VOLUMETRIC SURVEY
OF
LAKE O' THE PINES

Prepared for:

U. S. Army Corps of Engineers, Fort Worth District

In Cooperation with

Northeast Texas Municipal Water District

Prepared by:

The Texas Water Development Board

August 3, 1999

Texas Water Development Board

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Published and Distributed
by the
Texas Water Development Board
P.O. Box 13231
Austin, Texas 78711-3231

TABLE OF CONTENTS

APPENDICES

LIST OF FIGURES

LAKE O' THE PINES
HYDROGRAPHIC SURVEY REPORT

INTRODUCTION

Staff of the Hydrographic Survey Unit of the Texas Water Development Board (TWDB) conducted a hydrographic survey of Lake O' the Pines during the period October 13 – November 11, 1998. The purpose of the survey was to determine the volume of the lake at conservation pool elevation. From this information, future surveys will be able to determine the location and rates of sediment deposition in the conservation pool over time. Survey results are presented in the following pages in both graphical and tabular form. All elevations presented in this report are reported in feet above mean sea level based on the National Geodetic Vertical Datum of 1929 (NGVD '29) unless noted otherwise. The conservation pool elevation for Lake O' the Pines is 228.5 feet. The design information estimates the original surface area at this elevation to be 18,700 acres and the total storage volume to be 254,900 acre-feet of water.

LAKE HISTORY AND GENERAL INFORMATION

Information in this section was obtained from Texas Water Development Board Report 126 (1974) and from results of the current, 1998, volumetric survey. Northeast Texas Municipal Water District owns the water rights to Lake O' the Pines. Ferrells Bridge Dam and the surrounding shoreline of Lake O' the Pines are owned by the United States Government and maintained by the U. S. Army Corps of Engineers, Fort Worth District. The lake is located on Cypress Creek in Marion County approximately nine miles west of Jefferson, Texas. The lake inundates parts of Harrison, Morris, Camp and Upshur Counties (see Figure 1). Records indicate the drainage area is approximately 880 square miles. At the conservation pool elevation, the lake has approximately 126 miles of shoreline and is 16.7 miles long. The widest point of the reservoir is approximately 4.3 miles (located about 2 miles upstream of the dam).

Federal authorization was granted for the Lake O' the Pines facility under the Flood Control Act and approved on July 24, 1946, Public Law No. 526, 79th Congress, second session. The reservoir's storage volume was originally used for flood control, water conservation, wildlife and recreation uses.

The Texas Water Commission granted Permit No. 1897 (Application No. 2065) to the Northeast Texas Municipal Water District on November 22, 1957. The District was granted authorization to impound 250,000 acre-feet of water between elevations 201.0 feet and 228.5 feet in Lake O' the Pines. Annual use was limited to 42,000 acre-feet of water for municipal purposes and 161,800 acre-feet of water for industrial purposes. Several amendments to the permit involving diversions were approved in the following years. Certificate of Adjudication No. 04-4590 was issued by the Texas Water Commission on October 13, 1986 to the Northeast Texas Municipal Water District. The certificate basically adjudicated the same water rights as stated in Permit No. 1897. Northeast Texas Municipal Water District was authorized to impound 251,000 acre-feet of water in Lake O' the Pines between elevations 201 feet and 228.5 feet. The District was authorized to divert and use not to exceed 42,000 acre-feet of water per annum from Lake O' the Pines and Lake Bob Sandlin for municipal and domestic purposes. Authorization was granted to divert and use not to exceed 161,800 acre-feet of water per annum from Lake O' the Pines and Lake Bob Sandlin for industrial purposes. The owner of the certificate was authorized to release sufficient amounts of industrial use water from Lake O' the Pines to provide for the transwatershed diversion of 18,000 acre-feet of water per annum for the Sabine River Basin. The owner was authorized to use the impounded waters of Lake O' the Pines for recreational purposes. In addition, Northeast Texas Municipal Water District must meet low-flow requirements for releases as provided in a contractual agreement with the U. S. Army Corps of Engineers.

Records indicate the construction for the Lake O' the Pines project started on January 10, 1955 and was completed June 25, 1958. Deliberate impoundment of water began August 21, 1957 and was officially declared operational December 11, 1959. The U. S. Army Corps of Engineers designed the project and Potashnick Construction Company was the general contractor. The estimated project cost was $13,405,475 (June 1971).

Ferrells Bridge Dam and appurtenant structures consist of an earthfill embankment 10,600 feet in length with a maximum height of 97 feet and a crest width of 30 feet at elevation 277.0 feet. The service spillway is an uncontrolled concrete chute located at the left (east) end of the embankment. The crest of the spillway is 200 feet in width at elevation 249.5 feet. The outlet works structure consists of a concrete tower located approximately 1,000 feet west of the service spillway with two 10.0 feet diameter conduits with invert elevations at 200.0 feet. Two electrically driven broom-type gates control the outlets, each gate 8 by 12.5 feet. There is a controlled 14- inch low-flow outlet at an invert elevation of 200.0 feet.

HYDROGRAPHIC SURVEYING TECHNOLOGY

The equipment used in the performance of the hydrographic survey consists of a 23-foot aluminum tri-hull SeaArk craft with cabin, equipped with twin 90-Horsepower Johnson outboard motors. Installed within the enclosed cabin are an Innerspace Helmsman Display (for navigation), an Innerspace Technology Model 449 Depth Sounder and Model 443 Velocity Profiler, a Trimble Navigation, Inc. 4000SE GPS receiver, an OmniSTAR receiver, and an on-board 486 computer. A water-cooled generator provides electrical power through an in-line uninterruptible power supply. Reference to brand names does not imply endorsement by the TWDB.

The GPS equipment, survey vessel, and depth sounder combine together to 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 survey vessel's on-board computer along with the corrected positional data generated by the boat's GPS receiver. The data files are downloaded daily from the computer and brought to the office for editing after the survey is completed. During editing, bad 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 and surface area can be quickly determined by creating a 3-D digital model of the reservoir from the collected data. The level of accuracy is equivalent to or better than previous methods used to determine lake volumes, some of which are discussed in Appendix F.

PRE-SURVEY PROCEDURES

The reservoir's boundary at elevation 228.5 feet was digitized prior to the survey using AutoCad. The work map was created from 7.5 minute USGS quadrangle maps, KELLYVILLE, TEX. 1962, HARLETON, TEX. 1961, Photo-revised 1978, LASSATER, TEX.1961, ORE CITY, TEX. 1962, LONE STAR, TEX. 1962, ASHLAND, TEX. 1962, Photo-revised 1978 and LA FAYETTE, TEX. 1960. The graphic boundary file created was then transformed into the proper projection, from NAD '27 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.

The survey layout was designed using the above boundary by placing survey track lines at 500 feet intervals across the lake or perpendicular to the natural streambed. The survey design for this lake required approximately 340 survey lines to be placed along the length of the lake. Survey setup files were created using Coastal Oceanographics, Inc. Hypack software for each group of track lines that represented a specific section of the lake. The setup files were copied onto diskettes for use during the field survey.

A second boundary was digitized from digital orthophoto quadrangle (DOQ) images that had recently been made available, including the following DOQ's: KELLYVILLE, TEX., HARLETON, TEX., LASSATER, TEX., ORE CITY, TEX., LONE STAR, TEX., ASHLAND, TEX., and LA FAYETTE, TEX. (The DOQ's were produced for the TEXAS Orthoimagery Program (TOP). DOQ products produced for the Department of Information Resources and the GIS Planning Council under the Texas Orthoimagery Program reside in the public domain and can be obtained on the Internet at http://www.tnris.state.tx.us/DigitalData/doqs.htm.) The boundary created with these DOQ's was originally in UTM Zone 15, and was subsequently converted to the NAD '83. The photographs used in the producing the DOQ's were taken in March 1995. The average lake elevation at the time the photographs were taken was 228.8 feet. This boundary was considered more accurate than the boundary digitized from USGS quadrangle maps described above, and was used in determining the outer lake boundary for subsequent use in calculating the lake's area and volume.

