VOLUMETRIC SURVEY OF LAKE TEXOMA

Prepared for:

U. S. Army Corps of Engineers, Tulsa District

Prepared by:

Texas Water Development Board

April 14, 2003

This report was prepared by staff of the Surface Water Section:

Barney Austin, Ph.D.

Duane Thomas
Randall Burns
Marc Sansom
Heidi Moltz

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

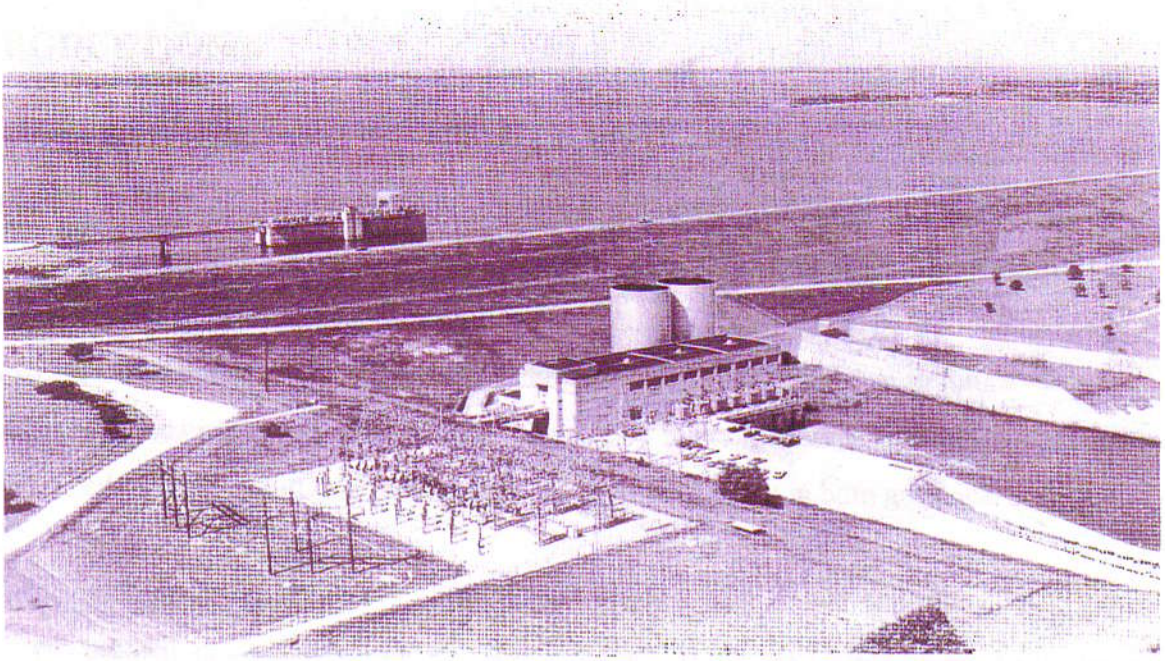
TABLE OF CONTENTS

APPENDICES

LIST OF FIGURES

LIST OF TABLES

LAKE TEXOMA and DENISON DAM



DAM AND LAKE
1966

DAM AND LAKE
1990

LAKE TEXOMA
VOLUMETRIC SURVEY REPORT

INTRODUCTION

Staff of the Surface Water Section of the Texas Water Development Board (TWDB) conducted a hydrographic survey of Lake Texoma during the period of June 3 through July 9, 2002. The purpose of the survey was to determine the current volume of the lake at the conservation pool elevation as part of a reallocation pool study conducted by the United States Army Corps of Engineers. 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.

The vertical datum used during this survey is that used by the United States Army Corps of Engineers (USACE) for the lake (Texoma) elevation gauge at Denison Dam. The official name of the gauge is "USCE 07331500 USCOE Lk Texoma nr Denison, TX". The datum for this gauge is reported as mean sea level (msl). Thus, elevations are reported here in feet (ft) above msl. Volume and area calculations in this report are referenced to water levels provided by the USACE gauge (http://www.swt-wc.usace.army.mil/ReservoirDailyReport/).

Denison Dam and Lake Texoma are located on the Red River (Red River Basin) five miles north of Denison, Texas (Figure 2). Lake Texoma is located in Texas and Oklahoma and inundates parts of Grayson and Cooke Counties, Texas and Marshall, Love, and Bryan Counties, Oklahoma. At conservation pool elevation (cpe) 617.0 ft above msl, the lake has approximately 580 miles of shoreline. Records indicate the drainage area is approximately 39,719 square miles of which 5,936 square miles is probably non-contributing (TWDB 1966).

Lake Texoma serves for flood control, water supply, hydroelectric power and recreation purposes. Benefits downstream of Lake Texoma include regulating the Red River flows and improvement in navigation.

LAKE HISTORY AND GENERAL INFORMATION

Denison Dam and appurtenant structures are owned by the U. S. Government and operated by the United States Army Corps of Engineers, Tulsa District. Authorization for the Lake Texoma Project was granted under several federal legislative acts beginning with the Flood Control Act approved June 28, 1938, Project Document HD 541, 75th Congress, 3rd Session (flood control and power). The latest federal legislation pertaining to Lake Texoma was Public Law 662, 99th Congress, 2nd Session that was approved November 17, 1986. The purpose of the legislation was to add recreation as a project purpose and authorized reallocation of additional storage for water supply (http://www.swt.usace.army.mil/projects/pertdata/laketexoma/laketexoma.htm).

The states of Texas and Oklahoma have granted authorization to individuals and entities for water rights to Lake Texoma. These individuals and entities entered into contracts with the USACE for storage in Lake Texoma. Major water rights holders in the state of Texas are as follows:

Red River Authority of Texas currently holds water rights under Certificate of Adjudication 02-4898 (Water Rights Permit No. 2969A) to impound and utilize water in Lake Texoma between elevations 590.0 ft to 617.0 ft. The owner is authorized to divert and use 250 acre-feet (ac-ft) of water per annum for irrigation use, 1,650 ac-ft of water for municipal purposes and 100 ac-ft of water per annum for mining purposes. Red River Authority of Texas also has water rights under Certificate of Adjudication 02-4899 (Permit No. 2295) to impound 450 ac-ft of water in Lake Texoma and can divert and use 250 ac-ft of water per annum for municipal purposes (Texas Water Commission 1987, Certificate of Adjudication 02-4898 and 02-4899).

The City of Denison currently owns water rights to Lake Texoma under Certificate of Adjudication 02-4901 (Permit No. 1622). Authorization is granted to impound 24,400 ac-ft of water in Lake Texoma and to divert and use this amount for municipal purposes (Texas Water Commission 1987, Certificate of Adjudication 02-4901).

Greater Texoma Utility Authority was issued water rights under Permit No. 4301 on February 9, 1987. Greater Texoma Utility District is authorized to use 15,000 ac-ft of water annually for municipal purposes and 10,000 ac-ft of water annually for industrial purposes (Texas Water Commission 1987, Permit No. 4301).

Certificate of Adjudication 02-2410A (Permit No. 5003) was issued to North Texas Municipal Water District on January 15, 1986 (Texas Water Commission 1986 Certificate of Adjudication 02-2410A). Authorization was granted to divert 84,000 ac-ft of water annually from Lake Texoma via pipeline to West Prong Sister Grove Creek to transport Lake Texoma water to Lake Lavon and to divert and use not to exceed 77,300 ac-ft of water of Lake Texoma water from Lake Lavon for municipal purposes.

Texas Utilities (formerly Texas Utilities Electric Company) was granted water rights and currently holds Certificate of Adjudication 02-4900 (Permit No. 1939B). The owner is permitted to impound 16,400 ac-ft of water in Lake Texoma and divert and use 10,000 ac-ft of water annually for industrial (cooling) purposes (Texas Water Commission 1987, Certificate of Adjudication 02-4900).

The State of Oklahoma has issued water rights permits to 22 individuals and entities authorizing the use of 4,376 ac-ft of water per annum for irrigation purposes. Only 13 ac-ft of water per year from Lake Texoma is used by four entities in Oklahoma for municipal water supplies (Oklahoma Water Resources Board, Lake Texoma Reservoir Summary).

Lake Texoma is located in the Red River Basin; therefore, is under the jurisdiction of the Red River Compact by Act of Congress, Public Law No. 346 (84th Congress, First Session). The states associated with the Red River Compact are Arkansas, Louisiana, Oklahoma and Texas. As stated in Article I, Section 1.01, Chapter 46 of the "Vernon's Texas Codes Annotated Water Code (West Group, 2000), the principal purposes of the compact are:

(a) To promote interstate comity and remove causes of controversy between each of the affected states by governing the use, control and distribution of the interstate water of the Red River and its tributaries.

(b) To provide an equitable apportionment among the Signatory States of the water of the Red River and its tributaries.

(c) To promote an active program for the control and alleviation of natural deterioration and pollution of the water of the Red River Basin and to provide for enforcement of the laws related thereto;

(d) To provide the means for an active program for the conservation of water, protection of lives and property from floods, improvement of water quality, development of navigation and regulation of flows in the Red River Basin; and

(e) To provide a basis for state or joint state planning and action by ascertaining and identifying each state's share in the interstate water of the Red River Basin and the apportionment thereof.

The clearing of the lake basin started August 22, 1939. Construction for the project was completed in 1943 and deliberate impoundment of water began on October 31, 1943. The lake level reached the top of the conservation pool elevation (cpe) of 617.0 ft for the first time on March 15, 1945. This was also the first time that hydroelectric power was generated (TWDB 1966). The U. S. Army Corps of Engineers, Tulsa District was the design engineer. The estimated project cost was $78,000,000 (TWDB 1974).

Original design information shows the Denison Dam embankment is 15,200 ft long with a maximum height of 165 ft above the original streambed. The crest of the dam is at elevation 670.0 ft. Texas Highway 75-A (a two-lane asphalt road) occupies the dam's crest. The dam is a rolled-earth embankment composed of mostly impervious material and has rock riprap on the upstream face for erosion control.

The spillway for Lake Texoma consists of an approach channel, an uncontrolled concrete ogee crest and a gravity chute-type structure. The 2,000-ft long crest is at elevation 640.0 ft and is located in a saddle on the south (right) bank near the dam.

The outlet works are designed with an intake structure and service bridge (located immediately upstream of the dam near the south abutment). There are eight 20-ft diameter

reinforced concrete conduits that are 800 ft long with invert elevation of 523.0 ft. The conduits extend through the embankment and discharge releases into and stilling basin and discharge channel. Three of the eight conduits are dedicated for required downstream releases and floodwater releases. The three conduits are controlled by six 9-ft by 9-ft vertical lift gates and one emergency gate. The remaining five conduits are steel-lined penstocks designed for the delivery of water for hydroelectric power. Presently, two turbines and two 35,000 kW generators are in operation. Surge tanks for the two operating units are located on the downstream side of the dam.

The original design information for Lake Texoma was reported in a 1942 elevation-area-capacity table furnished by the USACE. The total storage capacity (volume) was 3,197,980 ac-ft of water with a surface area of 96,590 acres at pool elevation 617.25 ft. Several re-surveys were performed in the following years on Lake Texoma. Results of a 1985 sediment survey showed that Lake Texoma had a total storage capacity of 2,602,430 ac-ft of water and a surface area of 87,533 acres at pool elevation 617.25 ft. Table 4 provides more information on the area and capacity of Lake Texoma based on the past sedimentation studies and the 2002 volumetric survey results.

The USACE, Tulsa District considers the cpe for Lake Texoma to be 617.0 ft, but for various reasons, the lake level is operated at different elevations throughout the year. Table 1 demonstrates the seasonal elevations the lake level is operated during normal conditions.

Table 1. Lake Texoma Seasonal Operating Lake Elevations

Date	Seasonal Pool Plan
Jan. 1	617.07
Feb. 15	615
May 1	615
Jun. 1	619
Jul. 15	619
Aug. 20	617
Sep. 10	616.5

Oct. 1	616.5
Nov. 1	618.5
Dec. 1	618.5
Dec. 31	617.12

The USACE, Tulsa District considers the "active pool" of conservation storage is between elevations 617.0 ft and 590.0 ft. Between elevations 590.0 ft and 523.0 ft is considered the "inactive pool". Any capacity below elevation 523.0 ft (elevation of the lowest invert) is considered "dead pool". The following table summarizes information for Denison Dam and Lake Texoma.

Table 2. Denison Dam and Lake Texoma Pertinent Data

Owner of Denison Dam and Facilities

United States of America

Operator of Denison Dam and Facilities

U. S. Army Corps of Engineers, Tulsa District

Engineer and General Contractor

U. S. Army Corps of Engineers, Tulsa District

Location

Denison Dam is located on the Red River, 5 miles north of Denison, Texas. The lake inundates portions of Grayson and Cooke Counties, Texas and Marshall, Love and Bryan Counties, Oklahoma.

Drainage Area

39,719 square miles (5,936 square miles probably non-contributing)

Dam

Type	Earthfill
Length (total)	15,200 ft
Maximum Height	165 ft
Top width	40 ft

Spillway

Type	Ogee (Concrete)

Length	2,000 ft
Crest elevation	640.0 ft
Control	None

Outlet Works

Type	3 conduits for water release
	5 conduits for water to turbine
Size	20-ft diameter by 800 ft long
Control	6 gates, Vertical lift
Invert elevation	523.0 ft above msl

Reservoir Data (Based on TWDB 2002 volumetric survey)

Feature	**Elevation (Ft. above msl)**	**Volume (Ac-ft)**	**Area (Acres)**
***Upper Limits of 2002 TWDB Volumetric Survey	620.0	2,779,641	84,911
Conservation Storage			
(Top of Active Pool)	617.0	2,516,232	74,686
(Top of Inactive Pool)	590.0	1,048,949	40,434
Dead Pool (lowest outlet)	523.0	12	7

*Includes the active storage of Cumberland Pool with a volume of 4,592 ac-ft of water (between elev. 619.0 – 620.0 ft) and a surface area of 4,858 surface acres (at elev. 620.0 ft).

VOLUMETRIC SURVEYING TECHNOLOGY

The equipment used to perform the latest volumetric survey consisted of a 23-foot aluminum tri-hull SeaArk craft with cabin, equipped with twin 90-Horsepower Honda outboard motors. (Reference to brand names throughout this report does not imply endorsement by TWDB). Installed within the enclosed cabin are a Coastal Oceanographics' Helmsman Display (for navigation), an Innerspace Technology Model 449 Depth Sounder and Model 443 Velocity Profiler, Trimble Navigation, Inc. AG132 GPS receiver with differential GPS correction signal and an on-board PC. A water-cooled 4.5 kW generator provides electrical power through an in-line uninterruptible power supply. In shallow areas and where navigational hazards such as stumps were present, a 20-foot aluminum shallow-draft flat bottom SeaArk craft (River-runner)

with cabin and equipped with one 100-horsepower Yamaha outboard motor was used. The portable data collection equipment on-board the boat included a Knudsen 320 B/P Echosounder (depth sounder), a Trimble Navigation, Inc. XRS Pro GPS receiver with differential GPS correction signal and a laptop computer.

The GPS equipment, survey vessel, and depth sounder in combination provide an efficient hydrographic survey system. As the boat travels across the pre-plotted transect lines, the depth sounder takes approximately ten readings of the lake bottom each second. The depth readings are stored on the computer along with the positional data generated by the boat's GPS receiver. The data files collected are downloaded and transferred to the office for editing after the survey is completed. During editing, poor-quality data is removed or corrected, multiple data points are averaged to one data point per second, and the average depths are converted to elevation readings based on the water-level elevation recorded on the day the survey was performed. Accurate estimates of the lake volume can then be determined by building a 3-D TIN model of the lake from the collected data.

PRE-SURVEY PROCEDURES

The lake's boundary was digitized using Environmental Systems Research Institute's (ESRI) ArcView from digital orthophoto quadrangle images (DOQ's). The following table is a list of DOQ's that were furnished by the USACE, Tulsa District and initially used for the lake's boundary.

Table 3. Lake Texoma DOQ Coverage

Name	File Number	Date of Photograph
Platter SW	33096h54	Feb. 8, 1995
Platter SE	33096h53	Feb. 8, 1995
Platter NE	33096h52	Feb. 8, 1995
Platter NW	33096h51	Feb. 8, 1995
Little City SW	34096a54	Feb. 8, 1995
Little City SE	34096a53	Feb. 8, 1995
Little City NE	34096a52	Feb. 8, 1995

Little City NW	34096a51	Feb. 8, 1995
Kingston North SW	34096a64	Feb. 8, 1995
Kingston North SE	34096a63	Feb. 8, 1995
Kingston North NE	34096a62	Feb. 8, 1995
Kingston North NW	34096a61	Feb. 8, 1995
Tishomingo SE	34096b63	Feb. 8, 1995
Tishomingo NE	34096b62	Feb. 8, 1995
Milburn SW	34096b54	Feb. 8, 1995
Milburn NW	34096b51	Feb. 8, 1995
Dexter NE	3396092	Feb. 17, 1995
Lebanon SE	3396014	Feb. 17, 1995
Dexter NW	3396091	Feb. 17, 1995
Lebanon SW	3396013	Feb. 17, 1995
Lebanon NE	3396012	Feb. 17, 1995
Lebanon NW	3396011	Feb. 17, 1995
Gordonville SE	3396104	Mar. 8, 1995
Pottsboro NW	3396111	Mar. 8, 1995
Pottsboro NE	3396112	Mar. 8, 1995
Denison Dam NW	3396121	Mar. 8, 1995
Kingston South SE	3396034	Mar. 8, 1995
Gordonville SW	3396103	Mar. 8, 1995
Gordonville NE	3396102	Mar. 8, 1995
Gordonville NW	3396101	Mar. 8, 1995
Kingston South NE	33096h62	Mar. 8, 1995
Sadler NE	3396182	Mar. 8, 1995

The lake elevations, at the time the DOQ's were photographed (February 8, 1995, February 17, 1995 and March 8, 1995) were 616.11 ft, 615.45 ft, and 615.02 ft. respectively. The lake elevations varied between elevation 617.53 ft and 619.71 ft during the survey. Since the lake elevations in the DOQ's were lower than the lake elevations during the survey, the digitized points from the photographs (DOQ's) were used as elevation values corresponding to the date of the photograph. In order to utilize all the data collected from the survey boats, the 620.0 ft contour from the USGS 7.5 minute quadrangle maps was used as the elevation for the lake boundary. The TWDB Staff utilized this updated boundary and the data set digitized from the above DOQ's at their respective elevations in the model for the current study.

The survey layout was designed by placing survey track lines at 500-foot intervals within the digitized lake boundary using the HYPACK software. The survey design required the use of

approximately 1,550 survey lines placed perpendicular to the original river channel and tributaries along the length of the lake.

SURVEY PROCEDURES

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

Equipment Calibration and Operation

Prior to collecting data onboard the Hydro-survey boat, the depth sounder was calibrated with the Innerspace 443 Velocity Profiler, an instrument used to measure the variation in the speed of sound at different depths in the water column. The average speed of sound through the entire water column below the boat was determined by averaging local speed-of-sound measurements collected through the water column. The velocity profiler probe was first placed in the water to acclimate it. The probe was next raised to the water surface where the depth was considered zero. The probe was then gradually lowered on a cable to a depth just above the lake bottom, and then raised again to the surface. During this lowering and raising procedure, local speed-of-sound measurements were collected, from which the average speed was computed by the velocity profiler. This average speed of sound was entered into the ITI449 depth sounder, which then provided the depth of the lake bottom. The depth was then checked manually with a measuring tape to ensure that the depth sounder was properly calibrated and operating correctly.

While collecting data onboard the River-runner (shallow draft) boat, the Knudsen depth sounder was calibrated using the DIGIBAR-Pro Profiling Sound Velocimeter by Odem Hydrographic Systems. Basically, the steps to determine the speed of sound are the same as those used for the Innerspace 443 Velocity Profiler. The probe was first placed in the water to acclimate it, raised to the water surface where the depth was considered zero. The probe was then gradually lowered on a cable to a depth just above the lake bottom, and then raised again to the

surface. During this lowering and raising procedure, local speed-of-sound measurements were collected, from which the average speed was computed by the velocimeter. The speed of sound was then entered into the bar check feature in the Knudsen software program. The depth was then checked manually with a stadia (survey) rod or weighted measuring tape to ensure that the depth sounder was properly calibrated and operating correctly.

The speed of sound in the water column ranged from 4,892 feet per second to 4,945 feet per second during the Lake Texoma survey. Based on the measured speed of sound for various depths and the average speed of sound calculated for the entire water column, the depth sounder is accurate to within $\pm$0.2 ft. An additional estimated error of $\pm$0.3 ft arises from variation in boat inclination. These two factors combine to give an overall accuracy of $\pm$0.5 ft for any instantaneous reading. These errors tend to be fairly minimal over the entire survey, since some errors are positive and some are negative, canceling each other out. Further information on these calculations is presented in Appendix K.

During the survey, the horizontal mask setting on the onboard GPS receiver was set to 10 degrees and the PDOP (Position Dilution of Precision) limit was set to seven to maximize the accuracy of the horizontal positioning. An internal alarm sounds if PDOP rises above seven to advise the field crew that the horizontal position has degraded to an unacceptable level. Further positional accuracy is obtained through differential corrections from the Omnistar receiver. The lake's initialization file used by the HYPACK data collection program was set up to convert the collected Differential GPS positions to Oklahoma South, NAD 83 state-plane coordinates on the fly.

Field Survey

TWDB staff collected data at Lake Texoma for approximately 20 days during the period of June 3 through July 9, 2002. The USACE were able to maintain the lake levels above cpe during the survey. The lake level elevations varied between 617.53 and 619.71, thus allowing the survey crew to collect data in most areas of the lake that would be inundated at cpe 617.0 ft.

Weather conditions were favorable during most of the data collection. The survey crew experienced typical summer-like conditions. Temperatures ranged in the mid 80's to low 90's with winds generally 10 to 20 mph. Only twice during the survey, did the crews have to suspend data collection due to severe storms. TWDB operated two boats, each with two-member crews and collected data simultaneously during most of the survey.

Lake Texoma is one of the larger lakes in the United States. The lake extends more than 70 miles upstream on the Red River and approximately 51miles on the Washita River from their confluence (USACE, Tulsa District, Engineering Form 1878 Reservoir Sediment Data Summary). Prior to starting the survey, TWDB staff discussed the logistics of the survey with USACE, Tulsa District Officials. Concerns were expressed about the potential difference in water-level elevations in the upper reaches of the lake and the water-level elevation at the USACE water-level gauge located at the dam. TWDB staff deployed water level gauges (Global Water EZ Level pressure transducers) at strategic sites on the lake to monitor the water level during the survey. The results of the monitoring program showed that while there were small oscillations due to wind, there was none more than one-tenth of a foot difference between the pressure transducer gauges in the upper reaches of the lake as compared to the USACE gauge site (Denison Dam) during data collection. See Figure 3 for the monitoring locations and results of the monitoring program.

The design layout for collecting data at Lake Texoma required pre-plotting transects (cross-section lines) that were perpendicular to the old river/creek channel. These transects had an average spacing of 500 ft. While collecting data, the boat operator would steer the boat on course (with GPS navigation) starting from one shore and heading to the opposite shore. The data collector would monitor the data display and depth sounder to make sure the latitude, longitude and depth (x,y,z) values were being logged. Adjustments could be made if the instruments were receiving bad data at that time. The depth sounder and GPS equipment records 10 data points every second. These points are averaged to one data point per second for generating the model. The distance between data points depended on the speed of the boat. The maximum distance between data points during the Lake Texoma 2002 survey was about 30 ft.

Comparisons between the TWDB 2002 bathymetric data collected and previous sediment surveys results on pre-established range lines can be found in Appendix J. The coordinates of the endpoints for the pre-established sediment range lines are listed in Appendix I.

During the 20 plus days that the TWDB staff was either on or near the lake, they observed the different topography surrounding Lake Texoma. There were areas in both the Washita and Red River Basins that were typical floodplains, and other shorelines with steep slopes. Typically, outcrops of large limestone boulders were located on these steep slopes. There were areas of major shoreline erosion with large trees along the bank listing, their roots exposed and ready to fall.

Delta formations were noted at the mouths of both the Red and Washita Rivers, as these rivers discharge into the open water of Lake Texoma. As the crew collected data on cross sections over the deltas, an irregular lake bottom was noted on the depth sounder's analog chart. A twelve-year study by Adam Bradford Robinson documents the downstream movement of the lacustrine delta on the Red River (Lacustrine Deltaic Growth in Lake Texoma 2000). Large amounts of timber were either floating or submerged especially at the Washita River delta. The survey crew noticed the Washita River had been channeled upstream of the main body of Lake Texoma. The survey crew assumed this excavation was part of the Cumberland Levee system that was seen during the survey. The predominant vegetation on the Washita River is Willow Trees as opposed to Salt Cedar on the Red River.

Lake Texoma is a very popular fishing and recreational lake. There are approximately 50 parks and recreational areas with dozens of marinas located along the shore of the lake in Oklahoma and Texas. Data collection around these areas was more time consuming than data collection in the open water. The survey crew noticed a lot more boat traffic on the lake closer to the 4th of July holiday.

One other activity that the survey crew noticed throughout the survey was the oil and gas production in this region. Several abandoned wells with derricks were observed in the lake around Aylesworth, OK and upstream of the Roosevelt Bridge. Several active wells located on

pads or piers extended into the lake on Beaver Creek in the Hagerman National Wildlife Refuge. TWDB staff encountered seismic surveying crews in and around Lake Texoma during most of the data collection period.

On June 25th and 26th data were collected on what is commonly known as "Cumberland Pool", located in the Tishomingo National Wildlife Refuge near Tishomingo, Oklahoma. The survey crew noted a staff gauge (presumably set by the USACE) near the refuge headquarters. The water levels at the time data were collected on Cumberland Pool remained fairly constant at elevation 620.5 ft (staff gauge readings). For the corresponding dates, the lake level (Lake Texoma) at Denison Dam was 619.66 and 619.61 respectively. The datum for the staff gauge at Cumberland Pool was not verified but was assumed set at the same datum as the water level gauge at Denison Dam.

Cumberland Pool is more or less "bowl" shaped. The pre-plotted lines were designed in a north/south direction with the data collection beginning at the east bank and continuing to the west. As data were being collected on the first few lines, the crew observed what was assumed to be the discharge channel known as Pennington Outlet, located in the southeast corner of the pool; a large delta with heavy vegetation expanded across the mouth restricting access to the outlet. The crest of the delta in Pennington Outlet is obviously the critical point in elevation in determining usable (flood) storage in Cumberland Pool. Any available storage in Cumberland Pool above the effective crest elevation in Pennington Outlet is considered a part of Lake Texoma. Any storage below the crest elevation is considered unusable storage and disconnected from Lake Texoma. An evaluation by the USACE Tulsa District of the data collected by the TWDB staff concluded that an effective crest elevation of 619.0 ft for the Pennington Outlet should be used for the purposes of this report (Personnel Comm. 2003).

Cumberland Pool and Tishomingo National Wildlife Refuge were once part of a major working farm. There are still silos standing on the north shoreline of the pool as well as some of the old concrete structures that housed the farm laborers. Several of the houses are now partially or fully inundated in Cumberland Pool. These structures create great fishing habitat as well as serious underwater obstructions to boaters.

The survey crew noted one major tributary (Spring Creek) on the north side of Cumberland Pool near the refuge headquarters. Another observation worth noting was a rather large channel and delta located on the south shoreline and to the west of Pennington Outlet. At the time of the survey, the channel was dry but there were obvious signs that flooding from the Washita River would spill into Cumberland Pool. Attempts were made to gain access to this channel from the Washita River side but were unsuccessful. The crew did note the large timbers in the channel and leaning towards Cumberland Pool. These were obvious signs that flood events have occurred in the past and the direction of flow was into Cumberland Pool.

Figure 1: Cumberland Pool and Surrounding Area

In total, approximately 636,380 data points were collected over the 1,812 miles traveled during the data collection phase of Lake Texoma. The crews collected data on approximately 1,450 of the 1,550 pre-plotted transects that were designed for the survey. These points were stored digitally on the boat's computer in 2,347 data files. Random data were collected in those areas where the crew was not able to stay on course due to obstructions. Data were not collected in areas with significant obstructions or where the water was too shallow. Figure 4 shows the actual location of all data points collected.

Data Processing

The collected data were downloaded from diskettes onto TWDB's network computers. Tape backups were made for future reference as needed. To process the data, the EDIT routine in the HYPACK Program was run on each raw data file. Data points such as depth spikes or data with missing depth or positional information were deleted from the files. A correction for the lake elevation at the time of data collection was also applied to each file during the EDIT routine. During the survey, the water level elevation varied from 617.53 ft on June 3, 2002 to 619.71 ft on June 24, 2002 according to the USACE gauge. After all adjustments had been made to the raw data files, the edited files were saved.

The edited files were then combined into a single X, Y, Z data file, to be used with the GIS software to develop a model of the lake bottom elevation.

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

Volumes and areas were calculated from the TIN for the entire lake at one-tenth of a foot interval from the lowest elevation to the contour used for the lake boundary during the 2002 survey. From elevation 520.6 ft to 620.0 ft, the surface areas and volumes of the lake were

computed using Arc/Info software. The surface area and volume of Cumberland Pool above elevation 619.0 is considered part of Lake Texoma and is included in the total calculations. The computed lake volume table is presented in Appendix A and the area table in Appendix B for Lake Texoma. An elevation-volume graph and an elevation-area graph are presented in Appendix C and Appendix D respectively. Elevation-volume and elevation-area tables for Cumberland Pool between elevation 605.0 – 620.0 ft are presented in Appendix E and Appendix F. The graphs for the volume and area tables for Cumberland Pool are presented in Appendix G and Appendix H respectively.

