HYDROGRAPHIC SURVEY of MEEKER LAKE

Final Report

September 30, 2009

Prepared by:

State of Oklahoma

OWRB

WATER RESOURCES BOARD
the water agency

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INTRODUCTION

The Oklahoma Water Resources Board (OWRB) conducted a hydrographic survey of Meeker Lake in April of 2009. The purpose of this survey was to collect hydrographic data of the lake and convert this information into an elevation-area-capacity table. This project was funded by the OWRB's Dam Safety Program.

LAKE BACKGROUND

Meeker Lake, also known as Quapaw Creek Site 15, is located on a tributary of Quapaw Creek 2.3 miles southwest of Meeker, Oklahoma in Lincoln County (**Figure 1**). It was built in 1970. Its original purposes were water supply, flood control, and recreation. The dam is located in Sec. 24-T12N-R3E. The dam on this reservoir is classified as a high hazard dam. The "high hazard" classification means that dam failure, if it occurred, may cause loss of life, serious damage to homes, industrial or commercial buildings, important public utilities, main highways or railroads. This classification does not mean that it is likely to fail.
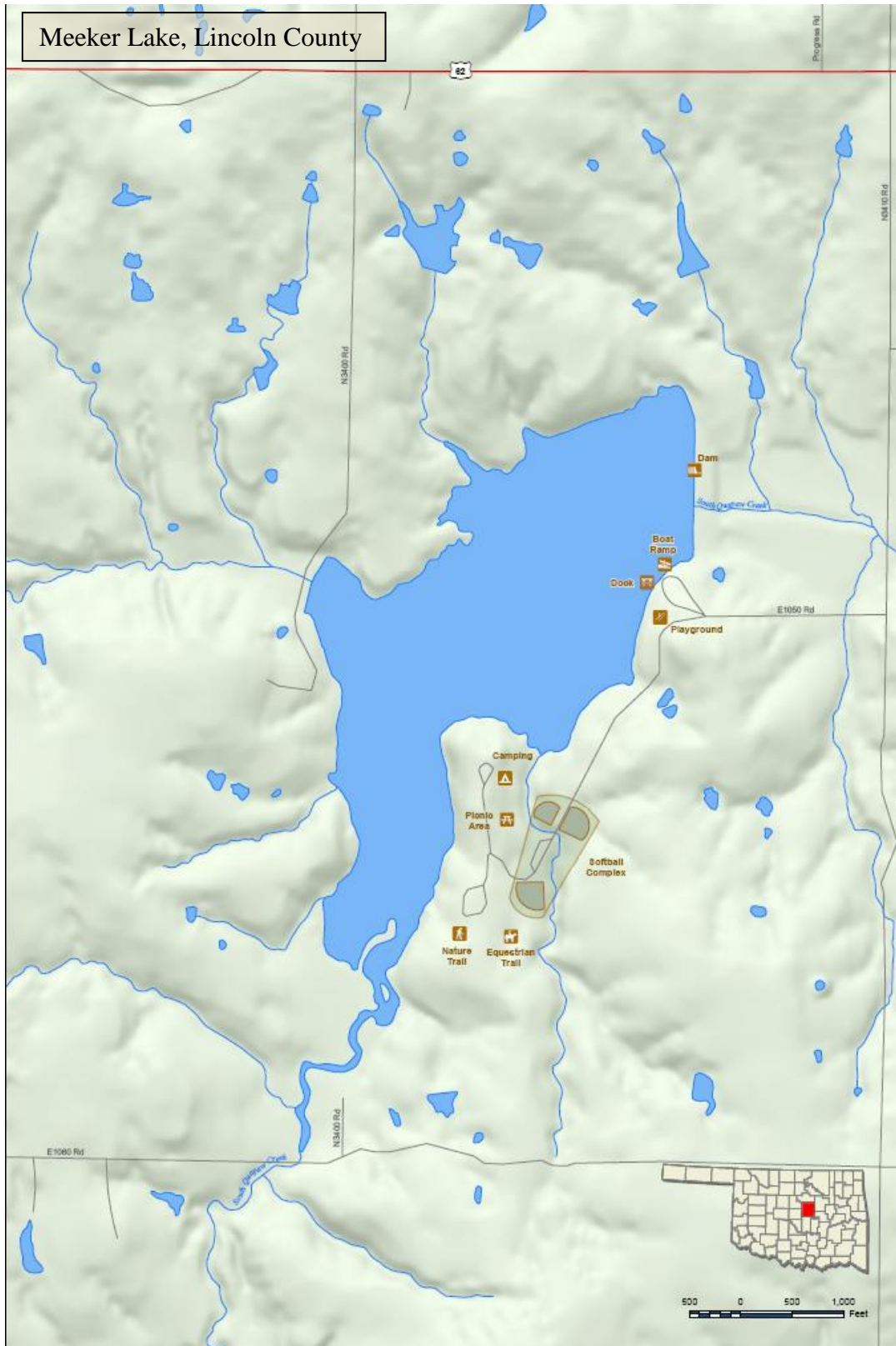
Figure 1: Location map for Meeker Lake.

