VOLUMETRIC SURVEY OF LAKE STAMFORD

Prepared for:

City of Stamford

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 Lake Stamford during the period of July 20-22, 27 and August 6,7, 1999. Data collected during this survey covered only the inundated area of the lake, which at the time of the survey was significantly below normal levels. A second survey was conducted by Alamo Consultants of San Antonio to include the area of the lake from the lake surface to 6.0 feet above conservation pool elevation. The two survey data sets were then combined to produce combined volume and area tables. The primary purpose of these surveys was to determine the current volume of the lake at the conservation pool elevation. This will establish a basis for comparison to future surveys from which the location and rates of sediment deposition in the conservation pool can be determined. Survey results are presented in the following pages in both graphical and tabular form.

Historically, two datums have been used in the engineering drawings and reports for Lake Stamford. The first datum, referred to on some plans as “United States Geological Survey (USGS) above mean sea level”, is equivalent to the National Geodetic Vertical Datum of 1929 (NGVD29). The second datum, used in the past as a reference for the USGS reservoir elevation gage at Lake Stamford, USGS #08084500, Lake Stamford near Haskell, Texas, is referred to as "gage datum". Gage datum is 2.77 feet above NGVD29. To obtain NGVD elevations from gage datum, one must add 2.77 feet to the NGVD elevation. As a footnote, following the completion of this report, the USGS plans to offset their gage datum to coincide with NGVD29.

Original design drawings and the USGS 7.5-minute quadrangle maps (Lake Stamford East, TX, (1966) and Lake Stamford West, TX (1966)) used in this study use the NGVD29 datum and show the conservation pool elevation to be 1416.8 feet. USGS reservoir elevations obtained prior to and during the study and corresponding area and volume calculations for the lake in the original design, the past two sediment surveys and the current survey are based on the "gage datum". These show conservation pool elevation for Lake Stamford at 1,414.0 feet. Original design information showed the surface area to be 4,901 acres with a storage volume of 57,632 acre-feet. A 1966 sediment survey by the Soil Conservation Service (SCS) (USDA, 1966) reported the volume of Lake Stamford to be 53,927 acre-feet. The SCS repeated the survey in 1982 and found the storage volume to be 43,678 acre-feet (USDA, 1982). This report will compare the 1999 survey results with the original design and the other previous studies.

LAKE HISTORY AND GENERAL INFORMATION

Historical information on Lake Stamford was obtained from several sources (references 1-5). The City of Stamford owns the water rights to Lake Stamford. The City also owns, operates and maintains associated Stamford Dam. The lake is located on Paint Creek (Brazos River Basin) in Haskell County, 14 miles northeast of Stamford, Texas (see Figure 1). Records indicate the drainage area is approximately 360 square miles. At the conservation pool elevation, the lake has approximately 63 miles of shoreline and is 6.4 miles long. The widest point of the lake is approximately 3.2 miles and is located about 1 mile upstream of the dam.

The Board of Water Engineers issued Water Rights Permit No. 1542 (Application No. 1650) to the City of Stamford on July 10, 1950. The permit authorized the construction of a dam on Paint Creek in Haskell County and to impound 60,000 acre-feet of water. Permission was granted to use, not to exceed, annually 10,000 acre-feet of water for domestic, municipal and industrial purposes. The Texas Water Commission issued Certificate of Adjudication No. 12-4179 on April 1, 1986. The certificate basically re-enforces the impoundment and uses as stated in Permit No. 1542 and authorizes the City of Stamford to maintain an existing dam and lake on Paint Creek known as Stamford Dam and Lake Stamford and to impound not to exceed 60,000 acre-feet of water.

Records indicate the construction for Lake Stamford and Stamford Dam started July 14, 1951 and was completed in March 1953. Deliberate impoundment began in June 1953. The design engineer for the project was Freese and Nichols and the general contractor was L. & S. Contractor. The estimated cost of the dam was $289,365.00.

According to the engineering design, Stamford Dam and appurtenant structures consist of an earthfill embankment approximately 3,600 feet in length, with a maximum height of 78 feet and a crest elevation of 1,436.8 feet NGVD29. The service spillway is an excavated channel cut through limestone rock located approximately 900 feet to the left of the dam. The uncontrolled spillway crest is 100 feet in length at elevation 1,416.8 feet NGVD29. The low-flow outlet works consist of a 24-inch diameter concrete pipe that is 442 feet in length bisects the embankment approximately 500 feet south of the old Paint Creek channel. The invert elevation is 1,382.8 feet NGVD29. The control for the outlet consists of two valves each 20-inches in diameter. The emergency spillway is a natural channel located at the right end of the embankment. The country-type spillway has a crest elevation of 1,425.8 feet NGVD29.

West Texas Utilities has an electric generating power plant located at Lake Stamford. Water is pumped directly from the lake for industrial (cooling) purposes. The City of Stamford also pumps directly from the lake to a treatment facility for municipal purposes.

VOLUMETRIC SURVEYING TECHNOLOGY

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

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

PRE-SURVEY PROCEDURES

The lake's outer boundary (elevation 1416 feet NGVD29) was digitized prior to the survey with AutoCad software. The boundary file was created from the USGS 7.5-minute quadrangle map, Lake Stamford East, TX. (1966) and Lake Stamford West, TX. (1966). 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 160 survey lines along the length of the lake.

SURVEY PROCEDURES

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 Lake Stamford, the speed of sound in the water column varied from 4,923 to 4,932 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 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

Due to low water levels, data collection was divided into two surveys. TWDB was responsible for collecting data in the inundated or wet portion of the lake. Alamo Consultants of San Antonio collected data on dry land from the water's edge to elevation 1,422.8 feet NGVD, or 6.0 feet above conservation pool elevation.

TWDB staff collected data at Lake Stamford during the period of July 20 – 22, 27 & August 6 & 7, 1999. The crew was exposed to high temperatures with mild winds. The survey crew was able to collect data on approximately 113 of the 160 pre-plotted survey transects in the lake. Random data was collected along the shoreline and in those areas that were too restricted to drive the pre-plotted lines. A smaller boat (Sea Ark) with portable GPS and depth sounder equipment was used in the areas of the main lake that could not be maneuvered by the larger boat. Approximately 604,000 data points were collected over the 45 miles traveled. These points, shown in Figure 2, were stored digitally on the boat's computer in 135 data files. Data were not collected in areas with significant obstructions unless these areas represented a large amount of water.

Paint Creek flows in a southwest to northeast direction with Stamford Dam being located at the northeast end of the lake basin. TWDB staff observed the land surrounding the lake to be generally flat. Exposed limestone was observed along the shoreline in the main basin of the lake. No major bank erosion was noted. A few residential communities (or camps) were located on Horse Creek and Buffalo Creek, these creeks being the largest of the tributaries (besides Paint Creek) to Lake Stamford. The City of Stamford established a park on the southeast shoreline at the confluence of Buffalo and Paint Creeks.

While performing the survey the field crew noted on the depth sounder chart that the bathymetry or contour of the lake bottom was fairly regular in the main basin of the lake. Shallower depths were noted along the shoreline and deeper depths were observed when the boat crossed the old channel. The bathemetry of the lake bottom was similar to the topography surrounding the lake. A defined channel (thalweg) for Paint Creek was still evident in the main basin of the lake.

As the field crew collected data in the Buffalo Creek arm, navigational hazards such as submerged stumps were encountered. Data was collected in this area but at a much slower rate. Data collection was halted when depths in the upper reaches of the lake became less than one and one-half feet.

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 subsequent 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 varied from elevation 1,404.38 to 1,404.76 feet NGVD29 according to elevation data provided by the USGS elevation gage at Lake Stamford. After all corrections were applied to the raw data file, the edited file was saved with a different extension. The edited files were combined into a single X, Y, Z data file, to be used with the GIS software to develop a model of the lake's bottom surface.

