VOLUMETRIC SURVEY OF LAKE GLADEWATER

Prepared for:

City of Gladewater

Prepared by
Texas Water Development Board

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Texas Water Development Board

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INTRODUCTION

Staff of the Surface Water Section of the Texas Water Development Board (TWDB) conducted a volumetric survey of Lake Gladewater on February 29, 2000. The primary purpose of this survey was to determine the current volume of the lake at conservation pool elevation. Results from this survey will serve as a basis for comparison to future surveys to allow the location and rates of sediment deposition to be determined. Survey results are presented in the following pages in both graphical and tabular form.

Historically, two datums have been used in the engineering drawings and reports for Lake Gladewater. The first datum, used in publication TWDB (1974), is referred to as mean sea level. Elevations are given as "elevation above msl", where msl is defined in the publication as the mean sea level of 1929 measured at Galveston. Engineering drawings in TWDB (1974) show the elevation of the service spillway, which is used in this report to define the elevation of the top of the conservation pool, to be 300.0 feet msl. The United States Geological Survey (USGS) maintains a reservoir elevation gage at Lake Gladewater, (08019900 LAKE GLADEWATER NR GLADEWATER, TX) that is also referenced closely to msl datum. Data collected during this survey, and volume and area calculations resulting from these measurements, were referenced to water levels provided by this USGS gage. As a footnote, at some point following the completion of this report, the USGS plans to re-establish the gage datum. The second datum, used in the USGS 7.5-minute quadrangle map (Gladewater, Tex., 1960), is the 1927 North American datum, and is also referred to as mean sea level. This map shows the elevation of the service spillway to be 301.0 feet. It is assumed that the elevations provided by both TWDB (1974) and the USGS 7.5-minute quadrangle map for the service spillway are equivalent.

TWDB (1974) shows the surface area to be 800 acres with a storage volume of 6,950 acre-feet. This report will compare the 2000 survey results with these original design plans.

LAKE HISTORY AND GENERAL INFORMATION

Historical information on Lake Gladewater was obtained from TWDB (1966) and TWDB (1974). The City of Gladewater owns the water rights to Lake Gladewater. The City also owns, operates and maintains associated Gladewater Dam. The lake is located on Glade Creek (Sabine River Basin) in Upshur County, in the northwest quadrant of the city limits of Gladewater, Texas (Figure 1). Records indicate the drainage area is approximately 35 square miles. At conservation pool elevation, the lake has approximately 11.9 miles of shoreline and is 3.6 miles long. The widest point of the lake is approximately 0.35 miles and is located about 0.5 miles upstream of the dam.

The Board of Water Engineers issued Water Rights Permit No. 1587 (Application No. 1710) to the City of Gladewater on August 30, 1951. The permit authorized the city to construct a dam on Glade Creek in Upshur County and to impound 6,950 acre-feet of water. Permission was granted to use up to 1,679 acre-feet of water annually for municipal and recreational purposes. The Texas Water Commission issued Certificate of Adjudication No. 05-4762 on December 31, 1986. The certificate basically re-authorizes the impoundment and uses as stated in Permit No. 1587, i.e. it authorizes the City of Gladewater to maintain an existing dam and lake on Glade Creek known as Gladewater Dam and Lake Gladewater and to impound not to exceed 6,950 acre-feet of water.

Construction for Lake Gladewater and Gladewater Dam started on October 15, 1951. The dam was completed and impoundment began on August 29, 1952. The design engineer for the project was Otto Staerker and Joe E. Ward. The general contractor was E. E. Contractor Co., from South Houston, Texas. The estimated cost of the dam was $137,000.00.

Engineering designs (TWDB, 1974) show Gladewater Dam and appurtenant structures to consist of a rolled-earth embankment approximately 1,203 feet in length, with a maximum height of 48 feet and a crest elevation of 312.0 feet msl. The service spillway is an uncontrolled concrete structure with a crest length of 200 feet at elevation 300.00 feet msl and is located immediately to the west of the embankment. The emergency spillway is located adjacent to and west of the service spillway. The emergency spillway is also a concrete structure with a crest length of 200 feet at elevation 304.0 feet msl. The outlet works consist of a vertical concrete structure located near the east end of the embankment. The structure consists of several openings at various elevations and controlled by slide gates. The invert elevation for the lowest gated outlet is 282.0 feet msl. Control valves for the gates are located at the top of the structure. Discharges flow into a 24-inch diameter concrete pipe that is 168 feet in length through the embankment to the downstream toe of the dam. An outlet from this pipe connects to the City of Gladewater filtration plant via pumps. The water from the lake is treated and is used for the city's municipal water supply.

VOLUMETRIC SURVEYING TECHNOLOGY

The equipment used to perform the volumetric survey consists of a 20-foot aluminum flat bottom SeaArk craft with cabin equipped with one 115-Horsepower Evinrude outboard motor. The surveying equipment included a Knudsen 320 B/P Echosounder (depth sounder), Trimble Navigation, Inc. 4000SE GPS receiver, an OmniSTAR receiver, and a 486 laptop computer. (Reference to brand names throughout this report does not imply endorsement by TWDB).

The GPS equipment, survey vessel, and depth sounder in combination provide an efficient hydrographic survey system. As the boat travels across the lake surface, the depth sounder takes approximately ten readings of the lake bottom each second. The depth readings are stored on the laptop computer along with the corrected positional data generated by the boat's GPS receiver. The daily data files collected are downloaded from the computer and brought to the office for editing after the survey is completed. During editing, poor-quality data is removed or corrected, multiple data points are averaged to get one data point per second, and average depths are converted to elevation readings based on the lake elevation recorded on the day the survey was performed. Accurate estimates of the lake volume can be quickly determined by building a 3-D model of the lake from the collected data.

PRE-SURVEY PROCEDURES

The reservoir's boundary was digitized using Environmental Systems Research Institute’s (ESRI) Arcview from digital orthophoto quadrangle images (DOQ’s). The DOQ's were produced by VARGIS of Texas LLC for the TEXAS Orthoimagery Program (TOP). The DOQ products produced for the Department of Information Resources and the GIS Planning Council under the Texas Orthoimagery Program reside in the public domain. More information can be obtained on the Internet at http://www.tnris.state.tx.us/DigitalData/doqs.htm. The map work was created from the Gladewater, Texas DOQ. The graphic boundary file was transformed from UTM Zone 15 datum to NAD '83, using Environmental Systems Research Institute’s (ESRI) Arc/Info PROJECT command with the NADCOM (standard conversion method within the United States) parameters.

Although the lake elevation at the time the DOQ was photographed is unknown, it was overlayed on the boundary shown in the USGS 7.5-minute quadrangle map, Gladewater, TX (1960). The two boundaries closely coincided. As stated earlier, the elevation of the service spillway, which defines the conservation pool elevation, shown on the USGS quad map (301.0 feet North American Datum 1927) is assumed to coincide with the elevation shown on engineering designs in TWDB, 1974 (300.0 feet msl).

The survey layout was designed by placing survey track lines at 500-foot intervals within the digitized lake boundary using HyPack software. The survey design required the use of approximately 45 survey lines along the length of the lake.

SURVEY PROCEDURES

Equipment Calibration and Operation

At the beginning of the survey, the depth sounder was calibrated using the bar check feature in the Knudsen software program. This was accomplished by positioning the transducer over a known (measured) depth. The speed of sound was then adjusted (either higher or lower) until the depths displayed matched the known depth. The depth was then checked manually with a stadia (survey) rod to ensure that the depth sounder was properly calibrated and operating correctly. During the survey of Lake Gladewater, the speed of sound in the water column was 4,859 feet per second. Based on the measured speed of sound for various depths and the average speed of sound calculated for the entire water column, the depth sounder is accurate to within $\pm$0.2 feet. An additional estimated error of $\pm$0.3 feet arises from variation in boat inclination. These two factors combine to give an overall accuracy of $\pm$0.5 feet for any instantaneous reading. These errors tend to be minimized over the entire survey, since some readings are positive and some are negative. Further information on these calculations is presented in Appendix E.

During the survey, the horizontal mask setting on the on-board GPS receiver was set to 10°, and the PDOP (Position Dilution of Precision) limit was set to 7 to maximize the accuracy of the horizontal positioning. An internal alarm sounds if PDOP rises above seven to advise the field crew that the horizontal position has degraded to an unacceptable level. The lake's initialization file used by the Hypack data collection program was set up to convert the collected DGPS positions on-the-fly to state-plane coordinates.

