VOLUMETRIC SURVEY REPORT

OF

LAKE LIMESTONE

APRIL 2002 SURVEY

Prepared by the:

TEXAS WATER DEVELOPMENT BOARD

July 2003

Prepared for:

Brazos River Authority

In cooperation with the

United States Army Corps of Engineers

Staff of the Surface Water Availability Section prepared this report:

Barney Austin, Ph.D.

Duane Thomas
Randall Burns
Marc Sansom
Heidi Moltz

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

TABLE OF CONTENTS

INTRODUCTION....1

PERTINENT DATA....2

VOLUMETRIC SURVEYING TECHNOLOGY....4

PRESURVEY PROCEDURES....5

SURVEY PROCEDURES....6

  Equipment Calibration and Operation....6

  Data Collection....8

  Data Processing....9

RESULTS....11

SUMMARY AND COMPARISONS....11

REFERENCES....13

APPENDICES

APPENDIX A - VOLUME TABLE 2002
APPENDIX B - VOLUME TABLE 1993 (Revised)
APPENDIX C - AREA TABLE 2002
APPENDIX D - AREA TABLE 1993 (Revised)
APPENDIX E - ELEVATION-VOLUME GRAPH
APPENDIX F - ELEVATION-AREA GRAPH
APPENDIX G - RANGELINE ENDPOINTS
APPENDIX H - RANGELINE PLOTS

LIST OF FIGURES

FIGURE 1 - LOCATION MAP
FIGURE 2 - LOCATION OF SURVEY DATA
FIGURE 3 - CONTOUR MAP

LIST OF TABLES

TABLE 1 - STERLING C. ROBERTSON DAM AND LAKE LIMESTONE PERTINENT DATA
TABLE 2 - AREA AND VOLUME COMPARISONS.

VOLUMETRIC SURVEY REPORT
ON LAKE LIMESTONE
SURVEY OF APRIL 2002

INTRODUCTION

Staff of the Surface Water Availability Section of the Texas Water Development Board (TWDB) conducted a volumetric survey of Lake Limestone during the period of April 11, 2002 through April 25, 2002. The primary purpose of the survey was to determine the current volume of the lake at conservation pool elevation (cpe). The results of the current survey will be compared to the baseline survey performed by TWDB in May of 1993. 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 Lake Limestone. The station number and name is 08110470 Lk Limestone near Marquez, TX. The datum for this gage is reported as mean sea level (msl) (NGVD29) (TWDB, 1993). 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 USGS gage.

Original design information for Lake Limestone was based on information furnished by Brazos River Authority (BRA). The equipment and methodology used in the current survey was similar to that used in the May 1993 survey. Please refer to the Volumetric Survey of Lake Limestone (TWDB September 23,1993) for more information.

PERTINENT DATA

Owner of Dam and Facilities:

BRA

Operator of Dam and Facilities:

BRA

Engineer and General Contractor

USR/Forrest and Cotton, Inc. (Engineer)

Texas Bitulithic Company (General Contractor)

Location:

Lake Limestone is located in Leon, Limestone and Robertson Counties, on the Navasota River a tributary of the Brazos River, approximately 18 miles west of Buffalo, TX. (Figure 1).

Authorization:

State: Certificate of Adjudication 12-5165 issued December 14, 1987 currently authorizes the owner to maintain an existing dam and reservoir and impound not to exceed 225,400 ac-ft of water at elevation 363.0 ft. A priority right was authorized to divert and use a maximum of 65,074 ac-ft of water annually for municipal, industrial, irrigation and mining purposes. For purposes of the system operation, the owner was authorized to exceed the priority right and to annually divert and use from Lake Limestone a maximum of 69,500 ac-ft of water for municipal use, 77,500 ac-ft of water for industrial use, 70,000 ac-ft of water if irrigation and 500 ac-ft of water for mining use. All diversions and uses of water from Lake Limestone in excess of 65,074 ac-ft per year would be charged against the sum of the amounts designated as priority rights in other reservoirs within the Brazos River Basin included in the System Operation Order. The owner was also authorized to use the impounded waters in Lake Limestone for nonconsumptive recreational use. Additional information on amendments to the Certificates of Adjudication and other matters relating to the water rights of Lake Limestone can be found at the Records Division of the Texas Commission on Environmental Quality.

Drainage area:

675 square miles

Dam:

Type	Rolled earthfill
Length	11,395 ft (including spillway)
Maximum Height	78 ft (at streambed)
Top Width	20 ft

Spillway:

Type	Broad-crested weir
Control	Uncontrolled
Length	3,000 ft

Outlet works:

Type	Gated ogee weir and stilling basin
Dimensions	200 ft long
Floodgate invert elevation	337.0 ft
Control	Five 40-ft by 28-ft tainter gates and two 4-ft x 8-ft slide gates in each of the two center piers that discharge to the stilling basin.
Low-flow outlet	One 10-in cast iron pipe in the left pier and two 36-in (O.D.) steel cylinder pipes located in the right pier.
Invert elevations	325.5 ft
Lowest gated invert	322.0 ft (reported as 320.0 ft in 1993)

Reservoir Data:

FEATURE	ELEVATION (Ft)	CAPACITY (Ac-ft)	AREA (ac)
Top of conservation storage space [1]	363.0	215,751	13,379
Invert of Lowest Intake for low flow and water supply release [1]	325.5	682	438
Lowest Gated Outlet (invert) [1]	320.0	3	3
Usable Conservation Storage Space [1]	363.0	215,748	13,379

1. Information at elevation 363.0 ft and below based on 1993 area and capacity data from the Texas Water Development Board (1993).

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 a 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 (range 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 products produced for the Department of Information Resources and the GIS Planning Council under the Texas Orthoimagery Program reside in the public domain. More information can be obtained on the Internet at http://www.tnris.state.tx.us/DigitalData/doqs.htm.

The water level elevations, at the time the DOQ's were photographed (February 6, 1995, March 8, 1995, January 24, 1996 and January 27, 1996) were 362.72 ft, 362.90 ft, 362.15 ft and 362.15 ft respectively. Approximately two-thirds of the total surface of the boundary was digitized from photos that were at or above elevation 362.72 ft. The boundary was inspected against the collected data points and digitized versions of USGS 7.5 minute topographic maps (DRG's) and adjusted to include all the data points collected during the 2002 field survey. The lake and island boundaries were given an elevation of 363.0 ft and TWDB Staff utilized these updated boundary conditions in modeling Lake Limestone for this report.

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 300 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 Lake Limestone 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 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. Basically, 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. 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 ranged from 4,838 ft per second to 4,890 ft per second during the Lake Limestone 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 Lake Limestone for approximately 8 days during the period of April 11th through April 25th, 2002. The lake level elevations varied between 363.18 ft and 363.41 ft, thus allowing the survey crew to collect data in most areas of the lake that would be inundated at conservation pool elevation 363.0 ft.

The design layout for collecting data at Lake Limestone 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 distance between data points depended on the speed of the boat. The maximum distance between data points on any one range line during the resurvey of Lake Limestone was approximately 30 ft.

Approximately 118,730 data points were collected over the 280 miles traveled during the data collection phase of Lake Limestone. The crews collected data on approximately 290 of the 300 pre-plotted transects that were designed for the survey. These points were stored digitally on the boat's computer in 376 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. During the survey, the water level elevation varied from 363.41 ft on April 11, 2002 to 363.16 ft on April 16, 2002 and had returned to 363.29 ft on April 25, 2002 the final day of the survey (USGS gage #08110470). 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. The surface areas and volumes of the lake from elevation 319.5 ft to 363.0 ft, were computed using Arc/Info software. The computed lake volume table is presented in Appendix A and the area table in Appendix C for Lake Limestone. The 1993 lake volume and area tables were revised using the updated 2002 boundary conditions 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 3. Finally, endpoint coordinates for 31 range lines can be found in Appendix G. These range line were used in comparing the current 2002 TWDB bathymetric TIN model and the TIN model based on the 1993 data using the current boundary conditions. These range line plots are presented in Appendix H. 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 1993 survey and in the methodology that Arc/Info uses to interpolate between points in developing the TIN model.

RESULTS

Results from the 2002 TWDB resurvey indicate Lake Limestone encompasses 12,553 surface acres and contains a total volume of 208,017 ac-ft at the conservation pool an elevation of 363.0 ft. The length of the shoreline at the digitized elevation of 363.0 ft was calculated to be 122 miles. The deepest point physically measured during the survey was at elevation 319.5 ft corresponding to a depth of 43.5 ft below cpe and was located approximately 2,110 ft upstream of Sterling C. Robertson Dam.

SUMMARY AND COMPARISONS

Sterling C. Robertson Dam was completed in 1978 and deliberate impoundment began on October 16, 1978. Original design information is based on a 1979 Texas Department of Water Resources correspondence. The original capacity (225,400 ac-ft) of Lake Limestone is based on Certificate of Adjudication 12-5165 and was a change from the original design capacity 217,494 ac-ft. The most recent survey report on Lake Limestone was published by the TWDB and based on a 1993 volumetric survey. In this report, the results of that survey have been revised based on more accurate boundary information.

At conservation pool elevation 363.0 ft, the 2002 TWDB survey measured 12,553 surface acres and reports a volume of 208,017 ac-ft of water. The capacity of the active pool (conservation storage) between elevations 322 ft and 363 ft is 208,015 ac-ft of water. The inactive pool, between elevation 322 ft and 319.5 ft has a capacity of 2 ac-ft. The dead pool storage or that capacity of water below the invert of the lowest outlet (elevation 322 ft) was 2 ac-ft of water.

The 1993 elevation-area-capacity table indicates that Lake Limestone had a volume of 215,748 ac-ft of water and a surface area of 13,379 ac. at conservation pool elevation 363.0 ft. The 1993 results were recalculated using boundary estimates from 1995 and 1996 DOQ's and the 1993 TWDB survey data set. The 1993-revised elevation-area-capacity indicates that Lake Limestone had a volume of 214,827 ac-ft of water and a surface area of 12,553 ac. at conservation pool elevation 363.0 ft. A comparative summary of the historical data and the results of the TWDB 2002 resurvey are presented in Table 2.

Comparisons between the USACE historical sediment surveys 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 Lake Limestone

	Original Design **1979**	TWDB Volumetric Survey **Revised 1993**	TWDB Volumetric Survey **2002**
Area (ac)	14,200	12,553	12,553
Total Volume (ac-ft)	225,400	214,827	208,017
Conservation Pool storage capacity (ac-ft)		214,825	208,015
Dead Pool storage capacity (ac-ft)	0	2	2

Notes:
1. All results for top of conservation pool elevation 363.0 ft
2. Conservation storage capacity (1993) is between elevations 636.0 and 620.0 ft. (2002) is between 636.0 ft. and 622.0 ft.
3. Dead Pool storage (1993) is that below elevation 620.0 ft
4. Dead Pool Storage (2002) is below elevation 622.0 ft.
5. 1993 TWDB volume and area revised with new boundary
6. Original design data obtained from Texas Commission on Environmental Quality records.

REFERENCES

1. United States Geological Survey. 2001. Water Data Report TX-01-3. “Water Resources Data Texas Water Year 2001”
2. Texas Water Commission, 1974, Permit No. 2950
3. Texas Water Commission, 1979, Permit No. 2950A
4. Texas Water Commission, 1979, Permit No. 2950B
5. Texas Water Commission, 1980, Permit No. 2950C
6. Texas Water Commission, 1987, Certificate of Adjudication 12-5165
7. Texas Water Development Board, 1993, “Volumetric Survey of Lake Limestone”

Appendix A

Lake Limestone

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
319						0	0	0	0	0
320	0	0	0	0	0	0	0	0	0	0
321	0	0	0	0	0	0	1	1	1	2
322	2	3	5	7	10	13	17	21	26	33
323	39	47	56	65	76	88	102	118	135	154
324	175	198	223	249	277	307	338	371	405	441
325	478	517	557	600	644	690	737	786	837	890
326	944	1000	1058	1117	1177	1240	1304	1370	1437	1506
327	1577	1650	1725	1803	1883	1966	2052	2139	2228	2320
328	2413	2507	2604	2702	2803	2905	3010	3116	3223	3333
329	3445	3558	3674	3792	3912	4033	4156	4282	4409	4539
330	4671	4804	4939	5076	5215	5356	5499	5643	5789	5937
331	6087	6238	6392	6547	6704	6863	7024	7187	7352	7519
332	7688	7859	8032	8207	8384	8563	8746	8932	9121	9313
333	9508	9706	9907	10110	10316	10525	10736	10950	11165	11384
334	11604	11827	12053	12280	12510	12742	12976	13213	13452	13693
335	13938	14185	14436	14689	14944	15203	15464	15729	15996	16266
336	16539	16814	17093	17374	17657	17943	18231	18521	18813	19107
337	19404	19702	20003	20306	20611	20918	21227	21539	21852	22167
338	22484	22803	23124	23447	23772	24098	24427	24757	25090	25424
339	25760	26099	26438	26780	27123	27468	27815	28164	28515	28868
340	29224	29581	29941	30303	30667	31035	31405	31778	32154	32532
341	32914	33298	33686	34076	34468	34864	35263	35665	36070	36478
342	36889	37303	37720	38140	38563	38990	39420	39855	40294	40738
343	41186	41639	42097	42560	43028	43501	43978	44459	44943	45432
344	45924	46419	46918	47420	47925	48434	48947	49462	49982	50504
345	51029	51558	52089	52624	53161	53702	54245	54793	55344	55899
346	56458	57021	57588	58158	58732	59311	59893	60479	61068	61661
347	62257	62857	63462	64071	64684	65303	65925	66551	67180	67814
348	68450	69090	69733	70378	71026	71678	72332	72990	73650	74314
349	74982	75653	76328	77005	77686	78370	79057	79746	80439	81134
350	81833	82534	83239	83948	84660	85376	86095	86819	87545	88276
351	89011	89749	90491	91237	91987	92742	93502	94266	95035	95809
352	96588	97371	98160	98953	99752	100556	101365	102178	102994	103816
353	104641	105469	106302	107138	107978	108821	109669	110521	111376	112235
354	113097	113964	114833	115707	116584	117465	118350	119239	120133	121031
355	121933	122840	123751	124667	125587	126510	127437	128368	129303	130242
356	131184	132131	133080	134033	134990	135951	136915	137883	138855	139831
357	140812	141796	142785	143778	144775	145777	146784	147795	148811	149832
358	150859	151890	152926	153967	155012	156063	157118	158178	159243	160313
359	161388	162467	163552	164642	165738	166839	167945	169056	170173	171295
360	172421	173553	174689	175830	176976	178126	179281	180439	181601	182766
361	183936	185109	186286	187466	188650	189837	191028	192221	193417	194617
362	195820	197026	198235	199446	200661	201880	203101	204325	205552	206783
363	208017									

Appendix B

Lake Limestone

RESERVOIR VOLUME TABLE

TEXAS WATER DEVELOPMENT BOARD | MAY 1993 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
317						0	0	0	0	0
318	0	0	0	0	0	0	0	0	0	0
319	1	1	1	1	1	1	1	2	2	2
320	2	3	3	3	4	4	5	5	6	6
321	7	8	9	10	11	12	13	14	15	17
322	19	21	24	27	30	35	39	44	50	56
323	63	71	80	89	100	112	125	140	156	174
324	193	214	237	262	289	317	346	378	410	445
325	481	518	557	597	639	682	726	773	821	871
326	922	976	1031	1089	1148	1210	1274	1340	1408	1478
327	1551	1626	1703	1783	1864	1949	2036	2125	2217	2310
328	2405	2502	2601	2701	2804	2909	3015	3124	3235	3348
329	3463	3581	3701	3823	3948	4074	4203	4334	4467	4602
330	4739	4879	5020	5163	5307	5453	5601	5751	5902	6056
331	6211	6368	6528	6690	6854	7021	7190	7361	7534	7710
332	7888	8069	8252	8438	8626	8817	9011	9207	9405	9607
333	9810	10017	10225	10435	10648	10863	11081	11301	11524	11750
334	11978	12209	12443	12679	12918	13159	13404	13652	13902	14156
335	14412	14671	14933	15198	15466	15737	16011	16287	16567	16849
336	17133	17420	17709	18000	18293	18588	18886	19185	19487	19790
337	20096	20404	20714	21025	21339	21654	21972	22292	22613	22936
338	23261	23588	23917	24247	24579	24913	25249	25587	25926	26268
339	26612	26958	27306	27656	28008	28363	28720	29079	29441	29805
340	30172	30541	30913	31288	31665	32045	32428	32814	33203	33596
341	33992	34390	34792	35196	35604	36014	36427	36843	37261	37683
342	38107	38534	38963	39396	39832	40270	40713	41159	41608	42063
343	42522	42986	43455	43928	44406	44888	45375	45865	46360	46858
344	47359	47863	48371	48881	49395	49912	50433	50957	51484	52015
345	52549	53087	53628	54173	54723	55276	55833	56394	56959	57530
346	58105	58683	59266	59852	60442	61036	61634	62235	62841	63450
347	64064	64681	65302	65927	66555	67187	67823	68462	69105	69750
348	70400	71053	71710	72369	73033	73700	74370	75045	75724	76407
349	77095	77786	78482	79182	79886	80594	81306	82022	82743	83467
350	84195	84927	85663	86403	87147	87894	88645	89400	90158	90921
351	91688	92460	93235	94015	94799	95587	96380	97178	97980	98786
352	99596	100411	101231	102054	102883	103715	104551	105391	106235	107083
353	107934	108789	109648	110511	111378	112248	113123	114001	114884	115771
354	116662	117557	118456	119359	120266	121178	122094	123014	123938	124866
355	125798	126733	127672	128614	129560	130510	131464	132422	133383	134349
356	135318	136292	137269	138251	139237	140228	141223	142222	143226	144234
357	145247	146265	147288	148315	149348	150386	151430	152478	153531	154590
358	155653	156720	157793	158870	159952	161039	162130	163226	164327	165434
359	166545	167662	168787	169918	171056	172199	173348	174503	175662	176826
360	177994	179168	180345	181526	182712	183901	185095	186292	187492	188696
361	189904	191116	192331	193549	194771	195997	197226	198459	199695	200936
362	202180	203428	204679	205934	207193	208456	209723	210993	212267	213545
363	214827									

