Volumetric and Sedimentation Survey of LAKE FORK RESERVOIR

October 2009 Survey

Prepared by:

The Texas Water Development Board

March 2012

Texas Water Development Board

Prepared for:

Sabine River Authority

With Support Provided by:

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

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Executive summary

In September 2009, the Texas Water Development Board entered into agreement with the U.S. Army Corps of Engineers, Fort Worth District, to perform a volumetric and sedimentation survey of Lake Fork Reservoir. The U.S. Army Corps of Engineers, Fort Worth District, provided 50% of the funding for this survey through their Planning Assistance to States Program, while the Sabine River Authority of Texas provided the remaining 50%. Surveying 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 select locations and correlated with the multi-frequency depth sounder signal returns to estimate sediment accumulation thicknesses and sedimentation rates.

Lake Fork Dam and Lake Fork Reservoir are located on Lake Fork Creek in the Sabine River Basin, approximately five miles west of Quitman, Texas. The conservation pool elevation of Lake Fork Reservoir is 403.0 feet above mean sea level (NGVD29). TWDB collected bathymetric data for Lake Fork Reservoir between July 28, 2009, and November 5, 2009. The daily average water surface elevations during that time ranged between 402.45 and 404.41 feet above mean sea level (NGVD29). Additional data was collected on May 25, 2010, while the daily average water surface elevation measured 403.1 feet above mean sea level.

The 2009 TWDB volumetric survey indicates that Lake Fork Reservoir has a total reservoir capacity of 636,504 acre-feet and encompasses 26,889 acres at conservation pool elevation (403.0 feet above mean sea level, NGVD29). Previous capacity estimates include original design estimate of 675,819 acre-feet at the time of impoundment in 1980, and a re-analysis of the 2001 TWDB volumetric survey data using current processing procedures that resulted in an updated capacity estimate of 645,995 acre-feet.

Based on two methods for estimating sedimentation rates, the 2009 TWDB sedimentation survey estimates Lake Fork Reservoir loses between 1,186 and 1,888 acre-feet per year of capacity due to sedimentation. Sediment accumulation is greater in the Lake Fork Creek branch of the lake than in the Caney Creek branch. The thickest sediment accumulations were found within the submerged river channels. TWDB recommends that a similar methodology be used to resurvey Lake Fork Reservoir in 10 years or after a major flood event.

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

Introduction

The Hydrographic Survey Program of the Texas Water Development Board (TWDB) was authorized by the 72nd Texas 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 September 2009, TWDB entered into agreement with U.S. Army Corps of Engineers, Fort Worth District, to perform a volumetric and sedimentation survey of Lake Fork Reservoir. The U.S. Army Corps of Engineers, Fort Worth District, provided 50% of the funding for this survey through their Planning Assistance to States Program, while the Sabine River Authority of Texas provided the remaining 50% (TWDB, 2009). This report describes the methods used to conduct the volumetric and sedimentation survey, including data collection and processing techniques. This report serves as the final contract deliverable from TWDB to the U.S. Army Corps of Engineers, Fort Worth District and contains as deliverables: (1) an elevation-area-capacity table of the lake acceptable to the Texas Commission on Environmental Quality [Appendix A, B], (2) a bottom contour map [Figure 6], (3) a shaded relief plot of the lake bottom [Figure 4], and (4) an estimate of sediment accumulation and location [Figure 12].

Lake Fork Reservoir general information

Lake Fork Dam and Lake Fork Reservoir are located on the Lake Fork Creek tributary of the Sabine River approximately five miles west of Quitman, Texas (Figure 1). Lake Fork Reservoir inundates parts of Wood, Rains, and Hopkins Counties (SRA, 2011). Lake Fork Reservoir was built primarily as a water supply reservoir for municipal and industrial uses. The Sabine River Authority owns and operates Lake Fork Reservoir and the cities of Dallas and Longview are the primary municipal users (SRA, 2011). The Texas Legislature created the Sabine River Authority in 1949 to be an official agency of the State of Texas (SRA, 2011). As a conservation and reclamation district, the Sabine River Authority is responsible for controlling, storing, preserving, and distributing, for useful purposes, the waters of the Sabine River and its tributary system within the state of Texas.

Construction on Lake Fork Dam began in the fall of 1975 and the dam was completed in February, 1980. Conservation pool elevation was reached in December, 1985 (SRA, 2011). Additional pertinent data about Lake Fork Dam and Lake Fork Reservoir can be found in Table 1.

Water rights for Lake Fork Reservoir have been appropriated to the Sabine River Authority through Certificate of Adjudication and amendment Nos. 05-4669, 05-4669A, 05-4669B, and 05-4669C. The complete certificates are on file in the Information Resources Division of the Texas Commission on Environmental Quality.

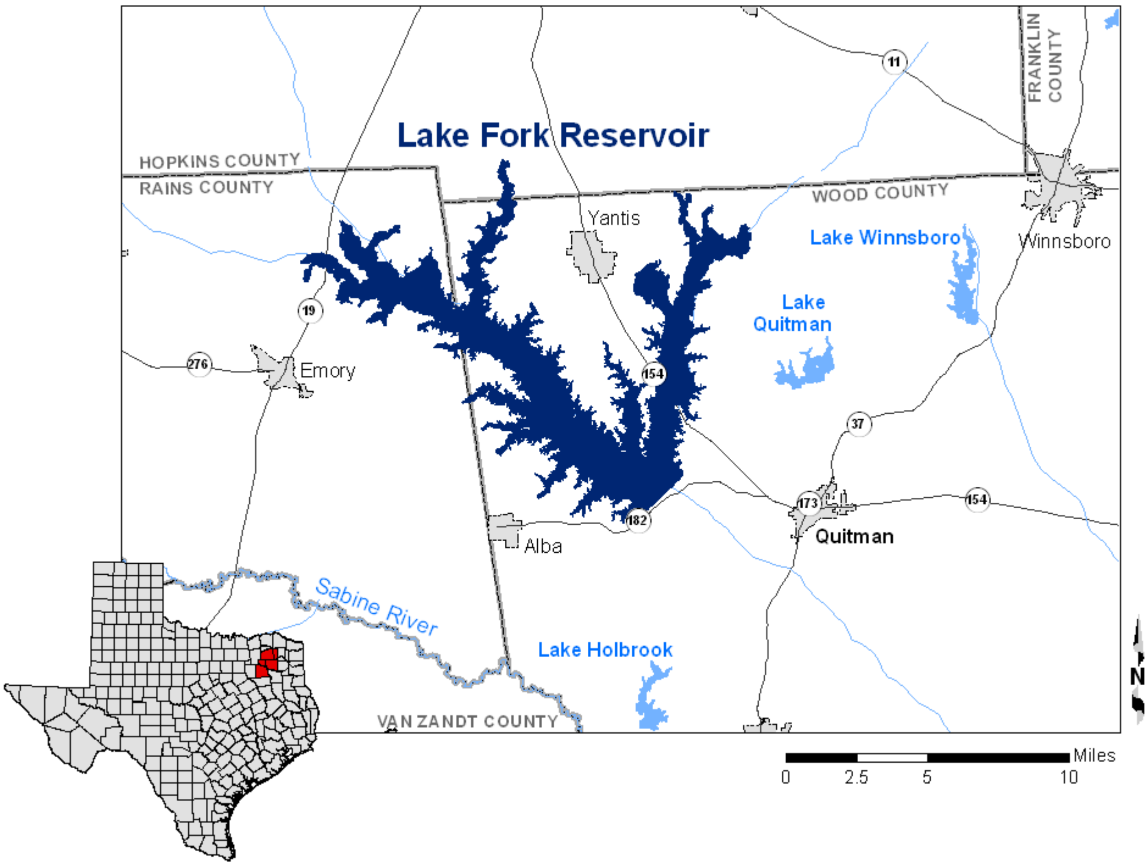

Figure 1. **Location Map – Lake Fork Reservoir**

Table 1. Pertinent Data for Lake Fork Dam and Lake Fork Reservoir

Owner		
	Sabine River Authority	
Engineer		
	Forrest and Cotton Consulting Engineers, Inc.	
Location of Dam		
	On Lake Fork Creek and Caney Creek (Sabine River Basin) in Wood County, 5 miles west of Quitman, Texas, and approximately 70 miles east of Dallas, Texas	
Drainage Area		
	493 square miles	
Dam		
	Type	Rolled-earthfill embankment
	Length	12,410 feet
	Maximum height	60 feet
	Top width	20 feet
	Top elevation	419.5 feet above mean sea level
Spillway		
	Location	Near the northeast end of the dam
	Type	Controlled concrete ogee weir
	Crest length	200 feet
	Crest elevation	385.0 feet above mean sea level
	Control	Sluice gates, spillway consists of 5 bays divided by concrete piers that support 5 tainter gates 40-feet wide by 20-feet tall, 2 center piers are bull nose piers that house two 5 by 8 feet low-flow outlets
	Invert elevation of sluice gates	360.0 feet above mean sea level
	Maximum design discharge	81,900 cubic feet per second
Outlet Works		
	Location	North pier of concrete spillway structure
	Type	Metered release outlets, two 36-inch diameter valve-controlled pipes and one 10-inch valve-controlled pipe

Reservoir Data (Based on 2009 TWDB survey)

Feature	**Elevation (feet NGVD29[a])**	**Capacity (acre-feet)**	**Area (acres)**
Conservation pool elevation	403.0	636,504	26,889
Spillway crest elevation	385.0	263,749	15,366
Invert elevation	360.0	31,443	4,144

Source: (SRA, 2011, TWDB, 2001)
[a] NGVD29 = National Geodetic Vertical Datum 1929

Volumetric and sedimentation survey of Lake Fork Reservoir

Datum

The vertical datum used during this survey is the National Geodetic Vertical Datum 1929 (NGVD29). This datum is also utilized by the United States Geological Survey (USGS) for the reservoir elevation gage *USGS 08018800 Lk Fk Res nr Quitman, TX* (USGS, 2011). Elevations herein are reported in feet above mean sea level relative to the NGVD29 datum. 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), and the horizontal coordinate system is State Plane Texas North Central Zone (feet).