Field Survey

TWDB staff collected data at Lake Gladewater on February 29, 2000. The lake was barely spilling (less than 0.1 feet) over the service spillway during the survey. The USGS reservoir gage reading at the time was 299.9 feet, or within 0.1 feet of the elevation given by TWDB (1974) for the service spillway. Weather conditions for that day at Lake Gladewater were warm temperatures with mild winds. The survey crew was able to collect data on all 45 pre-plotted survey transects in the lake. Random data was collected along the shoreline and in those areas that were too restricted to drive the pre-plotted lines. Approximately 14,817 data points were collected over the 52 miles traveled. These points, shown in Figure 2, were stored digitally on the boat's computer in 62 data files. Data were not collected in areas with significant obstructions unless these areas represented a large amount of water.

Glade Creek flows in a north to south direction with Gladewater Dam being located at the south end of the lake basin. Tributaries that contribute to the west of Lake Gladewater include Sand Spring and Mitchell Branch. Those tributaries that drain into the lake on the east shoreline include McKinley and McCoy Branch and Gum Creek. The survey crew was unable to collect much data in these tributaries due to the shallow depths. TWDB staff observed the terrain surrounding the lake to have the typical characteristics of east Texas rolling hills. Red sandy soil was observed along the shoreline in the main basin of the lake. No major bank erosion was noted. Residential developed surrounded the majority of the lake. There was still some undeveloped property in the upper reaches of the lake. The City of Gladewater established a park on the southwest shoreline near Gladewater Dam.

While performing the survey the field crew noted on the depth sounder chart that the bathymetry or contour of the lake bottom was fairly regular (meaning no major drops or rises in the bathymetry) in the main basin of the lake. Shallower depths were noted along the shoreline and deeper depths were observed when the boat crossed the old channel. The bathymetry of the lake bottom was similar to the topography surrounding the lake. A defined channel (thalweg) for Glade Creek was still evident in the main basin of the lake.

As the field crew collected data in the upper reaches of Lake Gladewater, navigational hazards such as submerged stumps were encountered. Data was collected in this area but at a much slower rate. Data collection was halted when depths in the upper reaches of the lake became less than one and one-half feet.

The collected data were stored in individual data files for each pre-plotted range line or random data collection event. These files were downloaded to diskettes at the end of the day for subsequent processing.

Data Processing

The collected data were downloaded from diskettes onto TWDB's computer network. Tape backups were made for future reference as needed. To process the data, the EDIT routine in the Hypack Program was run on each raw data file. Data points such as depth spikes or data with missing depth or positional information were deleted from the file. A correction for the lake elevation at the time of data collection was also applied to each file during the EDIT routine. During the survey, the water surface remained steady at elevation 299.9 feet msl according to elevation data provided by USGS elevation gage 08019900 LAKE GLADEWATER NR GLADEWATER, TX. After all corrections were applied to the raw data file, the edited file was saved with a different extension. The edited files were combined into a single (x,y,z) data file, to be used with the GIS software to develop a model of the lake's bottom surface.

The resulting data file was downloaded to a Sun Sparc 20 workstation running the UNIX operating system. Environmental System Research Institute's (ESRI) Arc/Info GIS software was used to convert the data to a MASS points file. The MASS points and the boundary file were then used to create a Digital Terrain Model (DTM) of the lake's bottom surface using Arc/Info's TIN software module. The module generates a triangulated irregular network (TIN) from the data points and the boundary file using a method known as Delauney's criteria for triangulation. A triangle is formed between three non-uniformly spaced points, including all points along the boundary. If there is another point within the triangle, additional triangles are created until all points lie on the vertex of a triangle. All of the data points are used in this method. The generated network of three-dimensional triangular planes represents the actual bottom surface. With this representation of the bottom, the software then calculates elevations along the triangle surface plane by determining the elevation along each leg of the triangle. The lake area and volume can be determined from the triangulated irregular network created using this method of interpolation.

Volumes presented in Appendix A were calculated from the TIN using Arc/Info software. Surface areas presented in Appendix B were computed using Arc/Info software below elevation 300.0 feet msl.

Other products developed from the model include a shaded elevation range map (Figure 3) and a shaded depth range map (Figure 4). To develop these maps, the TIN was converted to a lattice using the TINLATTICE command and then to a polygon coverage using the LATTICEPOLY command. Linear filtration algorithms were applied to the DTM to produce smooth cartographic contours. The resulting elevation contour map of the bottom surface at two-foot intervals is presented in Figure 5.

RESULTS

Results from the 2000 TWDB survey indicate Lake Gladewater encompasses 481 surface acres and contains a total volume of 4,738 acre-feet at the conservation pool elevation of 300.0 feet msl (gage datum). Dead pool storage, the volume below the invert elevation of the low-flow outlet pipe at 282.0 feet msl, is 101 acre-feet. Thus, the conservation storage (total volume - dead storage) for Lake Gladewater is 4,637 acre-feet. The shoreline at conservation pool elevation was calculated to be approximately 11.9 miles. The deepest point of the lake, at elevation 272 feet msl and corresponding to a depth of 28 feet, was located approximately 991 feet upstream from the center of Gladewater Dam.

SUMMARY AND COMPARISONS

Lake Gladewater was initially impounded in 1952. Storage calculations in 1951 (TWDB, 1974) reported the volume at conservation pool elevation 300.0 feet msl to be 6,950 acre-feet with a surface area of 800 acres. The dead pool below elevation 282.0 feet msl was was reported as 500 acre-feet, and thus the conservation storage was 6,450 acre-feet.

On February 29, 2000, TWDB staff completed a volumetric survey of Lake Gladewater. The 2000 survey utilized differential global positioning system and geographical information system technology to create a digital model of the lake's bathymetry. The survey was completed more quickly and significantly more bathymetric data were collected than in previous surveys. Results indicate that the lake's volume at the conservation pool elevation of 300.0 feet msl is 4,738 acre-feet, with a corresponding area of 481 acres. The dead pool below elevation 282.0 feet was found to be 101 acre-feet, and thus the conservation storage found in this survey is 4,637 acre-feet.

Comparing the findings from the original design and the current survey, the surface area at conservation pool elevation 300.0 feet msl decreased by 319 surface acres. The reduction in volume at conservation pool elevation is 2,212 acre-feet (-31.8%) or 45 acre-feet/year (since 1951). The average annual deposition rate of sediment in the lake can be estimated at 1.3 acre-feet/square mile of drainage area.

Based on the amount of data collected and the improved methods and technology used in the current survey, the current data set is considered to be an improvement over previous survey procedures. It is recommended that the same methodology be used in five to ten years or after major flood events to monitor changes to the lake's storage volume.

REFERENCES

1. Texas Water Development Board. 1966. Dams and Lakes in Texas, Historical and Descriptive Information. Report 48.

2. Texas Water Development Board. 1974. Engineering Data on Dams and Lakes in Texas. Part I. Report 126.

Appendix A

Lake Gladewater

RESERVOIR VOLUME TABLE

TEXAS WATER DEVELOPMENT BOARD — FEBRUARY 2000 SURVEY

VOLUME IN ACRE-FEET — ELEVATION INCREMENT IS ONE TENTH FOOT

ELEVATION IN FEET	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
272	0	0	0	0	0	0	0	0	0	0
273	0	0	0	0	0	0	0	0	0	0
274	0	0	0	0	0	0	0	0	0	0
275	0	0	0	1	1	1	1	1	1	1
276	1	1	2	2	2	3	3	3	4	4
277	5	5	6	6	7	8	8	9	10	11
278	12	13	14	15	16	17	18	19	21	22
279	23	25	26	28	29	31	33	34	36	38
280	40	42	44	46	49	51	53	56	59	61
281	64	67	71	74	77	81	85	89	92	96
282	101	105	109	114	118	123	128	133	139	144
283	150	156	162	168	174	181	188	195	202	210
284	218	226	234	242	251	260	269	278	287	297
285	307	317	327	337	348	358	369	381	392	404
286	417	429	442	455	468	482	496	510	524	539
287	554	569	584	599	615	631	648	664	681	699
288	716	734	752	770	789	807	826	846	865	885
289	905	925	946	966	987	1009	1030	1052	1074	1096
290	1119	1141	1164	1187	1211	1234	1258	1282	1306	1330
291	1355	1380	1405	1430	1456	1481	1507	1534	1560	1587
292	1614	1642	1669	1697	1726	1754	1783	1812	1842	1872
293	1902	1933	1964	1995	2027	2059	2092	2125	2159	2193
294	2227	2262	2296	2332	2367	2403	2439	2475	2512	2549
295	2586	2624	2662	2700	2739	2778	2817	2857	2896	2936
296	2976	3016	3057	3098	3138	3180	3221	3262	3304	3346
297	3389	3431	3474	3517	3560	3604	3647	3691	3735	3779
298	3823	3867	3911	3956	4001	4046	4091	4136	4181	4227
299	4273	4318	4364	4411	4457	4503	4550	4597	4644	4691
300	4738									

