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Managing Water in the West

Glendo Reservoir
2003 Sedimentation Survey

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13. ABSTRACT *(Maximum 200 words)*

The Bureau of Reclamation (Reclamation) surveyed Glendo Reservoir in May and July of 2003 and January 2005 to develop a new topographic map and compute a present storage-elevation relationship (area-capacity tables). The 2003 underwater survey, conducted between lake elevation 4626 (feet) and 4629 (project datum), 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. In January 2005, a GPS land survey was conducted on a small portion of the upper reach of the reservoir. The above-water topography was determined by digitizing reservoir contours from the U.S. Geological Survey quadrangle (USGS quad) maps. The new topographic map of Glendo Reservoir was developed from the digitized USGS quad contours (adjusted in the upper reach using the January 2005 data) and the 2003 underwater data. Due to the lack of complete above water data, this study assumed no change since the 1972 reservoir resurvey from elevation 4640 and above.

As of July 2003, at spillway crest elevation 4,653.0, the surface area was 17,986 acres with a total capacity of 763,039 acre-feet. Since dam closure on October 18, 1957, about 33,979 acre-feet of estimated change has occurred below elevation 4,653.0 resulting in a 4.26 percent loss in reservoir volume. This calculated change is due to sediment inflow and accuracy differences between the surveys.

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2003 Sedimentation Survey

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CONTENTS

Page

Introduction 1
Summary and Conclusions 2
Reservoir Operations 3
Hydrographic Survey Equipment and Method 3
Reservoir Area and Capacity 7
  Topography Development 7
  Development of 2003 Contour Areas 8
  2003 Storage Capacity 9
Reservoir Sediment Analyses 10
References 11

TABLES

Table

1 Reservoir sediment data summary (page 1 of 3) 13
1 Reservoir sediment data summary (page 2 of 3) 14
1 Reservoir sediment data summary (page 3 of 3) 15
2 Summary of 2003 survey results 16

FIGURES

Figure

1 Glendo Reservoir location map 1
2 Survey vessel with mounted hydrographic equipment on Jackson Lake in Wyoming 4
3 Multibeam collection system 5
4 Breach cofferdam upstream of Glendo Dam 6
5 Glendo Reservoir topographic map, No. 1 17
6 Glendo Reservoir topographic map, No. 2 19
7 Glendo Reservoir topographic map, No. 3 21
8 Glendo Reservoir topographic map, No. 4 23
9 Glendo Reservoir topographic map, No. 5 25
10 Glendo Reservoir topographic map, No. 6 27
11 2003 area and capacity curves 29

INTRODUCTION

Glendo Dam and Reservoir on the North Platte River in Platte and Converse Counties is about 4.5 miles southeast of Glendo, in east central Wyoming (figure 1). The dam, reservoir, and facilities are part of the Glendo Unit of the Pick-Sloan Missouri River Basin Project.

Glendo Dam, constructed from 1955 thru 1958, began initial storage on October 18, 1957. To enclose the reservoir about 2,400 feet of dikes were required across a low area on the south side of the reservoir located about 1.5 miles west of the dam. The dam is a zoned earthfill structure whose dimensions are:

Hydraulic height[1]	145	feet	Structural height	190	feet
Top width	35	feet	Crest length	2,096	feet
Crest elevation	4,675.0	feet[2]			

The spillway is a 45 feet wide uncontrolled concrete structure located 450 feet north of the right abutment of the dam. The spillway crest elevation is 4,653.0 and provides a discharge of 10,335 cubic feet per second (cfs) at maximum reservoir elevation 4,669.0. An outlet works is located on the south side of the reservoir about 0.5 miles upstream from the dam. The discharge capacity with the power outlets closed is 13,000 cfs at reservoir elevation 4,669.0. The Glendo Powerplant is located on the right bank of North Platte River about 4,000 feet south of Glendo Dam.

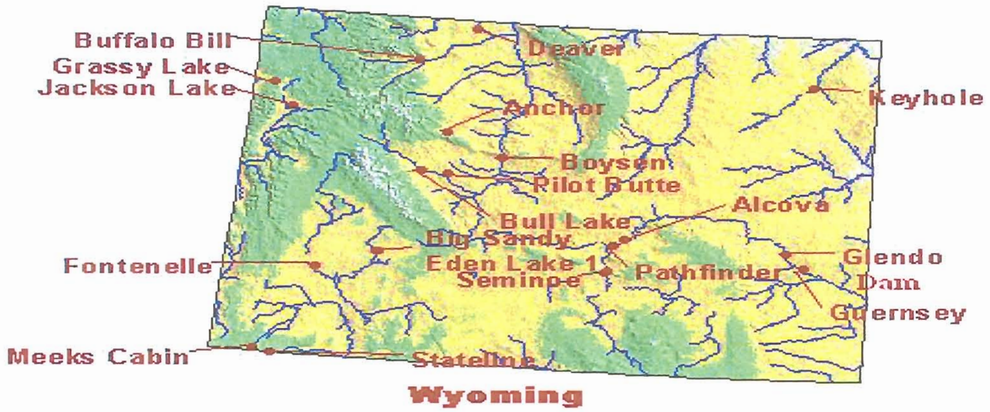

Figure 1 – Glendo Dam location map.

The drainage area above Glendo Dam is approximately 15,545 square miles and 4,330 square miles are considered sediment contributing. The total drainage area value is from the USGS

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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]Elevations are shown in feet. All elevations shown in this report are based on the original project datum established by U.S. Bureau of Reclamation that was report to be tied to the National Geodetic Vertical Datum of 1929 (NGVD29). The 2003 survey found Reclamation's datum to be around 2.55 feet less than the North American Vertical Datum of 1988 (NAVD88).

water resource data (USGS, 1990). The non-sediment contributing area includes the drainage area above Pathfinder Dam and surface area listed by the USGS as noncontributing. The reservoir is located on the North Platte River whose major tributaries include the Encampment, Medicine Bow, and Sweetwater Rivers. The drainage basin elevations range from approximately 10,300 feet at the headwaters to normal reservoir surface elevation 4,635. The reservoir is around 28.7 miles in length and around 1.0 miles in width.

SUMMARY AND CONCLUSIONS

This Reclamation report presents the 2003 results of the survey of Glendo Reservoir. The study is titled 2003 survey since only limited above water data was collected in 2005 in the upper portion of the reservoir. The primary objectives of the survey were to gather data needed to:

- develop reservoir topography
- compute area-capacity relationships
- estimate sediment deposition since dam closure in 1957 and the 1972 survey.

A static GPS control survey established a temporary horizontal and vertical control point, near the reservoir marina, utilized by the hydrographic survey crew. The GPS control survey set the base on the National Geodetic Survey (NGS) datum point "Orin" that is located several miles from the lake. The horizontal control was established in the Wyoming state plane east coordinate zone in the North American Datum of 1983 (NAD83) and the vertical control was tied to the North American Vertical Datum of 1988 (NAVD88) and the Reclamation project datum. All elevations are referenced to Reclamation's project or construction datum. Reclamation's vertical datums for this study are assumed tied to the NGVD29 that is around 2.55 feet less than the NAVD88.