TWDB bathymetric and sedimentation data collection

TWDB collected most of the bathymetric data for the Lake Fork Reservoir survey between July 28, 2009, and November 5, 2009. The daily average water surface elevations during that time ranged between 402.45 and 404.41 feet above mean sea level (NGVD29). Additional data was collected on May 25, 2010, while the daily average water surface elevation measured 403.1 feet above mean sea level. For data collection, TWDB used a Specialty Devices, Inc., single-beam, 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. Many of the survey lines were also surveyed by TWDB during the 2001 survey. 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 2009 survey, team members collected over 404,000 data points over cross-sections totaling approximately 450 miles in length. Figure 2 shows where data collection occurred during the 2009 TWDB survey.

All sounding data was collected and reviewed before sediment core sample sites were selected and sediment cores were collected. Sediment core samples are normally collected at regularly spaced intervals within the lake, or at locations where interpretation of the acoustic display would be difficult without site-specific sediment core data. Following analysis of the sounding data, TWDB selected six locations where sounding data had been previously collected (Figure 3) to collect sediment core samples. The samples were collected on March 16 and 17, 2010, with a custom-coring boat and SDI VibraCore system.

Analysis of the acoustic data collected during the bathymetric survey assists in determining the depth of penetration to which the tube must be driven during sediment sampling. The goal is to collect a core sample extending from the current lake bottom, through the accumulated sediment, and to the pre-impoundment surface. The cores are collected in 3 inch diameter aluminum tubes. After retrieving the sample, a stadia rod is inserted into the top of the tube to assist in locating the top of the sediment in the tube. This identifies the location of the layer corresponding to the current reservoir surface. The aluminum tube is cut to this level, capped, and transported back to TWDB headquarters for further analysis. During this time, some settling of the upper layer can occur.

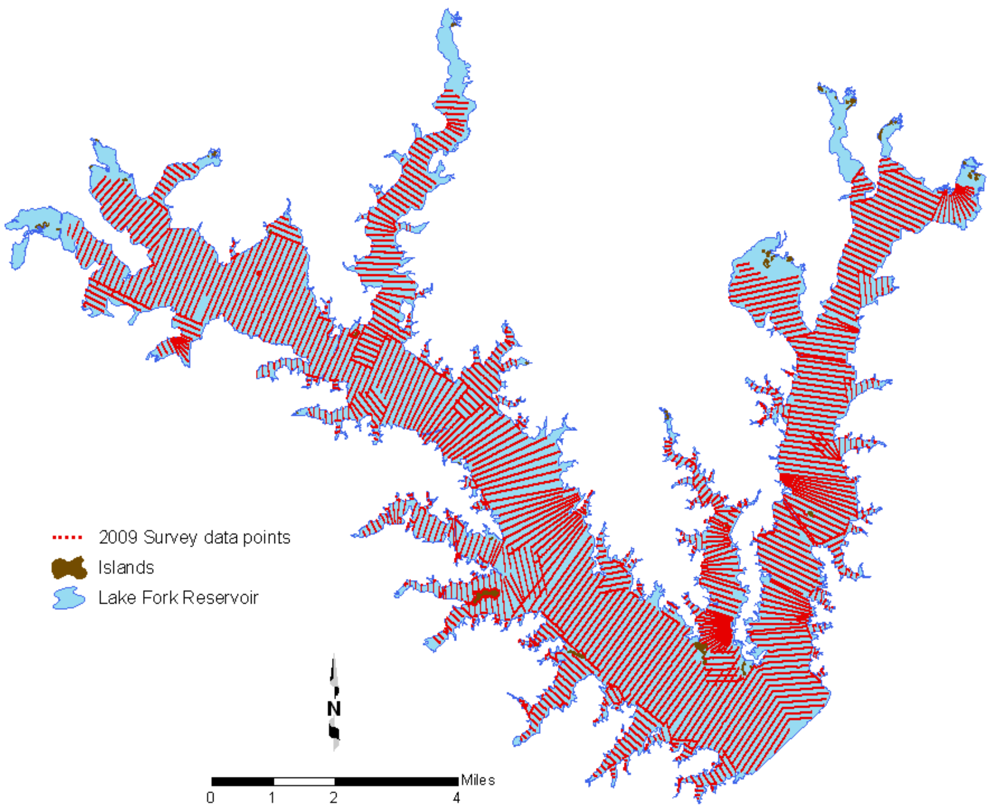

Figure 2. Data collected during 2009 TWDB Lake Fork Reservoir survey

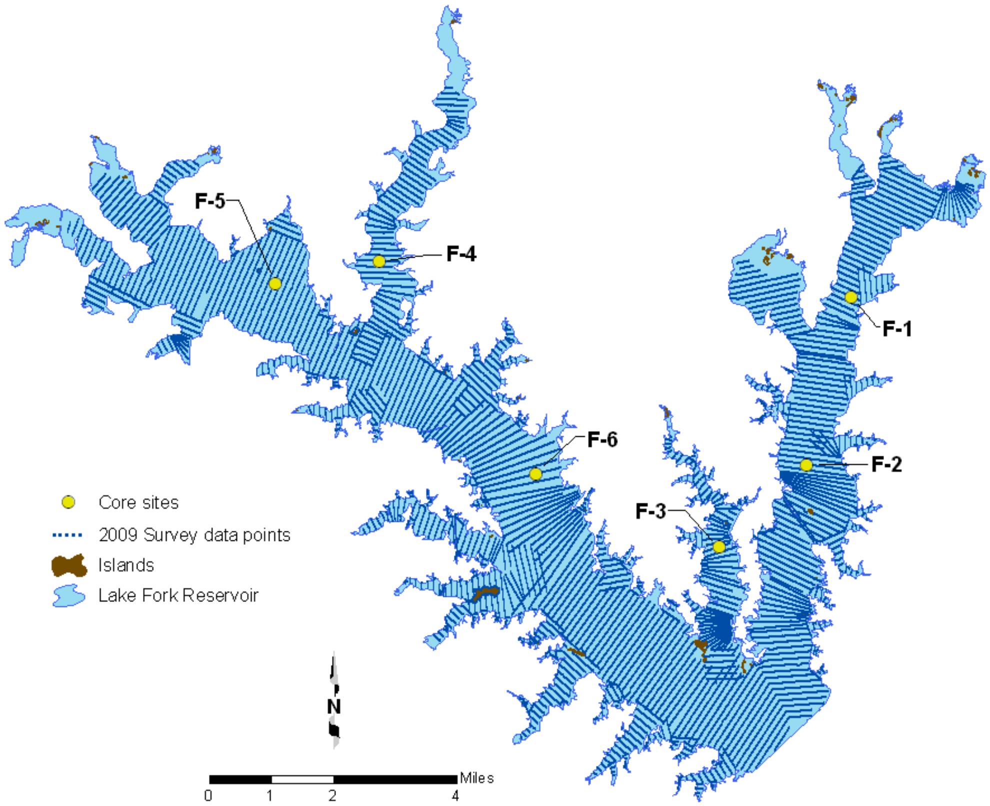

Figure 3. **Locations of sediment core samples relative to the 2009 TWDB survey data**

Data processing

Model boundaries

The reservoir boundary was digitized from aerial photographs, also known as digital orthophoto quarter-quadrangle images (DOQQs), obtained from the Texas Natural Resources Information System (TNRIS, 2012) using Environmental Systems Research Institute's ArcGIS 9.3.1 software. The quarter-quadrangles that cover Lake Fork Reservoir are Arbala (NW, NE, SW, SE), Yantis (NW, NE, SW, SE), Calvary (NW, NE, SW, SE), Pleasant Grove (NW, SW), Emory North (SE), and Alba (NE). The DOQQs were photographed on January 11, 2009, while the daily average water surface elevation measured 402.26 feet above mean sea level. According to the associated metadata, the 2009 DOQQS have a resolution of 0.5-meters with a horizontal accuracy of three to five meters to absolute ground control (TNRIS, 2010). For this analysis, the boundary digitized at the land-water interface in the 2009 photographs is assumed to be a good approximation of the lake boundary at conservation pool elevation. Therefore, the delineated boundary was given an elevation of 403.0 feet above mean sea level to facilitate calculating the area-capacity tables up to the conservation pool elevation.

Triangulated Irregular Network model

Following completion of data collection, the raw data files collected by TWDB were edited using HydroEdit and DepthPic to remove data anomalies. HydroEdit is used to automate the editing of the 200 kHz frequency signal and identify the current reservoir bottom. DepthPic is used to display, interpret, and edit the multi-frequency data and to manually identify the reservoir-bottom surface at the time of initial impoundment (i.e. pre-impoundment surface). The water surface elevation at the time of each sounding was used to convert sounding depths to corresponding reservoir-bottom elevations. For processing outside of DepthPic, the sounding coordinates were exported. Using the self-similar interpolation technique described below (Furnans, 2006), TWDB created additional interpolated bathymetric elevation data between surveyed cross sections. To approximate reservoir bathymetry in shallow, un-surveyed regions, TWDB used the line extrapolation technique described below (Furnans, 2006). The point files resulting from both the data interpolation and extrapolation were exported, and used in conjunction with the sounding and boundary files to create a Triangulated Irregular Network (TIN) model with the 3D Analyst Extension of ArcGIS. The 3D Analyst algorithm uses Delaunay's criteria for triangulation to create a grid composed of triangles from non-uniformly spaced points, including the boundary vertices (ESRI, 1995).

Area, volume, and contour calculations

Using ArcInfo software and the TIN model, volumes and areas were calculated for the entire reservoir at 0.1 feet intervals, from elevation 327.9 to 403.0 feet. The elevation-capacity table and elevation-area table, updated for 2009, are presented in Appendices A and B, respectively. The area-capacity curves are presented in Appendix C.

The TIN model was converted to a raster representation using a cell size of 2 feet by 2 feet. The raster data was then used to produce an elevation relief map (Figure 4) representing the topography of the reservoir bottom, a depth range map (Figure 5) showing shaded depth ranges for Lake Fork Reservoir, and a 5-foot contour map (Figure 6 - attached).

