VOLUMETRIC SURVEY OF NEW TERRELL CITY LAKE

Prepared for:

CITY OF TERRELL

Prepared by:

The Texas Water Development Board

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Texas Water Development Board

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INTRODUCTION

Staff of the Hydrographic Survey Unit of the Texas Water Development Board (TWDB) conducted a hydrographic survey of New Terrell City Lake on May 28, 1997. 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 noted otherwise. The conservation pool elevation for New Terrell City Lake is 504.0 feet. The original design information estimates the lake's original surface area at this elevation to be 830 acres and the storage volume to be 8,712 acre-feet of water.

HISTORY AND GENERAL INFORMATION OF THE RESERVOIR

New Terrell City Lake and dam is owned and operated by the City of Terrell. The lake is located on Muddy Cedar Creek in Kaufman County, six miles east of Terrell, Texas (see Figure 1). Records indicate the drainage area is approximately 14 square miles. At the conservation pool elevation, the lake has approximately 8.3 miles of shoreline and is two and one-half miles long. The widest point of the reservoir is approximately one mile (located one mile upstream of the dam).

The State Board of Water Engineers issued Permit No. 1700 on April 20, 1954 to City of Terrell authorizing the construction of a dam and reservoir and the right to impound 8,300 acre-feet of water. The city was granted the right to divert 6,000 acre-feet of water annually for municipal purposes. On April 30, 1969, Permit No. 1700 was amended to allow the City of Terrell to increase their storage capacity to 8,712 acre-feet of water. Certificate of Adjudication No. 08-4972 was issued by the Texas Water Commission on May 5, 1987. The certificate basically reinforces the authorization for the City of Terrell to impound 8,712 acre-feet of water and to divert and use not to exceed 6,000 acre-feet of water per year for municipal purposes. The certificate also authorizes the owner to use the impounded water of New Terrell City Lake for recreational purposes.

Records indicate the construction for New Terrell City Lake and Dam began in February, 1955 and was completed in November of the same year. Deliberate impoundment began when the construction was completed but the lake did not fill until May, 1957. The diversion of water from the lake began in 1960. The design engineer for the original facility was Joe E. Ward and the general contractor was John A. Petty.

New Terrell City Lake Dam and appurtenant structures consist of an earthfill embankment, 4,700 feet in length, with a maximum height of 45 feet and a crest elevation of 514.2 feet. (Note: the original crest elevation of the embankment was 512.0 feet but was modified and raised to 514.2 in 1969) The service spillway is an uncontrolled concrete weir and chute located near the left (east) end of the embankment. The concrete weir is 40 feet in length at elevation 508.8 feet. Encased in concrete below the weir crest are nine 24 inch diameter metal pipes with invert elevations of 504.0 feet. The emergency spillway, located at the right (west) end of the embankment, is an earth trench cut through the natural ground. The crest is 500 feet in length at elevation 507.0 feet. The service outlet is in a four feet square concrete tower that is located upstream of the dam and approximately 1,000 feet west of the service spillway. The tower has three 30 inch square gates at elevations 481.0, 488.0 and 495.0 feet. Discharges from these gates flow through a 30 inch diameter, concrete encased, steel pipe to the downstream side of the embankment.

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.

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.

GPS technology was developed in the 1960's by the United States Air Force and the defense establishment. 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) can determine positions of moving objects in real-time or "on-the-fly." In the early stages of this 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. The large positional errors experienced by a single receiver when S/A is active are greatly reduced by utilizing DGPS. The reference receiver calculates satellite corrections based on its known fixed position, which results in positional accuracies within three meters for the moving receiver. DGPS was used to determine horizontal position only. Vertical information was supplied by the depth sounder.

The need for setting up a stationary shore receiver for current surveys has been eliminated with the development of fee-based reference position networks. These networks use a small network of GPS receivers to create differential corrections for a large network of transmitting stations, Wide Area Differential GPS (WADGPS). The TWDB receives this service from ACCQPOINT, a WADGPS correction network over a FM radio broadcast. A small radio receiver purchased from ACCQPOINT, collects positional correction information from the closest broadcast station and provides the data to the GPS receiver on board the hydrographic surveying boat to allow the position to be differentially corrected.

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 ACCQPOINT FM receiver, and an on-board 486 computer. Power was provided by a water-cooled generator 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 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 lake's pool boundary (elevation 504.0) from 7.5 minute USGS quadrangle maps. The name of the quad maps used are as follows: ELMO, TX (Photo-revised 1981) and POETRY, TX (Provisional 1980).   The graphic boundary file created was then transformed into the proper datum, from NAD '27 datum to NAD '83, using Environmental Systems Research Institutes's (ESRI) Arc/Info project command with the NADCOM (standard conversion method within the United States) 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 36 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 New Terrell City Lake 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 New Terrell City Lake, the speed of sound in the water column was 4909 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 ±0.2 feet, plus an estimated error of ±0.3 feet due to the plane of the boat for a total accuracy of ±0.5 feet for any instantaneous reading. These errors tend to be minimized over the entire survey, since some are positive readings 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 New Terrell City Lake on May 28, 1997. Weather conditions were excellent with moderate temperatures and mild winds. Approximately 18,114 data points were collected over the 36 miles traveled along the pre-planned survey lines and the random data-collection lines. These points were stored digitally on the boat's computer in 45 data files. 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 stream bed 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 and used mostly for cattle grazing. A few houses with fishing piers were present along the east bank of the lake near the dam. The rest of the shoreline was void of any development. The main body of the lake was uniformed in width and had two distinct fingers in the upper reaches. There were no islands at the time of this survey. Due to gentle slope of the surrounding terrain, the survey crew experienced some minor difficulty in launching and loading the boat at the ramp that was used for the survey.

While performing the survey on the lake, TWDB noted the bathemetry below the water's surface 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's chart paper. The channel of Muddy Cedar Creek was located near the center of the lake in the upper reaches and meandered closer to the east shoreline downstream near the dam. The crew also noted that the waters of the lake were murky (brown in color), restricting any visual observations below the water's surface.

The lake was fairly clear of any 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 end of the survey occurred when the survey crew encountered a steel cable and fence stretching from bank to bank in Muddy Cedar Creek restricting the boat from traveling any further upstream. 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 down-loaded 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 elevation was reported to be 502.84 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.

The resulting data file was imported into the UNIX operating system used to run

Environmental System Research Institutes'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 down-sized 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. A review of these areas determined them to be insignificant on New Terrell City Lake. Therefore no additional points were required to be added to the data file for interpolation and contouring of the entire lake surface. Volumes and areas were calculated from the TIN for the entire reservoir at one-tenth of a foot intervals. The area of lake computed from the TIN, was calculated to be 849 surface acres. 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 504.0 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 1997 TWDB survey indicate New Terrell City Lake encompasses 849 surface acres and contains a volume of 8,594 acre-feet at the conservation pool elevation of 504.0 feet. The shoreline at this elevation was calculated to be 8.31 miles. The deepest point of the lake, elevation 474.86 or 29.14 feet of depth, was located approximately 240 feet upstream from the main dam. The dead storage volume, or the amount of water below the lowest outlet in the dam, was calculated to be 11 acre-feet based on the low flow outlet invert elevation of 489.0 feet. The conservation storage capacity, or the amount of water between the spillway and the lowest outlet, is therefore calculated to be, 8,580 acre-feet.

