THE 1972 SURVEY OF GLENDO RESERVOIR

Joe M. Lara
Engineering and Research Center
Bureau of Reclamation
Denver, Colorado

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ACKNOWLEDGEMENT

The hydrographic survey was made by Joe M. Lara, Hydraulic Engineer, Engineering and Research Center, Denver, Colorado. Survey personnel included Tito S. Padilla, Chief of Party, Ed Fanning, Mike Slane, and Gerald Olsen of the North Platte River Projects Office, Casper, Wyoming. They made the required land surveys and assisted in running the hydrograph survey. The field notes were transcribed for computer processing by personnel under the supervision of Barney F. Cronin, Chief, Engineering and Project Development Division, North Platte River Projects Office, Casper, Wyoming. This report was prepared under the supervision of Ernest L. Pemberton, Head, Flood and 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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The 1972 Survey of Glendo Reservoir

GENERAL INFORMATION

Location and Ownership

Glendo Reservoir is in Converse and Platte Counties of Wyoming. The dam is on the North Platte River about 4.5 miles southeast of Glendo, Wyoming. The dam and reservoir are owned and operated by the Bureau of Reclamation, U.S. Department of the Interior.

Description of the Dam

Glendo Dam (fig. 1) is an earthfill structure 190 feet high and 2,096 feet long. About 2,400 feet of dikes are required across a low area on the south side of the reservoir 1.5 miles west of the dam. An uncontrolled concrete spillway 45 feet wide is located about 450 feet north of the right abutment of the dam.

The power system consists of a two-unit plant having a rated head of about 100 feet. The installed capacity is 24 megawatts.

Description of the Reservoir

The original (1957) capacity of Glendo Reservoir (fig. 2) was 797,018 acre-feet at water surface elevation 4653 feet (uncontrolled spillway crest). The capacity in 1972 was 789,402 acre-feet at this elevation indicating a loss of 7,616 acre-feet since the dam was originally built. The length of the reservoir is about 14 miles.

Drainage Area Description

The net sediment contributing area above Glendo Reservoir is 4,190 square miles. This is determined by adjusting the total drainage area of 19,504 square miles above the reservoir as follows:

Station	Drainage area (mi^2)	Noncontributing area (mi^2)
Glendo	19,504	5,174
Alcova*	14,771	4,659
Difference	4,733	515

contributing area = 4,733 -515 -28** = 4,190 mi^2

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* North Platte River at Alcova Dam (closed for operation in 1938)
** Reservoir surface area in mi^2 at el 4653 ft (uncontrolled spillway crest)

The oldest rocks of the region form the erosion-resistant mountain cores and consist largely of pre-Cambrian granite with associated gneiss and schist. Paleozoic sediments, principally hard limestone, flank the granite mountain heights in steeply dipping beds. Mesozoic rocks are exposed in large areas of lower elevation west of Casper, between Casper and Douglas, and in the Laramie River Basin. Most of the sediments are thick shales with smaller amounts of sandstone, limestone, and coal.

The soils vary widely in nature even within relatively small portions of the basin. Generally, they are shallow and immature because of the arid climate and wind and water erosion. Except for the relatively small area of alluvial deposits, the soils are closely associated with the geology of the region.

Hydrographic Records

Streamflow records for the North Platte River at Orin, Wyoming, were used to estimate the inflow to Glendo Reservoir which showed an average of 1,077,220 acre-feet/yr, for 16 years of record (1958-73). Based on this same period, the average annual discharge of the North Platte River below Glendo Reservoir was 1,107,900 acre-feet, an indication of the outflow.

Figure 3 is a graph of the pool-duration curve showing the percent of time that pool elevations were equalled or exceeded.

SURVEY INFORMATION

This is the first survey of Glendo Reservoir since the dam was closed in 1957.

Surveying Methods

Initial fieldwork consisted of locating 68 of the reservoir sediment range ends that had been permanently monumented during the original survey. Standard land surveying procedures and equipment were used to run the levels on each range line above water. For ranges that were partly underwater, levels were run from the monuments to water's edge on each side of the reservoir. Temporary stations were established at the edge of the water to facilitate horizontal control.

The hydrographic survey was run in September, October, and November 1972, using sonic depth recording equipment to sound the submerged portions of the ranges. The sonic equipment was installed on the deck of a pontoon boat. First, the boat was positioned on a range line as near to the shore as possible. Then the line was profiled from the temporary station established on the water's edge to the

center point of the transducer using a chain to measure horizontal distances and a level rod to measure depths. The depth recorder was turned on and the boat propelled across the range to profile the remaining portion of the range line underwater. A man on shore 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 means of marking the "fix" lines on the sonar chart. Upon reaching the other end of the range line, the process of profiling the line from the transducer centerline to the end at the temporary station was repeated as in the beginning. When this was completed, the man on the opposite shore was told to release the wire of the distance measuring machine and a gasoline-powered engine was used to reel it back in.

Water surface elevations of the reservoir at the end of each range line were measured using a hand level and rod at the beginning and ending of the sounding run. The water surface elevations then provide the bases for transcribing the sonar charts.

RESERVOIR SEDIMENT DISTRIBUTION

The longitudinal thalweg profiles in figure 4 show how sediments were distributed in the reservoir. The thalweg elevation or lowest point of the range line was used to plot the profiles for the 1957 and 1972 conditions.

The greatest depths of sediment deposits occurred between 6 and 14 miles above the dam. Maximum depth of about 10 feet was deposited between ranges 9 and 10. An average of about 0.3 foot of sediment was deposited between 15 and 19 miles above the dam. The profiles showed slight degradation in the reach between ranges 24 and 26.

Table 1 summarizes the area, capacity, and sediment data for Glendo Reservoir based on the 1972 survey results. Total sediments that accumulated in the reservoir were 7,616 acre-feet since 1957 (see table 1, column 12).

A graph of the depth-capacity (fig. 5) relation using the original (1957) data indicated the reservoir to be a flood plain-foothill, Type II as classified.* The sediment disposition curves in figure 6 show the actual sediment distribution (1972 survey data) compared with the one from the Type II computations. The curves show the percent depth against the percent sediment. Examining the curves

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* See "Design of Small Dams," Second edition, Revised Reprint, 1974, p. 781, U.S. Department of the Interior, Bureau of Reclamation.

discloses that, for the most part, the sediment was actually distributed at lesser quantities than indicated by a Type II. This might be partially due to the small quantity of sediment that has heretofore accumulated. Other factors influencing this actual sediment distribution would include the type of reservoir operation and the size and texture of the inflowing sediments.

Profiles of 13 reservoir sedimentation ranges surveyed in 1972 and 1957 are shown in figures 7 through 19 to represent typical laterally distributed sediments in the reservoir.

SEDIMENT ANALYSES

Sediment Accumulations

A total volume of 7,616 acre-feet of sediments has accumulated in Glendo Reservoir since the dam was completed over 14 years ago. An average annual accumulation rate of 524 acre-feet was computed for the 14-year period.

Reservoir Sedimentation Summary

Table 2 summarizes the reservoir sediment data as of the May 1972 survey. The data include a tabulation of the sediment accumulation information mentioned in the previous section. A sediment yield rate of 0.13 acre-foot/mi^2/yr was computed from the 1972 survey data.

Since sediment samples were not collected during the survey, information on the unit weight or particle size analyses of the deposited sediments was not available. A unit weight of 70 lb/ft^3 was assumed to compute the sediment deposition of 198 tons/mi^2/yr.

DEGRADATION BELOW DAM

A system of six degradation ranges (fig. 20) was established below Glendo Dam. The ranges were originally surveyed in 1957 and resurveyed in 1972. The profiles of five of these ranges are shown in figures 21 through 25.

The profiles show negligible degradation at range 2; however, degradation occurred at the remaining ranges in the following amounts:

Range No.	Average Degradation (ft)
3	4
4	5.6
5	1.3
6	5.3

Based on these observations, the channel regime of the North Platte River, below Glendo Dam has undergone some degradation. From the preceding tabluation a degradation depth of greater than 5 feet is indicated at range 6, which is about 10 miles below the dam.

RESERVOIR AREA AND CAPACITY

The 1972 Glendo Reservoir surface areas were determined by using reservoir sedimentation range width ratios. Briefly, this method entailed comparing the 1972 range widths with the 1957 widths. The ratio, 1972 width/1957 width is used in the computations. The computations are simplified by subdividing the reservoir into segments using the sedimentation range lines as segmental boundaries. The 1957 reservoir topographic maps were planimetered to obtain the surface areas at 10-foot contour intervals. Significant changes were noted in the replanimetered results of these original areas, particularly for elevations from 4510 through 4540 feet (see table 1, columns 2 and 3). These differences were apparently due, in part, to the the borrow areas which were excavated after the 1957 reservoir areas were planimetered. Adjustments to the areas were made to account for these changes (see table 1, column 6). Because the areas at elevation 4550 feet and above (table 1, column 3) were replanimetered within the prescribed limit of practical accuracy (less than 3 percent), the original areas (column 2) were used for this upper range and tabulated in column 6.

The 1972 surface areas were the control parameters for computing the reservoir capacities by electronic computer. The program was written to compute areas at 1-foot increments by linear interpolation between the 10-foot contour intervals. Respective capacities and capacity equations were then obtained by integration of the area equations. The resulting capacity equations are of a second order polynomial form,

$$y = a_1 + a_2x + a_3x^2$$

where:

y = capacity
x = distance above an elevation base
a_1 = intercept
a_2 = coefficient
a_3 = coefficient

Results of the 1972 Glendo Reservoir area and capacity computations are listed in table 1, columns 9 and 10. Listed in columns 6 and 8 of the table are adjusted values of the original areas and capacities

for comparison with the 1972 values. The 1972 area and capacity curves are shown in figure 26. The original area and capacity curves were not included in this figure because the differences in values between surveys were too small to be made discernible. At the uncontrollable spillway crest elevation of 4653 feet, the present capacity of Glendo Reservoir is 789,402 acre-feet and the surface area is 17,986 acres.

SUMMARY AND CONCLUSIONS

The 1972 sediment survey report of Glendo Reservoir includes a discussion of the methods used to measure and study the 14.5 years of sediment accumulation in the reservoir. Also, the field surveying equipment is briefly described. The survey was run primarily to collect the data necessary for computing the present capacity of Glendo Reservoir.

Standard land surveying methods were used to run levels from the permanent range end monuments to stations temporarily established at the reservoir water's edge. Sonic depth recording equipment mounted on a boat was used to run the hydrographic survey. This system continuously recorded reservoir depths as the boat was propelled across the range line. Five men were needed to run the hydrographic survey. A distance measuring machine was used to maintain horizontal control across the range line.

Water surface elevations at each range line were measured with a hand level at the beginning and ending of the sounding run.

The greatest depths of sediment deposits occurred in the reservoir between 6 and 14 miles above the dam with the maximum depth of about 10 feet deposited between ranges 9 and 10.

Analyses of the reservoir sediment data collected during the 1972 survey indicated a total sediment inflow volume of 7,616 acre-feet at elevation 4653 feet (uncontrolled spillway crest) since the dam was closed in 1957. This indicates a loss in reservoir capacity of less than 1 percent. The average annual sediment accumulation rate of 524 acre-feet and the sediment yield rate of 0.13 acre-foot/mi^2/yr were noted during the 1957 to 1972 period. Degradation below the dam varied from 1 foot to greater than 5 feet as observed at four downstream ranges.

The capacity of Glendo Reservoir, as determined from the 1972 survey, is 789,402 acre-feet and the surface area is 17,986 acres at the uncontrollable spillway crest elevation of 4653 feet. The 1972 reservoir surface areas were computed by the width ratio method. Both reservoir area and capacity data were compiled at 1-foot intervals using electronic computer facilities.

Table 1. - Summary of reservoir area, capacity, and sediment data

1	2	3	4	5	6	7	8	9	10	11	12
	1958 Survey							1972 Survey		Sediment	
Elev. (ft)	Area (ac)	Area (ac)	Δ Area	% Error	Adj. Area	Cap. (ac-ft)	Adj. Cap. (ac-ft)	Area (ac)	Cap. (ac-ft)	Area (ac)	Vol. (ac-ft)
4508	0	0									
4510	16	19.09	-3.09	19.3	19	16	19	18	18	1	1
4520	99	92.61	6.39	6.5	93	558	579	74	478	25	101
4530	306	284.87	21.13	6.9	285	2,461	2,469	273	2,213	12	256
4540	687	641.77	45.23	6.6	642	7,192	7,104	642	6,788	0	316
4550	1,471	1,496.10	-25.10	1.7	1,470	17,774	17,664	1,470	17,348	0	316
4560	2,360	2,338.73	21.27	0.90	2,360	36,904	36,814	2,280	36,098	80	716
4570	3,210	3,198.91	11.09	0.35	3,210	64,780	64,664	3,130	63,148	80	1,516
4580	4,040	4,047.21	-7.21	0.18	4,040	100,904	100,914	4,000	98,798	40	2,116
4590	5,200	5,241.89	-41.89	0.81	5,200	146,858	147,114	5,090	144,248	110	2,866
4600	6,630	6,780.71	-150.71	2.3	6,630	205,993	206,264	6,520	202,298	110	3,966
4610	7,830	7,906.09	-76.09	0.97	7,830	278,303	278,564	7,770	273,748	60	4,816
4620	9,240	9,329.30	-89.30	0.97	9,240	363,375	363,914	9,170	358,448	70	5,466
4630	11,120	11,252.43	-132.43	1.2	11,120	464,658	465,714	10,970	459,148	150	6,566
4635					12,455	523,307	524,651	12,365	517,485	90	7,166
4640	13,790	14,093.77	-303.77	2.2	13,790	588,641	590,264	13,760	582,798	30	7,466
4650	17,050	17,212.19	-162.19	0.95	17,050	742,657	744,464	17,050	736,848	0	7,616
4653					17,986	795,196	797,018	17,986	789,402	0	7,616
4660	20,170	20,369.43	-199.43	0.99	20,170	928,643	930,564	20,170	922,948	0	7,616
4669	23,320	23,251.20	68.80	0.30	23,320	1,124,108	1,126,269	23,320	1,118,653	0	7,616
4670	23,670				23,670		1,149,764	23,670	1,142,148	0	7,616

Column Descriptions

Col. No.	Description
1	Reservoir elevation
2	Area measured in original (1958) survey
3	1958 areas measured by planimeter in 1974
4	Differences in areas measured in original survey (Col. 2) and by planimeter in 1974 (Col. 3)
5	Percent error in areas = (Col. 4/Col. 2) 100
6	1958 areas adjusted. Same areas from Col. 3 (rounded) for els. 4508 through 4540 which shows % error of 6.5 or greater in Col. 5. Areas from Col. 2 beginning at el. 4550 on up were used in remaining tabulation

Column Descriptions

Col. No.	Description
7	Capacities computed from areas in Col. 2 (Lagrangian interpolation method used)
8	Capacities computed from areas in Col. 6 (Linear interpolation used)
9	Areas computed from 1972 data
10	Capacities computed from areas in Col. 9
11	Differences in areas between surveys = Col. 6 - Col. 9
12	Sediment volumes = Col. 8 - Col. 10

Table 2. - Reservoir sediment data summary

RESERVOIR SEDIMENT DATA SUMMARY

Glendo
NAME OF RESERVOIR

DATA SHEET NO.

