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*Managing Water in the West*

**Technical Report No. SRH-2012-22**

# Swanson Lake – Trenton Dam 2011 Bathymetric Survey

**U.S. Department of the Interior**
**Bureau of Reclamation**
**Technical Service Center**
**Denver, Colorado**

**August 2012**

# ACKNOWLEDGMENTS

The Bureau of Reclamation's (Reclamation) Sedimentation and River Hydraulics (Sedimentation) Group of the Technical Service Center (TSC) prepared and published this report. Reclamation's Sedimentation Group and Nebraska-Kansas Area Office conducted the bathymetry survey of the reservoir in May 2011. Ron Ferrari completed the data processing to generate the 2011 topographic map and area-capacity tables presented in this report. Kent Collins of the Sedimentation Group performed the technical peer review of this document.


## Mission Statements

The U. S. Department of the Interior protects America's natural resources and heritage, honors our cultures and tribal communities, and supplies the energy to power our future.

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.

## Reclamation Report


This report was produced by the Bureau of Reclamation's Sedimentation and River Hydraulics Group (Mail Code 86-68240), PO Box 25007, Denver, Colorado 80225-0007, www.usbr.gov/pmts/sediment/.


## Disclaimer

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# Swanson Lake – Trenton Dam 2011 Bathymetric Survey

*prepared by*

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**Bureau of Reclamation**
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**Denver, Colorado**

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**BUREAU OF RECLAMATION**

**Technical Service Center, Denver, Colorado**
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# Swanson Lake – Trenton Dam 2011 Bathymetric Survey

**Trenton Dam**
**Nebraska**


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## Introduction

Trenton Dam and Swanson Lake are part of the Meeker-Driftwood Unit of the Frenchman-Cambridge Division and features of the Pick-Sloan Missouri Basin Projects. The dam and reservoir are located in Hitchcock County on the Republican River about 24 miles west of McCook, Nebraska (Figure 1). Additional features of the division are Enders, Harry Strunk, and Hugh Butler Reservoirs located in Nebraska on side tributaries downstream of Swanson Reservoir. Trenton Dam, operated by Reclamation's Nebraska-Kansas Area Office, provides water for irrigation and recreation along with water for fish and wildlife conservation. The drainage area above the dam is 8,620 square miles of which 3,940 contributes directly to surface runoff (USGS, 1987). The net sediment contributing area is 2,112 square miles that removes the drainage area of Bonny Reservoir... At elevation 2,773 the reservoir length is around 8.3 miles with an average width of 1.5 miles.

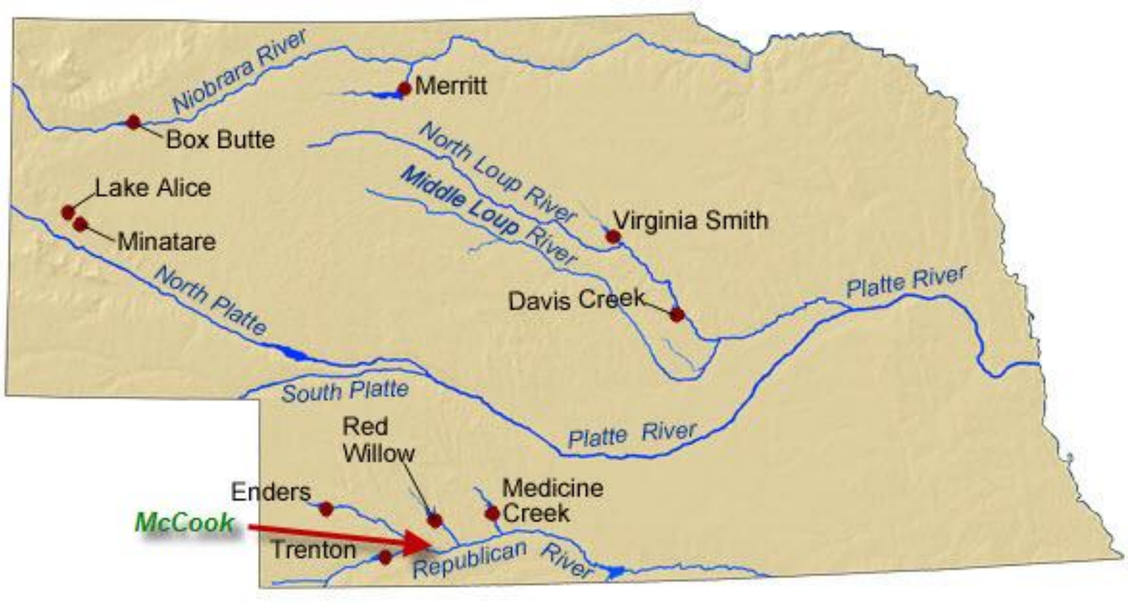


**Figure 1 - Reclamation Reservoirs Located in Nebraska.**

The dam was constructed between 1947 and 1953 with first storage in May 1953. The dam is a zoned earthfill dam with the following dimensions:

| | | | |
|---|---|---|---|
| Structural height[1] | 144 feet | Hydraulic height | 92 feet |
| Crest length | 8,600 feet | Crest elevation[2] | 2,793.0 feet |
| Top width | 30 feet | | |

Trenton Dam's spillway, located through the left abutment, is a concrete gated structure controlled by three 42- by 30-foot counterweighted radial gates mounted on the crest. The spillway crest elevation is 2,743.0 with the top radial gate elevation of 2,773.0. The spillway provides a discharge of 126,500 cubic feet per second (cfs) at maximum water surface elevation 2,785.0.

The river outlet works consists of two identical trains located under the left and right intermediate piers of the spillway with sill elevations of 2,720.0. Each train consists of a trash rack intake, a 6- by 7.5 foot high unlined outlet conduit, a high pressure emergency gate, and high-pressure regulating gate. The design discharge at each is 4,300 cfs at top of flood control elevation 2,773.0. The outlet provides flood control and flows to satisfy downstream water requirements. A Meeker-Driftwood Canal outlet works with a sill elevation of 2,710.0 is located on the right abutment of the embankment and consists of a trashrack, conduit, stilling well, and gate chamber.

# Control Survey Data Information

Prior to the 2011 bathymetric survey, a control network was established using the on-line positioning user service (OPUS) and RTK GPS to establish the horizontal and vertical control near the reservoir used for the hydrographic survey. OPUS is operated by the National Geodetic Survey (NGS) and allows users to submit GPS data files that are processed with known point data to determine positions relative to the national control network. The GPS base was set over a Reclamation brass cap stamped “BOR 15 DS” and located north of the reservoir and road that crosses the dam, Figure 2. The OPUS generated coordinates were used to determine positions and the vertical difference between the North American Vertical Datum of 1988 (NAVD88) and the recorded water surface elevation at the dam.

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[1] The definition of such terms as “top width, “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 in feet. Unless noted, all elevations based on the original project datum established during construction and confirmed to be tied to National Geodetic Vertical Datum of 1929 (NGVD29) and 1.1 feet lower than NAVD88.

**Figure 2 - Reclamation monuments located upstream of the dam and north of the reservoir.**

The horizontal control was established in Nebraska state plane coordinates on the North American Datum of 1983 (NAD83) in feet. The vertical control was tied to the project vertical datum reported to match the National Geodetic Vertical Datum of 1929 (NGVD29). Unless noted, all elevations and computations within this report are referenced to Reclamation's project datum that is tied to NGVD29 and 1.1 feet lower than NAVD88. The developed topographic maps presented in this report are tied to NGVD29. Following is the OPUS computation and RTK GPS coordinates of the monuments measured by this study:

## Monument Labels

| | BOR15DS | BOR127.5US | BOR15US | BOR2792.646 |
|---|---|---|---|---|
| North | 126,015.706 | 126,012.759 | 126,015.099 | 126,015.209 |
| East | 1,343,039.729 | 1,342,897.249 | 1,343,009.786 | 1,343,024.570 |
| Elev. (NAVD88) | 2,793.817 | 2,792.987 | 2,793.434 | 2,793.699 |
| Elev. (NGVD29) | 2,792.7 | 2,791.9 | 2,792.3 | 2,792.6 |

# Reservoir Operations

Swanson Lake's primarily purpose is an irrigation and flood control facility, but it also provides water for recreation, fish, and wildlife. The May 2011 area-capacity tables show 110,175 acre-feet of active conservation storage below elevation 2,752.0 and a total capacity of 352,018 acre-feet below maximum water surface elevation 2,785.0. The 2011 survey measured a minimum bottom elevation of around 2,702.4. The following values are from the May 2011 capacity table:

| | |
|---|---|
| 107,656 | acre-feet of surcharge pool storage between elevation 2,773.0 and 2,785.0. |
| 134,187 | acre-feet of flood pool storage between elevation 2,752.0 and 2,773.0. |
| 99,846 | acre-feet of conservation use storage between elevation 2,720.0 and 2,752.0. |
| 9,302 | acre-feet of inactive use storage between elevation 2,710.0 and 2,720.0. |
| 1,027 | acre-feet of dead pool storage below elevation 2,710.0. |

The Swanson Lake inflow and end-of-month stage records in Table 1 show the inflow and annual fluctuation for operation period May 1953 through May 2011. The average inflow into the reservoir during the first survey period, May 1953 through May 1982, was 72,800 acre-feet and significantly dropped during the second survey period, May 1982 through May 2011, to 32,600 acre-feet. The average inflow since the last survey in 1982 illustrates the effects of basin development during this period, including groundwater pumping and conservation practices. For the entire operation period the average inflow was 52,700 acre-feet per water year. Table 1 also shows the water level and storage fluctuations of Swanson Lake where since filling in 1957 the levels have ranged from a maximum elevation of 2,757.4 in 1962 to a low elevation of 2,724.3 in 2002.

