VOLUMETRIC SURVEY OF LAKE FORK RESERVOIR

Prepared for:
Sabine River Authority

In cooperation with the
United States Army Corps of Engineers

Prepared by
Texas Water Development Board

September 13, 2001

Texas Water Development Board

Craig D. Pedersen, Executive Administrator

Texas Water Development Board

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Texas Water Development Board

P.O. Box 13231

Austin, Texas 78711-3231

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INTRODUCTION

Staff of the Surface Water Section of the Texas Water Development Board (TWDB) conducted a volumetric survey of Lake Fork Reservoir between January 30 and March 13, 2001. The primary purpose of this survey was to determine the current volume of the lake at conservation pool elevation. Results from this survey will serve as a basis for comparison to future surveys to allow the location and rates of sediment deposition to be determined. 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 reservoir elevation gauge at Lake Fork Reservoir (08018800 LAKE FORK RESERVOIR NEAR QUITMAN, TX.). The datum for this gauge is reported as mean sea level (msl) (USGS, 1999). Thus, elevations are reported here, according to the same datum, in feet above mean sea level (msl). Volume and area calculations in this report are referenced to water levels provided by the USGS gauge.

In the original design, the surface area was 27,690 acres at conservation pool elevation (403.0 feet); the total storage volume was estimated to be 675,819 acre-feet of water (Sabine River Authority 1986). This report will compare the 2001 survey results with the original design information.

LAKE HISTORY AND GENERAL INFORMATION

Historical information on Lake Fork Reservoir was obtained from the Sabine River Authority (1986), and USGS (1999). The Lake Fork Reservoir project was originally designed to provide water for municipal and industrial purposes. Texas Utilities Generating Company Inc. and the Cities of Dallas, Henderson, Kilgore, Longview and Quitman have contracted for purchases of water from the reservoir.

The Sabine River Authority (SRA) owns the water rights to Lake Fork Reservoir. SRA also owns and maintains the dam and appurtenant structures. All releases from the reservoir and other water-related operations are under the control of the SRA.

Water Rights Permit # 2948 (Application # 3234) was granted to the Sabine River Authority (SRA) on August 1, 1974 by the Texas Water Rights Commission. The permit allowed SRA "to construct a dam and reservoir on Lake Fork Creek and impound therein not to exceed 675,819 acre-feet of water. SRA was authorized to divert from the proposed reservoir 44,940 acre-feet of water per annum for municipal use and 120,000 acre-feet of water per annum for industrial use. Permission was granted to use the banks and bed of Lake Fork Creek and the Sabine River to transport water from Lake Fork Reservoir to diversion points downstream as approved by the Commission. Authorization was given to divert and use not to exceed 300 acre-feet of water from Lake Fork Reservoir for initial construction of the dam. Permit # 2948 was amended numerous times in the following years.

SRA current authorization is based on Certificate of Adjudication # 05-4669 issued by the Texas Natural Resource Conservation Commission on May 2, 1988. The certificate authorizes SRA to maintain an existing dam and reservoir on Lake Fork Creek (Lake Fork Reservoir) and impound therein not to exceed 675,819 acre-feet (ac-ft) of water.

The owner of the certificate is authorized to divert and use not to exceed 37,000 ac-ft of water per annum for municipal purposes within the Sabine River Basin. This authorization is inclusive of the 20,000 ac-ft of water per annum of which the SRA agreed to provide to the City of Longview. SRA was authorized to divert and use not to exceed 131,860 ac-ft of water per annum for municipal purposes by the City of Dallas; however, not to exceed 120,000 ac-ft of water per annum may be transferred to the Trinity River Basin. This authorization was specifically made subject to the option of Texas Utilities Electric Company to purchase up to 17,000 ac-ft of water per annum for industrial purposes. The purchase would be from the City of Dallas as pursuant to the certain contract dated July 30, 1986 and referred to as "First Supplement to Water Supply Contract and Conveyance". Another authorized use was granted to SRA to divert and use not to exceed 19,500 ac-ft of water per annum for industrial purposes within the Sabine River Basin and to be used by Texas Utilities Electric Company. If the dedicated water is not used for industrial purposes, Texas Utilities Electric Company agrees to release and relinquish to SRA up to 7,500 ac-ft of water per annum to use for municipal purposes in the Sabine River Basin. One last authorization was granted to the SRA of Texas and the City of Dallas to operate Lake Fork and Lake Tawakoni reservoirs on a joint use basis. The term "Joint Use Basis" means that method of operation of the two reservoirs by which either party may sell, deliver or withdraw from one reservoir water which has been authorized to be diverted from either reservoir regardless of whether such party has the physical means to transport water from one reservoir to another. This authorization is subject to the "Special Conditions" listed in the Certificate of Adjudication.

Copies of the Permits and Certificate of Adjudication (original and amended) may be obtained from the Texas Natural Resource Conservation Commission's Central Records in Austin, Texas.

Lake Fork Reservoir is located on Lake Fork Creek and Caney Creek (Sabine River Basin) in Wood County, five miles west of Quitman, Texas (Figure 1). At conservation pool elevation the reservoir extends approximately 15 miles upstream on

Lake Fork Creek and 10 miles upstream on Caney Creek. Records indicate the drainage area is approximately 490 square miles (USGS 1999). At conservation pool elevation (403.0 feet), the reservoir has approximately 306 miles of shoreline. Lake Fork Reservoir and Dam were designed for conservation water supply.

Construction for the Lake Fork Reservoir Project started in October 1975 and was completed in February 1980. Deliberate impoundment began and water levels were raised in three stages to reach conservation pool elevation for the first time in December 1985. Forrest and Cotton Consulting Engineers Inc. designed the project and the general contractor was Holloway Construction of Wixom, Michigan.

Engineering designs (SRA, 1986) show Lake Fork Dam and appurtenant structures to consist of a rolled-earthfill embankment, approximately 12,410 feet in length with a maximum height of 60 feet and a crest elevation of 419.5 feet. A service road occupies the 20-foot wide crest. Soil cement was placed on the upstream slope of the dam to protect from wave action and erosion.

The spillway is a controlled concrete structure located within the embankment near the northeast end of the dam. The net length of the ogee crest weir is 200 feet with a crest elevation at 385.0 feet. The spillway is divided into five bays by concrete piers that support five tainter gates each 40-feet wide by 20-feet tall. The two center piers are bull nose piers that house two 5-feet by 8-feet low-flow outlets. The invert elevations of the sluice gates are 360.0 feet. Maximum design discharge is 81,900 cubic feet per second (cfs). Located in the north pier of the concrete spillway structure are the metered water release outlets. The outlets consist of two 36-inch diameter valve-controlled pipes and one 10-inch valve-controlled pipe. Releases are made for permitted uses, required downstream environmental and water rights flows, and flood control.

SURVEYING EQUIPMENT

The equipment used to perform the volumetric survey consists 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. 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. In shallow areas and where navigational hazards (stumps) were present, a 20-foot aluminum shallow-draft flat bottom SeaArk craft with cabin and equipped with one 115-horsepower Evinrude 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. 4000SE GPS receiver, an OmniSTAR receiver, and a 486 laptop computer.

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 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.

PRE-SURVEY PROCEDURES

The reservoir's boundary was digitized using Environmental Systems Research Institute's (ESRI) Arcview from digital orthophoto quadrangle images (DOQ's). The DOQ's were produced by VARGIS of Texas LLC 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 map boundary was created from the PLEASANT GROVE, YANTIS, ALBA ARBALA and CALAVERY, TEXAS DOQs. The lake elevations at the time the DOQs were photographed were 402.84 feet (February 2, 1995) and 402.54 feet (February 8, 1995).

The DOQ graphic boundary file was transformed from UTM Zone 14 datum to NAD '83, using Environmental Systems Research Institute's (ESRI) Arc/Info PROJECT command with the NADCOM (standard conversion method within the United States) parameters.

The survey layout was designed by placing survey track lines at 500-foot intervals within the digitized lake boundary using Coastal Oceanographics' HYPACK software. The survey design required the use of approximately 740 survey lines along the length of the lake and perpendicular to the original creek channels.

SURVEY PROCEDURES

Equipment Calibration and Operation

At the beginning of each day of the survey, 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 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.

On the shallow draft boat the depth sounder was calibrated using the bar check feature in the Knudsen software program. This was accomplished by positioning the transducer over a known (measured) depth. The speed of sound was then adjusted (either higher or lower) until the displayed depths matched the known depth. The depth was then checked manually with a stadia (survey) rod to ensure that the depth sounder was properly calibrated and operating correctly.

While surveying Lake Fork Reservoir, the speed of sound in the water column ranged from 4,717 feet per second to 4,758 feet per second. Based on the measured speed of sound for various depths and the average speed of sound calculated for the entire water column, the depth sounder is accurate to within +0.2 feet. An additional estimated error of +0.3 feet arises from variation in boat inclination. These two factors combine to give an overall accuracy of +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 E.

During the survey, the horizontal mask setting on the on-board GPS receiver was set to 10 degrees and the PDOP (Position Dilution of Precision) limit was set to 7 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. The lake's initialization file used by the HYPACK data collection program was set up to convert the collected DGPS positions to state-plane coordinates on the fly.

Field Survey

TWDB staff collected data at Lake Fork Reservoir for approximately 20 days during the period of January 30, through March 13, 2001. The lake-level elevations varied from 402.82 feet (Feb. 26) to 403.95 (Mar. 12). Weather conditions during the survey varied as dramatically as the water levels. At times the crew experienced temperatures in the 80's with little or no wind and the surface water conditions were calm. A series of winter cold fronts with abundant precipitation brought flooding to the Sabine watershed upstream of Lake Fork Reservoir during February and March 2001. These storms caused the data collection to be postponed twice. The survey crew would resume data collection after the water levels stabilized.

Prior to starting the survey, TWDB staff met with SRA officials to discuss the logistics of the survey. Concerns were expressed by the SRA about the difference in water-level elevations in the upper reaches of the reservoir and the water-level elevation at the USGS water-level gauge located at the dam. TWDB staff deployed four water level gauges at strategic sites on the reservoir to monitor the water level during the survey. The results of the monitoring program showed that there was no more than one-tenth of a foot difference between the gauge in the upper reaches of the reservoir as compared to the USGS gauge site when data collection was in progress. However analysis of the data showed a one-half foot difference between the gauges during the flood event of February 17, 2001; the water surface elevation rose approximately 2.0 feet during that particular event.

Lake Fork Dam is strategically located downstream of the confluence of Lake Fork Creek, Little Caney Creek and Big Caney Creek. With these major arms of the lake and the tributaries that feed into these arms, the physical formation of the reservoir resembles a “fork”.

The survey crew began at the dam and started collecting data on pre-plotted range lines (transects) that were spaced 500 feet apart and designed to be perpendicular to the channel for the best cross-section results. A data point that consisted of latitude, longitude and depth was collected each second. Data were collected on 693 of the 740 pre-plotted survey range lines. The survey crew would collect irregular transects when navigational hazards such as trees and stumps or shallow depths kept the crew from driving on the pre-plotted lines. Approximately 353,228 data points were collected over the 650 miles traveled during the survey. These points, shown in Figure 2, were stored digitally on the boat’s computer in 982 data files.

The topography surrounding Lake Fork Reservoir was typical of the East Texas rolling hills and occupied with native timbers such as pine, hickory and multiple varieties of oak trees. The inundated creek bottoms usually had wide floodplains, generally flat and also supported large amounts of timber. It was reported by the SRA that 80% of the timber in the inundated portion of Lake Fork Reservoir was kept standing for aquatic habitat purposes. The standing timber and stumps created quite a challenge for the survey crew. Along the shoreline of the reservoir, the survey crew observed both black and red sandy soils mixed with clay. Lake Fork Creek originates in Rains County and flows in a northwest to southeast direction (Wood County). The survey crew noted areas of shoreline erosion throughout reservoir but especially in the Lake Fork Creek arm. Contributing factors to the shoreline erosion could be the swath and the direction in which Lake Fork Creek lies is similar to the predominant winds that generate large waves. In several instances the survey crew noted fallen trees along the bank due to weakened root systems that may have been caused by shoreline erosion or saturated soils.

The survey crew used the larger boat to collect data for the first two weeks in the main body of the lake. This area included from the dam upstream on Big Caney Creek to Highway 154 bridge and on Lake Fork Creek up to Highway 515 bridge. Little Caney

Creek was also surveyed with the big boat. Logistically, it was easier to trailer and launch the shallow draft boat from the different ramps located around the reservoir and collect data. The shallow draft boat is more maneuverable in the smaller coves, shallow areas and those areas with heavy vegetation or other navigational hazards.

In general, the data collection was slow due to the numerous navigational hazards and weather delays. Fortunately, the boat lanes were well marked with buoys (a credit to SRA) and there were plenty of marinas with boat ramps and easy access. One other hazard worth noting was the speeding fishing boats that were on their way to catch that record-breaking large-mouth bass.

Data Processing

The collected data was downloaded from diskettes onto TWDB's computer network. Tape backups were made for future reference. 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 each 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 January to March survey, the water surface varied from elevation 402.82 to 403.95 feet msl according to elevation data provided by USGS elevation gauge (08018800 LAKE FORK RESERVOIR NEAR QUITMAN, TX.). 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 which was used with the GIS software to develop a model of the lake's bottom surface.

The resulting data file was downloaded to a Sun Ultra 10 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 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 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 lake area and volume can be determined from the triangulated irregular network created using this method of interpolation. Volumes and area were calculated from the TIN for the entire reservoir at one-tenth of a foot interval from minimum elevation to conservation pool level. From elevation 332.2 feet to 403.0 feet, the surface areas and volumes of the lake were computed using the Arc/Info software. The computed reservoir volume table is presented in Appendix A and the area table is presented in Appendix B. Graphs for the volume and area tables can be found in Appendix C and D respectively.

Other products developed from the model include a shaded elevation range 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 elevation contour map of the bottom surface at five-foot intervals is presented in Figure 5.

RESULTS

Results from the 2001 TWDB survey indicate Lake Fork Reservoir encompasses 27,264 surface acres and contains a total volume of 636,133 acre-feet at the conservation pool elevation of 403.0 feet msl (gauge datum). Dead pool storage, the volume below the invert elevation of the low-flow outlet pipe at 360.0 feet msl, is 31,206 acre-feet. Thus, the conservation storage (total volume - dead storage) for Lake Fork Reservoir is 604,927 acre-feet. The shoreline at conservation pool elevation was calculated to be approximately 306 miles. The deepest point that was measured during the survey was at elevation 332.0 feet msl and corresponding to a depth of 71 feet, was located approximately 1,160 feet upstream from Lake Fork Dam.

SUMMARY AND COMPARISONS

Lake Fork Reservoir was completed in February 1980 and reservoir storage reached conservation pool elevation 403.0 feet in December 1985. Storage calculations in 1980 (SRA, 1986) reported the volume at conservation pool elevation 403.0 feet msl to be 675,819 acre-feet with a surface area of 27,690 acres.

During January 30 through March 13, 2001, TWDB staff completed a volumetric survey of Lake Fork Reservoir. The 2001 survey utilized a differential global positioning system, depth sounder and geographical information system technology to create a digital model of the lake's bathymetry.

At conservation pool elevation, the original design estimated the surface area of Lake Fork Reservoir to be 27,690 acres. The current survey measured 27,264 surface acres, or a difference of 426 surface acres.

Results indicate that the lake's volume at the conservation pool elevation of 403.0 feet msl is 636,133 acre-feet. The dead pool below elevation 360.0 feet was found to be 31,206 acre-feet, and thus the conservation storage found in this survey is 604,927 acre-feet. The total design volume of the reservoir was 675,819 acre-feet.

Comparisons between the original design information and the 2001 data collection set is difficult and some apparent changes might simply be due to methodological differences. It is recommended that the similar survey be performed in five to ten years or after major flood events to monitor changes to the lake's storage volume.

Table 1. Area and volume comparisons at elevation 403.0 feet msl.

Year	1980 (Original Design)	2001 (TWDB Survey)
Area (acres)	27,690	27,264
Volume (acre-feet)	675,819	636,133

REFERENCES

1. Sabine River Authority of Texas. 1986 “Lake Fork Dam and Reservoir” Historical and Descriptive Information. Brochure.

2. Sabine River Authority of Texas. May 4, 1980 revised December 7, 1991 “Lake Fork Dam and Reservoir, Official Manual of Policies, Rules and Regulations”.

3. United States Geological Survey. 1999. "Water Resources Data – Texas. Water Year 1999". Volume 1. Arkansas River Basin, Red River Basin, Sabine River Basin, Neches River Basin and Intervening Coastal Basins. Water-Data Report TX-99-1.

Appendix A

Lake Fork Reservoir

RESERVOIR VOLUME TABLE

TEXAS WATER DEVELOPMENT BOARD — March 2001 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
332			0	0	0	0	0	0	0	0
333	0	0	0	0	0	0	0	0	0	0
334	0	0	0	0	0	0	0	1	1	1
335	1	1	1	1	1	1	1	2	2	2
336	2	2	2	3	3	3	3	4	4	4
337	5	5	5	6	6	7	7	8	8	9
338	9	10	11	11	12	13	14	15	16	17
339	18	19	21	22	24	25	27	29	30	32
340	34	36	38	40	43	45	48	50	53	56
341	59	62	65	68	72	76	80	84	88	93
342	98	103	109	114	120	127	133	140	148	155
343	163	172	181	190	200	211	222	233	246	258
344	272	286	301	317	334	351	370	389	410	431
345	454	478	503	529	556	585	615	647	681	716
346	753	793	835	880	928	980	1034	1092	1153	1217
347	1285	1356	1430	1507	1586	1668	1753	1840	1929	2020
348	2114	2211	2309	2409	2512	2617	2723	2832	2943	3055
349	3170	3287	3406	3528	3651	3777	3905	4036	4169	4304
350	4442	4583	4726	4873	5023	5175	5330	5488	5648	5810
351	5975	6143	6312	6484	6659	6836	7015	7197	7382	7568
352	7758	7949	8144	8341	8540	8743	8948	9156	9367	9581
353	9797	10016	10237	10461	10687	10916	11147	11381	11617	11856
354	12097	12340	12585	12832	13081	13332	13585	13841	14098	14358
355	14620	14885	15153	15423	15696	15971	16249	16529	16811	17096
356	17383	17672	17963	18257	18553	18851	19151	19454	19759	20067
357	20377	20690	21005	21323	21644	21968	22296	22626	22960	23297
358	23637	23981	24328	24679	25033	25390	25752	26116	26485	26857
359	27233	27613	27997	28385	28777	29173	29572	29976	30382	30792
360	31206	31623	32044	32469	32897	33329	33765	34204	34648	35096
361	35548	36005	36466	36930	37398	37870	38346	38825	39307	39794
362	40285	40780	41280	41784	42292	42804	43321	43841	44365	44893
363	45425	45961	46501	47045	47593	48144	48698	49256	49817	50381
364	50950	51522	52097	52676	53259	53845	54434	55027	55622	56222
365	56825	57432	58042	58655	59272	59893	60517	61144	61776	62411
366	63050	63693	64341	64991	65647	66306	66969	67635	68305	68979
367	69657	70338	71024	71712	72405	73102	73802	74506	75214	75926
368	76641	77361	78084	78811	79542	80277	81016	81759	82505	83256
369	84011	84770	85533	86300	87071	87846	88625	89409	90196	90987
370	91783	92582	93385	94192	95004	95821	96642	97467	98296	99130
371	99968	100810	101656	102507	103362	104222	105087	105956	106829	107708
372	108591	109479	110372	111269	112172	113079	113991	114907	115828	116753
373	117683	118617	119556	120499	121446	122398	123354	124314	125277	126246
374	127218	128194	129175	130159	131147	132140	133136	134137	135141	136151
375	137164	138182	139205	140232	141264	142301	143342	144389	145439	146495
376	147555	148620	149690	150764	151843	152927	154016	155110	156208	157312
377	158420	159534	160652	161775	162903	164037	165175	166319	167467	168620
378	169779	170943	172112	173286	174465	175651	176842	178038	179240	180447
379	181659	182877	184099	185325	186557	187793	189034	190280	191530	192785
380	194045	195310	196580	197855	199135	200420	201709	203004	204304	205609
381	206920	208236	209557	210883	212215	213552	214894	216241	217593	218951
382	220314	221682	223055	224433	225817	227205	228599	229997	231400	232809
383	234223	235642	237067	238496	239930	241369	242814	244263	245717	247177
384	248642	250111	251586	253066	254551	256042	257537	259038	260543	262054
385	263570	265091	266618	268149	269686	271229	272776	274330	275888	277452
386	279022	280597	282178	283763	285354	286951	288552	290159	291771	293387
387	295009	296636	298268	299905	301547	303195	304849	306508	308172	309844
388	311522	313206	314897	316594	318298	320008	321724	323445	325173	326907

Appendix A (continued)

Lake Fork Reservoir

RESERVOIR VOLUME TABLE

TEXAS WATER DEVELOPMENT BOARD — March 2001 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
389	328647	330393	332144	333901	335665	337434	339210	340991	342778	344572
390	346372	348178	349990	351808	353632	355463	357299	359142	360990	362845
391	364706	366573	368446	370325	372211	374103	376002	377907	379818	381735
392	383659	385588	387524	389464	391412	393366	395326	397293	399265	401245
393	403231	405224	407222	409227	411238	413255	415278	417308	419343	421385
394	423434	425489	427551	429618	431693	433775	435863	437958	440059	442167
395	444282	446403	448531	450665	452807	454955	457110	459272	461439	463615
396	465797	467986	470182	472384	474594	476810	479034	481264	483501	485745
397	487996	490254	492519	494790	497069	499355	501647	503947	506253	508568
398	510889	513217	515553	517895	520246	522604	524969	527342	529722	532110
399	534506	536910	539321	541739	544166	546600	549043	551492	553949	556413
400	558885	561363	563849	566341	568840	571346	573859	576378	578903	581436
401	583975	586520	589073	591631	594198	596771	599351	601938	604530	607129
402	609735	612347	614965	617588	620219	622855	625498	628148	630803	633465
403	636133									

Appendix B

Lake Fork Reservoir

RESERVOIR AREA TABLE

TEXAS WATER DEVELOPMENT BOARD — March 2001 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
332			0	0	0	0	0	0	0	0
333	0	0	0	0	0	0	0	0	0	0
334	0	0	0	0	1	1	1	1	1	1
335	1	1	1	1	1	1	1	1	2	2
336	2	2	2	2	2	3	3	3	3	3
337	3	4	4	4	4	5	5	5	5	6
338	6	7	7	8	8	9	9	10	11	11
339	12	13	14	14	15	16	17	17	18	19
340	20	21	22	22	23	24	25	27	28	29
341	30	32	33	35	37	39	41	43	45	48
342	50	53	56	59	62	65	68	72	75	79
343	83	87	91	96	102	108	114	120	126	132
344	139	146	154	162	171	180	190	200	210	221
345	232	244	256	269	282	296	310	325	342	362
346	384	409	437	468	499	528	560	593	628	662
347	695	725	754	781	806	832	857	881	904	928
348	951	973	994	1015	1036	1057	1077	1097	1117	1138
349	1159	1180	1202	1224	1246	1270	1293	1317	1341	1366
350	1393	1422	1453	1484	1511	1537	1562	1587	1612	1638
351	1662	1685	1709	1733	1757	1782	1807	1832	1856	1881
352	1905	1930	1956	1983	2010	2038	2067	2096	2123	2151
353	2176	2201	2225	2248	2274	2300	2325	2351	2376	2399
354	2420	2440	2460	2480	2502	2523	2544	2565	2587	2610
355	2635	2661	2688	2714	2740	2766	2790	2813	2836	2858
356	2880	2902	2923	2946	2969	2993	3017	3040	3063	3088
357	3114	3141	3168	3196	3225	3257	3290	3321	3355	3387
358	3420	3454	3488	3522	3557	3595	3631	3668	3704	3742
359	3779	3817	3858	3902	3941	3978	4013	4048	4084	4119
360	4155	4192	4228	4264	4300	4337	4376	4417	4459	4502
361	4545	4587	4626	4664	4700	4735	4771	4809	4847	4888
362	4930	4974	5017	5060	5104	5144	5184	5223	5261	5301
363	5341	5380	5419	5456	5492	5526	5560	5594	5630	5665
364	5701	5738	5774	5808	5842	5875	5909	5942	5977	6012
365	6048	6084	6119	6153	6187	6223	6258	6294	6332	6373
366	6412	6451	6491	6532	6571	6609	6647	6684	6721	6758
367	6796	6833	6870	6908	6946	6984	7022	7060	7099	7137
368	7175	7212	7251	7290	7329	7370	7409	7448	7487	7527
369	7568	7609	7650	7691	7732	7773	7813	7853	7893	7933
370	7972	8012	8053	8096	8142	8187	8230	8272	8314	8357
371	8400	8443	8486	8530	8575	8621	8668	8715	8762	8809
372	8855	8902	8951	8999	9047	9095	9141	9187	9232	9276
373	9320	9364	9408	9451	9494	9537	9579	9621	9662	9702
374	9742	9783	9823	9864	9904	9944	9985	10026	10069	10114
375	10159	10205	10250	10296	10343	10390	10437	10484	10532	10580
376	10627	10674	10720	10767	10815	10863	10913	10962	11012	11061
377	11109	11158	11208	11257	11307	11358	11409	11459	11510	11561
378	11612	11663	11715	11768	11823	11881	11938	11993	12046	12096
379	12147	12197	12244	12292	12339	12386	12432	12480	12528	12577
380	12625	12673	12723	12773	12823	12873	12923	12974	13026	13079
381	13133	13185	13237	13290	13342	13394	13446	13498	13550	13602
382	13654	13707	13758	13809	13860	13910	13959	14009	14060	14112
383	14165	14218	14269	14318	14367	14418	14469	14519	14569	14620

Appendix B (continued)

