Introduction

Managers of water-supply lakes need an accurate estimate of the lake capacity to ensure that enough water is available for uses such as: providing consistent recreation pool levels, preserving downstream aquatic habitat, flood abatement, water supply, and power generation. Lake capacity is particularly important for managers of water-supply lakes during periods of drought, unexpected population growth, or exceptionally high water use in the area supplied by the lake. Sedimentation, primarily from runoff into the lake, will cause a loss of storage capacity as a lake ages; as a result, the capacity table for the lake (if one exists) will overestimate the actual capacity. Lake bathymetric changes can be demonstrated through periodic surveying, and rates of sediment accumulation can be calculated so that managers can better regulate the water supply.

In cooperation with several Federal, State, and local agencies, the U.S. Geological Survey (USGS) completed bathymetric surveys of several water-supply lakes in Missouri in the early 2000s (Richards, 2013). The average water-surface elevation of the lakes. The USGS, in cooperation with the Missouri Department of Natural Resources, completed one such survey of Sugar Creek Lake in December 2003 using a boat-mounted survey-grade singlebeam echosounder and differentially corrected global positioning system equipment. Sugar Creek Lake (fig. 1), constructed in 1922, is about 4 miles northeast of Moberly, Missouri, in Randolph County and has a surface area of about 330 acres at the spillway elevation of 746.8 feet (ft) above North American Vertical Datum of 1988. Additional construction details of the lake and dam were provided in Wilson and Richards (2006). The lake primarily is used for recreation and drinking-water supply for the town of Moberly, Mo.

In September 2018, the USGS, in cooperation with the Missouri Department of Natural Resources and the City of Moberly, Mo., surveyed the bathymetry of Sugar Creek Lake to prepare an updated bathymetric map and a surface area and capacity table. The 2003 survey was compared with the 2018 survey to document the changes in the bathymetric surface of the lake and produce a bathymetric change map.

Methods

A bathymetric survey was done from September 4 to 6, 2018, at Sugar Creek Lake using similar methods to the previous survey completed in 2003 (Wilson and Richards, 2006; Richards, 2013). The average water-surface elevation of the lake during the 2018 survey was 745.75 ft and was 746.8 ft during the 2003 survey. A bathymetric surface, a bathymetric contour map, and a bathymetric change map were created from the survey data.

Bathymetric Data Collection

Bathymetric data (water depths and positions) were collected (fig. 2) using a high-resolution multibeam mapping system (MBMS). The various components of the MBMS used for this study are described in more detail in reports about studies on the Missouri and Mississippi Rivers in Missouri (for example, see Huizinga, 2010, 2017; Huizinga and others, 2010), and for the City of Cameron water-supply lakes (Huizinga, 2014). The survey methods used to obtain the data for Sugar Creek Lake were similar to these other studies, as were the methods used to ensure data quality. A brief description of the equipment and methods follows.

An MBMS is an integration of several individual components: the multibeam echosounder (MBES), an inertial navigation system (INS), and a data-collection and data-processing computer. The INS (Applanix OceanMaster) provides position in three-dimensional space and measures the heave, pitch, roll, and heading of the vessel (and, thereby, the MBES) to accurately position the data received by the MBES. The MBES that was used is the Norbit iWBMSh, operated at a frequency of 400 kilohertz. The iWBMSh is similar in operation to the MBES systems used in other previous studies in Missouri. The iWBMSh has a curved receiver array that enables bathymetric data to be collected throughout a swath range of 210 degrees. Optimum data usually are collected in a swath of less than 160 degrees (80 degrees on each side of nadir, or straight down below the MBES); nevertheless, the swath can be electronically rotated to either side of nadir, enabling data to be captured along sloping banks up to a depth just below the water surface.

Bathymetric Surface and Contour Map Creation

About 4,500,000 data points, spaced 1.64-ft horizontally, were exported from the raw data collected in the 2018 survey and are available as a USGS data release (Richards and Huizinga, 2019). The vertical datum for the survey was the North American Vertical Datum of 1988 using the geoid model GEOID12b, and the horizontal datum was the North American Datum of 1983. Geographic information system (GIS) software was used to filter the 1.64-ft spaced bathymetric data points so that the points would be no closer than about 3.28 ft apart. The data reduction retained about 1,100,000 surveyed data points from the 2018 MBES survey.

Data outside the MBES survey extent (fig. 2) and greater than 745 ft in elevation were obtained from 1/9 arc-second National Elevation Dataset data that were derived from data collected in 2012 using light detection and ranging (lidar) equipment (https://viewer.nationalmap.gov/basic/). These data points were resampled to a linear distance of about 3.28 ft (576,135 points) using GIS software and define the upland areas of the lake.

