Bathymetric and Sediment Survey of Fort Scott Lake, Bourbon County, Kansas

KANSAS BIOLOGICAL SURVEY

Kansas Biological Survey

Applied Science and Technology for Reservoir Assessment (ASTRA) Program

Report 2009-03 (February 2010)

This work was funded by the Kansas Water Office through the State Water Plan Fund in support of the Reservoir Sustainability Initiative.

SUMMARY

On September 17, 2009, the Kansas Biological Survey (KBS) performed a bathymetric survey of Fort Scott Lake in Bourbon County, Kansas. The survey was carried out using acoustic echosounding apparatus linked to a global positioning system. The bathymetric survey was georeferenced to both horizontal and vertical reference datums.

Sediment samples were collected from three sites within the reservoir: One sample was taken near the dam; a second at mid-lake; and a third in the upper end. Sampling was performed on the same day as the bathymetric survey, following completion of the survey. Sediment samples were analyzed for particle size distributions.

Summary Data:

Bathymetric Survey:		
	Date of survey:	September 17, 2009
Reservoir Statistics:		
	Elevation on survey date	861.49 ft
	Area on survey date:	344 acres
	Volume on survey date:	6372 acre-feet
	Maximum depth:	43.7 ft.
Elevation Benchmark (if applicable)		
	UTM location of elevation benchmark:	345014.05, 4183838.2
	UTM Zone:	15N
	UTM datum:	NAD83
	Elevation of benchmark, from GPS:	866.28 ft.
	Vertical datum, all data:	NAVD88
Sediment Survey:		
	Date of sediment survey:	September 17, 2009

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

<u>**LAKE HISTORY AND PERTINENT INFORMATION**</u>

Figure 1. Fort Scott Lake, west of Fort Scott, Kansas.

Fort Scott Lake: Constructed in 1959 and nestled in a lush, heavily wooded, rural setting teeming with wildlife, Fort Scott Lake provides residential living as well as public boat loading ramps for fishermen and water-skiers with restricted areas for all three. Stocked annually with channel cat, walleye, small mouth bass, crappie, muskie and blue gill the lake provides many hours of recreation for anglers. Lakeside campsite areas, shelter houses and picnic areas are available to residents and visitors alike. The lake is the site of annual sailboat regattas for the Fort Scott Sailing Club and serves as a reservoir for city and rural water systems. (text from http://www.fortscott.com/outdoor.php)

Bourbon County, Kansas

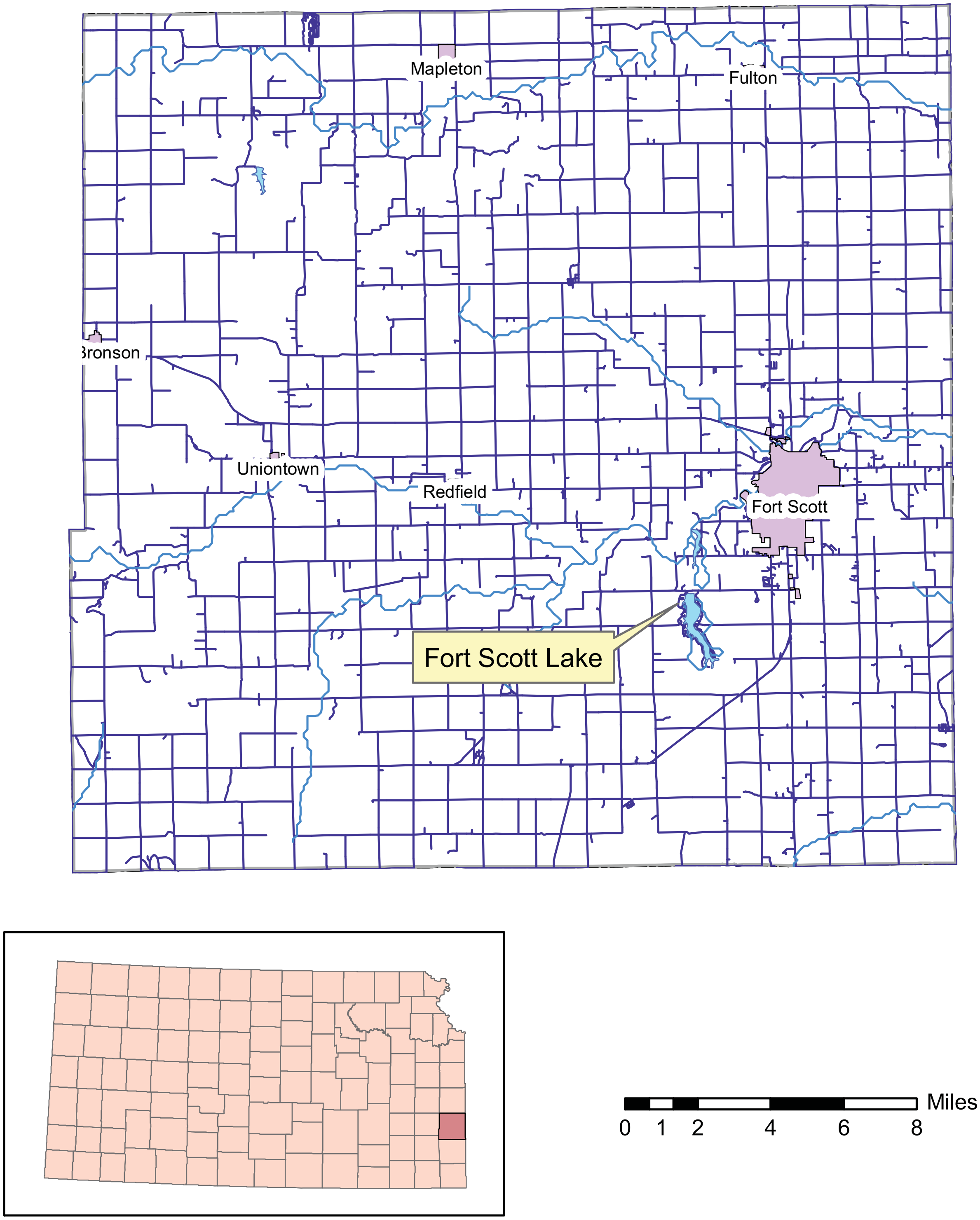

Figure 2. Location of Fort Scott Lake in Bourbon County, Kansas

Reservoir Bathymetric (Depth) Surveying Procedures

KBS operates a Biosonics DT-X echosounding system (www.biosonicsinc.com) with a 200 kHz split-beam transducer and a 38-kHz single-beam transducer. Latitude-longitude information is provided by a global positioning system (GPS) that interfaces with the Biosonics system. ESRI's ArcGIS is used for on-lake navigation and positioning, with GPS data feeds provided by the Biosonics unit through a serial cable. Power is provided to the echosounding unit, command/navigation computer, and auxiliary monitor by means of a inverter and battery backup device that in turn draw power from the 12-volt boat battery.

