Volumetric and Sedimentation Survey of EAGLE MOUNTAIN LAKE

February 2008 Survey

Prepared by:

The Texas Water Development Board

January 2009

Texas Water Development Board

J. Kevin Ward, Executive Administrator

Prepared for:

Tarrant Regional Water District

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Executive Summary

In July of 2007, the Texas Water Development Board entered into agreement with Tarrant Regional Water District, for the purpose of performing a volumetric and sedimentation survey of Eagle Mountain Lake. These surveys were performed simultaneously using a multi-frequency (200 kHz, 50 kHz, and 24 kHz) sub-bottom profiling depth sounder. In addition, sediment core samples were collected in selected locations and used in interpreting the multi-frequency depth sounder signal returns to derive sediment accumulation estimates.

Eagle Mountain Lake is located on the West Fork Trinity River, just north of Fort Worth, in Tarrant County, Texas. Eagle Mountain Lake, built primarily for water supply and flood control, is owned and operated by Tarrant Regional Water District. Bathymetric data collection for Eagle Mountain Lake occurred between February 5, 2008 and March 13, 2008, while the water surface elevation ranged between 646.42 feet and 648.39 feet above mean sea level (NGVD29). Additional data was collected on July 30, 2008, while the water surface elevation measured 646.58 feet above mean sea level.

The results of the TWDB 2008 Volumetric Survey indicate Eagle Mountain Lake has a total reservoir capacity of 179,880 acre-feet and encompasses 8,694 acres at conservation pool elevation (649.1 feet above mean sea level, NGVD29). Previously published[1] capacity estimates for Eagle Mountain Lake are 190,460 acre-feet, 178,440 acre-feet, and 182,505 acre-feet based on surveys conducted in 1968, 1988, and 2000, respectively (Table 2). Due to differences in the methodologies used in calculating areas and capacities from this 2008 survey and previous Eagle Mountain Lake surveys, comparison of these values is not recommended. The TWDB considers the 2008 survey to be a significant improvement over previous methods and recommends that a similar methodology be used to resurvey Eagle Mountain Lake in approximately 10 years or after a major flood event.

The results of the TWDB 2008 Sedimentation Survey indicate Eagle Mountain Lake has accumulated 15,861 acre-feet of sediment since impoundment began in 1934. Based on this measured sediment volume and assuming a constant sediment accumulation rate, Eagle Mountain Lake loses approximately 210 acre-feet of capacity per year. The thickest sediment deposits are within the main body of the lake adjacent to the submerged river channel, approximately two miles upstream from Eagle Mountain Dam. The maximum sediment thickness observed in Eagle Mountain Lake was 8.3 feet.

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Eagle Mountain Lake General Information

Eagle Mountain Dam and Lake are located on the West Fork Trinity River, just north of Fort Worth, in Tarrant County, Texas[1] (Figure 1). Eagle Mountain Lake, built primarily for water supply and flood control, is owned and operated by Tarrant Regional Water District. Dam construction began on January 23, 1930.[2] The dam was completed on October 24, 1932; and deliberate impoundment began on February 28, 1934.[2] On July 31, 1971, construction on a new spillway was completed. Additional pertinent data about Eagle Mountain Dam and Lake can be found in Table 1.[1]

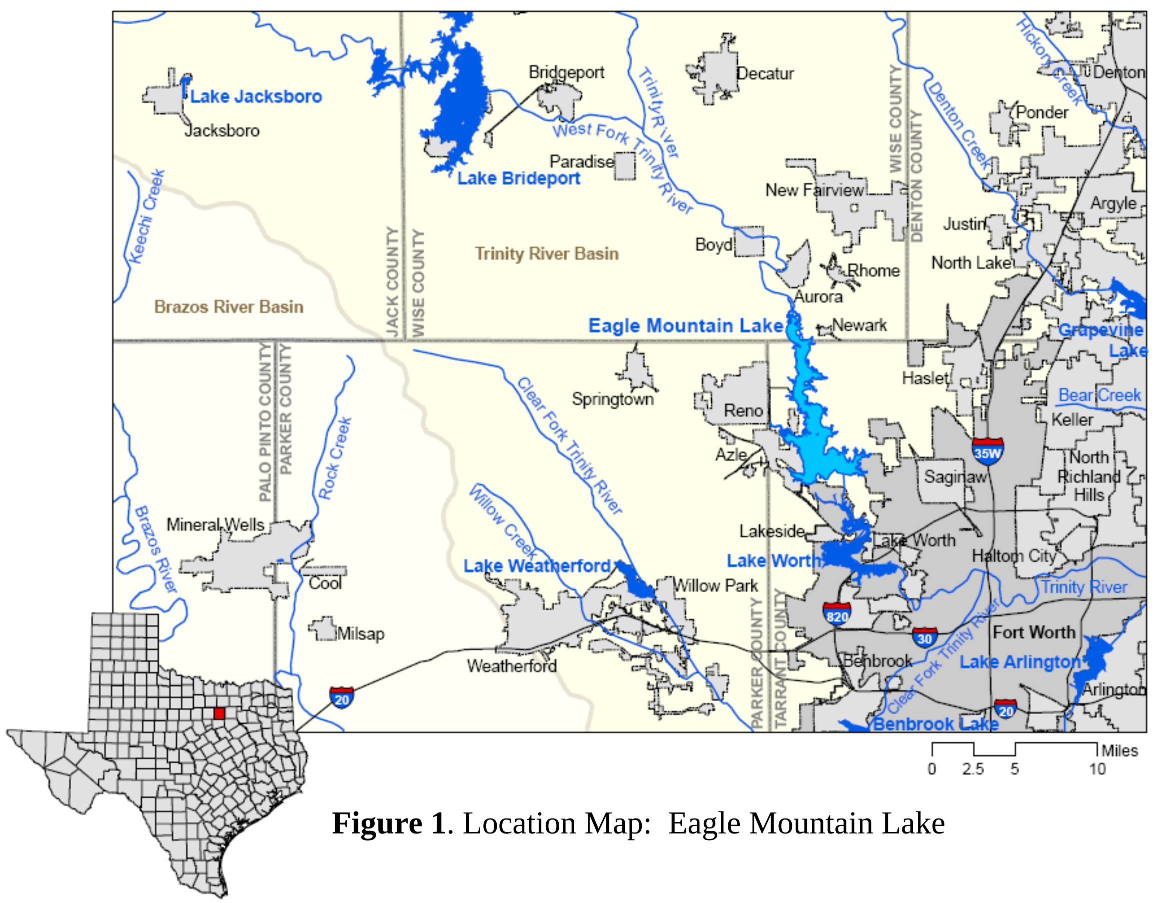

Figure 1. Location Map: Eagle Mountain Lake

Tarrant Regional Water District owns and operates four major water supply reservoirs: Richland-Chambers Reservoir, Eagle Mountain Lake, Cedar Creek Reservoir, and Lake Bridgeport.[3] Tarrant Regional Water District is one of the largest raw water suppliers in Texas, providing water to more than 30 customers, including cities such as Fort Worth, Arlington, Mansfield, and the Trinity River Authority. Their operations span a 10-county area and bring water to more than 1.6 million people in North Central

Texas[4,5] (Figure 2). Tarrant Regional Water District's Water Supply System features over 150 miles of pipelines to transport water from Richland-Chambers and Cedar Creek Reservoirs to balancing reservoirs in southeast Tarrant County. A pipeline to carry water from Richland-Chambers and Cedar Creek Reservoirs to Eagle Mountain Lake is currently under construction and will be completed in 2008.[4,5]

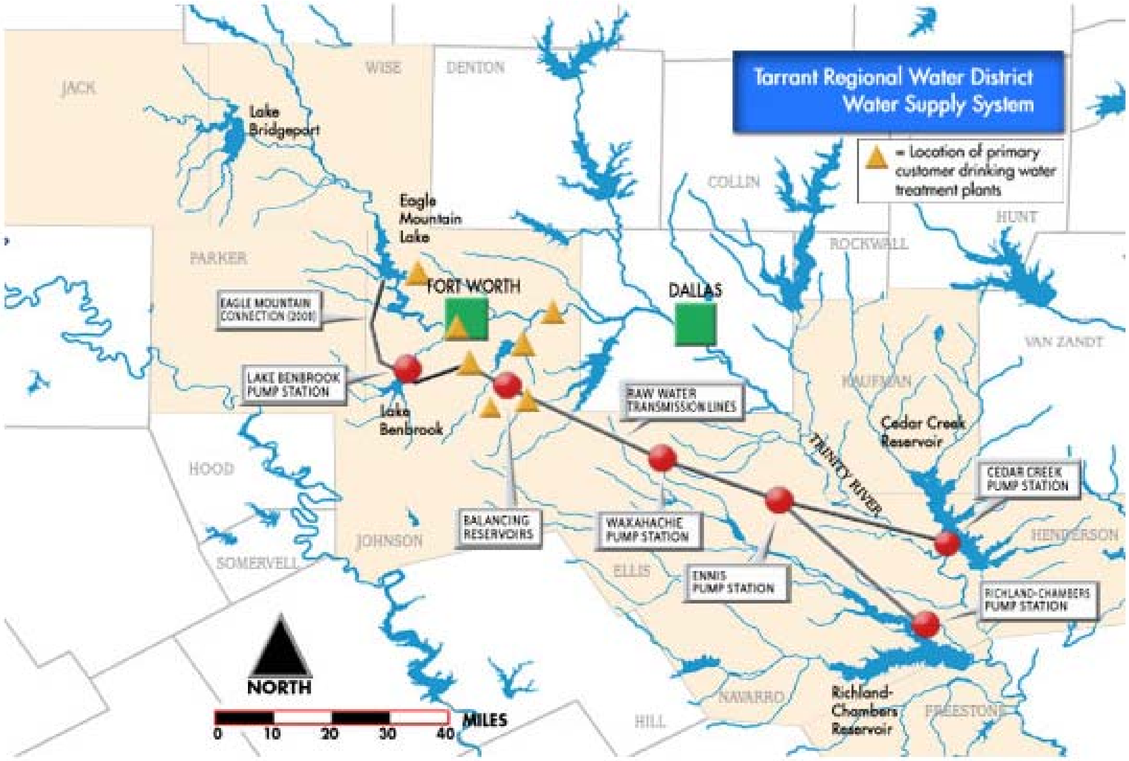

Figure 2. Tarrant Regional Water District Water Supply System and Service Area.

Source: Tarrant Regional Water District, Pipeline, 25 April 2008, http://www.trwd.com/prod/AboutUs_Pipeline.asp, 2007.

Table 1. Pertinent Data for Eagle Mountain Dam and Eagle Mountain Lake[2]

Owner		
	Tarrant Regional Water District (formerly Tarrant County Water Control and Improvement District No.1)	
Engineer (Design)		
	Hawley, Freese and Nichols (original) Freese, Nichols and Endress (1971 spillway)	
Location of Dam		
	On the West Fork Trinity River in Tarrant County, just north of Fort Worth, Texas	
Drainage Area		
	1,970 square miles	
Dam		
	Type	Two sections of earthfill and a concrete spillway separated by high ground of Eagle Mountain and Burgess Gap
	Length	4,800 feet
	Maximum height	85 feet
	Top Width	25 feet

Table 1. Pertinent Data for Eagle Mountain Dam and Eagle Mountain Lake (Continued)

Spillway (emergency)			
Location	At Burgess Gap, between dam and concrete spillway		
Type	Natural ground		
Length	1,300 feet		
Crest elevation, top of fuse plug	676.0 feet above mean sea level		
Crest elevation, bottom of fuse plug	670.0 feet above mean sea level		
New Side Channel Spillway			
Location	Spillway levee section		
Type	Concrete side channel ogee to forebay discharging through a 25 ft square conduit		
Control	6 roller gates, each 11.25 by 22.0 feet		
Crest elevation	637.0 feet above mean sea level		
Old Spillway			
Type	Concrete ogee with four bays, each 25 feet wide Three bays have vertical lift roller type gates		
Crest elevation	649.1 feet above mean sea level		
Reservoir Data (Based on TWDB 2008 Survey)			
Feature	**Elevation (ft above msl)**	**Capacity (Acre-feet)**	**Area (Acres)**
Top of Dam	682.0	N/A	N/A
Crest of emergency spillway	676.0	N/A	N/A
Base of emergency spillway	670.0	N/A	N/A
Crest of service spillway	649.1	179,880	8,694
Invert of low flow outlet	599.9	0	0
Usable conservation storage space	-	179,880	-

Water Rights

The water rights for Eagle Mountain Lake have been appropriated to the Tarrant Regional Water District (formerly the Tarrant County Water Control and Improvement District No. 1) through Certificate of Adjudication No. 08-3809 and its amendments. A brief summary of the certificate and each amendment follow. The complete certificates are on file in the Records Division of the Texas Commission on Environmental Quality.

Certificate of Adjudication No. 08-3809 Priority date: July 13, 1925

Authorizes the Tarrant County Water Control and Improvement District No. 1 to maintain an existing dam and reservoir on West Fork Trinity River (Eagle Mountain Lake), and impound therein a maximum of 210,000 acre-feet of water. The District is authorized to divert and use a maximum of 159,600 acre-feet of water per year for subsequent downstream diversion from the West Fork Trinity River for municipal and industrial purposes and for irrigation of land within the District's boundaries.

Amendment to Certificate of Adjudication No. 08-3809A Granted: April 23, 1985

Authorizes the Tarrant County Water Control and Improvement District No. 1 to change in purpose of use 1,105 acre-feet of water, out of the 159,600 acre-feet of water the District is authorized to divert and use from municipal, industrial, or irrigation, to mining purposes.

Amendment to Certificate of Adjudication No. 08-3809B Granted: January 4, 2000

Authorizes the Tarrant Regional Water District to divert and use the maximum amount of water previously authorized, 159,600 acre-feet, for municipal, industrial, mining, and irrigation purposes in the District's service area. This amendment retains the July 13, 1925 time priority.