The underwater survey, conducted in May and July of 2003, was between reservoir elevations 4,626 and 4,629. The bathymetric survey used 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 navigated along grid lines covering Glendo Reservoir. The positioning system provided information to allow the boat operator to maintain a course along these grid lines. Water surface elevations recorded by the Reclamation's reservoir gauge, during the time of collection, were used to convert the sonic depth measurements to true reservoir bottom elevations. The above-water topography was determined by digitizing the developed contour lines from the U.S. Geological Survey quadrangle (USGS quad) maps of the reservoir area. In January 2005, a GPS land survey was conducted in the upper reach of the reservoir on Elkhorn Creek and on the North Platte River. This data was used to adjust the digitized USGS contours to represent the January 2005 conditions. The survey found minimal changes on Elkhorn Creek. Due to a sediment delta formation, the survey found significant changes on the upper North Platte River of the reservoir upstream of the narrow canyon reach of the reservoir.

The Glendo Reservoir topographic map is a combination of the adjusted USGS quad contours and the 2003 underwater survey data. A computer graphics program generated the 2003 reservoir surface areas at predetermined contour intervals from the collected reservoir data. The

2003 area and capacity tables were computed by a computer program that uses measured contour surface areas and a curve-fitting technique to compute area and capacity at prescribed elevation increments (Bureau of Reclamation, 1985).

Tables 1 and 2 contain summaries of the Glendo Reservoir and watershed characteristics for the 2003 survey. The 2003 survey determined that the reservoir has a total storage capacity of 763,039 acre-feet and a surface area of 17,986 acres at spillway crest elevation 4,653.0. Since closure on October 18 of 1957, the reservoir has an estimated volume change of 33,979 acre-feet below reservoir elevation 4,653.0. This volume represents a 4.26 percent change in total capacity at this elevation.

RESERVOIR OPERATIONS

Glendo Reservoir is part of the Glendo Unit of the Pick-Sloan Missouri Basin Program that is a multiple-purpose natural resource project. The July 2003 capacity table shows 1,092,290 acre-feet of total storage below the maximum water surface elevation 4,669.0. The 2003 survey measured a minimum lake bottom elevation of 4,512.1. The following values are from the July 2003 capacity table:

- 329,251 acre-feet of surcharge elevation 4,653.0 and 4,669.0.
- 271,017 acre-feet of flood control elevation 4,635.0 and 4,653.0.
- 440,449 acre-feet of active conservation use between elevation 4,570.0 and 4,635.0.
- 44,563 acre-foot of inactive storage between elevation 4,545.0 and 4,570.0.
- 7,010 acre-foot of dead storage below 4,545.0.

Glendo Reservoir available inflow and end-of-month stage records listed on table 1, operation period 1958 through 2003, show the calculated inflow and annual fluctuation for these years of operation. The computed average inflow into the reservoir for these years was 1,185,500 acre-feet per year. The maximum-recorded elevation was 4,650.9 in May of 1973 and the minimum elevation of 4,548.1 in September of 1966.

HYDROGRAPHIC SURVEY EQUIPMENT AND METHOD

The hydrographic survey equipment was mounted in the cabin of a 24-foot trihull aluminum vessel equipped with twin in-board motors (figure 2). The hydrographic system included a GPS receiver with a built-in radio, a depth sounder, a helmsman display for navigation, a computer, and hydrographic system software for collecting the underwater data. An on-board generator supplied power to all the equipment. The shore equipment included a second GPS receiver with an external radio powered by a 12-volt battery. The GPS antenna and receiver were mounted on a survey tripod over a known datum point

The Sedimentation and River Hydraulics Group uses Real-time Kinematic (RTK) GPS with the major benefits being precise heights measured in real time to monitor water surface elevation changes and the ability to conduct land topographic surveys with minimal post-processing of data. The basic outputs from an RTK receiver are precise 3D coordinates in latitude, longitude,

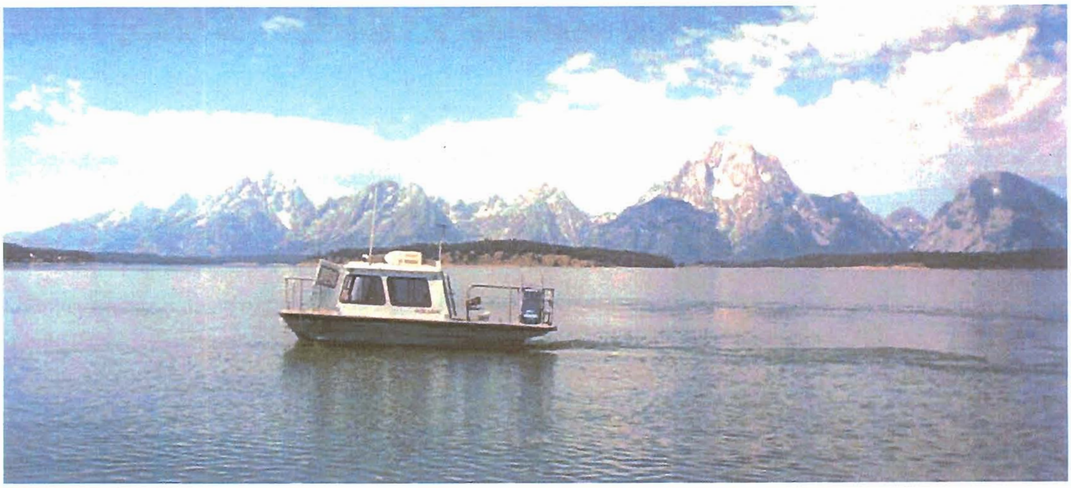

Figure 2 - Survey vessel with mounted hydrographic equipment on Jackson Lake in Wyoming

and height with accuracies on the order of two centimeters horizontally and three centimeters vertically. The output is on the GPS datum of WGS-84 that the hydrographic collection software converted into Wyoming's NAD83 east state plane coordinates. The RTK GPS system employs two receivers that track the same satellites simultaneously just like with differential GPS.

Glendo Reservoir bathymetric survey was conducted in May and July of 2003 between water surface elevations 4,626 and 4,629 (Reclamation project datum). The survey was conducted using sonic depth recording equipment, interfaced with an RTK GPS, capable of determining sounding locations within the reservoir. The survey system software continuously recorded reservoir depths and horizontal coordinates as the survey boat moved along closely spaced grid lines covering the reservoir area. Most transects (grid lines) were run in a perpendicular alignment to the reservoir at around 300-foot spacing. Data also was 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 2003 underwater data was collected by a depth sounder that was calibrated by lowering a weighted cable below the boat with beads marking known depths. The depth sounder was calibrated by adjusting the speed of sound, which can vary with density, salinity, temperature, turbidity, and other conditions. The collected data was 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 analyzed during post-processing, and when the analog charted depths indicated a difference from the computer recorded 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. The underwater data set from the single beam depth sounder included around 231,000 data points.

Due to the unstable weather conditions, the underwater survey in May was conducted prior to the control survey being conducted to establish the coordinates of a temporary control point set by the hydrologic survey crew. When the crew returned in July, a static GPS control survey established the coordinates for this temporary control point that was located near the marina area that overlooked the reservoir. The GPS control survey was conducted with the base set on the National Geodetic Survey (NGS) datum point "Orin" located several miles from the reservoir. The horizontal control was established in the Wyoming state plane coordinate east zone in the North American Datum of 1983 (NAD83) and the vertical control was tied to the North American Vertical Datum of 1988 (NAVD88) and the Reclamation project datum. All elevations in this report are referenced to the Reclamation project or construction datum that for this study was assumed tied to the NGVD29 and around 2.55 feet less than the NAVD88. During post processing all the bathymetric measurements collected in May were shifted slightly to match the horizontal and vertical control established by the GPS static control survey. The shift was determined to be (-) 5.2 feet to the north coordinates and (+) 3.7 feet to the west coordinates. All underwater measurements were tied to Reclamation's reservoir water surface gage readings recorded at the time of the underwater survey.

