VOLUMETRIC SURVEY REPORT

OF

GRANGER LAKE

APRIL 2002 SURVEY

Prepared by the:

TEXAS WATER DEVELOPMENT BOARD

July 2003

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ON GRANGER LAKE
SURVEY OF APRIL 2002

INTRODUCTION

Staff of the Surface Water Availability Section of the Texas Water Development Board (TWDB) conducted a volumetric survey of Granger Lake during the period of March 26, 2002 through April 1, 2002. The primary purpose of the survey was to determine the total volume when the lake level is at conservation pool elevation (CPE) 504.0 feet above mean sea level. For the purpose of this report, the term "top of conservation (TOC) pool" will be used to mean the conservation pool elevation (504.0 feet) for Granger Lake. The results of the current survey will be compared to the baseline survey performed by TWDB in October of 1995. Results from a sediment survey will be presented in a later report. 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 Geological Survey (USGS) for the lake elevation gage at Granger Lake. The station number and name is 08105600 GRANGER LAKE NEAR GRANGER, TX. The datum for this gage is reported as mean sea level (msl) NGVD29 (USGS, 2002). Thus, elevations are reported here in feet (ft) above mean sea level (msl) NGVD29. Volume and area calculations in this report are referenced to water levels provided by the USGS gage.

Original design information for Granger Lake was based on information furnished by the U.S. Army Corps of Engineers. The equipment and methodology used in the

current survey was similar to that used in the October 1995 survey. Please refer to the Volumetric Survey of Granger Lake (TWDB 1995) for more information.

PERTINENT DATA

Owner of Dam and Facilities:

U. S. Army Corps of Engineers

Operator of Dam and Facilities:

U. S. Army Corps of Engineers, Fort Worth District

Engineer and General Contractor

U. S. Army Corps of Engineers (Design)

J. D. Abrams (General Contractor)

Location:

Granger Lake is located in Williamson County on the San Gabriel River, tributary of the Little River, tributary of the Brazos River (Figure 1).

Purpose:

Multi-purpose reservoir for flood control and water supply.

Authorization:

Federal: Federal Flood Control Act 1954, modified by the Federal Control Act 1962, approved October 23, 1962.

State: Certificate of Adjudication 12-5163 was issued, by the Texas Water Commission on December 14, 1987, to the Brazos River Authority (BRA) to impound 65,500 ac-ft of water in an existing reservoir on the San Gabriel River. The BRA was authorized a priority right to divert and use not to exceed 19,840

ac-ft of water per annum for municipal, industrial, irrigation, and mining purposes. For the purposes of the system operation, the BRA was authorized to exceed the priority right and annually divert and use from Granger Lake not to exceed 30,000 ac-ft of water for municipal purposes; 5,500 ac-ft of water for irrigation purposes; 29,800 ac-ft of water for industrial purposes and 200 ac-ft of water for mining purposes. Any diversions and use of water from Granger Lake in excess of 19,840 ac-ft of water in any one calendar year would be charged against the sum of the amounts designated as priority rights in other reservoirs included in the System Operation Order. The BRA was also authorized to use the water impounded in Granger Lake for non-consumptive recreation purposes. Certificate of Adjudication 12-5167 (issued December 14, 1987) states the BRA is authorized to divert and use not to exceed, 30,000 ac-ft of water for municipal purposes and 170,000 ac-ft of water for industrial purposes, to be used in the San Jacinto-Brazos Coastal Basin. These waters are to be released from Granger Lake and other reservoirs owned and operated by the BRA.

Drainage area:

730 square miles

Dam:

Type	Rolled earth fill
Length	16,320 ft
Maximum height	115 ft (above natural streambed)
Top width	30 ft

Spillway:

Type	Concrete, ogee weir
Control	Uncontrolled
Length	950 ft

Outlet works:

Type	Concrete tower with conduit

Dimensions	Tower, conduit 18 ft diameter
Floodgate invert elevation	457.0 ft
Control	Two 8 ft wide x 18 ft high slide gates with hydraulic control
Low-flow outlet	Three 3 ft wide x 4 ft high slide gates
Invert elevations	486.0 ft, 494.0 ft, and 502.0 ft

Reservoir Data:

FEATURE	ELEVATION (Feet)	CAPACITY (Acre-feet)	AREA (Acres)
Top of Dam[1]	555.0	-----	21,000
Maximum Design Water Surface[1]	550.3	579,900	19,220
Top of Flood Control Storage Space and Spillway Crest[1]	528.0	244,200	11,040
Top of Conservation Storage Space[2]	504.0	53,844	3,913
Invert of Lowest Intake[2]	457.0	0	0
Usable Conservation Storage Space[2]	504.0	53,844	3,913

1.Information at elevations above 504.0 ft based on 1980 area and capacity data supplied by the U.S. Army Corp of Engineers.

2. Information at elevations at and below 504.0 ft based on 1995 **revised** area and capacity data by the Texas Water Development Board provided to the U.S. Army Corp of Engineers (See Appendices B & D).

VOLUMETRIC SURVEYING TECHNOLOGY

The equipment used to perform the latest volumetric survey consisted of a 23-foot aluminum tri-hull SeaArk craft with cabin, equipped with twin 90-Horsepower Honda outboard motors. (Reference to brand names throughout this report does not imply endorsement by TWDB). 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, Trimble Navigation, Inc. AG132 GPS receiver with Omnistar differential GPS correction signal and 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 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 vessel, and depth sounder in combination provide an efficient hydrographic survey system. As the boat travels across the pre-plotted transect lines, the depth sounder takes approximately ten readings of the lake bottom each second. The depth readings are stored on the computer along with the positional data generated by the boat's GPS receiver. The data files collected are downloaded and transferred 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 one data point per second, and the average depths are converted to elevation readings based on the water-level elevation recorded on the day the survey was performed. Accurate estimates of the lake volume can then be determined by building a 3-D TIN model of the lake from the collected data.

PRESURVEY PROCEDURES

The lake's boundary was digitized using Environmental Systems Research Institute's (ESRI) ArcGIS from digital orthophoto quadrangles (DOQ's). VARGIS of Texas LLC produced the DOQ's for the Texas Orthoimagery Program (TOP). The DOQ's produced for the Department of Information Resources and the GIS Planning Council under the TOP reside in the public domain. More information can be obtained on the Internet at http://www.tnris.state.tx.us/DigitalData/doqs.htm. The lake elevations, at the time the DOQ's were photographed (January 19, 1995, January 23, 1995 and January 31, 1995) were 504.2 ft, 504.18 ft, and 504.18 ft. respectively. The lake and island boundaries were given an elevation of 504.2 ft and TWDB Staff utilized these updated boundary conditions in modeling Granger Lake for this report. The lake elevations varied between elevation 504.28 ft and 504.36 ft during the survey (March 26, 2002 – April 1, 2002).

The survey layout was designed by placing survey track lines at 500-foot intervals within the digitized lake boundary using the HYPACK software. The survey design required the use of approximately 157 survey lines placed perpendicular to the original river channel and tributaries along the length of the lake.

SURVEY PROCEDURES

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

Equipment Calibration and Operation

Prior to collecting data onboard 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.

While collecting data onboard the River Runner (shallow draft) boat, the Knudsen depth sounder was calibrated using the DIGIBAR-Pro Profiling Sound Velocimeter by Odem Hydrographic Systems The steps to determine the speed of sound are similar to 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. The depth was then checked manually with a stadia (survey) 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 was 4810 feet per second during the Granger 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 ±0.2 ft. An additional estimated error of ±0.3 ft arises from variation in boat inclination. These two factors combine to give an overall accuracy of ±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 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 from the Omnistar receiver. The lake's initialization file used by the HYPACK data collection program was set up to convert the collected Differential GPS positions to NAD 83, State Plane, Texas Central Zone coordinates on the fly.

Data Collection

TWDB staff collected data at Granger Lake for approximately 4 days during the period of March 26 through April 1, 2002. The USACE were able to maintain the lake levels above TOC during the survey. The lake level elevations varied between 504.28 ft and 504.36 ft, thus allowing the survey crew to collect data in most areas of the lake that would be inundated at TOC 504.0 ft.

The design layout for collecting data at Granger Lake required pre-plotting transects (range lines) that were perpendicular to the old river and creek channels. These transects had an average spacing of 500 ft. While collecting data, the boat operator would steer the boat on course (with GPS navigation) starting from one shore and heading to the opposite shore. The data collector would monitor the data display and depth sounder to make sure the latitude; longitude and depth (x,y,z) values were being logged. Adjustments could be made if the instruments were receiving bad data at that time. The depth sounder and GPS equipment records 10 data points every second. These points are averaged to one data point per second for generating the model. The distance between data points depended on the speed of the boat. The maximum distance between data points during the resurvey of Granger Lake was approximately 30 ft.

Over 95,000 data points were collected over the 344 miles traveled during the data collection phase of Granger Lake. These points were stored digitally on the boat's computer in 191 data files. Random data were collected in those areas where the crew was not able to stay on course due to obstructions. Data were not collected in areas with significant obstructions or where the water was too shallow. Figure 2 shows the actual location of all data points collected.

Data Processing

The collected data were downloaded from diskettes onto TWDB's network computers. 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 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 adjustments had been made to the raw data files, the edited files were saved. The edited files were 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 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. 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 triangle 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 for the entire lake at one-tenth of a foot interval from the lowest elevation to the contour used for the lake boundary during the current survey. From elevation 463.2 ft to 504.2 ft, the surface areas and volumes of the lake were computed using Arc/Info software. The computed lake volume table is presented in Appendix A and the area table in Appendix C for Granger Lake. The 1995 lake volume and area tables were revised using the updated boundary conditions developed from 1995 photographs and are presented in Appendix B and Appendix D. An elevation-volume graph and an elevation-area graph are presented in Appendix E and Appendix F respectively.

Another product developed from the model includes a contour map. To develop this 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 4. Finally, endpoint coordinates for 13 range lines can be found in Appendix G. These range lines were used in comparing the current TWDB bathymetric TIN model (2002) and the TIN model based on the 1995 data using the current boundary conditions. Differences between cross-sections might be due to the fact that the 2002 range lines do not exactly match the range lines driven in the 1995 survey and in the methodology that Arc/Info uses to interpolate between points in developing the TIN model. The range line plots are presented in Appendix H.

RESULTS

Results from the 2002 TWDB resurvey indicate Granger Lake encompasses 4,064 surface acres and contains a total volume of 52,525 ac-ft at the conservation pool elevation of 504.0 ft. The length of the shoreline at the digitized elevation of 504.2 ft was calculated to be approximately 49 miles. The deepest point physically measured during the survey was at elevation 463.19 ft corresponding to a depth of 40.81 ft from TOC and was located approximately 580 ft upstream of Granger Dam near the outlet works.

SUMMARY AND COMPARISONS

The Federal Flood Control Act approved September 3, 1954 and the Public Works Appropriation Act of 1958 authorized the construction of Granger Dam and creation of

Granger Lake. Construction commenced October 24, 1972. Deliberate impoundment began January 21, 1980. Original design information, based on 1963-64 U.S. Geological Survey topographic maps, estimated the volume of the lake at the conservation pool elevation of 504.0 to be 65,510 ac-ft with surface area of 4,400 ac.

Prior to this report, the most recent volumetric survey report on Granger Lake was published by the TWDB in December 1995. For the purposes of this analysis, the results of the 1995 survey have been revised based on more accurate boundary information.

At TOC pool elevation 504.0 ft, the 2002 TWDB survey measured 4,064 surface acres and reports a volume of 52,525 ac-ft of water. The capacity of the active pool (conservation storage) between elevations 504.0 ft and 457.0 ft is 52,525 ac-ft of water. The dead pool storage or that capacity of water below the invert of the lowest outlet (elevation 457.0 ft) was 0 ac-ft of water.