Appendix B

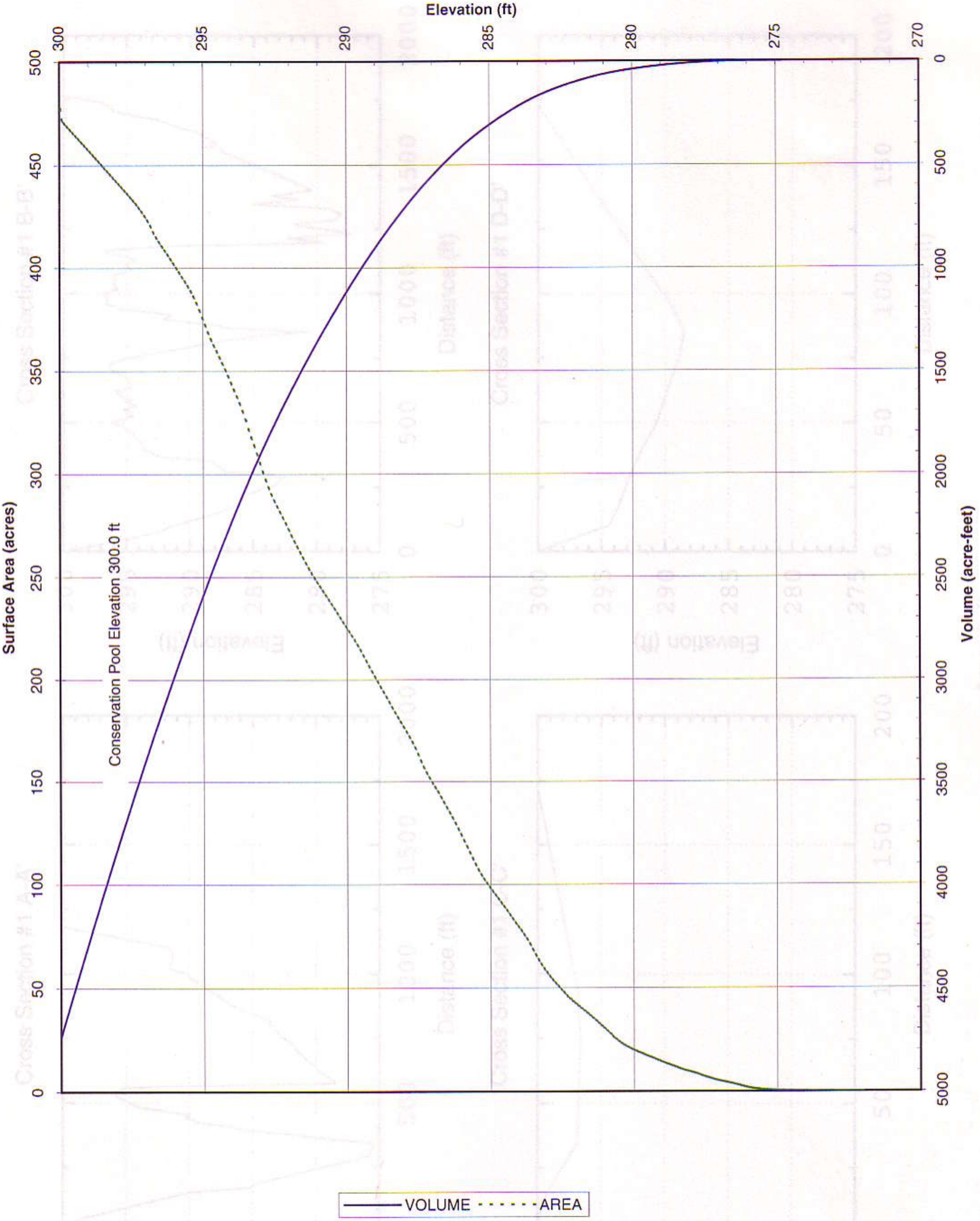
Lake Gladewater

RESERVOIR AREA TABLE

TEXAS WATER DEVELOPMENT BOARD — FEBRUARY 2000 SURVEY

AREA IN ACRES — ELEVATION INCREMENT IS ONE TENTH FOOT

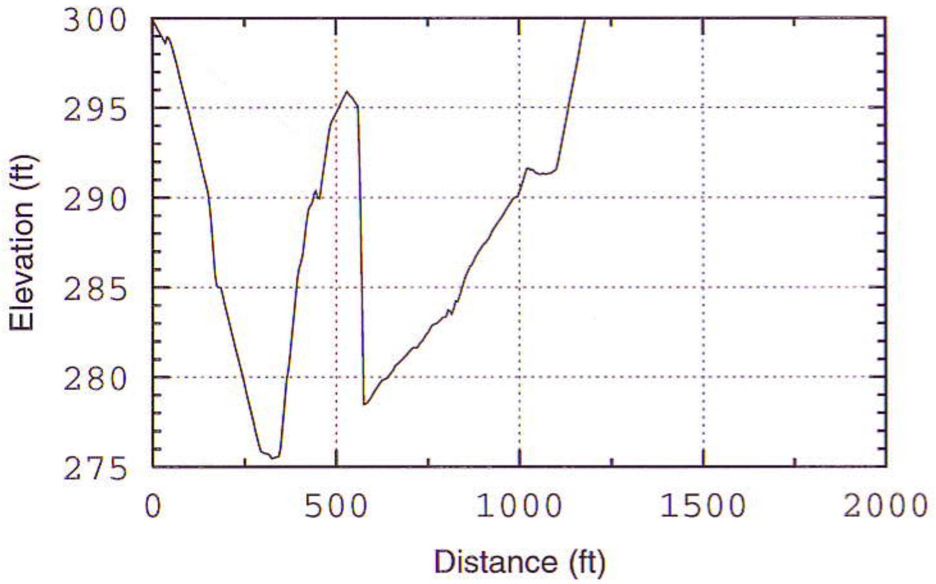
ELEVATION IN FEET	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
272	0	0	0	0	0	0	0	0	0	0
273	0	0	0	0	0	0	0	0	0	0
274	0	0	0	0	0	0	0	0	0	0
275	0	1	1	1	1	1	1	1	1	1
276	2	2	2	3	3	3	4	4	4	5
277	5	5	6	6	7	7	7	8	8	9
278	9	10	10	10	11	11	12	13	13	14
279	14	15	15	16	16	17	17	18	19	19
280	20	21	21	22	23	24	25	26	27	29
281	30	31	33	34	35	36	38	39	40	41
282	42	43	44	46	48	49	50	52	54	55
283	57	59	61	63	66	68	71	73	75	77
284	79	81	83	85	87	89	91	93	94	96
285	98	100	102	104	107	109	112	115	118	121
286	124	126	129	132	135	137	140	142	145	147
287	149	151	154	157	160	163	166	169	171	174
288	176	179	181	183	186	189	191	194	196	199
289	201	204	206	209	211	214	217	219	221	223
290	226	228	230	232	234	237	239	241	243	245
291	247	249	251	254	256	259	262	264	267	270
292	273	276	278	281	284	287	290	293	297	301
293	305	309	313	317	321	326	330	334	337	340
294	344	347	350	353	356	359	362	365	368	372
295	375	379	382	386	388	391	393	395	397	400
296	402	404	406	408	410	412	414	417	420	423
297	425	427	429	431	432	434	436	437	439	441
298	442	444	445	447	448	450	451	453	455	456
299	458	459	461	462	464	465	467	468	470	472
300	481									



