ENDERS RESERVOIR

1997 SEDIMENTATION SURVEY

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13. ABSTRACT *(Maximum 200 words)*

The Bureau of Reclamation (Reclamation) surveyed the underwater area of Enders Reservoir in May 1997 to develop a topographic map and compute a present storage-elevation relationship (area-capacity tables). The data were also used to calculate reservoir capacity lost due to sediment accumulation since dam closure on October 23, 1950. The survey used sonic depth recording equipment interfaced with a global positioning system (GPS) that gave continuous sounding positions throughout the underwater portion of the reservoir. Reservoir topography was developed by a computer program using collected underwater data along with above-water topography determined from digitized contour lines from the U.S. Geological Survey quadrangle (USGS quad) maps. The USGS quads of the reservoir area were developed from aerial photography obtained in 1973. The new topographic map of Enders Reservoir is a combination of digitized contours and 1997 underwater measured topography.

As of May 1997, at top of active conservation elevation 3,112.3 (feet), the surface area was 1,707 acres, the total capacity was 42,910 acre-feet, and the active capacity was 33,962 acre-feet. Since initial filling in October 1950, about 1,572 acre-feet of sediment has accumulated in Enders Reservoir below elevation 3105.0, resulting in a 1.95-percent loss in reservoir volume. Since 1950, the estimated average annual rate of reservoir capacity lost to sediment accumulation is 33.7 acre-feet.

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ENDERS RESERVOIR

1997 SEDIMENTATION SURVEY

by

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Water Resources Services
Technical Service Center
Denver, Colorado

August 1998

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The Bureau of Reclamation's (Reclamation) Sedimentation and River Hydraulics Group of the Technical Service Center (TSC) prepared and published this report. Ronald Ferrari conducted the hydrographic survey. Special thanks to Mr. David Moomey, the Great Plains Regional Superintendent at Enders Reservoir, for the field assistance during the hydrographic survey. Ronald Ferrari completed the data processing needed to generate the new topographic map and area-capacity tables. Sharon Nuanes of the TSC completed the USGS contour digitizing and was consulted during the map development. Cassie Klumpp of the TSC performed the technical peer review of this documentation.

U.S. Department of the Interior
Mission Statement

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.

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INTRODUCTION

Enders Dam and Reservoir are principal features of the Frenchman-Cambridge Division of the Pick-Sloan Missouri Basin Program. Additional storage features are Harry Strunk Lake, Hugh Butler Lake, and Swanson Lake. Enders Dam and Reservoir, on Frenchman Creek, are located in Chase County in southwestern Nebraska about 2 miles southeast of Enders, 9 miles east of Imperial, and 26 miles north of Benkelman (fig. 1).

Enders Dam was constructed between January 1947 and January 1951 with first storage on October 23, 1950. The dam is a rolled earthfill structure with riprap on the upstream face, whose dimensions are (fig. 2):

• Hydraulic height[1]	93	feet
• Structural height	134	feet
• Top width	30	feet
• Crest length	2,603	feet
• Crest elevation	3,137.5	feet

Enders Dam's spillway, located in the right abutment, consists of an approach channel, 10-foot uncontrolled overflow crest, six 5- by 30-foot radial gates, and a stilling basin. The crest of the 10-foot overflow notch is at elevation 3,112.3[2] and the crest of the radial gates is at elevation 3,097.0. The discharge capacity is 200,000 cubic feet per second (ft^3/s) at reservoir elevation 3,129.5 (Bureau of Reclamation 1981).

The outlet in the right center of the dam, consists of an 84-inch steel conduit with an emergency 6.0- by 7.5-foot hydraulic slide gate. There are two 60-inch hollow-jet regulating valves for releases to the river. The discharge capacity is 1,448 ft^3/s at reservoir elevation 3,129.5.

Enders Reservoir stores water from Frenchman Creek with an above-dam drainage area of 950 square miles. The drainage area ranges from elevation 3,082.4, top of inactive pool, to greater than elevation 4,500 at its headwaters. The reservoir length, at elevation 3,129.5, is around 4.5 miles with an average width of 0.3 mile.

SUMMARY AND CONCLUSIONS

This Reclamation report presents the 1997 results of the first extensive survey of Enders Reservoir. The primary objectives of the survey were to gather data needed to:

- develop reservoir topography
- compute area-capacity relationships

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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 levels are shown in feet.

- estimate storage depletion caused by sediment deposition since Enders Dam closure

The bathymetric survey was run using sonic depth recording equipment interfaced with a differential global positioning system (DGPS) 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 Enders Reservoir. The positioning system provided information to allow the boat operator to maintain course along these grid lines. Water surface elevations recorded by a Reclamation gauge during the time of collection were used to convert the sonic depth measurements to true reservoir bottom elevations.

The 1997 underwater surface areas at predetermined contour intervals were generated by a computer graphics program using the underwater collected data. The above-water reservoir contours were digitized from U.S. Geological Survey 7.5 minute quadrangle (USGS quad) maps of Enders Reservoir. The new topographic map of Enders Reservoir is a combination of the digitized and underwater measured topography. The 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. The 1997 area and capacity tables were generated using the 1997 measured areas at elevation 3,100.0 and less and the original measured areas for elevation 3,105.0 and greater.

Table 1 contains a summary of Enders Reservoir's watershed characteristics for the 1997 survey. The 1997 survey determined that the reservoir has a current storage capacity of 79,161 acre-feet and a surface area of 2,557 acres at reservoir elevation 3,129.5. Since closure in 1950, the reservoir has accumulated a sediment volume of 1,572 acre-feet below reservoir elevation 3,105.0. This volume represents a 1.95 percent loss in capacity and an average annual loss of 33.7 acre-feet.

RESERVOIR OPERATIONS

Enders Reservoir is primarily an irrigation and flood protection facility (the following values are from May 1997 area-capacity tables):

- 6,203 acre-feet of surcharge storage between elevations 3,127.0 and 3,129.5
- 30,048 acre-feet of flood control between elevations 3,112.3 and 3,127.0
- 33,962 acre-feet of active conservation storage between elevations 3,082.4 and 3,112.3
- 1,432 acre-feet of inactive storage between elevations 3,080.0 and 3,082.4
- 7,516 acre-feet of dead storage below elevation 3,080.0

The Enders Reservoir inflow and end-of-month stage records in table 1 show the annual (January through December) inflow and fluctuation for the operation period January 1951 through May 1997. The average annual reservoir inflow for this operation period was 42,052 acre-feet. The records show the annual elevation fluctuation of the reservoir water surface varied from a maximum elevation of 3,118.2, occurring March 25, 1960, to a minimum elevation of 3,080.7, occurring August 28, 1978, since normal reservoir operations began.

