BUREAU OF RECLAMATION

Technical Report No. ENV-2020-052

Shadow Mountain Reservoir 2019 Bathymetry Survey

Colorado-Big Thompson Project, Colorado
Great Plains Region

U.S. Department of the Interior May 2020

Mission Statements

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Acknowledgments

The Bureau of Reclamation's (Reclamation) Sedimentation and River Hydraulics (Sedimentation) Group of the Technical Service Center (TSC) prepared and published this report. Caroline Ubing, Mike Sixta, Kent Collins, and David Varyu of the Sedimentation Group conducted the bathymetry survey of Shadow Mountain Reservoir in May 2019. Steven Hollenback, Kent Collins, and David Varyu of the Sedimentation Group collected the sediment core samples in October 2019. Kent Collins of the Sedimentation Group performed the technical peer review of this document.

Cover: Shadow Mountain Reservoir, (Reclamation/Varyu)

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14. SHORT ABSTRACT **The 2019 multibeam bathymetric survey of Shadow Mountain Reservoir was combined with 2010 LiDAR data to produce a combined digital surface of the reservoir bottom. This survey produced a surface to be used in two-dimensional water quality modeling. An area-capacity table was developed using readily available tools in ArcMap. A discussion of the methods and locations of sediment core sampling is included.**						
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Technical Service Center, Denver, Colorado
Sedimentation and River Hydraulics Group, 86-68240

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Shadow Mountain Reservoir 2019 Bathymetry Survey

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Acronyms and Abbreviations

ft^3/s	cubic feet per second (cfs)
DOI	Department of the Interior
ft	foot or feet
GIS	Geographic Information System
GPS	Global Positioning System
HUC	Hydrologic Unit Code
LiDAR	Light Detection and Ranging
mi^2	square miles
NAD 1983	North American Datum, established 1983
NAVD 1988	North American Vertical Datum, established 1988
NGS	National Geodetic Survey
NGVD 1929	National Geodetic Vertical Datum, established 1929
NID	National Inventory of Dams
NRCS	Natural Resources Conservation Service
OPUS	Online Positioning User Service
Reclamation	Bureau of Reclamation
RPVD	Reclamation Project Vertical Datum
RSI	Reservoir Sedimentation Information
RTK	Real-Time Kinematic
SGMC	State Geologic Map Compilation
TSC	Technical Service Center
USGS	U.S. Geological Survey

Executive Summary

Shadow Mountain Dam and Shadow Mountain Reservoir are on the Colorado River where the reservoir abuts the south side of the town of Grand Lake, Colorado, and the dam is at the southern end of the reservoir approximately 3 miles south-southwest of the town.

A bathymetric survey of Shadow Mountain Reservoir was conducted in 2019 with the purpose of creating a surface to be used for two-dimensional water quality modeling. An area-capacity table was developed as a secondary deliverable.

The bathymetric survey was conducted from a boat using a multibeam depth sounder that was interfaced with real-time kinematic (RTK) global positioning system (GPS) instruments (for horizontal positioning) to map the reservoir bottom. The 2019 multibeam bathymetric survey of Shadow Mountain Reservoir was combined with 2010 aerial LiDAR data to produce a combined digital surface of the reservoir bottom.

This survey was conducted between May 13 and May 17, 2019, when the reservoir water surface elevation ranged between 8366.55 and 8366.73 feet (Reclamation Project Vertical Datum). The above-water topographic LiDAR data were measured in August 2010.

A sediment sampling effort took place between October 14 and October 16, 2019. Eleven core samples were collected and sent to a lab for analysis. The analysis data is not available in this report; methods and locations are discussed in this document.

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1. Introduction

Shadow Mountain Dam and Reservoir are on the Colorado River abutting the southwest border of the town of Grand Lake, CO (Figure 1). The dam and reservoir are operated by Northern Colorado Water Conservancy District as part of the Colorado-Big Thompson Project that supplies supplemental irrigation water to about 720,000 acres as well as water for municipal and industrial use, hydroelectric power, and water-oriented recreation opportunities. The Colorado-Big Thompson Project is one of the largest and most complex natural resource developments undertaken by the Bureau of Reclamation. It consists of over 100 structures integrated into a transmountain water diversion system (www.usbr.gov/projects/index.php?id=235).

A two-dimensional (2D) numerical water quality model being used by the Technical Service Center's (TSC) Water Resources Engineering and Management Group (86-68210) necessitated accurate geometry below the waterline. Lindsay Bearup (86-68210) requested the Sedimentation and River Hydraulics Group (86-68240) to conduct a bathymetric survey of the underwater portions of the reservoir that were accessible by boat. A bathymetric survey was conducted from May 13-17, 2019 with the primary objective of providing data sufficient for development of a surface to be used in the water quality model. Additionally, this surface could be compared to the original/predam topography to estimate the degree of reservoir sedimentation, but this was not done as it was outside the scope of this project. An updated area-capacity table was determined from the surface using tools readily available in ESRI's ArcMap software and is included in Appendix B.

A subsequent data collection campaign was conducted October 14-16, 2019 to estimate the gradation and thickness of sediment deposits within the reservoir. This report will document the data collection methods whereas the analysis of the collected sediments can be found in (Armstrong, 2020).

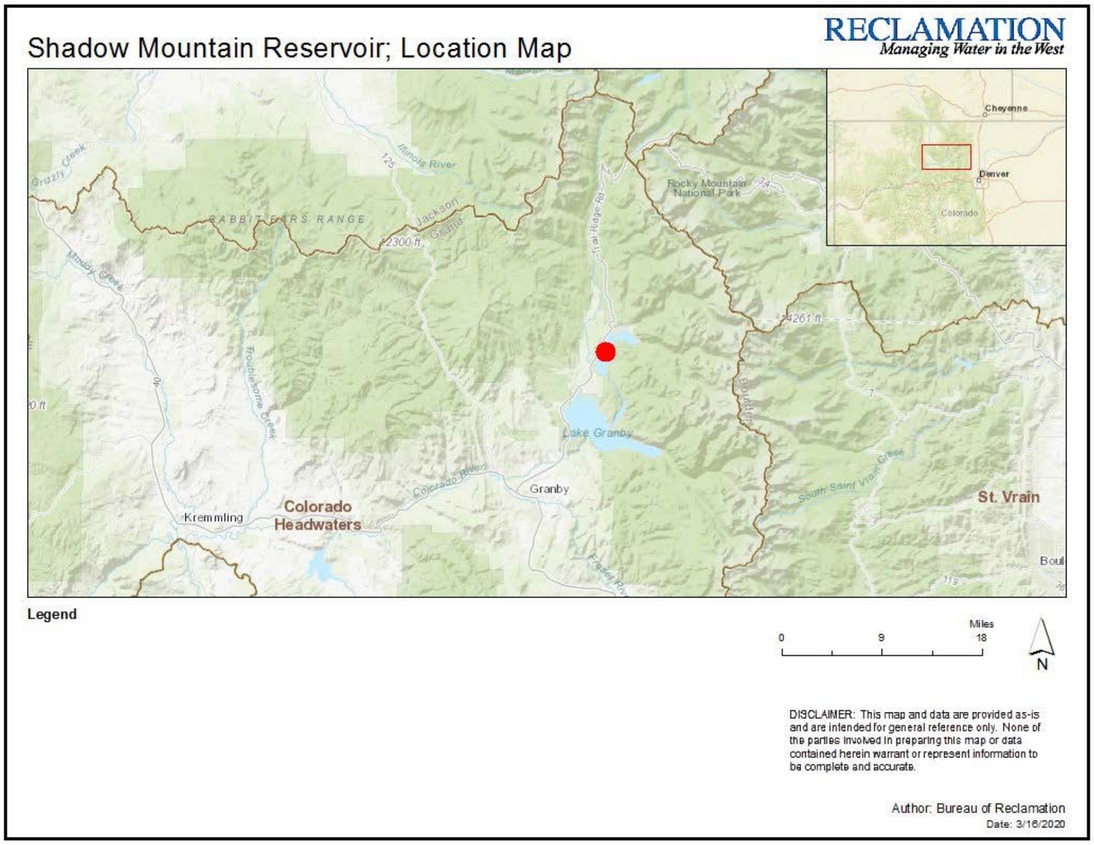

Figure 1.—Location map of Shadow Mountain Dam and Reservoir, adjacent to southwest border of the town of Grand Lake, CO and north of Lake Granby.

2. Watershed Description

The watershed upstream from Shadow Mountain Dam has a total contributing drainage area of 186 square miles (mi^2). The scale of the Colorado-Big Thompson River complicates the hydrology and related sediment contributing area that can be considered net sediment-contributing area. As the purpose of this study is not reservoir sedimentation rates, this point is not discussed further. The StreamStats website from USGS (streamstats.usgs.gov/ss/) was used to determine the drainage area upstream of Shadow Mountain Reservoir (Figure 2).

Natural reservoir inflows are primarily from the Colorado River and Little Columbine Creek. Shadow Mountain Reservoir also has a surface water connection to Grand Lake, which is by design as part of the Colorado-Big Thompson Project. Similarly, Shadow Mountain Reservoir is connected to Lake Granby. Both connections provide flow into and out of Shadow Mountain Reservoir depending on water delivery operations. Natural inflows (from the Colorado River and Little Columbine Creek) are discussed but this is not a complete discussion of water inflows and outflows for Shadow Mountain Reservoir.

