VOLUMETRIC SURVEY OF FAIRFIELD LAKE

Prepared for:

U. S. Army Corps of Engineers
Fort Worth District

In conjunction with
Sabine River Authority
And
TXU Electric Company

Prepared by:
Texas Water Development Board

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Texas Water Development Board

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INTRODUCTION

Staff of the Surface Water Section of the Texas Water Development Board (TWDB) conducted a volumetric survey of Fairfield Lake (formerly known as Big Brown Reservoir) during the period of May 10, 11 and June 3, 1999. The purpose of the survey was to determine the current volume of the lake at the conservation pool elevation. This survey will establish a basis for comparison to future surveys from which the location and rates of sediment deposition in the conservation pool over time can be determined. Survey results are presented in the following pages in both graphical and tabular form. All elevations presented in this report are reported in feet above mean sea level based on the National Geodetic Vertical Datum of 1929 (NGVD '29) unless noted otherwise. The conservation pool elevation for Fairfield Lake is 310.0 feet. Original design information (TWDB, 1973) showed the surface area at this elevation to be 2,350 acres and the storage volume to be 50,600 acre-feet.

LAKE HISTORY AND GENERAL INFORMATION

Historical information on Fairfield Lake was obtained from Texas Water Development Board Report 126 Part II (TWDB, 1973) and the URS Corporation Sediment Survey of Big Brown Reservoir (URS Corporation, 1985). The TXU Electric Company (formerly Texas Utilities) owns the water rights to Fairfield Lake. The company also owns the land surrounding Fairfield Lake and operates and maintains Fairfield Dam. The lake is located on Big Brown Creek (Trinity River Basin) in Freestone County, 11miles northeast of Fairfield, Texas (see Figure 1). Records indicate the drainage area is approximately 34 square miles with supplemental pumping from Trinity River. At the conservation pool elevation, the lake has approximately 33.7 miles of shoreline and is 4.5 miles long. The widest point of the reservoir is approximately 1.7 miles (located 2.5 miles upstream of the dam).

Water Rights Permit No. 2351A (Application No. 2561A) was issued to Texas Power and Light Company (presently TXU Electric Company) on May 9, 1968 and authorized the construction of a dam to impound 50,600 acre-feet of water. Of that total, 19,700 acre-feet of water could be diverted annually by pumping from the Trinity River. The permit allowed annual use not to exceed 14,150 acre-feet of water for cooling a steam-electric generating plant. The Texas Water Commission issued Certificate of Adjudication No. 08-5040 on May 5, 1987. The certificate basically re-enforces Permit No. 2351A and authorizes TXU Electric Company to maintain an existing dam and reservoir on Big Brown Creek (Fairfield Lake) and to impound not to exceed 50,600 acre-feet of water. The owner was authorized to divert and use not to exceed 14,150 acre-feet of water per year from Fairfield Lake for industrial (thermal-electric power generation) purposes. Under the Special Conditions section of the Certificate, the owner is authorized to store water diverted from the Trinity River in Fairfield Lake for subsequent diversion and use to the extent authorized.

Records indicate the construction for Fairfield Lake and Fairfield Dam started August 19, 1968 and was completed in December 1969, after which deliberate impoundment began. The design engineer for the project was Forrest and Cotton, Inc. and the general contractor was Spencer Construction Company. The estimated cost of the dam was $2,600,000.00.

Fairfield Dam and appurtenant structures consist of a rolled-earthfill embankment approximately 3,250 feet in length, with a maximum height of 77 feet and a crest elevation of 322.0 feet. The service spillway is located at the left (north) abutment and is a concrete chute with an ogee crest. The crest is 60 feet in net length at elevation 299.0 feet. Two tainter gates, each 14 feet tall and 30 feet wide, control the service spillway. The emergency spillway, located to the right (south) of the dam, is an earth trench cut through the natural ground. The uncontrolled broad-crested weir is 500 feet in length at elevation 314.0 feet.

The minimal operating elevation for the intake to the power plant is 305.0 feet.

Original design information (TWDB, 1973) estimated the surface area at conservation pool elevation 310.0 feet to be 2,350 acres and the storage volume to be 50,600 acre-feet of water. In 1985, URS Corporation performed a sedimentation survey of Fairfield Lake. Results of that survey showed the surface area at normal operating pool (conservation pool) to be 2,333 acres and a volume of 47,124 acre-feet. In 1987, Weaver and Walker Surveying conducted a hydrographic survey of the intake and discharge channels at the Big Brown Power Plant located on Fairfield Lake. This report will address the comparison of the 1999 survey results with the original design and the 1985 survey findings.

HYDROGRAPHIC SURVEYING TECHNOLOGY

The equipment used in the performance of the volumetric survey consists of a 23-foot aluminum tri-hull SeaArk craft with cabin, equipped with twin 90-Horsepower Johnson outboard motors. (Reference to brand names throughout this report does not imply endorsement by the TWDB). Installed within the enclosed cabin are an Innerspace Helmsman Display (for navigation), an Innerspace Technology Model 449 Depth Sounder and Model 443 Velocity Profiler, a Trimble Navigation, Inc. 4000SE GPS receiver, an OmniSTAR receiver, and an on-board 486 computer. A water-cooled generator provides electrical power through an in-line uninterruptible power supply.

The GPS equipment, survey vessel, and depth sounder in combination provide an efficient hydrographic survey system. As the boat travels across the lake surface, the depth sounder takes approximately ten readings of the lake bottom each second. The depth readings are stored on the survey vessel's on-board computer along with the corrected positional data generated by the boat's GPS receiver. The daily data files collected are downloaded from the computer and brought to the office for editing after the survey is completed. During editing, poor-quality data is removed or corrected, multiple data points are averaged to get one data point per second, and average depths are converted to elevation readings based on the lake elevation recorded on the day the survey was performed. Accurate estimates of the lake volume can be quickly determined by building a 3-D model of the reservoir from the collected data. The level of accuracy is equivalent to or better than previous methods used to determine lake volumes, some of which are discussed in Appendix F.

PRE-SURVEY PROCEDURES

The reservoir's surface area was determined prior to the survey by digitizing the lake's pool boundary (elevation 310.0 feet) with AutoCad software. The boundary file was created from the USGS 7.5-minute quadrangle map, Young, TX. (1961), Photo-revised 1982.

OR

The reservoir's boundary was digitized using ArcView software. The boundary file was created from recently produced digital orthophoto quadrangles (DOQ) images for Cryer Creek, Texas and Ennis West, Texas. (The DOQ's were produced for the TEXAS Orthoimagery Program (TOP). DOQ products produced for the Department of Information Resources and the GIS Planning Council under the Texas Orthoimagery Program reside in the public domain and can be obtained on the Internet at http://www.tnris.state.tx.us/DigitalData/doqs.htm.) The boundary created with these DOQ's was originally in UTM Zone 14, and was subsequently converted to the NAD '83. The photographs used in the producing the DOQ's were taken February 8, 1995. The average lake elevation at the time the photographs were taken, obtained from the U.S. Army Corps of Engineers, was 421.11 feet. This boundary was used in determining the outer lake boundary for subsequent use in calculating the lake's area and volume.

The survey layout was designed by placing survey track lines at 500-foot intervals within the digitized lake boundary using HyPack software. The survey design required the use of approximately ____ survey lines placed along the length of the lake.

SURVEY PROCEDURES

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

Equipment Calibration and Operation

At the beginning of each surveying day, the depth sounder was calibrated with the Innerspace

Velocity Profiler, an instrument used to measure the variation in the speed of sound at different depths in the water column. The average speed of sound through the entire water column below the boat was determined by averaging local speed-of-sound measurements collected through the water column. The velocity profiler probe was first placed in the water to moisten and acclimate the probe. The probe was next raised to the water surface where the depth was zeroed. The probe was then gradually lowered on a cable to a depth just above the lake bottom, and then raised to the surface. During this lowering and raising procedure, local speed-of-sound measurements were collected, from which the average speed was computed by the velocity profiler. This average speed of sound was entered into the ITI449 depth sounder, which then provided the depth of the lake bottom. The depth was then checked manually with a measuring tape to ensure that the depth sounder was properly calibrated and operating correctly. During the survey of Fairfield Lake, the speed of sound in the water column varied from 4,889 to 4,895 feet per second. Based on the measured speed of sound for various depths and the average speed of sound calculated for the entire water column, the depth sounder is accurate to within $\pm$0.2 feet. An additional estimated error of $\pm$0.3 feet arises from variation in boat inclination. These two factors combine to give an overall accuracy of $\pm$0.5 feet for any instantaneous reading. These errors tend to be minimized over the entire survey, since some readings are positive and some are negative. Further information on these calculations is presented in Appendix F.

During the survey, the onboard GPS receiver was set to a horizontal mask of 10° and a PDOP (Position Dilution of Precision) limit of 7 to maximize the accuracy of horizontal positions. An internal alarm sounds if the PDOP rises above seven to advise the field crew that the horizontal position has degraded to an unacceptable level. The lake's initialization file used by the Hypack data collection program was set up to convert the collected DGPS positions on-the-fly to state-plane coordinates. Both sets of coordinates were then stored in the survey data file.

Field Survey

Data were collected in the main basin of Fairfield Lake on May 10 and 11, 1999. The survey crew returned on June 3, 1999 to collect data in the restricted areas. A smaller boat with portable equipment was used to collect data in the restricted areas that included the intake channel and discharge pond (hot lake). During data collection, the crew had excellent weather with moderate temperatures and mild winds. Approximately 24,392 data points were collected over the 46 miles traveled. These points were stored digitally on the boat's computer in over 126 data files. Data were not collected in areas with significant obstructions unless these areas represented a large amount of water. Figure 2 shows the actual location of all data collection points.

Big Brown Creek flows in a southwest to northeast direction with Fairfield Dam being at the northeast end of the lake basin. TWDB staff observed the land surrounding the lake to be generally flat to rolling hills. There was no residential or commercial development around the perimeter of the lake. Fairfield State Park (recreational park) is located at the upper reaches of the lake and occupies the peninsula that divides Big Brown and Little Brown Creeks. Texas Utilities electric generating power plant is located near the dam on the west side of the lake.

While performing the survey on the lake, the field crew noted on the depth sounder chart that the bathymetry or contour of the lake bottom was relatively flat in the main basin of the lake. A definite slope was noted at the lake's shoreline as the boat traveled from the perimeter to the center of the lake. There was no defined channel (thalweg) of Big Brown Creek in the main basin of the lake. Between Fairfield Dam and the confluence of the two creeks, the crew noted only minor shoreline erosion. As the field crew collected data in the upper reaches of Big Brown Creek, navigational hazards such as submerged trees and stumps became apparent. In addition, sediment deposits and standing vegetation were observed. The crew was able to collect data in these areas, but at a much slower pace. Data collection in the headwaters was limited when the boat could no longer cross the lake due to shallow water and extensive vegetation. The survey crew returned to Fairfield Lake on June 3rd to collect data in the intake channel and discharge pond. The crew gathered data in most of this area but encountered areas that were cabled and inaccessible.

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

Data Processing

The collected data were downloaded from diskettes onto TWDB's computer network. Tape backups were made for future reference as needed. To process the data, the EDIT routine in the

Hypack Program was run on each raw data file. Data points such as depth spikes or data with missing depth or positional information were deleted from the file. A correction for the lake elevation at the time of data collection was also applied to each file during the EDIT routine. During the survey, the water surface remained at conservation pool elevation of 310.0 feet according to elevation data provided by TXU Electric Company. After all changes had been made to the raw data file, the edited file was saved with a different extension. The edited files were combined into a single X, Y, Z data file, to be used with the GIS software to develop a model of the lake's bottom surface.

The resulting data file was downloaded to a Sun Sparc 20 workstation running the UNIX operating system. Environmental System Research Institute’s (ESRI) Arc/Info GIS software was used to convert the data to a MASS points file. The MASS points and the boundary file were then used to create a Digital Terrain Model (DTM) of the reservoir's bottom surface using Arc/Info's TIN software module. The module generates a triangulated irregular network (TIN) network from the data points and the boundary file using a method known as Delauney's criteria for triangulation. A triangle is formed between three non-uniformly spaced points, including all points along the boundary. If there is another point within the triangle, additional triangles are created until all points lie on the vertex of a triangle. All of the data points are used in this method. The generated network of three-dimensional triangular planes represents the actual bottom surface. With this representation of the bottom, the software then calculates elevations along the triangle surface plane by determining the elevation along each leg of the triangle. The reservoir area and volume can be determined from the triangulated irregular network created using this method of interpolation.

The boundary file, in areas of significant sedimentation, was downsized as deemed necessary based on the data points collected and the observations of the field crew. The resulting boundary shape was used to develop each of the map presentations of the lake in this report.