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. The hydrographic system contained on the survey vessel consisted of a global positioning system (GPS) receiver with a built-in radio and an omnidirectional antenna, a depth sounder, a helmsman display for navigation, a plotter, a computer, and hydrographic system software for collecting underwater data. Power to the equipment was supplied by an on-board generator.

The shore equipment included a second GPS receiver with a built-in radio and an omnidirectional antenna. The GPS receiver and antenna were mounted on a survey tripod over a known datum point. The power for the shore unit was provided by a 12-volt battery.

GPS Technology and Equipment

The positioning system used at Enders Reservoir was Navigation Satellite Timing and Ranging (NAVSTAR) GPS, an all-weather, radio-based, satellite navigation system that enables users to accurately determine three-dimensional position. The NAVSTAR system's primary mission is to provide passive global positioning and navigation for land-, air-, and sea-based strategic and tactical forces and is operated and maintained by the Department of Defense (DOD). The GPS receiver measures the distances between the satellites and itself and determines the receiver's position from intersections of the multiple range vectors. Distances are determined by accurately measuring the time a signal pulse takes to travel from the satellite to the receiver.

The NAVSTAR system consists of three segments:

- The space segment is a network of 24 satellites maintained in precise orbit about 10,900 nautical miles above the earth, each completing an orbit every 12 hours.

- The ground control segment tracks the satellites, determining their precise orbits. Periodically, the ground control segment transmits correction and other system data to all the satellites, and the data are then retransmitted to the user segment.

- The user segment includes the GPS receivers which measure the broadcasts from the satellites and calculate the positions of the receivers.

The GPS receivers use the satellites as reference points for triangulating their position on earth. The position is calculated from distance measurements to the satellites that are determined by how long a radio signal takes to reach the receiver from the satellite. To calculate the receiver's position on earth, the satellite distance and the satellite's position in space are needed. The satellites transmit signals to the GPS receivers for distance measurements along with the data messages about their exact orbital location and operational status. The satellites transmit two "L" band frequencies (called L1 and L2) for the distance measurement signal. At least four satellite observations are required to mathematically solve for the four unknown receiver parameters (latitude, longitude, altitude, and time); the time unknown is caused by the clock error between the expensive satellite atomic clocks and the imperfect clocks in the GPS receivers. For hydrographic surveying of the altitude, Enders' water surface elevation parameter was known, which realistically meant only three satellite observations were needed to track the survey vessel. During the Enders Reservoir survey, the best six available satellites were used for position calculations.

The GPS receiver's absolute position is not as accurate as it appears in theory because of the function of range measurement precision and the geometric position of the satellites. Precision is affected by several factors--time, because of the clock differences, and atmospheric delays caused by the effect on the radio signal of the ionosphere. Geometric dilution of precision (GDOP) describes the geometrical uncertainty and is a function of the relative geometry of the satellites and the user. Generally, the closer together in angle two satellites are from the receiver, the greater the GDOP. GDOP is broken into components: position dilution of precision (x,y,z) (PDOP) and horizontal dilution of precision (x,y) (HDOP). The components are based only on the geometry of the satellites. The PDOP and HDOP were monitored during the Enders Reservoir survey, and for the majority of the time they were less than 3, which is within the acceptable limits of horizontal accuracy for Class 1 and 2 level surveys (Corps of Engineers 1991).

An additional and larger error source in GPS collection is caused by false signal projection, called selective availability (S/A). The DOD implements S/A to discourage the use of the satellite system as a guidance tool by hostile forces. Positions determined by a single receiver when S/A is active can have errors of up to 100 meters.

A method of collection to resolve or cancel the inherent errors of GPS (satellite position or S/A, clock differences, atmospheric delay, etc.) is called differential GPS (DGPS). DGPS was used during the Enders Reservoir survey to determine positions of the moving survey vessel in real time. DGPS determines the position of one receiver in reference to another and is a method of increasing position accuracies by eliminating or minimizing the uncertainties. Differential positioning is not concerned with the absolute position of each unit but with the relative difference between the positions of two units, which are simultaneously observing the same satellites. The inherent errors are mostly canceled because the satellite transmission is essentially the same at both receivers.

At a known geographical benchmark, one GPS receiver is programmed with the known coordinates and stationed over that geographical benchmark. This receiver, known as the master or reference unit, remains over the known benchmark, monitors the movement of the satellites, and calculates its apparent geographical position by direct reception from the satellites. The inherent errors in the satellite position are determined relative to the master receiver's programmed position, and the necessary corrections or differences are transmitted to the mobile GPS receiver on the survey vessel. For the Enders Reservoir survey, position corrections were determined by the master receiver and transmitted via an ultra-high frequency (UHF) radio link every 3 seconds to the survey vessel mobile receiver. The survey vessel's GPS receiver used the corrections along with the satellite information it received to determine the vessel's differential location. Using DGPS resulted in positional accuracies of

1 to 2 meters for the moving vessel compared to positional accuracies of 100 meters with a single receiver.

The Technical Service Center (TSC) mobile and reference GPS units are identical in construction and consist of a six-channel L1 coarse acquisition (C/A) code continuous parallel tracking receiver, an internal modem, and a UHF radio transceiver. The differential corrections from the reference station to the mobile station are transmitted using the industry standard Radio Technical Commission for Maritime Services (RTCM) message protocol via the UHF radio link. The programming to the mobile or reference GPS unit is accomplished by entering necessary information via a notebook computer. The TSC's GPS system has the capability of establishing or confirming the land base control points by using notebook computers for logging data and postprocessing software. The GPS collection system has the capability of collecting the data in 1927 or 1983 North American Datums (NAD) in the surveyed area's state plane coordinate system's zone. For Enders Reservoir, the data were collected in the Nebraska's 1983 NAD south state plane zone.

Survey Method and Equipment

The Enders Reservoir hydrographic survey was conducted May 27 through May 29, 1997 between reservoir water surface elevations 3,104.1 and 3,104.2. The bathymetric survey was run using sonic depth recording equipment interfaced with a DGPS 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 close-spaced grid lines covering the reservoir area. Most of the transects (grid lines) were run primarily in a north-south direction. Data were also collected along the shore as the boat traversed to the next transect and as it maneuvered in the open areas between the vegetation. Vegetation growth and shallow conditions in some of the coves and upper reservoir prevented the boat from surveying some areas. Figure 3 illustrates the reservoir area covered by the 1997 underwater survey versus the contours digitized from the USGS quad maps. The survey vessel's guidance system gave directions to the boat operator to assist in maintaining course along these predetermined lines. During each run, the depth and position data were recorded on the notebook computer hard drive for subsequent processing by TSC personnel. The underwater data set includes 39,788 data points. The water surface elevation recorded by a Reclamation gauge during the time of collection was used to convert the sonic depth measurements to true lake bottom elevations.

