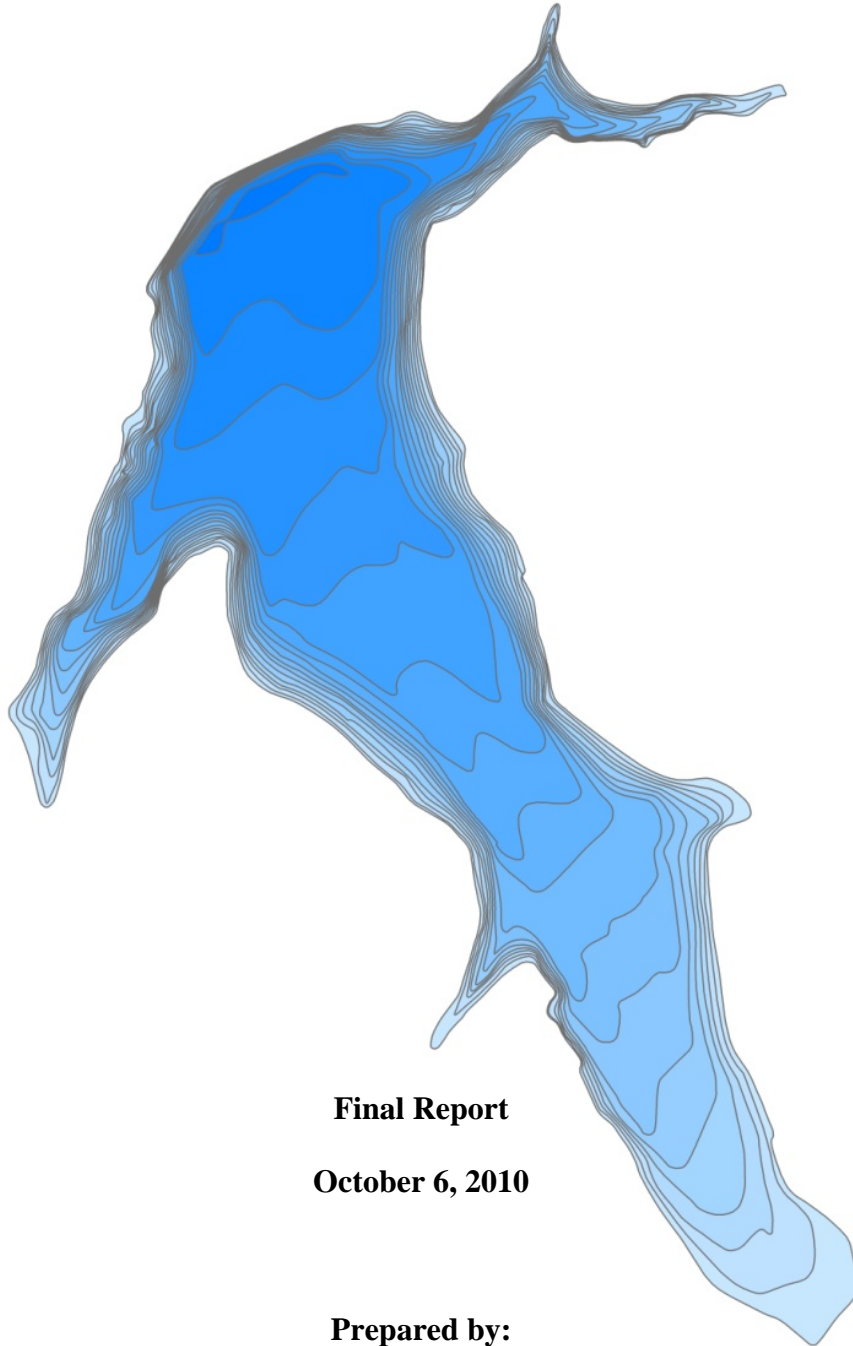


HYDROGRAPHIC SURVEY of GUTHRIE LAKE



Final Report

October 6, 2010

Prepared by:

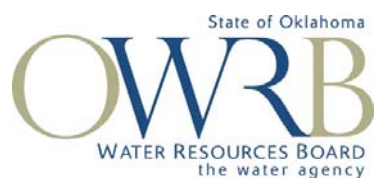


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GUTHRIE LAKE HYDROGRAPHIC SURVEY REPORT

INTRODUCTION

The Oklahoma Water Resources Board (OWRB) conducted a hydrographic survey of Guthrie Lake in March of 2010. 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

Guthrie Lake is located on a tributary of Cottonwood Creek in Logan County, approximately 3.5 miles south and 1 mile west of the city of Guthrie (**Figure 1**). It was built in 1919 as a water supply source for the city of Guthrie. The dam is located in Sec. 32-T16N-R2WIM. 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.