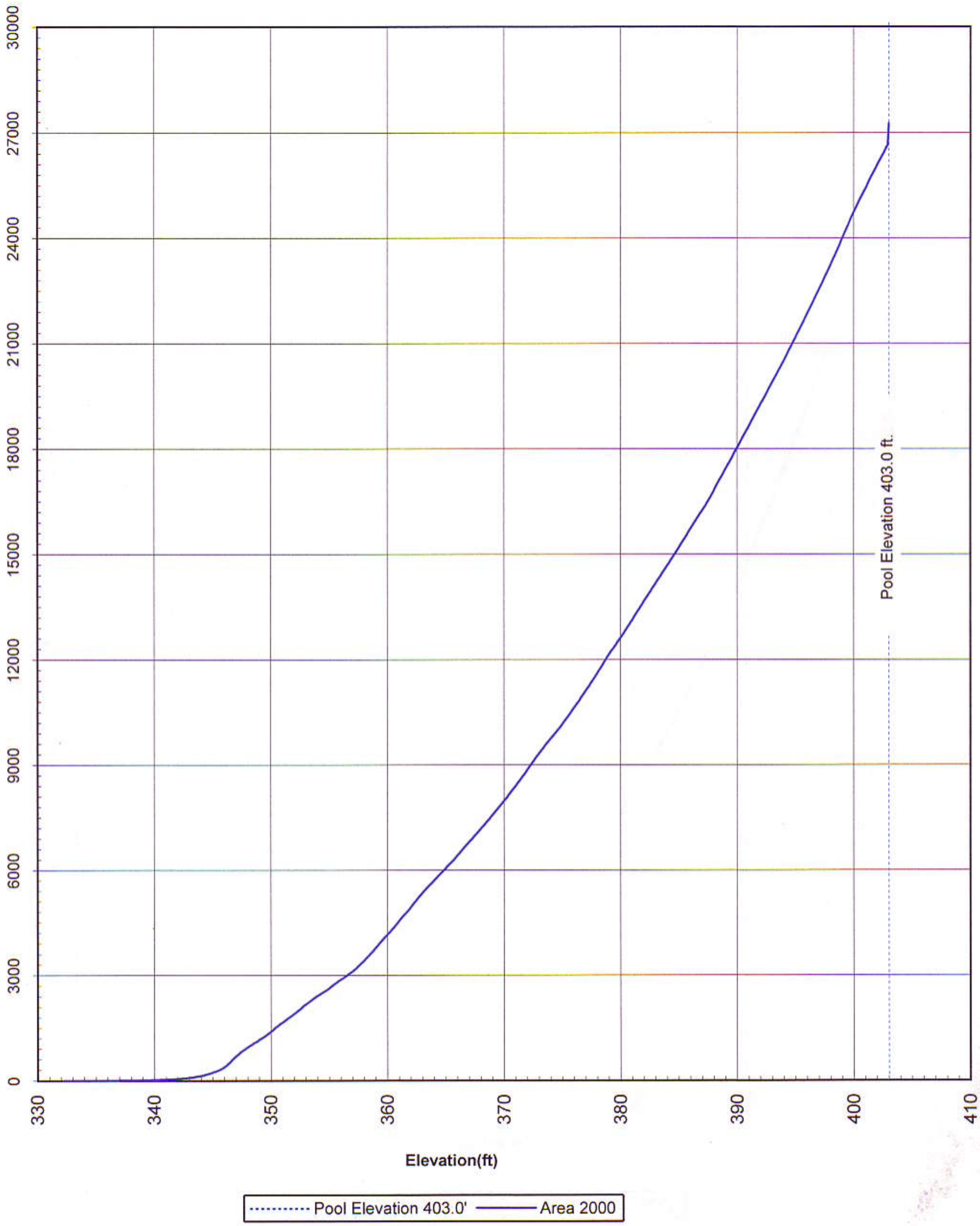
Lake Fork Reservoir

RESERVOIR AREA TABLE

TEXAS WATER DEVELOPMENT BOARD March 2001 SURVEY

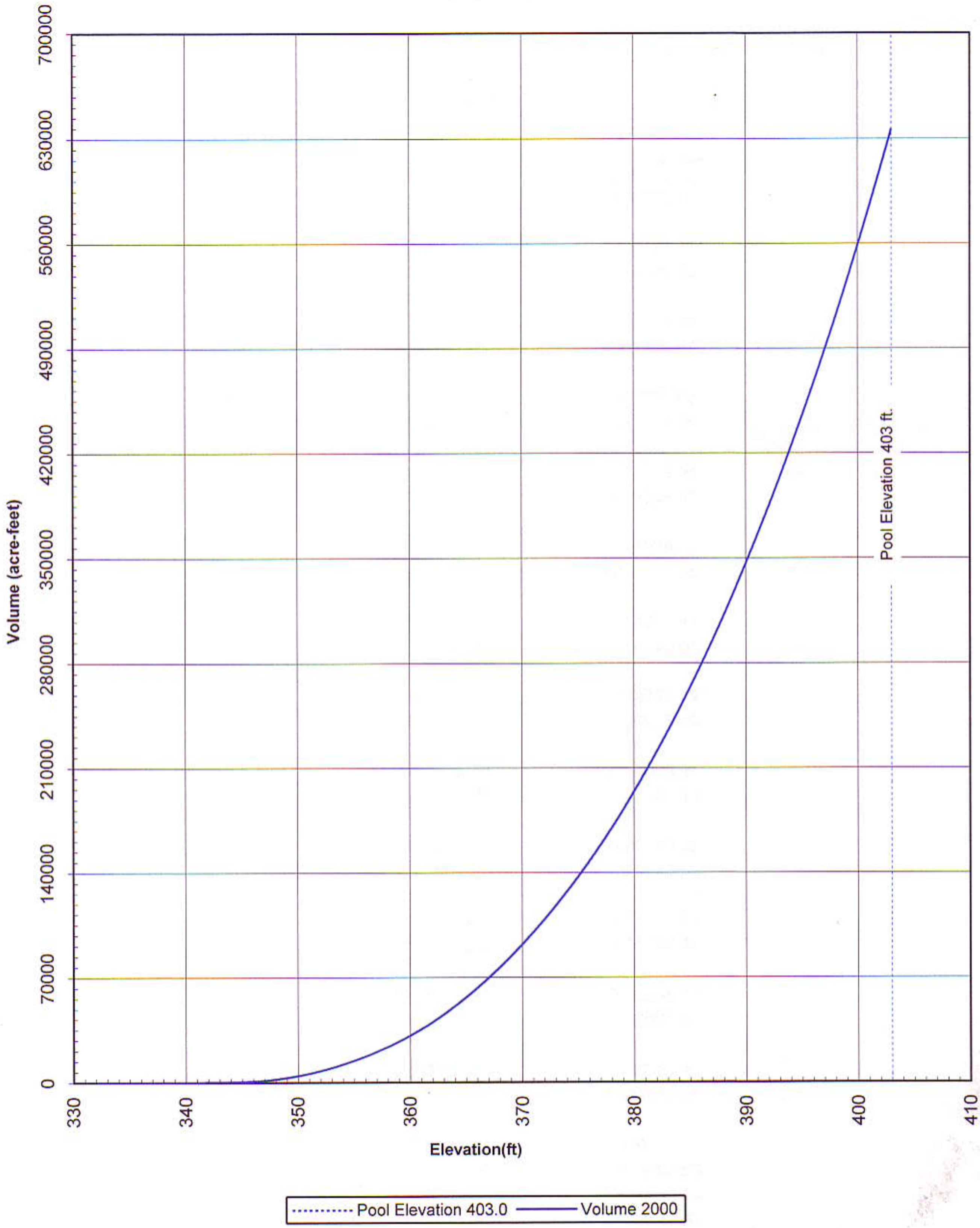
AREA IN ACRES ELEVATION INCREMENT IS ONE TENTH FOOT

ELEVATION in Feet	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
384	14672	14724	14775	14826	14877	14929	14979	15030	15082	15133
385	15185	15237	15291	15345	15397	15450	15505	15560	15614	15667
386	15723	15778	15832	15886	15938	15989	16040	16092	16143	16192
387	16242	16293	16345	16397	16451	16505	16560	16620	16683	16748
388	16811	16875	16941	17005	17067	17127	17187	17247	17308	17368
389	17428	17487	17546	17604	17662	17723	17784	17846	17907	17968
390	18029	18090	18150	18212	18273	18334	18394	18455	18516	18576
391	18638	18700	18763	18827	18890	18954	19018	19081	19144	19205
392	19264	19322	19381	19442	19505	19569	19635	19699	19763	19828
393	19891	19954	20017	20078	20139	20201	20263	20326	20390	20453
394	20517	20583	20649	20715	20781	20848	20915	20982	21047	21114
395	21180	21247	21312	21379	21446	21514	21582	21650	21718	21785
396	21853	21922	21992	22063	22132	22201	22268	22337	22405	22474
397	22543	22612	22681	22752	22822	22892	22962	23032	23104	23175
398	23247	23320	23392	23465	23540	23615	23690	23765	23841	23919
399	23997	24074	24151	24227	24304	24381	24460	24532	24606	24679
400	24751	24821	24891	24958	25025	25092	25158	25224	25290	25355
401	25422	25490	25558	25627	25697	25765	25831	25897	25961	26023
402	26085	26147	26210	26272	26334	26397	26461	26524	26588	26652
403	27264									



Lake Fork Reservoir
March 2001
Prepared by: TWDB

Appendix C Elevation vs. Area



Lake Fork Reservoir
March 2001
Prepared by: TWDB

Appendix D Elevation vs. Volume

Appendix E
Lake Fork Reservoir

TEXAS WATER DEVELOPMENT BOARD February 2001 SURVEY

Range Line Endpoints
State Plane NAD83 Units-feet

Range Line	X	Y
RL1-L	2881860.64	6994045.04
RL1-R	2873960.81	6985708.75
RL2-L	2875248.35	6996947.46
RL2-R	2869268.92	6988065.60
RL3-L	2870120.00	6999173.38
RL3-R	2864860.72	6991840.94
RL4-L	2862154.70	7007018.66
RL4-R	2856699.01	6999337.05
RL5-L	2859754.20	7011525.06
RL5-R	2852072.59	7009888.35
RL6-L	2854276.69	7017624.52
RL6-R	2848821.00	7013150.85
RL7-L	2846114.98	7023047.47
RL7-R	2842994.33	7015540.44
RL8-L	2840942.41	7024756.49
RL8-R	2838800.24	7019615.29
RL9-L	2836994.70	7033008.94
RL9-R	2832771.57	7023420.19
RL10-L	2828670.85	7032723.32
RL10-R	2825488.20	7025541.95
RL11-L	2825947.23	7034528.86
RL11-R	2822948.20	7031264.60
RL12-L	2821662.90	7038099.14
RL12-R	2819214.70	7035242.91
RL13-L	2820571.41	7040231.11
RL13-R	2818551.65	7037660.50
RL14-L	2882393.93	6998466.35
RL14-R	2874700.30	6998058.03
RL15-L	2882071.57	7003817.51
RL15-R	2875538.43	7006976.62
RL16-L	2884457.03	7013026.22
RL16-R	2876978.30	7013971.81
RL17-L	2884650.443	7018323.65
RL17-R	2878353.7	7019441.17

Appendix E (continued)

Lake Fork Reservoir

TEXAS WATER DEVELOPMENT BOARD February 2001 SURVEY

Range Line Endpoints

State Plane NAD83 Units-feet

Range Line	X	Y
RL18-L	2885080.254	7023556.61
RL18-R	2878009.85	7023599.59
RL19-L	2885252.178	7023986.42
RL19-R	2881125.985	7025770.14
RL20-L	2888862.597	7031884.22
RL20-R	2883532.932	7034291.16
RL21-L	2890861.224	7032948
RL21-R	2886283.729	7038213.2
RL22-L	2894922.945	7033463.78
RL22-R	2892644.942	7036794.82
RL23-L	2885209.2	7038793.44
RL23-R	2882608.838	7038062.76
RL24-L	2880223.384	7029520.25
RL24-R	2873152.98	7027929.95
RL25-L	2875624.4	7001614.72
RL25-R	2870402.187	7003248.01
RL26-L	2872379.321	7010898.66
RL26-R	2870831.999	7009179.41
RL27-L	2869907.903	7013477.53
RL27-R	2868962.317	7012445.98
RL28-L	2853596.546	7018721.23
RL28-R	2850802.771	7021235.63
RL29-L	2854563.623	7020547.93
RL29-R	2852994.811	7021966.31
RL30-L	2846182.294	7023287.98
RL30-R	2842851.253	7025372.57
RL31-L	2845408.633	7029391.31
RL31-R	2840315.363	7029520.25
RL32-L	2847837.07	7035311.97
RL32-R	2845150.747	7037289.1
RL33-L	2852135.191	7043639.57
RL33-R	2848030.488	7043768.52
RL34-L	2825422.388	7035226.01
RL34-R	2824068.481	7036214.57

Lake Fork Reservoir

TEXAS WATER DEVELOPMENT BOARD February 2001 SURVEY

Range Line Endpoints

State Plane NAD83 Units-feet

Range Line	X	Y
RL35-L	2827829.335	7037095.69
RL35-R	2825744.747	7038771.95
RL36-L	2871842.067	6986582.06
RL36-R	2872830.636	6985034.74
RL37-L	2865179.984	6990729.74
RL37-R	2867307.553	6988838.57
RL38-L	2863030.926	6987850
RL38-R	2864169.927	6986925.91
RL39-L	2858743.555	6997031.86
RL39-R	2861752.237	6994463.73
RL40-L	2856734.185	6992158.87
RL40-R	2858098.837	6990955.4
RL41-L	2857421.884	6999062.72
RL41-R	2858872.499	6997698.07
RL42-L	2854080.098	7003376.96
RL42-R	2854692.579	6998391.14
RL43-L	2851189.613	7002667.77
RL43-R	2851544.208	6999283
RL44-L	2849642.291	7000153.37
RL44-R	2850770.547	6998885.42
RL45-L	2847611.431	6997891.48
RL45-R	2848685.96	6996924.41
RL46-L	2850372.971	7002657.02
RL46-R	2850448.189	7001023.74
RL47-L	2846859.261	7002904.16
RL47-R	2846955.968	7001711.44
RL48-L	2853929.665	7006659.64
RL48-R	2853070.042	7004274.19
RL49-L	2851436.756	7007110.95
RL49-R	2850544.897	7004532.08
RL50-L	2848191.678	7008491.72
RL50-R	2847493.234	7006396.39
RL51-L	2842862.012	7008008.18
RL51-R	2843581.947	7006869.18

Lake Fork Reservoir

TEXAS WATER DEVELOPMENT BOARD February 2001 SURVEY

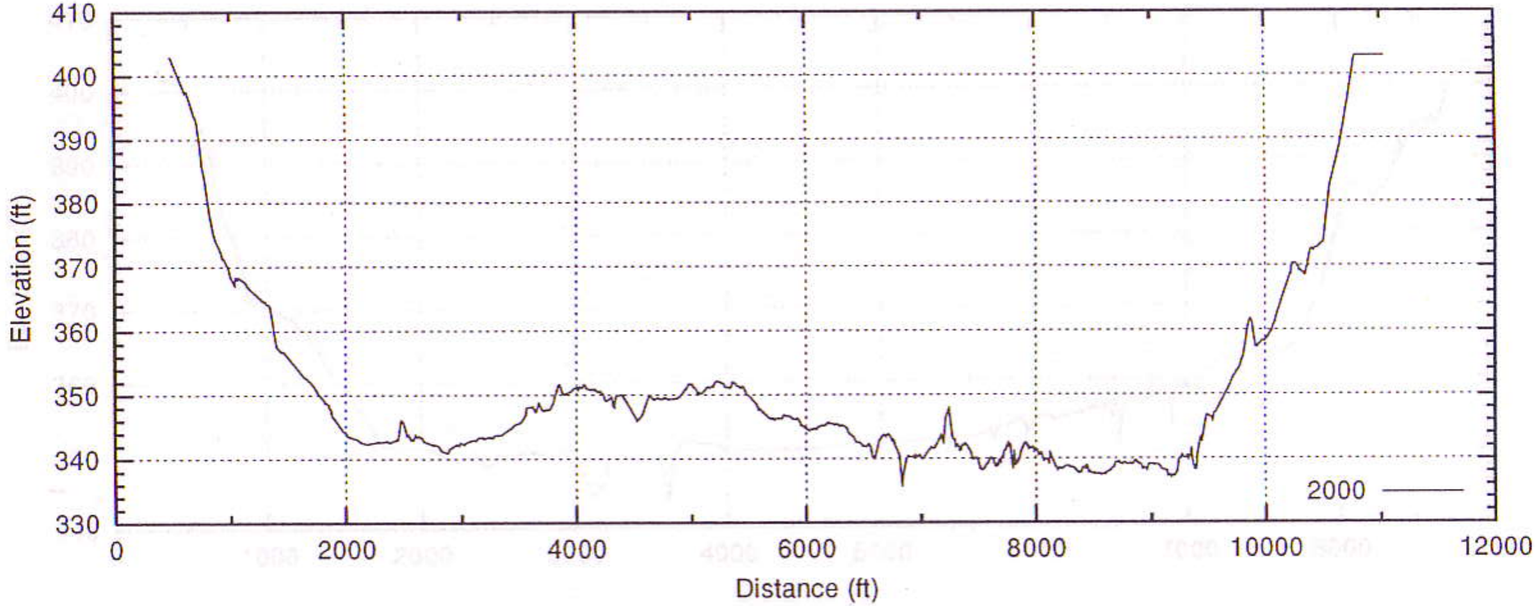
Range Line Endpoints

State Plane NAD83 Units-feet

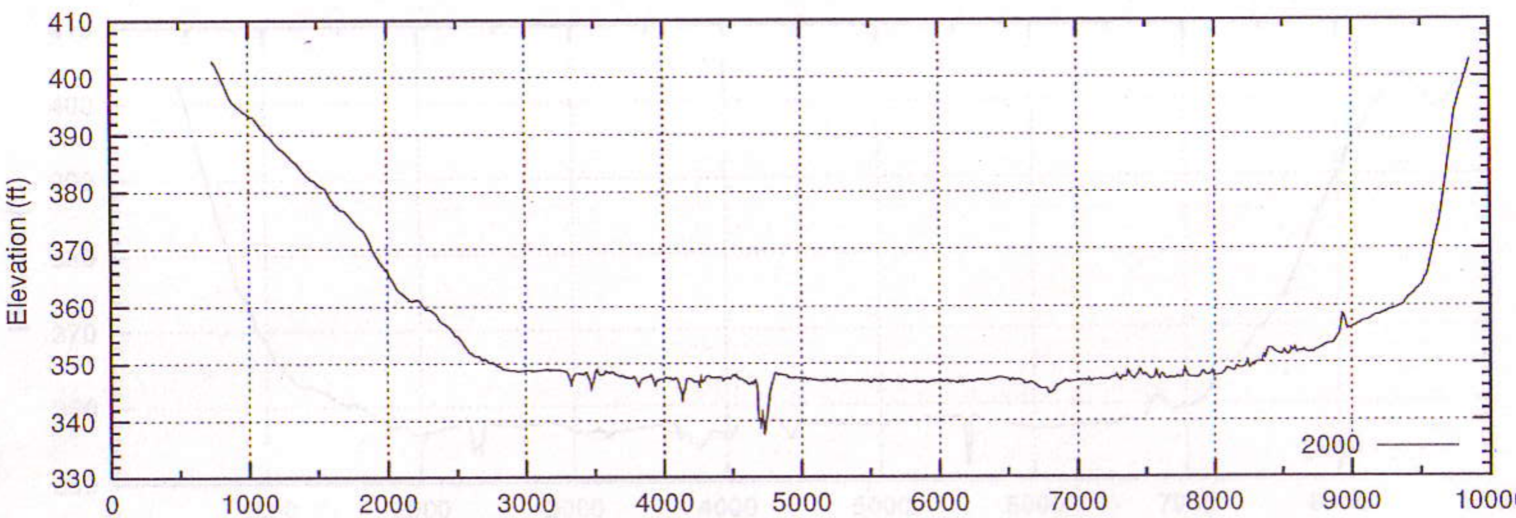
Range Line	X	Y
RL52-L	2843066.173	7015454.67
RL52-R	2844119.212	7015186.04
RL53-L	2839874.821	7015916.72
RL53-R	2840551.774	7015820.01
RL54-L	2840594.755	7017770.28
RL54-R	2840626.992	7016448.61
RL55-L	2838080.356	7017770.28
RL55-R	2838155.574	7016577.55
RL56-L	2837672.036	7021310.86
RL56-R	2838005.14	7019838.75
RL57-L	2836221.421	7021826.63
RL57-R	2836264.402	7020623.16
RL58-L	2833717.768	7021343.09
RL58-R	2833760.749	7020021.42
RL59-L	2826120.845	7025684.19
RL59-R	2828850.15	7024545.19
RL60-L	2824917.372	7023320.22
RL60-R	2825680.288	7021923.34
RL61-L	2824047.004	7029864.11
RL61-R	2822478.191	7025920.59
RL62-L	2819619.943	7032045.41
RL62-R	2818416.469	7029316.1
RL63-L	2813076.058	7034608.16
RL63-R	2814096.861	7032502.08

LAKE FORK

RL-1



RL-2

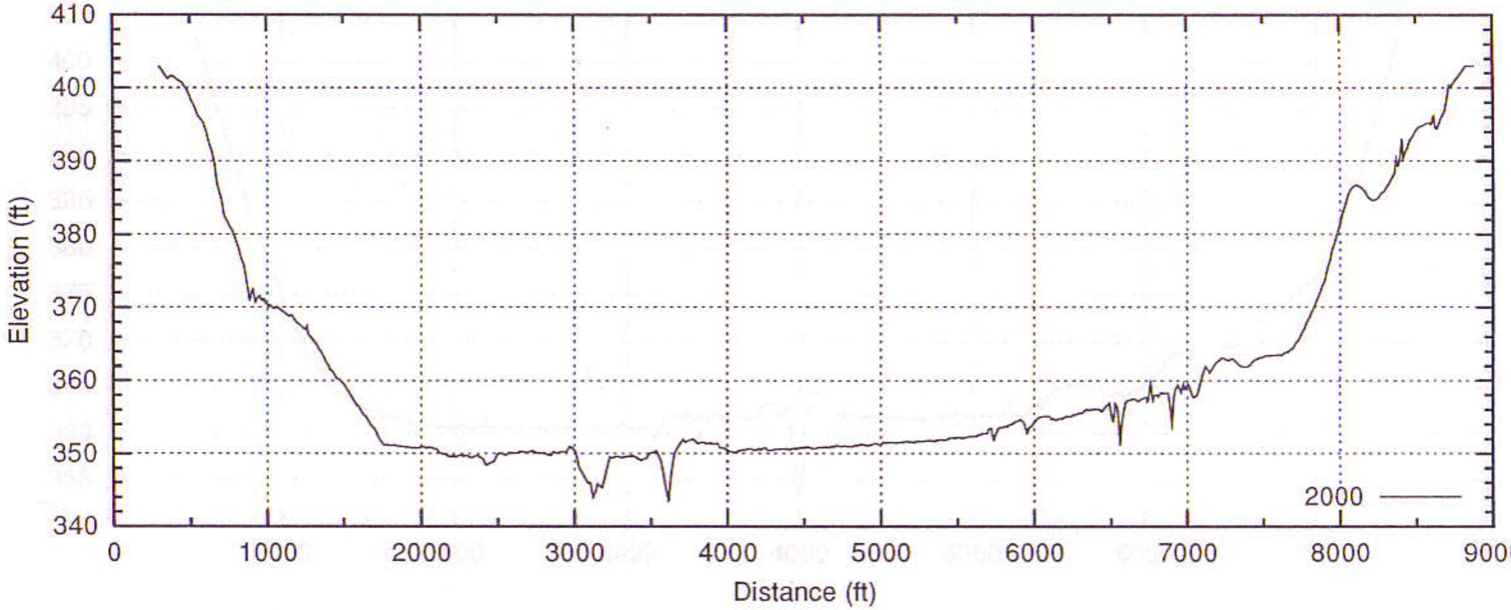


Distance (ft)

