RECLAMATION

Managing Water in the West

Box Butte Reservoir
2003 Survey

U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
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14. ABSTRACT

The Bureau of Reclamation (Reclamation) surveyed Box Butte Reservoir in June of 2003 to develop a topographic map and compute a present storage-elevation relationship (area-capacity tables). The underwater collection was conducted on June 9, 10, 27 and 28, 2003 at surveyed lake elevation 3994.8 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 vessels. The above-water topography was determined from digitized contour lines from the U.S. Geological Survey (USGS) quadrangle (quad) maps and the original reservoir topography map. The new topographic map of Box Butte Reservoir was developed from the combined above and below water data sets.

The surveys measured a minimum elevation 3,962.0 (feet) and lake contours were developed from elevation 3,992.0 and below. All elevations shown in this report are based on the project datum in feet that is tied to the National Geodetic Vertical Datum of 1929 (NGVD29) and 2.0 feet lower than the North American Vertical Datum of 1988 (NAVD88). The upper contour development was limited due to extensive vegetation growth around the reservoir. As of June 2003, at water surface elevation 4,007.0, the surface area was 1,605 acres with a total capacity of 29,161 acre-feet. Since initial closure, October 3, 1945, about 1,896 acre-feet of volume loss due to sediment was measured by the 2003 survey.

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Box Butte Reservoir
2003 Survey

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Bureau of Reclamation
Technical Service Center
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Denver, Colorado

April 2007

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 Indian Tribes and our commitments to island communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner.

Acknowledgments

Reclamation's Sedimentation and River Hydraulics Group of the Technical Service Center (TSC) prepared and published this report. Ronald Ferrari and Sharon Nuanes of the TSC conducted the underwater data collection using the TSC's large survey vessel. Ron Ferrari with assistance from Alexander Ferrari conducted the shoreline and shallow water collection using a smaller survey vessel. Ron Ferrari completed the data processing needed to generate the new topographic map, area-capacity tables, and report. Kent Collins of the TSC performed the technical peer review of this documentation.

Reclamation Report

This report was produced by the Bureau of Reclamation's Sedimentation and River Hydraulics Group (Mail Code 86-68540), PO Box 25007, Denver, Colorado 80225-0007, www.usbr.gov/pmts/sediment/.

Disclaimer

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Box Butte Reservoir 2003 Survey

Introduction

Box Butte Dam and Reservoir, located on the Niobrara River, are principal features of the Mirage Flats Project. The reservoir is located in Dawes County about nine miles north of Hemingford in northwest Nebraska (figure 1). The reservoir's primary function is water releases for irrigation, but the reservoir also provides flood control, fish and wildlife, and recreation benefits.

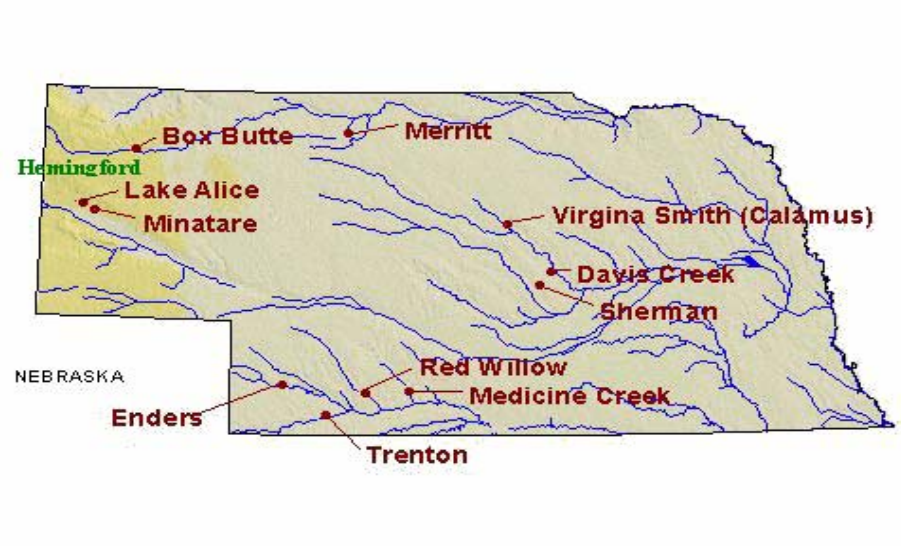

Figure 1 - Box Butte Reservoir location map.

The Box Butte Dam was completed in 1946 and the reservoir began filling with the closure of the outlet gates on October 3, 1945. The dam is a zoned earthfill embankment structure with the following dimensions:

Hydraulic height[1]	52	feet	Structural height	87	feet
Top width	24	feet	Crest length	5,508	feet
Crest elevation	4,024.0	feet[2]			

[1]The definition of such terms as "hydraulic height," "structural height," etc. may be found in manuals such as Reclamation's *Design of Small Dams and* ASCE's *Nomenclature for Hydraulics.*

[2]Elevations in feet. Unless otherwise noted, all elevations shown in this report are based on the project water surface gage datum that is reported to be tied to the National Geodetic Vertical Datum of 1929 (NGVD29) and 2.0 feet lower than the North American Vertical Datum of 1988 (NAVD88).

The Box Butte Dam structure contains a controlled outlet works for irrigation releases, a modified side channel service spillway, and a fuse plug emergency spillway. The gated outlet works passes through the base of the dam and has a capacity of 420 cubic feet per second (cfs) at reservoir water surface elevation 4,007.0. The service spillway is a reinforced concrete side channel located in the left abutment with a capacity of 2,700 cfs at elevation 4,007.0. The emergency spillway located around the left end of the dam is 450 feet wide, consisting of nine sections varying in elevation from 4,014.00 to 4,015.75. The emergency spillway fuse plugs are designed to erode in a controlled manner when overtopped and have a maximum capacity of 22,800 cfs. The drainage area above the dam is around 1,460 square miles.