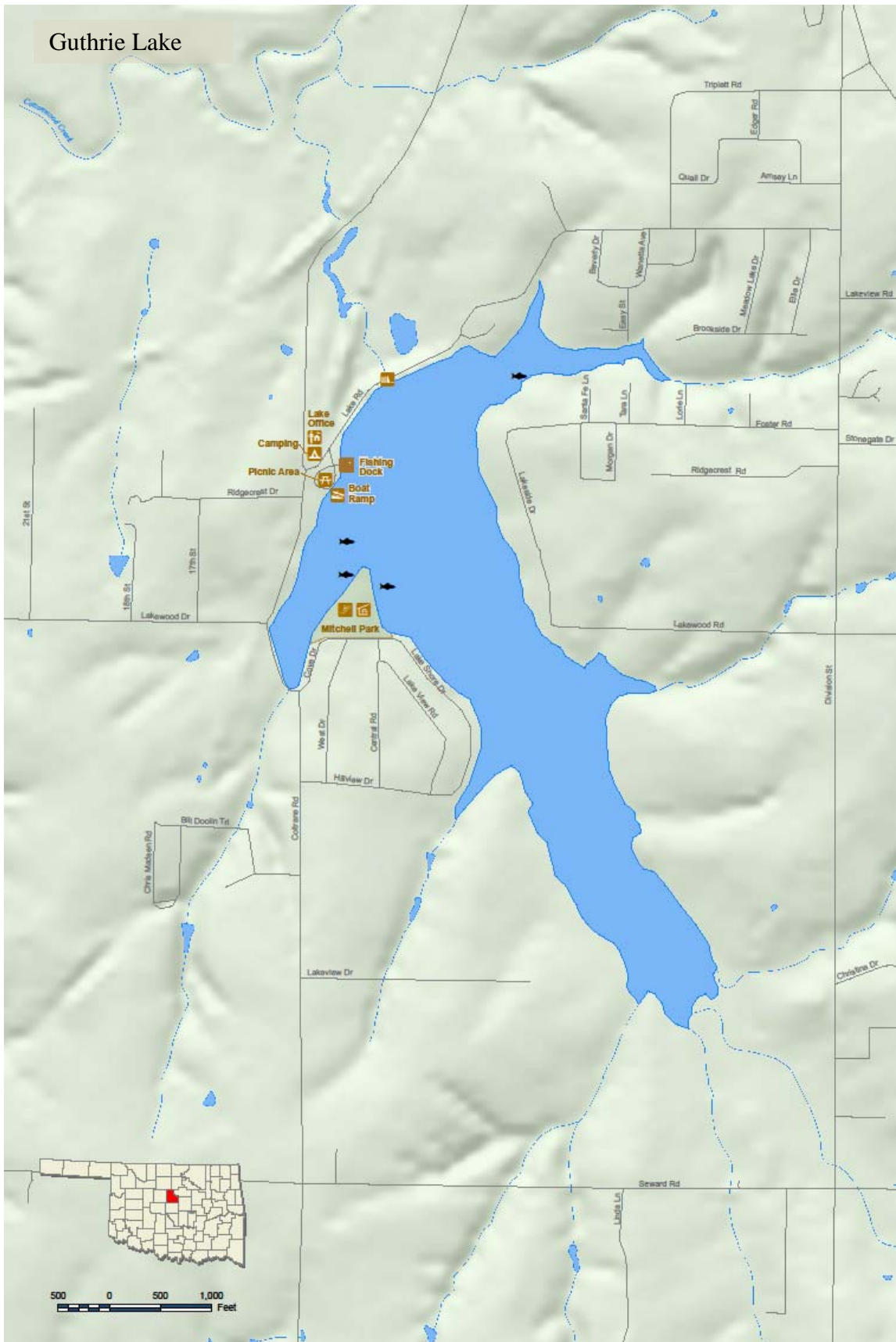


Figure 1: Location map for Guthrie Lake.

