VOLUMETRIC SURVEY OF LAKE NASWORTHY

Prepared for:

THE CITY OF SAN ANGELO

Prepared by:

The Texas Water Development Board

March 10, 2003

Texas Water Development Board

This report was prepared by the Hydrographic Survey group:

Carol R. Hearn, P.E., R.P.L.S.
Duane Thomas
Randall Burns

For more information, please call (512) 445-1471

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 NASWORTHY
HYDROGRAPHIC SURVEY REPORT

INTRODUCTION

Staff of the Hydrologic Survey Unit of the Texas Water Development Board (TWDB) conducted a hydrographic survey on Lake Nasworthy in September, 1993. The purpose of the survey was to determine the capacity of the lake at the normal pool elevation and to establish baseline information for future surveys. From this information, future surveys will be able to determine sediment deposition locations and rates over time. Survey results are presented in the following pages in both graphical and tabular form.

HISTORY AND GENERAL INFORMATION OF THE RESERVOIR

Lake Nasworthy, owned by the City of San Angelo, is located in Tom Green County, approximately six miles southwest of San Angelo, Texas. Lake Nasworthy Dam is located on the South Concho River, a tributary of the Colorado River. The dam was designed by Floyd and Lochridge of Dallas, and the general contractor was Callahan Construction Company. Construction commenced in January, 1929 and was completed in June, 1930. Impoundment of water began March 28, 1930.

Application No. 1196 was filed March 11, 1929 by West Texas Utilities Company, to construct a reservoir and impound 10,500 acre-feet of water. Permit No. 1190 was issued on December 17, 1941, and authorized the impoundment of 10,500 acre-feet as well as the annual diversion of 25,000 acre-feet for industrial, municipal and irrigation purposes. Application No. 1551 requested that the normal/conservation pool elevation be raised to 1872.2 feet above mean sea level, based on the National Geodetic Vertical Datum of 1929 (NGVD '29). All elevations presented in this report are reported in NGVD '29 unless noted otherwise. Permit No. 1446 was issued April 9, 1948 granting the applicant's request. The record conservation storage at this elevation is 12,390 acre-feet, encompassing a total of 1,596 acres. West Texas Utilities Company sold their water rights in Lake Nasworthy to the City of San Angelo in May, 1950, and the irrigation provision in Permit No. 1446 was removed at that time.

Certificate of Adjudication No. 1319 was granted November 17, 1980 to the City of San Angelo, authorizing the maximum impoundment of 12,500 acre-feet in Lake Nasworthy. The City of San Angelo was authorized to divert a maximum of 25,000 acre-feet annually, including 17,000 acre-feet for municipal use and 8,000 acre-feet for industrial purposes. The 25,000 acre-feet authorized by this Certificate of Adjudication was included in the 29,000 acre-feet authorized for municipal purposes under Certificate of Adjudication No. 1318 for Twin Buttes Reservoir.

A change in water use resulted in an amendment to the Certificate of Adjudication issued December 31, 1980 to the City of San Angelo. It stated the holder of Certificate of Adjudication No. 1319 was authorized to use a maximum of 17,000 acre-feet for municipal purposes, 7,000 acre-feet for industrial purposes and 1,000 acre-feet for irrigation purposes.

Lake Nasworthy Dam is an earthen embankment with a controlled concrete service spillway located at the north abutment and two uncontrolled emergency spillways at the south abutment. The total length of the structure is 5,480 feet with a maximum height of 50 feet. The service spillway is a concrete ogee structure, with a 450 feet long crest at elevation 1855.3 feet. Fifteen tainter gates, each 25 feet wide by 18 feet high, with a crest elevation of 1873.2 control the opening. One 25 feet long automatic collapsible gate, with a crest elevation of 1869.2 feet, is located at the most northern end of the service spillway. The primary emergency spillway is 300 feet wide, at elevation 1879.1 feet. The secondary emergency spillway is 1,300 feet wide, at elevation 1880.1 feet. The low-flow outlet system consists of two 36-inch sluice gates located near the center of the service spillway structure, at an invert elevation of 1836.0 feet. In addition, two 24-inch diameter pipes, at an invert elevation of 1860.0 feet, are located near each end of the structure.

HYDROGRAPHIC SURVEYING TECHNOLOGY

The following sections will describe the equipment and methodology used to conduct this hydrographic survey. Some of the theory behind Global Positioning System (GPS) technology and its accuracy are also addressed.

GPS Information

The following is a brief and simple description of Global Positioning System (GPS) technology. GPS is a 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 monitor the broadcasts from the satellites over time 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. Additional satellite readings would also produce a possible location on a sphere surrounding that satellite with a radius of the distance measured. The observation of two satellites from an unknown point 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 first utilized on February 22, 1978, when the initial satellite was launched. The NAVSTAR (NAVigation System with Time And Ranging) satellite constellation will consist of twenty-four Block II satellites when fully implemented. At the time of the survey, twenty-four satellites, including some Block I satellites, were fully operational. The United States Department of Defense (DOD) is 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 (1 to 3 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" and was used during the survey of Lake Nasworthy. 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 a second 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 3 meters for the moving receiver. DGPS was used to determine horizontal position only. Vertical information was supplied by the depth sounder.

Equipment

The equipment used in the hydrographic survey of Lake Nasworthy 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 Depth Sounder and Velocity Profiler, a Trimble Navigation, Inc. 4000SE GPS receiver, a Motorola Radius radio with an Advanced Electronic Applications, Inc. packet modem, and an on-board computer. The computer is supported by a dot matrix printer and a B-size plotter. Power is 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 shore station included a second Trimble 4000SE GPS receiver, Motorola Radius radio and Advanced Electronic Applications, Inc. packet modem, and an omni-directional antenna mounted on a modular aluminum tower to a total height of 40 feet. The combination of this equipment provided a data link with a reported range of 25 miles over level to rolling terrain that does not require that line-of-sight be maintained with the survey vessel in most conditions, thereby reducing the time required to conduct the survey.

As the boat traveled across the lake surface, the depth sounder gathered approximately ten readings of the lake bottom each second. The depth readings were averaged over the one-second interval and stored with the positional data to an on-board computer. After the survey, the average depths were corrected to elevation using the daily lake elevation. The set of data points logged during the survey were used to calculate the lake volume. Accurate estimates of the lake volume can be quickly determined using these methods, to produce an affordable survey. 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 strung 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 hooked itself 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 strung across the body of water, so surveying instruments were utilized to determine the path of the boat. Monumentation was set for each end point 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 across the body of water. 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 reading 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 it's 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 in 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 hard to detect after the fact. Large reservoirs required multiple shore stations and a crew to move the shore stations to the next location as the survey progressed. Land surveying was again a major cost.

Another method used mainly prior to construction utilized aerial photography to generate elevation contours which could then be used 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 $\pm$ five feet for a ten foot contour interval. This method could be quite costly, and was only applicable in areas that were not inundated.

Survey Methods

The Hydrographic Survey crew established coordinates for an existing monument known as

Gun Club Hill Monument B. These coordinates, based on the North American Datum of 1983 (NAD '83) served as control for the shore station site. This location was chosen because of its close proximity to the lake, the unobstructed view of the lake, and security of the area.