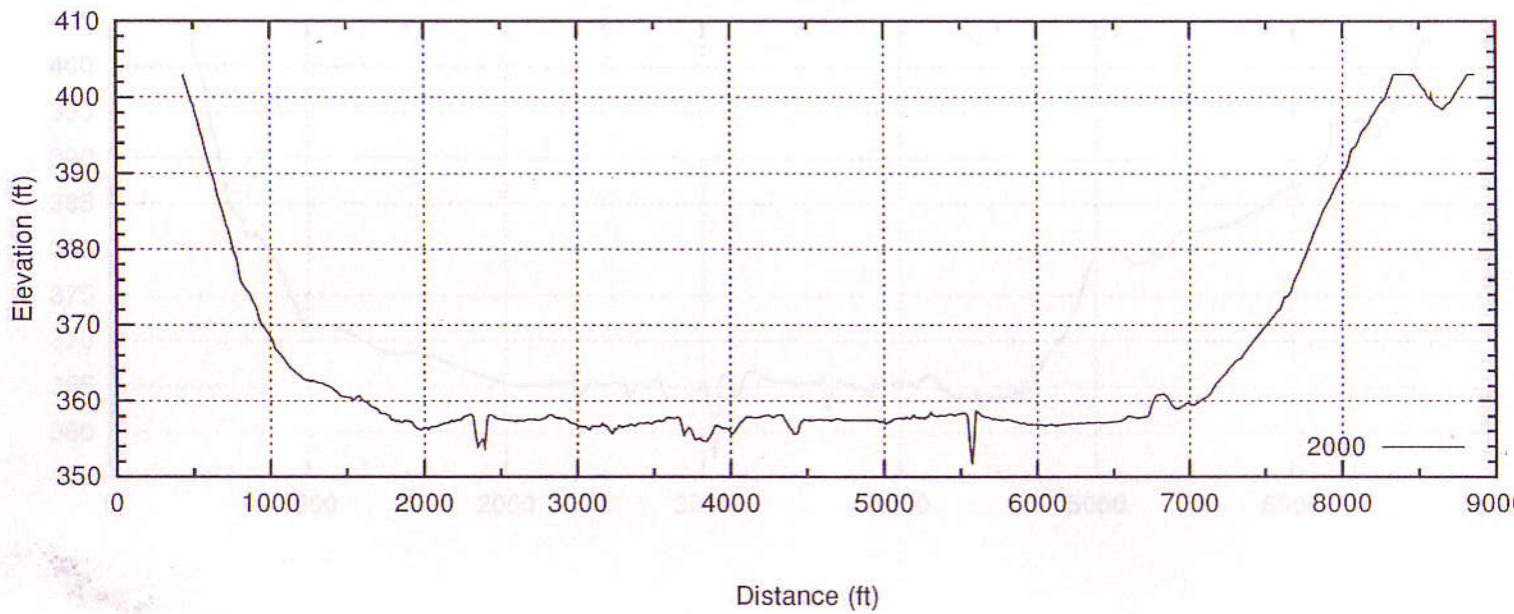
Appendix E

LAKE FORK

RL-3



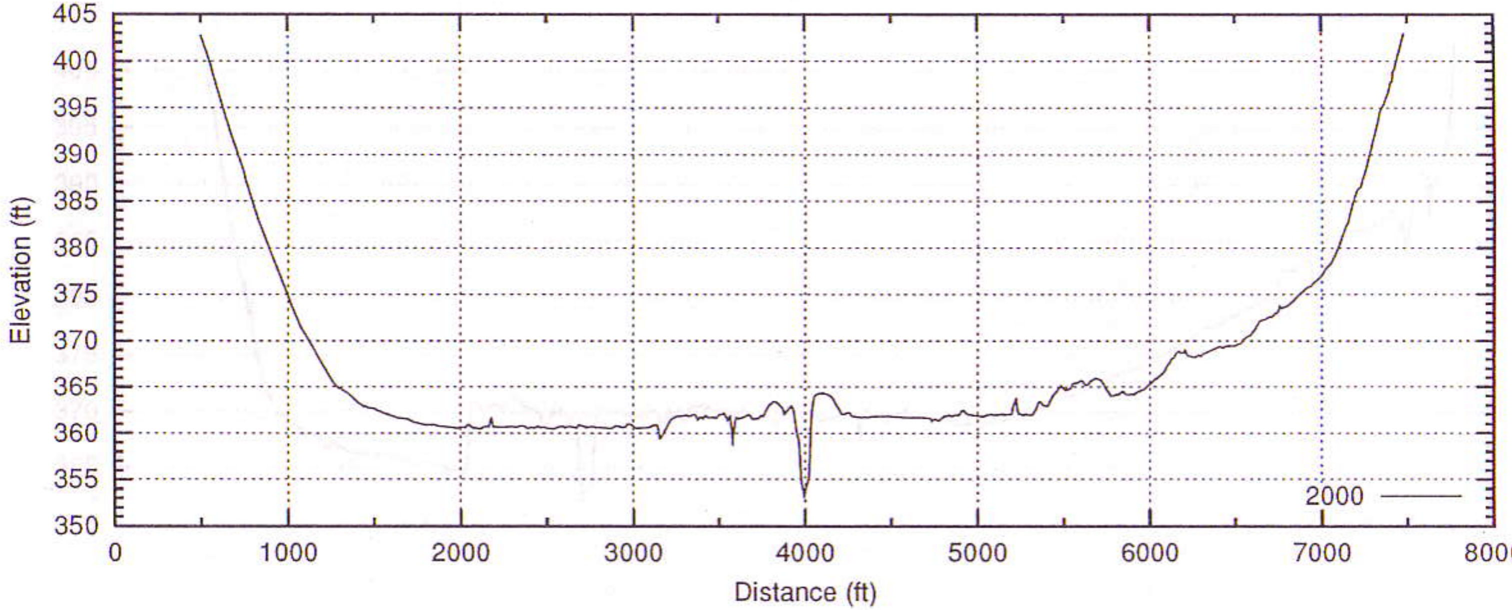
RL-4



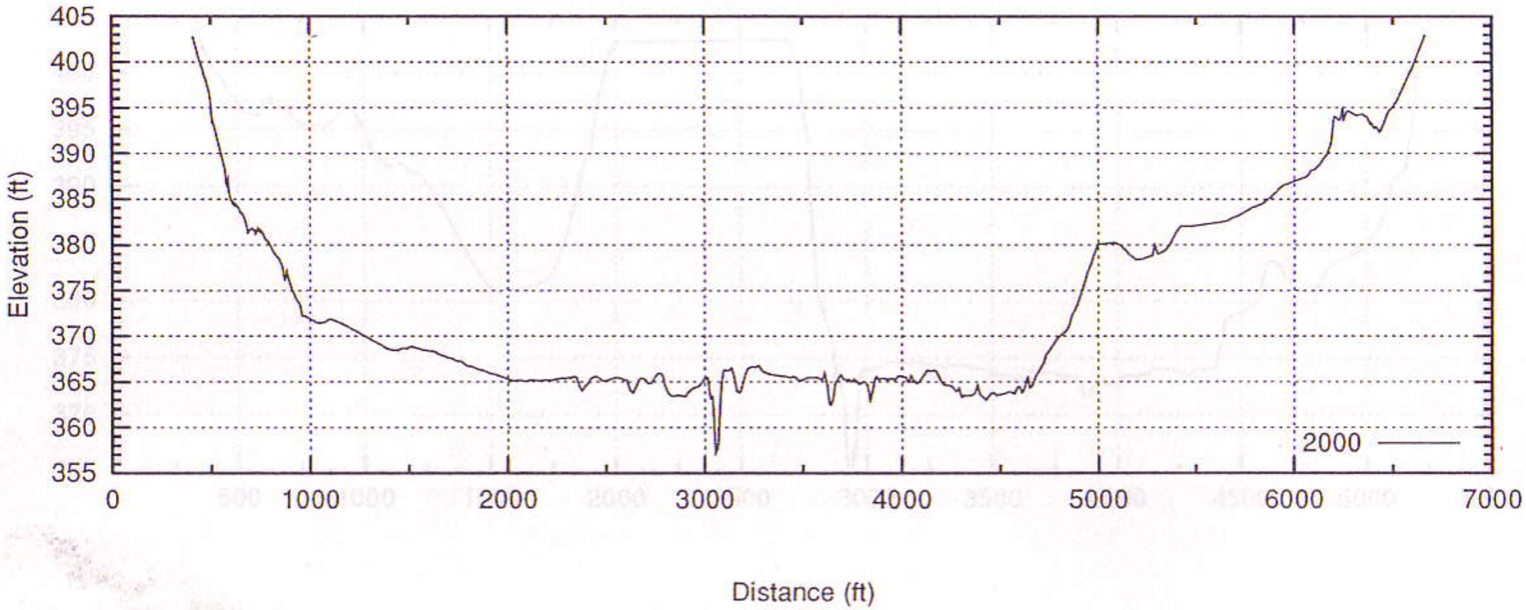
Appendix E

LAKE FORK

RL-5

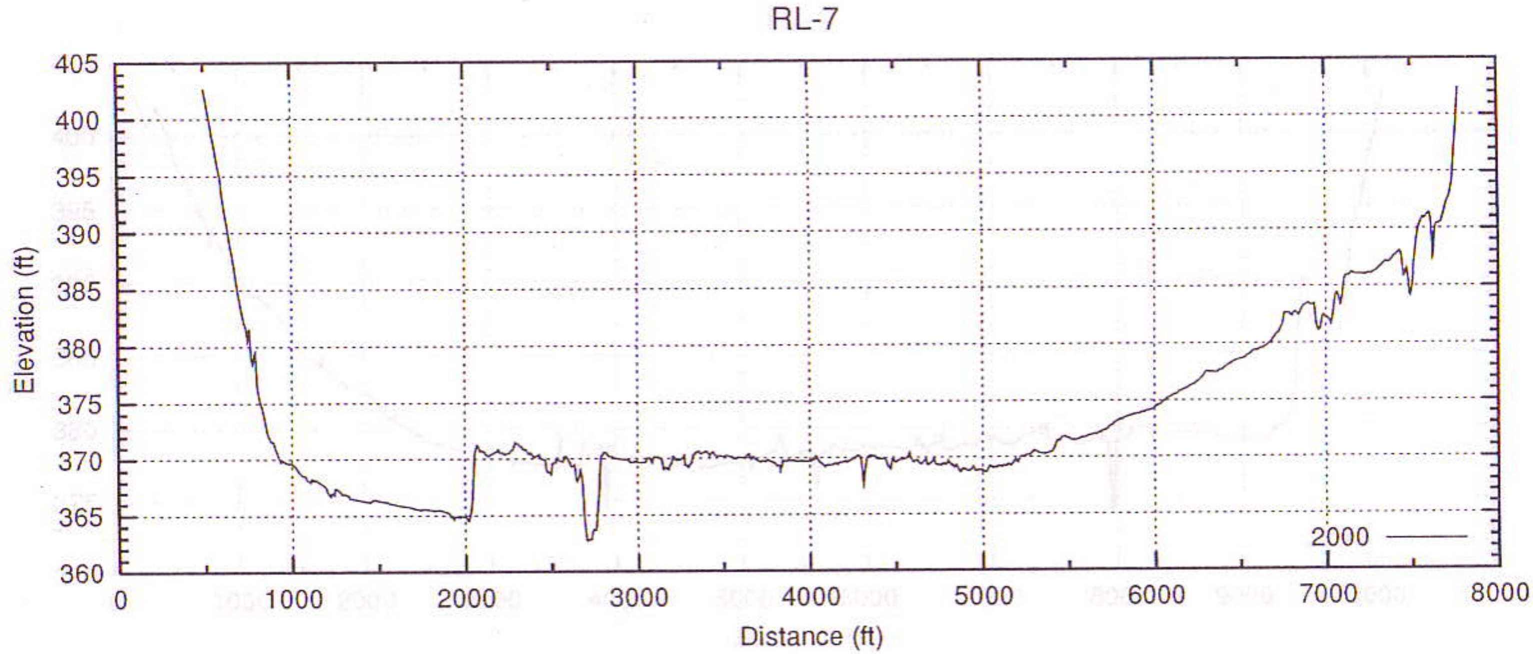


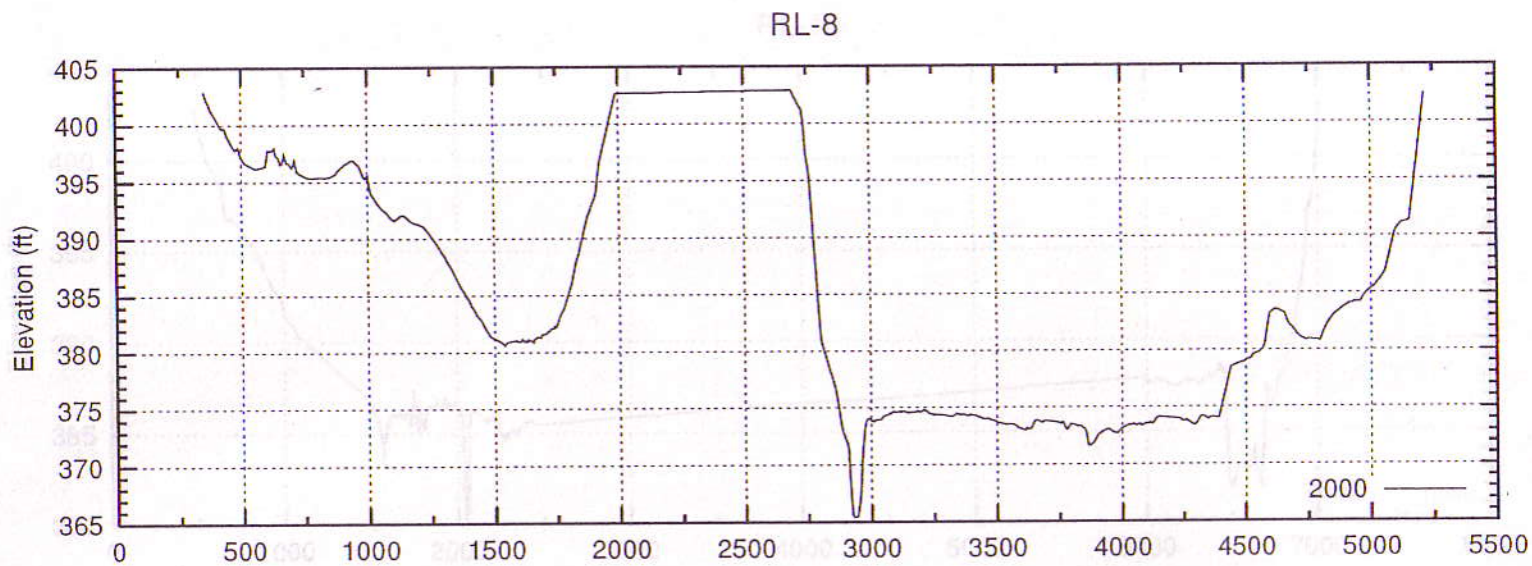
RL-6



Appendix E

LAKE FORK

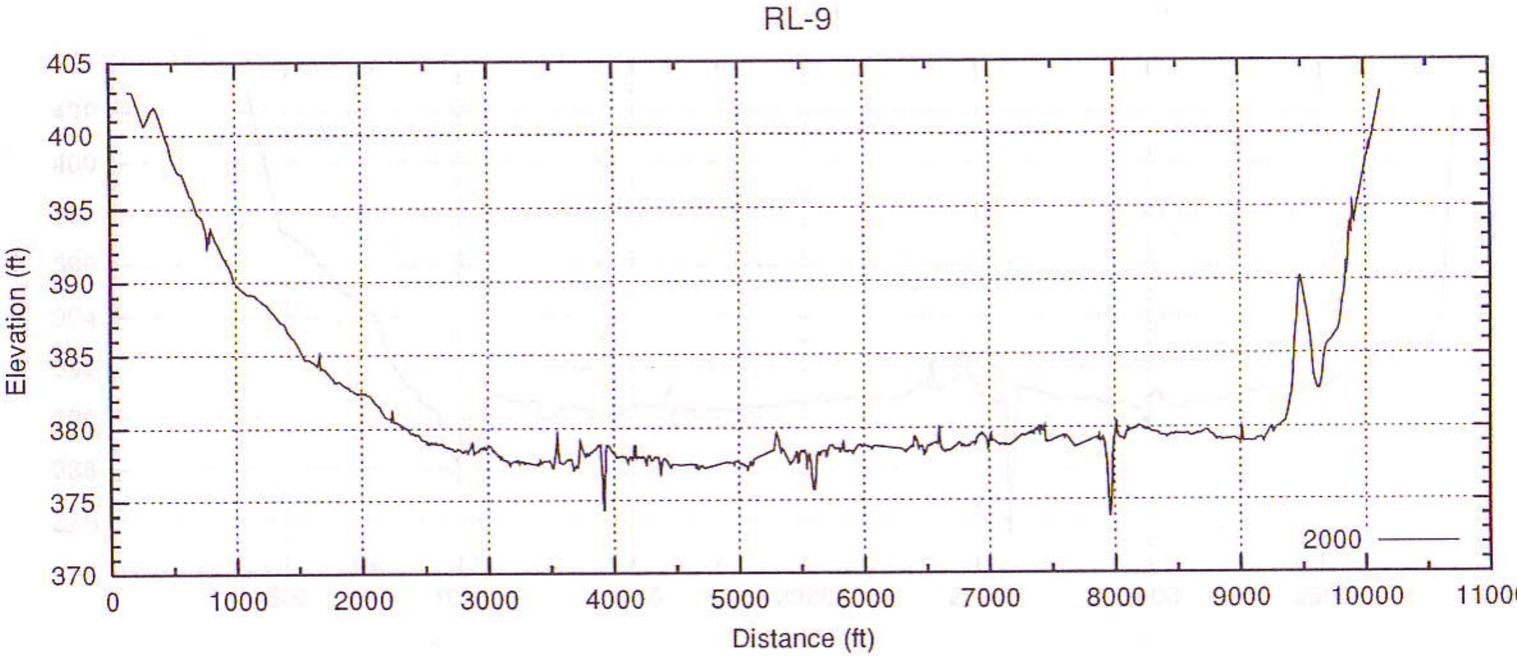




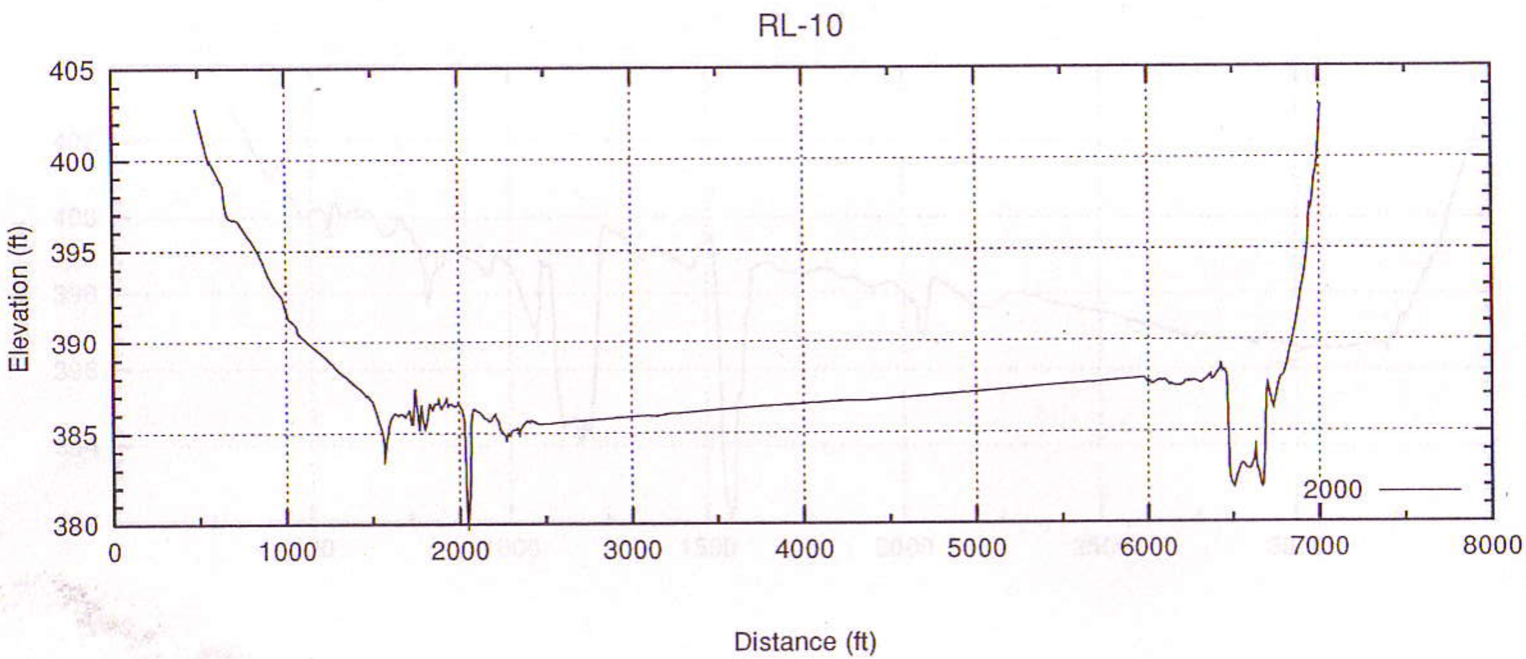
Distance (ft)

Appendix E

LAKE FORK

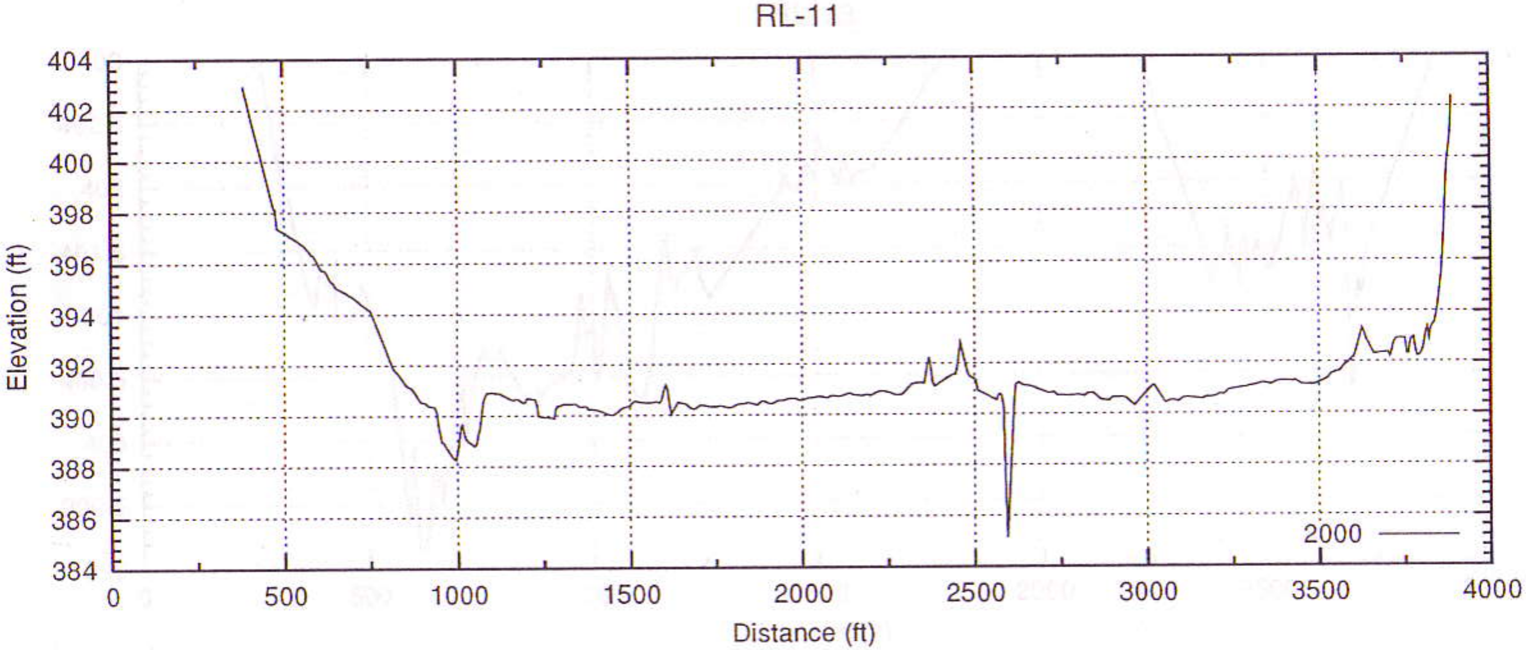


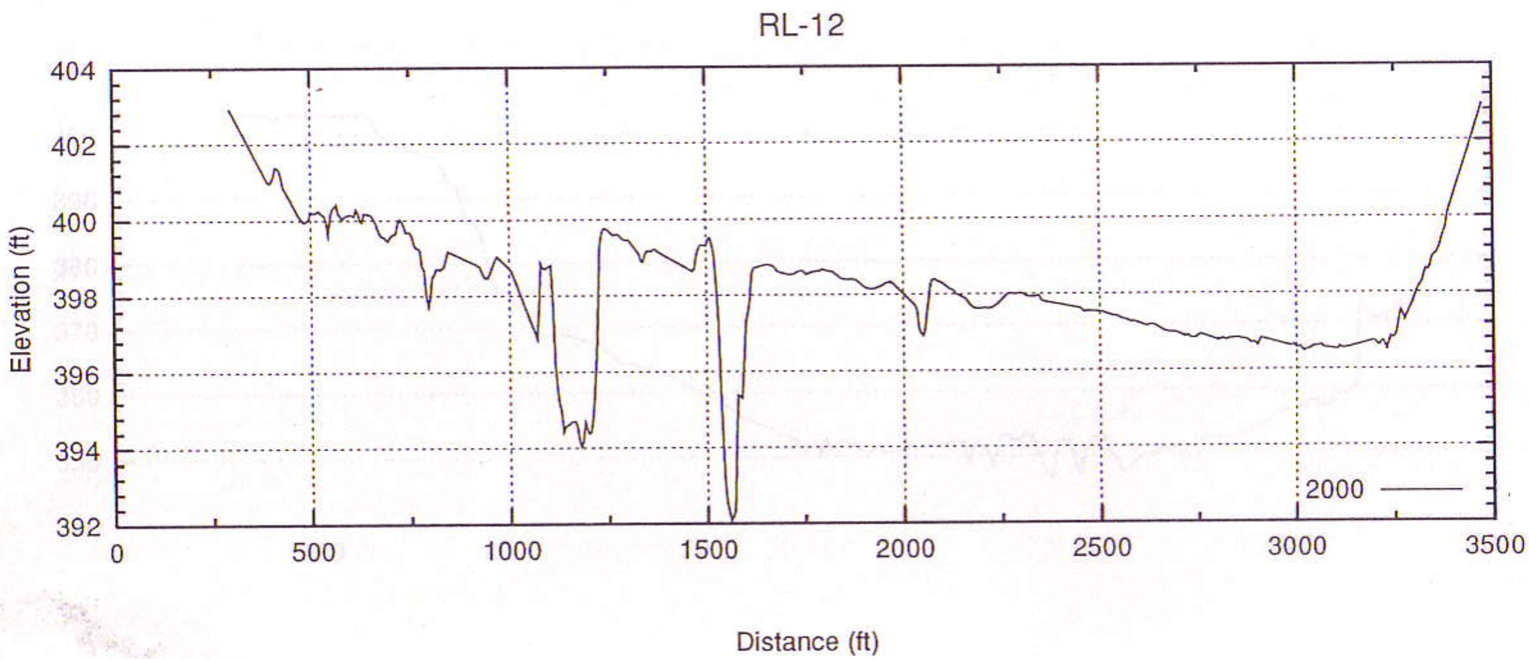
RL-9
405
400
395
390
385
380
375
370
Elevation (ft)
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
Distance (ft)
2000



RL-10
405
400
395
390
385
380
Elevation (ft)
0
1000
2000
3000
4000
5000
6000
7000
8000
2000
Distance (ft)

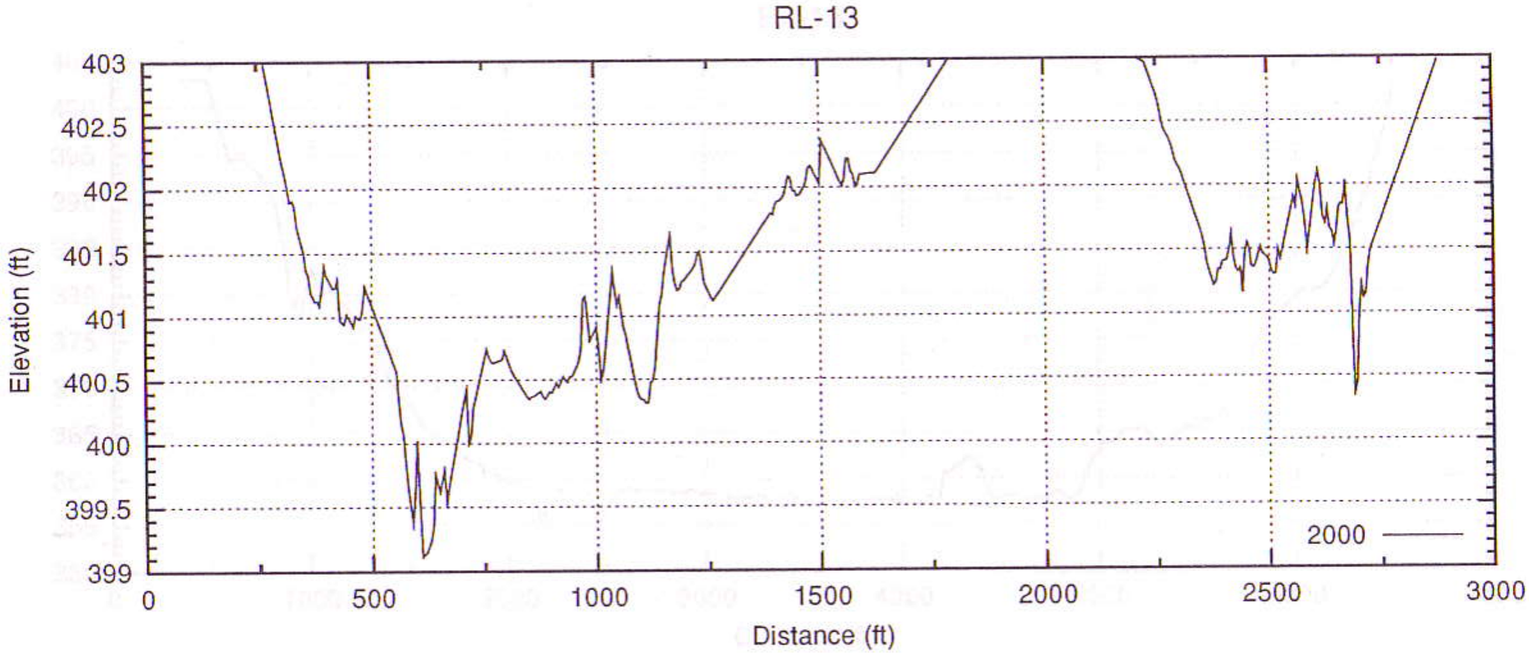
LAKE FORK

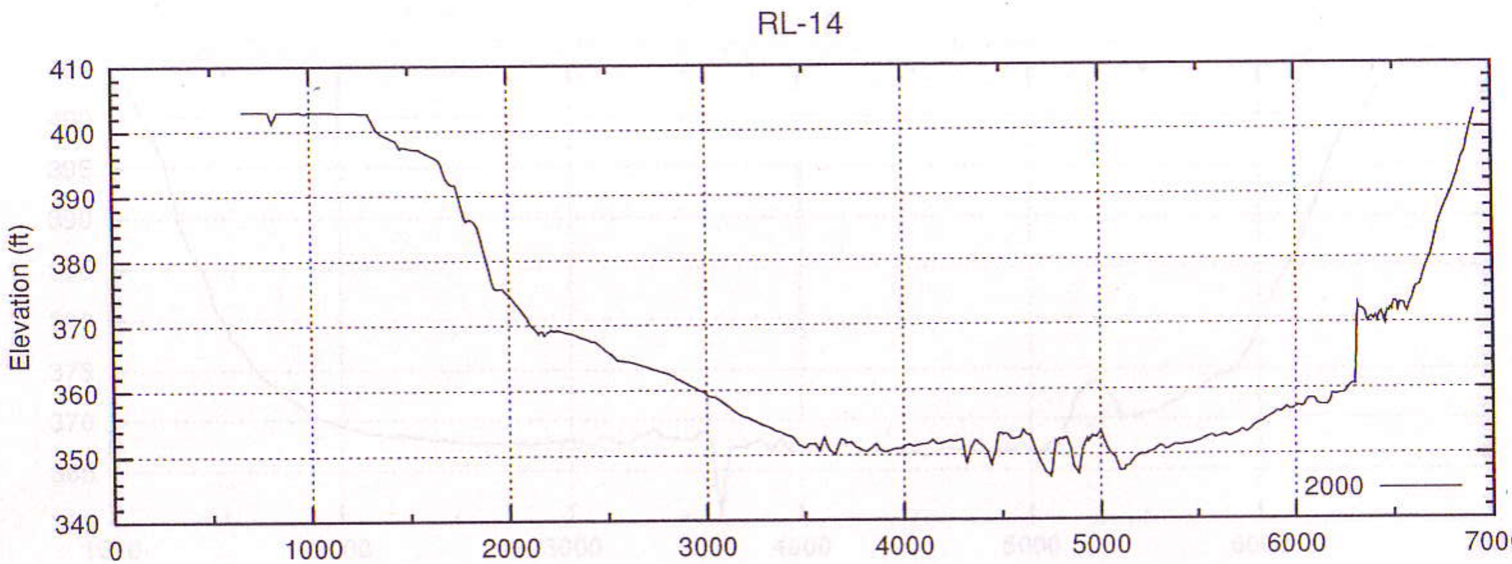




Appendix E

LAKE FORK

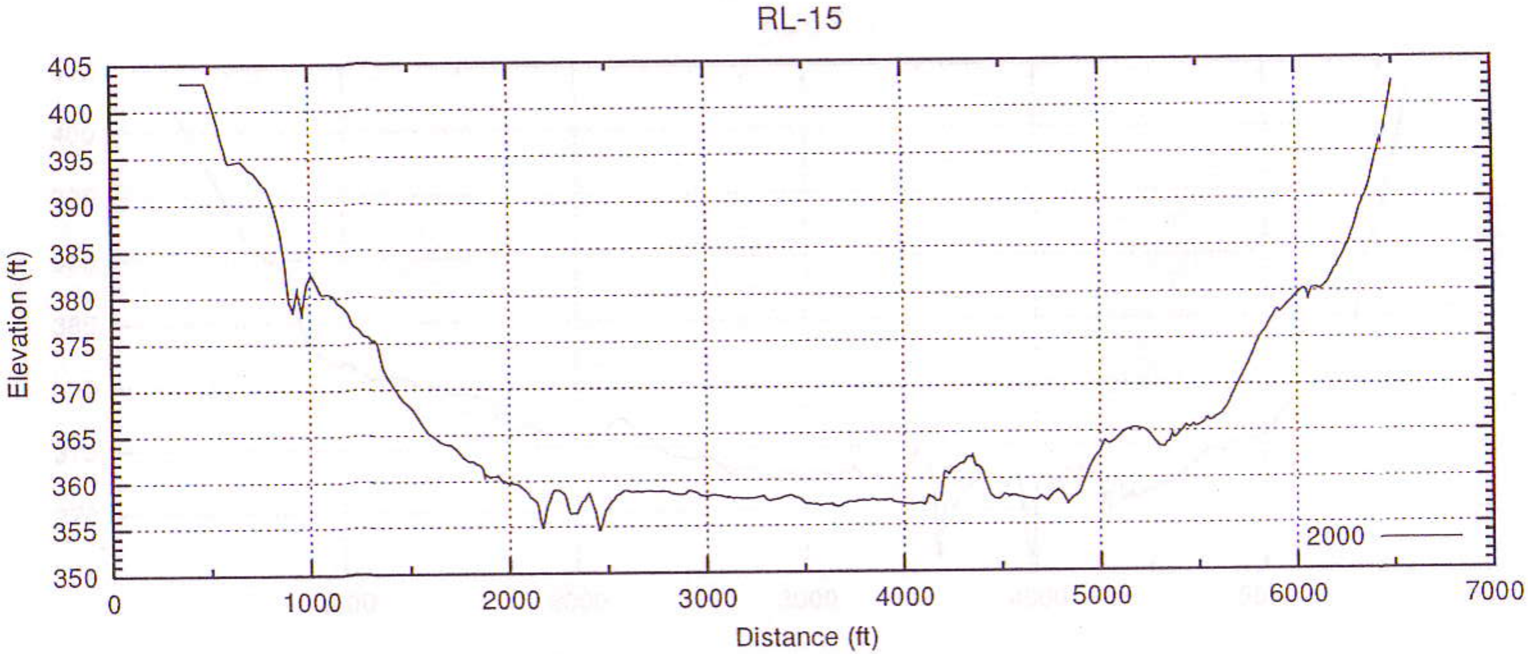


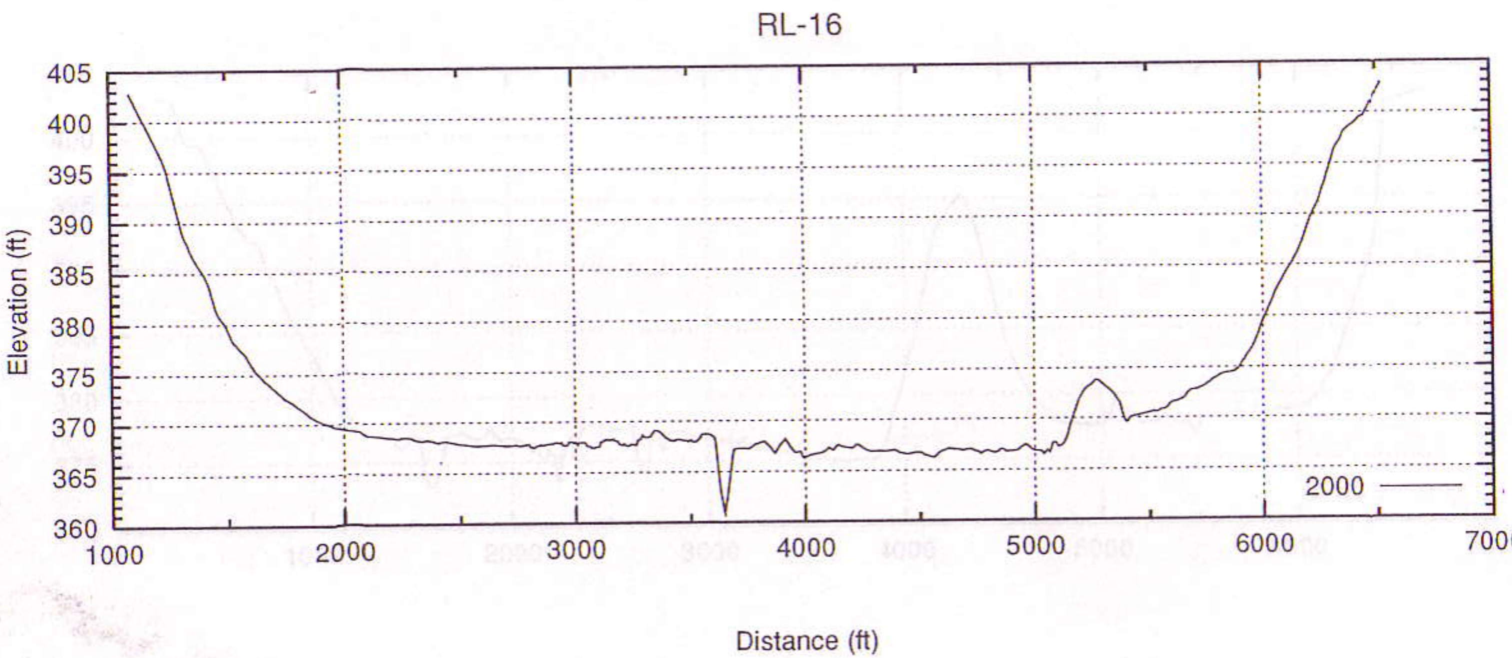


Distance (ft)

