RECLAMATION

Managing Water in the West

Lake Sherburne 2002 Survey

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Bureau of Reclamation
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13. ABSTRACT *(Maximum 200 words)*

The Bureau of Reclamation (Reclamation) surveyed Lake Sherburne in July of 2002 to develop a topographic map and compute a present storage-elevation relationship (area-capacity tables). The underwater survey was conducted near lake elevation 4,786 feet (project datum). The underwater survey used sonic depth recording equipment interfaced with a global positioning system (GPS) that gave continuous sounding positions throughout the underwater portions of the reservoir covered by the survey vessel. The above-water topography was determined by digitizing a developed reservoir contour line from the U.S. Geological Survey quadrangle (USGS quad) map of the reservoir area. The new topographic map of Lake Sherburne was developed from the combined digitized contours and July 2002 underwater measured topography. This study assumed no change since the 1983 survey from elevation 4,790 (feet) and above.

As of July 2002, at maximum water surface elevation 4,810.0, the surface area was 2,163 acres with a total capacity of 108,980 acre-feet. Since initial survey results in 1948, about 343 acre-feet of change have been measured below conservation elevation 4,788.0. Since the 1983 survey, about 1,707 acre-feet of change was measured at elevation 4,788.0. It is assumed the majority of the calculated differences are due to the methods of the surveys and vertical datum differences. It must be noted that the 2002 survey was conducted with a fairly stable survey vessel, but at times in rough water conditions.

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Lake Sherburne 2002 Survey

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Reclamation's Sedimentation and River Hydraulics Group of the Technical Service Center (TSC) prepared and published this report. Ronald Ferrari of the TSC conducted the underwater data collection and completed the data processing needed to generate the new topographic map, area-capacity tables and report. Kent Collins of the TSC performed the technical peer review of this documentation.

UNITED STATES DEPARTMENT OF THE INTERIOR

The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian tribes and our commitments to island communities.

BUREAU OF RECLAMATION

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.

CONTENTS

TABLES

Table

FIGURES

Figure

INTRODUCTION

Lake Sherburne Dam and Reservoir on Swiftcurrent Creek in Glacier County is about 5 miles southwest of Babb in northwest Montana (figure 1). The reservoir was formed on a natural lake and began storage behind the dam in 1919. The dam, reservoir, and facilities are part of the Milk River Project in north-central Montana that furnishes water for the irrigation of about 121,000 acres of land. Additional features include Nelson and Fresno storage dams, diversion dams, a pumping plant, canals, and laterals. Lake Sherburne Dam and Reservoir are operated and maintained by Reclamation and all water supply and distribution works are operated and maintained by the irrigation districts.

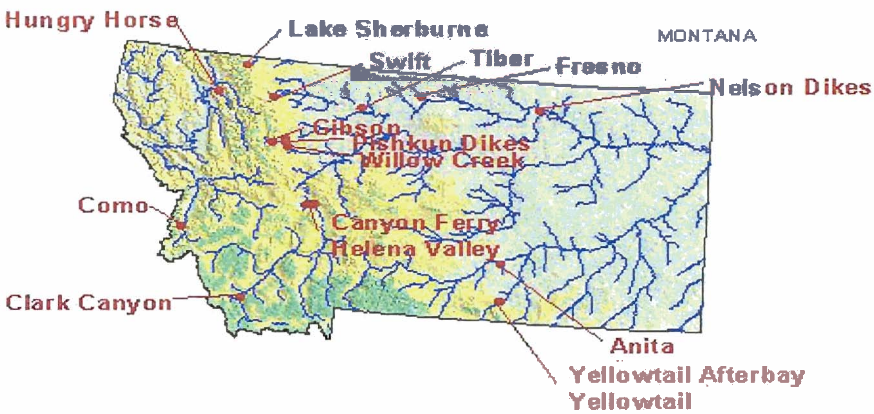

Figure 1 – Lake Sherburne location map.

Lake Sherburne Dam was initially constructed from 1914 through 1921 with a crest elevation of 4,803.0 feet and raised 13.5 feet in 1982. The dam is a compacted earthfill structure whose dimensions are:

Hydraulic height[1]	95	feet	Structural height	108.5	feet
Top width	24	feet	Crest length	1,200	feet
Crest elevation	4,816.5	feet[2]			

The spillway is a morning-glory structure around the outlet works tower where water flows over the crest, elevation 4,788.0, and through the tower into the outlet works conduit at the base of the tower. The outlet works, located under the right center portion of the dam, consists of the intake tower, trashracks, regulating gates, and riprap-lined outlet channel. The outlet discharge capacity

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[1]The definition of such terms as "hydraulic height," "structural 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.*

[2]Elevation in feet. All elevations shown in this report are based on the original project datum established by U.S. Bureau of Reclamation that was found to be 9.45 feet lower than the National Geodetic Vertical Datum of 1929 (NGVD29) and 13.75 feet lower than the North American Vertical Datum of 1988 (NAVD88).

is 2,100 cubic feet per second (cfs) at spillway crest reservoir elevation 4,788.0. The maximum combined discharge capacity of the spillway and outlet works at maximum reservoir elevation 4,810.0 is 4,000 cfs.