Summary and Conclusions

This Reclamation report presents the 2003 results of the survey of Box Butte Reservoir. The primary objectives of the survey were to gather data needed to:

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

A Real-time Kinematic (RTK) global positioning system (GPS) control survey was conducted by the bathymetric survey crew to establish a temporary horizontal and vertical control point near the boat ramp for the underwater collection and measurements of the water surface elevation during the survey. The RTK GPS control survey was conducted with the base set on the National Geodetic Survey (NGS) datum point "Hemingford." The horizontal control was established in Nebraska state plane coordinates in North American Datum of 1983 (NAD83) and the vertical control in NAVD88. All elevations in this report are referenced to the Reclamation project datum that is tied to NGVD29. Initially, the processing of the bathymetric data was delayed due to conflicts with the bathymetric survey crew control and a previous control survey conducted around the reservoir. Further details on the survey control are in the section "Control Survey Data Information."

The June 2003 underwater survey was conducted over four days near reservoir elevation 3,994.8. The water surface was measured by the hydrographic survey crew during the days of collection and was adjusted to Reclamation's project datum in NGVD29. The bathymetric survey used sonic depth recording equipment interfaced with RTK GPS for 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 Box Butte Reservoir. The positioning system provided information to allow the boat operator to

maintain a course along these grid lines. The equipment was later mounted in a small pontoon raft that allowed collection along the shallow shoreline around the reservoir. Due to extensive vegetation growth there were some areas of the reservoir where boat access was not possible. The vegetation also affected the digital sounding records, requiring additional time for processing to ensure accuracy. The initial above-water topography was determined by digitizing existing contour lines from the USGS quads and an original topographic drawing of the reservoir area. During the bathymetric survey, the boat location at times plotted outside of these contours indicating some shoreline erosion.

The Box Butte Reservoir topographic map is a combination of the digitized contours and the 2003 underwater survey data. A computer graphics program generated the 2003 reservoir surface areas at predetermined contour intervals from the collected and digitized reservoir area. The 2003 area and capacity tables were produced by a computer program that used 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 Box Butte Reservoir and watershed characteristics for the 2003 survey. The 2003 survey determined that the reservoir has a total storage capacity of 29,161 acre-feet and a surface area of 1,605 acres at conservation pool elevation 4,007.0. Since closure in October 1945, the reservoir has an estimated volume change of 1,896 acre-feet below top of conservation reservoir elevation 4,007.0. The 2003 underwater survey was conducted near reservoir elevation 3,995.0 and assumed no change since the original survey from elevation 4,000.0 and above. This volume represents a 6.1 percent loss in total original capacity at conservation elevation 4,007.0.

Control Survey Data Information

Prior to the bathymetric survey, a control network was set by the hydrographic survey crew that was used throughout the survey. Initially, the RTK GPS base station was set over NGS marker “Hemingford” that is located along State Highway 2 near the reservoir and allowed RTK GPS survey control shots. The RTK GPS survey established a temporary control point near the boat ramp that was used by the survey vessel during collection and for shots of existing reservoir brass caps and the water surface during the underwater collection. The horizontal control was in Nebraska state plane coordinates in NAD83 and the vertical control was tied to NAVD88 and the Reclamation project vertical datum in NGVD29. All elevations in this report are referenced to Reclamation’s project or construction vertical datum that is in NGVD29 and around 2.0 feet lower than NAVD88. The following coordinate information was used for this analysis.

NGS control point "Hemingford"

NAD83/NAVD88 (degree/feet)

42/17/48.27424 (latitude)	North 911,852.97
103/02/45.87229 (longitude)	West 816,665.05
4,180.30 feet (ellipsoid elevation)	(NAVD88) 4,240.25

Note: The NGS published sheet on Hemingford indicates around a two foot difference between NAVD29 and NGVD88.

Following are the state plane coordinates of the indicated points. The coordinates were surveyed by the hydrographic crew prior to underwater collection with some photographs taken of the brass caps. Many appeared to have been recently reset in concrete or repaired. As noted, the RTK GPS elevations in NAVD88 appeared to be around two feet higher than the stamped elevation on the brass caps, indicating elevations tied to NGVD29. The notes also show the provided 2001 survey control elevations. The 2001 survey data differed from the hydrographic survey control causing delay in processing of the underwater data until this was resolved with the 2006 control survey. A 2006 control survey conducted for a reservoir boundary survey confirmed the project control elevations for Box Butte Reservoir are in NGVD29.

Left Abutment, BOR cap, c/l stamped "4027.8"

North 971,678.94
East 811,798.22
Elevation 4,029.88 (NAVD88, difference of 2.08 feet)

The 2001 survey measured elevation 4,027.43, difference of 2.46 feet.

Left Abutment, BOR cap, d/s 15-ft stamped "4028.00"

North 971,669.62
East 811,810.00
Elevation 4,030.05 (NAVD88, difference of 2.05 feet)

Figure 2 – BOR cap, left abutment, d/s 15-feet, elevation 4028.00.

Left Abutment, BOR cap, u/s 15-feet stamped "4027.92"

North 971,688.15
East 811,786.48
Elevation 4,029.90 (NAVD88, difference of 1.98 feet)

Figure 3 - BOR cap, left abutment, u/s 15-feet, elevation 4027.92.