Appendix E

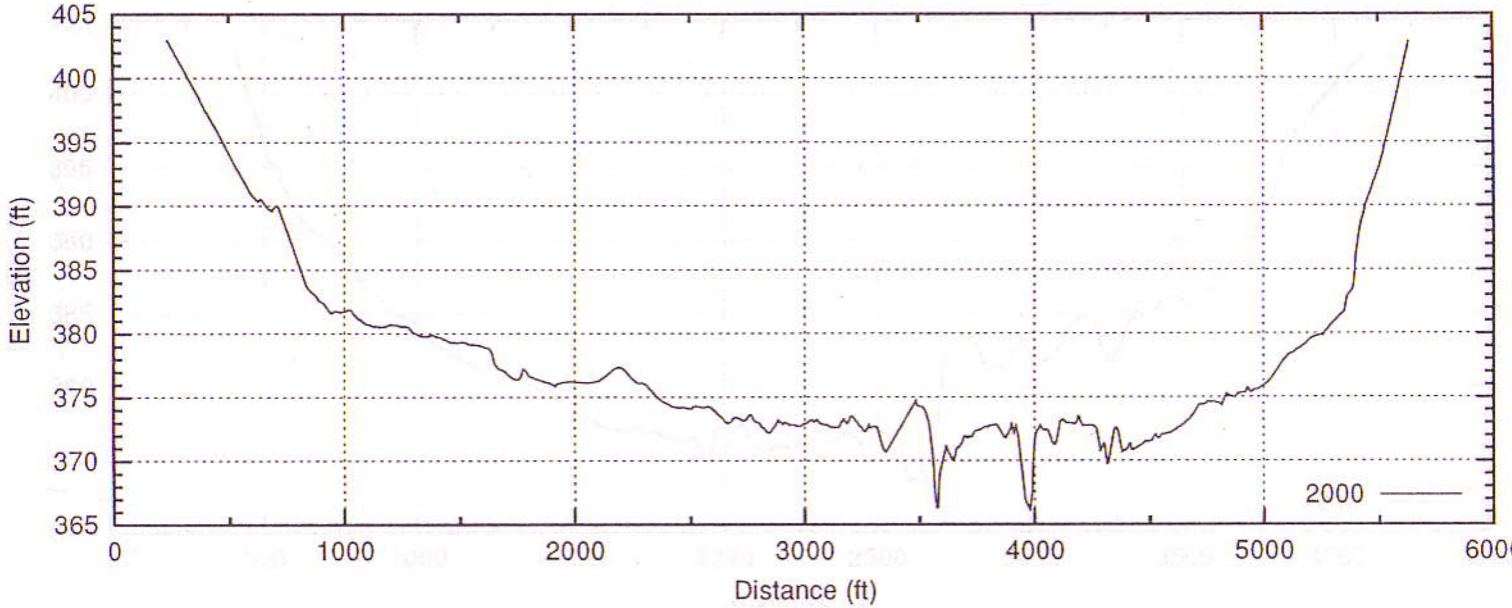
LAKE FORK


RL-15
405
400
395
390
385
380
375
370
365
360
355
350
Elevation (ft)
0
1000
2000
3000
4000
5000
6000
7000
Distance (ft)
2000

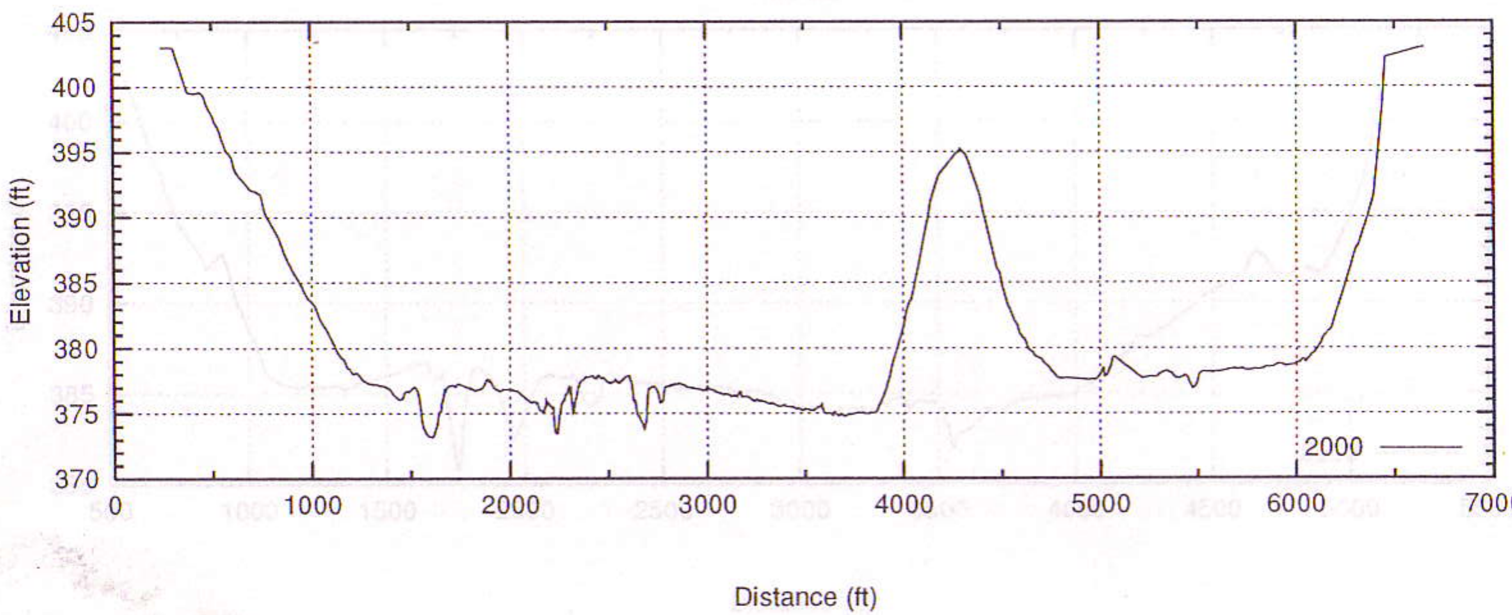

RL-16
405
400
395
390
385
380
375
370
365
360
Elevation (ft)
1000
2000
3000
4000
5000
6000
7000
Distance (ft)
2000

LAKE FORK

RL-17

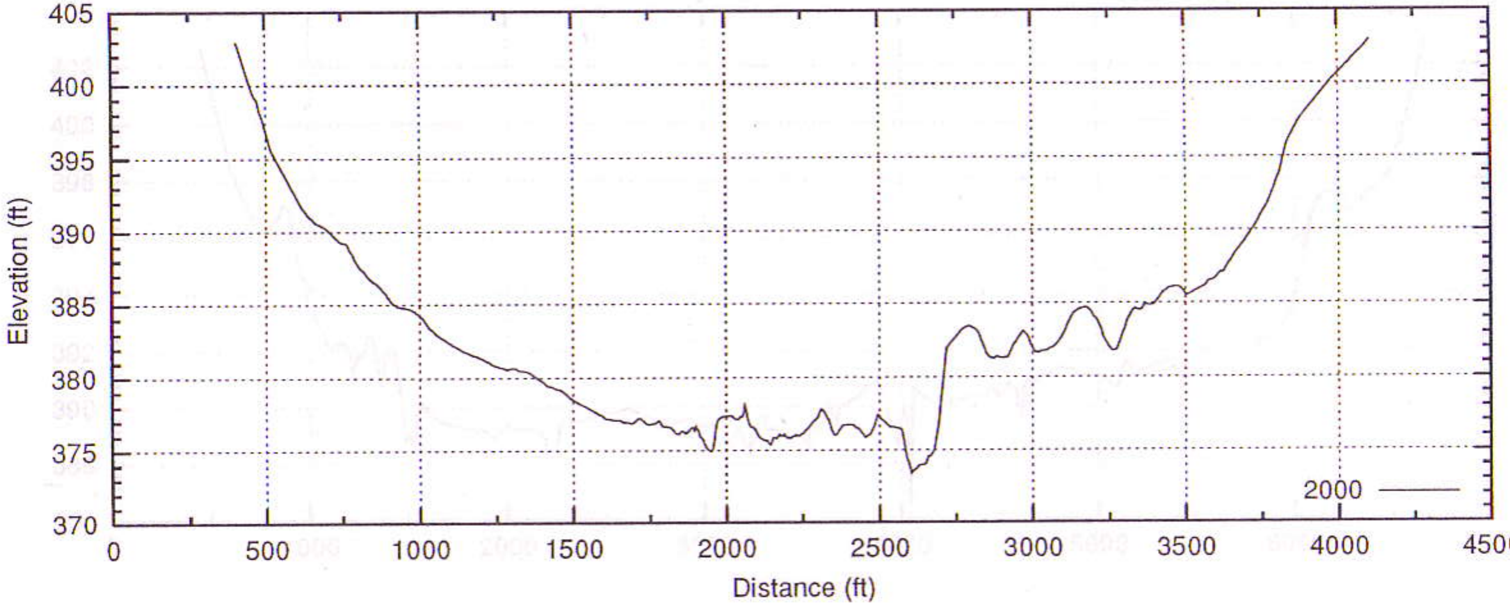


RL-18

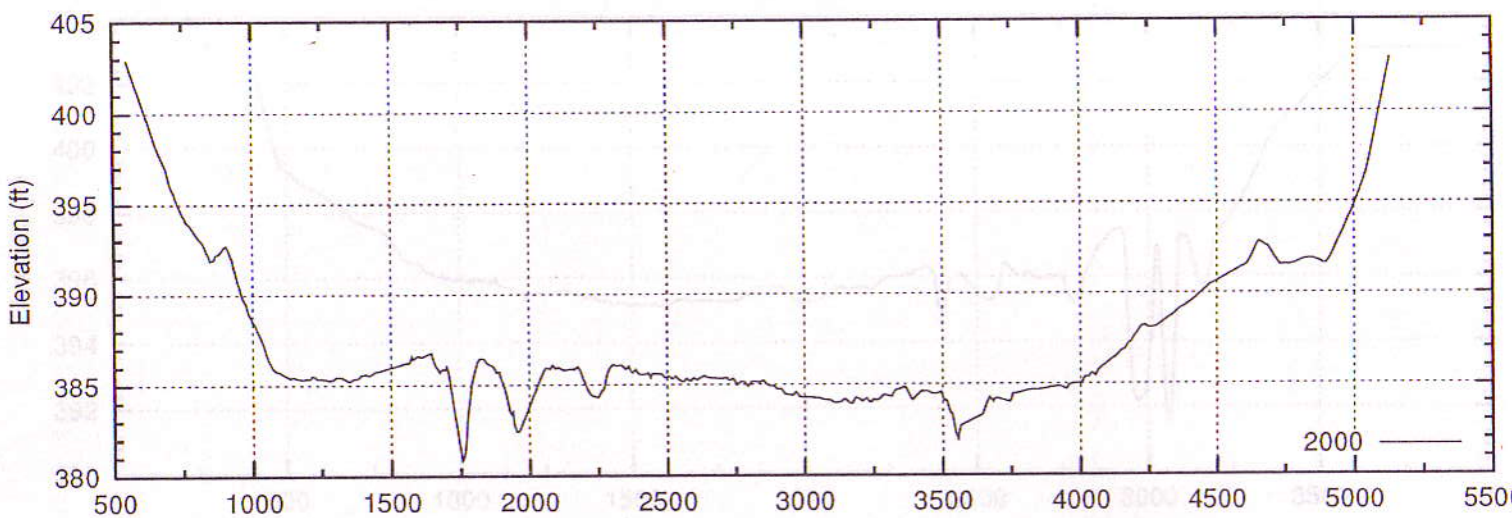


LAKE FORK

RL-19



RL-20

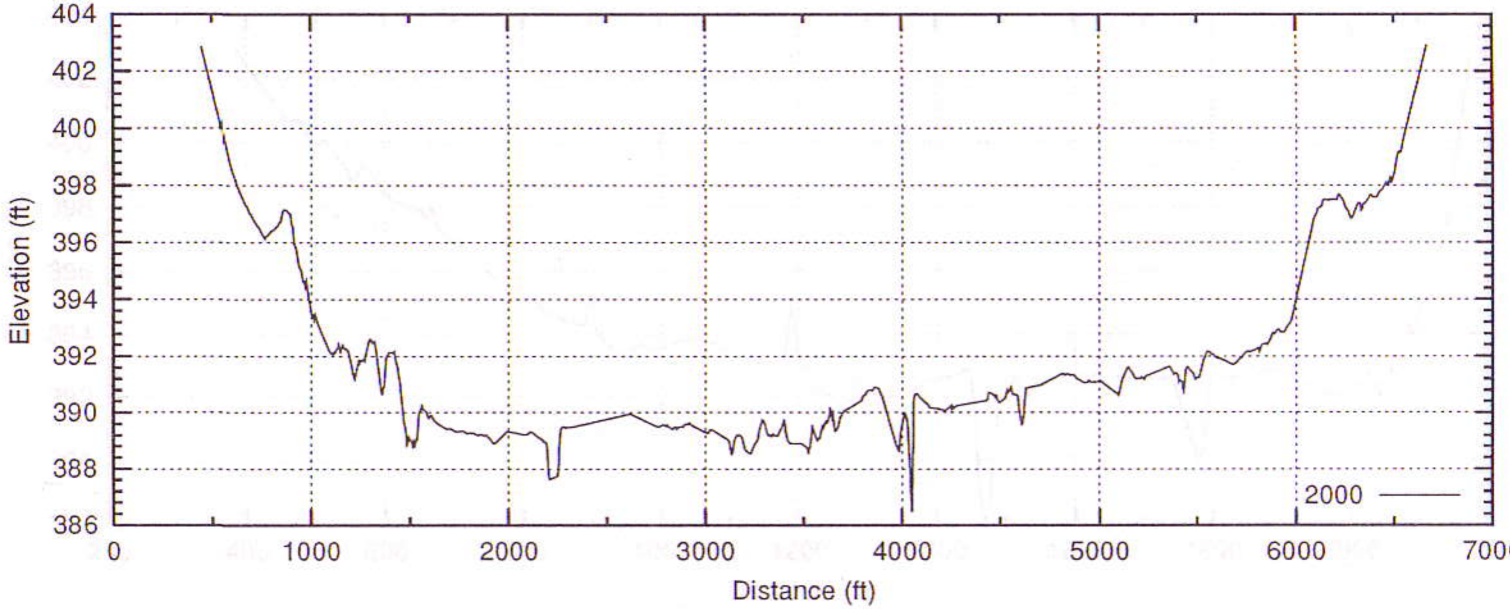


Distance (ft)