The drainage area above Sherburne Dam is 63.7 square miles and the basin elevations range over 9,000 feet on the Continental Divide. The basin perimeter is steep bedrock slopes and the lower elevations are timber-covered valleys. For this study, the majority of the basin is considered non-sediment contributing due to the upstream lakes located on Swiftcurrent Creek. Lake Sherburne is around 6.4 miles in length and around 0.5 miles in width.

SUMMARY AND CONCLUSIONS

This Reclamation report presents the 2002 results of the survey of Lake Sherburne. The primary objectives of the survey were to gather data needed to:

- develop reservoir topography
- compute area-capacity relationships

A Real-time Kinematic (RTK) GPS control survey was conducted to establish a temporary horizontal and vertical control point near where the boat was launched for the reservoir survey. The RTK GPS control survey was conducted with the base set on the National Geodetic Survey (NGS) datum point "Sherburne 1" located downstream of the dam on the outlet structure. The horizontal control was established in the Montana state plane coordinate zone in the North American Datum of 1983 (NAD83) and the vertical control was tied to the North American Vertical Datum of 1988 (NAVD88) and the Reclamation project datum. All elevations in this report are referenced to the Reclamation project or construction datum. A previous Reclamation regional survey determined the project datum was 13.75 feet lower than the NAVD88 and 9.45 feet lower than the NGVD29.

The underwater survey was conducted in July of 2002 near reservoir water surface elevation 4,786. The bathymetric survey used sonic depth recording equipment interfaced with RTK GPS making it capable of determining sounding locations within the reservoir. The system continuously recorded depth and horizontal coordinates of the survey boat as it navigated along grid lines covering Lake Sherburne. The positioning system provided information to allow the boat operator to maintain a course along these grid lines. Water surface elevations recorded by the reservoir gauge (tied to the Reclamation vertical datum) during the time of collection were used to convert the sonic depth measurements to true reservoir bottom elevations. The above-water topography was determined by digitizing a developed contour line from the U.S. Geological Survey quadrangle (USGS quad) maps of the reservoir area.

The 2002 Lake Sherburne map is a combination of the USGS quad contour and the underwater survey data. A computer graphics program using the collected reservoir data generated the 2002 reservoir surface areas at predetermined contour intervals. The 2002 area and capacity tables were produced by a computer program that uses measured contour surface areas and a curve-fitting technique to compute area and capacity at prescribed elevation increments (Bureau of Reclamation, 1985).

Tables 1 and 2 contain summaries of the Lake Sherburne and watershed characteristics for the 2002 survey. The 2002 survey determined that the reservoir has a total storage capacity of 66,147 acre-feet and a surface area of 1,719 acres at active conservation elevation 4,788.0. Since the 1983 survey, the 2002 survey estimates a volume difference of 1,707 acre-feet below reservoir elevation 4,788.0. Since the 1948 survey results, the 2002 survey estimates a volume difference of 343 acre-feet below reservoir 4,788.0. It is assumed the majority of the calculated differences are due to the method of the surveys and different vertical datums.

RESERVOIR OPERATIONS

Lake Sherburne is part of the Milk River Project that includes Fresno and Nelson Reservoirs and supplies water for irrigating 121,000 acres of land in north-central Montana. The July 2002 capacity table shows 108,980 acre-feet of total storage below the maximum water surface elevation 4,810.0. The 2002 survey measured a minimum lake bottom elevation of 4,719.8. The following values are from the July 2002 capacity table:

- 42,833 acre-feet of surcharge elevation 4,788.0 and 4,810.0.
- 64,248 acre-feet of conservation use between elevation 4,729.3 and 4,788.0.
- 1,899 acre-foot of dead storage below 4,729.3.

Lake Sherburne readily available inflow and end-of-month stage records in table 1, operation period 1955 through 2002, show the calculated inflow and annual fluctuation for these years of operation. The computed average inflow into the reservoir for these years was 142,700 acre-feet per year. The maximum-recorded elevation was 4,788.3 in 1986 and 1990 with minimum-recorded 4,730.5 in 1999.

HYDROGRAPHIC SURVEY EQUIPMENT AND METHOD

The hydrographic survey equipment was mounted in a large aluminum vessel equipped with an outboard motor supplied by the Tiber Reservoir operation office. The hydrographic system included a GPS receiver with a built-in radio, a depth sounder, a helmsman display for navigation, a computer, and hydrographic system software for collecting the underwater data. The shore equipment included a second GPS receiver with an external radio. The GPS receiver and antenna were mounted on a survey tripod over a known datum point. Batteries supplied power to all the equipment.

