VOLUMETRIC SURVEY
OF
TOWN LAKE

Prepared for:

City of Austin

In conjunction with

Lower Colorado River Authority

Prepared by:
Texas Water Development Board

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INTRODUCTION

Staff of the Surface Water Section of the Texas Water Development Board (TWDB) conducted a volumetric survey of Town Lake during the period of March 8-11 and July 15, 1999. The purpose of the survey was to determine the current volume of the lake at the normal pool elevation and to evaluate general sediment deposition by comparison to City of Austin data collected roughly every three years at a limited number of transects. This survey will establish a basis for comparison to future surveys from which the location and rates of sediment deposition in the normal pool can be more accurately determined. Survey results are presented in the following pages in both graphical and tabular form. All elevations presented in this report are reported in feet above mean sea level based on the National Geodetic Vertical Datum of 1929 (NGVD '29). The City of Austin normally maintains the pool elevation of Town Lake between elevations 428.0 feet and 429.0 feet. Calculations in this report are made to elevation 429.0 feet. Original design information in 1960 reported the total storage volume at elevation 428.0 to be 3,520 acre-feet of water (City of Austin, 1984).

LAKE HISTORY AND GENERAL INFORMATION

Historical information on Town Lake was obtained from several sources (references 1-9). Town Lake, a 5.4-mile long reservoir formed by Longhorn Dam, inundates the flood channel of the Colorado River as it flows eastwardly through Austin. Town Lake is a constant level riverine lake within the city limits of Austin, Texas, and is operated as a “pass through” reservoir. It is the last of the seven lakes in the chain of Highland Lakes on the Colorado River in central Texas. Land use surrounding Town Lake is multi-purpose including dedicated greenbelts, parks, and commercial and residential properties.

The City of Austin has water rights to Town Lake and owns, operates and maintains Longhorn Dam. The City of Austin operates releases at Longhorn Dam in coordination with upstream releases that are under the control of the Lower Colorado River Authority. The multi-purpose lake serves as a water supply for the Thomas Green Water Treatment facility, as a cooling reservoir for the Holly (and formerly for Seaholm) Electric Generating Power Plant and as a recreational facility for the City of Austin. The dam and lake were not designed to provide flood storage above the normal pool elevation. The widest point of the lake is approximately 0.6 miles and is located about 265 feet upstream of the dam. The approximate length of the lake is 5.4 miles. The drainage area for Town Lake is 157.5 square miles.

The City of Austin owned water rights under Certificate of Adjudication No.'s 14-5471, 14-5472 and 14-5490. As ordered by the Texas Water Commission on March 20, 1991 all water rights owned by the City of Austin under multiple adjudication numbers were combined into amended Certificate of Adjudication number 14-5471A. Included in the Certificate of Adjudication was the City of Austin's right to maintain an existing dam and reservoir on the Colorado River (known as Longhorn Dam and Town Lake) and to impound therein not to exceed 3,520 acre-feet of water. The owner was authorized to divert and use not to exceed 271,403 acre-feet of water per annum from Lake Austin and Town Lake for municipal purposes.

Among other authorized uses, the certificate owner was authorized to divert, circulate and recirculate water from Town Lake for industrial (cooling) purposes without limitation as to the amount, provided that not more than 24,000 acre-feet of water per annum is consumptively used. The owner was also authorized a right to the flow of the Colorado River and its tributaries to the extent needed to be impounded in Town Lake, and/or necessary to pass such flow through Town Lake. The purpose was to reduce the temperature of the water for industrial (cooling) purposes at all times. Finally, the City of Austin was also authorized to use the waters of Lake Austin, Barton Springs Pool and Town Lake for recreational purposes.

Construction for Town Lake and Longhorn Dam started April 1959 and was completed in September 1960. The design engineer for the project was Brown and Root, Inc. and the general contractor was H. B. Zachry Co. The estimated cost of the dam was $1,600,000.

Longhorn Dam and appurtenant structures consist of an earthen embankment approximately 760 feet in total length, with a maximum height of 65 feet and a crest elevation of 464.0 feet. A concrete gated spillway spans 506 feet in length over the natural river channel and divides the north and south embankment. The crest of the south embankment drops to elevation 434.0 near the south abutment and serves as the emergency spillway. The City of Austin has taken advantage of this vacant land and developed what today is known as the Krieg Softball Complex. Pleasant Valley Road (four lanes of concrete and asphalt) traverses the 64 feet wide crest of the dam and spillway.

The concrete service spillway structure consists of nine structural steel 50 feet wide gates to control discharges. Seven of the nine gates are lift gates and are 13 feet in height. These gates are lifted by electric hoist. The concrete crest on which these gates rest has an elevation of 416.0 feet. This crest is also the lowest outlet for the dam and spillway. Bascule gates control two of the inner bays of the spillway structure. These gates are eight feet high and rest on a concrete crest with an elevation of 420.0 feet. These gates are automatically controlled for releases to maintain the desired lake level elevation. The bascule gates also serve for low-flow releases.

Two other appurtenant structures that warrant mentioning are the intake structures for the Thomas Green Water Treatment Plant and the Holly Street Electric Generating Power Plant. Both facilities are located on the north shore of Town Lake. The minimum operating water level for the intake at Green Water Treatment Plant is 424.38 feet. The minimum operating water level for the intake at Holly Street Power Plant is 418.50 feet.

As part of an on-going monitoring program established by the City of Austin's Watershed Protection Department, Environmental Resources Management Division, cross-sectional transects were established along the length of the lake. The transects are to be measured every three years to detect any significant changes in sediment deposition and in the lake's volume.

Original design information in 1960 estimated the storage volume of Town Lake to be 3,520 acre-feet at pool elevation 428.0 feet (City of Austin, 1984). A more recent study (Armstrong, 1991) used channel cross-sections from a 1977 U. S. Army Corps of Engineers flood survey to compute the volume of Town Lake. The 1991 report found a storage volume of 5,168 acre-feet of water at elevation 428.0 feet. There was speculation that the reason for the increase in volume was in part due to the ongoing dredging activity at the dam basin from 1960 to 1975. Results of a 1992 survey and diagnostic study of Town Lake reported a surface area of 477 acres and volume of 6,784 acre-feet at pool elevation 428.25 feet. Again, a study had found a greater lake volume than the prior survey. Records indicate that the 1991 report (Armstrong, 1991) used data collected by the U. S. Army Corps of Engineers in 1977 and that survey was considered a flood study. Data collection for the flood study was done mostly around the bridges that crossed Town Lake. The off-channel cove at Fiesta Gardens and the basin at the dam were not included in the 1977 survey. This report will address the comparison of the 1999 survey results with the original design and the other previous studies.

VOLUMETRIC SURVEYING TECHNOLOGY

The equipment used in the performance of the volumetric survey consists of a 23-foot aluminum tri-hull SeaArk craft with cabin, equipped with twin 90-Horsepower Johnson outboard motors. (Reference to brand names throughout this report does not imply endorsement by TWDB). 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 provides electrical power through an in-line uninterruptible power supply.

The GPS equipment, survey vessel, and depth sounder in combination provide an efficient hydrographic survey system. As the boat travels across the lake surface, the depth sounder takes 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, poor-quality 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 lake elevation recorded 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 in Appendix F.

PRE-SURVEY PROCEDURES

The reservoir's surface area was determined prior to the survey by digitizing the lake's pool boundary (elevation 428.0 feet) with AutoCad software. The boundary file was created from three USGS 7.5-minute quadrangle maps - Montopolis, TX. (1988), Austin East, TX. (1988), and Austin West, TX. (1988). The survey layout was designed by placing survey track lines at 500-foot intervals within the digitized lake boundary using HyPack software. The survey design required the use of approximately 130 survey lines along the length of the lake.

SURVEY PROCEDURES

The following procedures were followed during the volumetric survey of Town Lake 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, 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 moisten and acclimate the probe. The probe was next raised to the water surface where the depth was zeroed. The probe was then gradually lowered on a cable to a depth just above the lake bottom, and then raised 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. During the survey of Town Lake, the speed of sound in the water column varied from 4,834 to 4,842 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 $\pm$0.2 feet. An additional estimated error of $\pm$0.3 feet arises from variation in boat inclination. These two factors combine to give an overall accuracy of $\pm$0.5 feet for any instantaneous reading. These errors tend to be minimized over the entire survey, since some readings are positive and some are negative. Further information on these calculations is presented in Appendix F.

