

# **Volumetric Survey of Lake Ray Hubbard**

**May 2005 Survey**



Prepared by:

**The Texas Water Development Board**

January 2006

# Texas Water Development Board

J. Kevin Ward, Executive Administrator

## Texas Water Development Board

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### **LopezGarcia Group**

In cooperation with:

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## Executive Summary

In March of 2005, the Texas Water Development Board (TWDB) entered into agreement with the LopezGarcia Group, for the purpose of performing a volumetric survey of Lake Ray Hubbard while the reservoir was near the top of the conservation pool elevation. This information was converted into updated Elevation-Volume and Elevation-Area Tables. Additionally, the results of the 2005 survey were compared to a previous survey of Lake Ray Hubbard conducted by Turner Collie & Braden Inc. (TCB) in 1989, and to the original design of 1968. Cross-sections from the 2005 survey are compared to similar cross-sections from the 1989 survey by TCB.

**The results of the TWDB 2005 Survey indicate Lake Ray Hubbard has a volume of 452,040 acre-feet and encompasses 20,963 acres at the conservation pool elevation of 435.5 feet above mean sea level.** In the 1989 TCB report on sedimentation, TCB indicated Lake Ray Hubbard had a volume of 413,500 acre-feet and encompassed 21,683 acres at conservation pool elevation. In the 1968 original design information, the City of Dallas reported the reservoir had a volume of 490,000 acre-feet and encompassed 22,745 acres. The results of the TCB survey indicate a 15.6% loss in volume between 1968 and 1989. However, the TWDB survey indicates only a 7.7% loss in volume since 1968.

In the 1989 TCB report, three of the twenty-five range lines surveyed were plotted to examine the characteristics of the lake bottom. The TWDB used a map from the TCB report showing locations of the 25 range lines to estimate new range lines for a cross-sectional comparison of the TCB survey with the TWDB 2005 survey. The original TCB endpoint coordinate data is unavailable. Therefore, the survey team estimated the range line endpoints by geo-referencing the TCB map to aerial photographs and visually inspecting the shoreline features to estimate where the range lines intersect the shoreline. The cross-sections are presented in Appendix H.

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## Lake Ray Hubbard General Information

Lake Ray Hubbard was built and paid for by the City of Dallas primarily as a drinking water supply lake for Dallas. Secondly, this lake is used for environmental and recreational purposes.<sup>1</sup> Lake Ray Hubbard is owned by the City of Dallas and operated by the City of Dallas Water Utilities, a not-for-profit department of the City of Dallas.<sup>2</sup> Lake Ray Hubbard features a lakeside power plant named for its proximity to the lake.<sup>3</sup> The Lake Ray Hubbard Steam Electric Station, a TXU power plant, is a two unit gas/oil fired power plant that has been operating since June 8, 1970 and November 20, 1973.<sup>4</sup>

The State owns the water in Lake Ray Hubbard and has granted the City of Dallas the rights to this water as follows<sup>1</sup>:

•**Certificate of Adjudication 08-2462**, priority date: February 2, 1955

Authorizes the City of Dallas to maintain Lake Ray Hubbard on the East Fork of the Trinity River and impound therein not to exceed 490,000 acre-feet of water. The City of Dallas is authorized to divert and use not to exceed 78,700 acre-feet of water per annum for municipal purposes, 10,000 acre-feet of water per annum for industrial purposes, and 1,000 acre-feet of water per annum for domestic purposes. Section 5D authorizes the City of Dallas to store in and divert from Lake Ray Hubbard water released from Lake Tawakoni on the Sabine River in the amount not to exceed 179,000 acre-feet of water per annum, provided such water is not stored above elevation 432 ft above mean sea level or if the total water impounded exceeds 440,000 acre-feet.

•**Amendment to Certificate of Adjudication 08-2462A**, granted January 25, 1984

Reduces the amount of water the City of Dallas can divert and use for industrial purposes from 10,000 acre-feet of water per annum to 9,665 acre-feet of water per annum. Authorizes the City of Garland to divert and use not to exceed 180 acre-feet of water, at a maximum diversion rate of 750 gpm, per annum for irrigation purposes out of Rowlett Creek, tributary of Lake Ray Hubbard, to fulfill a water supply agreement with the City of Garland dated October 13, 1982. This diversion from Rowlett Creek is deemed to be from the yield of Lake Ray Hubbard as though the diversions are actually from the lake. Also authorizes Eastern Hills County Club to divert and use not to exceed 155 acre-feet of water per annum from the lake for irrigation purposes, to fulfill a water supply agreement with the county club dated May 18, 1983.

•**Amendment to Certificate of Adjudication 08-2462B**, granted June 25, 1985

Reduces the amount of water the City of Dallas can divert and use for industrial purposes from 9,665 acre-feet of water per annum to 9,510 acre-feet of water per annum. Authorizes owner to divert and use not to exceed 155 acre-feet of water per annum from three reservoirs on Canyon Creek, tributary of Spring Creek, tributary of Rowlett Creek,

tributary of Lake Ray Hubbard, to be diverted by Richardson Country Club d/b/a Canyon Creek Country Club, to fulfill a water supply agreement dated March 3, 1983. The diversion and use is authorized for the irrigation of 50 acres of land out of 5 tracts containing 176.1 acres. This diversion is deemed to be from the yield of Lake Ray Hubbard as though the diversions were actually from the lake.

•**Amendment to Certificate of Adjudication 08-2462C**, granted December 17, 1985  
Changes the 1,000 acre-feet of water per annum that the City of Dallas was authorized to divert and use for domestic purposes originally granted in Certificate of Adjudication 08-2462, to change in purpose of use to 500 acre-feet per annum for domestic purposes, 450 acre-feet per annum for irrigation purposes, and 50 acre-feet per annum for recreational purposes. However, this amendment becomes null and void 20 years from its date of issuance, upon which the City of Dallas is authorized to divert and use the 1,000 acre-feet per annum for domestic purposes.

•**Amendment to Certificate of Adjudication 08-2462D**, granted January 9, 1996  
Recognizes that Certificate No. 08-2462 has been amended three times and authorizes owner to divert and use 78,700 acre-feet of water per annum for municipal purposes, divert and use 9,510 acre-feet of water per annum for industrial purposes, divert and use not to exceed 500 acre-feet of water per annum for domestic purposes, divert and use 940 acre-feet of water per annum for irrigation purposes, and to divert and use 50 acre-feet of water per annum for recreational purposes. Certificate 08-2462D authorizes an additional use of 2,000 acre-feet of the 78,700 acre-feet of water per annum for municipal purposes to be used for either municipal or irrigation purposes. Owner is also required to implement the updated “Dallas Water Conservation Plan (Sept. 20, 1995), such that owner shall provide for the practices, techniques, and technologies to conserve water, recycle water, and prevent the pollution of water, so that water is available for the future; and in every wholesale water supply contract entered into for the purpose of resale, the wholesale customer will be required to implement water conservation measures.

•**Amendment to Certificate of Adjudication 08-2462E**, granted March 1, 1996  
Changes the 9,510 acre-feet of water per annum authorized for industrial use to 9,212 acre-feet of water per annum to be used for industrial and municipal use. The remaining 298 acre-feet is changed in purpose from industrial to irrigation use, and is to be diverted by the City of Garland 3,000ft downstream of their current 180 acre-feet per annum diversion point on the Rowlett River with a maximum rate of 750 gpm, (agreement dated October 13, 1982, replaced by “Untreated Water Purchase Contract” between City of Garland and City of Dallas, March 24, 1993 and a February 8, 1995 “First Amendment to the Contract” –dated February 10, 1967- between Dallas Power and Light Company and the City of Dallas). 298 acre-feet may be diverted at a maximum rate of 1,000 gpm, with the following stipulation: owner is authorized to divert and use the 298 acre-feet of irrigation water per annum only when the flow of the creek at USGS Gauging Station No. 08061540 near Sachse, Texas equals or exceeds 25 cfs from January through June, or equals or exceeds 15 cfs from July through December. Section 3 provides for water conservation measures to be taken.

•**Amendment to Certificate of Adjudication 08-2462F**, granted June 6, 2002  
 Recognizes that owner is authorized to divert and use up to 89,700 acre-feet of water per annum for municipal, domestic, agricultural (irrigation), industrial, and recreational purposes, at a maximum combined diversion rate of 309.37 cfs (138,845 gpm).  
 Amendment authorizes change in maximum combined diversion rate from 309.37 cfs to 619 cfs (277,807 gpm) from Lake Ray Hubbard and other points authorized for diversion. Owners must continue to implement conservation plans as before. All amendments have a time priority of February 2, 1955. Complete certificates are on file in the Records Division of the Texas Commission on Environmental Quality (TCEQ).

More information about Lake Ray Hubbard and the Rockwall-Forney Dam are presented below in Table 1. A map showing the location of Lake Ray Hubbard is presented in Figure 1.

**Table 1. Pertinent Data for Rockwall-Forney Dam and Lake Ray Hubbard<sup>5</sup>**

<b>Owner of Lake Ray Hubbard and Facilities</b>	
City of Dallas	
<b>Engineer (Design)</b>	
Forrest and Cotton, Inc.	
<b>Location</b>	
On the East Fork Trinity River in Dallas, Kaufman, Rockwall, and Collin Counties, 15 miles east of Dallas	
<b>Drainage Area</b>	
1,074 square miles of which 770 square miles are above Lavon Dam	
<b>Dam</b>	
Type	Earthfill
Length	12,500 ft
Maximum Height	68 ft
Top Width	22 ft
<b>Spillway</b>	
Type	Concrete ogee
Control	14 tainter gates, each 40 by 28 ft
Crest length (net)	560 ft
Crest elevation	409.5 ft above msl
<b>Outlet Works (Water Supply)</b>	
Type	Concrete tower structure
Control	Gated openings at several elevations
Elevation low opening	392.0 ft above msl
<b>Outlet Works (low flow)</b>	
Type	3 sluiceways through piers
Control	3 slide gates, each 4 by 6 ft
Elevation	388.0 ft above msl

**Table 1. Pertinent Data for Rockwall-Forney Dam and Lake Ray Hubbard (Continued)**

<b>General</b>			
Construction started (land purchase)	September 17, 1963		
Construction started (actual phase I)	June 13, 1964		
Deliberate impoundment began	December 1, 1968		
Dam completed	January 17, 1969		
General Contractors	S. & A. Construction Company, Markham Brown, Brown and M.C. Winters Construction Company		
Estimated cost of dam	\$26,100,000		
<b>Reservoir Data (Based on TWDB 2005 Volumetric Survey)</b>			
<b>Feature</b>	<b>Elevation (ft above msl)</b>	<b>Capacity (Acre-feet)</b>	<b>Area (Acres)</b>
Top of Dam	450.0	N/A	N/A
Top of gates	437.5	N/A	N/A
Top of conservation pool	435.5	452,040	20,963
Spillway Crest	409.5	72,293	8,441
Invert of low flow outlet	388.0	0	0

## **Volumetric Survey of Lake Ray Hubbard**

### **Introduction**

In March of 2005, the Texas Water Development Board entered into agreement with the LopezGarcia Group, for the purpose of performing a volumetric survey of Lake Ray Hubbard while the reservoir was near the top of the conservation pool elevation. This information was converted into updated Elevation-Volume and Elevation-Area Tables. Additionally, the results of the 2005 survey are compared to a prior survey of Lake Ray Hubbard conducted by Turner Collie & Braden Inc. (TCB) in 1989, and to the original design. Cross-sections of the 2005 survey are compared to cross-sections from the 1989 TCB report.

### **Bathymetric Survey**

Bathymetric data collection for Lake Ray Hubbard occurred between April 14<sup>th</sup> and May 5<sup>th</sup> of 2005, while the water surface elevation was slightly below the conservation pool elevation of 435.5 ft above mean sea level (msl). The water surface elevation varied between 435.33 ft and 435.46 ft above msl during the TWDB survey.

The survey team used two boats equipped with depth sounders, velocity profilers, and integrated Differential Global Positioning System (DGPS) equipment to navigate along pre-planned range lines spaced approximately 500 feet apart in a perpendicular fashion to the original stream channel. During the 2005 survey, the team navigated over 450 miles of range lines and collected over 193,600 data points. Figure 2 shows the data points collected during the TWDB 2005 survey.

The depth sounders were calibrated each day using the velocity profilers to measure the speed of sound in the water column and a weighted tape or stadia rod to verify the depth reading. The average speed of sound through the water column varied between 4,830 and 4,899 feet per second during the 2005 survey.

## **Datum**

The vertical datum used during this survey is that used by the United States Geological Survey (USGS) for the reservoir elevation gauge USGS 081061550 Lk Ray Hubbard nr Forney, TX.<sup>6</sup> The datum for this gauge is reported as National Geodetic Vertical Datum 1929 (NGVD29) or mean sea level (msl), thus elevations reported here are in feet (ft) above msl. Volume and area calculations in this report are referenced to water levels provided by the USGS gauge. The horizontal datum used for this report is NAD83 State Plane Texas North Central Zone.

## **Survey Results**

The results of the TWDB 2005 Survey indicate Lake Ray Hubbard has a volume of 452,040 acre-feet and encompasses 20,963 acres at conservation pool elevation. The results of the TWDB survey are compared to previous surveys of Lake Ray Hubbard in Table 2.

Feature	City of Dallas	TurnerCollie&Braden Inc.	TWDB
	Original Design*	Sediment Survey	Volumetric Survey
Year	1968	1989	2005
Area (Acres)	22,745	21,683	20,963
Volume (Acre-feet)	490,000	413,500	452,040

\*Original design information from 1968 as reported by the City of Dallas.

In the 1989 report on sedimentation to the City of Dallas and Dallas Water Utilities, TCB indicated Lake Ray Hubbard decreased 4.7% in area and lost 15.6% of its original capacity. The 2005 TWDB survey indicates Lake Ray Hubbard has decreased 3.3% in area since 1989. However, the TWDB results indicate there is 9.3% more volume than computed in 1989. This indicates a 7.7% loss in capacity since 1968.

The TWDB collected data on over 480 range lines, not including random data collected in small coves and rivers, using modern acoustical depth sounders and GPS equipment. The following section on Data Processing describes the methods used to calculate area and volume. The original design capacities were estimated from 10-foot contour interval maps without survey data using the Average End Area Method, although the original working contour maps are unavailable.<sup>7</sup> TCB collected data on 25 range lines. For consistency with the Dallas Water Utilities methods of calculation, TCB also used the Average End Area Method to calculate area and volume for Lake Ray Hubbard.<sup>7</sup> Due to these methodological differences in computing the area and volume, direct comparisons of the TWDB 2005 survey with prior surveys of Lake Ray Hubbard are not recommended and are presented here for informational purposes only.<sup>8</sup>

## **Data Processing**

### **Model Boundary**

The reservoir boundary was digitized from aerial photographs using Environmental Systems Research Institute's (ESRI) ArcGIS 9.1 software. The aerial photographs, or digital orthophoto quadrangle images (DOQs), used for Lake Ray Hubbard were Forney North, Rockwall, Rowlett, Mesquite, and Lavon. These images were photographed on March 8th and March 20th of 1995. At the time of the

photographs the water surface elevation measured 435.73 ft and 435.62 ft, respectively. Although just above conservation pool elevation, at the recommended mapping scale of 1:12,000 for the DOQ's, the difference in the land water interface between photos of varying water surface elevations is indiscernible. Therefore, for modeling purposes, the boundary as digitized at the land water interface from the photos, was labeled 435.5 ft, conservation pool elevation.

VARGIS of Texas LLC produced the DOQs for the Texas Orthoimagery Program (TOP). The DOQs produced for the Department of Information Resources and the GIS Planning Council under the TOP reside in the public domain. More information can be obtained on the Internet at <http://www.tnris.state.tx.us/DigitalData/doqs.htm>.

### **Triangular Irregular Network (TIN) Model**

Upon completion of data collection, the raw data files are edited in HYPACK MAX to remove any data anomalies. The water surface elevations for each respective day are applied and the depths are converted to corresponding elevations and exported as a MASS points file. The MASS points and boundary files are used to create a Triangulated Irregular Network (TIN) model, a function of the 3D Analyst Extension of ArcGIS. The model uses Delauney's criteria for triangulation to place a triangle between three non-uniformly spaced points, including the boundary.<sup>9</sup>

Using Arc/Info software, volumes and areas are calculated from the TIN Model for the entire lake at one-tenth of a foot intervals, from elevation 388.0 ft to elevation 435.5 ft. The Elevation-Volume and Elevation-Area Tables, updated for 2005, are presented in Appendices A and B, respectively. An Elevation-Volume graph and an Elevation- Area graph are presented in Appendices C and D, respectively. Appendix E compares the Volume and Area Tables from 1968, 1989, and 2005, at one foot intervals. These values are presented graphically in Appendices F and G.

The TIN Model was interpolated and averaged using a cellsize of 10 ft and converted to a raster. The raster was used to produce Figure 3, an Elevation Relief Map representing the topography of the lake bottom, Figure 4, a map showing shaded depth ranges for Lake Ray Hubbard, and Figure 5, a 2 ft contour map.

