RECLAMATION

Managing Water in the West

Willow Creek Reservoir
2002 Survey

U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Denver, Colorado

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13. ABSTRACT *(Maximum 200 words)*

The Bureau of Reclamation surveyed Willow Creek Reservoir in June 2002 to develop new reservoir topography and compute a present storage-elevation relationship (area-capacity tables). The underwater survey, conducted near reservoir elevation 4,141 (project datum), used sonic depth recording equipment interfaced with a real-time kinematic (RTK) global positioning system (GPS) that gave continuous sounding positions throughout the underwater portion of the reservoir covered by the survey vessel. The above-water topography was obtained by digitizing the developed reservoir contour lines from the U.S. Geological Survey quadrangle (USGS quad) map. This study assumed no change, since the original survey, from elevation 4,135 (feet) and above.

As of June 2002, at maximum water surface elevation 4,149.0, the surface area was 1,644 acres with a total capacity of 42,691 acre-feet. Since initial survey in 1905, about 431 acre-feet of change have been measured below elevation 4,144.0, resulting in a 1.2 percent loss in reservoir volume. This calculated change is due to accuracy difference between the two surveys, shoreline erosion of the islands, and sediment inflow.

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Willow Creek Reservoir 2002 Survey

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UNITED STATES DEPARTMENT OF THE INTERIOR

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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

Willow Creek Dam and Reservoir on Willow Creek in Lewis and Clark County is about 15 miles southeast of Gibson Dam and 6 miles northwest of Augusta, Montana (figure 1). The dam, reservoir, and facilities are part of the Sun River Project operated by the Greenfields Irrigation District and supply water to Fort Shaw Irrigation District.

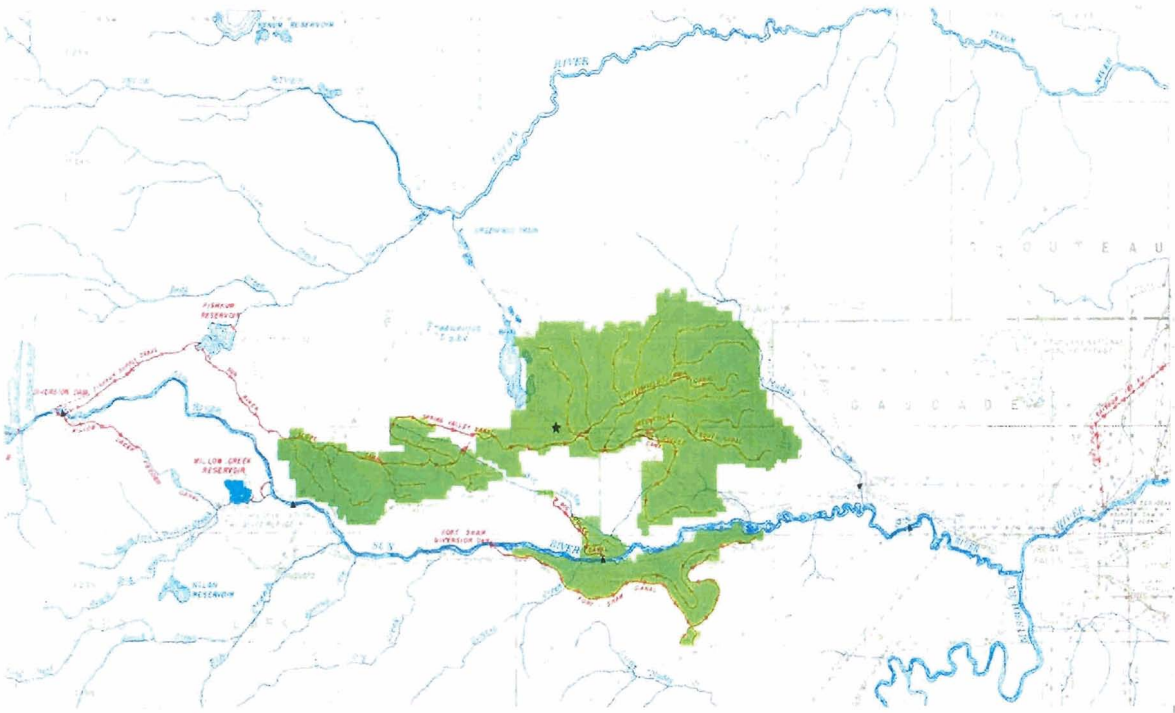

Figure 1 - Willow Creek Reservoir location map.