DAM

1. OWNER U.S. Dept. of Int., Bur. of Recl.	2. STREAM North Platte	3. STATE Wyoming
4. SEC. 13 & 24 TWP. 29N RANGE 68W	5. NEAREST P. O. Glendo 4.5 SE	6. COUNTY Platte–Converse
7. LAT. 42° 28′ 45″ LONG. 104° 56′ 59″	8. TOP OF DAM ELEVATION 4675	9. SPILLWAY CREST ELEV. [1] 4653

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	4653	17,986	272,367	797,018	
b. MULTIPLE USE	4635	12,455	[3] 459,987	524,651	Oct. 18, 1957
c. POWER					16. DATE NORMAL OPER. BEGAN
d. WATER SUPPLY					
e. IRRIGATION					
f. CONSERVATION					
g. INACTIVE	[2] 4570	3,210	[4] 64,664	64,664	April 1959

WATERSHED

17. LENGTH OF RESERVOIR [5] 28.7 MILES		AV. WIDTH OF RESERVOIR 1.00	MILES
18. TOTAL DRAINAGE AREA 19,504 SQ. MI.		22. MEAN ANNUAL PRECIPITATION 13.25 (30)	INCHES
19. NET SEDIMENT CONTRIBUTING AREA 4,190 SQ. MI.		23. MEAN ANNUAL RUNOFF 1.11	INCHES
20. LENGTH 151 MILES	AV. WIDTH 129 MILES	24. MEAN ANNUAL RUNOFF [6] 1,154,550	AC.-F T.
21. MAX. ELEV. 10,274	MIN. ELEV. 4508	25. ANNUAL TEMP: MEAN 47.1 RANGE [7] 25-72	

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.
Oct. 18, 1957			Contour (D)	68 (R) 10 ft (CI)	17,986	797,018	
May 3, 1972	14.54	14.54	Range (D)	68 (R)	17,986	789,402	0.68

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
Oct. 18, 1957						
May 3, 1972	13.07	1,077,220	1,674,790	15,709,430	1,077,220	15,709,430

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
Oct. 18, 1957						
May 3, 1972	7,616	524	0.13	7,616	524	0.13

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
Oct. 18, 1957							
May 3, 1972	*70	198	198	0.066	0.956	565	544

*Assumed.

26. DATE OF SURVEY	43. DEPTH DESIGNATION RANGE IN FEET BELOW, AND ABOVE, CREST ELEVATION											
	145-133	133-113	113-93	93-73	73-53	53-33	33-13	13-C-				
	PERCENT OF TOTAL SEDIMENT LOCATED WITHIN DEPTH DESIGNATION											
May 3, 1972	1.3	2.8	5.3	18.5	24.2	19.7	26.2	2.0				

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														
May 3, 1972	2.0	2.1	4.2	9.4	12.0	12.2	17.6	14.3	20.3	5.9					

45. RANGE IN RESERVOIR OPERATION

WATER YEAR	MAX. ELEV.	MIN. ELEV.	INFLOW, AC.-FT.	WATER YEAR	MAX. ELEV.	MIN. ELEV.	INFLOW, AC.-FT.
1958	4628.56	4508.00	1,242,550	1970	4645.34	4573.11	1,155,440
1959	4638.19	4573.00	875,050	1971	4649.08	4585.03	1,674,790
1960	4635.91	4570.97	909,680	1972	4637.16	4560.42	1,250,220
1961	4627.97	4569.39	693,870	1973	4650.94	4588.05	2,136,060
1962	4636.33	4567.52	960,590				
1963	4632.65	4567.32	1,092,430				
1964	4633.07	4561.08	1,115,090				
1965	4638.35	4577.84	1,051,680				
1966	4630.74	4548.10	1,072,710				
1967	4639.64	4564.79	921,510				
1968	4635.73	4571.50	1,175,090				
1969	4632.88	4560.73	1,145,980				

46. ELEVATION-AREA-CAPACITY DATA

ELEVATION	AREA	CAPACITY	ELEVATION	AREA	CAPACITY	ELEVATION	AREA	CAPACITY
1957 Survey			1972 Survey					
4508	0	0	4508	0	0			
4510	19	19	4510	18	18			
4520	93	579	4520	74	473			
4530	285	2,469	4530	273	2,213			
4540	642	7,104	4540	642	6,788			
4550	1,470	17,664	4550	1,470	17,348			
4560	2,360	36,814	4560	2,280	36,098			
4570	3,210	64,664	4570	3,130	63,148			
4580	4,040	100,914	4580	4,000	98,798			
4590	5,200	147,114	4590	5,090	144,248			
4600	6,630	206,264	4600	6,520	202,298			
4610	7,830	278,564	4610	7,770	273,748			
4620	9,240	363,914	4620	9,170	358,448			
4630	11,120	465,714	4630	10,970	459,148			
4640	13,790	590,264	4640	13,760	582,798			
4650	17,050	744,464	4650	17,050	736,848			
4653	17,986	797,018	4653	17,986	789,403			

47. REMARKS AND REFERENCES

[1] Uncontrolled.
[2] Top of dead storage—el. 4545.
[3] Includes irrigation use = 100,000 acre-ft and power and reregulation uses = 359,987 acre-ft.
[4] Includes dead storage capacity of 11,349 acre-ft at el. 4545.
[5] No. Platte R., 21.3 mi; Whiskey Gulch 2.1 mi; Cottonwood Cr, 1.0 mi; & Muddy Cr. 4.3 mi.
[6] Computed inflow for the 1958-73 period.
[7] Average temperature of coldest and warmest month at Glenrock, Wyo. station.

"Sedimentation Surveys of Pathfinder and Seminoe Reservoirs—North Platte River, Wyoming," U.S. Dept. of the Interior, Bureau of Reclamation, May 1953.

48. AGENCY MAKING SURVEY U.S. Dept. of the Interior, Bureau of Reclamation, No. Platte River Projects, Casper, Wyo.

49. AGENCY SUPPLYING DATA Bureau of Reclamation, U.S. Dept. of the Interior

50. DATE April 15, 1975

April 1966

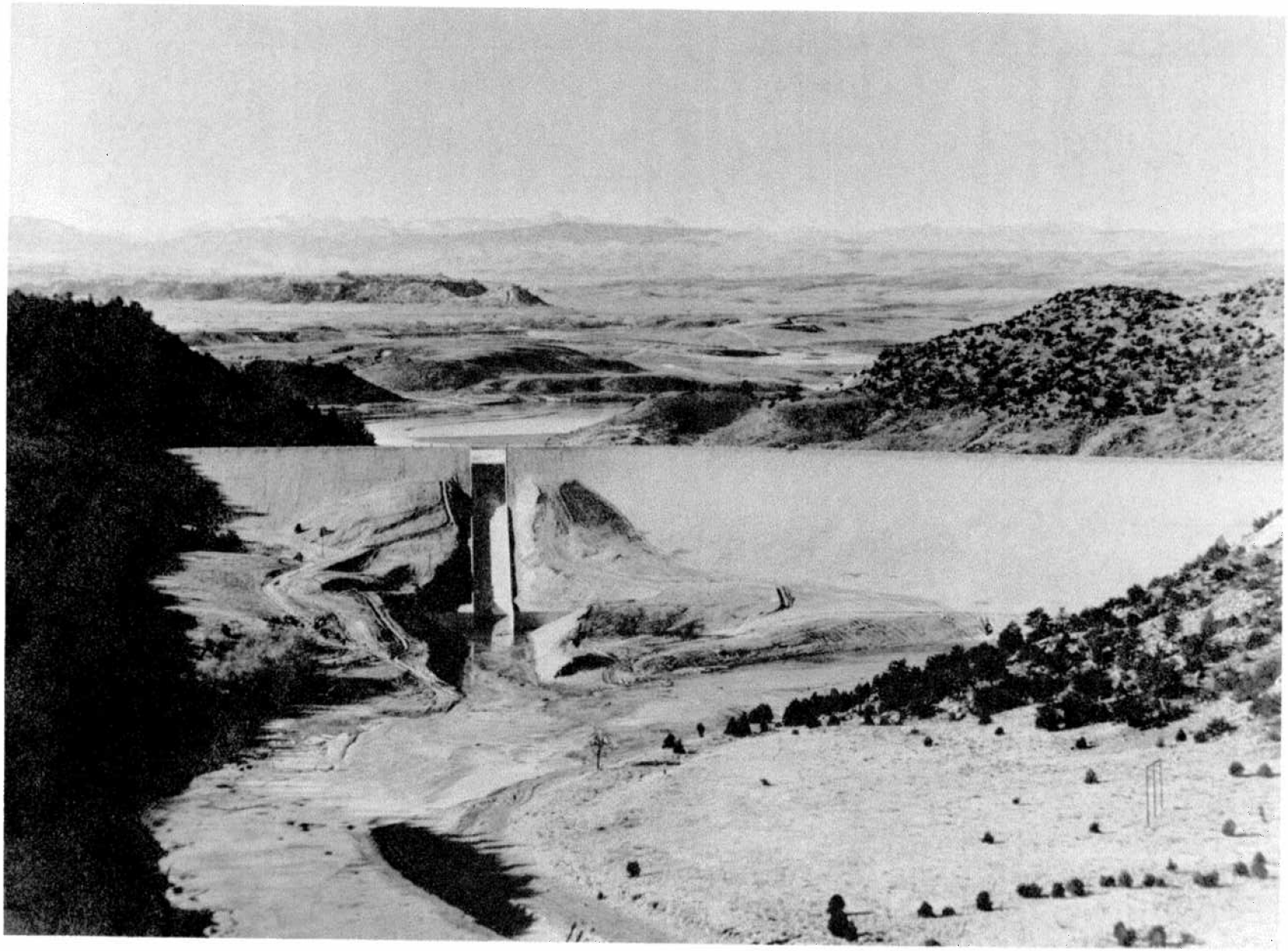

Figure 1. - Glendo Dam.

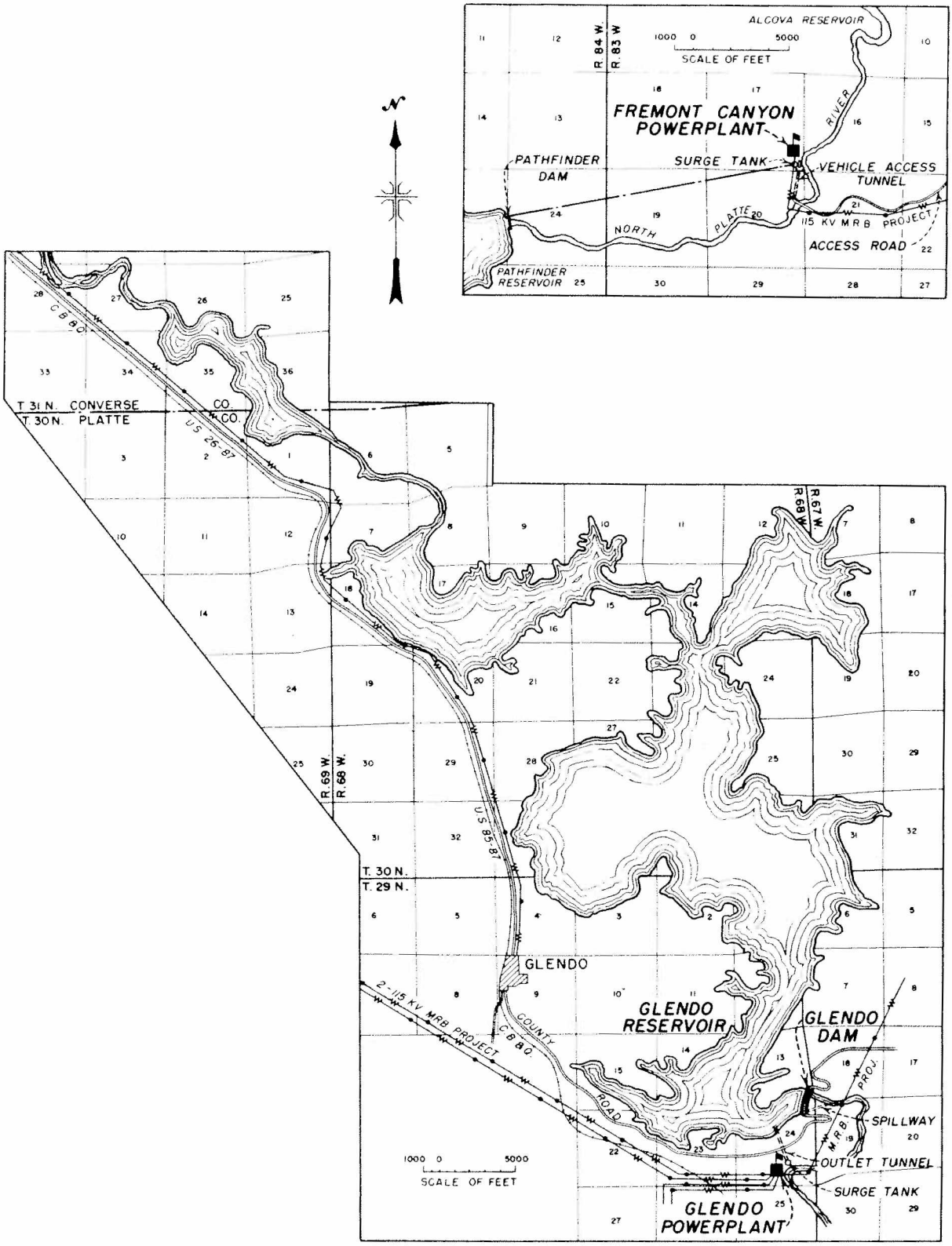

Figure 2. - Glendo Reservoir.