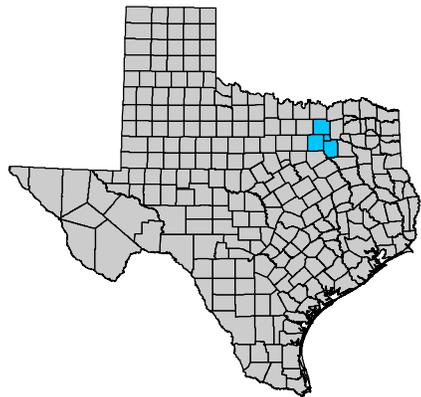
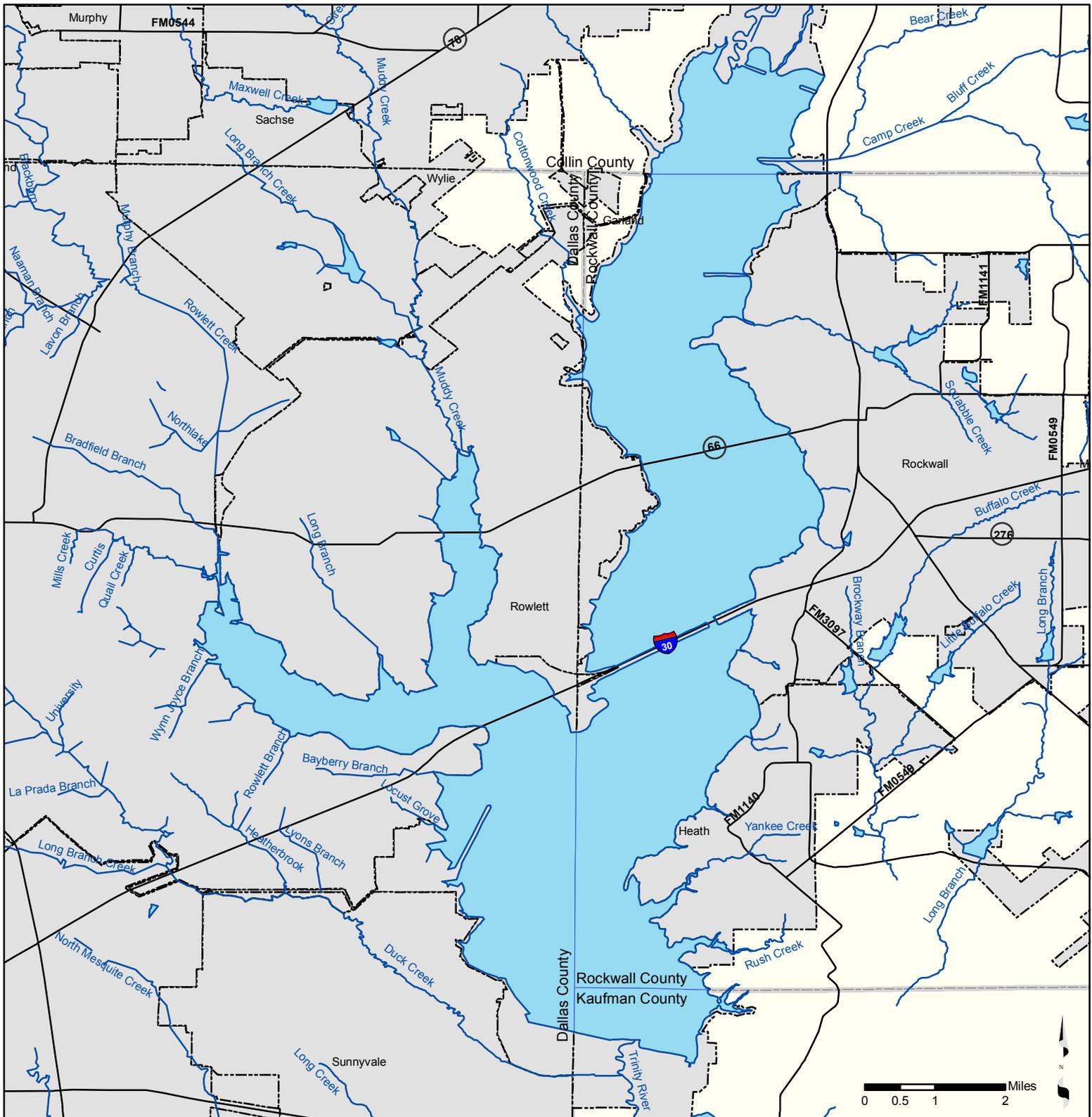
## **Sediment Range Lines**

In 1989, TCB surveyed 25 range lines to calculate the area, volume, and sedimentation rate of Lake Ray Hubbard. In the report TCB graphed three cross-sections and provided a map of the locations on the lake of all 25 ranges. The original data and endpoint coordinates for each line is unavailable; therefore, the survey team estimated the range line endpoints by geo-referencing the TCB map to aerial photographs and visually inspecting the shoreline features to estimate where the range lines intersect the shoreline. Cross-sections for 2005 were then extracted from the TIN Model.

The TWDB 2005 cross-sections are presented in Appendix H. Also in Appendix H is a map showing the location of the new range lines and Table 3, a list of the endpoint coordinates for each range line. Ranges 3, 8, and 22 compare the TWDB 2005 cross-sections with the TCB 1989 cross-sections. Each cross-section is plotted from left bank to right bank when looking downstream, except ranges 3, 8, and 22, which are plotted right bank to left bank.

## References

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7. TurnerCollie&Braden Inc., Report on Sedimentation, Lake Lewisville, Lake Ray Hubbard, Lake Palestine, to the City of Dallas, Dallas Water Utilities, November 1989.
8. Blanton III, James O. Bureau of Reclamation. 1982. "Procedures for Monitoring Reservoir Sedimentation."
9. ESRI, Environmental Systems Research Institute. 1995. ARC/INFO Surface Modeling and Display, TIN Users Guide.



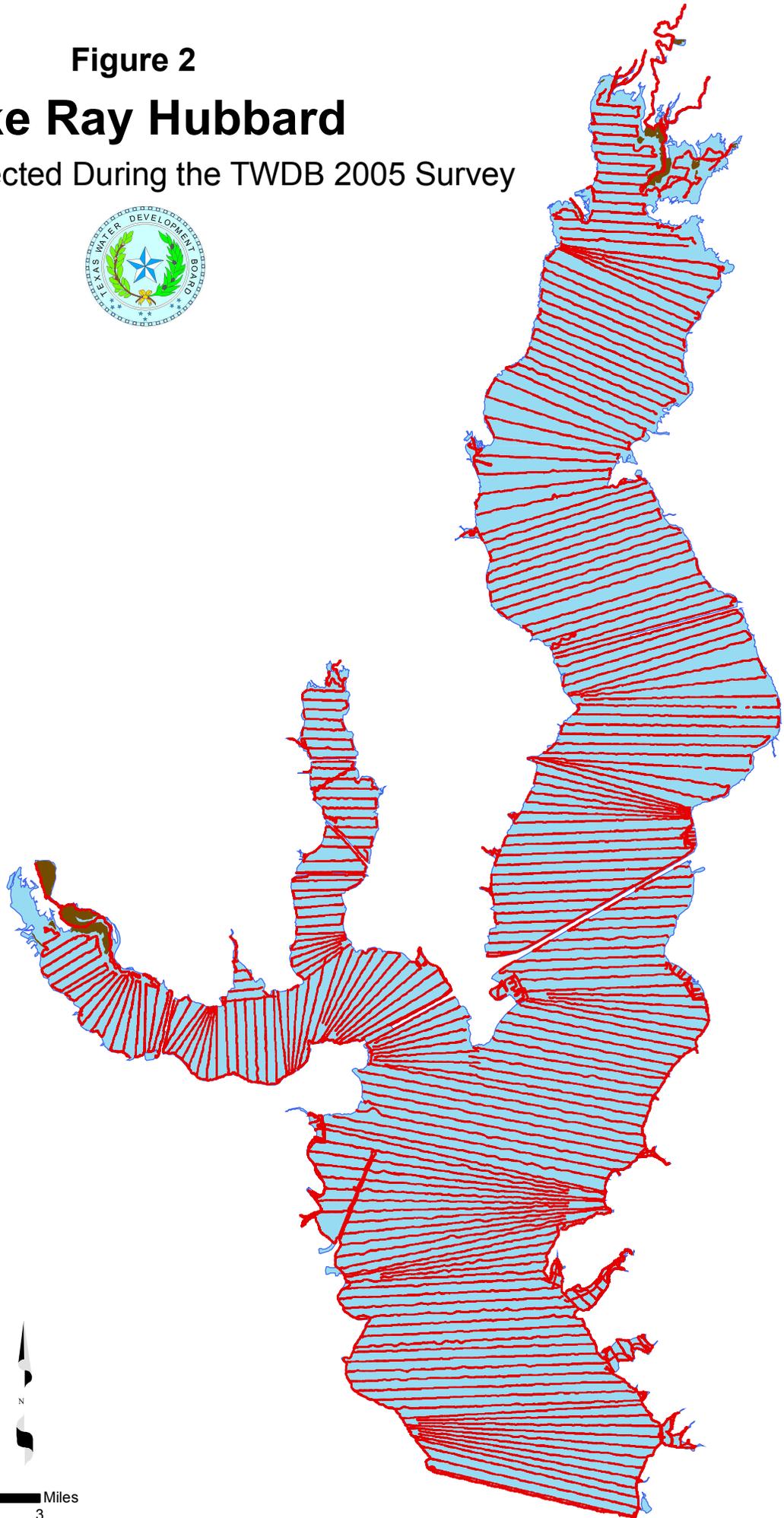
**Figure 1**  
**Lake Ray Hubbard**  
 Location Map



Figure 2

# Lake Ray Hubbard

Data Points Collected During the TWDB 2005 Survey



## Legend

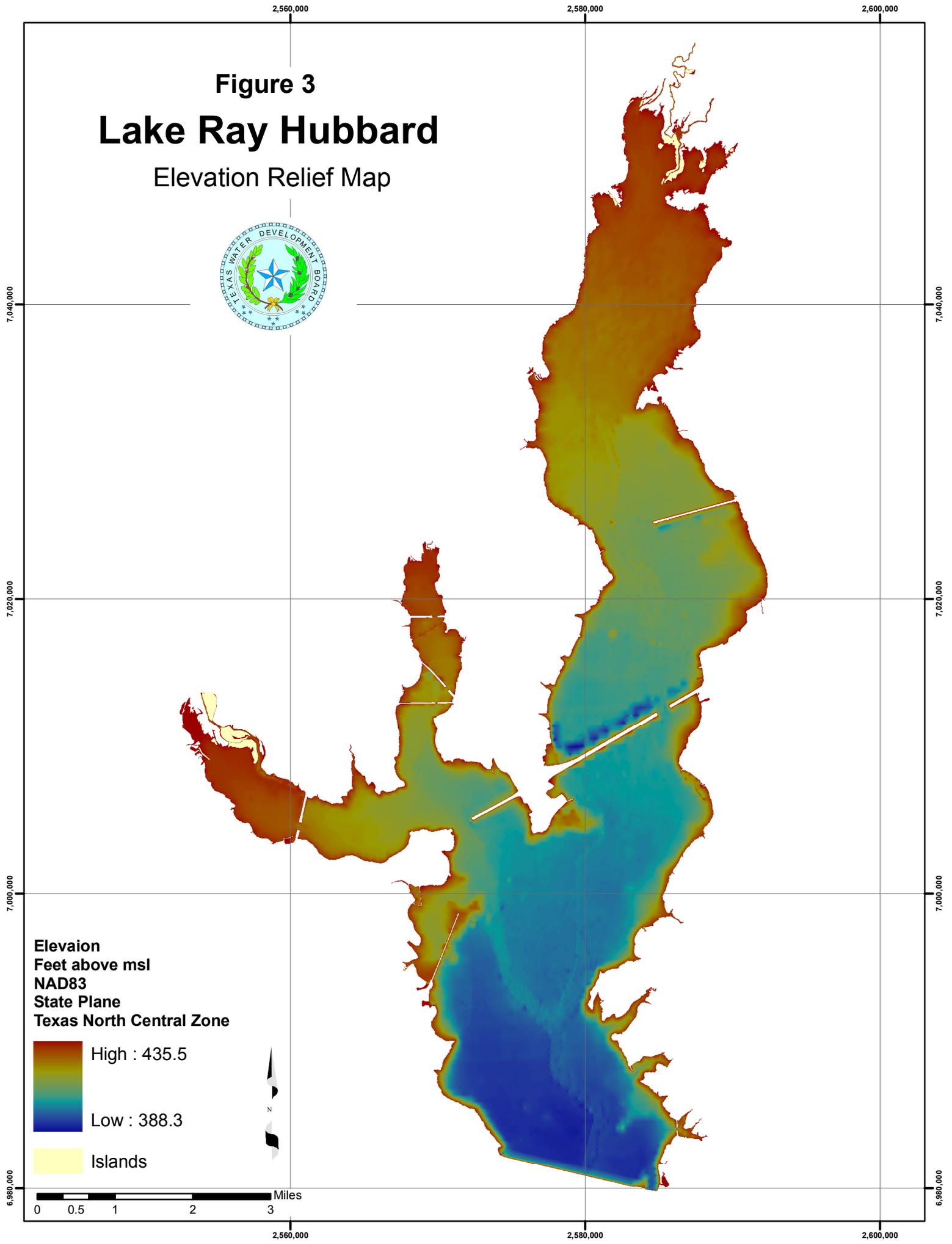
- ..... Data Points
- Islands
- Lake Boundary

0 0.5 1 2 3 Miles

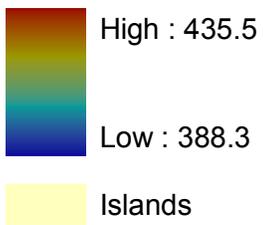
# Figure 3

## Lake Ray Hubbard

### Elevation Relief Map



Elevation  
Feet above msl  
NAD83  
State Plane  
Texas North Central Zone



2,560,000 2,580,000 2,600,000

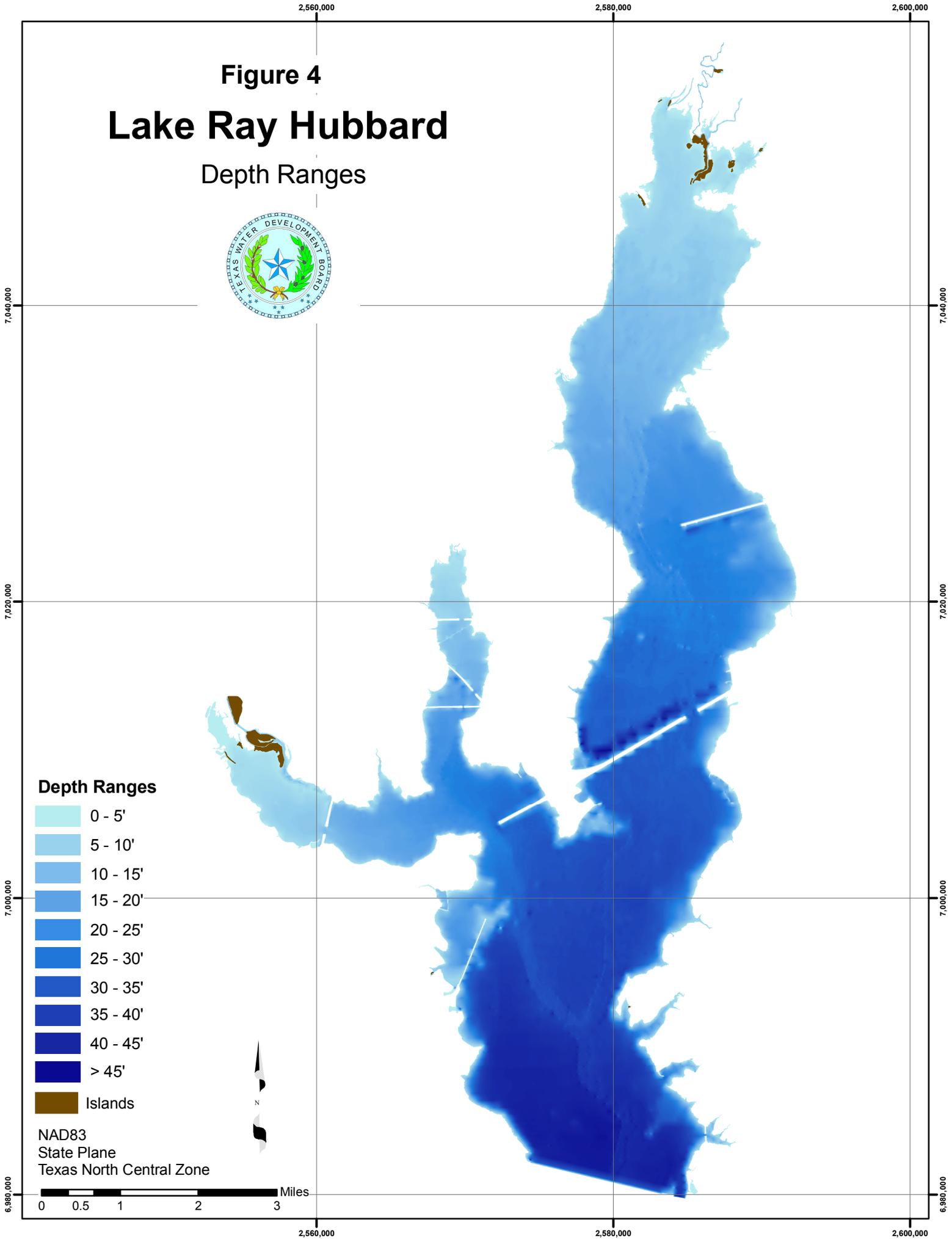
7,040,000  
7,020,000  
7,000,000  
6,980,000

7,040,000  
7,020,000  
7,000,000  
6,980,000

# Figure 4

## Lake Ray Hubbard

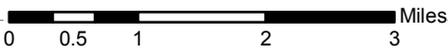
### Depth Ranges



#### Depth Ranges

- 0 - 5'
- 5 - 10'
- 10 - 15'
- 15 - 20'
- 20 - 25'
- 25 - 30'
- 30 - 35'
- 35 - 40'
- 40 - 45'
- > 45'
- Islands

NAD83  
State Plane  
Texas North Central Zone



Appendix A  
**Lake Ray Hubbard**  
**RESERVOIR VOLUME TABLE**

TEXAS WATER DEVELOPMENT BOARD

MAY 2005 SURVEY

Conservation Pool Elevation 435.5'