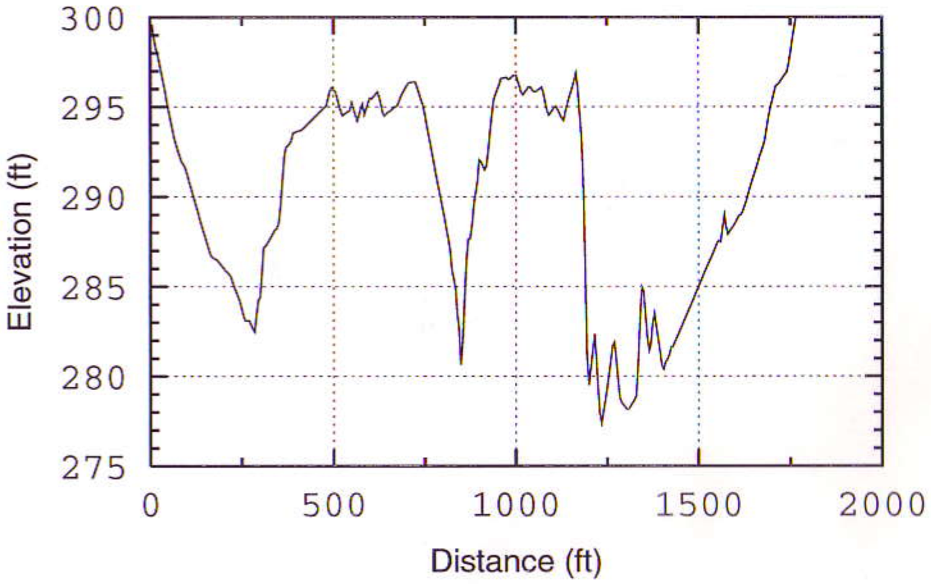
Lake Gladewater
February 2000 Survey
Prepared by: Texas Water Development Board

Lake Gladewater

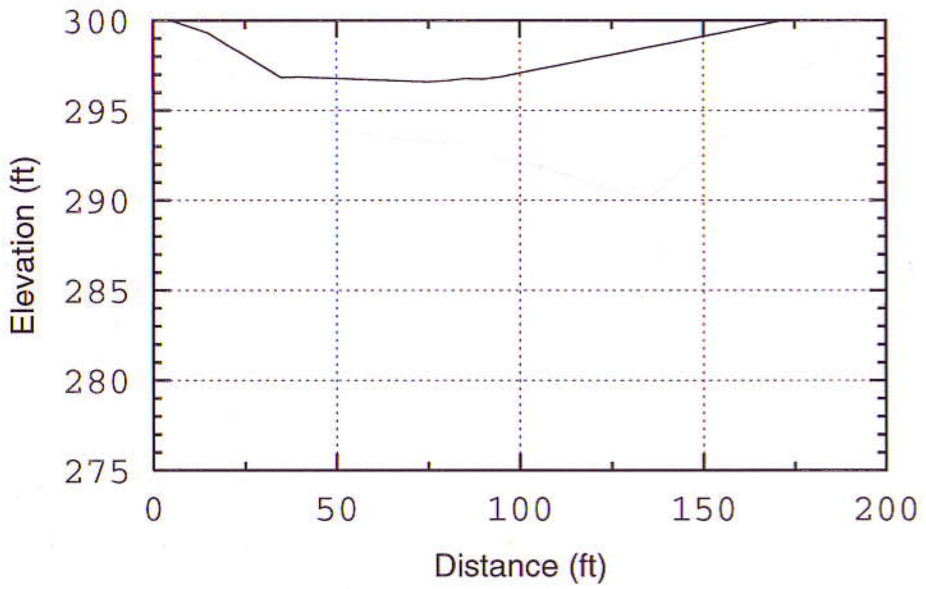
Cross Section #1 A-A'



Cross Section #1 B-B'



Cross Section #1 C-C'



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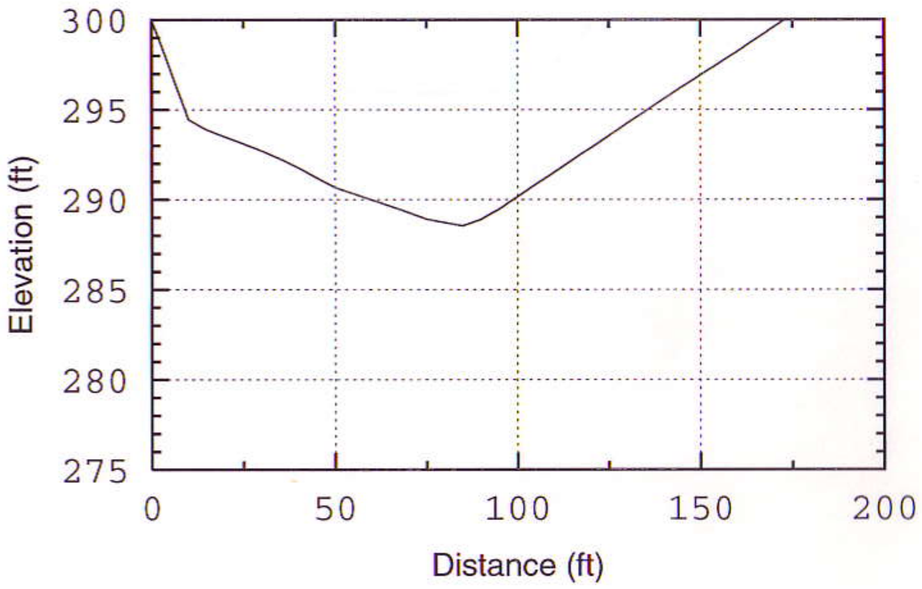
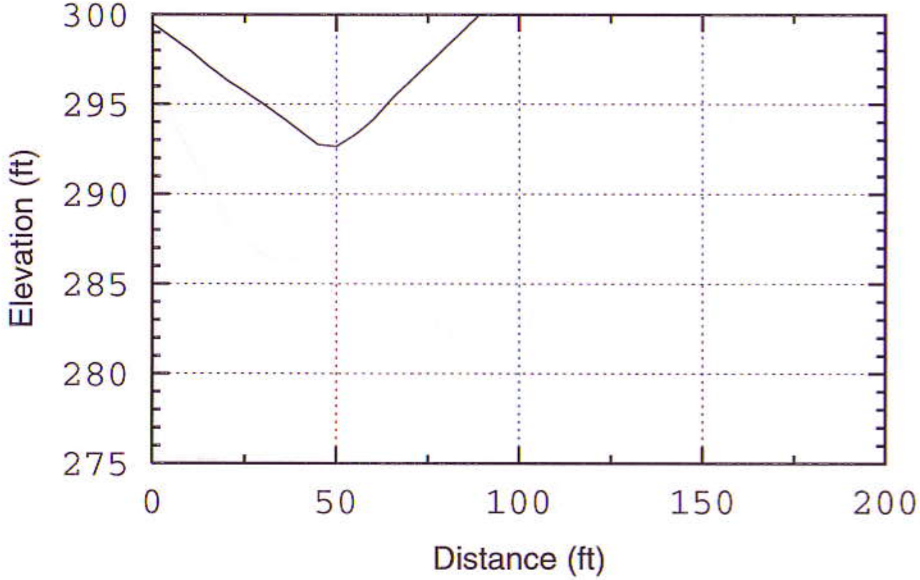
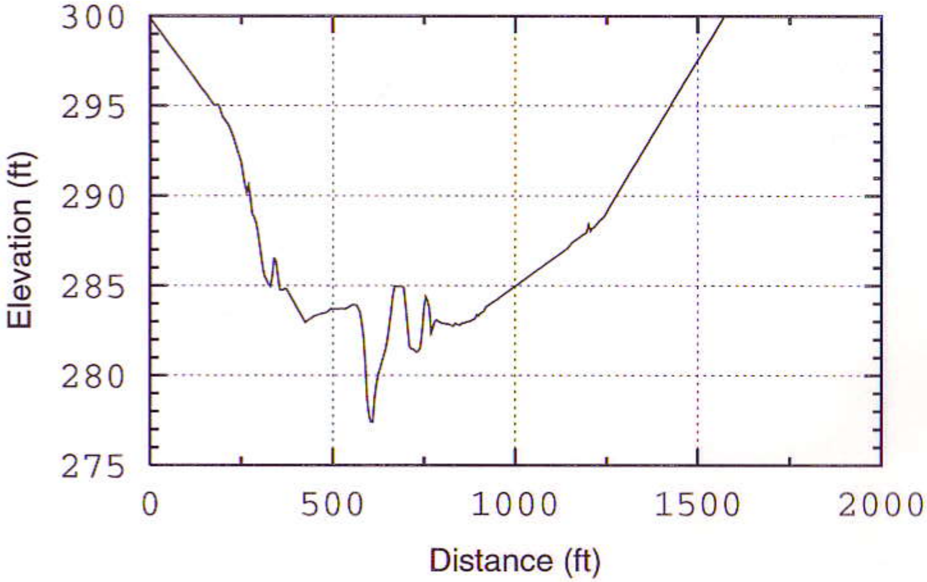


