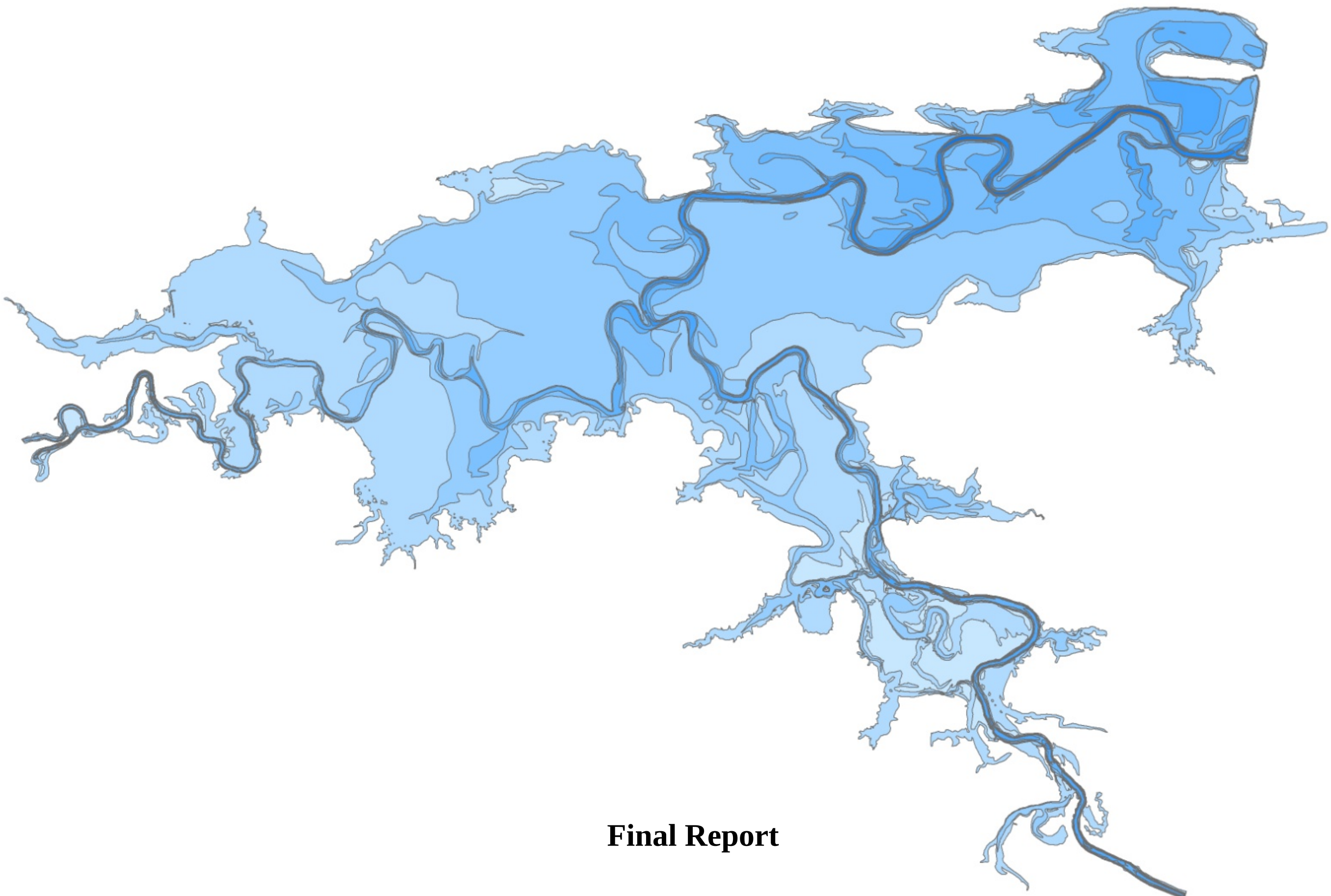
HYDROGRAPHIC SURVEY of WISTER LAKE



Final Report

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Prepared by:

State of Oklahoma
OWRB
WATER RESOURCES BOARD
the water agency

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WISTER LAKE
HYDROGRAPHIC SURVEY REPORT

INTRODUCTION

The Oklahoma Water Resources Board (OWRB) conducted a hydrographic survey of Wister Lake beginning in February of 2011 and ending in March of 2011. The purpose of this survey was to produce a new elevation-area-capacity table and bathymetric map for Wister Lake.

LAKE and DAM BACKGROUND

Wister Dam is located in the Arkansas River Basin and is on the Poteau River in LeFlore County (**Figure 1**) about 2 miles south of the town of Wister and about 7 miles northwest of Heavener, OK. Construction of the dam began in April 1946 and was completed in May of 1949. Its purposes are water supply, flood control, and conservation.