ELEVATION in Feet	VOLUME IN ACRE-FEET									
	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
388			0	0	0	0	0	0	0	0
389	0	0	0	0	0	0	0	0	0	0
390	0	1	1	1	1	1	2	2	3	4
391	6	8	11	16	23	31	41	54	69	87
392	108	130	155	182	212	245	283	325	371	422
393	477	536	598	663	732	805	882	966	1,056	1,150
394	1,249	1,351	1,456	1,565	1,678	1,796	1,918	2,045	2,176	2,312
395	2,452	2,596	2,743	2,894	3,048	3,207	3,369	3,536	3,706	3,879
396	4,055	4,234	4,416	4,601	4,788	4,979	5,172	5,368	5,567	5,767
397	5,971	6,177	6,386	6,598	6,813	7,031	7,253	7,478	7,706	7,937
398	8,171	8,409	8,649	8,893	9,140	9,391	9,646	9,904	10,165	10,430
399	10,698	10,969	11,244	11,522	11,804	12,090	12,380	12,675	12,974	13,278
400	13,589	13,907	14,233	14,567	14,910	15,260	15,618	15,985	16,359	16,742
401	17,132	17,532	17,941	18,358	18,783	19,216	19,657	20,105	20,560	21,022
402	21,491	21,967	22,449	22,937	23,431	23,931	24,436	24,946	25,461	25,982
403	26,509	27,041	27,581	28,126	28,677	29,234	29,797	30,365	30,939	31,521
404	32,109	32,704	33,306	33,914	34,528	35,148	35,775	36,408	37,046	37,689
405	38,338	38,991	39,649	40,312	40,980	41,652	42,329	43,011	43,698	44,391
406	45,089	45,792	46,499	47,211	47,927	48,647	49,371	50,099	50,831	51,568
407	52,309	53,055	53,805	54,560	55,320	56,084	56,854	57,629	58,409	59,194
408	59,984	60,778	61,577	62,380	63,187	63,999	64,814	65,633	66,455	67,280
409	68,109	68,940	69,774	70,611	71,450	72,293	73,139	73,988	74,840	75,695
410	76,554	77,416	78,282	79,152	80,026	80,904	81,788	82,676	83,570	84,469
411	85,375	86,285	87,202	88,123	89,051	89,983	90,922	91,867	92,817	93,773
412	94,735	95,702	96,674	97,651	98,634	99,622	100,615	101,614	102,617	103,624
413	104,637	105,653	106,673	107,698	108,727	109,761	110,798	111,839	112,884	113,932
414	114,983	116,038	117,095	118,156	119,220	120,288	121,360	122,437	123,517	124,602
415	125,692	126,788	127,888	128,994	130,107	131,225	132,350	133,479	134,614	135,754
416	136,899	138,048	139,203	140,363	141,527	142,696	143,869	145,047	146,228	147,414
417	148,604	149,800	151,001	152,206	153,418	154,634	155,855	157,081	158,311	159,547
418	160,788	162,033	163,283	164,537	165,797	167,061	168,329	169,602	170,879	172,161
419	173,447	174,736	176,030	177,327	178,629	179,935	181,245	182,560	183,879	185,203
420	186,532	187,866	189,204	190,546	191,893	193,245	194,602	195,964	197,331	198,704
421	200,082	201,466	202,855	204,249	205,649	207,054	208,463	209,877	211,295	212,717
422	214,143	215,573	217,007	218,444	219,885	221,329	222,776	224,227	225,681	227,138
423	228,598	230,061	231,527	232,996	234,469	235,945	237,426	238,910	240,399	241,894
424	243,394	244,898	246,408	247,922	249,443	250,969	252,501	254,039	255,582	257,131
425	258,684	260,243	261,806	263,374	264,948	266,527	268,113	269,703	271,299	272,900
426	274,506	276,117	277,733	279,353	280,977	282,606	284,239	285,877	287,520	289,168
427	290,822	292,482	294,148	295,818	297,494	299,175	300,861	302,552	304,248	305,949
428	307,655	309,367	311,084	312,807	314,538	316,275	318,018	319,769	321,525	323,287
429	325,055	326,829	328,610	330,396	332,191	333,992	335,800	337,615	339,435	341,262
430	343,096	344,938	346,786	348,641	350,503	352,371	354,246	356,127	358,014	359,909
431	361,809	363,716	365,629	367,547	369,473	371,404	373,340	375,281	377,227	379,178
432	381,134	383,096	385,064	387,037	389,017	391,001	392,991	394,984	396,982	398,986
433	400,994	403,005	405,019	407,036	409,056	411,079	413,104	415,131	417,160	419,193
434	421,227	423,265	425,304	427,346	429,390	431,437	433,486	435,538	437,592	439,649
435	441,708	443,769	445,834	447,899	449,968	452,040				

Appendix B  
**Lake Ray Hubbard**  
**RESERVOIR AREA TABLE**

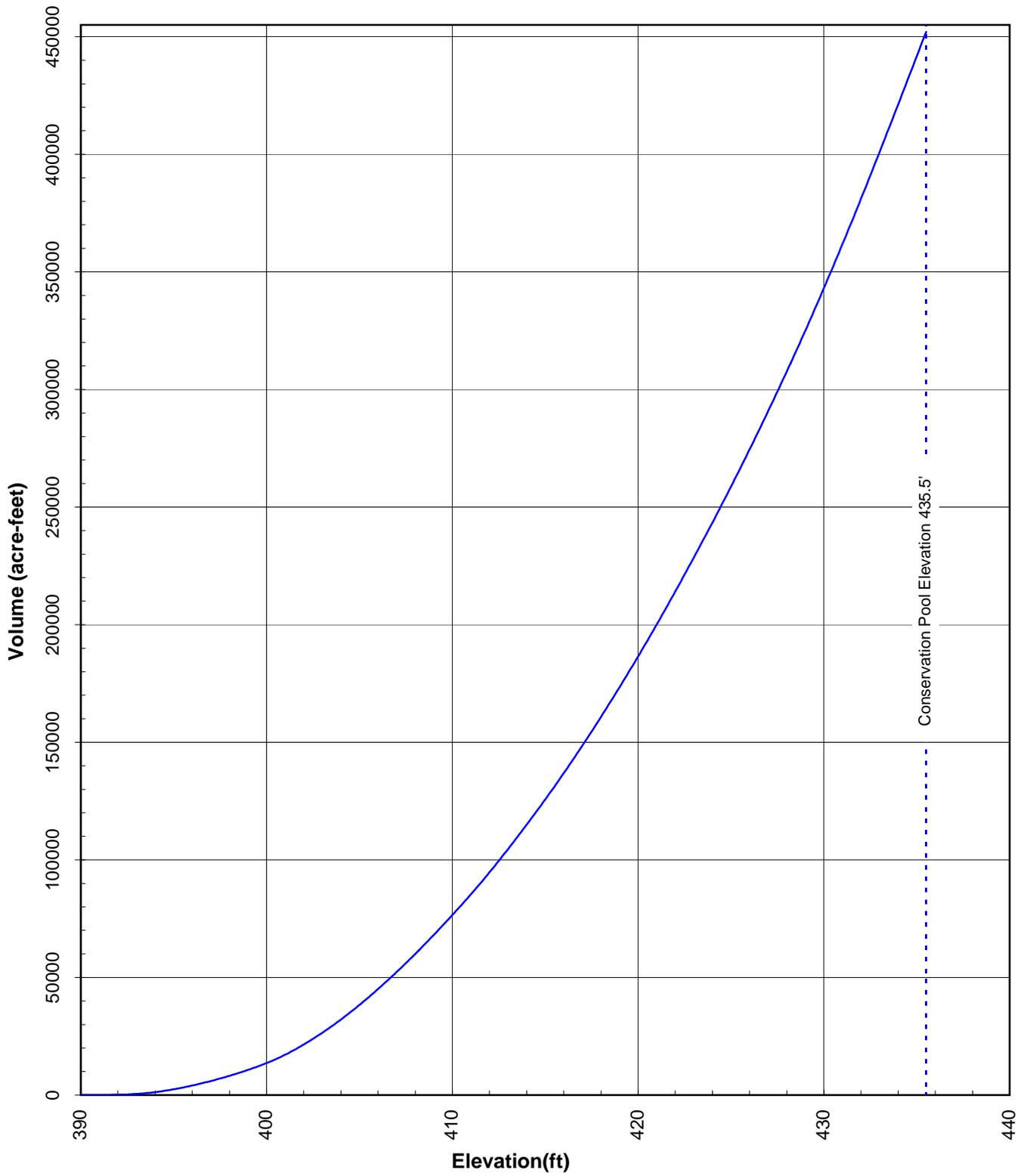
TEXAS WATER DEVELOPMENT BOARD

MAY 2005 SURVEY

Conservation Pool Elevation 435.5'

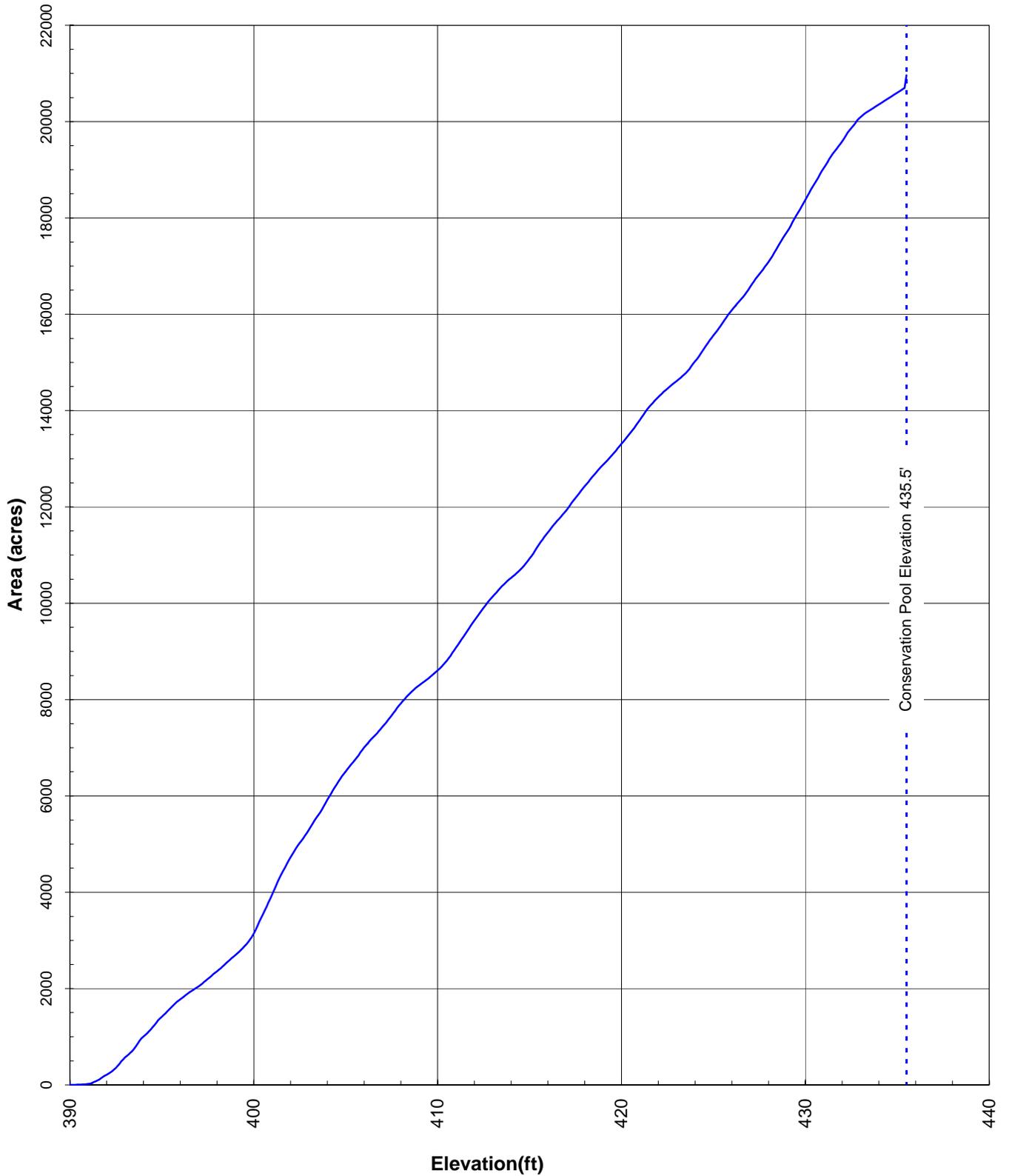
ELEVATION INCREMENT IS ONE TENTH FOOT

ELEVATION in Feet	AREA IN ACRES									
	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
388			0	0	0	0	0	0	0	0
389	0	0	0	0	0	0	0	1	1	1
390	1	1	1	2	3	4	5	7	10	13
391	19	26	38	56	74	92	115	141	168	191
392	211	235	260	286	316	353	395	439	488	530
393	571	604	636	670	706	752	807	868	922	967
394	1,004	1,038	1,072	1,110	1,152	1,198	1,245	1,293	1,339	1,380
395	1,416	1,451	1,489	1,528	1,567	1,605	1,645	1,681	1,715	1,747
396	1,777	1,805	1,833	1,863	1,892	1,920	1,947	1,971	1,996	2,020
397	2,047	2,075	2,105	2,137	2,168	2,199	2,231	2,263	2,297	2,329
398	2,359	2,390	2,422	2,454	2,490	2,527	2,564	2,598	2,631	2,663
399	2,696	2,729	2,764	2,800	2,839	2,880	2,922	2,968	3,018	3,074
400	3,141	3,217	3,302	3,386	3,465	3,544	3,624	3,703	3,785	3,867
401	3,950	4,041	4,130	4,213	4,294	4,371	4,446	4,516	4,585	4,655
402	4,725	4,789	4,851	4,911	4,968	5,023	5,075	5,127	5,180	5,236
403	5,296	5,360	5,424	5,483	5,541	5,596	5,652	5,713	5,778	5,849
404	5,918	5,984	6,048	6,111	6,173	6,234	6,298	6,356	6,409	6,460
405	6,509	6,558	6,608	6,653	6,699	6,745	6,793	6,847	6,901	6,953
406	7,004	7,051	7,095	7,139	7,180	7,221	7,261	7,301	7,343	7,388
407	7,434	7,480	7,526	7,575	7,623	7,672	7,722	7,774	7,825	7,875
408	7,922	7,967	8,010	8,052	8,092	8,133	8,171	8,206	8,237	8,268
409	8,298	8,326	8,354	8,382	8,412	8,441	8,472	8,505	8,539	8,572
410	8,605	8,641	8,678	8,719	8,762	8,808	8,858	8,911	8,966	9,023
411	9,080	9,135	9,190	9,245	9,300	9,358	9,417	9,476	9,532	9,588
412	9,643	9,696	9,749	9,801	9,854	9,906	9,957	10,008	10,055	10,099
413	10,141	10,184	10,227	10,270	10,313	10,354	10,393	10,429	10,463	10,497
414	10,530	10,561	10,593	10,625	10,660	10,699	10,740	10,782	10,828	10,877
415	10,928	10,979	11,033	11,092	11,154	11,215	11,270	11,322	11,374	11,424
416	11,472	11,522	11,573	11,620	11,665	11,710	11,753	11,796	11,838	11,882
417	11,929	11,979	12,033	12,088	12,139	12,186	12,233	12,283	12,333	12,383
418	12,430	12,475	12,521	12,567	12,616	12,662	12,706	12,751	12,795	12,837
419	12,878	12,918	12,956	12,995	13,036	13,080	13,125	13,172	13,217	13,265
420	13,311	13,357	13,402	13,448	13,495	13,544	13,594	13,646	13,699	13,753
421	13,807	13,863	13,917	13,970	14,024	14,073	14,118	14,160	14,201	14,240
422	14,279	14,317	14,355	14,390	14,424	14,458	14,492	14,524	14,555	14,585
423	14,615	14,646	14,677	14,710	14,745	14,781	14,821	14,867	14,920	14,974
424	15,023	15,070	15,119	15,175	15,233	15,294	15,350	15,405	15,458	15,511
425	15,560	15,609	15,658	15,710	15,765	15,822	15,879	15,933	15,985	16,035
426	16,083	16,132	16,180	16,225	16,266	16,309	16,356	16,405	16,455	16,507
427	16,567	16,628	16,683	16,736	16,786	16,835	16,883	16,932	16,984	17,035
428	17,088	17,145	17,207	17,268	17,334	17,402	17,471	17,534	17,595	17,652
429	17,709	17,769	17,836	17,908	17,978	18,047	18,113	18,175	18,239	18,305
430	18,377	18,447	18,519	18,587	18,651	18,715	18,777	18,841	18,910	18,976
431	19,035	19,096	19,159	19,220	19,280	19,336	19,388	19,437	19,485	19,534
432	19,587	19,645	19,712	19,769	19,820	19,867	19,912	19,960	20,011	20,056
433	20,094	20,128	20,159	20,187	20,212	20,236	20,261	20,285	20,309	20,334
434	20,358	20,383	20,407	20,431	20,456	20,480	20,505	20,529	20,554	20,578
435	20,603	20,627	20,652	20,676	20,701	20,726	20,751	20,776	20,801	20,826



