CASCADE RESERVOIR
1995 SEDIMENTATION SURVEY

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13. ABSTRACT ***(Maximum 200 words)***

The Bureau of Reclamation (Reclamation) surveyed the largest portion of Cascade Reservoir in the fall of 1995 and the upper area in June 1997 to compile field data for developing a reservoir topographic map and computing 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 in November 1947. The bathymetric survey used sonic depth recording equipment interfaced with a global positioning system (GPS) that gave continuous sounding positions throughout the reservoir. The above-water topography was measured from aerial photography obtained in October 1995. The reservoir topography was developed by a computer graphics program using the 1995 collected data.

As of September 1995, at top of spillway gate elevation (feet) 4,828.0, the reservoir surface area was 26,307 acres with a total capacity of 693,123 acre-feet. Since initial filling about 10,329 acre-feet of Cascade Reservoir capacity have been lost below elevation 4,828.0, resulting in 1.47 percent loss in reservoir volume and a average annual rate of reservoir capacity lost of 216.1 acre-feet.

Note: The May 1996 report "*Cascade Reservoir 1995 Sedimentation Survey*" incorrectly reported the reservoir surface areas (and resulting capacities) due to incorrect reservoir elevations being applied to the 1995 underwater collected depths. This report includes the elevation correction and also the area-capacity for the portions of the upper reservoir area surveyed in 1997.

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CASCADE RESERVOIR

1995 SEDIMENTATION SURVEY

by

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Water Resources Services
Technical Service Center
Denver, Colorado

May 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 was the TSC team leader and conducted the hydrographic survey. James Melena of the TSC and Doug Saint from the Pacific Northwest Region assisted during the 1995 bathymetric survey. Personnel from the Columbia Basin Project Office performed the required land survey for the hydrographic and aerial data collection. George "Al" Knight of the Mid-Pacific Region conducted the aerial photography interpretation. Ronald Ferrari completed the data processing needed to generate the new map topology and area-capacity tables. Sharon Nuanes of TSC completed the contour digitizing and edge matching of the U.S. Geological Survey maps of the reservoir for the above water topographic development. Ron Ferrari and Sharon Nuanes composed the final maps presented in this report. Cassie Klumpp of the TSC performed the peer review of this documentation.

U.S. Department of the Interior
Mission Statement

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 Tribes.

CONTENTS

TABLES

FIGURES

INTRODUCTION

Cascade Dam and Reservoir are the largest storage facilities of the Boise Project. The dam, located in Valley County, Idaho on the North Fork of the Payette River is approximately 0.5 mile northeast of Cascade and 60 miles north of Boise, Idaho (fig. 1).

Dam closure and first reservoir storage began on November 7, 1947. The multi-purpose reservoir provides primarily irrigation storage with additional storage for power generation and flood control. The original reservoir survey measured a surface area of about 26,487 acres at the reservoir's full pool and top of spillway gate elevation 4,828.0 (feet)[1]. The original calculated total capacity at reservoir elevation 4,828.0 was reported as 703,200 acre-feet, of which 50,000 acre-feet was inactive storage (Bureau of Reclamation, 1981). At elevation 4,828.0 the reservoir length is around 20.8 miles and has an average width of around 0.5 miles.

The reservoir regulates flow for Black Canyon Dam powerplant and serves as an irrigation supply for the Payette Division and the Emmett Irrigation District. Reclamation operates and maintains the facility, which, on an informal basis, provides flood control of the Payette River through Horseshoe Bend, Idaho. Reclamation recently committed to use uncontracted reservoir storage to maintain a minimum pool for maintenance of water quality and resident fisheries, and for downstream flow augmentation to assist in the salmon recovery (Bureau of Reclamation, 1995a).

The watershed above Cascade Reservoir, located in the western slope of the Sawtooth Mountains, is 620 square miles, of which 208 square miles is considered non-contributing because the upstream reservoirs being effective sediment traps. Payette Lake (drainage area = 144 square miles) and Lake Fork Reservoir (drainage area = 64 square miles) control the inflow. Basin elevations range from 4,787.5 (minimum allowable pool elevation) to 8,960 (Nick Peak) in Lake Fork of the Payette drainage above Lake Fork Reservoir. Most of the peaks bordering the watershed exceed elevation 7,000 feet; the mean elevation is 5,960.

Cascade Dam is a zoned earthfill structure (fig. 2) with:

- a structural height[2] of 107 feet
- a hydraulic height of 75 feet
- a crest elevation of 4840.0 feet
- a top crest width of 35 feet
- a crest length of 785 feet

---

[1]All elevations (vertical datum) based on U.S. Bureau of Reclamation levels that are 0.66 feet higher than U.S. Coast and Geodetic Survey datum.

[2]The definition of such terms as "structural height," "hydraulic height," etc. may be found in such manuals 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.

Cascade Dam's spillway has a crest elevation of 4,808.0 with an elevation of 4,828.0 at the top of the radial control gates. At elevation 4,828.0 the maximum capacity is 12,000 cubic feet per second (ft^3/sec). The spillway, located on the right abutment of the dam, consists of:

- an inlet channel
- a overflow weir crest and bridge pier
- a spillway bridge
- a concrete chute
- terminal flipbucket
- two 21- by 20-foot radial gates

The river outlet works is located on the right abutment, has a capacity of 2,530 ft^3/sec at elevation 4828.0, and consists of:

- an intake structure with 12-foot by 13.4-foot fixed-wheel gate
- 12-foot-diameter concrete-lined pressure tunnel
- 12-foot-diameter steel pipe encased in concrete
- control house with two 5- by 5-foot high pressure gates
- two 84-inch-diameter steel outlet pipes

SUMMARY AND CONCLUSIONS

This Reclamation report presents the 1995 results of the first extensive survey of Cascade Reservoir. The primary objectives of the survey were to gather data needed to:

- develop reservoir topography
- compute area-capacity relationships
- resolve conflicts about storage capacity
- estimate storage depletion caused by sedimentation deposition since closure of Cascade Dam.

The bathymetric survey was run using sonic depth recording equipment interfaced with a differential GPS (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 Cascade 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 gage during the time of collection were used to convert the sonic depth measurements to true lake bottom elevations.

The above-water Cascade Reservoir area was measured from aerial photography obtained in October of 1995. Photo interpretation produced horizontal positioning and elevations throughout the reservoir area. The new reservoir contour map is a combination of the aerial and underwater survey data. The 1995 reservoir surface areas at predetermined 2-foot contour intervals were generated by a computer graphics program using the collected data. 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 (Bureau of Reclamation, 1985).

Tables 1 and 2 contain a summary of the Cascade Reservoir sedimentation and watershed characteristics for the 1995 survey. The 1995 survey determined that the reservoir has a total storage capacity of 693,123 acre-feet and a surface area of 26,307 acres at water surface elevation 4828.0. The difference between the recomputed original and the 1995 capacities, at reservoir elevation 4828.0, indicated a volume of 10,329 acre-feet of sediment has accumulated since dam closure in November 1947. This volume represents a 1.47 percent loss in total capacity and an average annual loss of 216.1 acre-feet per year. All elevations in this report are based on U.S. Bureau of Reclamation levels that are 0.66 feet higher than the U.S. Coast and Geodetic Survey datum.

RESERVOIR OPERATIONS

The reservoir is a multiuse facility having (following values are from September 1995 area-capacity tables):

- 156,281 acre-feet of surcharge storage between elevations 4,828.0 and 4,833.6.
- 646,461 acre-feet of conservation storage for irrigation, power generation and flood control between elevations 4,787.5 and 4,828.0.
- 46,662 acre-feet of inactive and dead storage below elevation 4,787.5.

Cascade Reservoir receives the majority of its inflow from the north fork drainage of the Payette River. Available records for calendar years 1947 through 1995 show that the average inflow into the reservoir was 732,550 acre-feet per year. This inflow computes to a mean annual runoff of 22.2 inches for the 620-square mile basin. The inflow and end-of-month stage records in table 1 show the annual fluctuation of the reservoir. After initial filling to spillway gate elevation 4828.0 in July 1957, available records show Cascade Reservoir operation ranging from elevation 4,802.2 on February 8, 1962 to elevation 4,828.9 in June 10 and 11 of 1957.