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 Guthrie Lake was on-screen digitized from the 2006 color digital orthoimagery quarter quadrangle (DOQQ) mosaic of Logan 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 1995 DOQQs of the lakes were used as back ground reference. The reservoir boundaries were digitized in 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. Cross check transects were at 200 ft increments and ran parallel to the original stream channel. Approximately 25 virtual transects were created for the Guthrie Lake.

Field Survey

Lake Elevation Acquisition

The lake elevation for Guthrie Lake was obtained by collecting positional data over a period of approximately 180 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; 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 Guthrie Lake occurred in March of 2010. The water level elevation for Guthrie Lake at the time of collection was 982.3 ft National 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, 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 4739.1 ft/sec during the Guthrie 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 77 cross-sections points at Guthrie Lake were used to compute error estimates. A mean difference of 0.02 ft and a standard deviation of 0.25 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 ± 0.50 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 0.02 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. The elevation of the lake during the survey was 982.3 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 HYPACK raw and corrected data files for Guthrie Lake are located on the DVD entitled *FEMA 2010 HYPACK/GIS Metadata Disk 1*.

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 1-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: Guthrie Lake 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 *FEMA 2010 HYPACK/GIS Metadata Disk 1*.

RESULTS

Results from the 2010 OWRB survey indicate that Guthrie Lake encompasses 205 acres and contains a cumulative capacity of 2,403 ac-ft at the normal pool elevation (982 ft NGVD). The average depth for Guthrie Lake was 11.7 ft.

SUMMARY and COMPARISON

Confusion exists over the initial design specifications for the dam. Based on the 1978 Phase 1 Inspection Report for the National Dam Safety Program, the design specifications stated that Guthrie Lake had an area of 122 acres and cumulative volume of 2,246 acre-feet of water at

an elevation of 976 ft NGVD. This was believed to be the normal pool elevation of the lake. This figure is based on a US Geological Survey quadrangle map. Original blueprints, however, have the spillway crest, i.e. normal pool elevation, at 982 ft NGVD. This is also the elevation that the City of Guthrie stated as the principal spillway crest. A quick in-field elevation survey concluded that 982 ft NGVD was the correct height for the principal spillway. For the purpose of this report the normal pool elevation for this lake has been defined at 982 ft NGVD. Because of the lack of original design data, an analysis of surface area/capacity change cannot be conducted. It is the recommendation of the OWRB that another survey using the same method used in the 2010 survey be conducted in 10-15 years. By using the 2010 survey figures as a baseline, a future survey would allow an accurate sedimentation rate to be obtained.

Table 1: Area and Volume Comparisons of Guthrie Lake at normal pool (982 ft NGVD).

Feature	Survey Year	
	1919 Design Specifications	2010
Area (acres)	??	205
Cumulative Volume (acre-feet)	??	2,403
Mean depth (ft)	??	11.7
Maximum Depth (ft)	??	22.45

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. Phase 1 Inspection Report; National Dam Safety Program.