In 2001, the Sedimentation and River Hydraulics Group began utilizing an integrated multibeam hydrographic survey system. The system consists of a single transducer mounted on the center bow or forward portion of the boat. From the single transducer a fan array of narrow beams generate a detailed cross section of bottom geometry as the survey vessel passes over the areas mapped. The system transmits 80 separate 1-1/2 degree slant beams resulting in a 120-degree swath from the transducer. The 200 kHz high-resolution multibeam echosounder system measures the relative water depth across the wide swath perpendicular to the vessel's track. Figure 3 illustrates the swath of the sea floor that is about 3.5 times the water depth below the transducer.

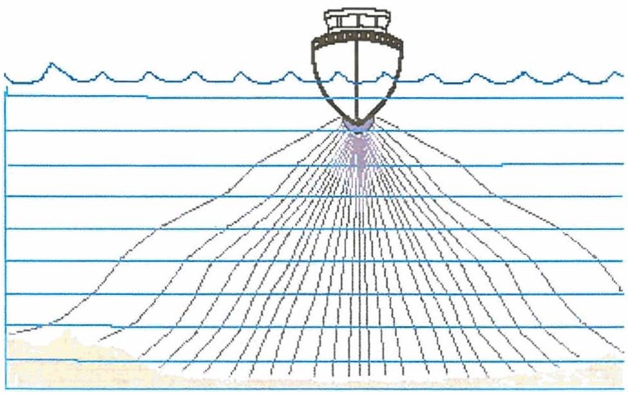

Figure 3. – Multibeam collection system

The multibeam system is composed of several instruments that are all in constant communication with a central on-board notebook computer. The components include the RTK GPS for positioning; a motion reference unit to measure the heave, pitch, and roll of the survey vessel; a gyro to measure the yaw or vessel attitude; and a velocity meter to measure the speed of sound through the vertical profile of the reservoir water. With proper calibration, the data processing software utilizes all the incoming information to provide an accurate detailed x,y,z data set of the lake bottom.

Due to component problems, the multibeam system was utilized on Glendo Reservoir for only the last two days of collection, July 11 and 12 of 2003. The surveyed areas included the main channel from the dam to about four miles upstream. This area was also surveyed by the single beam collection system. The multibeam data, combined with the single beam data, created a data set of around 2,143,000 data points that provided a detail map of the reservoir bottom conditions navigated by the survey vessel. The multibeam survey system software continuously recorded reservoir depths and horizontal coordinates as the survey vessel moved along closely spaced grid lines covering the reservoir area. Most transects (grid lines) were run parallel to the reservoir alignment with the multibeam swaths overlapping to provide full bottom coverage for the areas surveyed. The multibeam system could have provided more detailed bottom coverage throughout the reservoir, but time and budget did not allow for the rest of the reservoir to be surveyed by this method. The multibeam data provided better detail of the reservoir bottom versus the single beam data as illustrated on figure 4. The multibeam data mapped what appears to be the breach cofferdam just upstream of Glendo Dam. The single beam data set only showed this area as a high mound on the reservoir bottom. Even though the multibeam data provided more detail of the reservoir bottom versus the single beam data set, a comparison of the surface area and volume computation results found the differences were not significant between the two methods.

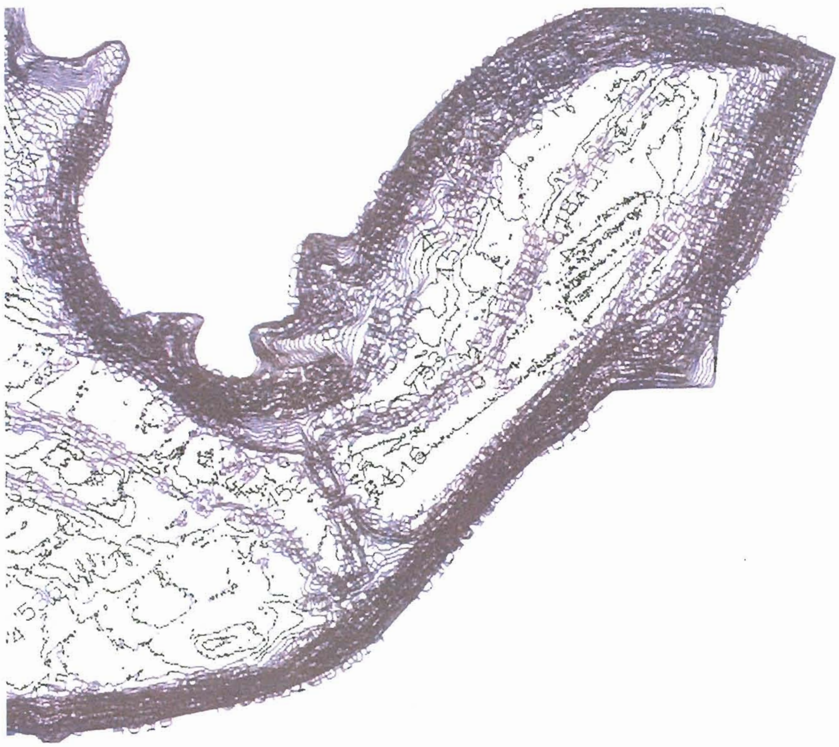

Figure 4 - Breach cofferdam upstream of Glendo Dam

The underwater collected data was processed using the hydrographic system software that was also used for the onboard data collection. The analysis included applying all measurements such as vessel location and corrections for the roll, pitch, and yaw effects. The other corrections included applying the sound velocity of the reservoir water column and converting all depth data points to elevations using the measured water surface elevation at the time of collection. Due to the massive amount of data, the multibeam data was filtered by taking the measured maximum depth and location for each 5-foot cell or grid of the reservoir area surveyed by the multibeam system. The resulting data set was in x,y,z format and contained over two million data points.

In January of 2005, a RTK GPS land survey was conducted on a limited portion of the upper reach of the reservoir on Elkhorn Creek and the North Platte River. These areas were surveyed with the reservoir drawn down to obtain more detail of the formed sediment deltas that were inaccessible during the 2003 boat survey. The survey was conducted on January 12 and 13 of 2005 during sunny but very cold conditions with the temperature near zero degrees. The survey was accomplished by mounting the RTK GPS rover on an all terrain vehicle and automatically collecting data every ten feet as it proceeded where it had access on the formed sediment delta. Access was limited to the west side of the North Platte reach by private property and the river. The collection focused more on the visual delta formation from elevation 4640 and below. The data was limited but provided adequate information for showing change from the digitized USGS contours. The 2005 elevation data was tied to the existing project datums near the area.

RESERVOIR AREA AND CAPACITY

Topography Development

The topography of Glendo Reservoir was developed from the 2003 collected underwater data and the digitized contours from the USGS quad maps. The digitized USGS contour lines were the Glendo Reservoir contours labeled elevations 4,620 and 4,635. The USGS quad maps were developed from aerial photography dated 1960. This study found the enclosed digitized contour area with the island surfaces removed to be within two to three percent of the original surface area at these elevations. ARC/INFO V7.0.2 geographic information system software was used to digitize the USGS quad contour. The digitized contours were transformed to Wyoming's NAD 1983 state plane coordinates, east zone, using the ARC/INFO PROJECT command. The 2005 survey data was used to adjust the 4635 contour and to project the surface area loss due to the above water deltas that had formed during sediment accumulation.