Water surface, June 9, 2003, 10:05am (gage projected at 3,993.4)

North 972,477.99
East 810,228.07
Elevation 3,996.8 (NAVD88)

During the time of collection, the reservoir gage was not working properly requiring readings to be estimated. A difference of 3.4 feet was found between NAVD88 and the estimated reservoir gage elevations. Since the hydrographic and 2006 control surveys determined that the project elevations are tied to NGVD29, all RTK GPS water surface shots were reduced 2.0 feet to match the project elevation used during data processing. On June 9, 2003, the project water surface elevation was 3,994.8.

Temporary hydrographic sediment survey control point near boat ramp.

North 972,509.94
East 810,618.70
Elevation 4,016.96 (NAVD88)

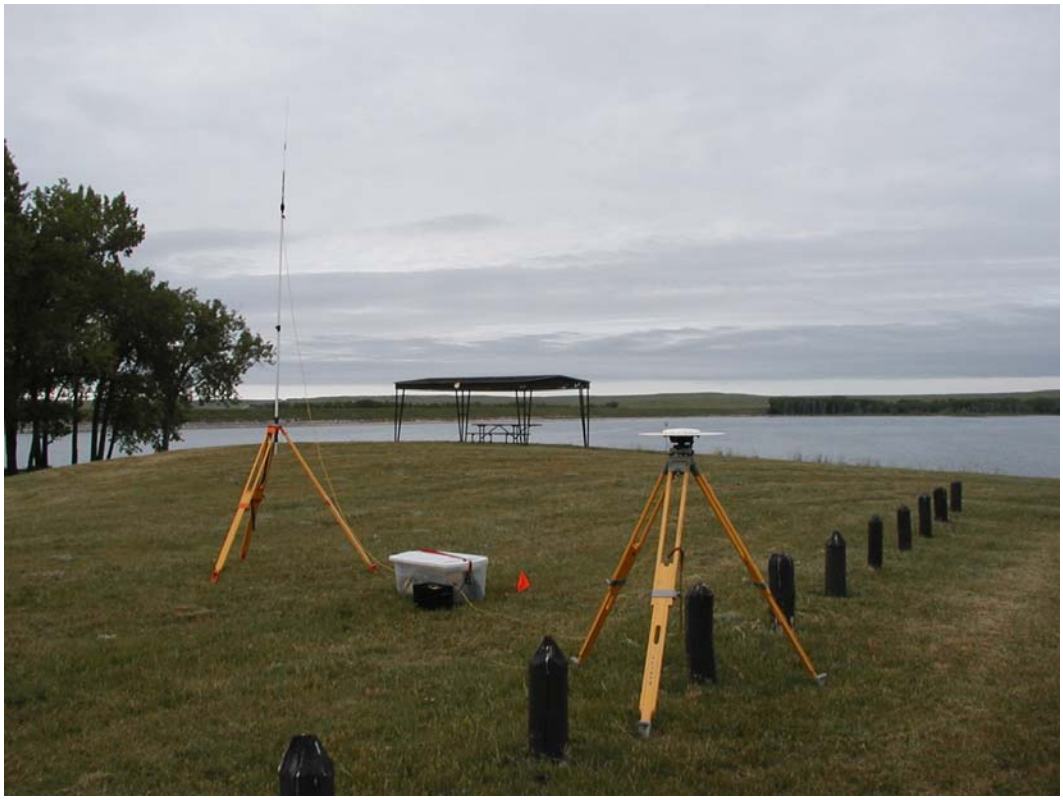

Figure 4 - Temporary hydrographic survey control point near boat ramp.

Reservoir Operations

Box Butte Reservoir is part of the Mirage Flats Project that provides storage for irrigation, flood control, fish and wildlife conservation, and recreation. The June 2003 capacity table lists 45,901 acre-feet of total storage below the maximum water surface elevation 4,016.0, table 1. The 2003 survey measured a minimum lake bottom elevation of 3,962. The following values are from the June 2003 capacity table:

- 16,740 acre-feet of surcharge between elevation 4,007.0 and 4,016.0.
- 28,973 acre-foot of conservation between elevation 3,969.0 and 4,007.0.
- 188 acre-foot of dead storage below 3,969.0.

Box Butte Reservoir computed annual inflow and reservoir stage records are listed by water year on table 1 for available period 1967 through 2003. The inflow values were computed by the Great Plains Regional Office and show annual fluctuation with a computed average inflow of 19,000 acre-feet per year. The maximum reservoir elevation was 4,002.1, recorded during water year 2000, and minimum recorded elevation was 3,968.2 during water year 1985.

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 5. 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. The GPS receiver and antenna were mounted on a survey tripod over a known datum point. A 12-volt battery provided the power for the shore unit. The collection gear was later mounted on a pontoon raft for mapping the shallow water areas of the reservoir around the shoreline and in the upper reaches. All equipment was run off 12-volt batteries.

The Sedimentation and River Hydraulics Group uses RTK GPS with the major benefit being precise heights measured in real time to monitor water surface elevation changes. The basic output from a RTK receiver are precise 3-D 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 that the hydrographic collection software converted into Nebraska's state plane coordinates in NAD83. The RTK GPS system employs

two receivers that track the same satellites simultaneously just like with differential GPS.

Figure 5 - Survey vessel with mounted instrumentation on Jackson Lake in Wyoming.