Willow Creek Dam was initially constructed from 1907 to 1911 and raised 2 feet in 1917. In 1941, the dam (dike 1) was raised an additional 12 feet and three small dikes (named dike 2, dike 4 and dike 5) were constructed about ½ mile northeast of the dam to form the present Willow Creek Reservoir. The dam is a homogeneous earthfill structure whose dimensions are:

Hydraulic height[1]	76 feet	Structural height	93 feet
Top width	30 feet	Crest length	650 feet
Crest elevation	4,154.0 feet[2]		

[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]Elevations in feet. All elevations in report based on the original project datum established by U.S. Bureau of Reclamation. The 2002 survey found Reclamation's datum to be around 3.4 feet less than the National Geodetic Vertical Datum of 1929 (NGVD29) and 6.7 feet less than North American Vertical Datum of 1988 NAVD88.

Dike 5 consists of two wing embankments where an uncontrolled grass lined overflow spillway is located. The spillway crest elevation is 4,144.0 and provides a maximum discharge of 280,800 cubic feet per second (cfs) at reservoir elevation 4,149.0. A river outlet works is located near the right abutment of the dam with a crest elevation of 4,085.28. The outlet capacity is 500 cfs at reservoir water surface elevation 4,142.0.

The drainage area above Willow Creek Dam is 118 square miles and all is considered sediment contributing. In addition to storing water from Willow Creek, the reservoir obtains diverted flows from the Sun River through the Willow Creek Feeder Canal. The lake is around 2.5 miles in length and around 1.1 miles in width.

SUMMARY AND CONCLUSIONS

This Reclamation report presents the 2002 results of the survey of Willow Creek Reservoir. 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 the boat ramp with the base set on the National Geodetic Survey (NGS) datum point "Choteau" that is located near the lake. The horizontal control was established in the Montana state plane coordinate zone in the North American Datum of 1983 (NAD83) and the vertical control tied to NAVD88 and the Reclamation project datum. All elevations in report are referenced to the Reclamation project or construction datum that for this study was found to be around 6.7 feet less than NAVD88 and 3.4 feet less than NGVD29.

The underwater survey was conducted in June of 2002 near reservoir water surface elevation 4,141.0. The bathymetric survey used sonic depth recording equipment interfaced with the 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 was navigated along grid lines covering Willow Creek Reservoir. 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 the developed contour lines from the U.S. Geological Survey quadrangle (USGS quad) maps of the reservoir area.

The 2002 Willow Creek Reservoir topographic map is a combination of the USGS quad contour and the underwater survey data. A computer graphics program generated the 2002 reservoir surface areas at predetermined contour intervals from the collected data. The 2002 area and capacity tables were computed 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 Willow Creek Reservoir and watershed characteristics for the 2002 survey. The 2002 survey determined that the reservoir has a total storage capacity of 34,819 acre-feet and a surface area of 1,509 acres at active conservation elevation 4,144.0. Since closure in 1911, the reservoir had an estimated volume change of 431 acre-feet below reservoir elevation 4,144.0. This volume represents a 1.2 percent change in total capacity at this elevation.

RESERVOIR OPERATIONS

Willow Creek Reservoir is part of the Sun River Project that includes Gibson and Pishkun Reservoirs that supply water for irrigating 91,000 acres of land along the Sun River. The June 2002 capacity table shows 42,691 acre-feet of total storage below the maximum water surface elevation 4,149.0. The 2002 survey measured a minimum lake bottom elevation of 4,084.2. The following values are from the June 2002 capacity table:

- 7,872 acre-feet of surcharge elevation 4,144.0 and 4,149.0.
- 34,818 acre-feet of conservation use between elevation 4,085.3 and 4,144.0.
- 1 acre-foot of dead storage below 4,085.3.

Willow Creek Reservoir available inflow and end-of-month stage records listed on table 1, operation period 1952 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 14,600 acre-feet per year. The maximum-recorded elevation was 4,144.0 on June 22, 1975 and the minimum recorded was no storage on July 31 and August 31 of 1940 (USGS, 2000).

HYDROGRAPHIC SURVEY EQUIPMENT AND METHOD

The hydrographic survey equipment was mounted in the cabin of a 24-foot trihull aluminum vessel equipped with twin in-board motors (figure 2). 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. An on-board generator supplied power to all the equipment. The shore equipment included a second GPS receiver with an external radio powered by a 12-volt battery. The GPS antenna and receiver were mounted on a survey tripod over a known datum point.

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.

Figure 2 - Survey vessel with mounted hydrographic equipment on Jackson Lake in Wyoming

Willow Creek hydrographic survey was conducted on June 16 and 17 of 2002 near water surface elevation 4,141 (Reclamation project datum). The bathymetric survey was conducted 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 somewhat in a northeast alignment on the reservoir at around 200-foot spacing. 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. The underwater data set includes 73,936 data points that are illustrated on figure3.