Volumes and areas were calculated from the TIN for the entire reservoir at one-tenth of a foot intervals. From elevation 257.4 to elevation 310.0, the surface areas and volumes of the lake were computed using Arc/Info software. The computed reservoir volume table is presented in Appendix A and the area table in Appendix B. An elevation-area-volume graph is presented in Appendix C.

Other products developed from the model include a shaded relief map (Figure 3) and a shaded depth range map (Figure 4). To develop these maps, the TIN was converted to a lattice using the TINLATTICE command and then to a polygon coverage using the LATTICEPOLY command. Linear filtration algorithms were applied to the DTM to produce smooth cartographic contours. The resulting contour map of the bottom surface at two-foot intervals is presented in Figure 5. Finally, cross-sections from the original survey and the 1985 re-survey by URS Corporation, shown on the map in Figure 5, are compared to cross-sections obtained from the current survey in the plots in Appendix D. Due to the difficulty in determining exact geographic coordinates for sedimentation range-line endpoint monuments in the main body of the lake reported in the 1985 survey, it was necessary to adjust the horizontal position of these range-lines in the comparisons shown in Figure D.

RESULTS

Results from the 1999 TWDB survey indicate Fairfield Lake encompasses 2,159 surface acres and contains a total volume of 44,169 acre-feet at the conservation pool elevation of 310.0 feet. The shoreline at this elevation was calculated to be 33.7 miles. The deepest point of the lake, elevation 257.4 feet and corresponding to a depth of 52.6 feet, was located approximately 650 feet upstream from the center of Fairfield Dam.

SUMMARY AND COMPARISONS

Fairfield Lake was initially impounded in 1969. Storage calculations in 1968 reported the volume at conservation pool elevation 310.0 feet to be 50,600 acre-feet with a surface area of 2,350 acres. A second survey in 1985 found the volume at conservation pool elevation to be 47,124 acre-feet and the area to be 2,333 acres.

During May 10, 11 and June 3, 1999, staff from the Texas Water Development Board's Hydrographic Survey Program completed a hydrographic survey of Fairfield Lake. The 1999 survey took advantage of technological advances such as differential global positioning system and geographical information system technology to create a digital model of the reservoir's bathymetry. With these advances, the survey was completed more quickly and significantly more bathymetric data were collected than in previous surveys. Results indicate that the lake's volume at the conservation pool elevation of 310.0 feet is 44,169 acre-feet, with a corresponding area of 2,159 acres.

Comparing the findings from the original (1968) survey and the current survey, the estimated reduction in area at conservation pool elevation 310.0 feet is 191 surface acres. The reduction in volume at conservation pool elevation is 6,431 acre-feet (-12.7%) or 207 acre-feet/year (since 1968). The average annual deposition rate of sediment in the reservoir can be estimated at 6.3 acre-feet/square mile of drainage area. This compares to sedimentation rates based on the original survey and the 1985 resurvey of 204 acre-feet/year and 6.2 acre-feet/square mile. Some differences among results may arise from differences in surveying procedures and technology. Based on the amount of data collected and the improved methods and technology used in the current survey, the current data set is considered to be an improvement over previous survey procedures. It is recommended that the same methodology be used in five to ten years or after major flood events to monitor changes to the lake's storage volume.

REFERENCES

Texas Water Development Board. 1973. Engineering data on dams and reservoirs in Texas. Part II. Report 126.

URS Corporation. 1985. Sediment Survey of Big Brown Reservoir. URS Corporation, Dallas, TX.

Appendix A

Fairfield Lake

RESERVOIR VOLUME TABLE

TEXAS WATER DEVELOPMENT BOARD MAY 1999 SURVEY

VOLUME IN ACRE-FEET ELEVATION INCREMENT IS ONE TENTH FOOT

ELEVATION IN FEET	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
257					0	0	0	0	0	0
258	0	0	0	0	1	1	1	2	2	3
259	4	5	6	7	8	9	11	12	14	16
260	18	20	22	25	27	30	33	36	39	42
261	45	49	52	56	60	64	69	73	78	83
262	89	94	100	106	112	118	125	131	138	146
263	153	161	169	177	186	194	203	212	221	231
264	240	250	260	270	281	291	302	313	323	334
265	346	357	369	380	392	404	416	428	441	453
266	466	479	493	506	520	534	548	562	577	591
267	606	621	636	651	666	682	698	714	730	746
268	763	779	796	813	831	848	866	884	903	922
269	941	960	980	1000	1020	1041	1062	1083	1105	1128
270	1151	1174	1197	1221	1245	1270	1294	1320	1345	1371
271	1397	1423	1449	1476	1503	1531	1559	1587	1615	1644
272	1673	1703	1732	1762	1793	1823	1854	1885	1916	1948
273	1980	2012	2044	2076	2109	2142	2176	2209	2243	2277
274	2312	2347	2382	2417	2453	2489	2526	2563	2600	2637
275	2675	2713	2751	2790	2830	2869	2909	2949	2989	3030
276	3071	3112	3154	3196	3238	3280	3323	3366	3409	3452
277	3496	3540	3584	3628	3673	3718	3764	3809	3855	3902
278	3949	3996	4043	4091	4139	4188	4237	4286	4336	4386
279	4436	4487	4538	4589	4640	4692	4745	4797	4851	4904
280	4958	5012	5067	5122	5177	5233	5289	5345	5402	5460
281	5517	5576	5635	5694	5754	5815	5876	5939	6001	6064
282	6128	6192	6257	6323	6389	6456	6523	6592	6660	6730
283	6800	6871	6942	7013	7085	7158	7231	7304	7378	7453
284	7529	7604	7681	7758	7836	7914	7993	8072	8152	8233
285	8314	8395	8477	8560	8643	8727	8811	8896	8981	9066
286	9153	9239	9326	9414	9502	9590	9679	9768	9858	9949
287	10039	10131	10223	10315	10408	10501	10595	10689	10783	10878
288	10974	11070	11166	11263	11360	11458	11556	11655	11755	11855
289	11955	12056	12158	12260	12362	12465	12568	12672	12776	12881
290	12986	13092	13198	13304	13411	13519	13627	13735	13844	13953
291	14063	14173	14284	14395	14507	14619	14731	14844	14958	15072
292	15187	15302	15418	15534	15650	15768	15885	16003	16122	16241
293	16361	16481	16602	16723	16845	16967	17090	17214	17338	17462
294	17587	17712	17838	17964	18091	18218	18346	18474	18603	18732
295	18862	18992	19123	19254	19386	19518	19651	19785	19919	20053
296	20188	20323	20459	20596	20733	20870	21008	21147	21285	21425
297	21565	21705	21846	21987	22129	22272	22414	22558	22702	22846
298	22991	23136	23282	23428	23575	23723	23870	24019	24168	24317
299	24467	24617	24768	24919	25071	25223	25376	25529	25682	25837
300	25991	26146	26302	26458	26615	26773	26930	27089	27247	27407
301	27567	27727	27888	28049	28211	28374	28537	28700	28864	29029
302	29194	29359	29525	29692	29859	30026	30195	30363	30532	30702
303	30872	31043	31214	31386	31558	31731	31905	32078	32253	32428
304	32603	32779	32956	33133	33311	33489	33668	33847	34027	34208
305	34389	34571	34753	34936	35119	35303	35488	35673	35859	36045
306	36232	36420	36608	36797	36987	37177	37368	37559	37751	37944
307	38137	38331	38526	38721	38916	39113	39310	39507	39704	39903
308	40101	40300	40500	40699	40900	41101	41302	41504	41706	41909
309	42112	42315	42520	42724	42929	43135	43341	43547	43754	43961
310	44169									