SURVEY PROCEDURES

Equipment Calibration and Operation

At the beginning of each surveying day, the depth sounder was calibrated with the Innerspace Velocity Profiler, an instrument that measures the local speed of sound. The average speed of sound in the vertical water column between the boat-mounted transducers (at a depth equal to the boat's draft of 1.2 ft) to the lake bottom was determined by averaging local speed-of-sound measurements collected by the velocity profiler through the water column. The velocity profiler probe was first placed in the water to moisten and acclimate the probe. The probe was next raised to the water surface where the depth was zeroed. The probe was then gradually lowered on a cable to a depth just above the lake bottom, and then raised to the surface. During this time the unit measured the local speed of sound. The average of the measurements collected through the water column was next computed and displayed by the unit. The displayed value of the average speed of sound was entered into the ITI449 depth sounder, which then provided the depth of the lake bottom. The depth was then checked manually with a measuring tape to ensure that the depth sounder was properly calibrated and operating correctly. During the survey of Lake O' the Pines, the speed of sound in the water column varied from 4812 to 4884 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 due to the 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 F.

During the survey, the onboard GPS receiver was set to a horizontal mask of 10° and a PDOP (Position Dilution of Precision) limit of 7 to maximize the accuracy of the measured horizontal position. An internal alarm sounds if the 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. Both sets of coordinates were then stored in the survey data file.

Field Survey

Data were collected at Lake O' the Pines during the period of October 13 through November 11, 1998. Weather conditions were favorable during the data collection phase of the survey. Temperatures were above normal and the wind varied out of the north and south. On most days the crew experienced mild winds, but with the onset of north fronts wind gusts of over 25 mph were experienced. Approximately 216,400 (1-second-average) data points were collected over the 290 miles traveled and were stored digitally on the boat's computer. Data were not collected in areas of shallow water (depths less than 3.0 feet) or with significant obstructions unless these areas represented a large amount of water. Random data lines were also collected parallel to the original streambed in the main body of the lake. Figure 2 shows the actual location of all data collection points.

TWDB staff observed many similarities between the lake's bathemetry and the surrounding topography. The main body of the reservoir is located in the flood plain of Cypress Creek. The terrain around the lake consists generally of rolling hills. The channels created by the submerged tributaries are aligned primarily north to south. Three major tributaries feed into the reservoir on the north side. Beginning at the dam and going upstream, these include the Hurricane, Johnson, and Alley Creeks. Several smaller creeks also feed into the reservoir from the south side. These include the Brushy, Copeland, Orms, Sandy, and Meddlin Creeks. The bathemetry of the lake bottom in the reaches of the submerged tributaries is somewhat steeper and "V" shaped. The topography in the submerged flood plain of Cypress Creek is less steep and "U" shaped. Within this flood plain, the original river and tributary channels were easily distinguishable on the depth sounder chart when they were crossed. The survey crew collected extra data around the intake tower near Oak Valley Park, the Cason and

Dangerfield Pump Stations.

Data collection started at the dam and proceeded upstream. The field crew did not encounter any navigational hazards such as submerged trees and stumps until they were upstream of Watts Island near the confluence of Johnson Creek. The crew collected data in some clear areas after that point but the majority of the lake had submerged trees and stumps. The crew did notice silt bars that extended on an average of 100 feet from the shoreline where bank erosion was occurring. Sediment deposits and aquatic vegetation were observed mainly in the upper reaches of the lake, especially upstream of the Highway 155 bridge. Data collection in the headwaters was discontinued when the boat could no longer maneuver due to shallow water and extensive vegetation. 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 each day for later processing.

Data Processing

The collected data were downloaded from diskettes onto the 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 varied between 227.98 and 228.26 feet. After all changes had been made to the raw data files, the edited files were 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 reservoir's bottom surface using Arc/Info's TIN (triangular irregular network) software module. The module generates a TIN from the data points and the boundary file using a method known as Delauney's criteria for triangulation. In this method, 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. 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 reservoir area and volume can be determined from the triangulated irregular network created using this method of interpolation.

Volumes and areas were calculated from the TIN for the entire reservoir at one-tenth of a foot intervals. From elevation 176.8 to elevation 228.5, the surface areas and volumes of the lake were mathematically estimated using Arc/Info software. The computed water surface area of the lake at elevation 228.5 was 16,919 surface acres, and the computed area of islands in the lake was 603 acres, giving a total enclosed area of 17,522 acres. The computed area was 1,178 surface acres less than originally calculated in 1955 (Texas Water Development Board, 1967). The computed reservoir volume table is presented in Appendix A and the area table in Appendix B. An elevation-area-volume graph is presented in Appendix C.

Other products developed from the model include a shaded relief 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 contour map of the bottom surface at two-foot intervals is presented in Figure 5.

Five range-lines were digitized from photocopies of measurements collected during Corps of Engineers surveys in 1949, 1958, 1966, 1972, and 1973. These are compared to cross-sections obtained from the current survey and are presented in Appendix D.

RESULTS

Results from the 1998 TWDB survey indicate Lake O' the Pines encompasses 16,919 surface acres and contains a total volume (conservation storage plus dead storage volume) of 241,081 acre-feet at the conservation pool elevation of 228.5 feet. The shoreline at this elevation was calculated to be 126 miles. The deepest point of the lake, elevation 177.08 feet or 51.4 feet of depth, was located approximately 3,506 feet upstream from Ferrells Bridge Dam near the northeast shore. The dead storage volume, or the amount of water below the lowest outlet invert elevation (200.0 feet), was calculated to be 2,148 acre-feet. Therefore, the conservation storage volume, or the amount of water contained between the conservation storage elevation (228.5') and the elevation of the lowest outlet, is 238,933 acre-feet.

SUMMARY

Lake O' the Pines was declared operational December 11, 1959. Initial storage calculations estimated the total volume at the conservation pool elevation of 228.5 feet to be 254,900 acre-feet with a surface area of 18,700 acres, and a conservation pool volume of 252,040 acre-feet.

During October 13 – November 11, 1998, staff from the Texas Water Development Board's Hydrographic Survey Program completed a hydrographic survey of Lake O' the Pines. The 1998 survey took advantage of technological advances such as differential global positioning system and geographical information system technology to create a digital model of the reservoir's bathemetry. With these advances, the survey was completed more quickly and significantly more bathymetric data were collected than in previous surveys. Results indicate that the lake's total volume at the conservation pool elevation of 228.5 feet was 241,081 acre-feet and the area was 16,919 acres.

The estimated reduction in storage volume at the conservation pool elevation of 228.5 feet since 1959 is 10,959 acre-feet or 274 acre-feet per year. The average annual deposition rate of sediment in the conservation pool of the reservoir can be estimated at 0.31 acre-feet per square mile of drainage area. *(Please note that this is just a mathematical estimate based on the difference between the original design and the current survey. Limited knowledge on actual sedimentation can be determined from one field survey.)*

It is difficult to compare the original design information and the TWDB performed survey

because little is know about the original design method, the amount of data collected, and the method used to process the collected data. However, the TWDB considers the 1998 survey to be a significant improvement over previous survey procedures and recommends 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

Texas Water Development Board. 1967. Dams and reservoirs in Texas, historical and descriptive information, Report 48, June 1967.

Texas Water Development Board. 1974. Engineering data on dams and reservoirs in Texas. Part I. Report 126. October 1974.