Pre-survey preparation:

Geospatial reference data: Prior to conducting the survey, geospatial data of the target lake is acquired, including georeferenced National Agricultural Imagery Project (NAIP) photography. The lake boundary is digitized as a polygon shapefile from the FSA NAIP georeferenced aerial photography obtained online from the Data Access and Service Center (DASC). Prior to the lake survey, a series of transect lines are created as a shapefile in ArcGIS for guiding the boat during the survey.

Survey procedures:

Calibration (Temperature and ball check): After boat launch and initialization of the Biosonics system and command computer, system parameters are set in the Biosonics Visual Acquisition software. The temperature of the lake at 1-2 meters is taken with a research-grade metric electronic thermometer. This temperature, in degrees Celsius, is input to the Biosonics Visual Acquisition software to calculate the speed of sound in water at the given temperature at the given depth. Start range, end range, ping duration, and ping interval are also set at this time. A ball check is performed using a tungsten-carbide sphere supplied by Biosonics for this purpose. The ball is lowered to a known distance (1.0 meter) below the transducer faces. The position of the ball in the water column (distance from the transducer face to the ball) is clearly visible on the echogram. The echogram distance is compared to the known distance to assure that parameters are properly set and the system is operating correctly.

On-lake survey procedures: Using the GPS Extension of ArcGIS, the GPS data feed from the GPS receiver via the Biosonics echosounder, and the pre-planned transect pattern, the location of the boat on the lake in real-time is shown on the command/navigation computer screen. The transect pattern is maintained except when modified by obstructions in the lake (e.g., partially submerged trees) or shallow water and mudflats. Data are automatically logged in new files every half-hour (approximately 9000-ping files) by the Biosonics system.

Establishment Of Lake Level On Survey Dates:

State and Local Reservoirs:

Most state and local lakes in Kansas do not have water surface elevation gauges. Therefore, a local benchmark at the edge of a lake is established, typically a concrete pad or wall adjacent to the water. The location of the benchmark is photographed and a description noted. On the day of the survey, the vertical distance between the water surface and the surface of the benchmark is measured. In cases where the benchmark must be established a distance away from the lake, a survey-grade laser level is used to establish the vertical distance between benchmark and water surface.

A TopCon HiPerLite+ survey-grade static global positioning system is used to establish the height of the benchmark. The unit is set at a fixed distance above the benchmark, and the vertical distance between the benchmark and the Antenna Reference Point recorded. The unit is allowed to record data points for a minimum of two hours at a rate of one point every 10 seconds.

Following GPS data acquisition, the data are downloaded at the office from the GPS unit, converted from TopCon proprietary format to RINEX format, and uploaded to the National Geodetic Survey (NGS) On-line Positioning User Service (OPUS). Raw data are processed by OPUS with respect to three NGS CORS (Continuously Operating Reference Stations) locations and results returned to the user.

The elevation of the benchmark is provided in meters as the orthometric height (NAVD88, computed using GEOID03). The vertical difference between the lake surface on the survey day is subtracted from the OPUS-computer orthometric height to produce the lake elevation value, in meters. This lake elevation value is entered as an attribute of the lake perimeter polygon shapefile in postprocessing.

The ASTRA elevation benchmark for Fort Scott Lake is the concrete Dumpster pad adjacent to the boat ramp at the northwest corner of the lake just south of the west end of the dam (Figure 3a, Figure 3b).

The water surface elevation of Fort Scott Lake on September 17, 2009 was 861.49 feet AMSL.

Location of Lake Elevation Benchmark:

Fort Scott Lake: Concrete Dumpster pad immediately south of boat ramp by dam.

UTM (NAD83, Zone 15): Easting (X) [meters] 345014.05, Northing (Y) [meters] 4183838.24

Figure 3a. View south from boat ramp.

Figure 3b. Close-up view. Lake level was measured from the water surface to the top of the concrete pad..

LAKE: Fort Scott Lake
FILE: log0225n.08O 000416322

NGS OPUS SOLUTION REPORT

All computed coordinate accuracies are listed as peak-to-peak values.
For additional information: www.ngs.noaa.gov/OPUS/Using_OPUS.html#accuracy

USER:	mjakub@ku.edu	DATE:	August 19, 2008
RINEX FILE:	log0225n.08o	TIME:	20:31:28 UTC
SOFTWARE:	page5 0612.06 master3.pl	START:	2008/08/12 13:20:00
EPHEMERIS:	igr14922.eph [rapid]	STOP:	2008/08/12 16:13:00
NAV FILE:	brdc2250.08n	OBS USED:	5636 / 5694 : 99%
ANT NAME:	TPSHIPER_PLUS NONE	# FIXED AMB:	24 / 33 : 73%
ARP HEIGHT:	.92	OVERALL RMS:	0.027(m)

REF FRAME:	NAD_83(CORS96)(EPOCH:2002.0000)		ITRF00 (EPOCH:2008.6137)	
X:	-418826.282(m)	0.102(m)	-418826.994(m)	0.102(m)
Y:	-5029605.313(m)	0.047(m)	-5029603.933(m)	0.047(m)
Z:	3887085.015(m)	0.060(m)	3887084.883(m)	0.060(m)
LAT:	37 47 19.57889	0.024(m)	37 47 19.60166	0.024(m)
E LON:	265 14 23.41338	0.105(m)	265 14 23.37970	0.105(m)
W LON:	94 45 36.58662	0.105(m)	94 45 36.62030	0.105(m)
EL HGT:	232.791(m)	0.067(m)	231.670(m)	0.067(m)
ORTHO HGT:	264.043(m)	0.091(m)	[NAVD88 (Computed using GEOID03)]	

