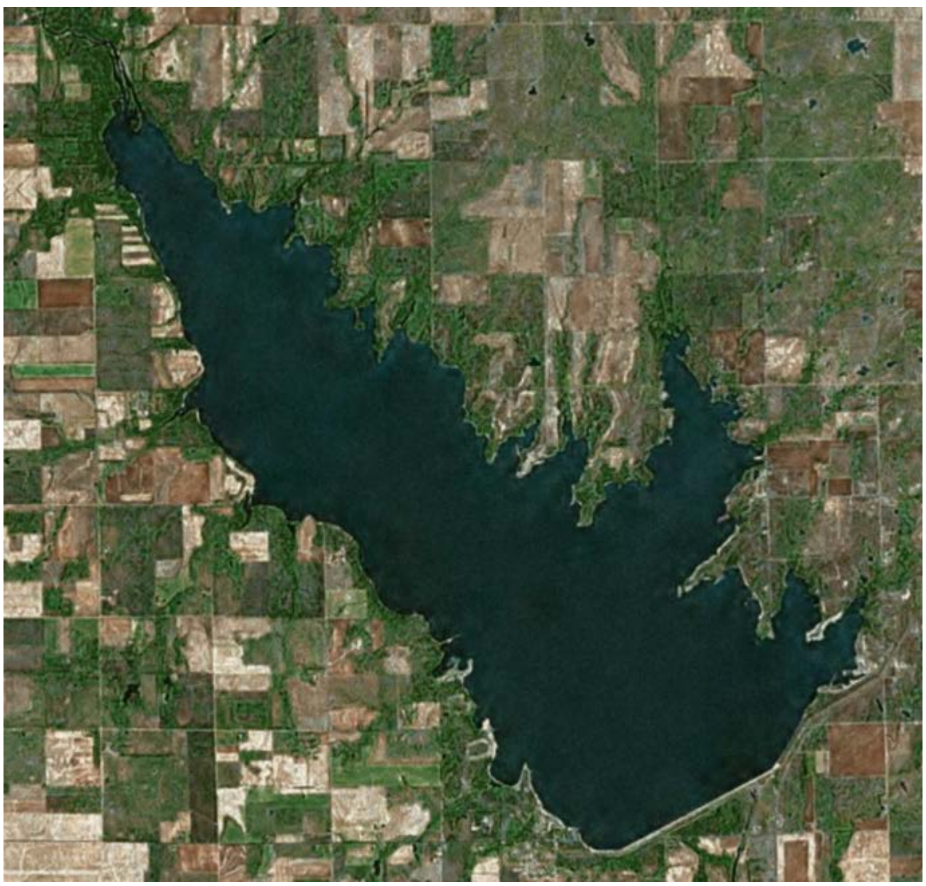
BUREAU OF RECLAMATION

Technical Report No. SRH-2018-03

Cheney Reservoir 2015 Sedimentation Survey

Wichita Project, Kansas
Great Plains Region



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

December 2019

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Cover Photo: ESRI image of Cheney Reservoir.

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14. ABSTRACT

The Bureau of Reclamation's (Reclamation) Sedimentation and River Hydraulics (Sedimentation) Group of the Technical Service Center (TSC) in Denver, Colorado conducted a partial bathymetric survey of Cheney Reservoir in Kansas in June 2015. The purpose of the bathymetric survey was to validate the 2010 Kansas Biological Survey assumption of no change near the dam since the U.S. Geological Survey (USGS) resurvey in 2007, to determine if sediment deposition had occurred anywhere in the reservoir since the 2010 survey, and to update area-capacity tables for more efficient dam and reservoir operations. Comparison of the 2015 bathymetric survey to previous surveys confirmed no change near the dam and indicated minimal bottom elevation change over the remainder of the reservoir. Area-capacity computations resulted in a 2015 surface area of 13,221 acres and a capacity of 262,736 acre-feet at spillway crest elevation 1,429.0 feet.

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2015 Sedimentation Survey

Technical Service Center, Denver, Colorado
Sedimentation and River Hydraulics Group, 85-824000

Technical Report No. SRH-2018-03

Wichita Project, Kansas
Great Plains Region

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The Bureau of Reclamation's (Reclamation) Sedimentation and River Hydraulics (Sedimentation) Group of the Technical Service Center (TSC) prepared and published this report. Rob Hilldale, David Varyu, and Kent Collins of the Sedimentation Group conducted the bathymetry survey of Cheney Reservoir in June 2015. The Sedimentation Group's Kent Collins processed the bathymetric survey data. Steven Hollenback of the Sedimentation Group generated the 2015 sediment range profiles from the processed bathymetry. Jakeb Prickett of Geographic Applications and Analysis Group developed the 2015 terrain for the area and capacity analysis. Rob Hilldale of the Sedimentation Group and Patrick Erger and Dale Lentz of the Great Plains Regional Office performed the technical peer review of this document.

Reclamation Report

This report was produced by the Bureau of Reclamation's Sedimentation and River Hydraulics Group (Mail Code 85-824000), PO Box 25007, Denver, Colorado 80225-0007, www.usbr.gov/pmts/sediment/.

Disclaimer

Acronyms and Abbreviations

ASTRA	Applied Science and Technology for Reservoir Assessment
ACAP	Reservoir area and capacity computation program
ESRI	Environmental Systems Research Institute
GPS	Global Positioning System
HYPACK	hydrographic survey software
IFSAR	Interferometric Synthetic Aperture Radar
KBS	Kansas Biological Survey
NAD 1983	North American Datum, established 1983
NGS	National Geodetic Survey
NGVD 1929	National Geodetic Vertical Datum, established 1929
NGVD 1988	National Geodetic Vertical Datum, established 1988
OTAO	Oklahoma Texas Area Office
Reclamation	Bureau of Reclamation
RTK	Real-Time Kinematic
Sedimentation Group	Sedimentation and River Hydraulics Group
TIN	triangular irregular network
TSC	Technical Service Center
USGS	U.S. Geological Survey

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Executive Summary

The Bureau of Reclamation's (Reclamation) Sedimentation and River Hydraulics Group (Sedimentation Group) of the Technical Service Center (TSC) in Denver conducted a partial bathymetric survey of Cheney Reservoir near Wichita, Kansas in June 2015. The purpose of the bathymetric survey was to validate the 2010 Kansas Biological Survey assumption of no change near the dam since the USGS resurvey in 2007, to determine if sediment deposition had occurred anywhere in the reservoir since the 2010 survey, and to update area-capacity tables for more efficient dam and reservoir operations. Comparisons of the 2015 bathymetric survey results to previous results confirmed that there were no changes near the dam and indicated that the minimal bottom elevation change was minimal over the remainder of the reservoir. Area-capacity computations resulted in a 2015 surface area of 13,221 acres and a capacity of 262,736 acre-feet at spillway crest elevation 1,429.0 feet.[1]

Introduction

Cheney Dam is located on the North Fork of the Ninnescah River 6 miles north of the town of Cheney, Kansas and 24 miles west of Wichita, Kansas. The dam forms Cheney Reservoir upstream with portions of the lake lying in three different counties: Sedgwick, Kingman, and Reno Counties (Figure 1). Cheney Dam was constructed between 1962 and 1965 as a principal feature of the Wichita Project to provide supplemental water to Wichita, flood protection for downstream areas, recreation, and fish and wildlife benefits. The flood control features of the dam and reservoir allow for the irrigation of approximately 3,700 acres of land downstream, although no direct flow from the reservoir is to be used for irrigation. Cheney Dam and Reservoir are operated by the City of Wichita's Public Works Department.

From June 21 to 24, 2015 Reclamation's Sedimentation Group conducted a hydrographic survey of Cheney Reservoir and Dam with three primary objectives:

1. Validate the 2010 Kansas Biological Survey assumption of no change near the dam since the USGS resurvey in 1998,
2. Determine if deposition had occurred upstream of dam since the 2010 survey, and
3. Compute new area-capacity relationship to assist in dam and reservoir operations.

[1] Unless otherwise noted, all elevations in this document are in NGVD29 coinciding with the Reclamation project vertical datum used at Cheney. NGVD29 was measured 0.479 feet lower than NAVD88, Geoid 12A (Orosco, 2014).

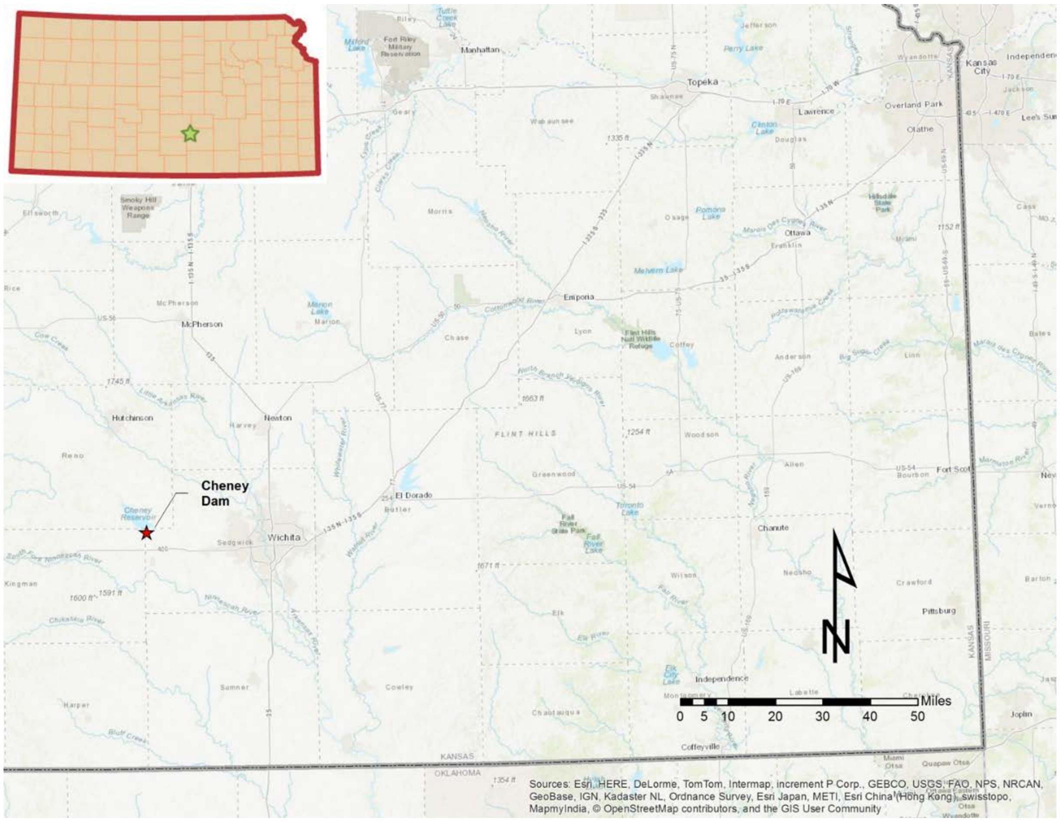

Figure 1. Map showing location of Cheney Dam and Reservoir approximately 24 miles west of Wichita in southeast Kansas.