HYDROGRAPHIC SURVEY EQUIPMENT AND METHOD

The hydrographic survey equipment was mounted in the cabin of a 24-foot tri-hull aluminum vessel equipped with twin in-board motors. The hydrographic system contained on the survey vessel consisted of a GPS receiver with a built-in radio and omnidirectional antenna, dual frequency depth sounder, helmsman display for navigation, plotter, computer, and hydrographic system software for collecting the 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 omnidirectional antenna. The GPS receiver and antenna were mounted on a survey tripod over a known datum point. The power for the shore units was provided by a 12-volt battery. To obtain the maximum radio transmission range, known datum points with clear line-of-sight to the survey boat were selected.

The 1997 survey of the upper underwater reservoir area was conducted with the same system, but a portable depth sounder allowed the system to be powered by 12-volt batteries and mounted in a 12-foot flat bottom boat.

GPS Technology and Equipment

The positioning system that was used at Cascade Reservoir was Navigation Satellite Timing and Ranging (NAVSTAR) GPS, an all weather, radio based, satellite navigation system that enables users to accurately determine 3-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 Department of Defense (DOD). The GPS receiver measures the distances between the satellites and itself and determines the receiver's position from the 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 orbits 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, and periodically transmits correction and other system data to all the satellites, then retransmitted to the user segment.

- The user segment is the GPS receivers that measure the broadcasts from the satellites and calculates the position 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 for the distance measurement signals called L1 and L2. A minimum of 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, the altitude or the Cascade Reservoir water surface elevation parameter was known, which realistically meant only three satellite observations were needed to track the survey vessel. During the Cascade Reservoir survey, a minimum of five satellites were used for position calculations. Most of time, the best six available satellites were used.

The GPS receiver's absolute position is not as accurate as it appears in theory because of the function of range measurement precision and 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 by 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 (PDOP) (x,y,z), and horizontal dilution of precision (HDOP) (x,y). The components are based only on the geometry of the satellites. The PDOP and HDOP were monitored during the Cascade 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 of 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 DGPS. DGPS was used during the Cascade 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 the 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 the 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 Cascade Reservoir Survey, position corrections were determined by the master receiver and transmitted via a 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 TSC mobile and reference GPS units are identical in construction and consist of a 6-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 post-processing software. The GPS collection system has the capability of collecting data in 1927 or 1983 North American Datums (NAD) in the surveyed area's state plane coordinate system's zone. For the 1995 Cascade Reservoir survey, the state plane coordinate system used was 1983 NAD in Idaho's West Zone.

Survey History

The original Cascade Reservoir area and capacity curves, dated August 7, 1950, were presented on drawing 3-100-140. The drawing notes indicate that the data for the curves were from drawing 3-D-1666, dated October 30, 1944. No other information on surface area and contour development was located. It is assumed the original surface areas were obtained by a planetable survey, prior to dam closure, at a 5-foot contour accuracy. The original surface area values from the 1944 drawing are listed in column (2) of table 2. Column (3) gives the original capacity of Cascade Reservoir recomputed using the area-capacity computer program ACAP (Bureau of Reclamation, 1985).

Survey Methods

The Cascade Reservoir hydrographic survey was completed using the contour method as outlined by Blanton (1982). The procedure involved collecting adequate coordinate data for developing a reliable contour map by bathymetric and aerial survey methods. The bathymetric survey used sonic depth recording equipment interfaced with GPS positioning that gave continuous sounding positions throughout Cascade Reservoir.

Reclamation's Columbia Basin Project Office personnel used GPS equipment and standard land surveying methods to establish horizontal and vertical control points for the hydrographic survey. The above-water data were collected by aerial photography obtained in October 1995 at approximate reservoir elevation 4824.7 feet. Reclamation's Mid-Pacific Regional office conducted the aerial photography interpretation and provided coordinated data at 200-foot cross section intervals to define the reservoir topography. The aerial data set includes 44,196 coordinate points.

The Cascade Reservoir bathymetric survey was conducted in 1995 and 1997. In 1995 the survey started on August 28, 1995 and concluded on September 4, 1995 at reservoir water surfaces ranging from elevation 4826.3 to 4826.8. The 1997 survey was conducted on June 20 and 21 at reservoir water surface elevation 4,827.4. The bathymetric surveys were run using sonic depth recording equipment interfaced with a DGPS capable of determining sounding locations within the reservoir. The survey system software was capable of recording depths and horizontal coordinates in 1-second increments as the survey boat moved along predetermined gridlines covering the reservoir.

To produce adequate data for developing contours of Cascade Reservoir, grid lines or transects accessible by the survey boat were collected at a spacing of 150 meters in a mostly east-west alignment. Transects were also run in a mostly north-south alignment at a spacing of around 500 meters. Data were collected at an average of 2-second intervals with additional data collected along the shore as the boat traversed to the next transect. The survey vessel's guidance system gave directions to the boat operator to assist in maintaining course along these predetermined gridlines. During each run, the depth and position data were recorded on the notebook computer hard drive for subsequent processing by TSC personnel.

A graphic plotter was used in the field to track the boat and ensure adequate coverage during the collection process. The underwater data set included 115,316 coordinate points. Water surface elevations recorded by a Reclamation gage at the dam were used to convert the sonic depth measurements to true lake bottom elevations. In 1995 boat access problems above Tamarack Falls Road prevented surveying of a small portion of the reservoir on the North Fork of the Payette River and on the Lake Fork Arm. These areas were surveyed in 1997 using a small flat bottom boat. Appending all the data sets gave a total of 159,512 coordinate points for contour development as illustrated on figure 3.

The TSC's depth sounder has a 208-kilohertz transducer that reflects off the first bottom surface. This surface represents the top of the accumulated sediment for the reservoir survey. The bottom is determined by measuring elapsed time between the transmission of the sound pulse from the transducer to the waterway bottom and the reception of its echo back to the transducer. Prior to data collection and periodically through the survey, the depth sounder 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 water density, salinity, temperature, turbidity, and other conditions. The accuracy of an instantaneous reading from the depth finder is estimated to be ±0.5 feet, which takes into consideration calibration error and data collection in a moving boat. The collected data was digitally transmitted to the computer collection system via a RS232 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. Problems with the digital records were encountered in the areas of the reservoir that were heavily vegetated. These areas were encountered periodically throughout the reservoir, mainly in depths of 12 feet or less. In the majority of these cases, the analog charts were utilized to determined the true lake bottom, and the computer files were modified to reflect the analog chart values.

RESERVOIR AREA AND CAPACITY

Topography Development

The topography of Cascade Reservoir was developed from the combined 1995 aerial, and the 1995 and 1997 underwater collected data. The upper contours of the reservoir were developed by digitizing a boundary around the edge of the 1995 collected data that covered the reservoir area. From the USGS (U.S. Geological Survey) quad maps, the roads, railroads, towns, and other features that cover the reservoir area were digitized. ARC/INFO V7.0.2 Geographic Information System software was used to digitize the USGS quad map features and the boundary or polygon that enclosed the collected data. The digitized information was transformed to state plane coordinates, NAD 1983, using the ARC/INFO PROJECT command (ESRI, 1992).

Contours for the reservoir area were computed from the collected data using the triangular irregular network (TIN) surface modeling package within ARC/INFO. The horizontal datum of the survey data was based on Idaho's state plane west zone coordinates in NAD 1983. The vertical datum is based on U.S. Bureau of Reclamation levels that are 0.66 feet higher than the U.S. Coast and Geodetic Survey datum. The collected data ranged in elevation from around 4760 feet for the underwater data to greater than 4845 feet for the aerial data. 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 know as Delaunay's criteria for triangulation. Triangles are formed between all collected 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. This requirement means that sample points are connected to their nearest neighbors to form triangles. Using the hardclip option of the ARC/INFO CREATETIN command, a clip or polygon boundary of the study area was developed. The digitized polygon enclosing the collected data was assigned an elevation of no data and was used to perform the clip of the Cascade Reservoir TIN such that interpolation was not allowed to occur outside the boundary. The elevation contours are interpolated along the triangle elements. The TIN method is discussed in great detail in the ARC/INFO V7.0.2 Users Documentation (ESRI, 1992).