HYDROGRAPHIC SURVEYING PROCEDURES

The process of surveying a reservoir uses a combination of Geographic Positioning System (GPS) and acoustic depth sounding technologies that are incorporated into a hydrographic survey vessel. As the survey vessel travels across the lake's surface, the echosounder gathers multiple depth readings every second. The depth readings are stored on the survey vessel's on-board computer along with the positional data generated from the vessel's GPS receiver. The collected data files are downloaded daily from the computer and brought to the office for editing. During editing, data "noise" is removed or corrected, and average depths are converted to elevation readings based on the daily-recorded lake level elevation on the day the survey was performed. Accurate estimates of area-capacity can then be determined for the lake by building a 3-D model of the reservoir from the corrected data. The process of completing a hydrographic survey includes four steps: pre-survey planning, field survey, data processing, and GIS application.

Pre-survey Planning
Boundary File
The boundary file for Meeker was on-screen digitized from the 2006 color digital orthoimagery quarter quadrangle (DOQQ) mosaic of Lincoln County, Oklahoma. The screen scale was set to 1:1,500. A line was digitized to represent the shoreline as closely as possible. Due to the photography being a summer photo, it was difficult to determine the actual shoreline when there are trees and other vegetation hanging over the lake. The 1995 DOQQs of the lakes were used as back ground reference. The reservoir boundaries were digitized in North American Datum (NAD) 1983 State Plane Coordinates (Oklahoma North-3501).

Set-up
HYPACK software from Hypack, Inc. was used to assign geodetic parameters, import background files, and create virtual track lines (transects). The geodetic parameters assigned were State Plane NAD 83 Zone OK-3501 Oklahoma North with distance units and depth as US Survey Feet. The survey transects were spaced according to the accuracy required for the project. The survey transects within the digitized reservoir boundary were at 300 ft increments and ran perpendicular to the original stream channels and tributaries. Approximately 30 virtual transects were created for the Meeker Lake.

Field Survey
Lake Elevation Acquisition
The lake elevation for Meeker Lake was obtained by collecting positional data over a period of 40+ minutes. This data was then uploaded to the On-line Positioning Users Service-Rapid Static (OPUS-RS) website. The National Geodetic Survey (NGS) operates the OPUS as a means to provide GPS users easier access to the National Spatial Reference System (NSRS). OPUS-RS allows users to submit their GPS data files to NGS, where the data is processed to determine a position using NGS computers and software. Each data file that is submitted is processed with respect to at least three Continuously Operating Reference Stations (CORS).

Method
The procedures followed by the OWRB during the hydrographic survey adhere to U.S. Army Corps of Engineers (USACE) standards (USACE, 2002). The quality control and quality assurance procedures for equipment calibration and operation, field survey, data processing, and accuracy standards are presented in the following sections.

Technology
The Hydro-survey vessel is an 18-ft aluminum Silverstreak hull with cabin, powered by a single 115-Horsepower Mercury outboard motor. Equipment used to conduct the survey included: a ruggedized notebook computer; Syqwest Bathy 1500 Echo Sounder, with a depth resolution of 0.1 ft; Trimble Navigation, Inc. Pro XR GPS receiver with differential global positioning system (DGPS) correction; and an Odom Hydrographics, Inc, DIGIBAR-Pro Profiling Sound Velocimeter. The software used was HYPACK.

Survey
A two-man survey crew was used during the project. Data collection for Meeker Lake occurred in April of 2009. The water level elevation for Meeker Lake was 908.0 ft NGVD. Data collection began at the dam and moved to the south. The survey crew followed the parallel transects created during the pre-survey planning while collecting depth soundings and positional data. Data was also collected along a path parallel to the shoreline at a distance that was determined by the depth of the water and the draft of the boat – generally, two to three feet deep. Areas with depths less than this were avoided.

Quality Control/Quality Assurance
While on board the Hydro-survey vessel, the Syqwest Bathy 1500 Echo Sounder was calibrated using A DIGIBAR-Pro Profiling Sound Velocimeter, by Odom Hydrographics. The sound velocimeter measures the speed of sound at incremental depths throughout the water column. The factors that influence the speed of sound—depth, temperature, and salinity—are all taken into account. Deploying the unit involved lowering the probe, which measures the speed of sound, into the water to the calibration depth mark to allow for acclimation and calibration of the depth sensor. The unit was then gradually lowered at a controlled speed to a depth just above the lake bottom, and then was raised to the surface. The unit collected sound velocity measurements in feet/seconds (ft/sec) at 1 ft increments on both the deployment and retrieval phases. The data was then reviewed for any erroneous readings, which were then edited out of the sample. The sound velocity corrections were then applied to the to the raw depth readings. The average speed of sound in the water column was 4791.97 ft/sec during the Meeker Lake survey.

A quality assurance cross-line check was performed on intersecting transect lines and channel track lines to assess the estimated accuracy of the survey measurements. The overall accuracy of an observed bottom elevation or depth reading is dependent on random and systematic errors that are present in the measurement process. Depth measurements contain both random errors and systematic bias. Biases are often referred to as systematic errors and are often due to observational errors. Examples of bias include a bar check calibration error, tidal errors, or incorrect squat corrections. Bias, however, does not affect the repeatability, or precision, of results. The precision of depth readings is affected by random errors. These are errors present in the measurement system that cannot be easily reduced by further calibration.

