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Scientific Investigations Map 3467
Sheet 1 of 2

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Abstract

The U.S. Geological Survey (USGS), in cooperation with the Grand River Dam Authority, completed a high-resolution multibeam bathymetric survey to compute a new area and capacity table for Grand Lake O’ the Cherokees in northeastern Oklahoma. Area and capacity tables identify the relation between the elevation of the water surface and the volume of water that can be impounded at each water-surface elevation. The area and capacity of Grand Lake O’ the Cherokees were computed from a triangular irregular network surface created in Global Mapper Version 21.0.1. The triangular irregular network surface was created from three datasets: (1) a multibeam mapping system bathymetric survey of Grand Lake O’ the Cherokees completed during April–July 2019, (2) a previous bathymetric survey of the Neosho, Spring, and Elk Rivers, and (3) a 2010 USGS lidar-derived digital elevation model. The digital elevation model data were used in areas with land-surface elevations greater than 744 feet above the North American Vertical Datum of 1988 where the multibeam sonar data could not be collected. The 2019 multibeam sonar data were the predominant data used to compute the new area and capacity table for Grand Lake O’ the Cherokees.

Introduction[1]

In February 2017, the Grand River Dam Authority (GRDA) filed a Pre-Application Document and Notice of Intent for relicensing the Pensacola Hydroelectric Project with the Federal Energy Regulatory Commission (FERC). The predominant feature of the Pensacola Hydroelectric Project (FERC license number 1494; GRDA, 2017) is Pensacola Dam, which impounds Grand Lake O’ the Cherokees (known locally and hereinafter referred to as “Grand Lake”) in northeastern Oklahoma. Identification of information gaps and assessment of project effects on stakeholders are central aspects of the FERC relicensing process (FERC, 2012). One of the information gaps is that a complete area and capacity table has not been produced since 1940. Area and capacity tables identify the relations between the elevation of the water surface and the volume of water that can be impounded at each water-surface elevation.

In the 80-year history of Grand Lake, only four area and capacity tables have been developed. The first area and capacity table was developed in 1940 by the U.S. Army Corps of Engineers (USACE) when the Pensacola Dam was built, spanning water-surface elevations from 612.33 to 758.33 feet (ft) (values adjusted to feet above the North American Vertical Datum of 1988) (NAVD 88) (Hunter and others, 2020). An updated area and capacity table was published in 1949, spanning water-surface elevations from 714.33 to 754.43 ft above NAVD 88 (Hunter and Labriola, 2019). In 2009, the Oklahoma Water Resources Board (OWRB) calculated a third area and capacity table, spanning water-surface elevations from 613.46 to 746.46 ft above NAVD 88 (OWRB, 2009). The fourth and most recent area and capacity table (Hunter and Labriola, 2019) was produced in 2019 by combining the bathymetric survey of Grand Lake (OWRB, 2009, 2016) and the 2017 U.S. Geological Survey (USGS) bathymetric survey of the Neosho, Spring, and Elk Rivers (Hunter and others, 2017; Smith and others, 2017). The area and capacity table for the 2019 study spanned water-surface elevations from 612 to 759 ft above NAVD 88. Although the Hunter and Labriola (2019) area and capacity table was published in 2019, it was produced by combining data obtained during 2009 and 2017, with most of the bathymetry data collected in 2009. Because the majority of the data used to compute the area and capacity table in Hunter and Labriola (2019) were more than 10 years old, it was determined that an up-to-date area and capacity table was needed and that the best way to achieve this goal was to complete a new bathymetric survey.

Over time, the capacity of reservoirs to store water decreases as the sediment load carried by the impounded river(s) is deposited on the lakebed and as the water-surface elevation associated with a given surface area of the reservoir changes (OWRB, 2009; Hunter and others, 2017). Because of this natural phenomenon, updated area and capacity tables are periodically needed to identify the volume of water that a reservoir can hold at any given elevation. Stakeholders need an updated version of the area and capacity table for Grand Lake to assist in making informed decisions for project operations and floodplain management. The stakeholders in the study area include the GRDA, USACE, and citizens living on property bordering Grand Lake and its tributaries. The data from USGS streamgage 07190000, Lake O’ the Cherokees at Langley, Okla. (USGS, 2019), along with the updated area and capacity values presented in this report, can be used by the GRDA and USACE when making decisions about the management of the lake.

Purpose and Scope

This report presents an updated area and capacity table for Grand Lake featuring bathymetric data collected in 2019 and augmented by previously collected data. Descriptions of the equipment and methods that were used are included. The updated area and capacity values are summarized and depicted in the report and are available in complete digital form in an associated data release (Hunter and others, 2020). The results of this bathymetric survey are compared with previous bathymetric surveys of Grand Lake.

