RECLAMATION

Managing Water in the West

Technical Report No. SRH-2013-03

Calamus Reservoir - Virginia Smith Dam 2012 Bathymetric Survey

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

January 2013

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 conducted the bathymetry survey of the reservoir in June 2012. Ron Ferrari of the Sedimentation Group completed the data processing to generate the 2012 reservoir topography and area-capacity information presented in this report. Kent Collins of the Sedimentation Group performed the technical peer review of this document.

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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/.

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Calamus Reservoir - Virginia Smith Dam 2012 Bathymetric Survey

prepared by

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U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Water and Environmental Resources Division
Sedimentation and River Hydraulics Group
Denver, Colorado

January 2013

BUREAU OF RECLAMATION

Technical Service Center, Denver, Colorado
Sedimentation and River Hydraulics Group, 86-68240

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Calamus Reservoir – Virginia Smith Dam 2012 Bathymetric Survey

Virginia Smith Dam
Nebraska

2/6/13

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Introduction

Virginia Smith Dam and Calamus Reservoir are part of the North Loup Division of the Pick-Sloan Missouri Basin Program that provides storage capacity for division irrigation needs and benefits for flood control, recreation, preservation, sediment control, stream pollution abatement, and fish and wildlife. The dam and reservoir are located in Garfield and Loup Counties on the Calamus River about 6 miles northwest of Burwell in central Nebraska (Figure 1).

Reclamation's Nebraska-Kansas Area Office administers the facility and the Twin Loups Reclamation District operates and maintains the dam and reservoir facilities. The total drainage area above the dam is 1,060 square miles of which 147 square miles contributes directly to surface runoff. At elevation 2,244 the reservoir length is around 9.9 miles with an average width of 1.2 miles.

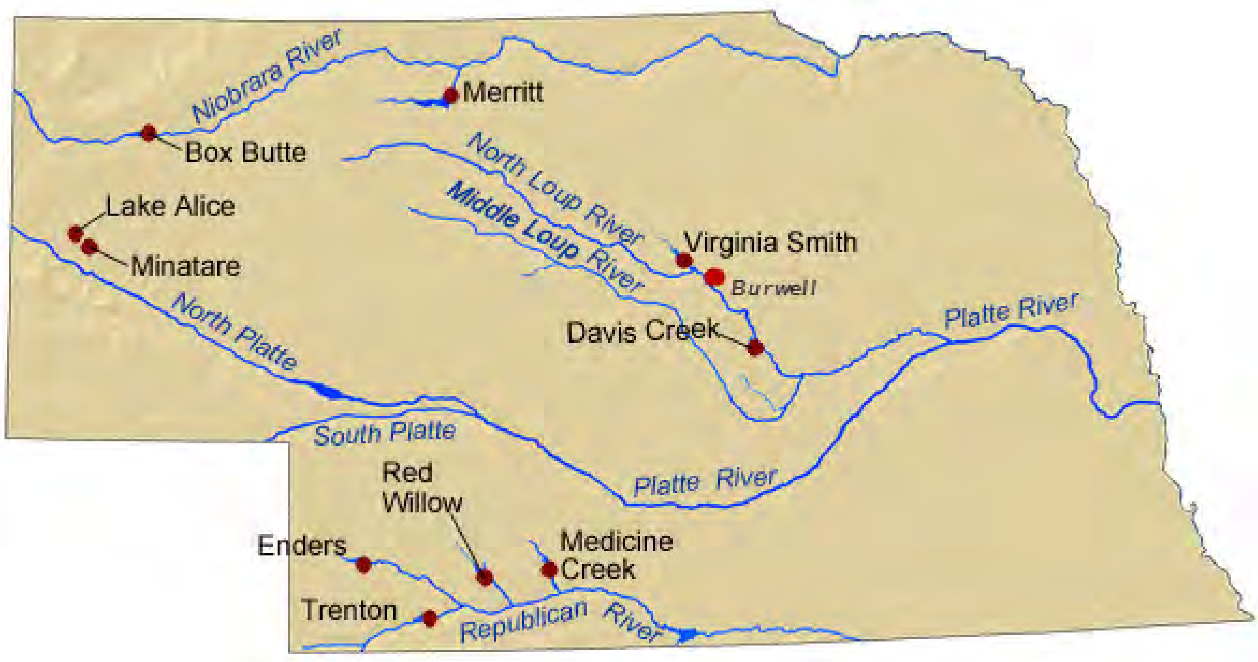

Figure 1 - Reclamation dams and reservoirs located in Nebraska.

The zoned earthfill dam was constructed between 1976 and 1985, with first storage in October 1985, and with following dimensions:

Structural height[1]	96 feet	Hydraulic height	74 feet
Crest length	7,295 feet	Crest elevation[2]	2,259 feet
Top width	30 feet		

Virginia Smith Dam's spillway, located in the left end of the embankment, consists of an uncontrolled morning-glory inlet structure that is 30-feet in diameter at crest elevation 2,244.5. The design discharge capacity is 3,080 cubic feet per second (cfs) at maximum water surface elevation 2,252.8.

The river and canal outlet works, located in the right abutment, are approximately 3,020 feet right of the spillway. The outlet works consist of a channel cut from the original river channel that divert flows to an intake structure with sill elevation 2,185.0. At reservoir elevation 2,252.8 the discharge capacity of the river outlet works is 2,460 cfs and canal outlet is 720 cfs. The combined outlet works and spillway discharge into a common channel downstream of the toe of the dam.

Control Survey Data Information

Prior to the 2012 bathymetric survey, a control network was established using the on-line positioning user service (OPUS) and RTK GPS to establish a temporary horizontal and vertical control point near the reservoir that was used for the hydrographic survey. OPUS, operated by the National Geodetic Survey (NGS), allows users to submit GPS data files that are processed with known point data to determine positions relative to the national control network. The OPUS generated coordinates were used to determine position and vertical difference between the North American Vertical Datum of 1988 (NAVD88) and the recorded water surface elevation at the dam.

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 as National Geodetic Vertical Datum of 1929 (NGVD29). Unless noted, all elevation computations and developed topographic maps, within this report, are referenced to Reclamation's project datum and

[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 near the National Geodetic Vertical Datum of 1929 (NGVD29) and 0.84 feet lower than NAVD88.

NGVD29 that is around 0.84 feet lower than NAVD88. RTK GPS water surface measurements taken during the bathymetric survey were around 1 foot higher than the water surface gage readings. However, surface waves due to wind and boating activities made it difficult to obtain accurate water surface readings during the 2012 survey.

Reservoir Operations

Calamus Reservoir's primarily purpose is irrigation storage, but it also provides benefits for flood control, recreation, fish and wildlife, and sediment control. The June 2012 total capacity was 119,469 acre-feet of conservation storage below elevation 2,244.0 and 169,530 acre-feet below maximum water surface elevation 2,252.8. The minimum bottom elevation measured during the 2012 survey was 2,181.5. The following values are from the June 2012 capacity table:

50,061	acre-feet of surcharge pool storage between elevation 2,244.0 and 2,252.8.
99,319	acre-feet of conservation use storage between elevation 2,213.3 and 2,244.0.
20,115	acre-feet of inactive use storage between elevation 2,185.0 and 2,213.3.
35	acre-feet of dead pool storage below elevation 2,185.0.

The Calamus Reservoir inflow and end-of-month stage records in Table 1 show the inflow and annual fluctuation for operation period October 1985 through September 2012. The average inflow into the reservoir during this period of record was 244,190 acre-feet. There were water years on record (1993 and 1996-97) missing several months of inflow computation values, resulting in a lower average. Table 1 also shows the water level and storage fluctuations of Calamus Reservoir: since filling in 1988 water levels have ranged from maximum elevation 2,246.0 in 2010 to minimum elevation 2,221.0 in September 2012, which occurred after this survey.

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 Group uses RTK GPS with the primary benefit being precise heights measured in real time to monitor water surface changes. The RTK GPS system employs two receivers that track the same satellites simultaneously, just like differential GPS. The basic outputs from the 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 Calamus Reservoir bathymetric survey was conducted June 20-22, 2012 between water surface elevation 2,241.4 and 2,241.8 (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 course along these predetermined lines. There were coves and deeper areas along the shoreline of the reservoir that were not covered by the survey vessel due to dense vegetation that grew during low reservoir levels and formed sand bars, blocking the clove entrance at time of survey. 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 tied to NGVD29 that is around 0.84 feet lower than NAVD88. Final processing of the June 2012 data resulted in 77,378 points, Figure 2.

The 2012 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 charts were analyzed during post-processing and when the charted depths indicated a difference from the computer recorded bottom depths, the computer data files were modified. Additional information on collection and analysis procedures is outlined in Chapter 9 of the *Erosion and Sedimentation Manual* (Ferrari and Collins, 2006).

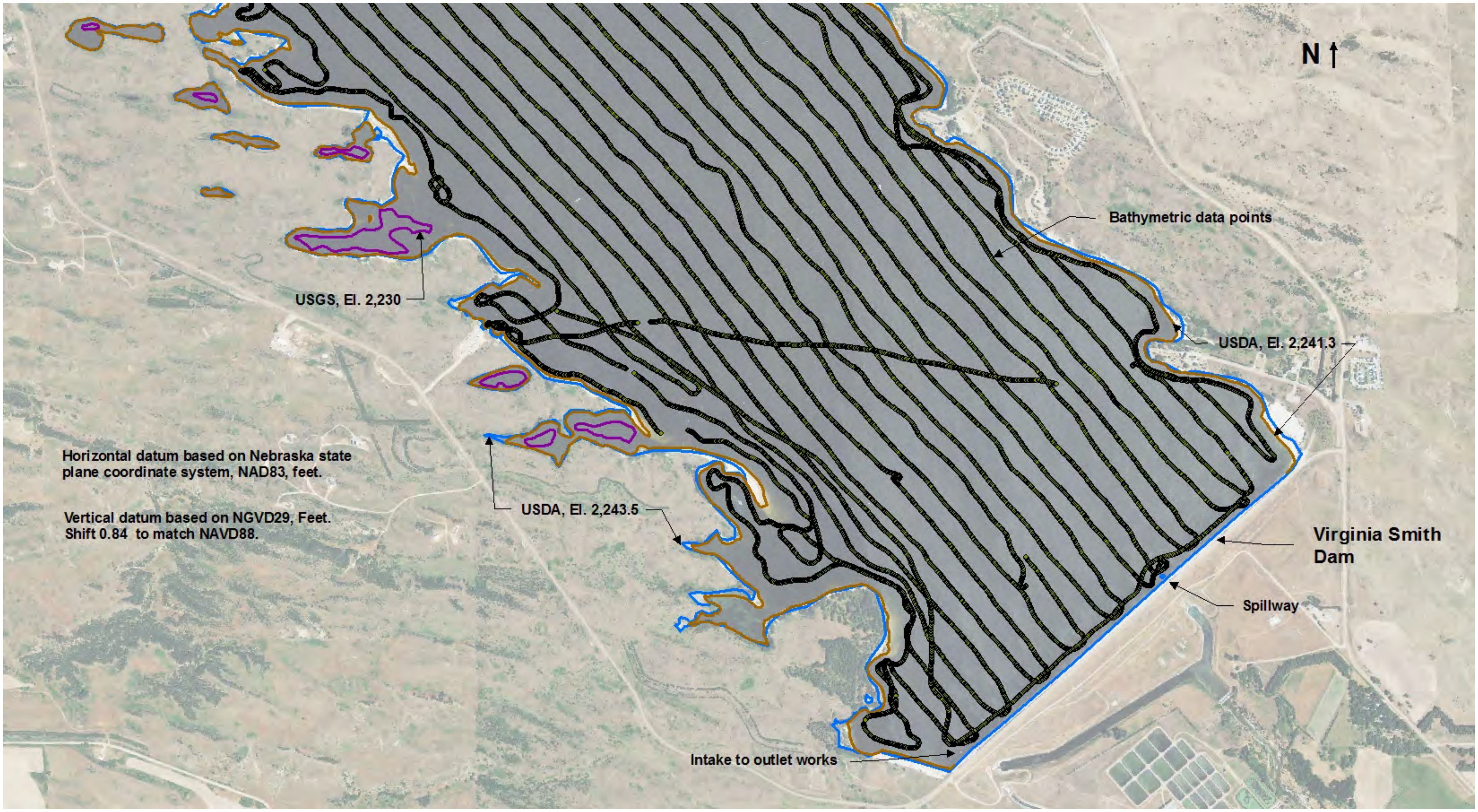

Figure 2 - Calamus Reservoir, bathymetric data from dam upstream (NGVD29).

