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THEODORE ROOSEVELT LAKE — 1981 SEDIMENTATION SURVEY

September 1982

Engineering and Research Center

Salt River Project
Phoenix, Arizona

U.S. Department of the Interior
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16. ABSTRACT

Theodore Roosevelt Lake was surveyed in 1981 to compile field data needed to compute the reservoir capacity. The data were also used to compute the volume of sediments that had accumulated in the reservoir since the gates of the dam were closed in 1909. Twenty-eight sediment samples from reservoir deposits were collected from various reservoir ranges throughout the lake. Sonic depth recording equipment interfaced with an automated survey system was used to run the hydrographic survey. Reservoir capacity was computed based on surface areas determined by a width-ratio method.

The capacity of the reservoir is now 1.65×10^9 m^3 (1,336,734 acre-ft), and the reservoir has a surface area of 7016 hectares (17,337 acres). Since 1909, 2.39×10^8 m^3 (193,765 acre-ft) of sediment accumulation have resulted in about a 13 percent loss of capacity.

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THEODORE ROOSEVELT LAKE —1981 SEDIMENTATION SURVEY

by
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Hydrology Branch
Division of Planning Technical Services
Engineering and Research Center
Denver, Colorado

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UNITED STATES DEPARTMENT OF THE INTERIOR * BUREAU OF RECLAMATION

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INTRODUCTION

Theodore Roosevelt Dam was the first major structure built by the Reclamation Service (now the Bureau of Reclamation) after its formation in 1902 by the Reclamation Act. Construction of the dam began in 1903 and was completed in 1911. Located about 129 km (80 mi) northeast of Phoenix, Arizona, on the Salt River, the dam is part of the multipurpose Salt River Project that controls floods, generates power, and stores irrigation water.

The dam is an 85.3-m (280-ft) high, rubble-masonry, thick-arch structure that is 220.4 m (723 ft) long; and impounds a reservoir of 1.65 x 10^9 m^3 (1 336 734 acre-ft). The dam originally had two uncontrolled overflow spillways. During the 1930's, radial gates were installed on both spillways to provide extra reservoir storage. The spillways were cut into each abutment, with each spillway crest oriented to continue the arch shape of the dam. The general plan and sections of the dam and spillways are shown on figure 1.

The original surface area of the reservoir, Theodore Roosevelt Lake, in 1909 was 7214 ha (17 826 acres), and the reservoir had a capacity of 1.88 x 10^9 m^3 (1 522 200 acre-ft) at elevation 651.0 m (2136 ft), top of the spillway gates. By processing the 1909 survey data using a current procedure programmed on an electronic computer, a more refined original capacity of 1.89 x 10^9 m^3 (1 530 499 acre-ft) was determined. The 1981 survey resulted in a surface area of 7016 ha (17 337 acres) and a capacity of 1.65 x 10^9 m^3 (1 336 734 acre-ft) at the top of the spillway gates. This indicated a loss of 2.39 x 10^9 m^3 (193 765 acre-ft) in capacity in the 72.4 years since the dam was built.

The reservoir is 25.4 km (15.8 mi) long along the Salt River Arm and 17.5 km (10.9 mi) along the Tonto Creek Arm. The average reservoir widths are 1.9 and 1.4 km (1.2 and 0.9 mi) on the Salt River and Tonto Creek Arms, respectively. The net sediment contributing drainage area above the dam is 14 786 km^2 (5709 mi^2).

Records on the inflow to the reservoir indicate an average of 8.96 x 10^8 m^3 (726 618 acre-ft) per year for 72.4 years. Based on 28 years of record, the average annual outflow was 5.96 x 10^8 m^3 (483 669 acre-ft). Theodore Roosevelt Lake operation ranged from a minimum elevation of 595.0 m (1952 ft) in 1930-31 to a maximum elevation of 651.306 m (2136.83 ft) in 1980.

SUMMARY AND CONCLUSIONS

This report includes a discussion of methods used to measure and study 72.4 years of reservoir sediment accumulations. It also briefly describes the field surveying and sediment sampling procedures and equipment. The primary purpose of running the 1981 survey was to gather data needed to compute the capacity of Theodore Roosevelt Lake.

Standard land surveying methods were used to establish horizontal control points for the survey. The hydrographic survey was run using sonic depth recording equipment interfaced with an automated survey system that consisted of a line-of-sight electronic positioning unit that was used to fix locations in the reservoir. The total system continuously recorded reservoir depth and horizontal distances from a fixed point as the survey boat was steered across the range line. Water surface elevations read at the gage of the dam were used to compute bottom elevations of the cross-sectional profile delineated in a sonar chart of each range line.

Twenty-eight sediment samples of the reservoir deposits were collected with a gravity core sampler. Analyses of the samples resulted in determining a unit mass of 789.7 kg/m^3 (49.3 lb/ft^3) and an average particle size of 46.6 percent clay, 46.9 percent silt, and 6.5 percent sand.

The capacity of the reservoir, determined from the 1981 survey, is 1.65 x 10^9 m^3 (1 336 734 acre-ft), with a surface area of 7016 ha (17 337 acres) at elevation 651.0 m (2136 ft), top of the spillway gates. 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. Capacity data were also compiled at the same elevation increments used for computing the area.

A comprehensive summary of the reservoir sediment data for the 1981 survey is contained in table 2. The volume of the sediments that have accumulated in the reservoir since the original survey amounted to 2.39×10^8 m^3 (193 765 acre-ft), indicating a loss in capacity of about 13 percent. An average annual sediment accumulation rate of 3.31×10^6 m^3 (2676 acre-ft) was found from 1909 to 1981. Sediments were deposited at a rate of 223 m^3/km^2 (0.469 acre-ft/mi^2) annually during the same period.

SURVEYS, SAMPLING, AND EQUIPMENT

Six different surveys of varying degrees of accuracy have been run previously, beginning in 1914. All these surveys, including the one in 1981, were run using the range method. Field work for the last survey began in February and ended September 4, 1981. A layout of the reservoir sedimentation range system is shown on figure 2.

Surveying Methods

The field survey work consisted of locating the existing sedimentation range end markers and relocating those which had been lost or destroyed. Of the 72 initial markers, 24 were found and 48 had to be reset. A triangulation network was established around the reservoir to provide horizontal control for all range lines and other required shore stations. It was decided not to profile the lines from range end to water's edge because the end part of the range profile would not be affected by any of the minor amounts of either sediment deposition or erosion that occurred along the shoreline in zones of reservoir water surface fluctuations (delta areas excepted). Standard land surveying procedures and equipment were used in the survey.

A hydrographic survey was run in July 1981, using sonic depth recording equipment to sound the underwater portion of 32 range lines. A depth recorder was interfaced with an automated positioning system (fig. 3) to give continuous reservoir depth and sounding position as the sounding boat traversed each range line. The positioning system transmitted a line-of-sight, microwave signal to fixed shore stations (fig. 4) and converted the time of reply to range distances, which were then used to compute the coordinate position of the sounding boat. The controls required for the system are reservoir elevation, horizontal grid coordinates for all range ends and fixed shore stations, and the elevation of the shore station antenna. Upon activating the system, the boat (fig. 5) was steered across the range line at about 2.4 m/s (8 ft/s). The system also gave directions to the boat operator for maintaining course. During each run, the depth and position data were recorded on magnetic tape for later processing on an electronic computer. A graph plotter was used to track the boat and to give an immediate plot of each range profile. Auxiliary field equipment included radios for communication between shore and boat personnel and a small boat to move equipment and personnel around the reservoir.

A contract was let by the Salt River Project to make a photogrammetric survey of all reservoir sedimentation range lines that were not underwater during the hydrographic survey. These included ranges 19 through 24 on the Salt River Arm, ranges 40 through 43 on the Tonto Creek Arm, and range 80 on Pinto Creek. All control for the photogrammetric survey was established by Salt River Project personnel.

Sampling Method and Equipment

A gravity core sampler was used to take 28 samples of the underwater reservoir sediment deposits. The sampler was suspended over the bow of the boat from a cable reeled off a power-operated winch (fig. 6). The sampler was allowed to fall free into the sediment deposits to obtain maximum possible penetration. The sampler was then retrieved and the plastic liner containing the sediment sample was withdrawn from the coring pipe. A hacksaw was used to separate that part of the liner holding the sample. The samples were capped with plastic caps on each end of the liner, sealed, and labeled for analysis.

RESERVOIR SEDIMENT DISTRIBUTION

Longitudinal Distribution

A study on sediment distribution in the reservoir was done by plotting the longitudinal profiles for the Salt River and Tonto Creek Arms, figures 7 and 8, respectively. The profiles were plotted in dimensionless form relating percent of depth to percent of distance for both the original and 1981 conditions. Percent of depth for both the Salt River and Tonto Creek Arms was computed as the ratio of the thalweg depth at each range to the total depth. Thalweg depth was computed as a difference between the thalweg elevation (lowest point) at a section and the lowest point on the reservoir profile. Total depth was determined to be 71.338 m (234.05 ft) computed as the difference between the original lowest point in the reservoir, 579.714 m (1901.95 ft), and the elevation at the top of the pool, 651.0 m. Percent of distance for the Salt River Arm was computed as the ratio of the distance between the dam and each range to the total distance of 25.48 km (15.83 mi), measured between the dam and the point where the longitudinal profile intersects the thalweg elevation 651.0 m upstream. Percent of distance for the Tonto Creek Arm was computed as the ratio of the distance between the confluence point of the Tonto Creek and Salt River Arms and each range to the total distance of 17.46 km (10.85 mi) measured between the confluence point and the point of intersection at the thalweg elevation. Maximum sediment deposits of 19.5 m (64 ft) occurred at the dam as indicated by the Salt River Arm relationship (fig. 7). This plotting also shows the sediment depositional depths of 12.8 m (42 ft) at range 12 (38.9 percent distance), reduced to 3.4 m (11 ft) at range 18 (73.8 percent distance). The Tonto Creek Arm plotting on figure 8 indicated a depth pattern of sediment deposits of 18.9 m (62 ft) at the confluence point, 7.3 m (24 ft) at range 34 (46.7 percent distance), and 1.5 m (5 ft) at range 40 (82.2 percent distance).

For 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 2.39 10^8 m^3 (193 765 acre-ft) equal to the volume measured by the 1981 survey. A plotting of the depth-capacity relationship (fig. 9), using the original data, indicated the reservoir to be types II and III.[1] Results of the sediment distribution computations are listed in columns (8), (9), and (10) of table 1 for a type II reservoir. These computations show the sediment would reach an elevation of 596.34 m (1956.5 ft) after 72.4 years of operation. This is comparable to the elevation of 599.2 m (1966 ft) determined from the 1981 survey. The sediment disposition curves plotted on figure 10 show how the actual distribution compares with distributions from a type II or III reservoir. The curves show the percentages of reservoir depth plotted against sediment deposited. The actual distribution compares best with the type II distribution.

[1] *Design of Small Dams*, 2nd edition, reprint, app. H, p. 767, Bureau of Reclamation, Washington, D.C., 1974.

Lateral Distribution

Ground profiles of the 39 reservoir sedimentation ranges are shown on figures 11 through 49 for both the original and 1981 surveys. The profiles show the general lateral distribution of sediments in the reservoir. Sediments are shown depositing laterally to depths ranging from 1.2 m (4 ft) in the headwaters area of the Tonto Creek Arm to 19.5 m (64 ft) in the reach immediately upstream of the dam.

SEDIMENT ANALYSES

Sediment Accumulation

Sediments have accumulated in Theodore Roosevelt Lake to a total volume of 2.39×10^8 m^3 (193 765 acre-ft) at elevation 651.0 m (2136 ft), top of the spillway gates, since the dam was built over 72 years ago. An average annual sediment accumulation rate of 3.31×10^6 m^3 (2676 acre-ft) was computed for the 72.4-year period.

Reservoir Sedimentation Survey

Table 2 contains a summary of the reservoir sediment data for the 1981 survey. The data include a tabulation of incremental sediment inflow volume and sediment accumulation computed for the period between the original and 1981 surveys. Both types of data are valuable for practical and research uses.

An attempt was made to reconcile the sediment data of the 1946 survey with the 1981 survey results, but was unsuccessful. Examining the 1946 survey records available disclosed the data and information were not detailed enough to verify the sediment volume computations. This prevented continuity of the type of sediment data recorded in table 2. Since the 1981 survey reservoir surface area was adjusted on the basis of the original area, the 1981 data in table 2 was referenced to the 1909 survey only.

Unit Mass Analyses

A total of 28 physical samples of the reservoir sediment deposits were collected in 1981. A summary of the results of each collected sample is contained in table 3 showing unit mass; percentages of clay, silt, and sand; and sample location. From these analyses, a dry unit mass of 789.7 kg/m³ (49.3 lb/ft³) was computed by the straight average method.

An empirical method[2] was used to compute the unit mass by applying the average clay, silt, and sand-size gradation values shown in the next section of this report.

Assuming a type III reservoir operation (see footnote 1, p. 845), an initial unit mass of 940.3 kg/m³ (58.7 lb/ft³) was computed as compared to the average 789.7 kg/m³ (49.3 lb/ft³) previously mentioned. A correction for compaction was not considered because the sediment samples were taken from only the top layer of the deposits.

Particle Size Analyses

A study was made of the particle-size anlyses tests run on the 28 samples collected in 1981. The graphs on figures 50 through 65 contain the particle-size analyses curves for each sample. On most of the ranges, two samples were collected and curves are shown for both. Particle sizes in the clay, silt, and sand ranges were determined by averaging the results obtained in the analyses shown in table 3. The average size was computed to be 46.6 percent clay, 46.9 percent silt, and 6.5 percent sand.

RESERVOIR AREA AND CAPACITY

The 1981 reservoir surface areas were computed by the width adjustment method described by Pemberton.[3] Briefly, the method entailed computing the new contour areas between any two ranges by applying an adjustment factor to the 1909 contour area between the two ranges.The adjustment factor was determined as a ratio of the new average width to the original average width for both the upstream and downstream ranges at a specific contour. Computations were facilitated by subdividing the reservoir into segments using the sedimentation range lines to delineate the limit of each segmental boundary. For any given elevation, the 1909 surface areas were multiplied by the adjustment factor to determine the 1981 surface area of each segment. The total surface area at a given elevation was computed by adding the segmental areas at that elevation.

The 1981 surface areas were used as control parameters for computing the reservoir capacities by electronic computer. The program was written to include the computation of 0.003- to 0.305-m (0.01- to 1-ft) area increments by linear interpolation between the 3.05-m (10-ft) contour intervals. 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 0.00001 in this case). This capacity equation is then used over the whole range that fits within the allowable error limit. For the next interval, beginning 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 exceeds the error limit. Thus, the capacity curve is defined by a series of curves or splines, 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,

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

where

y = capacity,
x = elevation above an elevation base,
a_1 = intercept, and
a_2 and a_3 = coefficients.

Results of the 1981 area and capacity computations are listed in columns (4) and (5) of table 1. Listed in columns (2) and (3) of this table are the original area and capacity values. A special set of area-capacity tables has been published separately[4] for the 0.003-, 0.030-, and 0.305-m (0.01-, 0.1-, and 1-ft) elevation increments. Both the original and 1981 area-capacity curves are plotted on figure 66. At elevation 651.0 m (2136 ft), top of the spillway gates, the 1981 capacity is 1.65×10^9 m³ (1 336 734 acre-ft) and the surface area is 7016 ha (17 337 acres).

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[2] Lara, J. M. and E. L. Pemberton, "Initial Unit Weight of Deposited Sediments," Paper No. 82, Proc. of the Federal Inter-Agency Sedimentation Conference, Misc. Pub. No. 970, U.S. Department of Agriculture, 1963.

[3] Pemberton, E. L., edited by H. W. Shen and H. Kikkawa, "Survey and Prediction of Sedimentation in Reservoirs," in *Applications of Stochastic Processes in Sediment Transport*, 1980.

[4] "Theodore Roosevelt Lake Area and Capacity Tables," Salt River Project, LC Region, Bureau of Reclamation, October 1981.

Table 1a. — *Summary of 1981 survey results and sediment distribution computations (metric units)*

(1) Elevation, m	(2) Original area, ha	(3) Original capacity, 10^6 m^3	(4) 1981 area, ha	(5) 1981 capacity, 10^6 m^3	(6) Measured sediment volume, 10^6 m^3	(7) Percent of measured sediment	(8) 1981 capacity, 10^6 m^3	(9) Computed sediment volume, 10^6 m^3	(10) Percent of computed sediment
651.06	7198	1888	7016	1649	239	100	1649	239	100
649.23	6962	1758	6783	1523	235	98.3	1521	237	99.2
646.18	6547	1552	6320	1323	229	95.8	1323	229	95.8
643.14	6109	1360	5844	1138	222	92.9	1139	221	92.5
640.09	5708	1180	5486	965	215	90.0	971	209	87.4
637.04	5361	1011	5158	802	209	87.4	813	198	82.8
633.99	4832	855	4586	654	201	84.1	671	184	77.0
630.94	4805	716	3983	523	193	80.8	545	171	71.5
627.90	3837	592	3331	412	180	75.3	435	157	65.7
624.85	3344	483	2744	319	164	68.6	339	144	60.3
621.80	2876	388	2254	244	144	60.3	259	129	54.0
618.75	2516	306	1962	180	126	52.7	191	115	48.1
615.70	2139	235	1705	124	111	48.4	134	101	42.3
612.66	1726	176	1371	76.0	100	41.8	88.9	87.1	36.4
609.61	1434	128	824	43.2	84.8	35.5	54.2	73.8	30.9
606.56	1110	89.2	528	23.0	66.2	27.7	28.6	60.6	25.4
603.51	803	60.3	365	9.4	50.9	21.3	12.3	48.0	20.1
600.46	578	39.4	155	1.0	38.4	16.1	3.5	35.9	15.0
597.42	413	24.4	0	0	24.4	10.2	0.1	24.3	10.2
596.35	365	20.3			20.3	8.49	0	20.3	8.49
594.37	274	14.0			14.0	5.86		14.0	5.86
591.32	170	7.3			7.3	3.05		7.3	3.05
588.27	91.9	3.4			3.4	1.42		3.4	1.42
585.22	47.3	1.3			1.3	0.54		1.3	0.54
582.18	21.0	0.3			0.3	0.13		0.3	0.13
579.74	0	0			0	0		0	0

Explanation of columns:

(1) Elevation of reservoir water surface.
(2) Original reservoir surface area.
(3) Original reservoir capacity.
(4) Reservoir surface area determined from 1981 survey.
(5) Reservoir capacity from 1981 survey.
(6) *Accumulated sediment volume = column (3) - column (5).*
(7) Measured sediment expressed as percentage of total measured sediment (239×10^6 m^3).
(8) Computed 1981 reservoir capacity using Empirical Area-Reduction Method (Type II).
(9) Computed sediment volume to date (72.4 years) = column (3) - column (8).
(10) Computed sediment expressed as a percentage of total computed sediment (239×10^6 m^3).

Table 1b. — *Summary of 1981 survey results and sediment distribution computations (inch-pound units)*

(1) Elevation, ft	(2) Original area, acres	(3) Original capacity, acre-ft	(4) 1981 area, acres	(5) 1981 capacity, acre-ft	(6) Measured sediment volume, acre-ft	(7) Percent of measured sediment	(8) 1981 capacity, acre-ft	(9) Computed sediment volume, acre-ft	(10) Percent of computed sediment
2136	17,785	1,530,499	17,337	1,336,734	193,765	100	1,336,734	193,765	100
2130	17,203	1,425,512	16,760	1,234,347	191,165	98.7	1,233,213	192,299	99.2
2120	16,177	1,258,547	15,617	1,072,370	186,177	96.1	1,072,252	186,295	96.1
2110	15,095	1,102,215	14,441	922,310	179.905	92.8	923,711	178,504	92.1
2100	14,104	956,455	13,555	782,550	173,905	89.8	786,882	169,573	87.5
2090	13,247	819,272	12,746	650,466	168,806	87.1	659,445	159,827	82.5
2080	11,939	693,315	11,331	530,047	163,268	84.3	543,836	149,479	77.1
2070	10,638	580,590	9,842	424,028	156,562	80.8	441,901	138,689	71.6
2060	9,482	479,928	8,230	333,799	146,129	75.4	352,341	127,587	65.8
2050	8,262	391,207	6,781	258,869	132,338	68.3	274,924	116,283	60.0
2040	7,106	314,623	5,569	197,577	117,046	60.4	209,751	104,872	54.1
2030	6,216	248,009	4,847	145,593	102,416	52.9	154,564	93,445	48.2
2020	5,286	190,334	4,212	100,268	90,066	46.5	108,250	82,084	42.4
2010	4,264	142,903	3,387	61,631	81,272	41.9	72,034	70,869	36.6
2000	3,544	103,787	2,036	35,038	68,749	35.5	43,907	59,880	30.9
1990	2,744	72,347	1,304	18,665	53,682	27.7	23,152	49,195	25.4
1980	1,985	48,867	903	7,612	41,255	21.3	9,971	38,896	20.1
1970	1,428	31,935	382	774	31,151	16.1	2,869	29,066	15.0
1960	1,020	19,743	0	0	19,743	10.2	93	19,650	10.1
1956.5	901	16,480			16,480	8.51	0	16,480	8.51
1950	677	11,328			11,328	5.85		11,328	5.85
1940	419	5,893			5,893	3.04		5,893	3.04
1930	227	2,735			2,735	1.41		2,735	1.41
1920	117	1,059			1,059	0.55		1,059	0.55
1910	52	211			211	0.11		211	0.11
1902	0	0			0	0		0	0

Explanation of columns:

(1) Elevation of reservoir water surface.
(2) Original reservoir surface area.
(3) Original reservoir capacity.
(4) Reservoir surface area determined from 1981 survey.
(5) Reservoir capacity from 1981 survey.
(6) Accumulated sediment volume = column (3) - column (5).
(7) Measured sediment expressed as percentage of total measured sediment (193,765 acre-ft).
(8) Computed 1981 reservoir capacity using Empirical Area-Reduction Method (Type II).
(9) Computed sediment volume to date (72.4 years) = column (3) - column (8).
(10) Computed sediment expressed as a percentage of total computed sediment (193,765 acre-ft).

Table 2.—*Reservoir sediment data summary*

Bureau of Reclamation

RESERVOIR SEDIMENT
DATA SUMMARY

Theodore Roosevelt Lake
NAME OF RESERVOIR

DATA SHEET NO.

DAM	1. OWNER Salt River Project	2. STREAM Salt R. & Tonto Cr.	3. STATE Arizona
	4. SEC. 20 TWP. 4N RANGE 12E	5. NEAREST P O Globe 30 NW.	6. COUNTY Gila
	7. LAT 33° 33′ 13″ LONG 111° 26′ 33″	8. TOP OF DAM ELEVATION 2142	9. SPILLWAY CREST ELEV. 2136

RESERVOIR	10. STORAGE ALLOCATION [1]	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					May 1909
	c. POWER					
	d. WATER SUPPLY	2136	17,826		1,522,200	16. DATE NORMAL OPER. BEGAN
	e. IRRIGATION					
	f. CONSERVATION					May 15, 1907[2]
	g. INACTIVE					
	17. LENGTH OF RESERVOIR [3]26.7 MILES			AV. WIDTH OF RESERVOIR 1.04 MILES		

WATERSHED	18. TOTAL DRAINAGE AREA 5,736 SQ. MI.	22. MEAN ANNUAL PRECIPITATION 21.0 INCHES
	19. NET SEDIMENT CONTRIBUTING AREA 5,709 SQ. MI.	23. MEAN ANNUAL RUNOFF 2.39 INCHES
	20. LENGTH 117 MILES; AV. WIDTH 50 MILES	24. MEAN ANNUAL RUNOFF 726,678 AC.-FT.
	21. MAX. ELEV. 11,000; MIN. ELEV. 1929	25. ANNUAL TEMP MEAN 56.7 RANGE 37.7-76.6

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.
Gates Closed 1909	0	0	Contour (D)	5-ft interval	17,785	[4]1,530,499	
Sept. 4, 1981	72.4	72.4	Range (D)	39	17,337	1,336,734	

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
Sept. 4, 1981	21.0	717,131		50,199,184	717,131	50,199,184

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
Sept. 4, 1981	193,765	2,676	0.469	193,765	2,676	0.469

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
Sept. 4, 1981	49.3	504	504	0.175	12.67	3,054	3,050

Table 2.—*Reservoir sediment data summary*—Continued

26. DATE OF SURVEY	43. DEPTH DESIGNATION RANGE IN FEET BELOW, AND ABOVE, CREST ELEVATION										
	Crest	-210-	210-190	190-170	170-150	150-130	130-110	110-90	90-70	70-64		
	250 Crest	PERCENT OF TOTAL SEDIMENT LOCATED WITHIN DEPTH DESIGNATION										
Sept. 4, 1981	2.7	6.3	5.7	5.9	11.5	15.1	11.2	13.2	2.7	25.7		

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														

45. RANGE IN RESERVOIR OPERATION

WATER YEAR	MAX. ELEV.	MIN. ELEV.	INFLOW, AC.-FT.	WATER YEAR	MAX. ELEV.	MIN. ELEV.	INFLOW, AC.-FT.
1910	2025	1984	454,365	1925	2066	1990	328,067
1911	2069	1963	800,250	1926	2075	1990	783,887
1912	2079	2051	548,027	1927	2093	2038	959,292
1913	2069	2033	401,857	1928	2068	2007	317,279
1914	2044	2012	530,770	1929	2005	1962	471,874
1915	2127	2012	1,782,758	1930	1995	1952	397,997
1916	2127	2106	2,582,996	1931	2019	1952	639,182
1917	2127	2092	816,505	1932	2114	1968	1,394,960
1918	2103	2045	394,512	1933	2099	2076	473,897
1919	2073	2036	991,274	1934	2076	1975	263,624
1920	2127	2072	1,890,016	1935	2071	1962	760,101
1921	2100	2068	546,283	1936	2070	2026	689,187
1922	2103	2072	688,488	1937	2107	2038	1,018,347
1923	2080	2052	612,431	1938	2082	2007	398,797
1924	2105	2053	903,937	1939	2008	1957	381,849

46. ELEVATION AREA CAPACITY DATA

ELEVATION	AREA	CAPACITY	ELEVATION	AREA	CAPACITY	ELEVATION	AREA	CAPACITY
	1981 Survey		2070	9,842	424,028			
1966	5	0	2080	11,331	503,047			
1970	382	774	2090	12,746	650,466			
1980	903	7,612	2100	13,555	782,550			
1990	1,304	18,665	2110	14,441	922,310			
2000	2,036	35,038	2120	15,617	1,072,370			
2010	3,387	61,631	2130	16,760	1,234,347			
2020	4,212	100,268	2136	17,337	1,336,734			
2030	4,847	145,593						
2040	5,569	197,577						
2050	6,781	258,869						
2060	8,230	333,799						

47. REMARKS AND REFERENCES

[1] Storage allocation breakdown unknown.

[2] Date of project operation. Date of normal dam operation unavailable.

[3] Salt River Arm = 15.8 mile. Tonto Creek Arm = 10.9 mile.

[4] 1909 area and capacity values recomputed by current methods for comparison with 1981 area and capacity values to compute sediment deposition.

48. AGENCY MAKING SURVEY Bureau of Reclamation, Salt River Project, Arizona

49. AGENCY SUPPLYING DATA Bureau of Reclamation

50. DATE October 9, 1981

April 1966

Table 2.—*Reservoir sediment data summary*—Continued

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

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														

45. RANGE IN RESERVOIR OPERATION

WATER YEAR	MAX. ELEV.	MIN. ELEV.	INFLOW, AC.-FT.	WATER YEAR	MAX. ELEV.	MIN. ELEV.	INFLOW, AC.-FT.
1940	1955	1991	309,658	1955	2082.93	2037.40	286,986
1941	2136	1955	2,267,919	1956	2044.70	1972.18	208,666
1942	2131	2117	609,213	1957	2032.88	1986.87	491,741
1943	2125	2102	595,101	1958	2079.02	2000.58	839,302
1944	2107	2086	427,664	1956	2076.75	2032.20	548,771
1945	2098	2081	349,100	1957	2032.88	1986.87	491,741
1946	2073.49	1986.65	396,127	1958	2079.02	2000.58	839,302
1947	2032.01	1954.95	312,384	1959	2076.75	2032.20	548,771
1948	2030.58	1976.54	464,169	1960	2119.58	2077.02	737,340
1949	2069.22	1993.95	815,771	1961	2103.50	2074.60	212,370
1950	2060.47	1970.93	205,444	1962	2107.83	2078.68	767,021
1951	2025.28	1971.08	367,416	1963	2091.90	2057.84	446,036
1952	2121.43	2009.51	1,345,066	1964	2068.13	2034.54	292,497
1953	2116.59	2087.03	296,554	1965	2132.46	2048.61	1,407,435
1954	2093.11	2077.69	391,262	1966	2135.47	2123.45	756,767

46. ELEVATION-AREA-CAPACITY DATA

ELEVATION	AREA	CAPACITY	ELEVATION	AREA	CAPACITY	ELEVATION	AREA	CAPACITY

47. REMARKS AND REFERENCES

48. AGENCY MAKING SURVEY Bureau of Reclamation, Salt River Project, Arizona

49. AGENCY SUPPLYING DATA Bureau of Reclamation 50. DATE October 9, 1981

April 1966

Table 2.—*Reservoir sediment data summary*—Continued

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

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														

45. RANGE IN RESERVOIR OPERATION

WATER YEAR	MAX. ELEV.	MIN. ELEV.	INFLOW, AC.-FT.	WATER YEAR	MAX. ELEV.	MIN. ELEV.	INFLOW, AC.-FT.
1967	2125.29	2105.35	383,794				
1968	2135.52	2114.60	1,006,598				
1969	2130.92	2114.88	617,967				
1970	2114.82	2080.46	349,271				
1971	2096.13	2068.54	471,764				
1972	2098.50	2032.45	748,406				
1973	2135.88	2096.68	1,642,102				
1974	2118.73	2081.88	266,586				
1975	2112.73	2086.85	621,110				
1976	2104.49	2082.44	419,679				
1977	2084.24	2015.12	211,884				
1978	2132.46	2024.05	2,037,484				
1979	2135.95	2117.70	1,743,995				
1980	2136.83	2118.75	1,729,915				

46. ELEVATION-AREA-CAPACITY DATA

ELEVATION	AREA	CAPACITY	ELEVATION	AREA	CAPACITY	ELEVATION	AREA	CAPACITY

47. REMARKS AND REFERENCES

48. AGENCY MAKING SURVEY Bureau of Reclamation, Salt River Project, Arizona

49. AGENCY SUPPLYING DATA Bureau of Reclamation

50. DATE October 9, 1981

April 1966

Table 3. — *Summary of reservoir sample data*

Range No.	Sample No.	Percent of Clay	Silt	Sand	Unit mass kg/m³	lb/ft³
1	1	80.0	19.9	0.1	459.7	28.7
2	2	73.1	26.9	0	565.4	35.3
3	3	76.0	23.6	0.4	567.0	35.4
4	4	72.2	27.1	0.7	677.6	42.3
4	5	74.5	25.2	0.3	589.5	36.8
5	6	52.4	47.4	0.2	695.2	43.4
5	7	63.8	35.9	0.3	501.4	31.3
30	8	74.1	25.5	0.4	531.8	33.2
30	9	83.4	16.5	0.1	461.3	28.8
31	10	70.1	29.4	0.5	757.6	47.3
31	11	72.6	26.9	0.5	623.1	38.9
32	12	53.3	45.9	0.8	738.4	46.1
32	13	58.8	32.8	8.4	599.1	37.4
33	14	57.2	42.3	0.5	711.2	44.4
33	15	45.1	54.1	0.8	780.1	48.7
34	16	24.9	67.4	7.7	916.2	57.2
34	17	18.5	43.6	37.9	951.5	59.4
35	18	27.5	71.3	1.2	523.8	32.7
35	19	18.5	65.7	15.8	1035.0	64.6
36	20	22.4	65.8	11.8	1024.0	63.9
36	21	16.9	53.9	29.2	1024.0	63.9
37	22	27.8	67.7	4.5	892.2	55.7
37	23	14.9	42.8	42.3	1121.0	70.0
38	24	28.4	68.0	3.6	917.8	57.3
38	25	34.9	64.6	0.5	959.5	59.9
39	26	15.9	73.6	10.5	1426.0	89.0
39	27	24.3	74.6	1.1	921.0	57.7
40	28	24.4	74.3	1.3	1134.0	70.8

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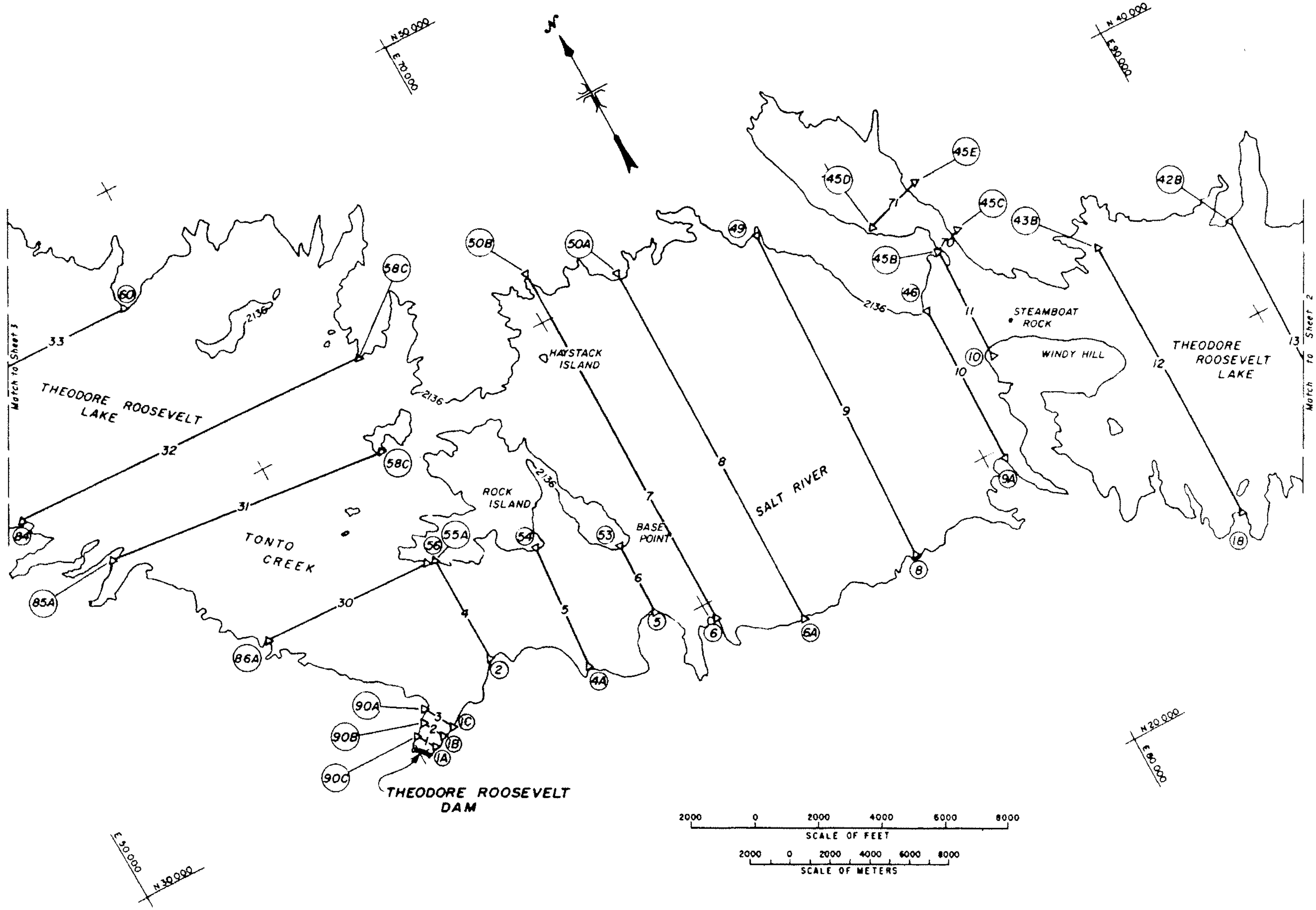

Figure 2.—Layout of reservoir sedimentation range system (sheet 1 of 3).

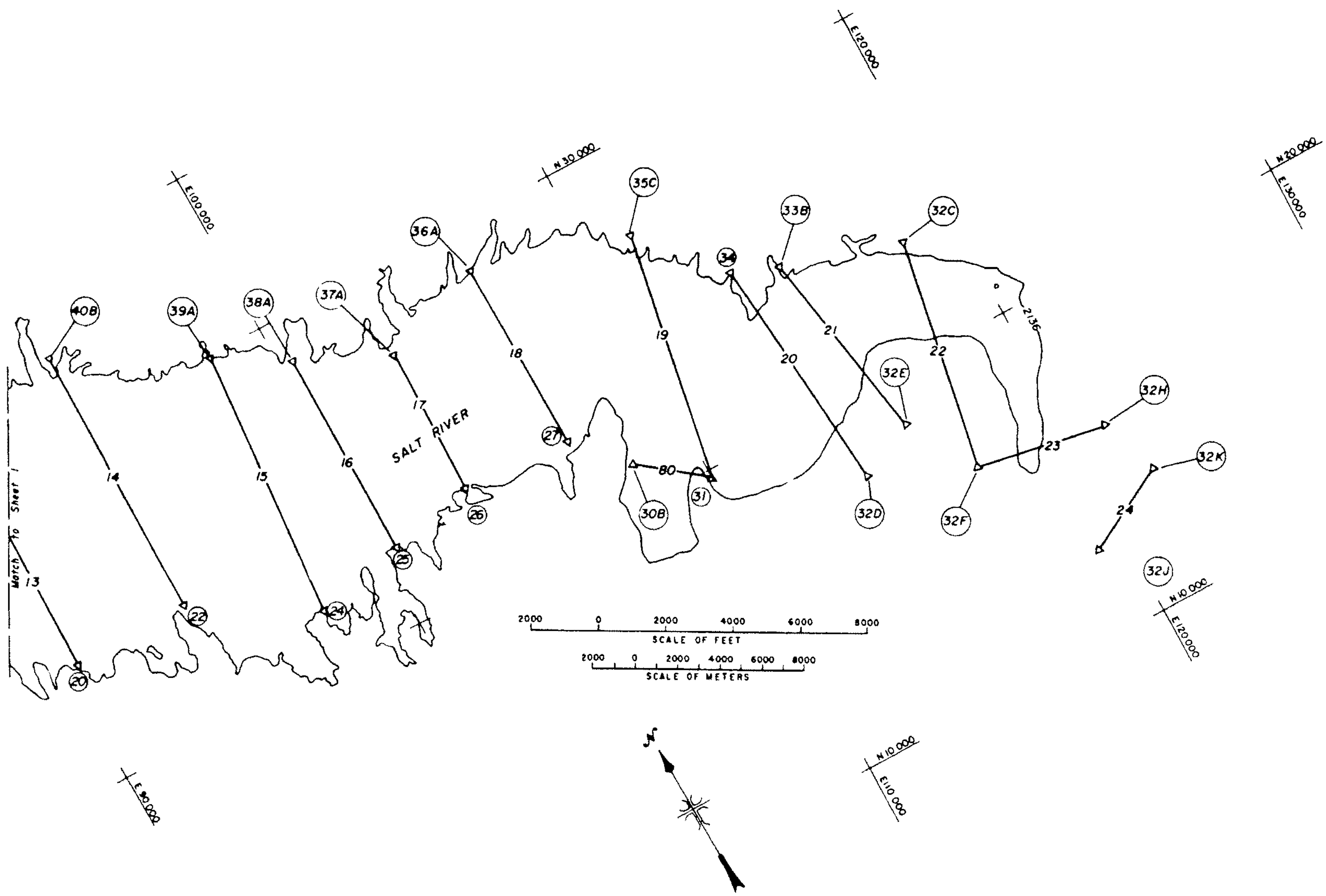

Figure 2.—Layout of reservoir sedimentation range system (sheet 2 of 3).