Description of the Study Area[1]

Grand Lake spans parts of Craig, Delaware, Mayes, and Ottawa Counties in northeastern Oklahoma and is the third largest reservoir in terms of surface area and capacity in the State (OWRB, 2015). Three major rivers in Oklahoma flow into Grand Lake: the Neosho, Spring, and Elk Rivers (fig. 1). The Neosho River and its tributaries are impounded by Pensacola Dam to form Grand Lake. Pensacola Dam spans 1 mile between the communities of Langley and Disney, Okla. (fig. 1). The hydroelectric energy produced by the lake is distributed to citizens in 75 of the 77 counties in Oklahoma (GRDA, 2015). Elevation data compiled by Grand Lake project engineers are referenced to a local datum established by the USACE for the Pensacola Dam referred to as the “Pensacola Datum” (PD). The PD has been used since the construction of the dam in March 1940 and can be converted to National Geodetic Vertical Datum of 1929 (NGVD 29) by adding 1.07 ft (USACE, 2018a) and to NAVD 88 by adding 1.40 ft (National Geodetic Survey [NGS], National Oceanic and Atmospheric Administration [NOAA], 2018) (fig. 2).

Grand Lake has seasonal conservation pool elevations. Pending environmental conditions, elevations of the top of the conservation pool (referenced to the PD) are as follows:

- May 1–31 (start of the annual season), 742.0 to 744.0 ft;
- June 1–July 31, 744.0 ft;
- August 1–15, 744.0 to 743.0 ft;
- August 16–September 15, 743.0 ft;
- September 16–30, 743.0 to 742.0 ft;
- October 1–April 30 (winter conservation pool elevation), 742.0 ft.

The top of the dam is 757.00 ft above PD or 758.40 ft above NAVD 88 (USACE, 2018b) (fig. 2).

Methods of Bathymetric Survey and Data Analysis

A bathymetric survey of Grand Lake was completed between April 1 and July 31, 2019. The methods and tools used in this study were similar to those described in Richards and others (2019) and Huizinga and others (2019). During data collection, the water-surface elevation of the lake ranged from a minimum elevation of 741.79 ft above PD on April 30, 2019, to a maximum elevation of 755.08 ft above PD on June 24, 2019, which was only 0.19 ft less than the peak of record for the lake (07190000; USGS, 2019). The extreme high-water-surface elevations in Grand Lake culminating with the maximum elevation of 755.08 ft in June 2019 facilitated the collection of a more extensive set of multi-beam bathymetric data than would have been possible if the lake had been at more typical water-surface elevations during the survey.

Bathymetric Data Collection

The multibeam mapping system (MBMS) used for sonar data collection of depths and positions (fig. 3; see sheet 2) consists of several different components that work together to output a high-resolution point-cloud dataset: the multibeam echosounder (MBES), an inertial navigation system (INS), and a data-collection and data-processing computer. The MBES used in this survey was a 400-kilohertz NORBIT iWBMSh mounted on a manned boat (NORBIT, 2014a). The iWBMSh has a curved array that allows data to be collected in a swath out to 210 degrees, meaning from nadir (directly below the MBES) to 105 degrees to either side. During this survey, most data were collected by using a swath of 140 degrees, but shallow areas were surveyed with 150-degree swaths. Even though most data were collected at 140- and 150-degree swaths, the iWBMSh can collect quality data from swaths as large as 160 degrees, although limiting the beam width reduced noise on the outer edges of the swath in some instances. The NORBIT iWBMSh swath also can electronically tilt the curved array allowing the user to accurately survey sloped banks or shallow areas up to the water surface in some instances.

The next component in the MBMS was the INS. The INS used in this survey was the Applanix OceanMaster (Applanix Corporation, 2017). The INS provides the position location of the survey vessel in three-dimensional space. The INS simultaneously measures heave, pitch, roll, and heading of the watercraft during the survey.

The MBES data were collected and stored by using HYPACK/HYSWEEP software (HYPACK, Inc., 2019). The MBES was mounted to a NORBIT Portus Pole made of flex-free carbon fiber (NORBIT, 2014b). The flex-free carbon fiber pole limited expansion and contraction, which provided repeatable offsets between the multibeam head and the global positioning system antennas during the survey.

Real-time navigation was guided by using global navigation satellite systems (GNSS) with two GNSS antennas mounted on the Portus Pole. These data were collected in real time on the boat and then were postprocessed using the POSPac Mobile Mapping Suite (MMS) software (Applanix Corporation, 2020). POSPac MMS is software that identifies and corrects sensor and environmental errors that occur during data collection. POSPac software blended the raw data with values collected by Applanix SmartBase (ASB) postprocessed virtual reference stations through a subroutine known as Applanix PP-RTX (Applanix Corporation, 2019). Once the data were blended, POSPac output a “smoothed best estimate of trajectory,” or “SBET” file. This SBET file was then used as the navigation data from each day to provide the best possible trajectory of the boat. The SBET file was coupled with the depth data from the MBES to correctly position the MBES data in three-dimensional space.

