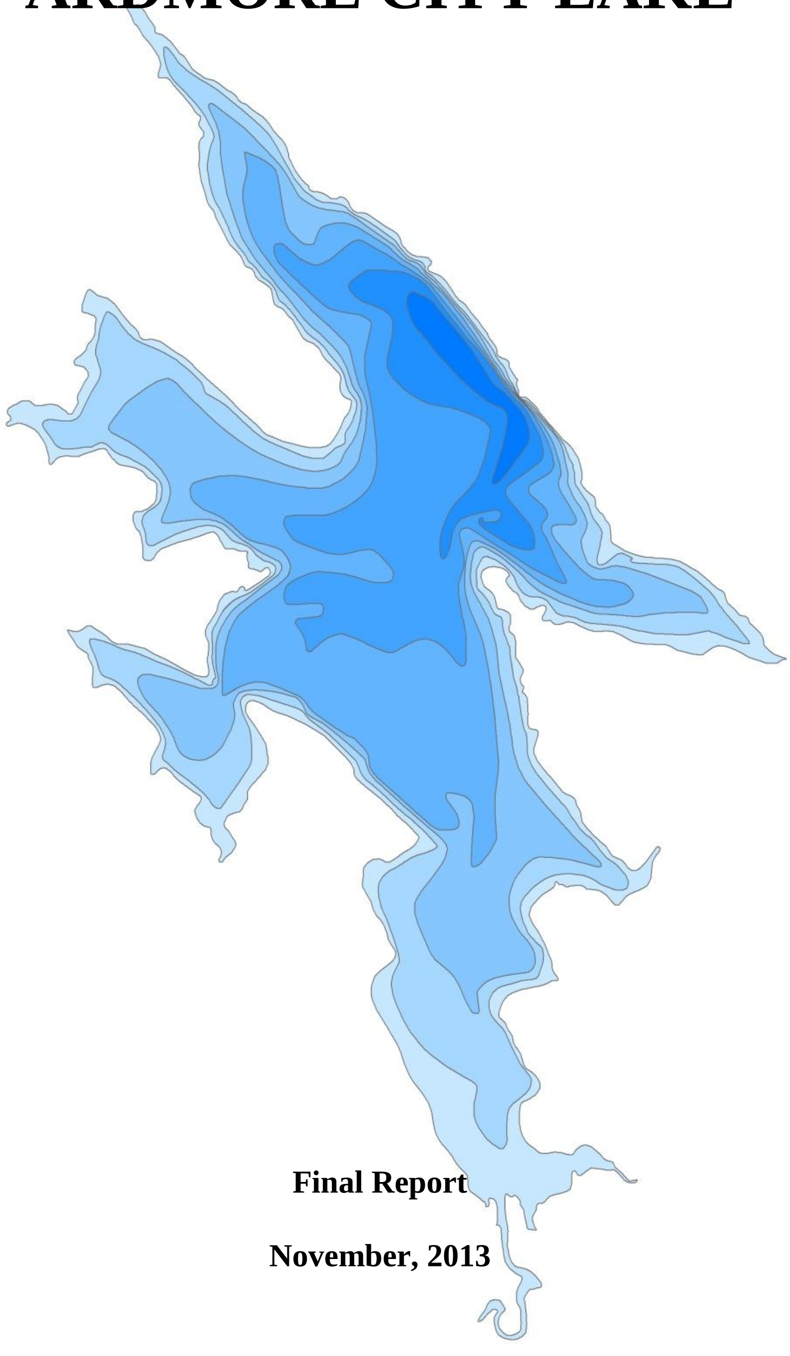
HYDROGRAPHIC SURVEY of ARDMORE CITY LAKE



Final Report

November, 2013

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 Ardmore City Lake beginning in November of 2012. 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 City of Ardmore.

LAKE BACKGROUND

Ardmore City Lake is located on the Caddo Creek Tributary in Carter County (**Figure 1**). The dam was completed in 1910 and is located approximately three miles north of the city of Ardmore, OK. Its purposes are water supply, and recreation.