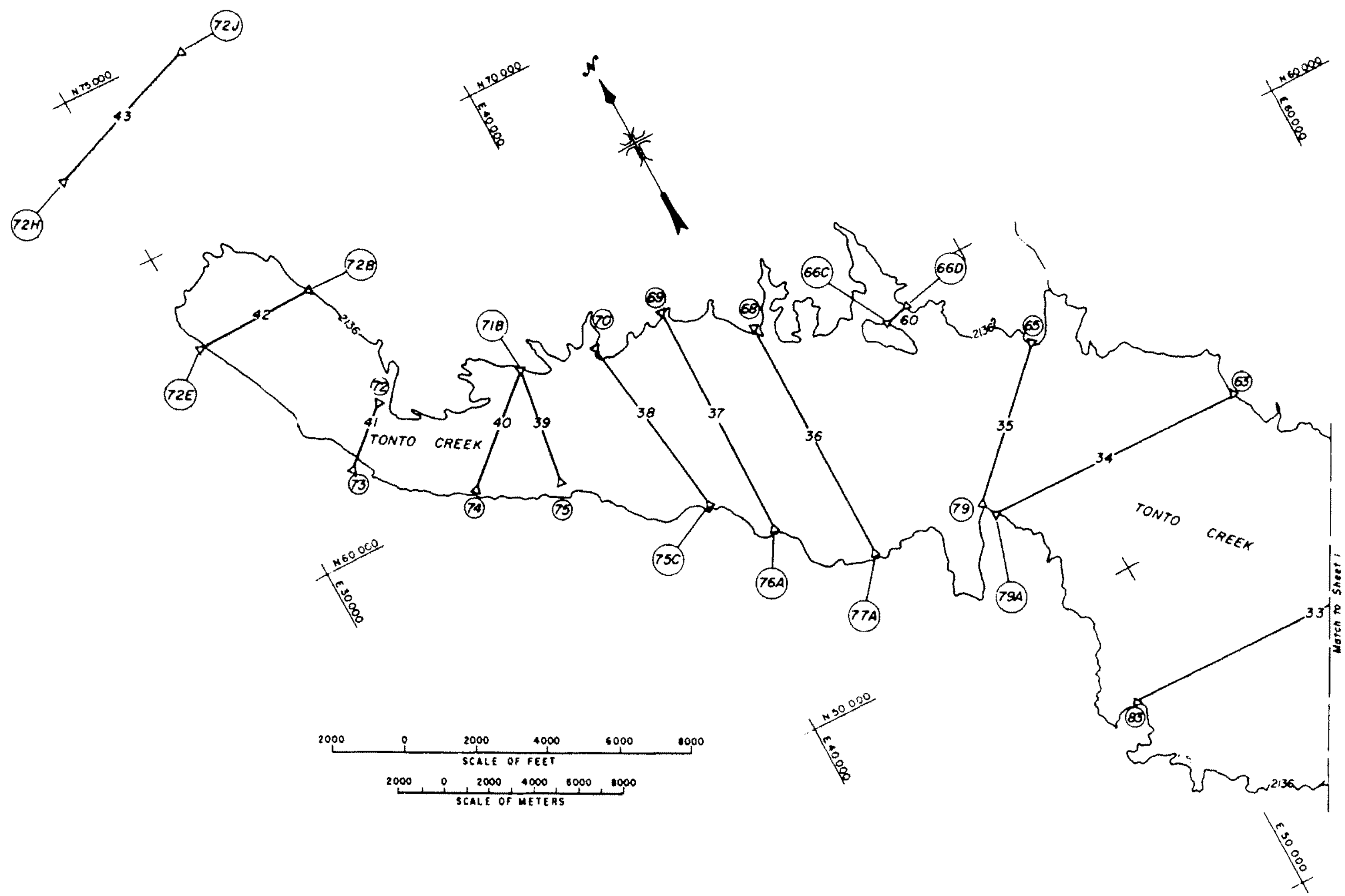

Figure 2.—Layout of reservoir sedimentation range system (sheet 3 of 3).

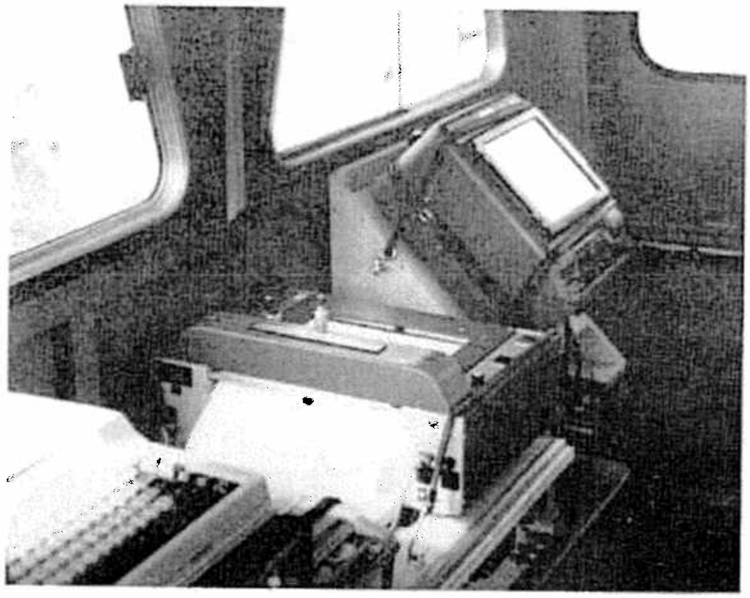

Figure 3.—Sonic depth recorder interfaced with automated positioning system. P801-D-80111

Figure 4.—Fixed shore station. P801-D-80112

Figure 5.—Boat used for sounding operations. P801-D-80113

Figure 6.—Gravity core sampler mounted on boat for sampling operations. P801-D-80114

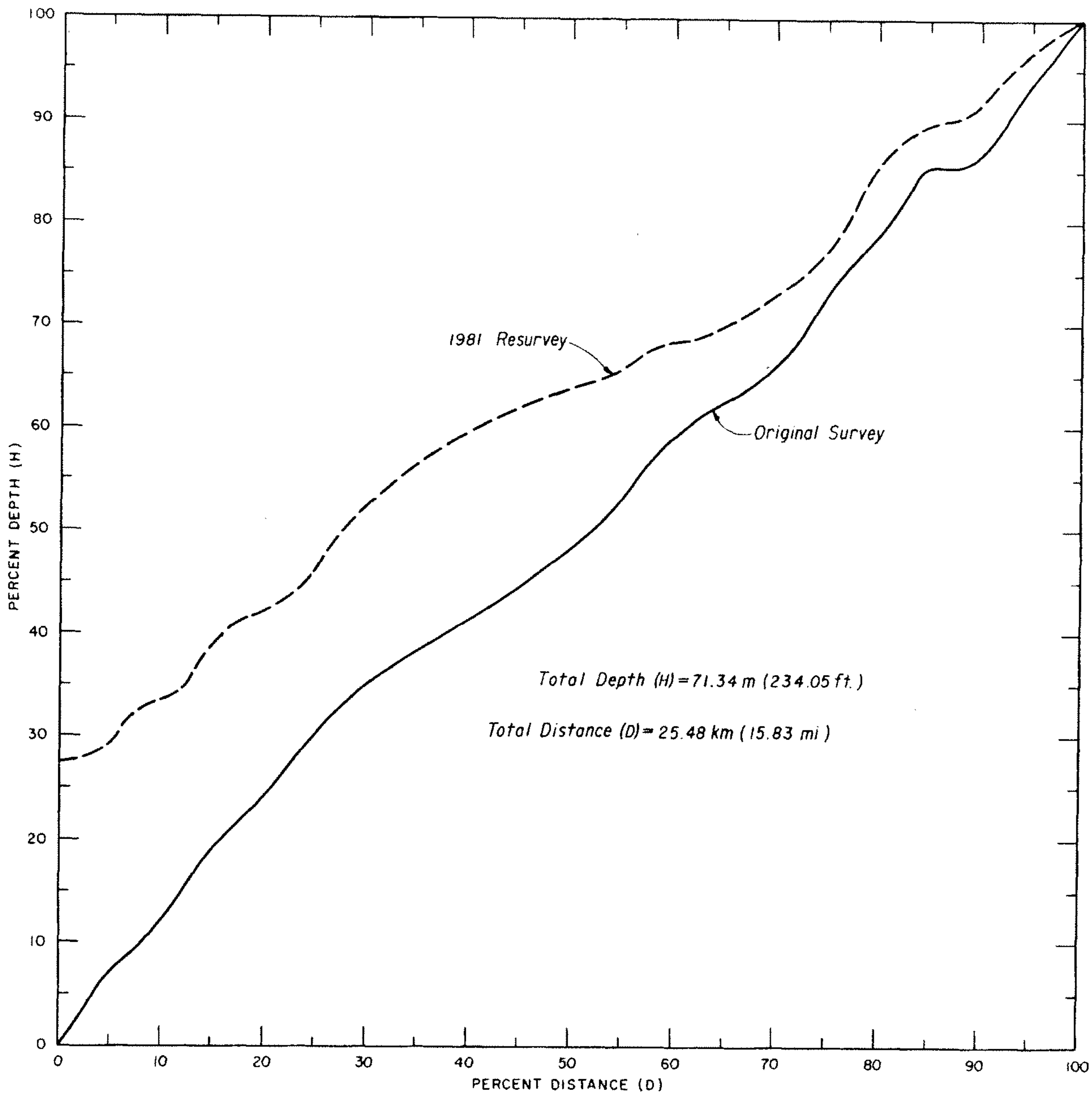

Figure 7.—Percent depth-percent distance relationship for Salt River Arm.

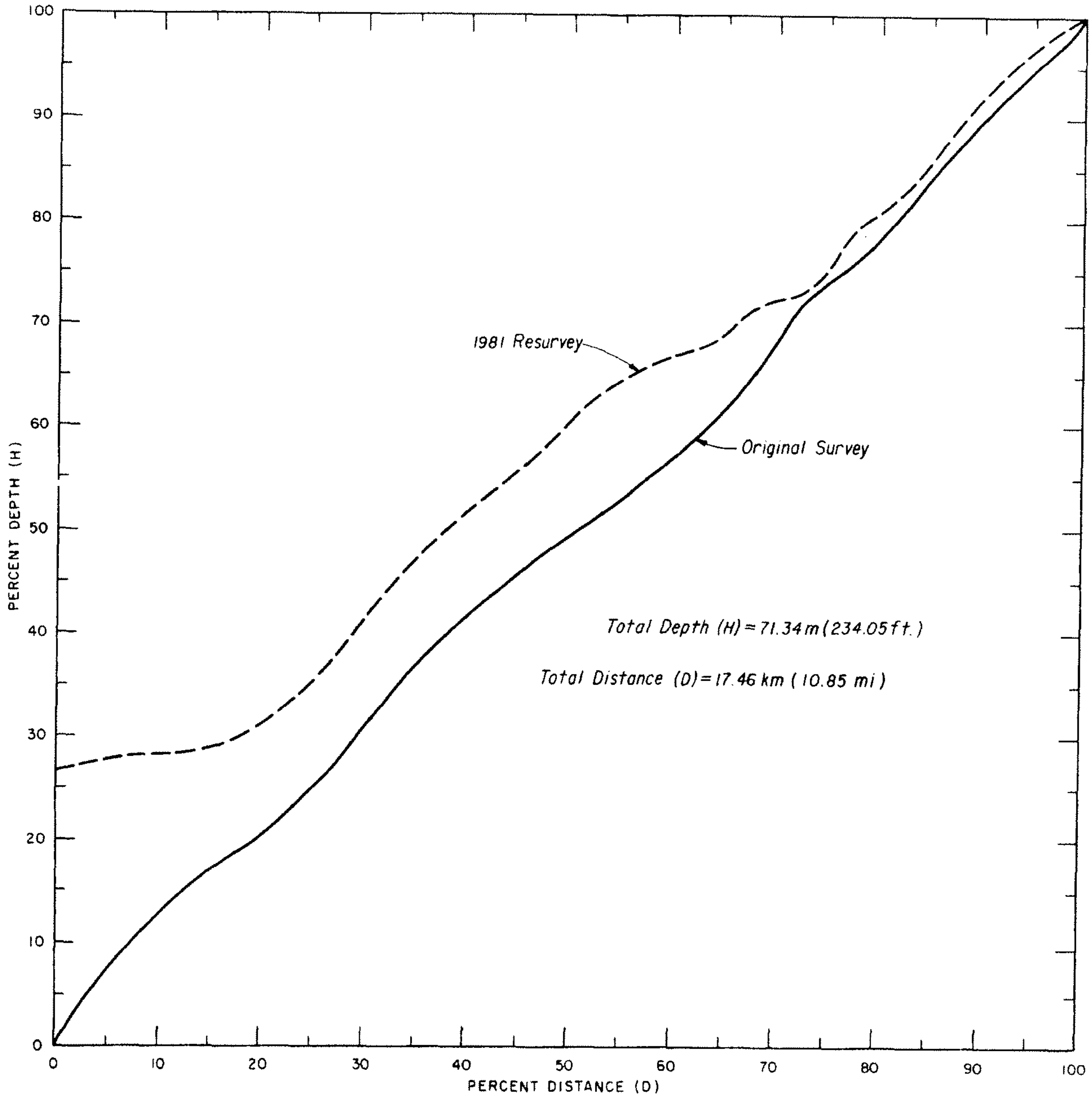

Figure 8.—Percent depth-percent distance relationship for Tonto Creek Arm.

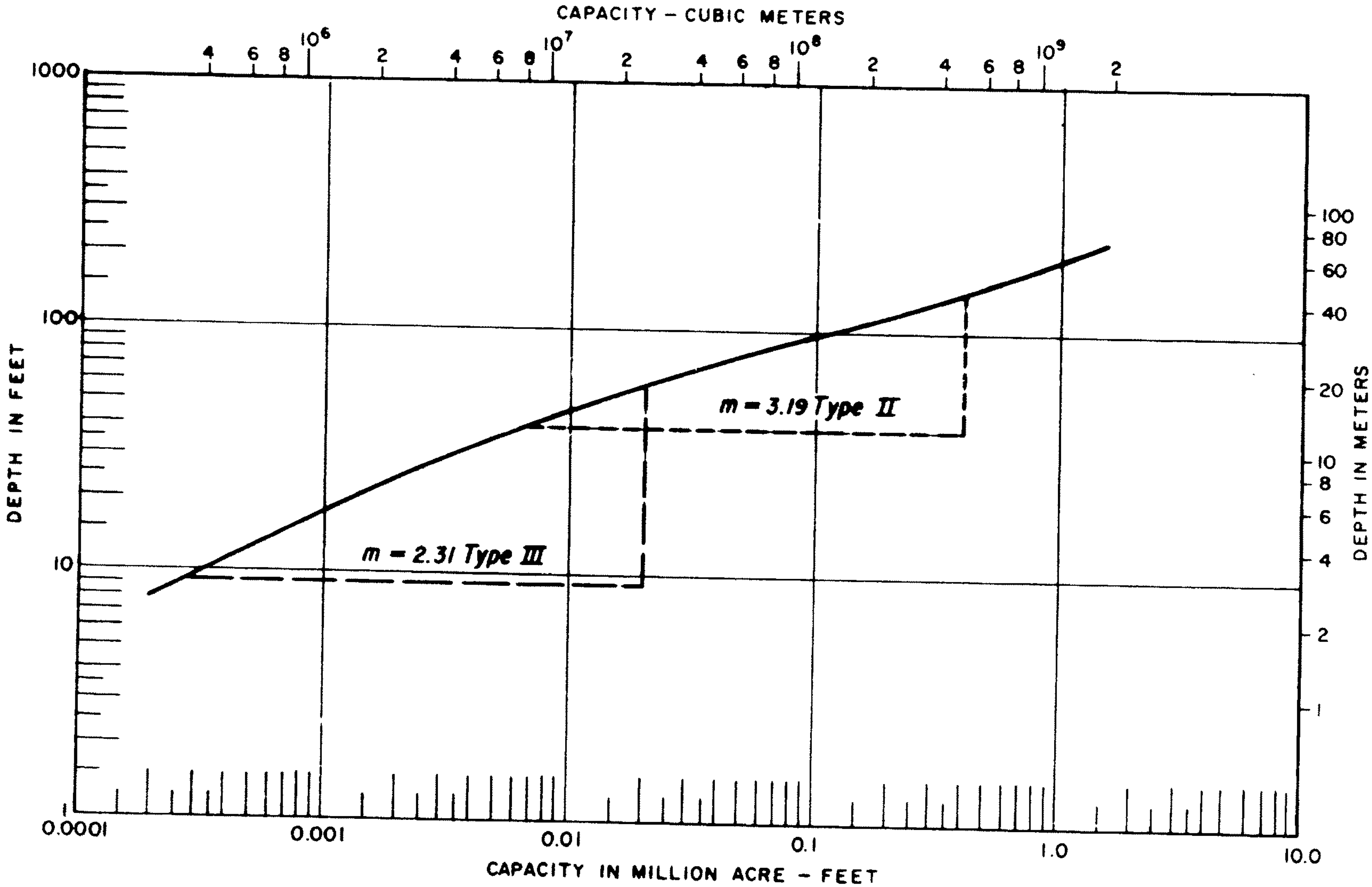

Figure 9.—Reservoir depth-capacity relationship.

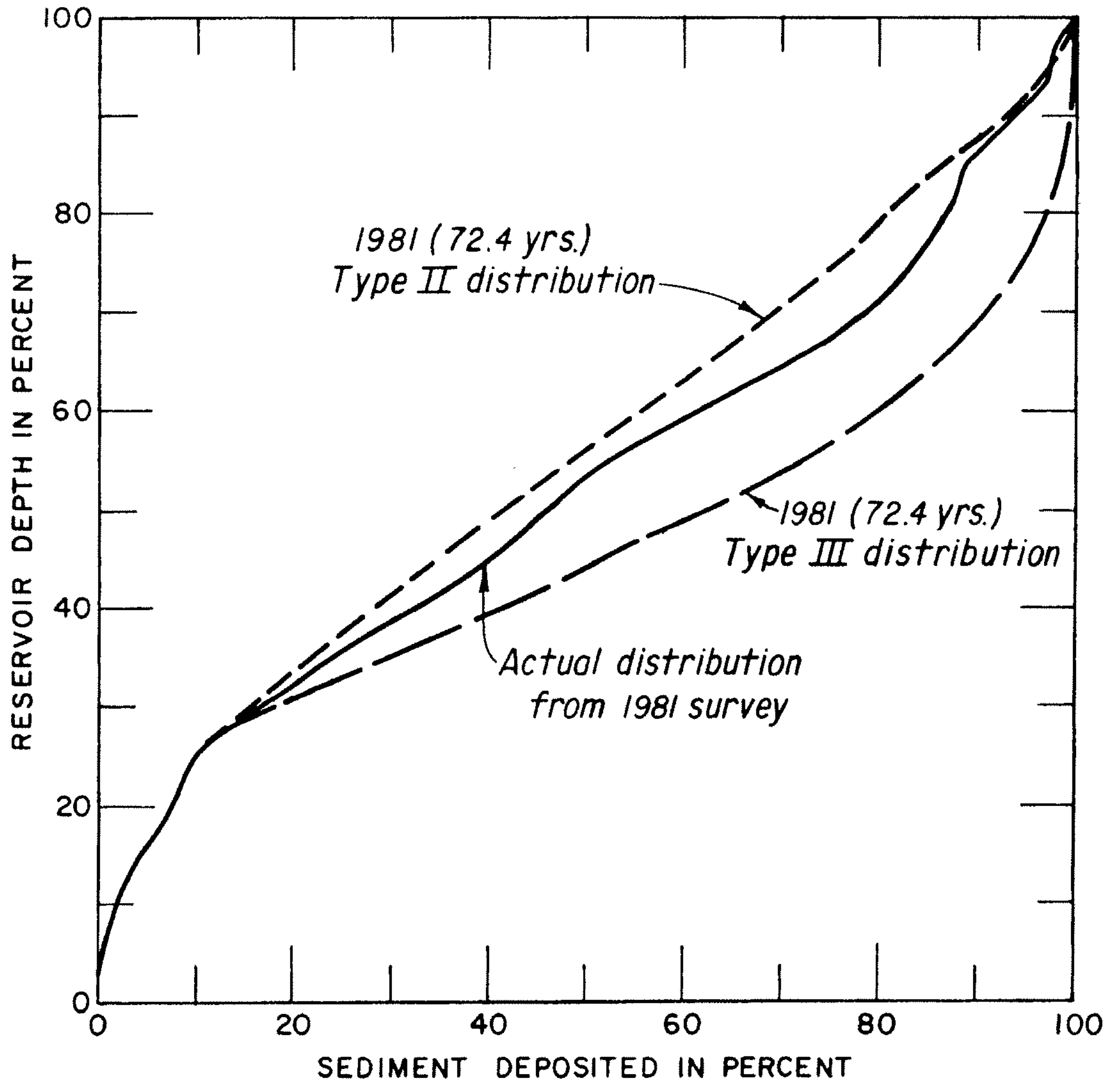

Figure 10.—Sediment disposition curves.

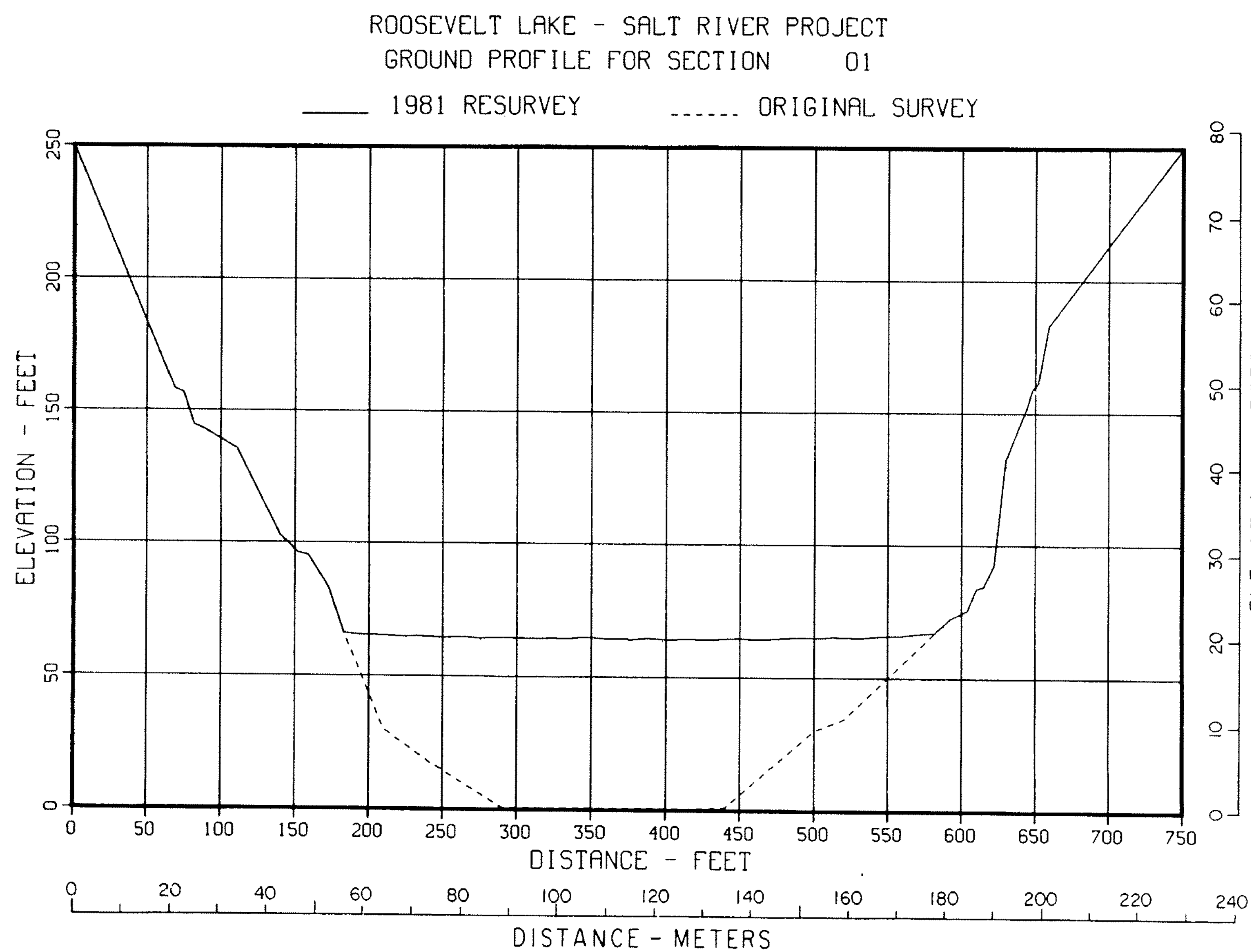

Figure 11.—Original and 1981 sedimentation range profiles — range 1, Salt River Arm.

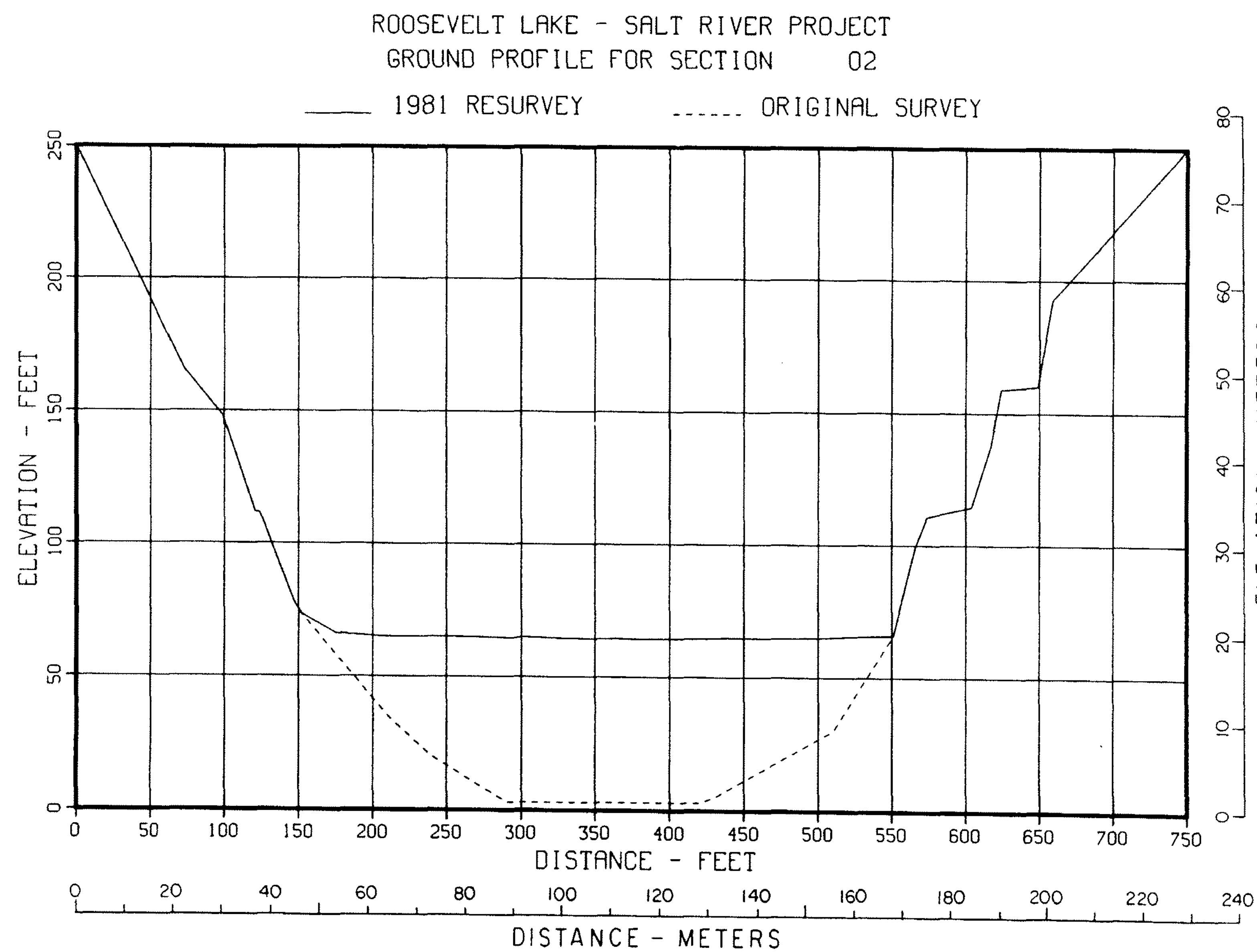

Figure 12.—Original and 1981 sedimentation range profiles — range 2, Salt River Arm.

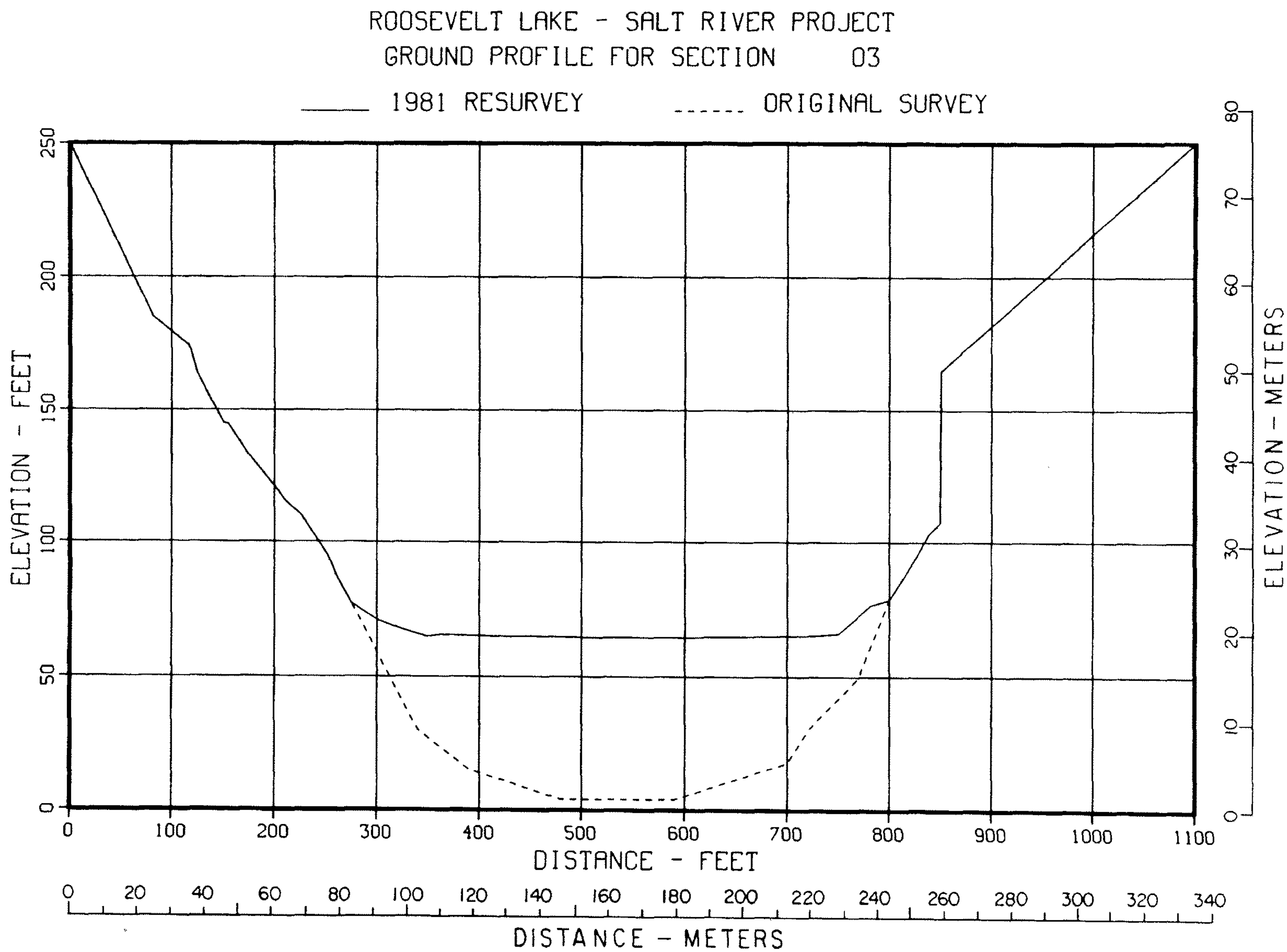

Figure 13.—Original and 1981 sedimentation range profiles — range 3, Salt River Arm.

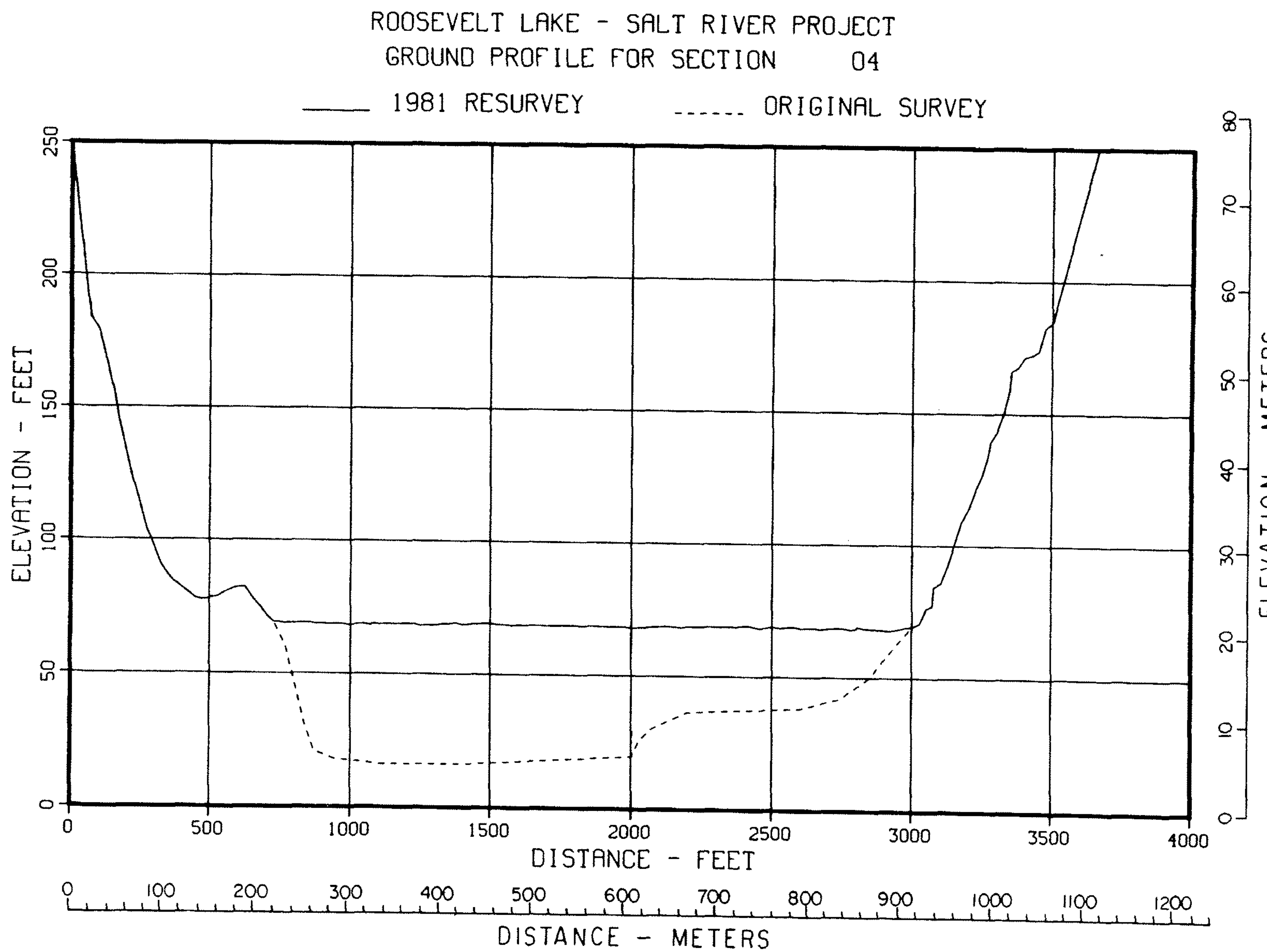

Figure 14.—Original and 1981 sedimentation range profiles — range 4, Salt River Arm.

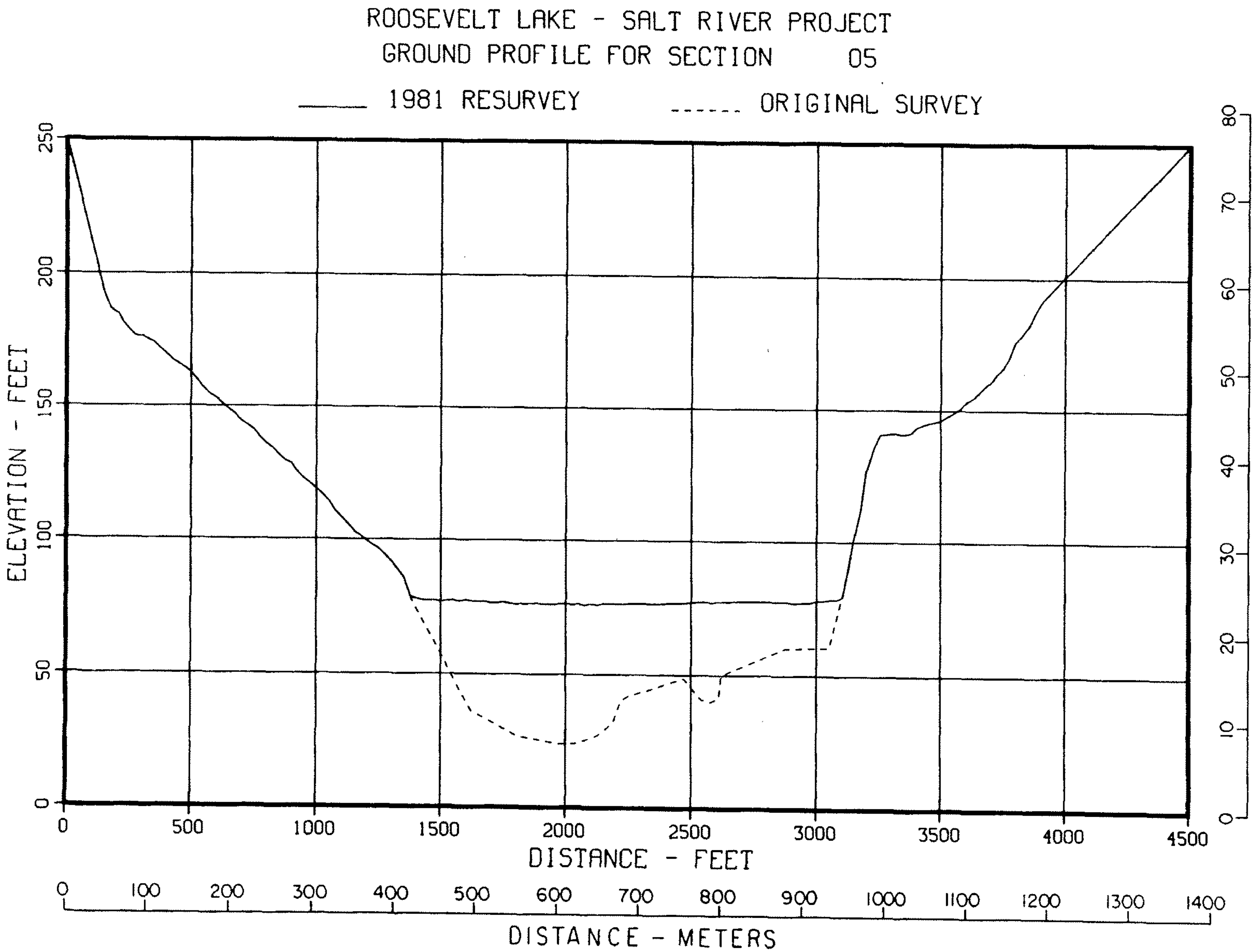

Figure 15.—Original and 1981 sedimentation range profiles — range 5, Salt River Arm.

