VOLUMETRIC SURVEY OF COPAN LAKE

Prepared for:

U. S. Army Corps of Engineers, Tulsa District

Prepared by:
Texas Water Development Board

June 17, 2003

Staff of the Surface Water Availability Section prepared this report:

Barney Austin, Ph.D.

Duane Thomas
Randall Burns
Marc Sansom
Heidi Moltz

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

TABLE OF CONTENTS

APPENDICES

LIST OF FIGURES

LIST OF TABLES

COPAN LAKE
VOLUMETRIC SURVEY REPORT

INTRODUCTION

Staff of the Surface Water Section of the Texas Water Development Board (TWDB) conducted a volumetric survey of Copan Lake during the period of September 12 – 15, 2002. The purpose of the survey was to determine the current volume of the lake at the conservation pool elevation (cpe) 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 reservoir elevation gage at Copan Dam. The datum for this gage 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/webdata/gagedata/CPLO2.current.html).

Copan Lake is located on Little Caney River, a tributary of the Caney River in the Verdigris River basin, in Washington County, nine miles north of Bartlesville, OK (Figure 1). At cpe 710.0 ft above msl, the reservoir has approximately 54 miles of shoreline. Records indicate the drainage area is approximately 505 square miles (http://www.swt.usace.army.mil/projects/pertdata/copan/copan.htm).

LAKE HISTORY AND GENERAL INFORMATION

Copan Dam, appurtenant structures and the surrounding shoreline of Copan Lake are owned by the U. S. Government and operated by the USACE, Tulsa District. The multipurpose lake is used for flood control, water supply, water quality control, recreation and fish and wildlife enhancement. Federal authorization for the Copan Lake Project was granted under the Flood Control Act approved October 23, 1962; Project Document HD 563, 87th Congress, 2d Session.

Oklahoma Water Resources Board currently adjudicates the water rights for Copan Lake. The Cities of Copan and Bartlesville have contracted with the USACE for use of water stored in the conservation pool between elevation 710.0 and 687.5 ft. Under Water rights permit number 19770120, the City of Copan is authorized to store, use and divert 2,240 ac-ft of water per annum for public water supply. The City of Bartlesville can store, use and divert 3,340 ac-ft of water per annum for public water supply under permit number 19890018 (Oklahoma Water Resources Board).

Construction started on Copan Dam in November 1972 and was completed in April 1983. Deliberate impoundment of water began at the time of completion.

Original design information shows Copan Dam is a rolled earthfill embankment, 7,730 ft long and rises approximately 70 ft above the original streambed to a crest elevation of 745.0 ft. The earthen embankment is composed of mostly impervious material and has rock riprap on the upstream face for erosion control. Oklahoma Highway 10 (a two-lane asphalt road) occupies the dam's crest. There is an earthen dike, with a maximum height of 30 ft that extends 1,115 ft across a saddle near the right abutment above the dam.

The spillway for Copan Lake consists of a concrete ogee weir, 495 feet wide, has a crest elevation of 696.5 ft and is gate controlled. This structure is located adjacent to the right abutment. Four tainter gates control the spillway, each 50- by 35.5- ft.

The outlet works are designed with one 36-in. diameter low-flow outlet that is gate controlled. There is also a 12-in. diameter pipe that is gate controlled and is designed for water supply releases.

The original design for Copan Lake at cpe 710.0 ft indicates a surface area of 4,850 acres and a total storage of 43,400 ac-ft of water. The original design shows the top of the inactive pool at elevation 687.5 ft with a capacity of 600ac-ft. The initial conservation storage capacity for Copan Lake was 42,800 ac-ft of water. The following table summarizes information for Copan Dam and Copan Lake based on information furnished by the USACE (http://www.swt.usace.army.mil/projects/pertdata/copan/copan.htm).

Table 1. Copan Dam and Copan Lake Pertinent Data

Owner of Copan Dam and Facilities

United States of America

Operator of Copan Dam and Facilities

U. S. Army Corps of Engineers, Tulsa District

Engineer

U. S. Army Corps of Engineers (Design)

Location

On Little Caney River, a tributary of Caney River (Verdigris River Basin) in Washington County, nine miles north of Bartlesville, Oklahoma.

Drainage Area

505 square miles

Dam

Type	Earthfill
Length (total)	7,730 ft
Maximum Height	70 ft

Spillway

Type	Ogee (Concrete)
Length	495 ft
Crest elevation	740.0 ft
Control	4 -Tainter Gates

Outlet Works

Type	1 Low-flow outlet
Size	36” dia.
Control	slide gate
Type	1 Water supply outlet
Size	12” dia.
Control	slide gate

Reservoir Data (Based on TWDB 2002 volumetric survey)

Feature	**Elevation (Above msl)**	**Capacity (Acre-feet)**	**Area (Acres)**
Conservation Pool Elevation (Total storage)	710.0	34,634	4449
Conservation Pool (Between elev. 710.0 - 687.5 ft)		33,888	
Inactive Pool	687.5	747	130

VOLUMETRIC SURVEYING TECHNOLOGY

The equipment used to perform the latest volumetric survey consisted of a 23-foot aluminum tri-hull SeaArk craft with cabin, equipped with twin 90-Horsepower Honda outboard motors. (Reference to brand names throughout this report does not imply endorsement by TWDB). Installed within the enclosed cabin are a Coastal Oceanographics’ Helmsman Display (for navigation), an Innerspace Technology Model 449 Depth Sounder and Model 443 Velocity Profiler, Trimble Navigation, Inc. AG132 GPS receiver with Omnistar differential GPS correction signal and 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. AG132 GPS receiver with Omnistar differential GPS correction signal and a laptop computer.

The GPS equipment, survey vessel, and depth sounder in combination provide an efficient hydrographic survey system. As the boat travels across the pre-plotted transect lines, 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 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 one data point per second, and the average depths are converted to elevation readings based on the water-level elevation recorded at the time the data was collected. Accurate estimates of the lake volume can be quickly determined by building a 3-D TIN model of the reservoir from the collected data.

PRE-SURVEY PROCEDURES

The lake’s boundary was digitized using Environmental Systems Research Institute’s (ESRI) Arc/Info Workstation GIS from a digital orthophoto quadrangle image (DOQ). Geo Information Systems, a department of the University of Oklahoma, furnished the DOQ. More information can be obtained on the Internet at http://www.geo.ou.edu/. The COPAN, OK (36095H84.sid, 36095H83.sid, 36095H82.sid and 36095H81.sid) DOQ was used to create the lake boundary. The lake elevation, at the time the DOQ was photographed (March 24,1995) was 709.85 ft. This photograph (DOQ) was used to digitize the boundary of the lake and an elevation of 710 ft was assumed for modeling purposes. The lake pool elevations varied between elevation 709.32 ft and 709.37 ft during the survey.

The survey layout was designed by placing survey track lines at 500-foot intervals within the digitized reservoir boundary using HYPACK software. The survey design required the use of approximately 130 survey lines placed perpendicular to the original creek channel and tributaries along the length of the reservoir.

SURVEY PROCEDURES

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

Equipment Calibration and Operation

While onboard the Hydro-survey boat and prior to collecting data, 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 onboard the River-runner (shallow draft) boat, the Knudsen depth sounder was calibrated using the DIGIBAR-Pro Profiling Sound Velocimeter by Odem Hydrographic Systems, the steps to determine the speed of sound are similar to 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 4,915 feet per second to 4,932 feet per second during the Copan Lake 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 G.

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 using the Omnistar receiver. The reservoir's initialization file used by the HYPACK data collection program was set to convert the collected Differential GPS positions to state-plane coordinates on the fly.

Field Survey

TWDB staff collected data at Copan Lake during the period of September 12 – 15, 2002. The water level elevations varied between 709.32 and 709.37 ft., approximately seven-tenths of a foot below cpe 710.0 ft. The survey crew experienced typical summer-like weather conditions while surveying Copan Lake. Temperatures ranged in the mid 80's to low 90's with winds generally 10 to 20 mph.

The catchment basin of Copan Lake occupies the flood plain of Little Caney River being the main stem of the lake. The river flows in a north to south direction with Copan Dam being located on the south end of the lake. The only other major tributary to Copan Lake is Cotton Creek that joins the lake in the upper reaches from the east bank. Copan Lake is located in the Osage Plains with gentle slopes in the rolling to hilly terrain.

The majority of land-use surrounding Copan Lake is dedicated for hunting and is under both state and federal regulations. There is some oil and gas production as well as ranching in the area. There are two public-use areas on the east shoreline between Copan Dam and Washington Cove and three public-use areas on the west shoreline.

Data collection began at the dam along parallel lines that were spaced in increments of 500 ft as the crew worked upstream. These parallel lines were designed to be perpendicular to the river or creek bed in order to secure a well-defined cross section on each transect. Data were also collected on parallel lines in the coves and contributing creeks. As the data was collected along the pre-plotted transects, the bathymetry or lake bottom profile was being plotted on an analog chart. As the boat passed over the river and creek beds, the acoustic depth sounder would indicate the location of the thalweg.

