LAKE LIVINGSTON
1991 SEDIMENTATION SURVEY

Owned and Operated by the Trinity River Authority of Texas
Lake Livingston Project

U.S. Department of the Interior
Bureau of Reclamation

7-2090 (4-81)
Bureau of Reclamation

TECHNICAL REPORT STANDARD TITLE PAGE

1. REPORT NO.	2. GOVERNMENT ACCESSION NO.	3. RECIPIENT'S CATALOG NO.
4. TITLE AND SUBTITLE LAKE LIVINGSTON – 1991 SEDIMENTATION SURVEY		5. REPORT DATE May 1993 6. PERFORMING ORGANIZATION CODE D-5753
7. AUTHOR(S) Ronald L. Ferrari		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Bureau of Reclamation Denver Office Denver CO 80225		10. WORK UNIT NO. 11. CONTRACT OR GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS Same		13. TYPE OF REPORT AND PERIOD COVERED DIBR 14. SPONSORING AGENCY CODE D-5753

15. SUPPLEMENTARY NOTES

Microfiche and hard copy available at the Denver Office, Denver, Colorado. Ed: TH

16. ABSTRACT

The Bureau of Reclamation Sedimentation Section surveyed Lake Livingston in 1991 to gather data needed to compute the capacity of the lake for reservoir operation. The data were also used to calculate the volume of sediment that has accumulated in the lake since water storage began in June 1969. Reclamation's large vessel system was used to collect range line data. The remaining data were collected by Reclamation's small boat bathymetric system. The 1991 reservoir surface areas were computed by the Width Adjustment Method. The storage-elevation relationships based on the 1991 underwater survey data were developed using Reclamation's area-capacity computer porgram ACAP85.

The 1991 survey determined that the reservoir has a storage capacity of 1,741,867 acre-feet and a surface area of 83,277 acres at the top of conservation storage elevation 131.0. Since closure in 1969, the reservoir has accumulated a volume of 64,227 acre-feet of sediment below elevation 131.0. This volume represents a 3.56-percent loss in total capacity and an average annual loss of 2,854 acre-feet for the operation period of June 1969 through December 1991.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS-- reservoir area and capacity/ sedimentation/ reservoir surveys/ sonar/ sediment distribution/ contour area/ reservoir area/ sedimentation survey/

b. IDENTIFIERS-- Lake Livingston/ Trinity River Authority/

c. COSATI Field/Group 13/B ***COWRR:*** 1302.66 ***SRIM:***

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS (THIS REPORT) *UNCLASSIFIED*	21. NO. OF PAGES 45
	20. SECURITY CLASS (THIS PAGE) *UNCLASSIFIED*	22. PRICE

LAKE LIVINGSTON

1991 SEDIMENTATION SURVEY

**Lake Livingston Project Owned and Operated by
Trinity River Authority of Texas**

1991 Sedimentation Survey Report prepared by

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DENVER, COLORADO

1992

ACKNOWLEDGMENTS

The Bureau of Reclamation prepared and published this report under the supervision of Robert I. Strand, Head, Sedimentation Section, Earth Sciences Division. The hydrographic survey was supervised by Ronald Ferrari, Hydraulic Engineer, and assisted by Steven Hughes, Engineer Technician, of the Denver Office. Personnel from the Trinity River Authority at Livingston, Texas, assisted in the hydrographic survey. A private contractor for the river authority performed the land survey required for the hydrographic survey. Ronald Ferrari completed the data processing, sediment computations, area-capacity tables, and the report. Robert I. Strand and James O. Blanton III, Hydraulic Engineer, consulted in the sediment computations and report preparation.

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FIGURES — Continued

INTRODUCTION

Livingston Dam was a major step taken by the City of Houston, in cooperation with the TRA (Trinity River Authority), to develop a source of water primarily for the expanding industry in the Houston Industrial Complex. TRA built, owns, manages, and operates the dam, reservoir, and recreational facilities associated with the project. Construction of the dam was completed in September 1968. Water storage operations began in June 1969. The dam, located on the Trinity River, is about 7 miles southwest of Livingston and 75 miles north of Houston (fig. 1). The reservoir impounded by the dam lies in Polk, San Jacinto, Walker, and Trinity Counties, and extends upstream about 36 air miles. The reservoir provides a multi-purpose project with the developed municipal and industrial water supply, fish and wildlife resources, and recreational uses.

TRA is a political subdivision charged by Texas legislative mandate with three functions:

- Maintaining a master plan for basin wide development.
- Serving as local sponsor for Federal water projects.
- Providing authorized services such as water and wastewater treatment, flood control, and recreational, hydroelectric, navigational, and reservoir facilities.

TRA operates as a governmental utility receiving no direct tax revenues or revenue sharing and is compensated for services rendered by each facility which is financed independently. These facilities are located throughout the basin from Dallas-Fort Worth to Houston.

The dam axis extends across the Trinity River about 11 river miles upstream from the U.S. Highway 59 Trinity River crossing. The dam is a rolled earthfill embankment structure consisting of an impervious center core section with an average structural height of 55 feet. The dam crest has a maximum elevation of 145 feet, mean sea level, which is 90 feet above the original streambed. The dam has a crest length, including spillway, of 13,480 feet, with an average base width of 310 feet and crest width of 24 feet. The spillway, located near the left end of the dam, is a 646-foot reinforced concrete gravity structure controlled by twelve 40- by 32-foot tainter gates with a discharge capacity of 313,000 ft^3/s (cubic feet per second) at maximum design water surface elevation 135.0. The outlet works for low-flow releases are located in a vertical concrete multi-gated inlet tower. Five gated openings are located at various elevations, minimum elevation 58.0, in the tower. All openings discharge into a 10-foot-diameter concrete conduit constructed through the dam.

Lake Livingston has a length of 55 miles and an average width of 0.42 miles at the normal pool elevation of 131.0. The average width is determined by dividing the surface area by the reservoir length at elevation 131.0. The total Trinity River drainage area above Livingston dam, which is 360 miles in length, is 16,583 square miles, of which 8,423 square miles contribute sediment inflow.

At the beginning of operations in 1969, the reservoir at maximum elevation 135.0 had a calculated surface area of 91,000 acres with a capacity of 2,135,324 acre-feet. This capacity included 347,200 acre-feet of flood surcharge between elevation 131.0 and 135.0, 1,787,773 acre-feet of conservation between elevation 58.0 and 131.0, and 351 acre-feet of inactive storage below elevation 58.0. At elevation 131.0, top of conservation, the calculated surface area was 82,600 acres with a capacity of 1,788,125 acre-feet.

SUMMARY AND CONCLUSIONS

This report presents the results of an investigation to monitor changes caused by sediment accumulations in Lake Livingston after 22.5 years of reservoir operations. It also describes the field surveying procedures and equipment used in the 1991 investigation, and provides some data needed for future surveys. The primary purpose of running the 1991 survey was to gather data needed to compute the capacity of Lake Livingston for reservoir operation.

Standard land surveying methods were used to augment previously established horizontal control for the survey. The hydrographic survey was completed using sonic depth recording equipment interfaced with both an automated positioning system and a land based distance meter. The systems continuously recorded reservoir depths and horizontal distances from fixed points as the boat was steered across the range line. Reservoir water surface elevations were used as control in converting the depth measurements to true bottom elevations.

Table 1 contains a summary of reservoir sediment data for the 1991 survey. The 1991 survey determined that the reservoir has a storage capacity of 1,741,867 acre-feet and a surface area of 83,277 acres at the top of conservation storage elevation 131.0. Since closure in 1969, the reservoir has accumulated a volume of 64,227 acre-feet of sediment below elevation 131.0. This volume represents a 3.56-percent loss in total capacity and an average annual loss of 2,854 acre-feet for the operation period of June 1969 through December 1991.

DESCRIPTION OF BASIN

The Trinity River drainage basin is only 360 miles long, but the river, because of its meandering course, is almost twice that length — 715 miles. The basin drops some 1,250 feet from North Central Texas to its mouth at the Gulf of Mexico (fig. 1). The mean annual runoff of the drainage basin above Livingston Reservoir is 4,925,000 acre-feet. The runoff was calculated using the average flow at the USGS (U.S. Geological Survey) gauge Trinity River at Riverside, Texas, which accounted for 94 percent of all reservoir area inflow. The average at this gauge was 4,630,00 acre-feet for the measured 48 years of record (January 1903 to December 1906 and October 1923 to September 1968). The gauge was discontinued in 1968 because of the backwater affect of Lake Livingston. The total Trinity River drainage area above Livingston dam is 16,583 square miles, of which 8,423 square miles contribute sediment inflow. Several reservoirs are located on the river system within the basin above Lake

Livingston Dam as seen on the map. The net contributing area includes removal of the area of Lake Livingston and all areas above the upstream developed reservoirs that are assumed to trap all sediment inflow. A listing of the reservoirs and their drainage areas, which were removed as nonsediment contributing, are listed in table 1 under item 47, Remarks and References.

SURVEYS

Survey History

The original sediment ranges were surveyed by a contractor for TRA prior to inundation of water behind Livingston Dam. These data were stored in field books and were not processed and plotted until the 1991 study. The present survey contractor processed the data from the original notes for range lines 1 through 18. The range lines were plotted by Reclamation (Bureau of Reclamation) from left to right bank looking downstream. For purposes of sediment computations, six additional range lines were located and surveyed in 1991. These range lines included and were labeled 1A or 101, 3A or 301, 6A or 601, 7A or 701, 12A or 121, and 12B or 122 and 123. A layout of the reservoir sediment range system is shown on figures 2 and 3. The original distance versus elevation data for these added range lines was determine from the 1972 photorevised USGS 7-1/2 quad maps of the reservoir area. The interpolated data were smoothed using the 1991 collected data.

The total original surface areas for the 10-foot increments of Lake Livingston, elevation 60.0 through 140.0, were obtained from the 1960 U.S. Geological Survey 7-1/2 minute quadrangle maps developed from photographic data obtained in 1958. For the purposes of the 1991 sedimentation analysis and to better represent storage changes, the reservoir was subdivided into segments using the range lines to delineate the limit of each segmental boundary. The total original contour areas for all segments of the range-line network system were needed as input. These areas were obtained by a TRA contractor using a computer digitizing program and the 1960 USGS 7-1/2 minute quad maps that were photorevised in 1972. The revised quads were used because a copy of the original 1960 maps was not located and it was assumed that the underwater contours on the revised maps were unchanged from the original. The photorevised maps have the reservoir area shaded in purple, which covered the original contours and made interpretation of the contours difficult. The photorevised maps also had contours drawn for reservoir elevations 131.0 and 135.0.

The contractor digitized the segmented areas of the 10-foot contours for elevations 60.0 through 130.0 and the upper reservoir contour elevation 135.0. A listing of these digitized segmented surface areas was made available to Reclamation for analysis. A comparison of the total segmented areas with the original areas found some disparities. The total segment areas for elevations 90.0 through 130.0 compared well with the original areas, but significant difference existed among the total areas at elevations 60.0, 70.0, and 135.0. A slight difference existed at elevation 80.0. Further investigation into these disparities concluded that in addition to the problem of distinguishing the contours on the photorevised shaded maps, the interpretation of the contour crossings at elevations 60.0, 70.0, and 80.0 was made more difficult because they were located within the original river channel area. These problems were resolved by using the original range line survey data. The cross section width at elevations 60.0, 70.0, and 80.0 was calculated for the segments where the contours were located within the river channel. The contour surface areas for the segments meeting these conditions were recalculated using the average width and river channel length for each segment. A summation of these calculated areas compared well with the total original areas and was used for the 1991 sedimentation analysis.

The summation of the digitized segmented areas for elevation 135.0 was found to be 3.8 percent higher (94,547 acres compared to 91,000 acres) than the original area at this elevation. This area was originally calculated using measured surface area data at contour elevations 130.0 and 140.0 from the USGS quad maps. For the 1991 sedimentation study, it was assumed that the digitized area at this elevation was more accurate than the original calculated area and should be used to develop the new area capacity tables. This assumption has no bearing on the total sediment calculation because the collected data found all measured changes to be below elevation 130. Because the original capacity data had to be recomputed for sediment computation purposes, it was decided to use this digitized area for elevation 135.0.

Survey Methods and Equipment

The preliminary field work for the 1991 survey began in October and consisted of locating and flagging the existing sediment range end markers, relocating the destroyed ones, and establishing additional points needed for the hydrographic survey. The hydrographic survey was completed from November 11 through November 15, 1991 (reservoir elevation 131.34 through 132.42), using the large vessel system, and from December 16 through December 18, 1991 (reservoir elevation 131.35 through 131.56), using the small boat system.

Following are descriptions of the Reclamation systems used to collect the hydrographic survey data:

1. Reclamation's large vessel system was used to collect the data for the range lines starting at 1A, near the dam, upstream to range line 8 (excluding 6A). Range line 6A was surveyed using the small boat system as described in the following paragraph. The large vessel bathymetric collection system consisted of electronic positioning equipment interfaced with a sonic depth recorder. The positioning system transmitted line-of-sight microwave signals to known shore stations and converted the reply time to range distances, which were used by the system data logger to compute the coordinate position of the survey vessel. The survey system continuously recorded reservoir depth and horizontal coordinates as the survey vessel moved across the reservoir. The system gave directions to the vessel operator to assist in maintaining course along the prescribed range line alignment. During each run, the depth and position data were recorded at two second intervals, by a lap-top computer, for subsequent processing by Denver Office personnel. Water surface elevations recorded during the time of collection were used to convert the sonic depth measurements to true lake bottom elevations.

2. The remaining data were collected by Reclamation's small boat bathymetric system. This system consisted of a sonic depth recorder and reflector prism mounted on a small boat. It was decided to use the Livingston Office's air boat even though it was harder to keep on-line because of its steering

limitation and boat noise, which made it difficult to hear directional communication from the shore-positioned personnel. Because the reservoir was nearly full, this type of boat was the only way to collect data for the majority of the upper reservoir range lines because of the shallow water and hazard conditions that covered large portions of the ranges. The hazards included downed trees, stumps, and shallow areas with tall grass. The distance from a known point to the small boat was determined as it proceeded along the range line by an EDM (electronic distance measuring) instrument set up on shore and aimed at the reflector target mounted on the survey boat. Range distances were communicated, by radio, from shore to the boat at preselected intervals and marked on the sonar charts as the boat proceeded across the reservoir. The boat was held on course as closely as possible by radio communication from the EDM operator to the survey boat.

RESERVOIR SEDIMENT DISTRIBUTION

Longitudinal Distribution

The distribution of sediment throughout the length of the reservoir is illustrated by a plot of the thalweg profile representing the original and 1991 resurveyed profiles as shown on figure 4. The thalweg is the line connecting the lowest or deepest point along the streambed. Thalweg elevations representing original and 1991 reservoir conditions were taken from the survey notes. Except for the possibility of some missed low point soundings during the original survey, the plotted profile should closely resemble the deepest channel bottom conditions during the original range line survey completed prior to inundation of the reservoir. Except for some minor inaccuracies in sounding and being slightly off line, the bottom of the 1991 profile should closely represent the deepest channel bottom conditions at the time of the resurvey. The channel distance used for range line location is the original river channel distance from the dam to each range line as you proceed upstream.

Lateral Distribution

Ground profiles for the 24 original sediment ranges are shown on figures 5 through 28. The 1991 range profile data are superimposed on these plots to indicate the changes which have occurred and to represent in general the lateral distribution of sediment within the reservoir. A 1991 survey was not accomplished for range line 19 because of location and weather conditions. This omission had no significant impact on storage capacity computations because this range is located and represents only the river channel of the extreme upstream part of the reservoir where little sediment deposition has occurred as indicated by range lines 17 and 18. Because the 1991 survey only covered the reservoir area of pool elevation 131.4 and below, it was assumed that no change occurred above this elevation. For sediment computation purposes, a complete section was needed for all ranges. For this reason, the original data was inserted into the 1991 data file to complete any areas not surveyed in 1991.

Concern exists for the future monitoring of the large reservoir surface area of segment 18, which is located between range lines 18 and 19 on the Trinity River and includes the Harmon Creek arm of the reservoir. The physical makeup of this portion of the reservoir has the potential to form a large sediment delta when high Trinity River inflows occur during high reservoir stage. As the high inflows pass range line 19, the sediment would be deposited as the inflow velocities decrease in this large bay area. Because of their location, surveying range lines 18 and 19 would not measure the sediment deposited outside of the original river channel. Future sedimentation surveys may need to consider mapping this bay area to measure any surface area change caused by sediment deposition.

SEDIMENT ANALYSES

1991 Surface Areas

The 1991 reservoir surface areas were computed by the Width Adjustment Method as described by Blanton (1982) and illustrated on figure 29. The method entails computing the new segmented contour area, A_1, between any two ranges by applying an adjustment factor to the original segmental contour area, A_0. To better represent storage changes the reservoir was subdivided into segments using the sedimentation range lines to delineate the limit of each segmental boundary. Segmental contour areas for each elevation were determined by digitizing the segmental contours on the 1972 photorevised USGS quads as described in the survey history section. A comparison of the simultaneous plots of original and 1991 range profiles indicated the lateral distribution of sediment at the different measured contour elevations. Where these plots indicate changes have occurred on the side slopes of the reservoir, a judgement decision was made to determine whether the change was caused by survey inaccuracies, actual deposition, or erosion. The adjustment factor for each segment was the ratio of the new average width to the original average width for both the upstream and downstream ranges at the specified contour elevation.

The above described calculation was completed by Reclamation's computer program RESSED. The input data included the original and 1991 range line data along with the segmented areas for the specified contour elevation. The program currently resides on Reclamation's CYBER mainframe computer. The program computes the 1991 surface area for each segment at the given contour elevations. The output lists the revised areas for each segment and notes where judgement led to overriding certain adjustment factors caused by survey inaccuracies. The total surface area at the given contour elevation was computed as the summation of all segmental areas at that elevation.

