LAKE COMO

1991 Reservoir Survey

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16. ABSTRACT

Lake Como was surveyed in 1991 to compile field data for developing a reservoir topographic map and computing the present storage-elevation relationship. This was the first survey to determine the natural lake capacity inundated because of construction of Como Dam. The original active capacity was based on topography collected prior to construction and did not include areas below the natural lake's water surface. The 1991 bathymetric survey used sonic depth recording equipment interfaced with an automated microwave positioning system that gave continuous depth and sounding positions. The above-water reservoir area was calculated from close interval cross sections measured from aerial photography obtained in 1990. A new reservoir contour map was developed by the computer graphics program SURFACE II using the collected data.

Reclamation is conducting a dam safety investigation with options of raising the dam and modifying the spillway. As of May 1991, at the present reservoir spillway crest elevation (feet) 4236.0, the surface area was 883 acres with a total capacity of 36,271 acre-feet and an active capacity of 29,439 acre-feet.

17. KEY WORDS AND DOCUMENT ANALYSIS

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LAKE COMO

1991 RESERVOIR SURVEY

by

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ACKNOWLEDGMENTS

The Bureau of Reclamation prepared and published this report under the supervision of Robert I. Strand, Head, Sedimentation Section, Earth Sciences Division. Ronald Ferrari and Joseph Lyons of the Denver Office conducted the hydrographic survey. Personnel from the Columbia Basin Projects Office of the Pacific Northwest Region assisted during the hydrographic survey and performed the required land survey for the hydrographic and aerial data collection. Special thanks to Jerry Harrod and Chuck Woodruff of the Columbia Basin Projects Office for the field assistance during the hydrographic survey and Gerald Schultz of the Denver Office for the office assistance. Ronald Ferrari completed the data processing needed to generate the new topographic map and area-capacity tables. James O. Blanton, Steven Gavlick, Robert I. Strand, and Dave Zimmer consulted in the engineering computations, topographic map development, and report preparation.

Mission

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

Photo by Joe Lyons of the Denver Office. Taken near dam looking upstream. This was the last hydrographic survey using the Sedimentation Section's MonArk survey boat, nicknamed the African Queen.

Lake Como with MonArk survey boat

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INTRODUCTION

Lake Como Dam and Reservoir, of the Bitter Root Project, is located on Rock Creek. The dam, located in Ravalli County of west-central Montana, is about 5 miles northwest of Darby and 16 miles southwest of Hamilton, Montana (fig 1).

Como Dam was originally constructed by the Bitter Root Valley Irrigation Company between 1908 and 1910. In 1920, the Bitter Root Irrigation District was formed, in accordance with Montana law, to replace the irrigation company. In 1930, Congress authorized the Bureau of Reclamation (Reclamation) to undertake measures for rehabilitation of the district's irrigation system and liquidation of its private indebtedness. Additional rehabilitation was performed in 1936, 1948, 1956, and 1974. Reclamation is conducting a dam safety investigation with options of raising the dam and modifying the spillway.

Como Dam (fig. 2) is an earth and gravel embankment constructed by the semi-hydraulic fill method. Material hauled to the site by rail was dumped from both the upstream and downstream sides of the fill where the finer materials washed to the lower and central part of the dam. At dam crest elevation 4249.0 (feet) the embankment has:

- a structural height* of 70 feet
- a top crest width of 25 feet
- a crest length of 2,550 feet

Closure of the dam and first reservoir storage occurred in 1909. The reservoir impounded by the dam inundated a natural lake on Rock Creek. At elevation 4245.0 the reservoir extends 3.2 miles up Rock Creek and has an average width of 0.4 mile.