APPENDIX A - LAKE O' THE PINES VOLUME TABLE

Appendix A

LAKE O' the PINES

RESERVOIR VOLUME TABLE

TEXAS WATER DEVELOPMENT BOARD NOVEMBER 1998 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
176										0
177	0	0	0	0	0	0	0	0	0	0
178	0	0	0	0	0	0	0	0	0	0
179	0	0	0	0	0	0	0	0	0	0
180	0	0	0	0	0	0	0	0	0	0
181	0	0	0	0	0	0	0	0	0	0
182	0	0	1	1	1	1	1	1	1	1
183	1	1	1	1	1	1	1	1	2	2
184	2	2	2	2	2	2	3	3	3	3
185	3	3	4	4	4	4	5	5	5	5
186	6	6	6	7	7	8	8	8	9	9
187	10	10	11	12	12	13	13	14	15	16
188	16	17	18	19	20	21	22	23	24	25
189	26	27	28	29	31	32	33	35	36	38
190	39	41	43	44	46	48	50	52	54	56
191	59	61	63	66	68	71	74	77	80	83
192	86	89	93	96	100	104	108	112	117	121
193	126	131	136	142	147	153	159	166	173	180
194	187	194	202	211	220	229	238	248	259	270
195	281	293	305	318	331	345	360	375	391	407
196	424	442	460	480	500	521	544	567	591	616
197	642	670	698	727	758	789	822	856	892	929
198	968	1008	1049	1092	1137	1184	1233	1283	1336	1390
199	1447	1506	1567	1631	1697	1766	1837	1910	1987	2066
200	2148	2232	2319	2409	2502	2598	2697	2800	2905	3014
201	3126	3242	3360	3482	3607	3735	3867	4002	4140	4283
202	4429	4579	4733	4891	5052	5217	5386	5558	5735	5915
203	6099	6287	6480	6677	6878	7083	7294	7508	7728	7952
204	8181	8415	8654	8898	9147	9402	9663	9930	10203	10482
205	10766	11056	11353	11655	11963	12276	12596	12921	13252	13588
206	13930	14278	14632	14991	15357	15728	16104	16487	16875	17268
207	17668	18073	18484	18901	19324	19752	20185	20624	21069	21519
208	21976	22438	22905	23379	23859	24344	24835	25332	25834	26342
209	26856	27376	27902	28434	28972	29516	30066	30622	31184	31751
210	32324	32903	33488	34079	34676	35278	35887	36501	37122	37748
211	38381	39019	39663	40313	40968	41629	42296	42969	43647	44331
212	45021	45715	46416	47122	47834	48552	49276	50005	50740	51480
213	52226	52977	53733	54495	55262	56034	56811	57594	58381	59174
214	59972	60776	61585	62399	63220	64046	64878	65715	66559	67407
215	68263	69124	69991	70864	71744	72630	73522	74421	75325	76236
216	77153	78076	79005	79940	80882	81830	82783	83744	84710	85683
217	86662	87647	88639	89637	90641	91652	92669	93692	94722	95759
218	96803	97854	98911	99976	101047	102126	103211	104302	105401	106505
219	107616	108734	109859	110990	112127	113272	114423	115580	116744	117914
220	119091	120274	121463	122659	123861	125070	126285	127507	128735	129970
221	131212	132460	133715	134977	136246	137522	138805	140093	141388	142689
222	143996	145309	146628	147953	149283	150620	151963	153311	154666	156027

Appendix A continued

LAKE O' the PINES
RESERVOIR VOLUME TABLE

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
223	157393	158766	160144	161529	162920	164317	165720	167129	168544	169965
224	171392	172825	174264	175709	177159	178615	180078	181546	183021	184501
225	185989	187484	188990	190503	192020	193541	195066	196595	198128	199664
226	201205	202750	204299	205852	207409	208971	210536	212105	213679	215257
227	216839	218425	220015	221610	223208	224812	226419	228031	229647	231267
228	232892	234521	236154	237792	239434	241081				

Appendix B

LAKE O' the PINES

RESERVOIR AREA TABLE

TEXAS WATER DEVELOPMENT BOARD — NOVEMBER 1998 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
176										0
177	0	0	0	0	0	0	0	0	0	0
178	0	0	0	0	0	0	0	0	0	0
179	0	0	0	0	0	0	0	0	0	0
180	0	0	0	0	0	0	0	0	0	0
181	0	0	0	0	0	0	0	0	0	0
182	0	0	0	0	0	0	0	1	1	1
183	1	1	1	1	1	1	1	1	1	1
184	1	1	1	1	1	1	2	2	2	2
185	2	2	2	2	2	3	3	3	3	3
186	3	3	4	4	4	4	4	4	5	5
187	5	5	6	6	6	6	7	7	7	8
188	8	8	9	9	9	10	10	10	11	11
189	11	12	12	13	13	14	14	14	15	15
190	16	17	17	18	18	19	20	20	21	22
191	23	24	24	25	26	27	28	29	30	32
192	33	34	35	37	38	40	41	43	45	47
193	49	51	53	56	58	60	63	65	68	72
194	75	78	82	86	89	93	98	102	107	111
195	116	121	126	131	136	142	148	154	160	167
196	174	182	190	199	209	218	227	237	247	257
197	267	277	288	299	311	323	336	349	363	378
198	393	408	424	440	457	476	495	515	535	555
199	577	600	625	650	675	699	724	751	778	804
200	831	858	886	915	944	976	1008	1040	1072	1105
201	1137	1169	1201	1233	1266	1299	1333	1367	1406	1444
202	1482	1519	1557	1594	1631	1669	1707	1745	1783	1822
203	1862	1904	1946	1989	2034	2080	2126	2172	2218	2266
204	2314	2364	2414	2466	2522	2580	2640	2698	2756	2815
205	2875	2933	2992	3049	3107	3165	3223	3280	3336	3393
206	3450	3508	3566	3624	3681	3738	3795	3852	3910	3967
207	4024	4082	4139	4196	4252	4308	4363	4419	4476	4532
208	4590	4649	4708	4766	4824	4881	4938	4995	5052	5110
209	5169	5230	5290	5352	5411	5471	5529	5587	5645	5703
210	5761	5820	5879	5938	5997	6055	6114	6175	6235	6295
211	6353	6411	6469	6527	6584	6641	6698	6755	6811	6866
212	6920	6975	7032	7091	7152	7209	7265	7321	7376	7429
213	7483	7537	7591	7644	7695	7747	7798	7850	7903	7956
214	8009	8062	8117	8175	8233	8290	8346	8403	8461	8520
215	8581	8641	8703	8765	8829	8891	8954	9016	9078	9138
216	9199	9260	9322	9383	9446	9508	9570	9633	9696	9759
217	9821	9884	9948	10011	10074	10138	10202	10267	10334	10403
218	10474	10544	10613	10681	10748	10815	10884	10950	11014	11079
219	11146	11212	11278	11344	11410	11476	11542	11607	11672	11735
220	11798	11861	11925	11990	12055	12119	12185	12250	12316	12382
221	12449	12518	12586	12656	12724	12790	12855	12918	12979	13039
222	13100	13160	13219	13278	13337	13396	13457	13517	13578	13637

