VOLUMETRIC SURVEY OF PROCTOR LAKE

Prepared for:

BRAZOS RIVER AUTHORITY

Prepared by:

The Texas Water Development Board

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INTRODUCTION

Staff of the Hydrologic Survey Program of the Texas Water Development Board (TWDB) conducted a hydrographic survey on Proctor Lake in December, 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

The water rights to Proctor Lake are owned by the Brazos River Authority. The dam and shoreline surrounding the lake are owned and operated by the United States Government (U.S. Army Corps of Engineers). The lake is located in Comanche County approximately three and one-half miles west of Proctor, Texas. Proctor Dam is located on the Leon River, a tributary of the Little River, that is a tributary of the Brazos River. Records show the drainage area for the facility to be 1,265 square miles. Dam construction commenced on June 29, 1960. Deliberate impoundment began in May 1963 and the dam was considered complete on January 2, 1964. The U.S. Army Corps of Engineers designed the dam with Armstrong and Ryan of Alberquerque, New Mexico as contractor. The estimated cost for the facility was $14,450,000. The structure consists of a rolled eathfill embankment, 13,460 feet in length with a maximum height of 86 feet above the natural streambed. The crest width is 20 feet with a maximum base width of 445 feet. The spillway is a 520 foot, gate controlled concrete ogee structure with 11 tainter gates, 40 feet wide by 35 feet high. The crest elevation of the ogee weir is 1,162 feet above mean sea level(msl) 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. The service outlet consist of two conduits, each 36 inches in diameter with controlled gates. The invert elevation for the low-flow outlet is 1,128.0 feet above msl. Based on a 1946 survey, records indicate that Proctor Lake has a surface area of 4,610 acres and a capacity of 59,400 acre/feet at the normal conservation pool elevation of 1162.0 feet above msl.

Application No. 2292 was filed June 11, 1962, with the Texas Water Commission by the Brazos River Authority to construct a dam and reservoir on the Leon River and to impound a maximum of 64,100 acre-feet of water.

Permit No. 2107 was issued July 24, 1964. Authorization was given to impound 59,400 acre-feet of water. Maximum allocations were set as follows: 18,000 acre-feet for municipal purposes; 18,000 acre-feet acre-feet for industrial purposes; and 18,000 acre-feet for irrigation purposes.

On September 13, 1979, Permit No. 2107 was amended to allow the Brazos River Authority the right to use the waters of Prooctor Lake for recreational purposes. All other authorizations in the original permit remained enforced.

Permit No. 2107 was amended a second time on November 25, 1980. Basically all authorizations remained the same except for 200 acre-feet of the 18,000 acre-feet allocated for industrial purposes could be used for mining purposes.

Certificate of Adjudication No. 5159 was issued to the Brazos River Authority on December 14, 1987. The owner was authorized to maintain an existing dam and reservoir and impound a maximum of 59,400 acre-feet of water at elevation 1162 feet above msl. The owner was authorized a priority right to divert and use not to exceed 19,658 acre-feet of water per annum from Proctor Lake for municipal, industrial, irrigational and mining purposes.

Certificate of Adjudication No. 5167 was also issued to the Brazos River Authority on December 14, 1987. The owner was authorized to divert and use not to exceed 30,000 acre-feet of water for municipal purposes and 170,000 acre-feet of water for industrial purposes in the San

Jacinto-Brazos Coastal Basin. These waters were to be used from Proctor Lake and other reservoirs in the Brazos River Authority's system.

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 continously 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 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 24 satellites when fully implemented. At the time of the survey, 23 satellites of the constellation were fully functional. 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 Proctor Lake. 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 Proctor Lake 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, 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 ± 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 benchmark known as "SR-18" to serve as control for the shore station site. "SR-18", a brass cap embedded in concrete, was established in 1962 by the U.S. Army Corps of Engineers. It is located on the upstream face of the dam's embankment, approximately 200 feet northeast of the spillway gates. These coordinates are based on the North American Datum of 1983 (NAD '83). This location was chosen because of the close proximity to the reservoir, the unobstructed view of the reservoir, and the security of the area.

A static survey using the two Trimble 4000SE GPS receivers was performed to obtain coordinates for "SR-18". One GPS receiver was positioned over a USGS first-order monument (with known coordinates and elevation) named "GIBSON". "GIBSON" was established in 1902 and is located approximately 14 miles southeast of the Dublin, Texas.. Satellite data were gathered from this station for approximately one hour, with a maximum of seven satellites visible to the receiver. During the same time period, data were gathered from the second receiver positioned over the "SR-18" monument.