# Hydrographic Survey, Equipment, and Method of Collection

## Bathymetric Survey Equipment

The bathymetric survey equipment was mounted on an aluminum vessel with the transducer and GPS unit located on the bow. 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. On-board batteries powered all the equipment. The shore equipment included a second GPS receiver with an external radio. The shore GPS receiver and antenna were mounted on survey tripods over a known datum point and powered by a 12-volt battery.

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 RTK GPS system employs two receivers that track the same satellites simultaneously just like with differential GPS. The basic outputs 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 WGS-84 datum that the hydrographic collection software converted into Nebraska's state plane coordinates, NAD83, in feet.

The Swanson Lake bathymetric survey was conducted on May 23 and 24 of 2011 between water surface elevation 2,744.5 and 2,744.7 (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 established grid lines throughout the reservoir. The survey vessel's guidance system provided directions to the boat operator to assist in maintaining a course along predetermined lines. There were coves and deeper areas along the shoreline, throughout the reservoir, that were not covered by the survey vessel due to the dense vegetation that had developed while reservoir levels were low during the extended dry period. As each line was traversed, the depth and position data were recorded on the laptop computer hard drive for subsequent processing. The water surface elevations at the dam, recorded by a Reclamation gage and RTK GPS measurements, were used to convert the sonic depth measurements to lake-bottom elevations. The elevations are all tied to NGVD29 that is around 1.1 feet lower than NAVD88. Final processing of the May 2011 collected data resulted in around 54,800 points, Figure 3.

The 2011 underwater data was collected using a depth sounder that was calibrated by adjusting the speed of sound through the water column which can vary with density, salinity, temperature, turbidity, and other conditions. The collected data were digitally transmitted to the computer collection system through a RS-232 serial port. The depth sounder also produced a digital analog chart of the measured depths. These digital 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. Additional information on collection and analysis procedures are outlined in Chapter 9 of the *Erosion and Sedimentation Manual* (Ferrari and Collins, 2006).

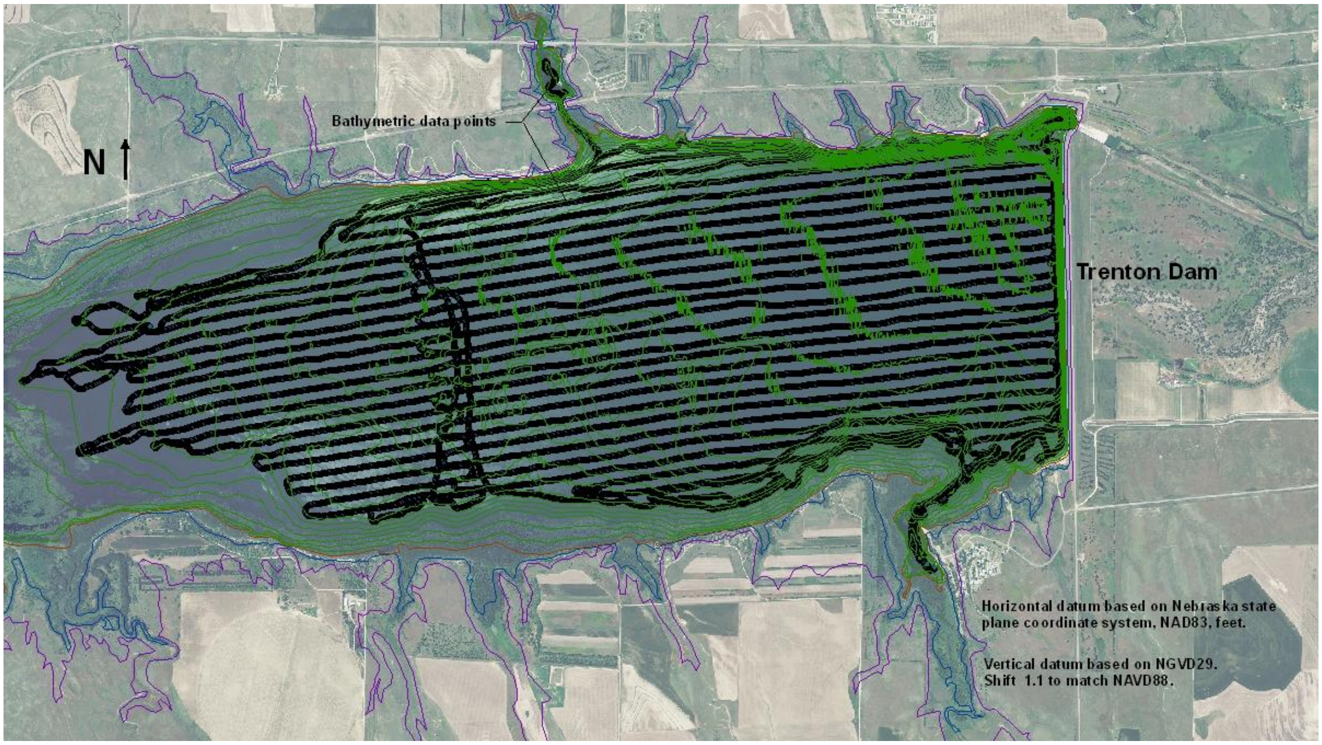


**Figure 3 – Swanson Lake, bathymetric data from dam upstream (NGVD29).**

## Above Water Data

The 2011 study of Swanson Lake focused on the collection of bathymetric or underwater data that was accessible by the survey vessel, meaning acquisition of the best available above water data was necessary to complete the topographic development. During the analysis, orthographic aerial images collected in 2004 at water surface elevation 2,730.1; in 2006 at water surface elevation 2,732.8; in 2009 at water surface elevation 2,740.4; and in 2010 at water surface elevation 2,745.6 were downloaded from the USDA data web site (USDA, 2010). Reservoir contours were developed by digitizing the water's edge from these aerial images and assigning an elevation from the day of each flight, Figures 4 and 5. For the years 2004 and 2006 the reservoir elevations were much lower and digitizing easier since there was little vegetation along the shoreline. As seen on the figures, the vegetation along portions of the shoreline made it more difficult to distinguish the location of the water surface for the 2009 and 2010 aerial flights when the water levels were 10 to 15 feet higher. Using multiple years of aerial photographs and the elevation 2,752 contour from the USGS quad map, the water surface alignments of elevations of 2,740.4 and 2,745.6 were interpolated within the vegetated areas. The 2,745.6 contour was the highest elevation of the aerial data and near the reservoir pool elevation when the 2011 bathymetric survey was conducted. The entire digitized 2,745.6 contour enclosed the 2011 bathymetric data and was used for this study's topographic development. For the lower elevations, the portions of the digitized contours overlapped by the 2011

bathymetric data were removed. The remaining portions of these contours were used as breaklines to develop the 2011 topography presented in this study.

As part of this analysis, Interferometric Synthetic Aperture Radar (IFSAR) digital data was obtained as bare earth data in Nebraska's state plane zone with vertical elevations tied to NAVD88. IFSAR airborne technology enables mapping of large areas quickly and efficiently resulting in detailed information at a much lower cost than other technologies such as aerial photogrammetry and LiDAR. The IFSAR data was collected when the reservoir was drawn down, allowing data in areas not covered by the 2011 bathymetric survey to be obtained and overlapping data to be compared to the bathymetry and USDA aerial water surface elevations. The IFSAR elevations were shifted to match the project's vertical datum, NGVD29. The IFSAR reported accuracies are 2 meters horizontally and 1 meter vertically for areas of unobstructed flat ground (Intermap, 2011). The IFSAR data provided a detailed topographic image of the main body of the reservoir, but did not represent the topography in many coves of the reservoir well. In the upper portion of the reservoir, where it is more wide open and somewhat flat, the elevations did not match well with the other data sets. In many cases the differences were in the 1 meter range, which met the specification of the IFSAR data, but a consistent shift could not be applied to make a reliable match with all other data sets. For this analysis, IFSAR data was not used since the accuracy difference would result in computation of unreliable sediment deposition values.

## Shoreline Erosion

During the 2011 bathymetric survey several areas of the reservoir with eroded shoreline were observed. This was further confirmed during the development of the contours from the USDA aerial photographs (elevation 2745.6 and below) where these contours crossed the elevation 2,752 contour developed from the USGS quad map of the reservoir at many locations. This condition mainly occurred in the lower portion of the reservoir and on the north shoreline, but was also observed at some south shore locations. In some areas, 200-300 feet of outward eroded shoreline material was observed from the analysis that has since settled into the lower elevation portions of the reservoir. It would require a detailed aerial survey to better estimate the surface area and resulting volume of the higher elevations of the reservoir from around elevation 2,740 and above.