Appendix C

Lake Limestone

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
319						0	0	0	0	0
320	0	0	0	0	0	0	0	0	0	0
321	0	0	0	1	1	1	1	2	4	6
322	10	14	19	24	29	34	41	48	57	65
323	73	82	91	102	114	129	146	165	182	201
324	219	237	255	273	289	305	319	334	349	364
325	380	397	415	433	450	468	484	500	517	535
326	552	566	582	598	616	634	651	667	682	699
327	718	741	764	787	816	843	865	885	904	921
328	938	956	976	996	1015	1034	1051	1068	1086	1105
329	1128	1149	1169	1187	1205	1223	1242	1264	1287	1307
330	1326	1343	1362	1380	1398	1416	1434	1453	1471	1489
331	1506	1525	1544	1563	1581	1600	1619	1640	1661	1680
332	1699	1717	1736	1757	1784	1812	1841	1873	1905	1936
333	1966	1997	2023	2047	2073	2098	2123	2147	2170	2195
334	2218	2241	2263	2286	2309	2332	2355	2378	2403	2432
335	2460	2488	2516	2542	2571	2601	2631	2659	2685	2713
336	2741	2771	2798	2822	2845	2867	2889	2910	2933	2955
337	2975	2997	3019	3040	3061	3083	3102	3122	3142	3162
338	3182	3201	3220	3237	3255	3275	3294	3314	3335	3354
339	3372	3389	3406	3423	3441	3460	3480	3501	3523	3543
340	3564	3585	3606	3632	3659	3687	3716	3744	3773	3802
341	3830	3858	3886	3914	3944	3974	4005	4036	4064	4094
342	4123	4154	4185	4216	4249	4284	4325	4369	4414	4459
343	4506	4552	4604	4658	4708	4750	4789	4827	4864	4900
344	4935	4970	5005	5039	5073	5106	5141	5176	5208	5240
345	5270	5299	5329	5358	5389	5422	5456	5494	5531	5571
346	5610	5646	5683	5722	5765	5806	5841	5875	5909	5943
347	5980	6023	6069	6115	6160	6202	6242	6279	6314	6349
348	6381	6412	6441	6470	6499	6527	6558	6590	6624	6660
349	6695	6728	6761	6792	6823	6853	6882	6911	6940	6969
350	6999	7033	7067	7103	7140	7177	7214	7252	7289	7327
351	7363	7401	7441	7482	7525	7571	7620	7668	7715	7763
352	7810	7859	7910	7962	8014	8063	8107	8149	8191	8231
353	8268	8305	8342	8380	8418	8458	8496	8534	8572	8608
354	8644	8679	8716	8753	8791	8831	8872	8913	8956	9001
355	9047	9093	9135	9177	9216	9253	9290	9329	9368	9406
356	9444	9480	9515	9550	9586	9623	9661	9702	9741	9783
357	9824	9865	9908	9951	9997	10041	10089	10138	10187	10237
358	10287	10337	10386	10432	10479	10527	10578	10626	10674	10723
359	10772	10822	10875	10929	10981	11034	11088	11143	11194	11241
360	11289	11337	11386	11435	11483	11524	11562	11600	11638	11676
361	11714	11751	11787	11821	11854	11886	11918	11950	11981	12012
362	12042	12073	12104	12135	12166	12197	12228	12259	12290	12321
363	12553									

Appendix D

Lake Limestone

RESERVOIR AREA TABLE

TEXAS WATER DEVELOPMENT BOARD

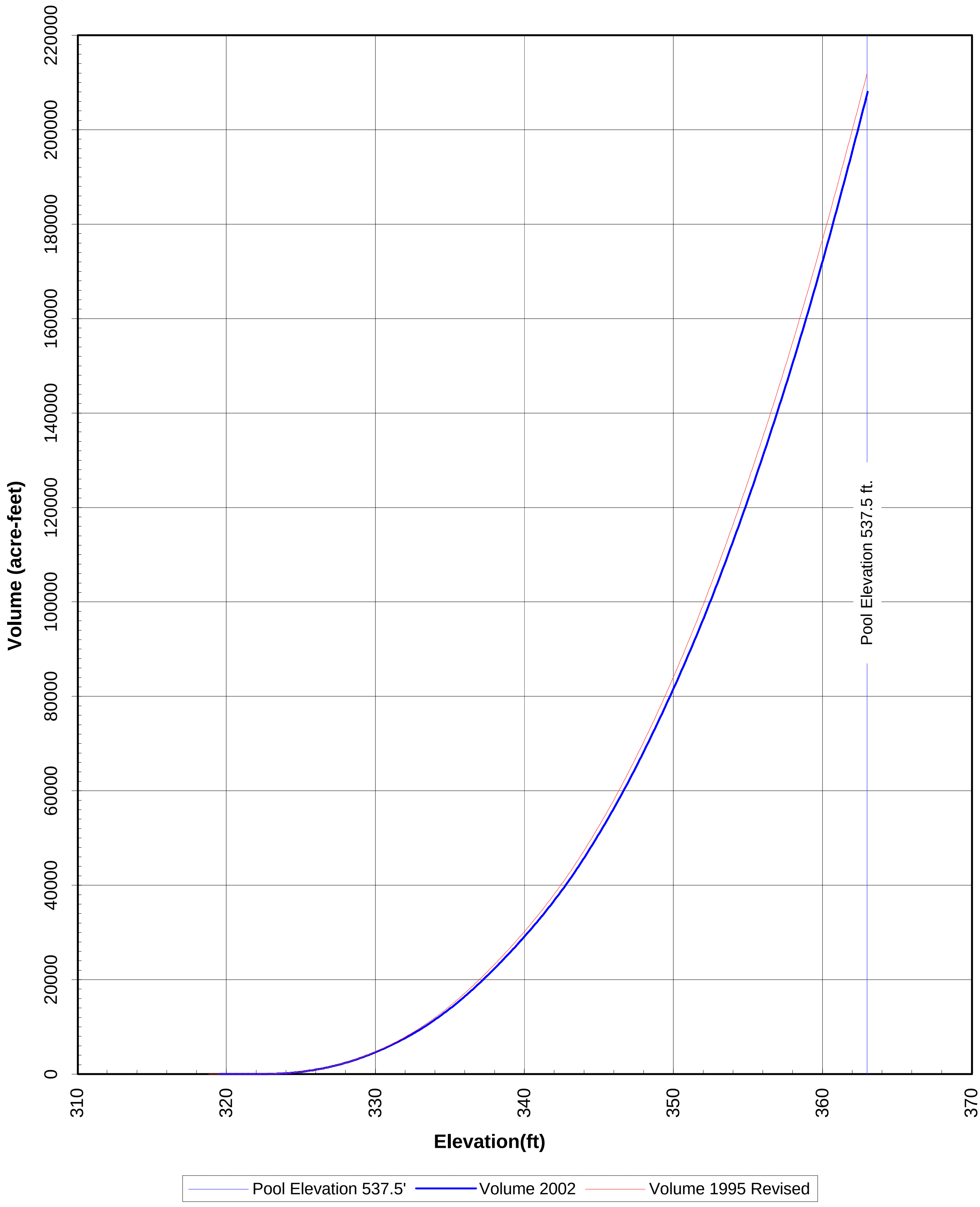
MAY 1993 SURVEY

REVISED

AREA IN ACRES

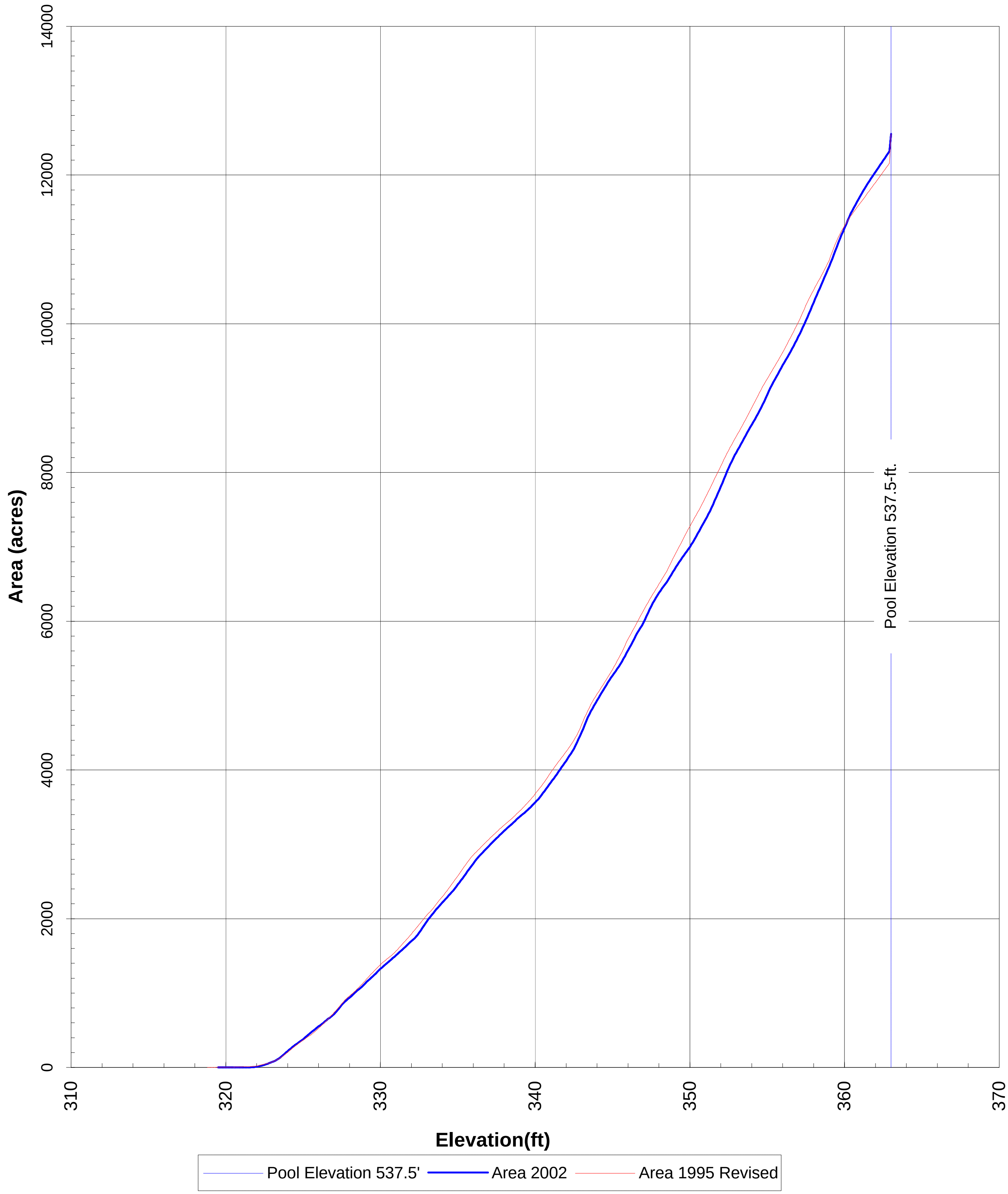
ELEVATION INCREMENT IS ONE TENTH FOOT

ELEVATION in Feet	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
319						0	0	0	0	0
320	0	0	0	0	0	0	0	0	0	0
321	0	0	0	1	1	1	1	2	4	6
322	10	14	19	24	29	34	41	48	57	65
323	73	82	91	102	114	129	146	165	182	201
324	219	237	255	273	289	305	319	334	349	364
325	380	397	415	433	450	468	484	500	517	535
326	552	566	582	598	616	634	651	667	682	699
327	718	741	764	787	816	843	865	885	904	921
328	938	956	976	996	1015	1034	1051	1068	1086	1105
329	1128	1149	1169	1187	1205	1223	1242	1264	1287	1307
330	1326	1343	1362	1380	1398	1416	1434	1453	1471	1489
331	1506	1525	1544	1563	1581	1600	1619	1640	1661	1680
332	1699	1717	1736	1757	1784	1812	1841	1873	1905	1936
333	1966	1997	2023	2047	2073	2098	2123	2147	2170	2195
334	2218	2241	2263	2286	2309	2332	2355	2378	2403	2432
335	2460	2488	2516	2542	2571	2601	2631	2659	2685	2713
336	2741	2771	2798	2822	2845	2867	2889	2910	2933	2955
337	2975	2997	3019	3040	3061	3083	3102	3122	3142	3162
338	3182	3201	3220	3237	3255	3275	3294	3314	3335	3354
339	3372	3389	3406	3423	3441	3460	3480	3501	3523	3543
340	3564	3585	3606	3632	3659	3687	3716	3744	3773	3802
341	3830	3858	3886	3914	3944	3974	4005	4036	4064	4094
342	4123	4154	4185	4216	4249	4284	4325	4369	4414	4459
343	4506	4552	4604	4658	4708	4750	4789	4827	4864	4900
344	4935	4970	5005	5039	5073	5106	5141	5176	5208	5240
345	5270	5299	5329	5358	5389	5422	5456	5494	5531	5571
346	5610	5646	5683	5722	5765	5806	5841	5875	5909	5943
347	5980	6023	6069	6115	6160	6202	6242	6279	6314	6349
348	6381	6412	6441	6470	6499	6527	6558	6590	6624	6660
349	6695	6728	6761	6792	6823	6853	6882	6911	6940	6969
350	6999	7033	7067	7103	7140	7177	7214	7252	7289	7327
351	7363	7401	7441	7482	7525	7571	7620	7668	7715	7763
352	7810	7859	7910	7962	8014	8063	8107	8149	8191	8231
353	8268	8305	8342	8380	8418	8458	8496	8534	8572	8608
354	8644	8679	8716	8753	8791	8831	8872	8913	8956	9001
355	9047	9093	9135	9177	9216	9253	9290	9329	9368	9406
356	9444	9480	9515	9550	9586	9623	9661	9702	9741	9783
357	9824	9865	9908	9951	9997	10041	10089	10138	10187	10237
358	10287	10337	10386	10432	10479	10527	10578	10626	10674	10723
359	10772	10822	10875	10929	10981	11034	11088	11143	11194	11241
360	11289	11337	11386	11435	11483	11524	11562	11600	11638	11676
361	11714	11751	11787	11821	11854	11886	11918	11950	11981	12012
362	12042	12073	12104	12135	12166	12197	12228	12259	12290	12321
363	12553									