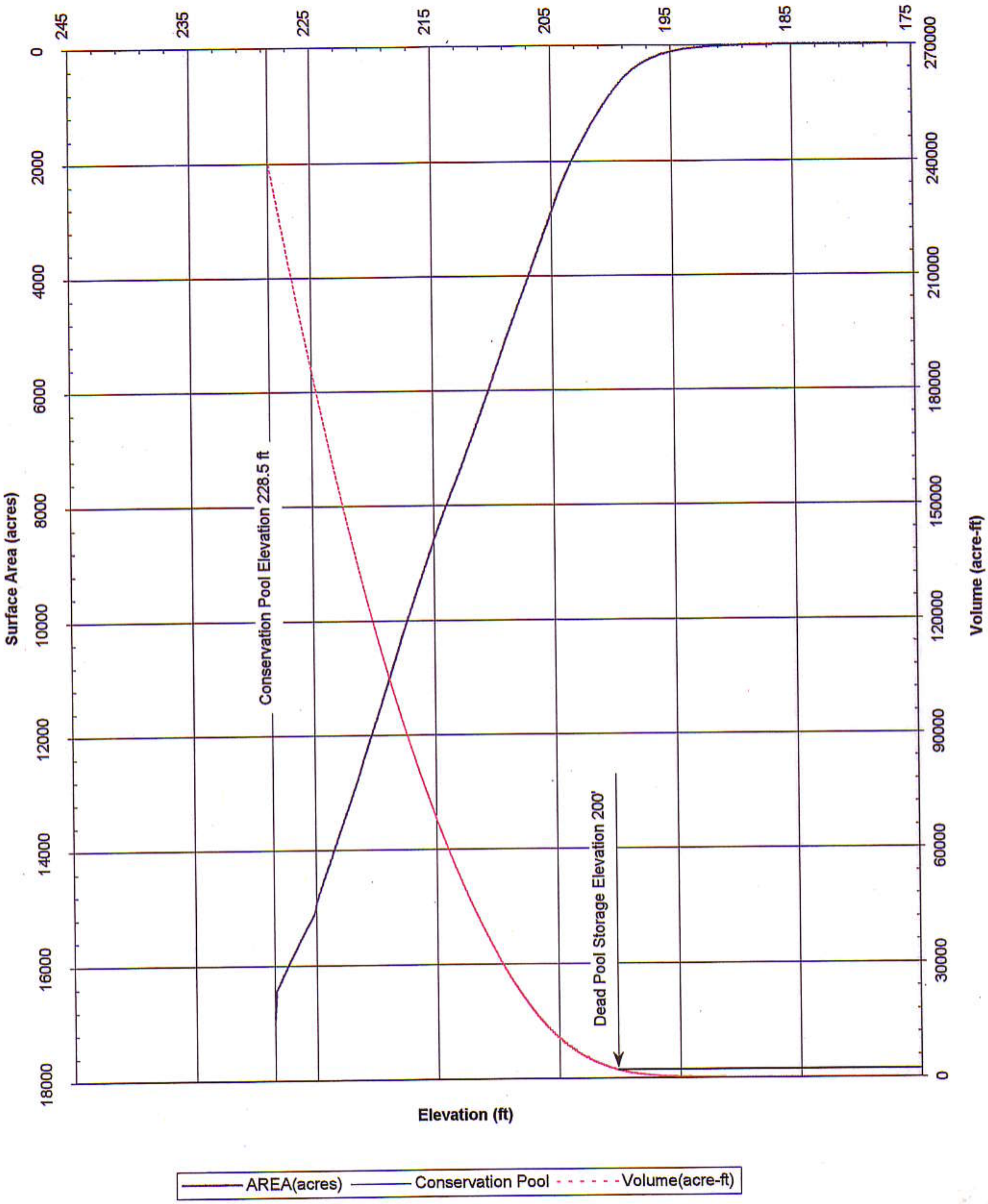
Appendix B continued

LAKE O' the PINES

RESERVOIR AREA TABLE

AREA IN ACRES — ELEVATION INCREMENT IS ONE TENTH FOOT

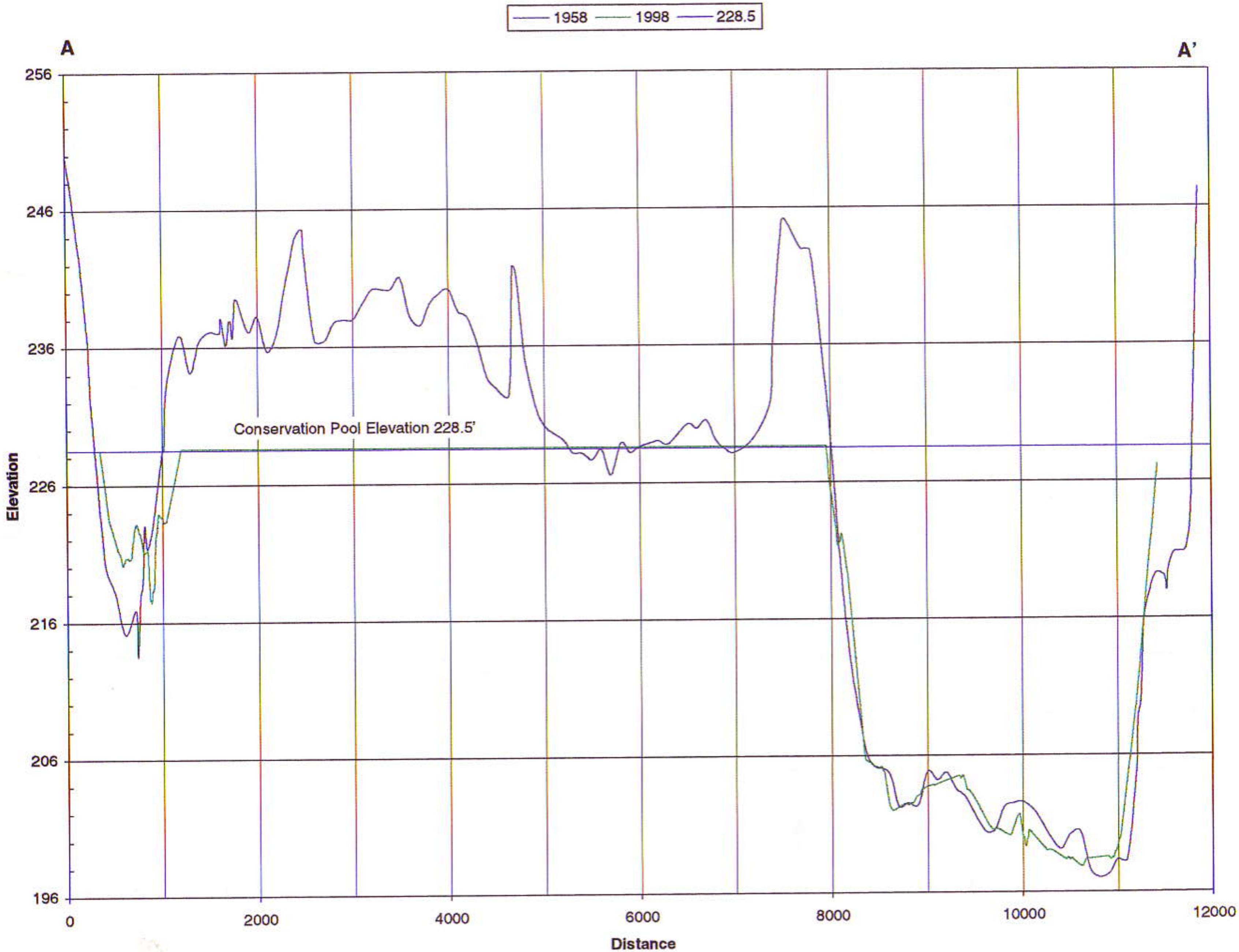
ELEVATION in Feet	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
223	13696	13756	13816	13876	13937	13999	14060	14120	14180	14241
224	14301	14360	14418	14477	14535	14593	14652	14714	14777	14841
225	14909	15026	15109	15151	15190	15230	15269	15309	15349	15389
226	15429	15469	15510	15551	15591	15633	15674	15715	15757	15798
227	15840	15882	15925	15967	16010	16052	16095	16138	16182	16225
228	16269	16312	16356	16400	16445	16919				