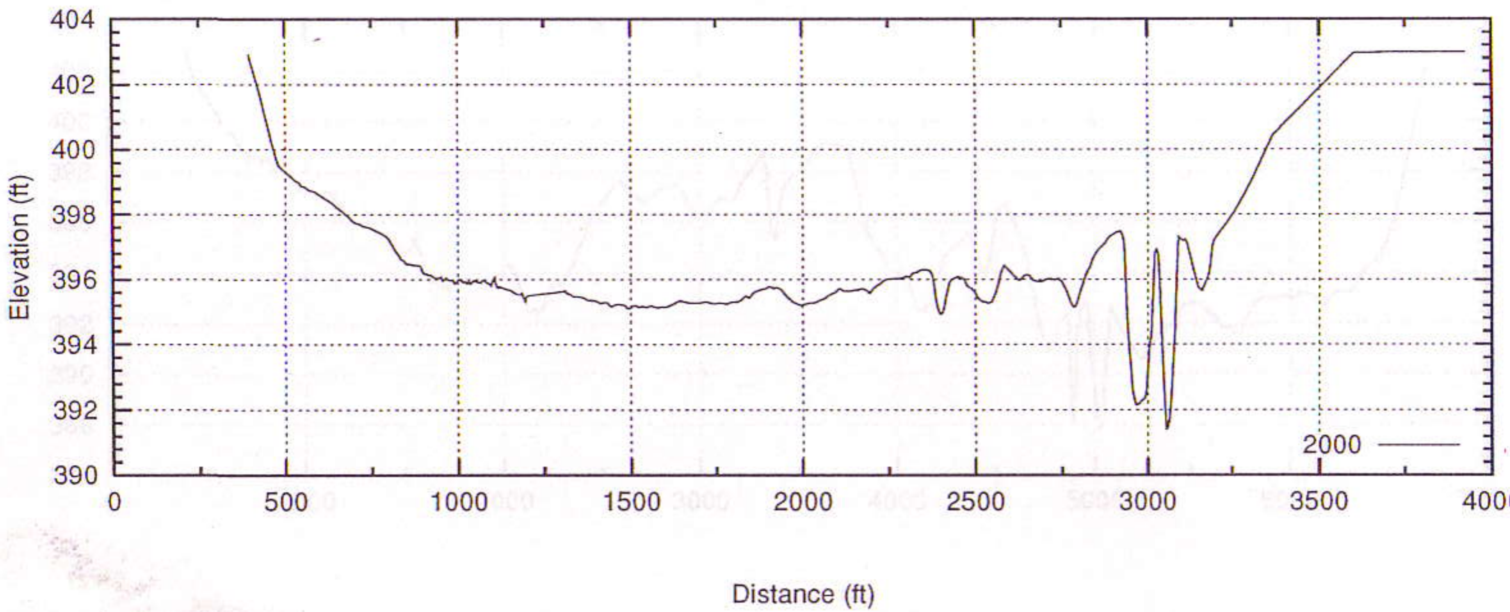
Appendix E

LAKE FORK

RL-21



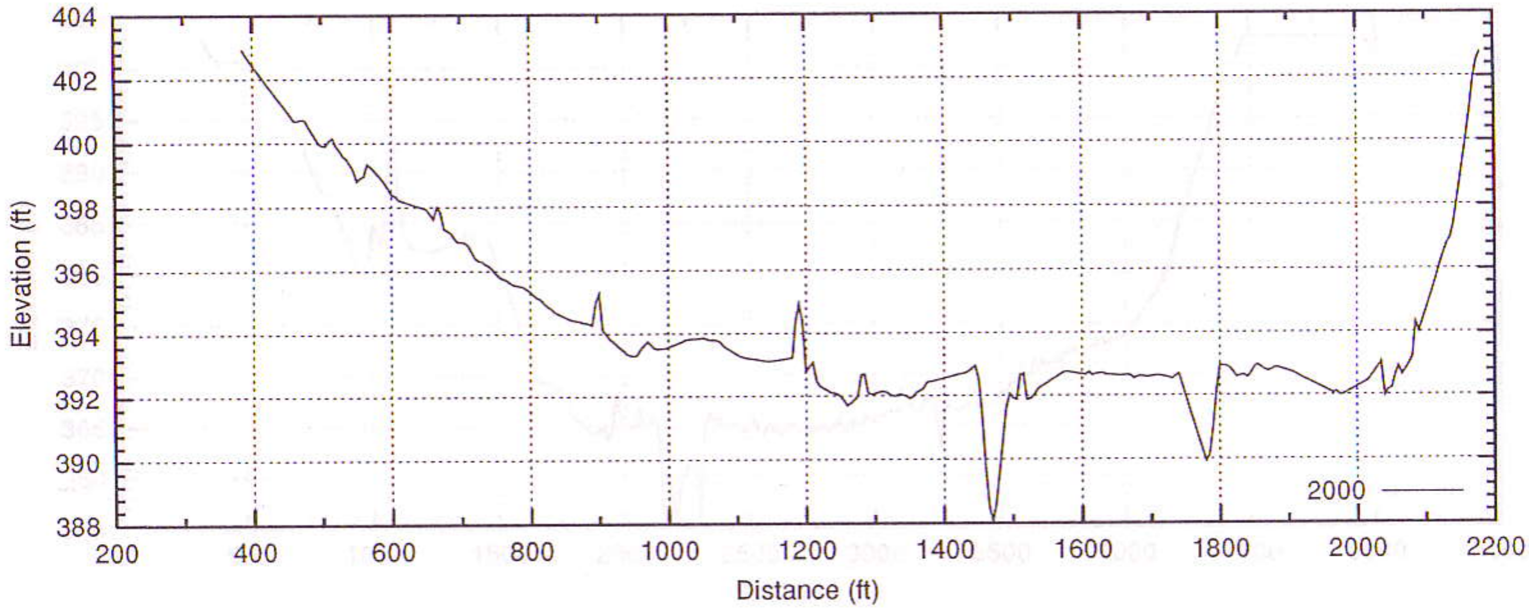
RL-22



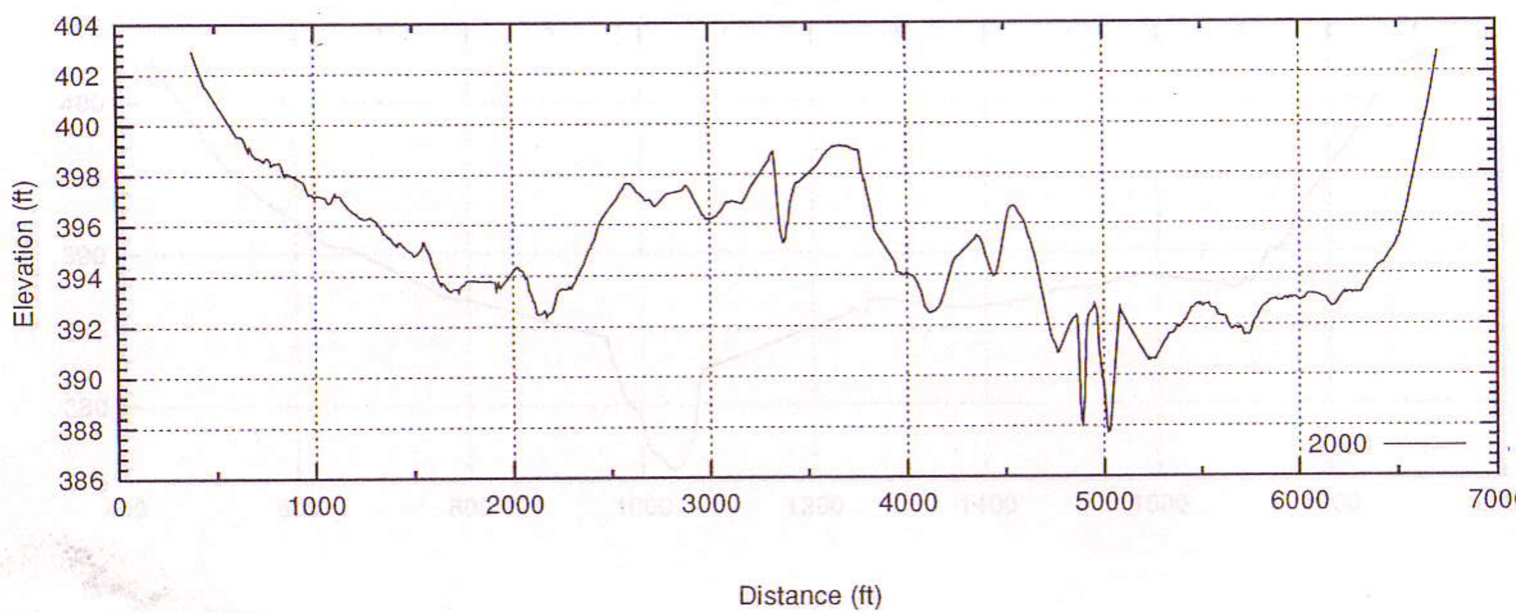
Appendix E

LAKE FORK

RL-23



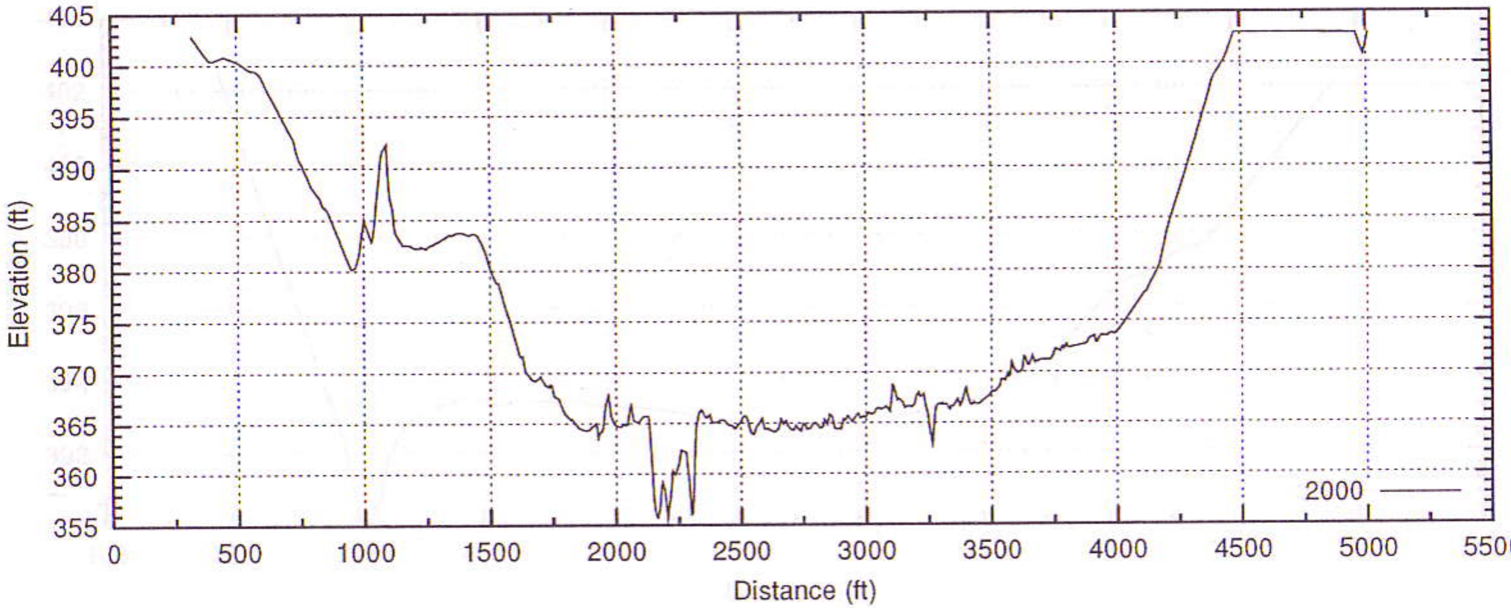
RL-24



Appendix E

LAKE FORK

RL-25



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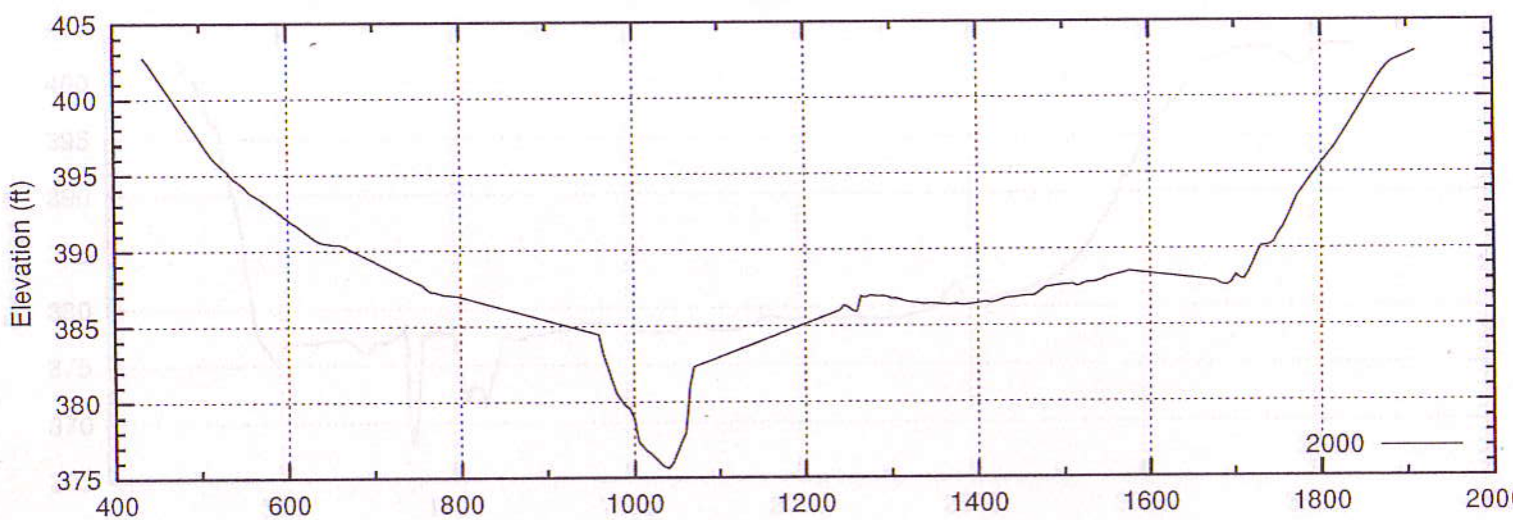
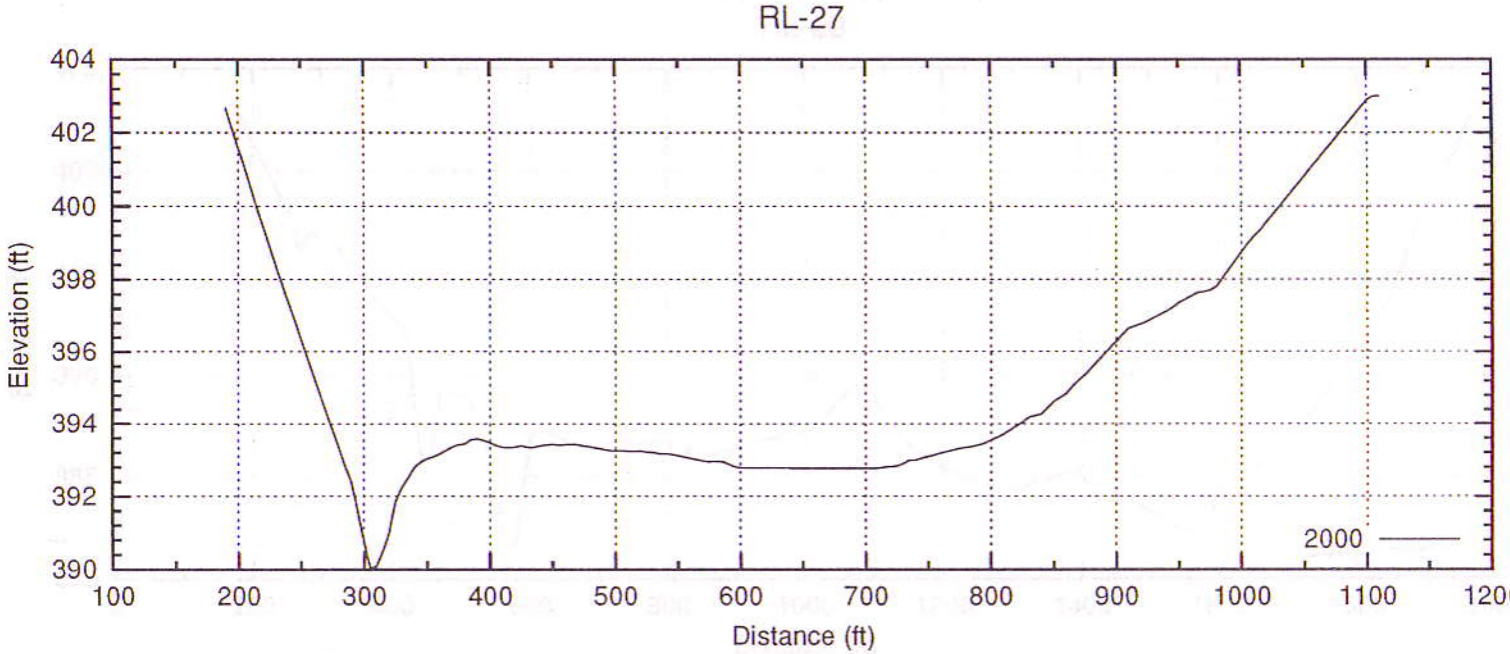
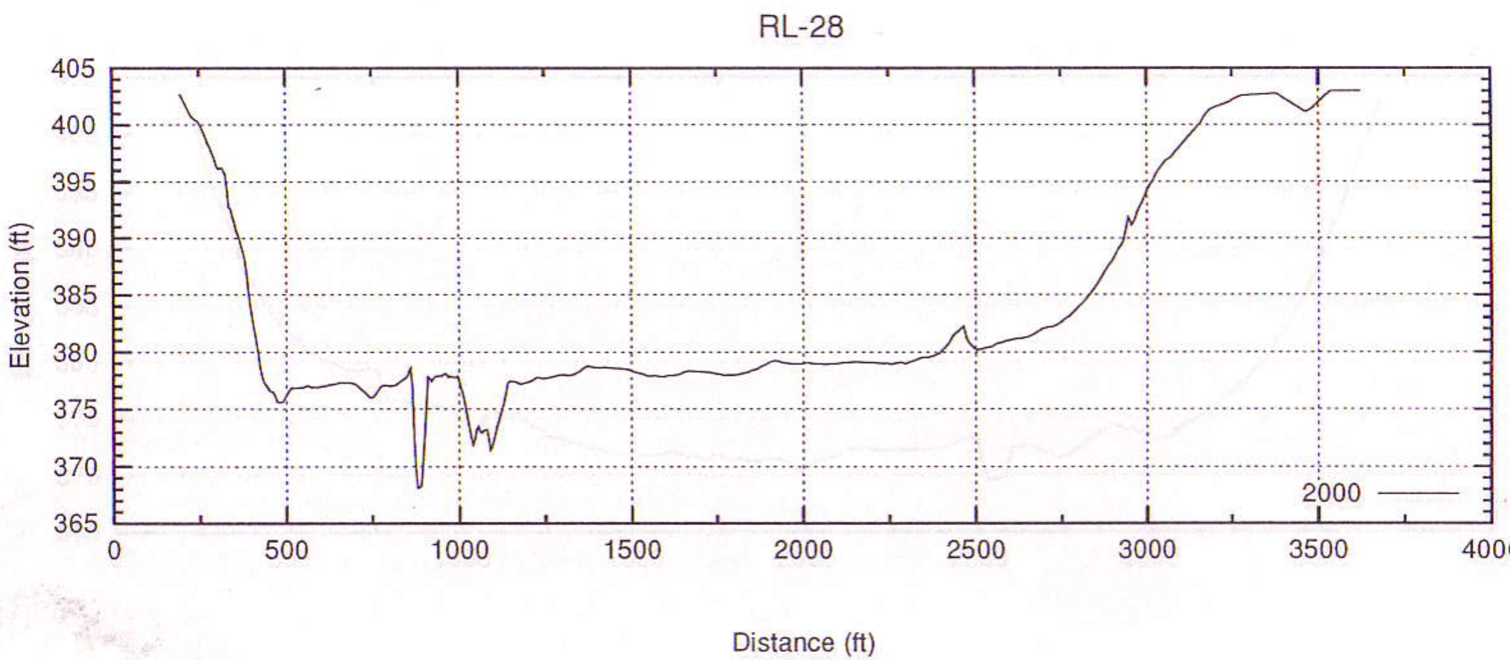


Distance (ft)