Other products developed from the model include a shaded relief map (Figure 5) and a shaded depth range map (Figure 6). 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 5-ft intervals is presented in Figure 7. Finally, the location of cross-section endpoints in Appendix I and the corresponding cross-section plots in Appendix J were approximated from those sediment range lines established by the USACE prior to 1942.

RESULTS

Results from the 2002 TWDB survey indicate Lake Texoma encompasses 74,686 surface acres and contains a total volume of 2,516,232 ac-ft at the conservation pool elevation of 617.0 ft. The length of the shoreline at the digitized elevation of 620.0 ft was calculated to be 607 miles. The deepest point physically measured during the survey was at elevation 521.0 ft and was located approximately 1.16 miles upstream of Denison Dam.

SUMMARY AND COMPARISONS

Denison Dam was completed in 1943 and deliberate impoundment began the same year. Several sediment surveys have been performed on Lake Texoma. Original design information is based on a 1942 elevation-area-capacity table furnished by the USACE. The most recent Sediment Survey Report on Lake Texoma was published by the USACE and based on a 1985 re-survey.

At conservation pool elevation 617.0 ft, the 2002 TWDB survey measured 74,686 surface acres and reports a volume of 2,516,232 ac-ft of water. The capacity of the active pool (conservation storage) between elevations 617.0 ft and 590.0 ft is 1,467,283 ac-ft of water. The inactive pool, between elevation 590.0 ft and 523.0 ft has a capacity of 1,048,942 ac-ft of water. The dead pool storage or that capacity of water below the invert of the lowest outlet (elevation 523.0 ft) was 7 ac-ft of water.

The 1942 elevation-area-capacity table indicates that Lake Texoma had a volume of 3,132,293 ac-ft of water and a surface area of 96,076 acres at conservation pool elevation (cpe) 617.0 ft. A comparative summary of the historical data and the results of the TWDB 2002 survey are presented in Table 4.

Comparisons between the USACE historical Sediment Surveys and the TWDB 2002 Volumetric Survey are 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 capacity.

Table 4. Area and Volume Comparisons of Lake Texoma

	USACE Original Design **1942**	USACE Re-survey **1969**	USACE Re-survey **1985**	TWDB Volumetric **2002**
Area (acres)	96,076	89,188	86,910	74,686
Total Volume (ac-ft)	3,132,293	2,688,411	2,580,389	2,516,232
Active Pool storage capacity (ac-ft)	1,887,283	1,652,501	1,570,219	1,467,283
Inactive Pool storage capacity (ac-ft)	1,241,123	1,035,910	1,010,170	1,048,942
Dead Pool storage capacity (ac-ft)	3,887	0	0	7

Notes:
1. All results for conservation pool elevation 617.0 ft
2. Active Pool storage capacity is between elevations 617.0 and 590.0 ft
3. Inactive Pool storage capacity is between elevations 590.00 and 523.0 ft
4. Dead Pool storage is that below elevation 523.0 ft
5. All pre-2002 data provided by Tulsa District USACE

REFERENCES

1. http://www.swt.usace.army.mil/projects/pertdata/laketexoma/laketexoma.htm
2. http://www.swt-wc.usace.army.mil/ReservoirDailyReport/
3. http://www.utdallas.edu/~jvolesky/RS2000/AR/TexomaPage.htm Lacustrine Deltaic Growth in Lake Texoma
4. Oklahoma Water Resources, Lake Texoma Reservoir Summary
5. Ron Bell, 2003, e-mail sent to Duane Thomas on Jan. 6, 2003 @ 2:12 pm
6. Texas Water Commission, 1987, Permit No. 4301
7. Texas Water Commission, 1987, Certificate of Adjudication 02-4898 and 02-4899
8. Texas Water Commission 1986 Certificate of Adjudication 02-2410A
9. Texas Water Commission, 1987, Certificate of Adjudication 02-4900
10. Texas Water Commission, 1987, Certificate of Adjudication 02-4901
11. Texas Water Development Board. 1966. Report 48. “Dams and Lakes in Texas, Historical and Descriptive Information”

12. Texas Water Development Board. 1973. Report 126 Part I. “Engineering Data on Dams and Lakes in Texas”
13. United Sates Army Corps of Engineers. Tulsa District. Engineering Form 1878 Reservoir Sediment Data Summary.
14. West Group. 2000. “Vernon’s Texas Codes Annotated Water Code. Section 26.001 to 51.300. Volume 1A

Appendix A

Lake Texoma

RESERVOIR VOLUME TABLE

TEXAS WATER DEVELOPMENT BOARD

JULY 2002 SURVEY

VOLUME IN ACRE-FEET

ELEVATION INCREMENT IS ONE TENTH FOOT

ELEVATION in Feet	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
520							0	0	0	0
521	0	0	0	0	0	0	0	0	0	0
522	1	1	1	1	2	2	3	4	5	6
523	7	8	9	11	13	15	18	20	23	27
524	30	34	38	42	46	51	55	60	66	71
525	77	83	89	95	101	108	115	122	130	137
526	145	154	162	172	181	192	203	215	228	242
527	257	273	289	306	325	344	363	384	405	427
528	450	474	498	523	549	575	602	629	658	686
529	716	746	777	809	842	876	912	948	985	1023
530	1062	1103	1145	1188	1232	1277	1323	1370	1418	1467
531	1517	1568	1620	1672	1726	1782	1838	1896	1955	2017
532	2081	2147	2216	2287	2362	2439	2519	2603	2690	2782
533	2879	2982	3089	3201	3317	3436	3560	3687	3817	3951
534	4089	4229	4373	4520	4670	4823	4978	5137	5298	5462
535	5629	5798	5970	6144	6321	6500	6682	6866	7052	7241
536	7432	7625	7821	8019	8219	8422	8627	8834	9043	9255
537	9469	9686	9904	10126	10349	10575	10804	11035	11269	11505
538	11744	11985	12230	12477	12726	12979	13234	13493	13754	14019
539	14287	14558	14832	15110	15391	15676	15963	16255	16549	16848
540	17149	17454	17763	18075	18391	18710	19032	19358	19687	20021
541	20357	20698	21043	21392	21746	22104	22466	22832	23203	23578
542	23958	24343	24734	25130	25531	25938	26349	26766	27187	27613
543	28043	28478	28917	29361	29809	30261	30717	31177	31642	32110
544	32583	33059	33541	34027	34519	35017	35519	36028	36541	37060
545	37585	38115	38651	39193	39740	40293	40851	41415	41985	42563
546	43146	43737	44335	44940	45552	46171	46797	47431	48071	48720
547	49377	50041	50715	51395	52084	52779	53482	54193	54910	55636
548	56369	57108	57856	58610	59372	60142	60919	61706	62499	63302
549	64111	64927	65752	66583	67422	68268	69122	69983	70852	71730
550	72616	73510	74413	75324	76244	77171	78108	79057	80017	80989
551	81974	82970	83979	84998	86029	87072	88126	89191	90268	91358
552	92457	93567	94687	95816	96955	98103	99260	100427	101603	102789
553	103983	105187	106401	107623	108855	110094	111341	112598	113862	115136
554	116416	117706	119004	120310	121625	122947	124276	125613	126957	128309
555	129669	131036	132411	133792	135182	136578	137980	139391	140807	142232
556	143662	145099	146544	147995	149454	150919	152392	153873	155361	156856
557	158357	159866	161381	162902	164431	165965	167505	169053	170607	172168
558	173735	175309	176891	178478	180073	181673	183279	184893	186511	188136
559	189766	191403	193046	194695	196350	198010	199677	201350	203027	204712
560	206401	208096	209798	211505	213219	214938	216663	218395	220132	221876
561	223625	225380	227142	228909	230682	232461	234245	236036	237833	239638
562	241447	243264	245090	246922	248763	250609	252462	254323	256189	258062
563	259941	261826	263718	265615	267520	269430	271346	273269	275198	277133
564	279074	281022	282976	284935	286901	288871	290847	292829	294816	296810
565	298808	300813	302826	304845	306872	308905	310945	312994	315049	317111
566	319179	321254	323338	325427	327524	329626	331734	333849	335970	338098
567	340231	342371	344518	346670	348830	350995	353165	355343	357526	359717
568	361913	364115	366326	368542	370767	372998	375236	377484	379738	382001
569	384271	386549	388836	391130	393432	395741	398058	400384	402716	405057
570	407404	409759	412123	414493	416871	419254	421646	424046	426452	428867
571	431288	433717	436154	438599	441052	443512	445980	448458	450942	453437
572	455939	458450	460972	463500	466040	468587	471144	473711	476285	478870
573	481461	484060	486668	489283	491908	494539	497179	499830	502488	505156
574	507832	510516	513211	515912	518623	521342	524069	526807	529552	532309
575	535073	537847	540633	543425	546228	549039	551859	554689	557527	560375

Lake Texoma

RESERVOIR VOLUME TABLE (continued)

TEXAS WATER DEVELOPMENT BOARD — JULY 2002 SURVEY

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

ELEVATION in Feet	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
576	563231	566095	568969	571850	574741	577639	580544	583460	586382	589315
577	592255	595203	598162	601128	604104	607088	610079	613081	616088	619106
578	622131	625164	628206	631254	634312	637375	640446	643527	646613	649709
579	652811	655922	659043	662170	665307	668450	671601	674762	677930	681108
580	684293	687486	690689	693899	697118	700344	703578	706823	710075	713338
581	716607	719886	723175	726471	729778	733092	736416	739750	743092	746445
582	749806	753178	756563	759957	763366	766784	770214	773658	777110	780575
583	784049	787532	791027	794529	798044	801566	805098	808642	812193	815756
584	819327	822907	826500	830101	833713	837332	840961	844602	848251	851911
585	855578	859254	862942	866637	870343	874056	877778	881511	885251	889002
586	892759	896525	900302	904084	907876	911674	915478	919292	923111	926939
587	930772	934613	938462	942315	946178	950045	953919	957802	961689	965585
588	969486	973393	977310	981231	985161	989095	993036	996986	1000941	1004904
589	1008872	1012847	1016832	1020821	1024819	1028823	1032833	1036852	1040876	1044910
590	1048949	1052995	1057050	1061110	1065180	1069254	1073335	1077426	1081522	1085628
591	1089739	1093858	1097986	1102120	1106265	1110415	1114573	1118742	1122917	1127103
592	1131294	1135494	1139705	1143922	1148149	1152383	1156625	1160879	1165140	1169412
593	1173691	1177979	1182280	1186587	1190907	1195233	1199568	1203916	1208271	1212639
594	1217013	1221396	1225791	1230192	1234605	1239024	1243453	1247893	1252340	1256798
595	1261262	1265736	1270221	1274712	1279215	1283723	1288241	1292770	1297307	1301854
596	1306408	1310970	1315543	1320123	1324715	1329312	1333919	1338538	1343165	1347804
597	1352450	1357106	1361774	1366450	1371139	1375834	1380540	1385258	1389983	1394720
598	1399463	1404216	1408980	1413751	1418533	1423322	1428119	1432928	1437743	1442571
599	1447405	1452248	1457103	1461965	1466839	1471719	1476609	1481511	1486421	1491344
600	1496276	1501218	1506174	1511138	1516115	1521101	1526097	1531107	1536124	1541156
601	1546195	1551246	1556311	1561385	1566472	1571568	1576674	1581795	1586924	1592066
602	1597216	1602378	1607554	1612737	1617935	1623141	1628357	1633589	1638828	1644083
603	1649345	1654619	1659907	1665204	1670515	1675834	1681165	1686509	1691863	1697231
604	1702608	1707996	1713398	1718807	1724232	1729665	1735109	1740568	1746035	1751518
605	1757009	1762512	1768030	1773556	1779097	1784647	1790207	1795782	1801366	1806965
606	1812573	1818193	1823829	1829474	1835135	1840805	1846487	1852185	1857892	1863614
607	1869345	1875088	1880847	1886615	1892398	1898189	1903991	1909810	1915637	1921480
608	1927331	1933194	1939072	1944959	1950861	1956771	1962694	1968631	1974577	1980539
609	1986509	1992491	1998490	2004496	2010519	2016550	2022593	2028653	2034722	2040807
610	2046901	2053008	2059132	2065265	2071414	2077573	2083744	2089932	2096129	2102343
611	2108567	2114804	2121059	2127323	2133606	2139900	2146208	2152535	2158874	2165232
612	2171603	2177990	2184398	2190817	2197257	2203709	2210179	2216669	2223172	2229698
613	2236237	2242795	2249375	2255972	2262593	2269229	2275886	2282567	2289265	2295989
614	2302729	2309490	2316277	2323081	2329912	2336762	2343635	2350537	2357460	2364411
615	2371383	2378379	2385403	2392448	2399525	2406625	2413755	2420918	2428103	2435319
616	2442556	2449818	2457109	2464419	2471759	2479118	2486499	2493906	2501329	2508774
617	2516232	2523707	2531204	2538712	2546240	2553779	2561333	2568905	2576488	2584089
618	2591700	2599325	2606968	2614621	2622293	2629974	2637668	2645382	2653104	2660845
619	2696769	2704972	2713198	2721438	2729700	2737976	2746270	2754587	2762918	2771273
620	2779641.02									

Top of Inactive Pool

Top of Conservation Pool

Appendix B

Lake Texoma

RESERVOIR AREA TABLE

TEXAS WATER DEVELOPMENT BOARD — JULY 2002 SURVEY

AREA IN ACRES — ELEVATION INCREMENT IS ONE TENTH FOOT

ELEVATION in Feet	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
520							0	0	0	0
521	0	0	0	0	0	0	0	1	1	1
522	2	2	3	4	5	6	7	8	9	11
523	12	14	16	18	21	23	26	29	31	33
524	36	38	40	42	45	47	49	51	53	55
525	57	59	62	64	66	68	70	73	75	78
526	81	85	90	96	102	109	117	126	134	143
527	152	160	169	177	186	195	203	210	217	224
528	231	239	246	253	260	266	272	278	285	292
529	299	307	316	326	335	345	355	366	376	388
530	400	412	424	436	447	457	466	475	485	494
531	503	513	523	534	545	557	571	586	605	627
532	650	675	701	728	759	789	818	851	894	946
533	1003	1053	1097	1137	1175	1214	1253	1288	1323	1357
534	1391	1423	1454	1484	1513	1542	1571	1599	1627	1653
535	1679	1705	1731	1756	1781	1806	1829	1852	1875	1898
536	1921	1945	1969	1992	2014	2037	2059	2083	2106	2129
537	2153	2177	2201	2225	2249	2273	2298	2324	2351	2376
538	2402	2428	2455	2483	2512	2540	2569	2600	2630	2660
539	2693	2727	2761	2795	2828	2861	2895	2930	2965	2999
540	3033	3068	3102	3139	3173	3208	3243	3277	3312	3348
541	3388	3428	3472	3516	3558	3599	3642	3685	3729	3775
542	3824	3879	3932	3986	4039	4091	4140	4188	4235	4282
543	4327	4372	4416	4458	4499	4540	4582	4623	4664	4705
544	4746	4790	4840	4892	4946	5001	5056	5109	5163	5218
545	5273	5331	5389	5444	5499	5554	5612	5672	5737	5804
546	5871	5942	6014	6084	6156	6227	6298	6371	6445	6526
547	6609	6692	6770	6845	6920	6994	7066	7140	7218	7291
548	7363	7434	7507	7582	7659	7738	7817	7899	7980	8058
549	8131	8205	8279	8352	8426	8499	8573	8650	8733	8818
550	8900	8984	9070	9154	9237	9323	9424	9540	9661	9785
551	9908	10024	10138	10252	10371	10485	10597	10712	10831	10944
552	11048	11148	11245	11340	11437	11529	11621	11712	11807	11902
553	11997	12090	12179	12265	12352	12437	12521	12604	12686	12770
554	12854	12938	13024	13104	13181	13256	13330	13404	13481	13559
555	13636	13711	13783	13854	13926	13996	14065	14134	14203	14272
556	14341	14409	14477	14548	14621	14696	14769	14841	14912	14983
557	15052	15119	15184	15248	15311	15375	15439	15505	15573	15641
558	15710	15778	15844	15910	15975	16037	16097	16156	16215	16275
559	16337	16399	16458	16518	16578	16637	16695	16753	16810	16868
560	16926	16985	17044	17103	17163	17222	17283	17345	17406	17466
561	17525	17583	17641	17700	17758	17817	17877	17939	18005	18068
562	18136	18213	18290	18362	18432	18501	18569	18633	18696	18759
563	18822	18885	18948	19011	19073	19133	19194	19256	19320	19382
564	19446	19509	19568	19623	19679	19733	19788	19844	19901	19960
565	20020	20086	20156	20227	20300	20374	20445	20515	20583	20650
566	20719	20792	20862	20929	20994	21056	21118	21180	21243	21305
567	21368	21432	21496	21559	21620	21681	21743	21805	21868	21931
568	21996	22064	22133	22204	22276	22350	22426	22506	22586	22665
569	22744	22824	22903	22980	23057	23135	23211	23287	23364	23441
570	23517	23593	23666	23737	23807	23881	23957	24030	24103	24177
571	24254	24331	24409	24488	24566	24646	24726	24809	24896	24984
572	25071	25162	25249	25339	25433	25527	25618	25705	25792	25874
573	25955	26036	26117	26197	26279	26363	26450	26539	26632	26719
574	26804	26893	26979	27062	27147	27236	27322	27411	27509	27603
575	27698	27797	27886	27975	28069	28159	28248	28342	28430	28518
576	28604	28691	28775	28858	28941	29022	29104	29189	29273	29358

Lake Texoma

RESERVOIR AREA TABLE (continued)

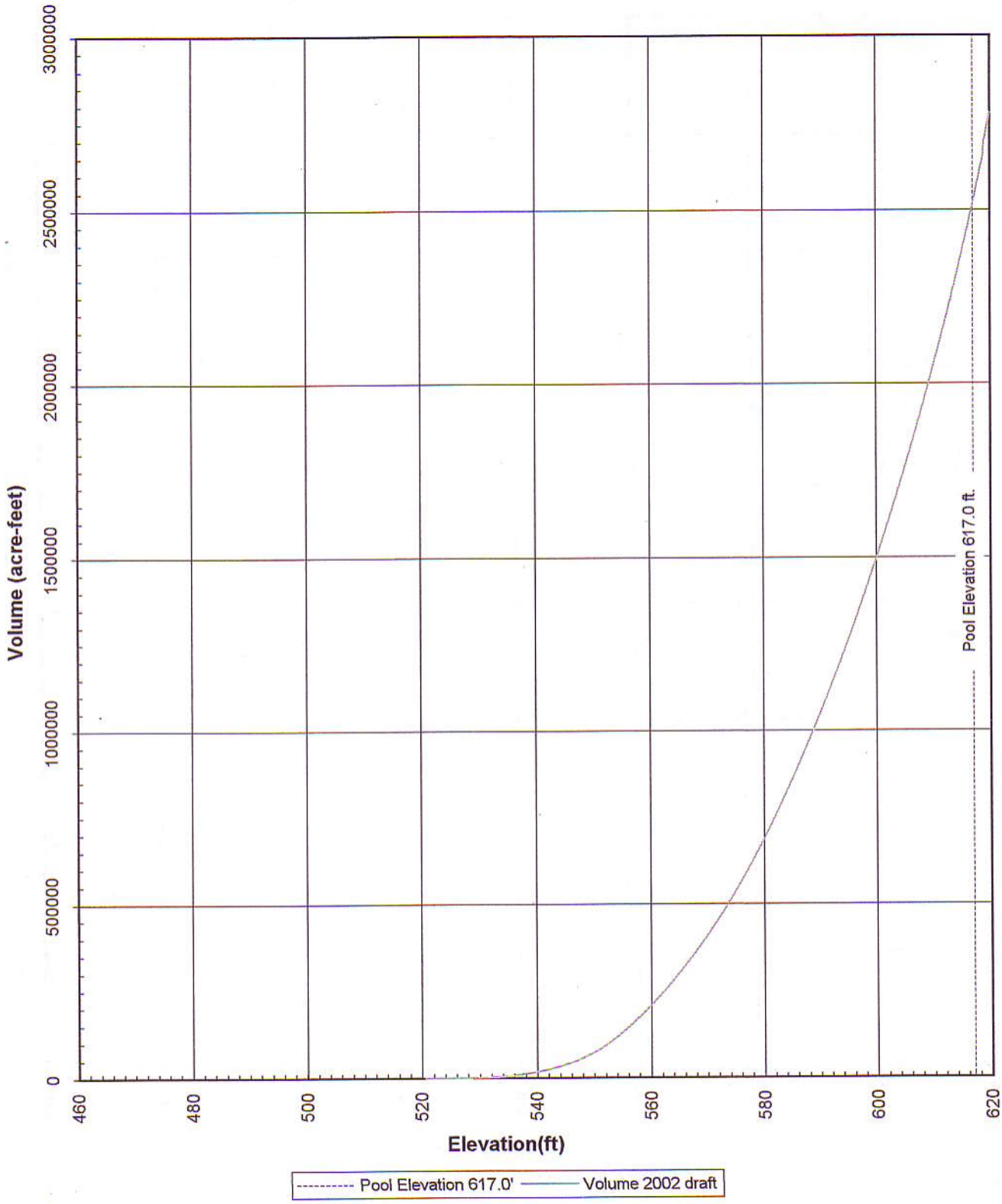
TEXAS WATER DEVELOPMENT BOARD — JULY 2002 SURVEY

AREA IN ACRES — ELEVATION INCREMENT IS ONE TENTH FOOT

ELEVATION in Feet	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
577	29448	29535	29623	29710	29796	29881	29964	30045	30127	30211
578	30294	30372	30450	30528	30605	30679	30754	30833	30910	30989
579	31071	31154	31238	31317	31398	31480	31562	31644	31728	31812
580	31896	31979	32062	32143	32224	32307	32393	32482	32571	32659
581	32748	32838	32926	33015	33103	33195	33286	33378	33472	33568
582	33671	33781	33896	34015	34134	34250	34364	34477	34588	34691
583	34791	34890	34986	35084	35183	35281	35377	35473	35568	35664
584	35765	35866	35965	36060	36155	36251	36347	36445	36540	36633
585	36727	36820	36913	37004	37094	37184	37271	37360	37451	37542
586	37627	37710	37789	37869	37947	38021	38092	38161	38231	38305
587	38377	38445	38512	38578	38646	38714	38782	38849	38915	38981
588	39049	39117	39184	39251	39319	39386	39454	39521	39589	39655
589	39723	39793	39866	39938	40007	40076	40145	40215	40288	40362
590	40434	40504	40574	40645	40716	40787	40859	40932	41007	41082
591	41157	41234	41311	41389	41467	41550	41632	41717	41803	41886
592	41968	42051	42135	42219	42303	42390	42478	42569	42659	42753
593	42847	42942	43038	43132	43226	43319	43414	43511	43611	43705
594	43797	43889	43979	44068	44158	44249	44340	44431	44521	44611
595	44702	44791	44878	44965	45053	45141	45232	45327	45418	45503
596	45588	45676	45764	45854	45942	46032	46127	46226	46324	46423
597	46520	46620	46721	46820	46917	47015	47114	47212	47306	47399
598	47492	47584	47673	47763	47851	47940	48029	48120	48212	48305
599	48398	48488	48579	48673	48767	48862	48958	49057	49162	49272
600	49380	49488	49597	49704	49812	49920	50026	50135	50242	50351
601	50463	50576	50690	50802	50913	51024	51134	51242	51350	51459
602	51572	51685	51795	51903	52012	52124	52237	52353	52467	52582
603	52695	52806	52921	53036	53148	53260	53372	53486	53605	53723
604	53835	53947	54057	54167	54283	54397	54511	54628	54748	54869
605	54986	55100	55216	55335	55448	55561	55676	55792	55911	56030
606	56151	56277	56402	56526	56651	56775	56897	57019	57142	57263
607	57386	57508	57629	57747	57865	57982	58103	58226	58348	58466
608	58583	58702	58823	58942	59059	59176	59294	59413	59534	59655
609	59779	59901	60021	60142	60263	60385	60510	60640	60767	60894
610	61022	61151	61279	61407	61535	61662	61790	61921	62052	62186
611	62321	62458	62592	62731	62878	63023	63170	63325	63482	63641
612	63809	63971	64130	64290	64459	64624	64790	64967	65140	65315
613	65498	65689	65882	66081	66284	66484	66685	66890	67103	67313
614	67524	67736	67953	68168	68396	68631	68874	69122	69365	69609
615	69854	70095	70340	70603	70879	71171	71461	71737	72002	72259
616	72516	72761	73000	73247	73490	73726	73941	74144	74334	74513
617	74686	74853	75018	75178	75335	75482	75627	75771	75914	76056
618	76197	76338	76478	76618	76757	76896	77035	77174	77313	77452
619	81965	82144	82324	82504	82686	82868	83052	83236	83421	83609
620	84911									

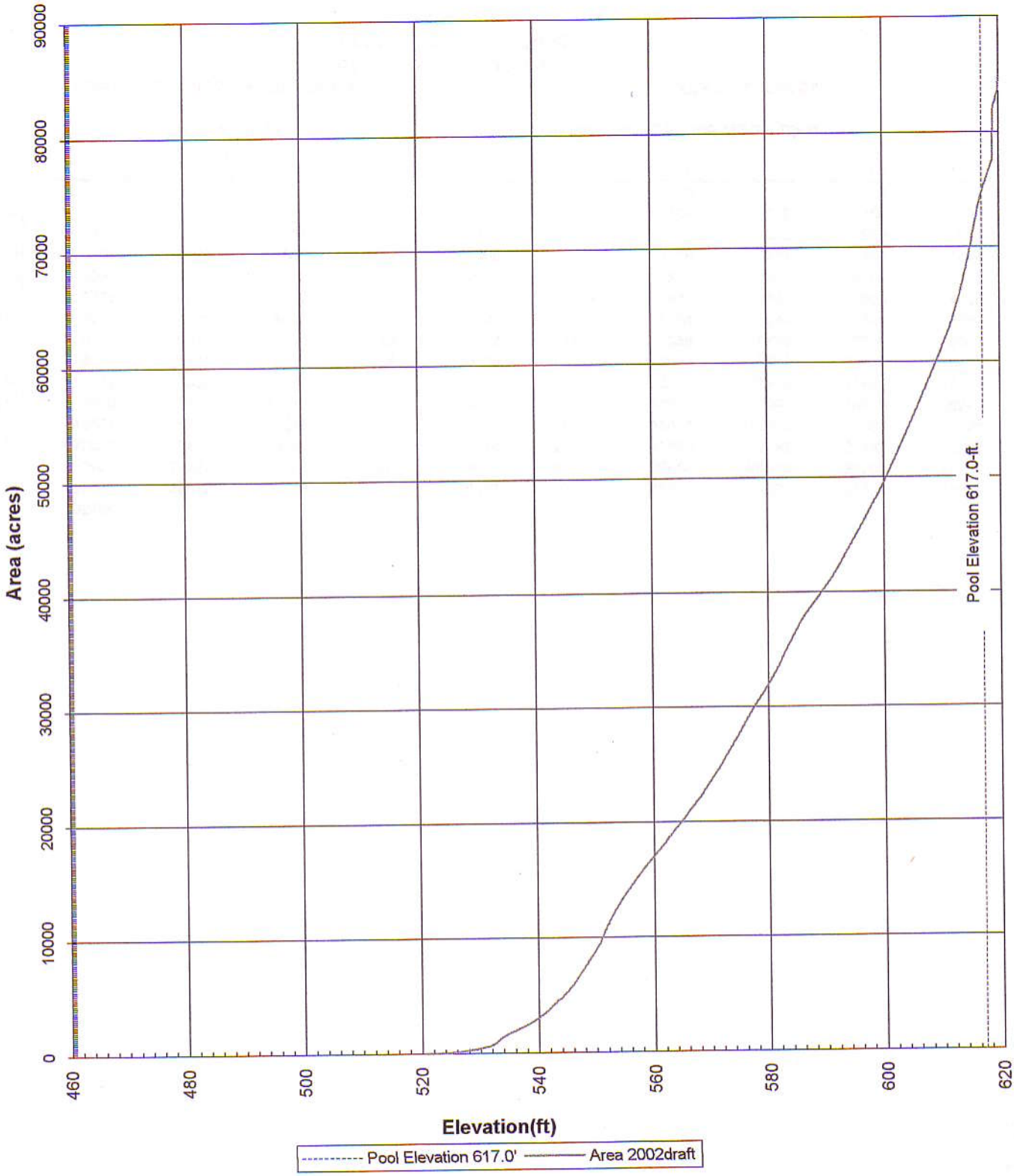
Top of Inactive Pool

Top of conservation pool



Lake Texoma
July 2002
Prepared by: TWDB

Appendix C Elevation vs. Volume



Lake Texoma
July 2002
Prepared by: TWDB

Appendix D Elevation vs. Area

Appendix E

Cumberland Pool (only)

