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Dolores Water Conservancy District

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Kohn, M.S., Bathymetry of Groundhog Reservoir, Dolores County, Colorado, 2011
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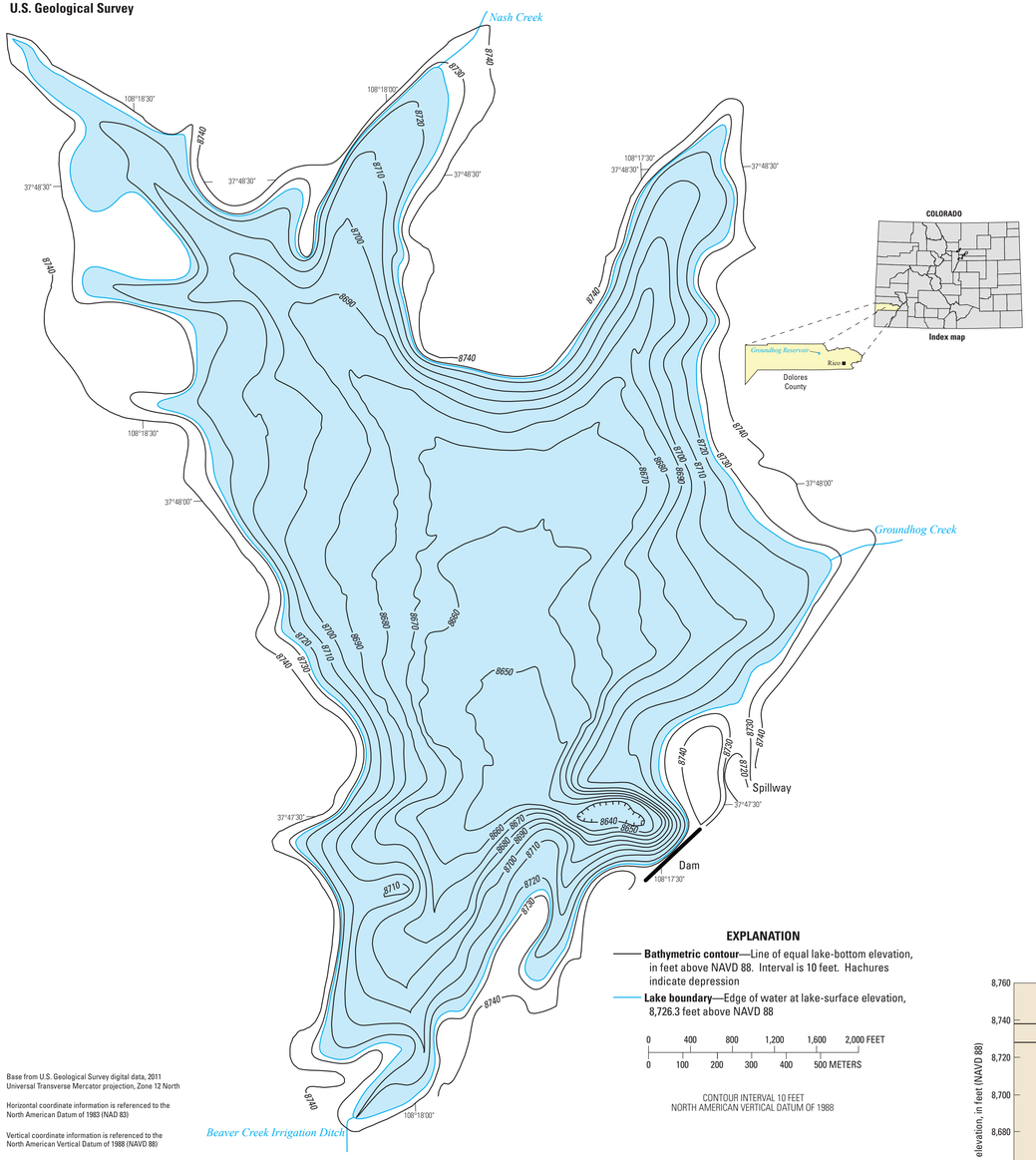

Figure 1. Bathyetric contours of Groundhog Reservoir, Dolores County, Colorado, 2011 (not for navigational use).

