Volumetric and Sedimentation Survey of NAVARRO MILLS LAKE

April 2008 Survey

Prepared by:

The Texas Water Development Board

April 2009

Texas Water Development Board

Prepared for:

City of Corsicana, Texas

With Support Provided by:

U.S. Army Corps of Engineers, Fort Worth District

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Executive Summary

In February of 2008, the Texas Water Development Board entered into agreement with the U.S. Army Corps of Engineers, Fort Worth District, for the purpose of performing a volumetric and sedimentation survey of Navarro Mills Lake. The U.S. Army Corps of Engineers, Fort Worth District, contributed 50% of the funding for this survey through their Planning Assistance to States Program, while the City of Corsicana, Texas contributed the remaining 50%. This survey was performed 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 were used in interpreting the multi-frequency depth sounder signal returns to derive sediment accumulation estimates.

Navarro Mills Lake and Navarro Mills Dam are located on Richland Creek in Navarro County, 16 miles southwest of Corsicana, Texas. Bathymetric data collection for Navarro Mills Lake occurred on March 26-27, 2008 and April 3-8, 2008, while the water surface elevation ranged between 427.65 and 425.17 feet above mean sea level (NGVD29). The conservation pool elevation of Navarro Mills Lake is 424.5 feet above mean sea level (NGVD29).

The results of the TWDB 2008 Volumetric Survey indicate Navarro Mills Lake has a total reservoir capacity of 49,827 acre-feet and encompasses 4,736 acres at conservation pool elevation. A 1956 survey conducted by the U.S. Army Corps of Engineers estimated the capacity of Navarro Mills Lake at conservation pool elevation to be 63,000 acre-feet encompassing 5,070 acres. Due to differences in the methodologies used in calculating capacities from this and previous Navarro Mills Lake surveys, comparison of these values is not recommended. TWDB recommends that a similar methodology be used to resurvey Navarro Mills Lake in approximately 10 years or after a major flood event.

The results of the TWDB 2008 Sedimentation Survey indicate Navarro Mills Lake has accumulated 5,695 acre-feet of sediment since impoundment in 1963. Based on this measured sediment volume and assuming a constant sediment accumulation rate, Navarro Mills Lake loses approximately 124 acre-feet of capacity per year. The maximum sediment thickness observed in Navarro Mills Lake was 6.3 feet.

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Navarro Mills Lake General Information

Navarro Mills Dam and Navarro Mills Lake are located on Richland Creek in the Trinity River Basin, sixteen miles southwest of the City of Corsicana in Navarro County, Texas (Figure 1). Navarro Mills Lake is owned by the U.S. Government and operated by the U.S. Army Corps of Engineers, Fort Worth District.[1] The residents of Corsicana, Dawson, Frost, and other communities in Navarro County depend upon Navarro Mills Lake for flood control, water supply, and recreation.[2] Construction of Navarro Mills Dam began December 23, 1959, with deliberate impoundment beginning on March 15, 1963. The dam was completed on May 10, 1963.[1] Additional pertinent data about Navarro Mills Dam and Navarro Mills Lake can be found in Table 1.

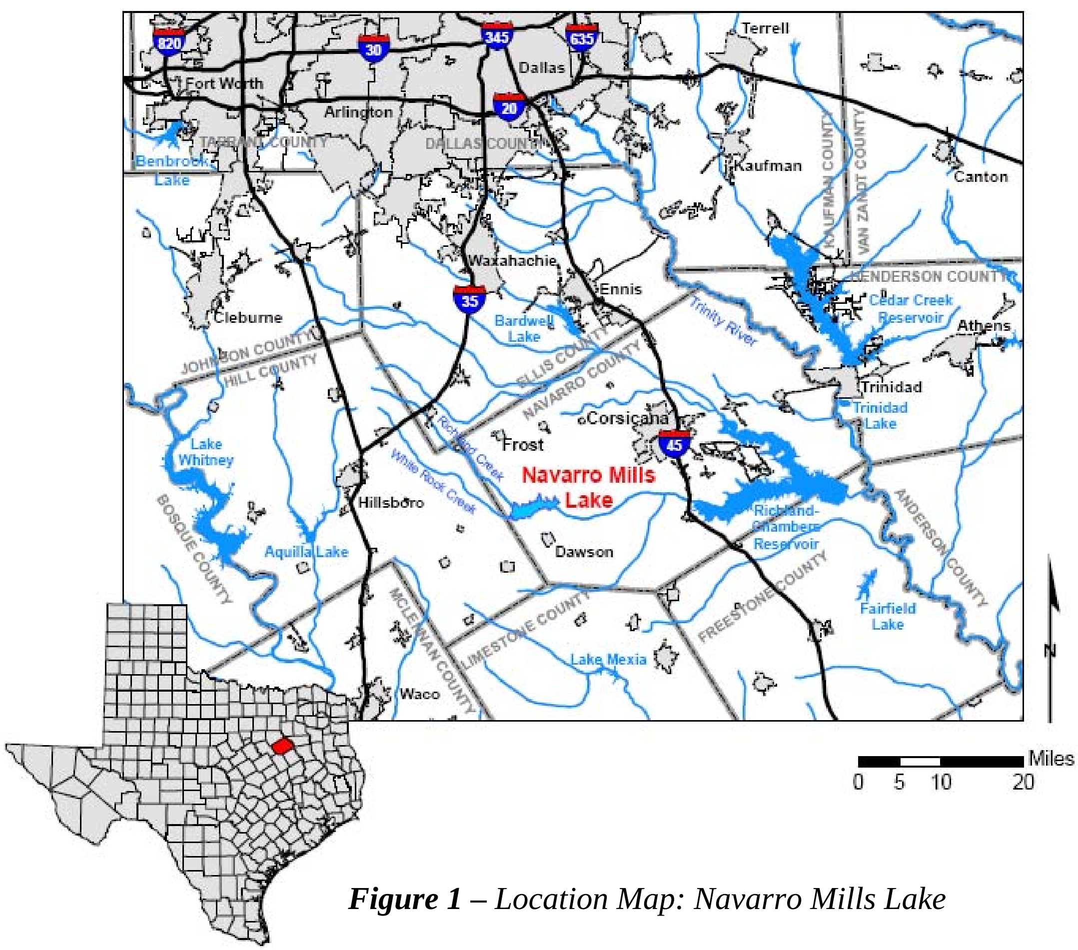

***Figure 1** – Location Map: Navarro Mills Lake*

Table 1. Pertinent Data for Navarro Mills Dam and Navarro Mills Lake[1]

Owner			
The U.S. Government, Operated by the U.S. Army Corps of Engineers, Fort Worth District			
Engineer (Design)			
U.S. Army Corps of Engineers			
Location of Dam			
On Richland Creek in Navarro County, 16 miles southwest of Corsicana, Texas			
Drainage Area			
320 square miles			
Dam			
Type	Earthfill		
Length	7,570 feet including spillway		
Maximum height	81.7 feet		
Top width	20 feet		
Spillway			
Type	Ogee		
Length	240 feet at the crest		
Crest elevation	414.0 feet above mean sea level		
Control	6 tainter gates, each 40 by 29 feet		
Outlet Works			
Type	2 conduits		
Size	Each 36-inch diameter		
Control	2 slide gates		
Invert elevation	400.0 feet above mean sea level		
Reservoir Data (Based on TWDB 2008 Volumetric Survey)			
Feature	**Elevation (ft above msl)**	**Capacity (Acre-feet)**	**Area (Acres)**
Top of Dam	457.0	N/A	N/A
Maximum design water surface	451.9	N/A	N/A
Top of flood-control storage space	443.0	N/A	N/A
Top of conservation storage space	424.5	49,827	4,736
Spillway Crest	414.0	13,240	2,174
Outlet Works Invert elevation	400.0	1	1
Streambed	375.3	0	0

Water Rights

The water rights for Navarro Mills Lake have been appropriated to the Trinity River Authority of Texas through Certificate of Adjudication No. 08-4992. A brief summary of the certificate follows. The complete certificate is on file in the Records Division of the Texas Commission on Environmental Quality.

