BULLY CREEK RESERVOIR
2000 RESERVOIR SURVEY

U.S. Department of the Interior
Bureau of Reclamation

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave Blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	March 2001	Final

4. TITLE AND SUBTITLE	5. FUNDING NUMBERS
Bully Creek Reservoir 2000 Reservoir Survey	PR
6. AUTHOR(S) Ronald L. Ferrari	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Bureau of Reclamation, Technical Service Center, Denver CO 80225-0007	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) Bureau of Reclamation, Denver Federal Center, PO Box 25007, Denver CO 80225-0007	10. SPONSORING/MONITORING AGENCY REPORT NUMBER DIBR

11. SUPPLEMENTARY NOTES

Hard copy available at Bureau of Reclamation Technical Service Center, Denver, Colorado

12a. DISTRIBUTION/AVAILABILITY STATEMENT	12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

The Bureau of Reclamation (Reclamation) surveyed Bully Creek Reservoir in May 2000 to develop a topographic map and compute a present storage-elevation relationship (area-capacity tables). The data were used to calculate reservoir capacity lost due to sediment accumulation since dam closure in February of 1963. The underwater survey was conducted near reservoir elevation 2,515 feet (project datum). The underwater survey used sonic depth recording equipment interfaced with a global positioning system (GPS) that gave continuous sounding positions throughout the underwater portions of the reservoir covered by the survey vessel. The above-water topography was determined by aerial data collected near reservoir elevation 2,495. The new topographic map of Bully Creek Reservoir was developed from the combined 2000 aerial and underwater measured topography.

As of May 2000, at spillway crest water surface elevation (feet) 2,516.0, the surface area was 911 acres with a total capacity of 24,380 acre-feet. Since initial filling in February of 1963, an estimated 7,210 acre-feet of sediment have accumulated in Bully Creek Reservoir below elevation 2,516.0, resulting in a 22.8 percent loss in reservoir volume. Since 1963, the estimated average annual rate of reservoir capacity lost to sediment accumulation is 193.6 acre-feet. The sediment values are computed by comparing the original reservoir capacity with the new computed capacity. A portion of this difference, which is reported as sediment accumulation, may be due to different methods of the original and 2000 surveys and, or a slight shift in the vertical datum.

14. SUBJECT TERMS	15. NUMBER OF PAGES
reservoir area and capacity/ sedimentation/ reservoir surveys/ sonar/ sediment distribution/ contour area/ reservoir area/ sedimentation survey/ global positioning system	
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UL	UL	UL	UL

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18
298-102

BULLY CREEK RESERVOIR

2000 RESERVOIR SURVEY

by

Ronald L. Ferrari

Sedimentation and River Hydraulics Group
Water Resources Services
Technical Service Center
Denver, Colorado

July 2001

ACKNOWLEDGMENTS

The Bureau of Reclamation's (Reclamation) Sedimentation and River Hydraulics Group of the Technical Service Center (TSC) prepared and published this report. Kent Collins and Ronald Ferrari of the TSC conducted 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 final map development. Kent Collins of the TSC performed the technical peer review of this documentation.

Mission Statements

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.

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

Page

TABLES

Table

FIGURES

Figure

INTRODUCTION

Bully Creek Reservoir and dam are located in Malheur County on Bully Creek about 9 miles northwest of Vale in east-central Oregon (fig. 1). Bully Creek Reservoir is one of three storage features of the Vale Project with the other two being Beulah and Warm Springs Reservoirs. Bully Creek Reservoir's water supply is from Bully Creek along with diverted Malheur River water.

Bully Creek Dam was constructed from 1962 through 1963 with first storage on February 1 of 1963. The dam is a zoned earthfill embankment structure whose dimensions are (fig. 2):

Hydraulic height[1]	99	feet[2]	Structural height	110	feet
Top width	30	feet	Crest length	3,070	feet
Crest elevation	2,529.0	feet			

The drainage area above Bully Creek Dam is 547 square miles and all is considered sediment contributing. Additional water is diverted from the Malheur River. Bully Creek Reservoir has an average width of 0.47 miles with a length of around 3.4 miles.

The spillway is located on the right abutment and includes a uncontrolled 70-foot wide overflow crest with an elevation of 2,516.0 and ten 48- by 48-inch sluice gates. The gates allow controlled spillway releases to be made when the reservoir is above the crest elevation of these outlets which is 2,494.0. The spillway provides a maximum discharge of 10,200 cubic feet per second (cfs) at maximum reservoir elevation 2,523.0 with flow through all gates and over the spillway crest.

The outlet work is a concrete conduit located in the left abutment leading to a gate chamber where the inlet splits into a canal outlet and the Bully Creek dam outlet. At reservoir elevation 2,516.0, the maximum discharge capacity of the canal outlet works is 270 cfs and for the Bully Creek outlet works it is 415 cfs. These outlets are generally limited to 60 cfs and 110 cfs respectively to avoid downstream damage.

SUMMARY AND CONCLUSIONS

This Reclamation report presents the 2000 results of the survey of Bully Creek Reservoir. The primary objectives of the survey were to gather data needed to:

- develop reservoir topography
- compute area-capacity relationships
- estimate storage depletion caused by sediment deposition since dam closure

---

[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. All elevations shown in this report are based on the original project datum established by U.S. Bureau of Reclamation which is 2.41 feet lower than North American Vertical Datum of 1988.