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 set up 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 initially collected on Town Lake on March 8 - 11, 1999. The survey crew returned on July 15, 1999 to collect data in shallow areas around the confluence of selected creeks. During data collection, the crew had excellent weather with moderate temperatures and mild winds. Approximately 30,189 data points were collected over the 42.5 miles traveled. These points, shown in Figure 2, were stored digitally on the boat's computer in 153 data files.

Extensive data was gathered in a 100 square foot grid pattern in the basin upstream of Longhorn Dam. This area of the lake was used historically as a gravel quarry and the need to document the bathymetry was considered a high priority. A second priority area included data collection at the mouths of several of the creeks contributing to Town Lake. On the north bank, these include Waller, Shoal, and Johnson Creeks. On the south shore, extra data were collected at the mouths of Harpers, Blunn, East Bouldin, West Bouldin and Barton Creek. A smaller boat with portable equipment was used in these areas because of the shoaling and sediment deposition. The crew noted extensive aquatic vegetation at the mouths of these creeks. Barton Creek was the only creek deep enough to allow data to be collected upstream of the mouth.

Several piers or pilings supporting bridges and one railroad trestle transect Town Lake. Data were collected downstream of these structures to document any scouring of the lake bottom. No unusual change in the bathymetry was observed. The crew also collected data in a zig-zag pattern to document a shallow water dam that spans across the lake near the intake structure at Green Water Treatment facility.

Longhorn Dam and the eastern end of Town Lake lie in the Gulf Coastal Plains Region, while the headwaters of Town Lake extend westward into the region known as the Balcones Escarpment. TWDB staff observed the land surrounding the eastern end of the lake to have generally flat to moderate relief from Longhorn Dam to Zilker Park with some steep bluffs outcropping on the south bank (Travis Heights). Farther west, upstream of MoPac (Loop 1) to the headwaters and Tom Miller Dam, the physical topography transitions into a major relief zone consisting of a deep valley with steep-sided walls. The average width of Town Lake (400 feet to 600 feet) narrows considerably near Red Bud Island. As the 500 feet spacing transects were collected, the recording analog chart for the depth sounder showed no distinct river channel. The bathymetry from Longhorn Dam to Red Bud Island was quite irregular. The crew was unable to collect data by boat upstream of Red Bud Trail (Emmett Shelton Bridge). The Lower Colorado River Authority collected cross-sections for this area from March to May 1999 and supplied this data to the Board.

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

Data Processing

The collected data were downloaded from diskettes onto 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. 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 pool elevation measured at Holly Power Plant and provided by City of Austin staff varied from 428.23 to 428.74 feet. After all corrections were applied 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, to be used with the GIS software to develop a model of the lake's bottom surface.

The resulting data file was downloaded to a Sun Sparc 20 workstation running the UNIX operating system. Environmental System Research Institute's (ESRI) Arc/Info GIS 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 reservoir'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. 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 actual bottom surface. With this representation of the bottom, the software then calculates elevations along the triangle surface plane by determining the elevation along each leg of the triangle. The reservoir area and volume can be determined from the triangulated irregular network created using this method of interpolation.

In areas of significant sedimentation, the boundary was adjusted based on the data points collected and the observations of the field crew. The resulting boundary was used to develop each of the map presentations of the lake in this report.

Volumes and surface areas, presented in Appendices A and B, respectively, were calculated from the TIN using Arc/Info software. Results are shown in one-tenth of a foot intervals from elevation 393.1 to elevation 429.0. An elevation-area-volume graph is presented in Appendix C.

Other products developed from the model include a shaded relief map (Figure 3) and a shaded depth range map (Figure 4). 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. Linear filtration algorithms were applied to the DTM to produce smooth cartographic contours. The resulting contour map of the bottom surface at two-foot intervals is presented in Figure 5. Finally, the location of the cross-sections obtained from City of Austin staff surveys between 1994 and 1998, shown on the map in Figure 5, are compared to cross-sections obtained from the current survey in Appendix D. The exact geographic coordinates for endpoints from the City of Austin surveys were unknown; therefore, it was necessary to adjust the horizontal position of these range-lines in Appendix D.

RESULTS

Results from the 1999 TWDB survey indicate Town Lake encompasses 469 surface acres and contains a total volume of 6,596 acre-feet at pool elevation 429.0 feet. The shoreline at this elevation was calculated to be 17 miles. The deepest point of the lake, at elevation 393.12 feet and corresponding to a depth of 35.88 feet, was located approximately 37 feet upstream from the center of Longhorn Dam.

SUMMARY AND COMPARISONS

Town Lake was initially impounded in 1960. Storage calculations in 1960 (City of Austin, 1984) reported the volume at pool elevation 428.0 feet to be 3,520 acre-feet. A subsequent, more complete, survey in 1991 (Armstrong, 1991) found the volume for elevation 428.0 feet to be 5,168 acre-feet. A 1992 (City of Austin, 1992a) survey found the volume at pool elevation 428.25 feet to be 6,784 acre-feet and a surface area of 477 acres.

During March 8-11, and June 15, 1999, staff from the Texas Water Development Board's Surface Water Section completed a volumetric survey of Town Lake. The 1999 survey took advantage of technological advances such as differential global positioning system and geographical information system technology to create a digital model of the reservoir's bathymetry. With these advances, the survey was completed more quickly and significantly more bathymetric data were collected than in previous surveys. Results indicate that the lake's volume and surface at pool elevation 428.0 feet are 6,135 acre-feet and 451 acres, respectively. At elevation 428.25, the volume and area are 6,248 acre-feet and 454 acres, and at elevation 429.0 feet, the volume and area are 6,596 acre-feet and 469 acres.

Comparisons between the 1992 survey data (City of Austin, 1992a), the transect data collected by the City of Austin between 1994 and 1998 (Appendix D), and the data collected in the current survey show conflicting results with regard to sediment accumulation in Town Lake. A comparison between the 1992 survey and the present survey shows a decrease in volume and area, while a comparison between the 1994 - 1998 City of Austin transect data and the present survey indicates little or no change in volume at some sites and possible increases at others. The decrease between the 1992 and present surveys could be due to sediment accumulation in Town Lake, differences in methods used, and in the quantity and location of data collected. Over 130 transects were collected in the current survey, with a high concentration collected immediately upstream of Longhorn Dam (Figure 2), while only 33 transects were collected in the 1992 survey (City of Austin, 1992a). A complicating factor in evaluating sedimentation during this period is the effect of flooding in October, 1998 that required the opening of flood gates at Longhorn Dam that may have removed sediment from Town Lake. Based on the amount of data collected and the improved methods and technology used in the current survey, the current data set is considered to be an improvement over previous survey procedures. Because of the difficulty in comparing results from the current survey to past surveys, it is recommended that the same methodology be used in five to ten years or after major flood events to monitor changes to the lake's storage volume and sedimentation characteristics.