•Certificate of Adjudication No. 08-4992 Issued: September 4, 1986

Authorizes the owner to maintain an existing dam and reservoir on Richland Creek (Navarro Mills Lake) and impound therein not to exceed 63,300 acre-feet of water. The owner is authorized to divert and use from Navarro Mills Lake a maximum of 100 acre-feet of water per year for domestic purposes; a maximum of 18,850 acre-feet of water per year for municipal purposes; and a maximum of 450 acre-feet which may be used for industrial purposes. Navarro Mills Lake may also be used for recreation purposes. The rights to divert water for domestic, municipal, and recreation purposes have a priority date of October 4, 1957. The right to divert water for industrial purposes has a priority date of November 22, 1982.

Volumetric and Sedimentation Survey of Navarro Mills 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 February of 2008, TWDB entered into agreement with the U.S. Army Corps of Engineers, Fort Worth District, for the purpose of performing a volumetric and sedimentation survey of Navarro Mills Lake. The U.S. Army Corps of Engineers, Fort Worth District, contributed 50% of the funding for this survey through their Planning Assistance to States Program, while the City of Corsicana, Texas contributed the remaining 50%. This survey was performed using a single-beam multi-frequency (200 kHz, 50 kHz, and 24 kHz) sub-bottom profiling depth sounder. The 200 kHz return measures the depth to the current bathymetric surface, while returns from the three frequencies are analyzed in conjunction with sediment core samples for indications 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 gage USGS 08063050 Navarro Mills Lk nr Dawson, TX.[3] The datum for this gage 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 gage. The horizontal datum used for this report is North American Datum 1983 (NAD83) State Plane Texas North Central Zone.

TWDB Bathymetric Data Collection

Bathymetric data collection for Navarro Mills Lake occurred on March 26-27, 2008 and April 3-8, 2008, while the water surface elevation ranged between 427.65 and 425.17 feet above mean sea level (NGVD29). The conservation pool elevation of Navarro Mills Lake is 424.5 feet above mean sea level (NGVD29). For data collection, TWDB used a Specialty Devices, Inc., multi-frequency 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 survey, team members collected over 52,900 data points over cross-sections totaling nearly 87.5 miles in length. Figure 2 shows where data points were collected during the TWDB 2008 survey.

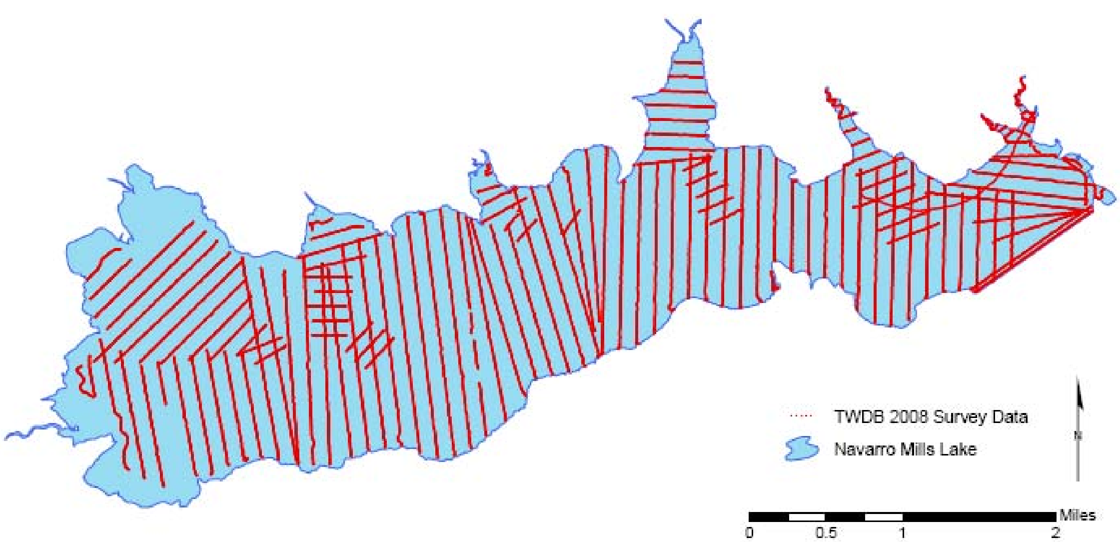

Figure 2 *- Data points collected during TWDB 2008 Survey*

Data Processing

Model Boundaries

The reservoir boundary was digitized from aerial photographs, or digital ortho quarter-quadrangle images (DOQQs)[4,5], using Environmental Systems Research Institute's (ESRI) ArcGIS 9.1 software. The quarter quadrangles that cover Navarro Mills Lake are Dawson NW, Dawson NE, Dawson SW, Dawson SE, Irene NW, Irene NE, Irene SW, and Irene SE. Each quarter-quadrangle image was photographed on September 8, 2004. The water surface elevation for this day averaged 424.18 feet. As these photographs have a 1-meter resolution; the physical lake boundaries may be within ± 1 meter of the location derived from the manual delineation. Therefore, the boundary was digitized at the land water interface visible in the photos and labeled 424.5 feet, or conservation pool elevation to allow the area-capacity tables to be calculated to conservation pool elevation.

Triangulated Irregular Network (TIN) Model

Upon completion of the bathymetric 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, 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) are exported as a MASS points file. TWDB also created a MASS points file of interpolated data located in-between surveyed cross sections. This point file is described in the section entitled "Self-Similar Interpolation." To represent reservoir bathymetry in shallow regions, additional points were added using the "Line Extrapolation" technique.[6] These MASS points files, along with the lake boundary file, are used in creating a Triangulated Irregular Network (TIN) model of the lake bathymetry using 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.[7]

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 397.3 feet to elevation 424.5 feet. The Navarro Mills Lake 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 an Elevation Relief Map, representing the topography of the reservoir bottom (Figure 3), a map showing shaded depth ranges for Navarro Mills Lake (Figure 4), and a 2-foot contour map (Figure 5, 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 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.[6] In the case of Navarro Mills 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 6). In areas where obvious geomorphic features indicate