For stationing the master GPS unit there were no known benchmarks or datums that overlooked the reservoir that had the needed control information. For the underwater collection, the hydrographic survey crew established a datum at a USBR brass cap marked R7R/R8R/R40L using a precision lightweight GPS receiver (PLGR). The PLGR unit utilizes the precise positioning service of the DOD GPS that is available to federal users only and has a horizontal accuracy of ±4 meters. This method calculated 1983 NAD state plane coordinates of North 221,402.25 and East 1,209,342.60 at this location. The shore-based master GPS unit, which transmits the correction information to the mobile GPS unit on the survey vessel, was stationed at this new datum site throughout the survey. This location was chosen because it was accessible and overlooked the reservoir. The location allowed for good radio transmission of the differential corrections to the mobile survey vessel throughout the reservoir survey. This precision met the accuracy for producing the 1997 reservoir contour map since no above-water aerial data were collected requiring using the USGS quad contour, with an accuracy of 1 inch equals 2,000 feet, for above water map development. During postprocessing of the collected underwater data, the few collected points without differential correction were removed.

The underwater data were collected by a depth sounder which was calibrated by lowering a deflector plate below the boat by cables with known depths marked by beads. 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 an 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 postprocessing, and when the analog charted depths indicated a difference from the recorded computer bottom depths, the computer data files were modified.

RESERVOIR AREA AND CAPACITY

Topography Development

The topography of Enders Reservoir was developed from the 1997 collected underwater data and from the USGS quad maps. The upper contours of Enders Reservoir were developed by digitizing the contour lines of elevation 3,112.0 and 3,137.5, from the USGS quad maps that covered the Enders Reservoir area. The USGS quad maps were developed from aerial photography dated 1973. ARC/INFO V7.0.2 geographic information system software was used to digitize the USGS quad contours. The digitized contours were transformed to Nebraska's NAD 1983 south state plane coordinates using the ARC/INFO PROJECT command.

The elevation 3,112.0 contour digitized from USGS quad maps was used to perform a clip of the Enders Reservoir triangular irregular network (TIN) such that interpolation was not allowed to occur outside the 3,112.0 contour. This complete contour was selected since it was the elevation that most nearly enclosed the 1997 underwater data collected below reservoir elevation 3,104. This clip was performed using the hardclip option of the ARC/INFO CREATETIN command. Using ARCEDIT, the underwater collected data and the digitized 3,112.0 contour from the USGS quad maps were plotted (fig. 3). The plot found that the majority of the underwater data occurred completely within the elevation 3,112.0 clip and required only minor adjustments to enclose all collected data.

Contours for elevations 3,100.0 and below were computed from the developed underwater data using the TIN surface modeling package within ARC/INFO. The underwater survey data were collected in the Nebraska south zone state plane coordinates in NAD 1983 (a TIN is a set of adjacent, nonoverlapping 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. Triangles are formed between all data points including all boundary points. This method preserves all collected survey points. 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. Elevation contours are then interpolated along the triangle elements. The TIN method is discussed in great detail in the ARC/INFO V7.0.2 *ARC Command References* (ESRI 1992).

The linear interpolation option of the ARC/INFO TINCONTOUR command was used to interpolate contours from the Enders Reservoir TIN. In addition, the contours were generalized by weeding 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 little bearing on the computation of surface areas and volumes for Enders Reservoir. The contour topography at 5-foot intervals is presented on figure 4, drawing number 328-D-2339.

Development of 1997 Contour Areas

The 1997 contour surface areas for Enders Reservoir were computed at 2-foot increments, from elevation 3,050.0 to 3,100.0, using the Enders Reservoir TIN discussed above. The 1997 survey measured the minimum reservoir elevation at 3,049.8 feet. 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. Due to the lack of 1997 survey data above water surface elevation 3.104, the final 1997 area computations assumed no change in surface area from elevation 3,105 and above.

1997 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). Surface areas at 2-foot contour intervals from minimum reservoir elevation 3,049.8 to elevation 3,100.0 and the original surface areas at 5-foot contour intervals from elevation 3,105.0 to 3,125.0 and elevations 3,127.0 and 3,129.5 were used as the control parameters for computing the Enders Reservoir capacity. The 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 Enders 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 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. 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
a_2 and a_3 = coefficients

Results of the 1997 Enders Reservoir area and capacity computations are listed in table 1 and columns (4) and (5) of table 2. Listed in columns (2) and (3) of table 2 are the original surface areas and recomputed capacity values. A separate set of 1997 area and capacity tables has been published for the 0.01-, 0.1-, and 1-foot elevation increments (Bureau of Reclamation 1997). A description of the computations and coefficients output from the ACAP85 program is included with these tables. Both the original and 1997 area-capacity curves are plotted on figure 5. As of May 1997, at active conservation elevation 3,112.3, the surface area was 1,707 acres with a total capacity of 42,910 acre-feet and an active capacity of 33,962 acre-feet.

SEDIMENT ANALYSES

Sediments have accumulated in Enders Reservoir to a total volume of 1,572 acre-feet since dam closure in October 1950. This volume was calculated at reservoir water surface elevation 3,105.0. It must be noted that the 1997 underwater survey was conducted at water surface elevation 3,104.2, and the final product relied on the original measured surface areas at elevation 3,105.0 and greater for computing the 1997 reservoir area and capacity tables. Column 6 of table 2 gives the measured sediment volume by elevation, and the area curve on figure 5 illustrates the resulting measured surface areas and calculated capacities. This table and figure illustrate that the majority of the sediment deposition is in the lower elevations of the reservoir with 84 percent of the sediment found below elevation 3,090. The average annual rate of sediment deposition between closure and May 1997 (46.6 years) was 33.7 acre-feet. The storage loss in terms of percent of original storage capacity was 1.95 percent. Tables 1 and 2 contain the Enders Reservoir sediment accumulation and water storage data based on the 1997 resurvey.

Reclamation's original 100-year sediment deposition prediction was 4,000 acre-feet or an average annual loss of 40 acre-feet. Of the predicted 4,000 acre-feet, 1,757 acre-feet or 44 percent was projected to settle above elevation 3,082.4. This compares to the 1997 study that measured an average annual loss of 33.7 acre-feet with 561 acre-feet or 36 percent above elevation 3,082.4. The annual maximum and minimum reservoir elevations in table 1 show that during several years the reservoir has operated as low as a few feet above the inactive pool elevation of 3,082.4. This provided the condition for portions of the upper reservoir sediment delta to be flushed into the lower portion of the reservoir.