The 2002 underwater data was collected by a depth sounder that was calibrated by lowering a weighted cable below the boat with beads marking known depths. The depth sounder was calibrated by adjusting the speed of sound, which can vary with density, salinity, temperature, turbidity, and other conditions. The collected data were digitally transmitted to the computer collection system via a RS-232 port. The depth sounder also produces an analog hard-copy chart of the measured depths. These graphed analog charts were printed for all survey lines as the data were collected and recorded by the computer. The charts were analyzed during post-processing, and when the analog charted depths indicated a difference from the recorded computer bottom depths, the computer data files were modified. The water surface elevations at the dam, recorded by a Reclamation gauge, were used to convert the sonic depth measurements to true lake-bottom elevations.

Willow Creek Datum

Upon completion of the underwater survey, a RTK GPS survey was conducted to tie the horizontal and vertical control of the hydrographic survey temporary point and the reservoir water surface to the NGS control point "Choteau". The survey found the horizontal shift of the temporary point to be (-) 16.7 feet north and (+) 6.8 west to match NGS control. The shift was

applied during post processing. The water surface measurement found the NGS vertical of NAVD88 to be around 6.7 feet higher then the Reclamation gauge readings. All vertical information for this study is referenced to the Reclamation reservoir water surface gauge measurements. The 2002 RTK GPS survey determined the Reclamation vertical datum to be around 3.4 feet lower than NGVD29. Note that all elevations in this report are tied to the Reclamation vertical elevations that were measured by the Reclamation gauge during the time of collection. The reported vertical shifts were from this one time RTK GPS survey and should be confirmed by a control survey.

RESERVOIR AREA AND CAPACITY

Topography Development

The topography of Willow Creek Reservoir was developed from the 2002 collected underwater and a digitized contour from the USGS quad map. The digitized USGS contour line was the Willow Creek water surface that was not labeled with an elevation. The USGS quad maps were developed from aerial photography dated 1982. This study found the enclosed digitized contour area with the island surfaces removed to correspond the original surface area at elevation 4,136. ARC/INFO V7.0.2 geographic information system software was used to digitize the USGS quad contour. The digitized contours were transformed to Montana's NAD 1983 state plane coordinates using the ARC/INFO PROJECT command.

The digitized contour line was used to perform a clip of the Willow Creek Reservoir triangular irregular network (TIN) 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 4,141). This clip was performed using the hardclip option of the ARC/INFO CREATETIN command. Using ARCEDIT, 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, which required modifications to include the entire underwater data set. Modified areas included the shoreline around the islands and some of the shoreline of the reservoir. It is assumed these changes were due erosion of the islands and the fact that the 2002 survey was conducted on a nearly full reservoir. Using select and move commands within ARCEDIT, the vertices of the clip were shifted to fit all the collected underwater data. The clip was assigned an elevation of 4,136.0 to reflect the original area of the developed polygons.

Contours for the reservoir below elevation 4,136.0 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 the ARC/INFO TINCONTOUR command was used to interpolate contours from the Willow Creek Reservoir 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 Willow Creek since the areas were calculated from the developed TIN. The areas of the enclosed contour polygons at one-foot increments were developed from the survey data for elevations 4,085.0 through 4,136.0. The 2002 study assumed no change in area since the original survey for elevation 4,135.0 and above. The contour topography at 2-foot intervals is presented on figure 4.

Development of 2002 Contour Areas

The 2002 TIN surface areas for Willow Creek Reservoir were computed at 1-foot increments from elevation 4,085.0 to 4,136.0. The 2002 underwater survey measured a minimum reservoir bottom elevation of 4,084.2. 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 4,141. For the purpose of this study, the measured 2002 survey areas at 2-foot increments from elevation 4,086.0 through 4,130.0 were used to compute the new area and capacity tables. Due to the limited amount of 2002 shallow water data, this study assumed no change in original area from elevation 4,135.0 and above. The area and capacity program computed the areas between elevation 4,130.0 and 4,135.0 by assuming a straight-line interpolation.

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 4,086.0 to elevation 4,130.0 were used as the control parameters for computing the 2002 Willow Creek Reservoir capacity. Since this study did not collect above water data, the original 5-foot surface areas from elevation 4,135.0 to 4,150.0 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 Willow Creek Reservoir. 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 Willow Creek Reservoir area and capacity computations are listed in table 1 and columns 4 and 5 of table 2. On table 2, columns 2 and 3 list the original surface areas and recomputed original capacities. 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 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 5. As of June 2002, at elevation 4,149.0, the surface area was 1,644 acres with a total capacity of 42,691 acre-feet.