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 benchmark. 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 "SR-18" were determined to be North latitude 31° 58' 14.79", West longitude 098° 29' 01.11", and ellipsoid height of 339.41 meters. The approximate NGVD '29 elevation is 1203.40 feet. These coordinates were then entered into the shore station receiver located over "SR-18" 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 by digitizing the lake boundary from the USGS 7.5 minute quadrangle topographic maps (PROCTOR-1979, DE LEON-1969, COMYN-1979, and COMANCHE-1969). AutoCad software was used to digitize the reservoir's 1,162.0 contour based on the North American Datum of 1927 (NAD '27) used for the maps. The graphic boundary was then transformed from NAD '27 to NAD '83 using Environmental Systems Research Institutes's (ESRI) Arc/Info project command with the NADCOM parameters to get the boundary into the NAD '83 datum that is compatible with the positional information received from the satellites. The surface area of the reservoir's boundary shape was the same in both datum. (NAD '83, a flat projected representation of the curved earth surface, was chosen to calculate areas and volumes because the satellite positional data is received in this datum. NAD '27 is also a flat projection, but has a slightly different point of origin, and distinctly different state plane false northing and false easting coordinates. The differences help to distinguish point coordinates between the two datum.)

The resulting shape was modified slightly to insure that all data points gathered were within the boundary. The modification resulted in 45.6 additional surface acres being added to the model. The surface acreage at the normal pool elevation was thereby estimated to be 4,761 acres, or 3.3 percent greater than the recorded 4,610 acres. A current aerial photo, taken when the lake was full, would provide better definition of the present boundary. However, this minimal increase in accuracy does not appear to offset the cost at this time.

The survey layout was pre-planned using approximately 162 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 manually collected wherever the boat could maneuver. The manually collected data points were entered into the data set utilizing the DGPS horizontal position and manual polings of the depth. Additional random data were collected lengthwise in the reservoir after the pre-planned survey grid was completed. Figure 2 shows the actual location of the data collection sites. The figure represents some areas where data were not collected because the areas were inaccessible due to shallow water or obstructions. The data set included approximately 44,930 data points.

TWDB staff verified the horizontal accuracy of the DGPS used in the Proctor Lake survey to be within the specified accuracy of three meters. The shore station was set up over a known United States Geological Survey (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.

During the survey, the GPS receivers were operated in the following DGPS modes. 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. A PDOP (Position Dilution of Precision) limit of 7 was set for both receivers. The DGPS positions are known to be within acceptable limits of horizontal accuracy when the PDOP is 7 or less. An internal alarm 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 20 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 depending 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, Page 1.

Manual poling of depths within shallow areas agreed with the depth obtained by the depth sounder typically within ± 0.3 feet; 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. During post-processing, all points with a zero depth were deleted.

Each of the resulting data points collected consisted of a latitude, longitude and depth reading. The depths were transformed to elevations with a simple awk Unix command based on the water surface elevation recorded each day, rounded to the nearest tenth of a foot since the depth sounder reads in tenths of a foot. The water surface ranged from 1162.06 to 1162.08 feet during the field survey. The latitude, longitude data set was converted to decimal degrees and loaded into Arc/Info along with the NAD '83 boundary file using the CREATETIN command. The data points and the boundary file were used to create a Digital Terrain Model (DTM) of the reservoir's bottom surface using the Arc\Info TIN module. 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. Areas that were too shallow for data collection or obstructed by vegetation were estimated by the Arc/Info's TIN product using this method of interpolation.

There were some areas where interpolation could not occur because of a lack of information along the boundary of the reservoir. "Flat triangles" were drawn at these locations.

ArcInfo does not use flat triangle areas in the volume or contouring features of the model. These areas were minimal on Proctor Lake. Therefore no additional points were required to allow for interpolation and contouring of the entire lake surface. From this three-dimensional triangular plane surface representation, the TIN 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 shaded by a GRIDSHADE command. Colors were assigned to different elevation values of the grid. Using the command COLORRAMP, a set of colors that varied from navy to yellow was created. The lower elevation was assigned the color of navy, and the lake normal pool elevation was assigned the color of yellow. Different intensities of these colors were assigned to the different depths in between. Figure 3 consists of the resulting depth-shaded representation of the lake. Figure 4 presents a two-dimensional version of the same map, using bands of color for selected contour intervals. The color increases in intensity from the shallow contour bands to the deep water bands.

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 1/1000 tolerance level to eliminate any duplicate points, and Round Corners with a maximum delta of 1/1000 of the model's maximum linear size, in an attempt to smooth some of the angularity of the contours. Contours of the bottom surface at two foot intervals and typical cross-sections are presented in Figure 5. Figure 6 presents additional surface contour information above the lake's normal pool elevation.

DATA

Proctor Lake inundates the confluence of the Leon River and Rush Creek and other tributaries. There are two distinct arms to the lake with a small island located at the confluence.

The deepest portions of the lake are found around the island, near the dam, at the confluence of the arms. The DTM shows a fairly deep pool of water at the confluence; arms bounded by relatively steep side walls, and a distinctive sloping canyon floor.

Proctor Lake was estimated by this survey to encompass 4,761 acres and to contain a volume of 55,588 acre-feet at the normal pool elevation of 1,162.0 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. At a minimum, the top two feet were estimated since the boat cannot negotiate in shallow water. This estimation was 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 corresponded well with the boundary obtained from the photo-revised 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 6.9 percent lower than the previous record information for the lake. The low flow outlet is at elevation 1,128.0 feet above msl, resulting in no dead storage volume. Therefore the conservation storage for the reservoir is calculated to be 55,590 acre-feet.