In many areas along the shoreline of the catchment basin, outcrops of sandstone were noted. Gentle relief was observed along the shoreline in the southern part (closer to the dam) of the lake while relatively flat terrain was noted in the upper reaches.

Approximately half of the lake (surface area) from Copan Dam to Washington Cove (located on the east bank) was clear of navigational hazards. The open area of the lake made for great conditions to collect data on the pre-plotted lines. From Washington Cove upstream to the headwaters, the standing timber in Copan Lake became quite a challenge for the survey crew to collect data. Data collection went slow but was accomplished after two days of navigating through exposed timber in order to stay on line as close as possible. It was also difficult to collect data around the delta where the Little Caney River empties into the main basin of the reservoir. Shallow depths with floating and submerged timber were encountered in this area.

Approximately 53,466 data points were collected over the 118 miles traveled. The crew was able to collect data on 125 of the 130 pre-plotted lines. Data were also collected on seven of the original 24 USACE sediment range lines (USACE 1993). The endpoints for these sediment range lines were not furnished; therefore, the survey crew estimated the location of the lines. Random data were collected in those areas where the crew could not navigate the boat to stay on course. As the channel of the Little Caney River became to narrow for perpendicular transects, data was collected and a zigzag pattern. Data were collected upstream on the Little Caney River until the survey crew encountered a logjam that kept them from continuing upstream. Data were not collected in areas with significant obstructions or where the depths were too shallow to navigate. These data points collected were stored digitally on the boat's computer in 250 data files. Figure 2 shows the actual location of all data points collected.

Data Processing

The collected data were downloaded from diskettes onto TWDB's network computers. Tape backups were made for future reference as needed. To process the data, the EDIT routine in the HYPACK Program was run on each raw data file. Data points such as depth spikes or data with missing depth or positional information were deleted from the files. A correction for the lake elevation at the time of data collection was also applied to each file during the EDIT routine. During the survey, the water level elevation varied from 709.32 ft on September 12, 2002 to 709.37 ft on September 15, 2002 according to the USACE gauge. After all changes had been made to the raw data files, the edited files were saved. The edited files were then combined into a single X, Y, and 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 reservoir'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 reservoir 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 reservoir at one-tenth of foot intervals from the lowest elevation 673.9 ft to the lake boundary elevation of 710.0 ft during the 2002 survey. The computed reservoir volume table is presented in Appendix A and the area table in Appendix B. An elevation-volume graph and an elevation-area graph are presented in Appendix C and Appendix D respectively.

Due to the lake pool elevation being approximately seven-tenths below CPE and northern areas of the lake being extremely shallow during the field survey, there was about 480 acres not covered by the survey vessels. This lack of data caused the model to under estimate surface areas between the 708.2 ft. to 709.9 ft. elevations.

Therefore 480 acres were distributed linearly over elevations 708.2 ft. to 709.9 ft. and the following formula was used to estimate the volume over this range: $V@elev_a = V@elev_{(a-1)} + (0.1ft. * A_{(a-1)}) + (A_{(a)} - A_{(a-1)} / 2) * 0.1ft.)$.

Where: V is volume and A is area.

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 2-ft intervals is presented in Figure 5. Finally, the location of cross-section endpoints in Appendix E and the corresponding cross-section plots in Appendix F were approximated from those sediment range lines established by the USACE.

RESULTS

Results from the 2002 TWDB survey indicate Copan Lake encompasses 4449 surface acres and contains a total volume of 34,334 ac-ft at the conservation pool elevation of 710.0 ft. The shoreline at this elevation was calculated to be 54 miles. The deepest point physically measured during the survey was at elevation 674 ft and was located approximately 3000 feet upstream of Copan Dam.

SUMMARY AND COMPARISONS

Copan Dam was completed in 1983 and deliberate impoundment began the same year. Original design information was furnished from the USACE. Records indicate that Copan Lake had a total volume of 43,400 ac-ft of water and a surface area of 4,850 acres at conservation pool elevation 710.0 ft. A summary of the comparisons is presented in Table 2.

TWDB staff performed a volumetric survey of Copan Lake on September 12 – 15, 2002. The 2002 survey utilized a differential global positioning system, depth sounder and geographical information system technology to create a digital model of the lake's bathymetry.

At conservation pool elevation 710.0 ft, the current survey measured 4449 surface acres, for a reduction of 401 surface acres compared to the USACE original design. The 2002 TWDB survey results indicate that the total volume at the conservation pool elevation of 710.0 ft is 34,634 ac-ft. The inactive pool below elevation 687.5 feet was found to be 747 ac-ft, and thus the conservation storage found in this survey is 33,887 ac-ft of water. Copan Lake lost 8,766 ac-ft of water or 21 percent in conservation storage compared to the original design information.

Comparisons between the historical USACE original design and the 2002 TWDB volumetric survey are difficult and some apparent changes might simply be due to methodological differences. It is recommended that another survey utilizing modern methods be performed in five to ten years or after major flood events to monitor changes to the reservoir's capacity.

Table 2. Area and Capacity Comparisons Copan Lake

Feature	USACE Original Design	TWDB 2002 Volumetric Survey
Area (acres)[1]	4,850	4,449
Total Volume (ac-ft)[1]	43,400	34,634
Active Pool storage capacity (ac-ft)[2]	42,800	33,887
Inactive Pool storage capacity (ac-ft)[3]	600	747

Notes:
1. Original Design for conservation pool elevation was 710.0 ft
2. Active pool storage capacity is between elevations 710.0 and 687.5 ft
3. Inactive pool storage capacity is below elevation 687.5 ft
4. Original design information provided by USACE, Tulsa District

REFERENCES

1. http://www.swt.usace.army.mil/projects/pertdata/copan/copan.htm
2. http://www.swt-wc.usace.army.mil/webdata/gagedata/CPLO2.current.html
3. Oklahoma Water Resources Board Reservoir Summary Sheet
4. USACE, Copan Lake Water Control Manual 1993.

Appendix A

Copan Reservoir

RESERVOIR VOLUME TABLE

TEXAS WATER DEVELOPMENT BOARD　　　　September 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
673										0
674	0	0	0	0	0	0	0	0	0	1
675	1	1	1	1	1	2	2	2	2	3
676	3	4	4	4	5	5	6	7	8	9
677	10	11	13	15	17	19	21	23	26	28
678	31	33	36	39	42	46	49	52	56	60
679	63	67	71	76	80	84	89	94	99	104
680	109	114	120	125	131	136	142	148	154	160
681	167	173	179	186	193	199	206	213	220	226
682	233	241	248	255	262	270	277	284	292	300
683	307	315	323	331	339	347	355	363	372	380
684	388	397	405	414	423	432	440	449	458	467
685	477	486	495	505	514	524	534	543	553	564
686	574	584	595	605	616	627	638	649	661	672
687	684	696	709	721	734	747	760	773	787	800
688	814	828	843	857	872	887	902	918	933	950
689	966	982	999	1017	1034	1052	1070	1088	1106	1125
690	1144	1164	1184	1204	1225	1246	1267	1289	1312	1335
691	1359	1383	1408	1434	1460	1488	1517	1546	1577	1609
692	1642	1676	1712	1749	1788	1828	1869	1913	1957	2004
693	2052	2102	2153	2206	2261	2318	2377	2437	2499	2563
694	2629	2697	2766	2837	2910	2984	3060	3137	3216	3296
695	3377	3459	3543	3628	3714	3801	3890	3979	4070	4162
696	4255	4349	4443	4539	4636	4733	4831	4930	5029	5130
697	5231	5333	5436	5539	5643	5748	5854	5960	6068	6177
698	6287	6398	6511	6625	6740	6856	6973	7091	7211	7331
699	7453	7576	7700	7826	7953	8080	8209	8339	8471	8603
700	8737	8871	9007	9144	9283	9423	9565	9708	9852	9998
701	10146	10295	10446	10599	10753	10908	11066	11225	11387	11550
702	11717	11886	12058	12233	12410	12590	12773	12959	13147	13338
703	13533	13730	13930	14133	14339	14548	14758	14972	15187	15405
704	15626	15848	16073	16300	16530	16761	16995	17231	17470	17711
705	17954	18201	18451	18705	18962	19223	19487	19755	20028	20305
706	20588	20878	21173	21472	21776	22083	22393	22707	23024	23344
707	23667	23992	24320	24652	24986	25324	25664	26008	26355	26706
708	27059	27415	27774	28136	28501	28868	29237	29608	29982	30357
709	30735	31114	31496	31880	32266	32655	33046	33439	33835	34233
710	34634									

