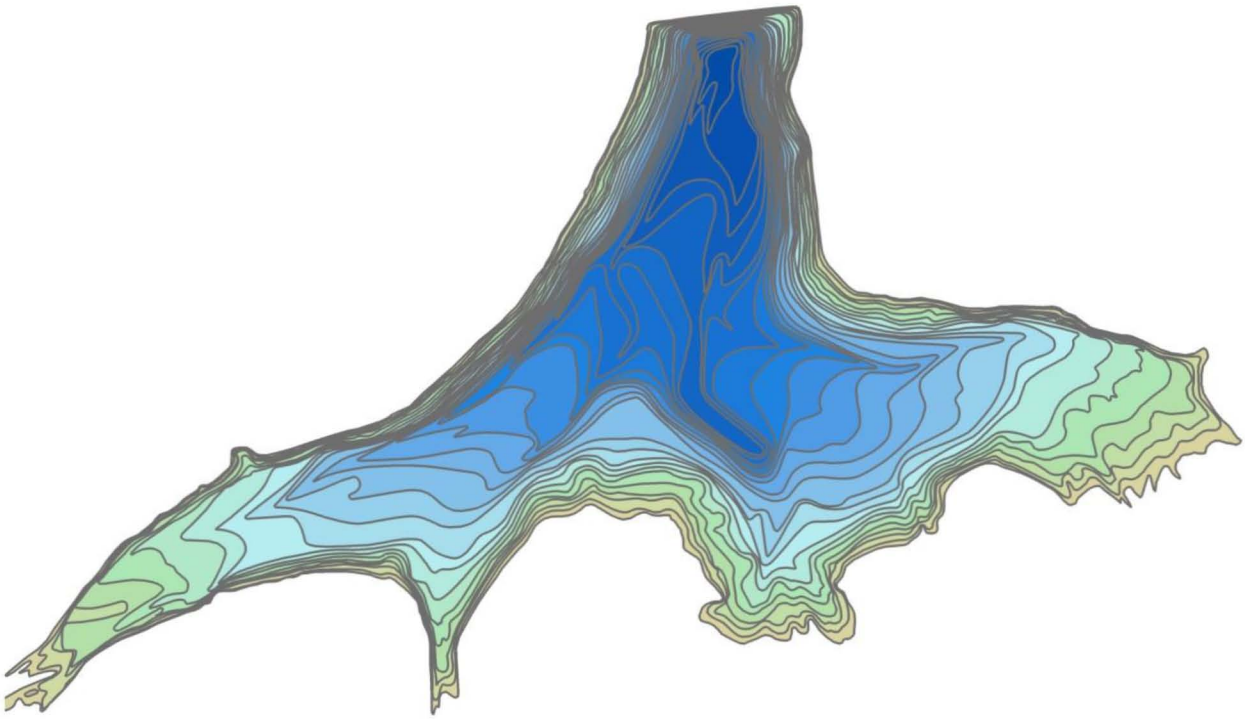
HYDROGRAPHIC SURVEY of LLOYD CHURCH LAKE



Final Report

September 30, 2009

Prepared by:

State of Oklahoma
OWRB
WATER RESOURCES BOARD
the water agency

TABLE OF CONTENTS

TABLE OF FIGURES

TABLE OF TABLES

LLOYD CHURCH LAKE
HYDROGRAPHIC SURVEY REPORT

INTRODUCTION

The Oklahoma Water Resources Board (OWRB) conducted a hydrographic survey of Lloyd Church Lake in May 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

Lloyd Church Lake, also known as Fourche Maline Creek site 7, is in Latimer County (**Figure 1**), two miles south of Wilburton, OK. It was built in 1964. Its original purposes were water supply, flood control, and recreation. The dam on this reservoir is classified as a high hazard dams. 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.

