VOLUMETRIC SURVEY OF LAKE BOB SANDLIN

Prepared for:

Titus County Fresh Water Supply District No. 1

Prepared by:

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INTRODUCTION

Staff of the Hydrographic Survey Unit of the Texas Water Development Board (TWDB) conducted a hydrographic survey of Lake Bob Sandlin during the period of February 9 – 18, 1998. The purpose of the survey was to determine the capacity of the lake at the 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 will be reported in feet above mean sea level based on the National Geodetic Vertical Datum of 1929 (NGVD '29) unless the elevation is noted otherwise. The conservation pool elevation for Lake Bob Sandlin is 337.5 feet. The design information/field survey estimates the original surface area at this elevation to be 9,460 acres and the storage volume to be 213,350 acre-feet of water.

HISTORY AND GENERAL INFORMATION OF THE RESERVOIR

Titus County Fresh Water Supply District No. 1 owns the water rights to Lake Bob Sandlin and operates and maintains associated Fort Sherman Dam. The lake is located on Big Cypress Creek in Camp, Franklin, Titus and Wood Counties, five miles southwest of Mt. Pleasant, Texas (see Figure 1). Records indicate the drainage area is approximately 239 square miles. At the conservation pool elevation, the lake has approximately 75.14 miles of shoreline and is 11.3 miles long. The widest point of the reservoir is approximately 2.8 miles (located 7.1 miles upstream of the dam).

Water Rights Permit No. 2794 (Application No. 2966), dated November 13, 1972, was issued to the Titus County Fresh Water Supply District No. 1. This permit authorized the construction of a dam and reservoir to impound 213,350 acre-feet of water. It granted the owner the right to divert and use annually 44,000 acre-feet of water for municipal and industrial purposes. The Texas Water

Commission issued Certificate of Adjudication No. 04-4564 on October 13, 1986. The certificate basically reinforces the authorization for the Titus County Fresh Water Supply District No. 1 to impound 213,350 acre-feet of water in an existing reservoir known as Lake Bob Sandlin. The owner was authorized to divert and use not to exceed 10,000 acre-feet of water per year for municipal purposes and 38,500 acre-feet of water annually for industrial purposes. Authorization was also granted to use the impounded water for recreational purposes.

Records indicate the deliberate impoundment for Lake Bob Sandlin began August 8, 1977 and the project was officially completed in April 1978. The design engineer for the facility was URS, Forrest and Cotton Consulting Engineers. The general contractor was H. B. Zachery Construction Company.

Fort Sherman Dam and appurtenant structures consist of a rolled earth fill embankment, 10,800 feet in length, with a maximum height of 69 feet and a crest elevation of 349.0 feet. The upstream slope of the embankment is covered by soil cement (two-foot thick) for erosion control. The service spillway is located at the left (north) abutment and is a concrete chute with an ogee crest. The crest is 160 feet in net length at elevation 316.5 feet. Four tainter gates, each 22.5 feet tall and 40 feet wide, control the service spillway. The emergency spillway, located to the left (north) of the dam, is an earth trench cut through the natural ground. The uncontrolled broad-crested weir is 4,500 feet in length at elevation 341.3 feet. The outlet work is a conduit located in a spillway gate pier with an invert elevation of 294.5* feet. The three and one-half feet by six feet opening is controlled by a sluice gate.

HYDROGRAPHIC SURVEYING TECHNOLOGY

The following sections will describe the theory behind Global Positioning System (GPS) technology and its accuracy. Equipment and methodology used to conduct the subject survey and previous hydrographic surveys are also addressed.

* Revision Date 3/20/01

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 broadcasts from the satellites 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 obviously in error because its location is in space, and it is ignored. 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, the DOD has 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 obtain a horizontal positional accuracy of within one meter. In addition, the large positional errors experienced by a single receiver when S/A is active are negated. Since a greater accuracy is needed in the vertical direction, the depth sounder supplies vertical data during a survey. The lake surface during the survey serves as the vertical datum for the readings from the depth sounder.

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 in a differential mode basically the same way as the shore station, except on a worldwide basis. 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 corrections from each of the sites within the network are automatically sent via a leased line to a "Network Control Center" where the data corrections are checked and repackaged for up-link to a "Geostationary" L-band satellite. The "real-time" corrections for the entire given area in the world are then broadcast by the satellite to users of the system in the area covered by the 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 one meter or less.

Equipment and Methodology

The equipment used in the performance of the hydrographic survey consisted 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 through an in-line uninterruptible power supply provided electric power. 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 gathers 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 daily data files collected are downloaded 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 daily-recorded lake elevation 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 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 below.

Previous Survey Procedures

Originally, reservoir surveys were conducted with a rope stretched across the reservoir along pre-determined range lines. A small boat would manually pole 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 again 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. Monumentation was set for 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 depth measurement locations 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. If triangulation could determine the boat location by electronic means, then the boat could take continuous depth soundings. A set of microwave transmitters positioned around the lake at known coordinates would allow 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 was generally one-half of the contour interval or ± five feet for a ten-foot contour interval. This method could be quite costly and was only applicable in areas that were not inundated.

PRE-SURVEY PROCEDURES

The reservoir's surface area was determined prior to the survey by digitizing with AutoCad software the 740-foot contour. The boundary file was created from the 7.5-minute USGS quadrangle maps, HARVARD, TX. 1964; MONTICELLO, TX. 1965; PURLEY, TX. 1964; and NEW HOPE, TX. 1965. The graphic boundary file created was then transformed into the proper datum, from NAD '27 datum to NAD '83, using Environmental Systems Research Institute's (ESRI) Arc/Info project command with the NADCOM parameters. The area of the lake boundary was checked to verify that the area was the same in both datums.

The survey layout was designed by placing survey track lines at 500-foot intervals across the lake. The survey design for this lake required approximately 169 survey lines to be placed along the length of the lake. Survey setup files were created using Coastal Oceangraphics, 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.

SURVEY PROCEDURES

The following procedures were followed during the hydrographic survey of Lake Bob Sandlin performed by the TWDB. Information regarding equipment calibration and operation, the field survey, and data processing is presented.

Equipment Calibration and Operation

At the beginning of each surveying day, the depth sounder was calibrated with the Innerspace Velocity Profiler. The Velocity Profiler calculates an average speed of sound through the water column of interest for a designated draft value of the boat (draft is the vertical distance that the boat penetrates the water surface). The draft of the boat was previously determined to average 1.2 ft. The velocity profiler probe is placed in the water to moisten and acclimate the probe. The probe is then raised to the water surface where the depth is zeroed. The probe is lowered on a cable to just below the maximum depth set for the water column, and then raised to the surface. The unit displays an average speed of sound for a given water depth and draft, which is entered into the depth sounder. The depth value on the depth sounder 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 Bob Sandlin, the speed of sound in the water column varied between 4,751 to 4,769 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, plus an estimated error of $\pm$0.3 feet due to the plane of the boat for a total accuracy of $\pm$0.5 feet for any instantaneous reading. These errors tend to be minimized over the entire survey, since some are positive and some are negative readings. Further information on these calculations is presented in Appendix A.

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 horizontal positions. 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 setup 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 Bob Sandlin during the period of February 9-18, 1998. Approximately 103,887 data points were collected over the 194.7 miles traveled along the 181 pre-planned survey lines and the random data-collection lines. These points were stored digitally on the boat's computer in 215 data files. Weather conditions varied during the nine days of data collection. Several of the days the crew experienced excellent weather with moderate temperatures and mild winds. Other times the winds were gusty, creating very rough water. On February 10, a large area-wide thunderstorm forced the crew to suspend data collection after just one hour of work. In addition, on February 11, seven lines of data were collected above the Highway 1520 bridge on Barefoot Bay using a small boat outfitted with a recording depth sounder. 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 the land surrounding the lake to be generally flat to rolling hills. Along the shoreline, the crew observed several older subdivisions with existing bulkheads, piers and boat slips. New home construction was observed in the area of Thunderbird and Cherokee Points. Across the lake from these subdivisions, the undeveloped areas were experiencing bank erosion. Within the lake, the crew noted that the main body of the lake was uniformed in width and that there were no islands at the water level during the survey.

While performing the survey on the lake, TWDB noted the bathemetry reflected the characteristics of the terrain surrounding the lake. A gradual slope from the shoreline to the center of the old creek bed was observed on the depth sounder chart paper. The channel of Big Cypress Creek was located near the center of the lake throughout the main body of the lake. The old creek channel could be observed on the analog chart as the boat traversed across the lake from bank to bank.