A static global positioning system (GPS) control survey was conducted to establish horizontal and vertical control points around the reservoir for the underwater and aerial surveys that were conducted in 2000. The horizontal control was established in Oregon south state plane coordinates in the North American Datum of 1983 (NAD83), international feet. The vertical control for the established points was in the North American Vertical Datum of 1988 (NAVD88) and the Reclamation project construction datum. The survey found that for the established control points the average elevations in NAVD88 were around 2.41 feet higher than the Reclamation project construction datum. All elevations in this report are referenced to the Reclamation project datum.

The underwater survey was conducted in May of 2000 around reservoir water surface elevation 2,515 and the aerial survey was flown in fall of 2000 around reservoir water surface elevation 2,495. 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 Bully 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 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 new Bully Creek Reservoir topographic maps are a combination of the aerial and underwater survey data with the developed aerial contours being used for elevation 2495.0 and above. The 2000 reservoir surface areas at predetermined contour intervals were generated by a computer graphics program using the collected reservoir data. The 2000 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 2 and 3 contain a summary of the Bully Creek Reservoir sedimentation and watershed characteristics for the 2000 survey. The 2000 survey determined that the reservoir has a total storage capacity of 24,380 acre-feet and a surface area of 911 acres at reservoir elevation 2,516.0. Since closure on February 1963, the reservoir had an estimated volume change of 7,210 acre-feet below reservoir elevation 2,516.0. This volume represents a 22.8 percent loss in total capacity and an average annual loss of 193.6 acre-feet per year.

RESERVOIR OPERATIONS

Bully Creek Dam operates in conjunction with several other reservoirs of the Vale Project to provide irrigation water. The May 2000 area-capacity tables show 31,236 acre-feet of total storage below elevation 2,523.0. The 2000 survey measured a minimum elevation of 2,440.4. The following values are from the May 2000 area-capacity tables:

- 6,856 acre-feet of surcharge storage between elevation 2,516.0 and 2,523.0.
- 23,676 acre-feet of joint use storage between elevation 2,456.58 and 2,516.0.
- 704 acre-feet of dead storage below elevation 2,456.58.

The Bully Creek Reservoir inflow and end-of-month stage records in table 2, operation period February 1963 through May 2000, show the inflow and annual fluctuation since dam closure. The estimated average inflow into the reservoir for this operation period was 182,855 acre-feet per year. Since initial filling, the extreme storage fluctuations of Bully Creek Reservoir ranged from elevation 2,417.2 in 1964 and a maximum recorded elevation of 2,518.9 in 1978.

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 GPS receiver with a built-in radio and an omnidirectional antenna, a depth sounder, a helmsman display for navigation, 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 an external radio and an omnidirectional antenna. The GPS receiver and antenna were mounted on a survey tripod over a known datum point. To obtain the maximum radio transmission range, known datum points with clear line-of-sight to the survey boat were selected. The power for the shore unit was provided by a 12-volt battery.

GPS Technology and Equipment

The hydrographic positioning system used at Bully Creek 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 a 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 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 (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.

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 of the ionosphere on the radio signal. 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 at the survey vessel's GPS receiver during the Bully Creek 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, 1994).

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. In May of 2000 the use of S/A was discontinued, but the errors of a single receiver are still around $\pm$10 meters.

A method of collection to resolve or cancel the inherent errors of GPS is called differential GPS (DGPS). DGPS is used during the 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 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 Bully Creek Reservoir survey, position corrections were determined by the master receiver and transmitted via an ultra-high frequency (UHF) radio link every second 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 can result in sub-meter positional accuracies for the survey vessel compared to positional accuracies of ±100 meters with a single receiver.

The Sedimentation and River Hydraulics Group conducts their bathymetric surveys using Real-time Kinematic (RTK) GPS. The major benefit of RTK versus DGPS is that precise heights can be measured in real time for monitoring 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 2 centimeters horizontally and 3 centimeters vertically. The output is on the GPS datum of WGS-84 which the hydrographic collection software converted into Oregon's NAD83 state plane south zone coordinate system, international feet. The system employs two receivers, like with DGPS, that collect additional satellite data that allows on-the-fly centimeter accuracy measurements.

Survey Method and Equipment

The Bully Creek Reservoir hydrographic survey collection was conducted from May 16 through May 18, 2000 at around water surface elevation 2,515 (Reclamation project datum). The bathymetric survey was run using sonic depth recording equipment, interfaced with an RTK GPS, capable of determining sounding locations within the reservoir. The survey system software continuously recorded reservoir depths and horizontal coordinates as the survey boat moved across closely-spaced grid lines covering the reservoir area. Most of the transects (grid lines) were run somewhat in a perpendicular direction to the center line of the reservoir at 300-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 2000 underwater data were collected by a depth sounder that 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 a RS-232 port. The depth sounder also produced 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.

Bully Creek Reservoir Datums

Prior to the aerial survey, a contract static global positioning system (GPS) control survey was conducted to establish horizontal and vertical control points around the reservoir. The horizontal control was established in Oregon state plane (south zone) coordinates in NAD83, international feet. The vertical controls for the established points were in NAVD88. The survey found that for the established points the average elevations in NAVD88 were around 2.41 feet higher than the Reclamation's project datum. The project datum elevation of the spillway overflow crest is 2,516.0 and all calculations and elevations in this report are based on the Reclamation project datum.