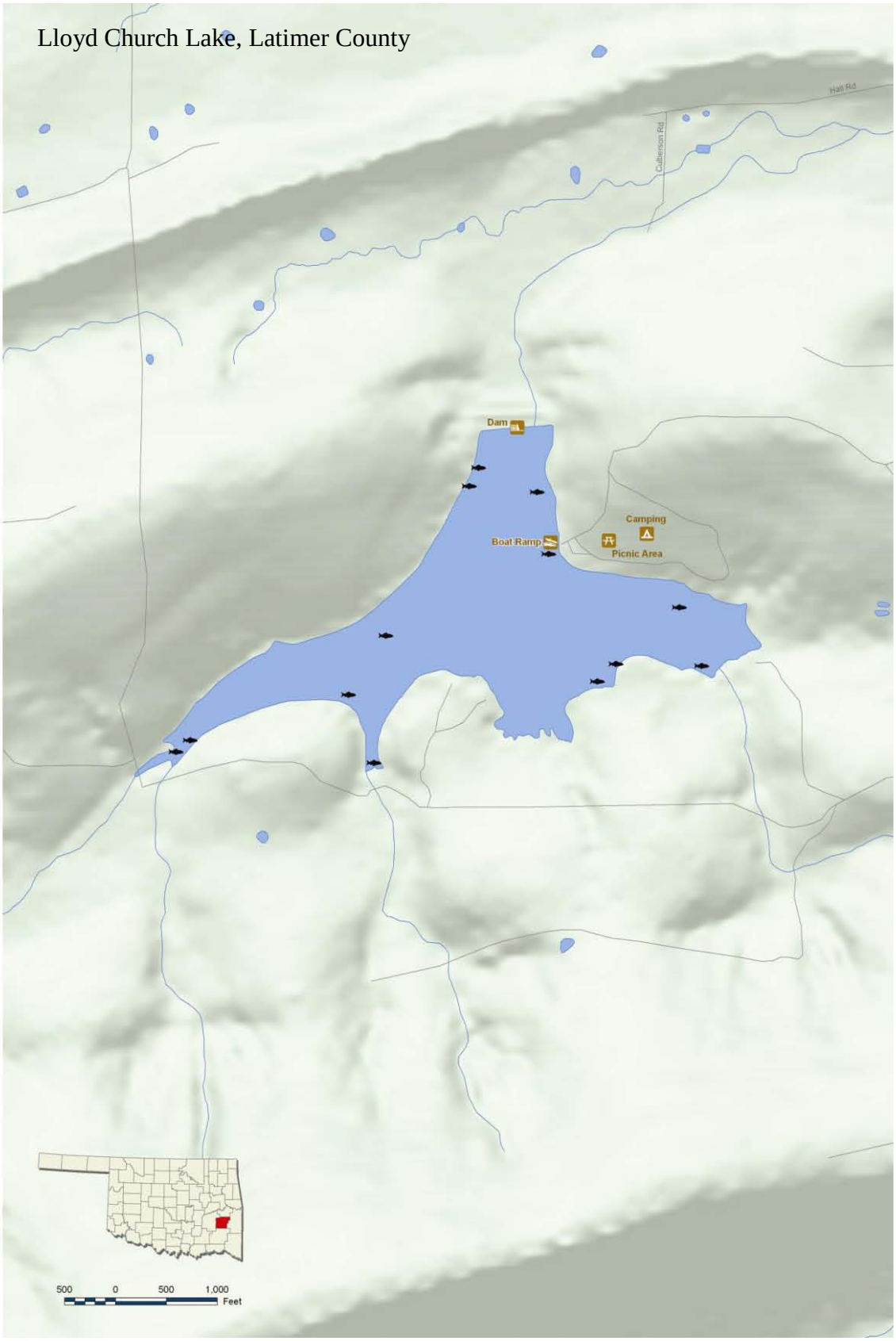


Figure 1: Location map for Lloyd Church Lake.

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 Lloyd Church Lake was on-screen digitized from the 2006 color digital orthoimagery quarter quadrangle (DOQQ) of Latimer 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 South-3502).

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-3502 Oklahoma South 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 25 virtual transects were created for the Lloyd Church Lake.