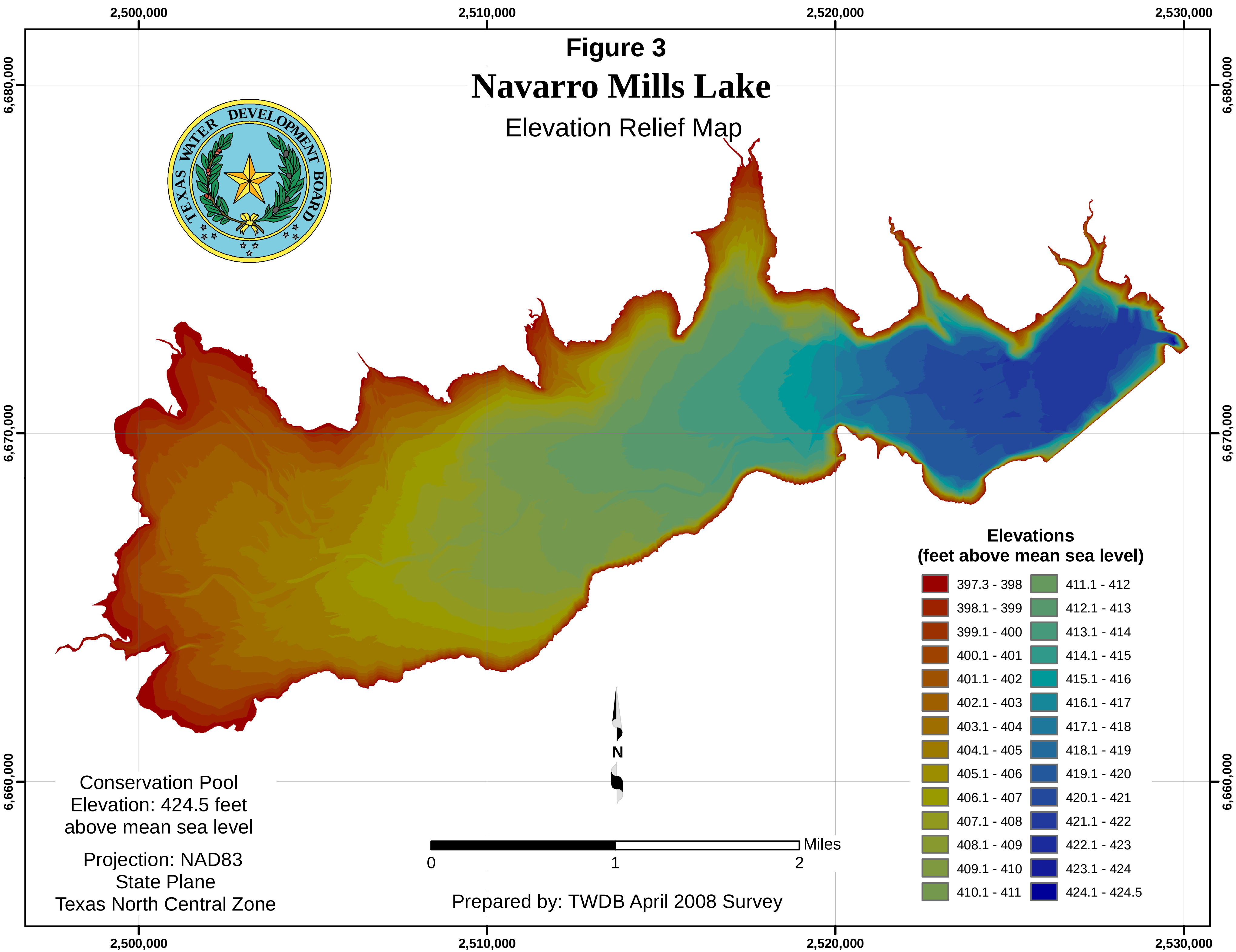
Figure 3
Navarro Mills Lake
Elevation Relief Map
TEXAS WATER DEVELOPMENT BOARD
2,500,000
2,510,000
2,520,000
2,530,000
6,680,000
6,670,000
6,660,000
Elevations
(feet above mean sea level)
397.3 - 398
398.1 - 399
399.1 - 400
400.1 - 401
401.1 - 402
402.1 - 403
403.1 - 404
404.1 - 405
405.1 - 406
406.1 - 407
407.1 - 408
408.1 - 409
409.1 - 410
410.1 - 411
411.1 - 412
412.1 - 413
413.1 - 414
414.1 - 415
415.1 - 416
416.1 - 417
417.1 - 418
418.1 - 419
419.1 - 420
420.1 - 421
421.1 - 422
422.1 - 423
423.1 - 424
424.1 - 424.5
N
Miles
0
1
2
Conservation Pool
Elevation: 424.5 feet
above mean sea level
Projection: NAD83
State Plane
Texas North Central Zone
Prepared by: TWDB April 2008 Survey

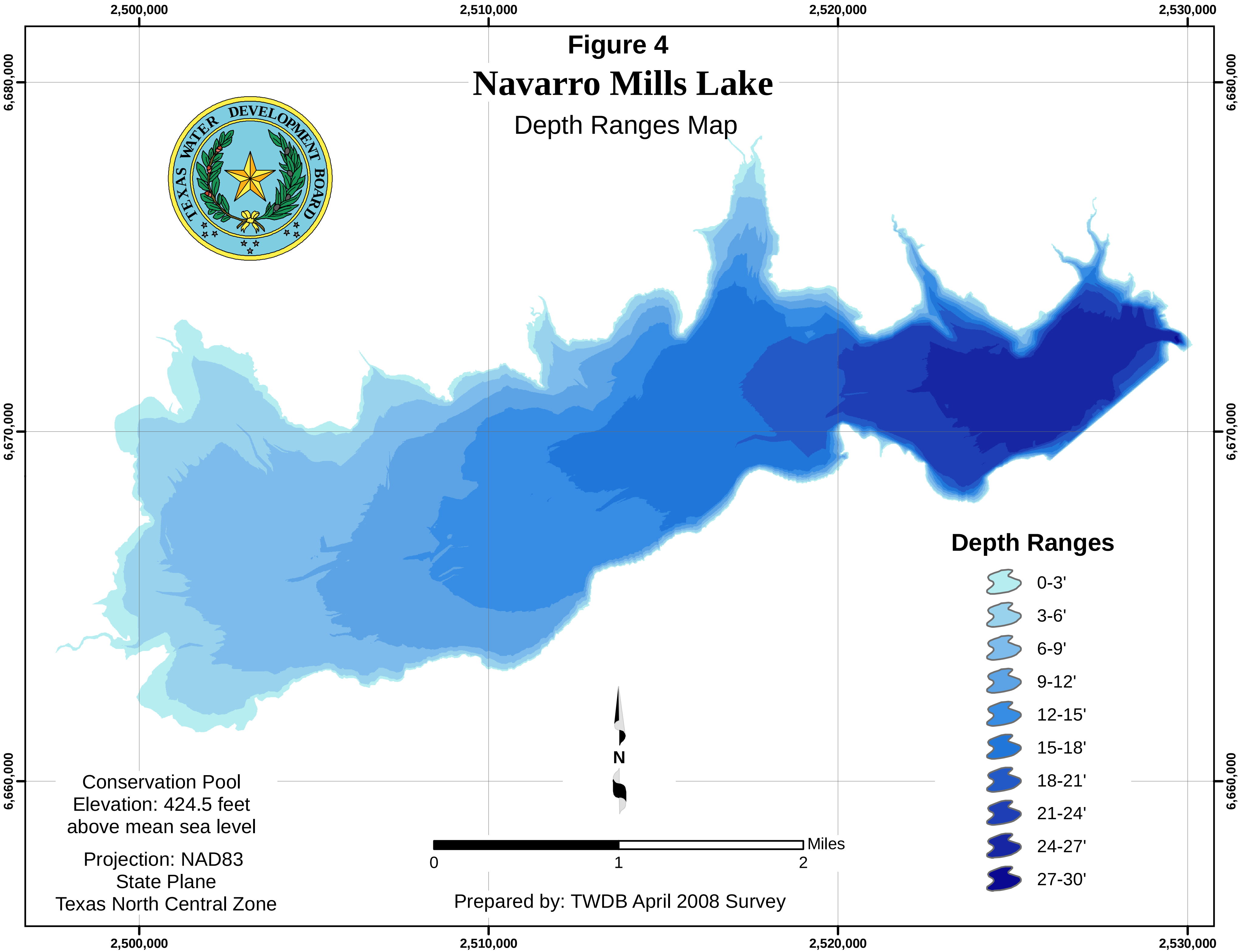

Figure 4
Navarro Mills Lake
Depth Ranges Map
TEXAS WATER DEVELOPMENT BOARD
2,500,000
2,510,000
2,520,000
2,530,000
6,680,000
6,670,000
6,660,000
Depth Ranges
0-3'
3-6'
6-9'
9-12'
12-15'
15-18'
18-21'
21-24'
24-27'
27-30'
N
Miles
0
1
2
Conservation Pool
Elevation: 424.5 feet
above mean sea level
Projection: NAD83
State Plane
Texas North Central Zone
Prepared by: TWDB April 2008 Survey

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. Self-Similar Interpolation was not used in areas of Navarro Mills Lake where a high probability of change between cross-sections exists.[6] Figure 6 illustrates typical results of the application of the Self-Similar Interpolation routine in Navarro Mills Lake, and the bathymetry shown in Figure 6C was used in computing reservoir capacity and area tables (Appendix A, B).