	UTM COORDINATES UTM (Zone 15)	STATE PLANE COORDINATES SPC (1502 KS S)
Northing (Y) [meters]	4183838.245	531141.843
Easting (X) [meters]	345014.057	729310.423
Convergence [degrees]	-1.07875833	2.29823500
Point Scale	0.99989586	0.99993844
Combined Factor	0.99985934	0.99990191

US NATIONAL GRID DESIGNATOR: 15SUB4501483838(NAD 83)

BASE STATIONS USED

PID	DESIGNATION	LATITUDE	LONGITUDE	DISTANCE(m)
DJ3671	KST5 TOPEKA 5 CORS ARP	N390240.554	W0960220.776	178626.7
AJ1832	NDS1 NEODESHA (2) CORS ARP	N371805.504	W0953605.332	91937.9
DF9221	ZKC1 KANSAS CTY WAAS 1 CORS ARP	N385248.550	W0944726.964	121179.3

NEAREST NGS PUBLISHED CONTROL POINT

HE1193	SCOTTPORT AZ MK	N374757.749	W0944608.543	1415.2

This position and the above vector components were computed without any knowledge by the National Geodetic Survey regarding the equipment or field operating procedures used.

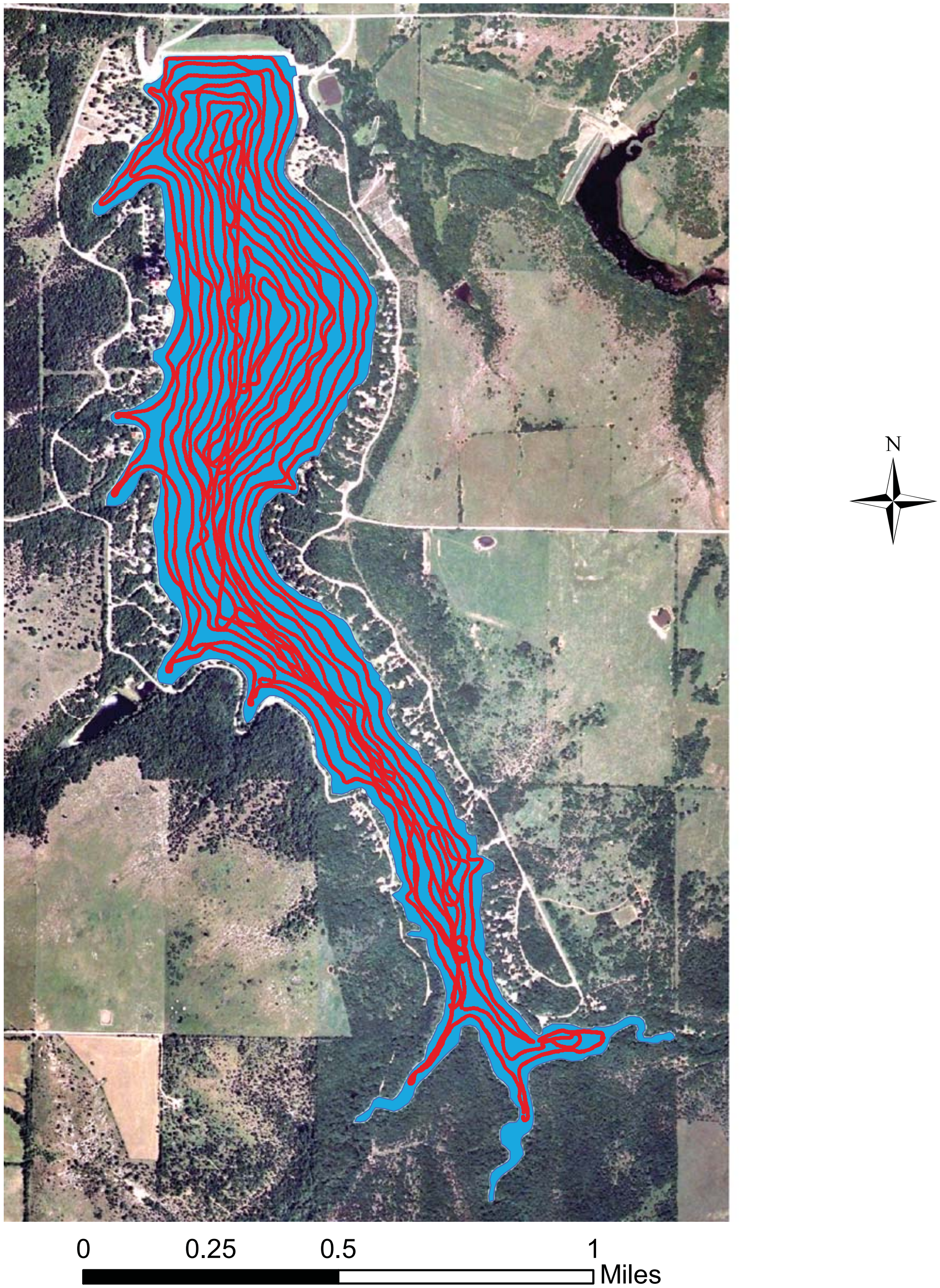

Figure 4. Bathymetric survey transects for Fort Scott Lake, September 17, 2009.

Post-processing *(Visual Bottom Typer)*

The Biosonics DT-X system produces data files in a proprietary DT4 file format containing acoustic and GPS data. To extract the bottom position from the acoustic data, each DT4 file is processed through the Biosonics Visual Bottom Typer (VBT) software. The processing algorithm is described as follows:

> *"The BioSonics, Inc. bottom tracker is an "end_up" algorithm, in that it begins searching for the bottom echo portion of a ping from the last sample toward the first sample. The bottom tracker tracks the bottom echo by isolating the region(s) where the data exceeds a peak threshold for N consecutive samples, then drops below a surface threshold for M samples. Once a bottom echo has been identified , a bottom sampling window is used to find the next echo. The bottom echo is first isolated by user_defined threshold values that indicate (1) the lowest energy to include in the bottom echo (bottom detection threshold) and (2) the lowest energy to start looking for a bottom peak (peak threshold). The bottom detection threshold allows the user to filter out noise caused by a low data acquisition threshold. The peak threshold prevents the algorithm from identifying the small energy echoes (due to fish, sediment or plant life) as a bottom echo."* (Biosonics Visual Bottom Typer User's Manual, Version 1.10, p. 70).

