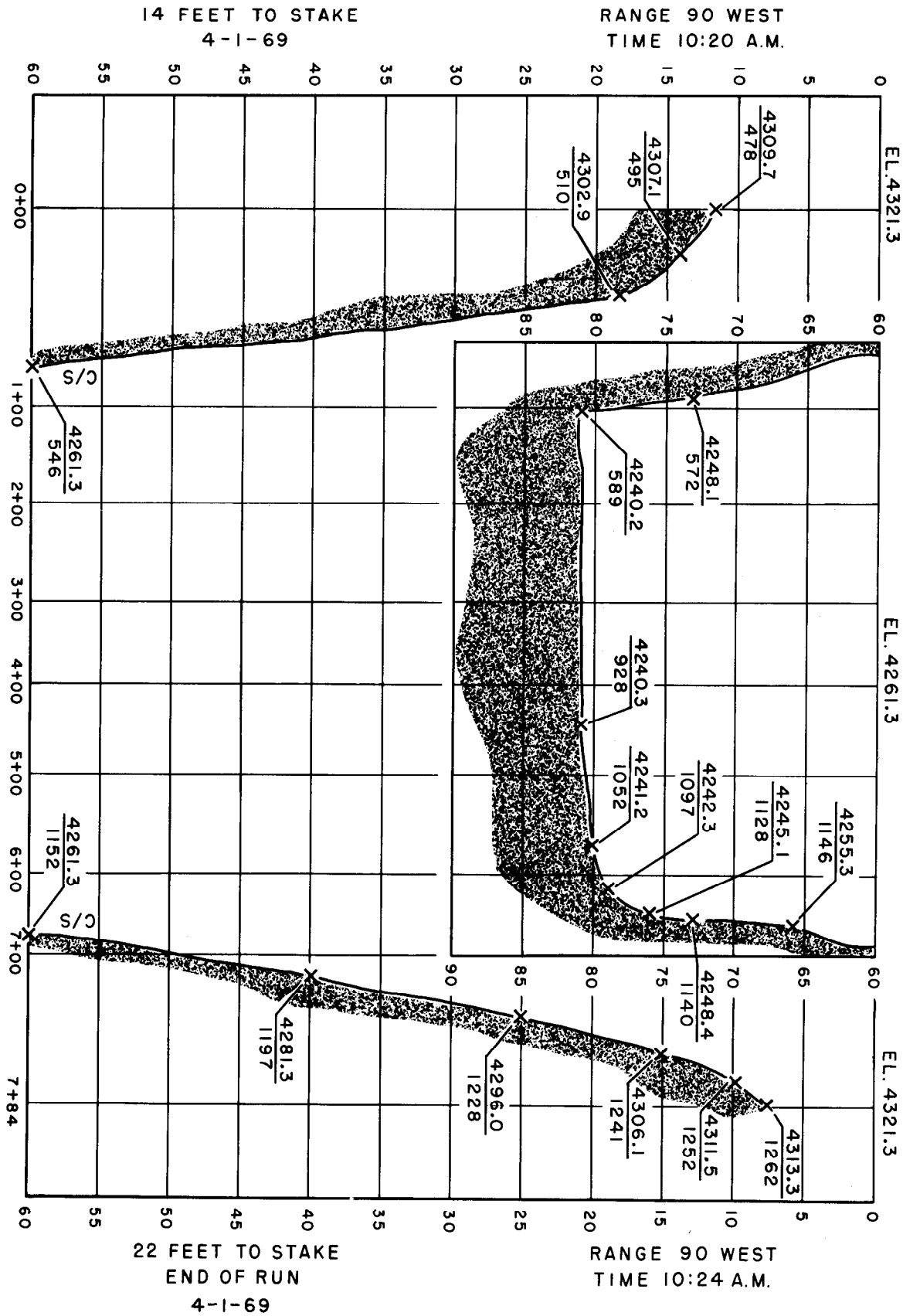


Figure 8. Example of a sonar chart for Range 90 (west portion).

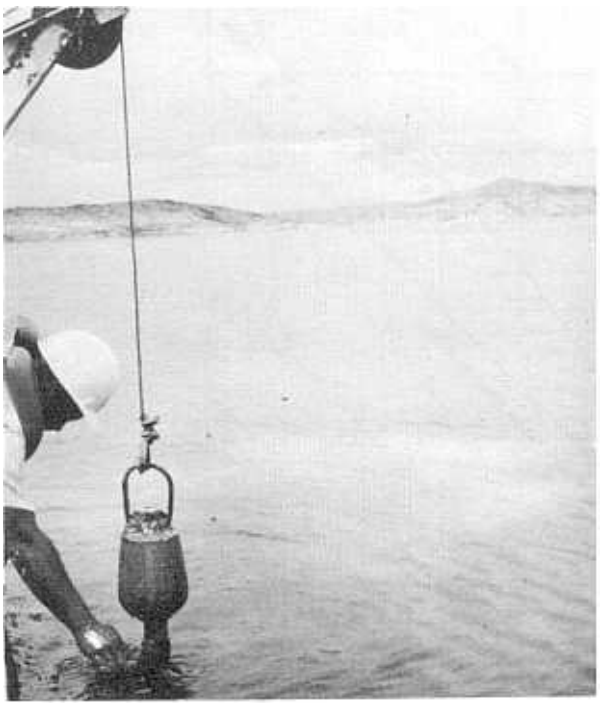


Figure 9. Gravity core sampler (only the head can be seen above water).

(9), and (10) of Table 1. These computations show the sediment would reach an elevation of 4257.5 ft compared to the elevation of 4240 ft determined in the 1969 survey after 54 years of operation. The sediment disposition curves plotted in Figure 14 show how the actual distribution compared with the one from the Type II computations. The curves show the percentages of reservoir depth plotted against the sediment deposited. Examining the curves discloses that the actual and Type II distributions compare reasonably well throughout the depth range. For the most part, the sediment was actually distributed at lesser quantities than those computed throughout the reservoir depth. A maximum deviation of about 13 percent occurs at the 70-percent reservoir depth between the two curves in relation to the percentage of sediment deposited.

Assuming for project planning purposes the conditions of an estimated sediment inflow volume of 497,600 acre-ft for a 54-year period, present day techniques using the Empirical Area-Reduction Method would have resulted in the Type II computations in columns (8), (9), and (10) of Table 1. As previously mentioned, these computations predicted the sediments would reach an elevation of 4257.5 ft or 17.5 ft higher than the elevation (4240 ft) determined in the 1969 survey. A probable explanation for existing sediment accumulating to a lower elevation than the one computed is that the lower outlet (valve centerline at el 4234 ft, see Figure 2) may have had a sluicing effect on the inflowing sediments. Such an effect could not be accounted for when applying the empirically developed technique for computing the depth.

A sediment accumulation curve covering the 1951-1969 period is plotted in Figure 15 using the values in columns (1) and (6) of Table 1. Also plotted as an inset in this figure is a bar diagram representing the sediment that accumulated within the 10-ft elevation intervals. About half of the total sediments had accumulated between el 4350 and 4400 ft for this period.

Lateral Distribution

Profiles of the 59 reservoir sedimentation ranges surveyed in 1969 and those transcribed from the 1915 topographic map are plotted in Figures 20 through 78 in the Appendix. The profiles show generally how

Figure 10. Plastic liner containing sediment sample.

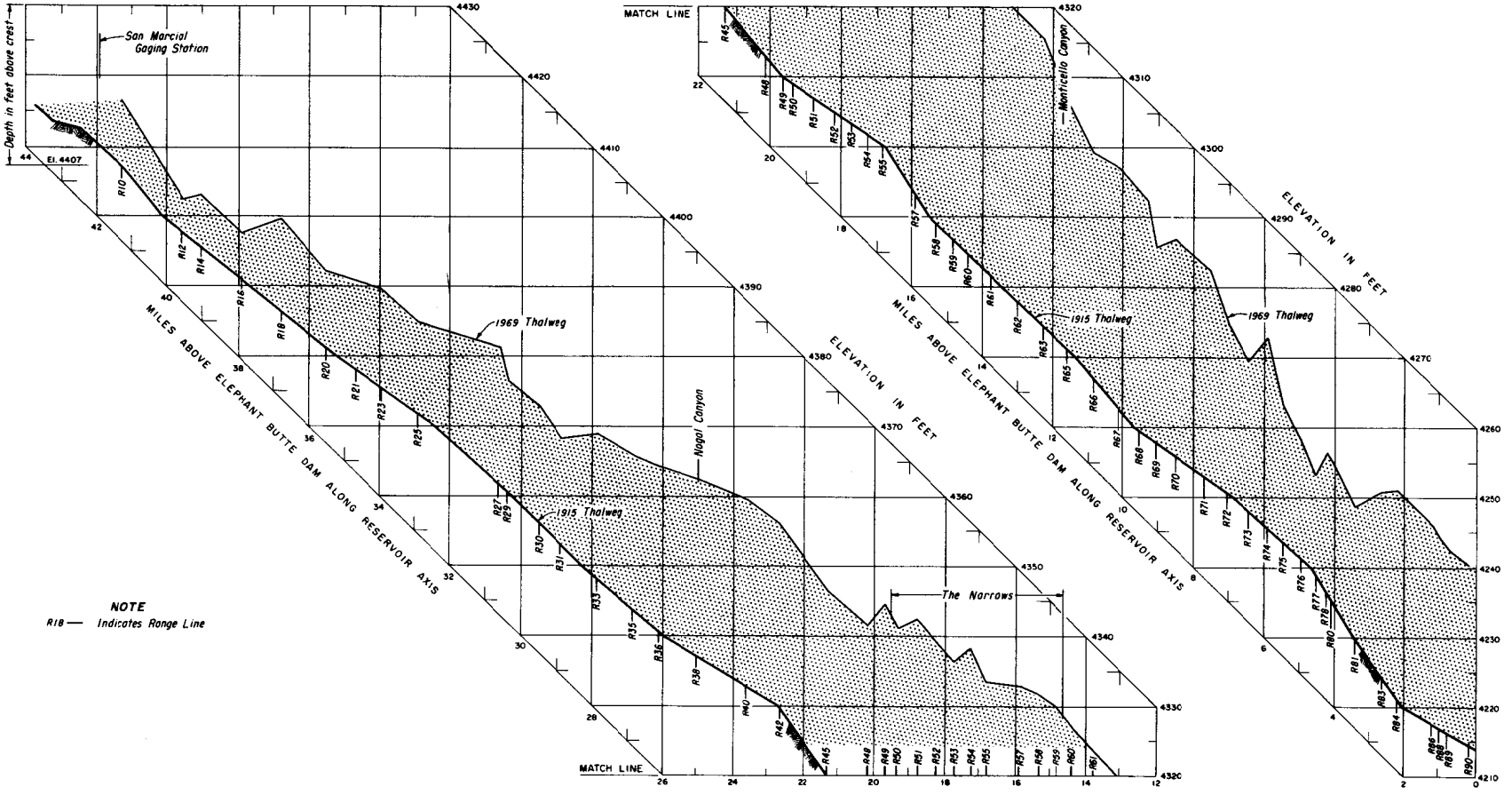


Figure 11. Longitudinal profiles.

Table 1

SUMMARY OF 1969 SURVEY RESULTS AND SEDIMENT DISTRIBUTION COMPUTATIONS

(1) Elevation (ft)	(2) 1915 area (acres)	(3) 1915 capacity (acre-ft)	(4) 1969 area (acres)	(5) 1969 capacity (acre-ft)	(6) Measured sediment volume (acre-ft)	(7) Percent of measured sediment	(8) 1969 capacity (acre-ft)	(9) Sediment volume (acre-ft)	(10) Percent
4407	40,060	2,634,800	36,569	2,137,219	497,581	100.0	2,137,200	497,600	100.0
4400	37,328	2,363,900	34,064	1,890,005	473,895	95.2	1,872,143	491,757	98.8
4390	33,451	2,010,300	28,744	1,575,965	434,335	87.3	1,539,403	444,367	89.3
4380	30,191	1,692,800	25,257	1,305,960	386,840	77.7	1,248,433	414,292	83.2
4370	26,620	1,408,000	21,328	1,073,035	334,965	67.3	993,708	381,802	76.7
4360	22,563	1,162,100	18,422	874,434	286,666	57.6	780,298	347,612	69.9
4350	19,194	954,400	16,122	701,715	252,685	50.8	606,788	312,287	62.8
4340	16,595	775,600	13,799	552,040	223,560	44.9	463,313	276,252	55.5
4330	14,240	621,400	12,162	422,235	199,165	40.0	345,148	239,932	48.2
4320	11,894	490,800	10,010	311,375	179,425	36.1	250,868	203,897	41.0
4310	10,202	380,800	8,241	220,120	160,680	32.3	176,903	168,572	33.9
4300	8,923	285,400	6,271	147,560	137,840	27.7	116,828	134,097	26.9
4290	7,715	202,100	4,679	92,810	109,290	22.0	68,003	100,757	20.2
4280	6,145	132,800	3,050	54,165	78,635	15.8	32,043	69,117	13.9
4270	4,691	78,600	2,197	27,930	50,670	10.2	9,483	39,607	8.0
4260	3,157	39,700	1,510	9,395	30,305	6.1	93	32,574	6.5
4250	1,684	15,800	369	0	15,800	3.2	*0	15,800	3.2
4240	671	4,660			4,660	0.9		4,660	0.9
4230	376	2,960			2,960	0.6		2,960	0.6
4220	98	490			490	0.1		490	0.1
4210	0	0			0	0		0	0
							*El. 4257.5		

EXPLANATION OF COLUMNS

(1) Elevation of reservoir water surface.
(2) Original reservoir surface area surveyed in 1915.
(3) Original reservoir capacity from 1915 survey.
(4) Reservoir surface area determined from 1969 survey.
(5) Reservoir capacity from 1969 survey.
(6) Accumulated sediment volume = column (3) minus column (5).
(7) Measured sediment expressed as percentage of total sediment (497,581 acre-ft).
(8) Computed 1969 reservoir capacity using Empirical Area–Reduction method.
(9) Computed sediment volume to date = column (3) minus column (8).
(10) Computed sediment expressed as percentage of total sediment (497,600 acre-ft).

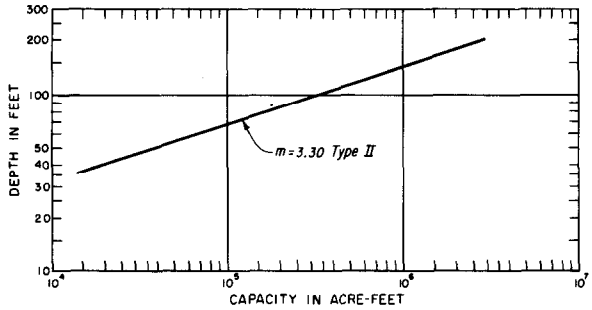


Figure 12. Reservoir depth-capacity relation.

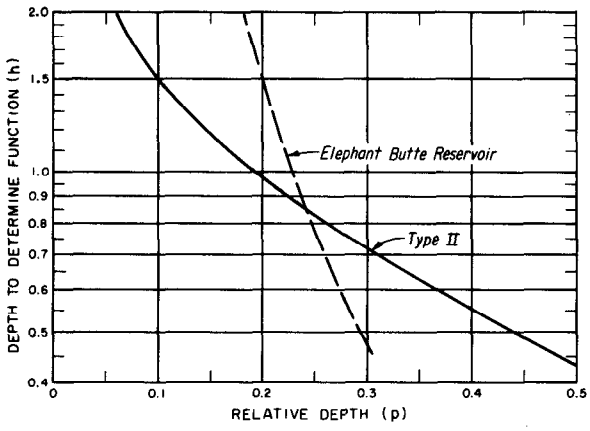


Figure 13. Curves to determine depth of sediment at dam.

sediments were laterally distributed in the reservoir. Sediments are shown depositing laterally to depths ranging from 10 to 44 ft in the following pattern:

From (in miles above dam)	To	Range in depths (ft)
Dam	3	20 to 27
3	5	10 to 20
5	9	20 to 30
9	15	28 to 39
15	17	36 to 44
17	20	29 to 37
20	28	23 to 32
28	36	16 to 25

It will be noted that the lateral sediment depths are similar to the longitudinal depths (listed on page 5) for the reservoir area about 27 miles above dam. Above this point, the lateral depths substantially exceed the longitudinal ones. The differences are due to the fact that the conveyance channel thalweg in this upper reach was used as the reference base to measure the longitudinal depths instead of the river thalweg as was used for all lateral depth determinations.

Cross sectional plottings of the reservoir ranges located in the reservoir area 26 miles above the dam show these ranges, for all practical purposes, were filled with sediment to the spillway crest el 4407 ft. Sediment accumulated to higher elevations at some of these ranges but this is not apparent from the cross-sectional plottings because the computer input data were limited to display only the range cross-sectional areas below el 4407 ft.

SEDIMENT ANALYSES

Sediment Accumulations

Sediments have accumulated in Elephant Butte Reservoir to a total volume of 497,600 acre-ft at spillway crest el 4407 ft since the dam was built over 54 years ago. An average annual sediment accumulation rate of 9,164 acre-ft was computed for the 54-year period.

Reservoir Sedimentation Summary

Tables 2 and 3 contain summaries of the reservoir sediment data with respect to each survey that has been run. The data include a tabulation of incremental sediment inflow volumes as well as sediment accumulation rates computed for periods between surveys. Both types of data are valuable for practical and research use.

Unit Weight Analyses

A total of 131 physical samples of the reservoir sediment deposits were collected in 1952, 1957, and 1969. A summary of the results of each sample taken in 1969 is contained in Table 4. Unit weights, percentages of clay, silt, and sand and sample location are tabulated.

Analyses were made of the sample data collected to determine a unit weight for the inflowing sediments that have deposited. 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 sediment volumes of the reservoir segments and the resulting products summed. The sum was divided by the total sediment volume giving a weighted unit weight of 62 pounds per cubic foot (pcf). This compares to the unit weight of 60 pcf determined for the 1957 survey.

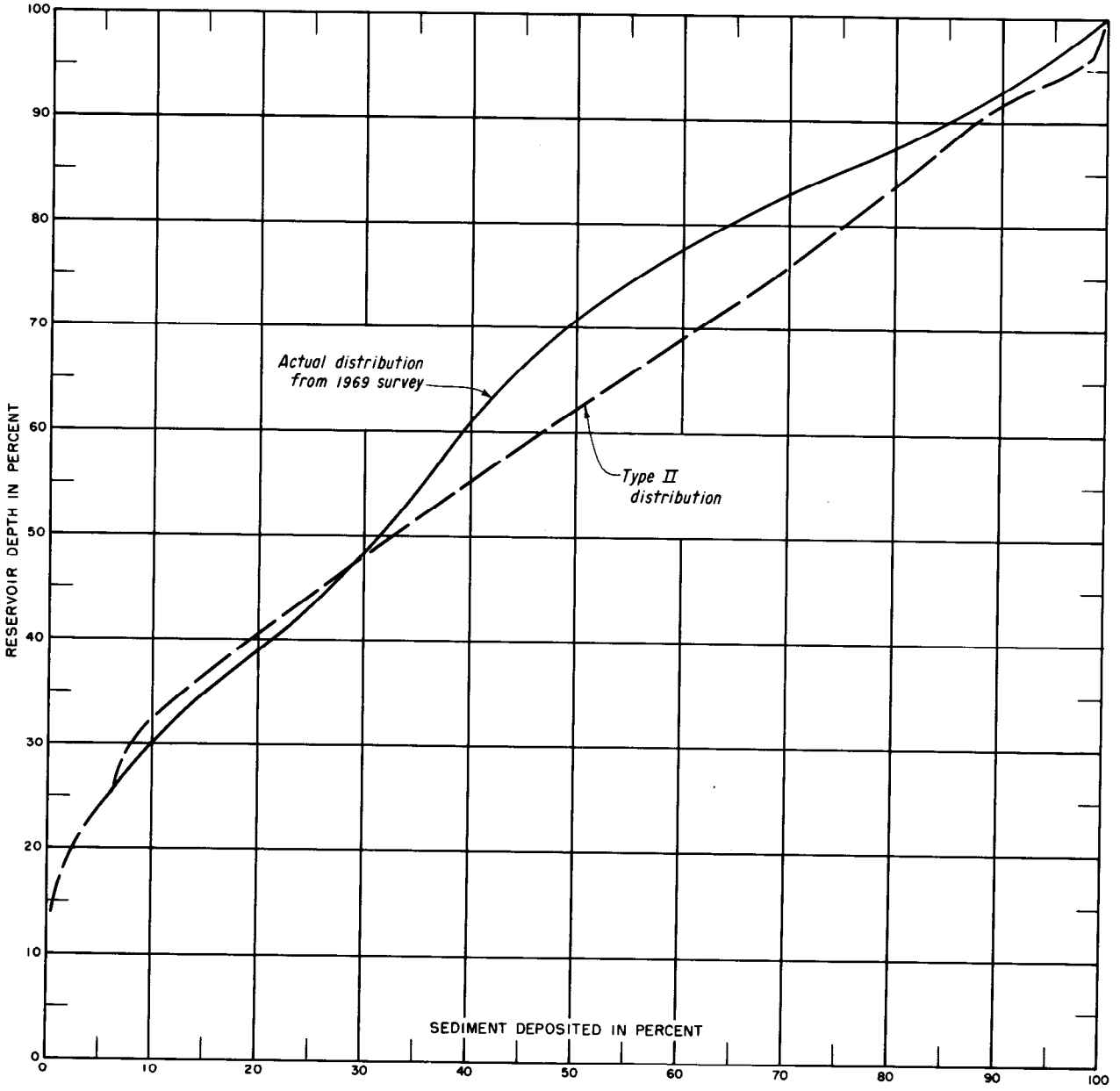


Figure 14. Sediment disposition curves.

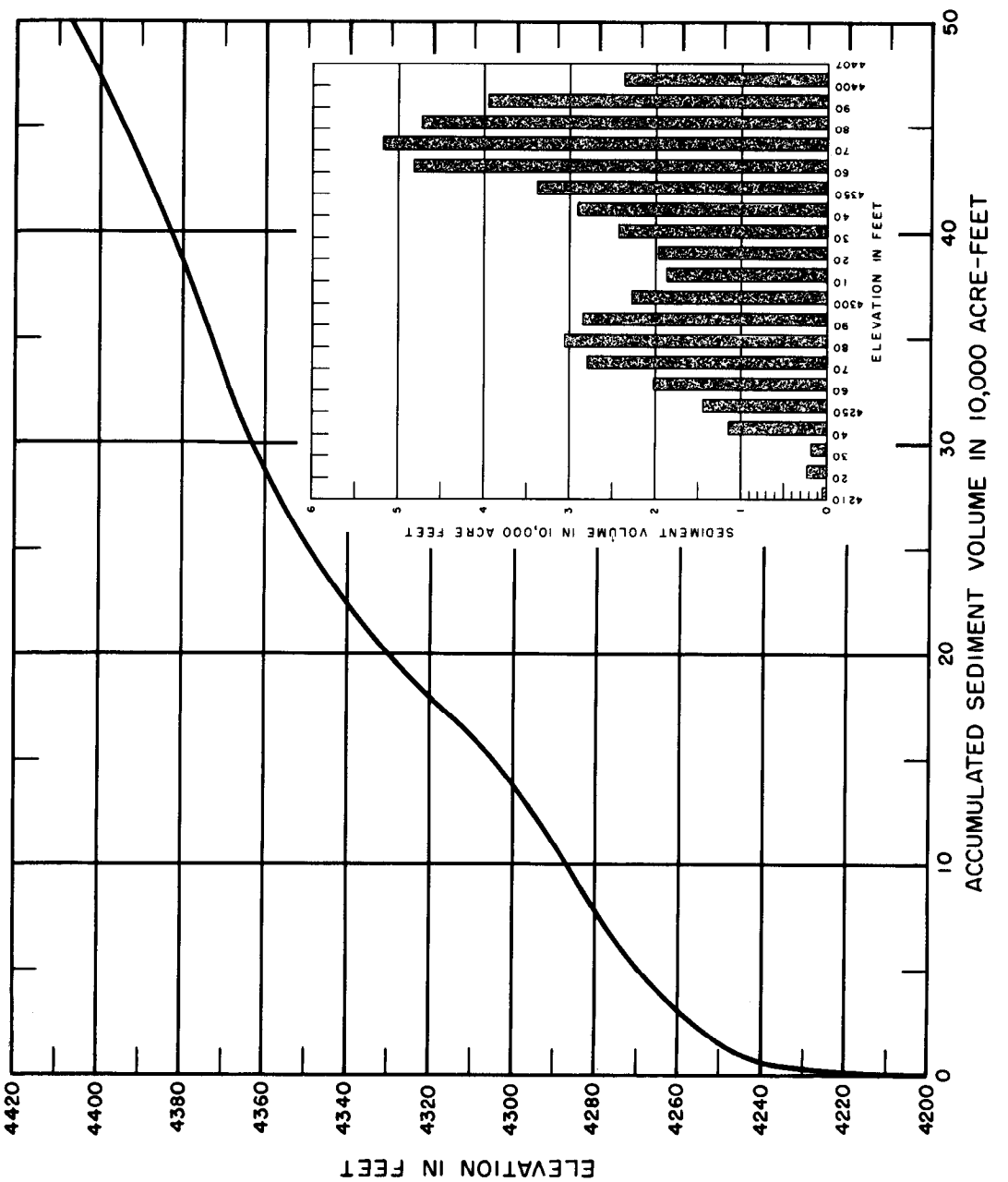


Figure 15. Sediment accumulation curve and diagram.