Above Water Data

Aerial Photography

The 2012 study of Calamus Reservoir focused on the collection of bathymetric or underwater data in areas accessible by the survey vessel. Acquisition of the best available above water data was necessary to complete development of the topographic map. During analysis, orthographic aerial images collected in 2010 at water surface elevation 2,243.5 and in 2012 at water surface elevation 2,241.3 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 the water surface elevation from the day of each flight. The 2,243.5 contour from the 2012 photos was the highest elevation of all available years and the 2,241.3 contour was near the reservoir pool elevation when the 2012 bathymetric survey was conducted. Both digitized contours enclosed the 2012 bathymetric data and were used for the topographic development. As seen on the included figures, vegetation along portions of the shoreline made it difficult to easily distinguish the the water's edge for both aerial flights, but there were openings in the vegetation were typically sufficient to project these shoreline contours.

Aerial IFSAR

As part of this analysis, Interferometric Synthetic Aperture Radar (IFSAR) was obtained as digital bare earth data in Nebraska's state plane coordinates with elevations tied to NAVD88. IFSAR airborne technology enables mapping of large areas quickly and efficiently resulting in detailed information at much lower costs than other technologies such as aerial photogrammetry and LiDAR. The data was collected when the reservoir was near elevation 2,240 (NAVD88), providing areas of overlap to compare with the USDA data. There were no overlap areas with the 2012 bathymetric data. To match NGVD29 the IFSAR NAVD88 elevations were shifted downward 0.84 feet.

The IFSAR data provided detailed topographic images of the shoreline of the main reservoir body, coves, and around the dam. The IFSAR reported accuracies are 2-meters horizontally and 1-meter vertically for areas of unobstructed flat ground (Intermap, 2011). For the open areas of the reservoir, with minimal vegetation along the shoreline, the developed contours from the IFSAR data matched well with the USDA digitized contours. For these areas, the elevation differences were less than 1 foot, much less than IFSAR reported 1-meter vertical accuracy. The reported dam crest was elevation 2,559 and IFSAR point data on top of the dam were near this elevation. For areas of dense vegetation, the IFSAR developed contours were sometimes very erratic and did not match well with the USDA contours. Following careful examination of the two data sets, it was determined the USDA developed contours were the best representation of the present reservoir condition in these densely vegetated and open areas of the reservoir. During processing, the IFSAR data in the vegetated areas and areas near USDA contours were removed, while the remaining IFSAR data was used in the final 2012 topographic development.

Some previous studies conducted by the Sedimentation Group produced less favorable results using IFSAR data. In those studies, the IFSAR data was used for topographic development, but due to the vertical inaccuracy, the computed surface areas from the IFSAR developed contours were not included in the final reservoir volumes. Such studies included Heron Reservoir in New Mexico, Gibson Reservoir in Montana, Jamestown Reservoir in North Dakota, and Swanson Reservoir in Nebraska. These reservoirs were characterized by steep topography and/or thick vegetation leading to the general conclusion that the IFSAR vertical inaccuracy was too great for valid reservoir surface area and resulting volume computations. In some cases however, the IFSAR data matched well with other data sources such as USDA aerial photos, and was used for mapping and computational purposes. For the 2010 Fresno Reservoir study, the IFSAR data was found to match well and was used in the final computational analysis. Information on these studies can be found on the Sedimentation Group web site (Reclamation, 2013).

The Calamus Reservoir topography is similar to these reservoirs, but the milder bank slopes and more sparse vegetation led to the use of IFSAR data for contour development from around elevation 2,240 and above. For the Calamus Reservoir shoreline and cove areas with vegetation, the IFSAR data points were removed, leaving the USDA contours as the primary data source for these areas during the reservoir map development. Also removed were the IFSAR data around the USDA developed contours. In many cases the IFSAR developed contours alinged with the USDA contours, but to clarify which data sets were used in these areas, the overlying IFSAR data were removed. In most cases the remaining IFSAR data points were outside and higher than the USDA contours, but as Figures 3 through 7 show, there were shallow water areas within the main reservoir body where the IFSAR data were retained. A reliable, constant vertical shift could not be determined to better match the remaining IFSAR data with the USDA elevations, but the difference was not considered great enough to warrant exclusion of all IFSAR data.

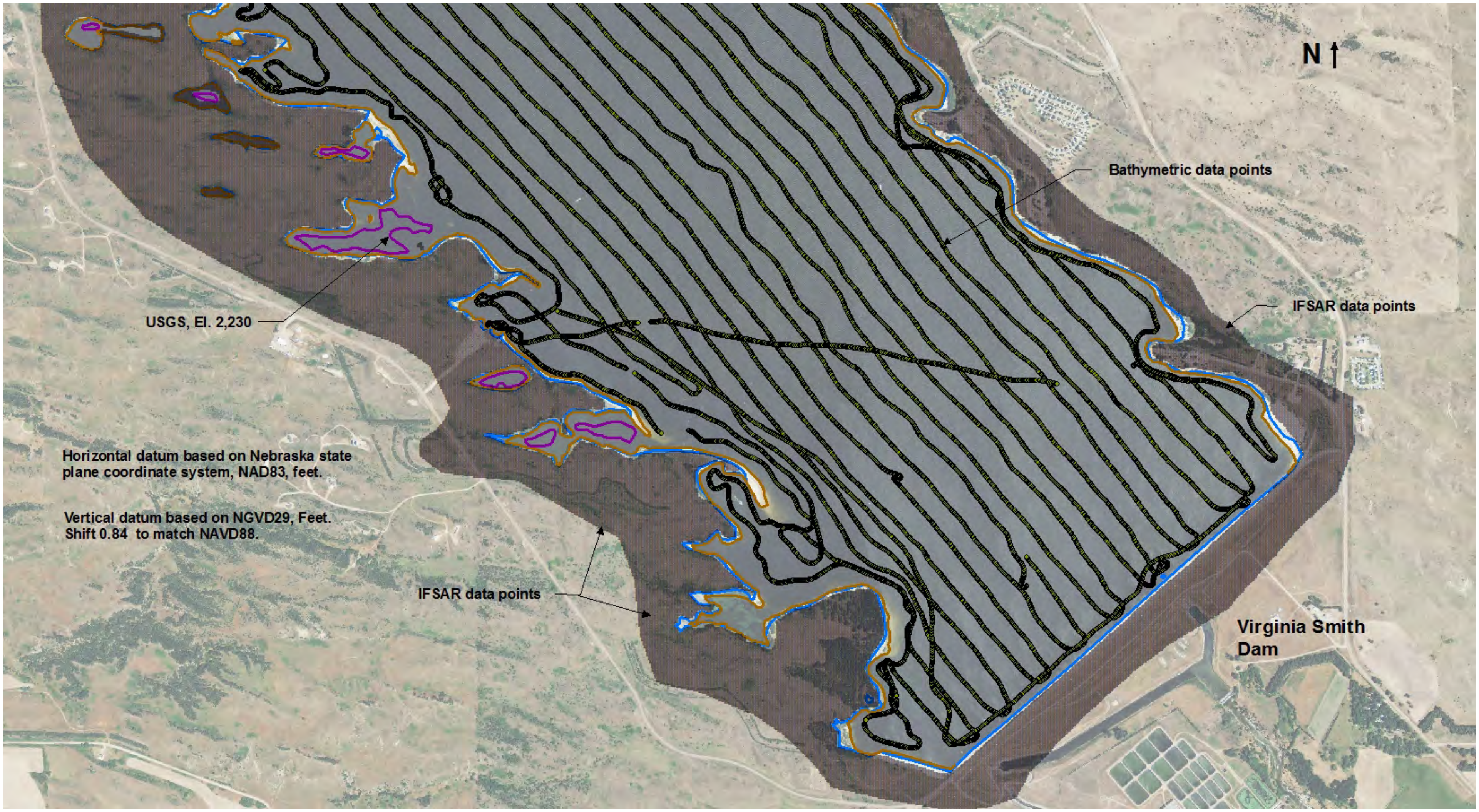

Figure 3 - Calamus Reservoir 2012 bathymetric, USDA aerial, IFSAR and USGS data sets (1 of 5).