There were some areas in the lake that the crew encountered navigational hazards such as standing or submerged trees and stumps. Sediment deposits and standing vegetation were observed mainly in the upper reaches of the lake. The crew was able to collect data in these areas, but at a much slower pace. Data collection in the headwaters was limited when the boat could no longer cross the lake 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 future 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. The depth information collected every 0.1 seconds was averaged to get one reading for each second of data collection. 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 337.57 and 337.76 feet. After all changes had been made 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, representative of the lake, to be used with the GIS software to develop a model of the lake's bottom surface. In addition, the seven lines collected using the recording depth sounder only, were digitized and converted to data points by incrementing each cross-section in 1 foot increments along both the X,Y and Z axes. This procedure was accomplished by running an Arc/Info script file developed by TWDB staff. The seven lines converted into 5,406 data points.

The resulting data file was imported into the UNIX operating system used to run Environmental System Research Institute's (ESRI) Arc/Info GIS software and converted 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 software module. The module builds an irregular triangulated network from the data points and the boundary file. This software uses 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 preserved for use in determining the solution of the model by using this method. The generated network of three-dimensional triangular planes represents the actual bottom surface. Once the triangulated irregular network (TIN) is formed, the software then calculates elevations along the triangle surface plane by solving the equations for elevation along each leg of the triangle. Information for the entire reservoir area can be determined from the triangulated irregular network created using this method of interpolation.

If data points were collected outside the boundary file, the boundary was modified to include the data points. The boundary file in areas of significant sedimentation was also downsized as deemed necessary based on the data points and the observations of the field crew. The resulting boundary shape was used to develop each of the map presentations of the lake in this report.

There were some areas where volume and area values could not be calculated by interpolation because of a lack of information within the reservoir. "Flat triangles" were drawn at these locations. Arc/Info does not use flat triangle areas in the volume or contouring features of the model. Approximately 8,984 additional points were required for interpolation and contouring of the entire lake surface at elevation 337.5. Volumes and areas were calculated from the TIN for the entire reservoir at one-tenth of a foot intervals. From elevation 329.5 to elevation 337.5, the surface areas and volumes of the lake were mathematically estimated. This was done first by distributing uniformly across each elevation increment; the surface areas digitized from USGS topographic maps. Volumes were then calculated in a 0.1 foot step method by adding to the existing volume, 0.1 of the existing area, and 0.5 of the difference between the existing area the area for the value being calculated. The computed area of lake at elevation 337.5 was 9,004 surface acres. The computed area was 456 surface acres less than originally calculated. The computed reservoir volume table is presented in Appendix B and the area table in Appendix C. An elevation-area-volume graph is presented in Appendix D.

Other presentations developed from the model include a shaded relief map and a shaded depth range map. 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. Using the POLYSHADE command, colors were assigned to the range of elevations represented by the polygons that varied from navy to yellow. The lower elevation was assigned the color of navy, and the 337.5 lake elevation was assigned the color of yellow. Different color shades were assigned to the intermediate depths. Figure 3 presents the resulting depth shaded representation of the lake. Figure 4 presents a similar version of the same map, using bands of color for selected depth intervals. The color increases in intensity from the shallow contour bands to the deep-water bands.

Linear filtration algorithms were then applied to the DTM smooth cartographic contours versus using the sharp-engineered contours. The resulting contour map of the bottom surface at two-foot intervals is presented in Figure 5.

RESULTS

Results from the 1998 TWDB survey indicate Lake Bob Sandlin encompasses 9,004 surface acres and contains a volume of 204,678 acre-feet at the conservation pool elevation of 337.5 feet. The shoreline at this elevation was calculated to be 75.14 miles. The deepest point of the lake, elevation 281.45 or 56.05 feet of depth was located approximately 3,935 feet north northwest from the center of the dam. The dead storage volume, or the amount of water below the lowest outlet in the dam, was calculated to be 4,099* acre-feet based on the low flow outlet invert elevation of 294.5* feet. The conservation storage capacity, or the amount of water between the spillway and the lowest outlet, is therefore 200,579* acre-feet.

SUMMARY

Lake Bob Sandlin was formed in 1978. Initial storage calculations estimated the volume at the conservation pool elevation of 337.5 feet to be 213,350 acre-feet with a surface area of 9,460 acres.

During the period of February 9 – 18, 1998, a hydrographic survey of Lake Bob Sandlin was performed by the Texas Water Development Board's Hydrographic Survey Program. The 1998 survey used technological advances such as differential global positioning system and geographical information system technology to build a model of the reservoir's bathemetry. These advances allowed a survey to be performed quickly and to collect significantly more data of the bathemetry of Lake Bob Sandlin than previous survey methods. Results indicate that the lake's volume* at the conservation pool elevation of 337.5 feet was 204,678 acre-feet and the area was 9,004 acres.

The estimated reduction in volume* at the conservation pool elevation of 337.5 feet since 1978 is 8,672 acre-feet or 433.6 acre-feet per year. The average annual deposition rate of sediment in the conservation pool of the reservoir can be estimated at 1.8142 acre-feet per square mile of drainage area.

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

__* Revision Date 3/20/01

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 capacity.

CALCULATION OF DEPTH SOUNDER ACCURACY

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

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

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')

TEXAS WATER DEVELOPMENT BOARD

May 13 1998

RESERVOIR VOLUME TABLE

Lake Bob Sandlin   February 1998 Survey

VOLUME IN ACRE-FEET   ELEVATION INCREMENT IS ONE TENTH FOOT

ELEV. FEET	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
282										
283			1	1	1	1	1	1	2	2
284	2	2	3	3	3	4	4	4	5	5
285	6	7	7	8	9	10	11	12	14	15
286	17	19	21	24	27	30	33	37	41	46
287	51	56	63	70	78	86	96	108	120	133
288	147	162	179	197	216	236	257	280	304	330
289	357	385	414	445	478	512	547	585	624	665
290	708	753	799	848	897	949	1001	1056	1111	1168
291	1226	1285	1346	1408	1472	1537	1603	1670	1739	1810
292	1881	1954	2028	2103	2179	2257	2335	2415	2496	2579
293	2663	2748	2835	2923	3013	3105	3198	3292	3388	3486
294	3584	3684	3786	3889	3993	4099	4207	4316	4427	4540
295	4654	4769	4887	5006	5127	5250	5374	5500	5628	5758
296	5890	6023	6157	6293	6431	6570	6710	6852	6995	7140
297	7286	7434	7584	7735	7888	8041	8196	8353	8510	8669
298	8830	8991	9154	9319	9484	9652	9820	9990	10161	10334
299	10508	10684	10862	11041	11221	11403	11586	11770	11956	12143
300	12331	12520	12711	12903	13096	13290	13485	13681	13879	14077
301	14277	14478	14681	14885	15090	15297	15506	15717	15929	16143
302	16358	16576	16794	17015	17237	17461	17686	17913	18142	18372
303	18605	18839	19074	19311	19550	19790	20032	20275	20519	20765
304	21012	21260	21509	21760	22012	22265	22519	22775	23032	23290
305	23549	23810	24072	24336	24601	24867	25135	25404	25675	25947
306	26220	26495	26771	27048	27327	27606	27887	28169	28453	28737
307	29023	29310	29599	29888	30179	30471	30764	31058	31353	31649
308	31947	32246	32546	32848	33151	33455	33760	34068	34376	34686
309	34998	35311	35626	35943	36262	36582	36904	37227	37552	37878
310	38206	38535	38866	39199	39534	39871	40209	40550	40892	41235
311	41581	41928	42277	42628	42980	43334	43690	44047	44406	44767
312	45130	45495	45862	46230	46601	46974	47348	47725	48103	48484
313	48866	49251	49637	50025	50415	50807	51201	51596	51994	52393
314	52794	53198	53603	54009	54418	54829	55241	55655	56070	56488
315	56907	57328	57751	58176	58602	59030	59460	59892	60325	60760
316	61196	61635	62075	62516	62959	63404	63851	64300	64751	65204
317	65659	66116	66574	67035	67498	67963	68430	68900	69372	69846
318	70322	70801	71281	71764	72249	72737	73227	73719	74214	74712
319	75212	75714	76219	76727	77237	77750	78265	78783	79302	79824
320	80348	80873	81401	81931	82463	82997	83533	84070	84609	85151
321	85694	86239	86786	87335	87885	88437	88991	89546	90103	90662
322	91223	91785	92349	92914	93481	94050	94621	95193	95767	96343
323	96921	97500	98081	98664	99248	99835	100423	101013	101605	102198
324	102794	103391	103990	104591	105194	105798	106405	107013	107623	108236
325	108850	109466	110085	110706	111329	111954	112581	113211	113842	114476
326	115112	115751	116392	117036	117682	118332	118984	119639	120297	120957
327	121619	122284	122950	123620	124291	124965	125641	126320	127001	127685
328	128371	129060	129751	130444	131140	131838	132538	133240	133945	134652
329	135371	136093	136816	137542	138270	139001	139733	140468	141205	141945
330	142686	143430	144176	144924	145675	146427	147182	147940	148699	149461