Island contours occurred in the lower reservoir area from the dam upstream throughout the reservoir. This condition occurred because of the meandering stream of the original river channel. The contour program could have completed the meandering channel contours if the area was saturated with additional data. It is assumed that the computed island areas for these elevations are only slightly less than if the contour were one enclosed area. These areas are a very small percentage of the overall reservoir area and have little effect on the overall volume computations.

The linear interpolation option of the ARC/INFO TINCONTOUR command was used to interpolate contours from the Cascade 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 no bearing on the computation of surface areas and volumes for Cascade Reservoir because the surface areas were computed from the developed TIN, which used all collected data points. The contour topography at five-foot intervals is presented on figures 4 through 9 (maps No.3-D-2813 through 3-D-2815 and 3-D-2877 through 3-D-2879).

Development of 1995 Contour Areas

The 1995 contour surface areas for Cascade Reservoir were computed in 1-foot intervals from elevation 4760.0 to 4845.0 using the Cascade Reservoir TIN discussed above. 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.

1995 Storage Capacity

The storage-elevation relationships based on the measured surface areas were developed using the area-capacity computer program ACAP (Reclamation, 1985). The 1995 surface areas at 2- and 5-

foot contour intervals from elevation 4,759.2 feet to 4,840.0 feet were used as the control parameters for computing the Cascade 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 Cascade 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:

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

where:

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

Results of the 1995 Cascade Reservoir area and capacity computations are listed in table 1 and 2 and plotted on figure 10. A separate set of 1995 area and capacity tables was published for the 0.01-, 0.1-, and 1-foot elevation increments (Bureau of Reclamation, 1998b). These tables include a description of the computations and coefficients output from the ACAP program. Computation results are listed in columns (4) and (5) of table 2. Column (2) gives original measured contour areas used in the original area and capacity computation, and column (3) gives original capacity recomputed using ACAP. Both the original and 1995 area and capacity curves are plotted on figure 10. As of September 1995, at spillway crest elevation 4828.0 feet, the surface area was 26,307 acres with a total capacity of 693,123 acre-feet.

RESERVOIR SEDIMENT ANALYSES

Reservoir sediment survey data for Cascade Reservoir are shown in tables 1 and 2. The computed volume difference between the original (1947 survey) and 1995 measured reservoir capacities for Cascade Reservoir is 10,329 acre-feet below top of spillway gate elevation 4,828.0. The average annual rate of lost capacity was 216.1 acre-feet per year, or 0.52 acre-foot per square mile from the sediment contributing drainage area of 412 square miles. The storage difference in terms of percent of original storage capacity was 1.47 percent.

The 1995 sediment calculations were based on the difference between the original and the 1995 measured reservoir capacities. The elevations for both the original and 1995 surveys were based on the U.S. Bureau of Reclamation vertical datum that is 0.66 feet higher than the U.S. Coast and Geodetic Survey datum. This method accounts for the sediment accumulation during the 47.8 years of reservoir operation, but the calculations are only as accurate as the two surveys. It is assumed that a portion of the 0.52 acre-foot per square mile yield rate is attributable to the different survey collection methods.

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RESERVOIR SEDIMENT
DATA SUMMARY

Cascade Reservoir
NAME OF RESERVOIR

1
DATA SHEET NO.

DAM	1. OWNER Bureau of Reclamation	2. STREAM N. Payette River	3. STATE Idaho
	4. SEC. 26 TWP. 14N RANGE 3E	5. NEAREST P.O. Cascade	6. COUNTY Valley
	7. LAT 44° 31' 30" LONG 116° 03' 00"	8. TOP OF DAM ELEVATION 4,840	9. SPILLWAY CREST EL. 4,808[1]

RESERVOIR	10. STORAGE	11. ELEVATION	12. ORIGINAL	13. ORIGINAL	14. GROSS STORAGE	15. DATE STORAGE BEGAN
	a. SURCHARGE	4,833.6		157,000	860,000	
	b. FLOOD CONTROL					11/07/47
	c. POWER					
	d. WATER SUPPLY					16. DATE NORMAL OPERATION BEGAN
	e. IRRIGATION					
	f. CONSERVATION	4,828.0	26,487	653,000	703,000	
	g. INACTIVE	4,787.5		50,000	50,000	06/57
	17. LENGTH OF RESERVOIR	20.8 MILES		AVG. WIDTH OF RESERVOIR 0.5 MILES		

BASIN		
	18. TOTAL DRAINAGE AREA 620 SQUARE MILES	22. MEAN ANNUAL PRECIPITATION 22-55[2] INCHES
	19. NET SEDIMENT CONTRIBUTING AREA 412[3] SQUARE MILES	23. MEAN ANNUAL RUNOFF 22.2[4] INCHES
	20. LENGTH MILES AV. WIDTH MILES	24. MEAN ANNUAL RUNOFF 732,550 ACRE-FEET
	21. MAX. ELEVATION 8960 MIN. ELEVATION 4787.5	25. ANNUAL TEMP. MEAN 41.3°F RANGE -40°F to 100°F[2]

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 AF/AF
11/47			Contour (R)[5]	5-ft	26,487[5]	703,452[5]	0.96
9/95	47.8	47.8	Contour (D)	5-ft	26,307	693,123	0.95

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
9/95	22-55	732,550	1,328,888	35,162,380	732,550	35,162,380

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.
9/95	10,329[6,7]	216.1[7]	0.52	10,329	216.1	0.52

26. DATE OF SURVEY	39. AV. DRY WT. (#/FT³)	40. SED. DEP. TONS/MI.²-YR.		41. STORAGE LOSS, PCT.		42. SEDIMENT	
		a. PERIOD	b. TOTAL TO	a. AV.	b. TOTAL TO	a.	b.
9/95				0.031[7]	1.47[7]		

26. DATE OF SURVEY	43. DEPTH DESIGNATION RANGE IN FEET BELOW, AND ABOVE, CREST ELEVATION											
					68.0-48.0	48.0-38.0	38.0-28.0	28.0-18.0	18.0-8.0	Crest--8.0	Crest-+5.6	
	PERCENT OF TOTAL SEDIMENT LOCATED WITHIN DEPTH DESIGNATION											
9/95					25.1	10.3	18.8	7.0	10.6	25.5	2.7	

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
1947			865,695	1948			874,693
1949			722,153	1950			793,334
1951	4,800.7	4,790.0	803,988	1952	4,812.1	4,792.8	987,022
1953	4,814.6	4,792.3	769,254	1954	4,814.9	4,796.3	792,440
1955	4,814.8	4,795.5	540,598	1956	4,822.5	4,799.8	995,215
1957	4,828.0	4,811.3	817,299	1958	4,828.0	4,810.8	769,738
1959	4,827.8	4,815.4	677,033	1960	4,828.1	4,814.4	686,856
1961	4,826.2	4,806.4	582,526	1962	4,826.8	4,802.8	647,808
1963	4,828.3	4,817.7	832,375	1964	4,828.0	4,811.8	719,800
1965	4,827.8	4,815.4	1,066,654	1966	4,827.4	4,809.1	482,285
1967	4,827.0	4,799.4	759,889	1968	4,826.5	4,812.2	575,346
1969	4,828.0	4,806.4	815,959	1970	4,828.3	4,809.4	856,338
1971	4,828.4	4,809.1	1,116,065	1972	4,827.5	4,807.3	858,821
1973	4,824.4	4,808.4	438,772	1974	4,828.4	4,807.0	1,328,888
1975	4,826.2	4,809.5	746,733	1976	4,827.8	4,813.1	897,415
1977	4,819.0	4,803.8	221,788	1978	4,827.6	4,804.6	943,230
1979	4,824.5	4,809.3	447,275	1980	4,827.8	4,805.6	774,141
1981	4,828.3	4,814.4	736,928	1982	4,828.2	4,813.2	1,185,059
1983	4,827.2	4,816.2	1,040,516	1984	4,827.7	4,817.2	953,386
1985	4,827.5	4,815.6	563,591	1986	4,827.7	4,815.2	820,936
1987	4,825.1	4,813.3	349,450	1988	4,823.7	4,812.0	370,503
1989	4,827.2	4,813.4	597,508	1990	4,827.8	4,817.1	488,844
1991	4,827.5	4,817.3	417,388	1992	4,823.3	4,813.0	344,958
1993	4,827.8	4,810.6	754,770	1994	4,824.5	4,811.0	298,885
1995	4,828.0	4,811.2	897,911				