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RESERVOIR SEDIMENT
DATA SUMMARY

Enders Reservoir
NAME OF RESERVOIR

1
DATA SHEET NO.

DAM	1. OWNER Bureau of Reclamation	2. STREAM North Fork Frenchman Ck	3. STATE Nebraska
	4. SEC. 9 TWP. 5N RANGE 37W	5. NEAREST P.O. Enders	6. COUNTY Chase
	7. LAT 40° 25' 05" LONG 101° 30' 55"	8. TOP OF DAM ELEVATION 3,137.5	9. SPILLWAY CREST EL.3,097.0[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. SURCHARGE	3,129.5	2,557	6,210	80,680	
	b. FLOOD CONTROL	3,127.0	2,405	30,000	74,470	10/23/50
	c. POWER					
	d. WATER SUPPLY	3,112.3	1,707	34,500	44,470	16. DATE NORMAL OPERATION BEGAN
	e. IRRIGATION					
	f. INACTIVE	3,082.4	658	1,500	9,970	
	g. DEAD	3,080.0	586	8,470	8,470	10/50
	17. LENGTH OF RESERVOIR 4.5 MILES			AVG. WIDTH OF RESERVOIR 0.3 MILES		

BASIN	18. TOTAL DRAINAGE AREA 950 SQUARE MILES	22. MEAN ANNUAL PRECIPITATION 20[2] INCHES
	19. NET SEDIMENT CONTRIBUTING AREA 950 SQUARE MILES	23. MEAN ANNUAL RUNOFF 0.83[3] INCHES
	20. LENGTH MILES / AV. WIDTH MILES	24. MEAN ANNUAL RUNOFF 42,052[4] ACRE-FEET
	21. MAX. ELEVATION 4,500 / MIN. ELEVATION 3,080	25. ANNUAL TEMP. MEAN 52°F RANGE -22°F to 110°F[5]

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
10/50			Contour (D)	5-ft	2,557[5]	80,732[5]	1.92
5/97	46.6	46.6	Contour (D)	2-ft	2,557[6]	79,161[6]	1.88

26. DATE OF SURVEY	34. PERIOD ANNUAL PRECIP.	35. PERIOD WATER INFLOW, ACRE FEET a. MEAN ANN.	b. MAX. ANN.	c. TOTAL	WATER INFLOW TO DATE, AF a. MEAN ANN.	b. TOTAL
5/97	20[2]	42,052[4]	75,500	1,959,600	42,052	1,959,600

26. DATE OF SURVEY	37. PERIOD CAPACITY LOSS, ACRE-FEET a. TOTAL	b. AV. ANN.	c. /MI.^{2}-YR.	38. TOTAL SEDIMENT DEPOSITS TO DATE, AF a. TOTAL	b. AV. ANNUAL	c. /MI.^{2}-YR.
5/97	1,572[7]	33.7	0.04	1,572	33.7	0.04

26. DATE OF SURVEY	39. AV. DRY WT. (#/FT^3)	40. SED. DEP. TONS/MI.^{2}-YR. a. PERIOD	b. TOTAL TO DATE	41. STORAGE LOSS, PCT. a. AV. ANNUAL	b. TOTAL TO DATE	42. SEDIMENT INFLOW, PPM a. PER.	b. TOT.
5/97				0.042[8]	1.95[8]		

26. DATE OF SURVEY	43. DEPTH DESIGNATION RANGE IN FEET BETWEEN ELEVATION										
	3042-3050	3050-3055	3055-3060	3060-3070	3070-3080	3080-3085	3085-3090	3090-3095	3095-3105			
	PERCENT OF TOTAL SEDIMENT LOCATED WITHIN DEPTH DESIGNATION											
5/97	14.3	18.3	11.3	8.1	8.5	9.4	14.1	11.2	4.8			

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[9]

YEAR	MAX. ELEV.	MIN. ELEV.	INFLOW, AF	YEAR	MAX. ELEV.	MIN. ELEV.	INFLOW, AF
1951	3,111.2	3,085.1	75,500	1952	3,112.8	3,101.0	66,000
1953	3,106.1	3,099.9	62,200	1954	3,112.0	3,104.0	60,500
1955	3,112.4	3,105.0	62,100	1956	3,112.3	3,104.4	61,000
1957	3,112.1	3,107.9	63,700	1958	3,113.7	3,109.9	65,600
1959	3,113.2	3,105.0	59,900	1960	3,116.5	3,106.0	73,100
1961	3,112.8	3,095.5	55,700	1962	3,113.2	3,096.1	64,200
1963	3,111.9	3,088.6	54,500	1964	3,112.6	3,090.9	54,000
1965	3,112.9	3,098.2	59,400	1966	3,113.6	3,096.0	58,700
1967	3,112.8	3,096.4	63,100	1968	3,112.9	3,086.6	52,600
1969	3,112.2	3,087.2	51,300	1970	3,108.9	3,082.4	47,600
1971	3,109.2	3,082.3	49,700	1972	3,108.2	3,084.4	44,000
1973	3,109.0	3,081.4	43,100	1974	3,108.2	3,085.9	38,100
1975	3,109.5	3,085.4	38,300	1976	3,107.0	3,082.8	33,700
1977	3,105.7	3,083.4	32,300	1978	3,103.9	3,081.0	30,300
1979	3,101.0	3,085.4	26,600	1980	3,102.9	3,083.9	26,600
1981	3,102.3	3,089.4	27,300	1982	3,105.5	3,094.0	30,100
1983	3,107.9	3,090.5	30,100	1984	3,106.5	3,089.9	29,200
1985	3,103.5	3,086.7	25,500	1986	3,101.5	3,088.0	23,900
1987	3,102.2	3,087.5	25,900	1988	3,102.2	3,088.5	21,600
1989	3,100.4	3,086.3	19,500	1990	3,099.6	3,082.7	19,400
1991	3,097.6	3,086.7	18,300	1992	3,097.8	3,090.7	19,500
1993	3,101.2	3,094.6	21,000	1994	3,104.1	3,094.4	18,300
1995	3,104.5	3,092.7	18,800	1996	3,103.4	3,095.8	20,100
1997	3,104.2	3,101.5	6,600[9]				