Data is output as a comma-delimited (*.csv) text file. A set number of qualifying pings are averaged to produce a single report (for example, the output for ping 31 {when pings per report is 20} is the average of all values for pings 12-31). Standard analysis procedure for all 2008 and later data is to use the average of 5 pings to produce one output value. All raw *.csv files are merged into one master *.csv file using the shareware program File Append and Split Tool (FAST) by Boxer Software (Ver. 1.0, 2006).

Post-processing (*Excel*)

The master *.csv file created by the FAST utility is imported into Microsoft Excel. Excess header lines are deleted (each input CSV file has its own header), and the header file is edited to change the column headers "#Ping" to "Ping" and "E1' " to "E11", characters that are not ingestable by ArcGIS. Entries with depth values of zero (0) are deleted, as are any entries with depth values less than the start range of the data acquisition parameter (0.49 meters or less) (indicating areas where the water was too shallow to record a depth reading).

In Excel, depth adjustments are made. A new field – Adj_Depth – is created. The value for AdjDepth is calculated as AdjDepth = Depth + (Transducer Face Depth), where the Transducer Face Depth represents the depth of the transducer face below water level in meters (Typically, this value is 0.2 meters; however, if changes were made in the field, the correct level is taken from field notes and applied to the data). Depth in feet is also calculated as DepthFt = Adj_Depth * 3.28084.

These water depths are RELATIVE water depths that can vary from day-to-day based on the elevation of the water surface. In order to normalize all depth measurements to an absolute reference, water depths must be subtracted from an established value for the elevation of the water surface at the time of the bathymetric survey. Determination of water surface elevation has been described in an earlier section on establishment of lake levels.

To set depths relative to lake elevation, two additional fields are added to the attribute table of the point shapefile: LakeElevM, the reference surface elevation (the elevation of the water surface on the day that the aerial photography from which the lake perimeter polygon was digitized)and Elev_Ft, the elevation of the water surface in feet above sea level (Elev_ft), computed by converting ElevM to elevation in feet (ElevM * 3.28084).

Particularly for multi-day surveys, Adj_Depth and Depth_Ft should **NOT** be used for further analysis or interpolation. If water depth is desired, it should be produced by subtracting Elev_M or Elev_Ft from the reference elevation used for interpolation purposes (for federal reservoirs, the elevation of the water surface on the day that the aerial photography from which the lake perimeter polygon was digitized).

Post-processing *(ArcGIS):*

Ingest to ArcGIS is accomplished by using the Tools – Add XY Data option. The projection information is specified at this time (WGS84). Point files are displayed as Event files, and are then exported as a shapefile (filename convention: ALLPOINTS_WGS84.shp). The pointfile is then reprojected to the UTM coordinate system of the appropriate zone (14 or 15) (filename convention ALLPOINTS_UTM.shp).

Raster interpolation of the point data is performed using the same input data and the Topo to Raster option within the 3D Extension of ArcGIS. The elevation of the reservoir on the date of aerial photography used to create the perimeter/shoreline shapefile was used as the water surface elevation in all interpolations from point data to raster data.

Contour line files are derived from the raster interpolation files using the ArcGIS command under 3D Analyst – Raster Surface – Contour.

Area-elevation-volume tables are derived using an ArcGIS extension custom written for and available from the ASTRA Program. Summarized, the extension calculates the area and volume of the reservoir at 1/10-foot elevation increments from the raster data for a series of water surfaces beginning at the lowest elevation recorded and progressing upward in 1/10-foot elevation increments to the reference water surface. Cumulative volume is also computed in acre-feet.