RESERVOIR VOLUME TABLE

Lake Bob Sandlin February 1998 Survey

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

ELEV. FEET	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
331	150225	150991	151759	152530	153303	154078	154855	155635	156417	157201
332	157987	158775	159566	160359	161154	161952	162752	163554	164358	165164
333	165973	166784	167597	168412	169230	170050	170872	171696	172523	173351
334	174183	175016	175851	176689	177529	178371	179216	180062	180911	181762
335	182616	183471	184329	185189	186052	186916	187783	188652	189524	190397
336	191273	192151	193031	193914	194798	195685	196574	197466	198360	199255
337	200154	201054	201957	202861	203769	204678	205589	206503	207419	208338
338	209258	210181	211106	212033	212962	213894	214828	215764	216703	217643
339	218586	219531	220479	221428	222380	223334	224290	225249	226210	227173
340	228138									

TEXAS WATER DEVELOPMENT BOARD

RESERVOIR AREA TABLE

May 13 1998

Lake Bob Sandlin February 1998 Survey

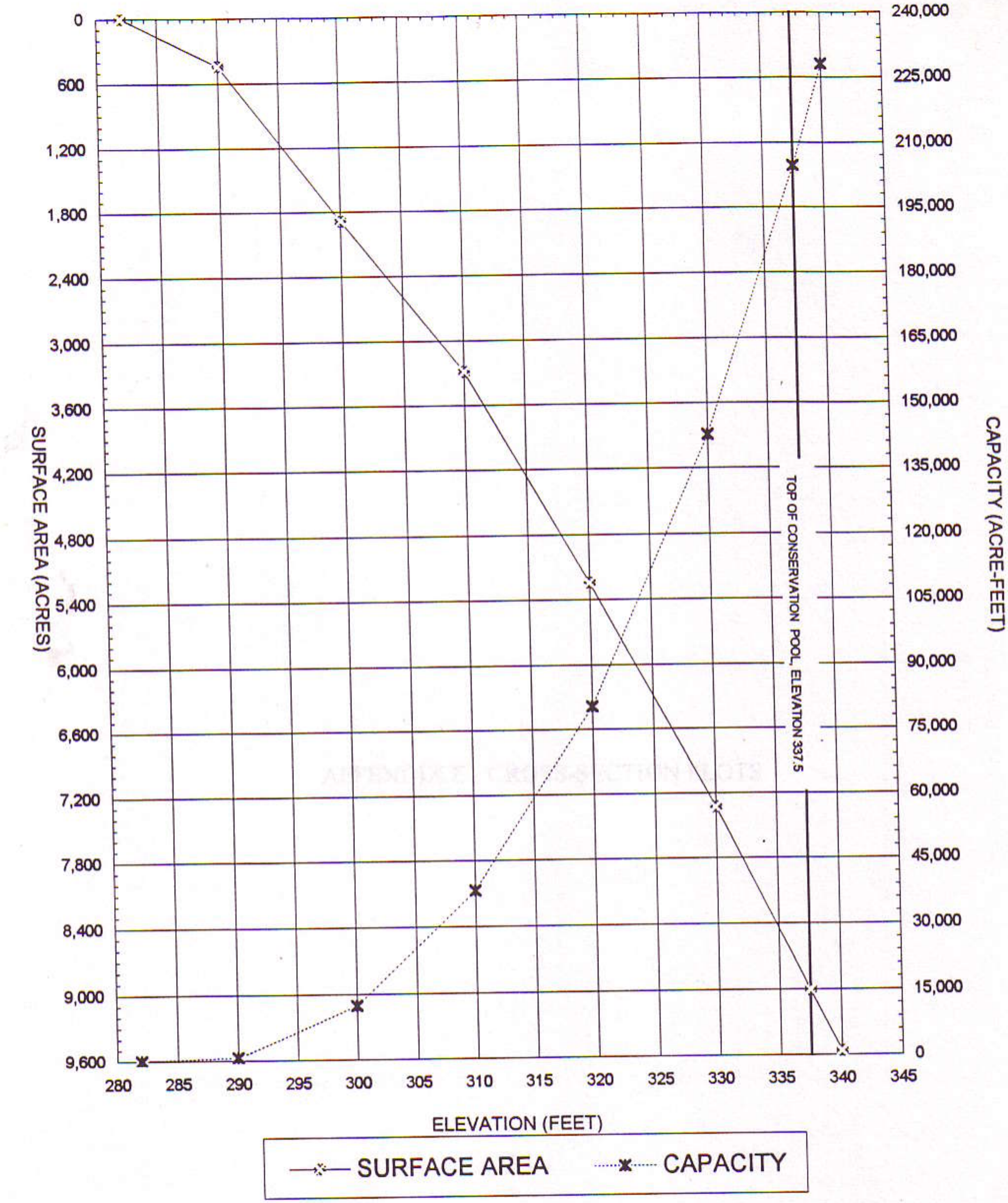
AREA IN ACRES ELEVATION INCREMENT IS ONE TENTH FOOT

ELEV. FEET	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
282								1	1	1
283	1	1	1	1	2	2	2	2	2	2
284	3	3	3	3	3	4	4	4	5	5
285	6	6	7	8	9	10	12	14	15	17
286	20	22	24	27	30	32	36	40	44	48
287	52	59	67	75	84	94	106	117	127	137
288	147	159	171	183	195	208	222	235	249	262
289	276	288	301	316	333	348	365	382	401	419
290	440	458	474	490	505	520	535	548	562	575
291	588	601	614	628	642	655	669	684	697	709
292	721	733	745	757	768	780	792	805	818	832
293	847	861	876	891	906	922	938	952	967	981
294	994	1008	1022	1037	1053	1069	1085	1100	1116	1133
295	1149	1166	1183	1200	1217	1235	1253	1272	1290	1307
296	1323	1338	1354	1368	1382	1396	1410	1425	1441	1457
297	1473	1489	1504	1518	1531	1544	1556	1569	1583	1596
298	1610	1623	1637	1650	1664	1679	1693	1706	1721	1736
299	1751	1766	1781	1796	1810	1824	1837	1851	1864	1877
300	1888	1900	1912	1923	1935	1946	1957	1969	1981	1993
301	2005	2018	2032	2047	2062	2079	2096	2114	2131	2148
302	2164	2180	2196	2212	2229	2246	2263	2279	2297	2314
303	2331	2347	2364	2379	2395	2410	2424	2436	2449	2462
304	2475	2487	2500	2513	2525	2537	2550	2562	2574	2587
305	2600	2614	2629	2644	2658	2672	2686	2700	2714	2727
306	2740	2753	2766	2778	2790	2802	2816	2828	2841	2853
307	2865	2877	2889	2900	2912	2924	2935	2946	2958	2970
308	2983	2996	3009	3022	3036	3049	3063	3078	3093	3109
309	3125	3142	3161	3178	3195	3210	3225	3240	3255	3270
310	3286	3302	3319	3338	3358	3377	3395	3412	3429	3446
311	3463	3481	3498	3515	3532	3548	3565	3583	3602	3620
312	3638	3656	3675	3696	3717	3738	3757	3776	3795	3815
313	3834	3853	3872	3891	3910	3928	3947	3966	3984	4003
314	4022	4041	4059	4078	4096	4113	4130	4148	4166	4184
315	4202	4220	4238	4255	4272	4290	4307	4324	4341	4357
316	4374	4390	4407	4423	4441	4461	4480	4500	4519	4538
317	4557	4577	4597	4618	4639	4661	4684	4707	4730	4753
318	4775	4796	4818	4840	4862	4887	4913	4938	4963	4988
319	5013	5038	5063	5089	5115	5139	5163	5185	5206	5227
320	5248	5268	5288	5309	5329	5348	5367	5385	5404	5423
321	5442	5460	5477	5495	5512	5529	5546	5563	5580	5596
322	5614	5631	5647	5663	5680	5697	5715	5732	5750	5767
323	5785	5802	5819	5836	5854	5872	5891	5909	5927	5946
324	5964	5982	6000	6018	6036	6055	6073	6093	6113	6134
325	6154	6176	6197	6218	6240	6262	6284	6305	6326	6349
326	6375	6399	6425	6453	6481	6510	6537	6563	6587	6611
327	6634	6657	6681	6703	6727	6751	6775	6800	6824	6849
328	6874	6899	6922	6945	6967	6990	7012	7035	7058	7080
329	7102	7125	7147	7169	7192	7214	7237	7259	7281	7304
330	7326	7348	7371	7393	7416	7438	7460	7483	7505	7527