SUMMARY

The lowest elevation encountered during this survey was 1127.2 feet, or 34.8 feet of depth. The conservation storage was calculated to be 55,590 acre-feet. The estimated reduction in storage capacity is 3,810 acre-feet, or 6.9 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')

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

Mar 4 1994

RESERVOIR VOLUME TABLE

PROCTOR LAKE DECEMBER 1993 SURVEY

VOLUME IN ACRE-FEET ELEVATION INCREMENT IS ONE TENTH FOOT

ELEV. FEET	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
1,126										
1,127										
1,128										
1,129										
1,130										
1,131										1
1,132	1	1	1	2	4	6	9	12	15	19
1,133	25	31	39	47	57	69	82	96	113	131
1,134	151	172	194	218	242	268	296	325	356	388
1,135	421	456	493	532	572	613	656	700	746	793
1,136	842	893	944	997	1051	1106	1162	1219	1278	1337
1,137	1398	1459	1522	1585	1649	1714	1780	1848	1916	1986
1,138	2057	2129	2202	2276	2350	2426	2503	2581	2660	2740
1,139	2821	2903	2986	3071	3157	3243	3331	3419	3509	3600
1,140	3691	3784	3877	3972	4067	4162	4259	4356	4454	4553
1,141	4652	4752	4853	4955	5057	5160	5263	5368	5473	5579
1,142	5685	5793	5901	6011	6121	6232	6345	6460	6576	6694
1,143	6814	6936	7058	7183	7308	7434	7562	7690	7820	7951
1,144	8083	8215	8349	8485	8621	8758	8897	9036	9177	9319
1,145	9462	9607	9752	9899	10046	10195	10344	10495	10647	10799
1,146	10953	11108	11264	11421	11579	11738	11899	12060	12222	12385
1,147	12549	12713	12879	13045	13213	13381	13551	13721	13893	14066
1,148	14240	14415	14591	14769	14947	15126	15306	15487	15669	15853
1,149	16037	16223	16410	16599	16788	16979	17170	17363	17558	17753
1,150	17950	18148	18348	18549	18752	18955	19160	19366	19574	19782
1,151	19991	20202	20414	20627	20841	21056	21273	21490	21709	21929
1,152	22149	22371	22595	22819	23045	23271	23499	23727	23957	24187
1,153	24419	24651	24885	25119	25355	25592	25829	26069	26310	26552
1,154	26795	27040	27286	27534	27782	28032	28283	28535	28789	29045
1,155	29302	29562	29826	30095	30370	30653	30942	31236	31536	31839
1,156	32145	32456	32771	33090	33412	33737	34065	34396	34731	35068
1,157	35410	35754	36102	36453	36808	37165	37526	37889	38255	38623
1,158	38993	39366	39742	40120	40501	40883	41269	41656	42047	42439
1,159	42834	43231	43630	44032	44435	44840	45247	45657	46068	46481
1,160	46896	47313	47732	48153	48576	49000	49426	49854	50284	50716
1,161	51149	51584	52021	52460	52901	53344	53789	54235	54685	55135
1,162	55588									

