Volumetric and Sedimentation Survey of LAKE WEATHERFORD

August 2008 Survey

Prepared by:

The Texas Water Development Board

January 2009

Texas Water Development Board

J. Kevin Ward, Executive Administrator

Prepared for:

City of Weatherford, 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 Lake Weatherford. 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 City of Weatherford, 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.

Weatherford Dam and Lake Weatherford are located on the Clear Fork Trinity River in Parker County, Texas. Bathymetric data collection for Lake Weatherford occurred on August 19, 2008, while the water surface elevation measured 892.73 feet above mean sea level (NGVD29). Additional data was collected on October 7, 2008, while the water surface elevation measured 891.53 feet above mean sea level (NGVD29). The conservation pool elevation of Lake Weatherford is 896.0 feet above mean sea level (NGVD29).

The results of the TWDB 2008 Volumetric Survey indicate Lake Weatherford has a total reservoir capacity of 17,812 acre-feet and encompasses 1,112 acres at conservation pool elevation. Previously published[1] capacity estimates for Lake Weatherford are 21,233 acre-feet, 19,866 acre-feet, and 18,714 acre-feet based on surveys conducted in 1957, 1973, and 1998, respectively. Due to differences in the methodologies used in calculating capacities from this and previous Lake Weatherford surveys, comparison of these values is not recommended. TWDB recommends that a similar methodology be used to resurvey Lake Weatherford in approximately 10 years or after a major flood event.

The results of the TWDB 2008 Sedimentation Survey indicate Lake Weatherford has accumulated 1,926 acre-feet of sediment since impoundment began in 1957. Based on this measured sediment volume and assuming a constant sediment accumulation rate, Lake Weatherford loses approximately 37 acre-feet of capacity per year. The maximum sediment thickness observed in Lake Weatherford was 4.5 feet.

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***Note:** References to brand names throughout this report do not imply endorsement by the Texas Water Development Board*

Lake Weatherford General Information

Weatherford Dam and Lake Weatherford are located on the Clear Fork Trinity River in the Trinity River Basin, seven miles east of the City of Weatherford in Parker County, Texas (Figure 1). Lake Weatherford is owned and operated by the City of Weatherford and serves primarily as a water supply source for municipal and industrial uses. Construction on Weatherford Dam began in June of 1956, with deliberate impoundment and completion of the dam occurring in March of 1957.[2] Additional pertinent data about Weatherford Dam and Lake Weatherford can be found in Table 1.

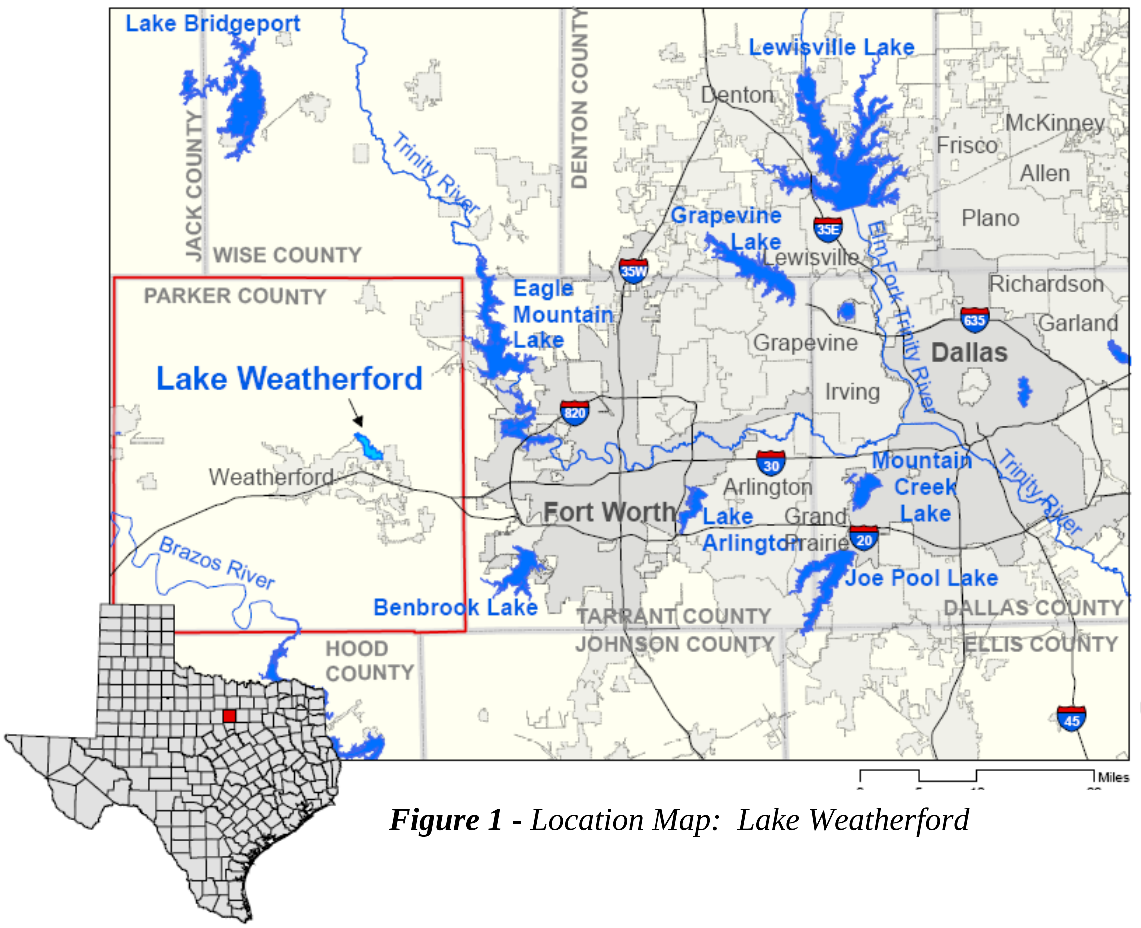

Figure 1 - Location Map: Lake Weatherford

Table 1. Pertinent Data for Weatherford Dam and Lake Weatherford[1,2]

Owner	
City of Weatherford	
Engineer (Design)	
Freese and Nichols	
Rady and Associates	
Location of Dam	
On Clear Fork Trinity River in Parker County, 7 miles east of Weatherford, TX	
Drainage Area	
109 square miles	
Dam	
Type	Earthfill
Length	4,055 feet
Maximum height	75 feet
Top width	20 feet
Top elevation	914.0 feet above mean sea level
Spillway (emergency)	
Location	Right end of dam
Type	Two-level earth section
Length (1st section)	500 feet
Crest elevation	903.0 feet above mean sea level
Length (2nd section)	500 feet
Crest elevation	906.0 feet above mean sea level
Spillway (service)**	
Type	Semi-circular drop inlet
Crest length	162 feet
Crest elevation	896.0 feet above mean sea level
Discharge conduit	9 by 9 feet, 425 feet long
Invert elevation	840.0 feet above mean sea level
Low Flow Outlet	
Type	Valve controlled, 18-inch concrete pipe
Invert elevation	857.0 feet above mean sea level
Invert for control valve	860.0 feet above mean sea level
Water Diversion	Pumping plant and pipeline, intake structure near the service spillway houses pumps that deliver water via a 24-inch concrete pipe to a water treatment facility beyond the west end of the dam.

**In 1993 the service spillway was modified to repair flood damages and increase the overall spillway capacity. The dam crest was raised 3 feet to elevation 917.0 feet above mean sea level. A new service spillway inlet consisting of a four-fingered radial labyrinth crest was constructed and connected to the existing 9-foot square discharge conduit. The second stage emergency spillway channel at elevation 906 feet was widened to a total length of 1,400 feet.[1]

Water Rights

The water rights for Lake Weatherford have been appropriated to the City of Weatherford through Certificate of Adjudication No. 08-3356 and its amendment. A brief summary of the certificate and amendment follows. The complete certificates are on file in the Records Division of the Texas Commission on Environmental Quality.

•Certificate of Adjudication No. 08-3356 Issued: April 5, 1985

Authorizes the City of Weatherford to maintain an existing dam and reservoir on the Clear Fork Trinity River and impound therein a maximum of 19,470 acre-feet of water. The City of Weatherford is authorized to divert and use from Lake Weatherford a maximum of 4,500 acre-feet of water per annum for municipal purposes; a maximum of 60,000 acre-feet of water per annum, of which 600 acre-feet may be consumptively used, for industrial purposes; and a maximum of 120 acre-feet per annum for irrigation purposes. Lake Weatherford may also be used for recreation purposes. The rights to divert water for municipal, industrial, and recreation purposes have a time priority date of August 16, 1954. The right to divert water for irrigation purposes has a time priority date of December 1, 1969.

•Amendment to Certificate of Adjudication No. 08-3356A Issued: September 8, 2004

In lieu of the authorizations granted to the City of Weatherford with Certificate of Adjudication No. 08-3356, the City of Weatherford is now authorized to divert and use a maximum of 5,220 acre-feet of water per annum for multiple purposes, including domestic, municipal, agricultural, industrial, mining, hydroelectric power, navigation, recreation and pleasure, public parks, and game preserves. The City of Weatherford is also authorized to divert and use a maximum of 59,400 acre-feet of water per annum for non-consumptive industrial purposes; use the 19,470 acre-feet of storage space in Lake Weatherford (bed and banks) for terminal storage of contract water diverted from Lake Benbrook and to subsequently divert this water for purposes authorized by Certificate of Adjudication No. 08-3358 and the owner's contracts with Tarrant Regional Water District; and use the impounded water for in-place recreational purposes.

Volumetric and Sedimentation Survey of Lake Weatherford

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 Lake Weatherford. 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 City of Weatherford, Texas contributed the remaining 50%. 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 08045800 Lk Weatherford nr Weatherford, TX.[3] 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 North American Datum 1983 (NAD83) State Plane Texas North Central Zone.