RESERVOIR VOLUME TABLE

TEXAS WATER DEVELOPMENT BOARD

JULY 2002 SURVEY

VOLUME IN ACRE-FEET

ELEVATION INCREMENT IS ONE TENTH FOOT

ELEVATION in Feet	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
605				0	0	0	0	1	4	8
606	15	24	35	49	65	83	104	128	153	182
607	214	248	285	326	370	417	467	522	580	642
608	708	777	850	927	1008	1092	1179	1271	1366	1464
609	1566	1672	1782	1895	2011	2130	2252	2377	2506	2638
610	2773	2911	3052	3196	3344	3494	3647	3804	3964	4126
611	4292	4461	4633	4808	4986	5167	5351	5538	5728	5922
612	6118	6317	6519	6724	6932	7144	7358	7576	7796	8020
613	8246	8475	8707	8942	9180	9421	9664	9911	10161	10415
614	10672	10932	11197	11465	11737	12012	12291	12573	12859	13148
615	13440	13736	14035	14338	14645	14956	15271	15590	15913	16240
616	16571	16905	17243	17585	17931	18281	18635	18995	19358	19726
617	20098	20473	20851	21233	21618	22005	22395	22788	23183	23582
618	23983	24387	24794	25204	25617	26034	26454	26878	27306	27738
619	28173	28612	29056	29504	29956	30412	30873	31339	31809	32285
620	32765									

Appendix F

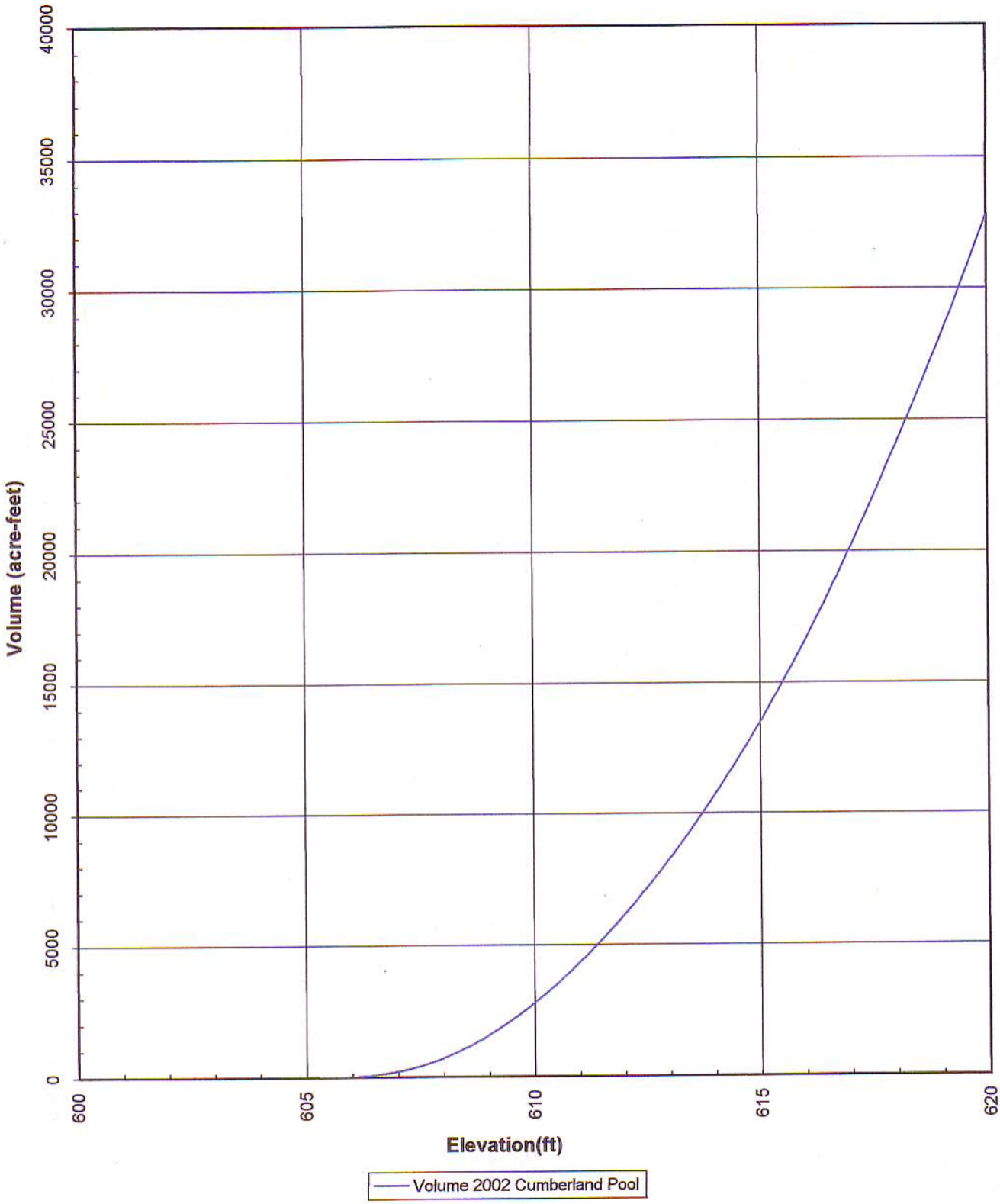
Cumberland Pool (only)

RESERVOIR AREA TABLE

TEXAS WATER DEVELOPMENT BOARD — JULY 2002 SURVEY

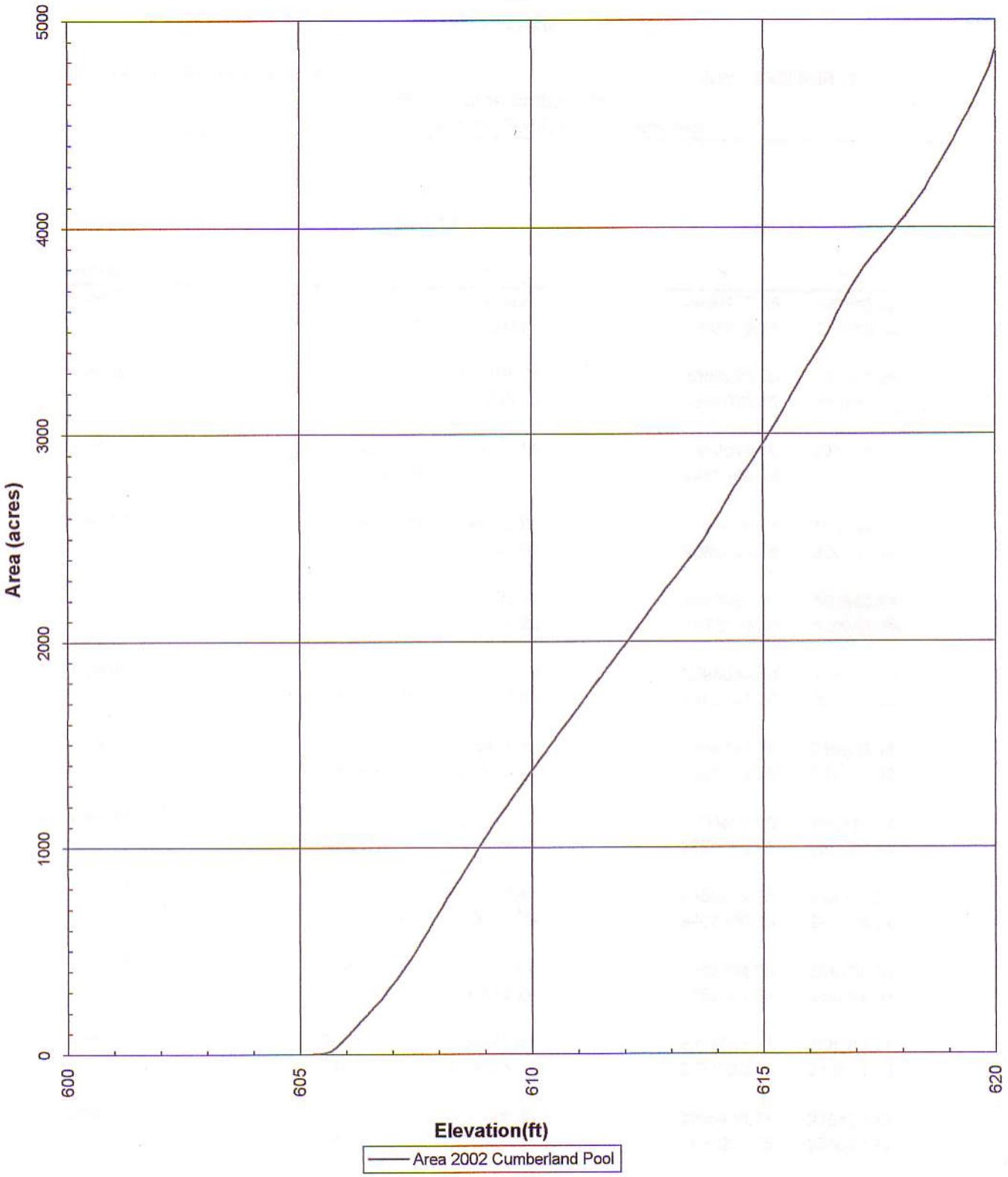
AREA IN ACRES — ELEVATION INCREMENT IS ONE TENTH FOOT

ELEVATION in Feet	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
605				0	0	2	6	15	32	54
606	77	101	125	149	174	198	221	245	272	301
607	330	359	389	421	455	488	525	562	600	638
608	676	713	752	788	823	858	894	931	967	1004
609	1041	1077	1111	1144	1175	1207	1239	1271	1303	1334
610	1365	1396	1427	1457	1488	1518	1550	1581	1612	1642
611	1672	1703	1735	1766	1798	1827	1857	1886	1917	1946
612	1975	2005	2035	2067	2098	2130	2161	2190	2221	2249
613	2278	2305	2333	2364	2393	2422	2452	2484	2520	2553
614	2587	2623	2662	2701	2738	2771	2805	2839	2872	2907
615	2941	2976	3012	3049	3088	3129	3169	3210	3250	3290
616	3329	3363	3398	3436	3477	3523	3570	3614	3657	3698
617	3734	3768	3801	3832	3860	3887	3914	3942	3970	3998
618	4027	4056	4085	4115	4147	4182	4222	4261	4298	4336
619	4375	4415	4456	4499	4542	4587	4633	4680	4728	4777
620	4858									



Lake Texoma
July 2002
Prepared by: TWDB

Appendix G Elevation vs. Volume



Lake Texoma
July 2002
Prepared by: TWDB

Appendix H Elevation vs. Area

Appendix I

Lake Texoma

TEXAS WATER DEVELOPMENT BOARD

JUNE 2002 SURVEY

Range Line Endpoints

State Plane Oklahoma South Zone - Units-feet

Range Line	NAD27 X	NAD27 Y	NAD83 X	NAD83 Y
Line 01	2431709.98	193606.84	2400117.25	193648.22
	2426968.51	178306.69	2395375.75	178348.02
Line 02	2414886.14	191166.35	2383293.50	191207.86
	2430621.61	191680.33	2399028.75	191721.70
Line 03	2414203.85	202651.59	2382610.75	202693.17
	2432097.39	203006.70	2400504.75	203048.13
Line 04	2415069.40	194002.88	2383476.75	194044.41
	2414444.76	200155.62	2382851.75	200197.19
Line 05	2408592.66	180461.13	2377000.00	180502.63
	2403886.35	180485.20	2372293.50	180526.75
Line 06	2426632.45	218465.19	2395039.50	218506.75
	2433713.97	207478.89	2402121.25	207520.33
Line 07	2426335.72	218497.92	2394742.75	218539.48
	2439636.29	217030.79	2408043.25	217072.23
Line 08	2436204.94	239717.56	2404612.00	239759.14
	2422743.24	235639.75	2391150.25	235681.44
Line 09	2421272.92	253909.42	2389679.75	253951.27
	2433623.98	249855.23	2402030.75	249896.92
Line 10	2420697.26	254088.67	2389104.00	254130.53
	2413894.84	244512.24	2382301.50	244554.06
Line 11	2410325.95	258840.41	2378732.75	258882.41
	2405574.04	249815.43	2373980.75	249857.39
Line-13	2428029.32	278448.30	2396435.75	278490.38
	2436655.32	285029.67	2405061.75	285071.72
Line 14	2422045.55	294229.89	2390451.75	294272.16
	2427719.54	299375.15	2396125.75	299417.44
Line 23	2418010.19	220996.49	2386417.25	221038.14
	2413407.67	207154.09	2381814.75	207195.70
Line 24	2398763.44	216939.73	2367170.50	216981.55
	2410580.84	207732.39	2378987.75	207774.03

Appendix I (continued)

Lake Texoma

TEXAS WATER DEVELOPMENT BOARD — JUNE 2002 SURVEY

Range Line Endpoints

State Plane Oklahoma South Zone - Units-feet

Range Line	NAD27 X	NAD27 Y	NAD83 X	NAD83 Y
Line 25	2391189.65	207178.79	2359596.75	207220.61
	2398763.44	216939.73	2367170.50	216981.55
Line 26	2396298.43	186111.51	2364705.50	186153.16
	2386050.88	193832.03	2354458.00	193873.81
Line 27	2381501.18	180170.17	2349908.25	180211.91
	2380937.48	190084.50	2349344.50	190126.30
Line 28	2365579.12	182032.46	2333985.75	182074.27
	2360298.06	185438.05	2328704.75	185479.91
Line 29	2361213.79	168911.13	2329620.50	168952.88
	2368026.27	172270.67	2336433.00	172312.42
Line 30	2372097.22	162378.13	2340504.25	162419.80
	2364533.70	159308.65	2332940.50	159350.34
Line 31	2377059.91	154442.88	2345467.00	154484.47
	2368485.32	152215.18	2336892.25	152256.80
Line 32	2364564.44	201672.96	2335753.00	201375.66
	2360895.72	202188.21	2332084.25	201890.92
Line 33	2355072.79	193374.81	2323479.25	193416.73
	2354639.01	202253.81	2323045.50	202295.78
Line 34	2348284.22	204271.47	2316690.75	204313.48
	2338983.80	193272.40	2307390.00	193314.39
Line 35	2344029.87	211012.49	2312436.25	211054.55
	2332986.00	207641.31	2301392.25	207683.39
Line 36	2343426.86	217635.29	2311833.00	217677.39
	2345834.15	215538.30	2314240.75	215580.38
Line 38	2324683.80	219166.67	2293089.75	219208.83
	2333305.50	228478.08	2301711.75	228520.27
Line 39	2329547.06	230523.21	2297953.25	230565.41
	2333324.80	230490.61	2301731.00	230532.80
Line 40	2332304.95	236823.42	2300711.25	236865.66
	2334275.13	237932.62	2302681.50	237974.86

Appendix I (continued)

Lake Texoma

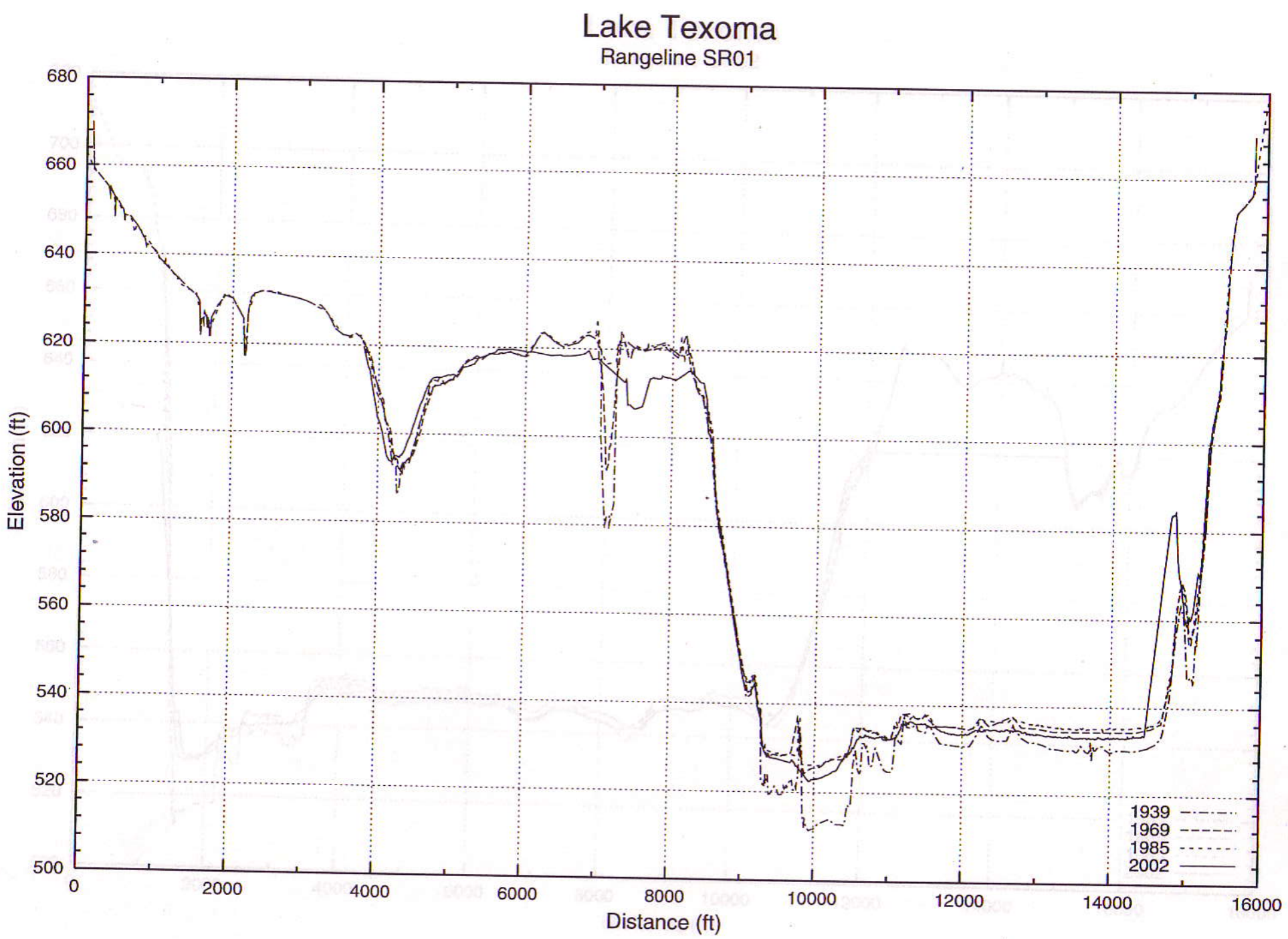
TEXAS WATER DEVELOPMENT BOARD JUNE 2002 SURVEY

Range Line Endpoints

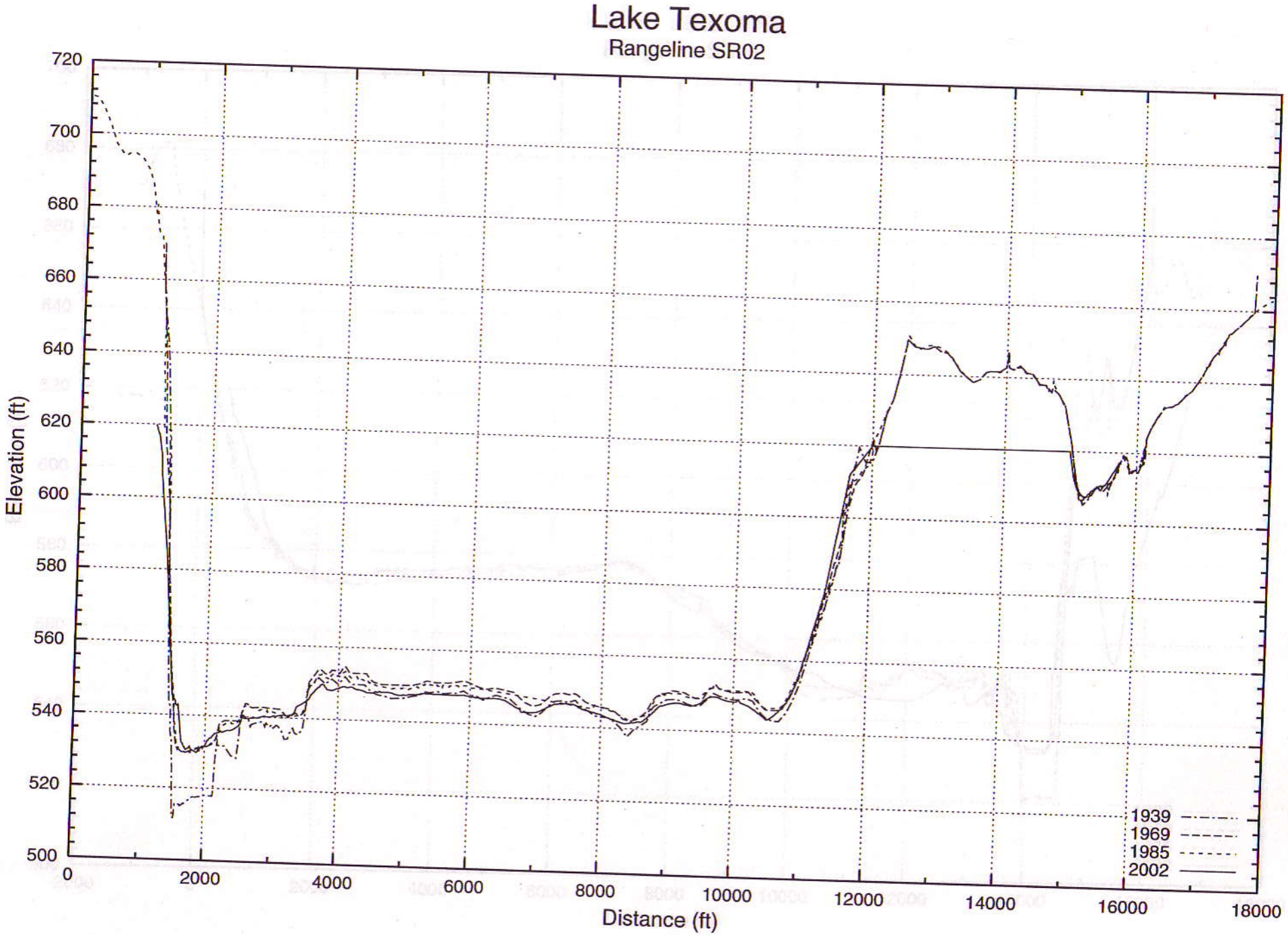
State Plane Oklahoma South Zone - Units-feet

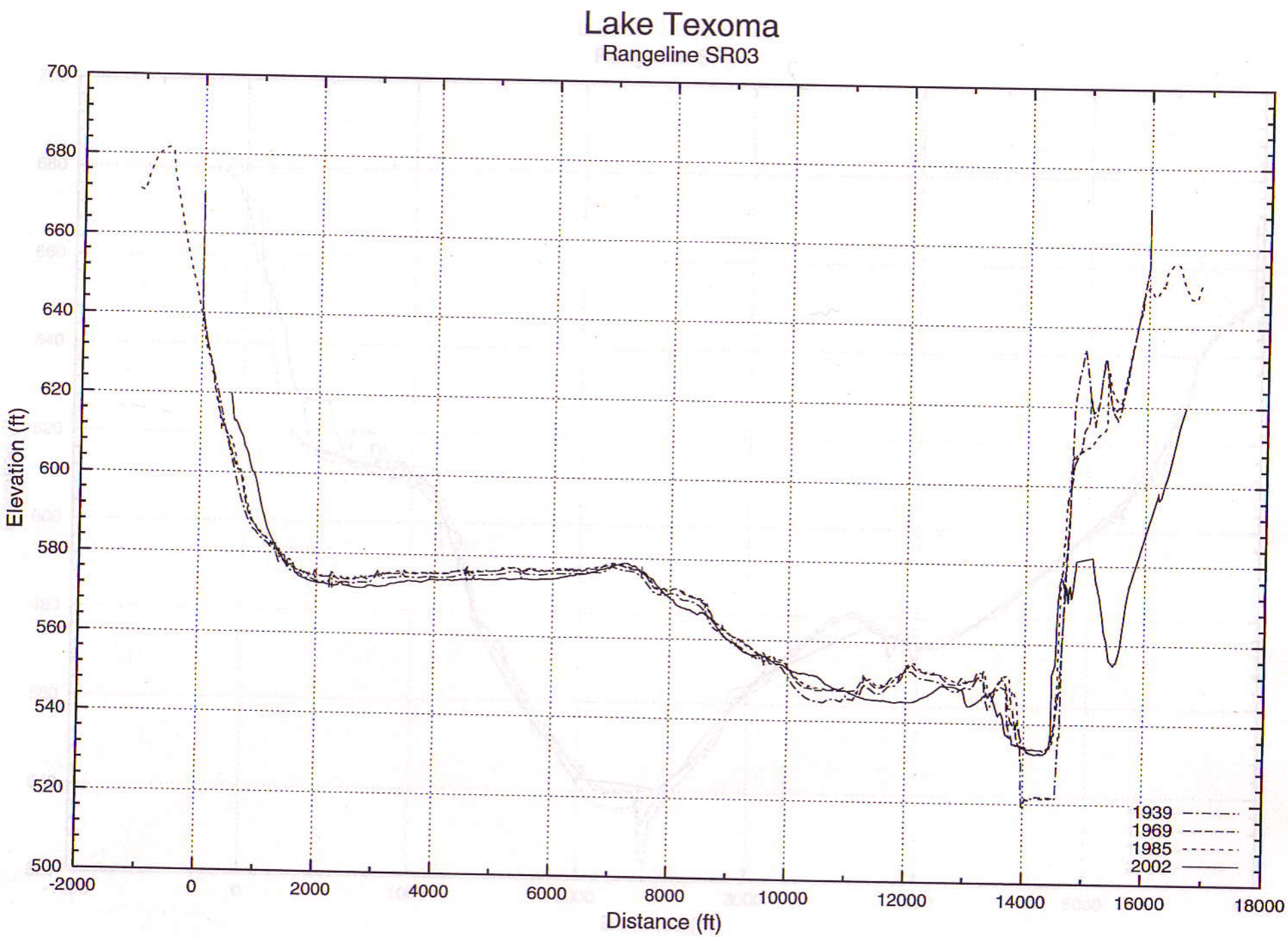
L-Left endpoint
R-right endpoint

Range Line	NAD27 X	NAD27 Y	NAD83 X	NAD83 Y
Line 41	2320493.44	234282.06	2288899.50	234324.31
	2323354.28	233992.85	2291760.25	234035.08
Line 43	2321211.72	220876.41	2289617.75	220918.59
	2314246.04	230786.96	2282652.00	230829.20
Line 44	2308520.47	231223.69	2276926.25	231265.95
	2314451.10	231374.73	2282857.00	231416.98
Line 45	2305141.99	231158.88	2273547.75	231201.16
	2307926.26	231406.83	2276332.00	231449.09
Line 46	2315833.45	218652.44	2284239.50	218694.63
	2303666.79	217288.63	2272072.50	217330.84
Line 47	2303010.91	211078.33	2271416.75	211120.52
	2308889.08	211445.80	2277295.00	211487.97
Line 48	2304248.19	199952.29	2272654.00	199994.44
	2308071.20	198187.34	2276477.25	198229.45


Lake Texoma
Rangeline SR01
Elevation (ft)
680
660
640
620
600
580
560
540
520
500
0
2000
4000
6000
8000
10000
12000
14000
16000
Distance (ft)
1939
1969
1985
2002

Appendix J

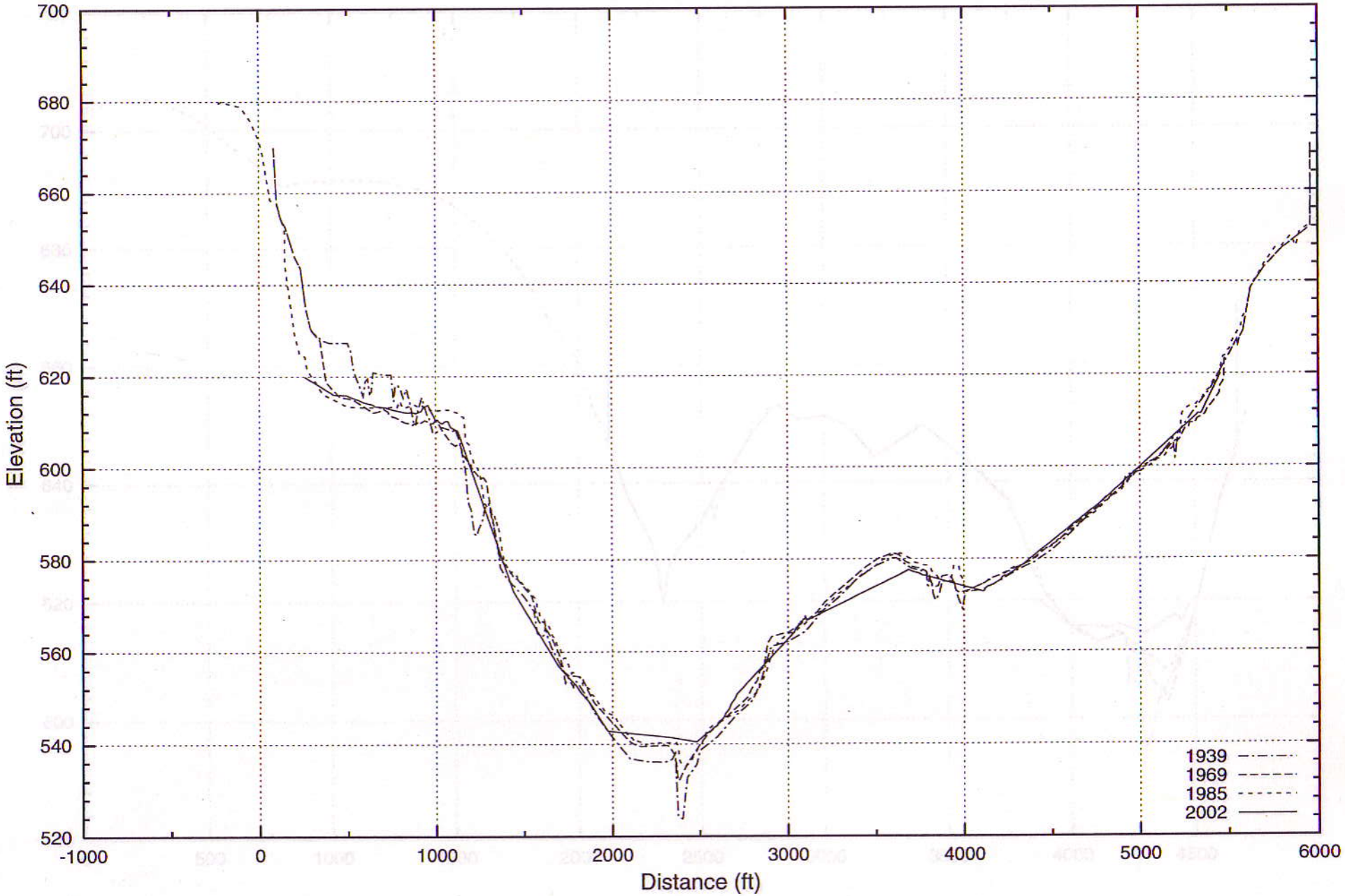

Lake Texoma
Rangeline SR02
Elevation (ft)
720
700
680
660
640
620
600
580
560
540
520
500
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
Distance (ft)
1939
1969
1985
2002