Using the linear enforcement techniques described in Wilson and Richards (2006), about 1,700 points were created based on surrounding 2018 data values and were used as additional data in bathymetric surface creation. These data were added to anchor the bathymetric surface in areas of sparse data in the upper ends of coves where the water was too shallow for the MBES equipment.

Data outside the MBES survey extent, but below 745 ft in elevation in the upper ends of the main and east arms of the lake, where the water was too shallow for the MBES equipment (fig. 2), were obtained from a 3.28-ft grid of points (46,310 points) interpolated from the 2003 bathymetric surface. These data were adjusted by adding 1 ft to the 2003 elevation value to account for the approximate vertical difference observed between the 2003 and 2018 bathymetric surfaces in the nearby areas where the surfaces were coincident.

The preceding point datasets were used to produce a three-dimensional TIN surface of the lake-bottom elevations. A surface area and capacity table was produced from the three-dimensional TIN surface showing surface area and capacity at specified lake water-surface elevations (table 1). The surface was contoured at a 2-ft interval using GIS software, and the contours were cartographically smoothed and edited to create a bathymetric contour map (fig. 2) using the techniques of Wilson and Richards (2006).
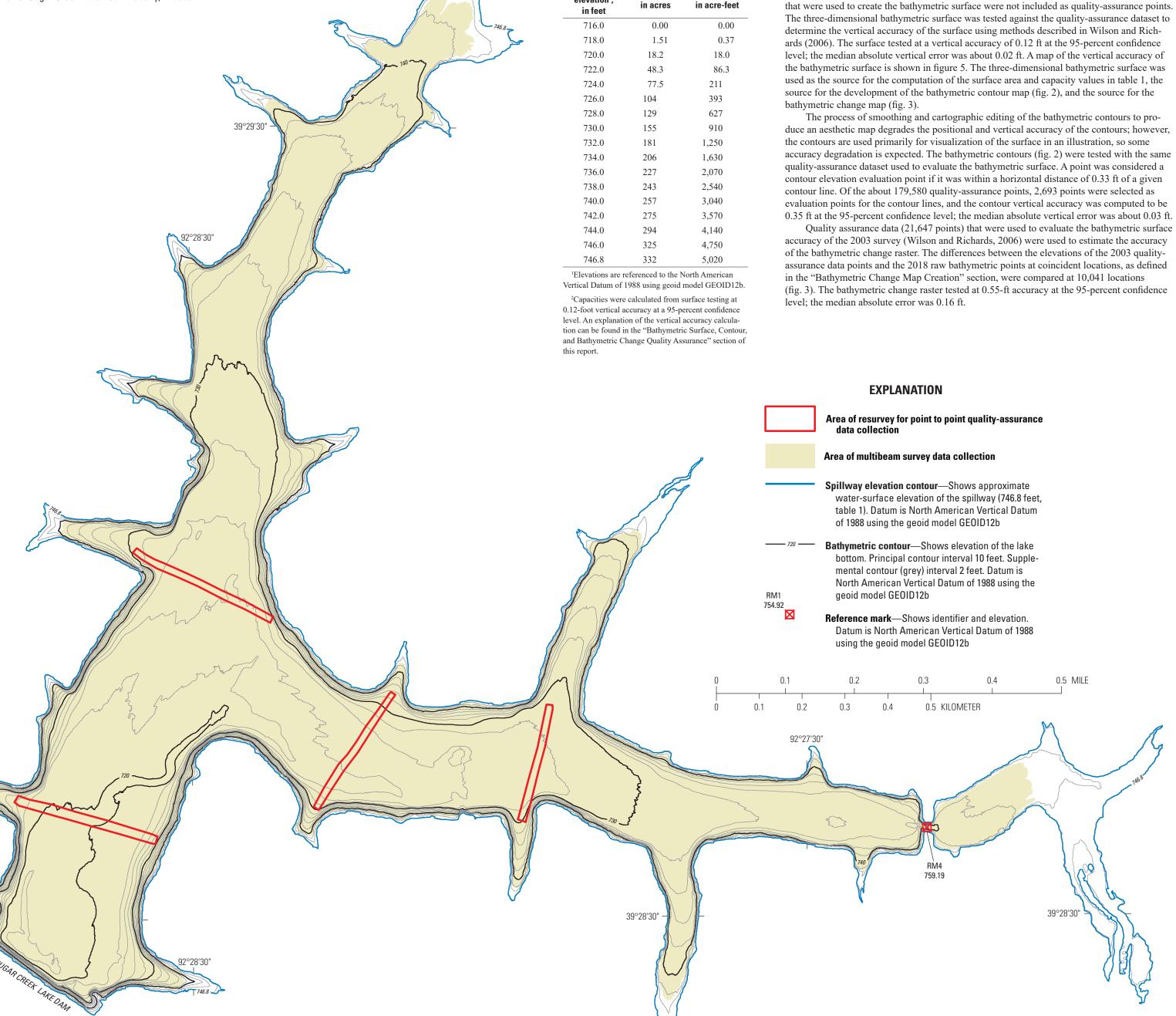
Real-time navigation during the survey used a differential global positioning system solution; however, the navigation information from Sugar Creek Lake survey was post-processed using the POS-Pac Mobile Mapping Suite (MMS) software (Applanix Corporation, 2009) to mitigate the effects of the degraded positional accuracy of the vessel from the differential global positioning system solution. POS-Pac MMS provides tools to identify and compensate for sensor and environmental errors and computes an optimally blended navigation solution from the Global Navigation Satellite Systems (GNSS) and inertial-measurement unit raw data from the INS. The location solution was further enhanced by collecting static GNSS data with a GNSS base receiver set up over a temporary reference mark near the lake; the coordinates for which were determined using techniques detailed in Rydlund and Densmore (2012). The blended navigation solution (called a "smoothed best estimate of trajectory" or "SBET" file) generated by postprocessing the daily navigation data was applied to the corresponding daily survey data.