Amendment to Certificate of Adjudication No. 08-3809C Granted: February 21, 2005

Authorizes the Tarrant Regional Water District terminal storage, within the authorized storage capacity of Eagle Mountain Lake, of water conveyed by pipeline from Cedar Creek and/or Richland-Chambers Reservoirs. Authorizes the District to divert and use the maximum 159,600 acre-feet of water per year from Eagle Mountain Lake, plus the amount of water conveyed from Cedar Creek and/or Richland-Chambers Reservoirs, less calculated conveyance and evaporative losses. The District is authorized to use the water from Cedar Creek and/or Richland-Chambers Reservoirs and stored in Eagle Mountain Lake for municipal, mining, industrial, and agricultural purposes in their service area in the Trinity River Basin. Tarrant Regional Water District is also authorized recreational use of the water stored in Eagle Mountain Lake.

Volumetric and Sedimentation Survey of Eagle Mountain Lake

The Texas Water Development Board's (TWDB) Hydrographic Survey Program was authorized by the state legislature in 1991. The Texas Water Code authorizes TWDB to perform surveys to determine reservoir storage capacity, sedimentation levels, rates of sedimentation, and projected water supply availability.

In July of 2007, TWDB entered into agreement with Tarrant Regional Water District, for the purpose of performing volumetric and sedimentation surveys of Eagle Mountain Lake. These surveys were performed simultaneously using a single-beam multi-frequency (200 kHz, 50 kHz, and 24 kHz) sub-bottom profiling depth sounder. The 200 kHz return measures the current bathymetric surface, while the combination of the three frequencies, along with core samples for correlating the pre-impoundment surface with the signal return, is analyzed for evidence of sediment accumulation throughout the reservoir.

Datum

The vertical datum used during this survey is that used by the United States Geological Survey (USGS) for the reservoir elevation gauge USGS 08045000 Eagle Mtn Res abv Fort Worth, TX.[6] The datum for this gauge is reported as National Geodetic Vertical Datum 1929 (NGVD29) or mean sea level, thus elevations reported here are in feet above mean sea level. 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.

TWDB Bathymetric Data Collection

Bathymetric data collection for Eagle Mountain Lake occurred between February 5, 2008 and March 13, 2008. During the survey the water surface elevation varied between 646.42 feet and 648.39 feet above mean sea level (NGVD29). Additional data was collected on July 30, 2008, while the water surface elevation measured 646.58 feet above mean sea level. For data collection, TWDB used a Specialty Devices, Inc., multi-frequency (200 kHz, 50 kHz, and 24 kHz) sub-bottom profiling depth sounder integrated with Differential Global Positioning System (DGPS) equipment. Data collection occurred while navigating along pre-planned range lines oriented perpendicular to the assumed location of the original river channels and spaced approximately 500 feet apart. The depth sounder was calibrated daily using a velocity profiler to measure the speed of sound in the water column and a weighted tape or stadia rod for depth reading verification. During the 2008 survey, team members collected approximately 103,800 data points over cross-sections totaling nearly 182 miles in length. Figure 3 shows where data points were collected during the TWDB 2008 survey.

Figure 3. Data points collected during TWDB 2008 Survey

Data Processing

Model Boundaries

The reservoir boundary was digitized from aerial photographs, or digital orthophoto quarter-quadrangle images (DOQQs)[7,8], using Environmental Systems

Research Institute's (ESRI) ArcGIS 9.1 software. The quarter-quadrangles that cover Eagle Mountain Lake are Azle NE, Azle SE, Avondale NW, Avondale SW, Boyd SE, Springtown SE NE, and Lake Worth NW. These images were photographed on August 3, 2004 and August 4, 2004, during which time the water surface elevation at Eagle Mountain Lake measured 648.74 feet and 648.68 feet above mean sea level, respectively. Although the water surface elevation measured slightly below conservation pool elevation at the time of the photos, TWDB determined that there was not a significant difference in lake area between 648.7 feet and 649.1 feet, as discernable from the photographs and given the photographs have a 1-meter resolution. Therefore, the boundary was digitized from the land water interface in the photos and labeled 649.1 feet to allow area and volume to be calculated to the top of conservation pool elevation.

Additional aerial photographs of Eagle Mountain Lake were taken on July 30, 2006 and August 19, 2006, while the water surface elevation measured 643.81 feet above mean sea level. From these, a 643.81 foot contour, verified for accuracy against the data collected during the survey, was digitized to supplement the TWDB survey data in locations where the survey data alone was insufficient to properly represent the reservoir bathymetry.

Triangulated Irregular Network (TIN) Model

Upon completion of data collection, the raw data files collected by TWDB were edited using HydroEdit and DepthPic to remove any data anomalies. HydroEdit is used to automate the editing of the 200 kHz frequency and determine the current bathymetric surface. DepthPic is used to display, interpret, and edit the multi-frequency data in tandem to correct any edits HydroEdit has flagged and to manually interpret the pre-impoundment surface. The water surface elevations at the times of each sounding are used to convert sounding depths to corresponding bathymetric elevations. For processing outside of DepthPic, the sounding coordinates (X,Y,Z) were exported as a MASS points file. TWDB also created additional MASS points files of interpolated and extrapolated data based on the sounding data. Using the "Self-Similar Interpolation" technique (described below), TWDB interpolated bathymetric elevation data located in-between surveyed cross sections. To better represent reservoir bathymetry in shallow regions, TWDB used the "Line Extrapolation" technique.[9] The point files resulting from both the data interpolation and extrapolation were exported as MASS points files, and were used in conjunction with the sounding and boundary files in creating a Triangulated Irregular Network (TIN) model with the 3D Analyst Extension of ArcGIS. The 3D Analyst algorithms use Delaunay's criteria for triangulation to place a triangle between three non-uniformly spaced points, including the boundary vertices.[10]

Using Arc/Info software, volumes and areas are calculated from the TIN model for the entire reservoir at one-tenth of a foot intervals, from elevation 599.7 feet to elevation 649.1 feet. The Elevation-Capacity Table and Elevation-Area Table, updated for 2008, are presented in Appendix A and B, respectively. The Area-Capacity Curves are presented in Appendix C.

The TIN model was interpolated and averaged using a cell size of 1 foot by 1 foot and converted to a raster. The raster was used to produce Figure 4, an Elevation Relief Map representing the topography of the reservoir bottom, Figure 5, a map showing shaded depth ranges for Eagle Mountain Lake, and Figure 6, a 2-foot contour map (attached).

Self-Similar Interpolation

A limitation of the Delaunay method for triangulation when creating TIN models results in artificially-curved contour lines extending into the reservoir where the reservoir walls are steep and the reservoir is relatively narrow. These curved contours are likely a poor representation of the true reservoir bathymetry in these areas. Also, if the surveyed cross sections are not perpendicular to the centerline of the submerged river channel (the location of which is often unknown until after the survey), then the TIN model is not likely to well-represent the true channel bathymetry.

To ameliorate these problems, a Self-Similar Interpolation routine (developed by TWDB) was used to interpolate the bathymetry in between many 500 foot-spaced survey lines. The Self-Similar Interpolation technique effectively increases the density of points input into the TIN model, and directs the TIN interpolation to better represent the reservoir topography.[9] In the case of Eagle Mountain Lake, the application of Self-Similar Interpolation helped represent the lake morphology near the banks and improved the representation of the submerged river channel (Figure 7). In areas where obvious geomorphic features indicate a high-probability of cross-section shape changes (e.g. incoming tributaries, significant widening/narrowing of channel, etc.), the assumptions used in applying the Self-Similar Interpolation technique are not likely to be valid;

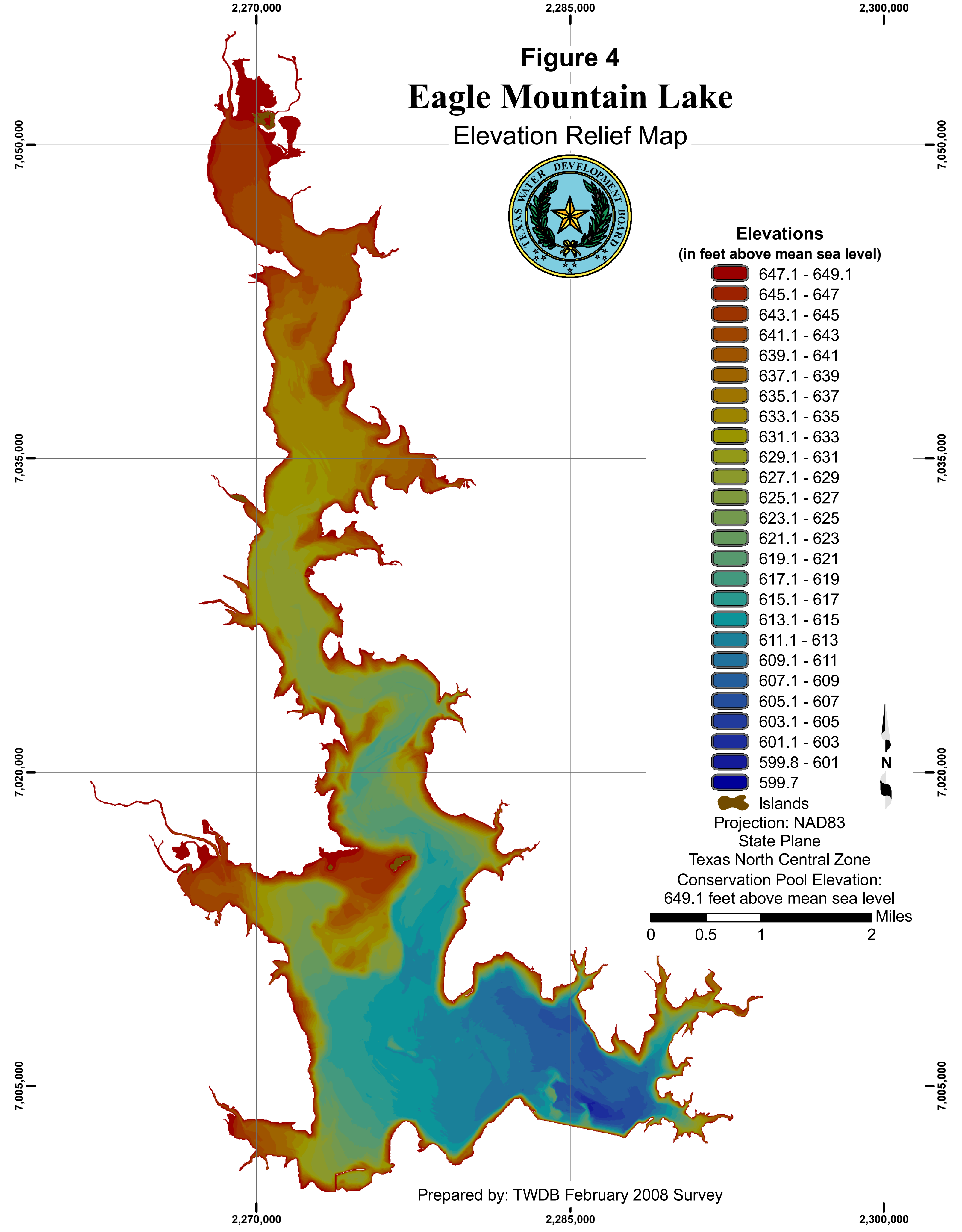

Figure 4
Eagle Mountain Lake
Elevation Relief Map
TEXAS WATER DEVELOPMENT BOARD
Elevations
(in feet above mean sea level)
647.1 - 649.1
645.1 - 647
643.1 - 645
641.1 - 643
639.1 - 641
637.1 - 639
635.1 - 637
633.1 - 635
631.1 - 633
629.1 - 631
627.1 - 629
625.1 - 627
623.1 - 625
621.1 - 623
619.1 - 621
617.1 - 619
615.1 - 617
613.1 - 615
611.1 - 613
609.1 - 611
607.1 - 609
605.1 - 607
603.1 - 605
601.1 - 603
599.8 - 601
599.7
Islands
Projection: NAD83
State Plane
Texas North Central Zone
Conservation Pool Elevation:
649.1 feet above mean sea level
Miles
0
0.5
1
2
N
2,270,000
2,285,000
2,300,000
7,050,000
7,035,000
7,020,000
7,005,000
Prepared by: TWDB February 2008 Survey