Lake Bob Sandlin February 1998 Survey

AREA IN ACRES ELEVATION INCREMENT IS ONE TENTH FOOT

ELEV. FEET	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
331	7550	7572	7594	7617	7639	7662	7684	7706	7729	7751
332	7773	7796	7818	7841	7863	7885	7908	7930	7952	7975
333	7997	8020	8042	8064	8087	8109	8131	8154	8176	8198
334	8221	8243	8266	8288	8310	8333	8355	8377	8400	8422
335	8445	8467	8489	8512	8534	8556	8579	8601	8623	8646
336	8668	8691	8713	8735	8758	8780	8802	8825	8847	8870
337	8892	8914	8937	8959	8981	9004	9026	9049	9071	9093
338	9116	9138	9160	9183	9205	9227	9250	9272	9295	9317
339	9339	9362	9384	9406	9429	9451	9474	9496	9518	9541
340	9563									



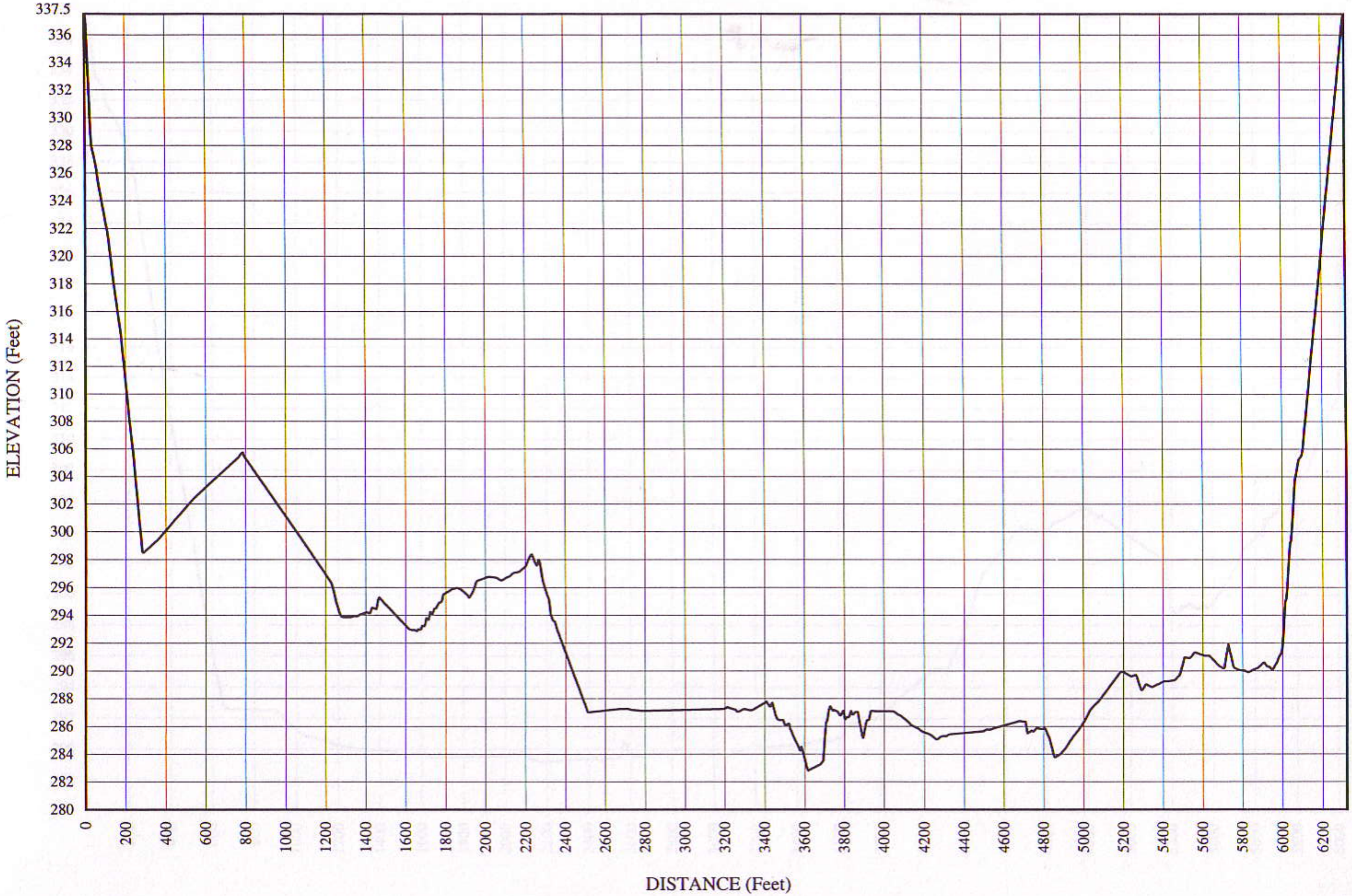
LAKE BOB SANDLIN

February 1998 Survey

Prepared by: TWDB May 1998

LAKE BOB SANDLIN

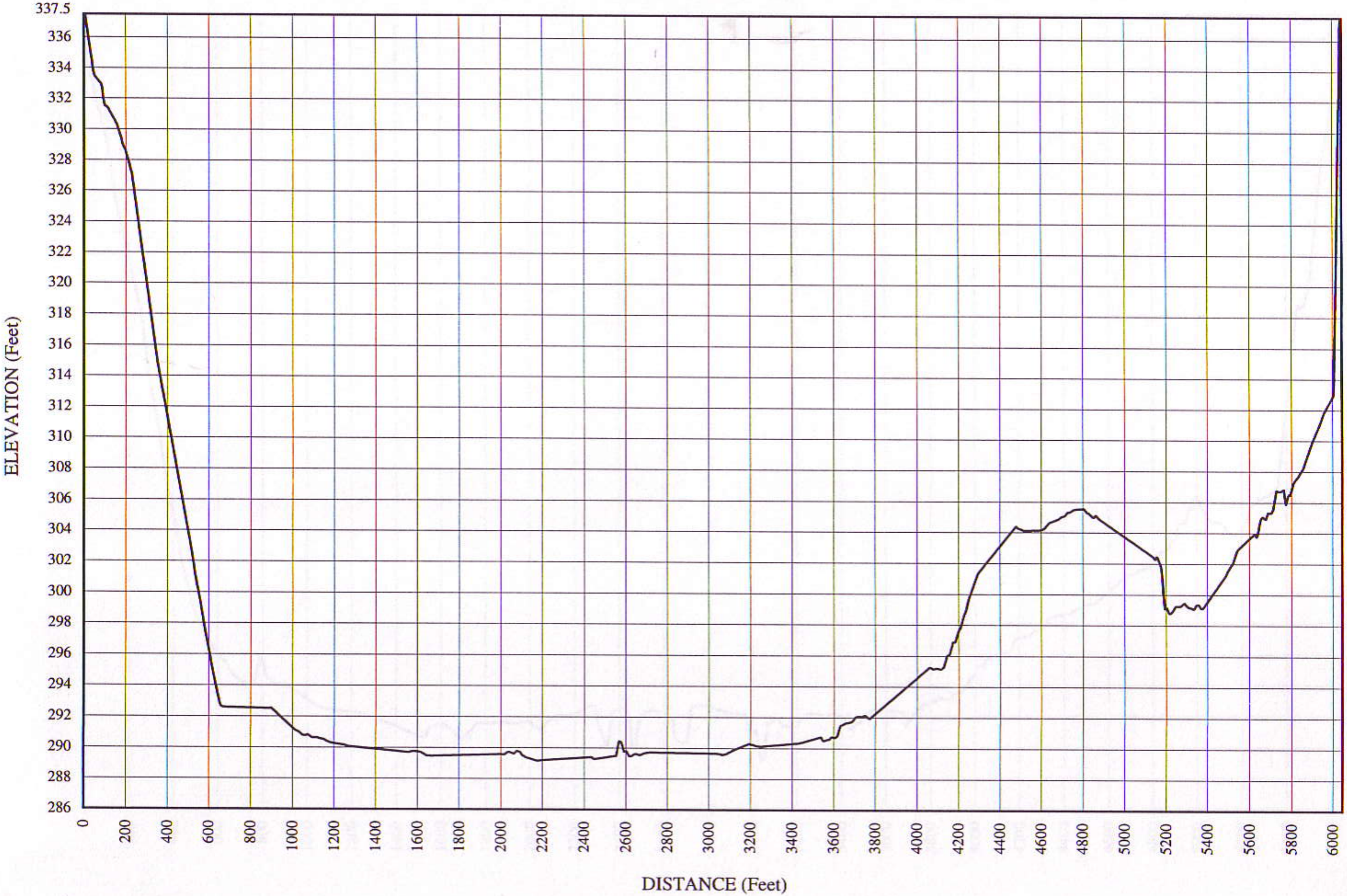
Cross Section A-A'