TWDB Bathymetric Data Collection

Bathymetric data collection for Lake Weatherford occurred on August 19, 2008 while the water surface elevation measured 892.73 feet above mean sea level. 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. TWDB returned to Lake Weatherford to collect additional data on October 7, 2008 while the water surface elevation measured 891.53 feet above mean sea level. Data on this day was collected using a Knudsen Engineering Ltd. dual-frequency (200 kHz and 50 kHz) depth sounder integrated with Differential Global Positioning System (DGPS) equipment. The depth sounders were 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 12,700 data points over cross-sections totaling nearly 21 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 Lake Weatherford are Lake Weatherford SW and Lake Weatherford SE. Each quarter-quadrangle image was photographed on August 4, 2004. The water surface elevation for this day is unavailable, however, the water surface elevation measured 895.33 feet on July 28, 2004 and 895.36 feet on August 14, 2004; therefore, it was assumed that on August 4, 2004 the lake level was similar. 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 896.0 feet, or conservation pool elevation to allow the area-capacity tables to be calculated to conservation pool elevation.

Additional aerial photographs of Lake Weatherford were taken on July 30, 2006, while the water surface elevation measured 886.78 feet above mean sea level. From these photographs, an 886.78-foot elevation contour was digitized and used to supplement the TWDB survey data in locations where the survey data alone was insufficient to properly represent the reservoir bathymetry. This elevation contour was verified for accuracy against data collected during the TWDB 2008 survey.

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 signal and determine the current bathymetric surface. DepthPic is used to display, interpret, and edit the multi-frequency data 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 MASS points files of interpolated data located between surveyed cross sections and extrapolated data in areas where the lake was too shallow to allow for boat passage. These points files are described in the sections entitled "Self-Similar Interpolation" and "Line Extrapolation."

To create a surface representation of the Lake Weatherford bathymetry, the 3D Analyst Extension of ArcGIS (ESRI, Inc.) is used. This extension applies Delaunay's triangulation criteria[6] and creates a triangulated irregular network (TIN) model of the bathymetry, where each MASS point and boundary node becomes the vertex of a triangular portion of the reservoir bottom surface. 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 857.6 feet to elevation 896.0 feet. The Lake Weatherford 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 Lake Weatherford (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.[7] In the case of Lake Weatherford, 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

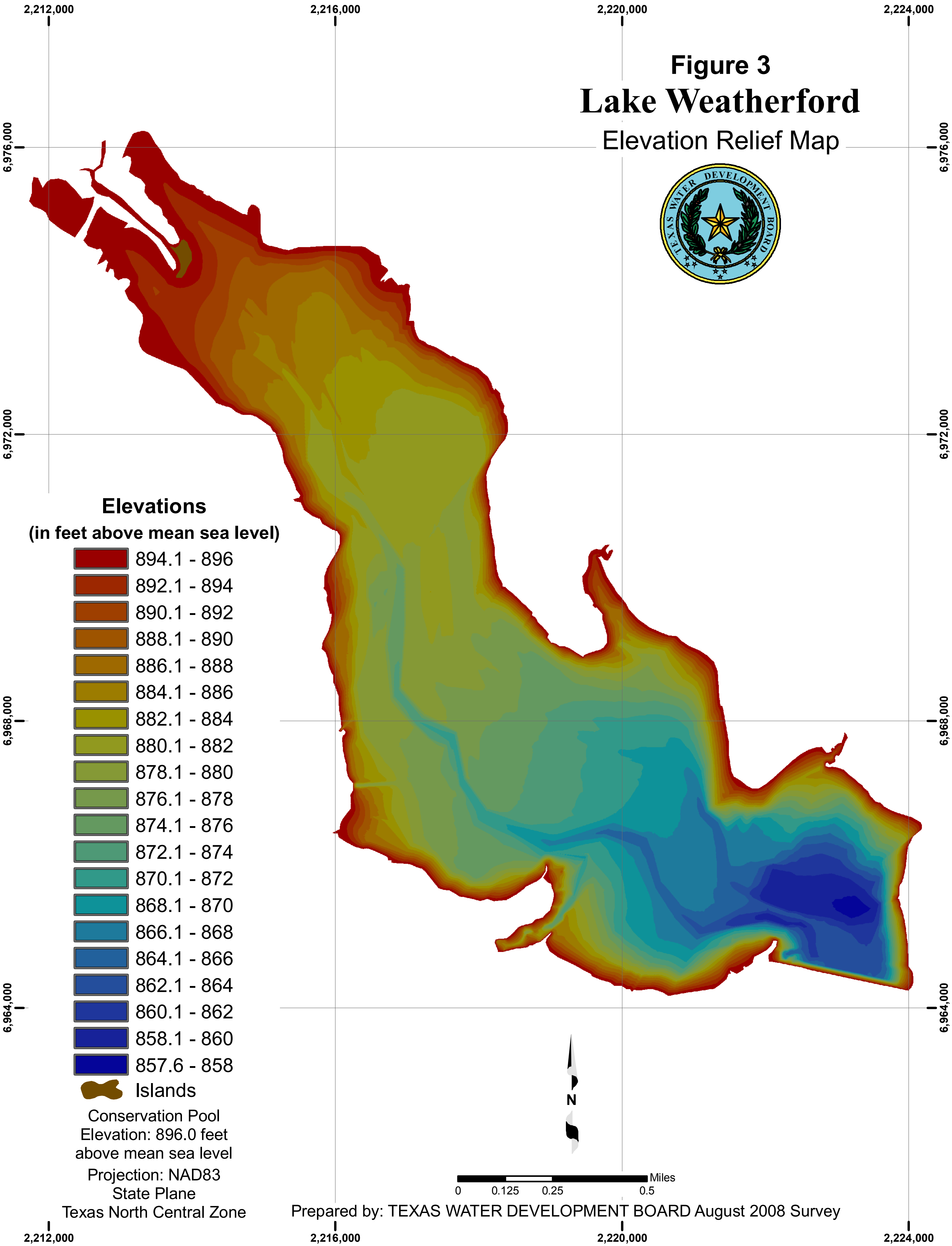
Figure 3
Lake Weatherford
Elevation Relief Map
TEXAS WATER DEVELOPMENT BOARD
2,212,000
2,216,000
2,220,000
2,224,000
6,976,000
6,972,000
6,968,000
6,964,000
Elevations
(in feet above mean sea level)
894.1 - 896
892.1 - 894
890.1 - 892
888.1 - 890
886.1 - 888
884.1 - 886
882.1 - 884
880.1 - 882
878.1 - 880
876.1 - 878
874.1 - 876
872.1 - 874
870.1 - 872
868.1 - 870
866.1 - 868
864.1 - 866
862.1 - 864
860.1 - 862
858.1 - 860
857.6 - 858
Islands
Conservation Pool
Elevation: 896.0 feet
above mean sea level
Projection: NAD83
State Plane
Texas North Central Zone
N
Miles
0
0.125
0.25
0.5
Prepared by: TEXAS WATER DEVELOPMENT BOARD August 2008 Survey

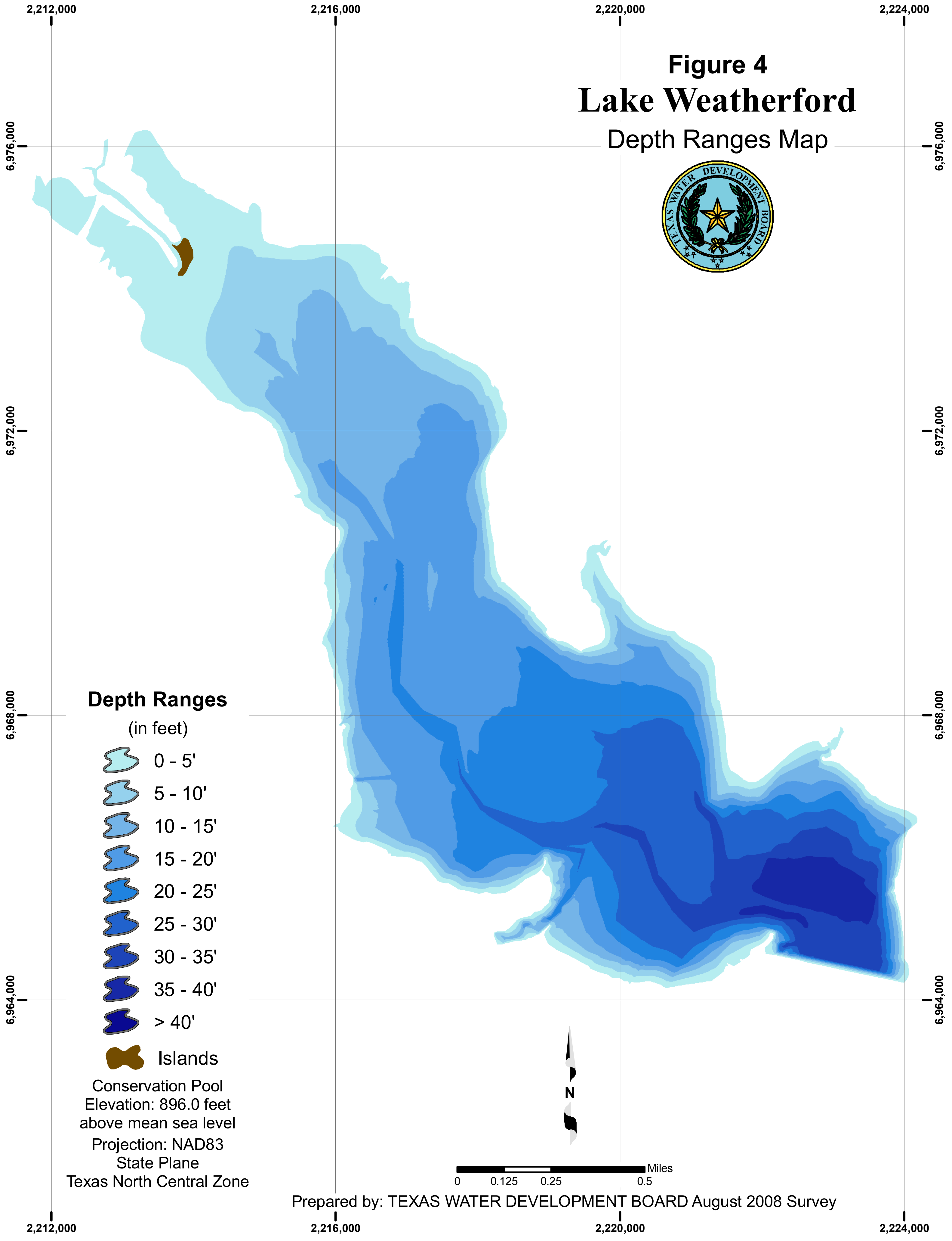

Figure 4
Lake Weatherford
Depth Ranges Map

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; therefore, Self-Similar Interpolation was not used in areas of Lake Weatherford where a high probability of change between cross-sections exists.[7] Figure 6 illustrates typical results of the application of the Self-Similar Interpolation routine in Lake Weatherford, and the bathymetry shown in Figure 6C was used in computing reservoir capacity and area tables (Appendix A, B).