The Sedimentation and River Hydraulics Group uses RTK GPS with the major benefit being precise heights measured in real time to monitor water surface elevation changes. The basic outputs from an RTK receiver are precise 3D coordinates in latitude, longitude, and height with accuracies on the order of two centimeters horizontally and three centimeters vertically. The output is on the GPS datum of WGS-84 that the hydrographic collection software converted into Montana's NAD83 state plane coordinate system. The RTK GPS system employs two receivers that track the same satellites simultaneously just like with differential GPS.

Lake Sherburne hydrographic survey was conducted on July 23 through 25 of 2002 near water surface elevation 4,786 (Reclamation project datum). The bathymetric survey was run using sonic depth recording equipment, interfaced with an RTK GPS, capable of determining sounding locations within the reservoir. The survey system software continuously recorded reservoir depths and horizontal coordinates as the survey boat moved across closely spaced grid lines covering the reservoir area. Most of the transects (grid lines) were run in a north-south alignment on the reservoir at around 200-foot spacing. The detail of collection in the lower portion of the reservoir was affected by afternoon high wind conditions and survey vessel problems. Data was also collected along the shore as the boat traversed between transects. The survey vessel's guidance system gave directions to the boat operator to assist in maintaining the course along these predetermined lines. During each run, the depth and position data were recorded on the notebook computer hard drive for subsequent processing.

Lake Sherburne Datum

A previous control survey determined that the Reclamation project datum is 13.75 feet lower than NAVD88 and 9.45 feet lower than NGVD29. All elevations in this report are tied to the Reclamation water surface elevations measured by the Reclamation gauge during the time of the July 2002 collection.

RESERVOIR AREA AND CAPACITY

Topography Development

The topography of Lake Sherburne was developed from the 2002 collected underwater and a digitized contour from the USGS quad maps. The digitized USGS contour line was the Lake Sherburne water surface that was labeled with an elevation of 4,788. The USGS quad maps were developed from aerial photography dated 1966. This study found the enclosed digitized contour area to correspond the 1983 surface area at elevation 4,788.2. ARC/INFO geographic information system software was used to digitize the USGS quad contour. The digitized contour was transformed to Montana's NAD 1983 state plane coordinates using the ARC/INFO PROJECT command.

The mapping was completed using ArcGIS version 8.3. Using ArcMap, the underwater data points and digitized contour line developed a triangular irregular network (TIN) of Lake Sherburne such that interpolation was not allowed to occur outside the enclosed polygon. This contour was selected since it was the only available data to represent the reservoir water surface at the time the survey was conducted (near reservoir elevation 4,786). Using ArcMap, the underwater collected data and digitized contour from the quad maps were plotted. The plot showed that the underwater data did not lie completely within this clip and required small modifications along the shoreline to include the entire underwater data set. Using edit commands the vertices of the clip were shifted to fit all the collected underwater data. The clip was assigned an elevation of 4,788.2 to reflect the 1983 surface area of the new polygon.

Contours for the reservoir below elevation 4,788.2 were computed from the underwater data set using the triangular irregular network (TIN) surface-modeling package within ARC/INFO. A

TIN is a set of adjacent non-overlapping triangles computed from irregularly spaced points with x,y coordinates and z values. TIN was designed to deal with continuous data such as elevations. The TIN software uses a method known as Delaunay's criteria for triangulation where triangles are formed among all data points within the polygon clip. The method requires that a circle drawn through the three nodes of a triangle will contain no other point, meaning that sample points are connected to their nearest neighbors to form triangles using all collected data. This method preserves all collected survey points. Elevation contours are then interpolated along the triangle elements. The TIN method is discussed in greater detail in the ARC/INFO V7.0.2 *Users Documentation,* (ESRI, 1992).

The linear interpolation option of ArcMap was used to interpolate contours from the Lake Sherburne TIN. In addition, the contours were generalized by filtering out vertices along the contours. This generalization process improved the presentability of the resulting contours by removing very small variations in the contour lines. This generalization had no bearing on the computation of surface areas and volumes for Lake Sherburne since the areas were calculated from the developed TIN. The areas of the enclosed contour polygons at two-foot increments were developed from the survey data for elevations 4,720.0 through 4,788.0. The 2002 study assumed no change in area since the 1983 survey for elevation 4,790.0 and above. The contour topography at 5-foot intervals is presented on figure 2.

Development of 2002 Contour Areas

The 2002 contour surface areas for Lake Sherburne were computed at 2-foot increments from elevation 4,720.0 to 4,788.0. The 2002 underwater survey measured a minimum reservoir bottom elevation of 4,719.8. These calculations were performed using the ARC/INFO VOLUME command. This command computes areas at user-specified elevations directly from the TIN and takes into consideration all regions of equal elevation. As indicated above, the 2002 underwater survey data was collected near reservoir elevation 4,786. For the purpose of this study, the measured 2002 survey areas at 2-foot increments from elevation 4,720.0 through 4,788.0 were used to compute the new area and capacity tables. The measured 5-foot surface areas from the 1983 survey for elevations 4,790.0 through 4,810.0 were used to complete the 2002 table. The 2002 study assumed no change since the 1983 survey from elevation 4,790.0 and above. It must be noted that the 1983 survey determined a control error from the 1972 survey results from elevation 4,785.0 and above.