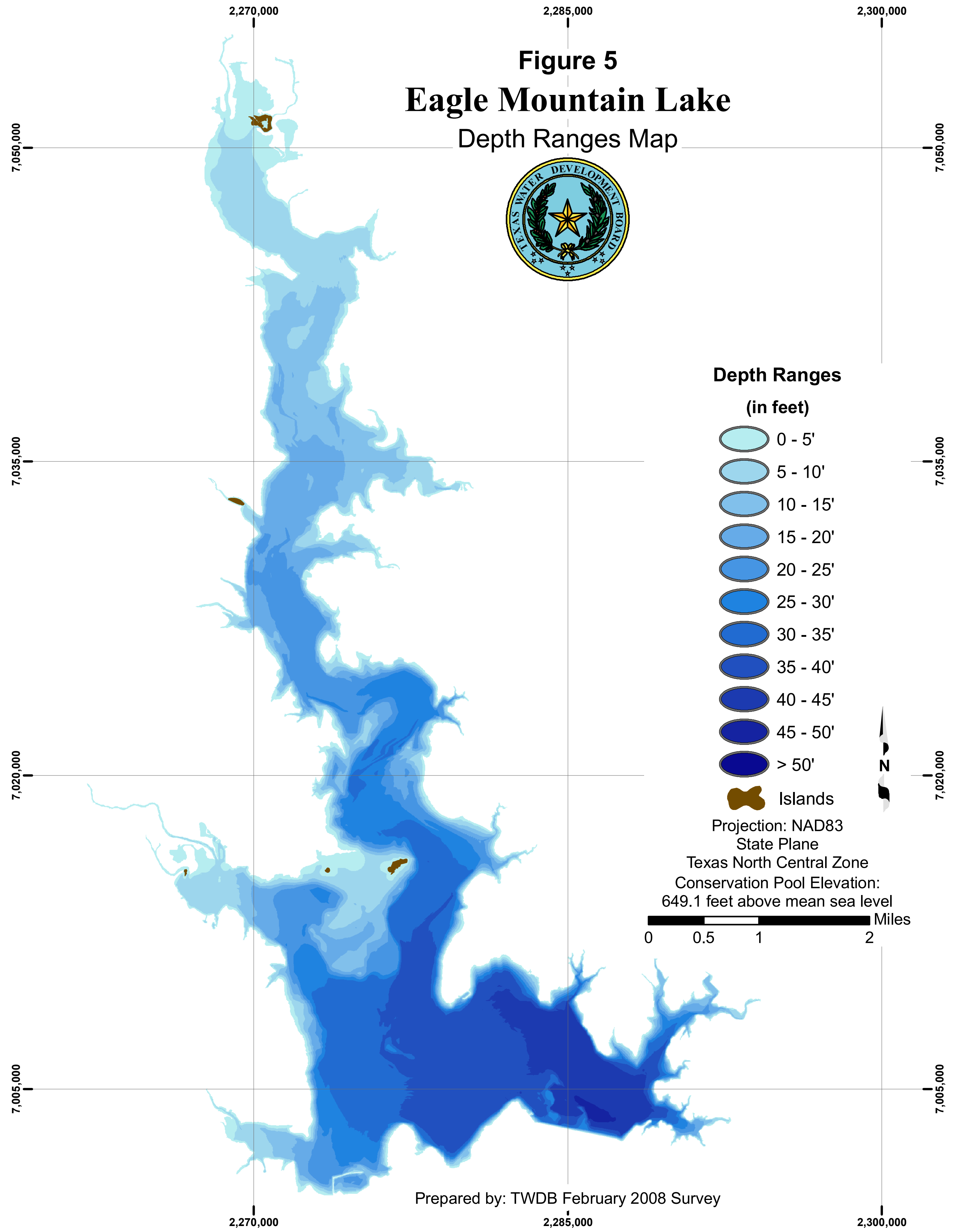
Figure 5
Eagle Mountain Lake
Depth Ranges Map
TEXAS WATER DEVELOPMENT BOARD
Depth Ranges
(in feet)
0 - 5'
5 - 10'
10 - 15'
15 - 20'
20 - 25'
25 - 30'
30 - 35'
35 - 40'
40 - 45'
45 - 50'
> 50'
Islands
N
Projection: NAD83
State Plane
Texas North Central Zone
Conservation Pool Elevation:
649.1 feet above mean sea level
Miles
0
0.5
1
2
2,270,000
2,285,000
2,300,000
7,050,000
7,035,000
7,020,000
7,005,000
Prepared by: TWDB February 2008 Survey

therefore, self-similar interpolation was not used in areas of Eagle Mountain Lake where a high probability of change between cross-sections exists.[9] Figure 7 illustrates typical results of the application of the Self-Similar Interpolation routine in Eagle Mountain Lake, and the bathymetry shown in Figure 7C was used in computing reservoir capacity and area tables (Appendix A, B).

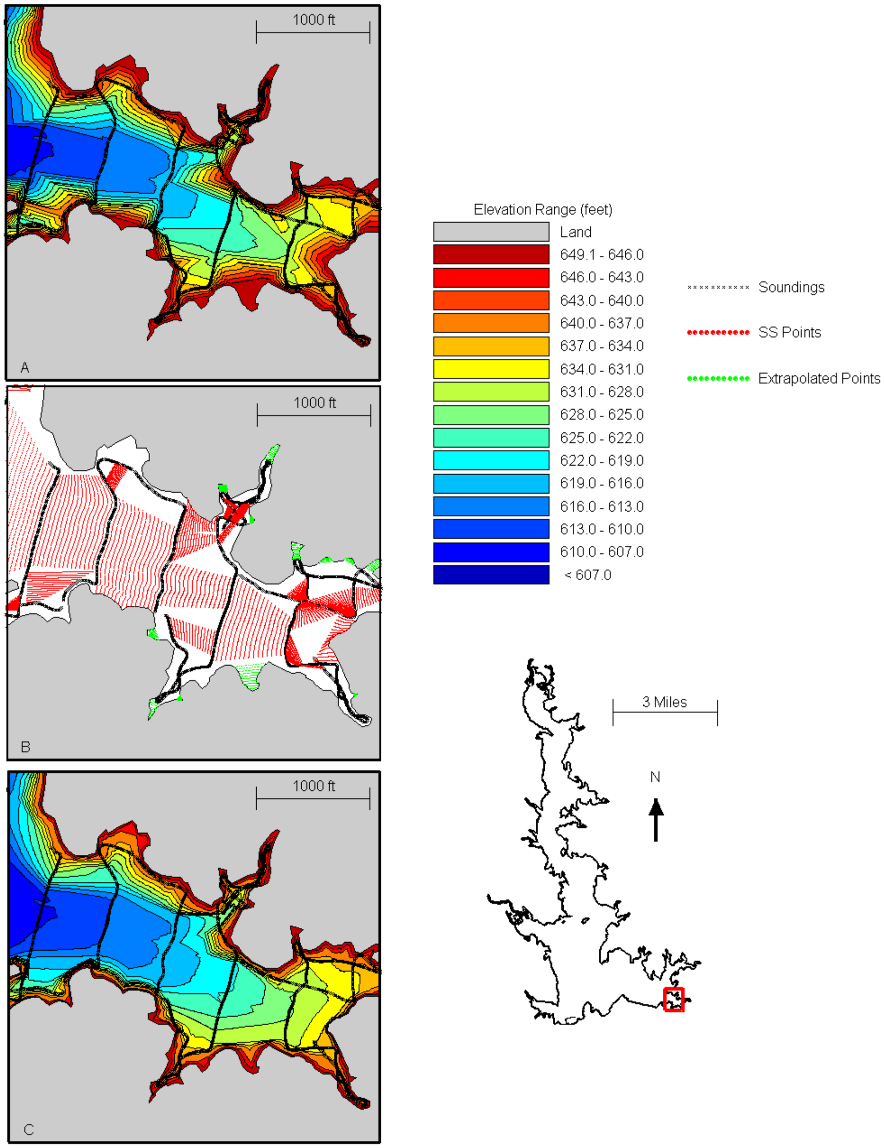

Figure 7. Application of the Self-Similar Interpolation technique to Eagle Mountain Lake sounding data – A) bathymetric contours without interpolated points, B) Sounding points (black) and interpolated points (red) with reservoir boundary shown at elevation 649.1 feet (black), C) bathymetric contours with the interpolated points. Note: In 7A the contours near the boundary bow out into the reservoir. This is an artifact of the TIN generation routine, rather than an accurate representation of the physical bathymetric surface. Inclusion of the interpolated points (7C) corrects this and smoothes the bathymetric contours.

Survey Results

Volumetric Survey

The results of the TWDB 2008 Volumetric Survey indicate Eagle Mountain Lake has a total reservoir capacity of 179,880 acre-feet and encompasses 8,694 acres at conservation pool elevation (649.1 feet above mean sea level, NGVD29).

Previously published[1] capacity estimates for Eagle Mountain Lake are 190,460 acre-feet, 178,440 acre-feet, and 182,505 acre-feet based on surveys conducted in 1968, 1988, and 2000, respectively (Table 2). Due to differences in the methodologies used in calculating areas and capacities from this 2008 survey and previous Eagle Mountain Lake surveys, comparison of these values is not recommended. The TWDB considers the 2008 survey to be a significant improvement over previous methods and recommends that a similar methodology be used to resurvey Eagle Mountain Lake in approximately 10 years or after a major flood event.

Table 2. Area and Volume Comparisons of Eagle Mountain Lake

Feature	U.S. Army Corps of Engineers	Freese and Nichols	TWDB Volumetric Survey	TWDB Volumetric and Sedimentation Survey
Year	1968	1988	2000	2008
Area (acres)	9,200	9,030	8,702	8,694
Capacity (acre-feet)	190,460	178,440	182,505	179,880

Sedimentation Survey

The 200 kHz, 50 kHz, and 24 kHz frequency data were used to interpret sediment distribution and accumulation throughout Eagle Mountain Lake. Figure 8 shows the thickness of sediment throughout the reservoir. To assist in the interpretation of post-impoundment sediment accumulation, ancillary data was collected in the form of five core samples. Sediment cores were collected on October 15, 2008 using a Specialty Devices, Inc. VibraCore system.

The results of the TWDB 2008 Sedimentation Survey indicate Eagle Mountain Lake has accumulated 15,861 acre-feet of sediment since impoundment

began in 1934. Based on this measured sediment volume and assuming a constant sediment accumulation rate, Eagle Mountain Lake loses approximately 210 acre-feet of capacity per year. The thickest sediment deposits are within the main body of the lake adjacent to the submerged river channel, approximately two miles upstream from Eagle Mountain Dam. Throughout most of the lake, the original river channel has been completely filled in with sediment. The maximum sediment thickness observed in Eagle Mountain Lake was 8.3 feet. A complete description of the sediment measurement methodology and sample results is presented in Appendix D. An analysis of sediment range line data for Eagle Mountain Lake is presented in Appendix E.

TWDB Contact Information

More information about the Hydrographic Survey Program can be found at:

http://www.twdb.state.tx.us/assistance/lakesurveys/volumetricindex.asp

Any questions regarding the TWDB Hydrographic Survey Program may be addressed to:

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Or

Jason Kemp
Team Leader, TWDB Hydrographic Survey Program
Phone: (512) 463-2465
Email: Jason.Kemp@twdb.state.tx.us

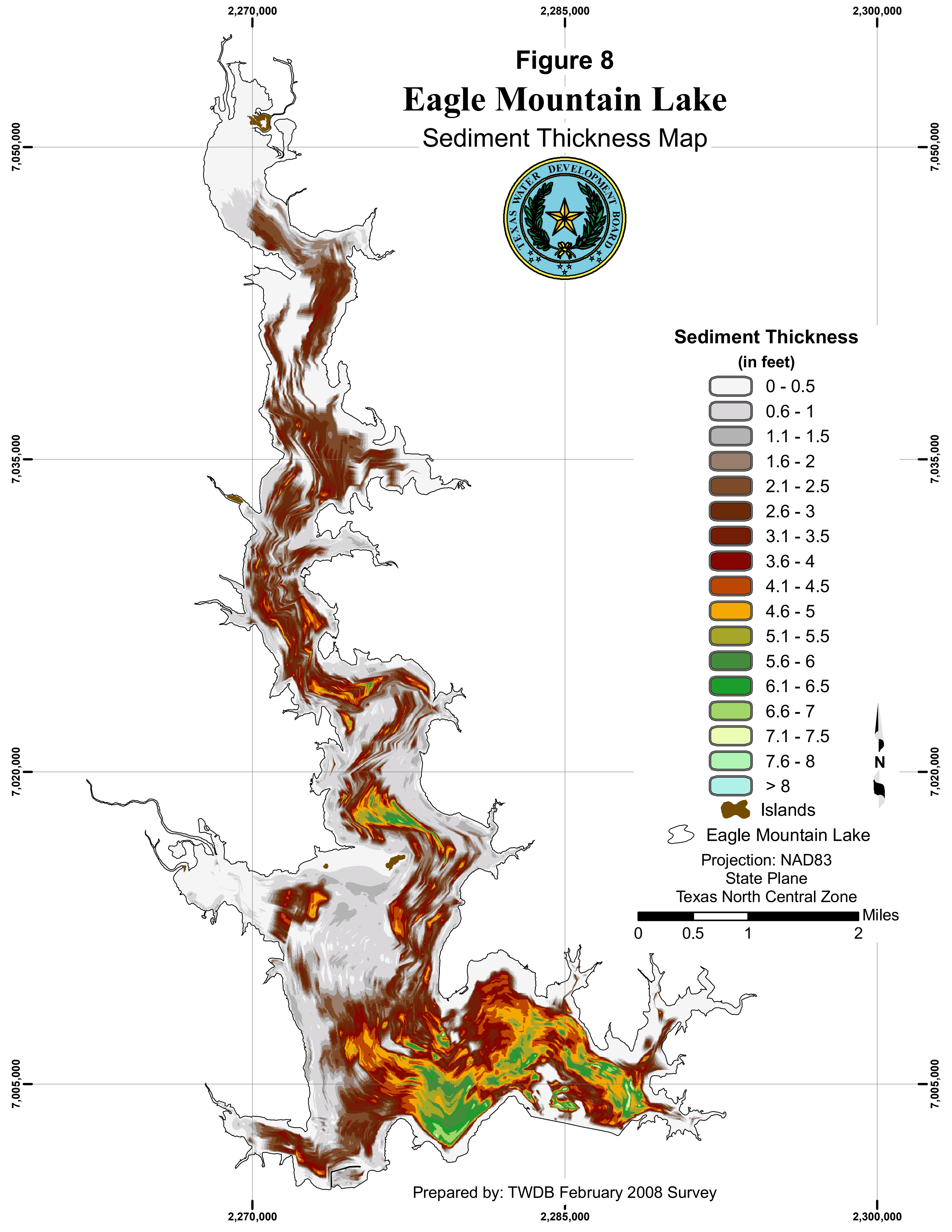

Figure 8

Eagle Mountain Lake

Sediment Thickness Map

Prepared by: TWDB February 2008 Survey

References

1. Texas Water Development Board, April 21, 2001, "Volumetric Survey of Eagle Mountain Lake."

2. Texas Water Development Board, Report 126, Engineering Data on Dams and Reservoirs in Texas, Part II, November 1973.

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6. U.S. Geological Survey National Water Information System – Site 08045000, http://waterdata.usgs.gov/tx/nwis/uv/?site_no=08045000&PARAmeter_cd=72020,00054

7. Texas Natural Resources Information System (TNRIS), viewed 31 October 2007, http://www.tnris.state.tx.us/.

8. U.S Department of Agriculture, Farm Service Agency, Aerial Photography Field Office, National Agriculture Imagery Program, viewed February 10, 2006 http://www.apfo.usda.gov/NAIP.html.

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10. ESRI, Environmental Systems Research Institute. 1995. ARC/INFO Surface Modeling and Display, TIN Users Guide.