RESERVOIR SEDIMENT ANALYSES

Figure 5 is a plot of Willow Creek Reservoir original surface area and capacity versus the 2002 measured surface area and capacity that illustrates the differences between the two surveys. Since Willow Creek Dam closure in 1911, the measured total volume change at reservoir elevation 4,144.0 was estimated to be 431 acre-feet. The estimated average annual rate of capacity lost for this period (91 years) was 4.7 acre-feet per year. The storage loss in terms of percent of original storage capacity was 1.2 percent at elevation 4,144.0. It must be noted that the 2002 area and capacity tables were generated assuming no change in original area and capacity from elevation 4,135.0 and above that in all probability is not the case.

Figure 5 plot and table 2 show the maximum volume change to be 671 acre-feet at elevation 4,115.0. It is assumed that a portion of this material is from island shoreline erosion that redistributed material from the upper reservoir elevations to the lower elevation areas.

A resurvey of Willow Creek Reservoir should be considered in the future if major sediment inflow events are observed. An above water survey should be conducted if better information is needed for elevation 4,135.0 and above. The 2002 survey has shown little change over the 91 years of reservoir operation.

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RESERVOIR SEDIMENT
DATA SUMMARY

Willow Creek Reservoir
NAME OF RESERVOIR

1
DATA SHEET NO.

DAM

1. OWNER Bureau of Reclamation	2. STREAM Willow Creek	3. STATE Montana
4. SEC. 30 TWP. 21 N RANGE 6 W	5. NEAREST P.O. Augusta	6. COUNTY Lewis & Clark
7. LAT 47° 32' 48" LONG 112° 25' 45"	8. TOP OF DAM ELEVATION 4,154.0[2]	9. SPILLWAY CREST EL 4,144.0[2]

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. SURCHARGE	4,149.0[3]	1,644	7,872	43,122	
b. FLOOD CONTROL					
c. POWER					1911
d. JOINT USE					
e. CONSERVATION	4,144.0	1,509	32,187	35,250	16. DATE NORMAL OPERATION BEGAN
f. INACTIVE					
g. DEAD	4,085.3	12	63	63	1911

17. LENGTH OF RESERVOIR 2.5 MILES — AVG. WIDTH OF RESERVOIR 1.1 MILES

BASIN

18. TOTAL DRAINAGE AREA 95	SQUARE	22. MEAN ANNUAL PRECIPITATION 19[4]	INCHES
19. NET SEDIMENT CONTRIBUTING AREA 95	SQUARE	23. MEAN ANNUAL RUNOFF 2.9[5]	INCHES
20. LENGTH MILES	AV. WIDTH	24. MEAN ANNUAL RUNOFF 14,600[6]	ACRE-FEET
21. MAX. ELEVATION	MIN. ELEVATION	25. ANNUAL TEMP. MEAN 45°F RANGE -49°F to 106°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
1911			Contour (D)	5-ft	1,509[3]	35,250[3]	2.41
6/02	91	91	Contour (D)	2-ft	1,509[7]	34,819[7]	2.38

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
6/02		14,600[8]	35,900	744,600	14,600	744,600

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.
6/02	431[9]	4.8	.05	431	4.8	.05

26. DATE OF SURVEY	39. AV. DRY WT. (#/FT^3)	40. SED. DEP. TONS/MI.^{2}-YR.		41. STORAGE LOSS, PCT.		42.	
		a. PERIOD	b. TOTAL TO	a. AV.	b. TOTAL TO	a.	b.
6/02				.01[9]	1.2[9]		