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Appendix A

Town Lake

RESERVOIR VOLUME TABLE

TEXAS WATER DEVELOPMENT BOARD — March 1999 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
393		0	0	0	0	0	0	0	0	0
394	0	0	0	0	0	0	0	0	0	0
395	0	0	0	0	0	0	0	0	0	0
396	0	0	0	0	0	0	0	0	0	0
397	0	1	1	1	1	1	1	1	1	1
398	1	1	2	2	2	2	2	2	3	3
399	3	3	3	4	4	4	5	5	6	6
400	7	7	8	8	9	10	10	11	12	13
401	14	16	17	18	20	21	23	24	26	28
402	30	32	34	36	39	41	44	46	49	52
403	55	58	61	64	67	71	74	78	82	85
404	89	94	98	102	107	111	116	121	126	131
405	136	142	147	153	159	165	171	177	184	190
406	197	204	211	218	226	233	241	249	257	265
407	273	281	290	298	307	316	325	334	343	353
408	362	372	381	391	401	412	422	432	443	454
409	465	476	487	499	510	522	534	546	559	571
410	584	597	610	623	636	650	664	678	692	707
411	721	736	751	766	782	798	814	830	846	863
412	880	897	914	932	949	967	986	1004	1023	1042
413	1061	1080	1099	1119	1139	1159	1180	1201	1222	1243
414	1264	1286	1308	1330	1352	1375	1398	1421	1444	1467
415	1491	1515	1540	1564	1589	1614	1639	1664	1690	1716
416	1742	1769	1795	1822	1849	1877	1904	1932	1960	1988
417	2017	2045	2074	2103	2133	2162	2192	2222	2252	2282
418	2313	2343	2374	2405	2437	2468	2500	2532	2564	2596
419	2628	2661	2693	2726	2759	2793	2826	2859	2893	2927
420	2961	2995	3030	3064	3099	3133	3168	3203	3239	3274
421	3310	3345	3381	3417	3453	3489	3526	3562	3599	3635
422	3672	3709	3746	3784	3821	3859	3896	3934	3972	4010
423	4049	4087	4125	4164	4203	4242	4281	4320	4359	4399
424	4439	4478	4518	4558	4598	4639	4679	4720	4760	4801
425	4842	4883	4924	4966	5007	5049	5091	5133	5175	5217
426	5260	5302	5345	5388	5431	5474	5517	5560	5603	5647
427	5691	5735	5779	5823	5867	5911	5956	6000	6045	6090
428	6135	6180	6225	6271	6316	6362	6409	6455	6502	6549
429	6596									

Appendix B

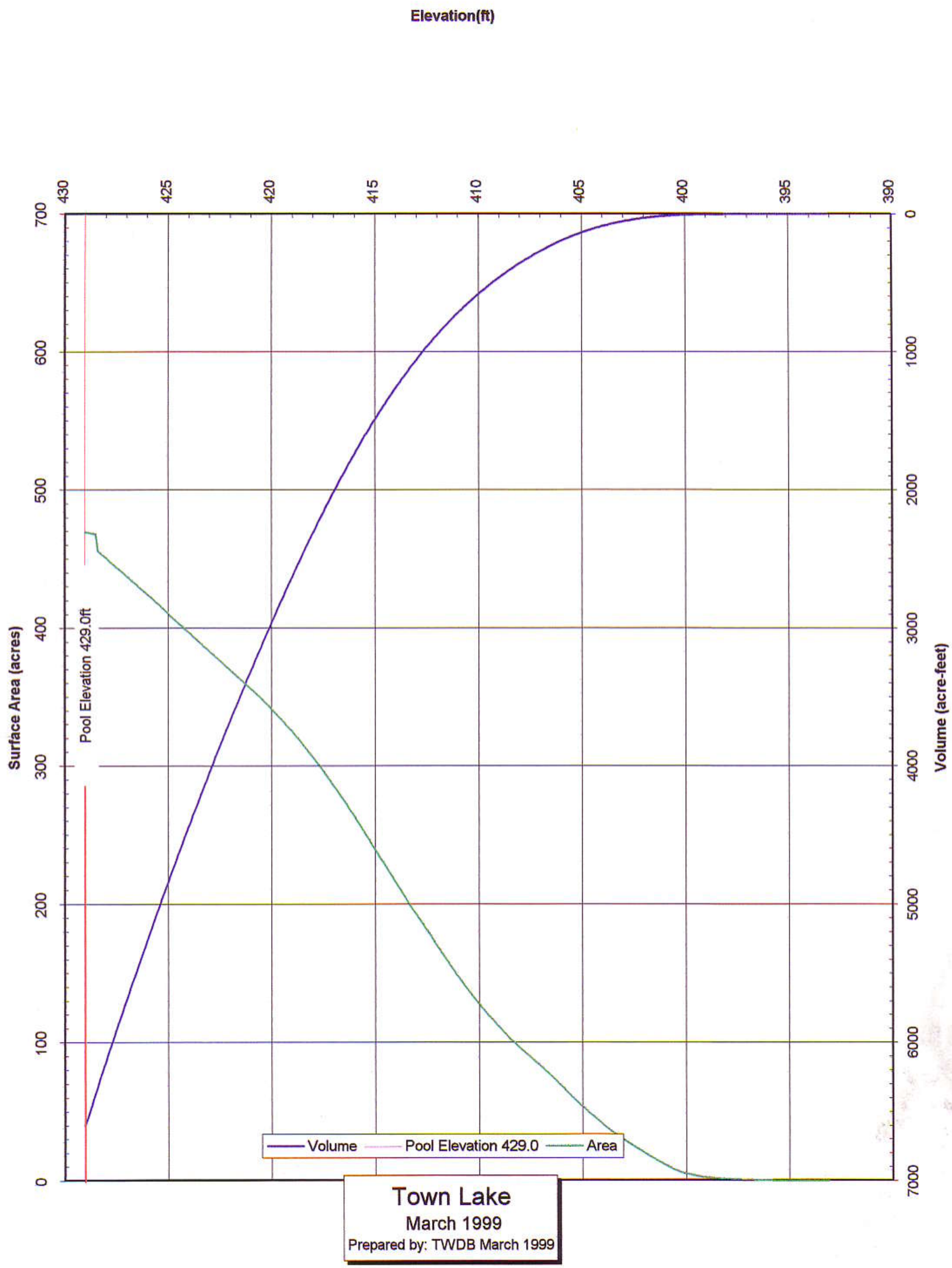
Town Lake

RESERVOIR AREA TABLE

TEXAS WATER DEVELOPMENT BOARD — March 1999 SURVEY

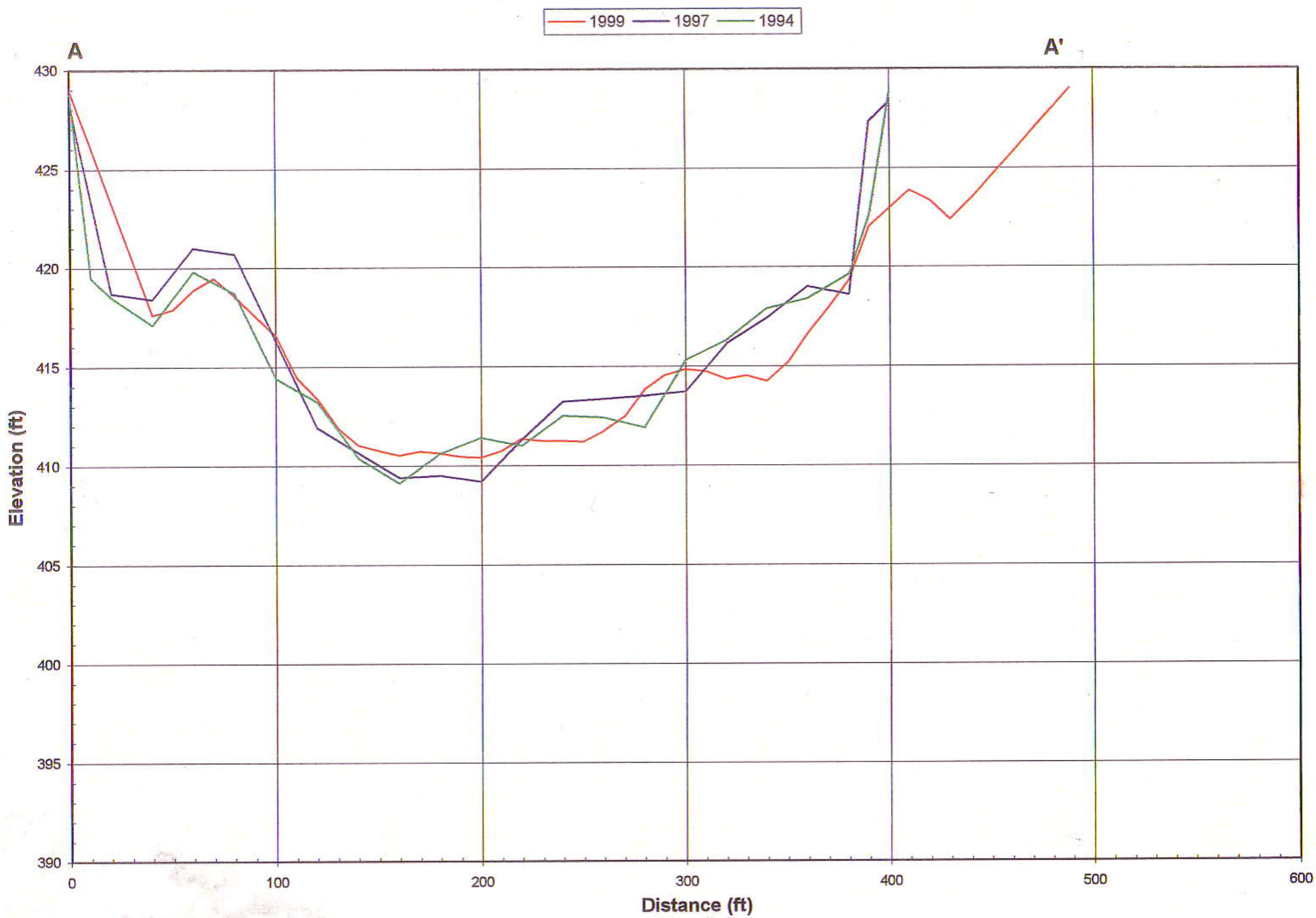
AREA IN ACRES — ELEVATION INCREMENT IS ONE TENTH FOOT