1991 Revised Storage Capacity

The storage-elevation relationships based on the 1991 underwater survey data were developed using Reclamation's area-capacity computer program ACAP85 (Bureau of Reclamation, 1985). The 1991 surface areas resulting from the RESSED computations at 10-foot contour intervals from elevation 60.0 through 130.0 and at elevation 135.0 were used as the control parameters for computing reservoir capacity. The program computes an area at 0.01- to 1.0-square foot area increments by linear interpolation between the given contour intervals. The program begins by testing the initial capacity equation over successive intervals to ensure that the equation fits within an allowable error limit, which was set at 0.000001 for Livingston Reservoir. This capacity equation is then used over the full range of intervals fitting within this allowable error limit. For the first interval at which the initial allowable error limit is exceeded, a new capacity equation (integrated from the basic area curve over that interval) begins testing the fit until it also exceeds the error limit. Thus, the capacity curve is defined by a series of curves, each fitting a certain region of data. Final area equations are derived by differentiating the capacity equations, which are of second order polynomial form:

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

where:

y = capacity,
x = elevation above a reference base,
a_1 = intercept, and
a_2 and a_3 = coefficients

Results of the 1991 Livingston Reservoir area and capacity computations are listed in tables 1 and 2 and plotted on figure 30. A separate set of 1991 area and capacity tables has been published for the 0.01-, 0.1-, and 1-foot elevation increments (Trinity River Authority, 1991). The 1991 area and capacity computations results are listed in columns (5) and (6) of table 2. Column (2) in the table gives the original measured contour areas used in the original area and capacity computation with the exception of the newly measured value at contour elevation 135.0. To make a valid comparison with the 1991 computed values, these original capacity values were also recomputed by ACAP85 using the same original surface areas and the newly measured value at elevation 135.0. Thus, the capacity values in column (4) differ somewhat from those found in column (3) and in the original area and capacity tables. Both the original and 1991 area and capacity curves are plotted on figure 29 for a visual comparison of changes. The 1991 survey determined that the reservoir has a storage capacity of 2,097,515 acre-feet and a surface area of 94,547 acres at maximum reservoir elevation 135.0, and a storage capacity of 1,741,867 acre-feet and a surface area of 83,277 acres at the top of conservation storage elevation 131.0.

The sediment computations would not be affected if it is determined that the original surface area of 91,000 acres should be used at elevation 135.0. The effect would only be noticed in the area and storage capacity computations above elevation 130.0. Using the 1991 survey data with this restriction, the reservoir would have a storage capacity of 2,088,648 acre-feet and a surface area of 91,000 acres at maximum reservoir elevation 135.0, and a storage capacity of 1,741,512 acre-feet and a surface area of 82,568 acres at the top of conservation storage elevation 131.0. This decision has little effect on the calculated capacity difference at elevation 131.0 (355 acre-feet), but has a major effect on the capacity calculation at elevation 135.0 (8,867 acre-feet) and ultimately on the available capacity for flood surcharge storage.

Reservoir Sedimentation Accumulation and Summary

Sediments have accumulated in Lake Livingston to a total volume of 64,227 acre-feet below elevation 131.0, top of reservoir conservation, since storage began in June 1969. This volume represents a 3.56-percent loss in total capacity and an average annual accumulation rate of 2,854 acre-feet for the 22.5-year period of operation. The net sediment accumulation rate from the contributing basin was 0.329 acre-feet per square mile per year for the same period.

The results of the sediment data and volume computations for the 1991 survey are shown in tables 1 and 2. The data include a tabulation of incremental sediment inflow volume and sediment accumulation computed for the period between initial conditions and the 1991 resurvey. Table 1 includes information on the drainage basin, records of inflow, reservoir operations and reservoir storage.

REFERENCES

Blanton, James O. III, *Procedures for Monitoring Reservoir Sedimentation: Technical Guideline*, Bureau of Reclamation, Denver, Colorado, 1982.

Bureau of Reclamation, *ACAP85 User's Manual*, Bureau of Reclamation, Denver Office, Denver, Colorado, 1985.

Trinity River Authority, *Lake Livingston Area and Capacity Tables*, Lake Livingston Project, Huntsville, Texas, 1991.

U.S. Army Corps of Engineers, *Water Resources Development in Texas, 1988*, Dallas, Texas, 1988.

RESERVOIR SEDIMENT
DATA SUMMARY

Livingston Reservoir
NAME OF RESERVOIR

1
DATA SHEET NO.

DAM	1. OWNER Trinity River Authority	2. STREAM Trinity River	3. STATE Texas
	4. SEC. TWP. RANGE	5. NEAREST P.O. Goodrich	6. COUNTY Polk - San Jacinto
	7. LAT 30° 38' 00" LONG 95° 00' 36"	8. TOP OF DAM ELEVATION 145.0	8. SPILLWAY CREST ELEV. 99.0[1]

RESERVOIR	10. STORAGE ALLOCATION	11. ELEVATION TOP OF POOL	12. ORIGINAL SURFACE AREA, Ac	13. ORIGINAL CAPACITY, AF	14. GROSS STORAGE ACRE- FEET	15. DATE STORAGE BEGAN
	a. FLOOD CONTROL	135.0	91,000	347,550	2,135,324	
	b. MULTIPLE USE					9/29/68[2]
	c. POWER					
	d. WATER SUPPLY					16. DATE NORMAL OPERATION BEGAN
	e. IRRIGATION					
	f. CONSERVATION	131.0	82,600	1,787,774	1,788,125	
	g. INACTIVE	58.0	234	351	351	6/26/69
	17. LENGTH OF RESERVOIR 55 MILES			AVG. WIDTH OF RESERVOIR 0.42 MILES		

BASIN			
	18. TOTAL DRAINAGE AREA 16,583 SQUARE MILES		22. MEAN ANNUAL PRECIPITATION INCHES
	19. NET SEDIMENT CONTRIBUTING AREA 8,423[3] SQUARE MILES		23. MEAN ANNUAL RUNOFF INCHES
	20. LENGTH 360 MILES	AV. WIDTH 46 MILES	24. MEAN ANNUAL RUNOFF 4,925,000[4] ACRE-FEET
	21. MAX. ELEVATION 1250	MIN. ELEVATION 58.0	25. ANNUAL TEMP. MEAN °F RANGE °F to °F

SURVEY DATA

26. DATE OF SURVEY	27. PER. YRS.	28. ACCL. YRS.	29. TYPE OF SURVEY	30. NO. OF RANGES OR INTERVAL	31. SURFACE AREA, AC.	32. CAPACITY ACRE-FEET	33. C/I RATIO AF/AF
6/69			Contour (R)[5]	10-ft	83,277[6]	1,806,094[6]	0.37
12/91	22.5	22.5	Range (D)	24	83,277	1,741,867	0.35

26. DATE OF SURVEY	34. PERIOD ANNUAL PRECIP.	35. PERIOD WATER INFLOW, ACRE FEET			WATER INFLOW TO DATE, AF	
		a. MEAN ANN.	b. MAX. ANN.	c. TOTAL	a. MEAN ANN.	b. TOTAL
12/91	22.5	4,240,000[7]	9,727,000[7]	95,409,000[7]	4,240,000[7]	95,409,000[7]

26. DATE OF SURVEY	37. PERIOD CAPACITY LOSS, ACRE-FEET			38. TOTAL SEDIMENT DEPOSITS TO DATE, AF		
	a. TOTAL	b. AV. ANN.	c. /MI.^{2}-YR.	a. TOTAL	b. AV. ANNUAL	c. /MI.^{2}-YR.
12/91	64,227	2,854	0.329[8]	64,227	2,854	0.329[8]

26. DATE OF SURVEY	39. AV. DRY WT. (#/FT^3)	40. SED. DEP. TONS/MI.^{2}-YR.		41. STORAGE LOSS, PCT.		42. SEDIMENT INFLOW, PPM	
		a. PERIOD	b. TOTAL TO DATE	a. AV. ANNUAL	b. TOTAL TO DATE	a. PER.	b. TOT.
12/91				0.158[9]	3.56[9]		

26. DATE OF SURVEY	43. DEPTH DESIGNATION RANGE IN FEET BELOW TOP OF CONSERVATION (ELEVATION 131.0.)										
	76.0-61.0	61.0-51.0	51.0-41.0	41.0-31.0	31.0-21.0	21.0-11.0	11.0-el.131				
	PERCENT OF TOTAL SEDIMENT LOCATED WITHIN DEPTH DESIGNATION										
12/91	6.3	8.7	14.0	21.5	20.2	17.9	11.4				

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	100-105	105-110	110-115	115-120	120-125
	PERCENT OF TOTAL SEDIMENT LOCATED WITHIN REACH DESIGNATION														
	N/A														

Table 1. – Reservoir sediment data summary.

45. RANGE IN RESERVOIR OPERATION [10]

WATER YEAR	MAX. ELEV.	MIN. ELEV.	INFLOW, AF[7]	WATER YEAR	MAX. ELEV.	MIN. ELEV.	INFLOW, AF[7]
1969[11]	103.6	100.7	214,000	1970	120.9	99.2	3,818,000
1971	126.6	123.0	979,000	1972	131.6	130.1	4,004,000
1973	131.6	131.0	5,895,000	1974	131.7	130.0	4,617,000
1975	131.4	130.6	8,338,000	1976	132.0	130.2	3,135,000
1977	131.6	129.7	4,711,000	1978	131.1	126.9	1,081,000
1979	131.3	126.6	4,066,000	1980	131.5	127.4	2,265,000
1981	132.2	127.4	2,697,000	1982	131.9	130.9	7,267,000
1983	131.9	130.8	3,257,000	1984	131.6	129.3	1,655,000
1985	132.2	129.2	4,322,000	1986	131.8	130.3	6,098,000
1987	132.3	130.1	4,957,000	1988	131.7	125.5	1,663,000
1989	132.6	125.4	6,265,000	1990	132.5	130.6	9,727,000
1991	131.7	130.8	4,378,000	1992	-	-	-

46. ELEVATION - AREA - CAPACITY DATA FOR ORIGINAL CAPACITY [6]

ELEV.	AREA	CAP.	ELEV.	AREA	CAP.	ELEV.	AREA	CAP.
55	0	0	90	5,930	64,775	130	80,460	1,724,225
60	390	975	100	19,840	193,625	131	(83,277)	1,806,094
70	1,180	8,825	110	41,520	500,425	135	94,547[12]	2,161,742
80	2,040	24,925	120	61,390	1,014,975			

46. ELEVATION - AREA - CAPACITY DATA FOR 1991 TOTAL CAPACITY

ELEV.	AREA	CAP.	ELEV.	AREA	CAP.	ELEV.	AREA	CAP.
59.6	0	0	85	3,086	26,119	115	50,310	682,519
60	82	16	90	4,933.7	46,168	120	59,920.6	958,095
65	476	1,411	95	11,500	87,253	125	70,190	1,283,372
70	869.0	4,773	100	18,066.7	161,170	130	80,460	1,659,998
75	1,054	9,579	105	29,383	279,794	131	83,277	1,741,867
80	1,238.2	15,309	110	40,698.8	454,998	135	94,547	2,097,515

47. REMARKS AND REFERENCES

[1] Sill of tainter gate, top of tainter gates is elevation 134.0.

[2] The dam was completed 9/29/68, with deliberate impoundment beginning 6/26/69.

[3] Represents loss of contributing areas since dam closing at Richland in 1987 (285 mi²), Navarro in 1963 (320 mi²), Bardwell in 1965 (178 mi²), Cedar in 1965 (1,007 mi²), Ray Hubbard in 1978 (184 mi²), Lavon in 1953 (770 mi²), Mountain Creek in 1937 (295 mi²), Arlington in 1957 (143 mi²), Benbrook in 1952 (429 mi²), Grapevine in 1952 (695 mi²), Lewisville in 1954 (1,660 mi²), and reservoir area (130 mi²).

[4] 48-year average of 4,630,000 acre-feet measured at USGS Trinity River at Riverside, TX, gage, which accounted for 94% of all area that drains into the reservoir.

[5] Original surface areas measured from USGS 7½ quads developed from 1958 photographic data.

[6] Surface area and capacity at elevation 131.0 recalculated from original measured surface areas using Bureau of Reclamations program ACAP85. Used original surface areas along with surface area of 94,547 acres, at elevation 135.0, which was measured using USGS 7½ quads photorevised in 1972.

[7] Values from USGS Trinity River near Crockett, TX, gage, which accounts for 84% of all area that drains into reservoir.

[8] Adjusted for upstream dams reducing contributing drainage areas in 1978 and 1987, see remark #3.

[9] Average annual and total sediment deposits divided by 1,806,094 acre-feet (capacity at El. 131 recomputed by ACAP85).

[10] End-of-month values from USGS publications. Reservoir levels provided by Trinity River Authority.

[11] Includes July, Aug., and Sept. 1969 data, since normal operation of 6/26/1969.

[12] Surface area measured from 1972 photorevised USGS 7½ quads.

48. AGENCY MAKING SURVEY Bureau of Reclamation

49. AGENCY SUPPLYING DATA Bureau of Reclamation | DATE December 1992

Table 1. – Reservoir sediment data summary — Continued.

(1) Elevation (feet)	(2) Original Area (acres)	(3) Original Capacity (acre-feet)	(4) Original Adjusted Capacity (acre-feet)	(5) 1991 Area (acres)	(6) 1991 Capacity (acre-feet)	(7) Measured Sediment Volume (acre-feet)	(8) Percent Measured Sediment	(9) Percent Reservoir Depth
135	94,547[1]		2,161,742	94,547	2,097,515	64,227	100.0	-
131	(83,277)	1,788,125	1,806,094	(83,277)	1,741,867	64,227	100.0	100.0
130	80,460	1,706,595	1,724,225	80,460.0	1,659,998	64,227	100.0	98.7
125		1,330,216	1,345,762	(70,190)	1,283,372	62,390	97.1	92.1
120	61,390	1,001,072	1,014,975	59,920.6	958,095	56,880	88.6	85.5
115		718,949	732,862	(50,310)	682,519	50,343	78.4	78.9
110	41,520	486,522	500,425	40,698.8	454,998	45,427	70.7	72.4
105		306,033	319,925	(29,383)	279,794	40,131	62.5	65.8
100	19,840	179,734	193,625	18,066.7	161,170	32,455	50.5	59.2
95		103,199	111,812	(11,500)	87,253	24,559	38.2	52.6
90	5,930	60,574	64,775	4,933.7	46,168	18,607	29.0	46.0
85		37,625	39,987	(3,086)	26,119	13,868	21.6	39.5
80	2,040	24,400	24,925	1,238.2	15,309	9,616	15.0	32.9
75		15,550	15,800	(1,054)	9,579	6,221	9.7	26.3
70	1,180	8,850	8,825	869.0	4,773	4,052	6.3	19.7
65		3,925	3,912	(476)	1,411	2,501	3.9	13.2
59.6		825	825	0	0	825	1.3	6.0
55	0	0	0	0	0	0	0.0	0.0

(1) Elevation of reservoir water surface.
(2) Original reservoir surface area, values in parentheses computed by Bureau of Reclamations program ACAP85.
(3) Original calculated reservoir capacity.
(4) Original reservoir capacity recomputed using ACAP85 from original measured surface areas and new area measured at elevation 135.
(5) Reservoir surface area from 1991 survey. Values in parentheses computed by ACAP85.
(6) 1991 calculated reservoir capacity from 1991 survey data.
(7) Measured sediment volume = column (4) - column (6).
(8) Measured sediment expressed in percentage of total sediment (64,227).
(9) Depth of reservoir expressed in percentage of total depth (76 feet).

[1] Surface area measured from 1972 photorevised USGS 7½ quads, previously used 91,000 acres, which was calculated using areas measured at El. 130.0 and El. 140.0.

Table 2. – Summary of 1991 survey results.

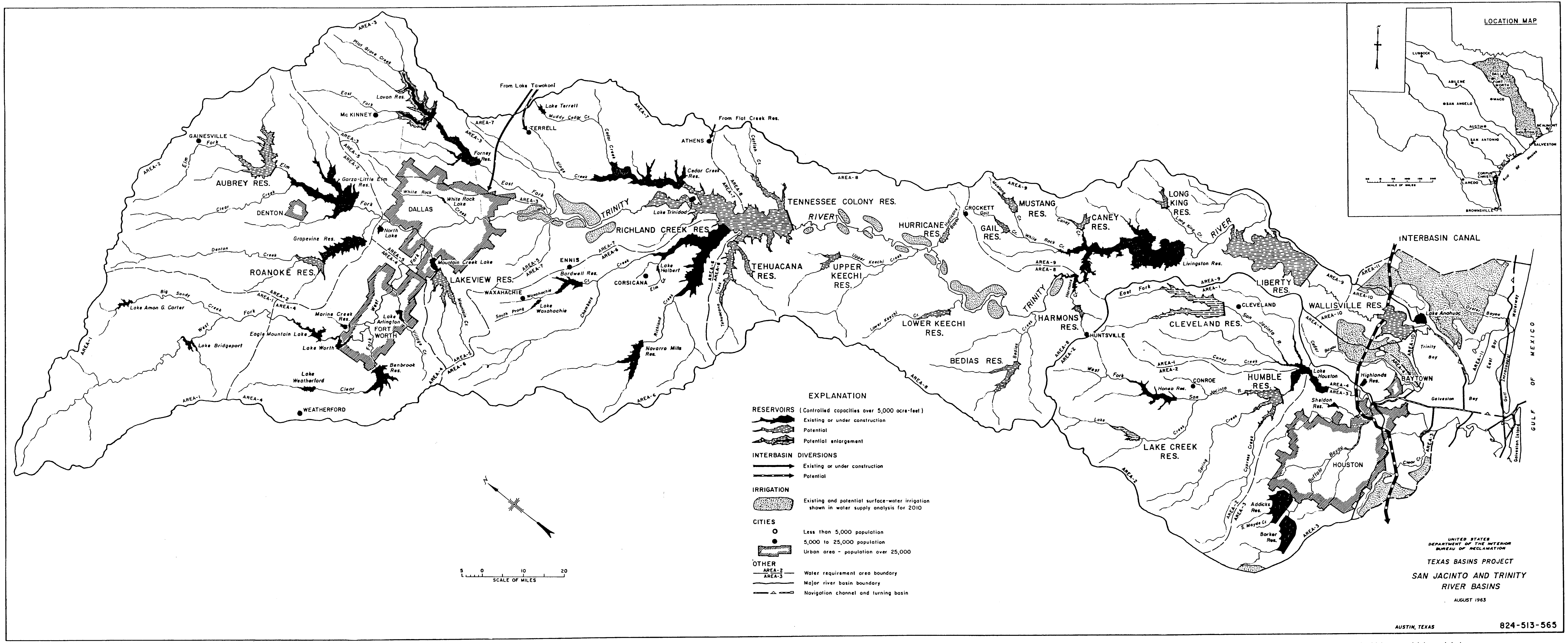


Figure 1. – Lake Livingston vicinity and drainage area map.