APPENDIX A: Area-Capacity Data

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

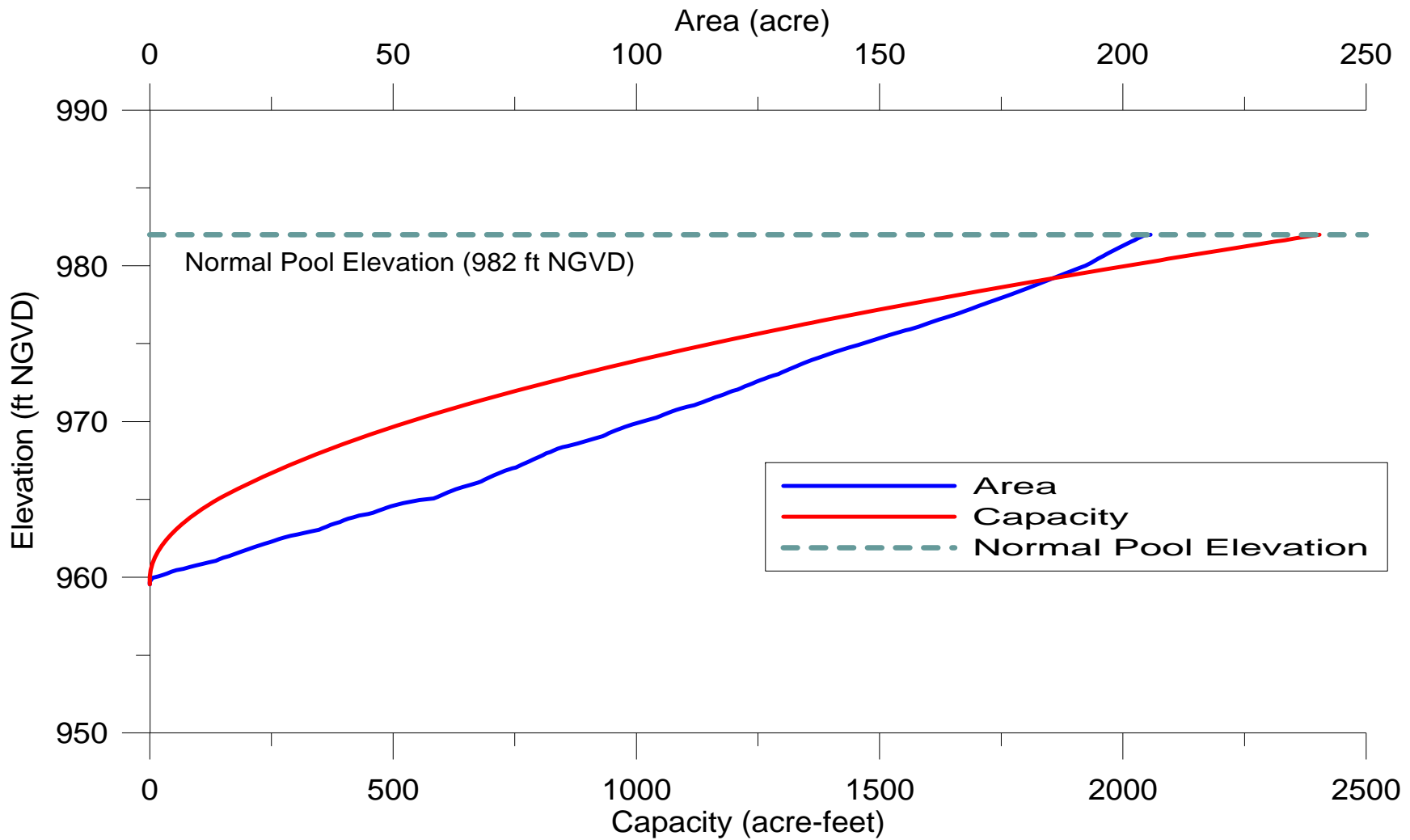
GUTHRIE LAKE AREA-CAPACITY TABLE OKLAHOMA WATER RESOURCES BOARD 2010 Survey Capacity in acre-feet by tenth foot elevation increments Area in acres by tenth foot elevation increments											
Elevation (ft NGVD)		0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
		959	Area							0.0	0.0
	Capacity							0.0	0.0	0.0	0.0
960	Area	0.5	1.8	2.8	3.5	4.4	5.5	6.9	8.2	9.5	10.8
	Capacity	0.1	0.2	0.4	0.7	1.1	1.6	2.2	3.0	3.9	4.9
961	Area	12.1	13.5	14.3	15.1	16.2	17.3	18.1	18.8	19.7	20.6
	Capacity	6.0	7.3	8.7	10.2	11.7	13.4	15.2	17.0	18.9	21.0
962	Area	21.6	22.8	23.6	24.7	25.6	26.5	27.6	29.0	30.4	31.8
	Capacity	23.1	25.3	27.6	30.0	32.5	35.1	37.9	40.7	43.6	46.7
963	Area	33.2	34.7	35.5	36.4	37.2	38.0	39.1	39.9	40.8	41.8
	Capacity	50.0	53.4	56.9	60.5	64.2	67.9	71.8	75.7	79.8	83.9
964	Area	43.0	44.9	45.9	46.9	47.8	48.7	49.6	50.9	52.1	53.7
	Capacity	88.1	92.5	97.1	101.7	106.5	111.3	116.2	121.2	126.4	131.7
965	Area	55.4	58.3	59.1	59.9	60.6	61.3	62.1	63.0	64.0	65.0
	Capacity	137.1	142.8	148.7	154.6	160.7	166.8	172.9	179.2	185.5	192.0
966	Area	66.1	67.4	68.1	68.7	69.4	70.0	70.7	71.5	72.2	73.1
	Capacity	198.5	205.2	212.0	218.8	225.7	232.7	239.7	246.9	254.0	261.3
967	Area	74.1	75.2	75.9	76.5	77.3	78.0	78.7	79.5	80.1	80.8
	Capacity	268.7	276.1	283.7	291.3	299.0	306.8	314.6	322.5	330.5	338.5
968	Area	81.5	82.3	83.0	83.8	84.9	86.1	87.5	88.6	89.7	90.8
	Capacity	346.7	354.9	363.1	371.5	379.9	388.5	397.1	406.0	414.9	423.9
969	Area	91.9	93.0	93.7	94.4	95.1	95.9	96.8	97.6	98.5	99.7