Examples of random error include uneven bottom topography, bottom vegetation, positioning error, extreme listing of survey vessel, and speed of sound variation in the water column. An assessment of the accuracy of an individual depth or bottom elevation must fully consider all the error components contained in the observations that were used to determine that measurement. Therefore, the ultimate accuracy must be estimated (thus the use of the term "estimated accuracy") using statistical estimating measures (USACE, 2002).

The depth accuracy estimate is determined by comparing depth readings taken at the intersection of two lines and computing the difference. This is done on multiple intersections. The mean difference of all intersection points is used to calculate the mean difference (MD). The mean difference represents the bias present in the survey. The standard deviation (SD), representing the random error in the survey, is also calculated. The mean difference and the standard deviation are then used to calculate the Root Mean Square (RMS) error. The RMS error estimate is used to compare relative accuracies of estimates that differ substantially in bias and precision (USACE, 2002). According the USACE standards, the RMS at the 95% confidence level should not exceed a tolerance of ± 2.0 ft for this type of survey. This simply means that on average, 19 of every 20 observed depths will fall within the specified accuracy tolerance.

HYPACK Cross Statistics program was used to assess vertical accuracy and confidence measures of acoustically recorded depths. The program computes the sounding difference between intersecting lines of single beam data. The program provides a report that shows the standard deviation and mean difference. A total of 45 cross-sections points at Meeker Lake were used to compute error estimates. A mean difference of 0.03 ft and a standard deviation of 0.20 ft were computed from intersections. The following formulas were used to determine the depth accuracy at the 95% confidence level.

$$RMS = \sqrt{\sigma^2{}_{Randomerror} + \sigma^2{}_{Bias}}$$

where:

        Random error = Standard deviation
        Bias = Mean difference
        RMS = root mean square error (68% confidence level)

and:

$$RMS\ (95\%)\ depth\ accuracy = 1.96 \times RMS\ (68\%)$$

An RMS of ± 0.40 ft with a 95% confidence level is less than the USACE's minimum performance standard of ± 2.0 ft for this type of survey. A mean difference, or bias, of 0.03 ft is well below the USACE's standard maximum allowable bias of ± 0.5 ft for this type of survey.

The GPS system is an advanced high performance geographic data-acquisition tool that uses DGPS to provide sub-meter positional accuracy on a second-by-second basis. Potential errors are reduced with differential GPS because additional data from a reference GPS receiver at a known position are used to correct positions obtained during the survey. Before the survey, Trimble's Pathfinder Controller software was used to configure the GPS receiver. To maximize the accuracy of the horizontal positioning, the horizontal mask setting was set to 15 degrees and the Position Dilution of Precision (PDOP) limit was set to 6. The position interval was set to 1 second and the Signal to Noise Ratio (SNR) mask was set to 4. The United States Coast Guard reference station used in the survey is located near Sallisaw, Oklahoma.

A latency test was performed to determine the fixed delay time between the GPS and single beam echo sounder. The timing delay was determined by running reciprocal survey lines over a channel bank. The raw data files were downloaded into HYPACK, LATENCY TEST program. The program varies the time delay to determine the "best fit" setting. A position latency of 0.1 seconds was produced and adjustments were applied to the raw data in the EDIT program.

Data Processing
The collected data was transferred from the field computer onto an OWRB desktop computer. After downloading the data, each raw data file was reviewed using the EDIT program within HYPACK. The EDIT program allowed the user to assign transducer offsets, latency corrections, tide corrections, display the raw data profile, and review/edit all raw depth information. Raw data files are checked for gross inaccuracies that occur during data collection.

Offset correction values of 3.2 ft. starboard, 6.6 ft. forward, and -1.1 ft. vertical were applied to all raw data along with a latency correction factor of 0.1 seconds. The speed of sound corrections were applied during editing of raw data.

A correction file was produced using the HYPACK TIDES program to account for the variance in lake elevation at the time of data collection. Within the EDIT program, the corrected depths were subtracted from the elevation reading to convert the depth in feet to an elevation. The average elevation of the lake during the survey was 907.1 ft (NGVD).

After editing the data for errors and correcting the spatial attributes (offsets and tide corrections), a data reduction scheme was needed due to accomplish large quantity of collected data. To accomplish this, the corrected data was resampled spatially at a 5 ft interval using the Sounding Selection program in HYPACK. The resultant data was saved and exported out as a xyz.txt file. The HYPACK raw and corrected data files for Meeker Lake are located on the DVD entitled *Meeker HYPACK/GIS Metadata.*

GIS Application
Geographic Information System (GIS) software was used to process the edited XYZ data collected from the survey. The GIS software used was ArcGIS Desktop and ArcMap, version 9.2, from Environmental System Research Institute (ESRI). All of the GIS datasets created are in Oklahoma State Plane North Coordinate System referenced to the North American

Datum 1983. Horizontal and vertical units are in feet. The edited data points in XYZ text file format were converted into ArcMap point coverage format. The point coverage contains the X and Y horizontal coordinates and the elevation and depth values associated with each collected point.