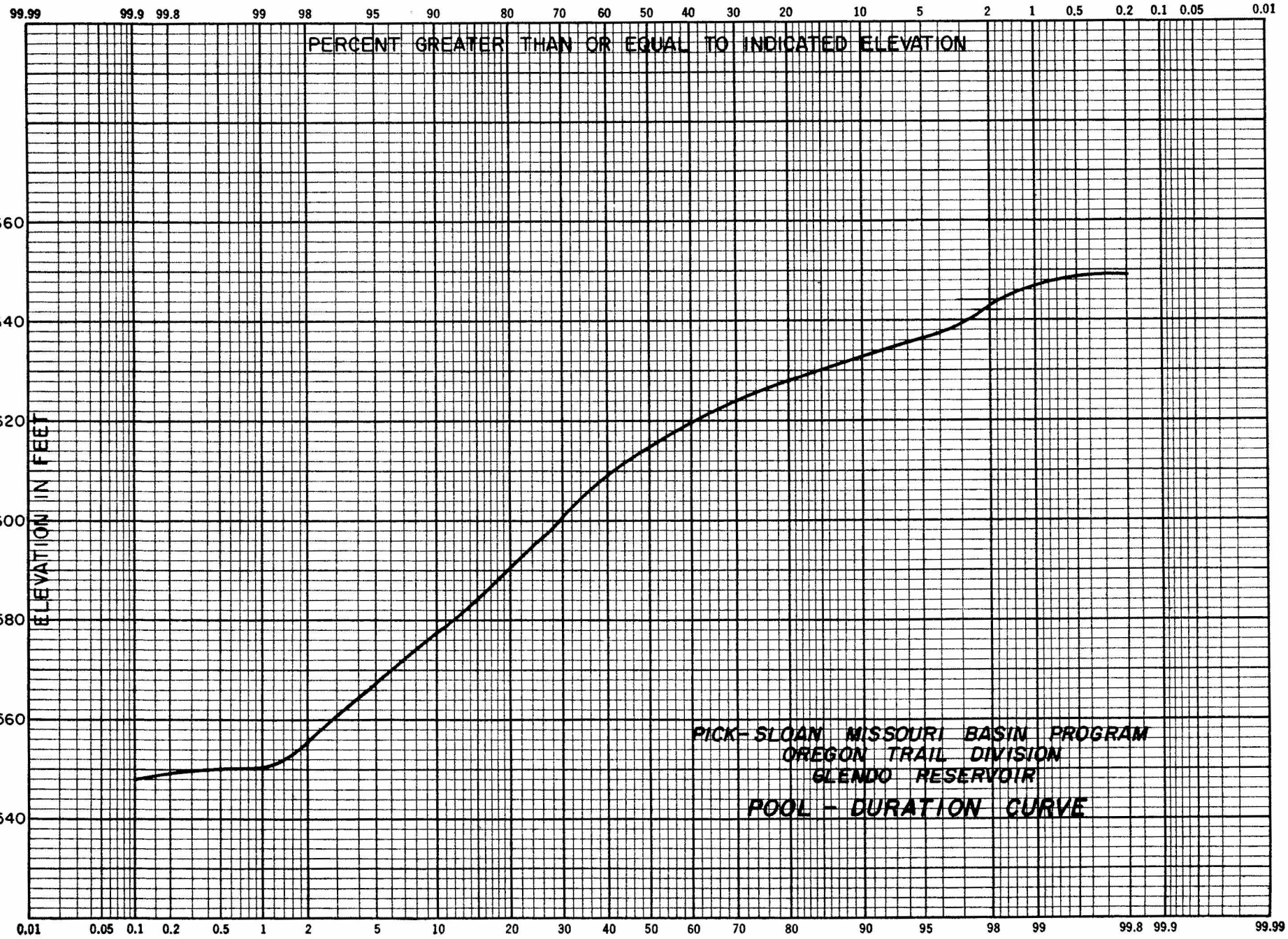

Figure 3. - Pool-duration curve.

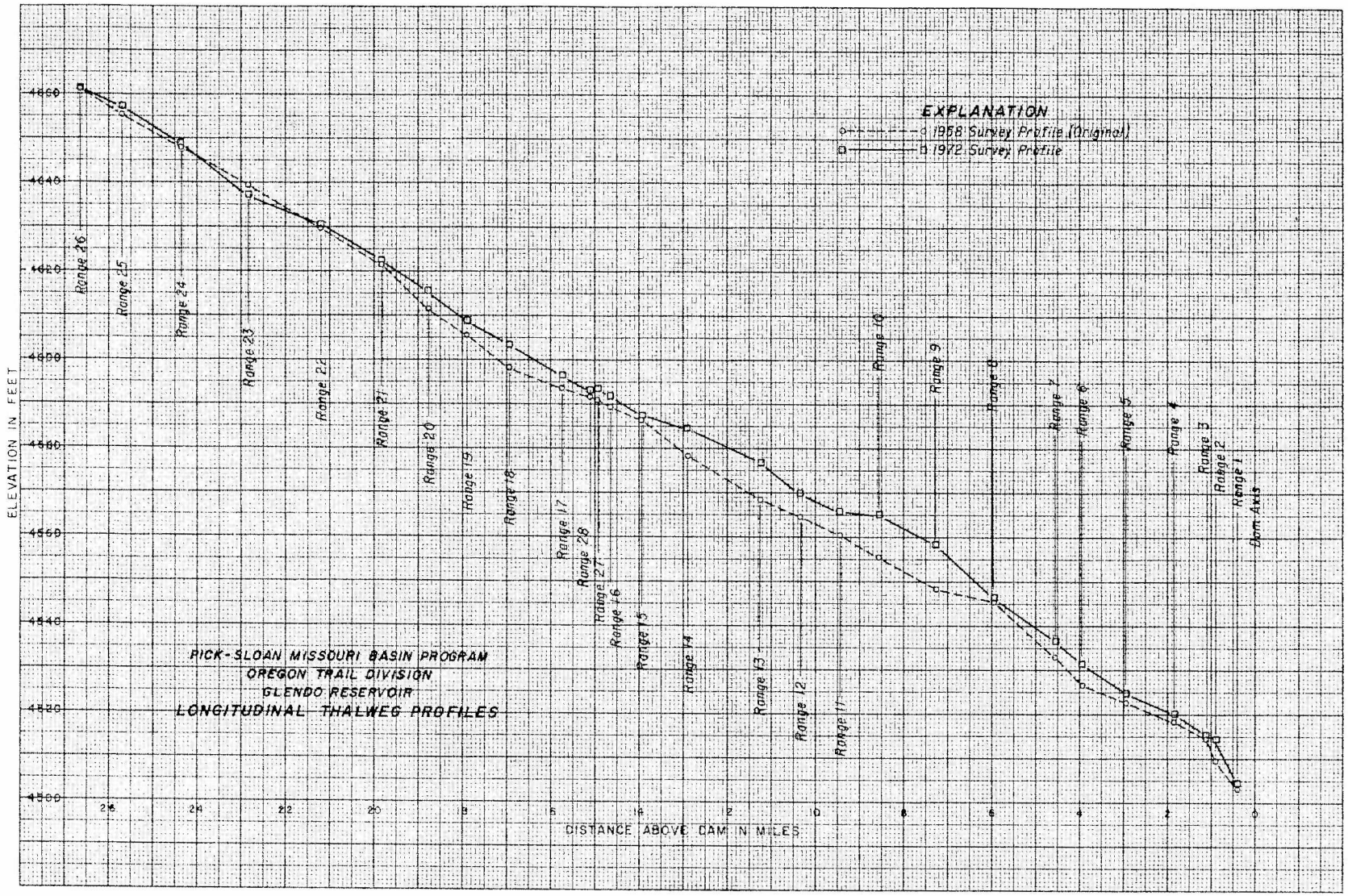

Figure 4. - Longitudinal thalweg profiles.

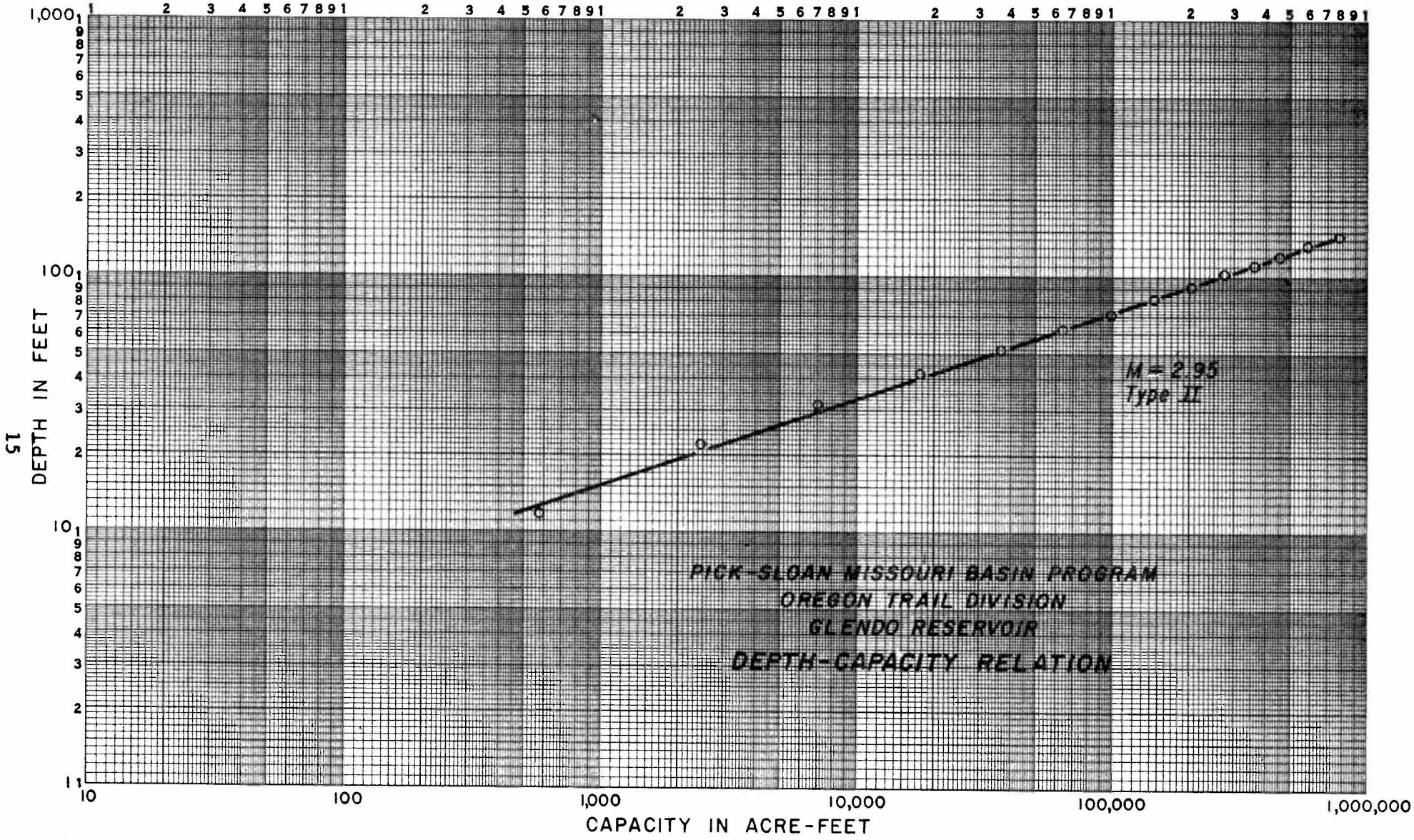

Figure 5. - Depth-capacity relation.

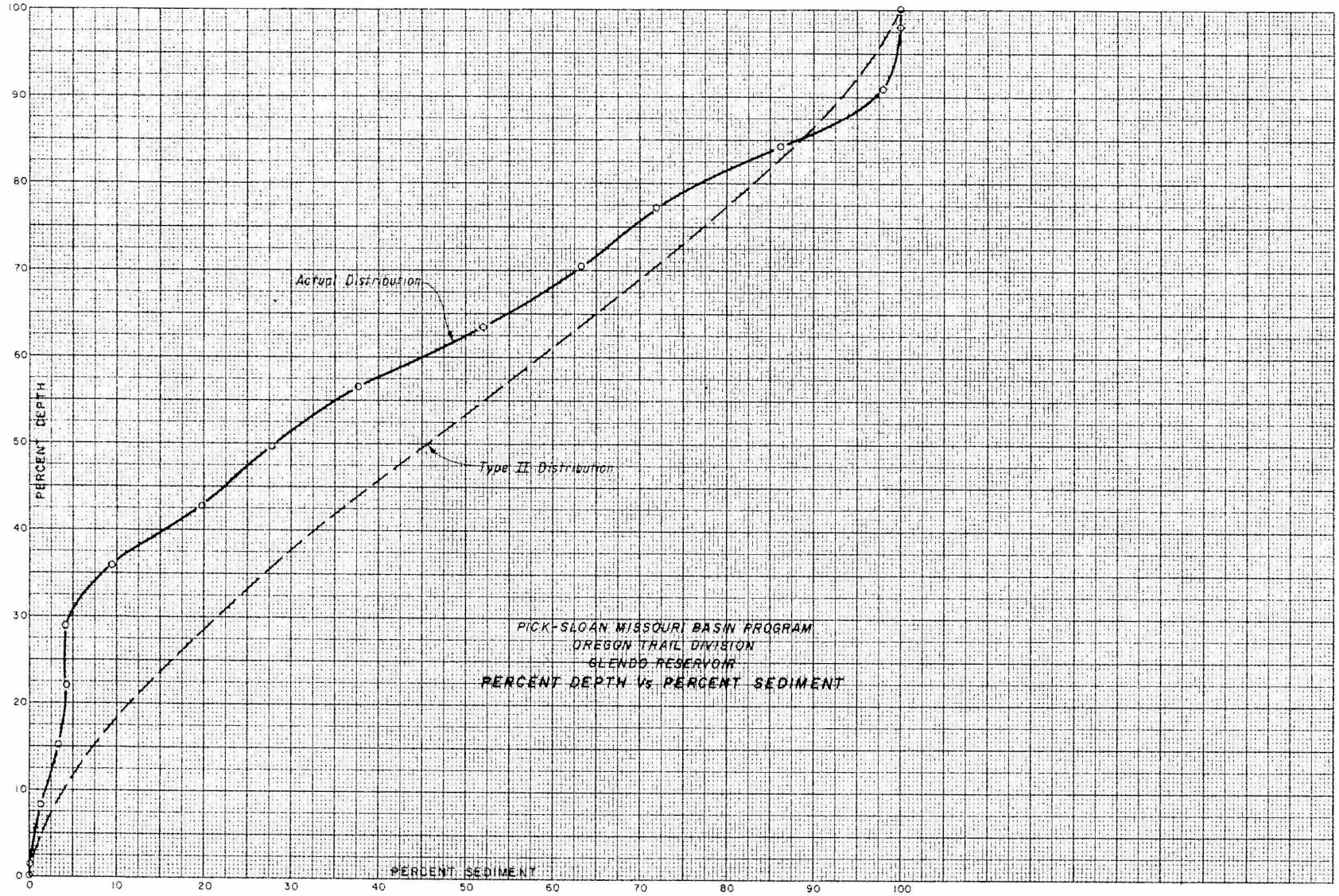

Figure 6. - Sediment disposition curves.