ABSTRACT

In order to better characterize the water supply capacity of Groundhog Reservoir, Dolores County, Colorado, the U.S. Geological Survey, in cooperation with the Dolores Water Conservancy District, conducted a bathymetric survey of Groundhog Reservoir. The study was performed in June 2011 using a man-operated boat-mounted multibeam echo sounder integrated with a global positioning system and a terrestrial real-time kinematic global positioning system. The two collected datasets were merged and imported into geographic information system software. A bathymetric map of the reservoir was generated in addition to plots for the stage-area and the stage-volume relations.

INTRODUCTION

Groundhog Reservoir is owned and operated by Montezuma Valley Irrigation Company, and water from the reservoir is used for the irrigation of agricultural land in Dolores and Montezuma Counties in southwestern Colorado. Because the storage capacity of Groundhog Reservoir is not documented and storage capacity information would aid water-resources managers in their operation of the reservoir during periods of drought and (or) high demand, the U.S. Geological Survey (USGS), in cooperation with the Dolores Water Conservancy District, conducted a bathymetric study of Groundhog Reservoir to determine the stage-surface area and stage-volume relations of the reservoir. This report provides water managers with a better understanding of available water supply in the reservoir and, should another bathymetric survey be conducted in the future, a dataset that also could be used to determine sedimentation infill rate and the useful lifespan of the reservoir. This report supports one of the USGS strategic directions of water supply by providing information related to the water census of the United States.

PURPOSE AND SCOPE

This report presents the results of the bathymetric evaluation of Groundhog Reservoir. The report contains a description of the data collection and analytical methods used to survey the reservoir and to develop datasets which aid water managers. A bathymetric map of the reservoir is presented with plots for the stage-area and the stage-volume relations.

DESCRIPTION OF STUDY AREA

Groundhog Reservoir is located in southwest Colorado at 37° 47' 26" N. latitude and 108° 17' 29" W. longitude relative to North American Datum of 1983 (NAD 83) at the confluence of Groundhog and Nash Creeks in eastern Dolores County (U.S. Geological Survey, 2011). Groundhog Reservoir is a man-made lake created by the impoundment of Groundhog Creek (Montezuma Valley Irrigation Company, 1938). Construction of the dam was completed in 1908, and it was enlarged in 1938 to its current dimensions (Montezuma Valley Irrigation Company, 1938). The drainage basin of the reservoir is 16.2 square miles (U.S. Geological Survey, 2011).

The rights to the water in the reservoir are owned by Montezuma Valley Irrigation Company; however, recreational activities are permitted on the reservoir. Approximately 6 miles downstream from Groundhog Reservoir, Groundhog Creek flows into the West Dolores River, a branch of the Dolores River, which is a tributary of the Colorado River (U.S. Geological Survey, 2011).

BATHYMETRIC MEASUREMENT AND STORAGE ANALYSIS

The USGS performed a bathymetric survey of Groundhog Reservoir using a man-operated boat-mounted multibeam echo sounder integrated with a global positioning system (GPS) and a terrestrial real-time kinematic (RTK) GPS in June 2011. For the purposes of this report, data collected from both the boat-mounted multibeam echo sounder and terrestrial RTK GPS will be considered bathymetric data. The multibeam echo sounder collected data at lake depths of approximately 3 feet (ft) and greater, whereas a terrestrial topographic survey was performed with the RTK GPS in shallow areas near the shore not navigable by boat to the elevation of the top of the dam plus about 2 to 3 additional feet.

BATHYMETRIC MEASUREMENTS USED IN DATA COLLECTION

Bathymetric data from the multibeam echo sounder were collected June 27–29, 2011, using a Teledyne Odom Hydrographic ES3PT–M integrated multibeam echo sounder and motion sensor (Teledyne Odom Hydrographic, Inc., 2011) equipped with a Trimble SPS461 GPS receiver using procedures described in Wilson and Richards (2006). The vertical and horizontal precision of the multibeam echo sounder GPS as rated by the manufacturer are ±0.065 ft and ±0.032 ft, respectively (Trimble Navigation Limited, 2009b). The multibeam echo sounder has a swath width of 120 degrees capable of collecting data to depths of 197 ft. The echo sounder collects 240 data points at a sample frequency of 12 hertz (Hz); however, this varies with depth. The GPS generates position data at a rate of 5 Hz and navigational data at a rate of 1 Hz. A Teledyne Odom Hydrographic Real Time Appliance (RTA) was used for data synchronization of all aforementioned instruments resulting in a data string recorded at 1 Hz. The bathymetry data from the multibeam echo sounder were compiled and stored using the hydrographic survey software, HYPACK 2010 from HYPACK, Inc. (HYPACK, Inc., 2010).