2002 Storage Capacity

The storage-elevation relationships based on the measured surface areas were developed using the area-capacity computer program ACAP85 (Bureau of Reclamation, 1985). The 2002 surveyed surface areas at 2-foot contour intervals from reservoir elevation 4,720.0 to elevation 4,788.0 were used as the control parameters for computing the 2002 Lake Sherburne capacity. Since this study did not collect above water data, the 1983 survey 5-foot surface areas from elevation 4,790.0 to 4,810.0 were used to complete the area and capacity table.

The ACAP85 program can compute an area and capacity at elevation increments 0.01- to 1.0-foot by linear interpolation between the given contour surface areas. The program begins by testing the initial capacity equation over successive intervals to ensure that the equation fits within an allowable error limit. The error limit was set at 0.000001 for Lake Sherburne. The 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 a basic area curve over that interval) is utilized until it exceeds the error limit. Thus, the capacity curve is defined by a series of curves, each fitting a certain region of data. By differentiating the capacity equations, which are of second order polynomial form, the final area equations are derived:

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

where:

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

Results of the Lake Sherburne area and capacity computations are listed in table 1 and columns 8 and 9 of table 2. On table 2, columns 2 and 3 list the 1948 surface areas and capacity values. A separate set of 2002 area and capacity tables has been published for the 0.01, 0.1 and 1-foot elevation increments (Bureau of Reclamation, July 2002). A description of the computations and coefficients output from the ACAP85 program is included with these tables. Both the original and 2002 area-capacity curves are plotted on figure 3. As of July 2002, at elevation 4,810.0, the surface area was 2,163 acres with a total capacity of 108,980 acre-feet.

RESERVOIR SURVEY ANALYSES

Figure 3 is a plot of Lake Sherburne 1948, 1972, 1983 surface area and capacity versus the 2002 measured surface area and capacity that illustrates the differences between all the surveys. Since Lake Sherburne closure in 1919, the measured total volume change at reservoir elevation 4,788.0 was estimated to be 343 acre-feet between the 1948 and 2002 surveys and 1,707 acre-feet between 1983 and 2002 surveys. Due to the upstream lakes, the loss due to sediment deposition in Lake Sherburne should be minimal so it is assumed the volume differences between the surveys are due to the different survey methods and the differences in the vertical datums.

For the 2002 analysis, there was little detailed history on the previous surveys of Lake Sherburne. On drawing number 15-600-95, it is noted the 1972 survey was a joint venture between Reclamation and Canada where the lake was surveyed up to elevation 4,803. In 1980 and 1981, Reclamation completed the survey of the reservoir from elevation 4,803 through elevation 4,810. The drawing also notes that the 1972 curves were adjusted from elevation 4,785 and above when a 1983 survey determined there was a survey control error. It must be noted that the 2002 area and capacity tables were generated assuming no change in the 1983 surface area values from elevation 4,790 and above which in all probability is not the case, but was the best information available to complete the 2002 area and capacity calculations.

A resurvey of Lake Sherburne should be considered in the future if a better understanding of the total volume is needed and if the resurvey consists of both above and below water collection.

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RESERVOIR SEDIMENT
DATA SUMMARY

Lake Sherburne
NAME OF RESERVOIR

1
DATA SHEET NO.

DAM	1. OWNER Bureau of Reclamation	2. STREAM Swiftcurrent Creek	3. STATE Montana
	4. SEC. 35 TWP. 36 N RANGE 15 W	5. NEAREST P.O. Babb	6. COUNTY Glacier
	7. LAT 48 49' 42" LONG 113 21' 16"	8. TOP OF DAM Elevation 4,816.5[1]	9. SPILLWAY CREST EL 4,788.0[2]

RESERVOIR	10. STORAGE ALLOCATION	11. ELEVATION TOP OF POOL	12. 2002 SURFACE AREA, AC	13. 2002 CAPACITY, AF	14. GROSS STORAGE ACRE-FEET	15. DATE STORAGE BEGAN
	a. SURCHARGE	4,810.0[3]	2,163	42,833	108,980	
	b. FLOOD CONTROL					1919
	c. POWER					
	d. JOINT USE					16. DATE NORMAL OPERATION BEGAN
	e. CONSERVATION	4,788.0	1,719	65,338	66,147	
	f. INACTIVE					
	g. DEAD	4,729.3	444	1,899	1,899	1919
	17. LENGTH OF RESERVOIR 6.4 MILES			AVG. WIDTH OF RESERVOIR 0.5 MILES		

BASIN	18. TOTAL DRAINAGE AREA 63.7 SQUARE MILES		22. MEAN ANNUAL PRECIPITATION 13[4] INCHES
	19. NET SEDIMENT CONTRIBUTING AREA 25[5] SQUARE MILES		23. MEAN ANNUAL RUNOFF 41.7[6] INCHES
	20. LENGTH MILES	AV. WIDTH	24. MEAN ANNUAL RUNOFF 142,700[7] ACRE-FEET
	21. MAX. ELEVATION	MIN. ELEVATION	25. ANNUAL TEMP. MEAN 42°F RANGE -56°F to 109°F[4]