Appendix B

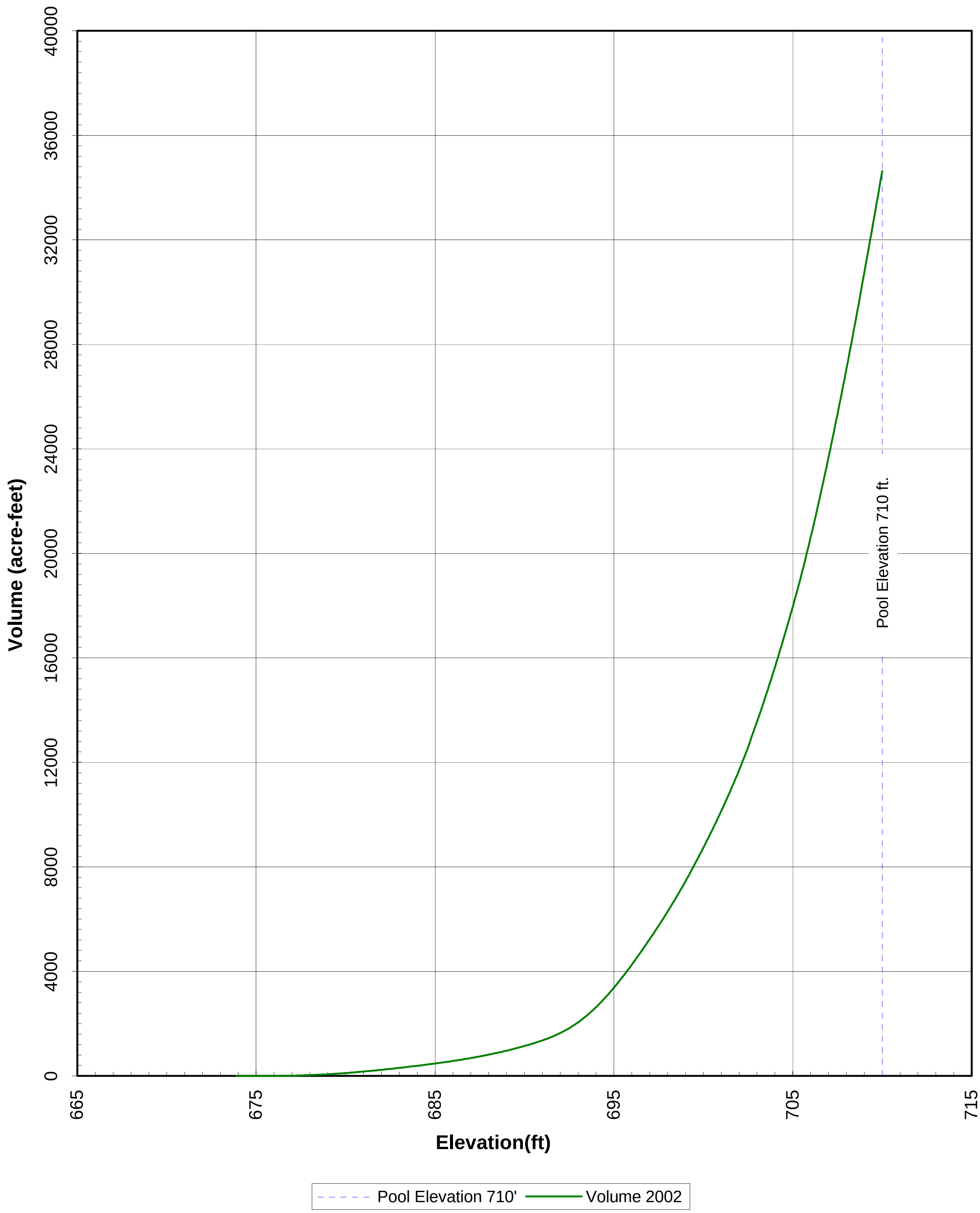
Copan Reservoir

RESERVOIR AREA TABLE

TEXAS WATER DEVELOPMENT BOARD September 2002 SURVEY

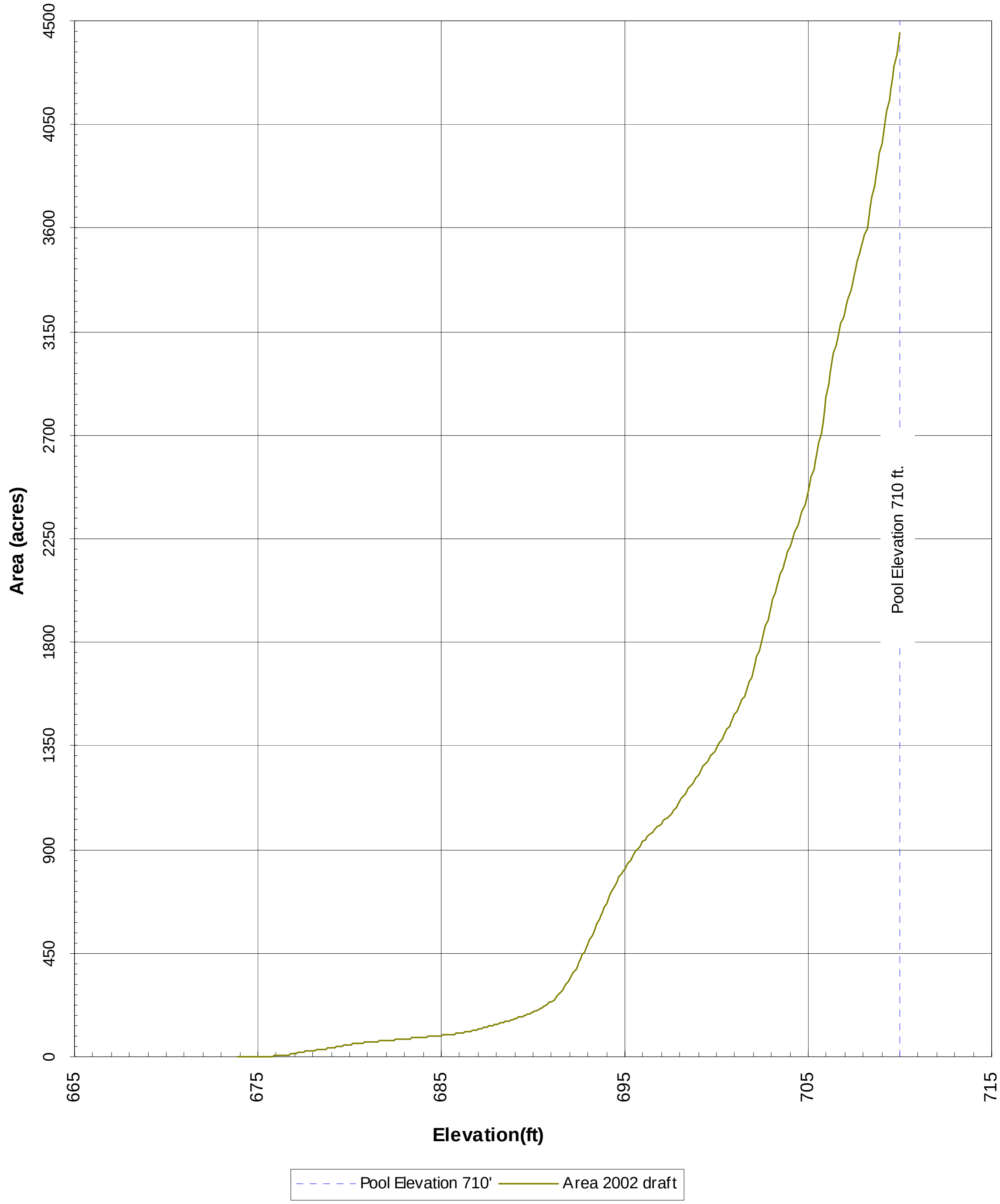
AREA IN ACRES ELEVATION INCREMENT IS ONE TENTH FOOT

ELEVATION in Feet	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
673										0
674	0	0	0	0	0	1	1	1	1	1
675	1	2	2	2	2	2	3	3	3	3
676	4	4	4	4	5	5	6	8	10	11
677	13	15	17	19	20	22	23	24	25	26
678	27	28	29	30	31	32	34	35	36	38
679	39	40	42	43	44	46	47	48	50	51
680	52	53	55	56	57	58	59	60	61	62
681	63	64	64	65	66	67	67	68	69	70
682	70	71	72	73	73	74	75	75	76	77
683	77	78	79	79	80	81	82	82	83	84
684	84	85	86	87	88	88	89	90	91	91
685	92	93	94	95	96	97	98	99	100	102
686	103	104	106	107	109	110	112	114	116	118
687	120	122	124	126	128	130	132	134	136	138
688	140	142	144	146	149	151	154	156	159	162
689	165	168	170	173	176	178	181	184	187	190
690	193	196	200	205	209	214	219	224	229	234
691	240	246	253	261	271	281	291	301	313	325
692	338	351	364	378	393	408	424	439	455	473
693	490	506	523	541	559	577	596	613	630	650
694	668	685	702	719	735	751	766	780	793	805
695	817	830	843	854	866	878	891	902	913	924
696	933	943	952	961	969	977	985	992	1000	1008
697	1016	1024	1031	1038	1045	1052	1060	1071	1083	1095
698	1107	1119	1132	1144	1155	1166	1178	1189	1200	1212
699	1225	1237	1249	1261	1273	1284	1295	1307	1318	1329
700	1340	1351	1364	1379	1395	1410	1424	1438	1452	1468
701	1485	1501	1517	1533	1549	1565	1583	1604	1626	1649
702	1678	1707	1734	1760	1786	1814	1843	1871	1899	1927
703	1958	1989	2018	2045	2071	2096	2120	2145	2168	2192
704	2215	2238	2260	2282	2305	2327	2350	2372	2396	2423
705	2453	2486	2519	2554	2587	2623	2664	2703	2747	2801
706	2864	2923	2972	3015	3055	3089	3122	3154	3185	3213
707	3240	3269	3298	3330	3360	3388	3419	3455	3494	3521
708	3548	3571	3596	3644	3691	3737	3783	3829	3874	3921
709	3967	4014	4061	4108	4156	4204	4252	4301	4350	4400
710	4449									