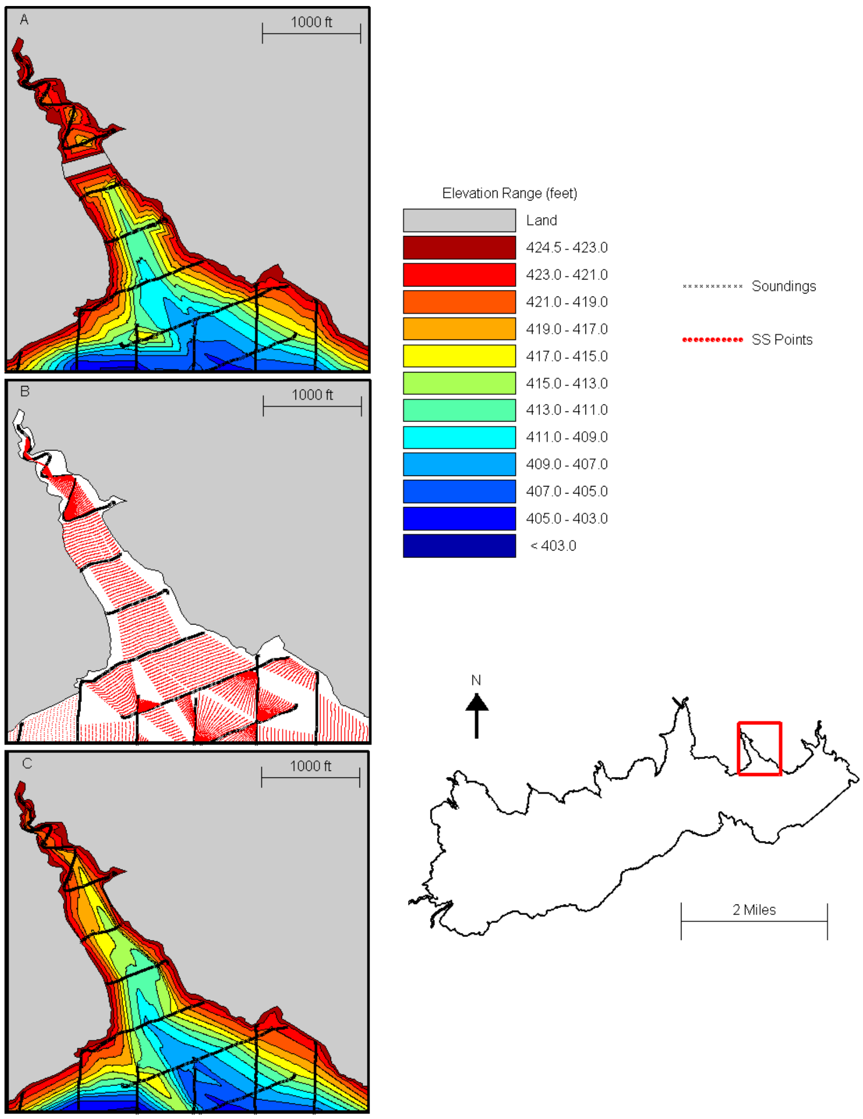

Figure 6 *- Application of the Self-Similar Interpolation technique to Navarro Mills Lake sounding data – A) bathymetric contours without interpolated points, B) Sounding points (black) and interpolated points (red) with reservoir boundary shown at elevation 424.5 (black), C) bathymetric contours with the interpolated points. Note: In 6A the submerged river channel indicated by the surveyed cross sections is not represented for the areas in-between the cross sections. This is an artifact of the TIN generation routine. Inclusion of the interpolated points (6C) corrects this and smoothes the bathymetric contours.*

Survey Results

Volumetric Survey

The results of the TWDB 2008 Volumetric Survey indicate Navarro Mills Lake has a total reservoir capacity of 49,827 acre-feet and encompasses 4,736 acres at conservation pool elevation (424.5 feet above mean sea level, NGVD29). A 1956 survey conducted by the U.S. Army Corps of Engineers estimated the capacity of Navarro Mills Lake at conservation pool elevation to be 63,000 acre-feet encompassing 5,070 acres.[1] Due to differences in the methodologies used in calculating areas and capacities from this and previous Navarro Mills Lake surveys, comparison of these values is not recommended. TWDB considers the 2008 survey to be a significant improvement over previous methods and recommends that a similar methodology be used to resurvey Navarro Mills Lake in approximately 10 years or after a major flood event.

Sedimentation Survey

The 200 kHz, 50 kHz, and 24 kHz frequency data were used to interpret sediment distribution and accumulation throughout Navarro Mills Lake. Figure 7 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 three core samples. One core was collected on October 7, 2008, while the other two cores were collected on October 14, 2008. All cores were collected with a custom-coring boat and SDI VibraCore system.

The results of the TWDB 2008 Sedimentation Survey indicate Navarro Mills Lake has accumulated 5,695 acre-feet of sediment since impoundment in 1963. Based on this measured sediment volume and assuming a constant sediment accumulation rate, Navarro Mills Lake loses approximately 124 acre-feet of capacity per year. The thickest sediment deposits are located within the main body of the lake and along the original stream channel. The maximum sediment thickness observed in Navarro Mills Lake was 6.3 feet. A complete description of the sediment measurement methodology and sample results is presented in Appendix D.