A static survey using the two Trimble 4000SE GPS receivers was performed to obtain coordinates for Gun Club Hill Monument B. One GPS receiver was positioned over a USGS first-order monument named ATKINSON, located approximately three and one-half miles southeast of San Angelo. ATKINSON was established in 1935. Satellite data were gathered from this station for one hour with up to six satellites visible to the receiver. During the same time period, data were gathered from the second receiver positioned over Gun Club Hill Monument B.

Once data collection ended, the data were retrieved from the two receivers using Trimble Trimvec software, and processed to determine coordinates for the shore station site. The NAVSTAR satellites use the World Geodetic System (WGS '84) spherical datum. WGS '84 is essentially identical to NAD '83. The WGS' 84 coordinates for Gun Club Hill Monument B were determined to be North latitude 31° 23' 16.23606", West longitude 100° 29' 56.13636", and ellipsoid height of 572.7159 meters. (The corresponding North American Datum of 1927 (NAD' 27) coordinates were calculated to be North latitude 31° 23' 15.6992", West longitude 100° 29' 54.7838", and the approximate NGVD '29 elevation was calculated to be 1,958 feet. The horizontal position is the most accurate reading - and a longer period of observation would result in a more accurate elevation. The NGVD '29 elevation was estimated for comparison purposes, although its accuracy is not represented by this survey.) The WGS '84 coordinates were then entered into the shore station receiver located over Gun Club Hill Monument B to fix its location and allow calculation and broadcasting of corrections through the radio and modem to the roving receiver located on the boat.

The reservoir's surface area was determined from a digital boundary provided by the City of San Angelo, which was digitized from a recent aerial photo. In order to register the boundary in a more recent datum compatible with the positions received from the satellites, Intergraph Microstation CADD software was used to digitize the lake boundary from 1954 and 1976 USGS quad sheets in NAD '27. The graphic boundary was then transformed from NAD '27 to NAD '83 using Microstation Projection Manager. This transformation does not affect the area of the boundary shape, but it does alter its global position so the boundary will align with the data points collected. NAD '83, a flat projected representation of the curved earth surface, was chosen to calculate areas and volumes. NAD '27 is also a flat projection, but the two datums have a slightly different point of origin, and distinctly different state plane false northing and false easting coordinate to be able to distinguish coordinate points between the datums. The NAD '83 shape was modified slightly to insure that all data points gathered were within the boundary. The resulting acreage at the normal pool elevation was thereby estimated to be 1,380 acres, or 13.5 percent less than the original recorded 1,596 acres.

The survey layout was pre-planned, using approximately forty survey lines at a spacing of 500 feet. Innerspace Technology Inc. software was utilized for navigation and to integrate and store positional data along with depths. In areas where vegetation or obstructions prevented the boat from traveling the planned line, random data were collected wherever the boat could maneuver. Additional random data were collected lengthwise in the reservoir. Data points were entered into the data set utilizing the DGPS horizontal position and manually poling the depth in shallow areas where the depth was less than the minimum recordable depth of the depth sounder, which is about 3.5 feet. Figure 2 shows the actual location of the data collection sites. Data were not collected in areas that were inaccessible due to shallow water or obstructions. The data set included approximately 27,000 data points.

TWDB staff verified the horizontal accuracy of the DGPS used in the Lake Nasworthy survey to be within the specified accuracy of three meters. The shore station was set up over a known United States Geological Service (USGS) first order monument and placed in differential mode. The second receiver, directly connected to the boat with its interface computer, was placed over another known USGS first order monument and set to receive and process the corrections. Based on the differentially-corrected coordinates obtained and the published coordinates for both monuments, the resulting positions fell within a three meter radius of the actual known monument position. For DGPS operation the reference station receiver was set to a horizontal mask of 0°, to acquire information on the rising satellites. A horizontal mask of 10° was used on the roving receiver for better satellite geometry and thus better horizontal positions. The DGPS positions were within acceptable limits of horizontal accuracy with a PDOP (Position Dilution of Precision) of seven (7) or less. The GPS receivers have an internal alarm that sounds if the PDOP rises above the maximum entered by the user, to advise the field crew that the horizontal position has degraded to an unacceptable level.

The depth sounder measures depth by measuring the time between the transmission of the sound pulse and the reception of its echo. The depth sounder was calibrated with the Innerspace Velocity Profiler typically once per day, unless the maximum depth varied by more than twenty feet. The velocity profiler calculates an average speed of sound through the water column of interest (typically set at a range of two feet below the surface to about ten feet above the maximum encountered depth), and the draft value or distance from the transducer to the surface. The velocity profiler probe is placed in the water to wet the transducers, then raised to the water surface where the depth is zeroed. The probe is then lowered on a cable to just below the maximum depth set for the water column, and then raised to the surface. The unit reads out an average speed of sound for the water column and the draft measurement, which are then entered into the depth sounder. The speed of sound can vary based on temperature, turbidity, density, or other factors. 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 plus readings and some are minus readings. Further information on these calculations is presented in Appendix A. Manual poling of depths within shallow areas agreed with the depth obtained by the depth sounder typically within ± 0.3 feet, and since the boat is moving much slower, the plane of the boat has much less effect.

Analog charts were printed for each survey line as the data were collected. The gate mark, which is a known distance above the actual depth that was recorded in the data file, was also printed on the chart. Each analog chart was analyzed, and where the gate mark indicated that the recorded depth was other than the bottom profile, depths in the corresponding data files were modified accordingly. The depth sounder was set to record bad depth readings as 0, and all points with a zero depth were deleted.

Each data point consisted of a latitude, longitude and depth. The depths were transformed to elevations with a simple awk Unix command based on the water surface elevation each day, which ranged from 1872.08 to 1872.15 feet. The data set was then loaded into an existing Microstation design file with the Microstation ASCII Loader product. The design file contained the NAD '83 boundary previously discussed in this report. The data points along with the boundary were used to create a digital terrain model (DTM) of the reservoir's bottom surface using the Microstation Terrain Modeler product. 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. This method preserves all data points for use in determining the solution. The set 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. Areas that were too shallow for data collection or obstructed by vegetation were estimated by the Modeler product using this method of interpolation. Any difference between the estimated volume and the actual volume is believed to be minor because the shallow areas do not contain significant amounts of water. From this three-dimensional triangular plane surface representation, the Modeler product calculated the surface area and volume of the entire reservoir at one-tenth of a foot intervals.

The three-dimensional triangular surface was then converted to a regular matrix of elevation values, or a grid. A grid spacing of fifty feet was chosen for this presentation, to produce an illustration that would be easy to visualize, but not so dense that it would obscure features. A vertical exaggeration of one hundred was used to create a perception of depth within the drawing. Figure 3 is a graphical representation of a grided version of the three-dimensional DTM.

The DTM was then smoothed and linear smoothing algorithms were applied to the smoothed model to produce smoother contours. The following smoothing options were chosen for this model: Douglas-Peucker option with a zero tolerance level to eliminate any duplicate points, and Round Corners with a delta of 25 feet in an attempt to smooth some of the angularity of the contours. Contours of the bottom surface at two foot intervals are presented in Figure 4.

DATA

Lake Nasworthy captures streamflow from the Middle Concho River immediately downstream of Twin Buttes Reservoir. The distance between Lake Nasworthy Dam and the Twin Buttes Dam is approximately three miles. The deepest portion of the lake is near the northern end of the dam, and numerous areas have been apparently dredged adjacent to boat docks. The DTM shows a shallow, almost bowl-shaped cross-section.