The Box Butte Reservoir bathymetric survey was conducted on June 9, 10, 27, and 28, 2003 at RTK GPS measured lake elevation 3,994.8, project datum in NGVD29. The bathymetric survey was conducted using sonic depth recording equipment, interfaced with a 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 perpendicular to the upstream-downstream inflow alignment of the reservoir. Data was collected along the shore by the survey vessels. The survey vessels' guidance system gave directions to the boat operator to assist in maintaining the course along the 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 an instrument that measured the sound velocity of the reservoir water column. The individual depth soundings were adjusted by the speed of sound of the measurements which can vary with density, salinity, temperature, turbidity, and other conditions. The soundings were further verified by lowering a weighted cable below the boat with beads marking known depths. The collected data were digitally transmitted to the computer collection system through 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. Due to thick reservoir bottom vegetation, these charts were relied upon to obtain true reservoir bottom depths. The water surface elevations of the reservoir were measured by the

hydrographic survey crew and were used to convert the sonic depth measurements to true lake-bottom elevations. Additional information on collection and analysis procedures is listed in the following references: Corps of Engineers, January 2002; Ferrari, R. and Collins, K., 2006.

Thick vegetation was a significant factor during the Box Butte Reservoir hydrographic survey, affecting the depth sounding signal in the most densely vegetated portions of the reservoir. Dense vegetation also hindered the survey vessels, damaging one outdrive of the larger vessel. In the upper portion of the reservoir the survey crew collected depth measurements using a range pole to confirm true reservoir depths. In late June 2003, the crew returned with a smaller boat that allowed the mapping along the banks and increased maneuverability in the shallow reservoir areas along the shore and upper end where there were openings in the vegetation. Following are two photographs of the reservoir vegetation, figures 6 and 7.

Figure 6 - Vegetation along shoreline of Box Butte Reservoir.

Figure 7 - Thick vegetation islands in upper reservoir that blocked survey vessels.

Reservoir Area and Capacity

Topography Development

The topography of Box Butte Reservoir was developed from the 2003 below water data and the digitized water surface contour from the USGS quad and the original project contour map of the reservoir. The developed USGS quad contours were developed from aerial photography dated in the 1940's and only included the maximum water surface elevation 4,007.0. Since the survey was conducted near elevation 3,995.0, the available USGS contour was too high for mapping purposes. As part of the analysis, the original contours (Reclamation drawing number 278-D-11) were digitally projected within the USGS quad contour. Using the quad contour and the 2003 underwater data as a guide, the digitized original project contour 3,995.0 was adjusted to surround the 2003 underwater data that was collected near elevation 3,995.0.

The USGS quad contour 4,007.0 was used during the underwater survey for setting up the collection gridlines for guiding the survey vessel to assure complete

reservoir coverage. During the 2003 underwater collection, the vessel occasionally plotted outside the contours indicating bank erosion, but it did not appear that bank erosion was extensive on Box Butte Reservoir. During the field survey, the collection vessels were forced to stop well short of the upper reaches of the 4,007.0 contour due to thick vegetation and assumed sediment delta. However, a plot of the adjusted 3,995.0 contour versus original topography showed that the upper end of the 2003 survey was near the upper portion of the original elevation 3,995.0 contour, indicating a lack of substantial delta formation in this area since dam closure in 1946.

The adjusted contour, elevation 3,995.0, was used to perform a hardclip around the 2003 data of Box Butte Reservoir. The hardclip was used during the triangular irregular network (TIN) development so interpolation did not occur outside the enclosed polygon. This contour was selected since it was the closest data available to represent the water surface during the 2003 survey. Using ARCEDIT, the 2003 below water data along with the contours were plotted. The plot showed that the underwater data did not lie completely within these contours which were then modified to include the entire underwater data set within the enclosed polygon. Using select and move commands within ARCEDIT, the vertices of the clip were shifted to develop the final clip that was assigned an elevation of 3,995.0.

Contours for the reservoir below elevation 3,995.0 were computed from the 2003 data sets 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 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 Box Butte Reservoir TIN. The areas of the enclosed contour polygons at one-foot increments were developed from the survey data for elevations 3,961.0 through 3,995.0. Since no complete reservoir aerial data was collected for this study, no change was assumed in original reservoir surface area for elevation 4,000.0 and above. The reservoir contour topography at 2- and 5-foot intervals is presented on figure 8.

Horzontal datum based on Nebraska's State Plane Coordinate System. (NAD83).

Vertical datum based on original project datum established by U.S. Bureau of Reclamation in NGVD29. Control surveys measured datum around 2.0 feet lower than NAVD88.