Line Extrapolation

In order to estimate the bathymetry within the un-surveyed portions of Lake Weatherford, TWDB applied a line extrapolation technique[7] similar to the Self-Similar interpolation technique discussed above. The line extrapolation method is often used by TWDB in extrapolating bathymetries in shallow coves near the upstream ends of reservoirs, where the water is often too shallow to allow boat passage. The method assumes that cross-sections within the “extrapolation area” have a “V-shaped” profile, with the deepest section located along a line drawn along the longitudinal axis of the area. Elevations along this “longitudinal line” are interpolated linearly based on the distance along the line from the line’s start (nearest the reservoir interior) to the line’s end (where the line crosses the reservoir boundary). The elevations at points along each extrapolated cross-section are linearly interpolated from an elevation on the longitudinal line (at the intersection with the cross-section) and the elevation at the extrapolation area boundary. The line extrapolation method requires that the user specify the position of the longitudinal line and the elevation at the beginning of the longitudinal line. This elevation is usually assumed equivalent to the elevation of the TIN model near the beginning of the longitudinal line. As shown in Figure 7, the line extrapolation method for Lake Weatherford was implemented using both the 886.78-foot contour (derived from the 2006 DOQQs) and the outer boundary of the lake (at elevation 896.0 feet derived from the 2004 DOQQs) as the bounding extents of the extrapolation areas.

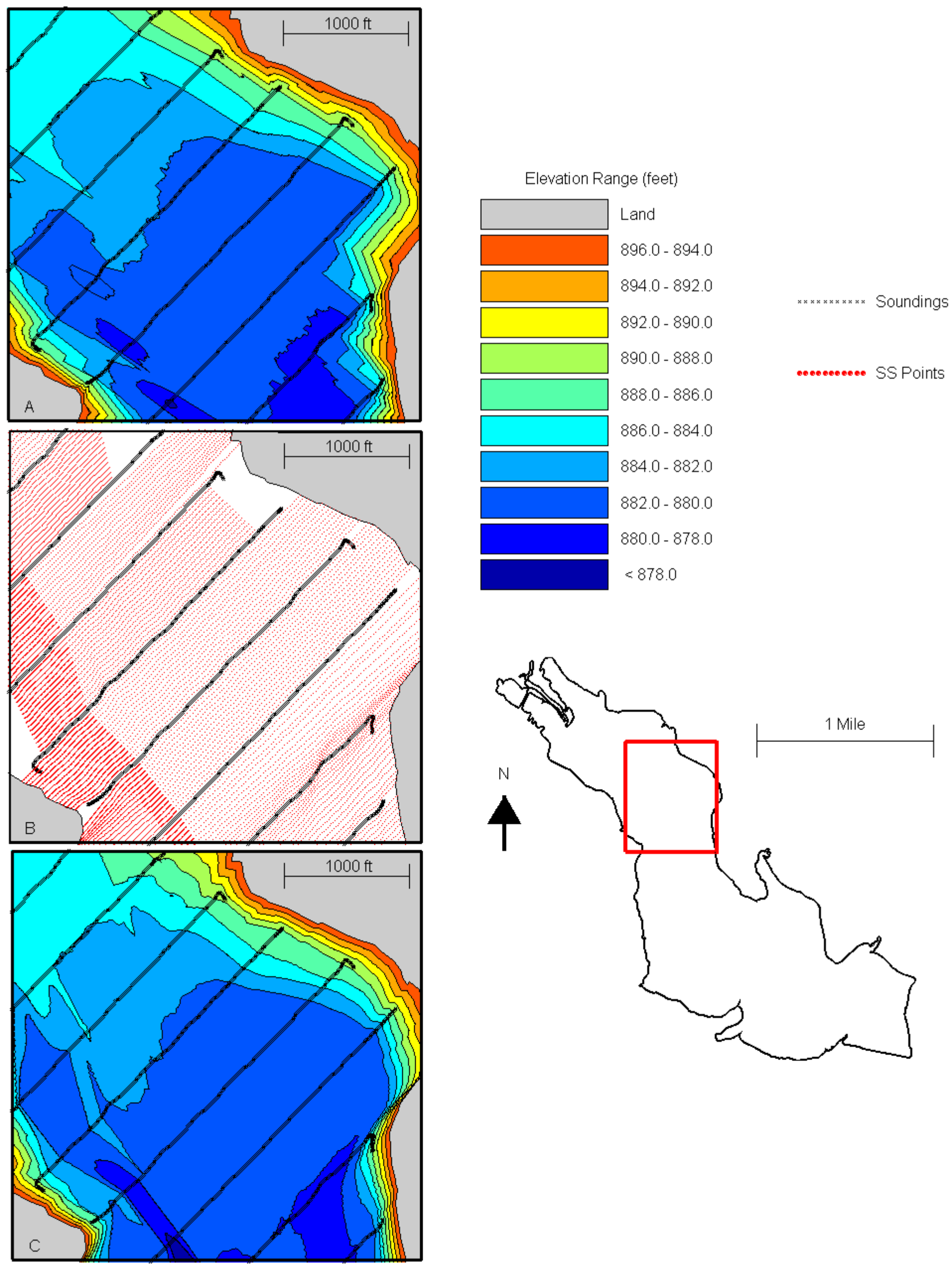

Figure 6 *- Application of the Self-Similar Interpolation technique to Lake Weatherford sounding data – A) bathymetric contours without interpolated points, B) Sounding points (black) and interpolated points (red) with reservoir boundary shown at elevation 896.0 (black), C) bathymetric contours with 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, rather than an accurate representation of the physical bathymetric surface. Inclusion of the interpolated points (6C) corrects this and smoothes the bathymetric contours.*

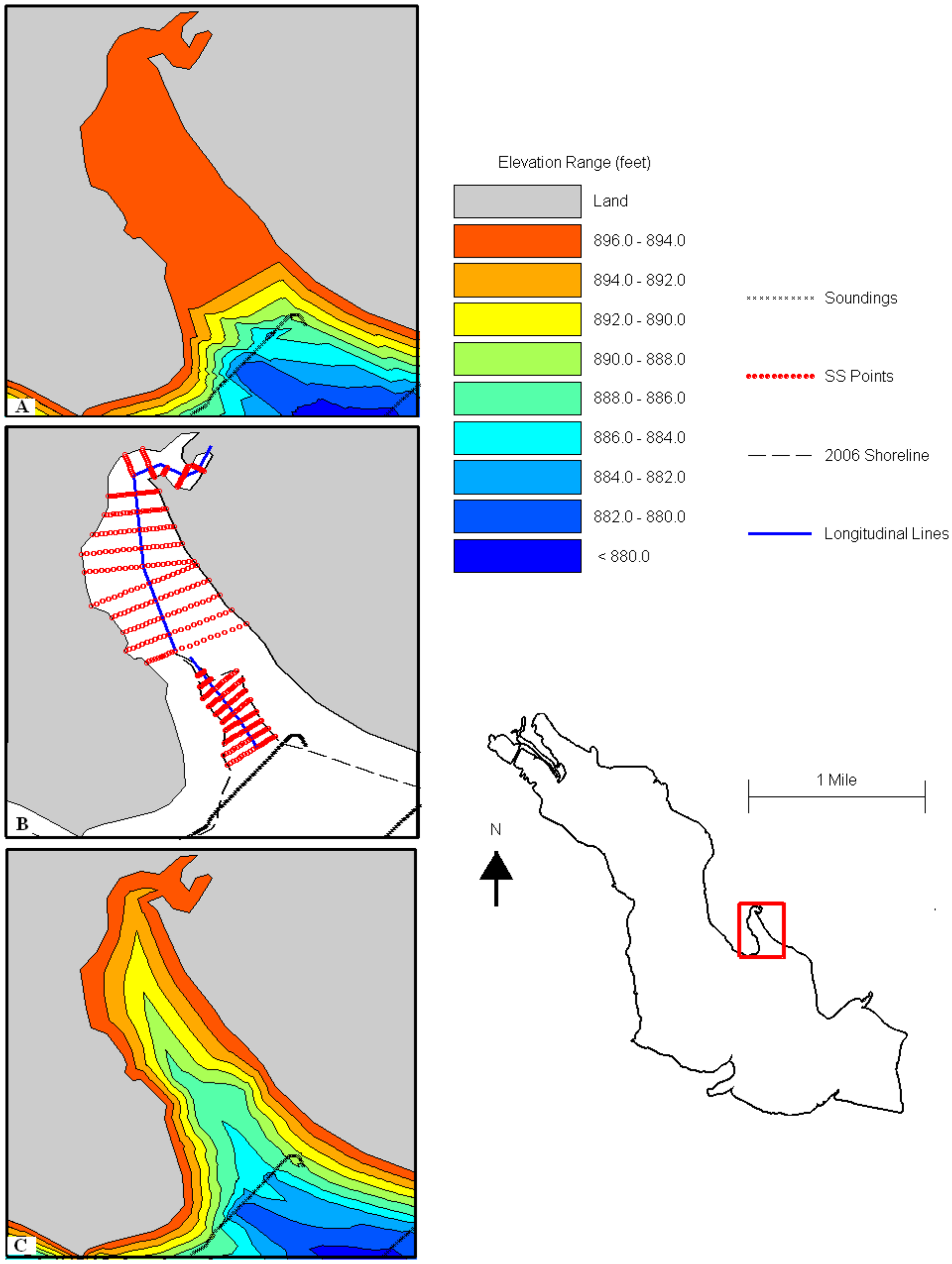

Figure 7 *- Application of the Line Extrapolation technique to Lake Weatherford sounding data – A) bathymetric contours without extrapolated points, B) Sounding points (black) and extrapolated points (red) with the "longitudinal lines" (blue), reservoir boundary shown at elevation 896.0 feet (black,) and the 886.78-foot contour (dashed black), C) bathymetric contours with the extrapolated points. Note: In 7A the bathymetric contours do not extend into the un-surveyed area and "flat" triangles are formed connecting the nodes of the reservoir boundary. This is an artifact of the TIN generation routine when data points are absent from portions of the reservoir. Inclusion of the extrapolated points (7C) corrects this and smoothes the bathymetric contours.*