Field Survey

Lake Elevation Acquisition

The lake elevation for Lloyd Church Lake was obtained by collecting positional data over a period of 1 hour 25 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 Lloyd Church Lake occurred in May of 2009. The water level elevation for Lloyd Church Lake was 755.8 ft NGVD. Data collection began at the dam and moved southward. 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 4822.79 ft/sec during the Lloyd Church 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. Cross check data from Meeker Lake was used to calculate the quality control statistics. These two lakes were surveyed within a month of each other using the same equipment and setup, so no additional bias or error is expected. 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

= σ +σ = ×

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 755.8 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 the 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 xyz file consisted of 9,368 data points. The HYPACK raw and corrected data files for Lloyd Church Lake are located on the DVD entitled *Lloyd Church 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 South 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: Lloyd Church 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 *Lloyd Church HYPACK/GIS Metadata.*

RESULTS

Results from the 2009 OWRB survey indicate that Lloyd Church Lake encompasses 155.6 acres and contains a cumulative capacity of 3,025.4 ac-ft at the normal pool elevation (755 ft National Geodetic Vertical Datum (NGVD)). The average depth for Lloyd Church Lake was 19.4 ft.

SUMMARY and COMPARISON

Table 1 is comparison of area and volume changes of Lloyd Church Lake at the normal pool elevation. Based on the design specifications, Lloyd Church Lake had an area of 164 acres and cumulative volume of 3,000 acre-feet of water at normal pool elevation (755 ft NGVD). The surface area of the lake has had a decrease of 9 acres or approximately 5.5%. The 2009 survey also shows that Lloyd Church Lake had a nominal increase in capacity of <1% or 25

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 Lloyd Church Lake at normal pool (755 ft NGVD).

Feature	Survey Year	
	1964 Design Specifications	2009
Area (acres)	164	156
Cumulative Volume (acre-feet)	3,000	3,025
Mean depth (ft)	19.1	19.4
Maximum Depth (ft)		47.9

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. Oklahoma Water Atlas.

Oklahoma Water Resources Board (OWRB). 1978. Examination Report; Oklahoma Safety of Dams Program.

APPENDIX A: Area-Capacity Data

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

LLOYD CHURCH 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)		0.02	0.12	0.22	0.32	0.42	0.52	0.62	0.72	0.82	0.92
707	Area		0	0.0079	0.0249	0.0397	0.0568	0.0778	0.103	0.1326	0.1718
	Capacity		0	0.0002	0.002	0.0052	0.01	0.0167	0.0257	0.0375	0.0526
708	Area	0.2112	0.249	0.2845	0.3191	0.3576	0.4054	0.4535	0.5043	0.5621	0.6292
	Capacity	0.0718	0.0948	0.1215	0.1517	0.1855	0.2236	0.2665	0.3144	0.3676	0.4271
709	Area	0.8494	0.9127	0.9674	1.018	1.068	1.116	1.164	1.213	1.264	1.318
	Capacity	0.4969	0.585	0.6791	0.7784	0.8828	0.992	1.106	1.225	1.349	1.478
710	Area	1.377	1.443	1.511	1.583	1.657	1.735	1.817	1.908	2.010	2.134
	Capacity	1.613	1.754	1.901	2.056	2.218	2.388	2.565	2.751	2.947	3.154
711	Area	3.084	3.323	3.431	3.504	3.580	3.657	3.735	3.816	3.898	3.982
	Capacity	3.389	3.713	4.051	4.398	4.752	5.114	5.483	5.861	6.247	6.641
712	Area	4.068	4.156	4.246	4.337	4.432	4.533	4.638	4.753	4.873	4.998
	Capacity	7.043	7.455	7.875	8.304	8.742	9.191	9.649	10.119	10.600	11.094
713	Area	5.725	5.843	5.964	6.088	6.214	6.342	6.474	6.609	6.748	6.889
	Capacity	11.61	12.19	12.78	13.38	14.00	14.63	15.27	15.92	16.59	17.27
714	Area	7.218	7.371	7.528	7.685	7.845	8.001	8.158	8.319	8.484	8.649
	Capacity	17.97	18.70	19.45	20.21	20.98	21.78	22.58	23.41	24.25	25.10
715	Area	9.518	9.706	9.881	10.05	10.23	10.41	10.60	10.78	10.97	11.15
	Capacity	25.99	26.95	27.93	28.93	29.94	30.98	32.03	33.10	34.18	35.29
716	Area	11.34	11.53	11.72	11.91	12.10	12.29	12.48	12.68	12.87	13.07
	Capacity	36.41	37.56	38.72	39.90	41.10	42.32	43.56	44.82	46.10	47.39
717	Area	14.16	14.39	14.61	14.83	15.05	15.25	15.44	15.63	15.82	16.01
	Capacity	48.73	50.16	51.61	53.08	54.57	56.09	57.62	59.18	60.75	62.34
718	Area	16.20	16.38	16.57	16.75	16.93	17.11	17.29	17.47	17.66	17.85
	Capacity	63.95	65.58	67.23	68.90	70.58	72.28	74.00	75.74	77.50	79.27
719	Area	19.20	19.54	19.86	20.16	20.46	20.75	21.04	21.32	21.60	21.87
	Capacity	81.09	83.03	85.00	87.00	89.03	91.09	93.18	95.30	97.45	99.62
720	Area	22.13	22.39	22.64	22.90	23.15	23.40	23.65	23.89	24.14	24.41
	Capacity	101.8	104.0	106.3	108.6	110.9	113.2	115.6	117.9	120.3	122.8
721	Area	22.13	22.39	22.64	22.90	23.15	23.40	23.65	23.89	24.14	24.41
	Capacity	101.8	104.0	106.3	108.6	110.9	113.2	115.6	117.9	120.3	122.8
722	Area	28.03	28.25	28.46	28.66	28.87	29.07	29.26	29.45	29.64	29.82
	Capacity	152.0	154.8	157.7	160.5	163.4	166.3	169.2	172.2	175.1	178.1
723	Area	30.13	30.34	30.55	30.77	30.99	31.21	31.42	31.62	31.82	32.03
	Capacity	181.1	184.1	187.2	190.2	193.3	196.4	199.6	202.7	205.9	209.1
724	Area	32.33	32.53	32.73	32.92	33.12	33.32	33.52	33.72	33.92	34.12
	Capacity	212.3	215.5	218.8	222.1	225.4	228.7	232.0	235.4	238.8	242.2
725	Area	34.81	35.14	35.48	35.85	36.17	36.47	36.74	37.01	37.25	37.48
	Capacity	245.6	249.1	252.7	256.2	259.8	263.5	267.1	270.8	274.5	278.3
726	Area	37.70	37.91	38.13	38.34	38.55	38.82	39.08	39.32	39.56	39.79
	Capacity	282.0	285.8	289.6	293.4	297.3	301.1	305.0	309.0	312.9	316.9
727	Area	40.21	40.45	40.69	40.92	41.16	41.39	41.62	41.86	42.11	42.37
	Capacity	320.9	324.9	328.9	333.0	337.1	341.3	345.4	349.6	353.8	358.0

