# VOLUMETRIC SURVEY OF HUGO LAKE

**Prepared for:**

**U. S. Army Corps of Engineers, Tulsa District**

**Prepared by:**
**Texas Water Development Board**

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# EXECUTIVE OVERVIEW

The United States Army Corps of Engineers, Tulsa District requested the Texas Water Development Board to perform a volumetric survey of Hugo Lake, Oklahoma. The goal of the study was to produce updated elevation-area and elevation-volume tables using current GPS, acoustical depth sounder and GIS technology.

Records indicate the conservation pool elevation (cpe) for Hugo Lake is 404.5 feet above mean sea level (msl). A lake boundary was digitized from digital orthophoto quadrangle images (DOQs). Depth and positional data was collected along a layout of transects or pre-plotted navigation lines spaced approximately 500 feet using commercially available software.

Data were collected at Hugo Lake during the period of August 19 to 22, 2003. During that period, the water levels varied between elevations 404.74 ft and 404.90 ft. Approximately 146,000 data points were collected over 265 miles of pre-planned transects.

The results of the current survey indicate the lake encompasses 12,338 surface acres and contains a total of 141,040 acre-feet (ac-ft) at the cpe (404.5 ft.) When last surveyed in 1985, the lake encompassed 13,144 surface acres and had a total volume of 158,617ac-ft. This survey indicates the lake has experienced a reduction in surface area of approximately 6% and a loss in total volume at cpe of approximately 11%.

# HUGO LAKE
# VOLUMETRIC SURVEY REPORT

## INTRODUCTION

Staff of the Hydrographic Survey Team of the Texas Water Development Board (TWDB) conducted a volumetric survey of Hugo Lake during the period of August 19 through 22, 2003. The purpose of the survey was to determine the capacity of the lake at the conservation pool elevation. Survey results are presented in the following pages in both graphical and tabular form.

The vertical datum used during this survey is that used by the United States Army Corps of Engineers (USACE), Tulsa District for the lake elevation gauge at Hugo Dam. The datum for this gauge is reported as mean sea level (msl). Thus, elevations are reported here in feet (ft) above msl. Volume and area calculations in this report are referenced to water levels provided by the USACE gauge: HGLO2: Hugo Lake[1].

Hugo Lake is located on the Kiamichi River at river mile 17.6, about 7 miles east of Hugo in Choctaw County, OK and 30 miles north of Paris, TX (Figure 1).

## LAKE HISTORY AND GENERAL INFORMATION

Hugo Lake and Dam were originally authorized under the Flood Control Act approved 24 July, 1946 (Project Document, HD 602, 79th Congress, 2d Session) [2]. The multi-purpose project provides for flood control, water supply, fish and wildlife management and recreation. The drainage area is approximately 1,434 square miles[2]. Hugo Dam, appurtenant structures and the surrounding shoreline of Hugo Lake are owned by the U. S. Government and operated by the U. S. Army Corps of Engineers (USACE), Tulsa District.

Construction started on Hugo Dam on September 6, 1968 and the embankment closure was completed October 29, 1971. Deliberate impoundment began January 18, 1974 and the lake filled to conservation pool elevation (cpe) 404.5 by March 12, 1974.

Hugo Dam is a rolled earth embankment. The structure is 10,200 ft long (including the gate-controlled concrete spillway) with a maximum height of 101 ft above the streambed. The 32 ft wide crest allows for an access road across the embankment and spillway.

The gate-controlled spillway consists of a concrete gravity weir with a crest elevation of 387.5 ft. The spillway is designed with six 40- by 50-foot gates and a nonbaffled-stilling basin. Discharge capacity of the spillway is 365,000 cubic feet per second (cfs) at maximum pool elevation 445.2 ft.

Low-flow releases for downstream requirements and for water supply are through two, 48-inch diameter pipes located in the spillway.

The following table summarizes information for Hugo Dam and Hugo Lake based on information furnished by the USACE[2].

**TABLE 1. Hugo Dam and Hugo Lake Pertinent Data**

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**Owner of Hugo Dam and Facilities**

United States of America

**Operator of Hugo Dam and Facilities**

U. S. Army Corps of Engineers, Tulsa District

**Engineer**

U. S. Army Corps of Engineers, Tulsa District (Design)

**Location**

On the Kiamichi River at river mile 17.6, about 7 miles east of Hugo in Choctaw County, OK and 30 miles north of Paris, TX.

**Drainage Area**

1,434 square miles

**Dam**

| | |
|---|---|
| Type | Rolled earth |
| Length (including spillway) | 10,200 ft |
| Maximum Height | 101 ft |

**Spillway**

| | |
|---|---|
| Type | Concrete gravity weir |
| Length | 240 ft |
| Crest elevation | 387.5 ft |
| Control | Six Gates, each 40 ft long by 50 ft high |

**Outlet Works**

| | |
|---|---|
| Type | Two conduits |
| Size | 48- inch diameter |
| Control | Valve |
| Type | Low-flow and water supply releases |

**Reservoir Data** (Based on TWDB 2003 volumetric survey)

| **Feature** | **Elevation (Above msl)** | **Capacity (Acre-feet)** | **Area (Acres)** |
|---|---|---|---|
| Top of Conservation Pool (Volume or Total Storage) | 404.5 | 141,040 | 12,338 |
| Conservation Storage | 390.0 – 404.5 | 118,850 | N/A |
| Top of Inactive Pool | 390.0 | 22,190 | 3,981 |

## VOLUMETRIC SURVEYING TECHNOLOGY

Prior methodologies for calculating volumes and areas from bathymetric data included the range survey and contour survey methods[3, 4]. Comparisons between those methods and the current method described below are not recommended[4].

The equipment used to perform the latest volumetric survey consisted of a 23-foot aluminum tri-hull SeaArk craft with cabin (Hydro-survey boat), equipped with twin 90-Horsepower Honda outboard motors. Installed within the enclosed cabin are a Coastal Oceanographics' Helmsman Display (for navigation), an Innerspace Technology Model 449 Depth Sounder and Model 443 Velocity Profiler, a Trimble Navigation, Inc. AG132 GPS receiver with Omnistar differential GPS correction signal, and an on-board PC. A water-cooled 4.5 kW generator provides electrical power through an in-line uninterruptible power supply.

In shallow areas and where navigational hazards such as stumps were present, a 20-foot aluminum shallow-draft flat bottom SeaArk craft (River-runner) with cabin and equipped with one 100-horsepower Yamaha outboard motor was used. The portable data collection equipment on-board the boat included a Knudsen 320 B/P Echosounder (depth sounder), a Trimble Navigation, Inc. AG132 GPS receiver with Omnistar differential GPS correction signal, and a laptop computer. The GPS equipment, survey vessels, and depth sounders in combination provide efficient hydrographic survey systems. Accurate estimates of the lake volume can be quickly determined by building a 3-D TIN[5] model of the lake from the collected data. Reference to brand names throughout this report does not imply endorsement by TWDB.

## PRE-SURVEY PROCEDURES

The lake's boundary was digitized using Environmental Systems Research Institute's (ESRI) [6] ArcGIS 8.3 from digital orthophoto quadrangle images (DOQs). Geo Information Systems, a department of the University of Oklahoma, furnished the DOQs. More information

can be obtained on the Internet at http://www.geo.ou.edu/. The identification numbers for the DOQs used to create the lake's boundary were 34095a41.sid, 34095a42.sid, 34095a43.sid, 34095a44.sid, 34095b41.sid, 34095b42.sid, 34095b43.sid and 34095b44.sid. The lake level elevations, at the time the DOQs were photographed were 404.70 ft (March 9, 1995) and 404.76 ft (March 16, 1996). These photographs (DOQs) were used to digitize the boundary of the lake and were given the elevation 404.5 ft (cpe) for modeling purposes. The lake elevation varied between 404.74 ft and 404.90 ft during the survey.

The survey layout was designed by placing survey track lines at 500-foot intervals (Figure 2) within the digitized lake boundary using HYPACK[7] software. The survey design required the use of approximately 210 survey lines placed perpendicular to the original creek channel and tributaries.

## SURVEY PROCEDURES

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

### Equipment Calibration and Operation

Prior to collecting data each day on-board the Hydro-survey boat, the depth sounder was calibrated with the Innerspace 443 Velocity Profiler, an instrument used to measure the variation in the speed of sound at different depths in the water column. The average speed of sound through the entire water column below the boat was determined by averaging local speed-of-sound measurements collected through the water column. The velocity profiler probe was first placed in the water to acclimate it. The probe was next raised to the water surface where the depth was considered zero. The probe was then gradually lowered on a cable to a depth just above the lake bottom, and then raised again to the surface. During this lowering and raising procedure, local speed-of-sound measurements were collected, from which the average speed

was computed by the velocity profiler. This average speed of sound was entered into the ITI449 depth sounder, which then provided the depth of the lake bottom. The depth was then checked manually with a measuring tape to ensure that the depth sounder was properly calibrated and operating correctly.

On-board the River-runner boat, the Knudsen depth sounder was calibrated using the DIGIBAR-Pro Profiling Sound Velocimeter by Odem Hydrographic Systems[8]. The steps to determine the speed of sound are the same as those used for the Innerspace 443 Velocity Profiler. The probe was first placed in the water to acclimate it, raised to the water surface where the depth was considered zero. The probe was then gradually lowered on a cable to a depth just above the lake bottom, and then raised again to the surface. During this lowering and raising procedure, local speed-of-sound measurements were collected, from which the average speed was computed by the velocimeter. The speed of sound was then entered into the bar check feature in the Knudsen software program[9]. The depth was then checked manually with a surveying stadia rod or weighted measuring tape to ensure that the depth sounder was properly calibrated and operating correctly.

The speed of sound in the water column ranged from 4,923 feet per second to 4,955 feet per second during the Hugo Lake survey. 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 $\pm$0.2 ft. An additional estimated error of $\pm$0.3 ft arises from variation in boat inclination. These two factors combine to give an overall accuracy of $\pm$0.5 ft for any instantaneous reading. These errors tend to be fairly minimal over the entire survey, since some errors are positive and some are negative, canceling each other out.

During the survey, the horizontal mask setting on the onboard GPS receiver was set to 10 degrees and the PDOP (Position Dilution of Precision) limit was set to seven to maximize the accuracy of the horizontal positioning. 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. Further positional accuracy is obtained through differential corrections using the Omnistar

receiver. The lake's initialization file used by the HYPACK data collection program was set up to perform an "on-the-fly" conversion from the collected Differential GPS positions to state-plane coordinates.