Volumetric and area calculations were derived using a Triangulated Irregular Network (TIN) surface model. The TIN model was created in ArcMap, using the collected survey data points and the lake boundary inputs. The TIN consists of connected data points that form a network of triangles representing the bottom surface of the lake. The lake volume was calculated by slicing the TIN horizontally into planes 0.1 ft thick. The cumulative volume and area of each slice are shown in **APPENDIX A: Area-Capacity Data.**

Contours, depth ranges, and the shaded relief map were derived from a constructed digital elevation model grid. This grid was created using the ArcMap Topo to Raster Tool and had a spatial resolution of five feet. A low pass 3x3 filter was run to lightly smooth the grid to improve contour generation. The contours were created at a 2-ft interval using the ArcMap Contour Tool. The contour lines were edited to allow for polygon topology and to improve accuracy and general smoothness of the lines. The contours were then converted to a polygon coverage and attributed to show 2-ft depth ranges across the lake. The bathymetric maps of the lakes are shown with 2-ft contour intervals in **APPENDIX B: Meeker Maps**.

All geographic datasets derived from the survey contain Federal Geographic Data Committee (FGDC) compliant metadata documentation. The metadata describes the procedures and commands used to create the datasets. The GIS metadata file for both lakes is located at on the DVD entitled *Meeker HYPACK/GIS Metadata.*

RESULTS

Results from the 2009 OWRB survey indicate that Meeker Lake encompasses 212 acres and contains a cumulative capacity of 1,962 ac-ft at the normal pool elevation (908 ft National Geodetic Vertical Datum (NGVD)). The average depth for Meeker Lake was 9.3 ft.

SUMMARY and COMPARISON

Table 1 is comparison of area and volume changes of Meeker Lake at the normal pool elevation. Based on the design specifications, Meeker Lake had an area of 270 acres and cumulative volume of 2,350 acre-feet of water at normal pool elevation (908 ft NGVD). The surface area of the lake has had a decrease of 58 acres or approximately 21%. The 2009 survey shows that Meeker Lake had a decrease in capacity of 16.5% or approximately 388 acre-feet. Caution should be used when directly comparing between the design specifications and the 2009 survey conducted by the OWRB because different methods were used to collect the data and extrapolate capacity and area figures. It is the recommendation of the OWRB that another survey using the same method used in the 2009 survey be conducted in 10-15 years. By using the 2009 survey figures as a baseline, a future survey would allow an accurate sedimentation rate to be obtained.

Table 1: Area and Volume Comparisons of Meeker Lake at normal pool (908 ft NGVD).

Feature	Survey Year	
	Design Specifications (1970)	2009
Area (acres)	270	212
Cumulative Volume (acre-feet)	2,350	1,962
Mean depth (ft)	8.7	9.3
Maximum Depth (ft)	--	24.2

REFERENCES

U.S. Army Corps of Engineers (USACE). 2002. Engineering and Design - Hydrographic Surveying, Publication EM 1110-2-1003, 3rd version.

Oklahoma Water Resources Board (OWRB). 1970. <u>Oklahoma Water Atlas</u>.

Oklahoma Water Resources Board (OWRB). Phase 1 Inspection Report; National Dam Safety Program.
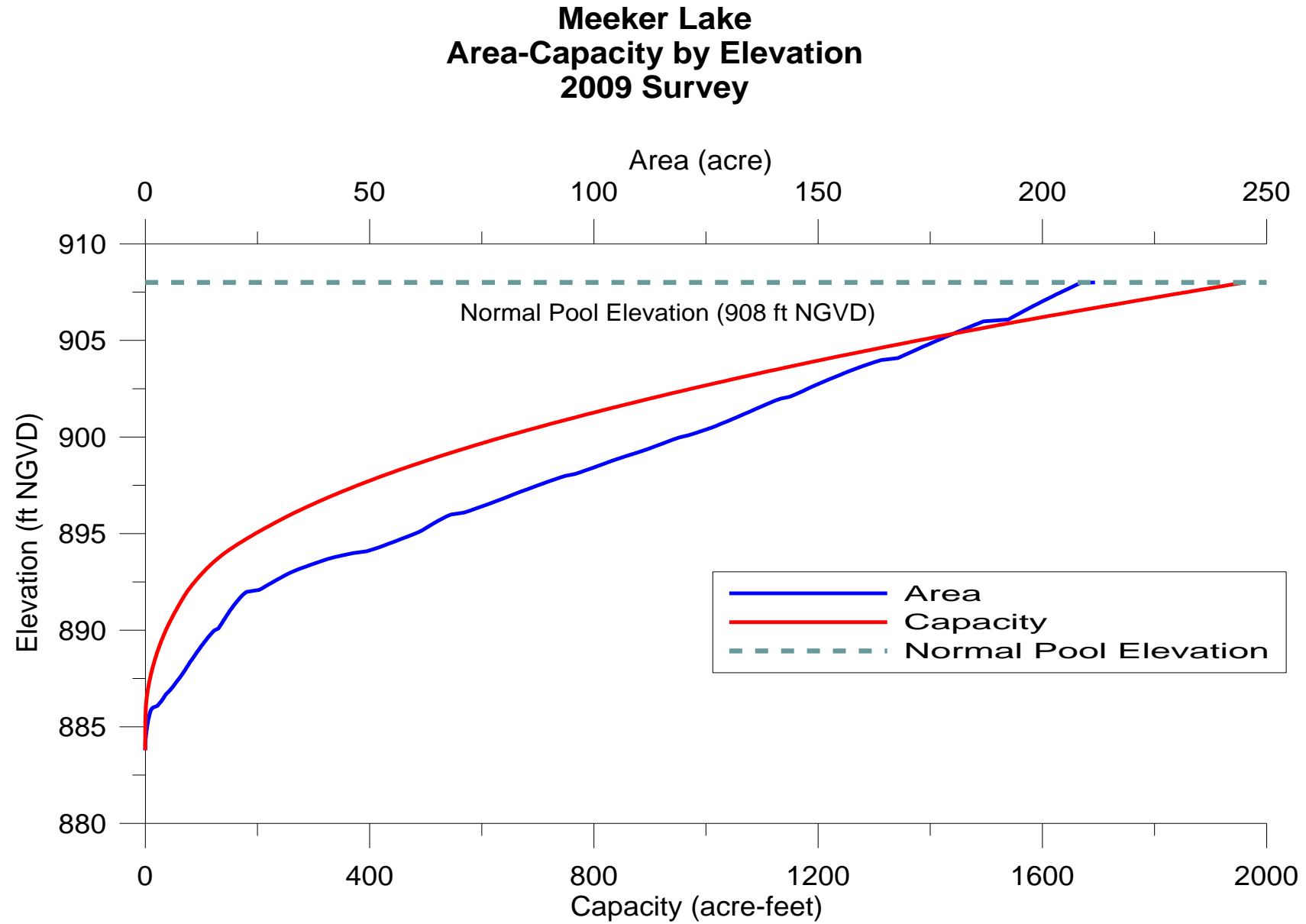
APPENDIX A: Area-Capacity Data