In a bathymetric survey, the velocity of sound in water must be known in order to accurately calculate depth based on acoustic wave two-way travel time. For this survey, a series of sound velocity casts were collected by using an AML Oceanographic Base X_2 sound velocity profiler (SVP) (AML Oceanographic, 2020). Casts were collected once an hour at different locations to determine the velocity of sound throughout the water column at various locations. These data were then applied to the MBES data during postprocessing.

The bathymetric survey preparation and data collection were completed using HYPACK/HYSWEEP software (HYPACK, Inc., 2019). Once data collection was completed, data were visualized in HYPACK/HYSWEEP as a point cloud. This point cloud was georeferenced using the SBET file provided by POSPac. After the data were georeferenced, they were further corrected by the removal of extreme outliers (data spikes) and the application of sound velocity and patch test corrections (Huizinga, 2017). The georeferenced data were output to a comma-delimited file (CSV) where the data were filtered and reduced to a 3.28-ft data resolution, which were used for bathymetric surface and contour map creation. The georeferenced data, associated metadata, and shapefiles (Blue Marble Geographics, 2019) are provided in Hunter and others (2020).

Surveying revealed several interesting features on the lakebed, including what appeared to be several sunken boats. During the 1930s, several small communities were evacuated in order to create this lake; the displaced populace left behind homes, businesses, and other structures. The foundations of many of those structures were evident in the MBES data. A notable finding was a large cavity in the lakebed close to the entrance of Duck Creek (fig. 1). This cavity measured about 10 ft wide, 25 ft long, and 90 ft deep. When the lake is at summer conservation pool elevation of 744.00 ft, the total depth over this cavity exceeds 130 ft.

Bathymetric Surface and Contour Map Creation

A bathymetric surface was derived from a triangulated irregular network (TIN) created in Global Mapper Version 21.0.1 (Blue Marble Geographics, 2019) using multibeam sonar data collected during this study, a 4-ft-resolution single-beam sonar elevation raster for the Spring and Neosho Rivers and a 2-ft resolution for the Elk River (Hunter and others, 2017), a 1/9 arc-second light detection and ranging (lidar) digital elevation model (DEM) completed in 2010 near Grand Lake (USGS, 2012), and a lidar dataset in the LASer (LAS) data format used for three-dimensional point lidar cloud data (USGS, 2014; Arms and others, 2020). The LAS dataset was used to supplement points along Pensacola Dam to better define elevations. Centroids from the single-beam sonar rasters and the lidar DEM were extracted and used to supplement the creation of the bathymetric surface. For this survey, the vertical datum was the NAVD 88 using the geoid model GEOID12b (National Geodetic Survey, 2017), and the horizontal datum was the North American Datum of 1983 (NAD 83). The DEM data were used in areas with land-surface elevations above 744 ft above NAVD 88 where the multibeam data could not be collected. With the 2019 multibeam sonar data representing the predominant source of data, the area and capacity data documented by this report reflect lake conditions during 2019 when the multibeam data were collected.

Linear enforcement (Wilson and Richards, 2006) was used to define areas with steep topography, areas with V-shaped stream channels bordering the lake, and areas with gaps between the lidar data and multibeam data. Linear enforcement was primarily used along gaps between the multibeam sonar data and the lidar data to enforce steep topography that would otherwise be interpolated as flat by the TIN algorithm. Linear enforcement entailed generating linear vectors and linearly interpolating points along those vectors. End points of each linear vector were used to extract elevation values from either the multibeam data or lidar data. Elevations were interpolated from the minimum elevation to the maximum elevation. These points were then used to calculate the bathymetric surface.

Contour lines were generated at 2-ft intervals from the bathymetric TIN surface. Contour lines were then filtered to remove small, closed contour lines that did not affect the lake capacity depicted by the contour map and only distracted from the visual appearance of the map. Small, closed contours of less than 1,000 ft in length were removed from the contour lines for the multibeam data below 743 ft. For the lidar data, contour lines above 743 ft in elevation and less than 300 ft in length were also removed. Contours were filtered to improve the visual appearance of contour lines without affecting the lake capacity depicted by the contour map (fig. 3; see sheet 2).

Bathymetric Data-Collection Quality Assurance

The bathymetric data-collection quality was assessed in real time while collecting data. The MBMS chief operator continually monitored the data as it was being collected. The operator monitored the MBES screen as well as the INS screen looking for inconsistencies and alarms that would reveal bad data collection or loss of satellite connection. The overlapping transects were also monitored for inconsistencies. The real-time quality assurance was part of the data screening in addition to collection of beam-angle checks and patch tests to maintain data integrity. Uncertainty estimations were also computed from those data that were collected to help quantify the accuracy of the survey results.

Beam-Angle Check

The beam-angle check is required to verify that the MBES is operating within the USACE-approved standards, particularly in the outer beams (greater than 25 degrees from nadir [vertical]) of the MBES. The beam-angle check was done at the beginning of this project and was completed following guidance set by the USACE; the results were within the recommended performance standards described by the USACE (USACE, 2013).