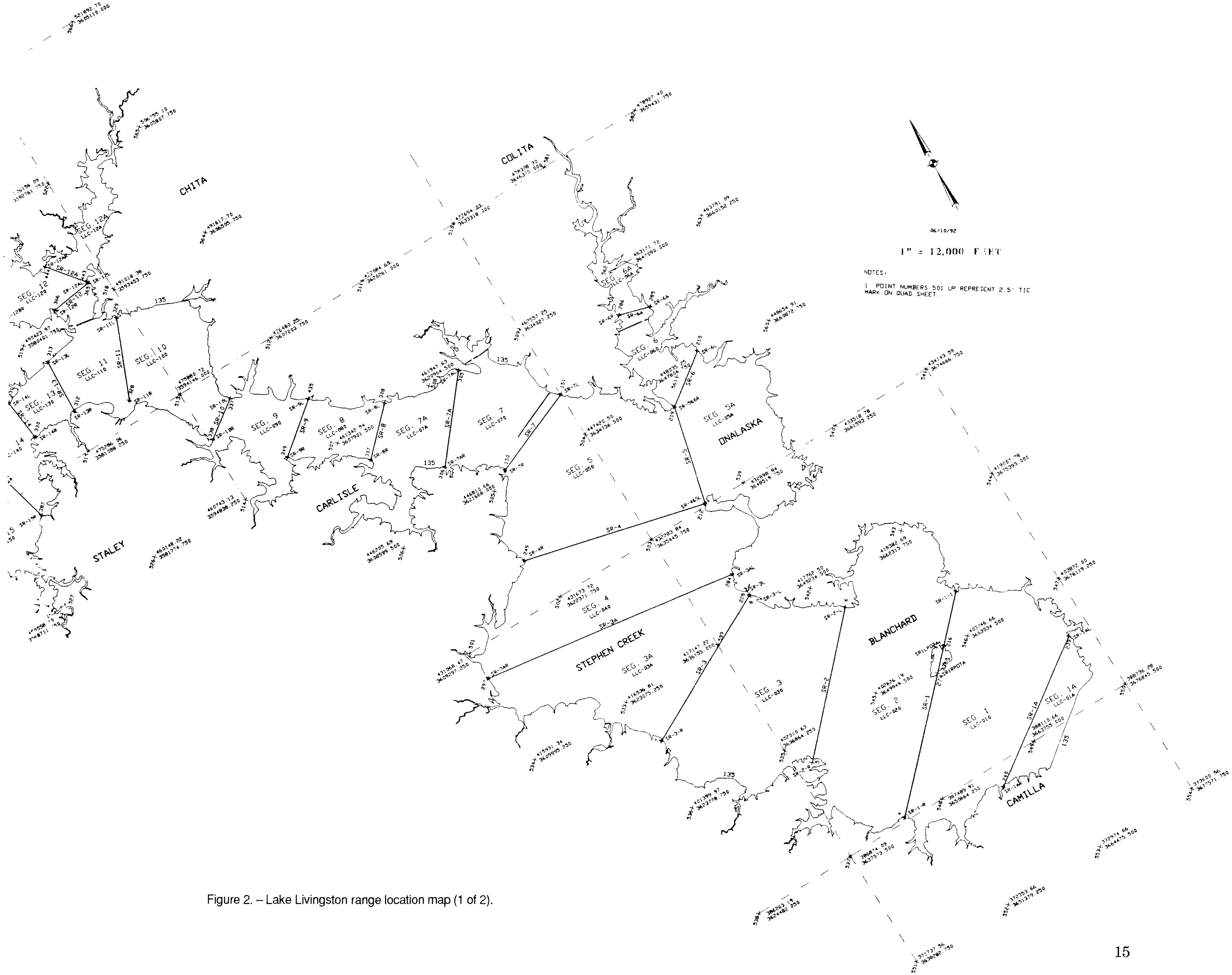


Figure 2. – Lake Livingston range location map (1 of 2).

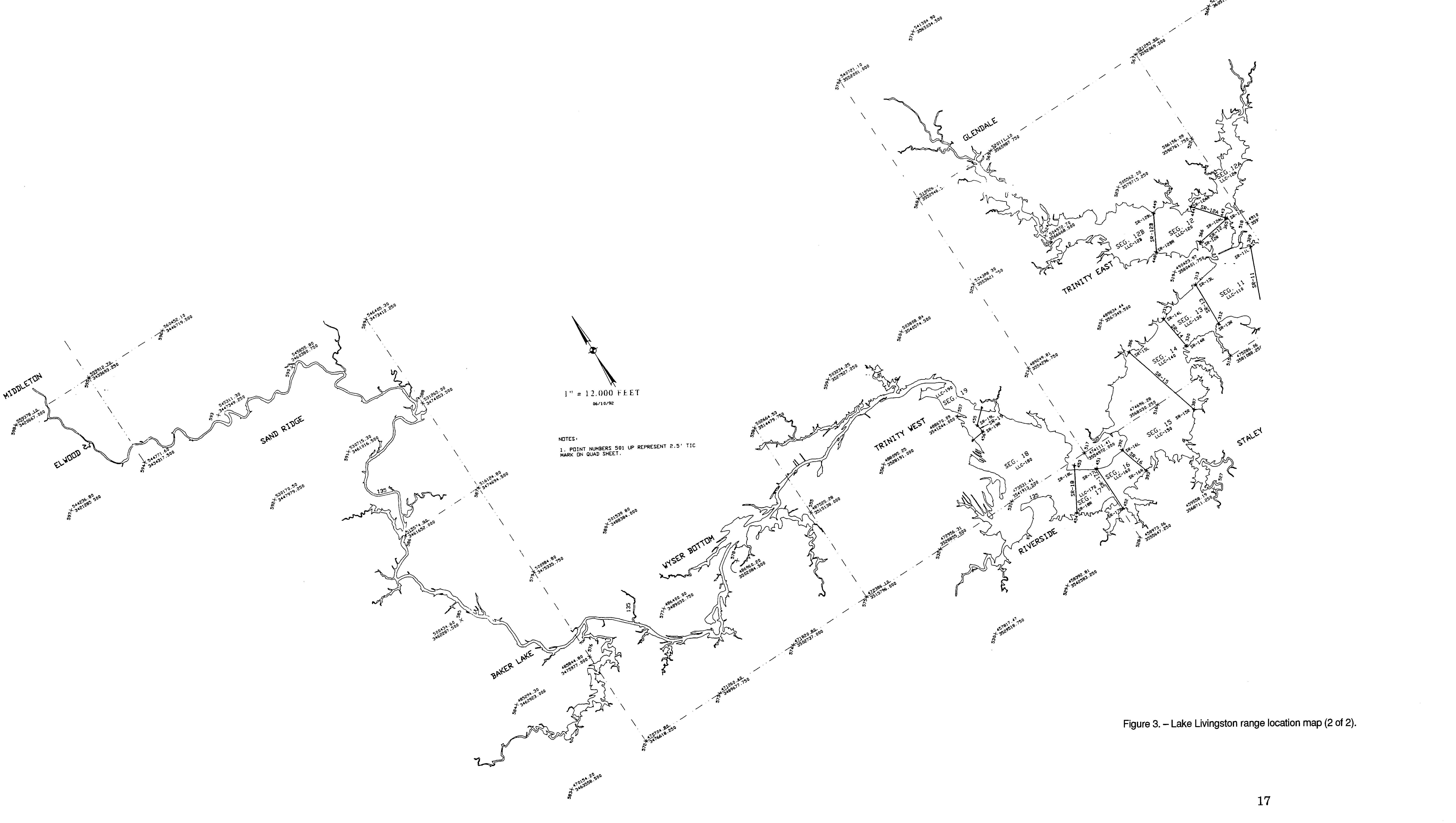


Figure 3. – Lake Livingston range location map (2 of 2).

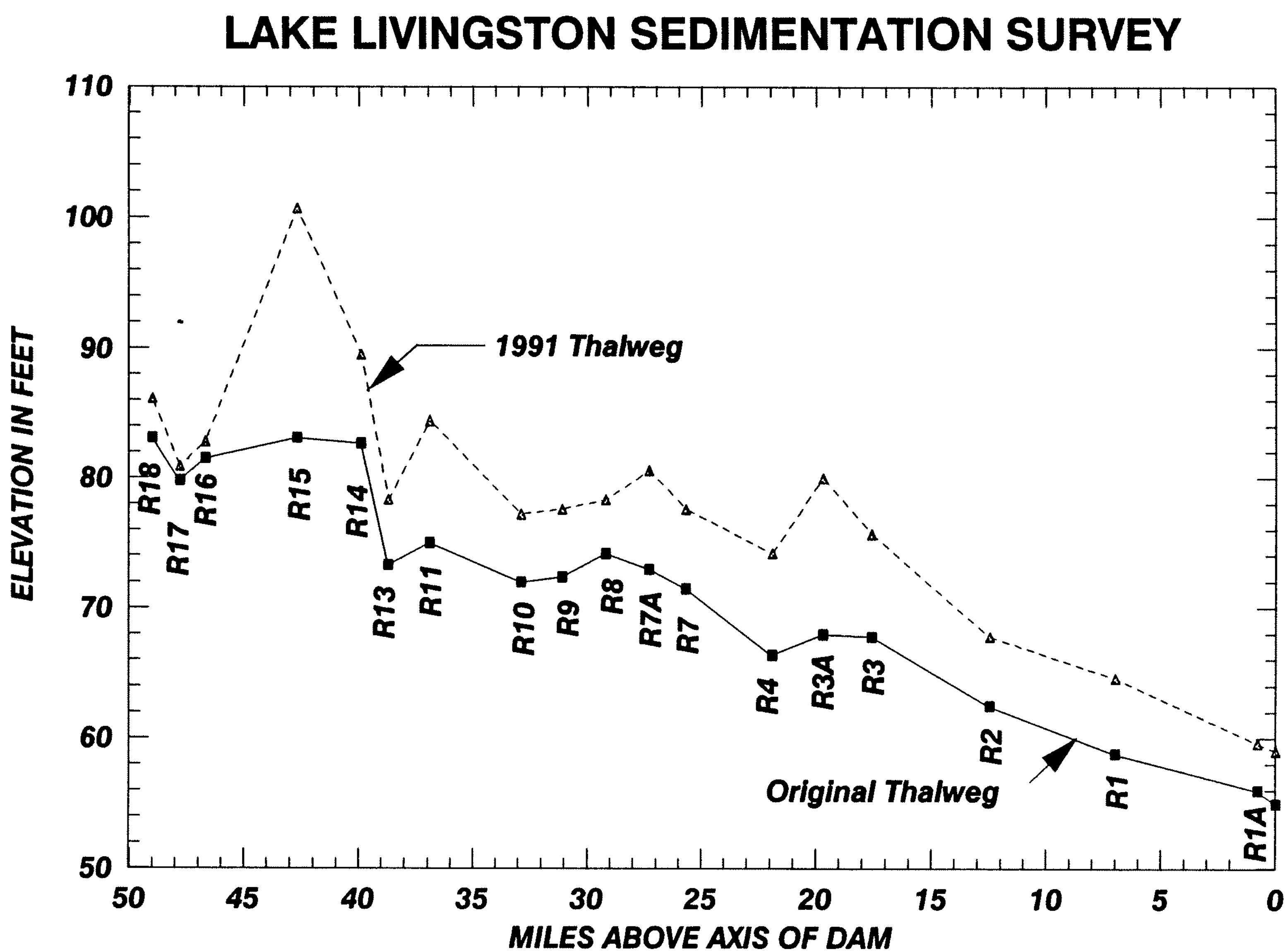


Figure 4. – Longitudinal profile – Trinity River.

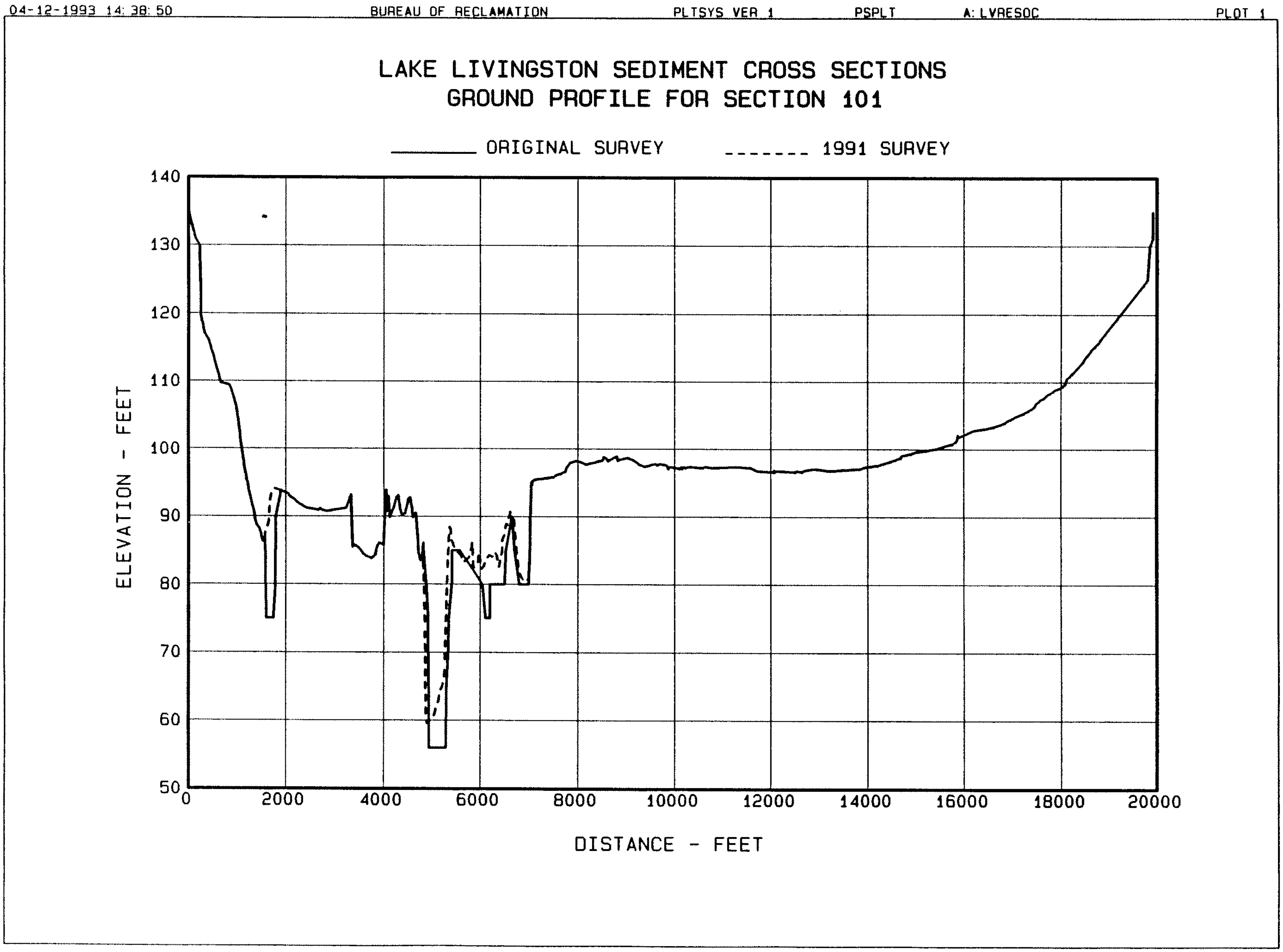


Figure 5. – Sediment Range 101 (1A) – Trinity River.

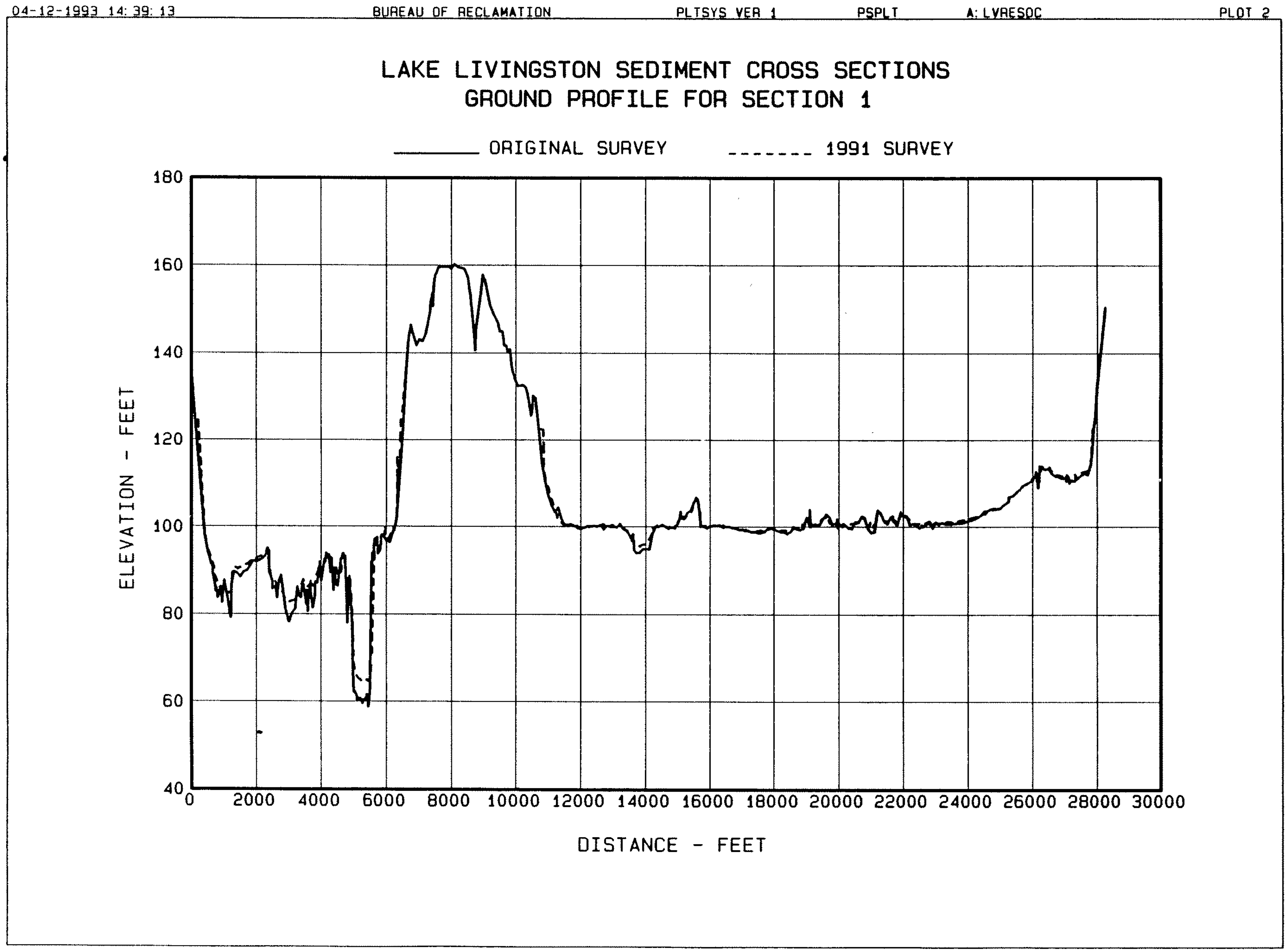


Figure 6. – Sediment Range 1 – Trinity River.