Copan Reservoir
September 2002
Prepared by: TWDB

Appendix C Elevation vs. Volume



Copan Reservoir
September 2002
Prepared by: TWDB

Appendix D Elevation vs. Area

Appendix E

Copan Lake

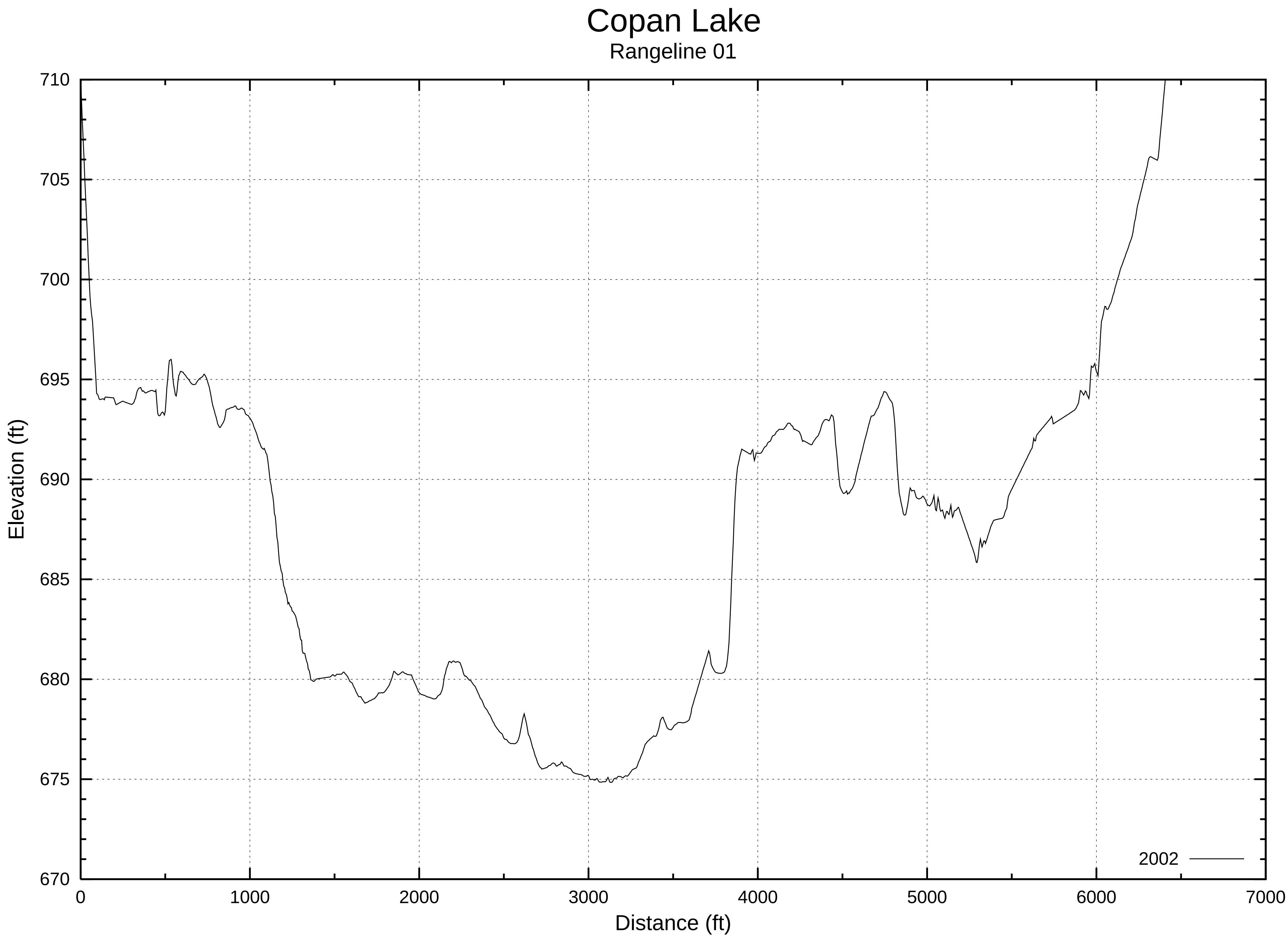
TEXAS WATER DEVELOPMENT BOARD SEPTEMBER 2002 SURVEY

Range Line Endpoints

State Plane NAD83 Units-feet

L-Left endpoint
R-right endpoint

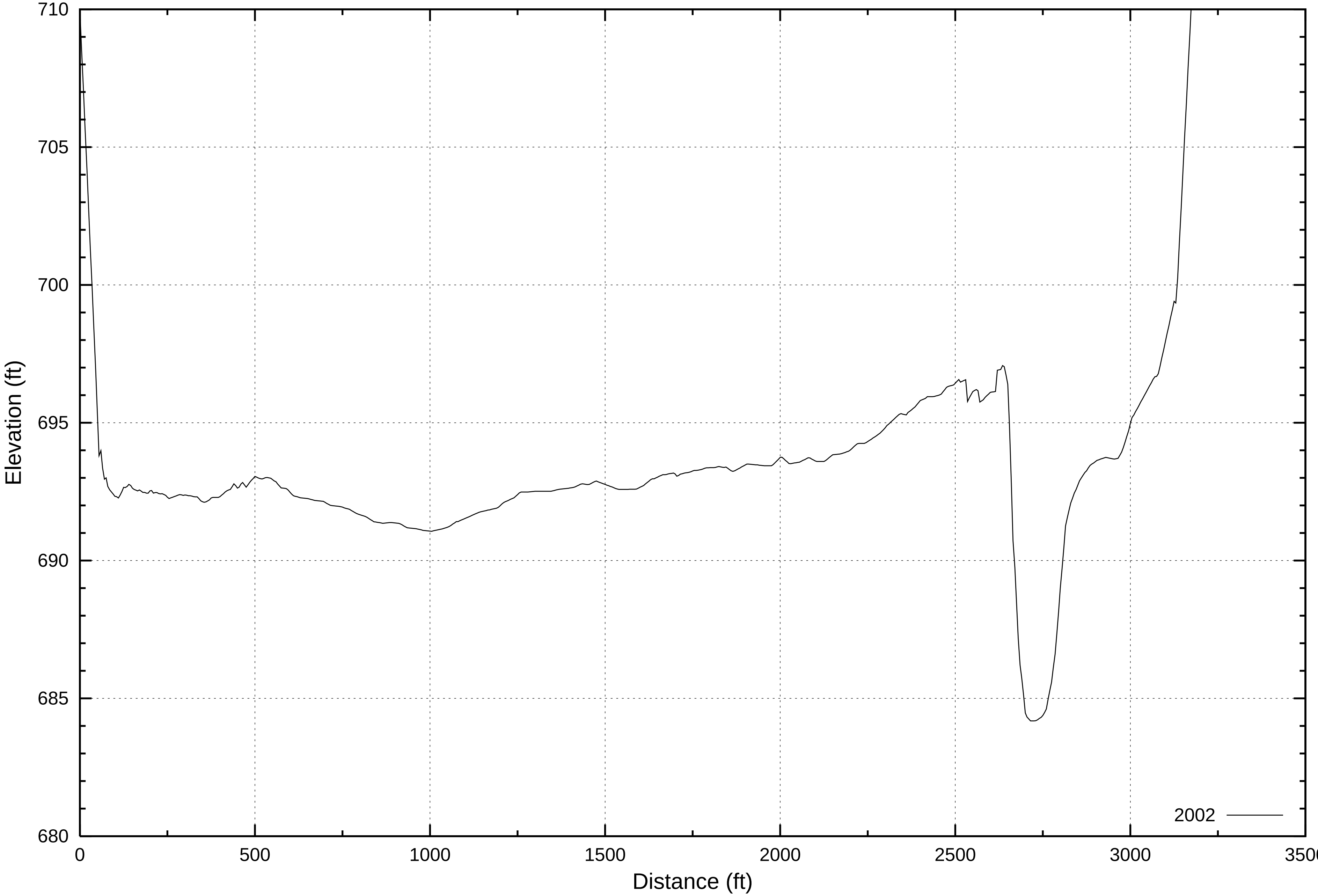
Range Line	X	Y
Line 01-L	2566660.0	693097.3
Line 01-R	2560338.5	694138.0
Line 02-L	2567714.8	699171.6
Line 02-R	2564796.3	700417.6
Line 03-L	2568767.5	704935.6
Line 03-R	2565494.5	706157.9
Line 04-L	2570698.3	707856.4
Line 04-R	2567221.8	709718.7
Line 05-L	2574719.5	713973.8
Line 05-R	2565454.5	715438.6
Line 06-L	2564192.8	714904.1
Line 06-R	2564115.5	711525.1