RESERVOIR SEDIMENT
DATA SUMMARY

Table 2

Elephant Butte
NAME OF RESERVOIR

DATA SHEET NO.

DAM

1. OWNER U. S. Dept. of Int., Bur. of Recl.	2. STREAM Rio Grande	3. STATE New Mexico
4. SEC. 30 TWP. 13S RANGE [1] 3W	5. NEAREST P. O. Elephant Butte, N. Mex. 0.6NW	6. COUNTY Sierra
7. LAT. 33° 9′ 16″ LONG. 107° 11′ 29″	8. TOP OF DAM ELEVATION [2] 4414	9. SPILLWAY CREST ELEV. 4407

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[3]	4407	40,064	2,631,585	2,634,800	Jan. 6, 1915
c. POWER					
d. WATER SUPPLY					16. DATE NORMAL OPER. BEGAN
e. IRRIGATION					
f. CONSERVATION					
g. INACTIVE	4231.5	[4] 420	3,215	3,215	1915

WATERSHED

17. LENGTH OF RESERVOIR	41 MILES		AV. WIDTH OF RESERVOIR	1.39	MILES
18. TOTAL DRAINAGE AREA	25,923 SQ. MI.		22. MEAN ANNUAL PRECIPITATION	15.1 (8-22)	INCHES
19. NET SEDIMENT CONTRIBUTING AREA	25,866 SQ. MI.		23. MEAN ANNUAL RUNOFF	0.67	INCHES
20. LENGTH	305 MILES	AV. WIDTH 85 MILES	24. MEAN ANNUAL RUNOFF	[5] 923,430 (73)	AC.-FT.
21. MAX. ELEV.	12,000	MIN. ELEV. 4210	25. ANNUAL TEMP.: MEAN	52.3 RANGE	38.8-61.2

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.
Jan. 6, 1915			Contour (D)	10 ft (CI)	40,064	2,634,800	
Feb. 12, 1957[6]	–	42.1	Range (D)	73 (R) 10 ft (CI)	36,584	2,206,780	2.20
Apr. 1, 1969	12.2	54.3	Range (D)	60 (R)	36,569	2,137,219	2.31

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
Jan. 6, 1915						
Feb. 12, 1957		918,439	2,440,000	38,647,900	918,439	38,647,900
Apr. 1, 1969		537,075	1,391,000	6,552,317	832,416	45,200,217

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
Jan. 6, 1915						
Feb. 12, 1957	[7]	–	–	428,000	10,200	0.390
Apr. 1, 1969	69,561 [8](69,925)	5,702 (5,732)	0.220 (0.222)	497,581 (508,065)	9,164 (9,357)	0.354 (0.362)

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
Jan. 6, 1915							
Feb. 12, 1957	60	–		0.463	19.4	–	–
Apr. 1, 1969	62	357 (402)	478 (489)	0.348 (0.339)	18.9 (18.4)	12,650 (14,250)	10,940 (11,170)

Table 2—Continued

26. DATE OF SURVEY	43. DEPTH DESIGNATION RANGE IN FEET BELOW, AND ABOVE, CREST ELEVATION											
	193-175.5	175.5-167	167-147	147-127	127-107	107-87	87-67	67-47	47-27	27-11	11-Cr.	Cr. +3
	PERCENT OF TOTAL SEDIMENT LOCATED WITHIN DEPTH DESIGNATION											
Apr. 1, 1969	0.6	0.3	5.1	9.5	11.6	8.2	8.7	12.6	19.5	14.4	7.4	2.1

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														
Apr. 1, 1969	0.8	4.1	8.3	13.1	8.3	8.8	10.0	16.6	22.4	7.6					

45. RANGE IN RESERVOIR OPERATION

WATER YEAR	MAX. ELEV.	MIN. ELEV.	INFLOW, AC.-FT.	WATER YEAR	MAX. ELEV.	MIN. ELEV.	INFLOW, AC.-FT.
[9]1915	4321.81		1,302,250	1930	4384.5	4372.27	930,000
1916	4346.85	4306.6	1,421,000	1931	4374.17	4349.74	418,000
1917	4353.8	4331.8	1,305,000	1932	4384.5	4351.75	1,440,000
1918	4337.0	4290.30	379,100	1933	4377.9	4365.02	717,000
1919	4358.8	4285.5	1,527,000	1934	4367.8	4325.00	298,300
1920	4393.87	4350.9	1,970,000	1935	4342.2	4322.80	917,600
1921	4392.5	4377.5	1,470,000	1936	4354.90	4331.83	872,900
1922	4389.5	4370.7	1,044,000	1937	4380.7	4333.87	1,597,000
1923	4377.4	4366.5	964,000	1938	4377.1	4365.6	1,004,000
1924	4395.8	4368.9	1,662,000	1939	4378.4	4351.20	615,700
1925	4382.1	4354.7	321,000	1940	4357.04	4323.2	333,100
1926	4378.10	4354.6	1,120,000	1941	4399.2	4324.3	2,440,000
1927	4373.95	4363.02	1,180,000	1942	4409.15	4397.00	2,322,000
1928	4379.10	4359.70	773,000	1943	4398.96	4380.82	441,600
1929	4374.80	4353.70	1,240,000	1944	4385.68	4369.16	982,500

46. ELEVATION–AREA–CAPACITY DATA

ELEVATION	AREA	CAPACITY	ELEVATION	AREA	CAPACITY	ELEVATION	AREA	CAPACITY
1915 Survey			4300	8,923	285,400	4400	37,328	2,363,900
4210	0	0	4310	10,202	380,800	4407	40,060	2,634,800
4220	98	490	4320	11,894	490,800	4410	41,283	2,756,600
4230	376	2,960	4330	14,240	621,400			
4240	671	4,660	4340	16,595	775,600	1969 Survey		
4250	1,684	15,800	4350	19,194	954,400	4250	369	0
4260	3,157	39,700	4360	22,563	1,162,100	4260	1,510	9,395
4270	4,691	78,600	4370	26,620	1,408,000	4270	2,197	27,930
4280	6,145	132,800	4380	30,191	1,692,800	4280	3,050	54,165
4290	7,715	202,100	4390	33,451	2,010,300	4290	4,679	92,810

47. REMARKS AND REFERENCES

[1]Sections projected. Dam located in Pedro Armendariz Grant No. 33 which is unsurveyed.
[2]All elevations listed are based on project datum. Add 43.3 feet to adjust elevations to msl.
[3]Irrigation and power.
[4]Estimated by interpolation.
[5]Rio Grande at San Marcial, New Mexico.
[6]For intermediate surveys see Data Sheets 57-1 and 57-1a.
[7]Total storage showed gain of 9,180 acre-feet since 1947 survey.
[8]Values in parentheses at elevation 4410.
[9]From January 1915 through September 1915.

48. AGENCY MAKING SURVEY U.S. Dept. of the Interior, Bureau of Reclamation, Rio Grande Project, New Mexico-Texas.

49. AGENCY SUPPLYING DATA Bureau of Reclamation, U.S. Dept. of the Interior 50. DATE October 15, 1971

Table 2--Continued

45. RANGE IN RESERVOIR OPERATION

WATER YEAR	MAX. ELEV.	MIN. ELEV.	INFLOW, AC.-FT.	WATER YEAR	MAX. ELEV.	MIN. ELEV.	INFLOW, AC.-FT.
1945	4385.60	4372.28	851,500	1957	4337.12	4269.10	
1946	4375.66	4339.52	224,900	1958		4336.20	1,391,000
1947	4339.36	4311.94	419,200	1959	4362.80	4334.46	341,900
1948	4349.22	4313.08	1,036,000	1960	4339.04	4322.40	563,400
1949	4351.30	4329.69	1,031,000	1961	4329.10	4301.99	437,700
1950	4346.01	4315.46	364,100	1962	4329.80	4304.38	748,100
1951	4315.79	4262.30	132,900	1963	4327.52	4282.07	405,500
1952	4324.59	4261.64	967,000	1964	4299.23	4275.51	164,200
1953	4320.49	4283.19	286,800	1965	4323.01	4277.46	821,700
1954	4297.30	4258.03	198,500	1966	4338.30	4311.03	725,340
1955	4295.46	4276.58	257,900	1967	4321.84	4293.03	391,600
1956	4304.40	4268.44	174,800	1968	4319.70	4295.09	646,230

46. ELEVATION-AREA-CAPACITY DATA

ELEVATION	AREA	CAPACITY	ELEVATION	AREA	CAPACITY	ELEVATION	AREA	CAPACITY
4300	6,271	147,560	4400	34,064	1,890,005			
4310	8,241	220,120	4407	36,569	2,137,219			
4320	10,010	311,375	4410	37,642	2,248,535			
4330	12,162	422,235						
4340	13,799	552,040						
4350	16,122	701,715						
4360	18,422	874,434						
4370	21,328	1,073,035						
4380	25,257	1,305,960						
4390	28,744	1,575,965						

UNITED STATES
DEPARTMENT OF THE INTERIOR

Table 3

BUREAU OF RECLAMATION

RESERVOIR SEDIMENTATION DATA SUMMARY

Elephant Butte — NAME OF RESERVOIR

57- — DATA SHEET NO.

DAM

1. OWNER Bureau of Reclamation	2. RIVER Rio Grande	3. STATE New Mexico[1]
4. SEC. 2 TWP. 13S RANGE 4W	5. NEAREST TOWN Truth or Consequences	6. COUNTY Sierra
7. STREAM BED ELEV.	8. TOP OF DAM ELEV.	9. SPILLWAY CREST ELEV. 4407

RESERVOIR

10. STORAGE ALLOCATION	11. ELEVATION TOP OF POOL	12. SURFACE AREA ACRES	13. STORAGE ACRE-FEET	14. ACCUMULATED ACRE-FEET	15. DATE STORAGE BEGAN
a. FLOOD CONTROL	4407	36,584		2,206,780	
b. POWER					Jan. 6, 1915
c. WATER SUPPLY					16. DATE NORMAL OPER. BEGAN
d. IRRIGATION					
e. CONSERVATION					
f. INACTIVE	4231.5	Negligible	Negligible		1915

17. LENGTH OF RESERVOIR 41 MILES | AV. WIDTH OF RESERVOIR 1.69 MILES

WATERSHED

18. TOTAL DRAINAGE AREA 25,923 SQ. MI.		22. MEAN ANNUAL PRECIPITATION 10 to 15	INCHES
19. NET SEDIMENT CONTRIBUTING AREA 25,866 SQ. MI.		23. MEAN ANNUAL RUNOFF	INCHES
20. LENGTH 305 MILES	AV. WIDTH 85 MILES	24. MEAN ANNUAL RUNOFF 1,004,000 (60)	AC.-FT.
21. MAX. ELEV. 12,000	MIN. ELEV. 4407	25. CLIMATIC CLASSIFICATION Semi-arid	

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/W RATIO AC.-FT. PER SQ. MI.
Jan. 6, 1915	0	0	Contour	10 feet	40,060	2,634,800	102
Dec. 1916	1.9	1.9				2,584,865	100
Aug. 1920	3.7	5.6				2,498,850	96
Aug. 1925	5.0	10.6	Contour		39,406	2,389,380	92
April 1935	9.7	20.3	Contour	5 feet	38,140	2,270,300	88
Oct. 1940	5.5	25.8	Contour		37,670	2,219,000	86

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
Jan. 6, 1915						
Dec. 1916		1,573,665		3,005,700	1,573,665	3,005,700
Aug. 1920		1,413,845	2,250,100	5,188,810	1,463,305	8,194,510
Aug. 1925		1,130,348	1,690,900	5,651,742	1,306,250	13,846,252
April 1935		853,428	1,444,200	8,252,648	1,088,616	22,098,900
Oct. 1940		945,761	1,597,000	5,201,730	1,058,164	27,300,630

26. DATE OF SURVEY	37. PERIOD SEDIMENT DEPOSITS 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
Jan. 6, 1915						
Dec. 1916	49,900	26,300	1.02	49,900	26,300	1.02
Aug. 1920	86,000	23,200	0.899	136,000	24,300	0.939
Aug. 1925	109,000	21,900	0.846	245,000	23,200	0.895
April 1935	119,000	12,300	0.475	365,000	18,000	0.694
	(125,000)	(12,900)	(0.498)	(370,000)	(18,200)	(0.705)

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. ANNUAL	b. TOT. TO DATE	a. PERIOD	b. TOT. TO DATE
Jan. 6, 1915							
Dec. 1916				0.998	1.89		
Aug. 1920				0.922	5.16		
Aug. 1925				0.881	9.30		
April 1935	60 (est)	621	907	0.683	13.9	13,900	15,900
		(651)	(921)			(14,600)	(16,100)

Table 3—Continued

26. DATE OF SURVEY	43. DEPTH DESIGNATION RANGE IN FEET ABOVE, AND BELOW, CREST ELEVATION											
	193-175.5	175.5-167	167-147	147-127	127-107	107-87	87-67	67-47	47-27	27-11	11-Cr.	Cr.-3
	PERCENT OF TOTAL SEDIMENT LOCATED WITHIN DEPTH DESIGNATION											
Aug. 1925	1.26	−0.057	7.18	11.1	9.03	5.86	9.19	14.3	25.1	8.99	4.53	
April 1935	0.869	0.380	5.70	8.38	7.22	4.81	8.14	16.4	27.1	12.9	6.54	1.46
Oct. 1940	0.760	0.330	5.10	7.45	6.83	5.06	8.32	15.4	26.1	16.3	6.69	1.70
Apr. 28, 1947	0.719	0.321	4.75	7.07	6.53	5.64	8.66	15.0	24.9	16.0	8.14	2.21
Feb. 12, 1957	0.734	0.325	6.04	10.0	7.64	5.42	7.83	13.1	22.5	15.6	8.40	2.31

26. DATE OF SURVEY	44. REACH DESIGNATION PERCENT OF TOTAL ORIGINAL LENGH 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														
	Data not available due to contour method of sediment computation.														

45. RANGE IN RESERVOIR OPERATION

WATER YEAR	MAX. ELEV.	MIN. ELEV.	INFLOW AC.-FT.	WATER YEAR	MAX. ELEV.	MIN. ELEV.	INFLOW AC.-FT.
1915	4321.81		1,443,900	1923	4374.20*	4368.3*	964,500
1916	4346.85	4307.29*	1,420,900	1924	4395.80	4370.4*	1,690,900
1917	4354.0	4331.0*	1,310,600	1925	4379.20	4354.7*	320,800
1918	4326.28	4290.30*	379,100	1926	4378.10	4355.68*	1,120,900
1919	4364.0	4267.70*	1,527,000	1927	4371.96*	4363.02*	1,178,400
1920	4393.87	4351.5*	2,250,100	1928	4379.10	4359.70*	772,700
1921	4392.5	4378.2*	1,607,300	1929	4374.80	4354.00*	1,238,900
1922	4389.50*	4377.5*	1,069,100	1930	4384.5	4372.27*	930,200

46. ELEVATION—AREA—CAPACITY DATA

ELEVATION	AREA	CAPACITY	ELEVATION	AREA	CAPACITY	ELEVATION	AREA	CAPACITY
4220	1	1	4310	8,993	259,940	4390	29,226	1,642,790
4240	4	22	20	10,804	358,450	4396	32,140	1,826,570
50	312	1,298	30	12,556	475,150	4400	34,117	1,959,060
60	1,220	8,590	40	14,290	608,930	07	36,584	2,206,780
70	2,343	26,253	4350	16,506	762,940	4410	37,884	2,318,460
80	4,004	57,680	60	18,504	937,850			
90	6,005	107,730	70	21,328	1,135,660			
4300	7,698	176,810	80	25,455	1,369,870			

47. REMARKS AND REFERENCES

[1] Headquarters for operation of dam located at El Paso, Texas.
[2] Sections not determined—Located in Amendariz Grant No. 33.
*Mean monthly elevations.

48. AGENCY SUPPLYING DATA Bureau of Reclamation

49. DATE January 8, 1959

UNITED STATES
DEPARTMENT OF THE INTERIOR

Table 3—Continued

BUREAU OF RECLAMATION

RESERVOIR SEDIMENTATION DATA SUMMARY

Elephant Butte—Continued
NAME OF RESERVOIR

DATA SHEET NO.

DAM

1. OWNER	2. RIVER	3. STATE
4. SEC. TWP. RANGE	5. NEAREST TOWN	6. COUNTY
7. STREAM BED ELEV.	8. TOP OF DAM ELEV.	9. SPILLWAY CREST ELEV.

RESERVOIR

10. STORAGE ALLOCATION	11. ELEVATION TOP OF POOL	12. SURFACE AREA ACRES	13. STORAGE ACRE-FEET	14. ACCUMULATED ACRE-FEET	15. DATE STORAGE BEGAN
a. FLOOD CONTROL					
b. POWER					
c. WATER SUPPLY					16. DATE NORMAL OPER. BEGAN
d. IRRIGATION					
e. CONSERVATION					
f. INACTIVE					

17. LENGTH OF RESERVOIR MILES | AV. WIDTH OF RESERVOIR MILES

WATERSHED

18. TOTAL DRAINAGE AREA SQ. MI.		22. MEAN ANNUAL PRECIPITATION	INCHES
19. NET SEDIMENT CONTRIBUTING AREA SQ. MI.		23. MEAN ANNUAL RUNOFF	INCHES
20. LENGTH MILES	AV. WIDTH MILES	24. MEAN ANNUAL RUNOFF	AC.-FT.
21. MAX. ELEV.	MIN. ELEV.	25. CLIMATIC CLASSIFICATION	

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/W RATIO AC.-FT. PER SQ. MI.
Apr. 28, 1947	6.5	32.3	Range	90 feet	36,772	2,197,600	85
Feb. 12, 1957	9.75	42.1	Contour	10 feet	36,584	2,206,780	85

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
Apr. 28, 1947		1,154,862	2,440,000	7,506,600	1,077,623	34,807,230
Feb. 12, 1957		441,776	1,036,000	4,307,318	930,191	39,114,548

26. DATE OF SURVEY	37. PERIOD SEDIMENT DEPOSITS 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
Oct. 1940	51,300	9,330	0.361	416,000	16,100	0.623
Apr. 28, 1947	21,400	3,290	0.127	437,000	13,500	0.523
	(43,000) [3]	(6,620)	(0.256)	(465,000)	(14,400)	(0.556)
Feb. 12, 1957				428,000	10,200	0.390

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. ANNUAL	b. TOT. TO DATE	a. PERIOD	b. TOT. TO DATE
Oct. 1940				0.611	15.8		
Apr. 28, 1947	65.9 (est)	182	751	0.512	16.6	3,010	13,300
		(367) [3]	(798)			(6,050)	(14,100)
Feb. 12, 1957	60.0			0.463	19.4		

Table 3–Continued

26. DATE OF SURVEY	43. DEPTH DESIGNATION RANGE IN FEET ABOVE, AND BELOW, CREST ELEVATION											
	PERCENT OF TOTAL SEDIMENT LOCATED WITHIN DEPTH DESIGNATION											

26. DATE OF SURVEY	44. REACH DESIGNATION PERCENT OF TOTAL ORIGINAL LENGH 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														

45. RANGE IN RESERVOIR OPERATION

WATER YEAR	MAX. ELEV.	MIN. ELEV.	INFLOW AC.-FT.	WATER YEAR	MAX. ELEV.	MIN. ELEV.	INFLOW AC.-FT.
1931	4374.17	4351.66*	417,900	1948	4349.22	4313.08	1,036,000
1932	4384.5	4353.26*	1,444,200	1949	4351.30	4329.69	1,031,000
1933	4377.9	4365.01*	716,800	1950	4346.02*	4315.46	364,100
1934	4367.2	4325.00*	298,300	1951	4315.79	4262.30	132,900
1935	4342.2	4324.50*	917,700	1952	4324.59	4261.64	487,500
1936	4354.90	4331.83	872,800	1953	4320.49	4283.19	286,800
1937	4380.7	4336.48*	1,597,400	1954	4297.30	4258.03	198,500
1938	4377.1	4365.6	1,003,500	1955	4295.46	4276.58	257,900
1939	4378.4	4348.6	615,700	1956	4304.40	4268.44	174,830
1940	4357.04	4323.2	333,100				
1941	4399.2	4324.3	2,440,500				
1942	4409.15	4397.00	2,322,000				
1943	4398.96	4380.82	441,600				
1944	4385.68	4369.16	982,500				
1945	4385.60	4372.28	851,500				
1946	4375.66	4339.52	224,900				
1947	4339.36	4311.94	419,200				

47. REMARKS AND REFERENCES

Values listed in parentheses include above crest deposits.

[3] Total storage shows a gain of 9,180 acre-feet since 1947 survey attributable primarily to compaction.

USDA Technical Bulletin No. 524, August 1939, "Silting of Reservoirs."

Bureau of Reclamation, February 1949, "Sedimentation Surveys of Elephant Butte Reservoir." Only the upper two-thirds of the reservoir was surveyed in 1925 and 1940. Curves from these data were extended over the remaining lower one-third of the reservoir.