Lake Limestone
April 2002
Prepared by: TWDB

Appendix E Elevation vs. Volume



Lake Limestone
April 2002
Prepared by: TWDB

Appendix F Elevation vs. Area

Appendix G

Lake Limestone

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
Line 01-L	3552494.8	10469586.0
Line 01-R	3545655.5	10469361.0
Line 02-L	3552436.0	10471477.0
Line 02-R	3545227.0	10472919.0
Line 03-L	3552161.5	10477834.0
Line 03-R	3545477.0	10477664.0
Line 04-L	3551292.5	10482119.0
Line 04-R	3545659.5	10481369.0
Line 05-L	3549432.8	10489461.0
Line 05-R	3542346.8	10486245.0
Line 06-L	3545710.8	10494538.0
Line 06-R	3542569.0	10493008.0
Line 07-L	3542824.3	10501082.0
Line 07-R	3539080.5	10499622.0
Line 08-L	3540785.5	10505945.0
Line 08-R	3532336.0	10502432.0
Line 09-L	3532264.3	10509403.0
Line 09-R	3530623.3	10506675.0
Line 10-L	3527877.0	10512890.0
Line 10-R	3526156.8	10507557.0
Line 11-L	3523232.8	10515919.0
Line 11-R	3521286.3	10514557.0
Line 12-L	3518452.8	10519562.0
Line 12-R	3515588.3	10516381.0
Line-13-L	3544811.0	10472623.0
Line-13-R	3544060.8	10471141.0
Line 14-L	3542009.8	10474601.0
Line 14-R	3540593.0	10472395.0
Line 15-L	3539491.8	10476072.0
Line 15-R	3538965.5	10475011.0
Line 16-L	3540362.3	10491279.0
Line 16-R	3539999.0	10489641.0

Appendix G (Continued)

Lake Limestone

TEXAS WATER DEVELOPMENT BOARD APRIL 2002 SURVEY

Range Line Endpoints

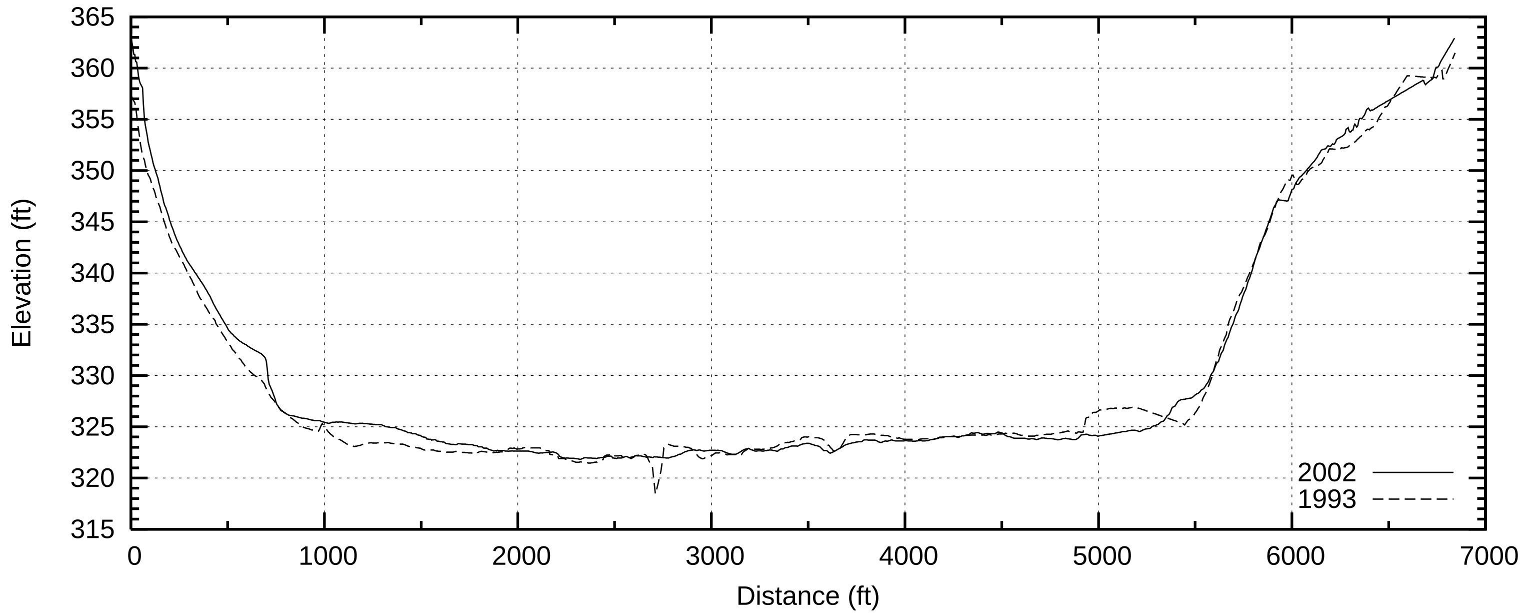
State Plane NAD83 Units-feet

L-Left endpoint
R-right endpoint

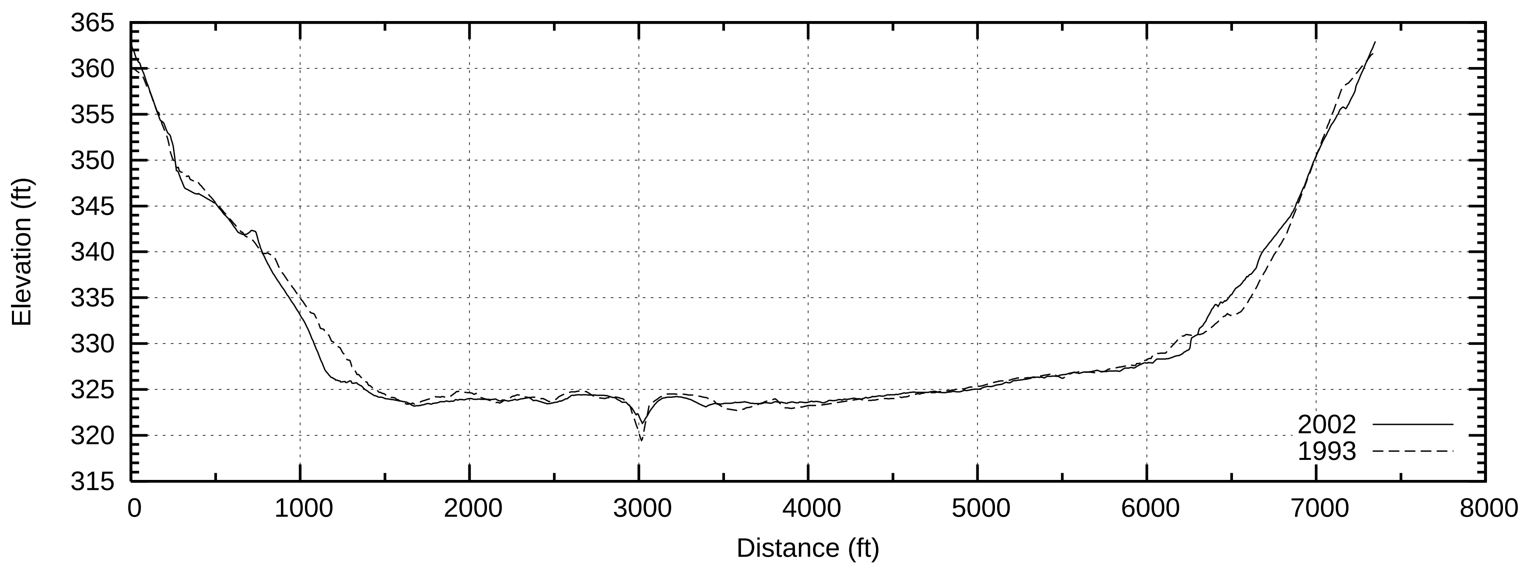
Range Line	X	Y
Line 17-L	3538841.8	10492508.0
Line 17-R	3538026.5	10491655.0
Line 18-L	3532146.8	10503842.0
Line 18-R	3531995.3	10502789.0
Line 19-L	3530568.0	10504087.0
Line 19-R	3530195.0	10502478.0
Line 20-L	3552689.0	10479472.0
Line 20-R	3552525.5	10480989.0
Line 21-L	3553504.0	10479232.0
Line 21-R	3554511.0	10480070.0
Line 22-L	3554813.3	10480742.0
Line 22-R	3553804.5	10481551.0
Line 23-L	3555707.3	10482934.0
Line 23-R	3555135.8	10483247.0
Line 24-L	3553121.0	10485007.0
Line 24-R	3551239.5	10488599.0
Line 25-L	3555638.5	10488475.0
Line 25-R	3554168.3	10490899.0
Line 26-L	3558696.5	10490845.0
Line 26-R	3557573.3	10492087.0
Line 27-L	3542957.5	10502047.0
Line 27-R	3542110.3	10504960.0
Line 28-L	3546061.3	10505374.0
Line 28-R	3543674.0	10508177.0
Line 29-L	3540805.5	10506447.0
Line 29-R	3538646.5	10507028.0
Line 30-L	3539775.3	10511124.0
Line 30-R	3537624.8	10510184.0
Line 31-L	3537499.5	10515960.0
Line 31-R	3536311.5	10516128.0