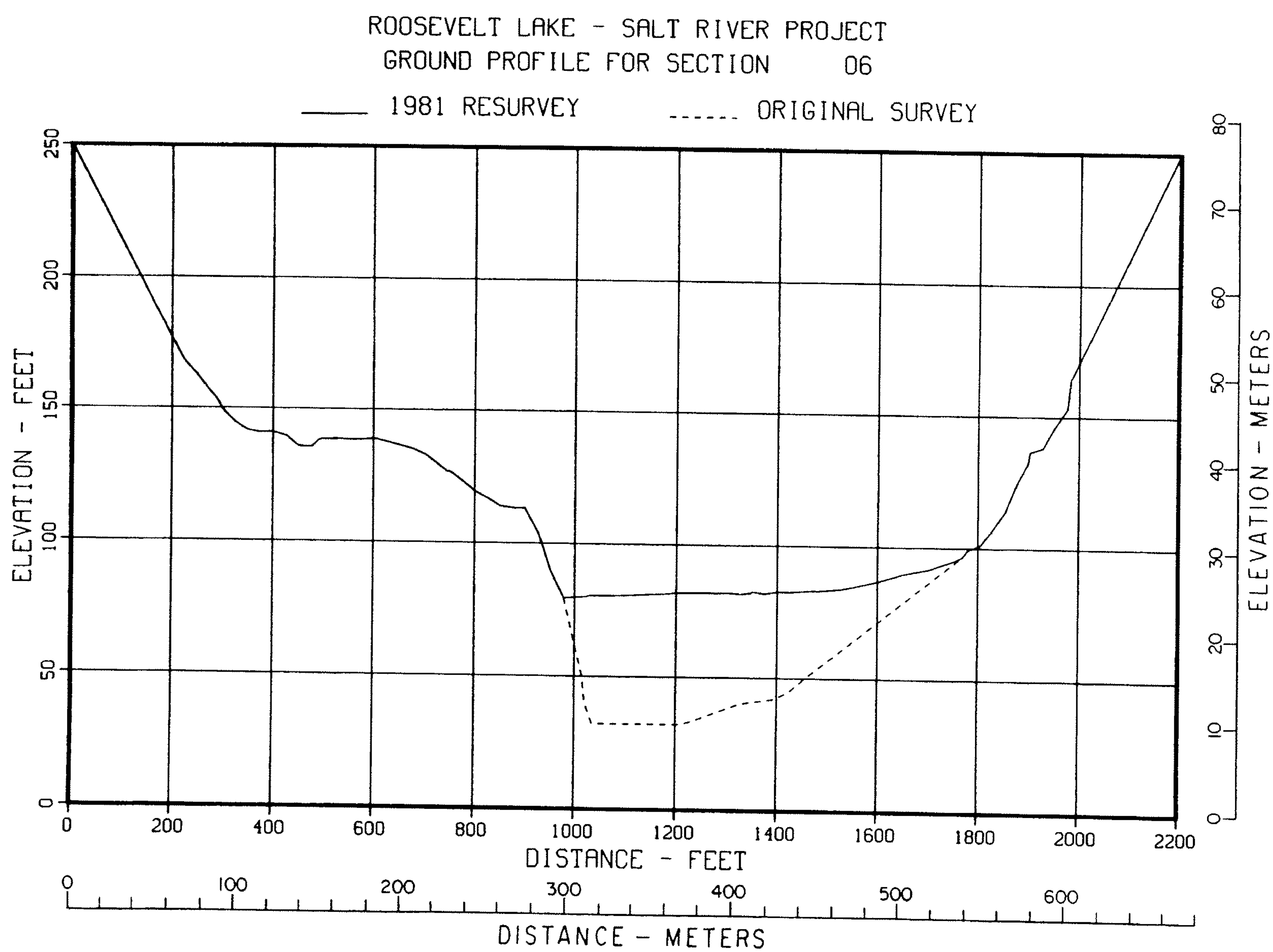

Figure 16.—Original and 1981 sedimentation range profiles — range 6, Salt River Arm.

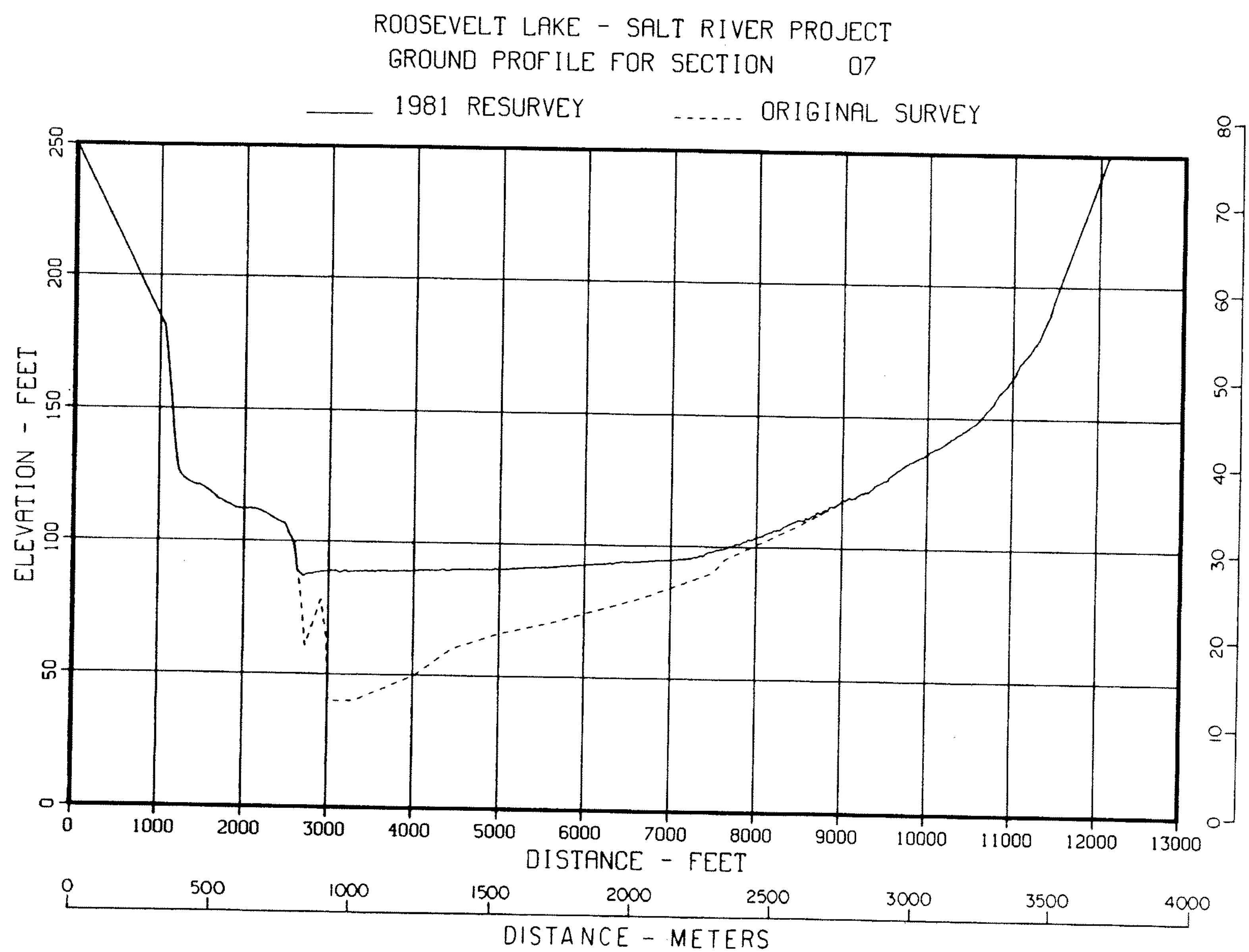

Figure 17.—Original and 1981 sedimentation range profiles — range 7, Salt River Arm.

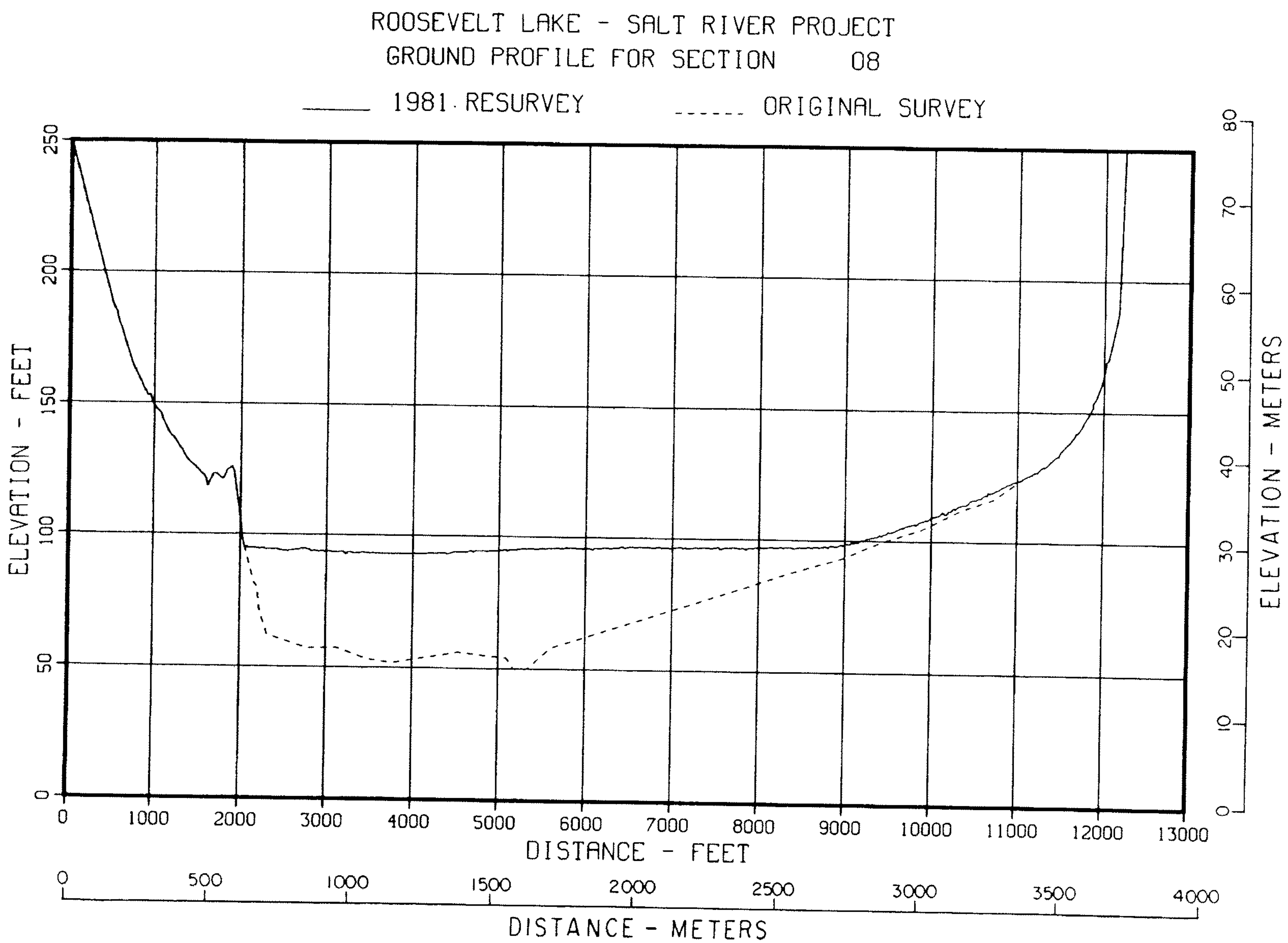

Figure 18.—Original and 1981 sedimentation range profiles — range 8, Salt River Arm.

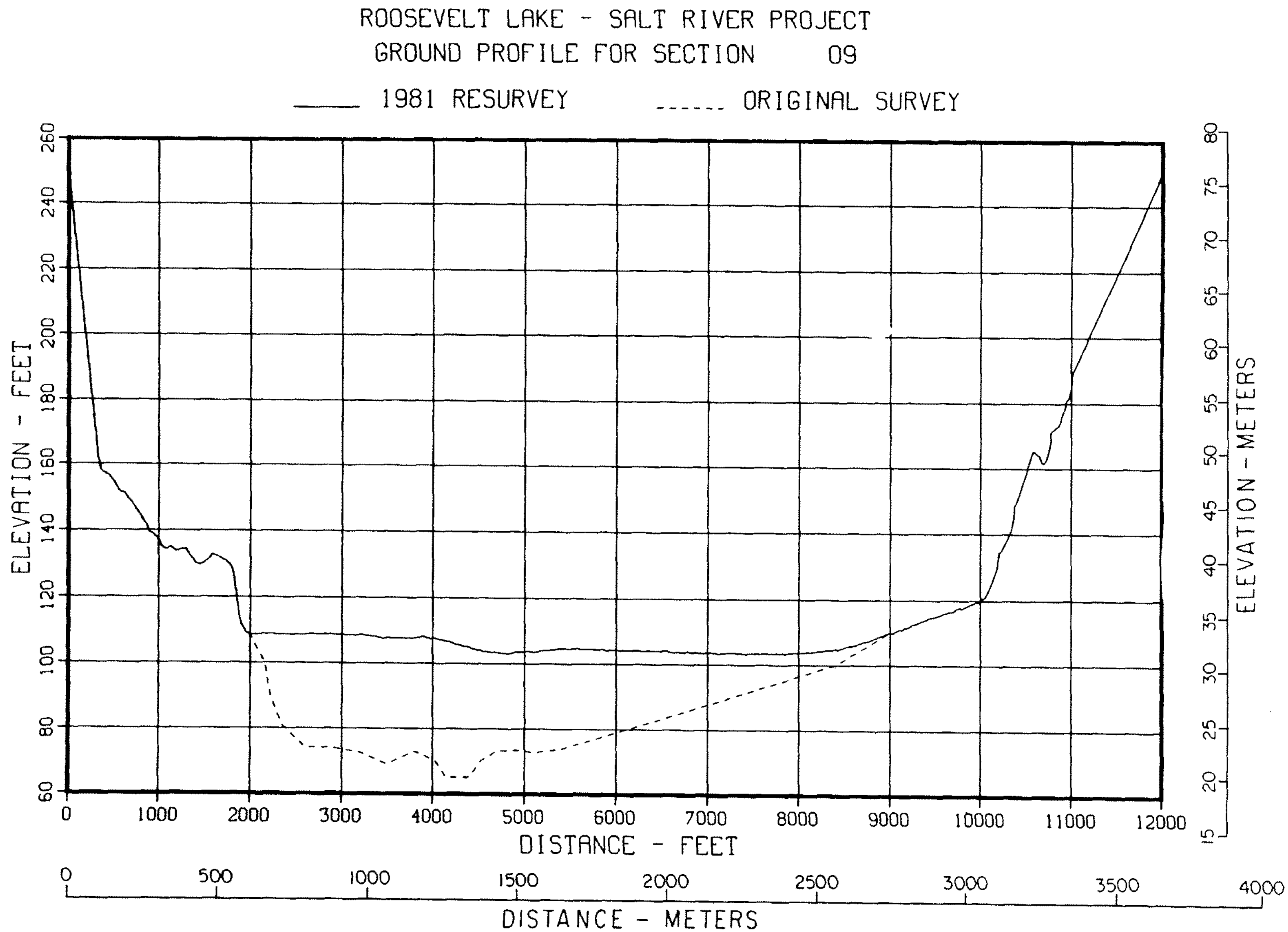

Figure 19.—Original and 1981 sedimentation range profiles — range 9, Salt River Arm.

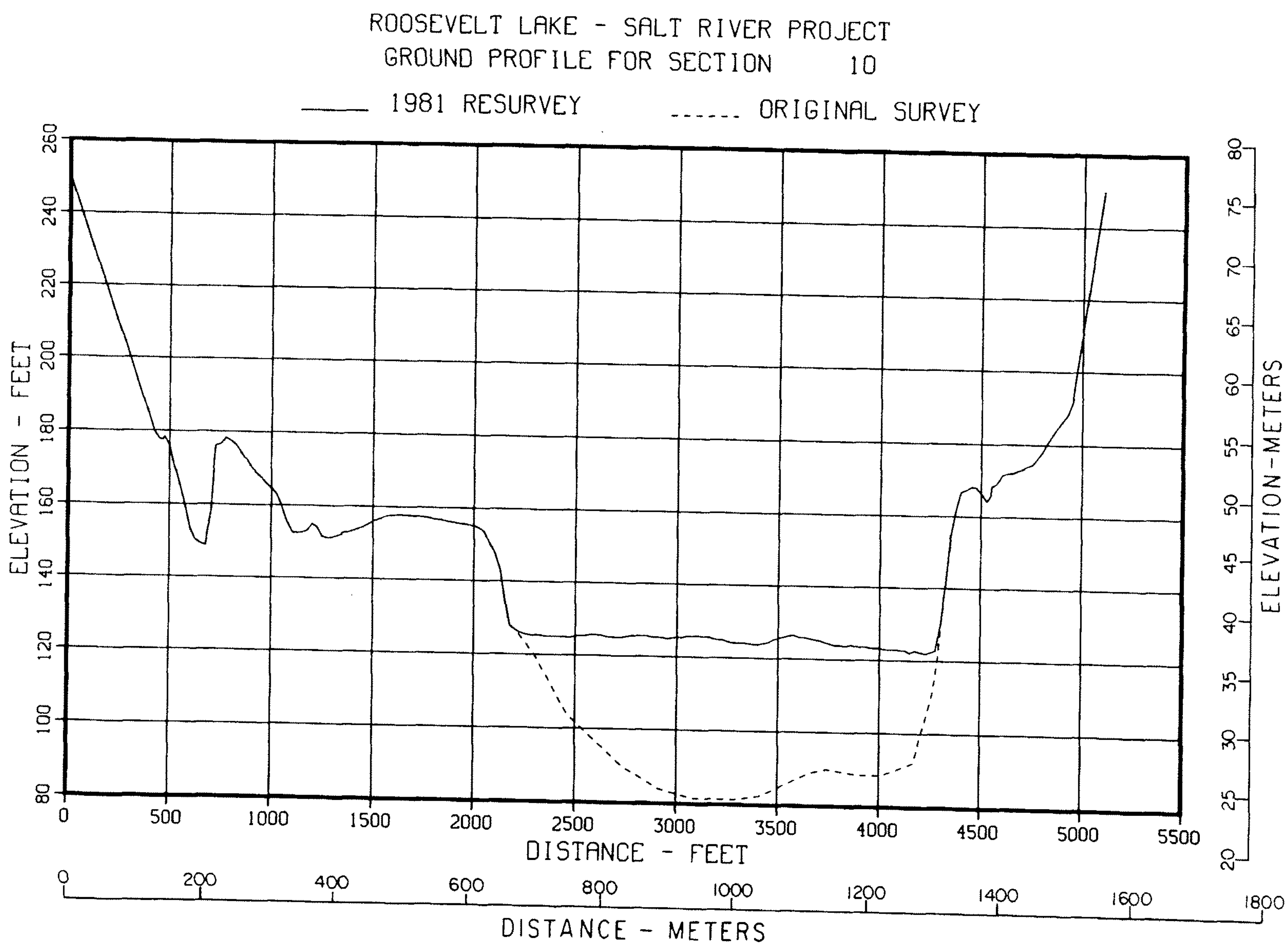

Figure 20.—Original and 1981 sedimentation range profiles — range 10, Salt River Arm.

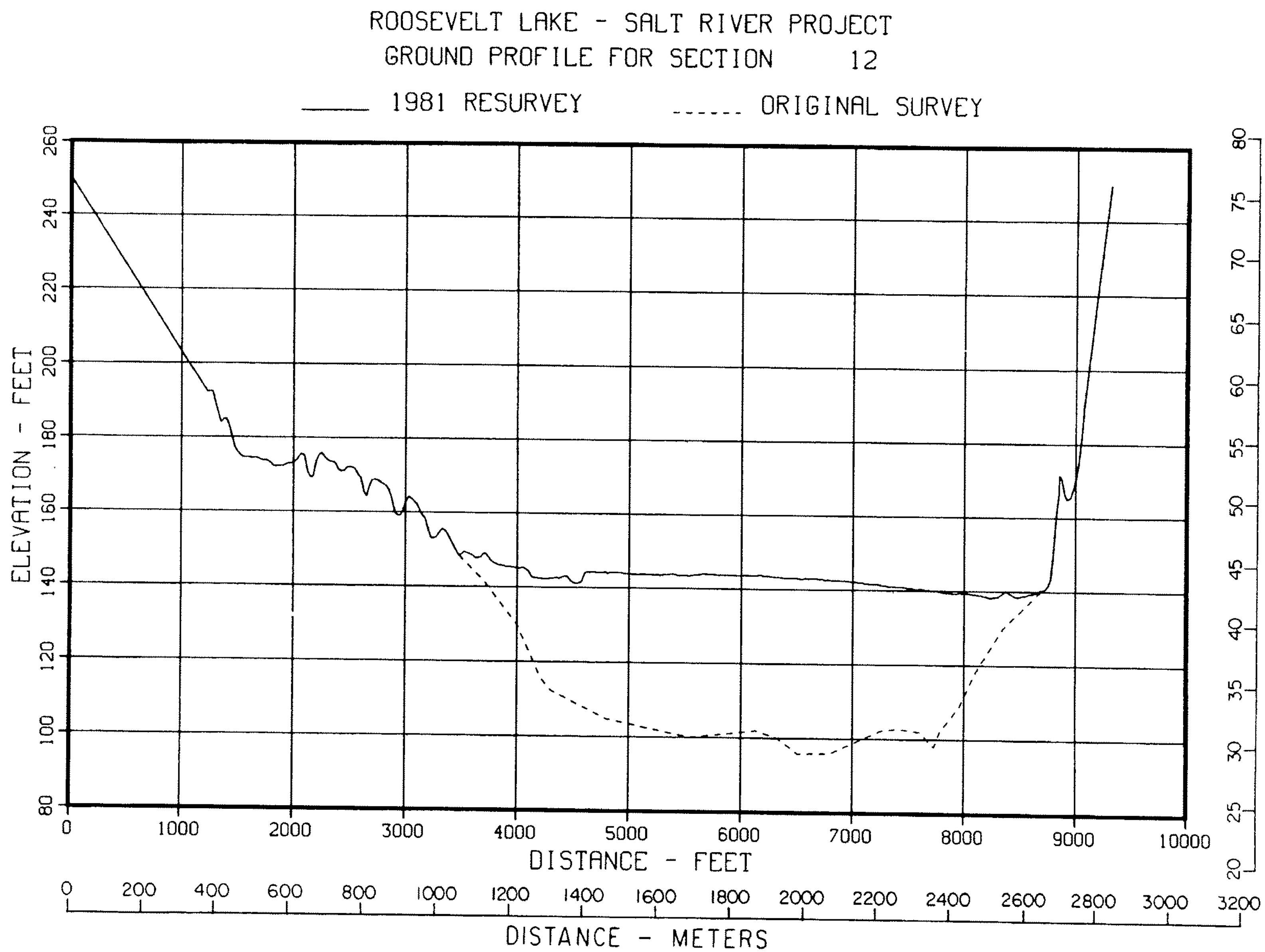

Figure 21.—Original and 1981 sedimentation range profiles — range 12, Salt River Arm.

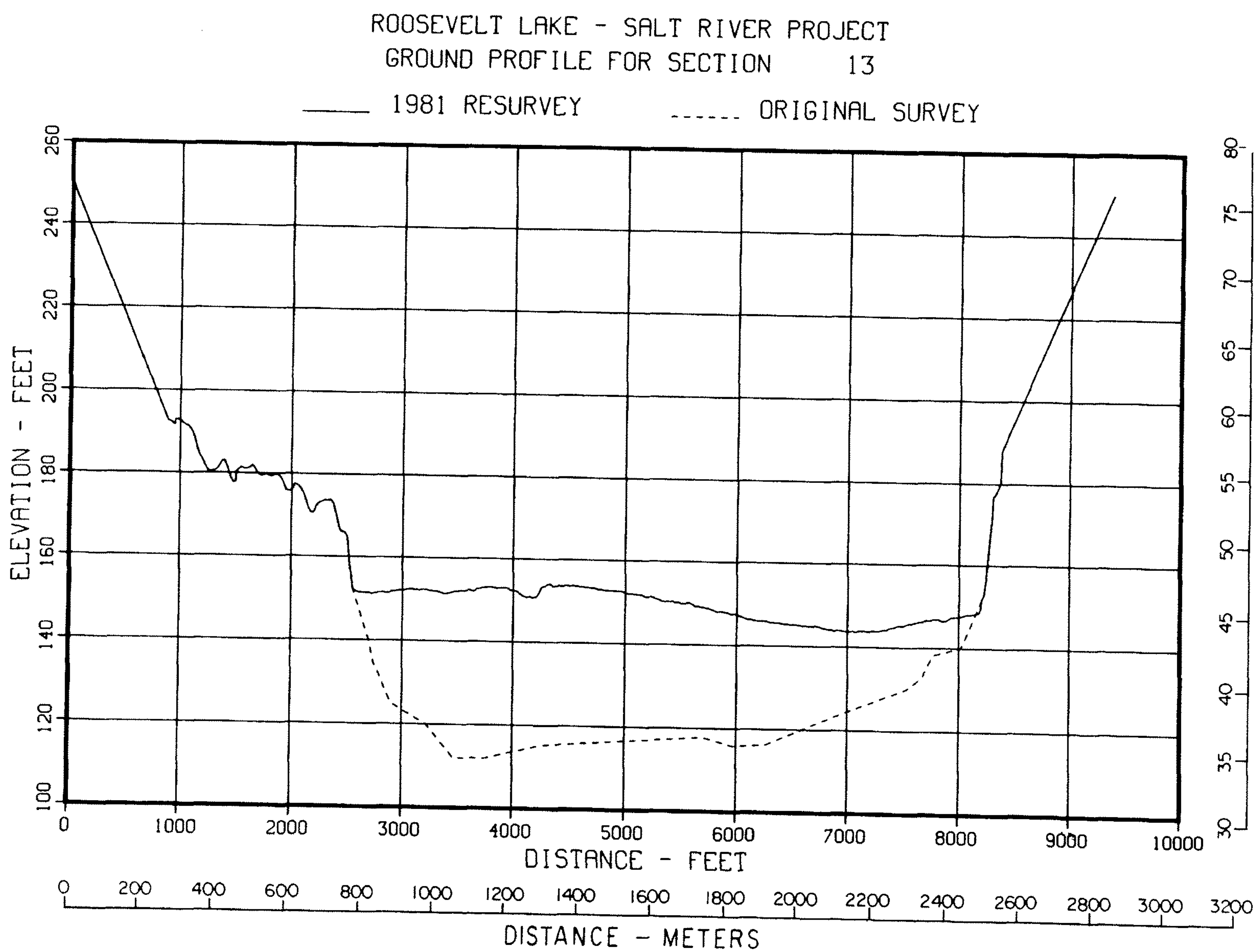

Figure 22.—Original and 1981 sedimentation range profiles — range 13, Salt River Arm.

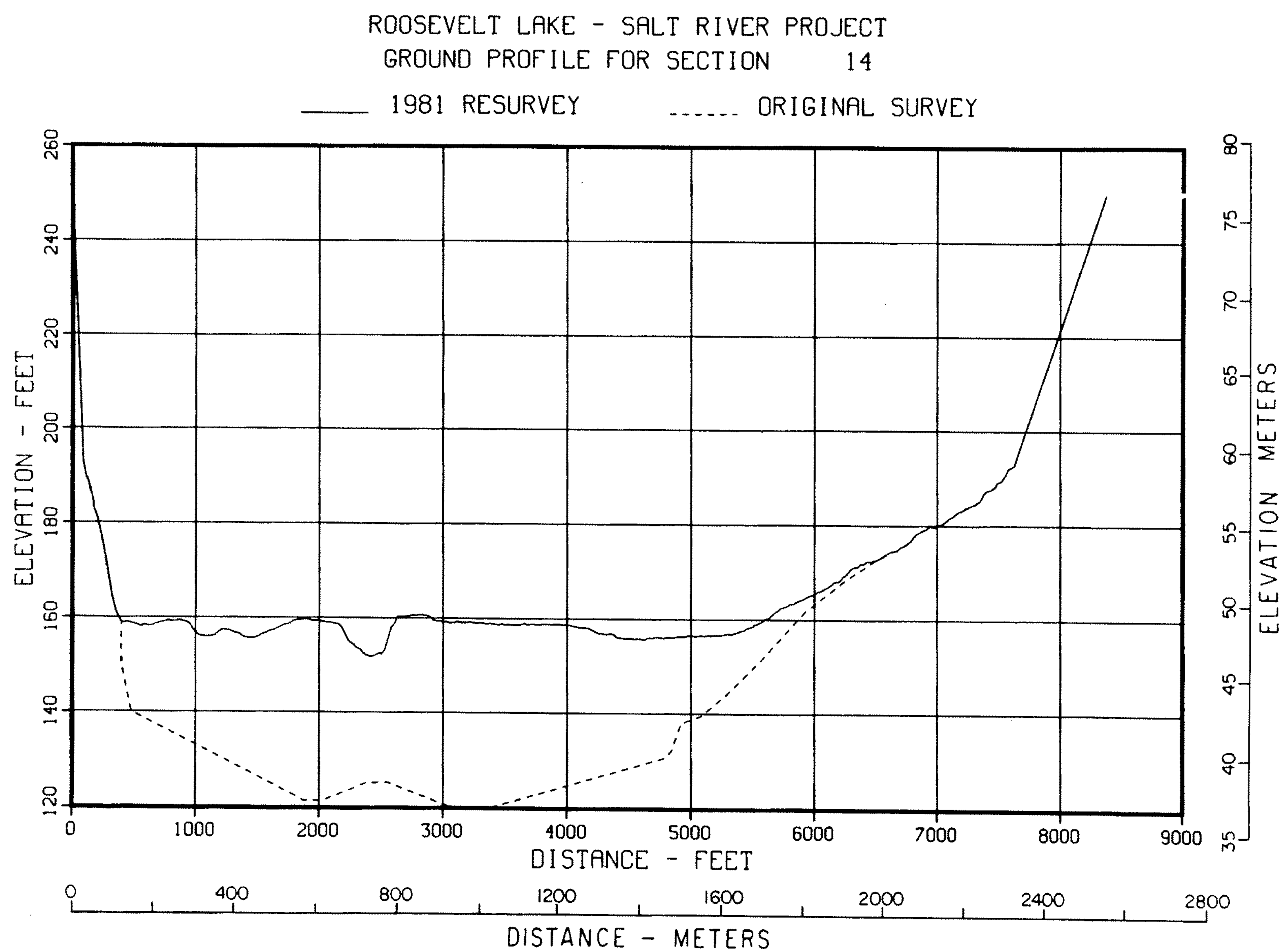

Figure 23.—Original and 1981 sedimentation range profiles — range 14, Salt River Arm.

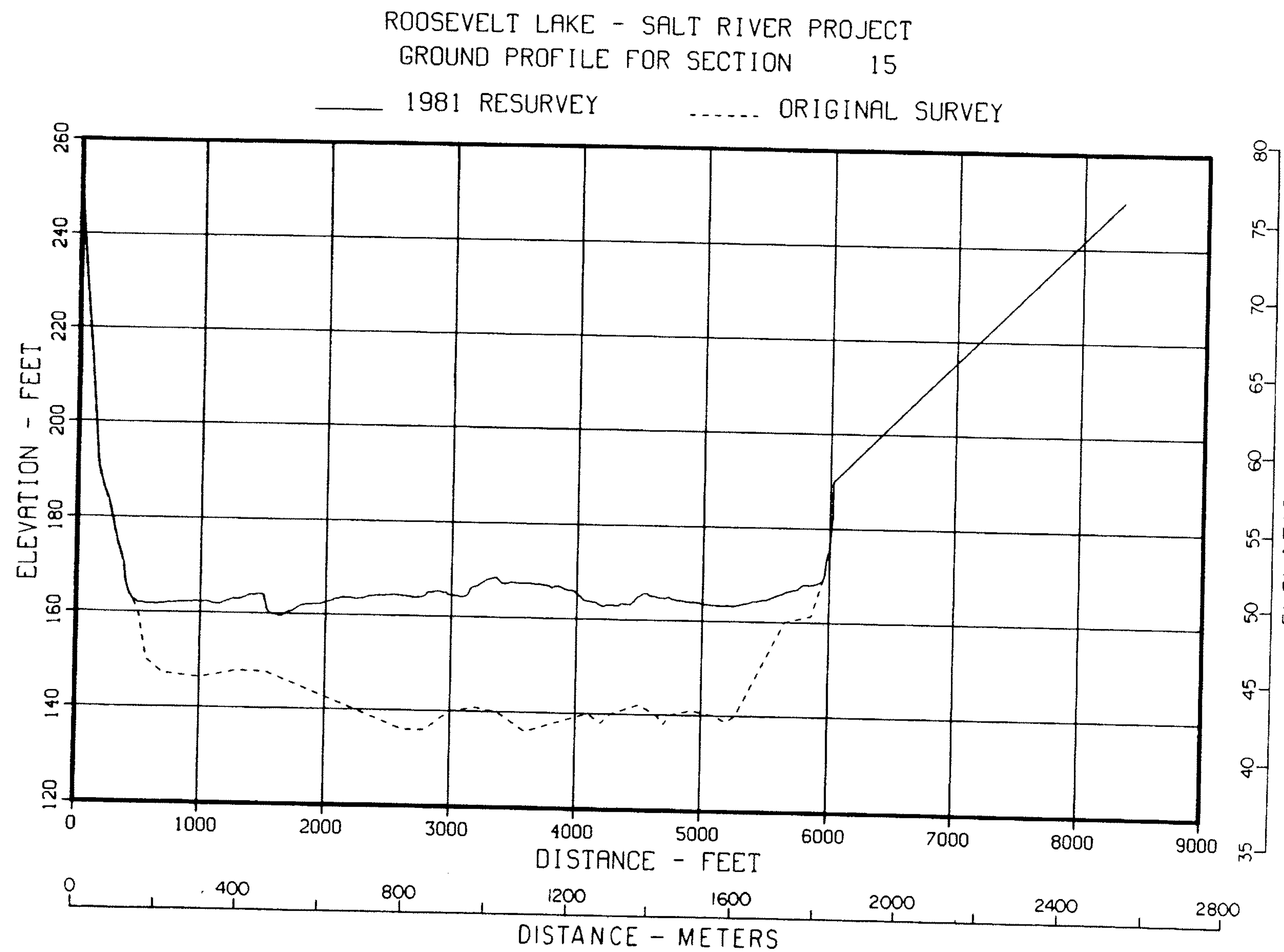

Figure 24.—Original and 1981 sedimentation range profiles — range 15, Salt River Arm.

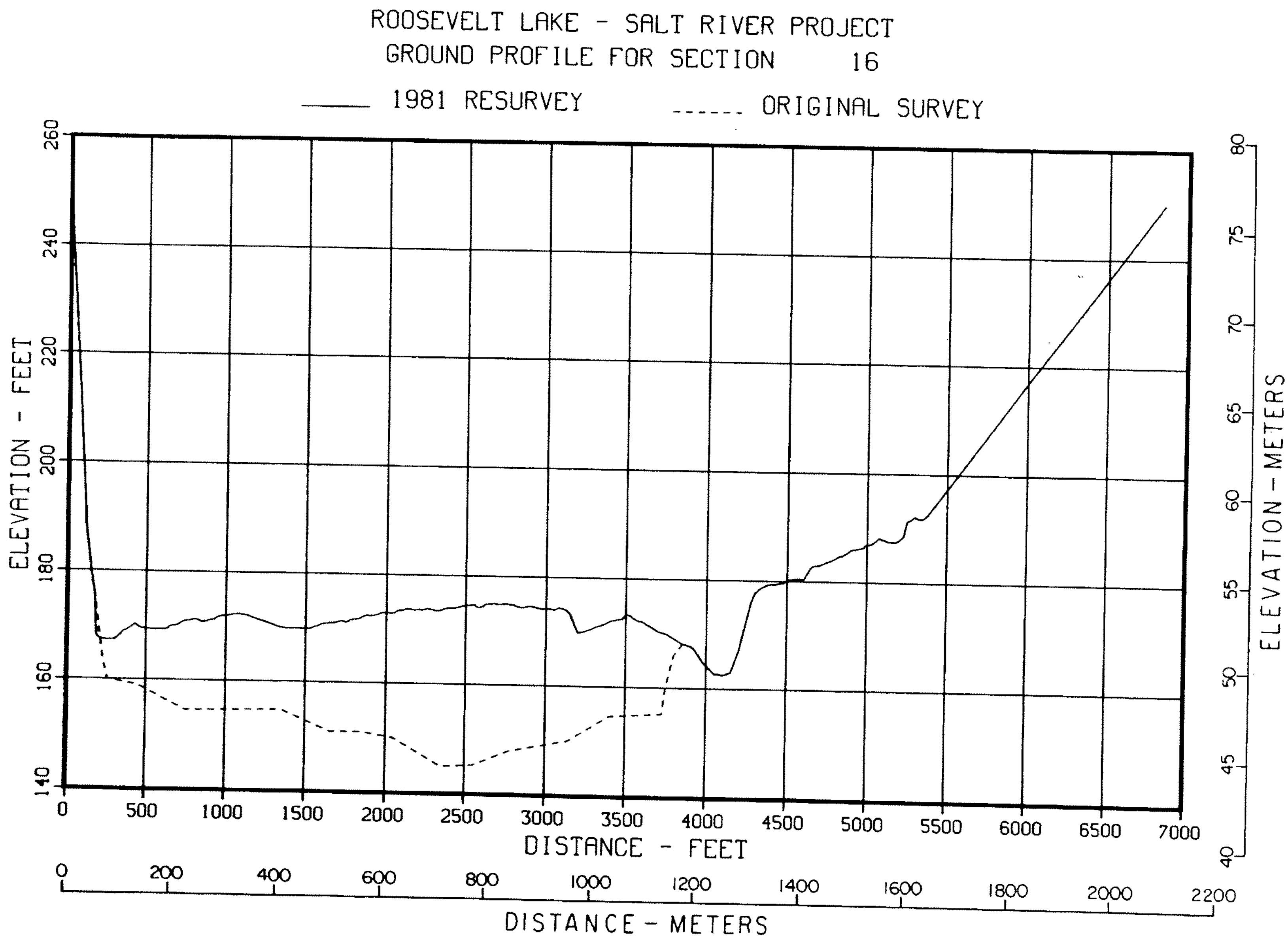

Figure 25.—Original and 1981 sedimentation range profiles — range 16, Salt River Arm.

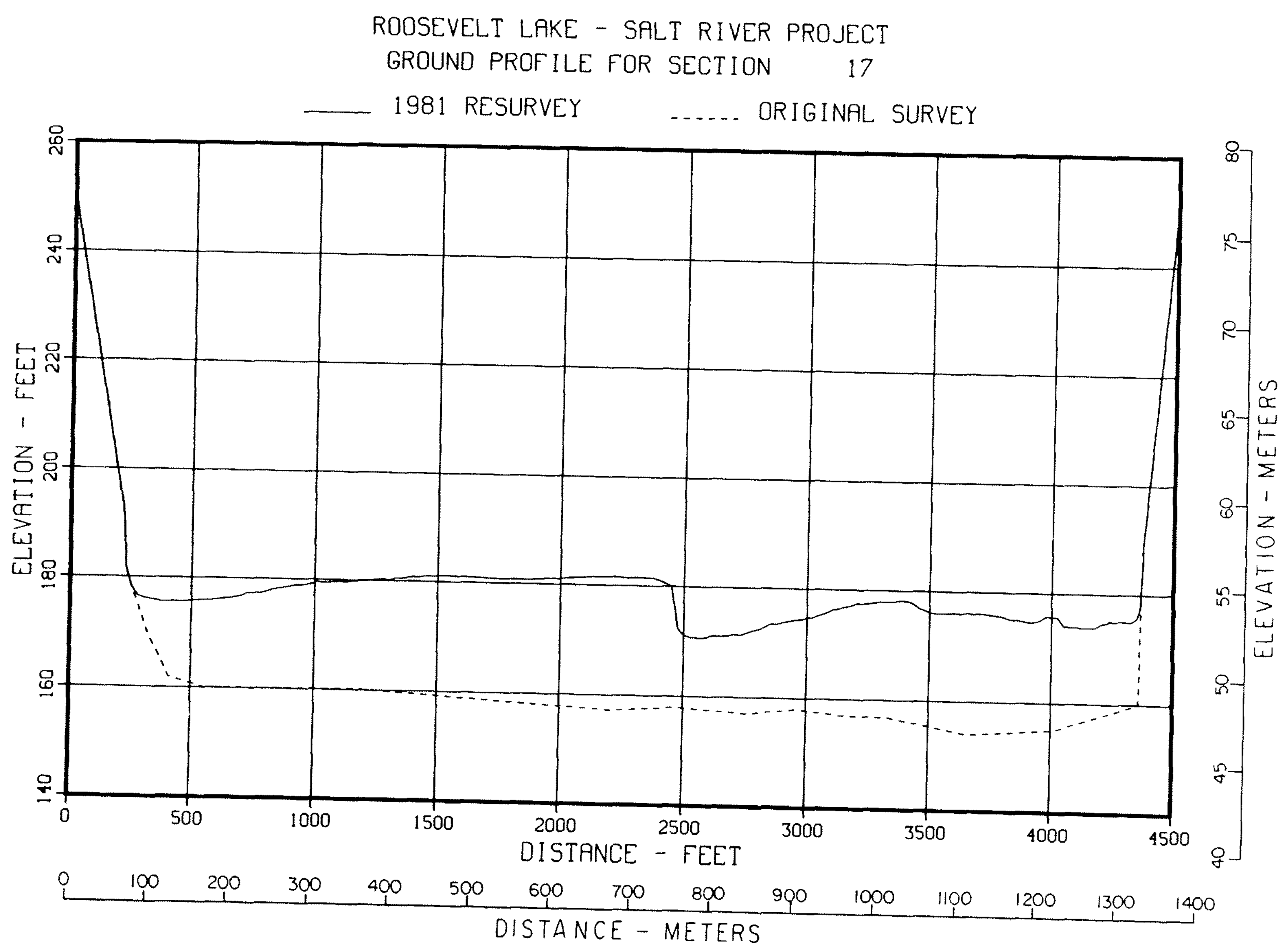

Figure 26.—Original and 1981 sedimentation range profiles — range 17, Salt River Arm.