Most of the bathymetric survey data within Sugar Creek Lake (fig. 2) were collected with the swath range limited to 140 degrees, 70 degrees on each side of nadir. Along the banks and in the shallow areas at the upstream ends of the lake arms, however, the swath range was widened to 160 degrees to cover a wider swath of the bottom. In these areas the receiver array also was electronically tilted to port or starboard as needed to enhance acquisition of bathymetric data in the shallow areas near the banks, in coves, and in the upper reaches of the lake arms. The electronically tilted swath generally was about 120 degrees wide, extending from about 10 degrees above horizontal on the bankward side of the survey vessel to about 20 degrees past nadir below the vessel.

The bathymetric data were collected along transect lines oriented longitudinally in the main lake area. In the main body of the lake, the transect lines were spaced to create about 10- to 25-percent overlap of the survey swaths in attempt to ensure complete coverage of the lake bottom and minimize sonic shadows. Data along the shoreline were collected by navigating the boat parallel to the shore while overlapping the data collected in the main body of the lake. Cove data were collected by navigating into a cove along the approximate centerline of the cove as far as practical (usually, the point at which forward progress was blocked by vegetation, or water depth decreased to less than about 3 ft), pivoting the boat 180 degrees, and egressing the cove along the ingress line.

In a lake, it is not unusual for the speed of sound in the water to change over time and to vary spatially. The speed of sound also can vary over the water column because of water temperature variations with depth. Although sound velocity data are collected at the MBES head throughout the survey to mitigate these variations near the water surface, the changes in the speed of sound with depth needs to be known to accurately determine the depths acquired by the MBES. Sound velocity profiles, therefore, were measured with a sound velocity probe at various locations throughout each survey day and applied during postprocessing in the HYPACK/HYSWEEP software.

Preparation for the bathymetric survey was done in HYPACK/HYSWEEP software (HYPACK, Inc., 2015). To collect the survey data, a computer onboard the survey vessel ran HYPACK/HYSWEEP data acquisition software. After completing the survey, the acquired depth data were processed further to apply sound velocity profiles and to remove data spikes and other spurious points, often caused by fish and submerged woody debris, in the MBES swath trace. The data were georeferenced using the navigation and position solution data from the SBET file from POS-Pac MMS and visualized in HYPACK/HYSWEEP as a triangulated irregular network (TIN) surface or a point cloud. The georeferenced data were output to a comma-delimited file that was filtered and reduced to a 1.64-ft data resolution.

Bathymetric Change Map Creation

The bathymetric change map (fig. 3) was generated from the difference between the 2003 and 2018 bathymetric survey data points that were coincident. The data points between the two surveys were considered coincident if a 2018 raw survey data point was within a horizontal distance of 0.16 ft from a 2003 survey data point. Of the possible 258,865 survey points collected along transects spaced about 49 ft apart in 2003 (Richards, 2013), there were 147,051 coincident locations found in the survey points collected in 2018. A bathymetric change TIN was generated using the coincident point data. The TIN was converted to a raster surface with a spacing of 3.28 ft for use in further analysis and creation of the map. The bathymetric change map was limited to the intersection of the 2003 and 2018 MBES survey extents so that only data that were surveyed by the MBES were compared. In areas of steeper slope, observed in figure 2 as areas where the contours are closely spaced, raster cells that had a 2018 slope greater than 6 degrees were removed from the bathymetric change raster because sediment deposition was assumed to be relatively minor in these areas.