ELEVATION in Feet	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
393		0	0	0	0	0	0	0	0	0
394	0	0	0	0	0	0	0	0	0	0
395	0	0	0	0	0	0	0	0	0	0
396	0	0	0	0	0	0	0	0	1	1
397	1	1	1	1	1	1	1	1	1	1
398	1	1	1	1	2	2	2	2	2	2
399	2	2	3	3	3	3	4	4	4	5
400	5	5	6	6	7	8	8	9	10	10
401	11	12	13	14	15	16	16	17	18	19
402	20	21	22	23	24	25	26	27	28	29
403	30	30	32	33	34	35	36	37	38	39
404	41	42	43	44	46	47	48	49	51	52
405	54	55	56	58	59	61	62	64	65	67
406	68	70	71	73	74	76	77	79	80	81
407	83	84	85	87	88	89	90	92	93	94
408	96	97	99	100	101	103	104	106	107	109
409	111	112	114	116	117	119	121	122	124	126
410	128	130	131	133	135	137	139	141	143	145
411	148	150	152	154	156	158	160	163	165	167
412	169	172	174	177	179	181	183	186	188	190
413	192	194	196	199	201	203	206	208	211	213
414	215	218	220	222	225	227	230	232	234	237
415	239	241	244	246	249	251	254	256	258	261
416	263	265	268	270	272	275	277	279	281	283
417	286	288	290	292	294	296	298	300	302	304
418	306	308	310	312	314	315	317	319	321	323
419	325	326	328	330	331	333	334	336	338	339
420	341	343	344	346	347	349	350	352	353	354
421	356	357	359	360	361	363	364	365	367	368
422	369	371	372	374	375	376	378	379	380	382
423	383	384	386	387	389	390	391	393	394	396
424	397	398	400	401	402	403	405	406	408	409
425	410	412	414	415	416	418	419	420	422	423
426	424	426	427	428	430	431	432	434	435	436
427	438	439	440	442	443	444	445	447	448	449
428	451	452	453	455	456	468	468	468	469	469
429	469									

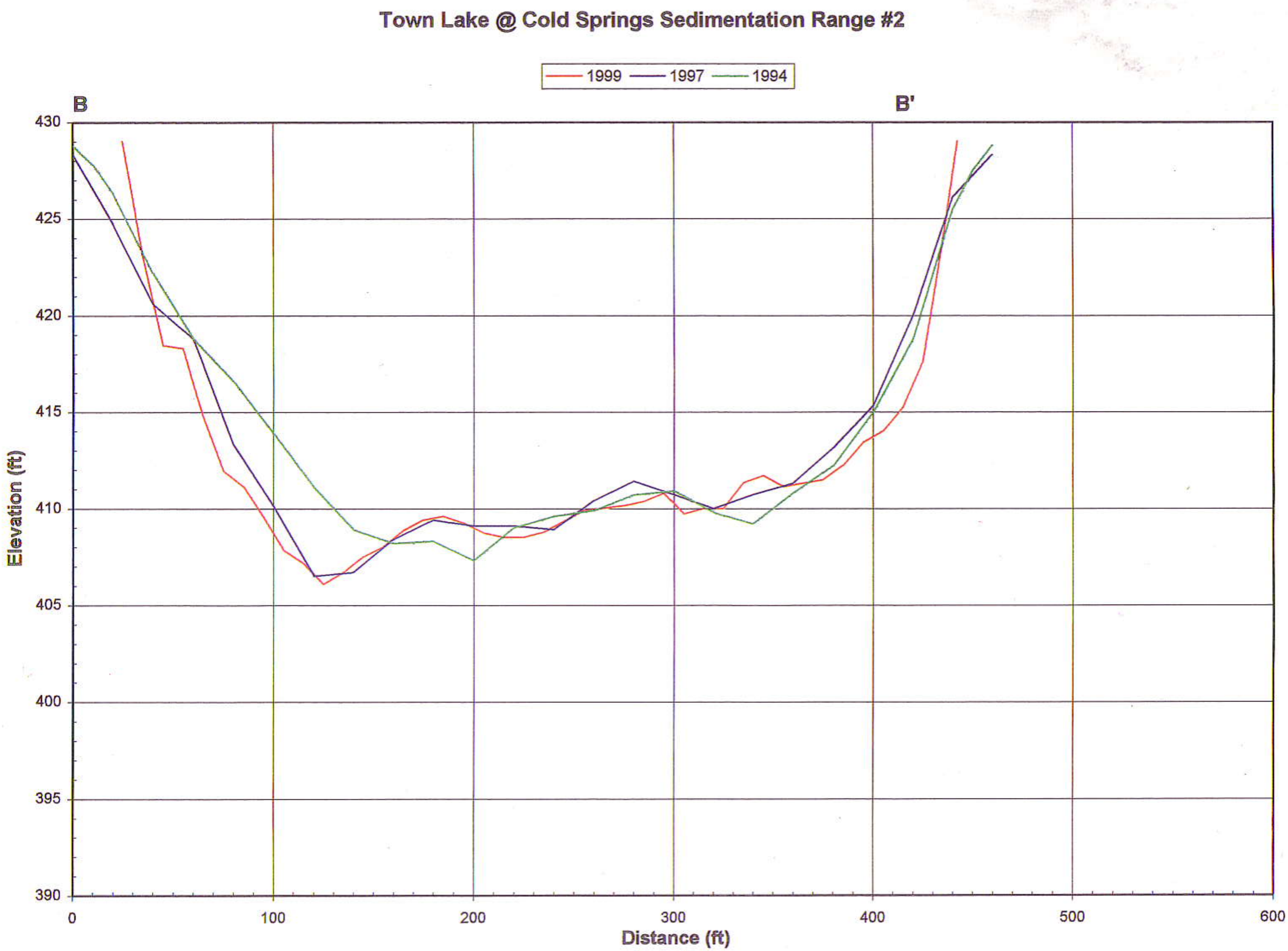


Elevation(ft)
430
425
420
415
410
405
400
395
390
Surface Area (acres)
700
600
500
400
300
200
100
0
Volume (acre-feet)
0
1000
2000
3000
4000
5000
6000
7000
Pool Elevation 429.0ft
Volume
Pool Elevation 429.0
Area
Town Lake
March 1999
Prepared by: TWDB March 1999