Lake Nasworthy was estimated by this survey to encompass 1,380 acres and to contain a volume of 10,108 acre-feet at the normal pool elevation of 1872.2 feet. The reservoir volume table is presented in Appendix B, and the area table in Appendix C. The one-tenth foot intervals are based on actual calculations from the model. An elevation-area-volume graph is presented in Appendix D. Cross-sections of the reservoir can be found in Appendix E. The surface elevation of the lake was approximately 0.1 feet below the normal pool elevation during the survey. The survey vessel cannot negotiate in water less than about 1.8 feet of depth, and the minimum depth that the depth sounder can acquire is about three feet. Therefore the upper two to four feet are based on a straight-line interpolation from the last data points collected to the normal pool elevation lake boundary as digitized. The positional data collected in the field corresponds well with the boundary obtained from the USGS map. The Board does not represent the boundary, as depicted in this report, to be a detailed actual boundary. It is an approximation of the actual boundary used to compute the volume and area within the upper elevations.

The storage volume calculated by this survey is approximately 18.4 percent less than the previous record information for the lake. The low flow outlet is at elevation 1860.0 feet, resulting in dead storage of 493 acre-feet. Therefore the conservation storage for the reservoir is calculated to be 9,615 acre-feet.

SUMMARY

The lowest elevation encountered during this survey was 1836.2 feet, or 36 feet of depth. The conservation storage was calculated to be 10,108 acre-feet. None of the area, or volume, south of the perimeter road was included in the calculations. The estimated reduction in storage capacity is 2,282 acre-feet, or 18.4 percent less than that recorded in the permit. It is assumed that the reduction in estimated storage is due to both a combination of sedimentation, and improved data and calculation methods. Repeating this survey with the same calculation methodology in five to ten years or after major flood events should remove any noticeable error due to improved calculation techniques and will help isolate the storage loss due to sedimentation.

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')

TEXAS WATER DEVELOPMENT BOARD
RESERVOIR VOLUME TABLE

Dec 2 1993

LAKE NASWORTHY - SURVEY DATE AUG/SEPT 1993

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

ELEV. FEET	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
1,840										
1,841										
1,842										
1,843										
1,844									1	1
1,845	1	1	1	1	1	1	1	1	1	1
1,846	1	1	1	1	1	1	1	1	1	1
1,847	1	1	1	1	1	1	1	1	1	1
1,848	1	1	1	1	1	1	1	1	1	1
1,849	1	2	2	2	2	2	2	2	2	2
1,850	2	2	2	2	2	2	2	2	2	2
1,851	2	2	2	2	2	2	3	3	3	3
1,852	3	3	3	3	3	3	3	4	4	4
1,853	4	4	5	5	5	6	6	6	7	8
1,854	8	9	10	11	12	13	14	15	17	18
1,855	20	22	25	27	30	33	36	40	43	47
1,856	51	55	59	64	69	74	79	84	90	95
1,857	102	108	115	122	129	137	145	153	162	171
1,858	181	191	202	214	226	239	252	266	280	295
1,859	311	327	343	360	378	396	414	433	452	472
1,860	493	514	536	558	581	605	629	654	680	706
1,861	733	761	790	819	849	879	911	944	977	1012
1,862	1048	1085	1124	1163	1204	1246	1290	1334	1380	1427
1,863	1474	1523	1573	1624	1677	1730	1784	1839	1895	1952
1,864	2010	2069	2128	2189	2251	2313	2377	2441	2506	2573
1,865	2640	2708	2777	2847	2918	2990	3063	3137	3212	3288
1,866	3365	3443	3522	3602	3683	3765	3848	3933	4018	4104
1,867	4192	4281	4370	4461	4553	4646	4740	4835	4931	5028
1,868	5127	5226	5327	5428	5530	5634	5738	5842	5948	6054
1,869	6161	6269	6378	6487	6597	6708	6820	6932	7045	7159
1,870	7273	7388	7504	7620	7737	7855	7974	8093	8214	8334
1,871	8456	8578	8701	8824	8949	9074	9200	9326	9454	9582
1,872	9711	9862	10108							

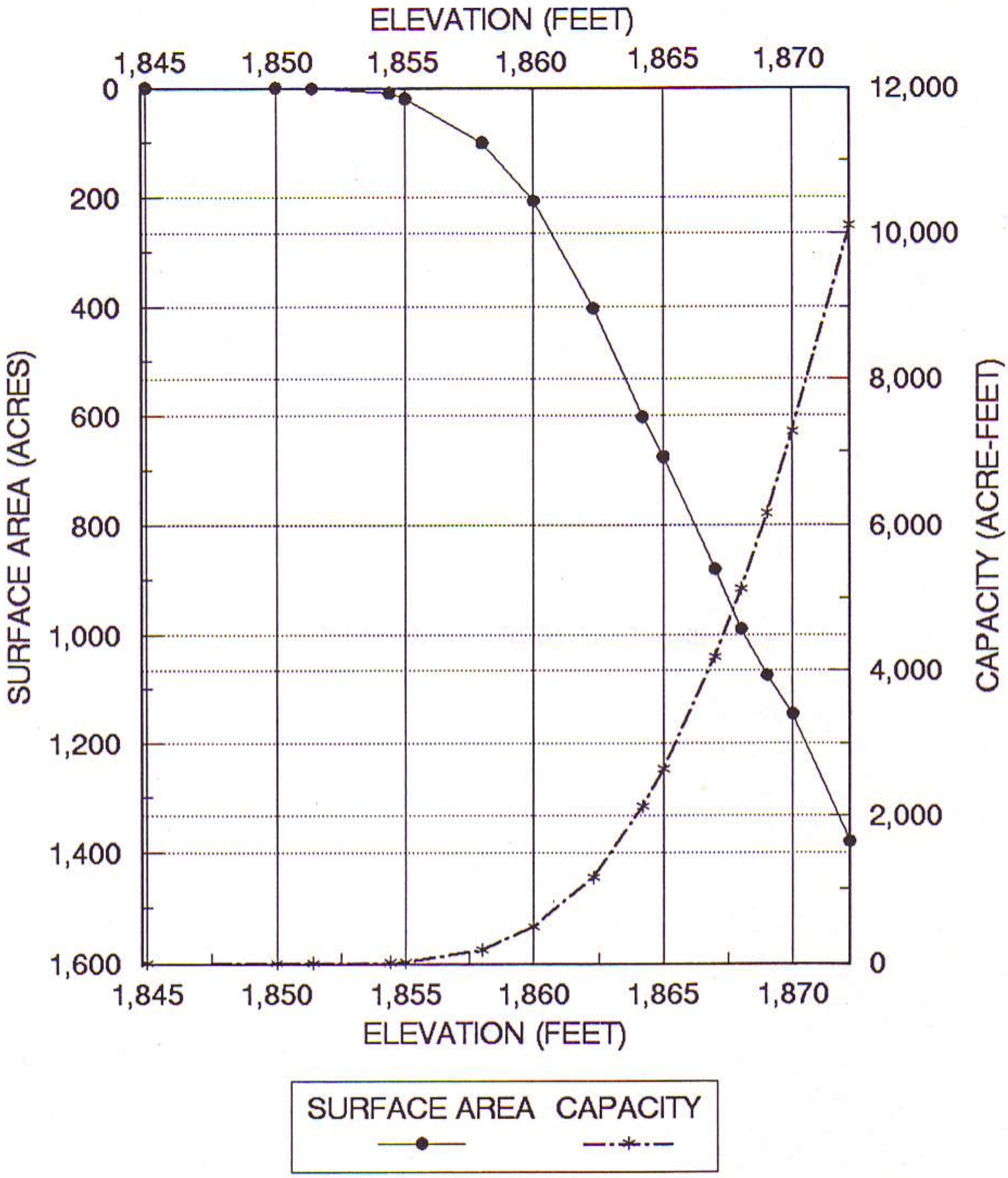
TEXAS WATER DEVELOPMENT BOARD
RESERVOIR AREA TABLE