Lake Limestone

Rangeline SR01



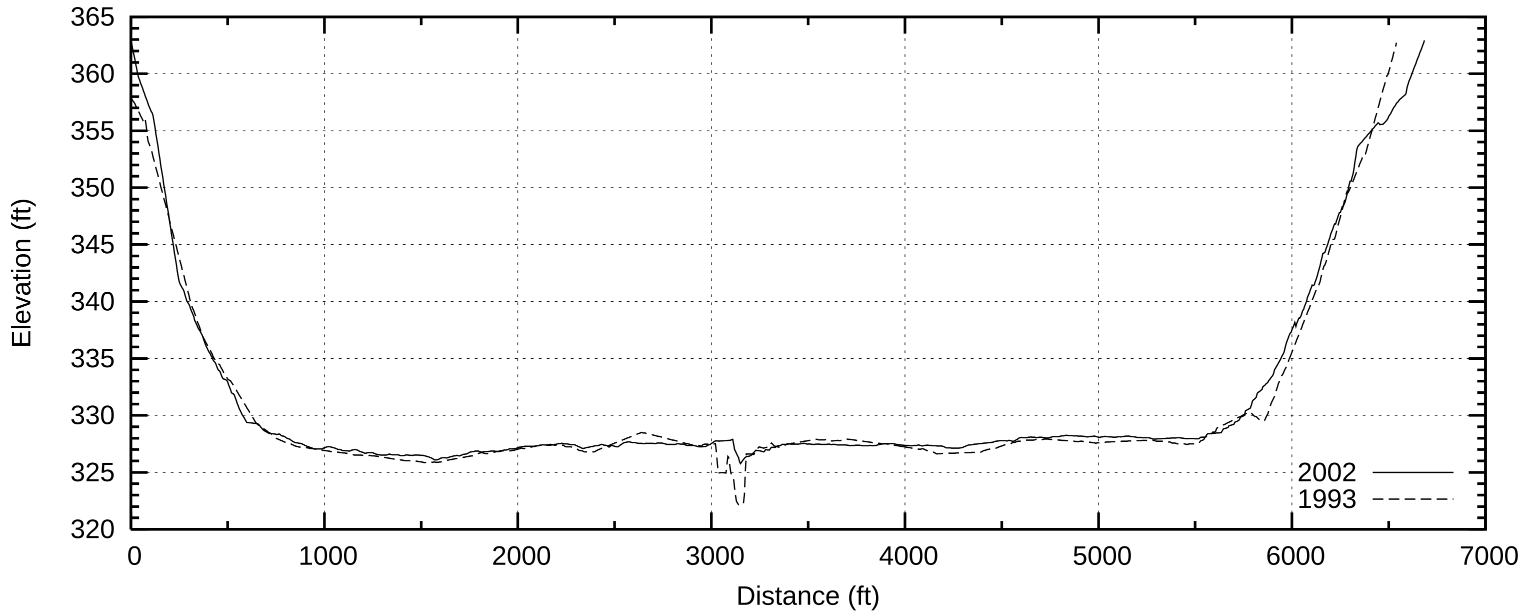
Rangeline SR02



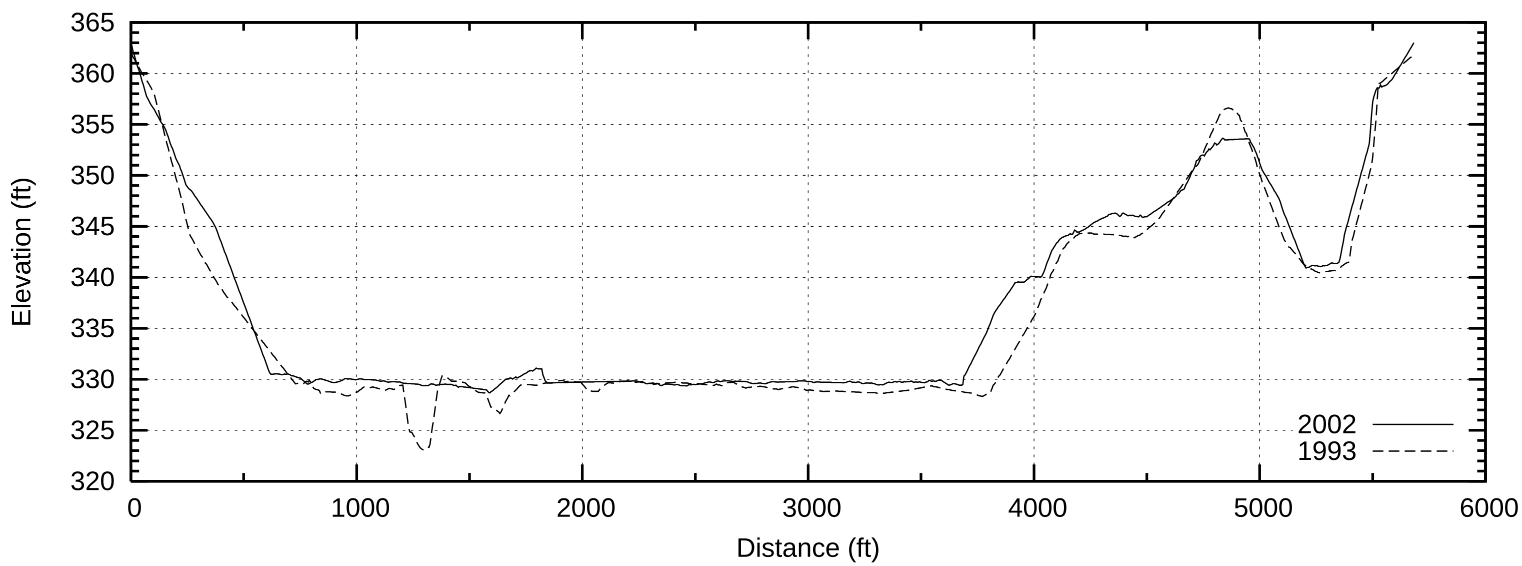
Appendix H

Lake Limestone

Rangeline SR03

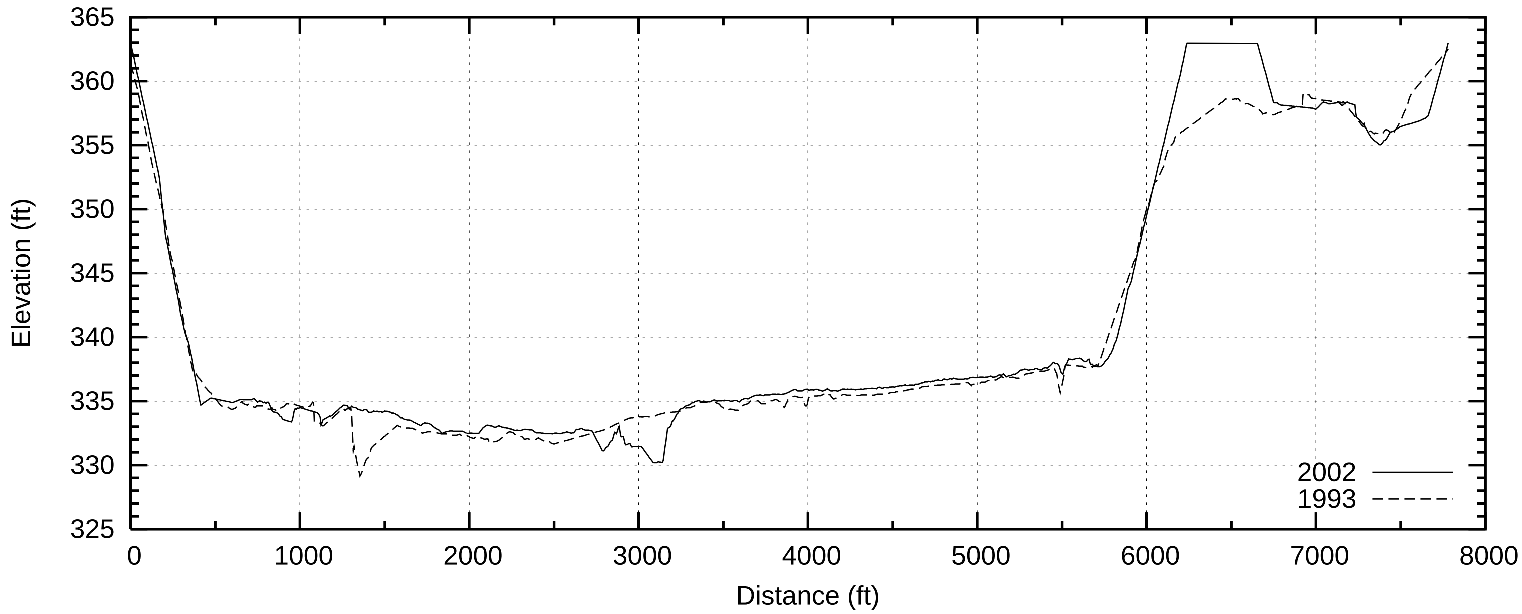


Rangeline SR04

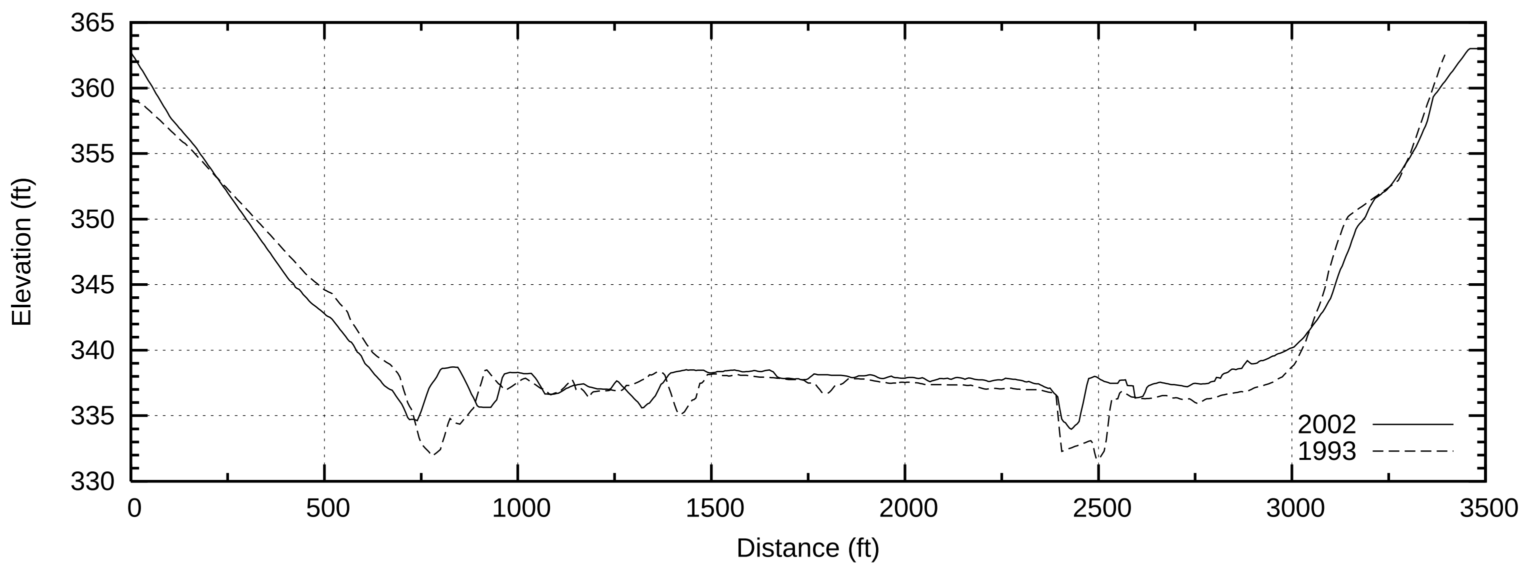


Lake Limestone

Rangeline SR05

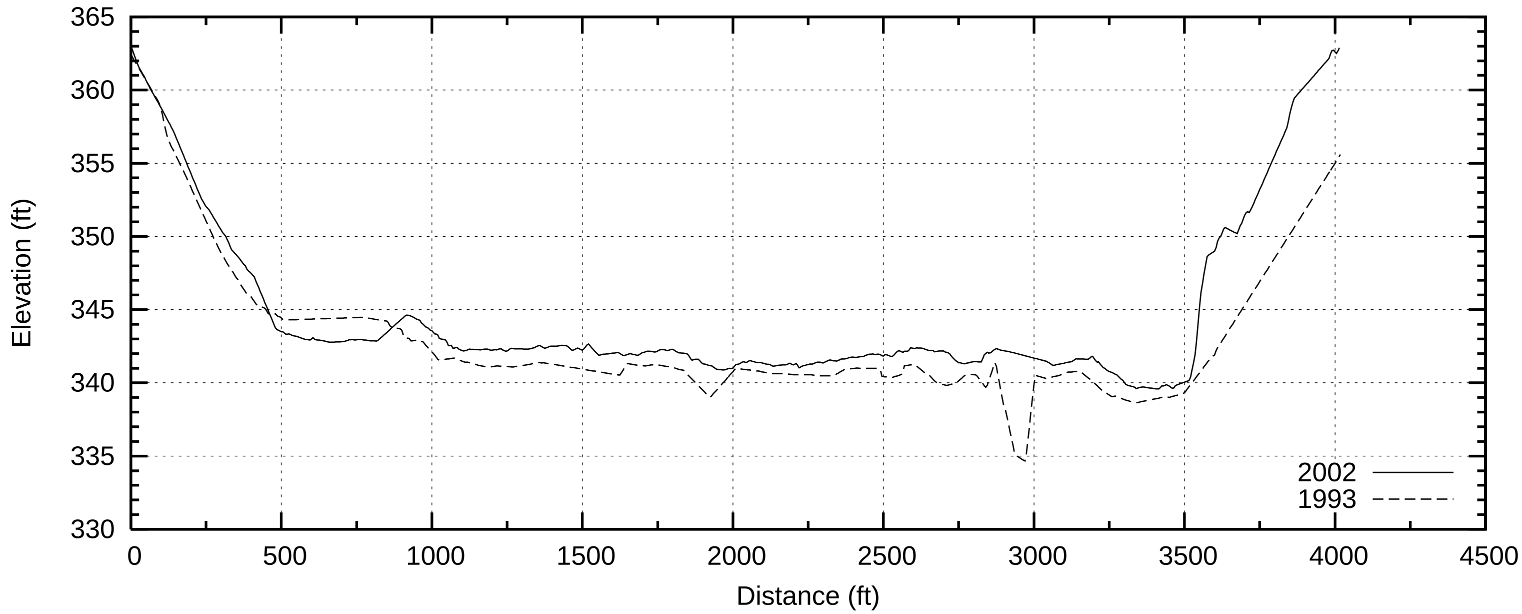


Rangeline SR06

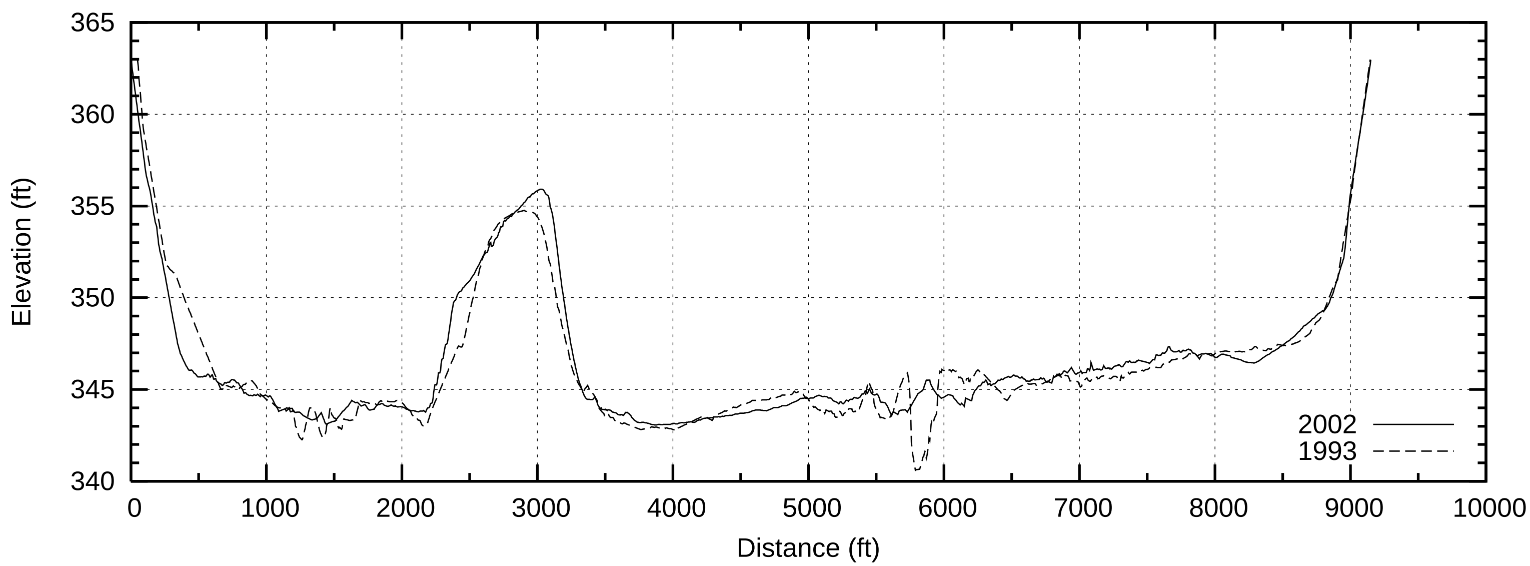


Lake Limestone

Rangeline SR07