SUMMARY

New Terrell City Lake was formed in 1955. Initial storage calculations estimated the volume at the conservation pool elevation of 504.0 feet to be 8,712 acre-feet with a surface area of 830 acres.

On May 28, 1997, a hydrographic survey of New Terrell City Lake was performed by the

Texas Water Development Board's Hydrographic Survey Program. The 1997 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 New Terrell City Lake than previous survey methods. Results indicate that the lake's capacity at the conservation pool elevation of 504.0 feet was 8,594 acre-feet and the area was 849 acres.

The estimated reduction in storage capacity at elevation 504.0 since 1955 was 118 acre-ft or 2.81 acre-ft per year. The average annual deposition rate of sediment in the conservation pool of the reservoir can be estimated at 0.201 acre-ft per square mile of drainage area.

It is difficult to compare the original design information and the survey performed by the TWDB because little is known about the procedures and data used in calculating the original storage information. However, the TWDB considers the 1997 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. The second survey will remove any noticeable errors between the original design information and the 1997 survey and will facilitate accurate calculations of sedimentation rates and storage losses presently occurring in New City Terrell Lake.

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
RESERVOIR VOLUME TABLE

Sep 11 1997

NEW TERRELL CITY LAKE   MAY 1997 SURVEY

VOLUME IN ACRE-FEET   ELEVATION INCREMENT IS ONE TENTH FOOT

ELEV. FEET	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
475										
476						1	1	1	1	1
477	1	1	1	1	2	2	2	2	2	2
478	2	3	3	3	3	3	3	4	4	4
479	4	5	5	5	5	5	6	6	6	7
480	7	7	8	8	8	9	9	9	10	10
481	11	11	12	12	13	13	14	14	15	16
482	16	17	18	19	20	21	23	25	26	28
483	30	33	35	38	42	45	49	53	58	63
484	68	74	80	86	94	101	109	117	126	136
485	145	155	165	175	186	197	208	220	232	245
486	258	271	284	298	312	327	342	357	373	389
487	405	422	439	456	474	493	511	530	550	569
488	589	610	630	651	672	694	716	738	760	782
489	805	828	851	874	898	922	946	970	995	1020
490	1045	1070	1096	1123	1149	1176	1203	1231	1259	1287
491	1315	1344	1373	1403	1432	1462	1493	1523	1554	1585
492	1616	1648	1680	1712	1745	1777	1810	1844	1877	1911
493	1946	1980	2016	2051	2087	2123	2159	2195	2232	2270
494	2307	2345	2384	2422	2461	2501	2541	2581	2621	2662
495	2704	2746	2788	2831	2875	2918	2963	3008	3053	3099
496	3146	3193	3241	3289	3338	3387	3437	3488	3539	3590
497	3643	3696	3749	3803	3858	3913	3968	4024	4081	4138
498	4195	4253	4312	4371	4430	4490	4551	4612	4674	4736
499	4799	4862	4925	4990	5054	5120	5186	5252	5321	5390
500	5460	5530	5600	5671	5742	5814	5886	5959	6032	6106
501	6180	6254	6329	6404	6479	6556	6632	6709	6786	6864
502	6942	7021	7100	7179	7259	7339	7420	7501	7583	7665
503	7747	7830	7913	7997	8081	8165	8250	8336	8421	8508
504	8594									