46. ELEVATION - AREA - CAPACITY DATA FOR **1997 CAPACITY**[10]

ELEVATION	AREA	CAPACITY	ELEVATION	AREA	CAPACITY	ELEVATION	AREA	CAPACITY
3049.8	0	0	3052	23.2	17	3054	57.1	97
3056	93.3	247	3058	114.9	455	3060	136.6	707
3062	177.6	1,021	3064	219.8	1,419	3066	250.6	1,889
3068	289.0	2,429	3070	337.6	3,055	3072	380.5	3,773
3074	420.8	4,575	3076	465.5	5,461	3078	511.1	6,437
3080	567.1	7,516	3082	616.5	8,699	3084	670.6	9,986
3086	726.4	11,383	3088	777.4	12,887	3090	846.0	14,511
3092	926.8	16,283	3094	1,010.1	18,220	3096	1,102.2	20,333
3098	1,169.8	22,605	3100	1,227.3	25,002	3105	1,398	31,565
3110	1,613	39,092	3112.3	1,707	42,910	3115	1,818	47,669
3120	2,069	57,387	3125	2,284	68,269	3127	2,405	72,958
3129.5	2,557	79,161						

47. REMARKS AND REFERENCES

1 Top of spillway gates elevation 3,127.0. 10-ft wide uncontrolled overflow section in center, crest el. 3112.3.

2 Bureau of Reclamation Project Data Book, 1981.

3 Calculated using mean annual runoff value of 42,052 AF, item 24.

4 Computed annual inflows from 10/50 through 5/97 by calendar year.

5 Original surface area and capacity at elevation 3,129.5, top of surcharge. Original capacity recomputed by Reclamation's ACAP program using original surface areas.

6 Surface area and capacity at elevation 3,129.5 computed by ACAP program using 1997 and original surface areas. 1997 surveyed only underwater portion of reservoir below elevation 3104.7. Elevation 3,105.0 and above from original measured areas.

7 Computed sediment volume at reservoir elevation 3,105.0.

8 Capacity loss by comparing original recomputed capacity and 1997 capacity at reservoir elevation 3,129.5.

9 Maximum and minimum elevations and inflow values in acre-feet by calendar year, from 1950 through 5/97.

10 Capacities computed by ACAP computer program. Areas at elevation 3105 and above from original survey.

48. AGENCY MAKING SURVEY Bureau of Reclamation

49. AGENCY SUPPLYING DATA Bureau of Reclamation | DATE April 1998

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

1	2	3	4	5	6	7	8
Elevation (feet)	Original Area (acres)	Original Capacity (acre-feet)	1997 Area (acres)	1997 Capacity (acre-feet)	Computed Sediment Volume (acre-feet)	Percent of Measured Sediment	Percent Reservoir Depth
3129.5	2557	80732	2557	79161			100.0
3127.0	2405	74530	2405	72958			97.1
3125.0	2284	69841	2284	68269			94.9
3120.0	2069	58958	2069	57387			89.1
3115.0	1818	49241	1818	47669			83.4
3112.3	1707	44482	1707	42910			80.3
3110.0	1613	40664	1613	39092			77.7
3105.0	1398	33137	1398	31565	1572	100.0	72.0
3100.0	1240	26542	1227	25002	1540	98.0	66.3
3097.0	1142	22969	1136	21452	1517	96.5	62.9
3095.0	1077	20750	1056	19253	1497	95.2	60.6
3090.0	890	15832	846	14511	1321	84.0	54.9
3085.0	735	11770	699	10671	1099	69.9	49.1
3082.4	658	9959	627	8948	1011	64.3	46.2
3080.0	586	8467	567	7516	951	60.5	43.4
3075.0	460	5852	443	5007	845	53.8	37.7
3070.0	332	3872	338	3055	817	52.0	32.0
3065.0	244	2432	235	1646	786	50.0	26.3
3060.0	170	1397	137	707	690	43.9	20.6
3055.0	119	675	75	163	512	32.6	14.9
3050.0	61	225	0	0	225	14.3	9.1
3045.0	18	27	0	0	27	1.7	3.4
3042.0	0	0	0	0	0	0.0	0.0

1 Elevation of reservoir water surface.
2 Original reservoir surface area.
3 Original calculated reservoir capacity computed using ACAP.
4 Reservoir surface area from 1997 survey for elevations 3100 and below. Areas for elevation 3105 and greater are original measured areas.
5 1997 calculated reservoir capacity computed using ACAP from 1997 surface areas.
6 Measured sediment volume = column (3) - column (5).
7 Meaured sediment expressed in percentage of total sediment 1572 acre-feet at elevation 3105.
8 Depth of reservoir expressed in percentage of total depth (87.5 feet).

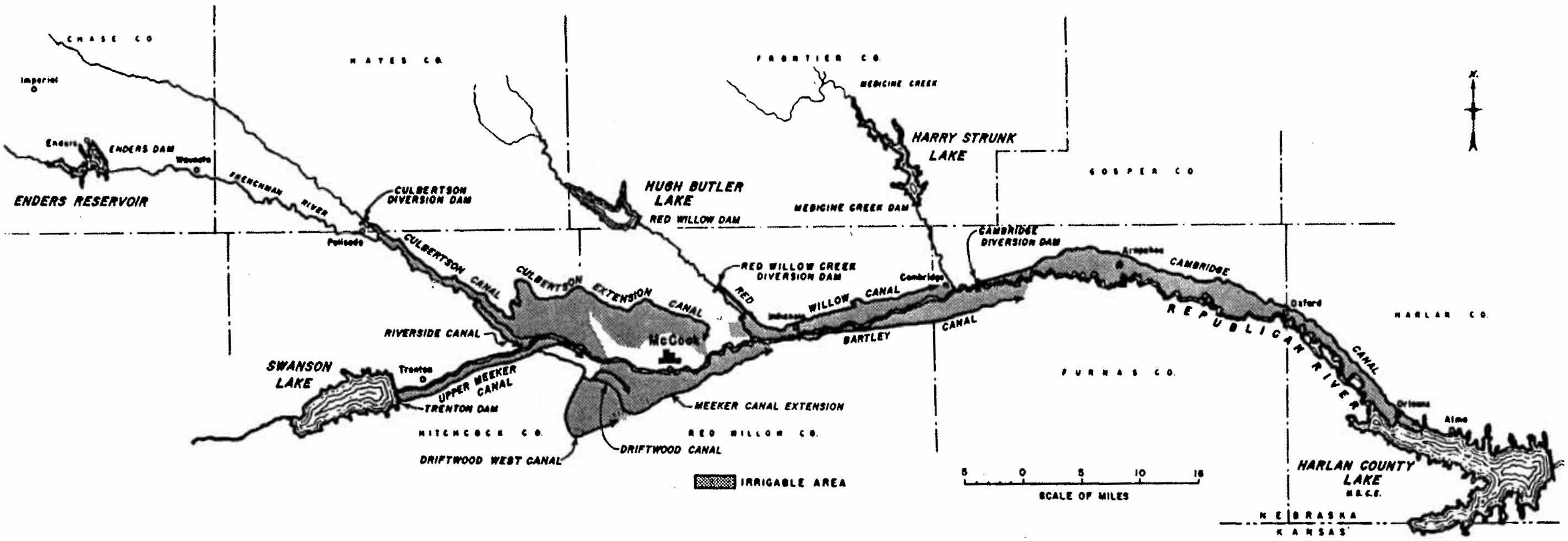


Figure 1. - Enders Reservoir location map.