RESERVOIR AREA AND CAPACITY

Topography Development

Using ARC/INFO the topography of Bully Creek Reservoir was developed from the combined 2000 aerial and underwater survey data. ARC/INFO is a software package for development and analysis of geographic information system (GIS) layers and development of interactive GIS applications (ESRI, 1992). GIS technology provides a means of organizing and interpreting large data sets.

The 5-foot reservoir contours for elevation 2,495.0 through 2,530.0 were provided by the aerial contractor as a data exchange format (DXF) file. The underwater contours of the reservoir were developed by using the elevation 2,515.0 contour as a boundary around the edge of the underwater data set. This polygon enclosed the data set, was assigned an elevation of 2,515.0, and was used to perform a clip such that interpolation was not allowed to occur outside of this boundary. This clip was performed using the hardclip option of the ARC/INFO CREATETIN command.

Contours for the reservoir below elevation 2,515.0 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 Bully Creek Reservoir TIN. In addition, the contours were generalized by eliminating certain 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 Bully Creek Reservoir since the areas were calculated from the developed TIN. The areas of the enclosed contour polygons developed from the aerial survey data were completed for elevations 2495.0 through elevation 2,530.0.

The map features such as the dam, roads and the contours, from elevation 2,495.0 and above, were imported from the aerial data. The contours from elevations 2,490.0 and below were developed and imported from the underwater data. The contour topography at 5-foot intervals are presented on figures 3 and 4 (drawing number 126-D-548 and 126-D549).

Development of 2000 Contour Areas

The 2000 contour surface areas for Bully Creek Reservoir were computed at 1-foot increments, from elevation 2,441.0 to 2,510.0, using the Bully Creek Reservoir TIN discussed above. The 2000 survey measured the minimum reservoir elevation at 2,440.4 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. The enclosed surface areas for the 5-foot reservoir contour increments of elevation 2,495.0 through 2,530.0 were measured from the provided DXF aerial contour files developed by the aerial contractor. The following table provides a comparison of the measured surface areas for the original and the 2000 underwater and aerial surveys. The table shows a very good comparison between the 2000 aerial and underwater surveys. The table shows the significant measured difference between the original and 2000 survey results.

Table 1
Surface Area Comparisons by Survey

Elevation (feet)	Original Survey (acre-feet)	2000 Underwater (acre-feet)	2000 Aerial Survey (acre-feet)
2495	637	467.6	466.8
2500	733	551.2	557.7
2505	817	649.8	635.2
2510	887	742.3	767.0

2000 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 5-foot contour intervals from reservoir elevation 2,440.0 to elevation 2,490.0 from the underwater survey results and from elevation 2495.0 to elevation 2530.0 from the aerial survey results were used as the control parameters for computing the Bully Creek 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 Bully 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 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 2000 Bully Creek Reservoir area and capacity computations are listed in table 2 and columns 4 and 5 of table 3. On table 3, columns 2 and 3 list the original surface areas and recomputed capacities. A separate set of 2000 area and capacity tables has been published for the 0.01, 0.1 and 1-foot elevation increments (Bureau of Reclamation 2000). A description of the computations and coefficients output from the ACAP85 program is included with these tables. Both the original and 2000 area-capacity curves are plotted on figure 5. As of May 2000, at elevation 2,523.0, the surface area was 1,032 acres with a total capacity of 31,236 acre-feet.

RESERVOIR SEDIMENT ANALYSES

The area curve plot on figure 5 and table 3 provides a comparison of the measured surface areas for the original and 2000 survey results. They show a significant change since dam closure in 1963. The table 1 comparison of the 2000 underwater and aerial survey results, which were computed independently of each other, illustrates that the same vertical datum was used for both surveys. It is assumed that the original survey is also tied to the same vertical datum since the 2000 control survey tied the vertical datum to the spillway overflow crest elevation of 2,516.0 as specified on the Reclamation Drawing Number 126-D-405.

The 2000 aerial mapping features such as the roads, dam, and contour lines where plotted and laid over the original and USGS quad of the reservoir area. The mapping features on all maps appeared to line up with the only significant change being the contour lines of the 2000 aerial data not extending as far upstream as the contours on the quad of the reservoir. This would indicate a large sediment delta forming in the upper portion of the reservoir. The hydrographic survey crew was in the area when the reservoir was nearly full so didn't observe this, but others in the area during low reservoir content observed the sediment buildup in the upper portion of the reservoir.

The original 100 year sediment inflow estimate, used during the design of Bully Creek Reservoir, was 8,000 acre-feet, or a 25.3 percent decrease in original capacity. This computes to an average annual rate of capacity loss of 80.0 acre-feet compared to the 2000 survey computed results of 193.6 acre-feet per year. The 2000 survey computed a very high sediment inflow, but it is computed by comparing the 2000 measured results with the original survey results. A portion of this difference can be attributed to the different methods of measurement and resulting accuracies between the two surveys. A resurvey of Bully Reservoir should be considered in the future if major sediment inflow events are observed and if the average annual rate of sediment accumulation needs to be further clarified.

Figure 5 is a plot of Bully Creek Reservoir's original area data versus the 2000 measured areas. This illustrates the difference between the original and the 2000 measured surface areas. Since dam closure in February 1963, the measured total volume change at reservoir elevation 2,516 was estimated to be 7,210 acre-feet. The estimated average annual rate of capacity lost for this time period (37.2 years) was 193.6 acre-feet per year. The storage loss in terms of percent of original storage capacity was 22.8 percent. Tables 2 and 3 contain the Bully Creek Reservoir sediment accumulation and water storage data based on the 2000 resurvey.