Dam and Reservoir

Cheney is a rolled earthfill dam containing 7,341,000 cubic yards of homogeneous fill. The dam has a structural height[2] of 126.2 feet and a hydraulic height of approximately 86 feet with a crest width of 30 feet, length of 24,458 feet, and elevation of 1,454.0 feet. When filled to spillway crest elevation 1,429 feet, the dam impounds 262,736 acre-feet of water according to 2015 bathymetric survey and analysis results.

The morning glory type spillway has an ungated crest 22.25 feet in diameter leading to a 9.5-foot diameter conduit through the dam that discharges into a chute, stilling basin, and outlet channel. Design spillway capacity at maximum reservoir water surface elevation 1,447.8 feet is 3,000 cubic feet per second.

[2] The definition of such terms as "hydraulic height", "structural height," etc. may be found in manuals such as Reclamation's *Design of Small Dams* and *Guide for Preparation of Standing Operating Procedures for Dams and Reservoirs*, or ASCE's *Nomenclature for Hydraulics.*

River outlet works consist of a trashrack protected intake structure, 11-foot diameter conduit, gate chamber with four 6-foot wide by 7.5-foot high pressure gates, and 15-foot diameter free flow conduit that discharges into an outlet chute, stilling basin, and outlet channel. The maximum release capability for the river outlet works is 4,580 cubic feet per second at reservoir elevation 1,447.8 feet (Reclamation, 2004).

Municipal outlet works at Cheney Dam are four 72-inch square slide gates and one emergency 72- by 96-inch square slide gate leading to an 8-foot concrete conduit, then 8-foot diameter steel pipe connecting to a pumping plant constructed by the City of Wichita. The capacity of the pumping plant works is 93 cubic feet per second.

Figure 2. Cheney Dam and Reservoir site map (Environmental Systems Research Institute [ESRI]).

Figure 2 shows the location of Cheney dam and the spillway and river outlet works. Detailed dimensions of the dam are summarized here in feet:

• Structural Height	126.2	• Crest Length	24,458	• Max Water Surface	1,453.4
• Hydraulic Height	50.5	• Top Width	30	• Spillway Crest El.	1,429.0
• Crest Elevation	1,454.0	• Max Base Width	650	• Spillway Crest Diam	22.25

Cheney Dam and Reservoir are maintained and operated by the Public Works Department of the City of Wichita according to the following storage allocation elevations in feet (National Geodetic Vertical Datum, established 1929 [NGVD29]):

• Top of Dead	1,378.5	• Top of Flood Control	1,429.0
• Top of Inactive	1,392.9	• Top of Surcharge	1,453.4
• Top of Active Conservation	1,421.6	• Top of Dam	1,454.0

Drainage Basin

Cheney Dam drains an area of 1,036 square miles that is fed primarily by the North Fork of the Ninnescah River (Figure 2). The drainage basin consists of nearly 50 percent cultivated crops and less than 2 percent forest (https://streamstats.usgs.gov/ss/). The mean annual precipitation in the basin is estimated at 29.1 inches.

Previous Surveys

The Sedimentation Group's 2015 survey was the first multibeam survey conducted at Cheney Reservoir, but multiple single beam bathymetric surveys have been conducted in the past:

- 1964 Original Survey – Traditional Land Survey – Sediment Ranges
- 1993 Reclamation –Single Beam Sediment Range Bathymetric Survey
- 1998 USGS – Single Beam Sediment Range Bathymetric Survey
- 2010 Kansas Biological Survey – Single Beam Full Reservoir Bathymetric Survey

Data from each of these previous surveys were used in the 2015 analysis comparison to 2015 multibeam results.

1964 Original Pre-Construction Survey

Prior to completion of dam construction, a survey of sediment ranges on Cheney Reservoir was conducted using traditional land survey techniques. The primary purposes of this survey were to determine the area-capacity relationship, document as-built conditions, and establish a baseline for monitoring of future sediment deposition (Kansas Biological Survey [KBS], 2012).

1993 Reclamation Sediment Range Survey

On April 5, 1993, the Sedimentation Group, along with assistance from Reclamation's Oklahoma Texas Area Office (OTAO) and the City of Wichita, conducted a partial survey of Cheney Reservoir to make recommendations for additional, full scale survey. Seven sediment ranges were surveyed using single beam sonar to check for deposition in the reservoir. The 1993 survey results measured approximately 5 feet of sediment deposition, primarily in the original river channel, between Range 1 and Range 10 (labeled R1 through R10 in Figure 3). Due to the "…small amount of sediment…" that was estimated to have accumulated in Cheney Reservoir since dam closure, a more complete survey and analysis was not recommended in 1993 (Ferrari, 1993).

1998 U.S. Geological Survey Survey

The U.S. Geological Survey (USGS) Kansas Office conducted a single beam bathymetric survey of Cheney reservoir in 1998. The 1998 USGS survey consisted primarily of cross sections spaced 0.25 to 0.5 miles apart and a few longitudinal passes along the length of the reservoir and along the east arm. Only sparsely spaced cross sections were surveyed near the dam, resulting in insufficient data to map the dam face and reservoir bottom immediately upstream. The 1998 USGS bathymetric coverage can be seen in KBS, 2012.

2010 Kansas Biological Survey

Over the course of six days in July and August 2010, the KBS collected closely spaced cross sections and continuous shoreline data throughout the entire reservoir using single beam sonar and Global Positioning Systems (GPS). This dense survey provided complete coverage, mapping the reservoir bottom in sufficient detail to compute accurate areas and capacities up to reservoir elevation 1,420.7 feet (NGVD29). In their 2012 report (KBS, 2012), KBS compared their 2010 bathymetry to the 1998 USGS bathymetry. Comparison of surfaces generated in ArcGIS from the two data sets indicated nearly 30 feet of scour or sediment removal along the upstream toe of the dam. However, as stated in their report, the change in bed elevation between the 1998 and 2010 data is likely due to the difference in survey density and surface development methods rather than actual scour or bed lowering near the dam.

KBS plotted their 2010 sediment ranges against the 1964 original, 1993 Reclamation, and 1998 USGS ranges which showed 1-2 feet of deposition in the low flow channel downstream of Range 8 (Figure 3) since 1993, but almost no change since 1998. A three-dimensional surface was created from the 2010 KBS data in ArcGIS to compute updated areas and capacities. The 2010 KBS survey measured a surface area of 9,937 acres and storage capacity of 167,006 acre-feet at maximum measured bottom elevation 1,420.7 feet (KBS, 2012).

Survey Control

In July 2014, a surveyor from the Engineering Services Office of Reclamation's Lower Colorado Region conducted a forensic survey[3] at Cheney Reservoir to verify water surface elevations reported by dam operators (Orosco, 2014). Control points measured during that survey were used as a GPS base location and as confirmation of the vertical datum during the 2015 bathymetric survey. Horizontal and vertical control were further verified through GPS measurement of published National

[3] The term "forensic survey" in this case refers to a GPS survey conducted using existing control points to verify the vertical reference frame at Cheney Reservoir.

Geodetic Survey (NGS) points found in the Cheney Reservoir area and water surface elevations at the O'Brien's Marina boat ramp. Measurements collected on control points in 2015 were compared to coordinates and elevations published in Orosco (2014), to validate horizontal and vertical datums used for the 2015 survey. GPS measurements of water surface elevation were compared to water levels recorded at Cheney Dam to verify the difference between National Geodetic Vertical Datum, established 1988 (NAVD88) (Geoid 12A) and the Cheney Dam vertical datum or NGVD29.

All 2015 bathymetry and GPS measurements were collected in North American Datum, established 1983 (NAD83) State Plane coordinates, Kansas South Zone (3951), US survey feet horizontally and NAVD88, Geoid 12A, US survey feet vertically. During processing, 2015 bathymetry and GPS measurements were converted to the Cheney Dam vertical datum which was found to coincide with NGVD29 (Orosco, 2014) and further confirmed by the Sedimentation Group's survey crew in 2015. Orosco (2014) measured NGVD29 0.48 feet lower than NAVD88 (Geoid 12A).

Figure 3 is a map of Cheney Reservoir showing GPS control points used during the 2015 hydrographic survey. Previously established sediment ranges for monitoring changes in reservoir bottom elevation are also plotted on Figure 3.

