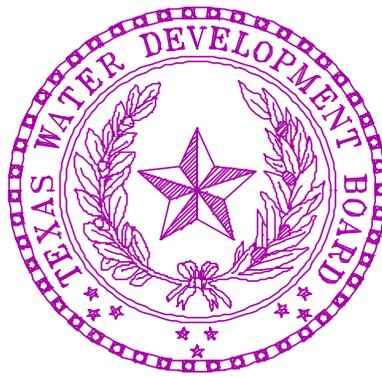


VOLUMETRIC SURVEY OF LAKE WEATHERFORD

Prepared for:

City of Weatherford



Prepared by:

The Texas Water Development Board

March 10, 2003

Texas Water Development Board

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LAKE WEATHERFORD HYDROGRAPHIC SURVEY REPORT

INTRODUCTION

Staff of the Hydrographic Survey Unit of the Texas Water Development Board (TWDB) conducted a hydrographic survey of Lake Weatherford during the periods of April 15 and 16, 1998. The purpose of the survey was to determine the capacity of the lake at the conservation pool elevation. From this information, future surveys will be able to determine the location and rates of sediment deposition in the conservation pool over time. Survey results are presented in the following pages in both graphical and tabular form. All elevations presented in this report will be reported in feet above mean sea level based on the National Geodetic Vertical Datum of 1929 (NGVD '29) unless the elevation is noted otherwise. The conservation pool elevation for Lake Weatherford is 896.0 feet. An April 1973 sedimentation survey performed by the United States Department of Agriculture, Soil Conservation Service estimated the original volume in 1957 at this elevation to be 21,233 acre-feet with a surface area of 1,144 acres. The 1973 survey calculated a new volume of 19,866 acre-feet and a surface area of 1,144 acres.

HISTORY AND GENERAL INFORMATION OF THE RESERVOIR

The City of Weatherford owns the water rights to Lake Weatherford and operates and maintains the associated Weatherford Dam. The lake is located on the Clear Fork Trinity River in Parker County, about seven miles east of Weatherford, TX. (See Figure 1). Records indicate the drainage area is approximately 109 square miles. At the conservation pool elevation of 896.0 feet, the lake has approximately 11.9 miles of shoreline and is 3.1 miles long. The widest point of the reservoir is approximately 1.5 miles (located 0.33 miles upstream of the dam).

Water Rights Permit No. 1771 (Application No. 1880), dated July 21, 1955, was issued to the City of Weatherford. This permit authorized the construction of a dam and reservoir to impound 19,470 acre-feet of water. It granted the owner the right to divert and use annually 4,500 acre-feet of

water for municipal and 1,500 acre-feet of water for industrial purposes. The Texas Water Commission issued Certificate of Adjudication No. 08-3356 on April 5, 1985. The certificate basically reinforces the authorization for the City of Weatherford to impound 19,470 acre-feet of water in an existing reservoir known as Lake Weatherford. The owner was authorized to divert and use not to exceed 4,500 acre-feet of water per year for municipal purposes and to divert, not to exceed 60,000 acre-feet of water per annum of which 600 acre-feet of water may be consumptively used for industrial purposes. Authorization was also granted to use 120 acre-feet of water per annum for irrigation purposes and that the impounded water could be used for recreational purposes.

Records indicate construction started for Lake Weatherford and Weatherford Dam in June 1956. Deliberate impoundment began in May 1957 when the project was officially completed. The design engineers for the facility were Freese and Nichols Engineering and Rady and Associates.

Weatherford Dam is a somewhat “L” shaped rolled earth fill embankment, 4,055 feet in length, with a maximum height of 75 feet. The original crest of the dam was 914.0 feet. The service spillway originally consisted of a semi-circular drop inlet located near the bend in the embankment with a crest elevation of 896.0 feet. Discharge is through a 9-foot square reinforced concrete conduit. The 425 feet long conduit extends through the embankment with an invert elevation at the discharge end of 840.0 feet. The emergency spillway is located on the far right (west) end of the dam. The design is a two-stage vegetated earth cut channel. The first level (located furthest from the embankment) is 500 feet in length with a crest elevation of 903.0 feet. The second channel section was originally also 500 feet in length with a crest elevation of 906.0 feet. A low-flow outlet consisting of an 18-inch valve-controlled steel lined concrete pipe exists near the maximum section of the dam. The invert elevation is 857.0 feet; however, the invert for the control valve is 860.0 feet. An intake structure in the reservoir near the service spillway houses pumps which deliver water via a 24-inch concrete pipe to a water treatment facility beyond the west end of the dam.

Modifications to repair flood damages to the service spillway inlet and to increase the overall spillway capacity of the dam were completed in 1993. The dam crest was raised three feet to elevation 917.0 feet. A new service spillway inlet consisting of a four-fingered radial labyrinth crest was constructed and connected to the existing 9-foot square discharge conduit. The second stage

emergency spillway channel at elevation 906 feet was widened to a total length of 1,400 feet.

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.

The United States Air Force and the defense establishment developed GPS technology in the 1960's. After program funding in the early 1970's, the initial satellite was launched on February 22, 1978. A four-year delay in the launching program occurred after the Challenger space shuttle disaster. In 1989, the launch schedule was resumed. Full operational capability was reached on April 27, 1995 when the NAVSTAR (NAVigation System with Time And Ranging) satellite constellation was composed of 24 Block II satellites. Initial operational capability, a full constellation of 24 satellites,

in a combination of Block I (prototype) and Block II satellites, was achieved December 8, 1993. The NAVSTAR satellites provide data based on the World Geodetic System (WGS '84) spherical datum. WGS '84 is essentially identical to the 1983 North American Datum (NAD '83).

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

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

The need for setting up a stationary shore receiver for current surveys has been eliminated by registration with a fee-based satellite reference position network (OmniSTAR). This service works in a differential mode basically the same way as the shore station, except on a worldwide basis. For

a given area in the world, a network of several monitoring sites (with known positions) collect GPS signals from the NAVSTAR network. GPS corrections are computed at each of these sites to correct the GPS signal received to the known coordinates of the site. The corrections from each of the sites within the network are automatically sent via a leased line to a “Network Control Center” where the data corrections are checked and repackaged for up-link to a “Geostationary” L-band satellite. The “real-time” corrections for the entire given area in the world are then broadcast by the satellite to users of the system in the area covered by the satellite. The OmniSTAR receiver translates the information and supplies it to the on-board Trimble receiver for correction of the boat’s GPS positions. The accuracy of this system in a real-time mode is normally one meter or less.

Equipment and Methodology

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

The GPS equipment, survey vessel, and depth sounder combine together to provide an efficient hydrographic survey system. As the boat travels across the lake surface, the depth sounder gathers approximately ten readings of the lake bottom each second. The depth readings are stored on the survey vessel's on-board computer along with the corrected positional data generated by the boat's GPS receiver. The daily data files collected are downloaded from the computer and brought to the office for editing after the survey is completed. During editing, bad data is removed or corrected, multiple data points are averaged to get one data point per second, and average depths are converted to elevation readings based on the daily-recorded lake elevation on the day the survey was performed. Accurate estimates of the lake volume can be quickly determined by building a 3-D model of the reservoir from the collected data. The level of accuracy is equivalent to or better than previous methods used to determine lake volumes, some of which are discussed below.