The 1995-revised elevation-area-capacity table indicates that Granger Lake had a volume of 53,844 ac-ft of water and a surface area of 3,913 ac at conservation pool elevation 504.0 ft. Figures 3, 3a, 3b and 3c show the 1995 and 2002 datasets and the 1995 boundary superimposed on the 2002 boundary. In many of the coves and shallow areas the 2002 data set extends beyond the 1995 boundary and consequently the 1995 data set. These data points change the way the TIN model extrapolates to the boundary in the upper elevations and accounts for differences in area and volume at upper elevations between the 1995 and 2002 data sets when using the 2002 boundary. A comparative summary of the historical data and the results of the TWDB 2002 resurvey are presented in Table 2.

Comparisons between initial volume calculations and the TWDB volumetric surveys are difficult and some apparent changes might simply be due to methodological

differences. It is recommended that a similar survey be performed in five to ten years or after major flood events to monitor changes to the lake's capacity.

Table 2. Area and Volume Comparisons of Granger Lake

	USACE Original Design **1968**	TWDB Volumetric Survey **1995**	TWDB Volumetric Survey **2002**
Area (acres)	4,400	3,913	4,064
Total Volume (ac-ft)	65,510	53,844	52,525

Notes:
1. All pre-1995 data provided by Fort Worth District USACE and TCEQ Permit No. 2366
2. All results for top of conservation pool elevation 504.0 ft

REFERENCES

1. http://www.swf-wc.usace.army.mil/
2. http://www.swf-wc.usace.army.mil/granger/
3. Texas Water Commission, 1968, Permit No. 2366
4. Texas Water Commission, 1979, Permit No. 2366A
5. Texas Water Commission, 1980, Permit No. 2366B
6. Texas Water Commission, 1987, Certificate of Adjudication 12-5163
7. Texas Water Commission, 1987, Certificate of Adjudication 12-5167
8. Texas Water Development Board, 1995, “Volumetric Survey of Granger Lake”
9. United States Geological Survey, 2001, Water Data Report TX-01-3. “Water Resources Data Texas Water Year 2001”

Appendix A

Granger Lake

RESERVOIR VOLUME TABLE

TEXAS WATER DEVELOPMENT BOARD — APRIL 2002 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
463			0	0	0	0	0	0	0	0
464	0	0	0	0	0	0	0	0	0	0
465	0	0	0	0	0	0	0	0	0	0
466	0	0	0	0	0	1	1	1	1	1
467	1	2	2	3	4	5	6	8	10	12
468	14	17	20	22	25	29	32	36	40	44
469	48	53	58	63	68	74	80	86	92	99
470	106	113	121	129	137	145	154	163	172	181
471	191	201	212	222	233	245	256	268	280	293
472	305	319	332	346	359	374	388	403	418	433
473	448	464	480	496	513	530	547	564	582	599
474	617	636	655	674	694	714	734	755	776	798
475	820	842	865	888	912	935	960	984	1009	1035
476	1061	1088	1115	1142	1171	1199	1229	1259	1291	1323
477	1355	1389	1423	1459	1495	1532	1570	1608	1648	1689
478	1731	1773	1817	1862	1908	1955	2003	2052	2102	2153
479	2205	2258	2312	2367	2423	2481	2540	2599	2660	2722
480	2786	2850	2915	2981	3048	3117	3186	3257	3329	3401
481	3475	3549	3624	3701	3778	3856	3934	4014	4094	4175
482	4257	4339	4423	4507	4592	4678	4765	4852	4940	5029
483	5119	5209	5300	5392	5485	5580	5675	5771	5867	5965
484	6064	6164	6265	6367	6470	6574	6678	6784	6891	6998
485	7107	7217	7329	7441	7555	7669	7785	7903	8021	8140
486	8261	8383	8506	8631	8756	8883	9010	9139	9269	9400
487	9532	9665	9799	9934	10070	10207	10345	10484	10623	10764
488	10906	11049	11193	11338	11484	11632	11780	11930	12080	12231
489	12384	12538	12692	12848	13005	13163	13322	13482	13643	13805
490	13968	14133	14298	14465	14633	14802	14972	15144	15316	15490
491	15665	15841	16019	16198	16378	16560	16742	16927	17112	17299
492	17486	17676	17866	18058	18251	18446	18642	18840	19039	19239
493	19441	19644	19848	20054	20261	20470	20680	20892	21105	21320
494	21537	21755	21975	22196	22419	22644	22870	23098	23327	23558
495	23791	24025	24262	24500	24739	24981	25224	25469	25716	25964
496	26215	26467	26721	26978	27236	27497	27759	28024	28290	28559
497	28830	29102	29377	29653	29932	30212	30494	30778	31063	31351
498	31640	31930	32223	32517	32813	33110	33409	33710	34013	34318
499	34625	34934	35244	35557	35871	36187	36505	36826	37148	37472
500	37798	38126	38456	38789	39123	39459	39798	40138	40481	40825
501	41172	41521	41872	42225	42580	42937	43296	43656	44018	44383
502	44749	45118	45489	45862	46238	46616	46997	47381	47767	48154
503	48543	48934	49327	49720	50116	50513	50912	51313	51715	52119
504	52525	52932	53341							

Values above Top of Conservation Pool

Appendix B

Granger Lake

RESERVOIR VOLUME TABLE

TEXAS WATER DEVELOPMENT BOARD — OCTOBER 1995 SURVEY

REVISED

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
463		0	0	0	0	0	0	0	0	0
464	0	0	0	0	0	0	1	1	1	2
465	2	2	3	4	4	5	6	6	7	8
466	9	10	12	14	16	19	22	25	28	32
467	36	40	45	50	55	60	66	72	78	84
468	90	97	103	110	118	125	133	140	148	157
469	165	174	183	192	202	212	222	233	244	255
470	266	277	289	301	313	326	339	352	365	379
471	393	407	421	436	451	467	483	499	515	532
472	549	566	584	602	620	639	658	677	697	717
473	738	759	780	802	824	847	869	893	916	940
474	964	989	1014	1040	1065	1091	1118	1145	1172	1200
475	1228	1257	1286	1315	1345	1376	1407	1438	1470	1503
476	1536	1570	1604	1639	1675	1711	1748	1786	1825	1864
477	1904	1945	1987	2030	2073	2117	2162	2208	2255	2302
478	2350	2399	2449	2500	2552	2606	2661	2717	2775	2834
479	2894	2955	3017	3081	3145	3211	3277	3345	3413	3482
480	3552	3624	3696	3769	3843	3918	3994	4070	4148	4227
481	4306	4386	4467	4549	4632	4715	4799	4884	4969	5055
482	5142	5229	5317	5406	5496	5586	5678	5770	5863	5956
483	6051	6147	6243	6340	6438	6537	6637	6738	6839	6942
484	7045	7149	7255	7361	7468	7577	7686	7797	7909	8022
485	8136	8251	8367	8484	8602	8722	8842	8963	9086	9210
486	9335	9461	9589	9717	9847	9978	10110	10243	10377	10512
487	10648	10786	10925	11064	11205	11347	11490	11633	11778	11924
488	12071	12219	12369	12519	12670	12822	12976	13130	13286	13443
489	13600	13759	13919	14080	14242	14406	14570	14735	14902	15069
490	15238	15408	15580	15752	15926	16101	16277	16455	16633	16813
491	16994	17176	17359	17544	17729	17916	18105	18294	18485	18677
492	18870	19065	19261	19459	19658	19859	20061	20264	20469	20675
493	20882	21091	21302	21514	21727	21942	22158	22376	22596	22817
494	23040	23264	23490	23717	23946	24177	24409	24643	24879	25116
495	25354	25595	25837	26081	26326	26573	26822	27073	27326	27580
496	27837	28095	28355	28617	28881	29146	29413	29682	29952	30224
497	30497	30772	31048	31326	31606	31887	32170	32454	32740	33027
498	33316	33607	33899	34193	34488	34785	35084	35384	35686	35990
499	36296	36603	36912	37223	37536	37850	38166	38484	38804	39125
500	39448	39773	40100	40428	40759	41091	41426	41763	42102	42444
501	42789	43136	43484	43834	44185	44538	44893	45248	45605	45964
502	46324	46686	47049	47414	47780	48147	48517	48887	49259	49633
503	50008	50385	50763	51143	51524	51907	52291	52677	53064	53453
504	53844	54236	54629							

Values above Top of Conservation Pool

Appendix C

GRANGER Lake

RESERVOIR AREA TABLE

TEXAS WATER DEVELOPMENT BOARD — APRIL 2002 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
463			0	0	0	0	0	0	0	0
464	0	0	0	0	0	0	0	0	0	0
465	0	0	0	0	0	0	0	0	0	0
466	0	1	1	1	1	1	1	2	2	2
467	3	3	5	7	11	14	16	18	20	22
468	24	26	27	29	31	33	36	38	40	43
469	45	48	50	53	55	58	60	63	66	68
470	71	74	77	80	82	85	88	91	94	96
471	99	102	105	108	111	114	117	120	123	127
472	129	132	135	138	141	143	146	148	151	153
473	156	159	161	164	166	169	172	174	177	179
474	182	186	190	195	200	204	207	211	214	218
475	222	225	229	233	237	240	244	249	253	258
476	263	268	273	279	286	292	300	307	316	324
477	332	340	348	357	366	375	384	393	402	412
478	423	433	444	454	464	474	484	494	504	515
479	525	535	546	558	569	581	593	604	615	626
480	636	647	657	668	679	690	701	711	721	730
481	740	749	758	766	775	782	790	798	806	814
482	822	831	839	847	855	863	870	877	885	892
483	900	908	917	926	936	946	955	964	973	983
484	993	1004	1014	1024	1033	1043	1052	1062	1072	1083
485	1095	1107	1118	1130	1142	1154	1166	1178	1190	1201
486	1213	1225	1237	1249	1261	1272	1283	1294	1305	1315
487	1325	1335	1345	1354	1364	1373	1383	1393	1403	1412
488	1423	1434	1445	1457	1468	1479	1490	1500	1510	1520
489	1531	1542	1552	1563	1573	1584	1595	1605	1616	1627
490	1639	1650	1662	1673	1684	1696	1708	1720	1732	1745
491	1757	1769	1782	1796	1809	1821	1834	1847	1860	1873
492	1886	1899	1912	1926	1940	1954	1968	1982	1996	2010
493	2024	2038	2052	2066	2080	2095	2110	2125	2141	2157
494	2173	2190	2206	2222	2238	2254	2270	2286	2302	2319
495	2336	2353	2371	2388	2406	2423	2440	2458	2477	2495
496	2514	2534	2553	2573	2595	2615	2636	2656	2675	2696
497	2716	2736	2755	2774	2793	2812	2830	2847	2864	2882
498	2898	2915	2932	2949	2966	2984	3001	3020	3039	3058
499	3078	3096	3115	3134	3153	3171	3192	3212	3231	3251
500	3272	3292	3313	3333	3353	3373	3395	3416	3436	3456
501	3477	3497	3523	3541	3559	3578	3596	3614	3633	3654
502	3675	3697	3720	3745	3772	3799	3825	3847	3866	3883
503	3899	3916	3932	3948	3964	3981	3997	4014	4031	4048
504	4064	4081	4215							