Appendix A

Eagle Mountain Lake

RESERVOIR CAPACITY TABLE

TEXAS WATER DEVELOPMENT BOARD
CAPACITY IN ACRE-FEET
ELEVATION INCREMENT IS ONE TENTH FOOT

February 2008 Survey
Conservation Pool Elevation 649.1 feet NGVD29

ELEVATION in Feet	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
599	0	0	0	0	0	0	0	0	0	0
600	0	0	0	0	0	0	0	0	0	0
601	1	1	1	1	2	2	3	3	4	5
602	6	7	8	9	10	11	12	14	15	16
603	18	20	21	23	25	27	28	30	32	35
604	37	39	41	44	46	49	51	54	57	60
605	63	66	70	73	77	80	84	88	92	97
606	102	108	115	123	131	140	150	162	175	190
607	207	227	249	274	301	330	361	394	429	465
608	502	541	581	622	664	708	753	799	846	895
609	944	995	1,046	1,099	1,152	1,208	1,264	1,322	1,381	1,441
610	1,502	1,565	1,629	1,695	1,762	1,830	1,900	1,972	2,046	2,121
611	2,198	2,277	2,358	2,441	2,526	2,614	2,704	2,796	2,892	2,991
612	3,092	3,196	3,301	3,409	3,520	3,632	3,748	3,867	3,988	4,113
613	4,242	4,373	4,509	4,648	4,790	4,935	5,083	5,234	5,387	5,543
614	5,701	5,861	6,024	6,189	6,356	6,525	6,696	6,870	7,047	7,227
615	7,409	7,595	7,784	7,975	8,170	8,367	8,566	8,769	8,973	9,180
616	9,390	9,603	9,818	10,034	10,253	10,474	10,696	10,921	11,147	11,374
617	11,604	11,834	12,067	12,301	12,537	12,775	13,014	13,255	13,497	13,741
618	13,986	14,233	14,482	14,731	14,982	15,235	15,489	15,744	16,001	16,259
619	16,518	16,778	17,040	17,303	17,567	17,833	18,101	18,370	18,641	18,913
620	19,186	19,461	19,737	20,015	20,294	20,574	20,856	21,140	21,426	21,713
621	22,002	22,293	22,588	22,884	23,182	23,482	23,783	24,085	24,389	24,695
622	25,002	25,310	25,620	25,931	26,243	26,558	26,873	27,191	27,510	27,830
623	28,152	28,476	28,800	29,126	29,453	29,781	30,111	30,441	30,773	31,106
624	31,440	31,776	32,114	32,452	32,793	33,134	33,477	33,821	34,166	34,513
625	34,861	35,210	35,562	35,915	36,270	36,626	36,984	37,344	37,705	38,068
626	38,433	38,800	39,168	39,538	39,911	40,284	40,660	41,037	41,416	41,797
627	42,180	42,565	42,952	43,340	43,730	44,121	44,514	44,910	45,307	45,707
628	46,108	46,512	46,918	47,326	47,737	48,150	48,565	48,982	49,402	49,823
629	50,247	50,674	51,103	51,535	51,970	52,406	52,844	53,284	53,726	54,169
630	54,614	55,060	55,509	55,958	56,409	56,862	57,316	57,771	58,228	58,687
631	59,147	59,608	60,071	60,536	61,003	61,470	61,940	62,411	62,884	63,359
632	63,835	64,314	64,795	65,277	65,762	66,248	66,737	67,228	67,721	68,217
633	68,714	69,213	69,714	70,216	70,722	71,228	71,737	72,249	72,762	73,279
634	73,798	74,319	74,845	75,374	75,907	76,443	76,982	77,525	78,072	78,623
635	79,176	79,733	80,292	80,853	81,416	81,981	82,547	83,115	83,684	84,255
636	84,827	85,401	85,976	86,553	87,132	87,712	88,294	88,878	89,464	90,052
637	90,642	91,233	91,827	92,422	93,019	93,618	94,220	94,824	95,430	96,038
638	96,648	97,260	97,876	98,493	99,112	99,734	100,357	100,983	101,611	102,242
639	102,874	103,509	104,146	104,786	105,429	106,075	106,723	107,374	108,028	108,686
640	109,348	110,013	110,681	111,352	112,025	112,700	113,377	114,057	114,740	115,426
641	116,115	116,806	117,500	118,196	118,896	119,598	120,303	121,012	121,724	122,439
642	123,158	123,879	124,604	125,330	126,060	126,792	127,527	128,264	129,004	129,747
643	130,491	131,238	131,988	132,741	133,497	134,255	135,017	135,782	136,550	137,332
644	138,116	138,902	139,689	140,478	141,268	142,058	142,851	143,644	144,439	145,235
645	146,032	146,831	147,631	148,432	149,234	150,038	150,842	151,649	152,456	153,265
646	154,074	154,885	155,698	156,511	157,326	158,142	158,959	159,778	160,598	161,420
647	162,242	163,066	163,892	164,718	165,546	166,375	167,206	168,038	168,871	169,707
648	170,543	171,381	172,222	173,063	173,908	174,753	175,601	176,452	177,304	178,160
649	179,018	179,880								

Appendix B

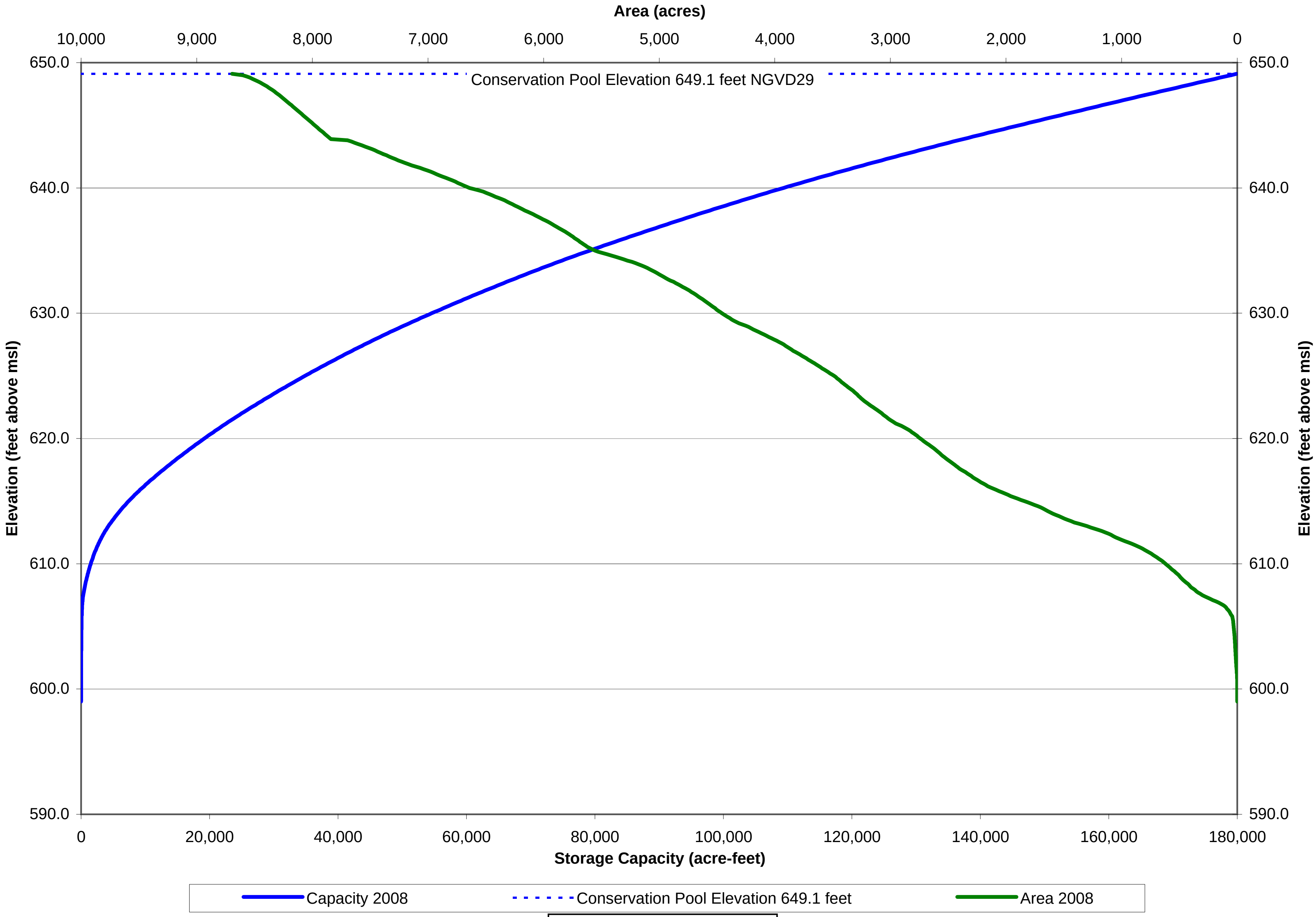
Eagle Mountain Lake

RESERVOIR AREA TABLE

TEXAS WATER DEVELOPMENT BOARD
AREA IN ACRES
ELEVATION INCREMENT IS ONE TENTH FOOT

February 2008 Survey
Conservation Pool Elevation 649.1 feet NGVD29

ELEVATION in Feet	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
599	0	0	0	0	0	0	0	0	0	0
600	0	0	0	0	0	0	1	1	1	1
601	2	2	3	4	4	5	5	6	8	8
602	9	10	10	11	12	12	13	13	14	15
603	16	16	17	17	18	19	19	20	21	21
604	22	23	24	24	25	26	27	28	29	30
605	31	33	34	35	36	37	39	41	44	50
606	57	64	71	78	87	97	107	121	140	162
607	185	212	236	258	281	302	321	340	353	366
608	381	396	407	417	428	442	455	468	479	490
609	499	508	519	533	545	558	570	583	596	608
610	621	634	647	662	678	694	710	726	744	762
611	781	800	820	841	863	886	914	942	970	1,000
612	1,025	1,049	1,069	1,090	1,114	1,141	1,171	1,202	1,234	1,267
613	1,301	1,336	1,370	1,409	1,439	1,467	1,493	1,519	1,543	1,569
614	1,594	1,618	1,638	1,657	1,679	1,701	1,725	1,753	1,785	1,812
615	1,841	1,872	1,901	1,930	1,959	1,984	2,009	2,034	2,059	2,086
616	2,112	2,137	2,159	2,178	2,196	2,215	2,234	2,252	2,269	2,285
617	2,301	2,316	2,334	2,350	2,368	2,386	2,402	2,417	2,431	2,445
618	2,459	2,475	2,490	2,504	2,519	2,533	2,546	2,559	2,572	2,584
619	2,597	2,609	2,623	2,637	2,652	2,668	2,684	2,700	2,714	2,728
620	2,742	2,755	2,769	2,783	2,798	2,813	2,828	2,845	2,863	2,881
621	2,903	2,930	2,953	2,971	2,988	3,004	3,019	3,033	3,048	3,062
622	3,076	3,089	3,103	3,118	3,136	3,151	3,167	3,182	3,197	3,213
623	3,227	3,240	3,253	3,264	3,276	3,287	3,298	3,311	3,324	3,338
624	3,352	3,366	3,380	3,395	3,408	3,421	3,434	3,447	3,460	3,474
625	3,488	3,503	3,522	3,539	3,556	3,572	3,589	3,606	3,623	3,640
626	3,658	3,676	3,693	3,711	3,728	3,746	3,764	3,782	3,801	3,821
627	3,840	3,858	3,874	3,890	3,906	3,923	3,942	3,962	3,985	4,008
628	4,029	4,050	4,072	4,093	4,116	4,140	4,164	4,185	4,205	4,226
629	4,252	4,280	4,310	4,333	4,354	4,372	4,389	4,407	4,424	4,441
630	4,458	4,474	4,489	4,503	4,517	4,532	4,547	4,563	4,578	4,593
631	4,608	4,623	4,639	4,656	4,672	4,687	4,703	4,721	4,739	4,757
632	4,775	4,795	4,815	4,835	4,855	4,876	4,903	4,923	4,942	4,961
633	4,980	4,999	5,019	5,039	5,059	5,079	5,101	5,124	5,150	5,176
634	5,206	5,236	5,275	5,309	5,342	5,375	5,410	5,450	5,488	5,524
635	5,553	5,580	5,602	5,621	5,638	5,654	5,669	5,684	5,700	5,715
636	5,731	5,747	5,762	5,778	5,794	5,812	5,830	5,849	5,868	5,888
637	5,906	5,924	5,943	5,962	5,983	6,006	6,027	6,048	6,069	6,092
638	6,114	6,138	6,161	6,183	6,204	6,226	6,248	6,270	6,292	6,314
639	6,336	6,360	6,386	6,415	6,443	6,468	6,494	6,524	6,559	6,598
640	6,639	6,669	6,693	6,716	6,740	6,763	6,788	6,816	6,845	6,874
641	6,900	6,926	6,951	6,978	7,006	7,036	7,069	7,104	7,139	7,171
642	7,201	7,228	7,256	7,283	7,309	7,334	7,359	7,387	7,411	7,435
643	7,459	7,485	7,512	7,542	7,573	7,603	7,632	7,662	7,695	7,839
644	7,852	7,865	7,878	7,891	7,904	7,916	7,929	7,941	7,954	7,967
645	7,979	7,992	8,004	8,017	8,029	8,042	8,054	8,067	8,079	8,092
646	8,104	8,117	8,130	8,142	8,155	8,168	8,181	8,194	8,207	8,220
647	8,233	8,246	8,259	8,273	8,286	8,300	8,313	8,328	8,343	8,358
648	8,375	8,392	8,410	8,429	8,449	8,470	8,492	8,515	8,540	8,568
649	8,602	8,694								



Eagle Mountain Lake
February 2008 Survey
Prepared by: TWDB

Appendix C: Area and Capacity Curves

Appendix D

Analysis of Sediment Accumulation Data from Eagle Mountain Lake

Executive Summary

The results of the TWDB 2008 Sedimentation Survey indicate Eagle Mountain Lake has accumulated 15,861 acre-feet of sediment since impoundment in 1934. Based on this measured sediment volume and assuming a constant sediment accumulation rate, Eagle Mountain Lake loses approximately 210 acre-feet of capacity per year. The thickest sediment deposits are within the main body of the lake adjacent to the submerged river channel approximately two miles upstream from Eagle Mountain Dam. Throughout most of the lake, the original river channel has been completely filled in with sediment. The maximum sediment thickness observed in Eagle Mountain Lake was 8.3 feet.