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
1952	4,139.0	4,131.0	13,800	1953	4,139.3	4,131.7	33,629
1954	4,139.8	4,135.5	10,700	1955	4,140.0	4,136.0	4,700
1956	4,139.7	4,135.3	2,400	1957	4,139.5	4,131.3	5,900
1958	4,141.7	4,131.4	30,200	1959	4,140.9	4,085.3	9,700
1960	4,139.6	4,121.2	35,900	1961	4,142.2	4,122.8	20,600
1962	4,141.1	4,122.7	23,700	1963	4,141.9	4,133.4	3,200
1964	4,138.8	4,130.0	28,300	1965	4,138.9	4,127.5	21,300
1966	4,142.0	4,129.5	9,900	1967	4,141.2	4,128.9	27,100
1968	4,141.0	4,128.2	15,400	1969	4,140.4	4,129.5	6,500
1970	4,141.2	4,130.5	12,400	1971	4,141.5	4,132.4	8,800
1972	4,141.8	4,132.5	11,300	1973	4,141.6	4,117.3	9,200
1974	4,141.2	4,128.7	17,800	1975	4,141.7	4,136.2	29,600
1976	4,141.0	4,137.1	13,500	1977	4,138.4	4,125.0	-2,800
1978	4,137.8	4,125.9	13,800	1979	4,140.7	4,132.6	5,700
1980	4,140.9	4,131.1	14,300	1981	4,140.6	4,131.1	13,200
1982	4,140.9	4,134.5	9,800	1983	4,140.2	4,135.2	9,100
1984	4,141.2	4,122.2	7,900	1985	4,141.4	4,130.8	23,900
1986	4,141.6	4,128.5	18,100	1987	4,142.5	4,130.5	11,600
1988	4,141.0	4,118.2	3,100	1989	4,141.5	4,118.2	25,100
1990	4,141.9	4,139.2	1,900	1991	4,142.0	4,138.7	18,400
1992	4,141.0	4,132.0	600	1993	4,141.6	4,132.1	14,000
1994	4,141.6	4,124.8	8,400	1995	4,141.7	4,127.6	24,700
1996	4,140.7	4,114.0	21,200	1997	4,142.1	4,114.0	29,100
1998	4,141.4	4,133.4	12,300	1999	4,139.5	4,113.8	21,700
2000	4,134.7	4,113.8	19,200	2001	4,136.3	4,127.0	7,200
2002	4,142.5	4,126.9	18,400				

46. ELEVATION - AREA - CAPACITY DATA FOR **2002 CAPACITY**[10]

ELEVATION	AREA	CAPACITY	ELEVATION	AREA	CAPACITY	ELEVATION	AREA	CAPACITY
4,084.2	0	0	4,086	2	2	4,088	4	7
4,090	7	17	4,092	27	51	4,094	50	128
4,095	60	183	4,096	70	248	4,098	96	414
4,100	126	636	4,102	153	915	4,104	186	1,254
4,105	209	1,451	4,106	232	1,672	4,108	273	2,176
4,110	317	2,765	4,112	374	3,456	4,114	439	4,269
4,115	477	4,727	4,116	516	5,224	4,118	599	6,338
4,120	680	7,617	4,122	754	9,051	4,125	866	11,478
4,126	905	12,363	4,128	979	14,247	4,130	1,051	16,277
4,132	1,153	18,480	4,134	1,254	20,887	4,135	1,305	22,167
4,136	1,327	23,483	4,138	1,372	26,182	4,140	1,416	28,969
4,142	1,462	31,848	4,144	1,509	34,819	4,145	1,532	36,339
4,146	1,560	37,885	4,148	1,616	41,061	4,149	1,644	42,691

47. REMARKS AND REFERENCES

1 All elevations are in feet and based on the original project datum established by Reclamation that were found by the 2002 study to be around 6.7 feet less then the NAVD88.

2 Uncontrolled overflow spillway.

3 Capacity computed from surface areas measured in 1905 from a detailed topographic survey developed on a scale of one inch equals 1000 feet and 5-foot contour intervals.

4 Bureau of Reclamation Project Data Book, 1981. Values for Sun River Project.

5 Calculated using mean annual runoff value of 14,600 AF, item 24, 1952 through 2002. (See remark #6).

6 Annual computed inflows by water year, from 1952 through 2002. Inflows from Willow Creek drainage and diverted flows from the Sun River through the Willow Creek Feeder Canal.

7 Surface area & capacity at elevation 4,144.0 computed by ACAP program.

8 Annual computed inflows by water year, from 1952 through 2002. Inflows from Willow Creek drainage and diverted flows from the Sun River through the Willow Creek Feeder Canal. Maximum and minimum elevations from available Reclamation records by end of the month water year records.

9 Volume change at elevation 4,144.0. Value affected by accuracy difference between two surveys. 2002 survey assume no change from elevation 4,135 and above. Maximum capacity change at elevation 4,115.0. Assume portion of change in lower elevations due to island shoreline erosion.