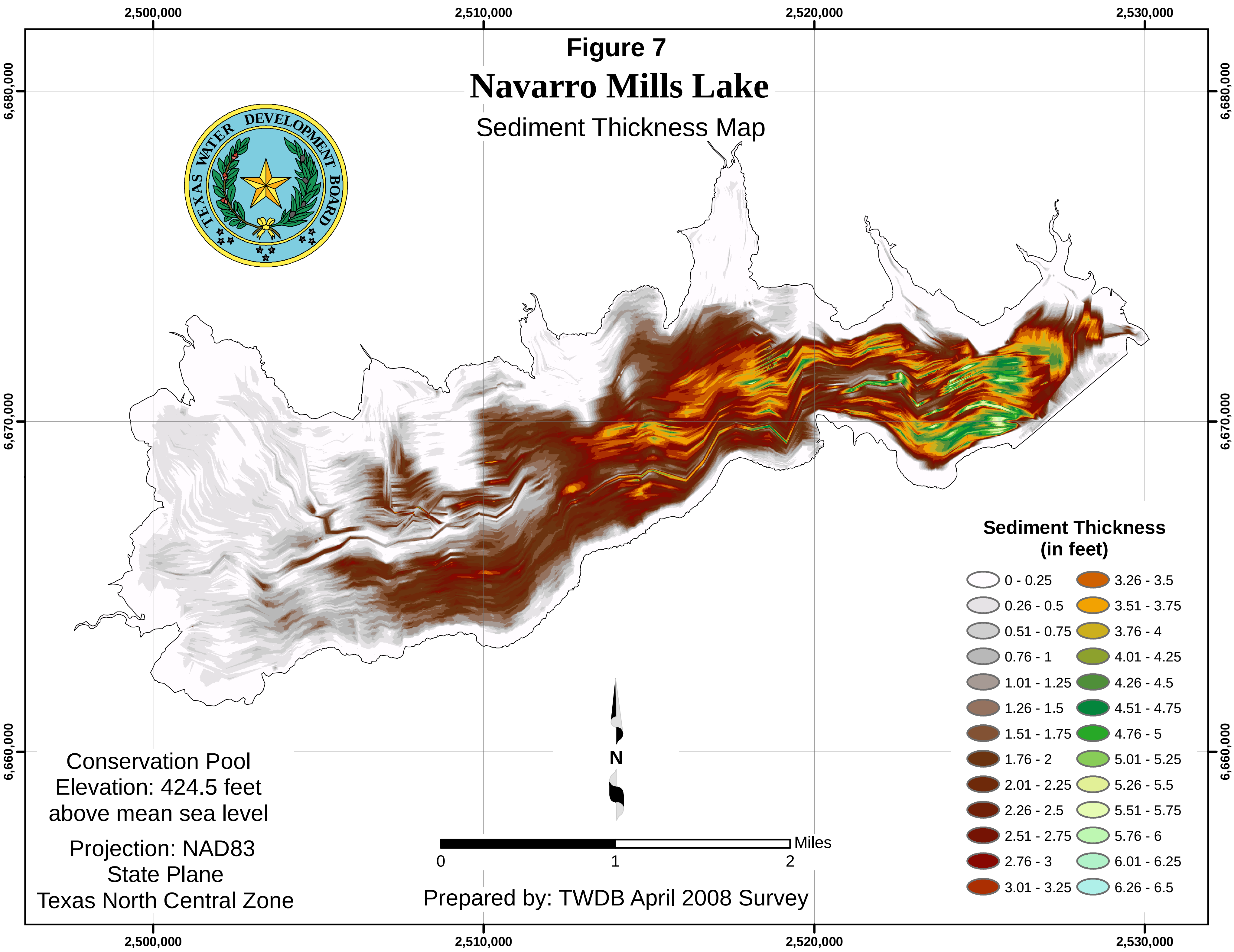

Figure 7
Navarro Mills Lake
Sediment Thickness Map
TEXAS WATER DEVELOPMENT BOARD
2,500,000
2,510,000
2,520,000
2,530,000
6,680,000
6,670,000
6,660,000
Sediment Thickness (in feet)
0 - 0.25
0.26 - 0.5
0.51 - 0.75
0.76 - 1
1.01 - 1.25
1.26 - 1.5
1.51 - 1.75
1.76 - 2
2.01 - 2.25
2.26 - 2.5
2.51 - 2.75
2.76 - 3
3.01 - 3.25
3.26 - 3.5
3.51 - 3.75
3.76 - 4
4.01 - 4.25
4.26 - 4.5
4.51 - 4.75
4.76 - 5
5.01 - 5.25
5.26 - 5.5
5.51 - 5.75
5.76 - 6
6.01 - 6.25
6.26 - 6.5
N
0
1
2
Miles
Conservation Pool
Elevation: 424.5 feet
above mean sea level
Projection: NAD83
State Plane
Texas North Central Zone
Prepared by: TWDB April 2008 Survey

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

References

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2. U.S. Army Corps of Engineers, Fort Worth District, U.S. Army Corps of Engineers – Lake Information, viewed 12 January 2009, http://www.swf-wc.usace.army.mil/navarro/Information/index.asp, April 17, 2007.

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6. Furnans, Jordan. Texas Water Development Board. 2006. "HydroEdit User's Manual."

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Appendix A

Navarro Mills Lake

RESERVOIR CAPACITY TABLE

TEXAS WATER DEVELOPMENT BOARD — APRIL 2008 SURVEY

CAPACITY IN ACRE-FEET — Conservation Pool Elevation 424.5 feet NGVD29

ELEVATION INCREMENT IS ONE TENTH FOOT

ELEVATION in Feet	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
397	0	0	0	0	0	0	0	0	0	0
398	0	0	0	0	0	0	0	0	0	0
399	0	0	0	0	0	0	1	1	1	1
400	1	1	1	2	4	9	17	27	39	53
401	68	85	103	123	146	171	198	228	259	293
402	328	365	403	443	485	529	575	622	671	720
403	771	822	875	929	983	1,039	1,095	1,152	1,209	1,267
404	1,326	1,386	1,446	1,506	1,567	1,629	1,691	1,754	1,818	1,882
405	1,946	2,011	2,077	2,144	2,211	2,279	2,348	2,417	2,487	2,557
406	2,628	2,699	2,771	2,844	2,917	2,991	3,065	3,141	3,217	3,293
407	3,371	3,449	3,528	3,608	3,689	3,772	3,855	3,939	4,024	4,110
408	4,197	4,285	4,375	4,465	4,557	4,651	4,746	4,844	4,944	5,046
409	5,149	5,255	5,362	5,472	5,583	5,696	5,812	5,929	6,049	6,171
410	6,295	6,421	6,549	6,679	6,812	6,946	7,083	7,223	7,364	7,508
411	7,655	7,804	7,955	8,109	8,265	8,424	8,587	8,753	8,921	9,093
412	9,268	9,445	9,625	9,808	9,993	10,181	10,371	10,563	10,758	10,954
413	11,153	11,354	11,556	11,761	11,967	12,175	12,384	12,595	12,808	13,023
414	13,240	13,458	13,678	13,900	14,123	14,349	14,576	14,805	15,036	15,269
415	15,504	15,740	15,979	16,220	16,463	16,708	16,955	17,204	17,455	17,709
416	17,965	18,224	18,485	18,748	19,015	19,284	19,556	19,830	20,106	20,386
417	20,667	20,952	21,239	21,528	21,820	22,115	22,413	22,713	23,018	23,326
418	23,638	23,954	24,273	24,595	24,921	25,250	25,583	25,918	26,256	26,597
419	26,941	27,288	27,638	27,992	28,349	28,708	29,071	29,437	29,806	30,178
420	30,553	30,931	31,311	31,694	32,080	32,469	32,860	33,255	33,652	34,053
421	34,456	34,862	35,272	35,683	36,097	36,514	36,933	37,355	37,778	38,203
422	38,630	39,059	39,489	39,920	40,354	40,788	41,224	41,662	42,101	42,542
423	42,985	43,429	43,874	44,321	44,770	45,221	45,673	46,127	46,583	47,040
424	47,500	47,961	48,425	48,890	49,357	49,827				