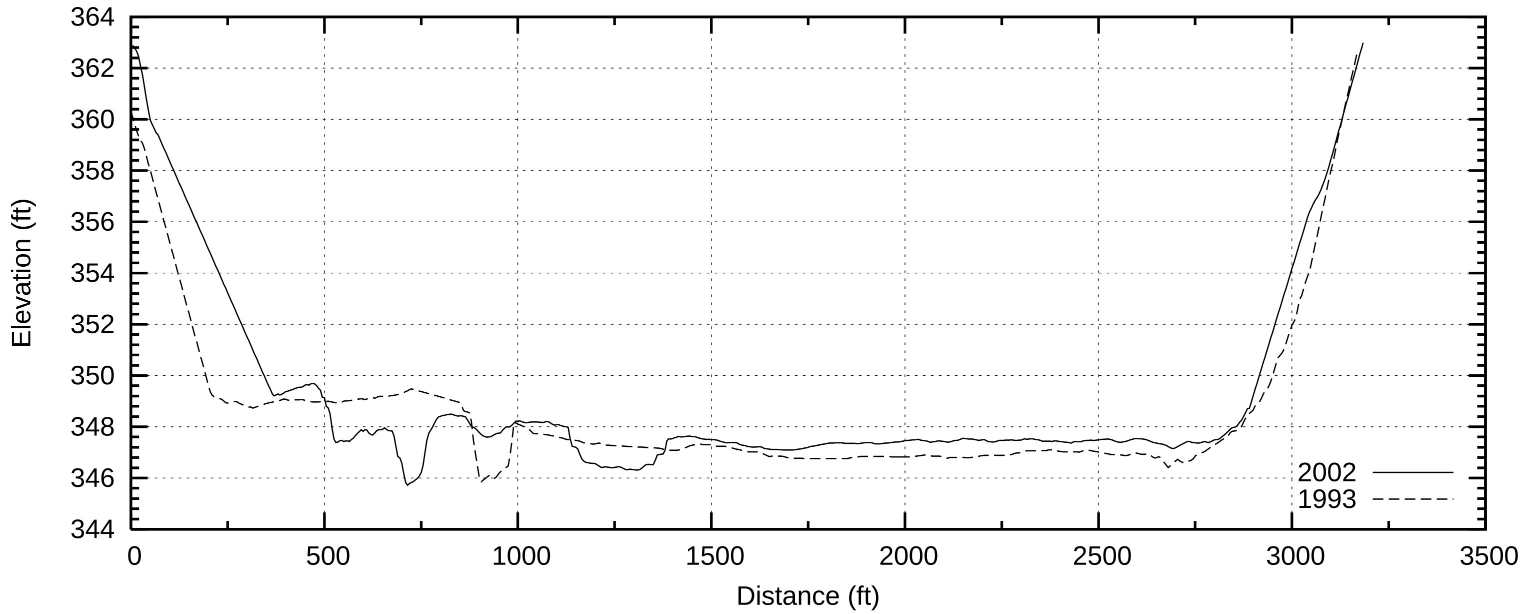


Rangeline SR08

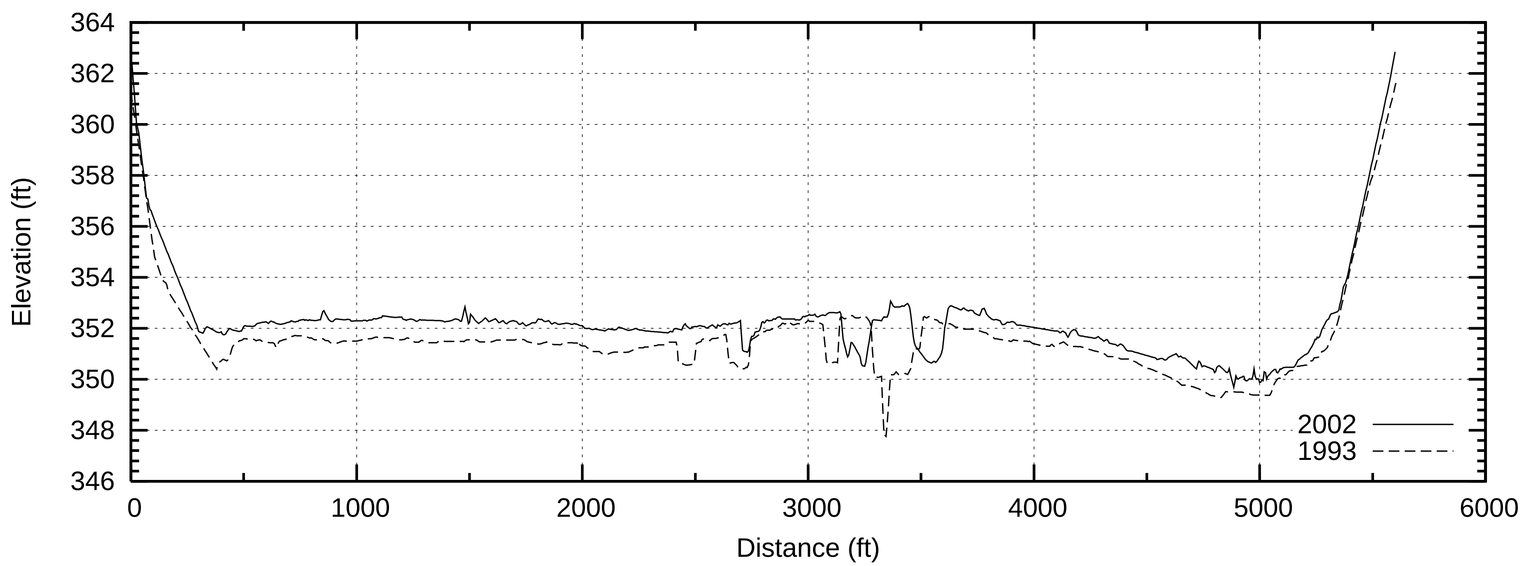


Lake Limestone

Rangeline SR09

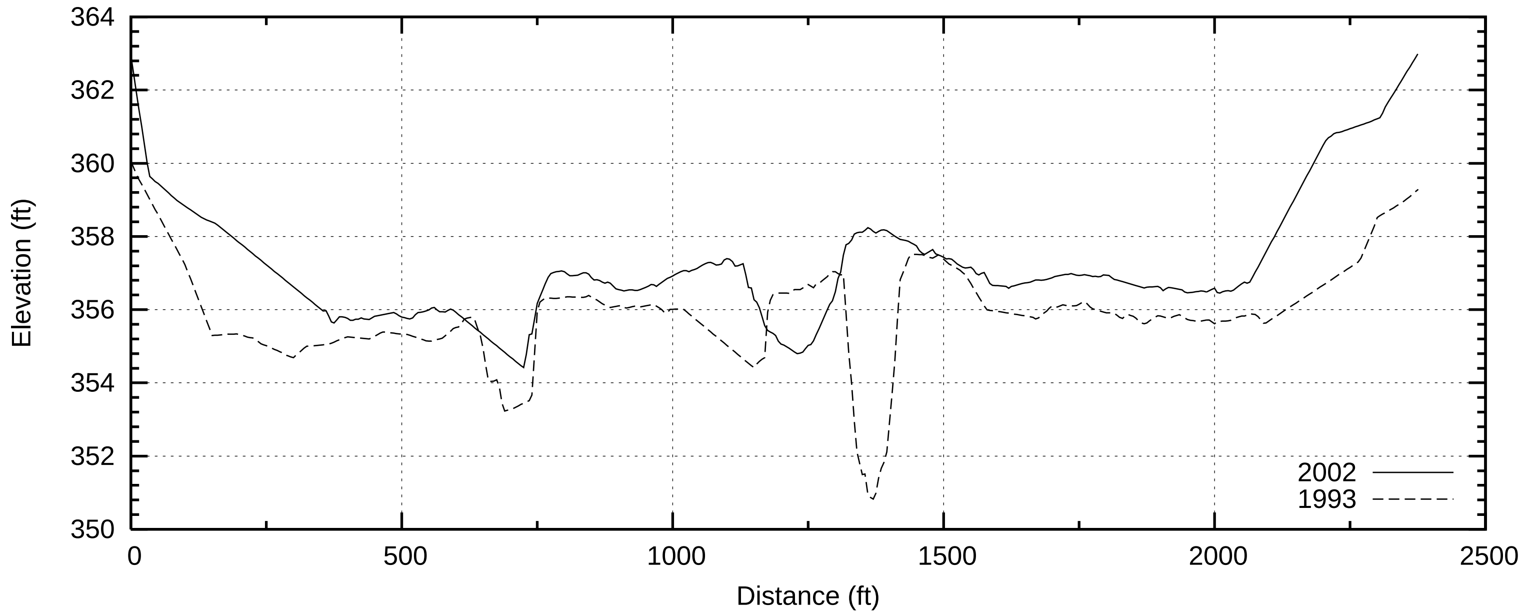


Rangeline SR10

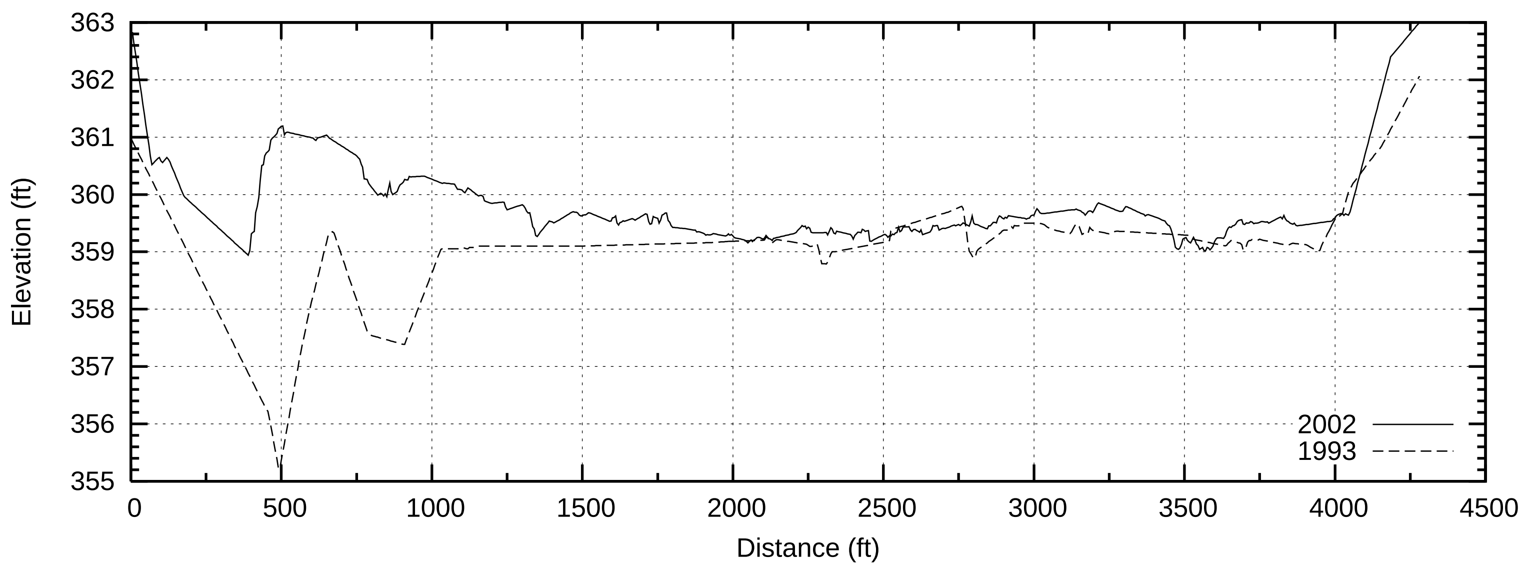


Lake Limestone

Rangeline SR11

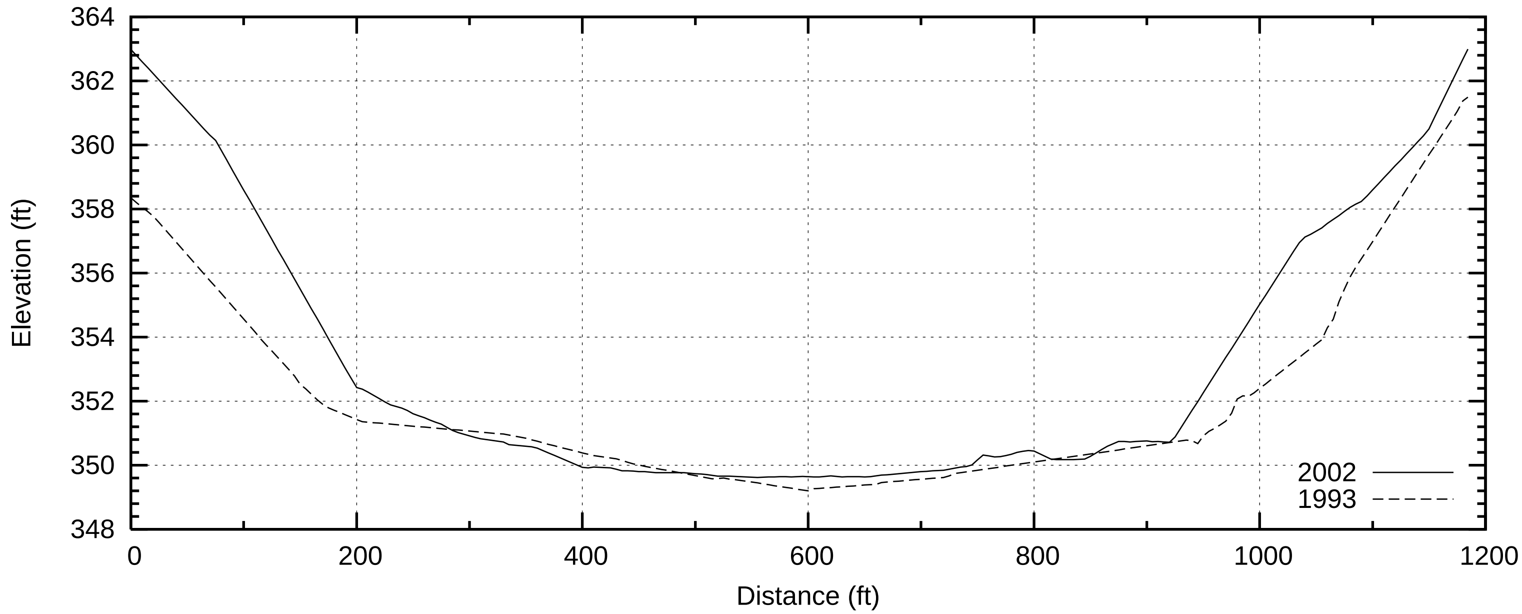


Rangeline SR12

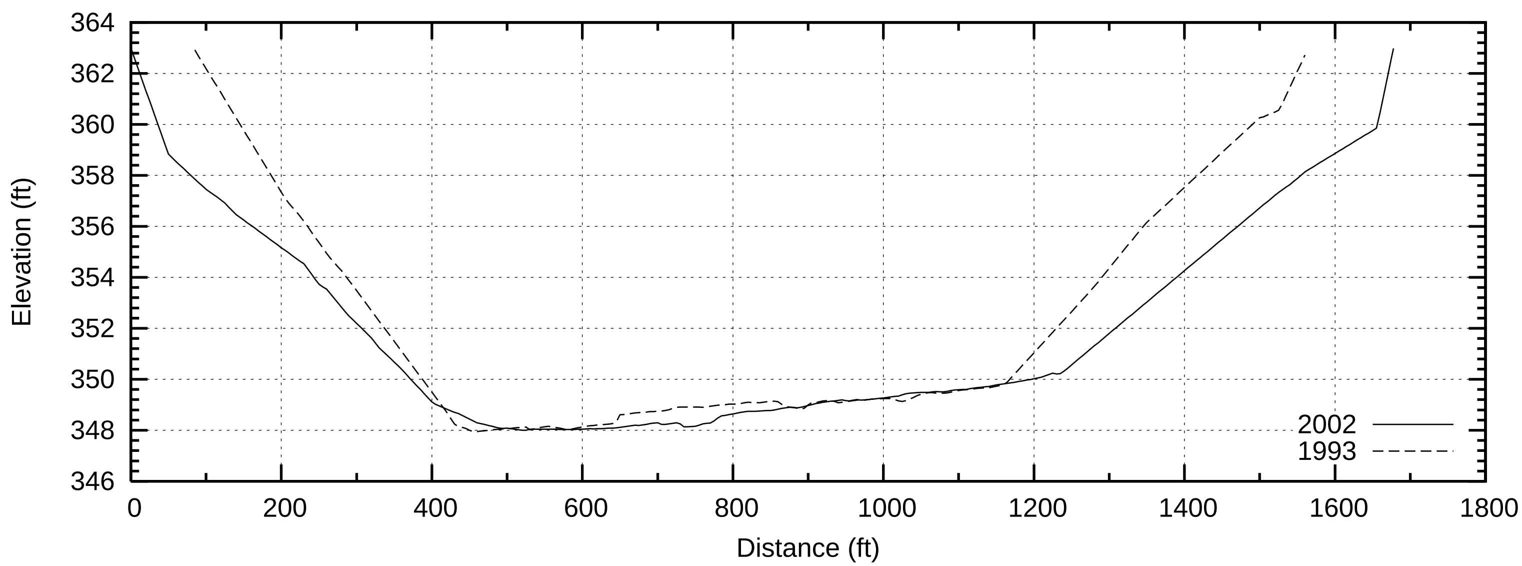


Lake Limestone

Rangeline SR15



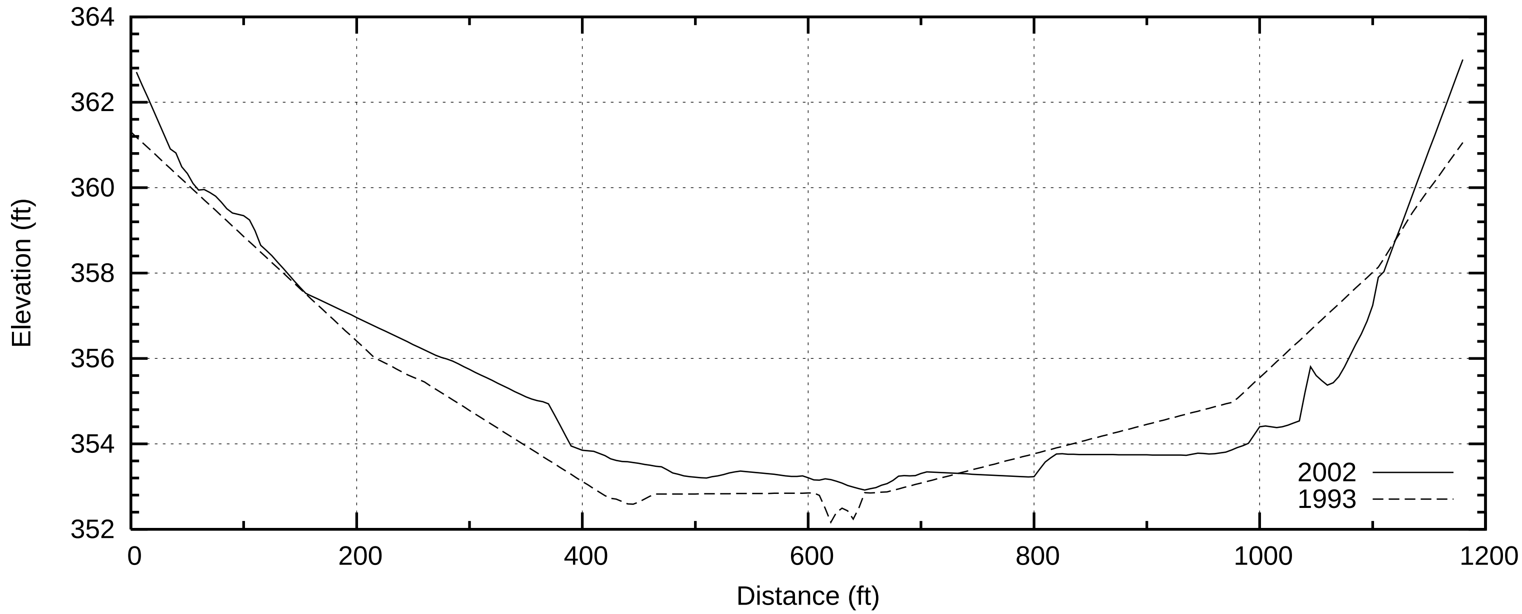
Rangeline SR16