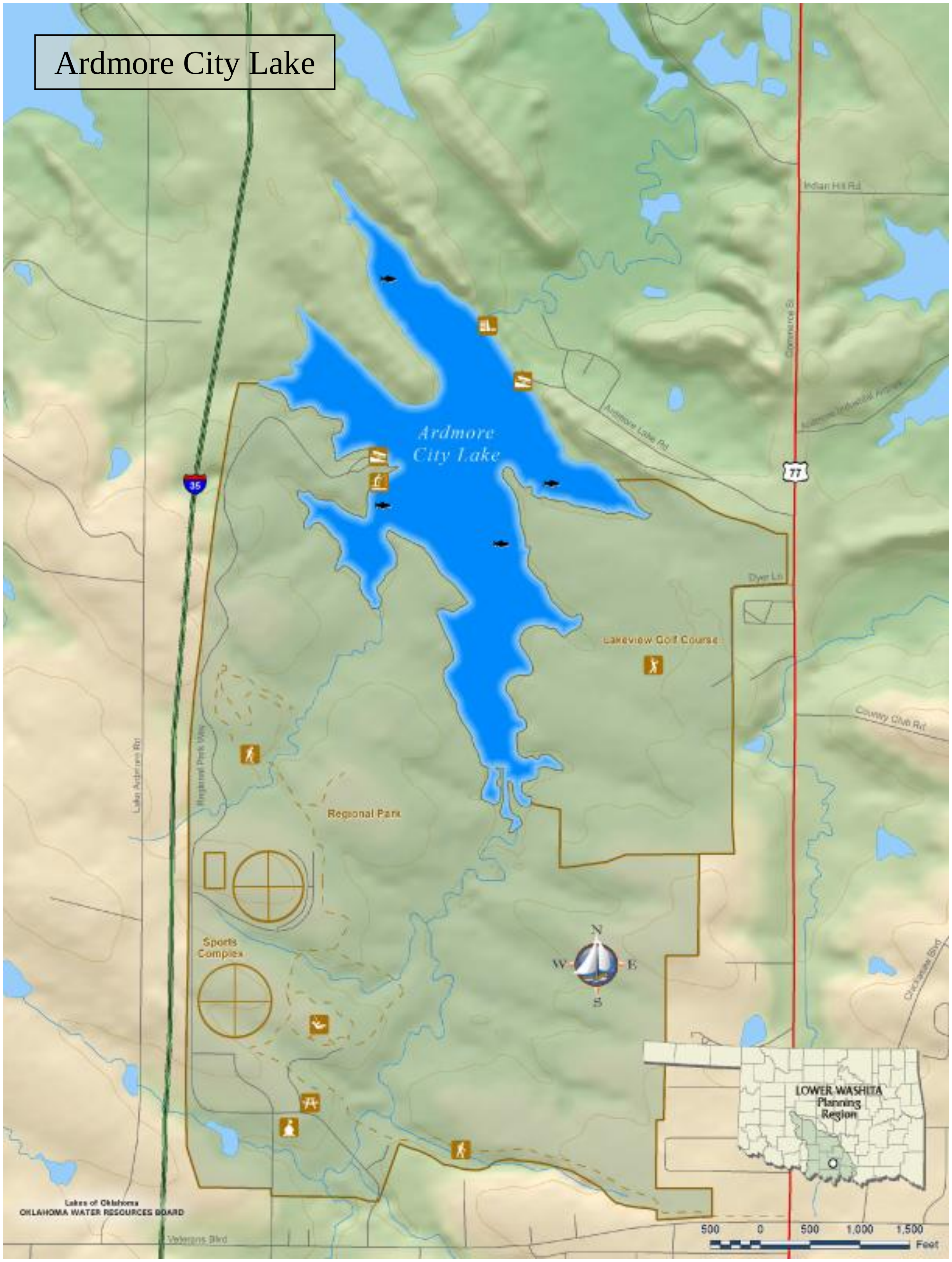


Figure 1: Location map for Ardmore City Lake.