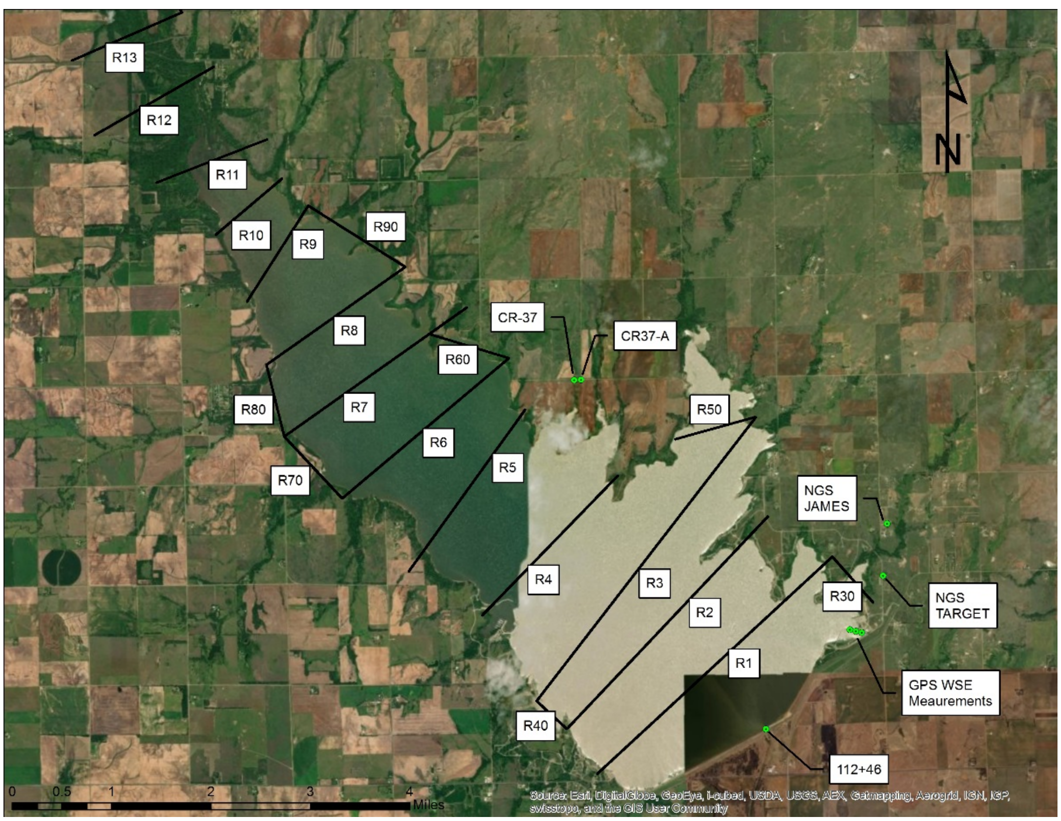

Figure 3. Map of Cheney sediment ranges and GPS control points measured during 2015 survey (ESRI).

The GPS base station was set on point CR37-A near the east end of Range 5 (Figure 3) for the entire 2015 hydrographic survey. CR37-A is at a relatively high elevation free from overhanging vegetation, power lines, or structures—unlike other areas surrounding the reservoir. Proximity to the reservoir (CR37-A was within 4 miles of all bathymetry and GPS measurements collected in 2015) and ease of access by vehicle were also key factors in the choice of CR37-A as a GPS base location. Figure 4 contains photos of the GPS base set up at the CR37-A location and a close-up of the survey marker.

Figure 4. GPS base location at CR37-A near east end of Range 5.

A series of pre-existing control points and water surface elevations were measured using GPS to ensure the horizontal and vertical datums used for the 2015 survey matched NAD83 state plane coordinates and NGVD29 or Cheney Dam vertical datum respectively. Figure 3 shows the location of each of the control points and water surface elevations measured during the 2015 control survey. The location and surrounding landmarks of each control point and a detailed photo of the marker are shown in Figure 5 through Figure 8.

Figure 5. CR-37 "X" chiseled in concrete near east end of Range 5 used to verify 2015 GPS measurements. Photos courtesy of Orosco (2014).

Figure 6. NGS point "JAMES" near east end of Range 1 used to verify 2015 GPS measurements.

Figure 7. NGS point "TARGET" near Range 30 used to verify 2015 GPS measurements.

Figure 8. Survey marker designated "112+46" on Cheney Dam crest used to verify 2015 GPS measurements. Photos courtesy of Orosco (2014).

2015 Bathymetric Survey Equipment and Method

Bathymetric and ground control surveys were conducted using real-time kinematic (RTK) GPS equipment for positioning. RTK GPS measures horizontal coordinates and heights (elevations) in real-time using base and rover components. The GPS base receiver is set up over a point on shore with known coordinates. Position corrections are transmitted to the GPS rover receiver using an external GPS radio and UHF antenna. The base station is powered by a 12-volt battery. Figure 4 shows the RTK GPS base set-up over point CR37-A used for the Cheney Reservoir survey.

The rover component consists of a second GPS receiver with internal radio and external antenna mounted on a range pole (ground survey) or survey vessel (bathymetric survey). The rover, reading the same satellites as the base at the same time, receives the corrected positions from the base, resulting in real-time positions with accuracies on the order of 2 centimeters horizontally and 3 centimeters vertically.

The bathymetric survey equipment was mounted on an 18-foot, flat-bottom aluminum Wooldridge boat powered by outboard jet and kicker motors (Figure 9). Survey equipment mounted to the boat included dual RTK GPS receivers for positioning and heading, rover radio to receive position corrections from the base, multibeam transducer to measure depths, and laptop computer with hydrographic survey software (HYPACK) to collect and combine position and depth data. Power to all of the hydrographic survey equipment was supplied by an inverter connected to a single 12-volt battery.

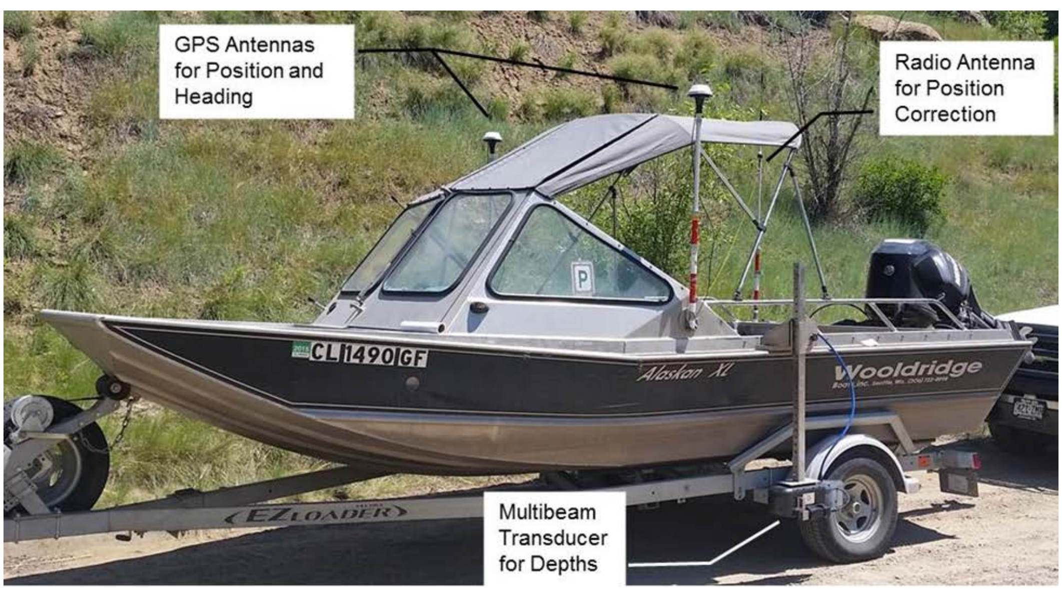

Figure 9. Wooldridge boat with multibeam system mounted on-board used at Cheney Reservoir.

The multibeam echo sounder used for the 2015 Cheney survey consisted of a variable-frequency transducer with integrated motion reference unit, near-surface sound velocity probe, two GPS receivers, an external GSP radio, and processor box for synchronization of all depth, sound velocity, position, heading, and motion sensor data. The multibeam transducer emits up to 512 beams (user selectable) capable of projecting a swath width up to 120º with a depth range of over 390 feet (120 meters). Sound velocity profiles were collected over the full water depth at various locations throughout the reservoir to measure the speed of sound through the water column. The speed of sound through the water column can be affected by various factors such as temperature and salinity. The sound velocity profile was used to calibrate the depth sounder during post-processing.

A laptop on the boat was connected to the GPS rover receivers and echo sounder system. Corrected positions from one GPS rover receiver and measured depths from the multibeam transducer were transmitted to the laptop through cable connections to the processor box. Hydrographic survey software (HYPACK) on the laptop collected and combined positions and depths to provide reservoir bottom topography in the user selected coordinate system (NAD83 State Plane Coordinates, Kansas South, US survey feet for the Cheney survey).

The Cheney Reservoir survey was conducted over a four-day period from June 21 through June 24, 2015 between water surface elevations 1,423.17 and 1,423.26 feet (NGVD29). Survey system software on the laptop combined the continuously recorded depth and position data and provided guidance to the boat operator as the boat traveled along gridlines established by the survey crew to cover the underwater portion of the reservoir. Surveyed lines consisted of cross sections near the dam, sediment ranges from Range 1 upstream to near Range 11, shoreline data, longitudinal profiles along the historical river channel and reservoir centerline, and cross sections and a longitudinal profile in the east arm. Figure 3 shows the layout of the previously established sediment ranges and Figure 10 is a map of the multibeam coverage achieved during the 2015 bathymetric survey. High winds experienced on three of the four survey days forced the survey crew off the water and prevented collection of additional data.

As each survey line was traversed in the survey vessel, the depth and position data were recorded on the laptop computer hard drive for subsequent processing. The water surface elevations recorded at the dam gage and RTK GPS measurements were used to convert the sonar depth measurements to reservoir-bottom elevations tied to the Cheney Dam vertical datum that is coincident with NGVD29. Final processing of the June 2015 bathymetric data resulted over 1,600,000 points.

Additional information on collection and analysis procedures is outlined in Chapter 9 of the *Erosion and Sedimentation Manual* (Ferrari and Collins, 2006).