TEXAS WATER DEVELOPMENT BOARD
RESERVOIR AREA TABLE

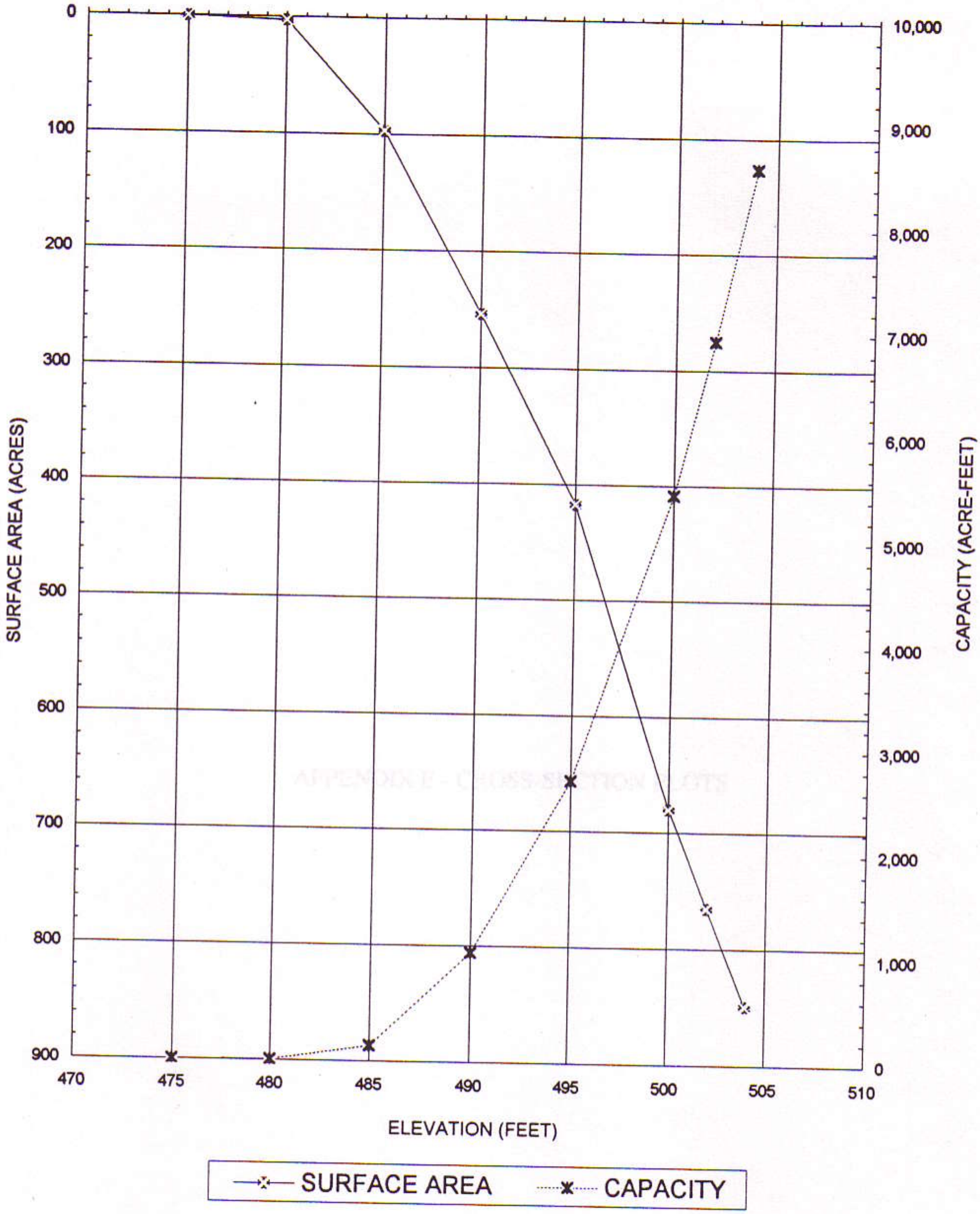
Sep 11 1997

NEW TERRELL CITY LAKE MAY 1997 SURVEY

AREA IN ACRES

ELEVATION INCREMENT IS ONE TENTH FOOT

ELEV. FEET	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
475										
476	1	1	1	1	1	1	1	1	1	1
477	1	1	1	1	1	1	1	1	2	2
478	2	2	2	2	2	2	2	2	2	2
479	2	2	2	2	2	3	3	3	3	3
480	3	3	3	3	4	4	4	4	4	4
481	4	5	5	5	5	6	6	6	7	7
482	8	9	9	11	12	13	15	17	19	21
483	22	25	27	31	35	38	41	44	47	50
484	54	59	64	68	73	78	82	87	91	94
485	97	100	102	105	108	111	115	119	123	127
486	131	134	137	141	144	148	151	154	158	162
487	165	169	172	177	181	185	189	193	196	199
488	202	205	208	211	213	216	218	221	223	225
489	228	230	233	235	237	240	242	244	247	250
490	254	257	261	264	268	271	274	277	280	283
491	287	289	292	295	298	301	304	307	309	312
492	315	318	321	323	326	329	332	335	338	342
493	345	349	352	355	358	361	364	368	371	375
494	378	381	385	388	392	396	400	404	408	412
495	417	422	427	431	436	442	447	452	457	463
496	468	474	479	485	491	497	503	508	514	520
497	526	532	538	543	548	552	557	562	567	573
498	578	583	588	593	598	603	609	614	619	624
499	629	634	639	645	650	656	662	667	671	675
500	680	684	688	692	697	701	705	709	714	718
501	722	726	731	735	739	743	748	752	756	760
502	765	769	773	777	782	786	790	794	799	803
503	807	811	816	820	824	828	833	837	841	845
504	849									