## Field Survey

The water levels remained above cpe during the survey. The survey crew experienced excellent weather conditions with no weather related delays. Upon arriving at Hugo Lake, TWDB staff met with personnel from the U. S. Army Corps of Engineers Lake Project Office. After discussing the logistics for the survey, the crew began data collection with the Hydro-survey boat in the main basin and with the River runner boat in the upper reaches of the lake.

The Kiamichi River flows in a west to east direction with Hugo Dam located on the east boundary of Hugo Lake. Approximately half of the main basin was clear of navigational hazard (trees and stumps). Hugo Lake is a highly recreated lake with nine parks located along the shoreline and hundreds of acres surrounding the lake that are dedicated for hunting[10].

Over 120,000 data points were collected over the 265 miles traveled. The crew was able to collect data on 200 of the 210 pre-plotted lines. Random data were collected in those areas where the crew could not stay on course because of navigational obstructions. As the channel of the Kiamichi River became too narrow for perpendicular transects, data were collected in a zigzag pattern. All data points were stored digitally on the boat's computer in 371 data files. Figure 2 shows the actual location of the data points collected.

## Data Processing

The collected data were transferred from the survey computers onto TWDB's network computers and backups were made for future reference as needed. Each raw data file was processed through the EDIT routine in the HYPACK Program. Anomalies such as depth spikes or data with missing depth or positional information were deleted from the files. A correction

for the lake elevation at the time of data collection was also applied to each file during the EDIT routine. After all changes had been made to the raw data files, the edited files were saved and then combined into a single X, Y, Z data file, to be used with the GIS software to develop a model of the lake bottom elevation.

The resulting data file was imported into Environmental System Research Institute's (ESRI) Arc/Info Workstation GIS 8.3 software. This software was used to convert the data to a MASS points file. The MASS points and the boundary file were then used to create a Digital Terrain Model (DTM) of the lake's bottom surface using Arc/Info's TIN software module. The module generates a triangulated irregular network (TIN) from the data points and the boundary file using a method known as Delauney's criteria for triangulation[5]. Using this method, 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 used in this method. The generated network of three-dimensional triangular planes represents the bottom surface. With this representation of the bottom, the software then calculates elevations along the triangular surface plane by determining the elevation along each leg of the triangle. The lake area and volume can be determined from the triangulated irregular network created using this method of interpolation.

Volumes and areas were calculated from the TIN from elevation 359.0 ft to 404.5 ft at one-tenth foot intervals using Arc/Info software. The computed lake volume table is presented in Appendix A and the area table in Appendix B. An elevation-volume graph and an elevation-area graph are presented in Appendix C and Appendix D respectively.

Other products developed from the model include a shaded relief map (Figure 3), a shaded depth range map (Figure 4) and a contour map (Figure 5). Figures 3 and 4 were developed directly from the tin model by assigning different colors to specified ranges. To develop the contour map, the TIN was converted to a lattice using the TINLATTICE command and then to a polygon coverage using the LATTICEPOLY command. Linear filtration

algorithms were applied to the DTM to produce smooth cartographic contours. The resulting contour map of the bottom surface at 2-ft intervals is presented in Figure 5. Finally, the cross-section endpoints are presented in Appendix E and the corresponding cross-section plots are presented in Appendix F.

## RESULTS

Results from the 2003 TWDB survey indicate Hugo Lake encompasses 12,338 surface acres and contains a total volume of 141,040 ac-ft at cpe 404.5 ft. The lake boundary (shoreline miles) was calculated to be 94 miles and was derived from the digitized boundary of the DOQs. The deepest point physically measured during the survey was a depth of 48.6 ft corresponding to elevation 355.9 ft and was located approximately 4,000 ft upstream of Hugo Dam.

## SUMMARY AND COMPARISONS

The 2003 survey utilized a differential global positioning system, depth sounder and geographical information system technology to create a digital model of the lake's bathymetry. For the purpose of this report, comparisons are being made to the most recent sediment survey (1985 USACE). Results of the 1985 USACE sediment survey showed that Hugo Lake had a surface area of 13,144 acres and a total volume of 158,617 ac-ft at top of conservation pool elevation, 404.5 ft. The results of the 2003 TWDB volumetric survey show that there was a reduction in the surface area of approximately 6% and a loss in total volume at cpe of approximately 11% when compared to the 1985 USACE survey. These figures are presented in Table 2.

Comparisons between the 1985 USACE sediment survey and the 2003 TWDB volumetric survey are difficult and some apparent changes might simply be due to methodological differences[4]. It is recommended that another survey utilizing modern methods

be performed in five to ten years or after a major flood event to monitor changes to the lake's capacity.

**TABLE 2. Area and Capacity Comparisons Hugo Lake**

| FEATURE | USACE Sediment Survey | TWDB Current Survey |
|---|---|---|
| Year | 1985 | 2003 |
| Area @ Conser. Pool Elev. 404.5 ft (ac) | 13,144 | 12,338 |
| Volume @ Conser. Pool Elev. 404.5 ft (ac-ft) | 158,617 | 141,040 |
| Inactive Storage below Elev. 390.00 ft (ac-ft) | 24,735 | 22,190 |
| Conservation Capacity Elev. 390.00 – 404.5 ft (ac-ft) | 133,882 | 118,850 |

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Appendix A

# Hugo Lake

## RESERVOIR VOLUME TABLE

TEXAS WATER DEVELOPMENT BOARD AUGUST 2003 SURVEY

VOLUME IN ACRE-FEET ELEVATION INCREMENT IS ONE TENTH FOOT

| ELEVATION in Feet | 0.0 | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 |
|---|---|---|---|---|---|---|---|---|---|---|
| 355 | | | | | | | | | | 0 |
| 356 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 357 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 358 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 359 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 360 | 1 | 2 | 2 | 2 | 2 | 3 | 3 | 4 | 4 | 5 |
| 361 | 5 | 6 | 6 | 7 | 8 | 8 | 9 | 10 | 11 | 11 |
| 362 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 20 | 21 | 22 |
| 363 | 23 | 25 | 26 | 28 | 29 | 31 | 33 | 34 | 36 | 38 |
| 364 | 40 | 42 | 44 | 46 | 48 | 51 | 53 | 56 | 58 | 61 |
| 365 | 63 | 66 | 69 | 72 | 75 | 79 | 82 | 86 | 89 | 93 |
| 366 | 97 | 101 | 105 | 109 | 114 | 118 | 123 | 127 | 132 | 137 |
| 367 | 142 | 148 | 153 | 159 | 164 | 170 | 176 | 182 | 188 | 195 |
| 368 | 201 | 208 | 215 | 222 | 229 | 236 | 244 | 251 | 259 | 267 |
| 369 | 275 | 283 | 292 | 300 | 309 | 318 | 327 | 336 | 345 | 355 |
| 370 | 365 | 375 | 385 | 395 | 406 | 417 | 428 | 439 | 450 | 462 |
| 371 | 474 | 486 | 498 | 510 | 523 | 536 | 549 | 563 | 577 | 591 |
| 372 | 605 | 619 | 634 | 649 | 664 | 680 | 696 | 712 | 728 | 745 |
| 373 | 762 | 779 | 796 | 814 | 832 | 851 | 869 | 888 | 908 | 927 |
| 374 | 947 | 967 | 988 | 1009 | 1030 | 1051 | 1073 | 1095 | 1118 | 1140 |
| 375 | 1164 | 1187 | 1211 | 1235 | 1260 | 1285 | 1310 | 1336 | 1362 | 1389 |
| 376 | 1416 | 1443 | 1471 | 1500 | 1529 | 1558 | 1588 | 1618 | 1649 | 1680 |
| 377 | 1712 | 1744 | 1777 | 1811 | 1845 | 1880 | 1915 | 1951 | 1987 | 2025 |
| 378 | 2063 | 2102 | 2141 | 2182 | 2223 | 2265 | 2308 | 2352 | 2397 | 2442 |
| 379 | 2489 | 2536 | 2585 | 2635 | 2685 | 2737 | 2790 | 2844 | 2900 | 2957 |
| 380 | 3015 | 3075 | 3136 | 3198 | 3262 | 3328 | 3395 | 3463 | 3533 | 3605 |
| 381 | 3678 | 3753 | 3830 | 3909 | 3989 | 4071 | 4155 | 4241 | 4329 | 4420 |
| 382 | 4512 | 4607 | 4704 | 4803 | 4905 | 5009 | 5116 | 5225 | 5336 | 5451 |
| 383 | 5568 | 5687 | 5809 | 5934 | 6061 | 6191 | 6324 | 6459 | 6597 | 6739 |
| 384 | 6883 | 7030 | 7180 | 7332 | 7488 | 7647 | 7809 | 7974 | 8142 | 8313 |
| 385 | 8488 | 8665 | 8846 | 9029 | 9216 | 9407 | 9600 | 9797 | 9998 | 10202 |
| 386 | 10409 | 10620 | 10835 | 11053 | 11275 | 11500 | 11730 | 11963 | 12199 | 12440 |
| 387 | 12685 | 12933 | 13186 | 13443 | 13704 | 13969 | 14238 | 14512 | 14790 | 15072 |
| 388 | 15359 | 15650 | 15946 | 16247 | 16553 | 16864 | 17181 | 17503 | 17830 | 18162 |
| 389 | 18500 | 18843 | 19192 | 19546 | 19907 | 20273 | 20644 | 21022 | 21405 | 21795 |
| 390 | 22190 | 22591 | 22998 | 23411 | 23832 | 24260 | 24694 | 25136 | 25584 | 26039 |
| 391 | 26499 | 26965 | 27436 | 27912 | 28394 | 28881 | 29373 | 29871 | 30374 | 30882 |
| 392 | 31396 | 31915 | 32439 | 32967 | 33501 | 34040 | 34583 | 35132 | 35686 | 36245 |
| 393 | 36809 | 37379 | 37954 | 38533 | 39118 | 39709 | 40305 | 40906 | 41513 | 42126 |
| 394 | 42744 | 43368 | 43998 | 44635 | 45278 | 45929 | 46586 | 47250 | 47920 | 48596 |
| 395 | 49279 | 49968 | 50663 | 51363 | 52070 | 52783 | 53503 | 54228 | 54959 | 55697 |
| 396 | 56441 | 57190 | 57946 | 58707 | 59475 | 60249 | 61029 | 61815 | 62607 | 63406 |
| 397 | 64210 | 65020 | 65836 | 66658 | 67485 | 68319 | 69158 | 70003 | 70854 | 71711 |
| 398 | 72574 | 73443 | 74319 | 75200 | 76088 | 76983 | 77883 | 78789 | 79701 | 80620 |
| 399 | 81544 | 82474 | 83409 | 84351 | 85298 | 86251 | 87210 | 88174 | 89144 | 90121 |
| 400 | 91103 | 92091 | 93084 | 94083 | 95087 | 96097 | 97113 | 98133 | 99159 | 100191 |
| 401 | 101229 | 102272 | 103321 | 104376 | 105437 | 106504 | 107578 | 108658 | 109745 | 110840 |
| 402 | 111941 | 113048 | 114162 | 115282 | 116409 | 117543 | 118682 | 119826 | 120973 | 122124 |
| 403 | 123279 | 124438 | 125600 | 126766 | 127936 | 129109 | 130286 | 131466 | 132650 | 133838 |
| 404 | 135029 | 136224 | 137423 | 138625 | 139831 | 141040 | | | | |