SURVEY DATA	26. DATE OF SURVEY	27. PER.	28. ACCL	29. TYPE OF SURVEY	30. NO. OF RANGES OR	31. SURFACE AREA, AC.	32. CAPACITY ACRE-FEET	33. C/I RATIO
	1919							
	1948					1,730	66,490	
	1972					1,601	67,604	
	1983					1,718	67,854	
	7/02			Contour (D)	2-ft	1,719[8]	66,147[8]	0.46

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
7/02		142,700[7]	209,800	6,850,000	142,700	6,850,000

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.
7/02	10					

26. DATE OF SURVEY	39. AV. DRY WT. (#/FT³)	40. SED. DEP. TONS/MI.²-YR.		41. STORAGE LOSS, PCT.		42.	
		a. PERIOD	b. TOTAL TO	a. AV.	b. TOTAL TO	a.	b.
7/02				10	10		

26. DATE OF SURVEY	43. DEPTH DESIGNATION RANGE BY RESERVOIR 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[8]

YEAR	MAX. ELEV.	MIN. ELEV.	INFLOW, AF	YEAR	MAX. ELEV.	MIN. ELEV.	INFLOW, AF
1954	4,783.9	4,732.5		1955	4,783.3	4,732.4	165,100
1956	4,785.0	4,733.3	72,600	1957	4,781.5	4,734.6	136,000
1958	4,785.6	4,734.6	134,100	1959	4,784.8	4,739.8	184,200
1960	4,782.7	4,732.2	137,200	1961	4,787.3	4,731.2	147,400
1962	4,772.0	4,731.2	126,100	1963	4,783.0	4,733.1	152,700
1964	4,784.4	4,731.1	181,600	1965	4,786.1	4,737.7	160,700
1966	4,785.5	4,730.9	117,700	1967	4,784.9	4,730.9	155,400
1968	4,784.5	4,732.4	140,000	1969	4,787.1	4,731.7	138,600
1970	4,787.0	4,731.7	142,700	1971	4,787.9	4,736.6	168,900
1972	4,787.2	4,738.3	192,800	1973	4,779.4	4,733.2	111,100
1974	4,787.5	4,739.4	209,800	1975	4,787.1	4,735.4	180,100
1976	4,786.7	4,735.4	176,200	1977	4,753.7	4,736.1	92,000
1978	4,787.8	4,742.5	163,200	1979	4,781.2	4,735.0	120,000
1980	4,787.9	4,735.0	130,900	1981	4,787.8	4,731.7	158,700
1982	4,768.7	4,731.7	149,000	1983	4,769.9	4,735.3	119,900
1984	4,773.1	4,739.6	127,100	1985	4,783.2	4,732.1	134,700
1986	4,788.3	4,736.6	157,600	1987	4,788.2	4,754.5	132,500
1988	4,771.1	4,730.6	98,800	1989	4,787.6	4,735.4	167,100
1990	4,788.3	4,733.1	155,900	1991	4,788.2	4,744.5	197,500
1992	4,765.4	4,731.3	96,000	1993	4,782.1	4,746.5	117,300
1994	4,787.8	4,732.1	108,300	1995	4,787.2	4,734.1	152,800
1996	4,787.8	4,747.8	177,600	1997	4,787.8	4,746.3	160,500
1998	4,787.7	4,735.1	114,200	1999	4,787.8	4,730.5	140,600
2000	4,773.6	4,732.6	133,500	2001	4,763.4	4,730.9	95,700
2002	4,787.3	4,732.9	175,600				

46. ELEVATION - AREA - CAPACITY DATA FOR **2002 CAPACITY**[11]

ELEVATION	AREA	CAPACITY	ELEVATION	AREA	CAPACITY	ELEVATION	AREA	CAPACITY
4,719.8	0	0	4,720	0	0	4,722	75	75
4,724	161	310	4,728	378	1,365	4,729.3	444	1,899
4,730	481	2,223	4,732	545	3,249	4,734	612	4,405
4,736	661	5,678	4,738	707	7,046	4,740	742	8,494
4,742	779	10,015	4,744	820	11,614	4,746	856	13,291
4,748	893	15,040	4,750	926	16,858	4,752	958	18,742
4,754	994	20,694	4,756	1,031	22,719	4,758	1,063	24,812
4,760	1,097	26,973	4,762	1,127	29,197	4,764	1,159	31,483
4,766	1,191	33,833	4,768	1,224	36,248	4,770	1,264	38,736
4,772	1,348	41,348	4,774	1,409	44,105	4,776	1,463	46,976
4,778	1,513	49,952	4,780	1,556	53,020	4,782	1,600	56,176
4,784	1,643	59,419	4,682	1,682	62,745	4,788	1,719	66,147
4,790	1,762	69,628	4,795	1,817	78,711	4,800	1,970	88,313
4,803	2,028	94,310	4,810	2,163	108,980			