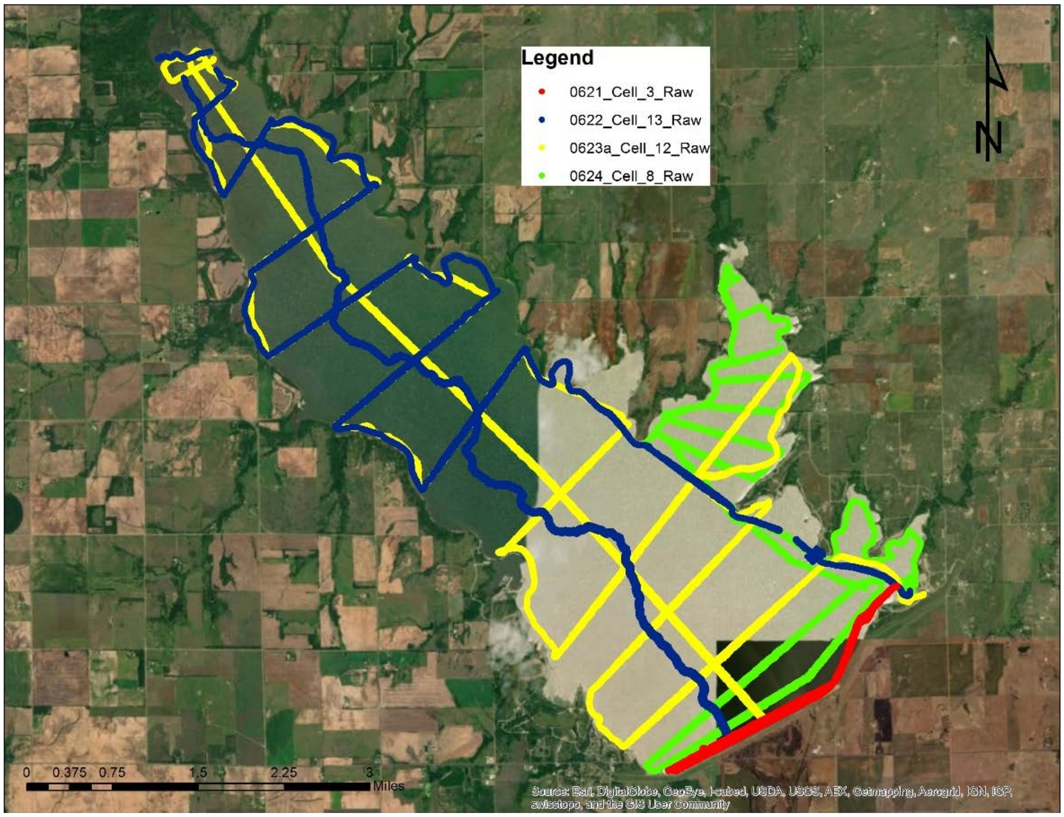

Figure 10. Coverage map of 2015 multibeam bathymetric survey.

Reservoir Area and Capacity

Comparison of the 2015 Reclamation to 2010 KBS bathymetry indicated minimal change in bottom topography between the two surveys. Therefore, the 2015 bathymetry data was combined with 2010 KBS bathymetry and LiDAR data for the above water areas to generate reservoir bottom topography. The 2015 topographical surface was used to compute surface areas for input to Reclamation's area and capacity calculation program. The computed capacity values from analysis of the 2015 data analysis were compared to the results of the 2010 KBS analysis to reach conclusions about the volume and distribution of deposited sediments in Cheney Reservoir.

Topography Development

The 3-dimensional surface used to generate the 2015 area-capacity tables for Cheney Reservoir was developed from three different sources of data:

- **2010 KBS Bathymetry**. In July and August 2010, KBS conducted a bathymetric survey of Cheney Reservoir using split beam and single beam depth sounders interfaced with a GPS for positioning. The water surface elevation varied between 1421.98 and 1427.19 feet (NGVD29) during the KBS survey. Area capacity tables up to elevation 1420.7 feet were generated from the KBS bathymetry data and are presented in their 2012 report (KBS, 2012).

- **2015 Reclamation Bathymetry.** Bathymetry collected by the Sedimentation Group in June 2015 was used in areas of the reservoir bottom not covered during the 2010 KBS survey. The water surface elevation during the 2015 Reclamation bathymetric survey fluctuated slightly between 1423.17 and 1423.26 feet. Water levels were 1422.70 feet when KBS conducted their cross-section survey of the upper reservoir (August 2, 2010). Marginally higher water levels and the relatively wide coverage swath of the multibeam system in 2015 allowed Sedimentation Group crews to collect data upstream of the 2010 KBS cross sections. Using the most recent data in the upper reservoir allowed more accurate mapping of the delta area where inflowing sediment would be expected to deposit first.

- **Light Detection and Ranging (LiDAR) data.** Matthew Warren from the OTAO provided a link to LiDAR collected between 2010 and 2012 in the State of Kansas (Data Access and Support Center, 2018 http://data.kansasgis.org/kslidar/BE/). LiDAR for the above water area surrounding Cheney Reservoir was downloaded and combined with the 2010 KBS and 2015 Sedimentation Group bathymetry to generate a complete map of Cheney Reservoir up to crest elevation 1454.0 feet.

The 2010 bathymetry, 2015 bathymetry, and LiDAR data were combined to create a terrain surface in ArcMap from minimum measured bottom elevation (1,379.0 feet) up to the highest elevations measured during the 2015 survey (about elevation 1,421 feet). Above the bathymetry data, LiDAR points were used for topography development. Figure 11 shows the 2015 terrain surface generated from the bathymetry and LiDAR data. In preparation for developing the terrain, a polygon was created to enclose the 2015 bathymetry and LiDAR data sets. This boundary polygon enclosed all the data sets, allowing for topography development of the reservoir study area along the dam alignment and the high ground surrounding Cheney Reservoir. The polygon was not assigned an elevation but was used as a hard boundary preventing development of the 2015 terrain outside of that boundary.

A Terrain is a multiresolution, triangular irregular network (TIN) -based surface built from topographic measurements such as LiDAR, sonar, and photogrammetry (ESRI, 2016). The advantage of a Terrain over a TIN is that it retrieves the surface data and displays a TIN on the fly depending on the specified level of detail for the given area of interest. Thus, a Terrain uses the minimal data necessary to display the features of the surface, significantly reducing the number of points accessed and time required to generate the viewing window within ArcMap. A TIN uses a fixed number of points and level of detail in each display. When developing surface data for the 2015 analysis, the full resolution of the terrain was used.

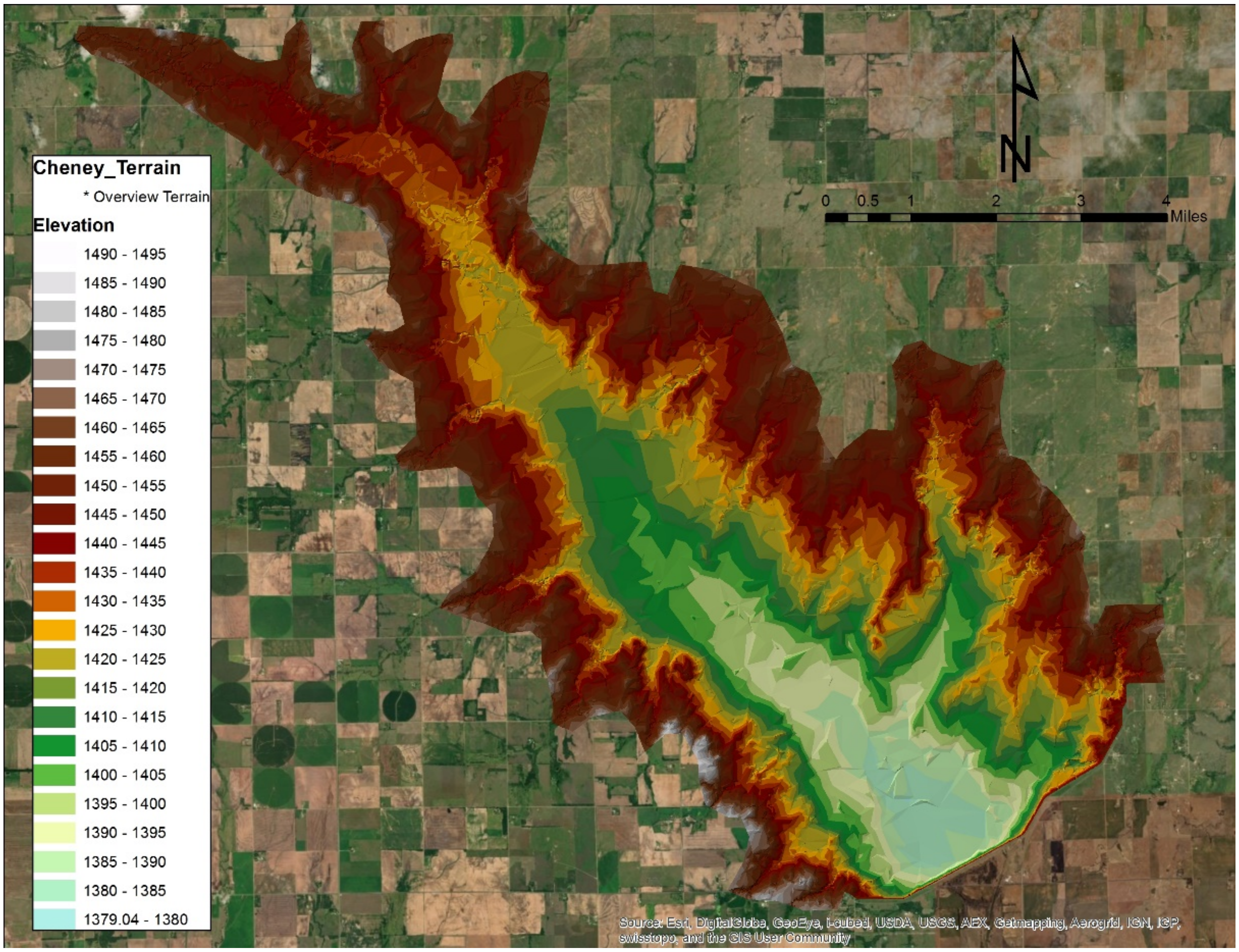

Figure 11. 2015 three-dimensional surface generated from 2010 KBS and 2015 Sedimentation Group bathymetry and 2010-2012 LiDAR.

It is standard practice in the Sedimentation Group to use the latest geometry data available to generate reservoir topography. However, in this case the majority of the bathymetry used to generate the 2015 bed surface was comprised of 2010 KBS data. Different project goals, time and budget constraints, and extremely windy conditions during the 2015 bathymetric survey resulted in less coverage than that achieved in 2010.