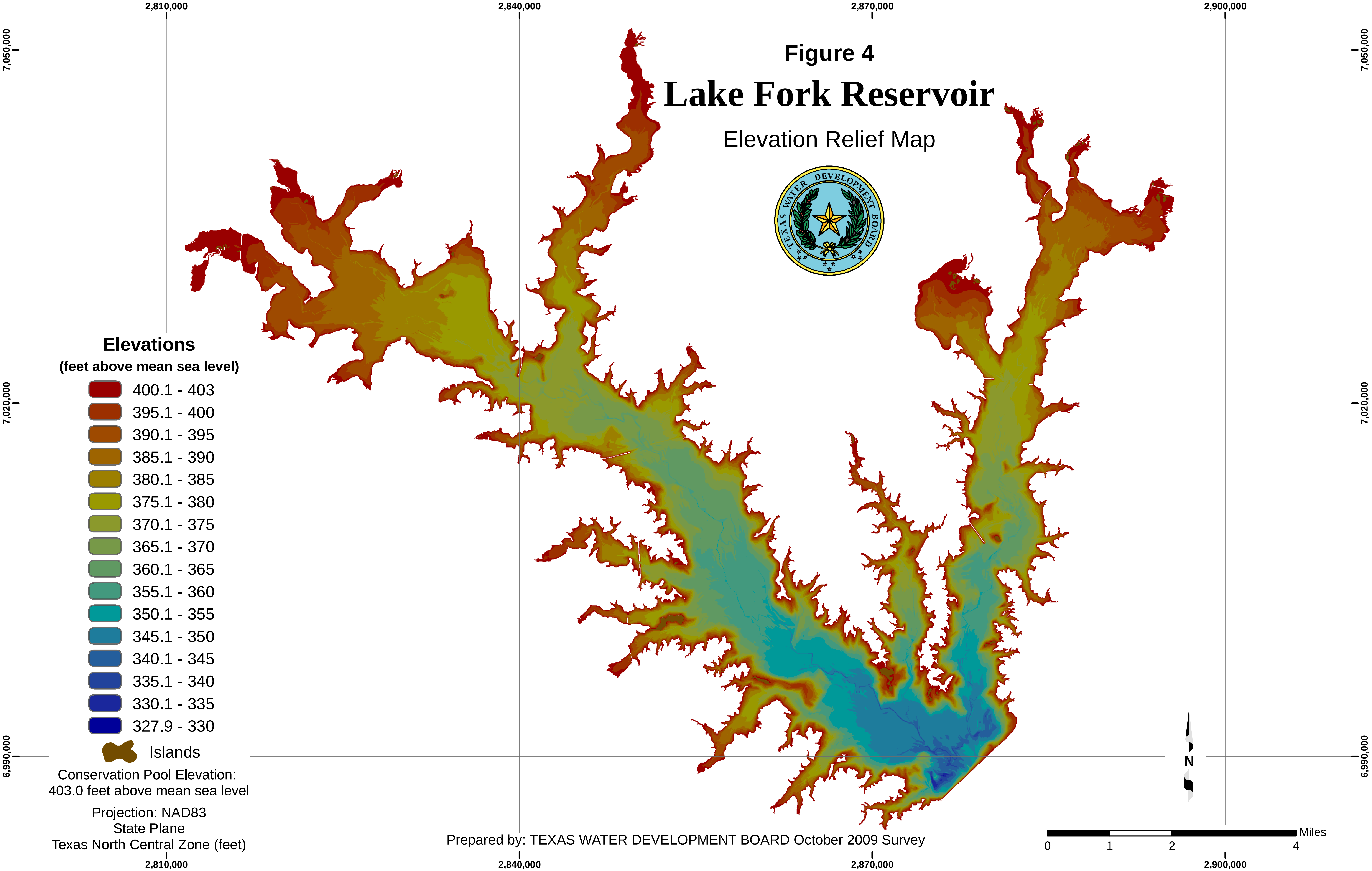
Figure 4
Lake Fork Reservoir
Elevation Relief Map
TEXAS WATER DEVELOPMENT BOARD
Elevations
(feet above mean sea level)
400.1 - 403
395.1 - 400
390.1 - 395
385.1 - 390
380.1 - 385
375.1 - 380
370.1 - 375
365.1 - 370
360.1 - 365
355.1 - 360
350.1 - 355
345.1 - 350
340.1 - 345
335.1 - 340
330.1 - 335
327.9 - 330
Islands
Conservation Pool Elevation:
403.0 feet above mean sea level
Projection: NAD83
State Plane
Texas North Central Zone (feet)
Prepared by: TEXAS WATER DEVELOPMENT BOARD October 2009 Survey
N
0
1
2
4
Miles
2,810,000
2,840,000
2,870,000
2,900,000
7,050,000
7,020,000
6,990,000

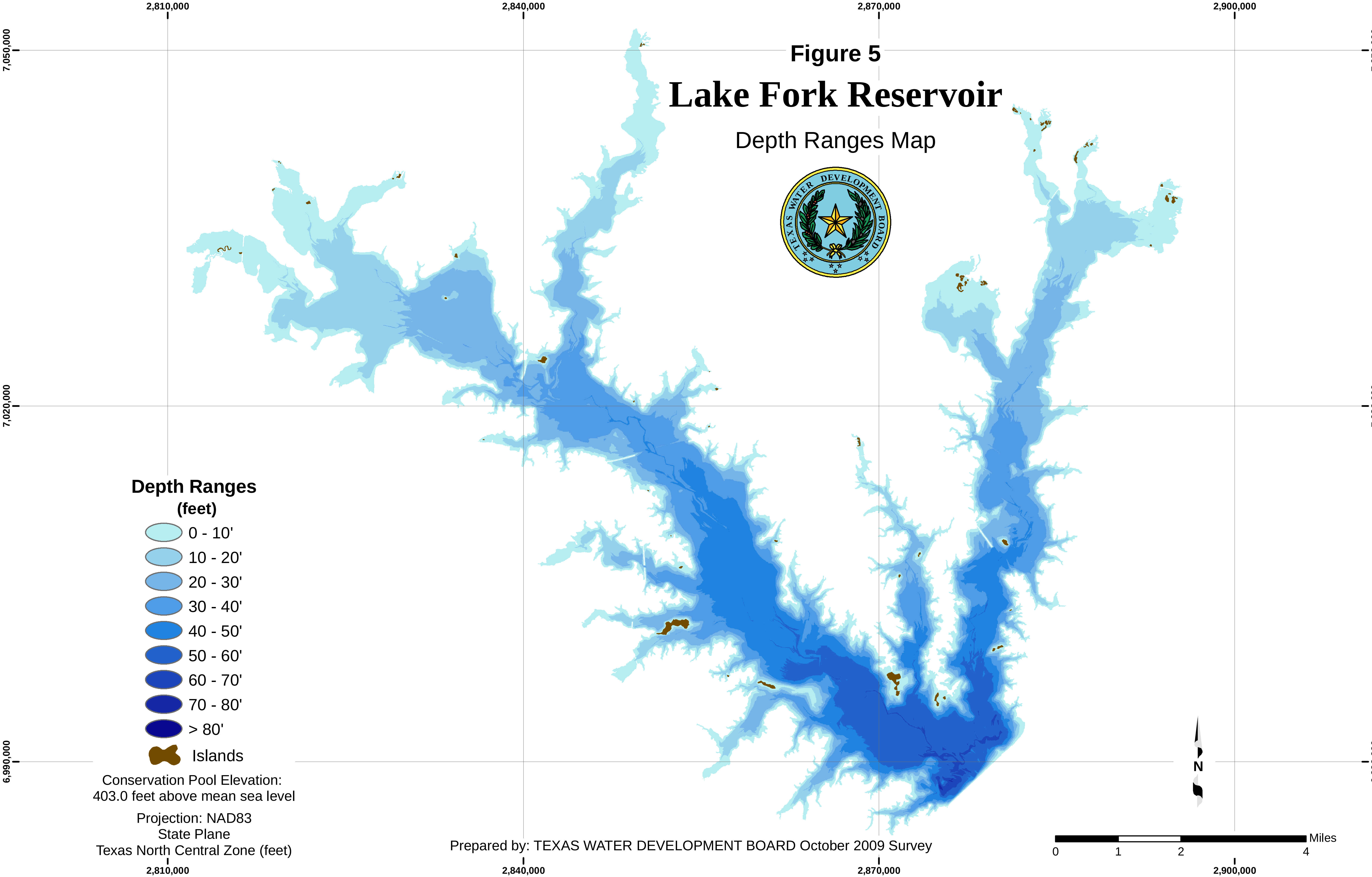
Figure 5
Lake Fork Reservoir
Depth Ranges Map
TEXAS WATER DEVELOPMENT BOARD
Depth Ranges
(feet)
0 - 10'
10 - 20'
20 - 30'
30 - 40'
40 - 50'
50 - 60'
60 - 70'
70 - 80'
> 80'
Islands
Conservation Pool Elevation:
403.0 feet above mean sea level
Projection: NAD83
State Plane
Texas North Central Zone (feet)
Prepared by: TEXAS WATER DEVELOPMENT BOARD October 2009 Survey
2,810,000
2,840,000
2,870,000
2,900,000
7,050,000
7,020,000
6,990,000
N
Miles
0
1
2
4

Self-similar interpolation

The 3D Analyst extension of ArcGIS utilizes the Delaunay method for triangulation. 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), the TIN model is not likely to represent the true channel bathymetry well.