48. AGENCY SUPPLYING DATA

49. DATE_____

Table 3–Continued

Depth below crest	CAPACITY						SEDIMENT VOLUME									
	Original	1925	1935	1940	1947	1957	1925	1935	1940	1947	1957	1925	1935	1940	1947	1957
193	0	0	0	0	0	0										
	3,215	0	0	0	0	0	3,215	3,215	3,215	3,215	3,215	1.26	0.869	0.760	0.719	0.734
175.5	3,215	0	0	0	0	1										
	1,445	1,590	40	50	10	21	-145	1,405	1,395	1,435	1,424	0.057	0.380	0.330	0.321	0.325
167	4,660	1,590	40	50	10	22										
	35,040	16,760	13,960	13,450	13,790	8,568	18,280	21,080	21,590	21,250	26,472	7.18	5.70	5.10	4.75	6.04
147	39,700	18,350	14,000	13,500	13,800	8,590										
	93,100	64,950	62,100	61,600	61,500	49,090	28,150	31,000	31,500	31,600	44,010	11.1	8.38	7.45	7.07	10.0
127	132,800	83,300	76,100	75,100	75,300	57,680										
	152,600	129,620	125,900	123,700	123,400	119,130	22,980	26,700	28,900	29,200	33,470	9.03	7.22	6.83	6.53	7.64
107	285,400	212,920	202,000	198,800	198,700	176,810										
	205,400	190,490	187,600	184,000	180,200	181,640	14,910	17,800	21,400	25,200	23,760	5.86	4.81	5.06	5.64	5.42
87	490,800	403,410	389,600	382,800	378,900	358,450										
	284,800	261,410	254,700	249,600	246,100	250,480	23,390	30,100	35,200	38,700	34,320	9.19	8.14	8.32	8.66	7.83
67	775,600	664,820	644,300	632,400	625,000	608,930										
	386,500	350,060	325,700	321,400	319,500	328,920	36,440	60,800	65,100	67,000	57,580	14.3	16.4	15.4	15.0	13.1
47	1,162,100	1,014,880	970,000	953,800	944,500	937,850										
	530,700	466,890	430,400	420,400	419,200	432,020	63,810	100,300	110,300	111,500	98,680	25.1	27.1	26.1	24.9	22.5
27	1,692,800	1,481,770	1,400,400	1,374,200	1,363,700	1,369,870										
	525,000	502,130	477,100	456,100	453,300	456,700	22,870	47,900	68,900	71,700	68,300	8.99	12.9	16.3	16.0	15.6
11	2,217,800	1,983,900	1,877,500	1,830,300	1,817,000	1,826,570										
	417,000	405,480	392,800	388,700	380,600	380,210	11,520	24,200	28,300	36,400	26,790	4.53	6.54	6.69	8.14	8.40
Crest	2,634,800	2,389,380	2,270,300	2,219,000	2,197,600	2,206,780	254,420									
	121,800		116,400	114,600	111,900	111,680		5,400	7,200	9,900	10,120		1.46	1.70	2.21	2.31
3	2,756,600		2,386,700	2,333,600	2,309,500	2,318,460		369,900	423,000	447,100	438,140					

Table 4

SUMMARY OF SEDIMENT DATA ANALYSES–1969 SURVEY

Range location	Sample No.	In percent			Unit weight pcf
		Clay	Silt	Sand	
90	24	68.4	28.4	3.2	34.3
89	23	76.9	20.1	3.0	31.8
88	22	84.3	15.7	0	30.9
87	20	85.6	14.4	0	29.0
86	18	85.6	14.4	0	29.4
85	16	88.1	11.9	0	29.4
84	14	85.1	14.9	0	33.1
83	12	79.3	17.7	3.0	40.6
82	11	85.3	14.7	0	35.0
81	10	73.1	26.9	0	36.2
80	9	86.3	13.7	0	31.2
79	8	85.6	14.4	0	33.7
78	7	86.4	13.6	0	33.1
76	5	86.7	13.3	0	33.1
75	4	82.4	17.6	0	35.0
74	3	84.3	15.7	0	35.0
73	1	81.3	18.7	0	35.0

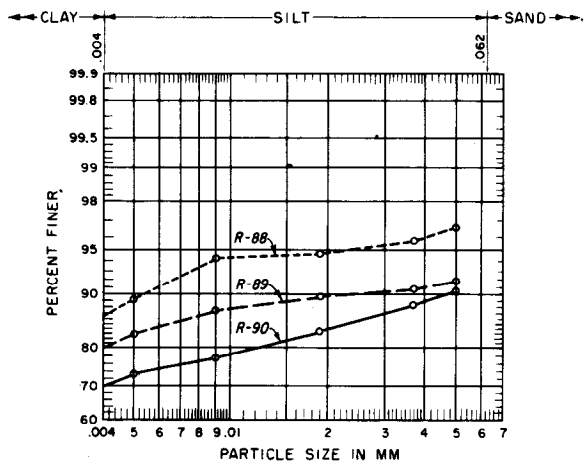
An empirical method[3] was used to compute the unit weight applying the representative clay, silt, and sand size gradations subsequently described. Assuming a Type II reservoir operation,[4] an initial unit weight of 52 pcf was computed. By considering a compaction correction, using the method of Miller,[5] a unit weight of 59 pcf was computed for a 54-year period (age of the dam). This computed value compared favorably with the 62 pcf, the weighted unit weight described above.

A factor having substantial influence in determining the unit weight on a weighted basis may be questioned as to how reliable is the assumption that the samples collected at the ranges are representative of conditions in the reservoir reach (or segment) between ranges. This may be questioned in that possibly more collected samples would give a better picture of the situation. The sites selected for taking samples and the depths of the sediment deposits sampled are two other factors that influence unit weight determinations. In computing the unit weight, the size gradation values of the deposited samples are used. A question can be posed regarding the use of these values–are they reliable representations of the actual inflowing sediment particles? An answer to this question and resolving the other factors mentioned await further research study. Also, in this connection, improvement in sampling methods, analyses, and equipment must continually be sought.

Particle Size Analyses

A study was made of the particle size analyses tests run on the 131 samples collected in 1952, 1957, and 1969. The graphs in Figures 16, 17, and 18 contain the particle size analyses curves for only the samples collected in 1969. Representative particle sizes in the clay, silt, and sand ranges were determined in a similar weighting fashion as was done in the unit weight analyses. The representative size was computed to be 60 percent clay, 31 percent silt, and 9 percent sand.

[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. Department of the Interior, Bureau of Reclamation, February 1953.



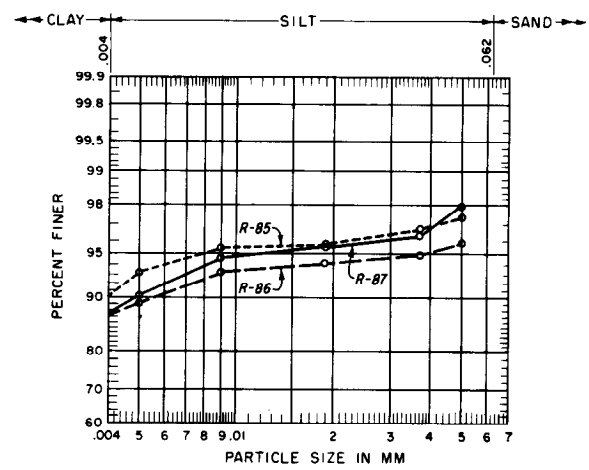
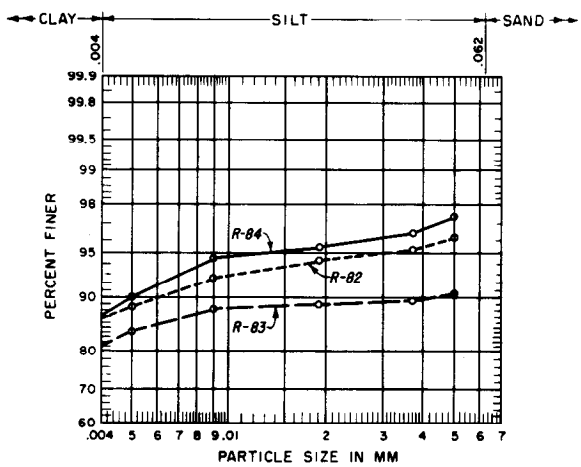


Figure 16. Particle size analyses curves.



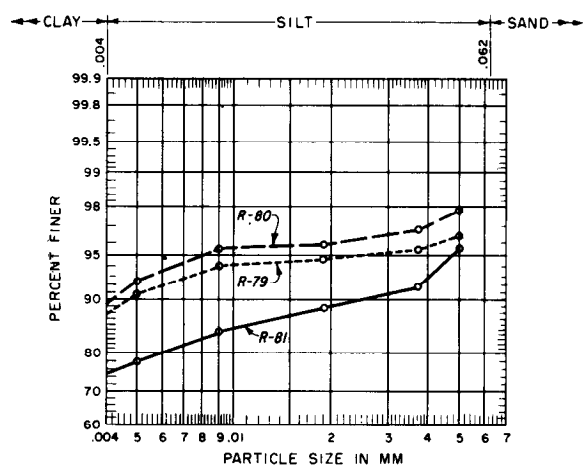
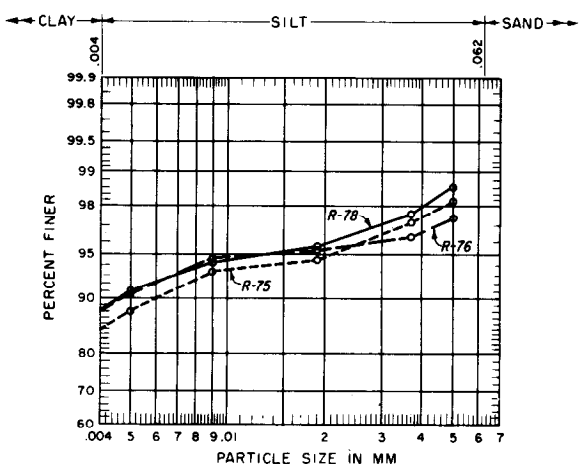


Figure 17. Particle size analyses curves.



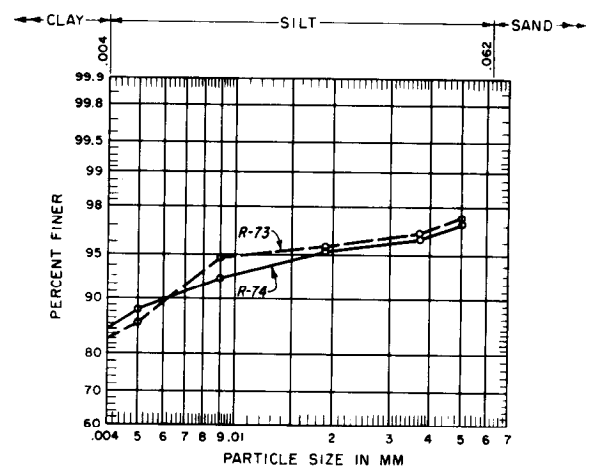


Figure 18. Particle size analyses curves.

RESERVOIR AREA AND CAPACITY

The 1969 Elephant Butte Reservoir surface areas were determined by a method using reservoir sedimentation range width ratios. Briefly, this method entailed comparing the 1969 range widths with the 1915 widths at corresponding elevations. The results are tabulated in the ratio form 1969 width/1915 width. Computations are made easier by dividing the reservoir into segments using the sedimentation range lines as segmental boundaries. The 1915 reservoir topographic maps were used to planimeter the surface areas at 10-ft contour intervals. For given elevations, these areas were multiplied by the width ratios and the 1969 surface areas resulted.

The 1969 surface areas were the control parameters for computing the reservoir capacities by the electronic computer. The program was written to compute 1-ft area increments by linear interpolation between the 10-ft contour intervals. Respective capacities and capacity equations are then obtained by integration of the area equations. The progressive computational procedure begins by testing the initial capacity equation over successive intervals to check whether it fits within an allowable error limit (set at 0.01 in this case). This one equation is 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 was 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 polynomial form,

$$y = a_1 + a_2 x + a_3 x^2,$$

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 1969 Elephant Butte Reservoir area and capacity computations are listed in columns (4) and (5) of Table 1 (page 9). Also listed in columns (2) and (3) of the table are the original area and capacity values for comparison purposes. Both the original and 1969 area and capacity curves are plotted in Figure 19. At spillway crest el 4407 ft, the present capacity of Elephant Butte Reservoir is 2,137,200 acre-ft and the surface area is 36,570 acres.

SUMMARY AND CONCLUSIONS

The 1969 sediment survey report of Elephant Butte Reservoir includes a discussion of the methods used to measure and study the nearly 54.5 years of reservoir sediment accumulation. It also briefly describes the field surveying and sediment sampling procedures and equipment. The survey was primarily run to gather the necessary data for use in computing the present capacity of Elephant Butte 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 across the range line. The water surface elevations read at the gage of the dam were used as bases to obtain the bottom elevations at selected points on the cross sectional profile traced by the sonic sounder chart.

Seventeen sediment samples of the reservoir deposits were collected with a gravity core sampler. Analyzing these samples along with others collected during 1952 and 1957 resulted in determining a unit weight of 62 pcf and a representative size of 60 percent clay, 31 percent silt, and 9 percent sand.

Longitudinally, the sediments were deposited between the 1915 and 1969 surveys to average depths ranging from 8 to 42 ft (see page 5). Laterally, the reservoir range cross sectional profiles for the 1915 and 1969 surveys showed sediments deposited to depths from 10 to 44 ft (see page 10). For all practical purposes sediments have deposited to at least the spillway crest el 4407 ft in the reservoir area beginning at 37 miles above the dam.

The capacity of Elephant Butte Reservoir as determined from the 1969 survey is 2,137,000 acre-ft and the surface area 36,570 acres at spillway crest elevation (see area-capacity curves in Figure 19). The 1969 reservoir surface areas were determined by a width-ratio method described on page 23. The electronic computer was used to compute areas at 1-ft

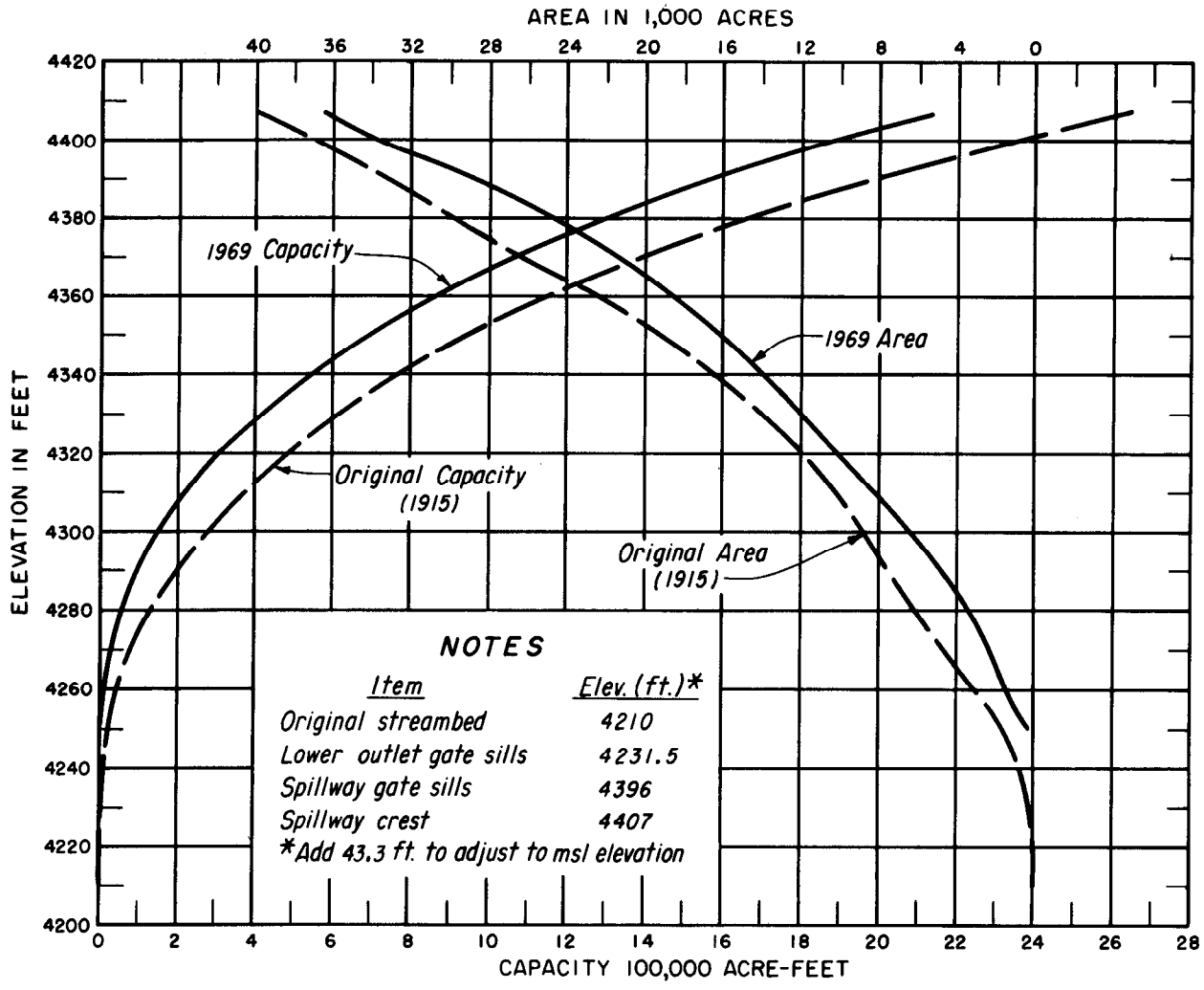


Figure 19. Reservoir area-capacity curves.

increments by linear interpolation. The reservoir capacity was computed 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-ft intervals.

A comprehensive summary of the reservoir sediment data for the 1969 survey is contained in Table 2. Volume of the sediments that have accumulated in the dam since 1915 amounted to 497,600 acre-ft at el 4407 ft. This indicates a loss in reservoir capacity of about 19 percent. An average annual sediment accumulation rate of 9,160 acre-ft was found for the 1915 to 1969 period. Sediments deposited at a rate of 0.354 acre-ft per square mile annually during this same period.

APPENDIX

Profiles run for the 59 reservoir sedimentation ranges surveyed in 1915 and 1969—plotted in Figures 20 through 78.

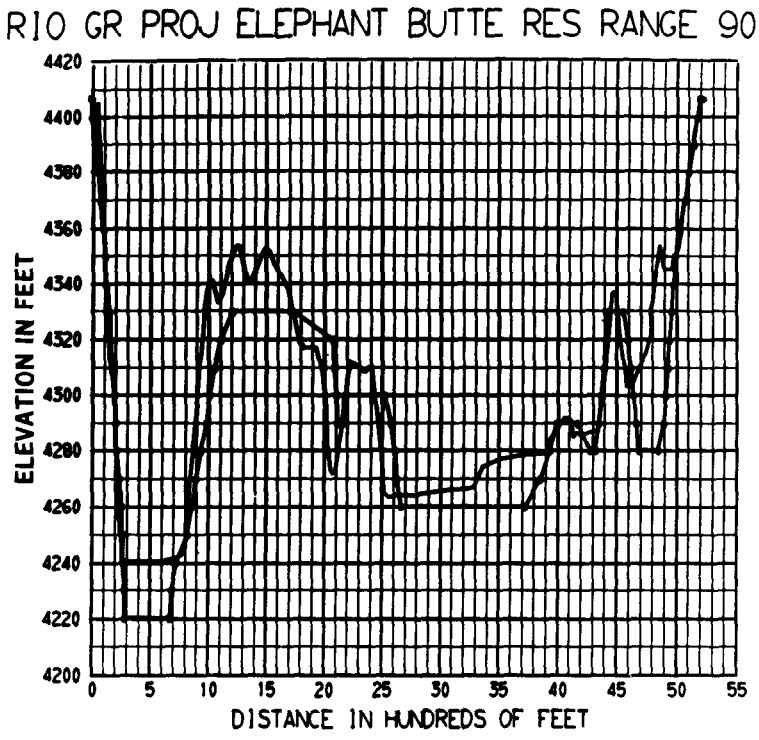


Figure 20. 1915 and 1969 sedimentation range profiles—Range 90.

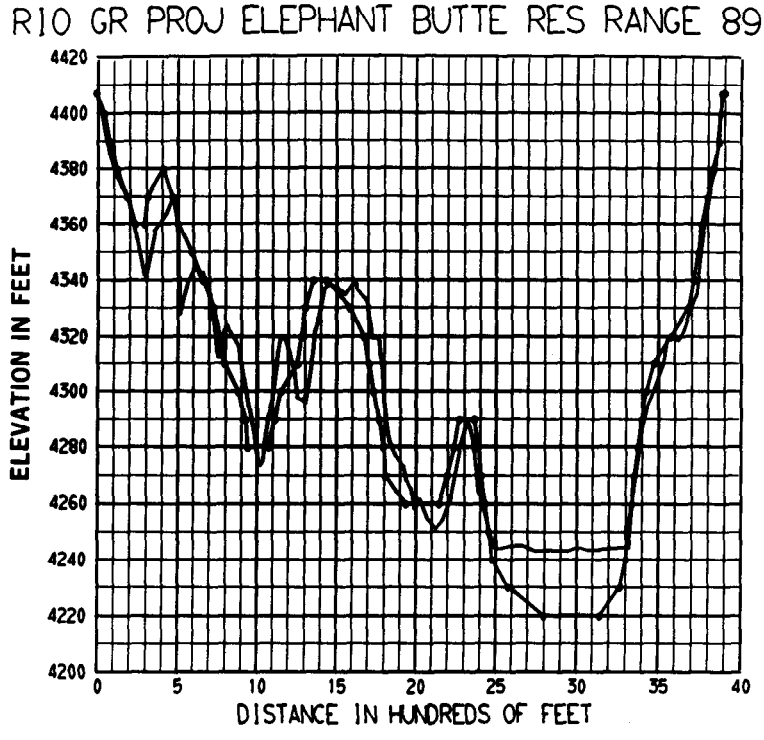


Figure 21. 1915 and 1969 sedimentation range profiles—Range 89.

NOTE (applicable to Figures 20 through 78)

1915 profile

1969 profile

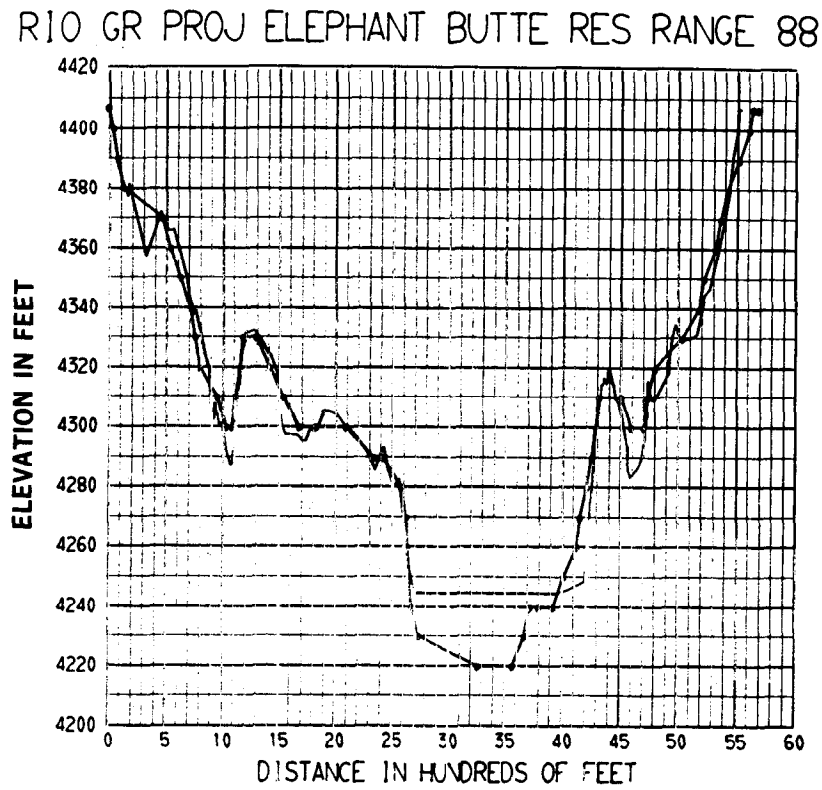


Figure 22. 1915 and 1969 sedimentation range profiles—Range 88.

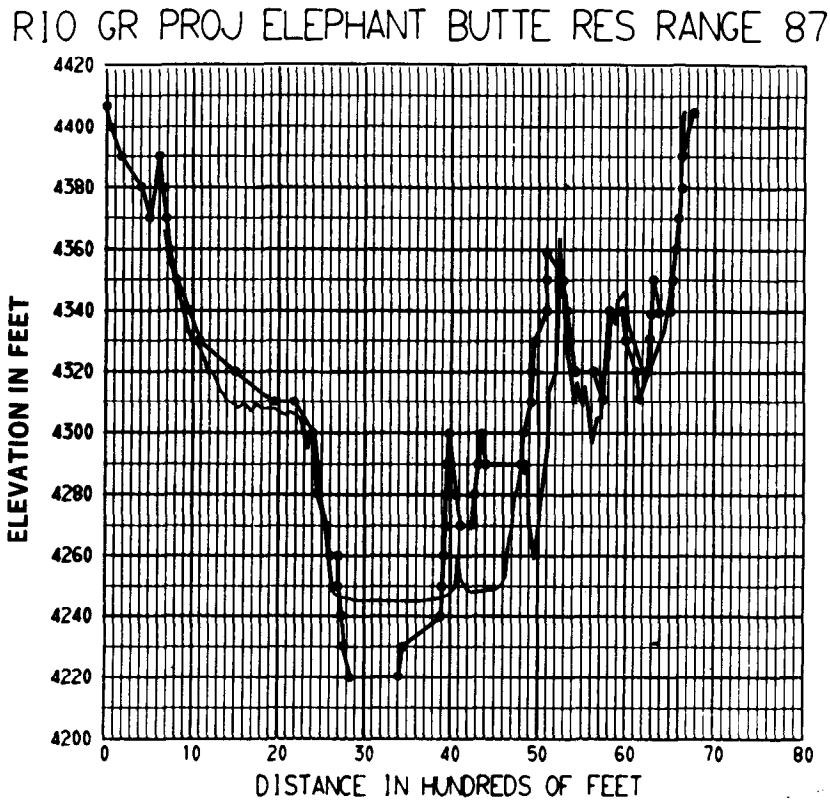


Figure 23. 1915 and 1969 sedimentation range profiles—Range 87.