The dam is a rolled impervious earthfill structure with rock-protected slopes, having a length of 5,700 feet and a maximum height of 99 feet above the streambed. The uncontrolled concrete chute-type spillway is 600 feet wide and has a maximum capacity of 170,910 cfs at maximum pool elevation.

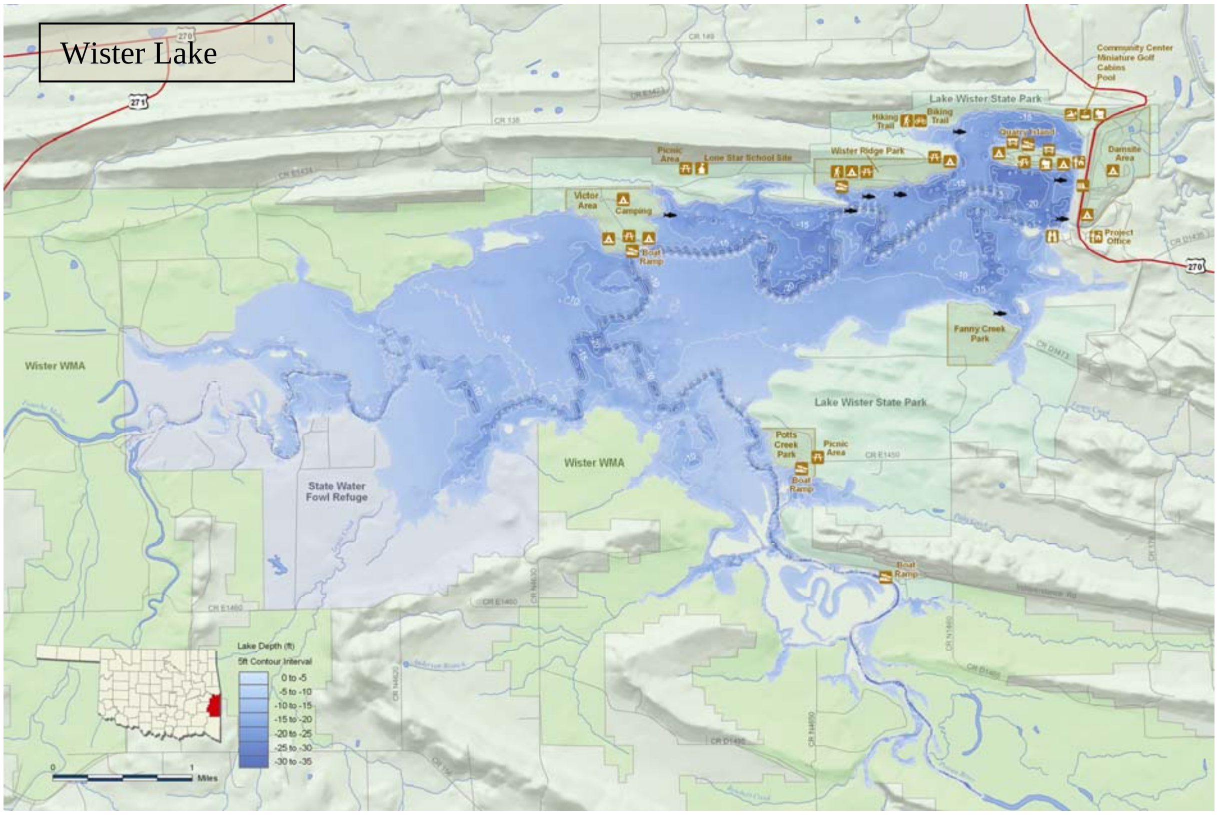


Figure 1: Location map for Wister Lake.

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 Wister Lake was on-screen digitized from the 2006 color digital orthoimagery quarter quadrangle (DOQQ) mosaic of LeFlore County, Oklahoma. The screen scale was set to 1:1,500. A line was created 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 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.

Field Survey

Lake Elevation Acquisition

The lake elevation for Wister Lake was obtained from a gauge maintained by the U.S. Army Corps of Engineers.

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 Wister Lake occurred in February and March of 2011. The water level elevation during data collection for Wister Lake ranged from 478.8 to 479.9 ft Geodetic Vertical Datum (NGVD). 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 152 cross-sections points at Wister Lake were used to compute error estimates. A mean difference (arithmetic mean) of 0.1 ft and a standard deviation of 0.226 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 ± 0.48 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 0.1 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 0.4 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 0.4 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 Wister Lake are located on the DVD entitled *Wister 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 9.3.1.3500, 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, the lake boundary inputs for normal pool elevations, and Light Detection and Ranging (LIDAR) data points supplied by the US Army Corp of Engineers for flood pool elevations. The TIN consists of connected data points that form a network of triangles representing the bottom surface of the lake and flood pool. 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: Wister 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 is located at on the DVD entitled *Wister HYPACK/GIS Metadata.*

RESULTS

Results from the 2011 OWRB survey indicate that Wister Lake encompasses 6,200 acres and contains a cumulative capacity of 50,500 ac-ft at the normal pool elevation (478 ft NGVD). The average depth for Wister Lake was 8.1 ft.