Bathymetric Data Collection Quality Assurance

For the MBMS, the principal quality-assurance measures were assessed in real time during the survey. The MBMS operator continuously assessed the quality of the data collected during the survey by making observations of across-track swaths (such as convex, concave, or skewed bed returns in flat, smooth bottoms), noting data-quality flags and alarms from the MBES and the INS, and inspecting comparisons between adjacent overlapping swaths. In addition to the real-time quality-assurance assessments during the survey, beam-angle checks and a suite of patch tests were done on September 5 during the survey to ensure quality data were acquired from the MBMS. These tests were completed in the deepest part of the lake near the dam (fig. 2).

Beam-Angle Check

A beam-angle check is used to determine the accuracy of the depth readings obtained by the outer beams (greater than 25 degrees from nadir [vertical]) of the MBES (U.S. Army Corps of Engineers, 2013), which may change with time because of inaccurate sound velocities, physical configuration changes, and water depth. A beam-angle check was done on September 5, and the results were within the recommended performance standards used by the U.S. Army Corps of Engineers for hydrographic surveys for all the representative angles below 70 degrees (U.S. Army Corps of Engineers, 2013), permitting the use of the central 140 degrees of the sound navigation and ranging (sonar) swath with confidence.

Patch Tests

Patch tests are a series of dynamic calibration tests that are used to check for subtle variations in the orientation and timing of the MBES with respect to the INS and real-world coordinates. The patch tests are used to determine timing offsets caused by latency between the MBES and the INS, and angular offsets to roll, pitch, and yaw caused by the alignment of the transducer head (Huizinga, 2017). These offsets have been observed to be essentially constant for a given survey, barring an event that causes the mount to change such as striking a floating or submerged object (see Huizinga, 2017). The offsets determined in the patch test are applied when processing the data collected during a survey. Patch tests were completed on September 5, at Sugar Creek Lake, and angular offsets were updated in the data collection software as appropriate. For this study, there was no measured timing offset, which is consistent with latency test results for this boat and similar equipment configurations used in other surveys (Huizinga, 2010, 2017; Huizinga and others, 2010).

Uncertainty Estimation

Similar to the previous studies of bathymetry in Missouri (Huizinga, 2010, 2017), uncertainty in the survey was estimated by computing the total propagated uncertainty (TPU) for each 1.64-ft survey-grid cell in the surveyed area using the Combined Uncertainty and Bathymetric Estimator (CUBE) method (Calder and Mayer, 2003). The CUBE method allows all random system component uncertainties and resolution effects to be combined and propagated through the data processing steps, which provides a robust estimate of the spatial distribution of possible uncertainty within the survey area (Czuba and others, 2011). Thus, the TPU of a point is a measure of the accuracy to be expected for such a point when all relevant error sources are considered (Czuba and others, 2011).