REFERENCES

American Society of Civil Engineers, 1962. ***Nomenclature for Hydraulics***, ASCE Headquarters, New York.

Bureau of Reclamation, 1981. ***Project Data,*** Denver Office, Denver CO.

Bureau of Reclamation, 1985. Surface Water Branch, ***ACAP85 User's Manual***, Technical Service Center, Denver CO.

Bureau of Reclamation, 1987(a). ***Guide for Preparation of Standing Operating Procedures for Bureau of Reclamation Dams and Reservoirs***, U.S. Government Printing Office, Denver, CO.

Bureau of Reclamation, 1987(b). ***Design of Small Dams***, U.S. Government Printing Office, Denver CO.

Bureau of Reclamation, May 2000. Denver Office, ***Bully Creek Reservoir Area and Capacity Tables, Vale Project***, Pacific Northwest Region, Boise, ID.

Corps of Engineers, October 1994. Engineer and Design - ***Hydrographic Surveying***, EM 1110-2-1003 (FR), Department of the Army, Washington DC (www.usace.army.mil/inet/usace.docs/eng-manuals/em.htm).

Environmental Systems Research Institute , Inc. (ESRI), 1992. ***ARC Command References***.

RESERVOIR SEDIMENT DATA SUMMARY

Bully Creek Reservoir
NAME OF RESERVOIR

1
DATA SHEET NO.

D	1. OWNER Bureau of Reclamation	2. STREAM Bully Creek	3. STATE Oregon
A	4. SEC. 12 TWP. 18 S RANGE 43 E	5. NEAREST P.O. Vale	6. COUNTY Malheur
M	7. LAT 44° 00' 55" LONG 117° 23' 45"	8. TOP OF DAM ELEVATION 2529.0	9. SPILLWAY CREST EL 2494.0[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	2523.0		7,300	38,950	
	b. FLOOD CONTROL					2/63
	c. POWER					
	d. JOINT USE	2516.0	983	30,000	31,650	16. DATE NORMAL OPERATION BEGAN
	e. CONSERVATION					
	f. INACTIVE					
	g. DEAD	2456.58	137	1,650	1,650	2/63
	17. LENGTH OF RESERVOIR 3.4 MILES			AVG. WIDTH OF RESERVOIR 0.47 MILES		

BASIN		
	18. TOTAL DRAINAGE AREA 547 SQUARE MILES	22. MEAN ANNUAL PRECIPITATION 9.1[2] INCHES
	19. NET SEDIMENT CONTRIBUTING AREA 547 SQUARE MILES	23. MEAN ANNUAL RUNOFF 9.27[3] INCHES
	20. LENGTH MILES / AV. WIDTH MILES	24. MEAN ANNUAL RUNOFF 270,490[4] ACRE-FEET
	21. MAX. ELEVATION / MIN. ELEVATION	25. ANNUAL TEMP. MEAN 52°F RANGE -27°F to 106°F[2]

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
2/63			Contour (D)	5-ft	983[5]	31,590[5]	.12
5/00	37.2	37.2	Contour (D)	5-ft	911[6]	24,380[6]	.09

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
5/00		182,855[7]	270,490	6,811,350	182,855	6,811,350

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.
5/00	7210[8]	193.6	0.354	7210	193.6	0.354

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.
5/00				0.613[9]	22.8[9]		

26. DATE OF SURVEY	43. DEPTH DESIGNATION RANGE BY RESERVOIR ELEVATION										
		2460-2425	2470-2460	2480-2470	2490-2480	2500-2490	2510-2500	2516-2510			
	PERCENT OF TOTAL SEDIMENT LOCATED WITHIN DEPTH DESIGNATION										
5/00		11.7	7.2	8.8	17.1	24.3	22.9	8.0			

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

45. RANGE IN RESERVOIR OPERATION[7]

YEAR	MAX. ELEV.	MIN. ELEV.	INFLOW, AF	YEAR	MAX. ELEV.	MIN. ELEV.	INFLOW, AF
				1963	2,491.2	2,452.2	32,720
1964	2,505.7	2,417.2	111,050	1965	2,515.3	2,476.0	253,410
1966	2,509.1	2,464.0	166,370	1967	2,513.5	2,463.1	168,500
1968	2,510.2	2,478.3	168,040	1969	2,516.0	2,477.4	184,780
1970	2,515.5	2,483.4	228,580	1971	2,515.9	2,498.8	220,460
1972	2,513.4	2,481.4	163,060	1973	2,506.1	2,479.2	113,060
1974	2,516.0	2,488.1	205,950	1975	2,516.0	2,489.4	213,610
1976	2,512.5	2,498.1	188,960	1977	2,499.4	2,486.5	105,000
1978	2,518.9	2,461.0	183,050	1979	2,516.2	2,487.5	183,720
1980	2,514.4	2,504.2	221,990	1981	2,515.4	2,487.8	225,980
1982	2,516.8	2,486.5	256,000	1983	2,516.8	2,500.1	270,490
1984	2,516.3	2,494.1	243,930	1985	2,516.2	2,484.2	212,580
1986	2,516.0	2,480.8	195,110	1987	2,510.1	2,458.1	152,430
1988	2,497.1	2,458.5	52,960	1989	2,516.8	2,458.7	164,590
1990	2,500.1	2,458.7	105,630	1991	2,489.3	2,458.4	52,930
1992	2,496.6	2,458.8	61,230	1993	2,517.5	2,458.9	180,990
1994	2,507.0	2,458.8	154,430	1995	2,517.0	2,458.8	211,420
1996	2,516.4	2,493.3	237,570	1997	2,515.6	2,492.1	237,960
1998	2,517.2	2,491.1	251,390	1999	2,516.5	2,497.7	260,840
2000	2,516.3	2,496.4	170,330				