Appendix B

Fairfield Lake

RESERVOIR AREA TABLE

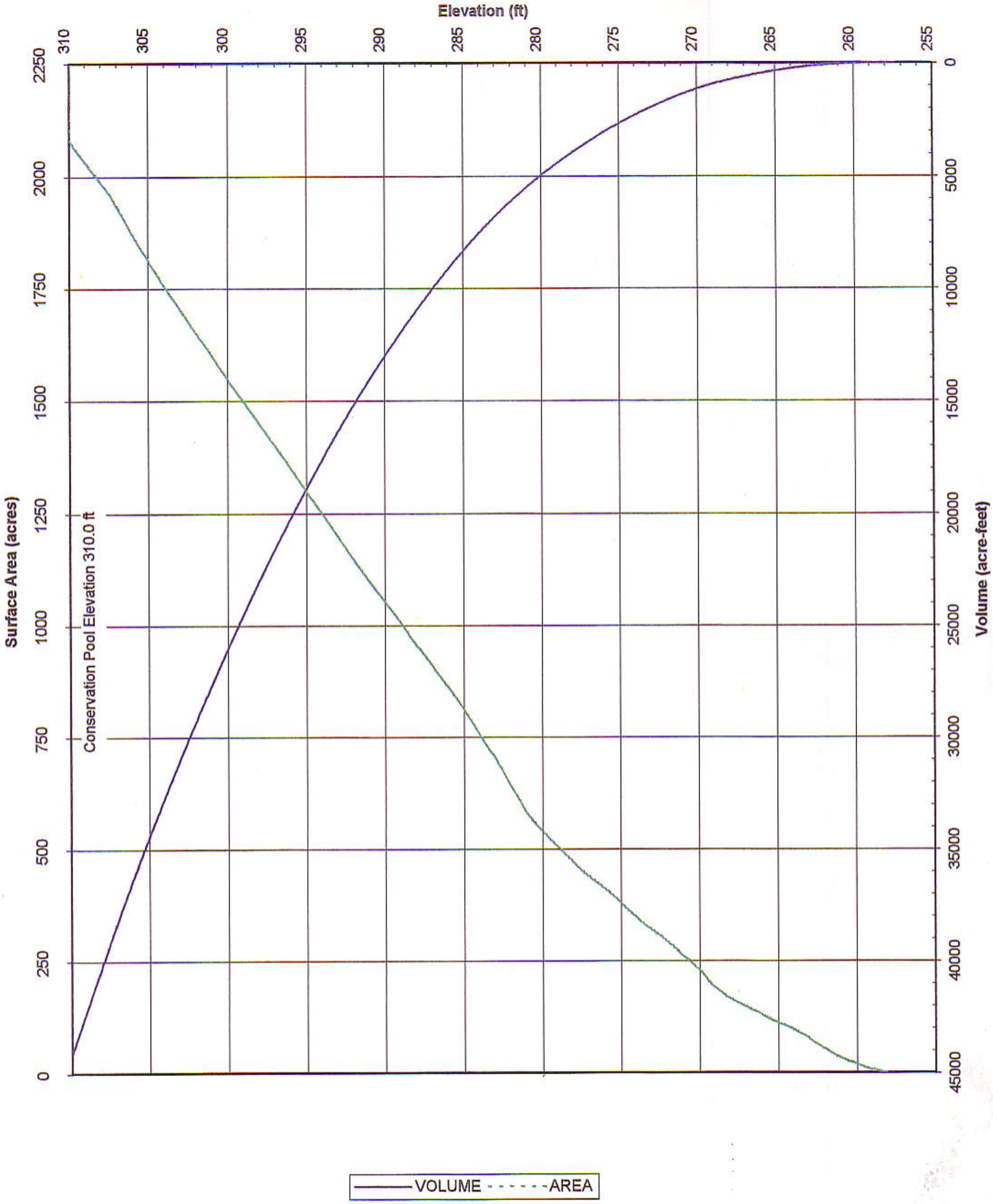
TEXAS WATER DEVELOPMENT BOARD

MAY 1999 SURVEY

AREA IN ACRES

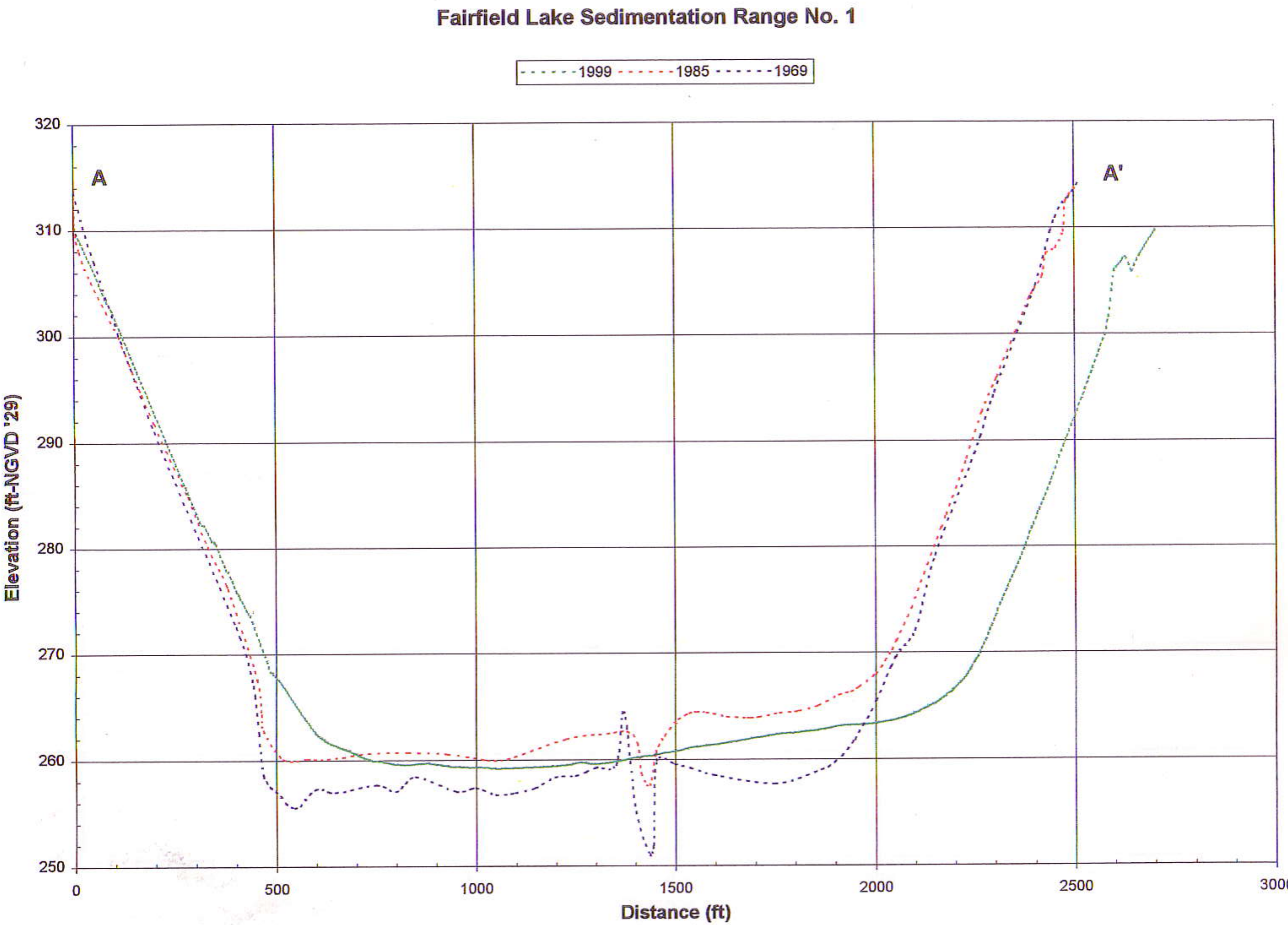
ELEVATION INCREMENT IS ONE TENTH FOOT

ELEVATION IN FEET	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
257					0	0	0	0	0	0
258	0	1	1	2	3	4	5	6	7	8
259	9	9	10	11	12	14	15	17	18	19
260	21	22	23	25	26	27	28	30	31	33
261	34	36	37	39	41	43	45	47	50	52
262	54	56	58	60	62	64	67	69	71	74
263	77	79	81	83	85	87	89	91	93	95
264	97	99	101	102	104	105	107	108	110	111
265	113	114	116	117	119	120	122	124	126	128
266	130	132	135	137	138	140	141	143	144	146
267	148	150	151	153	155	157	159	160	162	164
268	166	168	170	172	175	178	180	184	186	189
269	192	195	197	201	205	209	214	219	223	226
270	230	233	236	239	243	246	250	253	256	258
271	261	263	266	270	273	277	280	284	287	290
272	293	296	299	301	304	307	309	312	314	317
273	319	321	324	327	329	332	335	338	341	344
274	347	350	353	357	360	363	366	369	373	376
275	379	383	387	390	394	397	400	403	405	408
276	411	414	416	419	422	425	428	430	433	435
277	438	441	444	446	449	452	456	459	462	466
278	470	473	477	481	484	487	491	494	498	501
279	504	508	511	515	518	522	525	529	533	537
280	540	544	548	551	555	559	563	567	571	576
281	581	586	591	598	605	611	618	623	629	634
282	640	646	652	659	666	673	679	685	691	697
283	704	709	713	718	722	728	733	739	745	750
284	756	762	768	774	780	786	791	797	802	807
285	813	818	824	829	834	840	845	849	854	859
286	863	868	873	877	882	887	891	896	901	906
287	911	916	921	925	930	935	939	944	948	952
288	957	961	966	970	976	981	987	992	997	1002
289	1007	1012	1017	1022	1026	1031	1036	1040	1045	1049
290	1054	1058	1063	1067	1072	1077	1081	1086	1090	1095
291	1100	1105	1110	1114	1119	1124	1129	1134	1139	1144
292	1149	1154	1159	1164	1169	1174	1179	1184	1190	1195
293	1200	1205	1210	1215	1221	1226	1231	1236	1241	1246
294	1251	1255	1260	1265	1270	1275	1280	1285	1290	1295
295	1300	1305	1311	1316	1321	1326	1331	1337	1342	1347
296	1352	1357	1362	1367	1372	1377	1382	1387	1391	1396
297	1401	1406	1411	1416	1421	1426	1431	1436	1441	1446
298	1451	1456	1461	1466	1471	1476	1481	1486	1491	1495
299	1500	1505	1510	1515	1520	1524	1529	1534	1539	1544
300	1550	1555	1560	1565	1570	1575	1580	1586	1591	1596
301	1601	1607	1612	1617	1622	1627	1632	1637	1642	1647
302	1652	1657	1663	1668	1673	1678	1684	1689	1694	1700
303	1705	1710	1715	1721	1726	1731	1736	1741	1747	1752
304	1758	1763	1769	1774	1780	1785	1791	1797	1803	1809
305	1815	1820	1826	1832	1838	1843	1849	1855	1861	1867
306	1873	1879	1885	1892	1899	1905	1912	1918	1924	1930
307	1936	1941	1947	1956	1961	1965	1970	1974	1979	1983
308	1988	1992	1997	2001	2006	2011	2015	2020	2024	2029
309	2034	2038	2043	2048	2053	2057	2062	2067	2072	2077
310	2159									



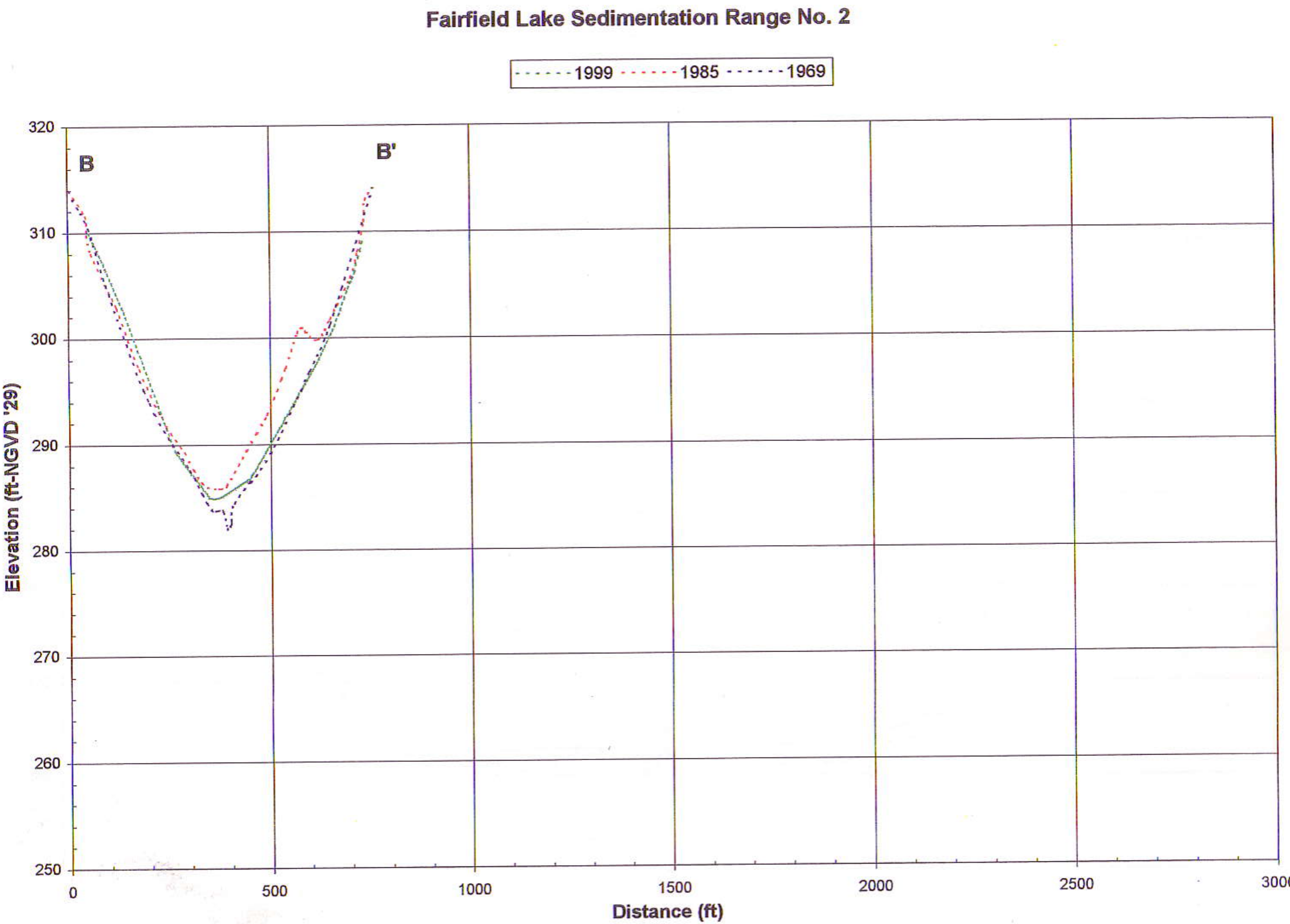
Fairfield Lake
May 1999
Prepared by: TWDB August 1999

Appendix C



Fairfield Lake Sedimentation Range No. 1
1999
1985
1969
A
A'
320
310
300
290
280
270
260
250
Elevation (ft-NGVD '29)
0
500
1000
1500
2000
2500
3000
Distance (ft)