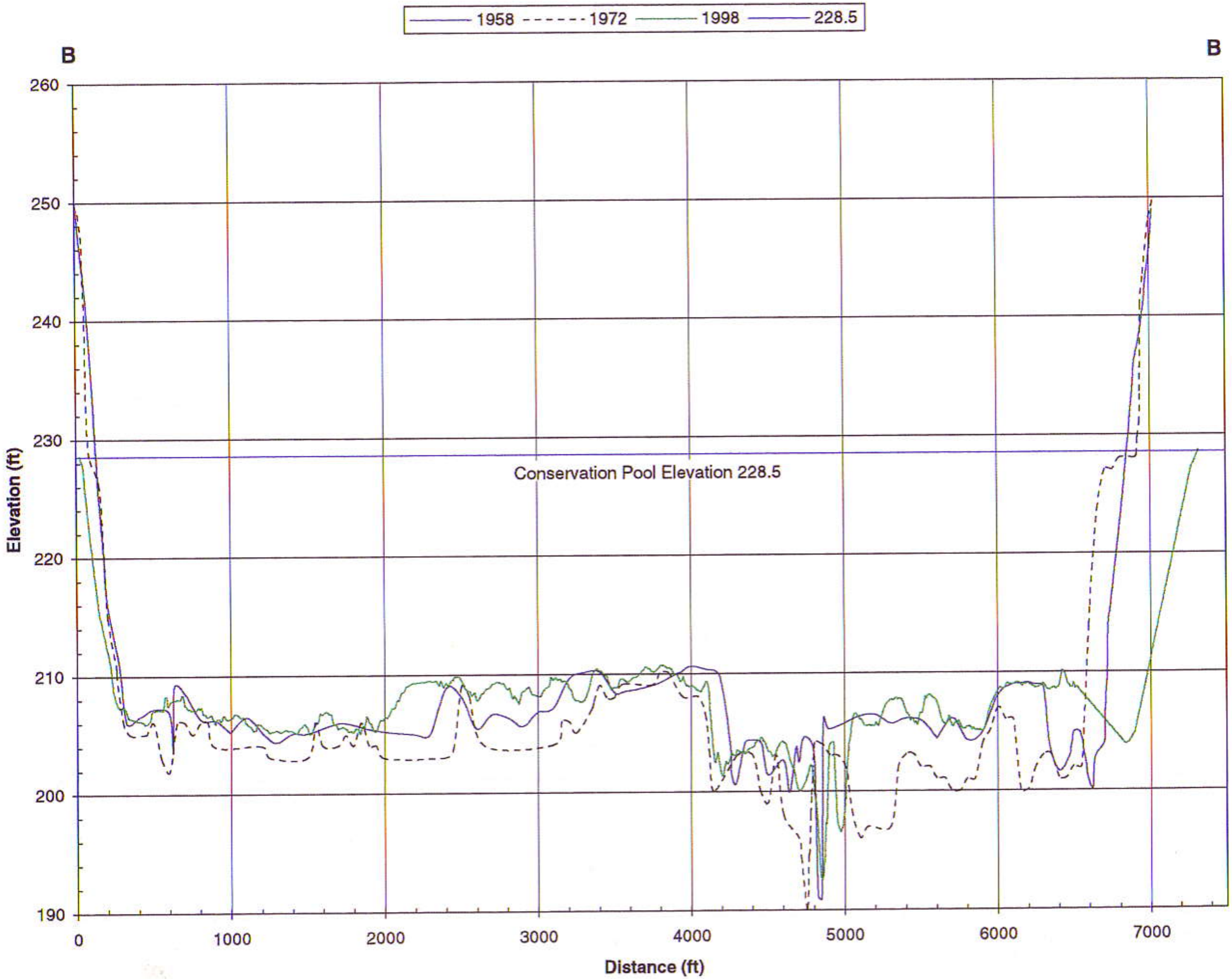
LAKE O' the PINES
November 1998
Prepared by: TWDB MARCH 1999