Appendix B

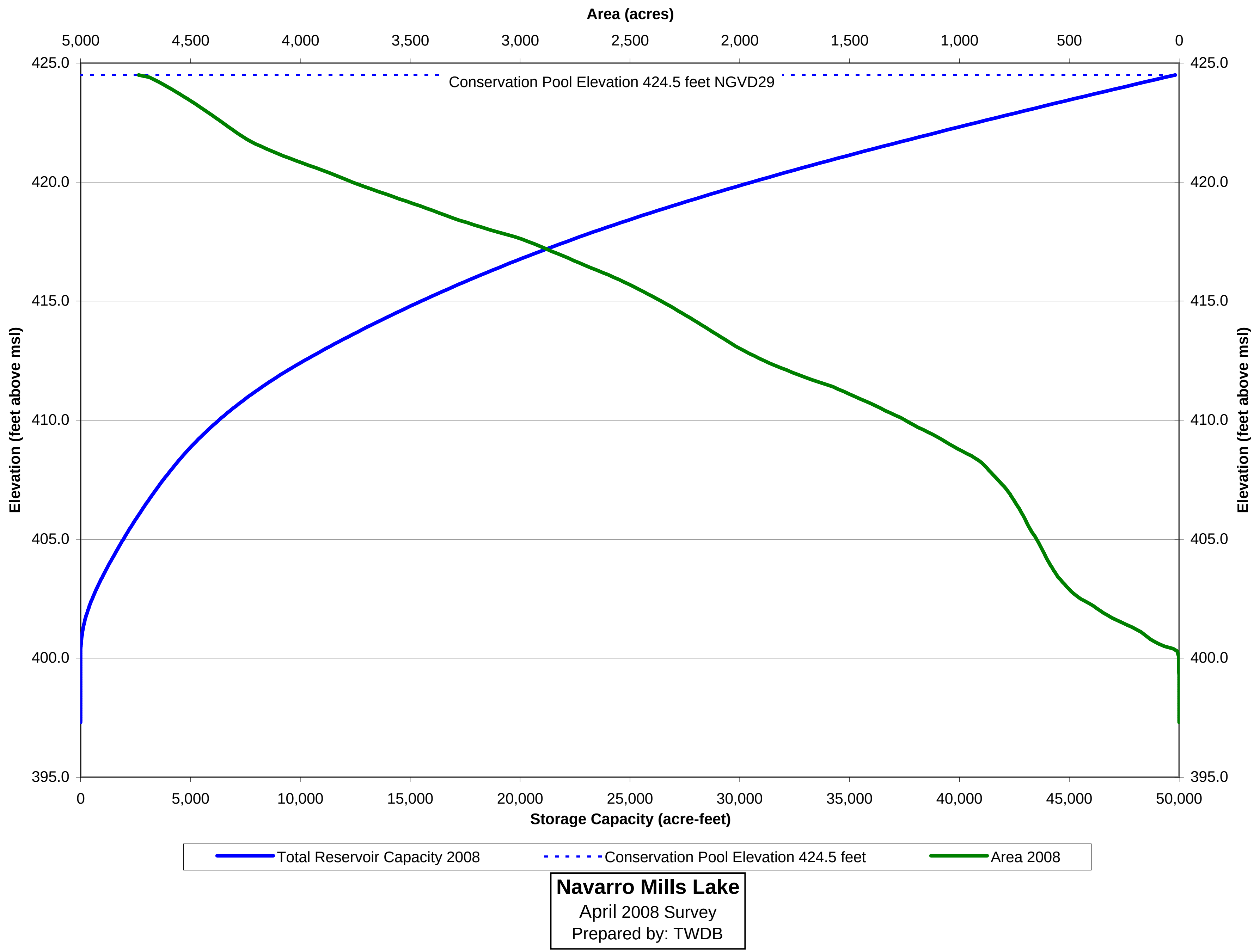
Navarro Mills Lake

RESERVOIR AREA TABLE

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

APRIL 2008 SURVEY
Conservation Pool Elevation 424.5 NGVD29

ELEVATION in Feet	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
397	0	0	0	0	0	0	0	0	0	0
398	0	0	0	0	0	0	0	0	0	0
399	0	0	0	0	1	1	1	1	1	1
400	1	3	6	9	28	65	93	114	131	146
401	160	174	193	214	237	261	285	307	325	344
402	361	376	391	409	429	449	464	479	491	501
403	511	521	531	541	550	558	565	572	579	585
404	591	598	604	609	615	620	626	631	637	643
405	649	655	663	670	677	683	689	694	699	704
406	710	717	723	729	736	743	750	757	764	770
407	778	787	796	806	816	826	836	846	857	867
408	876	886	898	912	928	946	967	988	1,009	1,028
409	1,046	1,064	1,083	1,102	1,123	1,144	1,166	1,189	1,209	1,228
410	1,248	1,268	1,291	1,315	1,338	1,358	1,381	1,403	1,427	1,454
411	1,479	1,502	1,526	1,551	1,576	1,606	1,641	1,672	1,703	1,732
412	1,760	1,786	1,813	1,841	1,866	1,890	1,912	1,934	1,956	1,977
413	1,998	2,017	2,035	2,052	2,069	2,087	2,104	2,122	2,139	2,157
414	2,174	2,191	2,208	2,227	2,245	2,263	2,282	2,300	2,318	2,338
415	2,358	2,377	2,398	2,418	2,439	2,460	2,481	2,503	2,526	2,548
416	2,573	2,597	2,623	2,651	2,677	2,704	2,730	2,755	2,779	2,804
417	2,831	2,858	2,883	2,907	2,934	2,962	2,990	3,024	3,061	3,103
418	3,138	3,173	3,208	3,241	3,277	3,308	3,338	3,367	3,396	3,426
419	3,455	3,487	3,519	3,551	3,581	3,612	3,645	3,676	3,705	3,736
420	3,763	3,790	3,816	3,843	3,872	3,900	3,930	3,961	3,991	4,020
421	4,048	4,077	4,104	4,130	4,155	4,179	4,203	4,224	4,243	4,261
422	4,277	4,293	4,309	4,324	4,339	4,354	4,370	4,385	4,400	4,416
423	4,432	4,448	4,464	4,480	4,497	4,514	4,531	4,549	4,567	4,585
424	4,604	4,623	4,643	4,664	4,687	4,736				



Appendix C: Area and Capacity Curves

Appendix D

Analysis of Sediment Accumulation Data from Navarro Mills Lake

Executive Summary

The results of the TWDB 2008 Sedimentation Survey indicate Navarro Mills Lake has accumulated 5,695 acre-feet of sediment since impoundment in 1963. Based on this measured sediment volume and assuming a constant rate of sediment accumulation over the 46 years since impoundment, Navarro Mills Lake loses approximately 124 acre-feet of capacity per year. The thickest sediment deposits are located within the main body of the lake and along the original stream channel. The maximum sediment thickness observed in Navarro Mills Lake was 6.3 feet.

Introduction

This appendix includes the results of the sediment 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 Navarro Mills Lake.

Data Collection & Processing Methodology

TWDB conducted the bathymetric data collection for Navarro Mills Lake on March 26-27, 2008, and April 3-8, 2008. For all data collection efforts, 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 2008 survey, team members collected over 52,900 data points over cross-sections totaling nearly 87.5 miles in length. Figure D1 shows where data points were collected during the TWDB 2008 Navarro Mills Lake survey.

Core samples collected by TWDB 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 N3. At this location, TWDB collected 27 inches of sediment, with the upper sediment layer (Figure D2) having high water content, consisting of clay material and lacking in vegetation. The pre-impoundment boundary was evident from this core at a distance of 7 inches above the core base; above this location, the moisture content in the sediment greatly increases (Figure D2).