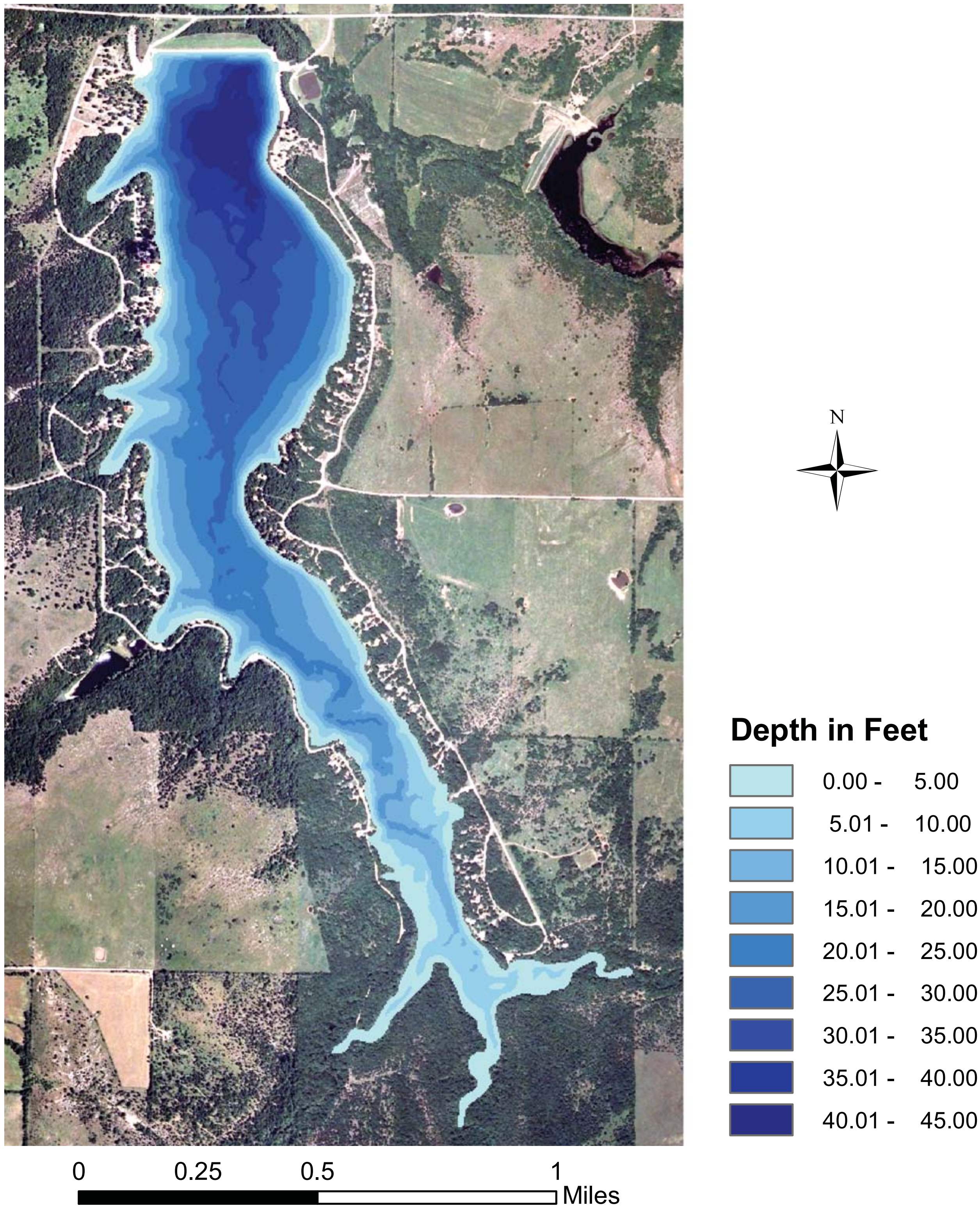

Figure 5. Water depth based on September 17, 2009 bathymetric survey.for Fort Scott Lake. Depths are based on a pool elevation of 861.49 feet.

Table 1

Cumulative area in acres by tenth foot elevation increments

Elevation (ft NGVD)	0.00	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90
817	0	0	0	0	1	1	1	1	1	2
818	2	2	3	3	3	3	4	4	4	4
819	5	5	5	6	6	7	8	8	9	9
820	9	10	10	10	11	11	12	12	12	13
821	13	14	14	14	15	15	15	15	16	16
822	16	16	17	17	17	17	17	18	18	18
823	18	19	19	19	20	20	20	20	21	21
824	21	22	22	22	22	23	23	23	24	24
825	24	25	25	25	26	26	26	27	27	27
826	28	28	28	29	29	30	30	30	31	31
827	31	32	32	33	33	33	34	34	34	35
828	35	35	36	36	37	37	38	38	39	39
829	40	40	41	41	42	43	43	44	45	45
830	46	47	48	49	49	50	51	52	53	53
831	54	55	56	57	58	59	60	61	62	63
832	64	65	66	67	68	69	70	71	71	72
833	73	74	75	76	76	77	78	79	80	81
834	82	83	84	85	86	87	88	88	89	90
835	91	92	93	93	94	95	96	97	98	99
836	100	101	102	103	103	104	105	106	107	107
837	108	109	110	111	112	113	114	115	116	117
838	118	119	120	121	122	123	124	125	126	127
839	128	129	131	132	133	134	135	136	137	138
840	139	140	141	142	143	144	145	146	147	148
841	149	150	151	152	153	154	155	156	157	158
842	158	159	160	161	162	163	164	165	166	166
843	167	168	169	170	171	172	173	173	174	175
844	176	177	178	179	180	181	182	183	184	185
845	186	187	188	189	190	191	192	194	195	196
846	197	198	199	200	201	202	203	204	205	206
847	207	208	209	210	211	212	213	214	215	216
848	217	218	219	220	221	222	223	224	225	226
849	227	227	228	229	230	231	232	233	233	234
850	235	236	237	238	239	239	240	241	242	243
851	244	245	245	246	247	248	249	250	251	252
852	253	254	255	256	257	257	258	259	260	261
853	262	263	264	265	266	267	268	269	270	271
854	272	273	274	275	276	277	278	279	279	280
855	281	282	283	284	285	286	287	288	289	290
856	291	292	293	294	294	295	296	297	298	299
857	301	302	303	304	305	306	307	308	309	310
858	311	312	312	313	314	315	316	317	318	319
859	319	320	321	322	323	324	325	325	326	327
860	328	329	330	331	332	333	334	335	336	337
861	338	339	340	341	342	344				

Table 2

Cumulative volume in acre-feet by tenth foot elevation increments

Elevation (ft NGVD)	0.00	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90
817	0	0	0	0	0	0	0	0	1	1
818	1	1	1	2	2	2	2	3	3	4
819	4	5	5	6	6	7	8	8	9	10
820	11	12	13	14	15	16	17	18	20	21
821	22	24	25	26	28	29	31	32	34	35
822	37	39	40	42	44	45	47	49	51	52
823	54	56	58	60	62	64	66	68	70	72
824	74	76	78	81	83	85	87	90	92	94
825	97	99	102	104	107	109	112	115	117	120
826	123	126	128	131	134	137	140	143	146	149
827	152	156	159	162	165	169	172	175	179	182
828	186	189	193	196	200	204	208	211	215	219
829	223	227	231	235	239	243	248	252	257	261
830	266	270	275	280	285	290	295	300	305	311
831	316	321	327	333	338	344	350	356	362	369
832	375	381	388	394	401	408	415	422	429	436
833	444	451	458	466	473	481	489	497	505	513
834	521	529	538	546	555	563	572	581	590	599
835	608	617	626	635	645	654	664	673	683	693
836	703	713	723	734	744	754	765	775	786	797
837	807	818	829	840	851	863	874	885	897	909
838	920	932	944	956	968	981	993	1005	1018	1031
839	1043	1056	1069	1082	1096	1109	1123	1136	1150	1164
840	1177	1191	1205	1220	1234	1248	1263	1277	1292	1307
841	1322	1337	1352	1367	1382	1398	1413	1429	1444	1460
842	1476	1492	1508	1524	1540	1556	1572	1589	1605	1622
843	1639	1655	1672	1689	1706	1724	1741	1758	1775	1793
844	1811	1828	1846	1864	1882	1900	1918	1936	1955	1973
845	1992	2010	2029	2048	2067	2086	2105	2124	2144	2163
846	2183	2203	2223	2243	2263	2283	2303	2324	2344	2365
847	2385	2406	2427	2448	2469	2490	2512	2533	2555	2576
848	2598	2620	2641	2663	2685	2707	2730	2752	2774	2797
849	2820	2842	2865	2888	2911	2934	2957	2980	3004	3027
850	3051	3074	3098	3122	3145	3169	3193	3217	3242	3266
851	3290	3315	3339	3364	3388	3413	3438	3463	3488	3513
852	3539	3564	3589	3615	3641	3666	3692	3718	3744	3770
853	3796	3822	3849	3875	3902	3929	3955	3982	4009	4036
854	4063	4091	4118	4146	4173	4201	4228	4256	4284	4312
855	4340	4369	4397	4425	4454	4482	4511	4540	4568	4597
856	4626	4656	4685	4714	4743	4773	4803	4832	4862	4892
857	4922	4952	4982	5013	5043	5074	5104	5135	5166	5197
858	5228	5259	5290	5321	5353	5384	5416	5448	5479	5511
859	5543	5575	5607	5640	5672	5704	5737	5769	5802	5835
860	5867	5900	5933	5966	5999	6033	6066	6100	6133	6167
861	6201	6235	6269	6303	6337	6372				