Based on USGS data presented in Table 1, the mean annual flow into Shadow Mountain Reservoir is 90 ft^3/s from the Colorado River and 2.4 ft^3/s from Little Columbine Creek. The mean annual flow in the Colorado River below Shadow Mountain Dam is 154 ft^3/s. These flow records exemplify the complex plumbing infrastructure related to the Colorado-Big Thompson Project and that any discussion of storage capacity ratios for the Reservoir is irrelevant. Gage locations present in Table 1 one are presented spatially in Figure 2 (right).

Table 1.—Summary of USGS gages representing riverine inflow to and outflow from Shadow Mountain Reservoir (USGS StreamStats)

Name	USGS Gage #	Daily Record		Drainage area (mi^2)	Mean Annual Flow (ft^3/s)
COLORADO RIVER NEAR GRAND LAKE, CO.	09011000	10/1/1904	9/30/1986	102	90
L COLUMBINE C AB SHADOW MTN LK, AT GRAND LK, CO.	09011500	10/1/1950	9/30/1955	1.65	2.4
COLORADO RIVER BL SHADOW MOUNTAIN RESERVOIR, CO.	09015000	10/1/1947	9/30/1959	190	154

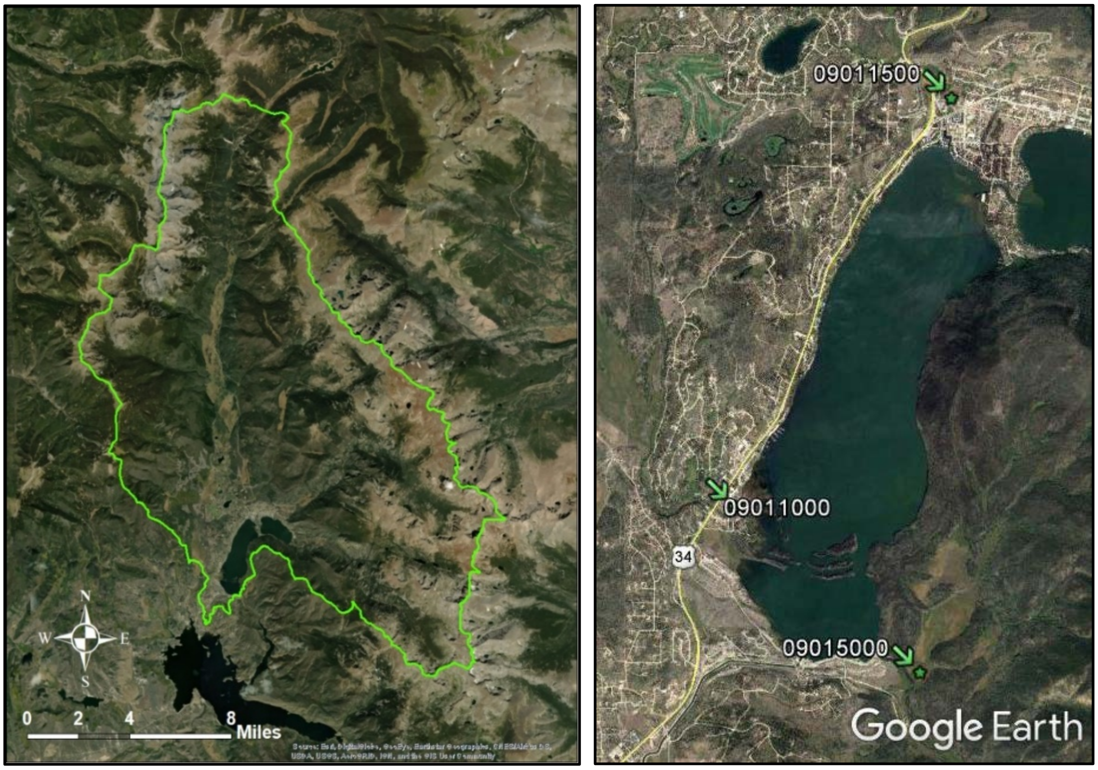

Figure 2.—The watershed above Shadow Mountain Dam has a total drainage area of 186 mi² (left). Three USGS gages (not all still active) used to estimate mean inflow and outflow rates (right).

3. Survey Control and Datum

For the 2019 survey, all bathymetry and GPS control measurements were collected in North American Datum 1983 (NAD 1983) State Plane (horizontal) coordinates, Colorado North 0501, US survey feet and North American Vertical Datum 1988 (NAVD 1988), Geoid 12A, US survey feet elevations. The GPS base station receiver was set up over a temporary monument located at the southern end of the reservoir, west of the Granby pump canal (Figure 3). State plane and elevation coordinates for the GPS base station were computed using the Online Positioning User Service (OPUS) developed by the National Geodetic Survey (NGS) (www.ngs.noaa.gov/OPUS/). Water surface elevations were collected using rod and rover measurements periodically during the bathymetry survey.

The time series of reservoir level during the survey was obtained to maintain a consistent vertical datum. The water surface elevations as recorded by a gage at the dam and posted on the Northern Water website (www.northernwater.org/WaterProjects/WestSlopeWaterData.aspx?WDType=S) were used for data processing; horizontal positions from the RTK-GPS were retained and elevations for the bathymetry were adjusted based on comparing RTK-GPS rover measurements of WSE with the time series of reservoir level from

Northern Water. A statistical analysis of the WSE comparison demonstrates that RPVD is 6.22 feet lower than NAVD88. Figure 4 presents the two data sources plotted on separate vertical axes; the RTK-GPS data in NAVD88 elevation on the left vertical axis and the reservoir level elevation in RPVD on the right vertical axis. The range on the right axis is 6.22 feet lower than the range on the left axis. Notice that the reservoir level varies by less than 0.2 feet during the data collection period.

A series of RTK-GPS rover points were collected along the dam crest centerline and the centerline of the bridge over the spillway (Figure 5). The gravel road on the dam has variability as modifications and grading over time may have adjusted elevations relative to initial construction. The station-elevation plot in Figure 6 presents the dam crest and bridge data shifted vertically by -6.22 ft to be consistent with RPVD. The project website (www.usbr.gov/projects/index.php?id=235) states the dam crest has an elevation of 8375 ft which is within 0.15 feet of the low point of dam crest (the bridge corners crossing the spillway).

During processing, all bathymetry and GPS measurements were converted to Reclamation Project Vertical Datum (RPVD) for Shadow Mountain. All elevations discussed in following sections are referenced to RPVD.

Figure 3.—Location of GPS base station(s) along Shadow Mountain Reservoir. Inset photo looking at base station from the west.

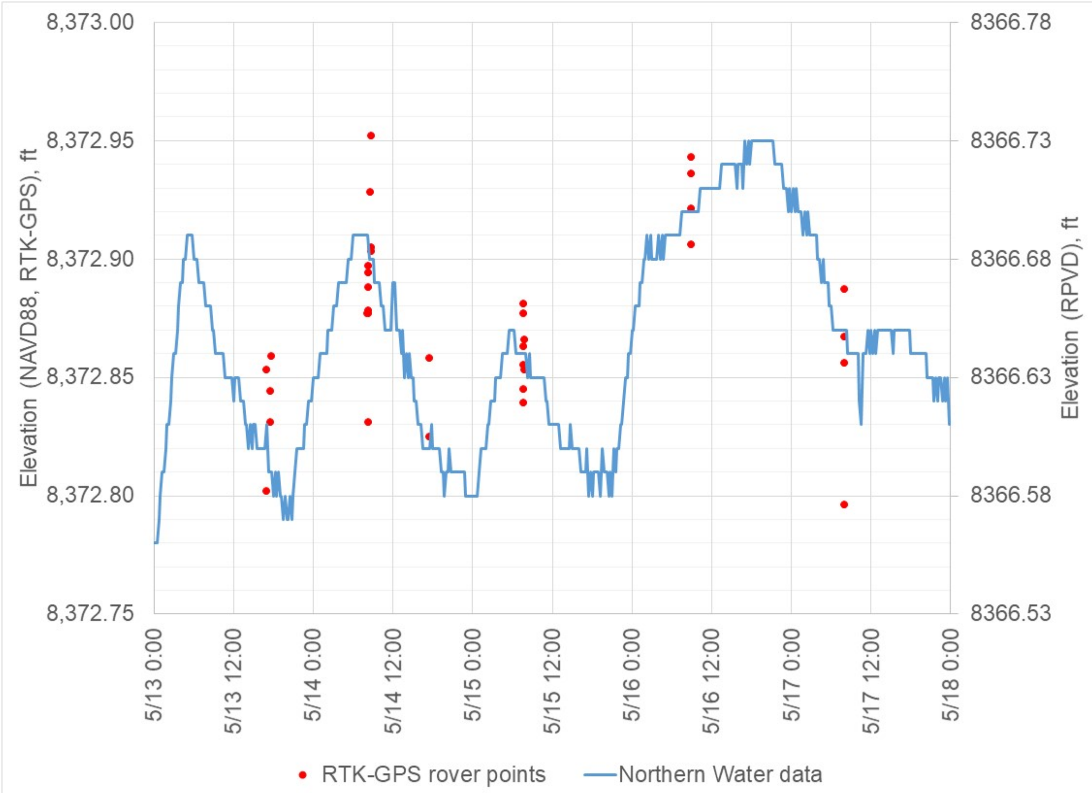

Figure 4.—Water surface shots from RTK-GPS survey (points) on left vertical axis in NAVD88 and reservoir level elevation (solid blue line) plotted on the right vertical axis in RPVD.