46. ELEVATION - AREA - CAPACITY DATA FOR **2000 CAPACITY**[10]

ELEVATION	AREA	CAPACITY	ELEVATION	AREA	CAPACITY	ELEVATION	AREA	CAPACITY
2440.4	0	0	2445	15.0	38	2450	51.6	204
2455	89.3	556	2460	117.2	1,073	2465	141.0	1,718
2470	191.0	2,548	2475	244.1	3,636	2480	279.8	4,946
2485	319.9	6,445	2490	375.4	8,183	2495	466.8	10,289
2500	557.7	12,850	2505	635.2	15,832	2510	767.0	19,338
2515	889.9	23,480	2516	911	24,380	2520	995.7	28,194
2523	1,032	31,236	2525	1,056.9	33,325	2530	1,116.9	38,759

47. REMARKS AND REFERENCES

1 Top of sluice gates, elevation 2,516.0.
2 Bureau of Reclamation Project Data Book, 1981.
3 Calculated using mean annual runoff value of 270,490 AF, item 24, 2/63-5/00.
4 Computed annual inflows from 2/63 through 5/00.
5 Original surface area and capacity at el. 2,516.0. For sediment computation purposes the original capacity was recomputed by the Reclamation ACAP program using the original surface areas.
6 Surface area & capacity at el. 2,516.0 computed by ACAP program.
7 Inflow values in acre-feet and maximum and minimum elevations in feet by water year from 2/63 through 5/00. Some months of missing records. Elevation data for 1963 through 1970 from USGS water records.
8 Computed sediment volume at elevation 2516.0.
9 Storage losses at elevation 2516.0.
10 Capacities computed by Reclamation's ACAP computer program. At elevation 2,456.58 (dead capacity elevation) the calculated surface areas was 98 acres with a capacity of 704 acre-feet.

48. AGENCY MAKING SURVEY Bureau of Reclamation
49. AGENCY SUPPLYING DATA Bureau of Reclamation | DATE March 2001

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

1	2	3	4	5	6	7	8
					2000	2000	Percent of
Elevations	Original	Original	2000	2000	Sediment	Percent of	Reservoir
	Survey	Capacity	Survey	Survey	Volume	Sediment	Depth
(feet)	(acres)	(acre-feet)	(acres)	(acre-feet)	(acre-feet)		
2,530.0			1117	38759			
2,525.0			1057	33325			
2,523.0			1032	31236			100.0
2,520.0	1033.0	35623	995.7	28194			96.9
2,516.0	983.0	31590	911.0	24380	7210	100.0	92.9
2,515.0	971.0	30613	889.9	23480	7133	98.9	91.8
2,510.0	887.0	25968	767.0	19338	6630	92.0	86.7
2,505.0	817.0	21708	635.2	15832	5876	81.5	81.6
2,500.0	733.0	17833	557.7	12850	4983	69.1	76.5
2,495.0	637.0	14408	466.8	10289	4119	57.1	71.4
2,490.0	560.0	11415	375.4	8183	3232	44.8	66.3
2,485.0	440.0	8915	319.9	6445	2470	34.3	61.2
2,480.0	350.0	6940	279.8	4946	1994	27.7	56.1
2,475.0	310.0	5290	244.1	3636	1654	22.9	51.0
2,470.0	243.0	3908	191.0	2548	1360	18.9	45.9
2,465.0	200.0	2800	141.0	1718	1082	15.0	40.8
2,460.0	152.0	1920	117.2	1073	847	11.7	35.7
2,456.6	137.0	1439	98.0	704	735	10.2	32.2
2,455.0	130.0	1215	89.3	556	659	9.1	30.6
2,450.0	100.0	640	51.6	204	436	6.0	25.5
2,445.0	41.0	288	15.0	38	250	3.5	20.4
2,440.0	20.0	135	0.0	0	135	1.9	15.3
2,435.0	14.0	50			50	0.7	10.2
2,430.0	3.0	8			8	0.1	5.1
2,425.0	0.0	0			0	0.0	0.0
1	Elevation of reservoir water surface.						
2	Original reservoir surface area.						
3	Original reservoir capacity recomputed using ACAP.						
4	Reservoir surface area from 2000 survey.						
5	Reservoir capacity computed using ACAP, from 2000 measured surface areas.						
6	Measured sediment volume = column (3) - column (5).						
7	Measured sediment expressed in percentage of total sediment 7,210 at el. 2,516.0.						
8	Depth of reservoir expressed in percentage of total depth of 95 feet.						