The assumption inherent in the line extrapolation method is that a V-shaped cross section is a reasonable approximation of the actual unknown cross-section within the extrapolated area. As of yet, TWDB has been unable to test this assumption, and therefore can only assume that the results of the usage of the line extrapolation method are "more accurate" than those derived without line extrapolation. For the purpose of estimating the volume of water within Lake Weatherford, the line extrapolation method is justified in that it produces a reasonable representation of reservoir bathymetry in the un-surveyed areas. The use of a V-shaped extrapolated cross-section likely provides a conservative estimate of the water volume in un-surveyed areas, as most surveyed cross-sections within Lake Weatherford have shapes more similar to U-profiles than to V-profiles. The V-profiles are thus conservative in that a greater volume of water is implied by a U-profile than a V-profile. Further information on the line extrapolation method is provided in the HydroEdit User's Manual.[7]

Survey Results

Volumetric Survey

The results of the TWDB 2008 Volumetric Survey indicate Lake Weatherford has a total reservoir capacity of 17,812 acre-feet and encompasses 1,112 acres at conservation pool elevation (896.0 feet above mean sea level, NGVD29. Previously published[1] capacity estimates for Lake Weatherford are 21,233 acre-feet, 19,866 acre-feet, and 18,714 acre-feet based on surveys conducted in 1957, 1973, and 1998, respectively (Table 2). Due to differences in the methodologies used in calculating areas and capacities from this and previous Lake Weatherford 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 Lake Weatherford in approximately 10 years or after a major flood event.

Table 2. Area and Volume Comparisons of Lake Weatherford					
Feature	Permit No. 1771 and Certificate of Adjudication No. 08-3356	Original Design	U.S. Department of Agriculture, Soil Conservation Service	TWDB	TWDB
Year	1955 and 1985	1957	April 1973	1998	2008
Area (acres)	N/A	N/A	1,144	1,158	1,112
Capacity (acre-feet)	19,470	21,233	19,866	18,714	17,812

Sedimentation Survey

The 200 kHz, 50 kHz, and 24 kHz frequency data were used to interpret sediment distribution and accumulation throughout Lake Weatherford. 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 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 Lake Weatherford has accumulated 1,926 acre-feet of sediment since impoundment began in 1957. Based on this measured sediment volume and assuming a constant sediment accumulation rate, Lake Weatherford loses approximately 37 acre-feet of capacity per year. The thickest sediment deposits are adjacent to the submerged river channel approximately two miles upstream from Weatherford Dam. The maximum sediment thickness observed in Lake Weatherford was 4.5 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 Lake Weatherford is presented in Appendix E.

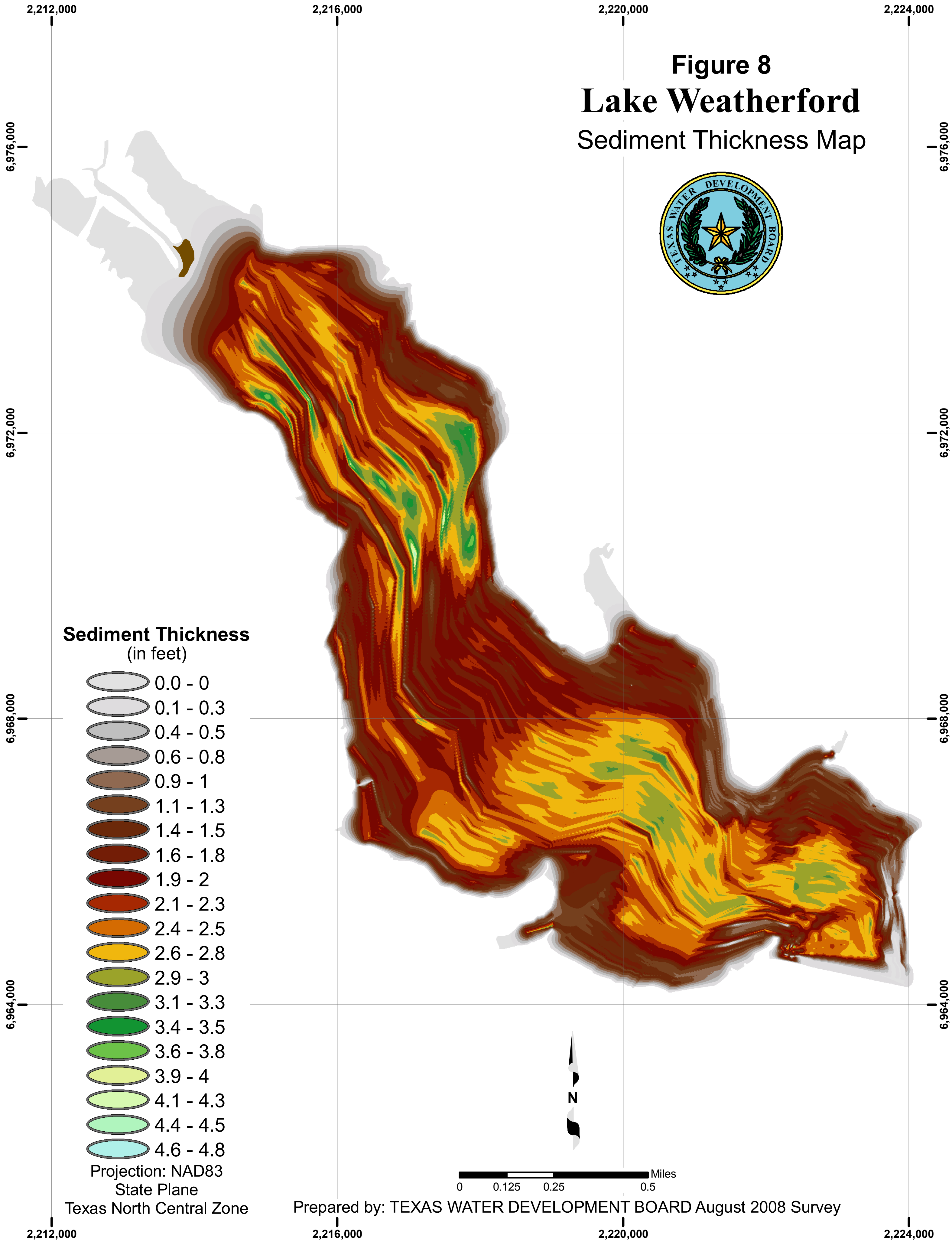

Figure 8
Lake Weatherford
Sediment Thickness Map
TEXAS WATER DEVELOPMENT BOARD
2,212,000
2,216,000
2,220,000
2,224,000
6,976,000
6,972,000
6,968,000
6,964,000
Sediment Thickness
(in feet)
0.0 - 0
0.1 - 0.3
0.4 - 0.5
0.6 - 0.8
0.9 - 1
1.1 - 1.3
1.4 - 1.5
1.6 - 1.8
1.9 - 2
2.1 - 2.3
2.4 - 2.5
2.6 - 2.8
2.9 - 3
3.1 - 3.3
3.4 - 3.5
3.6 - 3.8
3.9 - 4
4.1 - 4.3
4.4 - 4.5
4.6 - 4.8
Projection: NAD83
State Plane
Texas North Central Zone
N
Miles
0
0.125
0.25
0.5
Prepared by: TEXAS WATER DEVELOPMENT BOARD August 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

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Appendix A

Lake Weatherford

RESERVOIR CAPACITY TABLE

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

AUGUST 2008 SURVEY
Conservation Pool Elevation 896.0 Feet NGVD 29

ELEVATION in Feet	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
857	0	0	0	0	0	0	0	0	0	0
858	0	1	1	2	2	3	3	4	5	6
859	7	8	10	11	13	14	16	18	20	21
860	23	26	28	30	32	35	37	40	42	45
861	47	50	53	56	59	62	65	68	72	75
862	78	82	86	90	94	98	102	107	111	116
863	121	126	131	136	142	147	153	158	164	170
864	175	181	187	193	199	206	212	219	225	232
865	239	246	253	260	268	275	283	291	299	307
866	315	324	332	341	350	359	369	378	388	398
867	408	419	430	441	452	464	476	488	501	514
868	527	540	554	568	582	596	611	626	641	656
869	672	687	703	720	736	753	770	787	805	823
870	841	859	878	897	916	936	956	976	997	1,018
871	1,039	1,060	1,082	1,104	1,126	1,149	1,171	1,195	1,218	1,242
872	1,265	1,290	1,314	1,339	1,364	1,389	1,414	1,440	1,466	1,493
873	1,519	1,546	1,574	1,601	1,629	1,657	1,685	1,714	1,743	1,773
874	1,802	1,832	1,863	1,893	1,924	1,955	1,987	2,019	2,051	2,084
875	2,117	2,151	2,185	2,219	2,254	2,289	2,325	2,361	2,397	2,434
876	2,471	2,509	2,547	2,585	2,623	2,662	2,702	2,741	2,781	2,822
877	2,862	2,904	2,945	2,987	3,029	3,072	3,115	3,159	3,203	3,247
878	3,292	3,337	3,382	3,428	3,475	3,522	3,569	3,617	3,665	3,713
879	3,762	3,811	3,861	3,911	3,962	4,013	4,065	4,117	4,170	4,223
880	4,278	4,332	4,387	4,444	4,500	4,558	4,617	4,676	4,735	4,796
881	4,857	4,918	4,981	5,043	5,107	5,171	5,235	5,300	5,366	5,432
882	5,498	5,565	5,632	5,700	5,768	5,837	5,906	5,975	6,044	6,114
883	6,184	6,254	6,325	6,396	6,467	6,539	6,610	6,682	6,755	6,827
884	6,900	6,973	7,046	7,120	7,194	7,269	7,343	7,418	7,493	7,569
885	7,645	7,721	7,798	7,874	7,952	8,029	8,107	8,185	8,264	8,343
886	8,423	8,502	8,583	8,663	8,744	8,826	8,907	8,990	9,072	9,155
887	9,239	9,322	9,406	9,490	9,575	9,660	9,745	9,830	9,916	10,001
888	10,088	10,174	10,261	10,348	10,435	10,522	10,610	10,698	10,786	10,875
889	10,964	11,052	11,142	11,231	11,321	11,411	11,501	11,591	11,682	11,773
890	11,864	11,955	12,046	12,138	12,230	12,322	12,414	12,507	12,600	12,693
891	12,787	12,880	12,974	13,068	13,162	13,257	13,352	13,447	13,542	13,638
892	13,734	13,830	13,926	14,023	14,120	14,217	14,315	14,412	14,510	14,609
893	14,707	14,806	14,905	15,005	15,105	15,205	15,305	15,406	15,506	15,608
894	15,709	15,811	15,913	16,016	16,119	16,222	16,325	16,429	16,533	16,638
895	16,742	16,848	16,953	17,059	17,166	17,272	17,379	17,487	17,595	17,703
896	17,812									