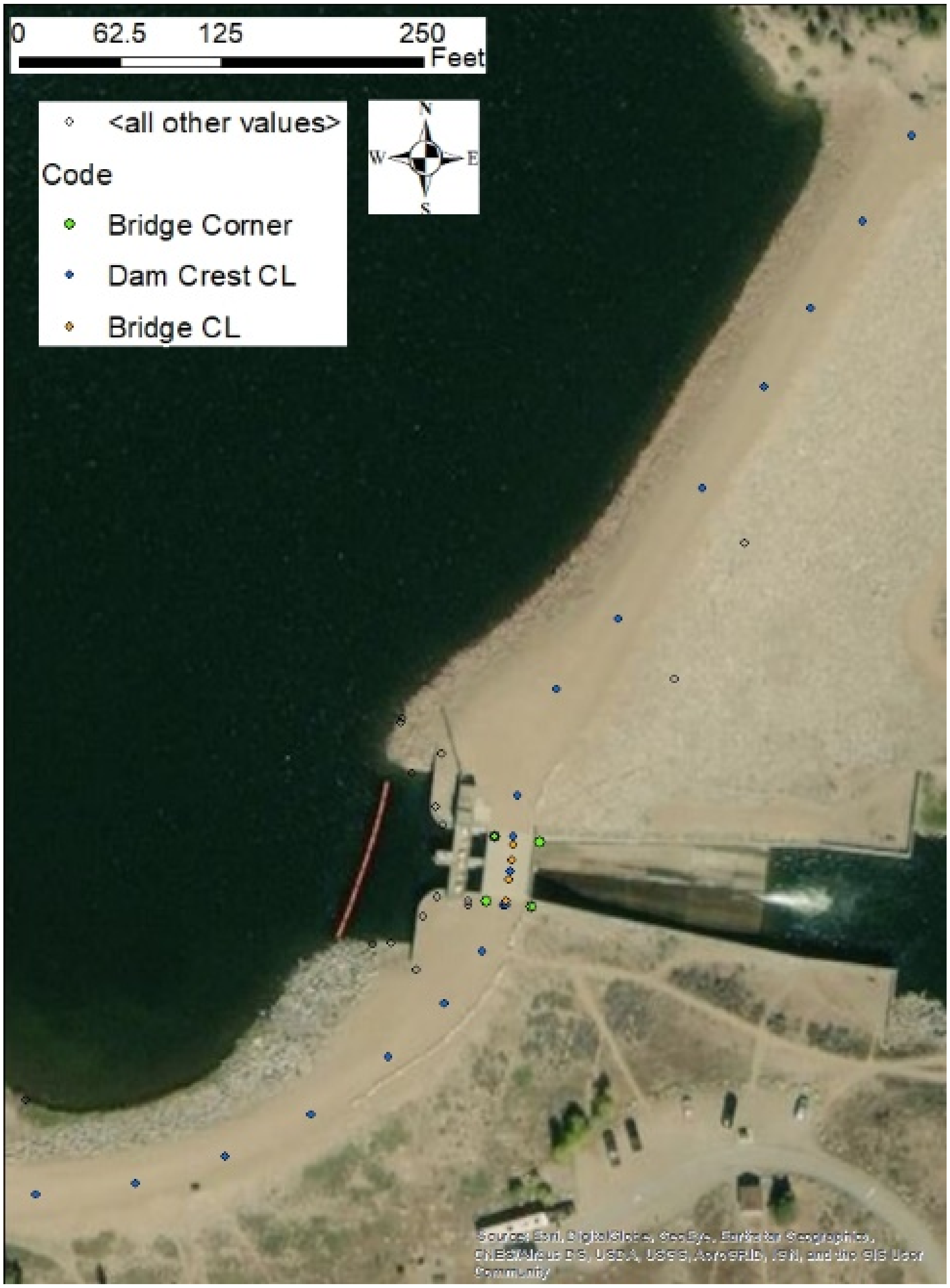

Figure 5.—GPS rover points on dam crest and bridge over spillway. These points are plotted in Figure 6.

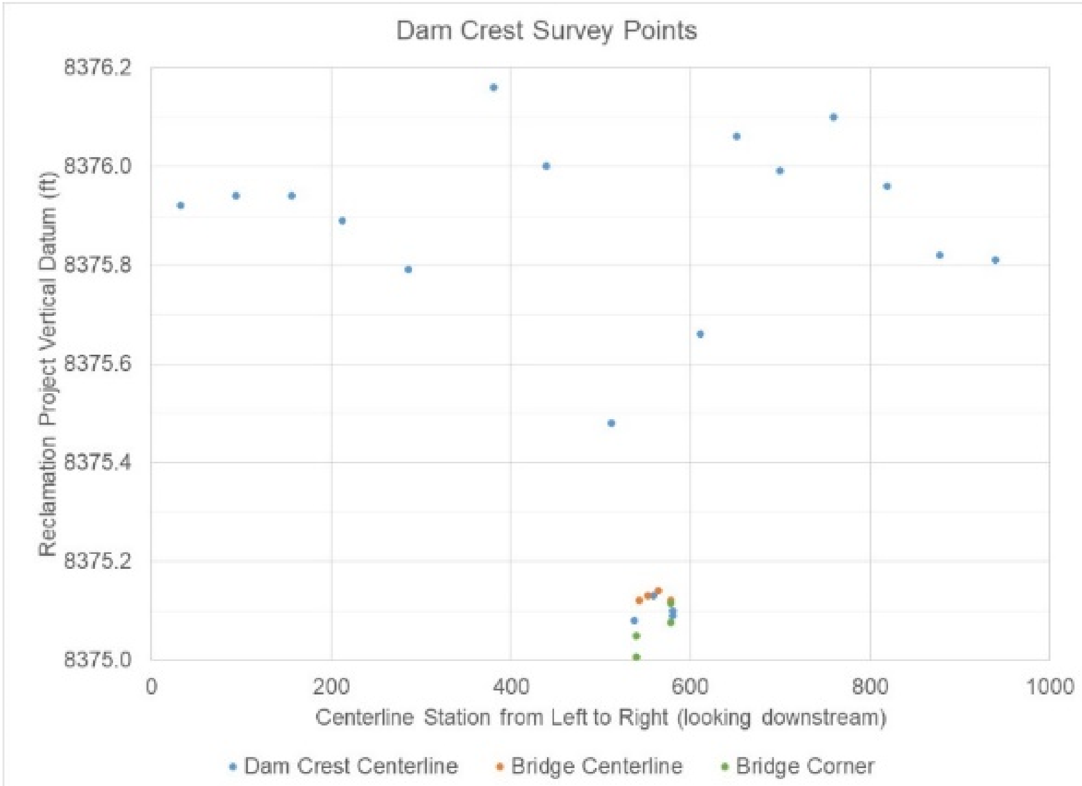

Figure 6.—Rod and rover survey data plotted in RPVD across the dam crest (see Figure 5).

4. Methods Summary

4.1. Bathymetric Survey: May 13-17, 2019

A bathymetric survey was conducted during May 2019 from a boat using a multibeam depth sounder to continuously measure water depths. The horizontal position of the moving boat was continually tracked using RTK GPS. A map of the data points collected is presented in Figure 7. Complete, 100% coverage was not obtained. The data collection effort balanced the ability to accurately represent the underwater portion of the reservoir with data collection costs.

Appendix A provides more details of the hydrographic survey methods. These bathymetric data were combined with LiDAR data collected above water during August 2010 (USGS 2014) to produce a digital surface of the reservoir bottom surface.

The LiDAR data was converted to a TIN using the tool "LAS dataset to TIN" in ArcMap. This TIN was converted to points so elevations could be shifted to RPVD and used in the terrain development. Prior to shifting, the elevations from the LAS-derived points were compared to the RTK-GPS points along the dam crest.

Figure 8 presents a plan view of the points derived from the LAS data with an inset plot of vertical error as compared to the RTK-GPS points as distance from RTK-GPS points increase (to increase the sample size).

The LiDAR data was filtered to remove any points representing the reservoir water surface by means of clipping the data using a digitized polygon. This polygon was also used in the generation of the continuous surface with an assigned elevation of 8365.36 ft (RPVD) based on a comparison of minimum LiDAR elevation data and maximum bathymetric surface elevation; it is not a representation of a water surface elevation, but a continuous breakline between bathymetric data and LiDAR data.

The LiDAR data was further filtered to remove any points with an elevation greater than 8370 ft (RPVD) as these data weren't necessary for this study. The surface was generated in ArcMap as a terrain using three primary data sources: 1) bathymetry output from the survey at three-foot grid spacing, 2) LiDAR data points representing the above-water ground surface (up to 8370 ft RPVD), and 3) a polygon separating these two datasets with an assigned elevation of 8365.36 ft.