To ameliorate these problems, a self-similar interpolation routine developed by TWDB was used to interpolate the bathymetry between many survey lines. The self-similar interpolation technique increases the density of points input into the TIN model, and directs the TIN interpolation to better represent the reservoir topography between cross sections (Furnans, 2006). In the case of Lake Fork Reservoir, application of self-similar interpolation improved representation of the lake morphology near the banks and submerged river channels (Figure 7). In areas where obvious geomorphic features indicate a high-probability of cross-sectional shape changes (e.g. incoming tributaries, significant widening/narrowing of channel, etc.), the assumptions used in applying self-similar interpolation are not likely to be valid. Therefore, interpolation was not used in areas of Lake Fork Reservoir where a high probability of change between cross-sections exists. Figure 7 illustrates typical results from the self-similar interpolation routine for Lake Fork Reservoir. The bathymetry shown in Figure 7C was used in computing reservoir capacity and area tables (Appendix A, B).

In Figure 7A the deeper channels indicated by the surveyed cross sections are not continuously represented in the areas between survey cross sections. This is an artifact of the TIN generation routine, rather than an accurate representation of the physical bathymetric surface. Inclusion of interpolation points, represented in Figure 7B, in creation of the TIN model directs the Delaunay method for triangulation to better represent the lake bathymetry between survey cross-sections.

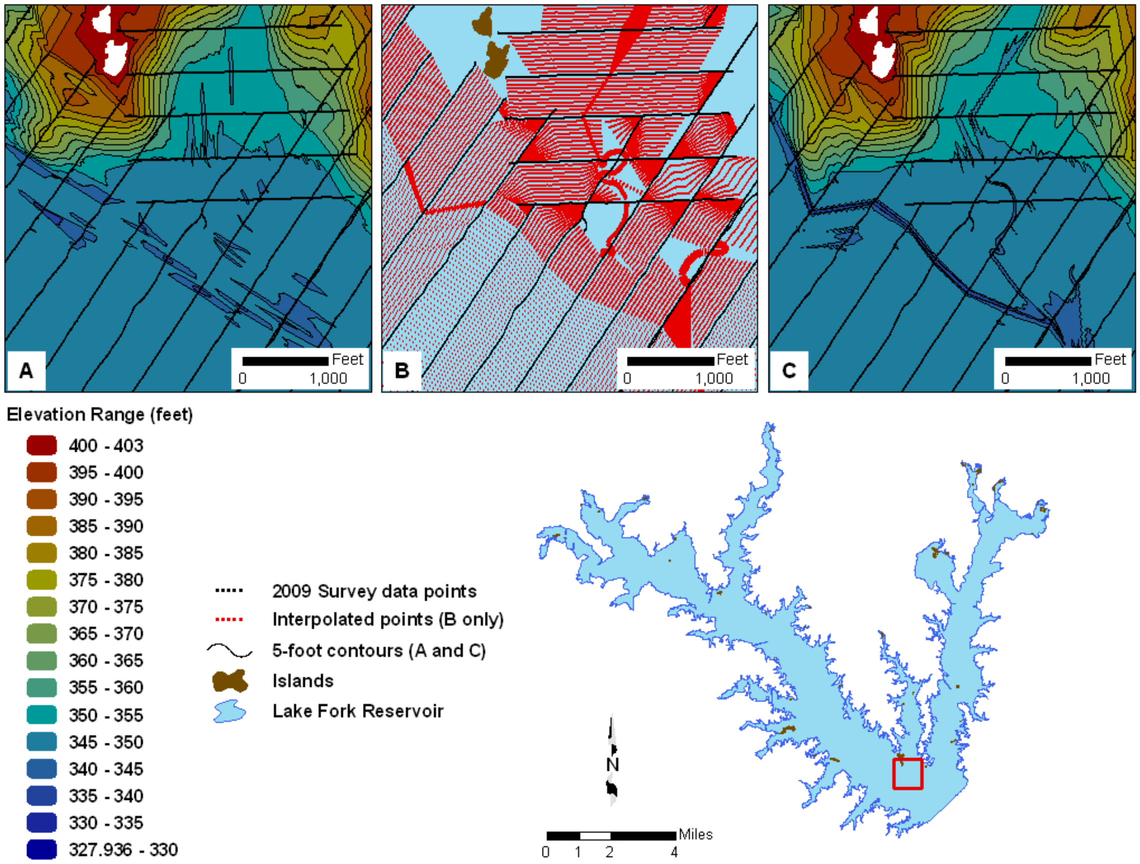

Figure 7. **Application of the self-similar interpolation technique to Lake Fork Reservoir sounding data – A) bathymetric contours without interpolated points, B) sounding points (black) and interpolated points (red), C) bathymetric contours with the interpolated points**

Line extrapolation

In order to estimate the bathymetry within the small coves and other un-surveyed portions of Lake Fork Reservoir, TWDB applied a line extrapolation technique similar to the interpolation discussed above. TWDB uses line extrapolation to project bathymetries in small coves or where water depths are too shallow to allow boat passage. Line extrapolation requires the user to define (1) a center line approximately bisecting the small cove, (2) the elevation at the beginning of the center line, (3) the number of cross sections along the center line, and (4) the number of points between the center line and the cove boundary. The starting elevation of the center line is estimated based on the nearest surveyed depth.

Line extrapolation assumes a V-shaped profile for cross-sections within the extrapolation area, with the deepest section of the profile located along the center line. Elevations along the center line are linearly interpolated based on the distance along the line from the start (nearest the reservoir interior) to the end (where the center line crosses the reservoir boundary). The elevations at points along each extrapolated cross-section are linearly interpolated from an elevation on the center line (at the intersection with the cross-section) and the elevation at the extrapolation area boundary. Figure 8 illustrates line extrapolation as applied to Lake Fork Reservoir.

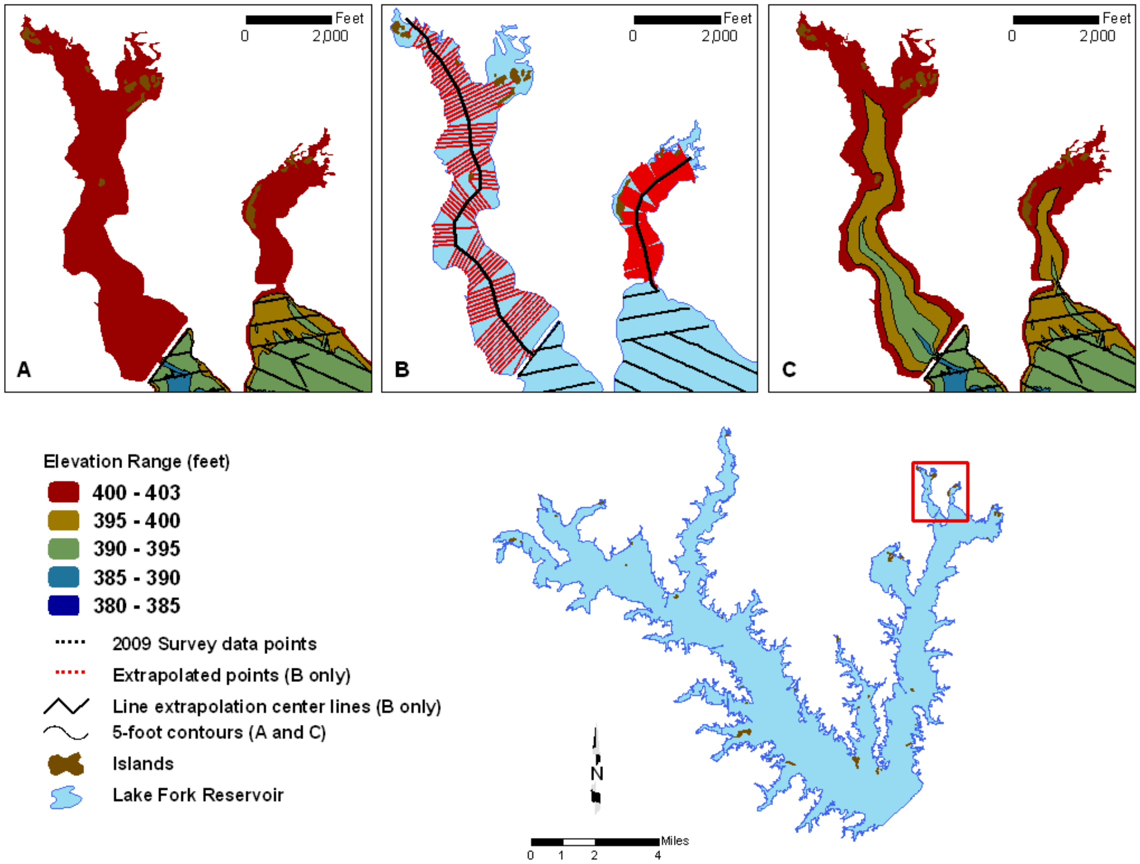

Figure 8. **Application of the line extrapolation technique to Lake Fork Reservoir sounding data – A) bathymetric contours without extrapolated points, B) Sounding points (black), extrapolated points (red), with reservoir boundary shown at elevation 403.0 feet, and C) bathymetric contours with extrapolated points**

As shown in Figure 8A, 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 model generation routine when data points are too far apart or are absent from portions of the reservoir.

The inherent assumption of line extrapolation is that a V-shaped cross section is a reasonable approximation of the actual unknown cross-section within the extrapolated area. 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 Fork Reservoir had shapes more similar to U-profiles than to V-profiles. The V-profiles are thus conservative due to a greater implied volume of water for a U-profile when compared to a V-profile. Further information on line extrapolation is provided in the HydroEdit User's Manual (Furnans, 2006).

Analysis of sediment data from Lake Fork Reservoir

Sedimentation in Lake Fork Reservoir was determined by analyzing all three depth sounder frequencies in the DepthPic software. The 200 kHz signal was used to determine the current bathymetric surface of the lake, while the 50 kHz and 24 kHz frequencies were used to determine the reservoir bathymetric surface at the time of initial impoundment (i.e. pre-impoundment surface). Sediment core samples collected in the lake were used to assist in identifying the location of the pre-impoundment surface in the acoustic signals. The difference between the current surface and the pre-impoundment surface yields a sediment thickness value at each sounding location.