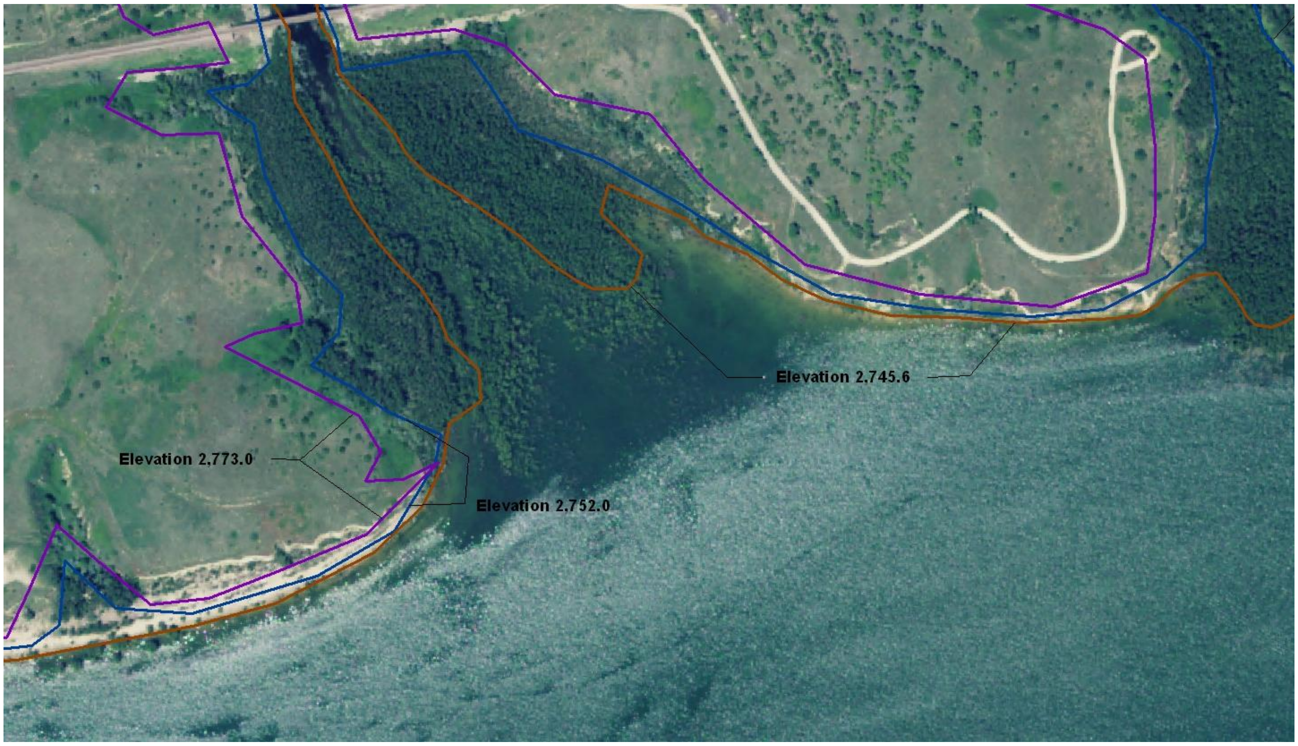


**Figure 4 - Aerial image of Swanson Lake at water surface elevation 2,745.6 (NGVD29), flown in 2010 (USDA 2010).**

**Figure 5 - Aerial image of right abutment of Trenton Dam and Swanson Lake at water surface elevation 2,745.6 (NGVD29), flown in 2010 (USDA, 2010).**

# Reservoir Area and Capacity

## Topography Development

This section discusses the methods used for generating topographic contours for Swanson Lake. The data sources included the 2011 bathymetric survey, the digitized reservoir water surface edges from the USDA aerial photographs, and the digitized contours from the USGS quad maps. These data were processed into a triangulated irregular network (TIN) that was then used to develop 2-foot contours tied vertically to NGVD29, Figure 6. The resulting surface areas and volumes presented in this report are from the developed TIN and are tied to NGVD29 where the elevations can be shifted upward 1.1 feet to match NAVD88. In preparation for developing the TIN, a polygon was created to enclose all of the data sets. The polygon, not assigned an elevation, was used as a hard boundary for the 2011 developed contours, allowing mapping within the reservoir area outlined by the hardclip polygon only. The hardclip was used during the TIN development to prevent interpolation outside the enclosed polygon.

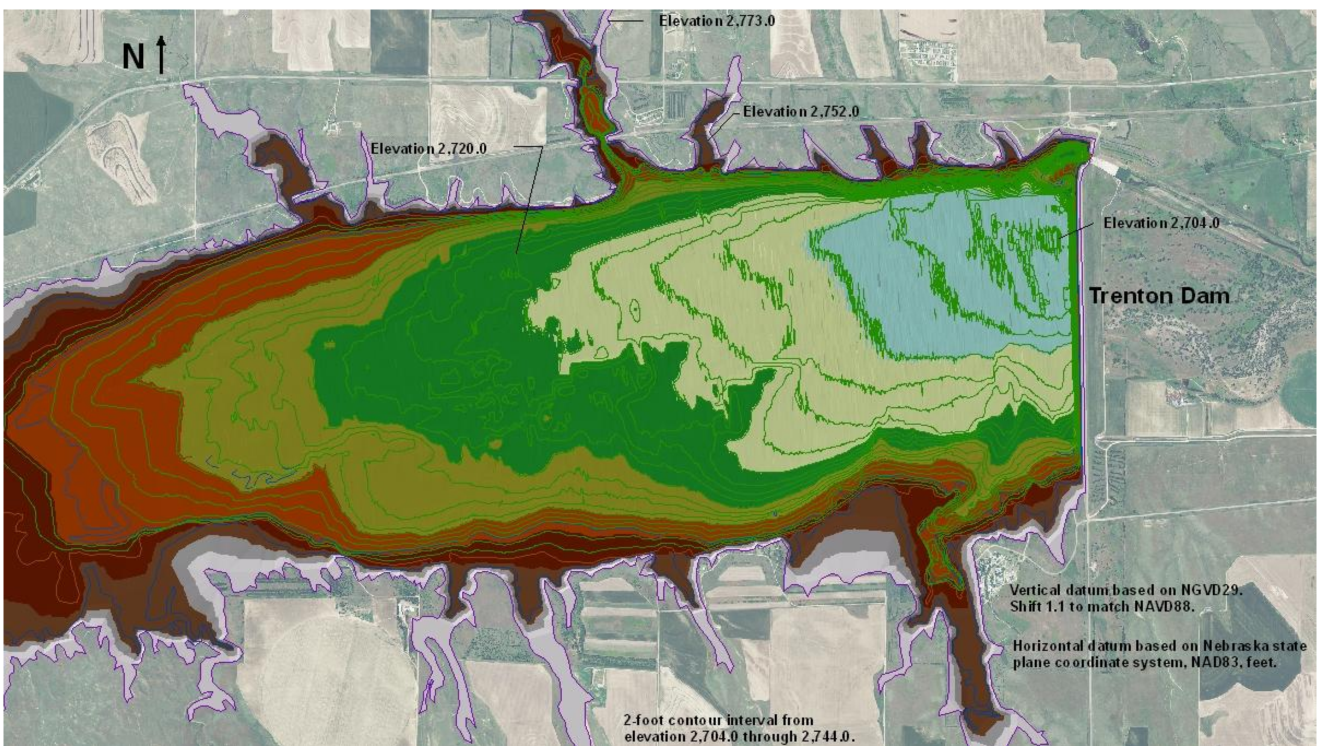


**Figure 6 - Swanson Lake 2011 TIN (NGVD29).**

Contours for the reservoir from Trenton Dam upstream were developed from the TIN generated within ArcGIS. A TIN is a set of adjacent non-overlapping triangles computed from irregularly spaced points with x,y coordinates and z values. A TIN is designed to deal with continuous data such as elevations. ArcGIS 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 all the data points are connected to their nearest neighbors to form triangles. This method preserves all the collected data points. The TIN method is described in more detail in the ArcGIS user's documentation (ESRI, 2006).

The linear interpolation option of the ArcGIS TIN and CONTOUR commands was used to interpolate contours from the Swanson Lake TIN. The surface areas of the enclosed contour polygons at 2-foot increments were computed for elevation 2,702.0 and above. The reservoir contour topography at 2-foot intervals is presented on Figures 7 and 8 from elevation 2,704.0 through elevation 2,744.0. The contours presented above 2,744.0 are the digitized images from the USDA aerial and USGS quad contours.