Appendix C

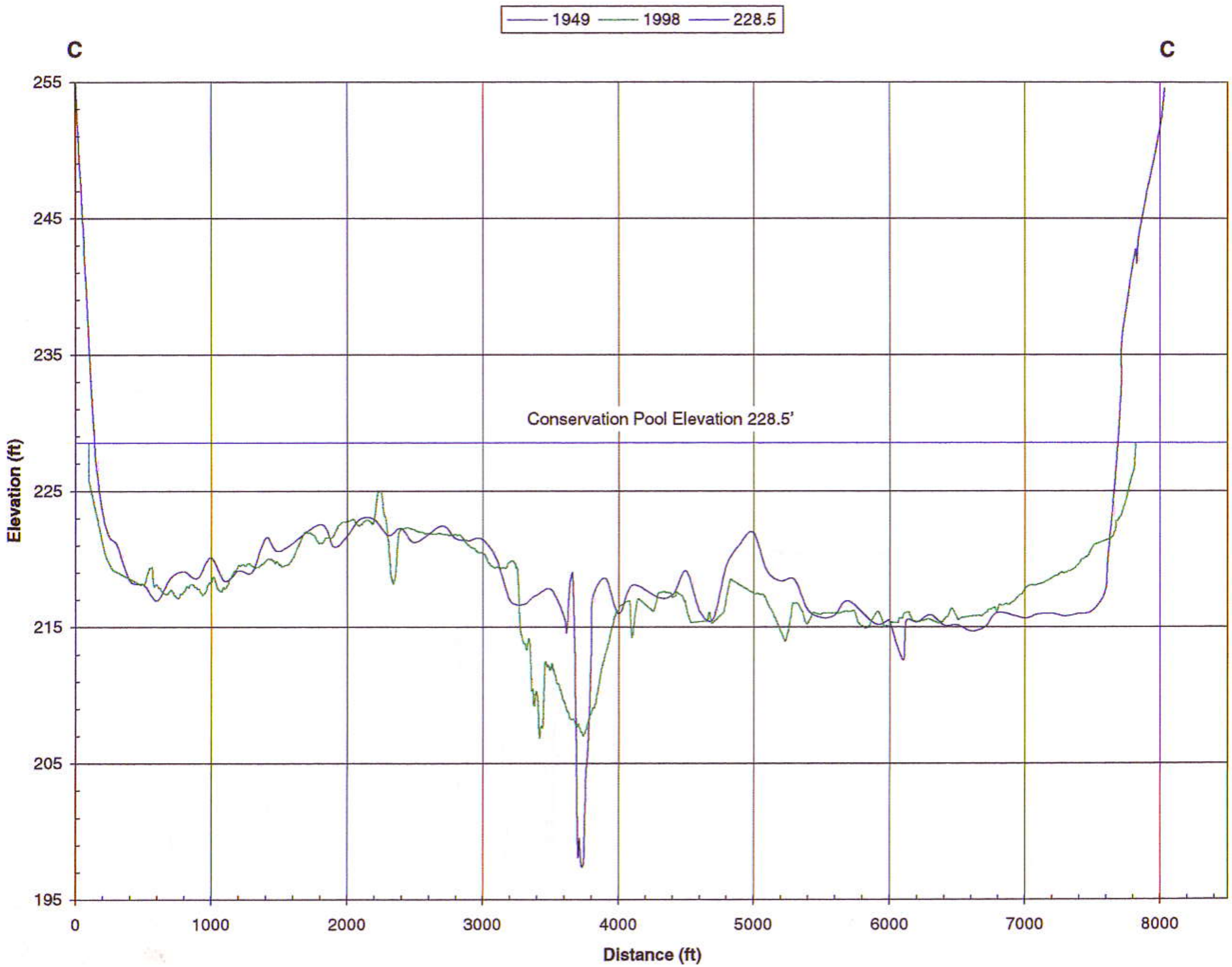
Sedimentation Range No. 1



Sedimentation Range No. 8

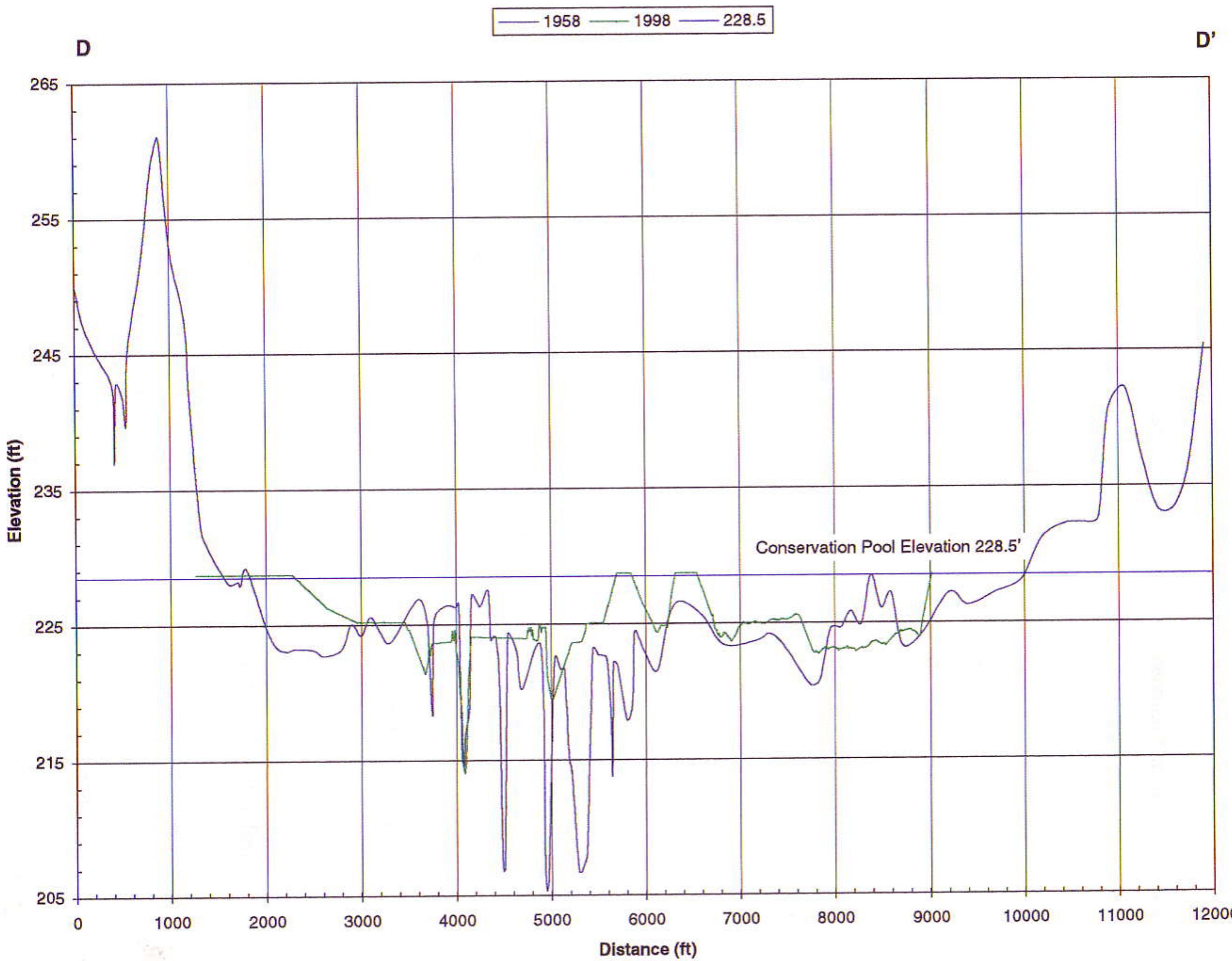


Sedimentation Range No. 14



Appendix D

Sedimentation Range No. 17



Appendix D

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):

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

APPENDIX F - GPS BACKGROUND

GPS Information

The following is a brief and simple description of Global Positioning System (GPS) technology. GPS is a relatively new technology that uses a network of satellites, maintained in precise orbits around the earth, to determine locations on the surface of the earth. GPS receivers continuously monitor the satellite broadcasts to determine the position of the receiver. With only one satellite being monitored, the point in question could be located anywhere on a sphere surrounding the satellite with a radius of the distance measured. The observation of two satellites decreases the possible location to a finite number of points on a circle where the two spheres intersect. With a third satellite observation, the unknown location is reduced to two points where all three spheres intersect. One of these points is located in space, and is ignored, while the second is the point of interest located on earth. Although three satellite measurements can fairly accurately locate a point on the earth, the minimum number of satellites required to determine a three dimensional position within the required accuracy is four. The fourth measurement compensates for any time discrepancies between the clock on board the satellites and the clock within the GPS receiver.

The United States Air Force and the defense establishment developed GPS technology in the 1960’s. After program funding in the early 1970's, the initial satellite was launched on February 22, 1978. A four-year delay in the launching program occurred after the Challenger space shuttle disaster. In 1989, the launch schedule was resumed. Full operational capability was reached on April 27, 1995 when the NAVSTAR (NAVigation System with Time And Ranging) satellite constellation was composed of 24 Block II satellites. Initial operational capability, a full constellation of 24 satellites, in a combination of Block I (prototype) and Block II satellites, was achieved December 8, 1993. The NAVSTAR satellites provide data based on the World Geodetic System (WGS '84) spherical datum. WGS '84 is essentially identical to the 1983 North American Datum (NAD '83).

The United States Department of Defense (DOD) is currently responsible for implementing and maintaining the satellite constellation. In an attempt to discourage the use of these survey units as a guidance tool by hostile forces, DOD implemented means of false signal projection called Selective Availability (S/A). Positions determined by a single receiver when S/A is active result in errors to the actual position of up to 100 meters. These errors can be reduced to centimeters by performing a static survey with two GPS receivers, one of which is set over a point with known coordinates. The errors induced by S/A are time-constant. By monitoring the movements of the satellites over time (one to three hours), the errors can be minimized during post processing of the collected data and the unknown position computed accurately.

Differential GPS (DGPS) is an advance mode of satellite surveying in which positions of moving objects can be determine in real-time or "on-the-fly." This technological breakthrough was the backbone of the development of the TWDB’s Hydrographic Survey Program. In the early stages of the program, one GPS receiver was set up over a benchmark with known coordinates established by the hydrographic survey crew. This receiver remained stationary during the survey and monitored the movements of the satellites overhead. Position corrections were determined and transmitted via a radio link once per second to another GPS receiver located on the moving boat. The boat receiver used these corrections, or differences, in combination with the satellite information it received to determine its differential location. This type of operation can provide horizontal positional accuracy within one meter. In addition, the large positional errors experienced by a single receiver when S/A is active are negated. The lake surface during the survey serves as the vertical datum for the bathymetric readings from a depth sounder. The sounder determines the lake's depth below a given horizontal location at the surface.