Dec 2 1993

LAKE NASWORTHY - SURVEY DATE AUG/SEPT 1993

AREA IN ACRES — ELEVATION INCREMENT IS ONE TENTH FOOT

ELEV. FEET	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
1,840										
1,841										
1,842										
1,843										
1,844										
1,845										
1,846										
1,847										
1,848										
1,849										
1,850										
1,851					1	1	1	1	1	1
1,852	1	1	1	1	1	1	1	2	2	2
1,853	2	2	3	3	3	4	5	5	6	6
1,854	7	8	9	9	10	11	12	14	16	18
1,855	20	22	24	27	29	31	33	35	37	39
1,856	41	42	44	46	48	50	52	55	57	60
1,857	63	65	68	71	75	78	82	86	90	95
1,858	101	107	112	118	124	130	136	142	147	153
1,859	158	163	168	172	177	182	187	192	197	202
1,860	207	214	220	227	234	241	248	254	261	267
1,861	274	281	288	296	304	312	321	332	342	353
1,862	365	377	390	403	415	428	440	451	462	473
1,863	484	495	505	516	526	536	546	555	565	575
1,864	584	594	603	612	621	630	639	649	658	667
1,865	676	685	695	705	715	724	734	744	754	765
1,866	775	786	796	807	817	827	837	847	858	869
1,867	881	892	902	913	924	935	946	957	968	979
1,868	990	1000	1009	1018	1027	1036	1044	1052	1060	1067
1,869	1075	1083	1090	1097	1104	1112	1119	1126	1133	1140
1,870	1147	1154	1161	1168	1176	1183	1190	1197	1204	1211
1,871	1218	1226	1233	1240	1247	1255	1262	1270	1277	1285
1,872	1294	1312	1380							



LAKE NASWORTHY SURVEY

Aug./Sept. 1993

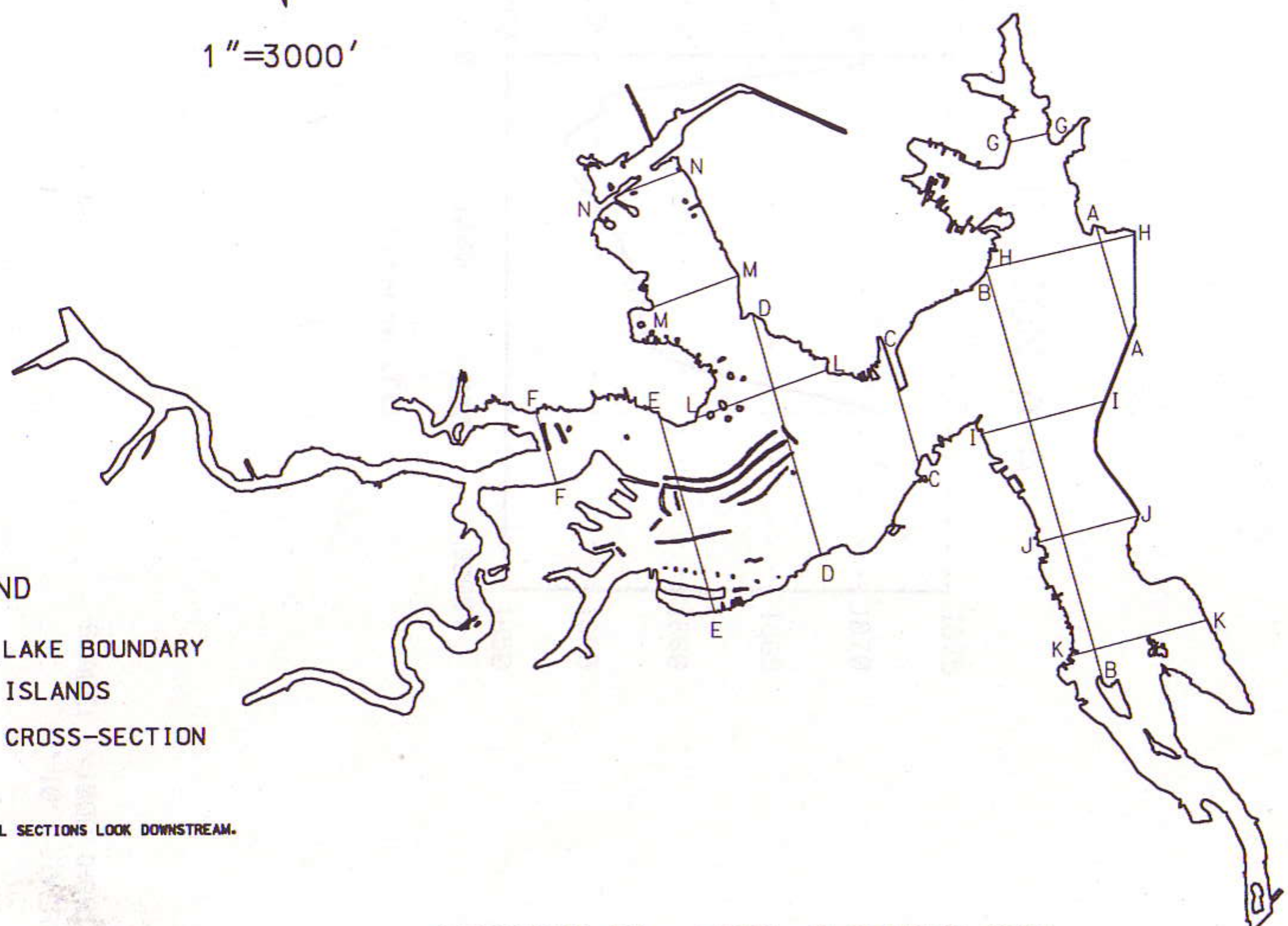
Prepared by : TWDB December 1993

LAKE NASWORTHY

CROSS-SECTIONS

N

1"=3000'



