VOLUMETRIC SURVEY
OF
MEDINA LAKE AND
DIVERSION LAKE

Prepared for:

BEXAR-MEDINA-ATASCOSA COUNTIES WATER CONTROL AND IMPROVEMENT DISTRICT NUMBER ONE

Prepared by:

The Texas Water Development Board

March 10, 2003

Texas Water Development Board

Craig D. Pedersen, Executive Administrator

This report was prepared by the Hydrographic Survey group:

Scot Sullivan, P.E.
Duane Thomas
Steve Segura
Marc Robichaud
Wayne Elliott

For more information, please call (512) 936-0848

Published and Distributed
by the
Texas Water Development Board
P.O. Box 13231
Austin, Texas 78711-3231

TABLE OF CONTENTS

APPENDICES

LIST OF FIGURES

MEDINA LAKE AND DIVERSION LAKE

HYDROGRAPHIC SURVEY REPORT

INTRODUCTION

Staff of the Hydrographic Survey Unit of the Texas Water Development Board (TWDB) conducted hydrographic surveys on Medina Lake and Diversion Lake in July, 1995. The purpose of the surveys was to determine the capacity of the lakes at the conservation 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. All elevations presented in this report will be reported according to the Medina datum. The Medina datum is approximately 7.8 feet below mean sea level based on the National Geodetic Vertical Datum of 1929 (NGVD '29). Based on a survey made prior to 1912, the surface area of Medina Lake at the conservation pool elevation of 1,072.0 feet was calculated to be 5,575 acres with a corresponding capacity of 254,000 acre-feet. There was no previous information for Diversion Lake. Information presented in the following report will deal mainly with the Medina Lake survey. Information regarding the procedures and processing of data for the Diversion Lake survey will be presented in the section, "Diversion Lake Survey."

HISTORY AND GENERAL INFORMATION OF THE RESERVOIR

Medina Lake is located on the Medina River approximately 16 miles southeast of Bandera, Tx. The lake and dam facility are owned by the Bexar-Medina-Atascosa Counties Water Control and Improvement District Number One. Inflows to the lake originate over a 634 square mile drainage area. At the conservation capacity pool elevation of 1072.0 feet, the lake is approximately 18 miles long and about 3 miles wide at it's widest point.

Originally the project was built by the Medina Valley Irrigation Company. The water rights were conveyed by the State Board of Water Engineers under Certificate of Filing # 18 on February 14, 1914. The Medina Valley Irrigation Company went into receivership in 1917 and several years later became Bexar-Medina-Atascosa Counties Water Improvement District Number One. On November 1, 1979, a resolution was passed, broadening its powers as a water district and changing its name to the presently known Bexar-Medina-Atascosa Counties Water Control and Improvement District Number One (BMA). On August 1, 1981, a Certificate of Adjudication # 2130 was issued by the Texas Water Commission to BMA authorizing the owner to maintain an existing dam and reservoir known as Medina Lake and to impound not to exceed 237,874 acre-feet of water. BMA was also authorized to maintain an existing dam and reservoir, known as Diversion Lake and impound therein not to exceed 4,500 acre-feet of water. Authorization was granted to BMA to use, not to exceed, 66,000 acre-feet of water per annum from both Medina and Diversion Lake for irrigation of a maximum 33,000 acres of land within the boundaries of the Bexar-Medina-Atascosa Counties Water Control and Improvement District Number One. It also authorized the BMA to use , not to exceed 750 acre-feet of water per annum by the residents of the district for domestic and livestock purposes. Certificate of Adjudication # 2130 was amended several times. The latest amendment, # 2130C, was filed September 3, 1993 for the purpose to clarify all use authorizations. The total amount of water for usage did not change but the purpose was changed to include irrigation, municipal and industrial purposes.

Medina Dam construction commenced in 1912 and was completed in 1913. Deliberate impoundment of water began on May 7, 1913. The project was designed by Bartlett and Ranney of San Antonio, and the total cost of Medina and Diversion Dams was $2,739,300.

Medina Dam is a gravity-type concrete dam with a length of 1,580 feet, rising 164 feet above the natural stream bed to an elevation of 1084.0 feet. The uncontrolled spillway is a cut through natural rock and is 880 feet long with a 3 foot wide cutoff wall located near the right end of the dam. The water supply outlets consist of 3 steel pipes, 5 feet in diameter, with lift type gates. The invert elevation of these outlets is elevation 966.5. The low flow outlets consist of 2 steel pipes, 2.5 feet in diameter, with lift type gates. The invert elevation of these pipes is 920.0

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 it’s 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 continuously monitor the broadcasts from the satellites to determine the position of the receiver. With only one satellite being monitored, the point in question could be located anywhere on a sphere surrounding the satellite with a radius of the distance measured. The observation of two satellites decreases the possible location to a finite number of points on a circle where the two spheres intersect. With a third satellite observation, the unknown location is reduced to two points where all three spheres intersect. One of these points is obviously in error because its location is in space, and it is ignored. Although three satellite measurements can fairly accurately locate a point on the earth, the minimum number of satellites required to determine a three dimensional position within the required accuracy is four. The fourth measurement compensates for any time discrepancies between the clock on board the satellites and the clock within the GPS receiver.