Analysis of the core samples was conducted at TWDB headquarters in Austin. Each sample was split longitudinally and analyzed to identify the location of the pre-impoundment surface. The pre-impoundment surface is identified within the sediment core sample by one of the following methods: (1) a visual examination of the sediment 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 (Van Metre et al, 2004). The total sample length, sediment thickness and the pre-impoundment thickness were recorded. Physical characteristics of the sediment core, including color, texture, relative water content, and presence of organic materials, were also recorded (Table 2).

Table 2. Sediment core sampling analysis data – Lake Fork Reservoir

Core	Easting[a] (ft)	Northing[a] (ft)	Total core sample/ post-impoundment sediment	Core description	Munsell soil color
F-1	2884178.05	7026847.73	44"/25"	0-25" loam, gelatinous consistency, high water content, no soil structure (peds)	5Y 3/2
				25-44" decreased water content, increased soil structure, clay loam, organics at 25" and 30", wood pieces at 32"	5Y 4/1 w/ 5Y 4/4 20%
F-2	2880330.27	7012438.46	30"/24"	0-24" loam, gelatinous texture, high water content, no soil structure	gley 1 3/5G
				24-30" clay loam, major increase in soil structure, organics at 25" and 29", decreased water content	5Y 4/1
F-3	2872847.65	7005401.38	44"/32"	0-32" high water content, loam, no soil structure, gelatinous texture	gley 1 3/5G
				32-44" silt, low water content, increased soil structure (silt peds), root material at 36"	5Y 4/1
F-4	2843668.05	7029923.67	39"/30"	0-30" loam, high water content, root material at 12", no structure	5Y 4/1
				30-39" clay loam, slight decrease in water content, high soil structure, large defined peds, roots/ organics at 17", 30", and 33"	5Y 5/1
F-5	2834741.64	7011637.36	23"/14"	0-14" loam, high water content, no structure	2.5Y 3/1
				14-23" loamy clay, high soil structure, abundant organics from 14-20", decreased water content	2.5Y 2/1
F-6	2857122.33	7023817.07	50"/35"	0-35" fine sandy loam, high water content, low soil structure	5Y 3/1
				35-50" high soil structure, clay loam, decreased water content, root material at 36"	2.5Y 4/1

[a] Coordinates are based on NAD83 State Plane Texas North Central System (feet)

A photograph of sediment core F-6 is shown in Figure 9 and is representative of the sediment cores sampled from Lake Fork Reservoir. The 200 kHz frequency measures the top layer as the current bottom surface of the reservoir.

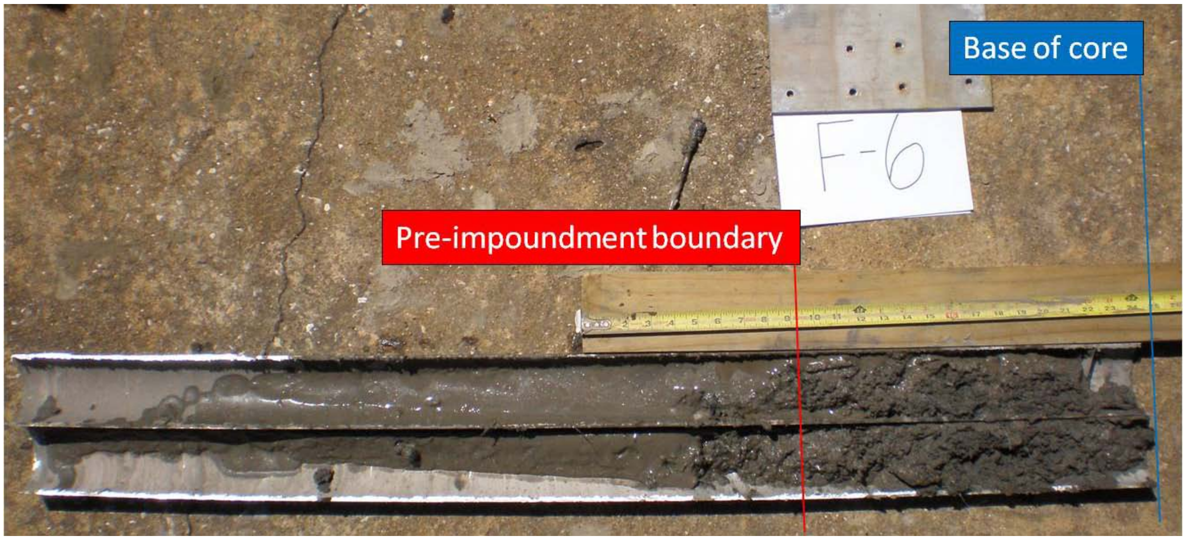

Figure 9. Sediment Core F-6 from Lake Fork Reservoir

Sediment core sample F-6 consisted of 50 inches of total sediment corresponding to the length of the aluminum sampling tube (tape measure is shown for scale). The upper sediment layer (horizon), 0 – 35 inches, had high water content, low soil structure, consisted of fine sandy loam, and was a 5Y 3/1 color on the Munsell soil color chart. The second horizon, beginning at 35 inches and extending to 50 inches below the surface, consisted of a 2.5Y 4/1 Munsell soil color, clay loam, lower water content, and well defined soil structure. The base of the sample is denoted by the blue line in Figure 9.

The pre-impoundment boundary (red line in Figure 9) was evident within this sediment core sample at 35 inches and is identified by the change in soil color, texture, moisture, porosity, and structure. Identification of the pre-impoundment surface for the remaining sediment cores followed a similar procedure.

Figures 10 and 11 illustrate how the sediment thickness identified from a sediment core sample is used with the sounding data to help identify the post-impoundment sediment interface in the acoustic signal. Within DepthPic, the current surface is automatically determined based on the signal returns from the 200 kHz transducer and verified by TWDB staff, while the pre-impoundment surface must be determined visually.

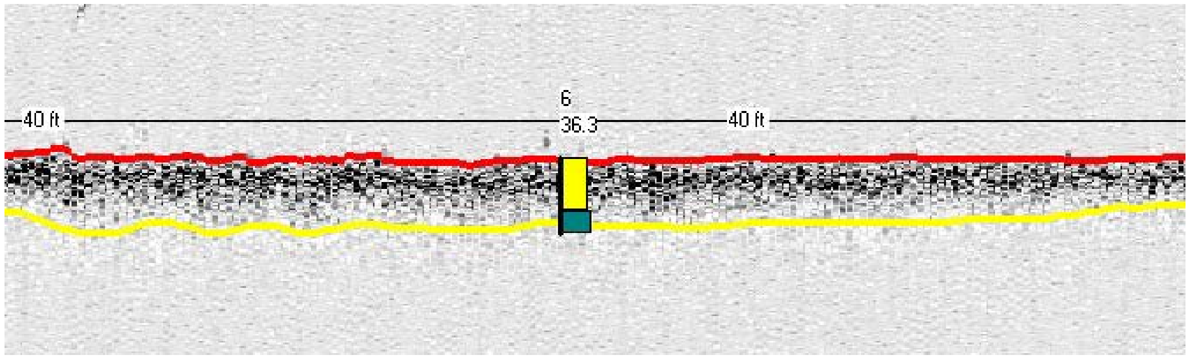

Figure 10. Cross-section of data collected during 2009 survey, displayed in DepthPic (50 kHz frequency), correlated with sediment core sample F-6 and showing the current surface in red and pre-impoundment surface in yellow

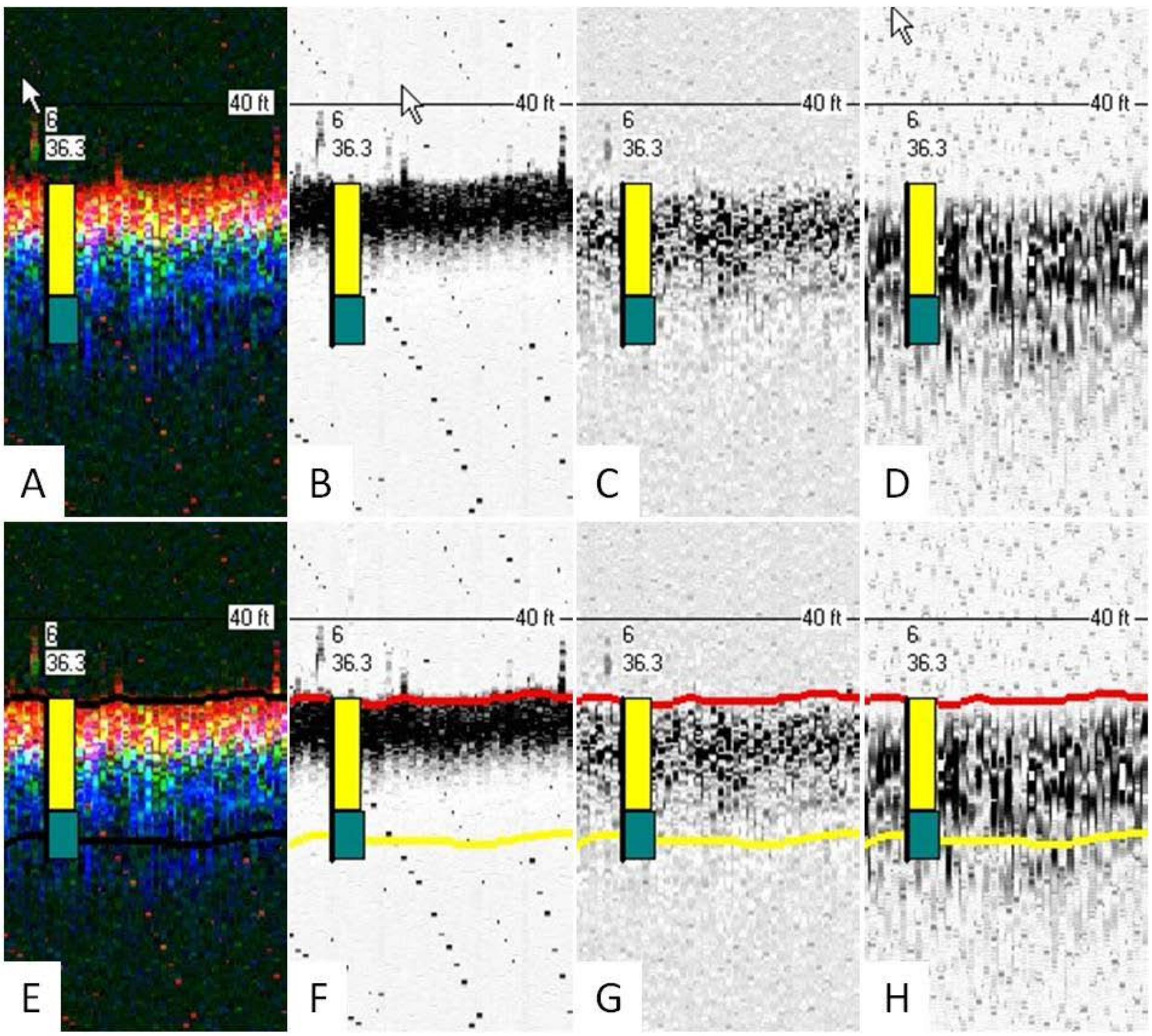

Figure 11. Comparison of sediment core F-6 with acoustic signal returns A,E) combined acoustic signal returns, B,F) 200 kHz frequency, C,G) 50 kHz frequency, D,H) 24 kHz frequency