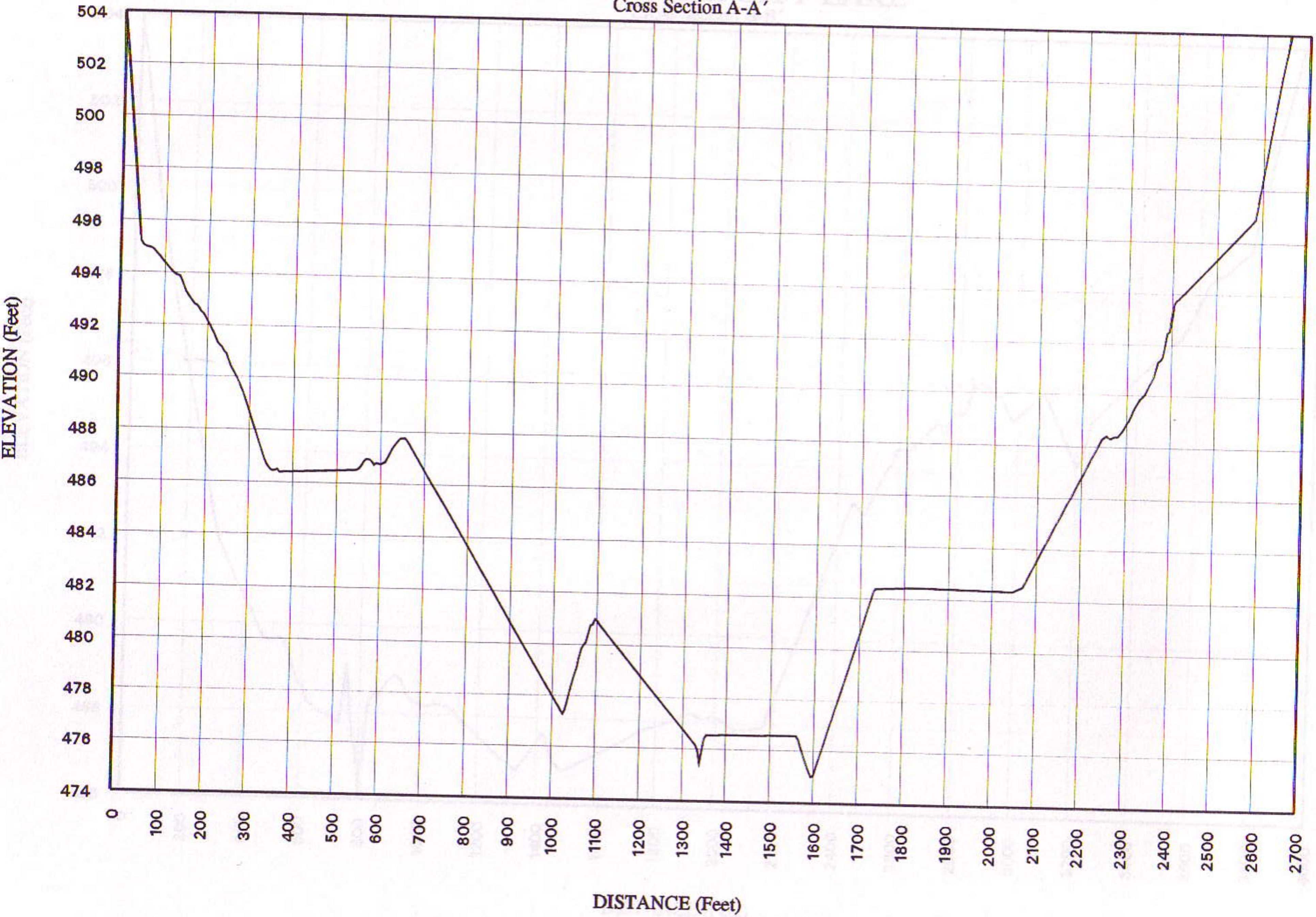
NEW TERRELL CITY LAKE

May 1997 Survey

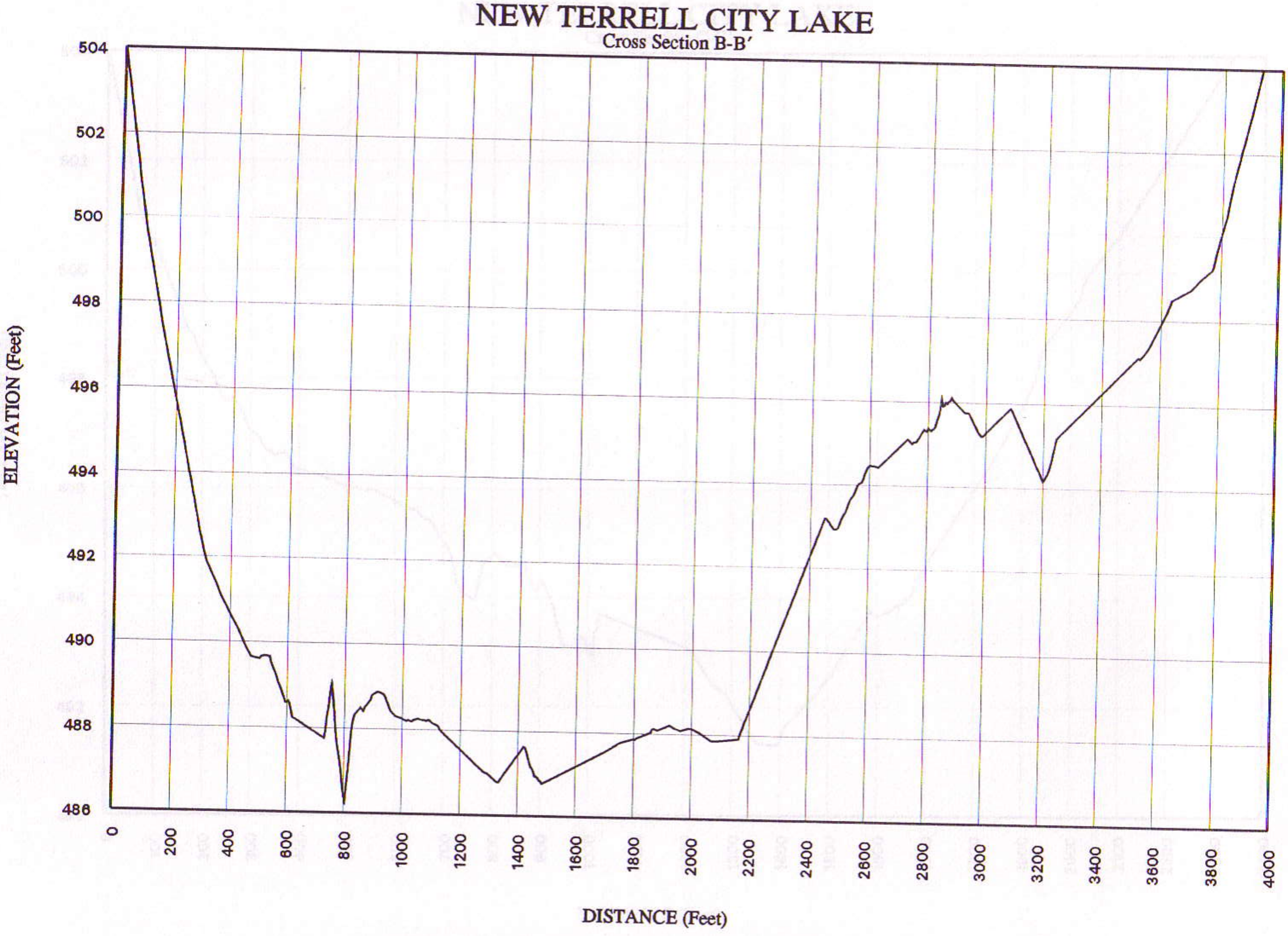
Prepared by: TWDB September 1997

NEW TERRELL CITY LAKE

Cross Section A-A′



PREPARED BY: TWDB SEPTEMBER 1997



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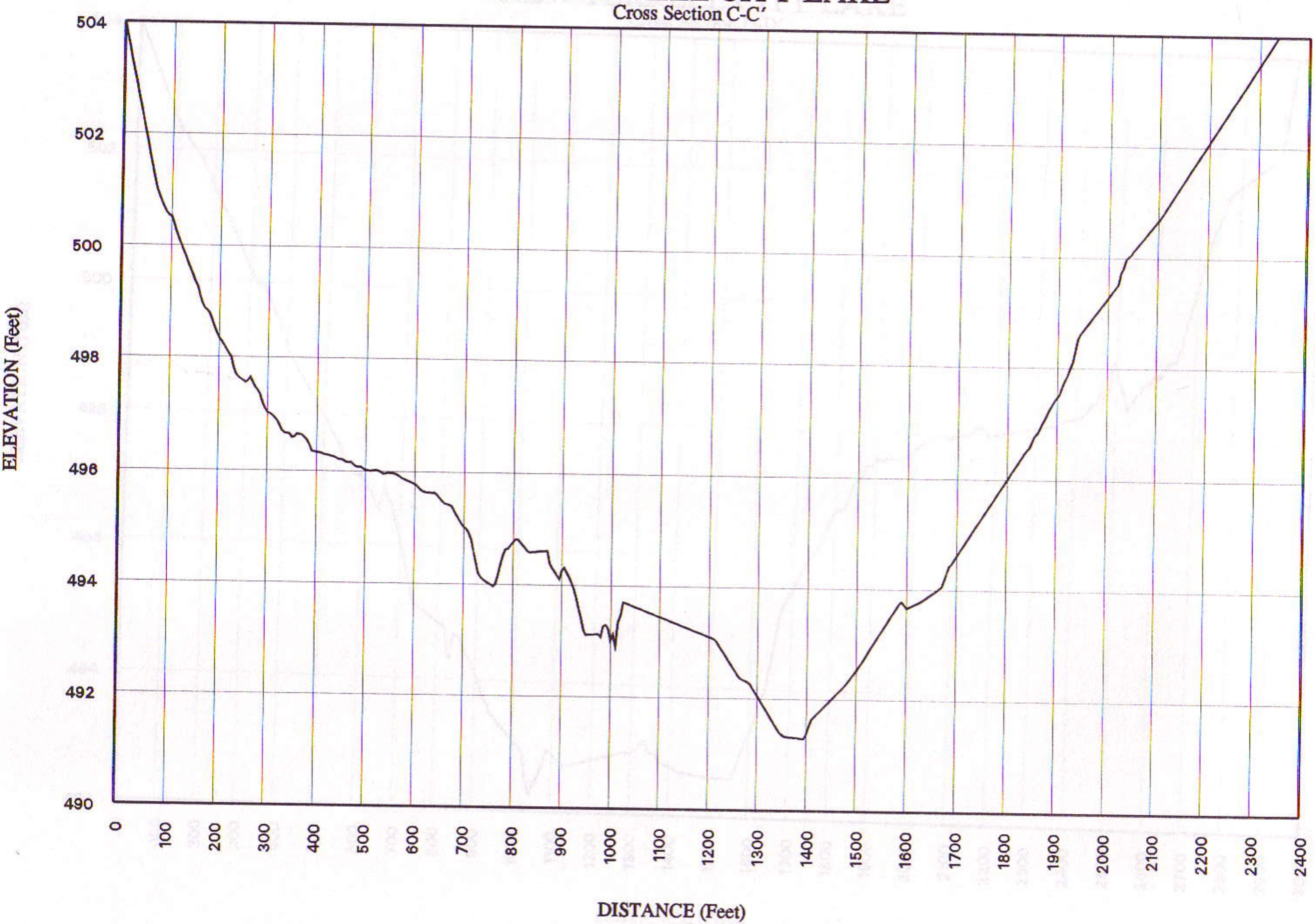
NEW TERRELL CITY LAKE