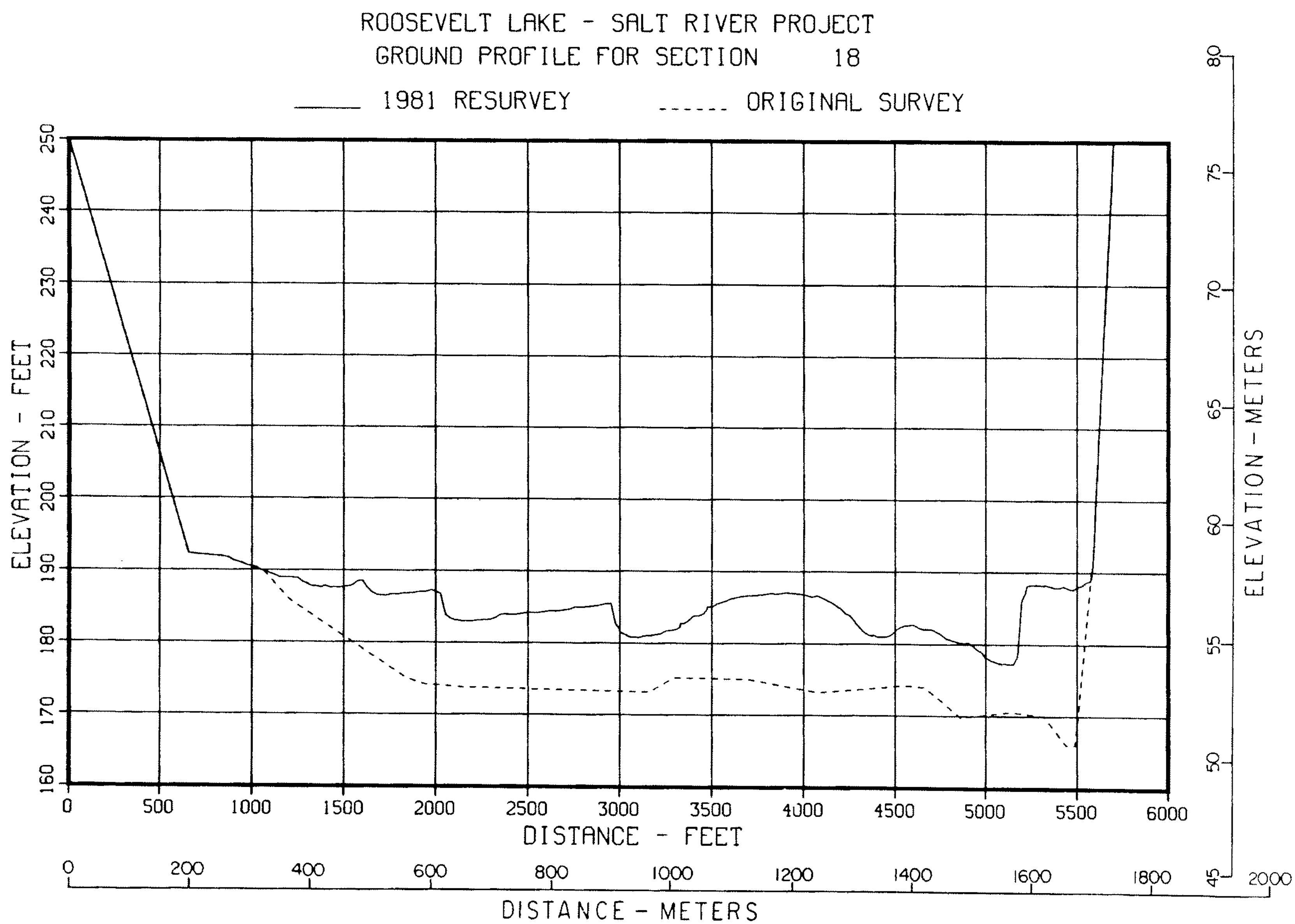

Figure 27.—Original and 1981 sedimentation range profiles — range 18, Salt River Arm.

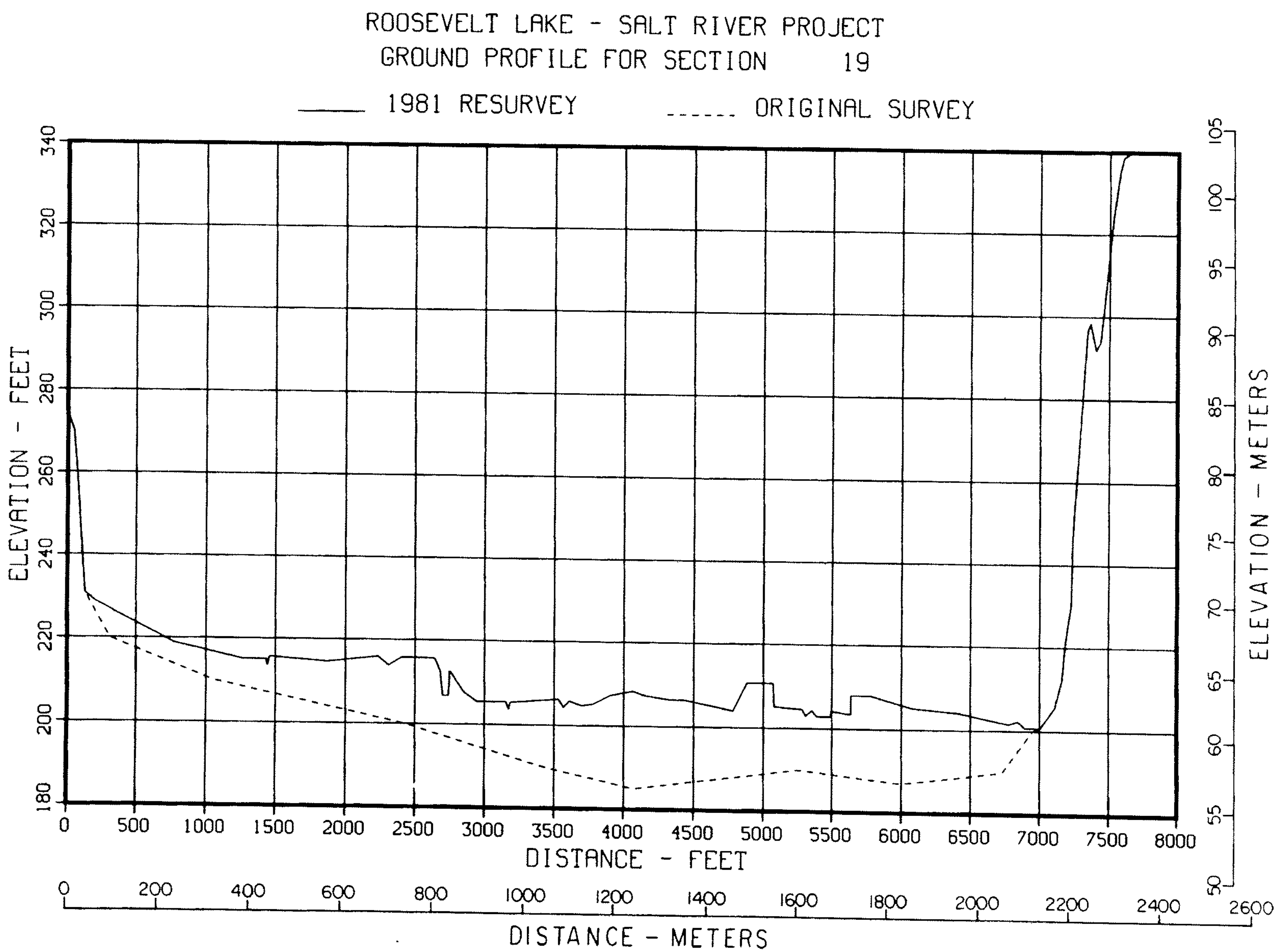

Figure 28.—Original and 1981 sedimentation range profiles — range 19, Salt River Arm.

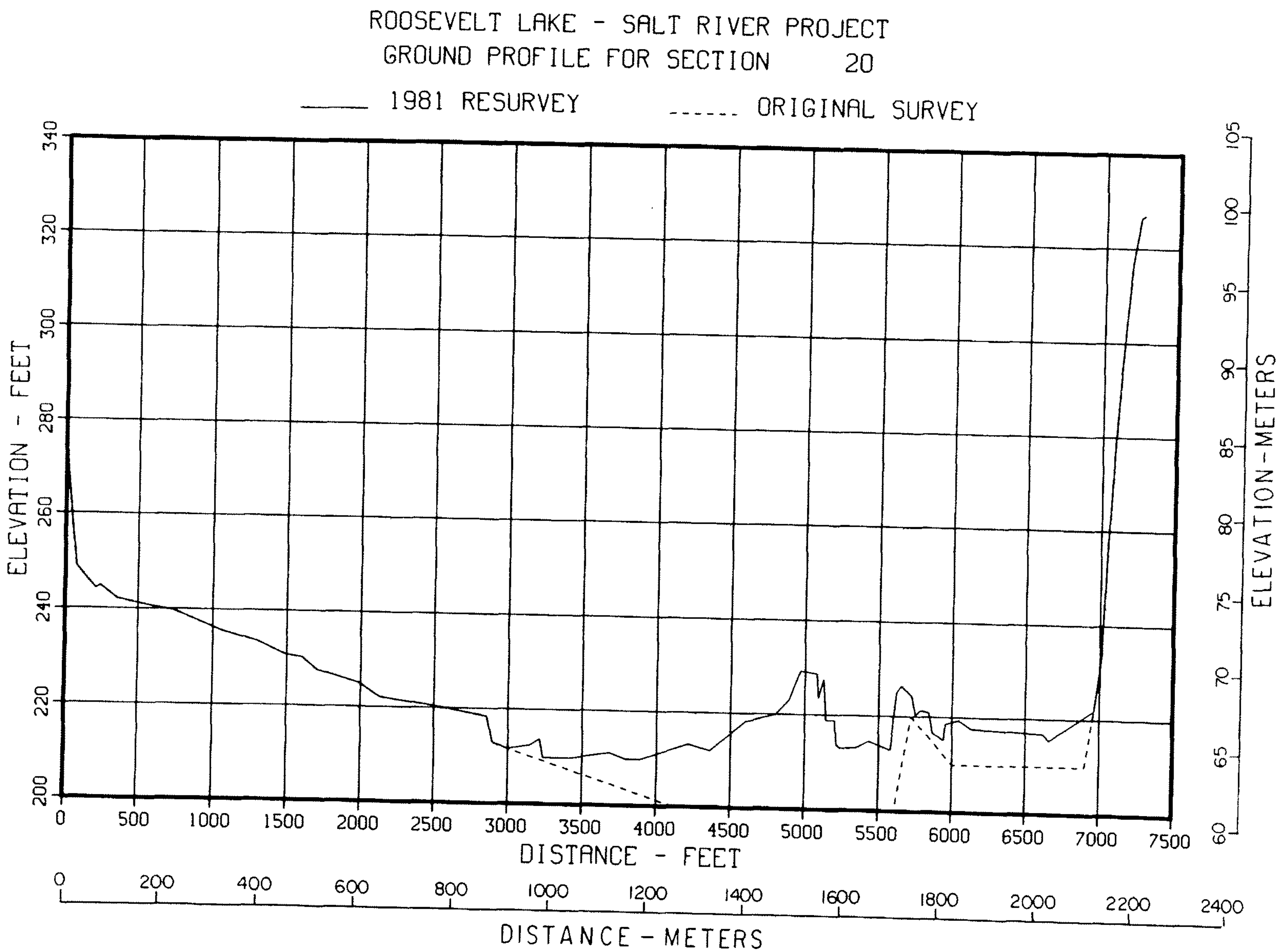

Figure 29.—Original and 1981 sedimentation range profiles — range 20, Salt River Arm.

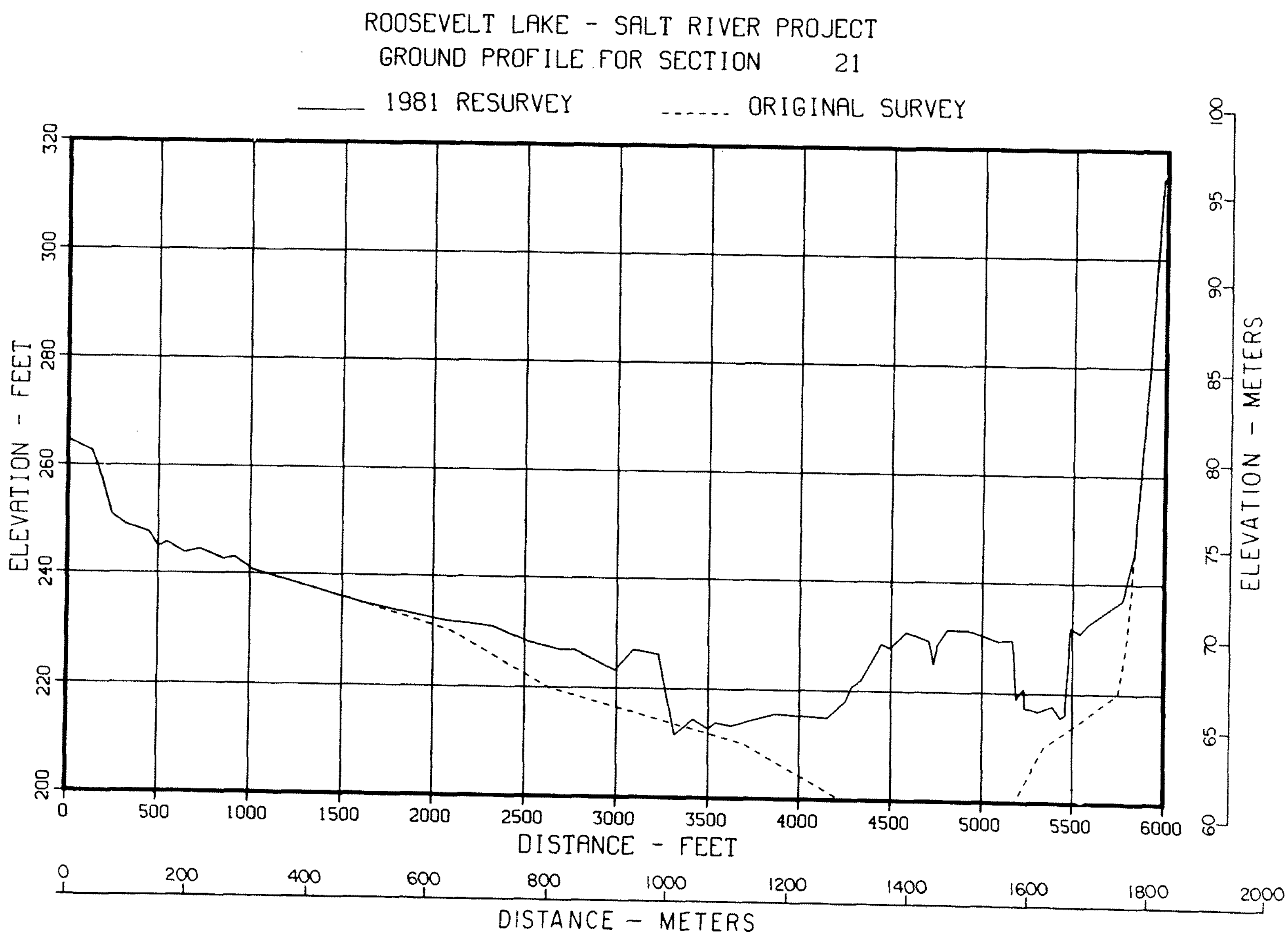

Figure 30.—Original and 1981 sedimentation range profiles — range 21, Salt River Arm.

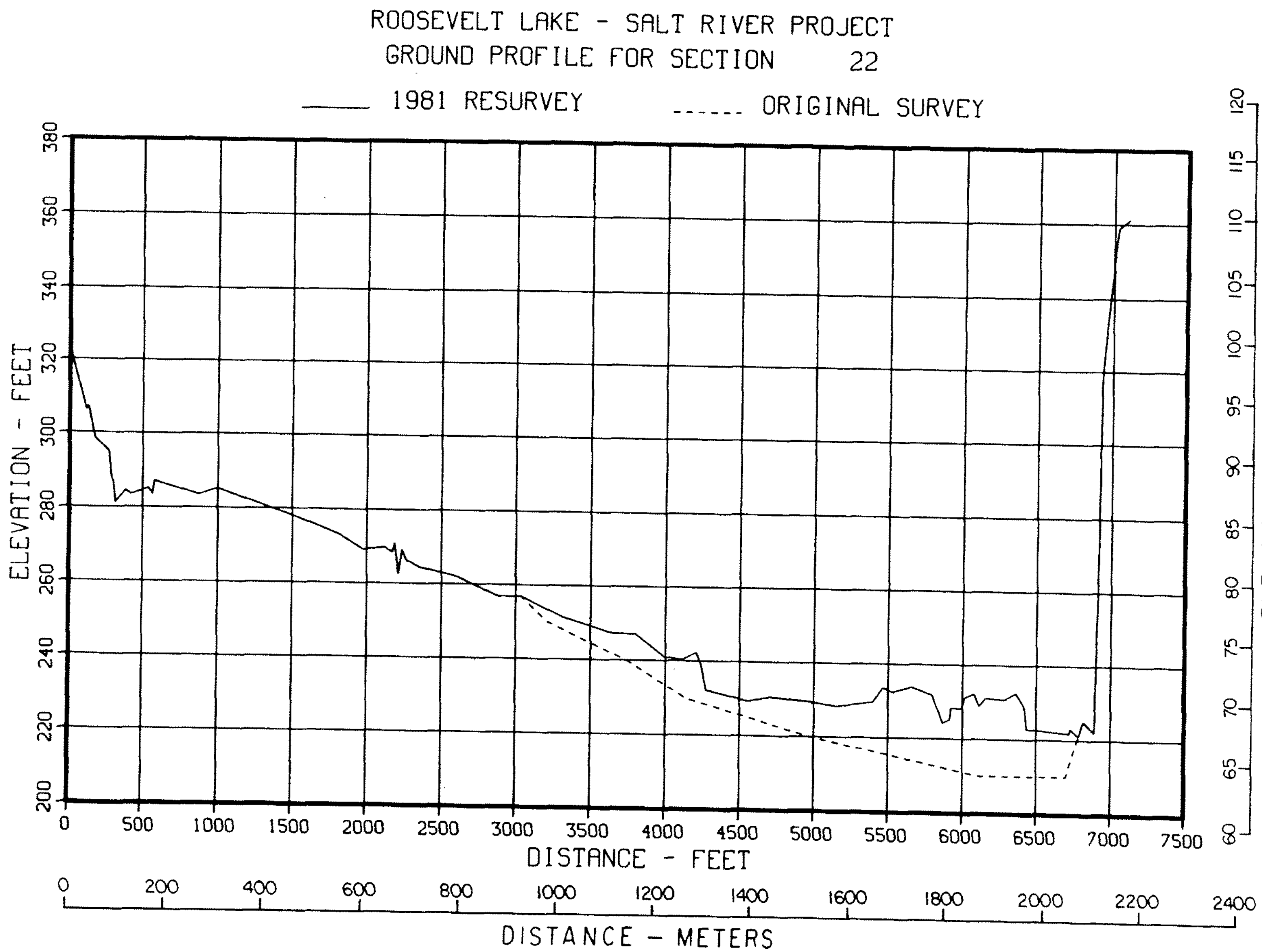

Figure 31.—Original and 1981 sedimentation range profiles — range 22, Salt River Arm.

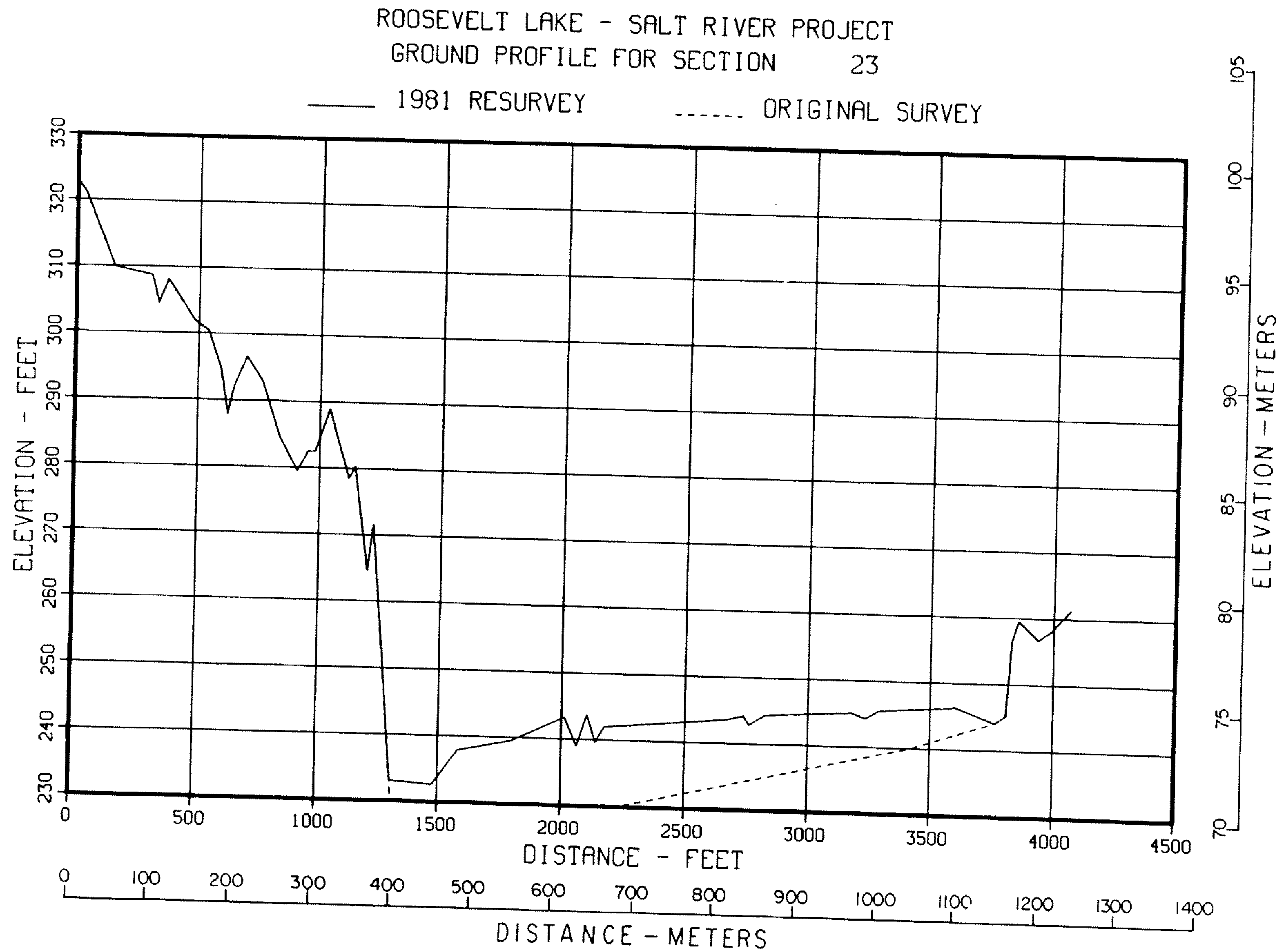

Figure 32.—Original and 1981 sedimentation range profiles — range 23, Salt River Arm.

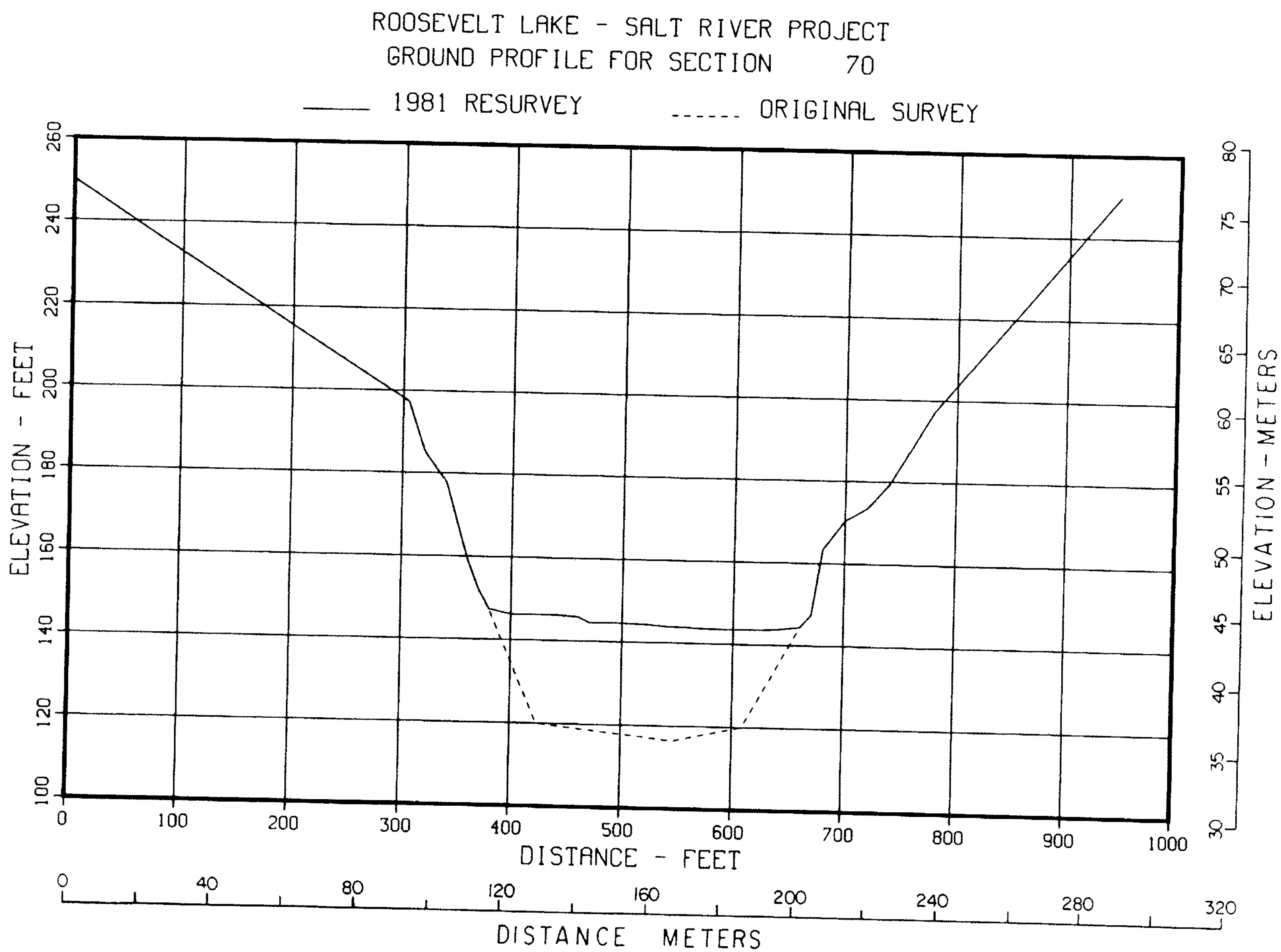

Figure 33.—Original and 1981 sedimentation range profiles — range 70, Salt River Arm.

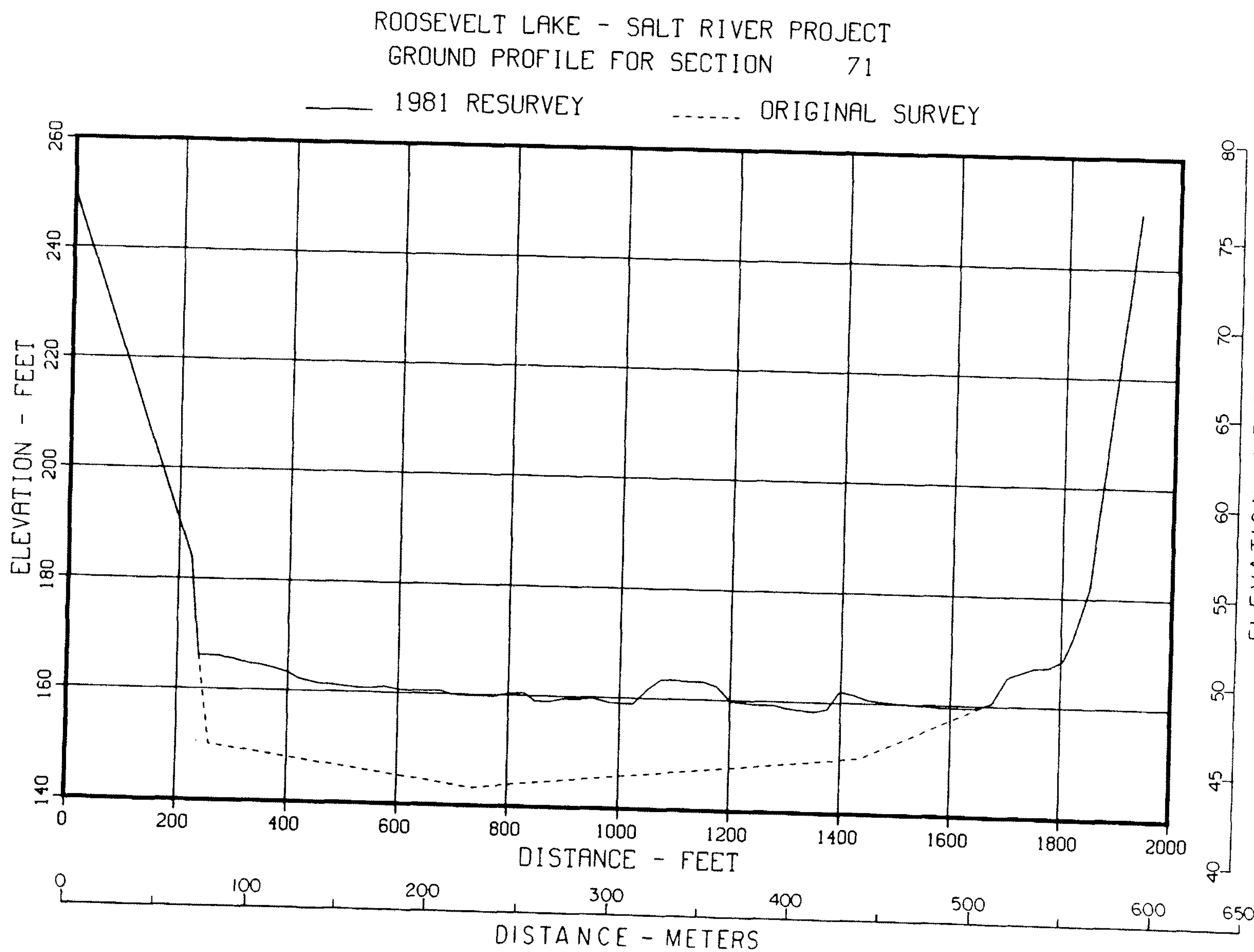

Figure 34.—Original and 1981 sedimentation range profiles — range 71, Salt River Arm.

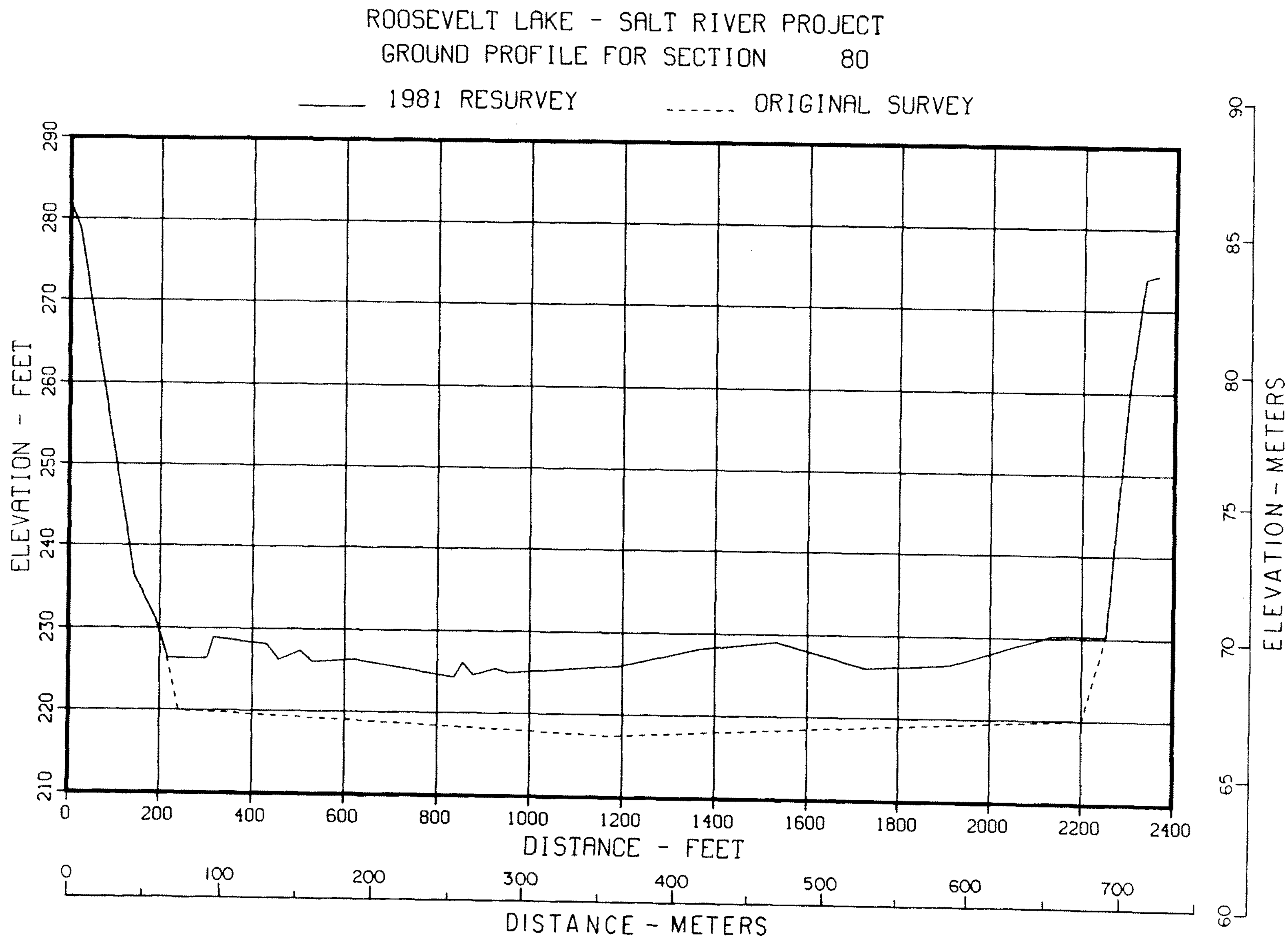

Figure 35.—Original and 1981 sedimentation range profiles — range 80, Salt River Arm.

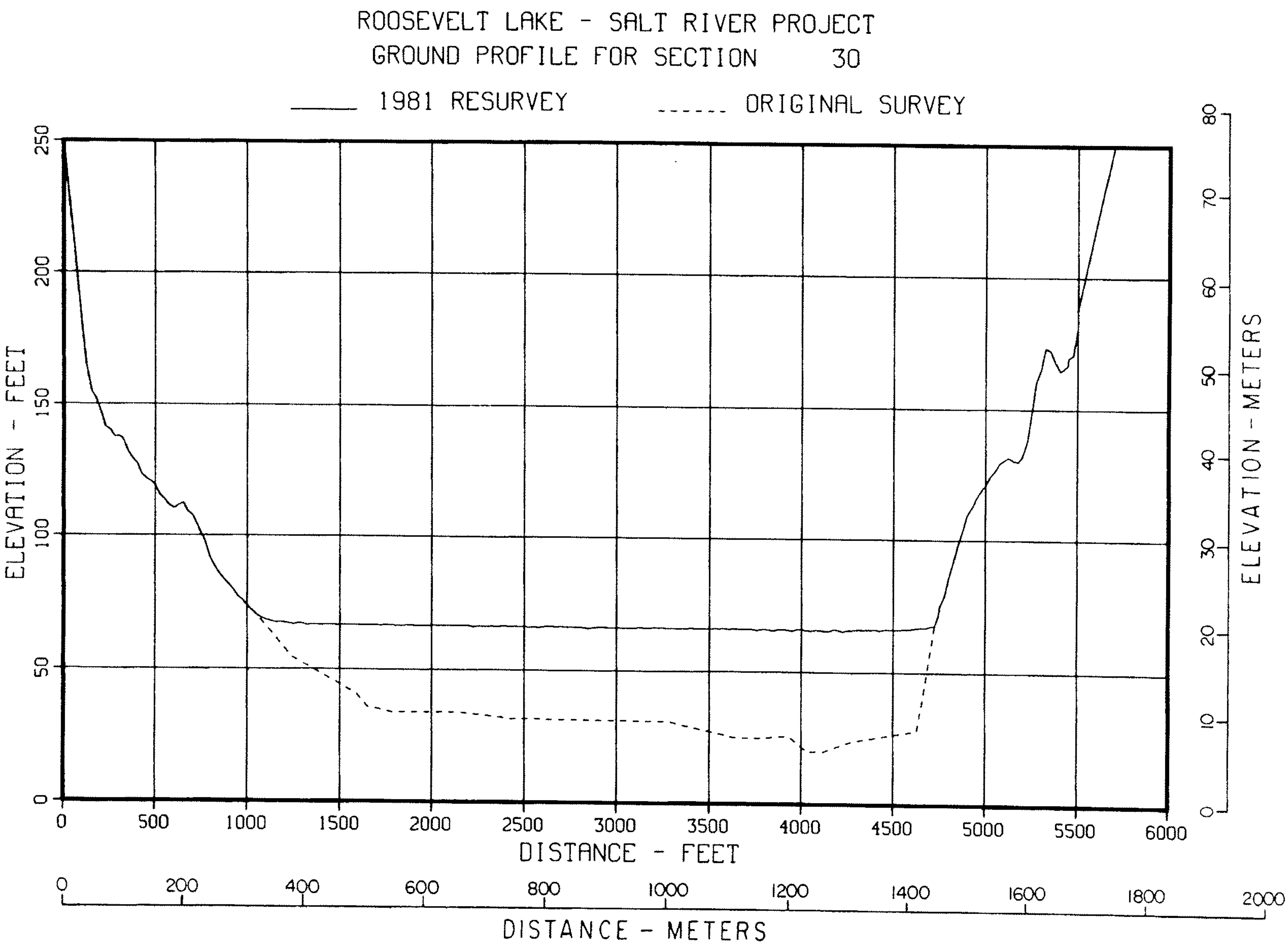

Figure 36.—Original and 1981 sedimentation range profiles — range 30, Tonto Creek Arm.