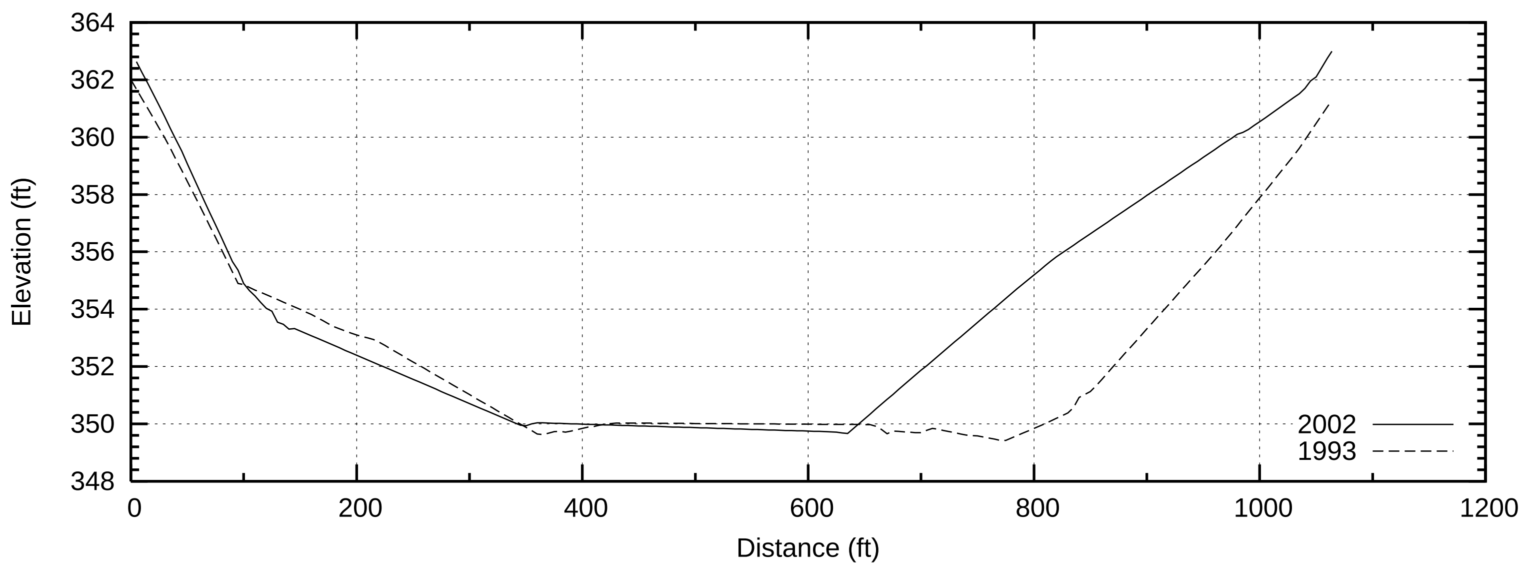
Appendix H

Lake Limestone

Rangeline SR17

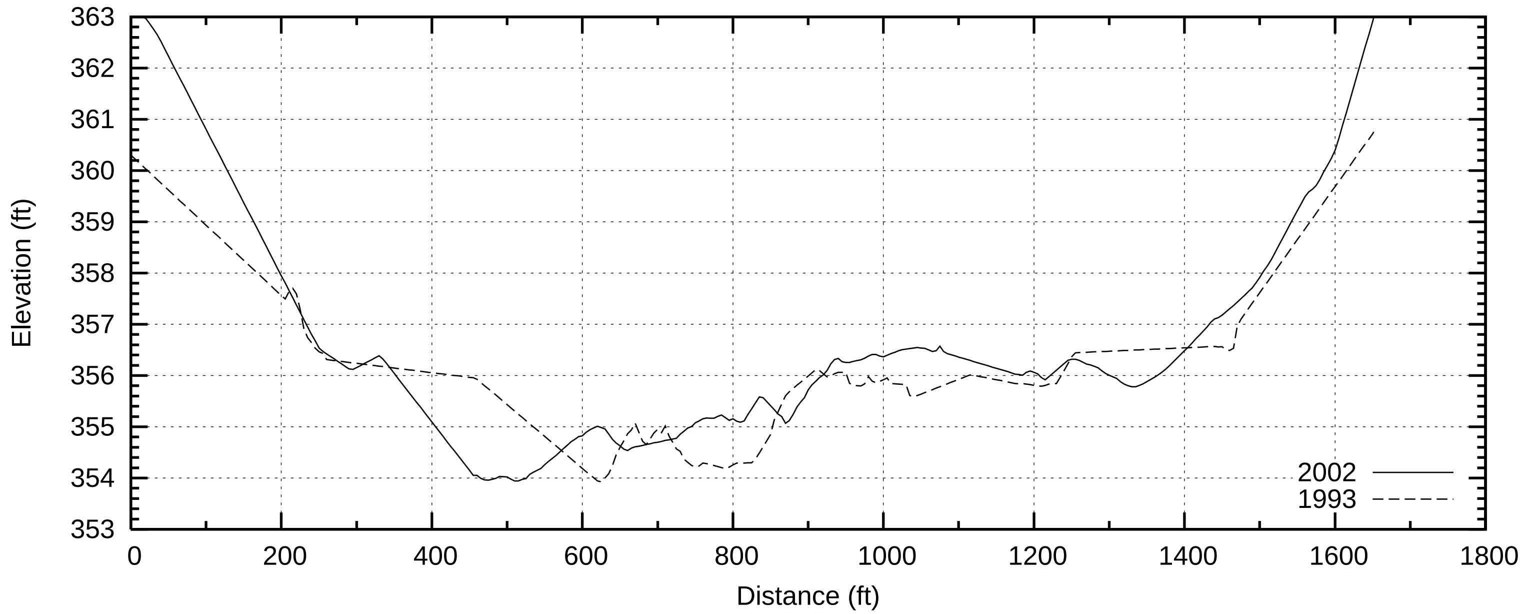


Rangeline SR18

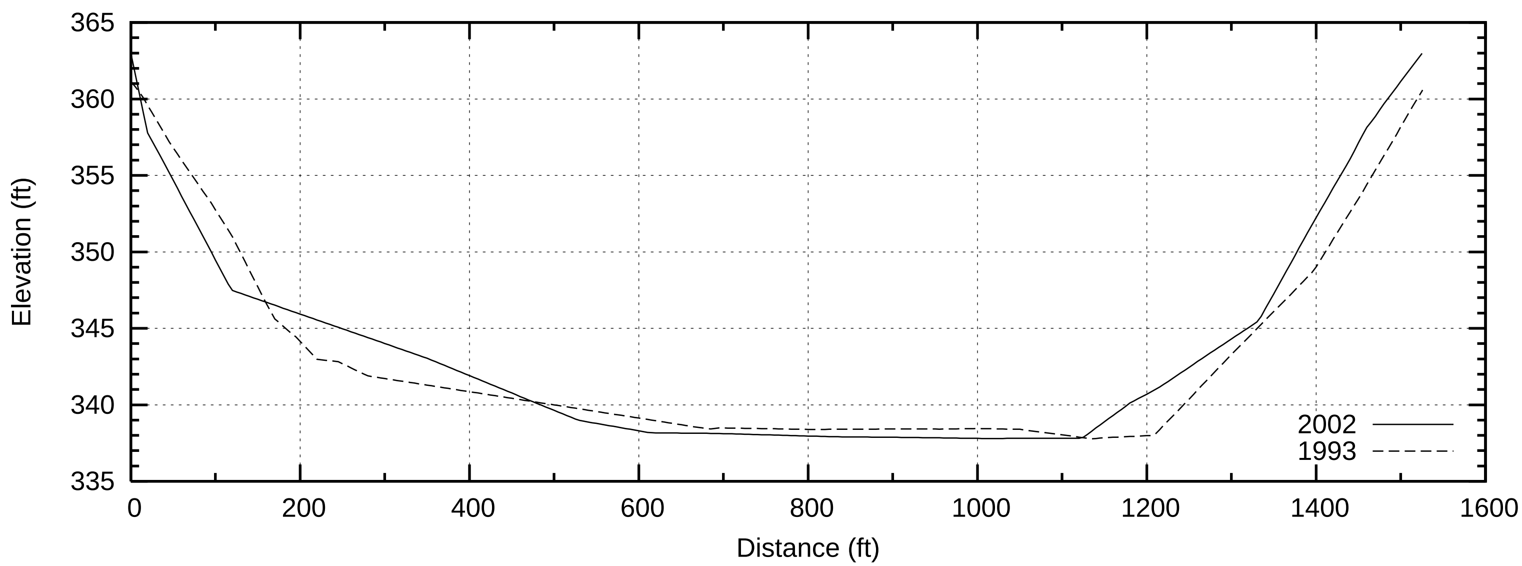


Lake Limestone

Rangeline SR19

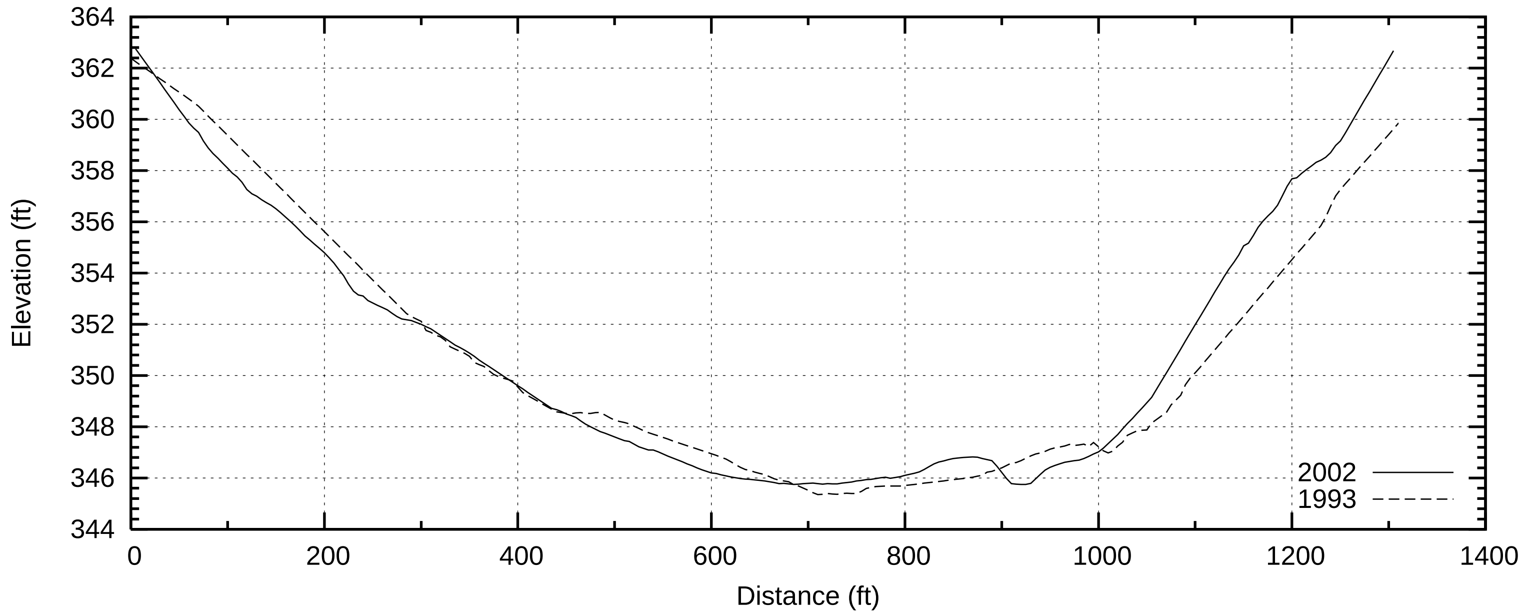


Rangeline SR20

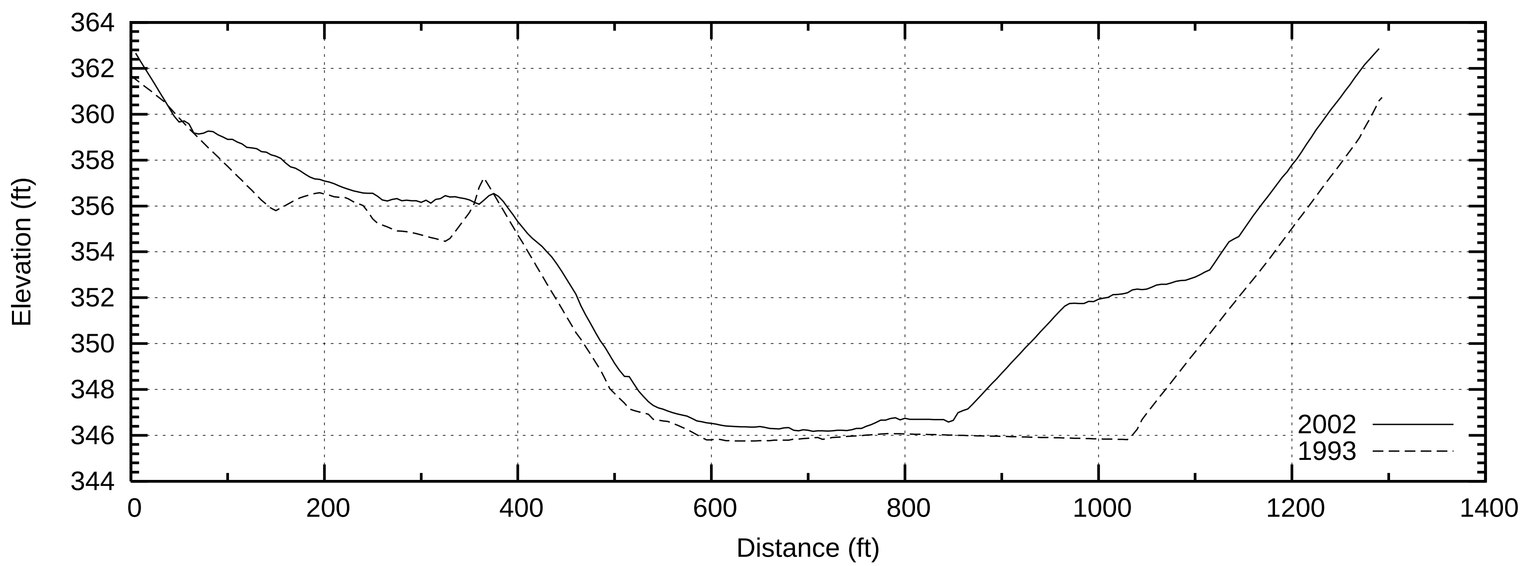


Lake Limestone

Rangeline SR21

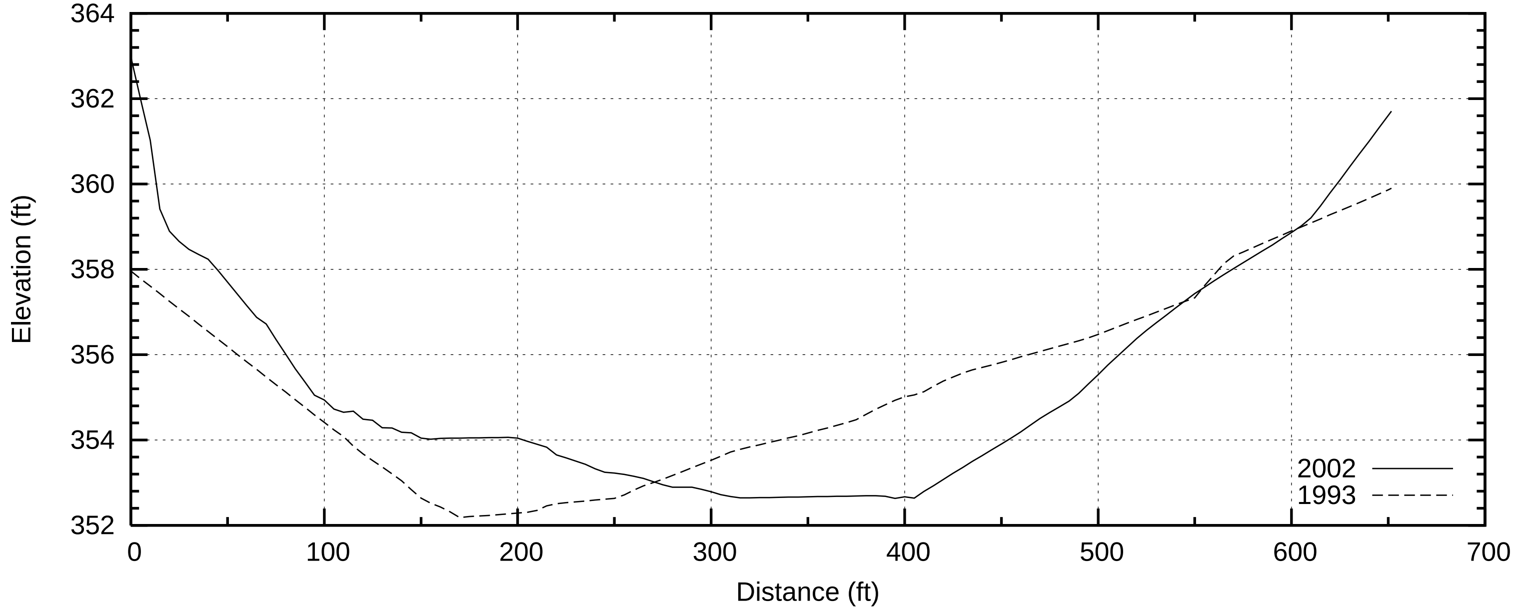


Rangeline SR22

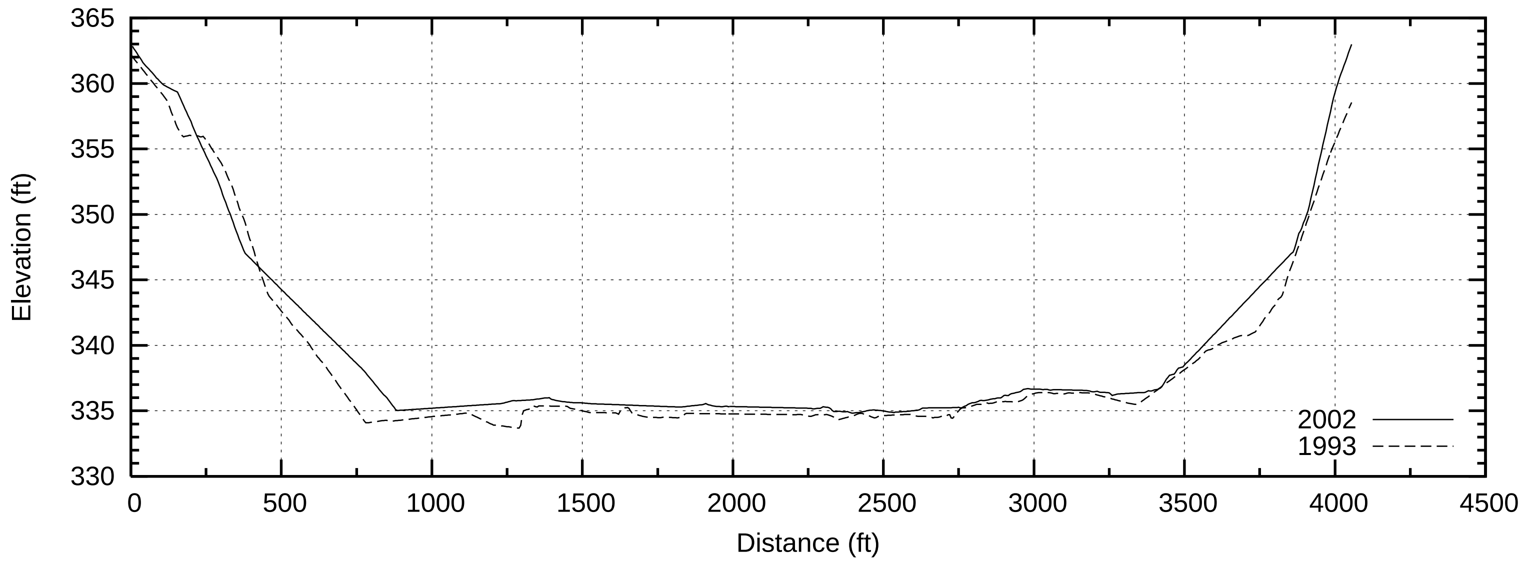


Lake Limestone

Rangeline SR23