	Capacity	433.0	442.3	451.6	461.0	470.5	480.1	489.7	499.4	509.2	519.1
970	Area	100.7	101.8	102.9	104.1	104.9	105.7	106.5	107.4	108.3	109.3
	Capacity	529.2	539.3	549.5	559.9	570.3	580.9	591.5	602.2	612.9	623.8
971	Area	110.4	111.9	112.8	113.7	114.5	115.4	116.3	117.1	118.0	118.9
	Capacity	634.8	645.9	657.2	668.5	679.9	691.4	703.0	714.7	726.4	738.3
972	Area	119.8	120.7	121.5	122.3	123.1	123.9	124.7	125.5	126.3	127.2
	Capacity	750.2	762.2	774.3	786.5	798.8	811.1	823.6	836.1	848.7	861.3
973	Area	128.2	129.2	129.9	130.7	131.4	132.2	132.9	133.7	134.4	135.2
	Capacity	874.1	887.0	900.0	913.0	926.1	939.3	952.5	965.9	979.3	992.8
974	Area	136.1	137.1	138.0	138.9	139.8	140.7	141.7	142.7	143.7	144.8
	Capacity	1,006.3	1,020.0	1,033.7	1,047.6	1,061.5	1,075.6	1,089.7	1,103.9	1,118.2	1,132.6
975	Area	145.9	147.1	148.0	149.0	149.9	150.9	152.0	153.1	154.2	155.3
	Capacity	1,147.2	1,161.8	1,176.6	1,191.4	1,206.4	1,221.4	1,236.6	1,251.8	1,267.2	1,282.7
976	Area	156.5	157.7	158.5	159.4	160.3	161.3	162.3	163.3	164.3	165.3
	Capacity	1,298.3	1,314.0	1,329.8	1,345.7	1,361.7	1,377.8	1,393.9	1,410.2	1,426.6	1,443.1
977	Area	166.3	167.2	168.0	168.9	169.7	170.6	171.5	172.4	173.3	174.2
	Capacity	1,459.7	1,476.3	1,493.1	1,510.0	1,526.9	1,543.9	1,561.0	1,578.2	1,595.5	1,612.9
978	Area	175.1	176.0	176.9	177.8	178.6	179.5	180.3	181.1	181.9	182.7
	Capacity	1,630.3	1,647.9	1,665.6	1,683.3	1,701.1	1,719.0	1,737.0	1,755.1	1,773.2	1,791.5
979	Area	183.5	184.4	185.2	186.0	186.8	187.6	188.4	189.2	190.1	190.9
	Capacity	1,809.8	1,828.2	1,846.7	1,865.2	1,883.9	1,902.6	1,921.4	1,940.3	1,959.3	1,978.3