Most of the TPU values (more than 95 percent) were less than 0.20 ft, which is within the specifications for a "Special Order" survey, the most-stringent survey standard of the International Hydrographic Organization (International Hydrographic Organization, 2008). The median TPU value of the data was about 0.07 ft. The largest TPU in this survey was about 15 ft; however, TPU values of this magnitude typically are near high-relief features, such as near vertical surfaces such as bridge abutments or submerged cliffs that may exist on some parts of the lake (fig. 2). The TPU values were larger near moderate-relief features (steep banks and submerged channels and ridges; fig. 2). The TPU values also were sometimes larger in the outermost beam extents of the MBES swath in the overlap with an adjacent swath, particularly when the swath was tilted for the survey lines along the banks or widened in the upper extent of the lake (fig. 4).
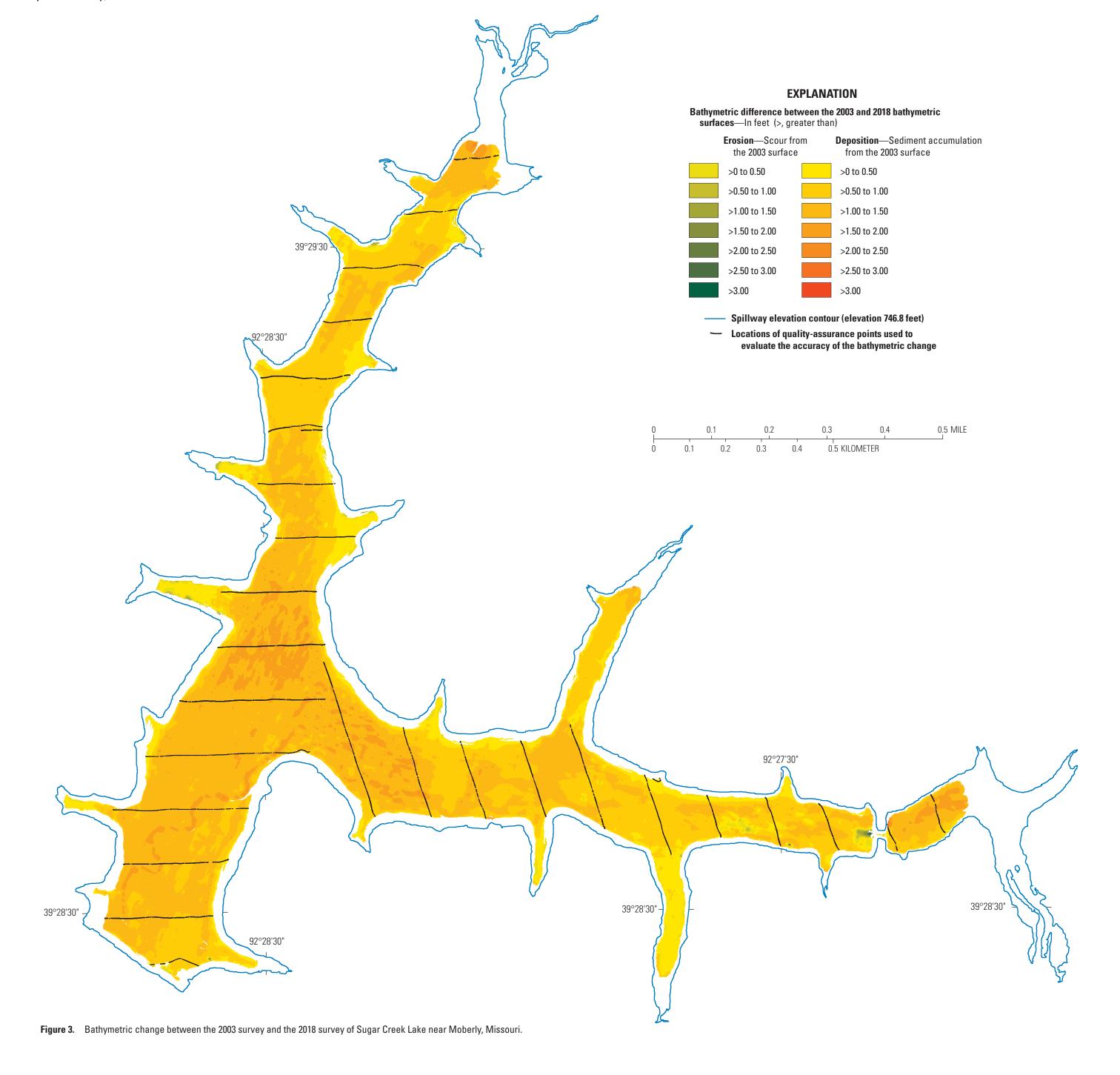
Bathymetric Surface, Contour, and Bathymetric Change Quality Assurance

Accuracy of the bathymetric surface and contours is a function of the survey data accuracy, density of the survey data, and the processing steps involved in the surface and contour creation. The process of data reduction done to obtain the 1.64-ft gridded dataset from the raw survey data likely degraded the accuracy of the 1.64-ft gridded dataset relative to the raw data. Four areas of the lake were surveyed twice (fig. 2) to collect a dataset that could be used to estimate the accuracy of the 1.64-ft gridded dataset used to produce the bathymetric surface. The four areas had a combined total of about 8,680,000 raw survey points (Richards and Huizinga, 2019). Raw points that were within a horizontal distance of 0.16 ft of a 1.64-ft gridded point were selected as quality-assurance points, and the elevation values of these points were compared to the 1.64-ft gridded points. The 59,903 selected raw points were compared to 1.64-ft gridded points, and the data tested at a vertical accuracy of 0.25 ft at a 95-percent confidence level; the median absolute vertical error was about 0.09 ft.

The quality-assurance dataset used to evaluate the bathymetric surface included about 179,580 data points selected at random from the about 4,500,000, 1.64-ft data points. Points that were used to create the bathymetric surface were not included as quality-assurance points. The three-dimensional bathymetric surface was tested against the quality-assurance dataset to determine the vertical accuracy of the surface using methods described in Wilson and Richards (2006). The surface tested at a vertical accuracy of 0.12 ft at the 95-percent confidence level; the median absolute vertical error was about 0.02 ft. A map of the vertical accuracy of the bathymetric surface is shown in figure 5. The three-dimensional bathymetric surface was used as the source for the computation of the surface area and capacity values in table 1, the source for the development of the bathymetric contour map (fig. 2), and the source for the bathymetric change map (fig. 3).

The process of smoothing and cartographic editing of the bathymetric contours to produce an aesthetic map degrades the positional and vertical accuracy of the contours; however, the contours are used primarily for visualization of the surface in an illustration, so some accuracy degradation is expected. The bathymetric contours (fig. 2) were tested with the same quality-assurance dataset used to evaluate the bathymetric surface. A point was considered a contour elevation evaluation point if it was within a horizontal distance of 0.33 ft of a given contour line. Of the about 179,580 quality-assurance points, 2,693 points were selected as evaluation points for the contour lines, and the contour vertical accuracy was computed to be 0.35 ft at the 95-percent confidence level; the median absolute vertical error was about 0.03 ft.