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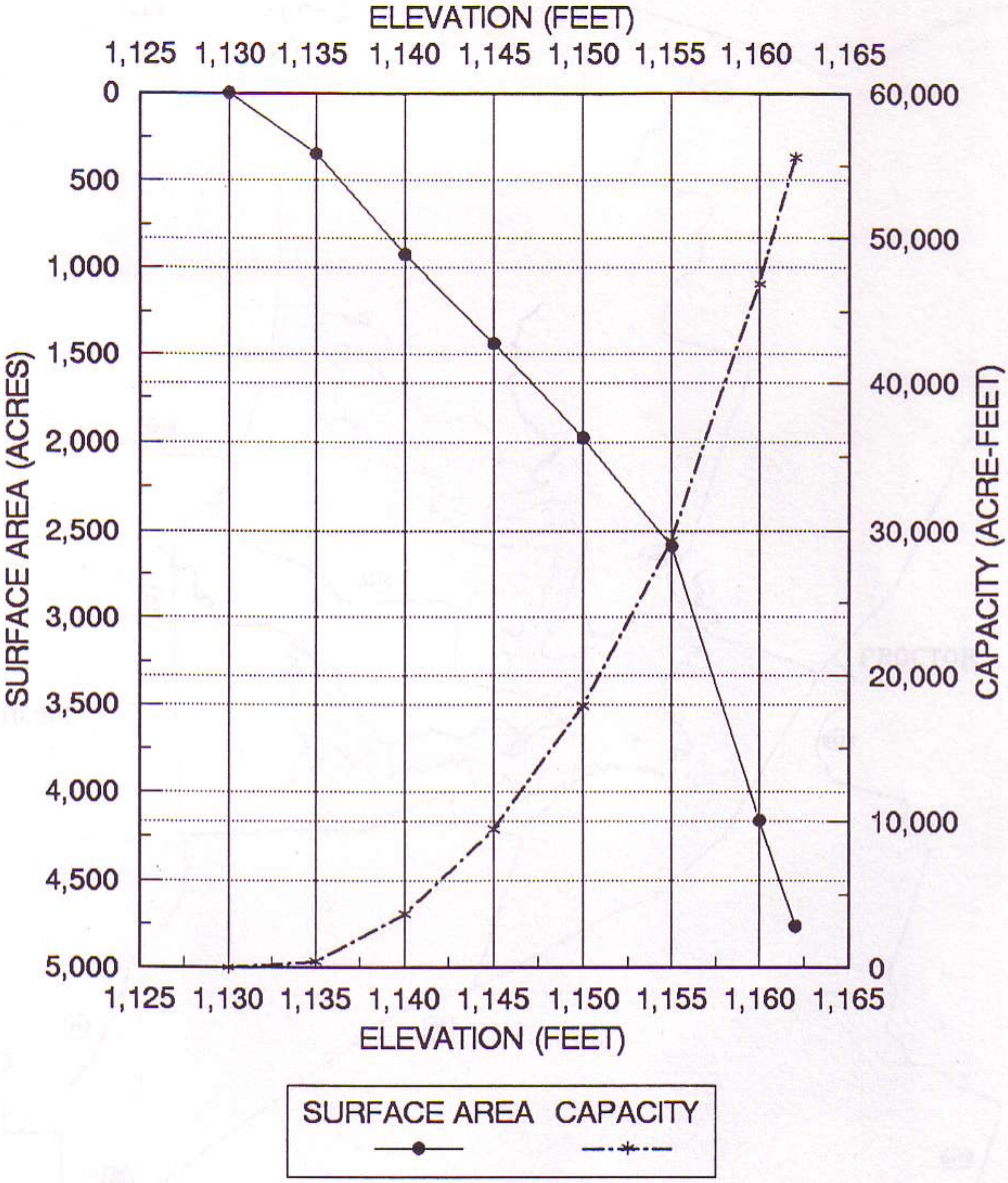
RESERVOIR AREA TABLE