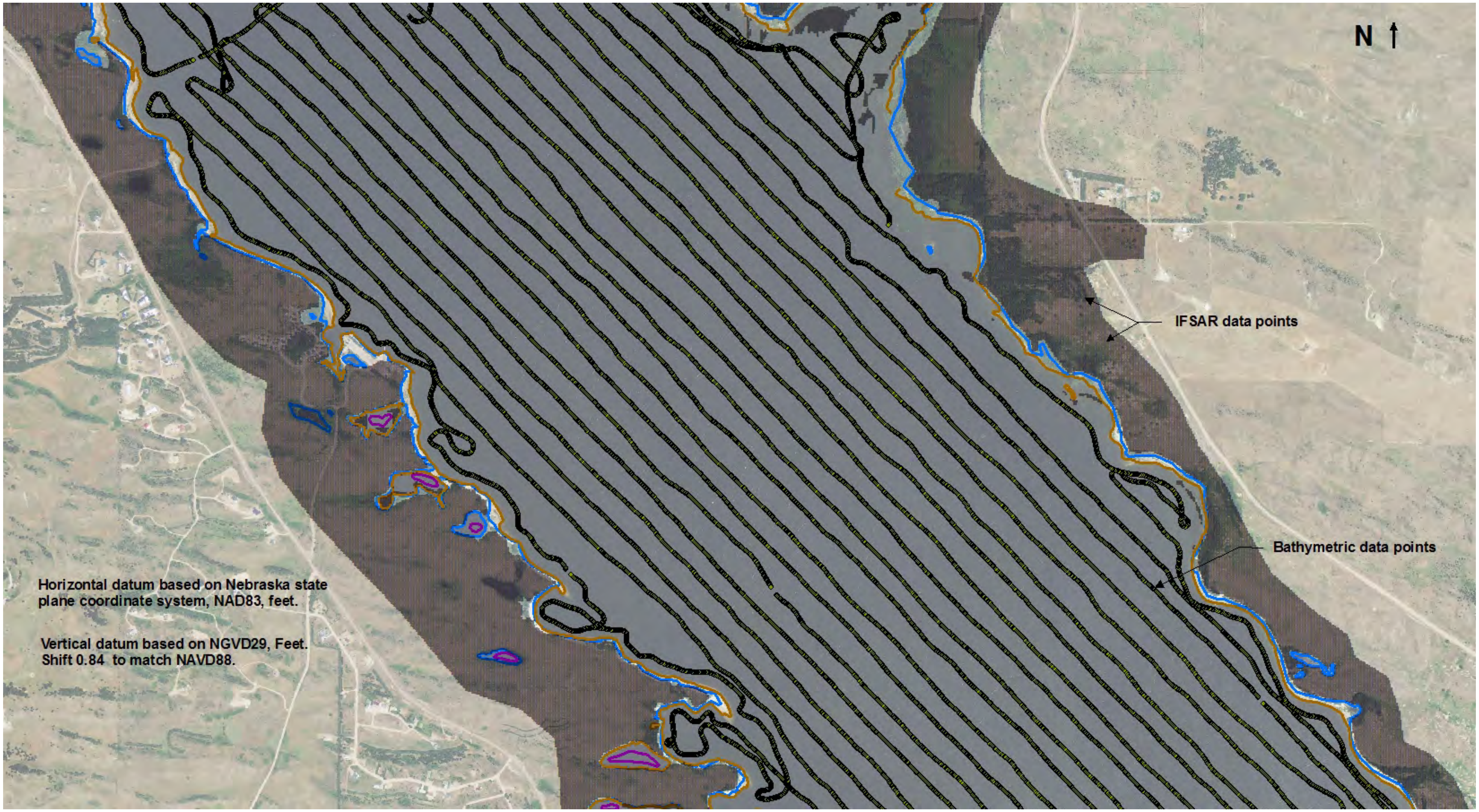

Figure 4 - Calamus Reservoir 2012 bathymetric, USDA aerial, IFSAR and USGS data sets (2 of 5).

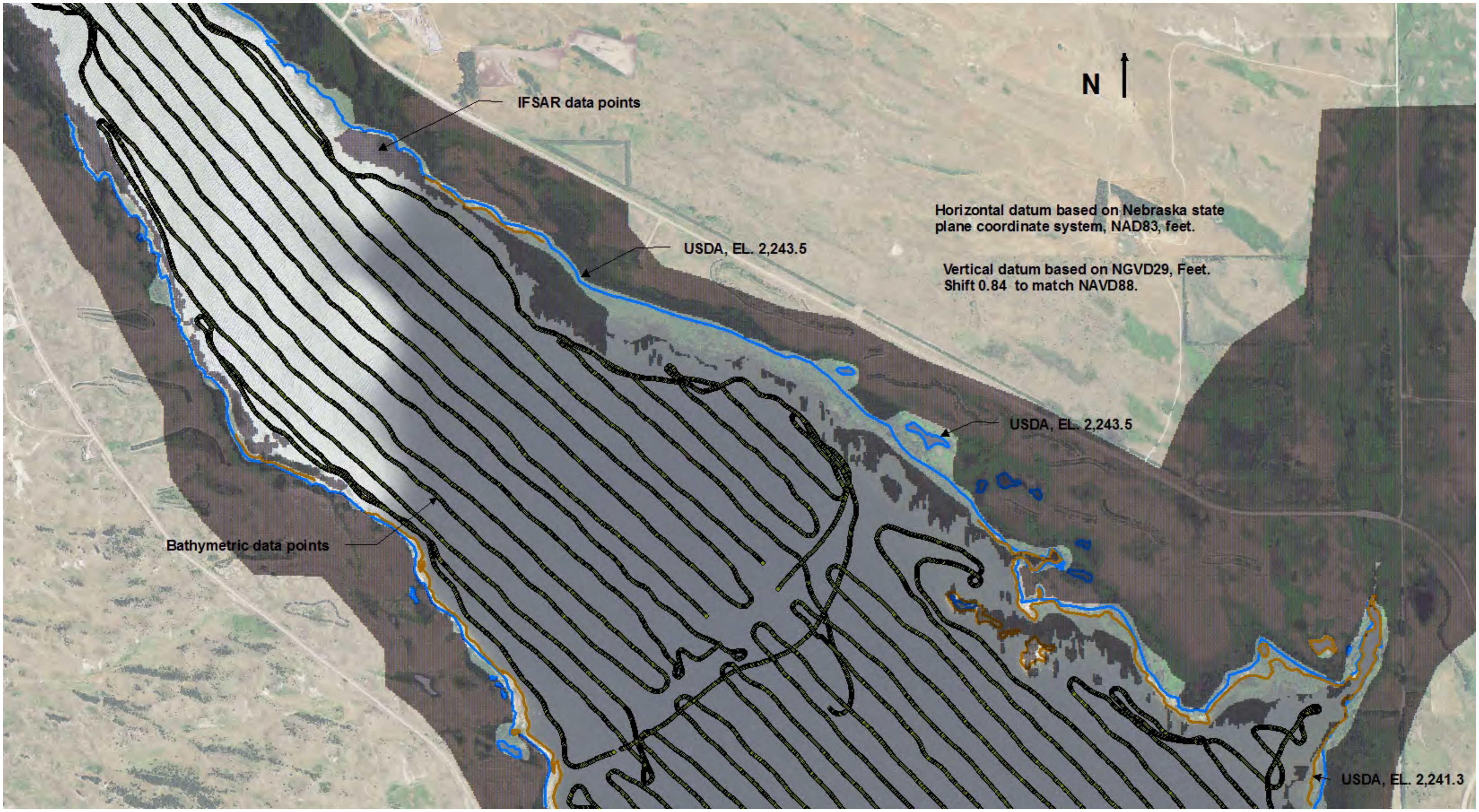

Figure 5 - Calamus Reservoir 2012 bathymetric, USDA aerial, IFSAR and USGS data sets (3 of 5).

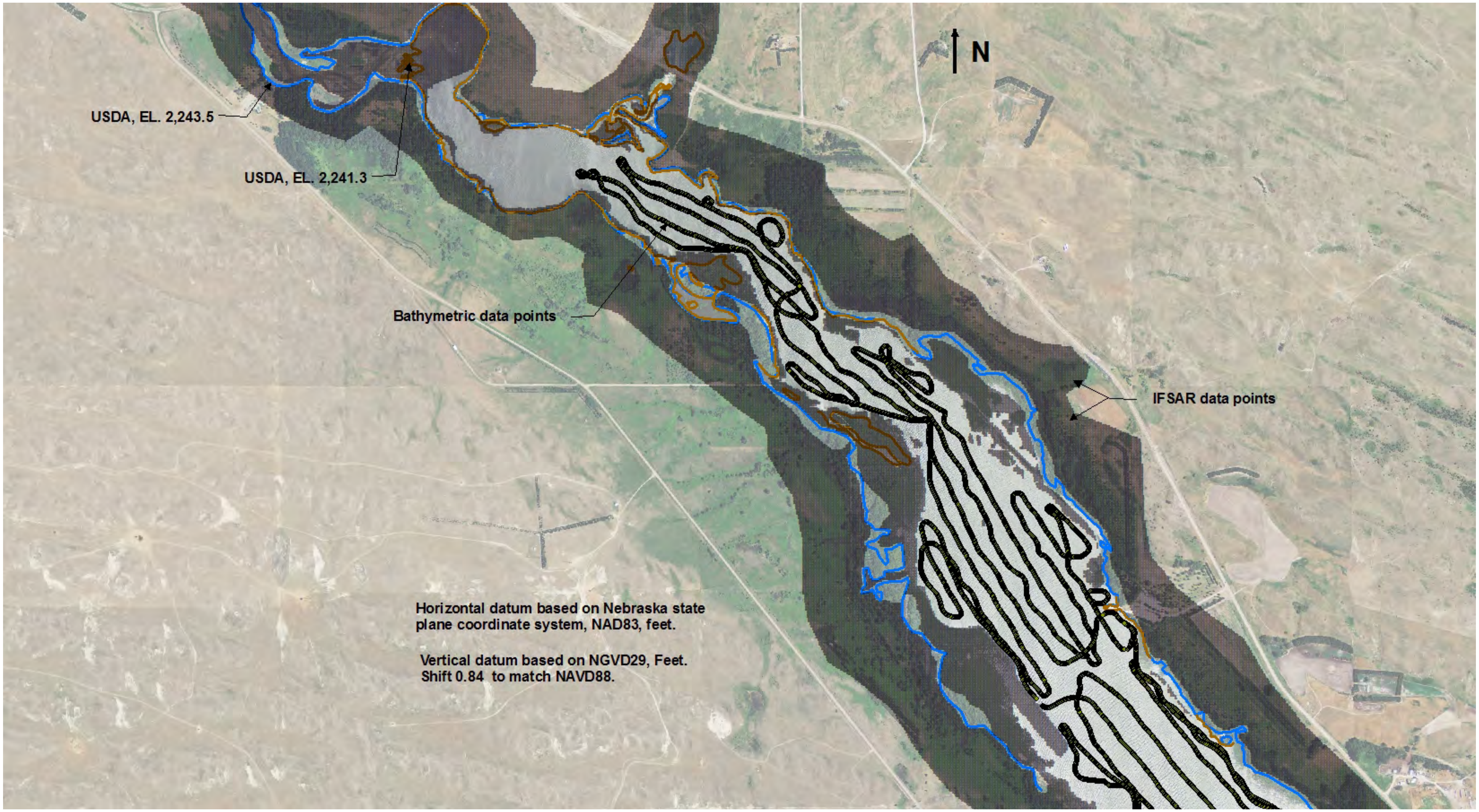

Figure 6 - Calamus Reservoir 2012 bathymetric, USDA aerial, IFSAR and USGS data sets (4 of 5).