Introduction

This appendix includes the results of the sedimentation investigation using multi-frequency depth sounder and sediment core data collected by the Texas Water Development Board (TWDB). Through careful analysis and interpretation of the multi-frequency signal returns, it is possible to discern the pre-impoundment bathymetric surface, as well as the current surface and sediment thickness. Such interpretations are aided and validated through comparisons with sediment core samples which provide independent measurements of sediment thickness. The remainder of this appendix presents a discussion of the results from and methodology used in the core sampling and multi-frequency data collection efforts, followed by a composite analysis of sediment measured in Eagle Mountain Lake.

Data Collection & Processing Methodology

TWDB conducted the initial bathymetric survey for Eagle Mountain Lake between February 5, 2008 and March 13, 2008, while the water surface elevation ranged between 646.42 feet and 648.39 feet above mean sea level (NGVD29). Additional data collection occurred on July 30, 2008 while the water surface elevation was 646.58 feet above mean sea level (NGVD29). For each data collection effort, TWDB used a Specialty Devices, Inc. (SDI), multi-frequency (200 kHz, 50 kHz, and 24 kHz) sub-bottom profiling depth sounder integrated with Differential Global Positioning System (DGPS) equipment. Data collection occurred while navigating along pre-planned range lines oriented perpendicular to the assumed location of the original river channels and spaced approximately 500 feet apart. For all data collection efforts, the depth sounder was calibrated daily using a velocity profiler to measure the speed of sound in the water column and a weighted tape or stadia rod for depth reading verification. During the initial 2008 survey, team members collected 103,827 data points over cross-sections totaling nearly 182 miles in length. Figure D1 shows where data points were collected during the TWDB 2008 survey.

TWDB collected five sediment cores from Eagle Mountain Lake on October 15, 2008. Core samples were collected at locations where sounding data had been previously collected (Figure D1). All cores were collected with a custom-coring boat and SDI VibraCore system. Cores were analyzed by TWDB and both the sediment thickness and the distance the core penetrated the pre-impoundment boundary were recorded. The coordinates and a description of each core sample are provided in Table D1. Figure D2 shows the cross-section of sediment core E-2. At this location, TWDB collected 38 inches of sediment, with the upper sediment layer (Figure D2) having a high water content and consisting of silty-loam material. The pre-impoundment boundary was evident from this core at a distance of 4 inches above the core base. Below this location, the sediment soil structure was well developed, organic material was present, and the soil moisture content was low. Above this location, the soil becomes rapidly less structured and the moisture content generally increases (Figure D2).

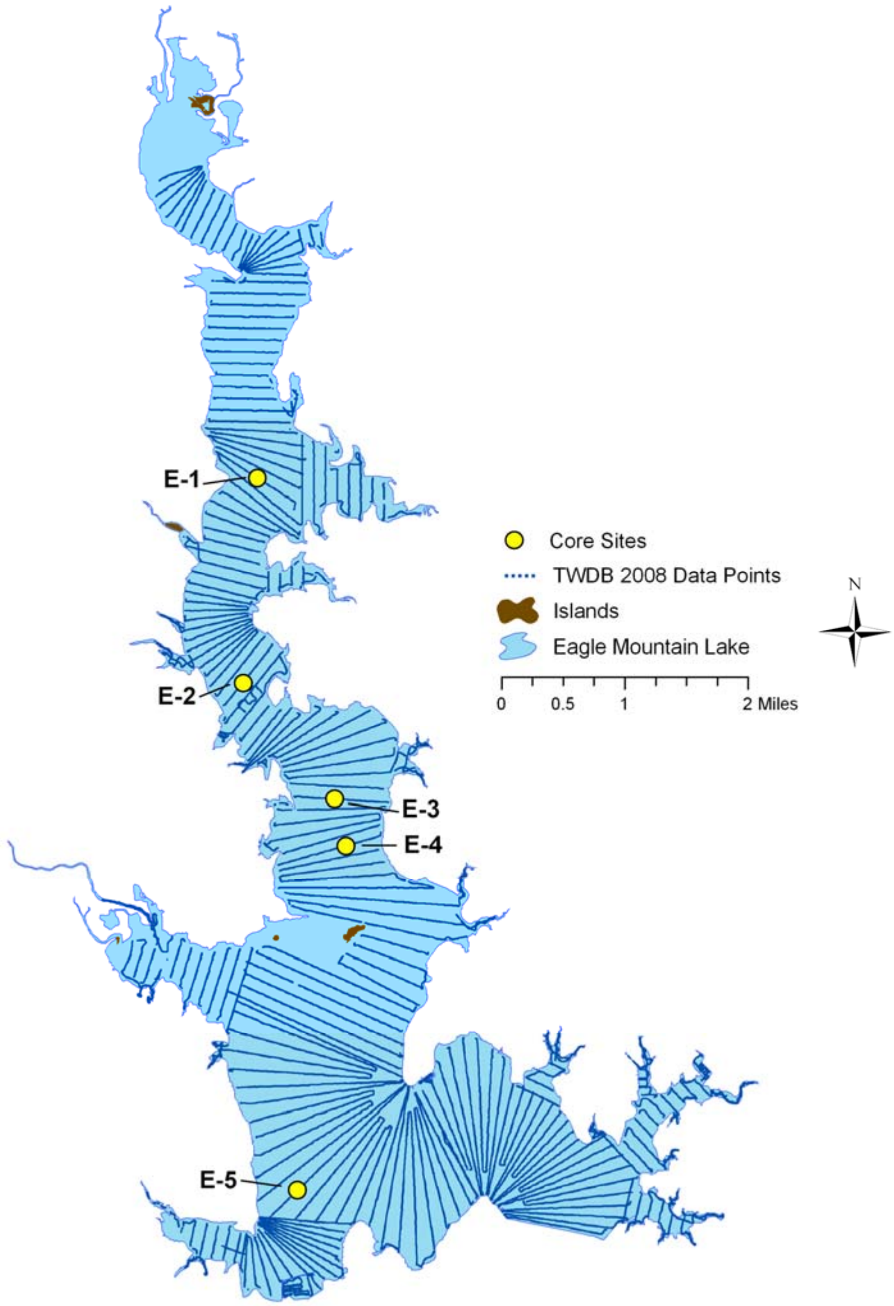


Figure D1 – TWDB 2008 survey data points for Eagle Mountain Lake. Sounding data used in assessing sediment content are shown in blue.

Table D1 – Core Sampling Analysis Data – Eagle Mountain Lake

Core	Easting** (ft)	Northing** (ft)	Description
E-1	2272672.79	7035221.22	22” of muddy, silty-loam sediment, lacking soil structure
E-2	2272080.01	7026387.58	38” of muddy, silty-loam sediment with minimal plant material visible with depth, decreasing water content with depth
E-3	2276022.79	7021411.59	17” of muddy silty-loam sediment, lacking soil structure
E-4	2276520.46	7019423.41	15” of sandy sediment with low water content and compact soil structure
E-5	2274438.42	7004625.67	24” of muddy silty-loam sediment, lacking soil structure

** Coordinates are based on NAD 1983 State Plane Texas North Central System

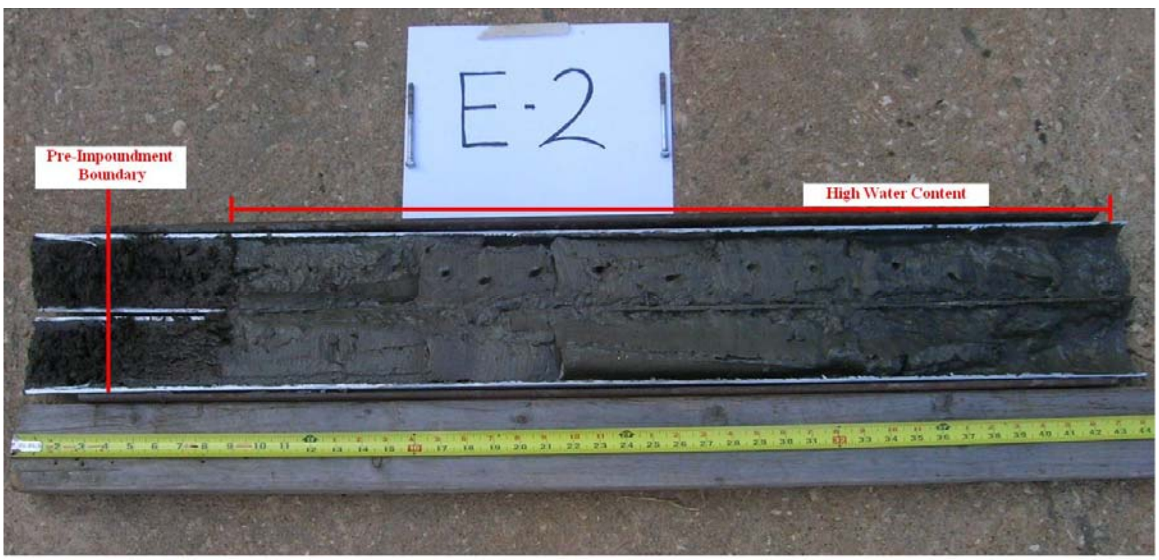


Figure D2 – Sediment Core E-2 from Eagle Mountain Lake, showing the pre-impoundment boundary 4 inches above the base of the core (left). The pre-impoundment boundary is marked by the change in soil structure below and above the area 4 inches up from the core base. Above 8.5 inches from the core base, the sediment moisture content is extremely high.

All sounding data is processed using the DepthPic software, within which both the pre-impoundment and current bathymetric surfaces are identified and digitized manually. These surfaces are first identified along cross-sections for which core samples have been collected – thereby allowing the user to identify color bands in the DepthPic display that correspond to the sediment layer(s) observed in the core samples. This process is illustrated in Figure D3 where core sample E-2 is shown with its corresponding sounding data. The 38 inches of sediment in core sample E-2 are represented by the yellow, red, and green boxes in the core sample shown in Figure D3. The yellow box shows the extent of the high-moisture content sediment shown in Figure D2, and the red box represents the 4.5 inches of gradually changing moisture content and soil structure between the pre-impoundment boundary and the high-moisture content region. The green box represents pre-impoundment sediment. The pre-impoundment surface is usually identified within the core sample by one of the following methods: (1) a visual examination of the core for in-place terrestrial materials, such as leaf litter, tree bark, twigs, intact roots, etc., concentrations of which tend to occur on or just below the pre-impoundment surface, (2) changes in texture from well sorted, relatively fine-grained sediment to poorly sorted mixtures of coarse and fine-grained materials, and (3) variations in the physical properties of the sediment, particularly sediment water content and penetration resistance with depth.

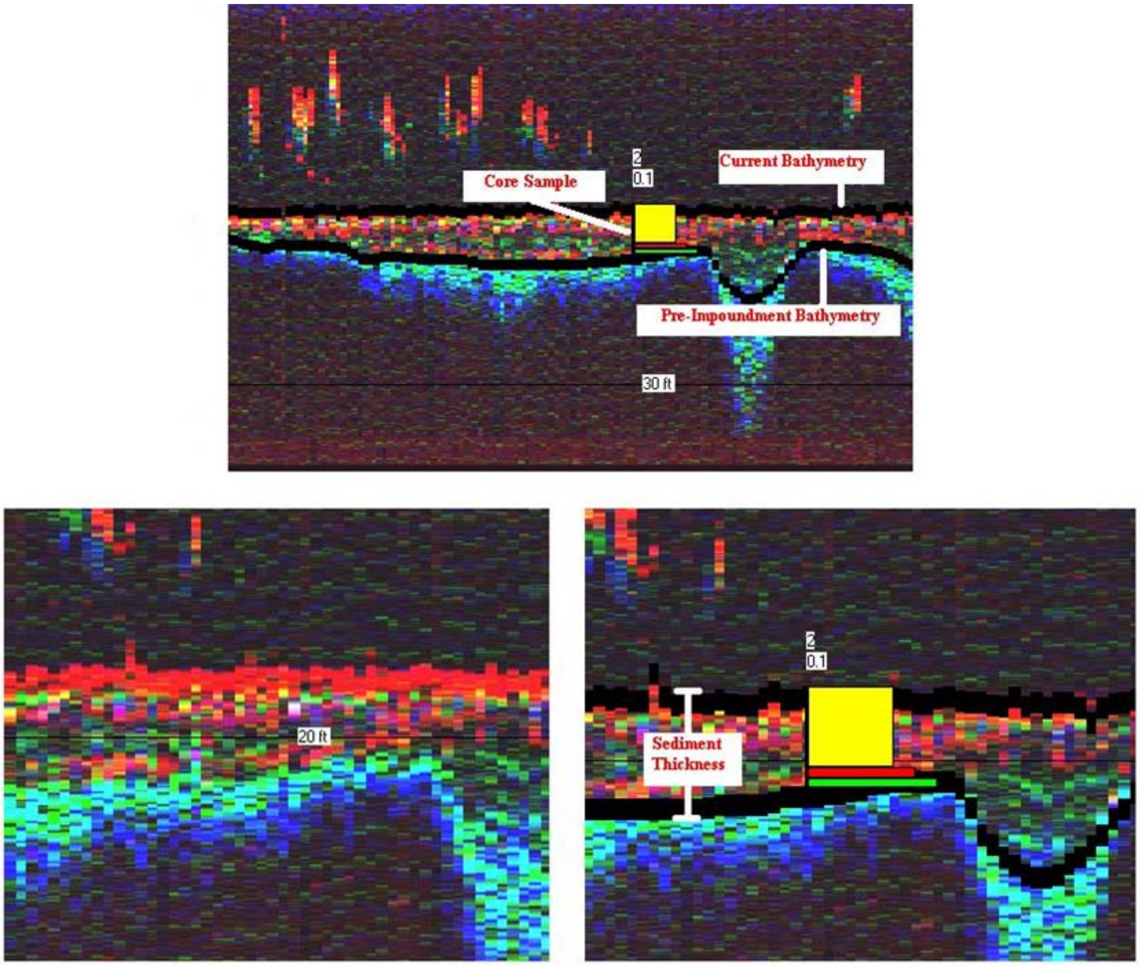


Figure D3 – DepthPic and core sample use in identifying the pre-impoundment bathymetry.