PROCTOR LAKE DECEMBER 1993 SURVEY

AREA IN ACRES ELEVATION INCREMENT IS ONE TENTH FOOT

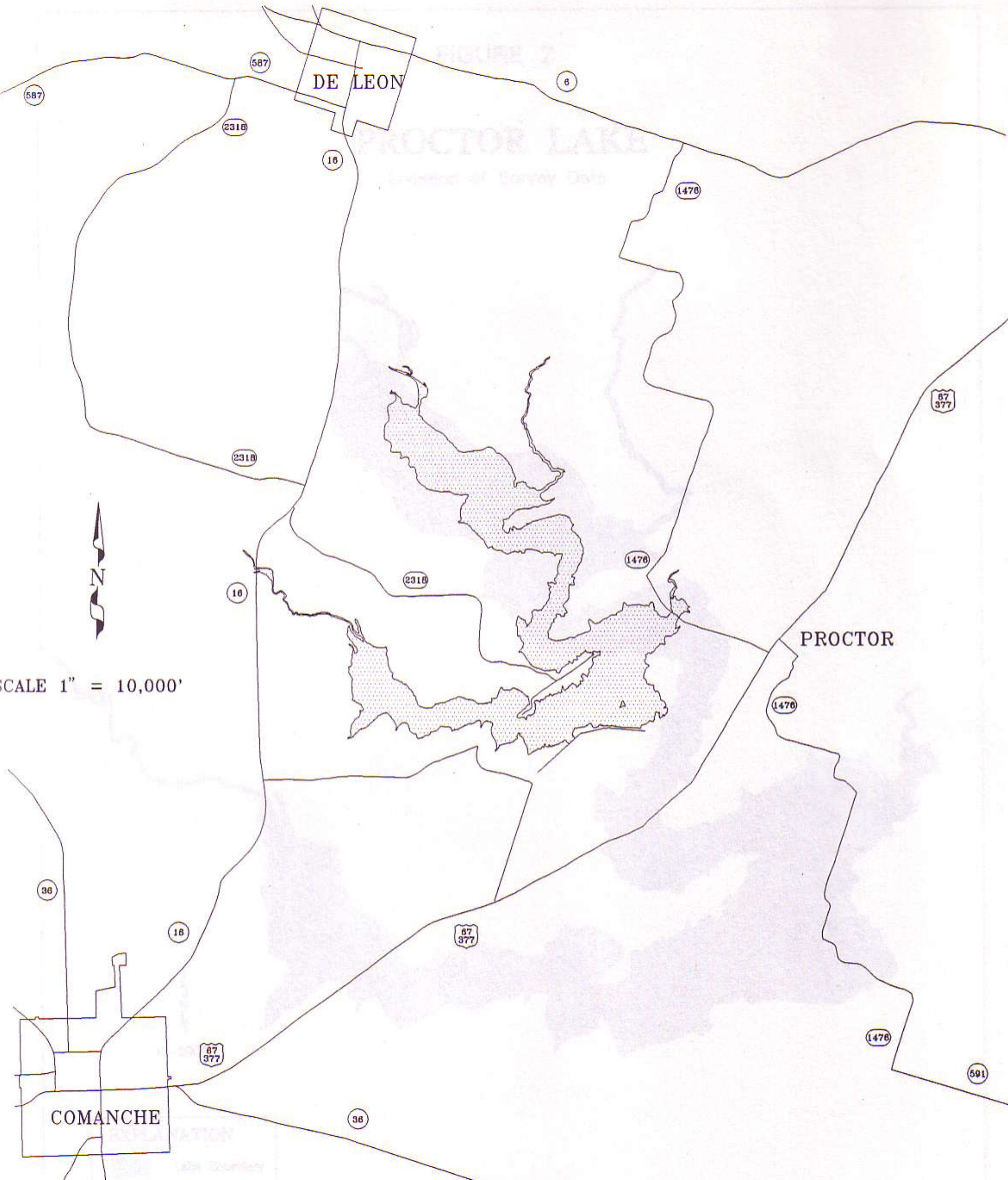
ELEV. FEET	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
1,126										
1,127										
1,128										
1,129										
1,130										
1,131									1	1
1,132	2	3	6	12	18	24	28	33	39	48
1,133	58	69	80	93	107	122	139	157	175	191
1,134	205	217	227	240	253	269	284	298	313	328
1,135	344	361	378	392	406	421	436	450	466	482
1,136	497	510	522	534	544	555	566	577	590	600
1,137	610	621	630	638	647	656	667	679	692	702
1,138	713	725	734	744	753	762	773	784	795	806
1,139	817	828	840	850	861	871	881	892	902	912
1,140	922	930	938	946	954	961	969	976	983	990
1,141	998	1005	1012	1019	1026	1033	1040	1047	1055	1062
1,142	1071	1079	1088	1098	1109	1121	1137	1155	1172	1190
1,143	1209	1223	1235	1248	1260	1270	1280	1291	1301	1312
1,144	1323	1334	1346	1357	1368	1380	1392	1402	1414	1426
1,145	1437	1449	1460	1470	1481	1491	1501	1511	1521	1532
1,146	1543	1555	1566	1577	1587	1597	1607	1616	1625	1634
1,147	1643	1651	1660	1669	1679	1690	1701	1713	1724	1736
1,148	1747	1757	1767	1776	1785	1795	1806	1818	1829	1841
1,149	1852	1864	1876	1889	1901	1913	1924	1936	1948	1960
1,150	1974	1991	2006	2018	2030	2044	2055	2067	2078	2089
1,151	2101	2113	2125	2136	2147	2159	2169	2180	2191	2202
1,152	2215	2227	2240	2251	2261	2270	2280	2289	2299	2309
1,153	2320	2330	2341	2351	2361	2373	2386	2400	2416	2430
1,154	2443	2455	2467	2480	2491	2504	2517	2531	2546	2562
1,155	2588	2622	2663	2713	2788	2863	2922	2969	3011	3049
1,156	3089	3130	3169	3203	3235	3267	3296	3327	3360	3395
1,157	3429	3463	3496	3529	3561	3591	3618	3644	3669	3693
1,158	3718	3745	3769	3793	3816	3841	3865	3888	3913	3936
1,159	3960	3983	4003	4023	4043	4064	4085	4103	4121	4141
1,160	4161	4181	4201	4218	4236	4253	4270	4288	4306	4324
1,161	4343	4361	4380	4399	4419	4438	4458	4478	4498	4518
1,162	4761									