Table 3. - Summary of 2000 survey results

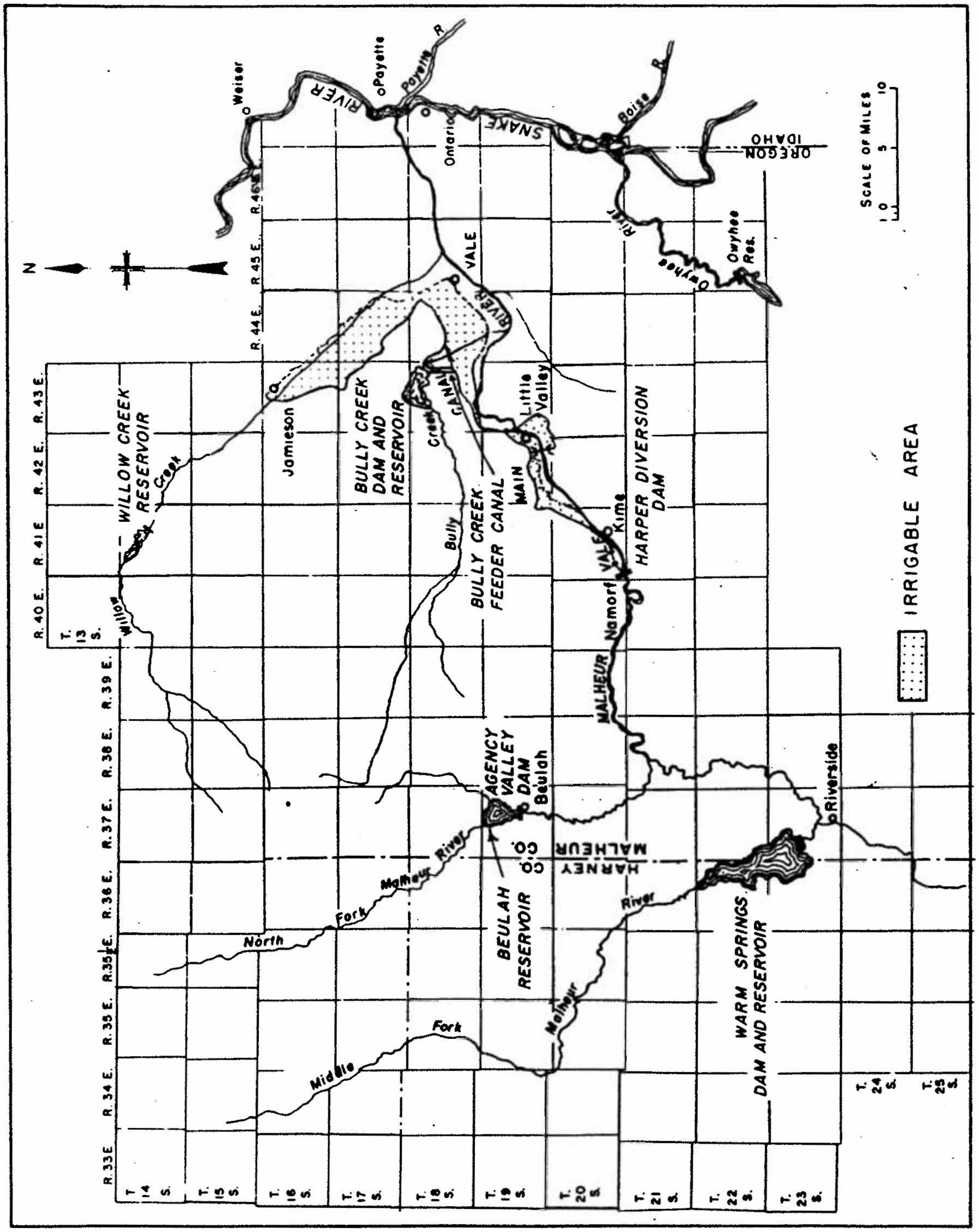


Figure 1. - Bully Creek Reservoir location map.