GPS technology was developed in the 1960s by the United States Air Force and the defense establishment. After program funding in the early 1970s, 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 will be reached when the NAVSTAR (NAVigation System with Time And Ranging) satellite constellation is composed of 24 Block II satellites. At the time of the survey, the system had achieved initial operational capability. A full constellation of 24 satellites, in a combination of Block I (prototype) and Block II satellites, was fully functional. The NAVSTAR satellites provide data based on the World Geodetic System (WGS '84) spherical datum. WGS '84 is essentially identical to NAD '83.

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

Differential GPS (DGPS) can determine positions of moving objects in real-time or "on-the-fly." 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 three meters for the moving receiver. DGPS was used to determine horizontal position only. Vertical information was supplied by the depth sounder.

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, a Motorola Radius radio with an Advanced Electronic Applications, Inc. packet modem, and an on-board computer. The computer was supported by a dot matrix printer and a B-size plotter. Power was provided by a water-cooled generator through an in-line uninterruptible power supply. Reference to brand names does not imply endorsement by the TWDB.

The 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.

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 together 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 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 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 was still 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.

PRE-SURVEY PROCEDURES

The reservoir's surface area was determined prior to the survey by digitizing with AutoCad software contour 1064.0 (the equivalent conservation pool capacity elevation in NGVD datum used by the USGS) upstream from the dam on two USGS quad sheets. The names of the quad sheets are as follows: MEDINA LAKE, TX 1964 (Photorevised 1982) and PIPE CREEK, TX 1970 (Photorevised 1982). The graphic boundary file created was then transformed into the proper datum, from NAD '27 datum to NAD '83, using Environmental Systems Research Institutes's (ESRI) Arc/Info project command with the NADCOM 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 258 survey lines to be placed along the length of the lake. Survey setup files were created using Coastal Oceangraphics, Inc. Hypack software for each group of track lines that represented a specific section of the lake. The setup files were copied onto diskettes for use during the field survey.

SURVEY CONTROL SETUP

The first task of the Hydrographic Survey field staff after arriving at Medina Lake was to establish a horizontal reference control point. Figure 3 shows the location of the control point established. This location was chosen due to the close proximity to the reservoir and the security of the area.

Prior to the field survey, TWDB staff had researched locations of known first-order benchmarks and requested BMA staff to physically locate the associated monuments. Of the monuments found, the one chosen to provide horizontal control for the survey was a U. S. Geological Survey first-order monument named SCHMIDT located approximately 10 miles east of Hondo, Tx.. The coordinates for the monument are published as Latitude 29° 22' 14.23872"N and Longitude 99° 00' 14.54646"W.

On July 5, 1995, TWDB staff performed a static survey to determine the WGS'84 coordinates of the lake survey control point. The control point used for the shore station was a nail set in concrete at the west end of the dam's crest. The GPS receivers were set up over each point and satellite data were gathered for approximately one hour, with up to six satellites visible at the same time to the receivers.

Once data collection ended, the data were retrieved and processed from both receivers, using

Trimble Trimvec software, to determine the coordinates for the control point. The WGS' 84 coordinates were determined to be North latitude 29° 32' 27.28214" and West longitude 98° 56' 12.47555".

Using the newly determined coordinates, a shore station was set up over the control point to provide horizontal control during the survey. The coordinates from the static survey were entered into the GPS receiver located over the control point to fix its location. Data received during the survey could then be corrected and broadcast to the GPS receiver on the moving boat during the survey.

SURVEY PROCEDURES

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

Equipment Calibration and Operation

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 the purpose of calculating 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 seven (7) or less. 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.

Prior to the survey, TWDB staff verified the horizontal accuracy of the DGPS used during the Medina Lake survey to be within the specified accuracy of three meters by the following procedure. 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 data was collected for 60 minutes in the same manner as during a survey. 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.

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 Medina Lake, the speed of sound in the water column varied daily between 4,936 and 4,942 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 plus readings and some are minus readings. Further information on these calculations is presented in Appendix A.