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 Ardmore City Lake was on-screen digitized from the 2006 color digital orthoimagery quarter quadrangle (DOQQ) mosaic of Carter County, Oklahoma. The screen scale was set to 1:1,500. A line was 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 2008 and 2010 DOQQs of the lakes were used as back ground reference. The reservoir boundaries were digitized in 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 17 virtual transects were created for Ardmore City Lake.

Field Survey

Lake Elevation Acquisition

The lake elevation for Ardmore City Lake was obtained by collecting positional data over a period of approximately 280 minutes with a survey-grade Global Positioning System (GPS) receiver. The receiver was placed over the water's surface. A measurement was taken from the antenna to the surface of the water. The collected data and antenna height was then uploaded to the On-line Positioning Users Service (OPUS) website. The National Geodetic Survey (NGS) operates OPUS as a means to provide GPS users easier access to the National Spatial Reference System (NSRS). OPUS allows users to submit their GPS data files to NGS, where the data is processed to determine a position using NGS computers and software. Calculated coordinates are averaged from three independent single-baseline solutions computed by double-differenced, carrier-phase measurements between the collected data file and 3 surrounding Continuously Operating Reference Stations (CORS). Under ideal conditions, OPUS can easily resolve most positions to within centimeter accuracy. A report containing the newly calculated positional data was electronically returned via email. This report contained the elevation of the surface of the water corrected for the antenna height.

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; Innerspace 456Xpe 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 Ardmore City Lake occurred in November of 2012. The water level elevation for Ardmore City Lake was 818.2 ft Geodetic Vertical Datum (NAVD 88). Data collection began at the dam and moved upstream. 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, a sound velocity profile was collected each day 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.

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 54 cross-sections points at Ardmore City Lake were used to compute error estimates. A mean difference (arithmetic mean) of 0.128 ft and a standard deviation of 0.391 ft were computed from intersections. The following formulas were used to determine the depth accuracy at the 95% confidence level.

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

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 ± 0.81 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 0.128

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. 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 0.2 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.

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 HYPACK raw and corrected data files for Ardmore City Lake are located on the DVD entitled *Ardmore City Lake 2012 Disk 1 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 10.1, 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 5-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 5-ft depth ranges across the lake. The bathymetric maps of the lakes are shown with 5-ft contour intervals in **APPENDIX B: Ardmore City Lake M**.

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 *Ardmore City Lake 2012 Disk 1 HYPACK/GIS Metadata.*

RESULTS

Results from the 2012 OWRB survey indicate that Ardmore City Lake encompasses 159 acres and contains a cumulative capacity of 2057 ac-ft at the normal pool elevation (818.5 ft NAVD 88). The average depth for Ardmore City Lake was 13.4 ft.

SUMMARY and COMPARISON

Table 1 is a comparison of area and volume changes of Ardmore City Lake at the normal pool elevation. Due to the age of the dam, original design specifications for Ardmore City Lake could not be found. It is the recommendation of the OWRB that another survey using the same method used in the 2012 survey be conducted in 10-15 years. By using the 2012 survey figures as a baseline, a future survey would allow an accurate sedimentation rate to be obtained.

Table 1: Area and Volume Comparisons of Ardmore City Lake at normal pool (818.5 ft NAVD 88).

Feature	Survey Year	
	1910 Design Specifications	2012
Area (acres)	--	159
Cumulative Volume (acre-feet)	--	2057
Mean depth (ft)	--	13.38
Maximum Depth (ft)	--	31.7

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). 2010. Lakes of Oklahoma.