Previous Survey Procedures

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

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

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

More recently, aerial photography has been used prior to construction, to generate elevation contours from which to calculate the volume of the reservoir. Fairly accurate results could be obtained, although the vertical accuracy of the aerial topography was generally one-half of the contour interval or \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.

PRE-SURVEY PROCEDURES

The reservoir's surface area was determined prior to the survey by digitizing with AutoCad software the conservation pool elevation contour line. The boundary file was created from the 7.5-minute USGS quadrangle maps, LAKE WEATHERFORD, TX (photo-revised 1979). The graphic boundary file created was then transformed into the proper datum, from NAD '27 datum to NAD '83, using Environmental Systems Research Institute's (ESRI) Arc/Info project command with the NADCOM parameters. The area of the lake boundary was checked to verify that the area was the same in both datums.

The survey layout was designed by placing survey track lines at 500-foot intervals across the lake. The survey design for this lake required approximately 41 survey lines to be placed along the length of the lake. Survey setup files were created using Coastal Oceanographics, Inc. Hypack software for each group of track lines that represented a specific section of the lake. The setup files were copied onto diskettes for use during the field survey.

SURVEY PROCEDURES

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

Equipment Calibration and Operation

At the beginning of each surveying day, the depth sounder was calibrated with the Innerspace Velocity Profiler. The Velocity Profiler calculates an average speed of sound through the water column of interest for a designated draft value of the boat (draft is the vertical distance that the boat penetrates the water surface). The draft of the boat was previously determined to average 1.2 ft. The velocity profiler probe is placed in the water to moisten and acclimate the probe. The probe is then raised to the water surface where the depth is zeroed. The probe is lowered on a cable to just below the maximum depth set for the water column, and then raised to the surface. The unit displays an average speed of sound for a given water depth and draft, which is entered into the depth sounder. The depth value on the depth sounder was then checked manually with a measuring tape to ensure that the depth sounder was properly calibrated and operating correctly. During the survey of Lake Weatherford, the speed of sound in the water column was determined to vary between 4,845 and 4,855 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 and some are negative readings. Further information on these calculations is presented in Appendix A.

During the survey, the onboard GPS receiver was set to a horizontal mask of 10° and a PDOP (Position Dilution of Precision) limit of 7 to maximize the accuracy of horizontal positions. An internal alarm sounds if the PDOP rises above seven to advise the field crew that the horizontal position has degraded to an unacceptable level. The lake's initialization file used by the Hypack data collection program was setup to convert the collected DGPS positions on the fly to state plane coordinates. Both sets of coordinates were then stored in the survey data file.

Field Survey

Data were collected at Lake Weatherford on April 15 & 16, 1998. Weather conditions during data collection were favorable. Temperatures ranged in the upper 80's with mild to gusty north winds. Approximately 15,403 data points were collected over the 47 miles traveled along the 50 pre-

planned survey lines and the random data-collection lines. These points were stored digitally on the boat's computer in 53 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. Basically, data were collected in 500 foot grids over the majority 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. Residential development (with boat slips and piers) was observed around the majority of the lake's shoreline. Almost all of the residents had bulkheads in place along the shoreline for erosion control. Along the west shoreline of the lake, the crew observed the City of Weatherford's water filtration plant, one marina and an electricity generating power plant.

The main body of the lake was uniformed in width. No navigational hazards such as islands, standing trees, brush, submerged trees, or stumps were noted within the lake. In the upper reaches of the lake, where the Clear Fork Trinity River discharges into the lake below the Highway 730 bridge, there was an extensive sediment plain built up. The crew was able to collect some data in this area, but at a much slower pace. The crew was forced to turn around each time the boat encountered the sediment deposits extending out from the bridge while collecting data on the pre-plotted cross section track lines in this area. No data were collected upstream of the Highway 730 bridge.

All of the collected data were stored in individual data files for each pre-plotted range line or random collection event. Each of these files is tagged with a unique file tag, representative of the lake being surveyed. At the end of each day, the data files were copied to diskettes, for future processing in the office.

Data Processing

The collected data were downloaded from diskettes onto the TWDB's computer network. Tape backups were made for future reference as needed. To process the data, the EDIT routine in the Hypack Program was run on each raw data file. Data points such as depth spikes or data with missing depth or positional information were deleted from the file. The depth information collected every 0.1

seconds was averaged to get one reading for each second of data collection. A correction for the lake elevation at the time of data collection was also applied to each file during the EDIT routine. During the survey, the water surface varied between 896.06 and 896.02 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 Institute's (ESRI) Arc/Info GIS software and converted to a MASS points file. The MASS points and the boundary file were then used to create a Digital Terrain Model (DTM) of the reservoir's bottom surface using Arc/Info's TIN software module. The module builds an irregular triangulated network from the data points and the boundary file. This software uses a method known as Delauney's criteria for triangulation. A triangle is formed between three non-uniformly spaced points, including all points along the boundary. If there is another point within the triangle, additional triangles are created until all points lie on the vertex of a triangle. All of the data points are preserved for use in determining the solution of the model by using this method. The generated network of three-dimensional triangular planes represents the actual bottom surface. Once the triangulated irregular network (TIN) is formed, the software then calculates elevations along the triangle surface plane by solving the equations for elevation along each leg of the triangle. Information for the entire reservoir area can be determined from the triangulated irregular network created using this method of interpolation.

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

There were some areas where volume and area values could not be calculated by interpolation because of a lack of information within the reservoir. "Flat triangles" were drawn at these locations. Arc/Info does not use flat triangle areas in the volume or contouring features of the model. Approximately 1,788 additional points were required for interpolation and contouring of the entire

lake surface at elevation 896.0. Volumes and areas were calculated from the TIN for the entire reservoir at one-tenth of a foot intervals. From elevation 892.0 to elevation 896.0, the surface areas and volumes of the lake were mathematically estimated. This was done first by distributing uniformly across each elevation increment; the surface areas digitized from USGS topographic maps. Volumes were then calculated in a 0.1 foot step method by adding to the existing volume, 0.1 of the existing area, and 0.5 of the difference between the existing area the area for the value being calculated. The computed area of lake at elevation 896.0 was 1,158 surface acres. The computed area was 52 surface acres less than originally calculated. The computed reservoir volume table is presented in Appendix B and the area table in Appendix C. An elevation-area-volume graph is presented in Appendix D.