Table A. 1: Meeker Lake Capacity/Area by 0.1-ft Increments.

MEEKER LAKE AREA-CAPACITY TABLE OKLAHOMA WATER RESOURCES BOARD 2009 Survey Capacity in acre-feet by tenth foot elevation increments Area in acres by tenth foot elevation increments											
Elevation (ft NGVD)		**0.08**	**0.18**	**0.28**	**0.38**	**0.48**	**0.58**	**0.68**	**0.78**	**0.88**	**0.98**
883	Area								0.000	0.001	0.002
	Capacity								0.000	0.000	0.000
884	Area	0.009	0.040	0.063	0.092	0.136	0.185	0.234	0.286	0.342	0.402
	Capacity	0.001	0.003	0.009	0.016	0.028	0.044	0.065	0.091	0.122	0.159
885	Area	0.467	0.538	0.617	0.702	0.798	0.896	1.000	1.121	1.320	1.610
	Capacity	0.203	0.253	0.311	0.376	0.451	0.536	0.631	0.736	0.858	1.003
886	Area	2.746	3.054	3.440	3.79	4.08	4.33	4.62	5.04	5.48	5.85
	Capacity	1.245	1.53	1.86	2.22	2.61	3.04	3.48	3.96	4.49	5.06
887	Area	6.20	6.52	6.84	7.15	7.51	7.84	8.14	8.44	8.72	9.00
	Capacity	5.66	6.30	6.97	7.66	8.40	9.17	9.96	10.79	11.65	12.54
888	Area	9.28	9.54	9.83	10.11	10.42	10.71	11.00	11.30	11.61	11.91
	Capacity	13.45	14.39	15.36	16.36	17.39	18.44	19.53	20.64	21.79	22.97
889	Area	12.23	12.54	12.87	13.19	13.53	13.87	14.22	14.6	15.0	15.4
	Capacity	24.17	25.4	26.7	28.0	29.3	30.7	32.1	33.5	35.0	36.5
890	Area	16.3	16.6	16.9	17.1	17.4	17.7	18.0	18.2	18.5	18.8
	Capacity	38.1	39.8	41.5	43.2	44.9	46.6	48.4	50.2	52.1	53.9
891	Area	19.1	19.4	19.8	20.1	20.4	20.8	21.2	21.6	22.0	22.6
	Capacity	55.8	57.8	59.7	61.7	63.7	65.8	67.9	70.0	72.2	74.4
892	Area	25.4	26.2	26.9	27.7	28.4	29.2	29.9	30.7	31.6	32.4
	Capacity	76.9	79.5	82.2	84.9	87.7	90.6	93.5	96.6	99.7	102.9
893	Area	33.4	34.5	35.7	36.9	38.1	39.4	40.7	42.2	44.2	46.3
	Capacity	106.2	109.6	113.1	116.7	120.4	124.3	128.3	132.5	137	141
894	Area	49.3	50.7	52.0	53.2	54.4	55.5	56.6	57.8	58.9	60.0
	Capacity	146	151	156	162	167	172	178	184	190	196
895	Area	61.1	61.9	62.6	63.3	64.0	64.7	65.5	66.3	67.2	68.2
	Capacity	202	208	214	220	227	233	240	246	253	260
896	Area	71.1	72.3	73.6	74.8	76.0	77.2	78.3	79.5	80.6	81.7
	Capacity	267	274	281	289	296	304	311	319	327	335
897	Area	82.8	83.9	85.1	86.2	87.4	88.6	89.8	91.0	92.3	93.6
	Capacity	344	352	360	369	378	387	395	405	414	423
898	Area	95.8	97.1	98.3	99.5	100.7	101.9	103.1	104.3	105.5	106.8
	Capacity	432	442	452	462	472	482	492	503	513	524
899	Area	108.2	109.6	110.9	112.1	113.3	114.5	115.6	116.8	117.9	119.2
	Capacity	534	545	556	567	579	590	602	613	625	637
900	Area	121.0	122.4	123.7	125.0	126.3	127.4	128.4	129.5	130.5	131.5
	Capacity	649	661	673	686	698	711	724	737	750	763
901	Area	132.5	133.5	134.5	135.5	136.5	137.4	138.4	139.4	140.4	141.7
	Capacity	776	789	803	816	830	844	857	871	885	899
902	Area	143.7	144.8	145.8	146.7	147.6	148.5	149.5	150.4	151.4	152.5
	Capacity	914	928	943	957	972	987	1,002	1,017	1,032	1,047
903	Area	153.6	154.6	155.7	156.7	157.8	159.0	160.2	161.4	162.7	164.1
	Capacity	1,062	1,078	1,093	1,109	1,124	1,140	1,156	1,172	1,189	1,205