The present spillway, located at the left abutment, was constructed in 1923 with a crest length of 75 feet at elevation 4236.0. The current maximum capacity is 5,460 cubic feet per second at reservoir water surface elevation 4245.9. The spillway consists of:

- an excavated approach channel
- a concrete control and transition section
- flashboard bays
- a concrete chute
- a natural rock-formed stilling basin
- a downstream channel

* The definition of terms such as "structural height," "hydraulic height," etc., may be found in manuals such as Reclamation's *Design of Small Dams* and *Guide for Preparation of Standing Operating Procedures for Dams and Reservoirs*, or ASCE's *Nomenclature for Hydraulics*.

The outlet works, located in the right one-third of the dam, consists of:

- a trashracked intake structure
- a 6-foot-diameter concrete conduit with redwood stave and steel plate lining
- two tandem 5.5-foot diameter gate valves
- a stilling basin

The outlet's hydraulic capacity is 450 cubic feet per second at reservoir elevation 4203.4.

Lake Como had an original calculated active capacity of 29,087 acre-feet at the present reservoir spillway crest elevation 4236.0. The original capacity of the natural lake (dead storage) was unknown, but was estimated to be 1,800 acre-feet.

SUMMARY AND CONCLUSIONS

This report presents the results of the first extensive survey of Lake Como by Reclamation since construction of Como Dam. The primary objective of the 1991 survey was to gather necessary data for computing the current total and active capacities of Lake Como. This was the first detailed survey to determine the area and capacity of the natural lake inundated by the reservoir created by the dam.

Standard land surveying methods were used to establish horizontal and vertical control points for the aerial and hydrographic surveys. A local horizontal grid system was established for both surveys using monumented control points located in the reservoir area. The bathymetric survey was run using sonic depth recording equipment interfaced with an automated survey system consisting of a line-of-sight microwave positioning unit capable of determining sounding locations within the reservoir. The system continuously recorded reservoir depth and horizontal coordinates as the survey boat was steered across close-spaced range lines covering the reservoir area. The positioning system provided information to allow the boat operator to maintain course along these range lines. Water surface elevations measured by the land surveyors at the time of data collection were used to convert the sonic depth measurements to true reservoir bottom elevations.

The 1991 surface areas at predetermined 5-foot contour intervals were generated by a computer graphics program that produced a new contour map of the reservoir (fig 3). The ACAP85 computer program computed the reservoir capacity and surface area at prescribed increments of elevation by using a curve-fitting technique from the generated contour surface areas (Reclamation, 1985).

Table 1 contains a comprehensive summary of the reservoir data and watershed characteristics for the 1991 survey. The 1991 survey determined that the reservoir has a surface area of 883 acres at the present reservoir spillway crest elevation 4236.0, providing a total capacity of 36,271 acre-feet, and an active capacity of 29,439 acre-feet. The survey measured a reservoir dead storage of 6,832 acre-feet between elevations 4122.1 and 4188.5. Lake Como had an original calculated active capacity of 29,087 acre-feet with an interpolated surface area of 880 acres at the same reservoir elevation. The original capacity of the natural lake (dead storage) was unknown, but was estimated to be 1,800 acre-feet. The

1991 survey found that the natural lake area was much larger than originally estimated. A summary of reservoir sediment data was not presented because this was the first survey to compute the total reservoir capacity.

Because of low sediment production in the drainage area, a resurvey of Lake Como should not be necessary unless major sediment inflow occurs in the future.

DESCRIPTION OF WATERSHED

The drainage area of Lake Como basin (above the dam) is 54.6 square miles and is part of the Bitterroot Mountain Range. The elevation of the basin ranges from elevation 4188.5 at the intake of the outlet tower to elevations nearly 10,000 feet at the mountain peaks. The minimum elevation of the natural lake, which was inundated by the reservoir, was measured to be 4122.1 feet.

The Bitterroot Range is not a continuous mountain ridge, but is a complex of mountain masses separated by low saddles or valleys. Within the mountain groups the higher peaks are not located on the divide between the Bitterroot and Selway (and Lochsa) River watersheds, but are situated within the watersheds of the east slope streams, such as El Capitan Peak (9965 feet) and Como Peak (9552 feet) in the Rock Creek watershed. Rock Creek watershed is steep and rocky, and aside from bare rock faces of the higher peaks and its talus slopes, the basin is quite heavily forested.