Quality assurance data (21,647 points) that were used to evaluate the bathymetric surface accuracy of the 2003 survey (Wilson and Richards, 2006) were used to estimate the accuracy of the bathymetric change raster. The differences between the elevations of the 2003 quality-assurance data points and the 2018 raw bathymetric points at coincident locations, as defined in the "Bathymetric Change Map Creation" section, were compared at 10,041 locations (fig. 3). The bathymetric change raster tested at 0.55-ft accuracy at the 95-percent confidence level; the median absolute error was 0.16 ft.

Bathymetry, Capacity, and Bathymetric Change

A bathymetric surface was created from the current (2018) surveyed data and used to produce a bathymetric contour map (fig. 2). The 2018 bathymetric map is similar to the map produced from the 2003 survey (Wilson and Richards, 2006; appendix of Richards, 2013) in that evidence of the submerged river channel is still present in some areas (fig. 2), but a clearly defined channel is not observed in most of the lake. There is evidence of the river channel, although somewhat muted, all the way to Sugar Creek Lake Dam (fig. 2).

A surface area and capacity table (table 1) was computed from the bathymetric surface TIN. At the spillway elevation of 746.8 ft, the surface area of the lake is 332 acres, and the capacity is 5,020 acre-feet (table 1). The surface area and capacity table is similar to the table prepared for the previous 2003 survey (Wilson and Richards, 2006; appendix of Richards, 2013); however, the capacity is less in the 2018 table compared to the 2003 table for the 50-ft transect interval at each corresponding elevation. At the spillway elevation of 746.8 ft, the capacity of the lake in 2018 is 230 acre-feet less than the capacity of the lake in 2003, which represents a capacity loss of about 4.4-percent during a period of about 14.7 years. The average capacity loss per year is about 15.6 acre-feet for the period between the 2003 and 2018 surveys.

The bathymetric change map indicates some erosional and depositional areas. Erosion seems to have occurred downstream from the bridge opening on the east arm of the lake, presumably where the water velocity, and the sediment carrying capacity, increased as water flowed through the bridge. Deposition seems to be relatively uniform across the lake area. The mean bathymetric change computed from the bathymetric change raster is about 0.96 ft, and the surface area of the bathymetric change raster is about 241 acres. Multiplying these values gives a total volume of sediment of 231 acre-feet, which is consistent with the change in the lake capacity between the 2003 survey and the 2018 survey.

References Cited

Applanix Corporation, 2009, POS-Pac™ MMS™ GNSS-inertial tools user guide, rev. 4: Richmond Hill, Ontario, Canada, PUBS–MAN–001768, 523 p.

Calder, B.R., and Mayer, L.A., 2003, Automatic processing of high-rate, high-density multibeam echosounder data: Geochemistry, Geophysics, Geosystems (G³), v. 4, no. 6, 22 p. [Also available at https://doi.org/10.1029/2002GC000486.]

Czuba, J.A., Best, J.L., Oberg, K.A., Parsons, D.R., Jackson, P.R., Garcia, M.H., and Ashmore, P., 2011, Bed morphology, flow structure, and sediment transport at the outlet of Lake Huron and in the Upper Saint Clair River: Journal of Great Lakes Research, v. 37, no. 3, p. 480–493. [Also available at https://doi.org/10.1016/j.jglr.2011.05.011.]

Huizinga, R.J., 2010, Bathymetric surveys at highway bridges crossing the Missouri River in Kansas City, Missouri, using a multibeam echo sounder, 2010: U.S. Geological Survey Scientific Investigations Report 2010–5207, 61 p. [Also available at https://pubs.usgs.gov/sir/2010/5207/.]

Huizinga, R.J., 2014, Bathymetric surveys and area/capacity tables of water-supply reservoirs for the city of Cameron, Missouri, July 2013: U.S. Geological Survey Open-File Report 2014–1005, 15 p. [Also available at https://doi.org/10.3133/ofr20141005.]

Huizinga, R.J., 2017, Bathymetric and velocimetric surveys at highway bridges crossing the Missouri and Mississippi Rivers near St. Louis, Missouri, May 23–27, 2016: U.S. Geological Survey Scientific Investigations Report 2017–5076, 102 p. [Also available at https://doi.org/10.3133/sir20175076.]

Huizinga, R.J., Elliott, C.M., and Jacobson, R.B., 2010, Bathymetric and velocimetric survey and assessment of habitat for pallid sturgeon on the Mississippi River in the vicinity of the proposed Interstate 70 Bridge at St. Louis, Missouri: U.S. Geological Survey Scientific Investigations Report 2010–5017, 28 p. [Also available at https://pubs.usgs.gov/sir/2010/5017/.]