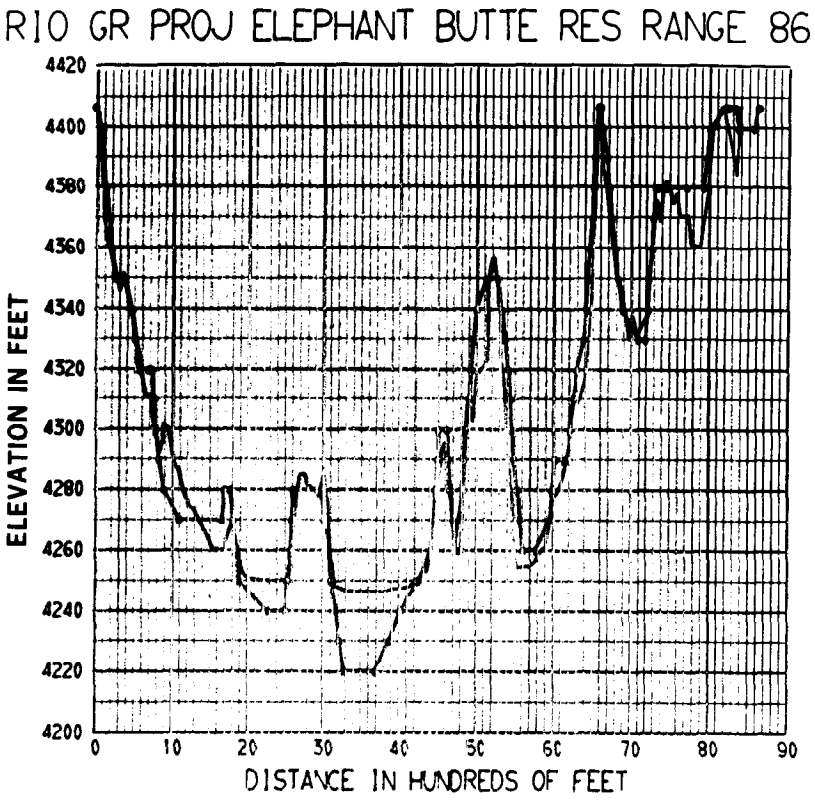


Figure 24. 1915 and 1969 sedimentation range profiles—Range 86.

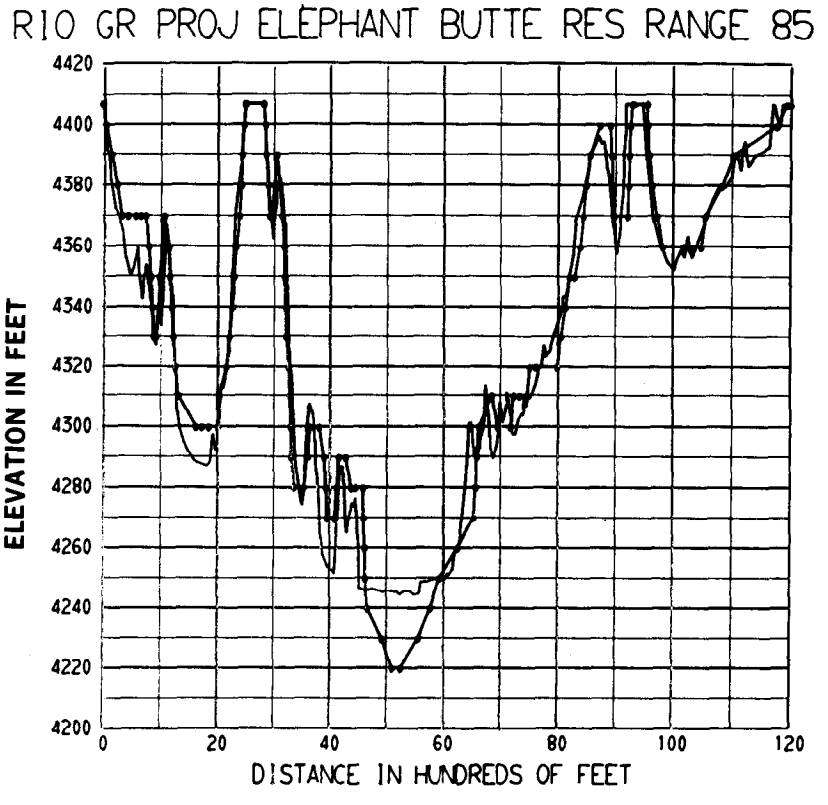


Figure 25. 1915 and 1969 sedimentation range profiles—Range 85.

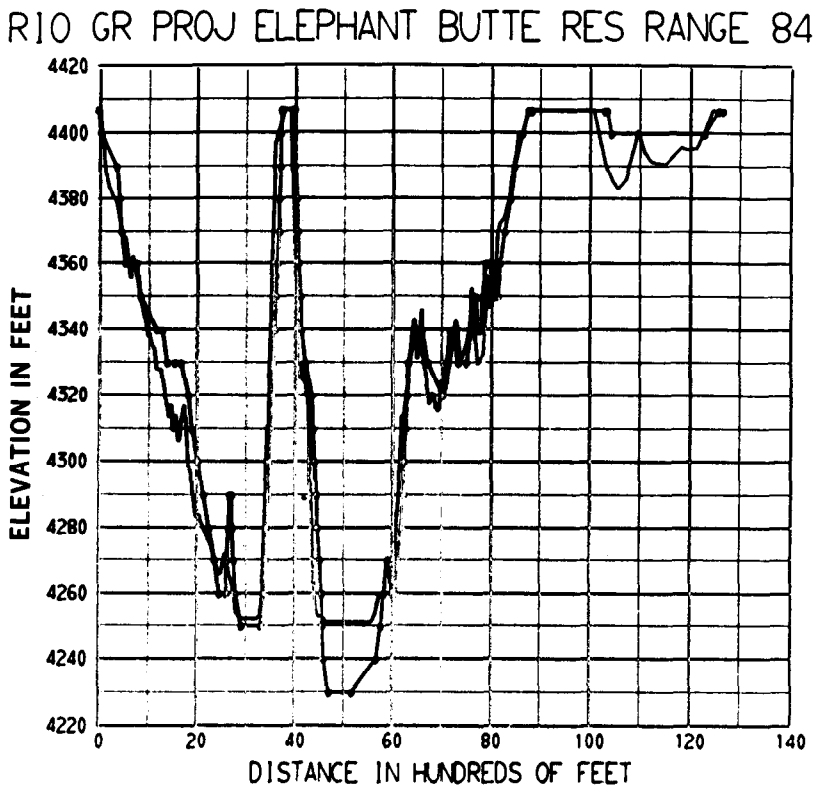


Figure 26. 1915 and 1969 sedimentation range profiles—Range 84.

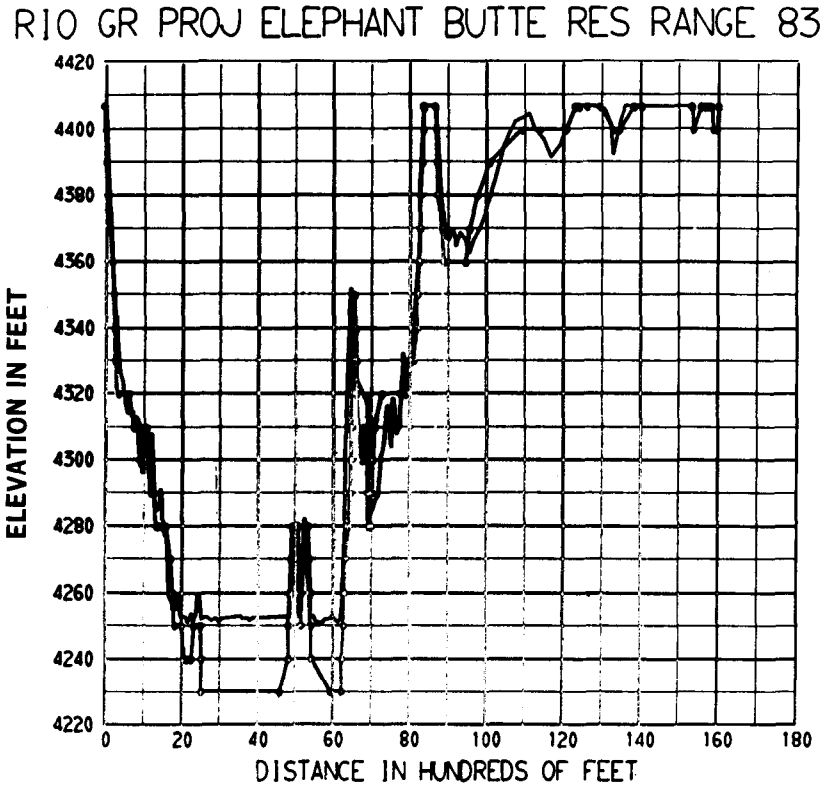


Figure 27. 1915 and 1969 sedimentation range profiles—Range 83.

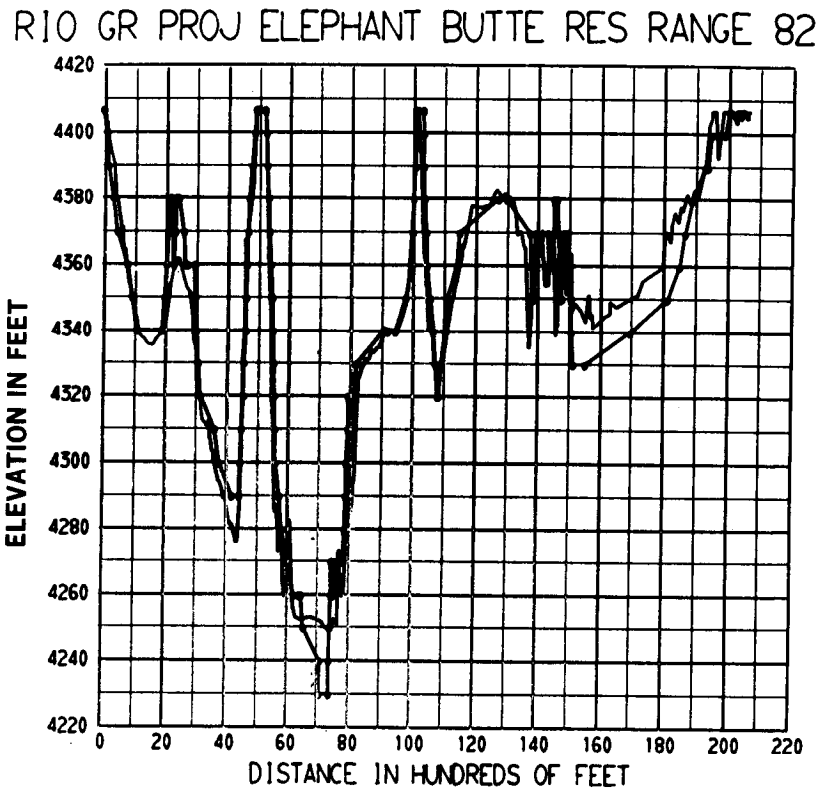


Figure 28. 1915 and 1969 sedimentation range profiles—Range 82.

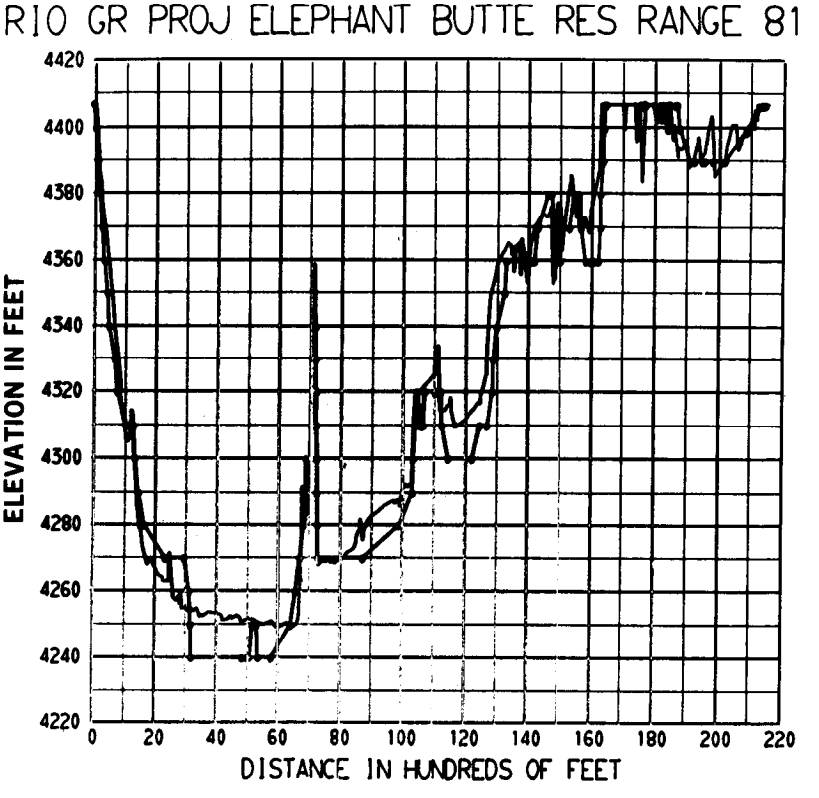


Figure 29. 1915 and 1969 sedimentation range profiles—Range 81.

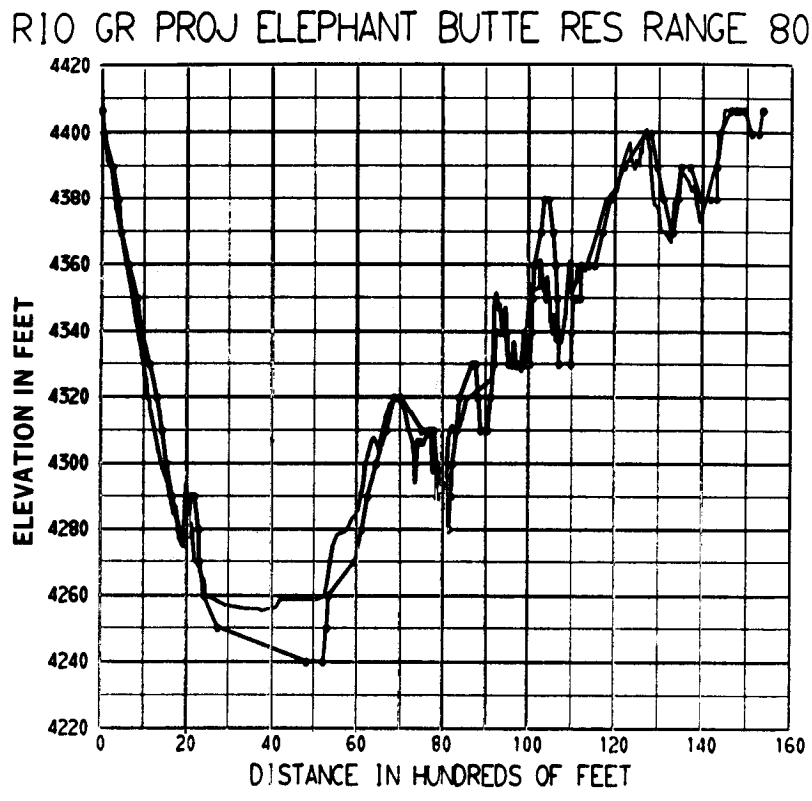


Figure 30. 1915 and 1969 sedimentation range profiles—Range 80.

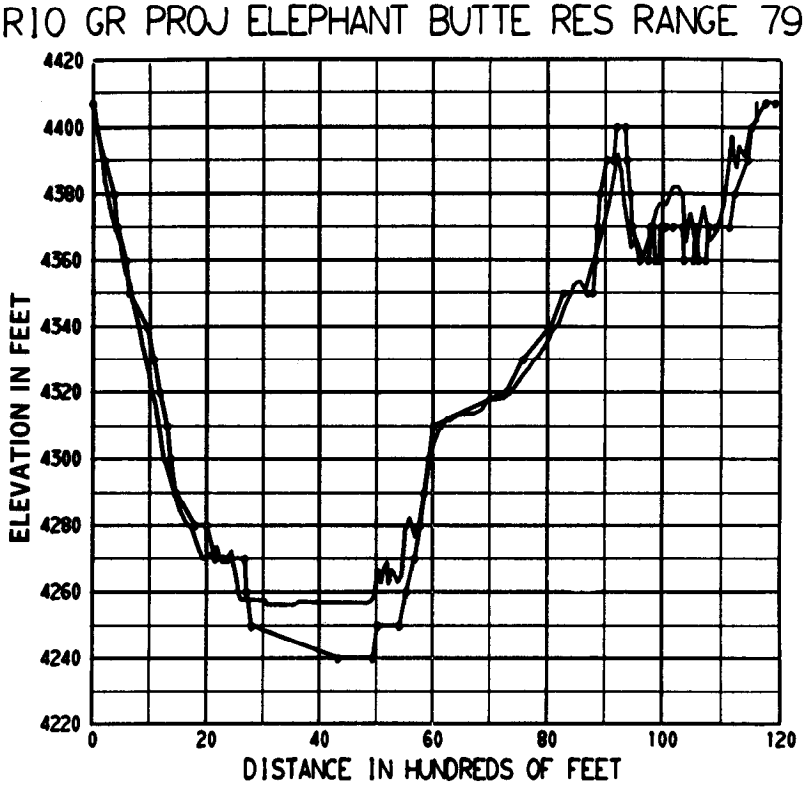


Figure 31. 1915 and 1969 sedimentation range profiles—Range 79.

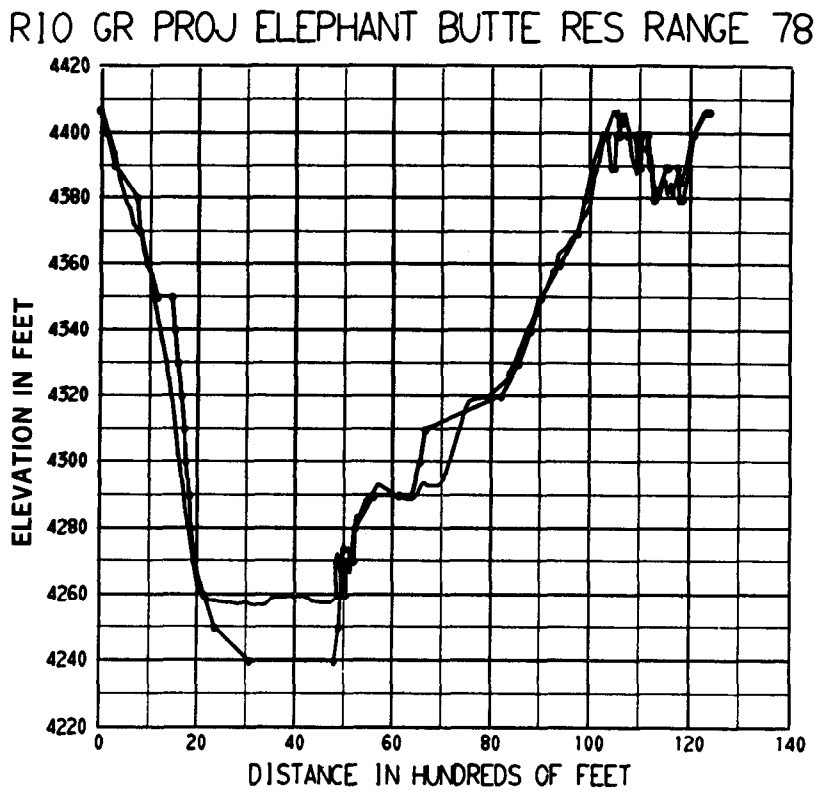


Figure 32. 1915 and 1969 sedimentation range profiles—Range 78.

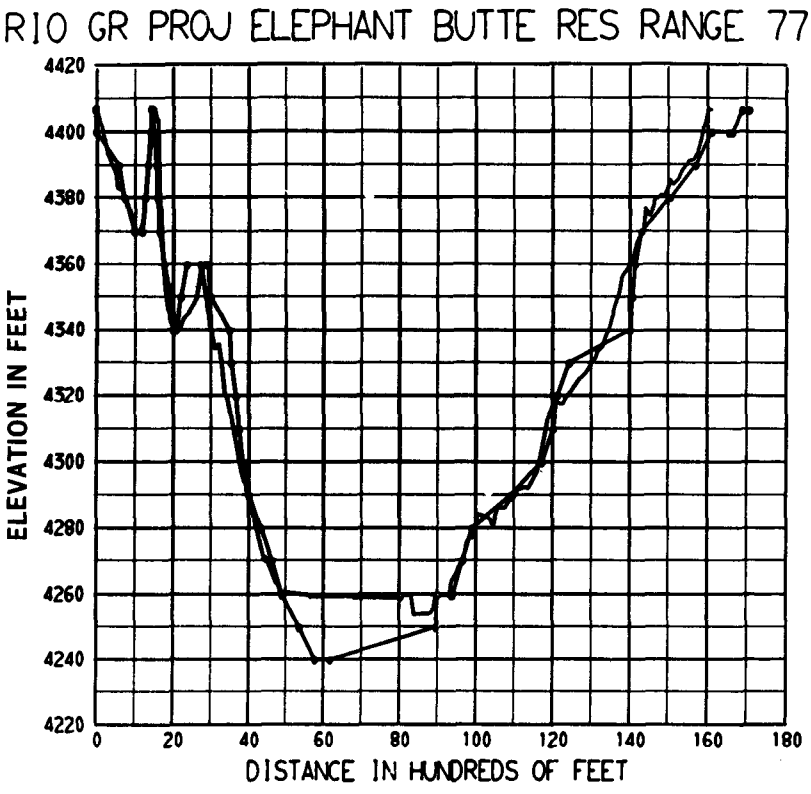


Figure 33. 1915 and 1969 sedimentation range profiles—Range 77.

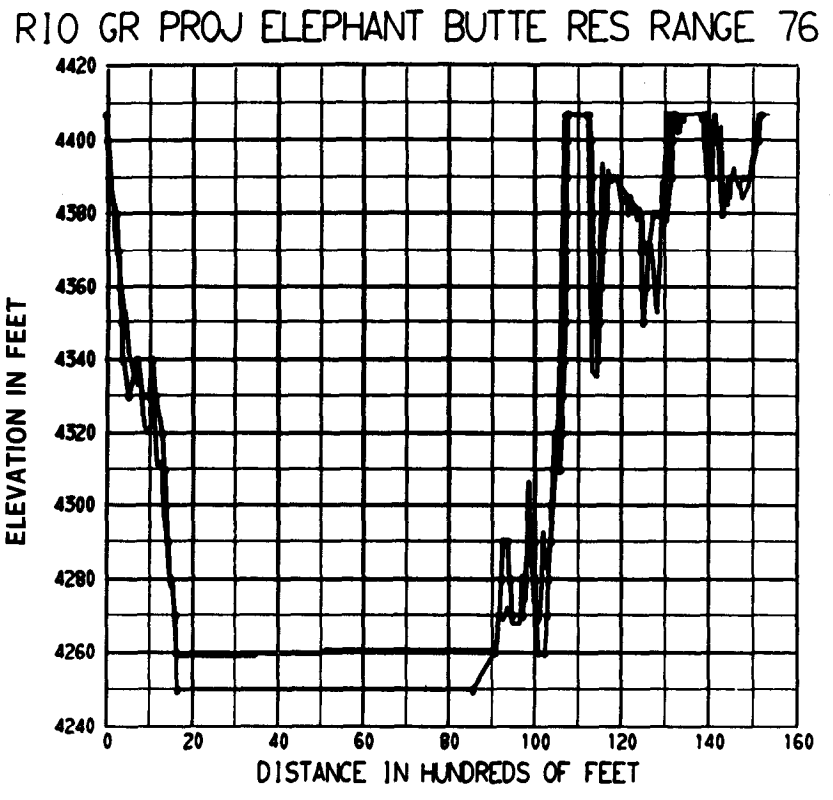


Figure 34. 1915 and 1969 sedimentation range profiles—Range 76.