RESERVOIR OPERATIONS

The records of monthly inflow and end-of-month stage for Lake Como are limited (see table 1). The available records show an average unregulated inflow of 92,214 acre-feet per year with a calculated mean annual runoff from the basin of 31.7 inches. The available end-of-month stage records show the extreme annual fluctuations of Lake Como with a minimum elevation of 4188.0 occurring in several years to a maximum elevation of 4244.7 in June 1945.

SURVEY METHOD AND EQUIPMENT

The Lake Como survey was completed using the contour method (Blanton, 1982). The procedure involved collecting adequate coordinate data for developing a reliable contour map by photogrammetric and bathymetric survey methods. Standard land surveying methods were used by Columbia Basin Project Office personnel to establish horizontal and vertical control points for both survey methods. A local horizontal grid system was established for both surveys using monumented points located in the reservoir area. The above-water data was collected by aerial photography obtained in 1991 at water surface elevation 4205.2. The field survey work for the bathymetric survey involved establishing a triangulation network around the reservoir to provide horizontal and vertical control for all required range lines and shore station locations. No previously established range lines existed on the reservoir and permanent range lines were not established during this survey. Because of the size and shape of the reservoir, any future survey would also employ the contour method; therefore, permanent range line end markers were not necessary.

The hydrographic survey took place May 5 and May 6, 1991, at reservoir water surface elevations 4222.85 and 4222.6, respectively. The bathymetric survey was run using sonic depth recording equipment interfaced with an automated survey system consisting of a line-of-sight microwave positioning unit capable of determining sounding locations within the reservoir. This positioning system transmitted line-of-sight microwave signals to fixed 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 sounding boat. The survey system continuously recorded reservoir depth and horizontal coordinates as the survey boat moved across close-spaced range lines covering the reservoir area. To produce adequate data for developing contours of Lake Como, a grid spacing of 200 feet was selected for the main body; 300-foot intervals were used in the upper portion of the reservoir. The system gave directions to the boat operator to assist in maintaining course along the close-spaced range lines. During each run, the depth and position data were recorded on a floppy disk for subsequent processing by Denver Office personnel. A graph plotter was used in the field to track the boat and determine adequate coverage during the data collection process. Water surface elevations surveyed at the time of collection were used in converting the sonic depth measurements to true reservoir bottom elevations.

SEDIMENT ANALYSES

The total sediment accumulation in Lake Como cannot be computed because this was the first survey of the natural lake area (dead storage) since the dam was constructed. Because of the large reservoir dead storage measured in 1991 and the low sediment production of the drainage area, a resurvey of Lake Como should not be necessary unless major sediment inflow occurs in the future.

RESERVOIR AREA AND CAPACITY

Development of 1991 Contour Areas

The 1991 contour surface areas for Lake Como were developed by generating a contour map from the collected aerial and underwater coordinate data. Five-foot contour intervals of the reservoir area were created by a computer graphics software program (Kansas Geological Survey, 1978). A modification of this program by the Denver Office calculated surface areas of the closed contours of the generated map. The generated contours and the calculated surface areas were done using a local horizontal grid system that was established for the 1991 field collection. After completion of the 1991 sedimentation survey, state plane coordinates were established on the control points. The final reservoir map with state plane coordinates was generated and prepared by the Denver Office Computer Drafting Unit of the Drafting Section. The map shown on figure 3 has a scale of 1 inch equals 500 feet with 5-foot contour intervals.