2- and 5-foot contour interval

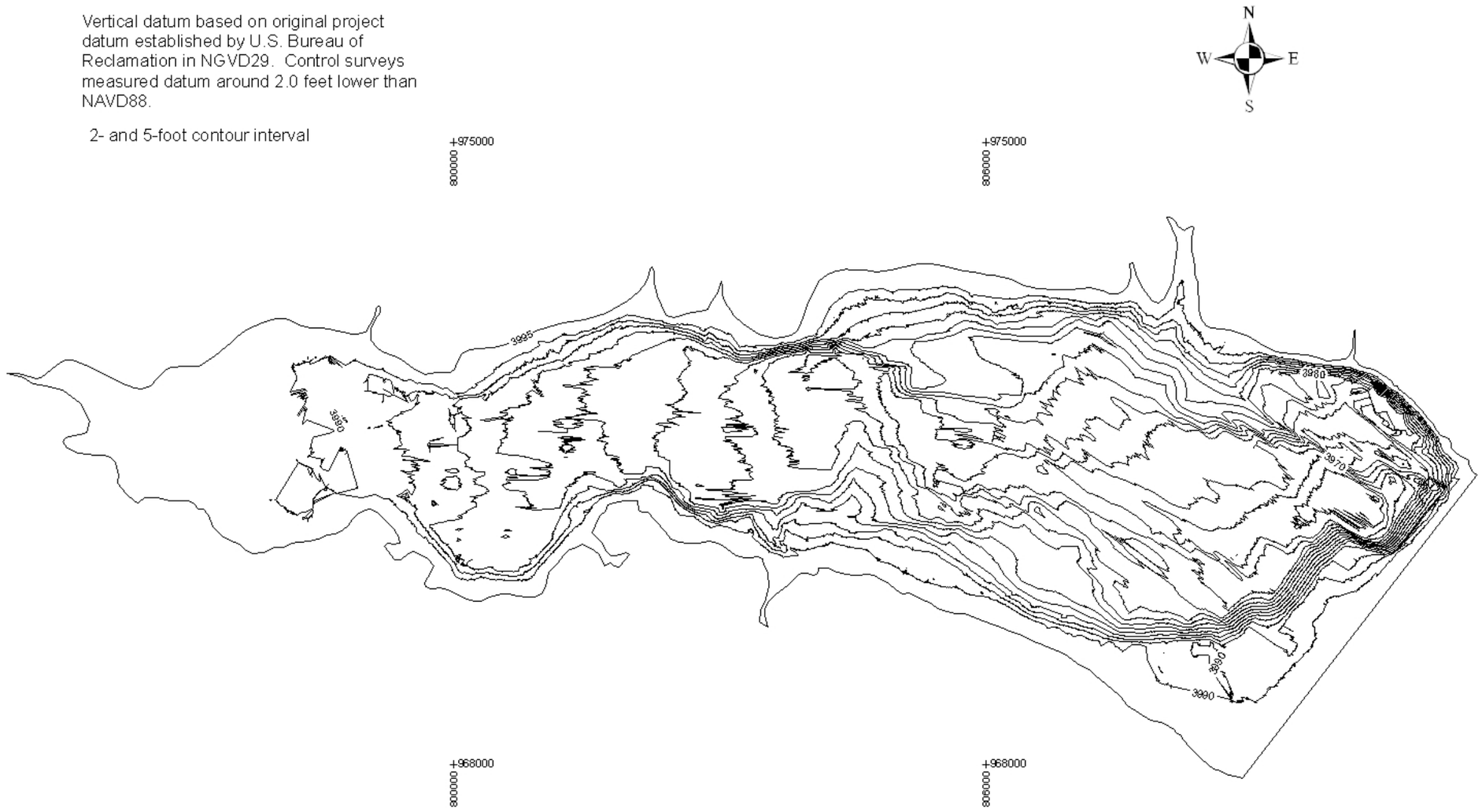

Figure 8 – Box Butte Reservoir topographic map.

Development of the 2003 Box Butte Reservoir Surface Areas

The 2003 surface areas for Box Butte Reservoir were computed at 1-foot increments, from elevation 3,992.0 through 3,995.0, directly from the TIN that covered the Box Butte Reservoir within the hard clip area only. This TIN was developed from the 2003 collected data within the hardclip polygon that was developed from the adjusted digitized 3,995.0 contour as described previously. These calculations were performed using the ARCGIS surface area and volume command that computes areas at user-specified elevations directly from the TIN and includes all regions of equal elevation. For the purpose of this study, the measured 2003 survey areas at 2- and 5-foot increments from elevation 3,962.0 through 3,992.0 were used to compute the new area and capacity tables. For elevation 4,000.0 and above, the surface areas of the original developed topography were used assuming no change. There were insufficient 2003 surveyed data points for accurate computer development of surface areas at elevations above 3,992.0. Straight line interpolation was used to compute the surface areas between elevations 3,992.0 and 4,000.0.

2003 Storage Capacity

The storage-elevation relationships based on the measured surface areas were developed using the area-capacity computer program ACAP (Bureau of Reclamation, 1985). The ACAP program can compute the area and capacity at elevation increments from 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 Box Butte Reservoir. The capacity equation is then used over the full range of intervals fitting within the 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, 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 Box Butte Reservoir area and capacity computations are listed in a separate set of 2003 area and capacity tables that have 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 ACAP program is included with these tables. The original and 2003 area-capacity relationships are listed on table 2 and the curves are plotted on figure 9. As of June 2003, at conservation use elevation 4,007.0, the surface area was 1,605 acres with a total capacity of 29,161 acre-feet.

2003 Reservoir Sediment Analyses

Results of the 2003 Box Butte Reservoir area and capacity computations are listed in table 1 and columns 4 and 5 of table 2. Columns 2 and 3 of table 2 list the original area and recomputed capacity values. Column 7 lists the capacity differences between the original and 2003 survey results due to sediment inflow. Figure 9 is a plot of the Box Butte Reservoir surface area and capacity values for the original and 2003 surveys and illustrates the differences. The comparisons show that the total reservoir capacity in 2003 was 1,896 acre-feet less than the original volume at conservation reservoir elevation 4,007.0. It must be noted that the 2003 area and capacity tables were generated assuming no surface area change since the original survey at elevation 4,000.0. This is not likely the case, but with no new above water data available, it is assumed any loss due to sediment deposition above this elevation would not be significant since the original survey. The only means to verify this would be by an extensive above water survey, but the thick above water vegetation would greatly hinder any such collection.