There were some additional data employed using engineering judgement to create a surface that is more likely to represent reality. First, a coffer dam or other longitudinal feature was identified in the bathymetry data. As the survey did not cover this entire feature, additional data was used in the terrain to reflect the likely continuous nature of this feature (Figure 9, left). Second, the meandering nature of the Colorado River prior to closing Shadow Mountain Dam combined with the shallow water conditions made it difficult to completely survey the channel and banks. Three lines were digitized and elevations interpolated so a continuous channel feature would be represented in the final product (Figure 9, right). The terrain was converted to a raster with cell size of 5 feet as an end product for generating surface area and storage capacity tables as well as delivery to 86-68210 to be employed in the 2D numerical water quality modeling.

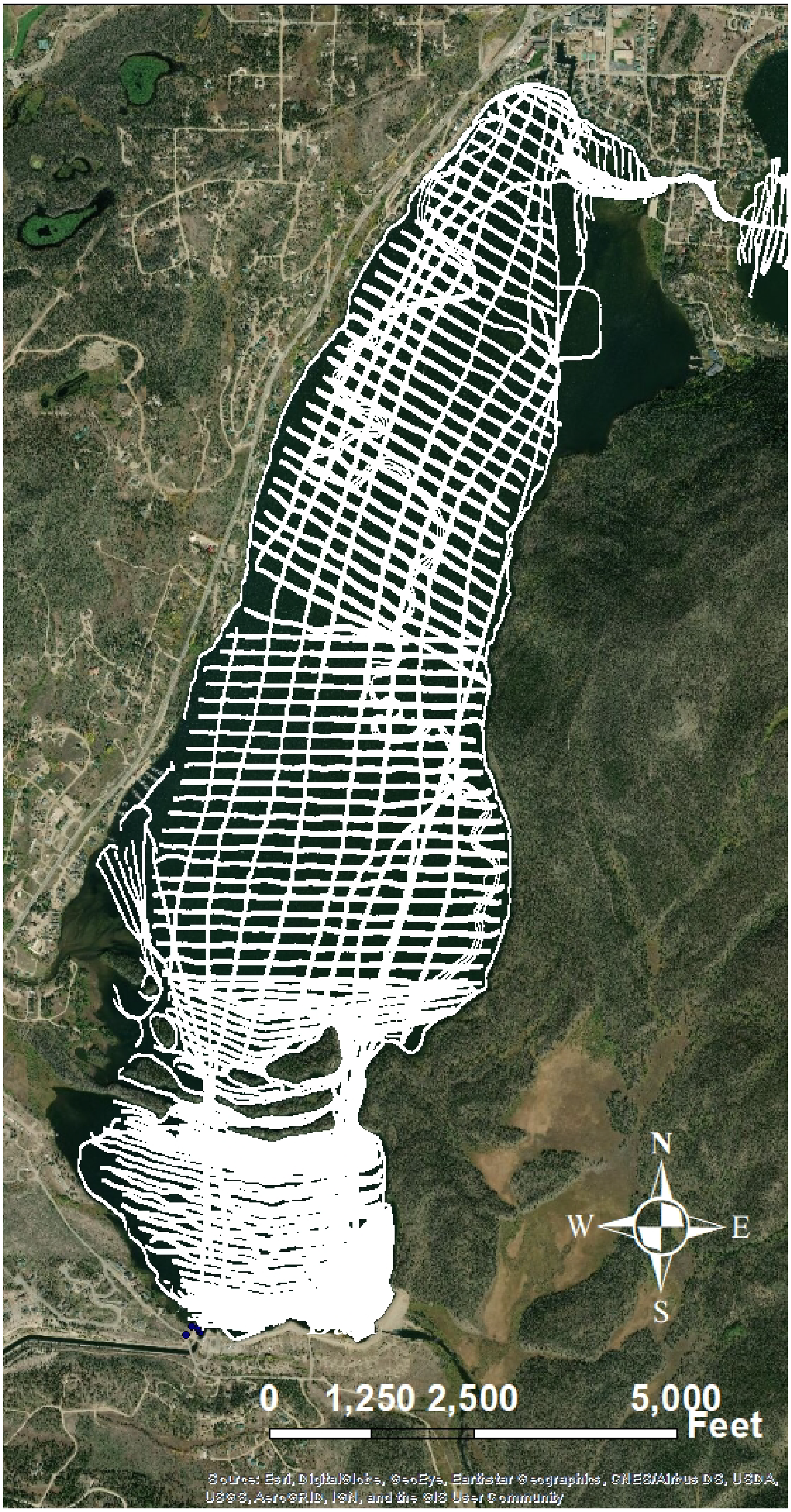

Figure 7.—Map of bathymetric survey data coverage.

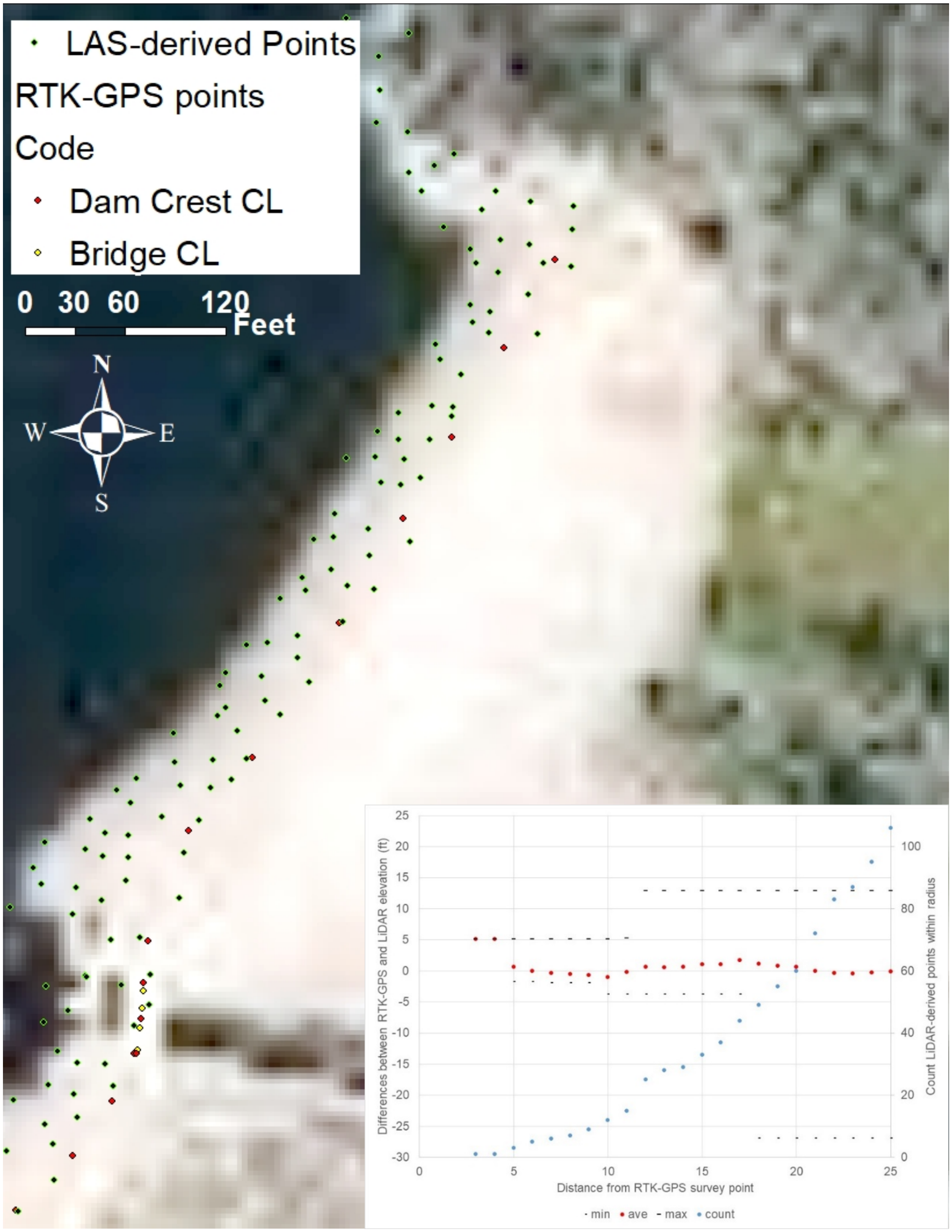

Figure 8.—Dam Crest RTK-GPS survey points and LAS derived elevation points. Inset plot shows small average differences depending on the distance included to find LAS point around RTK-GPS points.