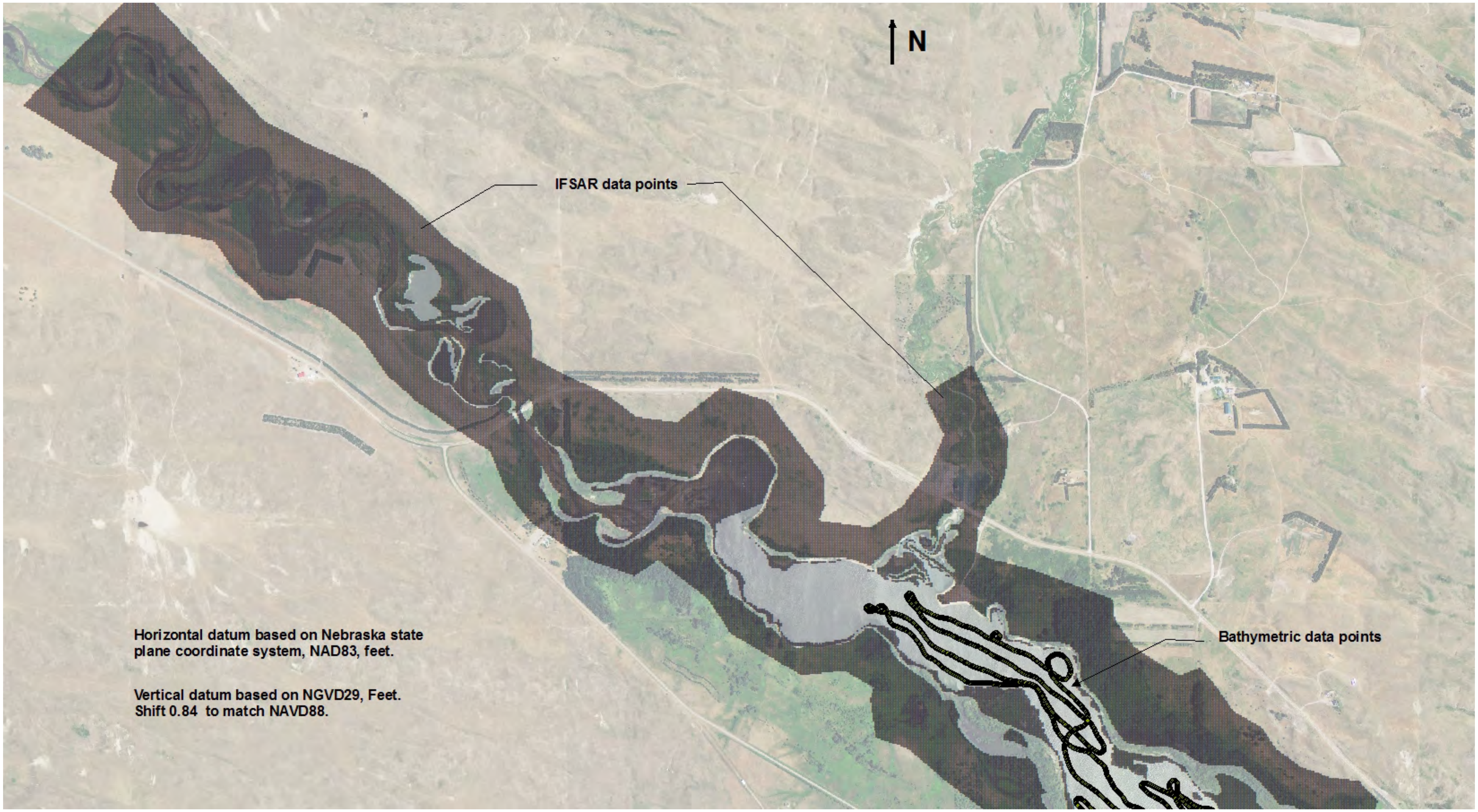

Figure 7 - Calamus Reservoir 2012 bathymetric, USDA aerial, IFSAR and USGS data sets (5 of 5).

Reservoir Area and Capacity

Topography Development

This section discusses the methods for generating topographic contours of Calamus Reservoir. The data sources included the 2012 bathymetric data points, digitized reservoir water surface edges from the USDA aerial photographs, IFSAR aerial data points, and small portions of digitized contours from the USGS quad maps not covered by other data sources. To form the intake side channel to the outlet works, break lines were projected from the 2012 bathymetric data points where they crossed the intake channel alignment. Design drawings showed a channel extending from the intake a short distance upstream of the dam. This study assumed the intake channel continued upstream to the original channel based on the 2012 bathymetric crossings. These breaklines forming the assumed intake channel had little effect on the surface area calculations. These data were processed into a triangulated irregular network (TIN) that was used to develop 2-foot contours tied vertically to NGVD29, Figure 8. The resulting surface areas and volumes presented in this report are from the developed TIN and tied to NGVD29. These elevations can be shifted upward 0.84 feet to match NAVD88. In preparation for developing the TIN, a polygon or hardclip was created to enclose all of the data sets. This polygon, not assigned an elevation, was used as a hard boundary for the 2012 developed contours, allowing mapping only within the hardclip polygon by preventing interpolation outside it. For surface area computation a second polygon was developed along the alignment of Virginia Smith Dam to enclose the data within the reservoir boundary.

Contours for the reservoir from Virginia Smith 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, preserving 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 Calamus Reservoir TIN. The surface areas of the enclosed contour polygons at 2- and 5-foot increments were computed for elevation 2,182.0 and above. The reservoir contour topography at

2-foot intervals is presented on Figures 9 through 13 from elevation 2,182.0 through elevation 2,260.0.

Using ArcGIS commands to compute areas at user-specified elevations, the 2012 surface areas for Calamus Reservoir were computed at 2- and 5-foot increments directly from the reservoir TIN from elevation 2,182.0 to elevation 2,250.0. The computed surface area at elevation 2,250.0 was within 1.5 percent of the original or 1985 computed surface area at the same elevation. As previously indicated, the data above the highest USDA developed contour, elevation 2,243.5, was from the IFSAR point data and small portions of the USGS contours. Also as previously described, the IFSAR data points in the dense vegetated areas were removed since the IFSAR contours in these areas were erratic when compared to the USDA contours.

Final contours were developed in these heavily vegetated areas by interpolating topography from the surrounding data sets. Due to the uncertainty associated with these projections, this study used elevation 2,244.0 as the upper most 2012 computed surface area entry for development of the 2012 area capacity tables. This elevation was chosen due to its proximity to the highest USDA elevation data and normal high water level for most years of operation (the reported maximum reservoir level was only 2 feet higher at elevation 2,246). The IFSAR data did provide reliable elevation data points for developing contours above elevation 2,244.0. Even though surface area computations where within 1.5 percent of original measurements at elevation 2,250.0, no change was assumed since the original computations from elevation 2,250.0 and above. The area and capacity computation program calculated the values between elevation 2,244.0 and 2,250.0.

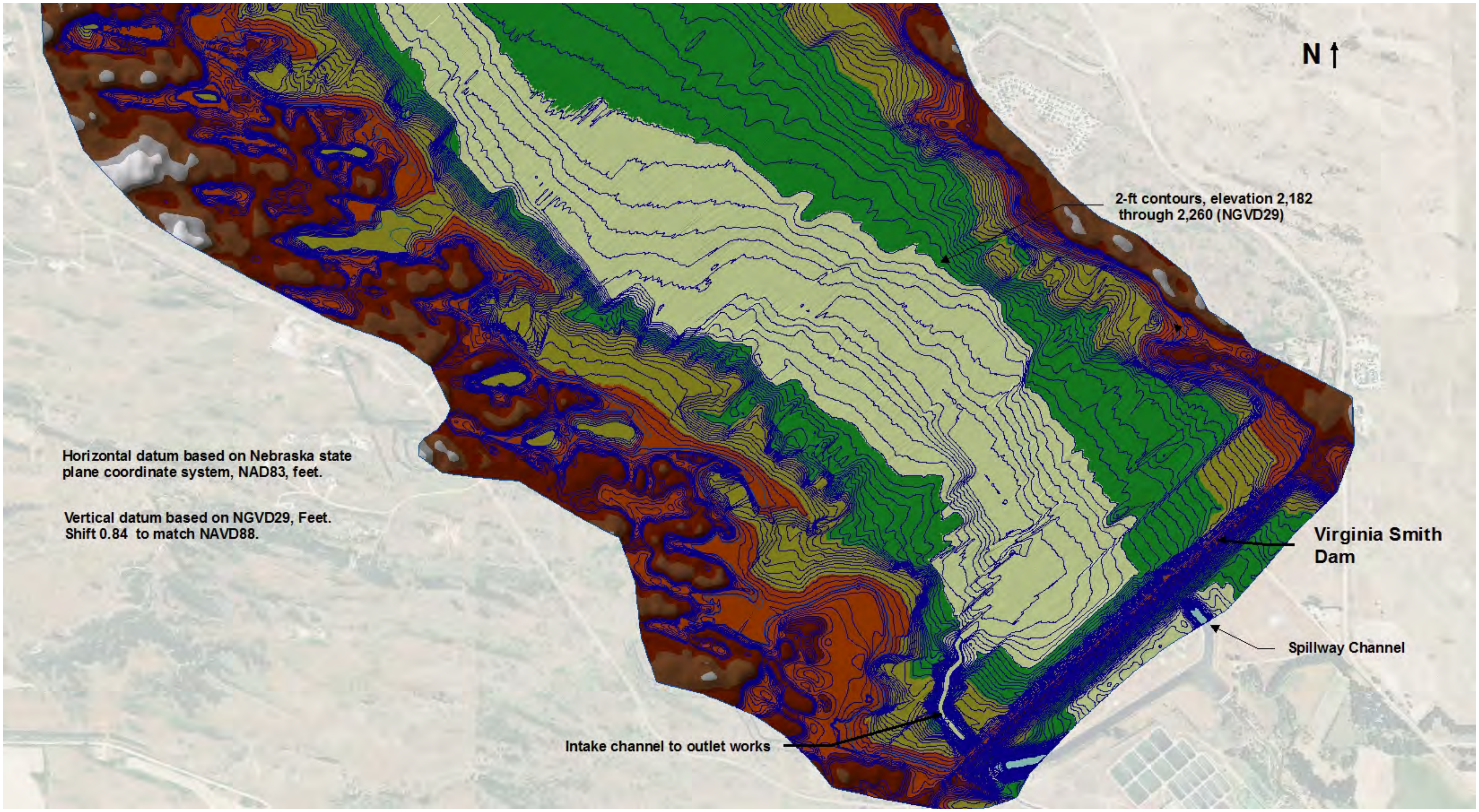

Figure 8 - Calamus Reservoir 2012 TIN.

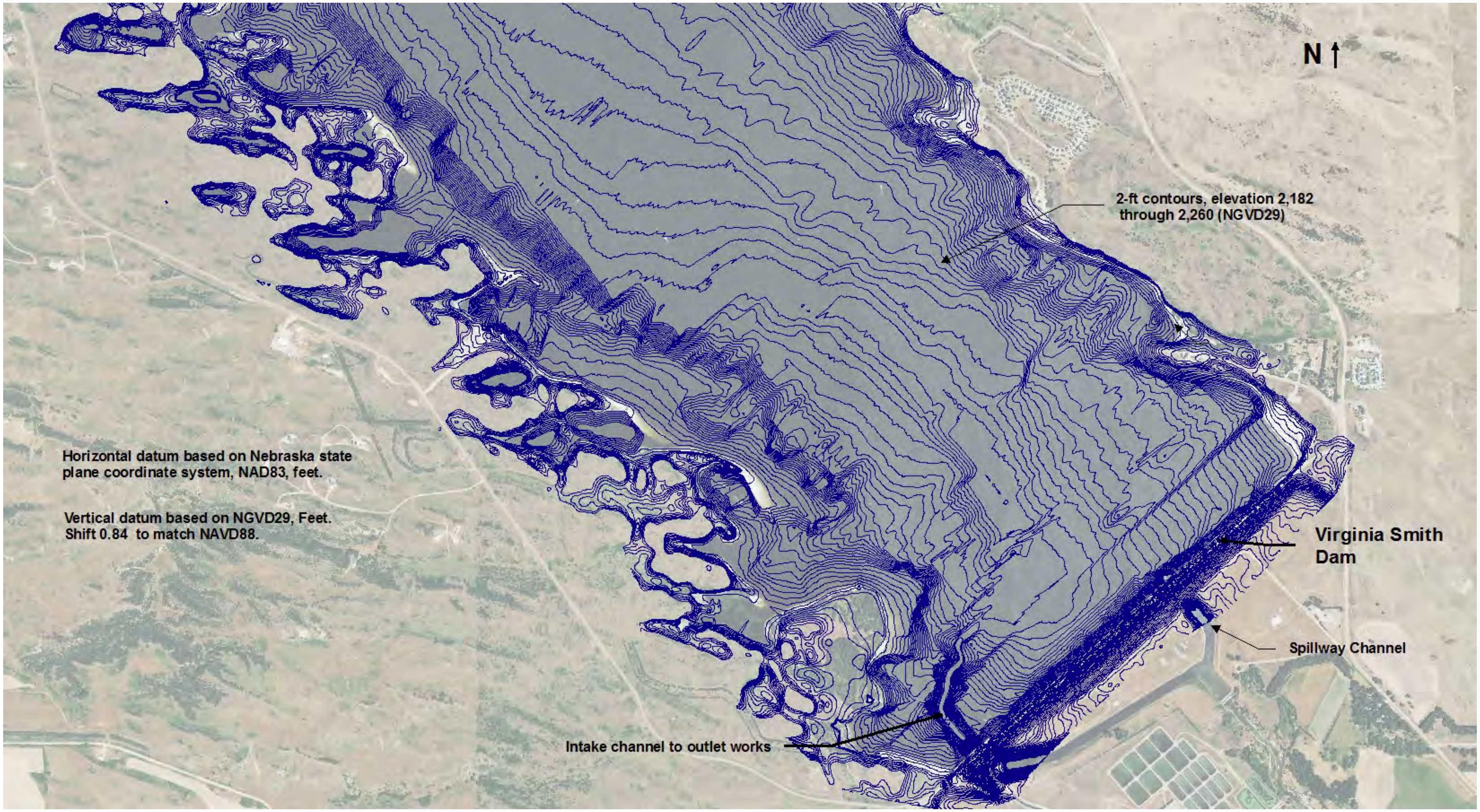

Figure 9 - Calamus Reservoir topography, NGVD29 (map 1 of 5).