PROCTOR LAKE

December 1993 Survey

Prepared by: TWDB March 1994



LAKE PROCTOR

Figure 1
Location Map

FIGURE 2

PROCTOR LAKE

Location of Survey Data

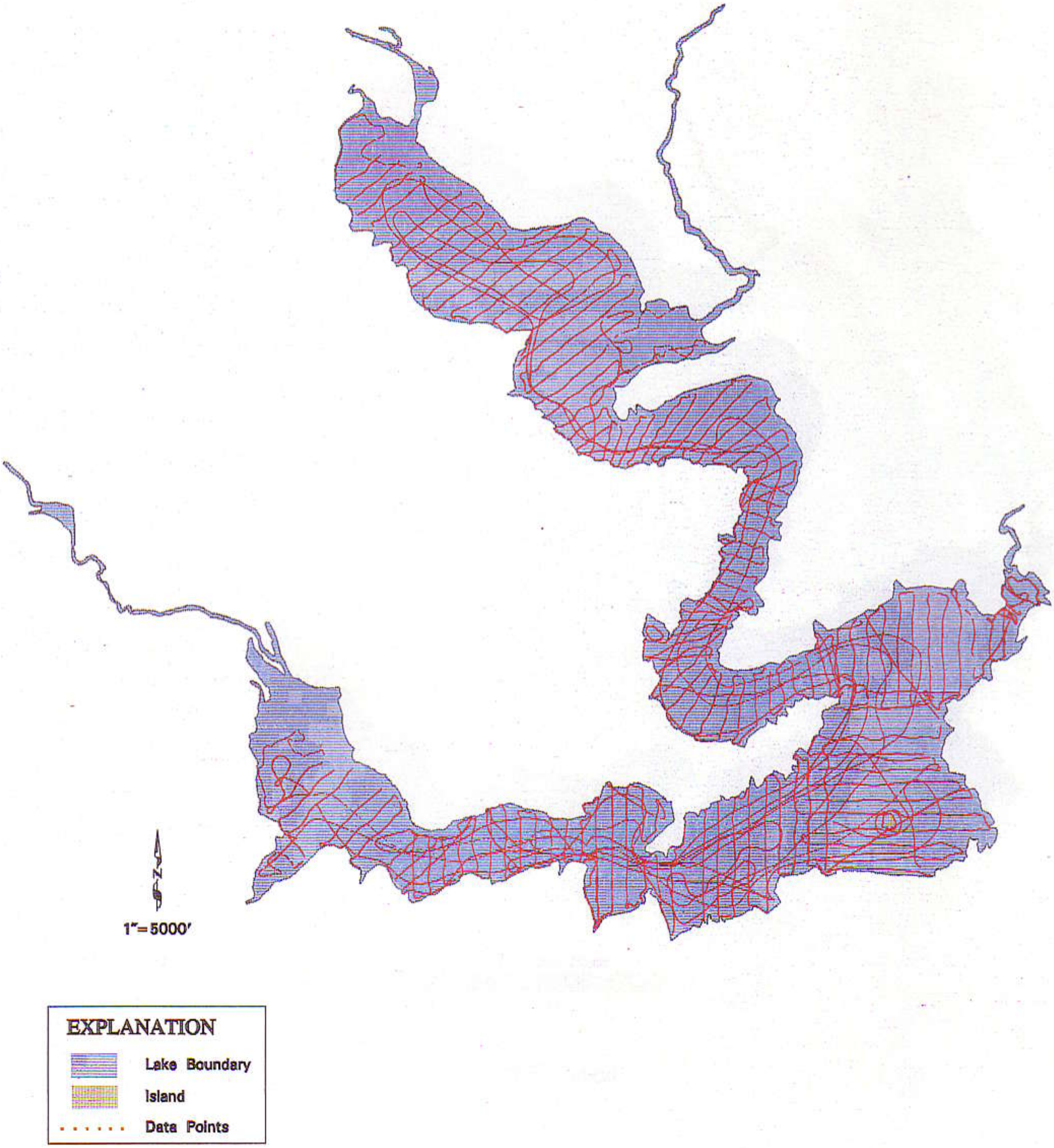