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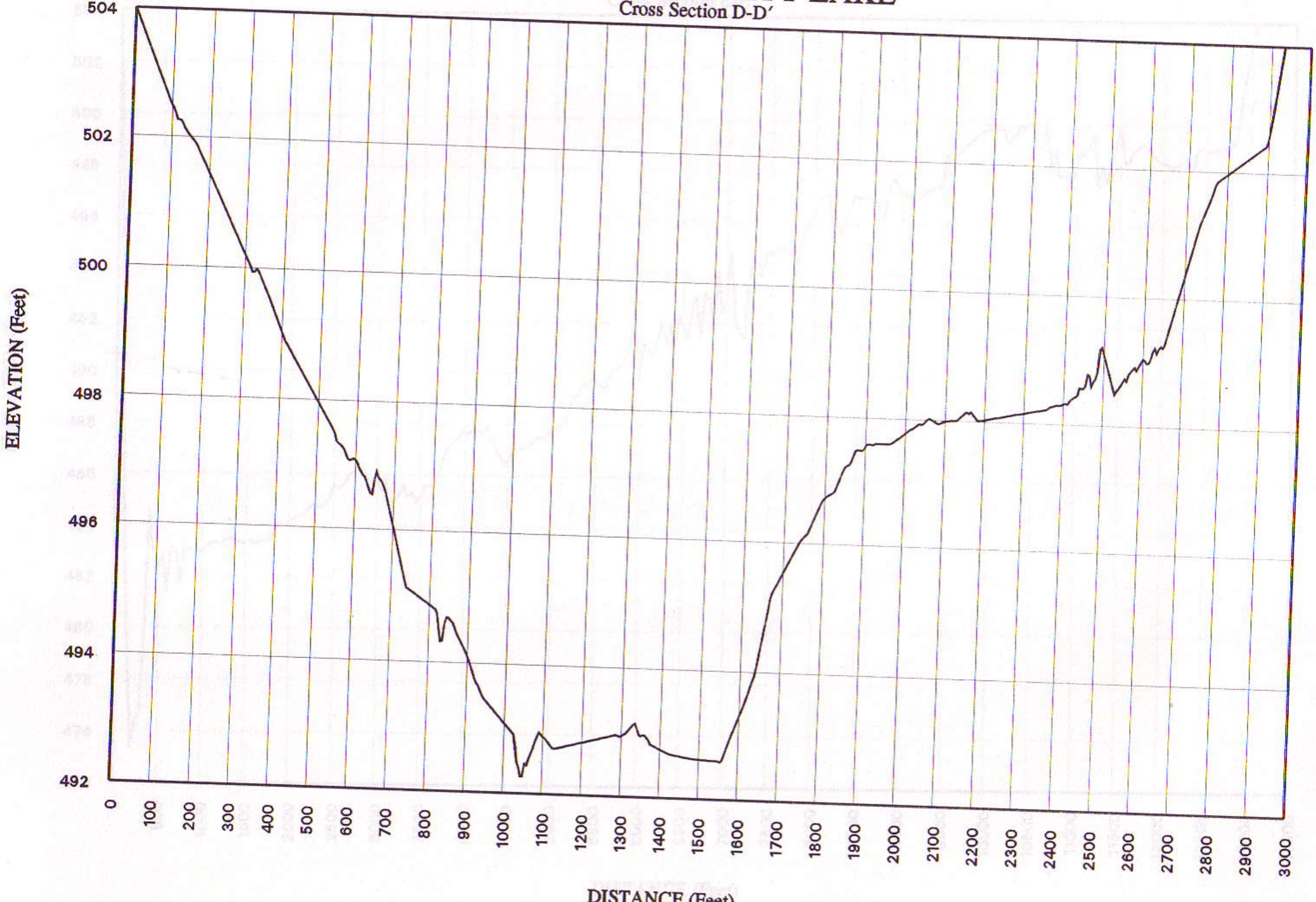
NEW TERRELL CITY LAKE