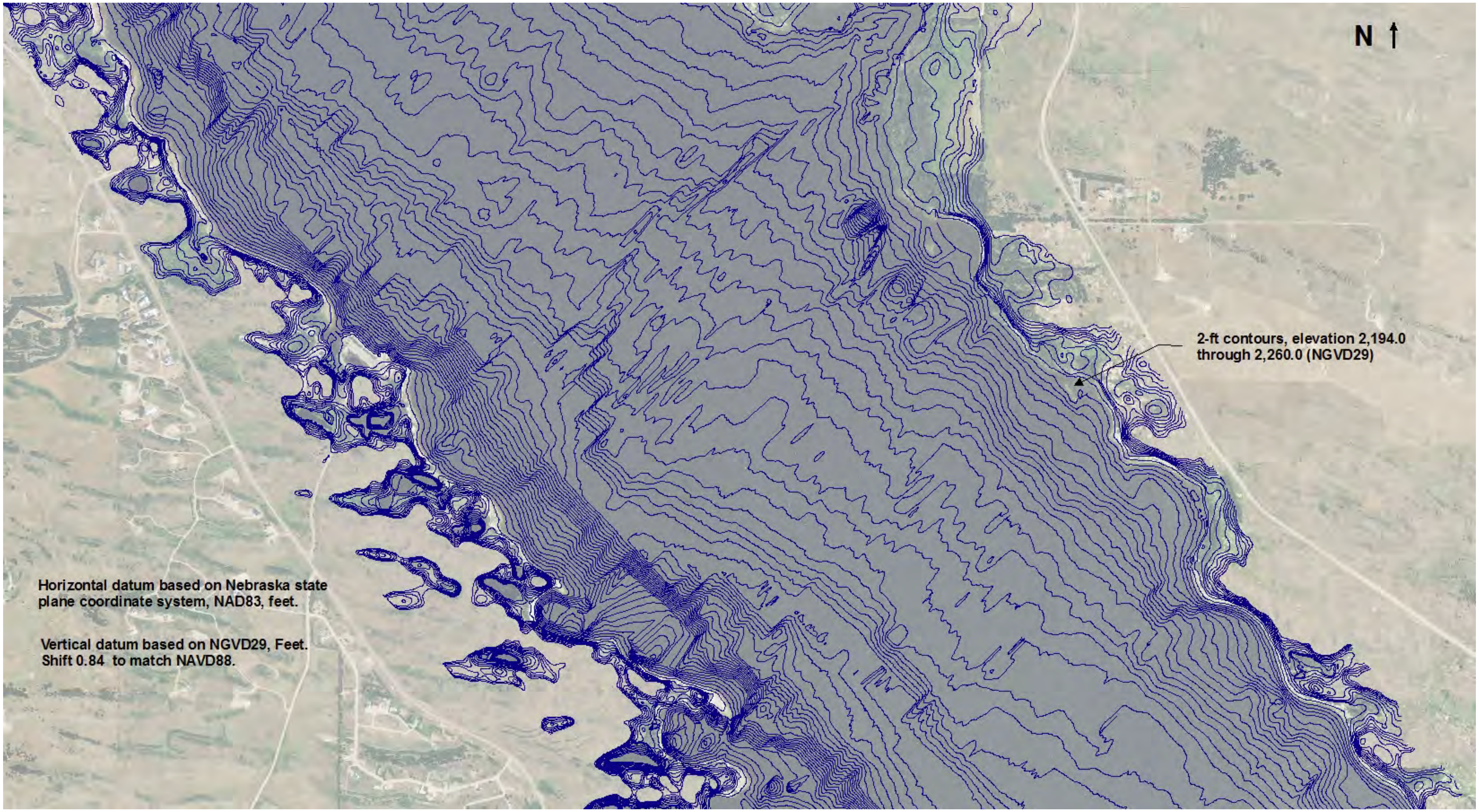

Figure 10 - Calamus Reservoir topography, NGVD29 (map 2 of 5).

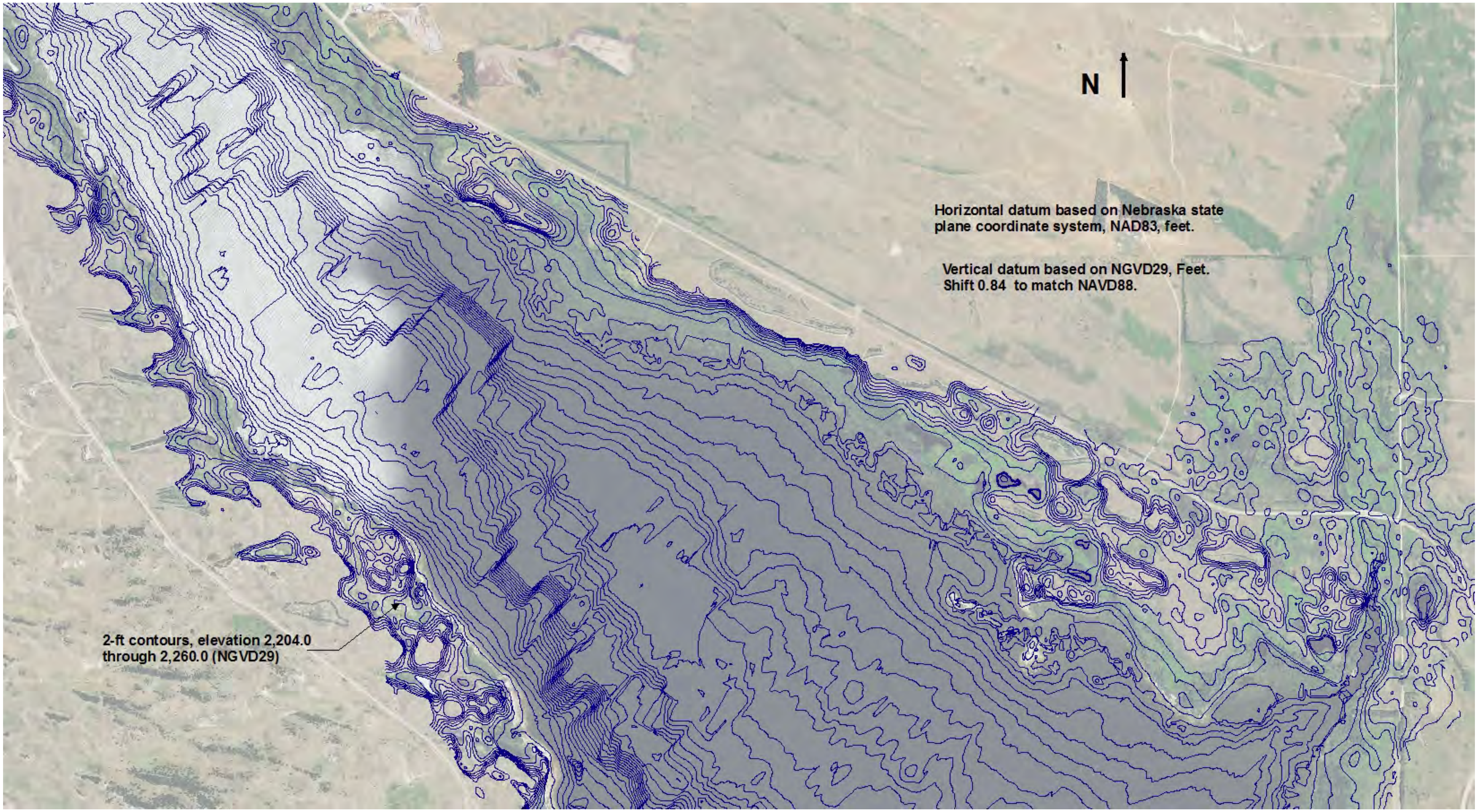

Figure 11 - Calamus Reservoir topography, NGVD29 (map 3 of 5).