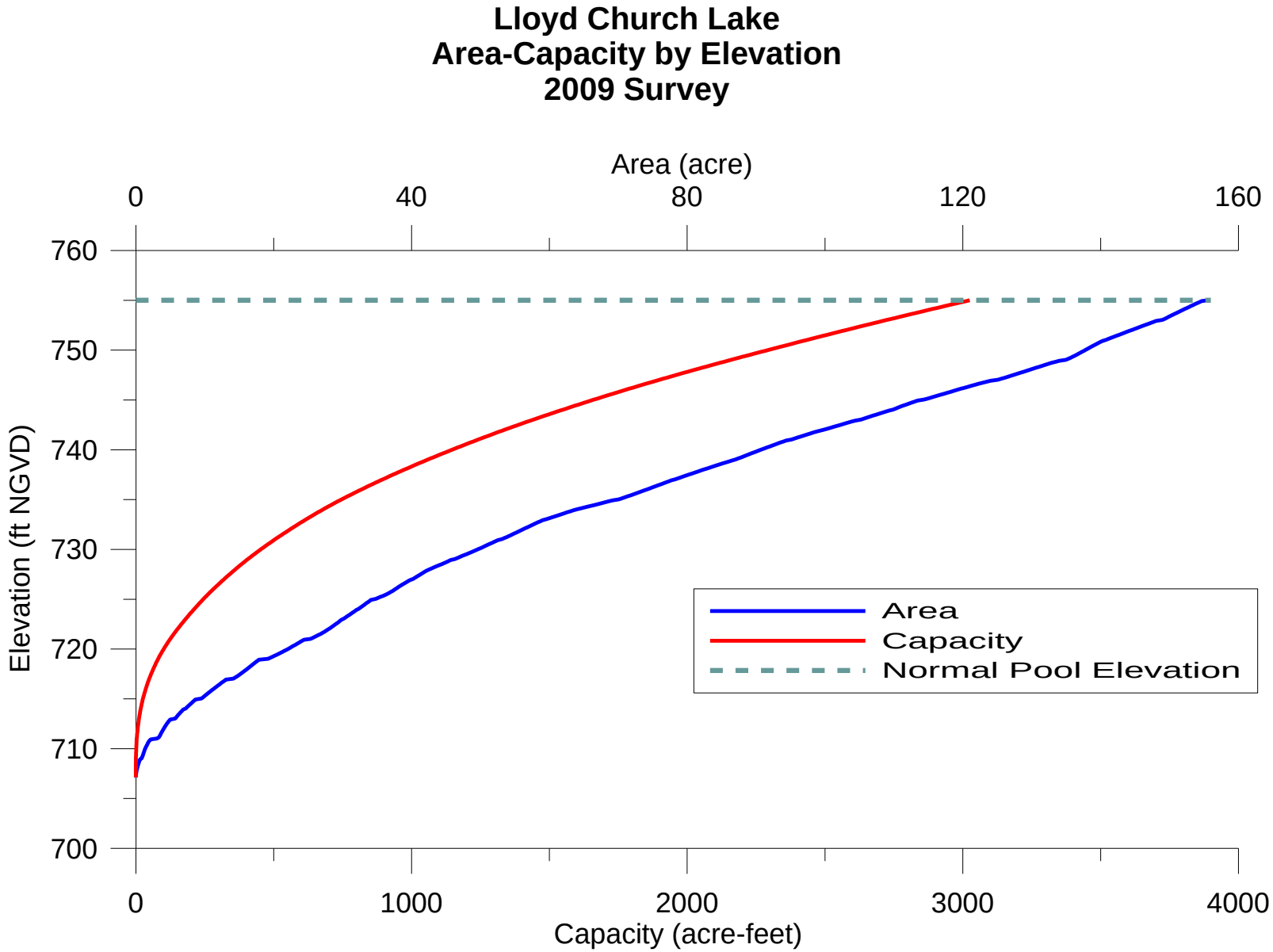
Table A. 2: Lloyd Church Lake Capacity/Area by 0.1-ft Increments (cont).