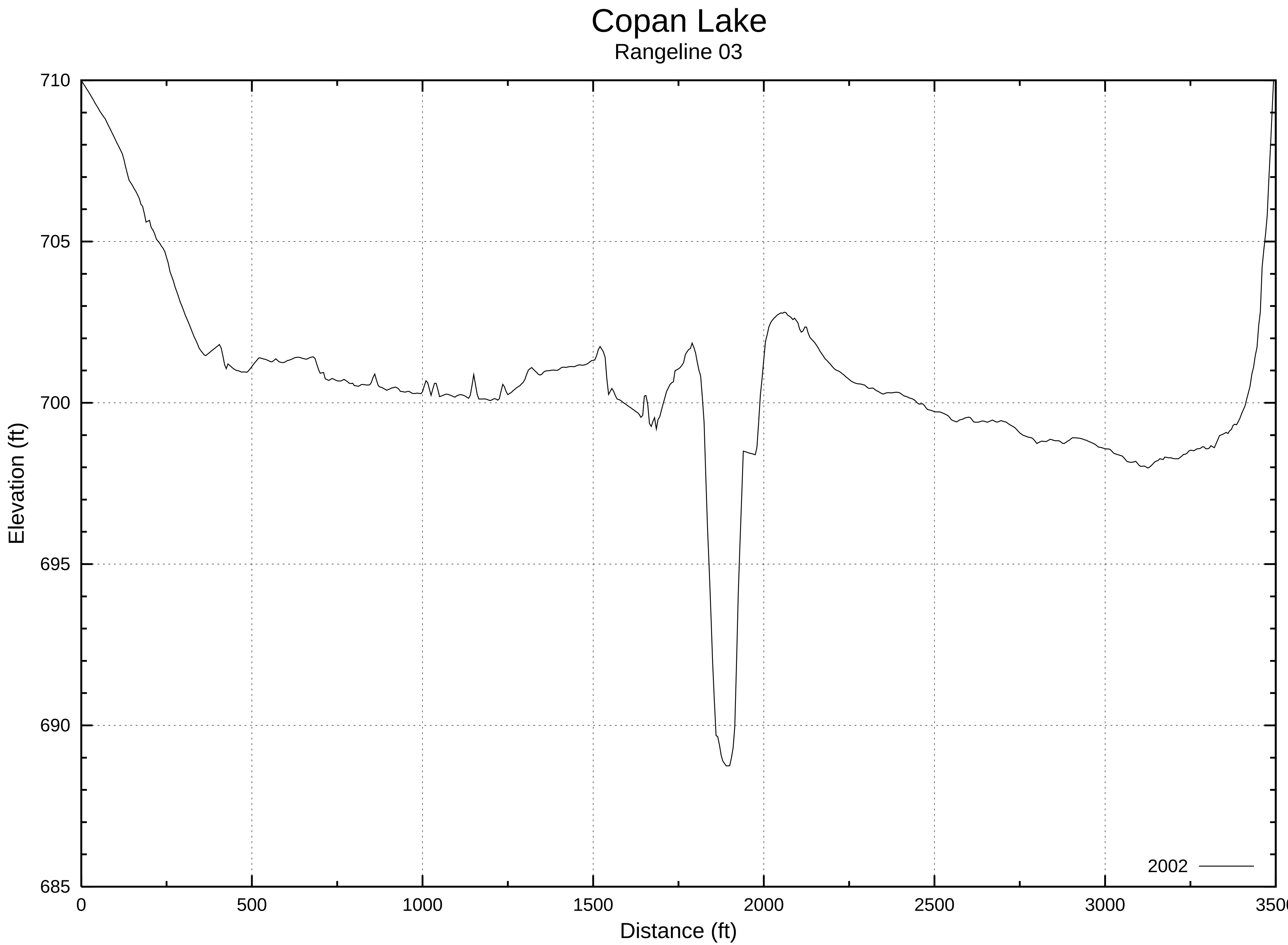


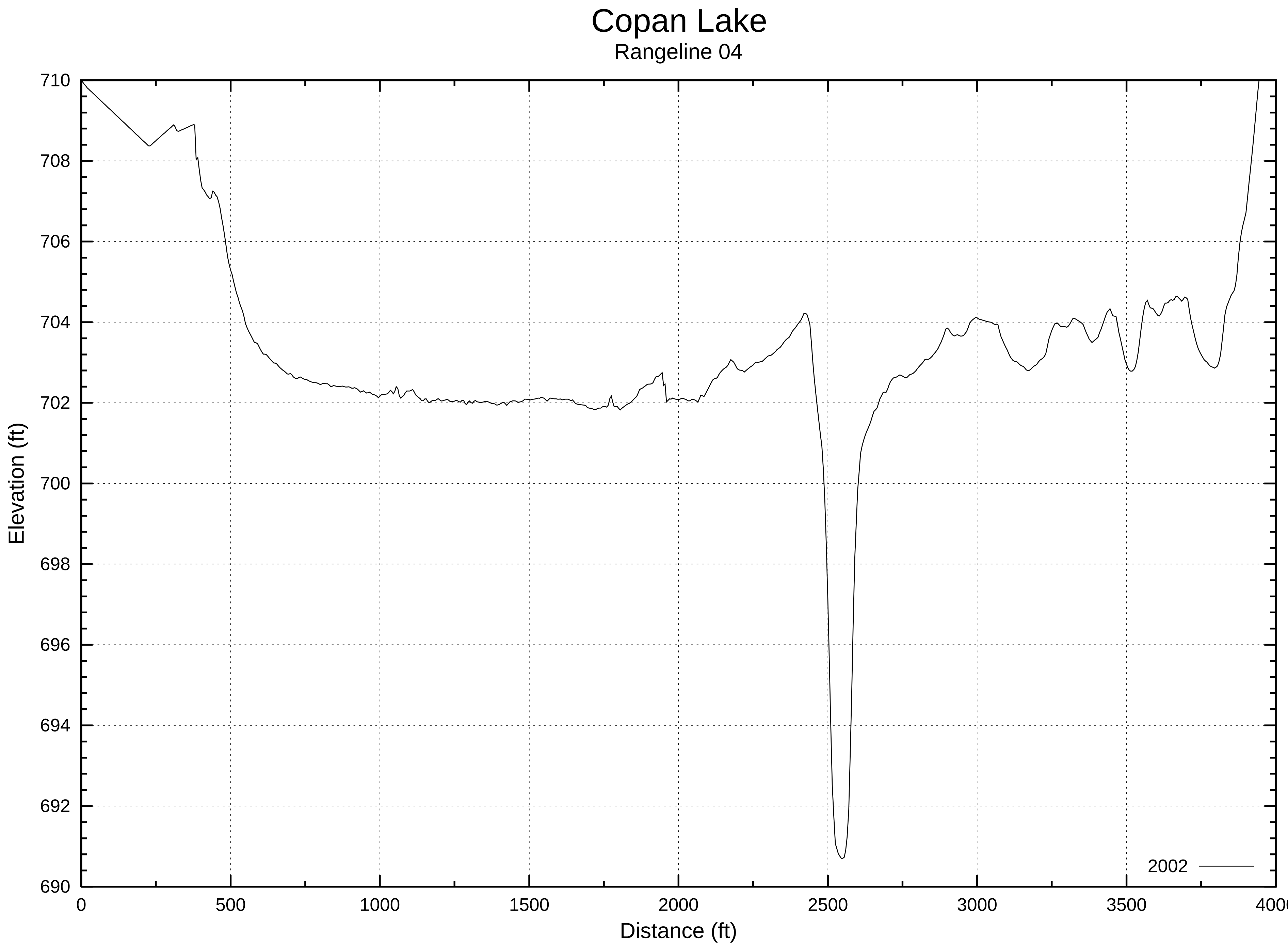
Copan Lake
Rangeline 01
Elevation (ft)
710
705
700
695
690
685
680
675
670
0
1000
2000
3000
4000
5000
6000
7000
Distance (ft)
2002