The estimated 100 years of sediment accumulation for Box Butte Reservoir was 25.8 percent or around 8,000 acre-feet at conservation pool elevation 4,007.0. This computes to an annual loss of 80 acre-feet. Table 1 shows that the 2003 survey measured an average annual loss of 32.9 acre-feet since dam closure. The information used to project the 100 year sediment accumulation is unknown. It must be noted that the 2003 study estimated no change in capacity from elevation 4,000.0 and above. Due to lack of new topography data in that range, surface areas and volumes between the 2003 measured surface area at elevation 3,992.0 and the original surface area at elevation 4,000 were linearly interpolated. An aerial survey would be needed to more accurately map the reservoir from elevation 3,992.0 and above, but the thick vegetation there may prevent aerial data collection in certain areas.

RESERVOIR SEDIMENT
DATA SUMMARY

Box Butte Reservoir
NAME OF RESERVOIR

1
DATA SHEET NO.

DAM	1. OWNER Bureau of Reclamation		2. STREAM Neobrara River		3. STATE Nebraska	
	4. SEC 28 TWP. 29N RANGE 49 W		5. NEAREST P.O. Heminford		6. COUNTY Dawes	
	7. LAT 42 ° 27 ' 30 " LONG 103 ° 04 ' 03 "		8. TOP OF DAM ELEVATION 4,024.0 [1]		9. SPILLWAY CREST EL 4,007.0 [2]	
RESERVOIR	10. STORAGE ALLOCATION	11. ELEVATION TOP OF POOL	12. ORIGINAL SURFACE AREA, AC-FT	13. ORIGINAL CAPACITY, AC-FT	14. GROSS STORAGE ACRE-FEET	15 DATE STORAGE BEGAN
	a. SURCHARGE	4,016.0 [3]	2,116	17,395	47,797	10/1945
	b. FLOOD CONTROL					
	c. POWER					
	d. JOINT USE					16 DATE NORMAL
	e. CONSERVATION	4,007.0	1,605	30,402	31,057	OPERATIONS
	f. INACTIVE					BEGAN
	g. DEAD	3,969.0	132	655	655	10/1945
	17. LENGTH OF RESERVOIR 4.5 [4] MILES		AVG. WIDTH OF RESERVOIR 0.6 MILES			
BASIN	18. TOTAL DRAINAGE AREA 1460 [5] SQUARE MILES		22. MEAN ANNUAL PRECIPITATION 15.1 [6] INCHES			
	19. NET SEDIMENT CONTRIBUTING AREA 1460 [5] SQUARE MILES		23. MEAN ANNUAL RUNOFF 0.24 [7] INCHES			
	20. LENGTH MILES	AVG. WIDTH MILES	24. MEAN ANNUAL INFLOW 19,000 [7] ACRE-FEET			
	21. MAX. ELEVATION	MIN. ELEVATION	25. ANNUAL TEMP, MEAN 47 °F RANGE -32 °F to 104 °F [6]			

DATA	26. DATE OF SURVEY	27. PER. YRS	28. PER. YRS	29. TYPE OF SURVEY	30. NO. OF RANGES OR INTERVALS	31. SURFACE AREA, AC.	32. CAPACITY ACRE - FEET	33. C/ RATIO AF/AF
SURVEY	10/45			Contour (D)	5 - ft	1,605 [8]	31,057 [8]	1.63
	6/03	57.7	57.7	Contour (D)	2 - ft	1,605 [9]	29,161 [9]	1.53

DATA	26. DATE OF SURVEY	34. PERIOD ANNUAL PRECIPITATION	35. PERIOD WATER INFLOW, ACRE-FEET			36 WATER INFLOW TO DATE, AF	
			a. MEAN ANN.	b. MAX. ANN.	c. TOTAL	a. MEAN ANN.	b. TOTAL
	6/03	15.1	19,000 [7]	27,500	664,900	19,000	664,000

	26. DATE OF SURVEY	37. PERIOD CAPACITY LOSS, ACRE-FEET			38. TOTAL SEDIMENT DEPOSITS TO DATE, AF		
		a. TOTAL	b. AVG. ANN.	c. /MI.^{2}-YR.	a. TOTAL	b. AVG. ANN.	c. /MI.^{2}-YR.
	6/03	1,896 [10]	32.9	0.02	1,896	32.9	0.02

	26. DATE OF SURVEY	39. AVG. DRY WT. (#/FT^3)	40. SED. DEP. TONS/MI.^{2}-YR		41. STORAGE LOSS, PCT.		42 SEDIMENT
			a. PERIOD	b. TOTAL TO DATE	a. AVG. ANNUAL	b. TOTAL TO DATE	INFLOW, PPM a. PER. b. TOT.
	6/2003				0.11	6.1	

26. DATE OF SURVEY	43. DEPTH DESIGNATION RANGE BY RESERVOIR ELEVATION									
		bottom-3,969	3,969-3,975	3,975-3,980	3,980-3,985	3,985-3,990	3,990-3,995	3,995-4,000	4000-4,007	
	PERCENT OF TOTAL SEDIMENT LOCATED WITHIN DEPTH DESIGNATION									
6/03		24.6	13.5	10.6	13.4	20.9	13.1	3.9	0.0	

26. DATE OF SURVEY	44. REACH DESIGNATION PERCENT OF TOTAL ORIGINAL LENGTH OF RESERVOIR													
	0-10	10-20	20-30	30-40	50-60	60-70	70-80	80-90	90-100	100-105	105-111	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 [7]