LLOYD CHURCH 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)		0.02	0.12	0.22	0.32	0.42	0.52	0.62	0.72	0.82	0.92
728	Area	42.71	43.04	43.37	43.72	44.06	44.41	44.76	45.08	45.39	45.70
	Capacity	362.3	366.6	370.9	375.2	379.6	384.0	388.5	393.0	397.5	402.1
729	Area	46.29	46.63	46.96	47.30	47.65	48.00	48.35	48.70	49.05	49.38
	Capacity	406.7	411.3	416.0	420.7	425.5	430.2	435.1	439.9	444.8	449.7
730	Area	49.71	50.03	50.34	50.66	50.97	51.28	51.59	51.91	52.23	52.55
	Capacity	454.7	459.7	464.7	469.7	474.8	479.9	485.1	490.2	495.5	500.7
731	Area	53.13	53.46	53.78	54.10	54.41	54.72	55.02	55.33	55.63	55.93
	Capacity	506.0	511.3	516.7	522.1	527.5	532.9	538.4	543.9	549.5	555.1
732	Area	56.23	56.53	56.84	57.14	57.45	57.76	58.07	58.38	58.70	59.02
	Capacity	560.7	566.3	572.0	577.7	583.4	589.2	595.0	600.8	606.7	612.5
733	Area	59.56	60.00	60.44	60.88	61.32	61.76	62.19	62.63	63.06	63.49
	Capacity	618.5	624.4	630.5	636.5	642.6	648.8	655.0	661.2	667.5	673.8
734	Area	64.05	64.64	65.23	65.81	66.39	66.96	67.53	68.09	68.64	69.20
	Capacity	680.2	686.7	693.2	699.7	706.3	713.0	719.7	726.5	733.3	740.2
735	Area	70.13	70.55	70.97	71.38	71.80	72.22	72.62	73.03	73.42	73.81
	Capacity	747.2	754.2	761.3	768.4	775.6	782.8	790.0	797.3	804.6	812.0
736	Area	74.21	74.60	74.99	75.38	75.77	76.17	76.56	76.95	77.33	77.73
	Capacity	819.4	826.8	834.3	841.8	849.4	857.0	864.6	872.3	880.0	887.8
737	Area	78.23	78.64	79.06	79.48	79.91	80.34	80.77	81.19	81.61	82.03
	Capacity	895.6	903.4	911.3	919.2	927.2	935.2	943.3	951.4	959.5	967.7
738	Area	82.49	82.92	83.35	83.80	84.25	84.71	85.16	85.62	86.08	86.55
	Capacity	975.9	984.2	992.5	1,001	1,009	1,018	1,026	1,035	1,043	1,052
739	Area	87.05	87.43	87.80	88.17	88.54	88.91	89.28	89.66	90.04	90.42
	Capacity	1,061	1,069	1,078	1,087	1,096	1,105	1,114	1,123	1,131	1,141
740	Area	90.81	91.20	91.59	91.99	92.38	92.77	93.17	93.56	93.96	94.37
	Capacity	1,150	1,159	1,168	1,177	1,186	1,195	1,205	1,214	1,223	1,233
741	Area	95.16	95.59	96.02	96.47	96.92	97.38	97.85	98.33	98.81	99.31
	Capacity	1,242	1,252	1,261	1,271	1,281	1,291	1,300	1,310	1,320	1,330
742	Area	99.92	100.4	100.9	101.4	101.9	102.4	102.9	103.4	103.9	104.4
	Capacity	1,340	1,350	1,360	1,370	1,380	1,390	1,401	1,411	1,421	1,432
743	Area	105.2	105.7	106.1	106.5	107.0	107.4	107.9	108.4	108.8	109.3
	Capacity	1,442	1,453	1,463	1,474	1,485	1,495	1,506	1,517	1,528	1,539
744	Area	109.8	110.2	110.6	111.0	111.4	111.7	112.2	112.6	113.0	113.4
	Capacity	1,550	1,561	1,572	1,583	1,594	1,605	1,616	1,628	1,639	1,650
745	Area	114.3	114.8	115.3	115.8	116.3	116.8	117.3	117.8	118.3	118.8
	Capacity	1,662	1,673	1,684	1,696	1,708	1,719	1,731	1,743	1,755	1,766
746	Area	119.3	119.8	120.3	120.8	121.3	121.8	122.3	122.9	123.4	124.0
	Capacity	1,778	1,790	1,802	1,814	1,826	1,839	1,851	1,863	1,875	1,888
747	Area	125.1	125.6	126.1	126.5	127.0	127.5	127.9	128.4	128.8	129.3
	Capacity	1,900	1,913	1,925	1,938	1,951	1,963	1,976	1,989	2,002	2,015
748	Area	129.7	130.2	130.6	131.1	131.5	132.0	132.4	132.9	133.4	134.0
	Capacity	2,028	2,041	2,054	2,067	2,080	2,093	2,106	2,120	2,133	2,146