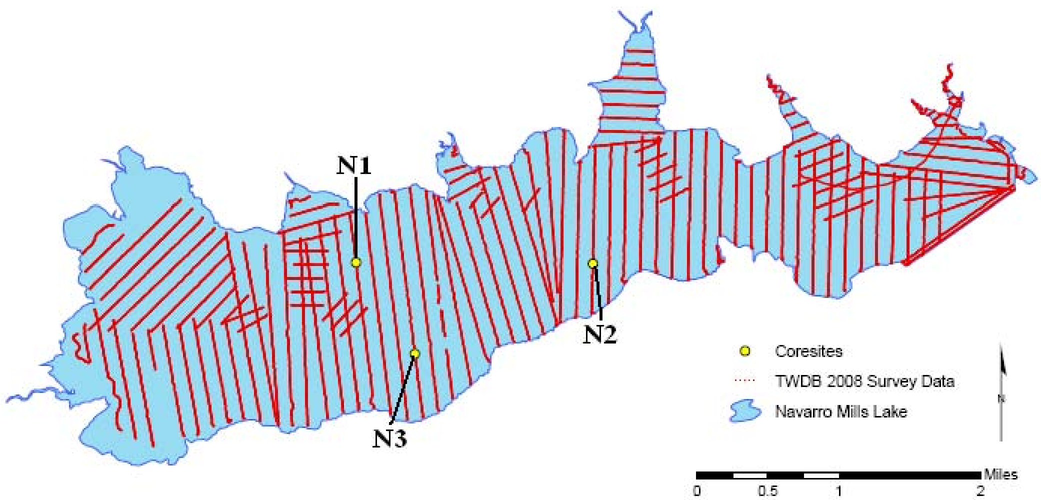


Figure D1 – TWDB 2008 survey data points for Navarro Mills Lake

Table D1 – Core Sampling Analysis Data – Navarro Mills Lake

Core	Easting** (ft)	Northing** (ft)	Description
N1	2508613.75	6669003.17	6" of sandy sediment with no plant material visible.
N2	2516131.85	6669084.69	6" of sediment with no plant material visible.
N3	2510547.48	6665670.02	27" of muddy sediment with no plant material visible.

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

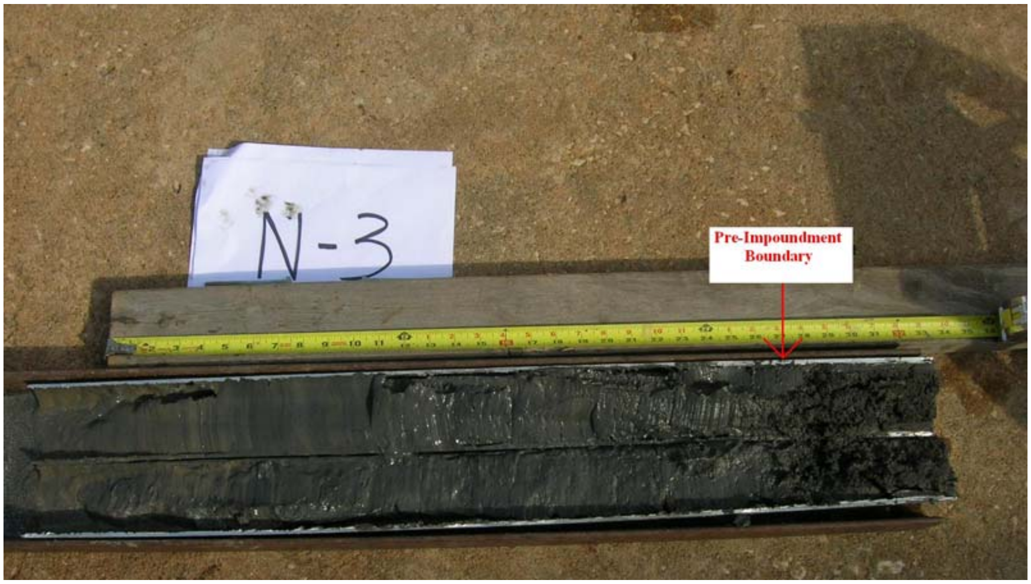


Figure D2 – Sediment Core N3 from Navarro Mills Lake, showing the pre-impoundment boundary 7 inches above the base of the core (right). The pre-impoundment boundary is marked by the change in sediment moisture content below and above the area 7 inches up from the core base.

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 N3 is shown with its corresponding sounding data. Core sample N3 contained 27 inches of sediment above the pre-impoundment boundary, as indicated by the yellow box in Figure D3. The top of the green box represents the pre-impoundment boundary identified in the core sample in Figure D2. 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.

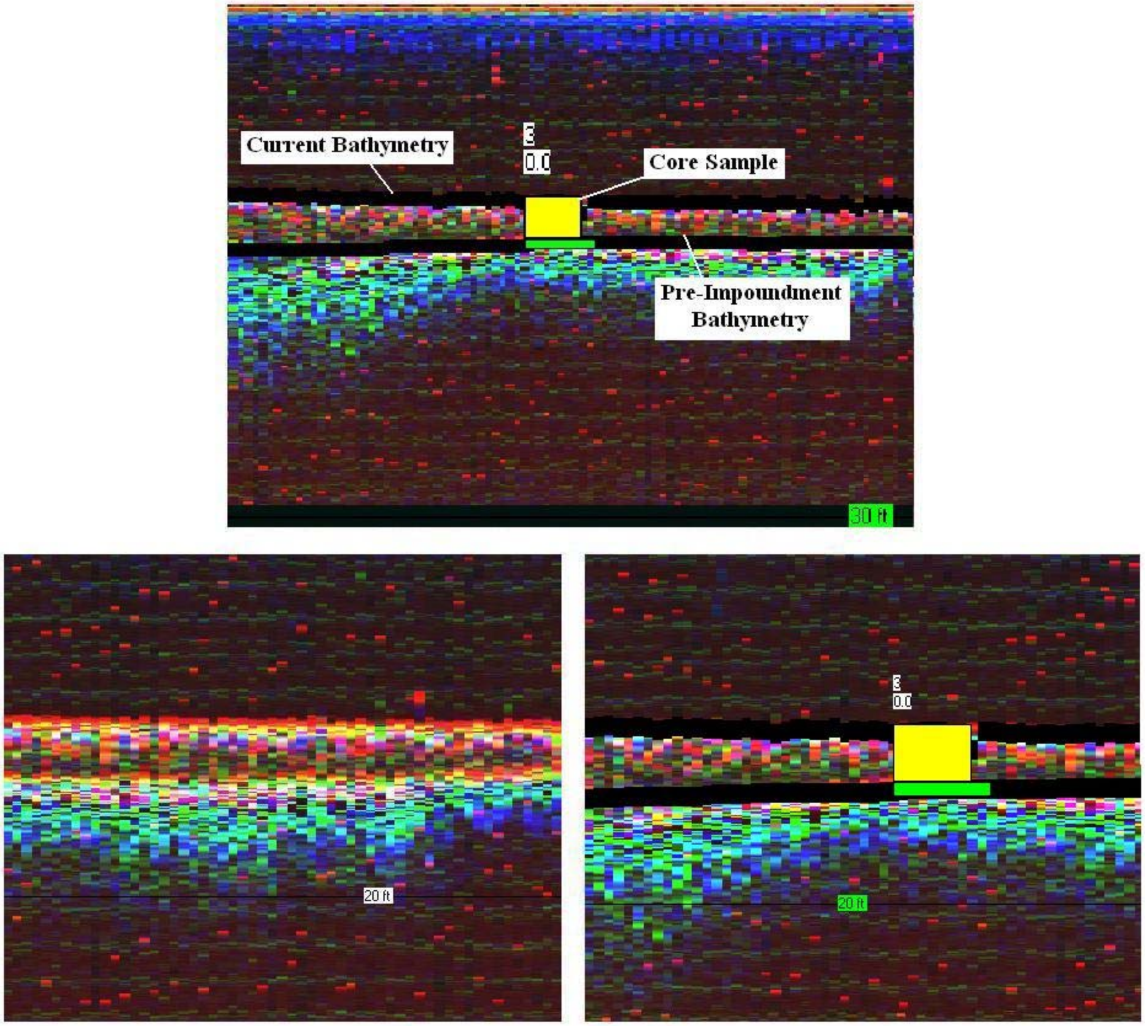


Figure D3 – DepthPic and core sample use in identifying the pre-impoundment bathymetry.