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FIGURE 3

PROCTOR LAKE

Shaded Relief

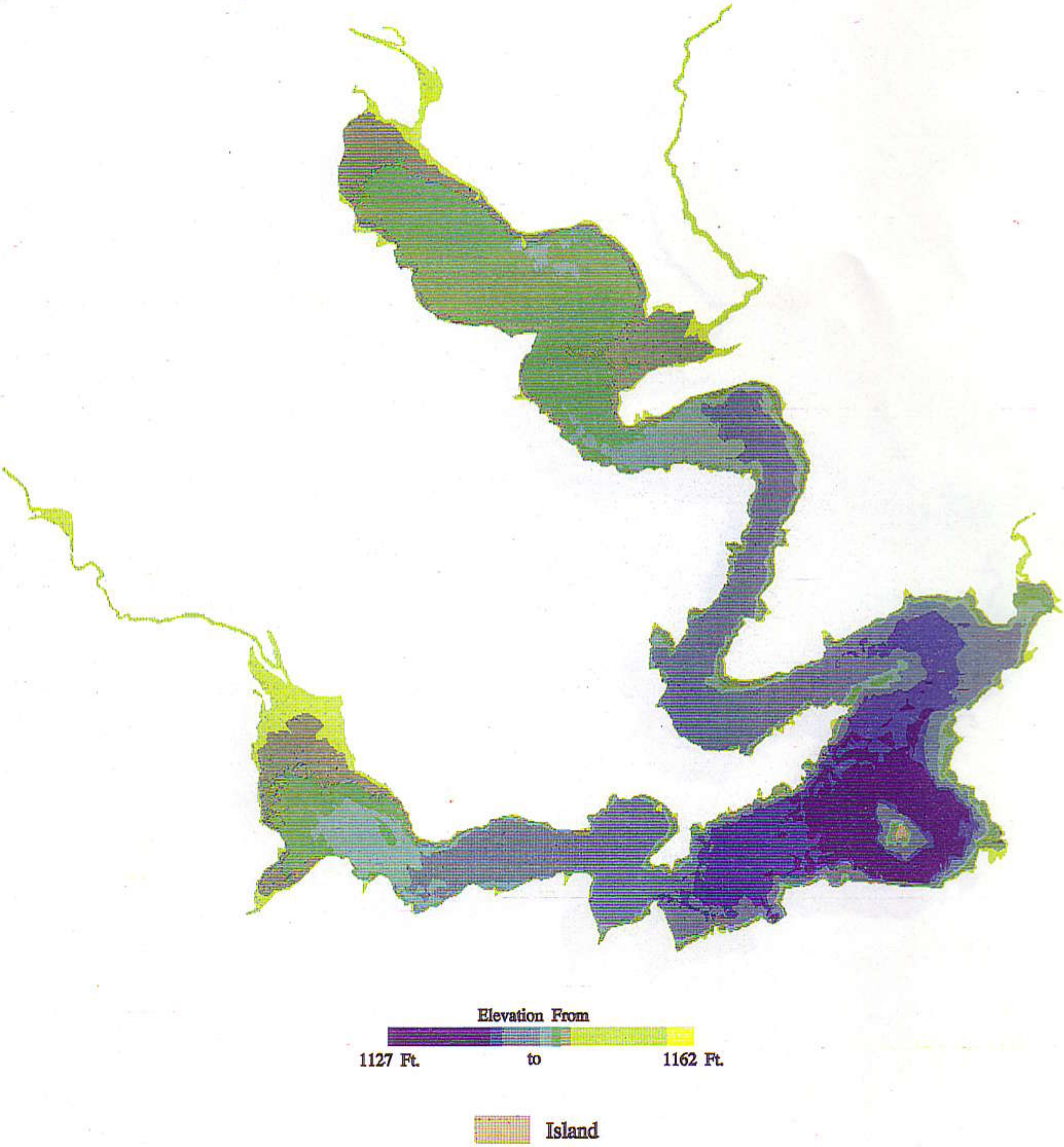

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FIGURE 4

PROCTOR LAKE

Depth Ranges