46. ELEVATION - AREA - CAPACITY DATA FOR **1995 CAPACITY**

ELEVATION	AREA	CAPACITY	ELEVATION	AREA	CAPACITY	ELEVATION	AREA	CAPACITY
4759.2	0	0	4764	11	16	4768	95	196
4772	634	1,427	4776	1,580	5,853	4780	2,836	14,405
4784	4,397	28,889	4787.5	5,837	46,662	4792	7,983	77,679
4796	10,274	114,299	4800	12,437	159,714	4804	14,295	213,314
4808	16,101	274,142	4812	17,894	342,155	4816	19,804	417,353
4820	22,062	501,099	4824	23,692	592,716	4828	26,307	693,123
4832	28,587	802,947	4833.6	29,484	849,404			

47. REMARKS AND REFERENCES

1 Top of spillway radial gates elevation 4828.0, spillway crest elevation 4,808.0. All elevations based on the U.S. Bureau of Reclamation vertical datum that is is 0.66 feet higher than the U.S. Coast and Geodetic Survey datum.

2 Bureau of Reclamation Probable Maximum Flood Study, April 1987.

3 Represents loss of sediment contributing areas behind Payette Lake (144 mi^2) and Lake Fork (64 mi^2).

4 Calculated using mean annual runoff value of 732,550 AF, item 24.

5 Surface area-capacity at elevation 4828.0, recomputed by Reclamation's ACAP program using original surface areas. Surface area values from Reclamation drawing No. 3-D-1666.

6 Total capacity loss calculated by comparing original recomputed capacity and 1995 capacity at reservoir elevation 4828.0. Portion of lost due to different methods of collection.

7 Portion of computed storage lost due to different method of measuring reservoir areas. Original surface area values projected from area curve.

8 End-of-month maximum and minimum elevations by water year, inflow values by calendar year.

Note: Area-capacity tables updated in 9/97 to account for reservoir elevation datum adjustment used to convert 1995 underwater collected data and to account for areas of upper reservoir not surveyed in 1995. All elevations based on the U.S. Bureau of Reclamation vertical datum that is 0.66 feet higher than the U.S. Coast and Geodetic survey datum.

48. AGENCY MAKING SURVEY Bureau of Reclamation

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

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

(1) Elevation (feet)	(2) Original Area (acres)	(3) Original Capacity (acre-feet)	(4) 1995 Area (acres)	(5) 1995 Capacity (acre-feet)	(6) Measured Sediment Volume (acre-feet)	(7) Percent Measured Sediment	(8) Percent Reservoir Depth
4840.0	32,967	1,059,857	32,909	1,049,146	-	-	-
4835.0	30,246	901,824	30,260	891,228	-	-	-
4833.6	(29,479)*	860,017	(29,484)	849,404	10,613	100.0	100.0
4830.0	27,506	757,444	27,466	746,895	10,549	99.4	95.1
4828.0	(26,487)	703,452	26,307	693,123	10,329	97.3	92.4
4825.0	24,958	626,284	24,512	616,819	9,465	89.2	88.3
4820.0	22,070	508,714	22,062	501,099	7,615	71.8	81.5
4815.0	19,371	405,112	19,245	397,828	7,284	68.6	74.7
4810.0	17,174	313,750	17,009	307,252	6,498	61.2	67.9
4805.0	14,807	233,797	14,746	227,835	5,962	56.2	61.1
4800.0	12,526	165,464	12,437	159,714	5,750	54.2	54.3
4795.0	10,014	109,114	9,731	104,297	4,817	45.4	47.6
4790.0	7,051	66,452	6,998	62,698	3,754	35.4	40.8
4787.5	(5,938)	50,216	(5,837)	46,662	3,554	33.5	37.4
4785.0	4,824	36,764	4,744	33,459	3,305	31.1	34.0
4780.0	3,053	17,072	2,836	14,405	2,667	25.1	27.2
4775.0	1,536	5,600	1,364	4,381	1,219	11.5	20.4
4770.0	391	782	251	542	240	2.3	13.6
4766.0	0	0	39	62	-	-	8.2
4765.0	-	-	22	32	-	-	6.8
4759.2	-	-	0	0	-	-	0.0

(1) Elevation of reservoir water surface based on U.S. Bureau of Reclamation vertical datum that is 0.66 feet higher than the U.S. Coast and Geodetic survey datum.
(2) Original reservoir surface areas from Reclamation drawing 3-D-1666.
(3) Original calculated reservoir capacity computed using ACAP from original measured surface areas.
(4) Reservoir surface area from 1995 and 1997 survey.
(5) 1995 calculated reservoir capacity computed using ACAP, from 1995 and 1997 measured surface areas.
(6) Measured sediment volume = column (3) - column (5).
(7) Measured sediment expressed in percentage of total sediment 10,613 acre-feet at elevation 4833.6.
(8) Depth of reservoir expressed in percentage of total depth (73.6 feet).

* Areas in ( ) computed by ACAP.

Table 2. - Summary of 1995 survey results.