Table A. 3: Lloyd Church Lake Capacity/Area by 0.1-ft Increments (cont).

LLOYD CHURCH 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)		0.02	0.12	0.22	0.32	0.42	0.52	0.62	0.72	0.82	0.92
749	Area	135.0	135.3	135.6	135.9	136.2	136.5	136.8	137.0	137.3	137.6
	Capacity	2,160	2,173	2,187	2,200	2,214	2,228	2,241	2,255	2,269	2,282
750	Area	137.8	138.1	138.4	138.6	138.9	139.1	139.4	139.7	140.0	140.3
	Capacity	2,296	2,310	2,324	2,338	2,352	2,366	2,379	2,393	2,407	2,421
751	Area	140.8	141.1	141.5	141.9	142.3	142.6	143.0	143.4	143.8	144.2
	Capacity	2,435	2,450	2,464	2,478	2,492	2,506	2,521	2,535	2,549	2,564
752	Area	144.6	144.9	145.3	145.7	146.1	146.5	146.9	147.3	147.7	148.1
	Capacity	2,578	2,593	2,607	2,622	2,636	2,651	2,666	2,680	2,695	2,710
753	Area	149.0	149.3	149.6	149.8	150.1	150.4	150.7	151.0	151.3	151.6
	Capacity	2,725	2,740	2,755	2,769	2,784	2,800	2,815	2,830	2,845	2,860
754	Area	151.9	152.2	152.5	152.8	153.1	153.4	153.7	154.1	154.4	154.7
	Capacity	2,875	2,890	2,906	2,921	2,936	2,951	2,967	2,982	2,998	3,013
755	Area	155.6									
	Capacity	3,025									

Figure A. 1. Area-Capacity Curve for Lloyd Church Lake



APPENDIX B: Lloyd Church Maps

Figure B. 1: Lloyd Church Lake Bathymetric Map with 2-foot Contour Intervals.