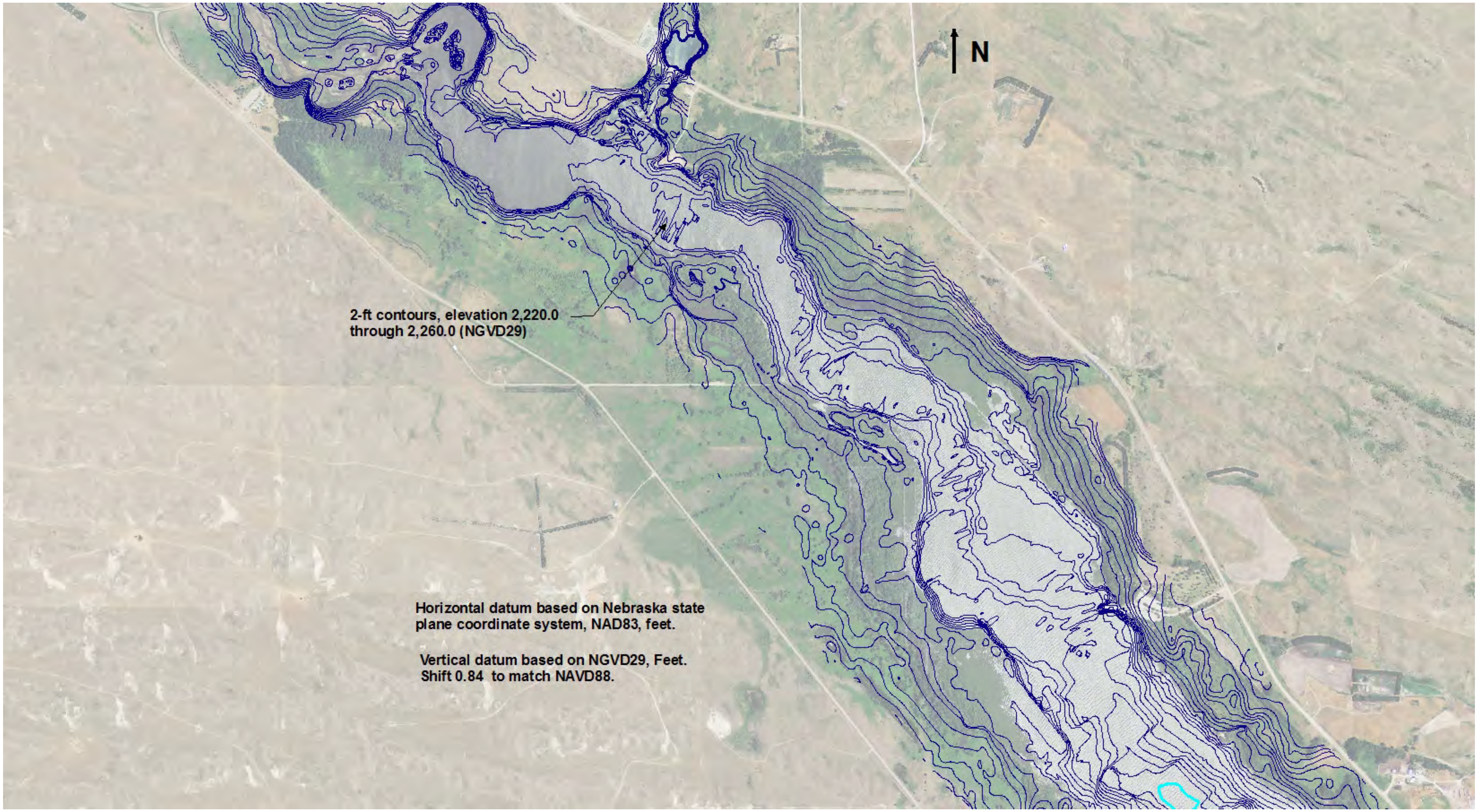

Figure 12 - Calamus Reservoir topography, NGVD29 (map 4 of 5).

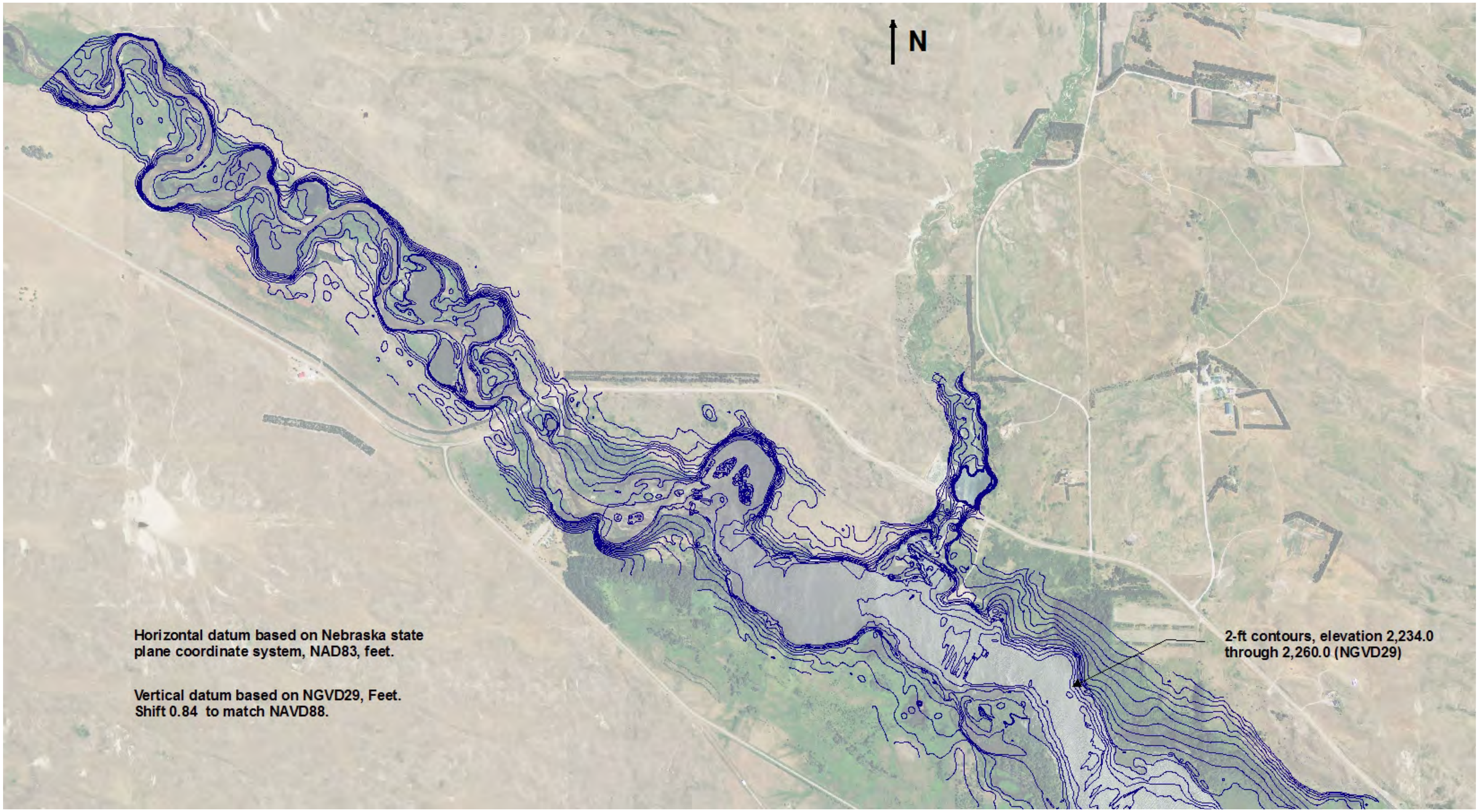

Figure 13 - Calamus Reservoir topography, NGVD29 (map 5 of 5).

2012 Calamus Reservoir 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. For this study the 2- and 5-foot computed surface areas from elevation 2,182.0 through 2,244.0 were used. The zero surface area was at elevation 2,181.0. The 2012 Calamus Reservoir area and capacity tables assumed no change from the original surface areas from elevation 2,250.0 and above. The program begins by testing the initial capacity equation over successive intervals to ensure that the equation fits within an allowable error limit that was set at 0.000001 for Calamus 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 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 Calamus Reservoir area and capacity computations are listed in a separate set of 2012 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 those tables. As of June 2012, at conservation use elevation 2,244.0, the surface area was 5,073 acres with a total capacity of 119,469 acre-feet. At maximum and top of surcharge elevation 2,252.8, the surface area was 6,348 acres with a total capacity of 169,530 acre-feet.

Calamus Reservoir Surface Area and Capacity Results

This section provides 2012 surface area and capacity results along with volume changes over time for Calamus Reservoir. Table 1 provides a summary of the changes in Calamus Reservoir storage, inflow, and topography between the time of dam closure in October 1985 and the June 2012 topographic survey. The area and capacity curves for the original and 2012 surveys are plotted on Figure 14. Table 2 provides a summary of the original and 2012 surface areas and capacities. The 2012 bathymetric survey and the other data sources summarized in the *Topographic Development* section provided adequate information for computing the surface areas from elevation 2,181.0 through 2,244.0. For 2012 computation purposes, no change was assumed at elevations 2,250.0 and 2,255.0 and the surface area results from the original survey were used to complete the area and capacity tables. The ACAP program was used to interpolate and compute the area and capacity values between elevations 2,255.0 and 2,181.0 from the surface area inputs.

RESERVOIR SEDIMENT
DATA SUMMARY

Calamus Reservoir
NAME OF RESERVOIR

1
DATA SHEET NO.

D	1. OWNER: Bureau of Reclamation	2. STREAM: Calamus River	3. STATE: Nebraska
A	4. SEC 31 TWP. 22 N RANGE 16 W	5. NEAREST P.O. Burwell	6. COUNTY Garfield
M	7. LAT 41 ° 49 ' 38 " LONG 99 ° 13 ' 11 "	8. TOP OF DAM ELEVATION: 2,259.0 [1]	9. SPILLWAY CREST EL. 2,244.5 [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	2,252.8 [3]	6,348	50,223	177,623	
E	b. FLOOD CONTROL					10/1985
S	c. POWER					
E	d. JOINT USE					16. DATE NORMAL OPERATIONS BEGAN
R	e. CONSERVATION	2,244.0	5,123	102,754	127,400	
V	f. INACTIVE	2,213.3	1,804	23,829	24,646	
O	g. DEAD	2,185.0	159	817	817	10/1985
I R	17. LENGTH OF RESERVOIR 9.9 MILES			AVG. WIDTH OF RESERVOIR 1.2 MILES		

B	18. TOTAL DRAINAGE AREA 1,060 [4] SQUARE MILES	22. MEAN ANNUAL PRECIPITATION 24 [3] INCHES
A	19. NET SEDIMENT CONTRIBUTING AREA 147 [4] SQUARE MILES	23. MEAN ANNUAL RUNOFF 4.4 [5] INCHES
S	20. LENGTH MILES AVG. WIDTH MILES	24. MEAN ANNUAL RUNOFF 244,187 [6] ACRE-FEET
I N	21.	25. ANNUAL TEMP, MEAN 50 °F RANGE -39 °F to 114 °F [3]

	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
SURVEY	10/85			Contour (D)	5-ft	5,123	127,400 [7]	0.52
	6/12	26.7	26.7	Contour (D)	2-ft	5,073 [8]	119,469 [8]	0.49

	26. DATE OF SURVEY	34. PERIOD ANNUAL PRECIPITATION	35. PERIOD WATER INFLOW, ACRE-FEET a. MEAN ANN.	35. b. MAX. ANN.	35. c. TOTAL	36. WATER INFLOW TO DATE, AF a. MEAN ANN.	36. b. TOTAL
DATA	6/12	13.0 [3]	244,190	339,900	6,031,490	244,190	6,031,490

26. DATE OF SURVEY	37. PERIOD CAPACITY LOSS, ACRE-FEET a. TOTAL	37. b. AVG. ANN.	37. c. /MI.^{2}-YR.	38. TOTAL SEDIMENT DEPOSITS TO DATE, AF a. TOTAL	38. b. AVG. ANN.	38. c. /MI.^{2}-YR.
6/12	7,931 [9]	297.0	2.0	7,931	297.0	2.0

26. DATE OF SURVEY	39. AVG. DRY WT. (#/FT^3)	40. SED. DEP. TONS/MI.^{2}-YR a. PERIOD	40. b. TOTAL TO DATE	41. STORAGE LOSS, PCT. a. AVG. ANNUAL	41. b. TOTAL TO DATE	42. SEDIMENT INFLOW, PPM a. PER.	42. b. TOT.
6/12				0.233 [9]	6.23 [9]		

26. DATE OF SURVEY	43. DEPTH DESIGNATION RANGE IN FEET, BY ELEVATION									
		2,170.0 - 2,185.0	2,185.0 - 2,200.0	2,200.0 - 2,213.3	2,113.3 - 2,220.0	2,220.0 - 2,230.0	2,230.0 - 2,244.0	2,244.0 - 2,252.8			
	PERCENT OF TOTAL SEDIMENT LOCATED WITHIN DEPTH DESIGNATION										
		9.7	28.0	17.9	7.7	14.4	20.3	2.0			