## 2011 Swanson Lake Surface Area Methods

Using ArcGIS commands to compute areas at user-specified elevations, the 2011 surface areas for Swanson Lake were computed at 2- and 5-foot increments directly from the reservoir TIN from minimum elevation 2,702.0 to elevation 2,744.0 to provide information for the area-capacity tables. The upper most 2011 surface area entry was at elevation 2,745.0 since the highest elevation data to develop the 2011 polygons from the developed TIN was 2,744.6 feet from the USDA aerial data. Due to the lack of recent and reliable data above elevation 2,750, the 2011 study assumed no change in the reservoir surface area, since the 1982 survey, starting at elevation 2,750.0 and above. A summary of the 2011 survey results and how they compare to previous survey results follows.

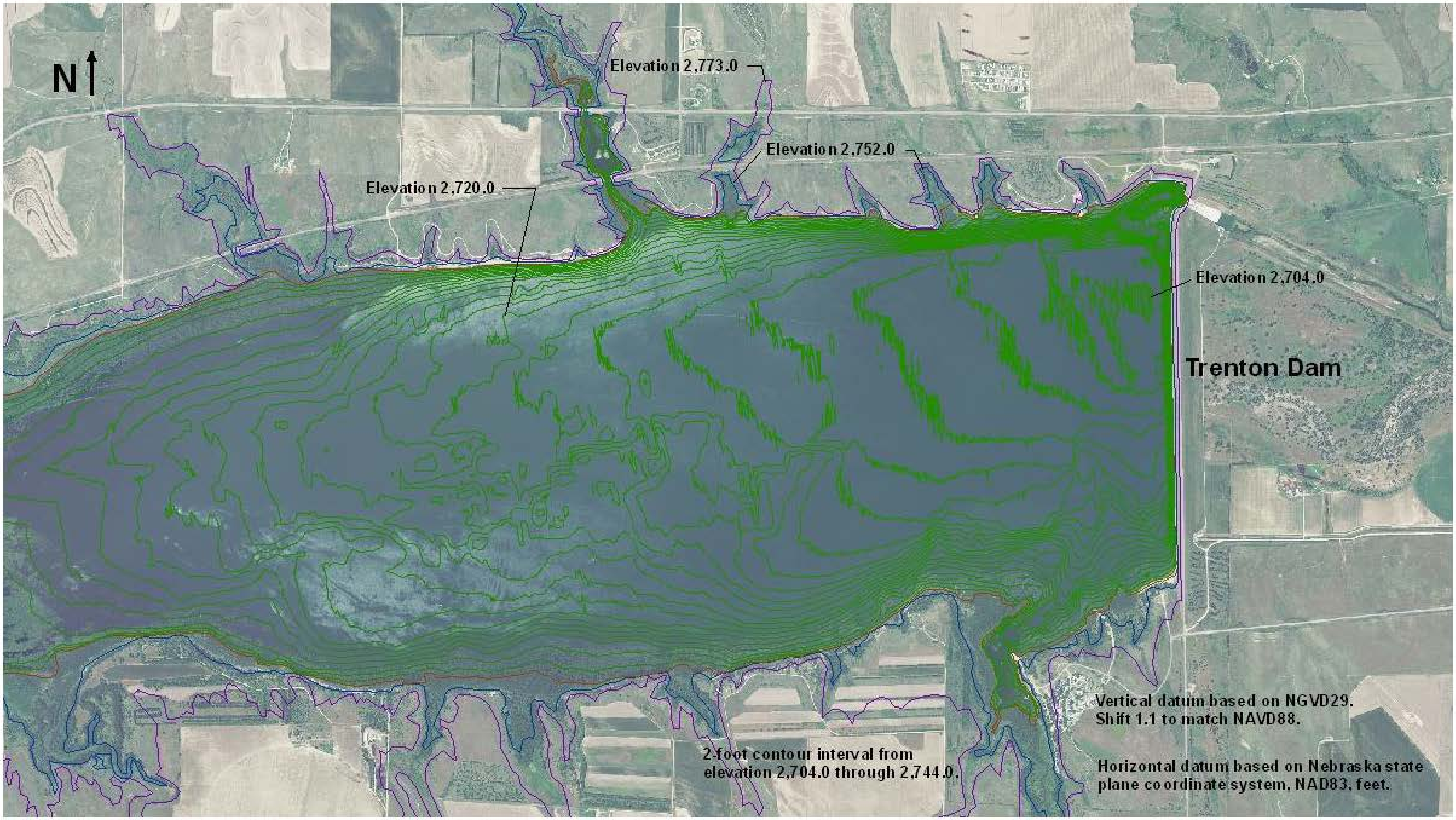


**Figure 7 - Swanson Lake topography, NGVD29 (map 1 of 2).**

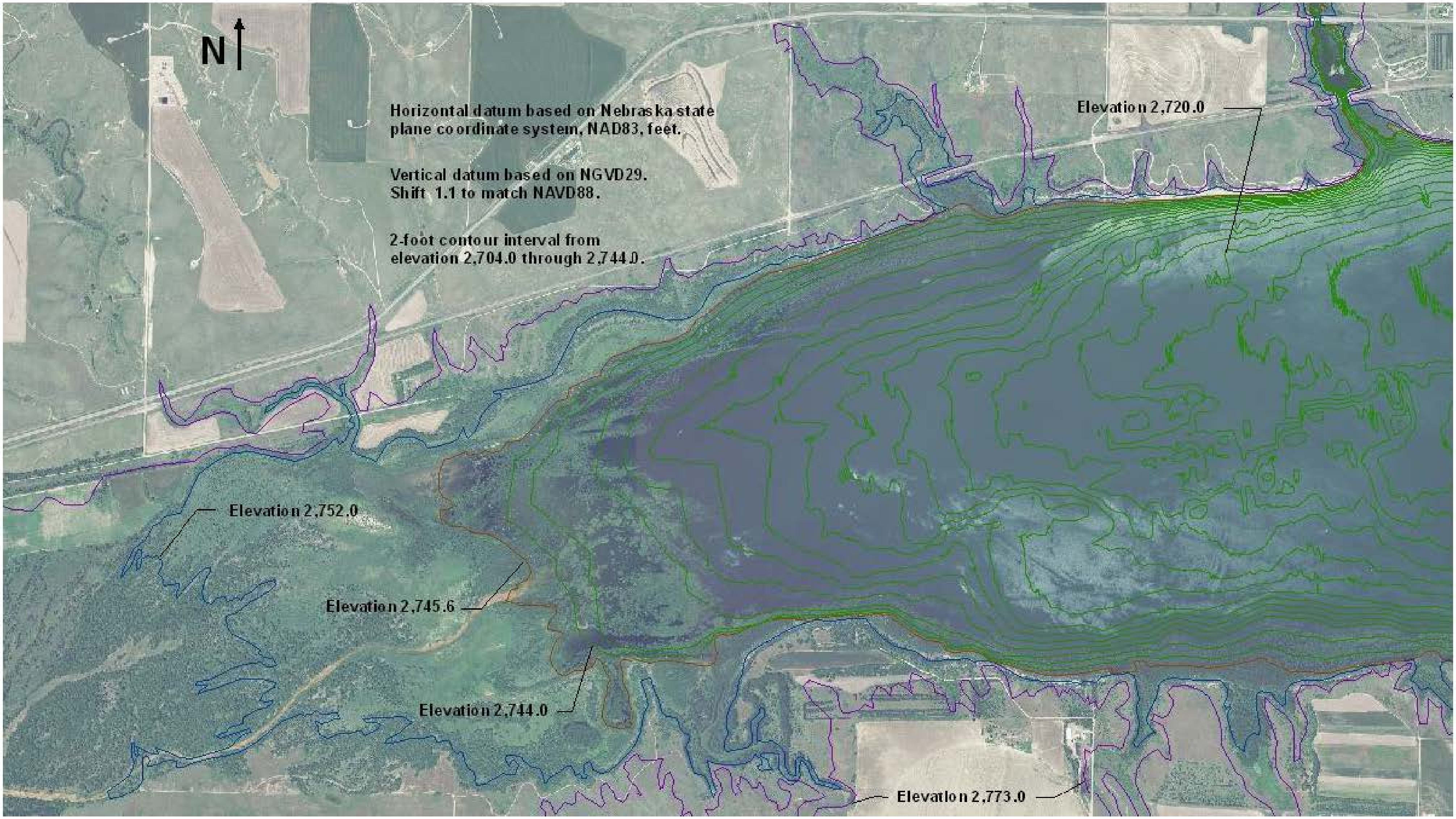


**Figure 8 - Swanson Lake topography, NGVD29 (map 2 of 2).**

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## 2011 Swanson Lake Storage Capacity Methods

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 Swanson Lake. 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 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. Through differentiation of 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 Swanson Lake area and capacity computations are listed in a separate set of 2011 area and capacity tables and have been published for 0.01, 0.1, and 1-foot elevation increments (Bureau of Reclamation, 2012). A description of the computations and coefficients output from the ACAP program is included with these tables. As of May 2011, at conservation use elevation 2,752.0, the surface area was 4,952 acres with a total capacity of 110,175 acre-feet. At maximum and top of surcharge elevation 2,785.0, the surface area was 10,035 acres with a total capacity of 352,018 acre-feet.