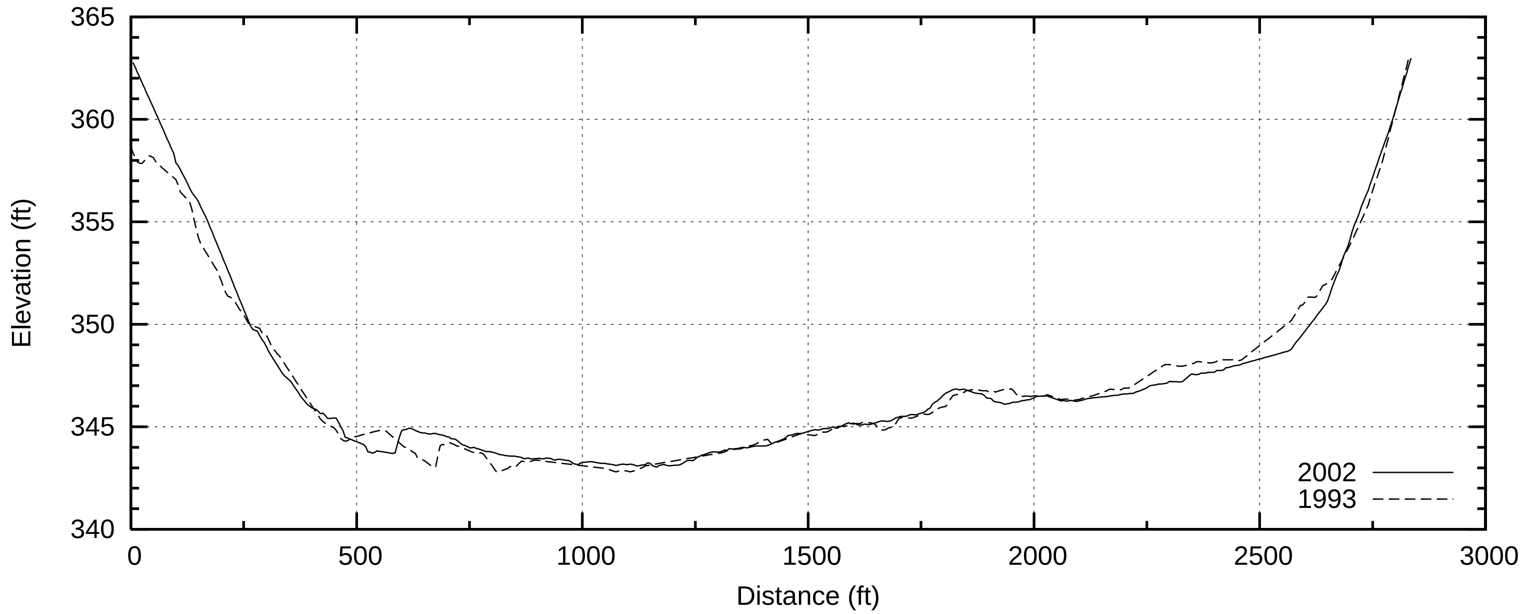


Rangeline SR24

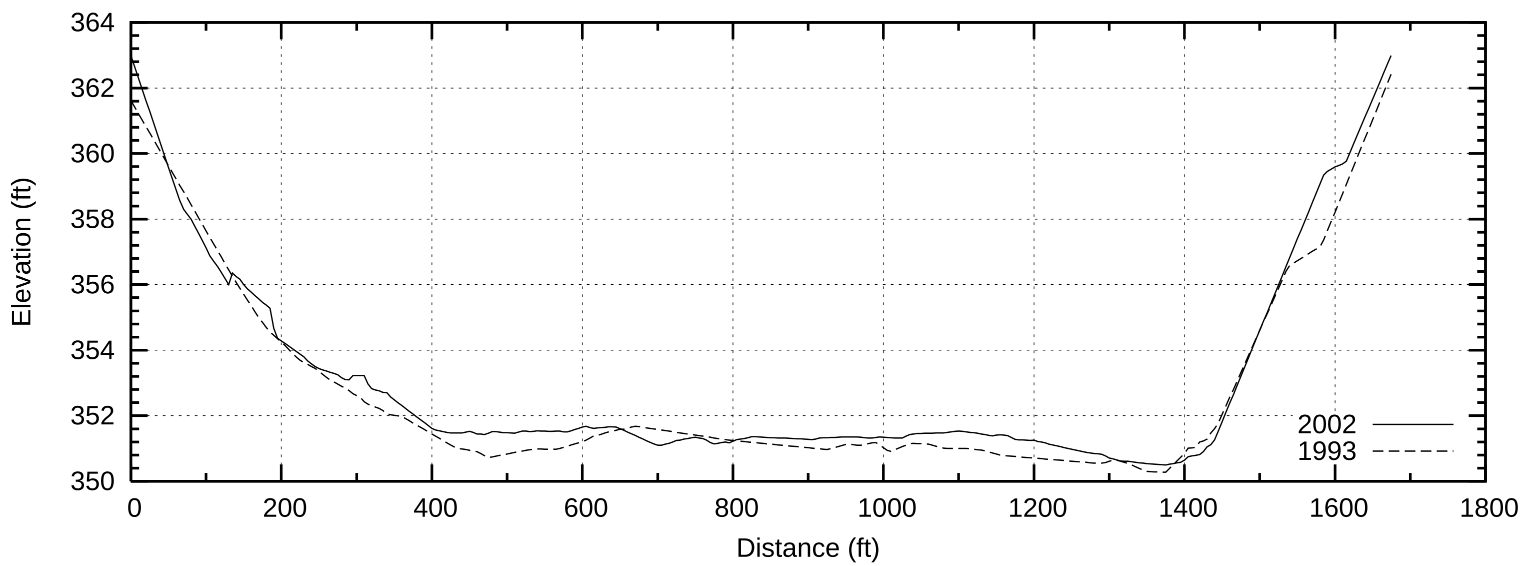


Lake Limestone

Rangeline SR25



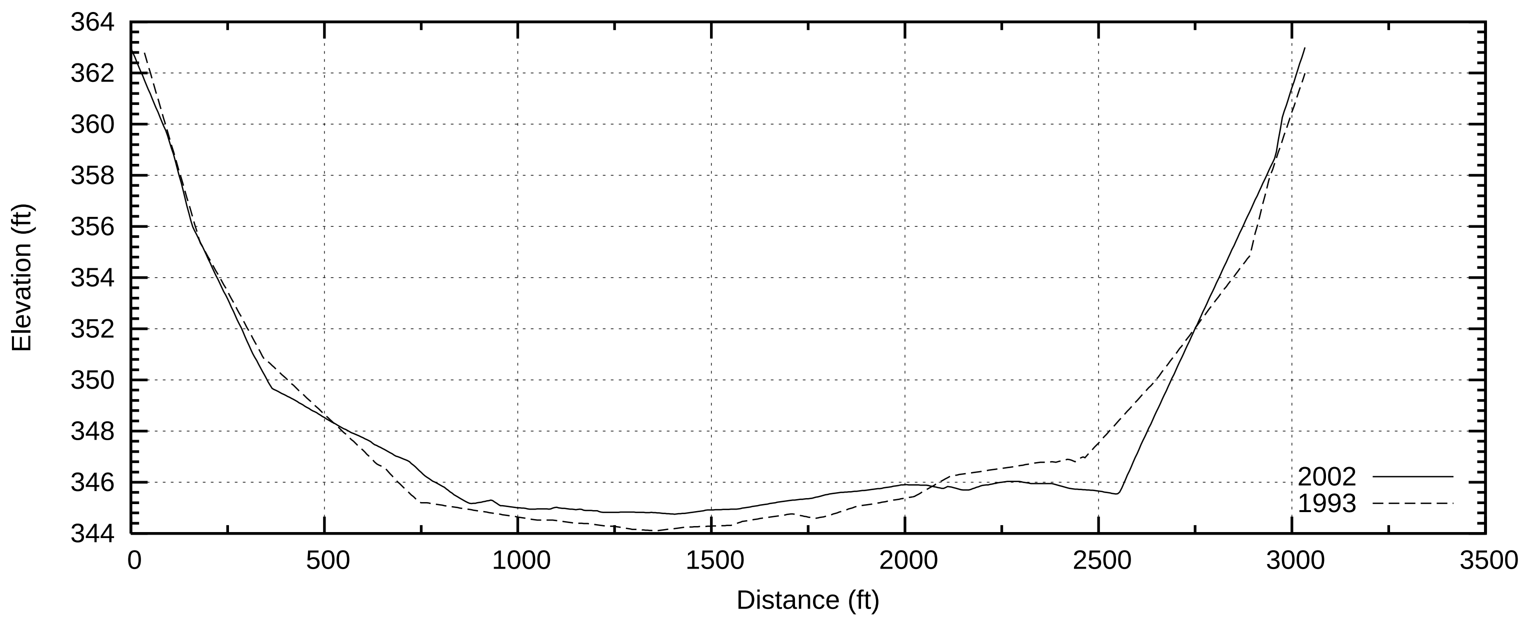
Rangeline SR26



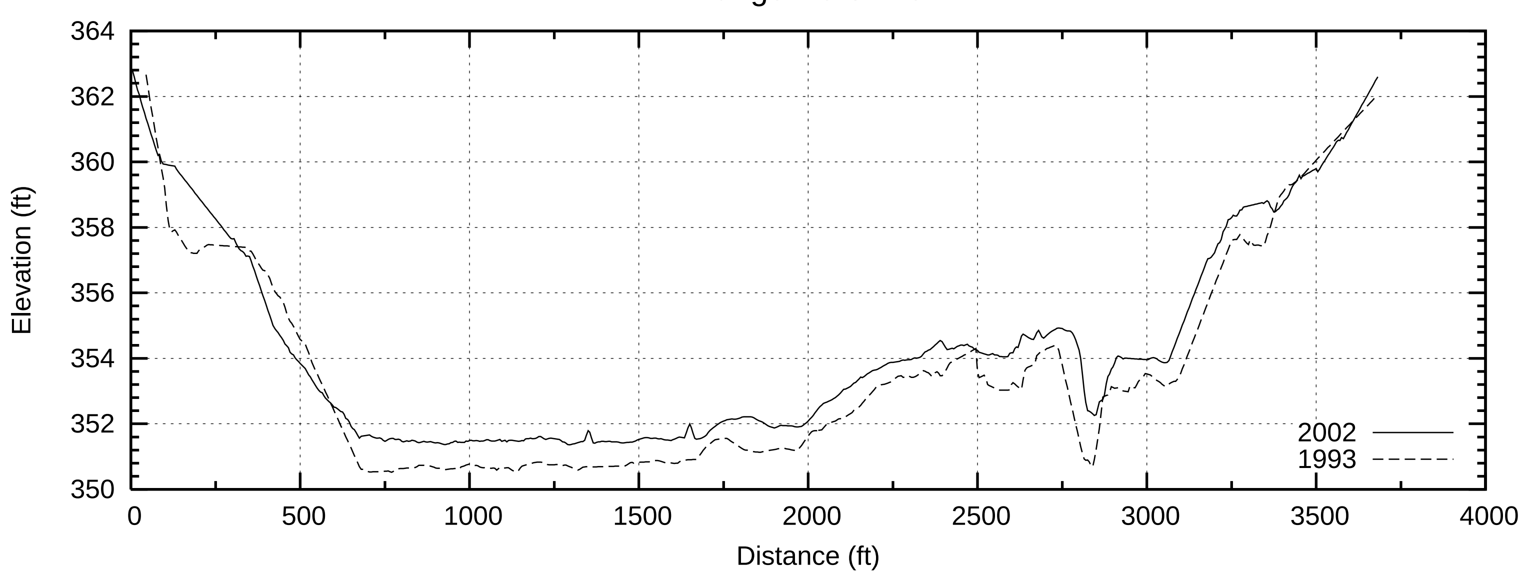
Appendix H

Lake Limestone

Rangeline SR27

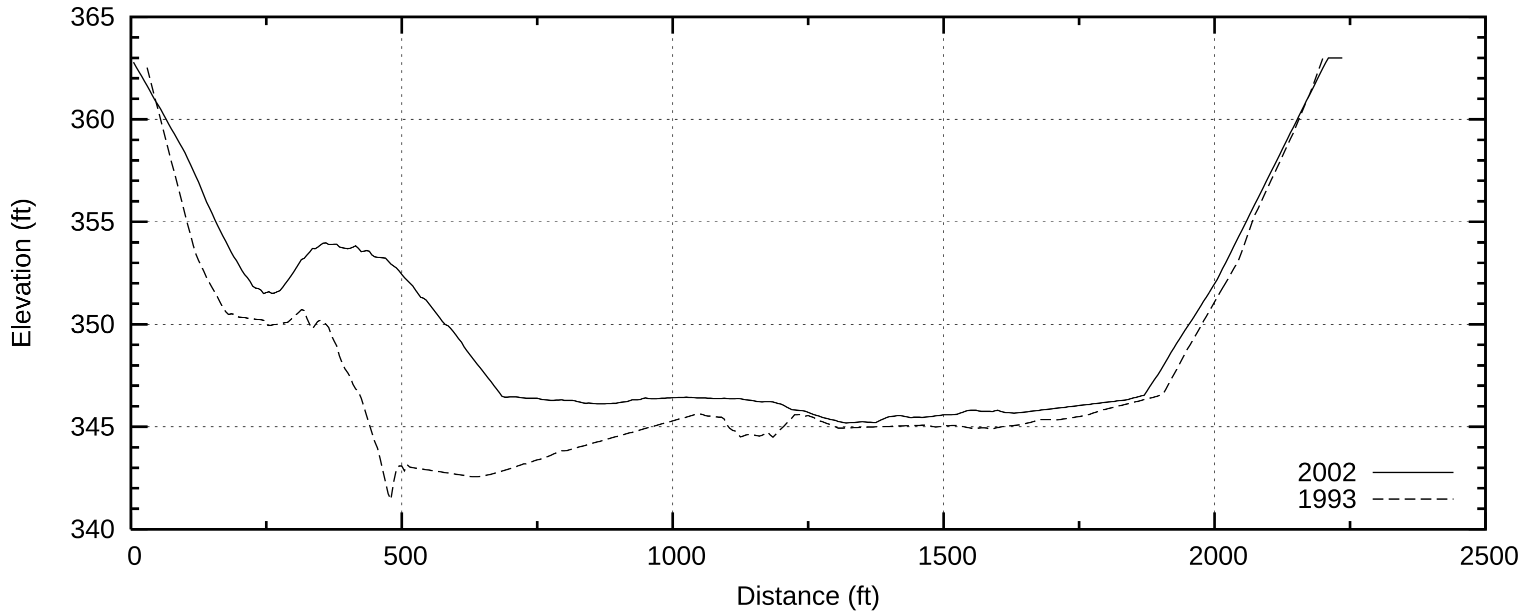


Rangeline SR28

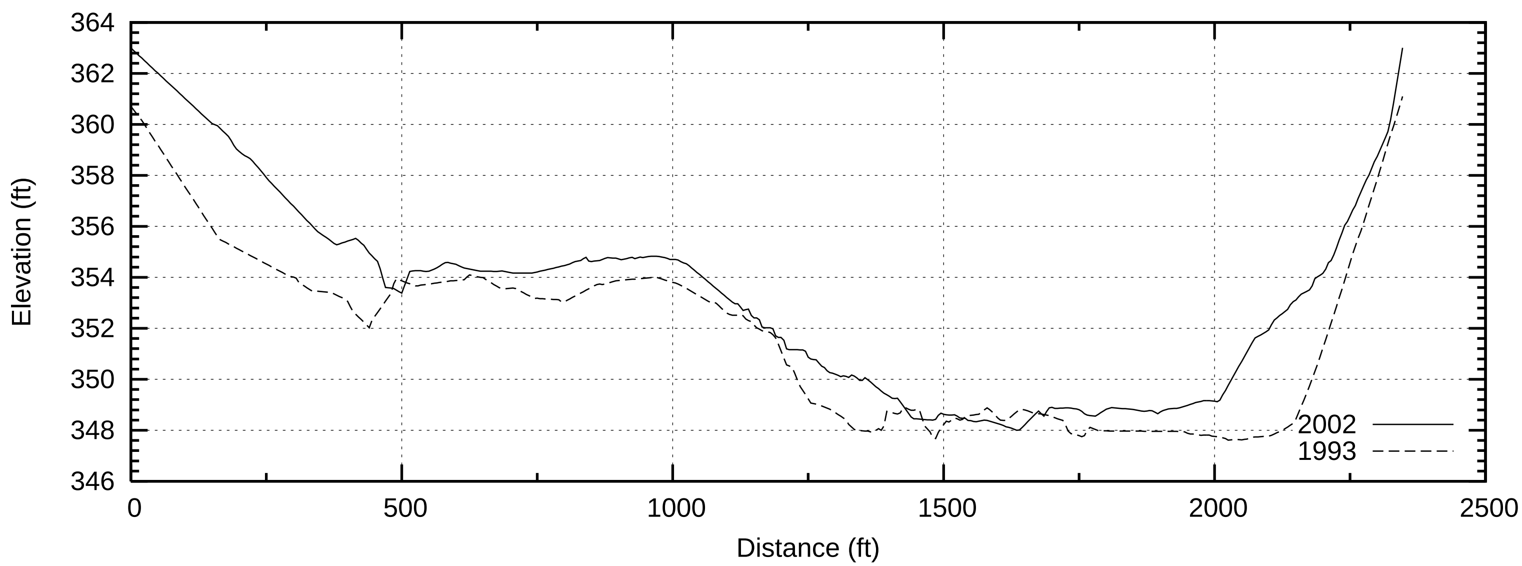


Lake Limestone

Rangeline SR29



Rangeline SR30



Lake Limestone

Rangeline SR31