Copan Lake

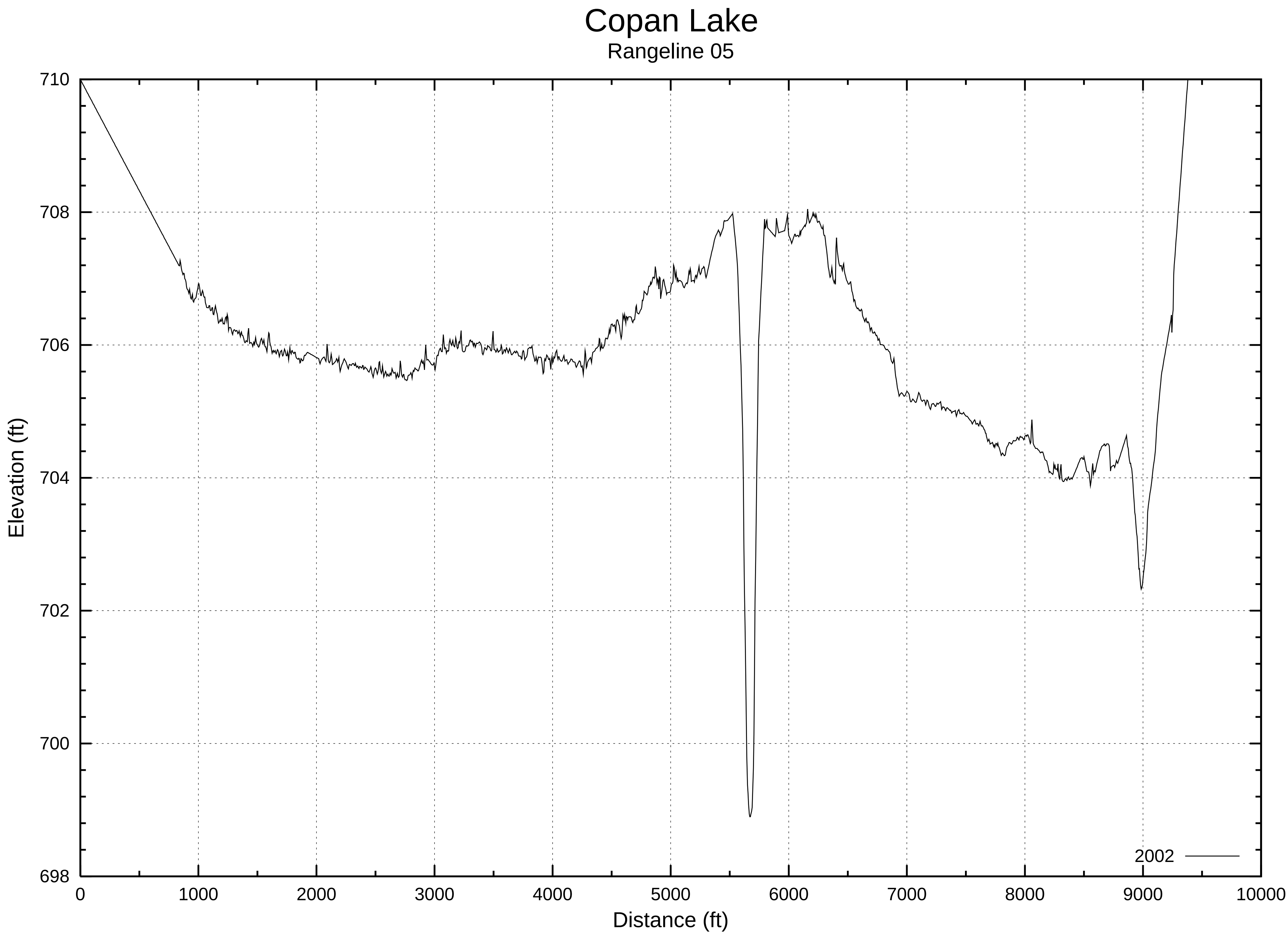
Rangeline 02




Copan Lake
Rangeline 03
Elevation (ft)
710
705
700
695
690
685
0
500
1000
1500
2000
2500
3000
3500
Distance (ft)
2002



Copan Lake
Rangeline 04
Elevation (ft)
710
708
706
704
702
700
698
696
694
692
690
0
500
1000
1500
2000
2500
3000
3500
4000
Distance (ft)
2002


Copan Lake
Rangeline 05
710
708
706
704
702
700
698
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
Elevation (ft)
Distance (ft)
2002

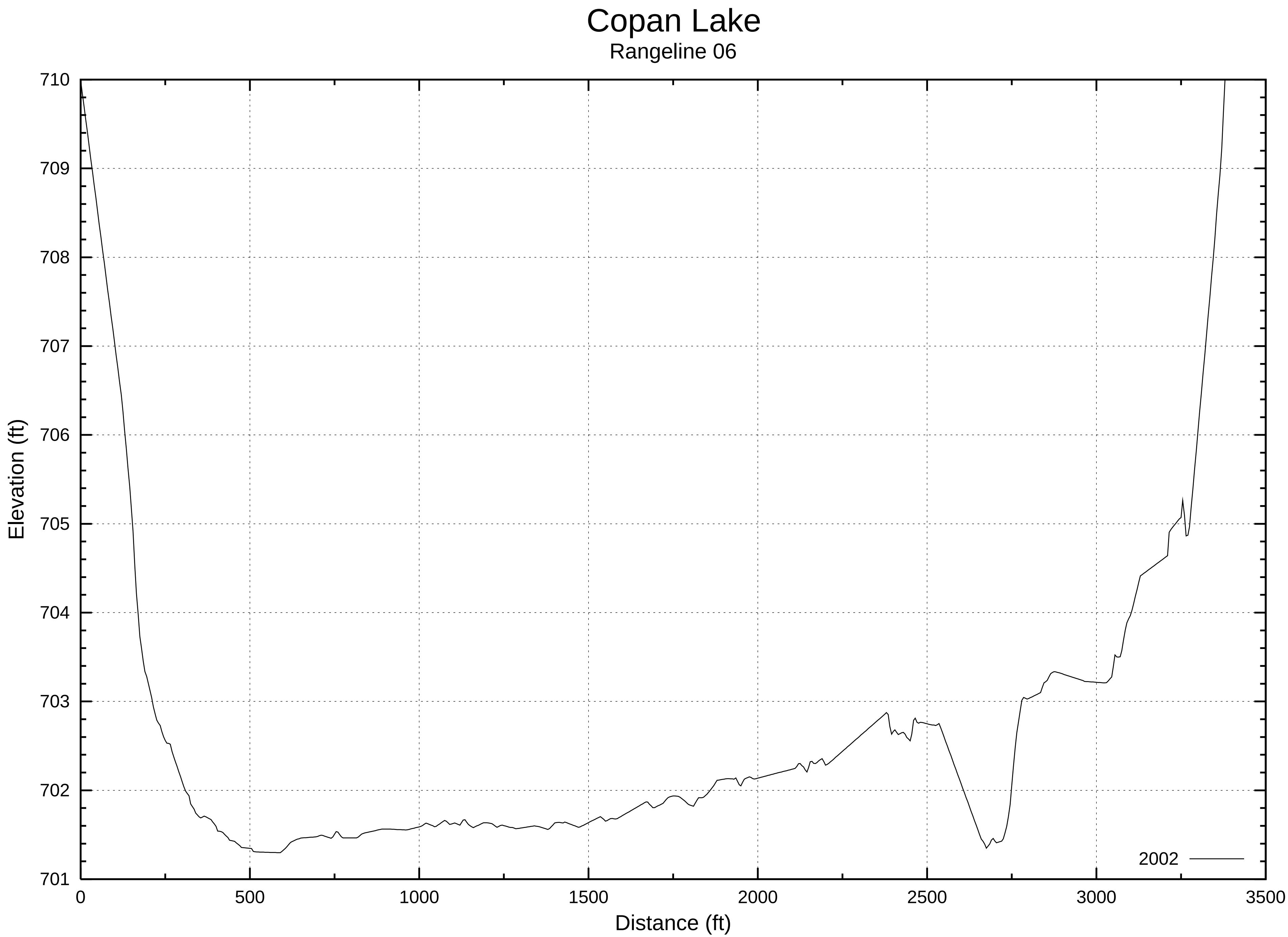
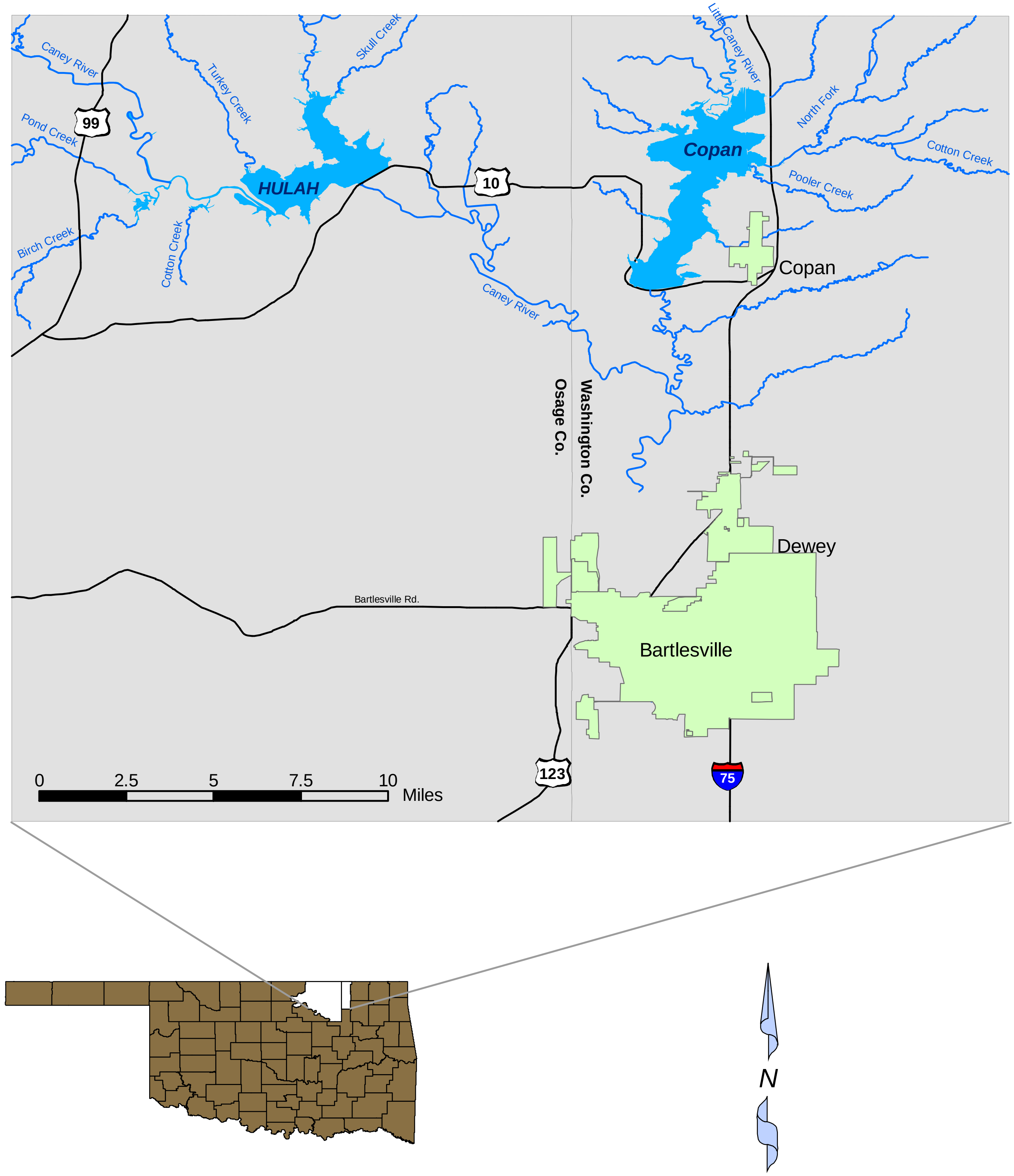