LEGEND

LAKE BOUNDARY

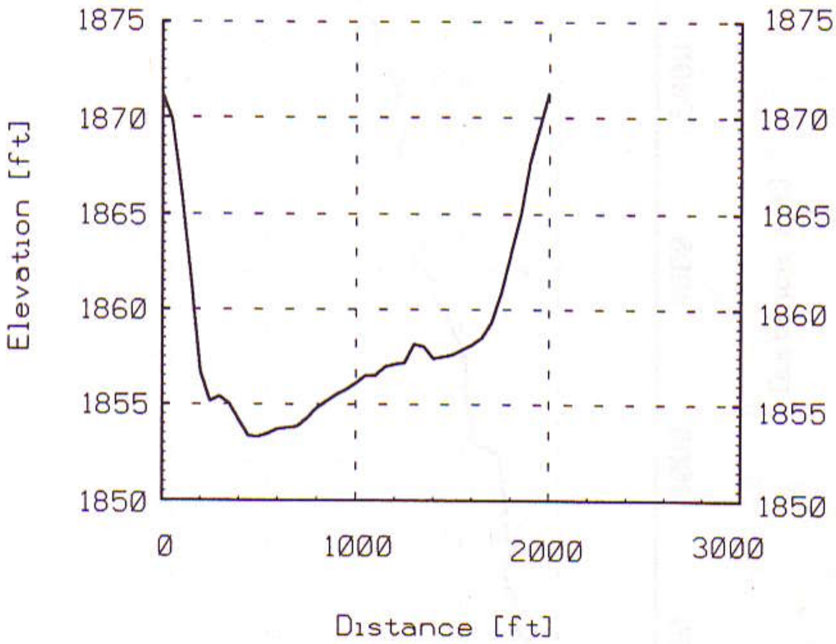
ISLANDS

A—A CROSS-SECTION

NOTE: ALL SECTIONS LOOK DOWNSTREAM.

PREPARED BY: TWDB DECEMBER 1993

SECTION A-A



SCALE: 1"=1000' (HORIZ)
1"=10' (VERT)

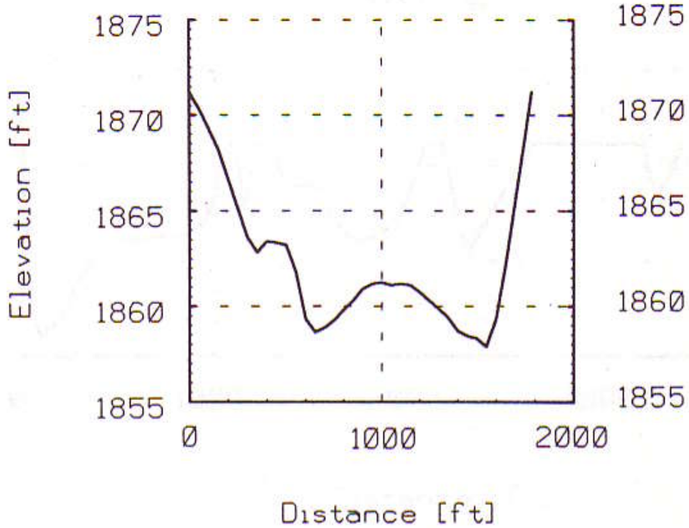
PREPARED BY: TWDB DECEMBER 1993

SECTION B-B

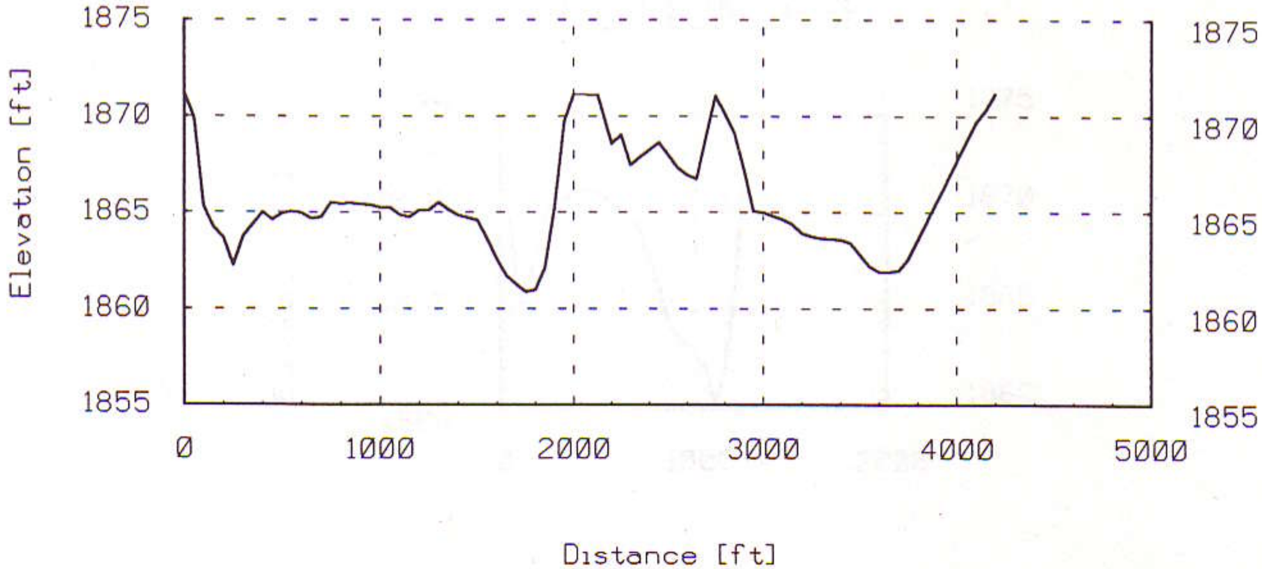
SCALE: 1"=1000' (HORIZ)
1"=10' (VERT)

PREPARED BY: TWDB DECEMBER 1993

SECTION C-C



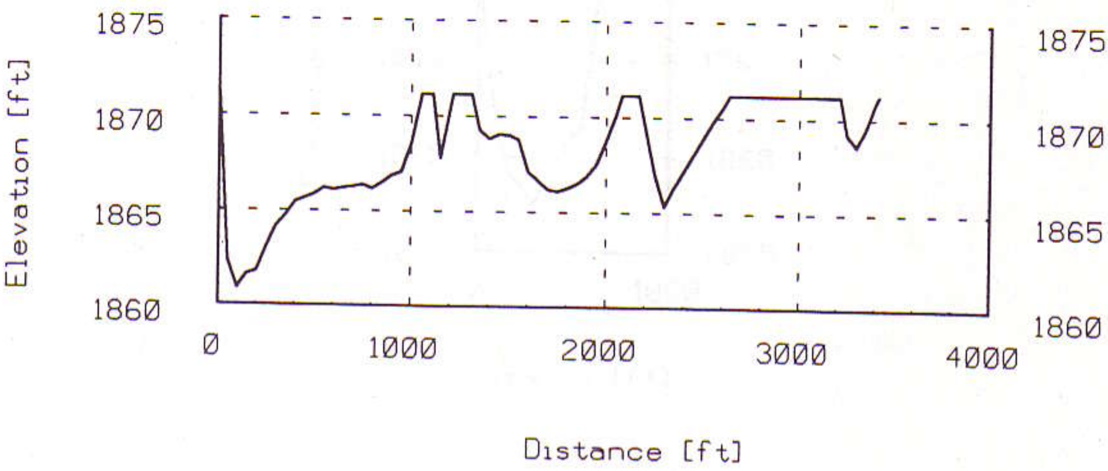
SECTION D-D



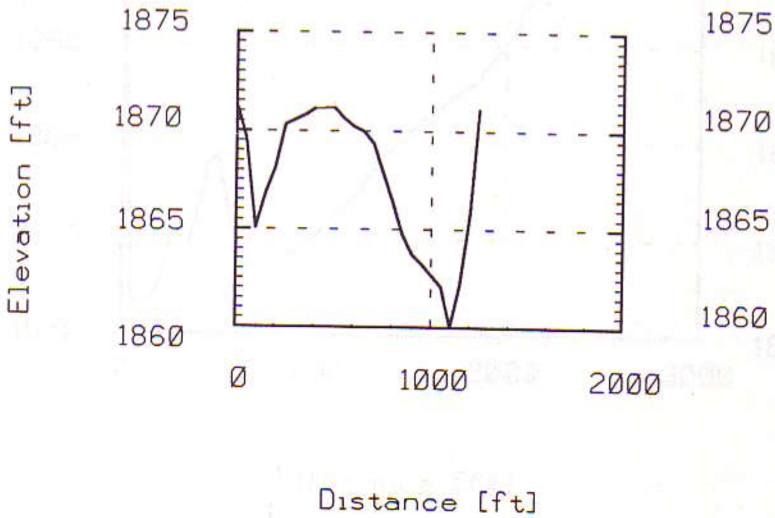
SCALE: 1"=1000' (HORIZ)
1"=10' (VERT)