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 N3, it is clear that the sediment layer is bounded by the layers of red and orange pixels. The pre-impoundment bathymetric surface for this cross-section is therefore identified by the thin line of orange-yellow pixels overlaying the areas of bright-colored pink and yellow pixels or green and blue pixels in the DepthPic display. The current bathymetric surface is identified as the upper-most layer of orange-yellow pixels. This upper-layer is generally slightly thicker than the layer of similar color indicating the pre-impoundment surface. (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.

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 Navarro Mills 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. 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 424.5 foot NGVD29 elevation contour).

Results

The results of the TWDB 2008 Sedimentation Survey indicate Navarro Mills Lake has accumulated 5,695 acre-feet of sediment since impoundment in 1963. The thickest sediment deposits are located within the main body of the lake and along the original stream channel. The maximum sediment thickness observed in Navarro Mills Lake was 6.3 feet. Figure D4 depicts the sediment thickness in Navarro Mills Lake.

Based on the measured sediment volume in Navarro Mills Lake and assuming a constant rate of sediment accumulation over the 46 years since impoundment, Navarro Mills Lake loses approximately 124 acre-feet of capacity per year. To improve the sediment accumulation rate estimates, TWDB recommends Navarro Mills Lake be re-surveyed using similar methods in approximately 10 years or after a major flood event.

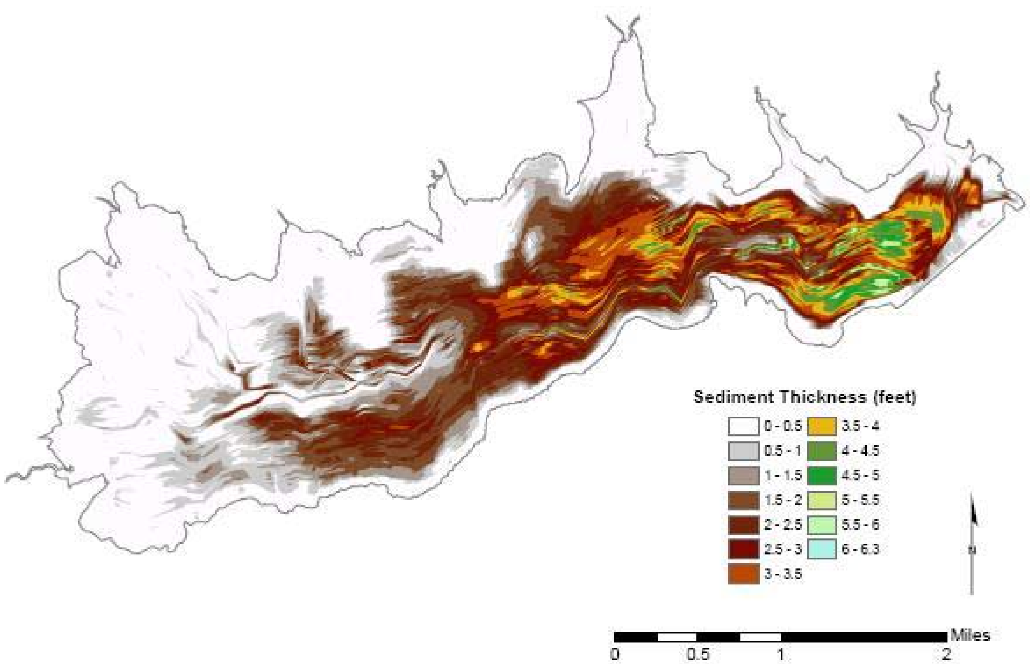
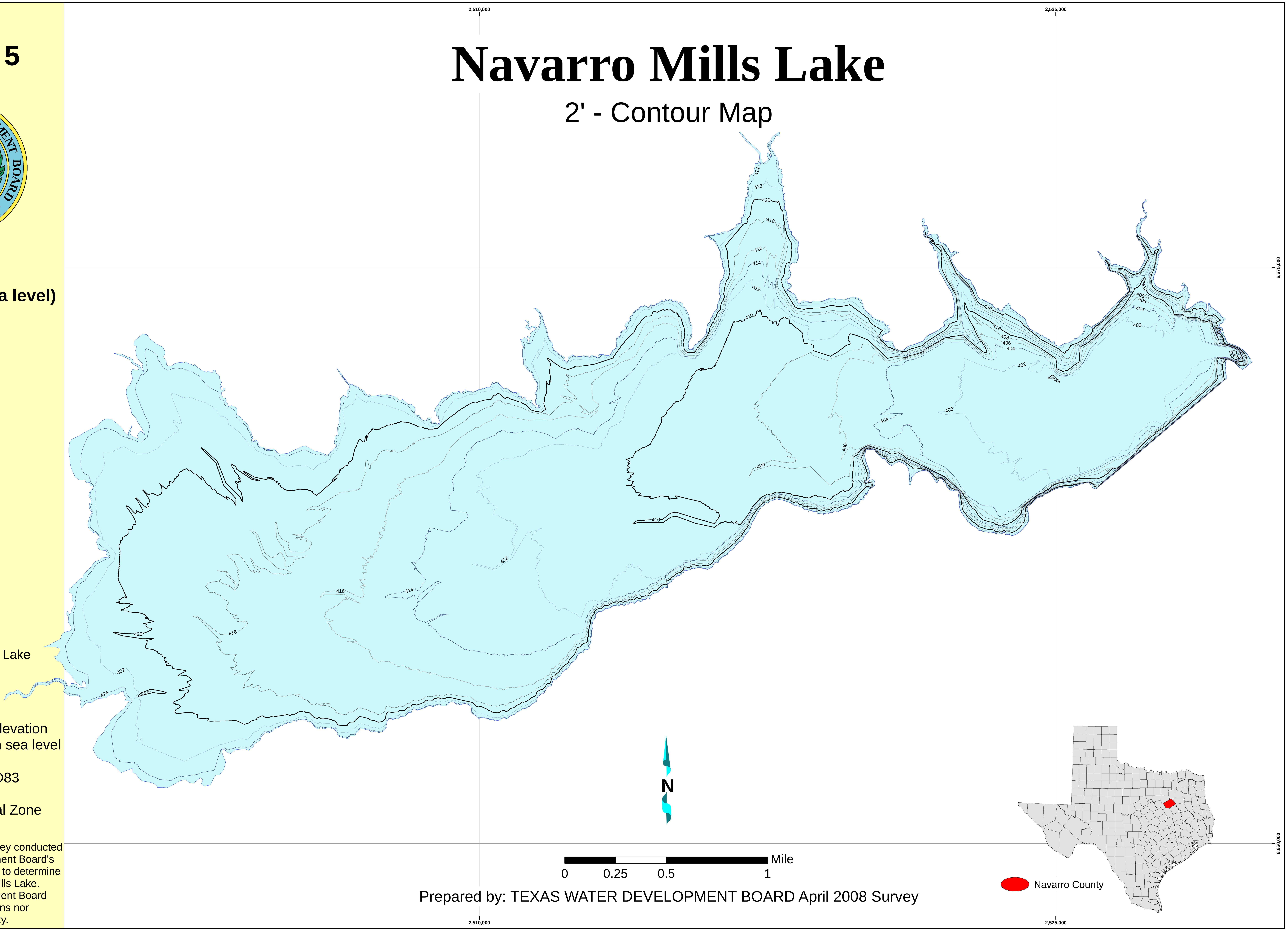


Figure D4 - Sediment thicknesses in Navarro Mills Lake derived from multi-frequency sounding data.

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."

Figure 5



Conservation Pool Elevation
424.5 feet above mean sea level

Projection: NAD83
State Plane
Texas North Central Zone

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

Prepared by: TEXAS WATER DEVELOPMENT BOARD April 2008 Survey