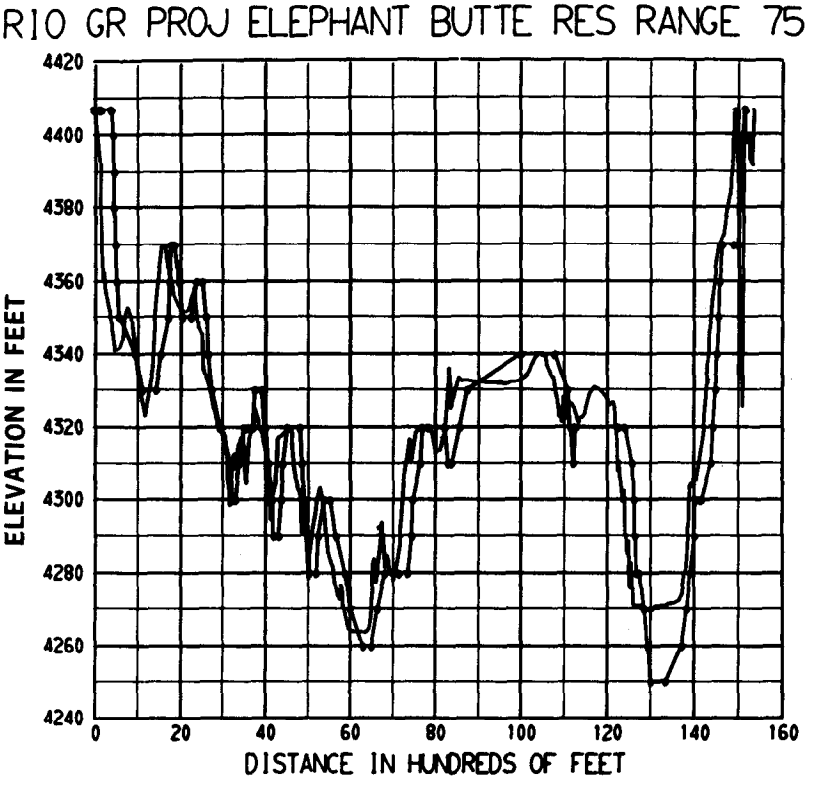


Figure 35. 1915 and 1969 sedimentation range profiles—Range 75.

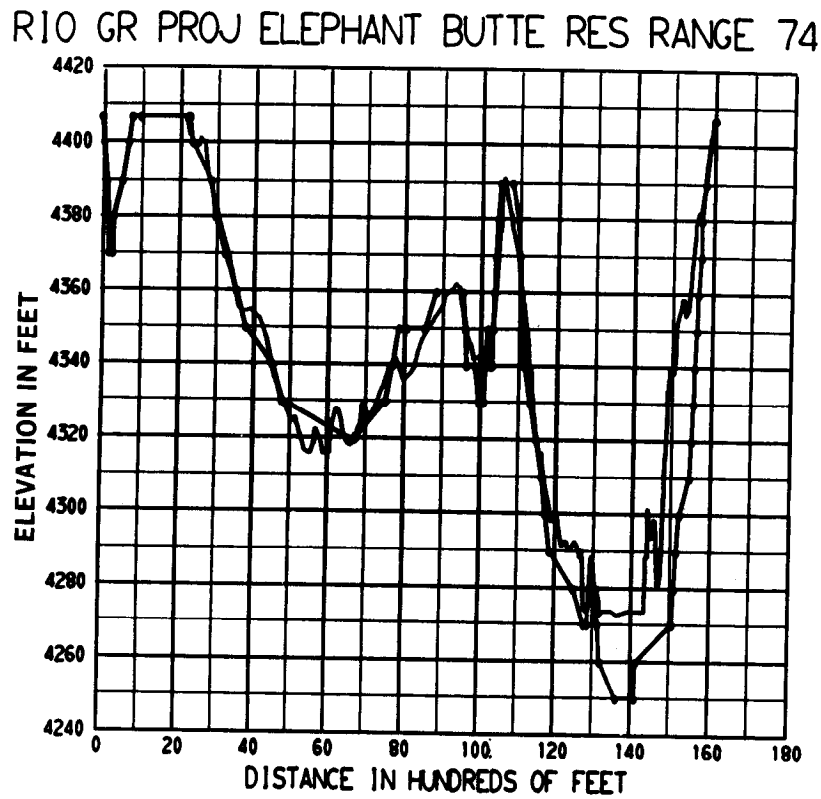


Figure 36. 1915 and 1969 sedimentation range profiles—Range 74.

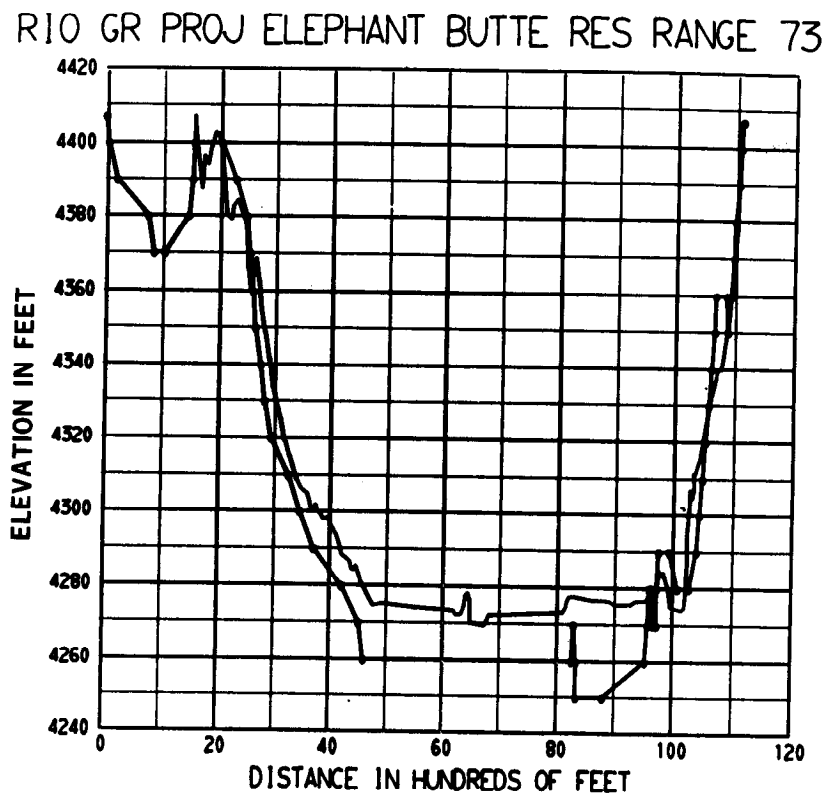


Figure 37. 1915 and 1969 sedimentation range profiles—Range 73.

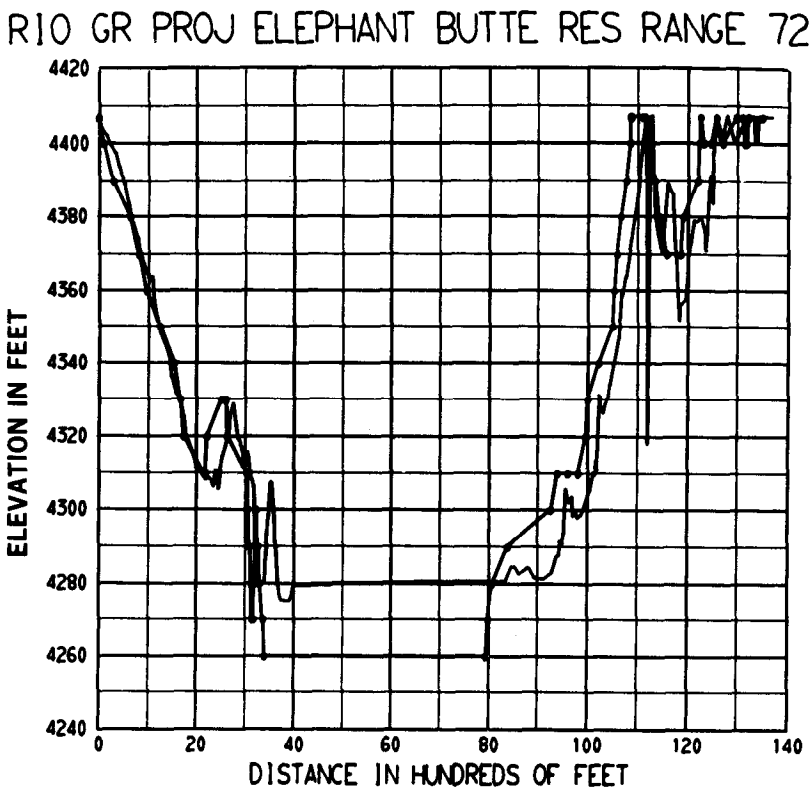


Figure 38. 1915 and 1969 sedimentation range profiles—Range 72.

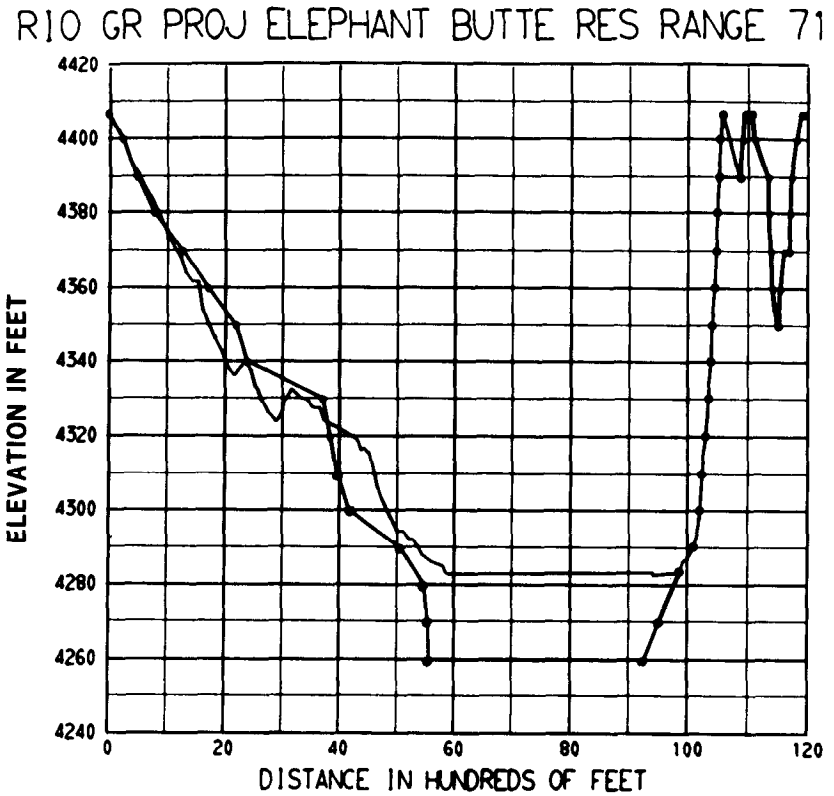


Figure 39. 1915 and 1969 sedimentation range profiles—Range 71.

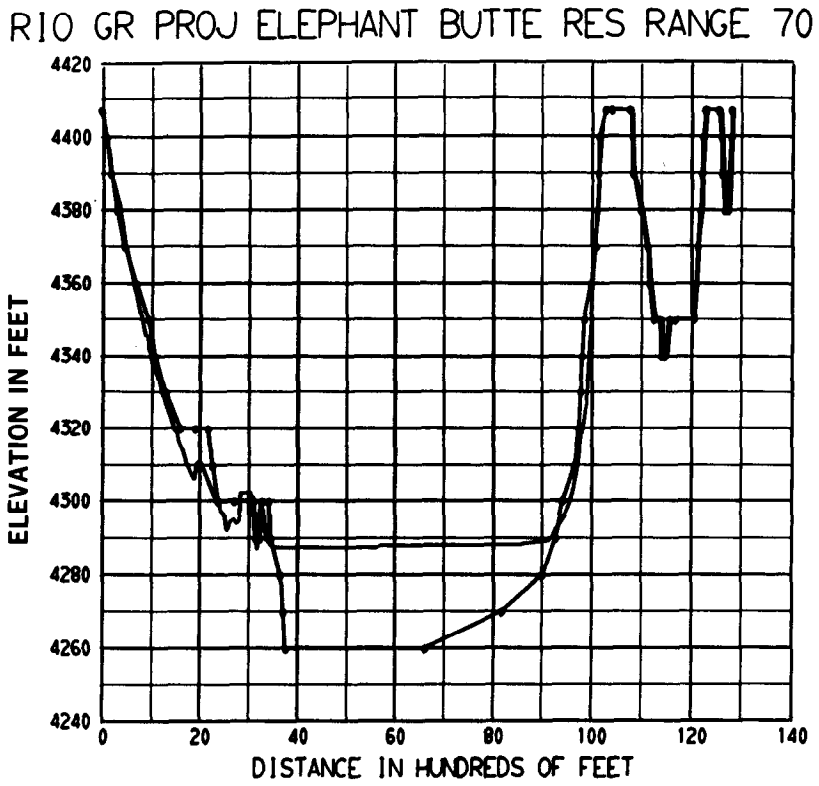


Figure 40. 1915 and 1969 sedimentation range profiles—Range 70.

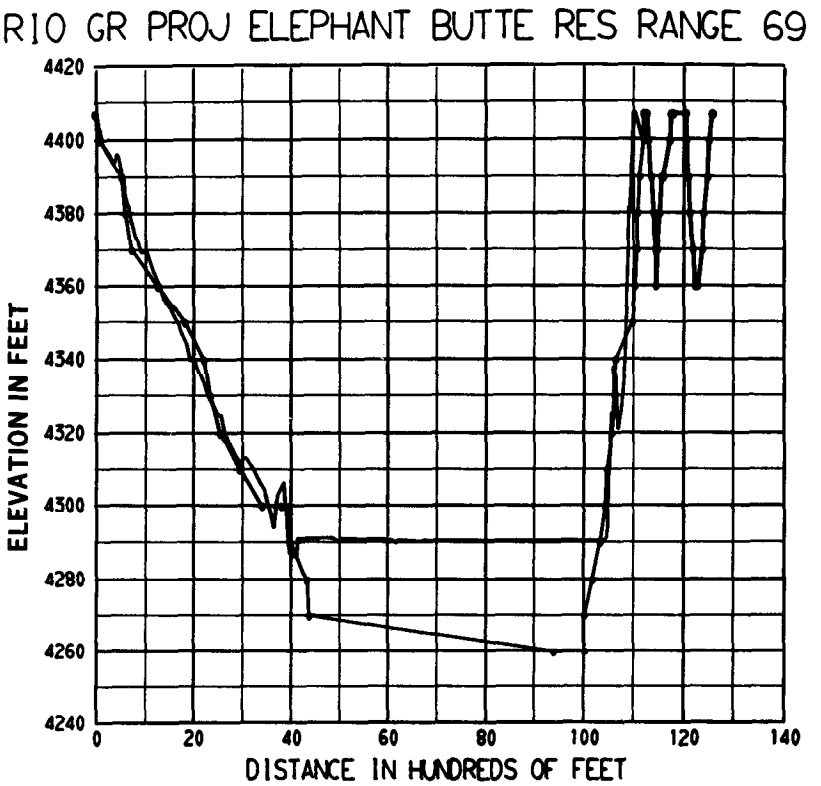


Figure 41. 1915 and 1969 sedimentation range profiles—Range 69.

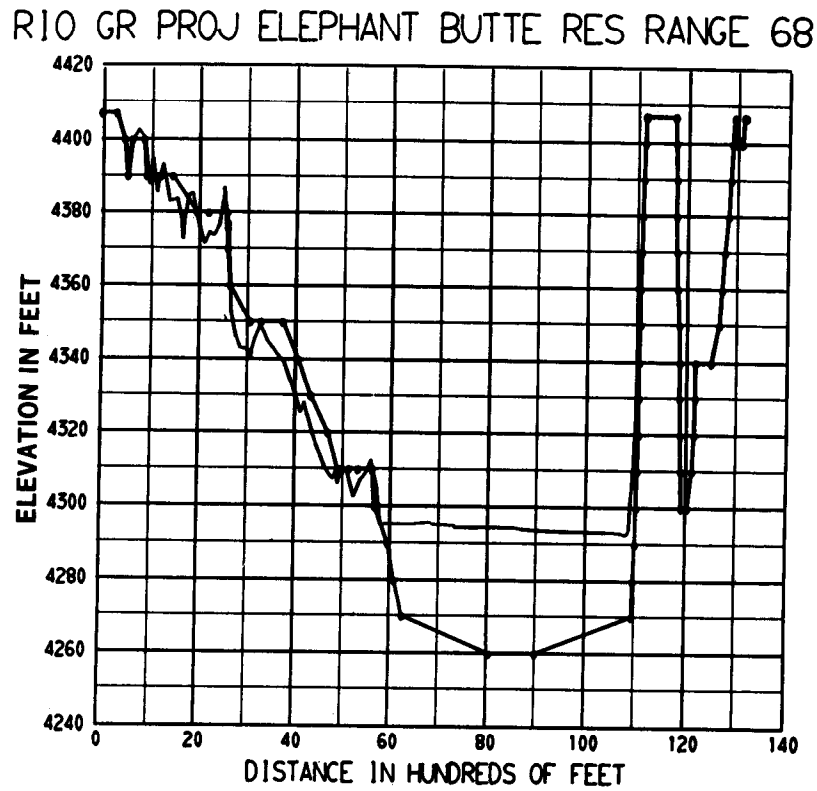


Figure 42. 1915 and 1969 sedimentation range profiles—Range 68.

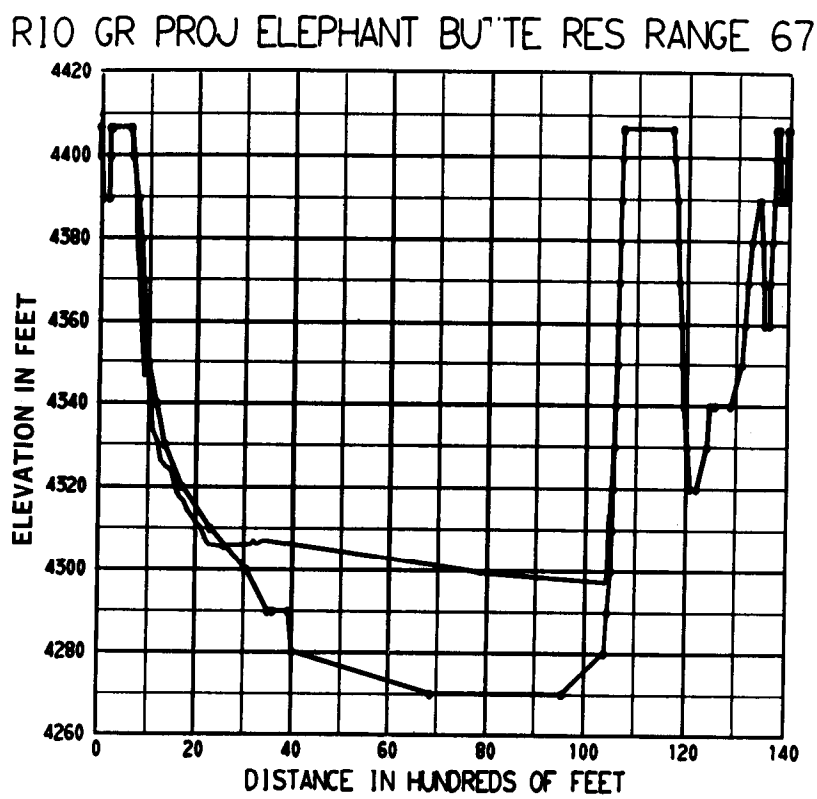


Figure 43. 1915 and 1969 sedimentation range profiles—Range 67.

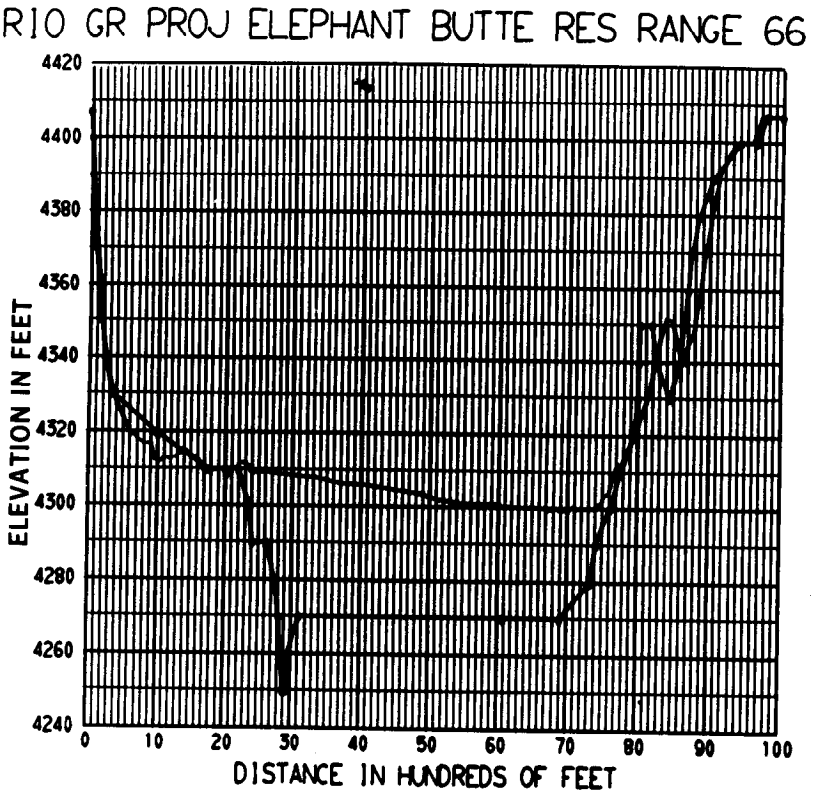


Figure 44. 1915 and 1969 sedimentation range profiles--Range 66.

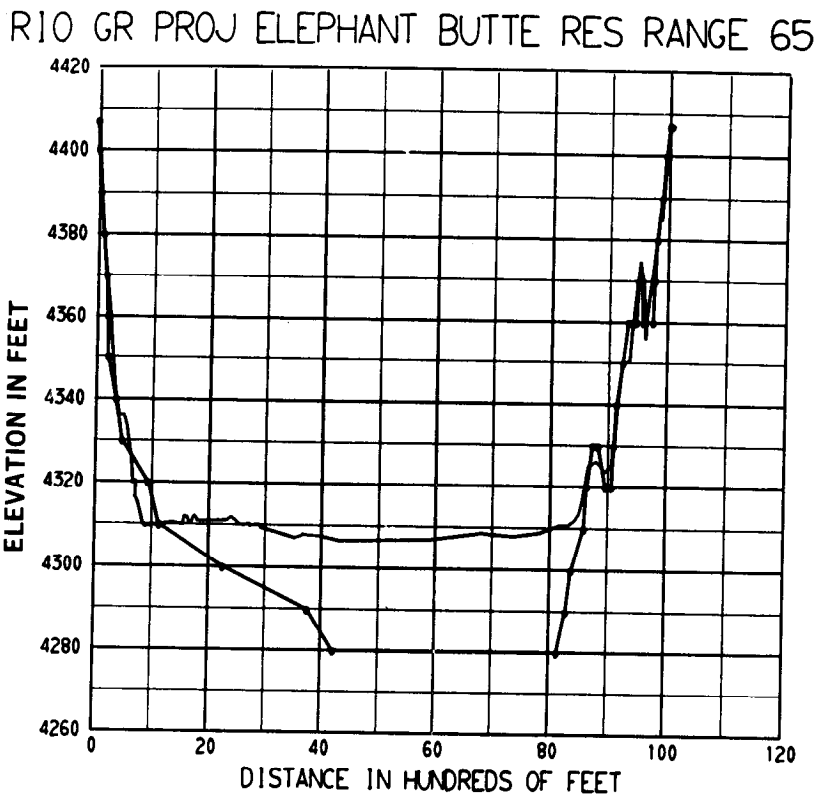


Figure 45. 1915 and 1969 sedimentation range profiles--Range 65.