The resulting data file was downloaded to a Sun Sparc 20 workstation running the UNIX operating system. Environmental System Research Institute's (ESRI) Arc/Info GIS software was used to convert the data to a MASS points file. The MASS points and the boundary file were then used to create a Digital Terrain Model (DTM) of the 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 presented in Appendix A were calculated from the TIN using Arc/Info software. Surface areas presented in Appendix B were computed using Arc/Info software below elevation 1405.0 NGVD29. Arc-Info software was also applied to the data above 1405.0 NGVD, the land survey data supplied by Alamo Consultants. However, the elevation-area curve generated by this process contained artificial "stair-steps", a common occurrence when creating a TIN model with contoured elevation data. To eliminate the artificial "stair-steps", a series of cubic splines were applied to the TIN-generated elevation-area data, resulting in a smoothed curve from which areas above elevation 1405.0 NGVD were obtained. Results for both volume and area tables are shown in one-tenth of a foot interval from elevation 1371.6 to elevation 1422.8 feet NGVD29. 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 provided in a 1982 Soil Conservation Service report (USDA, 1982), shown on the map in Figure 5, are compared to cross-sections obtained from the current survey in the plots in Appendix D.

RESULTS

Results from the 1999 TWDB survey indicate Lake Stamford encompasses 5,124 surface acres and contains a total volume of 51,573 acre-feet at the conservation pool elevation of 1416.8 feet NGVD29. Dead pool storage, the volume below the invert elevation of the low-flow outlet pipe at 1328.8 feet NGVD29, is 3 acre-feet. Thus, the conservation storage (total volume - dead storage) for Lake Stamford is 51,570 acre-feet. The shoreline at conservation pool elevation was calculated to be approximately 63 miles. The deepest point of the lake, at elevation 1371.5 feet and corresponding to a depth of 45.3 feet, was located approximately 6,070 feet upstream from the center of Stamford Dam.

SUMMARY AND COMPARISONS

Lake Stamford was initially impounded in June 1953. Storage calculations in 1950 reported the volume at conservation pool elevation 1416.8 NGVD29 feet to be 57,632 acre-feet with a surface area of

4,901 acres. A second survey in 1966 found the volume at conservation pool elevation to be 53,928 acre-feet and the area to be 4,690 acres. The last prior survey in 1982 found the conservation storage volume to be 43,678 acre-feet

During July 20-22, and August 6 and 7, 1999, staff from the Texas Water Development Board's Surface Water Section completed a volumetric survey of Lake Stamford. 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 lake'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 1416.8 feet is 51,570 acre-feet, with a corresponding area of 5,124 acres.

Comparing the findings from the original (1950) survey and the current survey, the surface area at conservation pool elevation 1416.8 feet NGVD29 increased by 209 surface acres. The reduction in volume at conservation pool elevation is 6,059 acre-feet (-10.5%) or 124 acre-feet/year (since 1950). The average annual deposition rate of sediment in the lake can be estimated at 0.3 acre-feet/square mile of drainage area. While the current survey shows a similar trend to the 1966 survey, there is a significantly larger volume reported here than in the 1982 survey. This anamoly may be the result of using different 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

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Survey, Lake Stamford, Haskell County, Texas.

3. Texas Water Development Board. 1971. Engineering Data on Dams and Lakes in Texas. Part III. Report 126.

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5. United States Geological Survey. 1997. Water Resources Data Texas. Volume 3.

APPENDIX A - VOLUME TABLE

Appendix A

Lake Stamford

RESERVOIR VOLUME TABLE

TEXAS WATER DEVELOPMENT BOARD — March 1999 SURVEY

VOLUME IN ACRE-FEET — ELEVATION INCREMENT IS ONE TENTH FOOT

ELEVATION in Feet (NGVD'29)	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
1371							0	0	0	0
1372	0	0	0	0	0	0	0	0	0	0
1373	0	0	0	0	0	0	0	0	0	0
1374	0	0	0	0	0	0	0	0	0	0
1375	0	0	0	0	0	0	0	0	0	0
1376	0	0	0	0	0	0	0	0	0	0
1377	0	0	0	0	0	0	0	1	1	1
1378	1	1	1	1	1	1	1	1	1	1
1379	1	1	1	1	1	1	1	1	1	1
1380	1	1	1	1	2	2	2	2	2	2
1381	2	2	2	2	2	2	2	2	2	2
1382	3	3	3	3	3	3	3	3	3	3
1383	4	4	4	4	5	5	6	6	7	8
1384	9	10	11	13	14	15	17	19	20	22
1385	24	26	28	30	33	35	38	41	44	47
1386	50	54	58	62	66	70	75	79	84	89
1387	94	99	104	110	115	121	127	133	139	146
1388	153	160	167	175	183	191	200	209	218	228
1389	238	248	259	270	282	294	306	319	332	345
1390	358	372	386	401	416	431	447	463	480	498
1391	516	535	554	575	595	617	639	661	684	708
1392	733	758	783	810	837	864	893	922	952	982
1393	1014	1046	1079	1113	1148	1184	1220	1258	1296	1335
1394	1374	1415	1456	1498	1541	1584	1628	1673	1719	1765
1395	1812	1860	1910	1960	2011	2063	2117	2172	2228	2285
1396	2344	2403	2464	2527	2590	2655	2722	2790	2859	2929
1397	3000	3073	3147	3222	3297	3374	3452	3532	3612	3693
1398	3775	3858	3942	4027	4113	4200	4288	4377	4468	4559
1399	4651	4744	4839	4935	5033	5131	5231	5332	5435	5538
1400	5643	5749	5857	5966	6076	6187	6300	6414	6529	6645
1401	6763	6882	7002	7124	7247	7371	7496	7623	7751	7880
1402	8010	8141	8274	8409	8544	8681	8820	8960	9101	9244
1403	9388	9534	9682	9831	9982	10134	10288	10443	10600	10759
1404	10920	11083	11248	11415	11584	11754	11926	12100	12276	12454
1405	12633	12815	12998	13183	13371	13559	13750	13943	14138	14335
1406	14533	14733	14934	15138	15343	15550	15759	15970	16191	16419
1407	16650	16883	17119	17357	17598	17841	18086	18334	18583	18834
1408	19087	19341	19598	19857	20117	20379	20643	20909	21178	21451
1409	21726	22002	22281	22562	22844	23128	23413	23701	23991	24282
1410	24575	24870	25167	25466	25767	26070	26376	26683	26996	27315
1411	27637	27962	28289	28620	28952	29288	29625	29966	30309	30654
1412	31001	31351	31704	32059	32417	32778	33141	33508	33881	34261
1413	34644	35030	35419	35811	36206	36603	37003	37406	37812	38220

Appendix A (continued)

Lake Stamford

RESERVOIR VOLUME TABLE

TEXAS WATER DEVELOPMENT BOARD March 1999 SURVEY

VOLUME IN ACRE-FEET ELEVATION INCREMENT IS ONE TENTH FOOT

ELEVATION in Feet (NGVD'29)	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
1414	38631	39045	39462	39882	40305	40731	41160	41593	42032	42479
1415	42929	43383	43840	44301	44764	45230	45700	46172	46648	47126
1416	47608	48093	48580	49071	49565	50062	50561	51064	51573	52091
1417	52612	53137	53665	54196	54730	55267	55807	56350	56897	57445
1418	57997	58551	59108	59669	60233	60799	61368	61940	62519	63106
1419	63696	64290	64886	65486	66088	66692	67300	67911	68525	69141
1420	69760	70381	71006	71634	72264	72897	73533	74173	74819	75474
1421	76134	76798	77464	78135	78808	79483	80162	80843	81528	82215
1422	82904	83596	84291	84989	85689	86393	87099	87808	88523	