Other presentations developed from the model include a shaded relief map and a shaded depth range map. To develop these maps, the TIN was converted to a lattice using the TINLATTICE command and then to a polygon coverage using the LATTICEPOLY command. Using the POLYSHADE command, colors were assigned to the range of elevations represented by the polygons that varied from navy to yellow. The lower elevation was assigned the color of navy, and the 896.0 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 1998 TWDB survey indicate Lake Weatherford encompasses 1,158 surface acres and contains a volume of 18,714 acre-feet at the conservation pool elevation of 896.0 feet. The shoreline at this elevation was calculated to be 11.9 miles. The deepest point of the lake, elevation 855.4 or 40.6 feet of depth was located approximately 1,075 feet north from the center of the dam.

The dead storage volume, or the amount of water below the lowest outlet in the dam, was calculated to be 69 acre-feet based on an invert elevation of 860.0 feet. The conservation storage capacity, or the amount of water between the spillway and the lowest outlet, is therefore calculated to be 18,650 acre-feet.

SUMMARY

Lake Weatherford was formed in 1957. The initial storage was estimated at the conservation pool elevation of 896.0 feet to be 21,233 acre-feet with a surface area of 1,144 acres.

An April 1973 sedimentation survey on Lake Weatherford performed by the United States Department of Agriculture, Soil Conservation Service calculated a volume of 19,866 acre-feet and a surface area of 1,144 acres at the conservation pool elevation of 896.0 feet. The estimated reduction in storage since 1957 was calculated to be 1,368 acre-feet or 85 acre-feet per year. The net drainage area of the lake was determined to be 63.06 square miles. The average annual deposition rate of sediment in the conservation pool of the reservoir can therefore be estimated at 1.35 acre-feet per square mile of net drainage area.

On April 15 and 16, 1998, a hydrographic survey of Lake Weatherford was performed by the Texas Water Development Board's Hydrographic Survey Program. The 1998 survey used technological advances such as differential global positioning system and geographical information system technology to build a model of the reservoir's bathymetry. These advances allowed a survey to be performed quickly and to collect significantly more data of the bathymetry of Lake Weatherford than previous survey methods. Results indicate that the lake's capacity at the conservation pool elevation of 896.0 feet was 18,714 acre-feet and the area was 1,158 acres. The estimated reduction in storage capacity since 1973 was calculated as 1,152 acre-feet or 46.08 acre-feet per year. The average annual deposition rate of sediment in the conservation pool of the reservoir can therefore be estimated at 0.731 acre-feet per square mile of net drainage area. Compared to the 1973 survey, the sedimentation rate calculated is about 46 percent below the rate determined between 1957 and 1973. Much of this reduction in sediment can be credited to the soil conservation measures and floodwater

retention structures constructed over the years in the drainage area above Lake Weatherford.

It is difficult to compare the original design information and the TWDB performed survey because little is known about the original design method, the amount of data collected, and the method used to process the collected data. However, the TWDB considers the 1998 survey to be a significant improvement over previous survey procedures and recommends that the same methodology be used in five to ten years or after major flood events to monitor changes to the lake's storage capacity.

CALCULATION OF DEPTH SOUNDER ACCURACY

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

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

where: t_D = travel time of the sound pulse, in seconds (at depth = D)

D = depth, in feet

d = draft = 1.2 feet

V = speed of sound, in feet per second

To calculate the error of a measurement based on differences in the actual versus average speed of sound, the same equation is used, in this format:

$$D = [t(V)]+d$$

For the water column from 2 to 30 feet: $V = 4832$ fps

$$\begin{aligned} t_{30} &= (30-1.2)/4832 \\ &= 0.00596 \text{ sec.} \end{aligned}$$

For the water column from 2 to 45 feet: $V = 4808$ fps

$$\begin{aligned} t_{45} &= (45-1.2)/4808 \\ &= 0.00911 \text{ sec.} \end{aligned}$$

For a measurement at 20 feet (within the 2 to 30 foot column with $V = 4832$ fps):

$$\begin{aligned} D_{20} &= [((20-1.2)/4832)(4808)]+1.2 \\ &= 19.9' \quad (-0.1') \end{aligned}$$

For a measurement at 30 feet (within the 2 to 30 foot column with $V = 4832$ fps):

$$\begin{aligned} D_{30} &= [((30-1.2)/4832)(4808)]+1.2 \\ &= 29.9' \quad (-0.1') \end{aligned}$$

For a measurement at 50 feet (within the 2 to 60 foot column with $V = 4799$ fps):

$$D_{50} = [((50-1.2)/4799)(4808)]+1.2$$

$$= 50.1' \quad (+0.1')$$

For the water column from 2 to 60 feet: $V = 4799$ fps Assumed $V_{80} = 4785$ fps

$$t_{60} = (60-1.2)/4799$$

$$= 0.01225 \text{ sec.}$$

For a measurement at 10 feet (within the 2 to 30 foot column with $V = 4832$ fps):

$$D_{10} = [((10-1.2)/4832)(4799)]+1.2$$

$$= 9.9' \quad (-0.1')$$

For a measurement at 30 feet (within the 2 to 30 foot column with $V = 4832$ fps):

$$D_{30} = [((30-1.2)/4832)(4799)]+1.2$$

$$= 29.8' \quad (-0.2')$$

For a measurement at 45 feet (within the 2 to 45 foot column with $V = 4808$ fps):