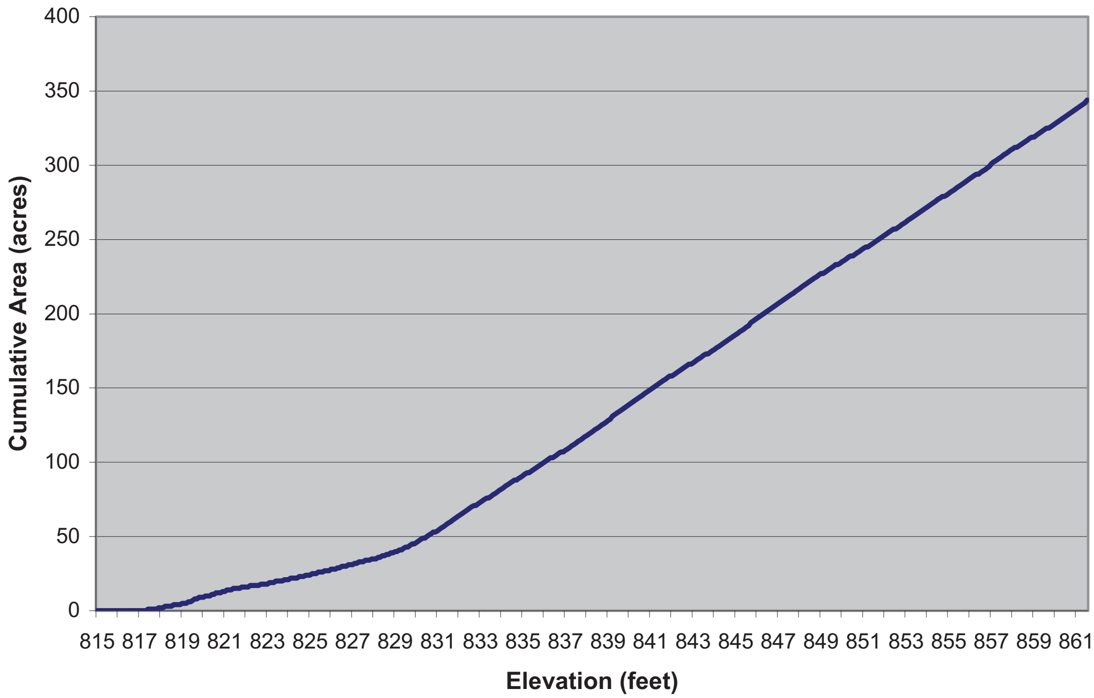

Figure 6. Cumulative area-elevation curve

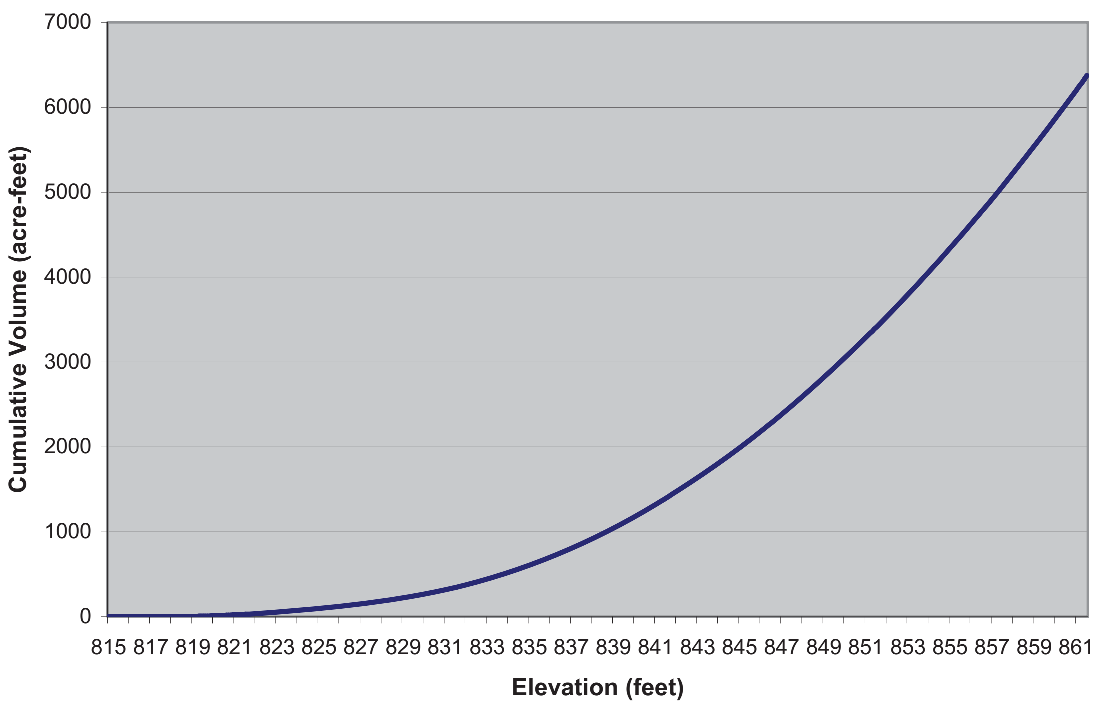

Figure 7. Cumulative volume-elevation curve

SEDIMENT SAMPLING PROCEDURES

Sediment samples were collected from three sites within the reservoir using a Wildco drop-corer (Wildlife Supply Company, Buffalo, NY). One sample is taken near the dam; a second at mid-lake; and a third in the upper end/transitional area. Sampling was performed on the same day as the bathymetric survey, following completion of the survey. As the drop-corer samples only the upper sediment, the entire sample in each case was collected and sealed in a sampling container. The samples were then shipped to the Kansas State University Soil Testing Laboratory (Manhattan, KS), for texture analysis. No bulk density sampling or analysis was performed for Fort Scott Lake.