- - - Conservation Pool Elevation 435.5'
 — Volume 2005

**Lake Ray Hubbard**  
 May 2005  
 Prepared by: TWDB



- - - Conservation Pool Elevation 435.5'
 — Area 2005

**Lake Ray Hubbard**  
 May 2005  
 Prepared by: TWDB

Appendix E

**Lake Ray Hubbard**  
**RESERVOIR AREA- VOLUME COMPARISON TABLE**  
 TEXAS WATER DEVELOPMENT BOARD

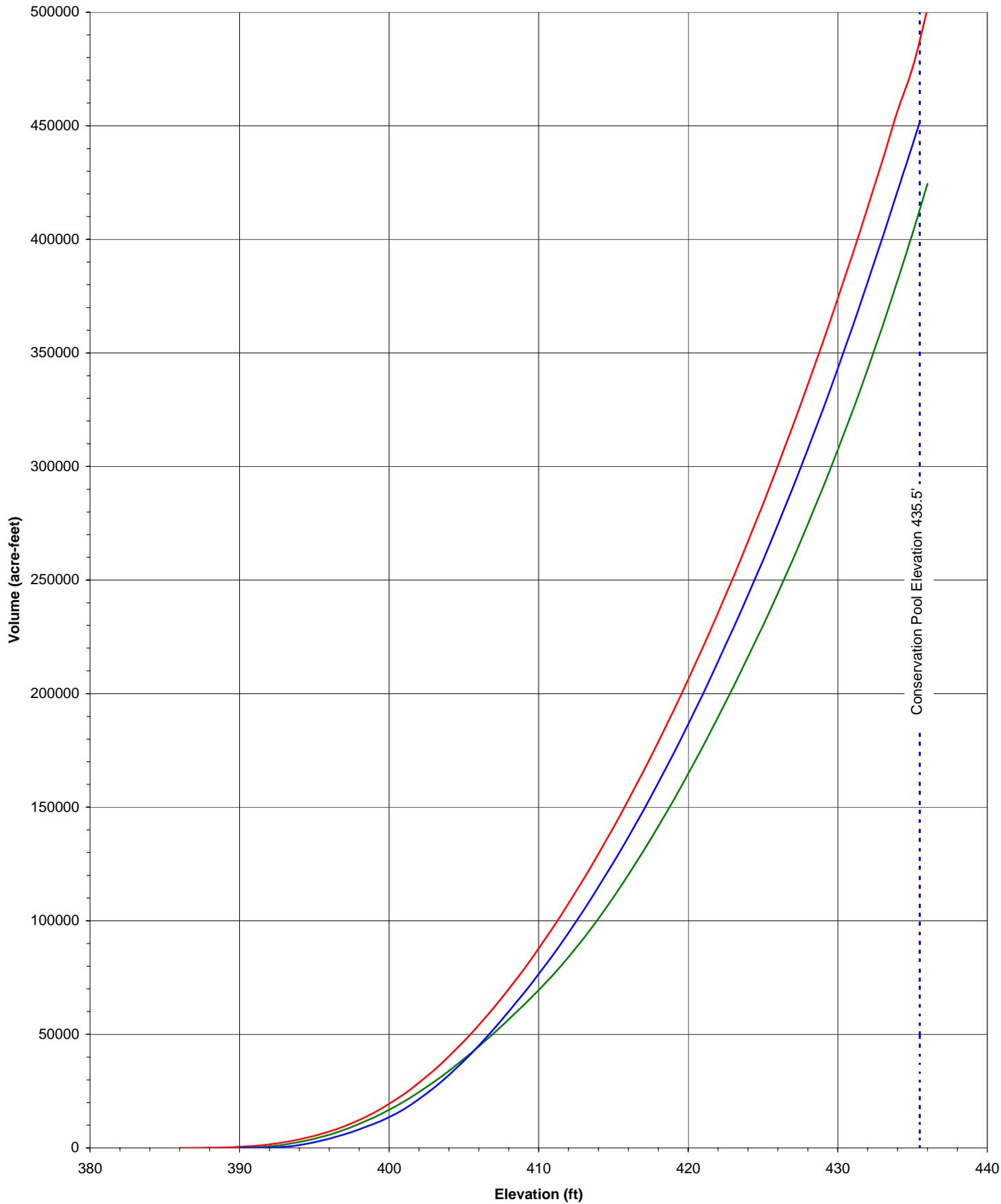
Conservation Pool Elevation 435.5'

MAY 2005 SURVEY

AREA IN ACRES			VOLUME IN ACRE-FEET			
ELEVATION	TCB 1989	TWDB 2005	ELEVATION	Original 1968	TCB 1989	TWDB 2005
in Feet	Area	Area	in Feet	Volume*	Volume	Volume
386	0	0	386	0	0	0
387	0	0	387	15	0	0
388	0	0	388	80	0	0
389	0	0	389	230	0	0
390	0	1	390	490	0	0
391	320	19	391	910	160	6
392	640	211	392	1,560	640	108
393	959	571	393	2,480	1,440	477
394	1,279	1,004	394	3,705	2,559	1,249
395	1,599	1,416	395	5,275	3,998	2,452
396	1,983	1,777	396	7,210	5,789	4,055
397	2,366	2,047	397	9,545	7,963	5,971
398	2,750	2,359	398	12,325	10,521	8,171
399	3,133	2,696	399	15,590	13,463	10,698
400	3,517	3,141	400	19,380	16,788	13,589
401	3,899	3,950	401	23,750	20,496	17,132
402	4,281	4,725	402	28,710	24,586	21,491
403	4,662	5,296	403	34,230	29,057	26,509
404	5,044	5,918	404	40,300	33,910	32,109
405	5,426	6,509	405	46,920	39,145	38,338
406	5,679	7,004	406	54,075	44,698	45,089
407	5,933	7,434	407	61,740	50,504	52,309
408	6,186	7,922	408	69,915	56,563	59,984
409	6,440	8,298	409	78,600	62,876	68,109
410	6,693	8,605	410	87,775	69,443	76,554
411	7,289	9,080	411	97,445	76,434	85,375
412	7,885	9,643	412	107,620	84,021	94,735
413	8,481	10,141	413	118,280	92,204	104,637
414	9,077	10,530	414	129,425	100,983	114,983
415	9,673	10,928	415	141,055	110,358	125,692
416	10,156	11,472	416	153,155	120,272	136,899
417	10,639	11,929	417	165,725	130,670	148,604
418	11,122	12,430	418	178,770	141,550	160,788
419	11,605	12,878	419	192,275	152,914	173,447
420	12,088	13,311	420	206,240	164,760	186,532
421	12,468	13,807	421	220,685	177,038	200,082
422	12,849	14,279	422	235,625	189,697	214,143
423	13,229	14,615	423	251,060	202,736	228,598
424	13,610	15,023	424	267,000	216,155	243,394
425	13,990	15,560	425	283,465	229,955	258,684
426	14,577	16,083	426	300,455	244,239	274,506
427	15,164	16,567	427	317,980	259,109	290,822
428	15,751	17,088	428	336,055	274,567	307,655
429	16,338	17,709	429	354,685	290,611	325,055
430	16,925	18,377	430	373,890	307,243	343,096
431	17,790	19,035	431	393,665	324,600	361,809
432	18,656	19,587	432	414,015	342,823	381,134
433	19,521	20,094	433	434,960	361,912	400,994
434	20,387	20,358	434	456,495	381,886	421,227
435	21,252	20,603	435	475,630	402,685	441,708
435.5	21,683	20,963	435.5	490,000**	413,500	452,040

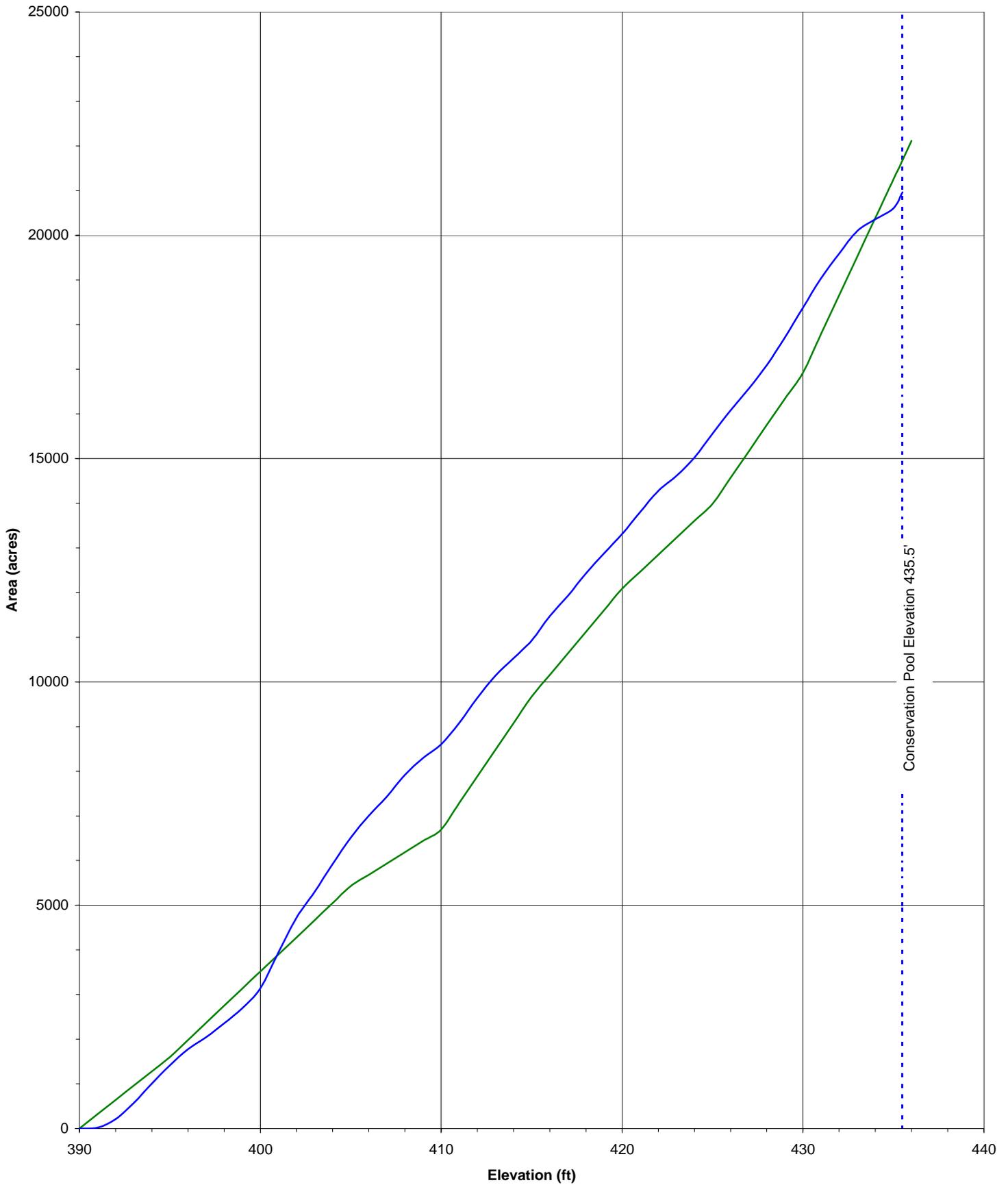
\*Values from a 1969 copy of the original US Department of the Interior, Geological Survey (Water Resources Division) Capacity Table, Table No. 1-C, Jan 1, 1968.

\*\*Value as reported by the City of Dallas<sup>5</sup>  
 Value from original 1968 Capacity Table= 489,926



- - - Conservation Pool Elevation 435.5'  
 — Original 1968  
 — TCB 1989  
 — TWDB 2005

**Lake Ray Hubbard**  
 May 2005  
 Prepared by TWDB



- - - Conservation Pool Elevation 435.5'
 — TCB 1989
 — TWDB 2005

**Lake Ray Hubbard**  
 May 2005  
 Prepared by: TWDB



# Appendix H

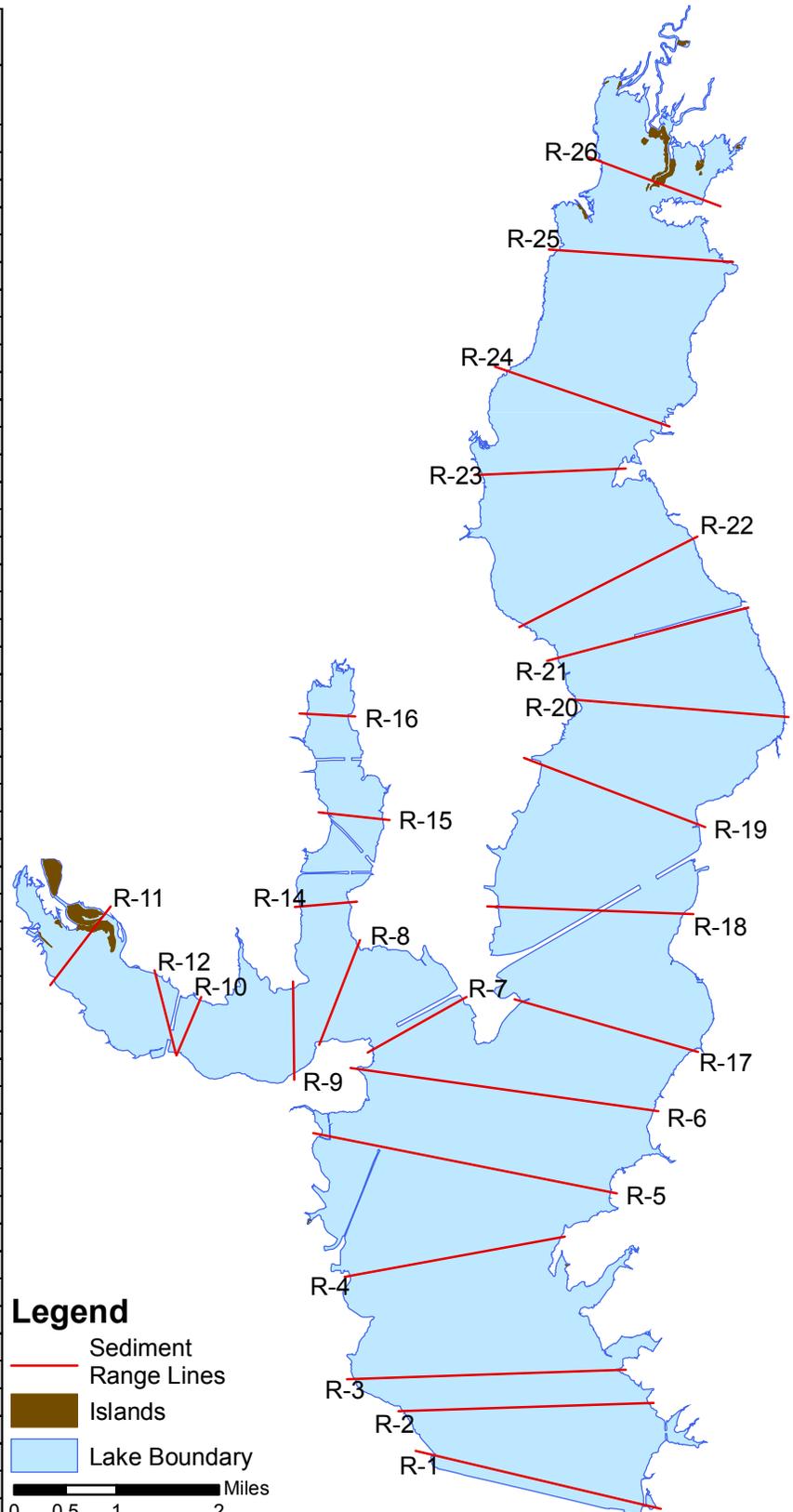
## Lake Ray Hubbard

### Location of Sediment Range Lines



**Table 3. Endpoint Coordinates for Ray Hubbard Sediment Range Lines est. 2005 TWDB**

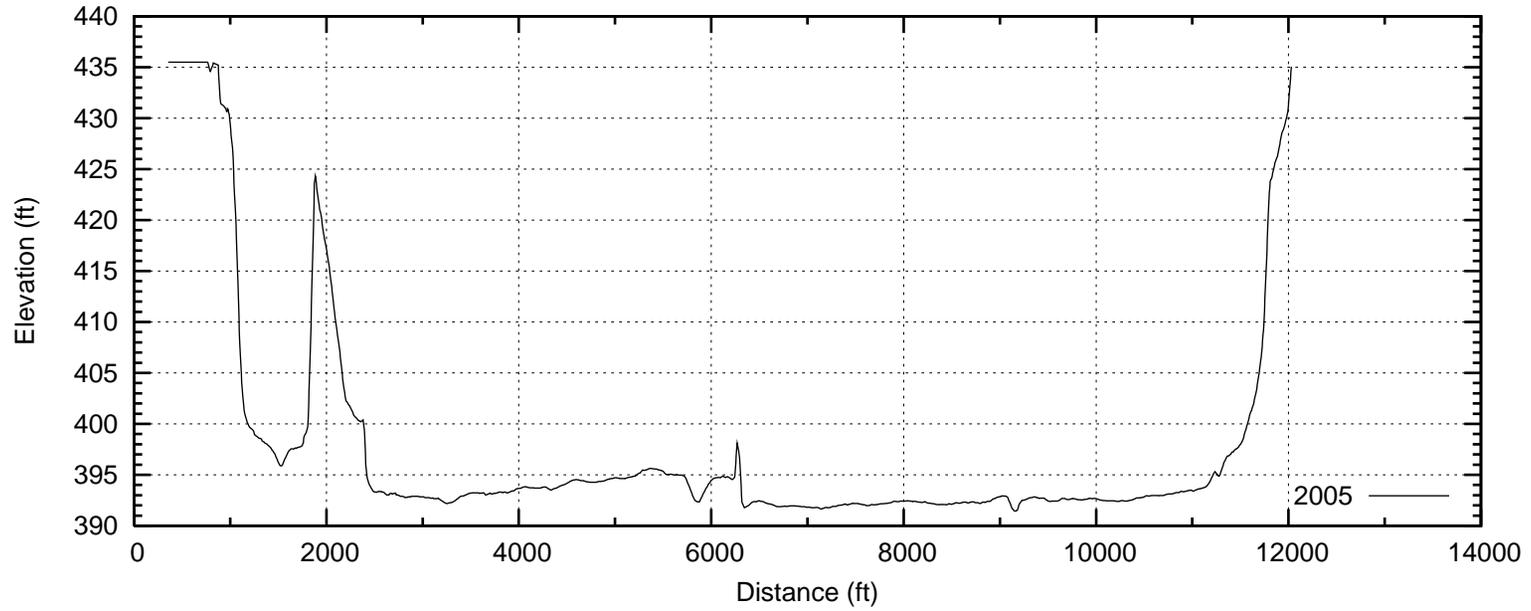
Range	L=Left R=Right	X	Y
R-1	L	2,585,956.02233	6,980,055.65663
	R	2,573,278.14405	6,983,049.69426
R-2	L	2,585,581.76761	6,985,529.13170
	R	2,572,389.28914	6,985,108.09516
R-3	L	2,584,154.92153	6,987,236.66886
	R	2,569,722.72440	6,986,768.85049
R-4	L	2,580,997.14745	6,994,136.99002
	R	2,569,605.76977	6,992,055.19827
R-5	L	2,583,687.10316	6,996,359.12736
	R	2,567,991.79640	6,999,493.51060
R-6	L	2,585,815.67686	7,000,616.27463
	R	2,569,909.85169	7,002,861.80295
R-7	L	2,575,921.31794	7,006,534.17723
	R	2,570,798.70661	7,003,657.09422
R-8	L	2,570,401.06104	7,009,458.04219
	R	2,568,295.87832	7,004,031.34894
R-9	L	2,566,939.20504	7,007,329.46849
	R	2,567,009.37771	7,002,253.63898
R-10	L	2,562,214.23927	7,006,534.17723
	R	2,560,922.34231	7,003,505.50714
R-11	L	2,557,512.66448	7,011,188.97019
	R	2,554,401.67222	7,007,142.34120
R-12	L	2,559,781.58365	7,007,914.24148
	R	2,560,898.01053	7,003,578.50234
R-14	L	2,570,237.32459	7,011,446.27029
	R	2,567,032.76868	7,011,165.57922
R-15	L	2,571,921.47077	7,015,656.63573
	R	2,568,272.48734	7,016,054.28143
R-16	L	2,570,167.15179	7,021,036.54716
	R	2,567,290.06878	7,021,176.89263
R-17	L	2,587,874.07776	7,003,680.48506
	R	2,578,377.36453	7,006,393.83176
R-18	L	2,587,616.77766	7,010,791.32450
	R	2,576,973.90930	7,011,212.36104
R-19	L	2,588,224.94150	7,015,305.77199
	R	2,578,868.57375	7,018,884.58261
R-20	L	2,592,552.26150	7,020,989.76534
	R	2,581,207.66572	7,021,902.01123
R-21	L	2,590,470.46970	7,026,650.36784
	R	2,580,084.90156	7,023,913.63030
R-22	L	2,587,827.29594	7,030,322.74211
	R	2,578,634.66463	7,025,644.55830
R-23	L	2,584,131.53068	7,033,831.38007
	R	2,576,318.96364	7,033,503.90717
R-24	L	2,586,400.44985	7,036,030.12644
	R	2,577,371.55500	7,039,117.72772
R-25	L	2,589,675.17856	7,044,521.03013
	R	2,580,155.07436	7,045,152.58494
R-26	L	2,589,043.62374	7,047,398.11314
	R	2,582,236.86623	7,049,924.33240