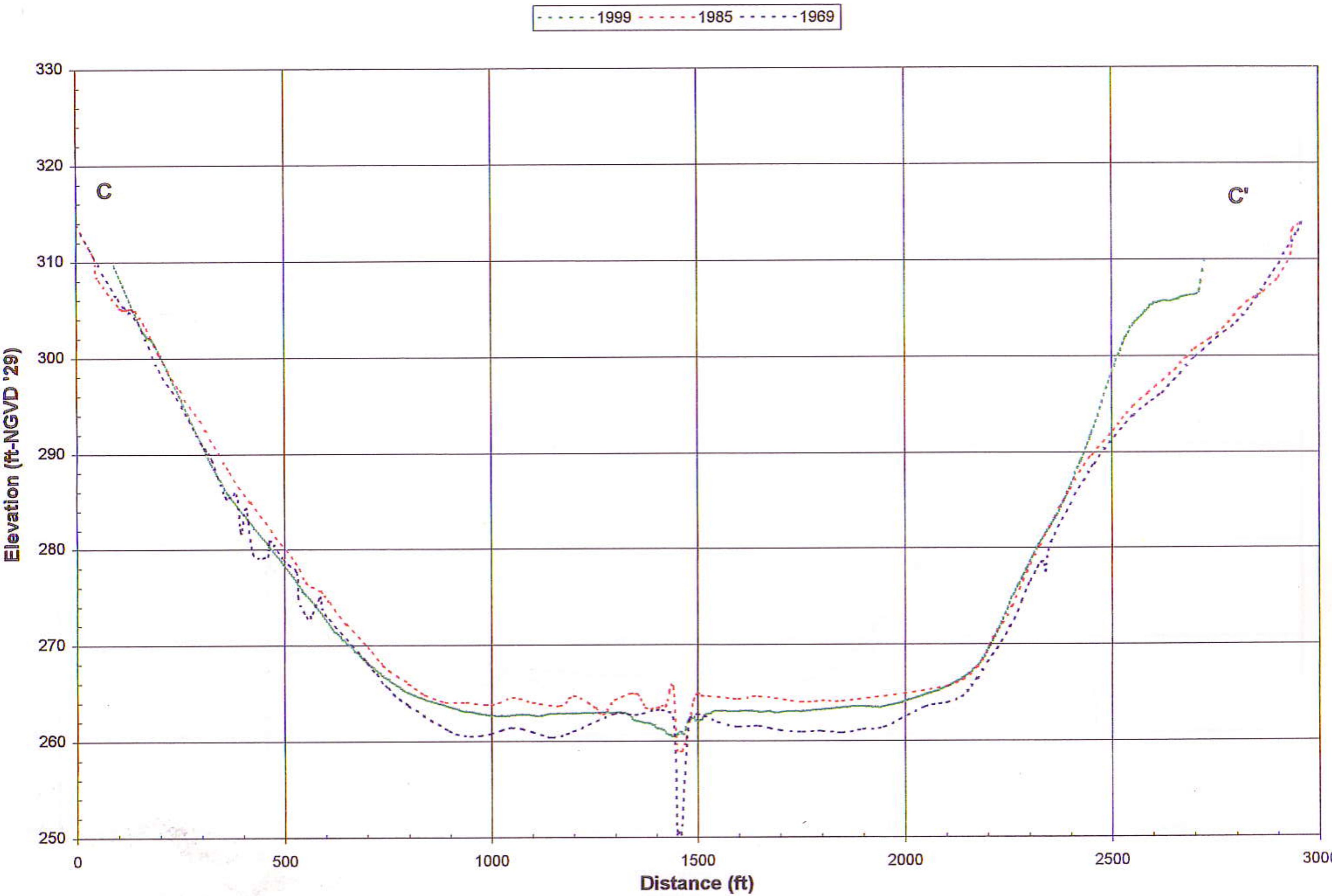
Appendix D



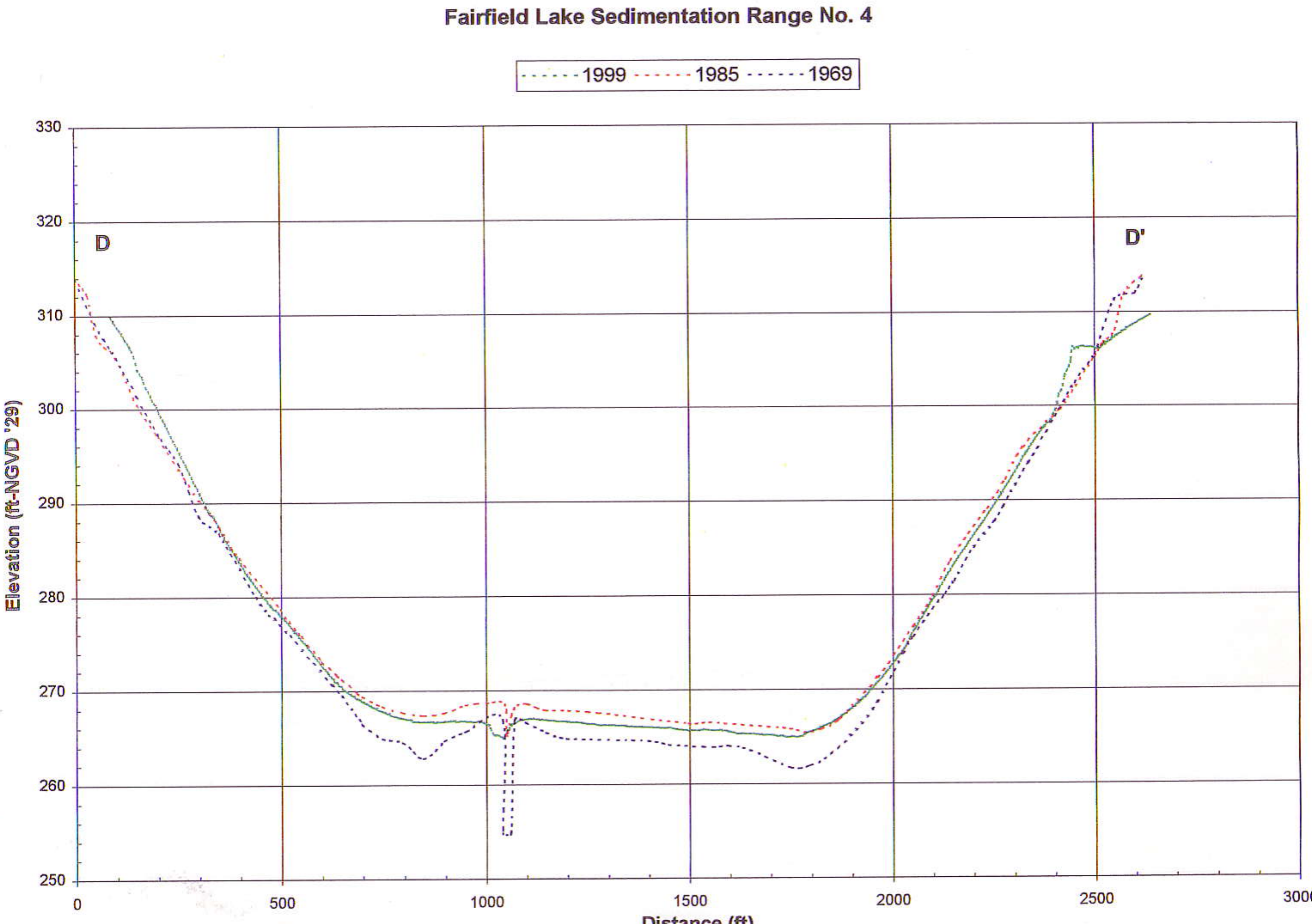
Fairfield Lake Sedimentation Range No. 2
1999
1985
1969
B
B'
Elevation (ft-NGVD '29)
320
310
300
290
280
270
260
250
0
500
1000
1500
2000
2500
3000
Distance (ft)

Appendix D

Fairfield Lake Sedimentation Range No. 3



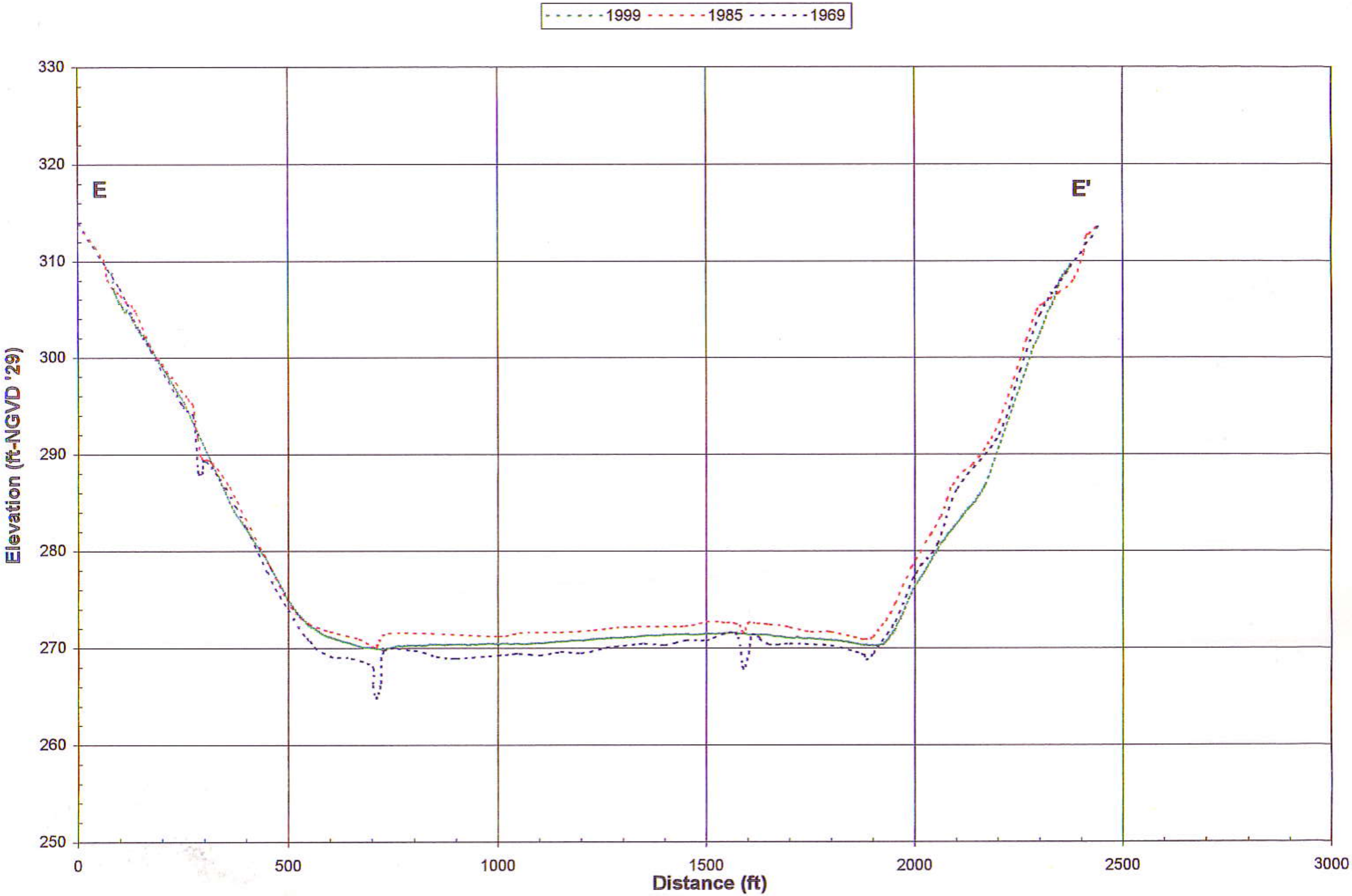
Appendix D



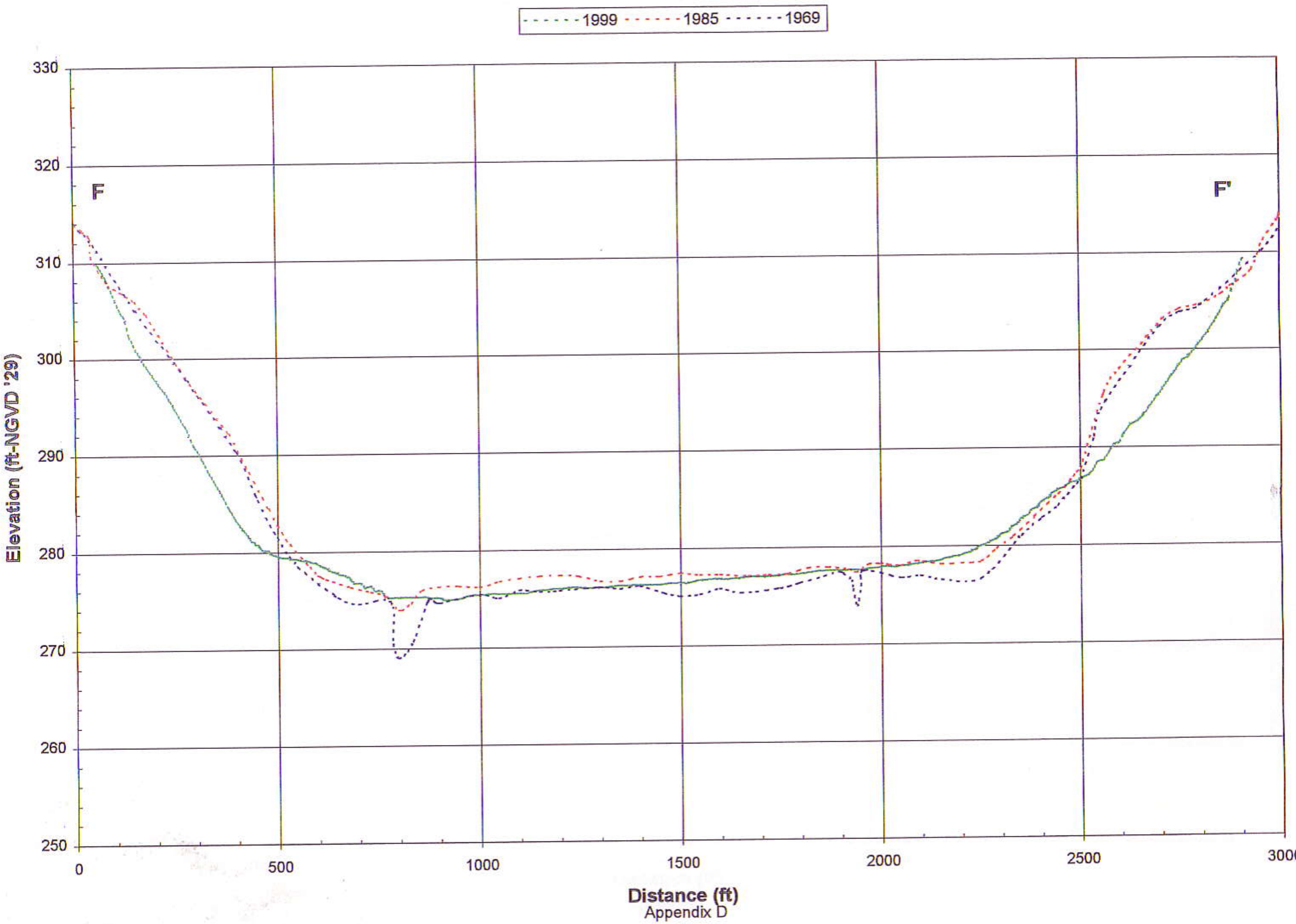
Fairfield Lake Sedimentation Range No. 4
1999
1985
1969
D
D'
Elevation (ft-NGVD '29)
330
320
310
300
290
280
270
260
250
0
500
1000
1500
2000
2500
3000
Distance (ft)