Figure 11 shows the acoustic signals for all frequencies combined (A, E), 200 kHz (B, F), 50 kHz (C, G), and 24 kHz (D, H). The sediment core sample is represented in each figure as colored boxes. The yellow box represents post-impoundment sediment, and is 35 inches in length based on analysis of Sample F-6 (Figure 9, Table 2).The blue box represents the pre-impoundment sediment with a well defined soil structure. In figure 11A-D, the bathymetric surfaces are not shown. In figure 11E, the current bathymetric surface is represented as the top black line and in Figures 11 F-H as the top red line. The pre-impoundment surface is visually identified by comparing boundaries observed in the 50 kHz and 24 kHz signals to the location of the pre-impoundment surface based on the core sample (designated by the location of the interface between the yellow and blue boxes). In this example, the boundary in the 50 kHz signal most closely matched the pre-impoundment interface based on the core sample, so the 50 kHz signal was used to locate the pre-impoundment layer. The pre-impoundment surface was manually drawn in and is represented by the bottom black line in Figure 11E, and by the yellow line in Figures 11F-H. The pre-impoundment surface identified along cross-sections where sediment core samples were collected is used as a guide for identifying the pre-impoundment surface along cross-sections where sediment core samples were not collected.

After manually digitizing the pre-impoundment surface from all cross-sections, a sediment thickness TIN model is created following standard GIS techniques (Furnans, 2007). Sediment thicknesses were interpolated between surveyed cross-sections using the TWDB self-similar interpolation technique (Furnans, 2006). For the purposes of the TIN model creation, TWDB assumed sediment thickness at the model boundary was zero feet (defined as the 403.0 foot NGVD29 elevation contour). This TIN model was converted to a raster representation using a cell size of 5 feet by 5 feet and used to produce a sediment thickness map (Figure 12) representing sediment accumulation throughout Lake Fork Reservoir.

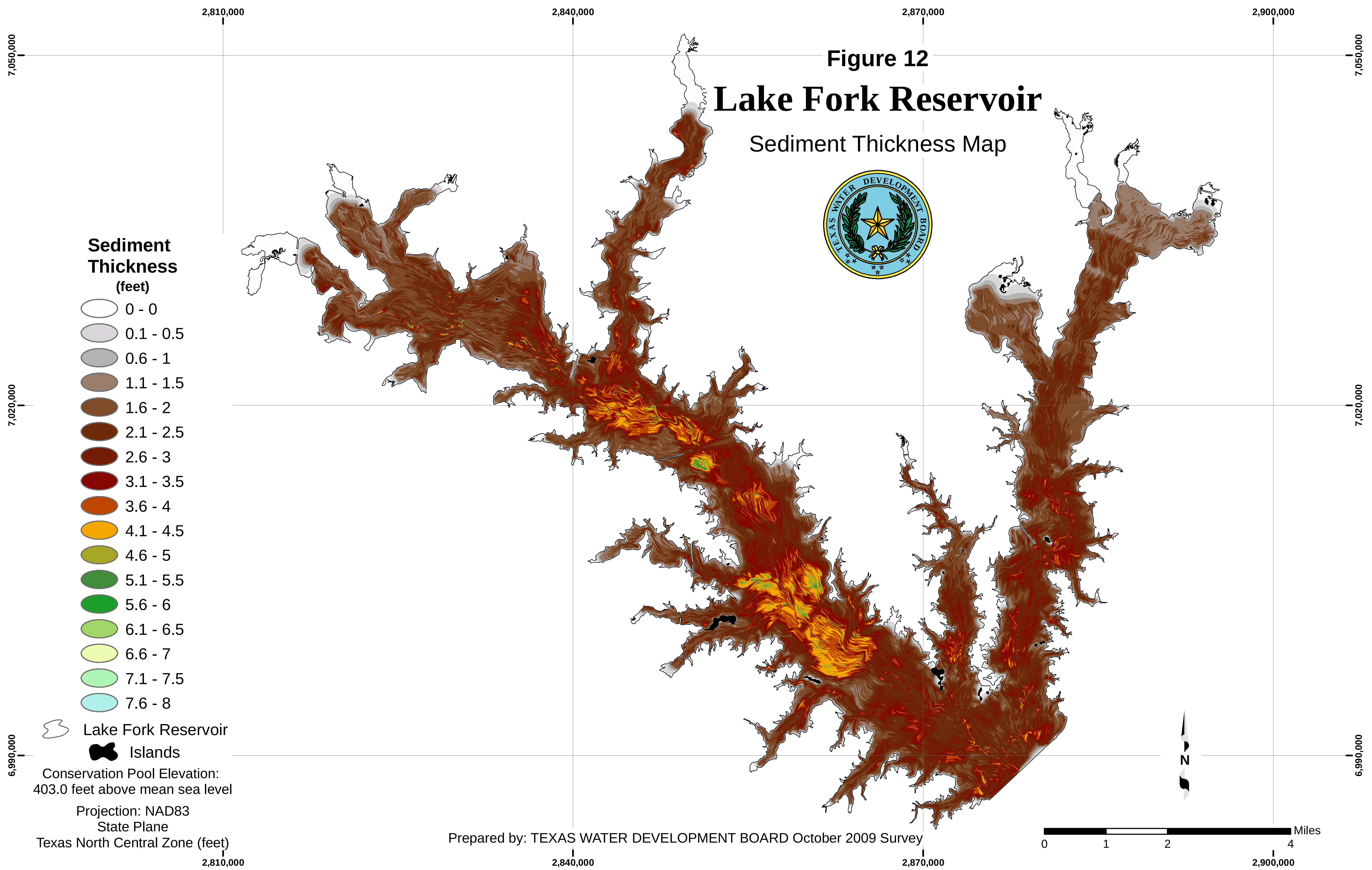

Figure 12
Lake Fork Reservoir
Sediment Thickness Map
TEXAS WATER DEVELOPMENT BOARD
Sediment Thickness (feet)
0 - 0
0.1 - 0.5
0.6 - 1
1.1 - 1.5
1.6 - 2
2.1 - 2.5
2.6 - 3
3.1 - 3.5
3.6 - 4
4.1 - 4.5
4.6 - 5
5.1 - 5.5
5.6 - 6
6.1 - 6.5
6.6 - 7
7.1 - 7.5
7.6 - 8
Lake Fork Reservoir
Islands
Conservation Pool Elevation: 403.0 feet above mean sea level
Projection: NAD83
State Plane
Texas North Central Zone (feet)
Prepared by: TEXAS WATER DEVELOPMENT BOARD October 2009 Survey
N
Miles
0
1
2
4
2,810,000
2,840,000
2,870,000
2,900,000
7,050,000
7,020,000
6,990,000

Survey results

Volumetric survey

The results of the 2009 TWDB volumetric survey indicate Lake Fork Reservoir has a total reservoir capacity of 636,504 acre-feet and encompasses 26,889 acres at conservation pool elevation (403.0 feet above mean sea level, NGVD29). The Sabine River Authority in 1980 estimated that the Lake Fork Reservoir had a total capacity of 675,819 acre-feet and encompassed 27,690 acres at conservation pool elevation (TWDB, 2001). Differences in past and present survey methodologies make direct comparison of volumetric surveys difficult and potentially unreliable.

To properly compare results from TWDB surveys of Lake Fork Reservoir, TWDB applied the 2009 data processing techniques to the survey data collected in 2001. Specifically, TWDB applied the self-similar interpolation and line extrapolation techniques to the 2001 survey dataset (Furnans, 2006). A revised TIN model was created using the original 2001 survey boundary. The 2001 survey boundary was digitized from DOQQs photographed on February 2, 1995, and February 8, 1995, while the daily average water surface elevation measured 402.84 feet and 402.54 feet above mean sea level. According to the associated metadata, the 1995 aerial photographs have a resolution of 1-meter. The boundary digitized at the land-water interface was assumed to be a good approximation of the lake at conservation pool elevation and was given the elevation 403.0 to facilitate calculating the area-capacity tables up to conservation pool elevation. Revision of the 2001 survey using current TWDB data processing methods resulted in a 9,862 acre-feet (1.6%) increase in reservoir capacity (Table 3).

Table 3. Current and previous survey capacity and surface area data

Survey	Surface area (acres)	Capacity (acre-feet)
SRA 1980 [a]	27,690	675,819
TWDB 2001	27,264	636,133
TWDB 2001 revised	27,246	645,995
TWDB 2009	26,889	636,504

[a] Source: (TWDB, 2001)

Sedimentation survey

Based on two methods for estimating sedimentation rates, the 2009 TWDB sedimentation survey estimates Lake Fork Reservoir loses between 1,186 and 1,888 acre-feet per year of capacity due to sedimentation (Table 4). Sediment accumulation is dispersed throughout the lake, though deposits in the Lake Fork Creek branch of the reservoir are thicker than in the Caney Creek branch of the reservoir. The thickest sediment deposits are in the submerged river channels.