Appendix B

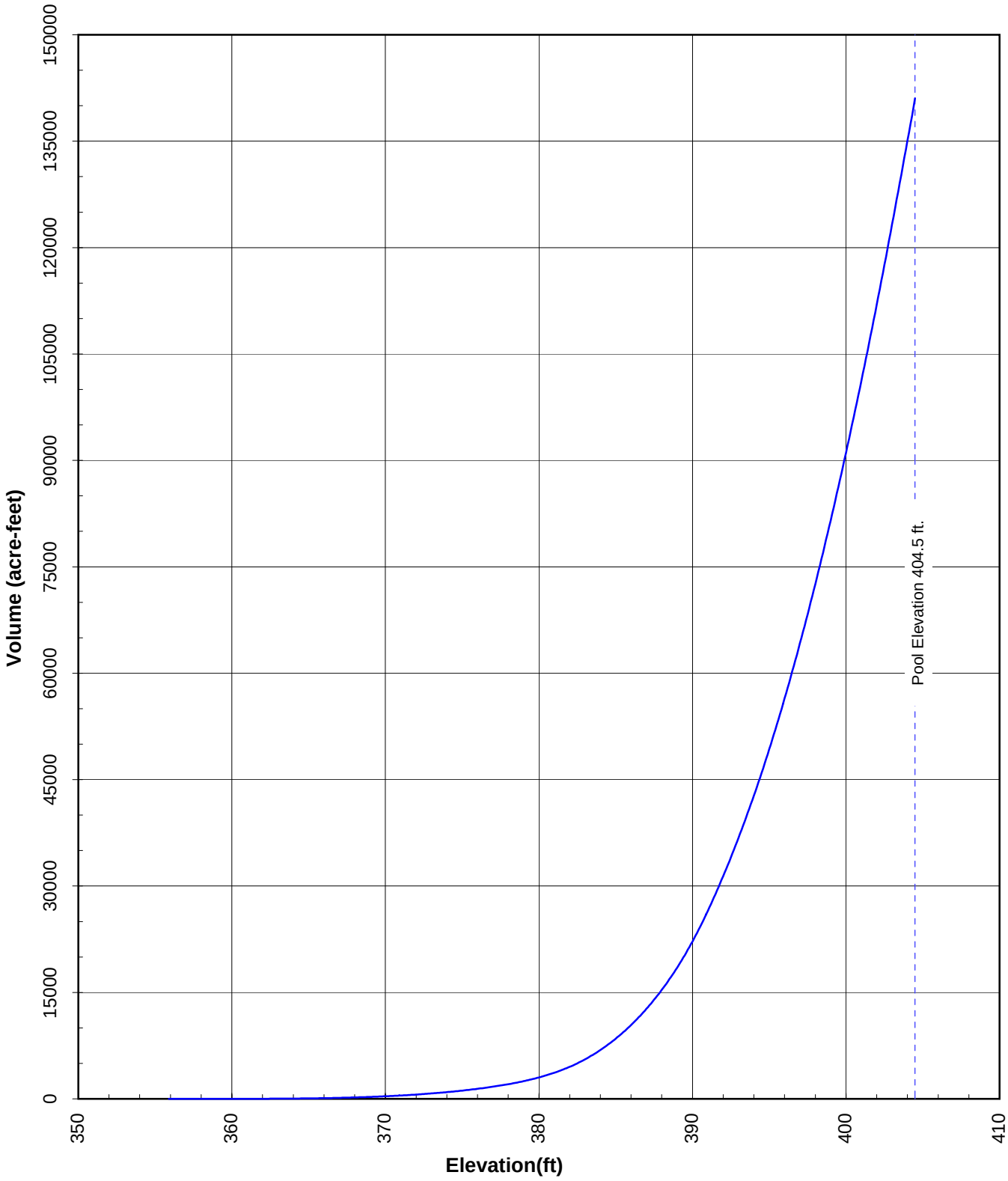
# Hugo Lake

## RESERVOIR AREA TABLE

TEXAS WATER DEVELOPMENT BOARD — AUGUST 2003 SURVEY

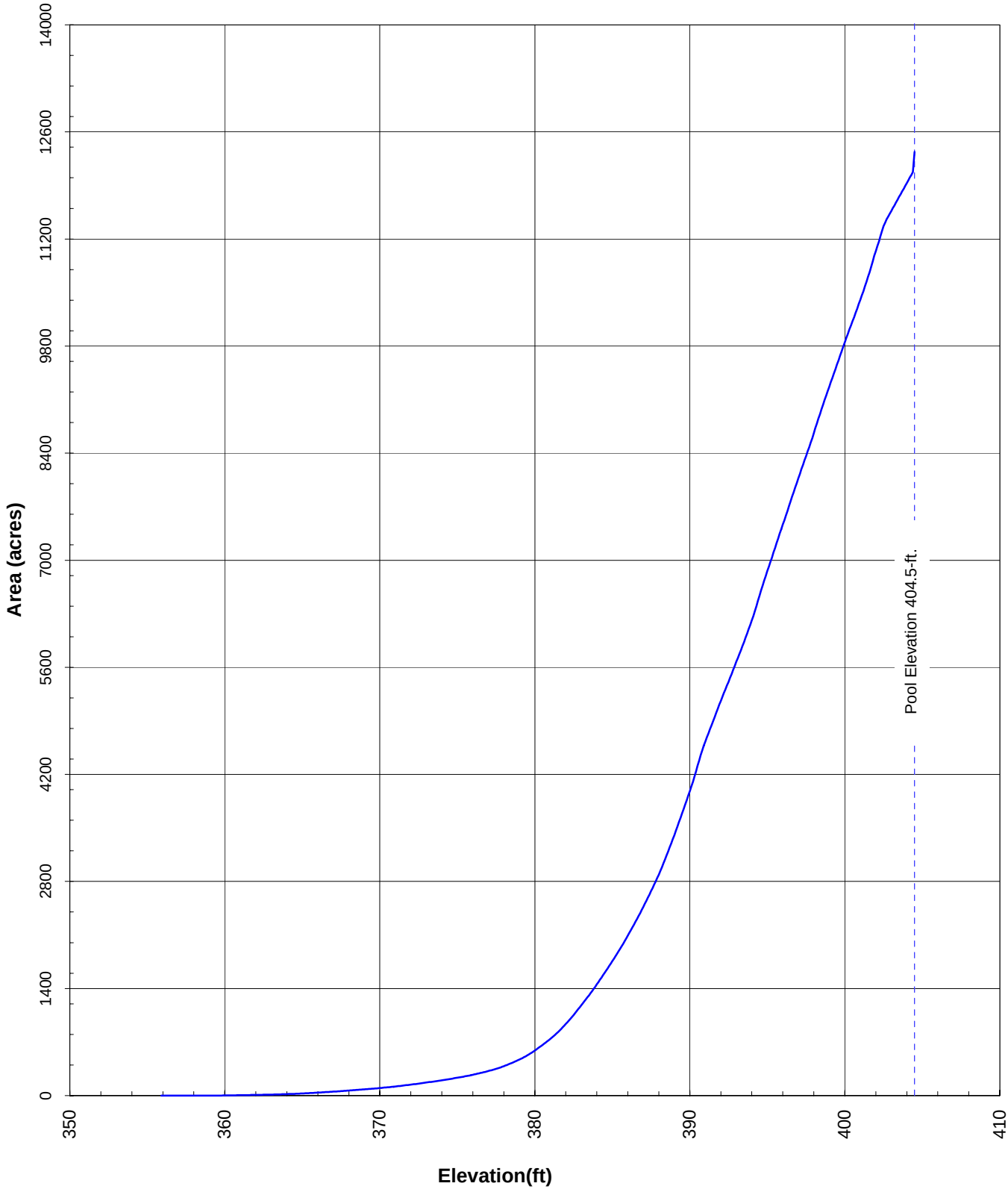
AREA IN ACRES — ELEVATION INCREMENT IS ONE TENTH FOOT