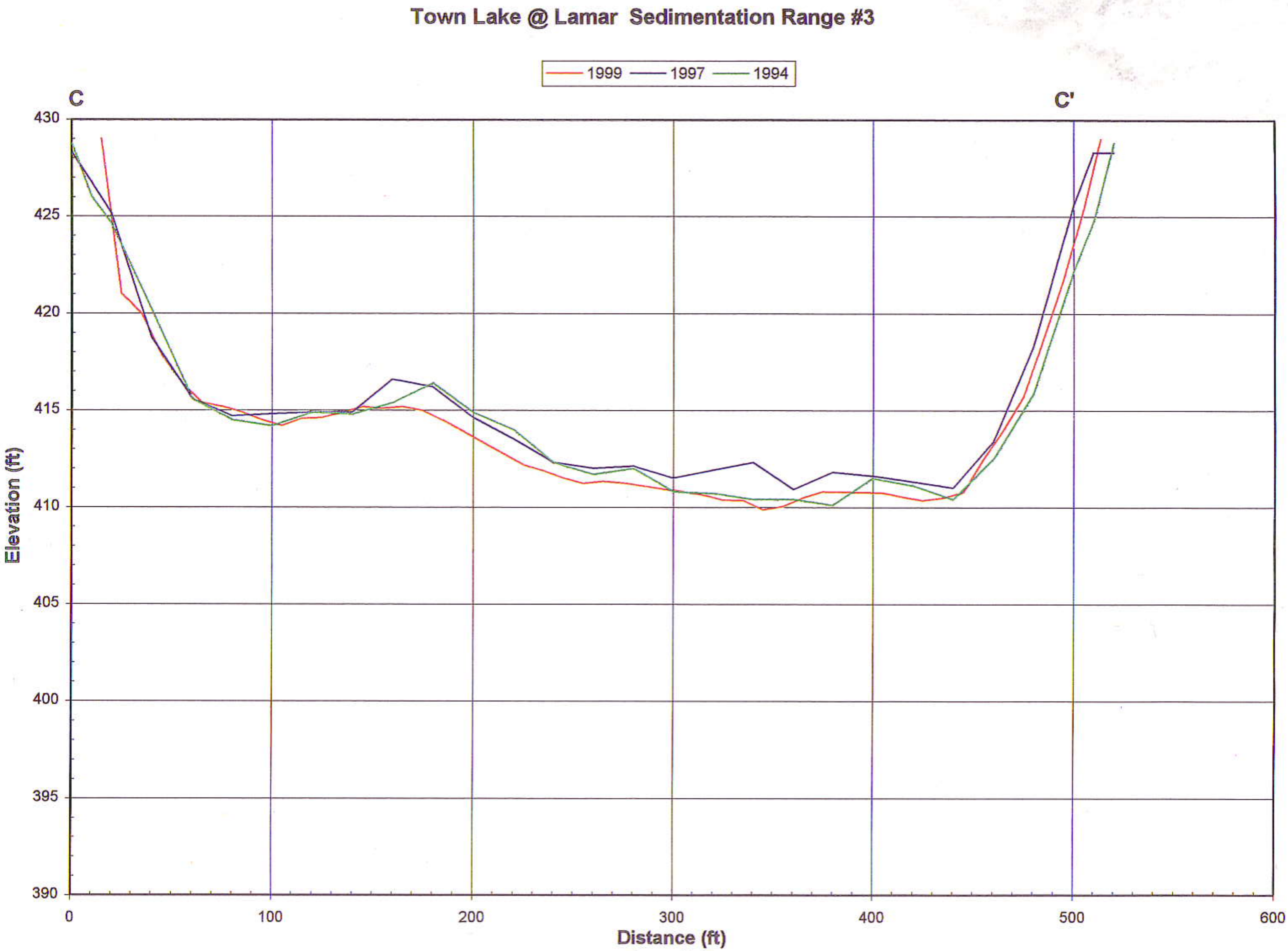
Red Bud Island Range #1



Appendix D

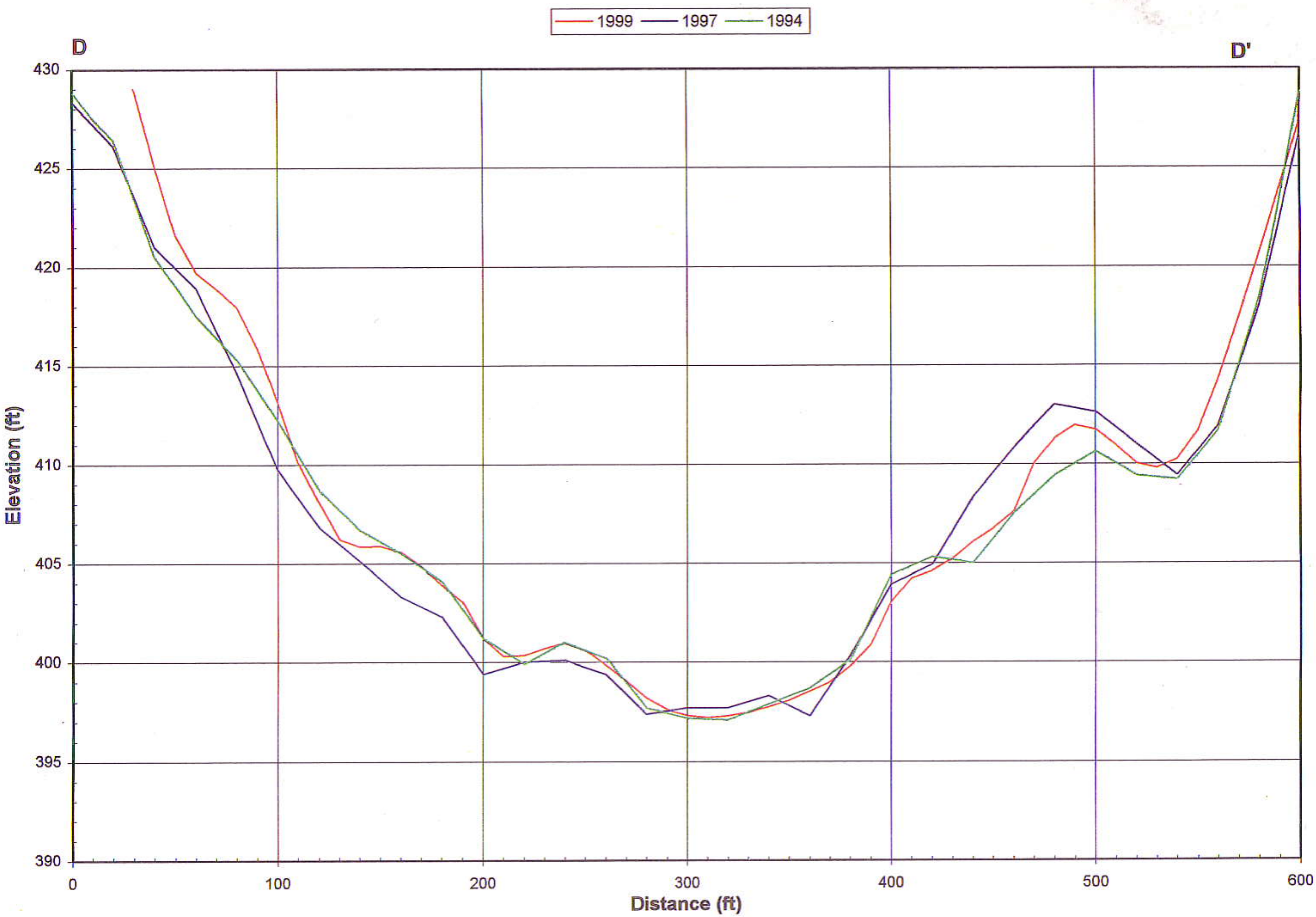

Town Lake @ Cold Springs Sedimentation Range #2
1999
1997
1994
B
B'
430
425
420
415
410
405
400
395
390
0
100
200
300
400
500
600
Elevation (ft)
Distance (ft)