Appendix E

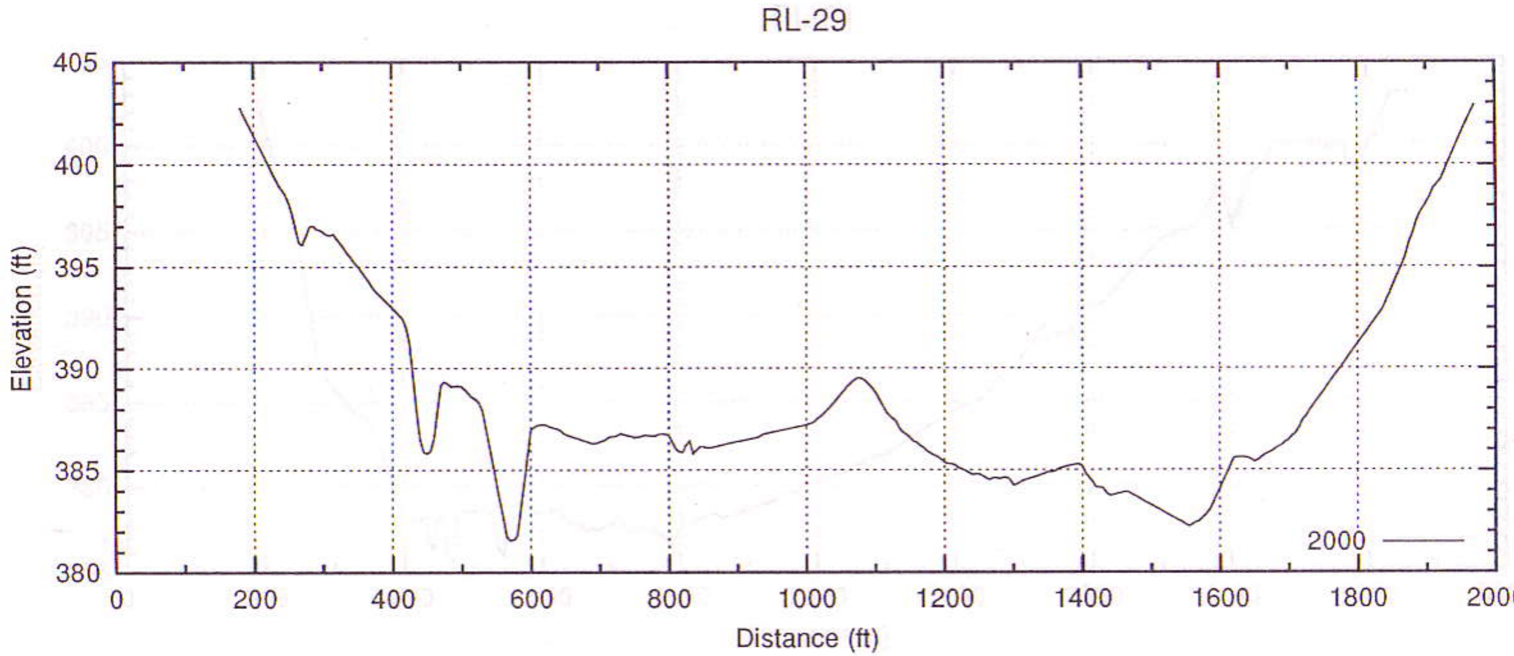
LAKE FORK

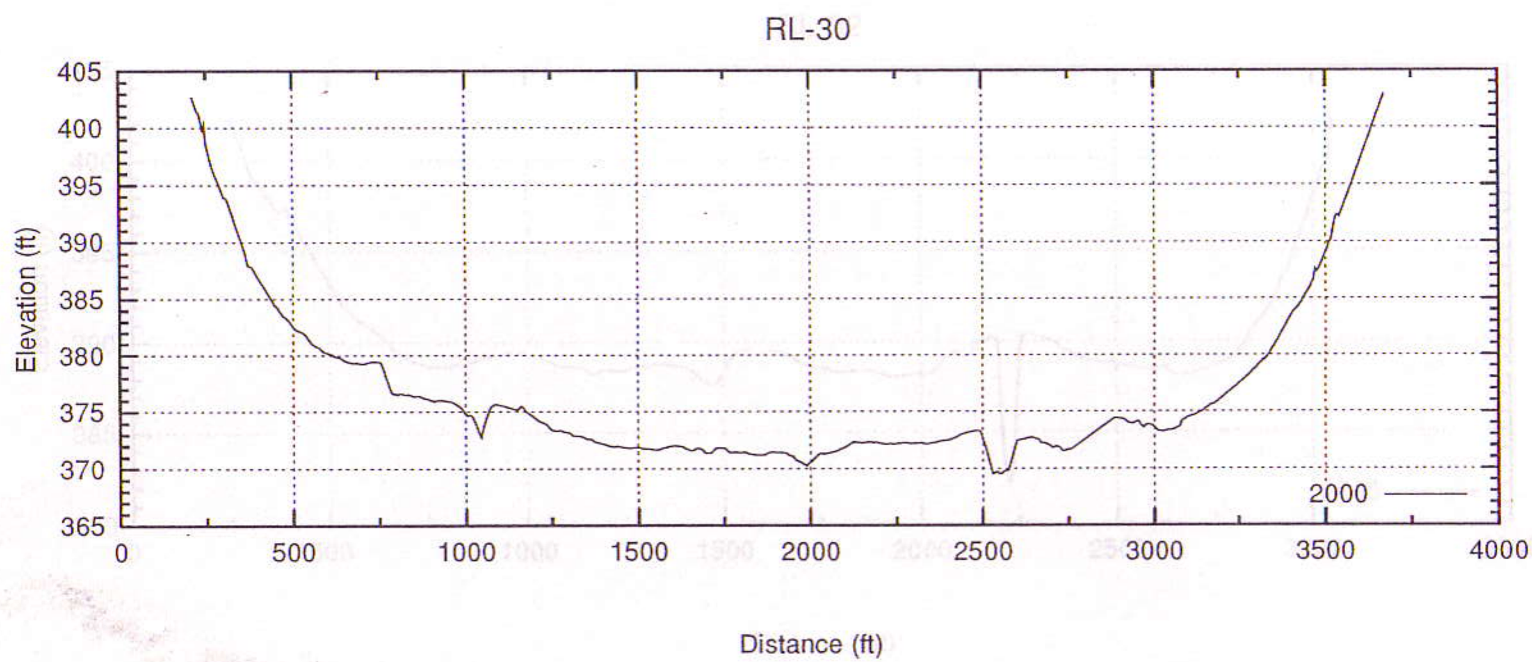




Appendix E

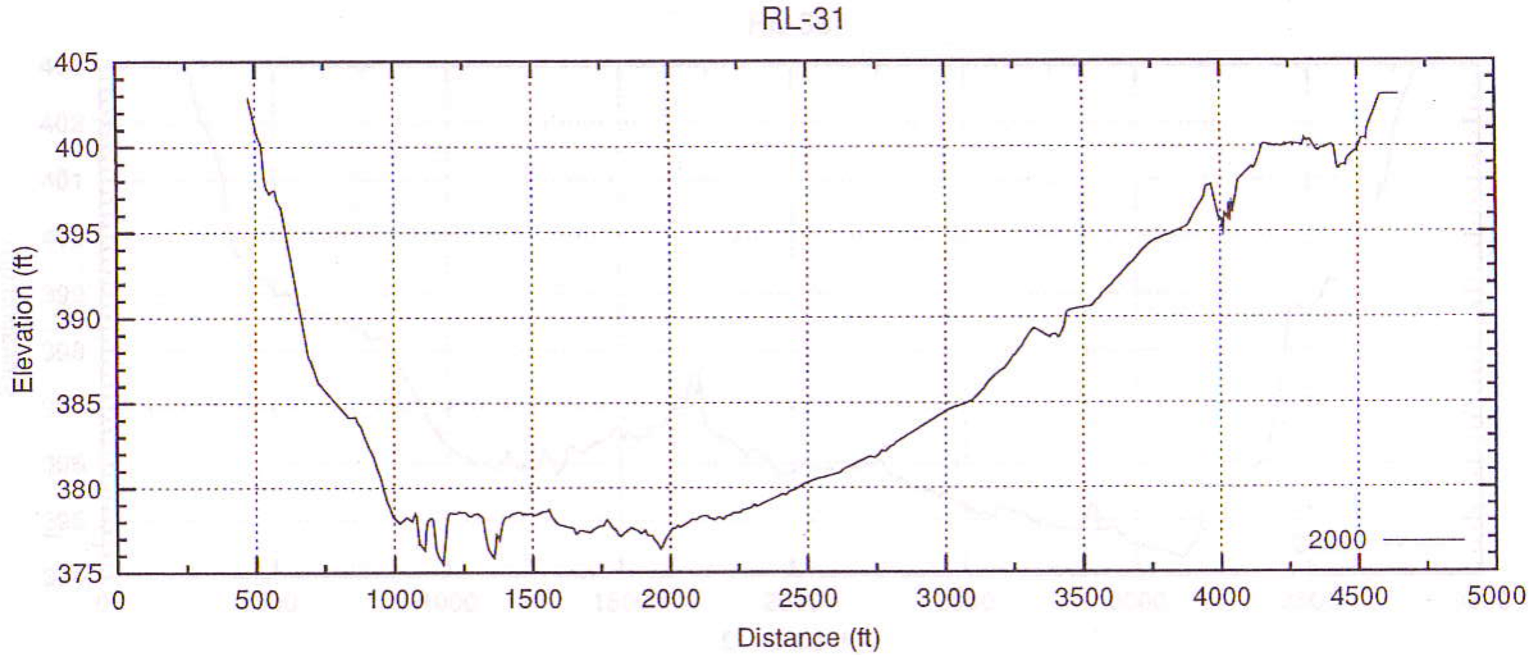
LAKE FORK

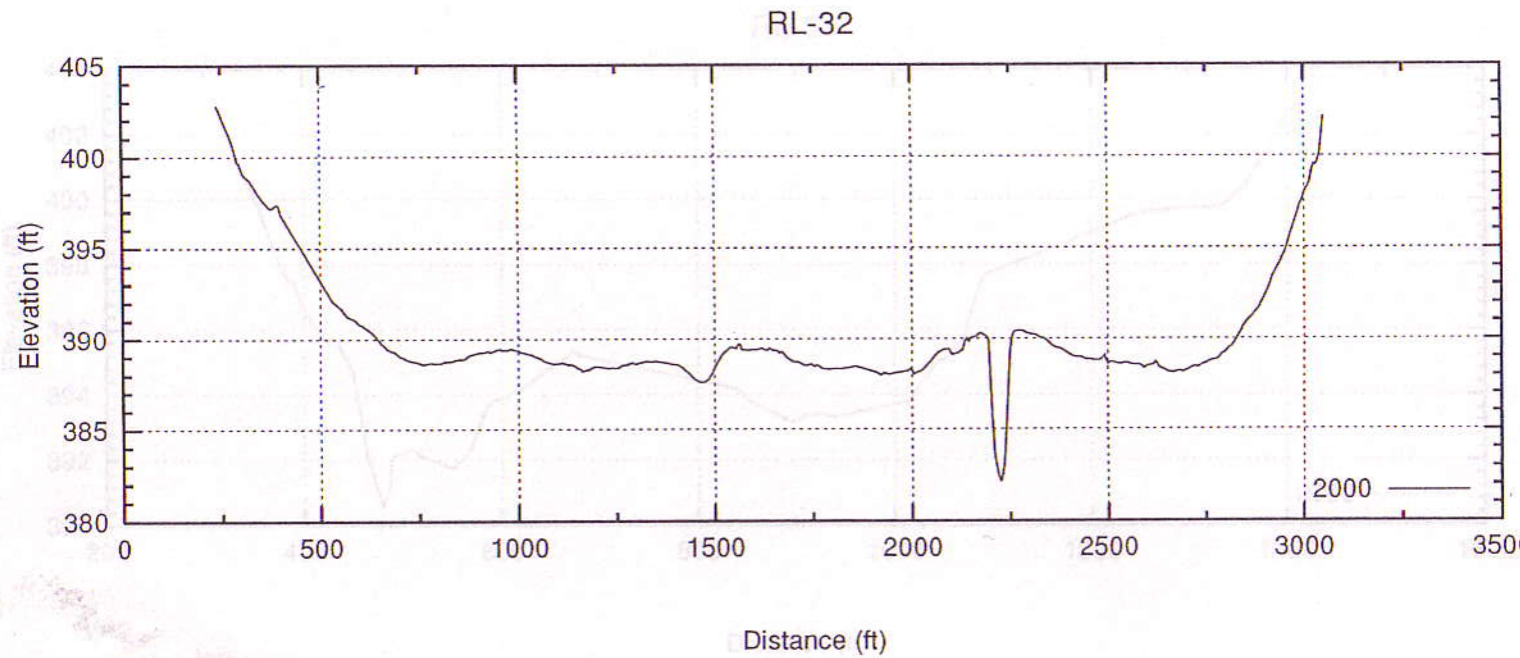




Appendix E

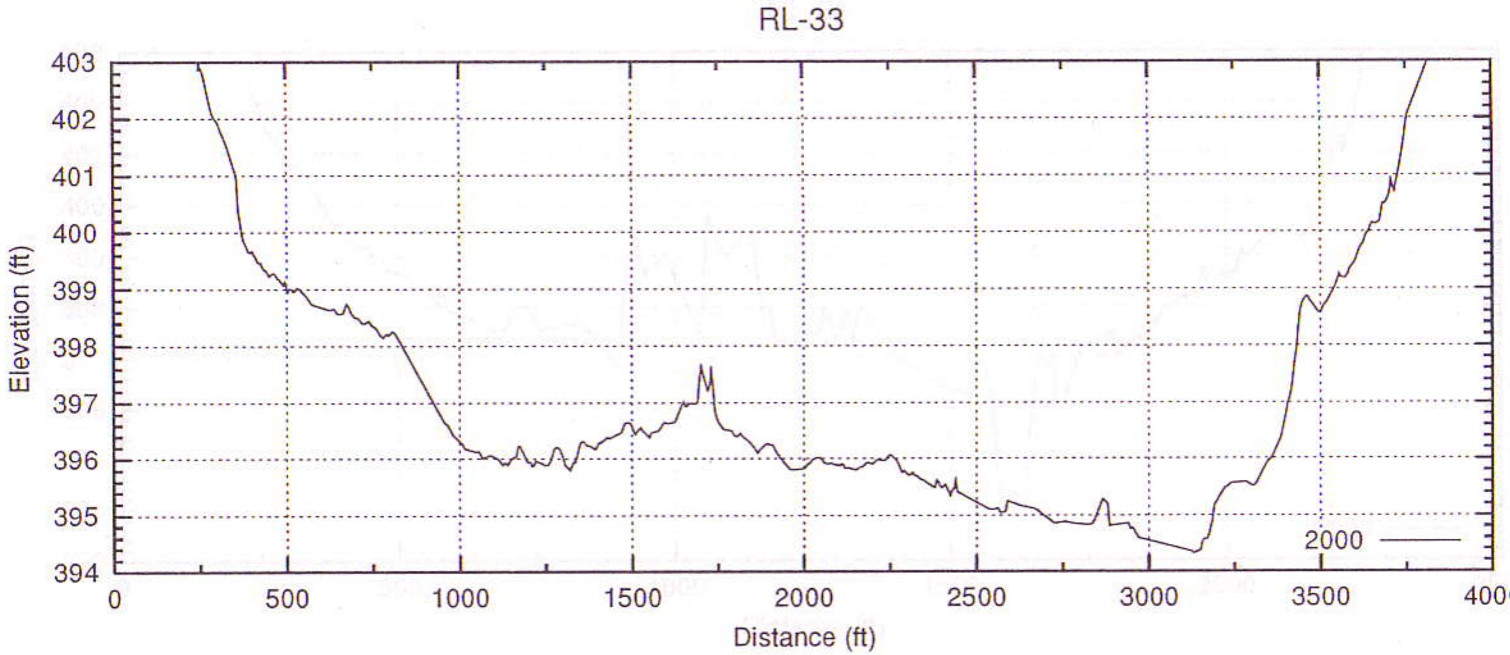
LAKE FORK

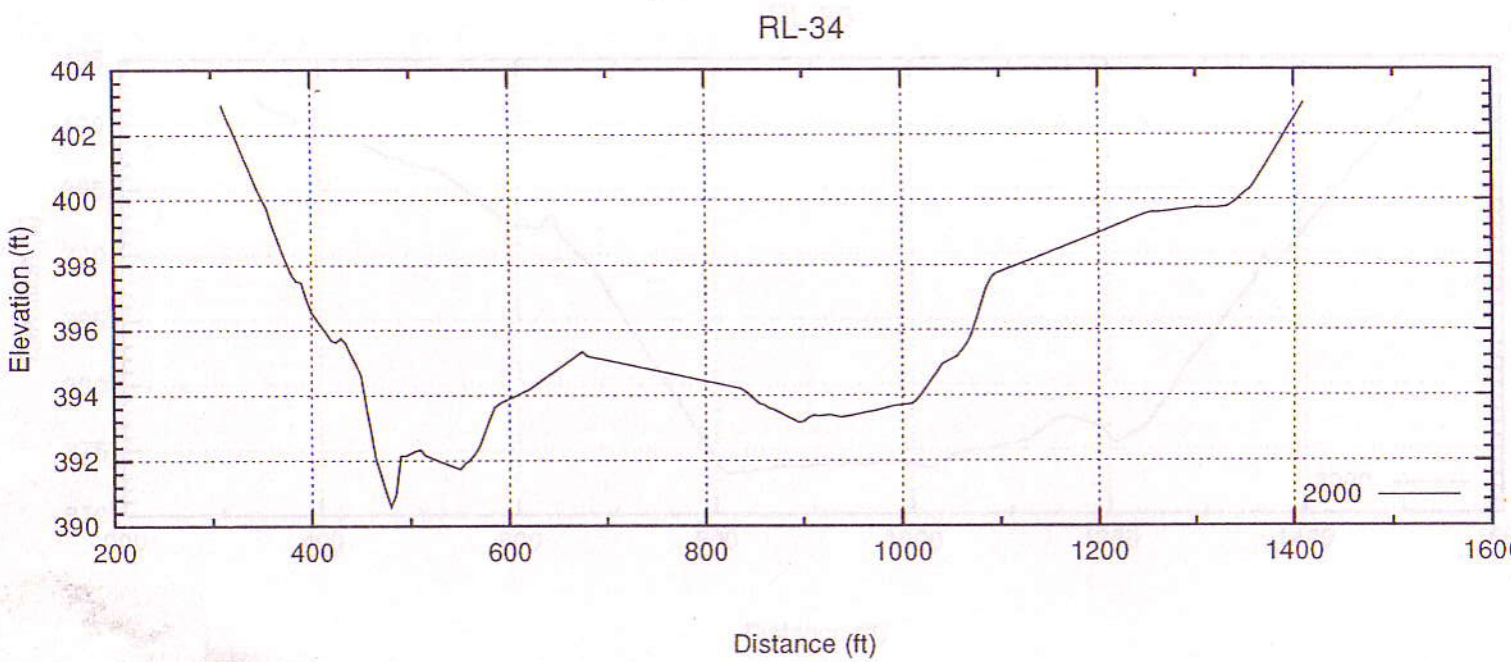




Appendix E

LAKE FORK

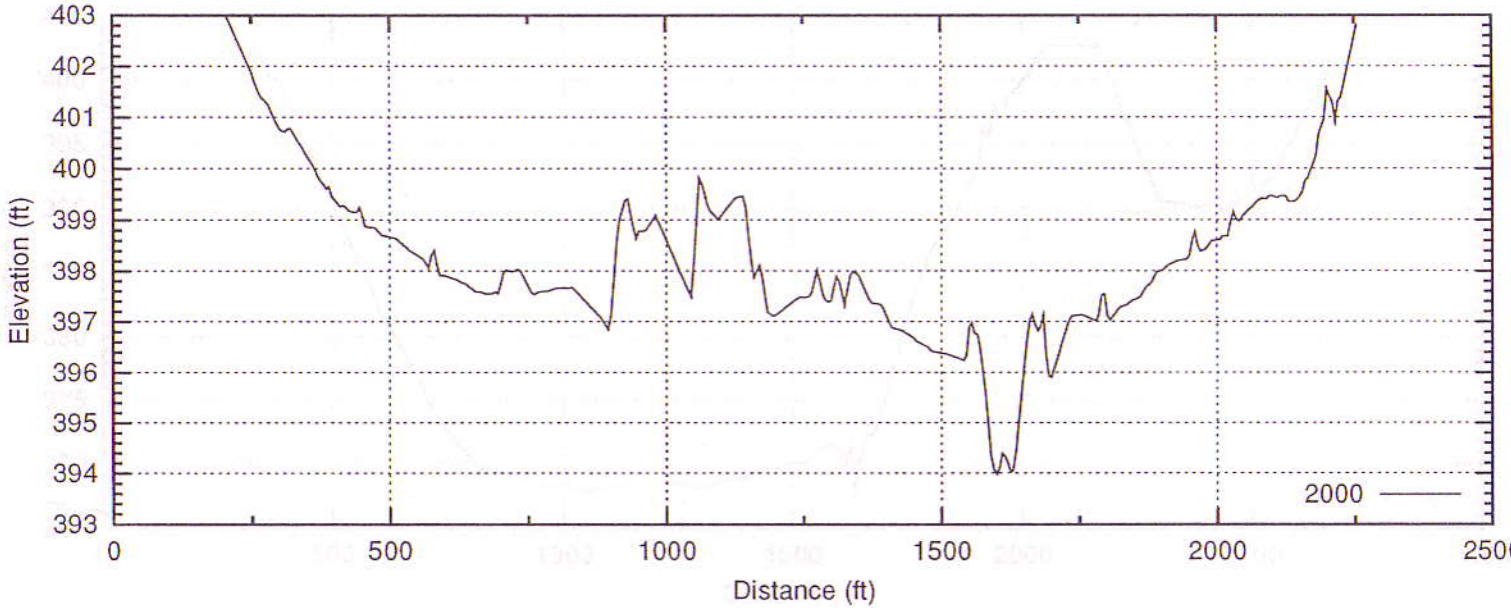




Appendix E

LAKE FORK

RL-35



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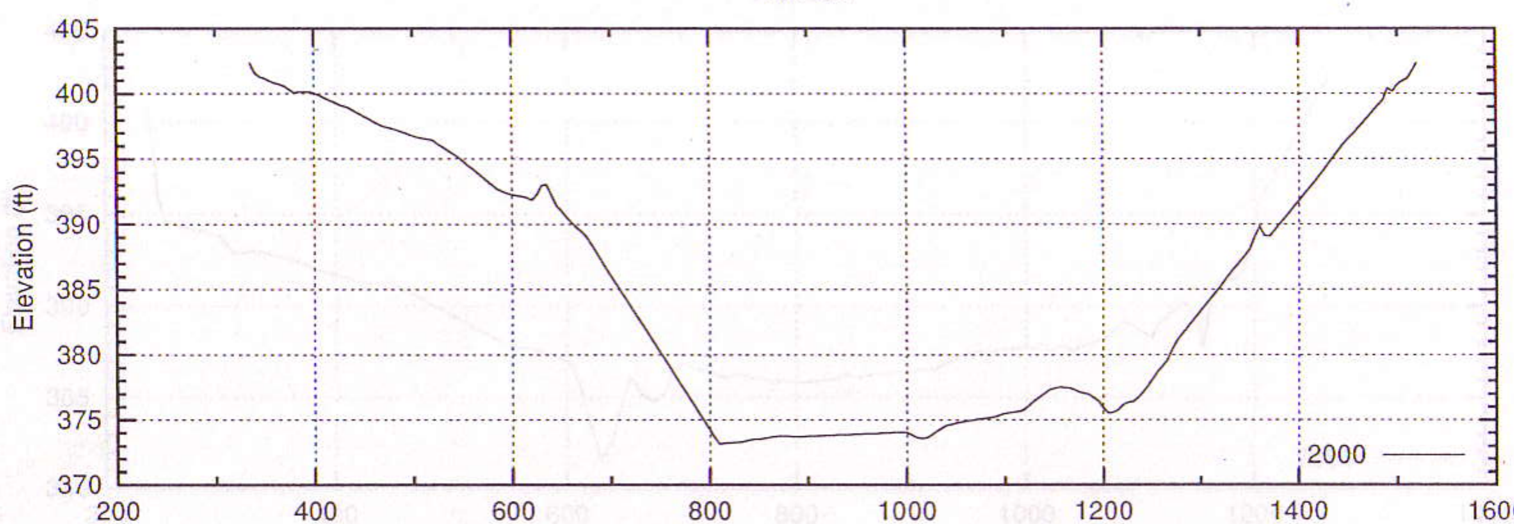
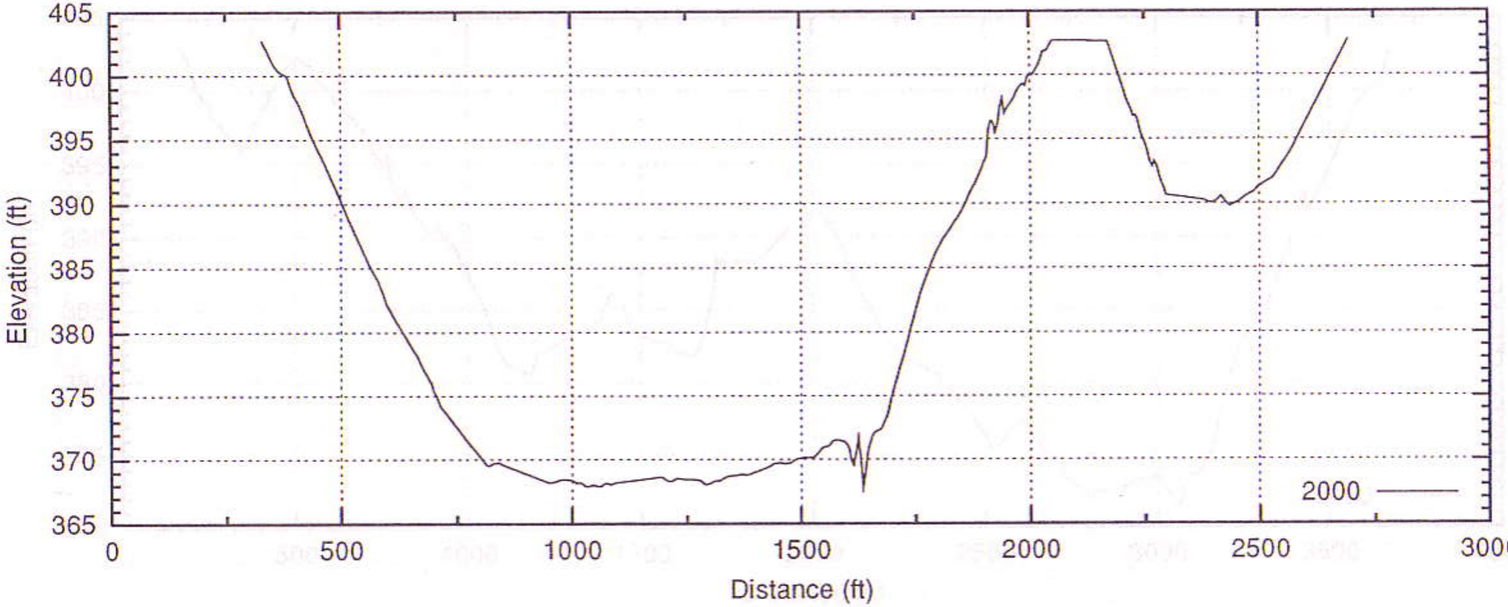


Distance (ft)

Appendix E

LAKE FORK

RL-37



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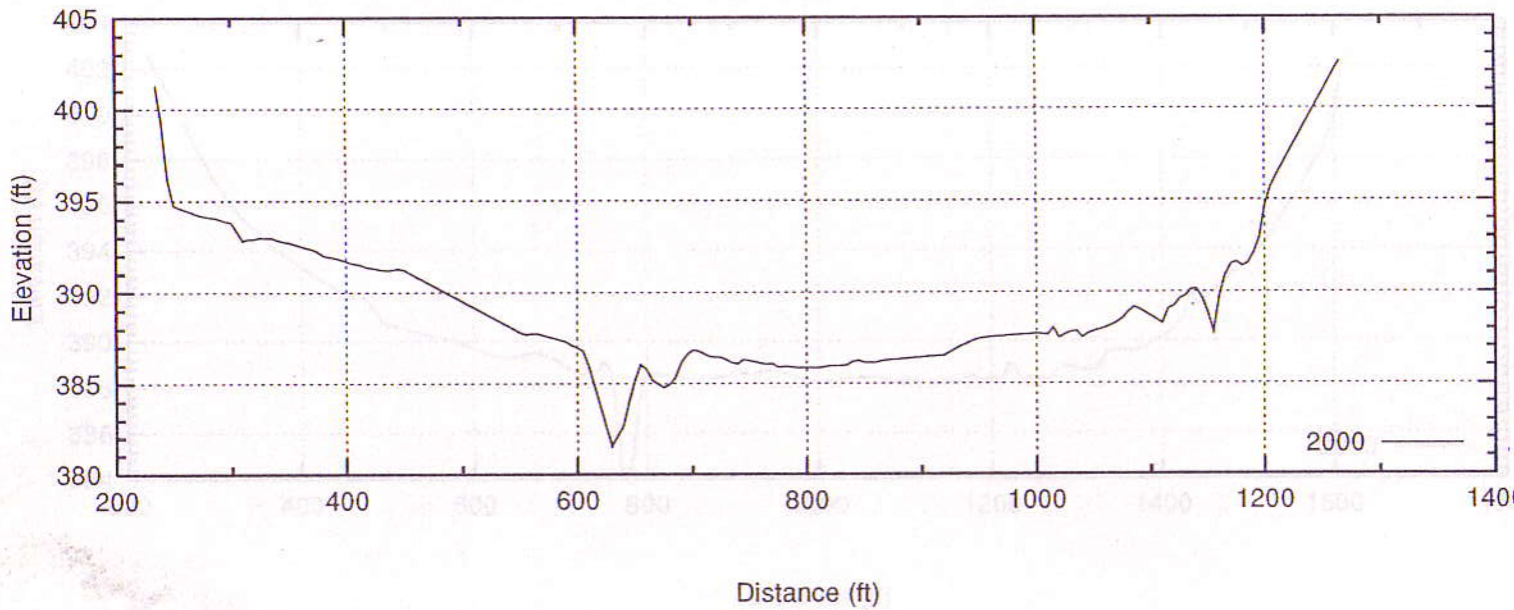

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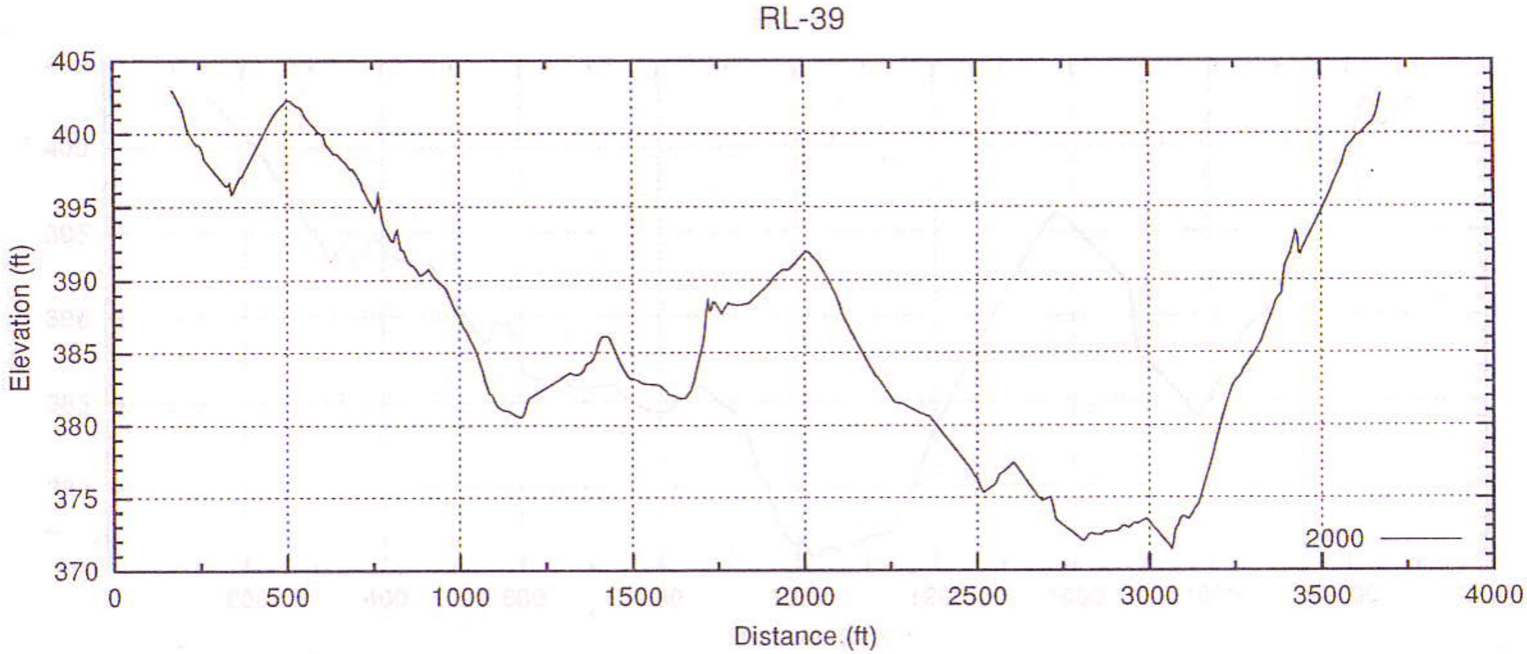
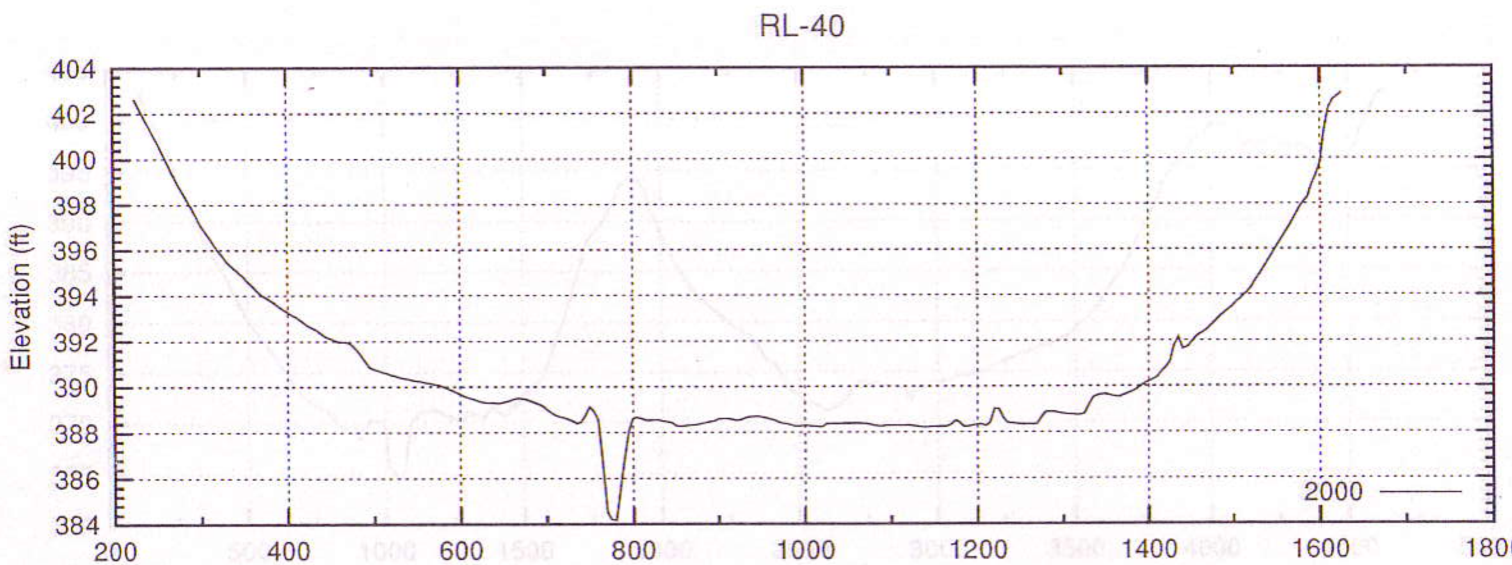
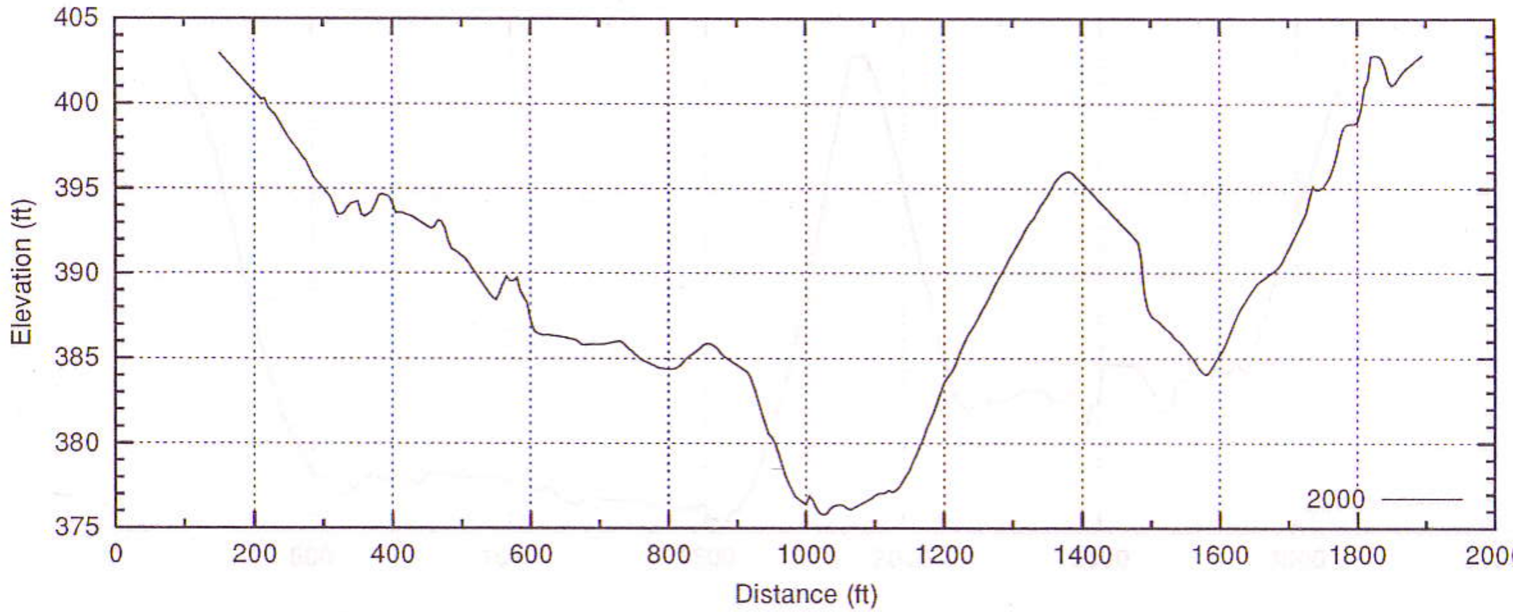




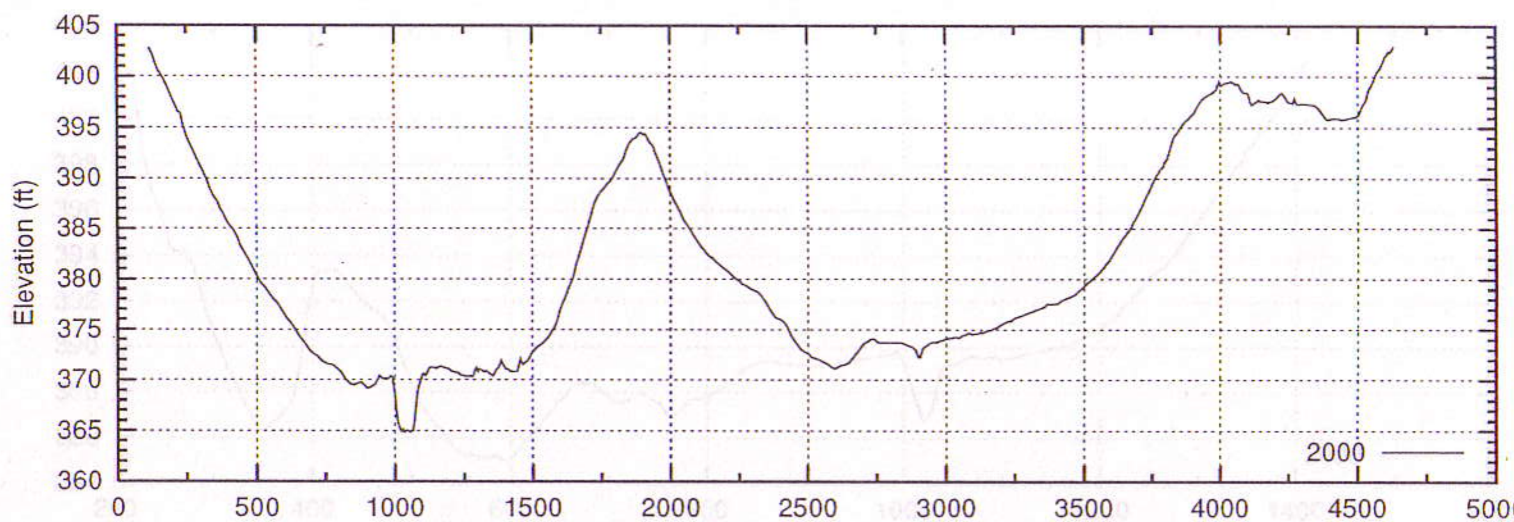
Distance (ft)

LAKE FORK

RL-41



RL-42

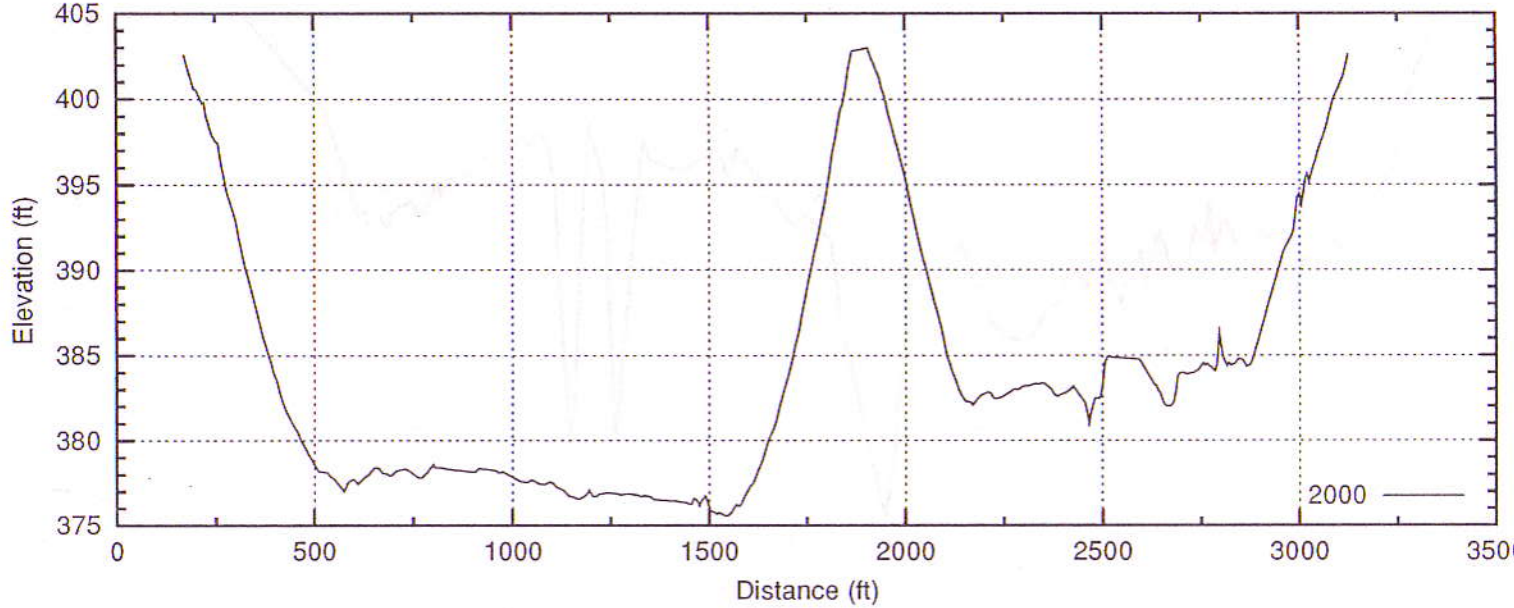


Distance (ft)

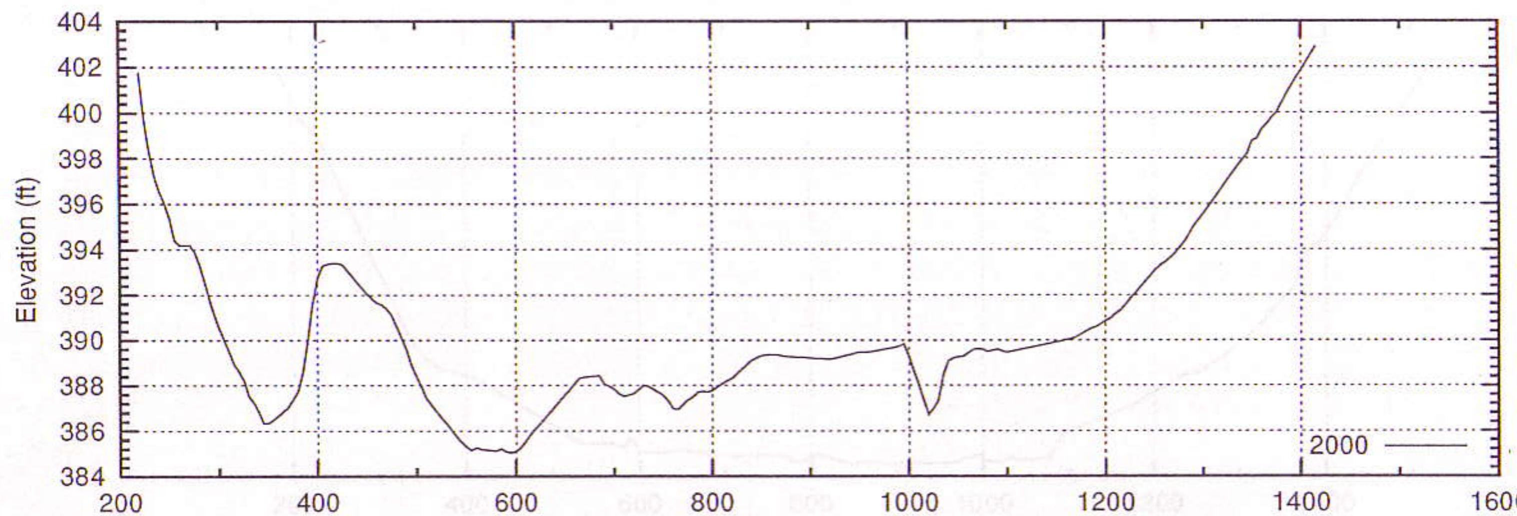
Appendix E

LAKE FORK

RL-43



RL-44

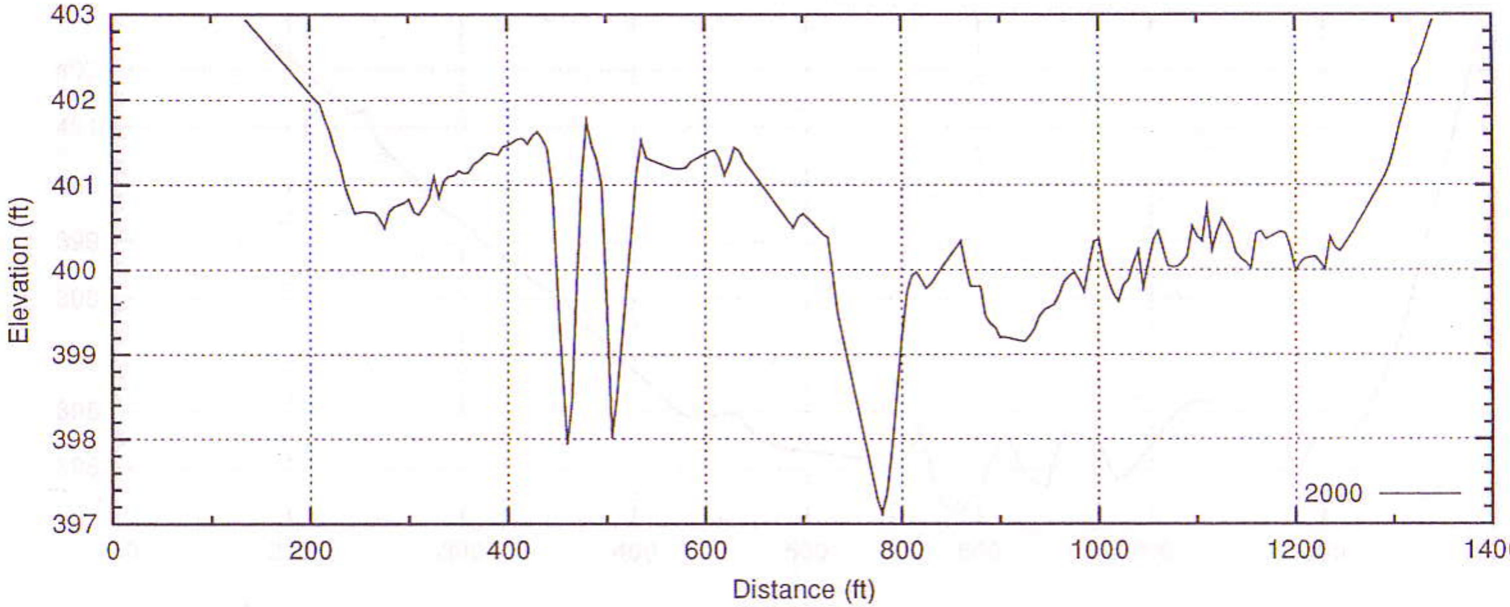


Distance (ft)