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

GUTHRIE LAKE AREA-CAPACITY TABLE OKLAHOMA WATER RESOURCES BOARD 2010 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
		980	Area	191.7	192.6	193.1	193.7	194.3	194.9	195.5	196.1
Capacity	1997.5		2,016.7	2,036.0	2,055.3	2,074.7	2,094.2	2,113.7	2,133.3	2,152.9	2,172.6
981	Area	197.9	198.5	199.1	199.8	200.4	201.0	201.7	202.3	203.0	203.7
	Capacity	2,192.4	2,212.2	2,232.1	2,252.0	2,272.0	2,292.1	2,312.3	2,332.5	2,352.7	2,373.1
982	Area	205.6									
	Capacity	2,403.7									

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

Guthrie Lake Area-Capacity by Elevation 2010 Survey



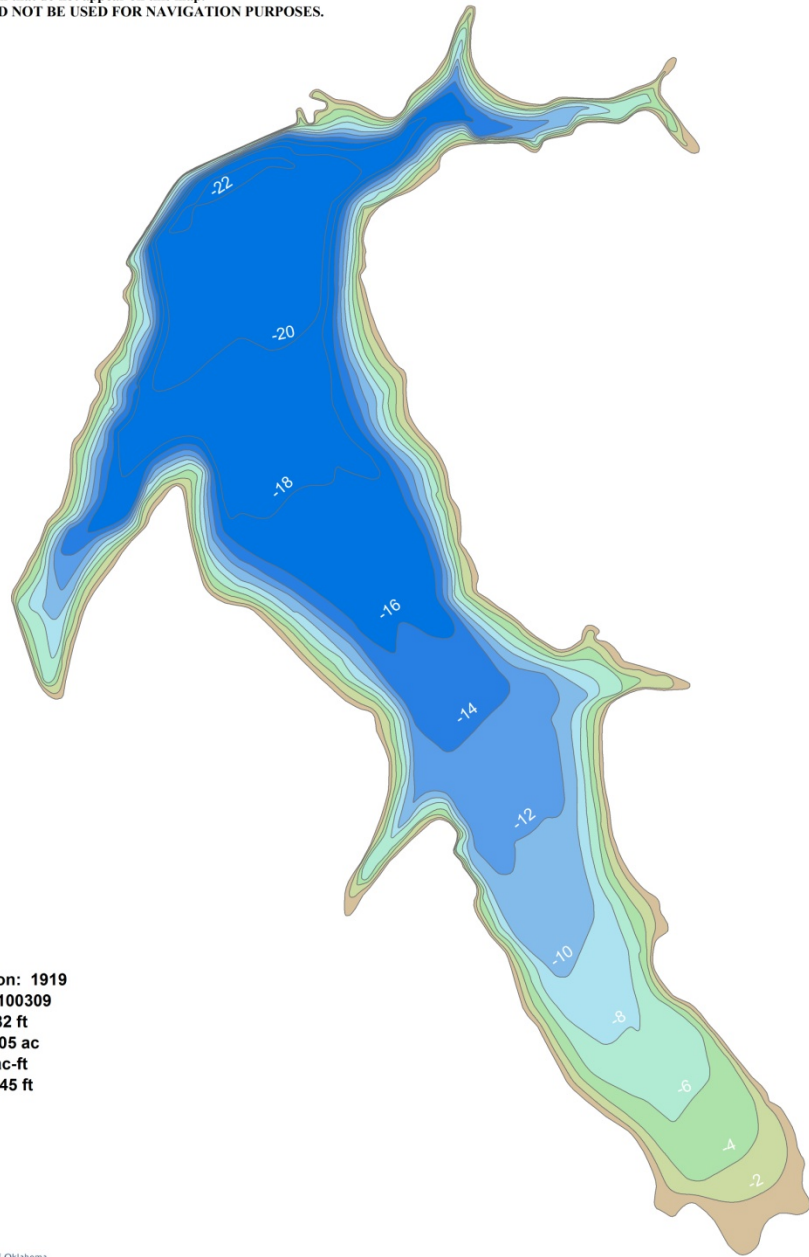
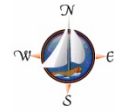
APPENDIX B: Guthrie Lake Maps