The multibeam echo sounder emits a pulse at a frequency of 240 kilohertz, which is reflected off the lake bed and detected by the receiver. The velocity of the pulse is affected by the lake temperature and salinity. For Groundhog Reservoir, a freshwater lake, the effect of salinity was assumed to be negligible (U.S. Army Corps of Engineers, 2002). Velocity profiles of Groundhog Reservoir were recorded using a Teledyne Odom Hydrographic Digibar-Pro velocity meter throughout the study and were used to correct the data during post-processing (Teledyne Odom Hydrographic, Inc., 2001). Calibration points were obtained with the RTK GPS while the multibeam echo sounder was simultaneously recording to confirm the results.

The dam, principle outlet structure, and spillway also were surveyed using the RTK GPS. The terrestrial topographic survey was performed June 27–29, 2011, using a Trimble R8 GNSS RTK GPS receiver, a Trimble HPB450 radio modem, and a Trimble TSC2 controller. The vertical and horizontal precision of the RTK GPS as rated by the manufacturer are ±0.066 ft and ±0.033 ft, respectively (Trimble Navigation Limited, 2009a). The RTK GPS setup consisted of a base station, which included a receiver and radio, and a rover which consisted of a receiver and controller. The base station was located at a fixed position on the east end of the dam and receives information from satellites and transmits data to the rover's receiver via the radio. The base station also continuously records its position. The rover communicates with the base station and is used to collect and record individual data points throughout the study area based on the position of the base station.

The daily water-surface elevation was determined from the RTK GPS survey-data points. The RTK GPS dataset not only included more than 700 water-surface elevation points over the course of the study, but almost 6,000 data points were obtained on the shoreline and in the shallow areas of the lake that were not navigable by boat. The shoreline was surveyed from a lake depth of 3 ft to 2–3 ft above the top of the dam.

All survey data were collected with a common coordinate system, geoid, ellipsoid, and datum. The coordinate system used was Universal Transverse Mercator (UTM), zone 12 north, the horizontal datum was NAD 83, and the vertical datum was North American Vertical Datum 1988 (NAVD 88), Geoid 03, ellipsoid World Geodetic System 1984 (WGS 84). Data from the base station collected throughout the study were submitted to the National Geodetic Survey's Online Positioning User Service (OPUS) Web site for processing (*http://www.ngs.noaa.gov/OPUS/*, accessed October 19, 2011). All survey data were recomputed to reflect the OPUS solution correction.

POST PROCESSING AND DATA ANALYSIS

The motion sensor in the multibeam sonar records the instrument's motion in terms of pitch, roll, and heave. Pitch is the alternating rise and fall of the boat's bow and stern, roll is rotation of the boat about its main axis, heave is the vertical rise and fall of the entire vessel, and yaw is the rotation of the sonar from the boat's main axis. The ambient offsets of pitch, roll, and yaw were corrected using a calibration test, otherwise known as a patch test, as the instrument was not installed exactly vertical and in line with the boat's main axis. From the patch test, the pitch offset angle was determined to be 10 degrees and the roll 0.40 degree. The yaw offset angle was not corrected as no consistent value could be determined from the patch test. On days 2 and 3 of the study, navigational and heave data were not collected due to instrument malfunction. As a result, pitch, roll, and yaw information was not collected during those days. After further examination, it was determined that the malfunction may have led to a positive bias of up to 1.5 percent or a total of 140 acre-feet (ac-ft) in reservoir volume based on the area surveyed on day two and three. Therefore, the volumes determined at each stage will reflect a positive bias of up to but no more than 140 ac-ft.

The post processing of the multibeam echo sounder bathymetry data was performed using HYPACK 2011 from HYPACK, Inc. (HYPACK, Inc., 2011). All the data were filtered using the automated search and filter tool. Then, manual filtering was performed on the multibeam echo sounder bathymetry data to edit any spikes or inconsistencies that the automated filter overlooked. Once all the data were filtered, the data were separated by the observation day. The multibeam echo sounder bathymetry data were interpolated onto a grid, with individual grid cells having sides of 6.56 ft, by computing the average depth in each cell and positioning the mean at the cell center.