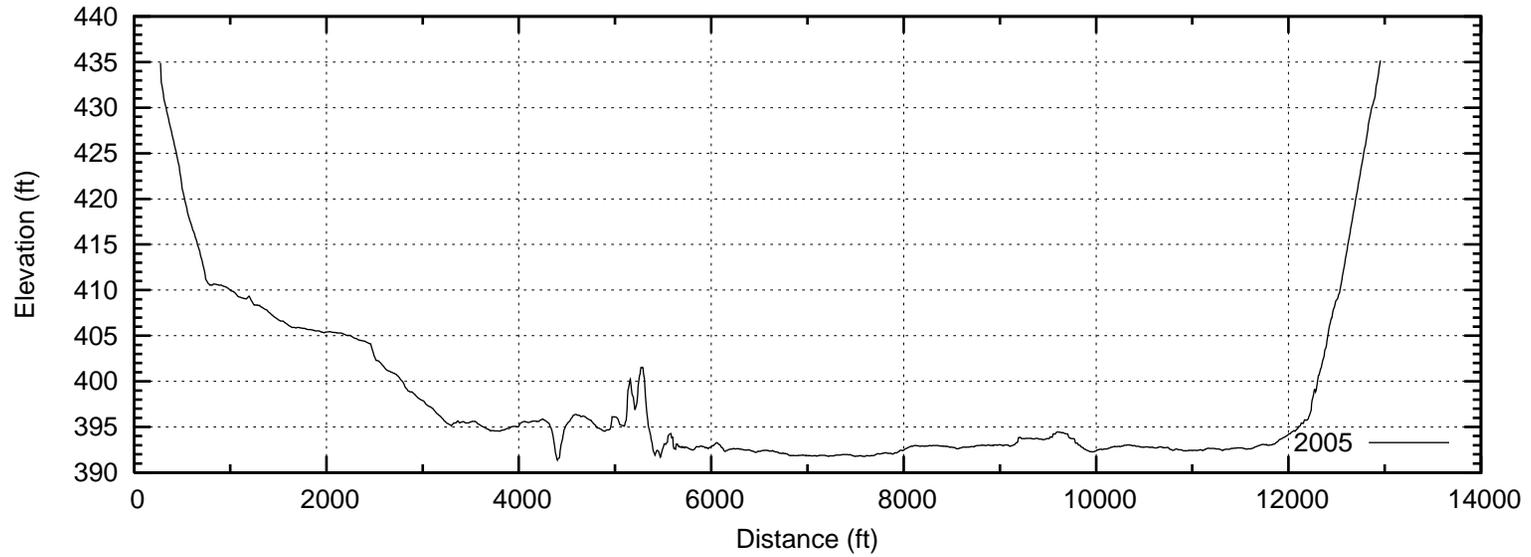
Coordinates in NAD83 (feet) State Plane Texas North Central Zone