PREPARED BY: TWDB MAY 1998

LAKE BOB SANDLIN

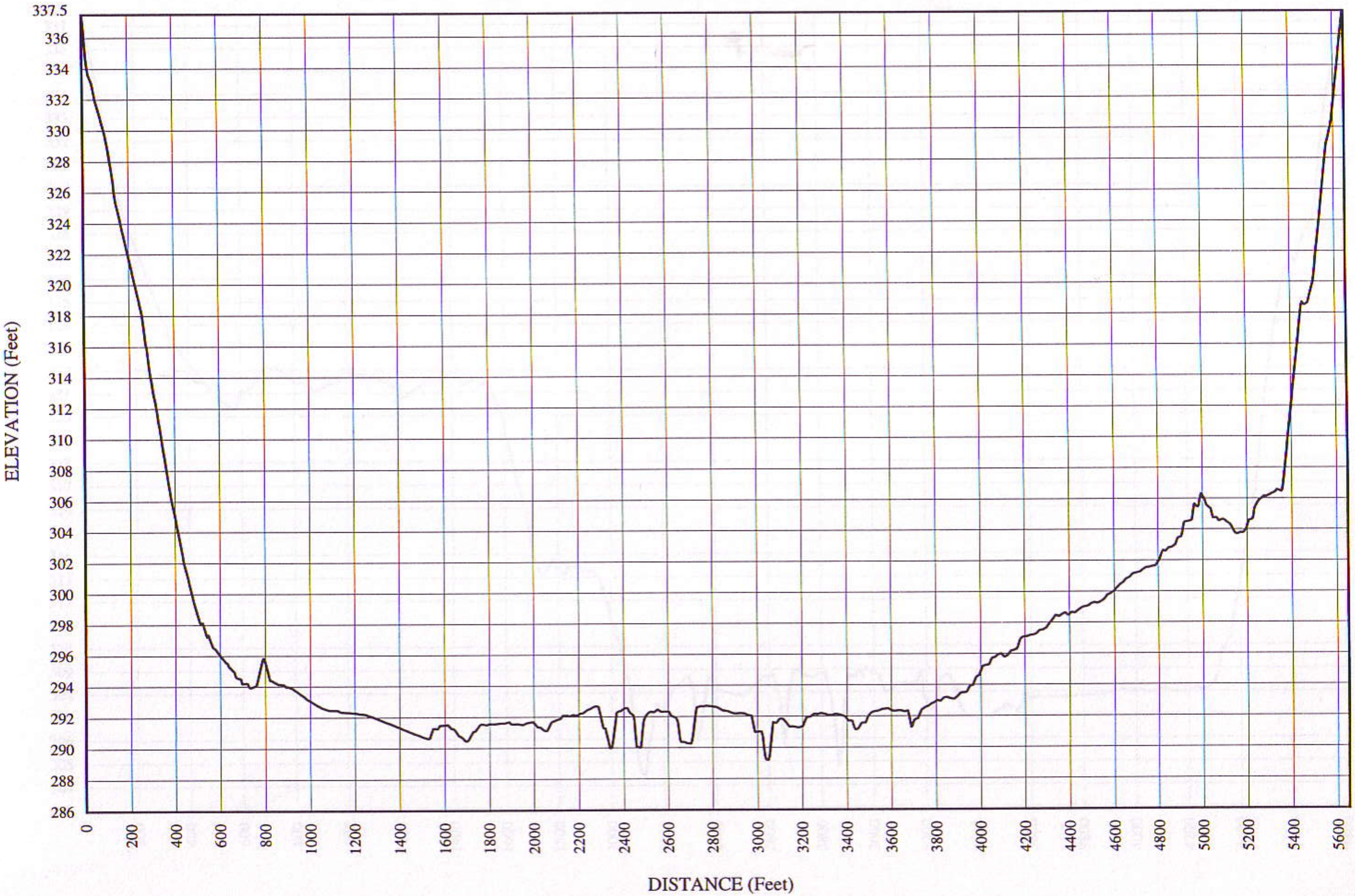
Cross Section B-B'



PREPARED BY: TWDB MAY 1998

LAKE BOB SANDLIN

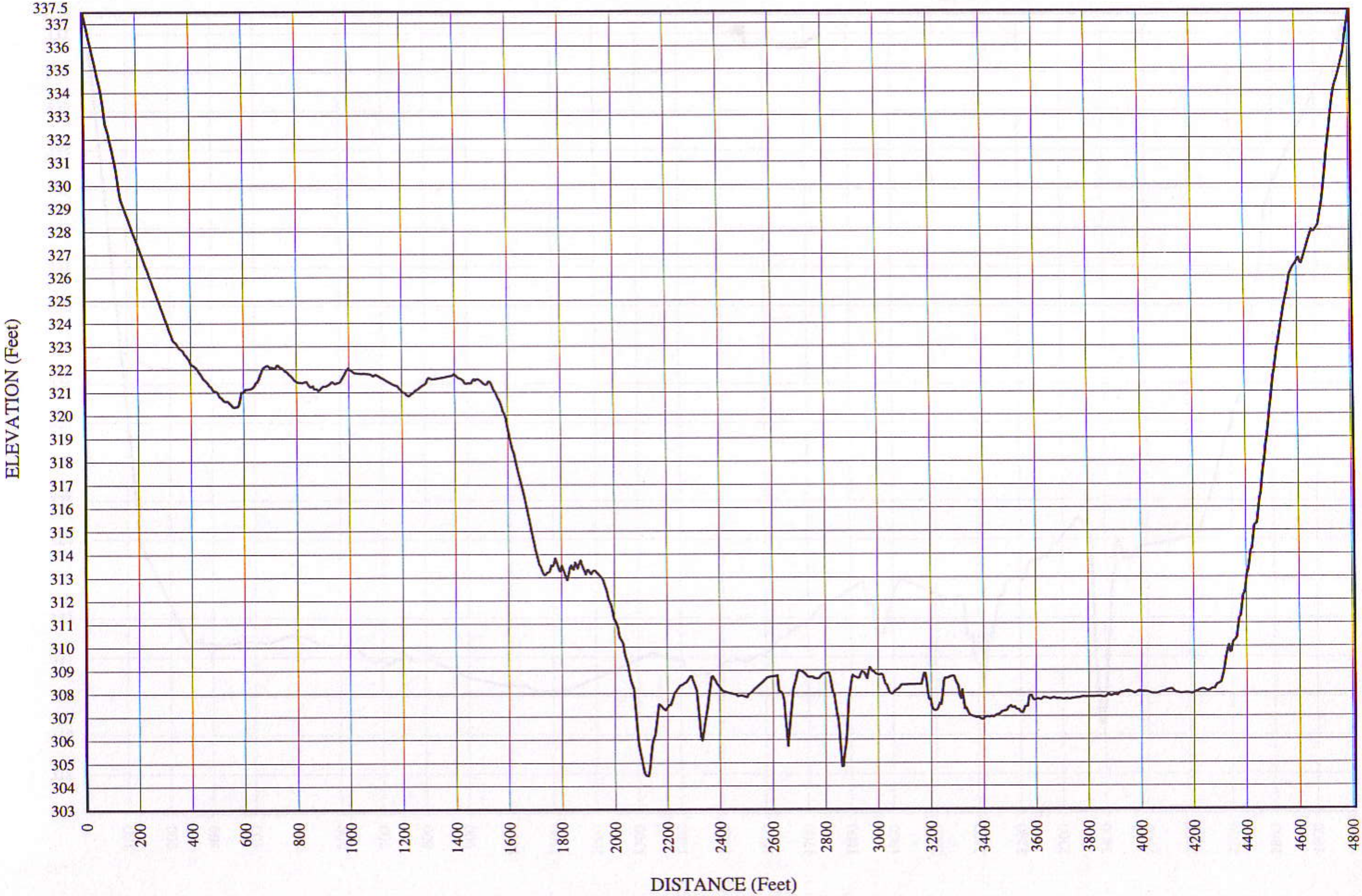
Cross Section C-C'