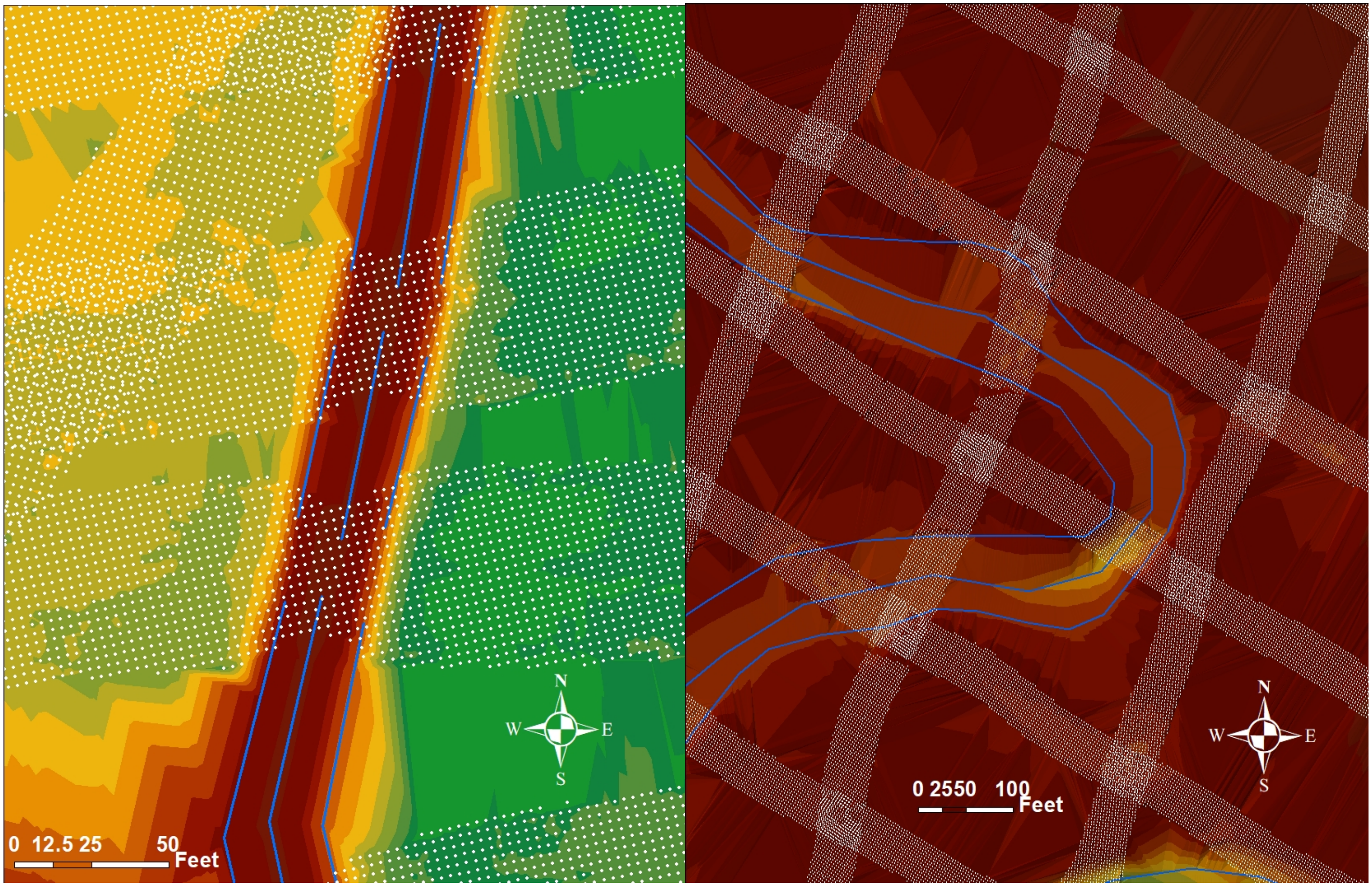

Figure 9.—Two cases of adding data to model surface; blue lines represent additional data to form continuous features and white points are bathymetry-derived elevations. Left: coffer dam downstream of islands. Right: river channel upstream of islands.

4.2. Sediment Core Sampling: October 14-16, 2019

A Vibecore-D vibrating core sampler was attached to a 10-foot aluminum crane mounted to the same Wooldridge vessel used for the multibeam bathymetric survey for collection of reservoir bottom sediment cores. Figure 10 presents the setup but this photo is from a 2016 campaign and not the Shadow Mountain campaign. Clear acrylic tubes (8 feet long, 3 inch diameter) were mounted to the vibrating head powered by two 12 volt batteries connected in series. The Vibecore-D sampler works by being lowered through the water column until the bottom tip of the sample tube just rests on the reservoir bed. The vibrating head is then turned on using the remote control box on the boat and the sample tube is pushed into the sediment through a combination of gravity and vibration until it reaches the head or encounters an impenetrable layer (SDI, 2012).

Figure 10.—VibeCore sampling configuration mounted to Wooldridge boat used to collect sediment samples at Paonia Reservoir in Colorado. No photo available of boat deployed at Shadow Mountain Reservoir.

Figure 11 presents a map of the sampling locations. Figure 12 depicts an example of two core samples collected (left) and presenting a photo at "SM-NOR-1" where the bed was too coarse to sample with the Vibecore-D system (right).

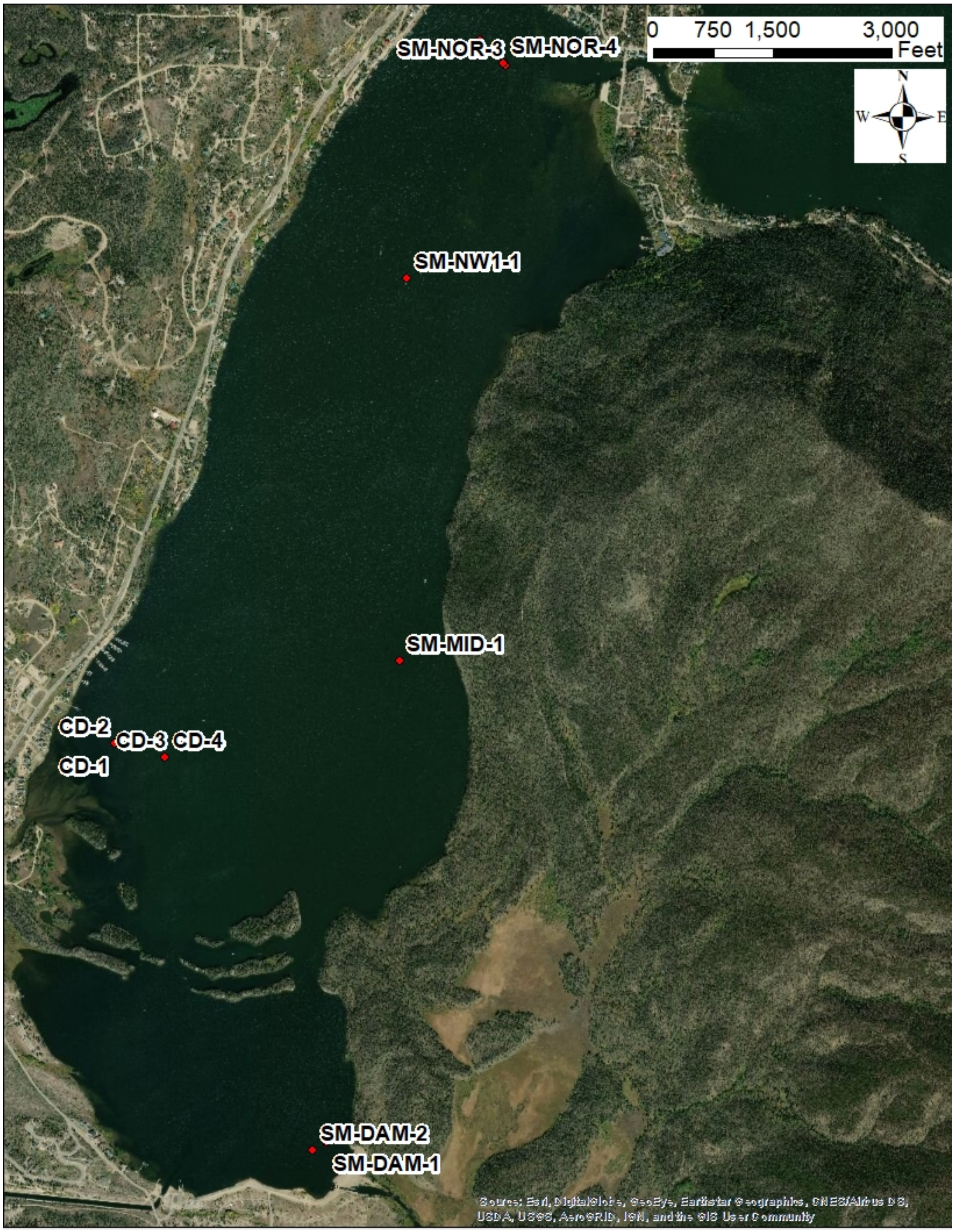

Figure 11.—Location of sediment sampling locations. Inset is a zoom-in of the "SM-NOR" area near connecting channel to Grand Lake.

Figure 12.—Sediment data collection during October 2019. *Left:* example of sediment cores collected during sampling campaign. *Right:* coarse sediment at "SM-NOR-1" that is too large for core sampling.

5. Reservoir Surface Area and Storage Capacity

Tables of reservoir surface area and storage capacity were produced for the full range of reservoir elevations. Plots of the 2019 area and capacity curves are presented in Figure 13. For the 2019 survey, area and capacity curves are based on the bathymetric (below-water) survey up to 8365.36 feet elevation (RPVD), while curves above this elevation are based on 2010 aerial LiDAR (USGS, 2014). The discontinuity in the area curve at the dashed line of 8365.36 feet is due to the transition between the two datasets. No comparison is made with previous area-capacity curves as this is outside the scope of this work request. At elevation 8365 ft (RPVD), which is the approximate top of bathymetry data, the area of Shadow Mountain Reservoir is 1257.93 acres and stores 13,812.13 acre-feet of water based on the 2019 data.