Patch Tests

For this bathymetric survey, patch tests were conducted on the first and last day of data collection. A patch test is a calibration test that is used to identify and correct for systematic errors that might be created by the mounting angle, timing, or position of the MBES with respect to the INS. After the initial offsets from a patch test are determined, they usually remain consistent, with the exception of an event that would change how the system is mounted, such as striking underwater or floating debris (Huizinga, 2017). The offsets provided by the patch test are used during post processing of the data. Proper calibration will yield consistent bathymetric results despite varying boat orientation, speed, and motion. The patch tests from the beginning and end of this survey were consistent, showing no systematic changes.

Uncertainty Estimations

Uncertainty associated with this bathymetry survey was estimated by computing the total propagated uncertainty (TPU) as described in Huizinga (2010, 2017). The TPU was calculated for each 3.28-ft (1 meter) survey-grid cell by using the Combined Uncertainty and Bathymetry Estimator (CUBE) method (Calder and Mayer, 2003; Richards and Huizinga, 2018). The CUBE method allows all random system component uncertainties and resolution effects to be combined and propagated through the data processing steps, thereby providing a robust estimate of the spatial distribution of possible uncertainty within the survey area. Thus, when all relevant error sources are considered, the TPU of a point is an estimate of the accuracy to be expected for such a point (Czuba and others, 2011; Richards and Huizinga, 2018). More than 95 percent of the TPU values were less than 0.30 ft, which is within the most stringent specifications for an International Hydrographic Organization (IHO) Special Order survey (IHO, 2008). The median TPU value of the data was about 0.07 ft. The largest TPU in this survey was 2.48 ft (fig. 4). The higher uncertainties were located near high relief features or along edges of transects where MBES side-lobe data were collected, which typically are sources of noisier data (Richards and Huizinga, 2018).

The process to create a raster dataset from various inputs with different resolutions requires resampling to incorporate all of the data into a single file with a single resolution. This process will create minor differences between the input and output raster datasets, which typically resulted in reduced resolution (larger cell size) compared to higher resolution (smaller cell size) raster datasets (Lowell and Jaton, 2020). Information provided in the data release associated with this publication helps illustrate some of the resampling differences between the raster dataset in this data release (Hunter and others, 2020) and the raster datasets used as inputs to generate a bathymetric surface along the Neosho, Elk, and Spring Rivers (Hunter and others, 2017).

Bathymetric Surface and Contour Quality Assurance

A quality-assurance (QA) dataset was created from the multibeam dataset generated from random points distributed throughout the survey area. These data were removed from the multibeam dataset and compared to data from the final TIN for QA and accuracy. The QA dataset consisted of about 4.2 percent (about 6.8 million points) of the total multibeam dataset. The QA data points were then used to extract elevation values from the TIN to compare the difference between the QA dataset and the TIN. Calculated error was about 0.47 ft at the 95th-percentile value for the approximately 6.8 million points in the QA dataset (Hyndman and Fan, 1996; Huizinga and others, 2019). A 1-ft buffer was generated around each contour line, and QA multibeam points were extracted from this buffer. The contour elevations were used to compare elevations to the QA dataset. Calculated error was 1.77 ft at the 95th-percentile value for the approximately 6.8-million-point QA dataset (Hyndman and Fan, 1996; Huizinga and others, 2019).

Bathymetry, Surface Area, and Capacity Results

The surface area and capacity data calculated in this study are reported in table 1, and the previous calculated capacities are graphed in figure 5, along with the capacities calculated as part of this study, for comparison. These newly calculated capacities are slightly less than those derived from the previous area and capacity tables (OWRB, 2009; Hunter and Labriola, 2019). At the conservation pool elevation of 743.40 ft above NAVD 88, the area and capacity table from 1940 gives the interpolated capacity of 1,584,600 acre-feet (acre-ft) (Hunter and others, 2020). The more recent hybrid 2009/2017 table gives a capacity of 1,424,400 acre-ft (Hunter and Labriola, 2019), and the calculated capacity table for this study gives a capacity of 1,307,300 acre-ft. At the top of the dam elevation of 758.40 ft above NAVD 88, the capacities were 2,387,400 acre-ft in 1940 (Hunter and others, 2020), 2,183,200 acre-ft in the hybrid 2009/2017 study (Hunter and Labriola, 2019), and 2,067,600 acre-ft for this study.

The capacity in Grand Lake has gradually decreased over time. Total capacity between the hybrid 2009/2017 capacity table that mostly consisted of data collected in 2009 and the capacity table from this study decreased by about 117,100 acre-ft (about −8.2 percent) at the conservation pool elevation of 743.40 ft above NAVD 88 and decreased by about 115,600 acre-ft (about −5.3 percent) at the top of the dam elevation of 758.40 ft above NAVD 88 (fig. 5). The interpolated 1940 capacity is 2,387,400 acre-ft at an elevation of 758.40 ft above NAVD 88, whereas the 2019 capacity is 2,067,600 acre-ft at an elevation of 758.40 ft above NAVD 88. The capacity of Grand Lake at conservation pool elevation has decreased about 277,300 acre-ft since 1940, and the capacity at the top of dam elevation has decreased about 319,800 acre-ft since 1940.