The decision was made to generate the 2015 underwater surface from the 2010 KBS bathymetry where available and the 2015 Reclamation bathymetry in areas not covered in 2010 due to several factors:

- The 2010 KBS survey mapped the underwater portion of the reservoir with greater coverage than the 2015 Reclamation survey. The most complete coverage typically produces the best representation of the reservoir bottom.

- Merging data of varying densities in overlapping areas and generating a 3-dimensional surface from that data is difficult and time consuming.

- Spot checks of 2015 data matched ±0.2 feet when overlaid with 2010 data. The use of either data set would result in a similar surface.

- Sediment range plot comparisons between 2010 KBS and 2015 Reclamation surveys matched well in shape and bottom elevation. Plots of the comparisons at previously established sediment ranges accessible by the survey vessel in 2015 are shown below in Figure 12 through Figure 21 with Range 1 nearest the dam and Range 10 furthest upstream of the dam. Survey data collected by the USGS in 1998 is plotted with the 2010 and 2015 surveys to show the minimal change in bottom elevation that occurred at Cheney Reservoir over a 17-year period.

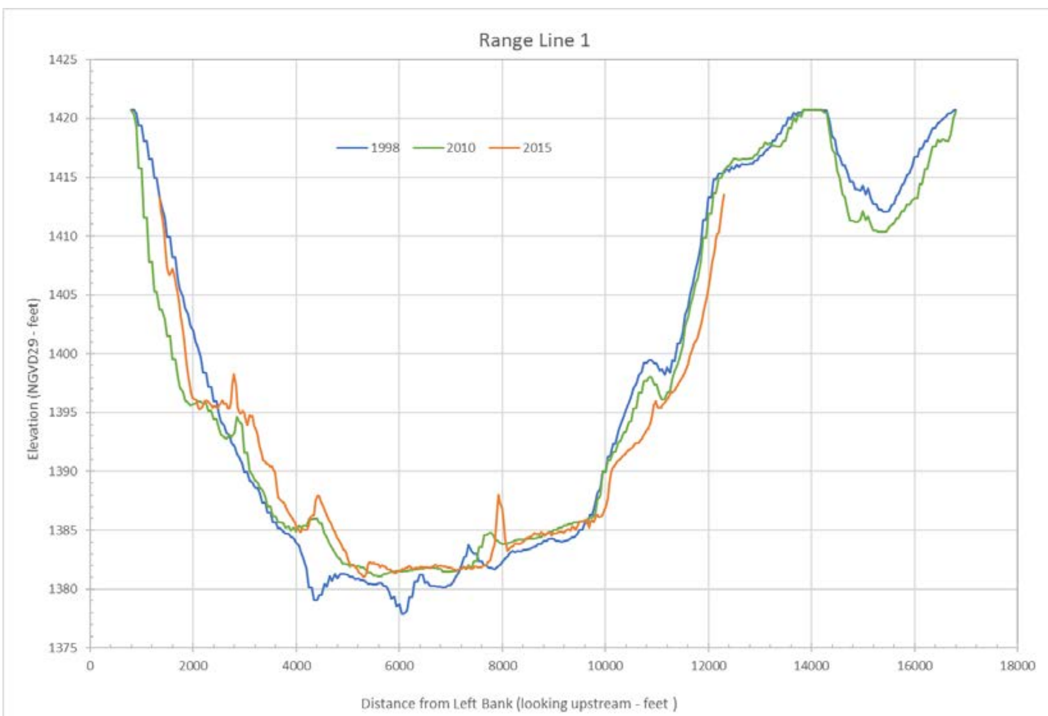

Figure 12. Cheney Reservoir Sediment Range 1.

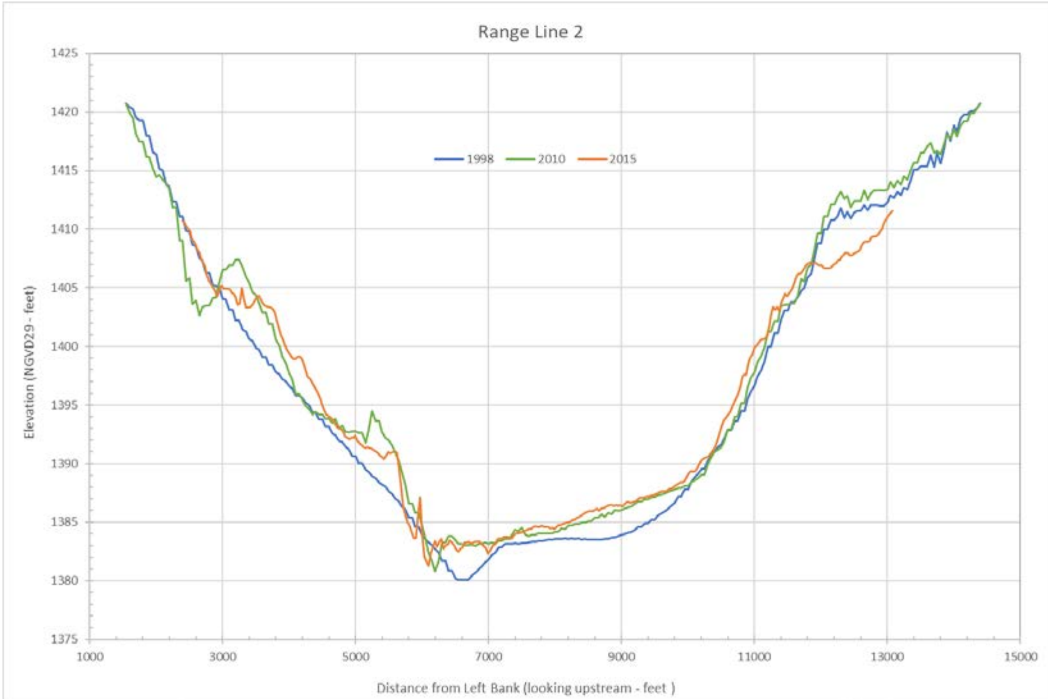

Figure 13. Cheney Reservoir Sediment Range 2.

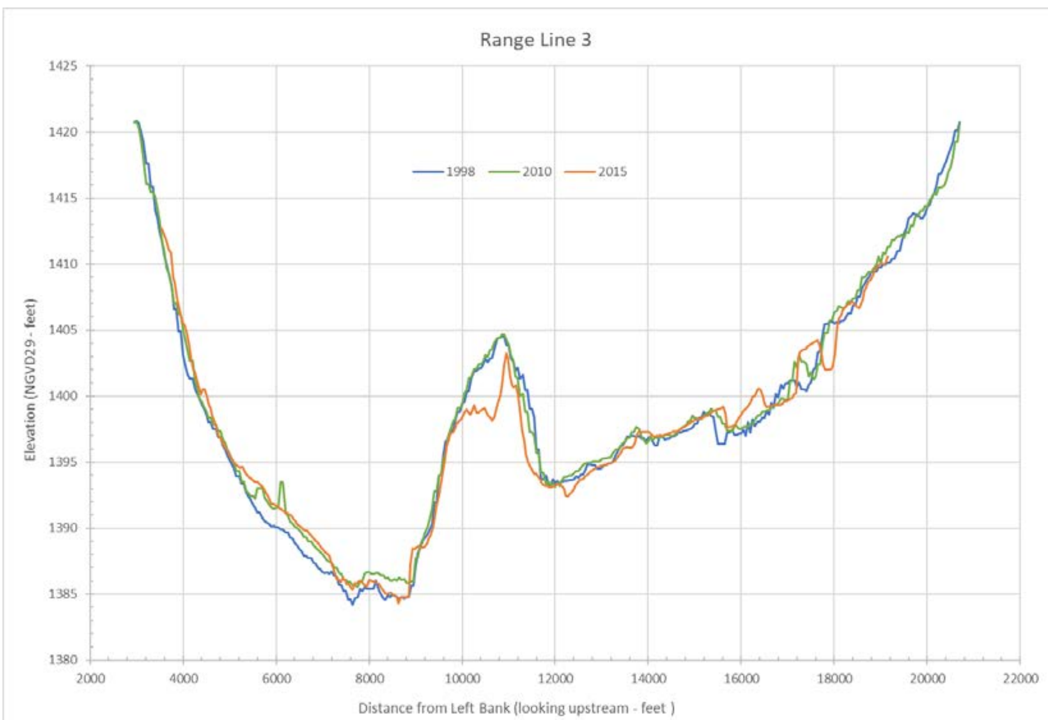

Figure 14. Cheney Reservoir Sediment Range 3.

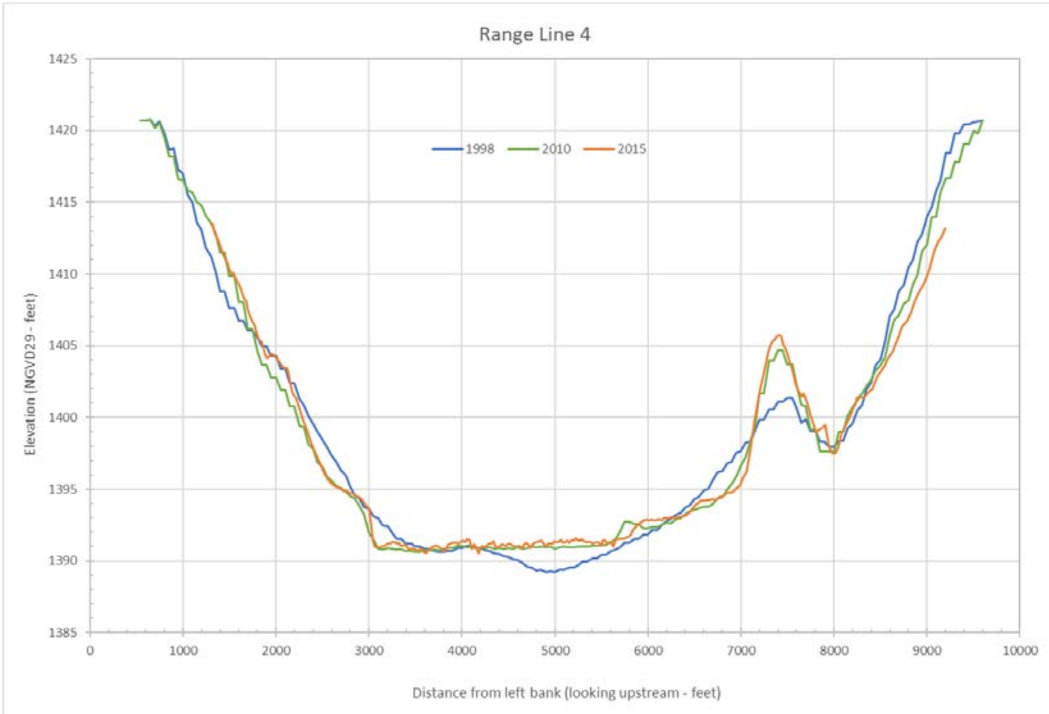

Figure 15. Cheney Reservoir Sediment Range 4.