HYPACK, Inc., 2015, HYPACK® hydrographic survey software user manual: Middletown, Conn., HYPACK, Inc., 2,041 p.

International Hydrographic Organization, 2008, IHO standards for hydrographic surveys (5th ed.): Monaco, International Hydrographic Bureau, Special publication no. 44, 27 p.

Richards, J.M., 2013, Bathymetric surveys of selected lakes in Missouri—2000–2008: U.S. Geological Survey Open-File Report 2013–1101, 9 p. with appendix [Also available at https://pubs.usgs.gov/of/2013/1101.]
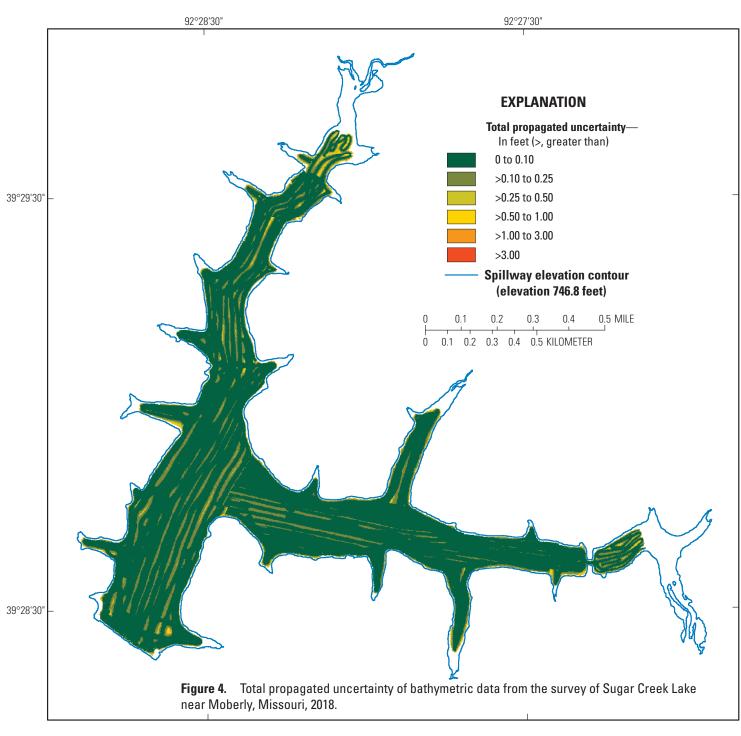
Richards, J.M., and Huizinga, R.J., 2019, Bathymetric and supporting data for Sugar Creek Lake near Moberly, Missouri, 2018: U.S. Geological Survey data release, https://doi.org/10.5066/P9XDVRMT.
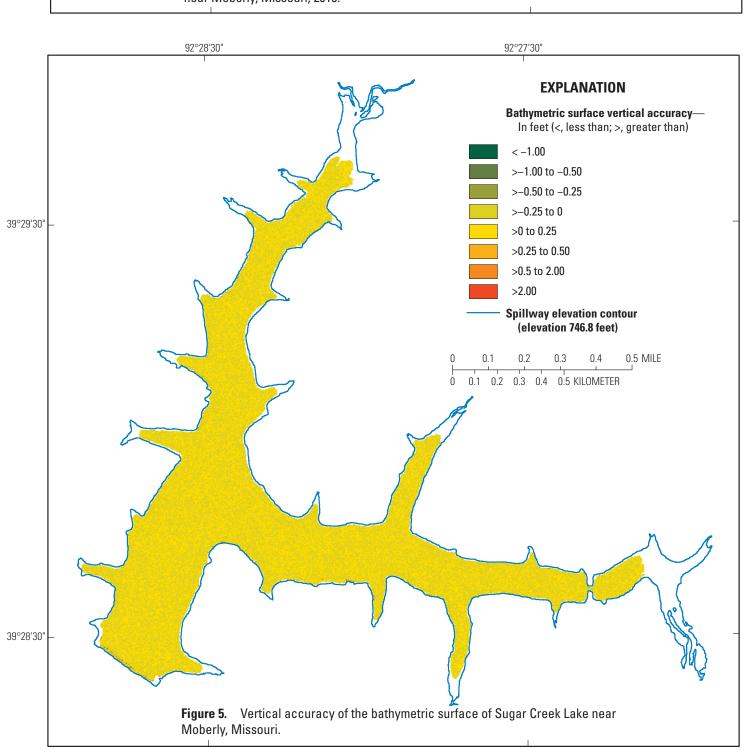
Rydlund, P.H., Jr., and Densmore, B.K., 2012, Methods of practice and guidelines for using survey-grade global navigation satellite systems (GNSS) to establish vertical datum in the United States Geological Survey: U.S. Geological Survey Techniques and Methods, book 11, chap. D1, 102 p. with appendixes. [Also available at https://doi.org/10.3133/tm11D1.]