Appendix B

Lake Stamford

RESERVOIR AREA TABLE

TEXAS WATER DEVELOPMENT BOARD March 1999 SURVEY

AREA IN ACRES ELEVATION INCREMENT IS ONE TENTH FOOT

ELEVATION in Feet (NGVD'29)	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
1371							0	0	0	0
1372	0	0	0	0	0	0	0	0	0	0
1373	0	0	0	0	0	0	0	0	0	0
1374	0	0	0	0	0	0	0	0	0	0
1375	0	0	0	0	0	0	0	0	0	0
1376	0	0	0	0	0	0	0	0	0	0
1377	0	0	0	0	0	0	0	0	0	0
1378	0	0	0	0	0	0	0	0	0	0
1379	0	0	0	0	0	0	0	0	0	0
1380	0	0	1	1	1	1	1	1	1	1
1381	1	1	1	1	1	1	1	1	1	1
1382	1	1	1	1	1	1	1	1	1	2
1383	2	2	2	3	3	5	7	8	9	10
1384	10	11	12	13	14	15	16	17	18	19
1385	20	20	22	23	24	25	27	29	32	34
1386	35	37	39	40	42	44	45	47	48	49
1387	51	52	54	55	57	59	61	62	64	67
1388	69	72	75	78	81	84	88	92	96	99
1389	103	107	111	114	118	121	124	127	130	133
1390	136	140	144	148	152	156	162	167	173	179
1391	185	191	198	204	210	217	223	229	235	242
1392	248	254	260	266	273	279	286	294	302	311
1393	319	328	337	345	353	361	369	377	385	393
1394	401	409	416	423	430	437	444	452	460	468
1395	477	486	496	507	518	530	543	554	566	579
1396	591	603	616	630	644	658	672	685	697	708
1397	720	731	743	754	765	775	786	796	806	816
1398	826	836	846	856	866	876	886	896	906	916
1399	928	941	955	968	980	992	1005	1017	1030	1043
1400	1056	1069	1082	1095	1108	1121	1133	1145	1157	1169
1401	1182	1196	1209	1223	1236	1249	1261	1272	1284	1296
1402	1309	1322	1336	1350	1364	1377	1392	1406	1421	1436
1403	1452	1468	1484	1499	1515	1530	1546	1563	1580	1597
1404	1617	1643	1660	1678	1695	1713	1731	1749	1768	1787
1405	1811	1831	1851	1872	1893	1915	1936	1958	1980	2002
1406	2024	2047	2070	2093	2116	2139	2163	2186	2210	2234
1407	2258	2283	2307	2332	2356	2381	2406	2431	2456	2481
1408	2506	2532	2557	2583	2608	2634	2660	2685	2712	2737
1409	2761	2785	2808	2832	2855	2878	2901	2924	2946	2967
1410	2989	3010	3031	3051	3071	3091	3110	3128	3150	3174
1411	3199	3224	3250	3276	3303	3330	3358	3387	3416	3446
1412	3477	3508	3540	3573	3607	3641	3677	3713	3747	3779
1413	3812	3845	3877	3911	3944	3977	4010	4044	4078	4111

Appendix B (continued)