As explained in the Introduction of this report, reservoirs slowly impound sediment carried by the rivers that drain into them, thus losing capacity over time. Although the methods used to collect data in 1940 are unknown (Hunter and Labriola, 2019), the multibeam data collected in the 2019 survey of Grand Lake are likely of much higher resolution and accuracy than previously collected bathymetry data (OWRB, 2009) because of technological advancements in the tools and methods used to collect bathymetric data. In addition, differences in data collection methods among 1940 (unknown), 2009 (single-beam sonar), 2009/2017 hybrid (single-beam sonar), and 2019 (multi-beam sonar) may have contributed to perceived changes in the capacity of Grand Lake. The single-beam sonar data collected in 2009 were collected along transects spaced about 300 ft apart, but the data density of the multi-beam sonar data was far greater in most areas. The multi-beam survey used a POS MV Ocean Master to correct for pitch, roll, and yaw of the survey boat (Applanix 2017). Failure to dynamically correct for these variables during data collection activities in previous surveys would increase calculated depths relative to this survey because any movement of the survey boat will cause the sonar beam to deviate from vertical, increasing the beam travel distance and thus overestimating depth for a surface with relatively flat topography (L-3 Communications SeaBeam Instruments, 2000). The Grand Lake lakebed consists of mostly flat topography (as illustrated by widely spaced contours [fig. 3; see sheet 2]). Previous surveys likely did not correct for boat movement to the same precision as this survey, and some of the reduced capacity could be attributed to this difference in data-collection techniques.

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[1] This section is modified from Hunter and Labriola (2019).

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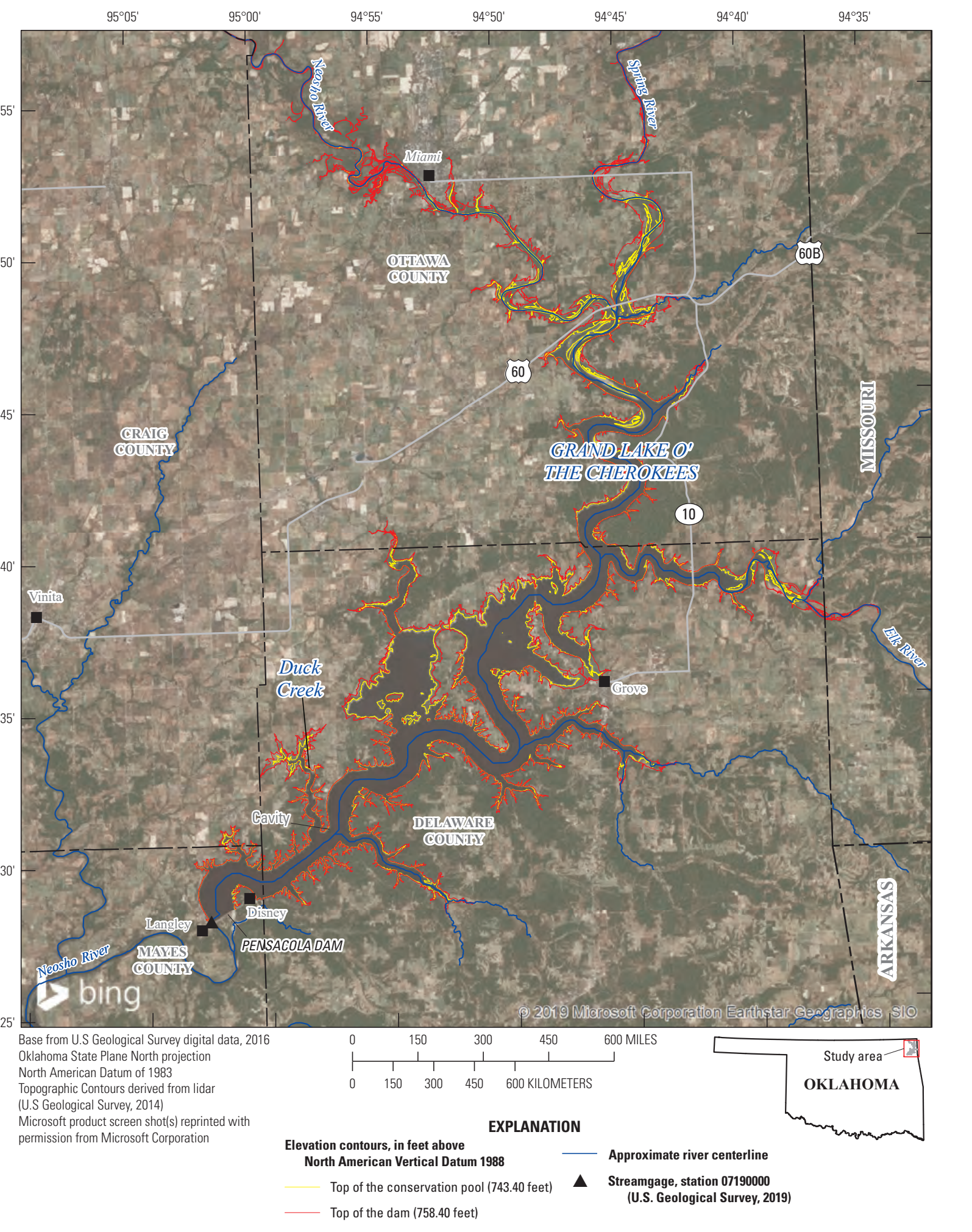