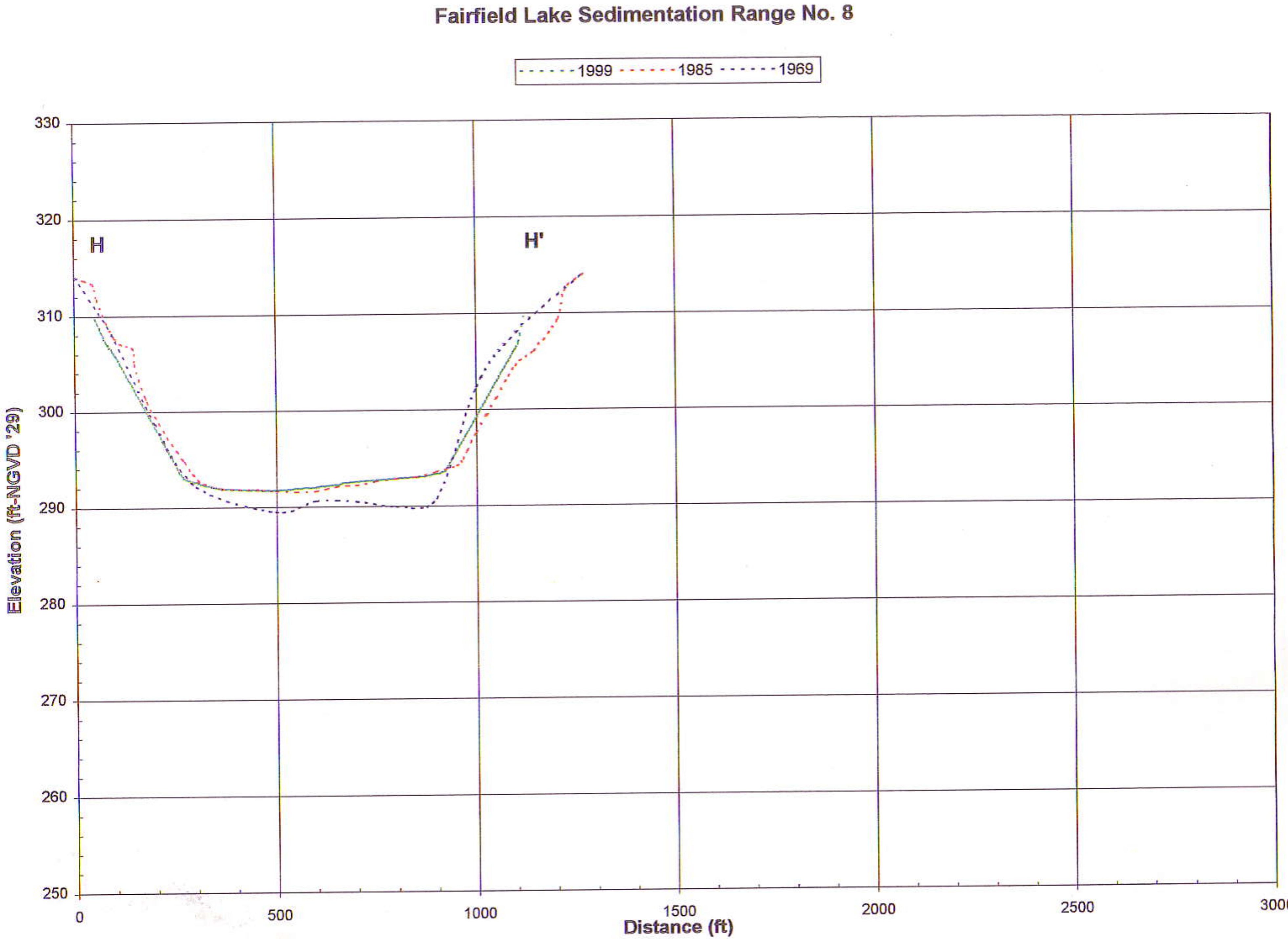
Appendix D

Fairfield Lake Sedimentation Range No. 5

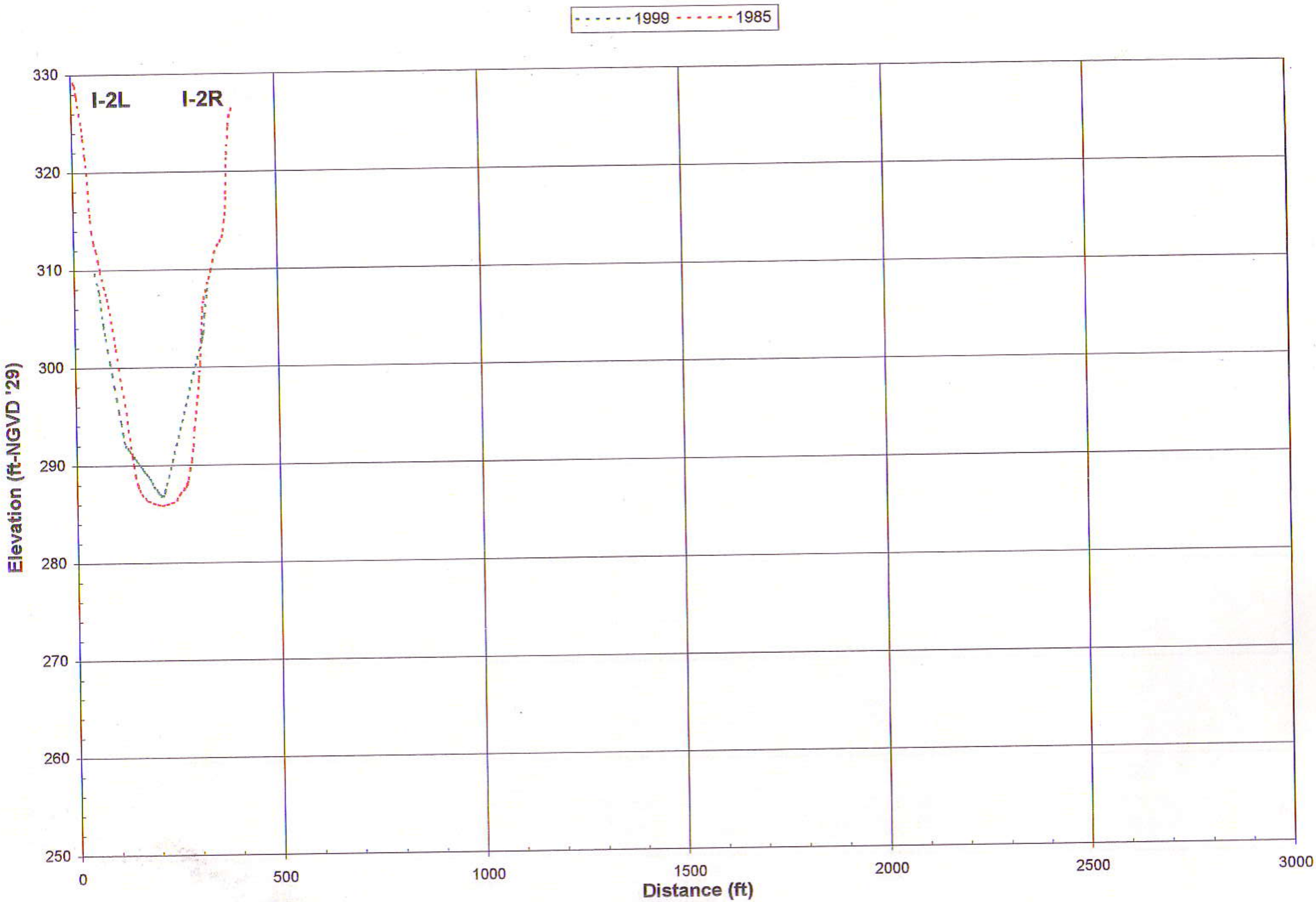


Fairfield Lake Sedimentation Range No. 6



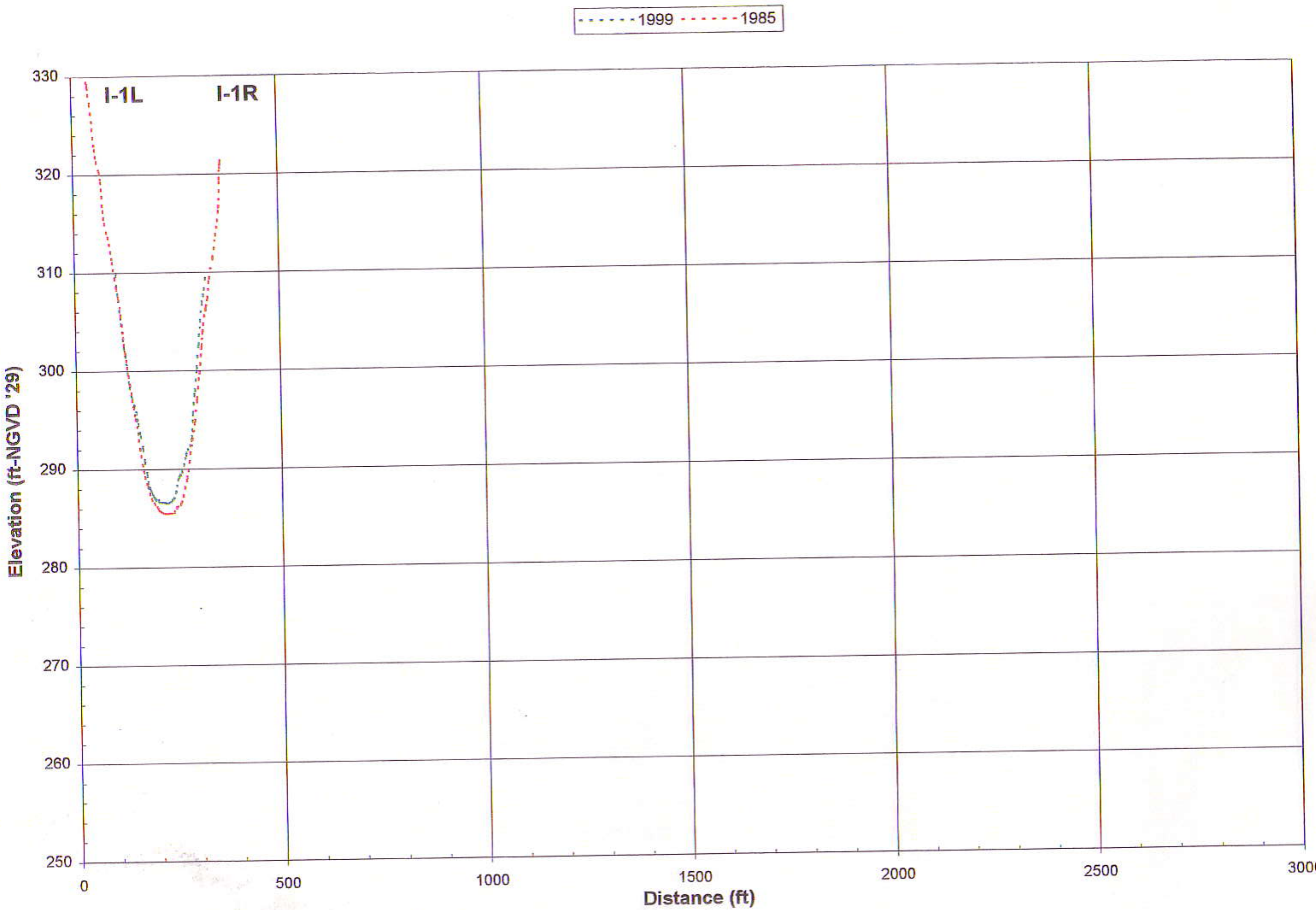

Fairfield Lake Sedimentation Range No. 8
1999
1985
1969
330
320
310
300
290
280
270
260
250
Elevation (ft-NGVD '29)
H
H'
0
500
1000
1500
2000
2500
3000
Distance (ft)
Appendix D