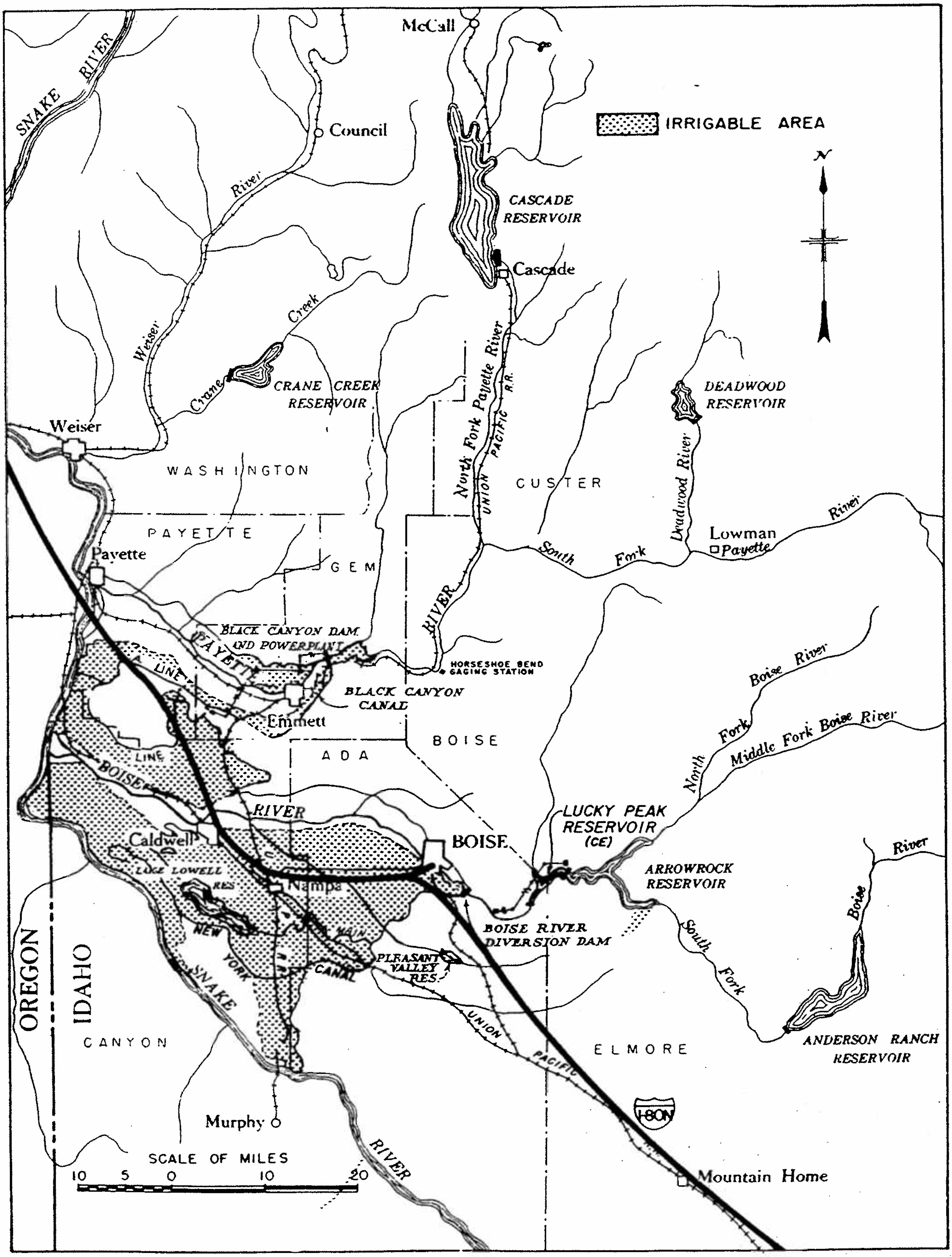

Figure 1. - Cascade Reservoir location map.

Space intentionally left blank due to security concerns

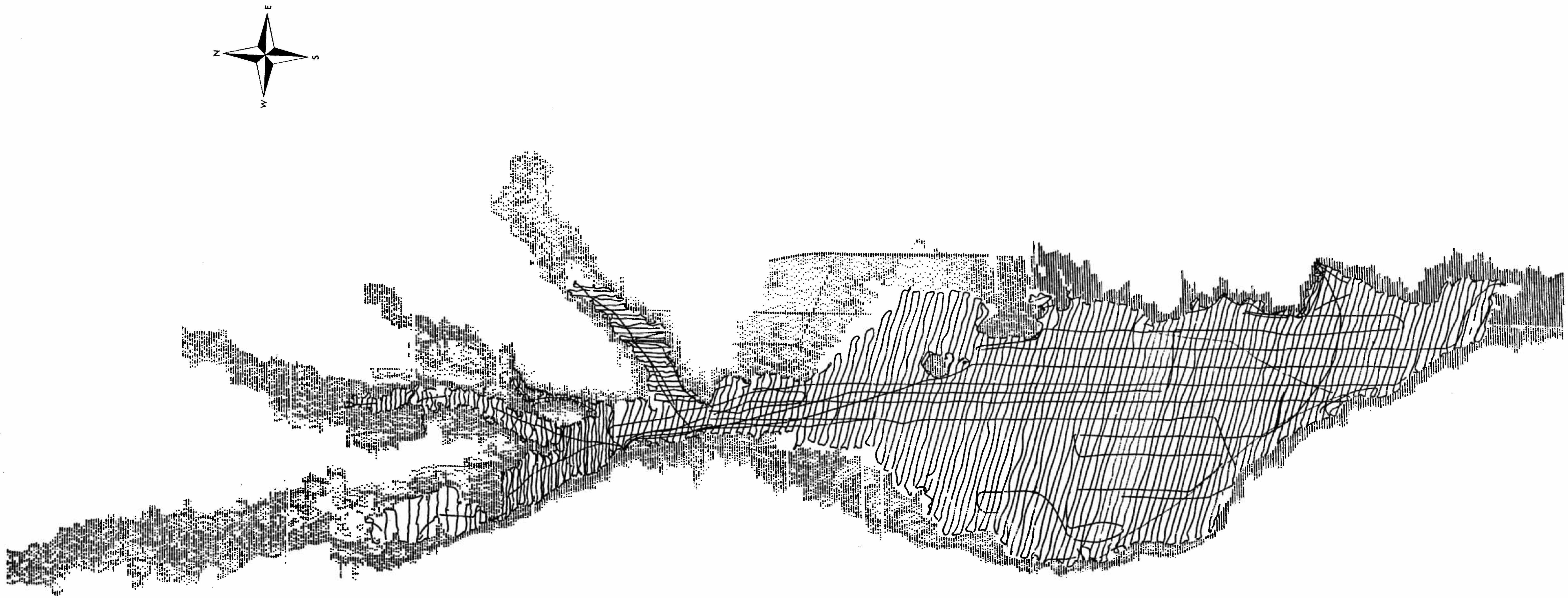

Figure 3. - Cascade Reservoir survey data.

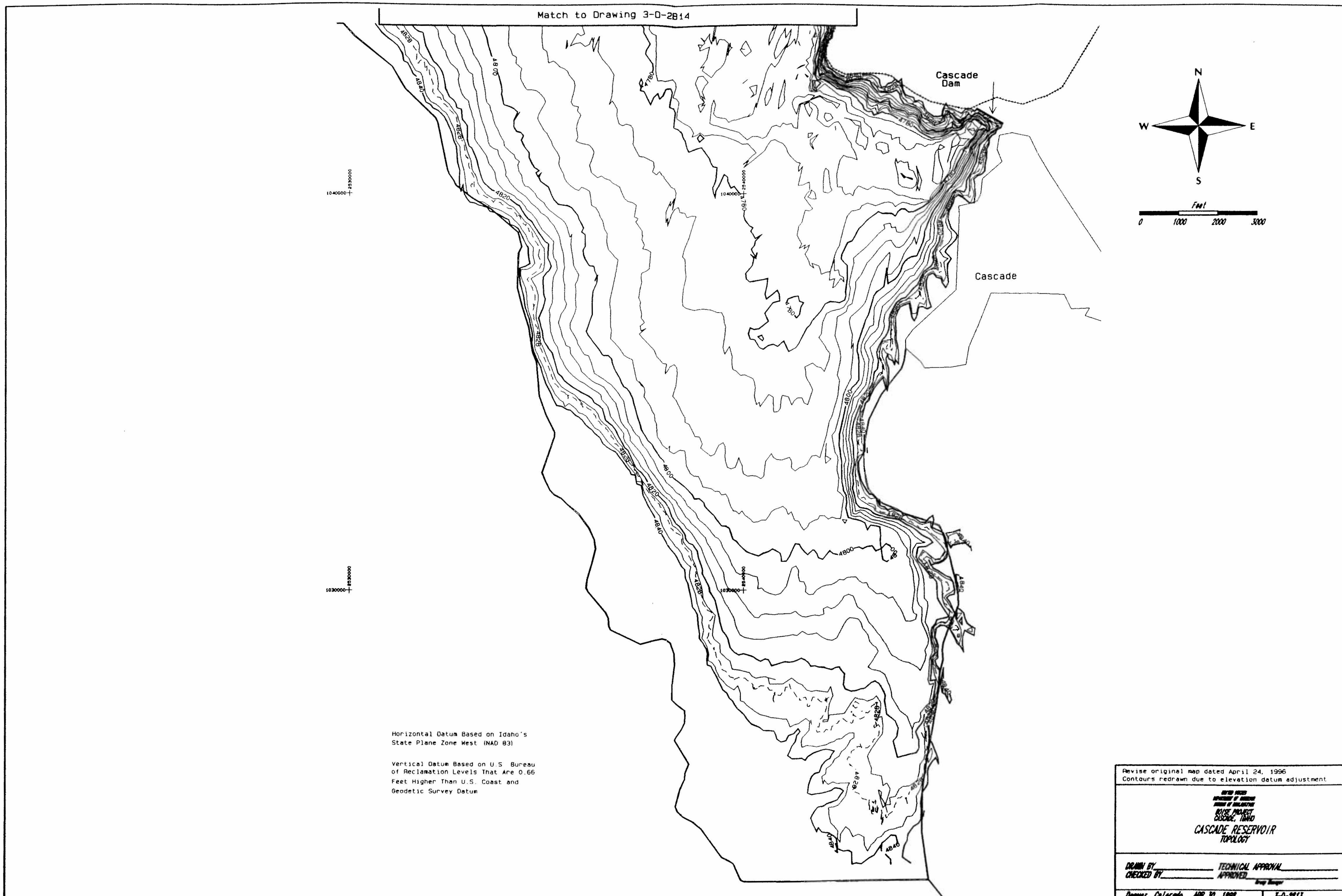

Figure 4. - Cascade Reservoir topology map, No. 3-D-2813.