APPENDIX A: Area-Capacity Data

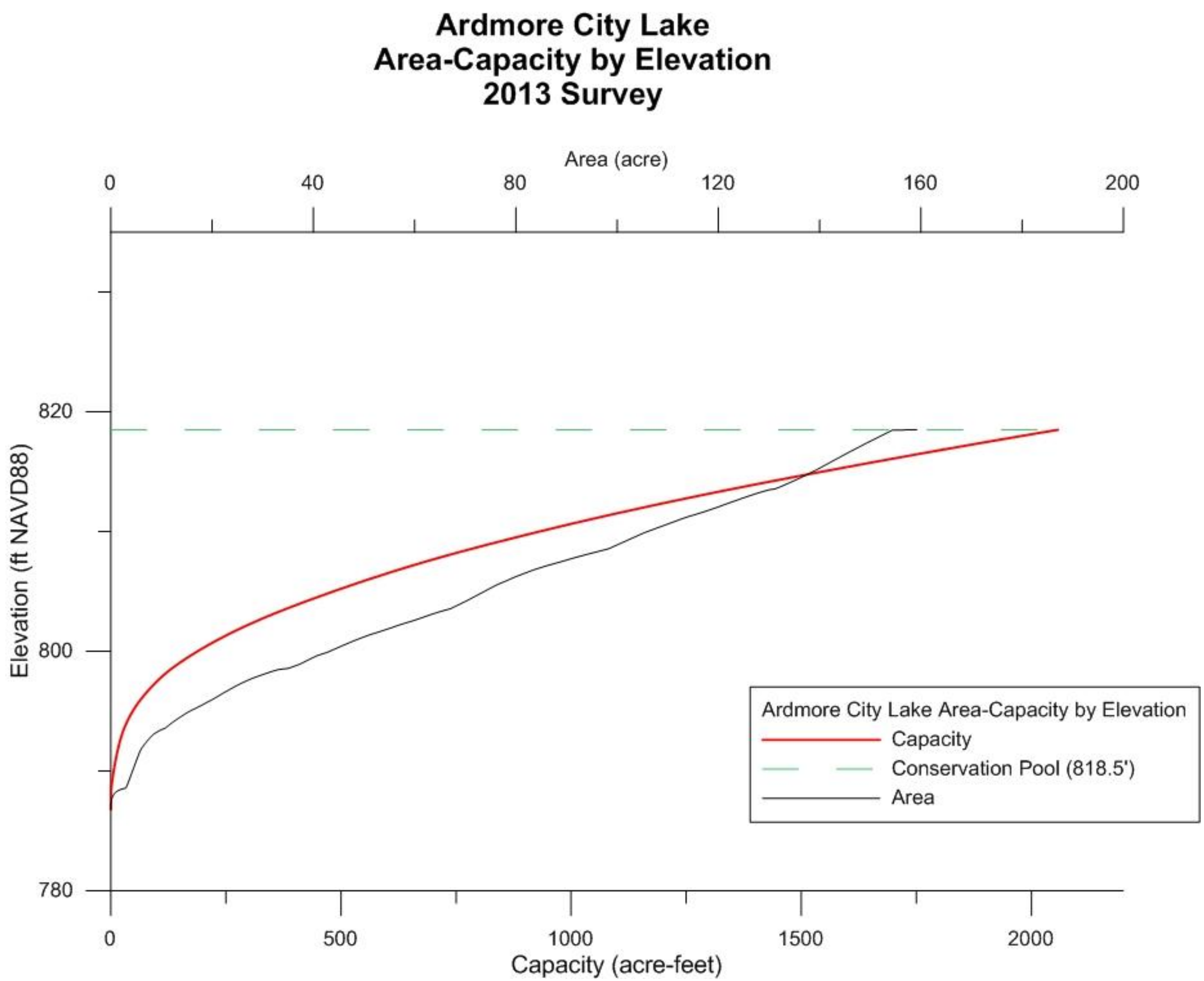
Table A.1 Ardmore City Lake Capacity/Area by 0.1-ft Increments.