Lake Gladewater

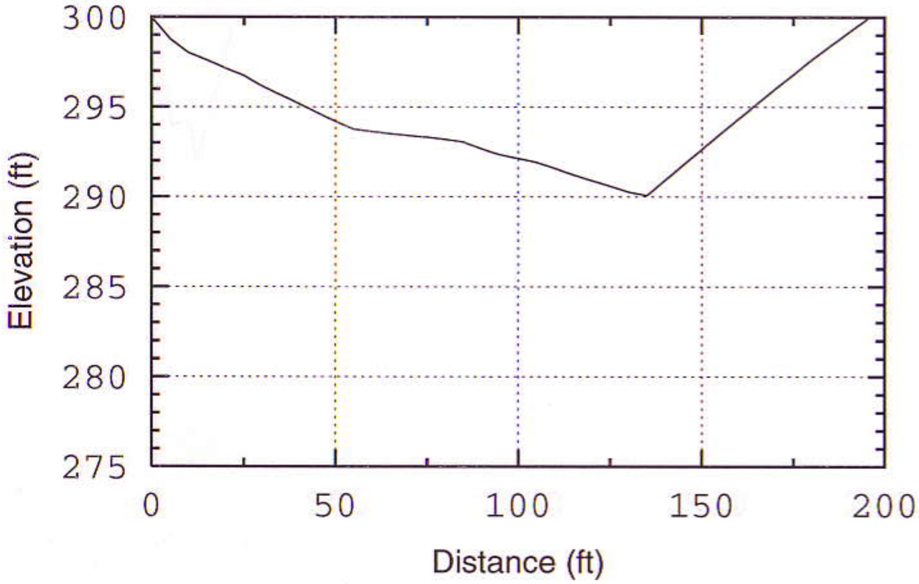
Cross Section #5 E-E'



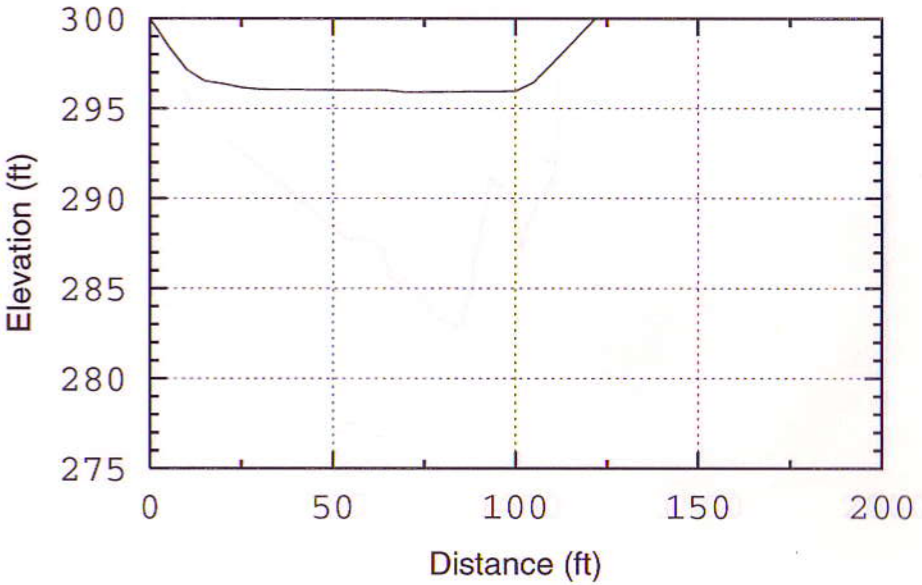
Cross Section #6 F-F'



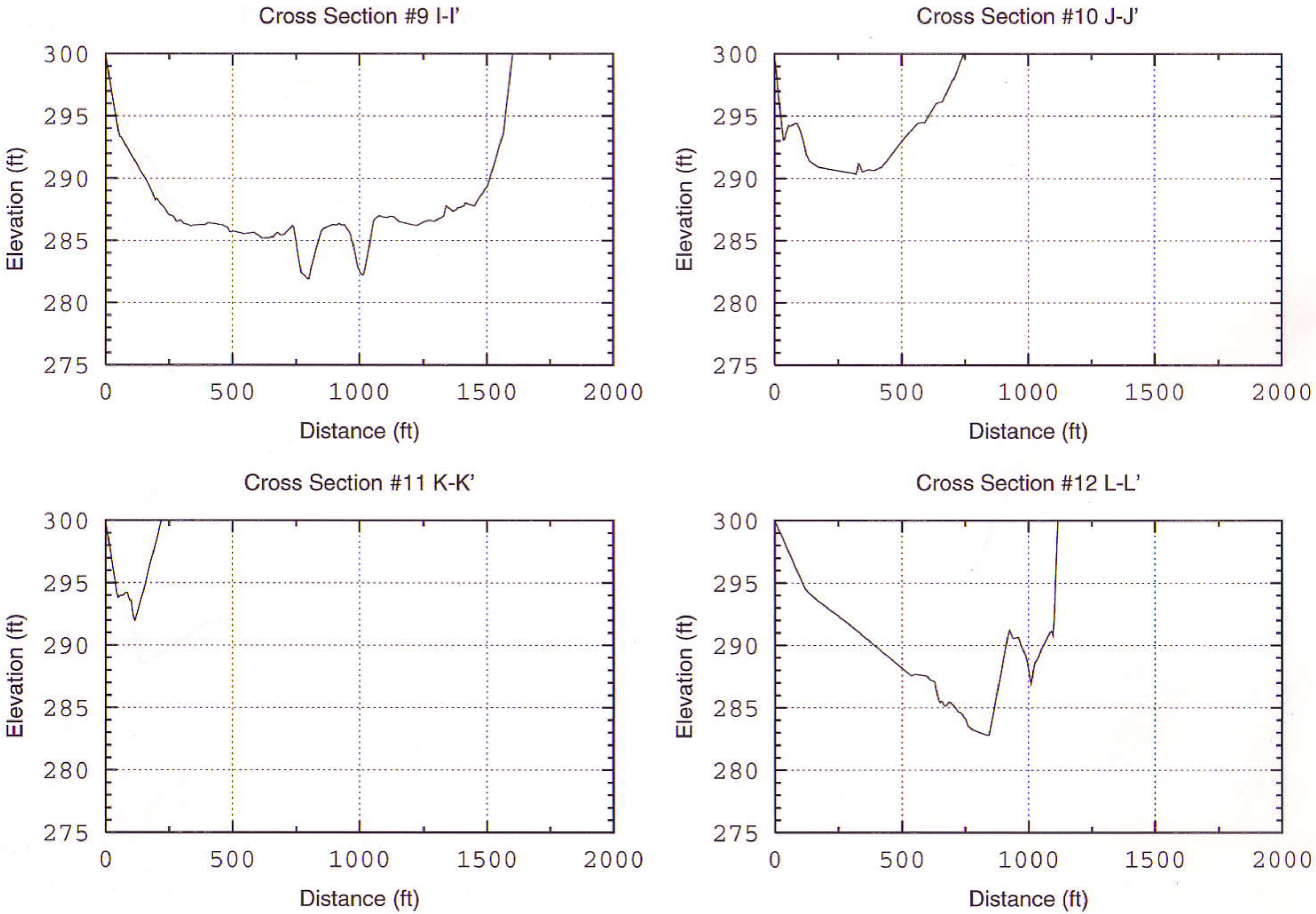
Cross Section #7 G-G'



Cross Section #8 H-H'



Lake Gladewater



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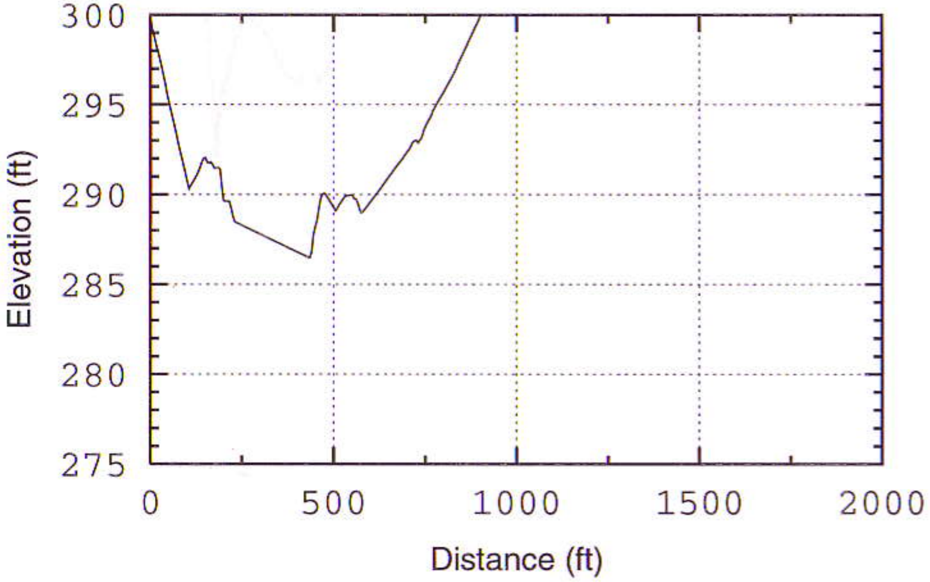
Cross Section #13 M-M'