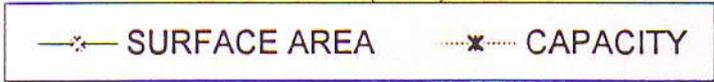
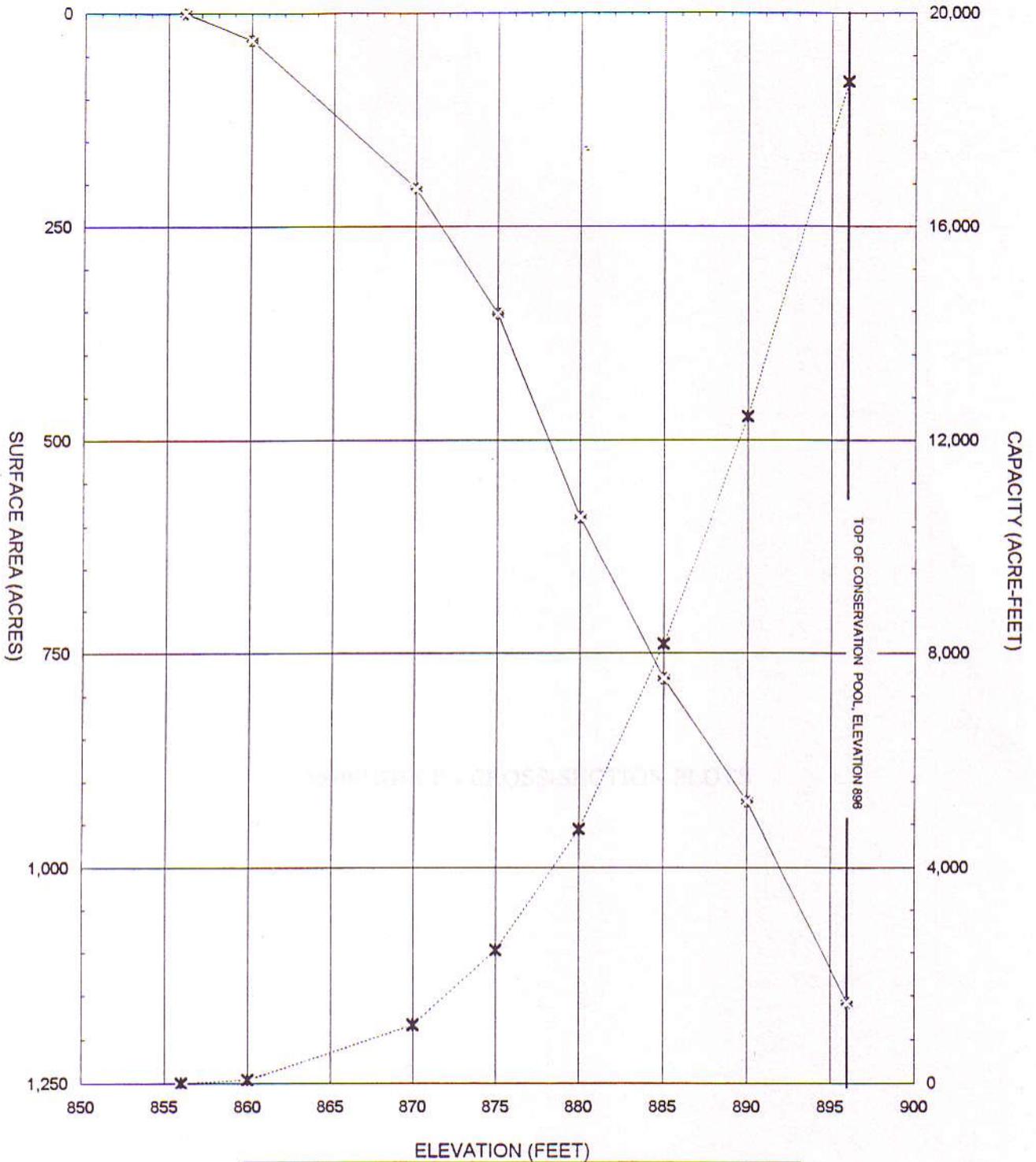
$$D_{45} = [((45-1.2)/4808)(4799)]+1.2$$

$$= 44.9' \quad (-0.1')$$

For a measurement at 80 feet (outside the 2 to 60 foot column, assumed $V = 4785$ fps):