The digitized contour line 4620 was used to perform a clip of the Glendo Reservoir triangular irregular network (TIN) such that interpolation was not allowed to occur outside the enclosed polygon. This contour was selected since it was the closest data available to represent the reservoir water surface at the time the 2003 survey was conducted (near reservoir elevation 4,626). This clip was performed using the hardclip option of the ARC/INFO CREATETIN command. Using ARCEDIT, the underwater collected data and digitized contours from the quad maps were plotted. The plot showed that the underwater data did not lie completely within this clip, which required modifications to include the entire underwater data set within the enclosed polygon. Modified areas included the shoreline around the islands and portions of the shoreline of the main reservoir. Some of this adjustment was due to the lake elevation during the 2003 survey being higher than this clip, but there were some areas where it was obvious that large areas of shoreline erosion had occurred. Using select and move commands within ARCEDIT, the vertices of the clip were shifted to fit all the collected underwater data. The clip was assigned an elevation of 4,622.0 to reflect the 1972 surface area of this developed polygon.

Contours for the reservoir below elevation 4,620.0 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 Glendo Reservoir TIN. In addition, the contours were generalized by filtering out vertices along the contours. This generalization process improved the present ability 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 Glendo Reservoir since the areas were calculated from the developed TIN. The areas of the enclosed contour polygons at one-foot increments were developed from the 2003 survey data for elevations 4,513.0 through 4,620.0.

A 2005 land survey was performed on the North Platte River reach on the upper reservoir to measure the sediment delta formation above the narrow canyon. The area above the narrows was not accessible during the 2003 underwater survey due to shallow water conditions. The data from the 2005 survey was used to adjust the USGS 4635 contour and to project the surface area loss since the original measured areas for contours 4630 and 4635. Since no complete reservoir aerial data was collected, this study assumed no change in reservoir surface area since the 1972 survey for elevation 4,640.0 and above. It must be noted that the 1972 range line survey only measured a 30-acre loss at elevation 4640 and no loss above this elevation from the original measured surface areas. The contour topography at 2-foot intervals is presented on figures 5 through 10.

Development of 2003 Contour Areas

The 2003 TIN generated surface areas for Glendo Reservoir were computed at 1-foot increments from elevation 4,513.0 to 4,620.0. The 2003 underwater survey measured a minimum reservoir bottom elevation of 4,512.1. 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. For the purpose of this study, the measured 2003 survey areas at 2-foot increments from elevation 4,514.0 through 4,620.0 were used to compute the new area and capacity tables. Due to the limited amount of 2003 shallow water data and 2005 above water data, this study assumed no change in original area from elevation 4,640.0 and above since the 1972 resurvey. The area and capacity program computed the areas between elevation 4,620.0 and 4,630.0 by assuming a straight-line interpolation.

2003 Storage Capacity

The storage-elevation relationships based on the measured surface areas were developed using the area-capacity computer program ACAP85 (Bureau of Reclamation, 1985). The 2003 surveyed surface areas at 2-foot contour intervals from reservoir elevation 4,514.0 to elevation 4,620.0 and the 2005 adjusted surface areas of contours 4630 and 4635 were used as the control parameters for computing the 2003 Glendo Reservoir capacity. Since this study collect only limited above water data, the 1972 survey 10-foot surface areas from elevation 4,640.0 to 4,670.0 were used to complete the area and capacity tables.

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

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

where:

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

Results of the Glendo Reservoir area and capacity computations are listed in table 1 and columns 8 and 9 of table 2. On table 2, columns 2 and 3 list the original surface areas and recomputed original capacities. A separate set of 2003 area and capacity tables has been published for the 0.01, 0.1 and 1-foot elevation increments (Bureau of Reclamation 2003). A description of the computations and coefficients output from the ACAP85 program is included with these tables. Both the original, 1972, and 2003 area-capacity curves are plotted on figure 11. As of July 2003, at maximum reservoir elevation 4,669.0, the surface area was 23,320 acres with a total capacity of 1,092,290 acre-feet.

RESERVOIR SEDIMENT ANALYSES

Figure 11 is a plot comparison of the surface areas and capacities of Glendo Reservoir's original, 1972, and 2003 survey results. Since Glendo dam closure in 1957, the measured total volume change at reservoir elevation 4,653.0 is 33,979 acre-feet. The estimated average annual rate of capacity lost for this period (45.7 years) was 743.5 acre-feet per year. The storage loss in terms of percent of original storage capacity was 4.26 percent at elevation 4,653.0. The 2003 area and capacity tables were generated assuming no change in area and capacity, since the 1972 resurvey, from elevation 4,640.0 and above. It must be noted the 1972 range line survey only measured a 30-acre loss at elevation 4640 and no losses above this elevation from the original measured surface areas. This is in all probability not the case, but the lack of total above water reservoir data only allows this assumption. The upper reach of Glendo Reservoir is very narrow compared to the rest of the reservoir so lost due sediment deposition in this reach is not significant compared to the total volume of this large reservoir. The 2005 data did help in determining these losses and measuring the location of the developed sediment delta.

The 2003 survey was able to note some areas where shoreline erosion has occurred by plotting the 2003 data versus the digitized USGS contours. In these areas, the upper elevation materials have eroded and deposited in the lower elevations of the reservoir. The shoreline erosion enlarges the surface area and volume of these upper elevations while it decreases the surface area and volume of the lower elevations where this material has deposited. The 2003 survey indicated the shoreline erosion, but the results appear to show it is not significant. The only means to measure these changes would be by a detailed above water survey.

The average annual 2003 sediment accumulation was 743.5 acre-feet: greater than the 525-acre-feet from the 1972 results, but less than the 100-year design estimate of 1,150 acre-feet per year. Even though the 2003 results measured an increase in the annual accumulation since the 1972 survey, it must be noted that the 1972 study used the range line method where the cross sections surveyed were located about every reservoir mile. For the 2003 survey, cross sections were surveyed at a maximum distance of 300 feet and with the multibeam system about every 5 feet.

A resurvey of Glendo Reservoir should be considered in the future if major sediment inflow events are observed or if the average annual rate of sediment accumulation requires further clarification. Since the majority of the basin sediment runoff is trapped in other upstream reservoirs, the sediment impact into Glendo Reservoir will be minimal unless a significant event occurs in the basin not controlled by these reservoirs or until these reservoirs begin bypassing sediment laden flows.