Space intentionally left blank due to security concerns

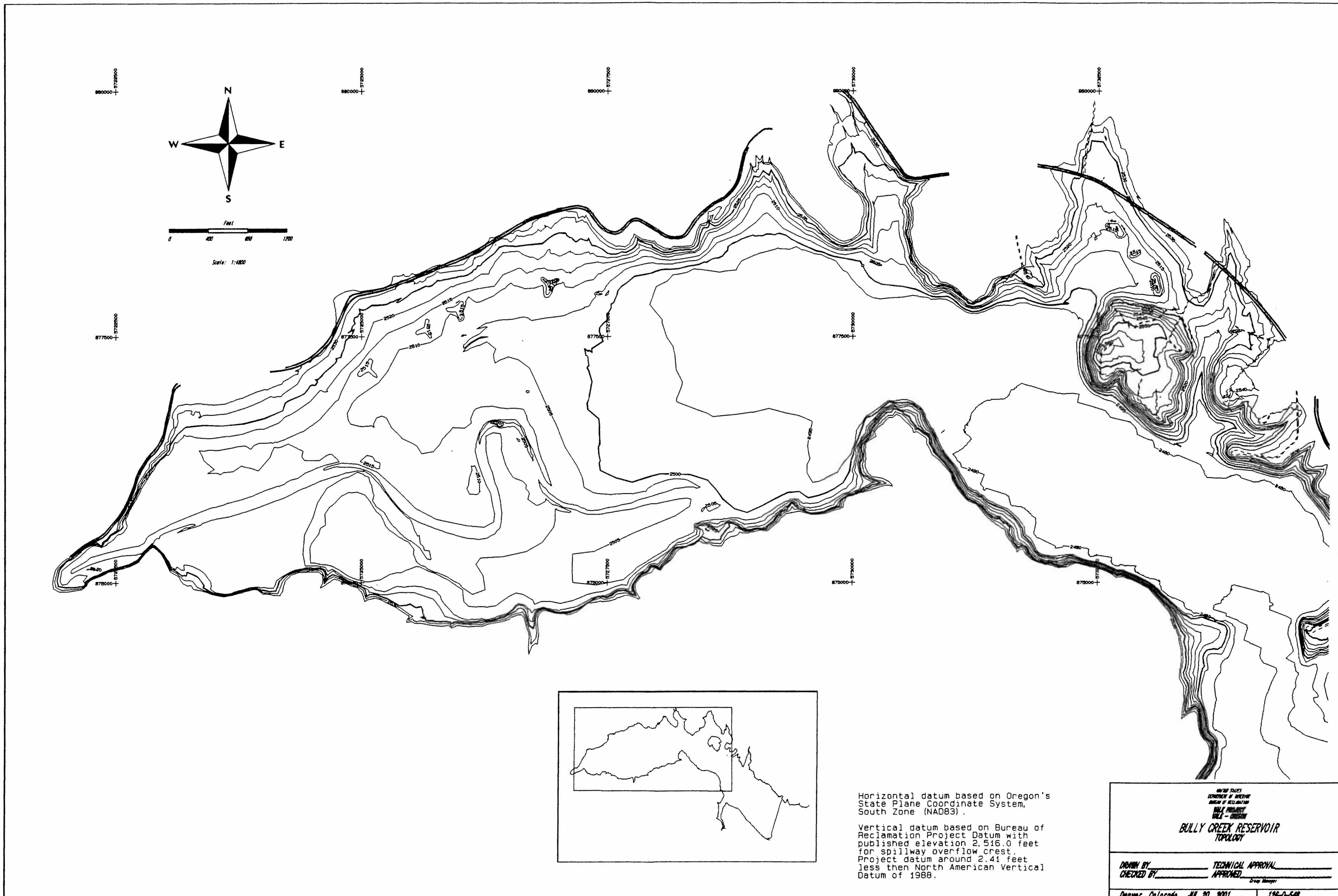
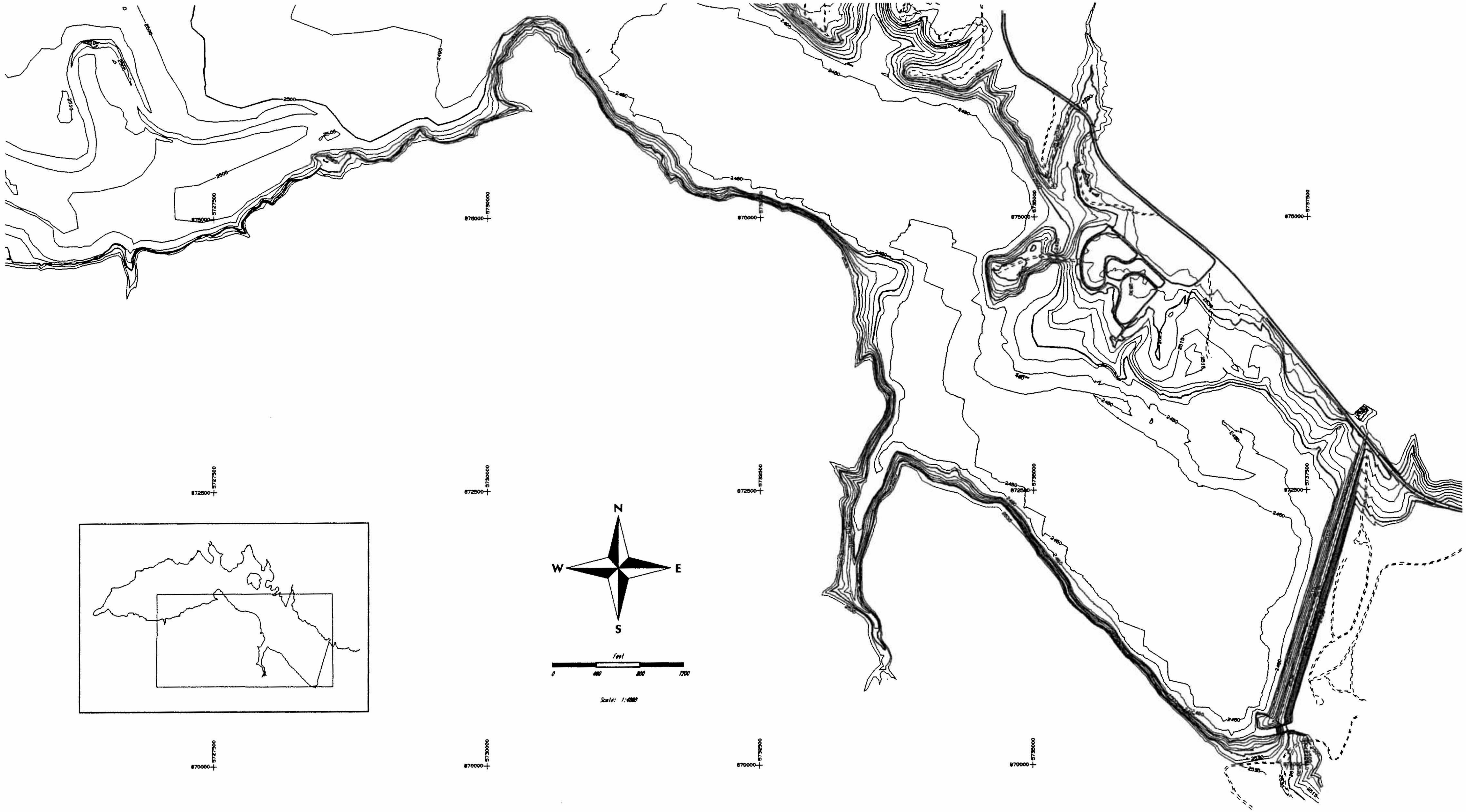