Values above Top of Conservation Pool

Appendix D

GRANGER Lake

RESERVOIR AREA TABLE

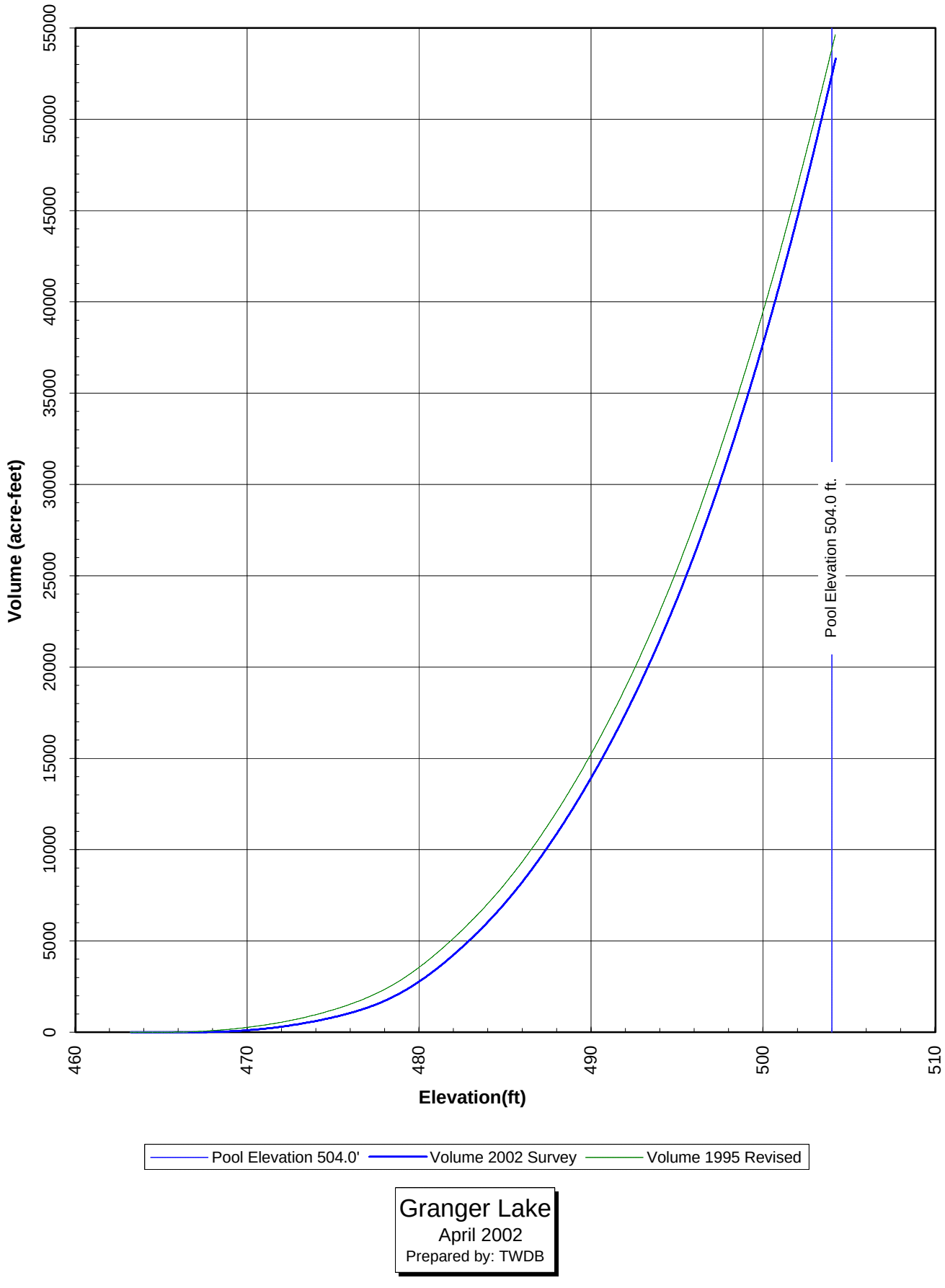
TEXAS WATER DEVELOPMENT BOARD — OCTOBER 1995 SURVEY

REVISED

AREA IN ACRES — ELEVATION INCREMENT IS ONE TENTH FOOT

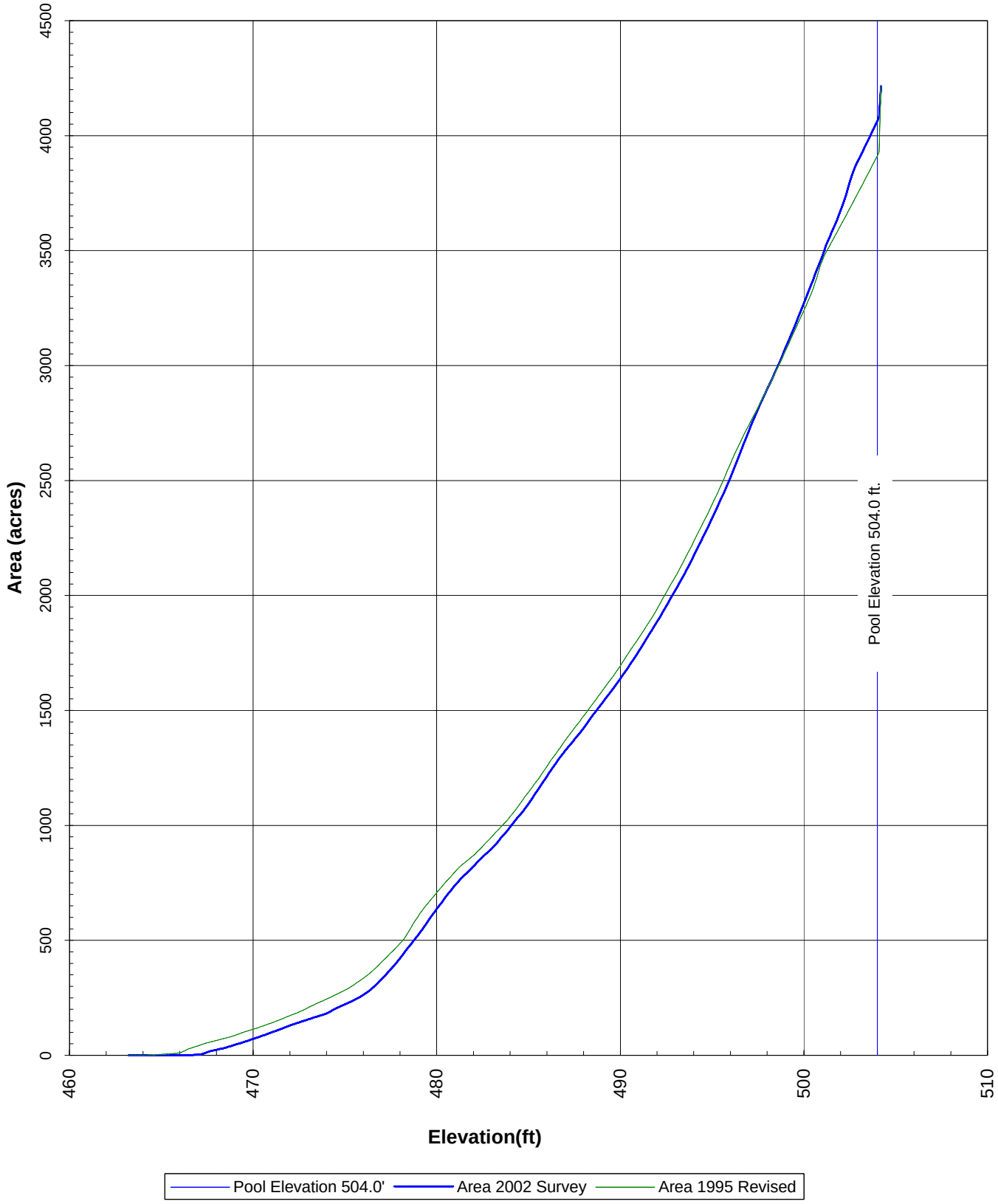
ELEVATION in Feet	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
463		0	0	0	0	0	0	0	0	0
464	0	0	0	1	1	2	2	3	3	4
465	5	5	6	6	6	7	7	8	8	9
466	11	14	17	21	25	29	31	34	36	39
467	41	44	47	50	52	54	57	59	61	63
468	65	67	69	71	73	75	77	79	81	84
469	86	90	93	96	99	101	103	106	108	111
470	113	116	119	121	124	127	129	132	135	138
471	141	144	147	150	153	156	159	163	166	169
472	172	175	179	182	185	189	192	196	200	204
473	208	212	216	219	223	227	230	234	237	241
474	245	248	252	256	260	264	267	271	275	279
475	283	287	292	297	302	307	313	319	324	329
476	335	341	347	354	360	367	374	382	390	398
477	406	414	422	430	438	446	453	461	469	478
478	487	495	505	515	529	543	556	569	582	594
479	607	618	629	640	650	660	669	679	688	698
480	707	717	726	736	745	754	763	772	780	789
481	798	808	816	823	830	837	843	850	856	863
482	870	877	884	892	900	909	917	926	934	942
483	951	960	969	977	985	994	1002	1010	1019	1029
484	1038	1048	1058	1068	1079	1090	1102	1113	1124	1134
485	1145	1156	1166	1177	1188	1198	1209	1221	1233	1244
486	1256	1268	1281	1292	1303	1313	1324	1335	1347	1359
487	1370	1380	1391	1402	1413	1423	1434	1444	1454	1465
488	1475	1486	1497	1507	1518	1529	1540	1551	1562	1572
489	1583	1594	1605	1616	1627	1638	1648	1659	1671	1682
490	1694	1707	1719	1732	1744	1756	1768	1780	1791	1803
491	1815	1827	1839	1852	1864	1876	1888	1901	1913	1927
492	1941	1956	1970	1984	1999	2013	2027	2041	2055	2068
493	2082	2096	2110	2125	2141	2157	2172	2187	2203	2219
494	2235	2251	2268	2283	2299	2315	2330	2346	2362	2379
495	2396	2413	2429	2446	2463	2481	2499	2518	2536	2555
496	2574	2593	2610	2627	2644	2661	2678	2694	2710	2726
497	2741	2757	2772	2787	2803	2819	2834	2851	2867	2883
498	2899	2914	2930	2946	2962	2979	2995	3012	3029	3046
499	3064	3083	3100	3117	3135	3153	3170	3187	3205	3222
500	3240	3258	3276	3294	3314	3334	3357	3380	3408	3438
501	3456	3476	3492	3506	3521	3535	3550	3565	3580	3594
502	3609	3624	3639	3654	3669	3684	3699	3714	3729	3744
503	3759	3774	3789	3805	3820	3835	3851	3866	3882	3897
504	3913	3928	4215							