The need for setting up a stationary shore receiver for current surveys has been eliminated by registration with a fee-based satellite reference position network (OmniSTAR). This service works on a worldwide basis in a differential mode basically the same way as the shore station. For a given area in the world, a network of several monitoring sites (with known positions) collect GPS signals from the NAVSTAR network. GPS corrections are computed at each of these sites to correct the GPS signal received to the known coordinates of the site. The correction corresponding to each site are automatically sent to a “Network Control Center” where they are checked and repackaged for up-link to a “Geostationary” L-band satellite. The “real-time” corrections are then broadcast by the satellite to users of the system in the area covered by that satellite. The OmniSTAR receiver translates the information and supplies it to the on-board Trimble receiver for correction of the boat’s GPS positions. The accuracy of this system in a real-time mode is normally 1 meter or less.

Previous Survey Procedures

Originally, reservoir surveys were conducted by stretching a rope across the reservoir along pre-determined range lines and, from a small boat, poling the depth at selected intervals along the rope. Over time, aircraft cable replaced the rope and electronic depth sounders replaced the pole. The boat was hooked to the cable, and depths were recorded at selected intervals. This method, used mainly by the Soil Conservation Service, worked well for small reservoirs.

Larger bodies of water required more involved means to accomplish the survey, mainly due to increased size. Cables could not be stretched across the body of water, so surveying instruments were utilized to determine the path of the boat. Monuments were set at the end points of each line so the same lines could be used on subsequent surveys. Prior to a survey, each end point had to be located (and sometimes reestablished) in the field and vegetation cleared so that line of sight could be maintained. One surveyor monitored the path of the boat and issued commands via radio to insure that it remained on line while a second surveyor determined the horizontal location by turning angles. Since it took a major effort to determine each of the points along the line, the depth readings were spaced quite a distance apart. Another major cost was the land surveying required prior to the reservoir survey to locate the range line monuments and clear vegetation.

Electronic positioning systems were the next improvement. Continuous horizontal positioning by electronic means allowed for the continuous collection of depth soundings by boat. A set of microwave transmitters positioned around the lake at known coordinates allowed the boat to receive data and calculate its position. Line of site was required, and the configuration of the transmitters had to be such that the boat remained within the angles of 30 and 150 degrees with respect to the shore stations. The maximum range of most of these systems was about 20 miles. Each shore station had to be accurately located by survey, and the location monumented for future use. Any errors in the land surveying resulted in significant errors that were difficult to detect. Large reservoirs required multiple shore stations and a crew to move the shore stations to the next location as the survey progressed. Land surveying remained a major cost with this method.

More recently, aerial photography has been used prior to construction to generate elevation contours from which to calculate the volume of the reservoir. Fairly accurate results could be obtained, although the vertical accuracy of the aerial topography is generally one-half of the contour interval or $\pm$ five feet for a ten-foot contour interval. This method can be quite costly and is applicable only in areas that are not inundated.

Figure 1
Lake O' the Pines

Prepared by: TWDB April 1999

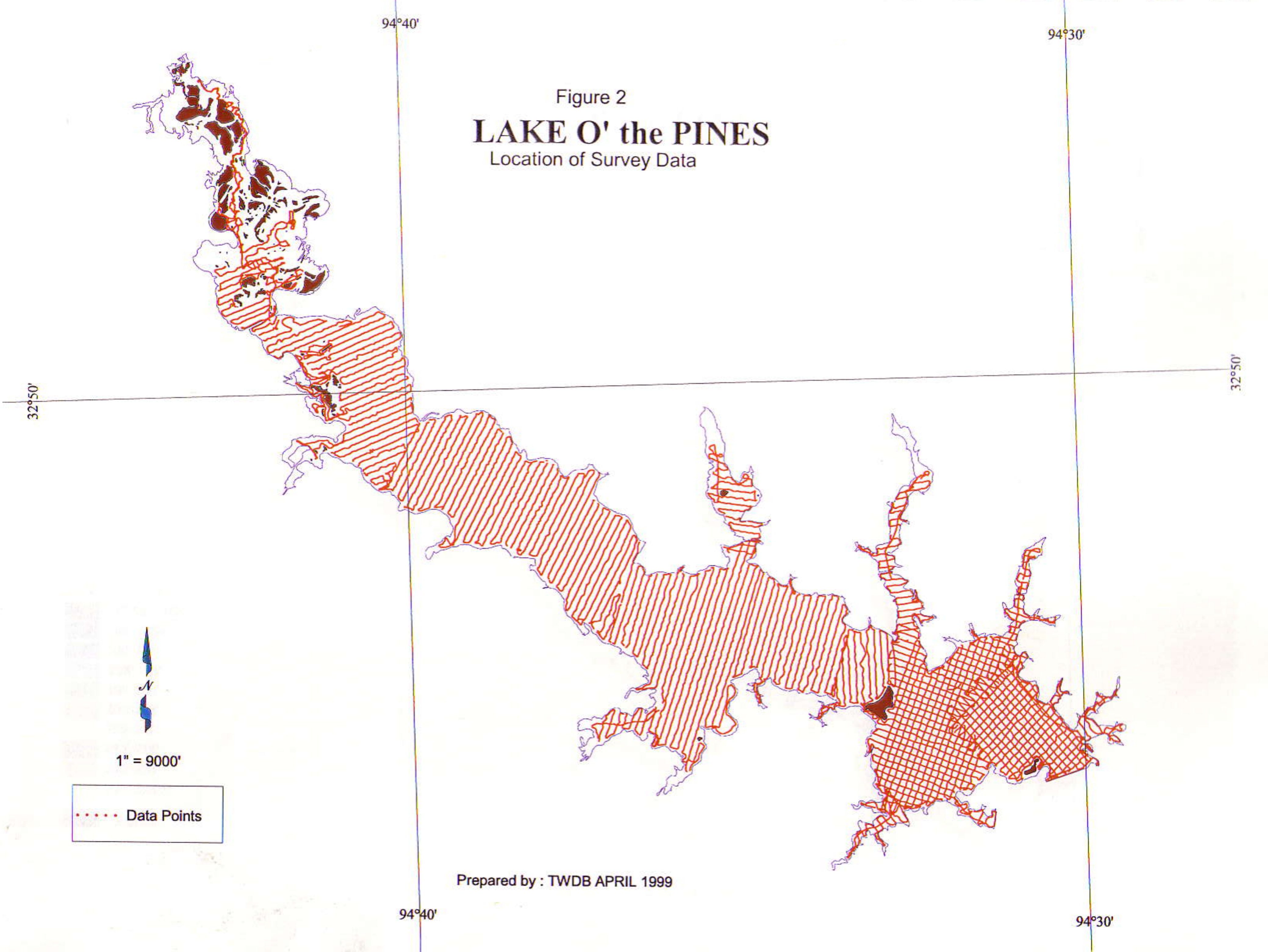
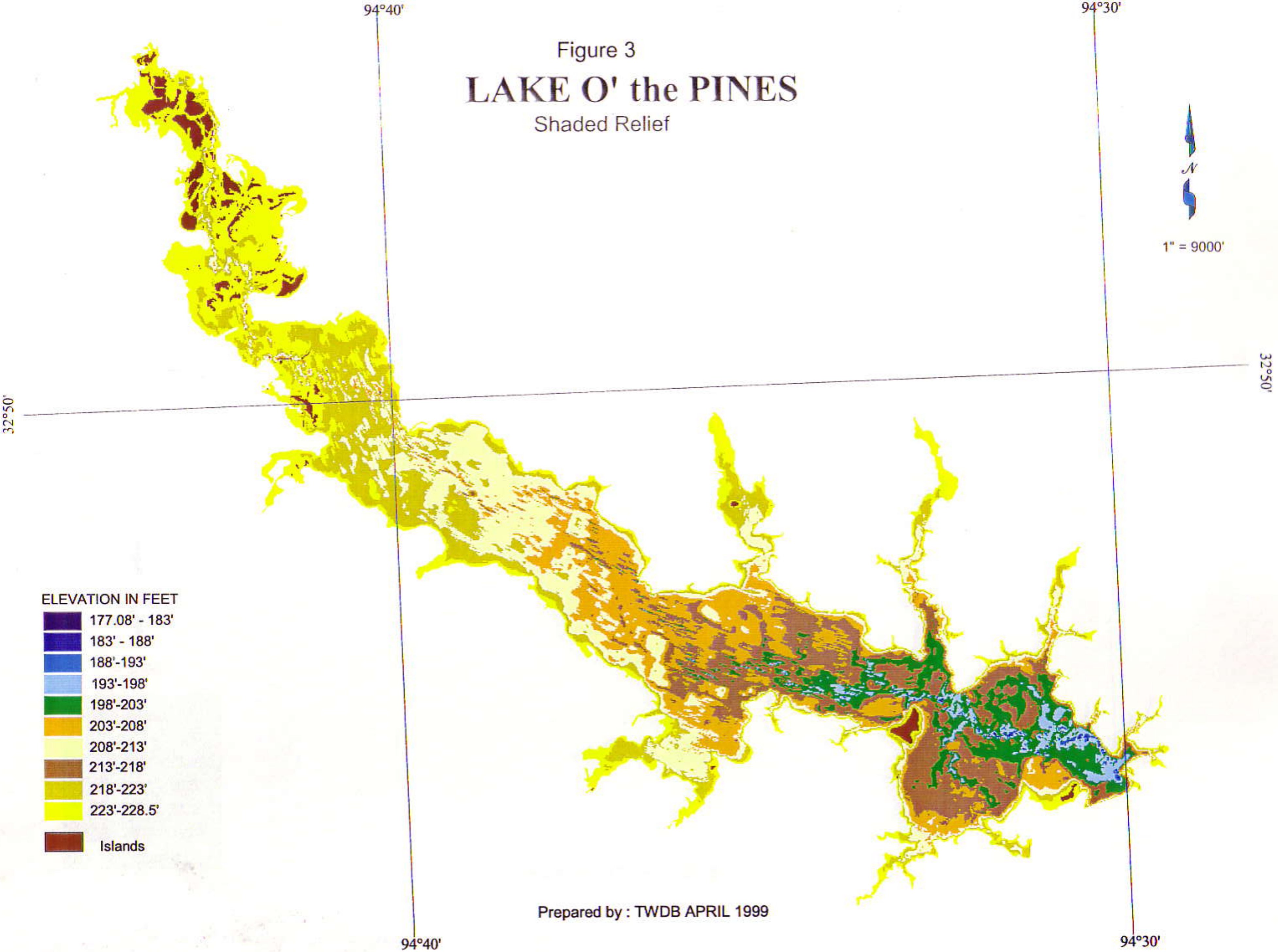