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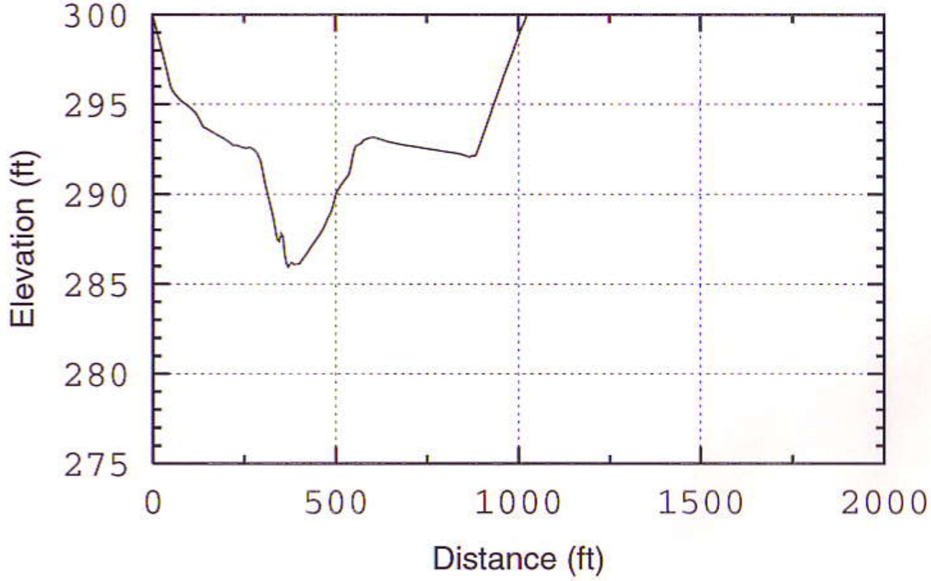

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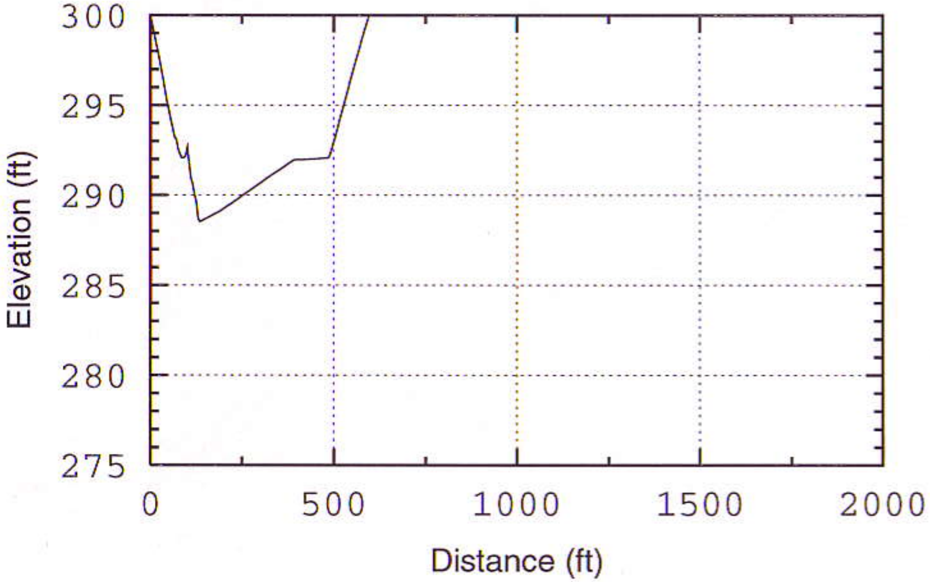

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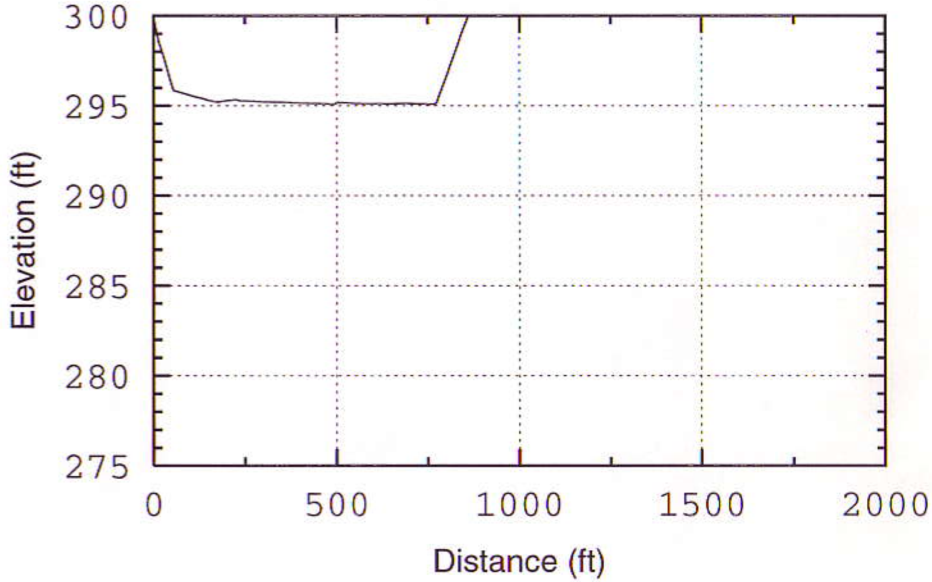
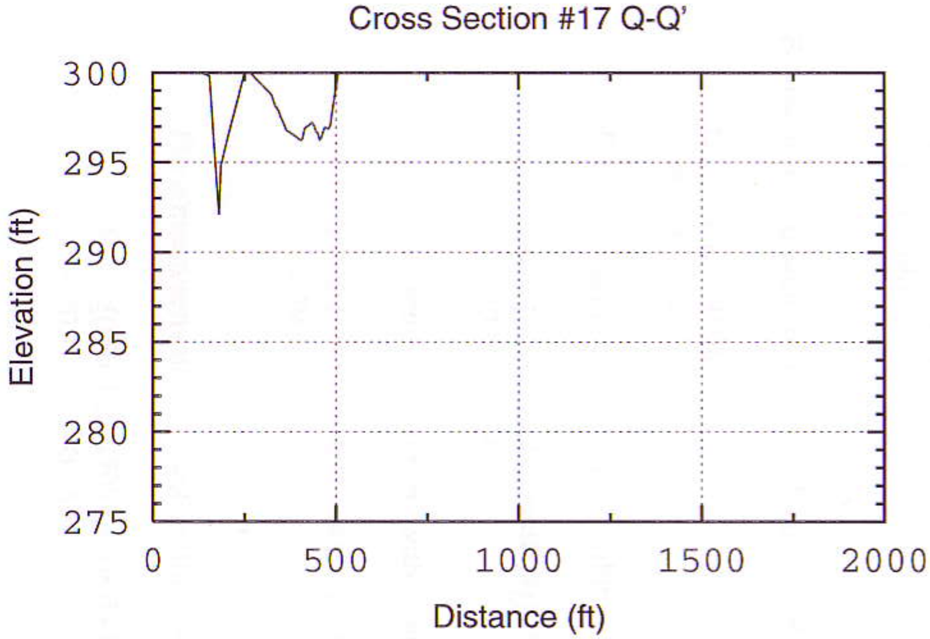


Lake Gladewater



APPENDIX E - DEPTH SOUNDER ACCURACY

This example was extracted from the Innerspace Technology, Inc. Operation Manual for the Model 443 Velocity Profiler.

For the following examples, $t_D = (D - d)/V$

Where: t_D = travel time of the sound pulse, in seconds (at depth = D)
D = depth, in feet
d = draft = 1.2 feet
V = speed of sound, in feet per second

To calculate the error of a measurement based on differences in the actual versus average speed of sound, the same equation is used, in this format:

$$D = [t\,(V)]+d$$

For the water column from 2 to 30 feet: V = 4832 fps

$t_{30} = (30-1.2)/4832$
$= 0.00596$ sec.

For the water column from 2 to 45 feet: V = 4808 fps

$t_{45} = (45-1.2)/4808$
$= 0.00911$ sec.