SEDIMENT SAMPLING RESULTS:

Sampling sites were distributed across the length of the reservoir (Figure 8). Silt percentages decreased from 72% at the inflow end (FSL-1) to 32% near the dam (FSL-3). Conversely, the clay fraction increased from the inflow end to the dam, while sand constituted a minor or non-existent fraction in all three samples (Table 3; Figure 9; Figure 10).

Table 3
Fort Scott Lake Sediment Sampling Site Data

CODE	UTMX	UTMY	%Sand	% Silt	% Clay
FSL-1	345953.9	4180954.3	0	72	28
FSL-2	345256.7	4182130.2	4	38	58
FSL-3	345270.4	4183620.3	0	32	68

Coordinates are Universal Transverse Mercator (UTM), NAD83, Zone 15 North

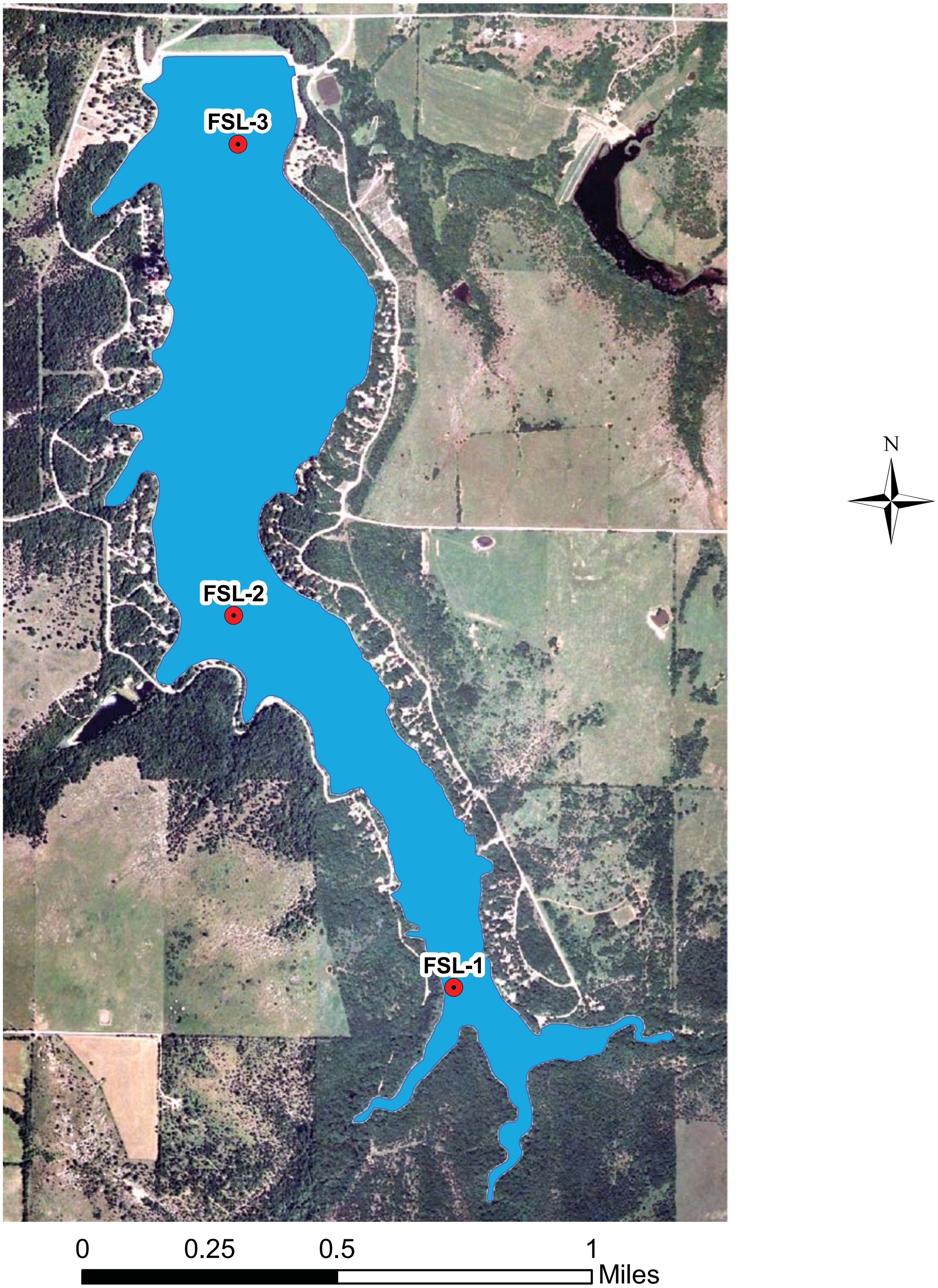

Figure 8. Location of sediment samples in Fort Scott Lake.