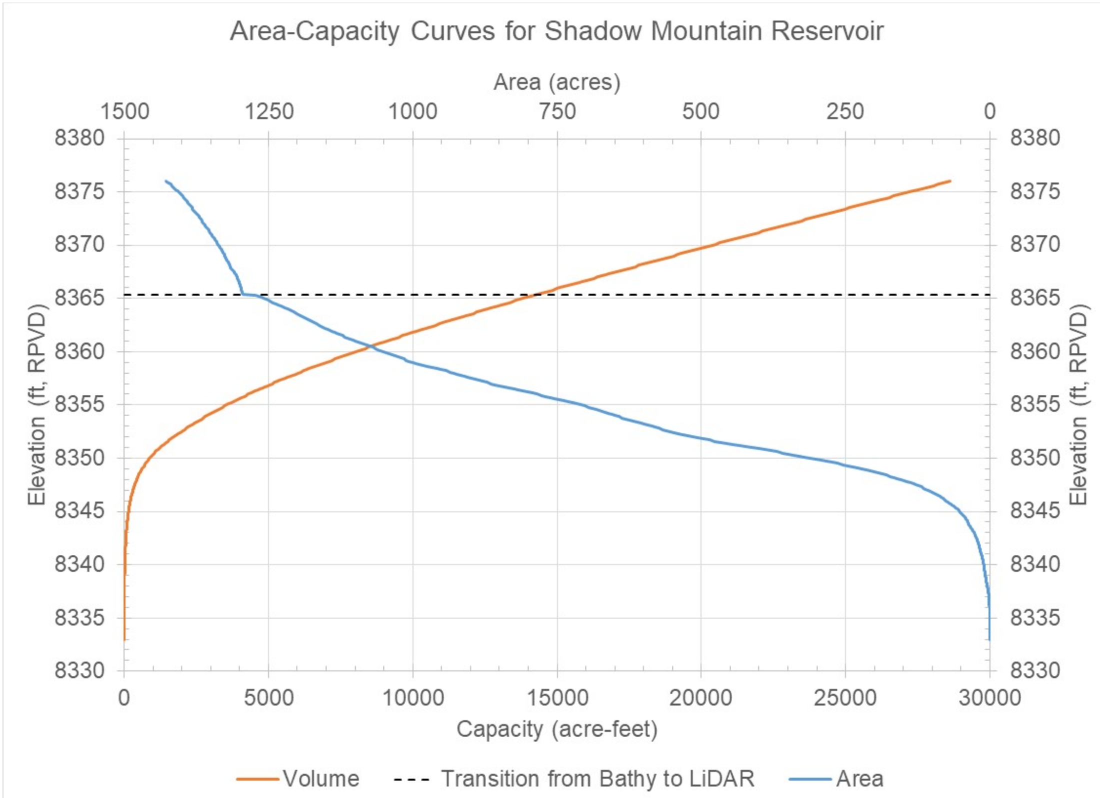

Figure 13.—Plot of Shadow Mountain Reservoir surface area and storage capacity versus elevation (Reclamation Project Vertical Datum).

6. Conclusions

The 2019 bathymetric survey, combined with 2010 LiDAR data of the above-water topography, has been used to produce an accurate digital surface of the reservoir bottom. There were no areas of overlapping bathymetric and above-water topographic data for comparison. The similarity in elevation between the minimum above water topography and the maximum below-water bathymetry lends confidence in the relative elevations. Reservoir surface areas were computed from this digital surface at 0.1-foot intervals to determine the 2019 storage capacity.

Sediment samples were collecting using a Vibecore-D sampler to characterize the nature of the material on the reservoir floor. Eleven samples were collected and sent to a lab for processing. Sample analysis is not included in this report.

7. References

Armstrong, B. 2020. Shadow Mountain Reservoir Sediment Erosion Testing, Technical Memorandum 8550-2019-24. Technical Service Center, Geotechnical Laboratory and Field Support Group, Denver, Colorado, February 2020.

Reclamation, 1981, Project Data, Colorado Big Thompson Project, US States Department of the Interior, prepared for the Water and Power Resources Service.

Reclamation, 2006. Erosion and Sedimentation Manual, Technical Service Center, Sedimentation and River Hydraulics Group, Denver, Colorado, November 2006.

Reclamation, 2019. Projects and Facilities Data, Colorado Big Thompson Project, available at: www.usbr.gov/projects/. Accessed 3/15/2019.

US Geological Survey, StreamStats, available online at: streamstats.usgs.gov/ss/ Accessed 3/15/2019.

U.S. Geological Survey, 20140929, USGS Lidar Point Cloud (LPC) ARRA-CO_GrandCo_2010_000457 2014-08-27 LAS: U.S. Geological Survey. Accessed 30 August 2019.

Appendix A — Hydrographic Survey Equipment and Methods

The 2019 bathymetric survey was conducted from May 13th to May 17th. during this period, reservoir water surface elevations varied from 8366.55 to 8366.73 feet (RPVD).

The survey was conducted along a series of predetermined cross section, longitudinal, and shoreline survey lines (Figure 5). The shallow nature or Shadow Mountain would have required a survey period of twice the May 2019 campaign to obtain 100% coverage. The coverage as shown in Figure 5 was sufficient to develop a quality surface at a reasonable expense to the client.

The survey employed an 18-foot, flat-bottom aluminum Wooldridge boat powered by outboard jet and kicker motors) (Figure A-1). Reservoir depths were measured using multibeam echo sounder which consisted of the following equipment:

- variable-frequency transducer with integrated motion reference unit,
- near-surface sound velocity probe,
- two GPS receivers to measure the boat position and heading,
- an external GSP radio, and
- processor box for synchronization of all depth, sound velocity, position, heading, and motion sensor data.

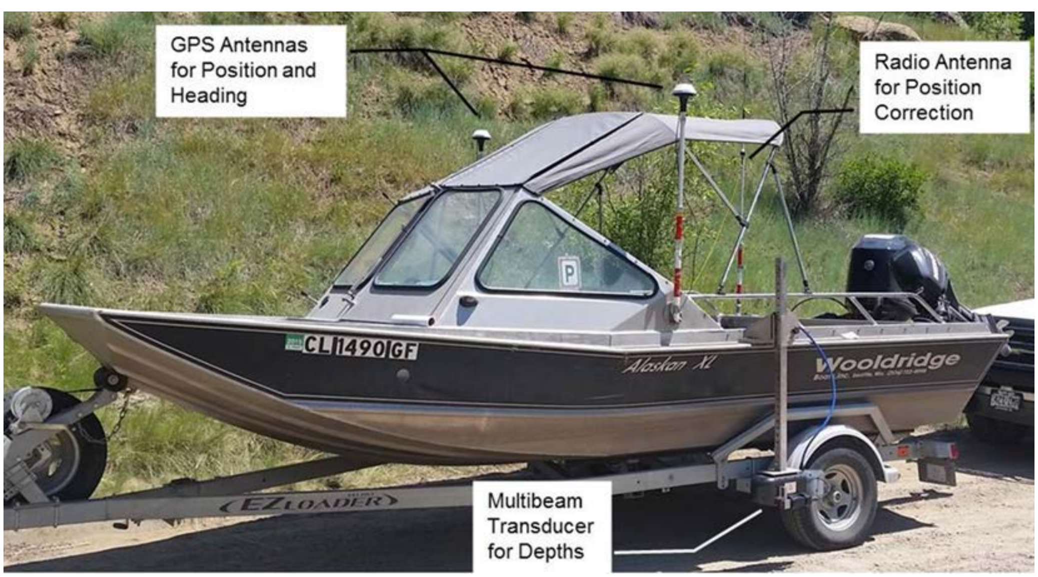

Figure A-1.—Wooldridge boat with RTK-GPS and multibeam depth sounder system.

The multibeam transducer emits up to 512 beams (user selectable) capable of projecting a swath width up to 120 degrees in 390 feet (120 meters) of water. Sound velocity profiles were collected over the full water depth at various locations throughout the reservoir. These sound velocity profiles measure the speed of sound through the water column, which can be affected by multiple characteristics such as water temperature and salinity. These sound velocity profiles were used to calibrate the depth sounder.

RTK GPS survey instruments were used to continuously measure the survey boat position and measure other ground control points. The GPS base station and receiver was set up on a tripod over a point overlooking the reservoir (Figure A-2). The coordinates of this point were computed using the Online Positioning User Service (OPUS) developed by the National Geodetic Survey (NGS) (www.ngs.noaa.gov/OPUS/). During the survey, position corrections were transmitted to the GPS rover receiver using an external GPS radio and UHF antenna (Figure A-2). The base station was powered by a 12-volt battery.