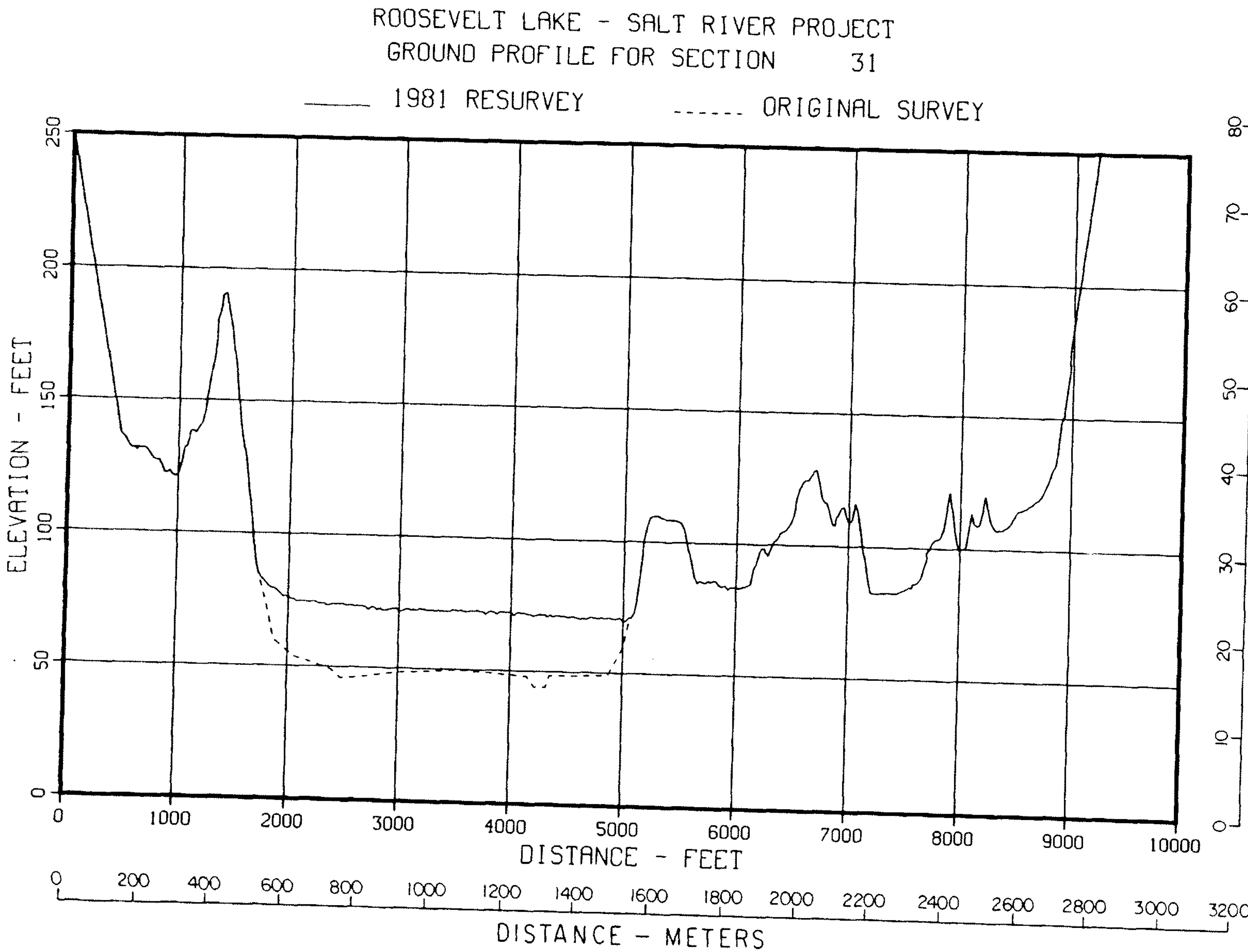

Figure 37.—Original and 1981 sedimentation range profiles — range 31, Salt River Arm.

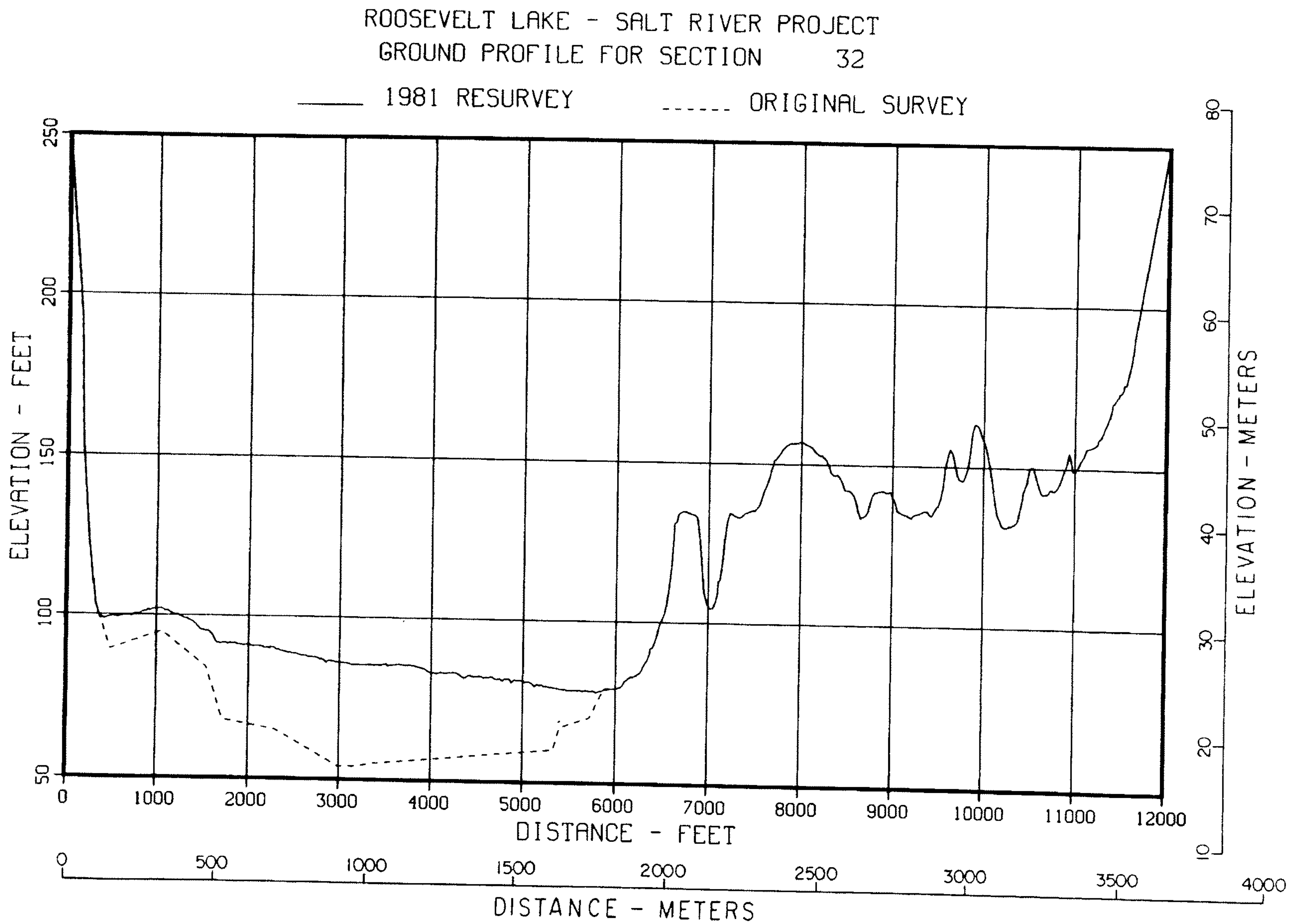

Figure 38.—Original and 1981 sedimentation range profiles — range 32, Salt River Arm.

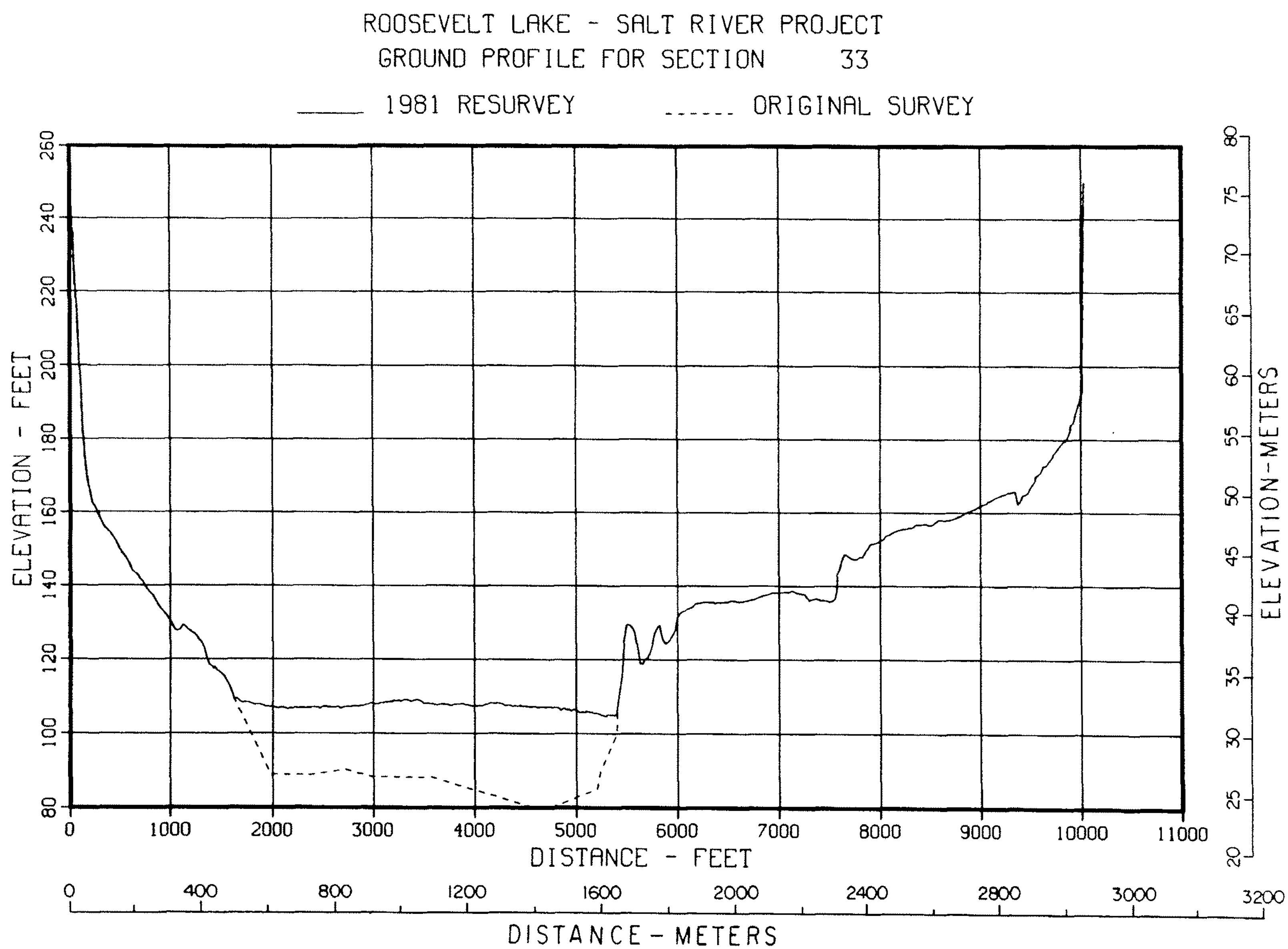

Figure 39.—Original and 1981 sedimentation range profiles — range 33, Salt River Arm.

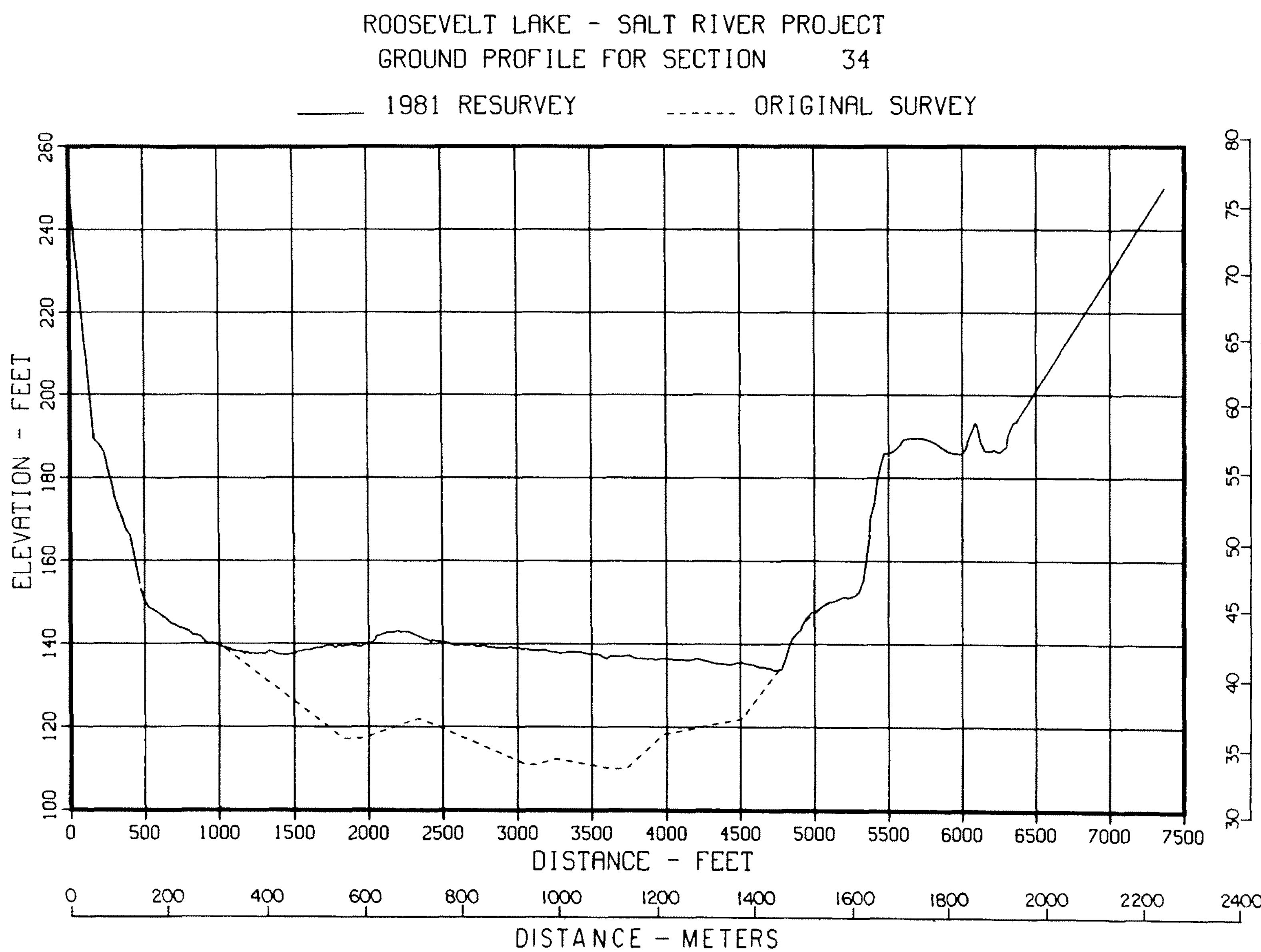

Figure 40.—Original and 1981 sedimentation range profiles — range 34, Salt River Arm.

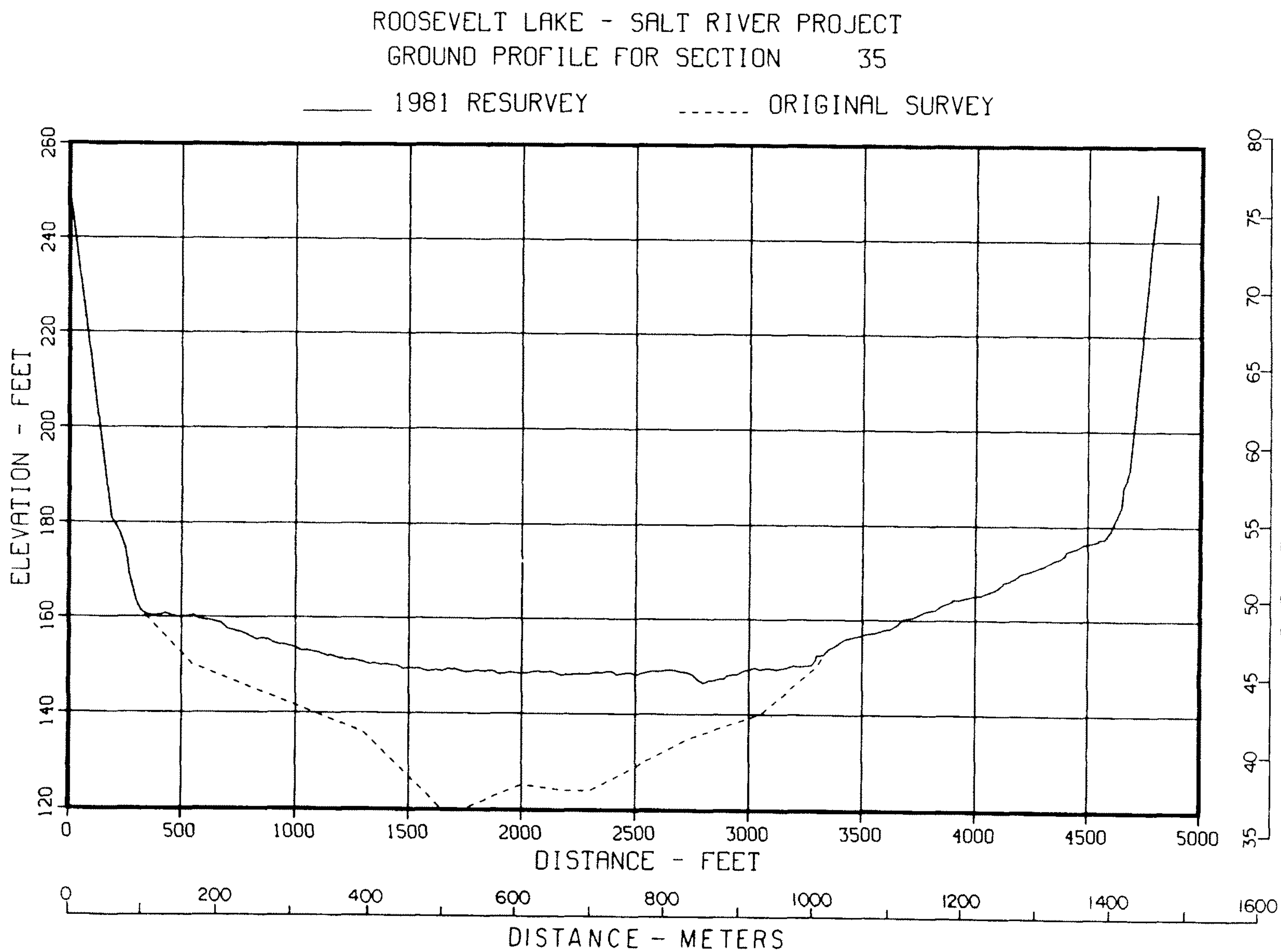

Figure 41.—Original and 1981 sedimentation range profiles — range 35, Salt River Arm.

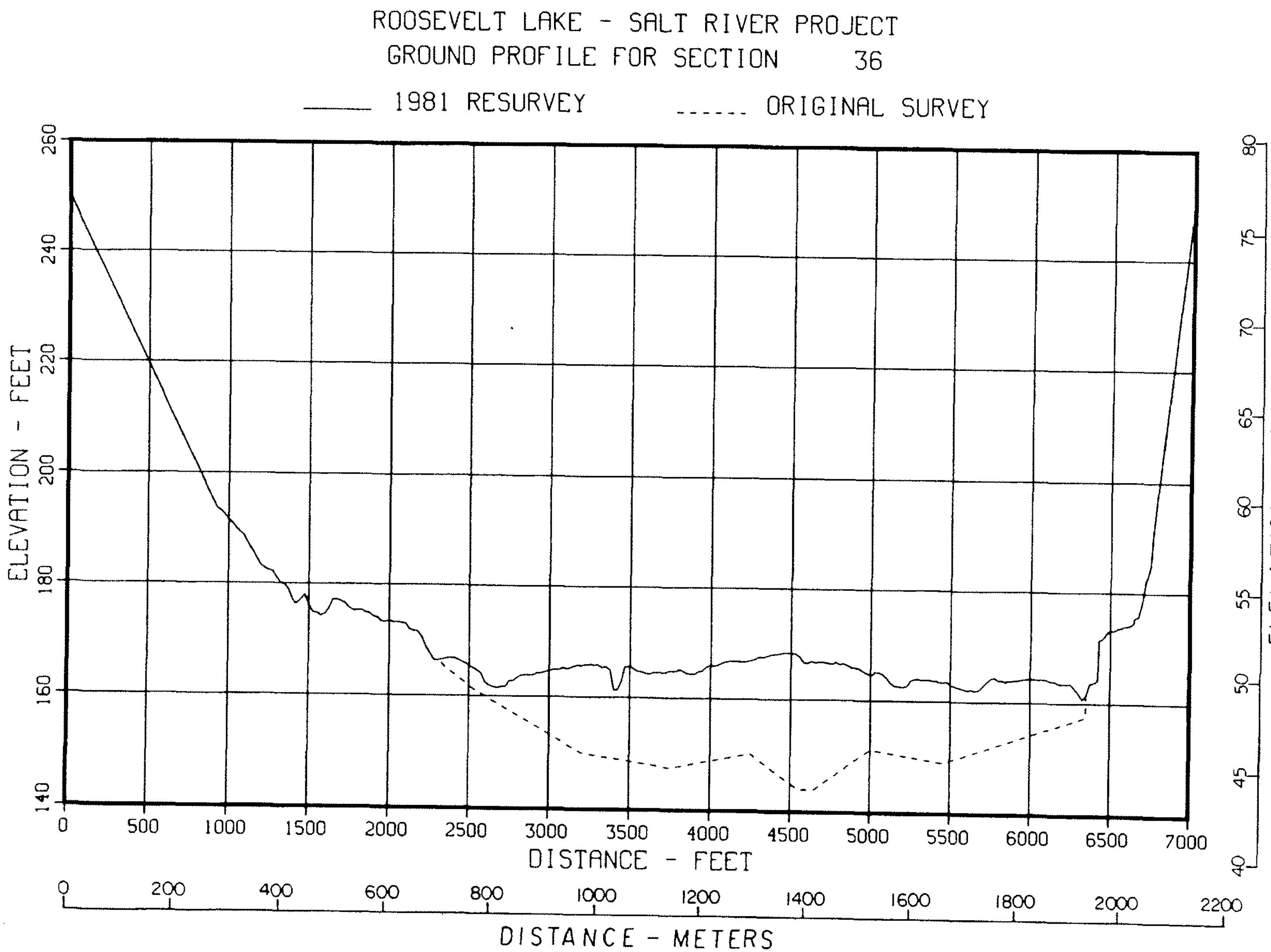

Figure 42.—Original and 1981 sedimentation range profiles — range 36, Salt River Arm.

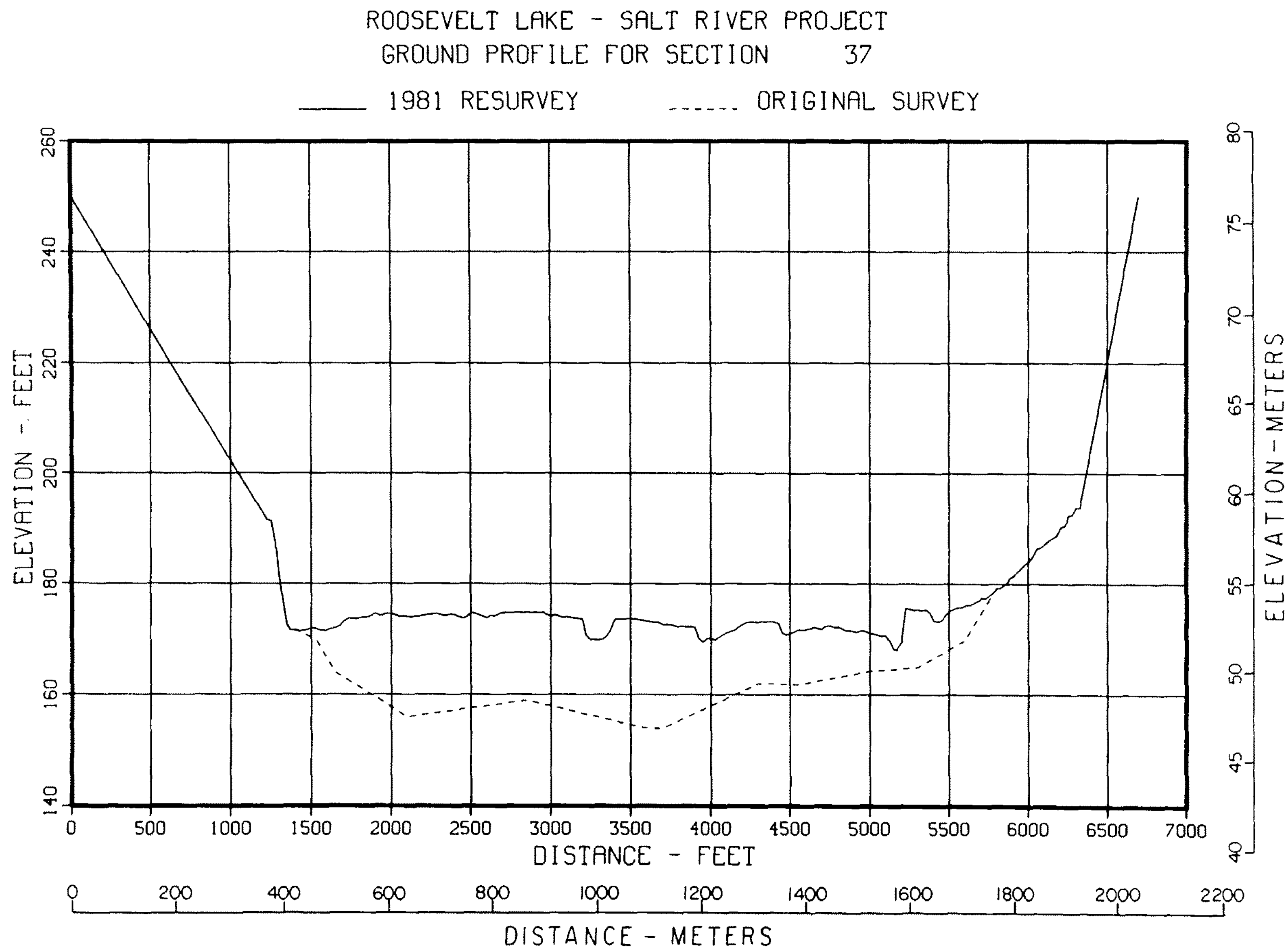

Figure 43.—Original and 1981 sedimentation range profiles — range 37, Salt River Arm.

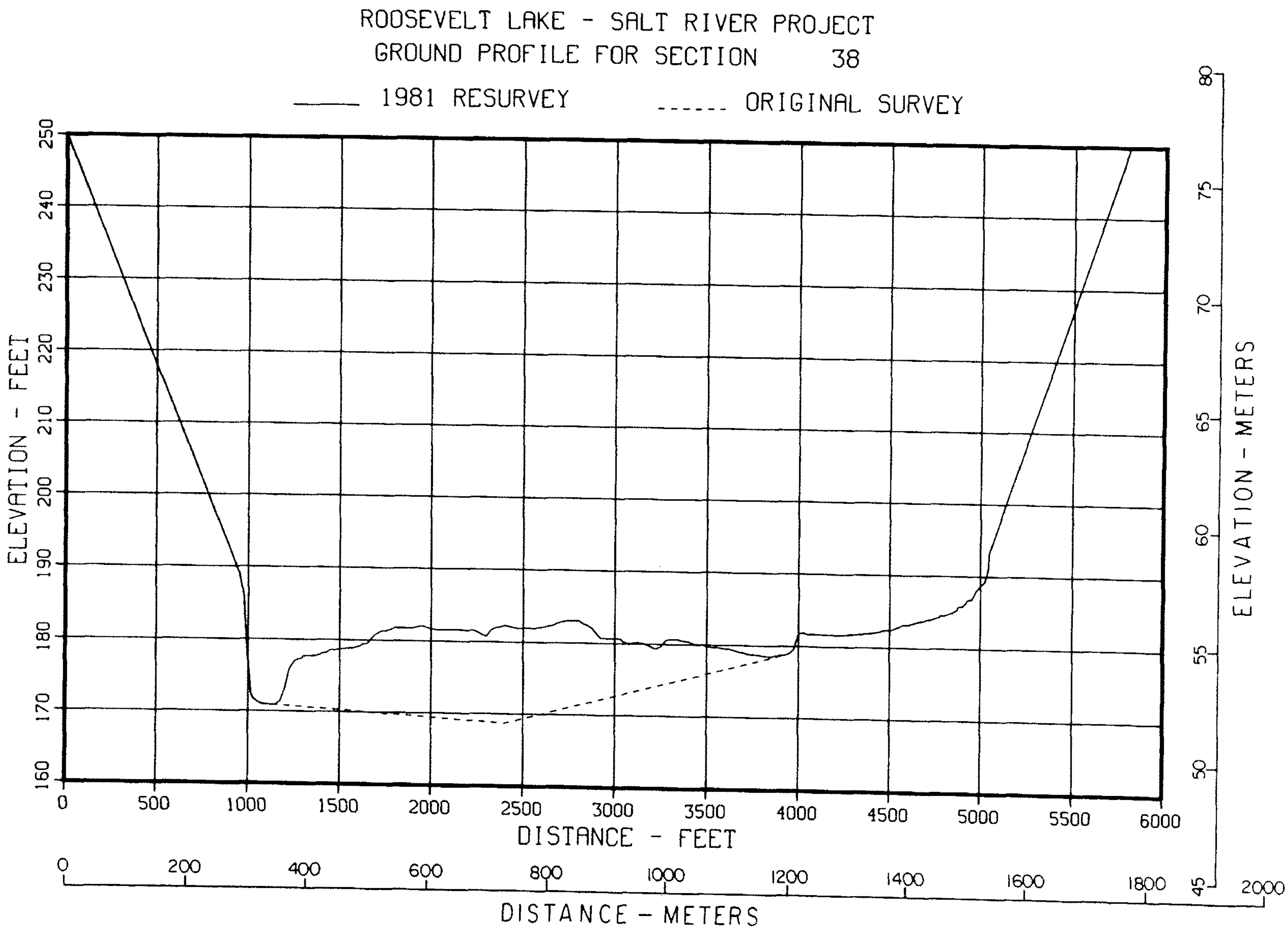

Figure 44.—Original and 1981 sedimentation range profiles — range 38, Salt River Arm.

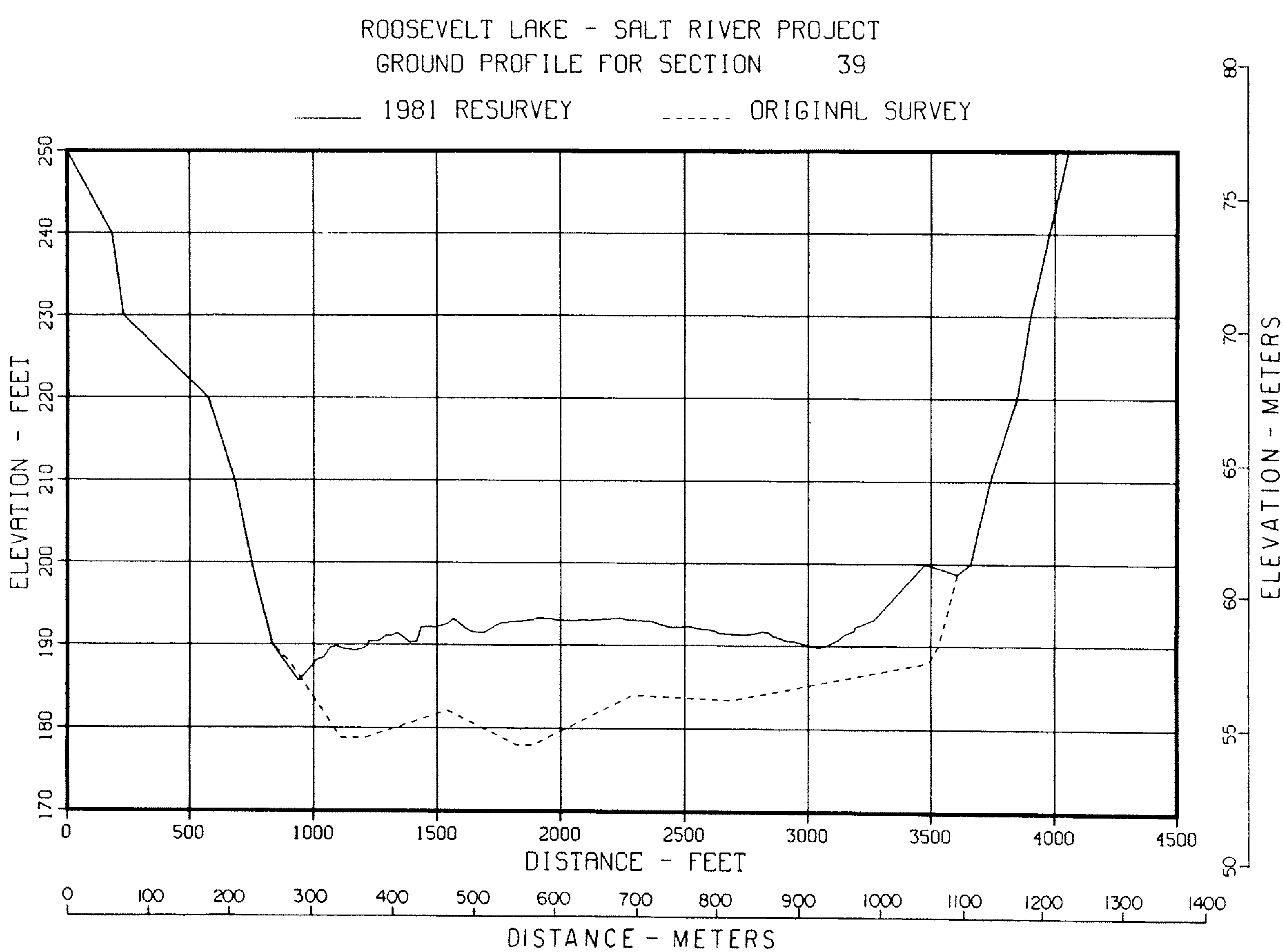

Figure 45.—Original and 1981 sedimentation range profiles — range 39, Salt River Arm.

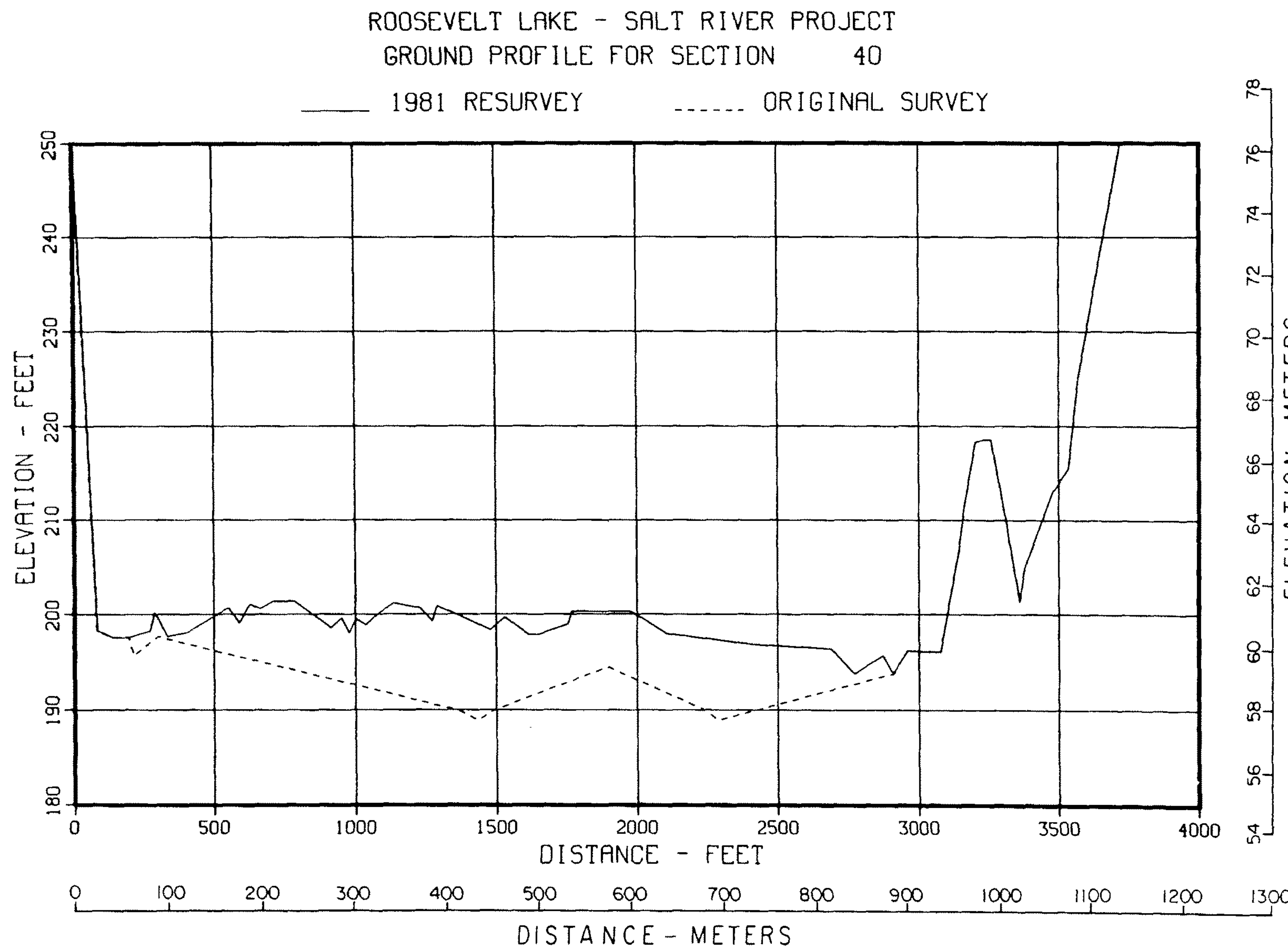

Figure 46.—Original and 1981 sedimentation range profiles — range 40, Salt River Arm.

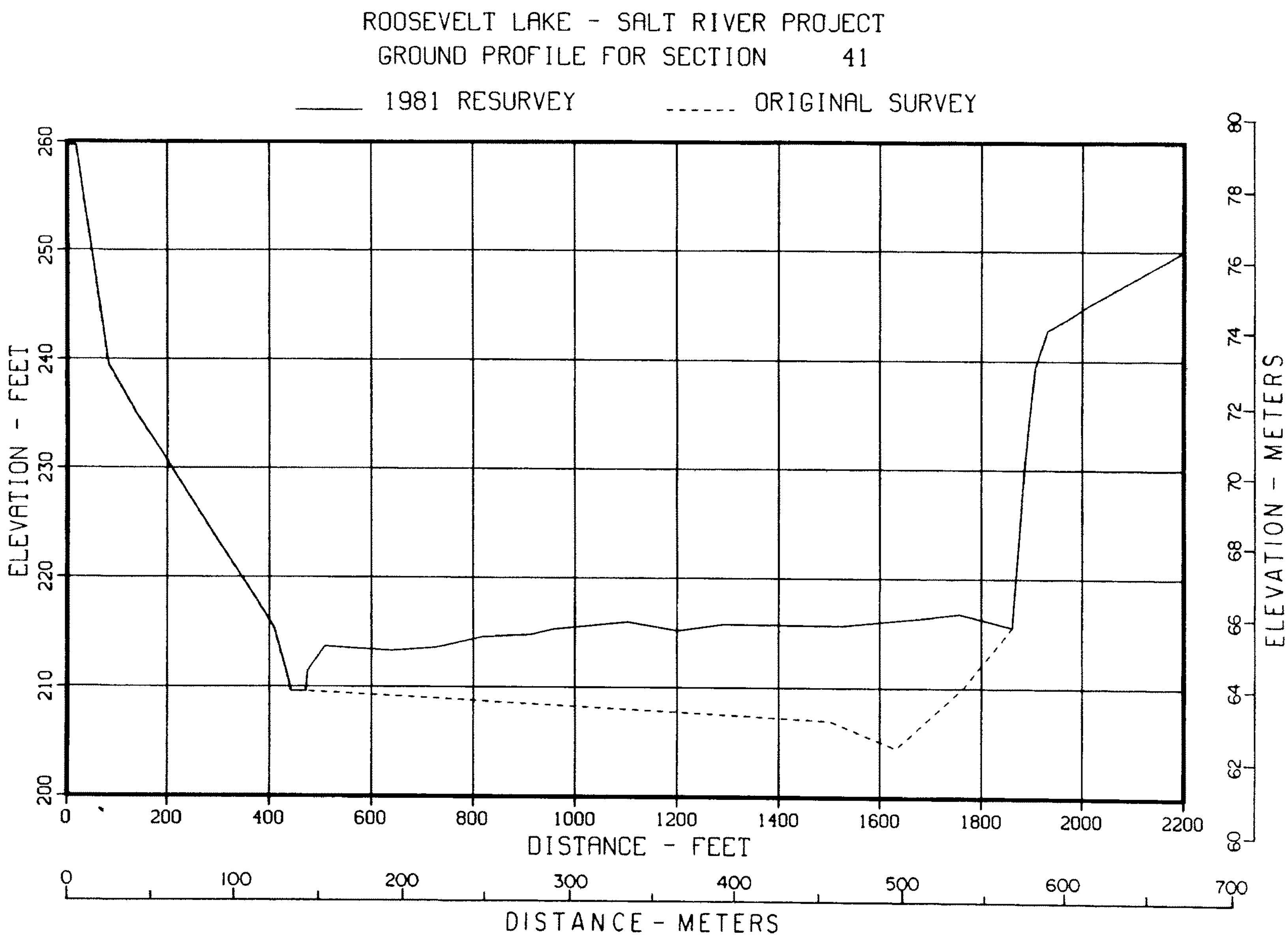

Figure 47.—Original and 1981 sedimentation range profiles — range 41, Salt River Arm.