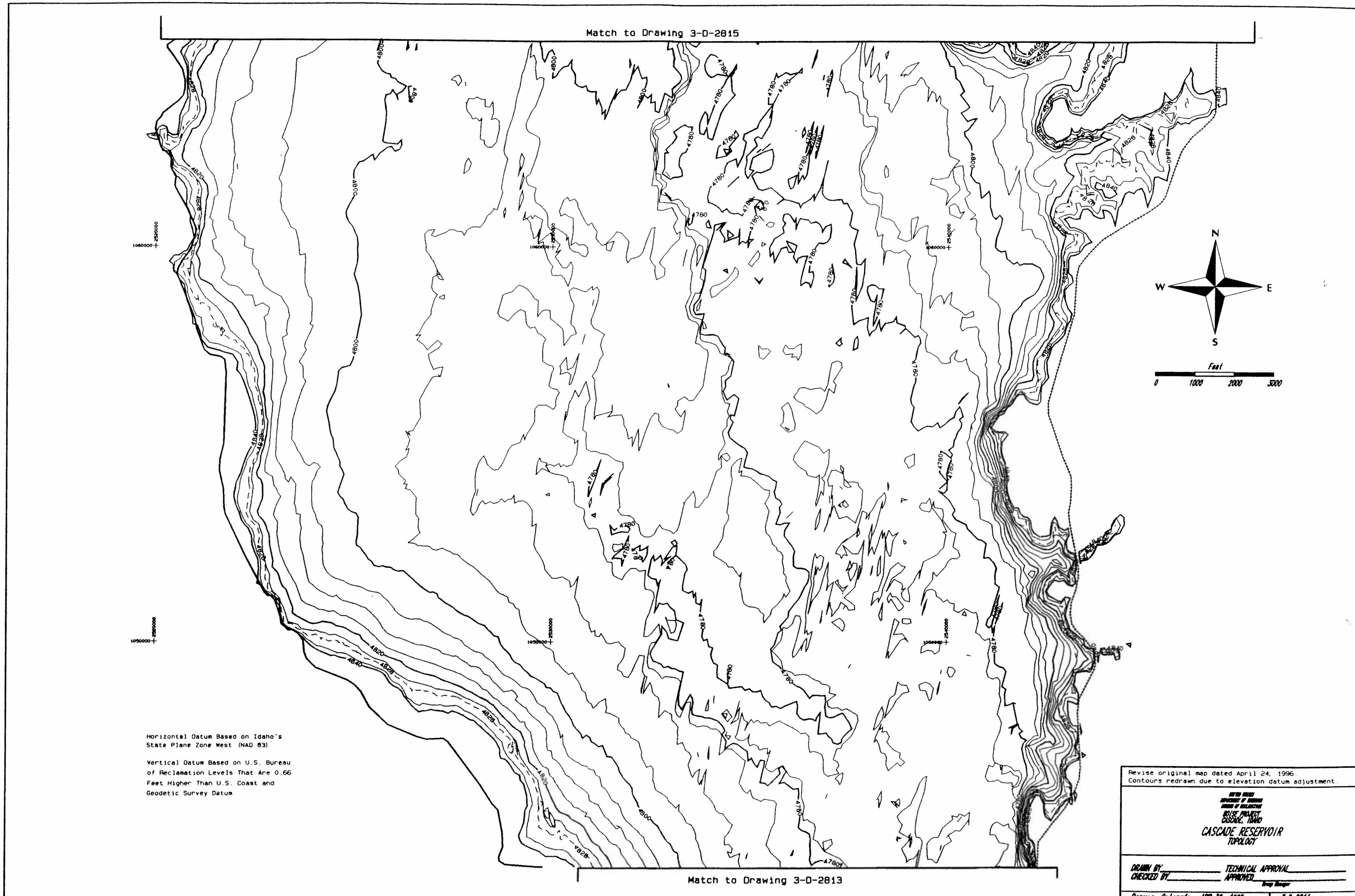

Figure 5. - Cascade Reservoir topology map, No. 3-D-2814.

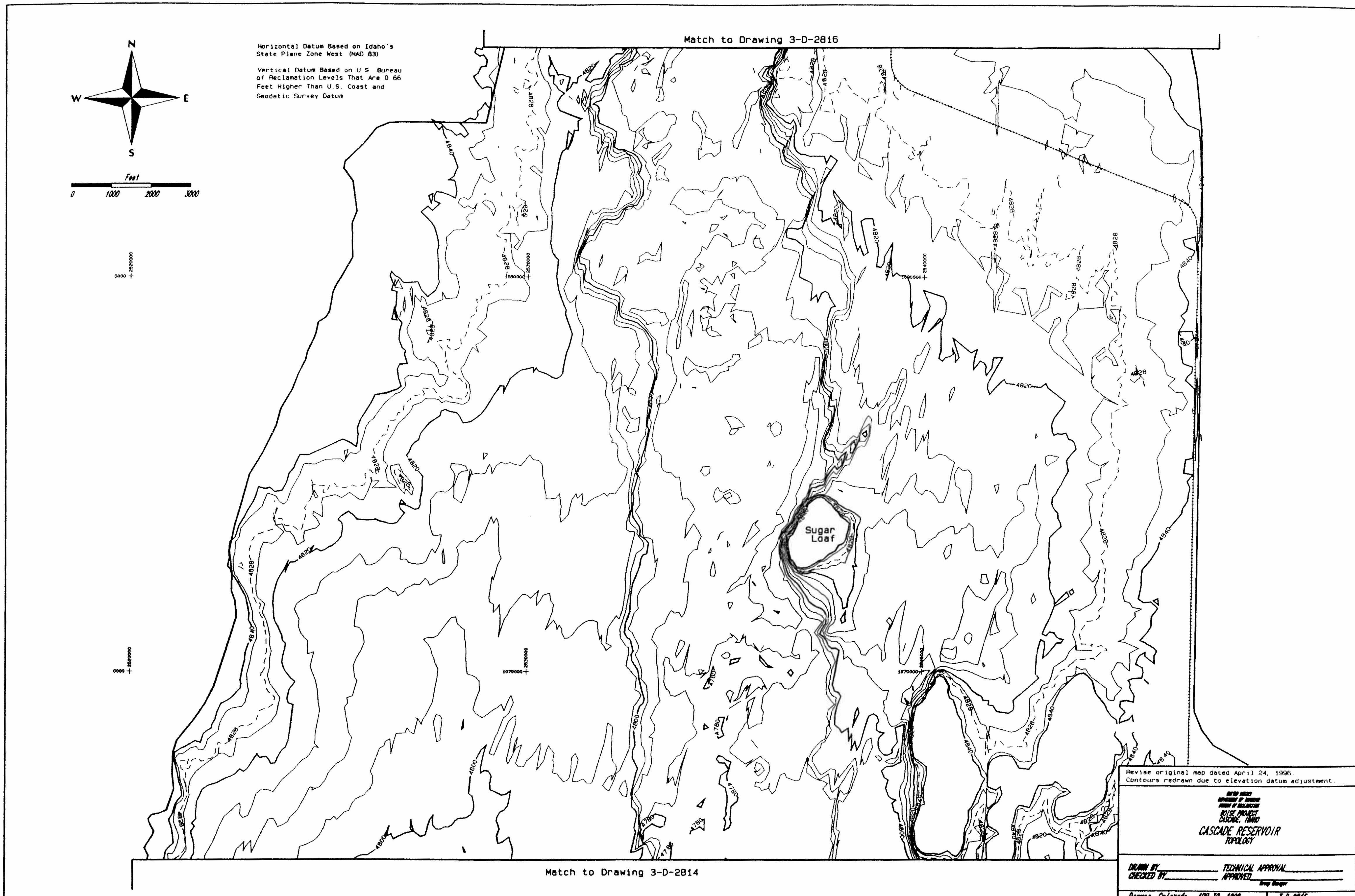

Figure 6. - Cascade Reservoir topology map, No. 3-D-2815.