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

Guthrie 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 -- 2
-2 -- -4
-4 -- -6
-6 -- -8
-8 -- -10
-10 -- -12
-12 -- -14
-14 -- -16
-16 -- -18
-18 -- -20
-20 -- -22

Dam Construction: 1919
 Survey Date: 20100309
 Normal Pool: 982 ft
 Surface Area: 205 ac
 Volume: 2,403 ac-ft
 Max Depth: -22.45 ft

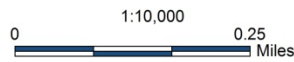
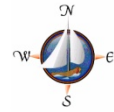


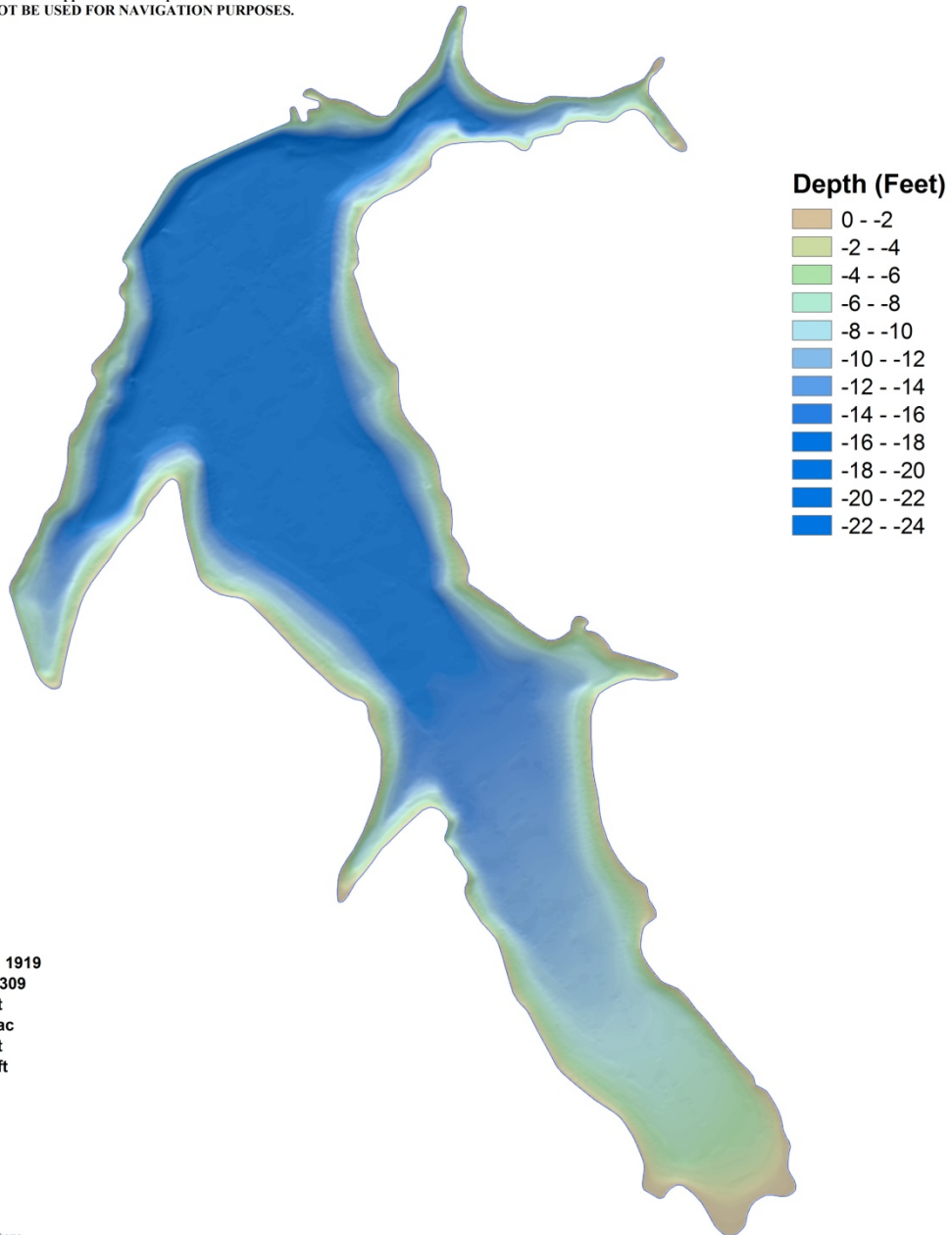
Figure B. 2: Guthrie Lake Shaded Relief Bathymetric Map.