Cross Section D-D′



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NEW TERRELL CITY LAKE

Cross Section E-E′

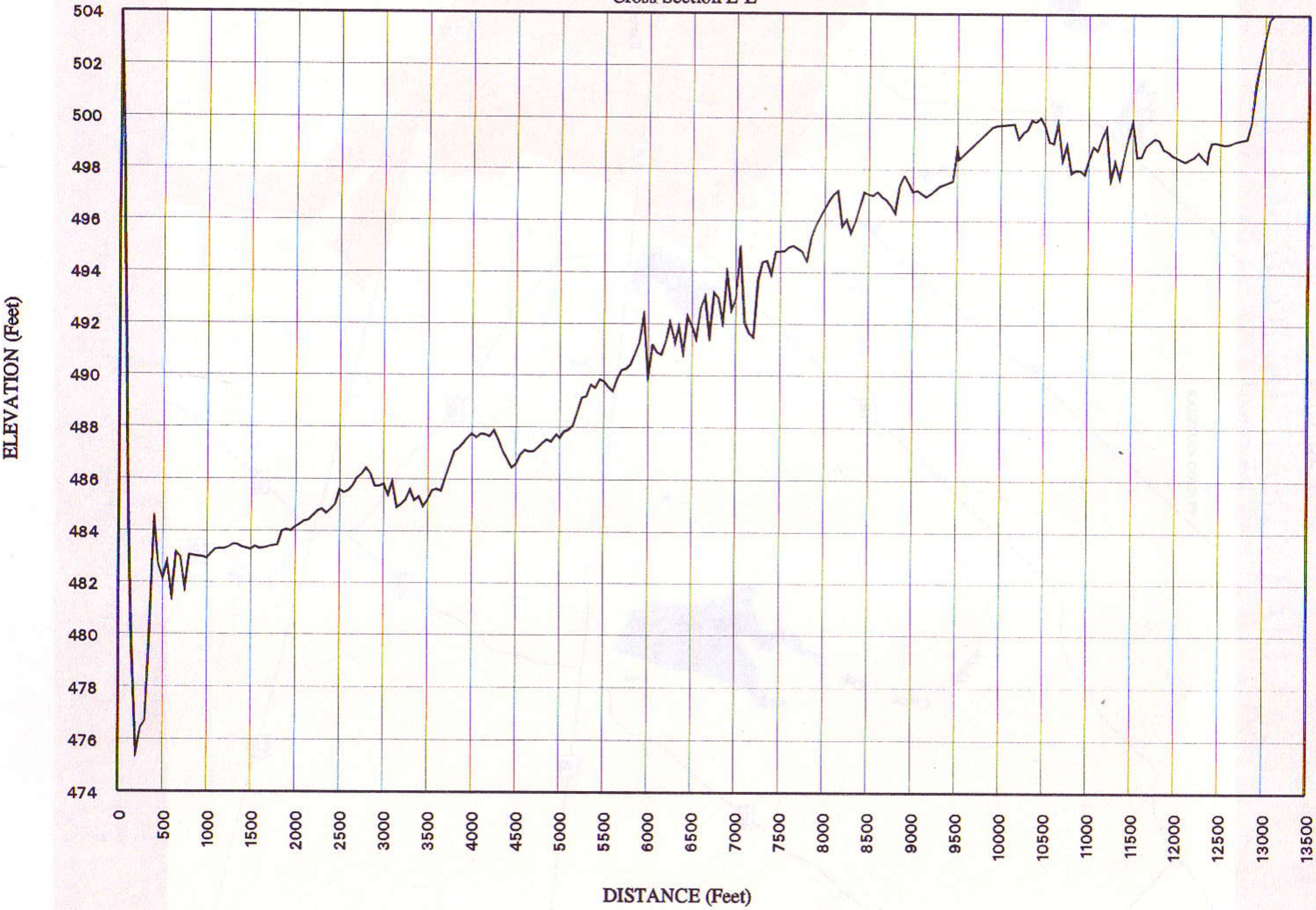

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FIGURE 1

NEW TERRELL CITY LAKE

Location Map

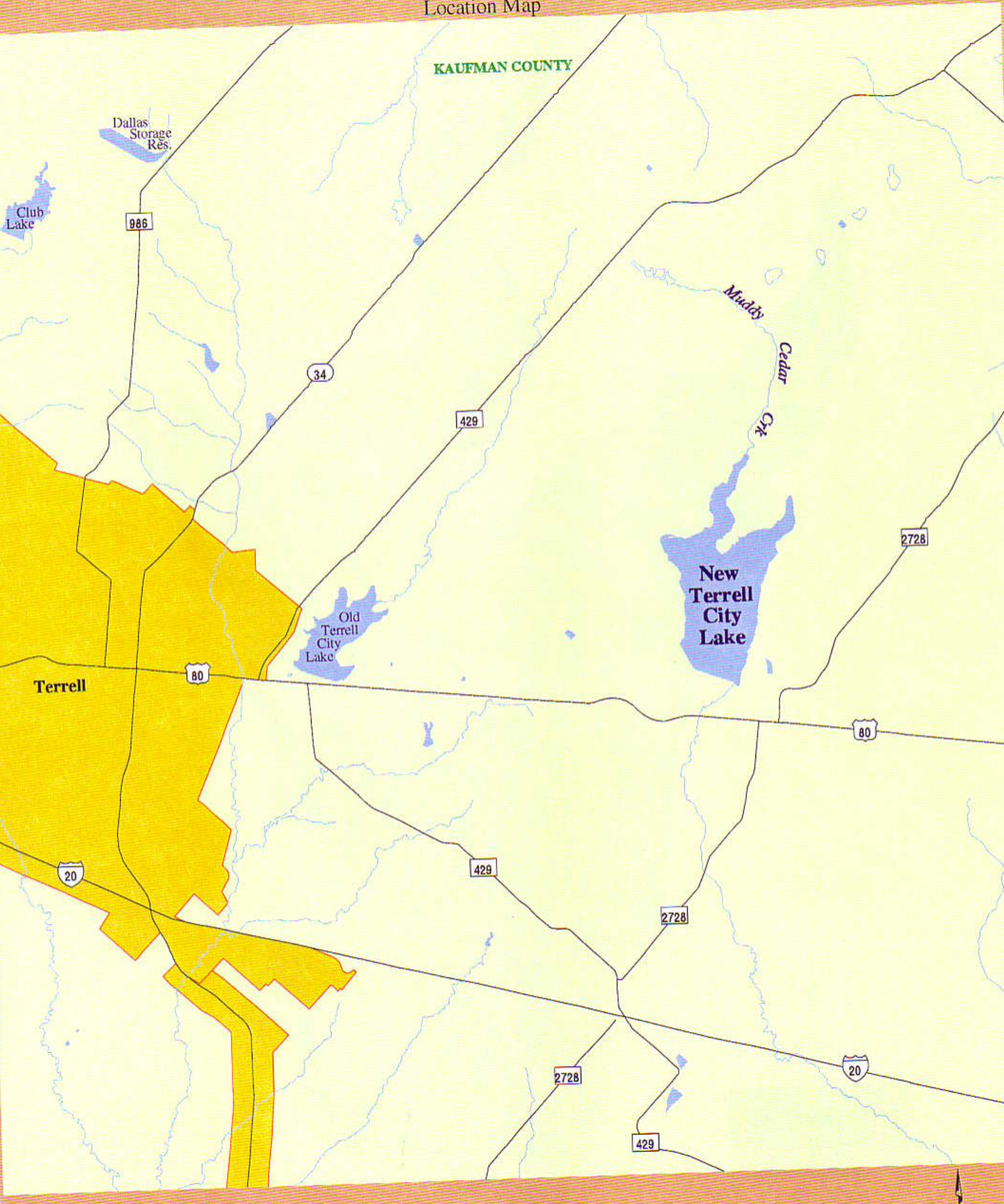