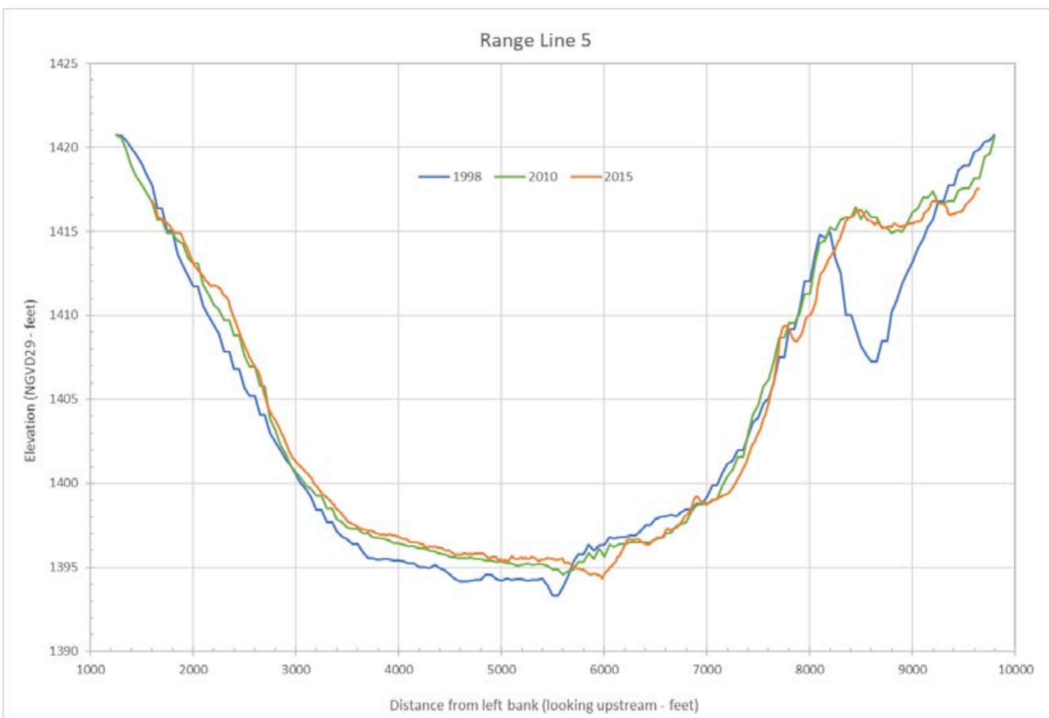

Figure 16. Cheney Reservoir Sediment Range 5.

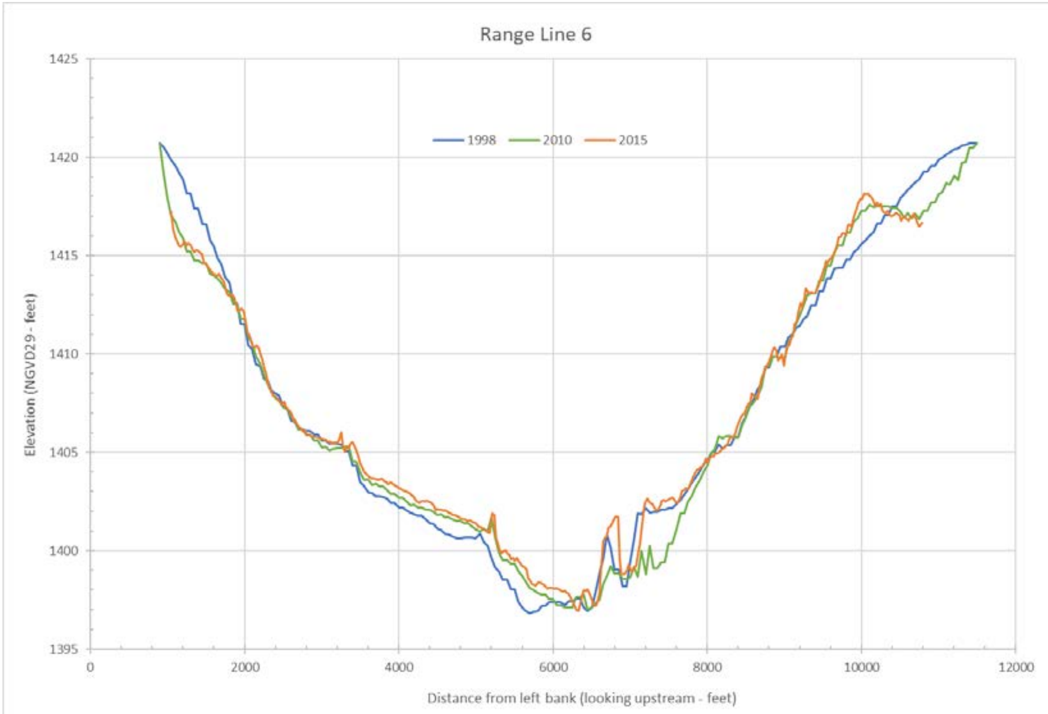

Figure 17. Cheney Reservoir Sediment Range 6.

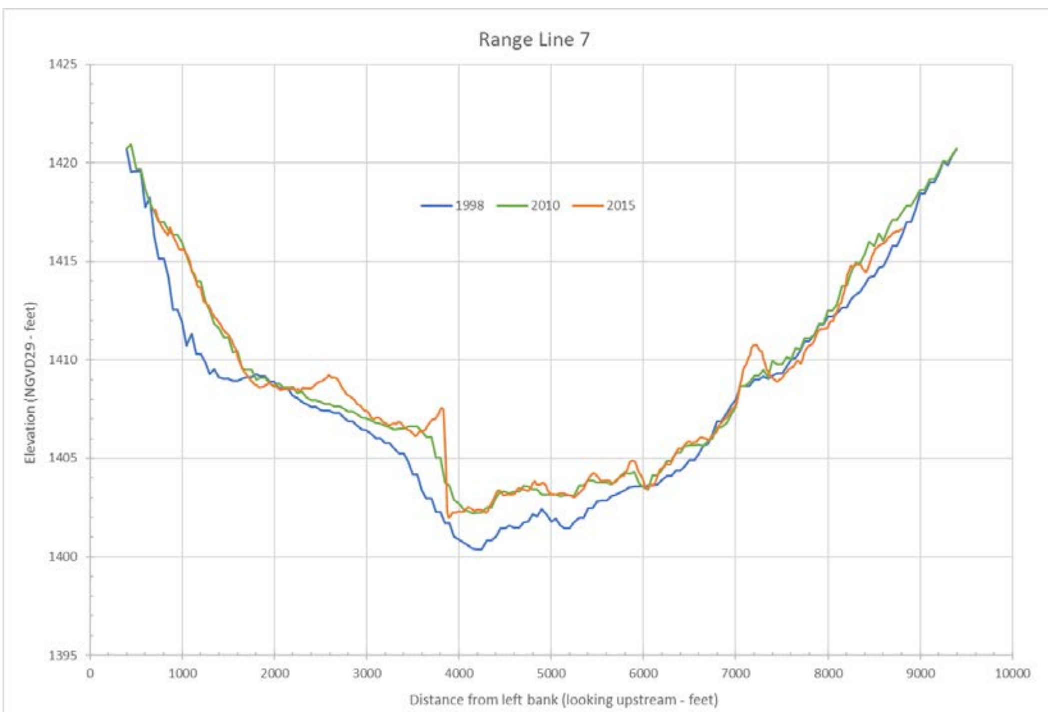

Figure 18. Cheney Reservoir Sediment Range 7.

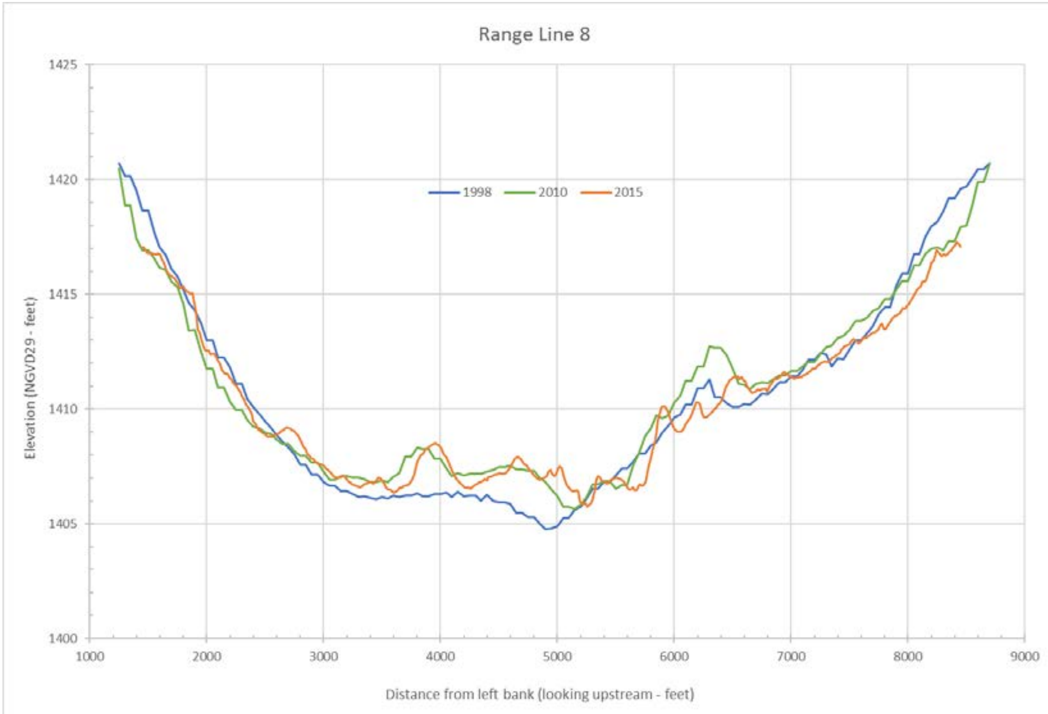

Figure 19. Cheney Reservoir Sediment Range 8.