Figure 2
LAKE O' the PINES
Location of Survey Data
94°40'
94°30'
32°50'
32°50'
94°40'
94°30'
N
1" = 9000'
Data Points
Prepared by : TWDB APRIL 1999

Figure 3

LAKE O' the PINES

Shaded Relief

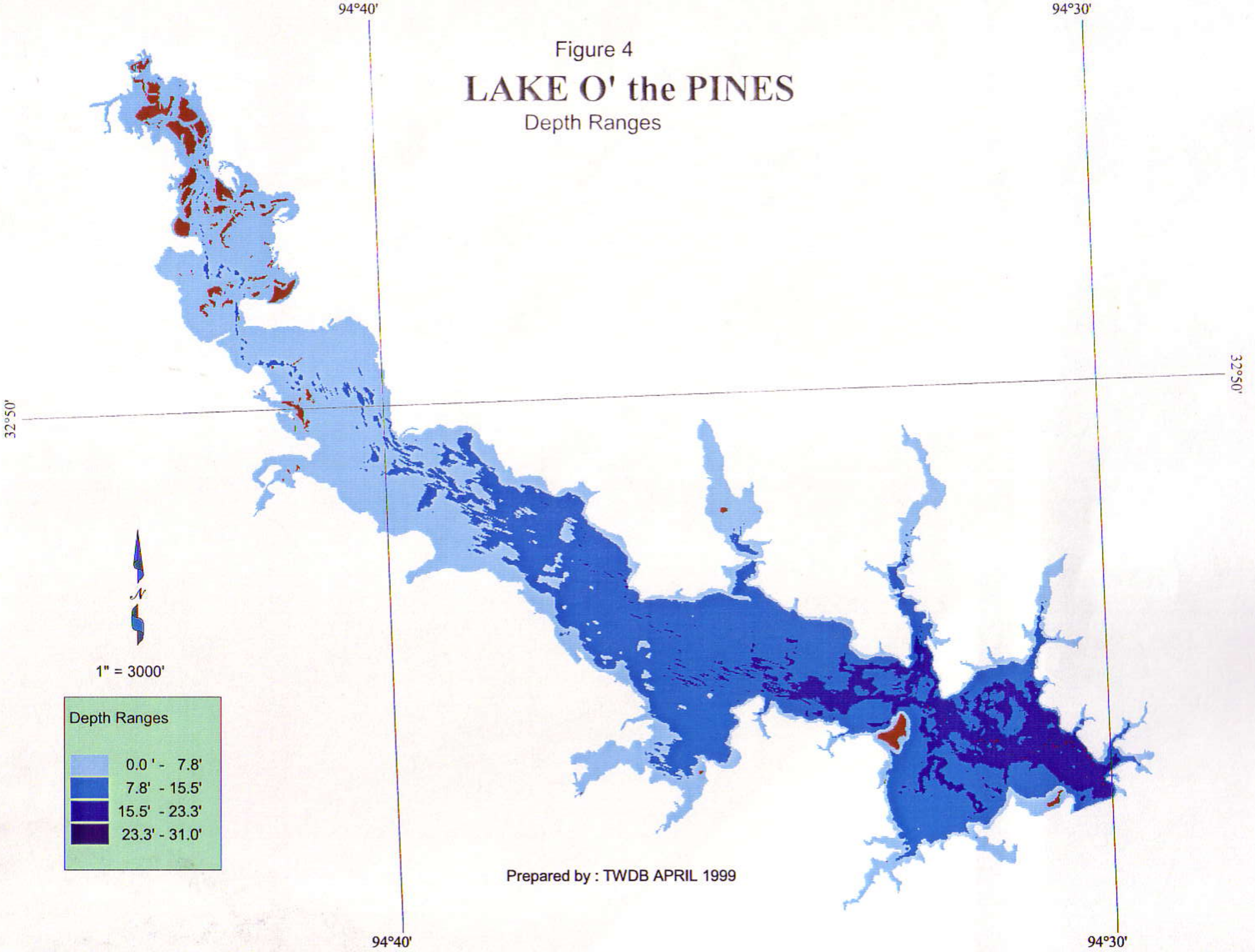


Prepared by : TWDB APRIL 1999

Figure 4

LAKE O' the PINES

Depth Ranges



Prepared by : TWDB APRIL 1999


LAKE O' the PINES
2' - Depth Contour Map
N
2000 0 2000 4000 6000 8000 10000 Feet
TEXAS WATER DEVELOPMENT BOARD
228.8' Surface Elevation
Water Surface
Islands
Depth Contours
0.8
2.8
4.8
6.8
8.8
10.8
12.8
14.8
16.8
18.8
20.8
22.8
24.8
26.8
28.8
30.8
32.8
34.8
This map is the product of a survey conducted by the Texas Water Development Board's Hydrographic Survey Program to determine the capacity of Lake O' the Pines. The Texas Water Development Board makes no representations and assumes no liability if this information is used for other purposes such as boating maps.
Prepared by : TEXAS WATER DEVELOPMENT BOARD APRIL 1999