Copan Lake
Rangeline 06
Elevation (ft)
710
709
708
707
706
705
704
703
702
701
0
500
1000
1500
2000
2500
3000
3500
Distance (ft)
2002

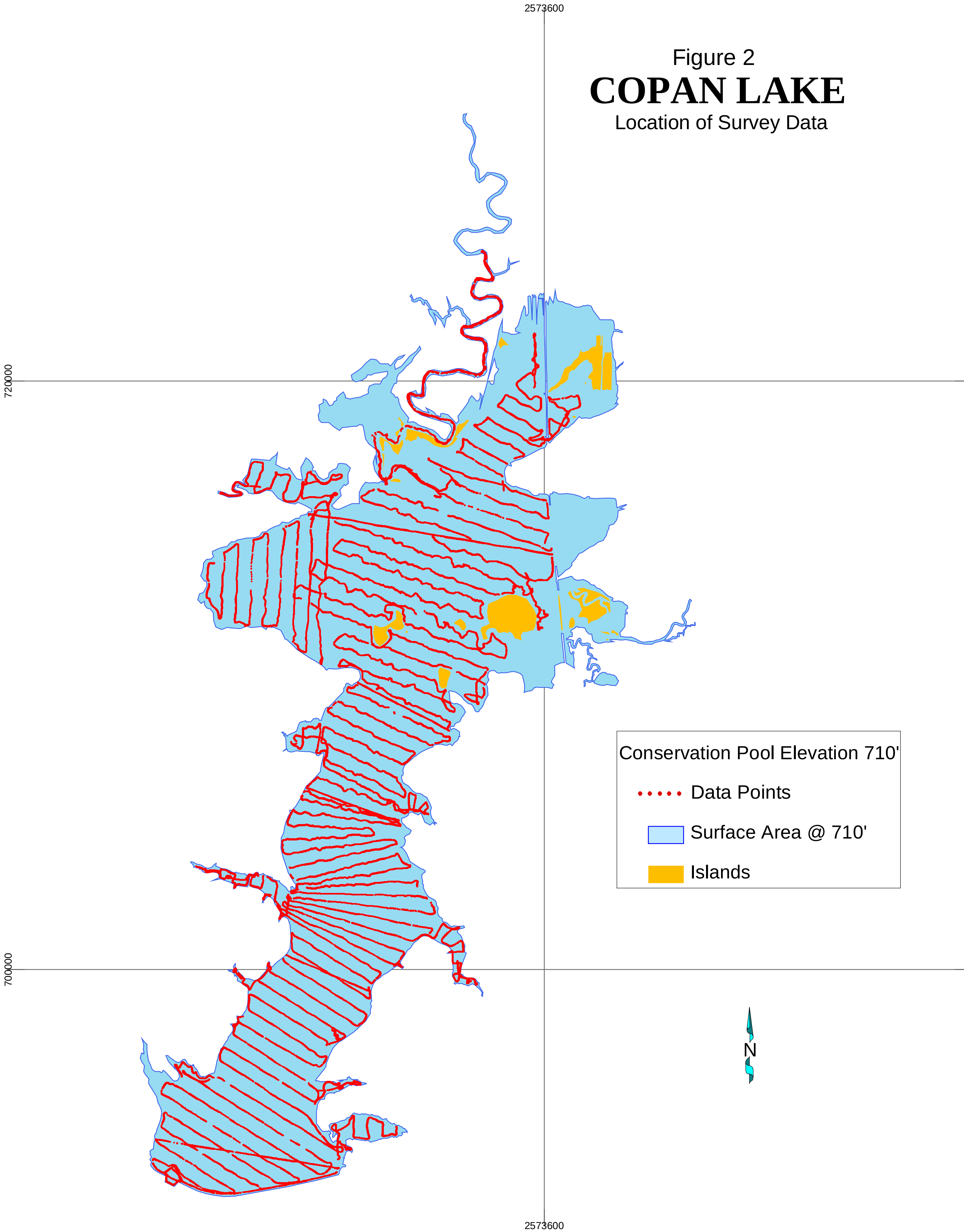
Figure 1

HULAH RESERVOIR AND COPAN LAKE

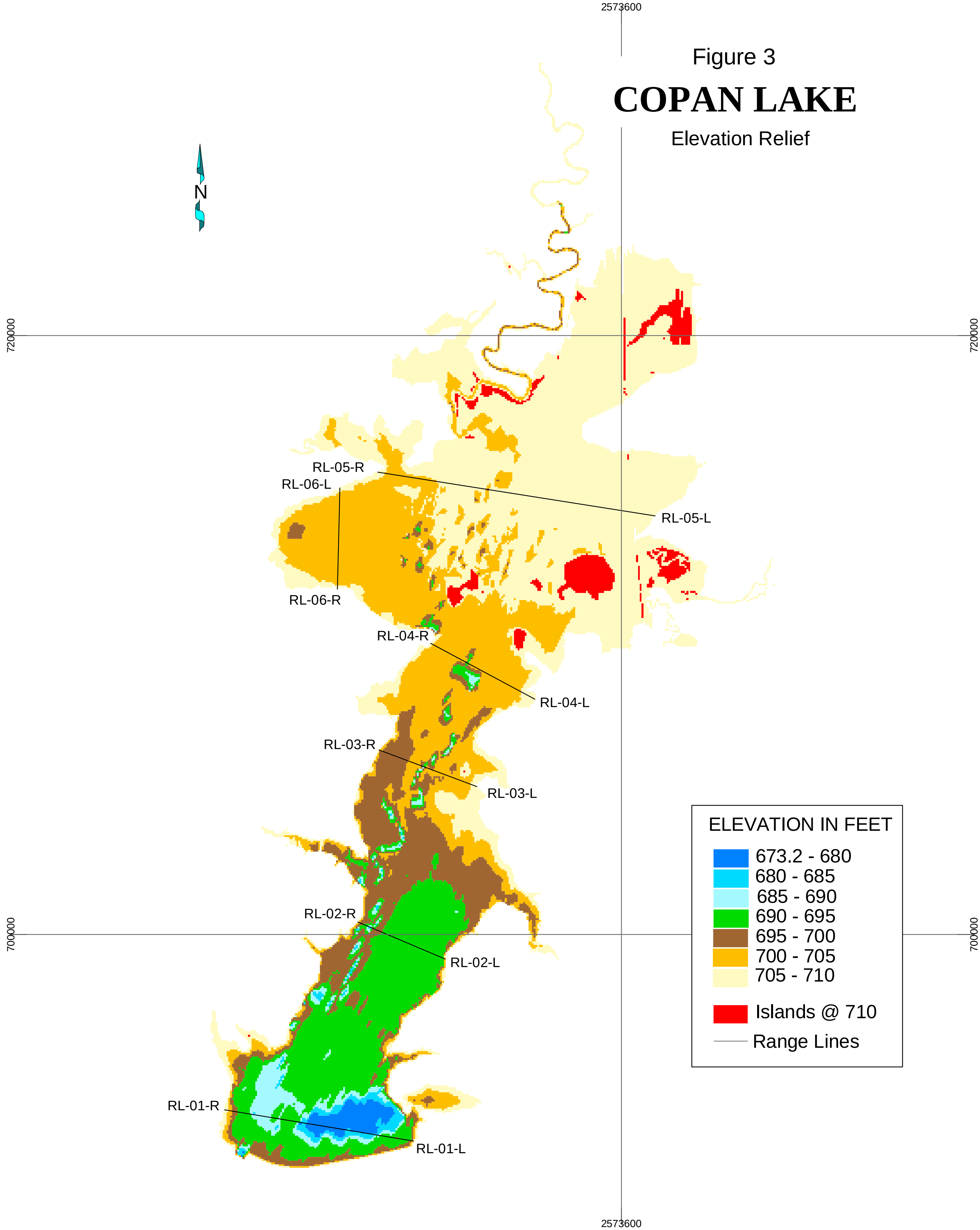
Location Map



TWDB Survey May 2002



TWDB Survey September 2002



TWDB Survey September 2002

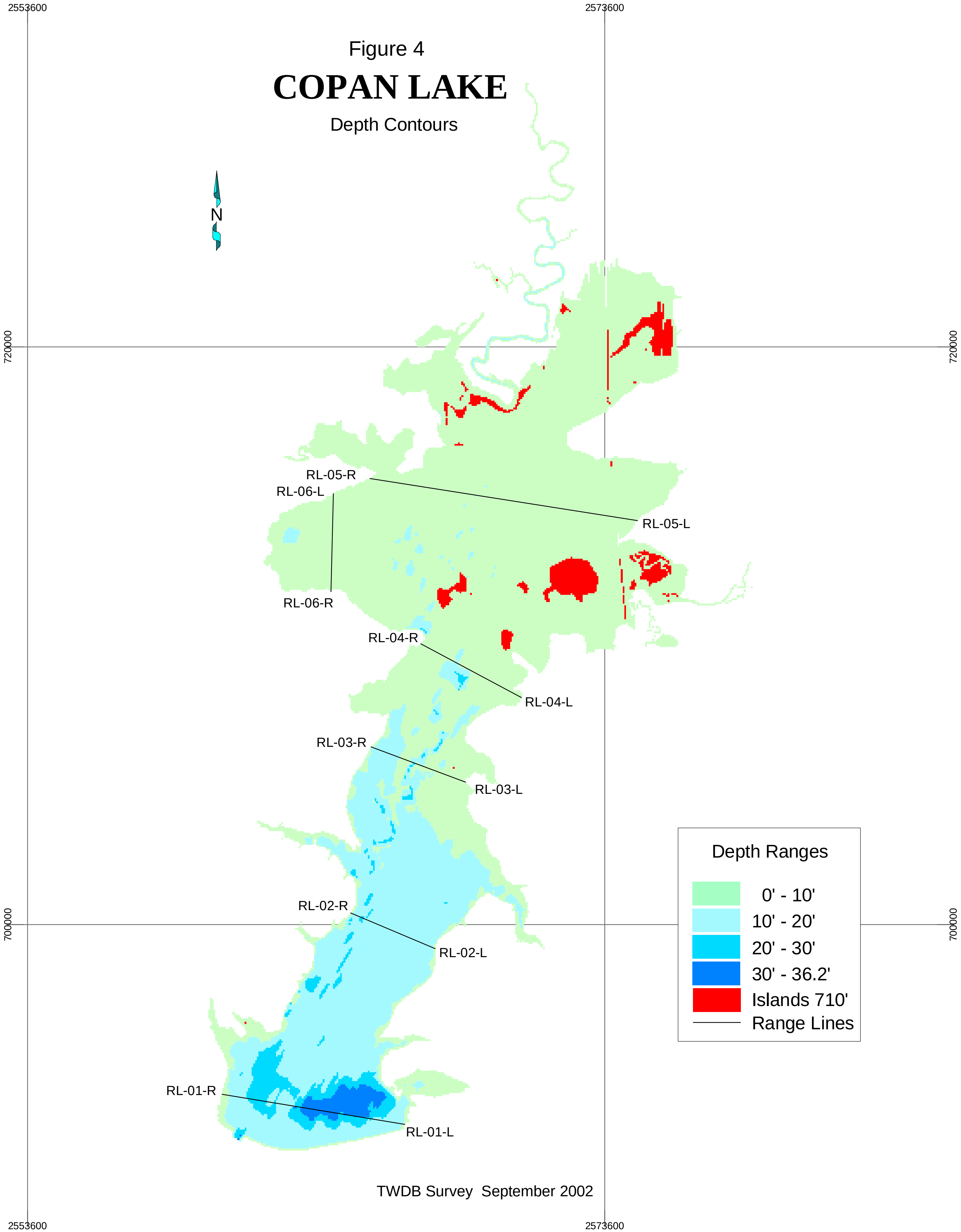


Figure 4

COPAN LAKE