SUMMARY and COMPARISON

Table 1 is a comparison of area and volume changes of Wister Lake at the normal pool elevation. Comparison to the 2001 survey shows that the lake has had an increase of 211 acres (approximately 3.4%) and an apparent increase in capacity of 3,115 acre-feet or approximately 6.6%. The apparent gain in volume and area could be attributed to a more accurate digitization of the lake boundary. Caution should be used when directly comparing between earlier (pre-2001) and later capacity figures because different methods were used to collect the data and extrapolate capacity and area figures.

Table 1: Area and Volume Comparisons of Wister Lake at lake elevation 478 ft.

Feature	Survey Year				
	1949	1972	1985	2001	2011
Area (acres)	7,342	7,532	7,386	6,077	6,200
Cumulative Volume	66,887	61,274	61,423	47,414	50,500
Mean depth (ft)	9.1	8.1	8.3	7.4	8.1
Maximum Depth (ft)	55	44	44	39.8	37.6
Change in Volume (acre-feet)[1]	--	-5,613	149	-14,009	3,086
Sedimentation Rate (acre-feet/yr)[1]	--	244.0	-11.5	875.6	-308.6

Notes:

1. Volume Loss and Sedimentation Rate for indicated year is calculated from the previous survey.

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). 1990. Oklahoma Water Atlas.

APPENDIX A: Area-Capacity Data

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

WISTER LAKE AREA-CAPACITY TABLE
OKLAHOMA WATER RESOURCES BOARD
2011 Survey
Capacity in acre-feet by tenth foot elevation increments
Area in acres by tenth foot elevation increments

Elevation (ft NGVD)		0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
440	Area					0.0000	0.0004	0.0015	0.0043	0.0099	0.0312
	Capacity					0.0000	0.0000	0.0001	0.0004	0.001	0.0029
441	Area	0.0631	0.0900	0.1233	0.1656	0.2234	0.2966	0.3851	0.4933	0.6275	0.7888
	Capacity	0.0075	0.0151	0.0258	0.0401	0.0594	0.0853	0.1192	0.1630	0.2188	0.2894
442	Area	0.9782	1.2001	1.4711	1.7755	2.1267	2.5399	3.0215	3.5874	4.2621	5.0404
	Capacity	0.3775	0.4861	0.6193	0.7814	0.9760	1.2088	1.4863	1.8161	2.2075	2.6720
443	Area	15.778	16.081	16.359	16.622	16.886	17.157	17.433	17.715	17.998	18.287
	Capacity	3.2212	4.8148	6.4372	8.0861	9.7618	11.464	13.194	14.952	16.737	18.552
444	Area	18.58	18.879	19.186	19.502	19.830	20.184	20.557	20.928	21.303	21.692
	Capacity	20.396	22.269	24.172	26.106	28.073	30.074	32.111	34.186	36.297	38.447
445	Area	22.092	22.495	22.911	23.340	23.779	24.237	24.717	25.206	25.699	26.192
	Capacity	40.637	42.867	45.137	47.449	49.806	52.207	54.655	57.151	59.696	62.291
446	Area	26.689	27.193	27.707	28.233	28.768	29.313	29.866	30.427	30.997	31.581
	Capacity	64.936	67.630	70.376	73.172	76.023	78.927	81.887	84.902	87.973	91.102
447	Area	32.181	32.794	33.419	34.057	34.718	35.412	36.149	36.956	37.830	38.814
	Capacity	94.291	97.540	100.85	104.22	107.66	111.17	114.75	118.40	122.14	125.97
448	Area	50.437	50.947	51.437	51.925	52.415	52.908	53.405	53.904	54.409	54.920
	Capacity	129.91	134.98	140.10	145.27	150.49	155.76	161.07	166.44	171.85	177.32
449	Area	55.443	55.978	56.523	57.076	57.640	58.213	58.794	59.398	60.008	60.621
	Capacity	182.84	188.41	194.04	199.72	205.46	211.25	217.10	223.01	228.98	235.01
450	Area	61.244	61.880	62.535	63.195	63.860	64.530	65.211	65.902	66.610	67.338
	Capacity	241.11	247.27	253.49	259.77	266.13	272.55	279.04	285.59	292.22	298.92
451	Area	68.078	68.848	69.625	70.423	71.251	72.099	72.966	73.853	74.757	75.663
	Capacity	305.69	312.54	319.46	326.46	333.55	340.72	347.97	355.31	362.74	370.26
452	Area	76.585	77.519	78.466	79.427	80.406	81.415	82.475	83.584	84.761	86.075
	Capacity	377.88	385.58	393.39	401.28	409.27	417.36	425.56	433.86	442.28	450.82
453	Area	98.85	100.09	101.23	102.34	103.48	104.66	105.88	107.09	108.37	109.72
	Capacity	459.51	469.46	479.53	489.70	500.00	510.41	520.93	531.58	542.36	553.26
454	Area	111.24	112.88	114.59	116.42	118.40	120.47	122.61	125.03	127.60	130.16
	Capacity	564.31	575.52	586.89	598.44	610.18	622.13	634.28	646.67	659.30	672.19
455	Area	132.87	135.81	139.02	142.62	146.63	150.49	154.41	157.98	161.27	164.45
	Capacity	685.34	698.77	712.51	726.59	741.05	755.91	771.16	786.79	802.75	819.04
456	Area	167.71	171.04	174.41	177.78	181.21	184.73	188.32	192.01	195.90	199.92
	Capacity	835.65	852.59	869.87	887.48	905.43	923.73	942.38	961.40	980.80	1000.6
457	Area	204.07	208.29	212.61	217.05	221.69	226.74	232.33	238.50	244.94	252.00
	Capacity	1020.8	1041.4	1062.5	1083.9	1105.9	1128.3	1151.3	1174.8	1199.0	1223.8
458	Area	284.81	289.57	293.99	298.27	302.45	306.64	310.85	315.1	319.47	323.91
	Capacity	1249.4	1278.1	1307.3	1336.9	1367.0	1397.4	1428.3	1459.6	1491.4	1523.5
459	Area	328.37	332.88	337.44	342.05	346.70	351.40	356.13	360.9	365.76	370.74
	Capacity	1556.2	1589.2	1622.7	1656.7	1691.2	1726.1	1761.5	1797.3	1833.6	1870.5
460	Area	375.87	381.1	386.66	392.29	398.28	404.71	411.84	419.34	427.98	436.58
	Capacity	1907.8	1945.7	1984.1	2023.0	2062.5	2102.7	2143.5	2185.1	2227.4	2270.7