Space intentionally left blank due to security concerns

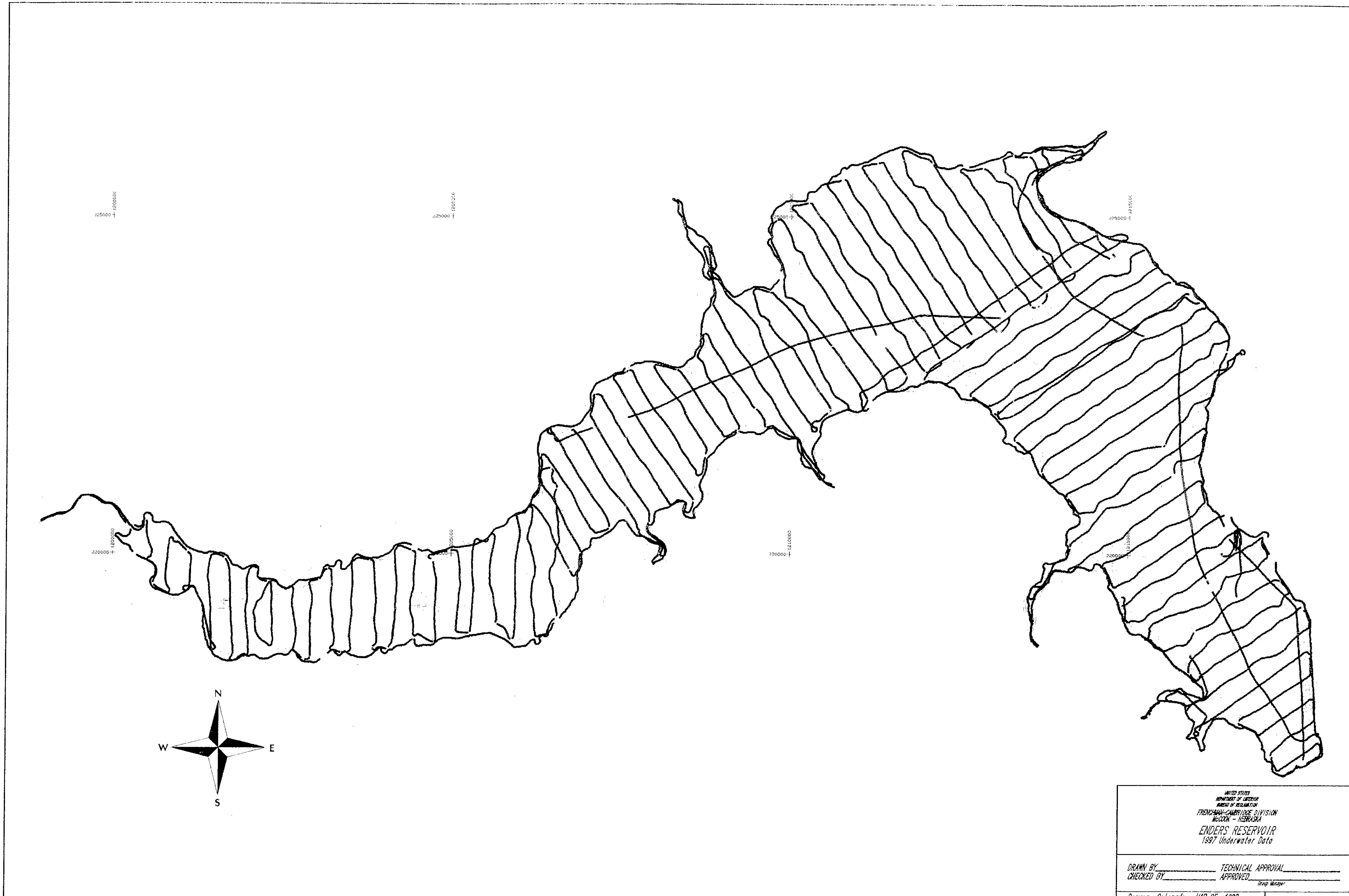
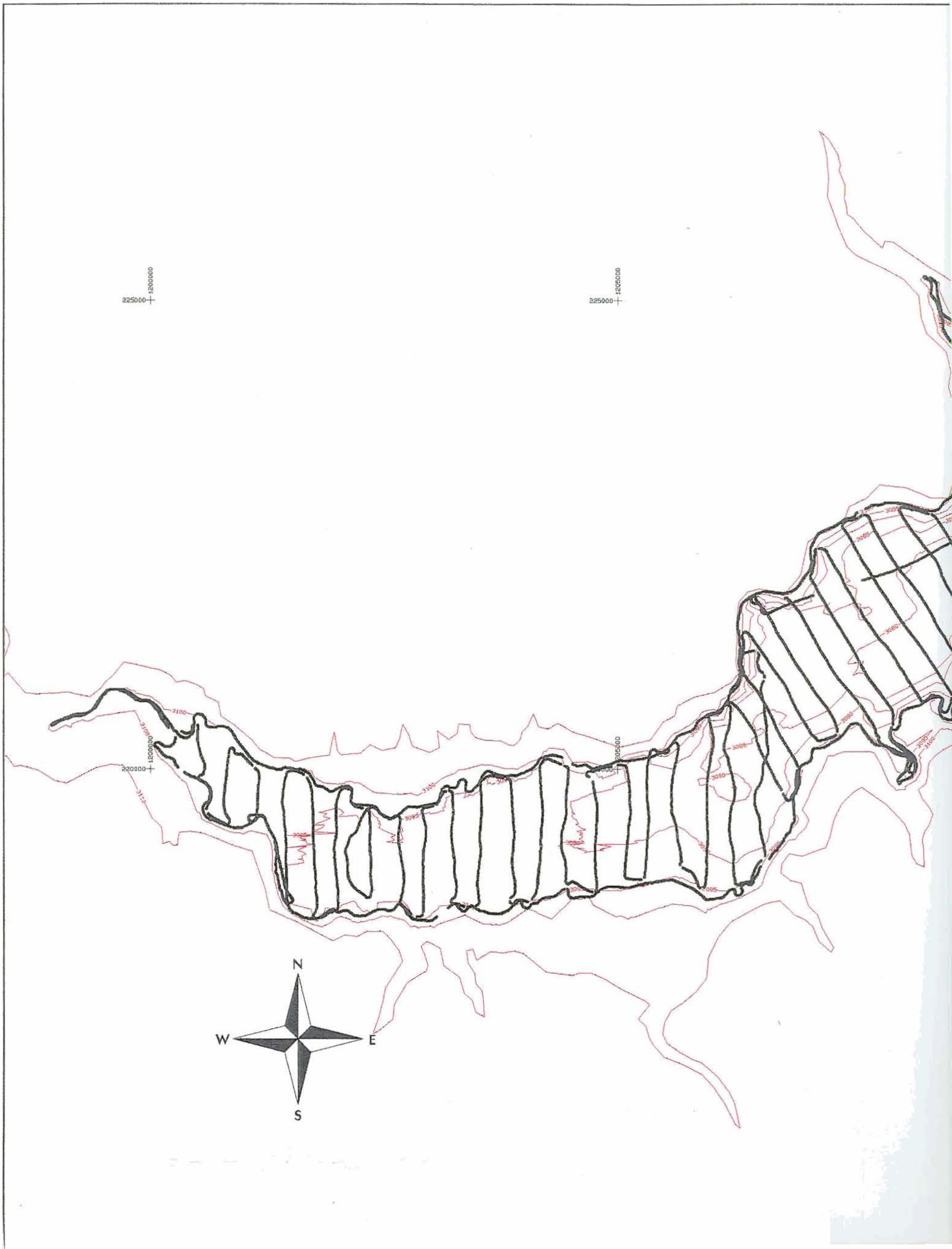