| ELEVATION in Feet | 0.0 | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 |
|---|---|---|---|---|---|---|---|---|---|---|
| 355 | | | | | | | | | | 0 |
| 356 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 357 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 358 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 359 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 |
| 360 | 2 | 2 | 2 | 3 | 3 | 4 | 4 | 4 | 5 | 5 |
| 361 | 5 | 6 | 6 | 6 | 7 | 7 | 7 | 8 | 8 | 9 |
| 362 | 9 | 10 | 10 | 10 | 11 | 11 | 12 | 12 | 13 | 13 |
| 363 | 14 | 14 | 15 | 15 | 16 | 16 | 17 | 18 | 18 | 19 |
| 364 | 20 | 20 | 21 | 22 | 23 | 23 | 24 | 25 | 26 | 27 |
| 365 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 36 | 37 | 38 |
| 366 | 39 | 41 | 42 | 43 | 44 | 46 | 47 | 48 | 49 | 51 |
| 367 | 52 | 53 | 55 | 56 | 57 | 59 | 60 | 62 | 63 | 65 |
| 368 | 66 | 68 | 69 | 71 | 72 | 74 | 75 | 77 | 78 | 80 |
| 369 | 81 | 83 | 85 | 86 | 88 | 90 | 91 | 93 | 95 | 97 |
| 370 | 99 | 101 | 103 | 105 | 107 | 109 | 111 | 113 | 115 | 117 |
| 371 | 119 | 122 | 124 | 126 | 129 | 131 | 134 | 136 | 139 | 141 |
| 372 | 144 | 146 | 149 | 151 | 154 | 157 | 160 | 162 | 165 | 168 |
| 373 | 171 | 174 | 176 | 179 | 182 | 185 | 188 | 191 | 194 | 197 |
| 374 | 200 | 203 | 207 | 210 | 213 | 217 | 220 | 223 | 227 | 230 |
| 375 | 234 | 237 | 241 | 245 | 248 | 252 | 256 | 260 | 264 | 268 |
| 376 | 272 | 277 | 281 | 286 | 291 | 295 | 300 | 305 | 310 | 316 |
| 377 | 321 | 327 | 333 | 338 | 344 | 350 | 356 | 363 | 369 | 377 |
| 378 | 384 | 392 | 400 | 409 | 417 | 426 | 435 | 443 | 452 | 461 |
| 379 | 470 | 480 | 491 | 501 | 513 | 524 | 536 | 549 | 562 | 576 |
| 380 | 590 | 604 | 618 | 633 | 647 | 662 | 677 | 693 | 709 | 725 |
| 381 | 741 | 758 | 776 | 793 | 812 | 831 | 851 | 872 | 893 | 915 |
| 382 | 937 | 959 | 981 | 1004 | 1028 | 1053 | 1078 | 1104 | 1130 | 1156 |
| 383 | 1182 | 1208 | 1234 | 1260 | 1287 | 1313 | 1340 | 1368 | 1396 | 1425 |
| 384 | 1455 | 1485 | 1514 | 1544 | 1574 | 1604 | 1635 | 1666 | 1696 | 1727 |
| 385 | 1758 | 1790 | 1821 | 1854 | 1887 | 1919 | 1953 | 1987 | 2022 | 2057 |
| 386 | 2092 | 2128 | 2164 | 2200 | 2237 | 2273 | 2311 | 2349 | 2387 | 2427 |
| 387 | 2467 | 2507 | 2547 | 2588 | 2630 | 2673 | 2715 | 2758 | 2801 | 2844 |
| 388 | 2889 | 2935 | 2985 | 3036 | 3088 | 3139 | 3191 | 3244 | 3296 | 3350 |
| 389 | 3404 | 3461 | 3518 | 3575 | 3631 | 3688 | 3746 | 3805 | 3863 | 3922 |
| 390 | 3981 | 4041 | 4103 | 4169 | 4240 | 4312 | 4381 | 4452 | 4515 | 4575 |
| 391 | 4631 | 4685 | 4737 | 4789 | 4842 | 4895 | 4949 | 5004 | 5059 | 5111 |
| 392 | 5163 | 5213 | 5263 | 5313 | 5362 | 5410 | 5461 | 5513 | 5566 | 5619 |
| 393 | 5671 | 5722 | 5772 | 5824 | 5876 | 5930 | 5986 | 6042 | 6098 | 6154 |
| 394 | 6211 | 6271 | 6333 | 6401 | 6469 | 6538 | 6606 | 6671 | 6734 | 6797 |
| 395 | 6858 | 6918 | 6977 | 7037 | 7100 | 7160 | 7222 | 7286 | 7348 | 7407 |
| 396 | 7466 | 7524 | 7583 | 7645 | 7708 | 7772 | 7833 | 7893 | 7952 | 8012 |
| 397 | 8071 | 8130 | 8190 | 8248 | 8306 | 8364 | 8422 | 8479 | 8538 | 8598 |
| 398 | 8661 | 8724 | 8787 | 8849 | 8910 | 8972 | 9034 | 9094 | 9152 | 9211 |
| 399 | 9270 | 9328 | 9385 | 9442 | 9500 | 9559 | 9617 | 9676 | 9734 | 9791 |
| 400 | 9849 | 9906 | 9962 | 10018 | 10072 | 10125 | 10178 | 10233 | 10291 | 10348 |
| 401 | 10405 | 10461 | 10519 | 10579 | 10642 | 10705 | 10768 | 10834 | 10909 | 10981 |
| 402 | 11043 | 11104 | 11167 | 11235 | 11307 | 11367 | 11415 | 11456 | 11494 | 11531 |
| 403 | 11567 | 11604 | 11641 | 11677 | 11714 | 11750 | 11786 | 11823 | 11859 | 11895 |
| 404 | 11931 | 11967 | 12003 | 12039 | 12075 | 12338 | | | | |




Hugo Lake
August 2003
Prepared by: TWDB

Appendix C Elevation vs. Volume




Hugo Lake
August 2003
Prepared by: TWDB

Appendix E

# Hugo Lake

TEXAS WATER DEVELOPMENT BOARD August 2003 SURVEY

**Range Line Endpoints**

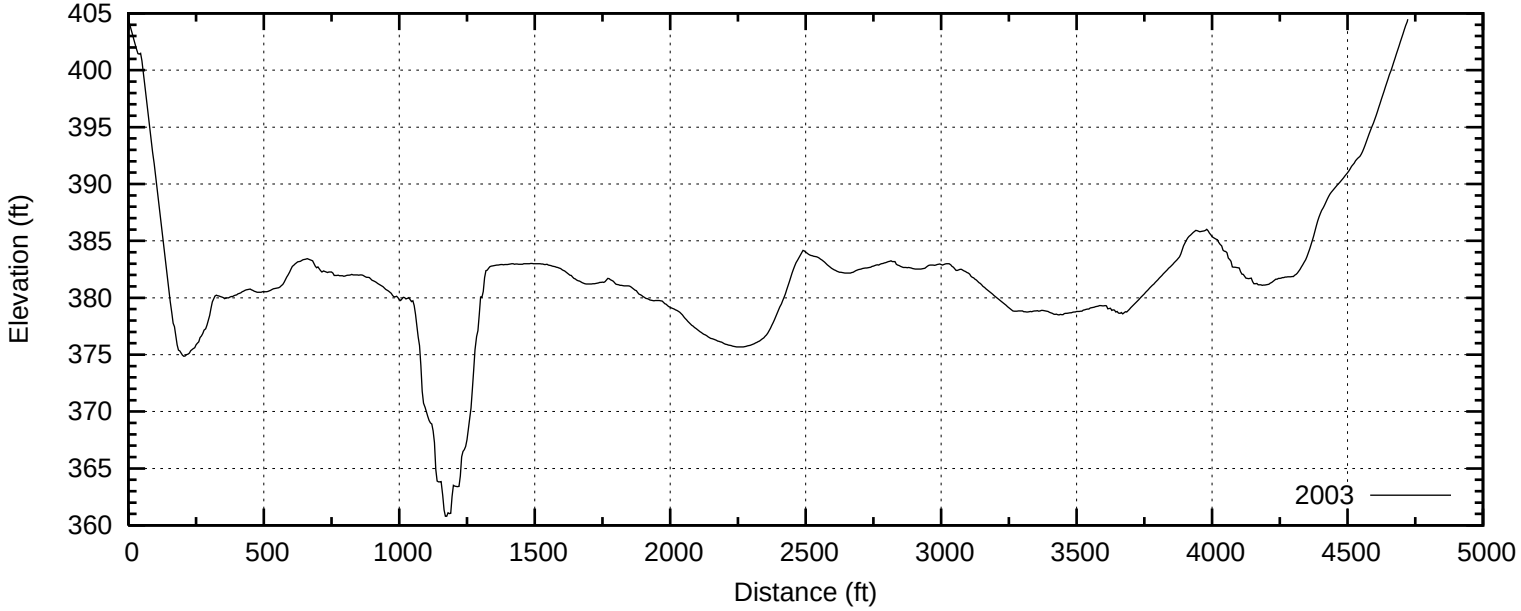
State Plane NAD83 Units-feet

L-Left endpoint
R-right endpoint

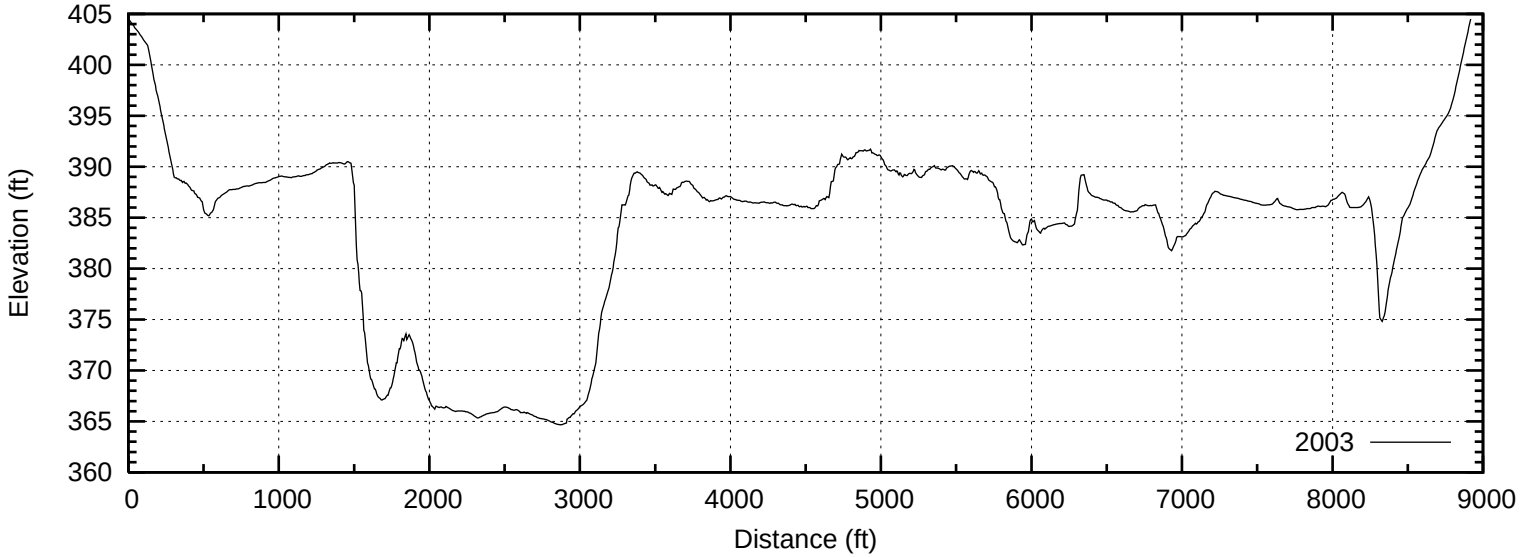
| Range Line | X | Y |
|---|---|---|
| Line 01-L | 2,761,431.0 | 260,233.9 |
| Line 01-R | 2,757,405.5 | 257,763.8 |
| Line 02-L | 2,756,235.5 | 270,656.8 |
| Line 02-R | 2,749,203.0 | 265,173.0 |
| Line 03-L | 2,757,536.8 | 284,831.7 |
| Line 03-R | 2,745,267.3 | 280,251.6 |
| Line 04-L | 2,752,323.8 | 293,139.4 |
| Line 04-R | 2,743,444.0 | 287,079.3 |
| Line 05-L | 2,746,153.8 | 296,760.9 |
| Line 05-R | 2,740,606.3 | 290,835.0 |
| Line 06-L | 2,758,250.8 | 257,255.3 |
| Line 06-R | 2,758,896.8 | 256,953.9 |
| Line 07-L | 2,750,589.3 | 263,565.6 |
| Line 07-R | 2,752,947.0 | 262,939.6 |
| Line 08-L | 2,744,848.8 | 269,246.8 |
| Line 08-R | 2,746,502.0 | 267,139.3 |
| Line 09-L | 2,744,539.5 | 283,212.2 |
| Line 09-R | 2,745,210.8 | 280,295.8 |
| Line 10-L | 2,739,583.8 | 280,907.3 |
| Line 10-R | 2,741,409.5 | 278,550.4 |