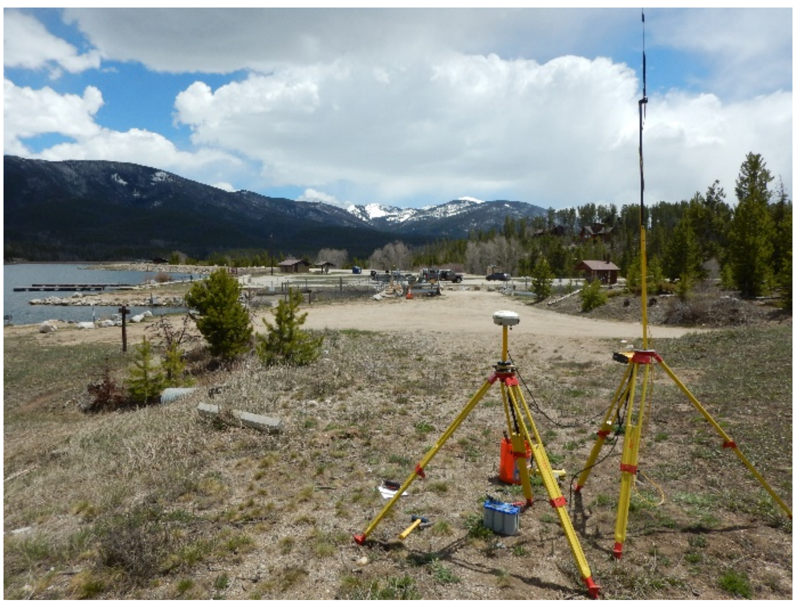

Figure A-2.—The RTK-GPS base station set-up used during the survey of Shadow Mountain Reservoir in Colorado is typical of the set up used for other reservoir surveys.

The GPS rover receivers include an internal radio and external antenna mounted on a range pole (ground survey) or survey vessel (bathymetric survey). The rover GPS units receive the same satellite positioning data as the base station receiver, and at the same time. The rover units also receive real-time position correction information from the base station via radio transmission. This allows rover GPS units to measure accurate positions with precisions of ±2 cm horizontally and ±3 cm vertically for stationary points and within ±20 cm for the moving survey boat.

During the survey, a laptop computer 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 computer through cable connections to the processor box. Using real-time GPS coordinates, the HYPACK software provided navigational guidance to the boat operator to steer along the predetermined survey lines.

The HYPACK hydrographic survey software was used to combine horizontal positions and depths to map the reservoir bathymetry in the user selected coordinate system. Water surface elevations from dam gage records and RTK GPS measurements were used to convert the sonar depth measurements to reservoir-bottom elevations in the RPVD. The multibeam depth sounder generates millions of data points. Sometimes fish, underwater vegetation, or anomalies mean that a small portion of depth measurements do not represent the reservoir bottom and these data are deleted during the post-processing. The processed data are output to a set of points in a grid pattern with 3-ft spacing. Each point is assigned the median elevation of all available data points within that grid spacing. The use of the median value reduces the influence of the highest and lowest elevations within the cell.

Appendix B — Area-Capacity Table from 2019 Survey

Elevation	Area (acres)	Volume (acre-feet)
8333.0	0.000	0.000
8333.1	0.001	0.000
8333.2	0.001	0.000
8333.3	0.001	0.000
8333.4	0.001	0.000
8333.5	0.001	0.000
8333.6	0.001	0.000
8333.7	0.001	0.000
8333.8	0.002	0.001
8333.9	0.003	0.001
8334.0	0.006	0.001
8334.1	0.009	0.002
8334.2	0.020	0.003
8334.3	0.034	0.006
8334.4	0.05	0.01
8334.5	0.06	0.02
8334.6	0.08	0.02
8334.7	0.10	0.03
8334.8	0.12	0.04
8334.9	0.15	0.06
8335.0	0.16	0.07
8335.1	0.18	0.09
8335.2	0.20	0.11
8335.3	0.22	0.13
8335.4	0.24	0.16
8335.5	0.27	0.18
8335.6	0.30	0.21
8335.7	0.35	0.24
8335.8	0.40	0.28
8335.9	0.47	0.32
8336.0	0.54	0.38
8336.1	0.65	0.44
8336.2	0.78	0.51
8336.3	0.90	0.59
8336.4	1.01	0.69
8336.5	1.10	0.79

Elevation	Area (acres)	Volume (acre-feet)
8336.6	1.22	0.91
8336.7	1.32	1.04
8336.8	1.46	1.18
8336.9	1.62	1.33
8337.0	1.78	1.50
8337.1	1.94	1.69
8337.2	2.10	1.89
8337.3	2.28	2.11
8337.4	2.52	2.35
8337.5	2.81	2.62
8337.6	3.10	2.92
8337.7	3.45	3.25
8337.8	3.81	3.61
8337.9	4.19	4.01
8338.0	4.53	4.45
8338.1	4.93	4.92
8338.2	5.32	5.44
8338.3	5.73	5.99
8338.4	6.07	6.59
8338.5	6.40	7.21
8338.6	6.75	7.87
8338.7	7.09	8.56
8338.8	7.42	9.29
8338.9	7.75	10.05
8339.0	8.01	10.84
8339.1	8.27	11.65
8339.2	8.50	12.50
8339.3	8.75	13.36
8339.4	9.00	14.25
8339.5	9.27	15.16
8339.6	9.57	16.10
8339.7	9.84	17.08
8339.8	10.14	18.07
8339.9	10.40	19.11
8340.0	10.67	20.16
8340.1	10.96	21.24
8340.2	11.27	22.36
8340.3	11.64	23.50
8340.4	12.05	24.69
8340.5	12.46	25.91
8340.6	12.93	27.18

Elevation	Area (acres)	Volume (acre-feet)
8340.7	13.44	28.51
8340.8	14.00	29.88
8340.9	14.50	31.31
8341.0	15.04	32.79
8341.1	15.54	34.31
8341.2	16.05	35.91
8341.3	16.52	37.53
8341.4	16.98	39.22
8341.5	17.43	40.93
8341.6	17.89	42.69
8341.7	18.38	44.52
8341.8	18.90	46.38
8341.9	19.40	48.31
8342.0	19.92	50.27
8342.1	20.49	52.28
8342.2	21.09	54.38
8342.3	21.77	56.52
8342.4	22.49	58.74
8342.5	23.22	61.02
8342.6	24.00	63.38
8342.7	24.82	65.84
8342.8	25.73	68.36
8342.9	26.60	70.99
8343.0	27.51	73.69
8343.1	28.58	76.49
8343.2	29.58	79.42
8343.3	30.65	82.43
8343.4	31.78	85.57
8343.5	32.88	88.80
8343.6	34.04	92.14
8343.7	35.25	95.63
8343.8	36.40	99.20
8343.9	37.45	102.92
8344.0	38.54	106.71
8344.1	39.56	110.60
8344.2	40.53	114.64
8344.3	41.55	118.73
8344.4	42.58	122.97
8344.5	43.81	127.27
8344.6	45.14	131.71
8344.7	46.62	136.33

Elevation	Area (acres)	Volume (acre-feet)
8344.8	48.29	141.06
8344.9	50.09	146.01
8345.0	51.98	151.11
8345.1	54.09	156.40
8345.2	56.23	161.96
8345.3	58.54	167.68
8345.4	60.97	173.70
8345.5	63.20	179.90
8345.6	65.60	186.33
8345.7	67.87	193.05
8345.8	70.39	199.95
8345.9	72.84	207.16
8346.0	75.46	214.56
8346.1	78.15	222.22
8346.2	80.98	230.24
8346.3	83.82	238.46
8346.4	86.65	247.05
8346.5	89.58	255.84
8346.6	92.75	264.93
8346.7	96.05	274.44
8346.8	99.58	284.20
8346.9	103.23	294.42
8347.0	106.99	304.91
8347.1	110.96	315.79
8347.2	114.89	327.16
8347.3	118.98	338.83
8347.4	123.25	351.03
8347.5	127.74	363.55
8347.6	132.53	376.53
8347.7	137.65	390.14
8347.8	142.89	404.14
8347.9	148.13	418.80
8348.0	153.66	433.86
8348.1	159.75	449.50
8348.2	165.91	465.90
8348.3	172.34	482.78
8348.4	178.66	500.47
8348.5	185.17	518.62
8348.6	191.99	537.44
8348.7	199.04	557.14
8348.8	206.06	577.35

Elevation	Area (acres)	Volume (acre-feet)
8348.9	213.31	598.47
8349.0	220.86	620.13
8349.1	228.65	642.57
8349.2	236.72	666.01
8349.3	245.49	690.07
8349.4	254.36	715.24
8349.5	263.32	741.07
8349.6	272.74	767.81
8349.7	282.03	795.76
8349.8	291.58	824.37
8349.9	301.14	854.23
8350.0	310.89	884.76
8350.1	320.54	916.25
8350.2	330.07	949.02
8350.3	339.56	982.41
8350.4	348.87	1017.08
8350.5	358.35	1052.36
8350.6	368.23	1088.59
8350.7	378.23	1126.17
8350.8	388.84	1164.43
8350.9	399.64	1204.13
8351.0	410.84	1244.55
8351.1	422.21	1286.10
8351.2	433.37	1329.20
8351.3	444.23	1372.96
8351.4	455.05	1418.24
8351.5	465.58	1464.15
8351.6	476.18	1511.11
8351.7	486.03	1559.55
8351.8	495.75	1608.49
8351.9	504.97	1658.88
8352.0	513.52	1709.65
8352.1	522.16	1761.28
8352.2	530.82	1814.27
8352.3	538.93	1867.60
8352.4	546.34	1922.22
8352.5	553.31	1977.03
8352.6	560.34	2032.53
8352.7	567.25	2089.29
8352.8	573.48	2146.14
8352.9	579.56	2204.16