# Lake Ray Hubbard

## Range Line SR01

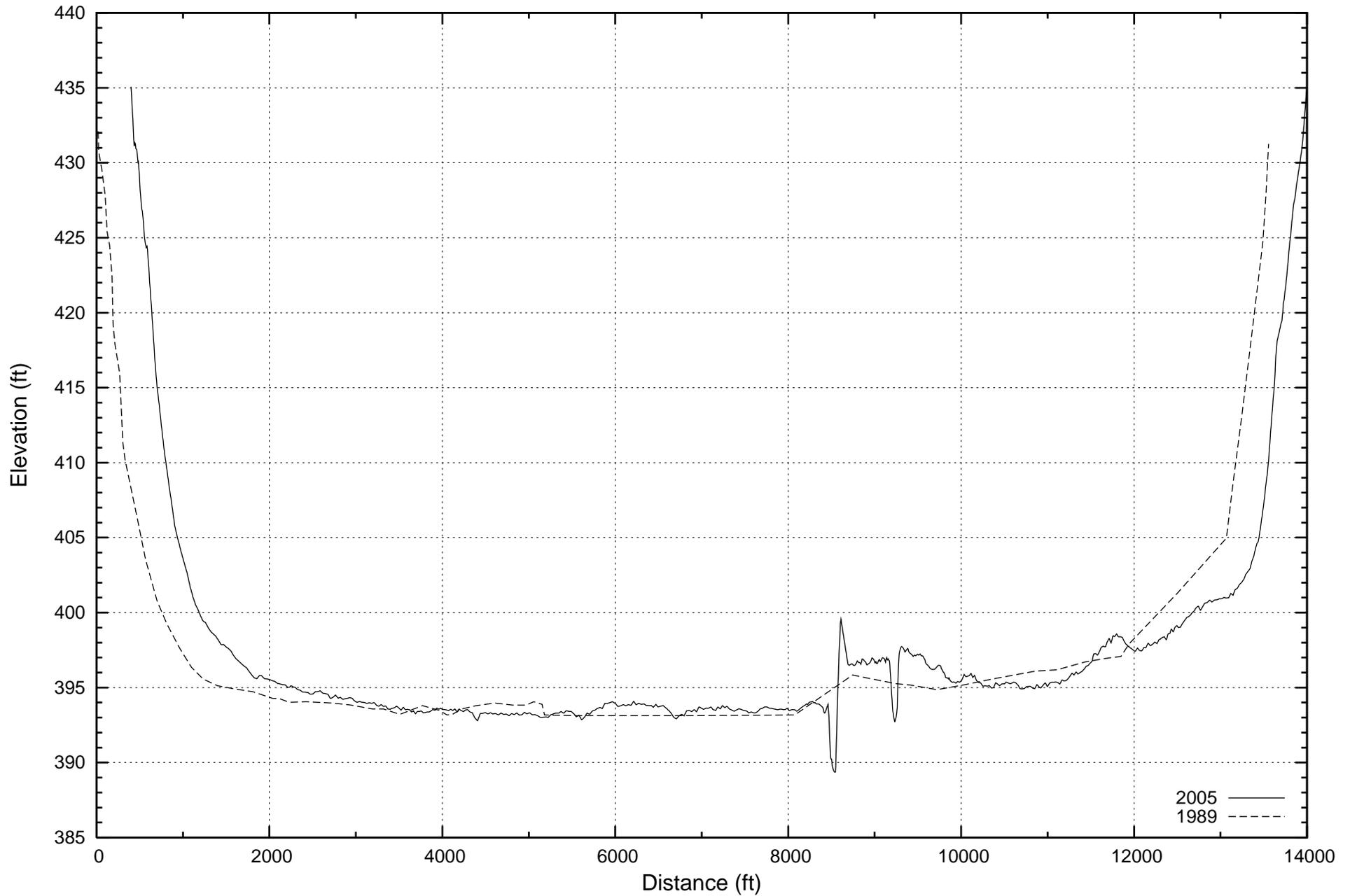


## Range Line SR02



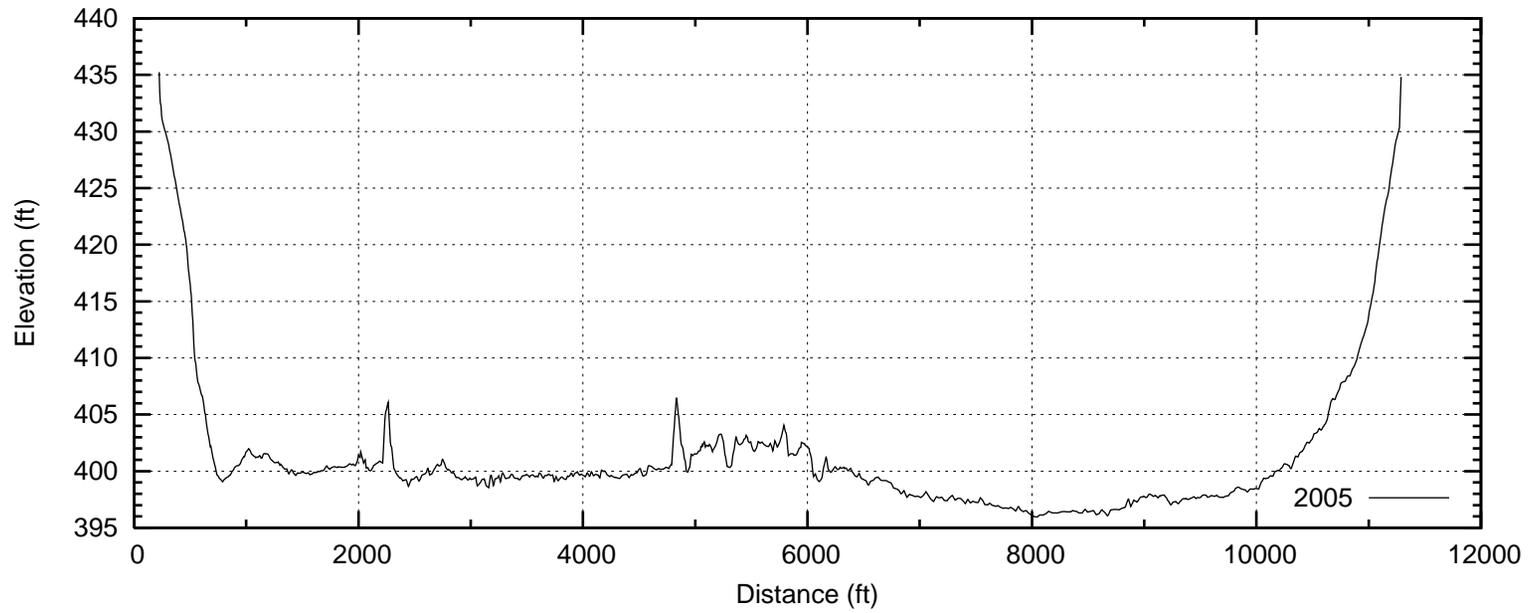
# Lake Ray Hubbard

## Range Line SR03

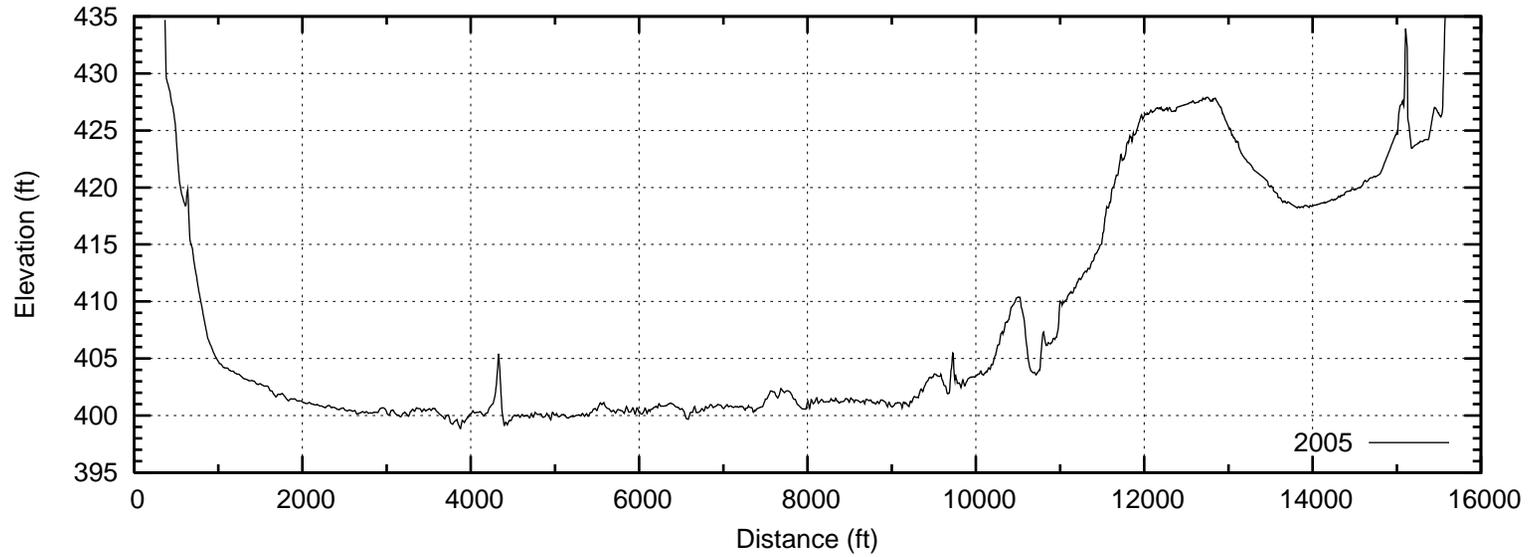


# Lake Ray Hubbard

## Range Line SR04

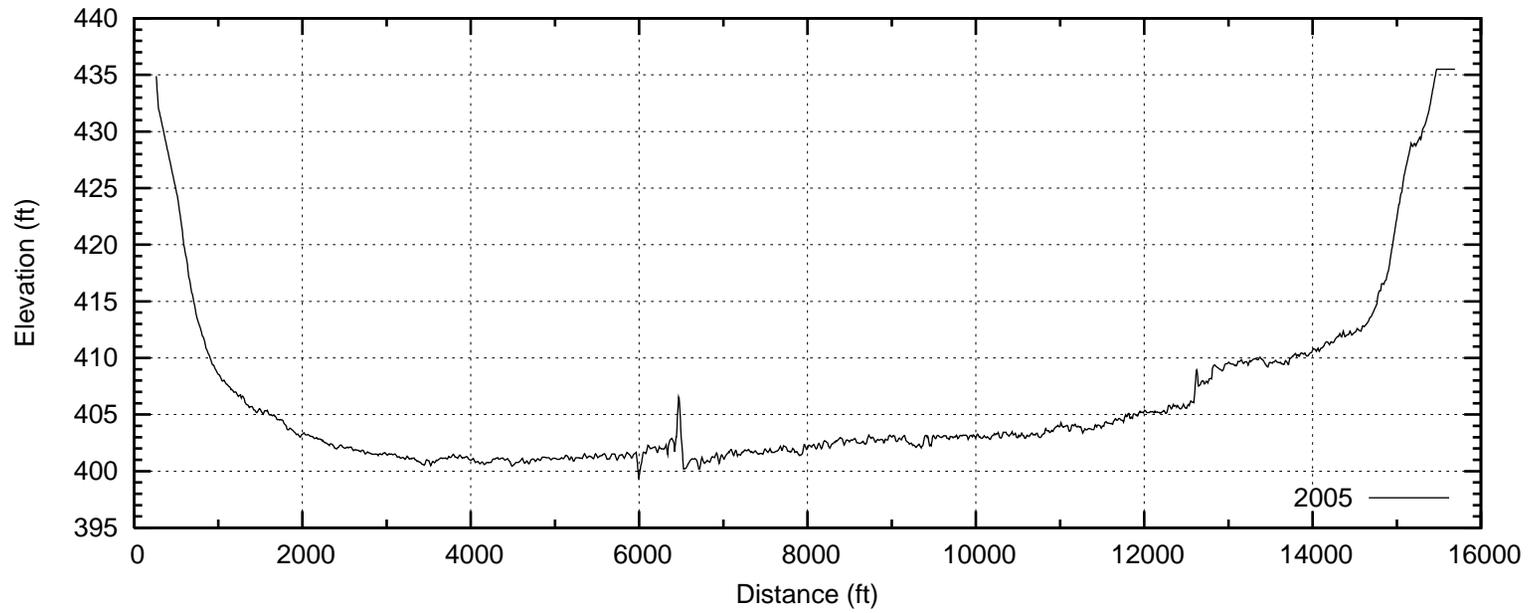


## Range Line SR05

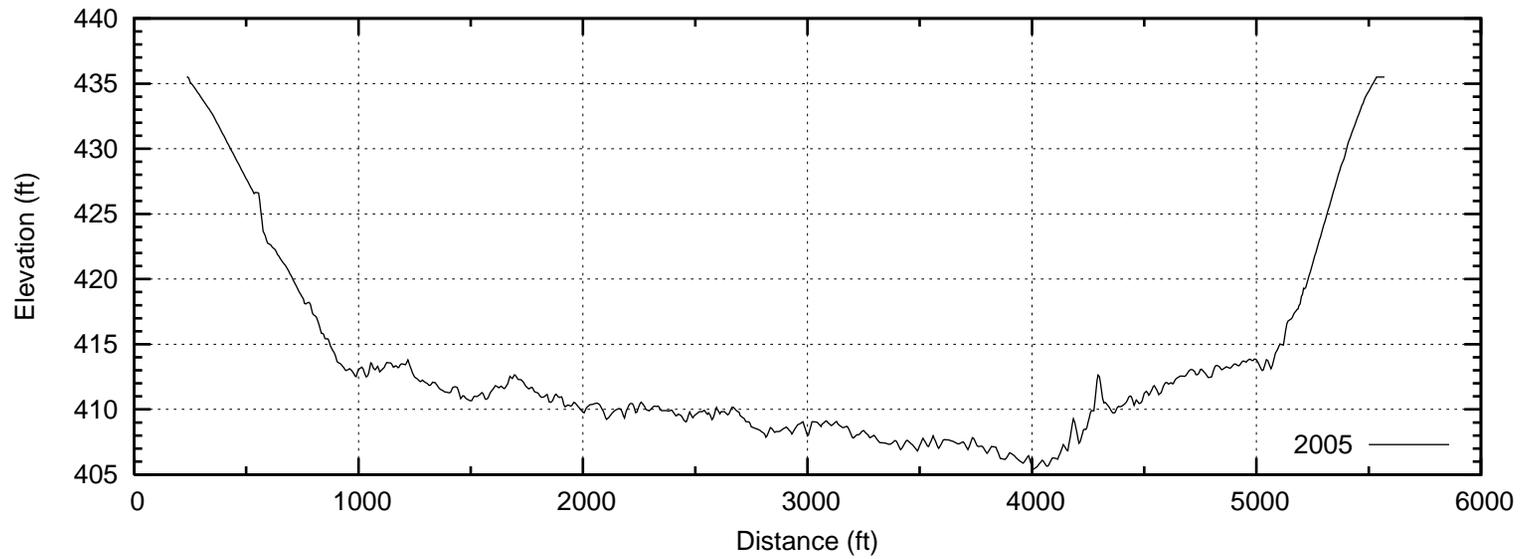


# Lake Ray Hubbard

## Range Line SR06

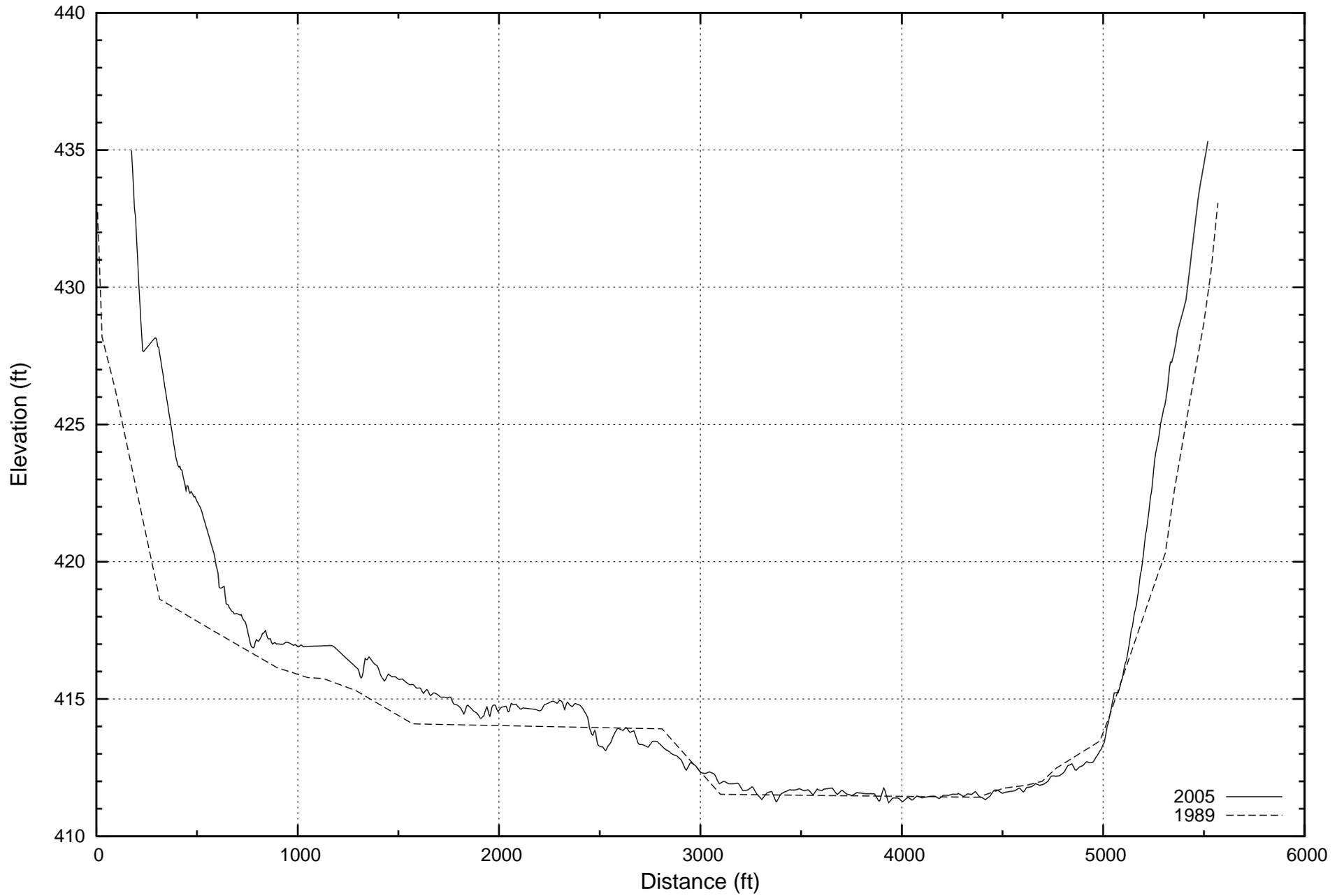


## Range Line SR07



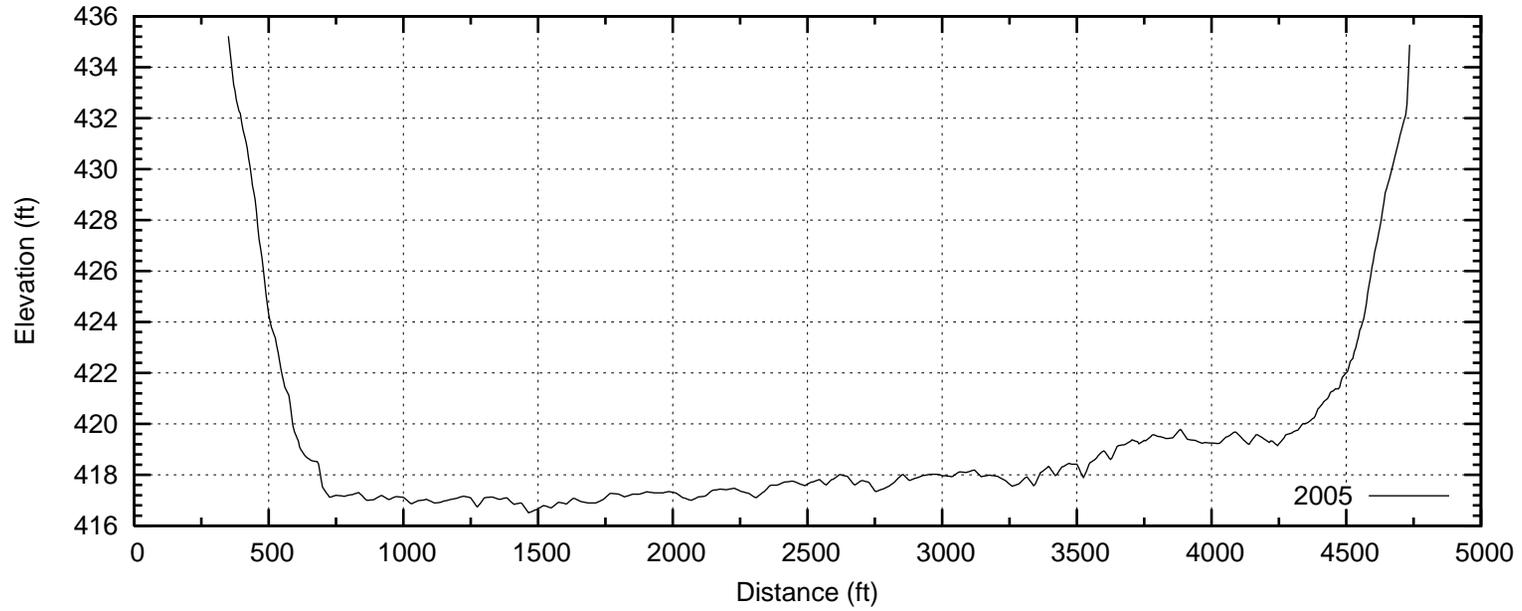
# Lake Ray Hubbard

## Range Line SR08

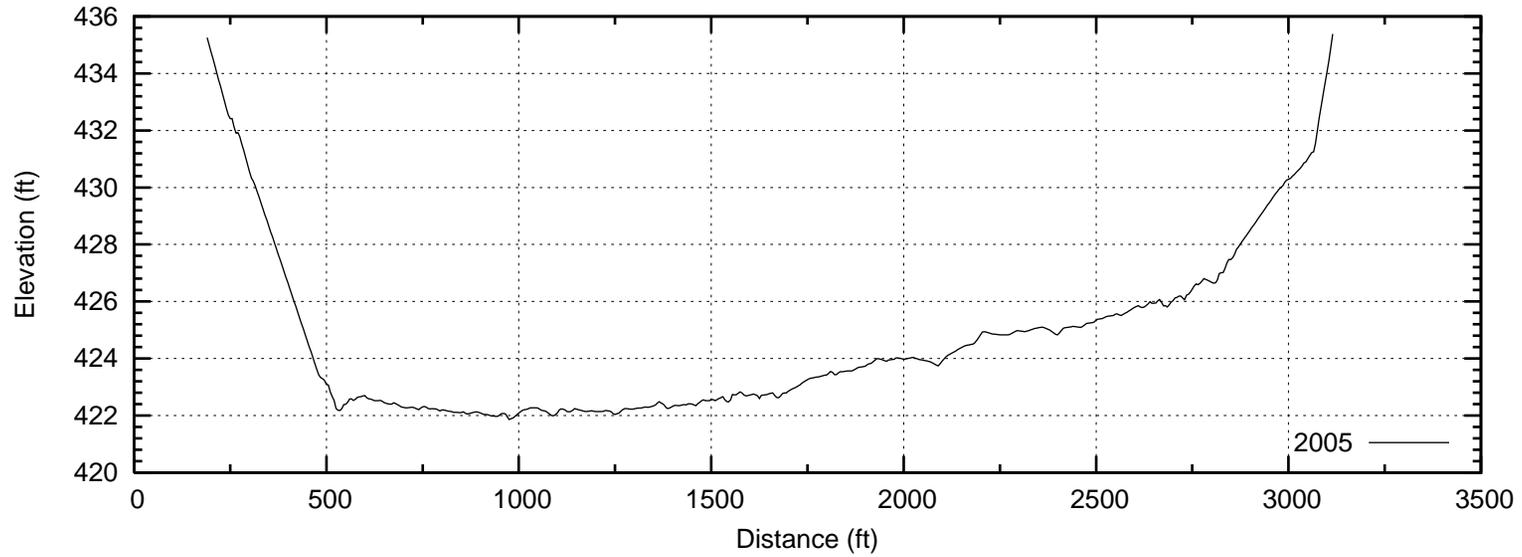