# Hugo Lake

## Range Line SR01

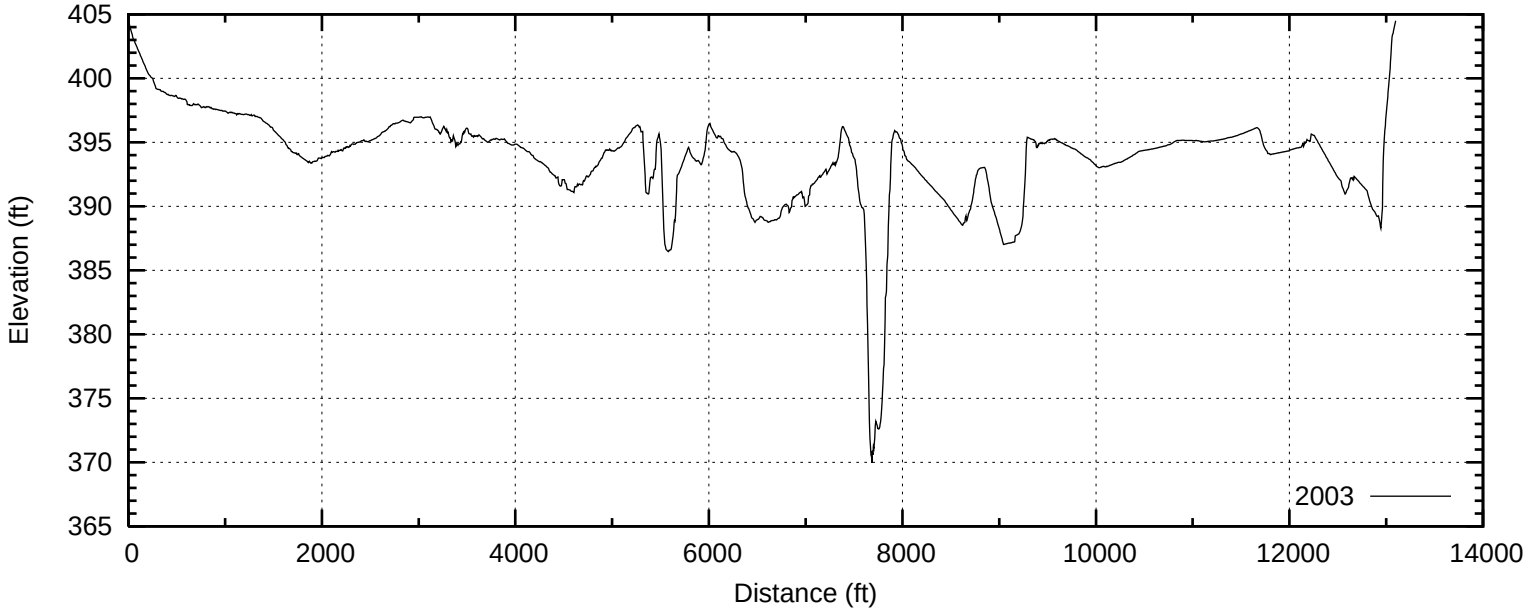



## Range Line SR02

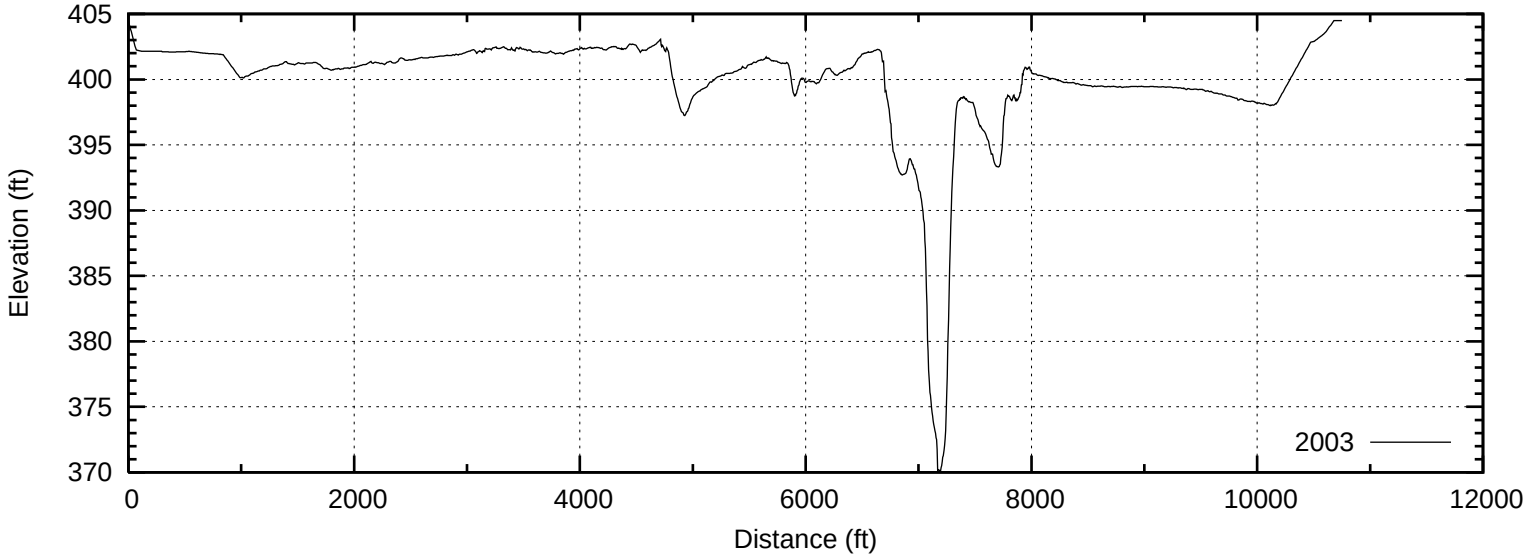


# Hugo Lake

## Range Line SR03

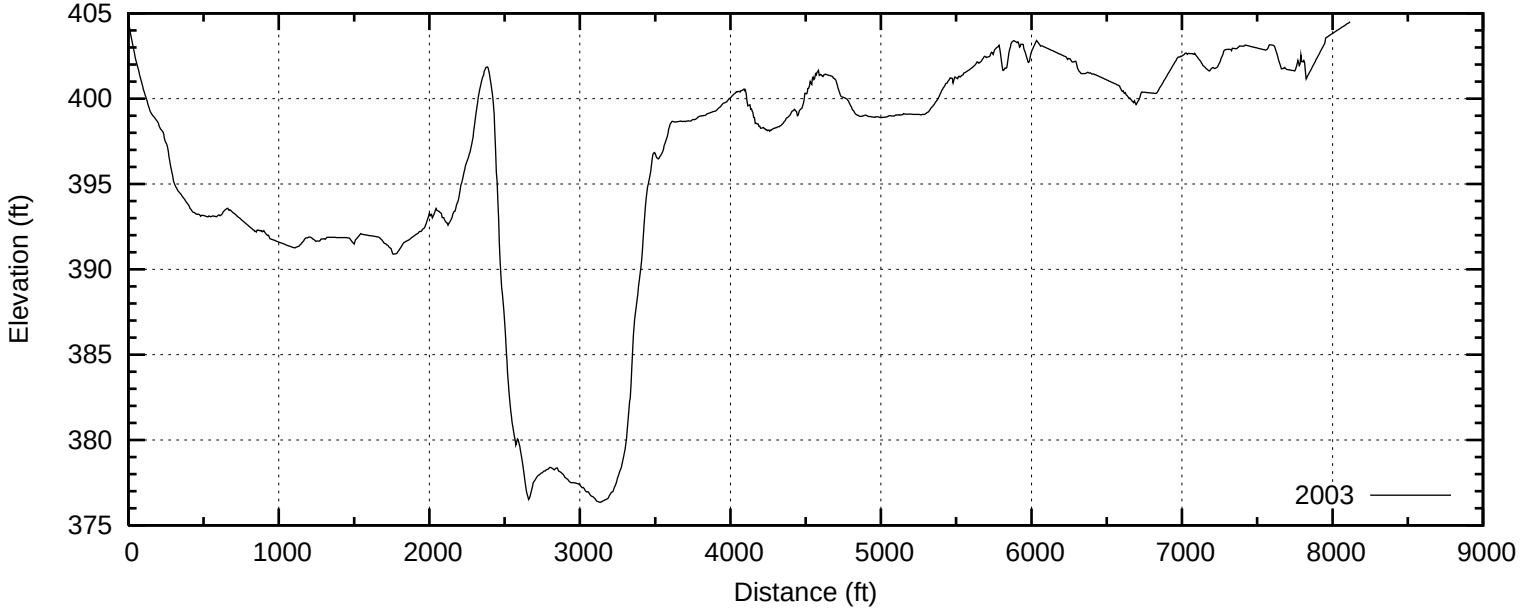