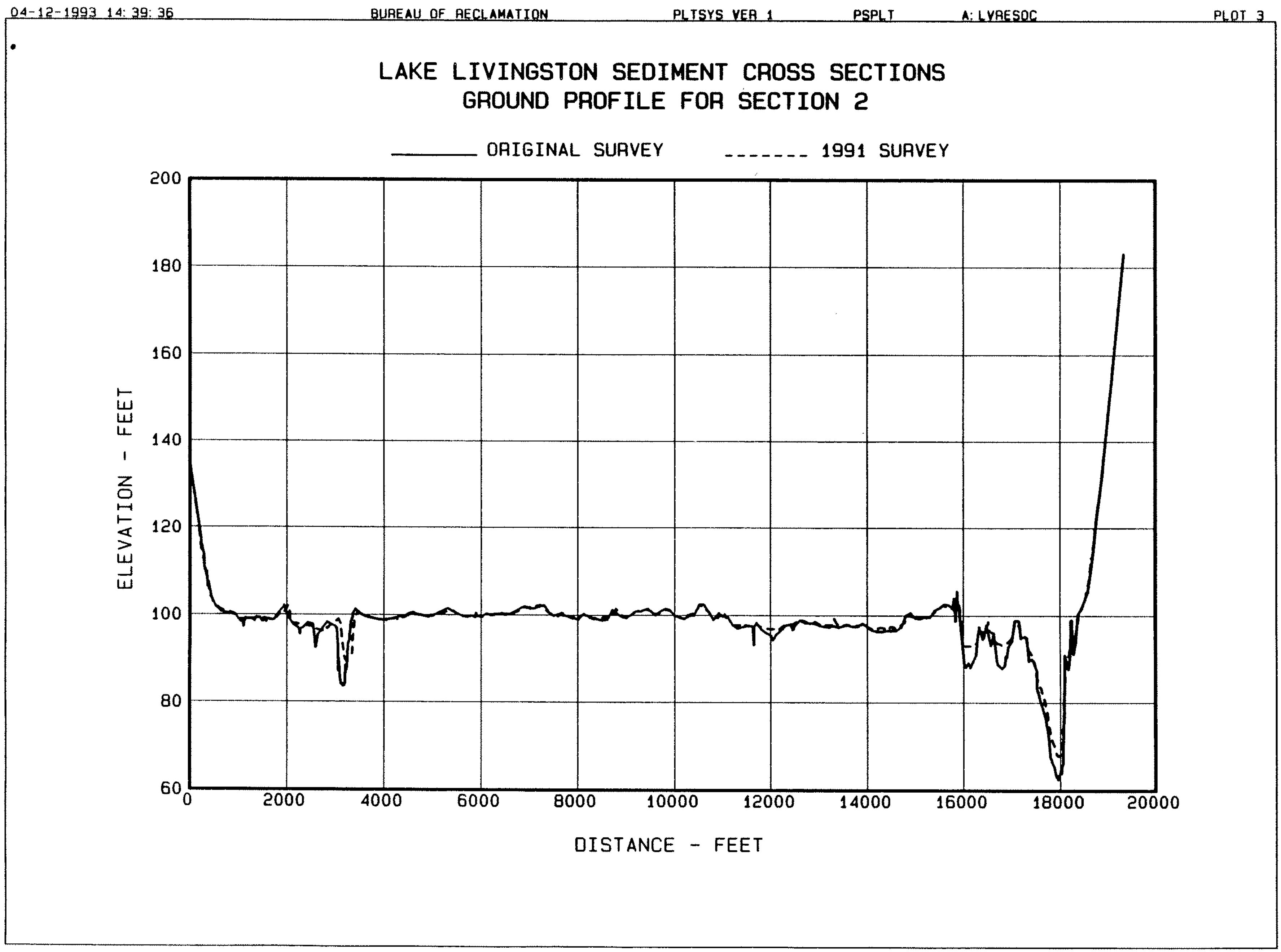


Figure 7. – Sediment Range 2 – Trinity River.

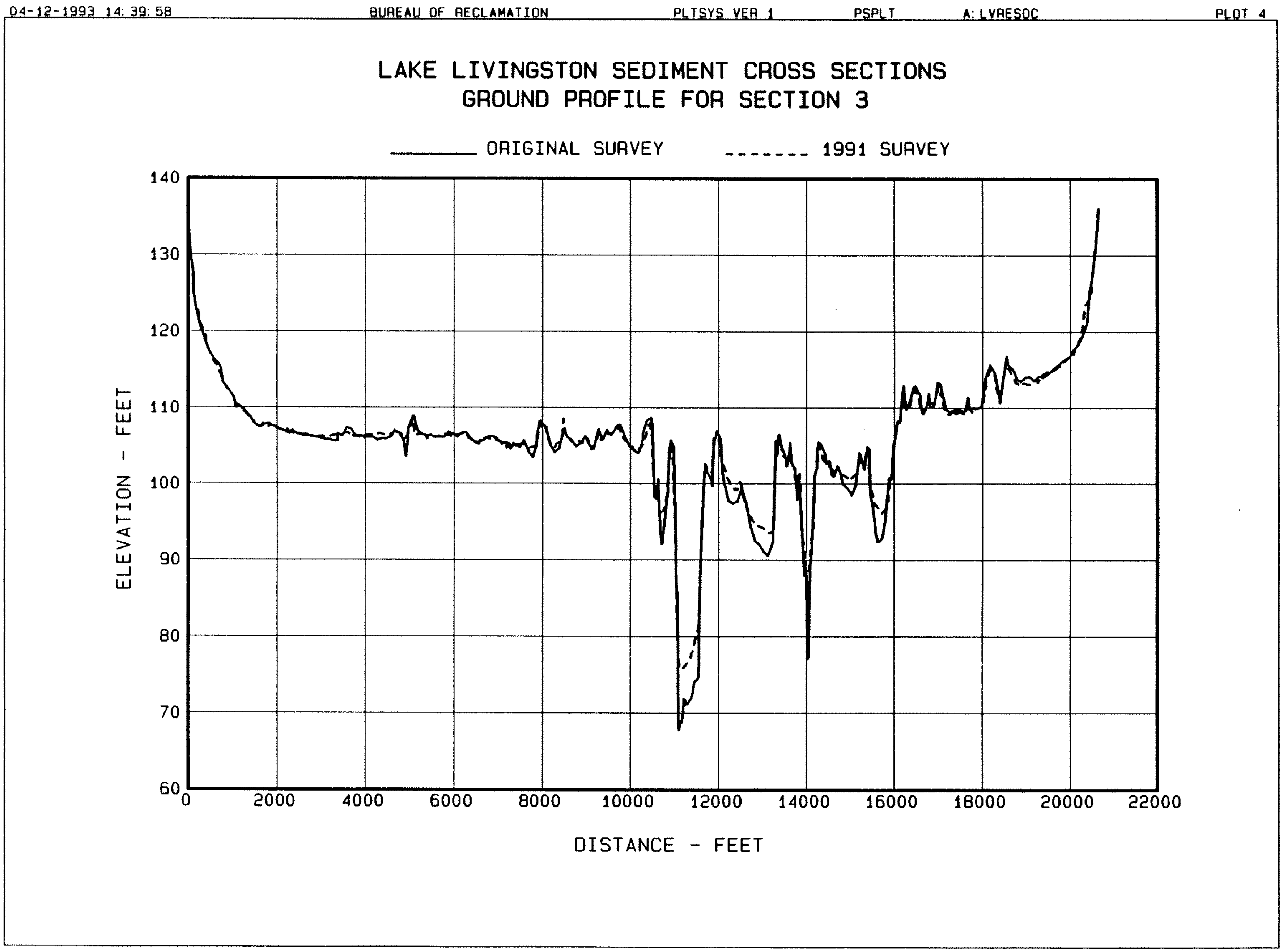


Figure 8. – Sediment Range 3 – Trinity River.

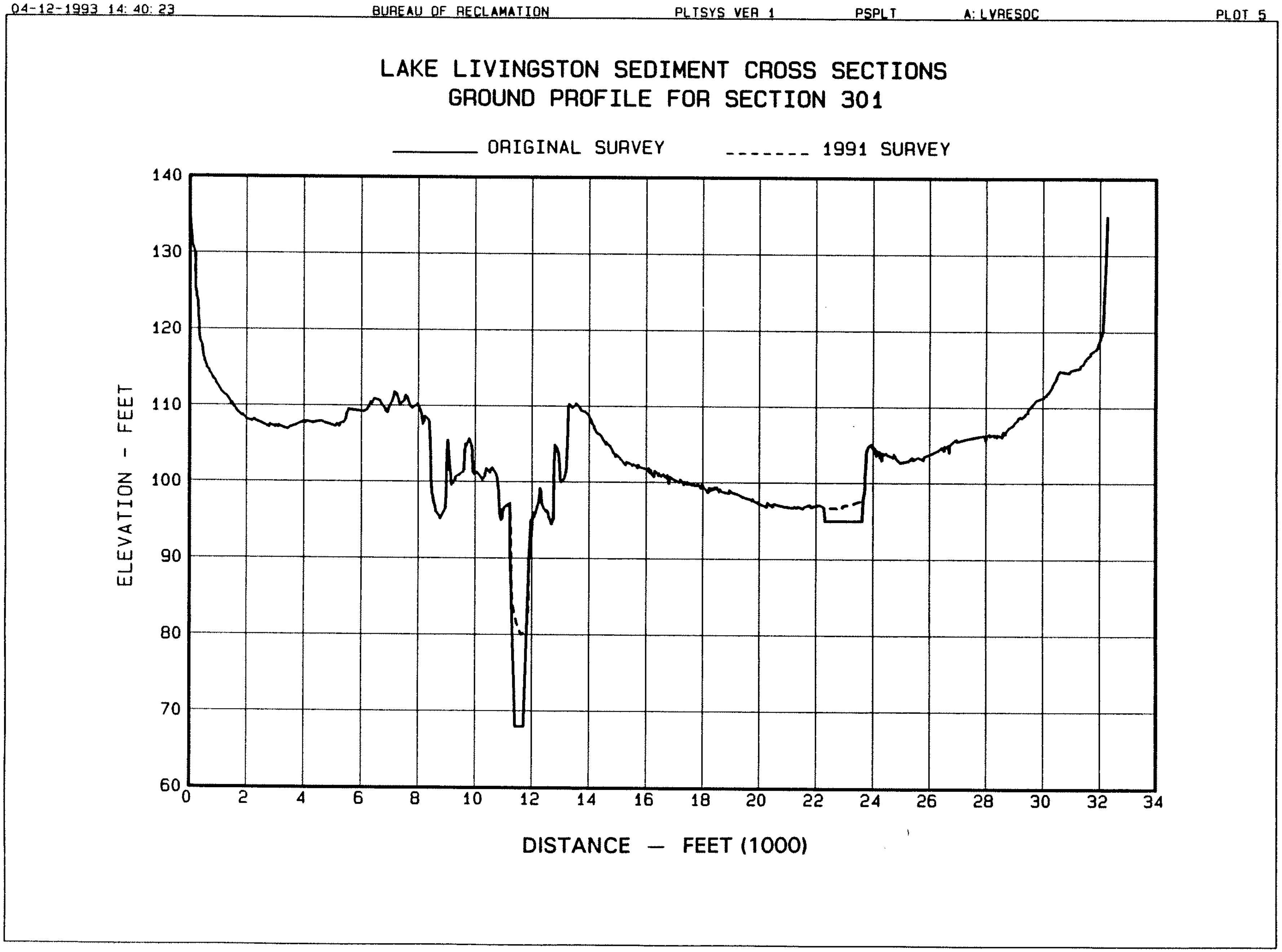


Figure 9. – Sediment Range 301 (3A) – Trinity River.

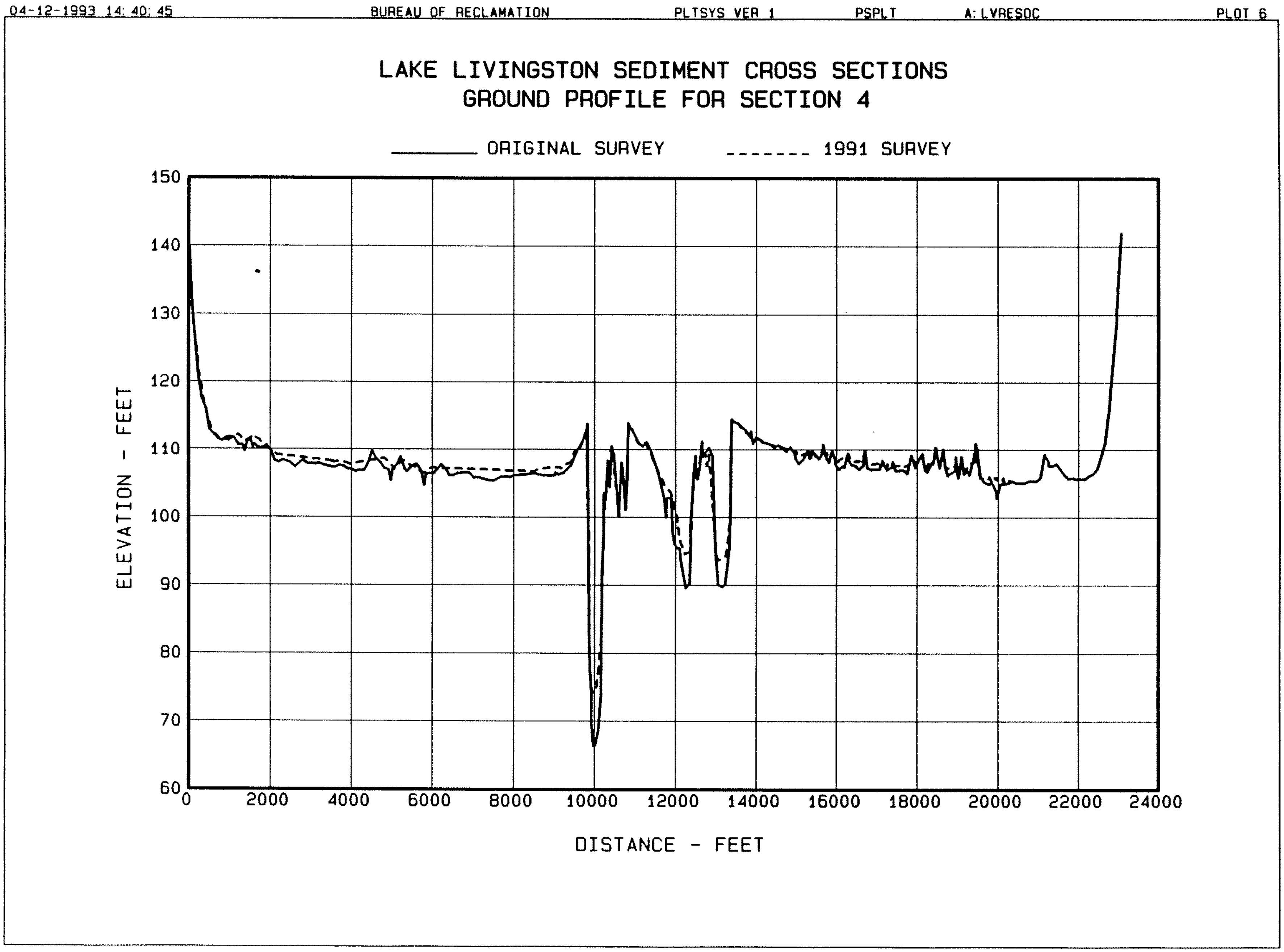


Figure 10. – Sediment Range 4 – Trinity River.