Base from U.S Geological Survey digital data, 2016
Oklahoma State Plane North projection
North American Datum of 1983
Topographic Contours derived from lidar
(U.S Geological Survey, 2014)
Microsoft product screen shot(s) reprinted with
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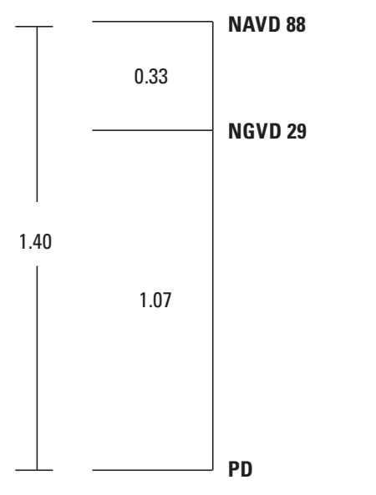
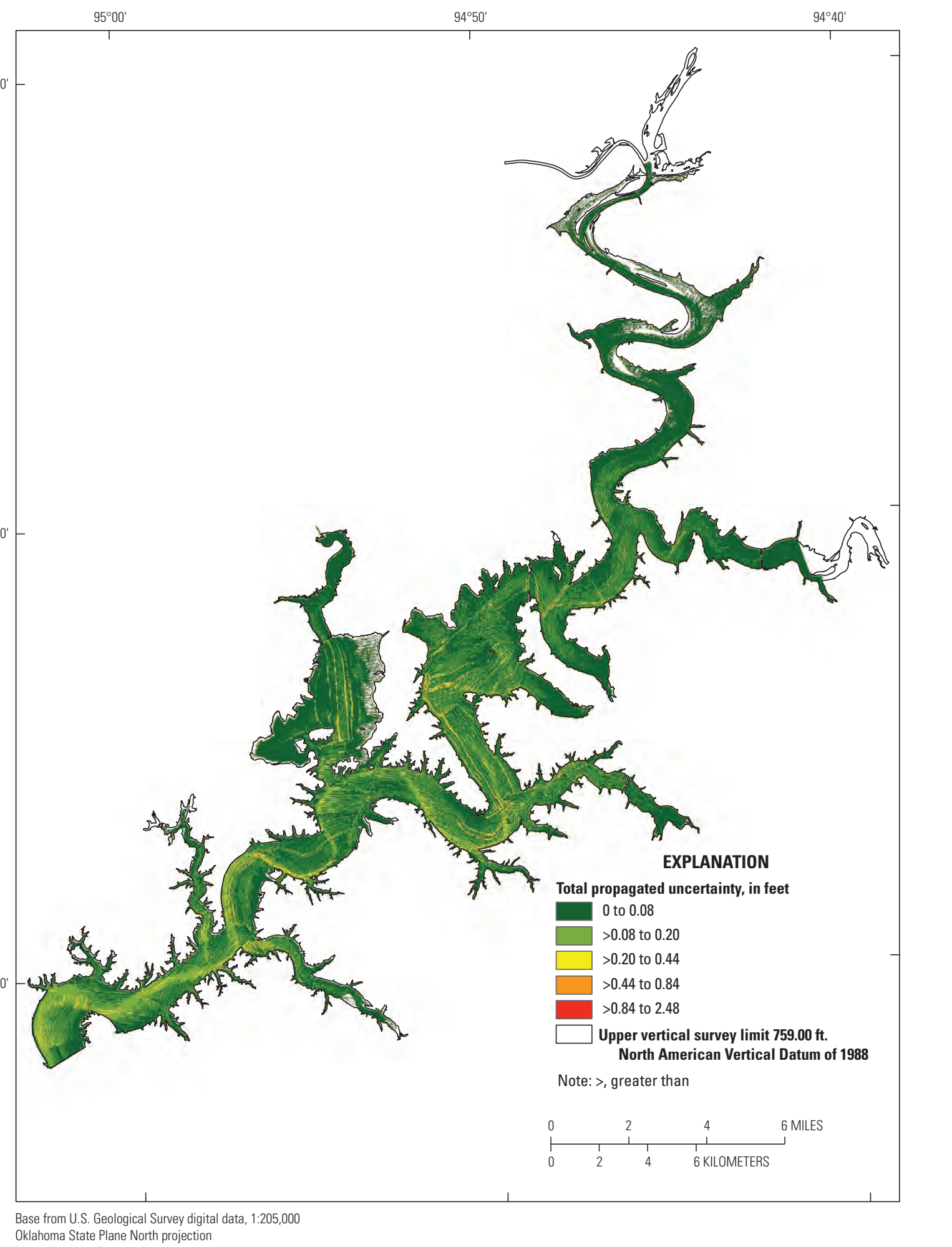
Figure 1. Elevation contours for the top of the conservation pool and top of the dam, Grand Lake O’ the Cherokees, northeastern Oklahoma. Modified from figure 1 in Hunter and Labriola (2019).