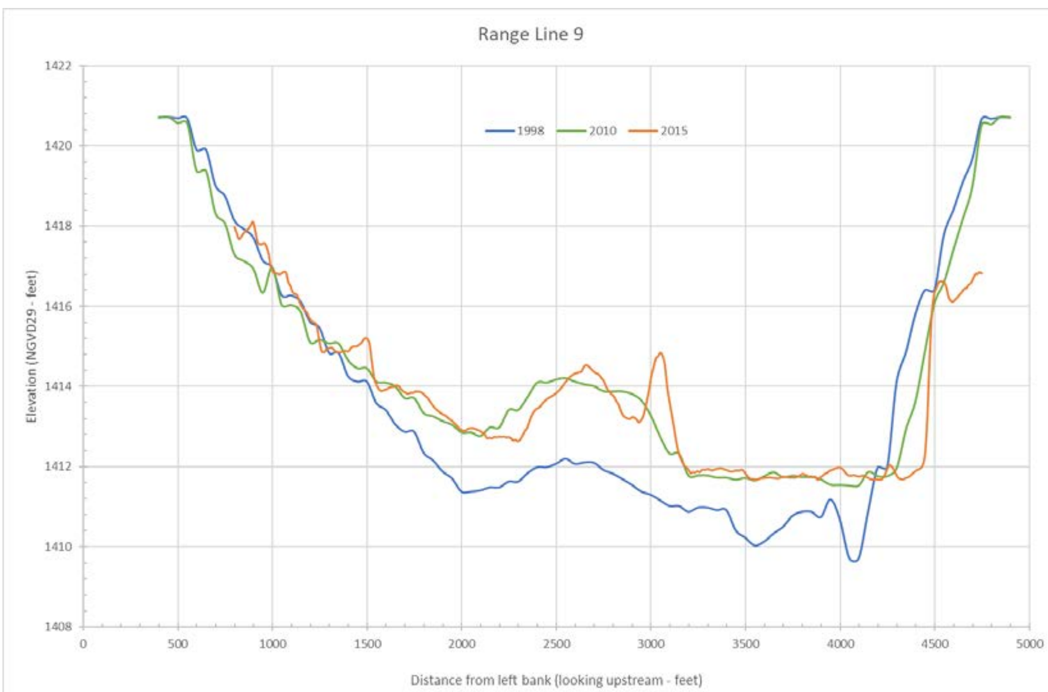

Figure 20. Cheney Reservoir Sediment Range 9.

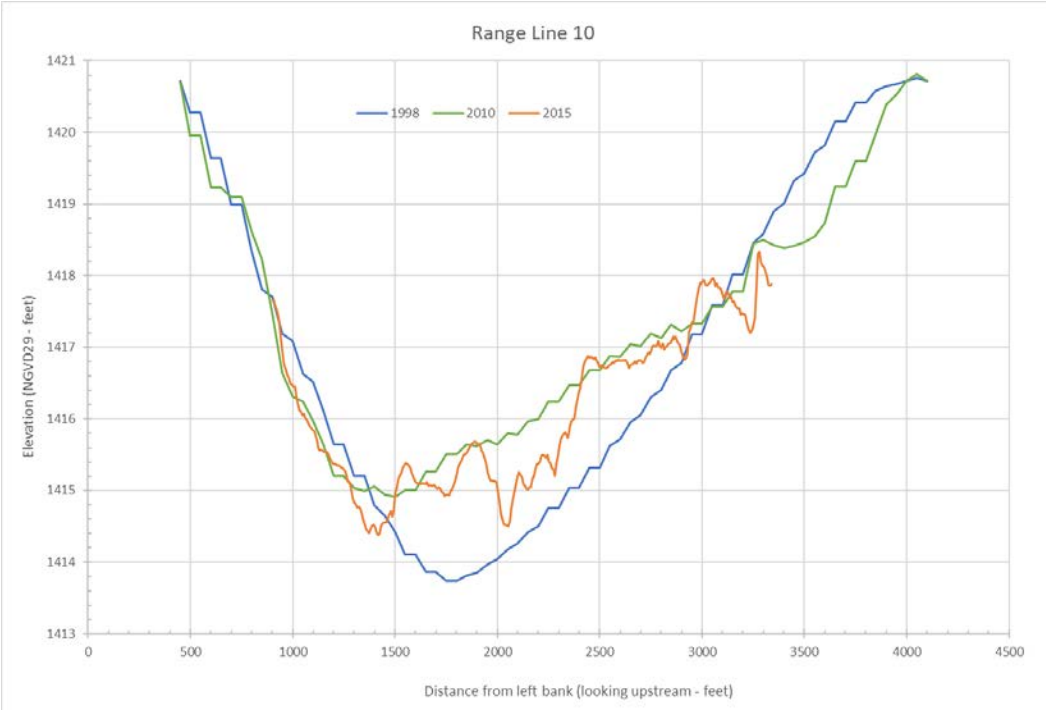

Figure 21. Cheney Reservoir Sediment Range 10.

Surface Area Methods

The surface areas of the 2015 terrain at 1-foot increments from elevation 1,377 feet through elevation 1,454 feet (Cheney Dam crest elevation) were computed using code written by the Sedimentation Group in ArcMap. The 2015 surface areas from AcrMap provided input information from elevation 1,454 feet and below for the computation of the 2015 areas and capacities.

2015 Storage Capacity Methods

The storage-elevation relationships based on the measured surface areas were developed using the area-capacity computer program ACAP (Reclamation, 1985). The ACAP program computes 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 (error limit set at 0.000001 for Cheney 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 used 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:

$$V = A_1 + A_2(y - y_b) + A_3(y - y_b)^2$$

where: V = storage capacity (acre-feet)
y = reservoir elevation
y_b = reservoir elevation at bottom of elevation increment
A_1 = intercept and storage capacity at elevation y_b (acre-feet)
A_2 = surface area at elevation y_b (acres) and coefficient for linear rate of increase in storage capacity
A_3 = coefficient (feet) for nonlinear rate of increase in storage capacity

The reservoir surface area is computed from the derivative of the volume equation:

$$S = A_2 + 2A_3(y - y_b)$$

where: S = surface area (acres)

Results of the Cheney Reservoir area and capacity computations were delivered in a separate set of 2015 area and capacity tables for 0.01, 0.1, and 1-foot elevation increments (Collins, 2019). A description of the computations and coefficients output from the ACAP program is included with those tables. Area-capacity tables are available in the Cheney Dam and Reservoir vertical datum, confirmed to be equivalent to NGVD29.

Surface Area and Storage Capacity Results

Results of the 2015 Cheney Reservoir area and capacity computations are summarized in Table 1 and plotted in Figure 22. The 2015 Sedimentation Group bathymetric survey measured a surface area of 26,185 acres and a storage capacity of 744,515 acre-feet at dam crest elevation 1,454.0 feet. At top of flood control pool elevation 1,429.0 feet, the 2015 survey measured surface areas and storage capacities of 13,221 acres and 262,736 acre-feet respectively.

Table 1. 2015 Areas and Capacities at Various Elevations

Elevation (NGVD29-feet)	Surface Area (acres)	Storage Capacity (acre-feet)	
1377.0	0	0	
1378.0	0	0	
1378.5	0	0	Top of Dead
1379.0	0	0	
1380.0	25	13	
1385.0	706	1697	
1390.0	1496	7266	
1392.9	1963	12270	Top of Inactive
1395.0	2430	16846	
1400.0	3541	31751	
1405.0	4822	52615	
1410.0	6271	80292	
1415.0	7928	115733	
1420.0	9690	159983	
1421.6	10284	176027	Top of Active Conservation
1425.0	11597	213122	
1429.0	13221	262736	Top of Flood Control
1430.0	13624	276158	
1435.0	15855	349702	
1440.0	18291	435082	
1445.0	20925	533019	
1450.0	23766	644653	
1453.4	25812	728916	Top of Surcharge
1454.0	26185	744515	Top of Freeboard

Comparison of Original 1964 and 2015 Areas and Capacities

According to Reclamation's Project Data Book (US Water and Power Resources Service, 1981), the original 1964 surface area of Cheney Reservoir at top of flood control pool elevation 1,429.0 feet was 12,417 acres with a storage capacity of 247,930 acre-feet. The 2015 Reclamation survey measured an area of 13,221 acres and storage capacity of 262,736 acres at that same elevation. Rather than an actual increase in area and capacity occurring at Cheney Reservoir since dam closure in 1965, larger values computed in 2015 can likely be attributed to different topographical survey and data analysis methods. Although it is uncertain how the original areas and capacities were derived, it is highly likely that 2010 and 2015 values were computed from a far denser data set than was originally available. Interpolation of data between surveyed areas can result in misrepresentation of reservoir bottom geometry. Low spots between survey lines may have been missed in the original survey. The 2015 areas and capacities were computed directly from the 3-dimensional surface, then used as input to the ACAP program.

The 2015 area and capacity computations included all tributaries, coves, and side channels below elevation 1,454.0 feet. It is unknown if these areas connected to the reservoir main body, that would be inundated at higher water surface elevations were included in the original survey and area-capacity calculations. Areas and capacities computed in the 2015 analysis compared closely to 2010 areas up to elevation 1,420.7 (highest elevation of 2010 KBS data published in 2012 report), further validating the 2015 results.