PREPARED BY: TWDB DECEMBER 1993

SECTION E-E



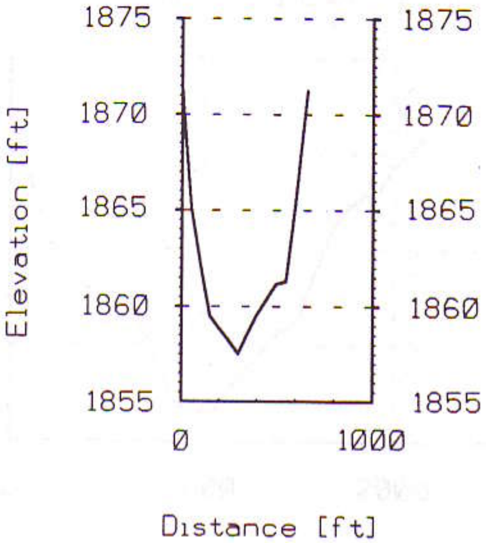
SECTION F-F



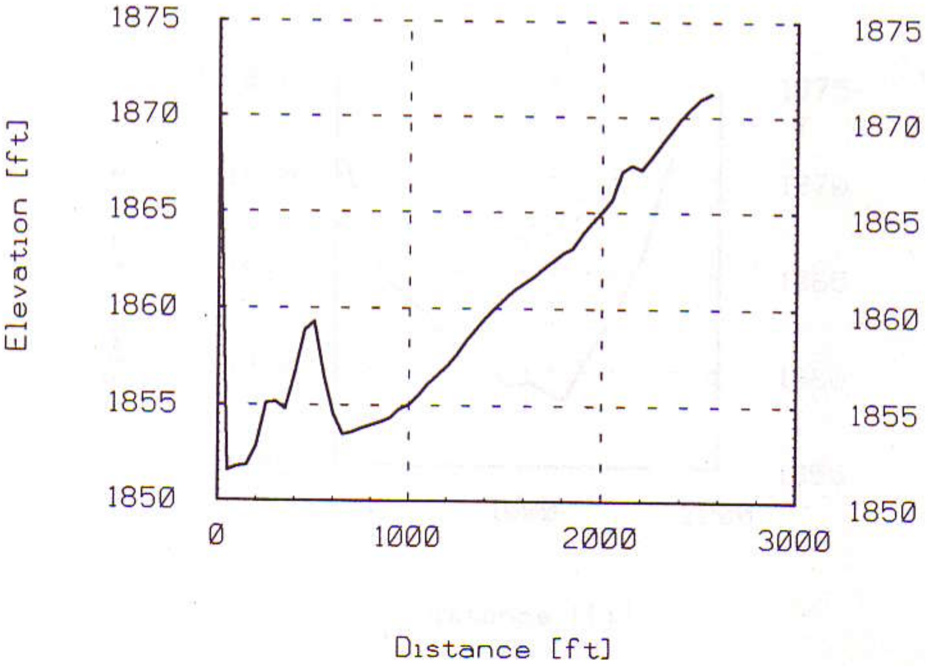
SCALE: 1"=1000' (HORIZ)
1"=10' (VERT)

PREPARED BY: TWDB DECEMBER 1993

SECTION G-G



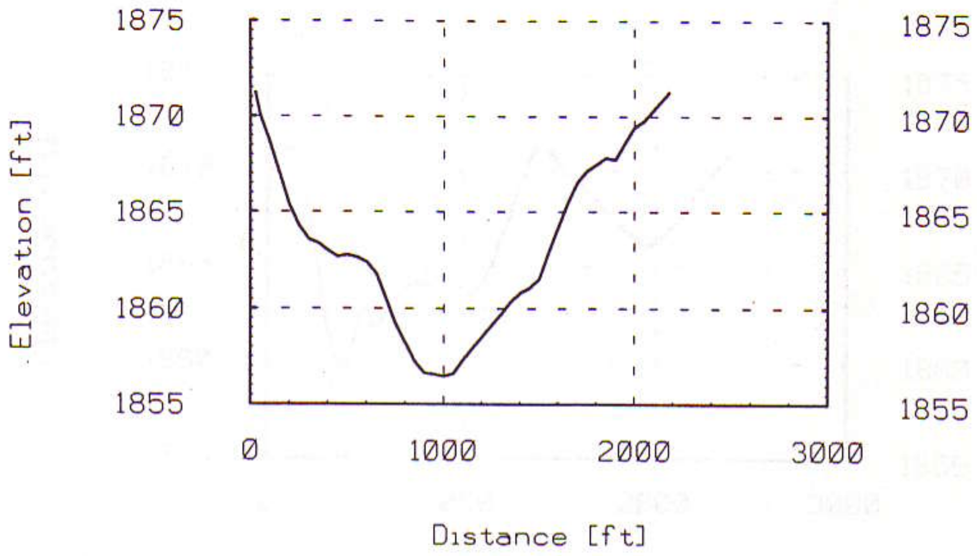
SECTION H-H



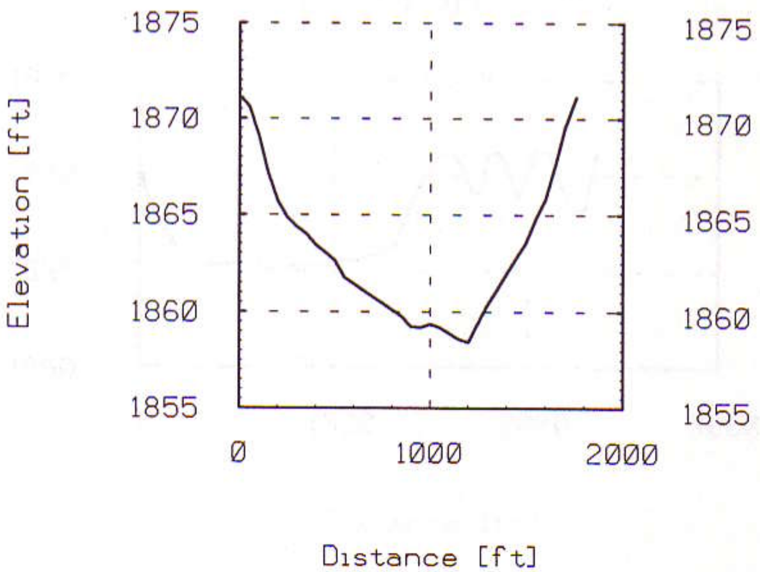
SCALE: 1"=1000′ (HORIZ)
1"=10′ (VERT)