Figure 3. - Bully Creek Reservoir topographic map, No. 126-D-548.



Horizontal datum based on Oregon's State Plane Coordinate System, South Zone (NAD83).

Vertical datum based on Bureau of Reclamation Project Datum with published elevation 2,516.0 feet for spillway overflow crest. Project datum around 2.41 feet less then North American Vertical Datum of 1988.

BULLY CREEK RESERVOIR
TOPOLOGY

DRAWN BY______ TECHNICAL APPROVAL______
CHECKED BY______ APPROVED______

Denver, Colorado JUL 20, 2001 | 126-D-549

Figure 4. - Bully Creek Reservoir topographic map. No. 126-D-549

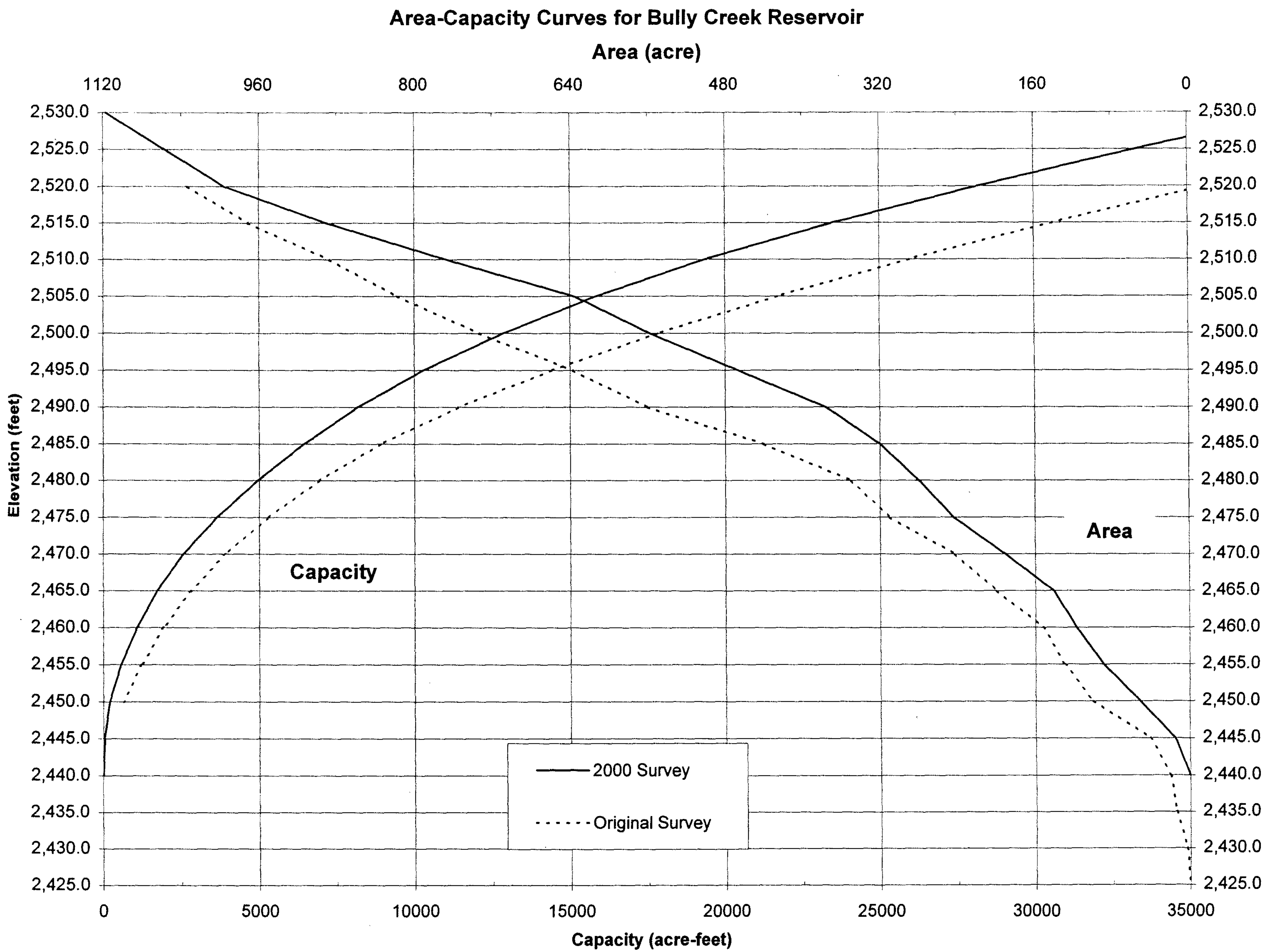


Figure 5. - 2000 area and capacity curves