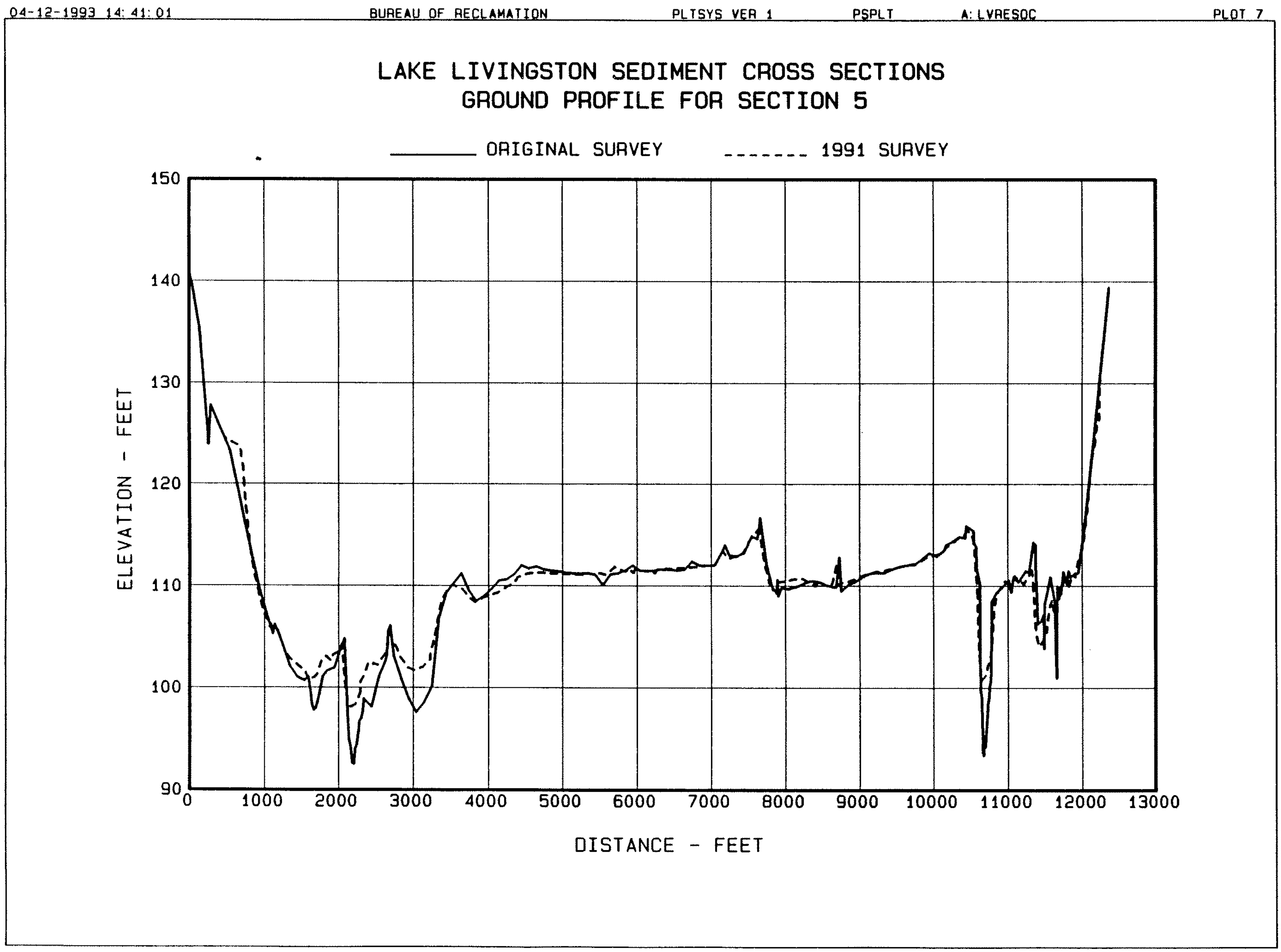


Figure 11. – Sediment Range 5 – Kickapoo Creek.

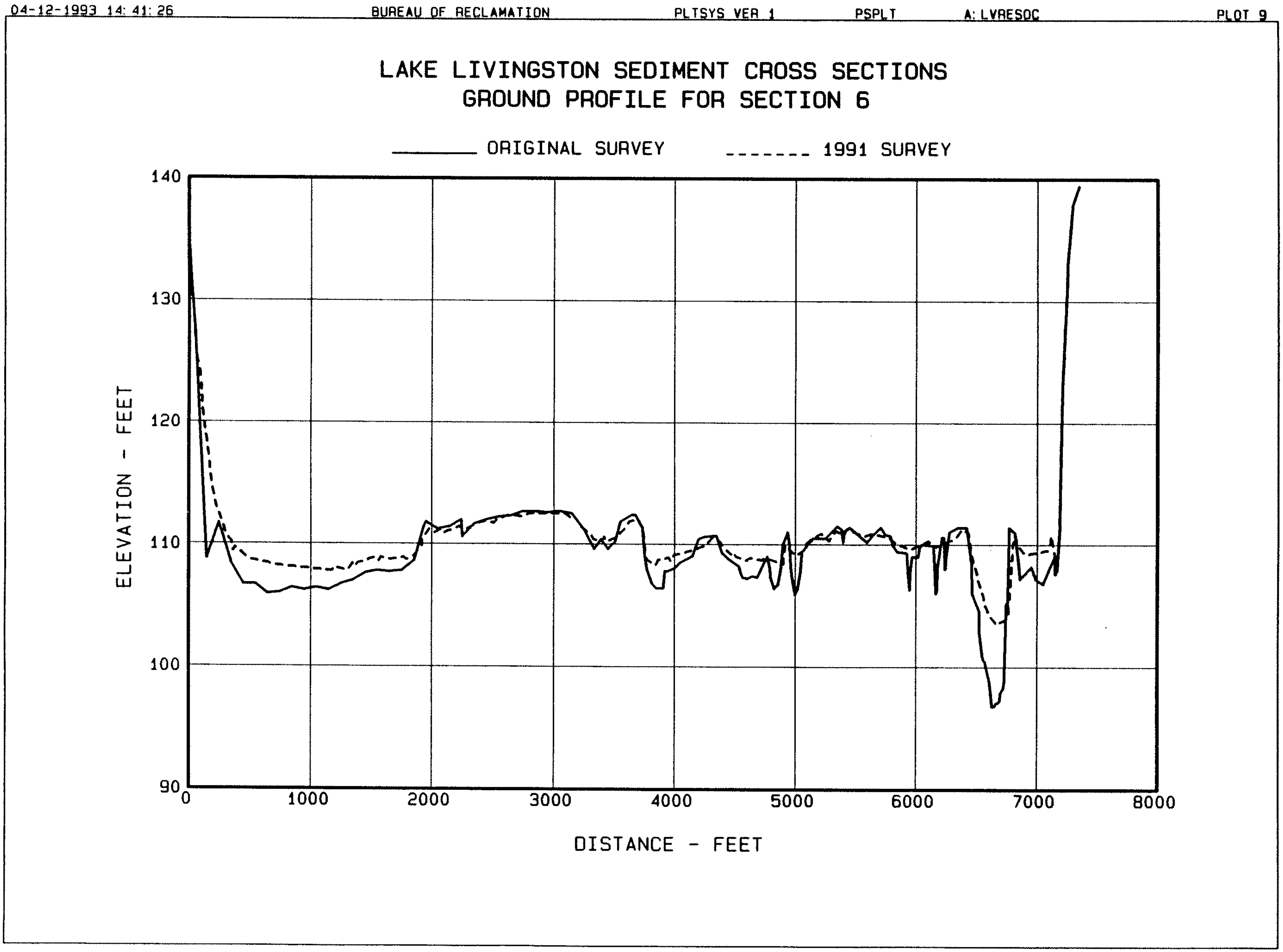


Figure 12. – Sediment Range 6 – Kickapoo Creek.

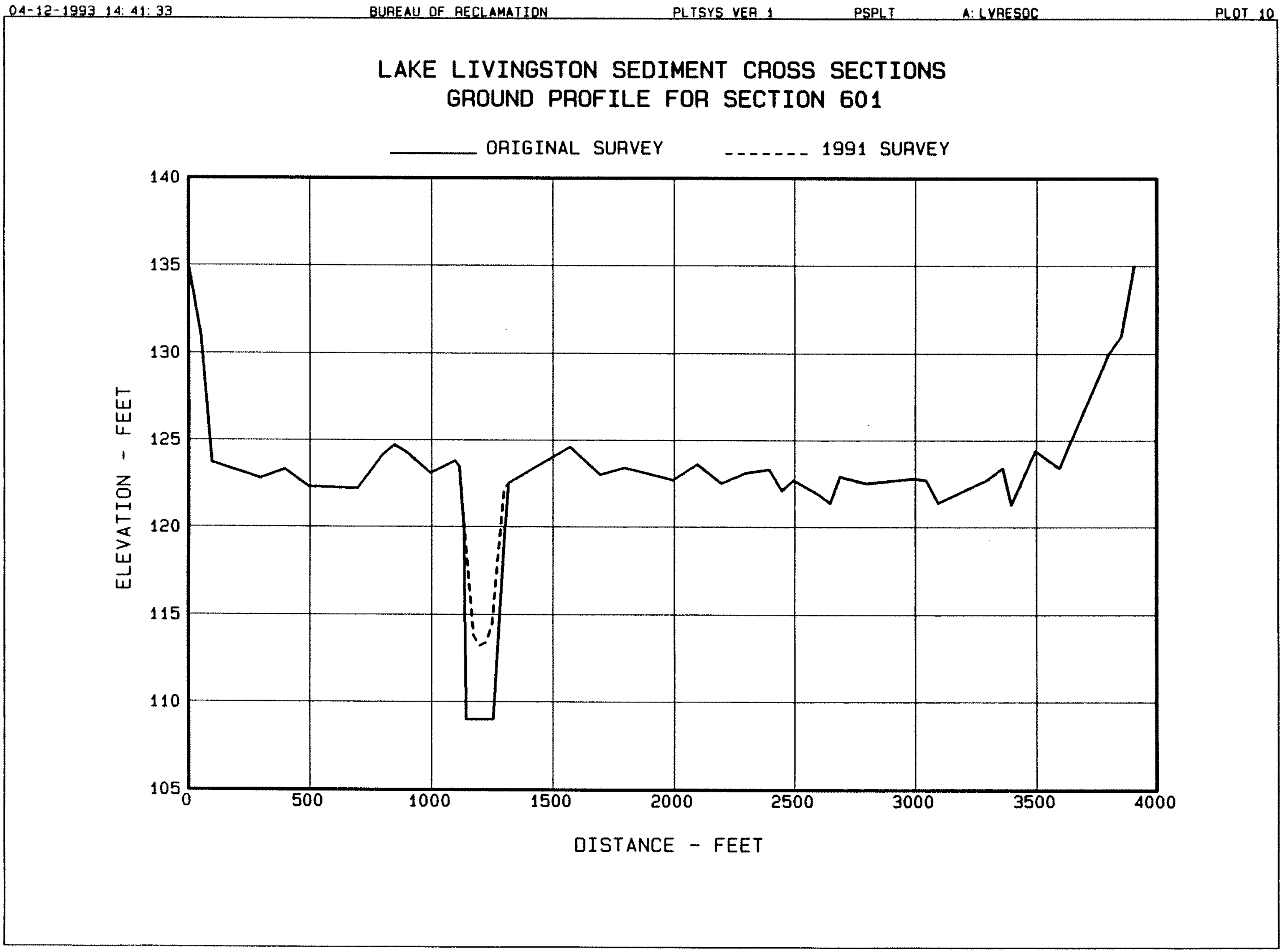


Figure 13. – Sediment Range 601 (6A) – Kickapoo Creek.

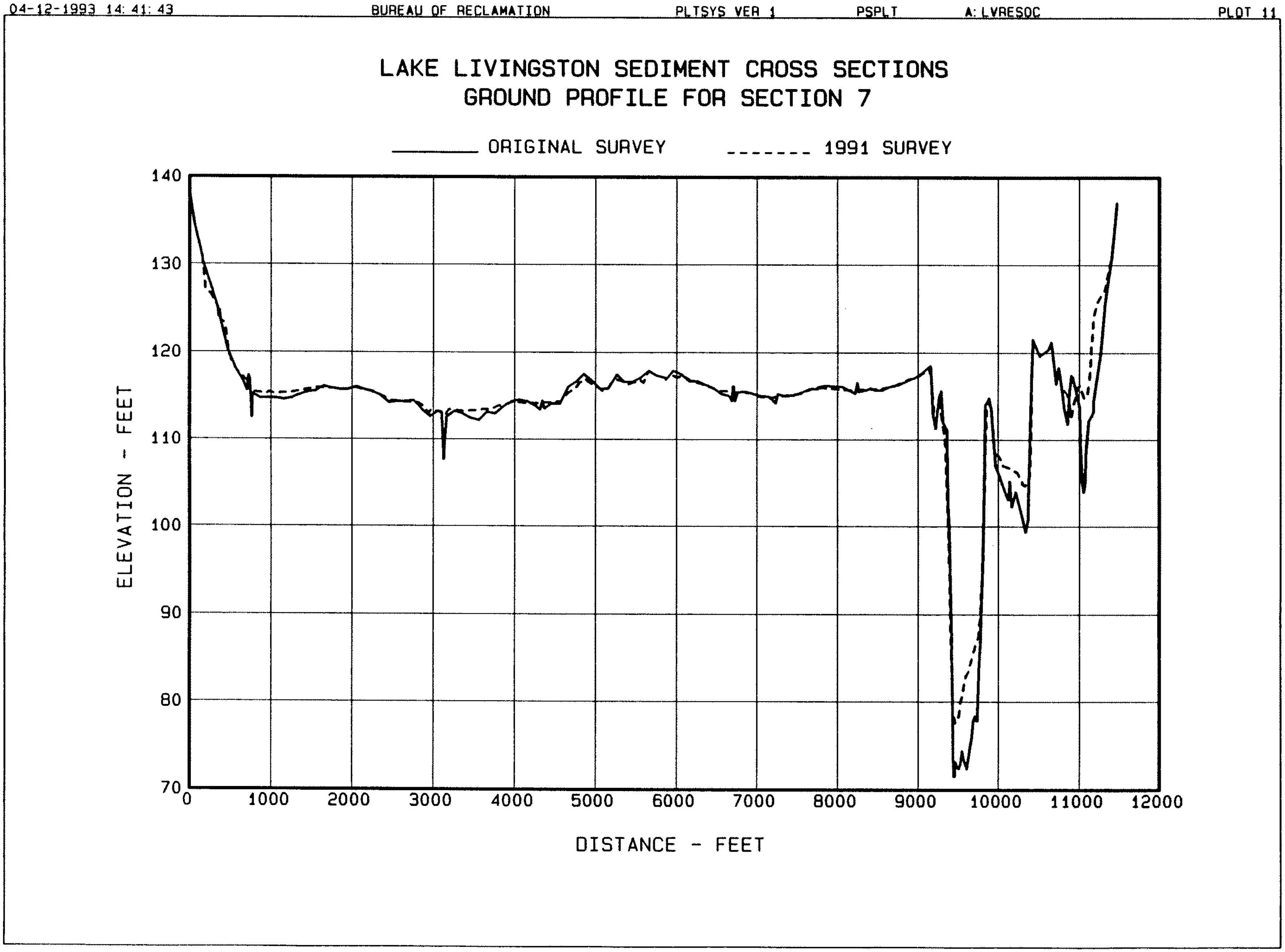


Figure 14. – Sediment Range 7 – Trinity River.

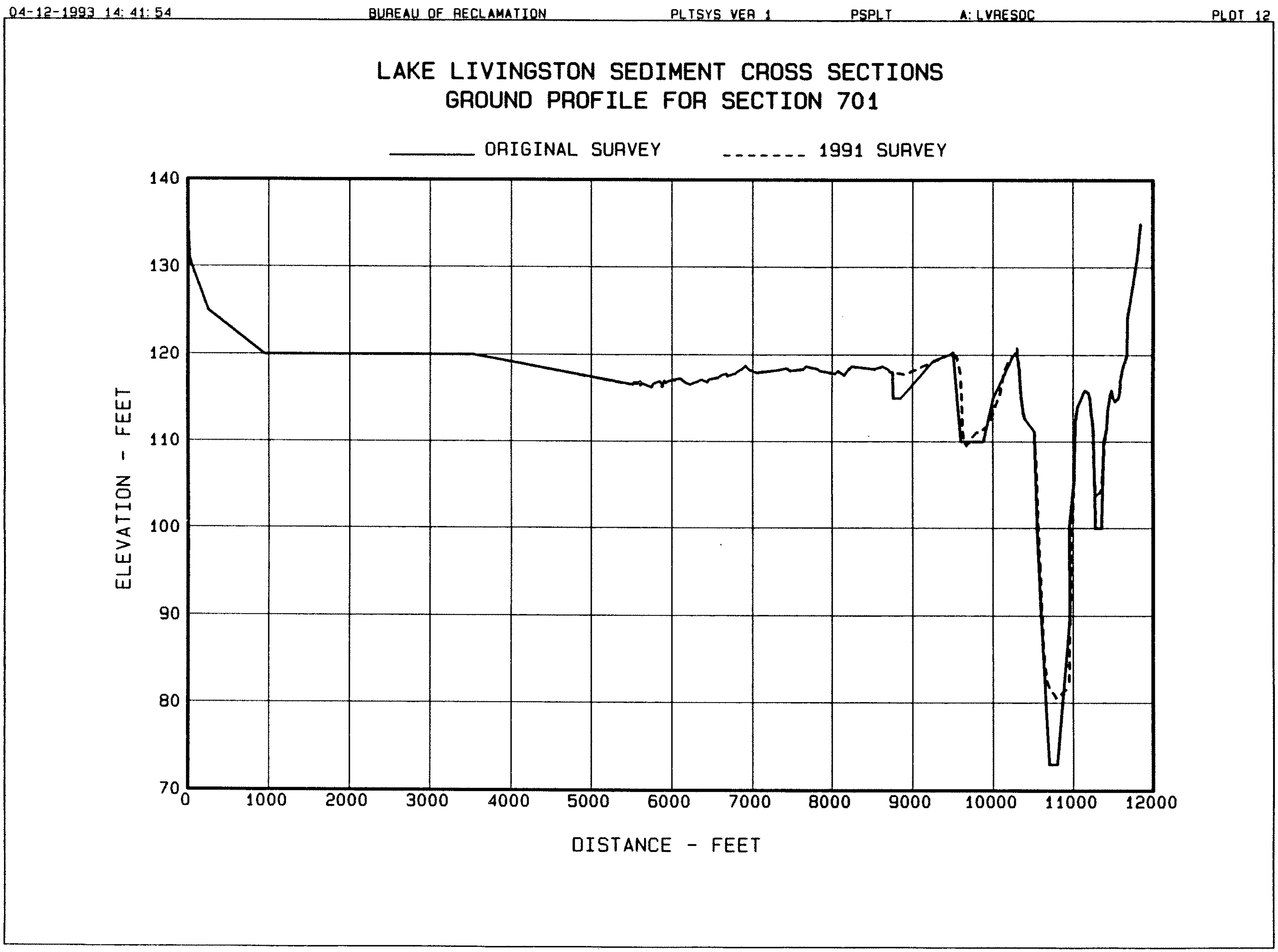


Figure 15. – Sediment Range 701 (7A) – Trinity River.