PREPARED BY: TWDB DECEMBER 1993

SECTION I-I



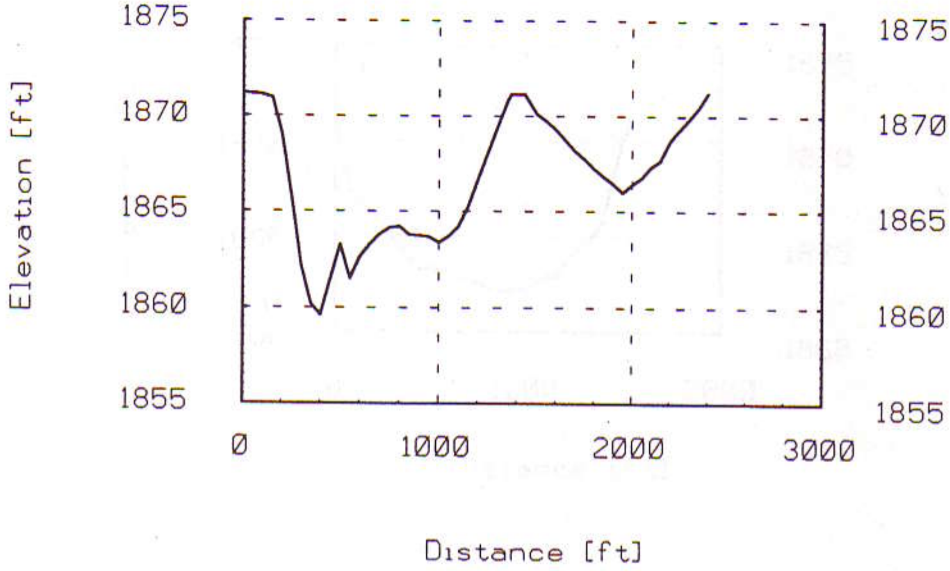
SECTION J-J



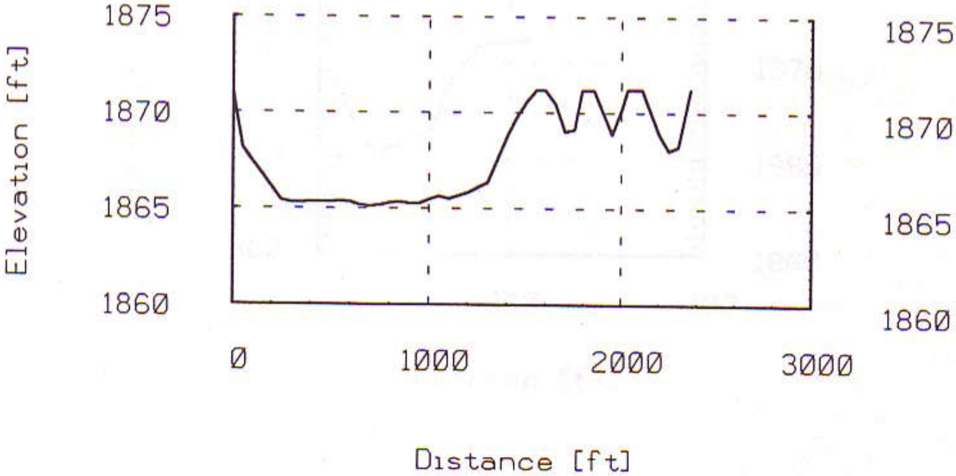
SCALE: 1"=1000' (HORIZ)
1"=10' (VERT)

PREPARED BY: TWDB DECEMBER 1993

SECTION K-K



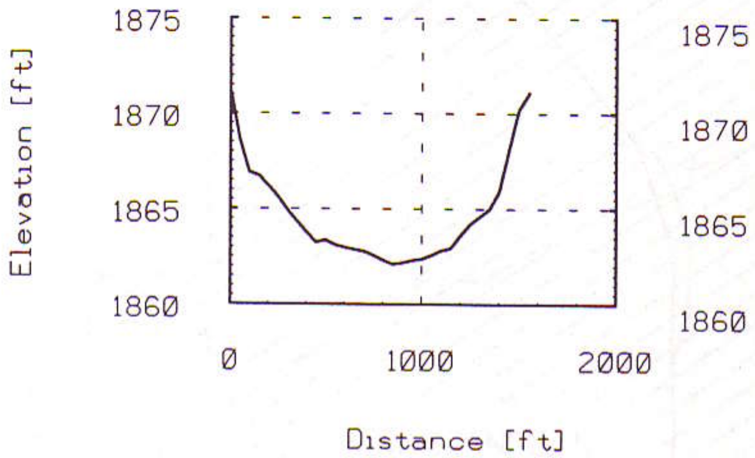
SECTION L-L



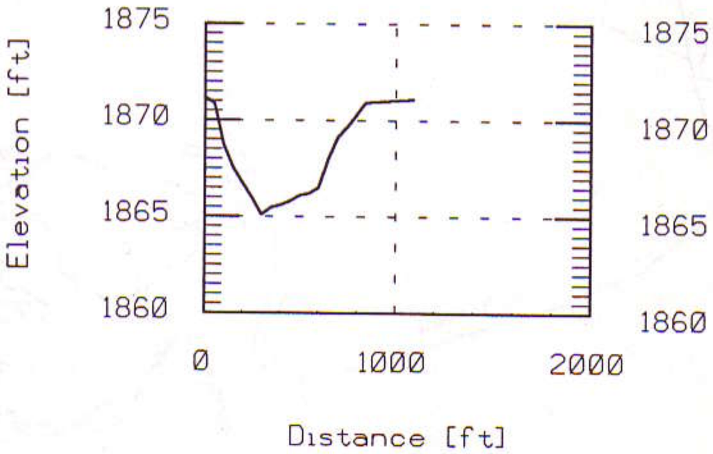
SCALE: 1"=1ØØØ' (HORIZ)
1"=1Ø' (VERT)