Elevation	Area (acres)	Volume (acre-feet)
8353.0	585.75	2262.23
8353.1	591.77	2320.90
8353.2	597.88	2380.76
8353.3	603.94	2440.65
8353.4	610.21	2501.75
8353.5	616.85	2562.89
8353.6	623.60	2624.71
8353.7	630.10	2687.79
8353.8	636.87	2750.92
8353.9	643.44	2815.35
8354.0	649.39	2879.77
8354.1	654.99	2944.77
8354.2	660.40	3010.95
8354.3	665.67	3077.02
8354.4	670.92	3144.26
8354.5	676.43	3211.39
8354.6	682.24	3279.09
8354.7	688.14	3348.03
8354.8	694.62	3416.93
8354.9	701.19	3487.16
8355.0	707.80	3557.37
8355.1	714.87	3628.26
8355.2	722.17	3700.57
8355.3	730.00	3772.93
8355.4	737.97	3846.80
8355.5	745.92	3920.75
8355.6	754.03	3995.49
8355.7	761.51	4071.75
8355.8	769.05	4148.02
8355.9	776.43	4225.78
8356.0	783.93	4303.53
8356.1	791.75	4382.05
8356.2	799.85	4462.13
8356.3	808.01	4542.24
8356.4	816.18	4623.97
8356.5	824.39	4705.72
8356.6	832.88	4788.30
8356.7	841.27	4872.54
8356.8	849.72	4956.80
8356.9	857.54	5042.71
8357.0	864.79	5128.53

Elevation	Area (acres)	Volume (acre-feet)
8357.1	871.68	5215.05
8357.2	878.44	5303.10
8357.3	885.01	5390.96
8357.4	891.45	5480.34
8357.5	897.66	5569.48
8357.6	903.97	5659.24
8357.7	910.27	5750.51
8357.8	916.66	5841.53
8357.9	922.93	5934.08
8358.0	929.34	6026.36
8358.1	935.94	6119.29
8358.2	942.78	6213.81
8358.3	950.18	6308.12
8358.4	958.07	6404.13
8358.5	965.97	6499.99
8358.6	973.74	6596.64
8358.7	981.12	6695.00
8358.8	988.22	6793.12
8358.9	994.34	6892.86
8359.0	1000.03	6992.22
8359.1	1005.52	7092.14
8359.2	1010.59	7193.56
8359.3	1015.58	7294.50
8359.4	1020.43	7396.92
8359.5	1025.33	7498.83
8359.6	1030.25	7601.24
8359.7	1035.18	7705.14
8359.8	1040.07	7808.52
8359.9	1045.01	7913.41
8360.0	1049.99	8017.78
8360.1	1055.00	8122.64
8360.2	1059.87	8229.03
8360.3	1064.64	8334.87
8360.4	1069.46	8442.22
8360.5	1074.27	8549.01
8360.6	1079.21	8656.29
8360.7	1084.21	8765.12
8360.8	1089.29	8873.39
8360.9	1094.07	8983.23
8361.0	1098.74	9092.47
8361.1	1103.50	9202.17

Elevation	Area (acres)	Volume (acre-feet)
8361.2	1108.18	9313.43
8361.3	1112.89	9424.07
8361.4	1117.40	9536.26
8361.5	1122.00	9647.82
8361.6	1126.45	9759.82
8361.7	1130.79	9873.37
8361.8	1135.01	9986.24
8361.9	1139.12	10100.63
8362.0	1143.29	10214.33
8362.1	1147.42	10328.43
8362.2	1151.40	10444.07
8362.3	1155.32	10558.97
8362.4	1159.07	10675.39
8362.5	1162.65	10791.04
8362.6	1166.25	10907.05
8362.7	1169.74	11024.55
8362.8	1173.28	11141.26
8362.9	1176.70	11259.46
8363.0	1180.16	11376.87
8363.1	1183.66	11494.61
8363.2	1187.17	11613.87
8363.3	1190.75	11732.32
8363.4	1194.28	11852.28
8363.5	1197.80	11971.44
8363.6	1201.39	12090.94
8363.7	1205.12	12211.99
8363.8	1208.86	12332.24
8363.9	1212.95	12454.06
8364.0	1216.69	12575.09
8364.1	1220.63	12696.50
8364.2	1224.53	12819.49
8364.3	1228.55	12941.68
8364.4	1232.54	13065.48
8364.5	1236.62	13188.47
8364.6	1240.75	13311.88
8364.7	1244.91	13436.91
8364.8	1249.17	13561.15
8364.9	1253.47	13687.03
8365.0	1257.93	13812.13
8365.1	1262.50	13937.69
8365.2	1267.20	14064.93

Elevation	Area (acres)	Volume (acre-feet)
8365.3	1272.01	14191.42
8365.4	1294.30	14320.36
8365.5	1294.90	14449.32
8365.6	1295.48	14578.33
8365.7	1296.06	14708.67
8365.8	1296.60	14837.80
8365.9	1297.12	14968.25
8366.0	1297.67	15097.49
8366.1	1298.23	15226.78
8366.2	1298.80	15357.39
8366.3	1299.39	15486.79
8366.4	1299.97	15617.53
8366.5	1300.53	15747.05
8366.6	1301.20	15876.63
8366.7	1302.09	16007.56
8366.8	1303.13	16137.32
8366.9	1303.98	16268.44
8367.0	1304.65	16398.37
8367.1	1305.41	16528.37
8367.2	1306.26	16659.72
8367.3	1307.41	16789.89
8367.4	1308.66	16921.47
8367.5	1309.89	17051.89
8367.6	1311.22	17182.44
8367.7	1312.60	17314.41
8367.8	1313.87	17445.22
8367.9	1315.05	17577.44
8368.0	1316.12	17708.49
8368.1	1317.14	17839.65
8368.2	1318.12	17972.19
8368.3	1319.05	18103.54
8368.4	1320.08	18236.27
8368.5	1321.08	18367.82
8368.6	1322.04	18499.46
8368.7	1322.98	18632.49
8368.8	1323.96	18764.33
8368.9	1324.88	18897.55
8369.0	1325.79	19029.57
8369.1	1326.69	19161.68
8369.2	1327.60	19295.18
8369.3	1328.66	19427.48

Elevation	Area (acres)	Volume (acre-feet)
8369.4	1329.69	19561.18
8369.5	1330.72	19693.69
8369.6	1331.82	19826.30
8369.7	1332.97	19960.32
8369.8	1334.16	20093.16
8369.9	1335.28	20227.42
8370.0	1336.46	20360.49
8370.1	1337.61	20493.68
8370.2	1338.80	20628.29
8370.3	1340.05	20761.72
8370.4	1341.28	20896.57
8370.5	1342.47	21030.24
8370.6	1343.69	21164.03
8370.7	1345.04	21299.26
8370.8	1346.36	21433.31
8370.9	1347.57	21568.81
8371.0	1348.77	21703.10
8371.1	1350.03	21837.52
8371.2	1351.33	21973.39
8371.3	1352.61	22108.06
8371.4	1353.90	22244.19
8371.5	1355.12	22379.12
8371.6	1356.39	22514.17
8371.7	1357.69	22650.68
8371.8	1359.00	22785.99
8371.9	1360.31	22922.75
8372.0	1361.64	23058.33
8372.1	1362.91	23194.03
8372.2	1364.14	23331.19
8372.3	1365.41	23467.14
8372.4	1366.70	23604.55
8372.5	1368.02	23740.76
8372.6	1369.40	23877.10
8372.7	1370.80	24014.92
8372.8	1372.20	24151.54
8372.9	1373.69	24289.65
8373.0	1375.19	24426.56
8373.1	1376.67	24563.63
8373.2	1378.20	24702.18
8373.3	1379.71	24839.55
8373.4	1381.14	24978.40

Elevation	Area (acres)	Volume (acre-feet)
8373.5	1382.54	25116.06
8373.6	1383.96	25253.85
8373.7	1385.31	25393.13
8373.8	1386.70	25531.19
8373.9	1388.09	25670.75
8374.0	1389.50	25809.10
8374.1	1390.91	25947.58
8374.2	1392.43	26087.57
8374.3	1393.96	26226.35
8374.4	1395.56	26366.65
8374.5	1397.17	26505.75
8374.6	1398.81	26645.01
8374.7	1400.48	26785.80
8374.8	1402.27	26925.40
8374.9	1404.05	27066.55
8375.0	1405.96	27206.51
8375.1	1407.98	27346.66
8375.2	1409.92	27488.39
8375.3	1411.91	27628.94
8375.4	1413.84	27771.07
8375.5	1415.76	27912.00
8375.6	1417.77	28053.14
8375.7	1419.82	28195.85
8375.8	1422.19	28337.40
8375.9	1425.16	28480.61
8376.0	1428.22	28622.73