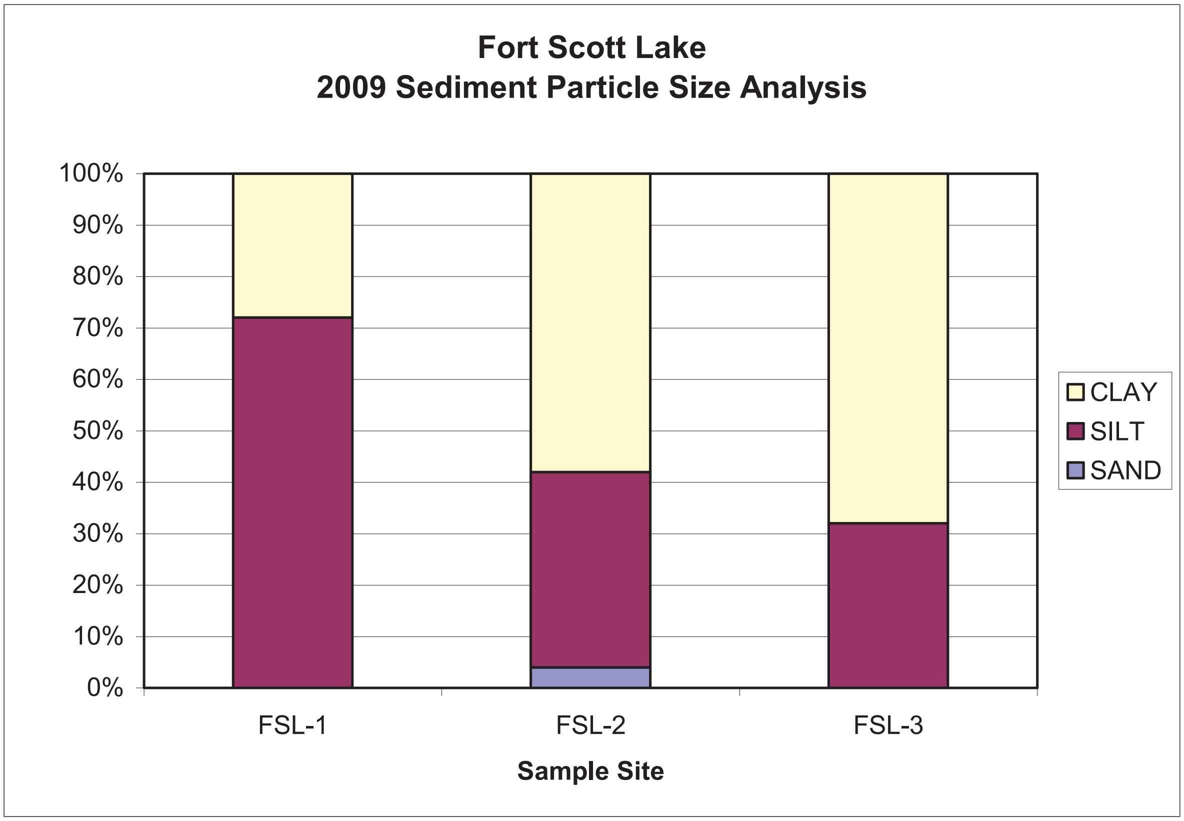

Figure 9. Sediment particle size analysis.

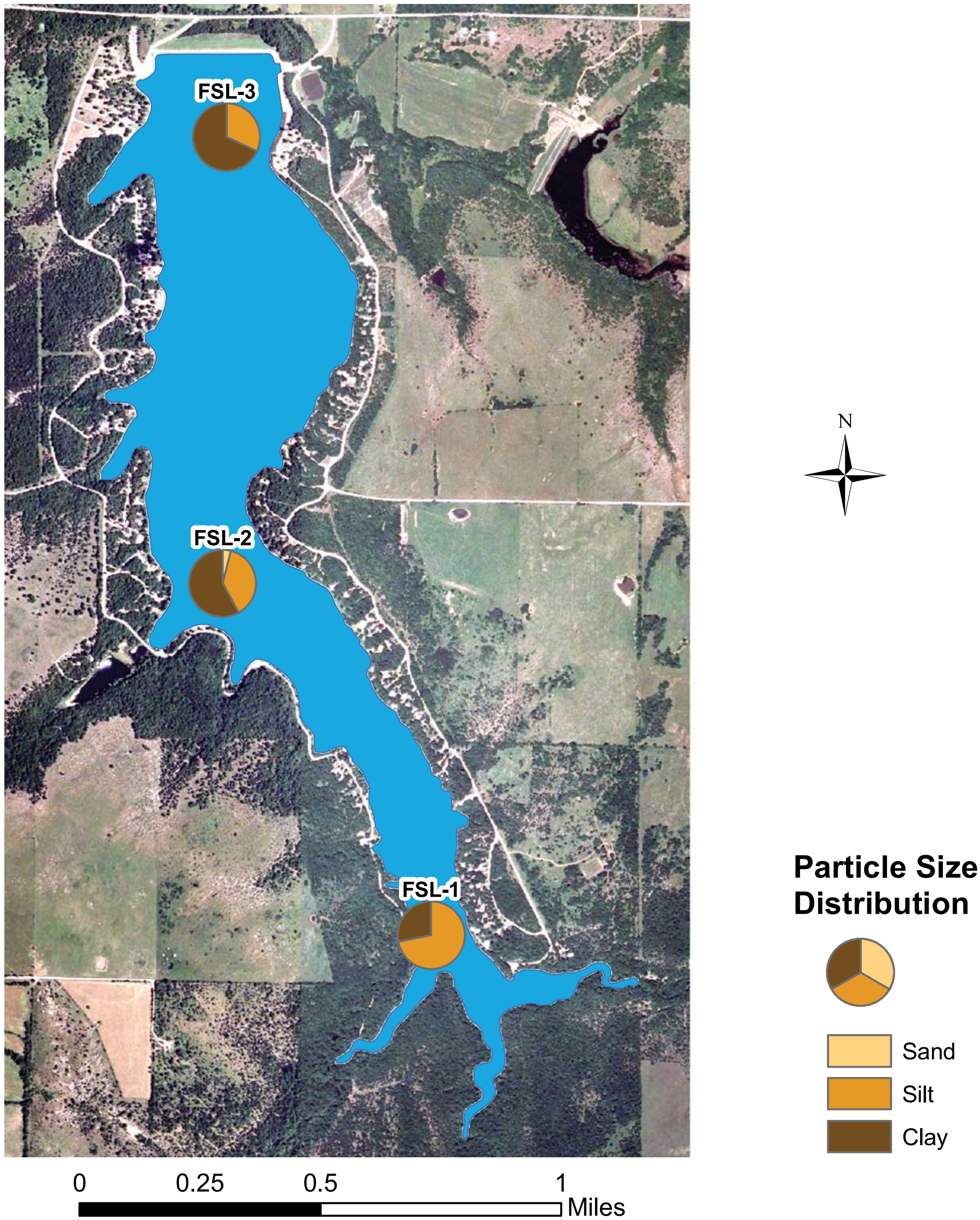

Figure 10. Particle size distribution of sediment samples in Fort Scott Lake.