Values above Top of Conservation Pool



Granger Lake
April 2002
Prepared by: TWDB

Appendix E Elevation vs. Volume



Granger Lake
April 2002
Prepared by: TWDB

Appendix F Elevation vs. Area

Appendix G

Ganger Lake

TEXAS WATER DEVELOPMENT BOARD APRIL 2002 SURVEY

Range Line Endpoints

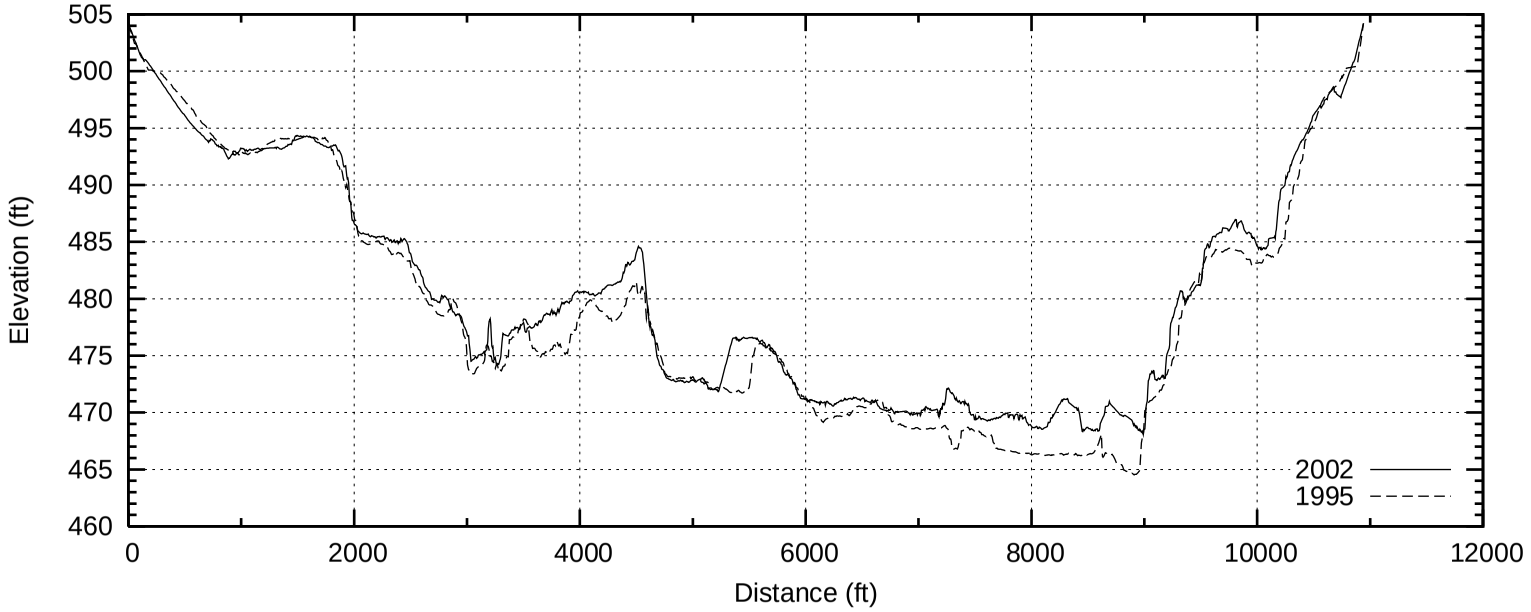
State Plane NAD83 Units-feet

L-Left endpoint
R-right endpoint

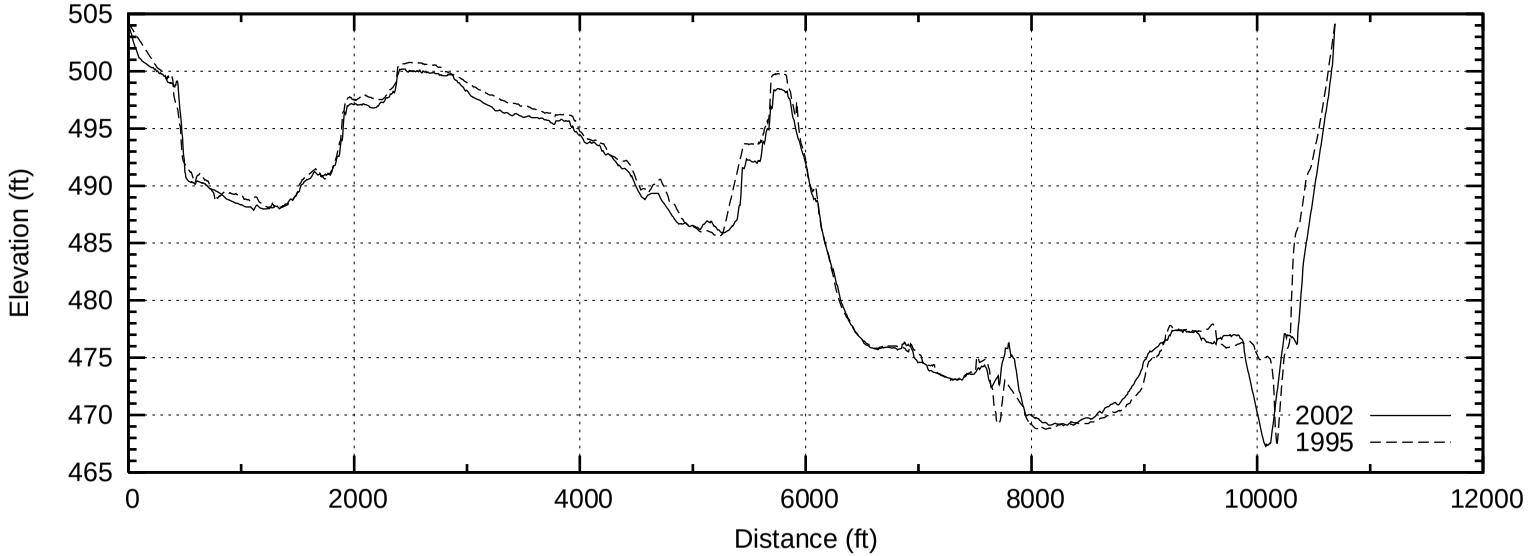
Range Line	X	Y
RL-1-R	3241000.0	10236271.0
RL-1-L	3236996.3	10226088.0
RL-2-R	3236293.3	10236773.0
RL-2-L	3235257.5	10226134.0
RL-3-R	3233154.5	10231563.0
RL-3-L	3233857.5	10225544.0
RL-4-R	3232630.3	10232383.0
RL-4-L	3231772.8	10229198.0
RL-5-R	3229319.0	10232779.0
RL-5-L	3228111.3	10230692.0
RL-6-R	3225660.5	10234434.0
RL-6-L	3226189.3	10230248.0
RL-7-R	3222713.3	10232534.0
RL-7-L	3223650.8	10229253.0
RL-8-R	3231641.8	10227990.0
RL-8-R	3232572.3	10224493.0
RL-9-R	3227197.8	10225892.0
RL-9-L	3229830.3	10223807.0
RL-10-R	3225781.5	10222266.0
RL-10-L	3227466.0	10220448.0
RL-11-R	3223523.8	10220844.0
RL-11-L	3224710.0	10218076.0
RL-12-R	3221721.3	10219973.0
RL-12-L	3222405.5	10217091.0
RL-13-R	3235234.3	10237388.0
RL-13-L	3234005.5	10234379.0