Figure 3. - Enders Reservoir underwater data points.



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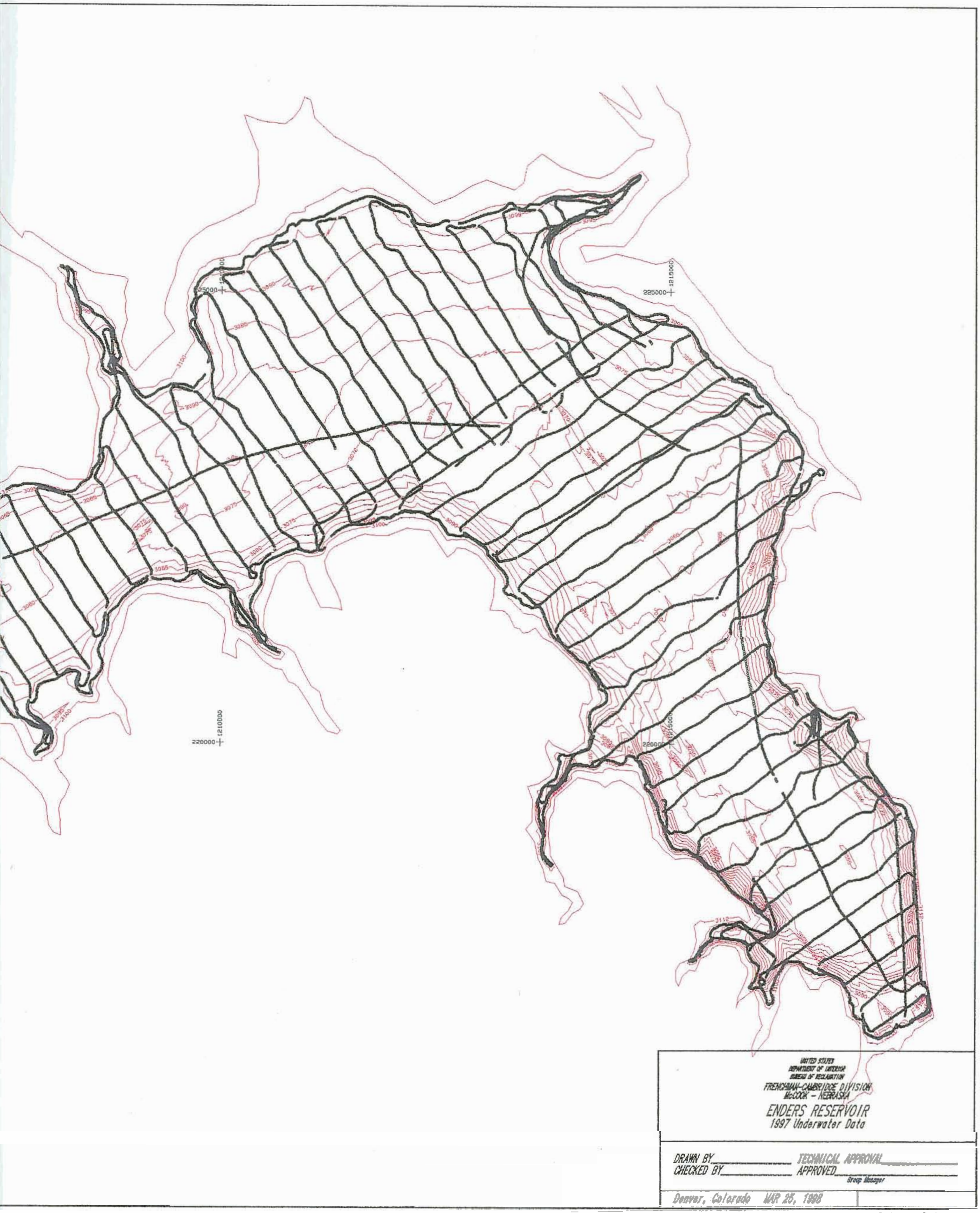

Figure 3. - Enders Reservoir underwater data points.