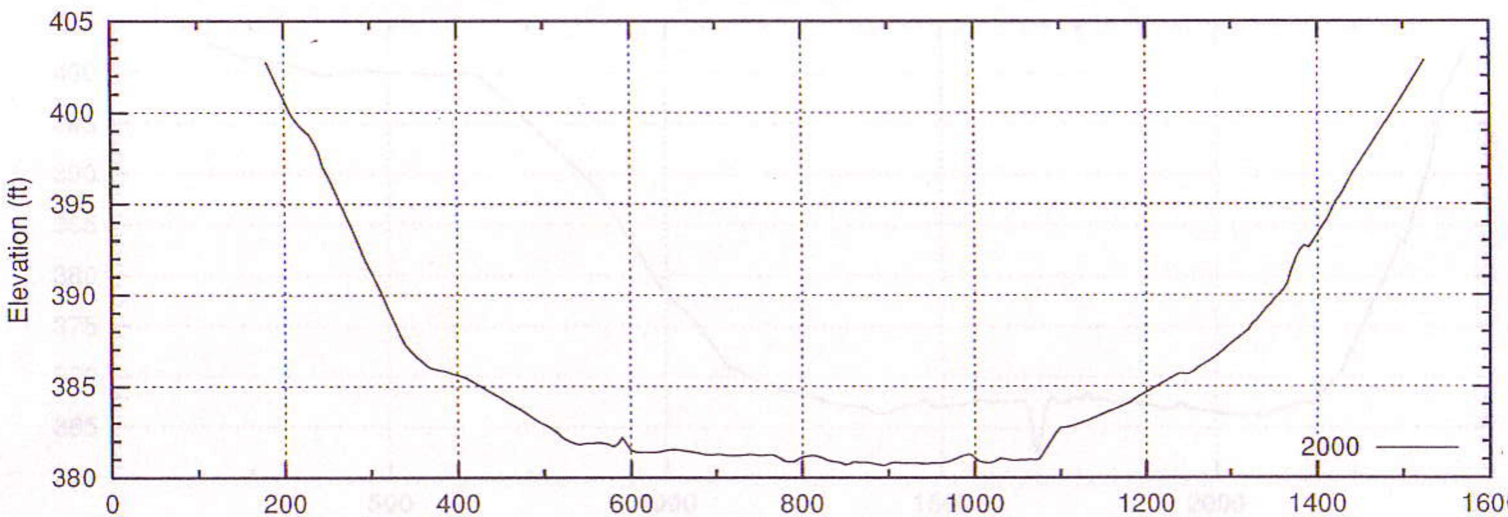
Appendix E

LAKE FORK

RL-45



RL-46

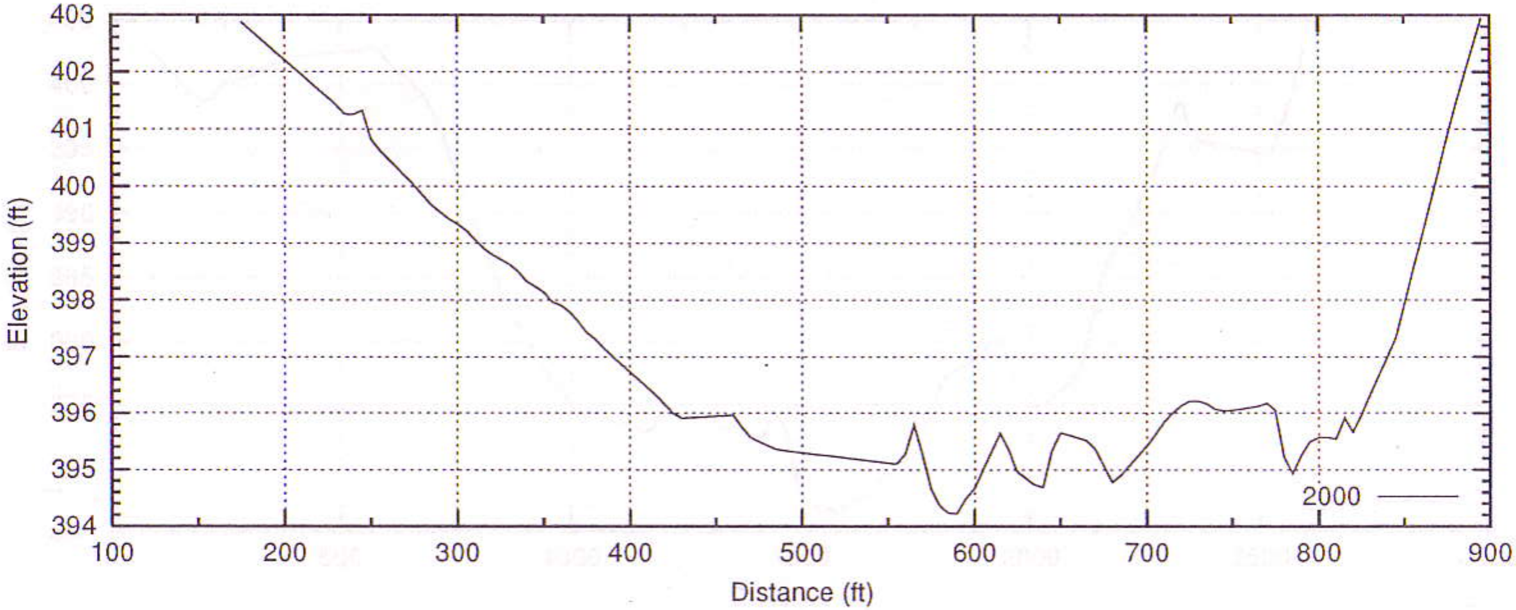


Distance (ft)

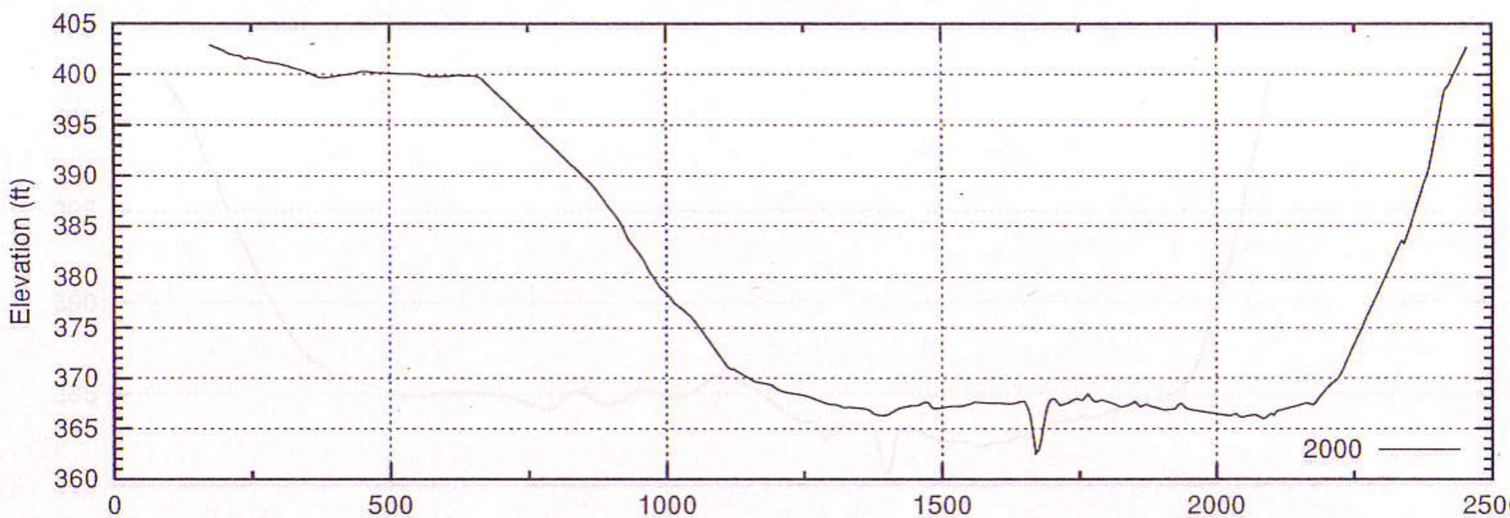
Appendix E

LAKE FORK

RL-47



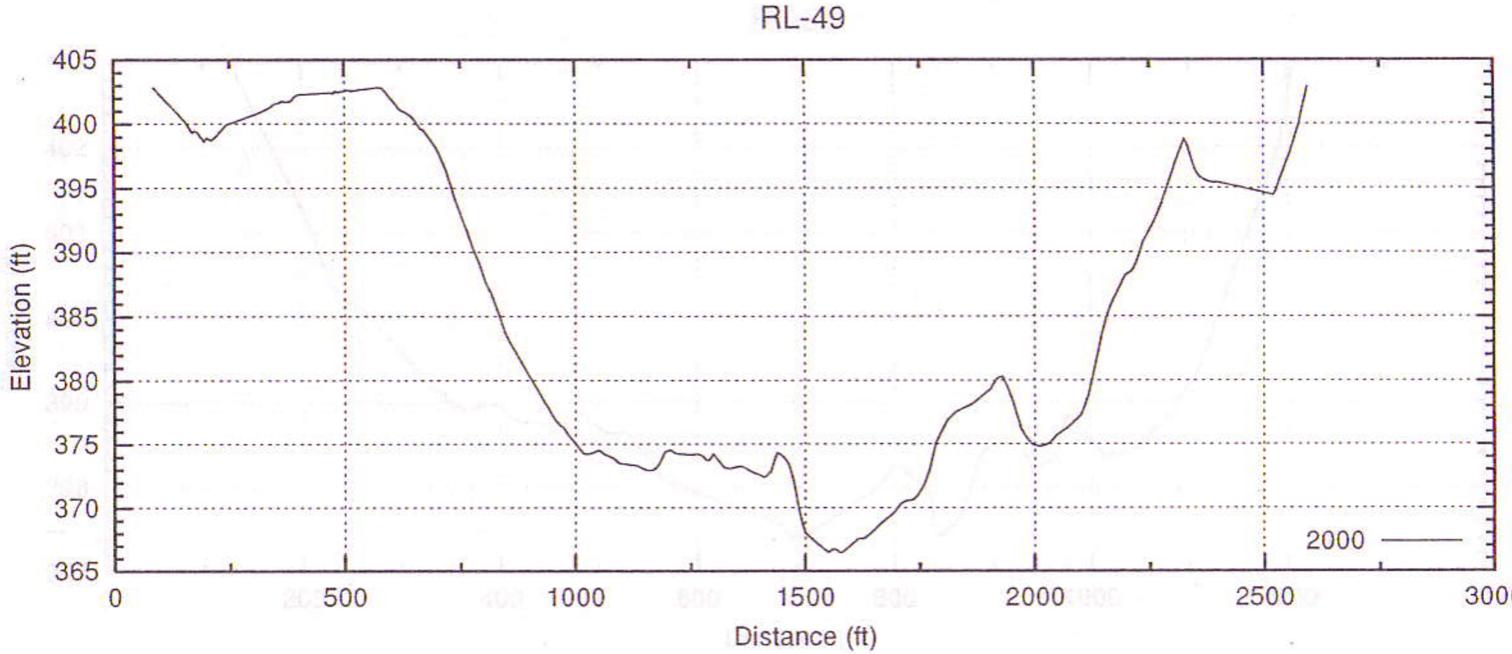
RL-48

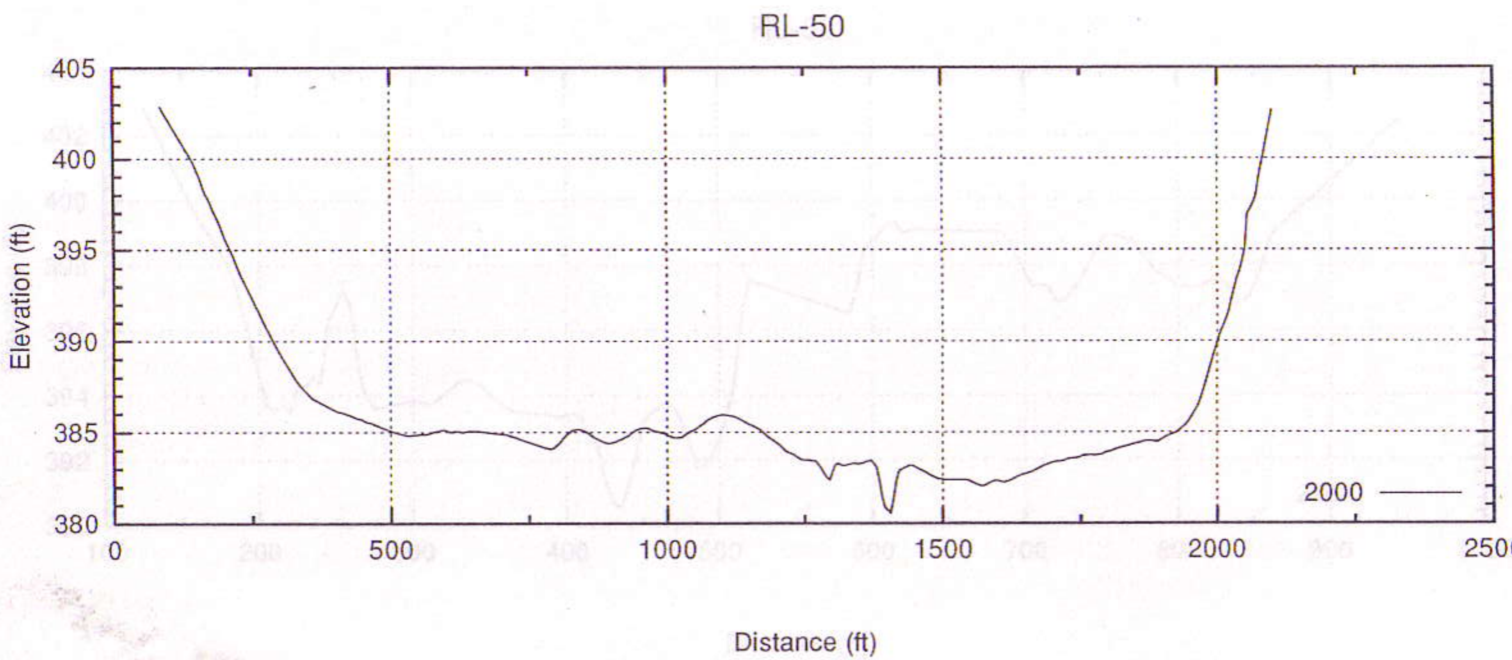


Distance (ft)

Appendix E

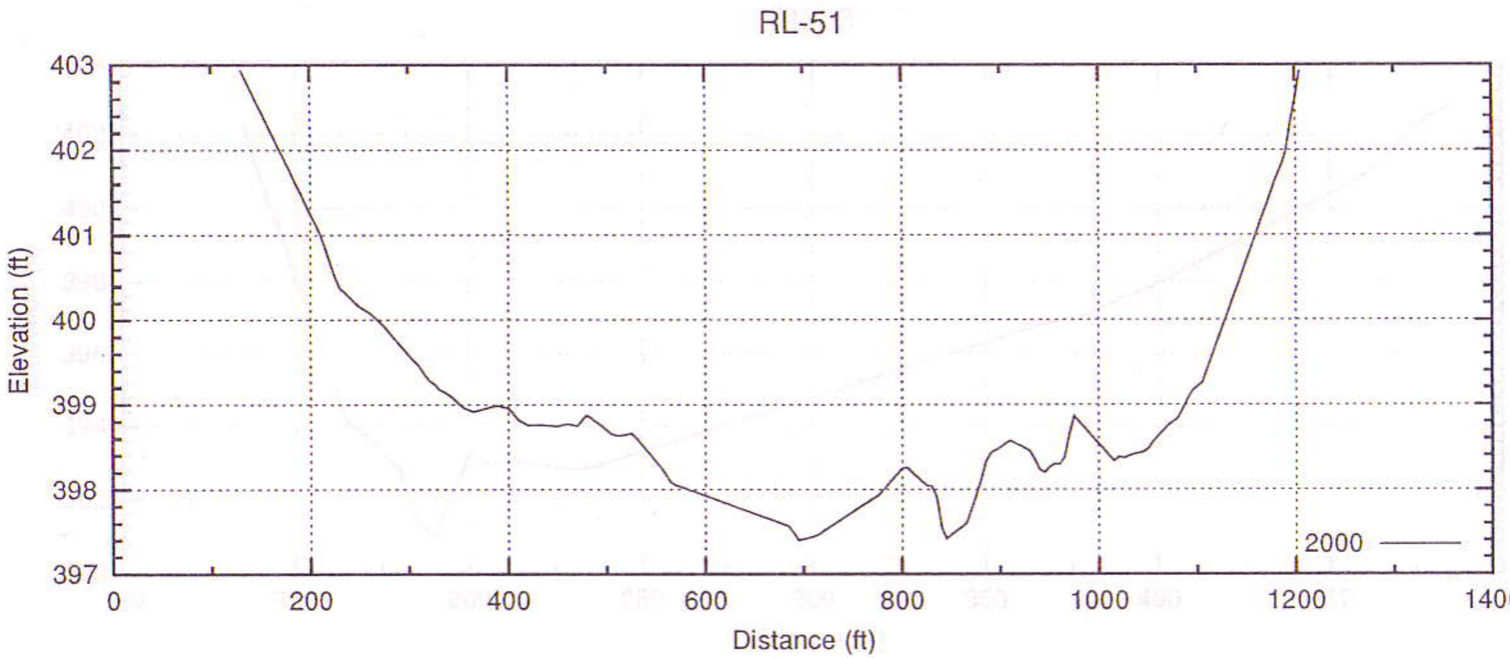
LAKE FORK

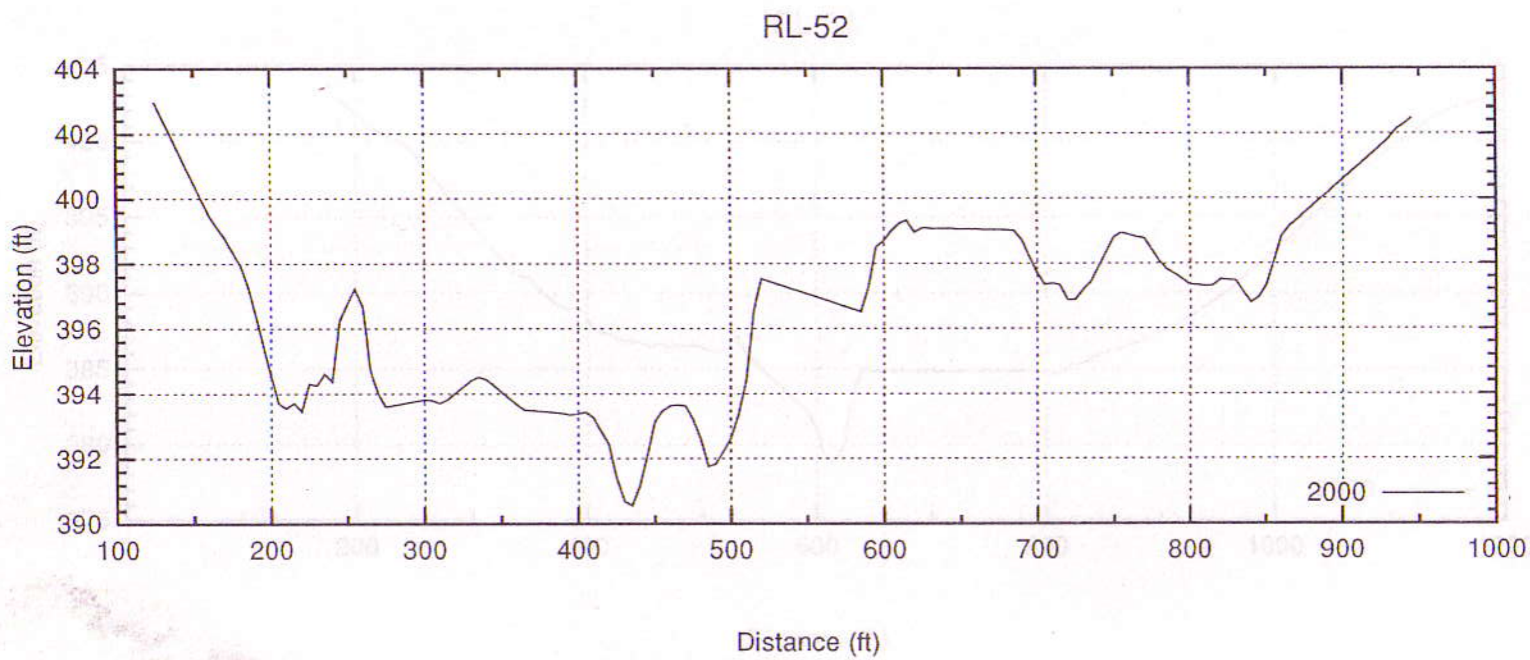




Appendix E

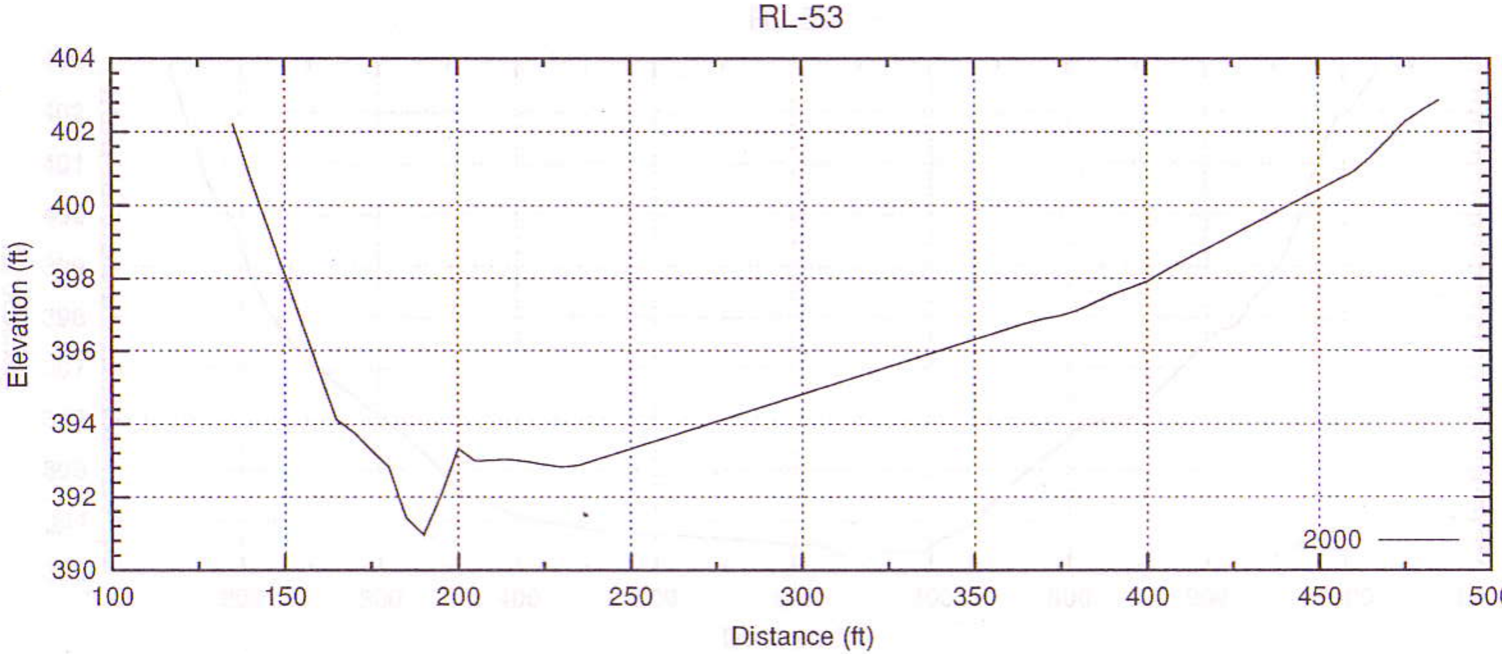
LAKE FORK

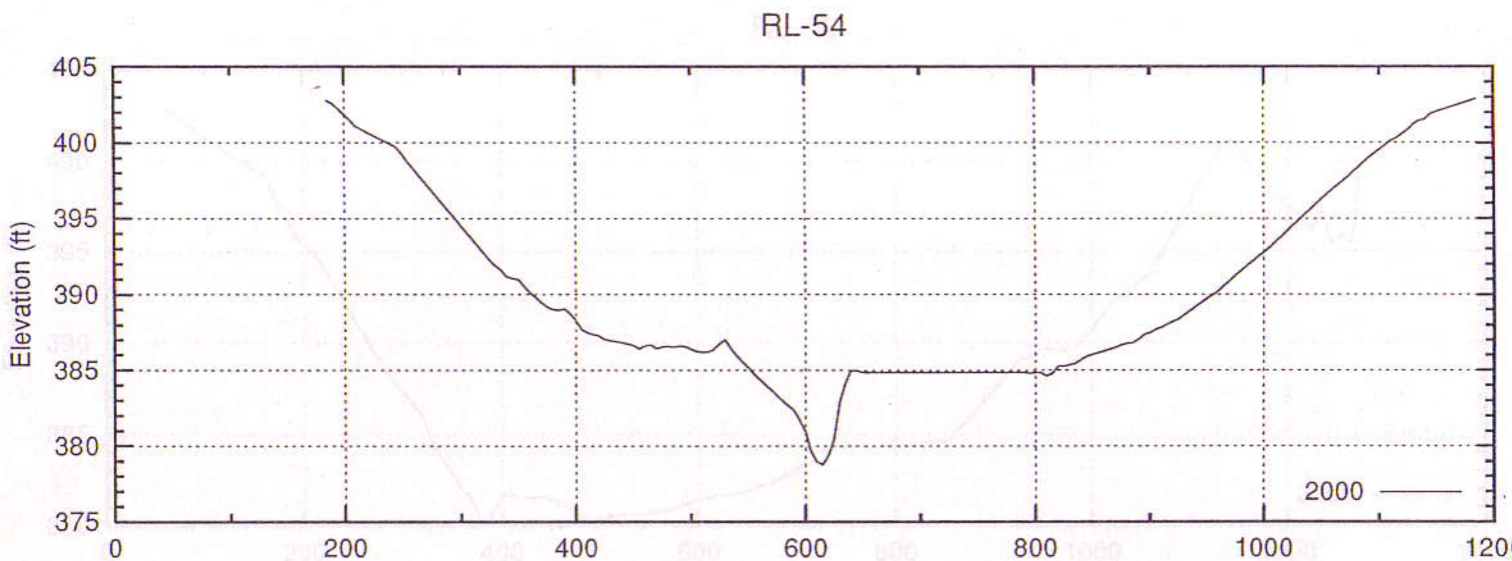




Appendix E

LAKE FORK

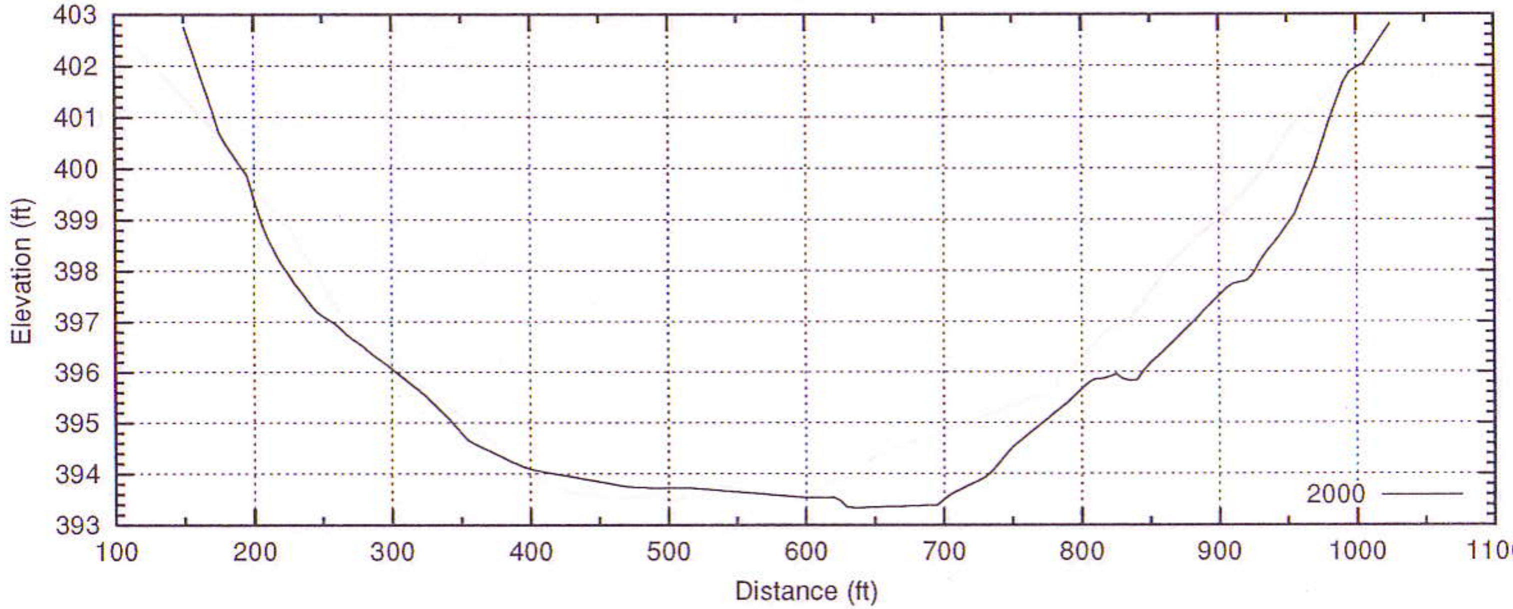




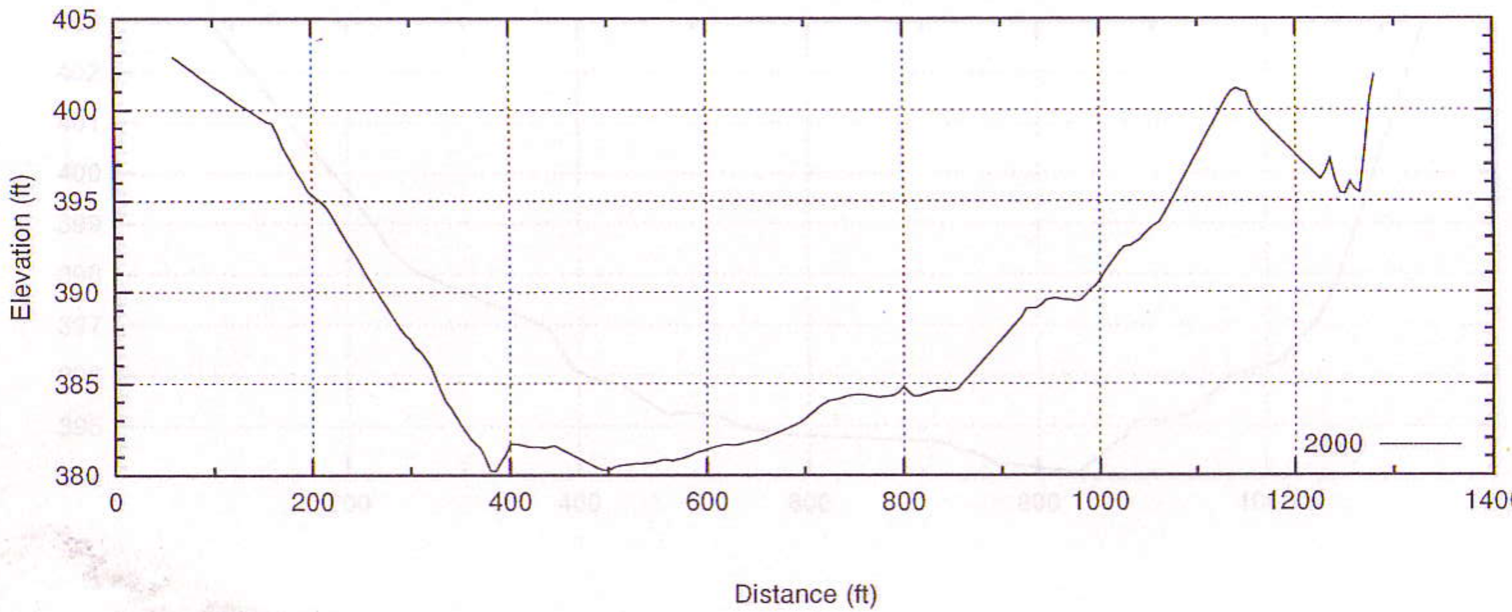
Distance (ft)