1991 Revised Storage Capacity

The storage-elevation relationships based on the 1991 aerial and underwater survey data were developed using the area-capacity computer program ACAP85 (Reclamation, 1985). Surface areas at 5-foot contour intervals computed from the aerial and underwater survey data were used as the control parameters for computing reservoir capacity. The program computes an area at elevation increments of 0.01- to 1.0-foot by linear interpolation between the 5-foot 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 Lake Como. Then the capacity equation is 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 basic area curve over that interval) tests 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 Lake Como area and capacity computations are listed in table 1 and plotted on figure 4. A separate set of 1991 area and capacity tables has been published for the 0.01-, 0.1-, and 1-foot elevation increments (Reclamation, 1991). The 1991 total capacity is 36,271 acre-feet with a surface area of 883 acres at the present reservoir spillway crest elevation 4236.0.

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Kansas Geological Survey, SURFACE II GRAPHICS SYSTEM, Lawrence, Kansas, 1978.

RESERVOIR SEDIMENT
DATA SUMMARY

Lake Como
NAME OF RESERVOIR

1
DATA SHEET NO.

DAM	1. OWNER Bitter Root Irrigation		2. STREAM Rock Creek			3. STATE Montana
	4. SEC. 32 TWP. 4N RANGE 21W		5. NEAREST P.O. Darby			6. COUNTY Ravalli
	7. LAT 46° 03' 40" LONG 114° 14' 00"		8. TOP OF DAM ELEVATION 4249.0[1]			9. SPILLWAY CREST 4236.0[1]
RESERVOIR	10. STORAGE ALLOCATION	11. ELEVATION TOP OF POOL	12. 1991[2] SURFACE AREA, Ac	13. 1991[2] CAPACITY, AF	14. 1991 GROSS STORAGE ACRE-	15. DATE STORAGE BEGAN
	a. FLOOD CONTROL					
	b. MULTIPLE USE	4236.0	883	29,439	36,271	1909
	c. POWER					
	d. WATER SUPPLY					16. DATE NORMAL OPERATION BEGAN
	e. IRRIGATION					
	f. CONSERVATION					
	g. INACTIVE	4188.5	203	6,832	6,832	1910
	17. LENGTH OF RESERVOIR 3.2[3] MILES			AVG. WIDTH OF RESERVOIR 0.4[3] MILES		
BASIN	18. TOTAL DRAINAGE AREA 54.6 SQUARE MILES			22. MEAN ANNUAL PRECIPITATION 13.2[4]		INCHES
	19. NET SEDIMENT CONTRIBUTING AREA 54.6 SQUARE MILES			23. MEAN ANNUAL RUNOFF 31.7[5]		INCHES
	20. LENGTH 12.2 MILES MI	AV. WIDTH 4.5 MILES		24. MEAN ANNUAL RUNOFF 92,214[6]		ACRE-FEET
	21. MAX. ELEVATION 9965	MIN. ELEVATION 4188.5		25. ANNUAL TEMP. MEAN 46°F[4] RANGE -38°F to 103°F[4]		

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
	1909					[2]	[2]	
	May 5,1991	82	82	Contour (D)[7]	5-ft	883	36,271[8]	0.39

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
May 5,1991	13.2[4]	92,214[6]	170,500[6]	[6]	92,214[6]	[6]

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.
May 5, 1991	[2]			[2]		

26. DATE OF SURVEY	39. AV. DRY WT. (#/FT[3])	40. SED. DEP. TONS/MI.[2]-YR.		41. STORAGE LOSS, PCT.		SED. INFLOW, PPM	
		a. PERIOD	b. TOTAL TO DATE	a. AV. ANNUAL	b. TOTAL TO DATE	a. PER.	b. TOT.
May 5,1991		[2]		[2]			

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

Table 1. - Reservoir sediment data summary (page 1 of 2).