Within DepthPic, the current surface is automatically determined based on the signal returns from the 200 kHz transducer. The pre-impoundment surface must be determined visually based on the pixel color display and any available core sample data. Based on core sample E-2, it is clear that the high-moisture content sediment is denoted by the band of bright pixels dominated by a red color. The pre-impoundment bathymetric surface for this cross-section is therefore identified as the base of the bright pixel band, where the pixels in the DepthPic display transition to turquoise. The current bathymetric surface is located at the top of the bright band of red pixels. (Figure D3).

In analyzing data from cross-sections where core samples were not collected, the assumption is made that sediment layers may be identified in a similar manner as when core sample data is available. To improve the validity of this assumption, core samples are collected at regularly spaced intervals within the lake, or at locations where interpretation of the DepthPic display would be difficult without site-specific core data. For this reason, all sounding data is collected and reviewed before core sites are selected and cores are collected. For shallow areas of the lake within which sounding data were not collected, sediment thicknesses are assumed negligible. This assumption may lead to the calculated sediment volume underestimating the physical sediment volume present within the lake.

After manually digitizing the pre-impoundment surface from all cross-sections, both the pre-impoundment and current bathymetric surfaces are exported as X-,Y-,Z-coordinates from DepthPic into text files suitable for use in ArcGIS. Within ArcGIS, the sounding points are then processed into TIN models following standard GIS techniques[1]. The accumulated sediment volume for Eagle Mountain Lake was calculated from a sediment thickness TIN model created in ArcGIS. Sediment thicknesses were computed as the difference in elevations between the current and pre-impoundment bathymetric surfaces as determined with the DepthPic software. Sediment thicknesses were interpolated for locations between surveyed cross-sections using the TWDB self-similar interpolation technique[2]. For the purposes of the TIN model creation, TWDB assumed 0-feet sediment thicknesses at the model boundaries (defined as the 649.1 foot NGVD29 elevation contour).

Results

The results of the TWDB 2008 Sedimentation Survey indicate Eagle Mountain Lake has accumulated 15,861 acre-feet of sediment since impoundment began in 1934. The thickest sediment deposits are within the main body of the lake adjacent to the submerged river channel approximately two miles upstream from Eagle Mountain Dam. Throughout most of the lake, the original river channel has been completely filled in with sediment. The maximum sediment thickness observed in Eagle Mountain Lake is 8.3 feet. Figure D4 depicts the sediment thickness in Eagle Mountain Lake.

Based on the measured sediment volume in Eagle Mountain Lake and assuming a constant rate of sediment accumulation over the 75 years since impoundment, Eagle Mountain Lake loses approximately 210 acre-feet of capacity per year. To improve the sediment accumulation rate estimates, TWDB recommends Eagle Mountain Lake be re-surveyed using similar methods in approximately 10 years or after a major flood event.

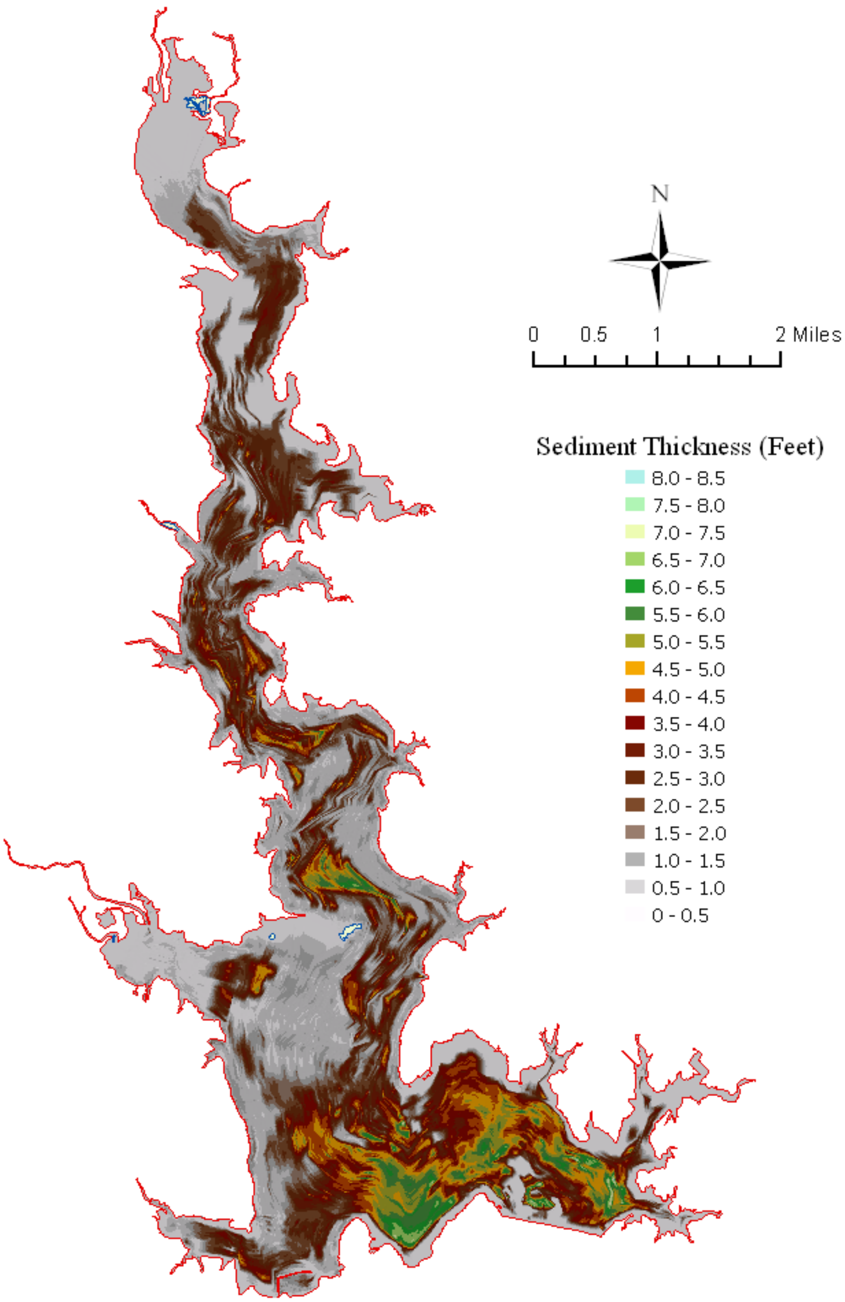


Figure D4 - Sediment thicknesses in Eagle Mountain Lake derived from multi-frequency sounding data.

References

1. Furnans, J., Austin, B., Hydrographic survey methods for determining reservoir volume, Environmental Modelling & Software (2007), doi: 10.1016/j.envsoft.2007.05.011
2. Furnans, Jordan. Texas Water Development Board. 2006. "HydroEdit User's Manual."

Appendix E

Analysis of Sediment Range Line Data from Eagle Mountain Lake

Executive Summary

The Texas Water Development Board (TWDB) conducted surveys of Eagle Mountain Lake in 2008 and 2000. Comparisons of cross-sections generated along established sediment range lines for Eagle Mountain Lake indicate that the pre-impoundment bathymetry derived from the 2008 survey data is largely consistent with the bathymetry derived from the 2000 TWDB survey. Of the seventeen sediment range lines comparisons, eight suggest greater sediment accumulation rates occurred between 1934 and 2000, whereas nine suggest sediment accumulated at a greater rate between 2000 and 2008. To improve the sediment accumulation rate estimates, TWDB recommends Eagle Mountain Lake be re-surveyed using similar methods in approximately 10 years or after a major flood event.

Introduction

This appendix includes cross-section data computed along established sediment range lines for Eagle Mountain Lake, as well as provides a simple comparison of Eagle Mountain Lake bathymetries as derived from the 2008 and 2000 surveys conducted by TWDB. Comparisons were made on seventeen previously established sediment range lines (Figure E1), whose endpoint coordinates are provided in Table E1. Cross-sections were extracted from ArcGIS TIN models of the lake bathymetry using standard GIS techniques[1]. Cross-sections of the approximate pre-impoundment (1934) bathymetry were derived by subtracting measured sediment-thickness values from the 2008 bathymetric elevations. All analysis and plotting of the sediment range line cross sections was performed using customized MATLAB scripts developed by TWDB staff.

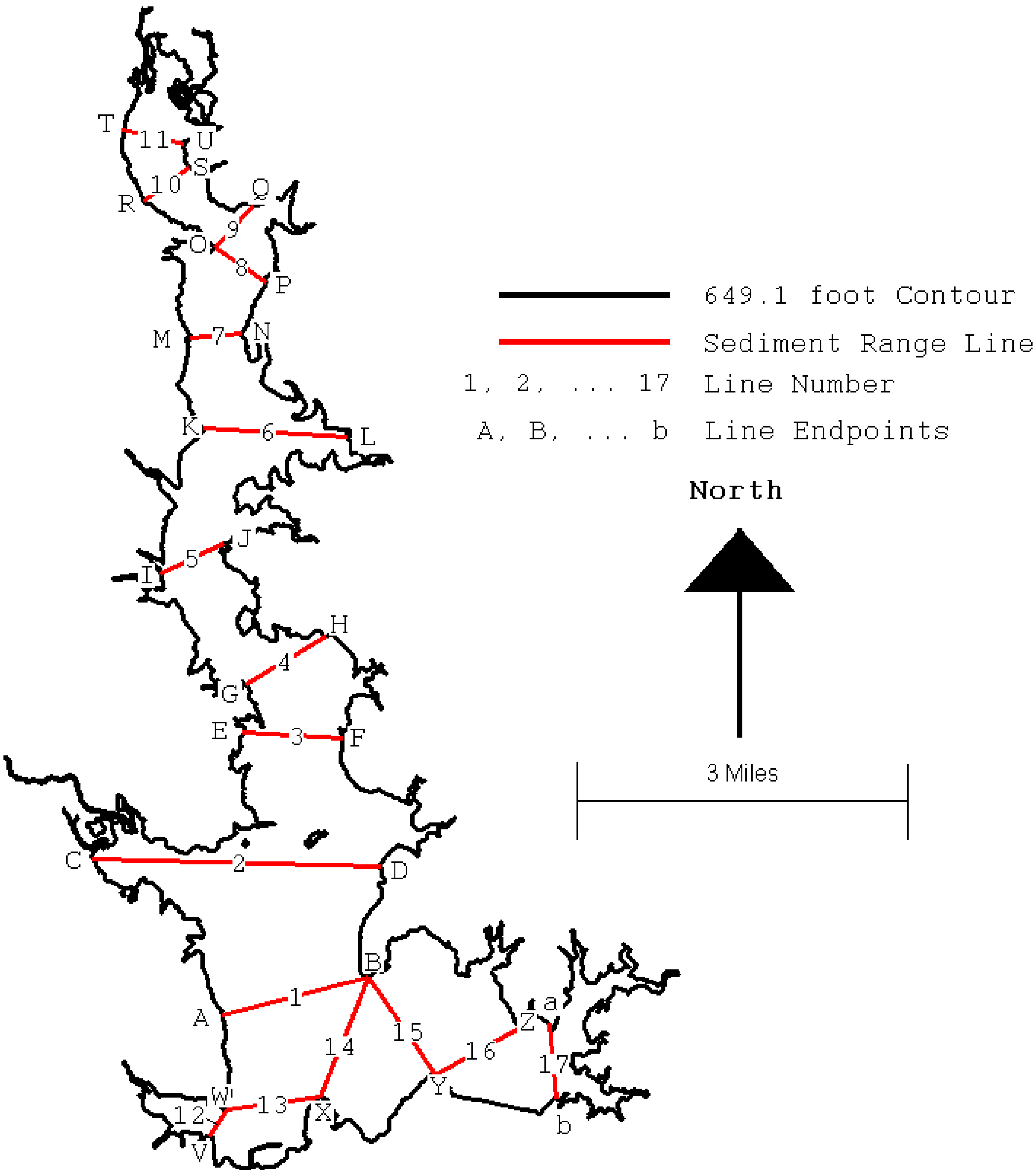


Figure E1 – Eagle Mountain Lake map showing the location of the seventeen sediment range lines compared in this appendix.

Table E1 – Sediment Range Line Coordinates for Eagle Mountain Lake

	Start Point (feet)		End Point (feet)		
Range Line	Northing	Easting	Northing	Easting	Labels^^
1	2272424.26	7007265.43	2279366.82	7009101.18	(A,B)
2	2266266.47	7014691.29	2280009.40	7014332.53	(C,D)
3	2273433.56	7020735.71	2278185.07	7020453.25	(E,F)
4	2273522.98	7023054.39	2277347.32	7025363.01	(G,H)
5	2269448.60	7028320.50	2272500.24	7029782.28	(I,J)
6	2271515.28	7035283.80	2278399.50	7034865.34	(K,L)
7	2270883.97	7039587.18	2273396.26	7039821.64	(M,N)
8	2272050.97	7043907.77	2274519.77	7042267.09	(O,P)
9	2272050.97	7043907.77	2273905.70	7045940.19	(O,Q)
10	2268661.92	7046119.38	2270861.94	7047757.34	(R,S)
11	2267657.16	7049525.10	2270601.52	7048812.34	(T,U)
12	2271773.24	7001503.12	2272614.24	7002766.11	(V,W)
13	2272614.24	7002766.11	2277109.67	7003350.66	(W,X)
14	2277109.67	7003350.66	2279366.82	7009101.18	(X,B)
15	2282551.03	7004428.43	2279366.82	7009101.18	(Y,B)
16	2282551.03	7004428.43	2286697.48	7006692.76	(Y,Z)
17	2288015.97	7006852.57	2288326.72	7003239.55	(a,b)

*** Coordinates referenced to the State Plane (NAD83-Feet) Texas North Central System*
^^ Labels are referenced to Figure E1 and are listed as (start point, end point)

Results

Plots of the pre-impoundment (1934), 2000, and 2008 bathymetries of Eagle Mountain Lake are presented in Figures E2-E18. TIN models from which the pre-impoundment (1934) and 2008 cross-sections were derived were adjusted using the self-similar interpolation technique as described in the main report. **Note: the TIN model used in producing the 2000 cross-section data was not rectified using the self-similar data interpolation technique. Some of the discrepancies between the 2000 data and the 2008/pre-impoundment data are due to the lack of data interpolation in the 2000 data and TIN model.