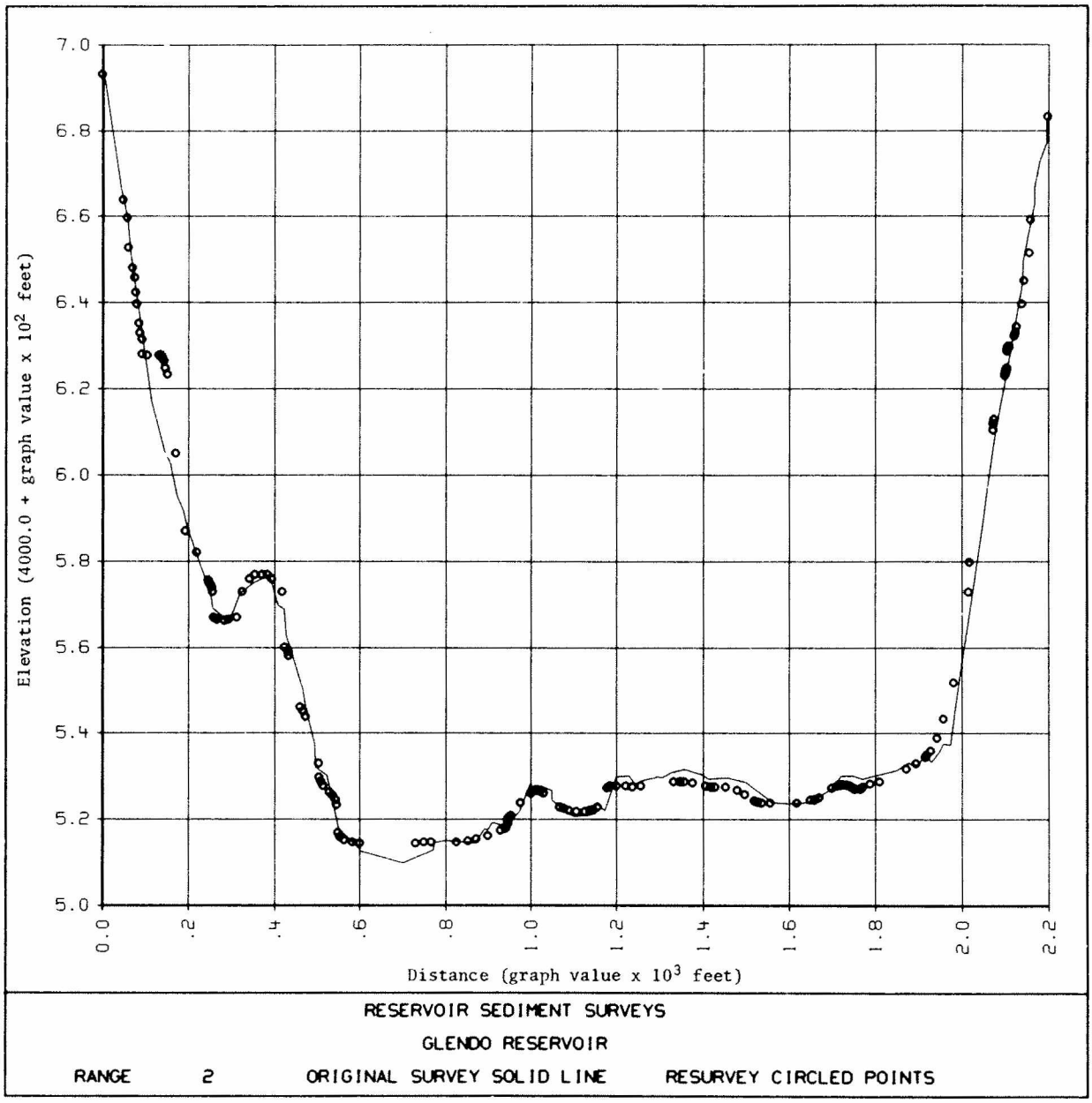

Figure 7. - 1957 and 1972 sedimentation range profiles - range 2.

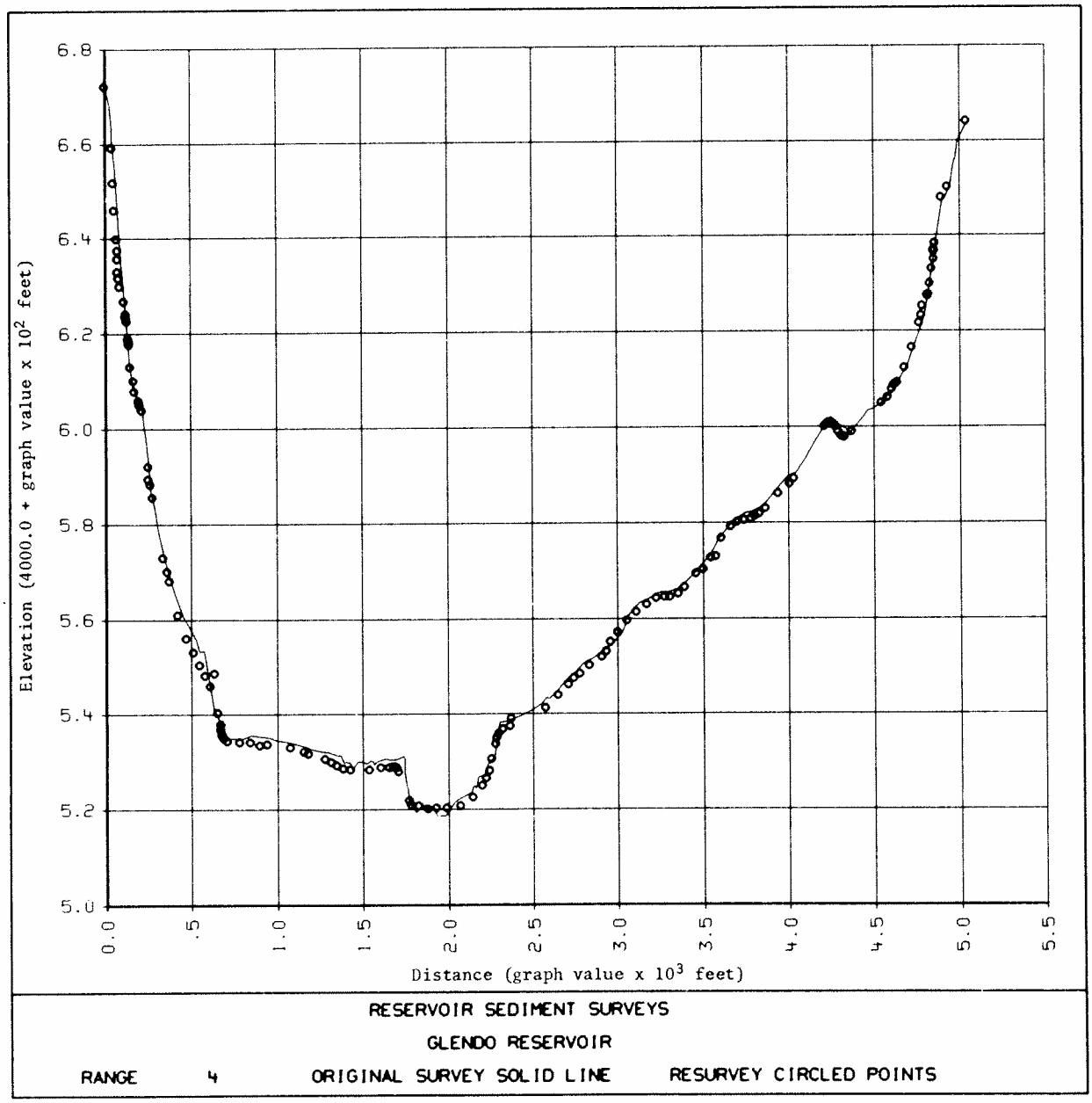

Figure 8. - 1957 and 1972 sedimentation range profiles - range 4.

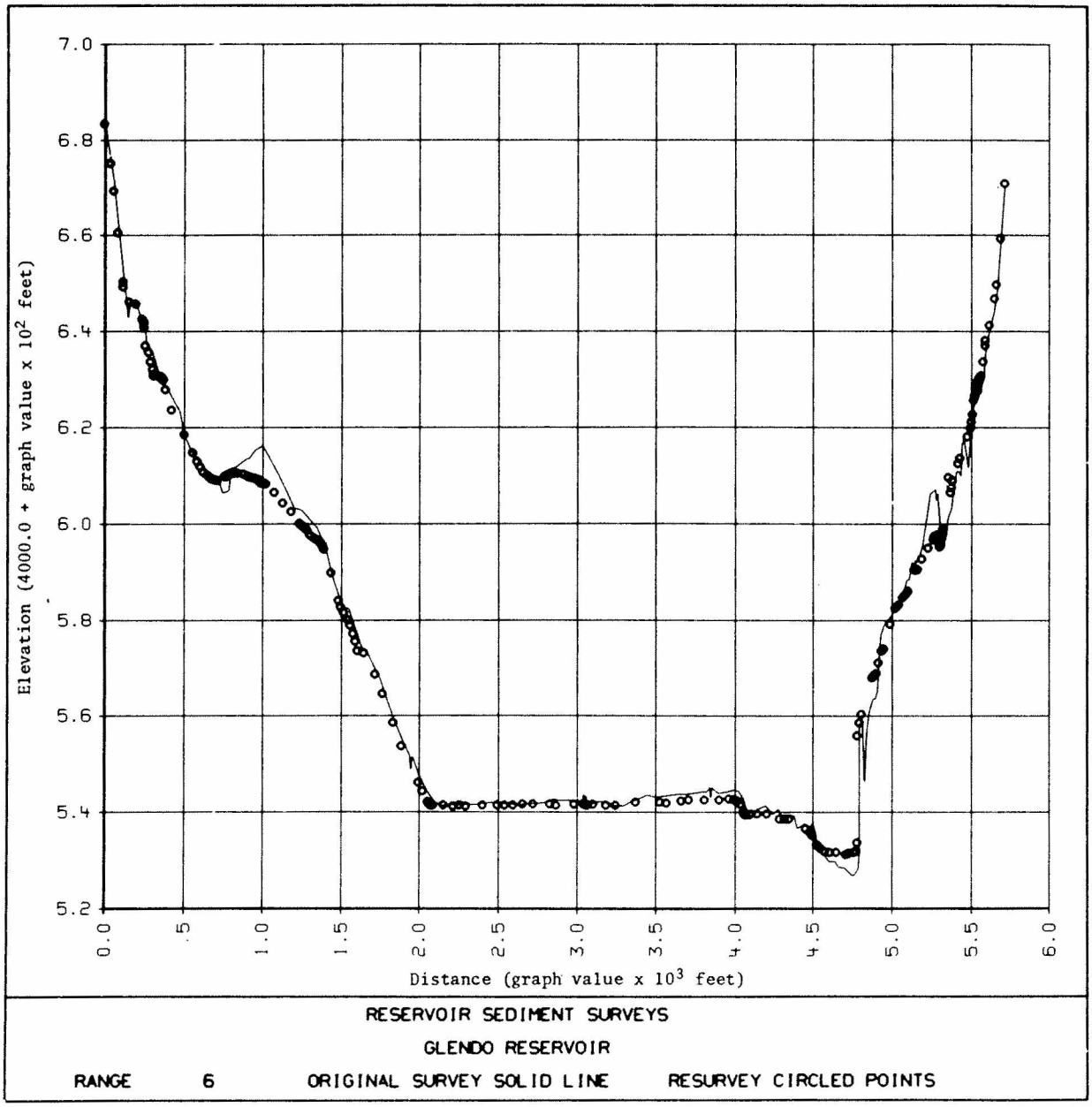

Figure 9. - 1957 and 1972 sedimentation range profiles - range 6.

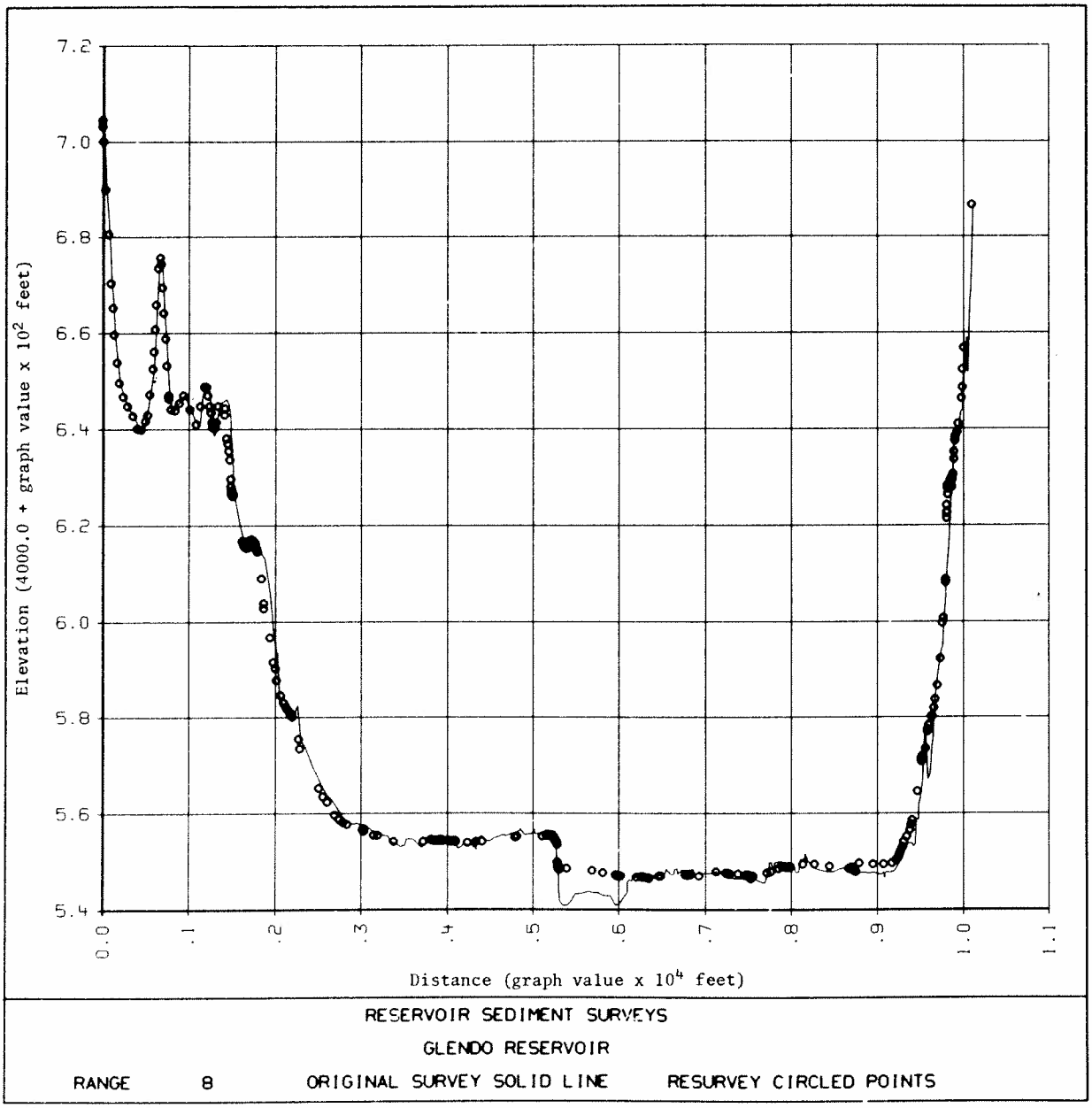

Figure 10. - 1957 and 1972 sedimentation range profiles - range 8.