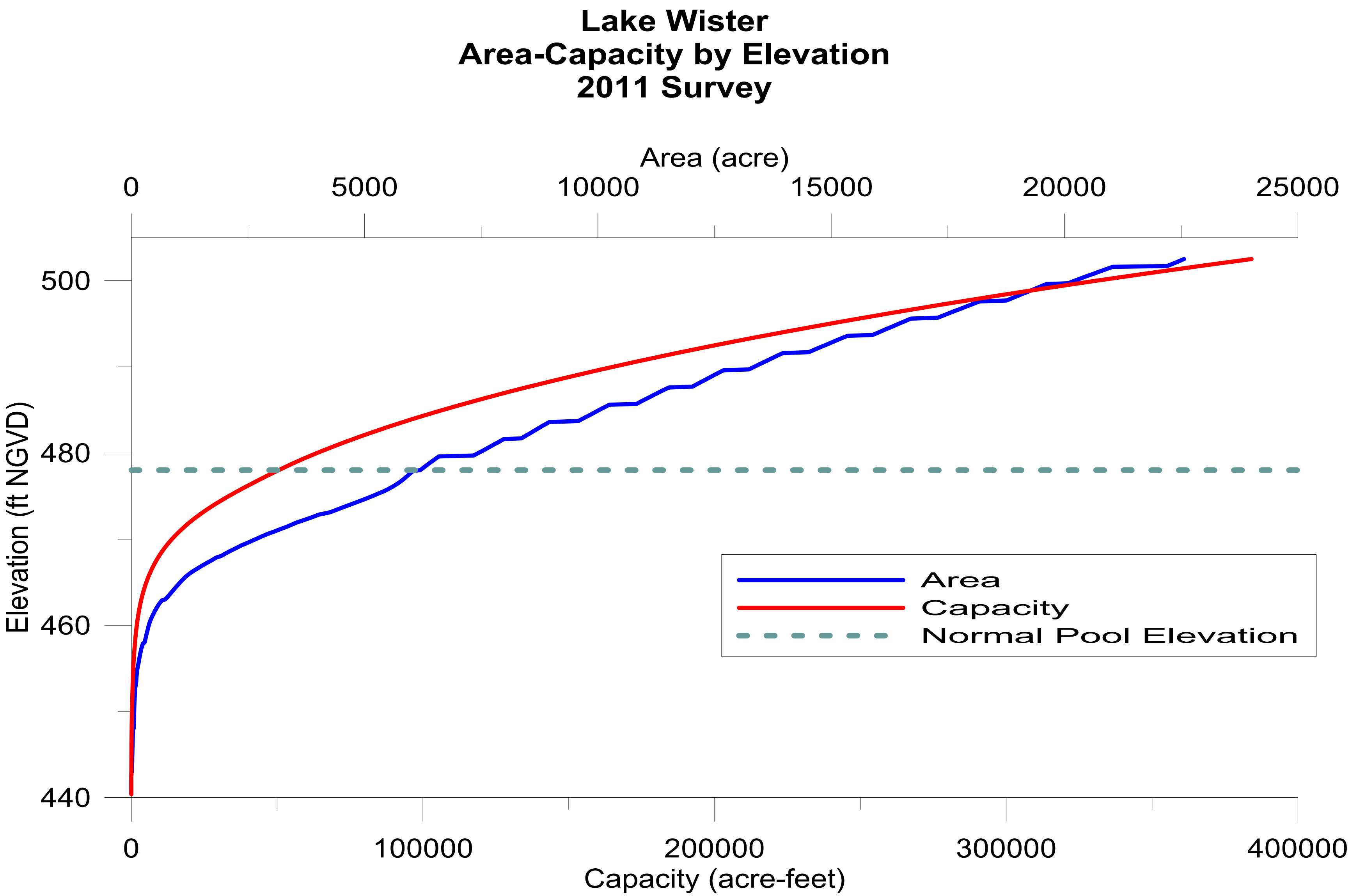
Table A. 2: Wister Lake Capacity/Area by 0.1-ft Increments (cont).