PREPARED BY: TWDB MAY 1998

LAKE BOB SANDLIN

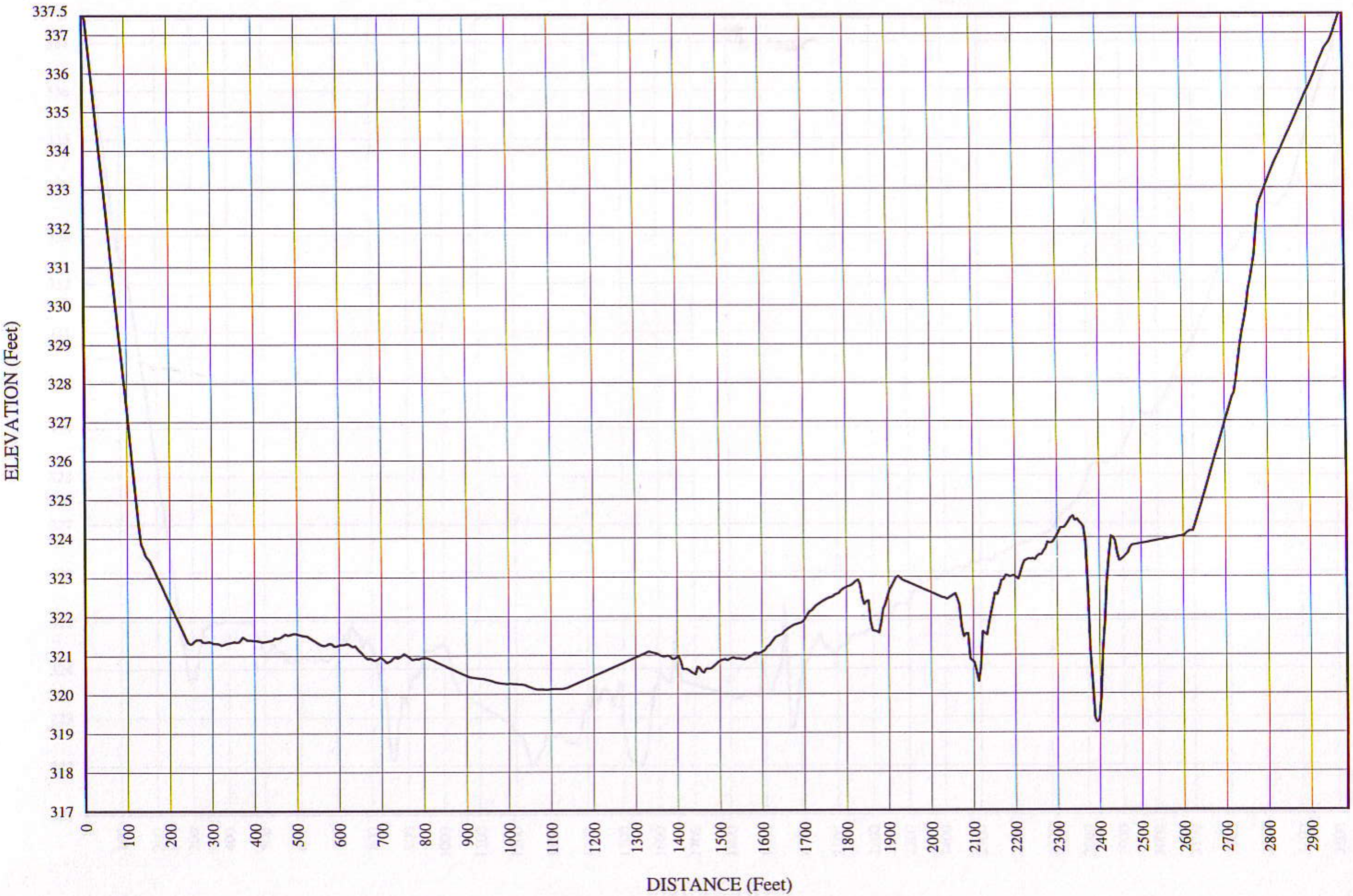
Cross Section D-D'



PREPARED BY: TWDB MAY 1998

LAKE BOB SANDLIN

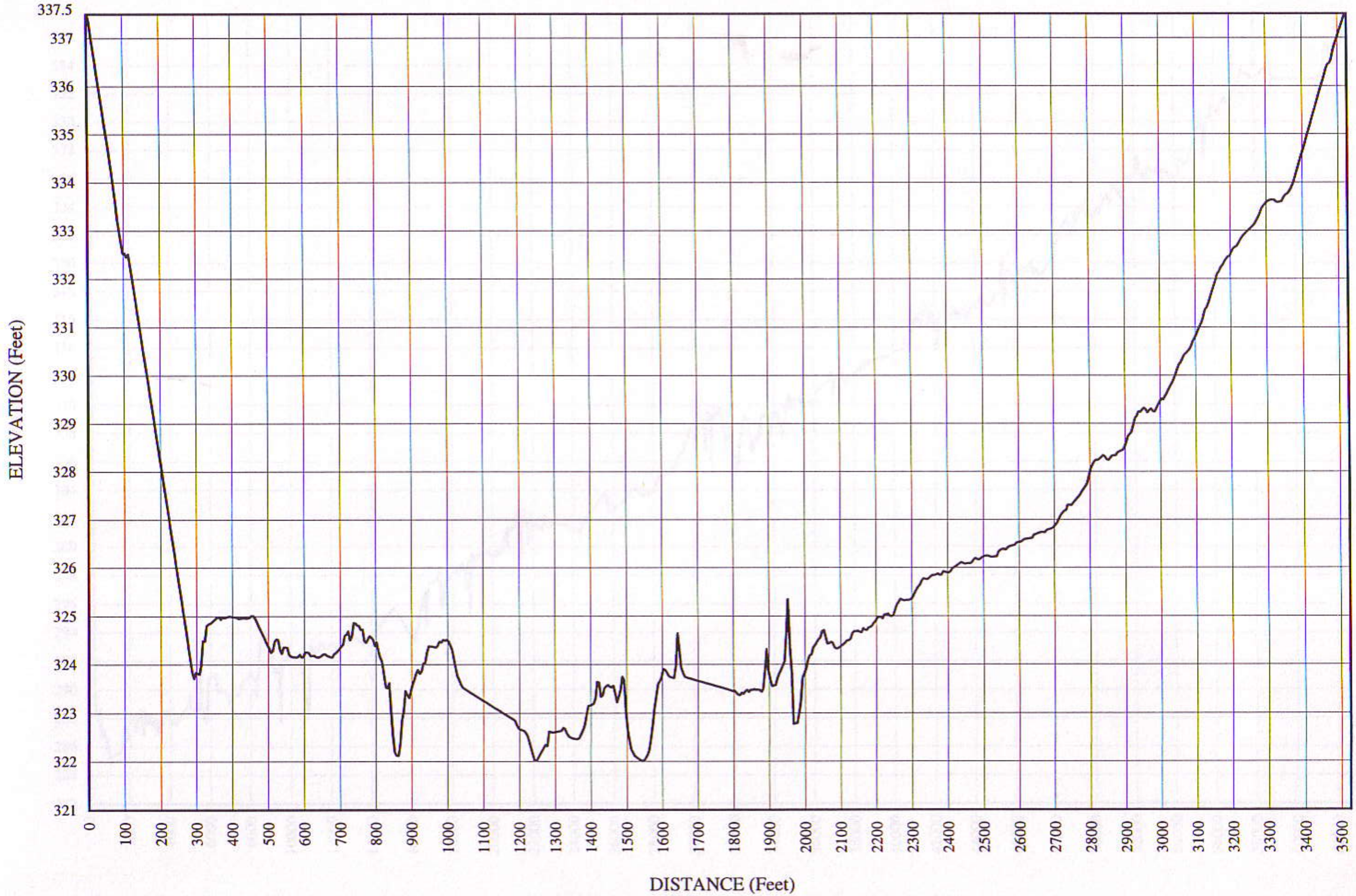
Cross Section E-E'



PREPARED BY: TWDB MAY 1998

LAKE BOB SANDLIN

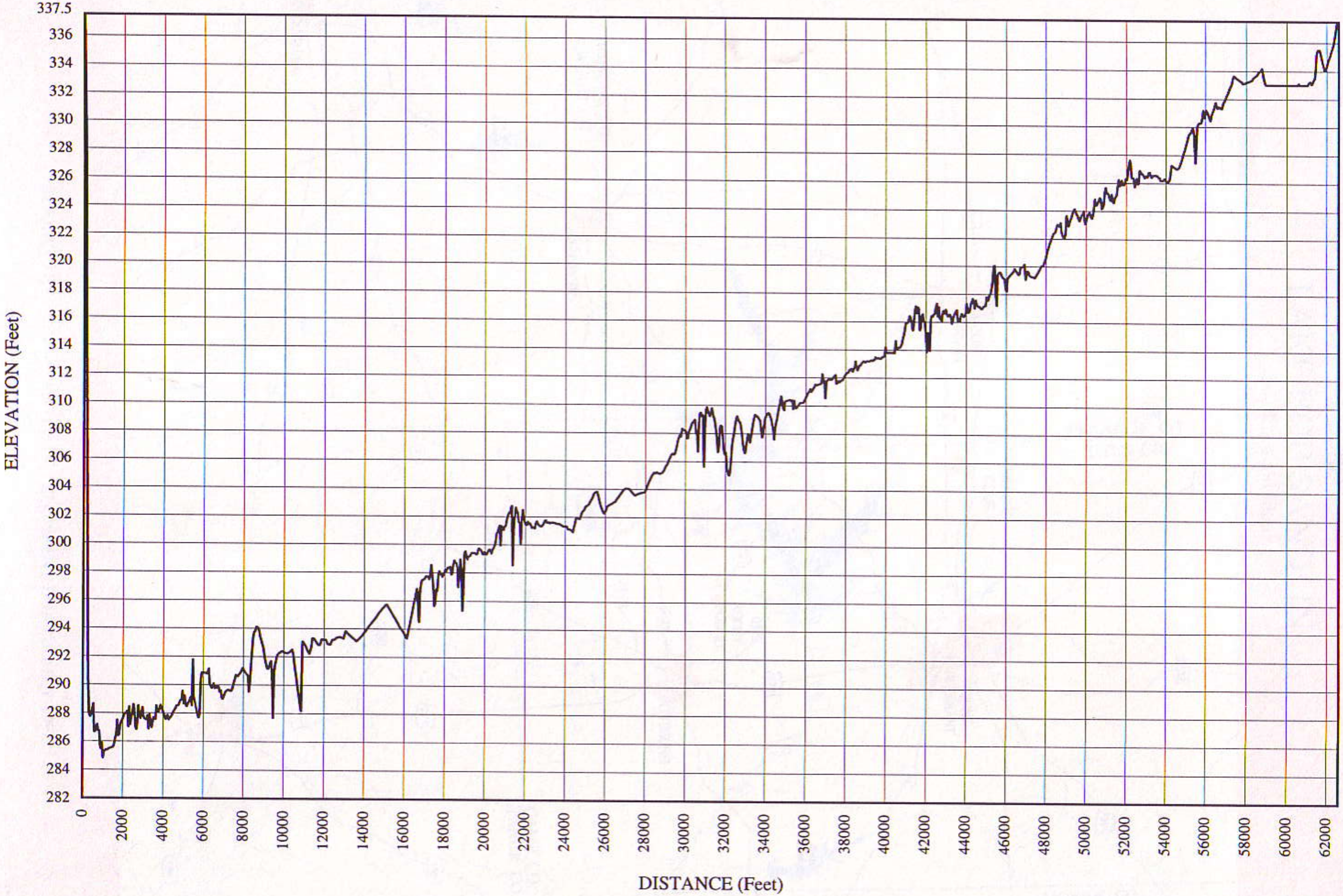
Cross Section F-F'