In principle, comparing lake volumes from multiple lake surveys allows for calculation of capacity loss rates. If all lost capacity is due to sediment accumulation, then comparisons of lake volumetric surveys would yield sediment accumulation rates. In practice, however, the differences in methodologies used in each lake survey may yield greater differences in computed lake volumes than the true volume differences. In addition, because volumetric surveys are not exact, small losses or gains in sediment may be masked by the imprecision of the computed volumes. For this reason, TWDB prefers to estimate sediment accumulation rates through sedimentation surveys, which directly measure the sediment layer thicknesses throughout the reservoir. The sediment accumulation rates derived from such surveys reflect the average rate of sediment accrual since the time of impoundment.

For informational purposes only, a capacity loss rate, i.e. sedimentation rate, was calculated based on the difference between the current volumetric survey and the original design estimate; the current capacity estimation and the 2009 pre-impoundment capacity estimation (i.e. based on the 2009 estimated sediment volume); as well as the current volumetric capacity estimation and the revised 2001 volumetric capacity estimation (Table 4). Based on the 2009 estimated sediment volume, Lake Fork Reservoir lost an average of approximately 1,888 acre-feet of capacity per year from 1980 to 2009. Comparison 3 in the Table 4 compares the current volumetric survey to the 2001 revised volumetric survey. This comparison suggests the current rate of sedimentation in Lake Fork Reservoir is approximately 1,186 acre-feet per year. Comparison of capacity estimates of Lake Fork Reservoir derived using differing methodologies are provided in Table 4 for sedimentation rate calculation; however, direct measurement of sediment accumulation and subsequent calculation of sedimentation rates is recommended.

Table 4. Capacity loss comparisons for Lake Fork Reservoir

Survey	Volume comparisons @ CPE (acre-ft)		Pre-impoundment (acre-ft)
	Comparison #1	Comparison #2	Comparison #3
Original design estimate[a]	675,819	<>	<>
TWDB pre-impoundment based on 2009 estimated sediment volume	<>	<>	691,255[b]
2001 TWDB volumetric survey (revised)	<>	645,995	<>
2009 volumetric survey	636,504	636,504	636,504
Volume difference (acre-feet)	39,315 (5.8%)	9,491 (1.5%)	54,751 (7.9%)
Number of years	29	8	29
Capacity loss rate (acre-feet/year)	1,356	1,186	1,888

[a] Source: (SRA, 2011, TWDB, 2001), note: Lake Fork Dam was completed, and deliberate impoundment began, in February, 1980.
[b] 2009 TWDB surveyed capacity of 636,504 acre-feet plus 2009 TWDB surveyed sediment volume of 54,751 acre-feet.

Recommendations

To improve estimates of sediment accumulation rates, TWDB recommends resurveying Lake Fork Reservoir in approximately 10 years or after a major flood event. To further improve estimates of sediment accumulation, TWDB recommends another sedimentation survey. A re-survey would allow a more accurate quantification of the average sediment accumulation rate for Lake Fork Reservoir.

TWDB contact information

More information about the Hydrographic Survey Program can be found at:
http://www.twdb.texas.gov/assistance/lakesurveys/volumetricindex.asp
Any questions regarding the TWDB Hydrographic Survey Program may be addressed to:

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Appendix A

Lake Fork Reservoir

RESERVOIR CAPACITY TABLE

TEXAS WATER DEVELOPMENT BOARD — October 2009 Survey

CAPACITY IN ACRE-FEET — Conservation Pool Elevation 403.0 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
327	0	0	0	0	0	0	0	0	0	0
328	0	0	0	0	0	0	0	0	0	0
329	0	0	0	0	0	0	0	0	0	0
330	0	0	0	0	0	0	0	0	0	0
331	0	0	0	0	1	1	1	1	1	1
332	1	1	1	1	1	2	2	2	2	2
333	3	3	3	4	4	4	5	5	6	6
334	7	7	8	9	9	10	11	11	12	13
335	14	15	16	17	18	19	20	21	22	23
336	24	26	27	28	30	31	33	34	36	38
337	39	41	43	45	47	49	51	53	55	57
338	60	62	65	68	71	74	77	80	83	86
339	90	94	98	101	106	110	114	119	123	128
340	133	138	143	148	154	160	166	172	178	184
341	191	198	205	212	220	227	235	244	252	261
342	271	280	290	301	311	322	334	346	358	371
343	385	398	413	428	443	459	476	493	510	529
344	548	568	588	609	631	654	678	702	728	754
345	781	809	838	868	899	932	965	1,000	1,037	1,075
346	1,115	1,156	1,199	1,244	1,292	1,344	1,398	1,455	1,514	1,576
347	1,640	1,708	1,778	1,853	1,930	2,010	2,094	2,180	2,269	2,361
348	2,455	2,552	2,651	2,752	2,856	2,961	3,069	3,178	3,290	3,404
349	3,520	3,639	3,759	3,882	4,006	4,133	4,263	4,394	4,528	4,665
350	4,804	4,946	5,090	5,237	5,387	5,539	5,694	5,852	6,012	6,175
351	6,340	6,508	6,678	6,850	7,025	7,202	7,382	7,563	7,747	7,934
352	8,122	8,313	8,507	8,703	8,901	9,103	9,306	9,512	9,721	9,932
353	10,147	10,364	10,585	10,808	11,034	11,262	11,493	11,726	11,962	12,200
354	12,440	12,682	12,926	13,172	13,421	13,671	13,924	14,179	14,436	14,696
355	14,958	15,222	15,489	15,758	16,030	16,304	16,580	16,859	17,139	17,423
356	17,708	17,996	18,286	18,578	18,873	19,170	19,469	19,771	20,075	20,382
357	20,692	21,004	21,319	21,637	21,958	22,281	22,607	22,936	23,268	23,603
358	23,941	24,282	24,627	24,974	25,325	25,679	26,036	26,397	26,761	27,128
359	27,499	27,875	28,254	28,637	29,026	29,418	29,815	30,216	30,621	31,030
360	31,443	31,859	32,279	32,702	33,128	33,559	33,992	34,430	34,871	35,316
361	35,765	36,219	36,677	37,138	37,603	38,072	38,544	39,020	39,499	39,983
362	40,471	40,963	41,460	41,960	42,464	42,972	43,484	44,000	44,520	45,043
363	45,570	46,101	46,636	47,173	47,715	48,260	48,808	49,360	49,915	50,473
364	51,035	51,601	52,170	52,743	53,319	53,899	54,482	55,068	55,658	56,252
365	56,850	57,451	58,055	58,663	59,275	59,890	60,509	61,131	61,757	62,386
366	63,018	63,654	64,293	64,935	65,582	66,232	66,885	67,543	68,204	68,869
367	69,538	70,211	70,888	71,568	72,252	72,940	73,632	74,327	75,026	75,730
368	76,438	77,150	77,866	78,586	79,310	80,039	80,771	81,508	82,250	82,995
369	83,744	84,497	85,255	86,016	86,783	87,553	88,327	89,106	89,888	90,675
370	91,466	92,261	93,060	93,863	94,670	95,481	96,297	97,117	97,941	98,770
371	99,603	100,441	101,283	102,129	102,979	103,834	104,693	105,556	106,424	107,296
372	108,173	109,054	109,940	110,831	111,727	112,628	113,533	114,443	115,358	116,279
373	117,204	118,133	119,068	120,007	120,951	121,899	122,852	123,809	124,771	125,737
374	126,707	127,681	128,660	129,642	130,629	131,621	132,616	133,616	134,619	135,627
375	136,638	137,654	138,675	139,699	140,728	141,762	142,801	143,844	144,893	145,947
376	147,007	148,071	149,141	150,215	151,295	152,380	153,470	154,565	155,664	156,769
377	157,879	158,994	160,114	161,239	162,370	163,506	164,648	165,795	166,947	168,105
378	169,268	170,436	171,610	172,789	173,974	175,164	176,359	177,560	178,766	179,978
379	181,194	182,417	183,644	184,877	186,114	187,357	188,605	189,857	191,114	192,377
380	193,644	194,915	196,192	197,473	198,760	200,052	201,349	202,651	203,958	205,270
381	206,589	207,912	209,242	210,577	211,918	213,265	214,617	215,975	217,337	218,706

Appendix A (Continued)

Lake Fork Resrvoir

RESERVOIR CAPACITY TABLE

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

October 2009 Survey
Conservation Pool Elevation 403.0 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
382	220,079	221,458	222,842	224,231	225,626	227,026	228,432	229,843	231,258	232,680
383	234,107	235,540	236,977	238,420	239,868	241,321	242,779	244,243	245,710	247,183
384	248,662	250,145	251,634	253,128	254,628	256,134	257,646	259,163	260,686	262,215
385	263,749	265,288	266,833	268,383	269,938	271,500	273,067	274,641	276,219	277,804
386	279,396	280,993	282,596	284,204	285,819	287,440	289,067	290,699	292,337	293,980
387	295,629	297,283	298,943	300,608	302,279	303,955	305,637	307,325	309,017	310,716
388	312,420	314,131	315,847	317,568	319,296	321,030	322,770	324,516	326,268	328,026
389	329,791	331,561	333,338	335,120	336,909	338,703	340,503	342,310	344,122	345,940
390	347,764	349,594	351,430	353,271	355,118	356,971	358,830	360,695	362,565	364,442
391	366,325	368,213	370,108	372,009	373,918	375,834	377,756	379,686	381,622	383,565
392	385,514	387,469	389,430	391,398	393,371	395,352	397,338	399,331	401,330	403,336
393	405,348	407,366	409,391	411,421	413,458	415,501	417,551	419,606	421,667	423,735
394	425,809	427,889	429,976	432,068	434,167	436,272	438,382	440,499	442,621	444,749
395	446,884	449,025	451,171	453,323	455,482	457,646	459,817	461,993	464,175	466,364
396	468,558	470,759	472,966	475,178	477,397	479,621	481,851	484,088	486,329	488,576
397	490,830	493,088	495,353	497,622	499,898	502,179	504,466	506,758	509,056	511,359
398	513,668	515,983	518,303	520,628	522,959	525,295	527,637	529,983	532,334	534,691
399	537,052	539,419	541,791	544,167	546,549	548,936	551,328	553,726	556,128	558,536
400	560,950	563,369	565,794	568,224	570,660	573,103	575,551	578,005	580,465	582,931
401	585,404	587,884	590,370	592,862	595,362	597,869	600,384	602,906	605,435	607,973
402	610,519	613,074	615,637	618,209	620,791	623,383	625,984	628,597	631,220	633,855
403	636,504									