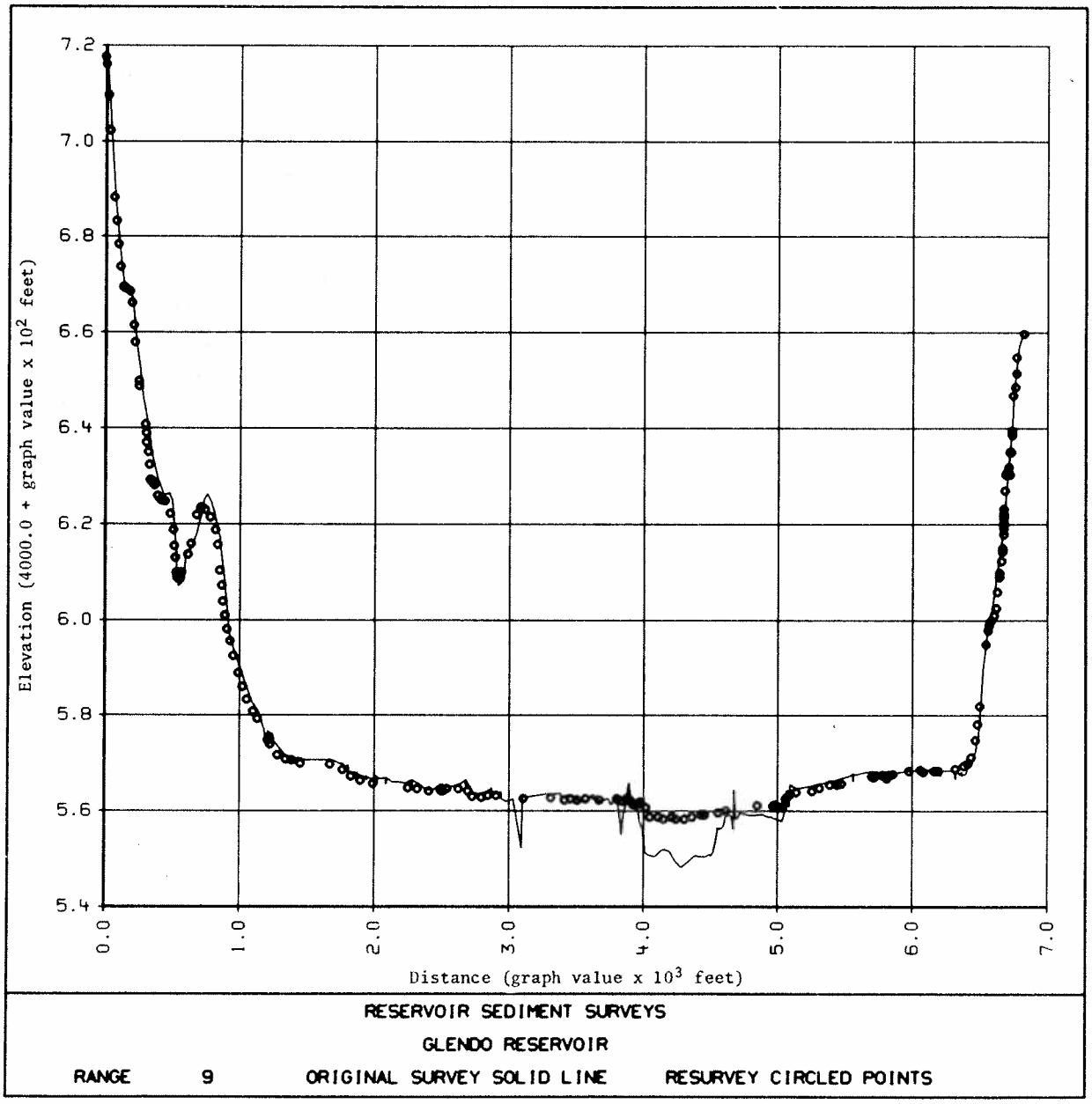

Figure 11. - 1957 and 1972 sedimentation range profiles - range 9.

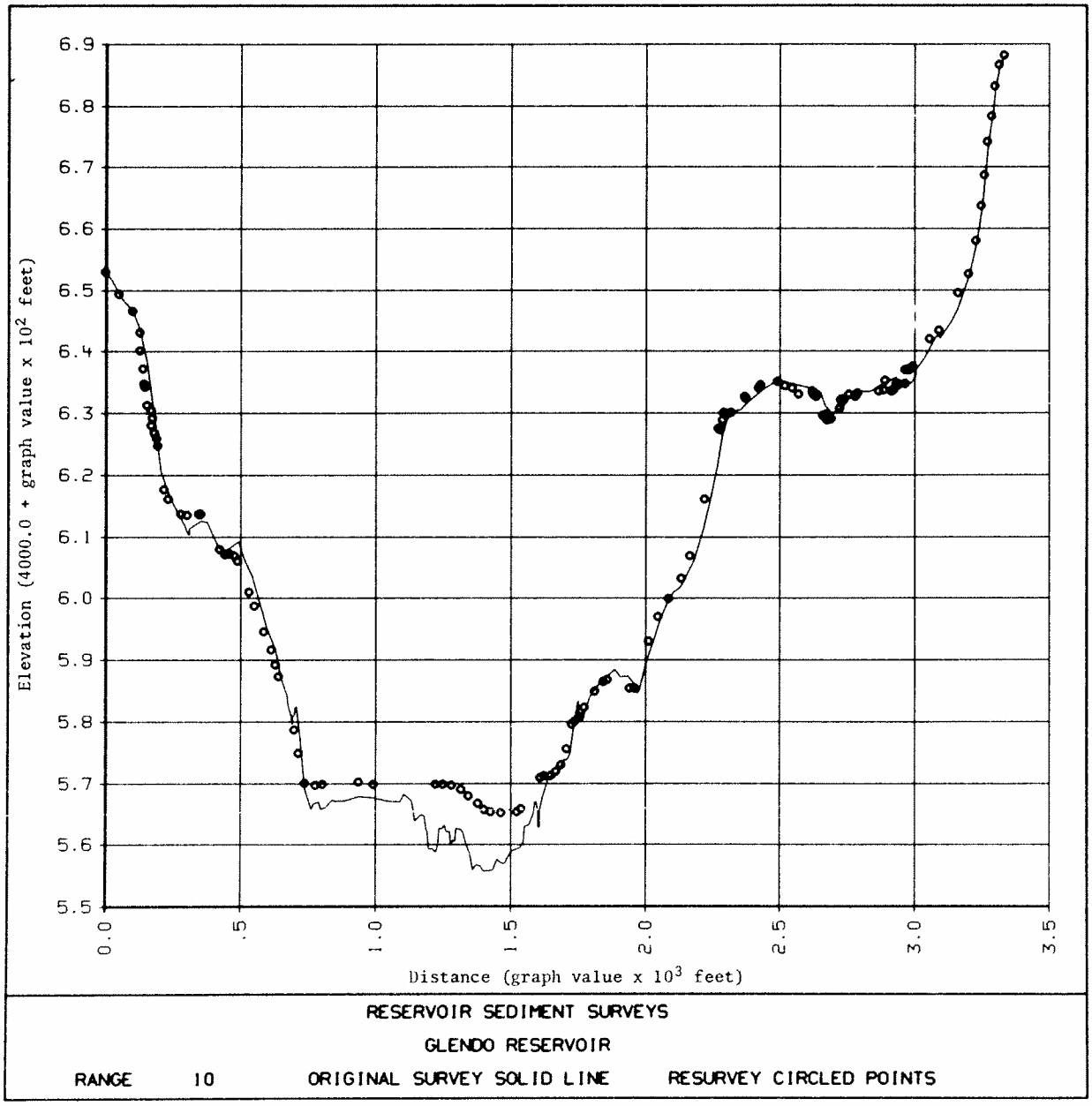

Figure 12. - 1957 and 1972 sedimentation range profiles - range 10.

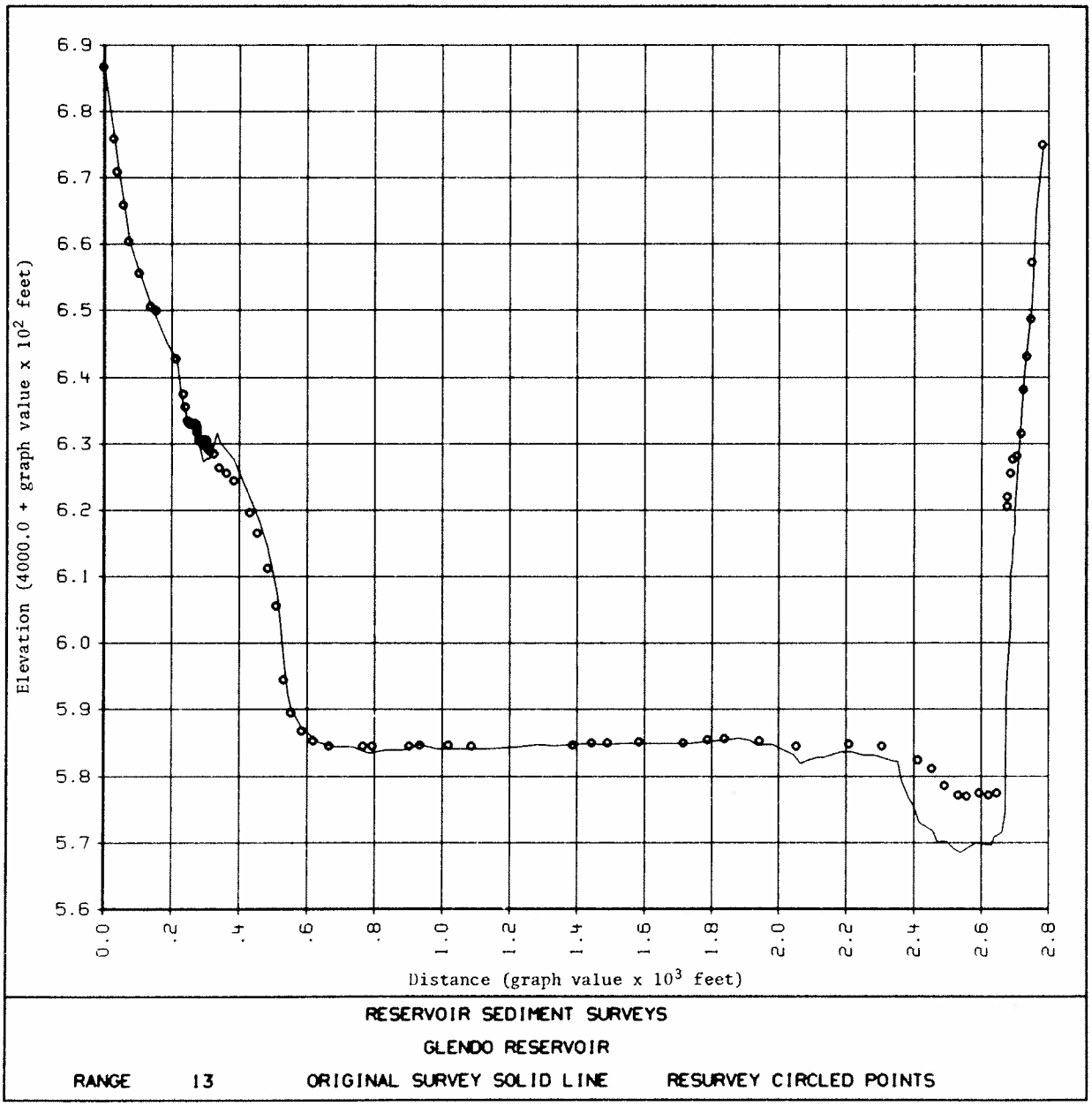

Figure 13. - 1957 and 1972 sedimentation range profiles - range 13.

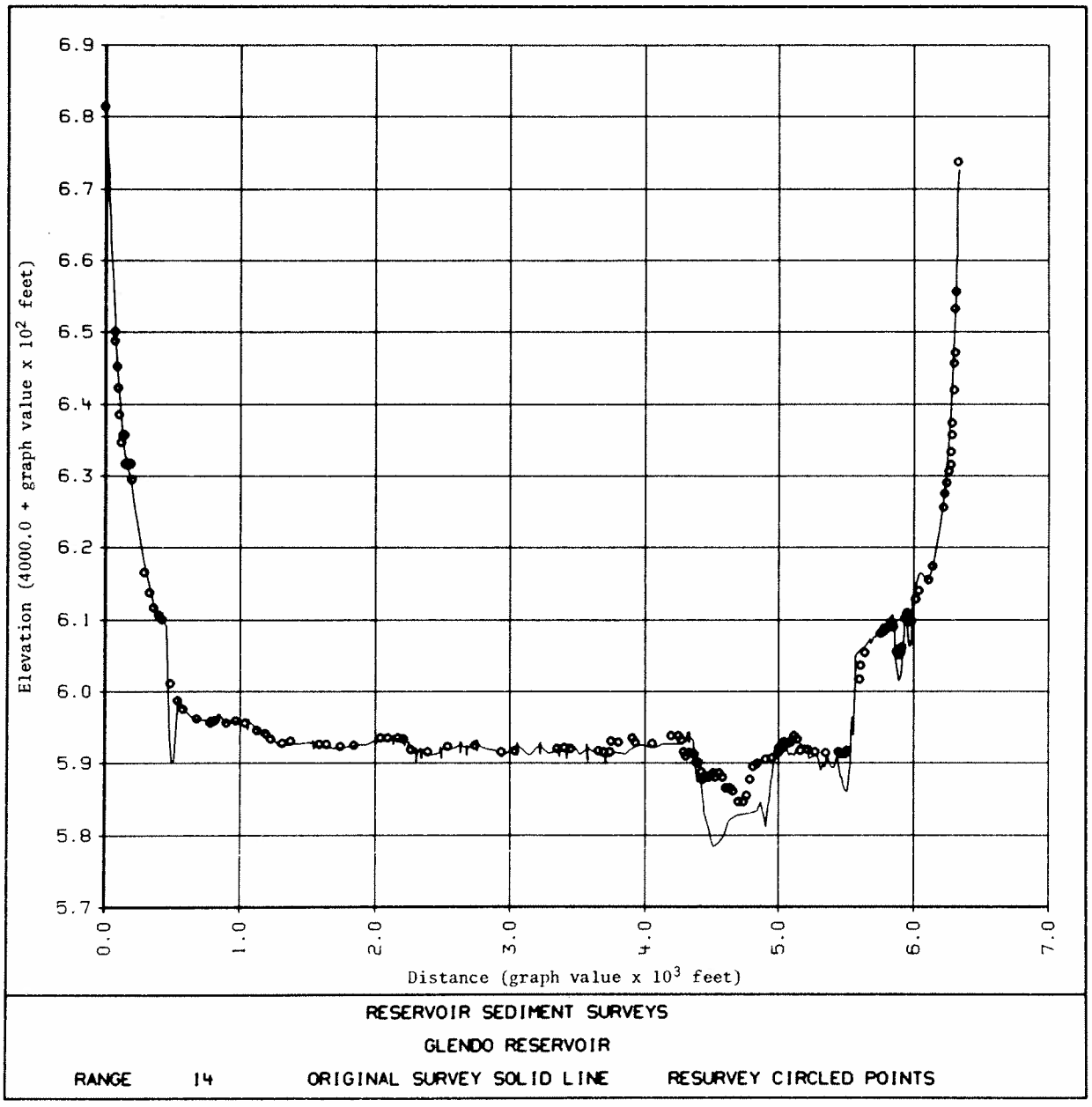

Figure 14. - 1957 and 1972 sedimentation range profiles - range 14.