U.S. Army Corps of Engineers, 2013, Engineering and design—Hydrographic surveying: Washington D.C., U.S. Army Corps of Engineers, manual no. EM 1110–2–1003, 560 p.

Wilson, G.L., and Richards, J.M., 2006, Procedural documentation and accuracy assessment of bathymetric maps and area/capacity tables for small lakes: U.S. Geological Survey Scientific Investigations Report 2006-5208, 24 p. [Also available at https://doi.org/10.3133/sir20065208.]

Figure 1. Location of Sugar Creek Lake near Moberly, Missouri.

Table 1. Surface area and capacity at specified water surface elevations for Sugar Creek Lake near Moberly, Missouri, September 4–6, 2018.

[Spillway elevation is about 746.8 feet (fig. 2); the average water-surface elevation during the survey was 745.75 feet]

Water surface elevation[1], in feet	Surface area, in acres	Capacity[2], in acre-feet
716.0	0.00	0.00
718.0	1.51	0.37
720.0	18.2	18.0
722.0	48.3	86.3
724.0	77.5	211
726.0	104	393
728.0	129	627
730.0	155	910
732.0	181	1,250
734.0	206	1,630
736.0	227	2,070
738.0	243	2,540
740.0	257	3,040
742.0	275	3,570
744.0	294	4,140
746.0	325	4,750
746.8	332	5,020

[1]Elevations are referenced to the North American Vertical Datum of 1988 using geoid model GEOID12b.

[2]Capacities were calculated from surface testing at 0.12-foot vertical accuracy at a 95-percent confidence level. An explanation of the vertical accuracy calculation can be found in the "Bathymetric Surface, Contour, and Bathymetric Change Quality Assurance" section of this report.

Figure 2. Bathymetric contours for Sugar Creek Lake near Moberly, Missouri, resulting from a survey done September 4–6, 2018.

EXPLANATION

- Area of resurvey for point to point quality-assurance data collection
- Area of multibeam survey data collection
- Spillway elevation contour—Shows approximate water-surface elevation of the spillway (746.8 feet, table 1). Datum is North American Vertical Datum of 1988 using the geoid model GEOID12b
- Bathymetric contour—Shows elevation of the lake bottom. Principal contour interval 10 feet. Supplemental contour (grey) interval 2 feet. Datum is North American Vertical Datum of 1988 using the geoid model GEOID12b
- Reference mark—Shows identifier and elevation. Datum is North American Vertical Datum of 1988 using the geoid model GEOID12b

Figure 3. Bathymetric change between the 2003 survey and the 2018 survey of Sugar Creek Lake near Moberly, Missouri.

EXPLANATION

Bathymetric difference between the 2003 and 2018 bathymetric surfaces—In feet (>, greater than)

Erosion—Scour from the 2003 surface
- >0 to 0.50
- >0.50 to 1.00
- >1.00 to 1.50
- >1.50 to 2.00
- >2.00 to 2.50
- >2.50 to 3.00
- >3.00

Deposition—Sediment accumulation from the 2003 surface
- >0 to 0.50
- >0.50 to 1.00
- >1.00 to 1.50
- >1.50 to 2.00
- >2.00 to 2.50
- >2.50 to 3.00
- >3.00

— Spillway elevation contour (elevation 746.8 feet)
— Locations of quality-assurance points used to evaluate the accuracy of the bathymetric change

Figure 4. Total propagated uncertainty of bathymetric data from the survey of Sugar Creek Lake near Moberly, Missouri, 2018.

EXPLANATION

Total propagated uncertainty—In feet (>, greater than)
- 0 to 0.10
- >0.10 to 0.25
- >0.25 to 0.50
- >0.50 to 1.00
- >1.00 to 3.00
- >3.00

— Spillway elevation contour (elevation 746.8 feet)

Figure 5. Vertical accuracy of the bathymetric surface of Sugar Creek Lake near Moberly, Missouri.

EXPLANATION

Bathymetric surface vertical accuracy—In feet (<, less than; >, greater than)
- < −1.00
- >−1.00 to −0.50
- >−0.50 to −0.25
- >−0.25 to >0
- >0 to 0.25
- >0.25 to 0.50
- >0.5 to 2.00
- >2.00

— Spillway elevation contour (746.8 feet)

Bathymetric Contour Map, Surface Area and Capacity Table, and Bathymetric Change Map for Sugar Creek Lake near Moberly, Missouri, 2018

By

Joseph M. Richards, Richard J. Huizinga, and Jarrett T. Ellis

2019