10 Capacities computed by Reclamation's ACAP computer program.

48. AGENCY MAKING SURVEY Bureau of Reclamation

49. AGENCY SUPPLYING DATA Bureau of Reclamation | DATE April 2003

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

1	2	3	4	5	6	7	8
Elevations (feet)	Original Survey (acres)	Original Capacity (acre-feet)	2002 Survey (acres)	2002 Survey (acre-feet)	2002 Volume Change	202 Percent of Change	Percent of Reservoir Depth
4,154.0	1,782	51,689	1,782	51,258			100.0
4,150.0	1,672	44,780	1,672	44,349			94.9
4,149.0	1,644	43,122	1,644	42,691	431	100.0	93.7
4,145.0	1,532	36,770	1,532	36,339	431	100.0	88.6
4,144.0	1,509	35,250	1,509	34,819	431	100.0	87.3
4,142.0	1,462	32,278	1,462	31,848	430	99.8	84.8
4,140.0	1,416	29,400	1,416	28,969	431	100.0	82.3
4,135.0	1,305	22,598	1,305	22,167	431	100.0	75.9
4,130.0	1,054	16,700	1,051	16,277	423	98.1	69.6
4,125.0	857	11,923	866	11,478	445	103.2	63.3
4,120.0	651	8,153	680	7,617	536	124.4	57.0
4,115.0	451	5,398	477	4,727	671	155.7	50.6
4,110.0	341	3,418	317	2,765	653	151.5	44.3
4,105.0	223	2,008	209	1,451	557	129.2	38.0
4,100.0	146	1,085	126	636	449	104.2	31.6
4,095.0	87	503	60	183	320	74.2	25.3
4,090.0	40	185	7	17	168	39.0	19.0
4,085.0	10	60	1	0	60	13.9	12.7
4,084.2	10	52	0	0	52	12.1	11.6
4,080.0	7	18	0	0	18	4.2	6.3
4,075.0	0	0	0	0	0	0.0	0.0

1	Elevation of reservoir water surface.
2	Original reservoir surface area from 1905 survey.
3	Original reservoir capacity computed from 1905 surface areas.
4	Reservoir surface area from 2002 survey.
5	Reservoir capacity computed from 2002 surface areas using ACAP.
6	Measured volume difference = column (3) - column (5).
7	Measured difference expressed in percentage of total 431 at elevation 4,144.0.
8	Depth of reservoir expressed in percentage of total depth of 79 feet.

Table 2. - Summary of 2002 results.