PREPARED BY: TWDB MAY 1998

LAKE BOB SANDLIN

Cross Section G-G'

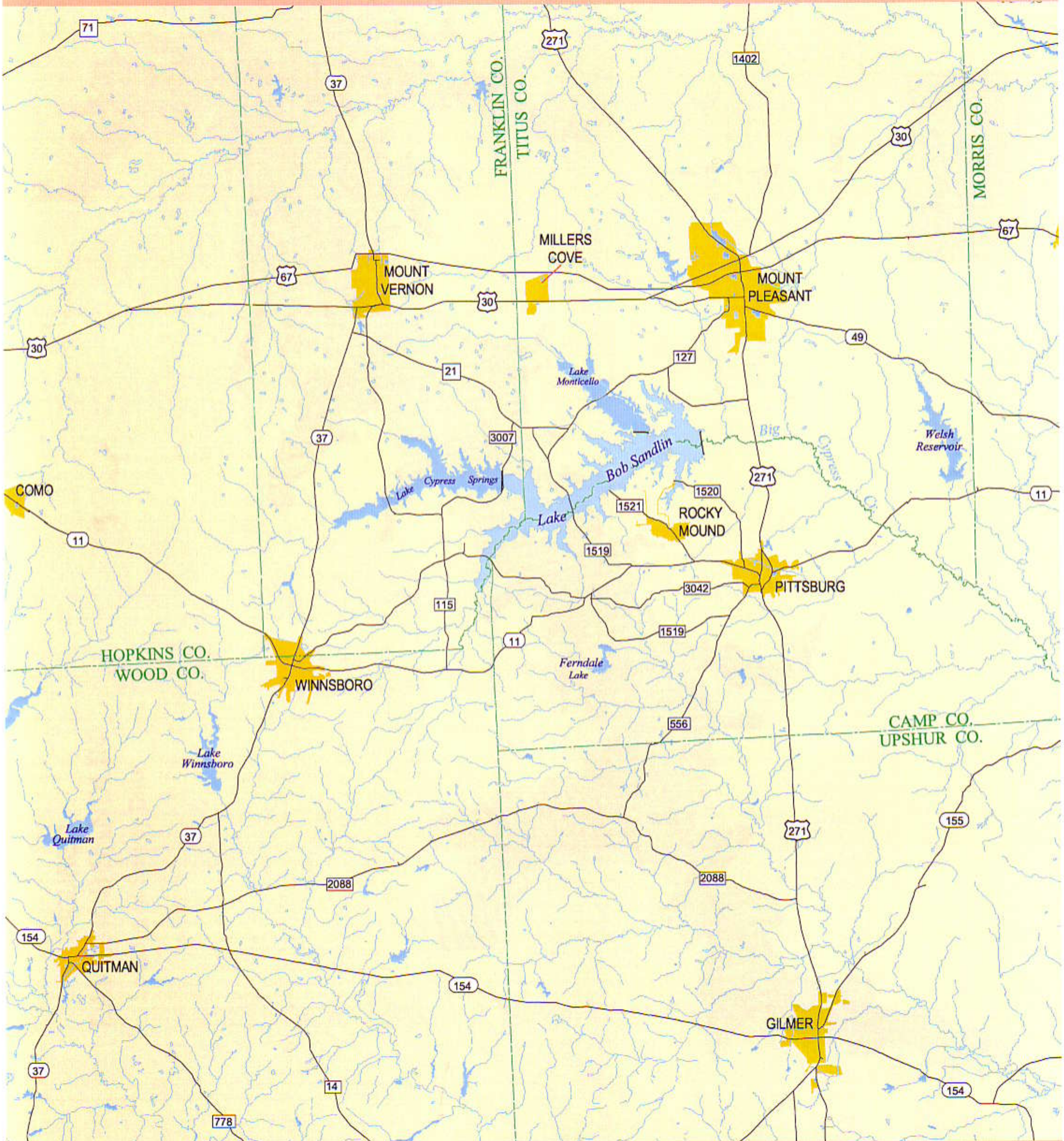


PREPARED BY: TWDB MAY 1998

FIGURE 1

LAKE BOB SANDLIN

Site Location Map



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N

1"= 30000'