Field Survey

Data was collected on Medina Lake during the period of July 18-20, 1995**.** Approximately 57,570 data points were collected over the 92.47 miles traveled along the pre-planned survey lines and the random data-collection lines. These points were stored digitally on the boat's computer in 234 data files. Data were not collected in areas of shallow water (depths less than 3.0 ft.) or with significant obstructions unless these areas represented a large amount of water. Random data points were collected, when determined necessary by the field crew, by manually measuring the depth with a surveying rod and entering the depth value into the data file. As each point was entered, the DGPS horizontal position was stored automatically with each return keystroke on the computer. The boat was moving slowly during this period so positions stored were within the stated accuracy of ± 3 meters to the point poled. Figure 2 shows the actual location of the data collection points.

The collected data were stored in individual data files for each pre-plotted range line or random data collection events. These files were downloaded to diskettes at the end of each day for future processing.

Data Processing

The collected data were down-loaded from diskettes onto the TWDB's computer network. The diskettes were then stored in a secured, safe location for future reference as needed. To process the data, the EDIT routine in the Hypack Program was run on each raw data file. Data points such as depth spikes or data with missing depth or positional information were deleted from the file. The depth information collected every 0.1 seconds was averaged to get one reading for each second of data collection. A correction for the lake elevation at the time of data collection was also applied to each file during the EDIT routine. During the survey, the water surface elevation ranged daily from 1,056.37 to 1,056.40 feet. After all changes had been made to the raw data file, the edited file was saved with a different extension. After all the files were edited, the edited files were combined into a single data file, representative of the lake, to be used with the GIS software to develop a model of the lake's bottom surface.

An aerial survey was flown by Tobin Surveys, Inc. of the lake in 1984 and 1985. Information from this survey was used to supplement the TWDB survey for the area from elevation 994.88 to elevation 1080.0. 39,947 data points inside the lake below elevation 1080.0 feet were determined from the aerial photos using photo-metric processes.

The resulting DOS data file was imported into the UNIX operating system used to run Environmental System Research Institutes's (ESRI) Arc/Info GIS software. The latitude and longitude coordinates of each point were then converted to decimal degrees by a UNIX awk command. The awk command manipulates the data file format into a MASS points format for use by the GIS software. The graphic boundary file previously digitized was also imported.

To develop a model of the lake using both the TWDB and Tobin data, a new boundary was digitized from the maps used to create the survey lines file in the Pre-survey Procedures. Contour elevation 1080.0 was digitized upstream from the dam. The file was then converted from NAD ‘27 to NAD ‘83. The NAD ‘83 file was then converted to the Medina datum by adding 7.8 feet to the contour elevation or elevation 1087.8. This file was then down-sized to elevation 1080 based on the location of any of the Tobin data that was at elevation 1080 or less. The Board does not represent any of the contour lines developed in this report to be actual land versus water boundaries. Instead, it is a graphical approximation of the actual boundary used solely to compute the volume and area of the lake.

The edited MASS points and modified boundary file were used to create a Digital Terrain Model (DTM) of the reservoir's bottom surface using Arc/Info's TIN 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.

There were some areas where values could not be calculated by interpolation because of a lack of information along the boundary of 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. These areas were determined to insignificant on Medina Lake. Therefore no additional points were required for interpolation and contouring of the entire lake surface. The TIN product then calculated the surface area and volume of the entire reservoir at one-tenth of a foot intervals from the three-dimensional triangular plane surface representation. 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 the shaded relief map, the three-dimensional triangular surface was modified 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 upper pool elevation was assigned the color of yellow. Different color shades were assigned to the different depths in between. Figure 4 presents the resulting depth shaded representation of the lake. Figure 5 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.

The DTM was then smoothed and linear smoothing algorithms were applied to the smoothed model to produce smoother contours. The resulting contour map of the bottom surface at ten-foot intervals is presented in Figure 6.

MEDINA LAKE SURVEY RESULTS

Medina Lake is located on the Medina River in Bandera and Medina Counties. The major tributaries that flow into the main body of the lake are Mescal and Elm Creeks. This pristine lake with it's clear waters lies west of San Antonio in the limestone outcrop of the Texas Hill Country. Over one dozen coves and hollows with steep canyon walls are located along the shoreline from the dam upstream to Turks Head on the west bank and Goat Hill on the east bank. The elevation relief becomes more gentle in the upper reaches of the lake's head waters. While collecting data the field crew rarely encountered any navigational hazards such as stumps. The crew did locate a few sand bars in the flats and upper reaches. Lake grasses were also encountered in the shallow areas at the upper end of the lake.

Results from the 1995 survey indicate Medina Lake now encompasses around 6,066 surface acres and contains a volume of 254,843 acre-feet at the conservation pool elevation of 1072.0 feet. The volume at elevation 1080.0 was 305,784 acre-feet and the surface area was 6,742 acres. The shoreline at conservation pool was calculated to be 71.09 miles. The shoreline for elevation 1080.0 was calculated to be 87.76 miles. The lowest elevation encountered was around elevation 933.2 feet, or 138.8 feet of depth when the lake is at the top of the conservation pool. This point was found 1,800 feet north of the dam.