## Range Line SR04

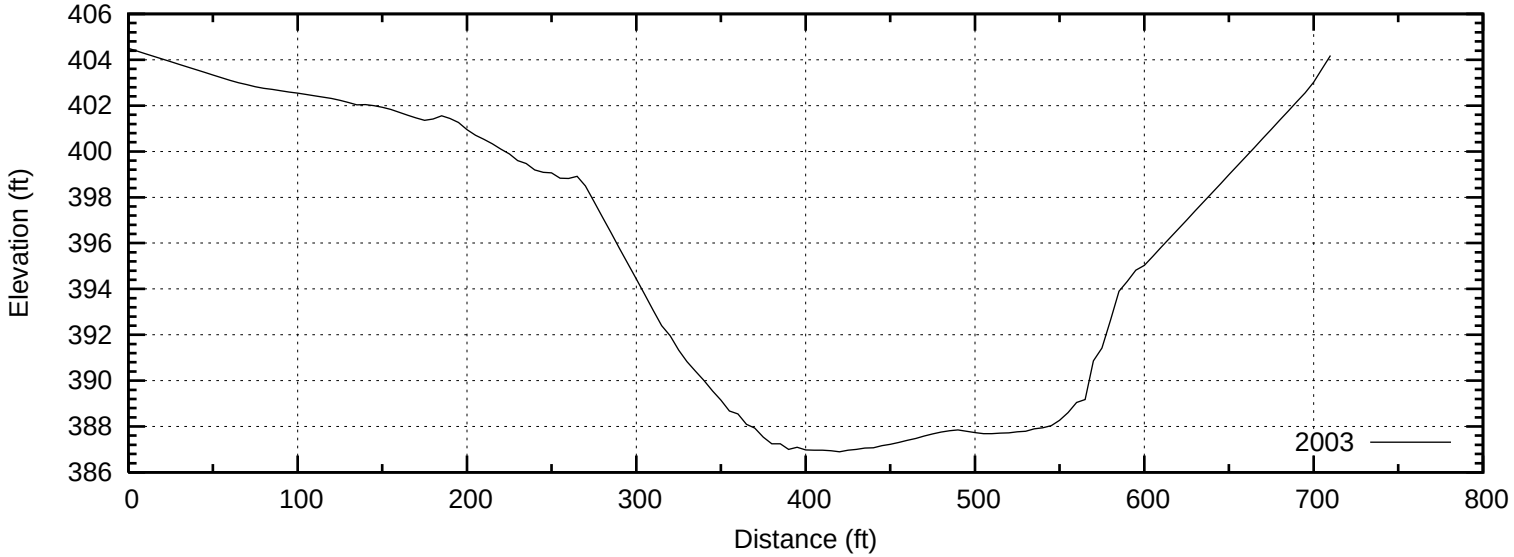


# Hugo Lake

## Range Line SR05

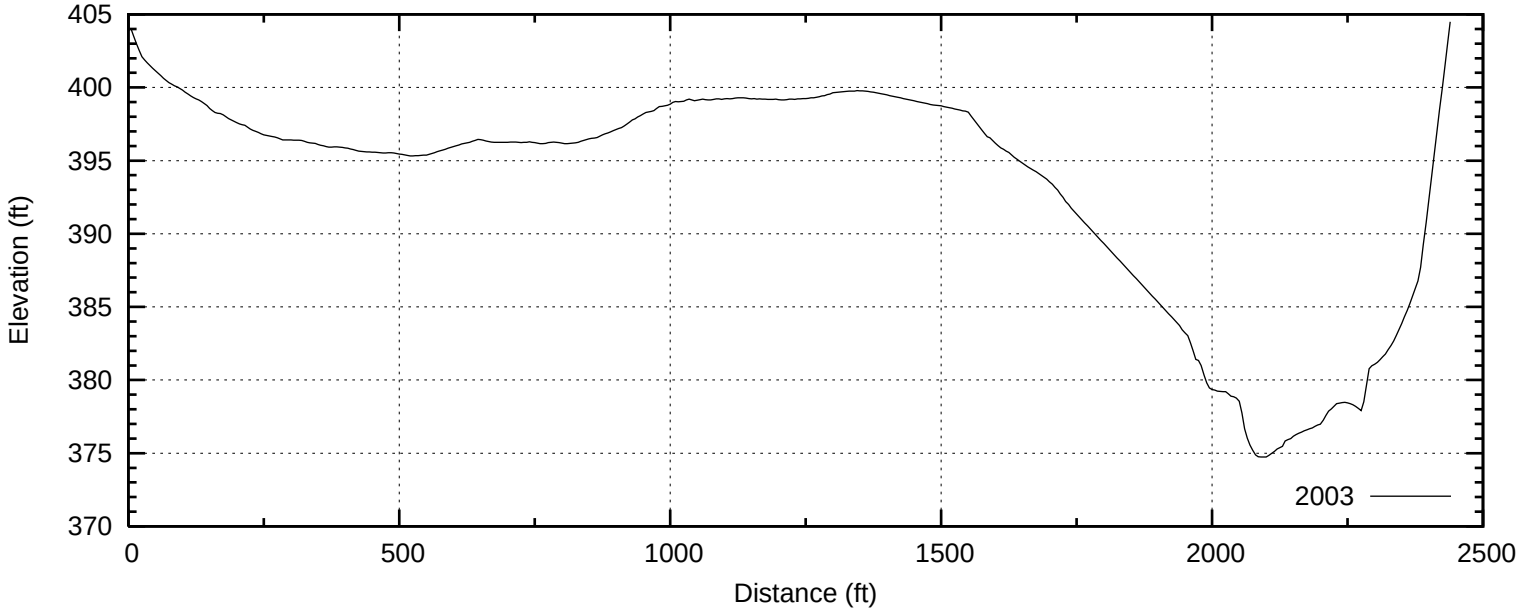



## Range Line SR06

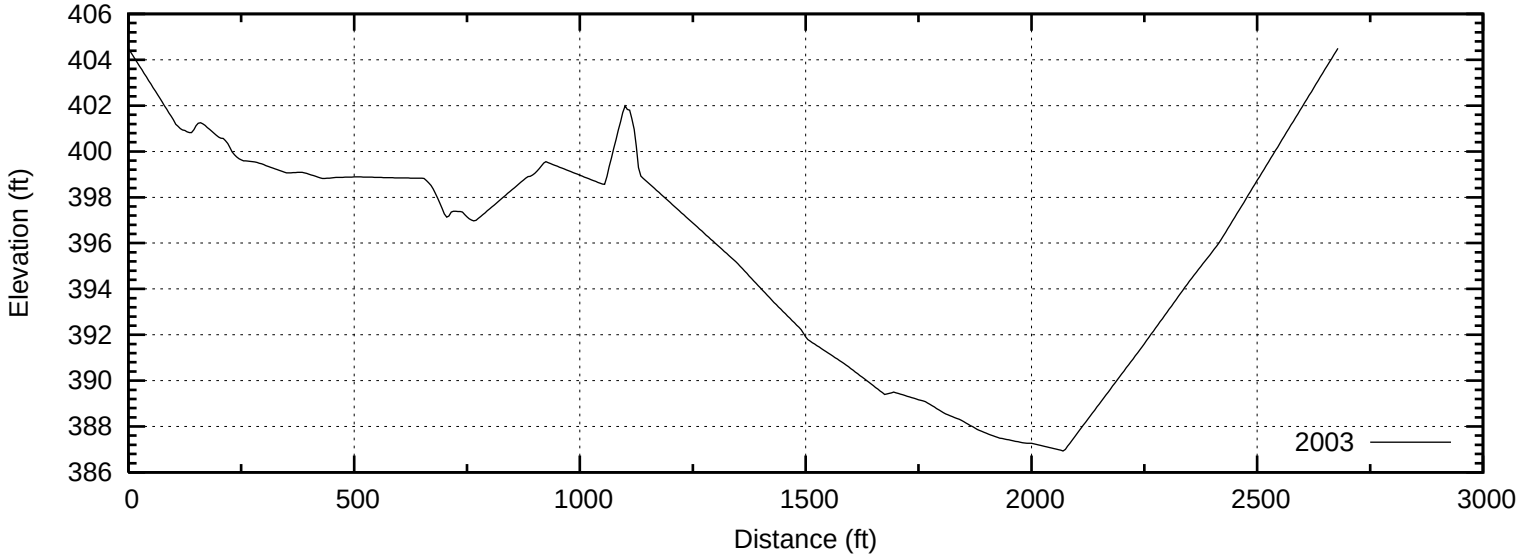


# Hugo Lake

## Range Line SR07

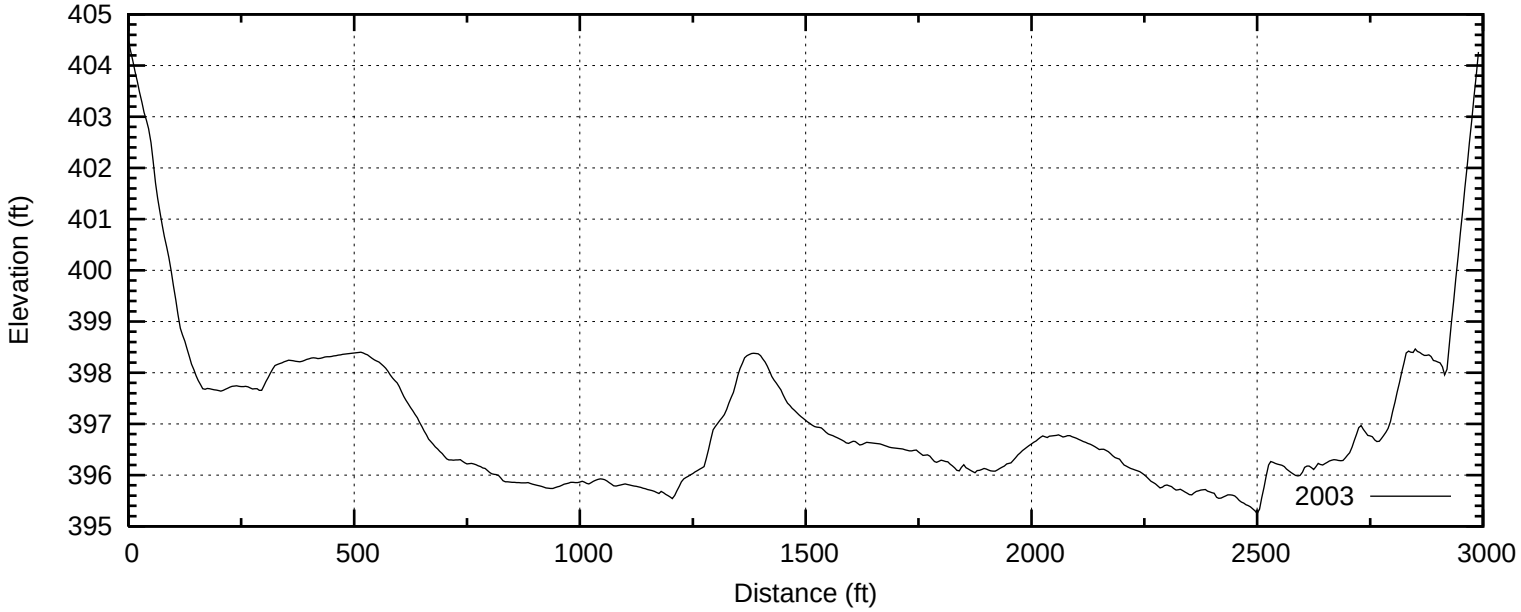