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FIGURE 2

NEW TERRELL CITY LAKE

Location of Survey Data

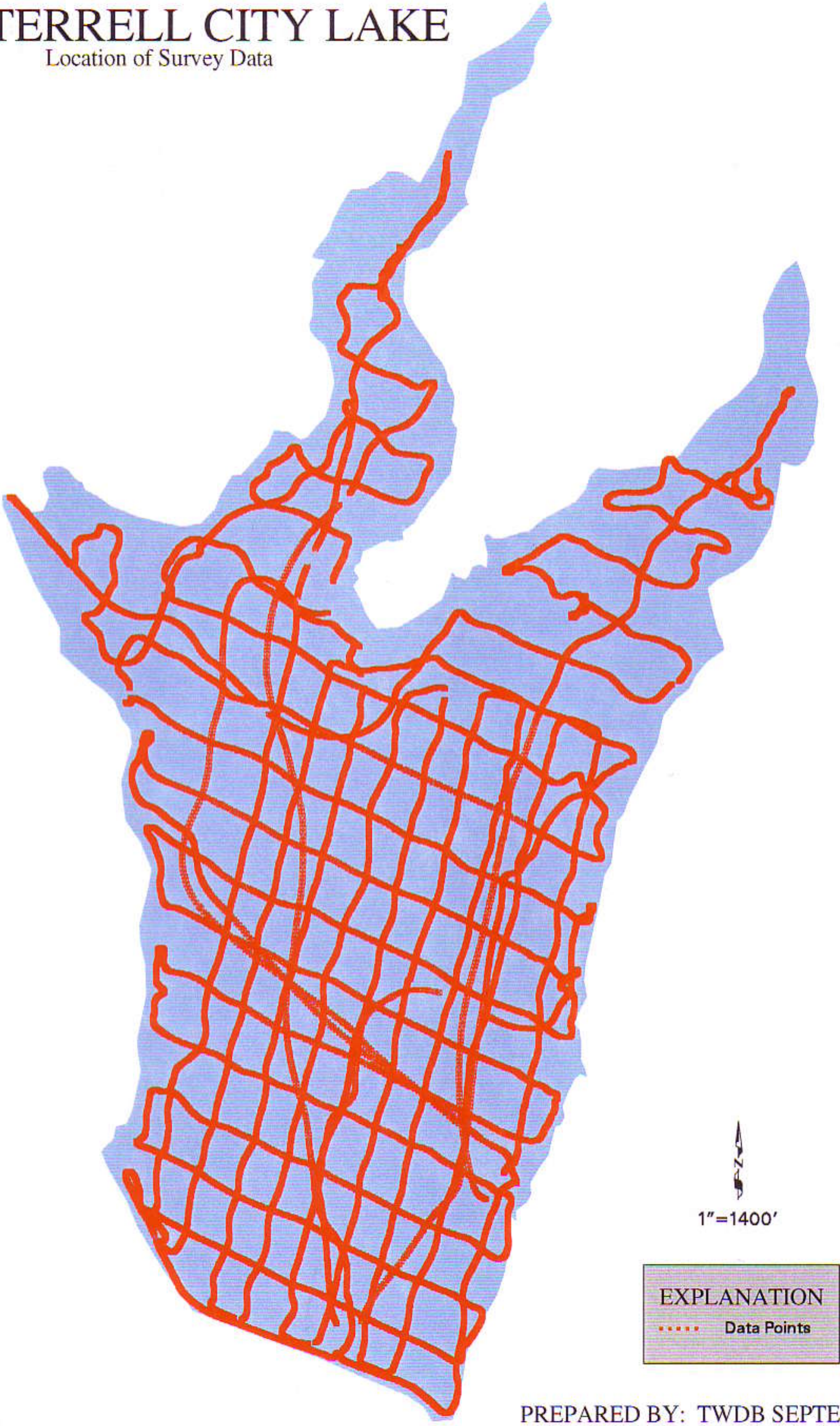

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FIGURE 3

NEW TERRELL CITY LAKE

Shaded Relief

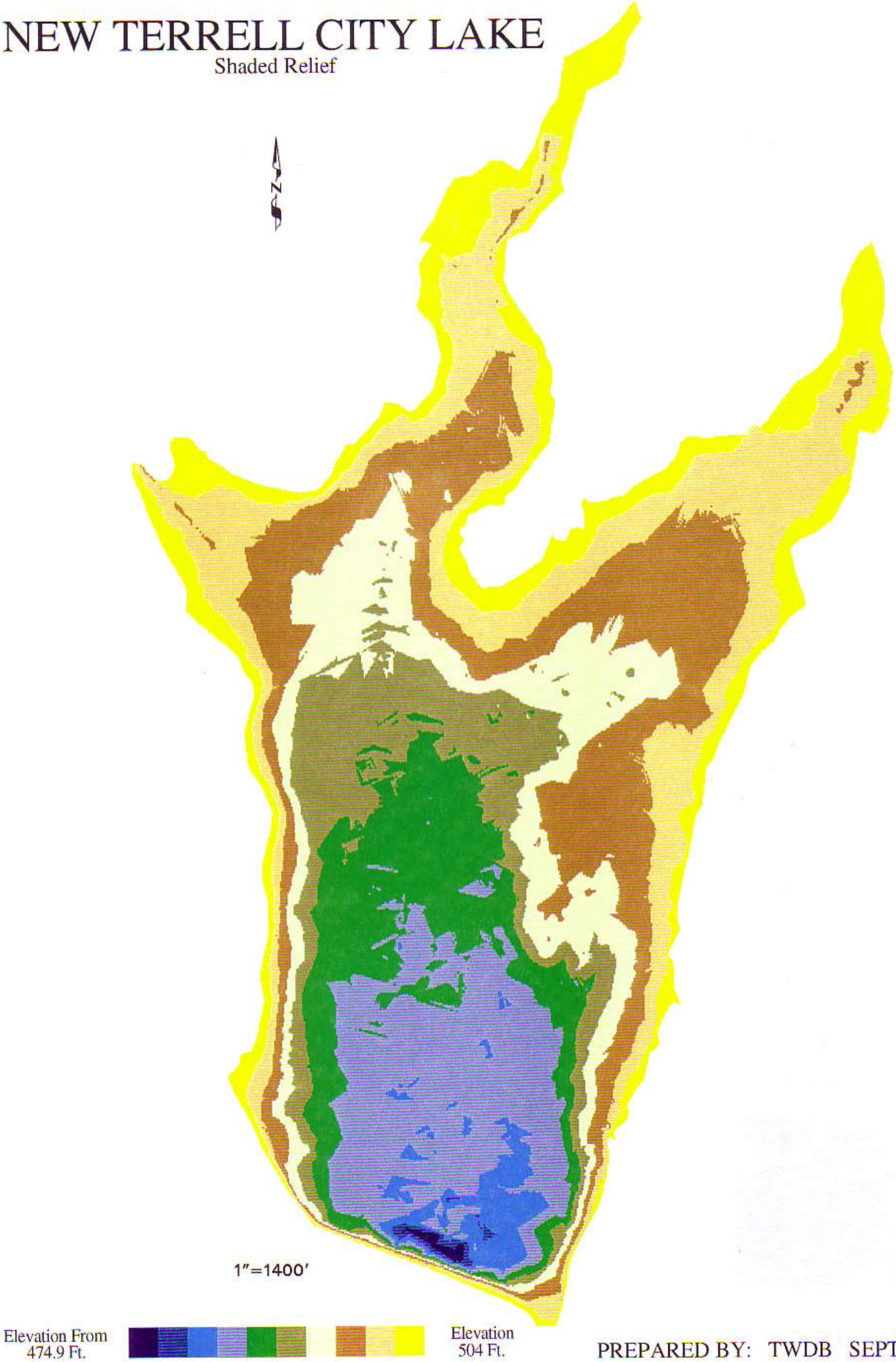