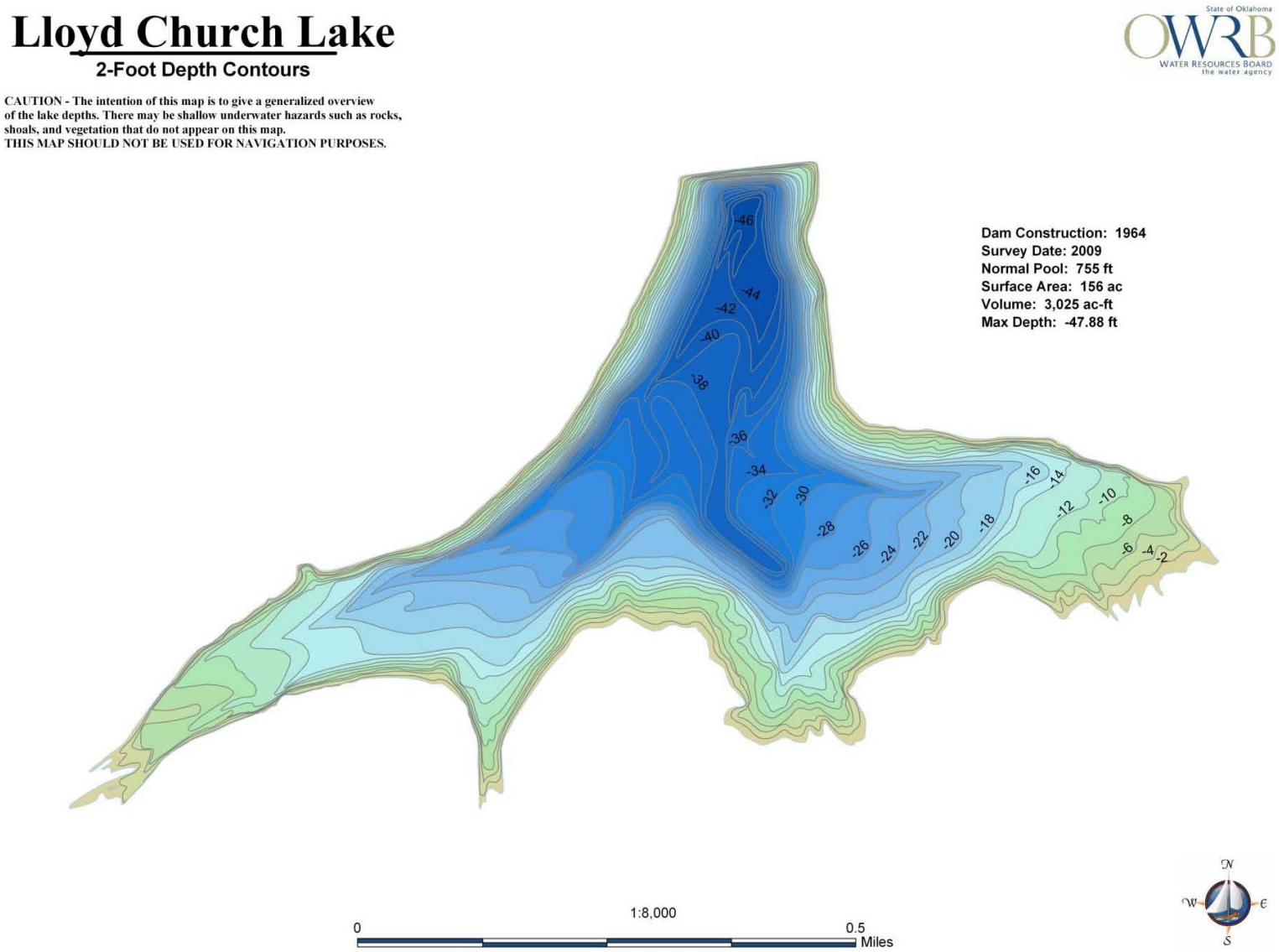


Figure B. 2: Lloyd Church Shaded Relief Bathymetric Map.