Lake Texoma
Rangeline SR03
Elevation (ft)
700
680
660
640
620
600
580
560
540
520
500
-2000
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
Distance (ft)
1939
1969
1985
2002

Appendix J

Lake Texoma

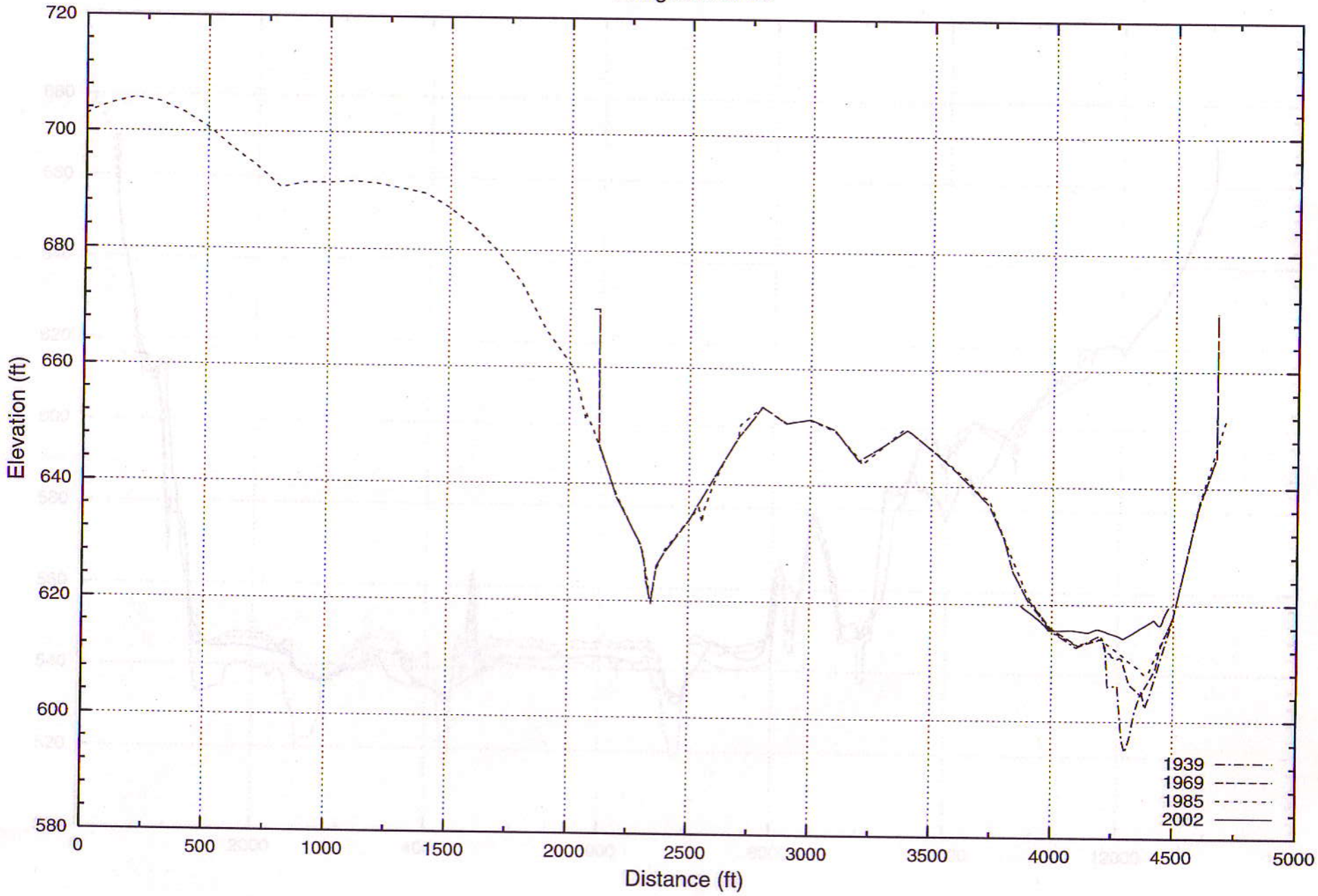
Rangeline SR04



Appendix J

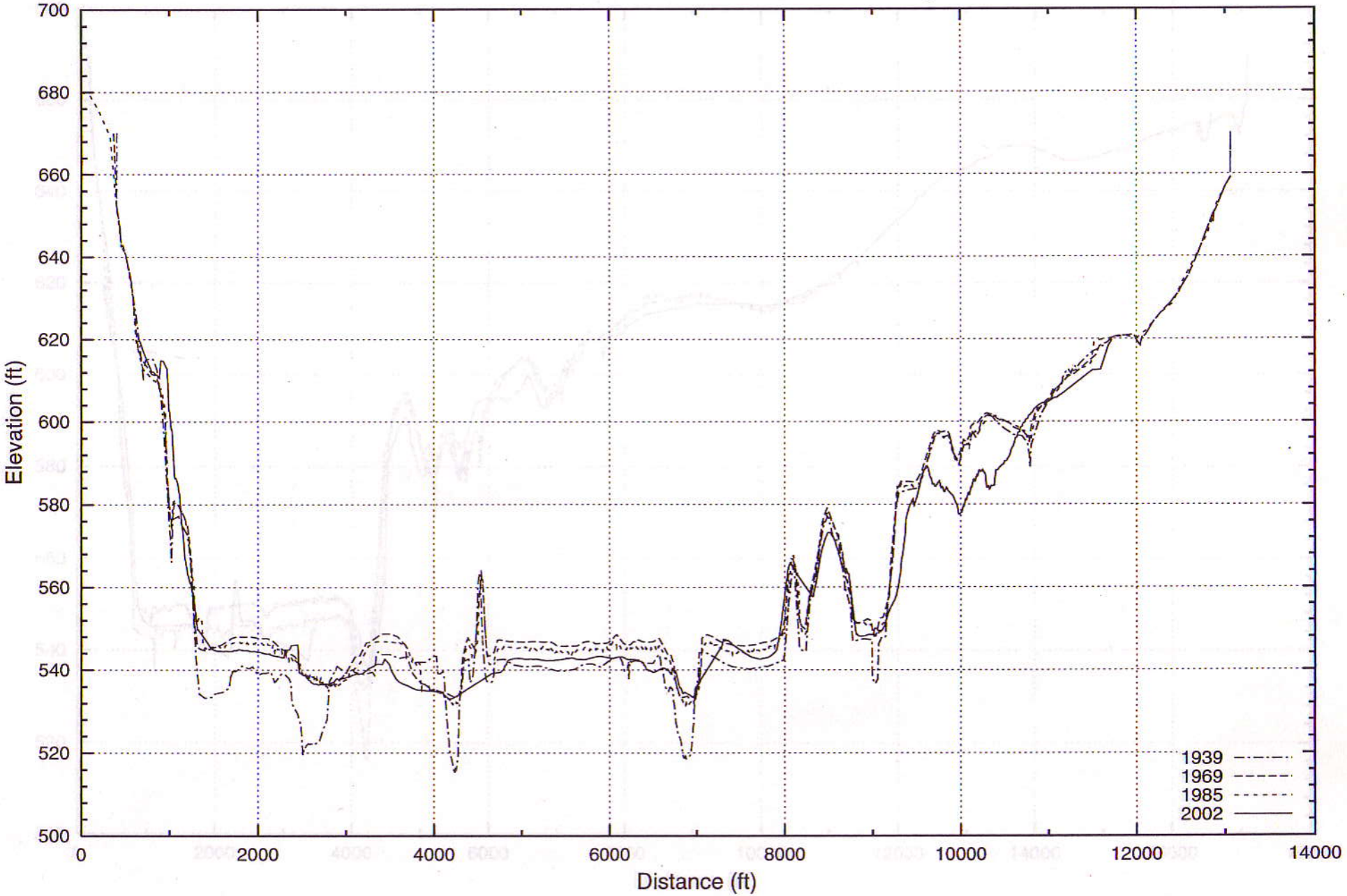
Lake Texoma

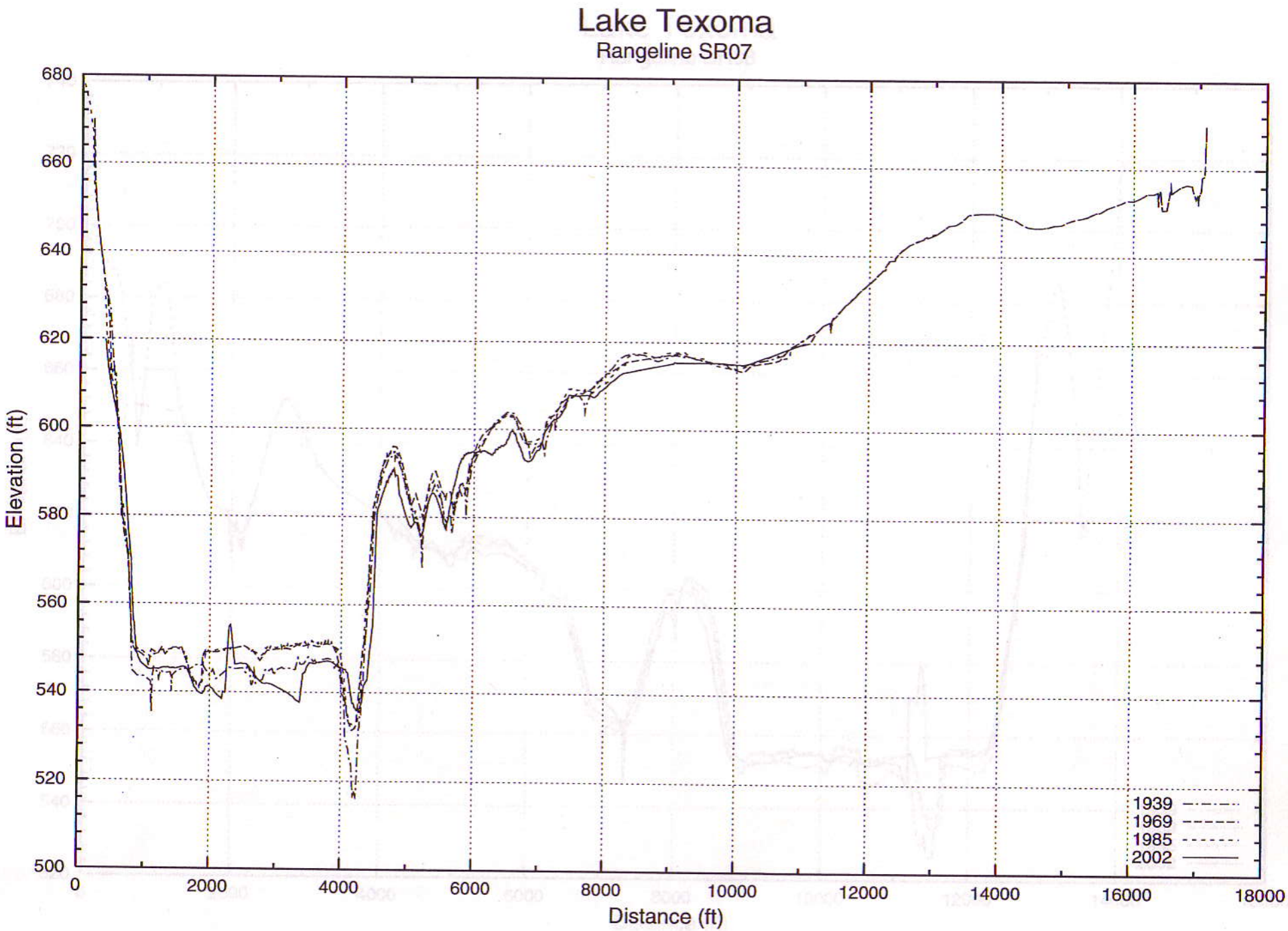
Rangeline SR05



Lake Texoma

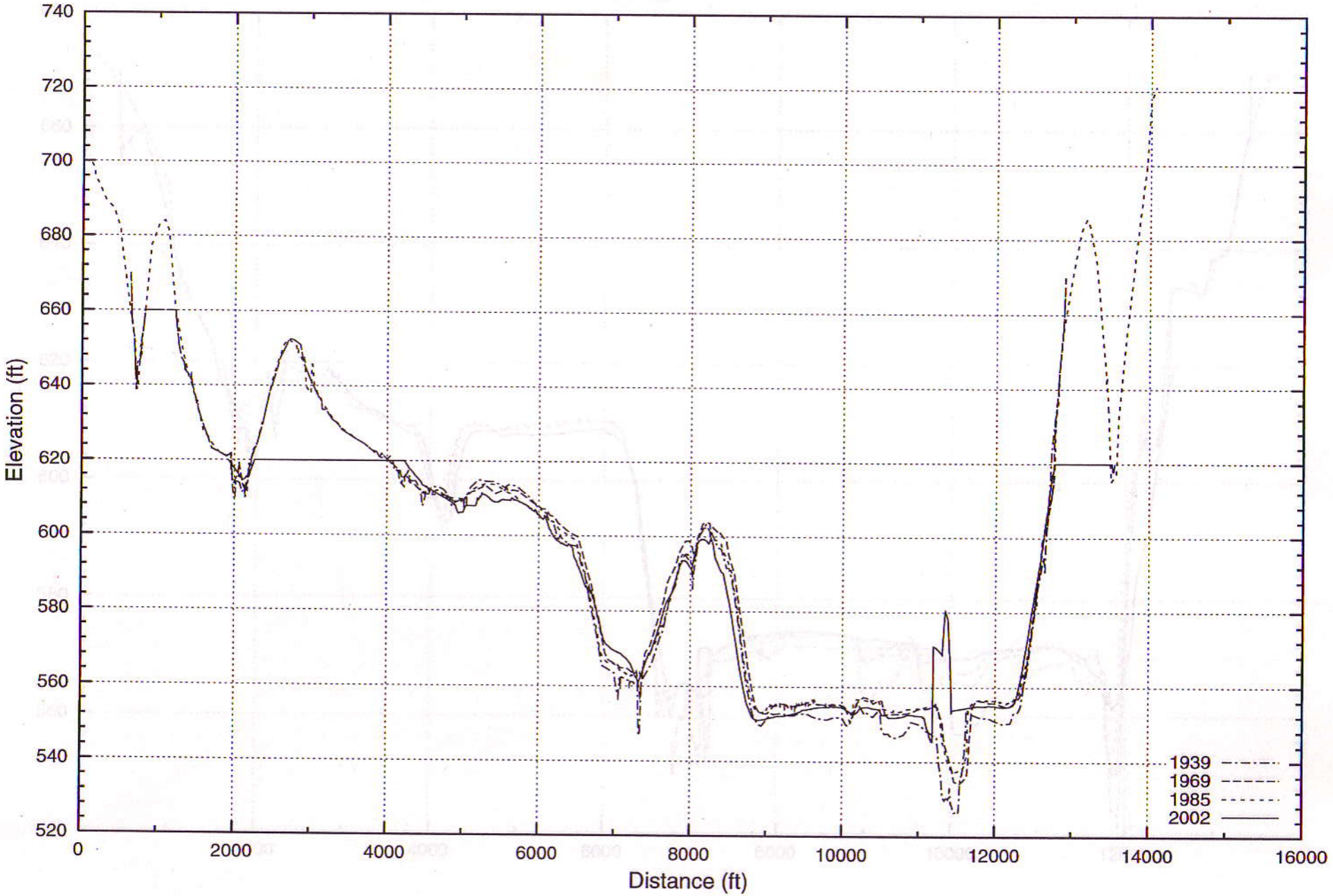
Rangeline SR06




Lake Texoma
Rangeline SR07
Elevation (ft)
680
660
640
620
600
580
560
540
520
500
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
Distance (ft)
1939
1969
1985
2002