In general, the 2000 cross-sections plot in between those from the pre-impoundment and 2008 datasets, indicating that sediment has been steadily accumulating in the lake over this time. The percentage area change per year (not shown) does not conclusively indicate an increase or decrease in sediment accumulation rates from 1934 to 2000 and from 2000 to 2008. Specifically, eight cross section comparisons indicate greater sediment accumulation rates before 2000, while nine cross section comparisons indicate greater rates after 2000.

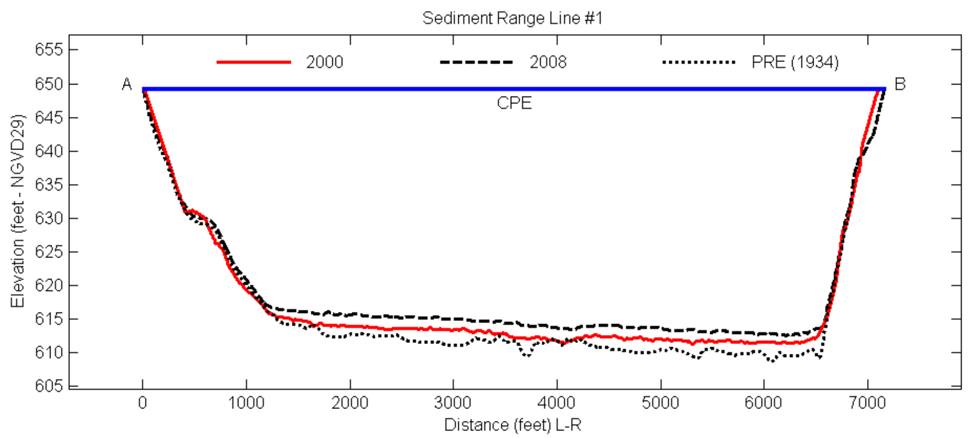


Figure E2– Cross-section plots for sediment range line #1 for Eagle Mountain Lake.

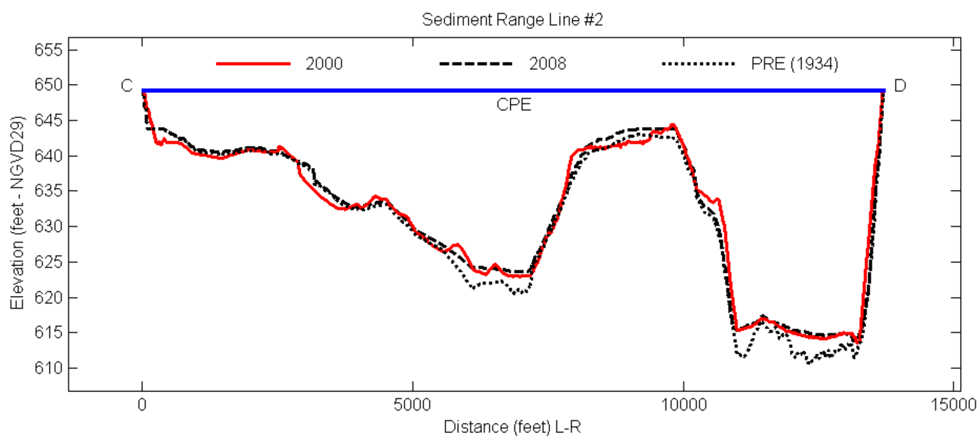


Figure E3– Cross-section plots for sediment range line #2 for Eagle Mountain Lake.

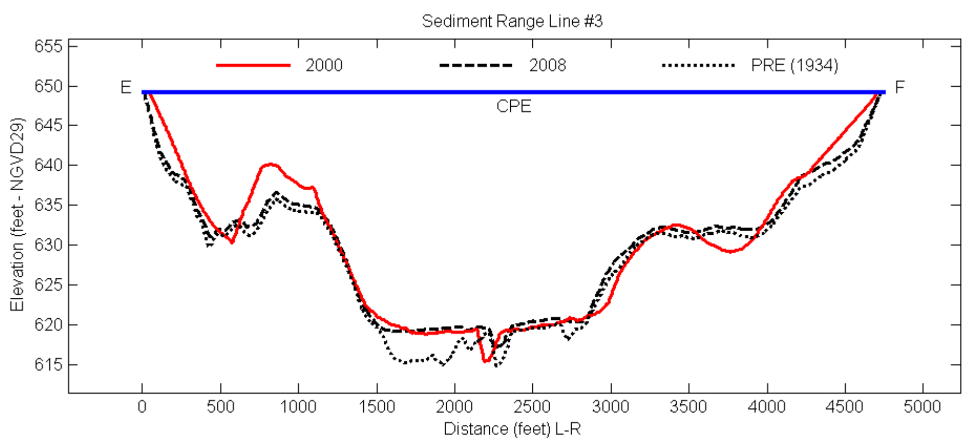


Figure E4– Cross-section plots for sediment range line #3 for Eagle Mountain Lake.

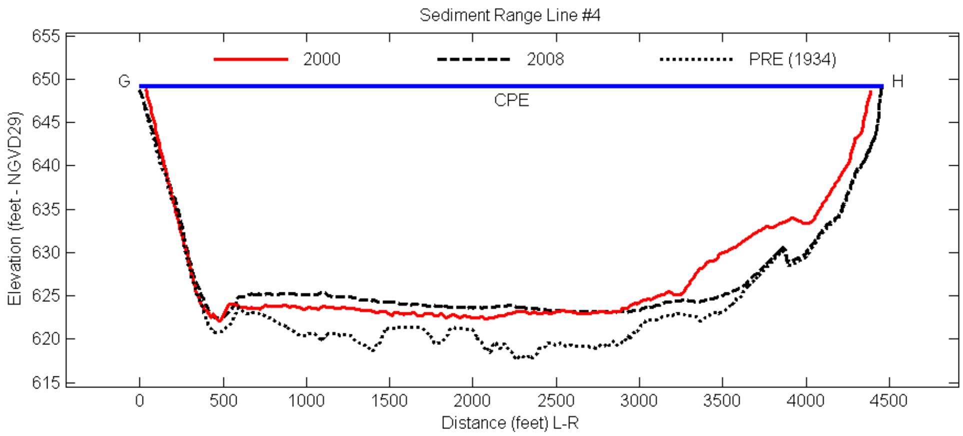


Figure E5– Cross-section plots for sediment range line #4 for Eagle Mountain Lake.

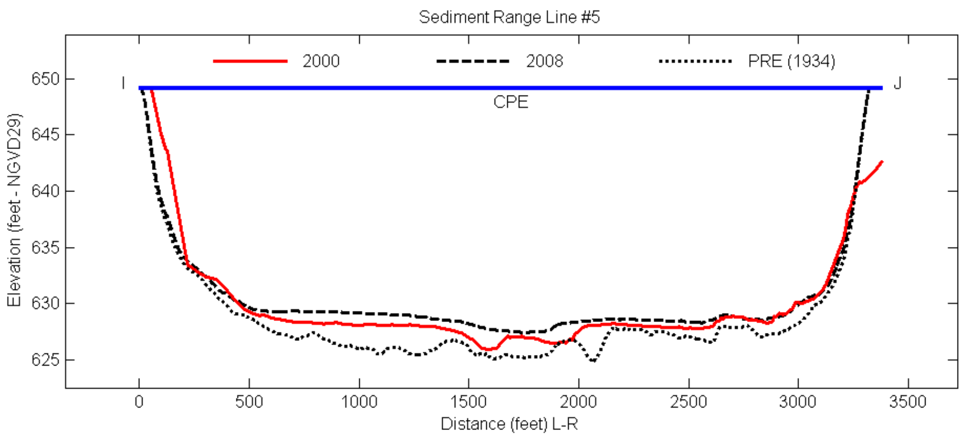


Figure E6– Cross-section plots for sediment range line #5 for Eagle Mountain Lake.

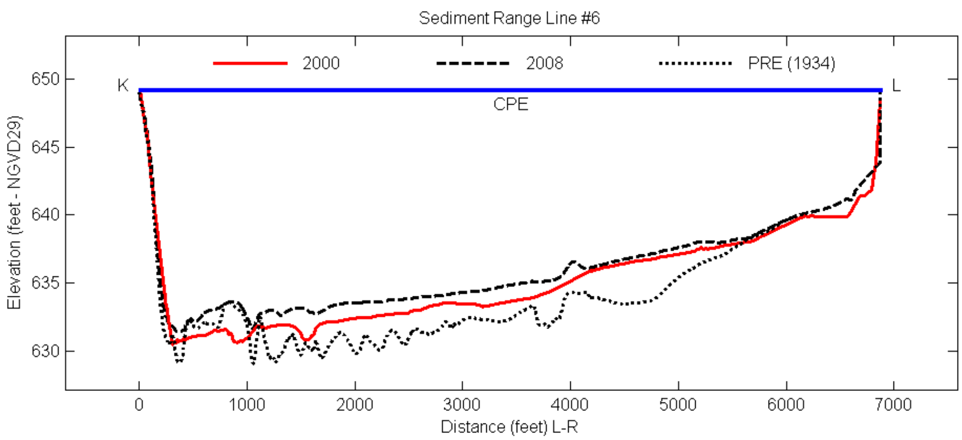


Figure E7– Cross-section plots for sediment range line #6 for Eagle Mountain Lake.

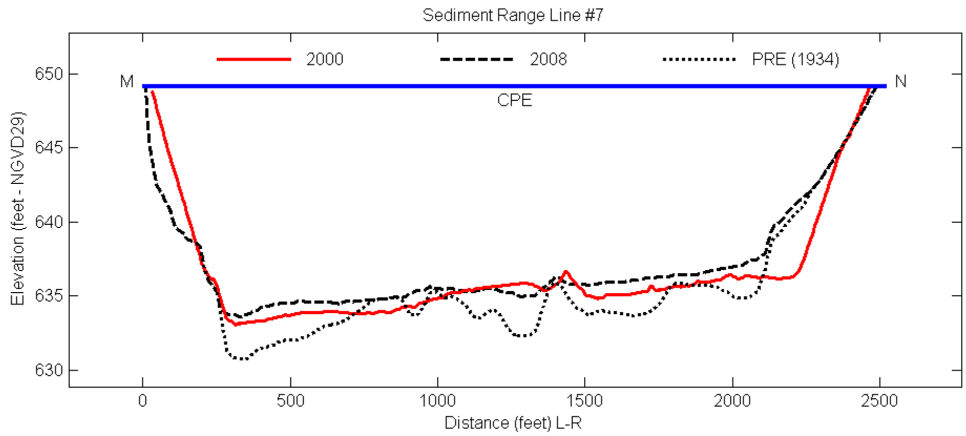


Figure E8– Cross-section plots for sediment range line #7 for Eagle Mountain Lake.

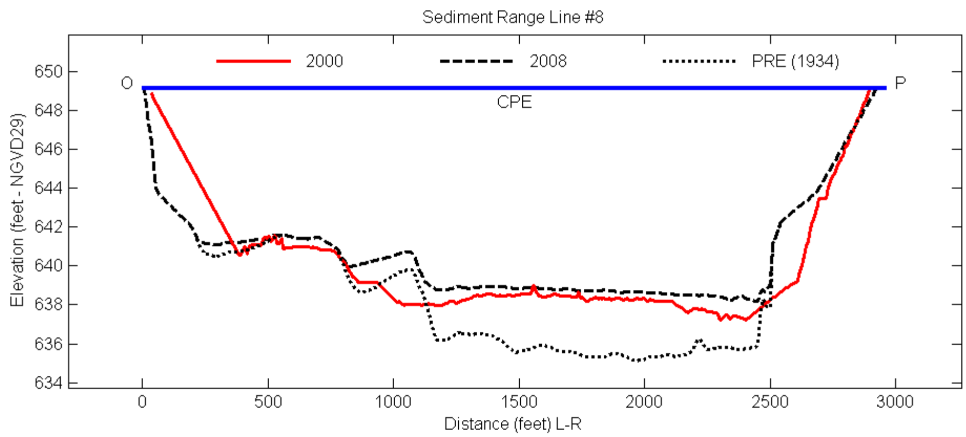


Figure E9– Cross-section plots for sediment range line #8 for Eagle Mountain Lake.

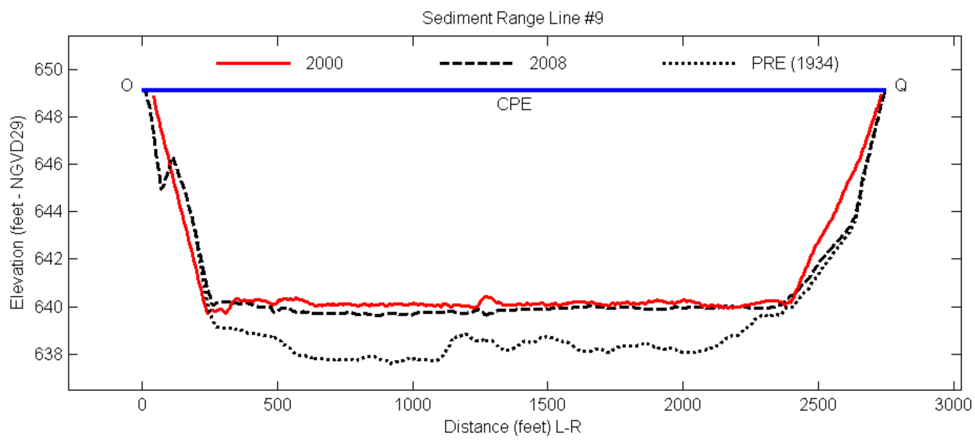


Figure E10– Cross-section plots for sediment range line #9 for Eagle Mountain Lake.