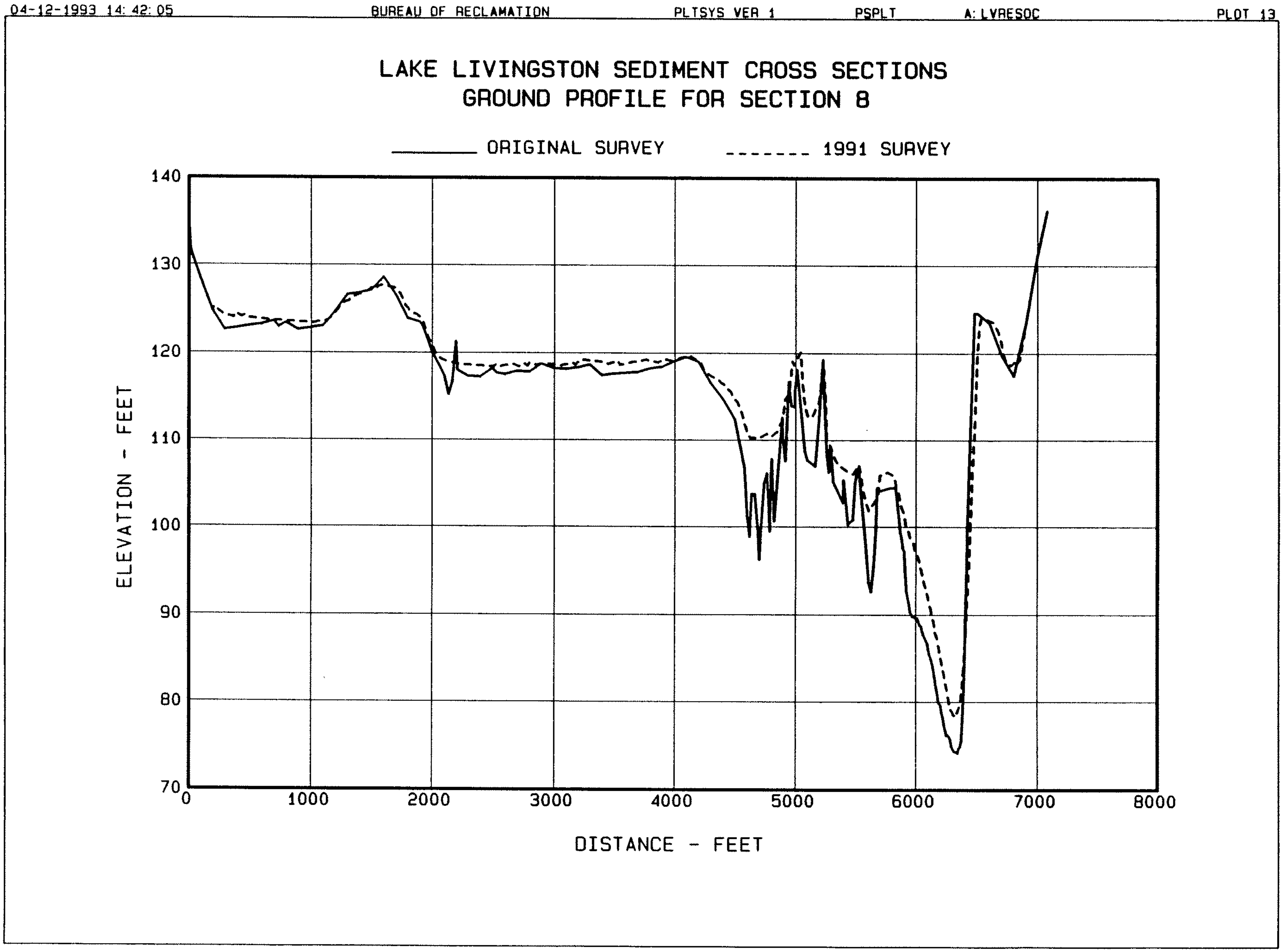


Figure 16. – Sediment Range 8 – Trinity River.

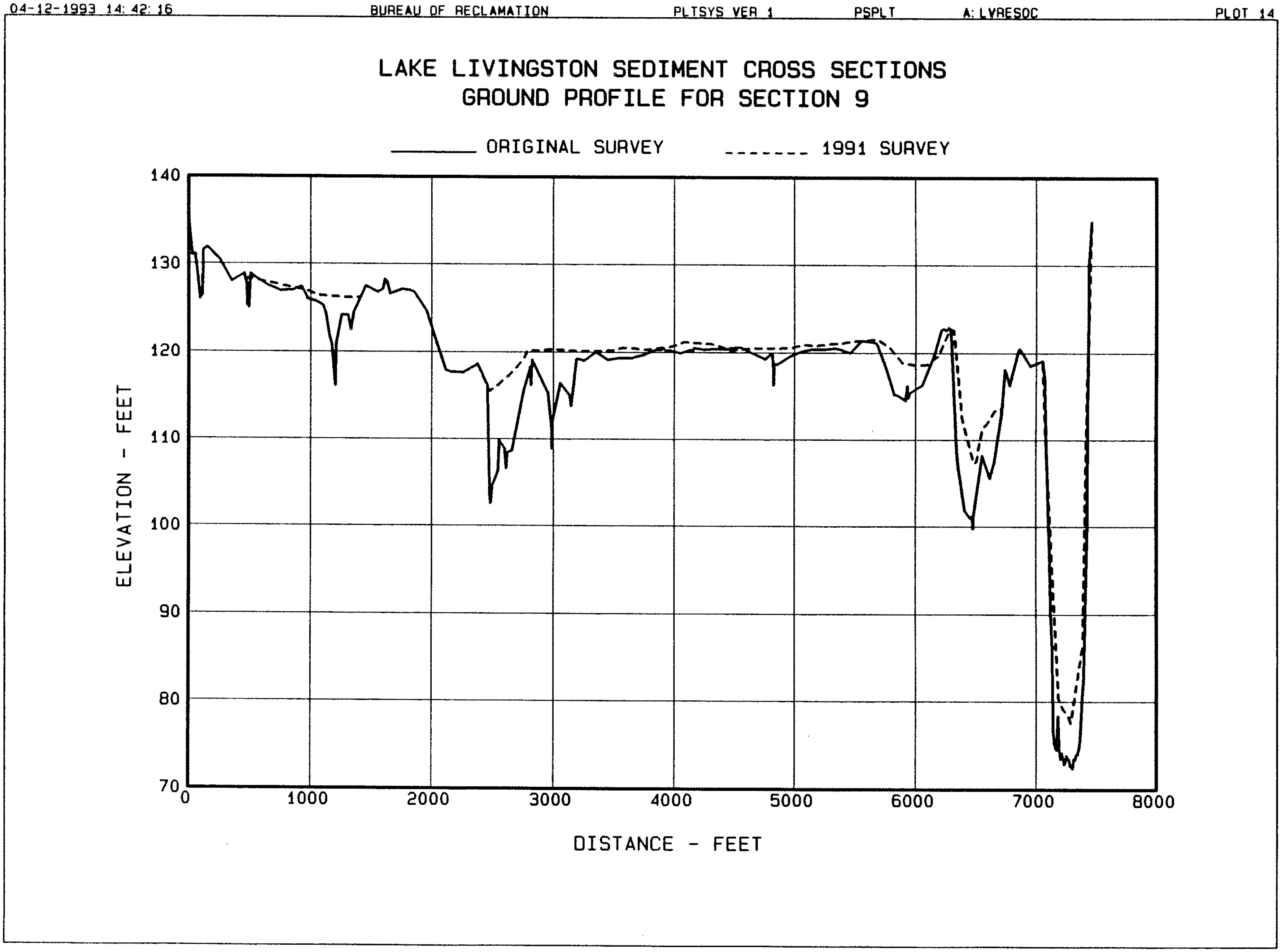


Figure 17. – Sediment Range 9 – Trinity River.

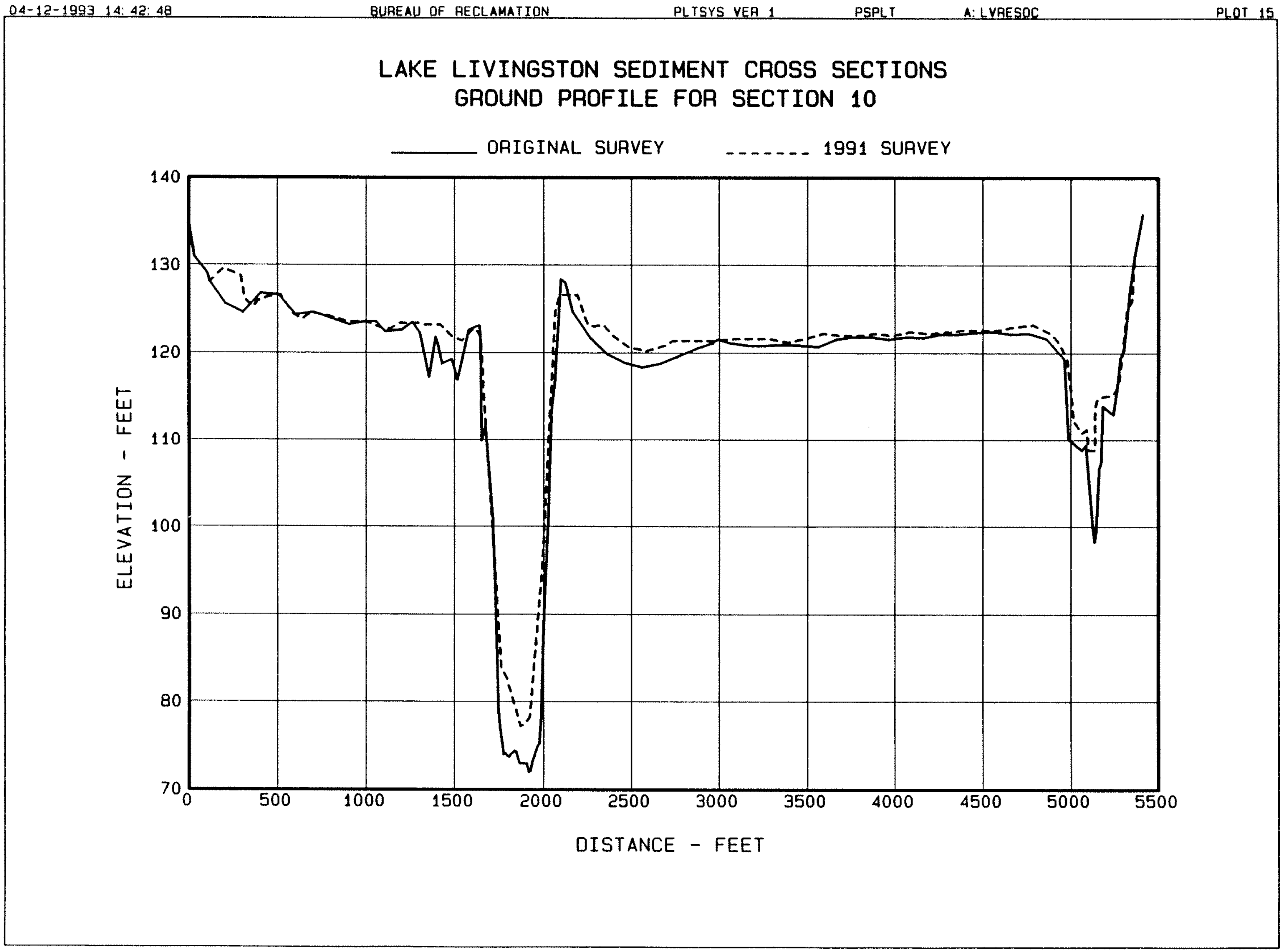


Figure 18. – Sediment Range 10 – Trinity River.

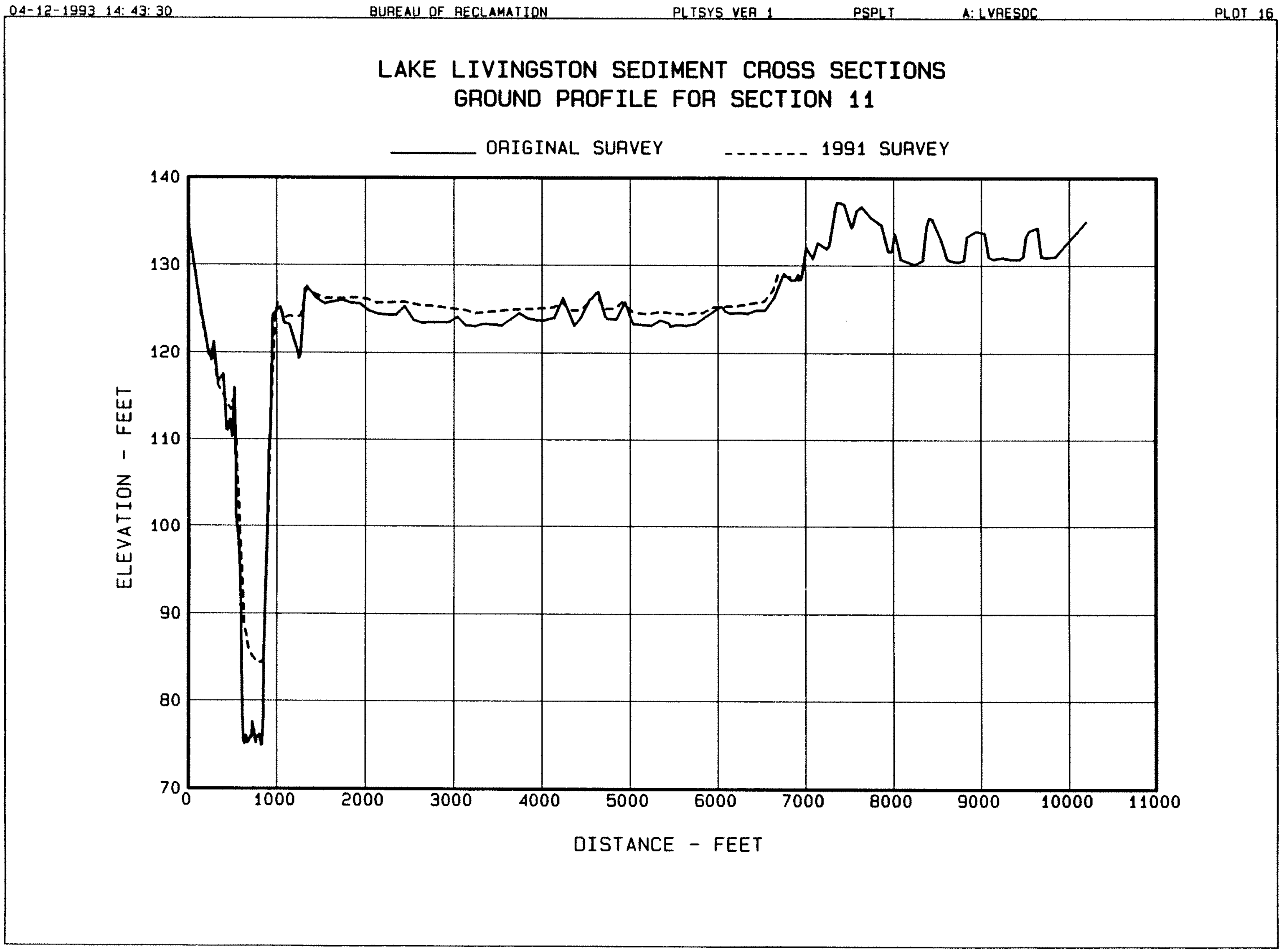


Figure 19. – Sediment Range 11 – Trinity River.

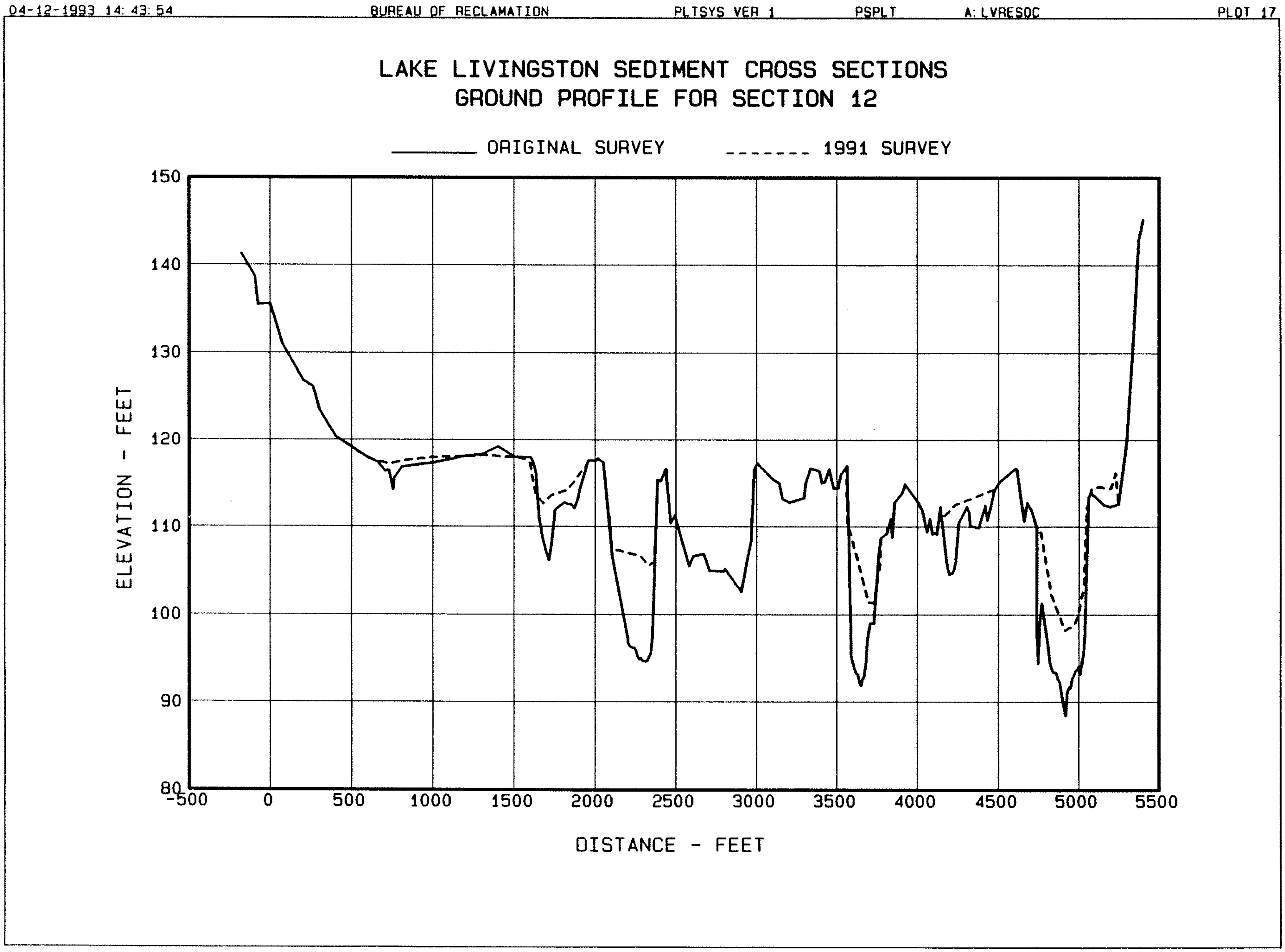


Figure 20. – Sediment Range 12 – White Rock and Caney Creeks.