45. RANGE IN RESERVOIR OPERATION

WATER YEAR	MAX. ELEV.	MIN. ELEV.	INFLOW, AF	WATER YEAR	MAX. ELEV.	MIN. ELEV.	INFLOW, AF
1940	4240.0	4188.0	[6]	1966	4244.5	4192.7	77,100
1941	4240.1	4197.2		1967	4243.3	4188.0	97,200
1942	4242.4	4188.0		1968	4243.4	4206.3	100,700
1943	4242.4	4198.1		1969	4244.2	4190.0	68,300
1944	4242.4	4188.0		1970	4243.4	4190.5	109,900
1945	4244.7	4188.0		1971	4243.0	4197.0	92,200
1946	4242.4	4188.0		1972	4242.6	4193.0	170,500
1947	4242.3	4213.2		1973	4232.6	4190.8	56,400
1948	4242.4	4205.3		1974	4242.4	4197.4	94,500
1949	4242.3	4195.3		1975	4244.0	4203.0	83,900
1950	4242.3	4198.5		1976	4243.0	4204.2	120,100
1951	4239.5	4209.4		1977	4227.2	4186.0	49,300
1952	4242.5	4192.4		1978	4242.8	4203.0	124,000
1953	4242.5	4191.6		1979	4242.7	4191.0	94,700
1954	4240.4	4198.1		1980	4242.2	4193.4	83,300
1955	4243.7	4188.0		1981	4242.6	4184.8	
1956	4244.3	4194.1		1982	4242.2	4194.1	115,600
1957	4244.6	4192.6		1983	4242.7	4209.6	54,500
1958	4244.1	4191.1		1984	4242.7	4209.1	
1959	4243.4	4190.7		1985	4240.0	4202.2	
1960	4244.6	4188.0		1986	4243.0	4193.3	
1961	4244.1	4192.4		1987	4238.6	4196.6	65,320
1962	4243.6	4193.0		1988	4241.0	4196.4	
1963	4244.6	4190.4	81,500	1989	4243.0	4202.0	90,740
1964	4244.6	4191.4	93,500	1990	4243.0	4200.0	101,070
1965	4243.2	4193.5	96,600	1991	4240.5	4205.7	

46. ELEVATION - AREA - CAPACITY DATA FOR 1991 Total Capacity[9]

ELEV.	AREA	CAP.	ELEV.	AREA	CAP.	ELEV.	AREA	CAP.
4122.1	0	0	4170	154	3,611	4220	792	22,826
4125	4	6	4175	164	4,407	4225	825	26,868
4130	22	70	4180	175	5,256	4230	853	31,063
4135	44	234	4185	184	6,154	4236	883	36,271
4140	60	494	4188.5	203	6,831	4240	902	39,840
4145	74	829	4195	240	8,267	4245	923	44,401
4150	85	1,227	4200	376	9,807	4249	938	48,124
4155	99	1,688	4205	563	12,155	4252	949	50,955
4160	119	2,232	4210	702	15,317			
4165	140	2,878	4215	755	18,958			

47. REMARKS AND REFERENCES

[1] Elevations from 1971 survey. Reclamation is conducting dam safety investigations with options of raising dam and modifying spillway.
[2] Reservoir inundated a natural lake. The original area-capacity of natural lake was unknown. The 1991 survey was first to determine total reservoir area and capacity.
[3] Measured from USGS topographic map at elevation 4245.
[4] Project data book, USBR, 1981. Climate for years 1966-80.
[5] Calculated from mean annual runoff value 92,214 acre-feet, item 24.
[6] Unregulated inflow monthly records for water years 1963-1990. Water years 1981, 84, 85, 86, and 89 have missing records. Records unavailable prior to 1963.
[7] Reservoir areas were measured using data from 1991 bathymetric survey and aerial photography.
[8] Total capacity of reservoir at present spillway crest El. 4236.0. Active capacity of 29,439 acre-feet from El. 4188.5 to 4236.0.
[9] Following table shows total capacity. A dead capacity (natural lake) of 6,832 acre-feet was computed from 1991 data. First survey of natural lake area.

48. AGENCY MAKING SURVEY Bureau of Reclamation
49. AGENCY SUPPLYING DATA Bureau of Reclamation | DATE August 1992

Table 1. - Reservoir sediment data summary (page 2 of 2).