Granger Lake

Rangeline SR01

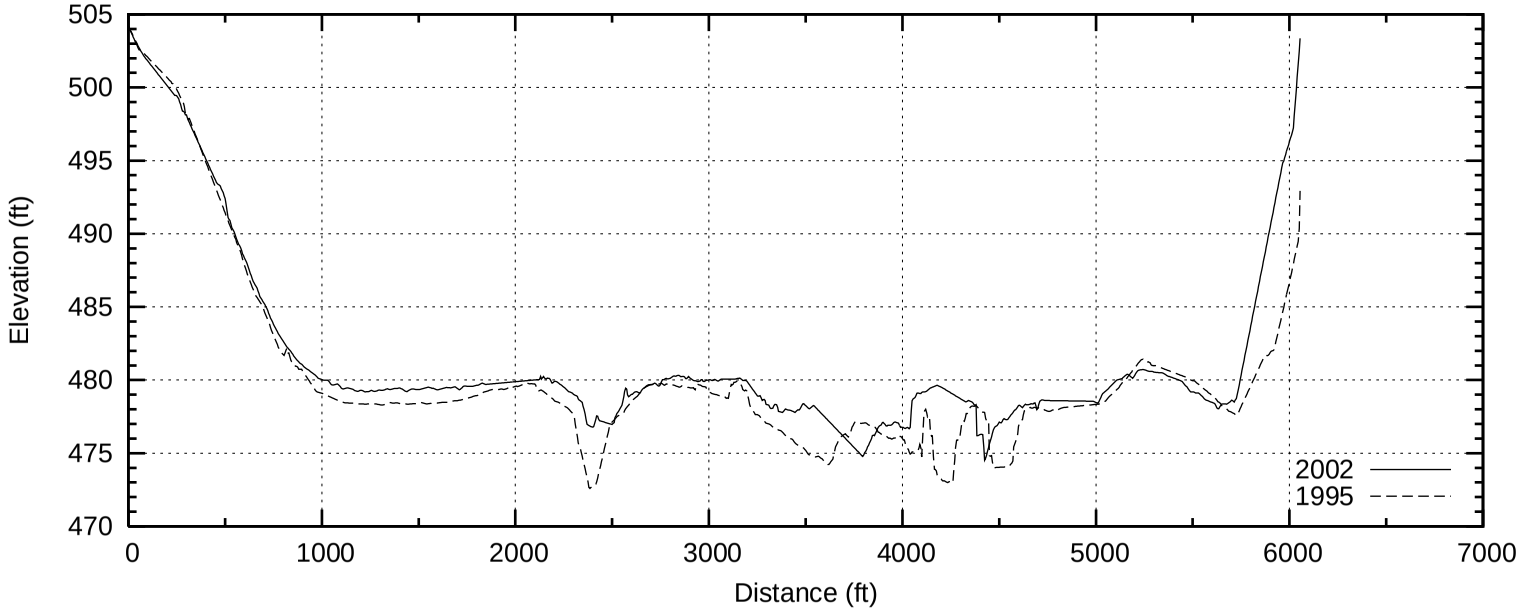


Rangeline SR02

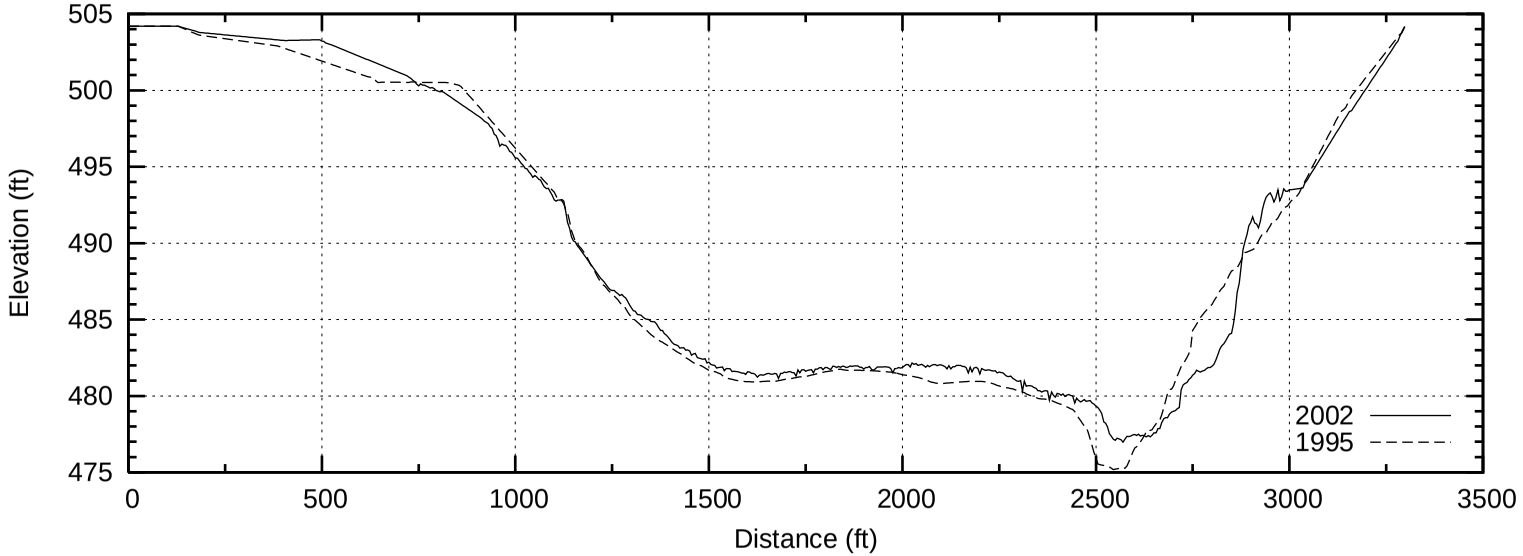


Granger Lake

Rangeline SR03

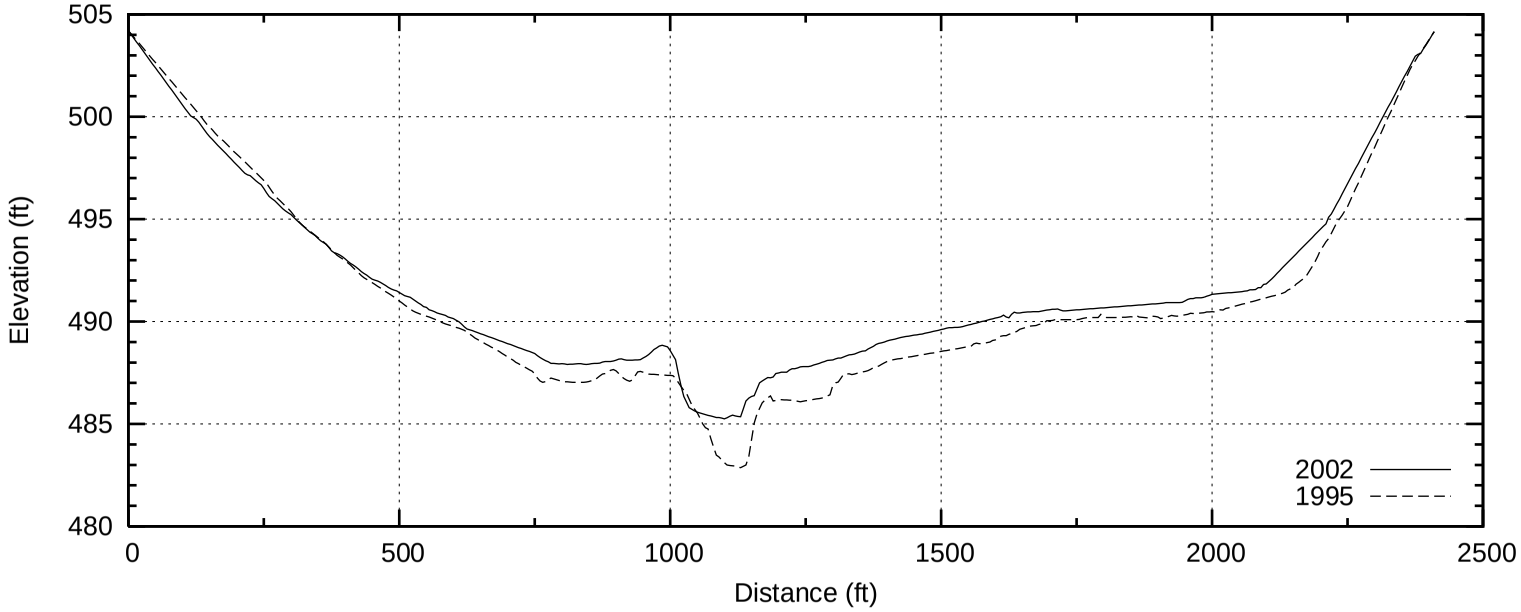


Rangeline SR04

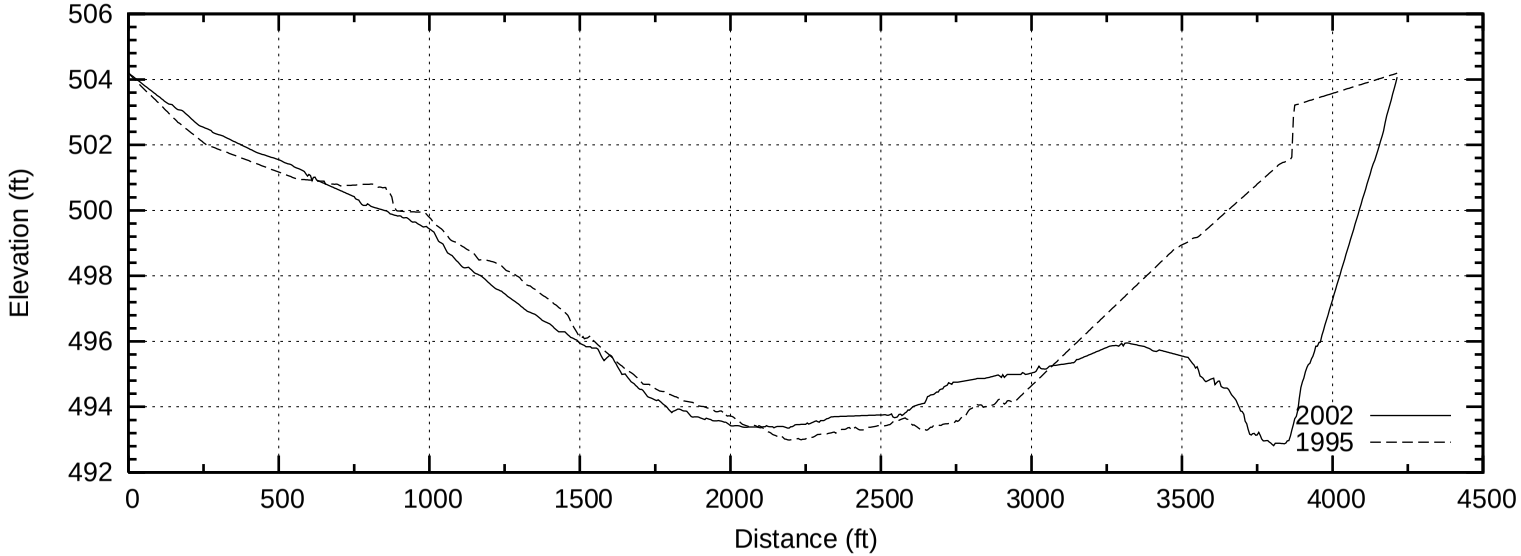


Granger Lake