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RESERVOIR SEDIMENT
DATA SUMMARY

Glendo Reservoir
NAME OF RESERVOIR

1
DATA SHEET NO.

DAM			
	1. OWNER Bureau of Reclamation	2. STREAM North Platte River	3. STATE Wyoming
	4. SEC. 13 & 24 TWP. 29 N RANGE 68 W	5. NEAREST P.O. Glendo	6. COUNTY Platte-Converse
	7. LAT 42° 28' 45" LONG 104° 56' 59"	8. TOP OF DAM ELEVATION 4,675.0[1]	9. SPILLWAY CREST EL 4,653.0[2]

RESERVOIR	10. STORAGE ALLOCATION	11. ELEVATION TOP OF POOL	12. ORIGINAL SURFACE AREA, ACRES	13. ORIGINAL CAPACITY, ACRE-FEET	14. GROSS STORAGE ACRE-FEET	15. DATE STORAGE BEGAN
	a. SURCHARGE	4,669.0[3]	23,320	352,746	1,126,269	
	b. FLOOD CONTROL	4,653.0	17,986	272,366	797,018	10/18/57
	c. POWER					
	d. JOINT USE					16. DATE NORMAL OPERATION BEGAN
	e. CONSERVATION	4,635.0	12,455	459,988	524,652	
	f. INACTIVE	4,570.0	3,210	53,315	64,664	
	g. DEAD	4,545.0	1,056	11,349	11,349	4/1959
	17. LENGTH OF RESERVOIR 28.7[4]			AVG. WIDTH OF RESERVOIR 1.0		

BASIN			
	18. TOTAL DRAINAGE AREA 15,545[5] SQUARE MILES		22. MEAN ANNUAL PRECIPITATION 13.5[6] INCHES
	19. NET SEDIMENT CONTRIBUTING AREA 4,330[5] SQUARE MILES		23. MEAN ANNUAL RUNOFF 1.4[7] INCHES
	20. LENGTH 151	AV. WIDTH 129	24. MEAN ANNUAL RUNOFF 1,185,000[8] ACRE-FEET
	21. MAX. ELEVATION 10,274	MIN. ELEVATION 4,508	25. ANNUAL TEMP. MEAN 48°F RANGE -35°F to 108°F[6]

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
10/18/57			Contour (D)	10-ft	17,986	797,018	
5/3/72	14.5	14.5	Range (D)	68 (R)	17,986[9]	789,402[9]	.67
7/03	31.2	45.7	Contour (D)	2-ft	17,986[9]	763,039[9]	.64

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
5/3/72	13.07	1,047,300	1,674,800	15,709,400	1,047,300	15,709,400
7/03	13.5	1,232,200[10]	1,749,900	38,196,800	1,185,500	54,532,600

26. DATE OF SURVEY	37. PERIOD CAPACITY LOSS, ACRE-FEET			38. TOTAL SEDIMENT DEPOSITS TO DATE, AF		
	a. TOTAL	b. AV. ANN.	c. /MI.²-YR.	a. TOTAL	b. AV. ANNUAL	c. /MI.²-YR.
5/3/72	7,616	525	0.12	7,616	525	0.12
7/03	26,363[11]	845.0	0.195	33,979	743.5	0.172

26. DATE OF SURVEY	39. AV. DRY WT. (#/FT³)	40. SED. DEP. TONS/MI.²-YR.		41. STORAGE LOSS, PCT.		42.	
		a. PERIOD	b. TOTAL TO	a. AV.	b. TOTAL TO	a.	b.
5/3/72		198	198	0.066	0.956	565	544
7/03				0.093[11]	4.26[11]		

26. DATE SURVEY	43. DEPTH DESIGNATION RANGE FEET BELOW, AND ABOVE, CREST ELEVATION										
		4508-4520	4520-4560	4560-4580	4580-4600	4600-4620	4620-4640	4640-4653			
	PERCENT OF TOTAL SEDIMENT LOCATED WITHIN DEPTH DESIGNATION										
5/72		1.3	8.1	18.4	24.3	19.7	26.2	2.0			
7/03		1.5	27.1	21.0	22.7	10.9	16.4	0.4			

26. DATE 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														
5/72	2.0	2.1	4.2	9.4	12.0	12.2	17.6	14.3	20.3	5.9					

Table 1. - Reservoir sediment data summary (page 1 of 3).

45. RANGE IN RESERVOIR OPERATION[8]							
YEAR	MAX. ELEV.	MIN. ELEV.	INFLOW, AF	YEAR	MAX. ELEV.	MIN. ELEV.	INFLOW, AF
1958	4,628.6	4,508.0	1,242,500	1959	4,638.2	4,573.0	875,000
1960	4,635.9	4,571.0	909,700	1961	4,628.0	4,569.4	693,100
1962	4,636.3	4,567.5	960,600	1963	4,632.6	4,567.3	1,092,400
1964	4,633.1	4,561.1	1,115,100	1965	4,638.4	4,569.4	1,051,700
1966	4,630.7	4,548.1	1,072,700	1967	4,639.6	4,549.6	921,600
1968	4,635.7	4,566.7	1,175,100	1969	4,632.9	4,560.7	1,146,000
1970	4,645.3	4,563.2	1,155,400	1971	4,649.1	4,573.5	1,674,800
1972	4,637.2	4,560.4	1,250,200	1973	4,650.9	4,563.5	2,136,100
1974	4,633.0	4,567.2	1,749,900	1975	4,634.3	4,568.8	1,239,900
1976	4,634.7	4,568.1	1,180,700	1977	4,633.5	4,571.2	1,085,900
1978	4,639.1	4,565.9	1,049,100	1979	4,633.2	4,569.4	1,105,300
1980	4,636.8	4,571.4	1,356,800	1981	4,637.1	4,572.3	985,000
1982	4,634.7	4,571.9	959,200	1983	4,650.3	4,578.1	2,014,400
1984	4,641.0	4,568.6	2,233,400	1985	4,633.7	4,569.5	1,485,200
1986	4,640.2	4,579.7	1,644,500	1987	4,636.2	4,578.8	1,089,800
1988	4,632.7	4,574.6	1,117,300	1989	4,630.4	4,570.0	965,400
1990	4,627.4	4,571.0	735,800	1991	4,638.1	4,574.7	910,500
1992	4,629.0	4,569.8	751,800	1993	4,632.6	4,573.9	954,000
1994	4,626.5	4,580.0	1,078,300	1995	4,641.7	4,575.4	975,100
1996	4,637.2	4,576.1	1,278,600	1997	4,639.2	4,581.0	1,670,400
1998	4,633.6	4,577.5	1,274,000	1999	4,642.5	4,583.8	1,486,100
2000	4,635.8	4,578.0	1,174,500	2001	4,634.2	4,575.3	1,075,800
2002	4,627.3	4,572.0	689,300	2003	4,631.1	4,582.0	744,700

46. ELEVATION - AREA - CAPACITY DATA FOR **(BY INDICATED YEARS) CAPACITY**[10]								
ELEVATION	AREA	CAPACITY	ELEVATION	AREA	CAPACITY	ELEVATION	AREA	CAPACITY
1957	**SURVEY**		4,508	0	0	4,510	19	19
4,520	93	579	4,530	285	2,469	4,540	642	7,104
4,550	1,470	17,664	4,560	2,360	36,814	4,570	3,210	64,664
4,580	4,040	100,914	4,590	5,200	147,114	4,600	6,630	206,264
4,610	7,830	278,564	4,620	9,240	363,914	4,630	11,120	465,714
4,640	13,790	590,264	4,650	17,050	744,464	4,653	17,986	797,018
1972	**SURVEY**							
4,508	0	0	4,510	18	18	4,520	74	473
4,530	273	2,213	4,540	642	6,788	4,550	1,470	17,348
4,560	2,280	36,098	4,570	3,130	63,148	4,580	4,000	98,798
4,590	5,090	144,248	4,600	6,520	202,298	4,610	7,770	273,748
4,620	9,170	358,448	4,630	10,970	459,148	4,640	13,760	582,798
4,650	17,050	736,848	4,653	17,086	789,402			
2003	**SURVEY**							
4,512.2	0	0	4,515	8	7	4,520	26	101
4,525	52	284	4,530	139	727	4,535	326	1,889
4,540	516	4,025	4,545	716	7,010	4,550	1,147	11,671
4,555	1,503	18,318	4,560	2,053	27,143	4,565	2,450	38,523
4,570	2,771	51,573	4,575	3,231	66,566	4,580	3,754	84,101
4,585	4,197	103,967	4,590	4,773	126,382	4,595	5,562	152,085
4,600	6,260	181,726	4,605	7,037	214,973	4,610	7,698	251,779
4,615	8,378	291,938	4,620	9,106	335,666	4,625	9,941	383,283
4,630	10,775	435,072	4,635	12,005	492,022	4,640	13,760	556,435
4,645	15,405	629,347	4,650	17,050	710,485	4,653	17,986	763,309
4,660	20,170	896,585	4,665	21,920	1,001,810	4,669	23,320	1,092,290

Table 1. - Reservoir sediment data summary (page 2 of 3).