Appendix B

Lake Weatherford

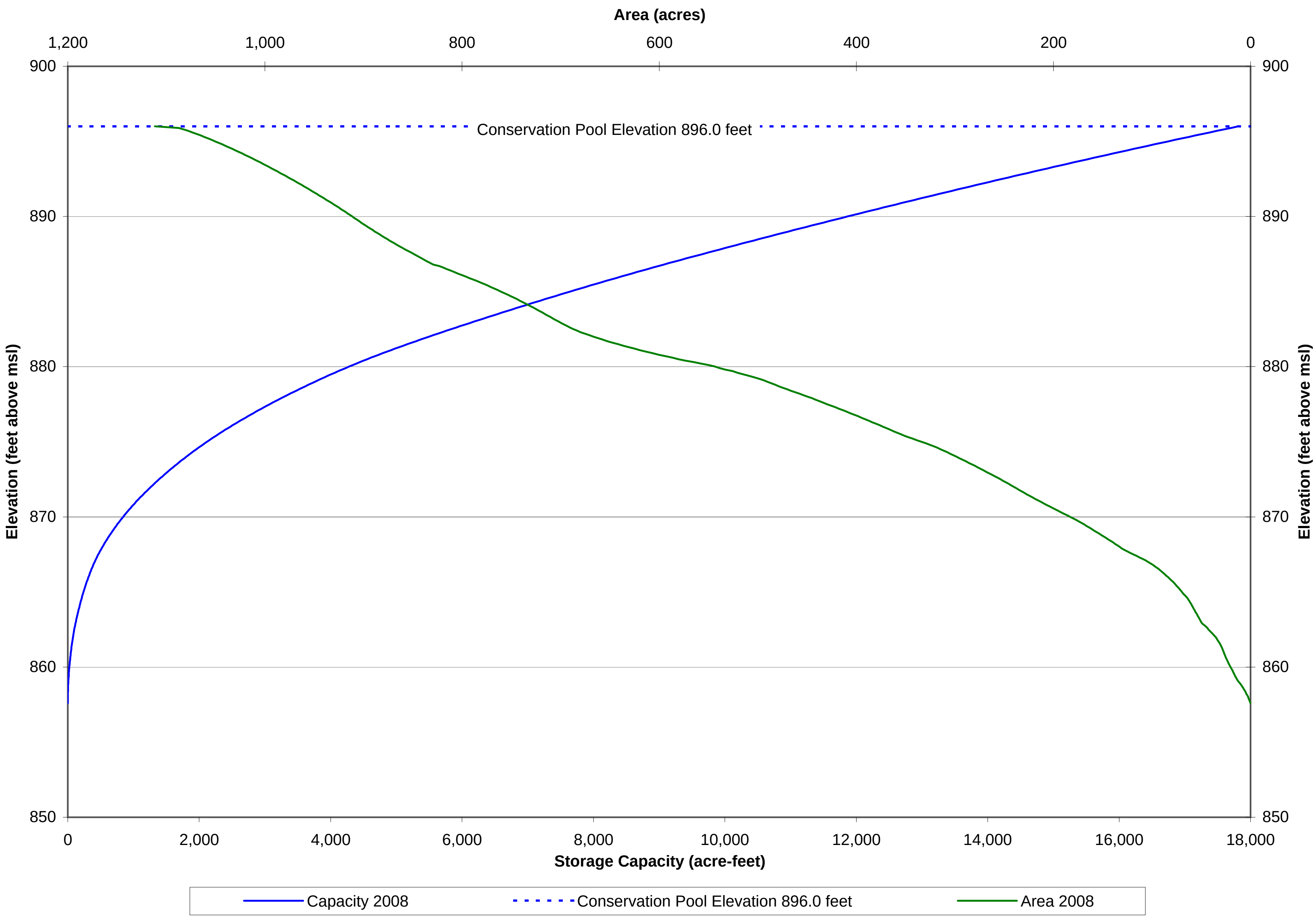
RESERVOIR AREA TABLE

TEXAS WATER DEVELOPMENT BOARD — AUGUST 2008 SURVEY

AREA IN ACRES — Conservation Pool Elevation 896.0 Feet NGVD 29

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
857	0	0	0	0	0	0	0	1	1	2
858	2	3	4	5	6	6	7	8	9	11
859	12	13	14	15	16	16	17	18	19	19
860	20	21	22	23	23	24	25	25	26	27
861	27	28	28	29	30	31	32	33	33	34
862	35	37	38	40	41	43	44	45	47	49
863	50	51	52	53	53	54	55	56	57	58
864	59	59	60	61	62	63	64	65	67	68
865	70	71	72	73	75	76	78	79	81	82
866	84	86	87	89	91	93	95	97	99	101
867	104	107	109	112	116	119	122	125	128	131
868	133	135	137	140	142	144	147	149	152	154
869	156	159	161	164	166	169	172	174	177	180
870	183	186	189	192	195	198	201	204	207	210
871	213	216	218	221	224	227	230	232	235	238
872	240	243	246	248	251	254	256	259	262	265
873	268	271	274	277	280	283	286	289	292	295
874	298	301	304	308	311	314	318	321	325	329
875	334	338	343	347	351	355	358	362	366	369
876	373	376	380	384	387	391	395	398	402	406
877	410	414	417	421	425	430	434	437	441	445
878	449	453	458	462	466	471	475	479	482	486
879	490	494	499	504	510	515	521	525	533	538
880	543	549	557	565	573	580	587	594	601	607
881	613	619	625	631	637	642	647	653	658	662
882	667	671	676	680	684	687	690	693	696	699
883	702	705	708	710	713	716	718	721	724	727
884	730	733	736	739	741	744	748	751	754	757
885	761	764	767	771	774	778	781	785	789	793
886	797	800	804	808	812	815	819	823	829	832
887	835	838	841	843	846	849	852	855	857	860
888	863	866	868	871	874	876	879	881	884	886
889	888	891	893	896	898	900	902	905	907	909
890	911	914	916	918	921	923	925	928	930	932
891	935	937	940	942	945	947	950	952	955	958
892	960	963	965	968	971	973	976	979	982	985
893	987	990	993	996	999	1,002	1,005	1,008	1,011	1,014
894	1,017	1,020	1,023	1,026	1,030	1,033	1,036	1,040	1,043	1,047
895	1,050	1,054	1,058	1,061	1,065	1,069	1,073	1,078	1,082	1,087
896	1,112									



Lake Weatherford
August 2008 Survey
Prepared by: TWDB

Appendix C: Area and Capacity Curves

Appendix D

Analysis of Sediment Accumulation Data from Lake Weatherford

Executive Summary

The results of the TWDB 2008 Sedimentation Survey indicate Lake Weatherford has accumulated 1,926 acre-feet of sediment since impoundment in 1957. Based on this measured sediment volume and assuming a constant sediment accumulation rate, Lake Weatherford loses approximately 37 acre-feet of capacity per year. The thickest sediment deposits are adjacent to the submerged river channel approximately two miles upstream from Weatherford Dam. The maximum sediment thickness observed in Lake Weatherford was 4.5 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 Lake Weatherford.

Data Collection & Processing Methodology

TWDB conducted the initial bathymetric survey for Lake Weatherford on August 19th, 2008 when the water surface elevation was 892.73 feet above mean sea level (NGVD29). Supplemental data was collected on October 7th, 2008 when the water surface elevation was 891.53 feet above mean sea level (NGVD29). For the initial 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. For the supplemental data collection effort, TWDB used a dual-frequency (200 kHz and 50 kHz) Knudsen Engineering, Ltd. Echosounder integrated with DGPS equipment. The supplemental data was used in improving the bathymetric TIN model for Lake Weatherford, and was not used in assessing the amount of accumulated sediment within the lake. All data collection and processing efforts discussed in the remainder of this appendix pertain only to the data collected during the initial Lake Weatherford bathymetric survey using the SDI multi-frequency echosounder.

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 more than 11,400 data points over cross-sections totaling nearly 19.5 miles in length. Figure D1 shows where data points were collected during the TWDB 2008 survey.

TWDB collected three sediment cores from Lake Weatherford, with one core collected on October 7, 2008 and two cores collected on October 14, 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 W-2. At this location, TWDB collected 35 inches of sediment, with the upper sediment layers (Figure D2) having a high water content, consisting of silty-loam material containing minimal vegetation. 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 and moisture content was low. Above this location, the soil becomes rapidly less structured and the moisture content generally increases (Figure D2).