## Range Line SR08



# Hugo Lake

## Range Line SR09




## Range Line SR10

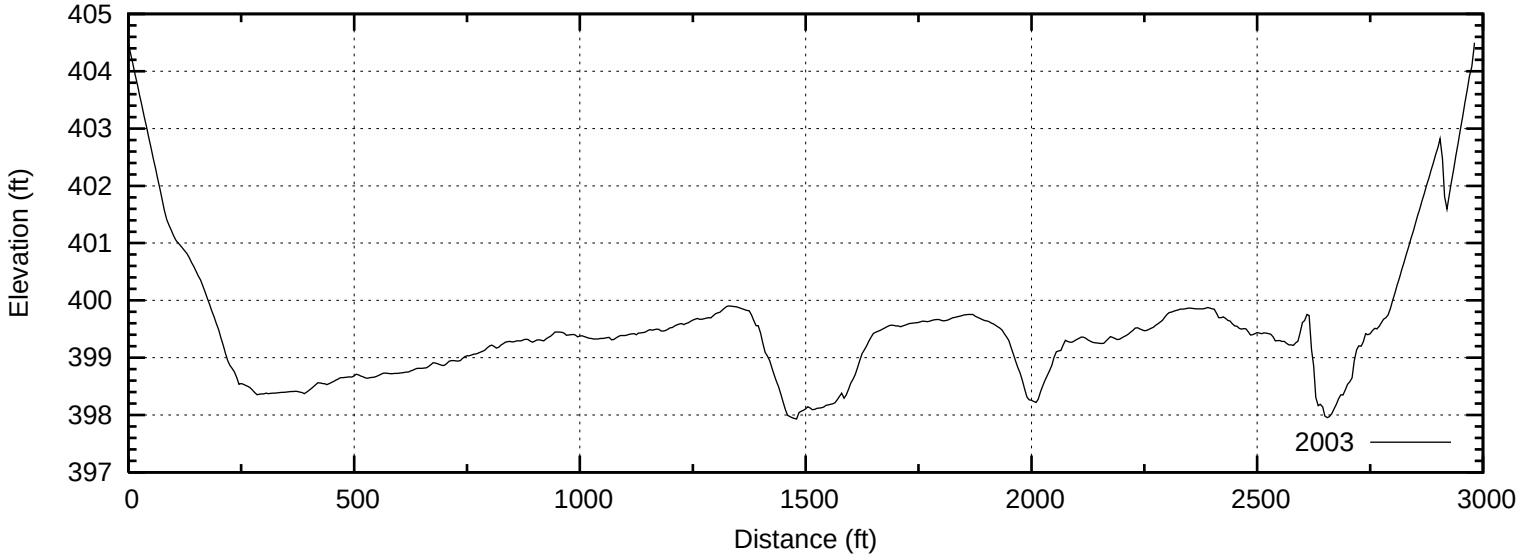
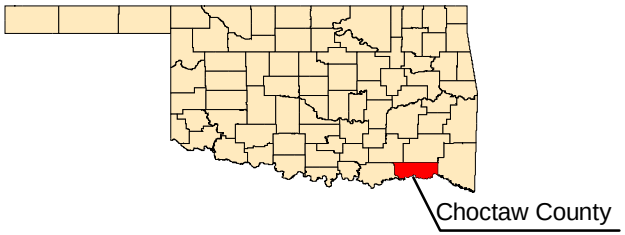
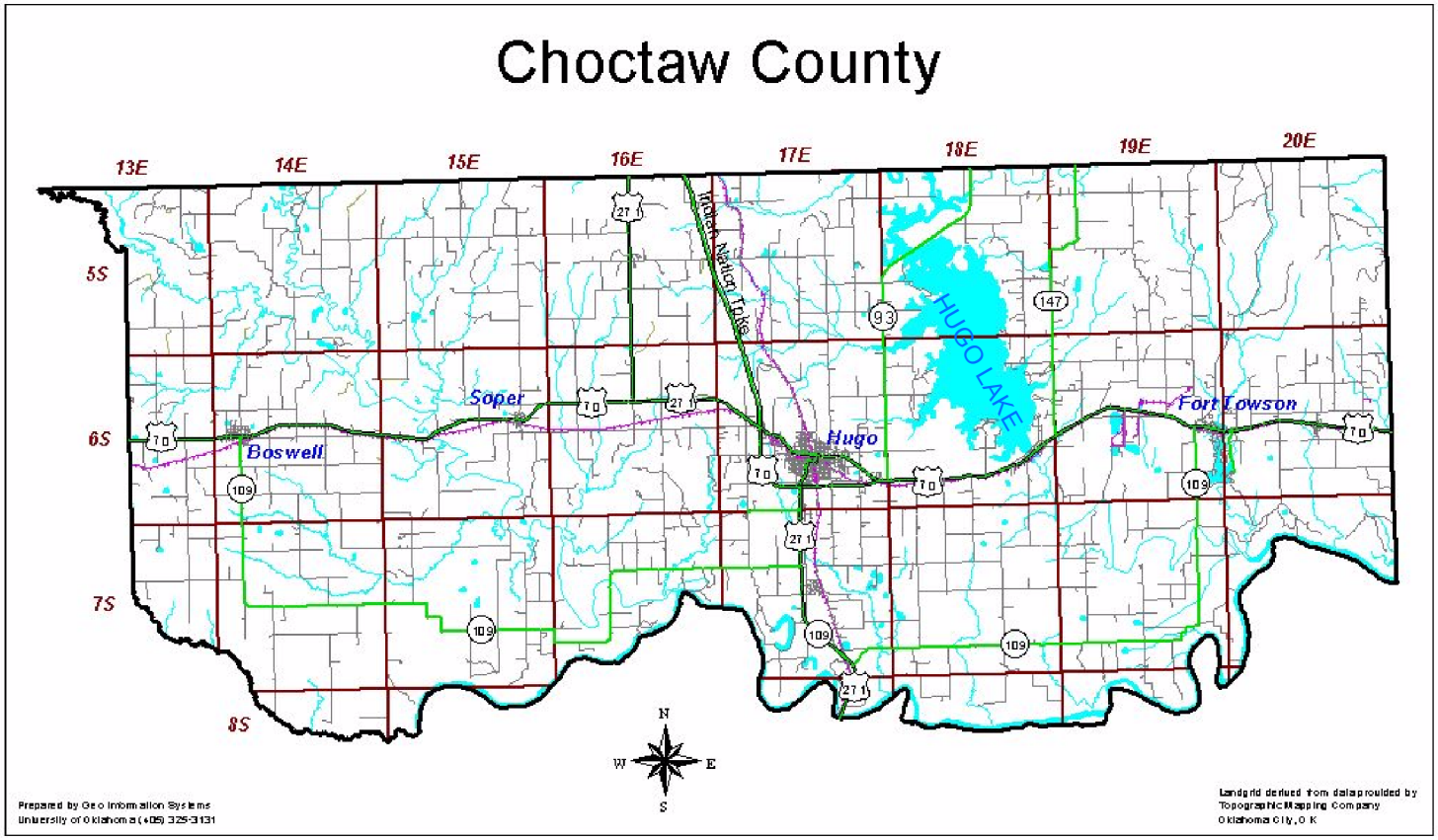