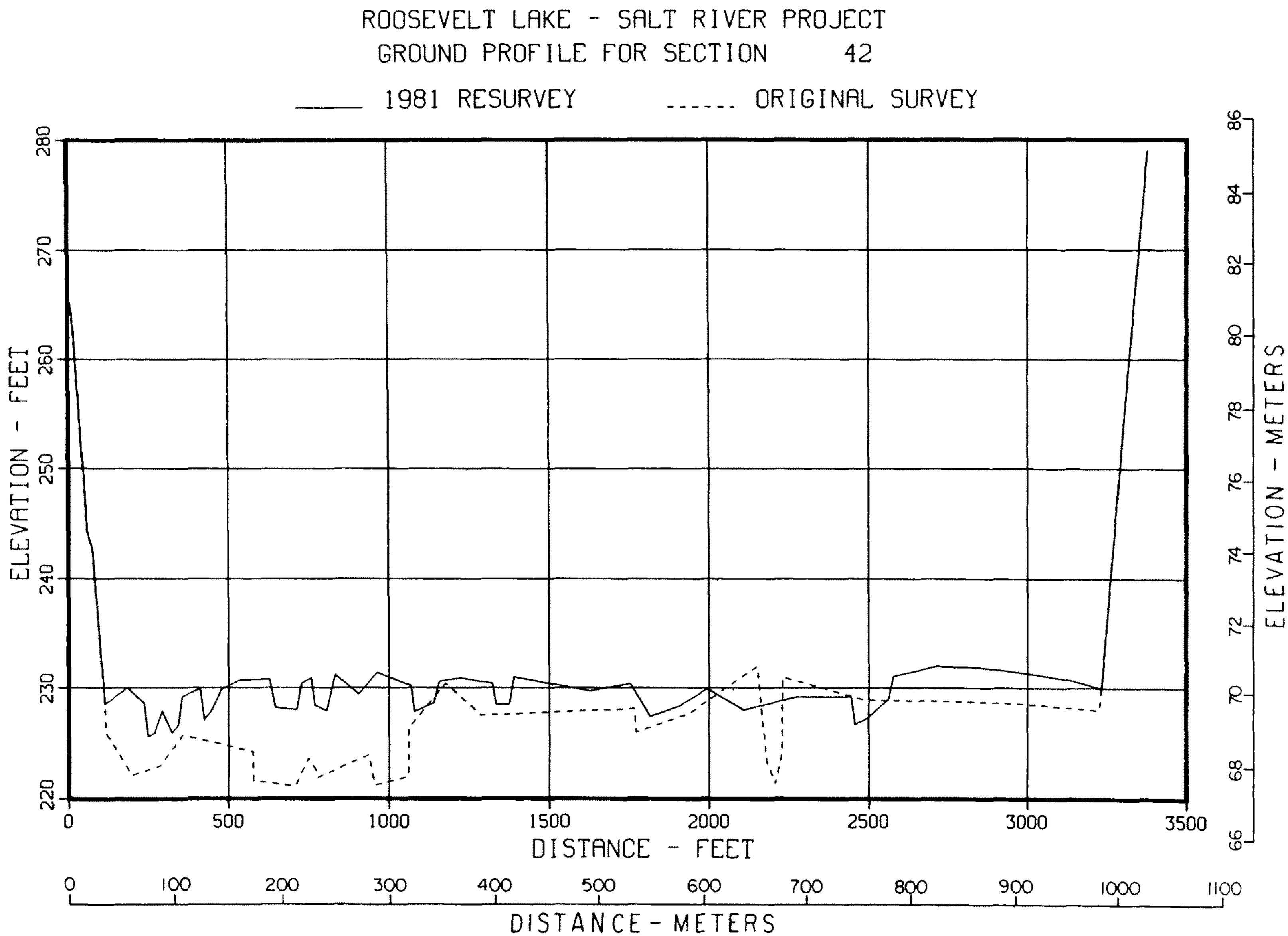

Figure 48.—Original and 1981 sedimentation range profiles — range 42, Salt River Arm.

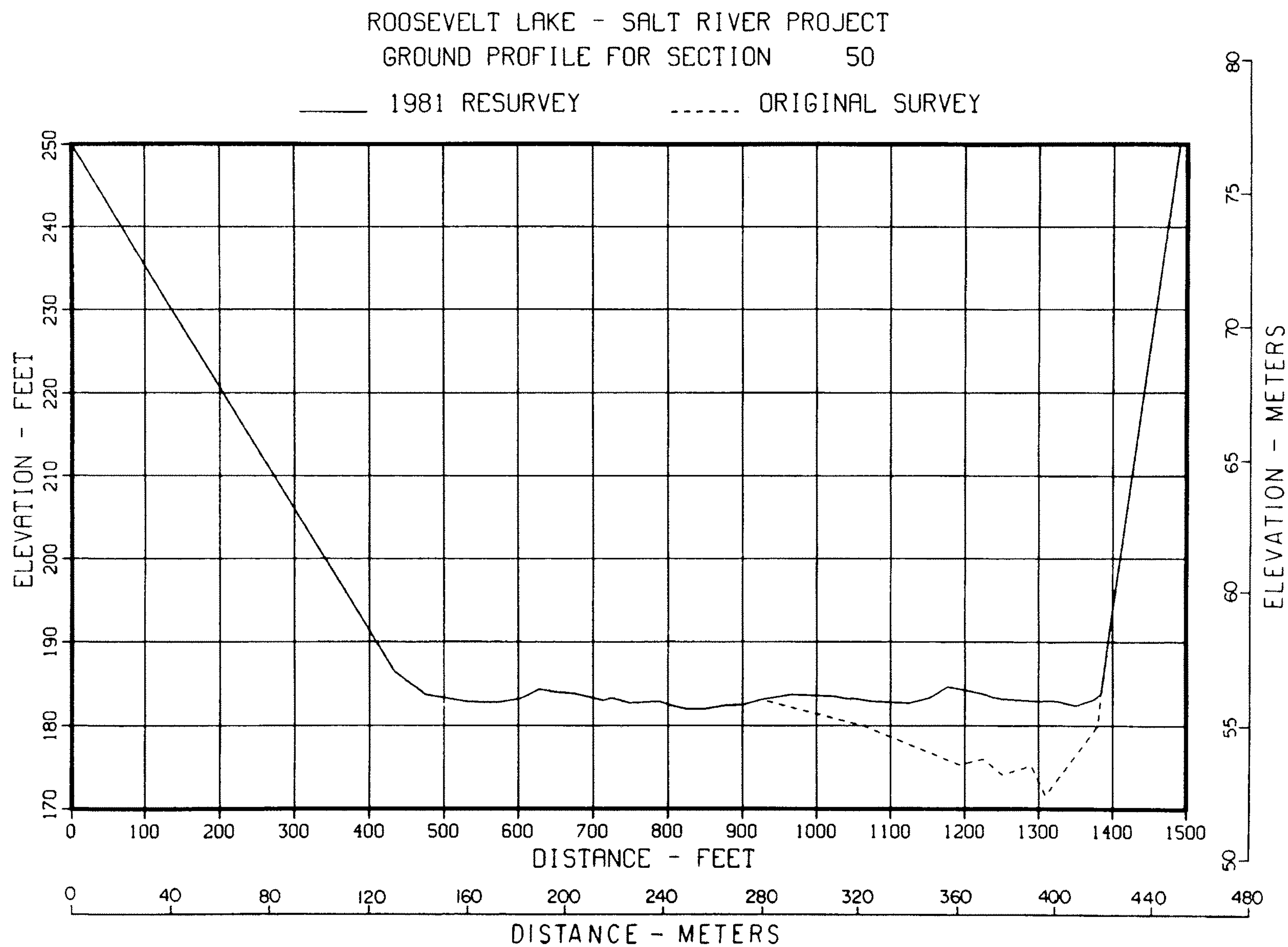

Figure 49.—Original and 1981 sedimentation range profiles — range 50, Salt River Arm.

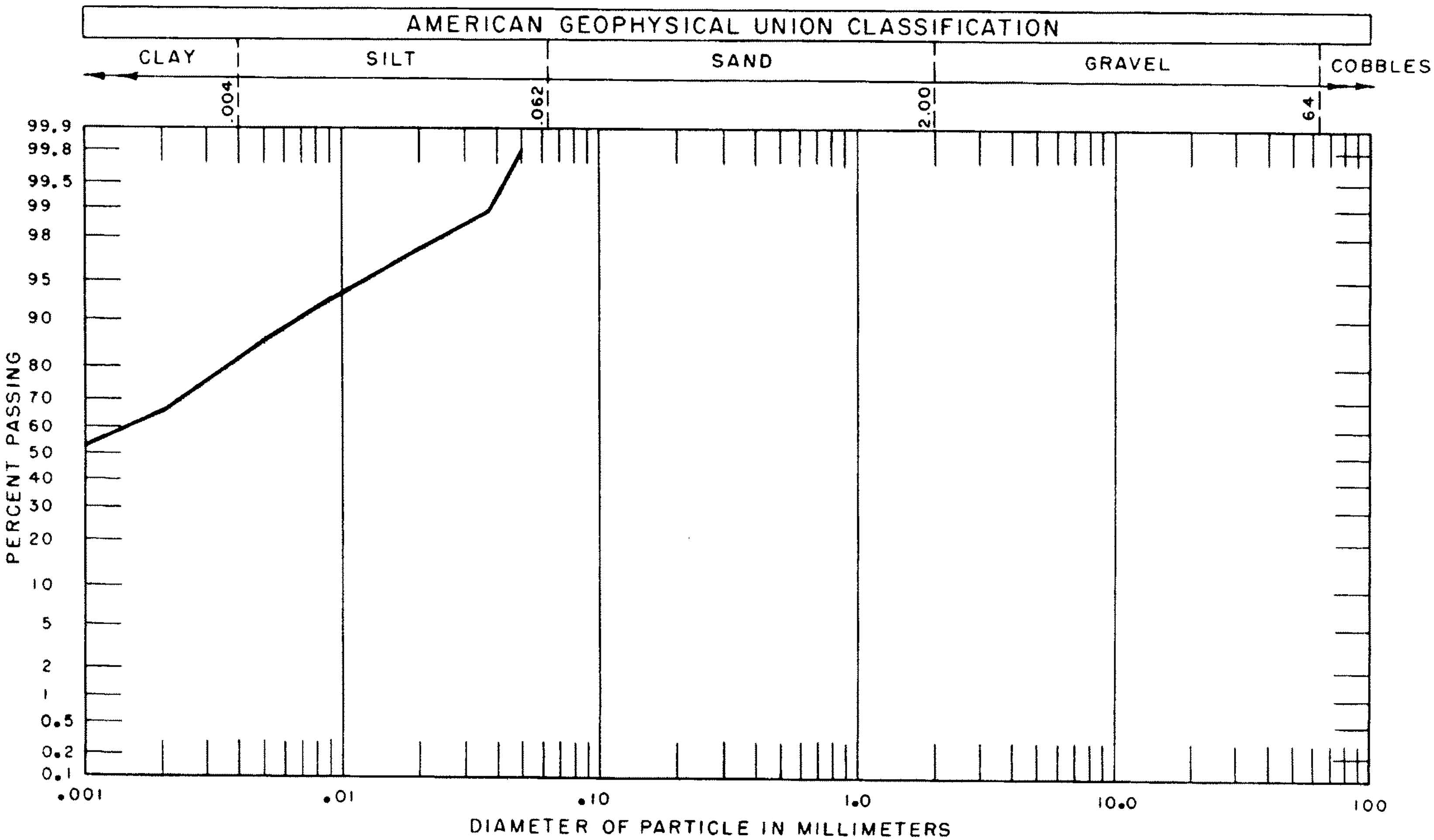

Figure 50.—Particle size analysis curve, range 1.

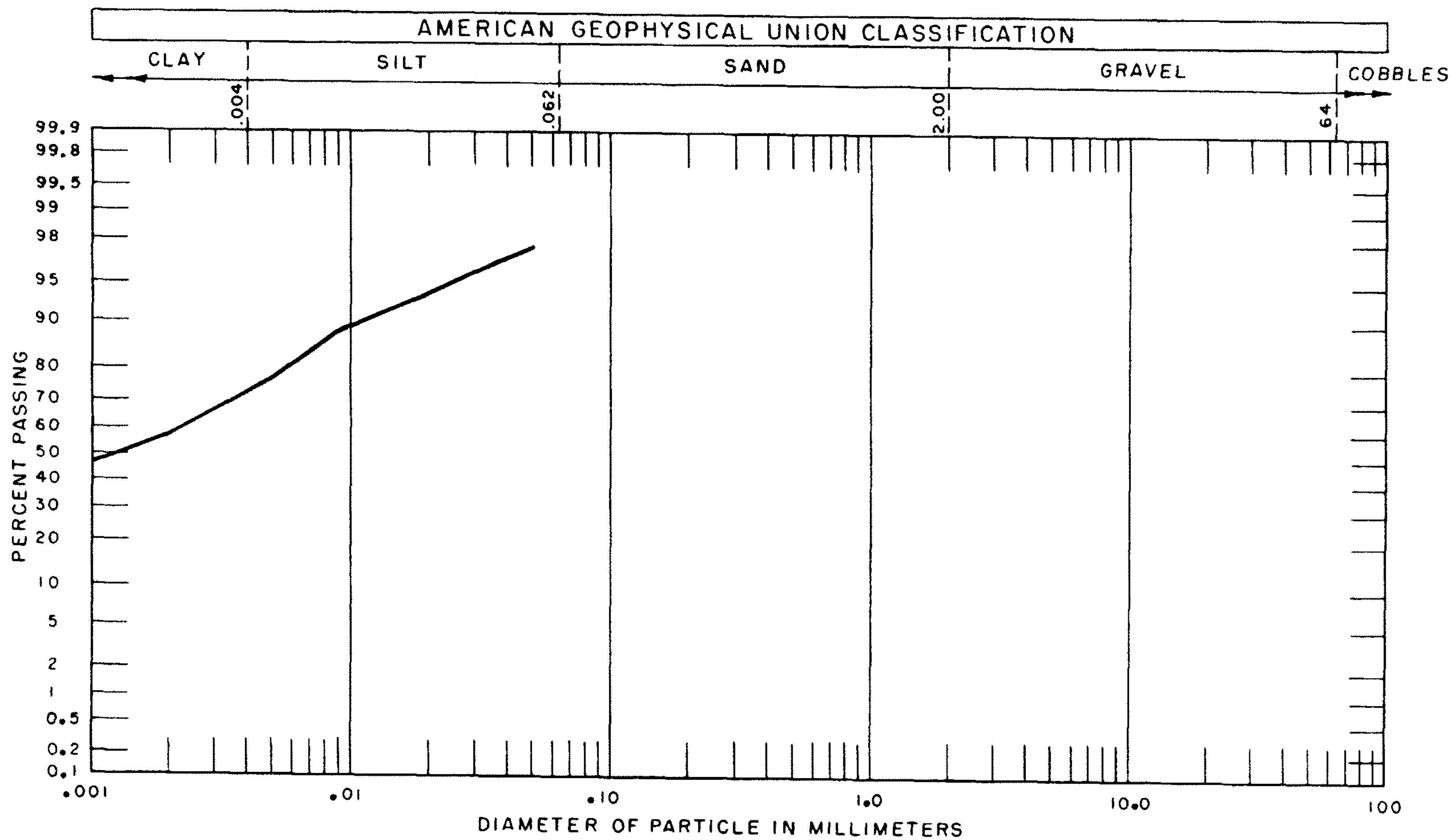

Figure 51.—Particle size analysis curve, range 2.

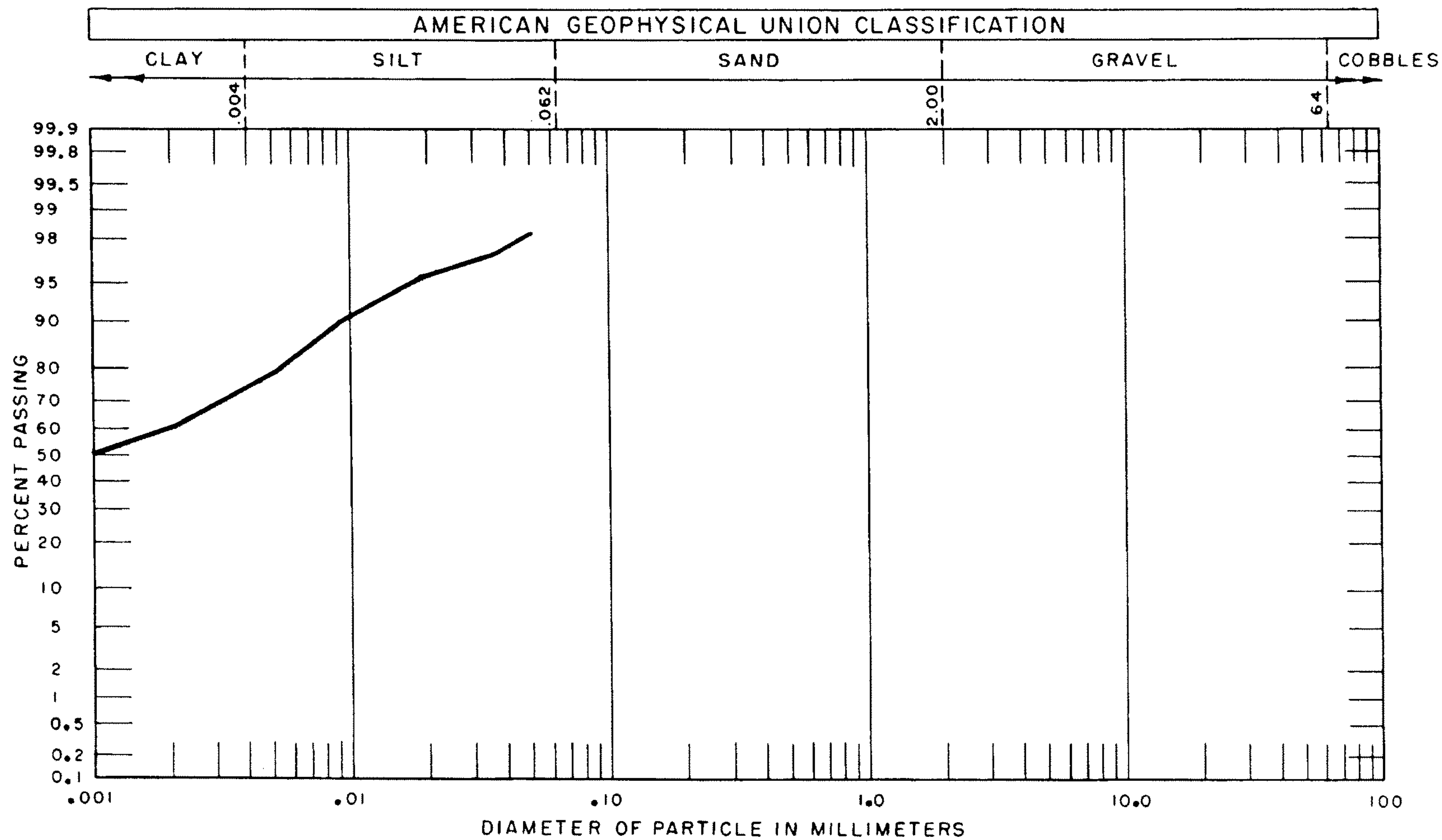

Figure 52.—Particle size analysis curve, range 3.

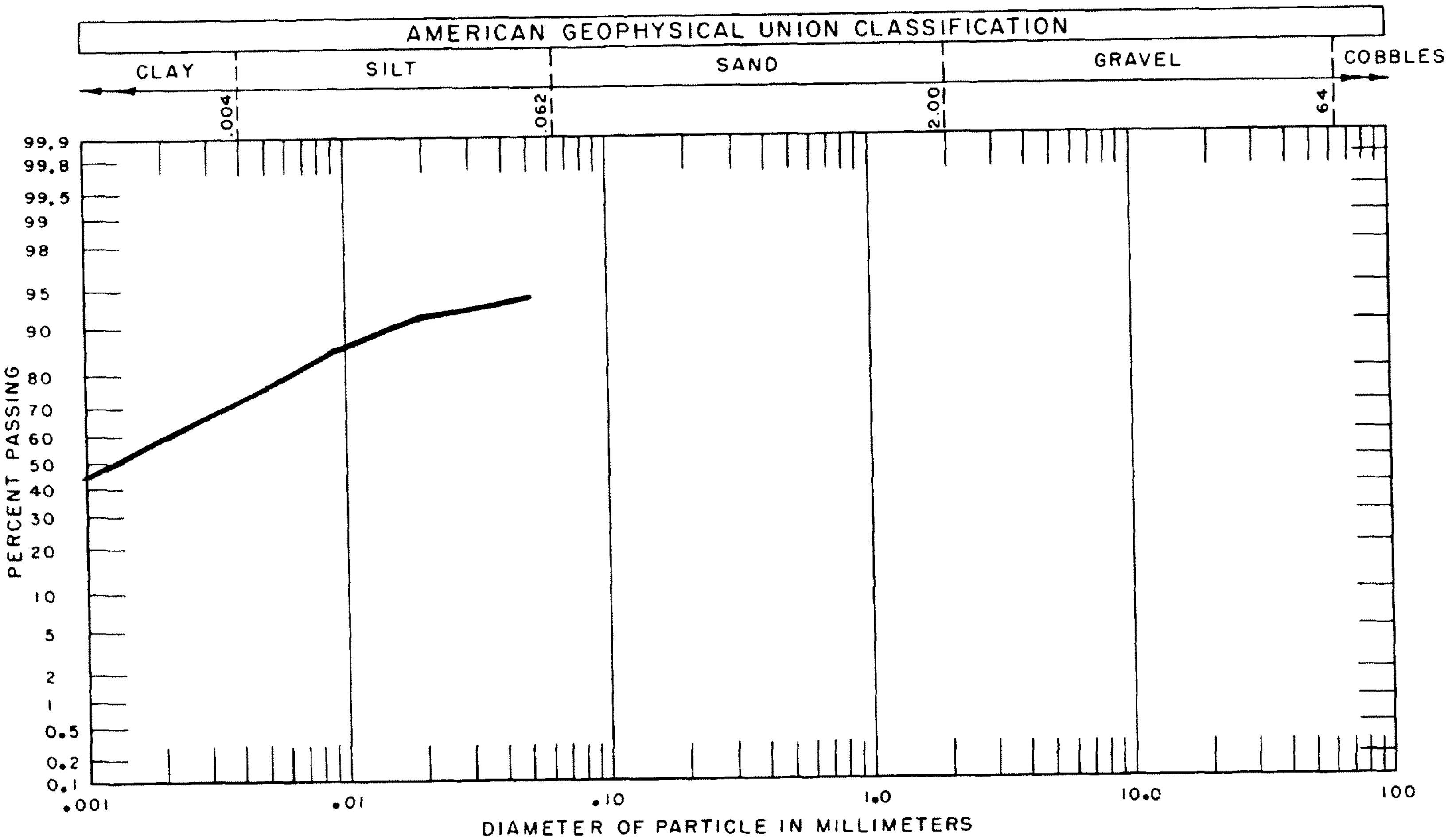

Figure 53.—Particle size analysis curve, range 4 (sheet 1 of 2).

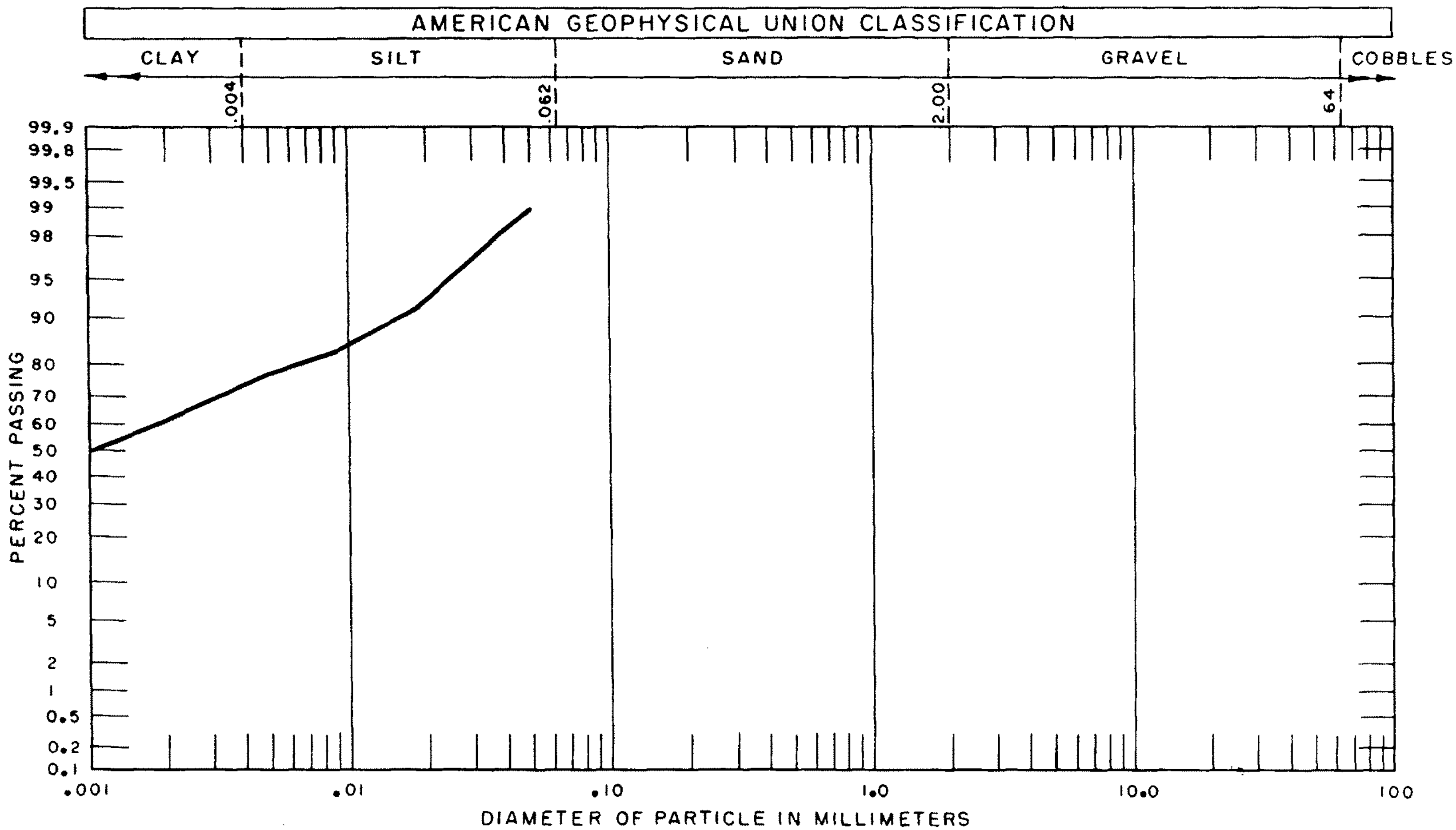

Figure 53.—Particle size analysis curve, range 4 (sheet 2 of 2).

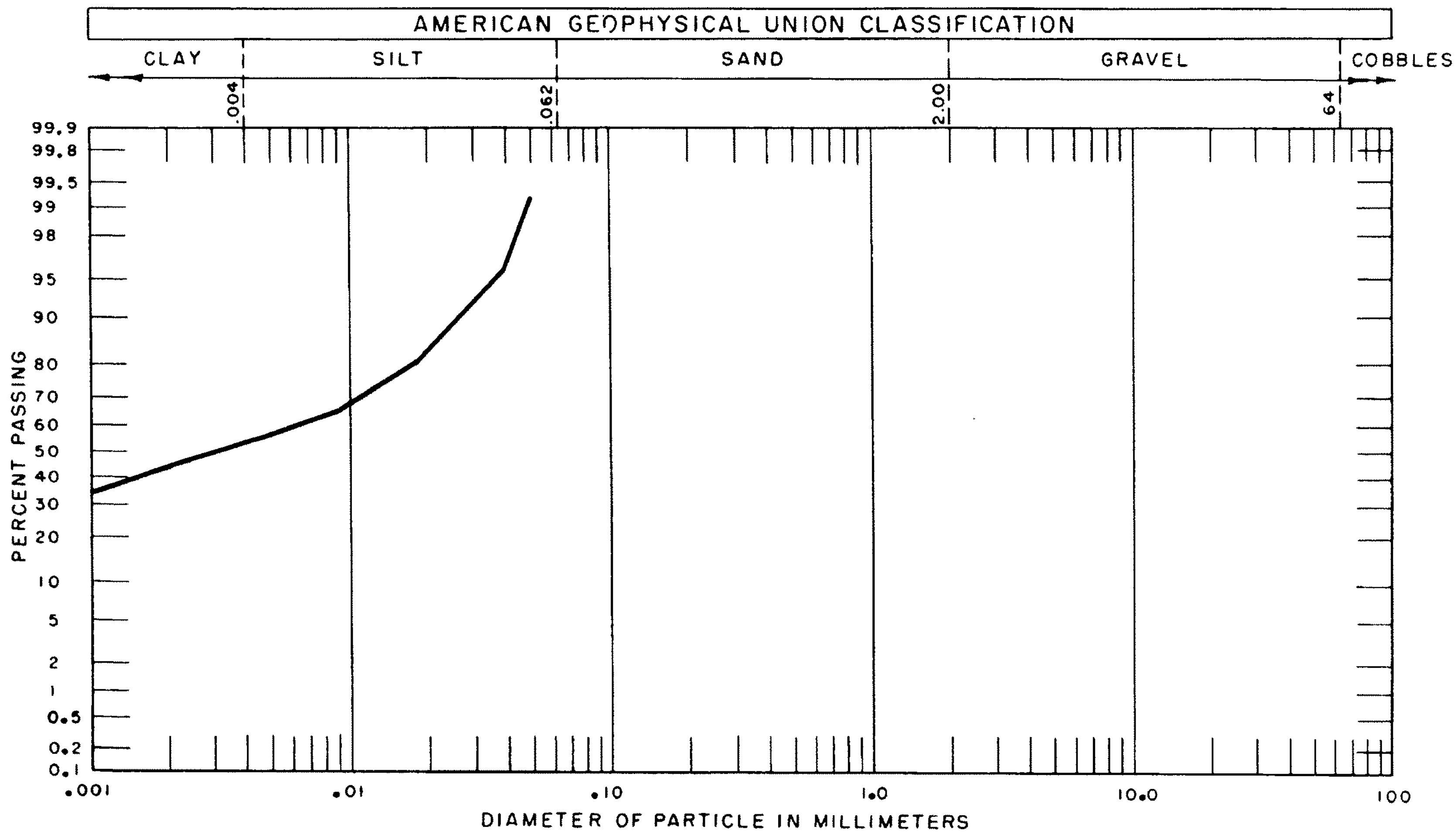

Figure 54.—Particle size analysis curve, range 5 (sheet 1 of 2).

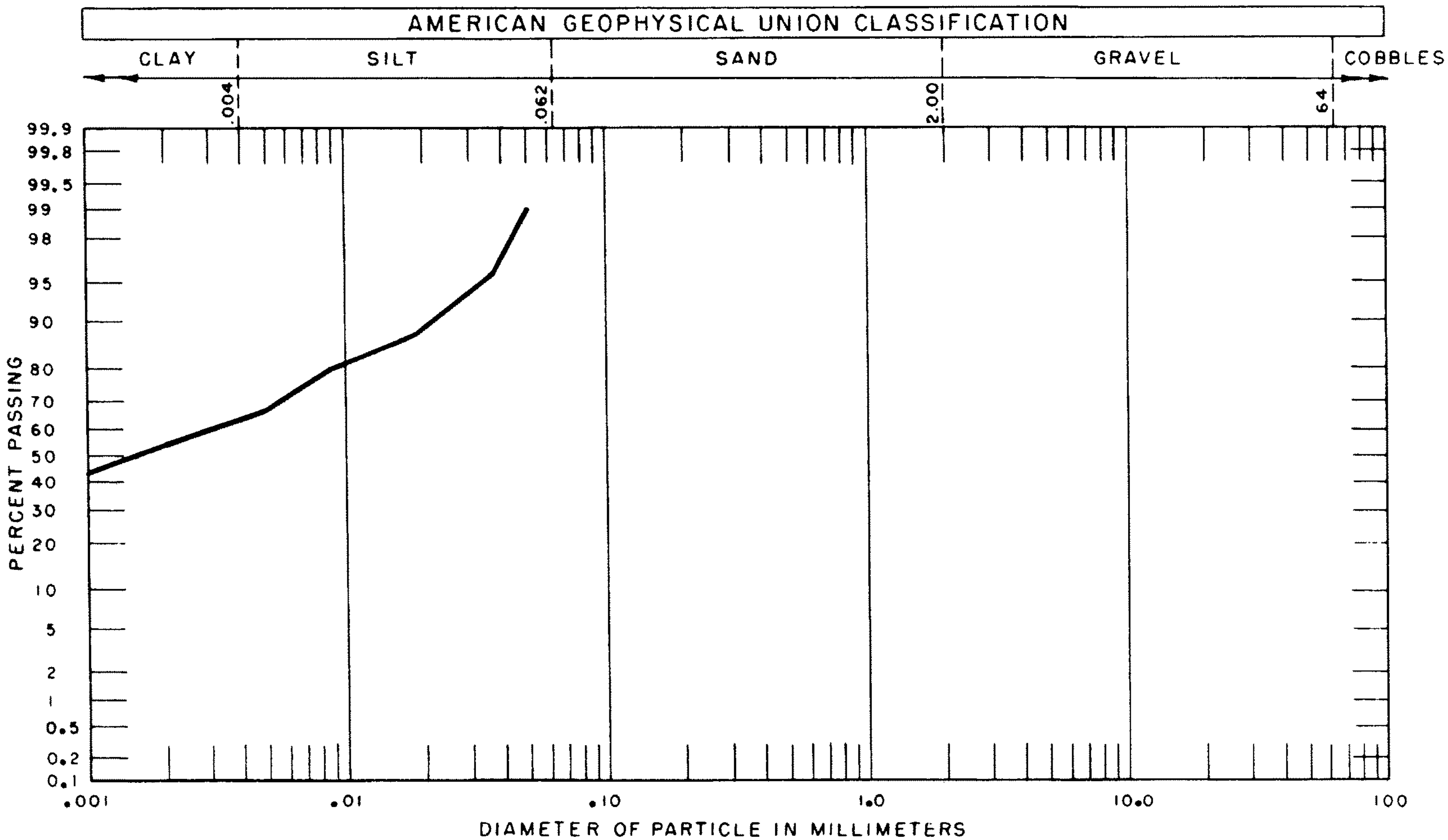

Figure 54.—Particle size analysis curve, range 5 (sheet 2 of 2).

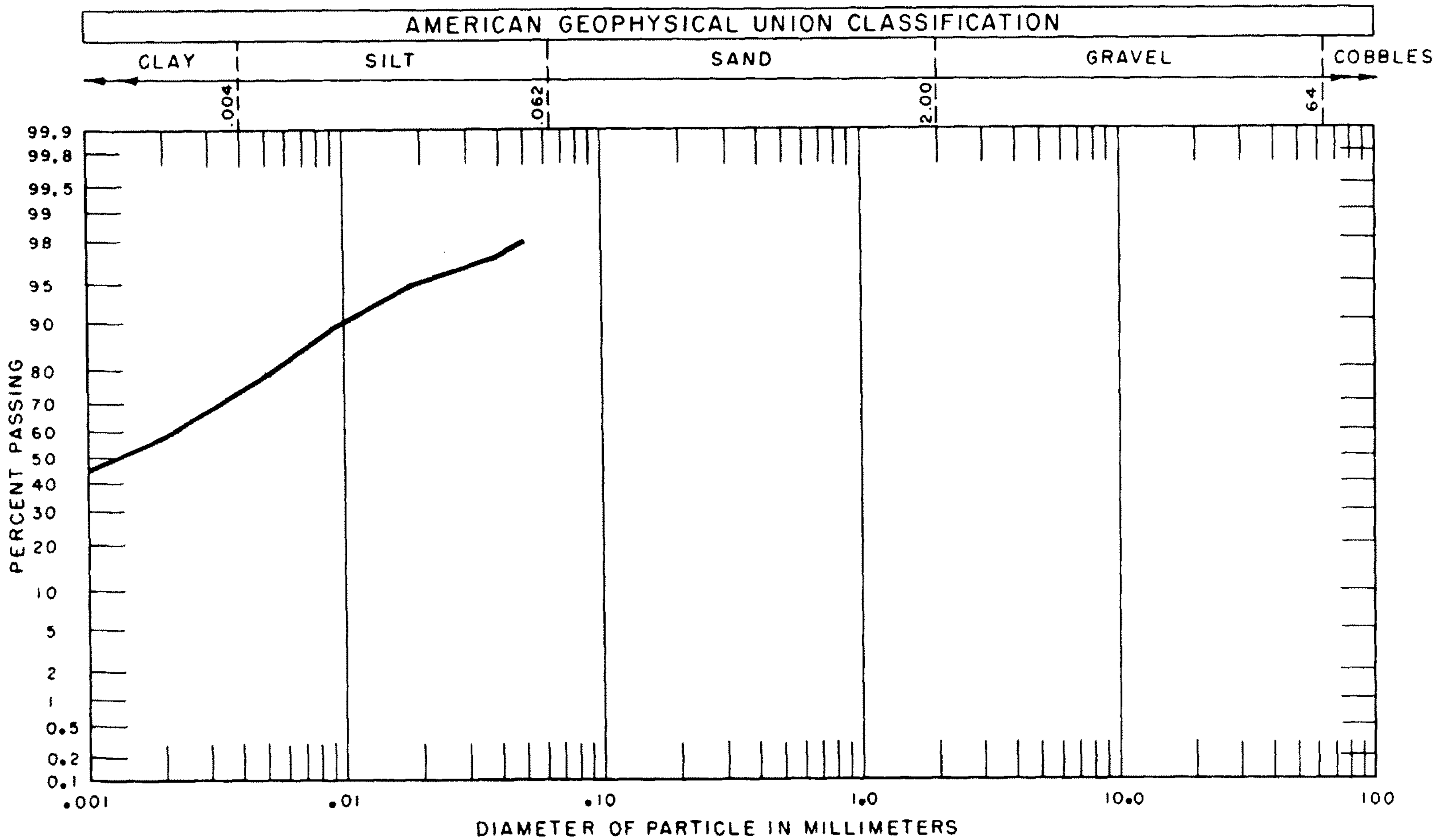

Figure 55.—Particle size analysis curve, range 30 (sheet 1 of 2).