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

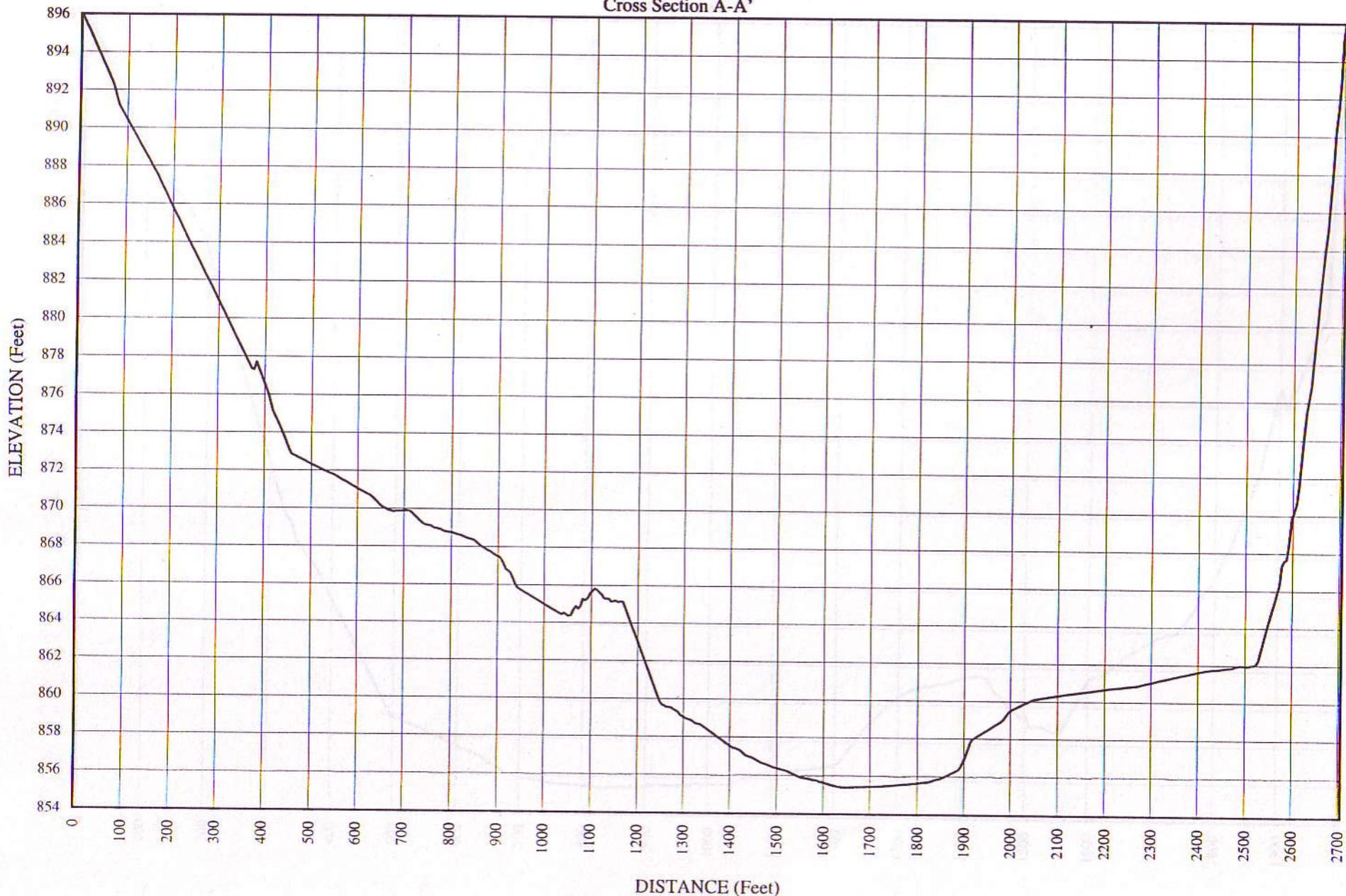
$$= 80.2' \quad (+0.2')$$



LAKE WEATHERFORD
 April 1998 Survey
 Prepared by: TWDB June 1998

LAKE WEATHERFORD

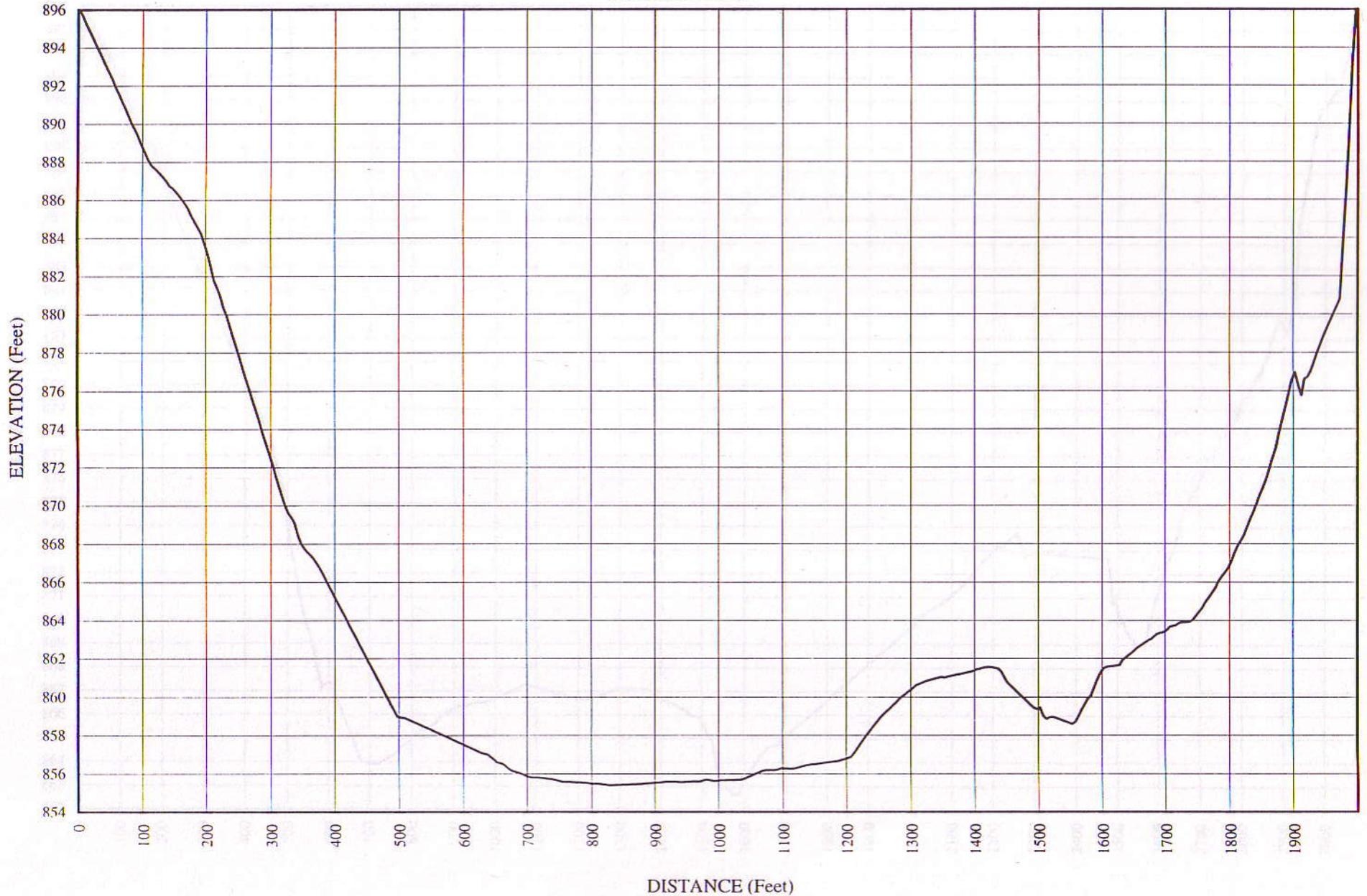
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LAKE WEATHERFORD

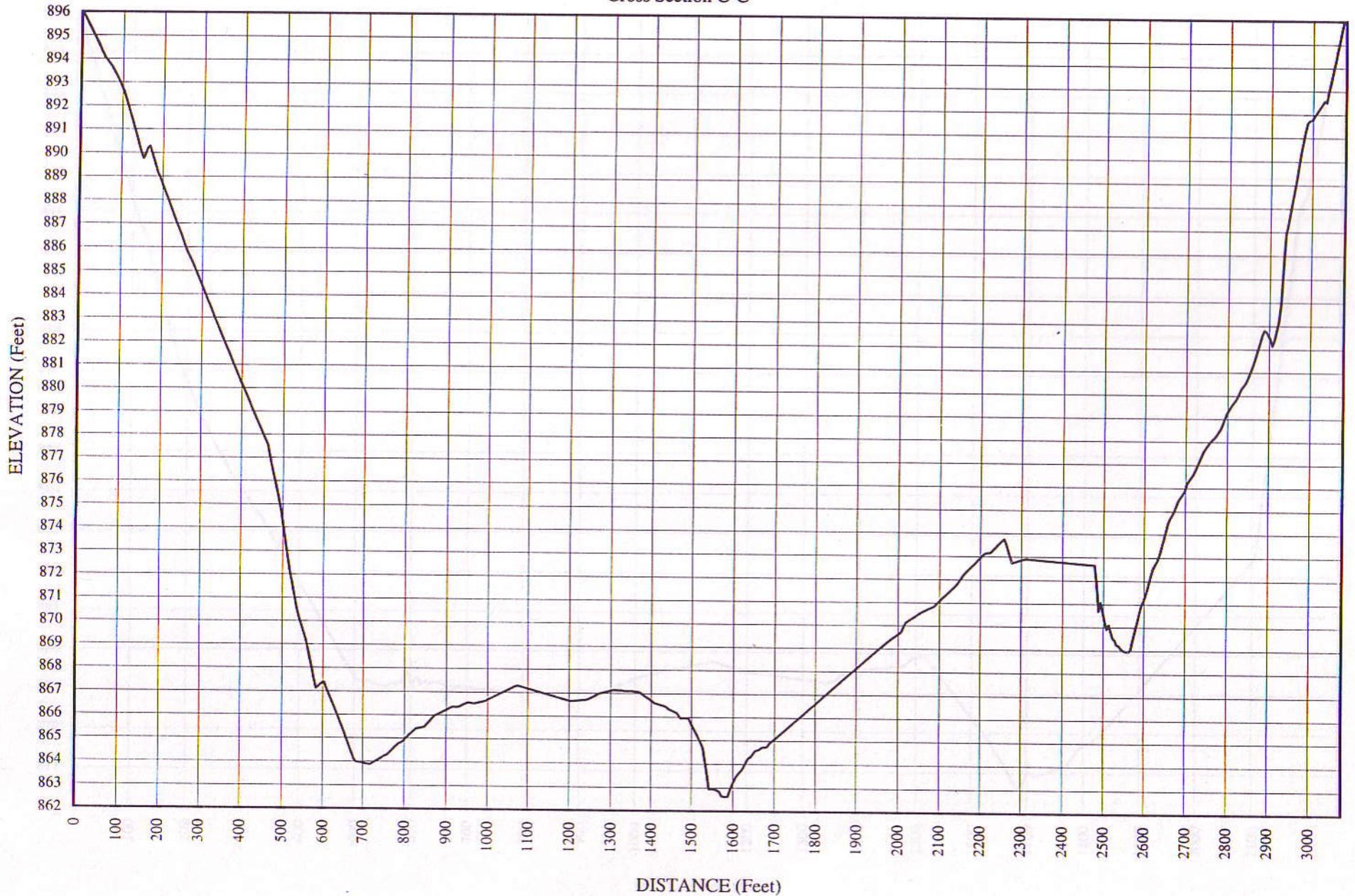
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LAKE WEATHERFORD