47. REMARKS AND REFERENCES

1 All elevations in feet based on the original project datum that is reported to be tied to NGVD29. Some values from 1972 survey analysis.
2 Uncontrolled spillway.
3 Original values computed from 10-foot contours.
4 North Platte River (21.3 mi), Whiskey Gulch (2.1 mi), Cottonwood Creek (1.0 mi), and Muddy Creek (4.3 mi).
5 From USGS water records. Runoff and sediment contributing area affected by Pathfinder Dam and areas listed by USGS as noncontributing.
6 Bureau of Reclamation Project Data Book, 1981. Values for Glendo Unit.
7 Calculated using mean annual runoff value of 1,185,500 AF, item 24, 1958 through 2003.
8 Annual computed inflows by water year from readily available records from 1958 through 2003.
9 Surface area & capacity at elevation 4,653.0, spillway crest elevation.
10 Annual computed inflows by water year, from 1958 through 2003. Maximum and minimum elevations from available Reclamation records by water year.
11 2003 survey assume no change from elevation 4,640 and above since the 1972 survey.
12 Capacities computed by Reclamation's ACAP computer program.

48. AGENCY MAKING SURVEY Bureau of Reclamation
49. AGENCY SUPPLYING DATA Bureau of Reclamation | DATE July 2005

Table 1. - Reservoir sediment data summary (page 3 of 3).

1 Elevation Feet	2 Original Survey Acres	3 Original Capacity Ac-Ft	4 1972 Survey Acres	5 1972 Survey Ac-Ft	6 1972 Computed Sediment Volume Ac-Ft	7 1972 Percent Computed Sediment	8 2003 Survey Acres	9 2003 Survey Ac-Ft	10 2003 Total Sediment Volume Ac-Ft	11 2003 Percent Computed Sediment	12 Sediment Volume 1972-2003 Ac-Ft	13 Percent Computed Sediment 1972-2003	14 Percent Reservoir Depth
4670	23670	1149764	23670	1142148			23670	1115785					
4669	23320	1126269	23320	1118653	7616	100.0	23320	1092290	33979	100.0	26363	100.0	100.0
4660	20170	930564	20170	922948	7616	100.0	20170	896585	33979	100.0	26363	100.0	94.4
4653	17986	797018	17986	789402	7616	100.0	17986	763039	33979	100.0	26363	100.0	90.1
4650	17050	744464	17050	736848	7616	100.0	17050	710485	33979	100.0	26363	100.0	88.2
4640	13790	590264	13760	582798	7466	98.0	13760	556435	33829	99.6	26363	100.0	82.0
4635	12455	524652	12365	517486	7166	94.1	12005	492022	32630	96.0	25464	96.6	78.9
4630	11120	465714	10970	459148	6566	86.2	10775	435072	30642	90.2	24076	91.3	75.8
4620	9240	363914	9170	358448	5466	71.8	9106	335666	28248	83.1	22782	86.4	69.6
4610	7830	278564	7770	273748	4816	63.2	7698	251780	26784	78.8	21968	83.3	63.4
4600	6630	206264	6520	202298	3966	52.1	6260	181726	24538	72.2	20572	78.0	57.1
4590	5200	147114	5090	144248	2866	37.6	4773	126382	20732	61.0	17866	67.8	50.9
4580	4040	100914	4000	98798	2116	27.8	3754	84101	16813	49.5	14697	55.7	44.7
4570	3210	64664	3130	63148	1516	19.9	2771	51573	13091	38.5	11575	43.9	38.5
4560	2360	36814	2280	36098	716	9.4	2053	27143	9671	28.5	8955	34.0	32.3
4550	1470	17664	1470	17348	316	4.1	1147	11671	5993	17.6	5677	21.5	26.1
4545	1056	11349	1056	11033	316	4.1	716	7010	4339	12.8	4023	15.3	23.0
4540	642	7104	642	6788	316	4.1	516	4025	3079	9.1	2763	10.5	19.9
4530	285	2469	273	2213	256	3.4	139	727	1742	5.1	1486	5.6	13.7
4520	93	579	74	478	101	1.3	26	101	478	1.4	377	1.4	7.5
4512.1	35	75	30	68	7	0.1	0	0	75	0.2	68	0.3	2.5
4510	19	19	18	18	1	0.0	0	0	19	0.1	18	0.1	1.2
4508	0	0	0	0	0	0.0	0	0	0	0.0	0	0.0	0.0

1 Elevation of reservoir water surface.
2 Original reservoir surface areas.
3 Original reservoir capacity computed using ACAP.
4 1972 measured reservoir surface area.
5 1972 reservoir capacity computed using ACAP.
6 1972 computed sediment volume, column (3) - column (5).
7 2003 measured sediment in percentage of total sediment, 7,616 acre-feet, by elevation.
8 2003 measured reservoir surface area. Areas for elevation 4,640 and above from 1972 survey.
9 2003 reservoir capacity computed using ACAP.
10 2003 measured sediment volume = column (3) - column (9).
11 2003 measured sediment in percentage of total sediment, 33,979 acre-feet, by elevation.
12 Measured sediment volume from 1972 to 2003, column (5) - column (9).
13 Measured sediment in percentage my elevation from 1972 to 2003. Total sediment volume of 26,363 acre-feet.
14 Depth of reservoir expressed in percentage of total depth (161), from maximum water surface.