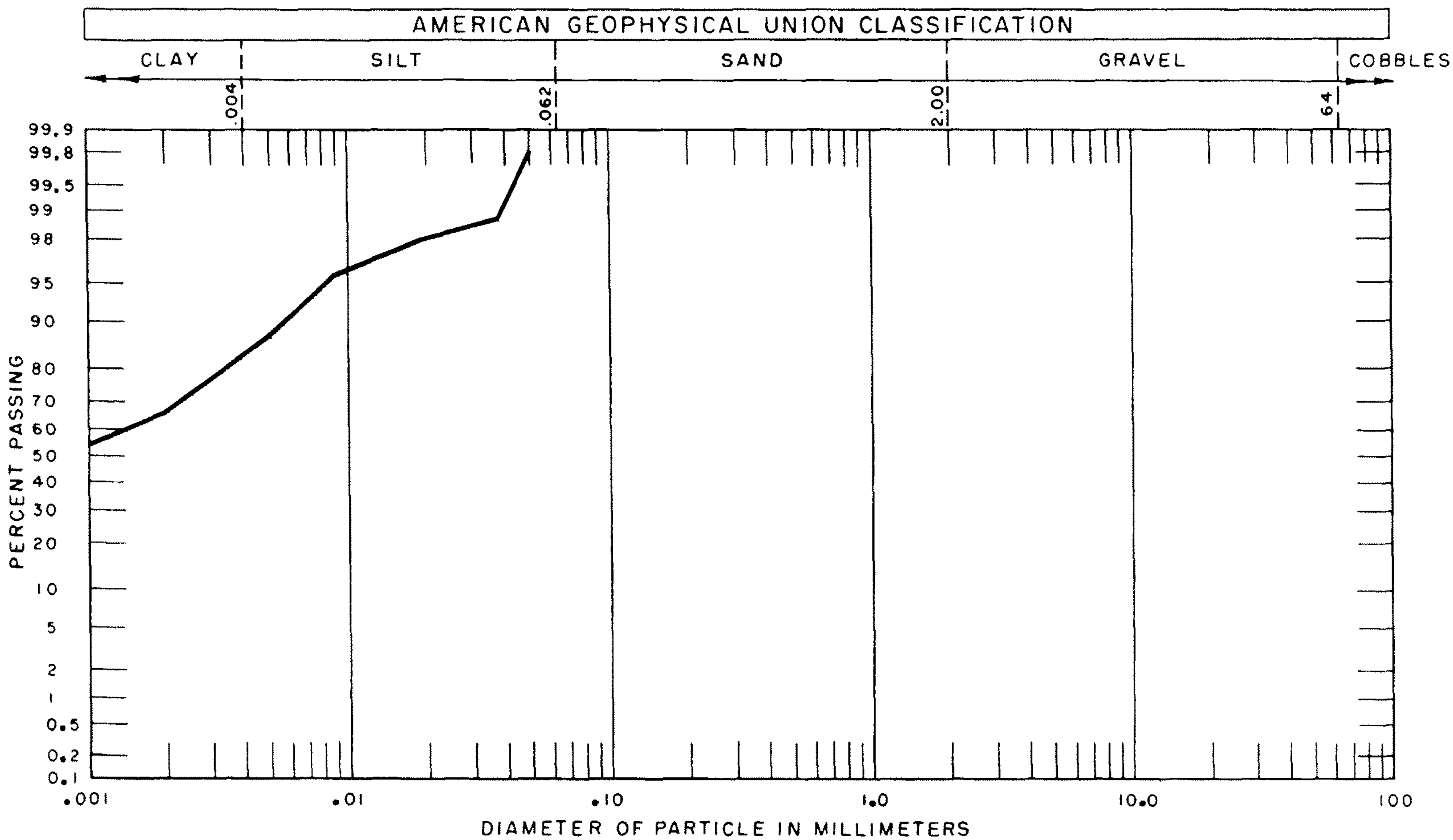

Figure 55.—Particle size analysis curve, range 30 (sheet 2 of 2).

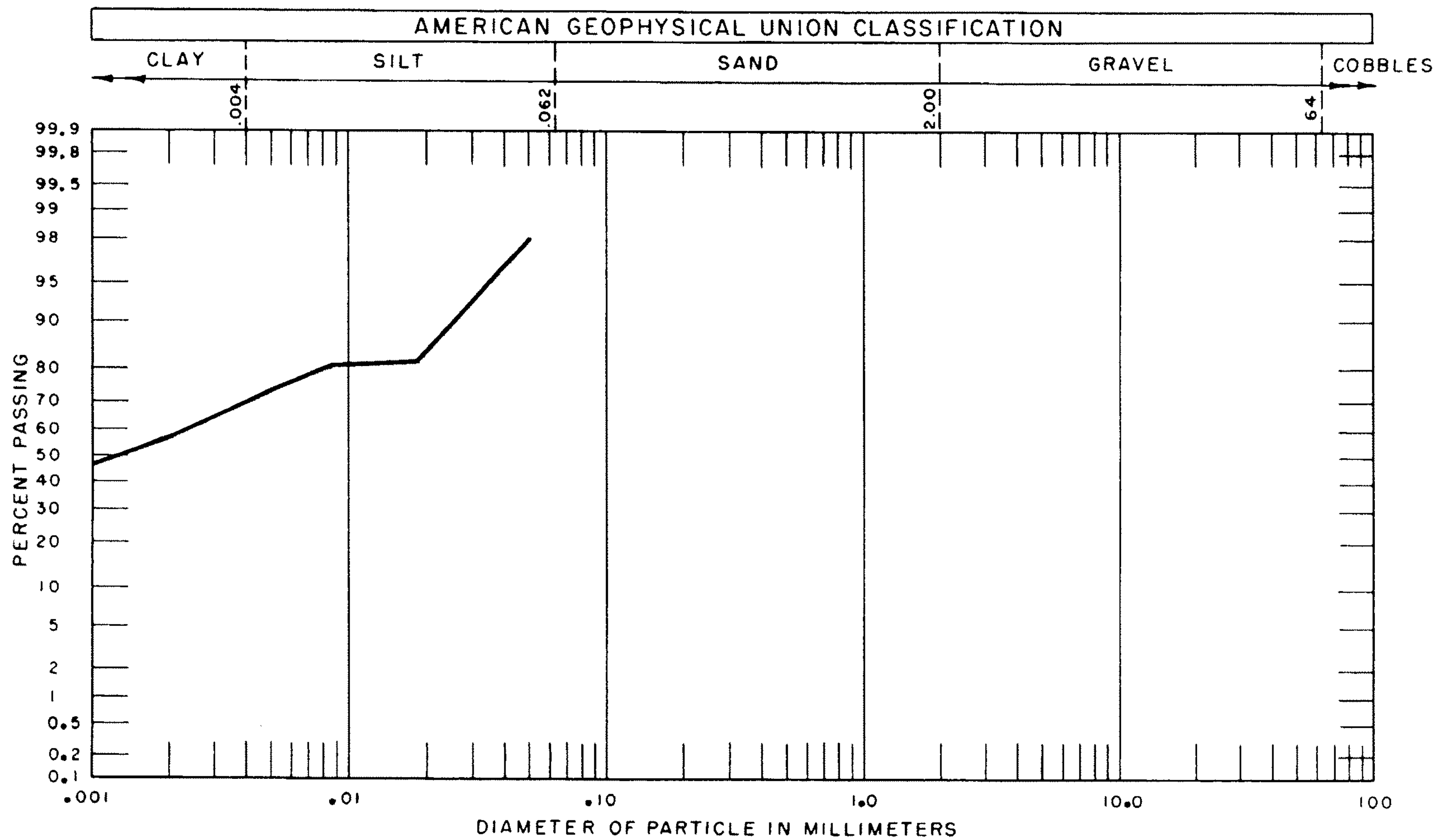

Figure 56.—Particle size analysis curve, range 31 (sheet 1 of 2).

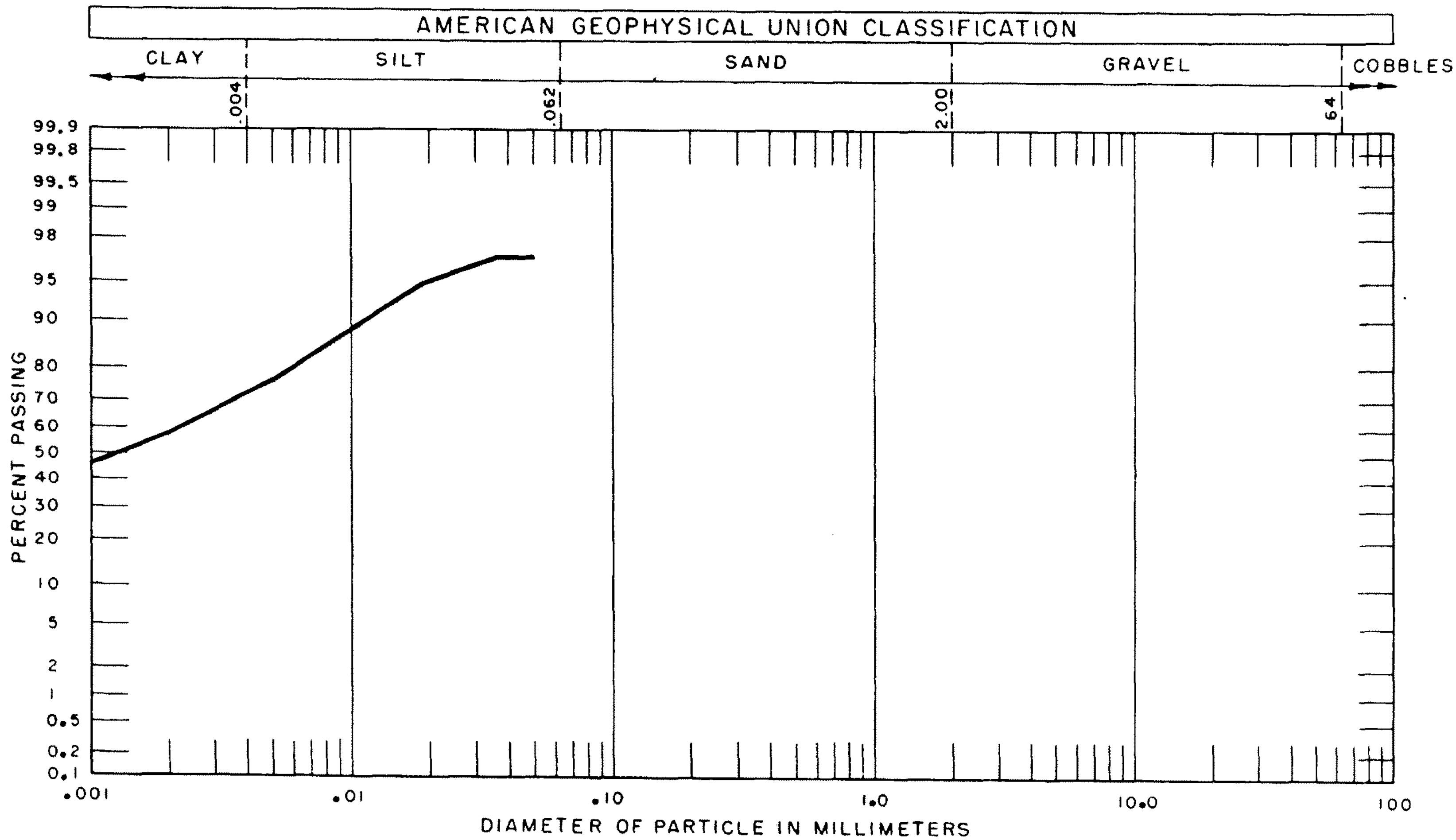

Figure 56.—Particle size analysis curve, range 31 (sheet 2 of 2).

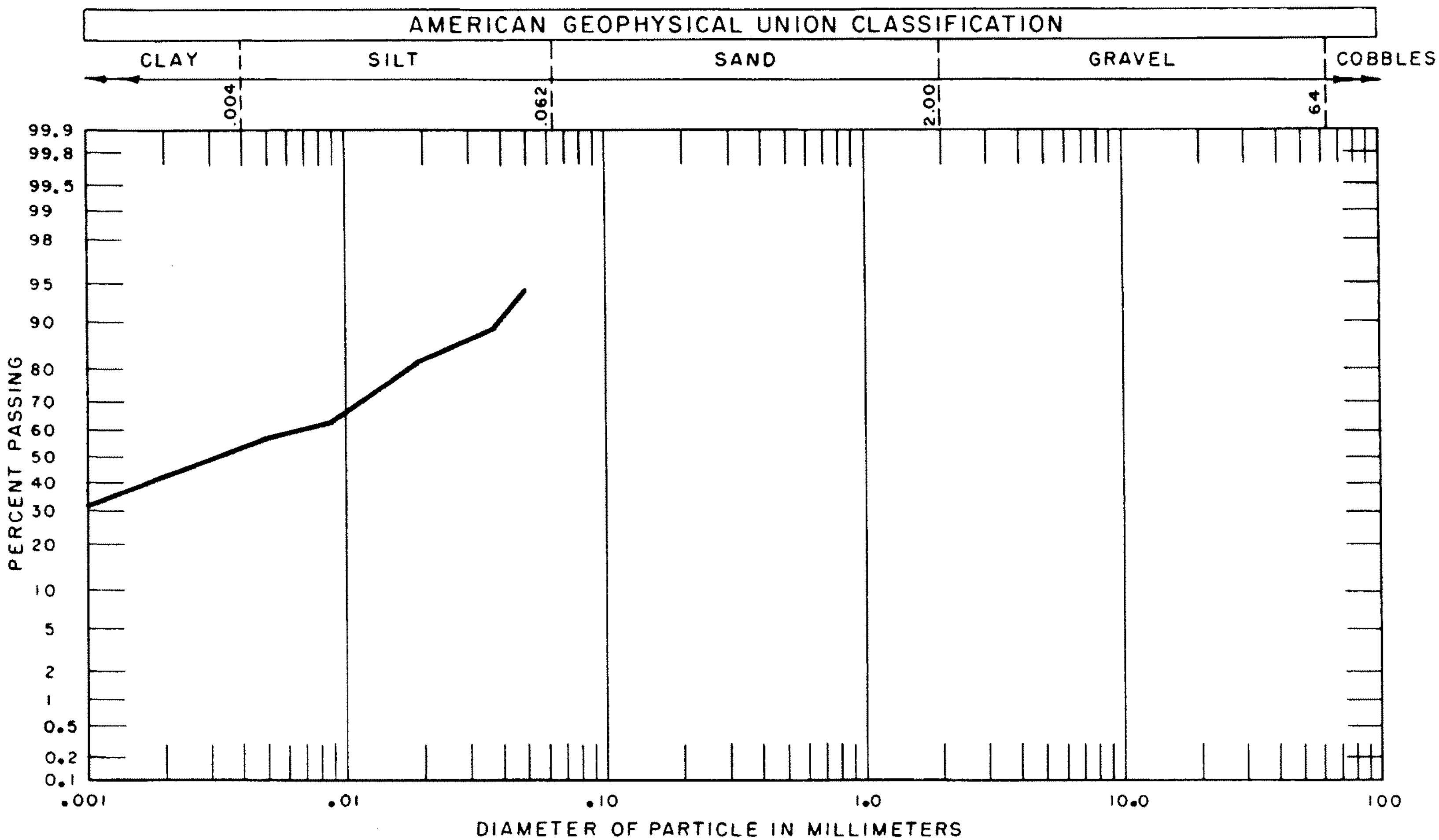

Figure 57.—Particle size analysis curve, range 32 (sheet 1 of 2).

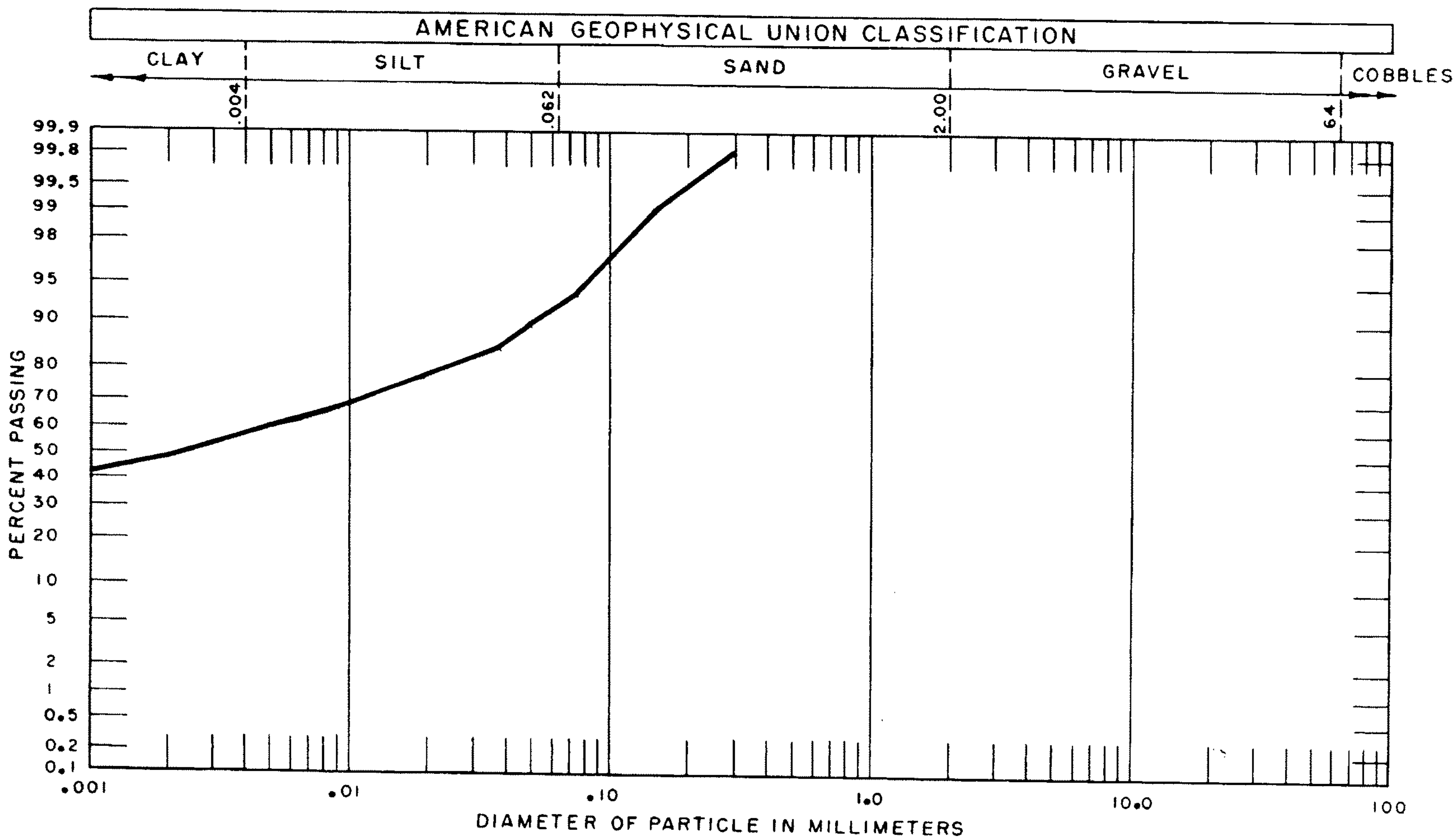

Figure 57.—Particle size analysis curve, range 32 (sheet 2 of 2).

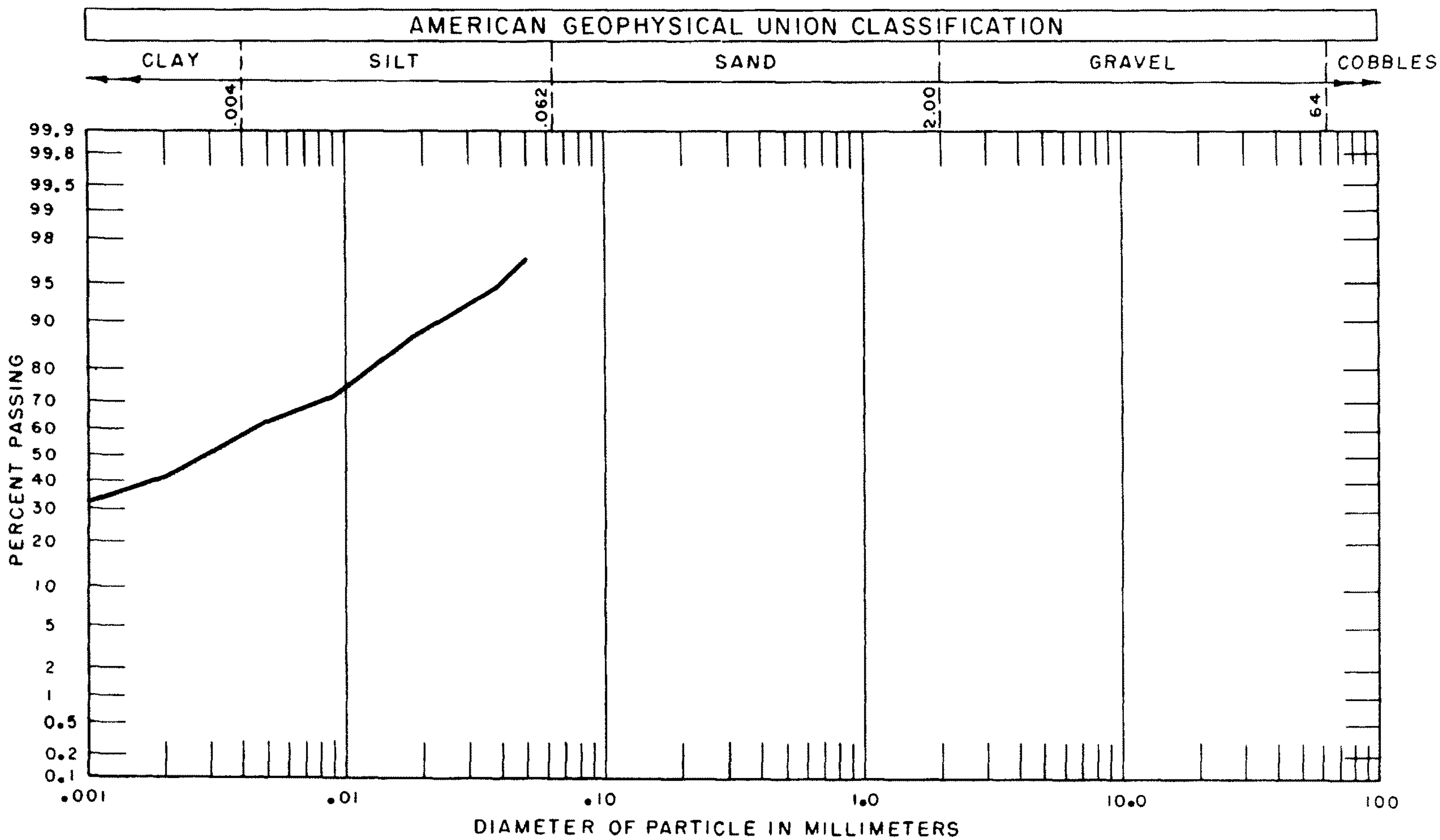

Figure 58.—Particle size analysis curve, range 33 (sheet 1 of 2).

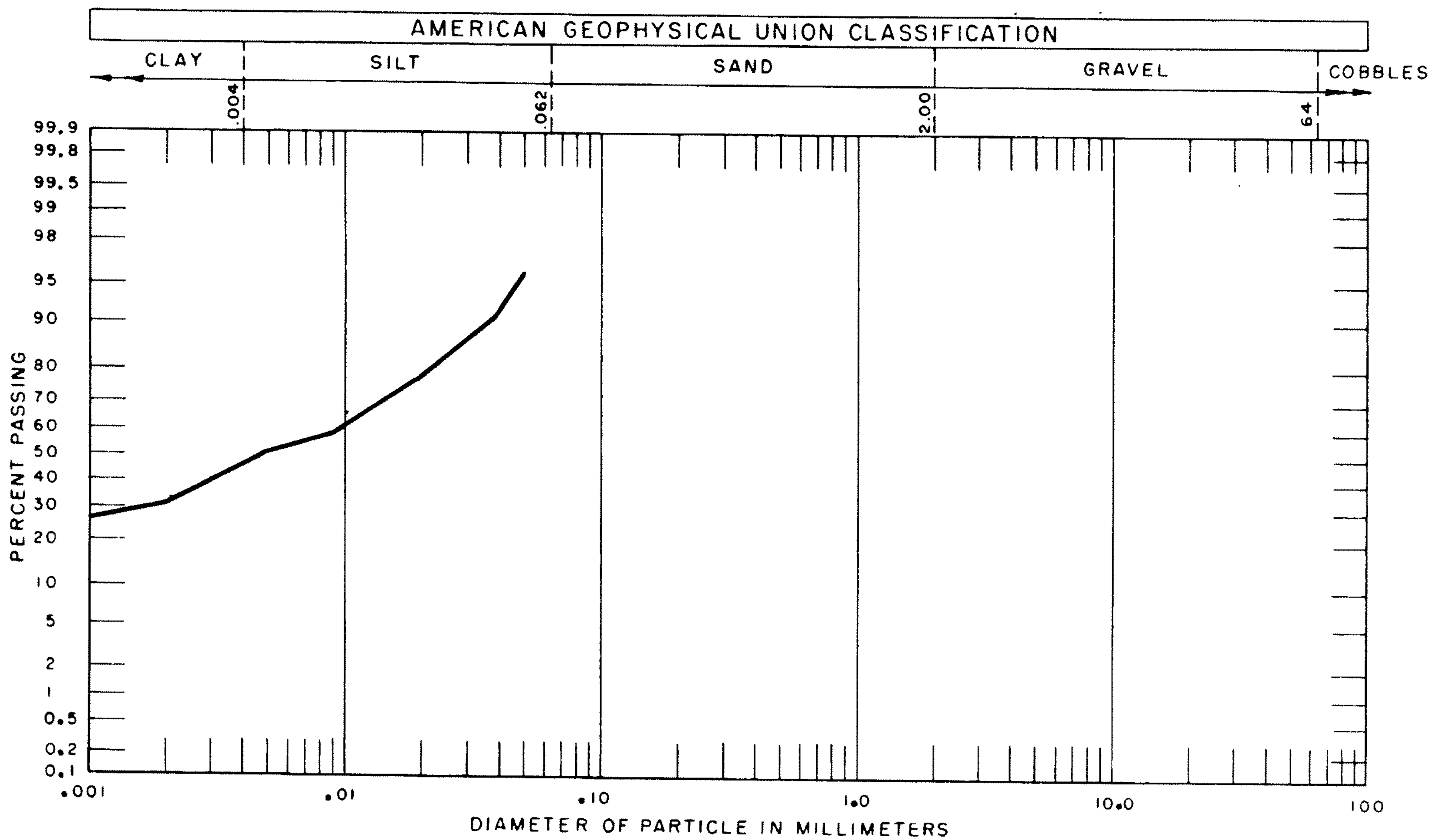

Figure 58.—Particle size analysis curve, range 33 (sheet 2 of 2).

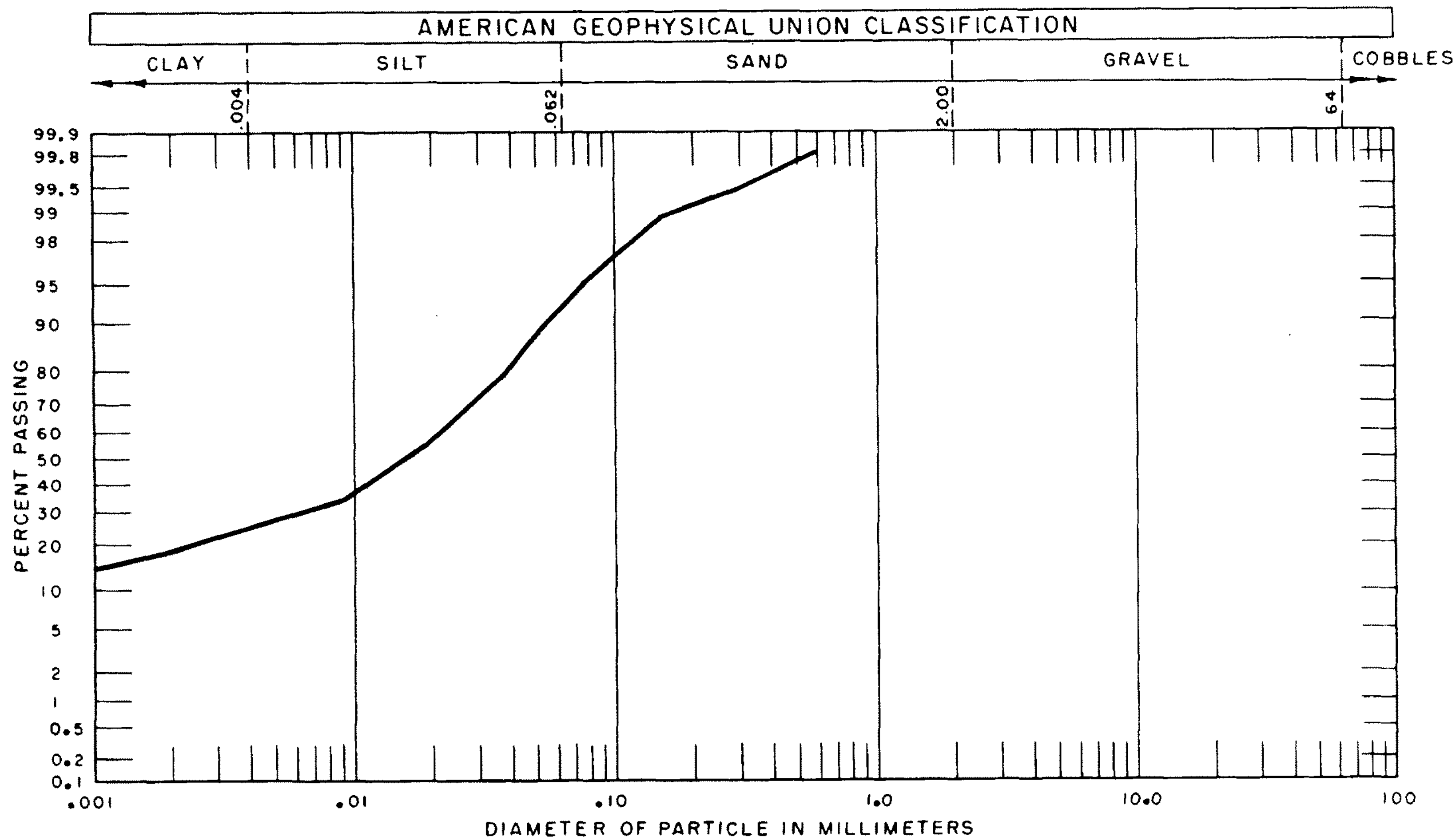

Figure 59.—Particle size analysis curve, range 34 (sheet 1 of 2).

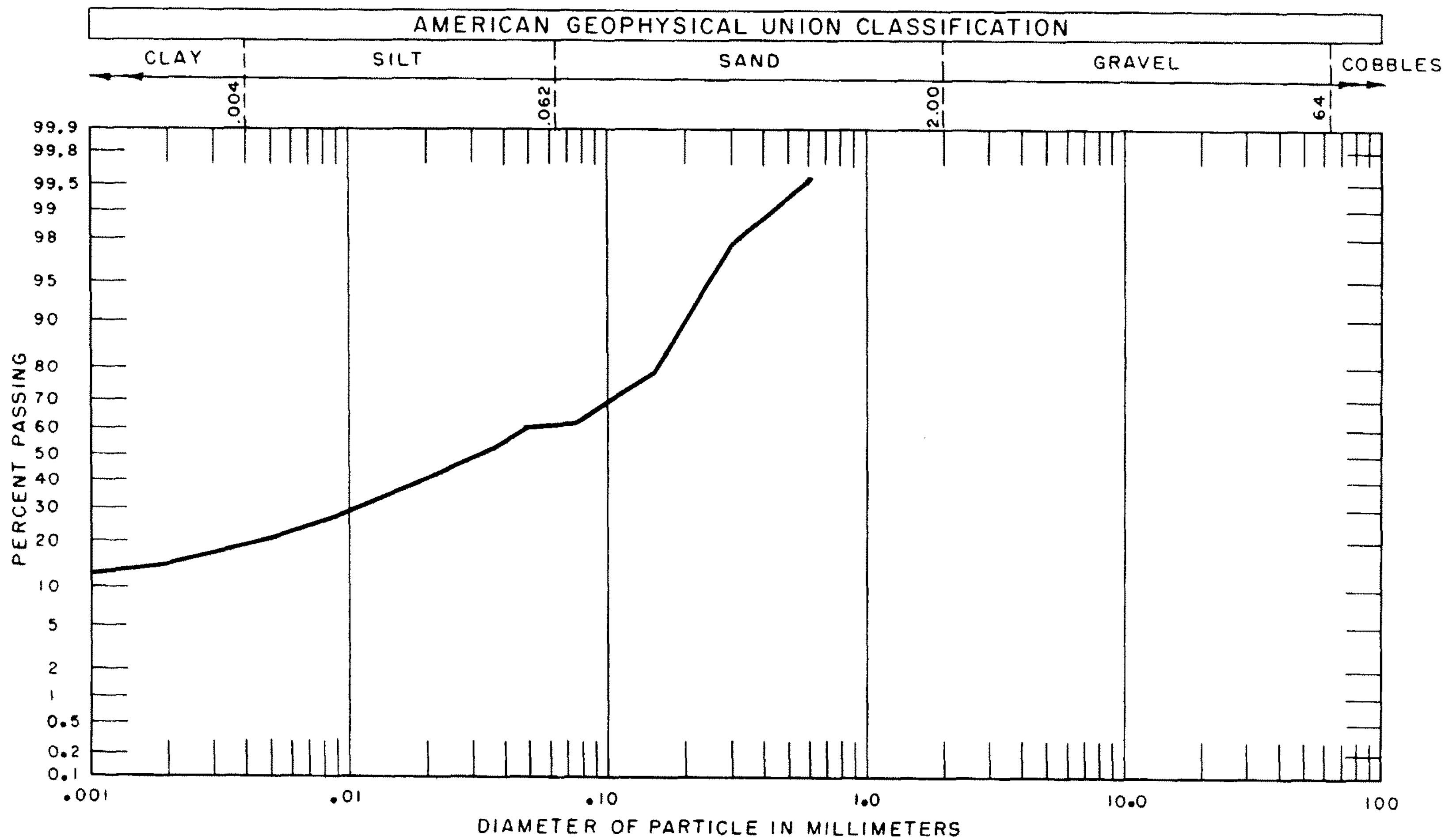

Figure 59.—Particle size analysis curve, range 34 (sheet 2 of 2).

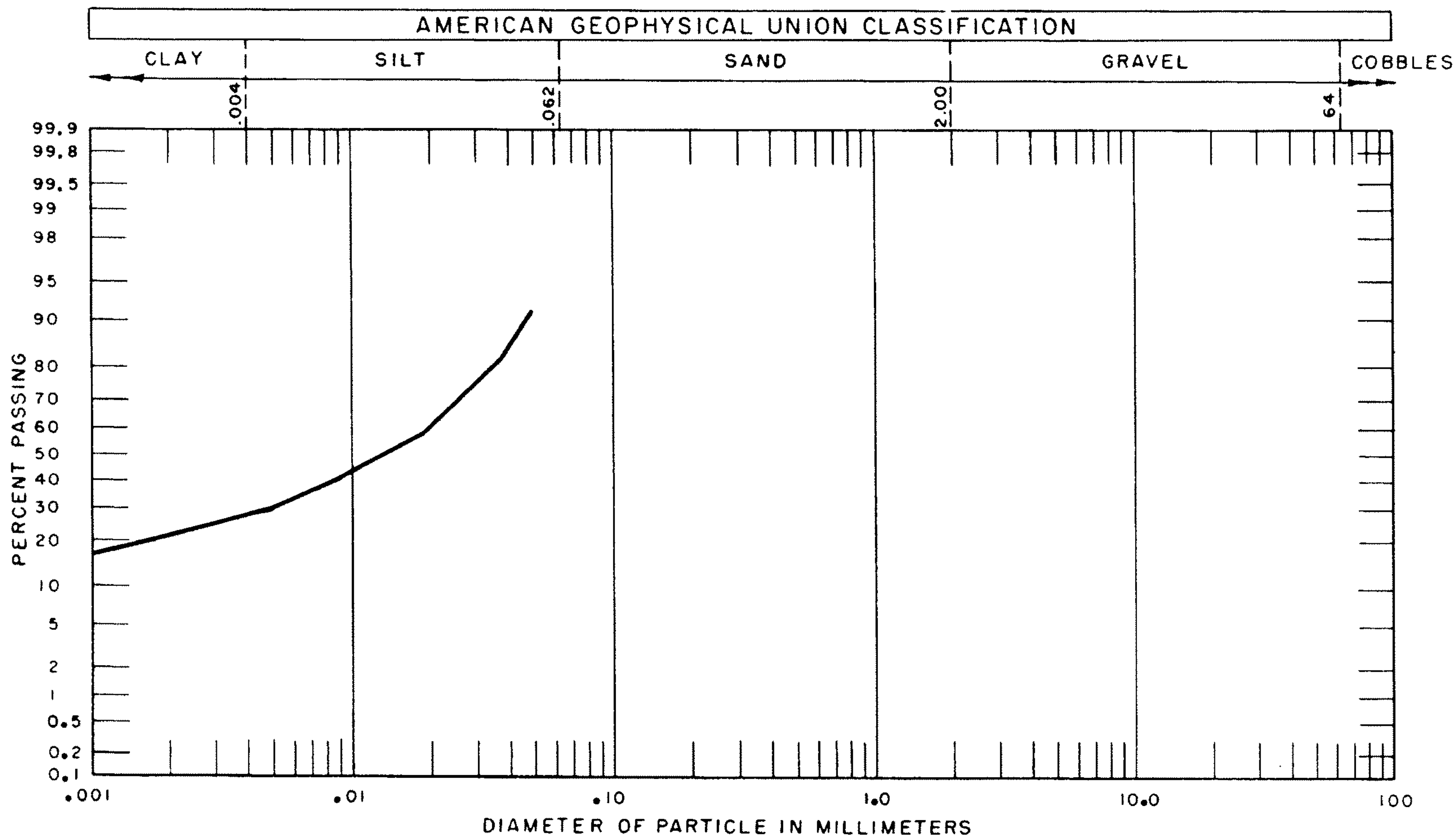

Figure 60.—Particle size analysis curve, range 35 (sheet 1 of 2).

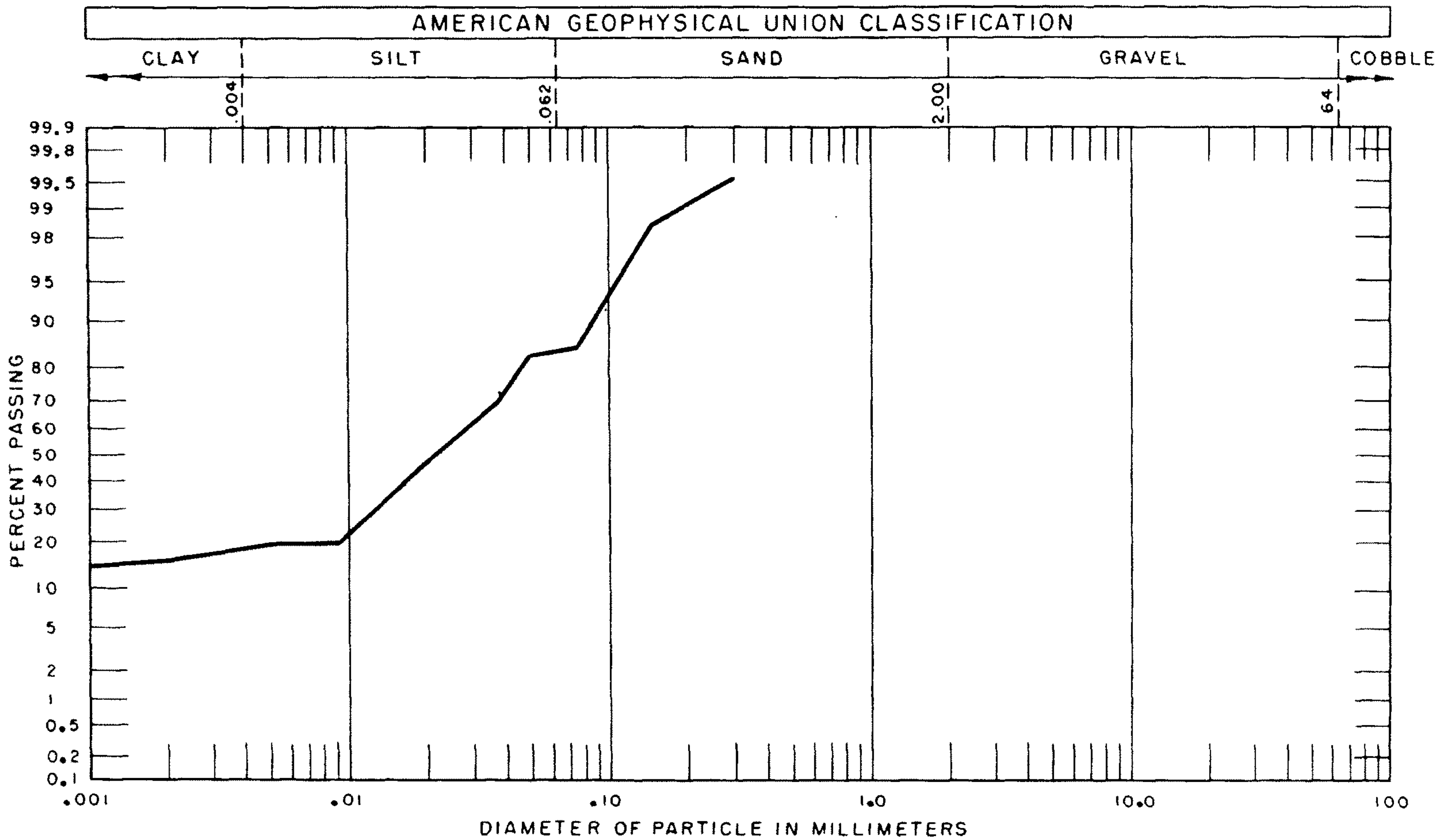

Figure 60.—Particle size analysis curve, range 35 (sheet 2 of 2).