Rangeline SR05

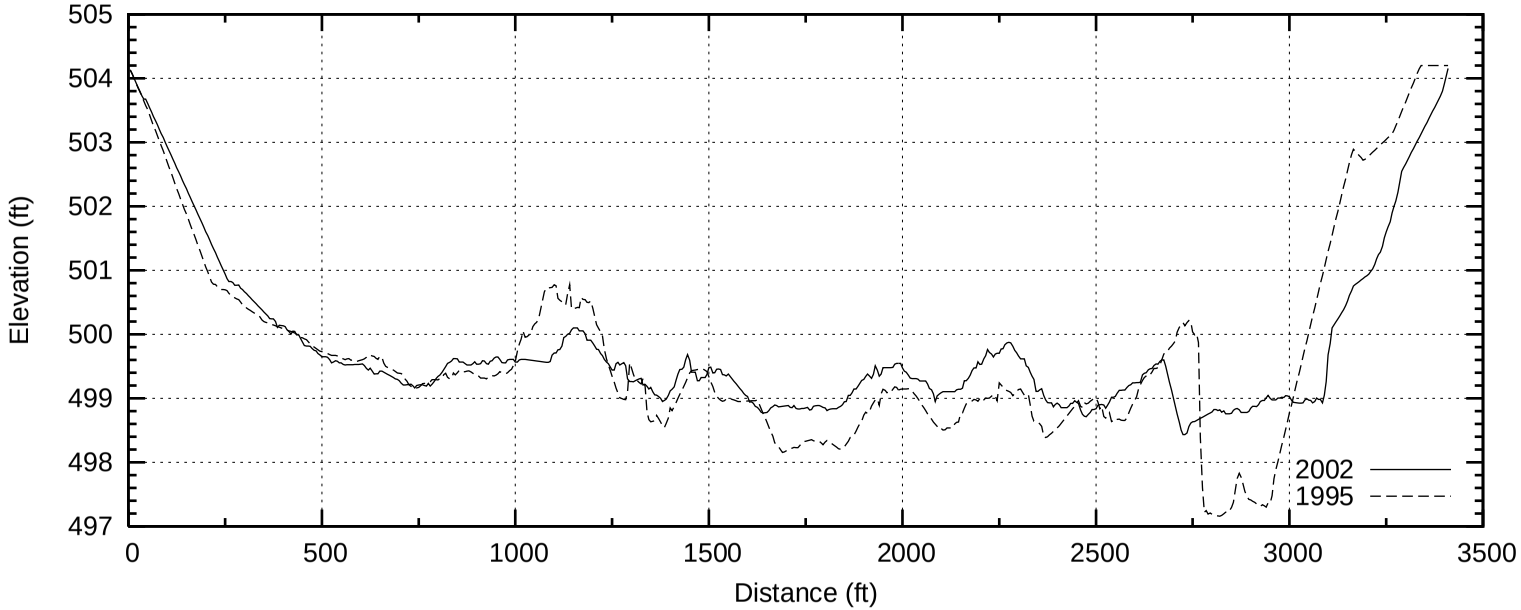


Rangeline SR06

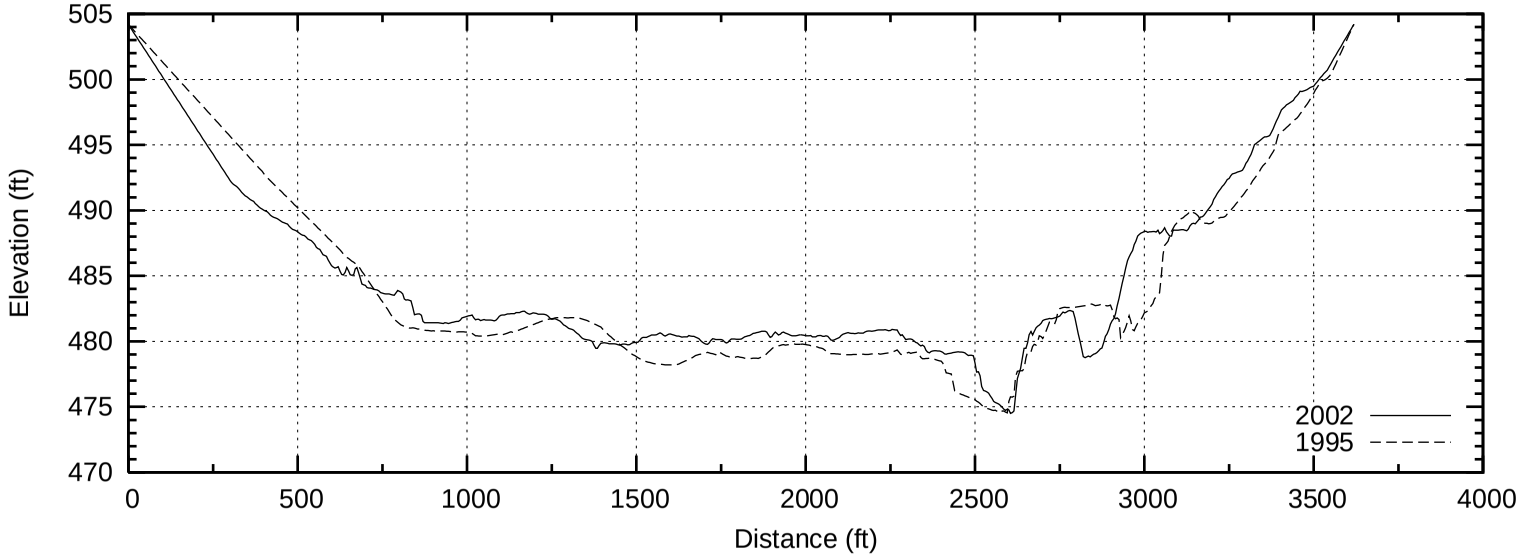


Granger Lake

Rangeline SR07

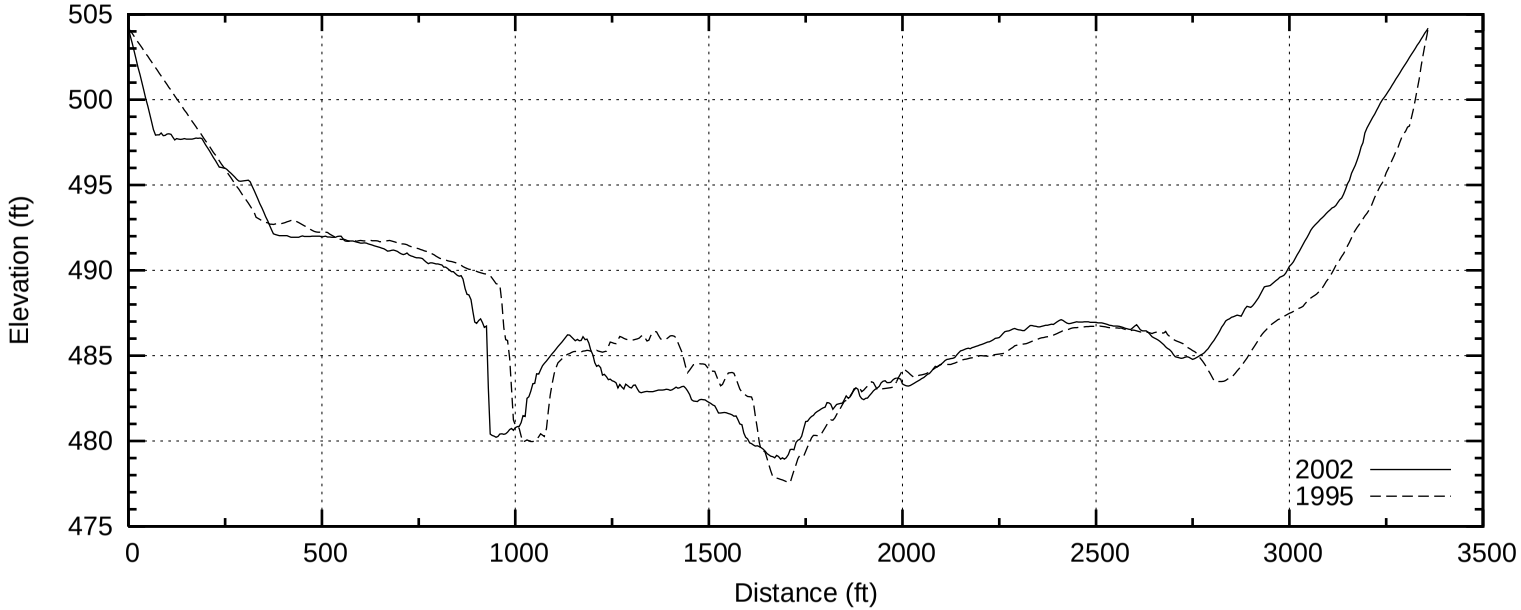


Rangeline SR08

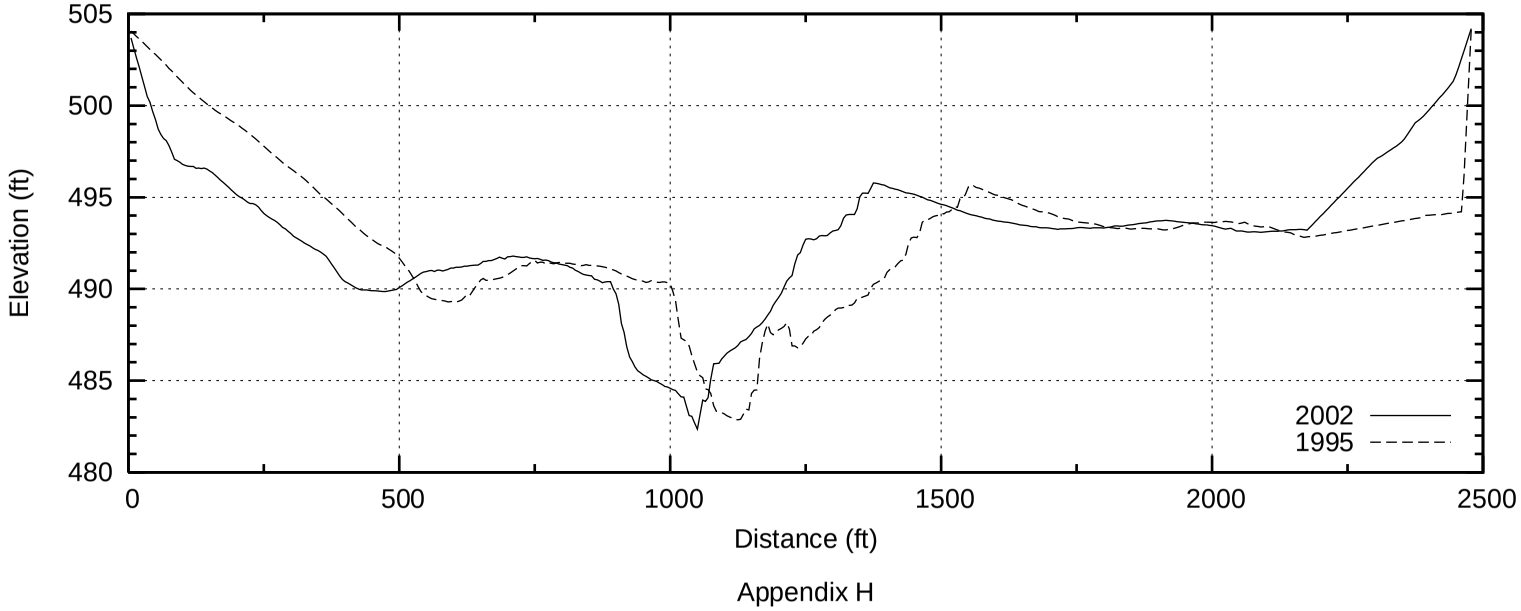


Granger Lake