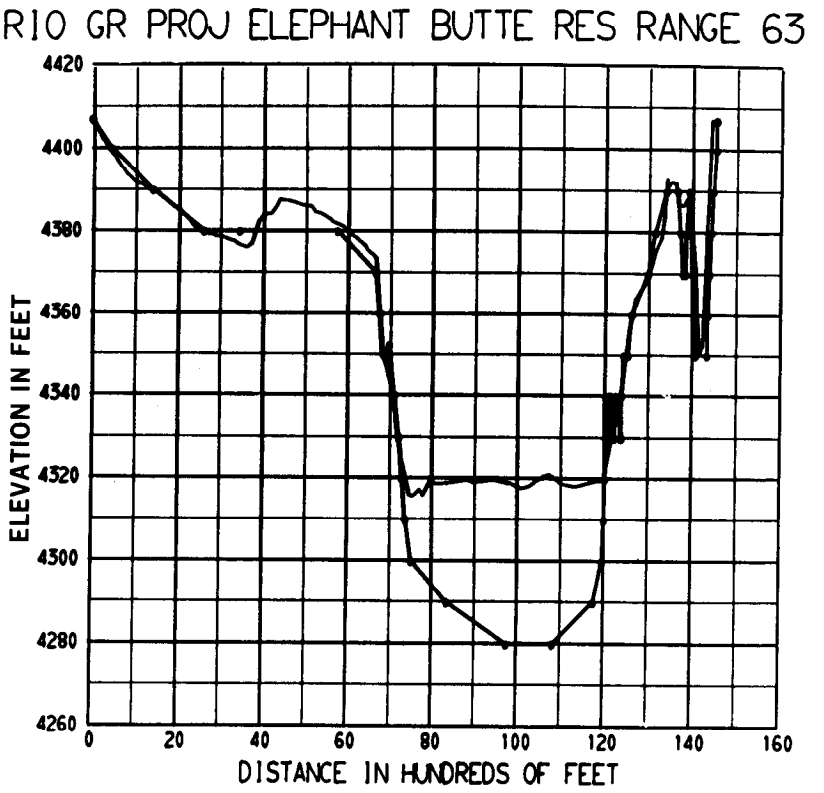


Figure 46. 1915 and 1969 sedimentation range profiles--Range 63.

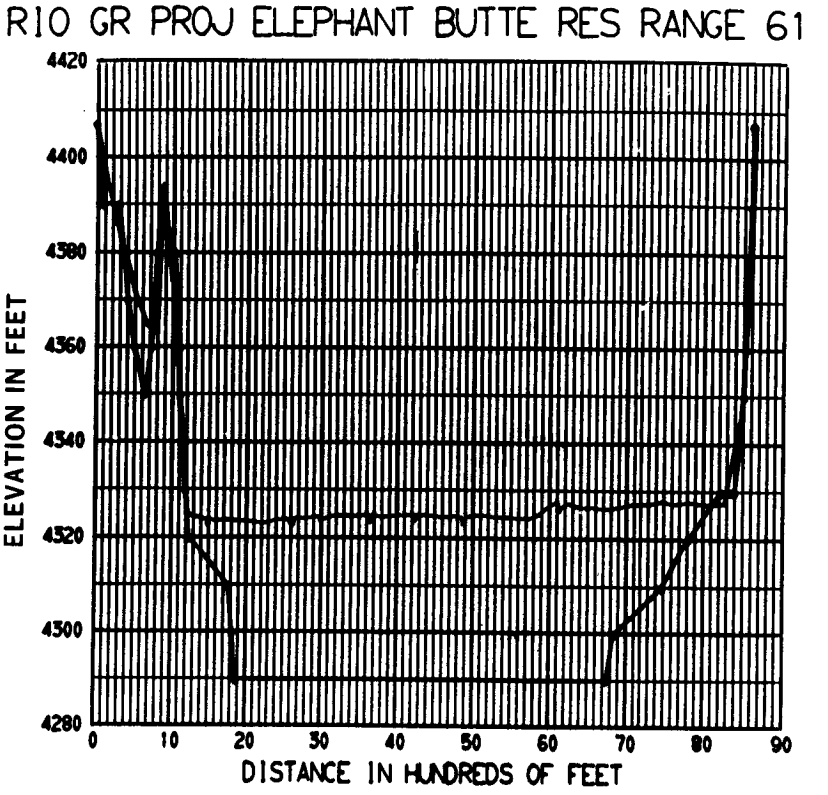


Figure 47. 1915 and 1969 sedimentation range profiles--Range 61.

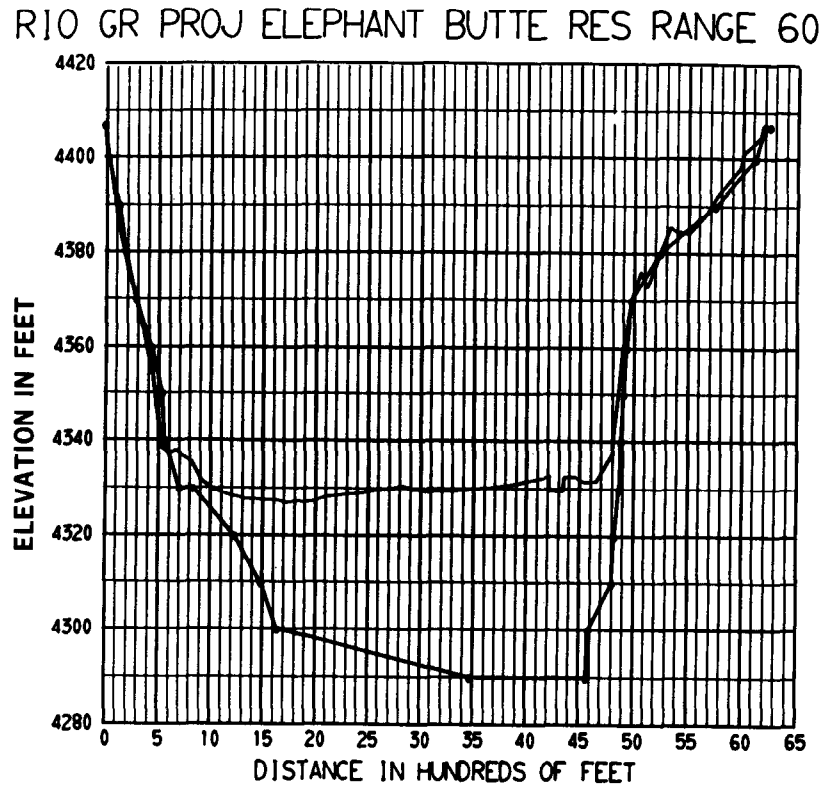


Figure 48. 1915 and 1969 sedimentation range profiles—Range 60.

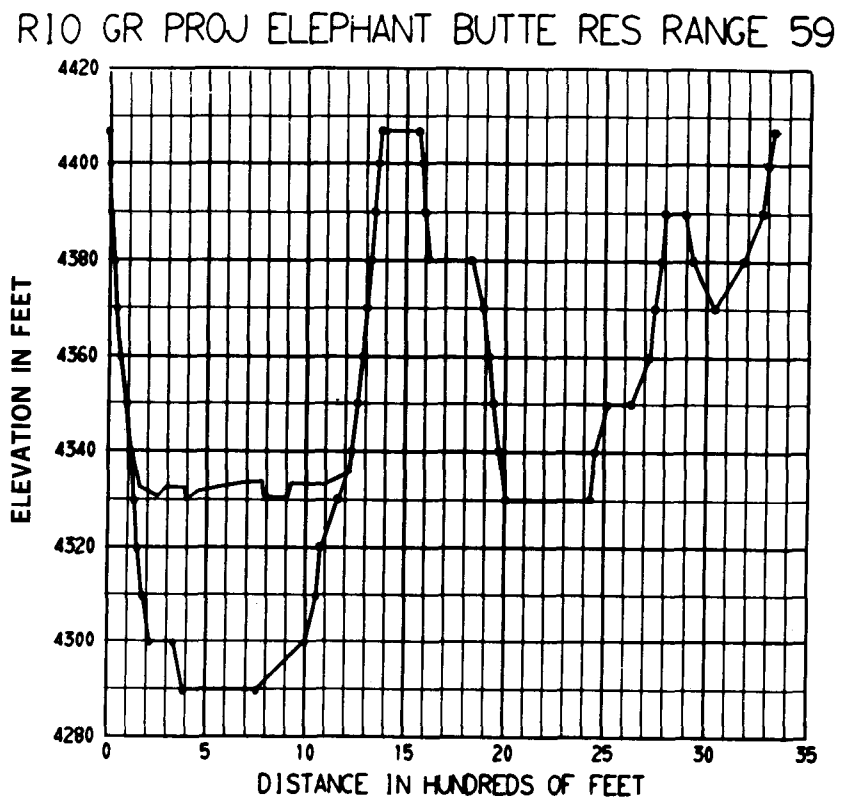


Figure 49. 1915 and 1969 sedimentation range profiles—Range 59.

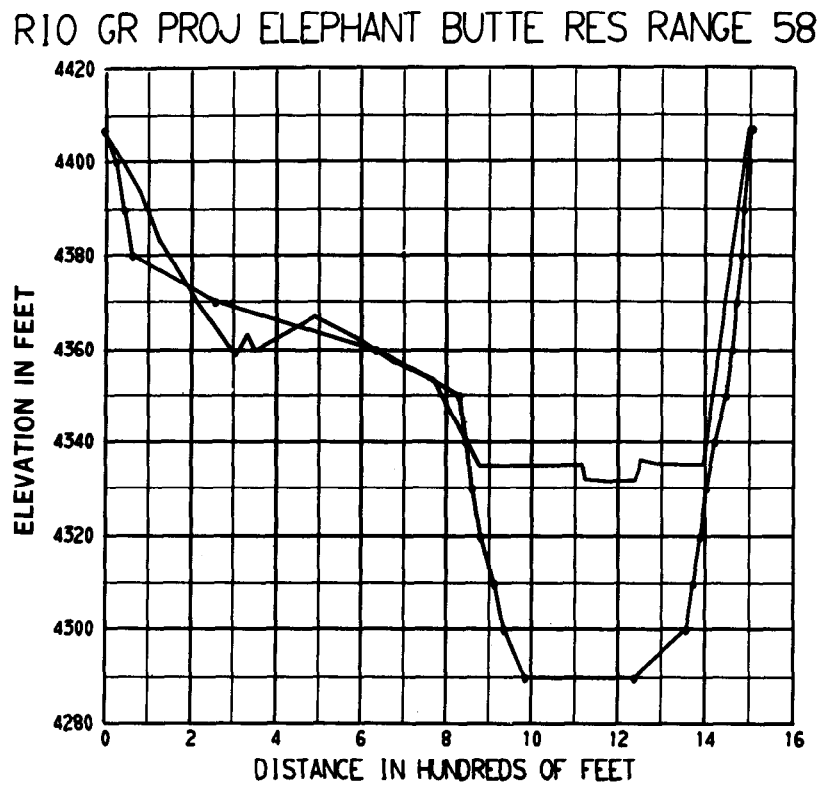


Figure 50. 1915 and 1969 sedimentation range profiles—Range 58.

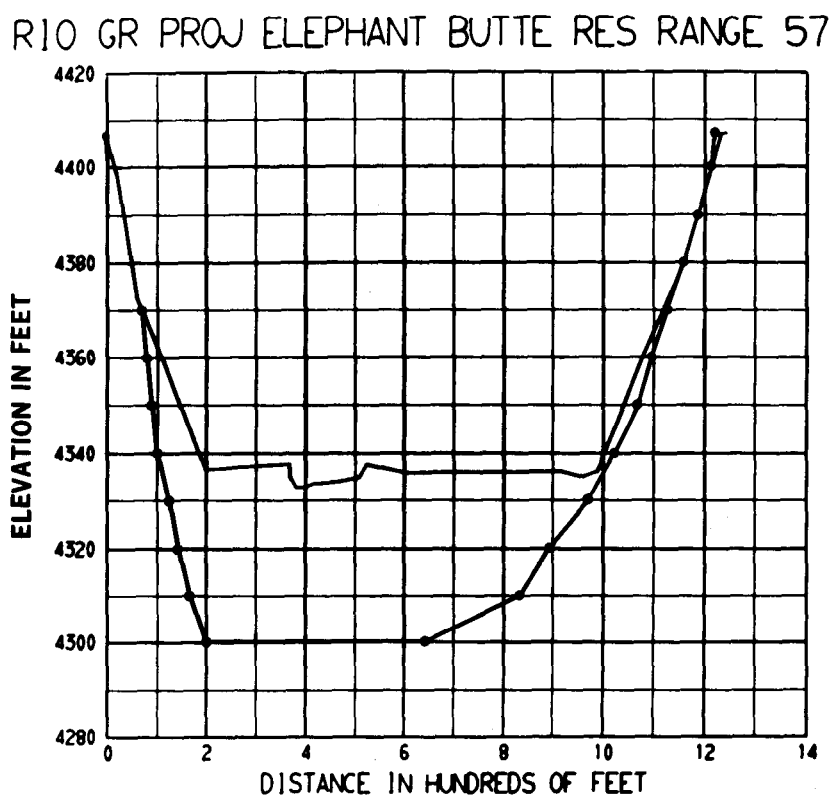


Figure 51. 1915 and 1969 sedimentation range profiles—Range 57.

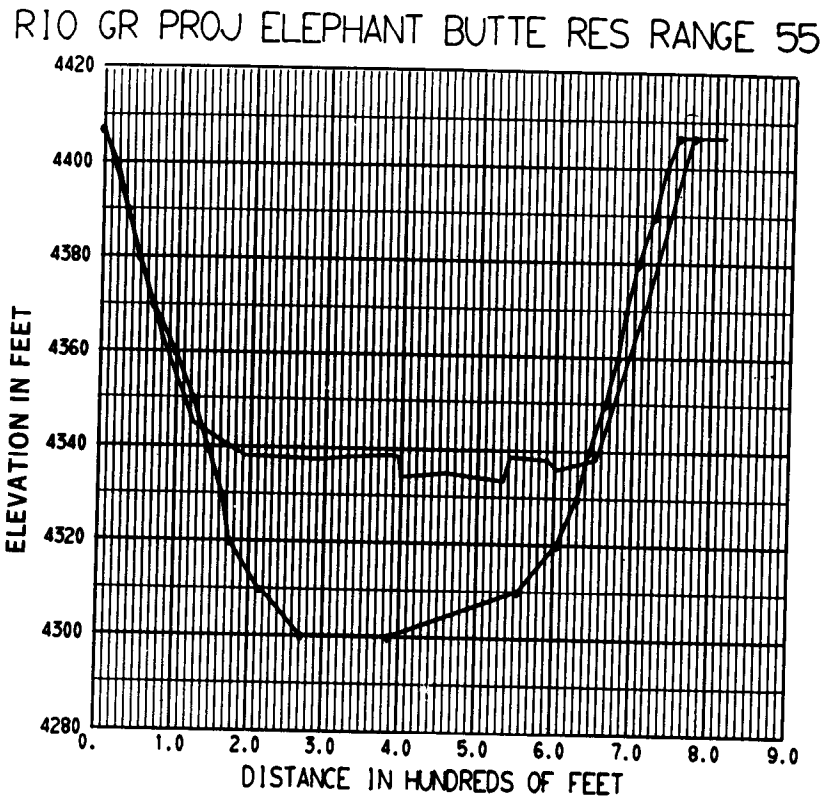


Figure 52. 1915 and 1969 sedimentation range profiles—Range 55.

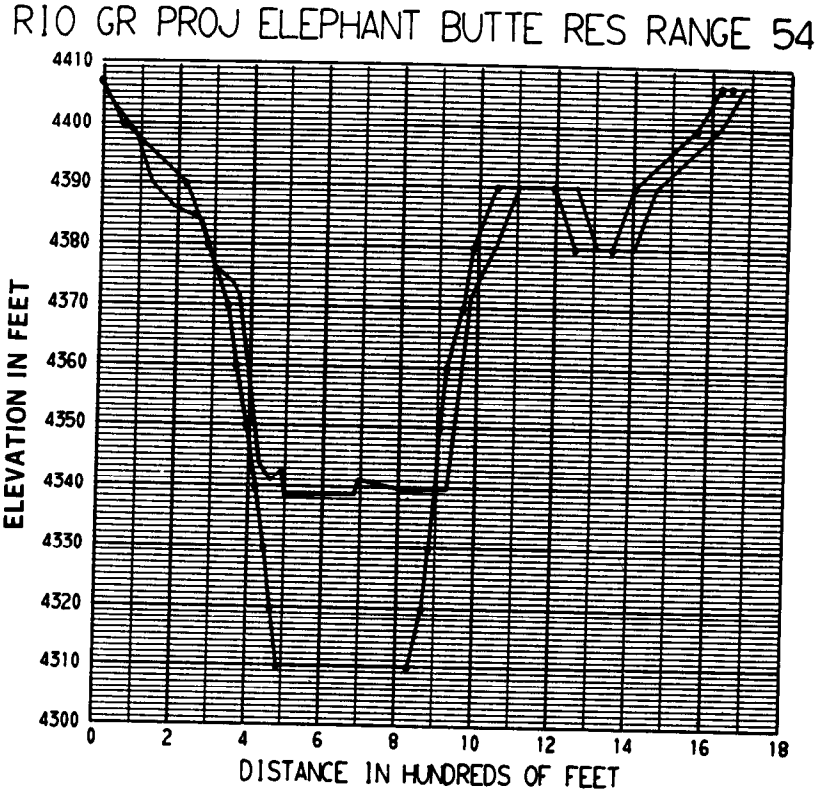


Figure 53. 1915 and 1969 sedimentation range profiles—Range 54.

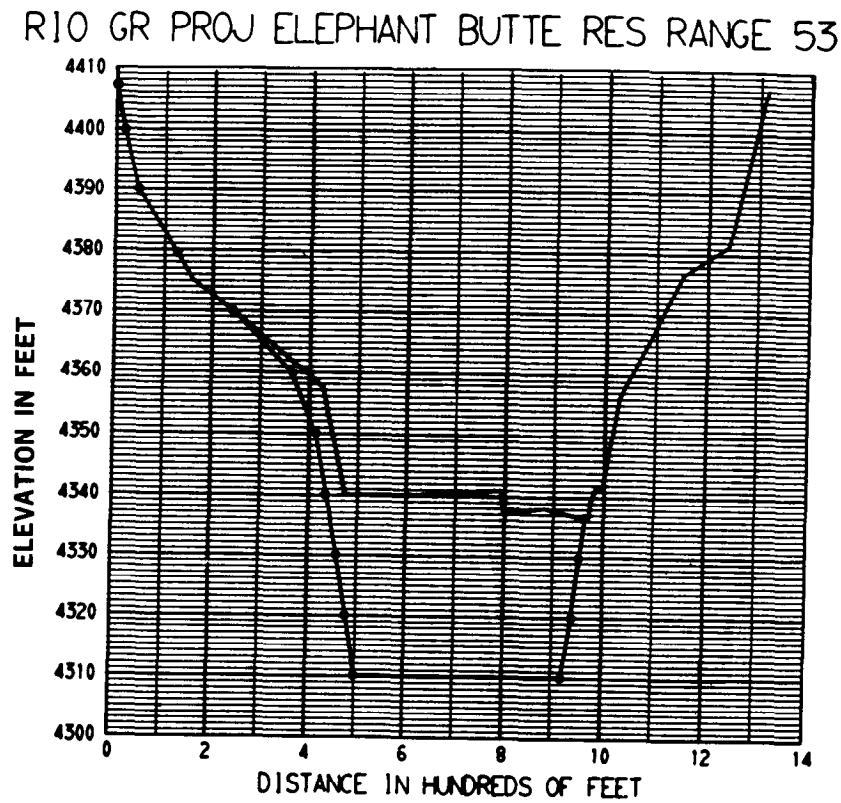


Figure 54. 1915 and 1969 sedimentation range profiles—Range 53.

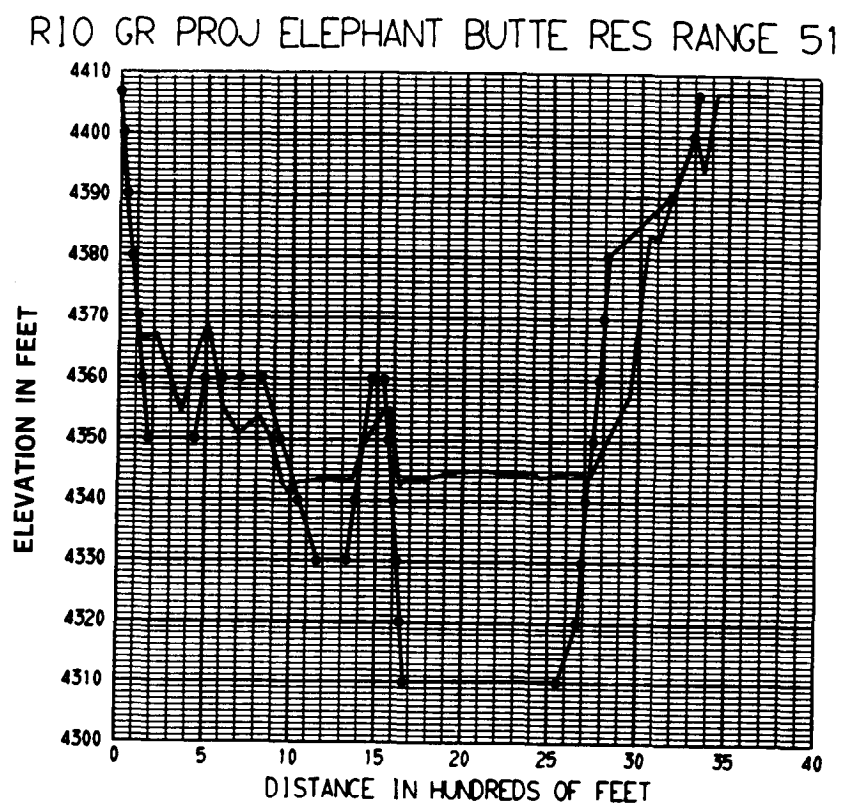


Figure 55. 1915 and 1969 sedimentation range profiles—Range 51.

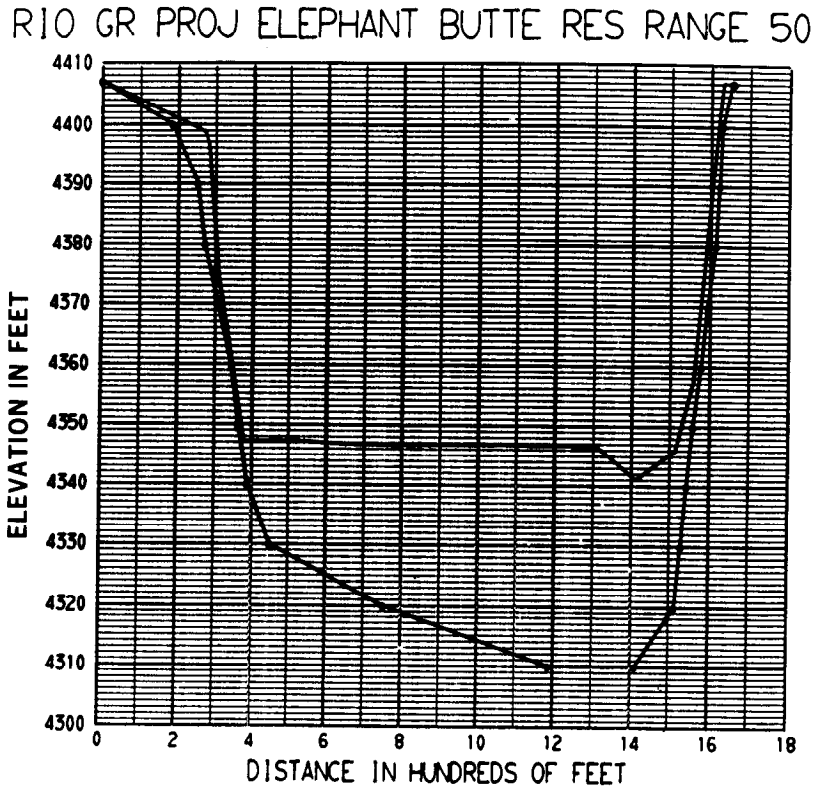


Figure 56. 1915 and 1969 sedimentation range profiles—Range 50.