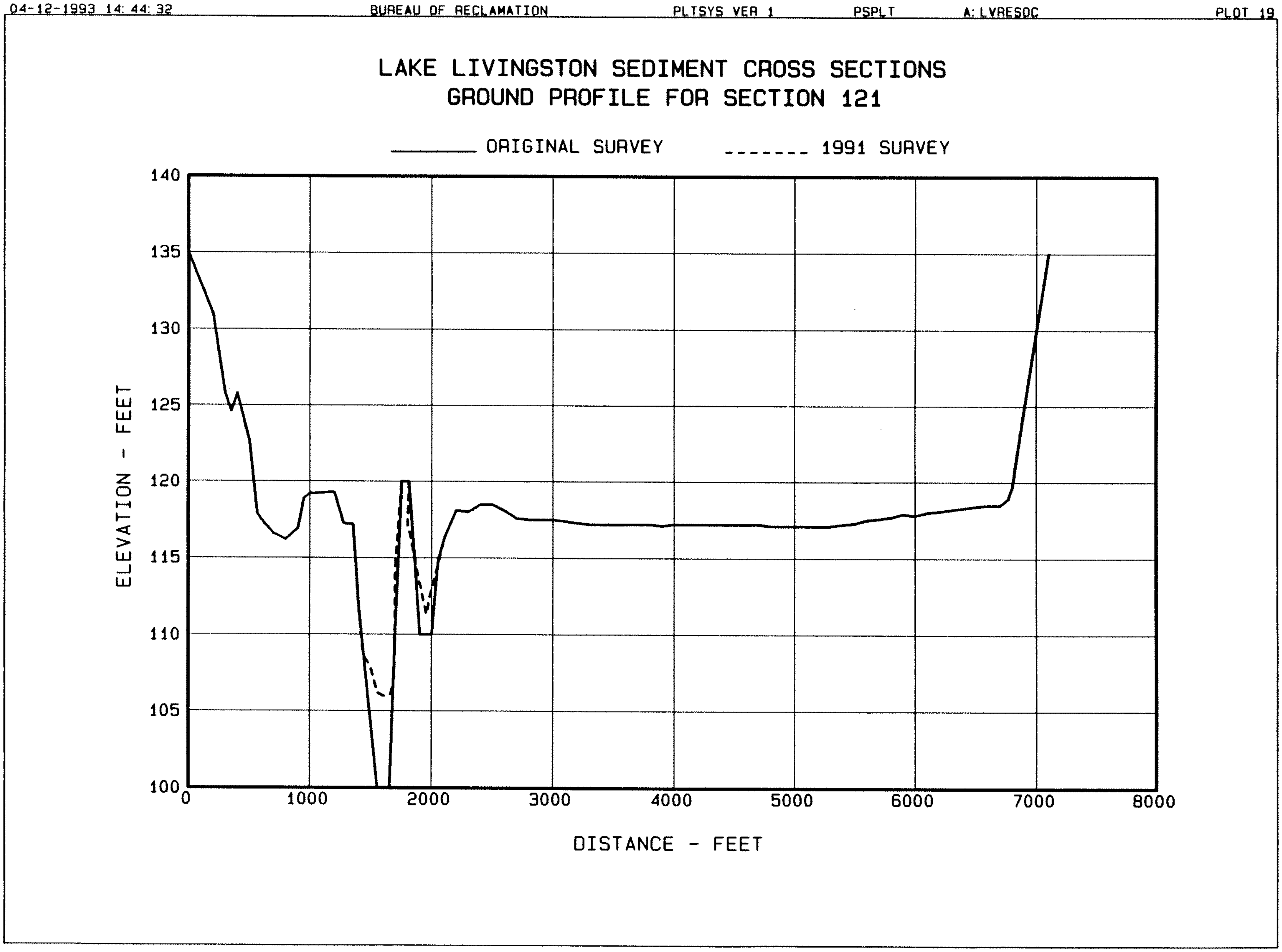


Figure 21. – Sediment Range 121 (12A) – Caney Creek.

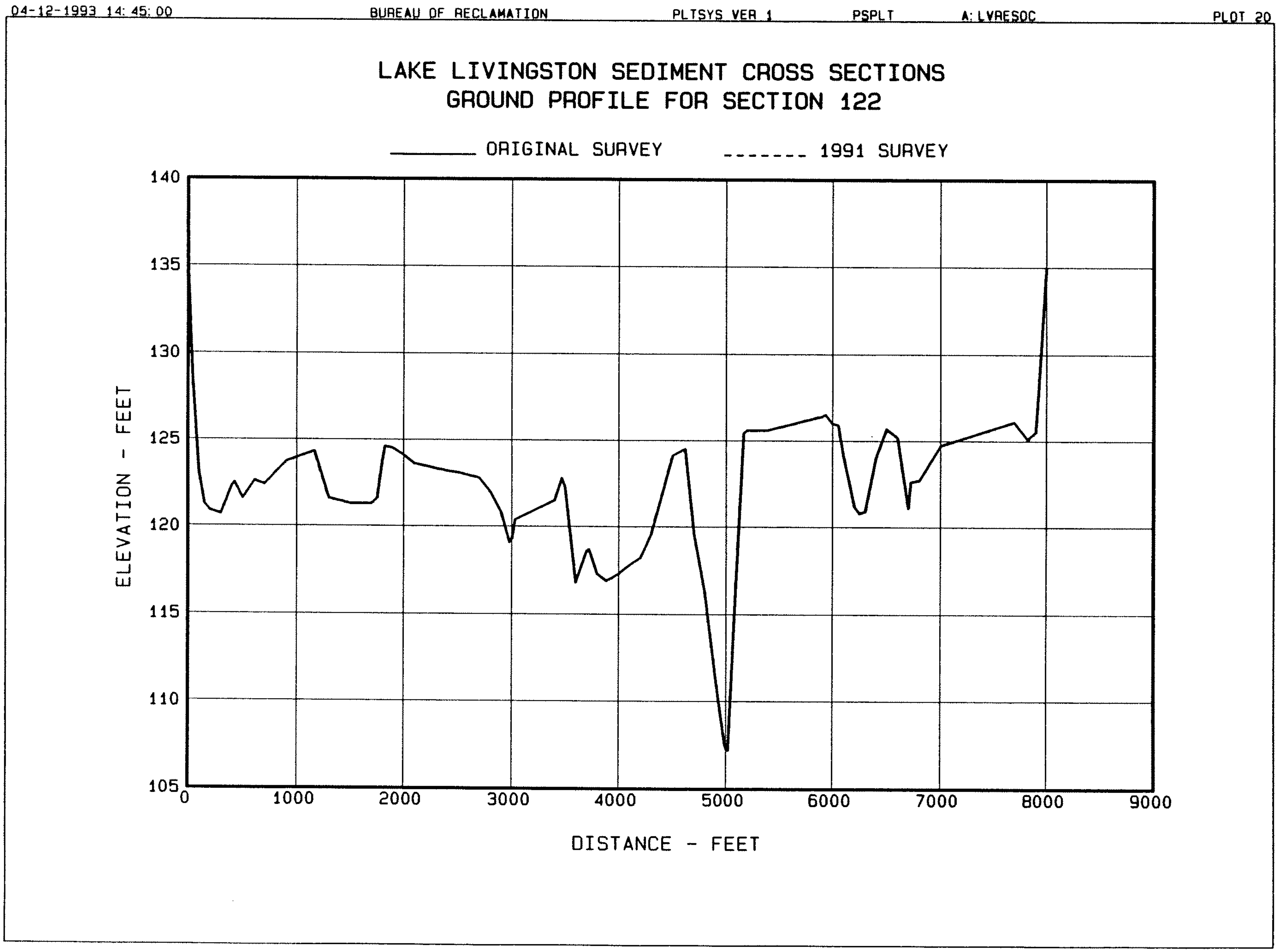


Figure 22. – Sediment Range 122 (12B) – White Creek.

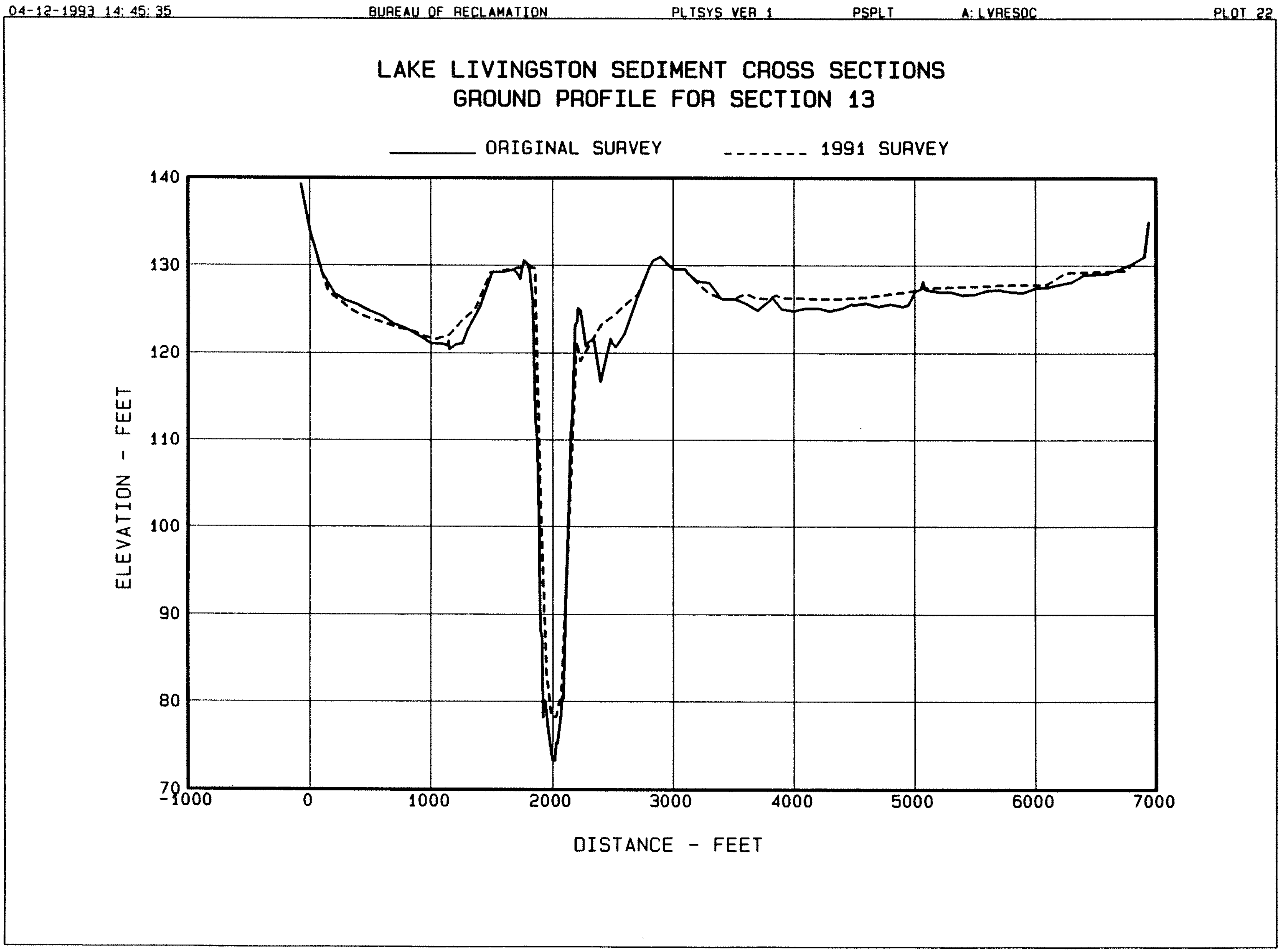


Figure 23. – Sediment Range 13 – Trinity River.

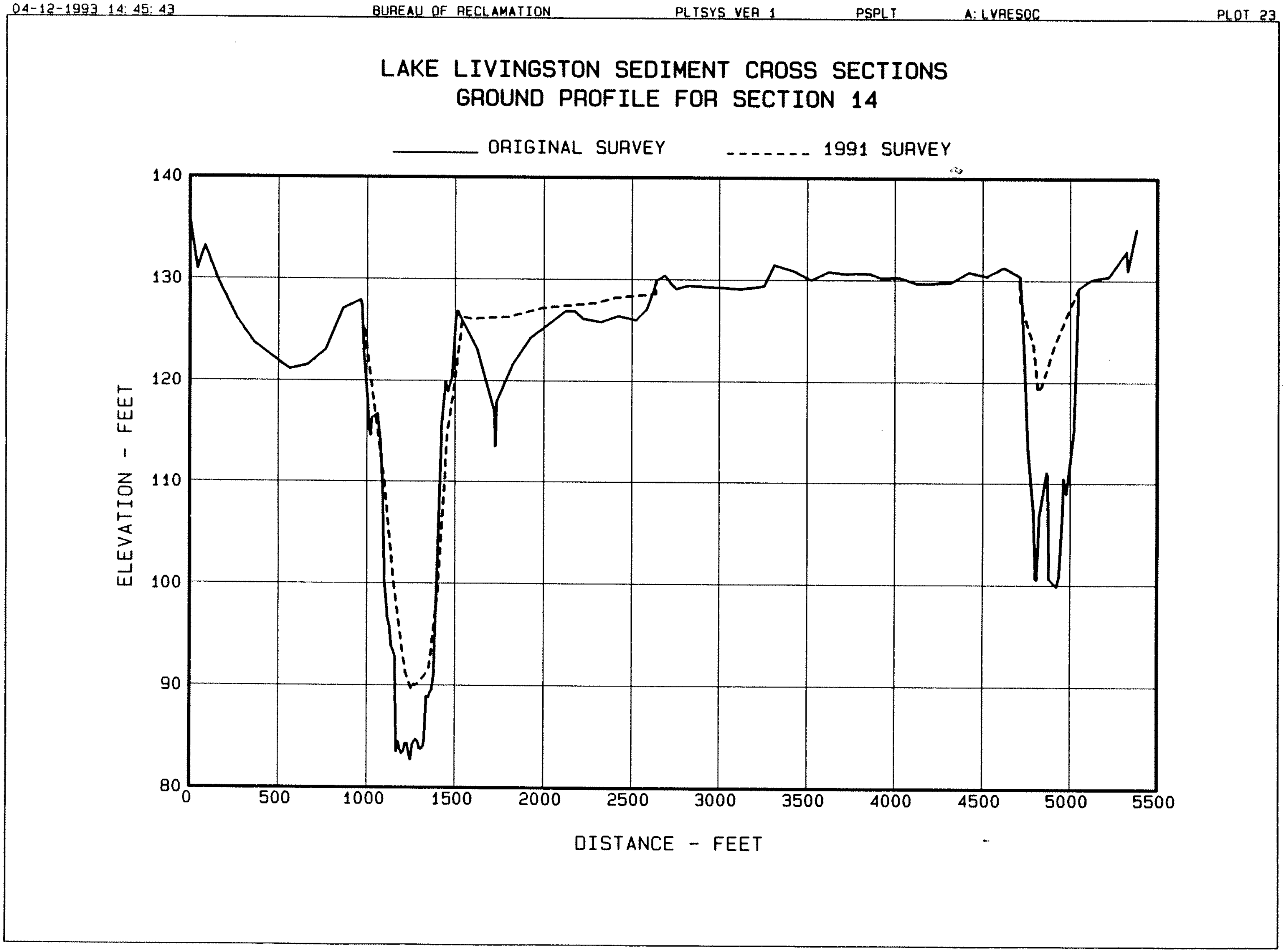


Figure 24. – Sediment Range 14 – Trinity River.

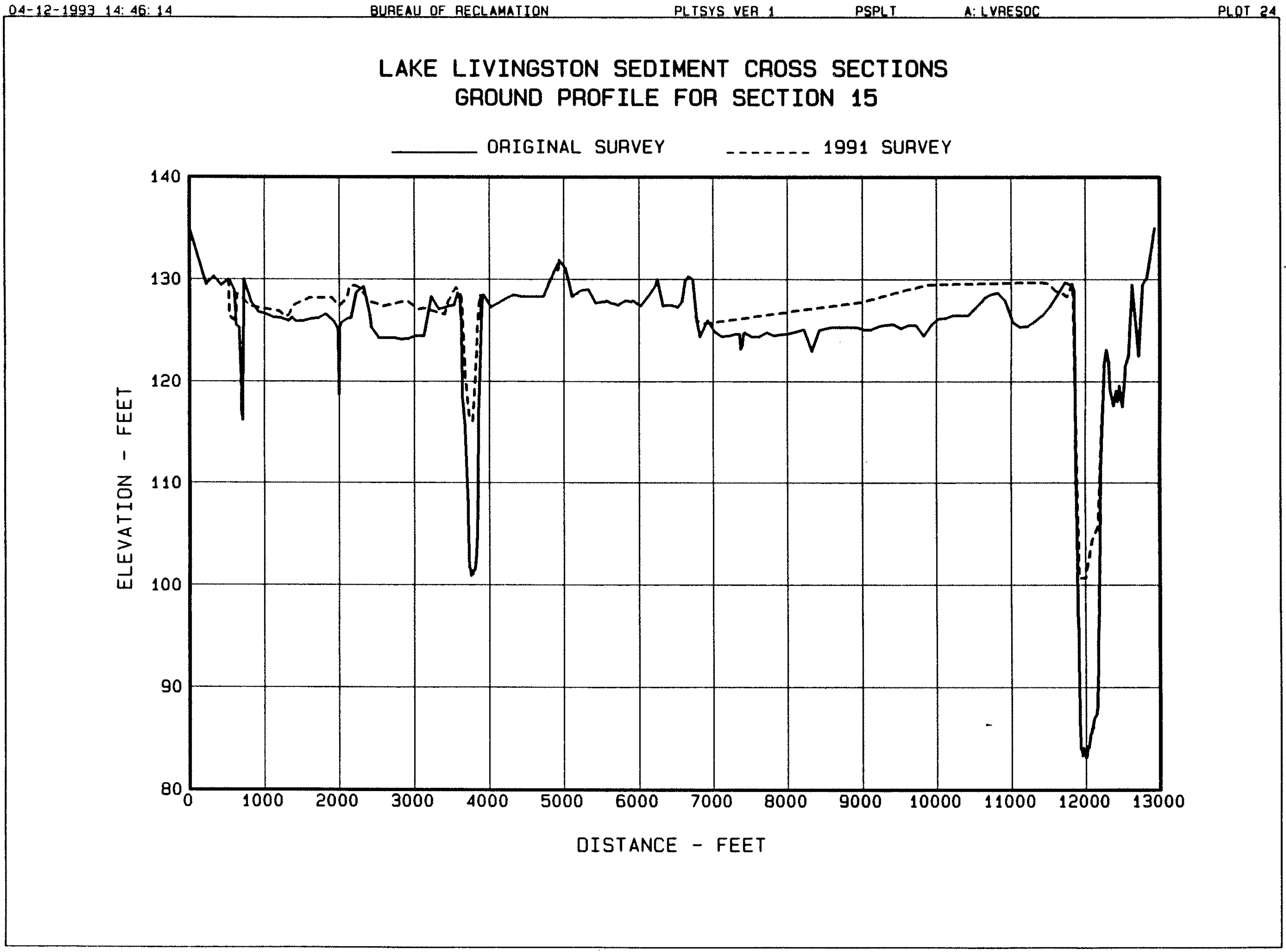


Figure 25. – Sediment Range 15 – Trinity River.