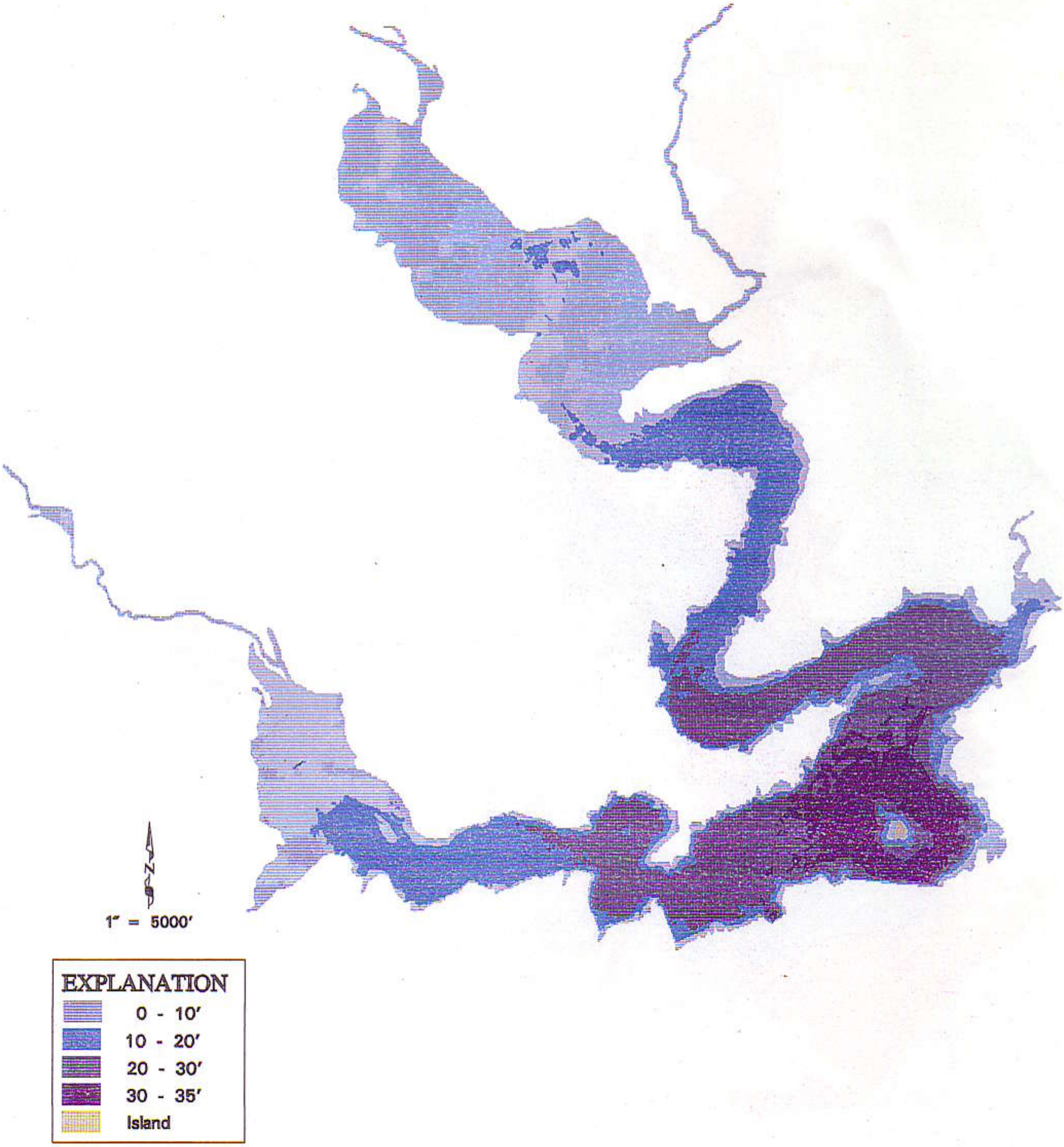

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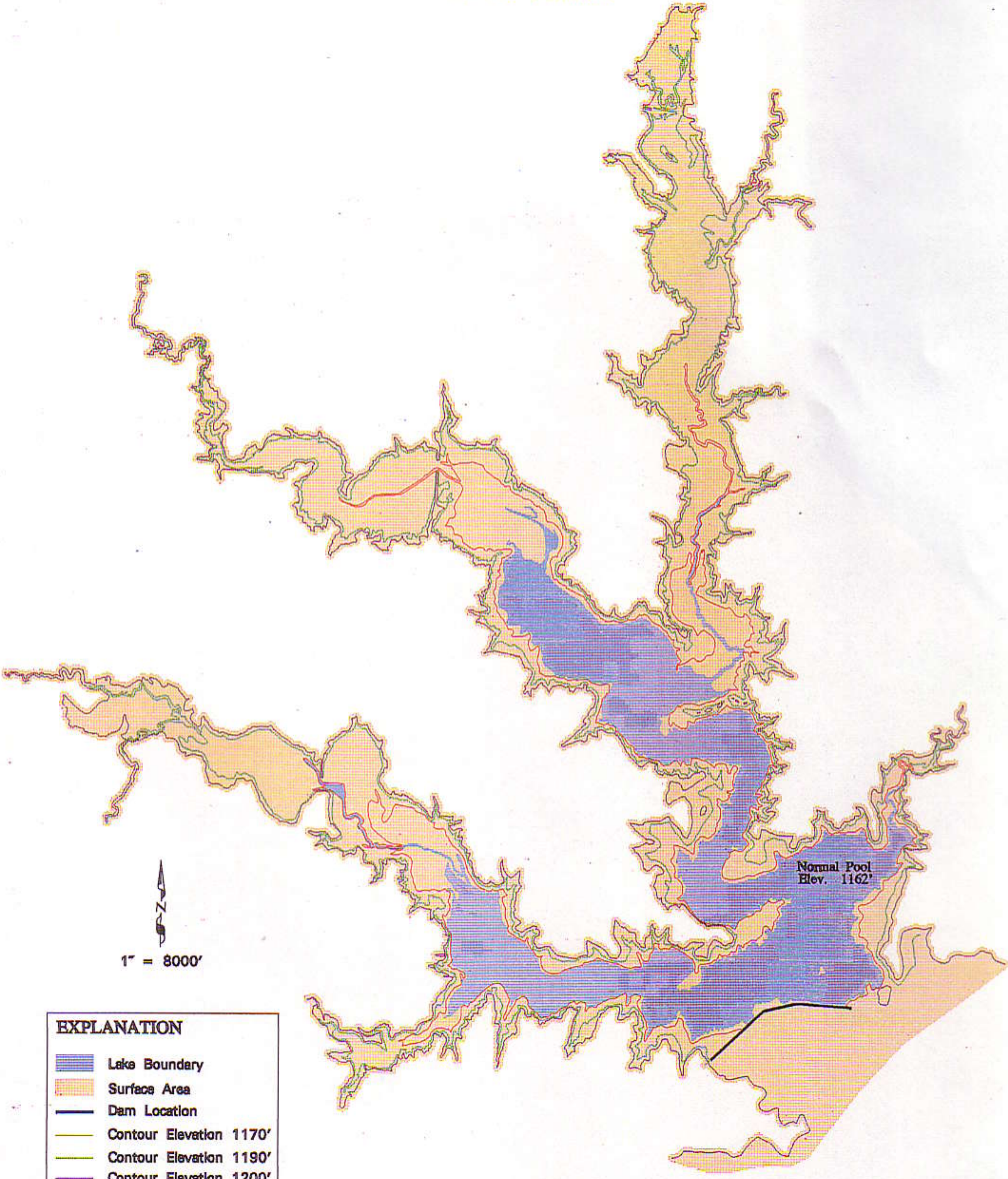
FIGURE 6

PROCTOR LAKE

Surface Contours



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