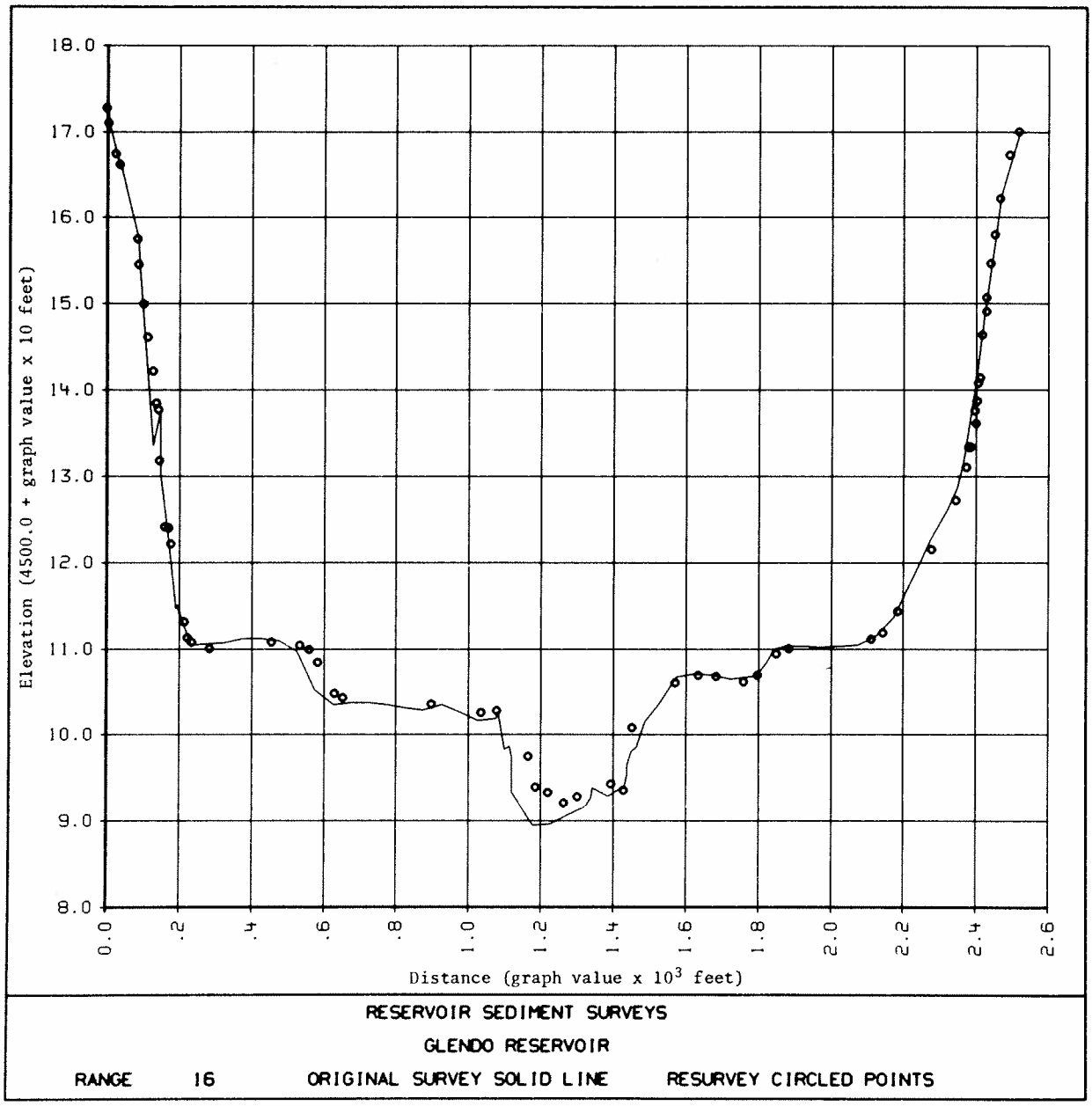

Figure 15. - 1957 and 1972 sedimentation range profiles - range 16.

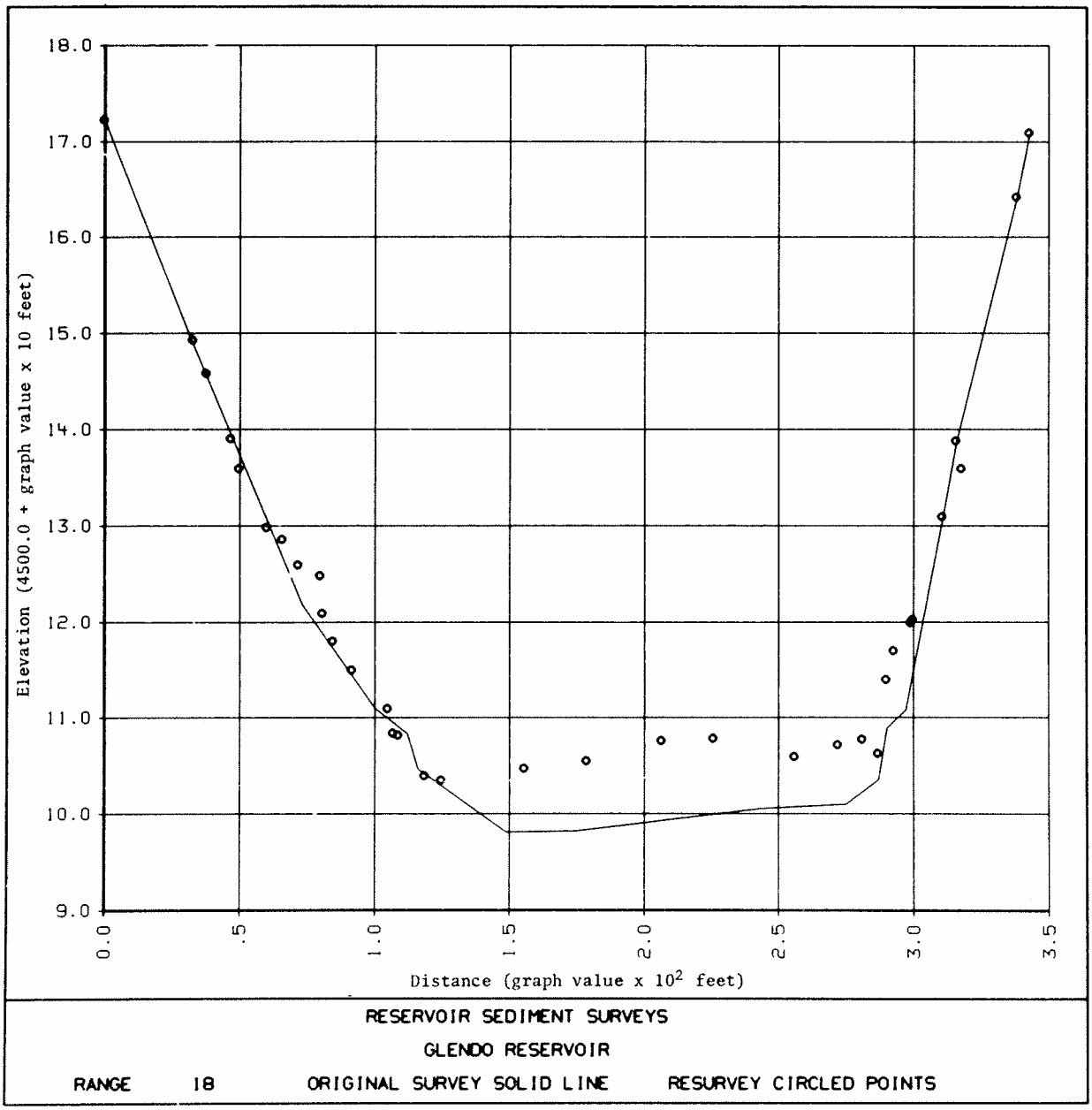

Figure 16. - 1957 and 1972 sedimentation range profiles - range 18.

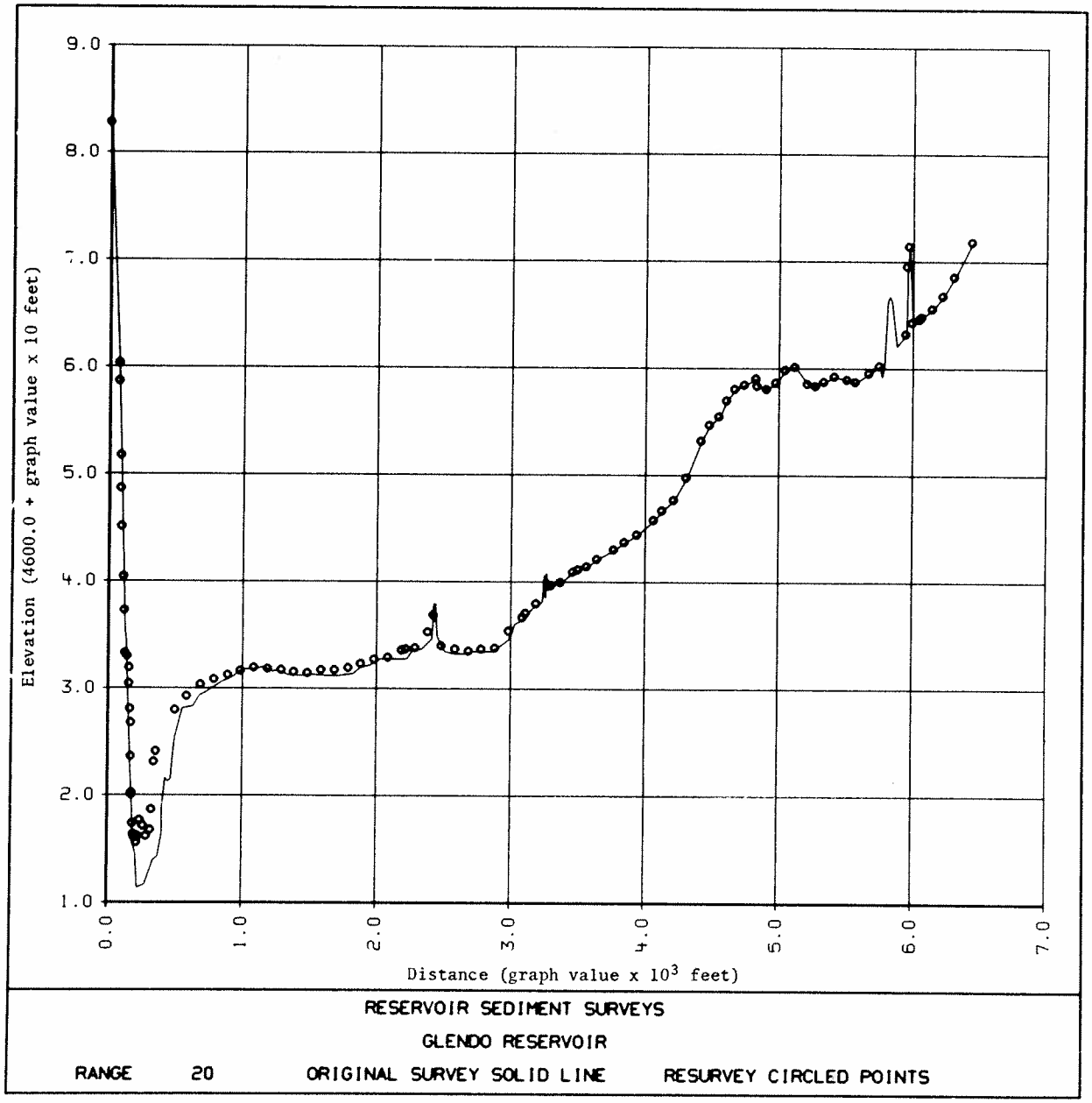

Figure 17. - 1957 and 1972 sedimentation range profiles - range 20.

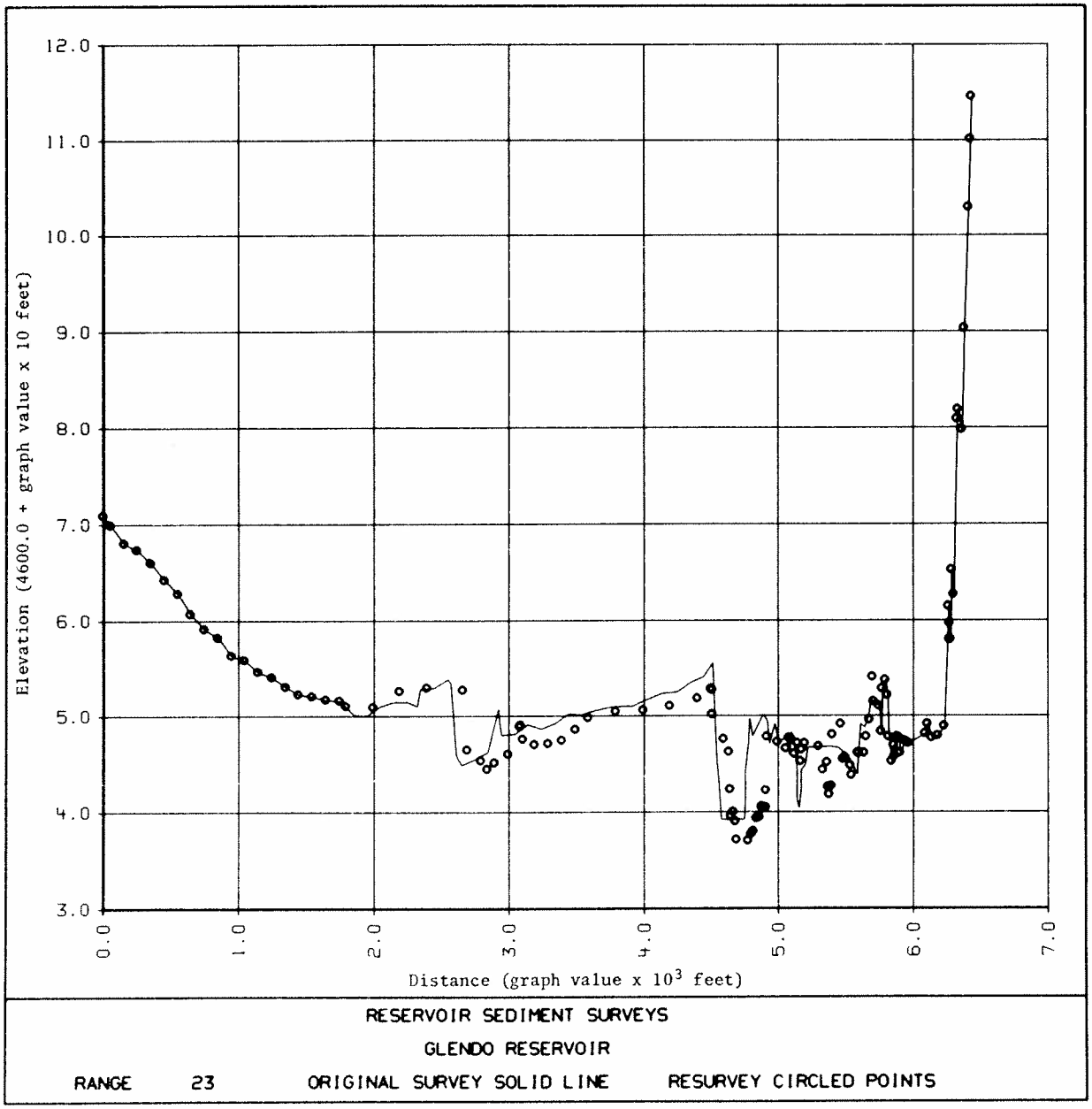

Figure 18. - 1957 and 1972 sedimentation range profiles - range 23.