	Elevations, in feet		
	NAVD 88	NGVD 29	PD
Conservation pool	743.40	743.07	742.00
Top of the dam	758.40	758.07	757.00

Figure 2. Datum transformations and conversions for the North American Vertical Datum of 1988 (NAVD 88), National Geodetic Vertical Datum of 1929 (NGVD 29), and Pensacola Datum (PD) used in the computation of area and capacity for Grand Lake O’ the Cherokees, northeastern Oklahoma. Reprinted from Hunter and Labriola (2019).



Base from U.S. Geological Survey digital data, 1:205,000
Oklahoma State Plane North projection
North American Datum of 1983

Figure 4. Extent of multibeam bathymetric data collected in 2019 and the total propagated uncertainty pertaining to the collected data, Grand Lake O’ the Cherokees, northeastern Oklahoma.

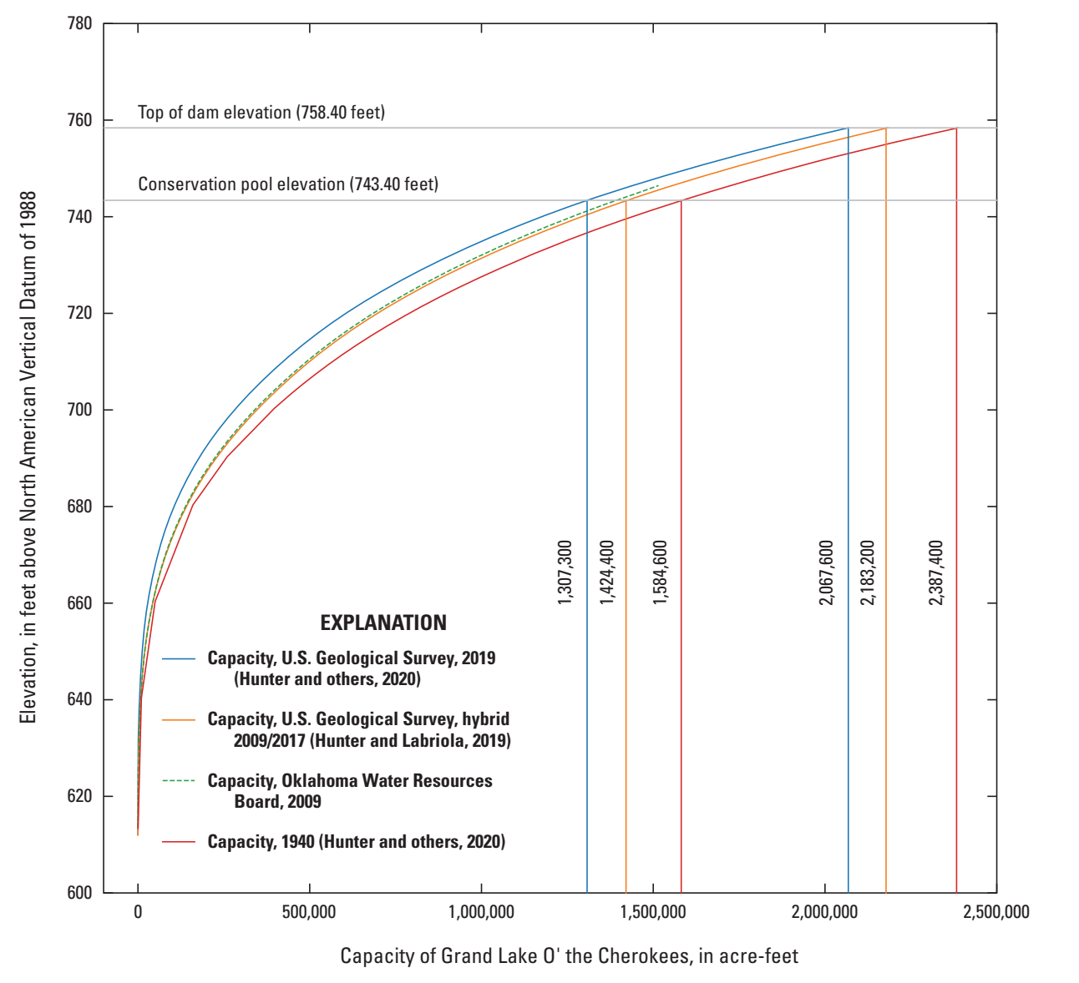


Figure 5. Capacity of Grand Lake O’ the Cherokees as calculated with elevation data from 1940, from the Oklahoma Water Resources Board (2009), from the U.S. Geological Survey hybrid 2009/17 study (Hunter and Labriola, 2019), and from bathymetric data collected in 2019 and compiled for this study. Modified from figure 4 in Hunter and Labriola (2019).