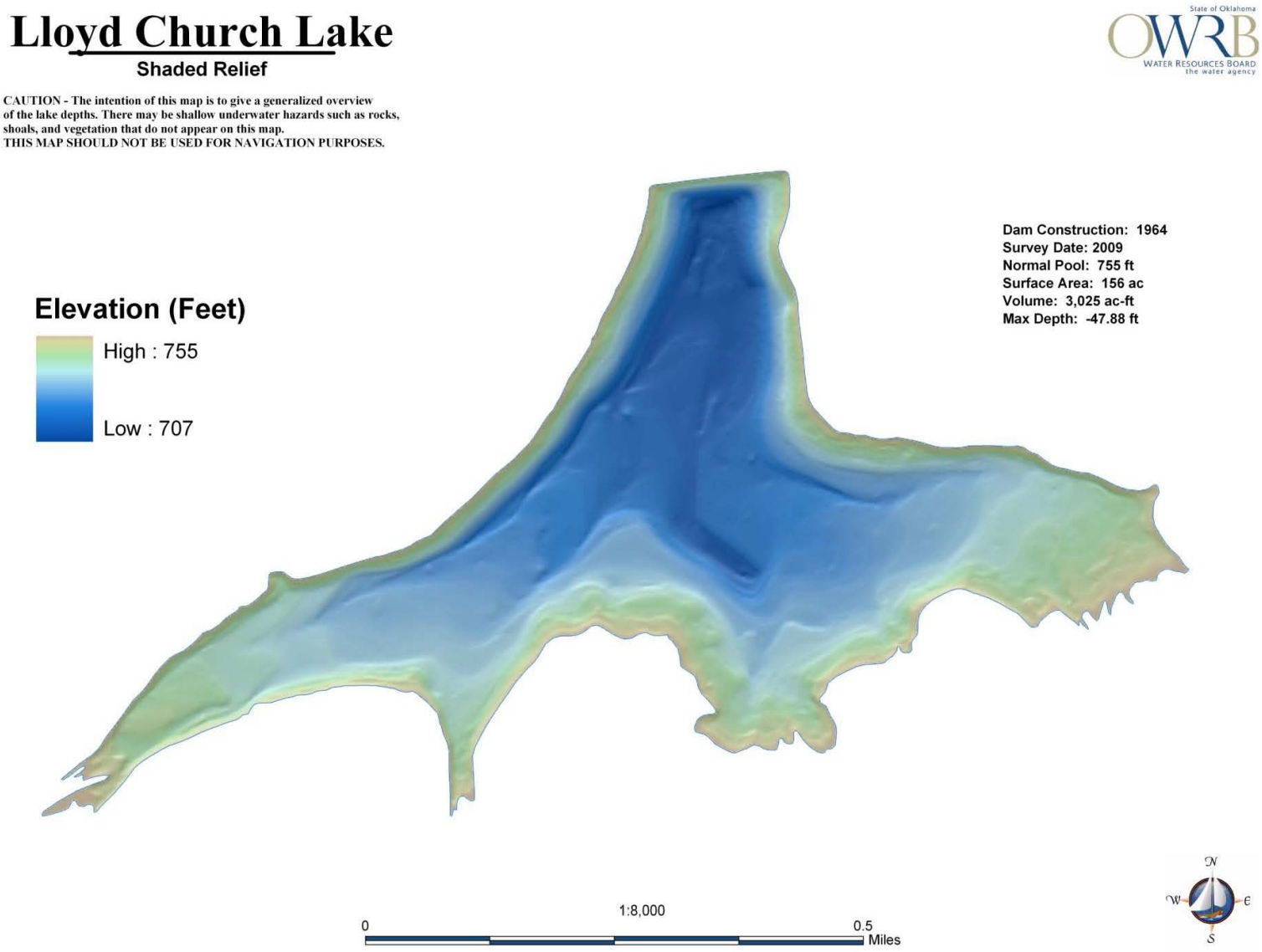


Figure B. 3: Lloyd Church Lake Collected Data Points.