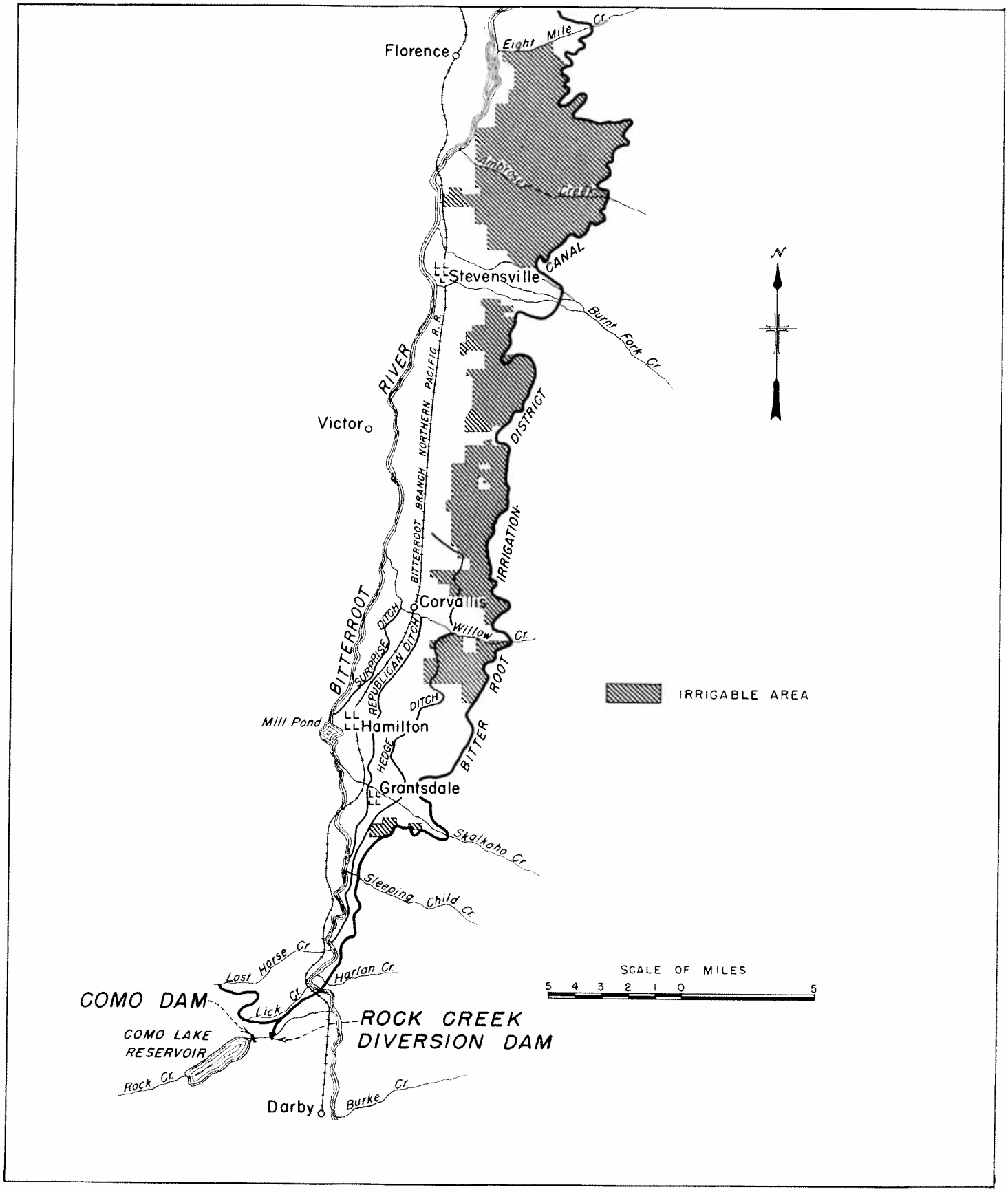

Figure 1. - Lake Como location map - Bitter Root Project.