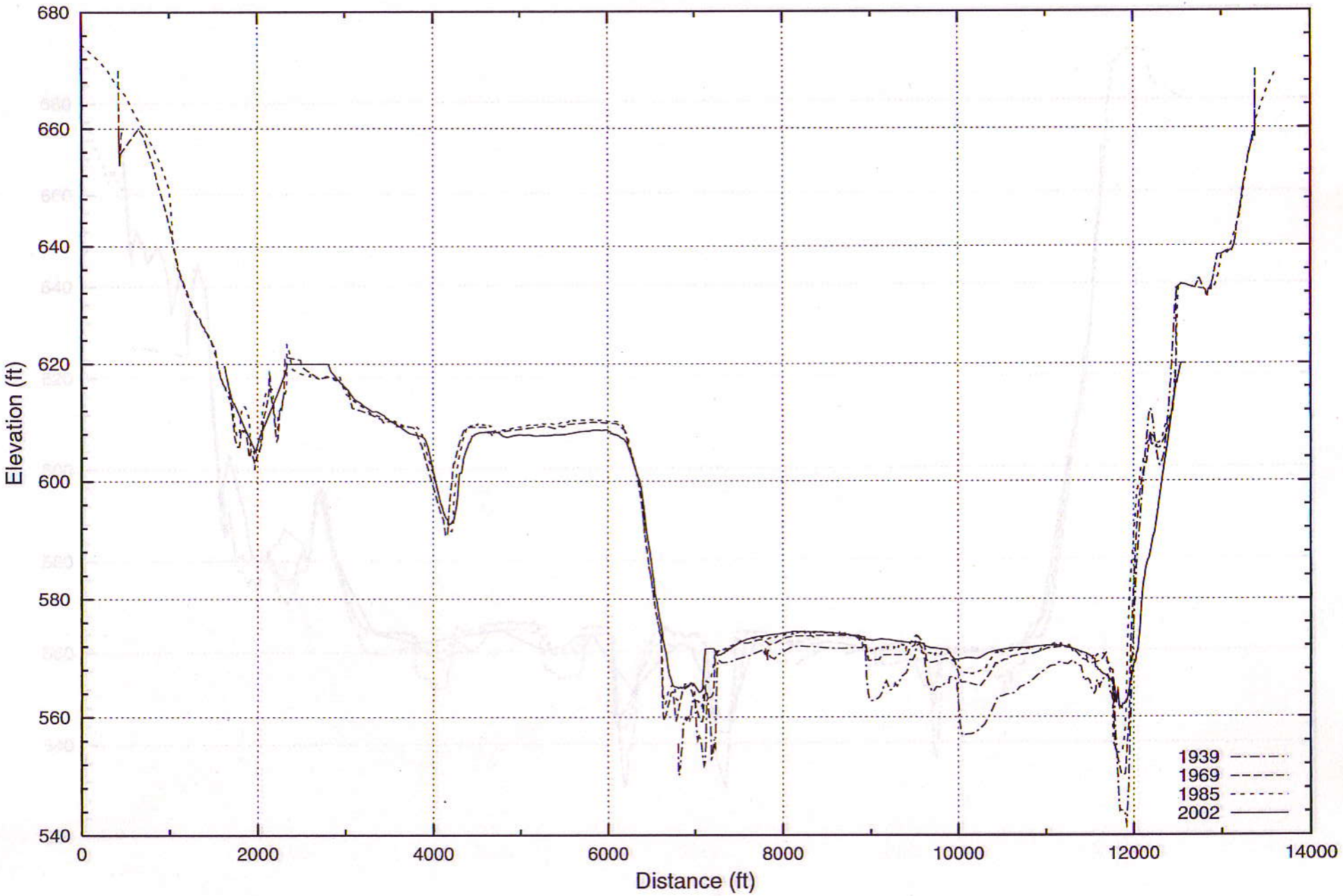
Lake Texoma

Rangeline SR08



Lake Texoma

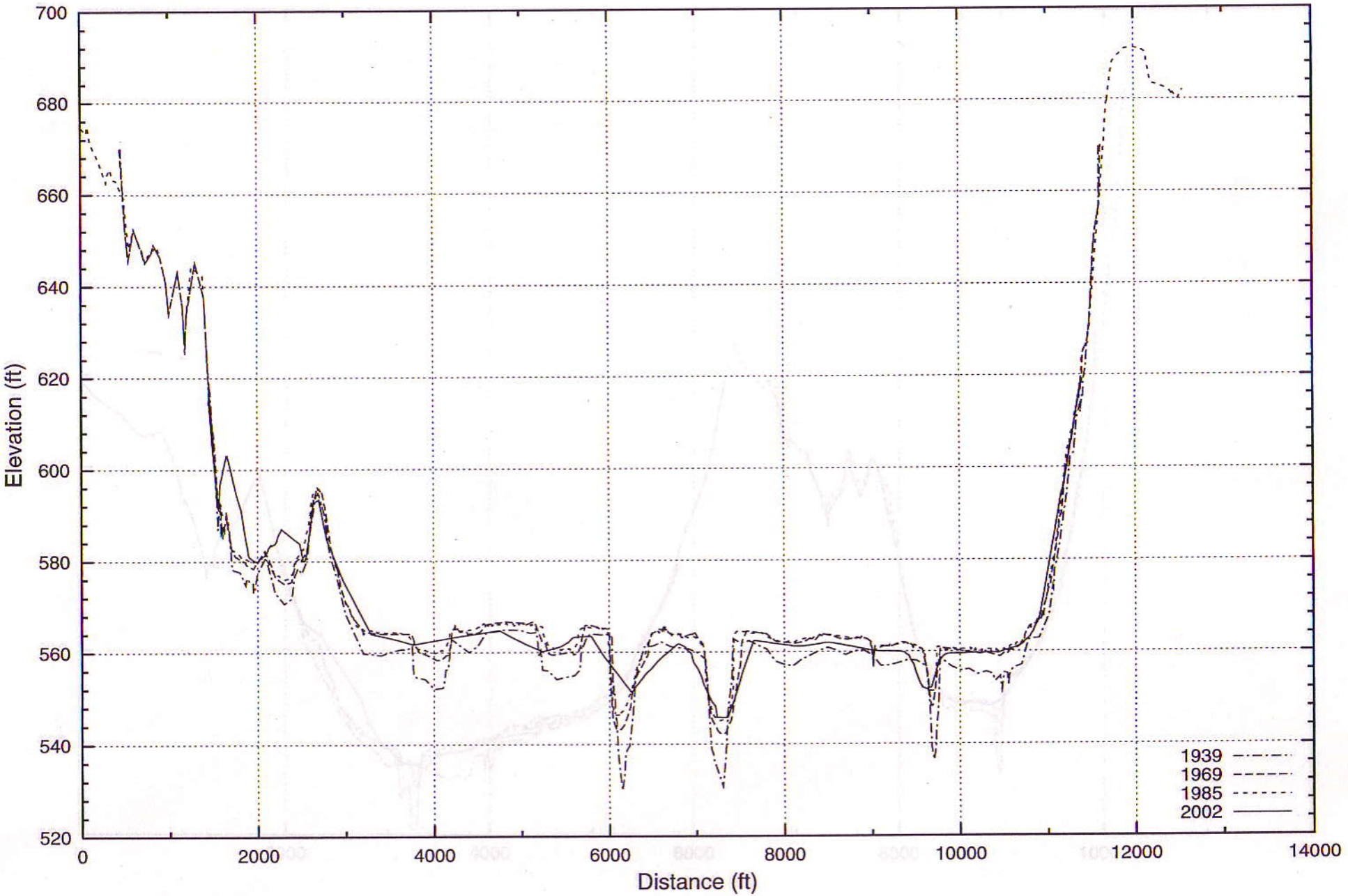
Rangeline SR09

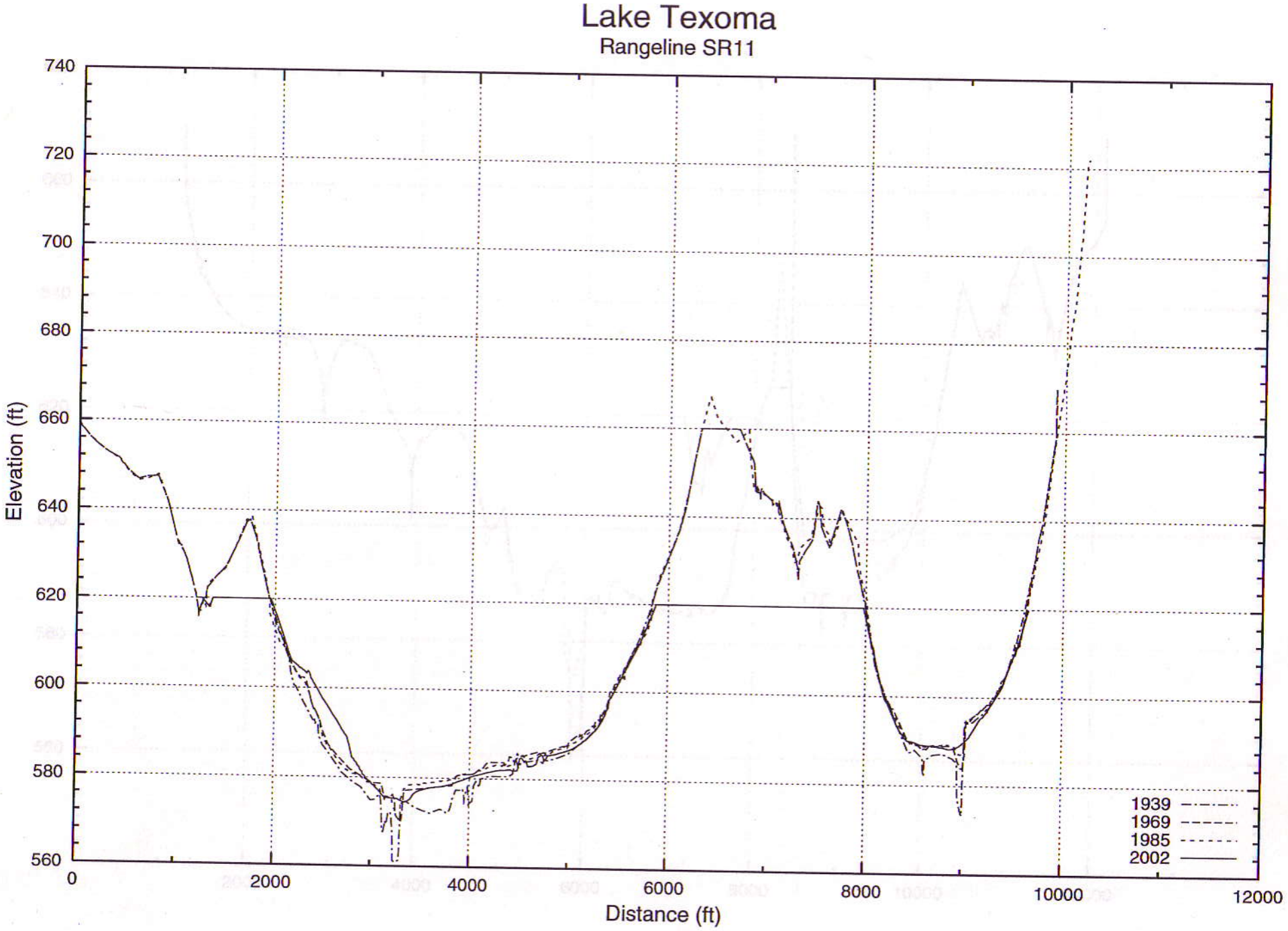


Appendix J

Lake Texoma

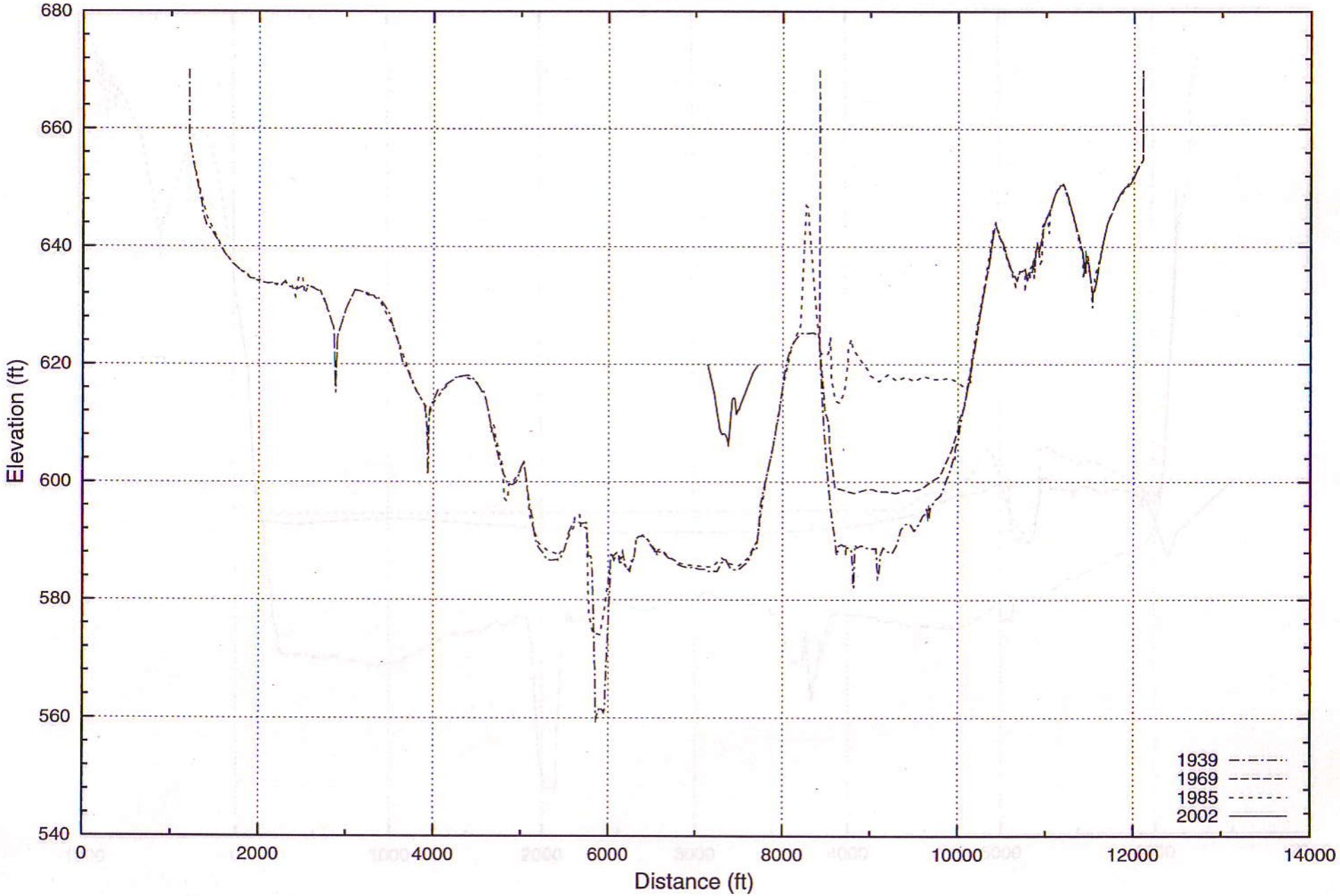
Rangeline SR10



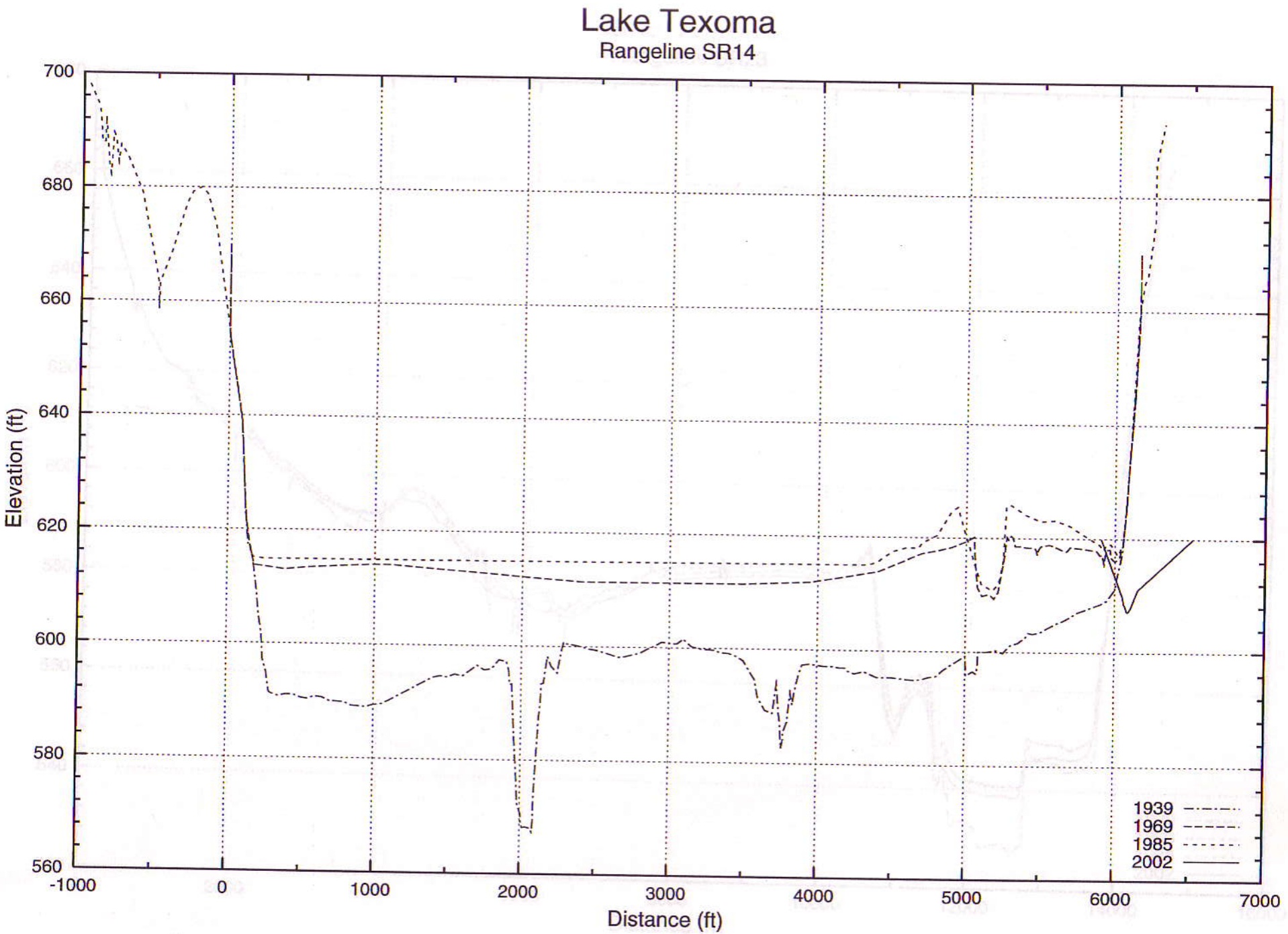

Lake Texoma
Rangeline SR11
740
720
700
680
660
640
620
600
580
560
Elevation (ft)
0
2000
4000
6000
8000
10000
12000
Distance (ft)
1939
1969
1985
2002

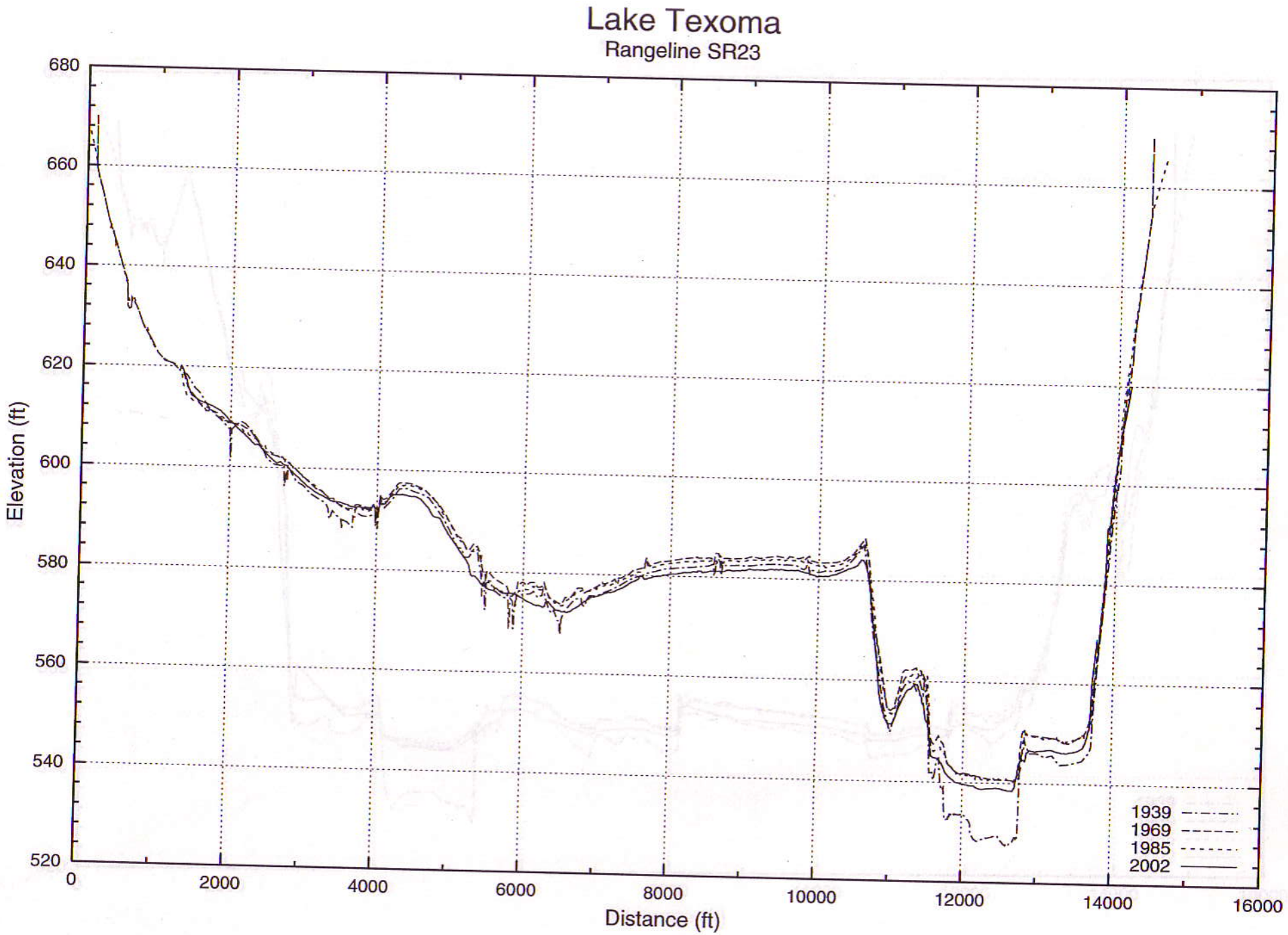
Lake Texoma

Rangeline SR13



Appendix J

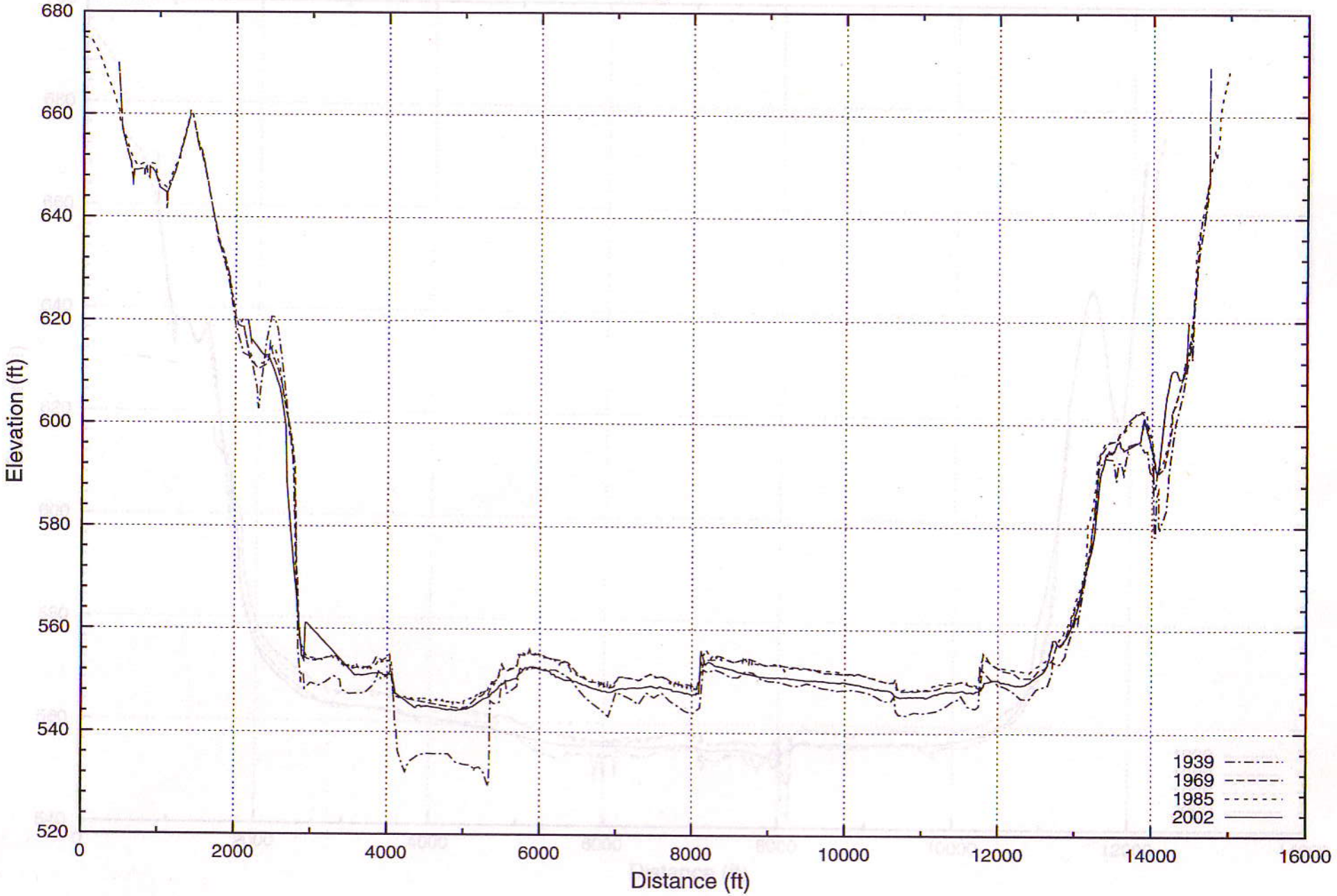

Lake Texoma
Rangeline SR14
Elevation (ft)
700
680
660
640
620
600
580
560
-1000
0
1000
2000
3000
4000
5000
6000
7000
Distance (ft)
1939
1969
1985
2002


Lake Texoma
Rangeline SR23
680
660
640
620
600
580
560
540
520
Elevation (ft)
0
2000
4000
6000
8000
10000
12000
14000
16000
Distance (ft)
1939
1969
1985
2002