Table A. 2: Meeker Lake Capacity/Area by 0.1-ft Increments (cont).

MEEKER LAKE AREA-CAPACITY TABLE OKLAHOMA WATER RESOURCES BOARD 2009 Survey Capacity in acre-feet by tenth foot elevation increments Area in acres by tenth foot elevation increments											
Elevation (ft NGVD)		**0.08**	**0.18**	**0.28**	**0.38**	**0.48**	**0.58**	**0.68**	**0.78**	**0.88**	**0.98**
904	Area	167.8	168.7	169.7	170.6	171.6	172.5	173.5	174.5	175.5	176.5
	Capacity	1,222	1,238	1,255	1,272	1,289	1,307	1,324	1,341	1,359	1,377
905	Area	177.5	178.5	179.5	180.5	181.6	182.6	183.7	184.7	185.8	186.9
	Capacity	1,394	1,412	1,430	1,448	1,466	1,484	1,503	1,521	1,540	1,558
906	Area	192	193	194	195	196	196	197	198	199	200
	Capacity	1,577	1,597	1,616	1,635	1,655	1,674	1,694	1,714	1,734	1,754
907	Area	201	201	202	203	204	205	206	207	208	209
	Capacity	1,774	1,794	1,814	1,834	1,855	1,875	1,896	1,916	1,937	1,958
908	Area	212									
	Capacity	1,962									

Meeker Lake
Area-Capacity by Elevation
2009 Survey

APPENDIX B: Meeker Maps

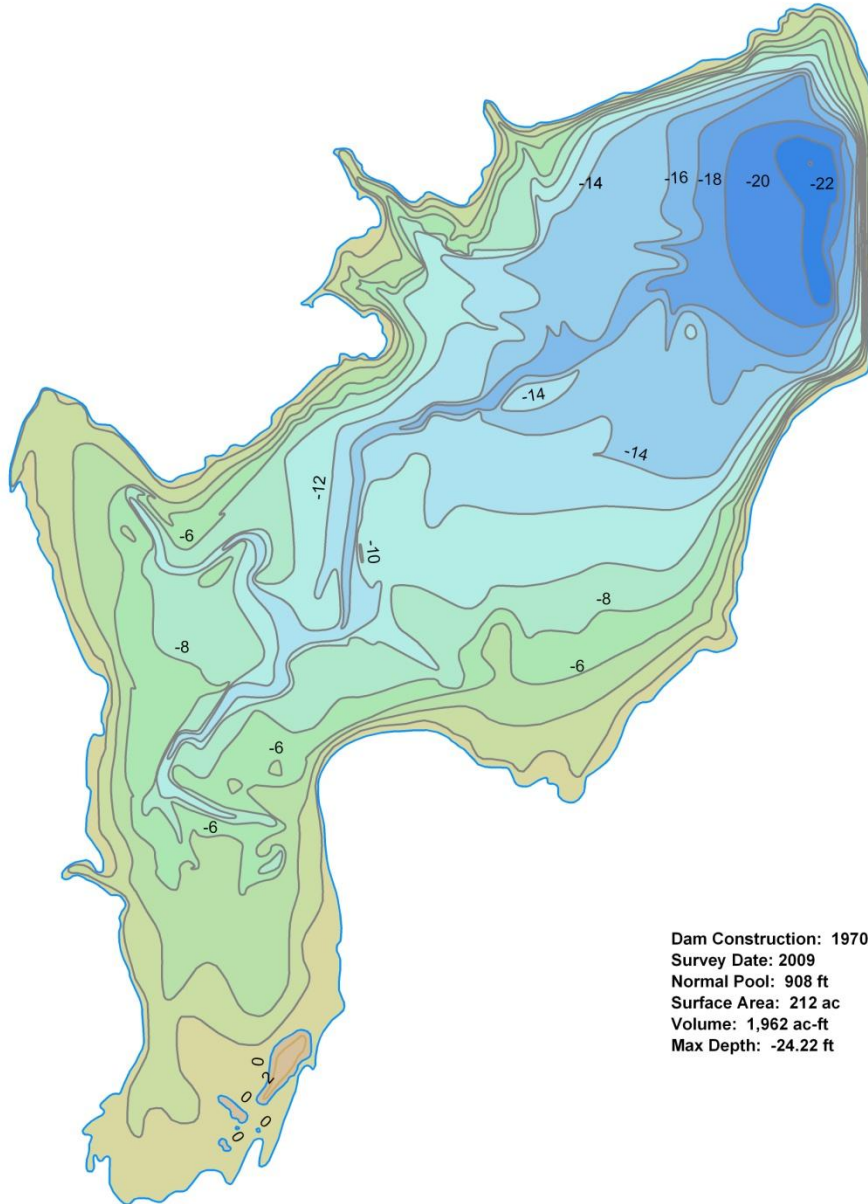**Figure B. 1: Meeker Lake Bathymetric Map with 2-foot Contour Intervals.**
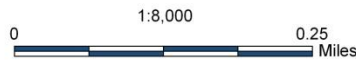