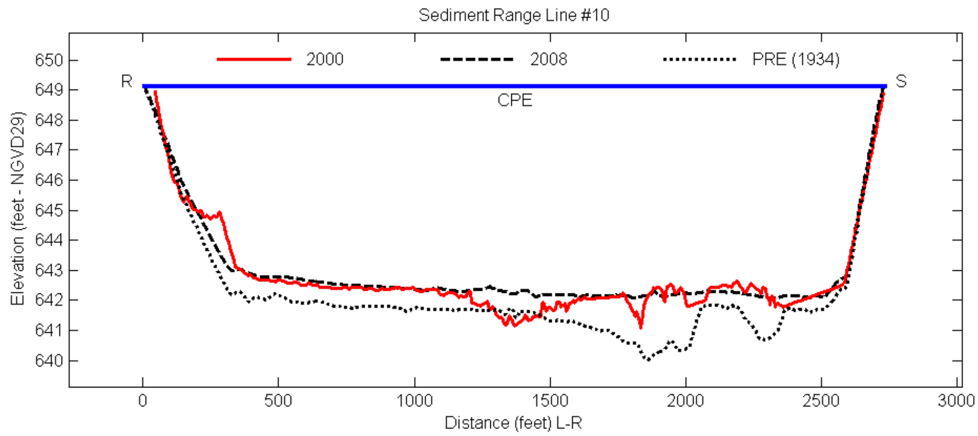


Figure E11– Cross-section plots for sediment range line #10 for Eagle Mountain Lake.

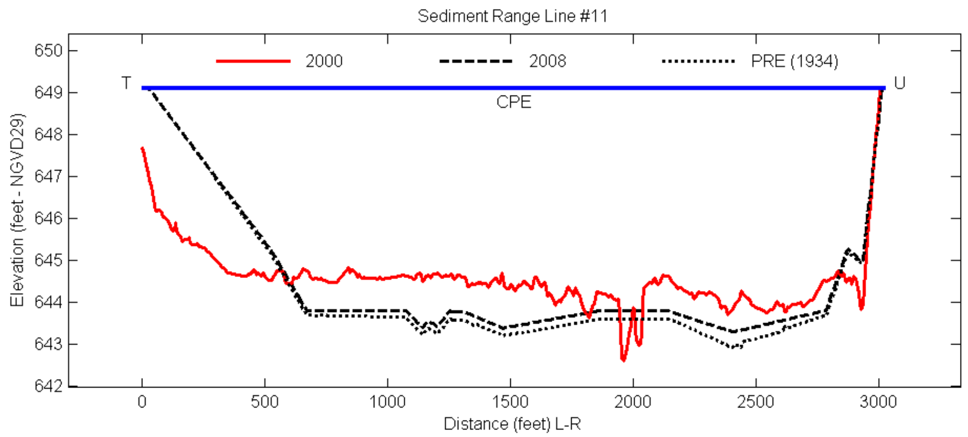


Figure E12– Cross-section plots for sediment range line #11 for Eagle Mountain Lake.

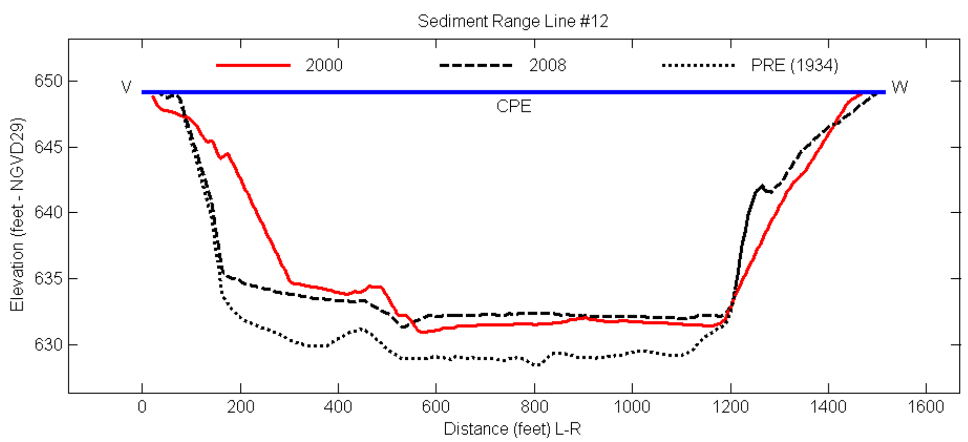


Figure E13– Cross-section plots for sediment range line #12 for Eagle Mountain Lake.

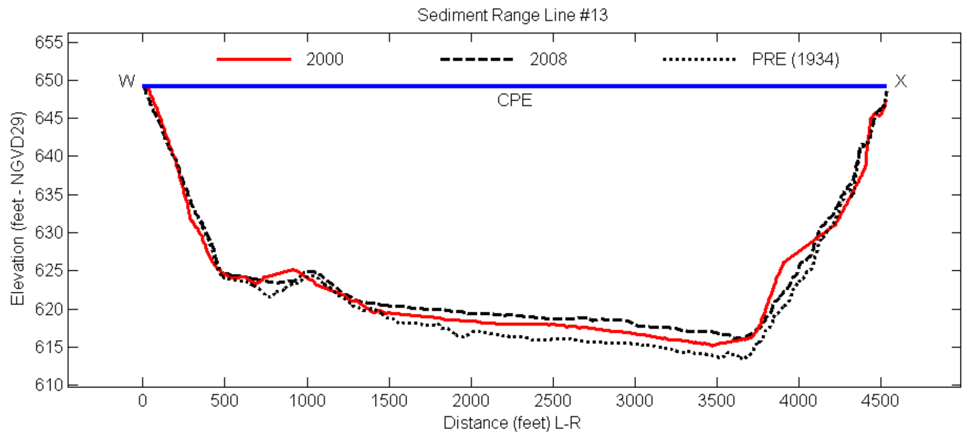


Figure E14– Cross-section plots for sediment range line #13 for Eagle Mountain Lake.

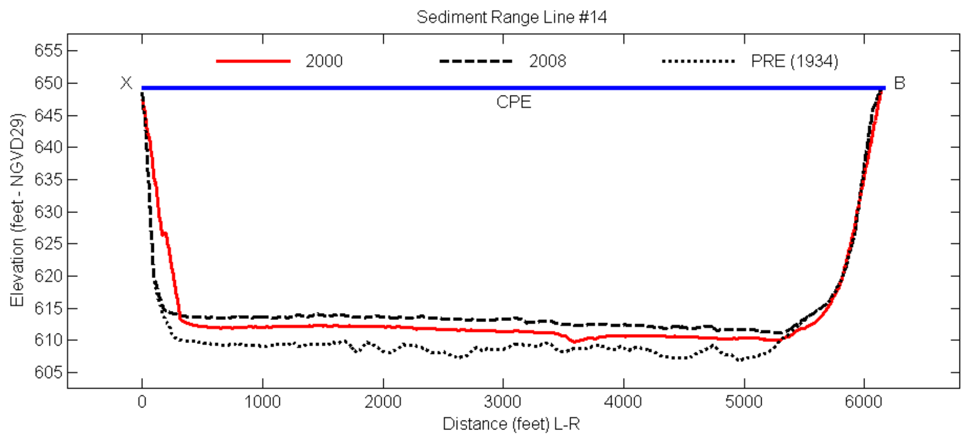


Figure E15– Cross-section plots for sediment range line #14 for Eagle Mountain Lake.

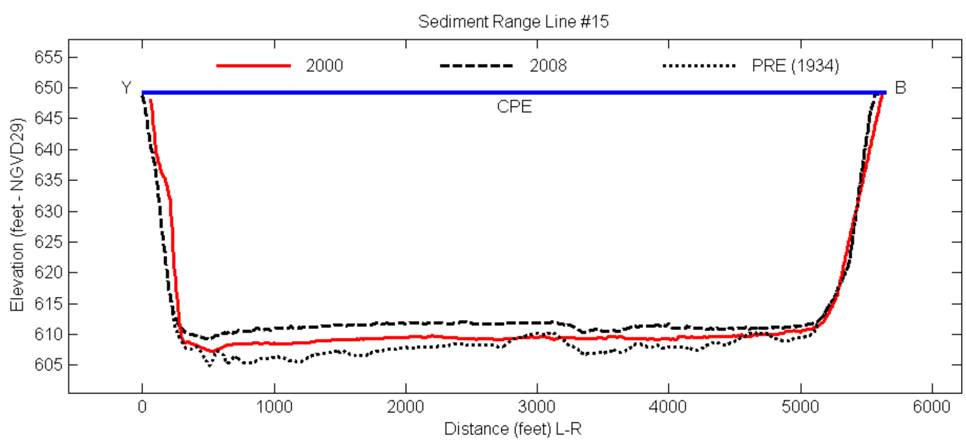


Figure E16– Cross-section plots for sediment range line #15 for Eagle Mountain Lake.

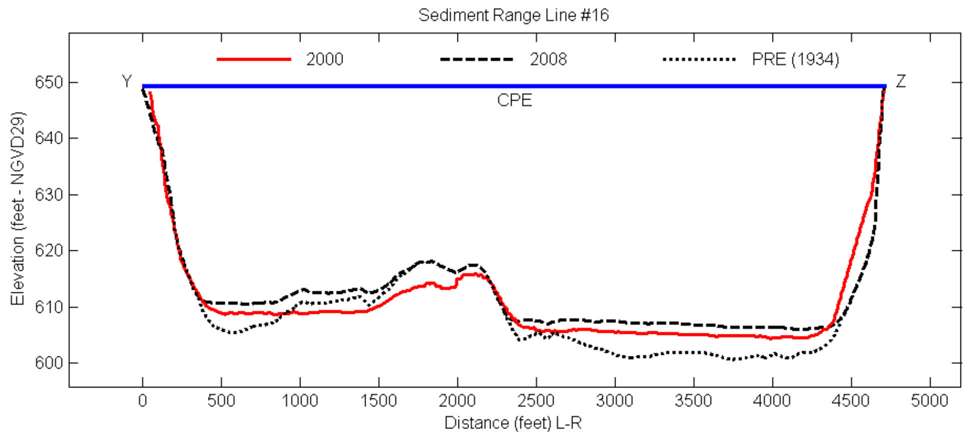


Figure E17– Cross-section plots for sediment range line #16 for Eagle Mountain Lake.

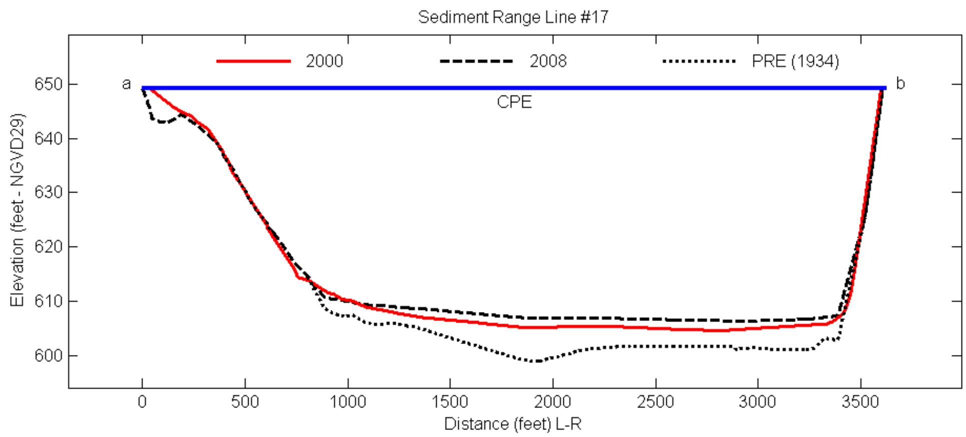


Figure E18– Cross-section plots for sediment range line #17 for Eagle Mountain Lake.

Figure 5

CONTOURS
(in feet above mean sea level)

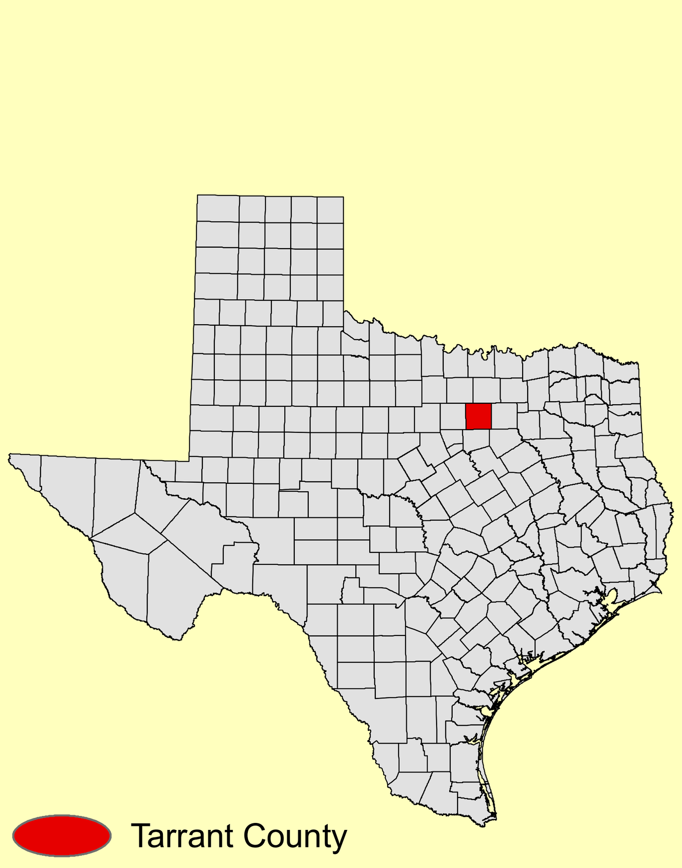
600
602
604
606
608
610
612
614
616
618
620
622
624
626
628
630
632
634
636
638
640
642
644
646
648

Islands

Eagle Mountain Lake

Conservation Pool Elevation:
649.1 feet above mean seal level

Projection: NAD83
State Plane
Texas North Central



This map is the product of a survey conducted by the Texas Water Development Board's Hydrographic Survey Program to determine the capacity of Eagle Mountain Lake. The Texas Water Development Board makes no representation or assumes any liability.