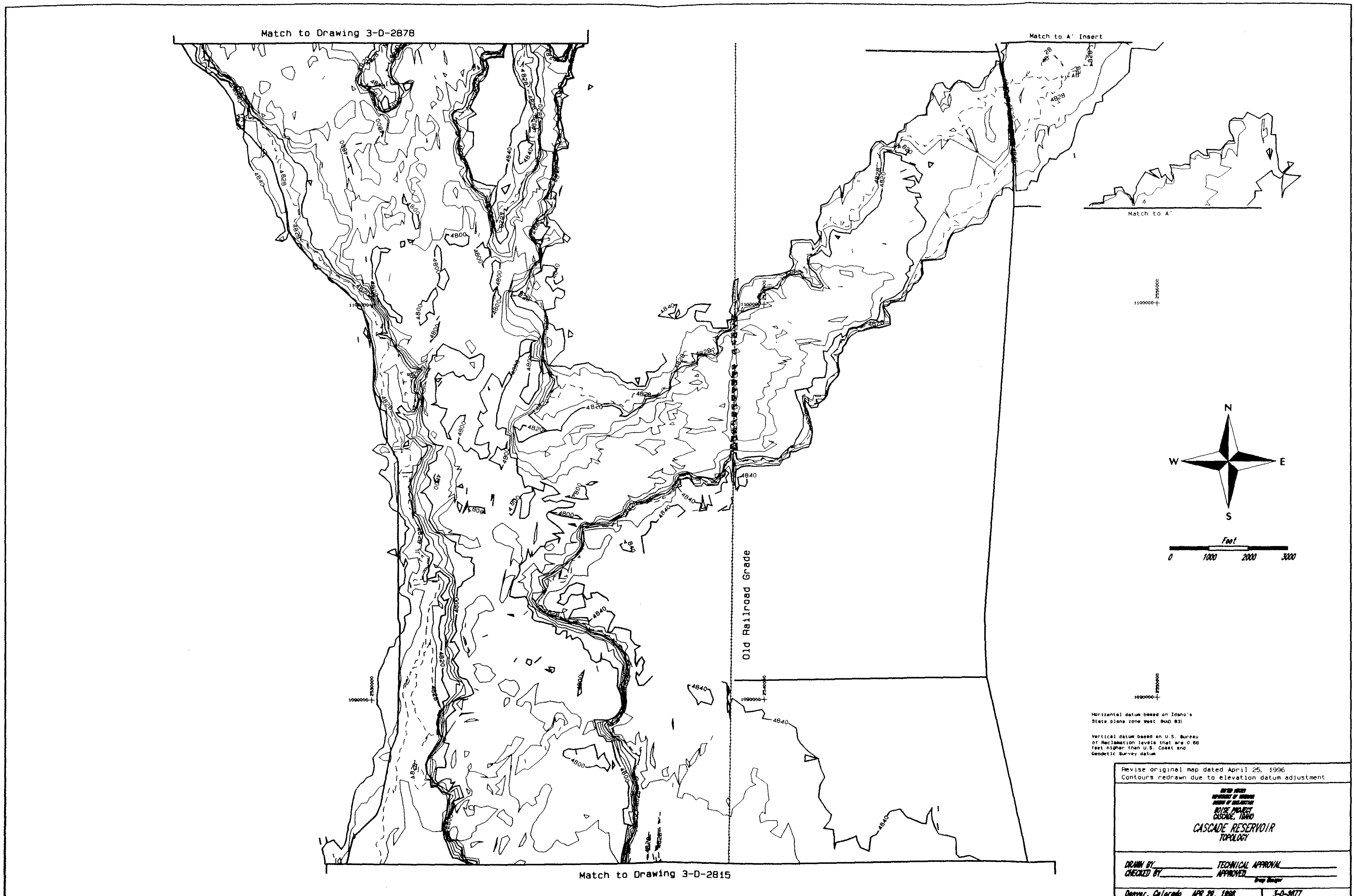

Figure 7. - Cascade Reservoir topology map. No. 3-D-2877.

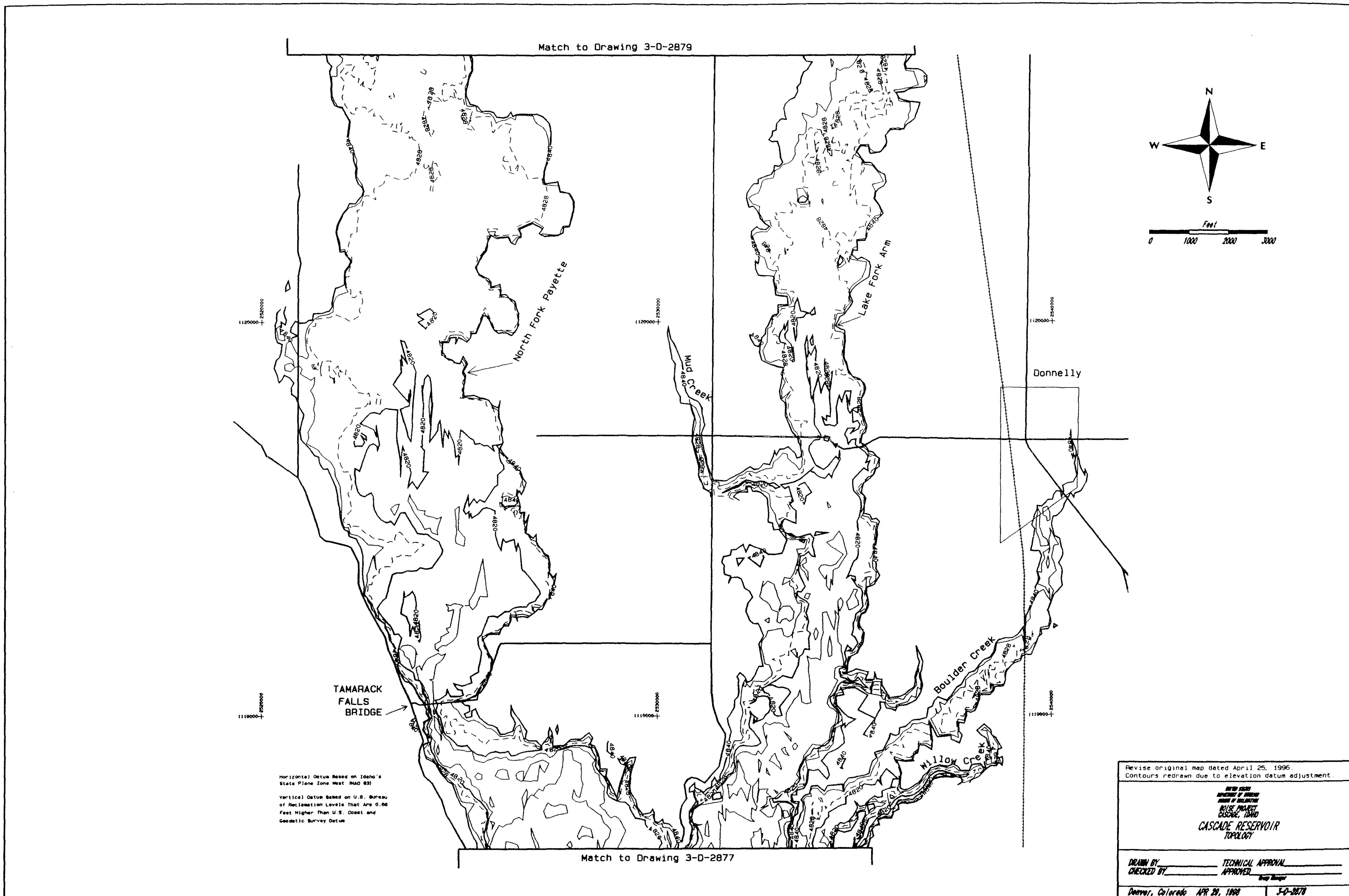

Figure 8. - Cascade Reservoir topology map, No. 3-D-2878.