Guthrie Lake

Shaded Relief



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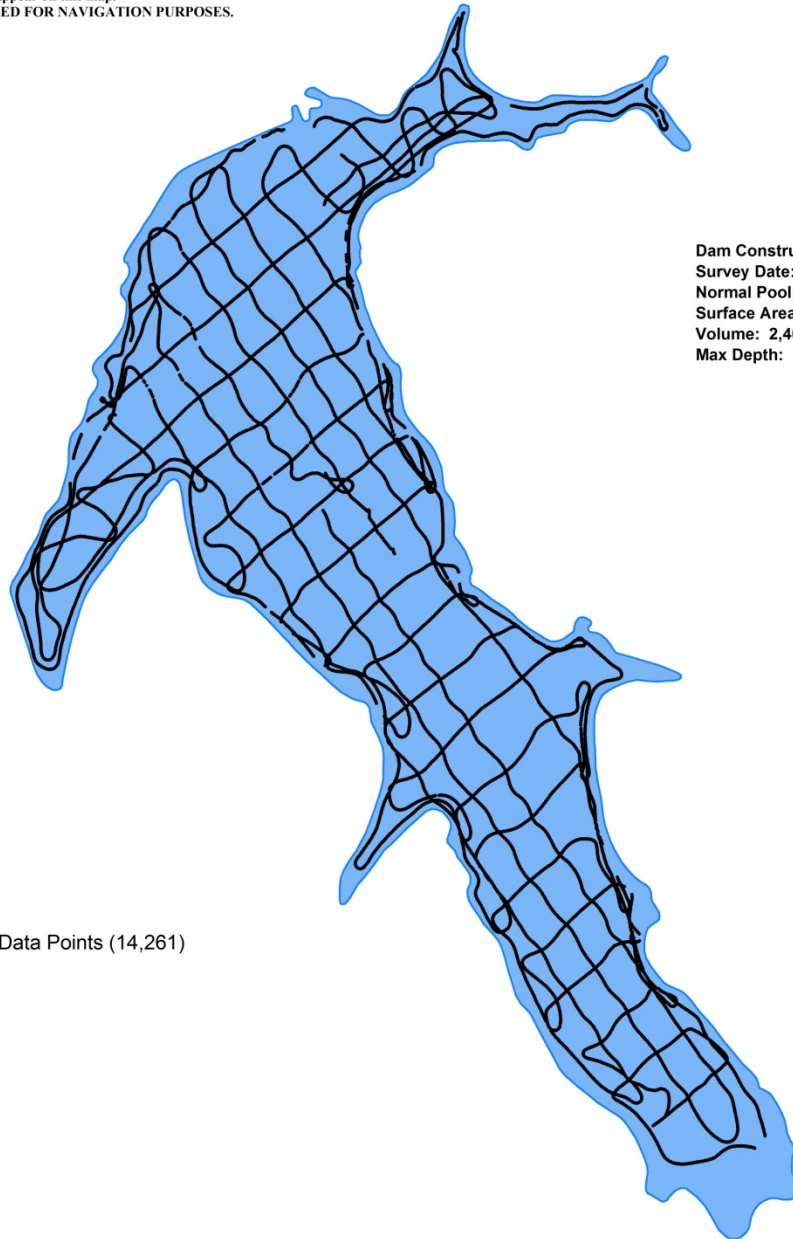
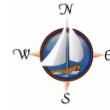


Figure B. 3: Guthrie Lake Collected Data Points.

Guthrie Lake

Collected Data Points

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Dam Construction: 1919
Survey Date: 20100309
Normal Pool: 982 ft
Surface Area: 205 ac
Volume: 2,403 ac-ft
Max Depth: -22.45 ft

- Collected Data Points (14,261)