Appendix D

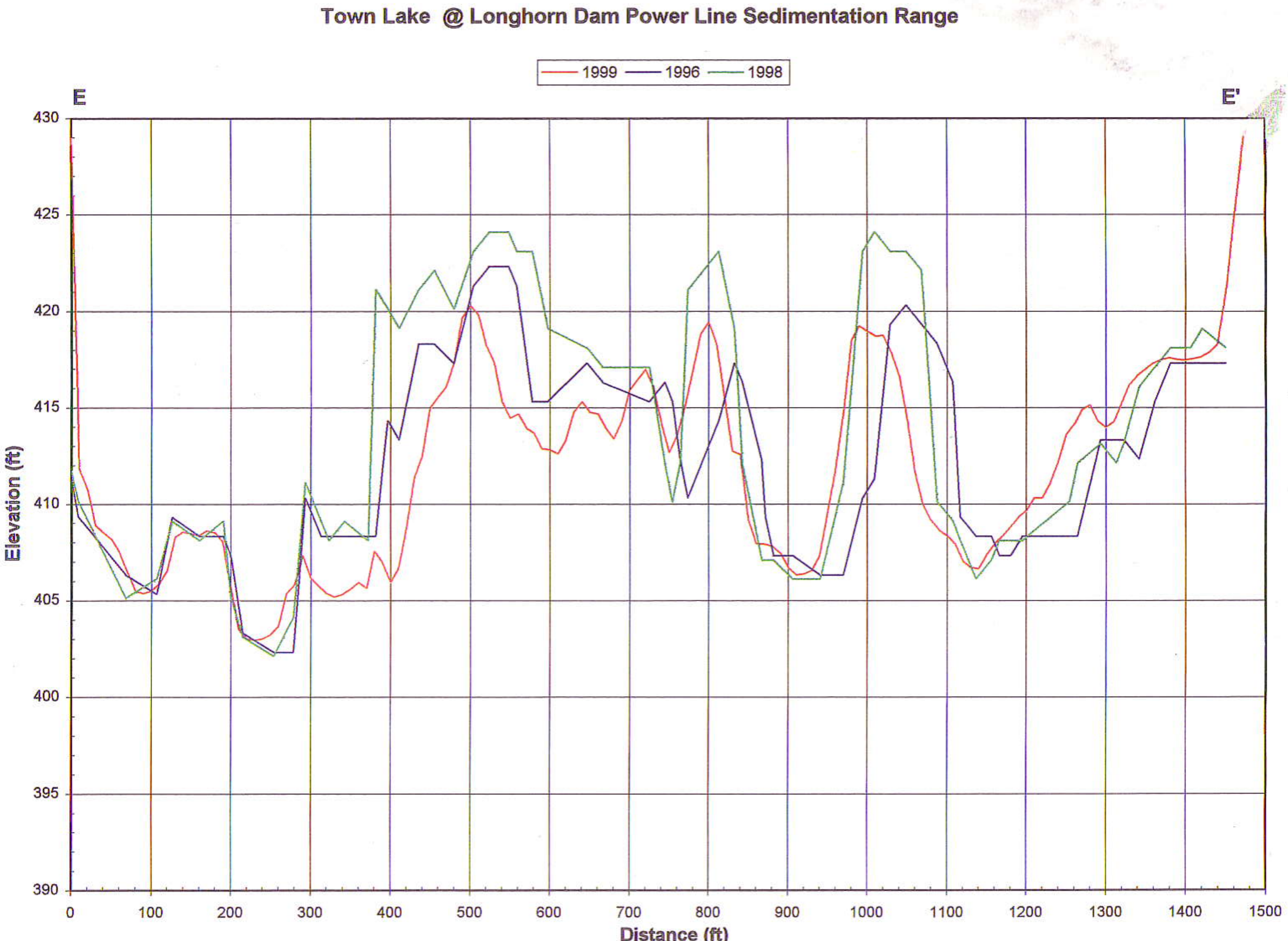

Town Lake @ Lamar Sedimentation Range #3
1999
1997
1994
C
C'
Elevation (ft)
430
425
420
415
410
405
400
395
390
0
100
200
300
400
500
600
Distance (ft)

Appendix D

Town Lake @ Harper's Branch Sedimentation Range #5



Appendix D



Town Lake @ Longhorn Dam Power Line Sedimentation Range
1999
1996
1998
E
E'
Elevation (ft)
Distance (ft)
430
425
420
415
410
405
400
395
390
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500