The RTK GPS water-surface elevation dataset was filtered manually to remove errant or poor data. Then, the daily mean water-surface elevation was computed from the edited dataset. The multibeam echo sounder bathymetry data, which initially used the water-surface elevation as a datum, were converted to elevation (NAVD 88) using the daily mean water-surface elevation. The result was one dataset with a common horizontal and vertical datum (NAD 83 and NAVD 88).

The bathymetry dataset was imported into Environmental Systems Research Institute (ESRI) ArcMap 9.3.1 (Environmental Systems Research Institute, Inc., 2010) so the elevation contours and reservoir area and volume could be determined from the lake bottom to approximately 2–3 ft above the top of dam. Once the 6.56-ft grid was created using HYPACK 2011, it was merged with the RTK GPS dataset in ArcMap by generating a triangulated irregular network (TIN) from both datasets. The TIN was then converted to a 6.56-ft horizontal grid, and using the contour tool in ArcMap, contours at intervals of 10 ft were produced. The areas and volumes at various elevations were computed using the surface volume tool in ArcMap (figs. 1–3, and table 1).

In figure 1, some of the upper contours are not continuous; this is mainly due to the spillway and irrigation canal not allowing for the continuation of the contours as the spillway and canal inverts are below the elevation of the top of the dam. However, in the northwest end of the reservoir and east of the Nash Creek inlet, sufficient data were not collected to resolve the contours causing the breaks. Where breaks in contours occurred, it was assumed the areas and volumes above that point were computed as if a vertical wall existed at that point. That assumption provided better results than using a high resolution digital elevation model. When comparing the 10-meter digital elevation model (DEM) (Gesch and others, 2002) at the reservoir with the data collected, it appeared that the DEM did not provide sufficient accuracy to improve the dataset collected for this report. Therefore, no DEM was used to supplement the dataset and the results of this report were generated only from field data.

BATHYMETRY OF GROUNDHOG RESERVOIR

From the RTK GPS data, the top of the dam was approximately 8,738 ft above NAVD 88, the spillway invert was 8,728 ft above NAVD 88, and full-pool elevation was 8,726 ft above NAVD 88. At the spillway elevation, the surface area of the lake is 734 acres (ac) and the volume is 25,700 ac-ft. The minimum elevation of the reservoir is located 100 ft below the spillway elevation. As shown in figure 3, the volume increases very rapidly with depth initially, but at elevations greater than 8,697 ft above NAVD 88, the stage-volume curve is approximately linear.

SUMMARY

A better understanding of available water supply aids water managers in their operation of reservoirs during periods of drought and (or) high demand, and, should another bathymetric survey be conducted in the future, provides a dataset that also could be used to determine sedimentation infill rate and the useful lifespan of the reservoir. The U.S. Geological Survey, in cooperation with the Dolores Water Conservancy District, carried out a bathymetry study of Groundhog Reservoir, Dolores County, Colorado, from June 27–29, 2011. The study was performed using a man-operated boat-mounted multibeam echo sounder integrated with GPS navigation and RTK GPS. The vertical and horizontal precision of the multibeam echo sounder GPS as rated by the manufacturer are ±0.065 ft and ±0.032 ft, respectively. The vertical and horizontal precision of the RTK GPS as rated by the manufacturer are ±0.066 ft and ±0.033 ft, respectively. From the RTK GPS data, the top of dam was approximately 8,738 ft above North American Vertical Datum 1988 (NAVD 88) and the spillway invert was 8,728 ft above NAVD 88. The two collected datasets were merged and imported into geographic information system software. The results of the study include a stage-surface area and stage-volume relations and bathymetric map. At the spillway elevation, the surface area of the lake is 734 acres and the volume is 25,700 acre-feet.

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Table 1. Stage-surface area and stage-volume relation for selected elevations of Groundhog Reservoir, Dolores County, Colorado, 2011.