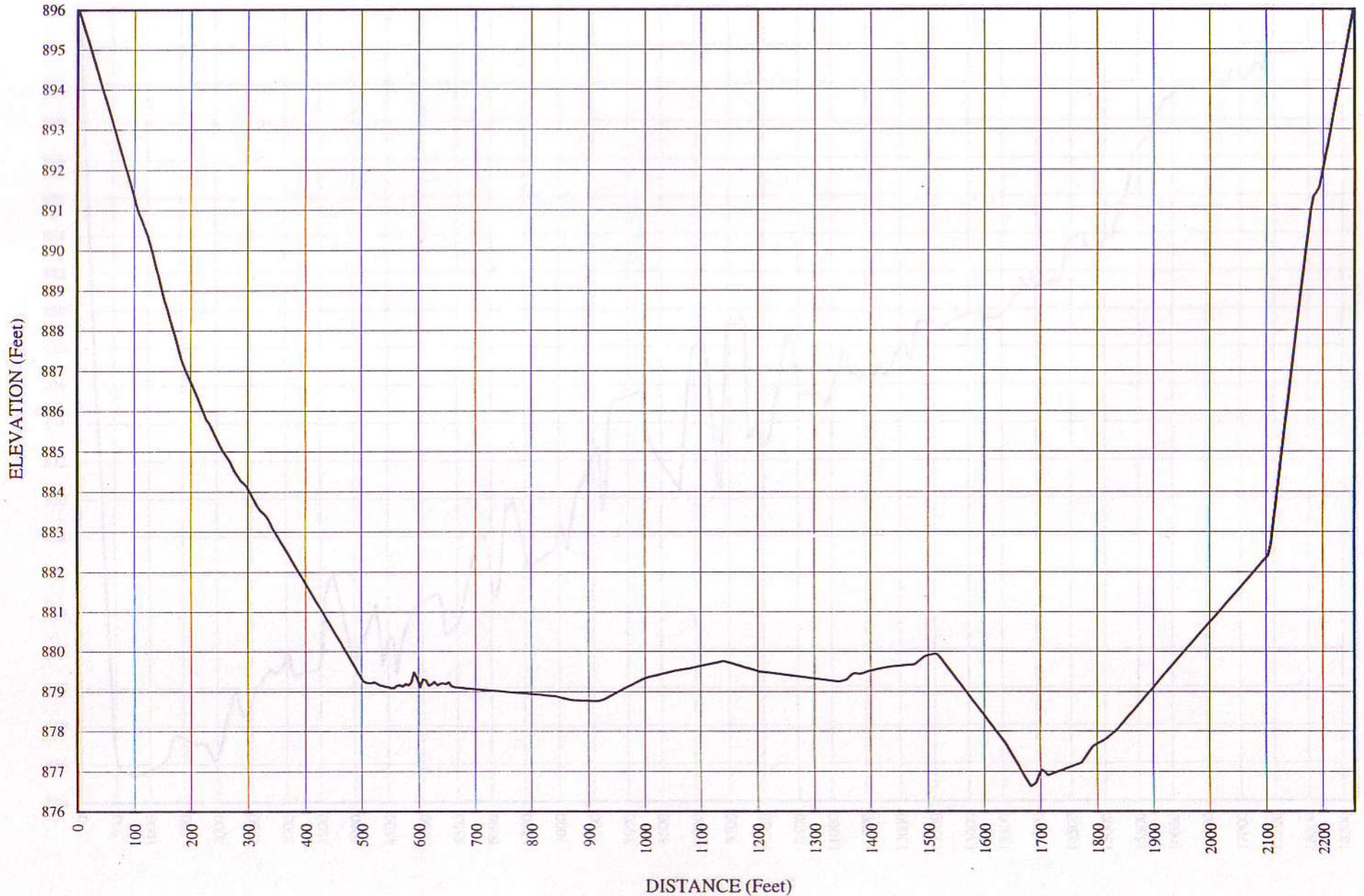
Cross Section C-C'



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LAKE WEATHERFORD

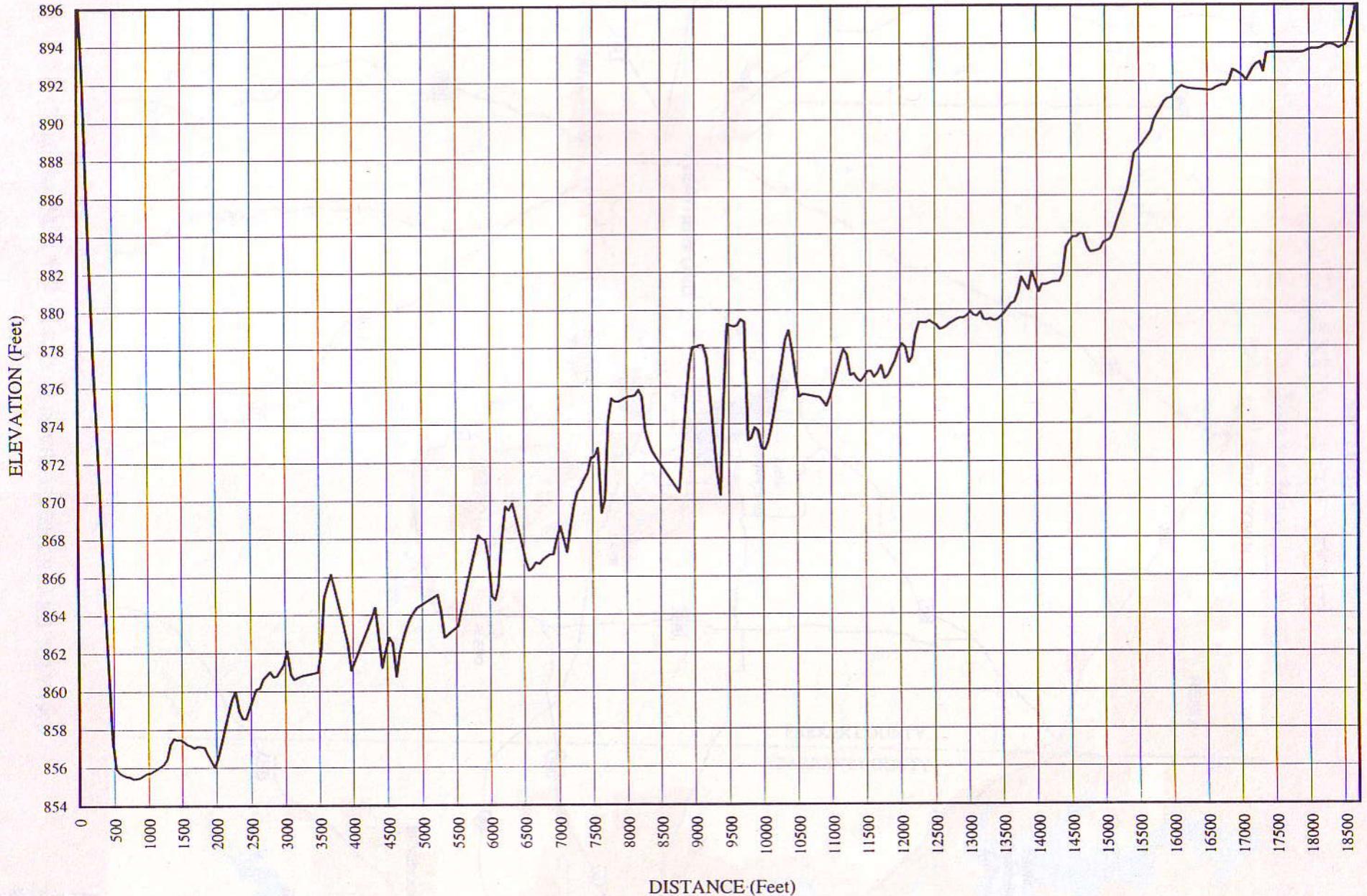
Cross Section D-D'