Fairfield Lake Sedimentation Range No. I2



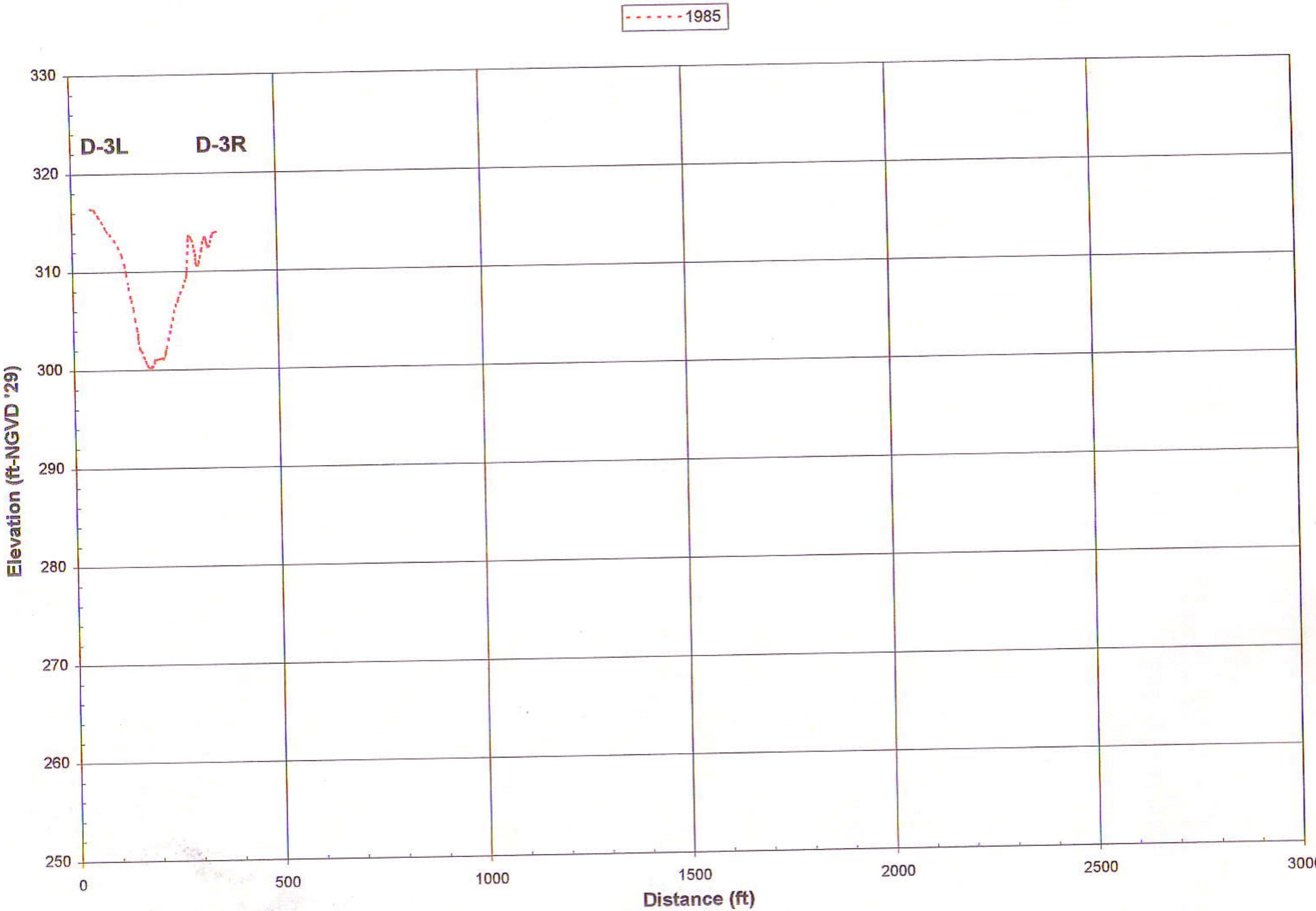
Appendix D

Lake Fairfield Sedimentation Range I-1

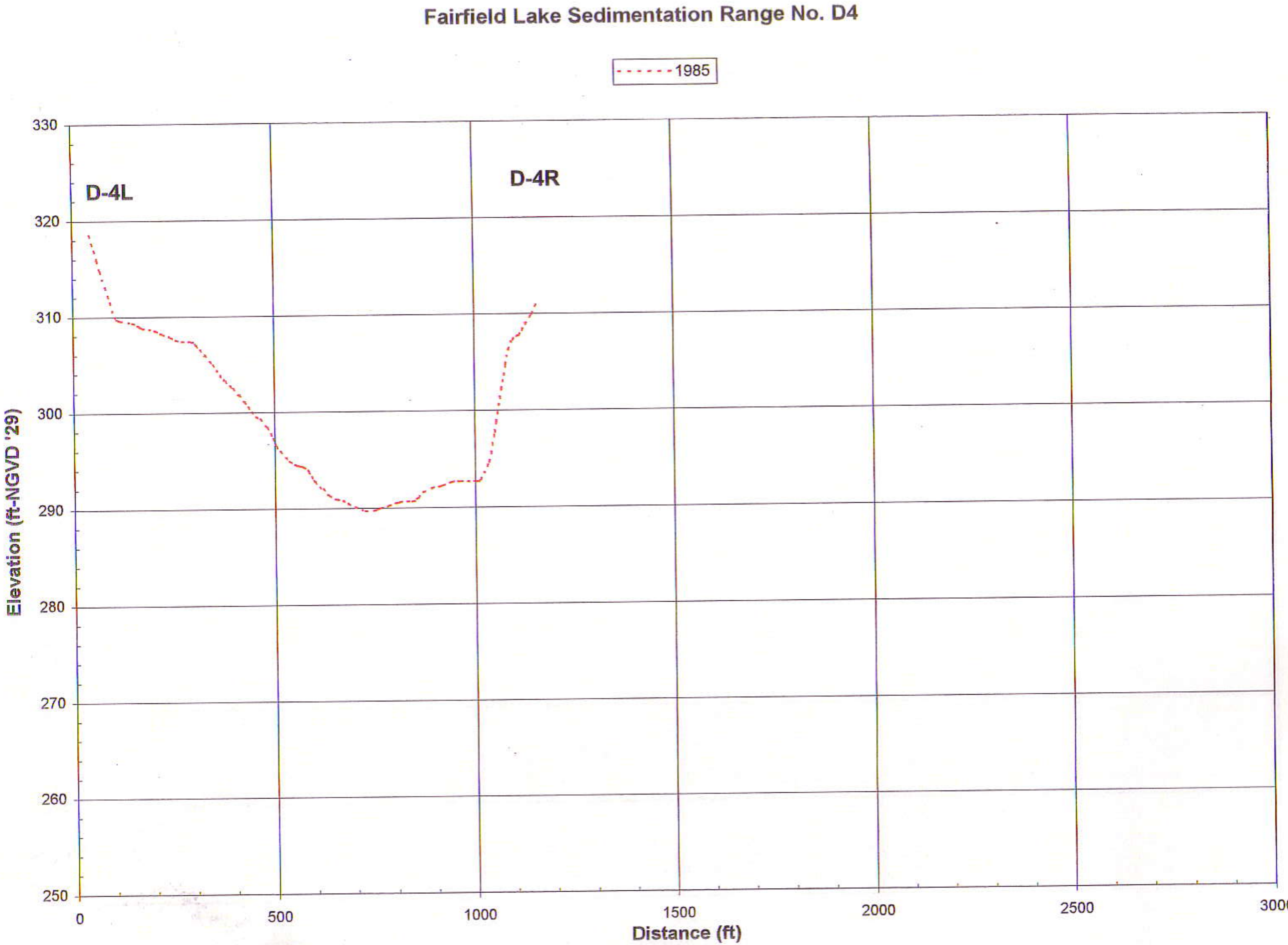


Appendix D

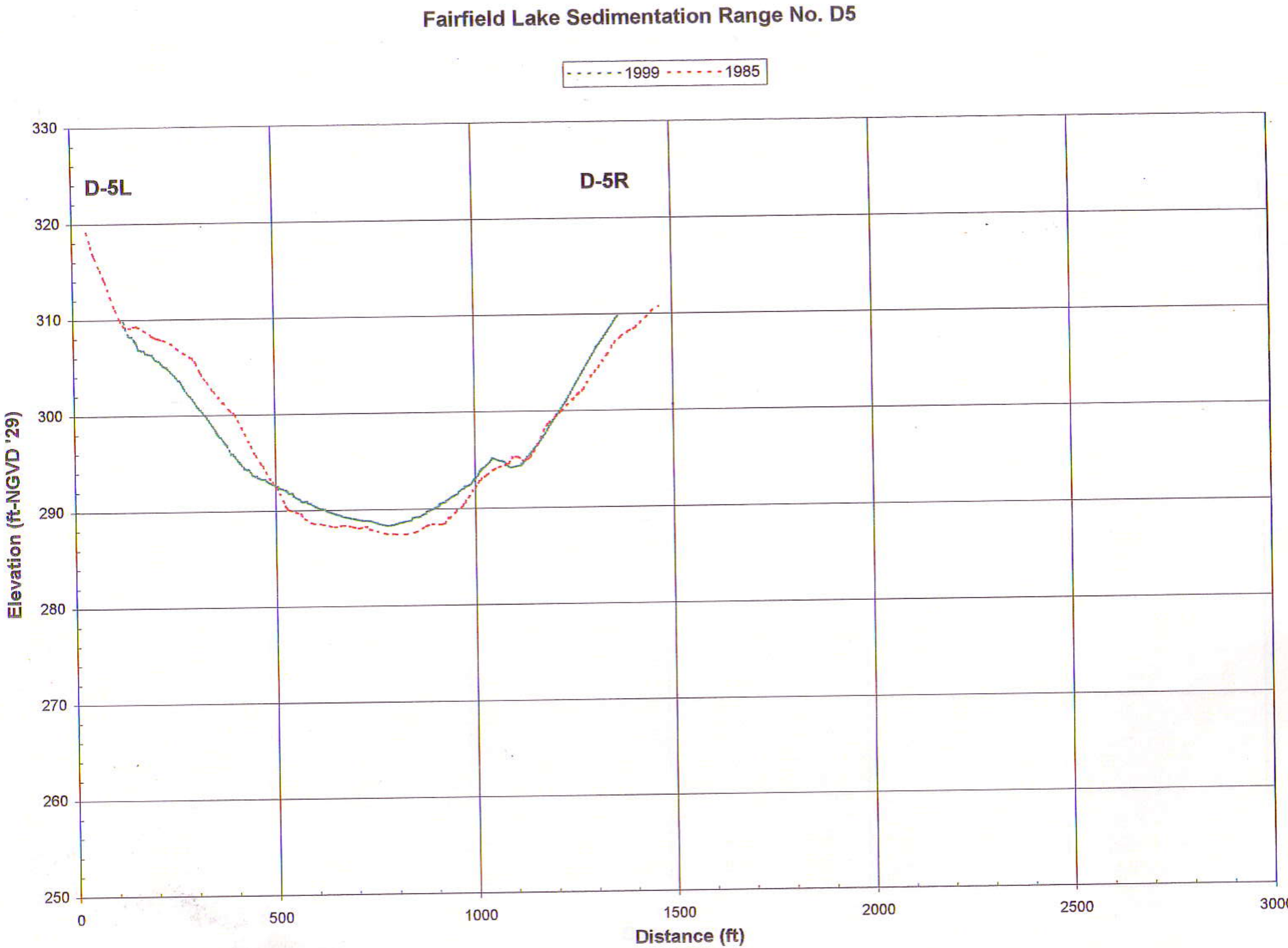
Fairfield Lake Sedimentation Range No. D3



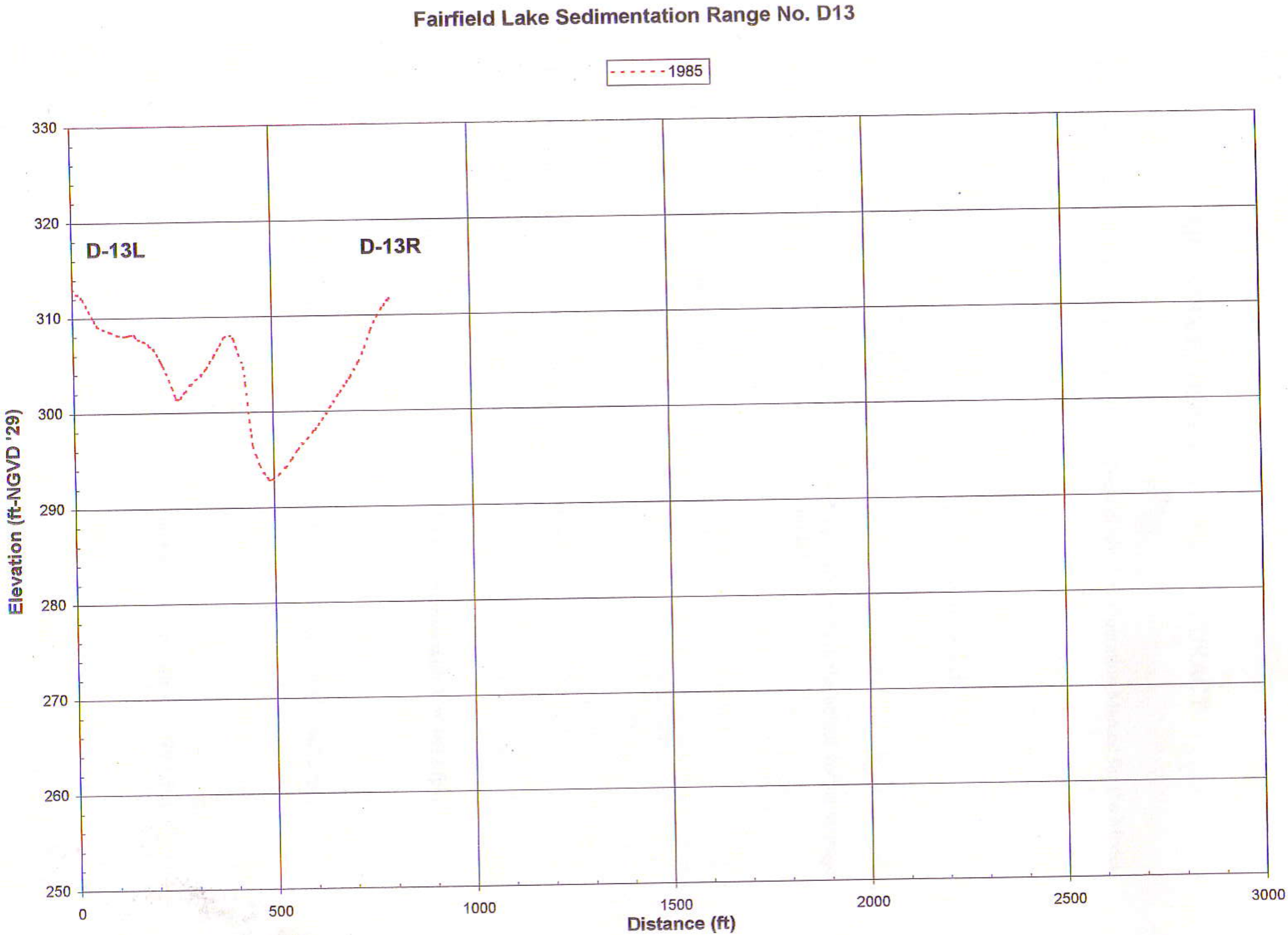
Appendix D


Fairfield Lake Sedimentation Range No. D4
1985
D-4L
D-4R
Elevation (ft-NGVD '29)
330
320
310
300
290
280
270
260
250
0
500
1000
1500
2000
2500
3000
Distance (ft)