YEAR	MAX. ELEV.	MIN. ELEV.	INFLOW, AF	YEAR	MAX. ELEV.	MIN. ELEV.	INFLOW, AF
				1967			18,800
1968			27,500	1969	3,999.2	3,975.3	17,700
1970	3,999.4	3,972.9	18,500	1971	3,999.4	3,972.9	21,700
1972	3,996.5	3,977.0	18,700	1973	3,997.5	3,981.2	24,200
1974	3,998.4	3,975.2	20,000	1975	3,996.5	3,970.4	18,000
1976	3,994.3	3,969.8	17,200	1977	3,994.7	3,976.2	20,000
1978	3,993.3	3,976.2	18,800	1979	3,995.8	3,980.5	18,300
1980	3,998.8	3,981.4	19,800	1981	3,995.7	3,977.8	18,200
1982	3,995.8	3,980.5	18,800	1983	4,001.1	3,986.5	23,700
1984	4,000.0	3,978.9	20,400	1985	3,995.3	3,968.2	17,400
1986	3,997.6	3,977.9	22,300	1987	3,998.4	3,975.1	20,400
1988	3,995.7	3,973.0	17,400	1989	3,992.1	3,973.0	14,000
1990	3,992.4	3,978.3	14,800	1991	3,998.4	3,981.5	22,600
1992	3,997.5	3,985.8	14,900	1993	3,998.5	3,998.0	23,500
1994	4,000.0	3,971.5	22,200	1995	4,000.7	3,986.2	16,600
1996	3,999.5	3,986.2		1997	4,000.0	3,988.1	
1998	4,000.1	3,973.6	16,000	1999	4,001.4	3,973.6	17,800
2000	4,002.1	3,988.4	18,600	2001	4,000.3	3,986.2	16,700
2002	3,997.0	3,980.6	16,700	2003	3,994.5	3,979.6	12,700

46. ELEVATION - AREA - CAPACITY - DATA FOR **2003 CAPACITY** [9]

ELEVATION	AREA	CAPACITY	ELEVATION	AREA	CAPACITY	ELEVATION	AREA	CAPACITY
2003	**SURVEY**		3,961.0	0	0	3,962.0	37	37
3,964.0	6	6	3,965.0	17	17	3,966.0	27	38
3,968.0	55	120	3,969.0	81	188	3,970.0	108	282
3,972.0	152	542	3,974.0	213	907	3,975.0	246	1,136
3,976.0	281	1,399	3,978.0	346	2,026	3,980.0	425	2,792
3,982.0	488	3,710	3,984.0	550	4,748	3,985.0	587	5,316
3,986.0	621	5,920	3,988.0	683	7,224	3,990.0	790	8,696
3,992.0	897	10,382	3,995.0	1,043	13,292	4,000.0	1,287	19,117
4,005.0	1,492	26,064	4,007.0	1,605	29,161	4,010.0	1,775	34,232
4,015.0	2,058	43,814	4,016.0	2,116	45,901			

47. REMARKS AND REFERENCES

[1] All elevations are in feet based on the original project datum that is reported as NGVD29 and two feet lower than NAVD88.

[2] Spillway crest elevation 4,007.0, located at left abutment of dam.

[3] Values from Reservoir Capacity Allocation table dated 9/1963. Capacity values recomputed using ACAP.

[4] Length at elevation 4,007.

[5] Total drainage area from USGS water records.

[6] Bureau of Reclamation's Project Data Book, 1981.

[7] Mean annual runoff of 19,000 acre-feet from available records, water years 1968 through 2003. Computations by Great Plains Region. Maximum and minimum from Reclamation available records. Some inflow years not available, 1967, 1996, 1997.

[8] Surface area and capacity at elevation 4,007.0, spillway crest elevation.

[9] All 2003 capacities computed by Reclamation's ACAP computer program. 2- and 5-foot surface data from elevation 3,992 and below. Assumed no change since original developed table from elevation 4,000 and above.

[10] Portion of computed loss, by comparing differences, is due to differences in detail between original and 2003 surveys.

48. AGENCY MAKING SURVEY Bureau of Reclamation

49. AGENCY SUPPLYING DATA Bureau of Reclamation DATE March 2007

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

1	2	3	4	5	6	7	8	9
					2003	2003	Percent	Percent of
Elevation	Original	Original	2003	2003	Area	Sediment	Computed	Reservoir
	Survey	Capacity	Survey	Survey	Difference	Volume	Sediment	Depth
(feet)	(acres)	(acre-feet)	(acres)	(acre-feet)	(acres)	(acre-feet)	Orig. - 2003	
4,016.0	2,116	47,797	2,116	45,901	0			100.0
4,015.0	2,058	45,710	2,058	43,814	0			98.4
4,010.0	1,775	36,128	1,775	34,232	0			90.2
4,007.0	1,605	31,057	1,605	29,161	0	1,896	100.0	85.2
4,005.0	1,492	27,960	1,492	26,064	0	1,896	100.0	82.0
4,000.0	1,287	21,013	1,287	19,117	0	1,896	100.0	73.8
3,995.0	1,072	15,115	1,043	13,292	29	1,823	96.1	65.6
3,992.0	948	12,084	896.6	10,382	51	1,702	89.8	60.7
3,990.0	866	10,270	789.8	8,696	76	1,574	83.0	57.4
3,988.0	778	8,626	682.5	7,224	96	1,402	73.9	54.1
3,986.0	689	7,160	621.0	5,920	68	1,240	65.4	50.8
3,985.0	645	6,493	586.6	5,316	58	1,177	62.1	49.2
3,984.0	609	5,865	550.2	4,748	59	1,117	58.9	47.5
3,982.0	538	4,719	487.6	3,710	50	1,009	53.2	44.3
3,980.0	466	3,715	425.2	2,792	41	923	48.7	41.0
3,978.0	390	2,859	345.9	2,026	44	833	43.9	37.7
3,976.0	315	2,153	280.8	1,399	34	754	39.8	34.4
3,975.0	277	1,858	246.0	1,136	31	722	38.1	32.8
3,974.0	251	1,593	212.5	907	39	686	36.2	31.1
3,972.0	200	1,143	152.1	542	48	601	31.7	27.9
3,970.0	148	795	107.8	282	40	513	27.1	24.6
3,969.0	132	655	81	188	51	467	24.6	23.0
3,968.0	116	531	54.7	120	61	411	21.7	21.3
3,966.0	85	329	26.8	38	58	291	15.3	18.0
3,965.0	69	253	16.5	17	53	236	12.4	16.4
3,964.0	58	189	5.6	6	52	183	9.7	14.8
3,962.0	37	93	0.0	0	37	93	4.9	11.5
3,961.0	27	61	0.0	0	27	61	3.2	9.8
3,960.0	16	40	0.0	0	16	40	2.1	8.2
3,955.0	0	0	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 2003 survey from elevation 3,992 and below. Original							
	surface area from elevation 4,000 and above assuming no change.							
	Elevation 3,995 surface area projected between 3,992 and 4,000 surface area values.							
5	Reservoir capacity computed using ACAP.							
6	Area difference between original and 2003 survey = column (3) - column (5).							
7	Sediment Volume from original (1945) and 2003 surveys = column (4) - column (5).							
8	Percent of sediment volume, total 1,896 acre-feet.							
9	Depth of reservoir expressed in percentage of total depth of 61.0 feet.							