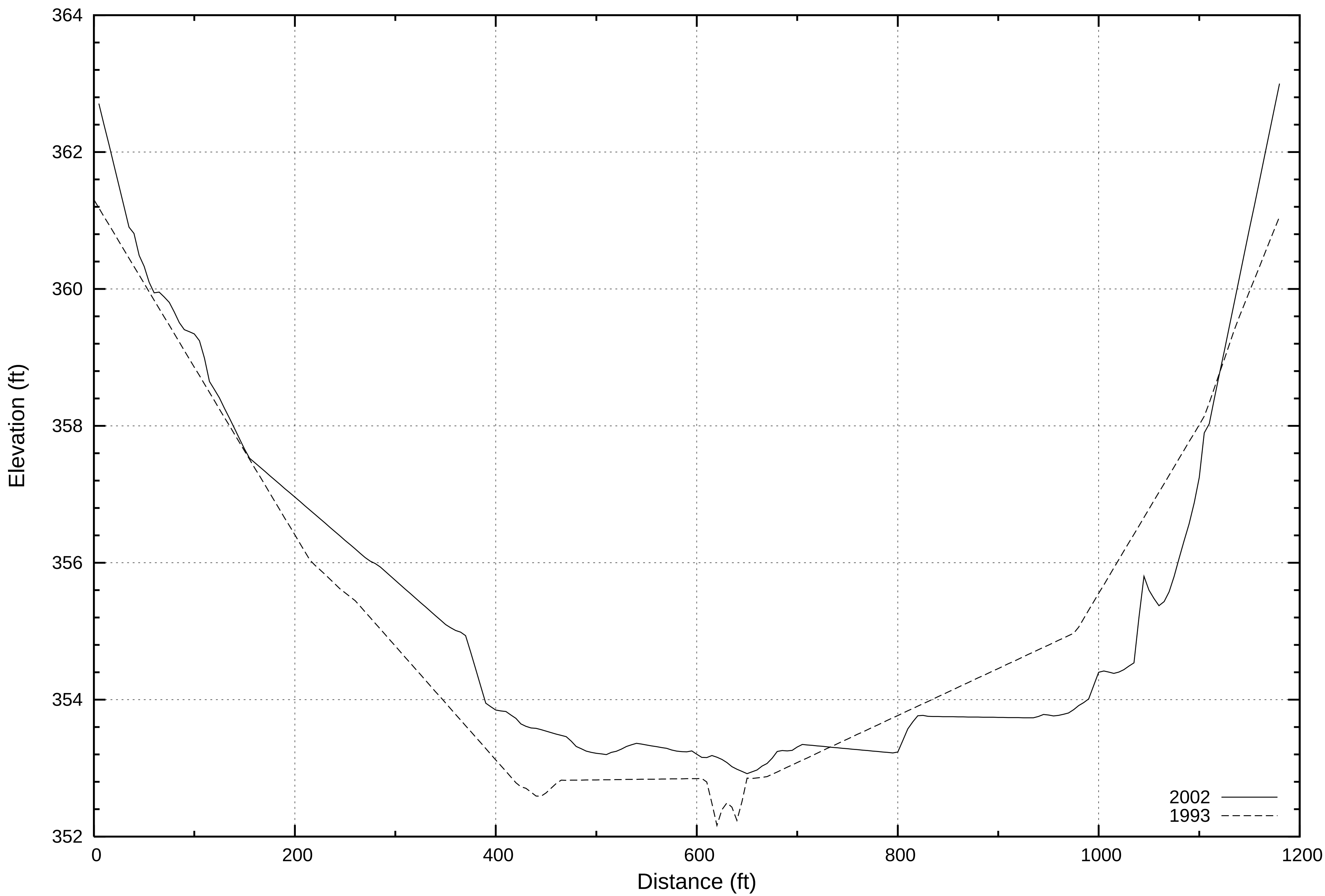
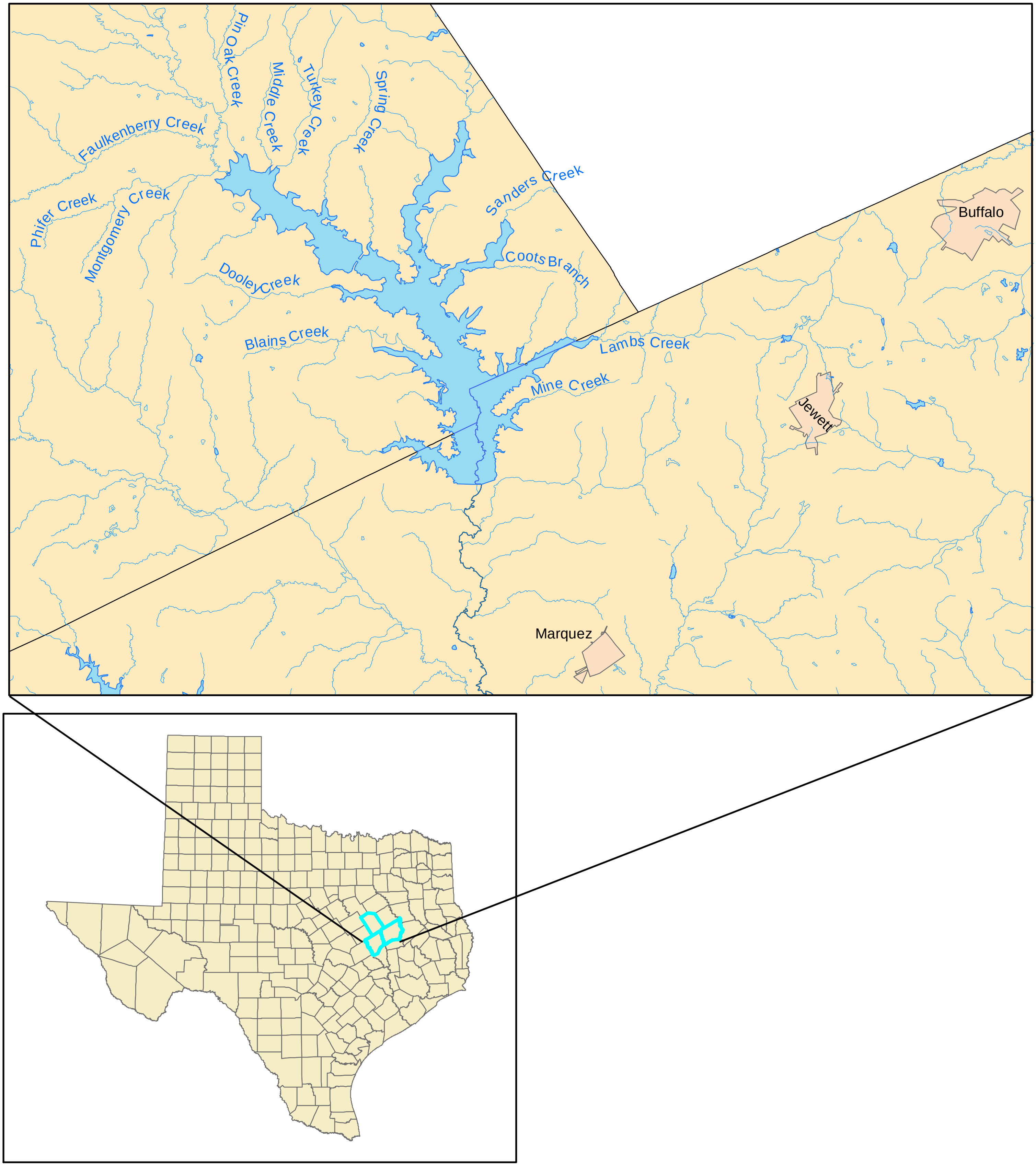


Figure 1

Lake Limestone

Location Map

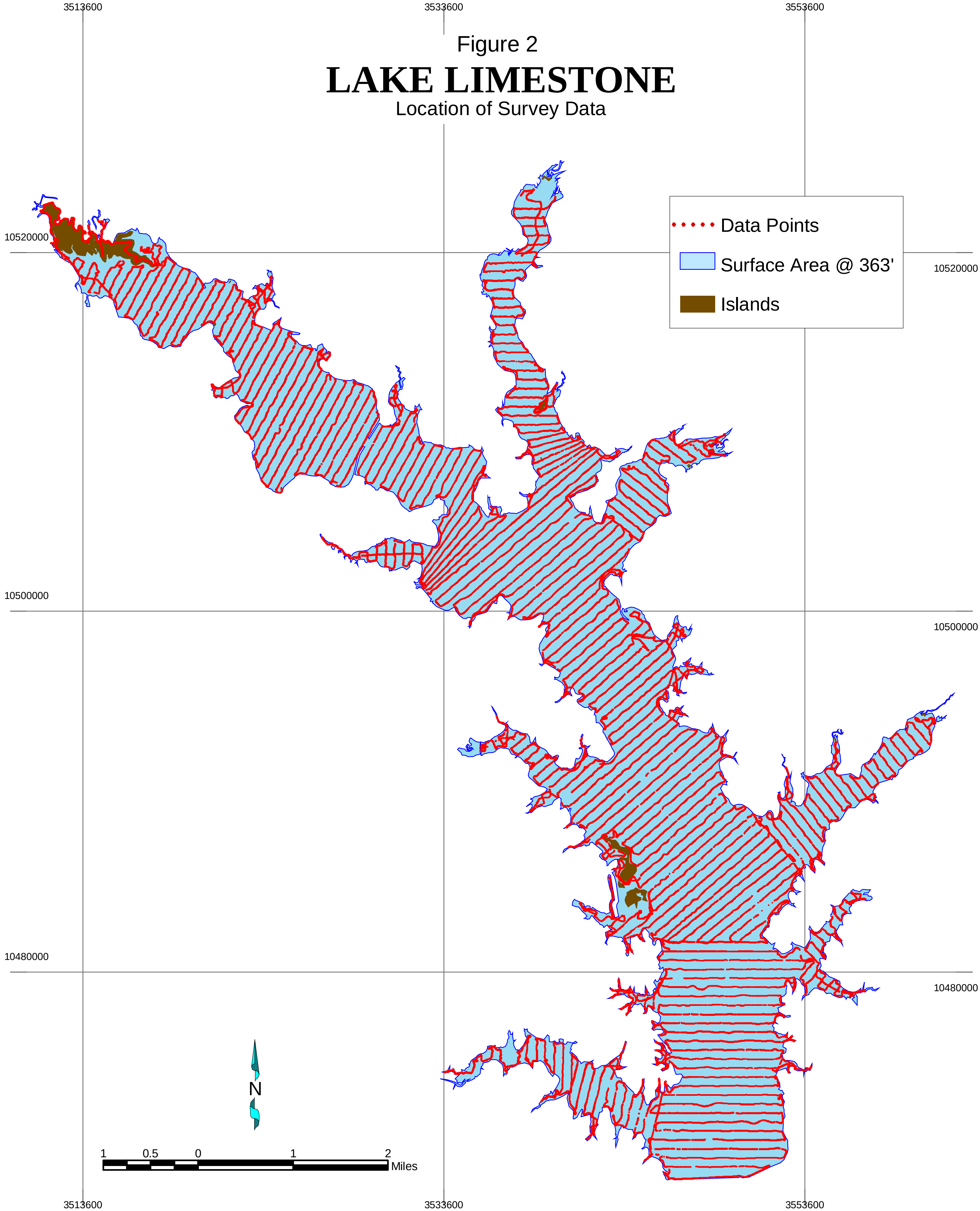


TWDB Survey April 2002

Figure 2

LAKE LIMESTONE

Location of Survey Data

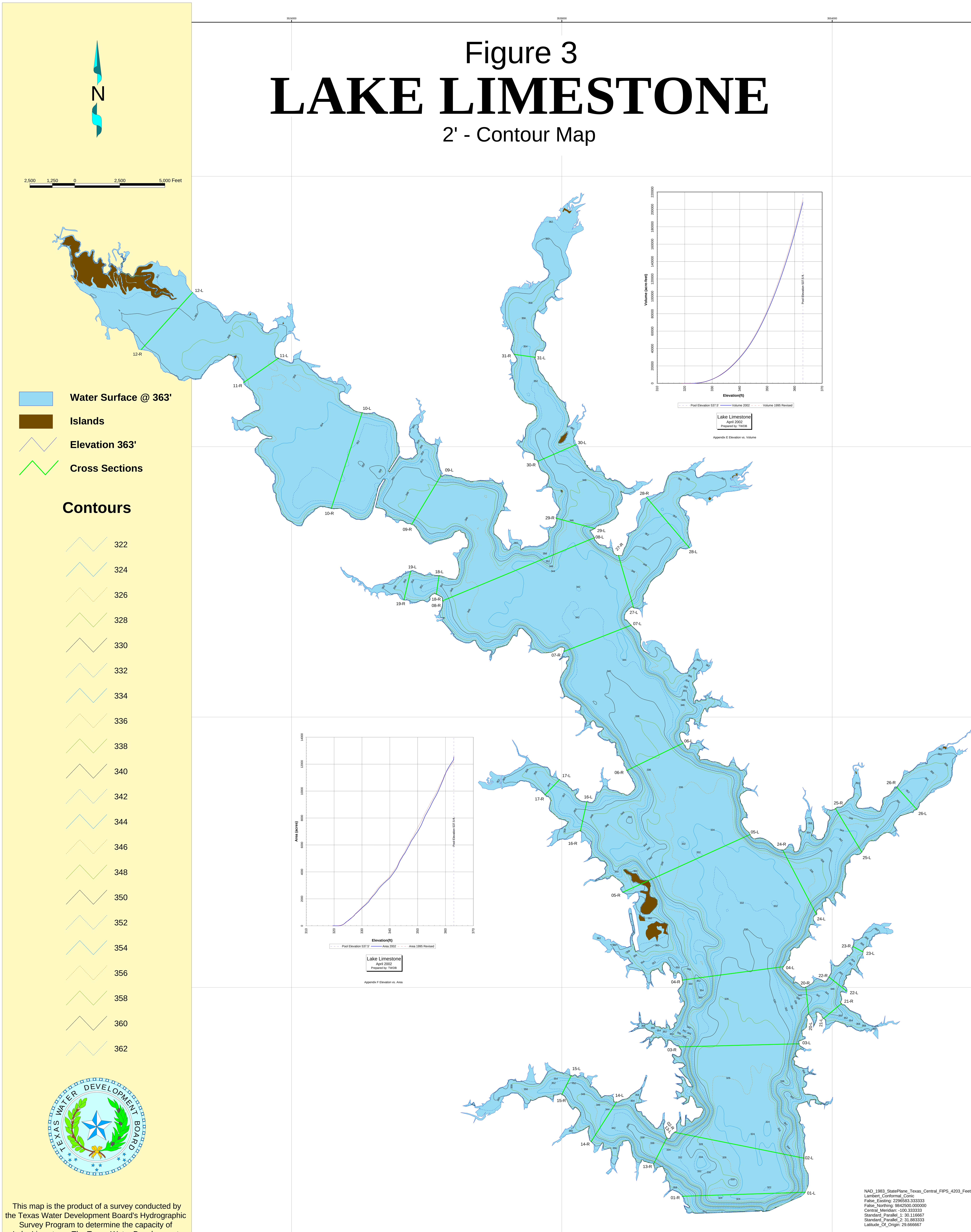


TWDB Survey April 2003

Figure 3

LAKE LIMESTONE

2' - Contour Map



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

TEXAS WATER DEVELOPMENT BOARD APRIL 2003 SURVEY