Lake Stamford

RESERVOIR AREA TABLE

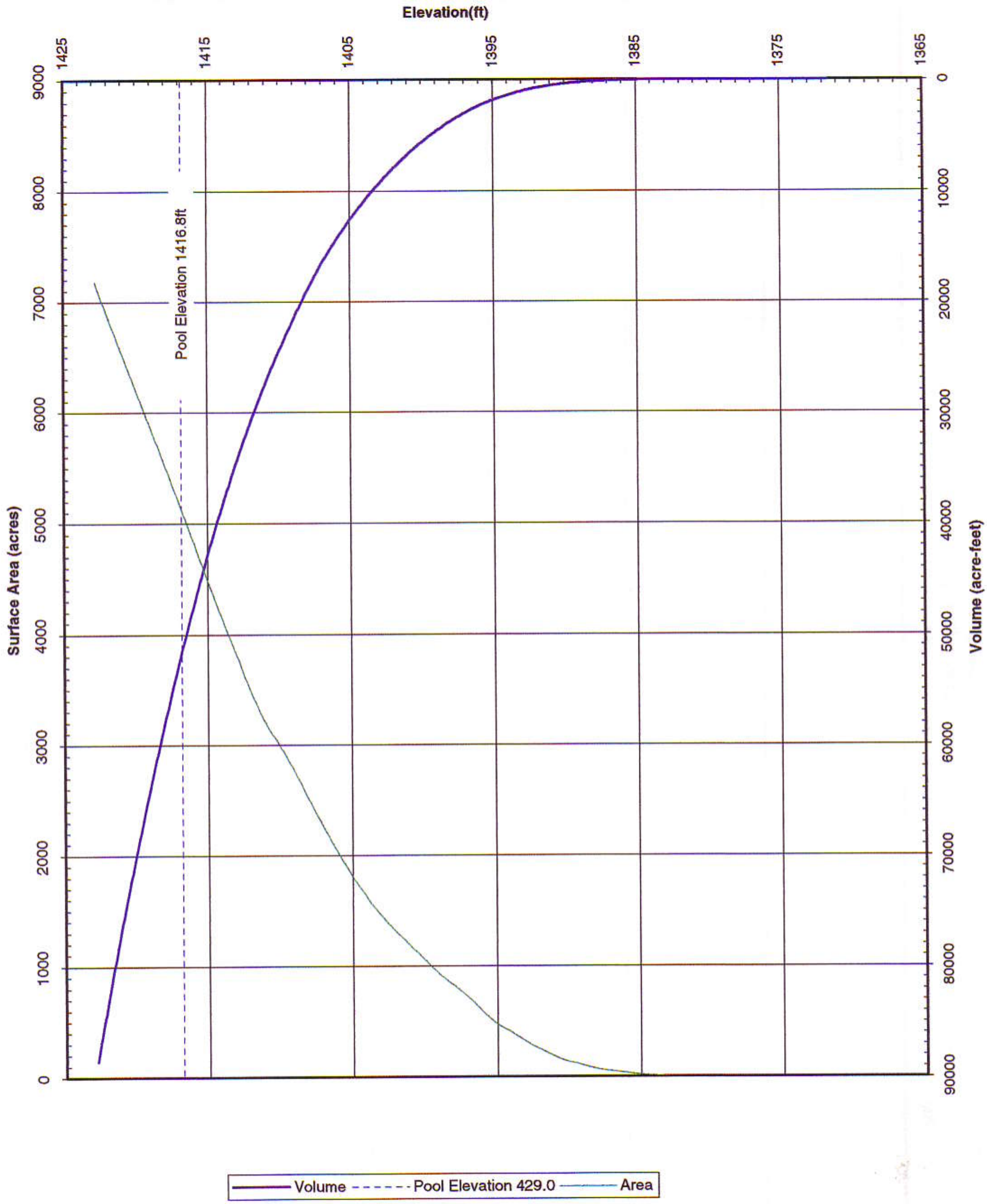
TEXAS WATER DEVELOPMENT BOARD

March 1999 SURVEY

AREA IN ACRES

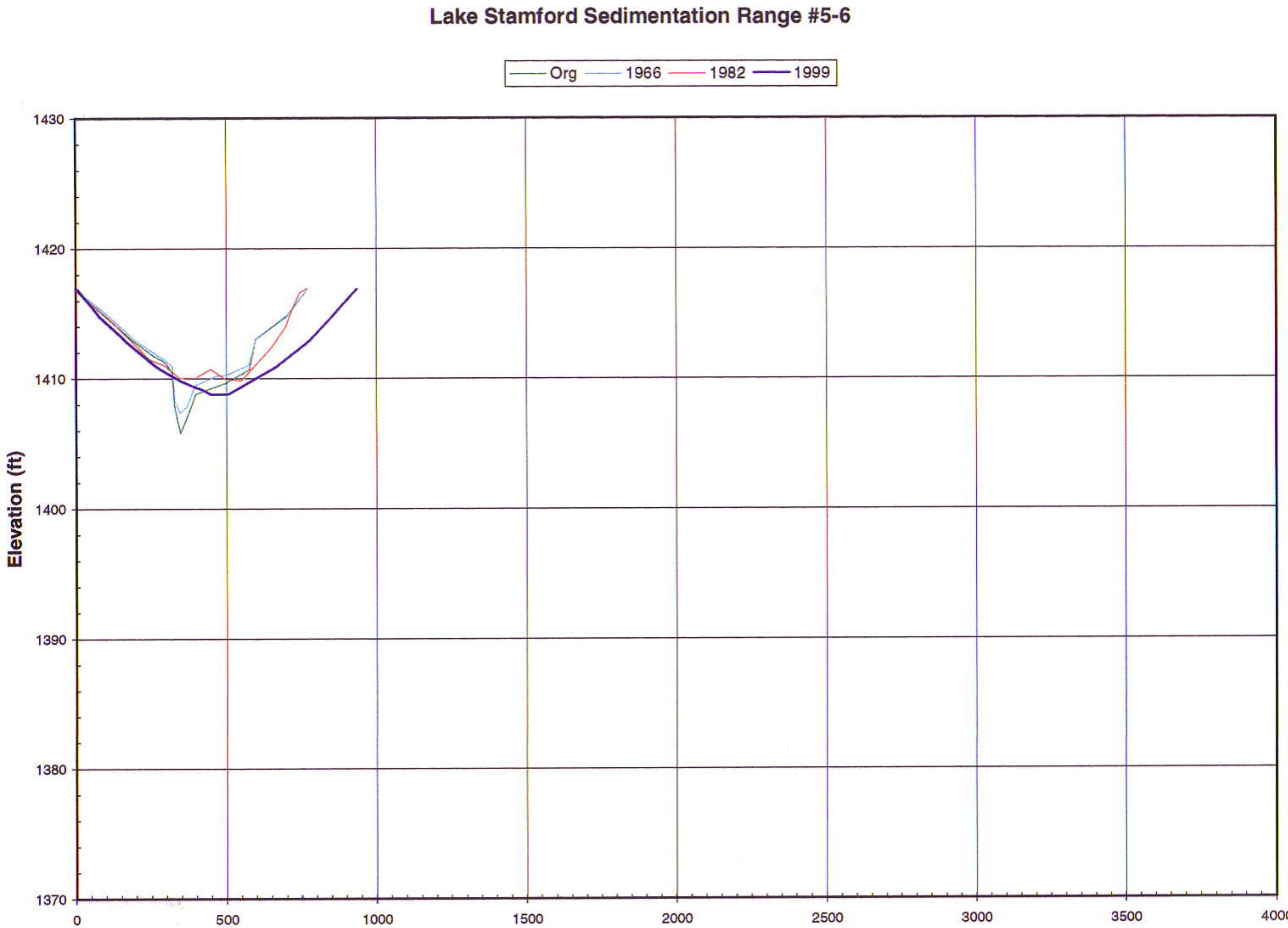
ELEVATION INCREMENT IS ONE TENTH FOOT

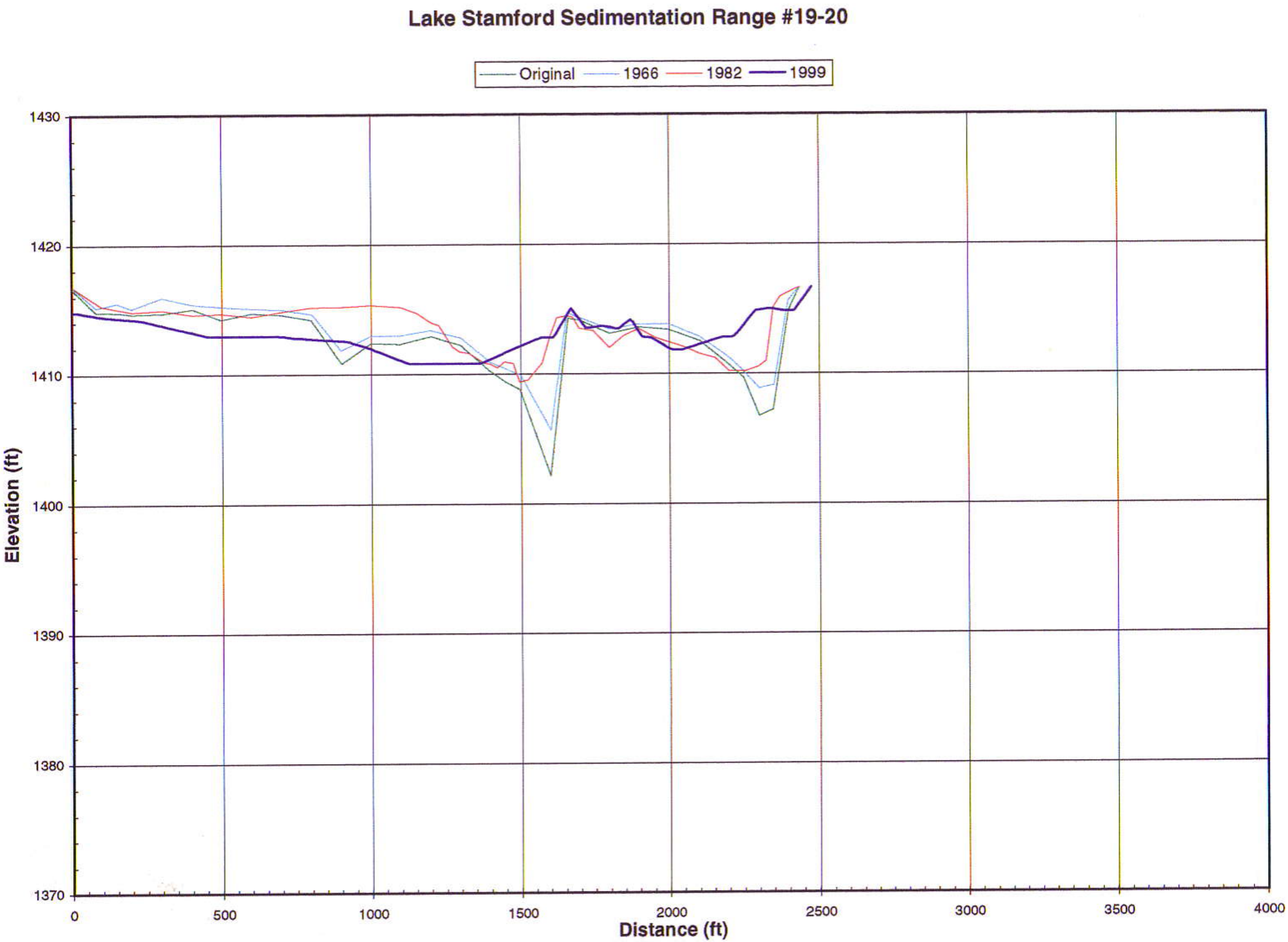
ELEVATION in Feet (NGVD'29)	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
1414	4145	4179	4213	4247	4281	4314	4348	4382	4418	4452
1415	4487	4522	4557	4592	4627	4663	4698	4733	4769	4804
1416	4840	4875	4911	4946	4982	5017	5053	5089	5124	5159
1417	5194	5229	5264	5299	5334	5369	5404	5438	5473	5507
1418	5541	5575	5609	5643	5677	5710	5743	5776	5810	5844
1419	5878	5912	5946	5980	6014	6048	6082	6116	6150	6185
1420	6219	6253	6287	6321	6355	6389	6424	6458	6492	6526
1421	6560	6595	6629	6663	6697	6732	6766	6800	6835	6869
1422	6903	6938	6972	7007	7041	7076	7111	7145	7180	