Figure 1

# HUGO LAKE

Location Map




Prepared by Geo Information Systems
University of Oklahoma (405) 325-3131

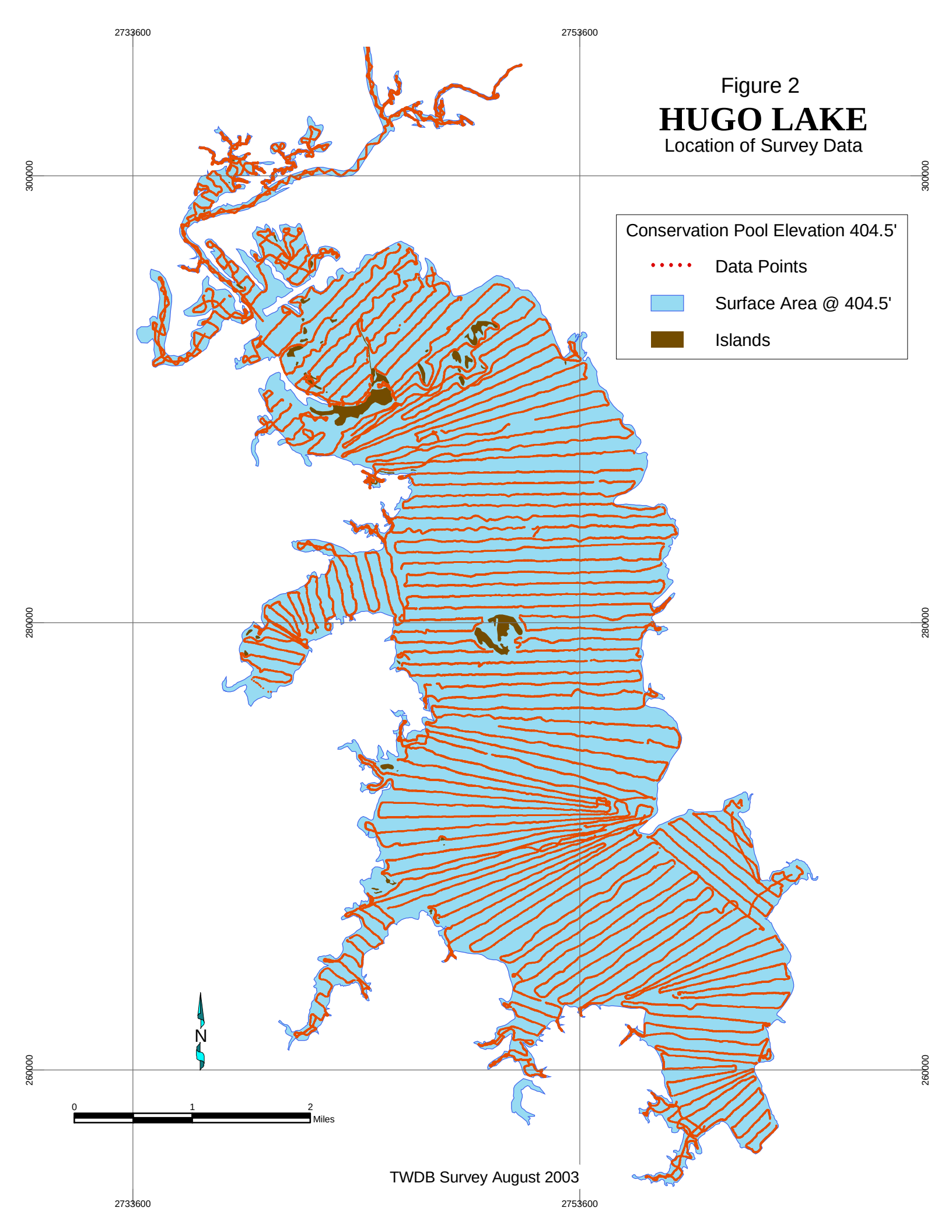
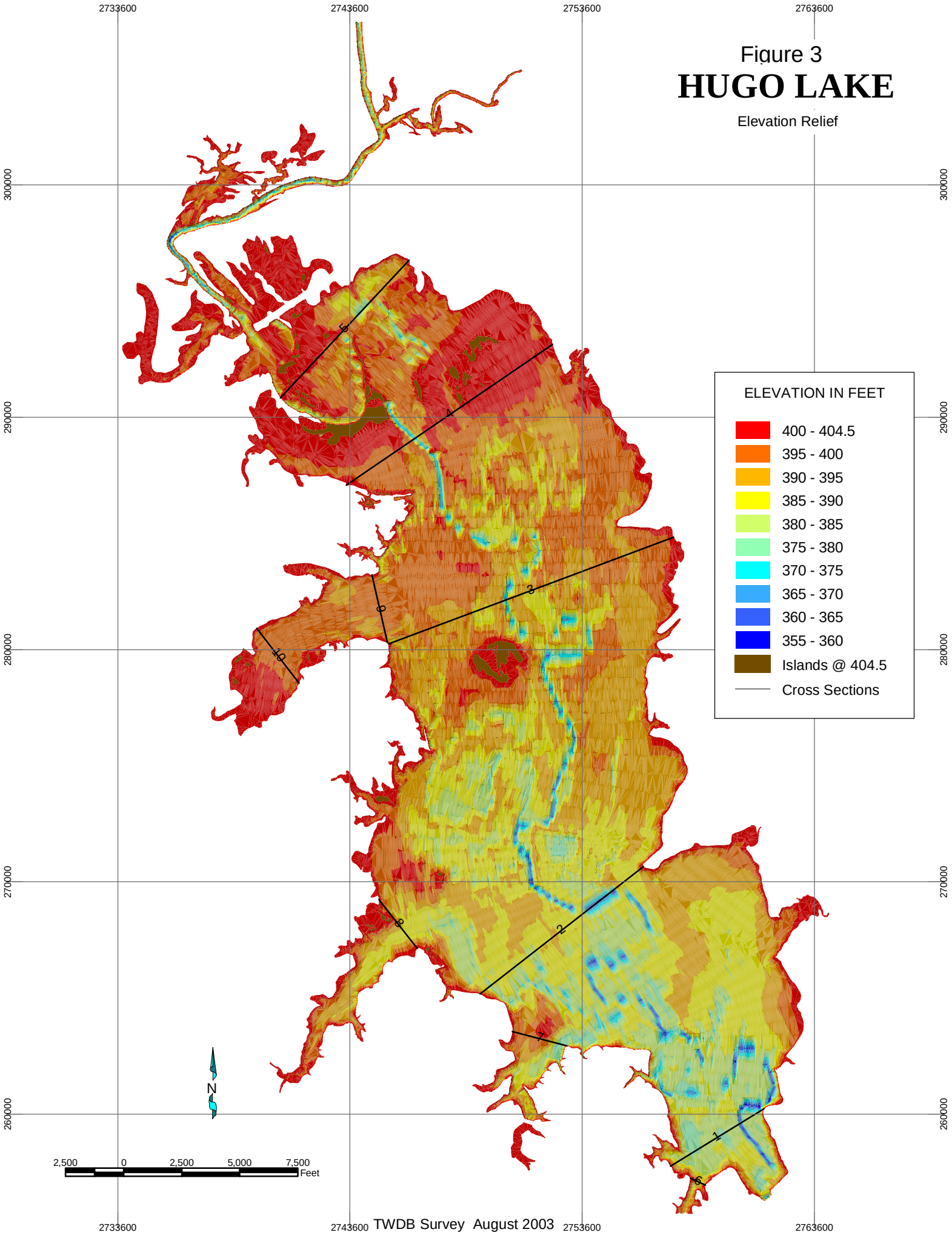


Figure 2
HUGO LAKE
Location of Survey Data
Conservation Pool Elevation 404.5'
Data Points
Surface Area @ 404.5'
Islands
2733600
2753600
300000
280000
260000
N
0
1
2
Miles
TWDB Survey August 2003

Figure 3

# HUGO LAKE

Elevation Relief

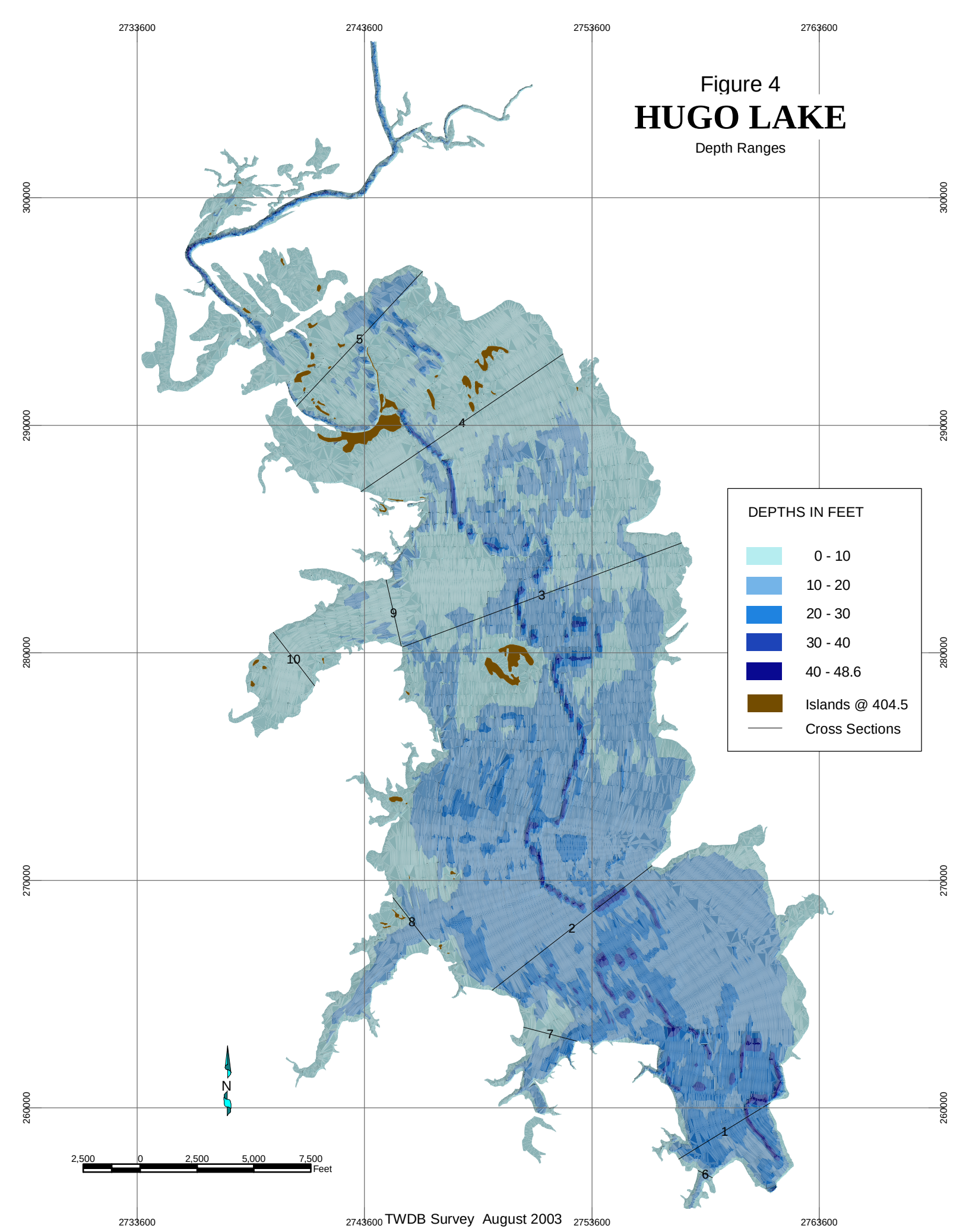



TWDB Survey August 2003

Figure 4

# HUGO LAKE

Depth Ranges




TWDB Survey August 2003

# Figure 5

# HUGO LAKE

## 2' Contours

N

0.5 0.25 0 0.5 Miles

**Conservation Pool Elevation 404.5'**

**Water Surface @ 404.5'**

**Islands @ 404.5'**

**Range Lines**

## Contours

362

364

366

368

370

372

374

376

378

380

382

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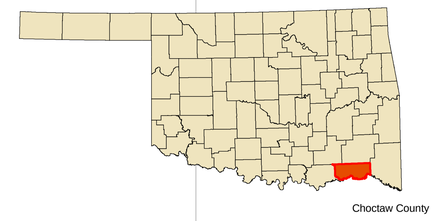
400

402

404




2740000 2760000 300000 280000 260000

This map is the product of a survey conducted by the Texas Water Development Board's Hydrographic Survey Program to determine the capacity of Hugo Lake. The Texas Water Development Board makes no representations nor assumes any liability.

TEXAS WATER DEVELOPMENT BOARD AUGUST 2003 SURVEY