Appendix D

Town Lake @ Longhorn Dam Sedimentation Range Line No. 6

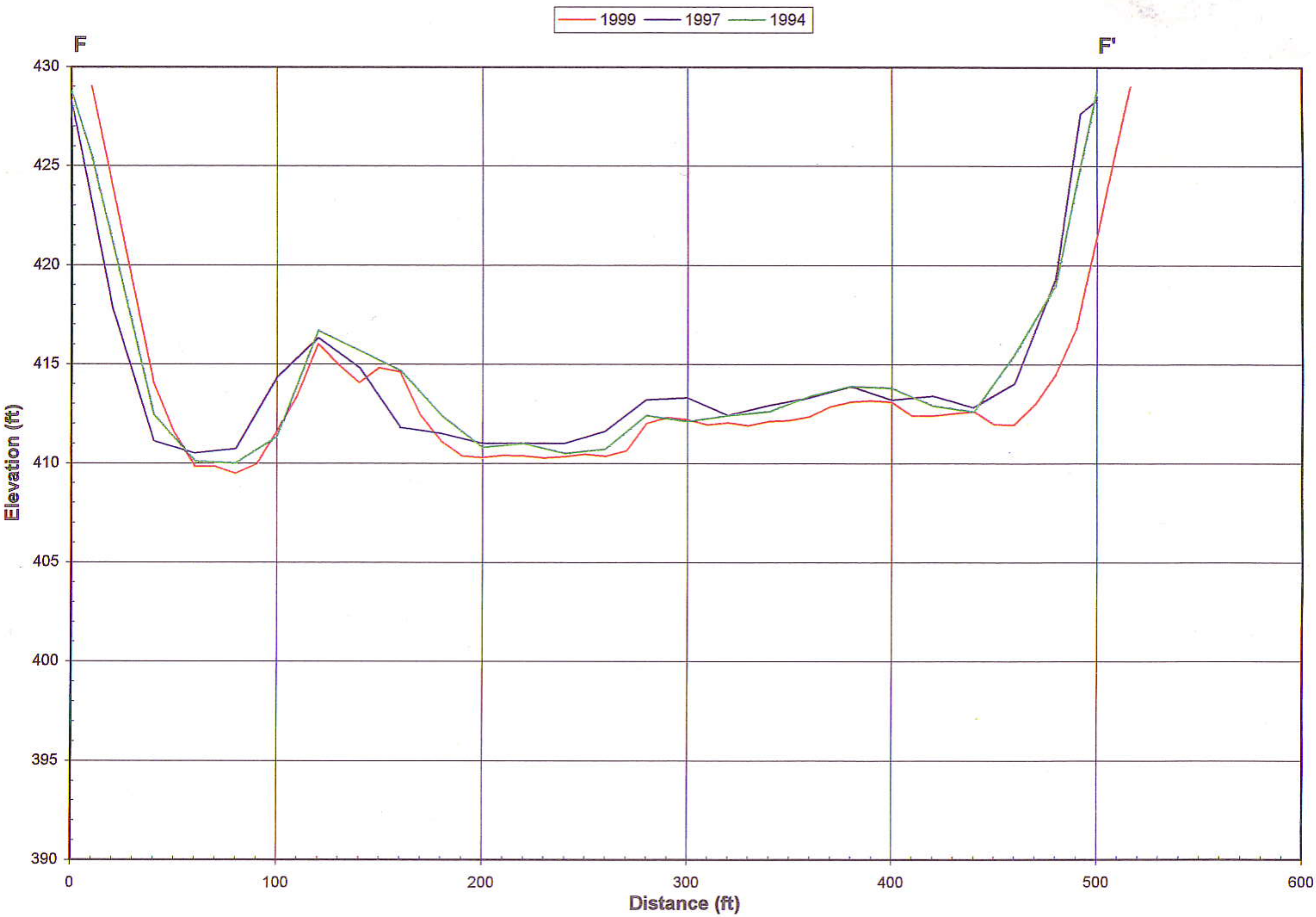
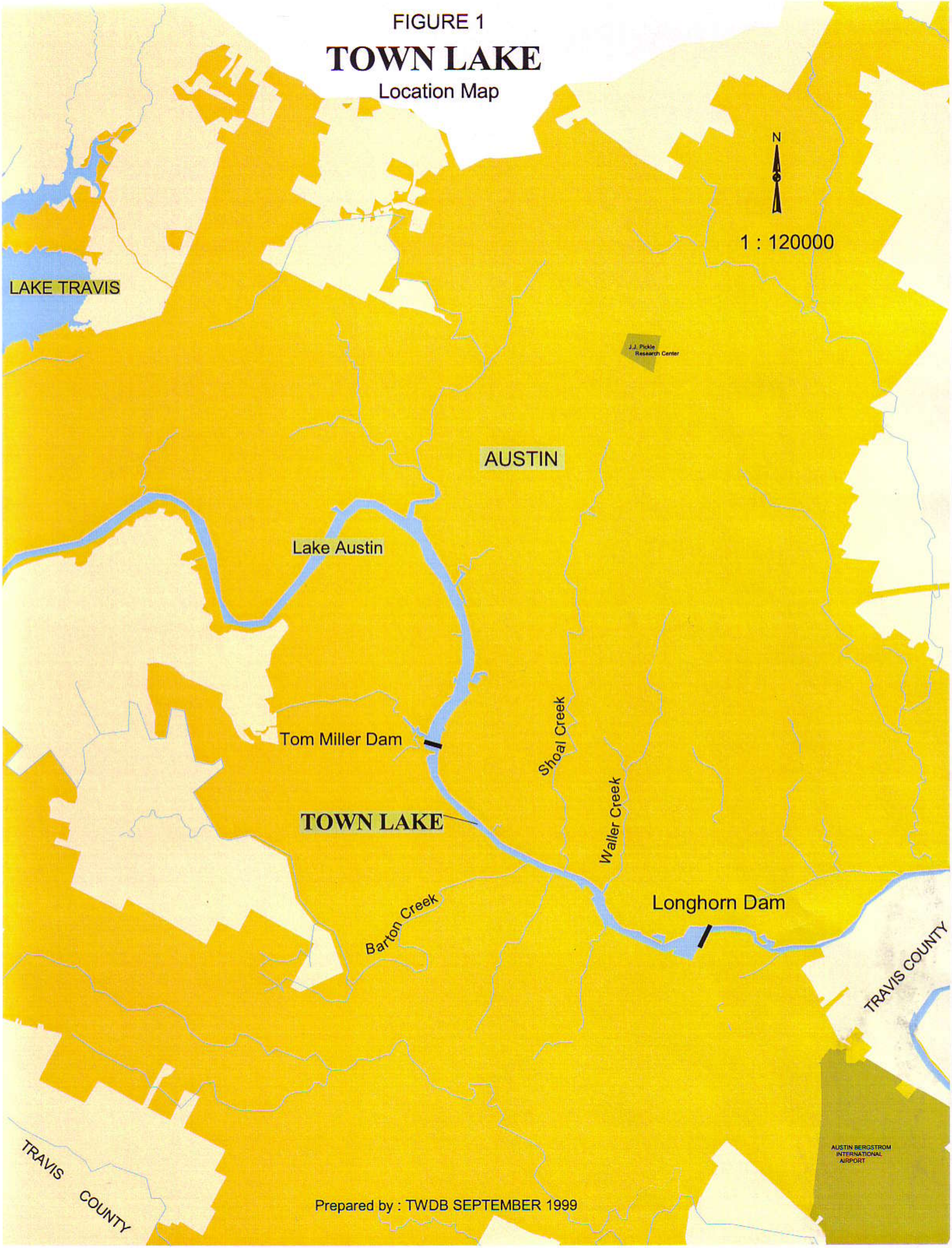
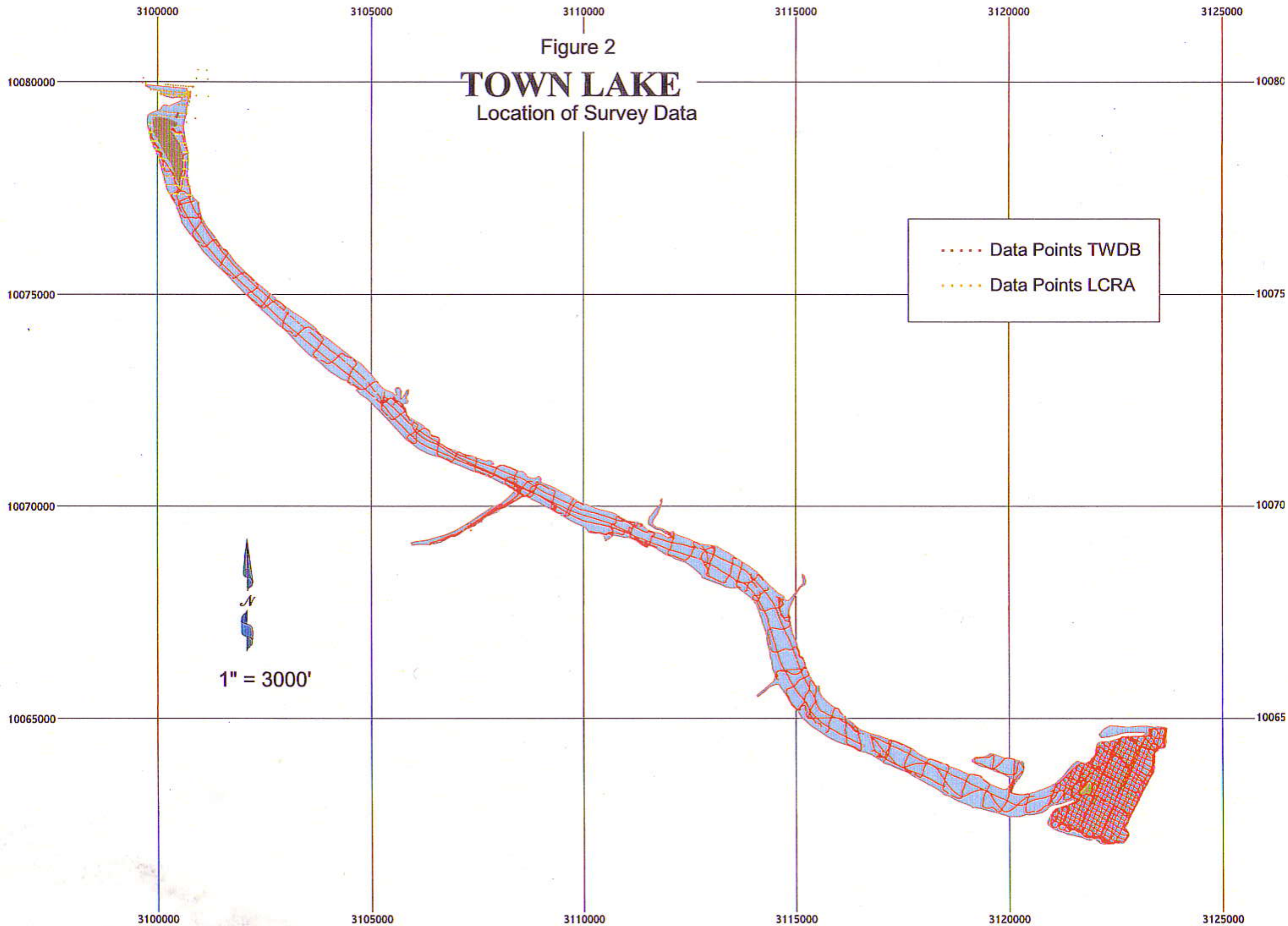