The storage volume calculated by the 1995 survey is approximately 2.5 percent less than the previous record information for the lake. The lowest gated outlet invert elevation is at elevation 920.0 feet. There is no dead storage volume at this elevation so the conservation storage capacity for the lake is 254,843 acre-feet.

DIVERSION LAKE SURVEY RESULTS

The field survey on the Diversion Lake was performed on July 12, 1995. The method used to performed the field survey was a modified range line survey. Cross-sections were located and an electronic distance measuring device was used to determined the lengths of the cross-sections. A 14 foot boat with a recording fathometer was then driven at a constant speed across the lake to create a bottom profile. The survey of Diversion Lake consisted of a total of 13 cross-sectional lines. After the survey, the data was processed and coverages were created in ArcInfo. A TIN model similar to the model created for Medina Lake was created. Additional data points were interpolated in between the cross-sections for contouring purposes. An area-elevation-capacity table was created from the resultant model. Figure 7 shows the cross-section locations and the contour lines that were created. The volume of the Diversion Lake was calculated from this survey to be 2,555 acre-feet at elevation 926.5 and the surface area was 169 acres.

SUMMARY

Medina Lake and Dam were completed in 1913 and deliberate impoundment of water began on May 7, 1913. Initial storage calculations estimated the volume of the lake at the conservation pool elevation of 1072.0 to be 254,000 acre-feet with a surface area of 5,575 acres. There was no prior information on the capacity of the Diversion Lake.

During the period July 18-20, 1995, a hydrographic survey of Medina Lake was performed by the Texas Water Development Board's Hydrographic Survey Program. The water elevation of the lake during this period ranged from 1056.37 - 1056.40 ft., or about 16 ft below the conservation pool elevation. Additional data from an aerial survey performed by Tobin Surveys, Inc. in 1984 and 1985 provided additional information from elevation 994.88 to 1080.0. The Tobin data was merged with the TWDB data at the request of BMA from which the TWDB developed a model of the entire depth range of the lake up to elevation 1080.0. Results from the survey indicate that the lake's capacity at the conservation pool elevation of 1072.0 feet was 254,843 acre-feet and the lake’s capacity at elevation 1080.0 was 305,784 acre-feet. The previous storage capacity for Medina Lake, based on a survey made prior to 1912, was estimated at 254,000 acre-feet for elevation 1072.0 and 300,000 acre-feet at elevation 1080.0. The storage information generated by the TWDB and Tobin Surveys, Inc. shows no loss of storage during the last 84 years in Medina Lake.

In addition to the survey on Medina Lake, TWDB staff performed a modified range line survey of Diversion Lake on July 12, 1995. From this survey, the capacity of Diversion Lake at elevation 926.5 was determined to be 2,555 acre-feet.

It is difficult to compare the original design information and the information generated from the TWDB and Tobin Surveys, Inc. because little is know about the original survey procedures and data. However, the TWDB considers the 1995 survey to be a significant improvement over previous survey procedures and recommends that the same methodology be used in five to ten years or after major flood events to monitor changes to the lake's storage capacity. The second survey will remove any noticeable errors between the previous survey and the 1995 survey and will facilitate accurate calculations of sedimentation rates and storage losses presently occurring in Medina Lake.

CALCULATION OF DEPTH SOUNDER ACCURACY

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

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

where: t_D = travel time of the sound pulse, in seconds (at depth = D)
D = depth, in feet
d = draft = 1.2 feet
V = speed of sound, in feet per second

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

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

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

$t_{30} = (30-1.2)/4832$
$= 0.00596$ sec.

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

$t_{45} = (45-1.2)/4808$
$= 0.00911$ sec.

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

$D_{20} = [((20-1.2)/4832)(4808)]+1.2$
$= 19.9'$ $(-0.1')$

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

$D_{30} = [((30-1.2)/4832)(4808)]+1.2$
$= 29.9'$ $(-0.1')$

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

$D_{50} = [((50-1.2)/4799)(4808)]+1.2$
$= 50.1'$ $(+0.1')$

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

t_{60} =(60-1.2)/4799
=0.01225 sec.

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

D_{10} = [((10-1.2)/4832)(4799)]+1.2
= 9.9' (-0.1')

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

D_{30} = [((30-1.2)/4832)(4799)]+1.2
= 29.8' (-0.2')

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

D_{45} = [((45-1.2)/4808)(4799)]+1.2
= 44.9' (-0.1')

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

D_{80} = [((80-1.2)/4785)(4799)]+1.2
= 80.2' (+0.2')