Lake Stamford
July-August 1999
Prepared by: TWDB October 1999

Appendix C

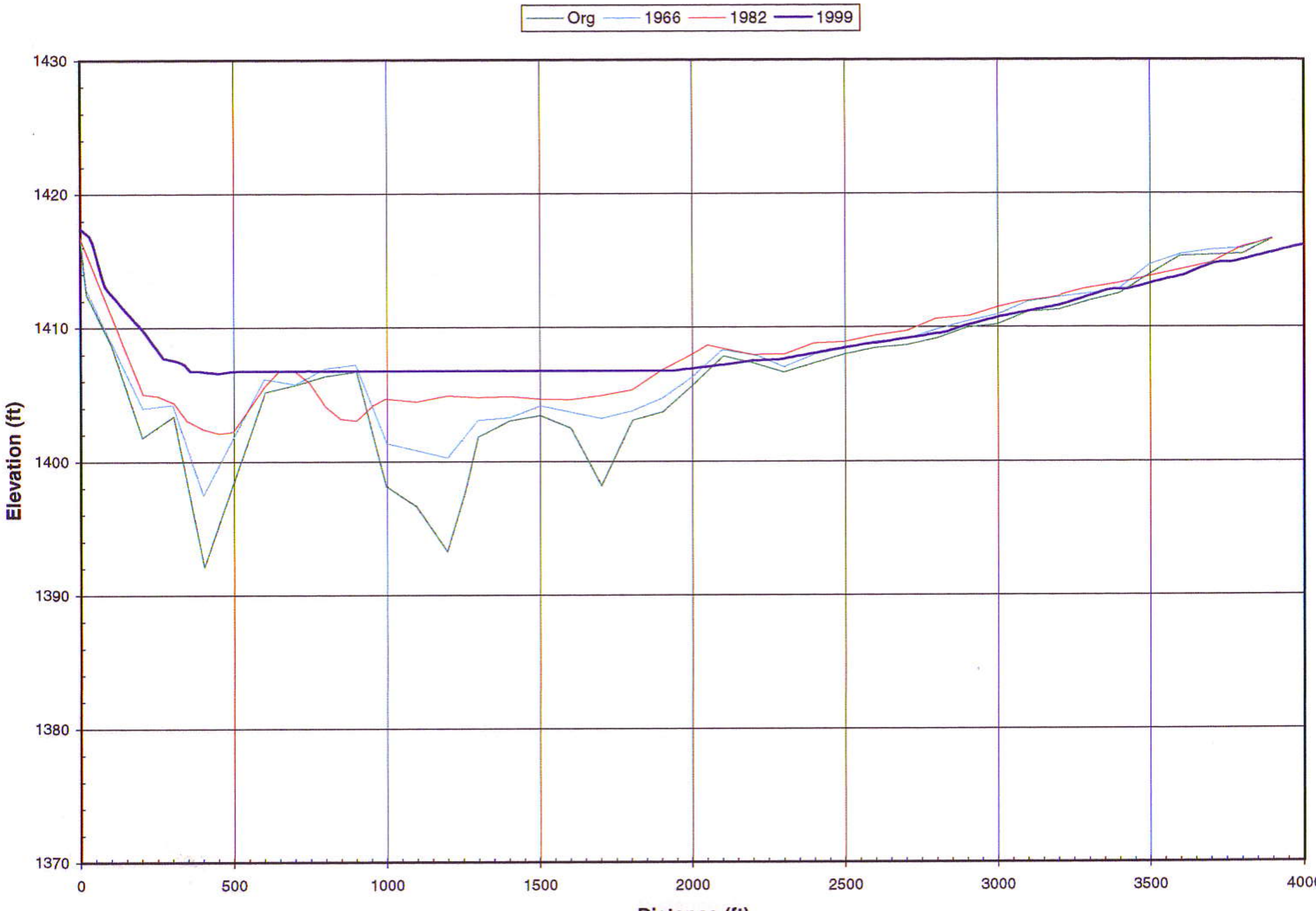

Lake Stamford Sedimentation Range #5-6
Org
1966
1982
1999
Elevation (ft)
1430
1420
1410
1400
1390
1380
1370
Distance (ft)
0
500
1000
1500
2000
2500
3000
3500
4000



Lake Stamford Sedimentation Range #19-20
Original
1966
1982
1999
1430
1420
1410
1400
1390
1380
1370
Elevation (ft)
0
500
1000
1500
2000
2500
3000
3500
4000
Distance (ft)