WISTER LAKE AREA-CAPACITY TABLE OKLAHOMA WATER RESOURCES BOARD 2011 Survey Capacity in acre-feet by tenth foot elevation increments Area in acres by tenth foot elevation increments											
Elevation (ft NGVD)		0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
461	Area	445.33	453.95	462.98	472.23	481.16	490.19	499.45	509.14	519.18	529.57
	Capacity	2314.8	2359.7	2405.6	2452.3	2500.0	2548.6	2598.1	2648.5	2699.9	2752.4
462	Area	540.06	551.48	563.19	575.17	587.66	600.54	613.8	627.48	642.04	657.47
	Capacity	2805.9	2860.4	2916.2	2973.1	3031.3	3090.7	3151.4	3213.5	3276.9	3341.9
463	Area	727.11	746.15	763.19	779.26	794.75	810.13	825.59	841.11	856.57	872.10
	Capacity	3408.5	3482.2	3557.7	3634.9	3713.6	3793.8	3875.6	3959.0	4043.9	4130.3
464	Area	888.00	904.30	920.55	936.27	951.96	967.95	983.83	999.89	1016.4	1033.1
	Capacity	4218.3	4308.0	4399.2	4492.1	4586.5	4682.5	4780.1	4879.3	4980.1	5082.6
465	Area	1050.1	1067.4	1085.3	1103.3	1121.1	1140.2	1159.7	1179.7	1201.3	1224.1
	Capacity	5186.8	5292.7	5400.3	5509.8	5621.0	5734.1	5849.1	5966.1	6085.1	6206.4
466	Area	1249.4	1275.5	1302.6	1329.9	1359.4	1390.3	1418.6	1449.3	1480.3	1511.3
	Capacity	6330.1	6456.3	6585.3	6716.9	6851.3	6988.9	7129.3	7272.7	7419.2	7568.8
467	Area	1542.9	1573.9	1606.1	1640.6	1676.2	1710.4	1743.6	1775.1	1804.8	1835.5
	Capacity	7721.5	7877.3	8036.3	8198.6	8364.5	8533.9	8706.6	8882.6	9061.6	9243.6
468	Area	1903.3	1942.5	1975.1	2007.6	2042.8	2078.4	2114.8	2152.6	2188.5	2224.5
	Capacity	9428.8	9621.3	9817.2	10016	10219	10425	10635	10848	11065	11286
469	Area	2260.4	2296.7	2332.5	2370.2	2412.2	2460.5	2507.2	2549.5	2590.9	2628.8
	Capacity	11510	11738	11969	12205	12444	12687	12936	13189	13446	13707
470	Area	2664.7	2703.5	2743.8	2788.2	2834.1	2881.9	2928.4	2976.1	3024.0	3071.1
	Capacity	13972	14240	14512	14789	15070	15356	15646	15942	16242	16547
471	Area	3117.8	3164.7	3214.1	3264.9	3315.9	3362.7	3406.0	3448.6	3492.5	3535.7
	Capacity	16856	17170	17489	17813	18142	18476	18815	19158	19505	19856
472	Area	3580.3	3633.1	3692.9	3747.3	3799.5	3852.6	3903.1	3952.0	4003.8	4062.3
	Capacity	20212	20573	20939	21311	21688	22071	22459	22852	23250	23653
473	Area	4170.2	4237.8	4294.4	4346.1	4395.2	4444.2	4491.4	4539.8	4590.5	4641.9
	Capacity	24063	24483	24910	25342	25779	26221	26668	27120	27576	28038
474	Area	4692.7	4741.0	4788.7	4834.8	4882.7	4932.1	4984.3	5035.4	5084.4	5128.8
	Capacity	28505	28976	29453	29934	30420	30911	31407	31908	32414	32925
475	Area	5170.6	5210.3	5254.2	5297.4	5342.2	5389.1	5431.3	5467.6	5502.6	5536.8
	Capacity	33440	33959	34482	35010	35542	36078	36619	37165	37713	38265
476	Area	5570.6	5603.9	5635.8	5665.3	5693.0	5719.6	5746.5	5772.8	5800.2	5823.7
	Capacity	38821	39379	39941	40506	41075	41645	42219	42795	43373	43955
477	Area	5844.6	5865.3	5886.0	5907.0	5928.1	5949.5	5971.0	5993.1	6015.8	6039.1
	Capacity	44538	45124	45712	46301	46893	47487	48083	48681	49282	49885
478	Area	6190.2	6214.4	6238.8	6263.2	6287.7	6312.4	6337.1	6361.9	6386.8	6411.8
	Capacity	50490	51110	51733	52358	52986	53616	54248	54884	55521	56161
479	Area	6437.0	6462.2	6487.5	6513.0	6538.5	6564.2	6589.9	7335.1	7370.3	7405.3
	Capacity	56804	57449	58096	58746	59399	60054	60712	61401	62136	62875
480	Area	7440.2	7475.0	7509.5	7544.0	7578.2	7612.4	7646.3	7680.1	7713.8	7747.4
	Capacity	63618	64364	65113	65866	66622	67381	68145	68911	69681	70454
481	Area	7780.8	7814.1	7847.4	7880.5	7913.5	7946.4	7979.2	8363.2	8393.7	8424.3
	Capacity	71230	72010	72794	73580	74370	75163	75959	76773	77611	78452