## Swanson Lake Surface Area and Capacity Results

This section provides 2011 surface area and capacity results for Swanson Lake and evaluates changes over time. Table 1 provides a summary of the changes in Swanson Lake storage, inflow, and topography between the time of original dam closure in May 1953, the May 1982 range line survey, and May 2011 topographic survey. The area and capacity curves for the original and all subsequent surveys are plotted on Figure 9. Table 2 provides a summary of the original, 1982, and 2011 surface areas and capacities.

The 2011 bathymetric survey and the other data sources summarized in the *Topographic Development* section provided adequate information for computing

the surface areas from elevation 2,702.0 through 2,745.0.  For computation purposes the surface area result from the 1982 survey at elevation 2,750.0 and above were used to complete the 2011 area and capacity tables.  The ACAP program was allowed to interpolate and compute the area and capacity values between elevation 2,702.0 and 2,785.0 from the surface area inputs.

# Longitudinal Distribution

To illustrate the reservoir bottom the Republican River thalweg plot from the dam upstream to the upper reservoir was developed.  The longitudinal profile (Figure 10) was cut through the 2011 developed contours.  The original and 1982 topography were not available for comparison to these study results, but the 2011 plot does illustrate the current bottom condition from the dam upstream.  The sill elevations for the canal and river outlets are currently around eight and eighteen feet respectfully above the current measured reservoir bottom.  From the previous survey results the 1982 survey measured about ten feet of bottom rise since dam closure in 1953 and the 2011 survey measured essentially no bottom change near the dam since 1982.  The plot appears to show a pivot point at around elevation 2,745 illustrating a typical reservoir delta formation in the upper reach, but this study did not have measured data from near elevation 2,745 and above to verify. The plot from elevation 2,750 and above was developed from the imported USGS quad contours.  The plot mainly illustrates the present condition of the reservoir and any major sediment inflow could eventually have an impact on the inlets of the outlet works, but currently there are no such issues.

RESERVOIR SEDIMENT
DATA SUMMARY

Swanson Lake
NAME OF RESERVOIR

1
DATA SHEET NO.

| | | | |
|---|---|---|---|
| D | 1. OWNER: Bureau of Reclamation | 2. STREAM: Republican River | 3. STATE: Nebraska |
| A | 4. SEC 5 TWP. 2 N RANGE 33 E | 5. NEAREST P.O. Trenton | 6. COUNTY Hitchcock |
| M | 7. LAT 40 ° 10 ' 10 " LONG 101 ° 03 ' 35 " | 8. TOP OF DAM ELEVATION: 2,793.0 [1] | 9. SPILLWAY CREST EL. 2,743.0 [2] |

| | 10. STORAGE ALLOCATION | 11. ELEVATION TOP OF POOL | 12. Original SURFACE AREA, ACRES | 13. Original CAPACITY, AC-FT | 14. GROSS STORAGE ACRE-FEET | 15. DATE STORAGE BEGAN |
|---|---|---|---|---|---|---|
| R | a. SURCHARGE | 2,785.0 [3] | 10,040 | 107,650 | 361,812 | |
| E | b. FLOOD CONTROL | 2,773.0 | 7,973 | 133,796 | 254,162 | 5/4/1953 |
| S | c. POWER | | | | | |
| E | d. JOINT USE | 2,752.0 | 4,975 | 104,653 | 120,366 | 16. DATE NORMAL OPERATIONS BEGAN |
| R | e. CONSERVATION | | | | | |
| V | f. INACTIVE | 2,720.0 | 1,572 | 11,408 | 15,713 | |
| O | g. DEAD | 2,710.0 | 739 | 4,305 | 4,305 | - |
| I R | 17. LENGTH OF RESERVOIR 8.3 [4] MILES | | AVG. WIDTH OF RESERVOIR 1.5 MILES | | | |

| | | |
|---|---|---|
| B | 18. TOTAL DRAINAGE AREA 8,620 [5] SQUARE MILES | 22. MEAN ANNUAL PRECIPITATION 20 [6] INCHES |
| A | 19. NET SEDIMENT CONTRIBUTING AREA 2,112 [5] SQUARE MILES | 23. MEAN ANNUAL RUNOFF 0.11 [6] INCHES |
| S | 20. LENGTH 160 MILES AVG. WIDTH 54 MILES | 24. MEAN ANNUAL RUNOFF 52,700 [7] ACRE-FEET |
| I N | 21. MAX. ELEVATION 6000 MIN. ELEVATION 2,700.0 | 25. ANNUAL TEMP, MEAN 52 °F RANGE -22 °F to 110 °F [6] |

| 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/I RATIO AF/AF |
|---|---|---|---|---|---|---|---|
| May 1953 | | | Contour (D) | 5-ft | 4,975 | 120,366 | 2.28 |
| May 1982 | 29.0 | 29.0 | Range (D) | 19 | 4,952 | 112,185 | 2.13 |
| May 2011 | 29.0 | 58.0 | Contour (D) | 5-ft | 4,952 [7] | 110,175 [7] | 2.09 |

| 26. DATE OF SURVEY | 34. PERIOD ANNUAL PRECIPITATION | 35. PERIOD WATER INFLOW, ACRE-FEET a. MEAN ANN. | b. MAX. ANN. | c. TOTAL | 36. WATER INFLOW TO DATE, AF a. MEAN ANN. | b. TOTAL |
|---|---|---|---|---|---|---|
| May 1982 | | 72,800 [8] | 172,100 | 2,111,000 | 72,800 | 2,110,000 |
| May 2011 | | 32,600 | 69,400 | 946,700 | 52,700 | 3,057,700 |

| 26. DATE OF SURVEY | 37. PERIOD CAPACITY LOSS, ACRE-FEET a. TOTAL | b. AVG. ANN. | c. /MI.$^2$-YR. | 38. TOTAL SEDIMENT DEPOSITS TO DATE, AF a. TOTAL | b. AVG. ANN. | c. /MI.$^2$-YR. |
|---|---|---|---|---|---|---|
| May 1982 | 8,181 [9] | 282.1 | 0.134 | 8,181 | 282.1 | 0.134 |
| May 2011 | 2,010 | 69.3 | 0.03 | 10,191 | 175.7 | 0.08 |

| 26. DATE OF SURVEY | 39. AVG. DRY WT. (#/FT$^3$) | 40. SED. DEP. TONS/MI.$^2$-YR a. PERIOD | b. TOTAL TO DATE | 41. STORAGE LOSS, PCT. a. AVG. ANNUAL | b. TOTAL TO DATE | 42. SEDIMENT INFLOW, PPM a. PER. | b. TOT. |
|---|---|---|---|---|---|---|---|
| May 1982 | | | | 0.234 [9] | 6.80 [9] | | |
| May 2011 | | | | 0.146 | 8.47 | | |

| 26. DATE OF SURVEY | 43. DEPTH DESIGNATION RANGE IN FEET BELOW AND ABOVE CREST ELEVATION | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | |
| | PERCENT OF TOTAL SEDIMENT LOCATED WITHIN DEPTH DESIGNATION | | | | | | | | | | |
| | | | | | | | | | | | |

| 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 [8]