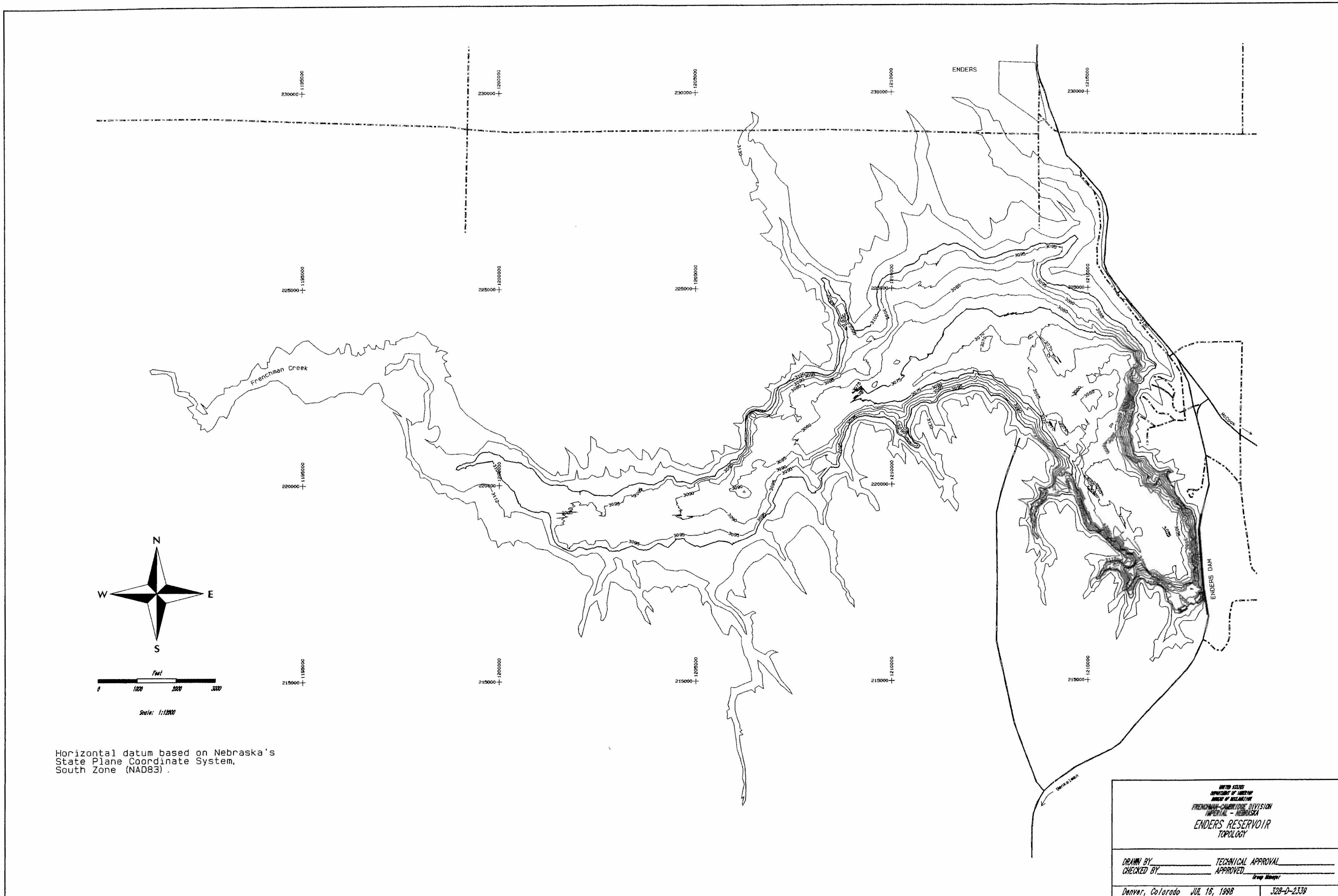

Figure 4. - Enders Reservoir topographic map.

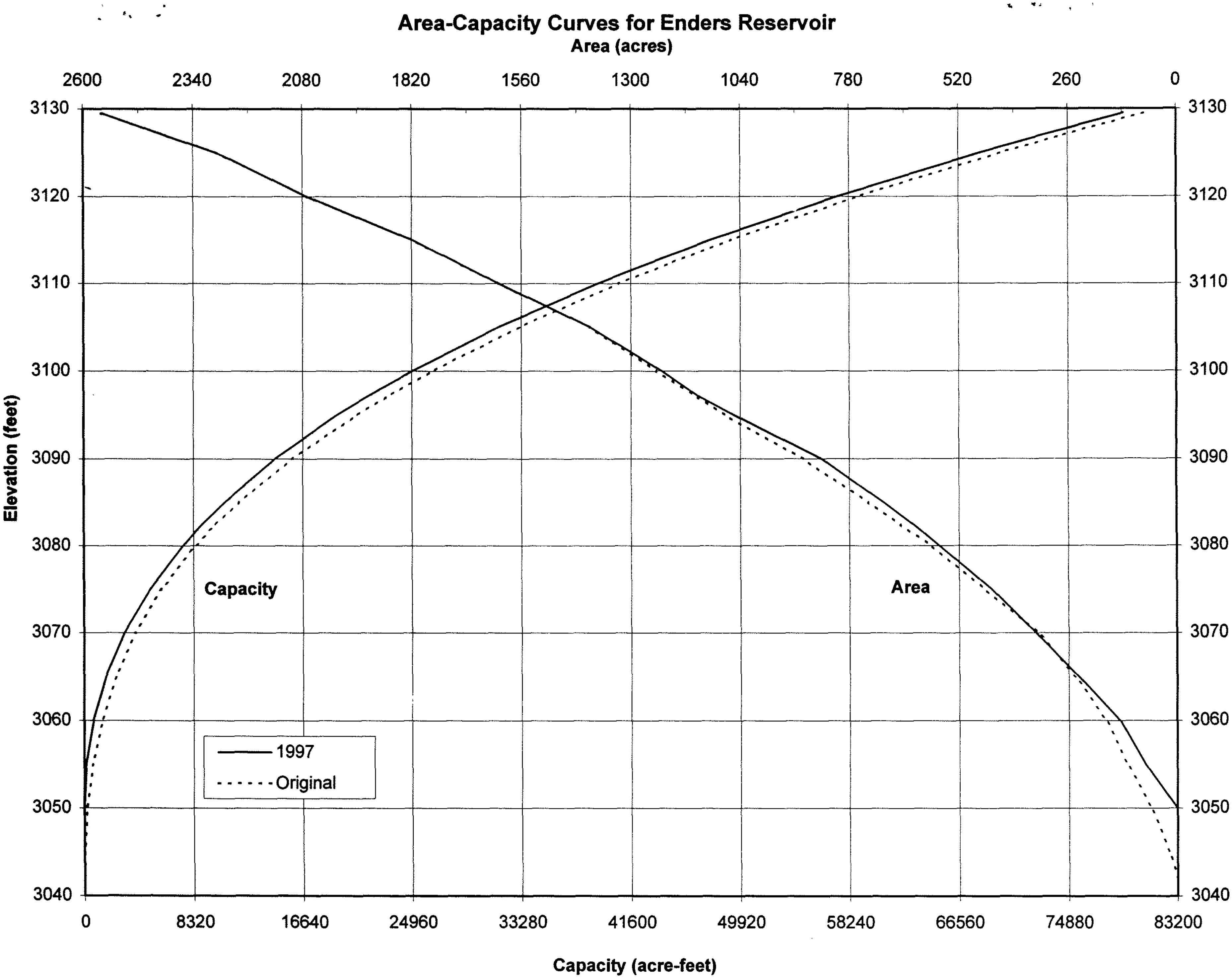

Figure 5. - Area and capacity curves – Enders Reservoir.

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.