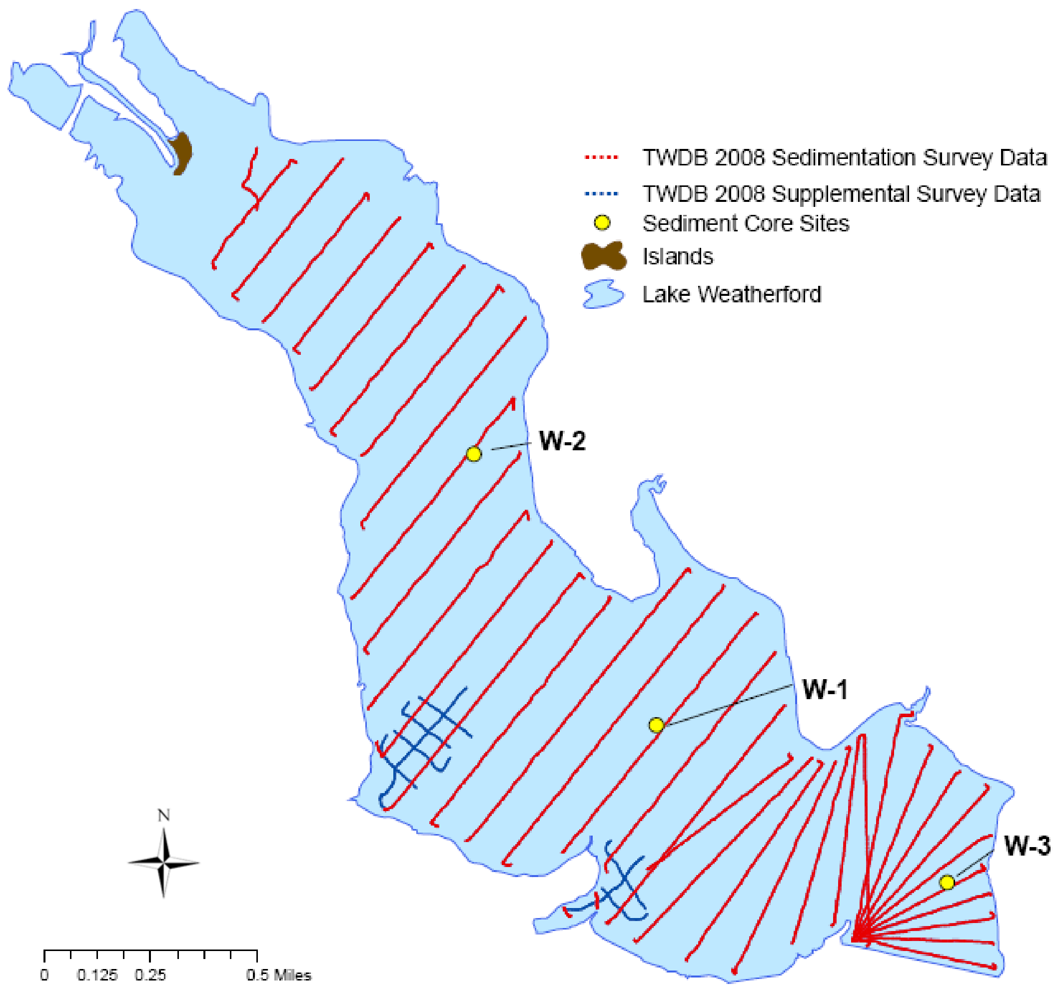


Figure D1 – TWDB 2008 survey data points for Lake Weatherford. Sounding data used in assessing sediment content are shown in red.

Table D1 – Core Sampling Analysis Data – Lake Weatherford

Core	Easting** (ft)	Northing** (ft)	Description
W-1	2217498.40	6970720.08	49" of muddy, silty-loam sediment without soil structure
W-2	2219758.45	6967355.65	35" of muddy, silty-loam sediment with minimal plant material visible, decreasing water content with depth
W-3^^	2223358.67	6965406.73	48" of silty-loam sediment with high water content, lacking plant material

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

^^ Core W-3 contained 120" of sediment which might be interpreted as post-impoundment deposits. The 48" sediment thickness layer attributed to this core is derived from analysis of the acoustic signal in DepthPic.

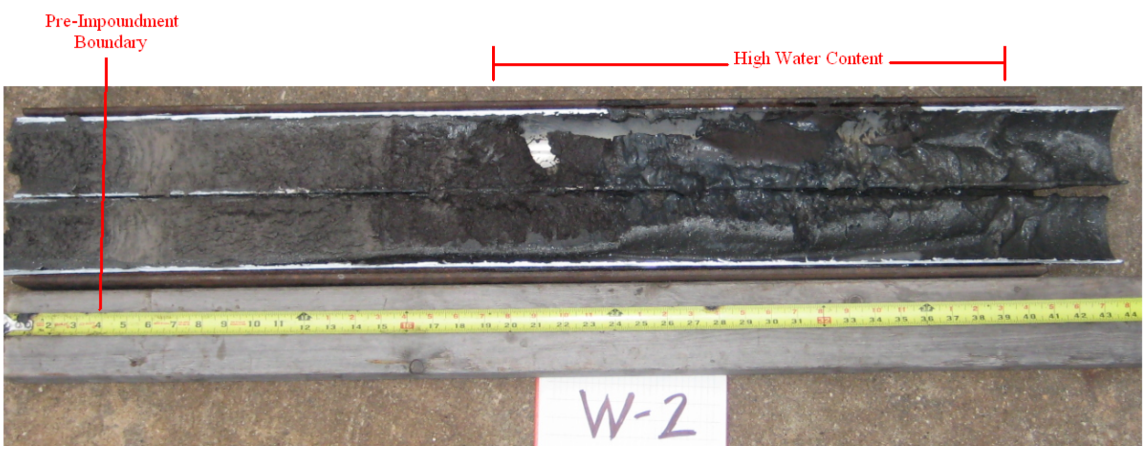


Figure D2 – Sediment Core W-2 from Lake Weatherford, showing the pre-impoundment boundary 4 inches above the base of the core (left). The pre-impoundment boundary is marked by the change in soil structure below and above the area 4" up from the core base. Above 20" from the core base, the sediment moisture 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 W-2 is shown with its corresponding sounding data. The 35 inches of sediment in core sample W-2 is 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 16 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.

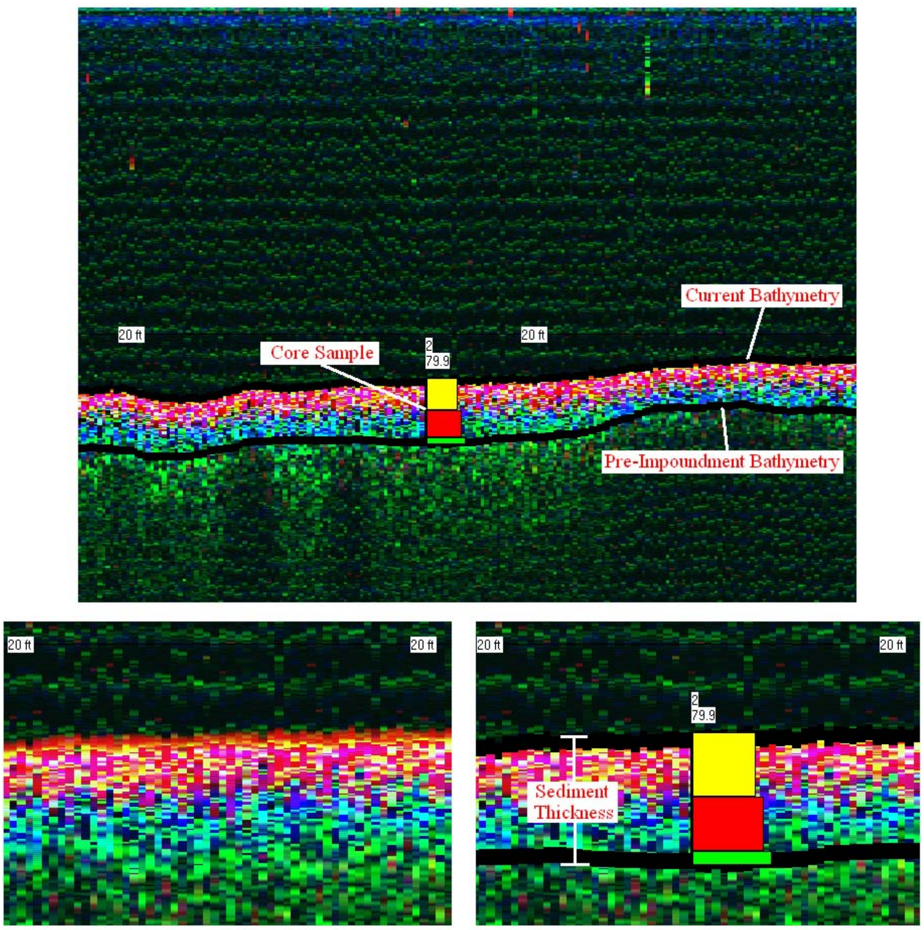


Figure D3 – DepthPic and core sample use in identifying the pre-impoundment bathymetry.

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 W-2, it is clear that the high-moisture content sediment is denoted by the band of pink and red pixels, and then the region of lower moisture content and increasing soil structure (with depth) is denoted by the blue pixel band. The pre-impoundment bathymetric surface for this cross-section is therefore identified as the base of the blue band of pixels, where the pixels in the DepthPic display transition to green. The current bathymetric surface is located at the top of the band of red and pink 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 Lake Weatherford 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 896.0 foot NGVD29 elevation contour).

Results

The results of the TWDB 2008 Sediment Survey indicate Lake Weatherford has accumulated 1,926 acre-feet of sediment since impoundment began in 1957. The thickest sediment deposits are adjacent to the submerged river channel approximately 2 miles upstream from Weatherford Dam. The maximum sediment thickness observed in Lake Weatherford is 4.5 feet. Figure D4 depicts the sediment thickness in Lake Weatherford.

Based on the measured sediment volume in Lake Weatherford and assuming a constant rate of sediment accumulation over the 52 years since impoundment, Lake Weatherford loses approximately 37 acre-feet of capacity per year. To improve the sediment accumulation rate estimates, TWDB recommends Lake Weatherford be re-surveyed using similar methods in approximately 10 years or after a major flood event.