| YEAR | MAX. ELEV. | MIN. ELEV. | INFLOW, AF | YEAR | MAX. ELEV. | MIN. ELEV. | INFLOW, AF |
|---|---|---|---|---|---|---|---|
| | | | | 1953 | 2,715.6 | 2,693.0 | 8,400 |
| 1954 | 2,730.0 | 2,708.7 | 41,400 | 1955 | 2,741.8 | 2,722.6 | 58,600 |
| 1956 | 2,740.7 | 2,731.8 | 46,500 | 1957 | 2,755.4 | 2,738.0 | 172,100 |
| 1958 | 2,754.1 | 2,750.1 | 137,600 | 1959 | 2,749.5 | 2,739.9 | 70,300 |
| 1960 | 2,757.0 | 2,739.8 | 101,400 | 1961 | 2,753.1 | 2,741.5 | 57,000 |
| 1962 | 2,757.4 | 2,743.0 | 164,200 | 1963 | 2,753.8 | 2,740.0 | 62,700 |
| 1964 | 2,752.7 | 2,742.3 | 60,400 | 1965 | 2,755.1 | 2,742.1 | 100,600 |
| 1966 | 2,752.7 | 2,742.2 | 92,900 | 1967 | 2,754.1 | 2,742.2 | 81,200 |
| 1968 | 2,752.7 | 2,742.4 | 45,800 | 1969 | 2,754.0 | 2,742.7 | 63,000 |
| 1970 | 2,752.4 | 2,737.4 | 65,100 | 1971 | 2,751.6 | 2,737.1 | 58,300 |
| 1972 | 2,749.9 | 2,738.0 | 57,200 | 1973 | 2,753.2 | 2,741.3 | 90,400 |
| 1974 | 2,753.8 | 2,738.6 | 73,800 | 1975 | 2,751.6 | 2,738.4 | 56,600 |
| 1976 | 2,747.2 | 2,726.1 | 32,400 | 1977 | 2,742.7 | 2,726.0 | 49,900 |
| 1978 | 2,742.1 | 2,726.7 | 34,400 | 1979 | 2,738.5 | 2,726.4 | 39,300 |
| 1980 | 2,746.9 | 2,729.8 | 57,900 | 1981 | 2,752.5 | 2,735.5 | 73,000 |
| 1982 | 2,756.8 | 2,745.0 | 58,600 | 1983 | 2,754.1 | 2,741.3 | 60,900 |
| 1984 | 2,754.2 | 2,741.0 | 59,200 | 1985 | 2,752.9 | 2,741.3 | 42,100 |
| 1986 | 2,750.8 | 2,738.9 | 40,400 | 1987 | 2,750.9 | 2,731.7 | 46,000 |
| 1988 | 2,750.4 | 2,739.3 | 44,200 | 1989 | 2,746.0 | 2,737.4 | 34,600 |
| 1990 | 2,747.7 | 2,731.9 | 4,300 | 1991 | 2,742.9 | 2,731.8 | 50,800 |
| 1992 | 2,745.5 | 2,732.0 | 69,400 | 1993 | 2,747.8 | 2,747.4 | 68,200 |
| 1994 | 2,756.0 | 2,744.3 | 41,900 | 1995 | 2,754.9 | 2,743.6 | 54,900 |
| 1996 | 2,752.1 | 2,743.3 | 51,100 | 1997 | 2,754.4 | 2,742.8 | 35,200 |
| 1998 | 2,749.4 | 2,736.9 | 27,600 | 1999 | 2,744.9 | 2,735.8 | 32,900 |
| 2000 | 2,743.2 | 2,727.0 | 23,200 | 2001 | 2,742.9 | 2,726.2 | 19,500 |
| 2002 | 2,730.5 | 2,724.3 | 9,500 | 2003 | 2,730.5 | 2,725.5 | 6,000 |
| 2004 | 2,728.2 | 2,727.8 | 9,700 | 2005 | 2,732.2 | 2,731.6 | 13,000 |
| 2006 | 2,733.7 | 2,731.3 | 2,000 | 2007 | 2,737.1 | 2,731.6 | 21,300 |
| 2008 | 2,738.5 | 2,731.8 | 3,800 | 2009 | 2,742.0 | 2,735.7 | 20,800 |
| 2010 | 2,745.6 | 2,735.6 | 34,200 | 2011 | 2,745.4 | 2,739.6 | 20,000 |

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

| ELEVATION | AREA | CAPACITY | ELEVATION | AREA | CAPACITY | ELEVATION | AREA | CAPACITY |
|---|---|---|---|---|---|---|---|---|
| **Original** | **SURVEY** | [10] | 2,691.3 | 0 | 0 | 2,695.0 | 15 | 30 |
| 2,700.0 | 121 | 370 | 2,705.0 | 357 | 1,565 | 2,710.0 | 739 | 4,305 |
| 2,715.0 | 1,126 | 8,968 | 2,720.0 | 1,572 | 15,713 | 2,725.0 | 2,064 | 24,803 |
| 2,730.0 | 2,514 | 36,248 | 2,735.0 | 3,180 | 50,483 | 2,740.0 | 3,800 | 67,933 |
| 2,745.0 | 4,280 | 88,133 | 2,750.0 | 4,731 | 110,660 | 2,755.0 | 5,340 | 135,838 |
| 2,760.0 | 5,965 | 164,100 | 2,765.0 | 6,670 | 195,688 | 2,770.0 | 7,460 | 231,013 |
| 2,775.0 | 8,315 | 270,450 | 2,780.0 | 9,095 | 313,975 | 2,785.0 | 10,040 | |
| **1982** | **SURVEY** | [10] | | | | | | |
| 2,701.9 | 0 | 0 | 2,705.0 | 224 | 336 | 2,710.0 | 488 | 2,116 |
| 2,715.0 | 1,113 | 6,119 | 2,720.0 | 1,411 | 12,429 | 2,725.0 | 1,958 | 20,851 |
| 2,730.0 | 2,376 | 31,686 | 2,735.0 | 3,033 | 45,209 | 2,740.0 | 3,519 | 61,589 |
| 2,745.0 | 4,104 | 80,646 | 2,750.0 | 4,665 | 102,569 | 2,755.0 | 5,382 | 127,686 |
| 2,760.0 | 5,983 | 156,099 | 2,765.0 | 6,675 | 187,744 | 2,770.0 | 7,491 | 223,159 |
| 2,775.0 | 8,314 | 262,671 | 2,780.0 | 9,097 | 306,199 | 2,785.0 | 10,035 | 354,028 |
| **2011** | **SURVEY** | | | | | | | |
| 2,702.0 | 0 | 0 | 2,704.0 | 10 | 10 | 2,705.0 | 58 | 44 |
| 2,706.0 | 93 | 119 | 2,708.0 | 210 | 422 | 2,710.0 | 396 | 1,027 |
| 2,712.0 | 620 | 2,043 | 2,714.0 | 832 | 3,495 | 2,715.0 | 937 | 4,379 |
| 2,716.0 | 1,040 | 5,368 | 2,718.0 | 1,233 | 7,641 | 2,720.0 | 1,455 | 10,329 |
| 2,722.0 | 1,652 | 13,436 | 2,724.0 | 1,909 | 16,998 | 2,725.0 | 2,012 | 18,958 |
| 2,726.0 | 2,111 | 21,019 | 2,728.0 | 2,301 | 25,430 | 2,730.0 | 2,511 | 30,242 |
| 2,732.0 | 2,728 | 35,480 | 2,734.0 | 2,904 | 41,112 | 2,735.0 | 2,999 | 44,063 |
| 2,736.0 | 3,095 | 47,110 | 2,738.0 | 3,284 | 53,489 | 2,740.0 | 3,491 | 60,264 |
| 2,742.0 | 3,737 | 67,491 | 2,744.0 | 3,878 | 75,105 | 2,745.0 | 3,950 | 79,020 |
| 2,750.0 | 4,665 | 100,558 | 2,755.0 | 5,382 | 125,676 | 2,760.0 | 5,983 | 154,088 |
| 2,765.0 | 6,675 | 185,733 | 2,770.0 | 7,491 | 221,148 | 2,775.0 | 8,314 | 260,661 |
| 2,780.0 | 9,097 | 304,188 | 2,785.0 | 10,035 | 352,018 | | | |

47. REMARKS AND REFERENCES

[1] Elevation in feet. Vertical datum tied to NGVD29. Add 1.1 feet to shift to NAVD88.
[2] Spillway crest, top of movable spillway gate is elevation 2,773.0.
[3] Elevations from Reclamation online information. www.usbr.gov/projects
[4] Reservoir length and drainage area information from 1982 study.
[5] Total drainage area above reservoir with only 3,940 $mi^2$ contributing directly. Net area removes drainage area of Bonny Reservoir. Recent operational changes at Bonny Reservoir drained the reservoir. If continued the net contributing area will need to be adjusted.
[6] Bureau of Reclamation Project Data Book, 1981 and www.usbr.gov.
[7] 2010-11 capacities computed by Reclamation's ACAP program. Assume no surface area change from elevation 2750 and above since 1982.
[8] Maximum and minimum elevations by water year. BOR computed inflows, differ from 1982 study publication.
[9] Values computed at joint use elevation 2,752.0.
[10] Original and 1982 capacity values recomputed using ACAP program for sediment computation purposes.