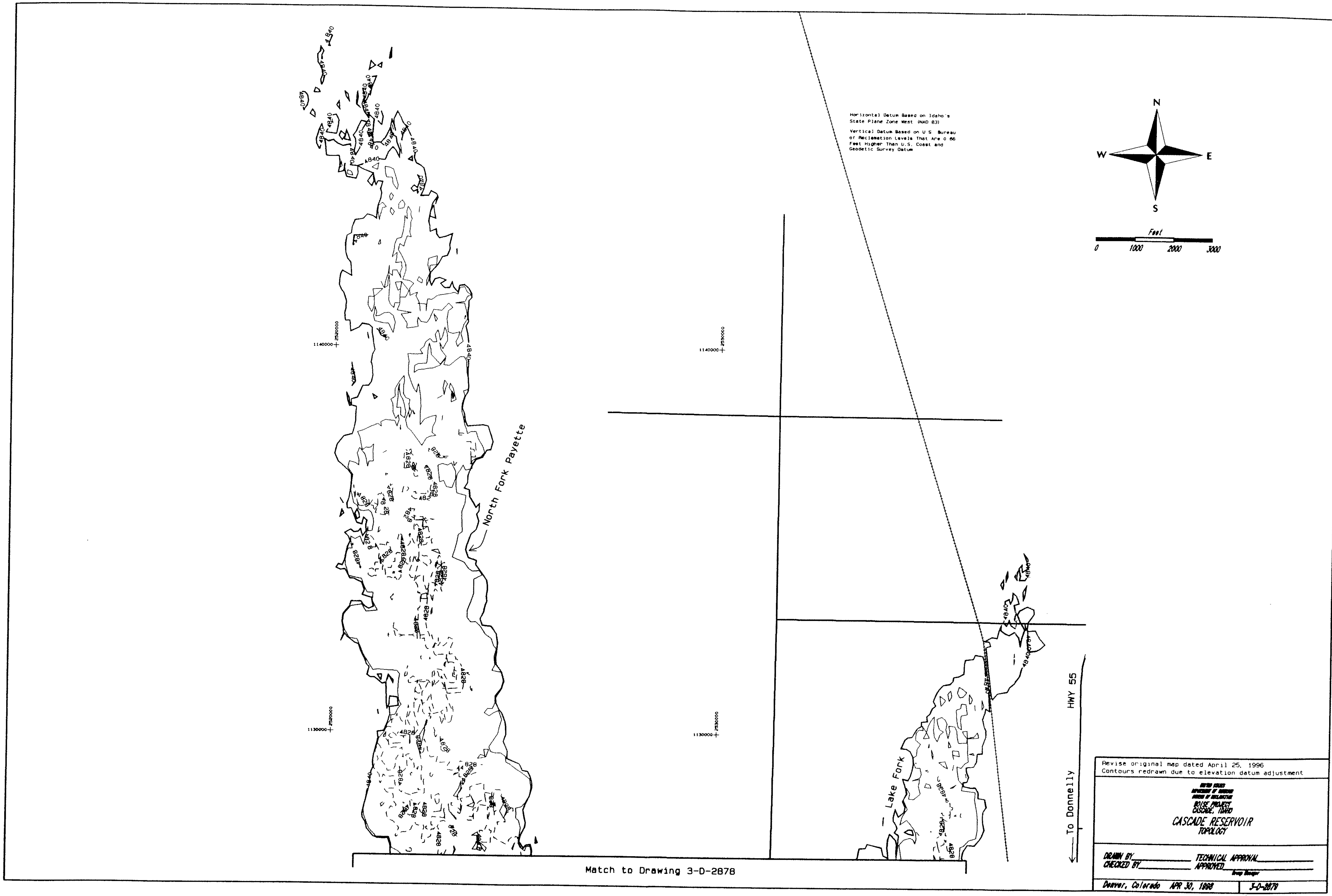

Figure 9. - Cascade Reservoir topology map, No. 3-D-2879.

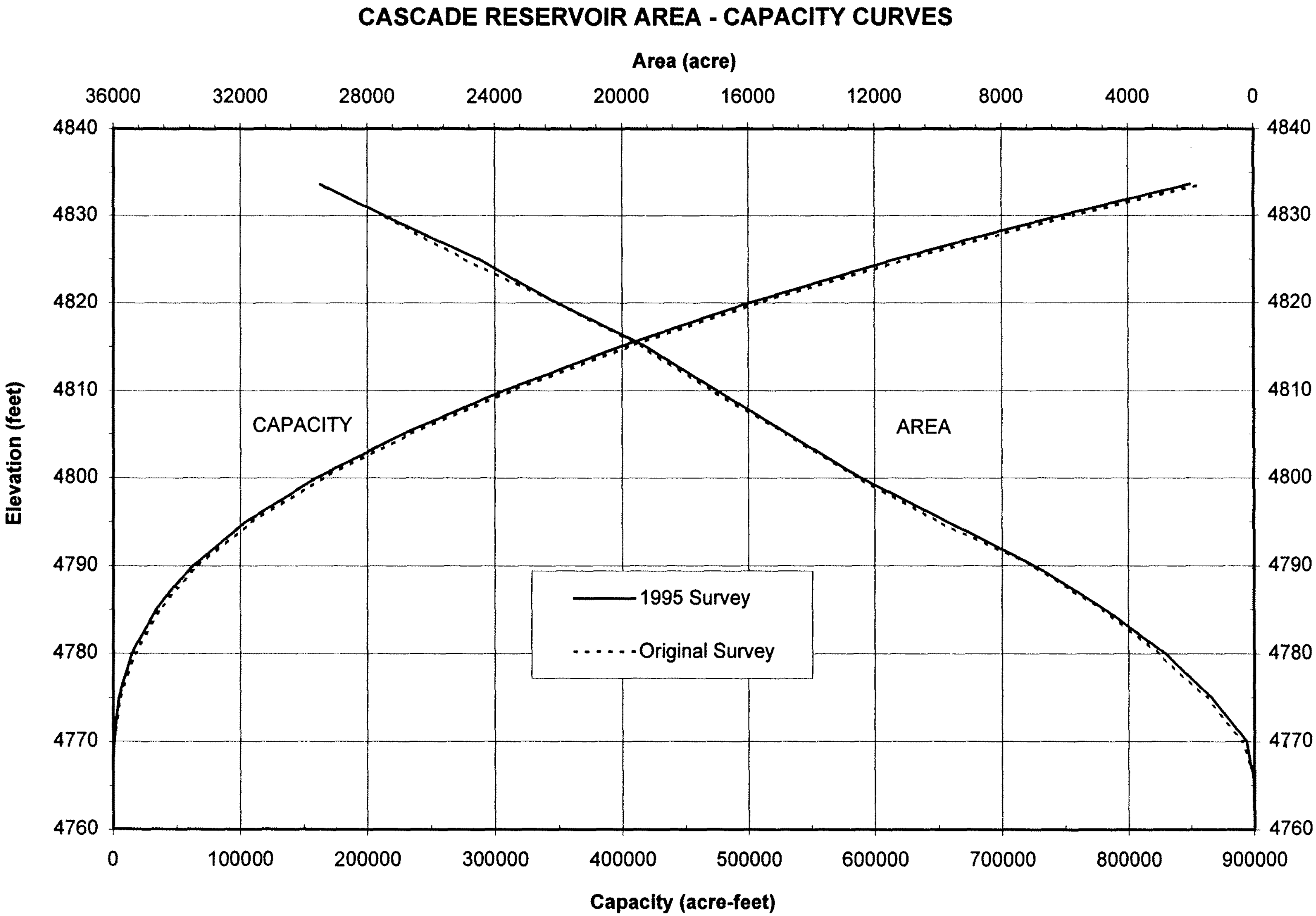

Figure 10. - 1995 area and capacity curves.

RECLAMATION'S 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.