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FIGURE 4

NEW TERRELL CITY LAKE

Depth Ranges

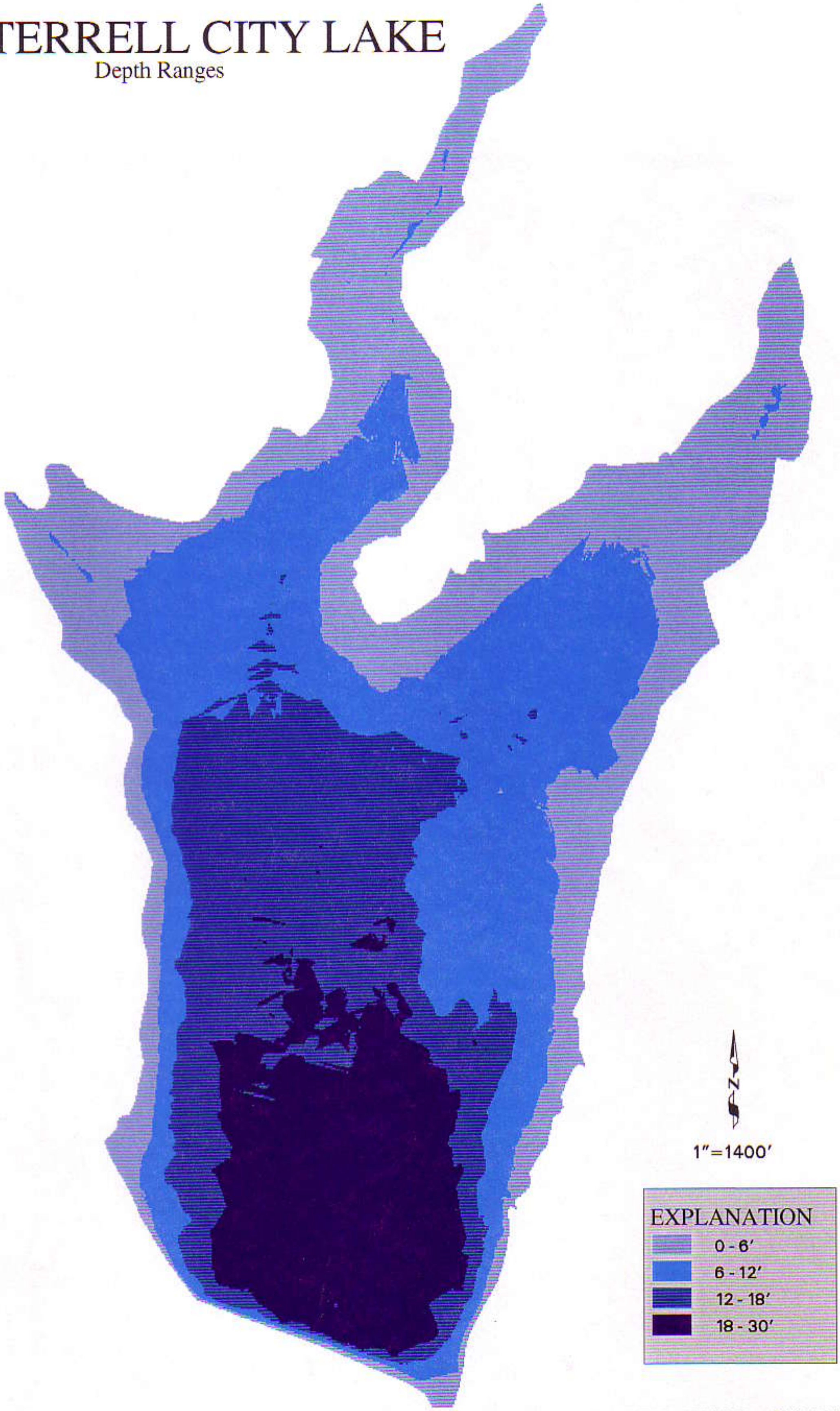

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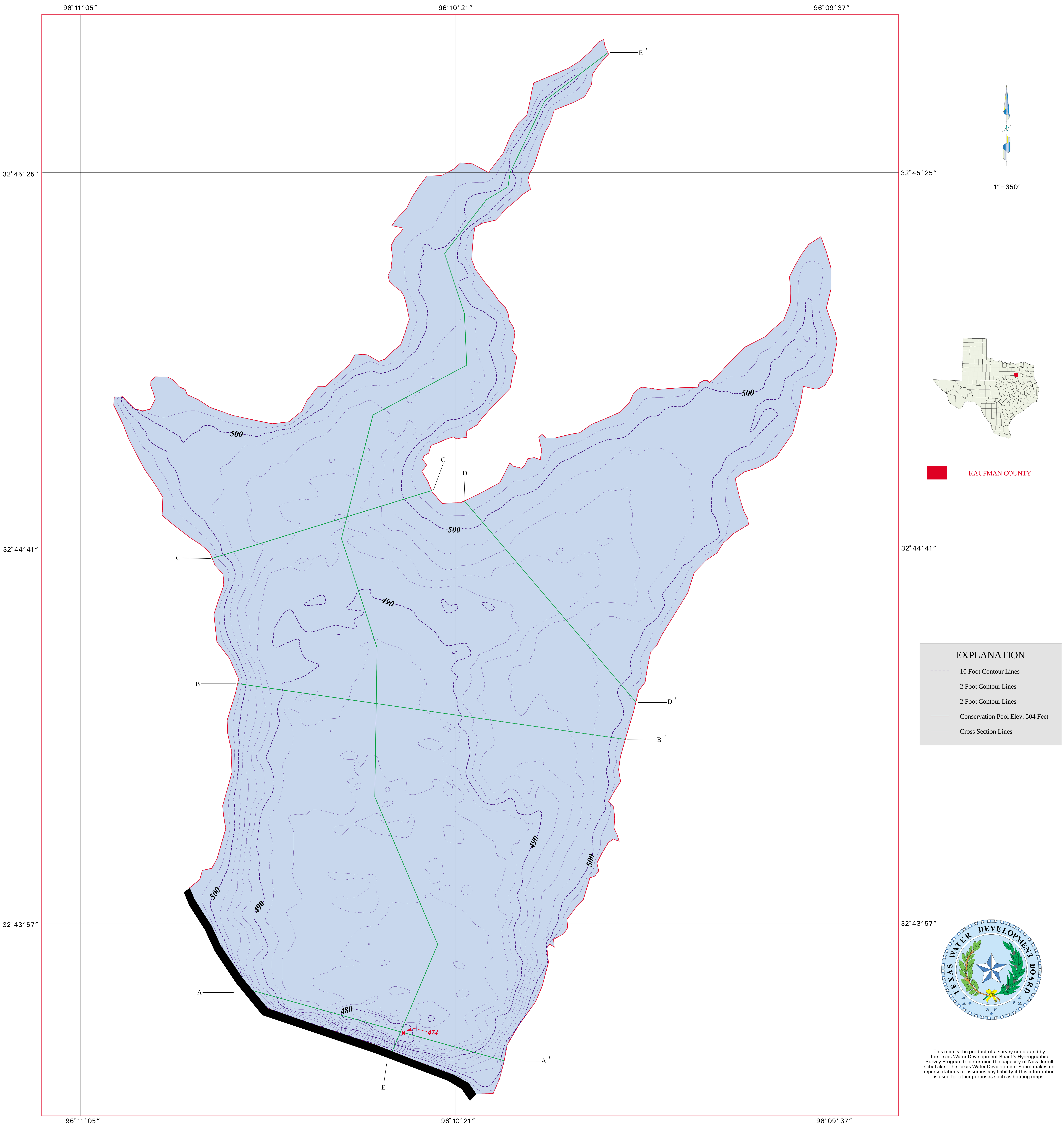
FIGURE 5

NEW TERRELL CITY LAKE

Contour Map



PREPARED BY: TEXAS WATER DEVELOPMENT BOARD SEPTEMBER 1997