For a measurement at 20 feet (within the 2 to 30 foot column with V = 4832 fps):

$D_{20} = [((20-1.2)/4832)(4808)]+1.2$
= 19.9' (-0.1')

For a measurement at 30 feet (within the 2 to 30 foot column with V = 4832 fps):

$D_{30} = [((30-1.2)/4832)(4808)]+1.2$
= 29.9' (-0.1')

For a measurement at 50 feet (within the 2 to 60 foot column with V = 4799 fps):

D_{50} = [((50-1.2)/4799)(4808)]+1.2
= 50.1' (+0.1')

For the water column from 2 to 60 feet: V = 4799 fps Assumed V_{80} = 4785 fps

t_{60} =(60-1.2)/4799
=0.01225 sec.

For a measurement at 10 feet (within the 2 to 30 foot column with V = 4832 fps):

D_{10} = [((10-1.2)/4832)(4799)]+1.2
= 9.9' (-0.1')

For a measurement at 30 feet (within the 2 to 30 foot column with V = 4832 fps):

D_{30} = [((30-1.2)/4832)(4799)]+1.2
= 29.8' (-0.2')

For a measurement at 45 feet (within the 2 to 45 foot column with V = 4808 fps):

D_{45} = [((45-1.2)/4808)(4799)]+1.2
= 44.9' (-0.1')

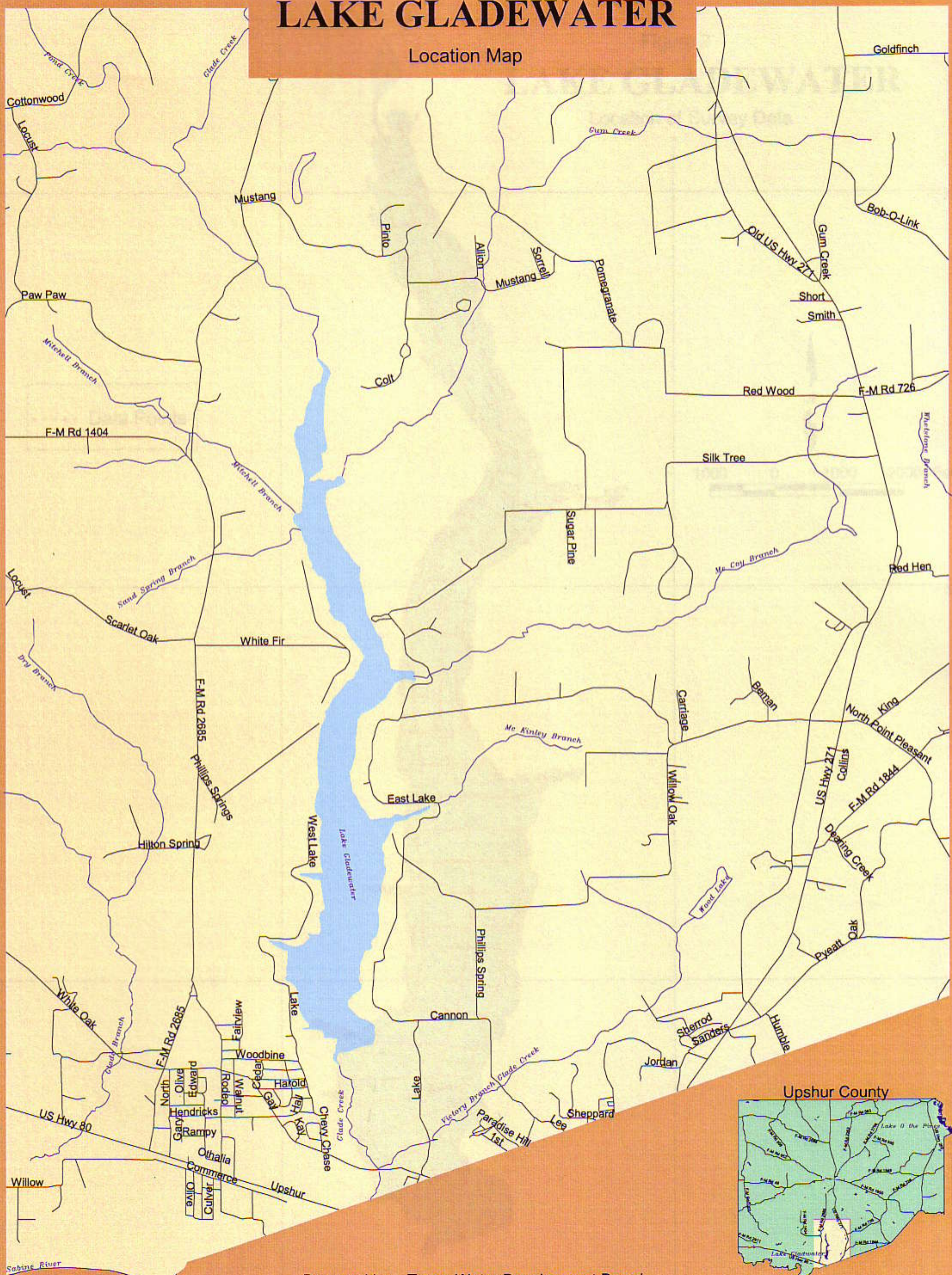
For a measurement at 80 feet (outside the 2 to 60 foot column, assumed V = 4785 fps):

D_{80} = [((80-1.2)/4785)(4799)]+1.2
= 80.2' (+0.2')

FIGURE 1

LAKE GLADEWATER

Location Map

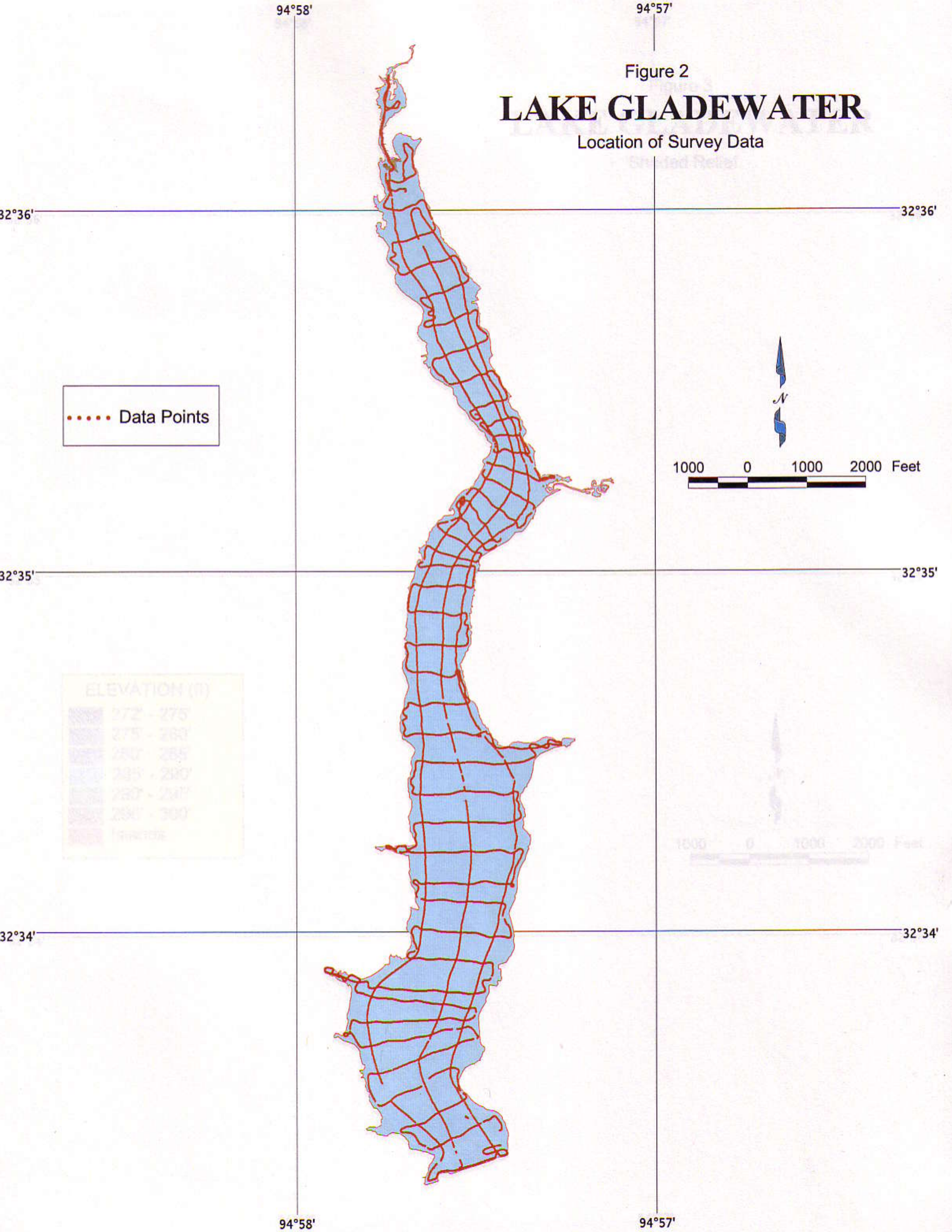


Prepared by : Texas Water Development Board
Source : U.S. Census Bureau TIGER/Line Files