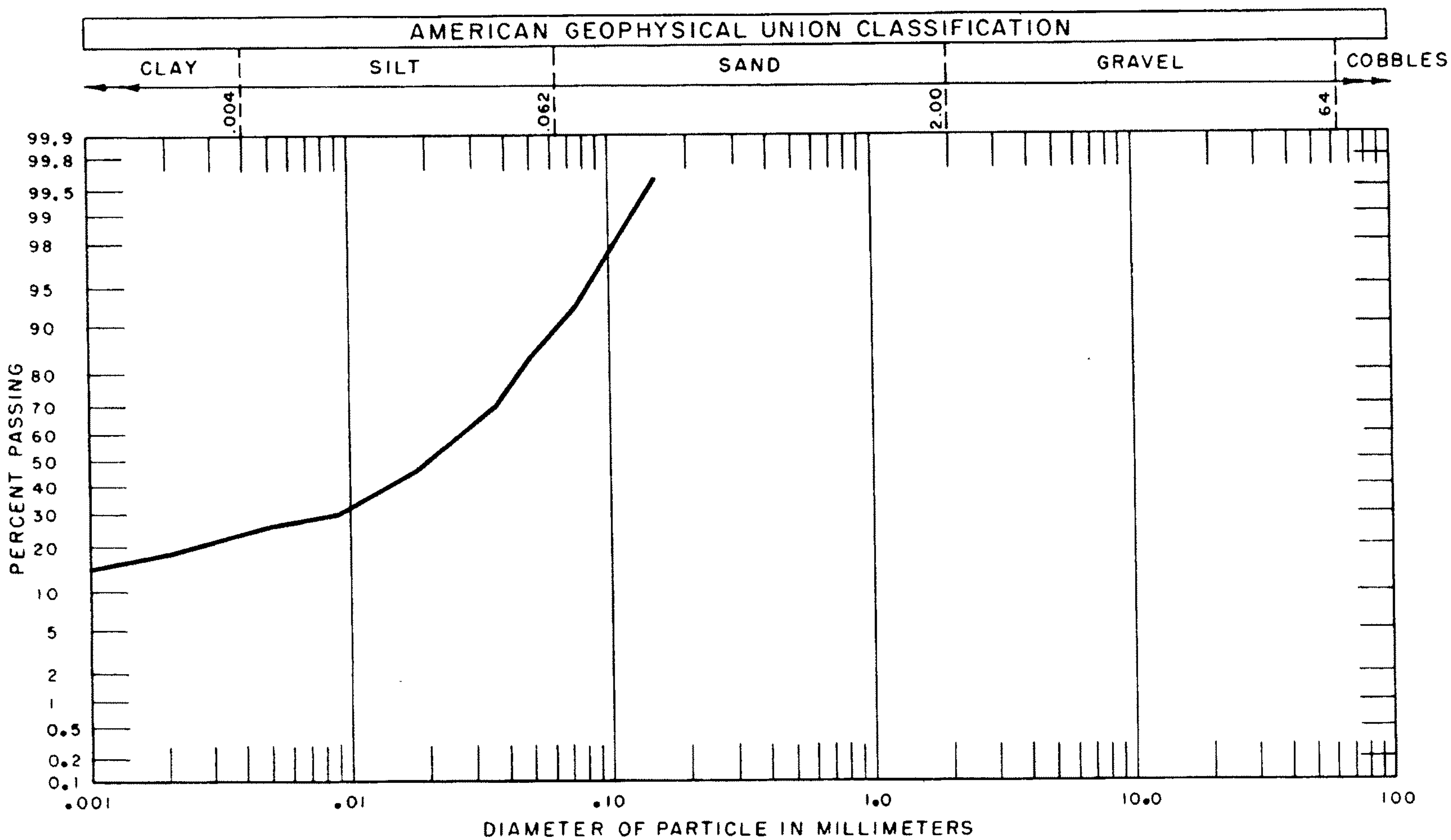

Figure 61.—Particle size analysis curve, range 36 (sheet 1 of 2).

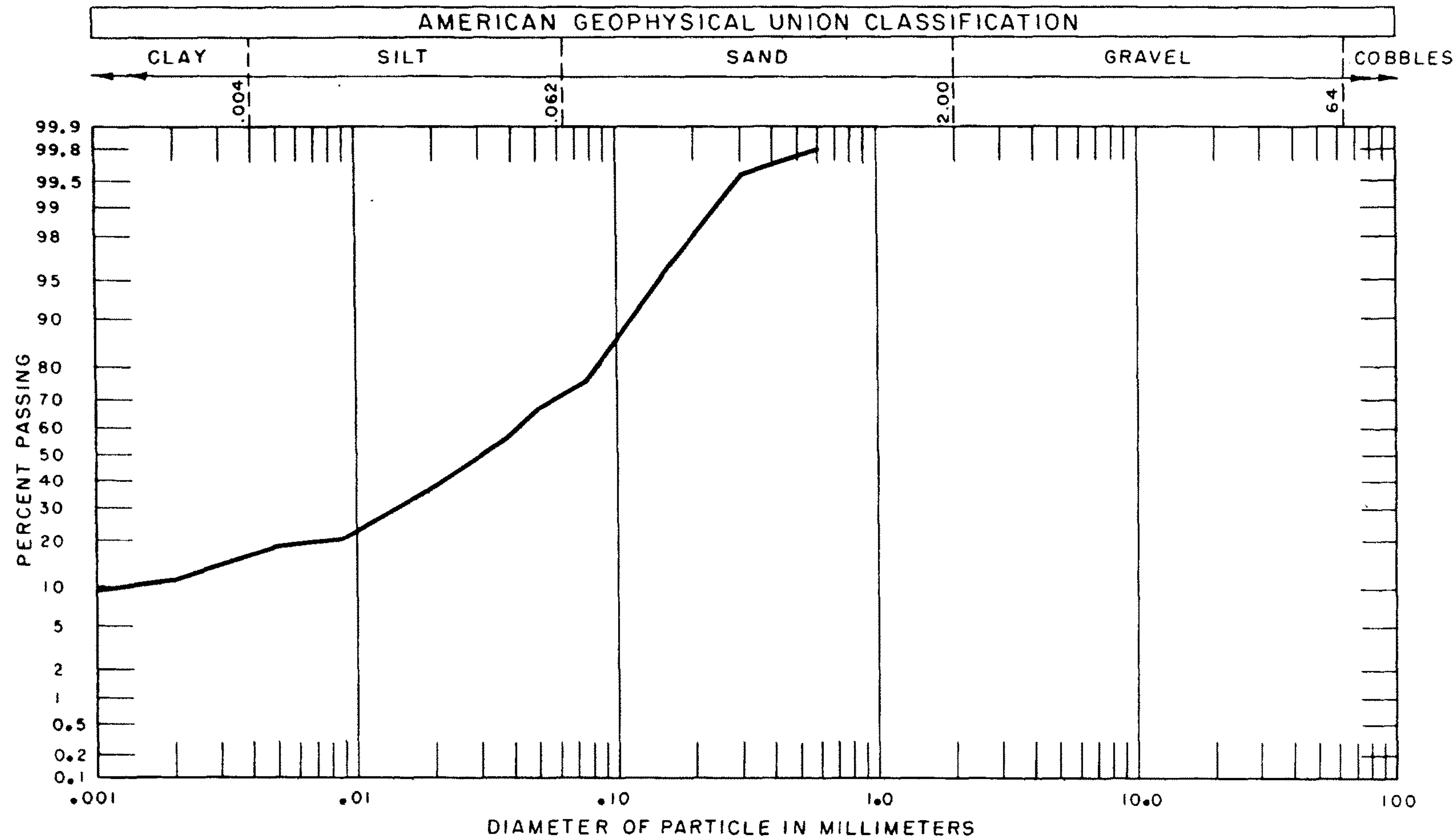

Figure 61.—Particle size analysis curve, range 36 (sheet 2 of 2).

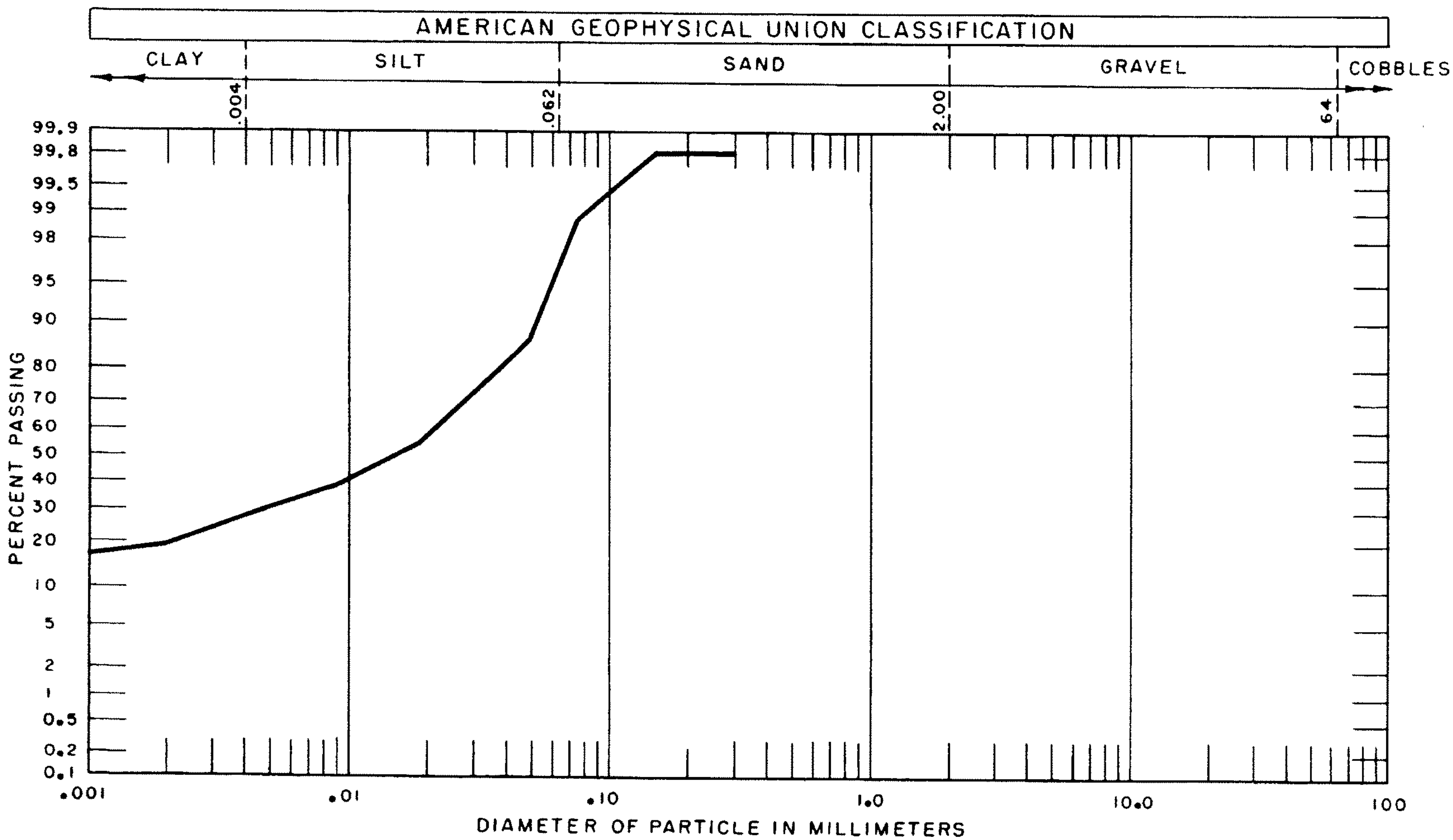

Figure 62.—Particle size analysis curve, range 37 (sheet 1 of 2).

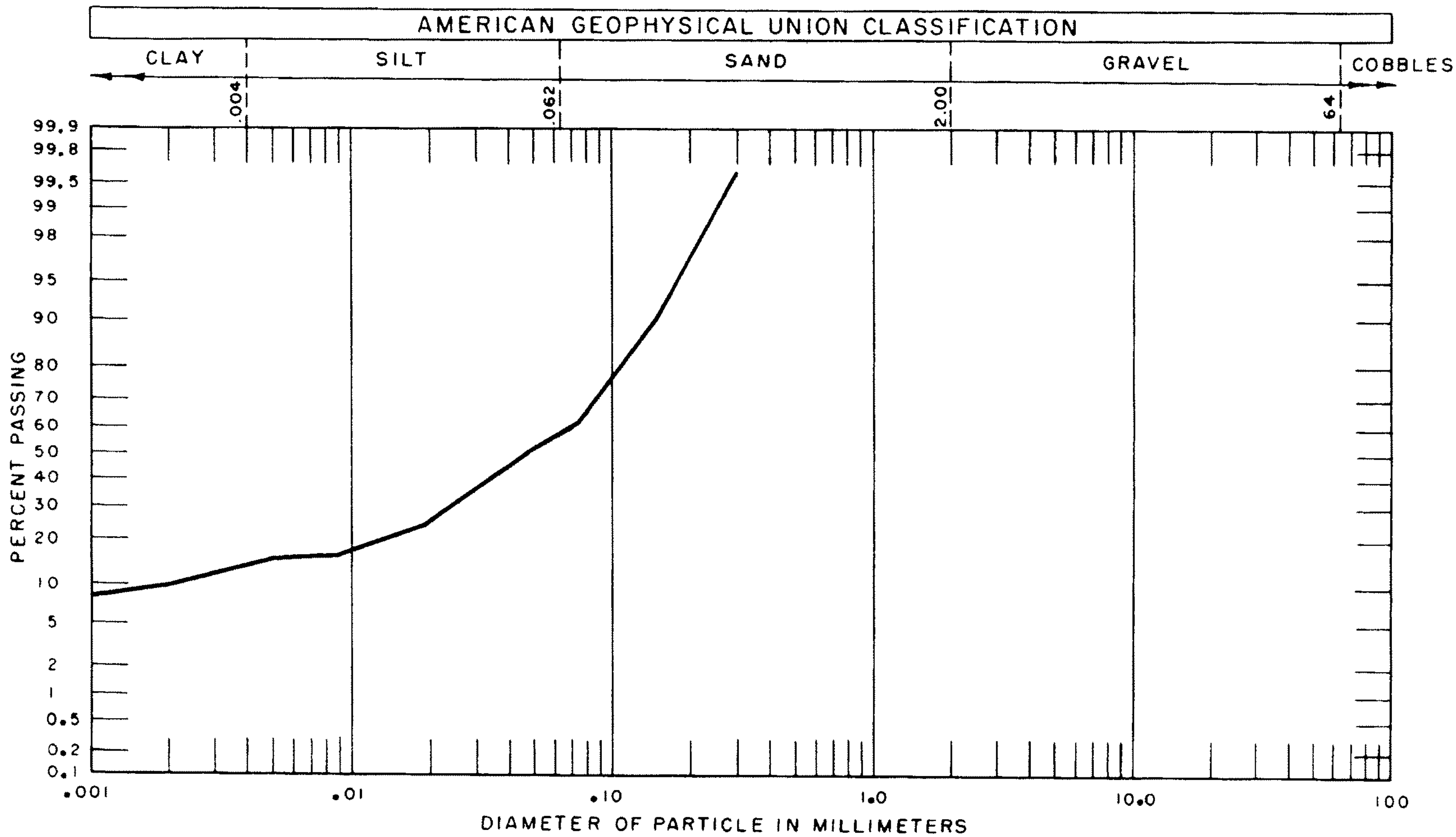

Figure 62.—Particle size analysis curve, range 37 (sheet 2 of 2).

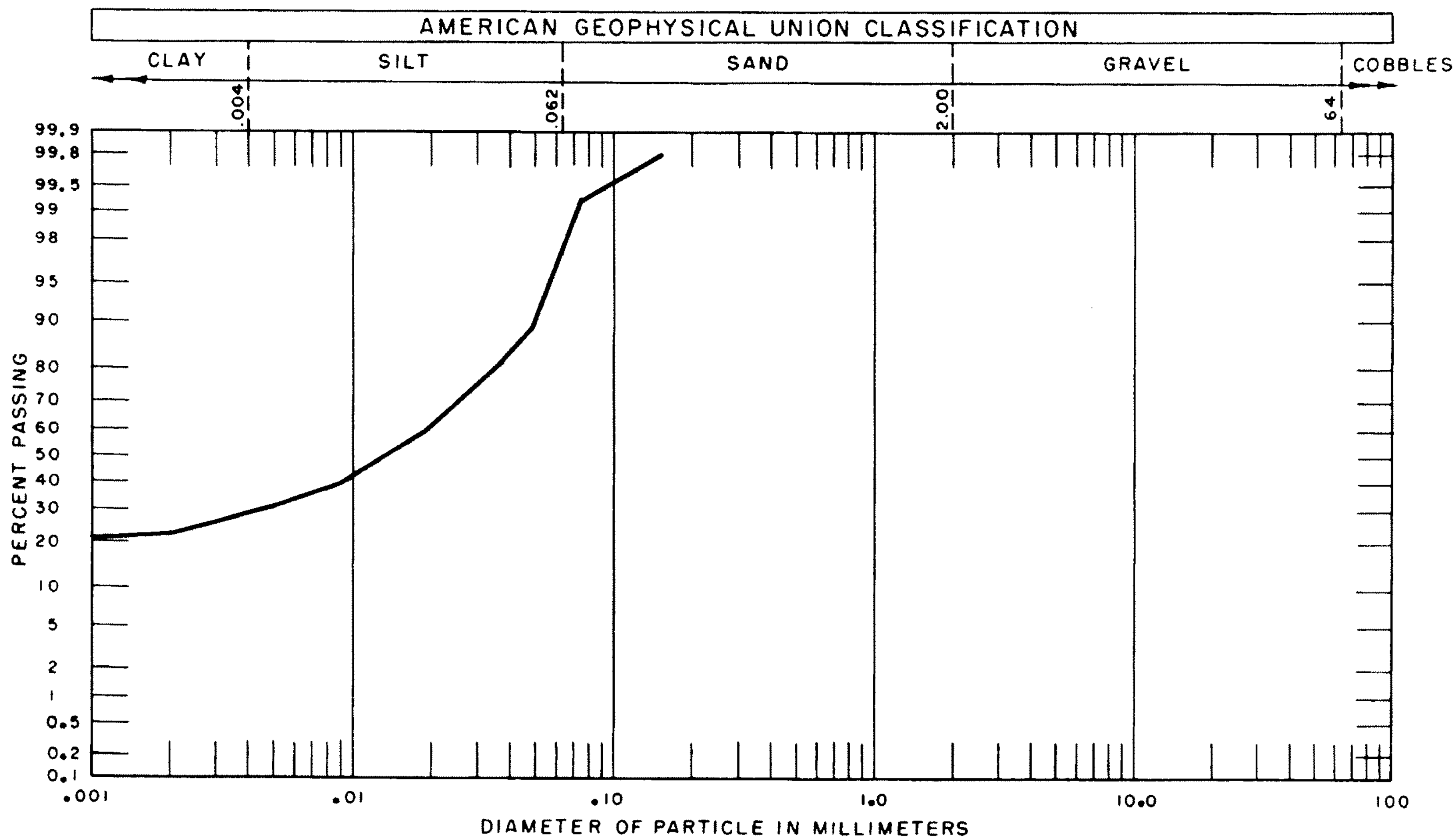

Figure 63.—Particle size analysis curve, range 38 (sheet 1 of 2).

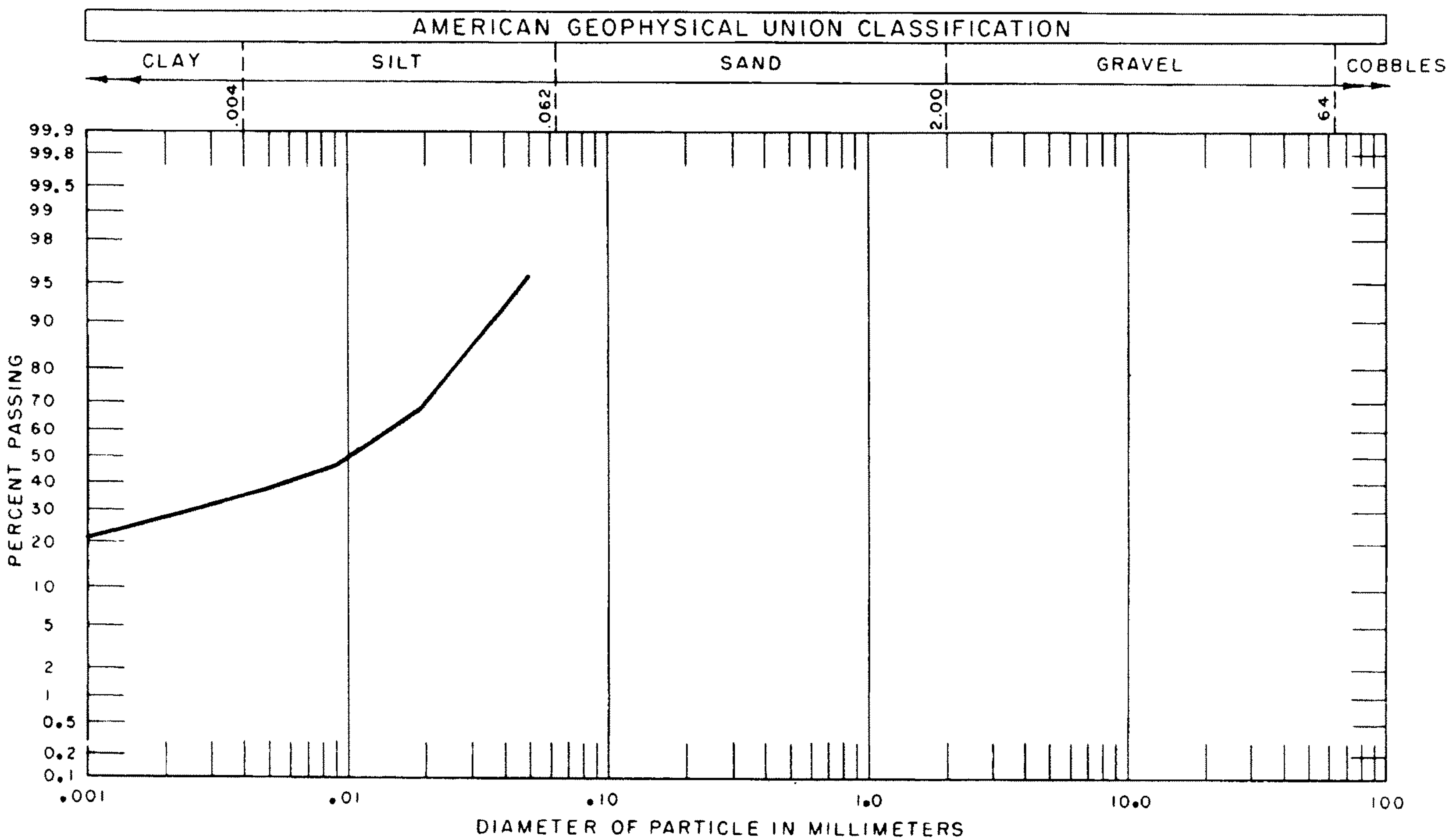

Figure 63.—Particle size analysis curve, range 38 (sheet 2 of 2).

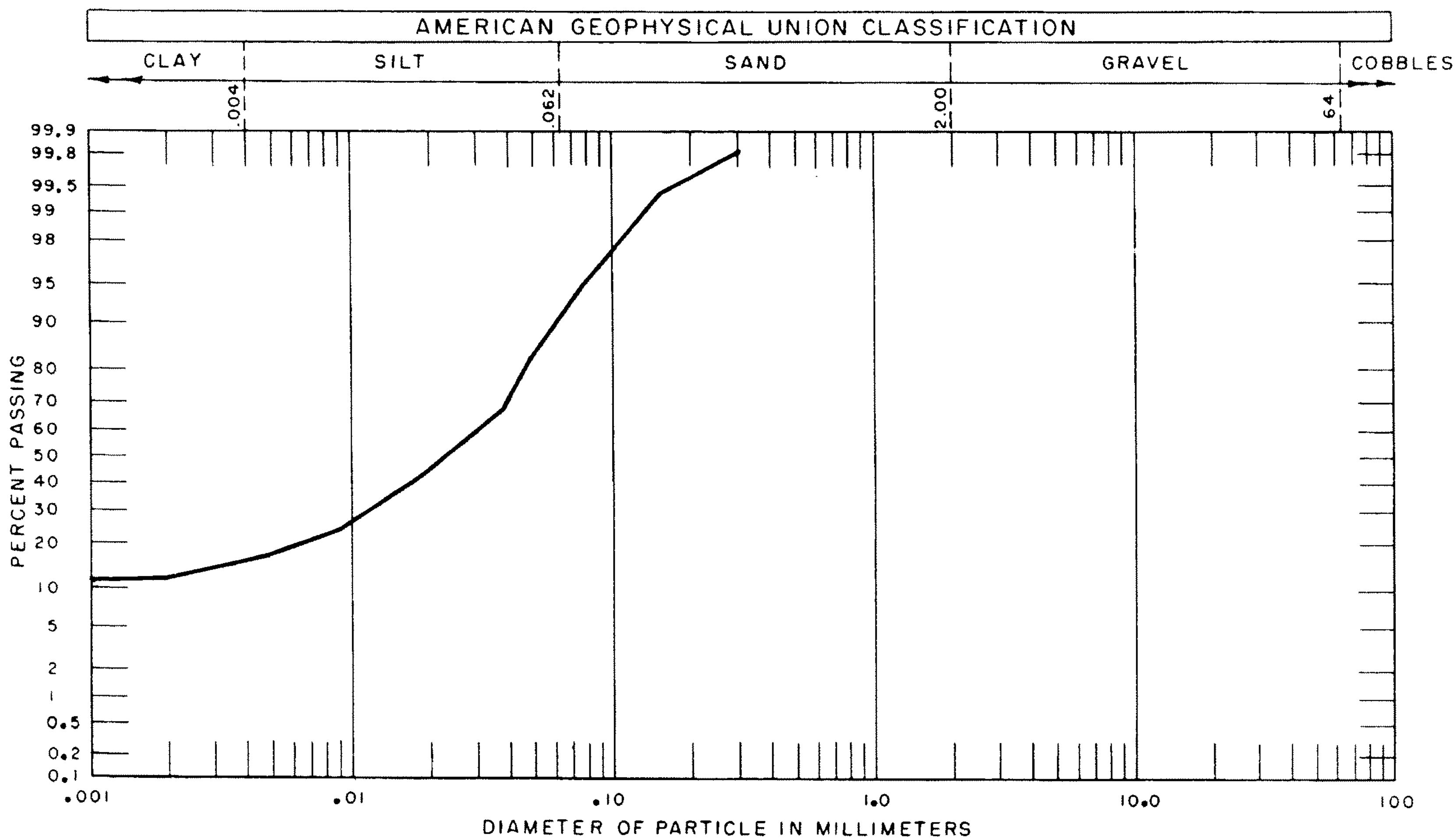

Figure 64.—Particle size analysis curve, range 39 (sheet 1 of 2).

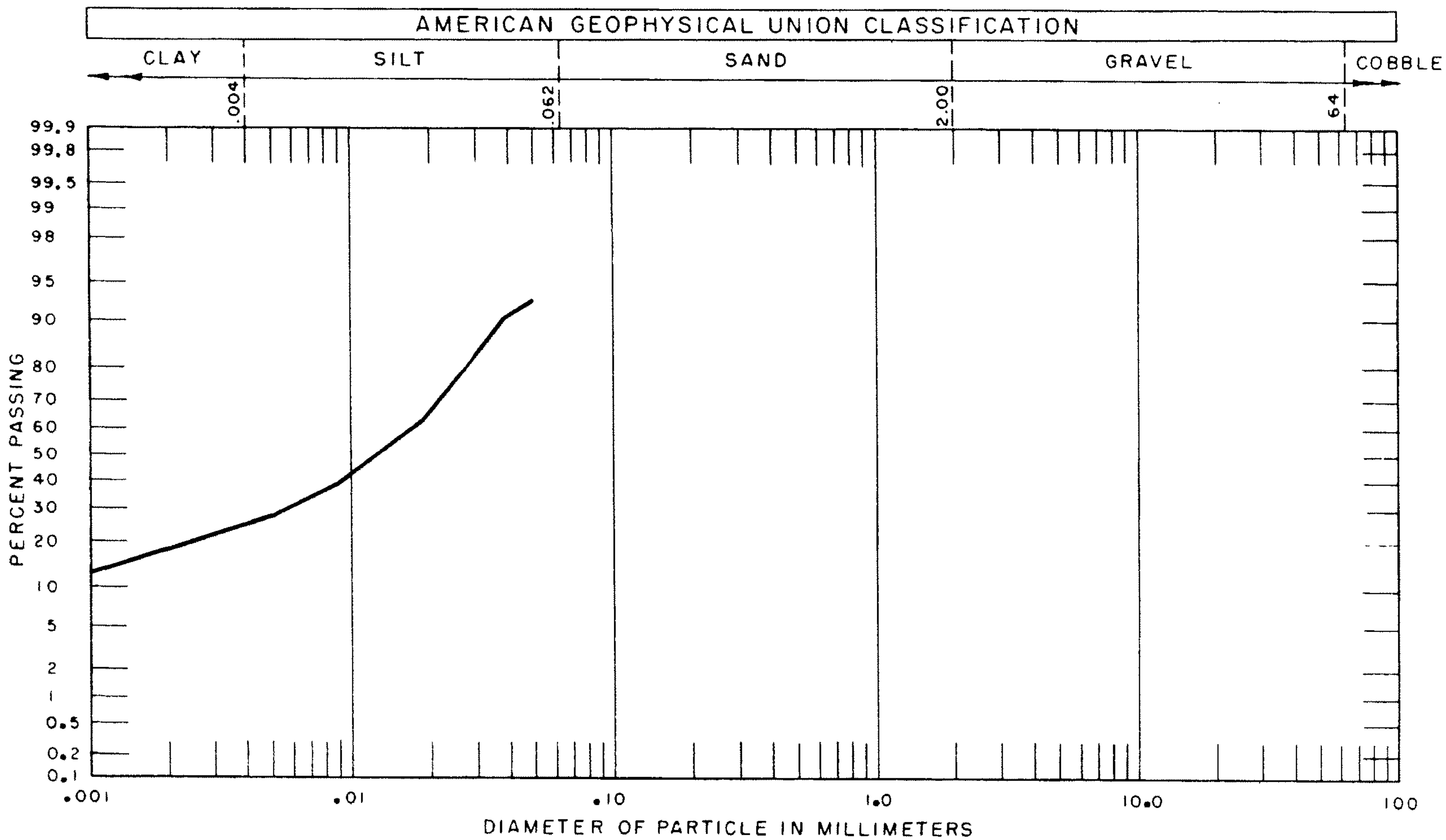

Figure 64.—Particle size analysis curve, range 39 (sheet 2 of 2).

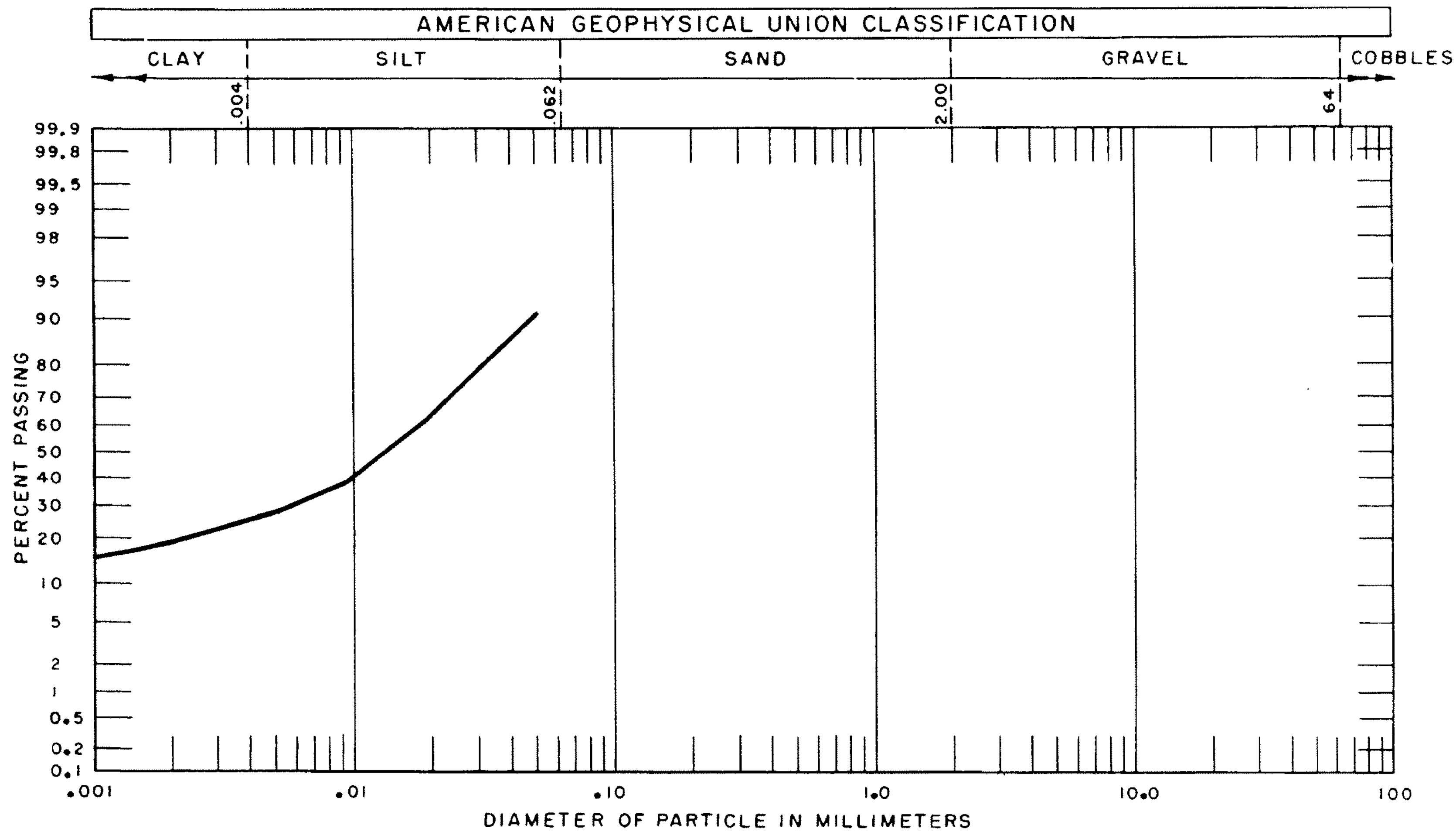

Figure 65.—Particle size analysis curve, range 40.

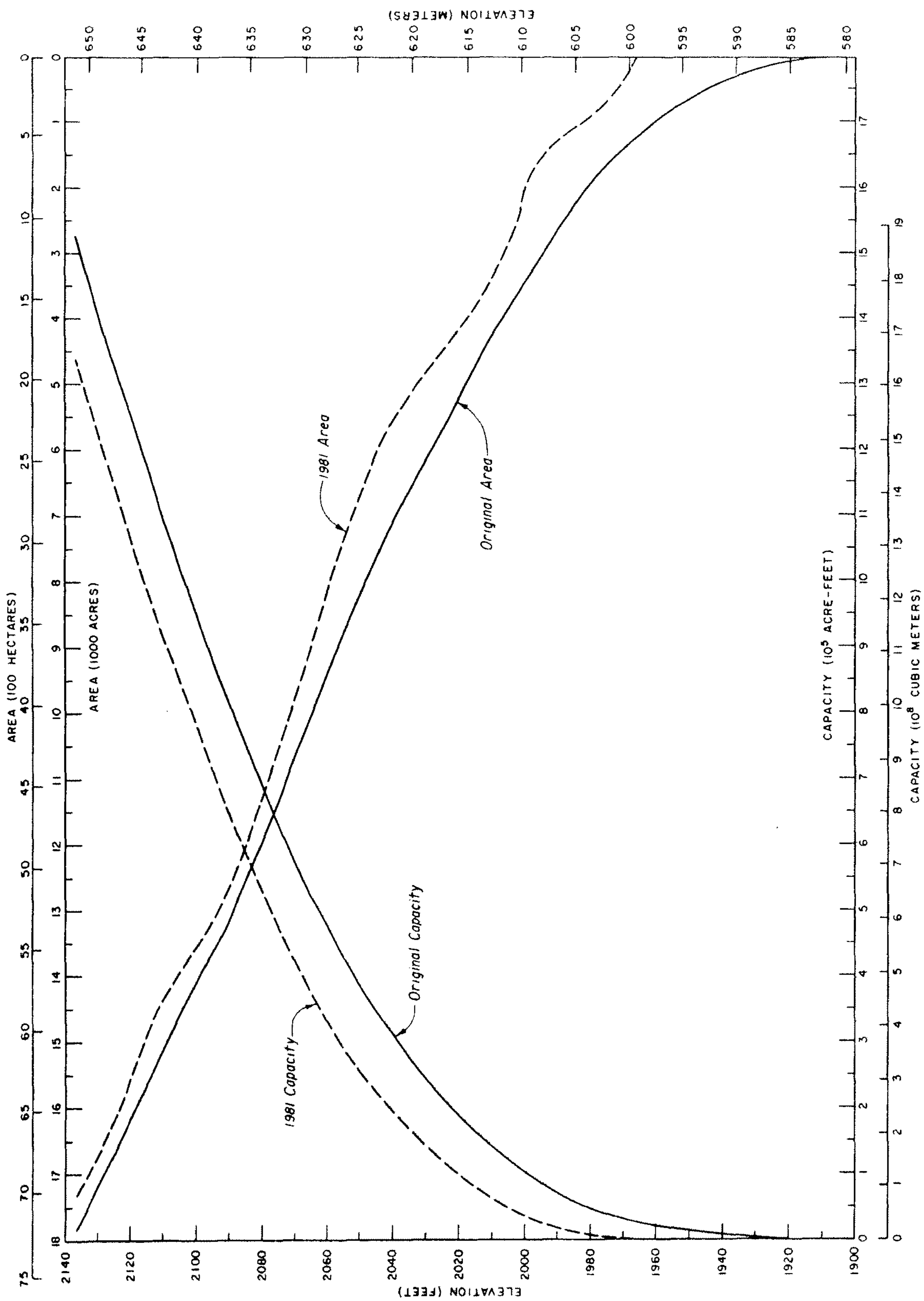

Figure 66.—Area-capacity curves.

GPO 839-213

Mission of the Bureau of Reclamation

The Bureau of Reclamation of the U.S. Department of the Interior is responsible for the development and conservation of the Nation's water resources in the Western United States.

The Bureau's original purpose "to provide for the reclamation of arid and semiarid lands in the West" today covers a wide range of interrelated functions. These include providing municipal and industrial water supplies; hydroelectric power generation; irrigation water for agriculture; water quality improvement; flood control; river navigation; river regulation and control; fish and wildlife enhancement; outdoor recreation; and research on water-related design, construction, materials, atmospheric management, and wind and solar power.

Bureau programs most frequently are the result of close cooperation with the U.S. Congress, other Federal agencies, States, local governments, academic institutions, water-user organizations, and other concerned groups.

A free pamphlet is available from the Bureau entitled, "Publications for Sale". It describes some of the technical publications currently available, their cost, and how to order them. The pamphlet can be obtained upon request from the Bureau of Reclamation, Attn D-922, P O Box 25007, Denver Federal Center, Denver CO 80225-0007.