ARDMORE CITY LAKE AREA-CAPACITY TABLE OKLAHOMA WATER RESOURCES BOARD 2012 Survey Capacity in acre-feet by tenth foot elevation increments Area in acres by tenth foot elevation increments											
Elevation (ft NAVD 88)		0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
786	Area								0	0	3E-04
	Capacity								0	0.001	0.004
787	Area	9E-04	0.002	0.005	0.01	0.018	0.029	0.045	0.065	0.094	0.135
	Capacity	0.009	0.02	0.037	0.064	0.096	0.133	0.178	0.236	0.345	0.481
788	Area	0.189	0.26	0.356	0.483	0.651	0.922	1.223	1.536	1.859	2.192
	Capacity	0.607	0.823	1.107	1.444	1.984	2.935	3.075	3.184	3.284	3.377
789	Area	2.535	2.886	3.245	3.613	3.99	4.376	4.77	5.174	5.585	6.006
	Capacity	3.465	3.552	3.638	3.725	3.812	3.9	3.987	4.074	4.162	4.25
790	Area	6.435	6.874	7.321	7.777	8.241	8.715	9.197	9.689	10.19	10.7
	Capacity	4.338	4.426	4.514	4.603	4.691	4.78	4.869	4.958	5.047	5.136
791	Area	11.22	11.74	12.28	12.82	13.38	13.94	14.52	15.1	15.7	16.31
	Capacity	5.226	5.315	5.405	5.496	5.59	5.686	5.785	5.901	6.052	6.21
792	Area	16.94	17.59	18.25	18.93	19.63	20.36	21.1	21.86	22.65	23.45
	Capacity	6.374	6.544	6.726	6.922	7.123	7.325	7.529	7.739	7.953	8.17
793	Area	24.28	25.14	26.04	26.98	27.96	29.01	30.1	31.21	32.36	33.53
	Capacity	8.409	8.786	9.176	9.597	10.05	10.72	11.01	11.31	11.6	11.9
794	Area	34.74	35.97	37.24	38.55	39.89	41.27	42.68	44.13	45.62	47.15
	Capacity	12.19	12.52	12.88	13.24	13.6	13.95	14.31	14.68	15.07	15.49
795	Area	48.72	50.34	52.01	53.72	55.48	57.29	59.14	61.03	62.97	64.95
	Capacity	15.92	16.44	16.91	17.4	17.85	18.28	18.7	19.13	19.62	20.06
796	Area	66.98	69.05	71.16	73.3	75.49	77.71	79.98	82.29	84.64	87.04
	Capacity	20.47	20.9	21.28	21.65	22.04	22.45	22.89	23.31	23.73	24.16
797	Area	89.48	91.96	94.48	97.06	99.68	102.4	105.1	107.9	110.7	113.6
	Capacity	24.59	25.04	25.51	25.99	26.49	27	27.55	28.17	28.83	29.47
798	Area	116.6	119.7	122.8	126	129.2	132.7	136.2	139.8	143.5	147.2
	Capacity	30.13	30.79	31.49	32.24	33.09	35.03	35.71	36.37	36.99	37.54
799	Area	151	154.8	158.7	162.6	166.6	170.6	174.7	178.8	183	187.3
	Capacity	38.04	38.51	38.98	39.44	39.92	40.44	41.02	41.71	42.47	43.06
800	Area	191.6	196	200.5	205	209.5	214.1	218.8	223.5	228.3	233.1
	Capacity	43.61	44.15	44.69	45.22	45.76	46.31	46.86	47.42	48	48.6
801	Area	238	242.9	247.9	253	258.2	263.4	268.7	274.1	279.5	285
	Capacity	49.21	49.83	50.48	51.13	51.83	52.59	53.33	54.05	54.76	55.47
802	Area	290.6	296.2	302	307.8	313.6	319.6	325.6	331.7	337.8	344.1
	Capacity	56.15	56.82	57.52	58.25	59.08	59.85	60.55	61.24	61.93	62.6
803	Area	350.4	356.7	363.2	369.7	376.3	383	389.7	396.5	403.3	410.2
	Capacity	63.29	63.97	64.71	65.5	66.41	67.2	67.67	68.15	68.63	69.1
804	Area	417.2	424.1	431.2	438.3	445.4	452.5	459.7	467	474.3	481.6
	Capacity	69.58	70.07	70.53	70.98	71.43	71.87	72.32	72.75	73.19	73.65
805	Area	489	496.5	503.9	511.5	519	526.6	534.3	542	549.8	557.6
	Capacity	74.09	74.54	74.98	75.44	75.91	76.39	76.92	77.48	78.07	78.59
806	Area	565.5	573.5	581.5	589.5	597.6	605.8	614.1	622.4	630.7	639.2
	Capacity	79.12	79.66	80.24	80.85	81.47	82.08	82.7	83.35	84.05	84.8