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 [10, 11]							
YEAR	MAX. ELEV.	MIN. ELEV.	INFLOW, AF	YEAR	MAX. ELEV.	MIN. ELEV.	INFLOW, AF
1986	2,225.4	2,190.0	213,540	1987	2,236.6	2,227.2	263,200
1988	2,244.7	2,238.0	245,030	1989	2,244.3	2,236.6	231,380
1990	2,243.6	2,237.0	219,640	1991	2,243.9	2,228.3	236,160
1992	2,244.2	2,232.6	333,760	1993	2,244.1	2,238.0	113,510
1994	2,244.0	2,235.9	239,610	1995	2,244.7	2,229.8	314,630
1996	2,244.4	2,229.9	80,601	1997	2,244.2	2,234.4	150,340
1998	2,244.5	2,234.4	298,261	1999	2,244.5	2,224.8	312,240
2000	2,244.3	2,224.9	272,590	2001	2,244.9	2,227.2	298,640
2002	2,244.2	2,225.8	258,890	2003	2,245.4	2,223.6	262,650
2004	2,244.4	2,223.6	249,160	2005	2,231.4	2,229.6	253,250
2006	2,244.3	2,229.6	236,090	2007	2,244.4	2,231.0	262,240
2008	2,244.2	2,231.5	258,810	2009	2,244.1	2,231.7	278,820
2010	2,246.0	2,227.4	339,900	2011	2,244.4	2,227.9	315,010
2012	2,244.1	2,221.0	277,800				

46. ELEVATION - AREA - CAPACITY - DATA FOR **2012**								
ELEVATION	AREA	CAPACITY	ELEVATION	AREA	CAPACITY	ELEVATION	AREA	CAPACITY
2012	**SURVEY**		2,181.0	0	0	2,182.0	0	0
2,183.0	8	4	2,184.0	15	15	2,185.0	25	35
2,186.0	39	67	2,188.0	104	209	2,190.0	166	479
2,192.0	239	883	2,194.0	335	1,456	2,195.0	396	1,822
2,196.0	450	2,245	2,198.0	565	3,260	2,200.0	687	4,512
2,202.0	827	6,025	2,204.0	954	7,806	2,205.0	1,030	8,798
2,206.0	1,113	9,870	2,208.0	1,276	12,259	2,210.0	1,434	14,968
2,212.0	1,599	18,000	2,213.3	1,709	20,150	2,214.0	1,769	21,367
2,215.0	1,859	23,181	2,216.0	1,951	25,086	2,218.0	2,143	29,180
2,220.0	2,353	33,675	2,222.0	2,529	38,557	2,224.0	2,701	43,787
2,225.0	2,803	46,539	2,226.0	2,903	49,392	2,228.0	3,102	55,396
2,230.0	3,306	61,804	2,234.0	3,767	75,935	2,235.0	3,893	79,765
2,236.0	4,003	83,712	2,238.0	4,177	91,893	2,240.0	4,423	100,493
2,242.0	4,740	109,656	2,244.0	5,073	119,469	2,244.5	5,142	122,023
2,245.0	5,210	124,611	2,250.0	5,899	152,384	2,252.8	6,348	169,530
2,255.0	6,700	183,883						

47. REMARKS AND REFERENCES

[1] Design elevations tied to project vertical datum near NGVD29 and 0.84 feet lower than NAVD88.

[2] Uncontrolled morning - glory spillway crest elevation.

[3] Bureau of Reclamation Project Data Book, www.usbr.gov, and SOP for Viriginia Smith Dam and Calamus Reservoir, December 2004.

[4] Total drainage area and contributing from Reclamation flood studies. Large areas within basin are closed and do not contribute surface flows.

[5] Calculated using mean annual runoff value, item 24. Total drainage 1,060 sq. mi with 147 sq. mi contributing surface flow other ground flow.

[6] Computed annual inflow for water years 1985-2012. Some years, 1993 and 1996-97, have several months of missing data.

[7] Surface area and capacity values at elevation 2,244.0 computed by ACAP.

[8] 2012 capacities computed by Reclamation's ACAP program. Surface areas from bathymetric survey and high flight LiDAR.

[9] Capacity loss calculated by comparing capacity at reservoir elevation 2,244.0 by year of survey.

[10] Maximum and minimum elevations and inflow values in acre-feet by water year, from 1986 through 2012 available from BOR web site.

[11] Missing inflow data for water years 1993, 1996, and 1997. Error with posted minimum elevation for 1996. Obtain minimum elevation from USGS.

48. AGENCY MAKING SURVEY Bureau of Reclamation

49. AGENCY SUPPLYING DATA Bureau of Reclamation DATE December 2012

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

1	2	3	4	5	6	7	8
					2012		
	Original	Original	2012	2012	Sediment	Percent	Percent
Elevation	Area	Capacity	Area	Capacity	Volume	Computed	Reservoir
Feet	Acres	Ac-Ft	Acres	Ac-Ft	Ac-Ft	Sediment	Depth
2,252.8	6,348	177,623	6,348	169,530	8,093	100.0	100.0
2,250.0	5,899	160,477	5,899	152,384	8,093	100.0	96.6
2,245.0	5,256	132,590	5,210	124,611	7,979	98.6	90.6
2,244.5	5,190	129,979	5,142	122,023	7,956	98.3	90.0
2,244.0	5,123	127,400	5,073	119,469	7,931	98.0	89.4
2,240.0	4,593	107,967	4,423	100,493	7,474	92.4	84.5
2,235.0	3,962	86,580	3,893	79,765	6,815	84.2	78.5
2,230.0	3,434	68,090	3,306	61,804	6,286	77.7	72.5
2,225.0	2,920	52,205	2,803	46,539	5,666	70.0	66.4
2,220.0	2,442	38,800	2,353	33,675	5,125	63.3	60.4
2,215.0	1,945	27,832	1,859	23,181	4,651	57.5	54.3
2,213.3	1,804	24,646	1,709	20,150	4,496	55.6	52.3
2,210.0	1,530	19,145	1,434	14,968	4,177	51.6	48.3
2,205.0	1,149	12,447	1,030	8,798	3,649	45.1	42.3
2,200.0	806	7,560	687	4,512	3,048	37.7	36.2
2,195.0	532	4,215	396	1,822	2,393	29.6	30.2
2,190.0	334	2,050	166	479	1,571	19.4	24.2
2,185.0	159	817	25	35	782	9.7	18.1
2,181.0	88	324	0	0	324	4.0	13.3
2,180.0	70	245	0	0	245	3.0	12.1
2,175.0	14	35	0	0	35	0.4	6.0
2,170.0	0	0	0	0	0	0.0	0.0
1	Reservoir water surface elevations tied to project datum that is near NGVD29 and 0.84 feet lower than NAVD88.						
2	Original, 1985, reservoir surface area.						
3	Original, 1985, reservoir capacity recomputed using ACAP.						
4	2012 measured reservoir surface area.						
5	2012 reservoir capacity computed using ACAP.						
6	2012 measured sediment volume, column (3) - column (5).						
7	Percent of total sediment, 8,093 acre-feet at elevation 2,252.8.						
8	Reservoir depth expressed in percentage total depth, 82.8 feet.						

Table 2 - Calamus Reservoir 2012 survey summary.

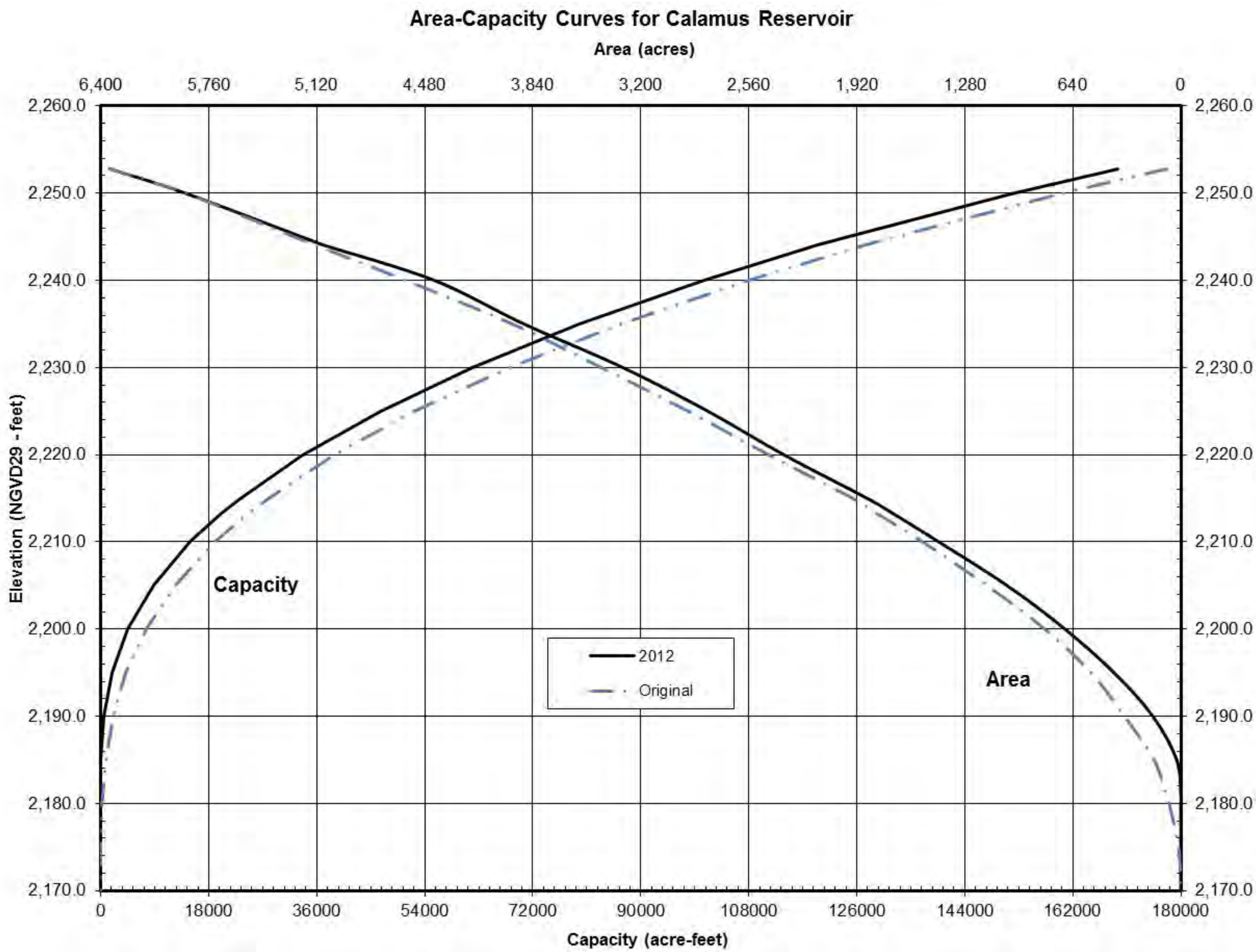

Figure 14 **- Calamus Reservoir area and capacity plots.**

Longitudinal Distribution

To illustrate the reservoir bottom, the Calamus River thalweg was plotted from the dam to the upper reservoir area for the original and 2012 conditions. The original longitudinal profile (Figure 14) was cut through the USGS predam quad 10-foot contours and the 2012 longitudinal profile was cut through the developed 2-foot topographic contours. The 2012 contours were used to develop the thalweg alignment and distances starting from the intake of the outlet works and continuing upstream through the side channel to the original river channel. The original thalweg started downstream where the dam crossed the original river channel and moved upstream along the original river alignment until it crossed the 2012 thalweg. From that point, the distances were oriented to the 2012 thalweg alignment to the upper reservoir area.