# Lake Ray Hubbard

## Range Line SR09

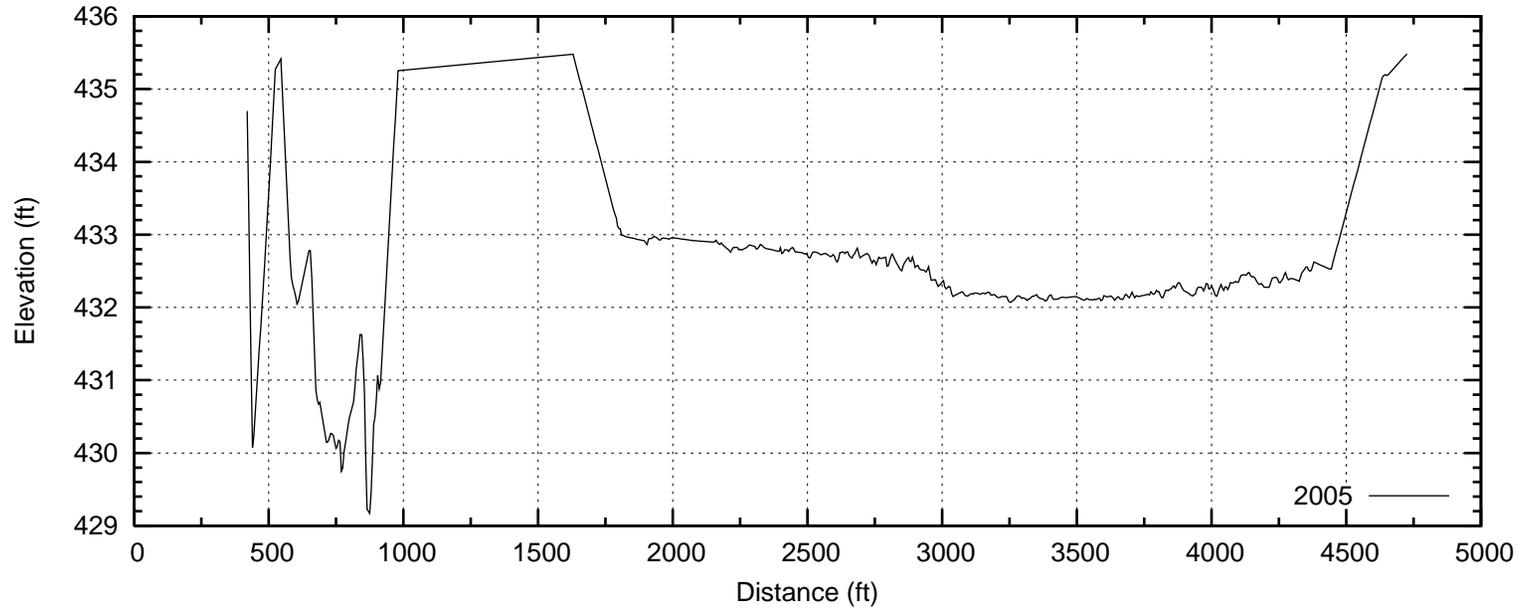


## Range Line SR10

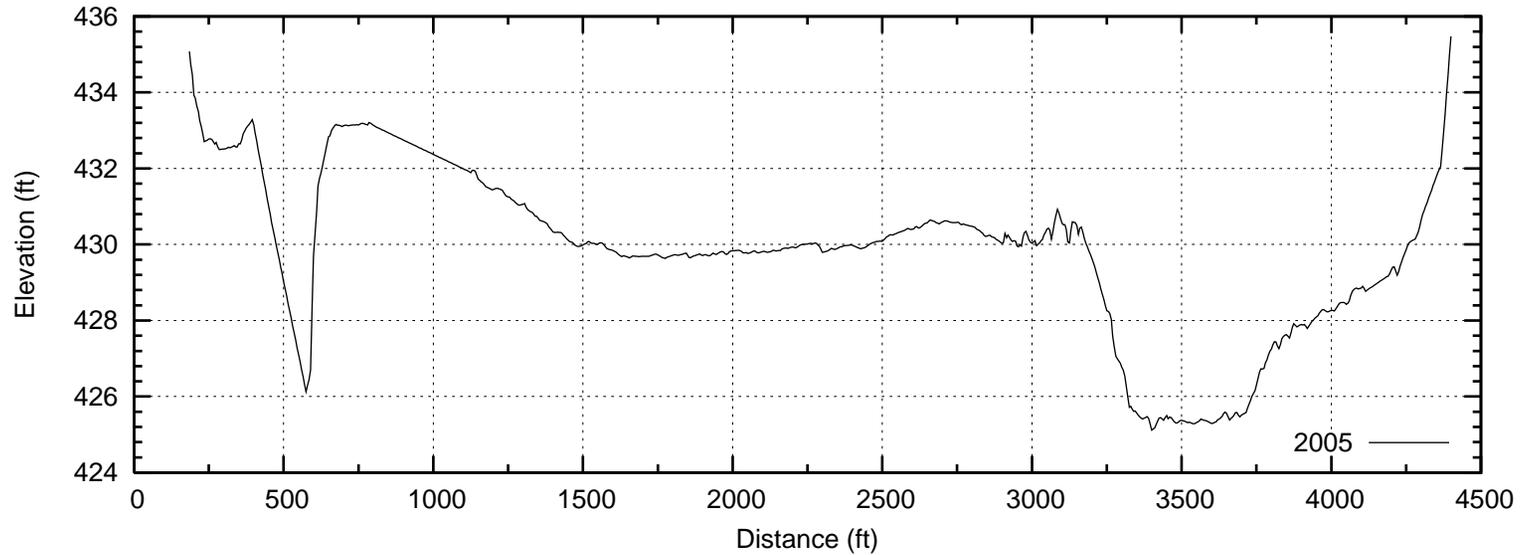


# Lake Ray Hubbard

## Range Line SR11

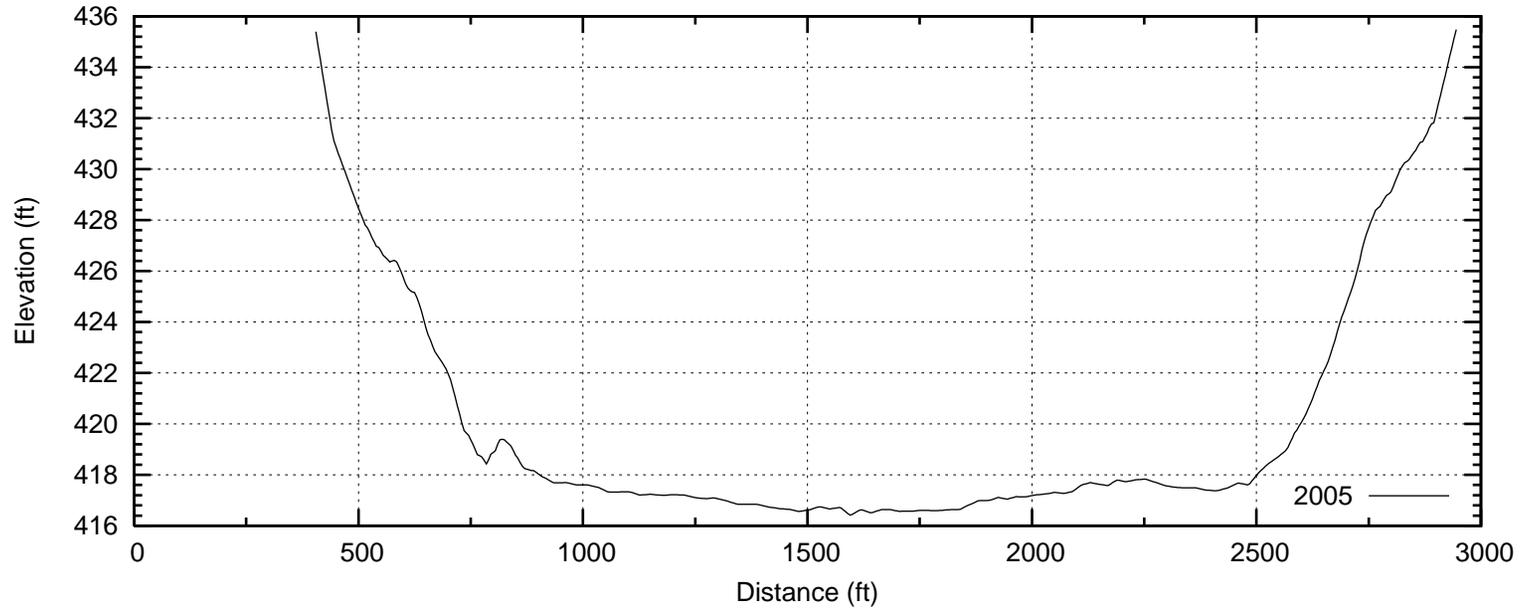


## Range Line SR12

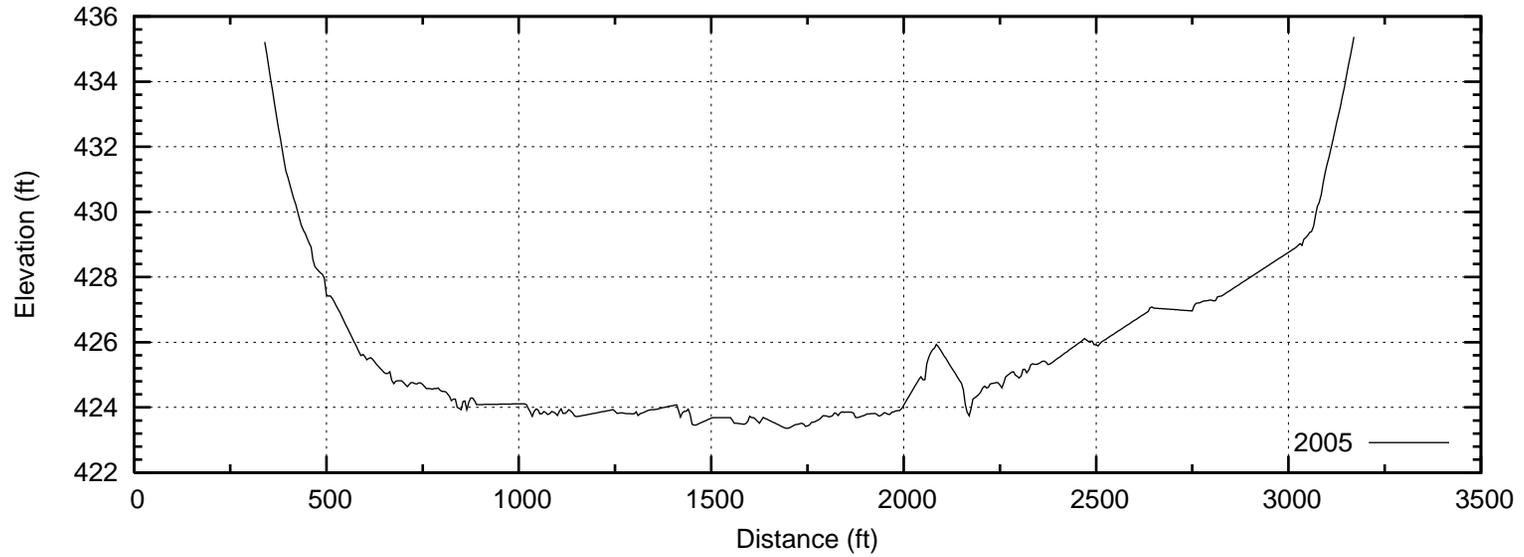


# Lake Ray Hubbard

## Range Line SR14

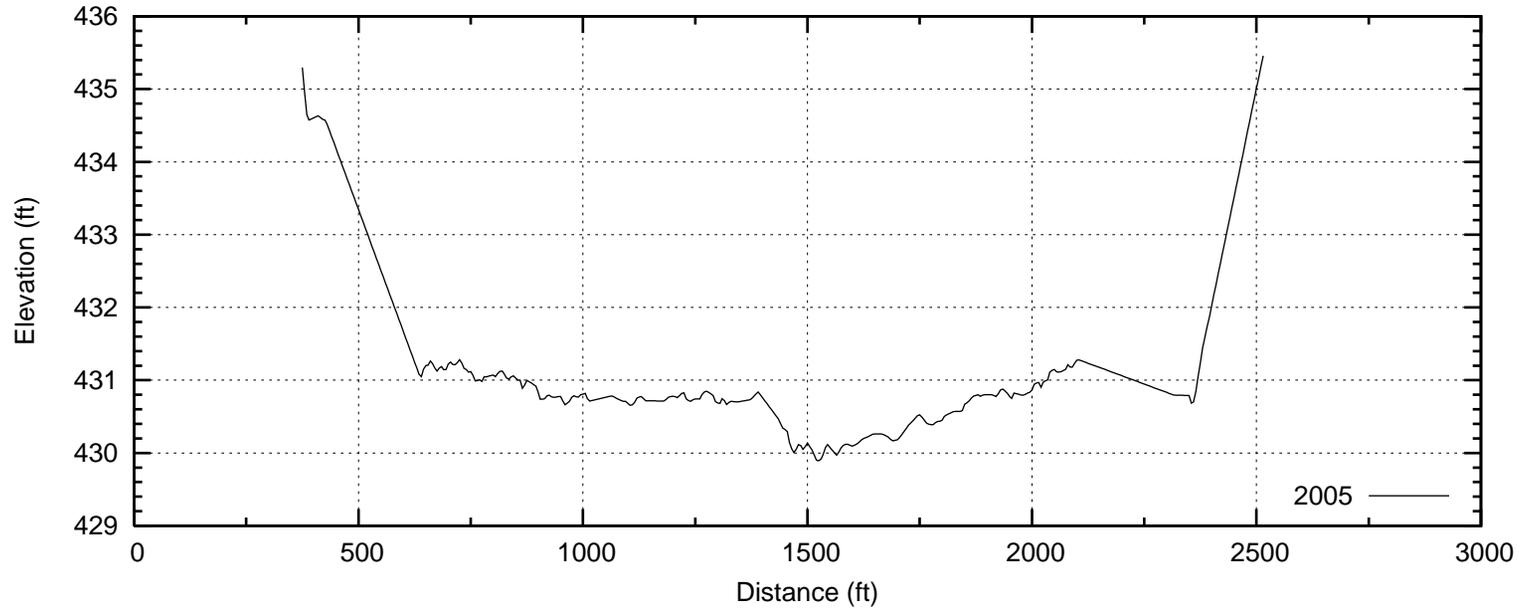


## Range Line SR15

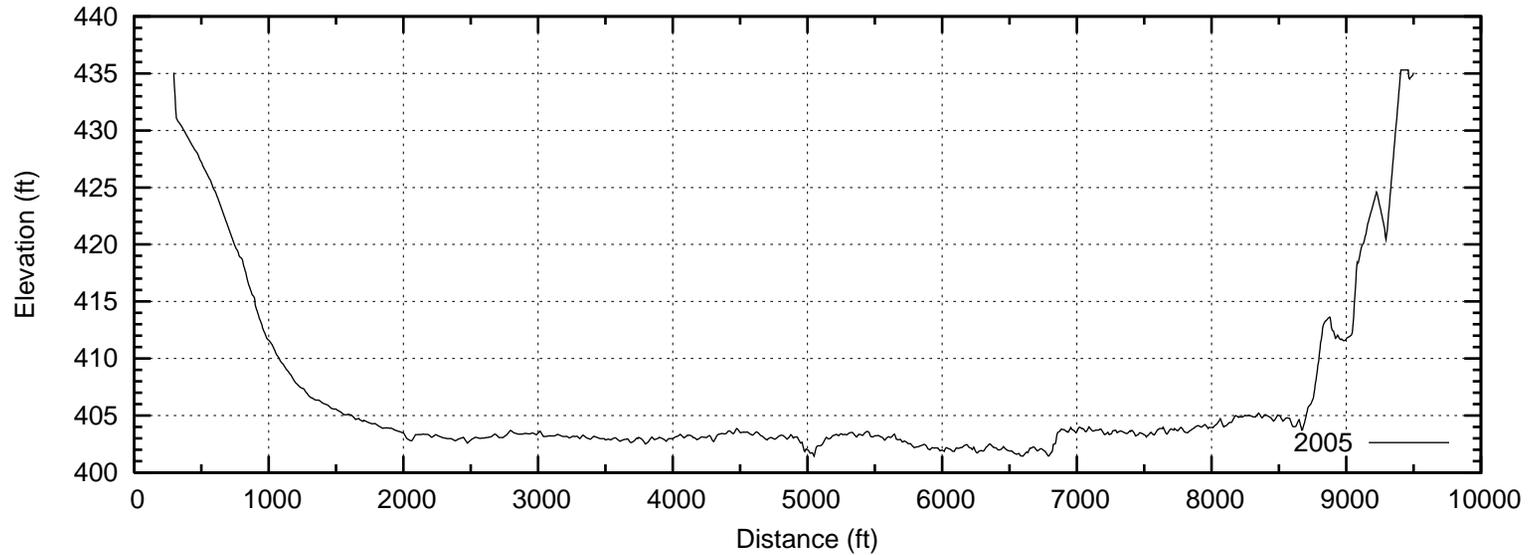


# Lake Ray Hubbard

## Range Line SR16

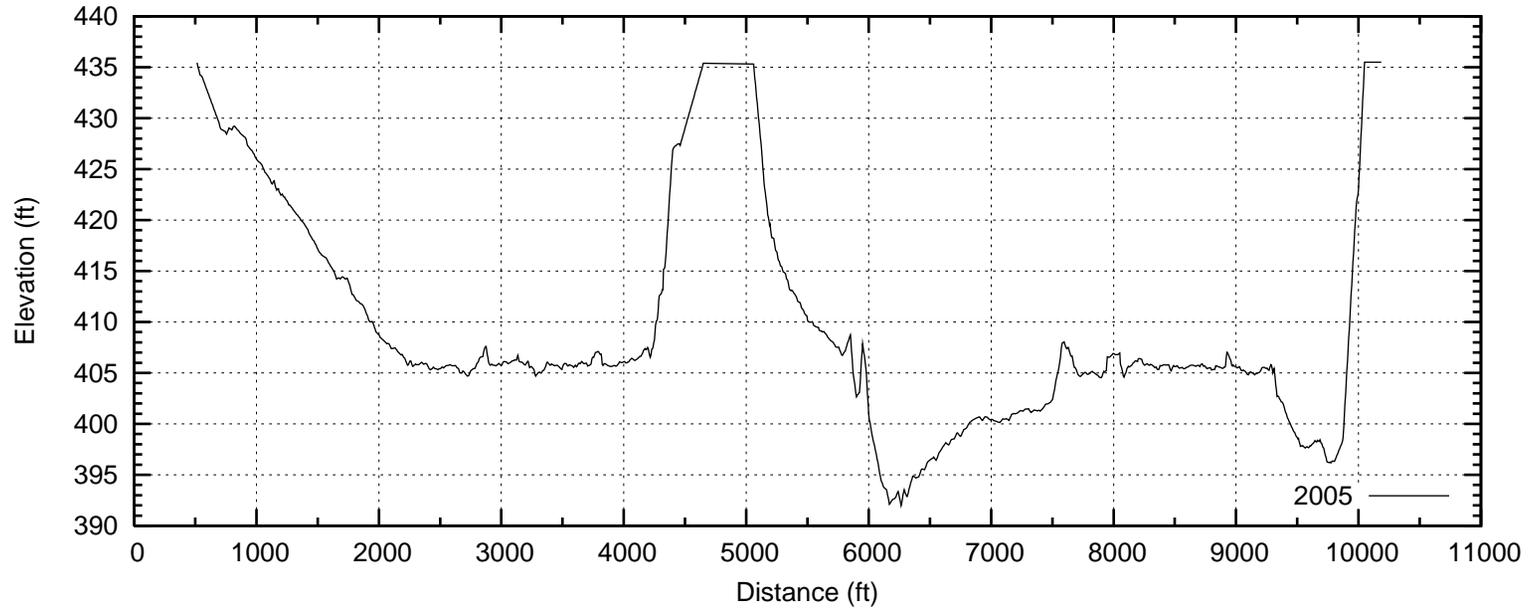