PREPARED BY: TWDB JULY 1998

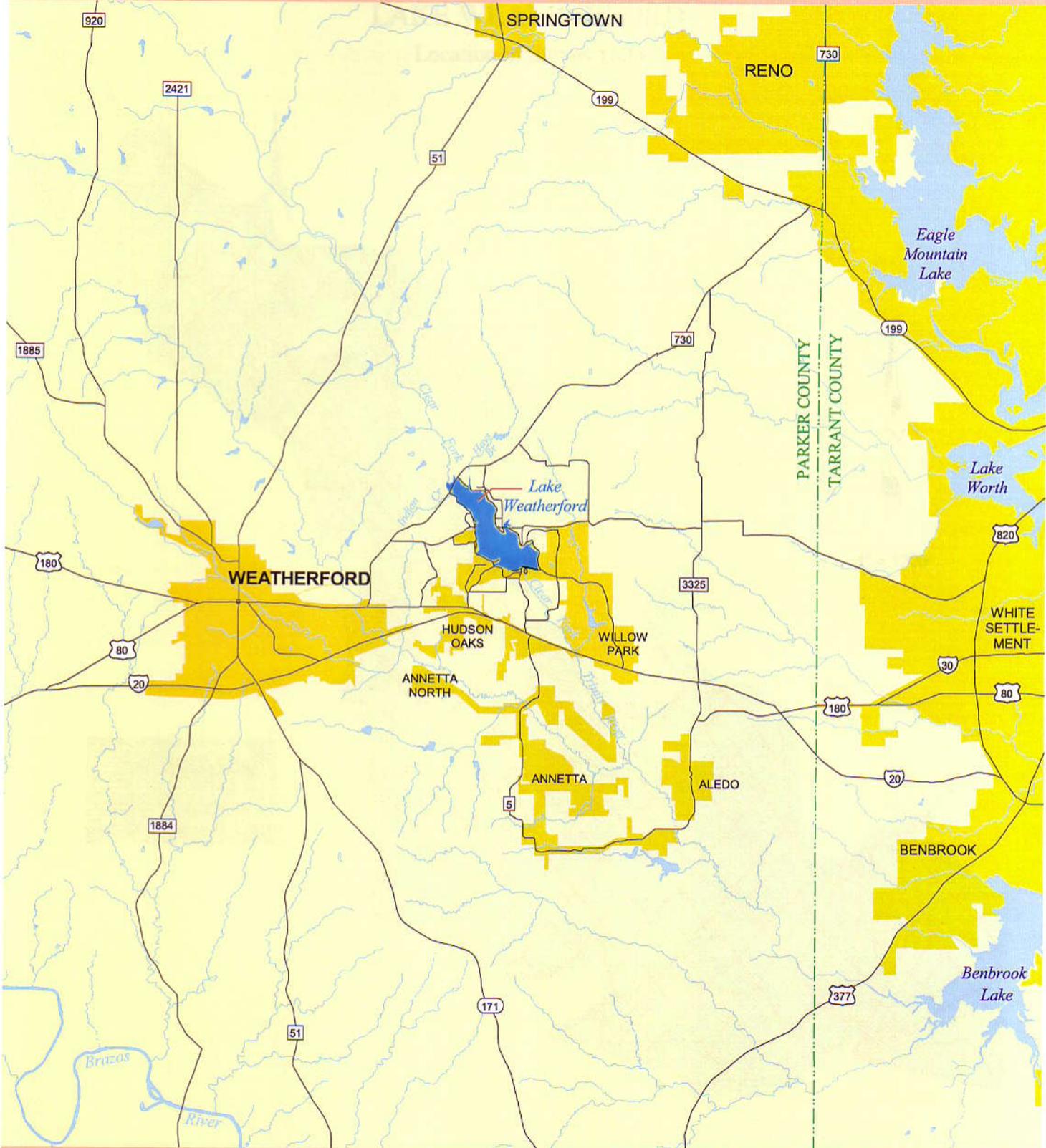
LAKE WEATHERFORD

Cross Section E-E'



PREPARED BY: TWDB JULY 1998

FIGURE 1
LAKE WEATHERFORD
Location Map



PREPARED BY: TEXAS WATER DEVELOPMENT BOARD JULY 1998



1" = 18,300'