Appendix J

Lake Texoma

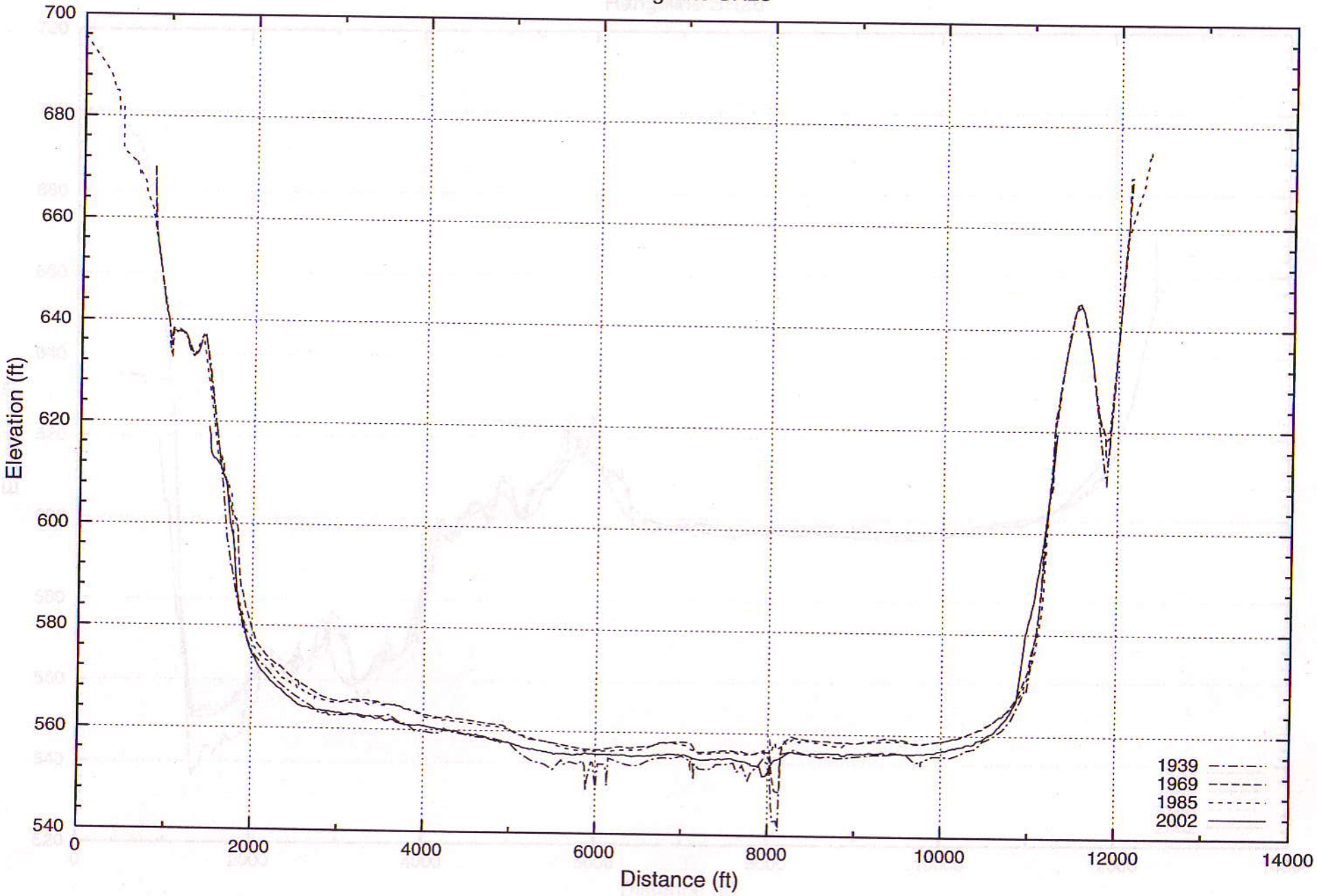
Rangeline SR24



Appendix J

Lake Texoma

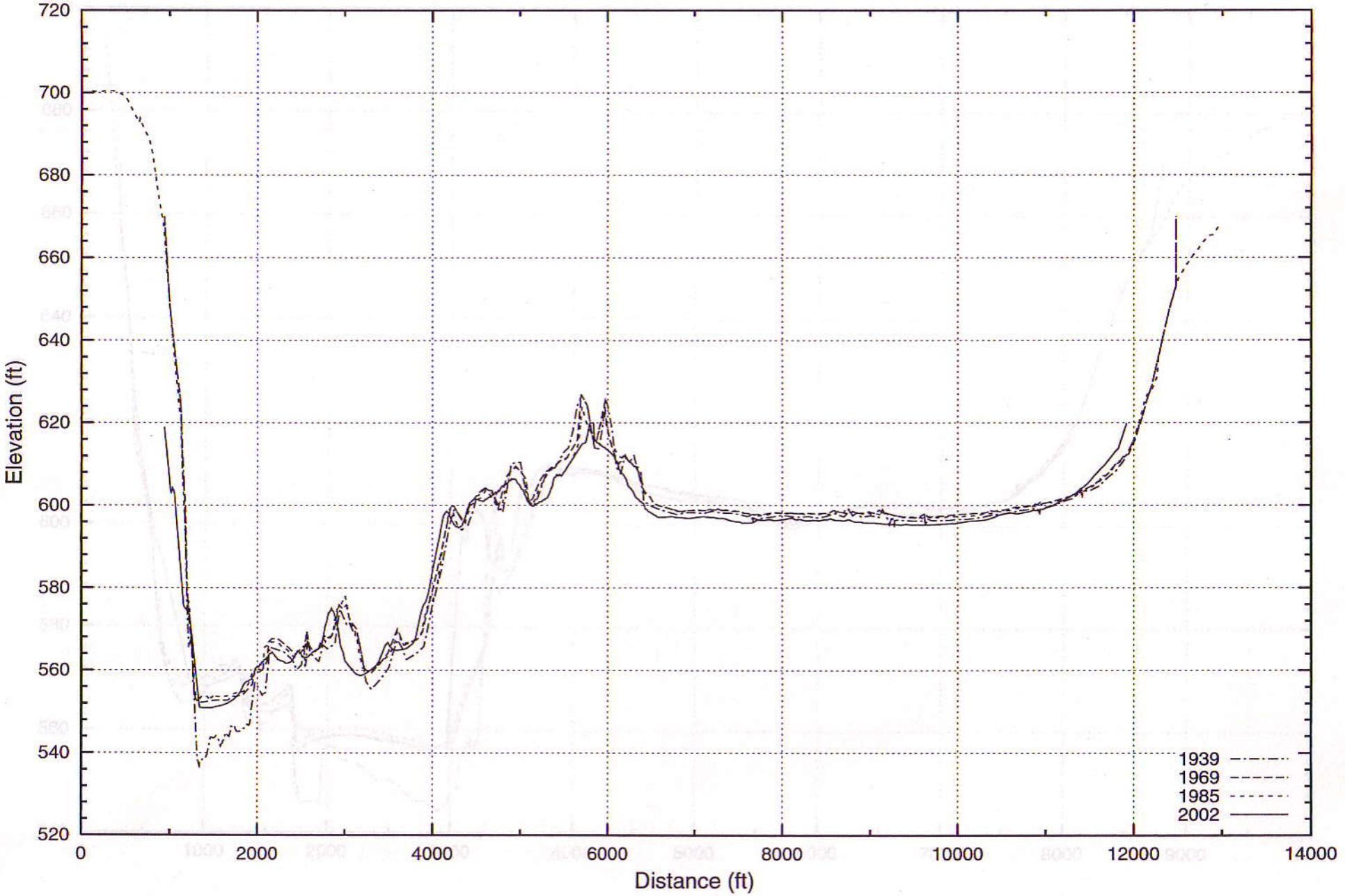
Rangeline SR25



Appendix J

Lake Texoma

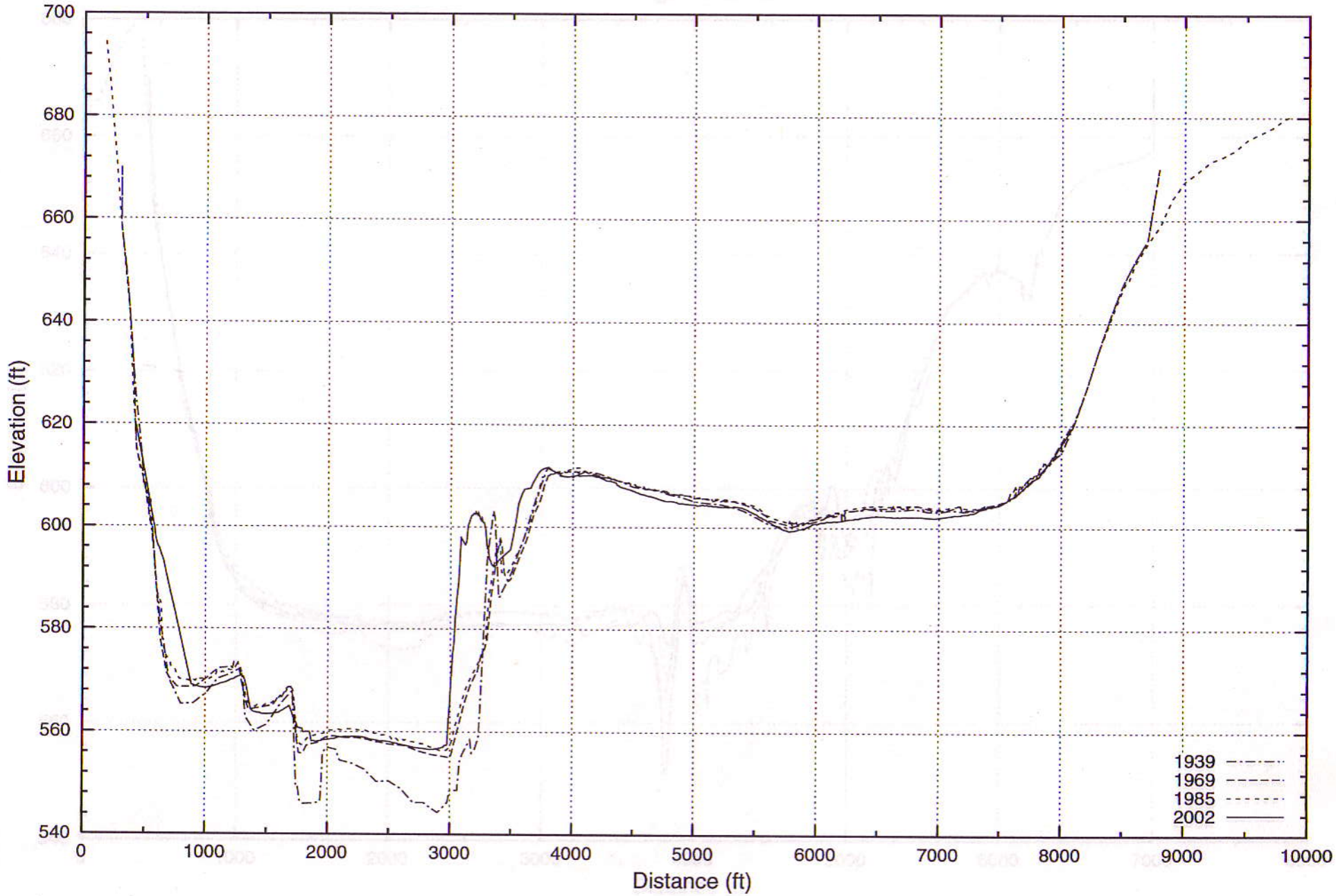
Rangeline SR26



Appendix J

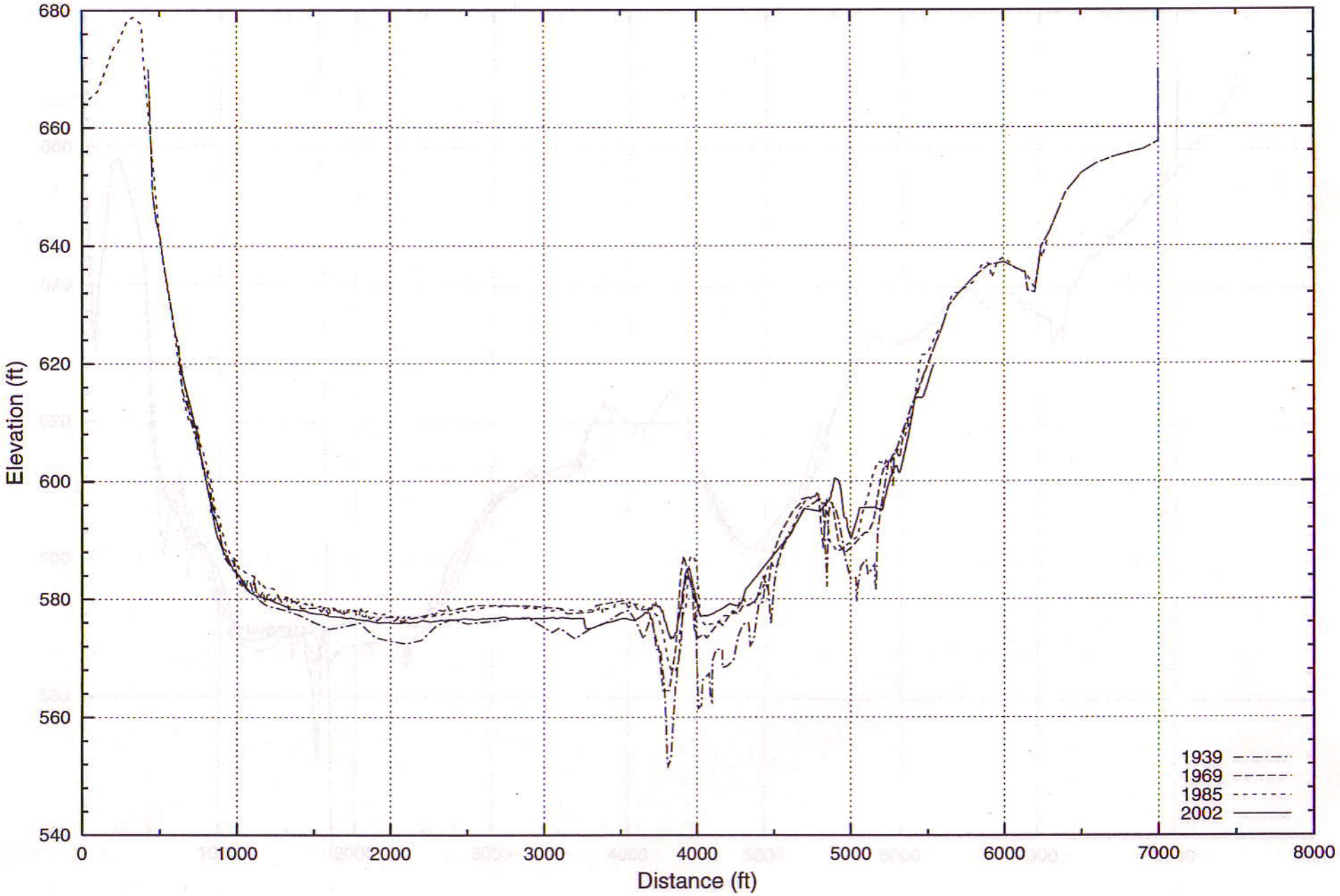
Lake Texoma

Rangeline SR27



Lake Texoma

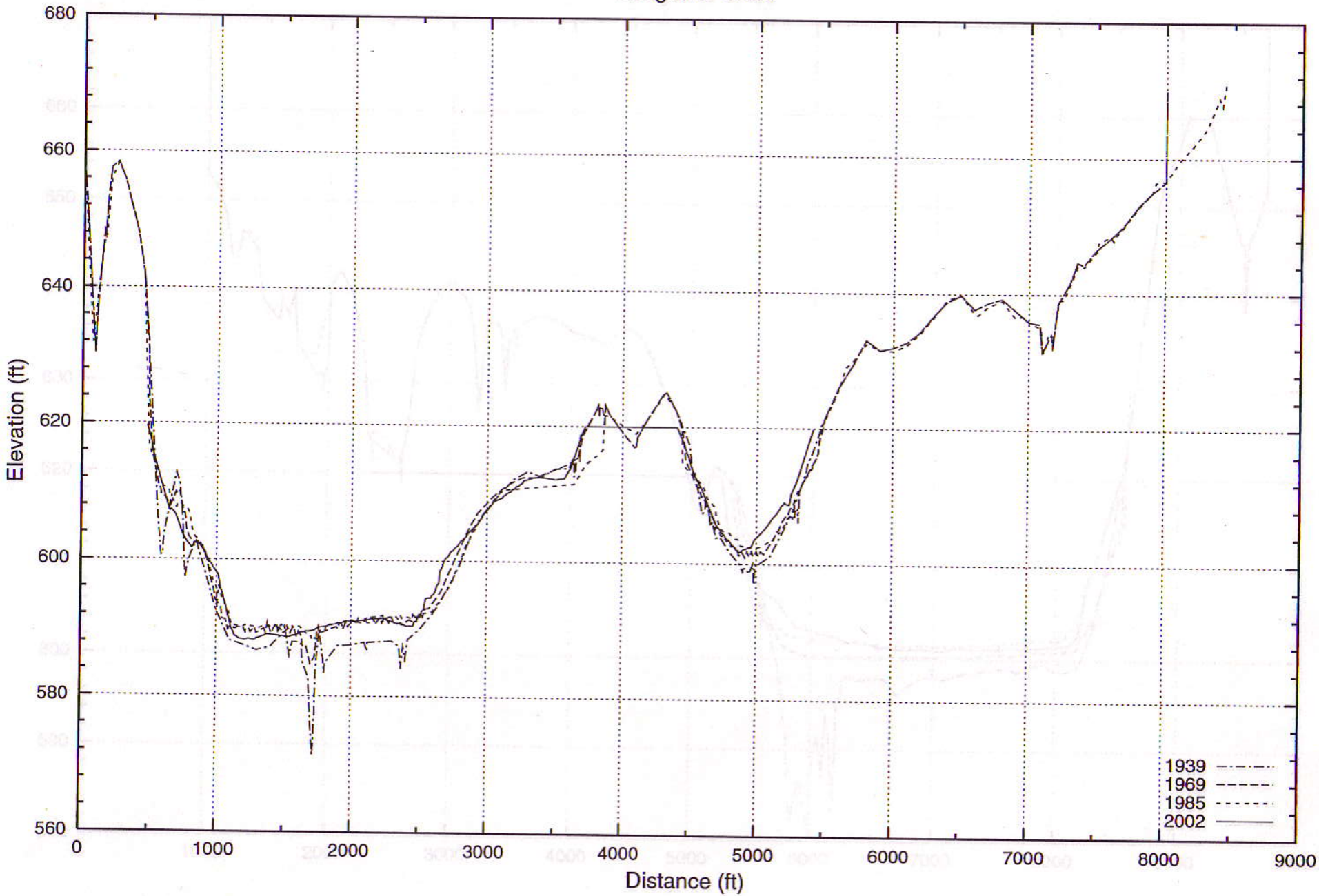
Rangeline SR28



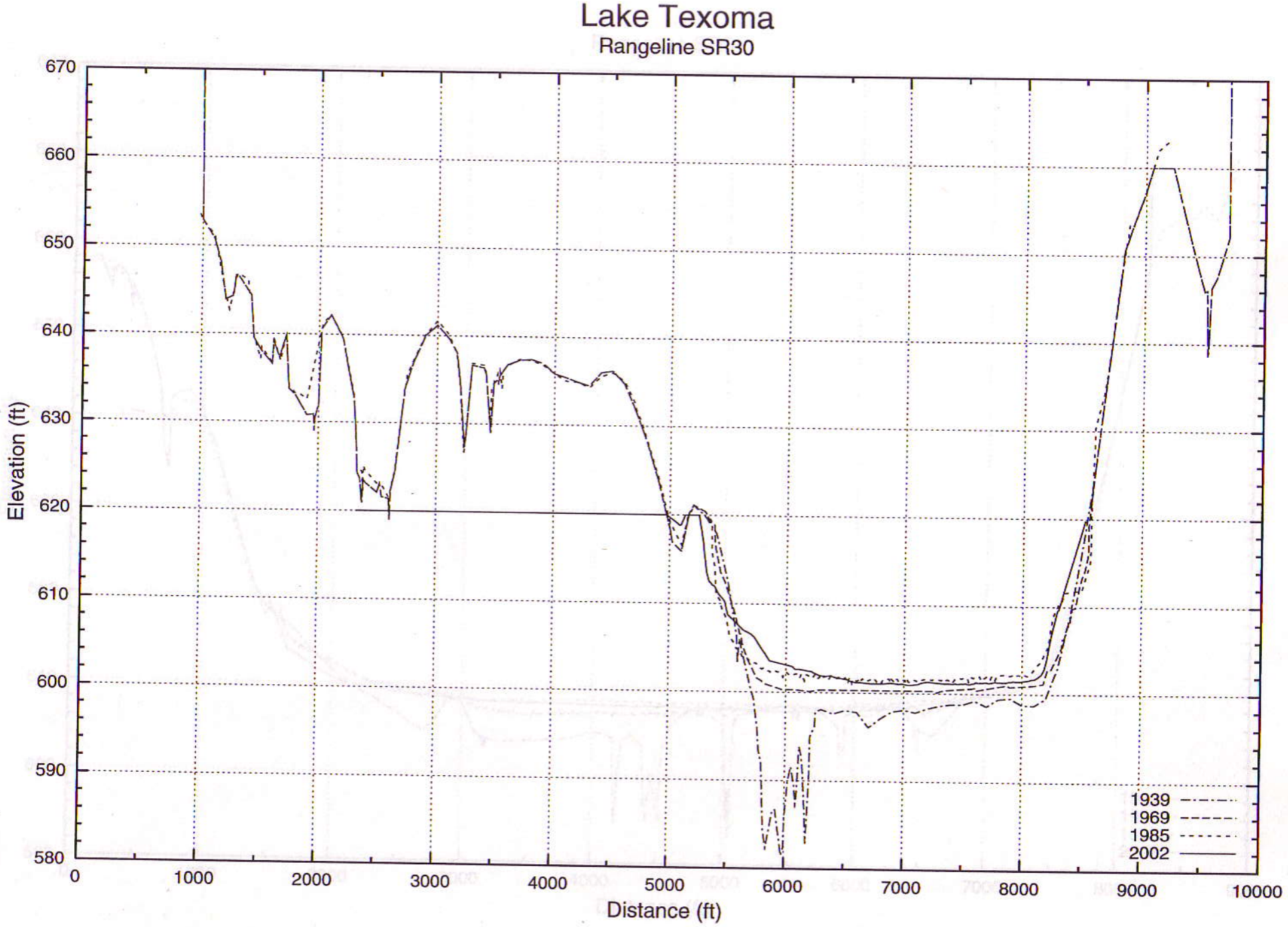
Appendix J

Lake Texoma

Rangeline SR29

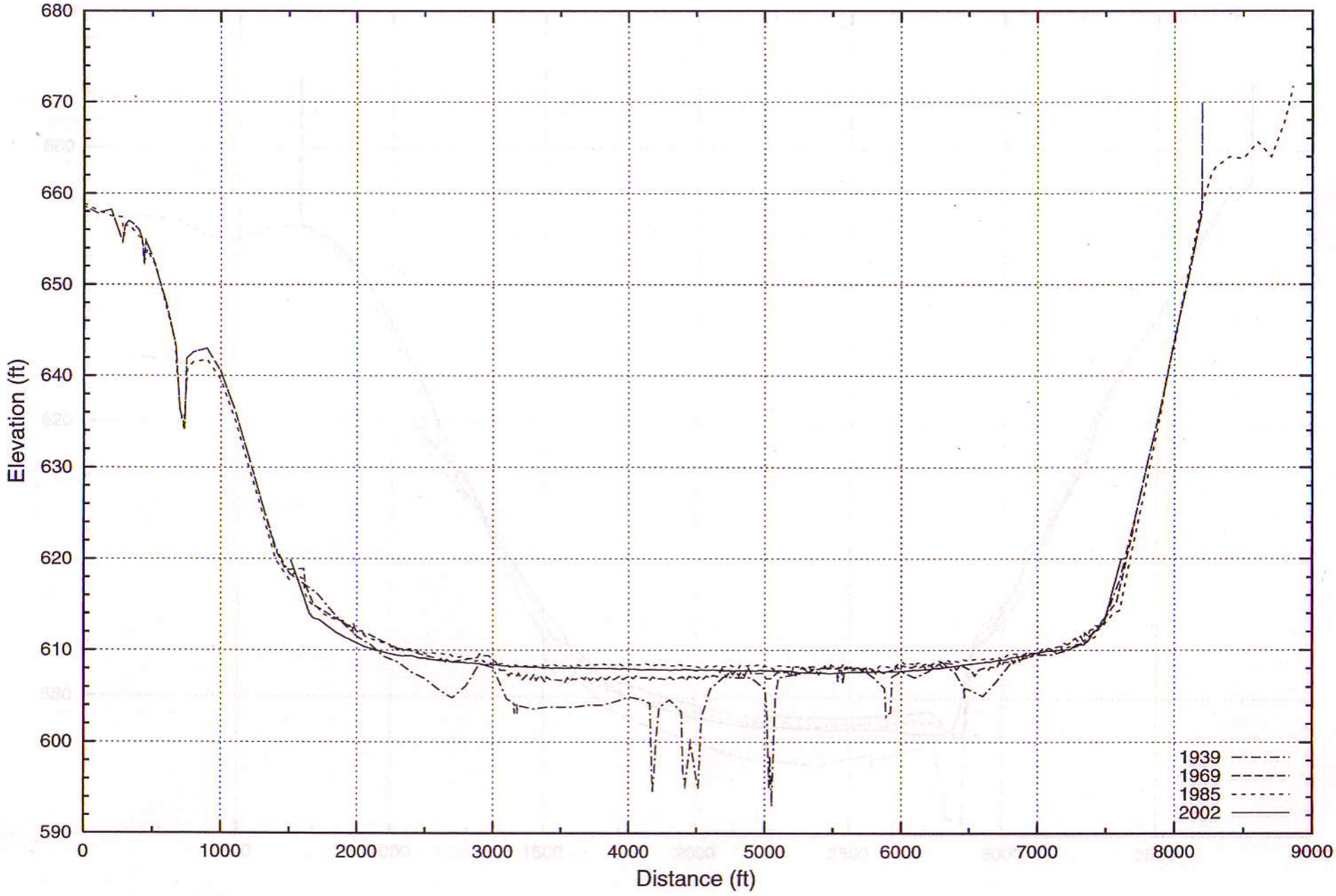


Appendix J

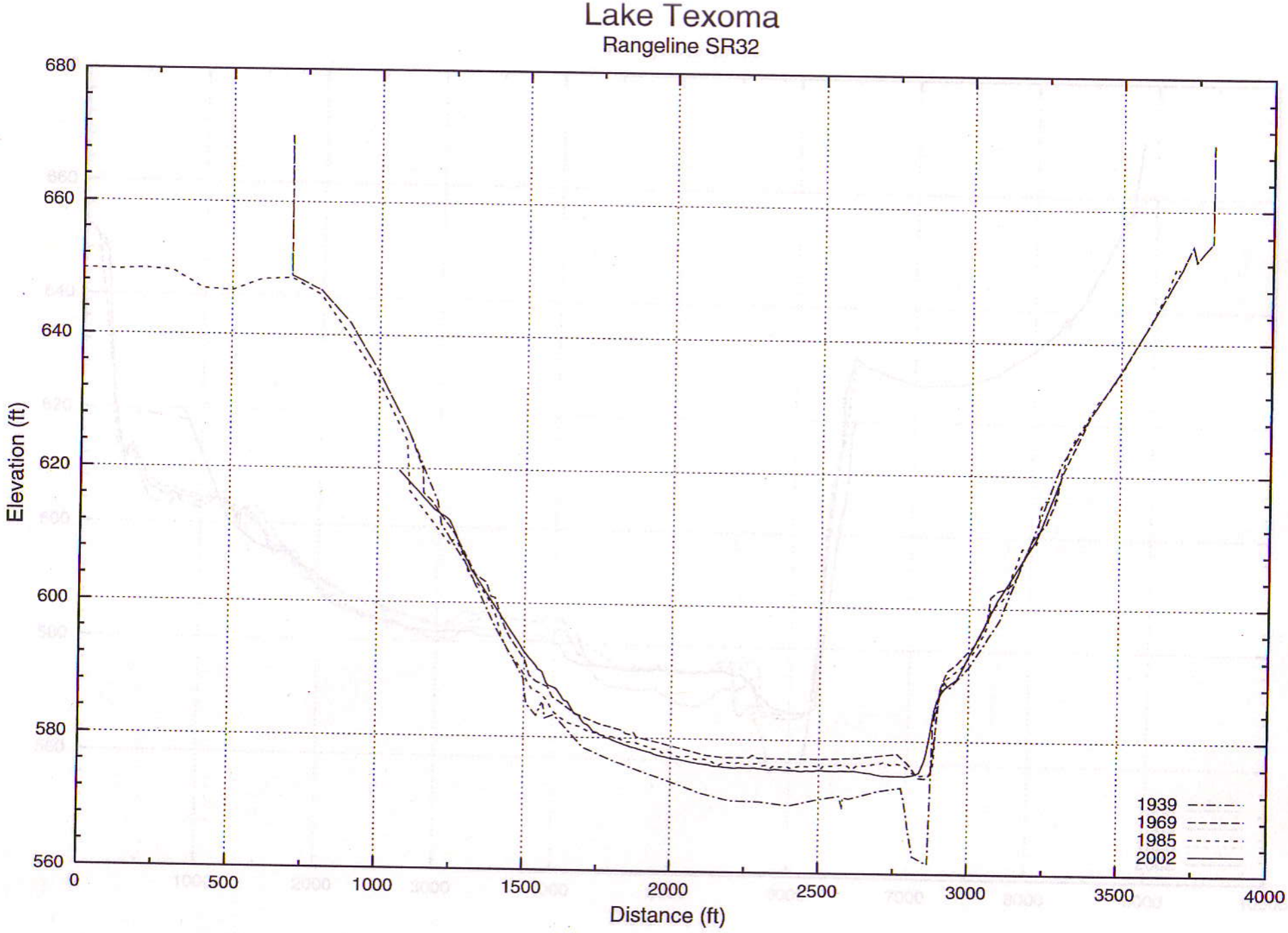

Lake Texoma
Rangeline SR30
Elevation (ft)
670
660
650
640
630
620
610
600
590
580
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
Distance (ft)
1939
1969
1985
2002

Lake Texoma

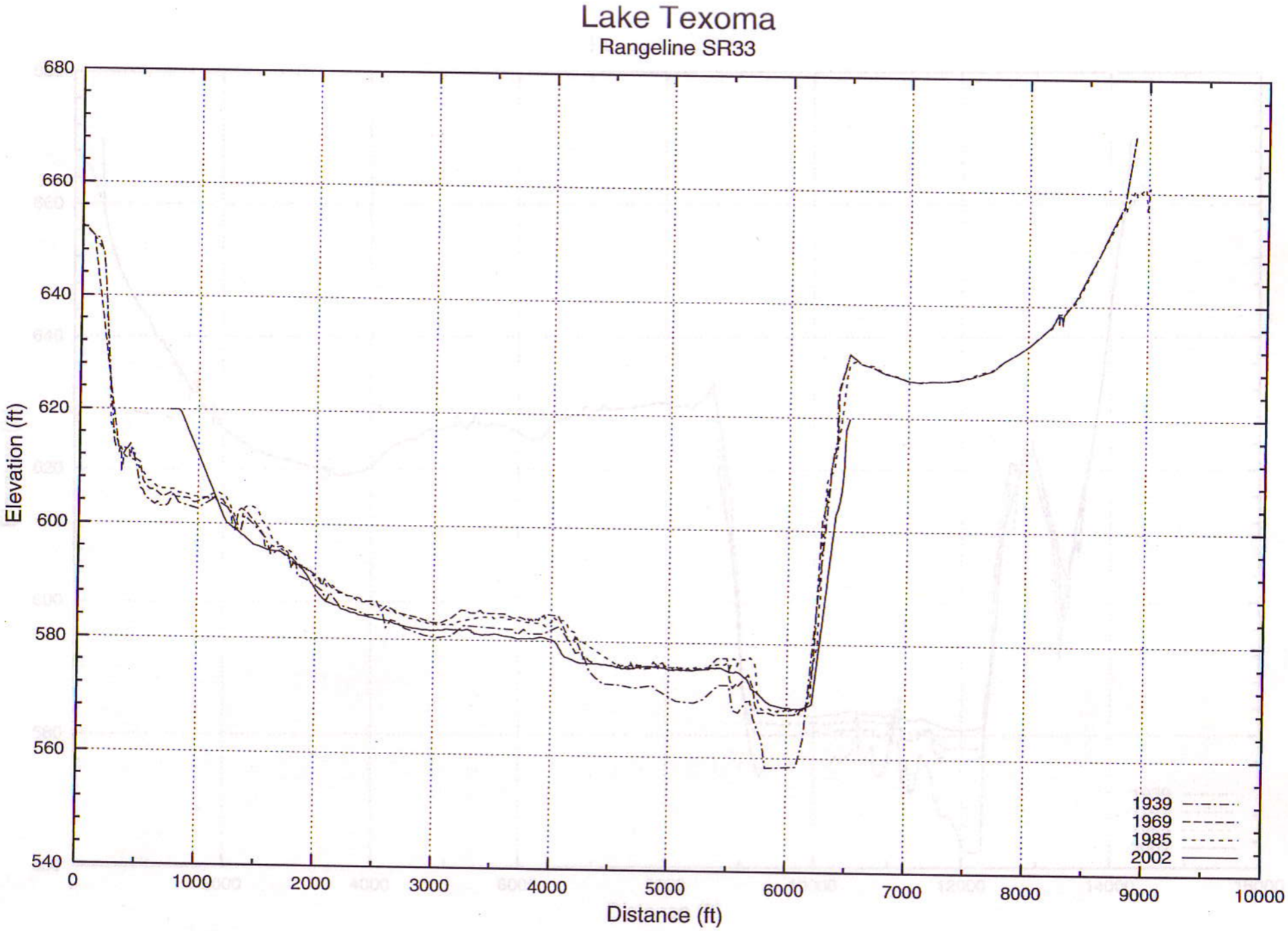
Rangeline SR31



Appendix J


Lake Texoma
Rangeline SR32
680
660
640
620
600
580
560
Elevation (ft)
0
500
1000
1500
2000
2500
3000
3500
4000
Distance (ft)
1939
1969
1985
2002

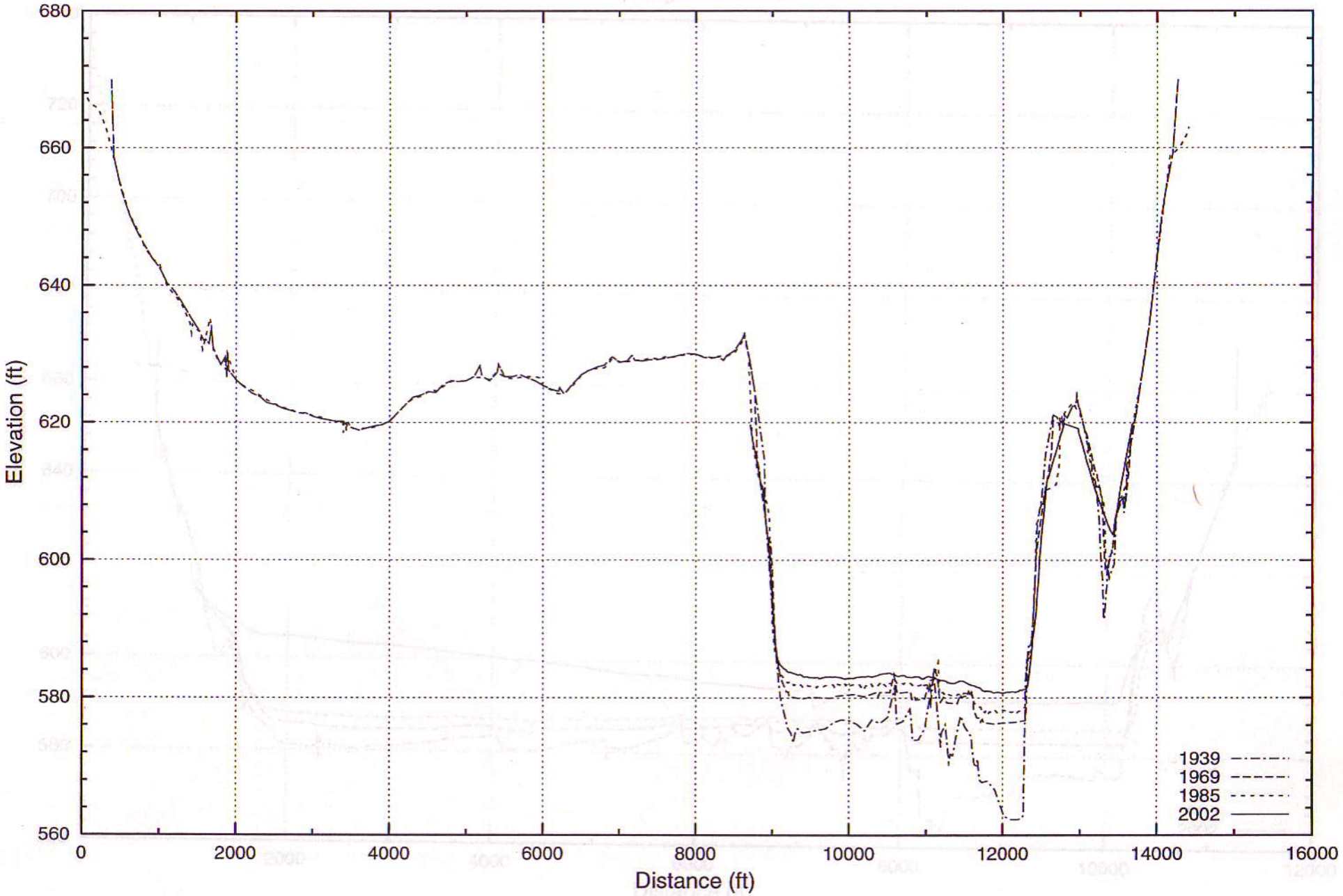
Appendix J


Lake Texoma
Rangeline SR33
Elevation (ft)
680
660
640
620
600
580
560
540
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
Distance (ft)
1939
1969
1985
2002