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

ARDMORE CITY LAKE AREA-CAPACITY TABLE OKLAHOMA WATER RESOURCES BOARD 2012 Survey Capacity in acre-feet by tenth foot elevation increments Area in acres by tenth foot elevation increments											
Elevation (ft NAVD 88)		0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
807	Area	647.7	656.3	665	673.7	682.6	691.5	700.5	709.6	718.8	728
	Capacity	85.56	86.34	87.22	88.07	88.87	89.66	90.44	91.28	92.16	93.01
808	Area	737.4	746.8	756.3	766	775.7	785.5	795.3	805.3	815.2	825.2
	Capacity	93.89	94.78	95.68	96.59	97.5	98.39	98.91	99.44	99.96	100.5
809	Area	835.3	845.5	855.6	865.9	876.1	886.5	896.9	907.3	917.8	928.4
	Capacity	101	101.5	102	102.6	103.1	103.6	104.2	104.7	105.2	105.8
810	Area	939	949.7	960.4	971.2	982.1	993	1004	1015	1026	1037
	Capacity	106.4	107.1	107.7	108.4	109	109.7	110.3	111	111.6	112.2
811	Area	1049	1060	1071	1083	1094	1106	1118	1129	1141	1153
	Capacity	112.8	113.5	114.3	115.1	115.9	116.6	117.3	118	118.7	119.4
812	Area	1165	1177	1189	1202	1214	1226	1238	1251	1263	1276
	Capacity	120.1	120.7	121.4	122	122.7	123.4	124	124.7	125.4	126.1
813	Area	1289	1301	1314	1327	1340	1353	1366	1379	1393	1406
	Capacity	126.8	127.5	128.3	129.1	129.9	131.3	131.9	132.4	133	133.5
814	Area	1419	1433	1446	1460	1473	1487	1501	1515	1528	1542
	Capacity	134.1	134.6	135.1	135.6	136.1	136.6	137.1	137.6	138.1	138.6
815	Area	1556	1570	1584	1598	1612	1626	1640	1654	1669	1683
	Capacity	139	139.5	139.9	140.3	140.8	141.2	141.7	142.1	142.5	143
816	Area	1697	1712	1726	1740	1755	1769	1784	1799	1813	1828
	Capacity	143.4	143.8	144.3	144.7	145.1	145.6	146	146.5	146.9	147.4
817	Area	1843	1858	1873	1887	1902	1917	1932	1948	1963	1978
	Capacity	147.8	148.3	148.8	149.2	149.7	150.2	150.6	151.1	151.6	152
818	Area	1993	2008	2024	2039	2054	2058				
	Capacity	152.5	153	153.5	153.9	154.4	159.2				

Figure A. 1. Area-Capacity Curve for Ardmore City Lake



APPENDIX B: Ardmore City Lake Maps

Figure B. 1: Ardmore City Lake Bathymetric Map with 5-foot Contour Intervals.