Space intentionally left blank due to security concerns

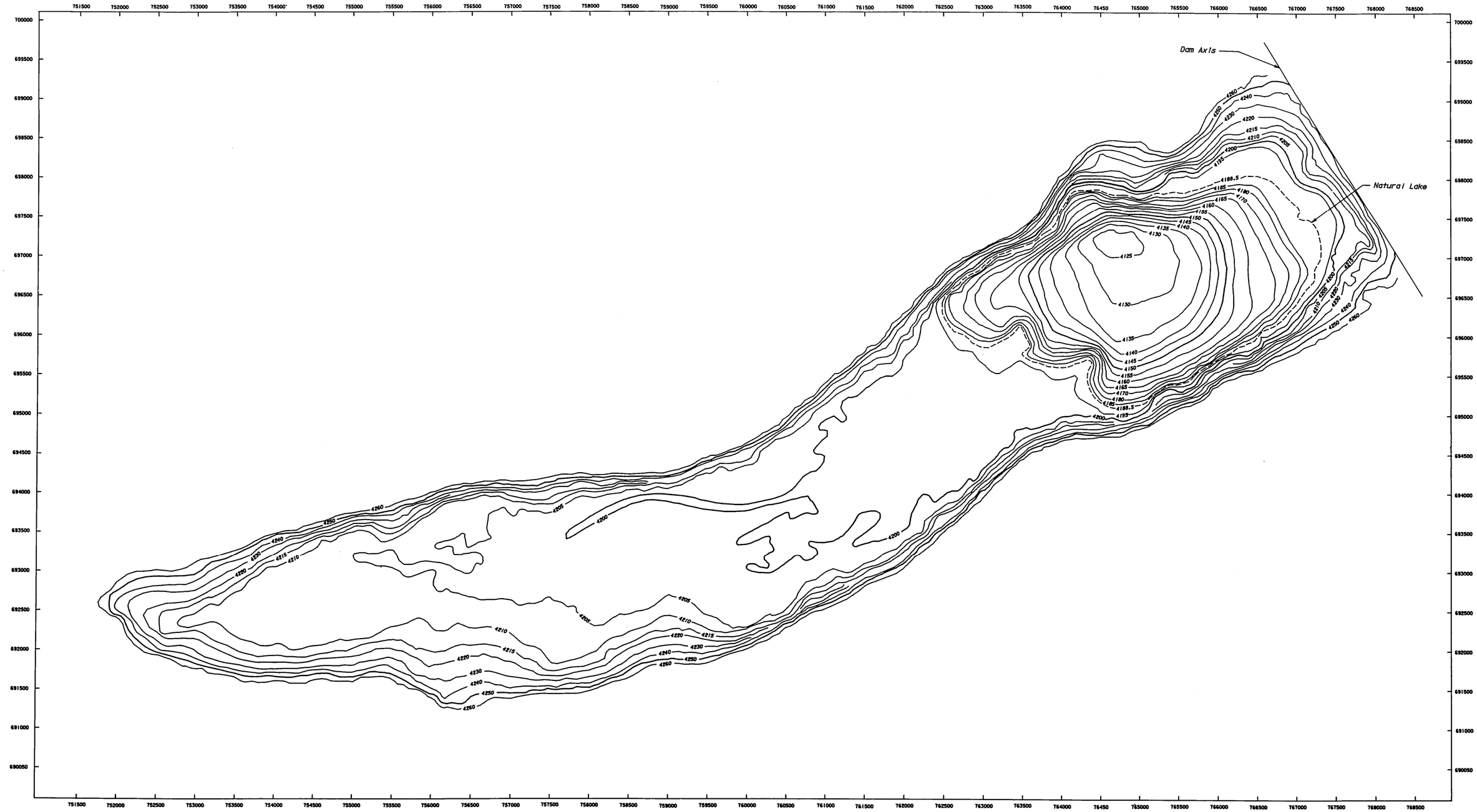

Figure 3. - Lake Como topographic map - drawing 82-D-178.