Table 2. - Summary of 2003 survey results

Figure 5. – Glendo Reservoir topographic map, No. 1

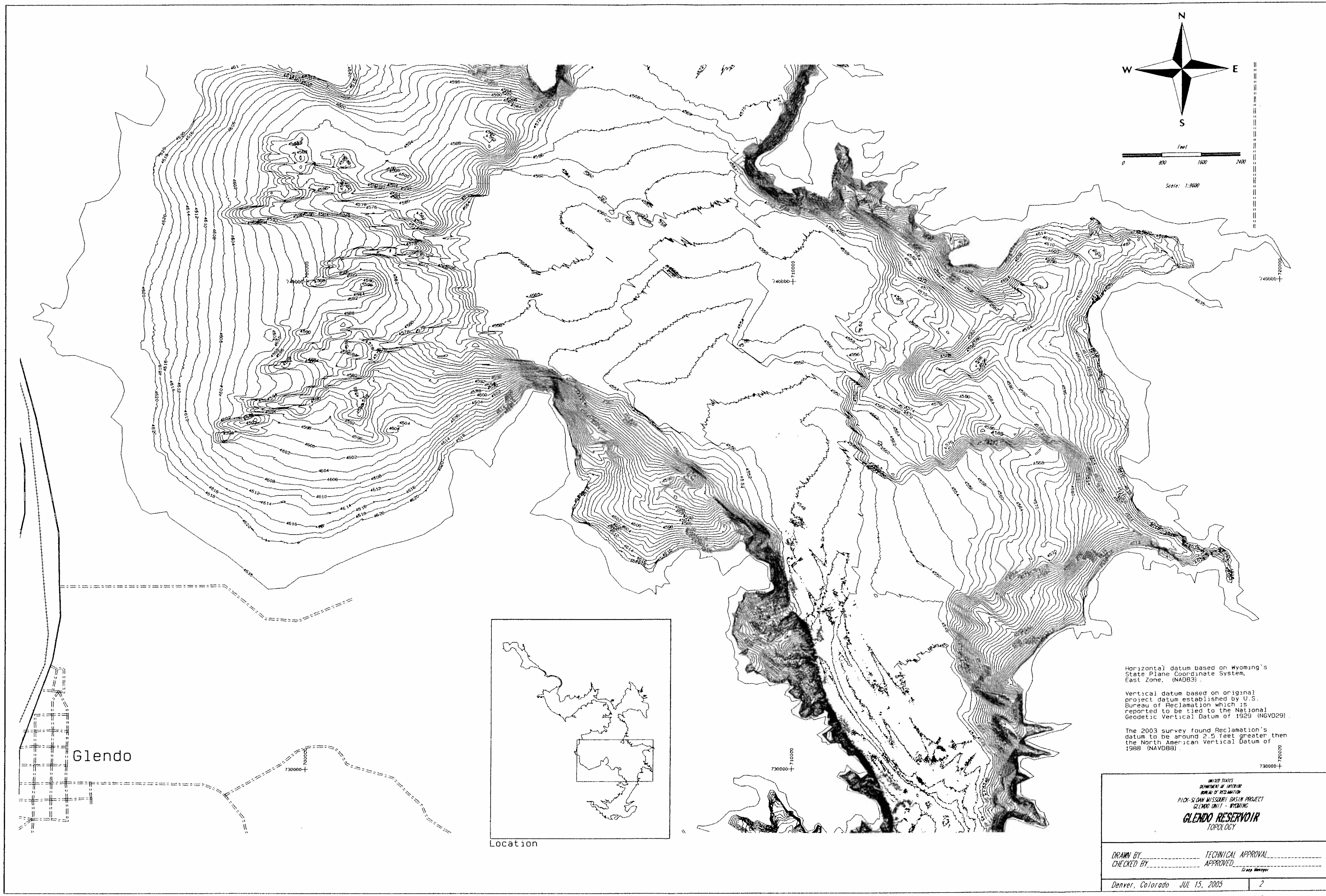

Figure 6. – Glendo Reservoir topographic map, No. 2

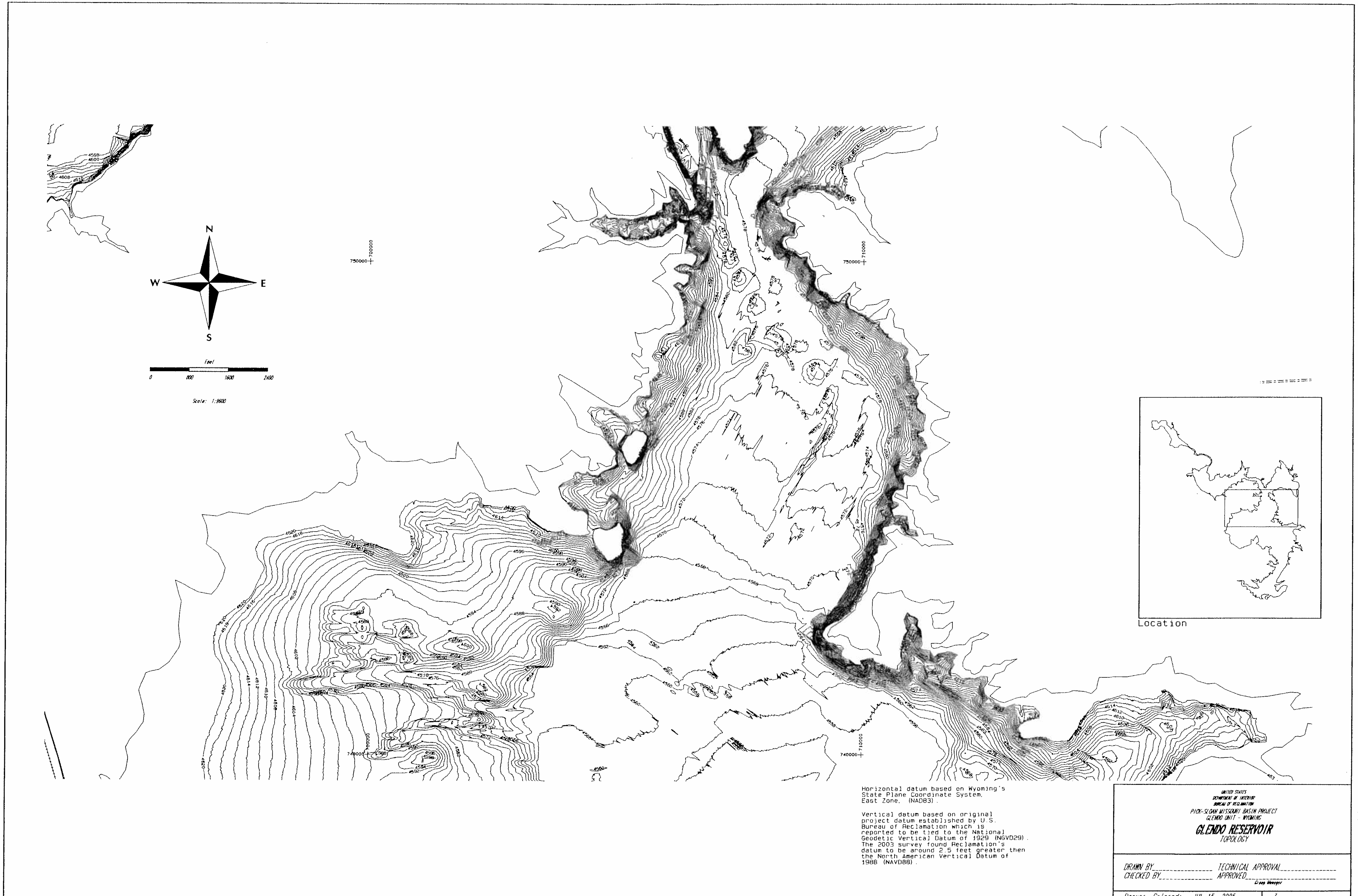

Figure 7. – Glendo Reservoir topographic map, No. 3