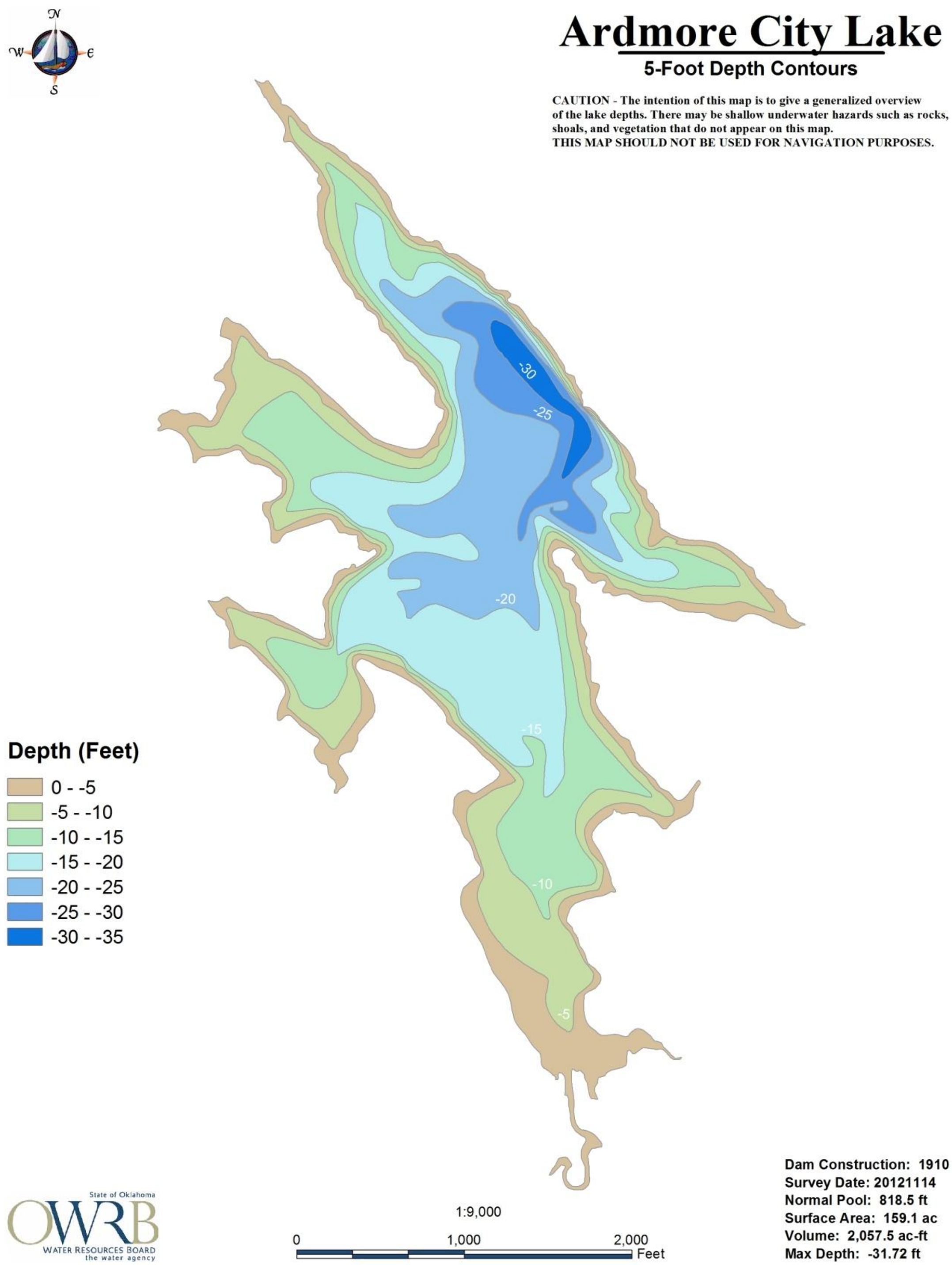


Figure B. 2: Ardmore City Lake Shaded Relief Bathymetric Map.