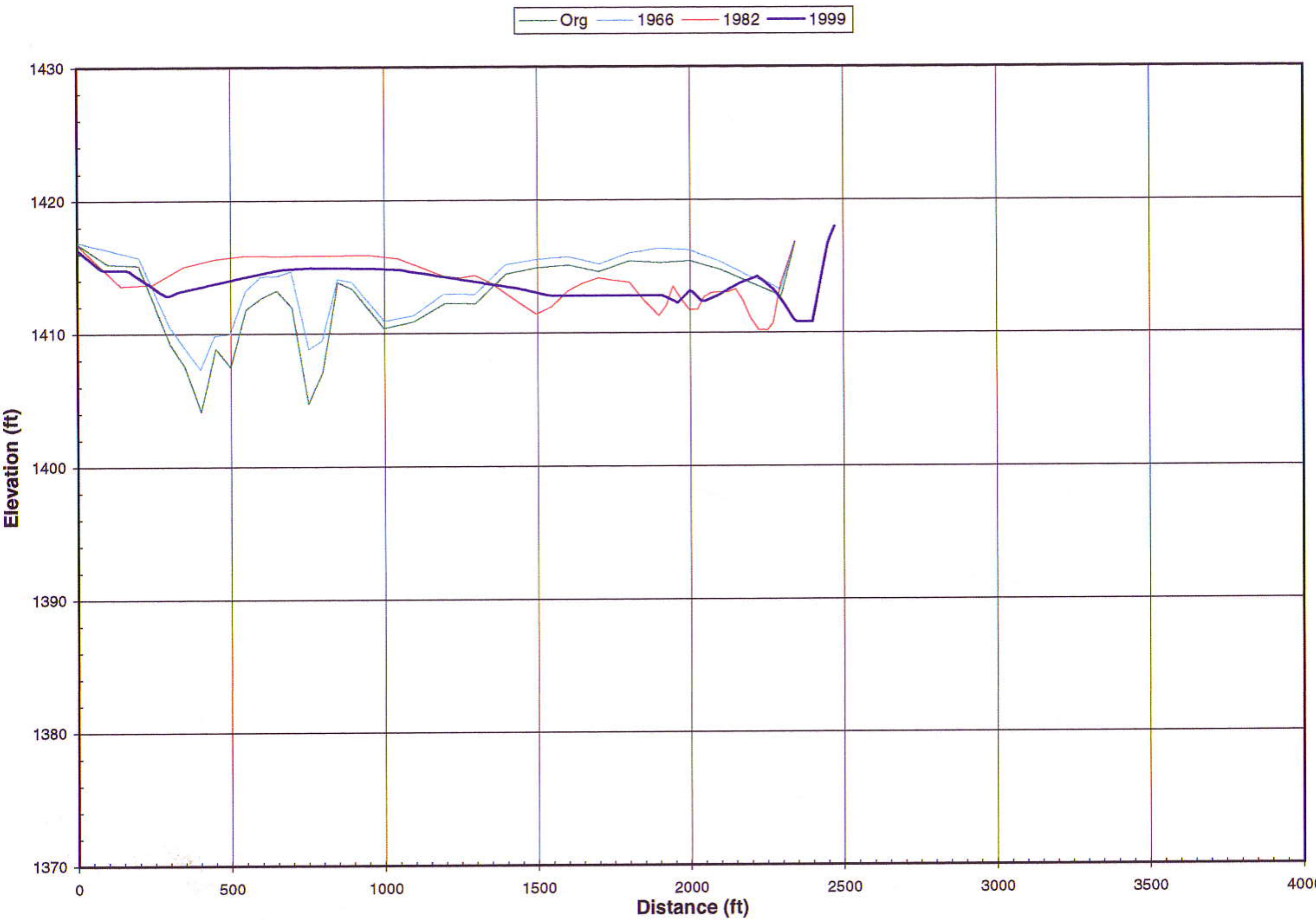
Appendix D

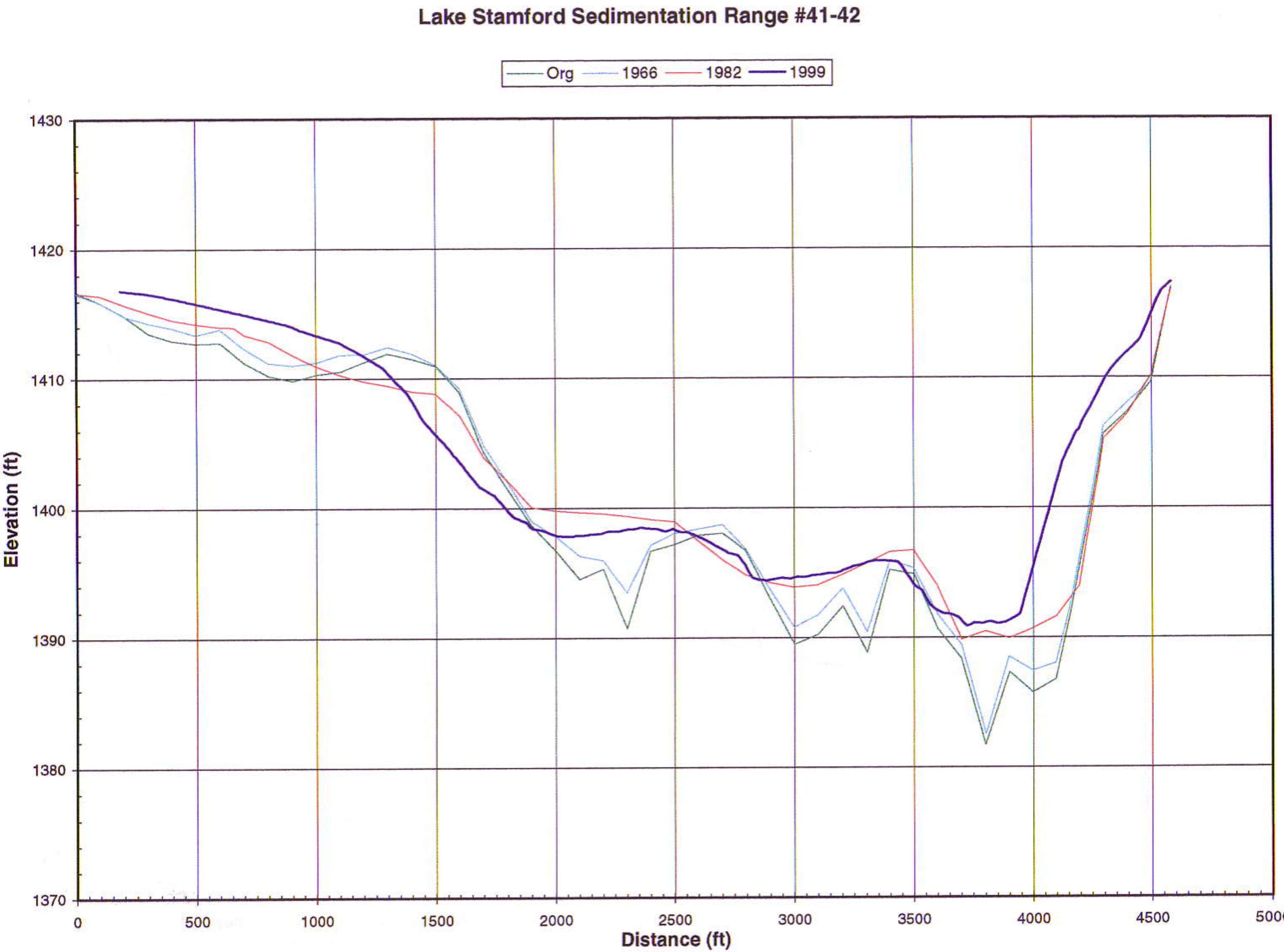
Lake Stamford Sedimentation Range #35-36



Appendix D

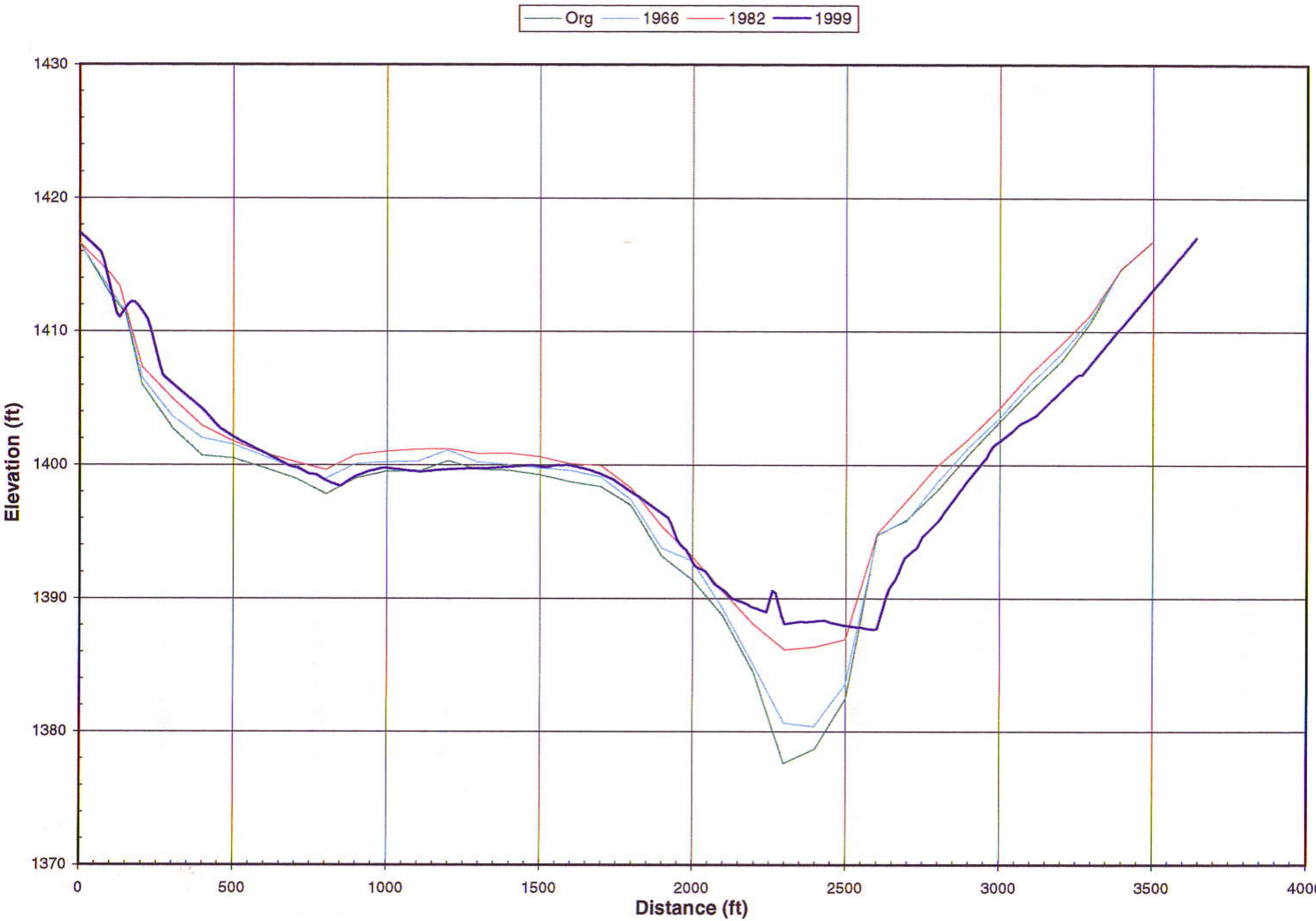
Lake Stamford Sedimentation Range #37-38




Lake Stamford Sedimentation Range #41-42
Org
1966
1982
1999
1430
1420
1410
1400
1390
1380
1370
Elevation (ft)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
Distance (ft)

Appendix D

Lake Stamford Sedimentation Range #43-44



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, lake surveys were conducted by stretching a rope across the lake 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 lakes.

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 lake survey to locate the range line monuments and clear vegetation.