PREPARED BY: TWDB DECEMBER 1993

SECTION M-M



SECTION N-N



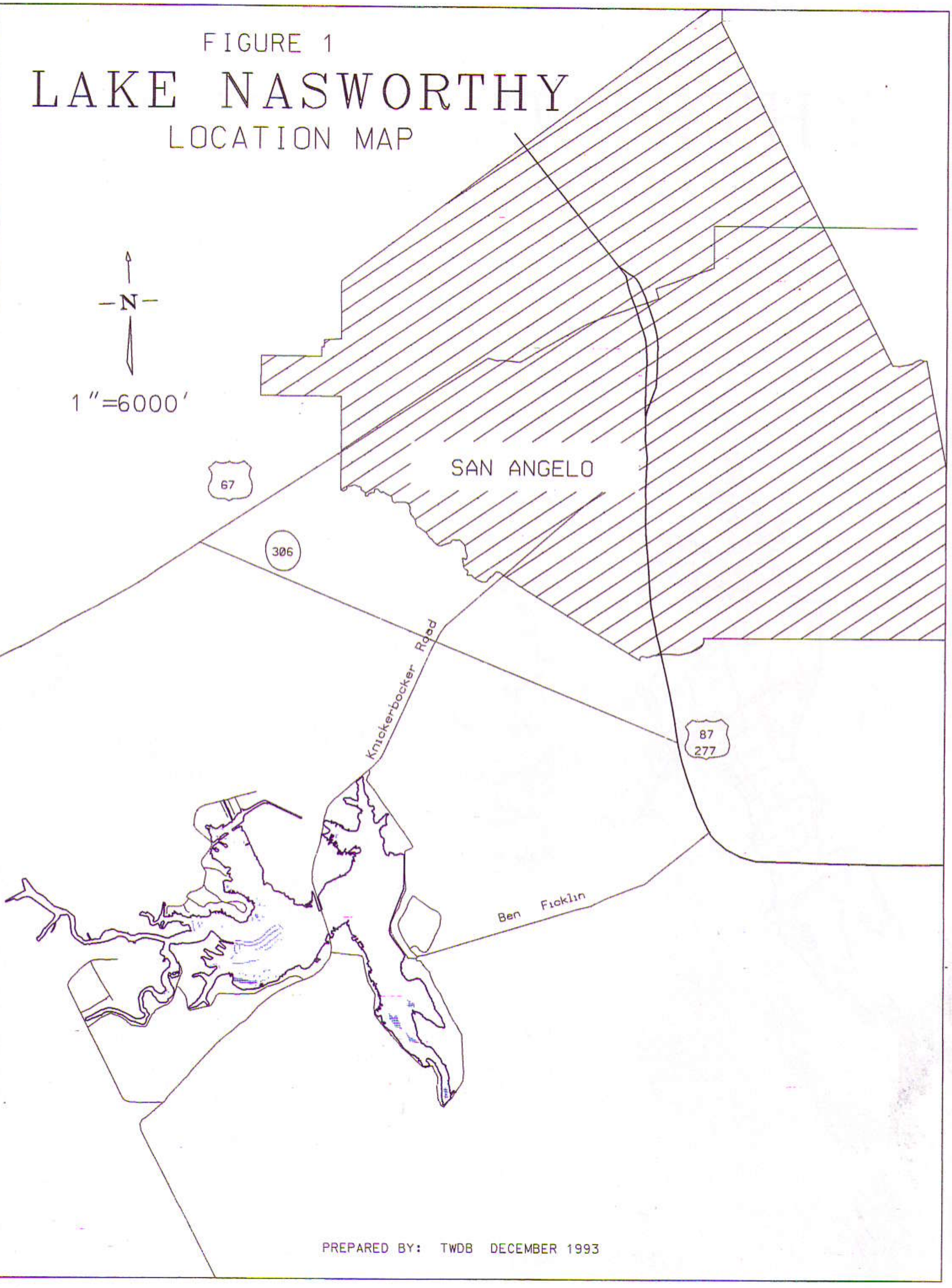
SCALE: 1"=1000' (HORIZ)
1"=10' (VERT)

PREPARED BY: TWDB DECEMBER 1993

FIGURE 1

LAKE NASWORTHY

LOCATION MAP



PREPARED BY: TWDB DECEMBER 1993

FIGURE 2

LAKE NASWORTHY

LOCATION OF DATA

LEGEND

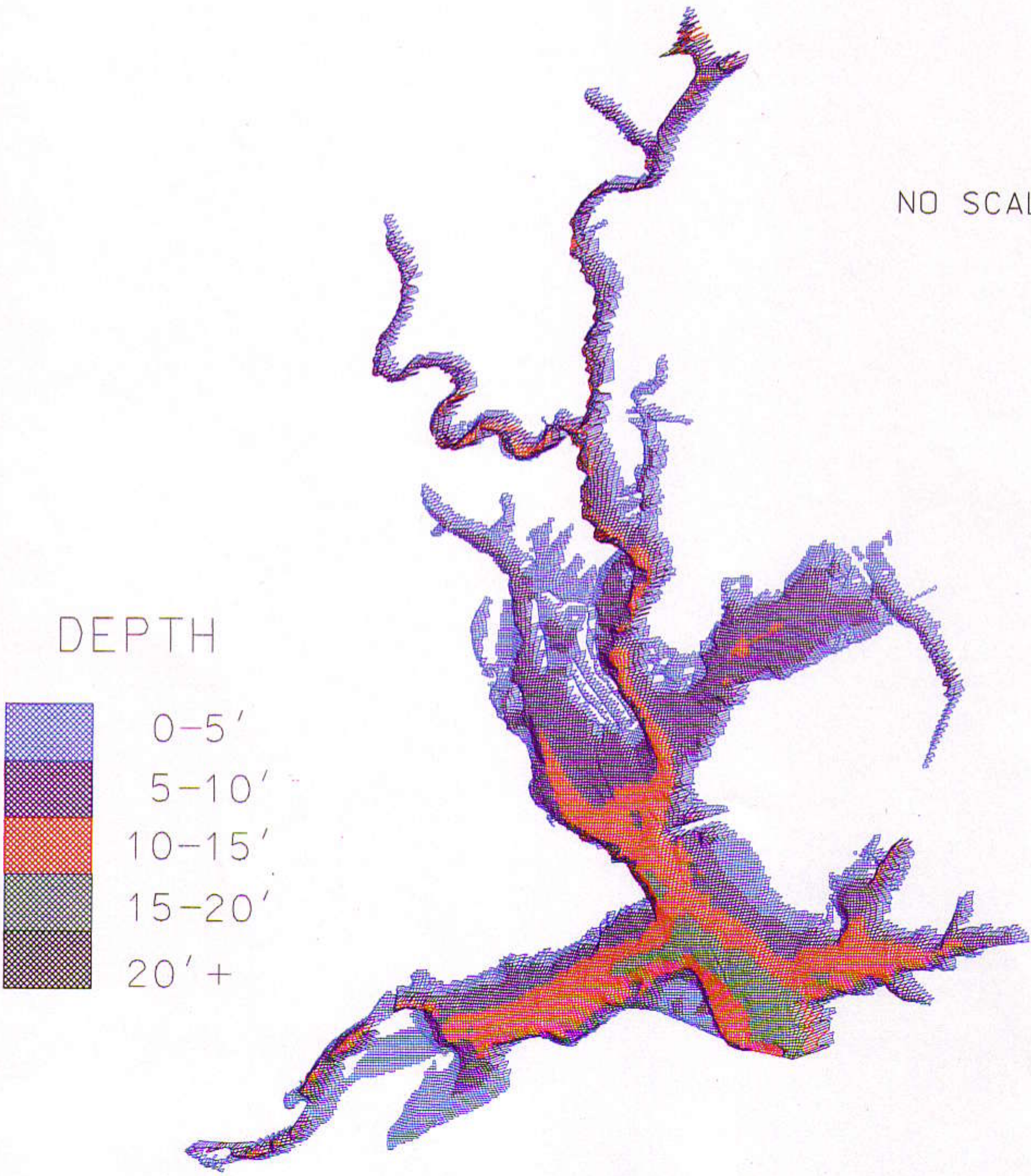
- LAKE BOUNDARY
- ISLANDS
- DATA POINTS
- ⊗ LOCATION OF SHORE STATION

PREPARED BY: TWDB DECEMBER 1993

FIGURE 3

LAKE NASWORTHY

3-D BOTTOM SURFACE



PREPARED BY: TWDB DECEMBER 1993