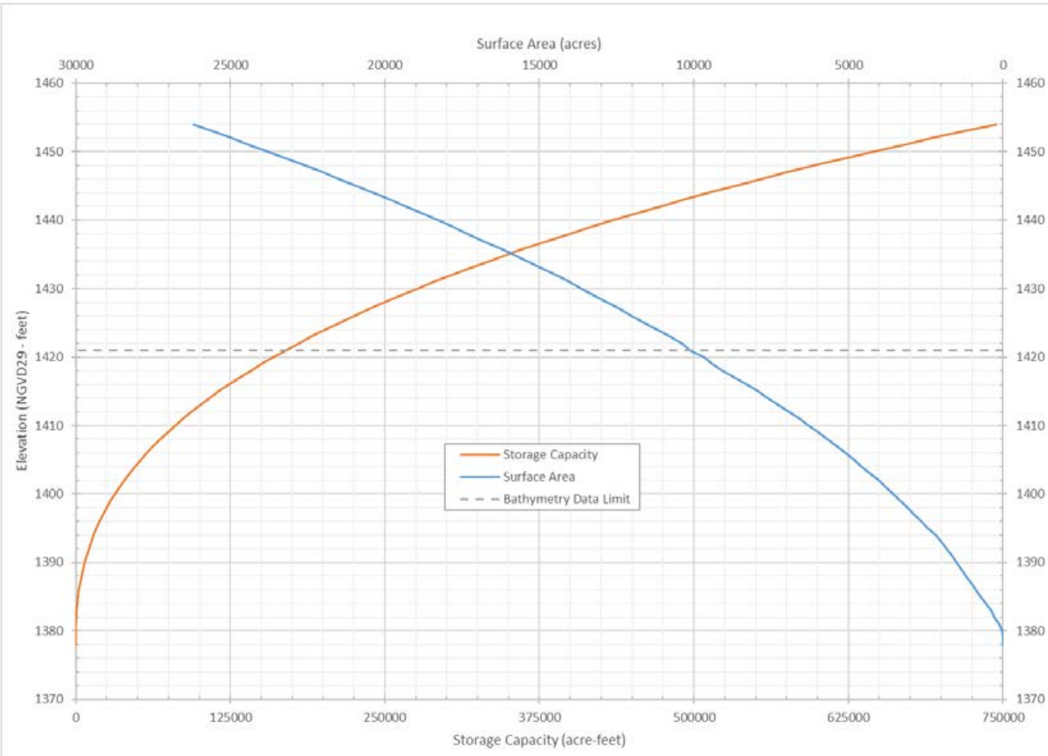

Figure 22. 2015 area and capacity plots for Cheney Reservoir.

Comparison of KBS and 2015 Areas and Capacities

As illustrated in the sediment range plots (Figure 12 through Figure 21), the 2015 bathymetry matched the 2010 data very closely. The 2010 survey resulted in a measured capacity of 167,006 acre-feet at elevation 1420.7 feet (NGVD29) while the 2015 survey measured a capacity of 166,877 acre-feet at the same elevation, a difference of only 129 acre-feet, equivalent to 0.08 percent of the reservoir capacity at that elevation. Such a minor difference in capacity may be unmeasurable given the equipment and techniques used in the 2010 and 2015 surveys and analyses. The majority of the change in volume computed between 2010 and 2015, if the change is indeed real, appears to have occurred between elevation 1410 and 1420. The smaller volume calculated in 2015 may be explained by several factors:

- As mentioned above, the 0.08 percent difference in capacity between 2010 and 2015 is well within accuracy of the respective surveys and analyses.

- During the 2015 survey, bathymetry data were collected upstream of the upmost cross section collected in 2010. Interpolation of 2010 bathymetry between the most upstream cross section and shoreline data may have slightly misrepresented the geometry in the areas not measured in 2010.

- A small amount of sediment deposition may have actually occurred in the upper reservoir since 2010. In August 2013, Cheney Reservoir experienced the highest month of recorded inflow since the dam closed in 1965. These high inflows were likely the cause of most of the deposition that occurred between 2010 and 2015.

- Although both analyses used the same GIS software, ArcGIS, different surface development/interpolation techniques were likely used in 2010 and 2015.

- Different area-capacity computation programs were used in 2010 and 2015. KBS used a program called Applied Science and Technology for Reservoir Assessment (ASTRA) for computation of the 2010 areas and capacities (KBS, 2012). In 2015, the Sedimentation Group used an ArcGIS area and volume tool (developed in house) to generate input to Reclamation's ACAP program.

According to Reclamation's Project Data Book, 929 acre-feet of dead storage existed below elevation 1,378.5 when Cheney Dam closed in 1965. The 2015 Reclamation bathymetric survey measured a minimum bottom elevation of 1,379.0 feet near the dam and results of the 2015 area-capacity computations indicate no storage exists below that elevation. Based on the original design data and 1964 survey, and the 2010 and 2015 measurements, it is estimated that the dead storage is completely full of sediment, meaning at least 929 acre-feet of deposition has occurred since dam closure. Due to differences in survey, data processing, and computational methods, comparison of 1964 to 2010 and 2015 data to determine changes in surface area and capacity throughout the full range of reservoir elevations is invalid.

Conclusions

This report presents the results of the June 2015 survey of Cheney Reservoir conducted at average water surface elevation 1423.2 feet. There were three primary objectives of the 2015 Reclamation bathymetric survey:

1. **Validate results of 2010 KBS survey**. KBS comparison of the 2010 KBS survey data to previous surveys (1964 - Original, 1993 - Reclamation, 1998 – USGS) at predefined sediment ranges indicated little-to-no sediment deposition since the dam closed in 1965. However, comparison of the 1998 USGS and 2010 KBS surveys near the dam indicated nearly 30 feet of erosion along the upstream face. In their 2012 report, KBS attributed that

difference to differences in bathymetric survey density rather than actual erosion of material at the dam. The 2015 Reclamation survey confirmed the 2010 KBS results in that area, indicating no change against the dam. Survey data density was much more similar in the 2010 KBS and 2015 Reclamation surveys than in the 1998 USGS survey;

2. **Identify areas of significant change** – The Sedimentation Group was requested to collect data necessary to identify areas of Cheney Reservoir where sediment had deposited since the previous survey in support of a decision to determine if a complete bathymetric survey was needed.

3. **Compute updated area-capacity tables and extend up to elevation 1454.0**.

A control survey was conducted using previously established survey markers with known coordinates and RTK GPS to establish horizontal and vertical control near the reservoir for the hydrographic survey. The GPS base was set over a brass cap on top of a pipe (CR37-A, Figure 4) near the east end of Range 5 (Figure 3) where it provided continuous radio link throughout the bathymetric survey. Existing control points, water surface elevations, and hard points on the dam were measured during the survey to reference the 2015 data to the Cheney Dam vertical datum (NGVD29) and NAVD88.

The horizontal control for the 2015 survey and analysis was in NAD83 state plane coordinates, Kansas South Zone (1502), in US survey feet. Vertical control was in NAVD88, Geoid 12A, US survey feet, which was confirmed to be 0.48 feet higher than NGVD29. All 2015 elevations were converted to NGVD29 during post processing. Unless noted, all elevations and the developed reservoir topography presented in this report are referenced to NGVD29.

The 2015 Cheney Reservoir bathymetric survey was conducted using a multibeam sonar interfaced with RTK GPS to determine sounding locations within the reservoir. The system continuously recorded depth and horizontal coordinates as the survey boat navigated along gridlines covering the reservoir. The GPS provided information to allow the boat operator to maintain a course along these gridlines. In addition to the gridlines, a partial pass was made around the perimeter of the reservoir to map the shallow areas near the shore. The bathymetric survey extended from the dam upstream near Range 11 (Figure 10).

Above the multibeam bathymetry data, the 2015 topography was developed from LiDAR provided by the State of Kansas. A single beam bathymetric survey conducted by the Kansas Biological Survey in 2010 resulted in a data set with far greater coverage than the 2015 Reclamation survey. Due to the bathymetric coverage and the minimal change measured between 2010 and 2015 in overlapping areas, the 2010 KBS bathymetry was used for the majority of the underwater mapping during the 2015 analysis. Reclamation's June 2015 bathymetry was used to represent the underwater areas not surveyed in 2010. The processed data used to generate the 2015 topography maps is available for download on the TSC website: www.usbr.gov/tsc/techreferences/reservoir.html.

Reclamation's ACAP program was used to compute updated areas and capacities for Cheney Reservoir. The data set used for the 2015 computations was a combination of 2010 KBS and 2015 Reclamation bathymetry up to elevation 1,421, 2010-2015 LiDAR from 1,421 up to dam crest elevation 1,454 feet.

The 2010 and 2015 data measured capacity increase since the original 1964 analysis. The larger capacities measured in 2010 and 2015 are not likely actual increases in storage, but rather result from differences in data density and survey, data processing, surface development, and computational methods. The 2015 analysis resulted in a surface area and storage capacity of 10,284 acres and 176,027 acre-feet respectively at top of active conservation pool elevation 1,421.6 feet. At top of flood control pool and spillway crest elevation 1,429.0 feet, a surface area of 13,221 acres and a storage capacity of 226,973 acre-feet were measured in 2015.

Comparison of sediment range plots in areas accessible by boat during the 2010 and 2015 bathymetric surveys indicate only very minor changes in reservoir bottom elevation have occurred since 2010. The sediment range plots in Figure 12 through Figure 21 show that 1 to 2 feet of deposition, likely fine sediment, may have occurred primarily in the former river channel between 2010 and 2015.

Based on the similarity in the results of the 2010 and 2015 bathymetric surveys and analyses, and the reasonable explanation of the differences, dam operators should consider using the 2015 areas and capacities for future facility water management decisions.

A resurvey should be scheduled in the future if a significant change in the sediment basin runoff is noted. Changes in sediment delivery to the reservoir can be caused by construction activities or significant changes in operations, basin hydrology, land use practices, or sediment supply (landslide, fire, etc.). It is recommended that any resurvey of Cheney Reservoir include a bathymetric survey when reservoir levels are relatively high and collection of aerial data (photogrammetry, LiDAR, Interferometric Synthetic Aperture Radar ([IFSAR], etc.) or land survey data when water levels are relatively low, exposing the sediment delta and providing the maximum overlap between the above water and underwater data.

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