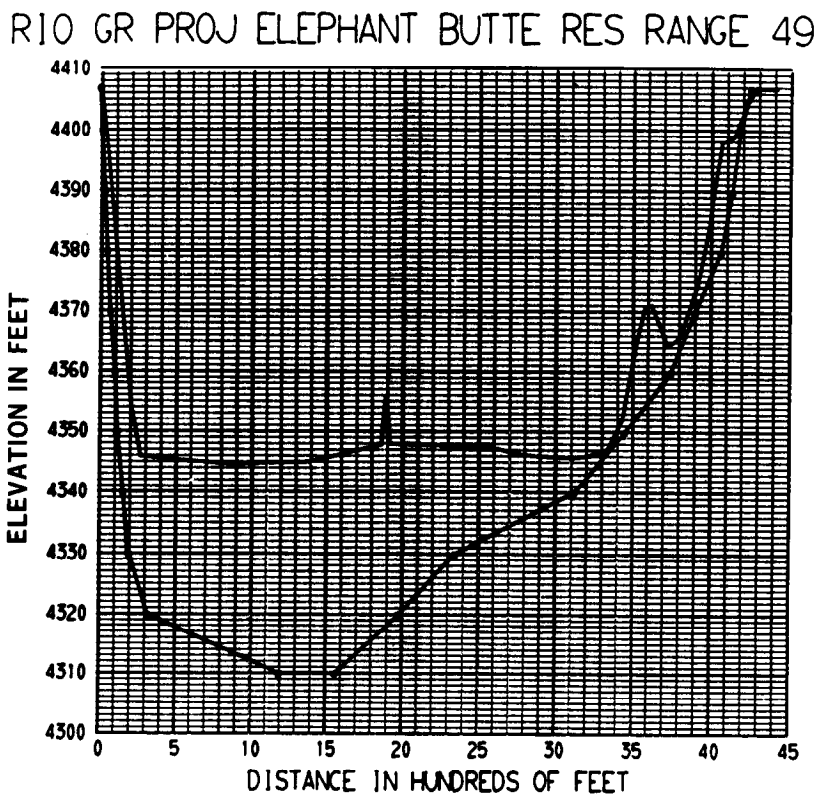


Figure 57. 1915 and 1969 sedimentation range profiles—Range 49.

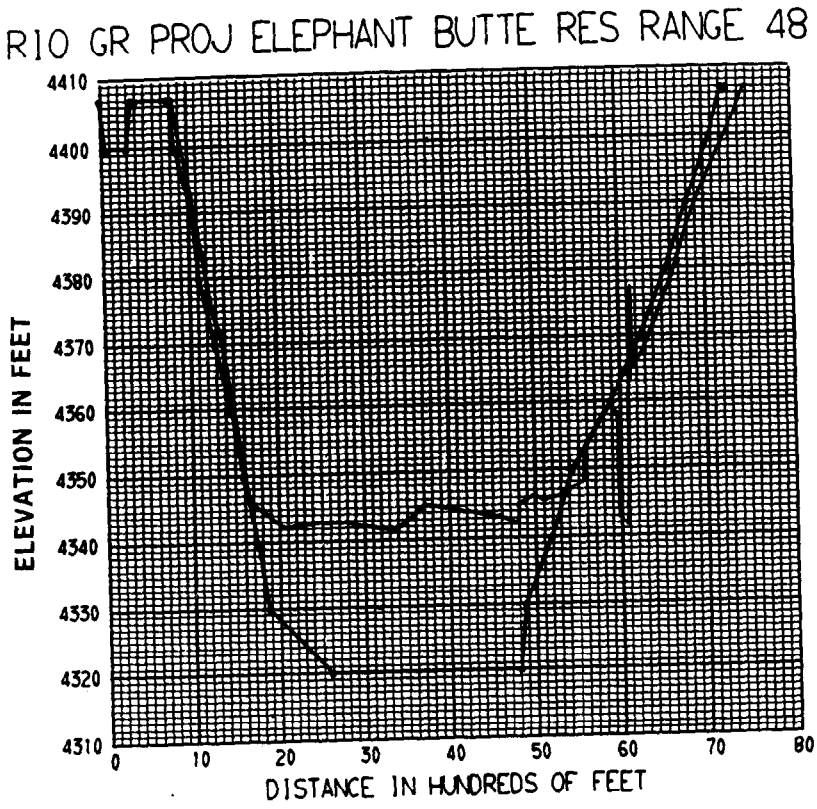


Figure 58. 1915 and 1969 sedimentation range profiles--Range 48.

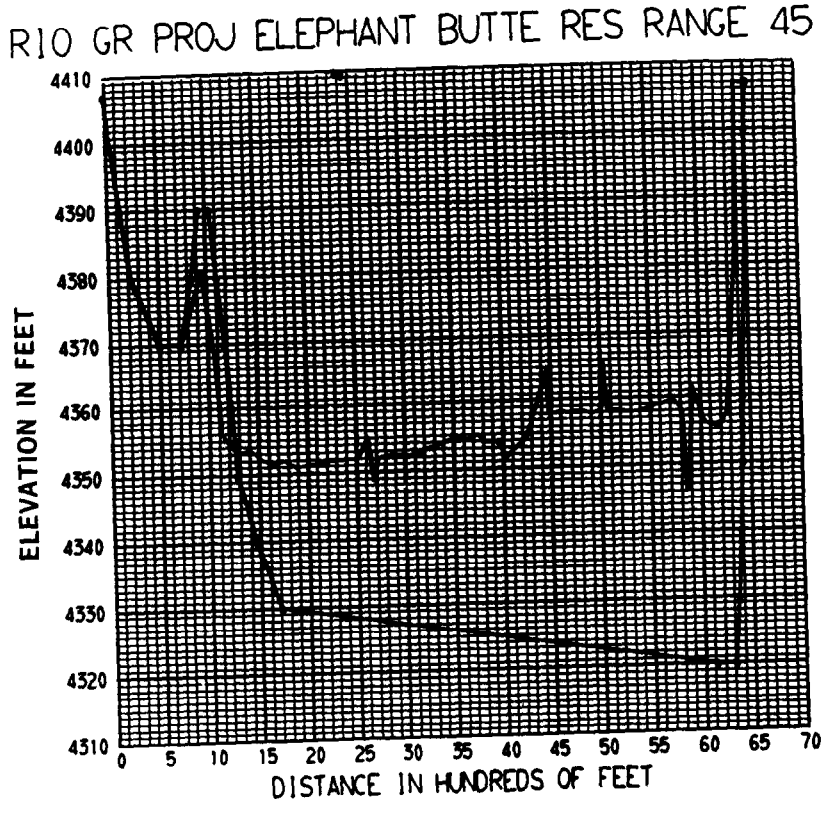


Figure 59. 1915 and 1969 sedimentation range profiles—Range 45.

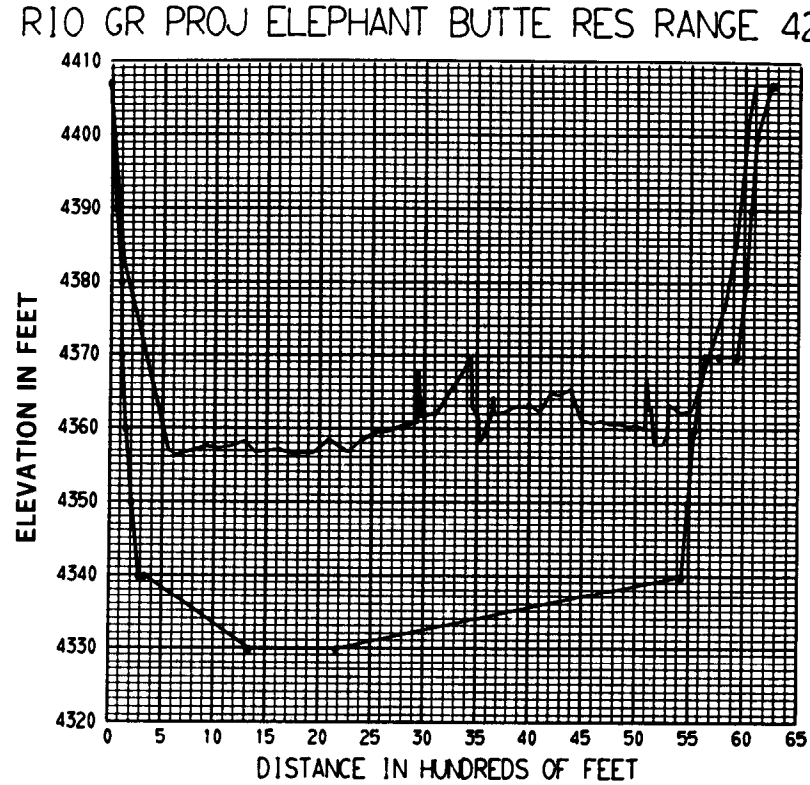


Figure 60. 1915 and 1969 sedimentation range profiles—Range 42.

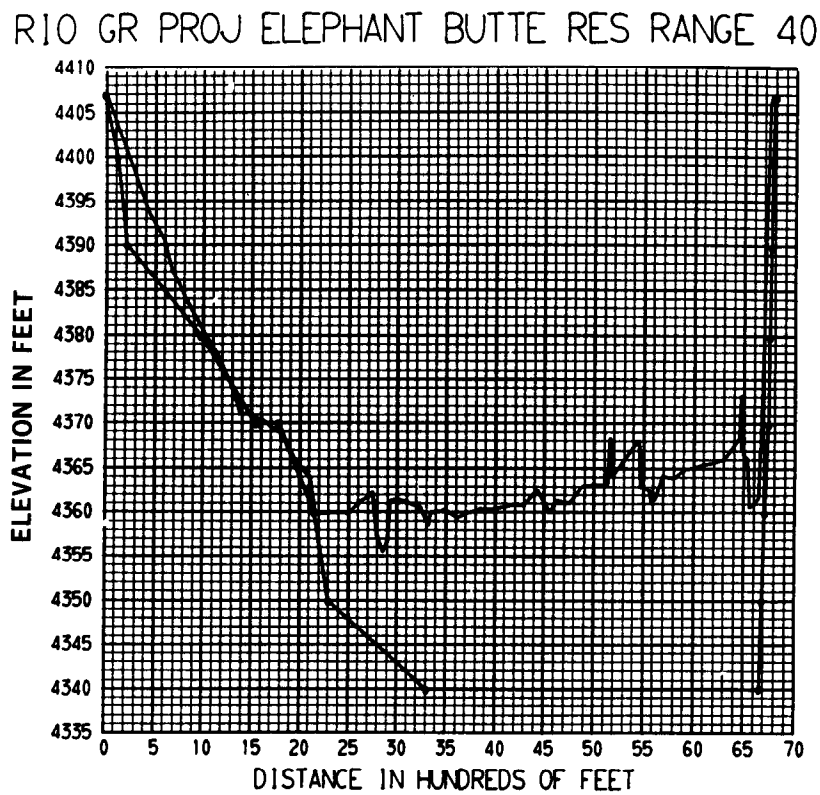


Figure 61. 1915 and 1969 sedimentation range profiles—Range 40.

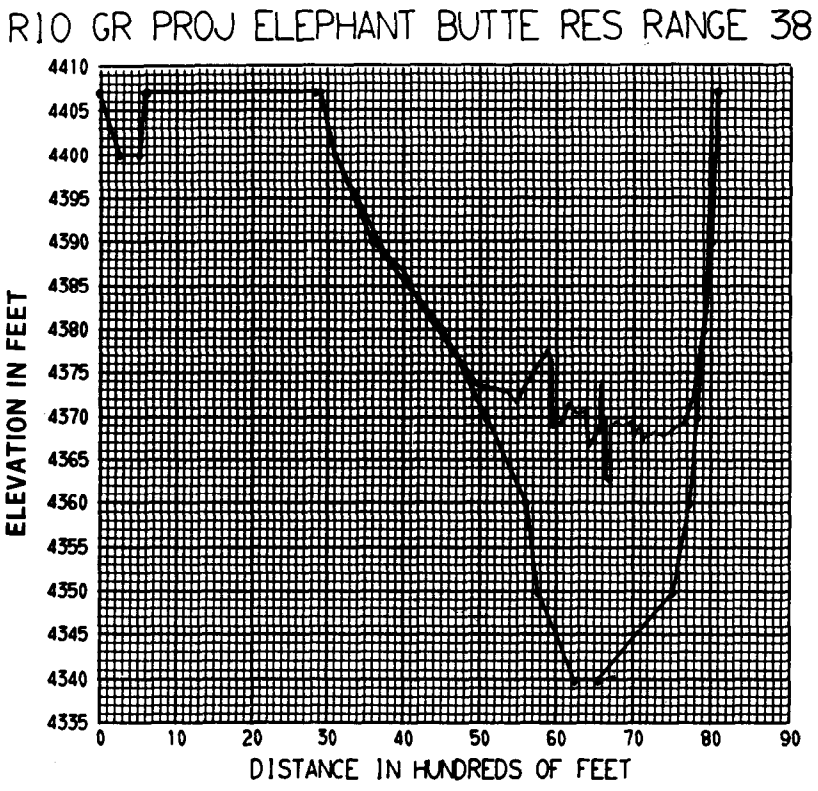


Figure 62. 1915 and 1969 sedimentation range profiles—Range 38.

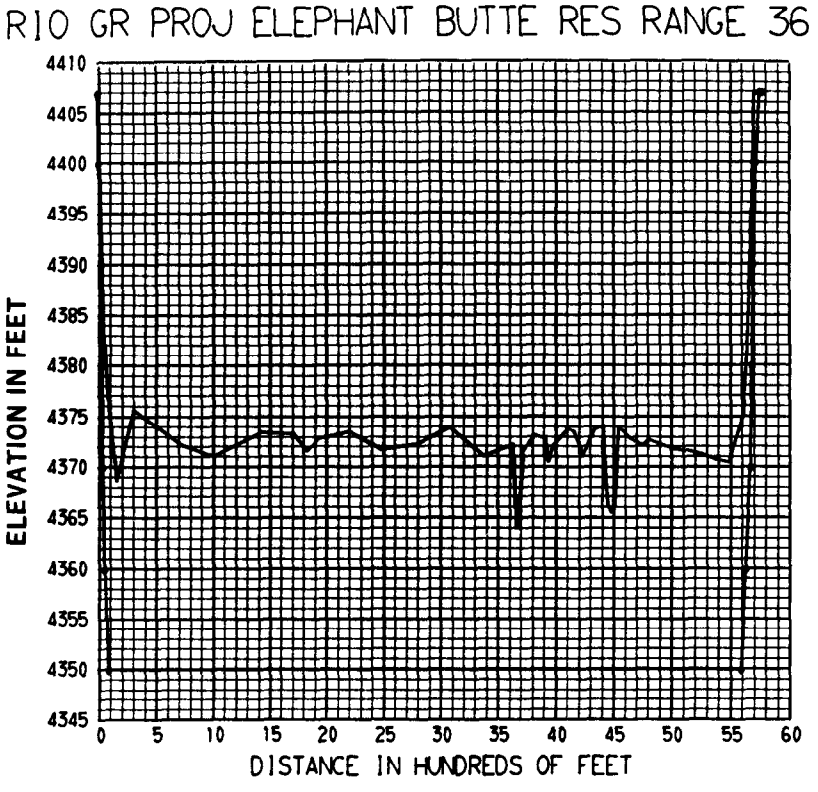


Figure 63. 1915 and 1969 sedimentation range profiles—Range 36.

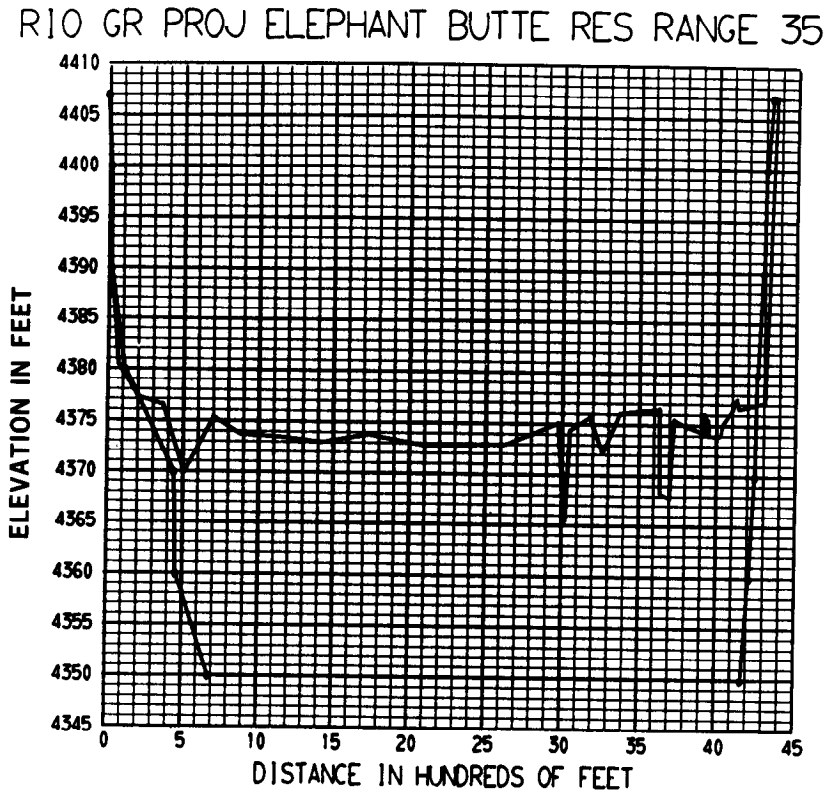


Figure 64. 1915 and 1969 sedimentation range profiles—Range 35.

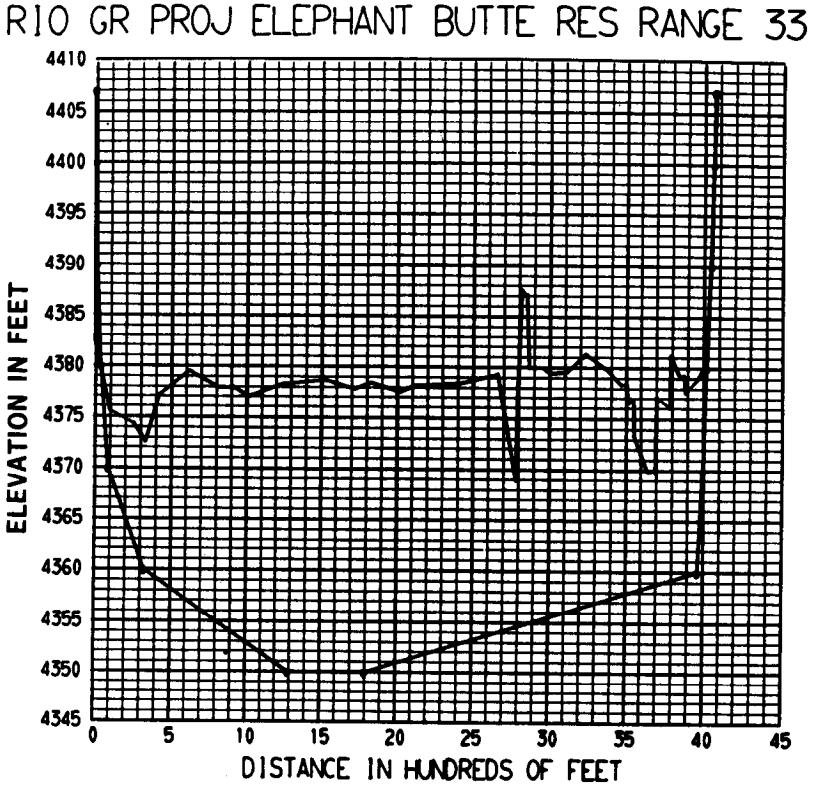


Figure 65. 1915 and 1969 sedimentation range profiles--Range 33.

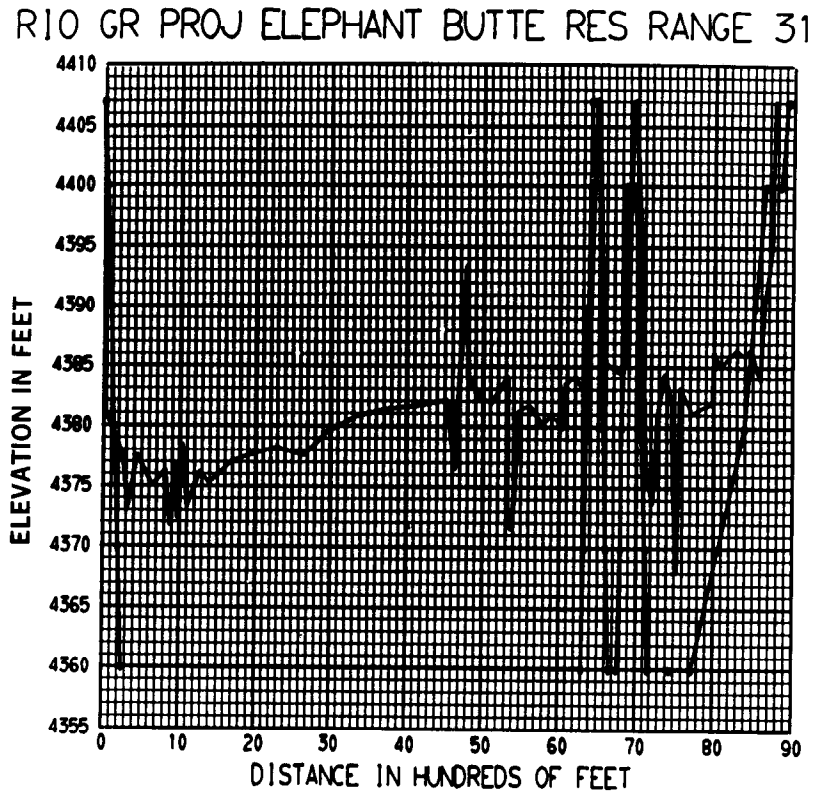


Figure 66. 1915 and 1969 sedimentation range profiles—Range 31.

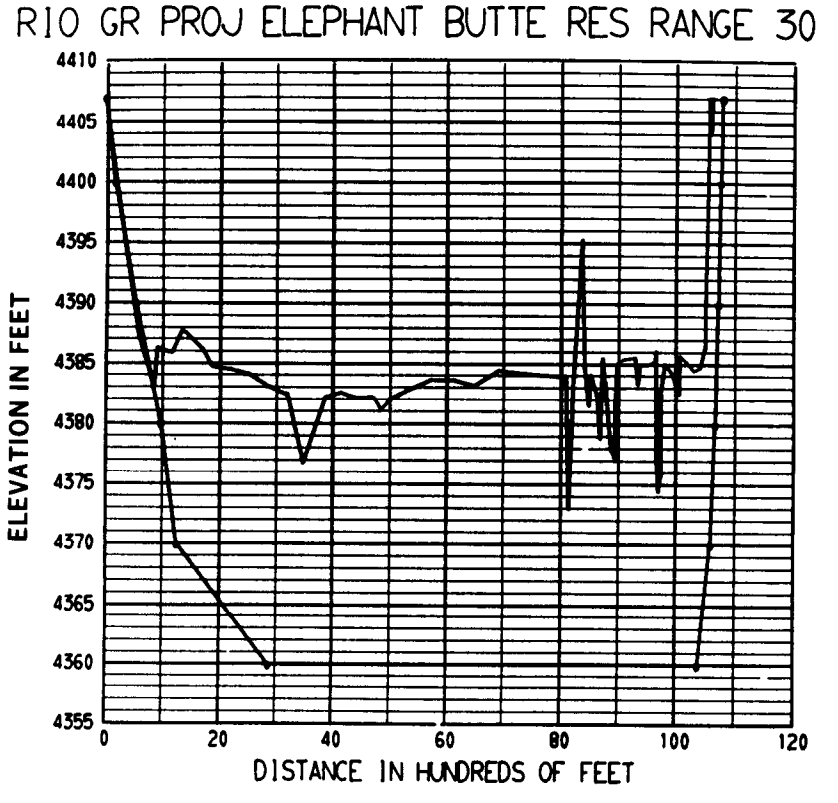


Figure 67. 1915 and 1969 sedimentation range profiles—Range 30.