Table 1. Surface area and capacity at specified water-surface elevations for Grand Lake O’ the Cherokees in northeastern Oklahoma from a bathymetric survey completed during April 1–July 31, 2019, augmented with previously collected single-beam sonar data and lidar point-cloud data.

[ft, feet; NAVD 88, North American Vertical Datum of 1988; winter conservation pool elevation is 742.0 ft above Pensacola Datum, 743.4 ft above NAVD 88, and the top of dam elevation is 757.0 ft above Pensicola Datum, 758.4 ft above NAVD 88]

Water-surface elevation,[1] in ft	Water-surface elevation,[2] in ft	Capacity,[3] in acre-ft	Surface area, in acres	Water-surface elevation,[1] in ft	Water-surface elevation,[2] in ft	Capacity,[3] in acre-ft	Surface area, in acres	Water-surface elevation,[1] in ft	Water-surface elevation,[2] in ft	Capacity,[3] in acre-ft	Surface area, in acres
626.00	624.60	100	60	672.00	670.60	65,400	4,040	718.00	716.60	563,900	19,960
628.00	626.60	300	110	674.00	672.60	73,900	4,470	720.00	718.60	605,100	21,260
630.00	628.60	500	170	676.00	674.60	83,300	4,960	722.00	720.60	649,000	22,660
632.00	630.60	1,000	270	678.00	676.60	93,700	5,420	724.00	722.60	695,700	24,020
634.00	632.60	1,600	360	680.00	678.60	105,100	5,930	726.00	724.60	745,100	25,330
636.00	634.60	2,400	430	682.00	680.60	117,400	6,420	728.00	726.60	797,100	26,730
638.00	636.60	3,300	500	684.00	682.60	130,800	6,950	730.00	728.60	852,100	28,220
640.00	638.60	4,400	580	686.00	684.60	145,200	7,460	732.00	730.60	910,100	29,760
642.00	640.60	5,600	640	688.00	686.60	160,600	7,990	734.00	732.60	971,000	31,260
644.00	642.60	7,000	710	690.00	688.60	177,100	8,570	736.00	734.60	1,035,300	33,010
646.00	644.60	8,500	840	692.00	690.60	195,000	9,300	738.00	736.60	1,103,200	34,900
648.00	646.60	10,300	950	694.00	692.60	214,400	10,050	740.00	738.60	1,174,900	36,860
650.00	648.60	12,300	1,070	696.00	694.60	235,100	10,760	742.00	740.60	1,250,900	39,240
652.00	650.60	14,600	1,210	698.00	696.60	257,400	11,490	**743.40**	**742.00**	**1,307,300**	**41,580**
654.00	652.60	17,200	1,410	700.00	698.60	281,100	12,190	744.00	742.60	1,332,500	42,390
656.00	654.60	20,300	1,690	702.00	700.60	306,200	12,930	746.00	744.60	1,419,400	44,580
658.00	656.60	24,000	1,970	704.00	702.60	332,900	13,710	748.00	746.60	1,510,900	46,850
660.00	658.60	28,200	2,270	706.00	704.60	361,000	14,460	750.00	748.60	1,606,900	49,190
662.00	660.60	33,000	2,530	708.00	706.60	390,600	15,160	752.00	750.60	1,707,800	51,690
664.00	662.60	38,400	2,800	710.00	708.60	421,700	15,910	754.00	752.60	1,813,800	54,390
666.00	664.60	44,200	3,070	712.00	710.60	454,300	16,740	756.00	754.60	1,925,500	57,300
668.00	666.60	50,700	3,360	714.00	712.60	488,800	17,720	758.00	756.60	2,043,300	60,520
670.00	668.60	57,700	3,680	716.00	714.60	525,200	18,750	**758.40**	**757.00**	**2,067,700**	**61,180**

[1] Elevations are referenced to the North American Vertical Datum of 1988.

[2] Elevations are referenced to the Pensacola Datum, a local datum established in 1940 by the U.S. Army Corps of Engineers for the Penscola Dam impounding Grand Lake O' the Cherokees. Pensacola Datum is calculated by subtracting 1.40 ft from NAVD 88.

[3] Capacities were computed from a surface triangulated irregular network that was computed at about 0.47 ft at the 95th-percentile value for the approximately 6.8-million-point quality-assurance dataset. The explanation of the vertical accuracy calculation is in the “Bathymetric Surface and Contour Quality Assurance” section of this report. Capacities have been rounded to the nearest hundred.

Bathymetric Map, Surface Area, and Capacity of
Grand Lake O’ the Cherokees, Northeastern Oklahoma, 2019

By

Shelby L. Hunter, Adam R. Trevisan, Jennifer Villa, and Kevin A. Smith

2020

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