Figure 2

LAKE GLADEWATER

Location of Survey Data



Prepared by : Texas Water Development Board

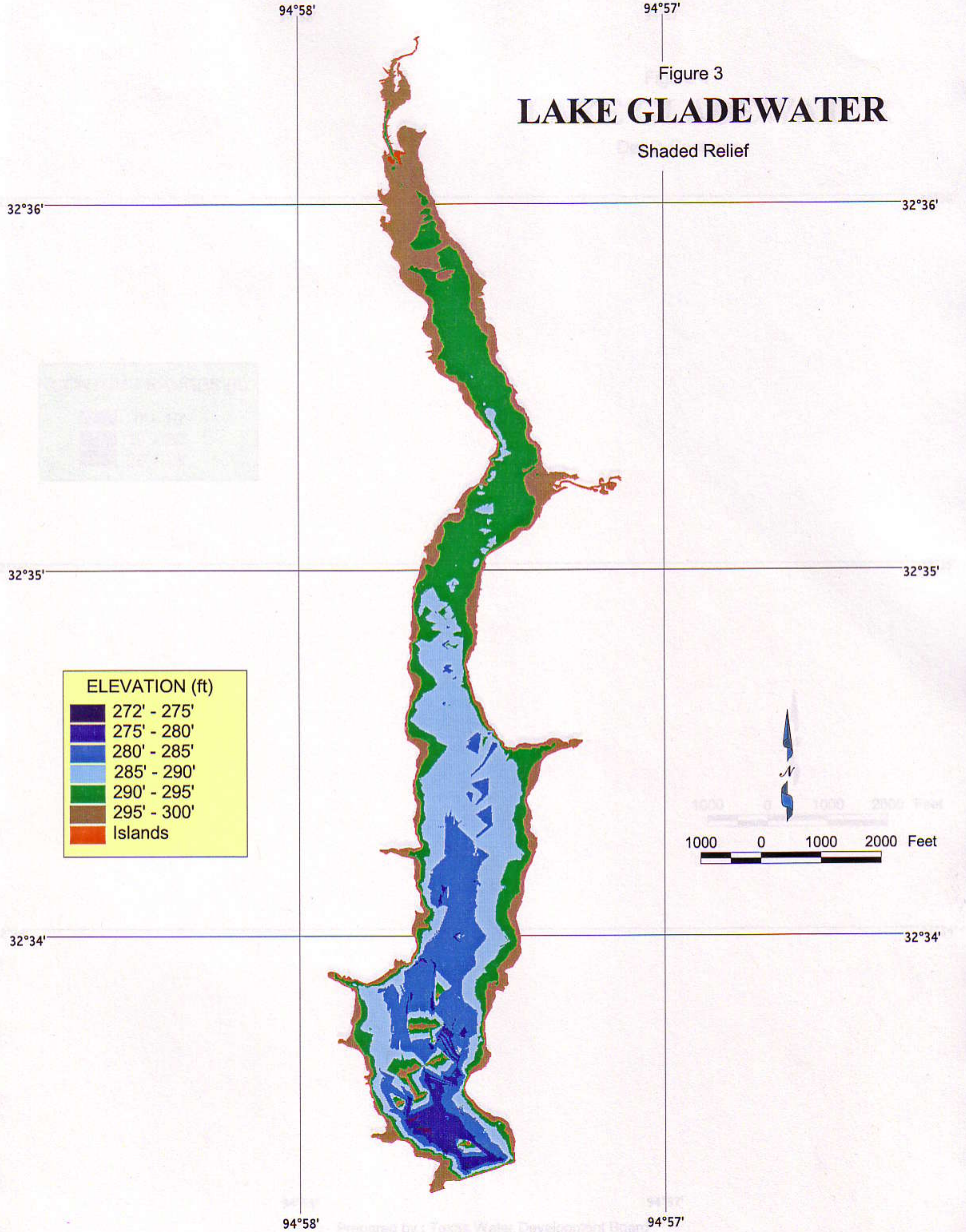


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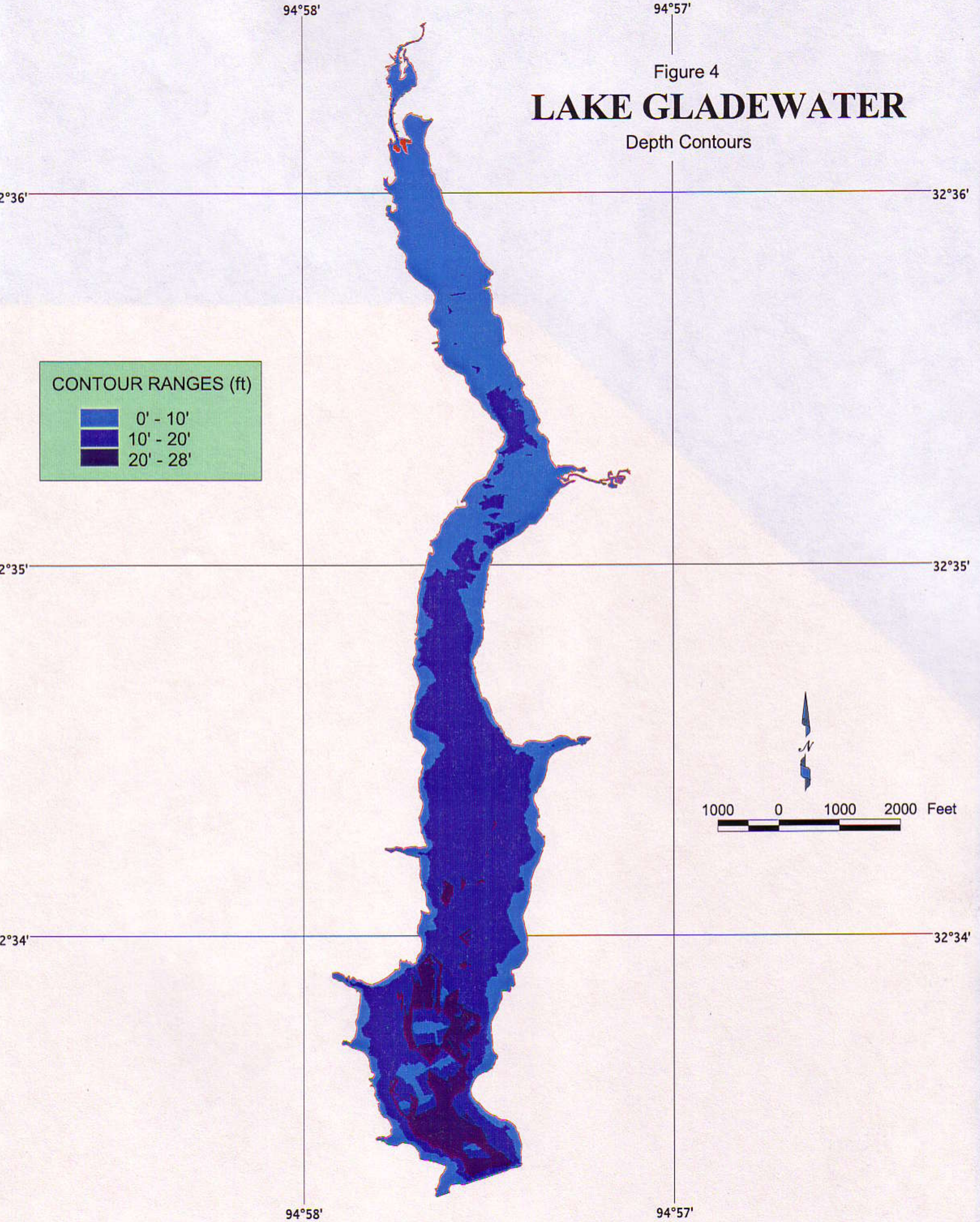
Figure 4

LAKE GLADEWATER

Depth Contours



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