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

WISTER LAKE AREA-CAPACITY TABLE OKLAHOMA WATER RESOURCES BOARD 2011 Survey Capacity in acre-feet by tenth foot elevation increments Area in acres by tenth foot elevation increments											
Elevation (ft NGVD)		0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
482	Area	8455.0	8485.9	8516.8	8547.8	8579.0	8610.2	8641.6	8673.1	8704.6	8736.3
	Capacity	79296	80143	80994	81847	82703	83563	84426	85292	86160	87033
483	Area	8768.1	8800.1	8832.1	8864.2	8896.5	8928.9	8961.3	9579.1	9613.7	9648.3
	Capacity	87908	88787	89668	90553	91441	92333	93227	94149	95108	96072
484	Area	9683	9717.8	9752.5	9787.3	9822.2	9857.1	9892.0	9926.9	9961.9	9997.0
	Capacity	97038	98009	98982	99959	100940	101924	102912	103903	104897	105895
485	Area	10032	10067	10102	10138	10173	10208	10243	10828	10863	10898
	Capacity	106897	107902	108911	109923	110938	111958	112980	114029	115113	116201
486	Area	10934	10969	11005	11041	11077	11113	11149	11185	11222	11259
	Capacity	117293	118389	119487	120590	121696	122805	123919	125036	126156	127280
487	Area	11296	11333	11370	11408	11445	11483	11521	12027	12061	12095
	Capacity	128408	129540	130675	131814	132957	134103	135254	136427	137631	138839
488	Area	12130	12164	12199	12234	12268	12303	12338	12373	12408	12443
	Capacity	140051	141266	142484	143705	144931	146160	147392	148628	149867	151109
489	Area	12478	12513	12548	12583	12619	12654	12690	13238	13275	13312
	Capacity	152356	153605	154859	156115	157375	158639	159907	161198	162524	163853
490	Area	13350	13388	13425	13463	13501	13539	13578	13616	13654	13693
	Capacity	165187	166524	167865	169209	170558	171910	173266	174626	175989	177357
491	Area	13732	13770	13809	13848	13888	13927	13966	14517	14560	14604
	Capacity	178729	180104	181483	182866	184253	185644	187039	188458	189912	191370
492	Area	14647	14691	14734	14778	14822	14865	14909	14953	14997	15041
	Capacity	192833	194301	195772	197248	198728	200212	201701	203195	204692	206194
493	Area	15084	15128	15172	15216	15261	15305	15349	15888	15931	15974
	Capacity	207701	209212	210727	212246	213771	215299	216832	218389	219980	221576
494	Area	16017	16060	16104	16147	16190	16233	16277	16320	16363	16407
	Capacity	223176	224780	226388	228001	229618	231239	232865	234495	236129	237768
495	Area	16450	16494	16537	16581	16624	16668	16712	17283	17329	17376
	Capacity	239411	241059	242711	244366	246027	247692	249361	251056	252786	254522
496	Area	17423	17470	17517	17564	17612	17659	17707	17754	17802	17849
	Capacity	256262	258007	259757	261511	263270	265034	266803	268576	270354	272137
497	Area	17897	17945	17993	18041	18090	18138	18186	18756	18801	18846
	Capacity	273924	275717	277514	279316	281123	282934	284751	286593	288471	290354
498	Area	18891	18936	18981	19027	19072	19117	19162	19207	19252	19297
	Capacity	292241	294133	296029	297929	299834	301744	303658	305577	307500	309428
499	Area	19342	19387	19432	19477	19522	19567	19612	20077	20125	20173
	Capacity	311360	313297	315238	317184	319134	321089	323048	325029	327039	329054
500	Area	20221	20269	20318	20367	20417	20466	20517	20567	20618	20669
	Capacity	331074	333099	335129	337163	339202	341247	343296	345351	347410	349475
501	Area	20720	20772	20824	20877	20929	20982	21036	22197	22244	22290
	Capacity	351545	353620	355700	357785	359875	361971	364073	366224	368446	370673
502	Area	22336	22382	22427	22472	22517	22561				
	Capacity	372905	375141	377382	379626	381876	384131				