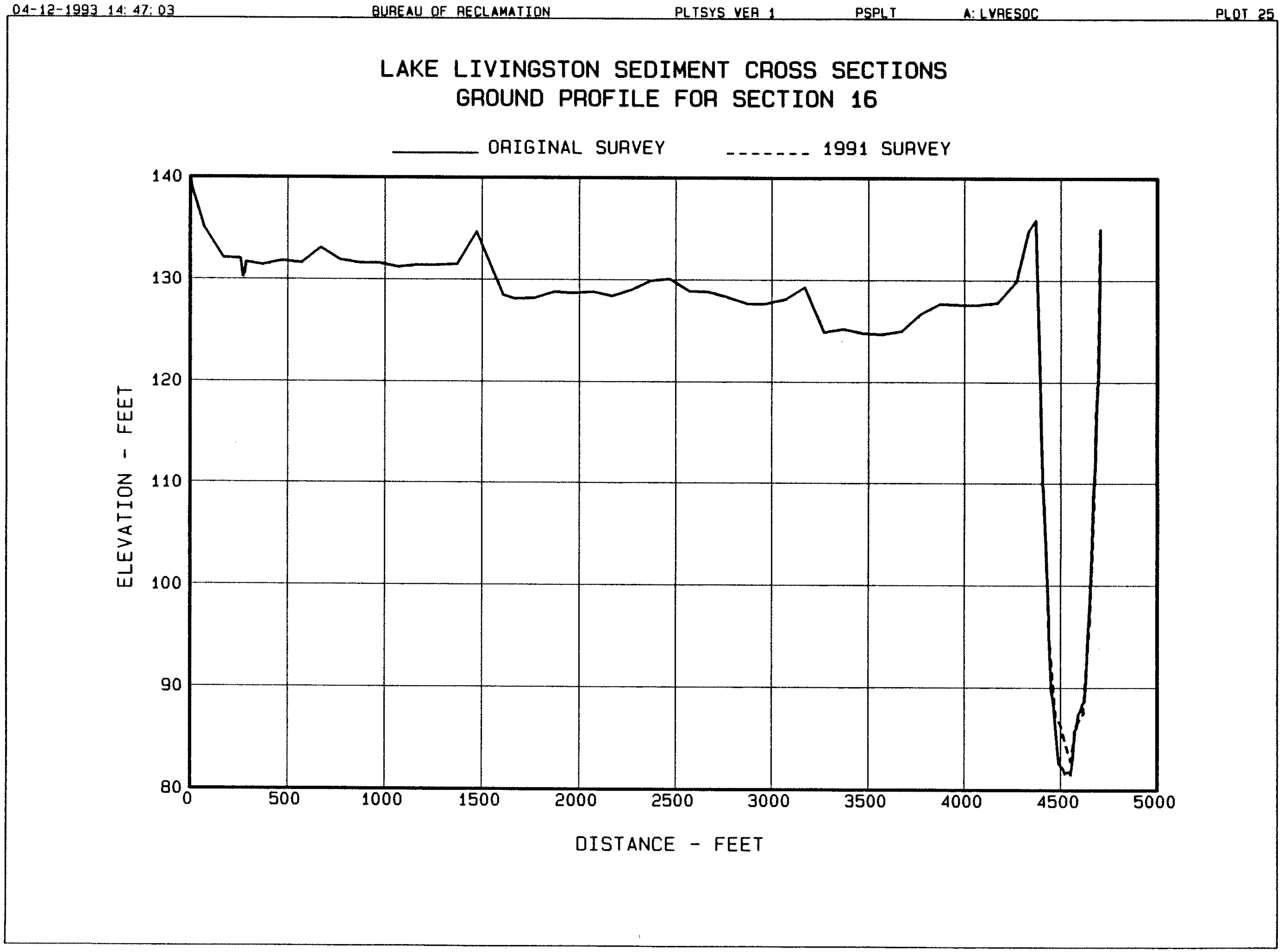


Figure 26. – Sediment Range 16 – Trinity River.

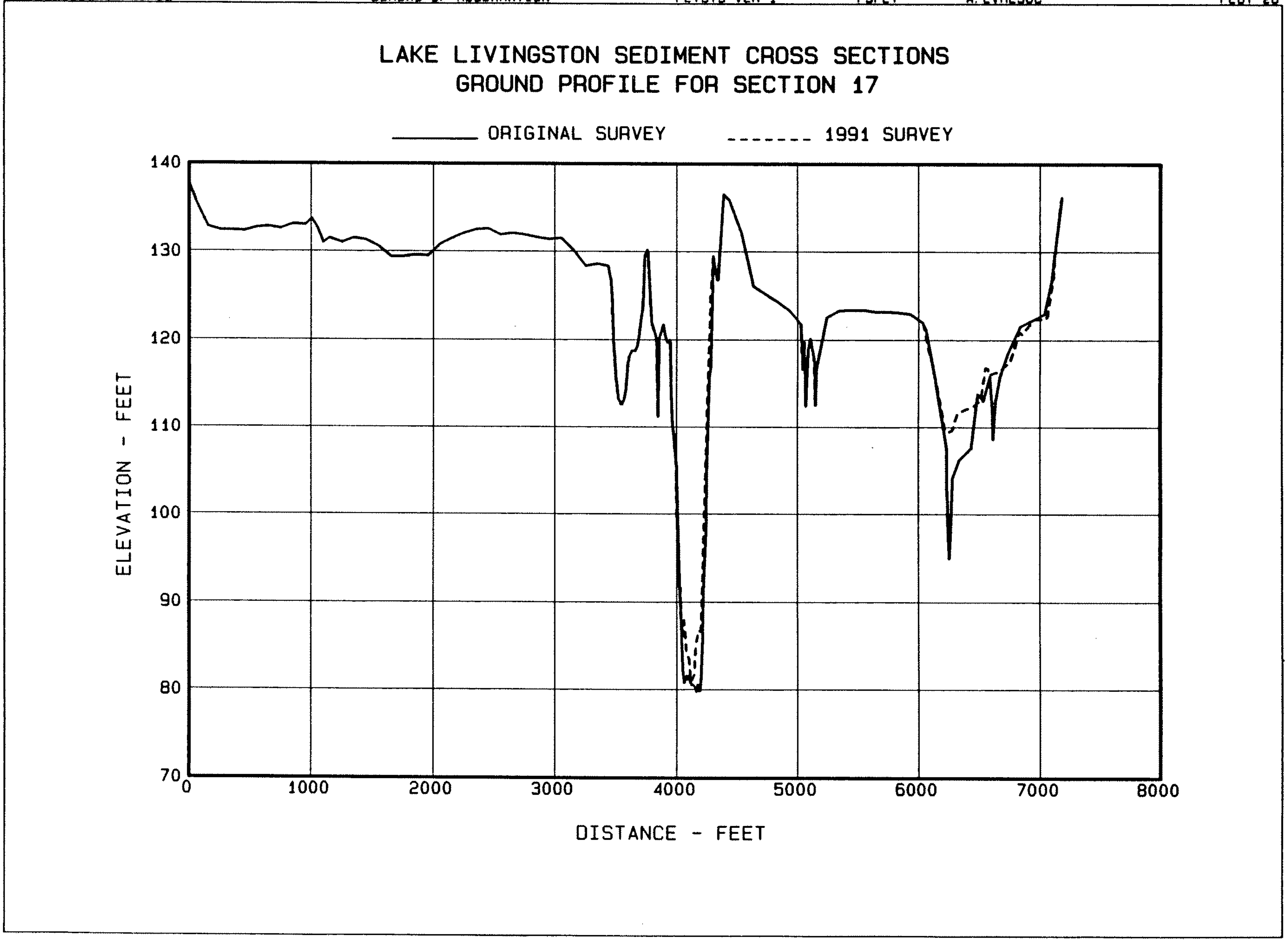


Figure 27. – Sediment Range 17 – Trinity River.

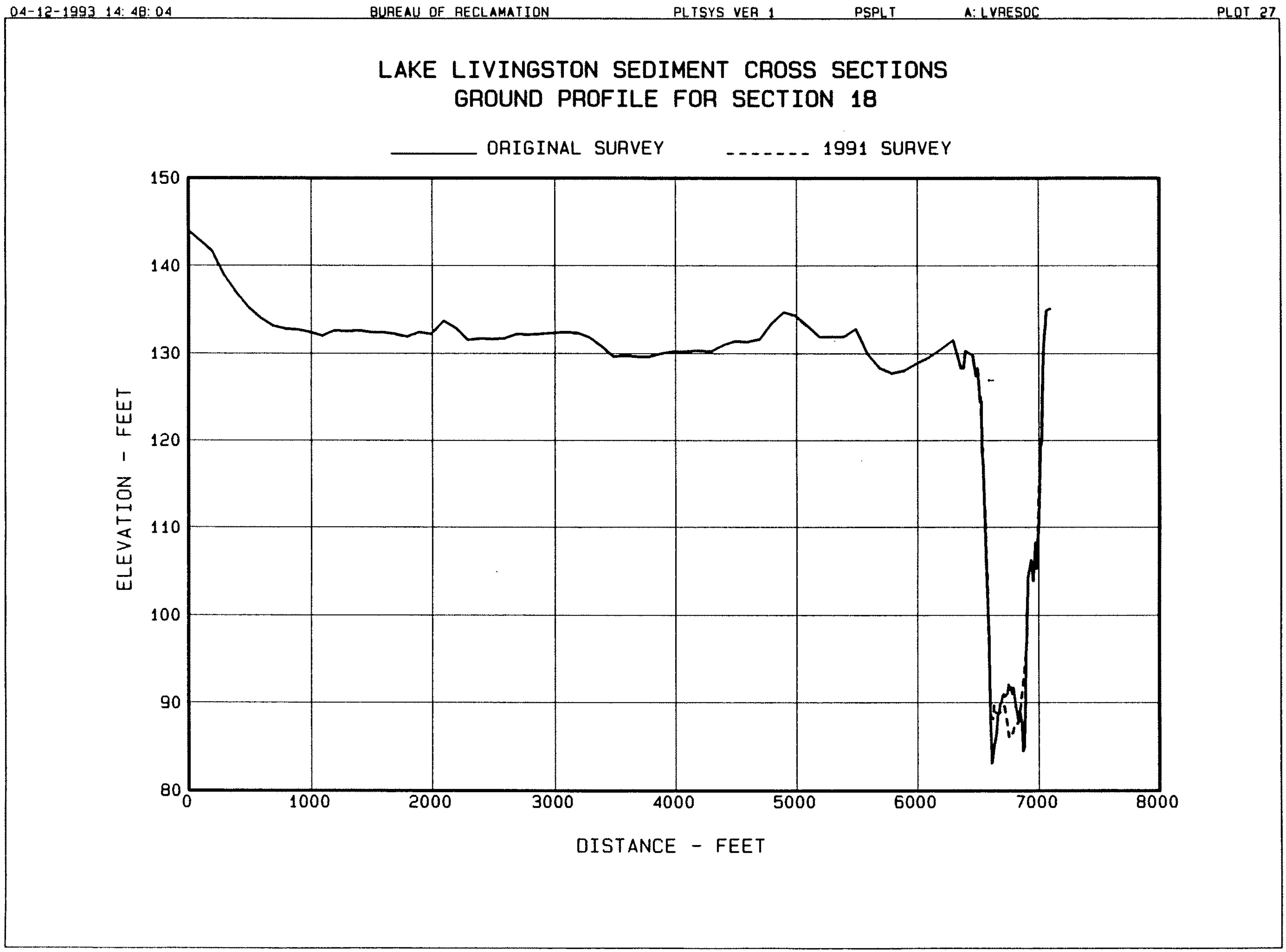
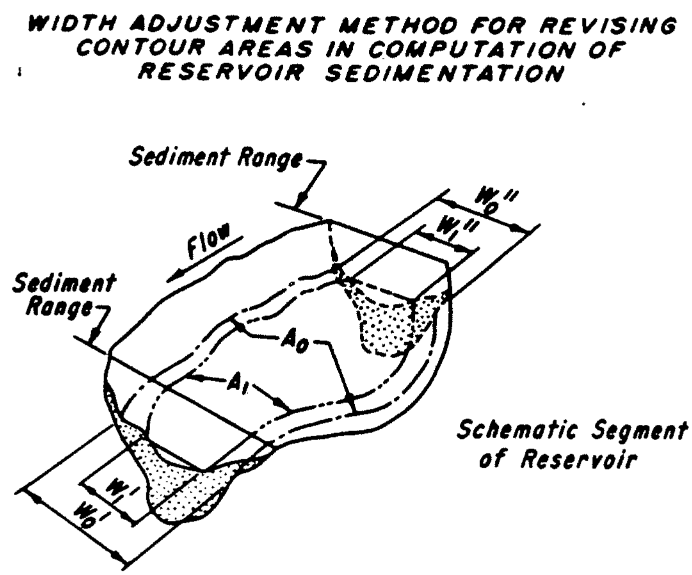


Figure 28. – Sediment Range 18 – Trinity River.



Initial Survey	New Survey
A_0 = Contour Area	A_1 = Contour Area (Computed)
W_0' = Downstream Width	W_1' = Downstream Width
W_0'' = Upstream Width	W_1'' = Upstream Width

$$A_1 = A_0 \left(\frac{\frac{W_1' + W_1''}{2}}{\frac{W_0' + W_0''}{2}} \right)$$

Figure 29. – Width adjustment method for revising contour areas.

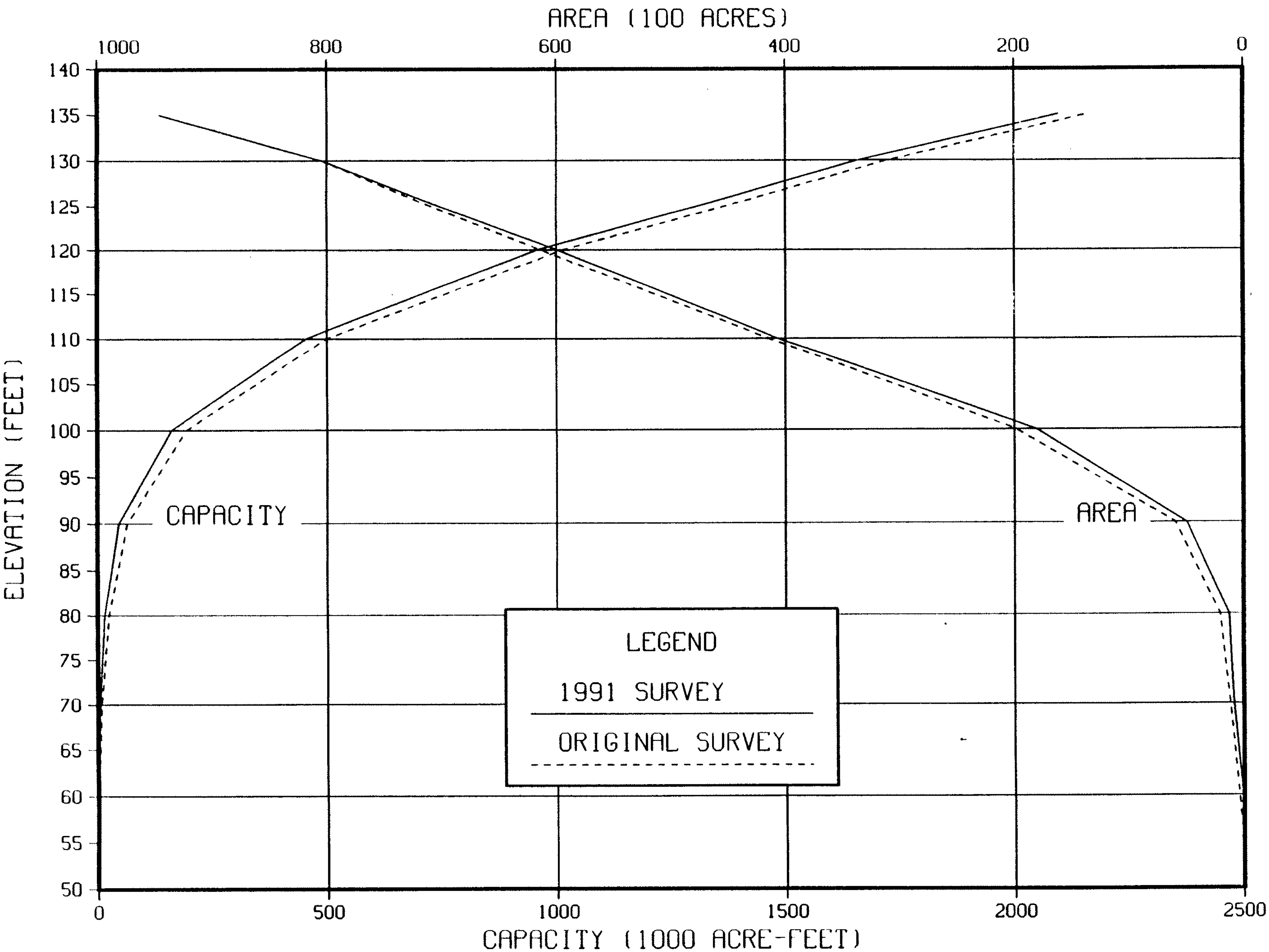


Figure 30. – Area and capacity curves – Lake Livingston.