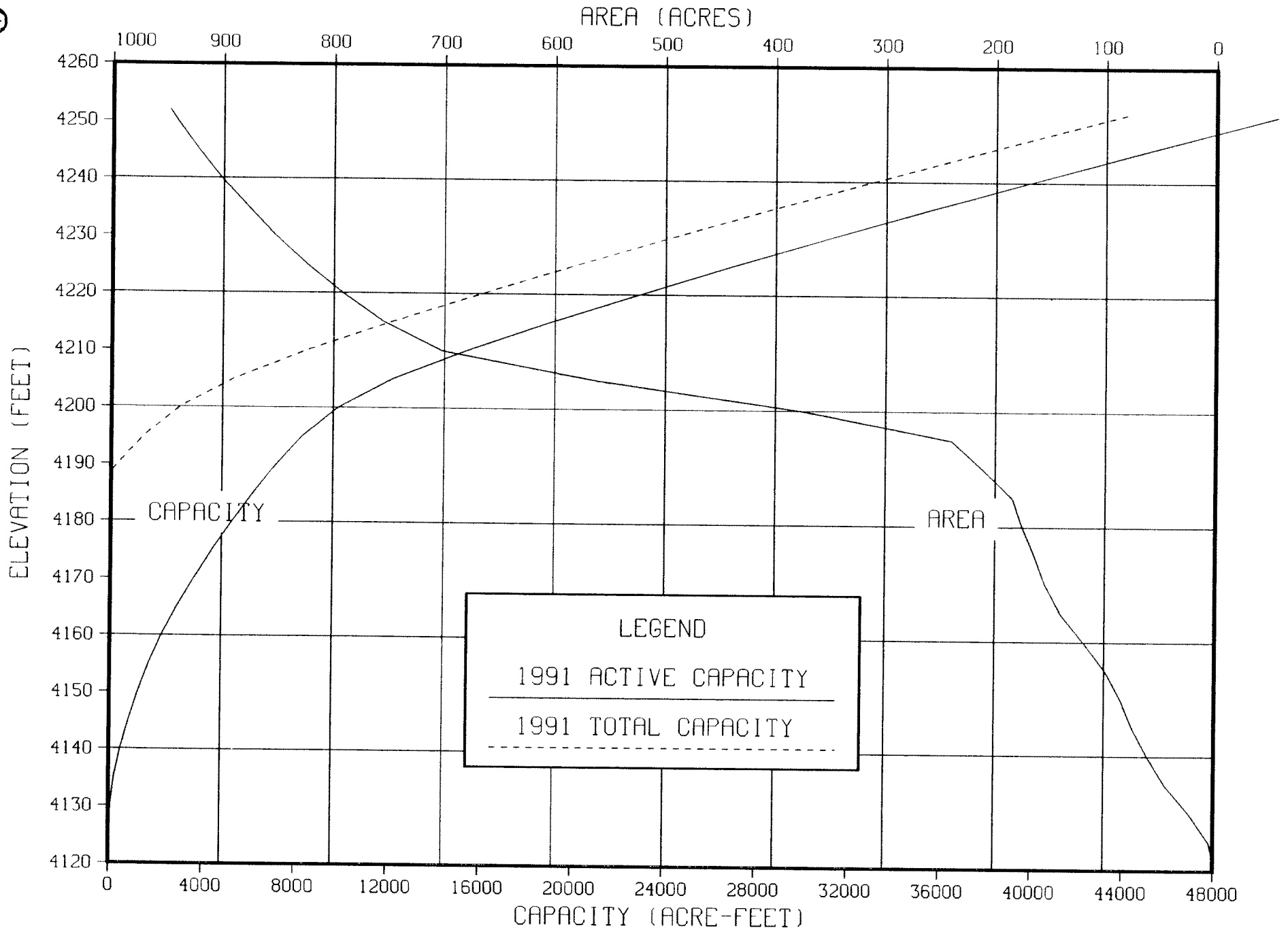

Figure 4. - Area and capacity curves - Lake Como, 1991.

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