Depth Contours

N

500 250 0 500 1,000 1,500 2,000 2,500 3,000 Feet

Water Surface @ 710'

Islands

Elevation 710'

Range Lines

Contours

676

678

680

682

684

686

688

690

692

694

696

698

700

702

704

706

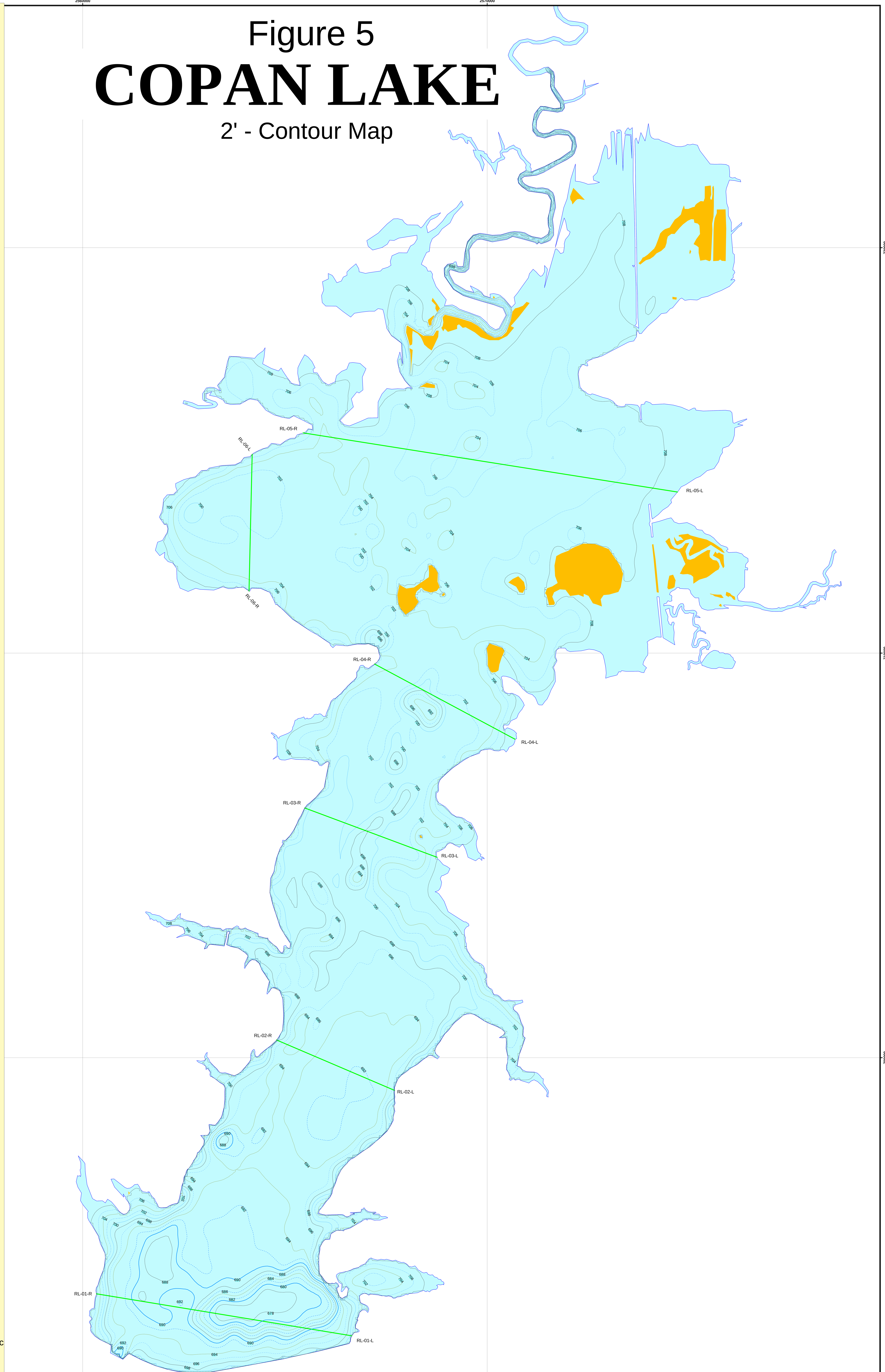
708

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

Figure 5

COPAN LAKE

2' - Contour Map



TEXAS WATER DEVELOPMENT BOARD SEPTEMBER 2002 SURVEY