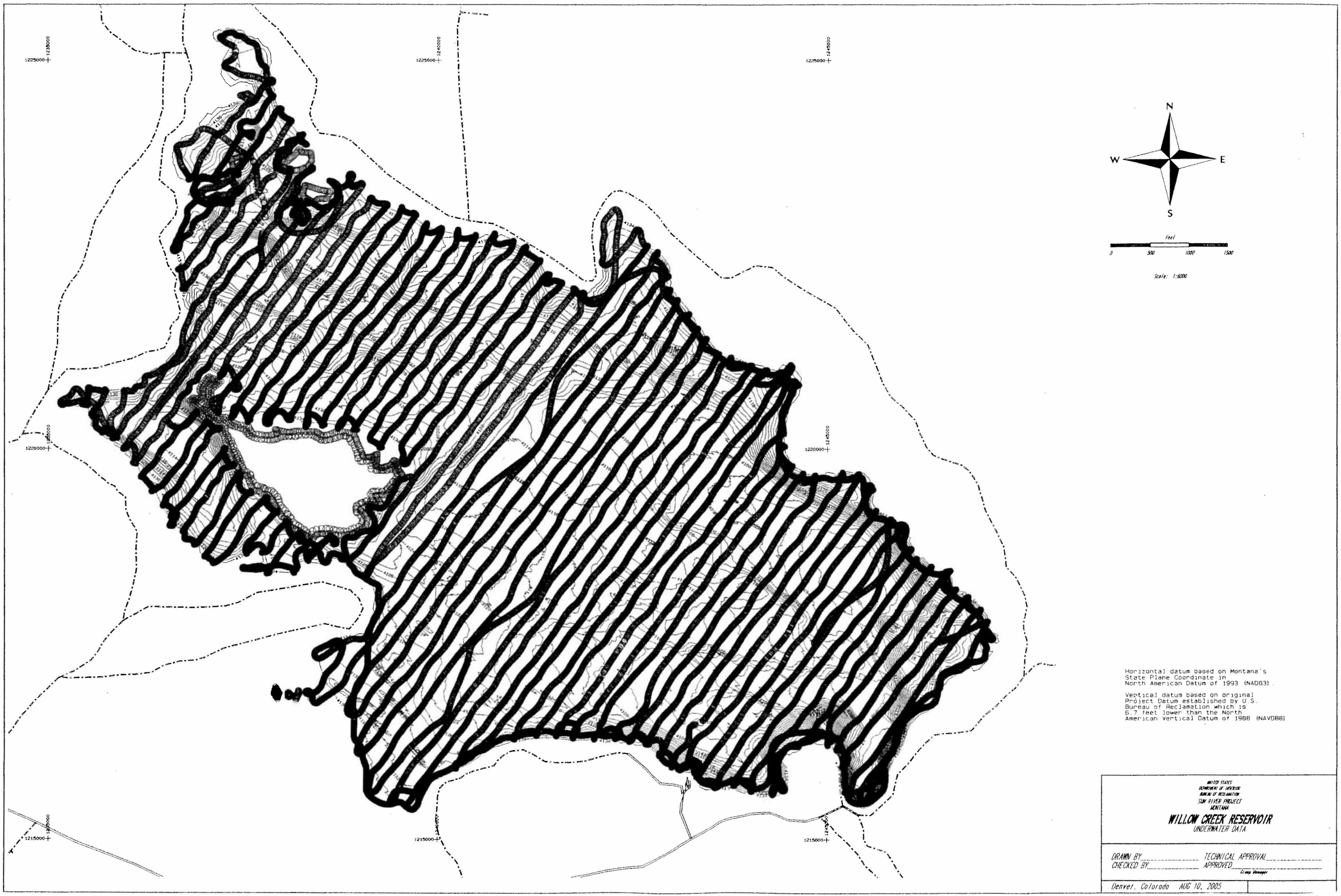

Figure 3. - Willow Creek 2002 underwater data.

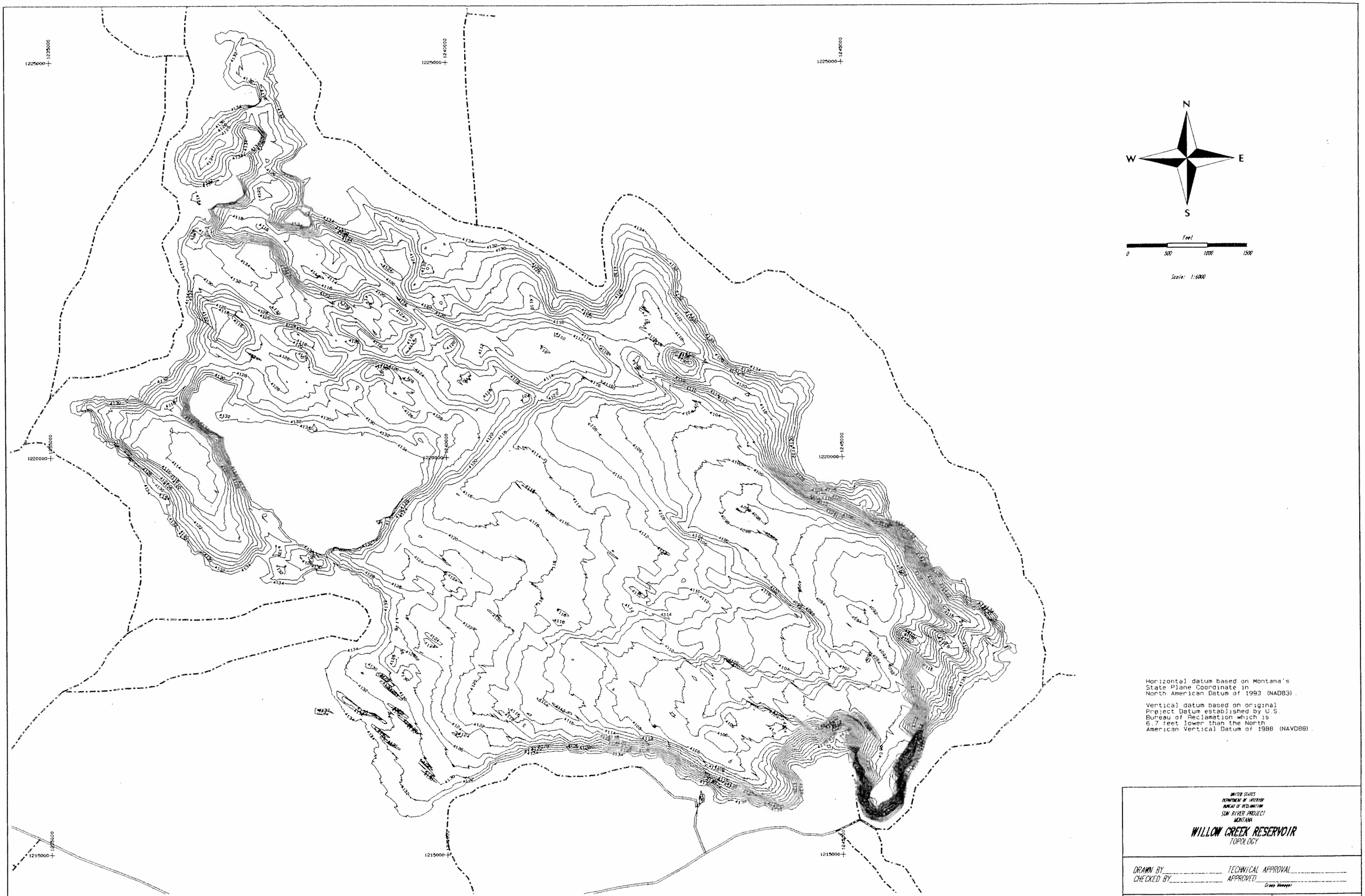

Figure 4. – Willow Creek Reservoir topographic map.