FIGURE 2

LAKE BOB SANDLIN

Location of Survey Data

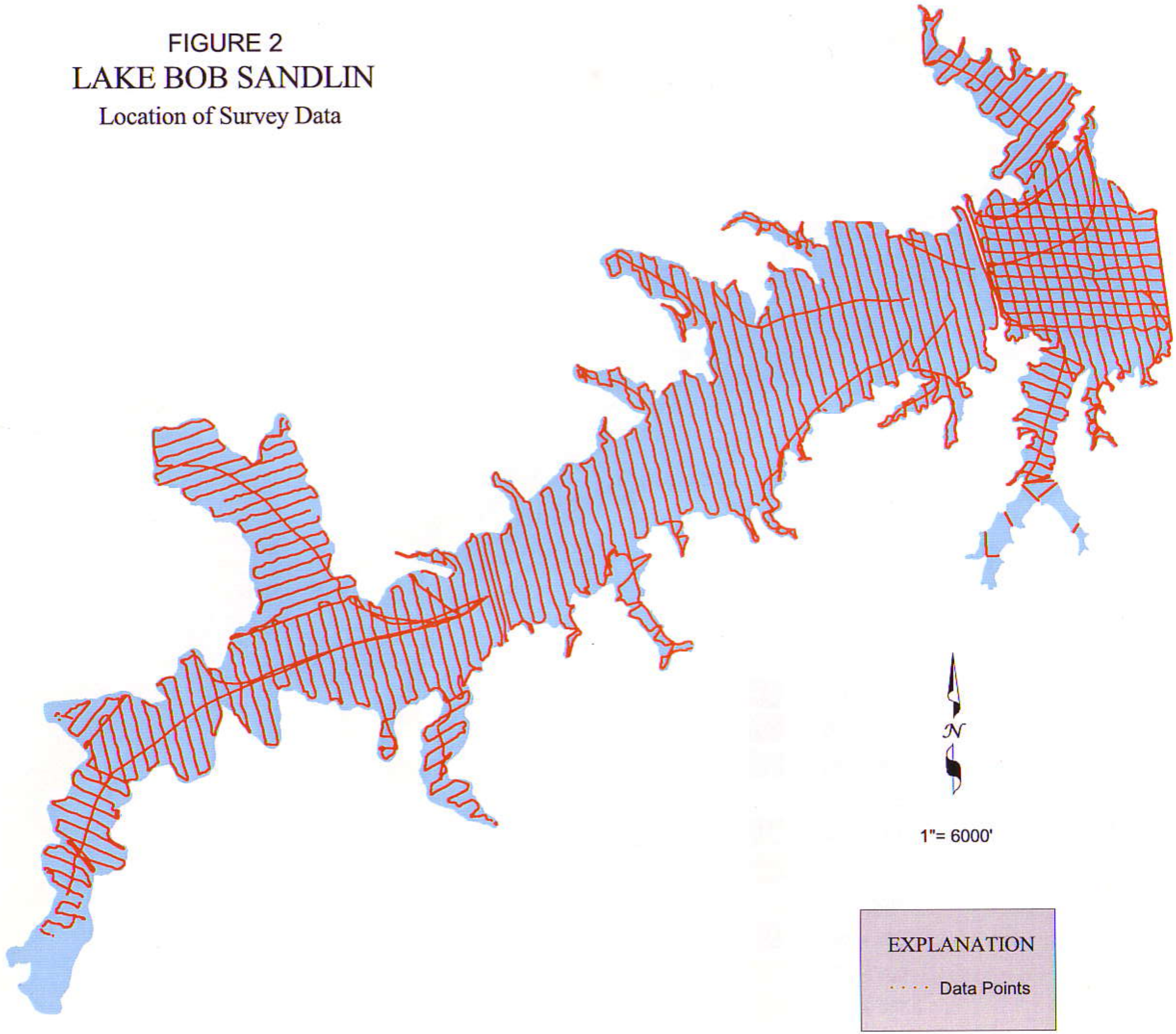

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FIGURE 3

LAKE BOB SANDLIN

Shaded Relief

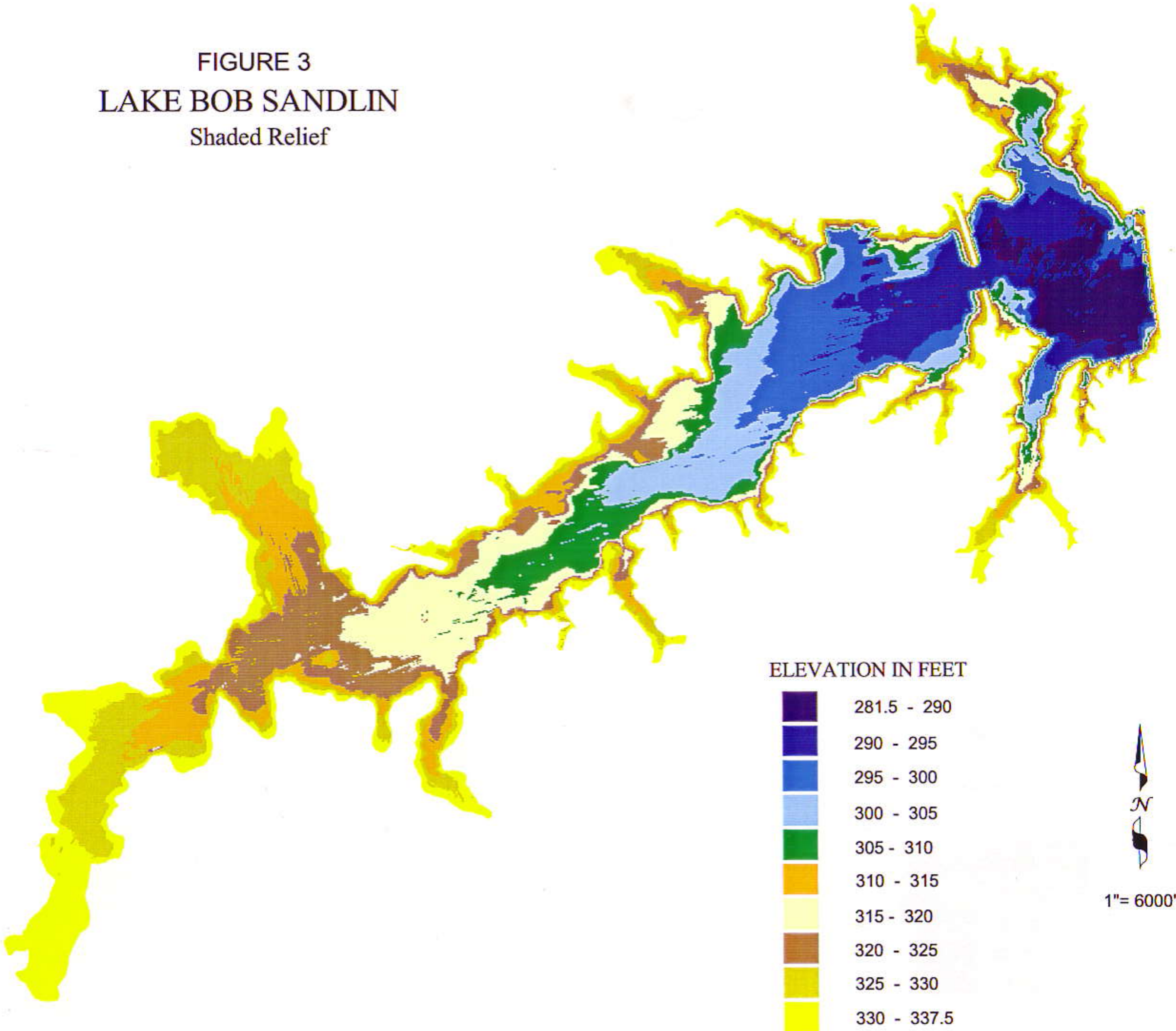

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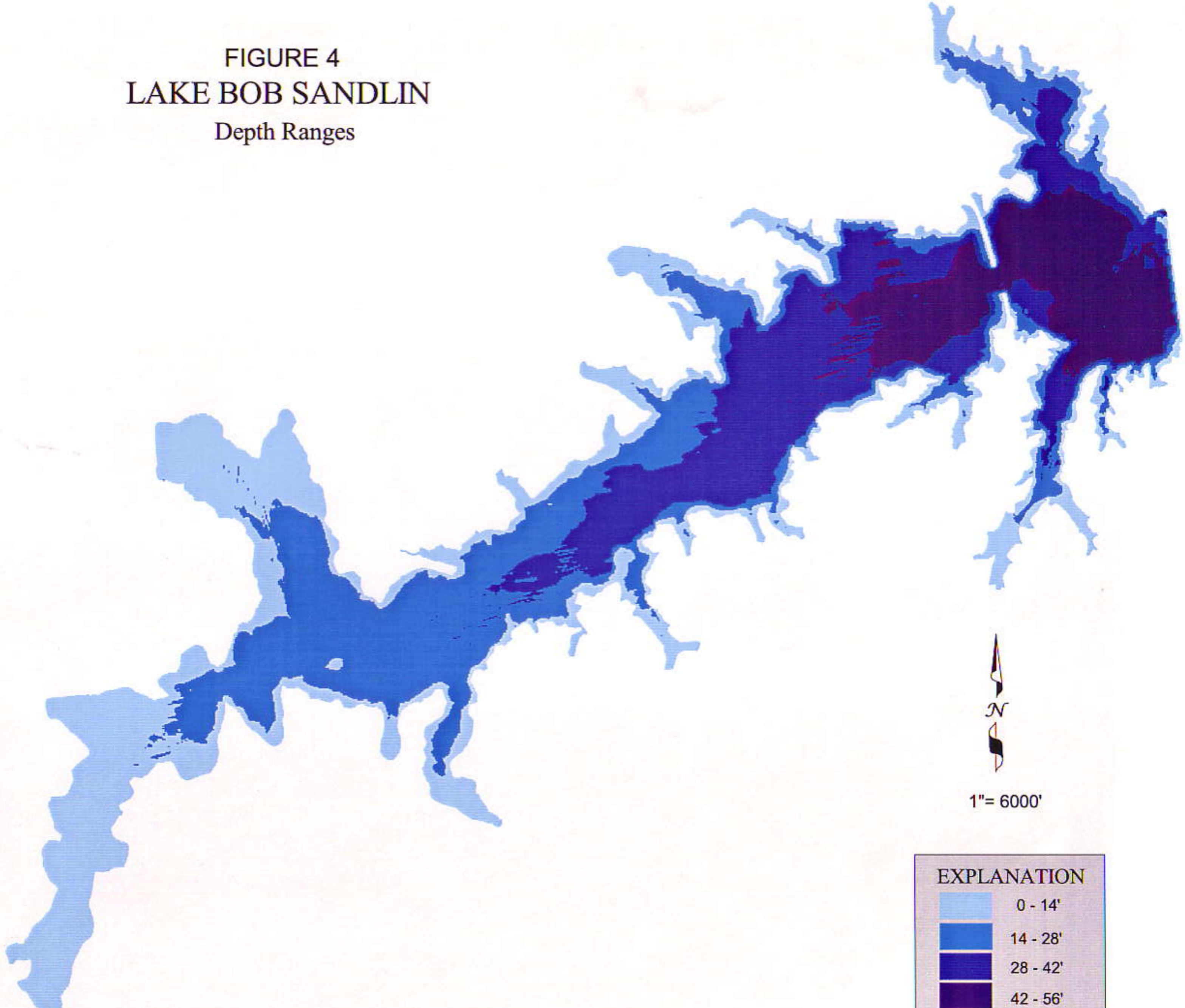
FIGURE 4
LAKE BOB SANDLIN
Depth Ranges



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