FIGURE 2
LAKE WEATHERFORD
Location of Survey Data

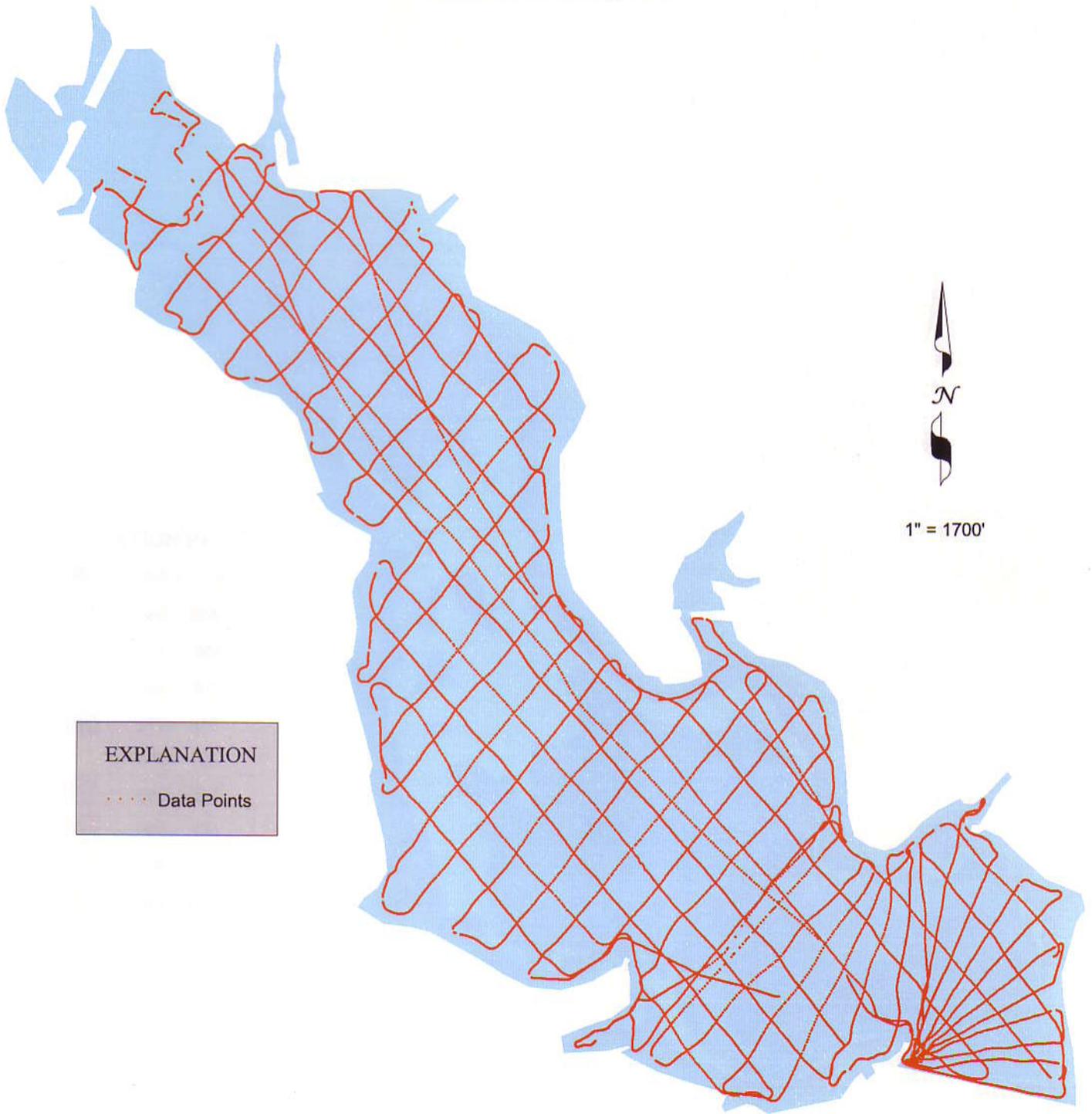


FIGURE 3
LAKE WEATHERFORD
Shaded Relief

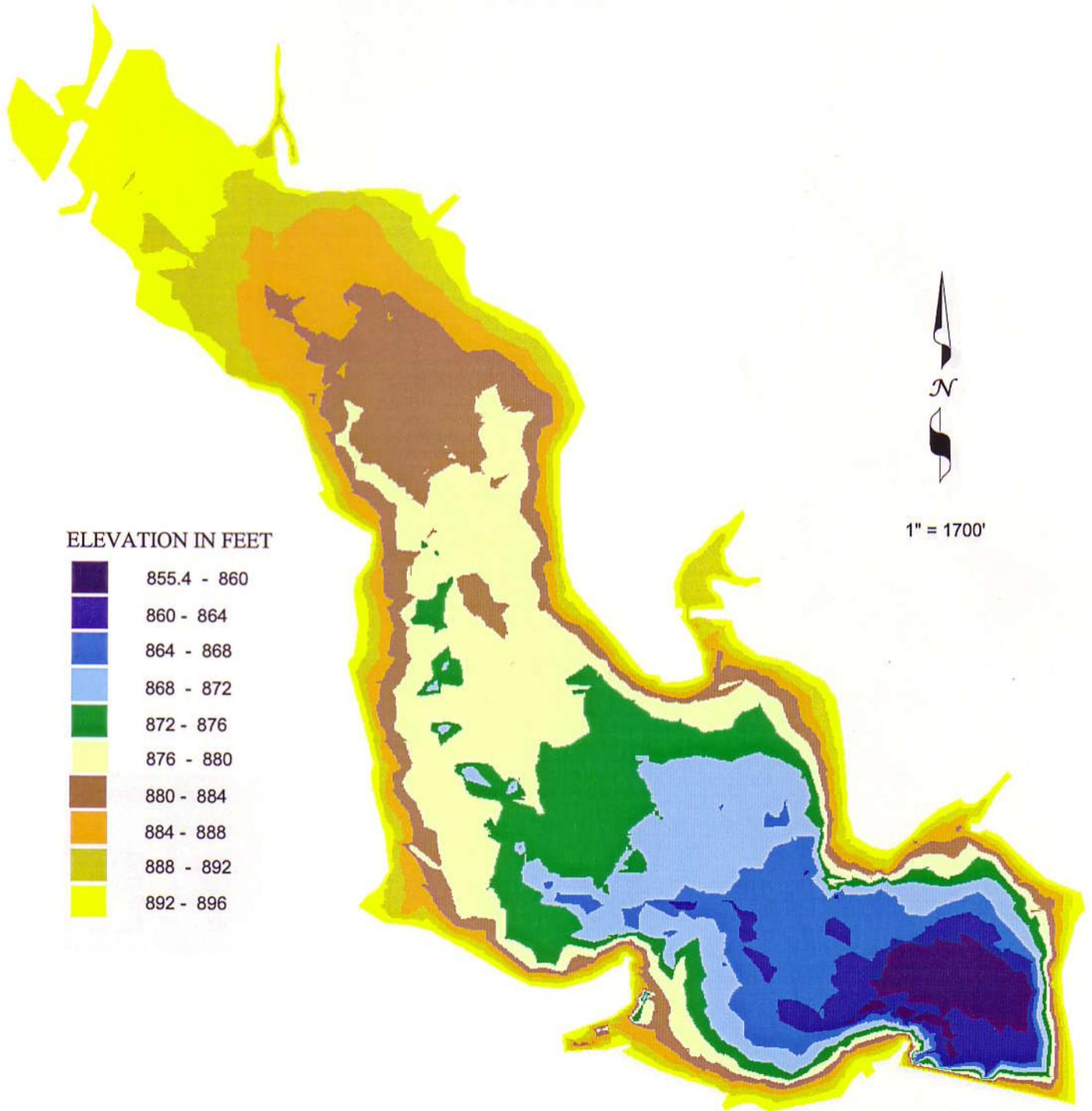


FIGURE 4
LAKE WEATHERFORD
Depth Ranges