Appendix D


Fairfield Lake Sedimentation Range No. D5
1999
1985
D-5L
D-5R
Elevation (ft-NGVD '29)
330
320
310
300
290
280
270
260
250
0
500
1000
1500
2000
2500
3000
Distance (ft)

Appendix D


Fairfield Lake Sedimentation Range No. D13
1985
D-13L
D-13R
Elevation (ft-NGVD '29)
330
320
310
300
290
280
270
260
250
0
500
1000
1500
2000
2500
3000
Distance (ft)
Appendix D

APPENDIX E - DEPTH SOUNDER ACCURACY

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

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

Where: t_D = travel time of the sound pulse, in seconds (at depth = D)
D = depth, in feet
d = draft = 1.2 feet
V = speed of sound, in feet per second

To calculate the error of a measurement based on differences in the actual versus average speed of sound, the same equation is used, in this format:

$$D = [t\ (V)]+d$$

For the water column from 2 to 30 feet: V = 4832 fps

$t_{30} = (30-1.2)/4832$
$= 0.00596$ sec.

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

$t_{45} =(45-1.2)/4808$
$=0.00911$ sec.

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

$D_{20} = [((20-1.2)/4832)(4808)]+1.2$
= 19.9' (-0.1')

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

$D_{30} = [((30-1.2)/4832)(4808)]+1.2$
= 29.9' (-0.1')

For a measurement at 50 feet (within the 2 to 60 foot column with V = 4799 fps):

$D_{50} = [((50-1.2)/4799)(4808)]+1.2$
= 50.1' (+0.1')

For the water column from 2 to 60 feet: $V = 4799$ fps Assumed $V_{80} = 4785$ fps

$t_{60} = (60-1.2)/4799$
$= 0.01225$ sec.

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

$D_{10} = [((10-1.2)/4832)(4799)]+1.2$
$= 9.9'$ $(-0.1')$

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

$D_{30} = [((30-1.2)/4832)(4799)]+1.2$
$= 29.8'$ $(-0.2')$

For a measurement at 45 feet (within the 2 to 45 foot column with V = 4808 fps):

$D_{45} = [((45-1.2)/4808)(4799)]+1.2$
$= 44.9'$ $(-0.1')$

For a measurement at 80 feet (outside the 2 to 60 foot column, assumed V = 4785 fps):

$D_{80} = [((80-1.2)/4785)(4799)]+1.2$
$= 80.2'$ $(+0.2')$

APPENDIX F - GPS BACKGROUND

GPS Information

The following is a brief and simple description of Global Positioning System (GPS) technology. GPS is a relatively new technology that uses a network of satellites, maintained in precise orbits around the earth, to determine locations on the surface of the earth. GPS receivers continuously monitor the satellite broadcasts to determine the position of the receiver. With only one satellite being monitored, the point in question could be located anywhere on a sphere surrounding the satellite with a radius of the distance measured. The observation of two satellites decreases the possible location to a finite number of points on a circle where the two spheres intersect. With a third satellite observation, the unknown location is reduced to two points where all three spheres intersect. One of these points is located in space, and is ignored, while the second is the point of interest located on earth. Although three satellite measurements can fairly accurately locate a point on the earth, the minimum number of satellites required to determine a three dimensional position within the required accuracy is four. The fourth measurement compensates for any time discrepancies between the clock on board the satellites and the clock within the GPS receiver.

The United States Air Force and the defense establishment developed GPS technology in the 1960's. After program funding in the early 1970's, the initial satellite was launched on February 22, 1978. A four-year delay in the launching program occurred after the Challenger space shuttle disaster. In 1989, the launch schedule was resumed. Full operational capability was reached on April 27, 1995 when the NAVSTAR (NAVigation System with Time And Ranging) satellite constellation was composed of 24 Block II satellites. Initial operational capability, a full constellation of 24 satellites, in a combination of Block I (prototype) and Block II satellites, was achieved December 8, 1993. The NAVSTAR satellites provide data based on the World Geodetic System (WGS '84) spherical datum. WGS '84 is essentially identical to the 1983 North American Datum (NAD '83).

The United States Department of Defense (DOD) is currently responsible for implementing and maintaining the satellite constellation. In an attempt to discourage the use of these survey units as a guidance tool by hostile forces, DOD implemented means of false signal projection called Selective Availability (S/A). Positions determined by a single receiver when S/A is active result in errors to the actual position of up to 100 meters. These errors can be reduced to centimeters by performing a static survey with two GPS receivers, of which one is set over a point with known coordinates. The errors induced by S/A are time-constant. By monitoring the movements of the satellites over time (one to three hours), the errors can be minimized during post processing of the collected data and the unknown position computed accurately.

Differential GPS (DGPS) is an advance mode of satellite surveying in which positions of moving objects can be determine in real-time or "on-the-fly." This technological breakthrough was the backbone of the development of the TWDB’s Hydrographic Survey Program. In the early stages of the program, one GPS receiver was set up over a benchmark with known coordinates established by the hydrographic survey crew. This receiver remained stationary during the survey and monitored the movements of the satellites overhead. Position corrections were determined and transmitted via a radio link once per second to another GPS receiver located on the moving boat. The boat receiver used these corrections, or differences, in combination with the satellite information it received to determine its differential location. This type of operation can provide horizontal positional accuracy within one meter. In addition, the large positional errors experienced by a single receiver when S/A is active are negated. The lake surface during the survey serves as the vertical datum for the bathymetric readings from a depth sounder. The sounder determines the lake's depth below a given horizontal location at the surface.

The need for setting up a stationary shore receiver for current surveys has been eliminated by registration with a fee-based satellite reference position network (OmniSTAR). This service works on a worldwide basis in a differential mode basically the same way as the shore station. For a given area in the world, a network of several monitoring sites (with known positions) collect GPS signals from the NAVSTAR network. GPS corrections are computed at each of these sites to correct the GPS signal received to the known coordinates of the site. The correction corresponding to each site is automatically sent to a “Network Control Center” where they are checked and repackaged for up-link to a “Geostationary” L-band satellite. The “real-time” corrections are then broadcast by the satellite to users of the system in the area covered by that satellite. The OmniSTAR receiver translates the information and supplies it to the on-board Trimble receiver for correction of the boat’s GPS positions. The accuracy of this system in a real-time mode is normally 1 meter or less.

Previous Survey Procedures

Originally, reservoir surveys were conducted by stretching a rope across the reservoir along pre-determined range lines and, from a small boat, poling the depth at selected intervals along the rope. Over time, aircraft cable replaced the rope and electronic depth sounders replaced the pole. The boat was hooked to the cable, and depths were recorded at selected intervals. This method, used mainly by the Soil Conservation Service, worked well for small reservoirs.

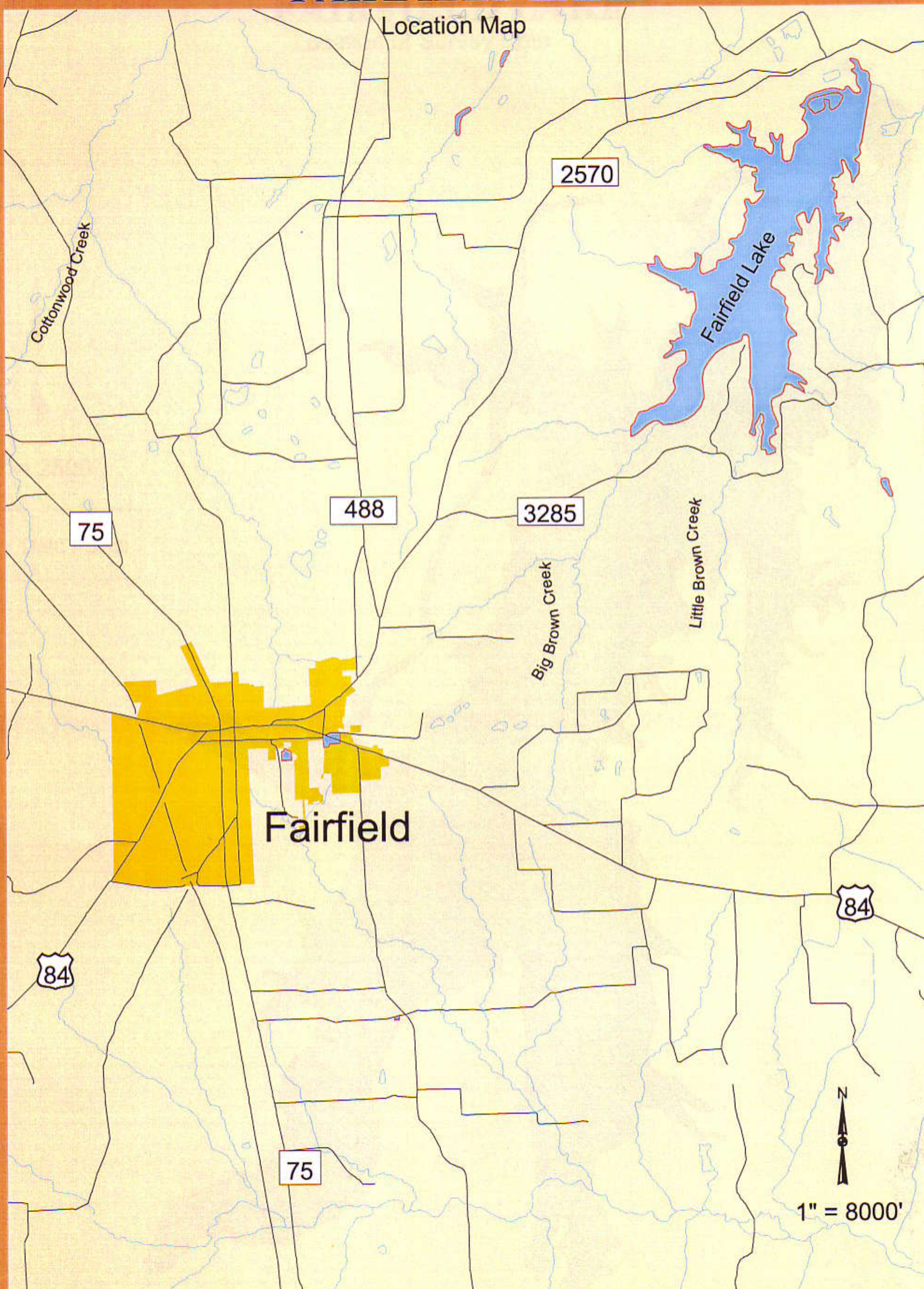
Larger bodies of water required more involved means to accomplish the survey, mainly due to increased size. Cables could not be stretched across the body of water, so surveying instruments were utilized to determine the path of the boat. Monuments were set at the end points of each line so the same lines could be used on subsequent surveys. Prior to a survey, each end point had to be located (and sometimes reestablished) in the field and vegetation cleared so that line of sight could be maintained. One surveyor monitored the path of the boat and issued commands via radio to insure that it remained on line while a second surveyor determined the horizontal location by turning angles. Since it took a major effort to determine each of the points along the line, the depth readings were spaced quite a distance apart. Another major cost was the land surveying required prior to the reservoir survey to locate the range line monuments and clear vegetation.