FIGURE 1

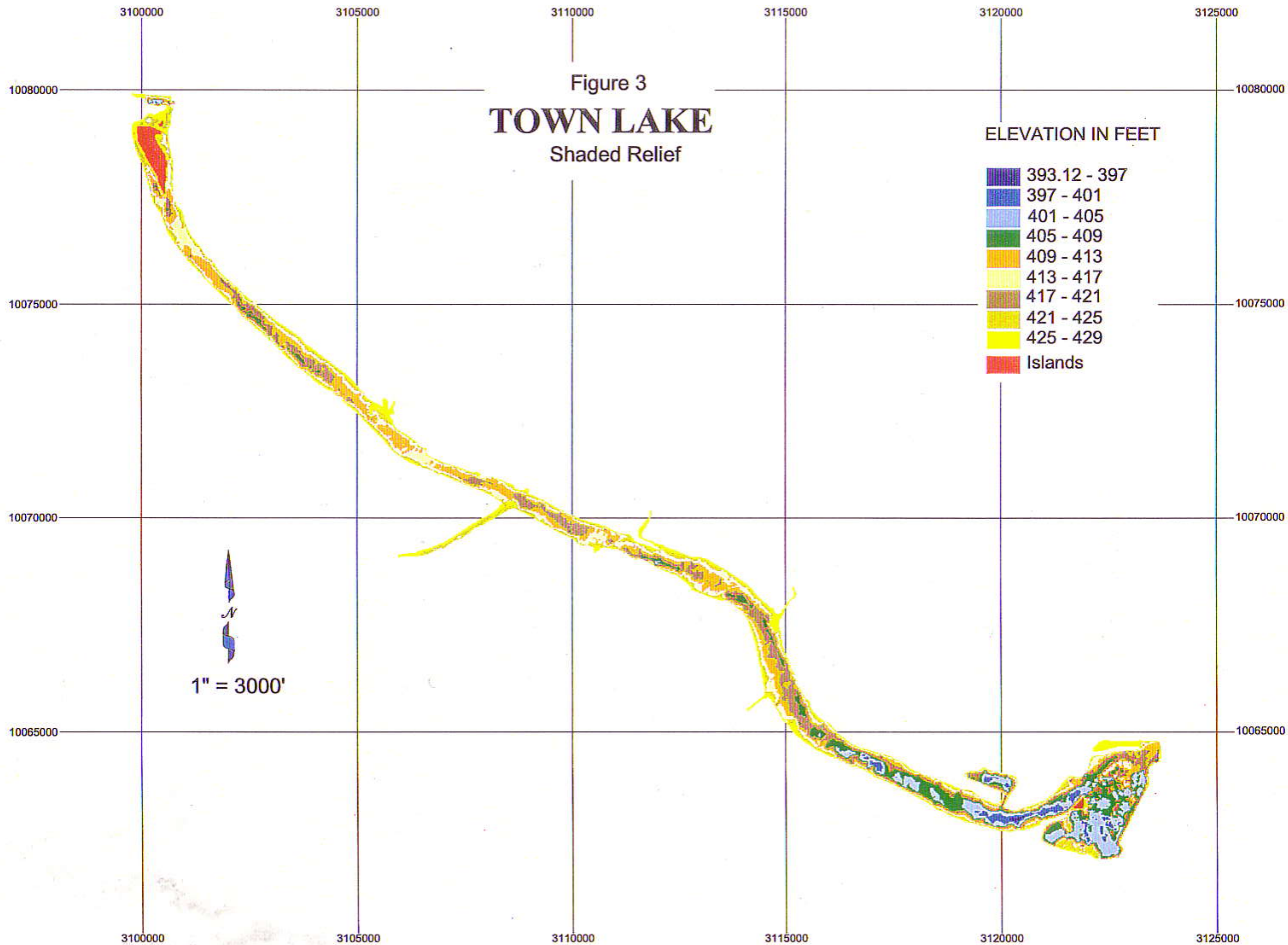
TOWN LAKE

Location Map





Prepared by : TWDB September 1999



Prepared by : TWDB SEPTEMBER 1999

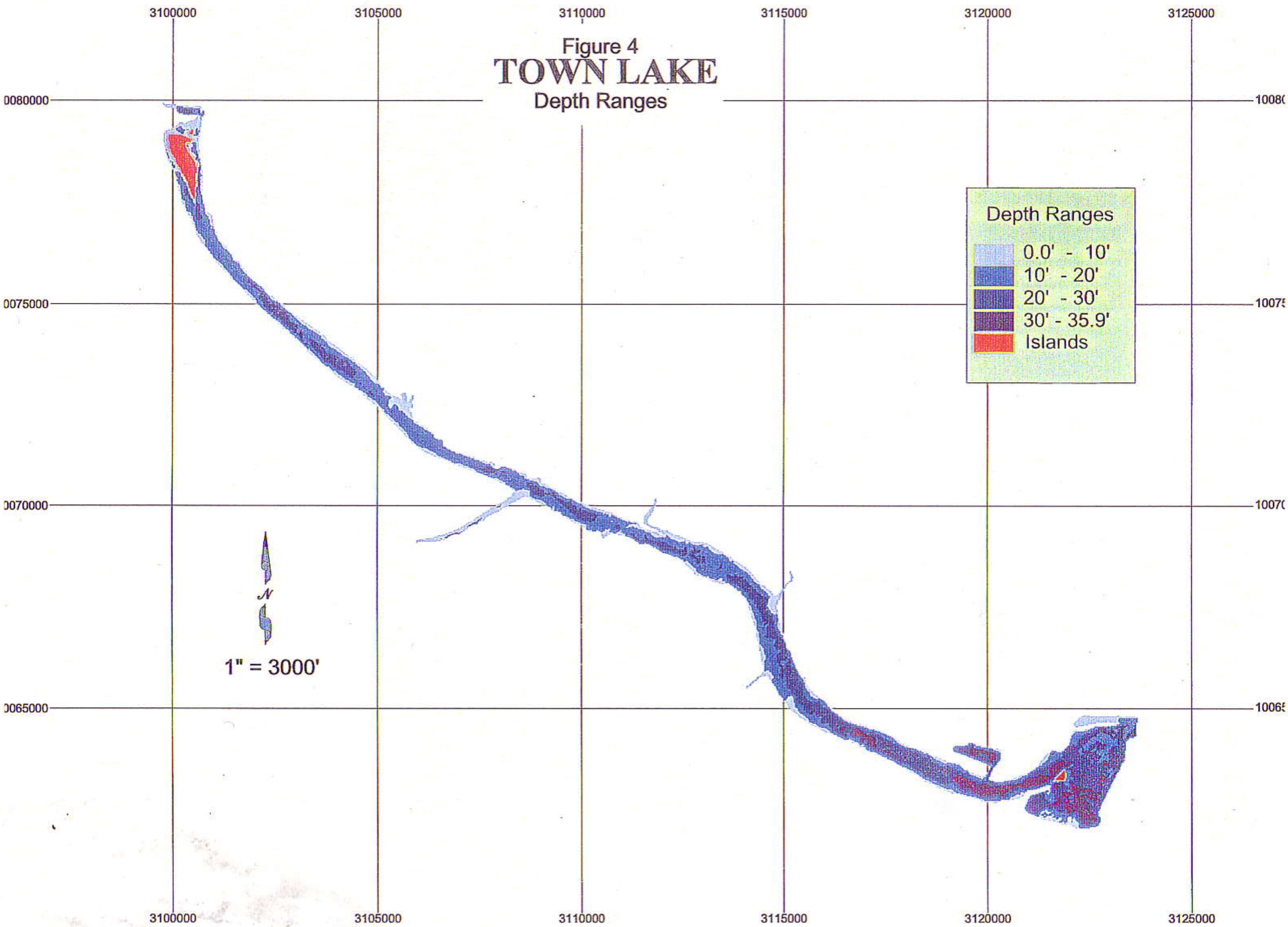


Figure 4
TOWN LAKE
Depth Ranges
Depth Ranges
0.0' - 10'
10' - 20'
20' - 30'
30' - 35.9'
Islands
1" = 3000'
3100000
3105000
3110000
3115000
3120000
3125000

APPENDIX E - DEPTH SOUNDER ACCURACY

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

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

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')

APPENDIX F - GPS BACKGROUND

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 satellite broadcasts 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 located in space, and is ignored, while the second is the point of interest located on earth. 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, DOD 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, of which one 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 provide horizontal positional accuracy within one meter. In addition, the large positional errors experienced by a single receiver when S/A is active are negated. The lake surface during the survey serves as the vertical datum for the bathymetric readings from a depth sounder. The sounder determines the lake's depth below a given horizontal location at the surface.

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 on a worldwide basis in a differential mode basically the same way as the shore station. 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 correction corresponding to each site is automatically sent to a “Network Control Center” where they are checked and repackaged for up-link to a “Geostationary” L-band satellite. The “real-time” corrections are then broadcast by the satellite to users of the system in the area covered by that 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 1 meter or less.

Previous Survey Procedures

Originally, reservoir surveys were conducted by stretching a rope across the reservoir along pre-determined range lines and, from a small boat, poling 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 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. Monuments were set at 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 the horizontal location 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. Continuous horizontal positioning by electronic means allowed for the continuous collection of depth soundings by boat. A set of microwave transmitters positioned around the lake at known coordinates allowed 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 is generally one-half of the contour interval or $\pm$ five feet for a ten-foot contour interval. This method can be quite costly and is applicable only in areas that are not inundated.

Prepared by : TEXAS WATER DEVELOPMENT BOARD SEPTEMBER 1999