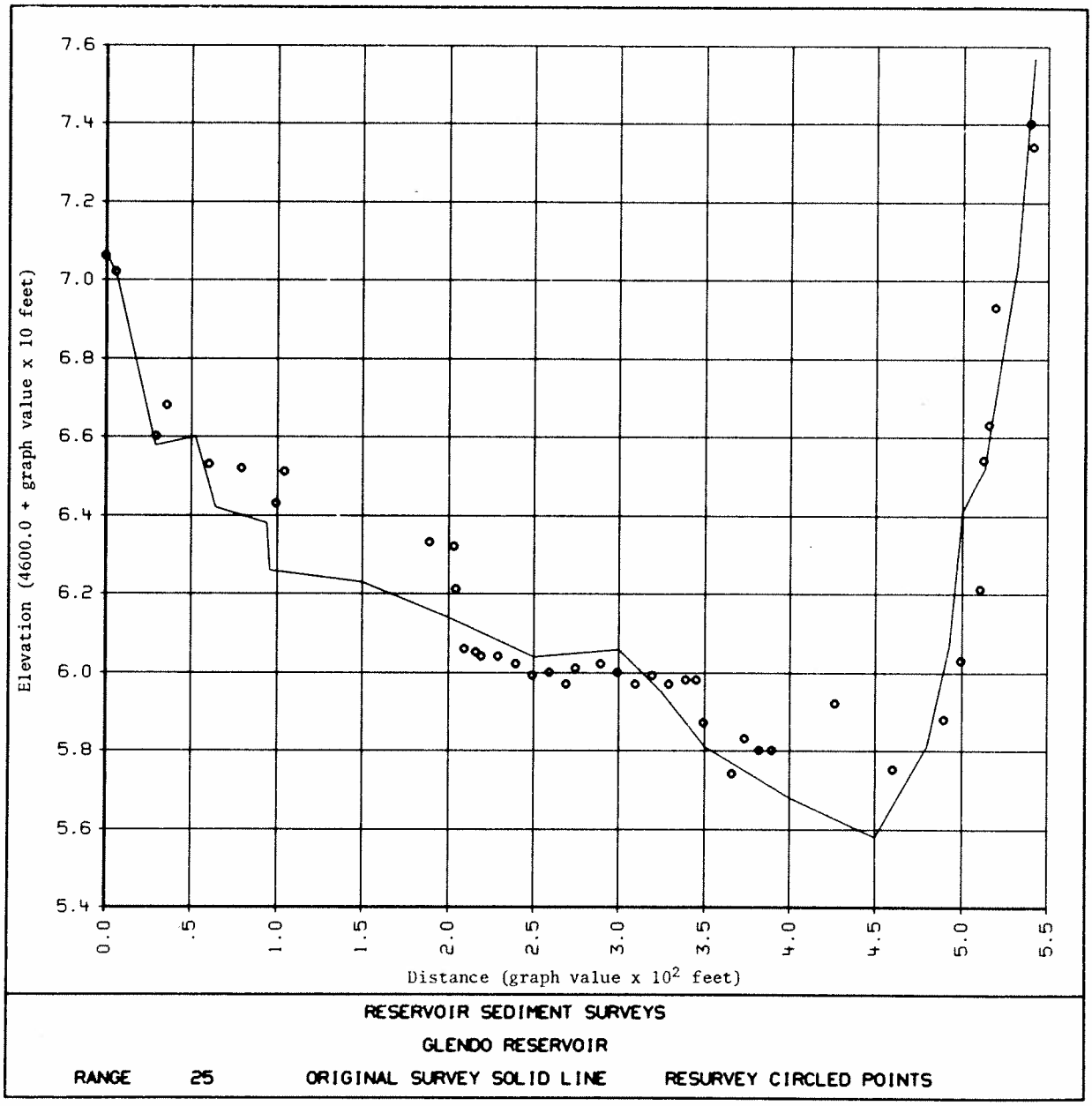

Figure 19. - 1957 and 1972 sedimentation range profiles - range 25.

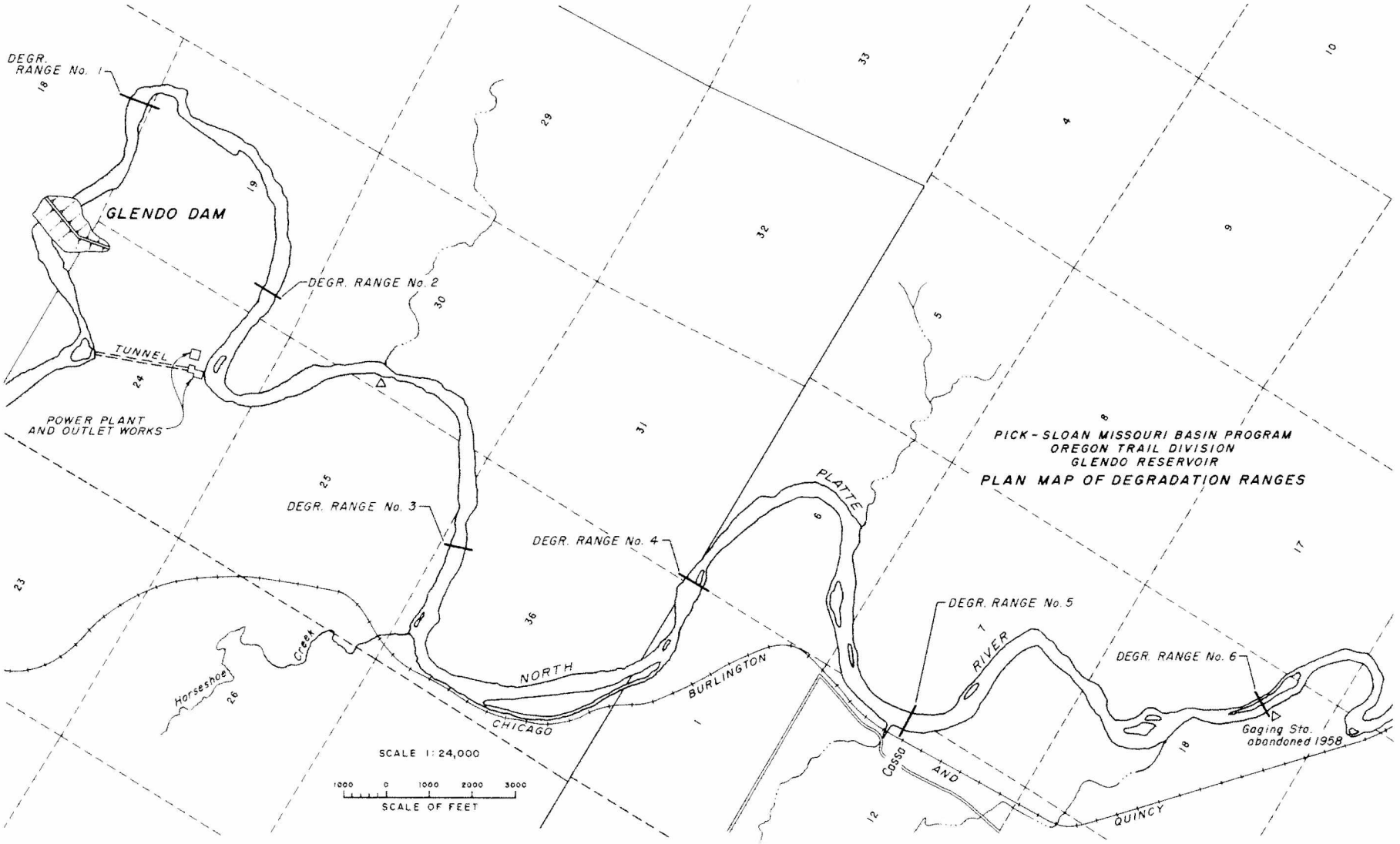

Figure 20. - Plan of degradation ranges.

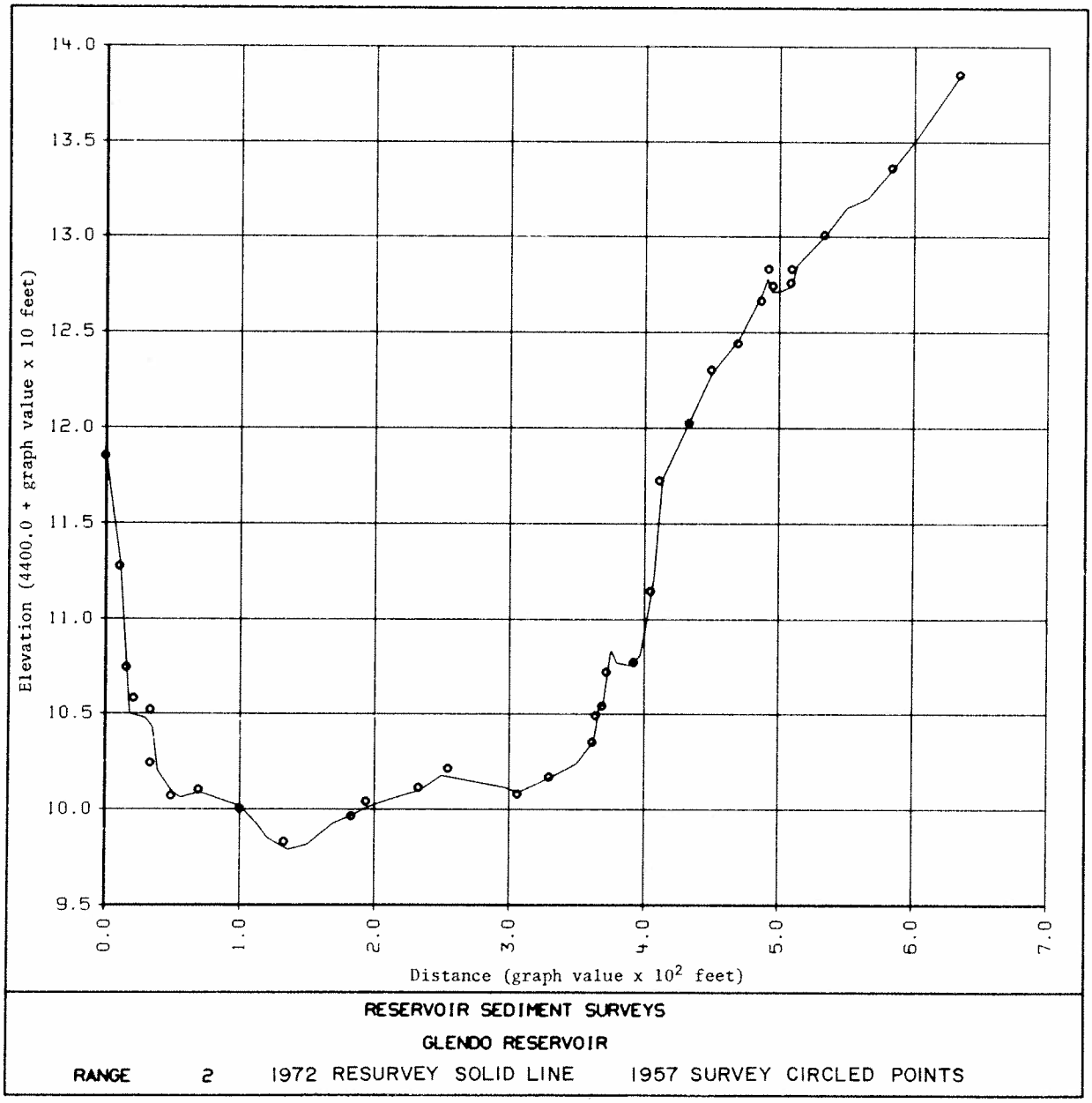

Figure 21. - Profile - Degradation range 2.

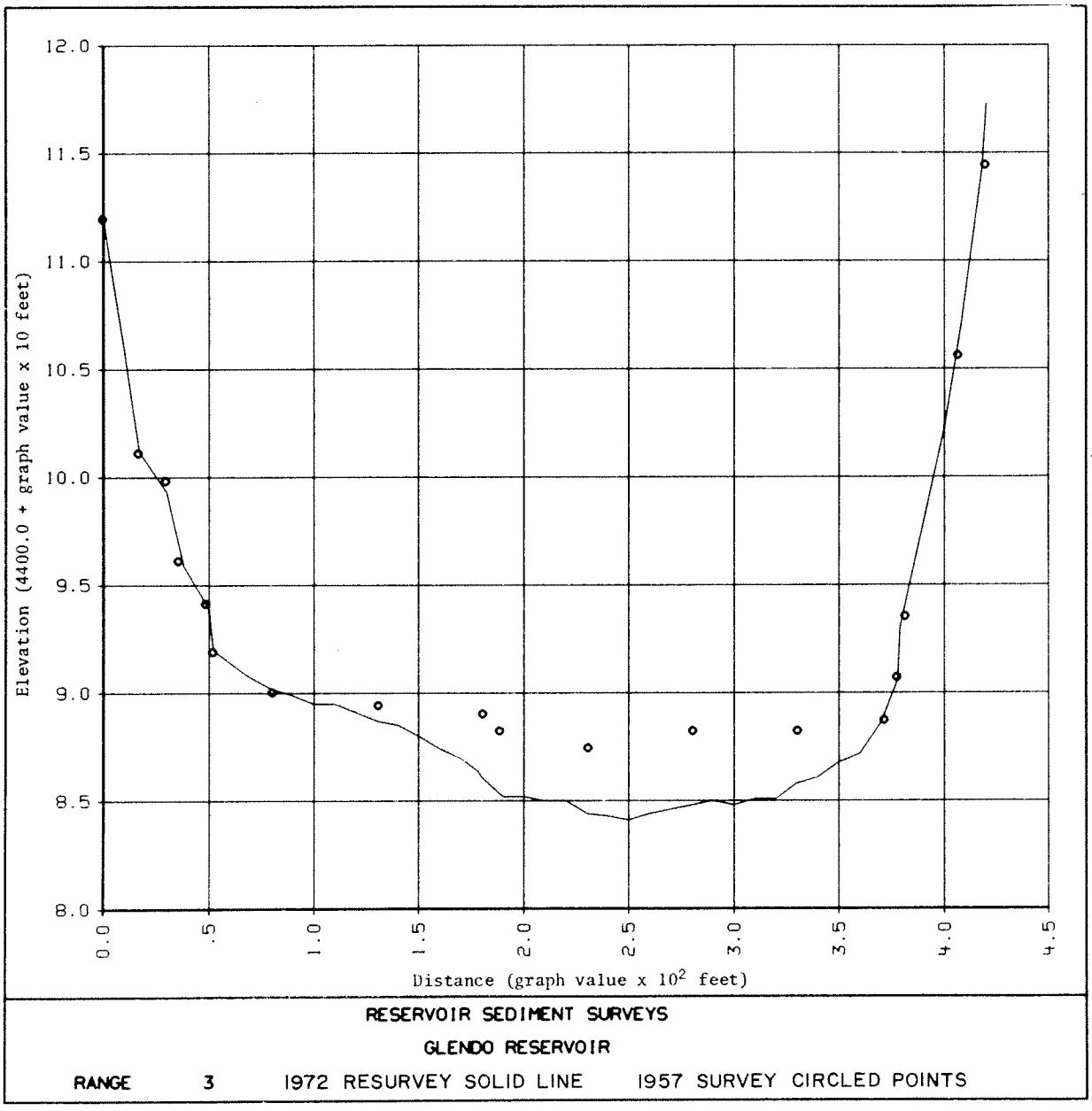

Figure 22. - Profile - Degradation range 3.