Figure 8. – Glendo Reservoir topographic map, No. 4

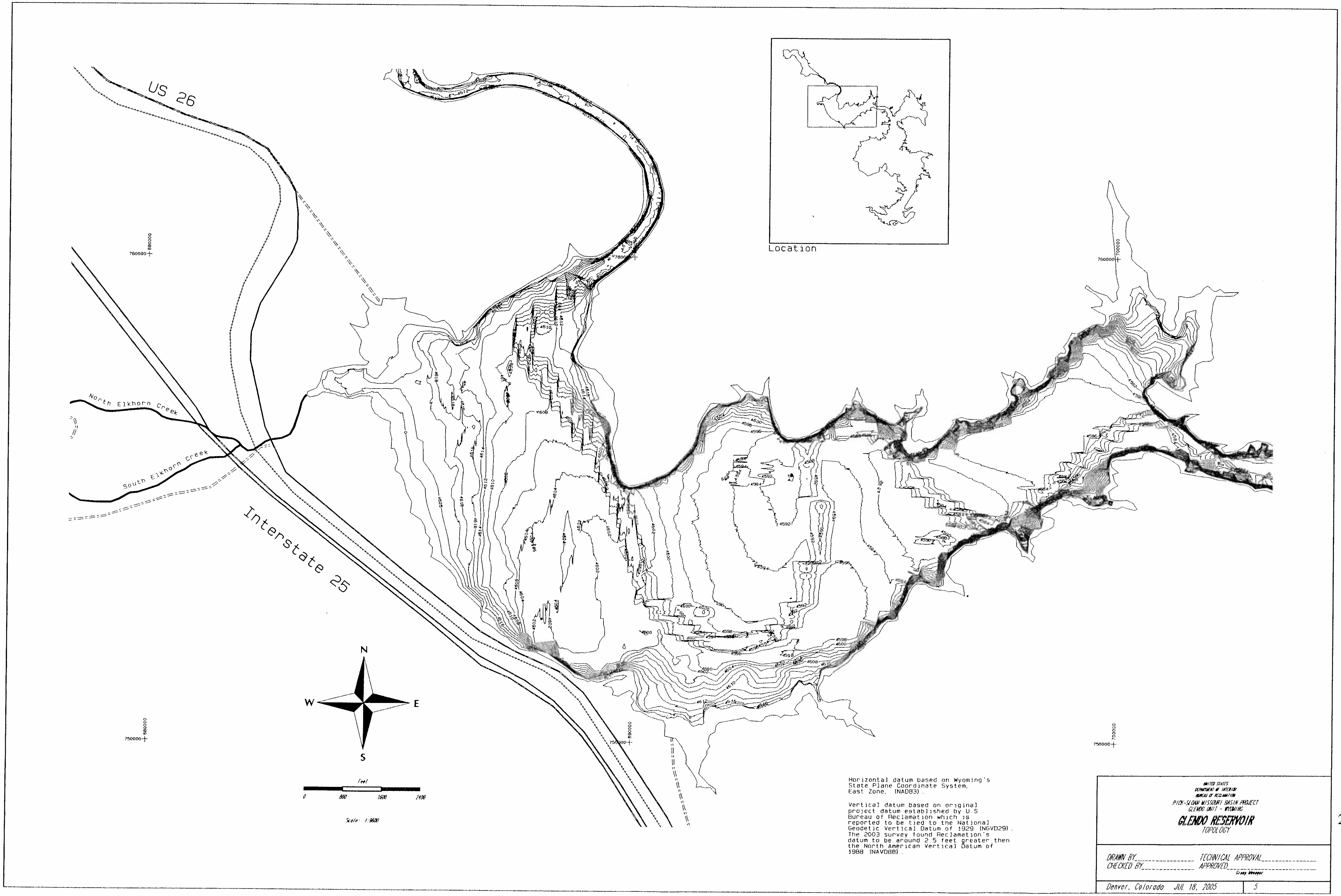

Figure 9. – Glendo Reservoir topographic map, No. 5

Figure 10. – Glendo Reservoir topographic map, No. 6

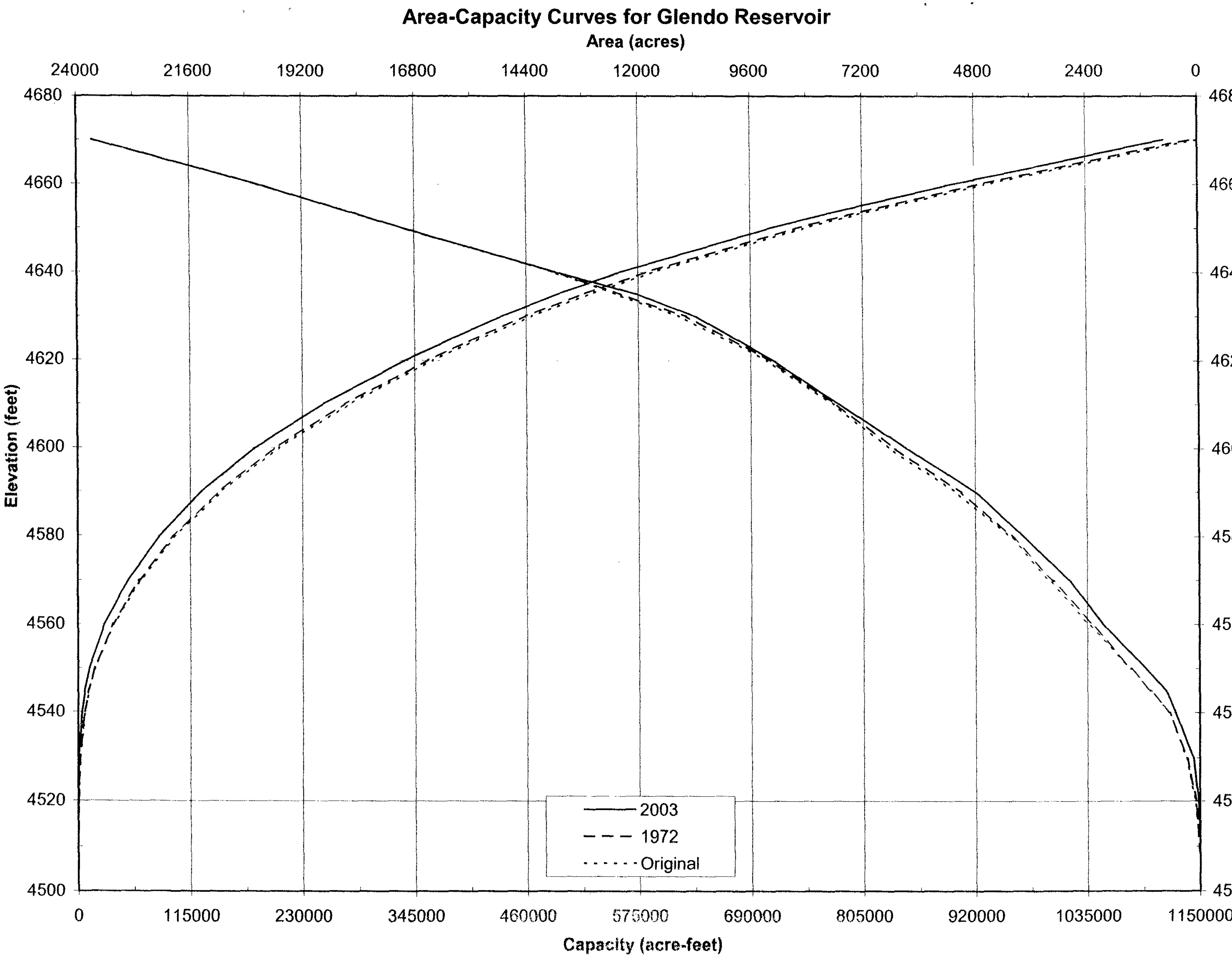

Figure 11. - 2003 area and capacity curves.