Stage elevation, in feet (NAVD 88)	Stage-surface area, in acres	Stage-volume, in acre-feet
8,629	0.000	0.000
8,630	0.070	0.026
8,631	0.181	0.146
8,632	0.345	0.409
8,633	0.481	0.817
8,634	0.622	1.37
8,635	0.757	2.06
8,636	0.878	2.87
8,637	1.23	3.87
8,638	1.69	5.32
8,639	2.22	7.27
8,640	2.78	9.77
8,641	3.16	12.7
8,642	3.41	16.0
8,643	3.83	19.6
8,644	4.82	23.8
8,645	6.89	29.6
8,646	10.3	38.1
8,647	13.6	50.0
8,648	17.4	65.4
8,649	22.1	85.2
8,650	26.3	109
8,651	29.9	138
8,652	33.7	169
8,653	37.7	205
8,654	43.2	245
8,655	48.9	291
8,656	55.9	343
8,657	64.7	404
8,658	71.6	472
8,659	78.7	547
8,660	86.7	630
8,661	94.1	720
8,662	101	818
8,663	108	922
8,664	115	1,030
8,665	124	1,150
8,666	133	1,280
8,667	141	1,420
8,668	148	1,560
8,669	154	1,710
8,670	161	1,870
8,671	168	2,040
8,672	176	2,210
8,673	183	2,390
8,674	189	2,570
8,675	195	2,760
8,676	201	2,960
8,677	207	3,170
8,678	213	3,380
8,679	220	3,590
8,680	227	3,820
8,681	235	4,050
8,682	242	4,290
8,683	249	4,530
8,684	257	4,780
8,685	265	5,050
8,686	273	5,310
8,687	281	5,590
8,688	289	5,880
8,689	298	6,170
8,690	308	6,470
8,691	316	6,790
8,692	326	7,110
8,693	335	7,440
8,694	345	7,780
8,695	355	8,130
8,696	364	8,490
8,697	374	8,850
8,698	383	9,220
8,699	393	9,620
8,700	404	10,000
8,701	414	10,400
8,702	424	10,800
8,703	434	11,300
8,704	445	11,700
8,705	455	12,200
8,706	466	12,600
8,707	476	13,100
8,708	486	13,600
8,709	497	14,100
8,710	507	14,600
8,711	518	15,100
8,712	530	15,600
8,713	542	16,100
8,714	553	16,700
8,715	564	17,300
8,716	576	17,800
8,717	588	18,400
8,718	600	19,000
8,719	612	19,600
8,720	625	20,200
8,721	639	20,900
8,722	652	21,500
8,723	665	22,200
8,724	678	22,800
8,725	692	23,500
8,726	705	24,200
8,727	719	24,900
Spillway — 8,728	734	25,700
8,729	750	26,400
8,730	766	27,200
8,731	783	27,900
8,732	798	28,700
8,733	810	29,500
8,734	822	30,300
8,735	835	31,200
8,736	848	32,000
8,737	861	32,900
Dam crest — 8,738	874	33,700
8,739	889	34,600
8,740	901	35,500
8,741	912	36,400
8,742	921	37,300

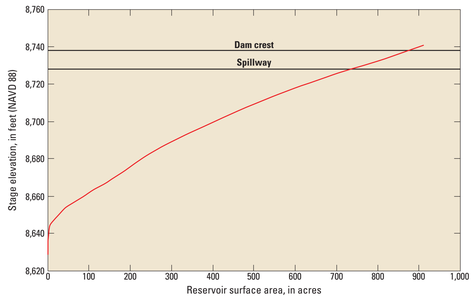

Figure 2. Stage-surface area curve of Groundhog Reservoir, Dolores County, Colorado, 2011.

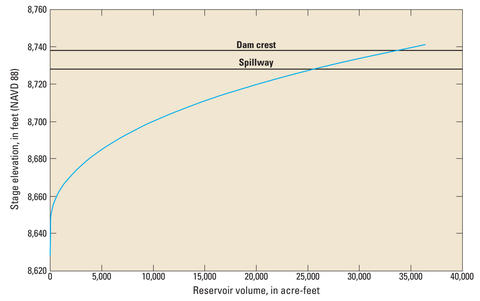

Figure 3. Stage-volume curve of Groundhog Reservoir, Dolores County, Colorado, 2011.

Bathymetry of Groundhog Reservoir, Dolores County, Colorado, 2011

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