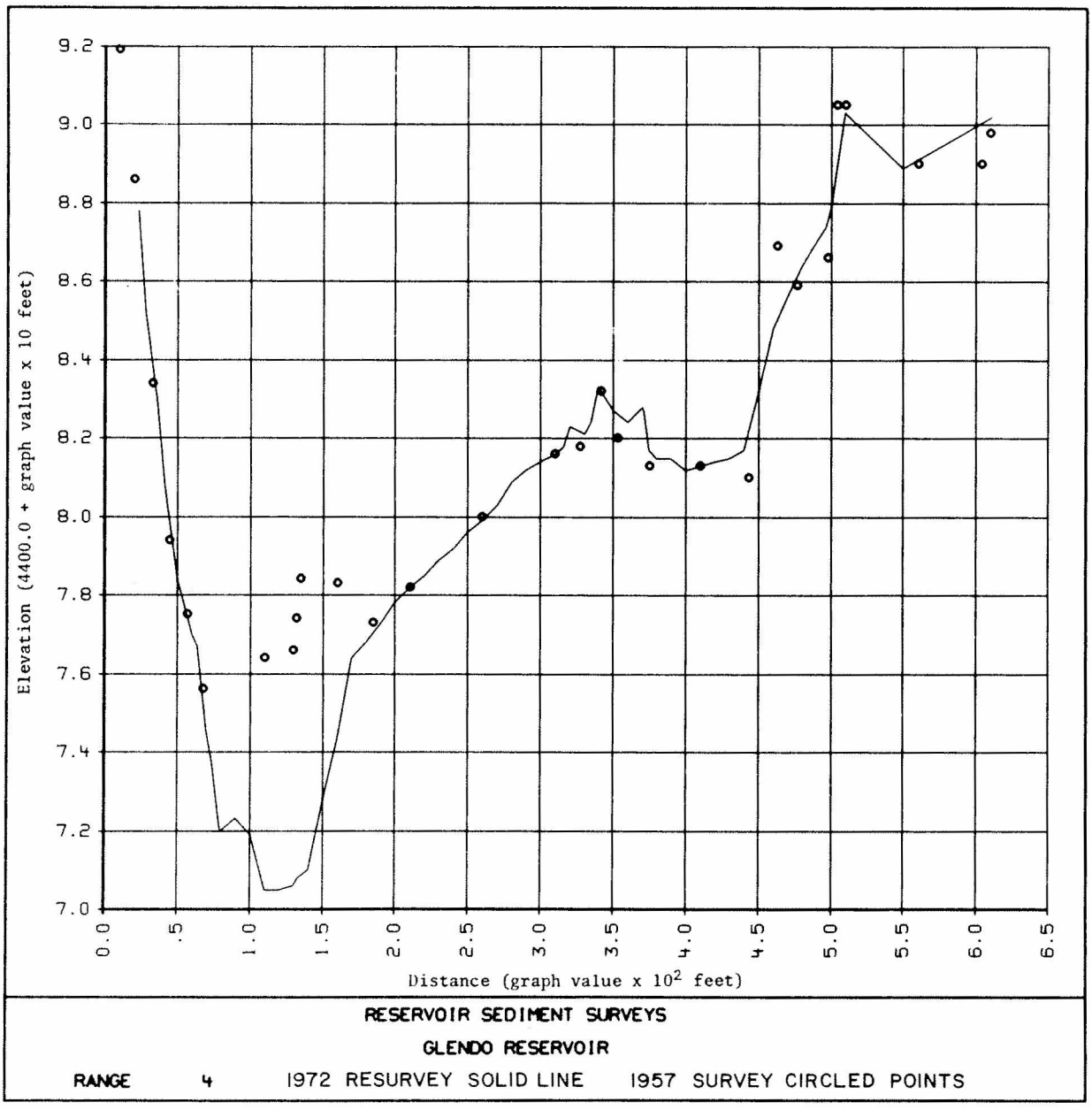

Figure 23. - Profile - Degradation range 4.

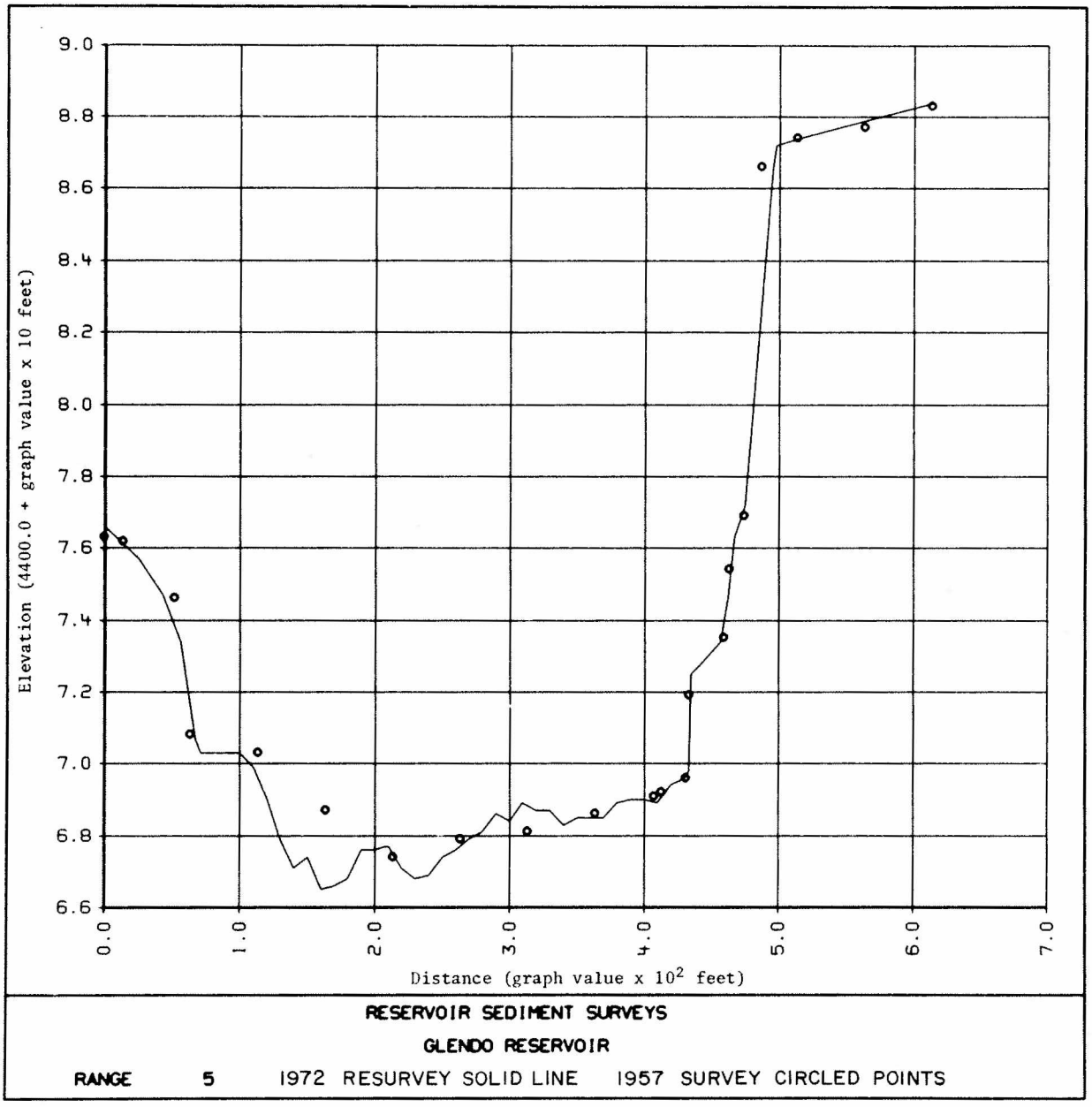

Figure 24. - Profile - Degradation range 5.

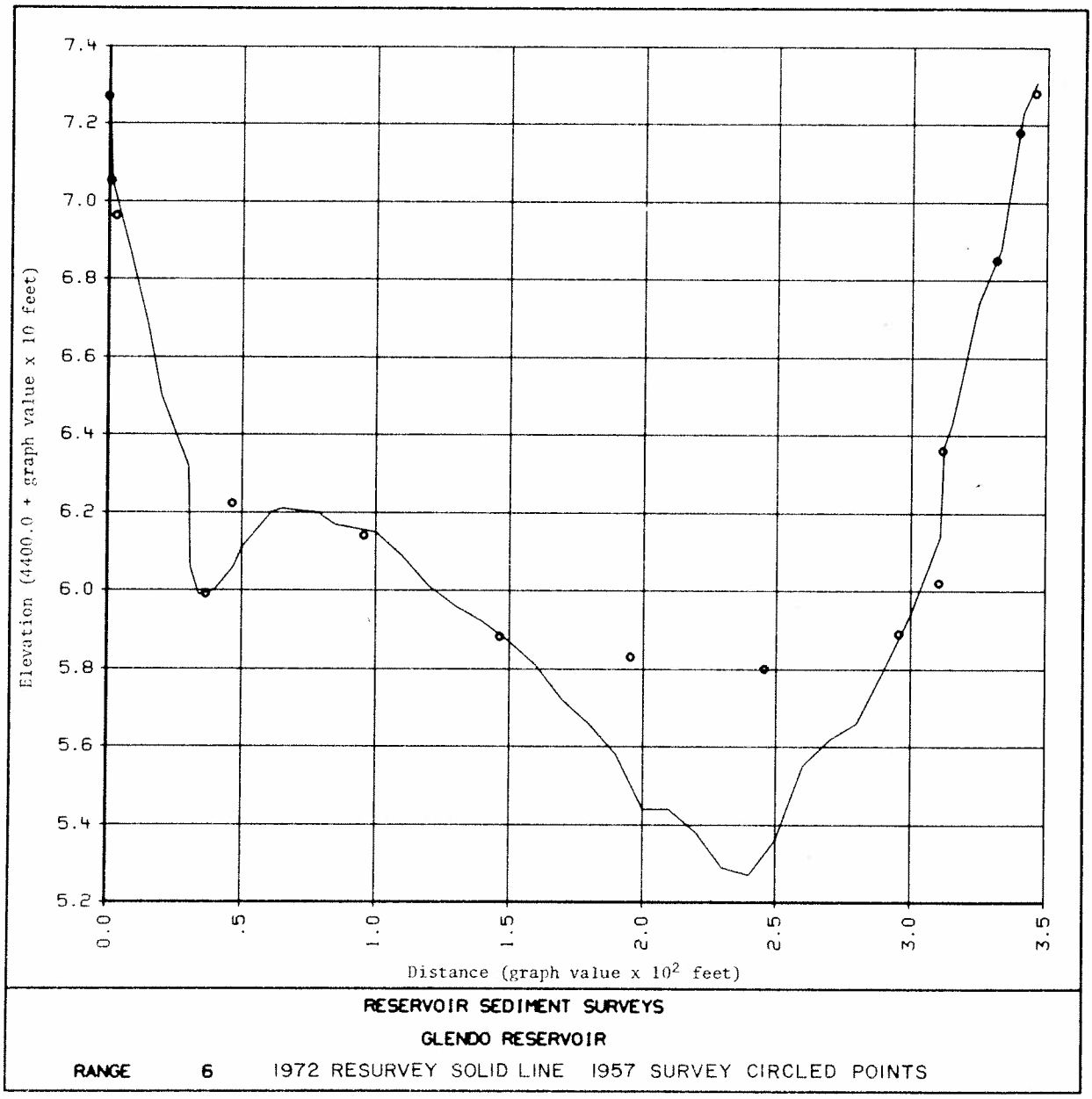

Figure 25. - Profile - Degradation range 6.

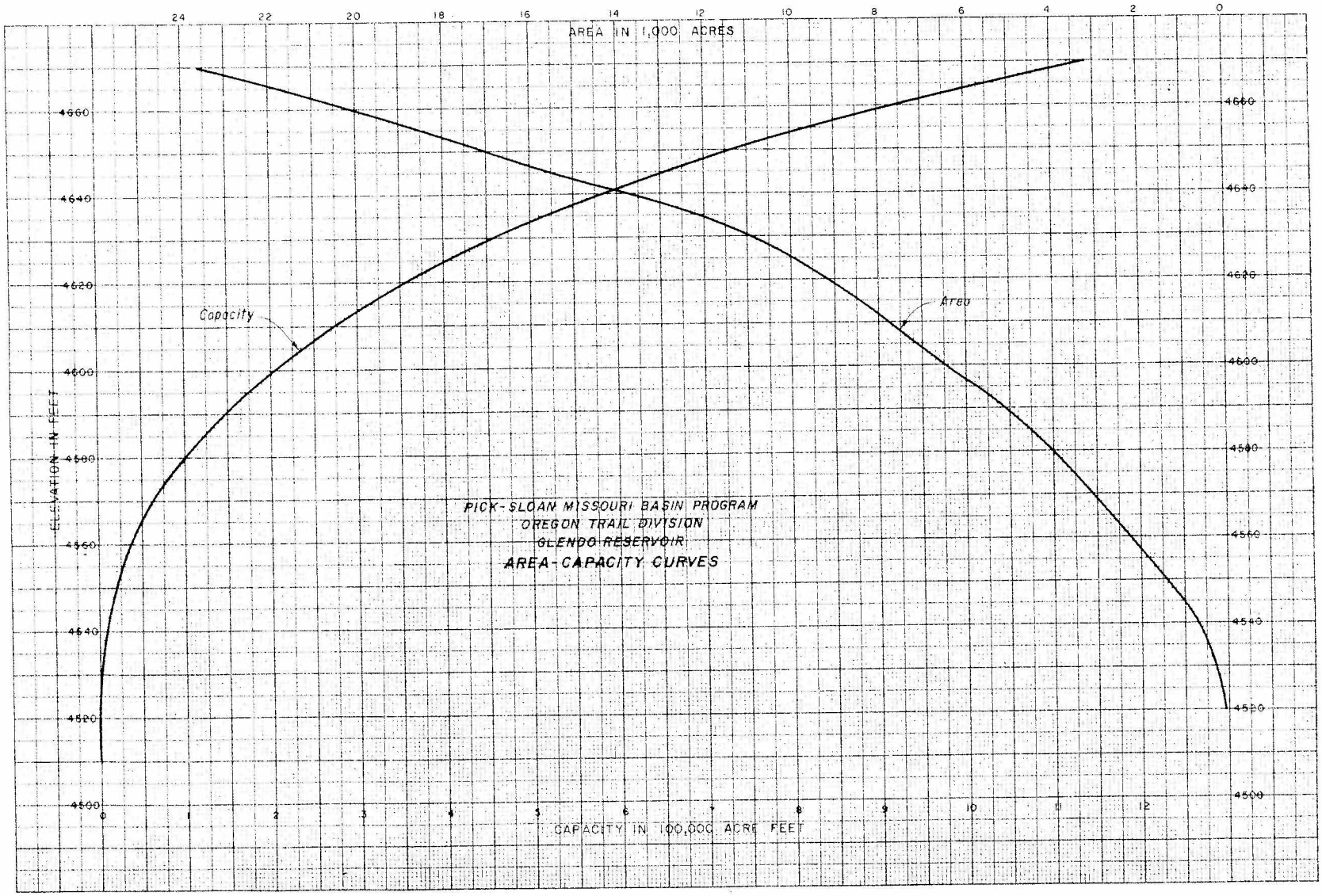

Figure 26. - Reservoir area-capacity curves.

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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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