Figure A. 1. Area-Capacity Curve for Wister Lake



APPENDIX B: Wister Lake Maps

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

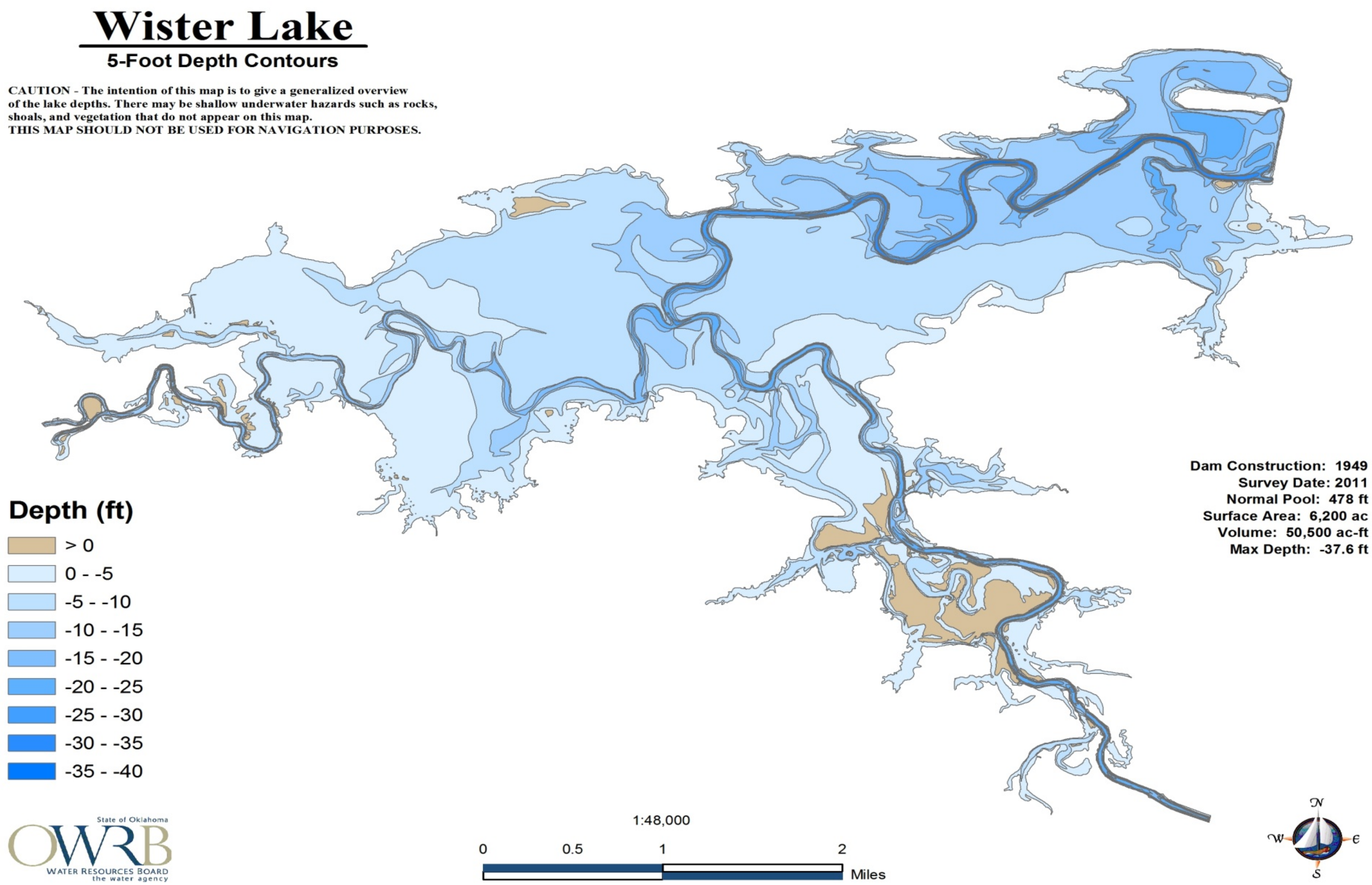