47. REMARKS AND REFERENCES

1 All elevations are in feet and based on the original project datum established by Reclamation that were found to be 13.75 feet lower than the NAVD88 and 9.45 feet lower than the NGVD29. Original top of dam elevation 4,803.0. Raised 13.5 feet in 1982.
2 Uncontrolled morning-glory overflow spillway.
3 2002 values. Dam raised in 1982. Uncertainties in original values.
4 Bureau of Reclamation Project Data Book, 1981. Values for Milk River Project.
5 Several lakes and ponds upstream of Lake Sherburne. Estimated they control 60% of sediment inflow.
6 Calculated using mean annual runoff value of 142,700 AF, item 24, 1952 through 2002. (See remark #6).
7 Annual computed inflows by water year, from 1955 through 2002.
8 Surface area & capacity at elevation 4,788.0, top of active conservation.
9 Annual computed inflows by water year, from 1955 through 2002 (Available records). Maximum and minimum elevations from available Reclamation records by water year.
10 2002 survey assume no change from elevation 4,788 and above since 1983 survey. Storage difference from previous surveys due to accuracy differences of surveys. Due to upstream lakes the loss due to sediment inflow from basin is reduced.
11 Capacities computed by Reclamation's ACAP computer program.

48. AGENCY MAKING SURVEY Bureau of Reclamation

49. AGENCY SUPPLYING DATA Bureau of Reclamation | DATE September 2005

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

1	2	3	4	5	6	7	8	9	10	11	12	13	14
									Area	Volume	Area	Volume	
									Diff.	Diff.	Diff.	Diff.	
Elev	1948	1948	1972	1972	1983	1983	2002	2002	1983-	1983-	1948-	1948-	
	Area	Cap.	Area	Cap.	Area	Cap.	Area	Cap.	2002	2002	2002	2002	%
Feet	Acre	Ac-Ft	Acre	Ac-Ft	Acre	Ac-Ft	Acre	Ac-Ft	Acre	Ac-Ft	Acre	Ac-Ft	Depth
4,810					2,163	110,679	2,163	108,980	0	1,699			100.0
4,803			1,700	92,438	2,028	96,010	2,028	94,310	0	1,700			92.4
4,800			1,693	87,369	1,970	90,012	1,970	88,313	0	1,699			89.1
4,795			1,655	79,000	1,871	80,414	1,871	78,711	0	1,703			83.7
4,793	1,860	75,435	1,639	75,706	1,827	76,707	1,827	75,012	0	1,695	33	423	81.5
4,790	1,770	69,990	1,617	70,822	1,762	71,334	1,762	69,628	0	1,706	8	362	78.3
4,788	1,730	66,490	1,601	67,604	1,718	67,854	1,719	66,147	-1	1,707	11	343	76.1
4,786	1,700	63,060	1,586	64,417	1,649	64,483	1,682	62,745	-33	1,738	18	315	73.9
4,782	1,610	56,430	1,536	58,161	1,535	58,162	1,600	56,176	-65	1,986	10	254	69.6
4,780	1,560	53,260	1,500	55,125	1,506	55,130	1,556	53,020	-50	2,110	4	240	67.4
4,778	1,510	50,190	1,464	52,160	1,466	52,158	1,513	49,952	-47	2,206	-3	238	65.2
4,776	1,460	47,220	1,428	49,267	1,427	49,265	1,463	46,976	-36	2,289	-3	244	63.0
4,772	1,340	41,600	1,332	43,726	1,337	43,727	1,348	41,348	-11	2,379	-8	252	58.7
4,770	1,280	38,980	1,270	41,124	1,268	41,122	1,264	38,736	4	2,386	16	244	56.5
4,768	1,230	36,470	1,212	38,651	1,214	38,650	1,224	36,248	-10	2,402	6	222	54.3
4,766	1,180	34,060	1,186	36,252	1,186	36,250	1,191	33,833	-5	2,417	-11	227	52.2
4,762	1,120	29,460	1,134	31,612	1,136	31,613	1,127	29,197	9	2,416	-7	263	47.8
4,760	1,100	27,240	1,108	29,371	1,107	29,369	1,097	26,973	10	2,396	3	267	45.7
4,758	1,070	25,070	1,081	27,182	1,079	27,183	1,063	24,812	16	2,371	7	258	43.5
4,756	1,040	22,960	1,049	25,052	1,050	25,054	1,031	22,719	20	2,335	10	241	41.3
4,752	970	18,950	984	20,987	984	20,986	958	18,742	26	2,244	12	208	37.0
4,750	930	17,050	952	19,051	952	19,051	926	16,858	26	2,193	4	192	34.8
4,748	890	15,230	922	17,178	924	17,179	893	15,040	31	2,139	-3	190	32.6
4,746	860	13,480	890	15,365	891	15,365	856	13,291	35	2,074	4	189	30.4
4,742	790	10,190	819	11,935	820	11,935	779	10,015	41	1,920	11	175	26.1
4,740	750	8,650	786	10,330	785	10,330	742	8,494	43	1,836	8	156	23.9
4,738	720	7,180	752	8,793	756	8,795	707	7,046	49	1,749	13	134	21.7
4,736	690	5,770	716	7,323	715	7,324	661	5,678	54	1,646	29	92	19.6
4,732	610	3,150	622	4,634	624	4,635	545	3,249	79	1,386	65	-99	15.2
4,730	530	2,010	565	3,447	563	3,448	481	2,223	83	1,225	50	-213	13.0
4,729.3	492	1,652	542	3,061	541	3,061	444	1,899	97	1,162	48	-247	12.3
4,728	420	1,060	492	2,390	491	2,389	378	1,365	113	1,024	42	-305	10.9
4,726	320	320	393	1,506	390	1,506	258	729	132	777	62	-409	8.7
4,722	0	0	181	374	179	374	75	75	104	299	-75	-75	4.3
4,720	0	0	96	88	105	87	0	0	105	87	0	0	2.2
4,718	0	0	0	0	0	0	0	0	0	0	0	0	0.0