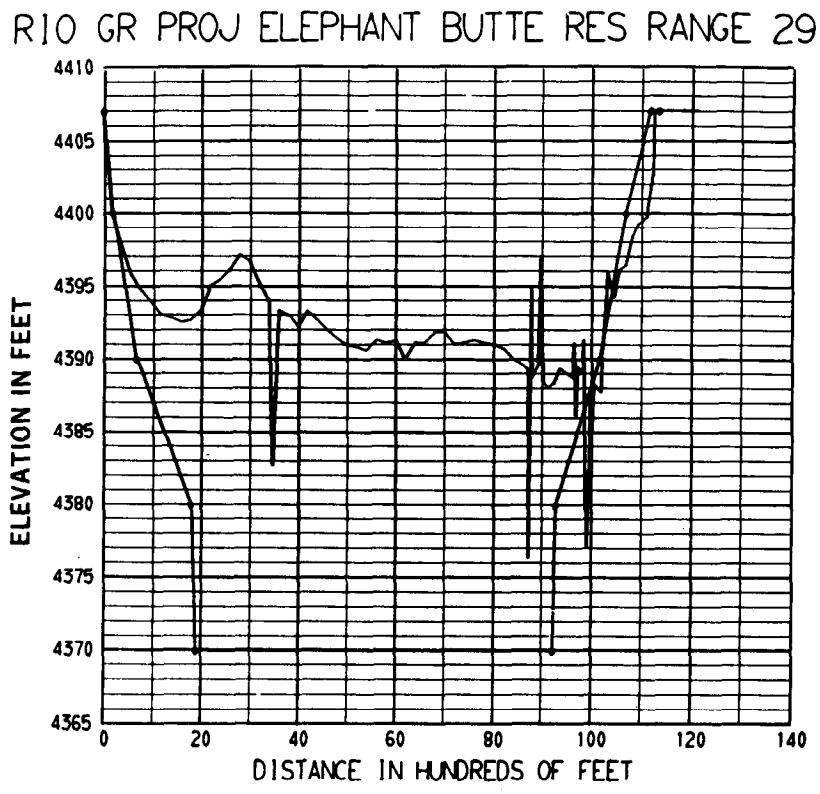


Figure 68. 1915 and 1969 sedimentation range profiles--Range 29.

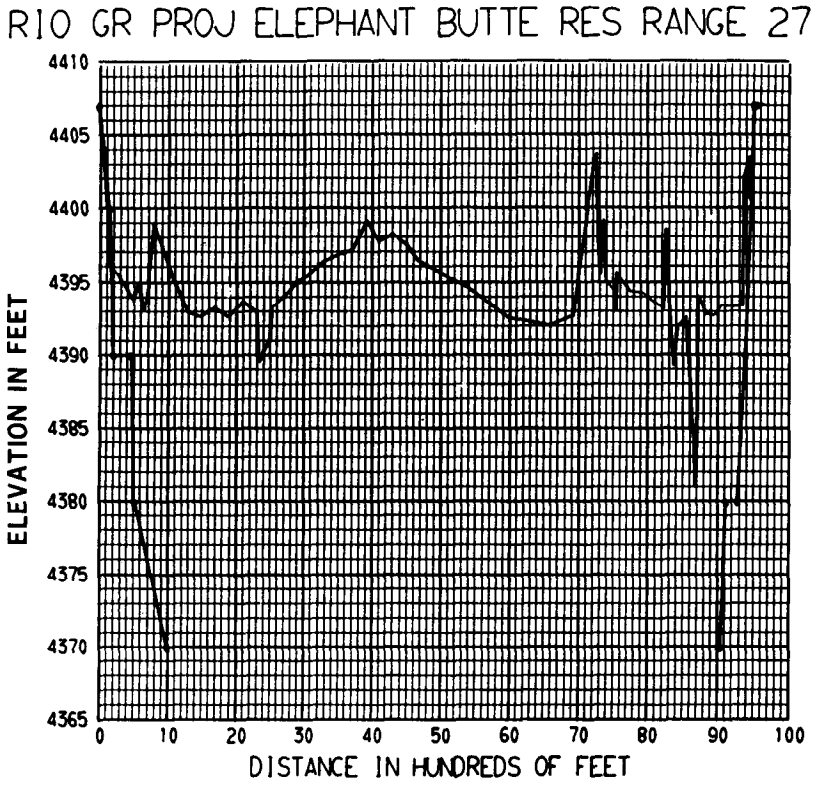


Figure 69. 1915 and 1969 sedimentation range profiles--Range 27.

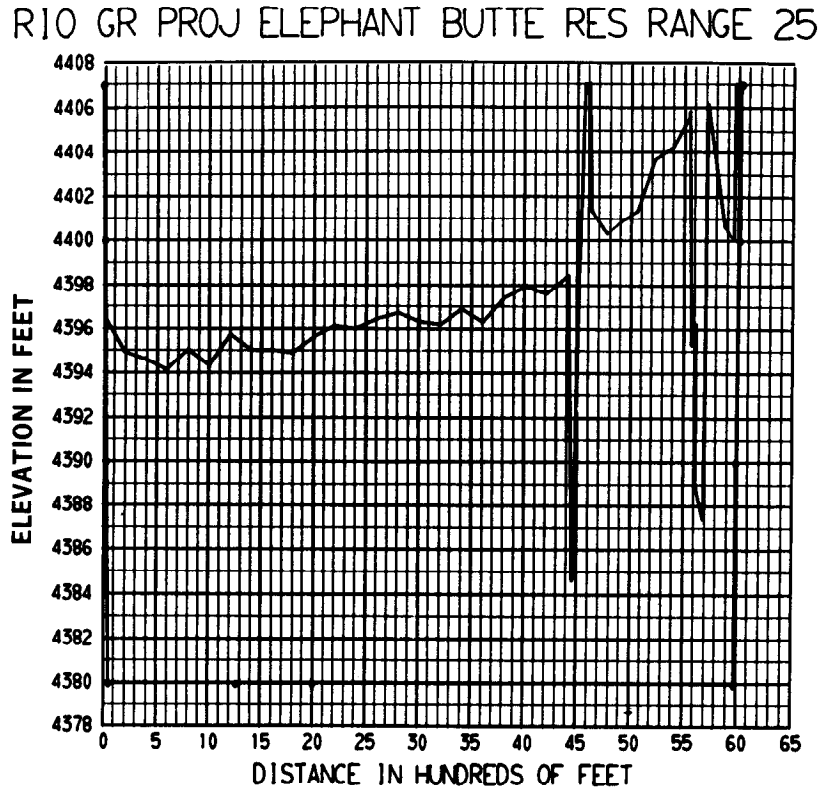


Figure 70. 1915 and 1969 sedimentation range profiles—Range 25.

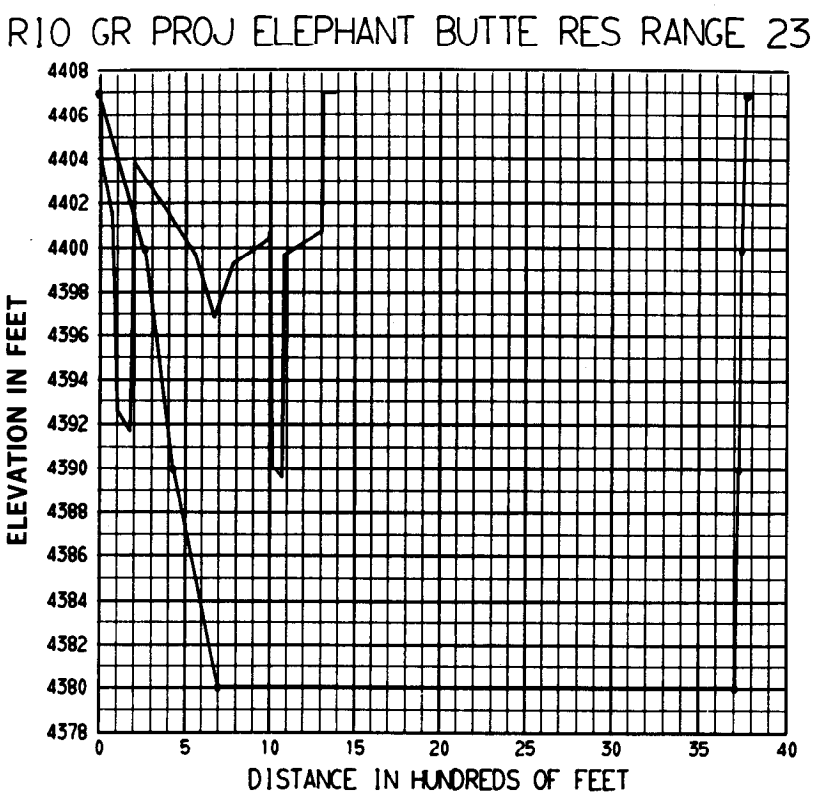


Figure 71. 1915 and 1969 sedimentation range profiles—Range 23.

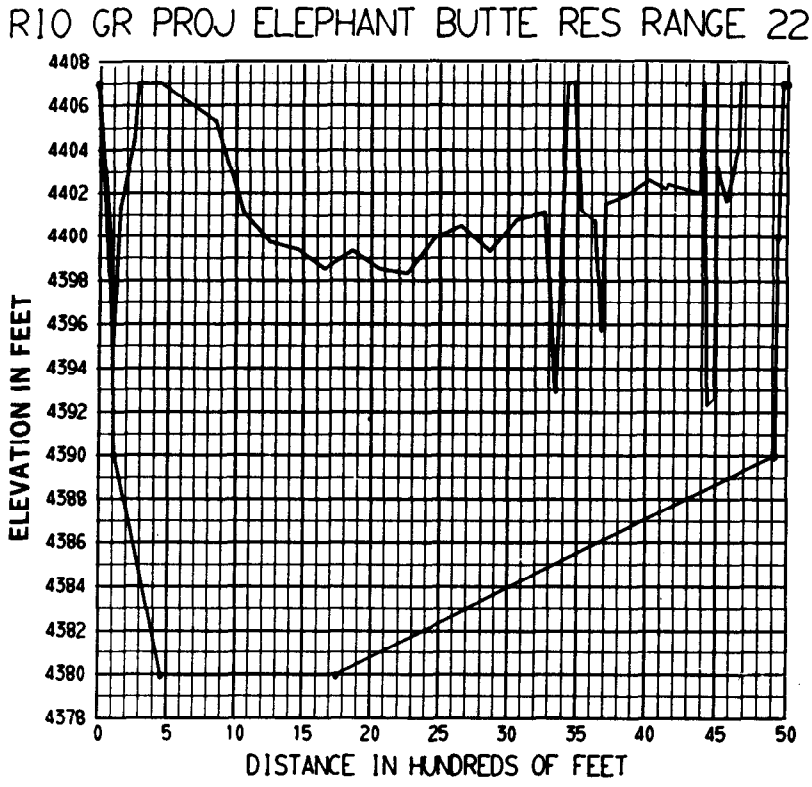


Figure 72. 1915 and 1969 sedimentation range profiles—Range 22.

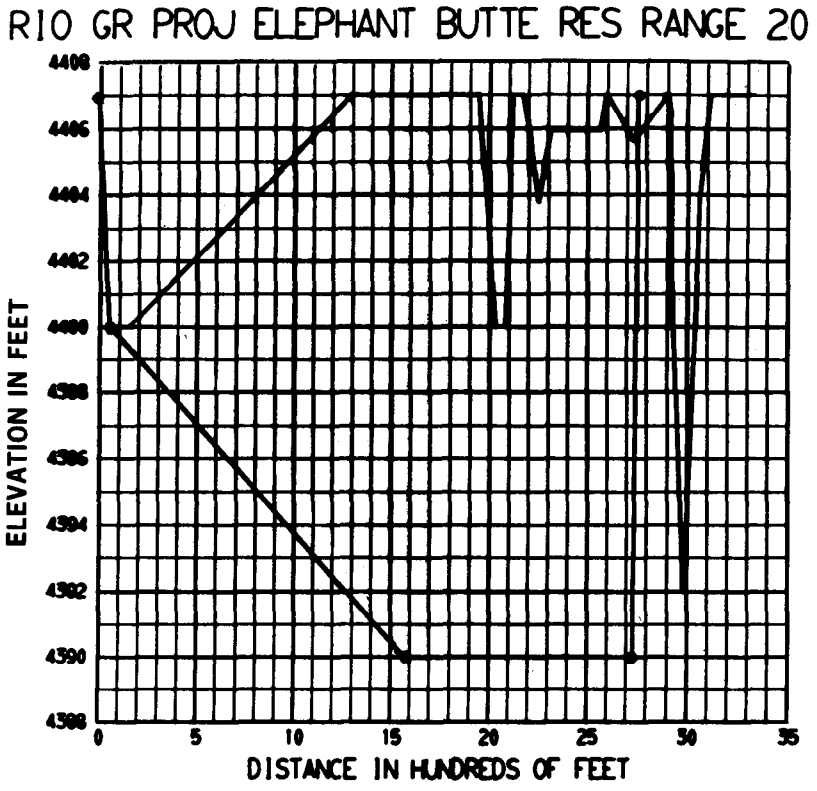


Figure 73. 1915 and 1969 sedimentation range profiles—Range 20.

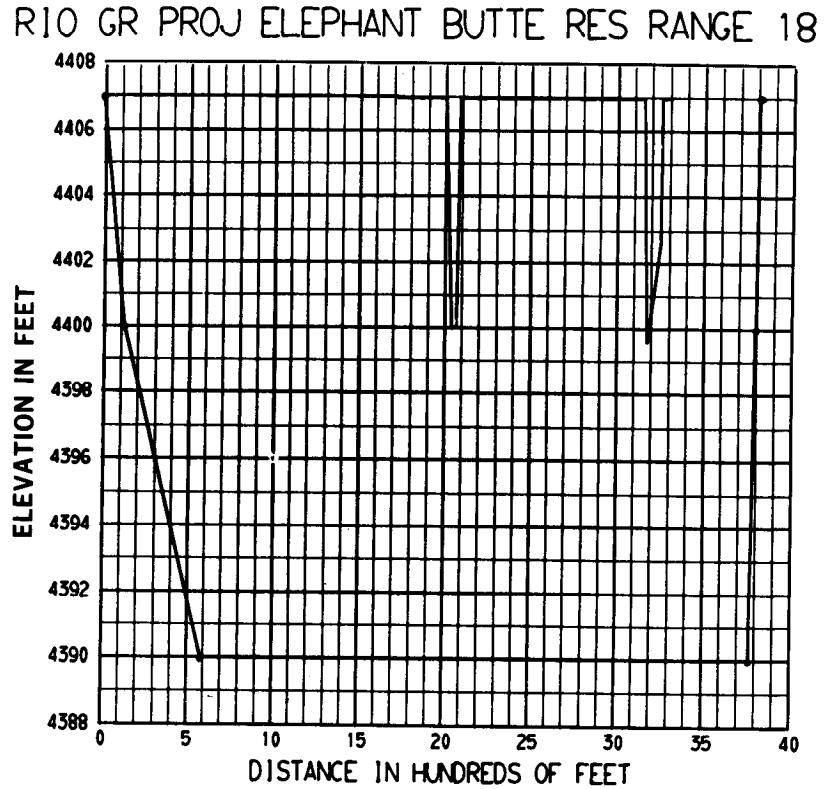


Figure 74. 1915 and 1969 sedimentation range profiles—Range 18.

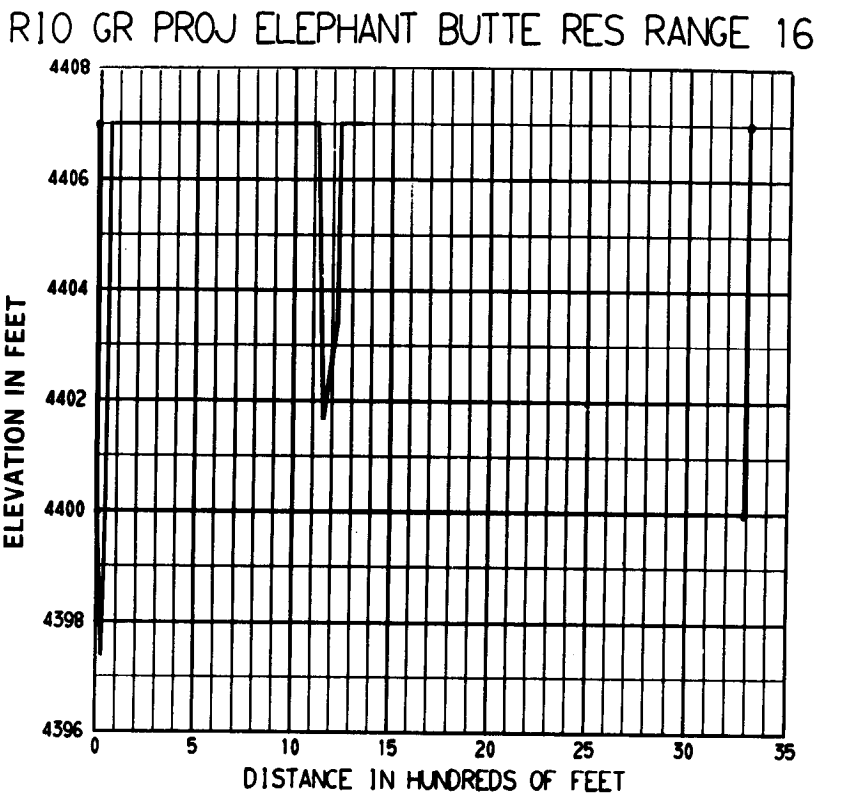


Figure 75. 1915 and 1969 sedimentation range profiles—Range 16.

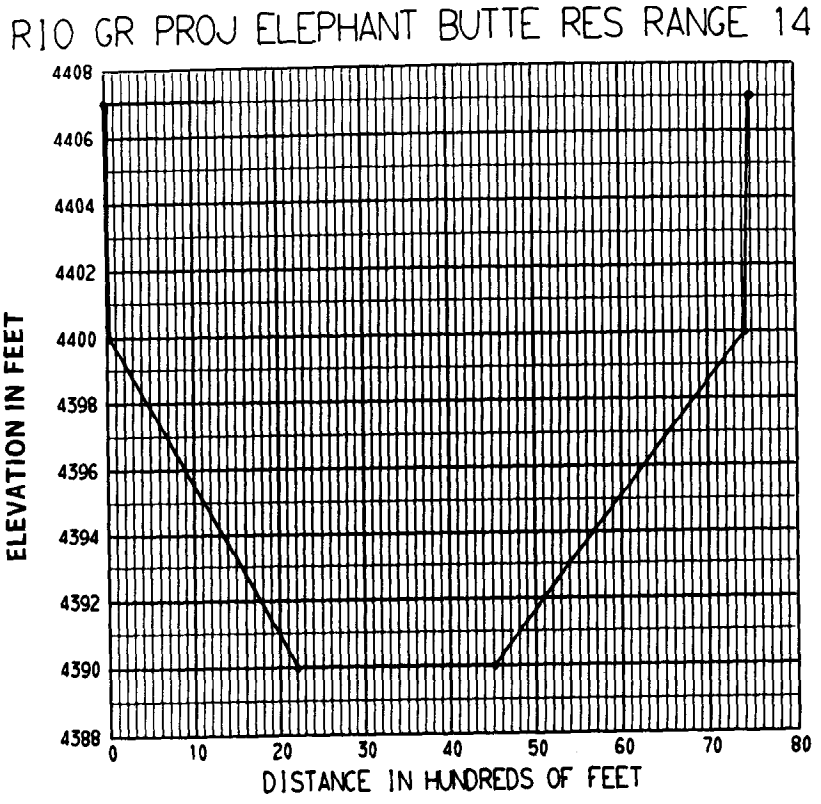


Figure 76. 1915 and 1969 sedimentation range profiles—Range 14.

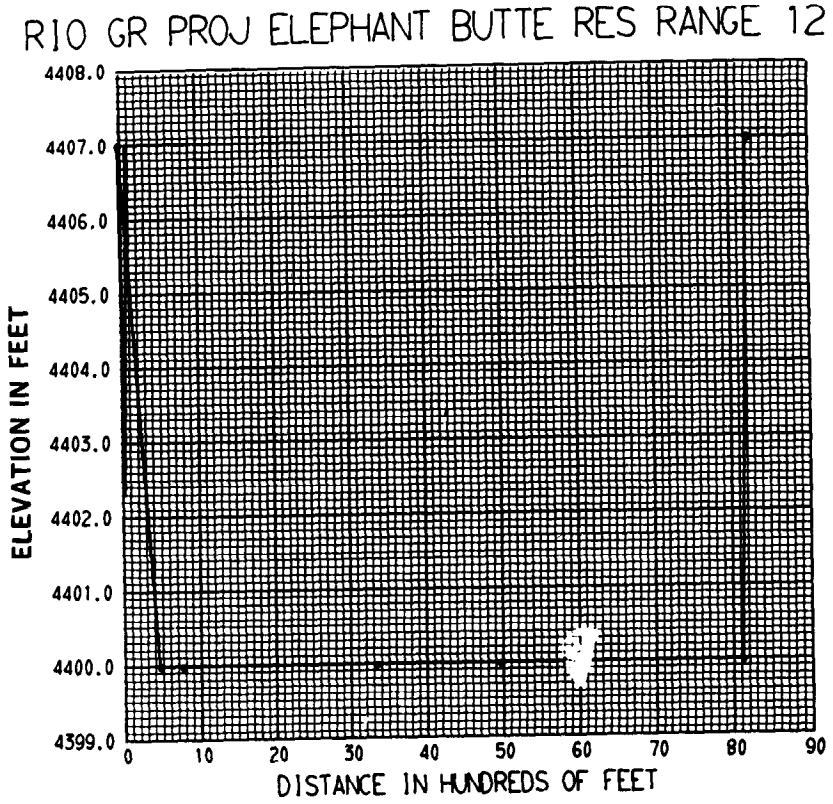


Figure 77. 1915 and 1969 sedimentation range profiles—Range 12.

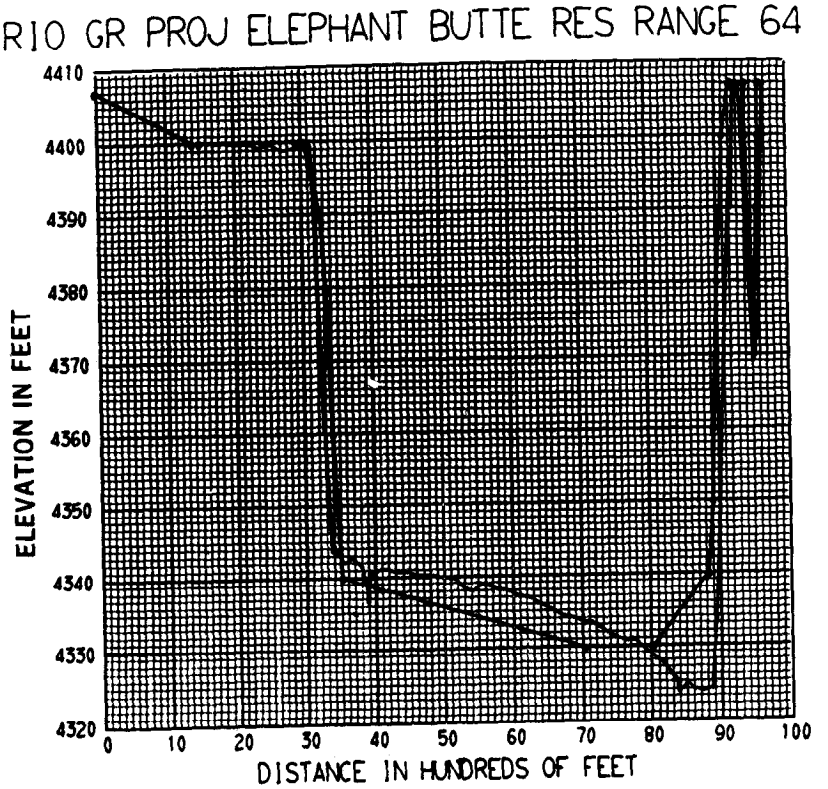


Figure 78. 1915 and 1969 sedimentation range profiles--Range 64 (located across mouth of Monticello Canyon).

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	1.12985×10^6	Centimeter-dynes
Foot-pounds	0.138255	Meter-kilograms
Foot-pounds	1.35582×10^7	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

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ABSTRACT

The Elephant Butte Reservoir was surveyed in 1969 to gather data needed in computing the present reservoir capacity. The data were also used to compute the volume of sediments that accumulated in the reservoir since the dam was closed in 1915. Reservoir capacity is 2,137,200 acre-feet and the surface area 36,600 acres at spillway crest elevation 4407 feet. Sediments accumulated at an annual rate of 9,164 acre-feet between 1915 and 1969. Seventeen sediment samples of reservoir deposits were collected from sites of the reservoir ranges immediately above the dam during the 1969 survey. An average unit weight of 62 lb/cu ft was determined from analyses of samples collected during 1952, 1957, and 1969. Particle size analyses of these samples indicated an average breakdown of 60 percent clay, 31 percent silt, and 9 percent sand. Sonic depth recording apparatus 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 8 to 42 feet throughout the reservoir length. Depths ranged from 10 to 44 feet for the laterally deposited sediments.

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REC-ERC-72-13
Lara, J M
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