48. AGENCY MAKING SURVEY Bureau of Reclamation
49. AGENCY SUPPLYING DATA Bureau of Reclamation DATE July 2012

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

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Original | Original | 1982 | 1982 | Sediment | Percent | 2011 | 2011 | Sediment | Percent | Percent |
| Elevation | Area | Capacity | Area | Capacity | Volume | Computed | Area | Capacity | Volume | Computed | Reservoir |
| Feet | Acres | Ac-Ft | Acres | Ac-Ft | Ac-Ft | Sediment | Acres | Ac-Ft | Ac-Ft | Sediment | Depth |
| 2,785.0 | 10,040 | 361,812 | 10,035 | 354,028 | | | 10,035 | 352,018 | | | 100.0 |
| 2,780.0 | 9,095 | 313,975 | 9,097 | 306,199 | | | 9,097 | 304,188 | | | 94.7 |
| 2,775.0 | 8,315 | 270,450 | 8,314 | 262,671 | | | 8,314 | 260,661 | | | 89.3 |
| 2,773.0 | 7,973 | 254,162 | 7,985 | 246,372 | | | 7,985 | 244,362 | | | 87.2 |
| 2,770.0 | 7,460 | 231,013 | 7,491 | 223,159 | | | 7,491 | 221,148 | | | 84.0 |
| 2,765.0 | 6,670 | 195,688 | 6,675 | 187,744 | | | 6,675 | 185,733 | | | 78.7 |
| 2,760.0 | 5,965 | 164,100 | 5,983 | 156,099 | | | 5,983 | 154,088 | | | 73.3 |
| 2,755.0 | 5,340 | 135,838 | 5,382 | 127,686 | | | 5,382 | 125,676 | | | 68.0 |
| 2,752.0 | 4,975 | 120,366 | 4,952 | 112,185 | 8,181 | 100.0 | 4,952 | 110,175 | 10,191 | 100.0 | 64.8 |
| 2,750.0 | 4,731 | 110,660 | 4,665 | 102,569 | 8,091 | 98.9 | 4,665 | 100,558 | 10,102 | 99.1 | 62.6 |
| 2,745.0 | 4,280 | 88,133 | 4,104 | 80,646 | 7,487 | 91.5 | 3,950 | 79,020 | 9,113 | 89.4 | 57.3 |
| 2,740.0 | 3,800 | 67,933 | 3,519 | 61,589 | 6,344 | 77.5 | 3,491 | 60,264 | 7,669 | 75.3 | 52.0 |
| 2,735.0 | 3,180 | 50,483 | 3,033 | 45,209 | 5,274 | 64.5 | 2,999 | 44,063 | 6,420 | 63.0 | 46.6 |
| 2,730.0 | 2,514 | 36,248 | 2,376 | 31,686 | 4,562 | 55.8 | 2,511 | 30,242 | 6,006 | 58.9 | 41.3 |
| 2,725.0 | 2,064 | 24,803 | 1,958 | 20,851 | 3,952 | 48.3 | 2,012 | 18,958 | 5,845 | 57.4 | 36.0 |
| 2,720.0 | 1,572 | 15,713 | 1,411 | 12,429 | 3,284 | 40.1 | 1,455 | 10,329 | 5,384 | 52.8 | 30.6 |
| 2,715.0 | 1,126 | 8,968 | 1,113 | 6,119 | 2,849 | 34.8 | 937 | 4,379 | 4,589 | 45.0 | 25.3 |
| 2,710.0 | 739 | 4,305 | 488 | 2,116 | 2,189 | 26.8 | 396 | 1,027 | 3,278 | 32.2 | 20.0 |
| 2,705.0 | 357 | 1,565 | 224 | 336 | 1,229 | 15.0 | 58 | 44 | 1,521 | 14.9 | 14.6 |
| 2,701.9 | 211 | 685 | 0 | 0 | 685 | 8.4 | 0 | 0 | 685 | 6.7 | 11.3 |
| 2,700.0 | 121 | 370 | 0 | 0 | 370 | 4.5 | 0 | 0 | 370 | 3.6 | 9.3 |
| 2,695.0 | 15 | 30 | 0 | 0 | 30 | 0.4 | 0 | 0 | 30 | 0.3 | 3.9 |
| 2,691.3 | 0 | 0 | 0 | 0 | 0 | 0.0 | 0 | 0 | 0 | 0.0 | 0.0 |

1 Reservoir water surface elevation tied to project datum that is report as NGVD29 and 1.1 feet less than NAVD88.
2 Original, 1953 reservoir surface area.
3 Original, 1953 reservoir capacity, recomputed using ACAP.
4 1982 reservoir surface area.
5 1982 reservoir capacity, recomputed using ACAP.
6 1982 computed sediment volume, column (3) - column (5).
7 1982 measured sediment in percentage of total sediment of 8,181 acre-feet.
8 2011 reservoir surface area.
9 2011 reservoir capacity, computed by ACAP.
10 2011 computed sediment volume, column (3) - column (9).
11 2011 measured sediment in percentage of total sediment of 10,191 acre-feet.
12 Depth of reservoir expressed in percentage of total depth, 93.7 feet, from maximum water surface 2,785.0.