1	Elevation of reservoir water surface.
2	1948 reservoir surface area.
3	1948 calculated reservoir capacity.
4	1972 reservoir surface area.
5	1972 calculated reservoir capacity.
6	1983 reservoir surface area.
7	1983 calculated reservoir capacity.
8	2002 reservoir surface area.
9	2002 calculated reservoir capacity computed using ACAP from original measured surface areas.
10	1983 through 2002 area difference = column (6) - column (8).
11	1983 through 2002 volume difference = column (7) - column (9).
12	1948 through 2002 area difference = column (2) - column (8).
13	1948 through 2002 volume difference = column (3) - column (9).
14	Depth of reservoir expressed in percentage of total depth (92), below spillway crest.

Table 2.- Summary of 2002 survey results.

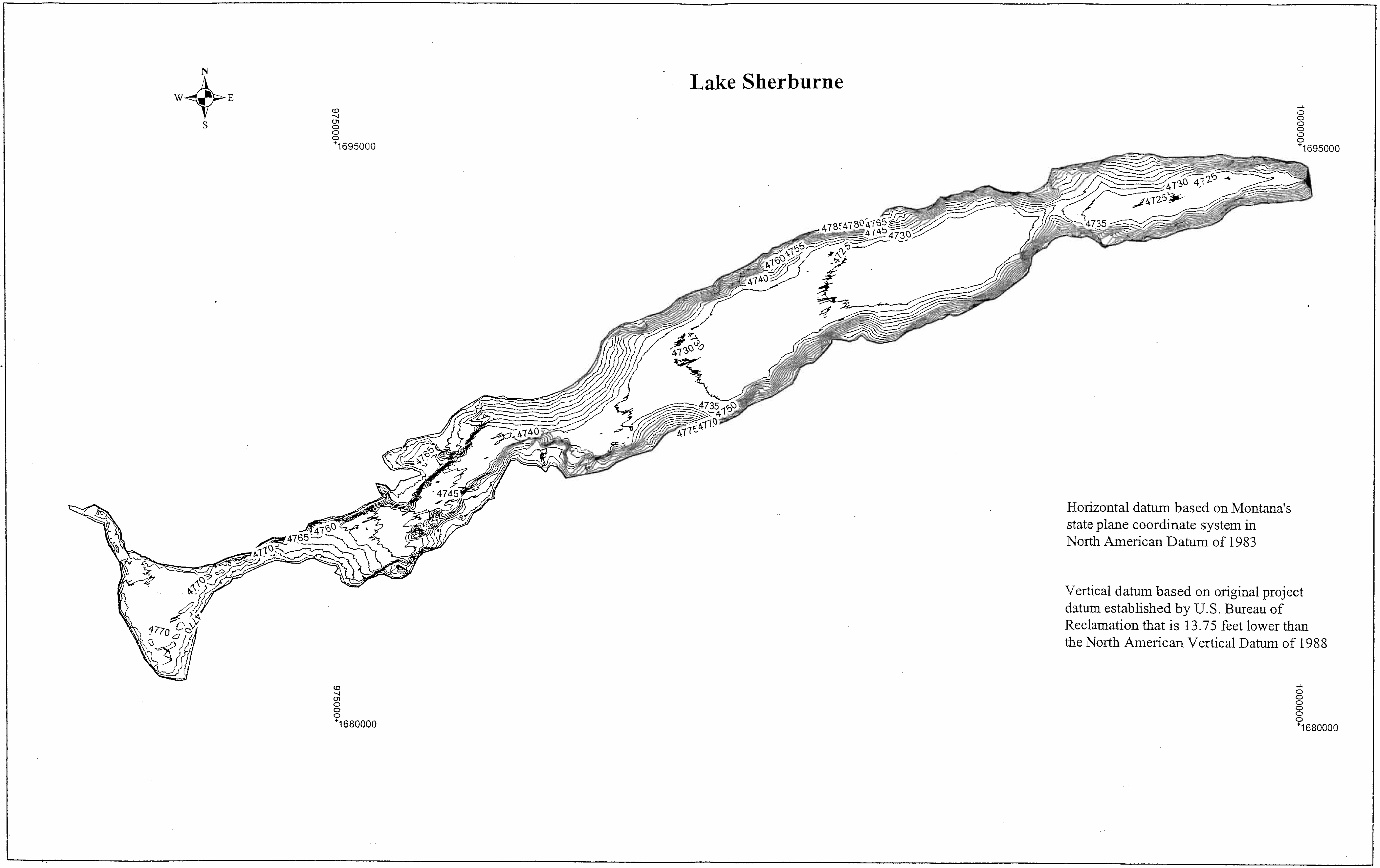

Figure 2. – Lake Sherburne topographic map.

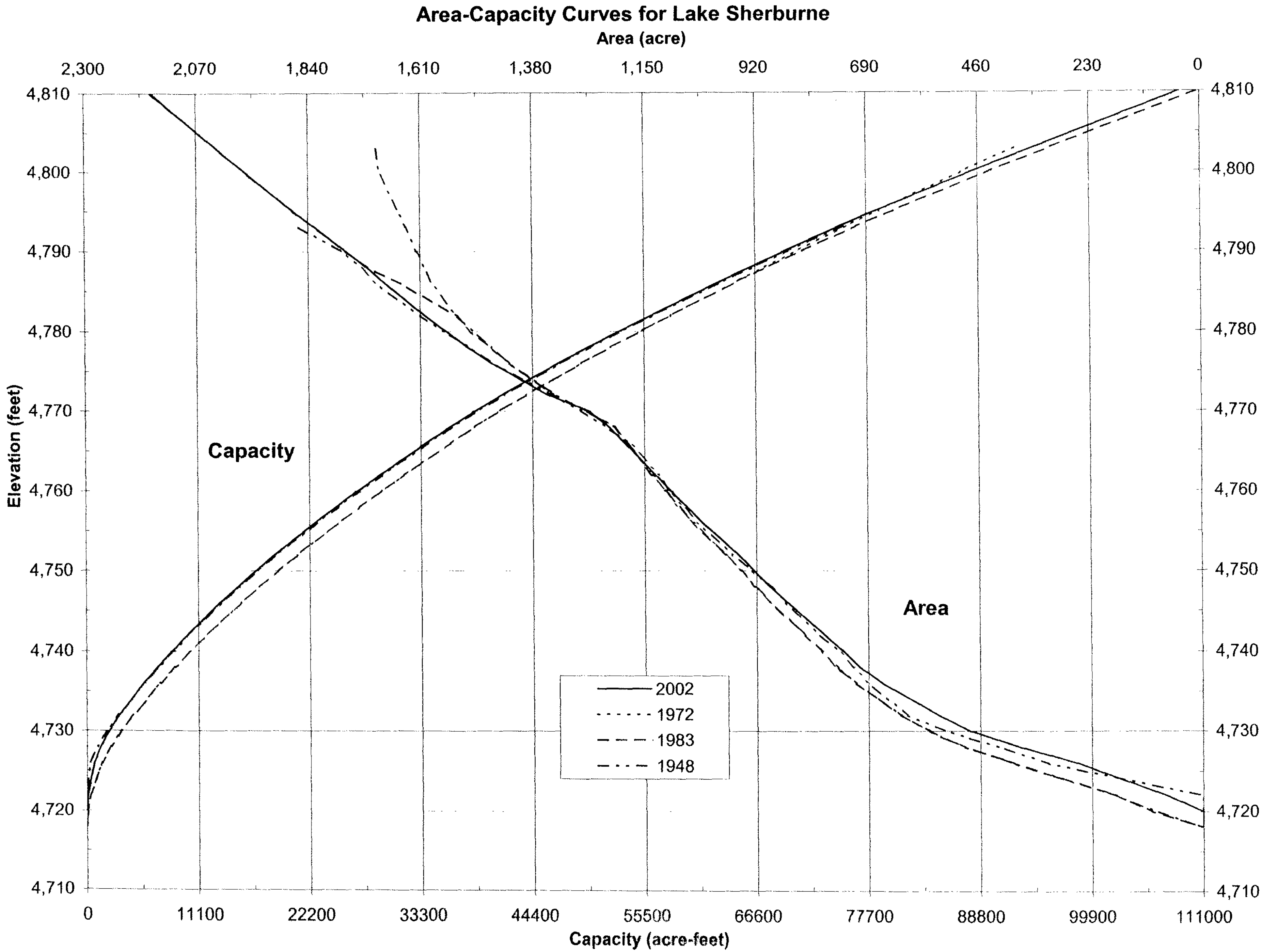

Figure 3. - 2002 area and capacity curves.