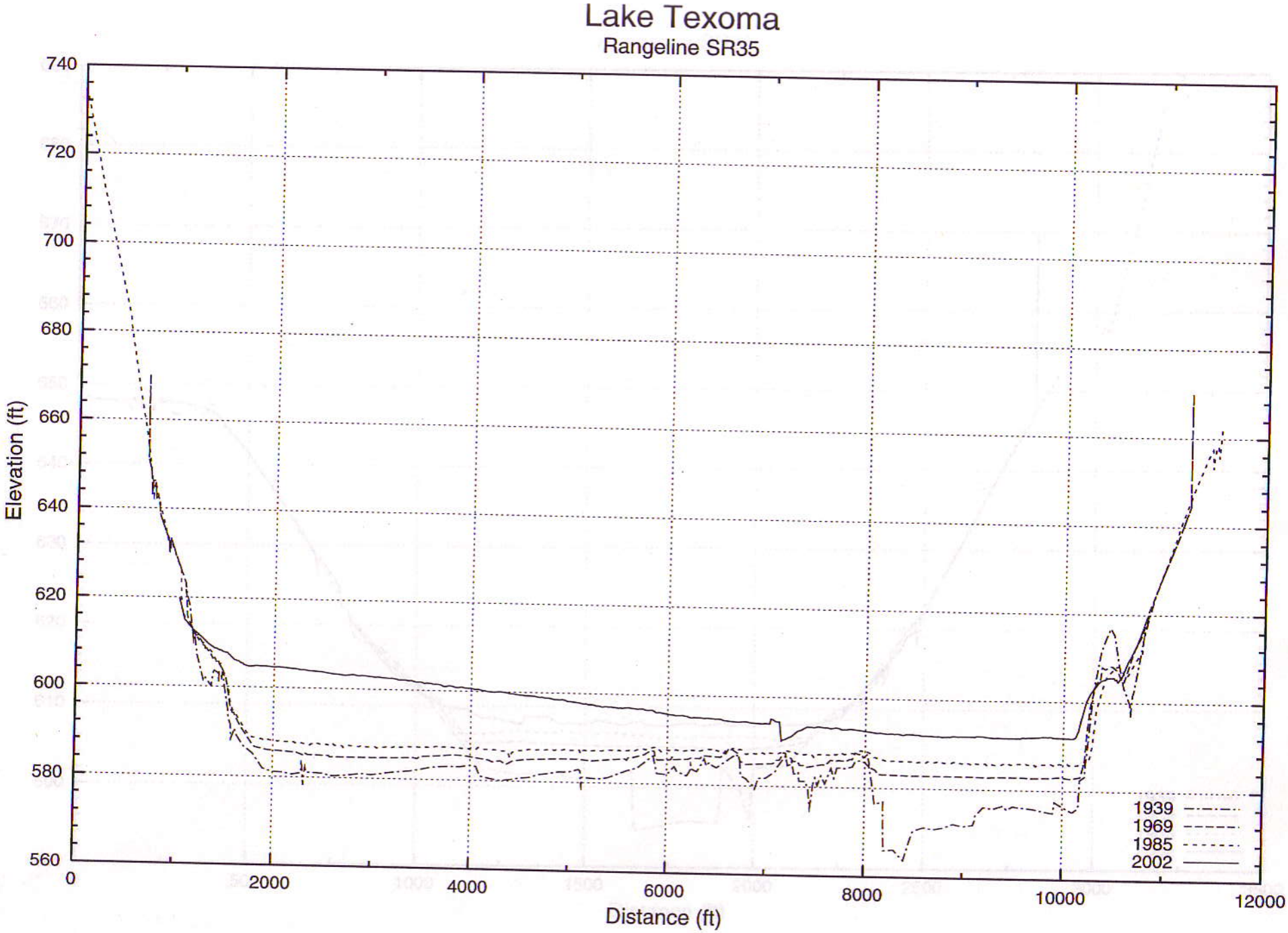
Appendix J

Lake Texoma

Rangeline SR34

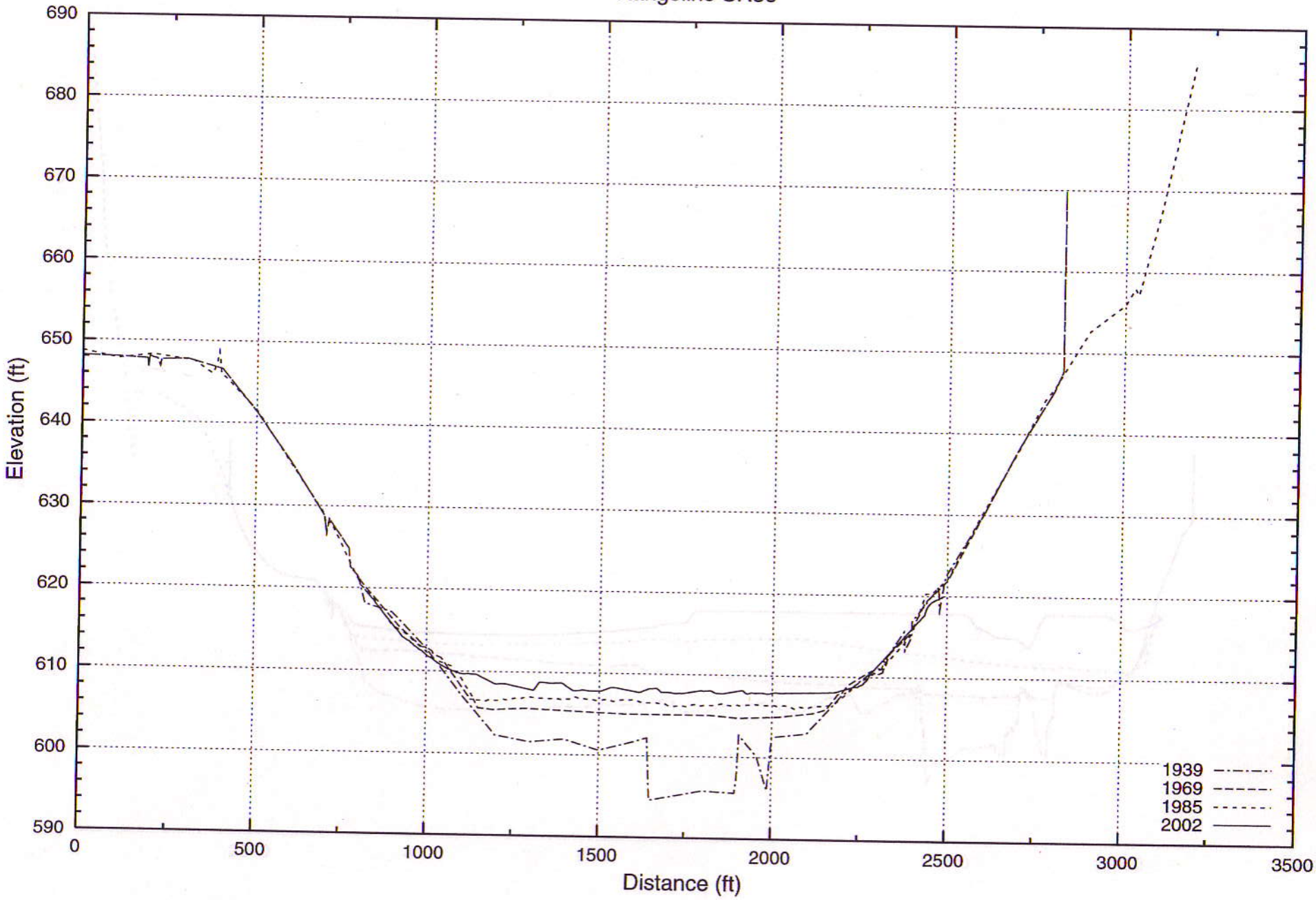


Appendix J

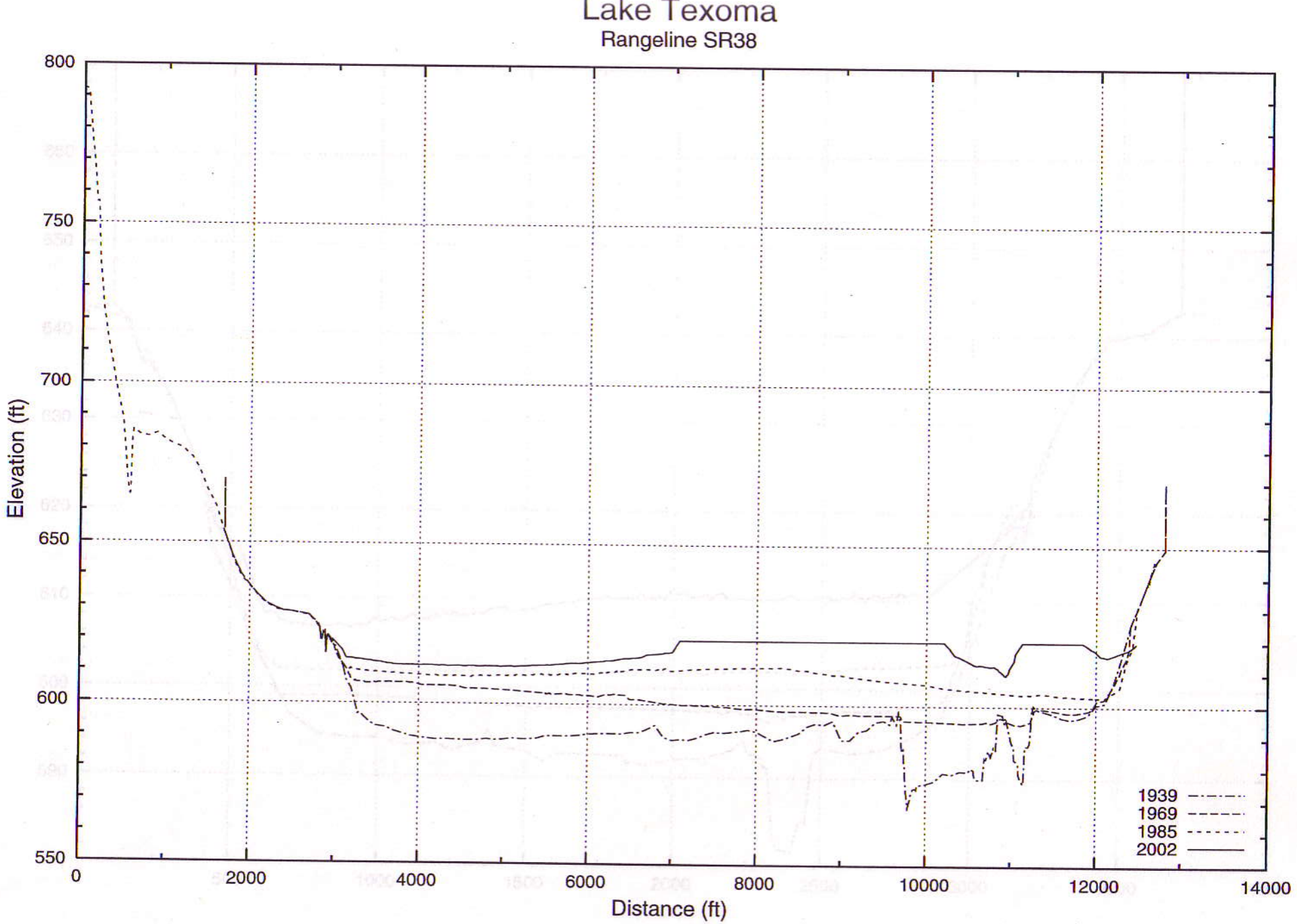

Lake Texoma
Rangeline SR35
740
720
700
680
660
640
620
600
580
560
Elevation (ft)
0
2000
4000
6000
8000
10000
12000
Distance (ft)
1939
1969
1985
2002

Lake Texoma

Rangeline SR36



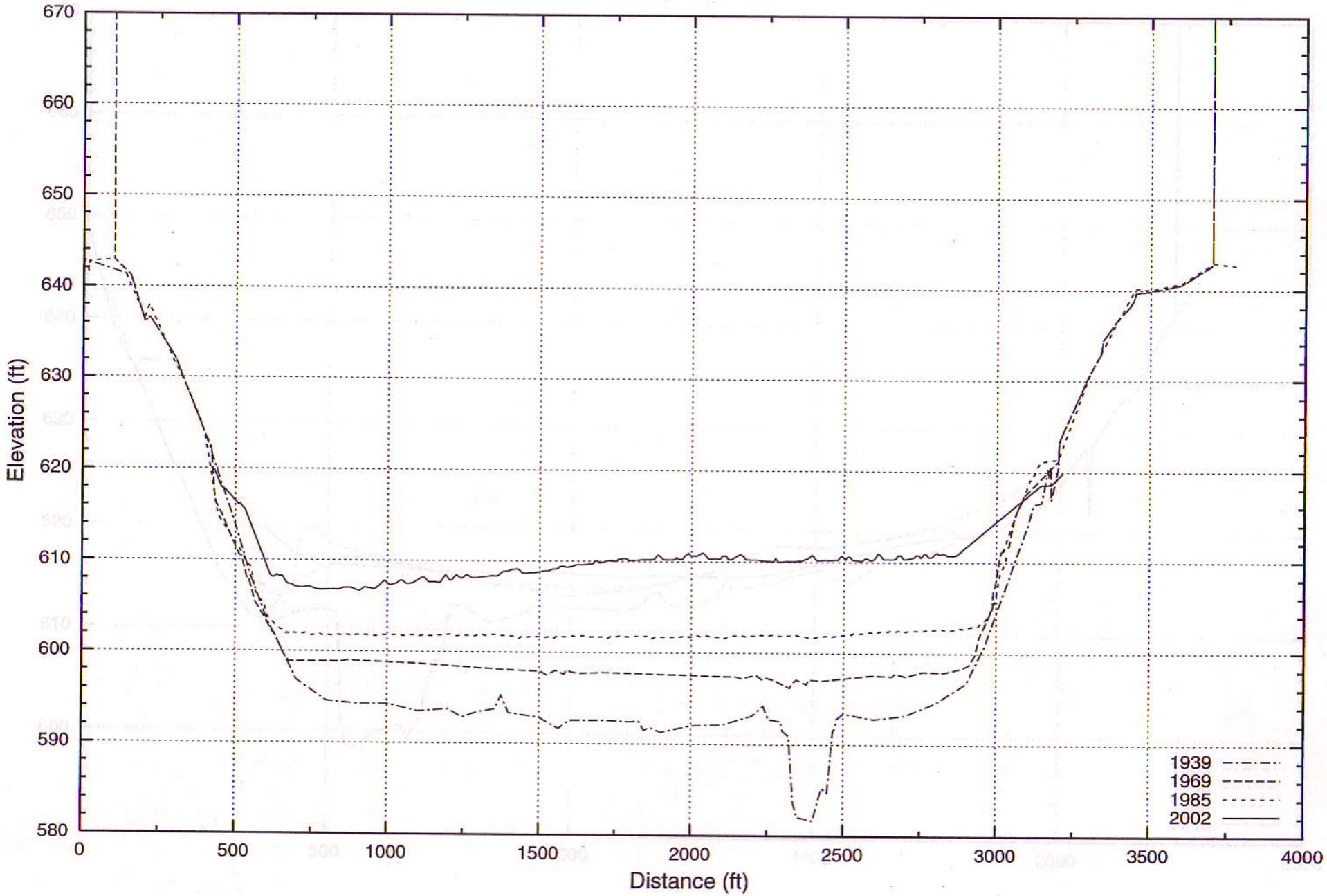
Appendix J


Lake Texoma
Rangeline SR38
800
750
700
650
600
550
Elevation (ft)
0
2000
4000
6000
8000
10000
12000
14000
Distance (ft)
1939
1969
1985
2002

Appendix J

Lake Texoma

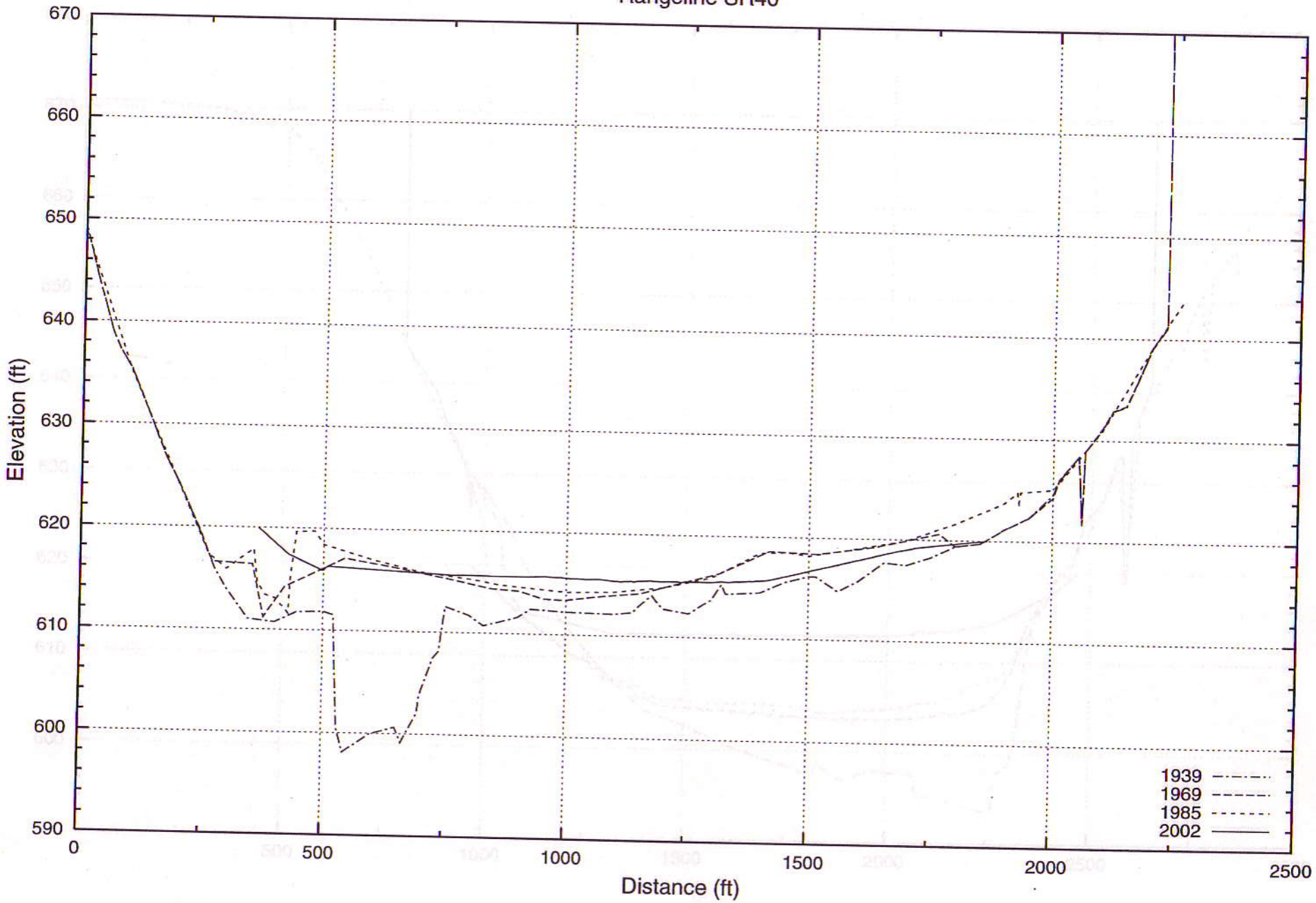
Rangeline SR39



Appendix J

Lake Texoma

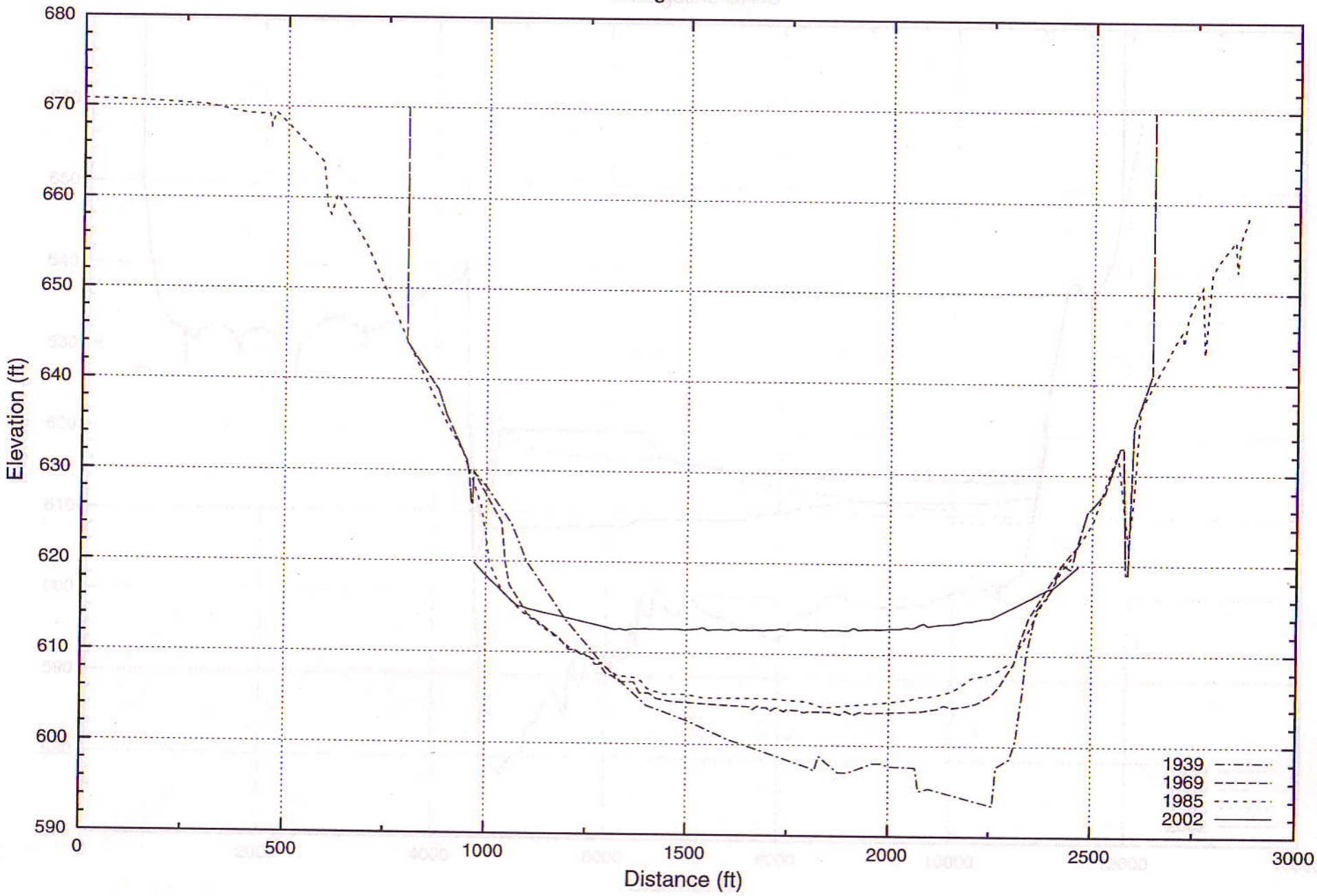
Rangeline SR40



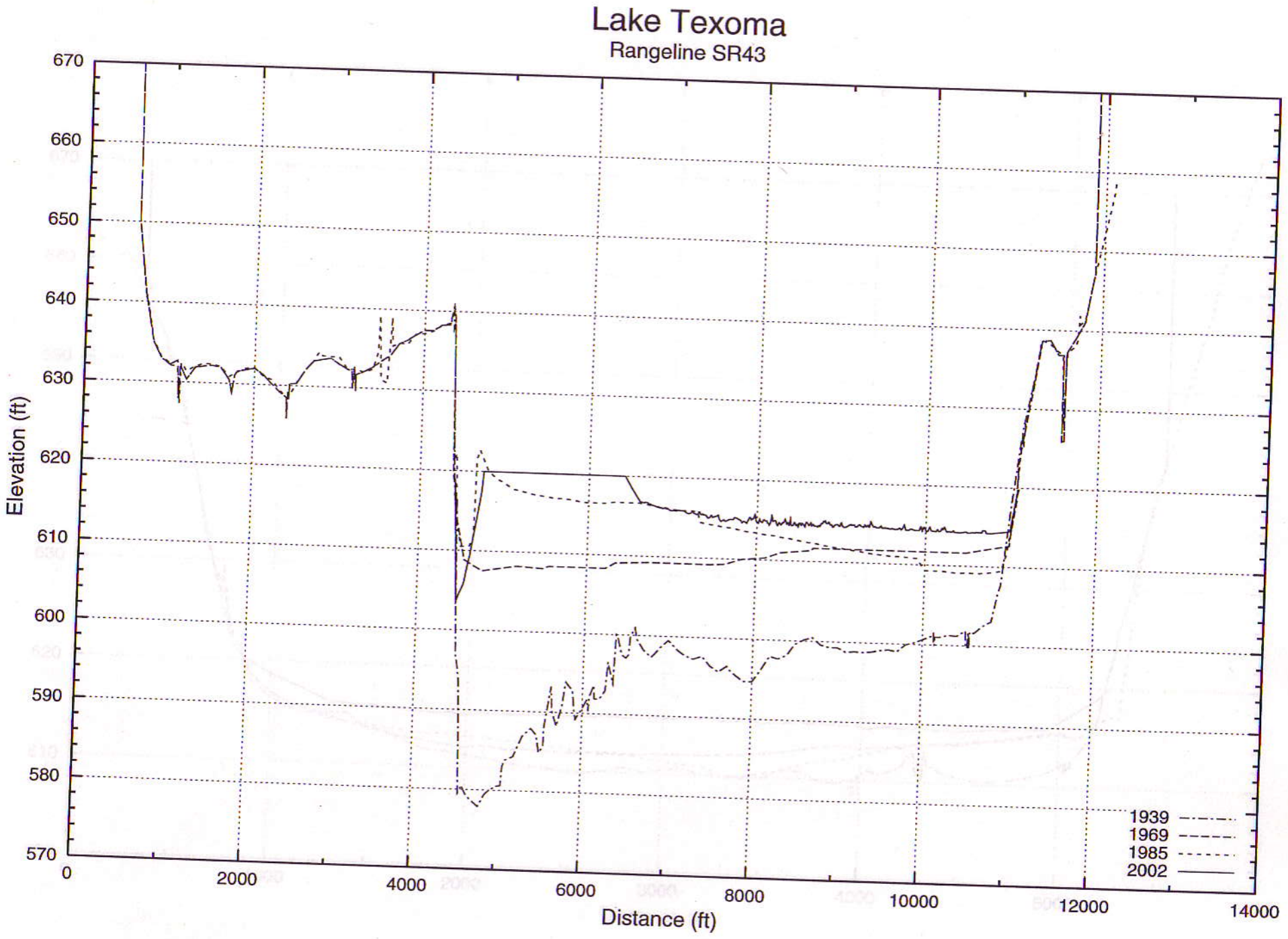
Appendix J

Lake Texoma

Rangeline SR41



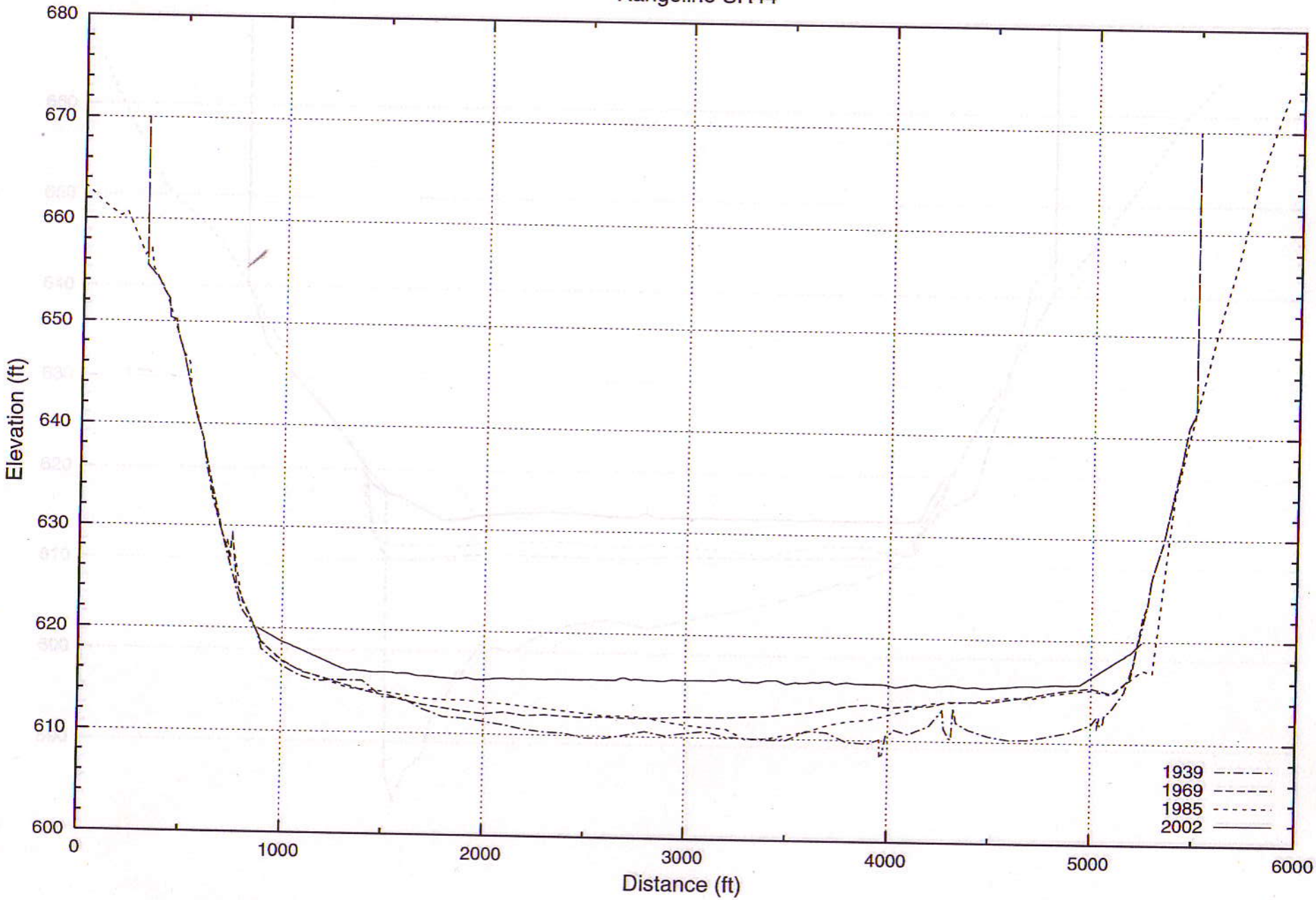
Appendix J


Lake Texoma
Rangeline SR43
Elevation (ft)
670
660
650
640
630
620
610
600
590
580
570
0
2000
4000
6000
8000
10000
12000
14000
Distance (ft)
1939
1969
1985
2002