LAKE FORK

RL-55



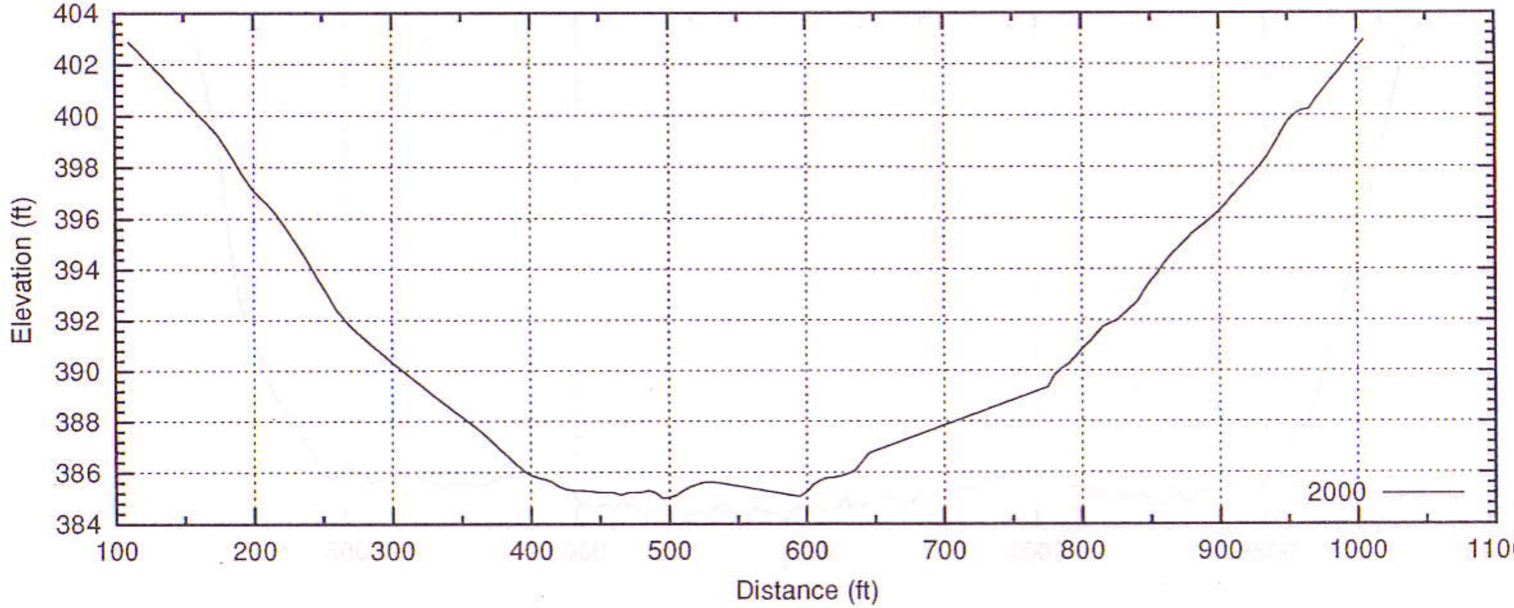
RL-56



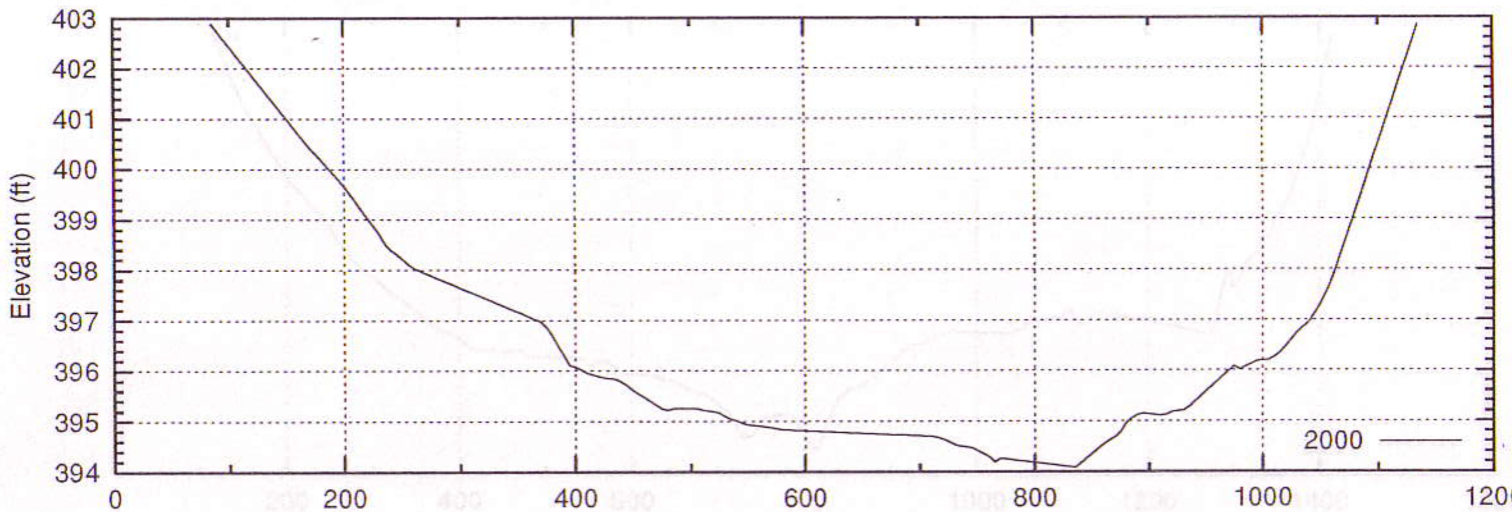
Appendix E

LAKE FORK

RL-57



RL-58

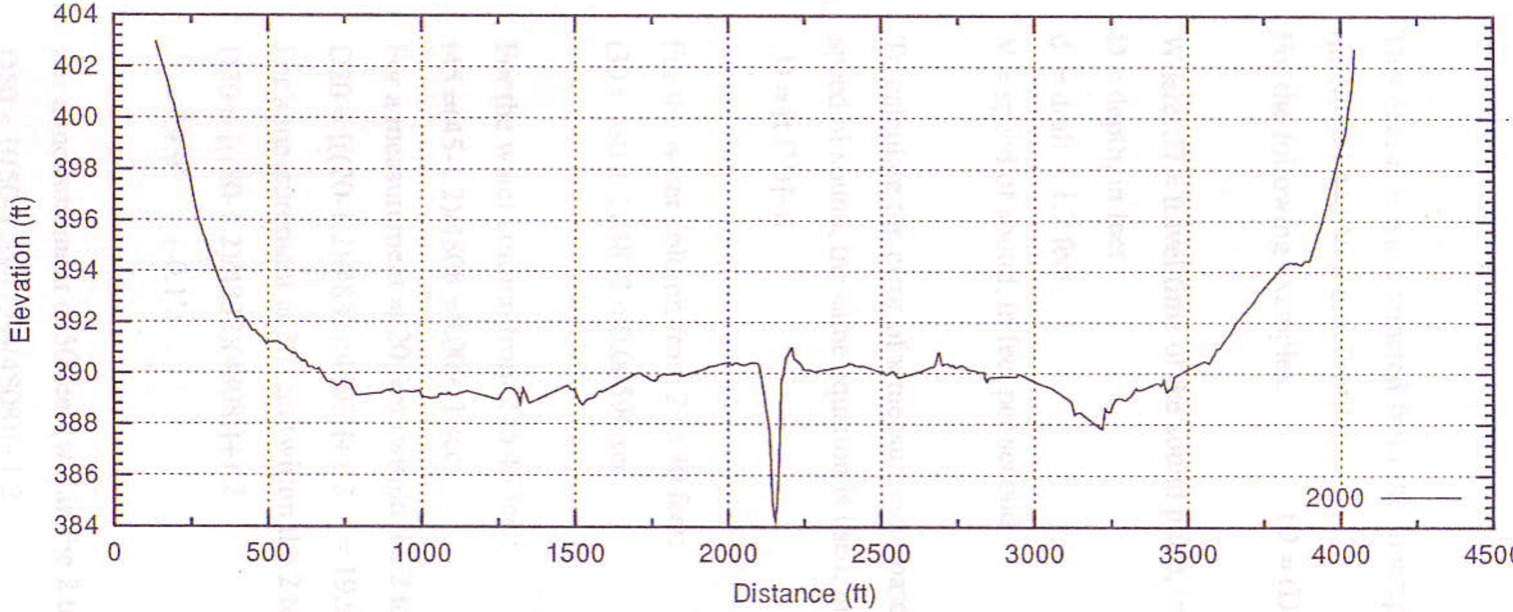


Distance (ft)

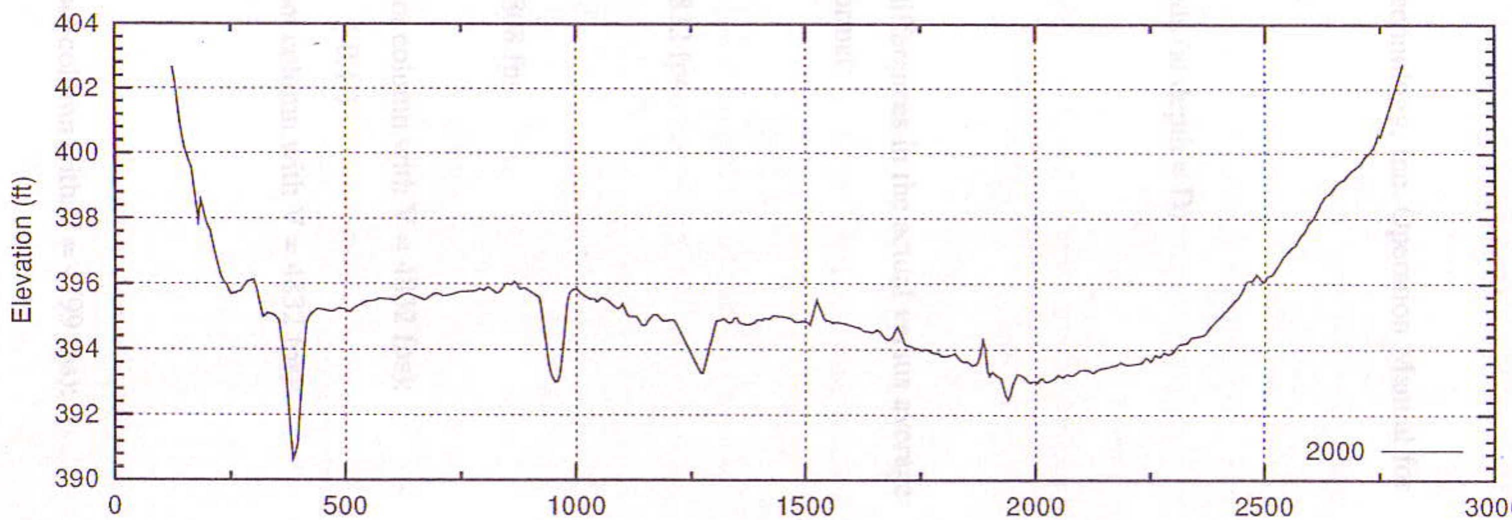
Appendix E

LAKE FORK

RL-61



RL-62



Distance (ft)

APPENDIX F - DEPTH SOUNDER ACCURACY

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

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

Where: tD = 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

$t30 = (30-1.2)/4832 = 0.00596$ sec.

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

$t45 =(45-1.2)/4808 =0.00911$ sec.

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

D20 = [((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):

D30 = [((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):

D50 = [((50-1.2)/4799)(4808)]+1.2

= 50.1’ (+0.1’)

For the water column from 2 to 60 feet: V = 4799 fps Assumed V80 = 4785 fps

t60 =(60-1.2)/4799

=0.01225 sec.

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

D10 = [((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):

D30 = [((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):

D45 = [((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):

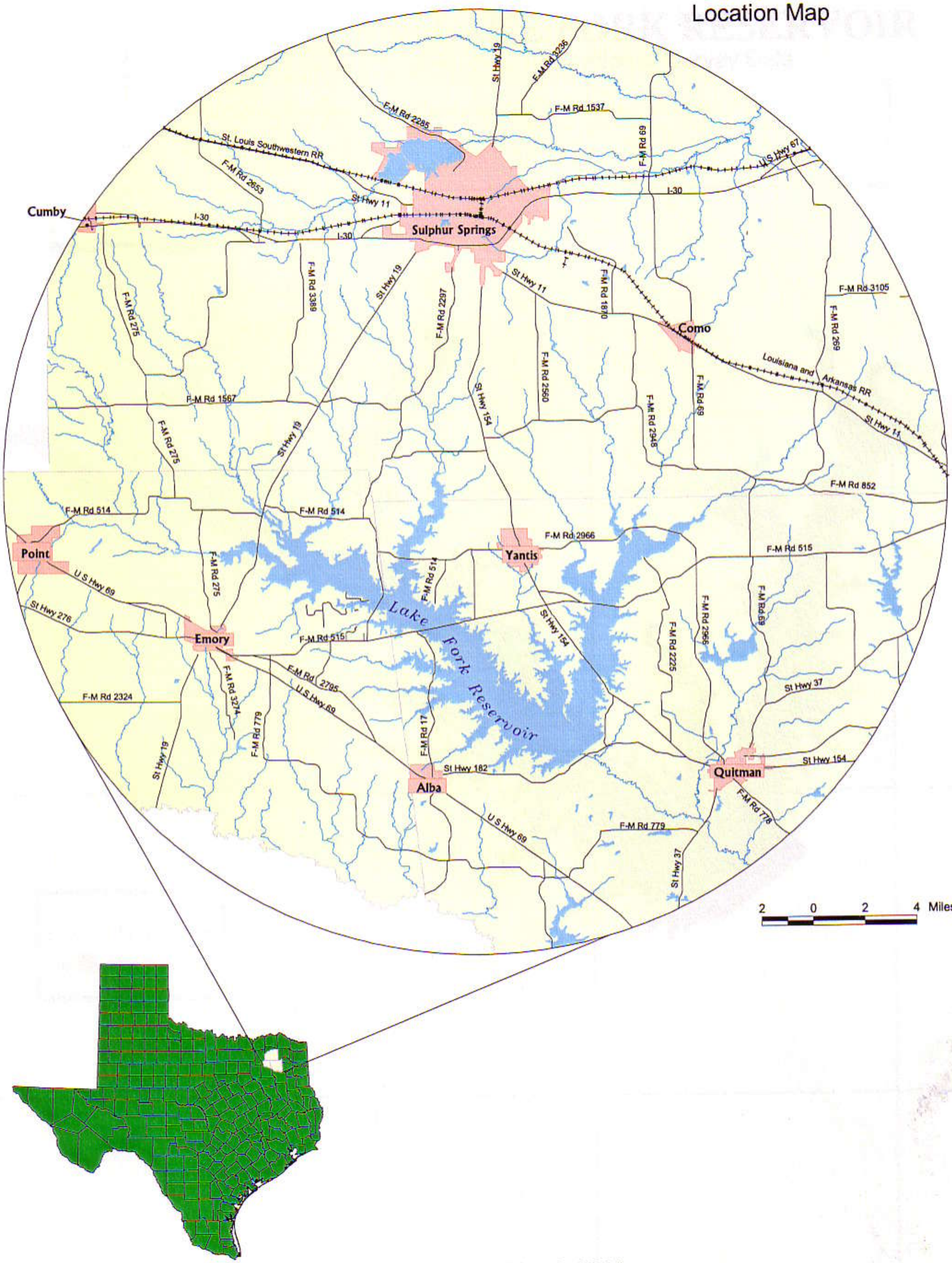
D80 = [((80-1.2)/4785)(4799)]+1.2

= 80.2’ (+0.2’)

Figure 1

LAKE FORK RESERVOIR

Location Map



TWDB Survey March 2001

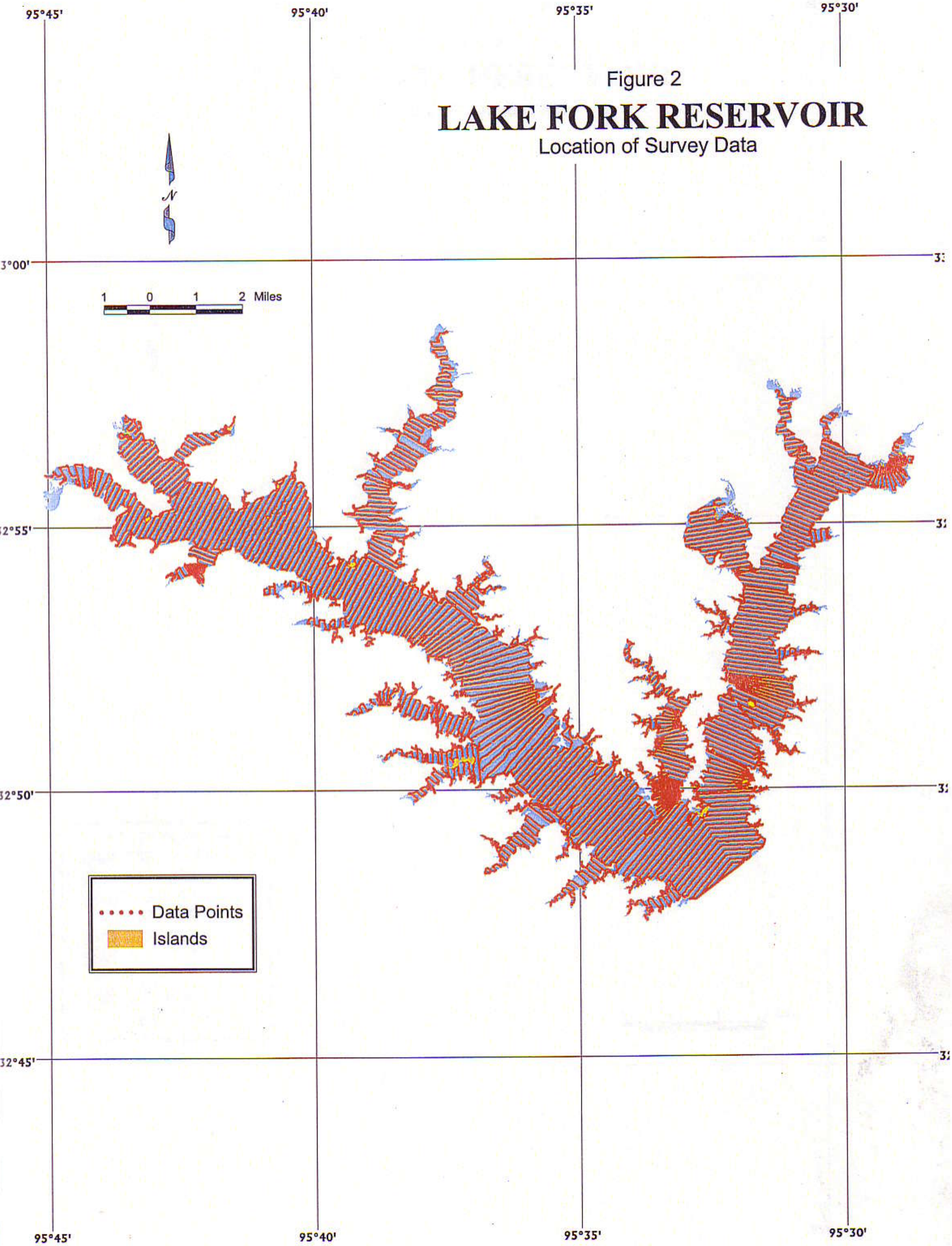


Figure 2

LAKE FORK RESERVOIR

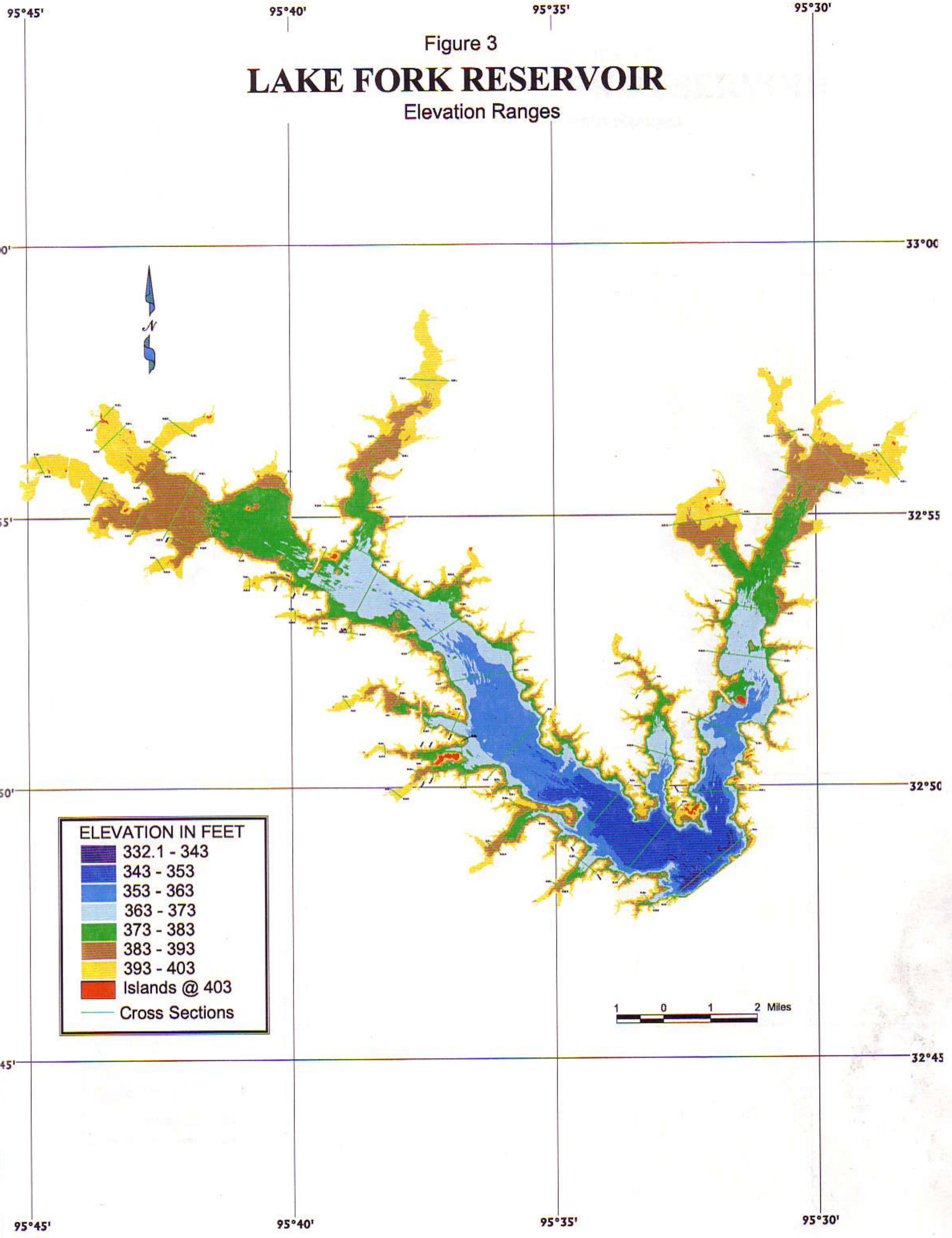
Location of Survey Data

TWDB Survey March 2001

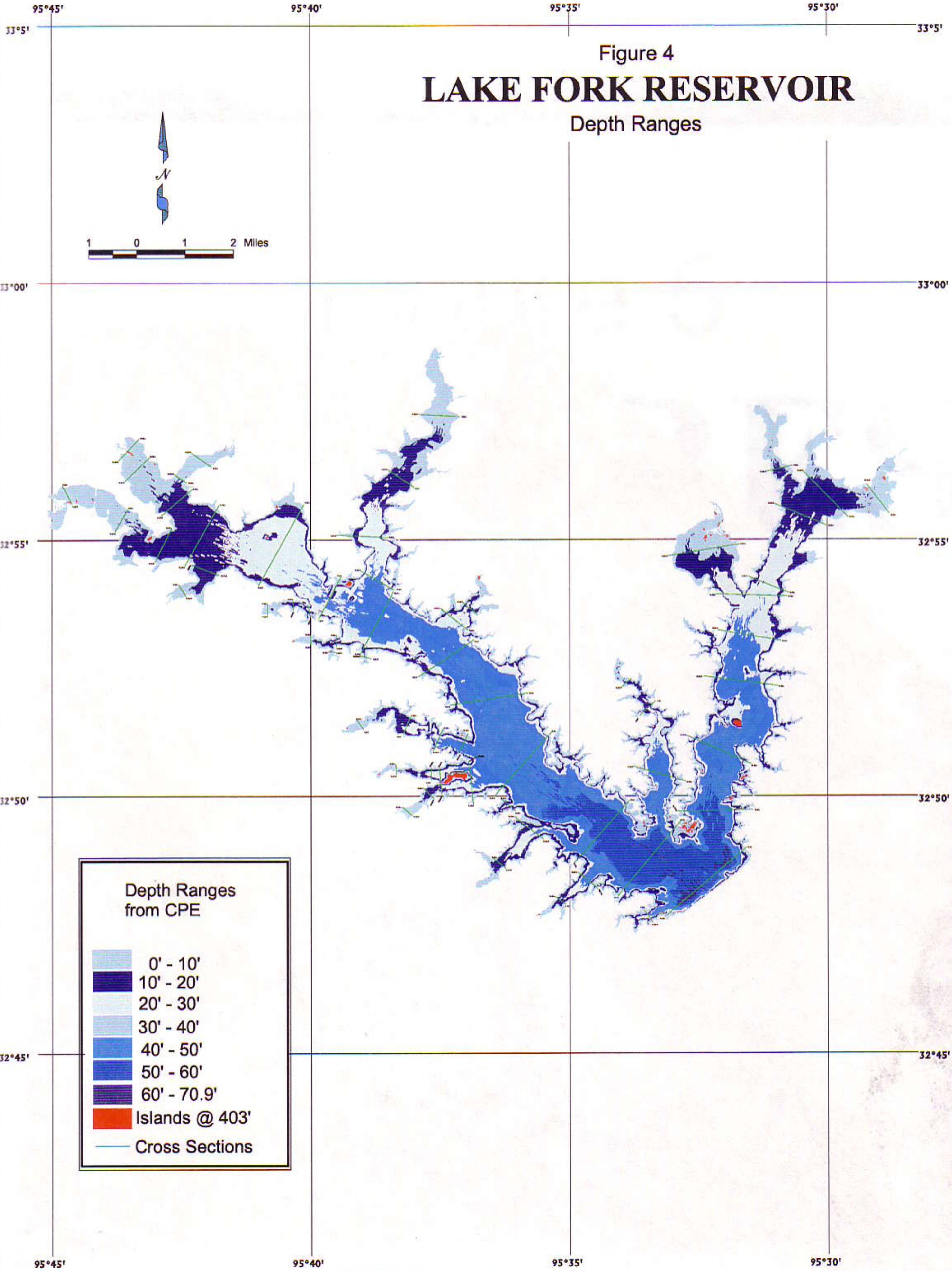
Figure 3

LAKE FORK RESERVOIR

Elevation Ranges



TWDB Survey March 2001



TWDB Survey March 2001