Table 2 - Summary of 2003 survey results.

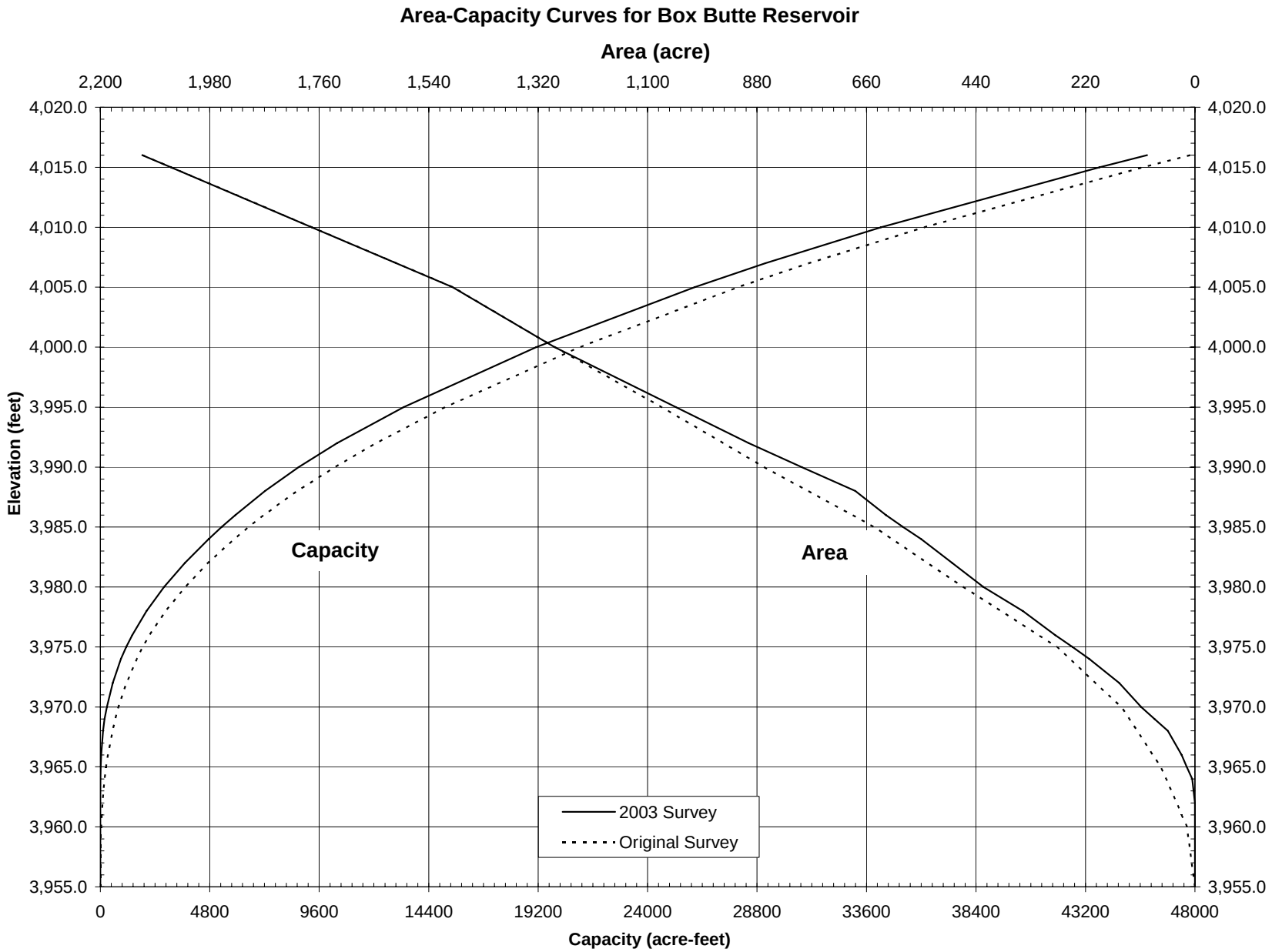

Figure 9 – Box Butte Reservoir area and capacity plots.

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