## Range Line SR17

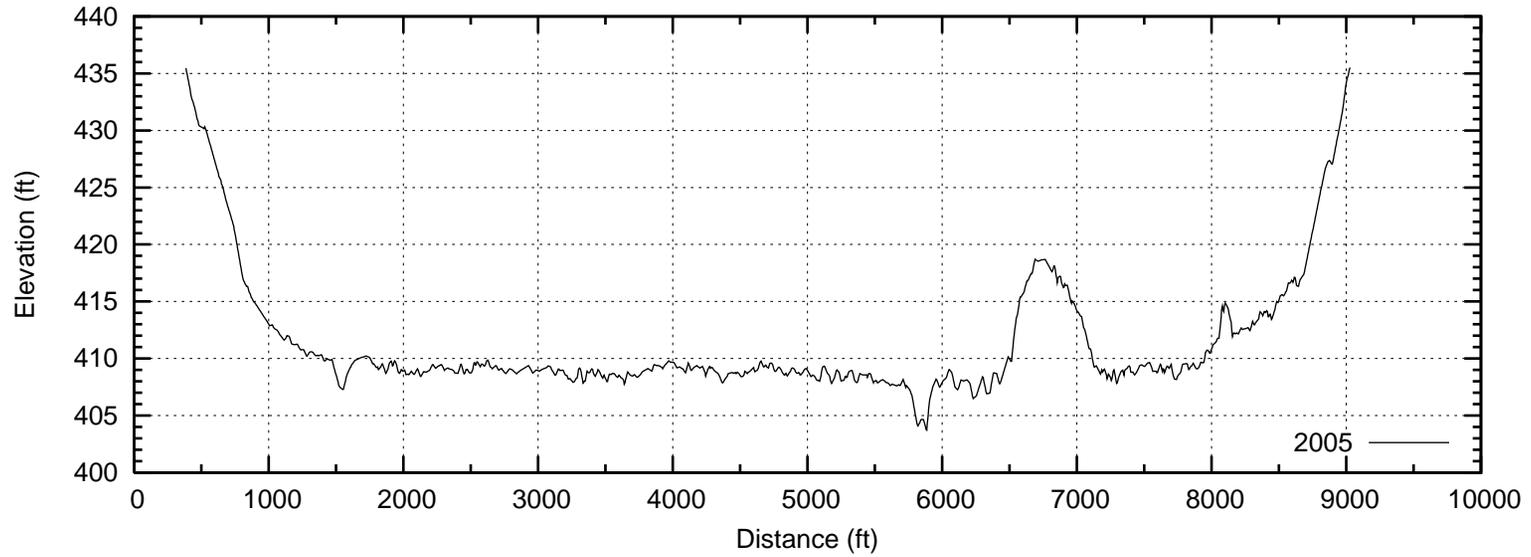


# Lake Ray Hubbard

## Range Line SR18

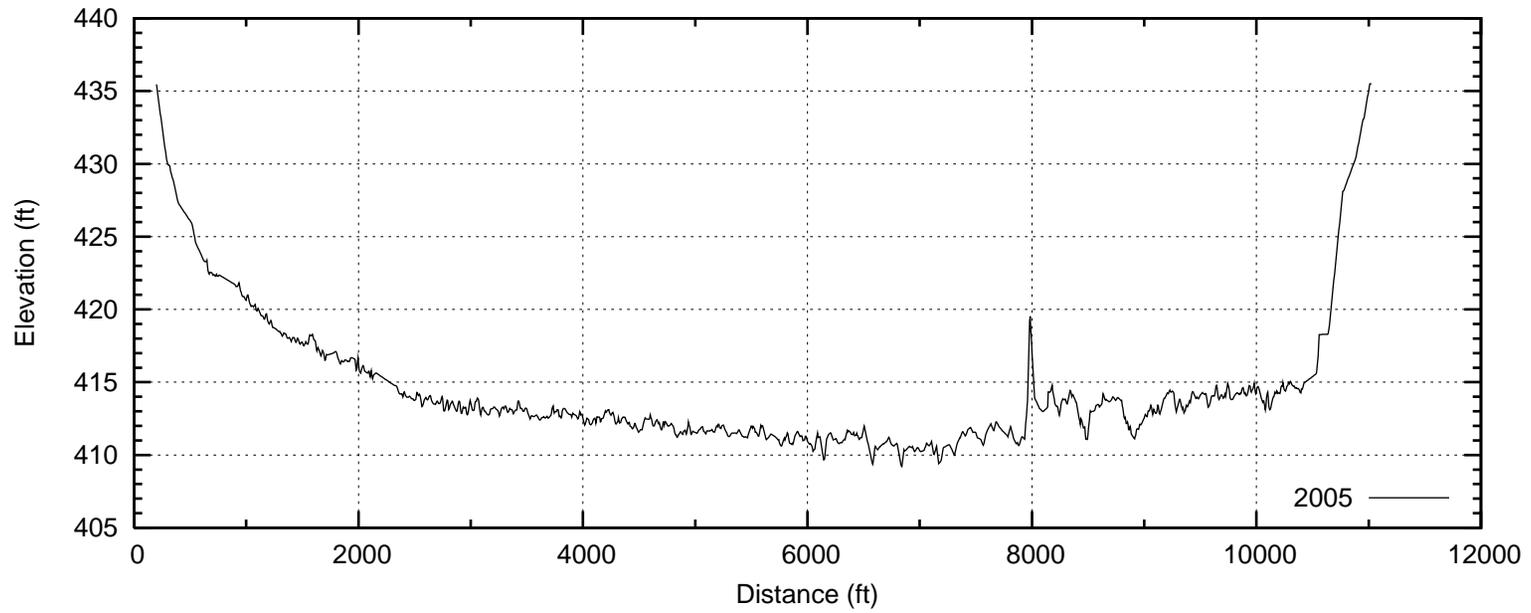


## Range Line SR19

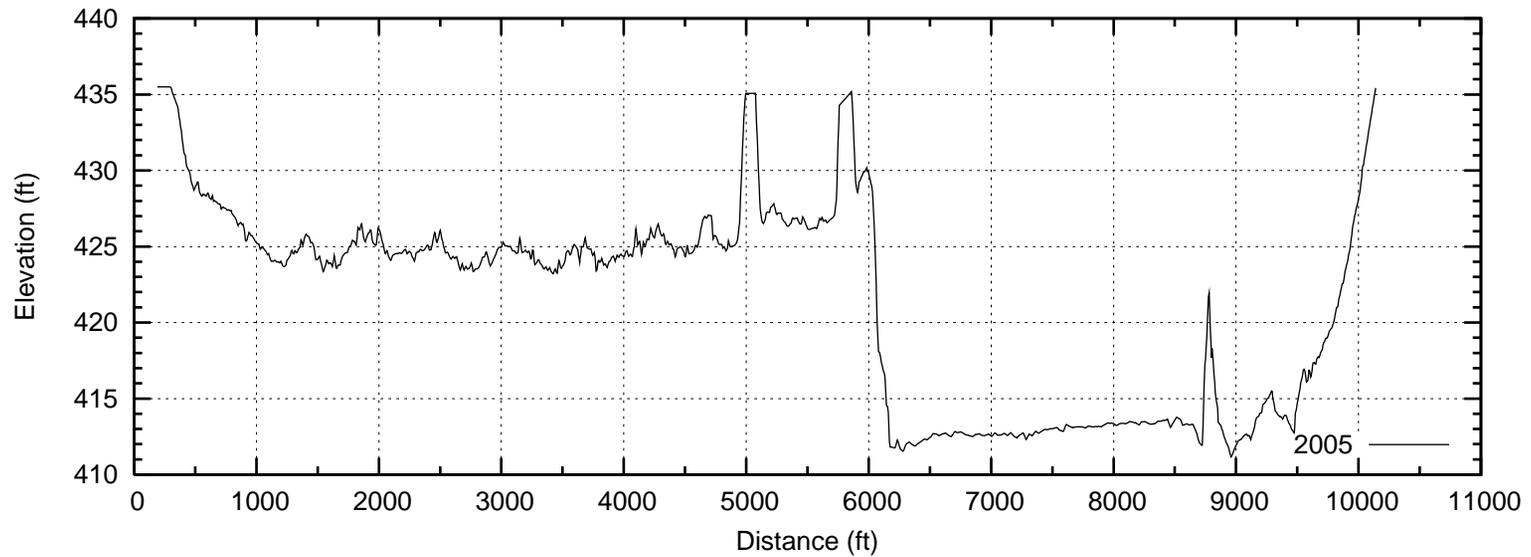


# Lake Ray Hubbard

## Range Line SR20

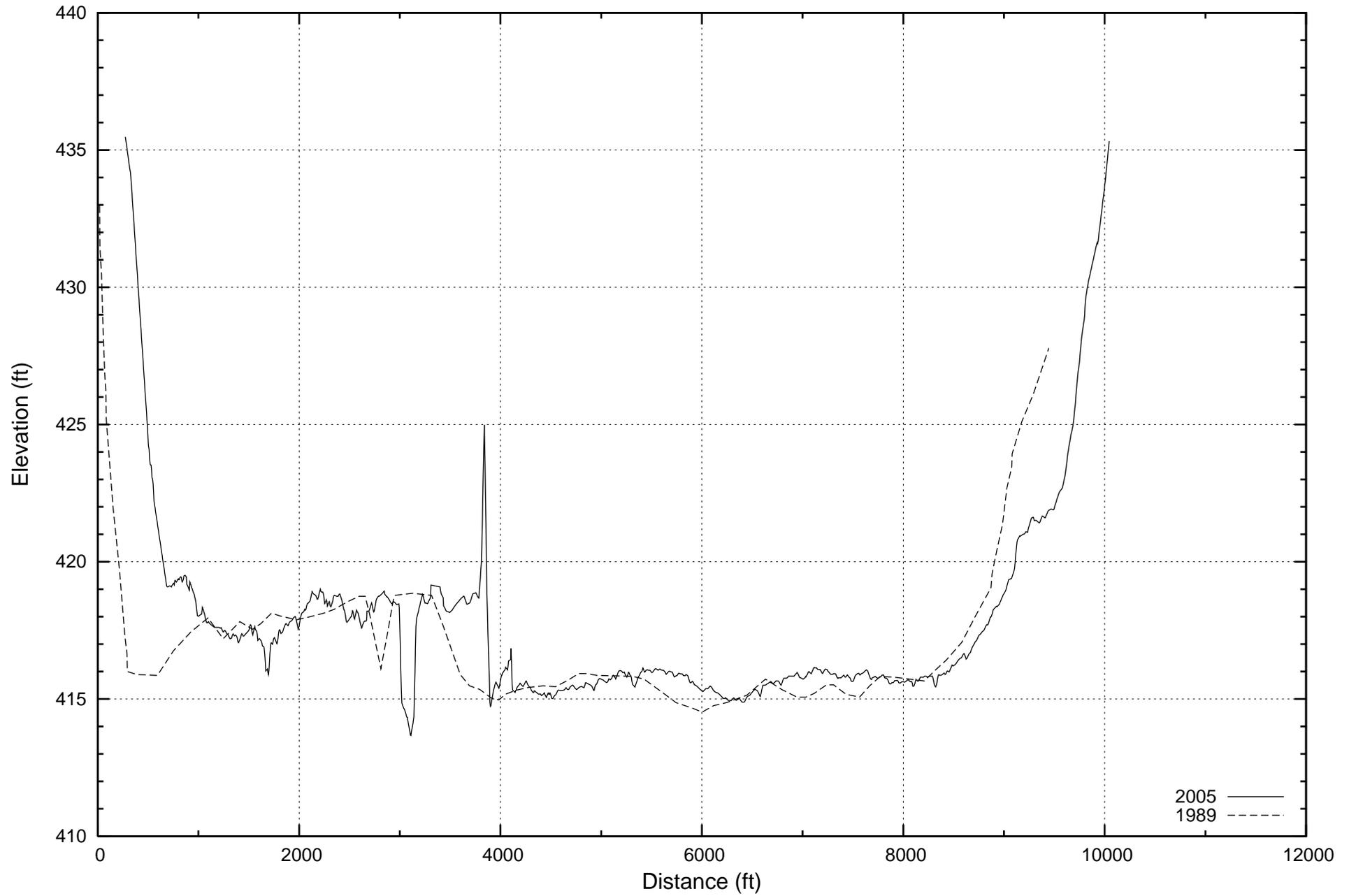


## Range Line SR21



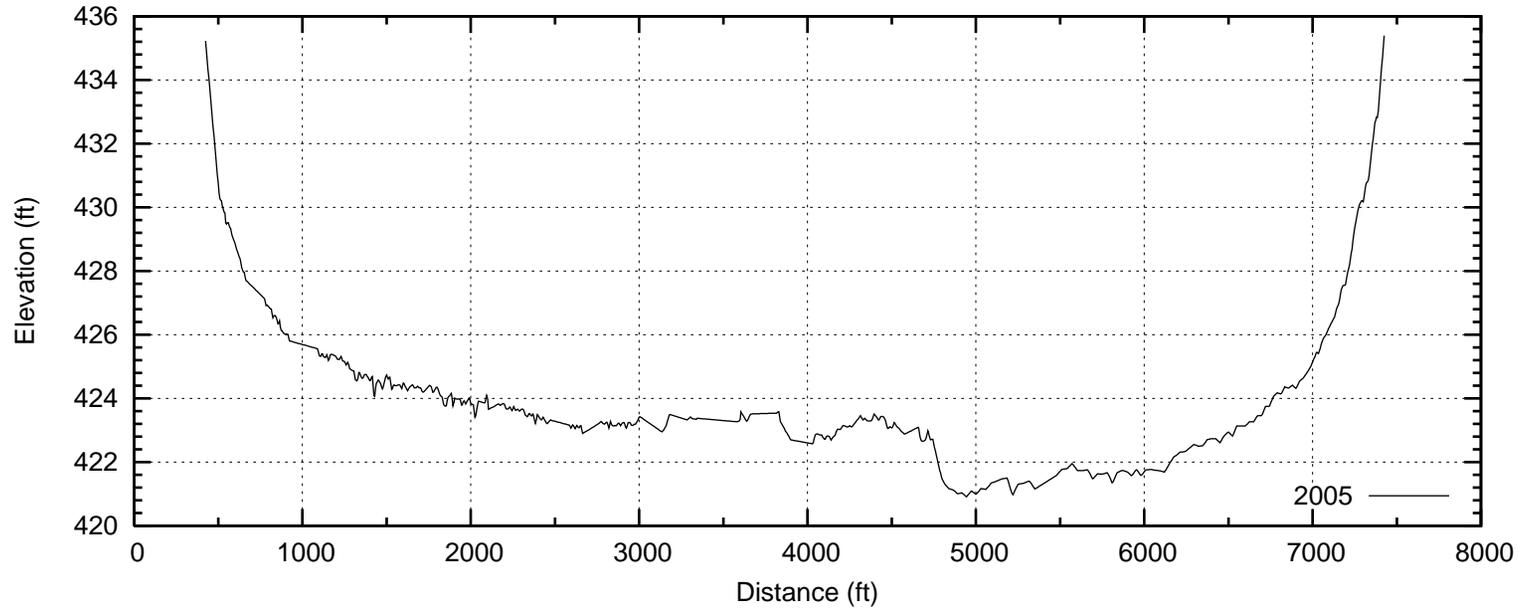
# Lake Ray Hubbard

## Range Line SR22

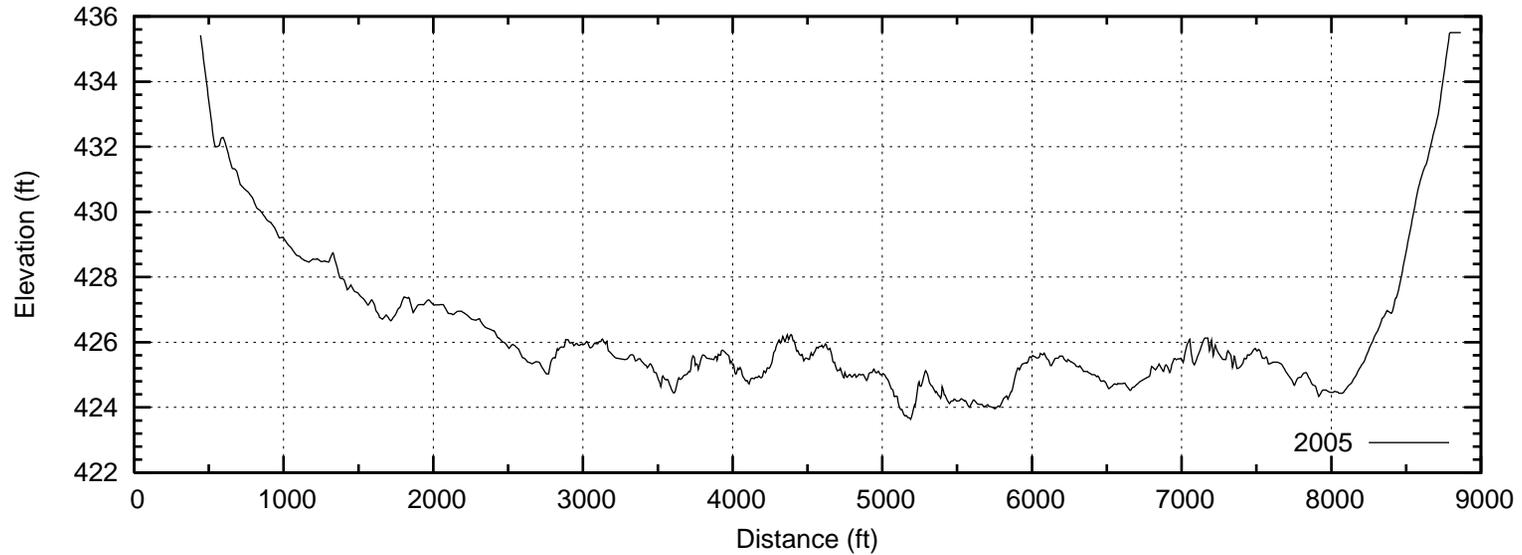


# Lake Ray Hubbard

## Range Line SR23

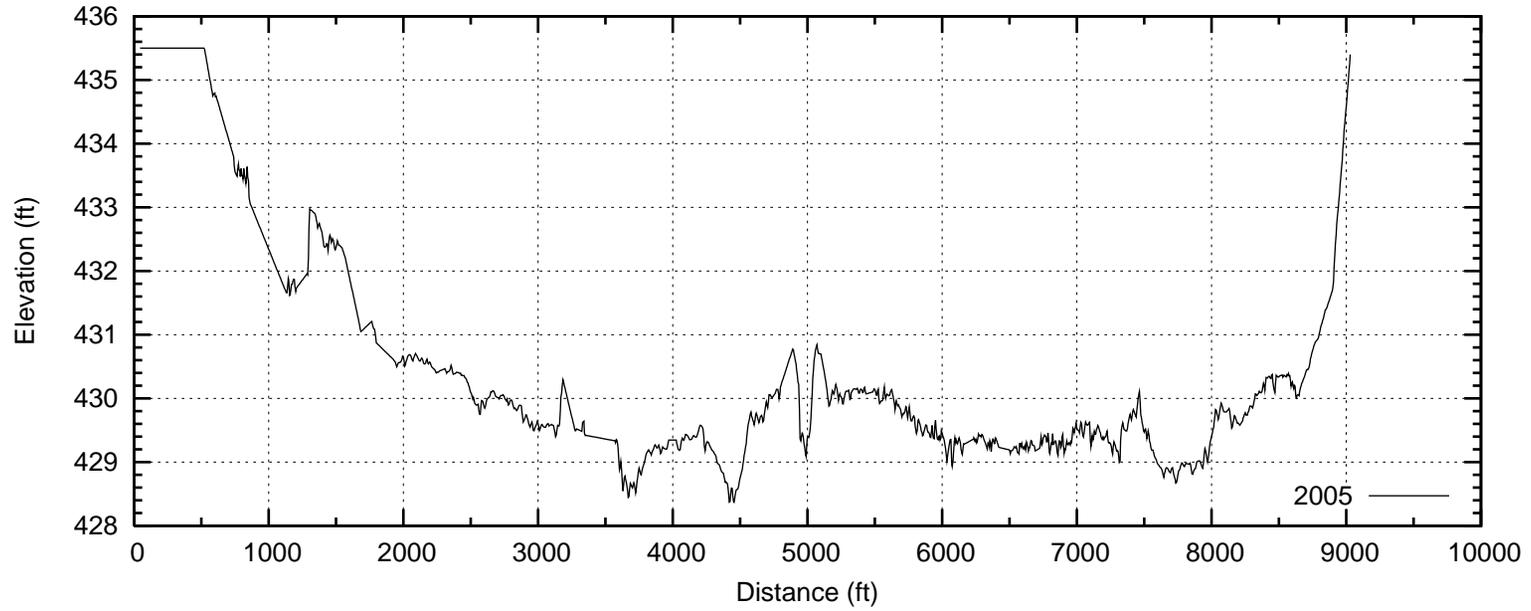


## Range Line SR24



# Lake Ray Hubbard

## Range Line SR25



## Range Line SR26