Rangeline SR09

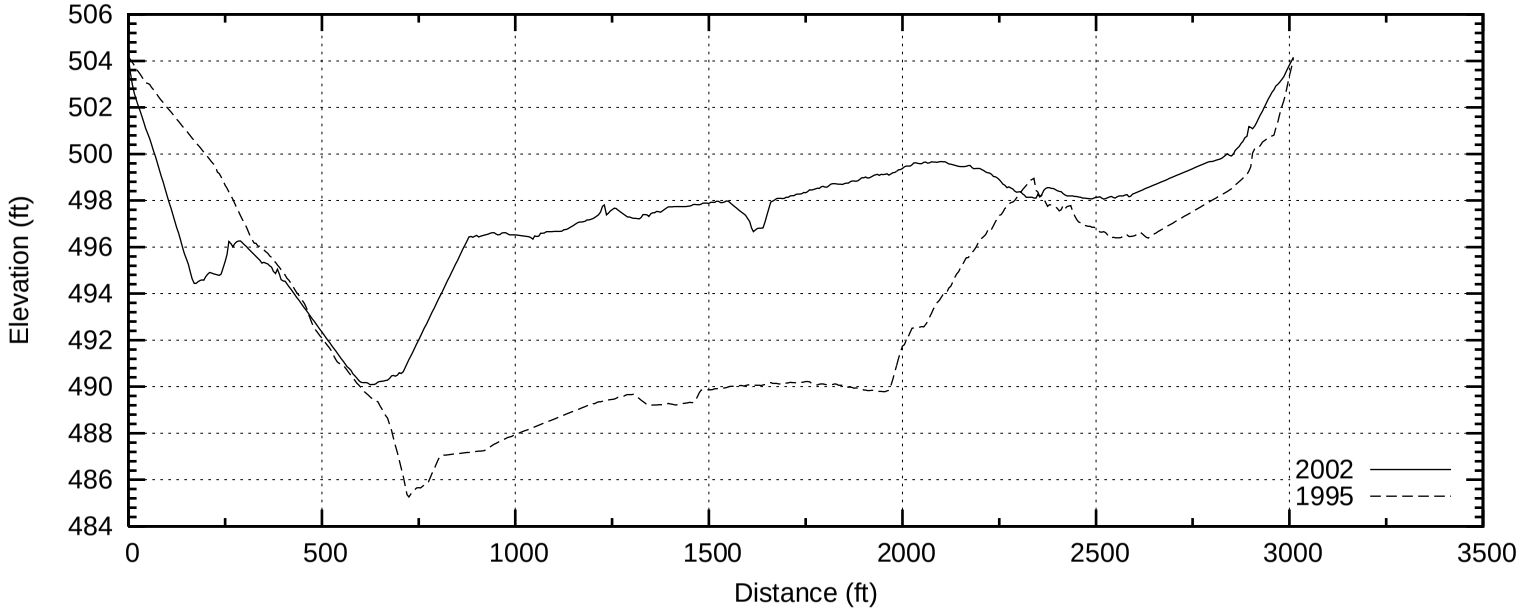


Rangeline SR10

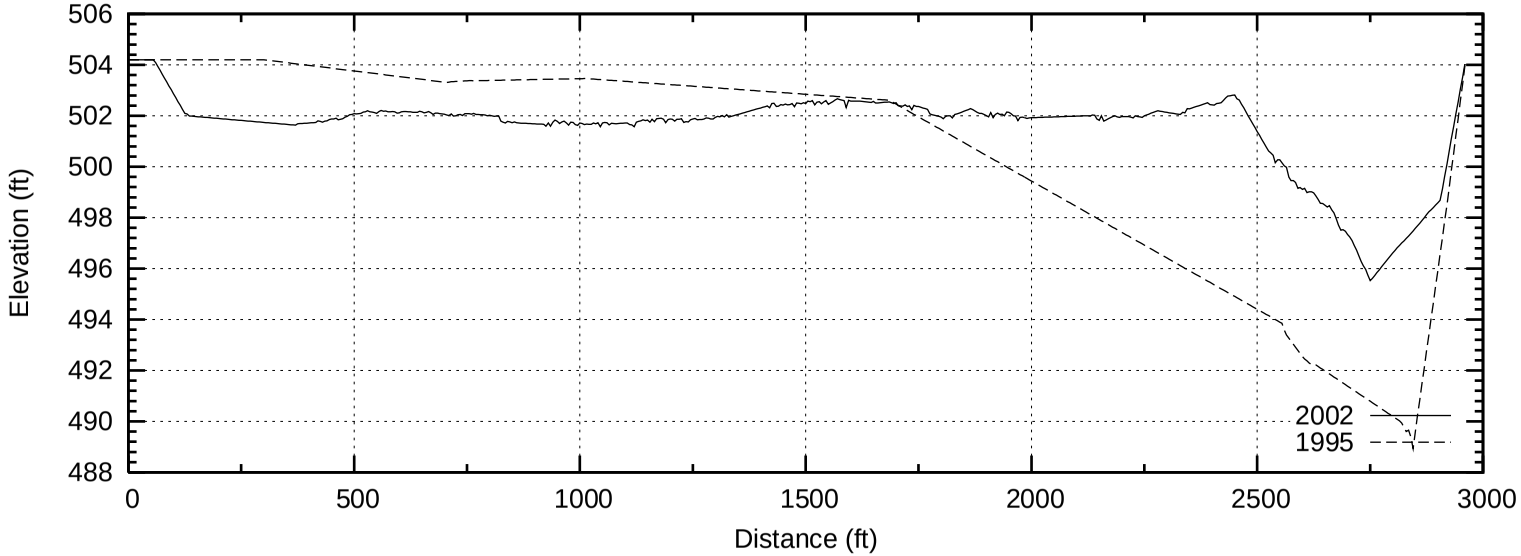


Granger Lake

Rangeline SR11



Rangeline SR12



Granger Lake

Rangeline SR13

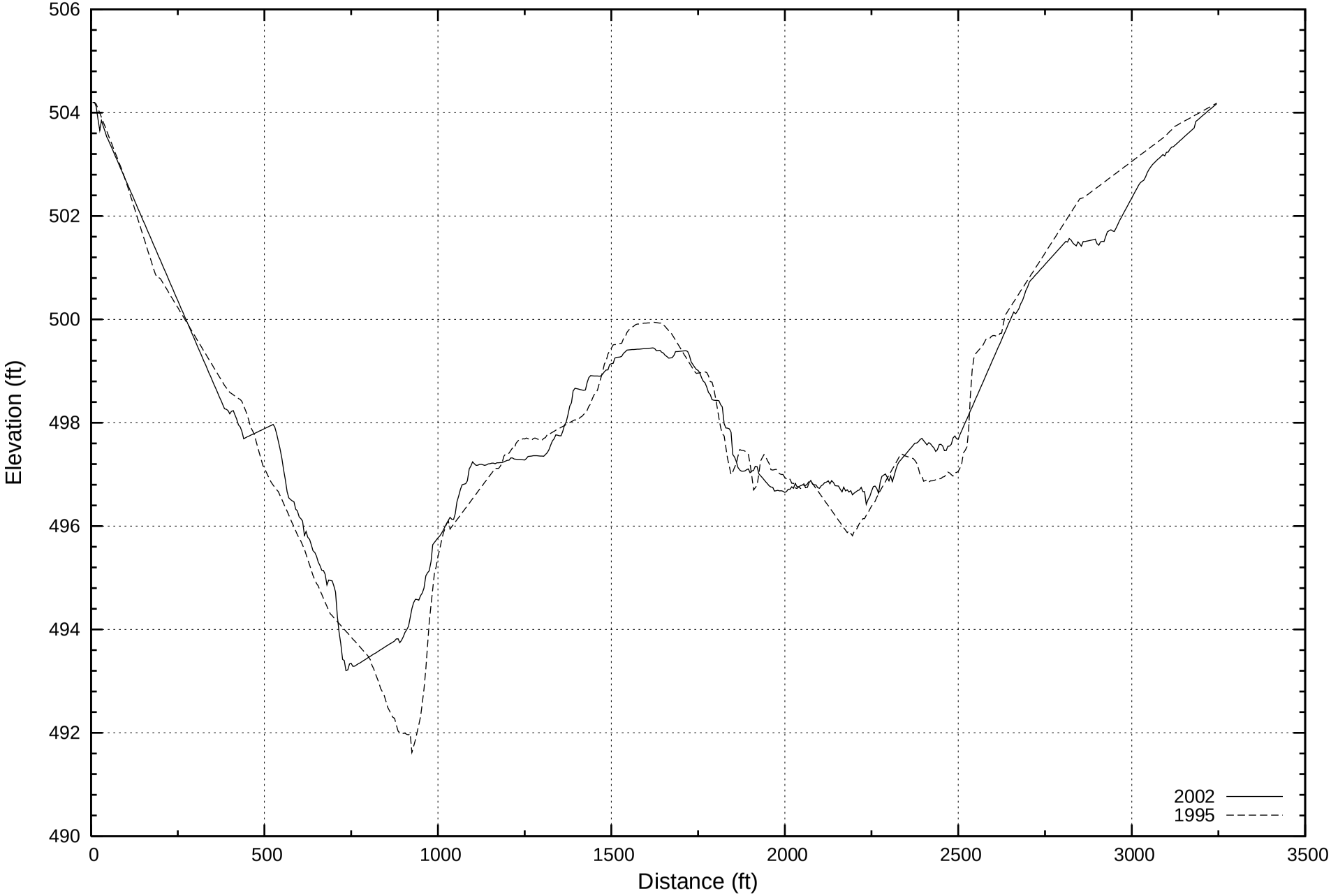
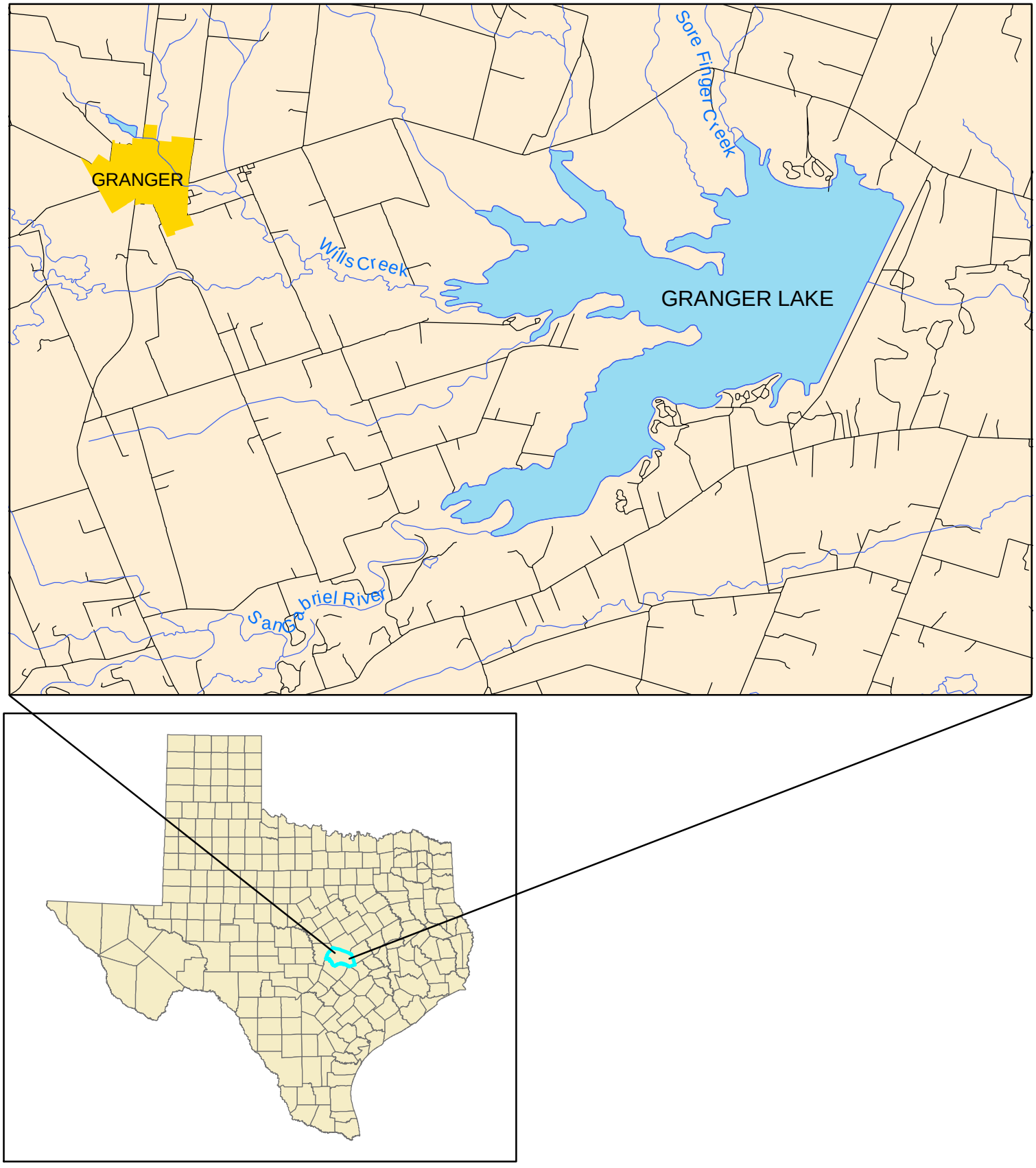