Electronic positioning systems were the next improvement. Continuous horizontal positioning by electronic means allowed for the continuous collection of depth soundings by boat. A set of microwave transmitters positioned around the lake at known coordinates allowed the boat to receive data and calculate its position. Line of site was required, and the configuration of the transmitters had to be such that the boat remained within the angles of 30 and 150 degrees with respect to the shore stations. The maximum range of most of these systems was about 20 miles. Each shore station had to be accurately located by survey, and the location monumented for future use. Any errors in the land surveying resulted in significant errors that were difficult to detect. Large reservoirs required multiple shore stations and a crew to move the shore stations to the next location as the survey progressed. Land surveying remained a major cost with this method.

More recently, aerial photography has been used prior to construction to generate elevation contours from which to calculate the volume of the reservoir. Fairly accurate results could be obtained, although the vertical accuracy of the aerial topography is generally one-half of the contour interval or $\pm$ five feet for a ten-foot contour interval. This method can be quite costly and is applicable only in areas that are not inundated.

FIGURE 1

FAIRFIELD LAKE

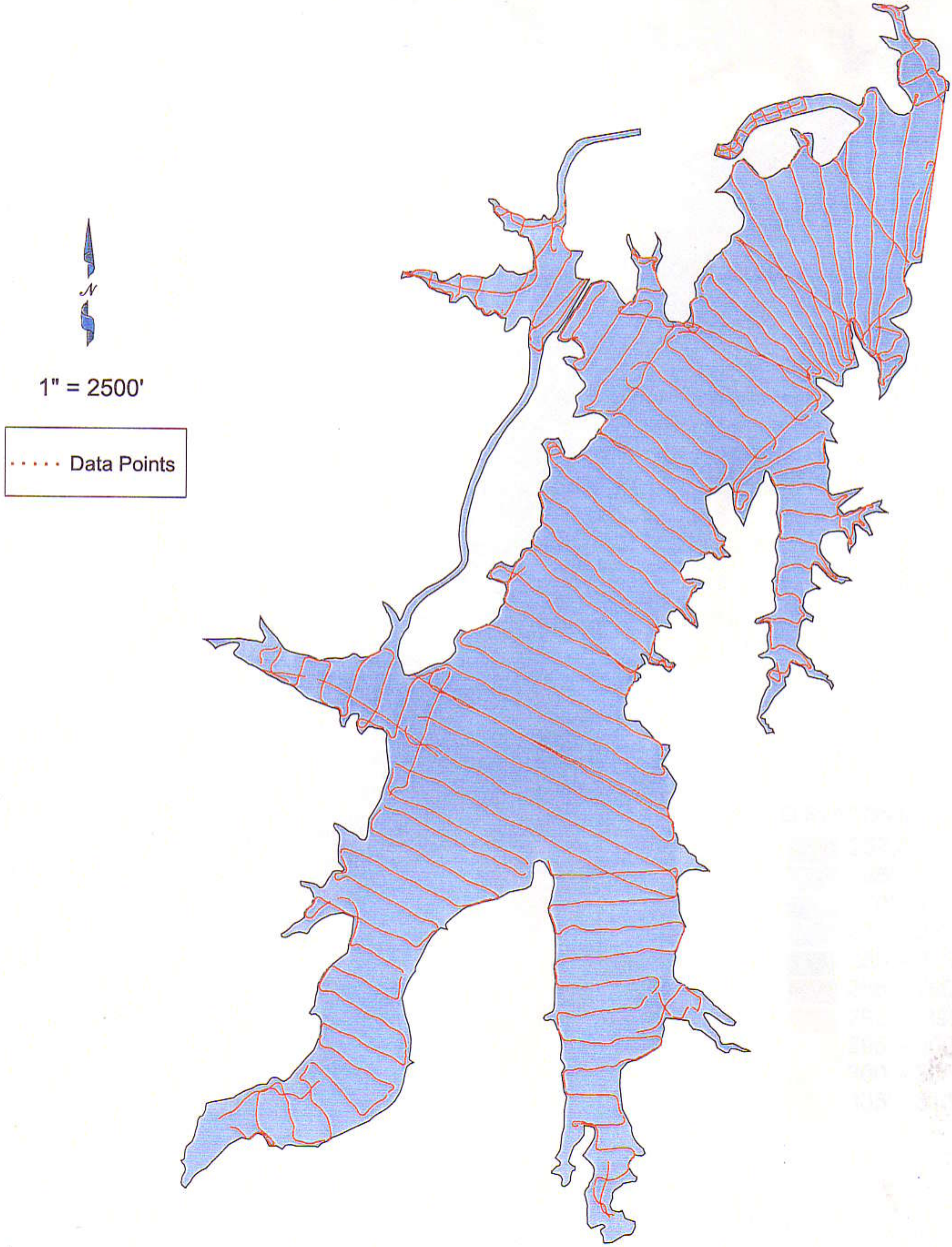


Prepared by : TWDB August 1999

Figure 2

FAIRFIELD LAKE

Location of Survey Data

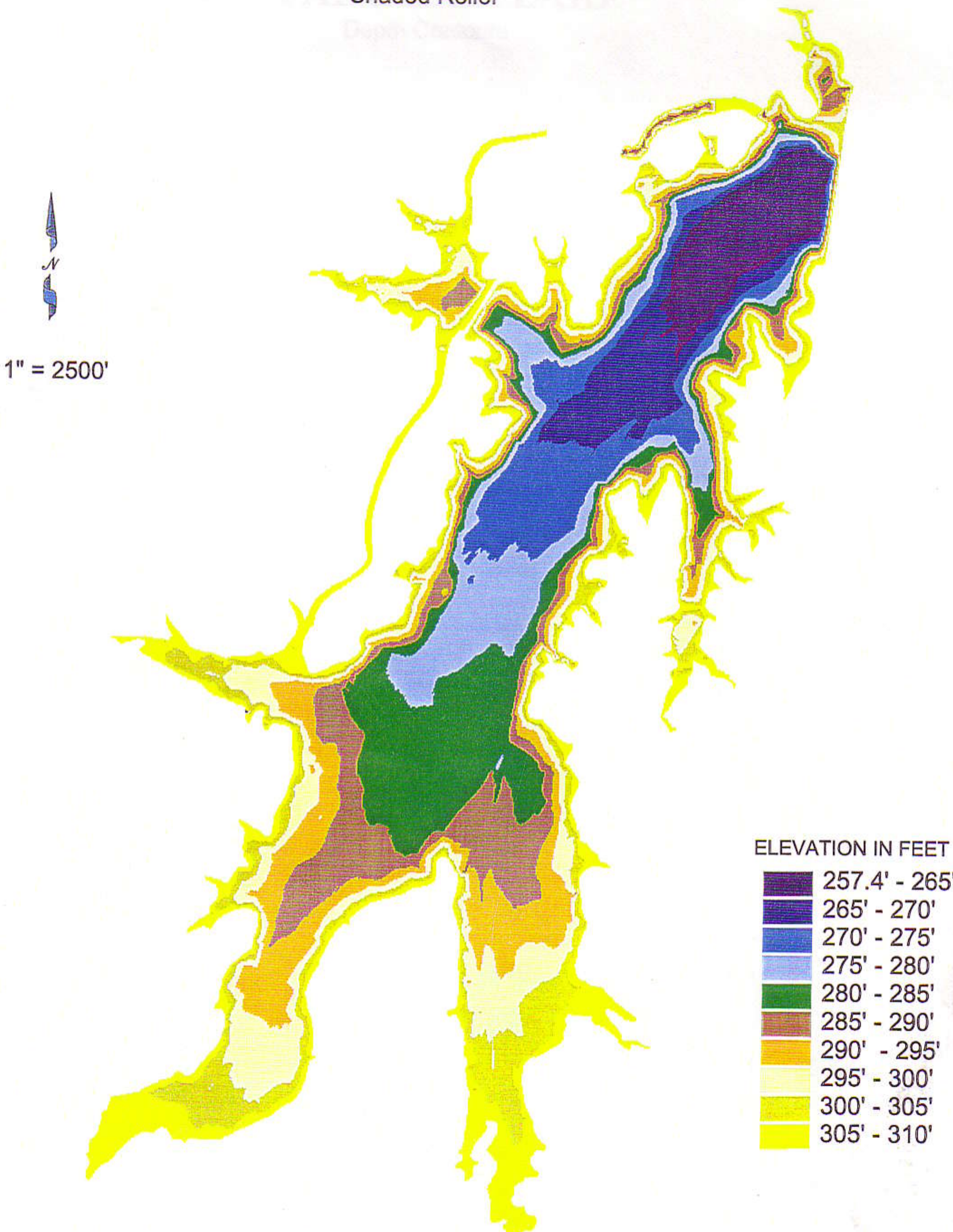


Prepared by : TWDB AUGUST 1999

Figure 3

FAIRFIELD LAKE

Shaded Relief

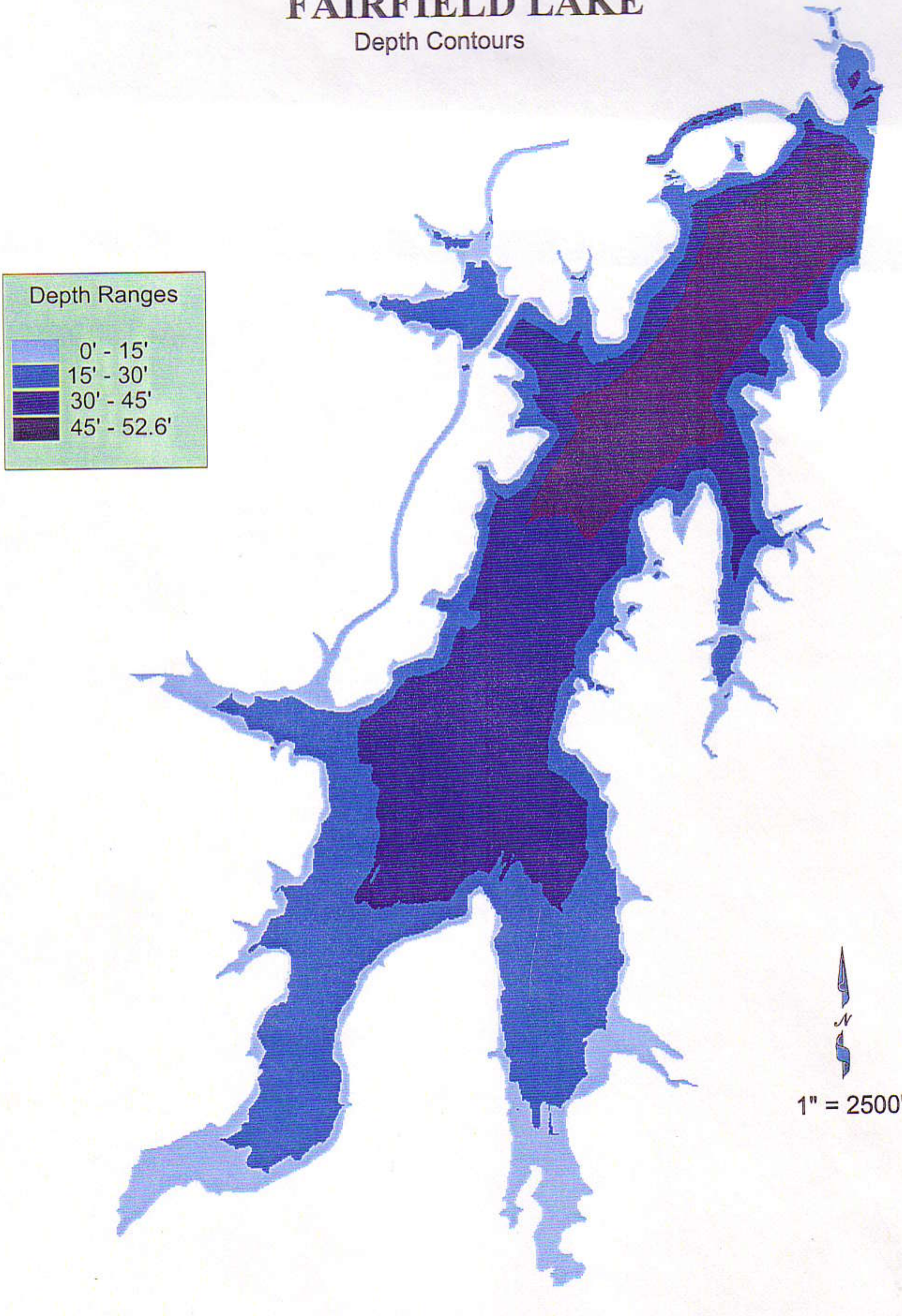


Prepared by : TWDB AUGUST 1999

Figure 4

FAIRFIELD LAKE

Depth Contours



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