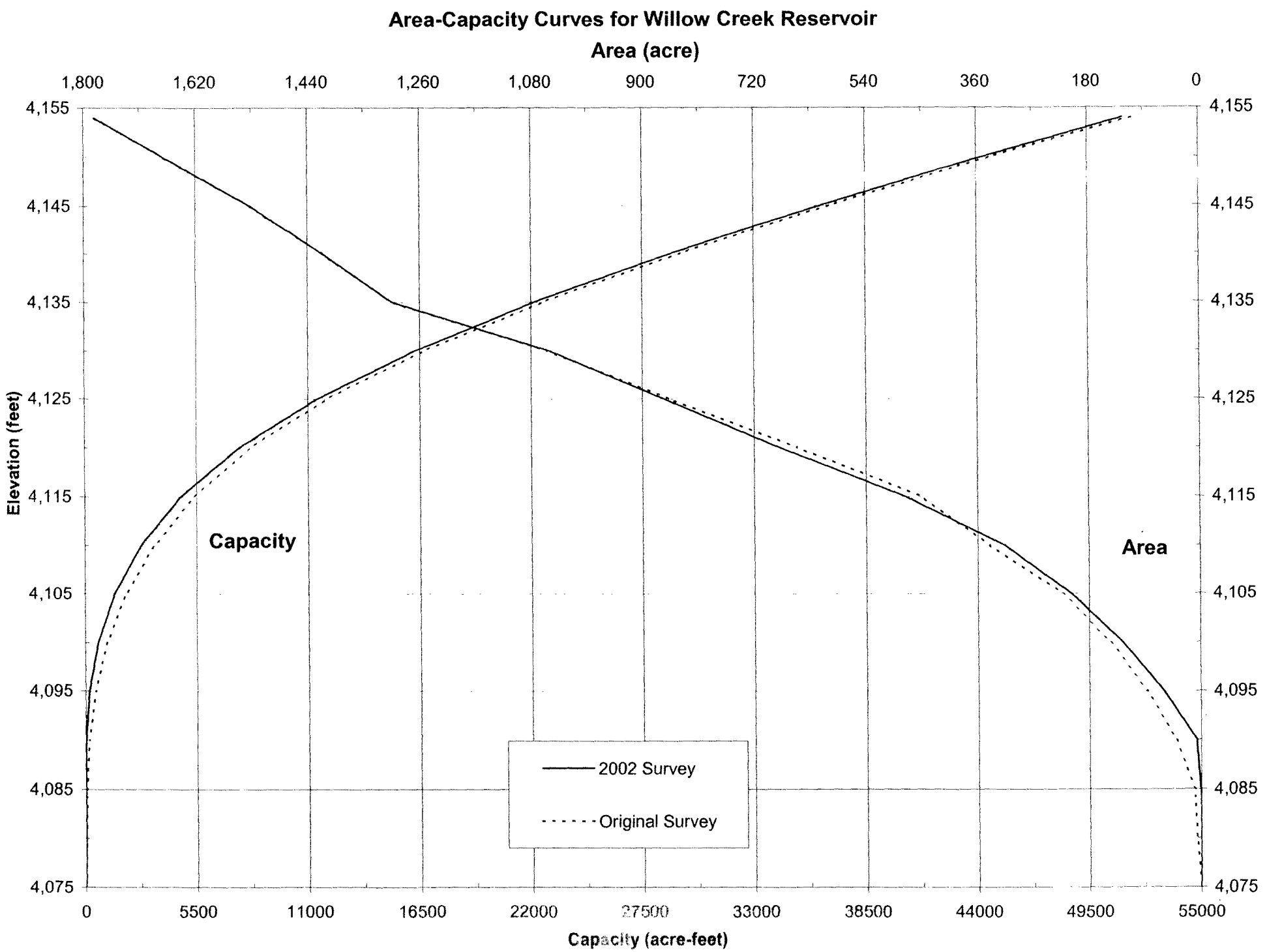

Figure 5. - 2002 area and capacity curves.