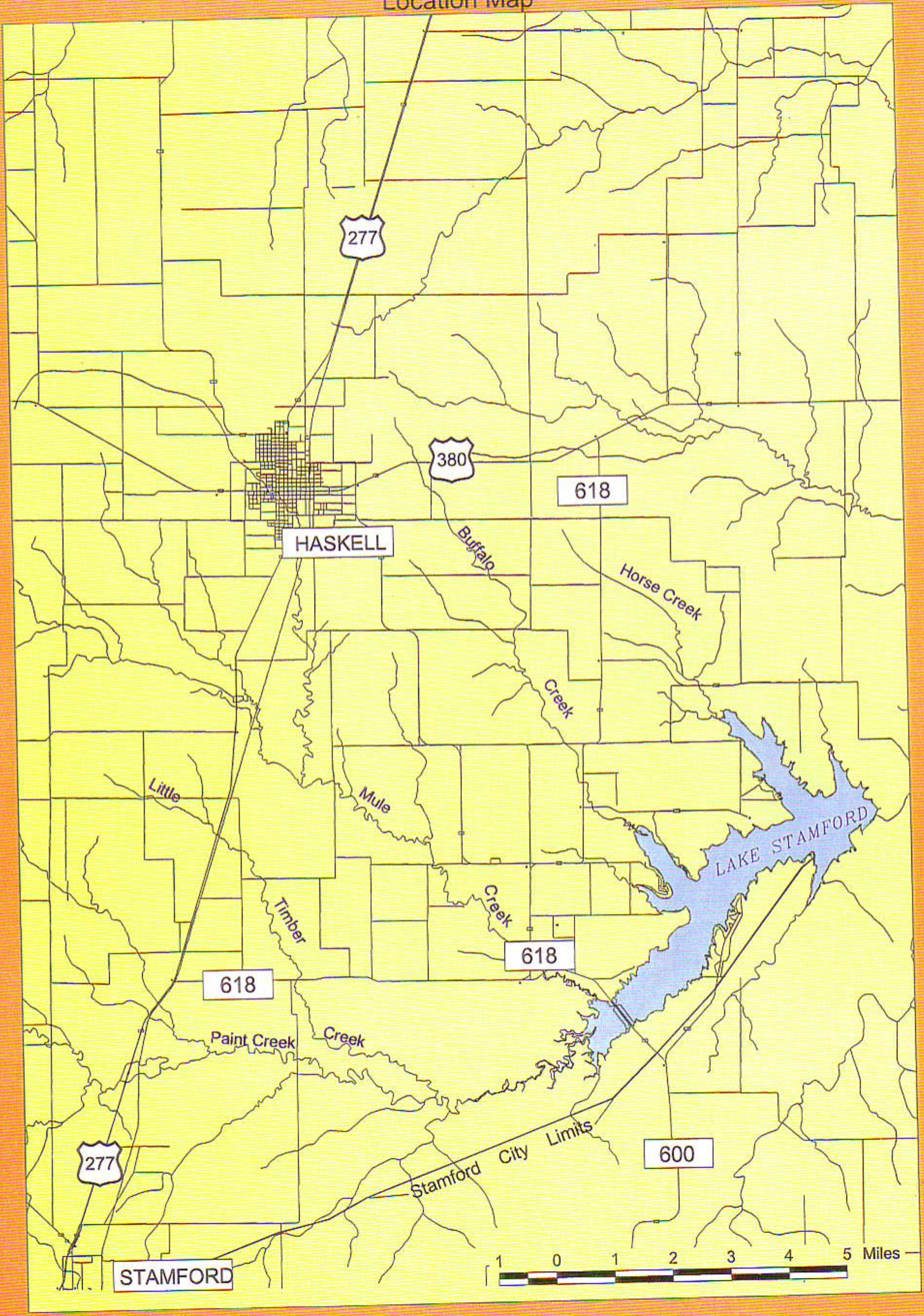
Electronic positioning systems were the next improvement. Continuous horizontal positioning by electronic means allowed for the continuous collection of depth soundings by boat. A set of microwave transmitters positioned around the lake at known coordinates allowed the boat to receive data and calculate 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 lakes 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 lake. Fairly accurate results could be obtained, although the vertical accuracy of the aerial topography is generally one-half of the contour interval or ± 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

LAKE STAMFORD

Location Map



Prepared by : TWDB DECEMBER 1999

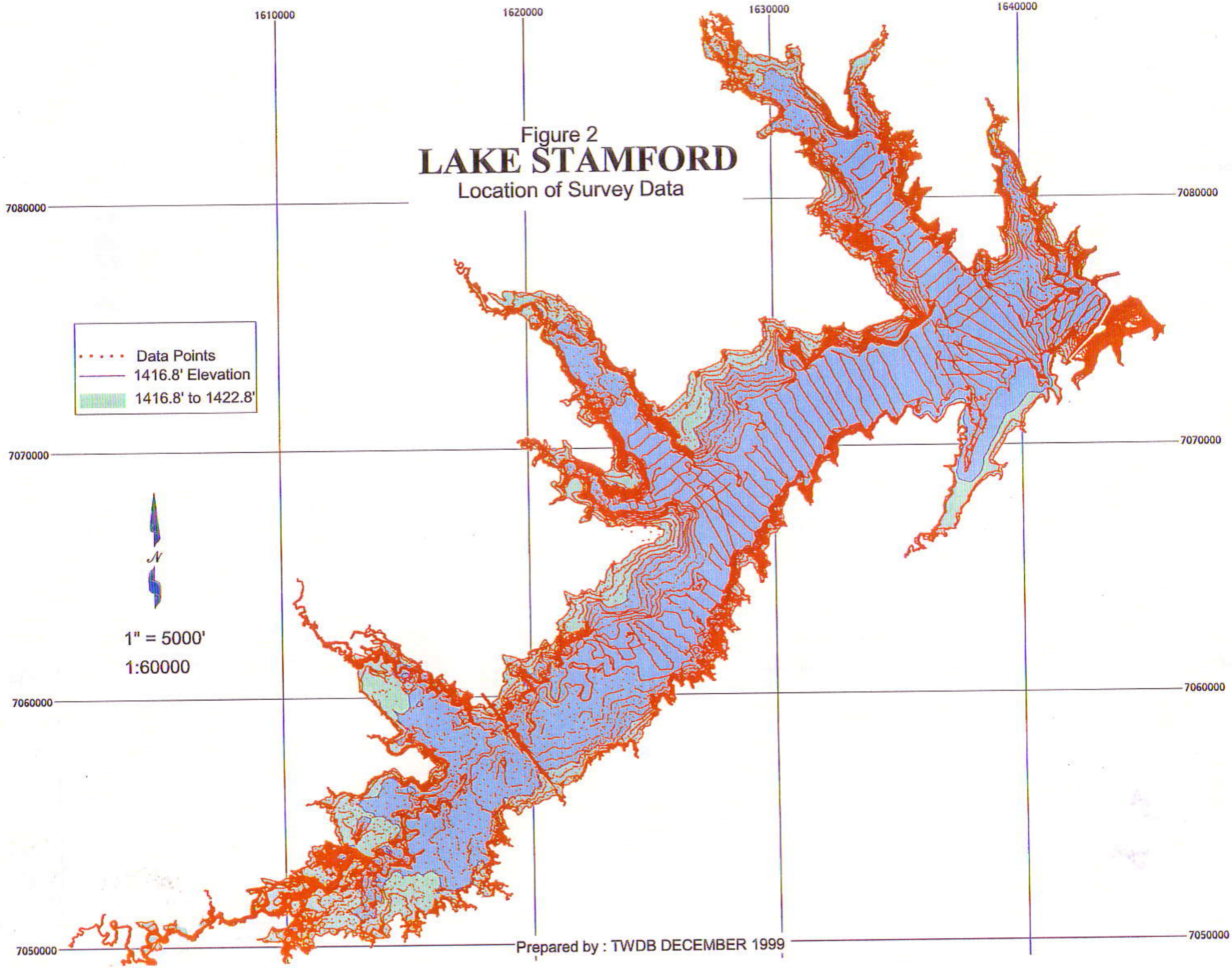
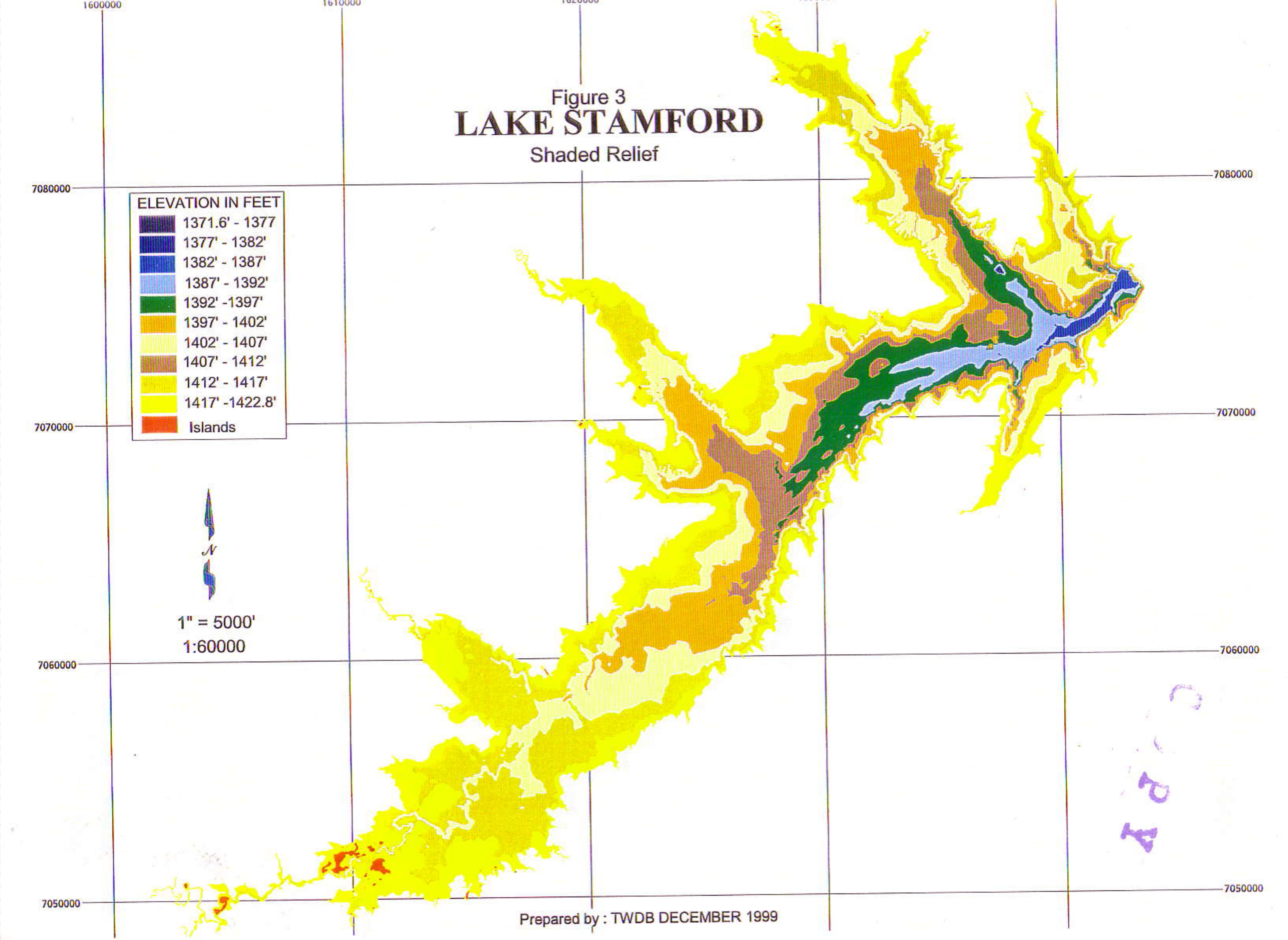