The 2012 thalweg started near elevation 2,184 at the outlet works. Once the 2012 thalweg joined the original river alignment, it crossed a contour at elevation 2,182.0 and from there sloped upstream near elevation 2,220 at the toe of a typical sediment delta that has formed. The pivot point of the delta is near elevation 2,228 and near the average annual minimum reservoir elevation for the last few years (Table 1).

The plot illustrates the present condition of the reservoir and how the sediment inflow appears to be impacting the inlet of the outlet works. The plot shows over 10 feet of sediment deposition in the main reservoir area upstream of the dam. The plot also illustrates that sediment inflows have settled in the very upper reservoir area where the delta has formed. From this formed delta the sediments have flushed downstream, filling the original river channel, reservoir area near the dam, and majority of the original dead pool. The 2012 contours along the original river channel alignment near the dam show more than 10 feet of sediment accumulation. With so much sediment deposited in the original river channel, it is assumed that a significant portion of the inflowing sediments now enter the excavated intake channel and are flushed downstream through the outlet works.

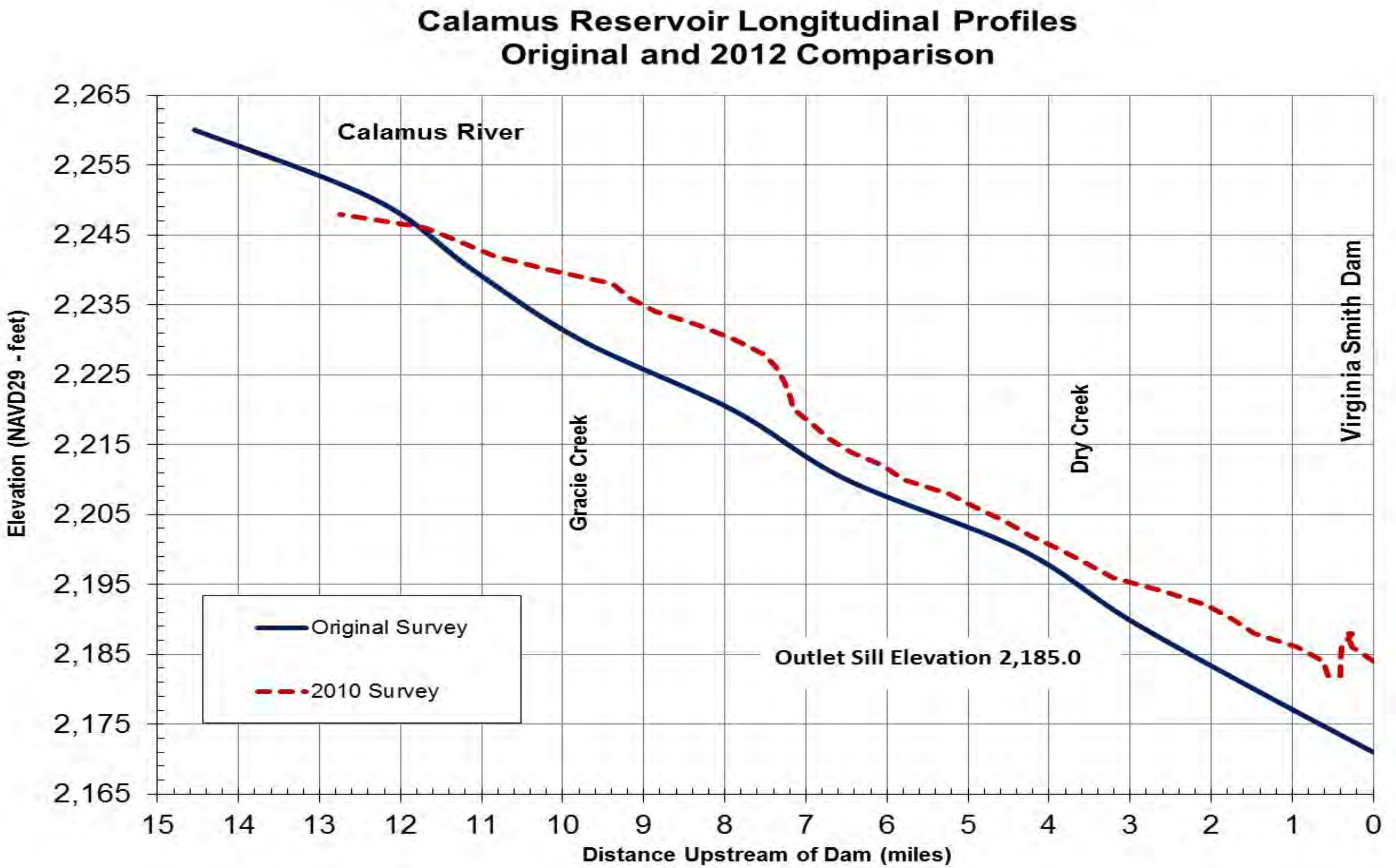

Figure 15 - Longitudinal profile of the Calamus River from the dam upstream.

2012 Calamus Reservoir Analyses

Results of the 2012 Calamus Reservoir area and capacity computations are listed in Table 1 and columns 4 and 5 of Table 2. Columns 2 and 3 in Table 2 list the original area and capacity values computed using the ACAP program. Figure 14 is a plot of the Calamus Reservoir surface area and capacity values for the surveys and illustrates the differences in surface area and storage. Table 1 shows the conservation use capacity at elevation 2,244.0 for both surveys along with the computed differences due to sediment deposition and methods of collection. Table 2 compares results from the original and 2012 surveys along with sediment computations from maximum water surface elevation 2,252.8 and below. As stated previously, this study assumed no change in original surface area from elevation 2,250.0 and above with the highest 2012 surface area input at elevation 2,244.0. As seen on the thalweg plot (Figure 15), the toe of the upper sediment delta was near elevation 2,220 and the delta proceeded upstreamfrom there, tapering off near elevation 2,245.

At conservation water surface elevation 2,244.0 the computed total change in reservoir volume was 7,931 acre-feet with the average annual change being 297.0 acre-feet. It is assumed the majority of the change is due to sediment accumulation occurring during the first 26.7 years of reservoir operation. The design sediment accumulation of Calamus Reservoir for the first 100 years of operation was only 6,500 acre-feet or 65 acre-feet per year. Information on how this value was determined could not be located.

Additional analysis, including evaluation of the drainage area, river inflow, and other survey results, would be required to obtain a better understanding of the results from the 2012 study. Under current reservoir operations, the majority of the inflows pass through the outlet works. It is assumed a large portion of the current and future sediment inflows will also flush downstream through the outlet works. Of the original 817 acre-feet of dead storage below elevation 2,185.0 the 2012 survey only measured 35 acre-feet of dead storage remaining. This means future inflowing sediments will deposit within the conservation reservoir capacity area if not flushed downstream through the outlet works.

A resurvey should be scheduled in the future if a significant change in the sediment basin runoff is noted and to monitor the reservoir volume changes from the inflowing sediments.

Summary and Conclusions

This Reclamation report presents the results of the June 2012 survey of Calamus Reservoir. 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 temporary rebar and cap located where it provided continuous 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 is near NGVD29 and 0.84 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 June 2012 underwater survey was conducted near reservoir elevation 2,241.7 as measured by the Reclamation gage at the dam and confirmed by RTK GPS measurements. 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 Calamus Reservoir. The positioning system provided information to allow the boat operator to maintain a course along these grid lines. Even though the June 2012 survey was conducted during normal high reservoir content, there were portions of the reservoir where the boat could not gain access due to vegetation and sand bars that blocked entry to some of the coves.

The above-water 2012 topography was from several sources such as digitized water surface edges of orthographic aerial images of the reservoir (USDA, 2010). The water surface elevation from these aerial photos ranged from elevation 2,241.3 to 2,243.5. Airborne 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. In the open areas of the reservoir the IFSAR data points matched well with known elevation information and were retained for this analysis. In areas with dense vegetation around the reservoir the IFSAR data did not match well and was removed from those areas for this analysis. The remaining IFSAR data points along with the other data sources were used to develop the 2012 Calamus Reservoir topography. For the reservoir areas where the IFSAR data was removed, the topographic program interpolated contours from the surrounding data sources.

The final 2012 Calamus Reservoir topographic map is a combination of the digitized water surface edge from the USDA photographs, small portions of the USGS quad map contours, IFSAR data points, and the 2012 underwater survey data, all tied vertically to NGVD29. A computer program was used to generate the 2012 topography and resulting reservoir surface areas at predetermined contour intervals from the combined reservoir data from elevation 2,260.0 and below. Assuming no change, the original measured surface areas for elevation 2,250.0 and 2,255.0 were used to complete the 2012 area and capacity tables for the reservoir. The surface area computed for this study at elevation 2,250.0 was within 1.5 percent of the original surface area, but for sediment computation purposes the decision was made to assume no change from elevation 2,250.0 and above due to the uncertainty in the IFSAR data in heavily vegetated areas. The input from the 2012 surface areas was from elevation 2,244.0 and below. The 2012 area and capacity tables were produced using the computer program (ACAP) that calculated area and capacity values at prescribed elevation increments using the measured contour surface areas and a curve-fitting technique that interpolated values between the input elevation surface areas.

Tables 1 and 2 contain summaries of the Calamus Reservoir and watershed characteristics for the 2012 survey. The 2012 survey determined the reservoir has a total storage capacity of 169,530 acre-feet with a surface area of 6,348 acres at maximum reservoir water surface elevation 2,252.8. At conservation water surface elevation 2,244.0 the total capacity was 119,469 acre-feet with a surface area of 5,073 acres. Since closure of Virginia Smith Dam in October 1985, this survey measured a 7,931 acre-foot loss in reservoir capacity below elevation 2,244.0. For the first 26.7 years of reservoir operation, the average annual loss was 297.0 acre-feet. The design annual sediment accumulation was 65 acre-feet or 21.9 percent of the 2012 measured annual inflow. Information on how the design inflow was computed was not found. The 2012 losses were computed by comparing the original and 2012 capacities for the reservoir. It is assumed the measured loss was mainly due to sediment deposition with some variation due to data accuracy differences between methods of collection and analysis. Future surveys should be considered if significant changes in sediment basin runoff are noted and to better monitor volume changes due to sediment inflows.

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14. ABSTRACT

Reclamation surveyed Calamus Reservoir in June 2012 to develop updated reservoir topography and compute the present storage-elevation relationship (area-capacity tables). The bathymetric survey, conducted near water surface elevation 2,241.7 (project datum in feet), used sonic depth recording equipment interfaced with a real-time kinematic (RTK) global positioning system (GPS) that provided continuous sounding positions throughout the underwater portion of the reservoir covered by the survey vessel. The above-water topography was developed by digitizing the reservoir water's edge from aerial photographs collected by the United States Department of Agriculture (USDA) and high altitude bare earth data from Interferometric Synthetic Aperture Radar (IFSAR).

As of June 2012, at conservation pool elevation 2,244.0, the reservoir surface area was 5,073 acres with a capacity of 119,469 acre-feet. Since October 1985 dam closure, a total capacity change of 7,931 acre-feet below elevation 2,244.0 was measured, equal to an average annual loss of 297.0 acre-feet. The capacity change is due to sediment deposition, shoreline erosion, and methodology differences between the surveys.

15. SUBJECT TERMS

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