Meeker Lake
2-Foot Depth Contours

CAUTION - The intention of this map is to give a generalized overview of the lake depths. There may be shallow underwater hazards such as rocks, shoals, and vegetation that do not appear on this map.
THIS MAP SHOULD NOT BE USED FOR NAVIGATION PURPOSES.

Depth (Feet)

	> 0
	0 - -2
	-2 - -4
	-4 - -6
	-6 - -8
	-8 - -10
	-10 - -12
	-12 - -14
	-14 - -16
	-16 - -18
	-18 - -20
	-20 - -22
	-22 - -24
	-24 - -26

Dam Construction: 1970
Survey Date: 2009
Normal Pool: 908 ft
Surface Area: 212 ac
Volume: 1,962 ac-ft
Max Depth: -24.22 ft

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1:8,000
0   0.25
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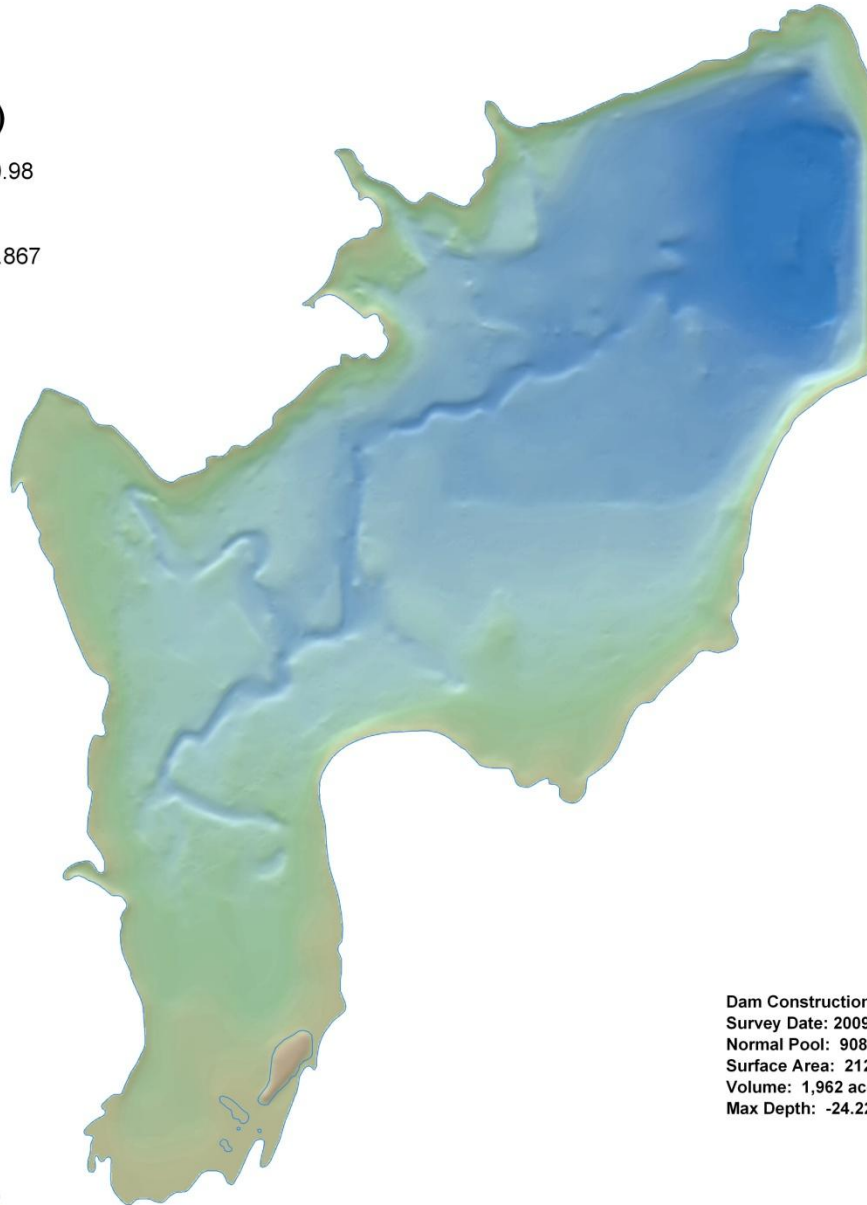**Figure B. 2: Meeker Shaded Relief Bathymetric Map.**
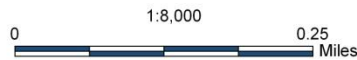