Appendix J

Lake Texoma

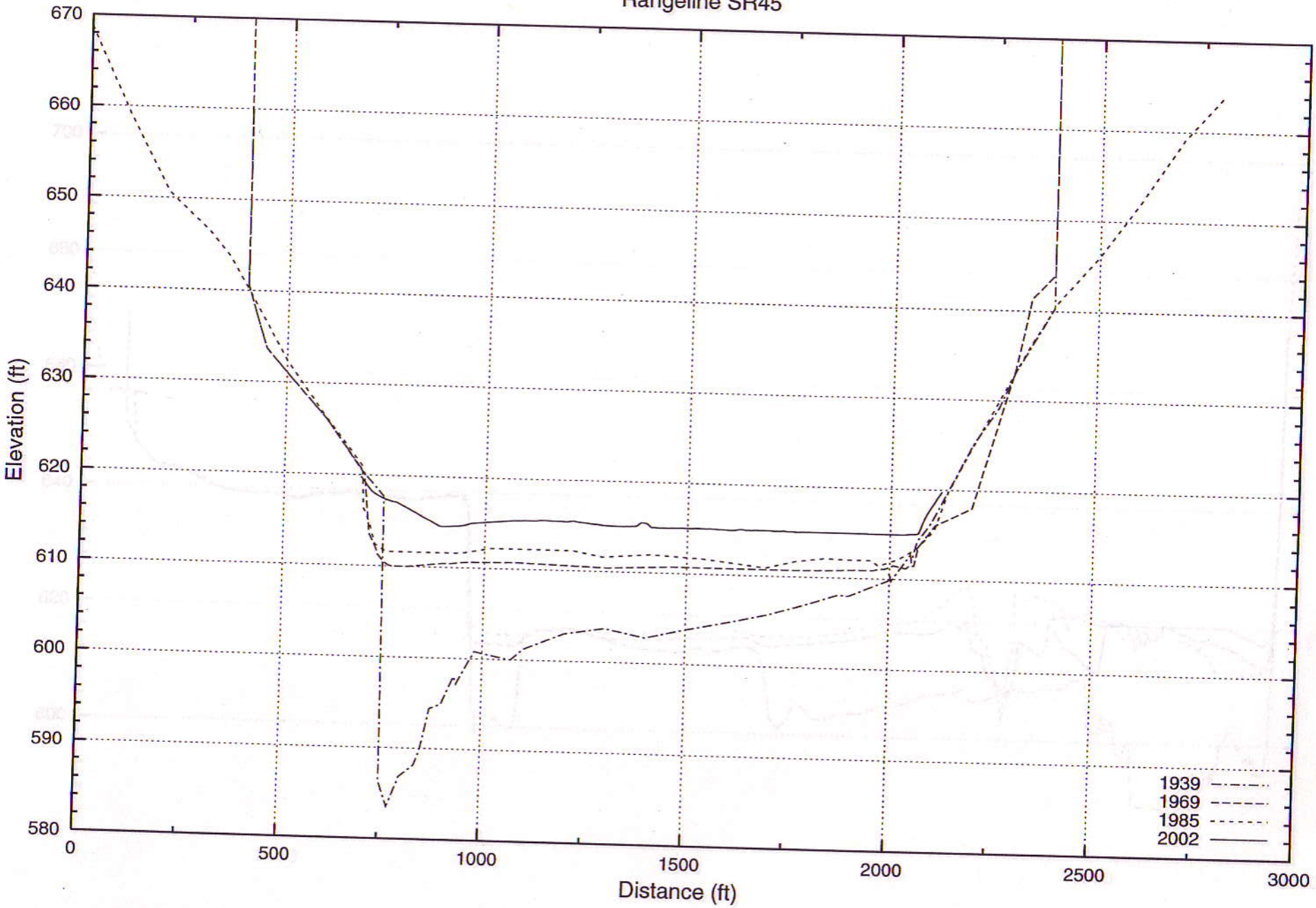
Rangeline SR44



Appendix J

Lake Texoma

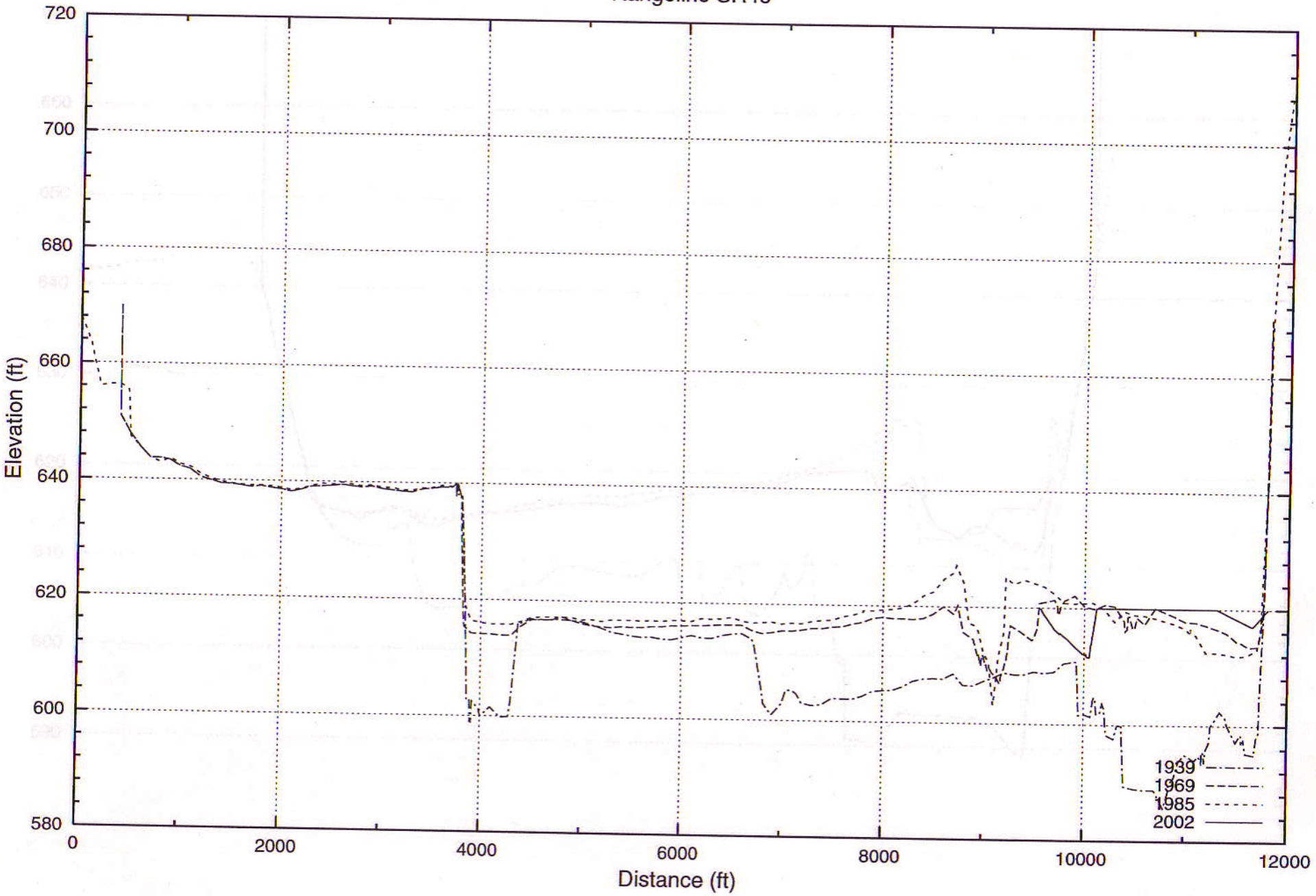
Rangeline SR45



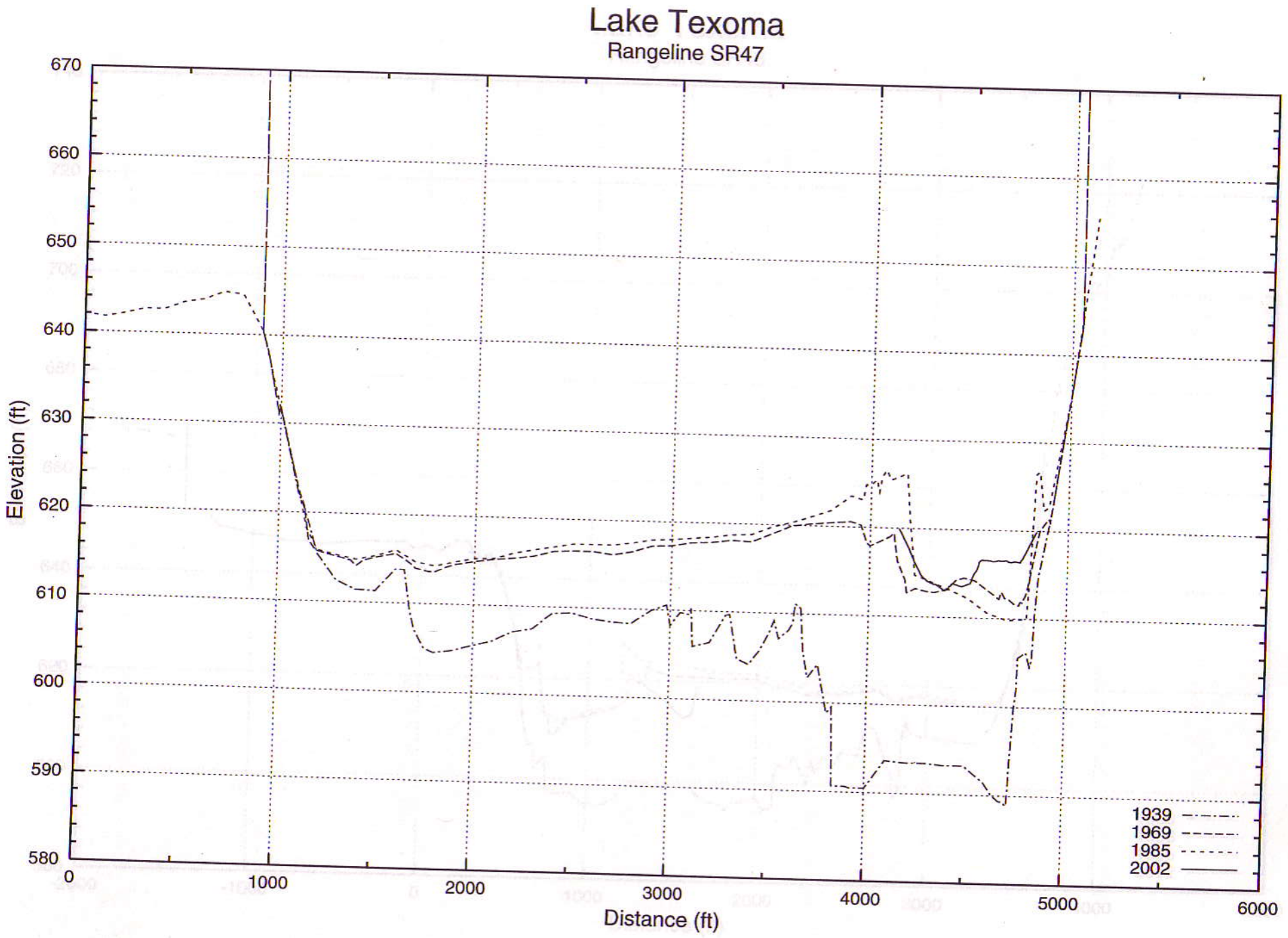
Appendix J

Lake Texoma

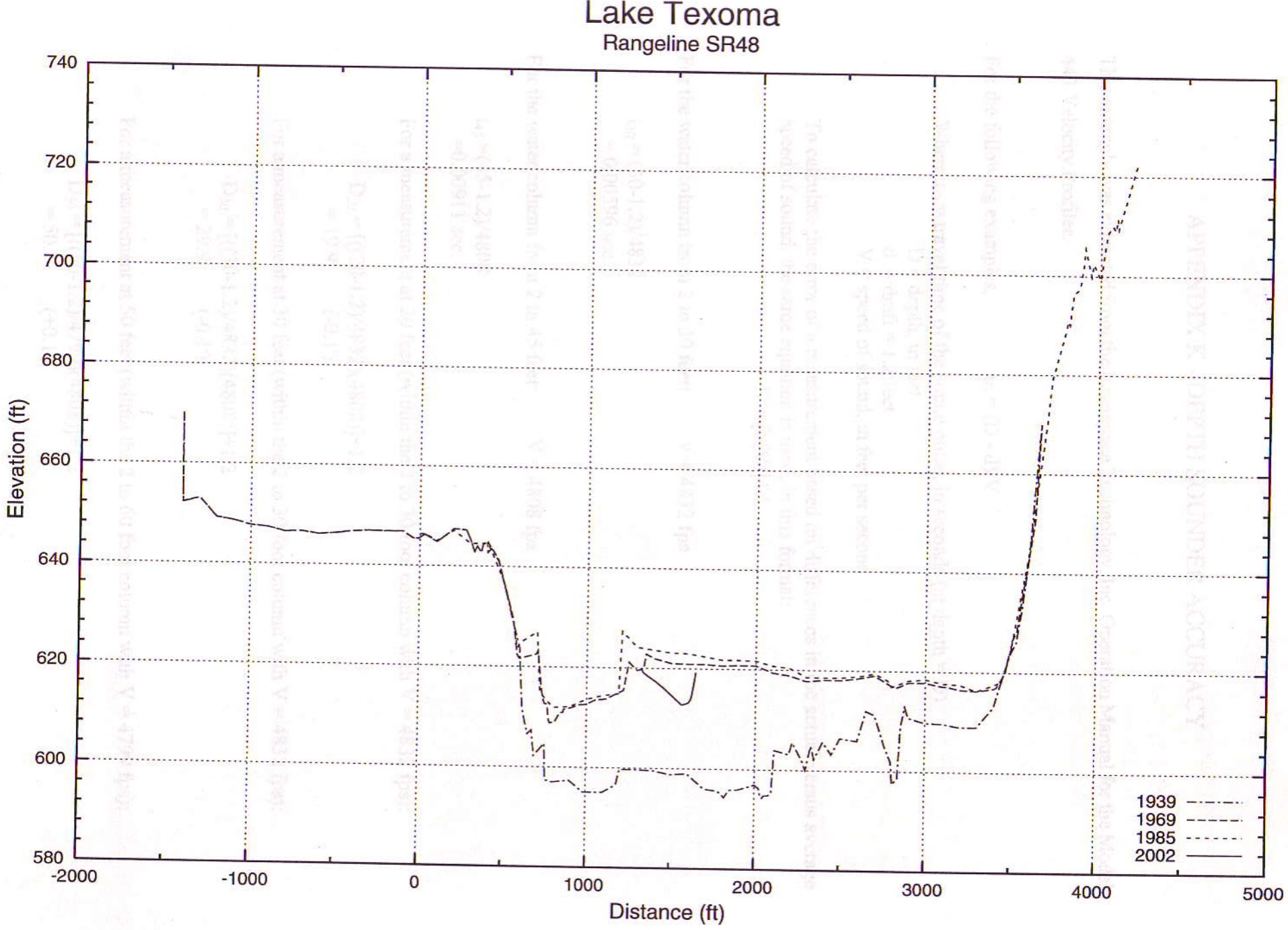
Rangeline SR46



Appendix J


Lake Texoma
Rangeline SR47
Elevation (ft)
670
660
650
640
630
620
610
600
590
580
0
1000
2000
3000
4000
5000
6000
Distance (ft)
1939
1969
1985
2002

Appendix J


Lake Texoma
Rangeline SR48
740
720
700
680
660
640
620
600
580
Elevation (ft)
-2000
-1000
0
1000
2000
3000
4000
5000
Distance (ft)
1939
1969
1985
2002

Appendix J

APPENDIX K - 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')

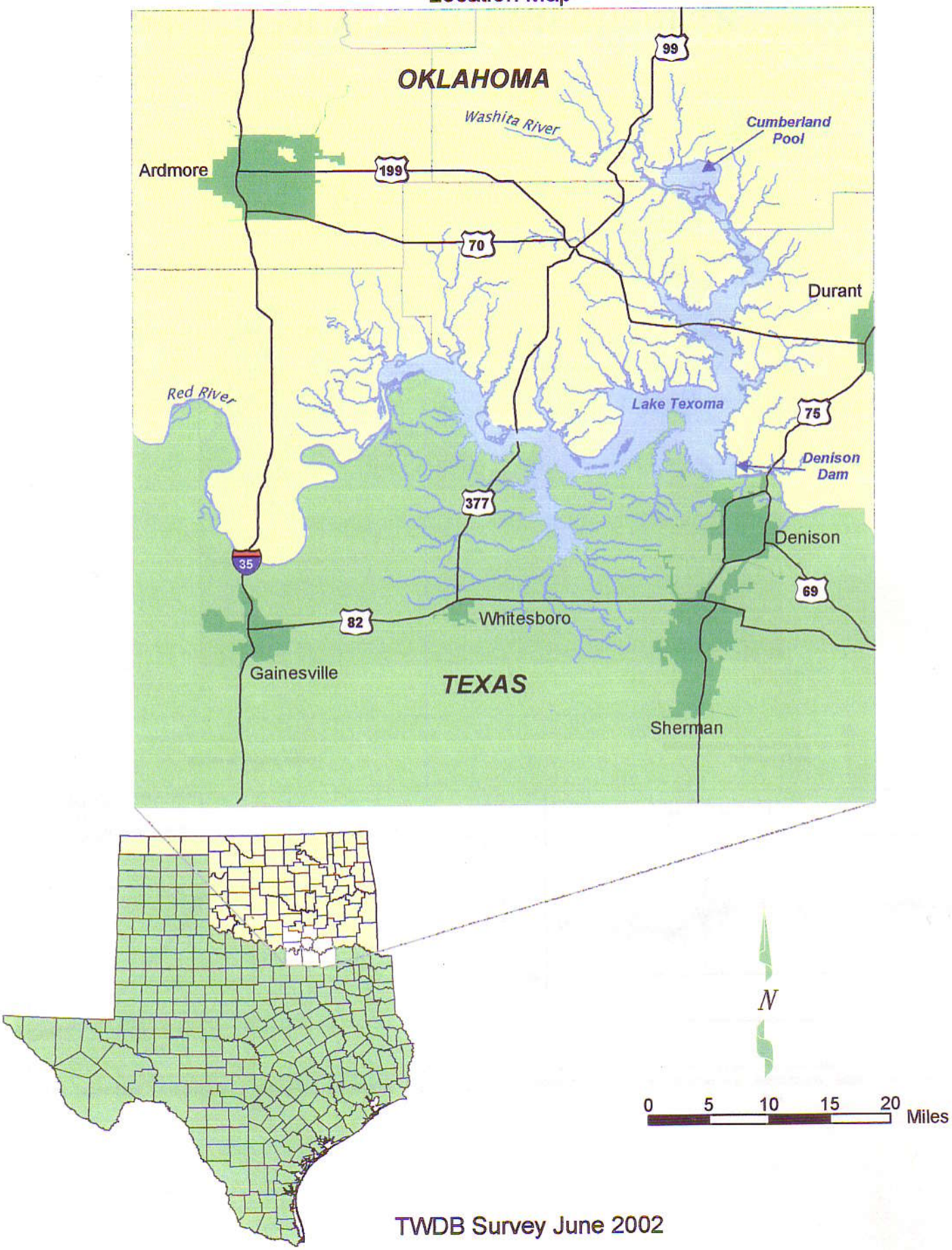
For a measurement at 80 feet (outside the 2 to 60 foot column, assumed V = 4785 fps):

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

Figure 2

LAKE TEXOMA RESERVOIR

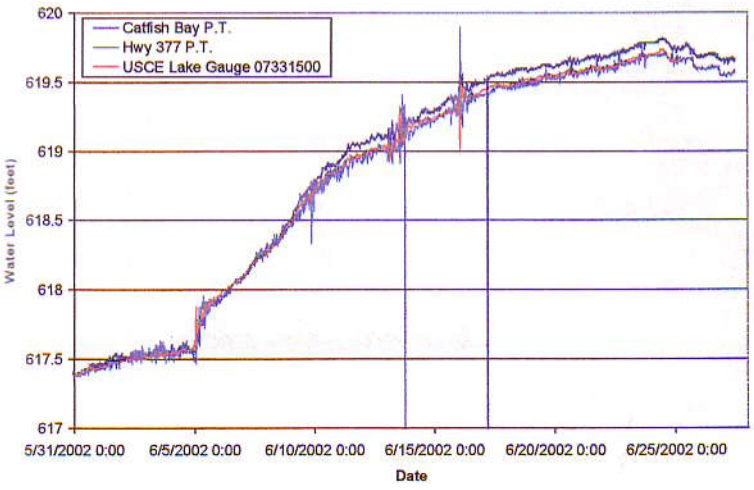
Location Map



TWDB Survey June 2002

Figure 3

WATER LEVEL GAUGING LOCATIONS AND RESULTS



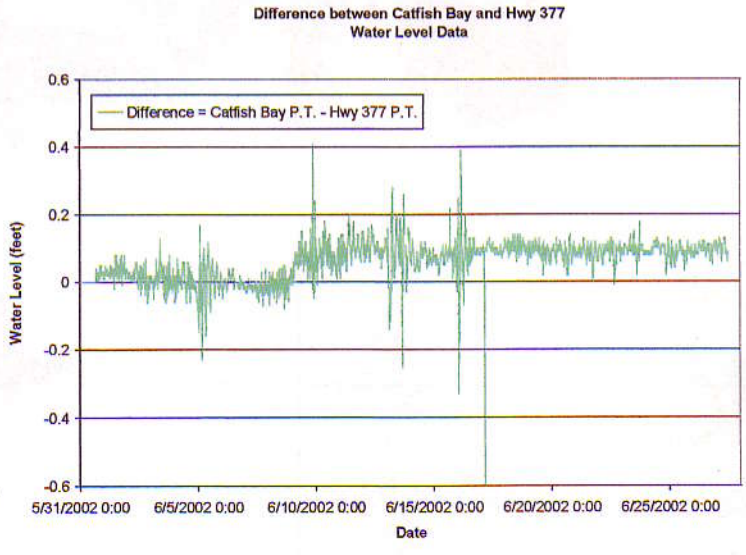
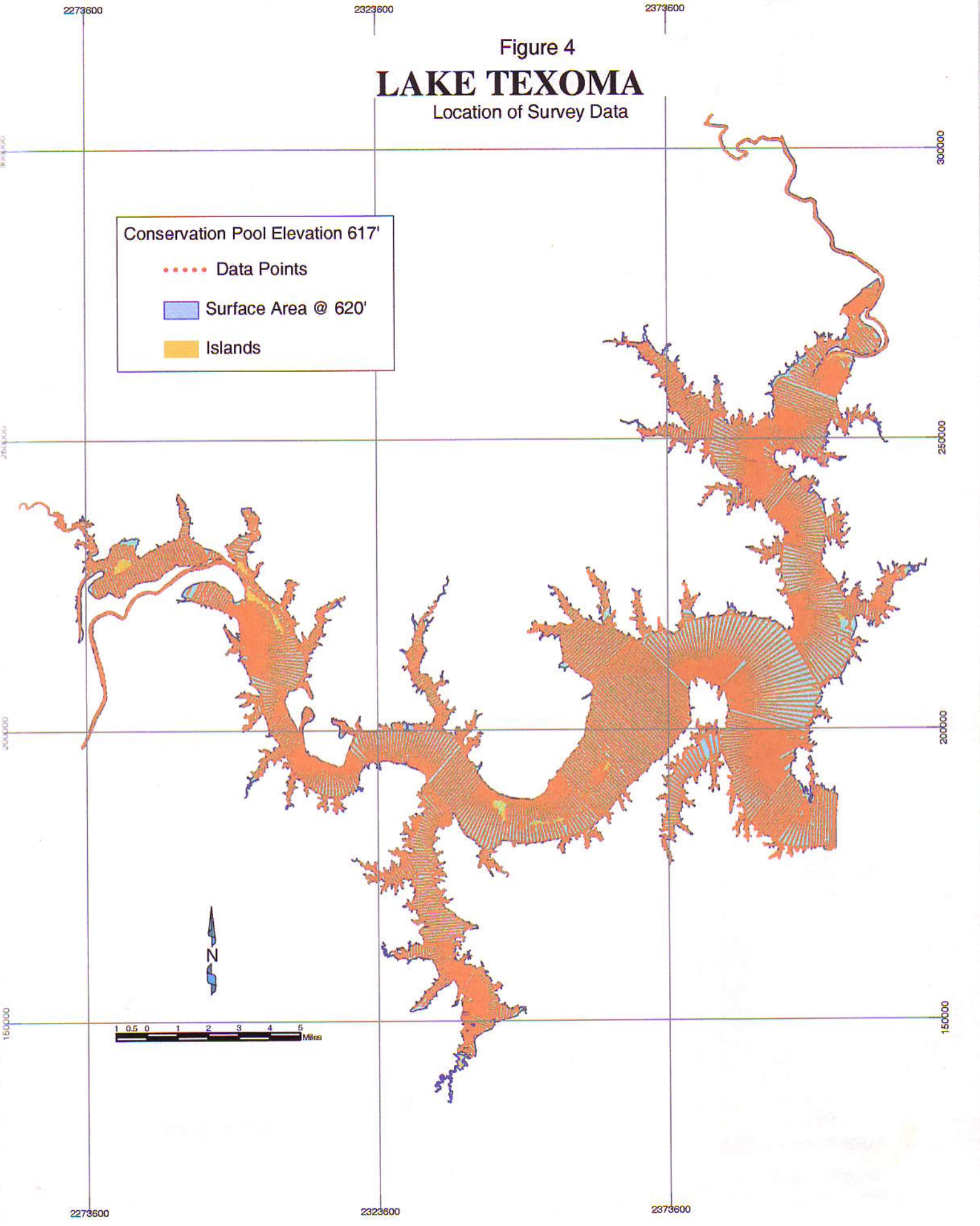


Figure 4

LAKE TEXOMA

Location of Survey Data

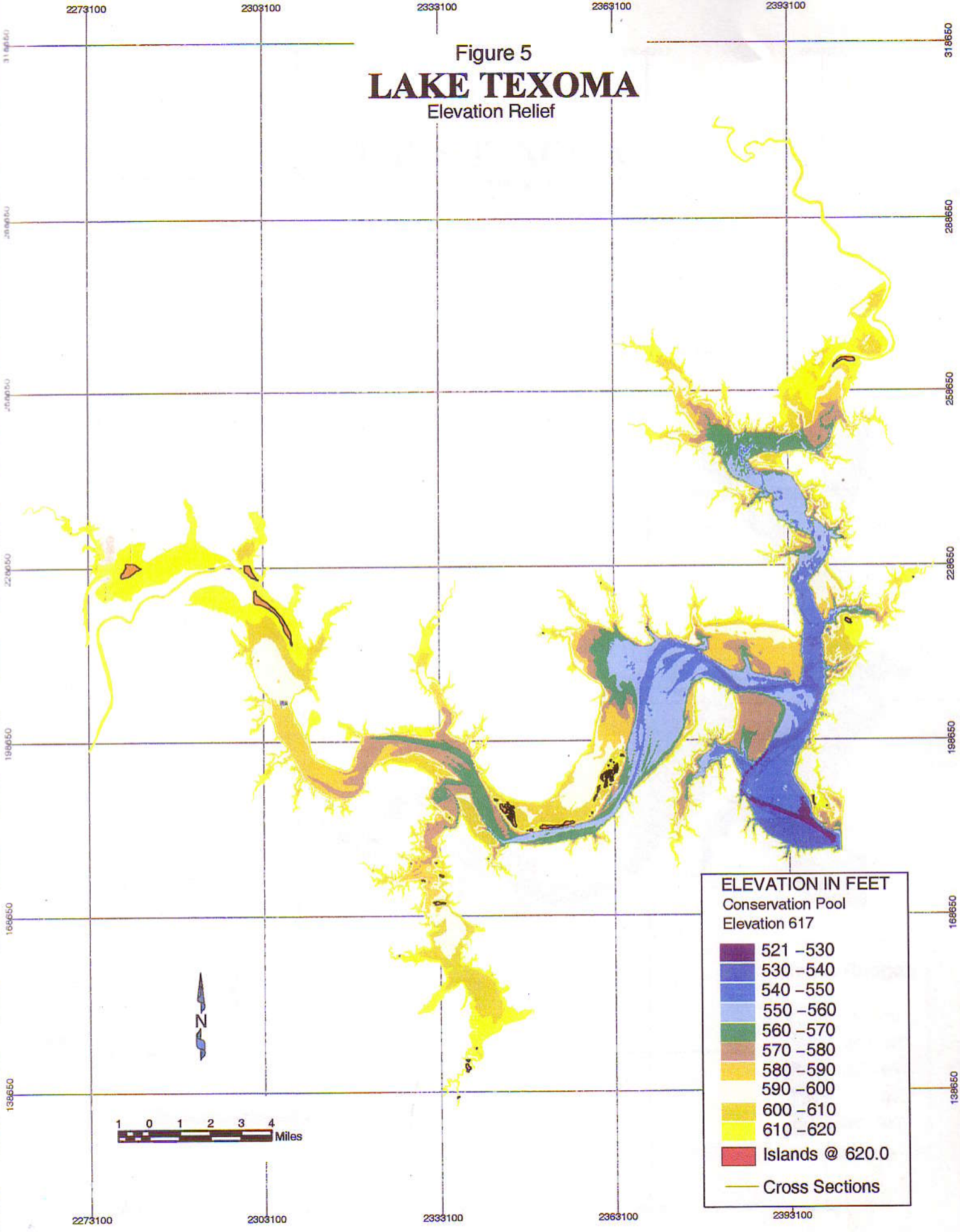


TWDB Survey June 2002

Figure 5

LAKE TEXOMA

Elevation Relief

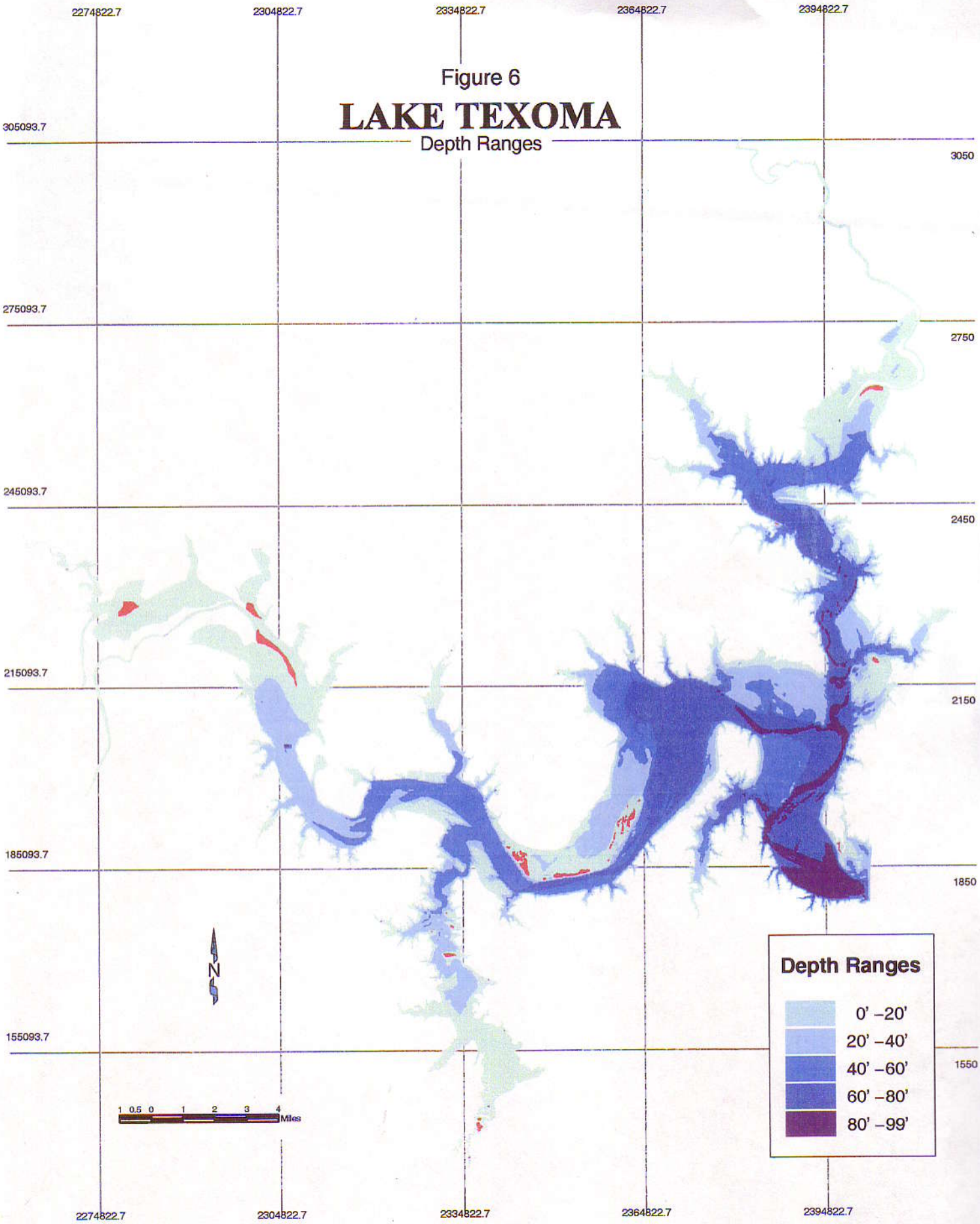


TWDB Survey June 2002

Figure 6

LAKE TEXOMA

Depth Ranges



TWDB Survey June 2002