Figure 2
LAKE STAMFORD
Location of Survey Data
Data Points
1416.8' Elevation
1416.8' to 1422.8'
N
1" = 5000'
1:60000
1610000
1620000
1630000
1640000
7080000
7070000
7060000
7050000
Prepared by : TWDB DECEMBER 1999

Figure 3
LAKE STAMFORD
Shaded Relief



Prepared by : TWDB DECEMBER 1999

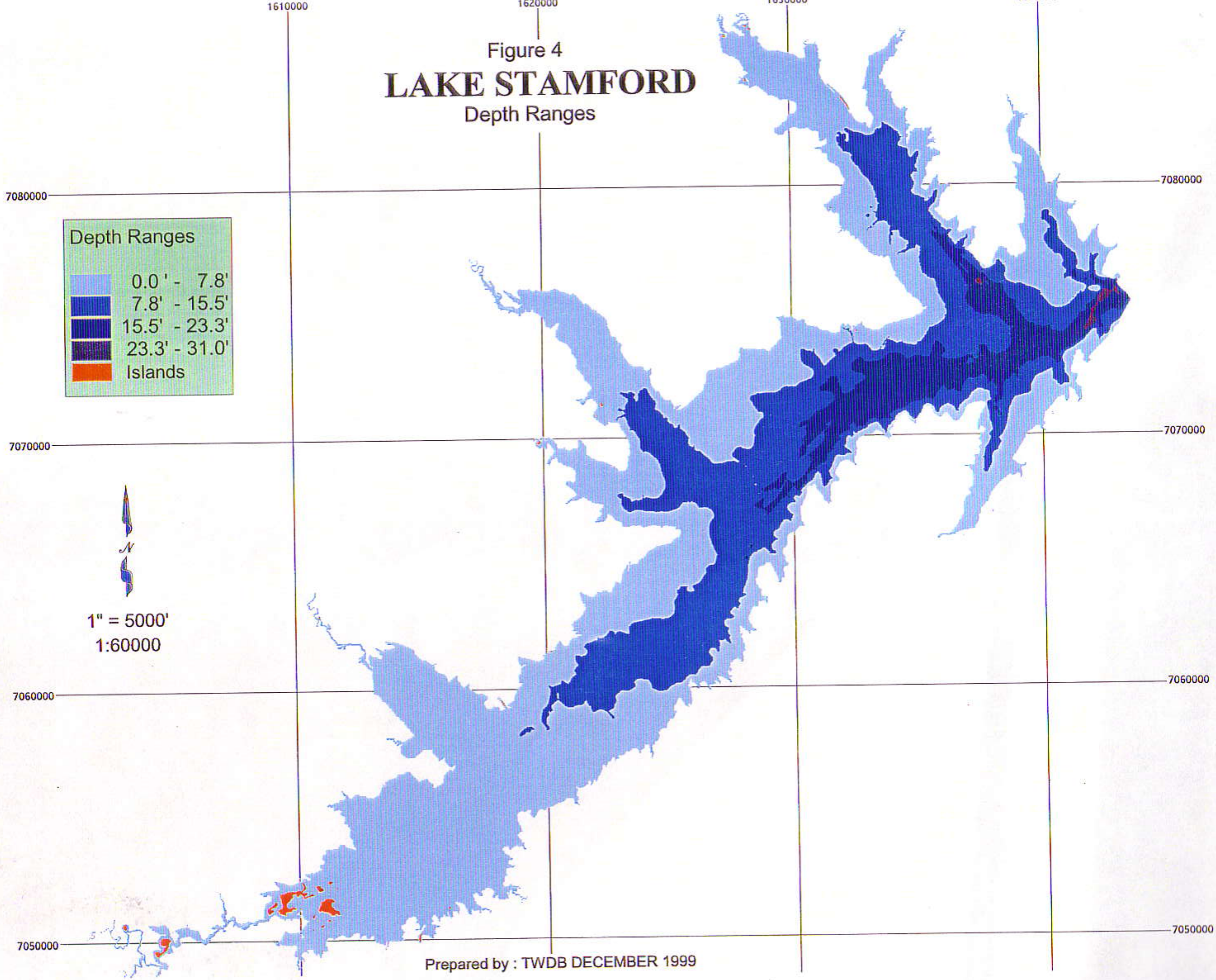


Figure 4
LAKE STAMFORD
Depth Ranges