Meeker Lake
Shaded Relief

CAUTION - The intention of this map is to give a generalized overview
of the lake depths. There may be shallow underwater hazards such as rocks,
shoals, and vegetation that do not appear on this map.
THIS MAP SHOULD NOT BE USED FOR NAVIGATION PURPOSES.

Depth (Feet)

High : 910.98

Low : 883.867

Dam Construction: 1970
Survey Date: 2009
Normal Pool: 908 ft
Surface Area: 212 ac
Volume: 1,962 ac-ft
Max Depth: -24.22 ft

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1:8,000

0   0.25
                Miles

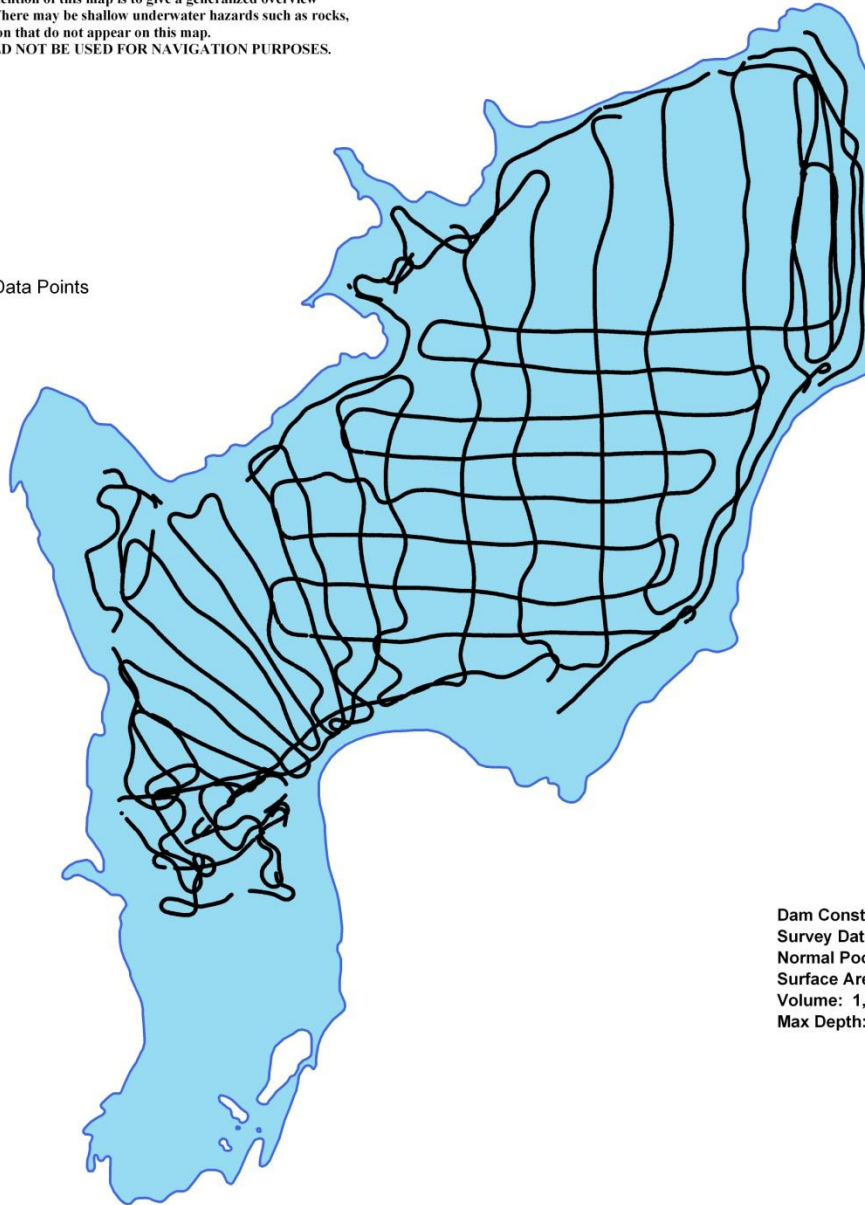**Figure B. 3: Meeker Lake Collected Data Points.**

Meeker Lake
Collected Data Points

CAUTION - The intention of this map is to give a generalized overview
of the lake depths. There may be shallow underwater hazards such as rocks,
shoals, and vegetation that do not appear on this map.
THIS MAP SHOULD NOT BE USED FOR NAVIGATION PURPOSES.

• Collected Data Points

Dam Construction: 1970
Survey Date: 2009
Normal Pool: 908 ft
Surface Area: 212 ac
Volume: 1,962 ac-ft
Max Depth: -24.22 ft

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0   1:8,000   0.25
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