**Table 2 - Swanson Lake 2011 survey summary.**

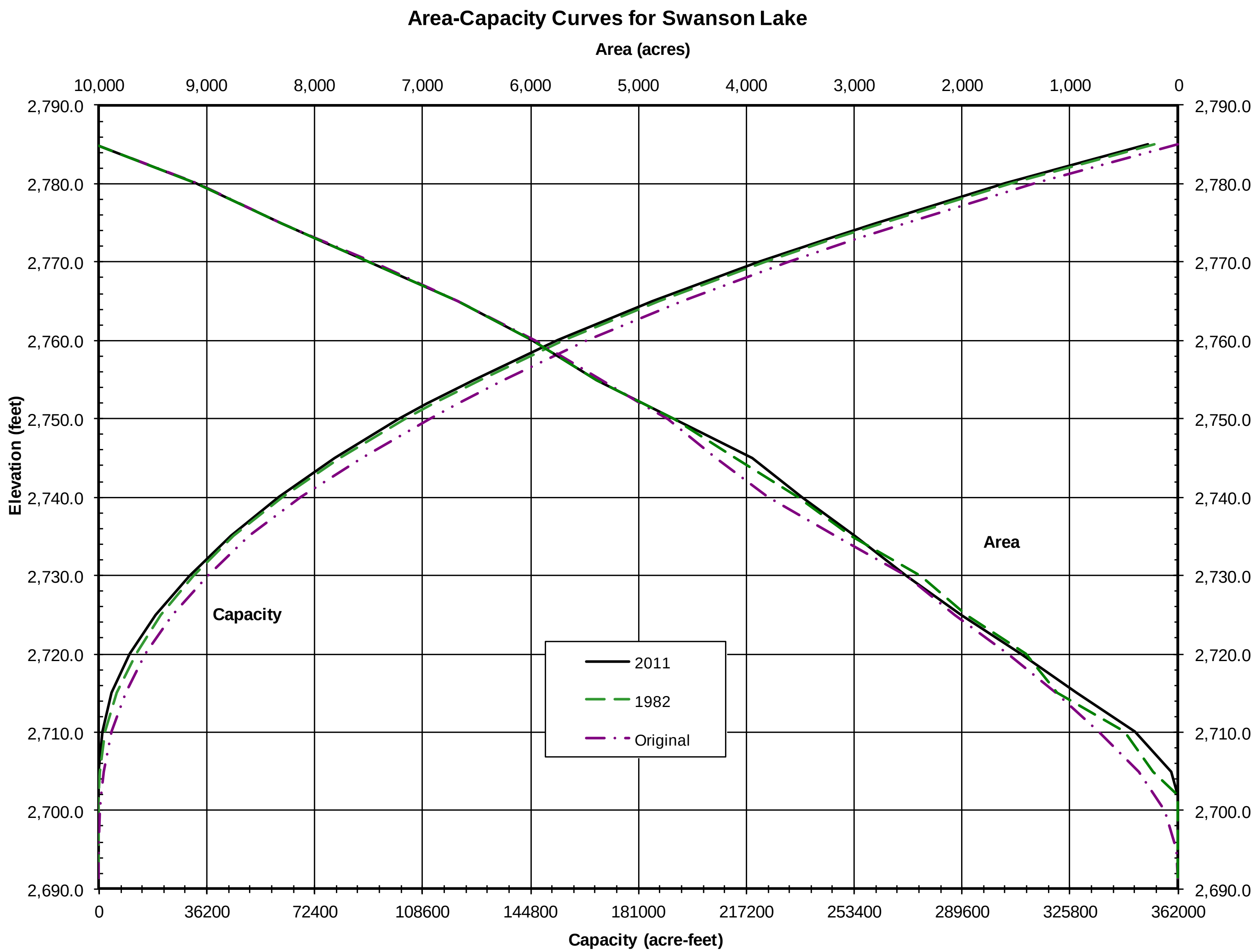


**Figure 9 - Swanson Lake area and capacity plots.**

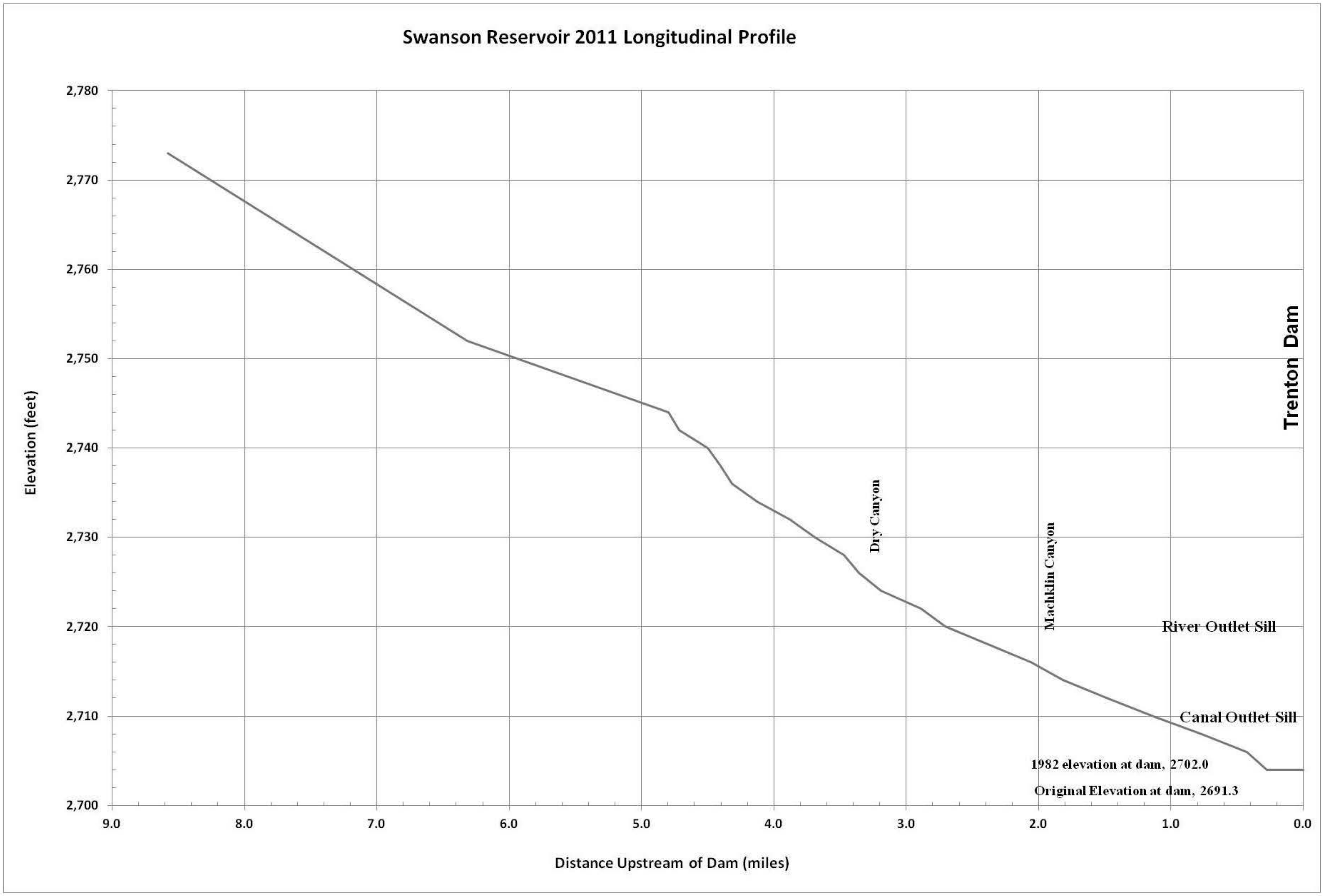


**Figure 10 - Longitudinal profile of the Republican River from the dam upstream.**

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# 2011 Swanson Lake Analyses

Results of the 2011 Swanson Lake area and capacity computations are listed in Table 1 and columns 8 and 9 of Table 2. Columns 2 and 3 in Table 2 list the original area and capacity values recomputed using the ACAP program. The tables also list the area and capacity results for the 1982 survey. Figure 10 is a plot of the Swanson Lake surface area and capacity values for the surveys and illustrates the differences in surface area and storage between them.

Table 1 shows the conservation use capacity at elevation 2,752.0 for all surveys along with the computed differences due to sediment deposition and methods of collections for all survey years. The 2011 survey measured an increase in surface areas since the 1982 survey from elevation 2,720.0 through 2,730.0. It is possible that the increase is due to the lower reservoir operation levels between 2002 and 2008 eroding previously measured deposited sediments. However, the increase is more likely due to the accuracy differences in the two survey methods. The 1982 study was a range line survey and the analysis required projecting changes from the original contours, not remapping the topography as was done for the 2011 survey.

Table 2 compares results from the original, 1982, and 2011 surveys. As stated previously, due to lack of reliable above water data, the 2011 study assumed no change from the 1982 survey from elevation 2,750.0 and above. The table also shows that the 1982 analysis computed a slight increase in surface areas from the original surface areas from elevations 2,755.0 through 2,780.0 indicating some shoreline erosion. The 1982 study was a survey and analysis of 19 sediment range lines within the reservoir. The data wasn't available for this analysis, but the resulting 1982 survey of the range lines would have showed an overall increase in width at these elevations indicating the shore erosion. As seen on the surface area plots on Figure 9, the increase surface area was small when compared to the total surface area at these elevations.

A resurvey should be scheduled in the future if a significant change in the sediment basin runoff is noted. Due to the relatively minor measured change in reservoir capacity since dam closure, it appears the present operation of the reservoir is flushing the majority of the finer sediments downstream through the outlets.

# Summary and Conclusions

This Reclamation report presents the results of the May 2011 survey of Swanson Lake. The primary objectives of the survey were to gather data needed to:

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

A control survey was conducted using the online positioning user service OPUS and RTK GPS to confirm the horizontal and vertical control network near the reservoir for the hydrographic survey. OPUS is operated by the NGS and allows users to submit GPS data files that are processed with known point data to determine positions relative to national control network. The GPS base was set over a permanent cap located where it could provide good radio link throughout the hydrographic survey.

The study's horizontal control was in feet, Nebraska state plane coordinates, in NAD83. The vertical control, in US survey feet, was tied to the project's vertical datum that matches NGVD29 and is 1.1 feet lower than NAVD88. Unless noted, all elevations in this report are referenced to the project or NGVD29 vertical datum. The developed reservoir topography presented in this report is tied to NGVD29.

The May 2011 underwater survey was conducted near reservoir elevation 2,745 as measured by the Reclamation gage at the dam and confirmed by RTK GPS measurements. Between 2002 and 2008 the reservoir was operated at much lower reservoir content due to the low basin runoff. During this period vegetation establish along the shoreline and upper reach of the reservoir. Even though the May 2011 survey was conducted at a high reservoir content, there were portions of the reservoir where the boat could not gain access due to this vegetation. The bathymetric survey used sonic depth recording equipment interfaced with a RTK GPS for determining sounding locations within the reservoir. The system continuously recorded depth and horizontal coordinates as the survey boat navigated along grid lines covering Swanson Lake. The positioning system provided information to allow the boat operator to maintain a course along these grid lines.

The initial above-water topography for the 2011 field survey was determined by digitizing contour lines from the USGS quads of the reservoir area. This outline was used to assure coverage of the reservoir during the May survey. During analysis, the water surface edges of previous orthographic aerial images (USDA, 2010) were digitized for topographic development. The water surface elevation from these aerial photos ranged from elevation 2,730.1 to 2,745.6.

Airborne collected digital data was obtained as IFSAR bare-earth information for the reservoir area (Intermap, 2011). IFSAR technology enables mapping of large areas quickly and efficiently, resulting in detailed information at a much reduced cost compared to other technologies such as aerial photogrammetry and LiDAR. The reported accuracies for the IFSAR data are 2 meters or better horizontally and 1 meter or better vertically in unobstructed flat-ground areas. Other technologies would produce more accurate data than IFSAR, but this study did not have funding to acquire these other data sets. The IFSAR data produced detailed topography of the upper reservoir area elevations, but for this study was not used since vertical accuracies of 1 meter didn't match well with the 2011 data sets. Due to this discrepancy, the 2011 reservoir computations were limited to elevation 2,745 and below.

The 2011 Swanton Lake topographic map is a combination of the digitized water surface edge from the USDA photographs and USGS quad maps along with the 2011 underwater survey data, all tied to the vertical datum NGVD29. A computer program was used to generate the 2011 topography and resulting reservoir surface areas at predetermined contour intervals from the combined reservoir data from elevation 2,745.0 and below. Assuming no change, due to lack of reliable and more recent data, the 1982 measured surface areas from elevation 2,750.0 through elevation 2,785.0 were used to complete the 2011 area and capacity tables for the reservoir. The 2011 area and capacity tables were produced by a computer program (ACAP) that calculated area and capacity values at prescribed elevation increments using the measured contour surface areas and a curve-fitting technique.

Tables 1 and 2 contain summaries of the Swanson Lake and watershed characteristics for the 2011 survey. The 2011 survey determined the reservoir has a total storage capacity of 352,018 acre-feet with a surface area of 10,035 acres at maximum reservoir water surface elevation 2,785.0. At conservation water surface elevation 2,752.0 the total capacity was 110,175 acre-feet with a surface area of 4,952 acres. Since closure of Trenton Dam in May 1953, this survey measured a 10,191 acre-foot loss in reservoir capacity below elevation 2,752.0. The losses were computed by comparing the original recomputed capacities and the 2011 capacities for the reservoir. The measured loss was due to sediment deposition, extensive shoreline erosion, and data accuracy differences between methods of collection and analysis.

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**14. ABSTRACT**

Reclamation surveyed Swanson Lake in May 2011 to develop updated reservoir topography and compute the present storage-elevation relationship (area-capacity tables). The bathymetric survey was conducted near water surface elevation 2,744.5 (project datum in feet). The collection was conducted using a single beam sonic depth sounder interfaced with a real-time kinematic (RTK) global positioning system (GPS) that provided continuous and detailed sounding positions throughout the underwater portion of the reservoir covered by the survey vessel. The above-water topography was developed from combination of United States Geologic Survey (USGS) mapping contours and digitized water's edge data from aerial photographs collected by the United States Department of Agriculture (USDA).

As of May 2011, at active conservation pool elevation 2,752.0, the reservoir surface area was 4,952 acres with a capacity of 110,175 acre-feet. Since May 1953 dam closure, a total capacity change of 10,191 acre-feet below elevation 2,752.0 was measured, equal to an average annual loss of 175.7 acre-feet. The capacity change is due to sediment deposition, shoreline erosion, and methodology differences of the survey studies.

**15. SUBJECT TERMS**
reservoir area and capacity/ sedimentation/ reservoir surveys/ global positioning system/ sounders/ contour area/ RTK GPS/

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