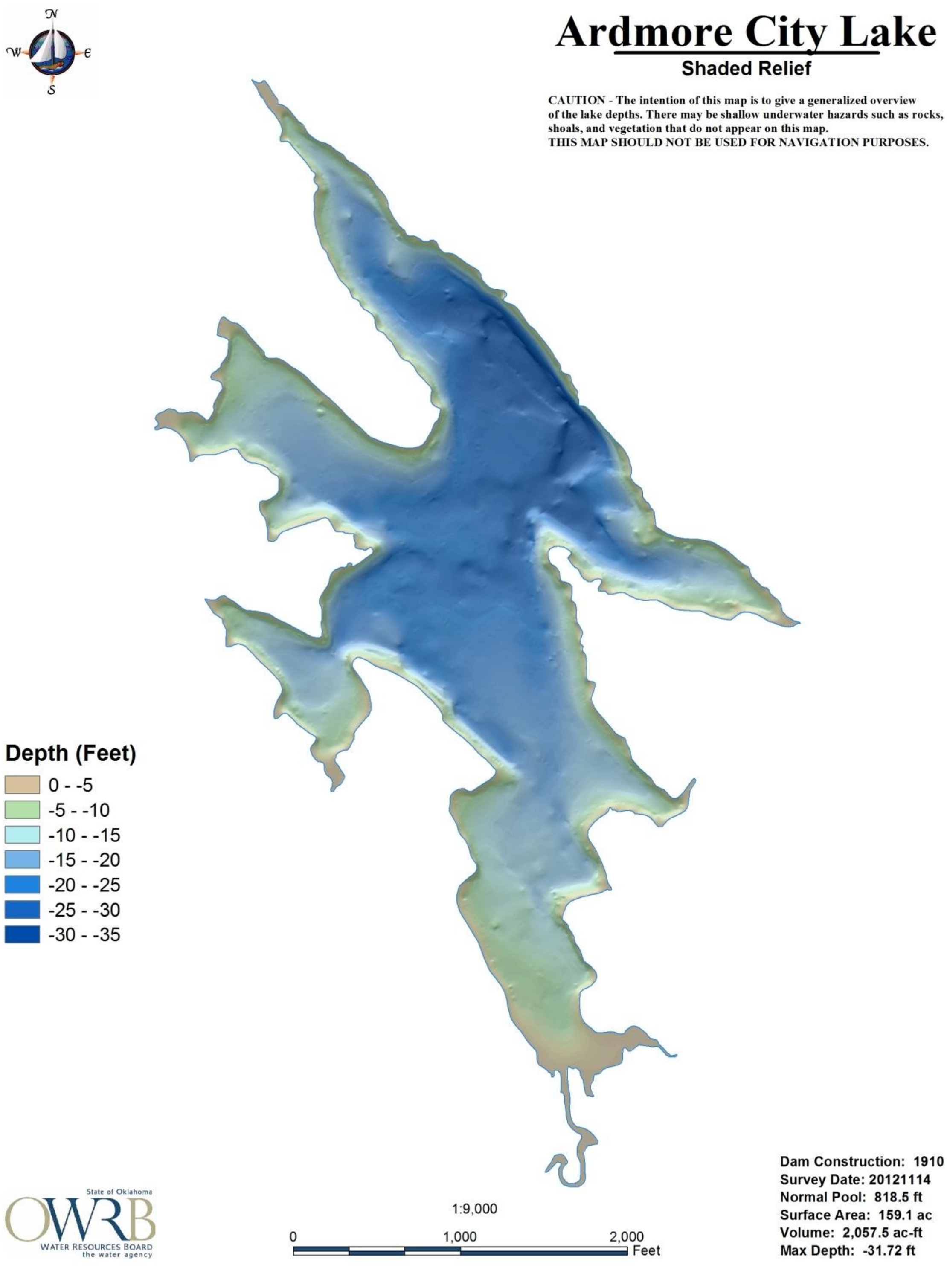


Figure B. 3: Ardmore City Lake Collected Data Points.