Figure B. 2: Wister Lake Shaded Relief Bathymetric Map.

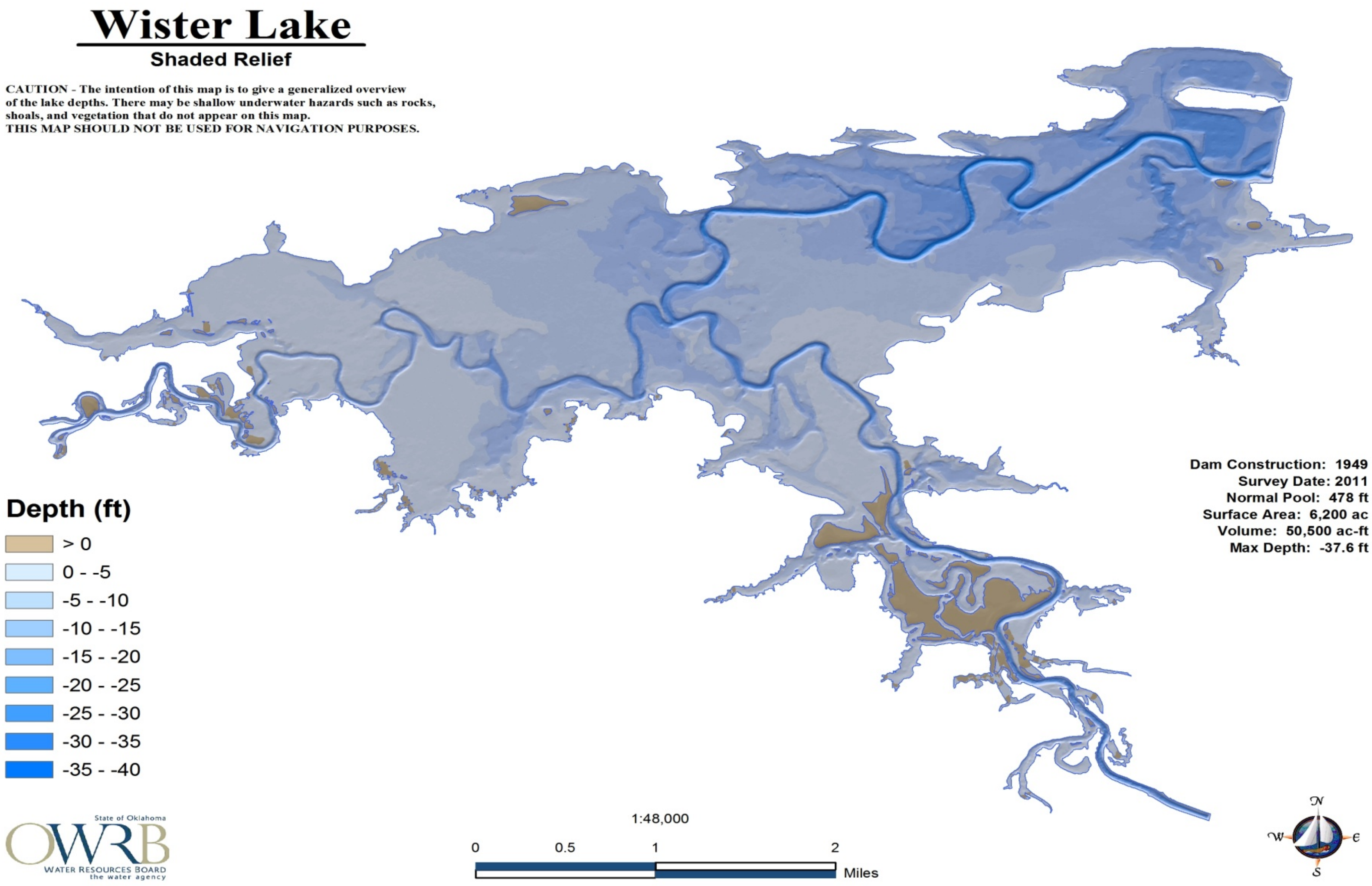


Figure B. 3: Wister Lake Collected Data Points.