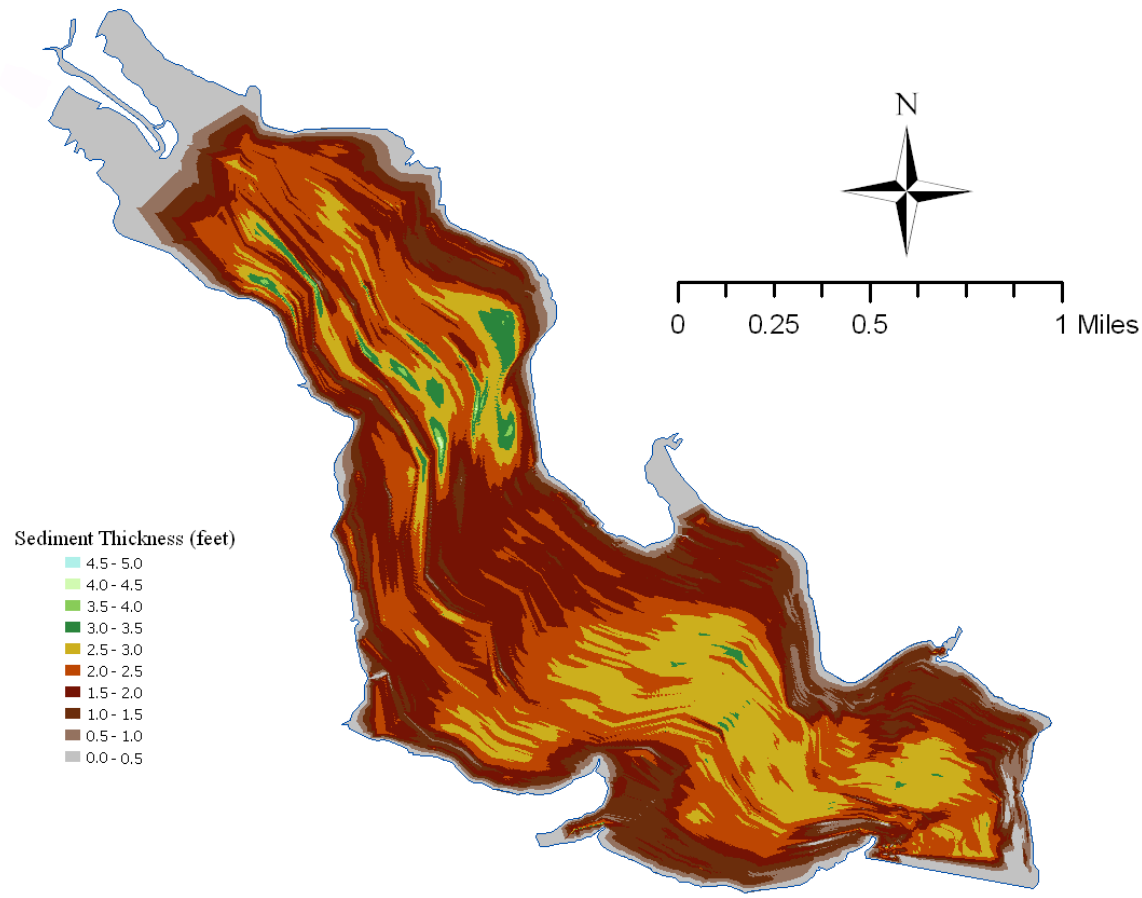


Figure D4 - Sediment thicknesses in Lake Weatherford derived from multi-frequency sounding data.

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 Lake Weatherford

Executive Summary

The Texas Water Development Board (TWDB) conducted surveys of Lake Weatherford in 2008 and 1998. Comparisons of cross-sections generated along established sediment range lines for Lake Weatherford indicate that the pre-impoundment bathymetry derived from the 2008 survey data is largely consistent with the bathymetry derived from the 1998 TWDB survey. Of the four sediment range lines comparisons, two suggest greater sediment accumulation rates occurred between 1957 and 1998, whereas two suggest sediment accumulated at a greater rate between 2008 and 1998. To improve the sediment accumulation rate estimates, TWDB recommends Lake Weatherford 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 Lake Weatherford, and also provides a simple comparison of Lake Weatherford bathymetries as derived from the 2008 and 1998 surveys conducted by TWDB. Comparisons were made on four 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 (1957) 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.

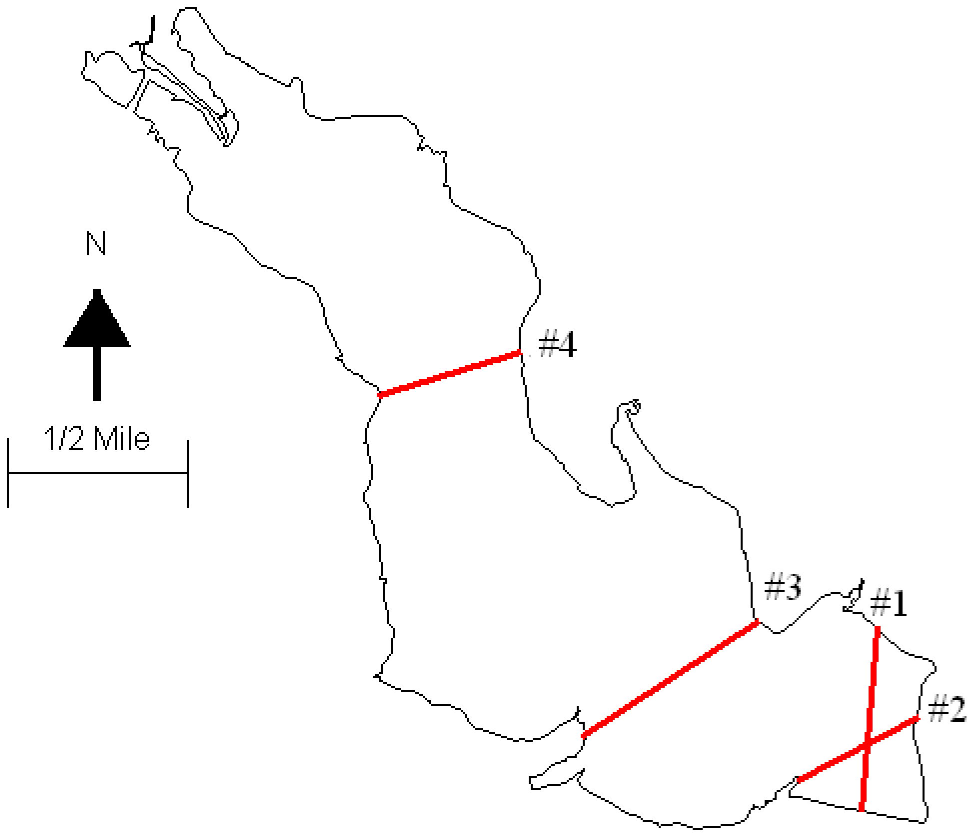


Figure E1 – Lake Weatherford Map showing the location of the four sediment range lines compared in this appendix.

Table E1 – Sediment Range Line Coordinates for Lake Weatherford

	Start Point		End Point		
Range Line	Northing	Easting	Northing	Easting	Length (feet)
1	2223341.63	6967116.77	2223082.35	6964405.12	2686
2	2223952.02	6965814.96	2222137.05	6964869.66	1989
3	2221613.09	6967219.40	2218987.86	6965550.28	3010
4	2218156.00	6971162.64	2216027.73	6970525.24	2500

*** Coordinates referenced to the State Plane (NAD83-Feet) Texas North Central System*

Results

Plots of the 1957, 1998, and 2008 bathymetries of Lake Weatherford are presented in Figures E2-E5. TIN models from which the pre-impoundment (1957) 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 1998 cross-section data was not rectified using the self-similar data interpolation technique. Some of the discrepancies between the 1998 data and the 2008/pre-impoundment data are due to the lack of data interpolation in the 1998 data and TIN model.

In general, the 1998 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 (as shown in Figures E2-E5) does not conclusively indicate an increase or decrease in sediment accumulation rates from 1957 to 1998 and from 1998 to 2008.

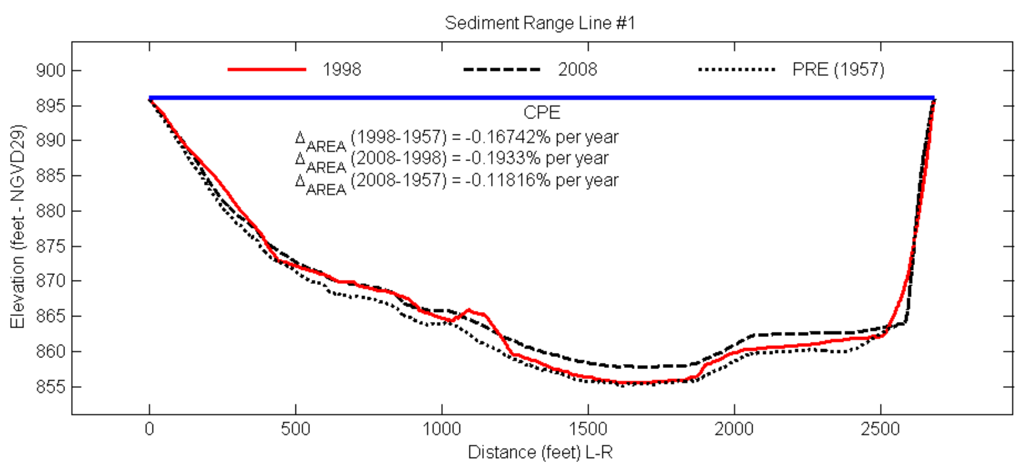


Figure E2– Cross-section plots for sediment range line #1 for Lake Weatherford.