Figure 1

GRANGER LAKE

Location Map

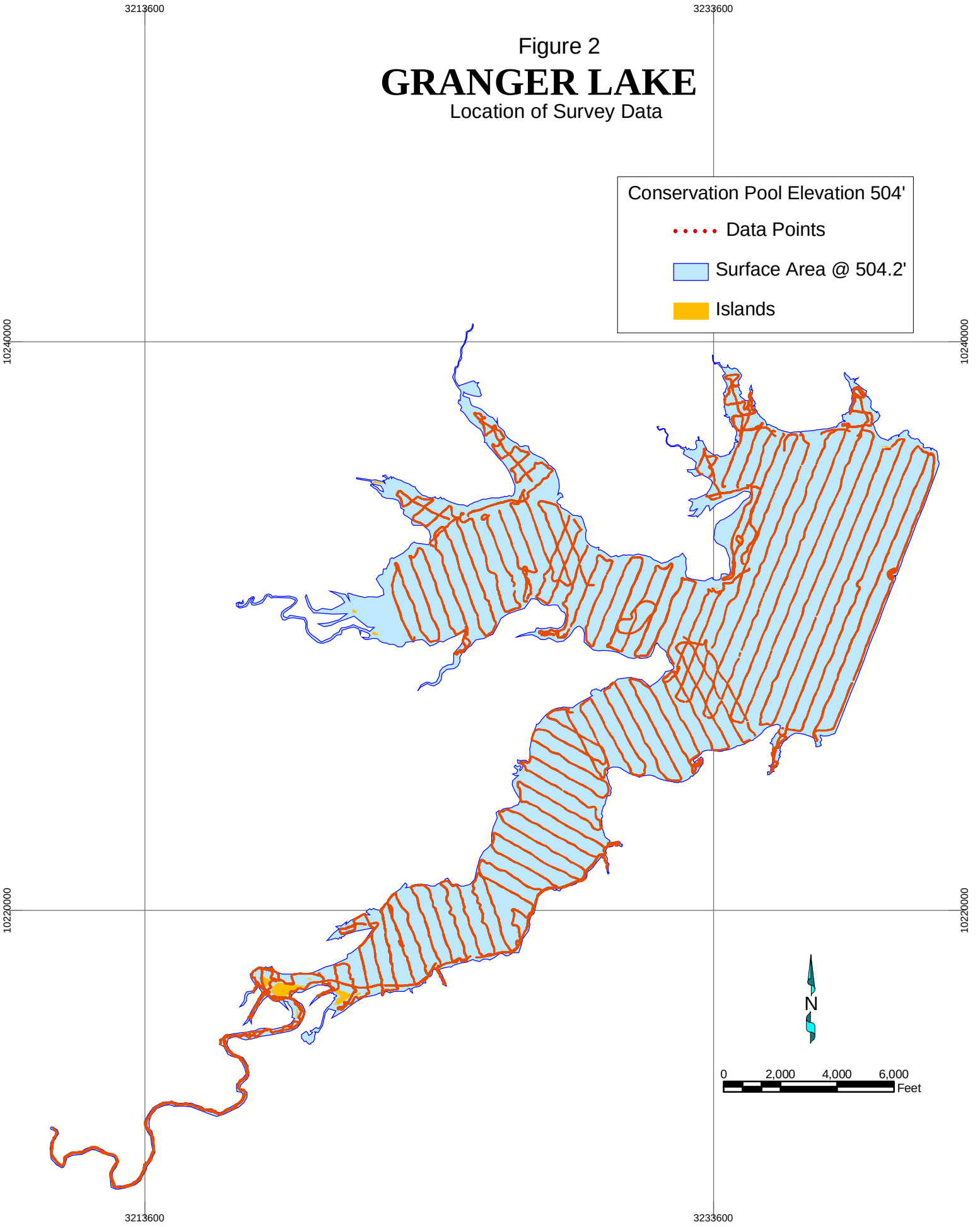


TWDB Survey April 2002

Figure 2

GRANGER LAKE

Location of Survey Data

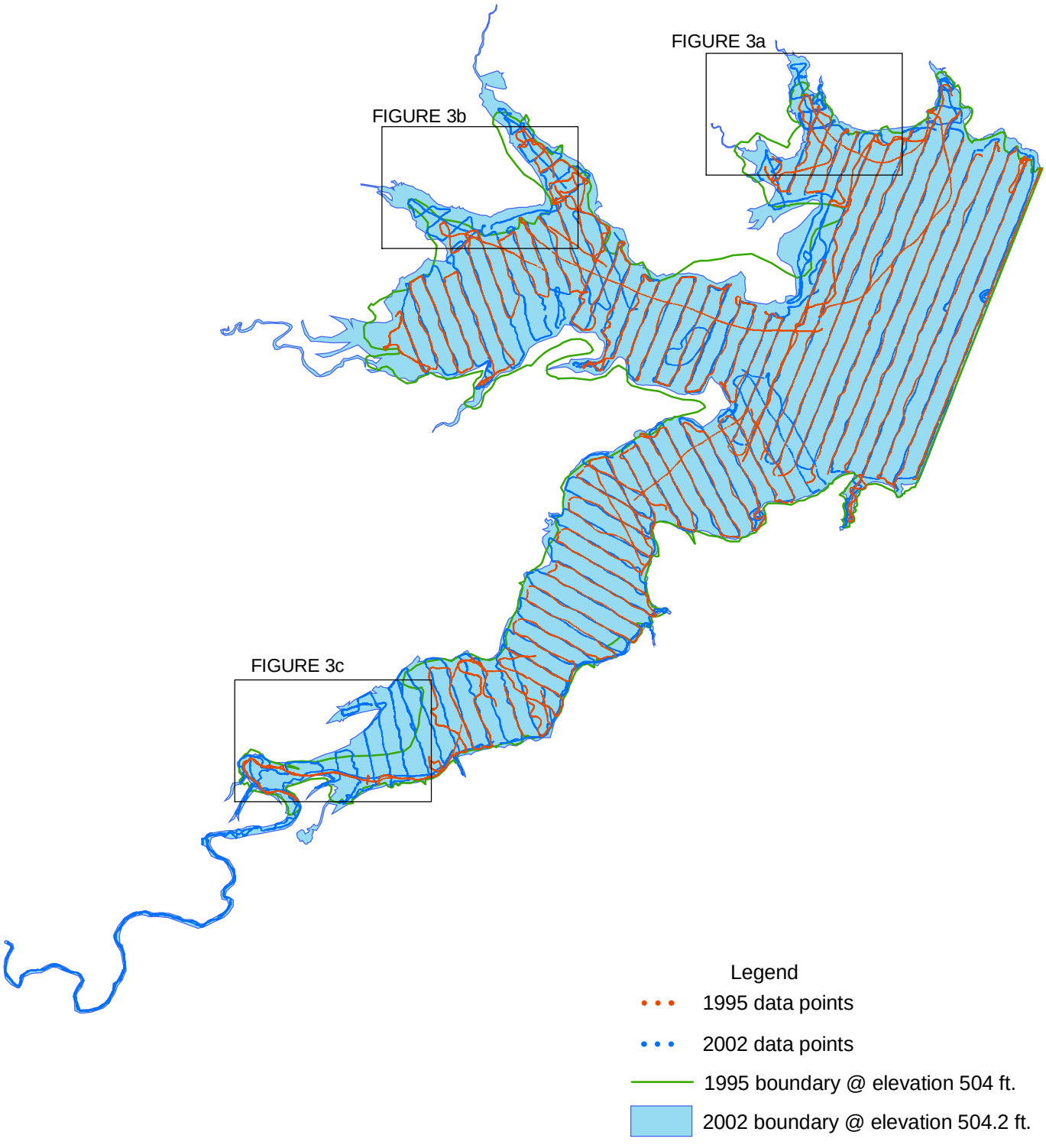


TWDB Survey May 2002

FIGURE 3

GRANGER LAKE

1995 and 2002 Boundaries and Data



TWDB 1995 and 2002

GRANGER LAKE

1995 and 2002 Boundaries and Data

FIGURE 3a

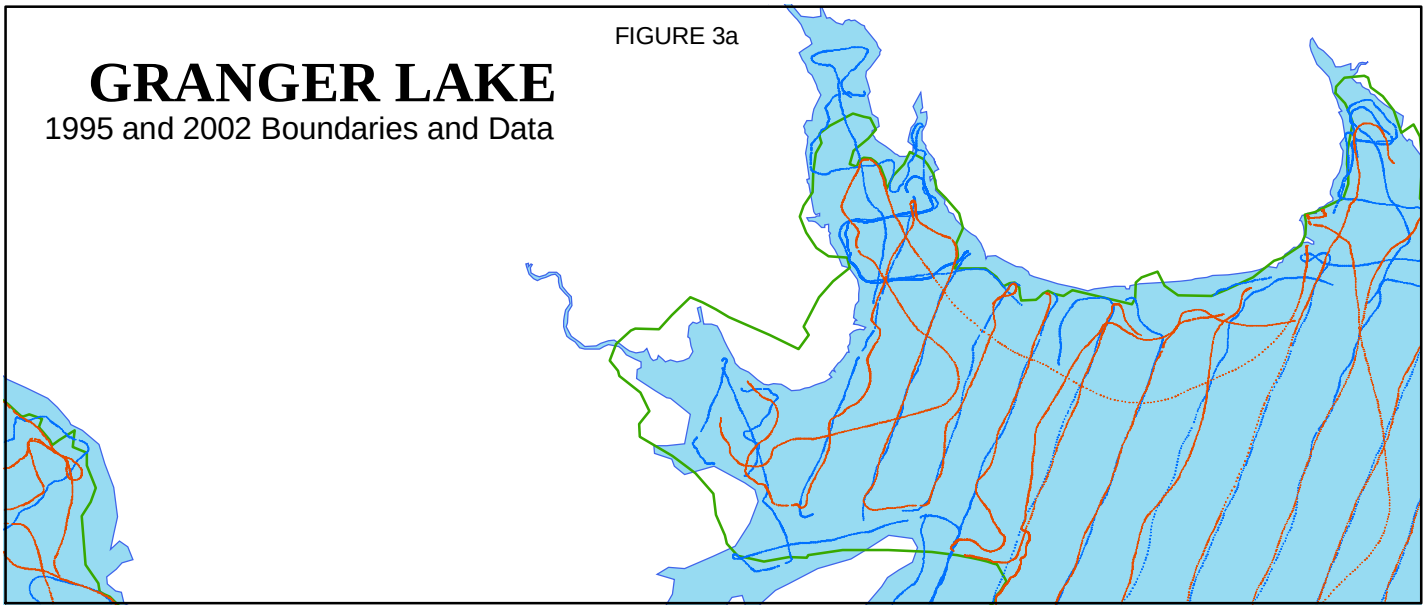


FIGURE 3b

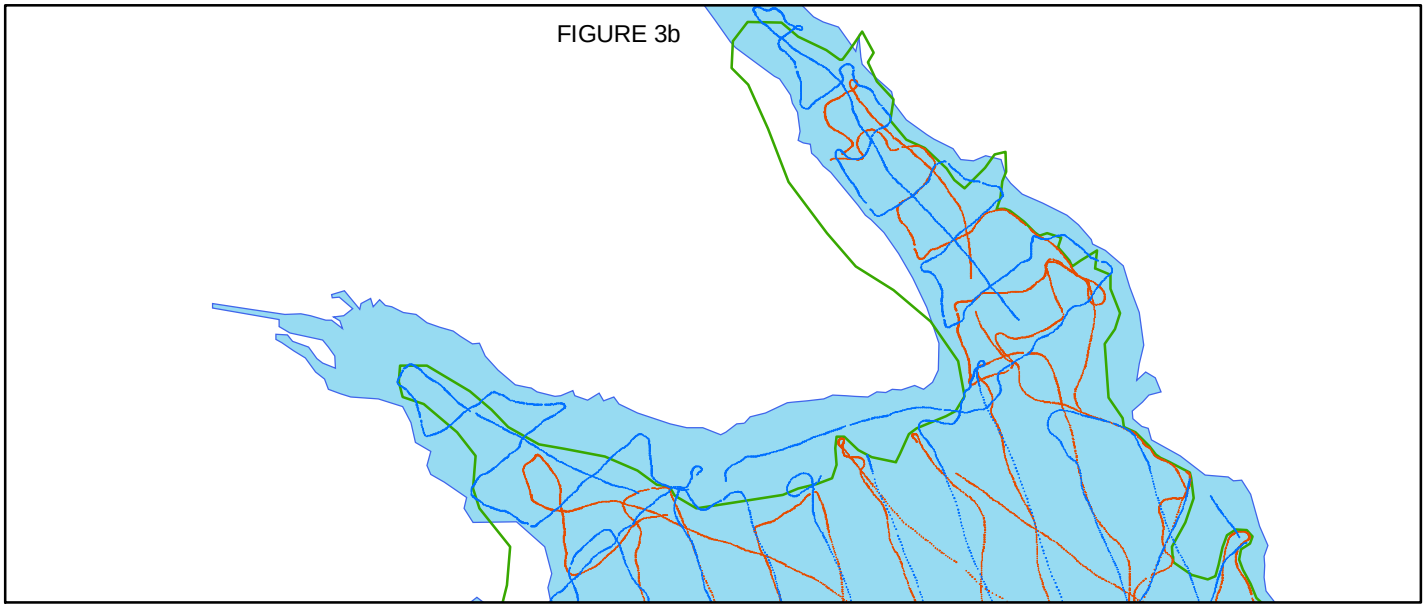
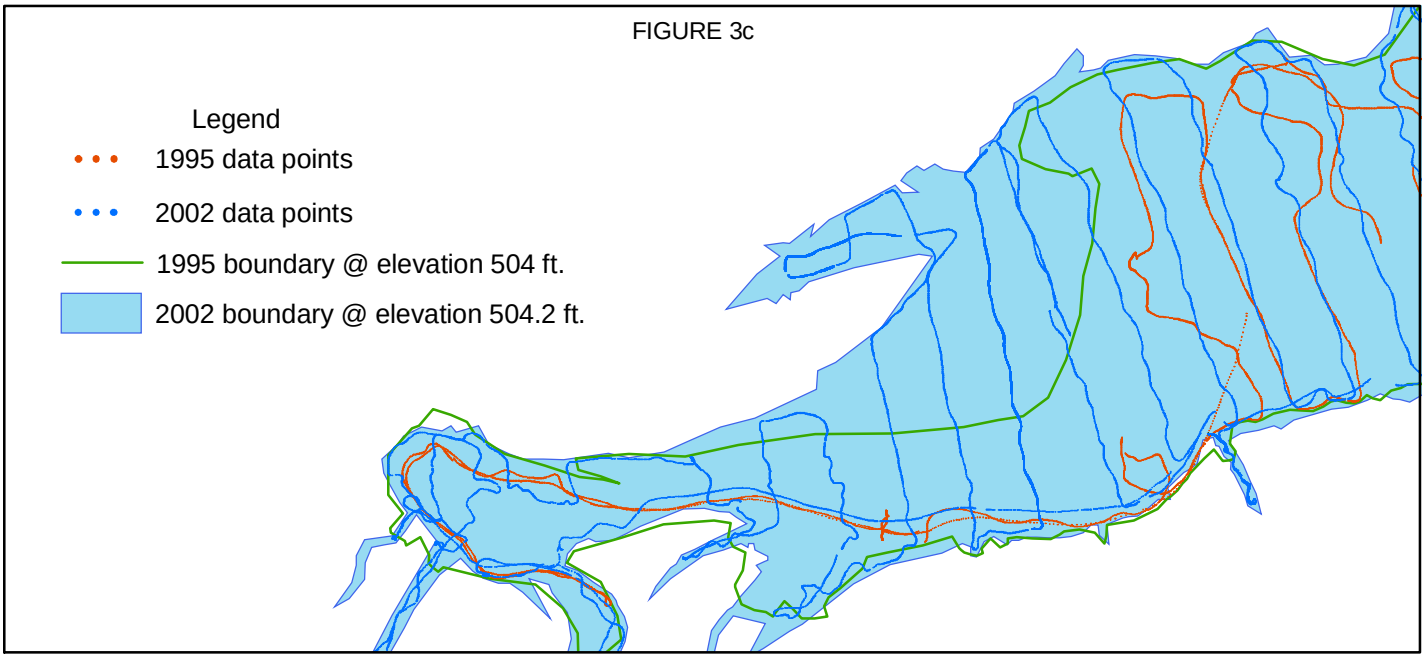


FIGURE 3c



TWDB 1995 and 2002

Figure 4

GRANGER LAKE

2' - Contour Map

N

1,500 750 0 1,500 3,000 Feet

Water Surface @ 504.2'

Islands

Elevation 504.2'

Cross Sections

Top of Conservation Pool 504.0'

Contours

470

472

474

476

478

480

482

484

486

488

490

492

494

496

498

500

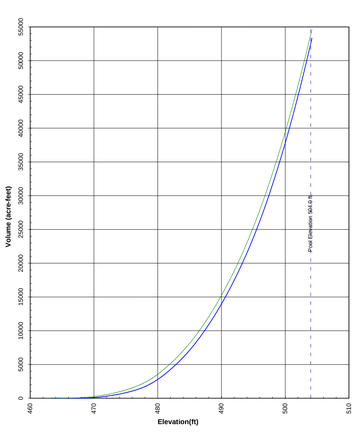
502

504

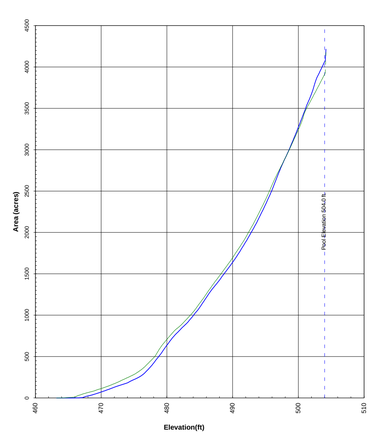
3220000 3230000 3240000

10240000 10230000 10220000 10210000

RL-13-L RL-2-L RL-1-L RL-6-L RL-7-L RL-5-L RL-4-L RL-3-L RL-13-R RL-5-R RL-6-R RL-7-R RL-4-R RL-8-L RL-9-L RL-2-R RL-1-R RL-3-R RL-8-R RL-9-R RL-10-L RL-11-L RL-12-L RL-10-R RL-11-R RL-12-R



Appendix E Elevation vs. Volume



Appendix F Elevation vs. Area

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

PROJECTION:

NAD_1983_StatePlane_Texas_Central_FIPS_4203_Feet
Lambert_Conformal_Conic
False_Easting: 2296583.333333
False_Northing: 9842500.000000
Central_Meridian: -100.333333
Standard_Parallel_1: 30.116667
Standard_Parallel_2: 31.883333
Latitude_Of_Origin: 29.666667

TEXAS WATER DEVELOPMENT BOARD APRIL 2002 SURVEY