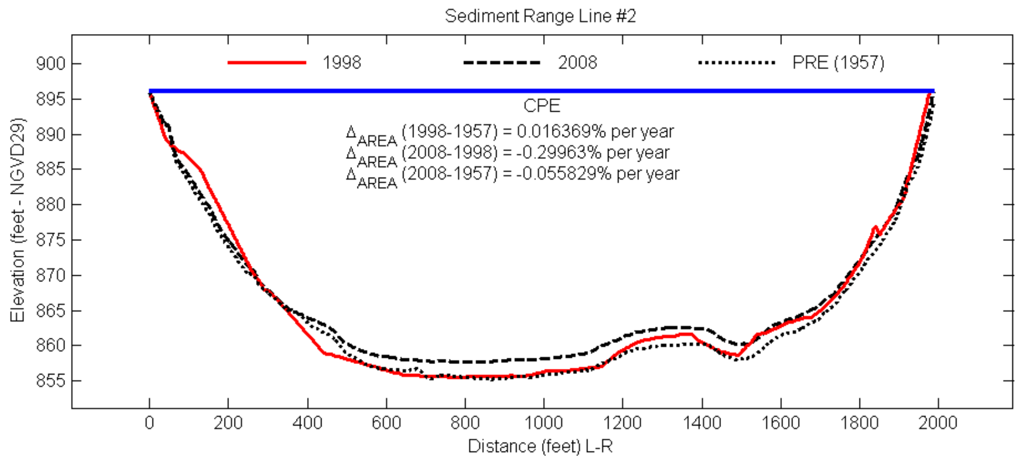


Figure E3– Cross-section plots for sediment range line #2 for Lake Weatherford.

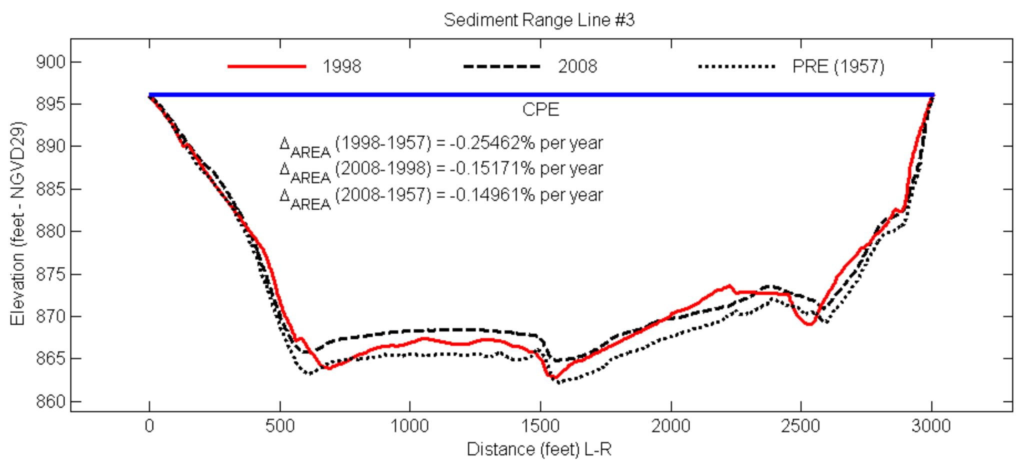


Figure E4– Cross-section plots for sediment range line #3 for Lake Weatherford.

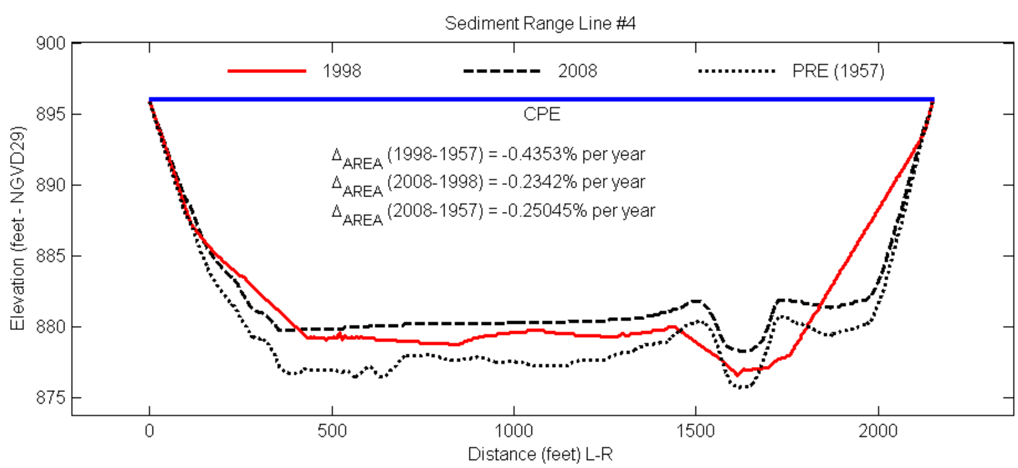
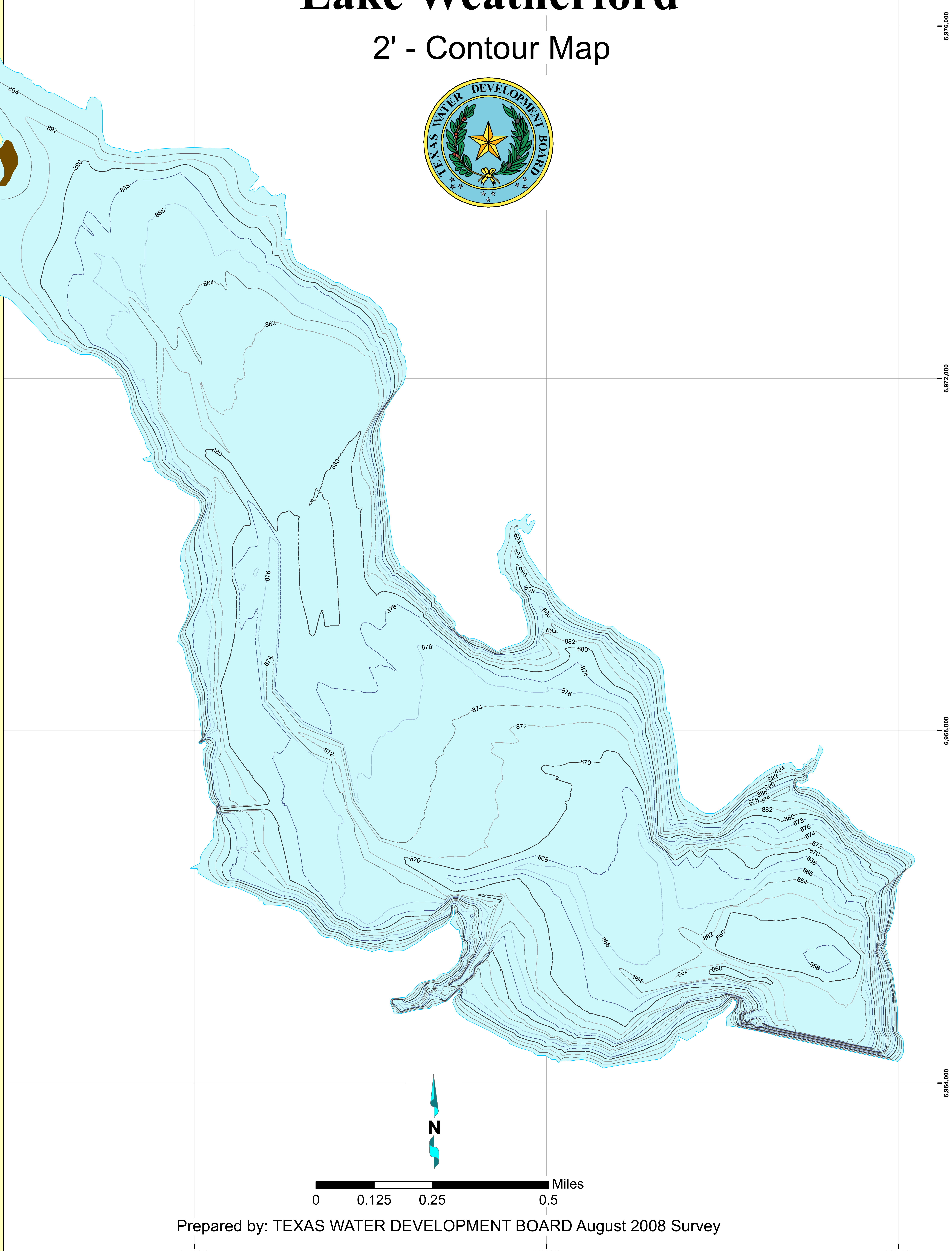


Figure E5– Cross-section plots for sediment range line #4 for Lake Weatherford.

Figure 5

Lake Weatherford

2' - Contour Map

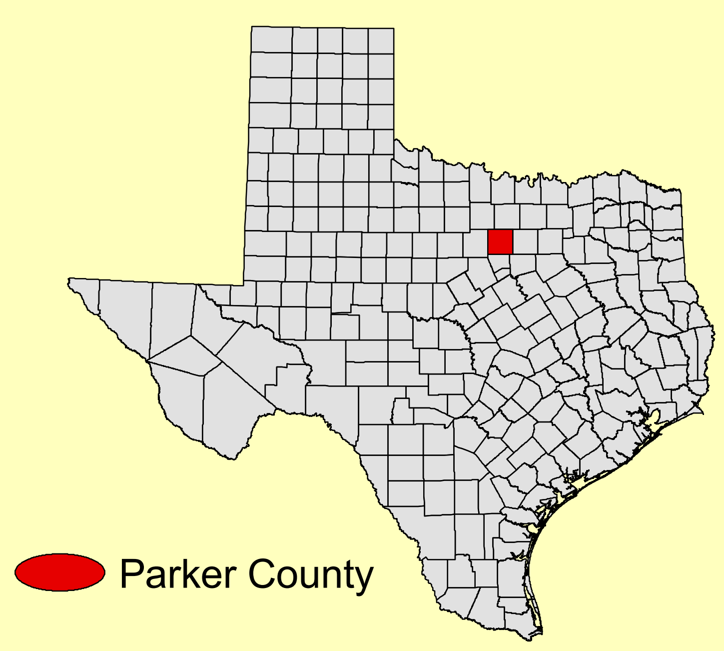


CONTOURS
(in feet above mean sea level)

- 858
- 860
- 862
- 864
- 866
- 868
- 870
- 872
- 874
- 876
- 878
- 880
- 882
- 884
- 886
- 888
- 890
- 892
- 894
- Islands
- Lake Weatherford

Conservation Pool Elevation:
896.0 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 Lake Weatherford. The Texas Water Development Board makes no representation or assumes any liability.

Prepared by: TEXAS WATER DEVELOPMENT BOARD August 2008 Survey