Appendix B

Lake Fork Reservoir

RESERVOIR AREA TABLE

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

October 2009 Survey
Conservation Pool Elevation 403.0 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
327	0	0	0	0	0	0	0	0	0	0
328	0	0	0	0	0	0	0	0	0	0
329	0	0	0	0	0	0	0	0	0	0
330	0	0	0	0	0	0	0	0	0	0
331	0	0	0	0	0	0	1	1	1	1
332	1	1	1	1	1	2	2	2	2	3
333	3	3	3	4	4	4	4	5	5	5
334	6	6	6	6	7	7	7	8	8	8
335	9	9	10	10	10	11	11	11	12	12
336	13	13	13	14	14	15	15	16	16	17
337	17	18	18	19	20	20	21	22	23	24
338	25	26	27	28	29	30	31	32	34	35
339	36	37	39	40	41	43	44	45	47	48
340	50	51	53	54	56	58	60	62	63	65
341	67	69	72	74	76	79	82	85	88	91
342	95	98	102	106	110	114	118	122	127	131
343	136	141	146	151	157	163	168	174	180	187
344	193	201	209	216	224	233	241	249	257	266
345	275	285	295	307	319	331	344	358	372	388
346	404	420	441	467	499	529	555	581	605	630
347	658	691	726	757	789	820	850	878	905	930
348	955	979	1,002	1,023	1,044	1,064	1,086	1,107	1,129	1,151
349	1,173	1,195	1,215	1,236	1,257	1,281	1,304	1,329	1,355	1,380
350	1,404	1,430	1,457	1,483	1,510	1,535	1,563	1,589	1,616	1,641
351	1,665	1,689	1,713	1,736	1,760	1,783	1,805	1,828	1,850	1,874
352	1,898	1,922	1,948	1,974	1,999	2,024	2,049	2,074	2,100	2,129
353	2,158	2,190	2,219	2,247	2,272	2,295	2,320	2,346	2,368	2,389
354	2,410	2,431	2,452	2,474	2,495	2,518	2,540	2,562	2,584	2,606
355	2,631	2,655	2,679	2,704	2,727	2,752	2,776	2,798	2,820	2,842
356	2,865	2,888	2,912	2,936	2,959	2,982	3,006	3,031	3,057	3,083
357	3,110	3,137	3,164	3,191	3,220	3,249	3,275	3,304	3,334	3,365
358	3,397	3,428	3,459	3,490	3,522	3,556	3,590	3,623	3,657	3,693
359	3,731	3,772	3,814	3,857	3,904	3,947	3,991	4,031	4,070	4,108
360	4,144	4,179	4,214	4,249	4,284	4,319	4,356	4,392	4,431	4,471
361	4,514	4,558	4,597	4,633	4,669	4,704	4,740	4,775	4,815	4,858
362	4,901	4,942	4,982	5,023	5,063	5,101	5,140	5,178	5,215	5,253
363	5,289	5,326	5,362	5,397	5,433	5,466	5,500	5,533	5,567	5,602
364	5,637	5,672	5,709	5,745	5,779	5,814	5,849	5,884	5,920	5,957
365	5,992	6,028	6,064	6,099	6,135	6,170	6,204	6,239	6,273	6,307
366	6,340	6,374	6,408	6,444	6,480	6,518	6,557	6,595	6,632	6,671
367	6,708	6,746	6,784	6,822	6,860	6,898	6,936	6,974	7,014	7,056
368	7,098	7,140	7,181	7,222	7,264	7,306	7,349	7,392	7,433	7,473
369	7,512	7,553	7,595	7,639	7,681	7,723	7,764	7,806	7,848	7,887
370	7,927	7,969	8,011	8,052	8,092	8,134	8,177	8,221	8,265	8,309
371	8,354	8,398	8,441	8,484	8,526	8,569	8,611	8,654	8,698	8,744
372	8,790	8,837	8,885	8,933	8,983	9,031	9,079	9,128	9,176	9,225
373	9,274	9,322	9,368	9,415	9,460	9,506	9,551	9,594	9,637	9,680
374	9,722	9,764	9,807	9,848	9,891	9,933	9,974	10,015	10,056	10,098
375	10,139	10,180	10,223	10,267	10,313	10,362	10,411	10,463	10,516	10,568
376	10,619	10,671	10,721	10,772	10,823	10,874	10,924	10,972	11,023	11,072
377	11,123	11,174	11,227	11,282	11,336	11,389	11,443	11,497	11,550	11,604
378	11,657	11,710	11,764	11,818	11,873	11,927	11,981	12,034	12,089	12,143
379	12,195	12,248	12,300	12,353	12,403	12,451	12,500	12,548	12,597	12,646
380	12,694	12,741	12,790	12,841	12,892	12,942	12,994	13,045	13,098	13,154
381	13,209	13,265	13,324	13,384	13,441	13,495	13,548	13,602	13,656	13,709

Appendix B (Continued)

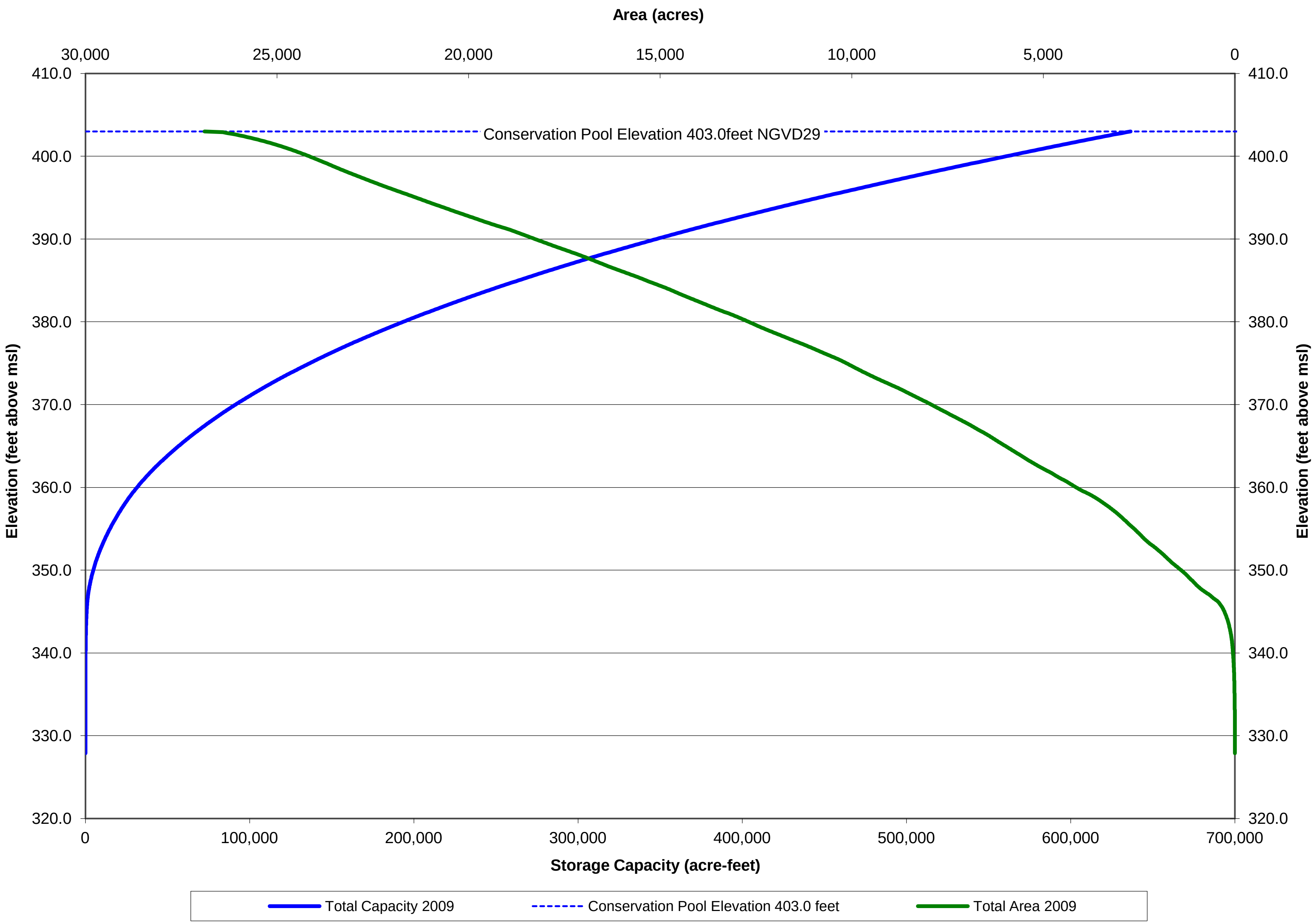
Lake Fork Reservoir

RESERVOIR AREA TABLE

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

October 2009 Survey
Conservation Pool Elevation 403.0 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
382	13,761	13,813	13,866	13,921	13,975	14,028	14,081	14,135	14,189	14,243
383	14,296	14,348	14,402	14,455	14,507	14,557	14,607	14,656	14,706	14,755
384	14,807	14,860	14,917	14,974	15,030	15,088	15,145	15,203	15,259	15,314
385	15,366	15,418	15,472	15,528	15,586	15,642	15,702	15,762	15,821	15,880
386	15,939	16,000	16,060	16,119	16,178	16,236	16,295	16,352	16,407	16,461
387	16,516	16,572	16,626	16,680	16,734	16,789	16,845	16,901	16,958	17,015
388	17,072	17,131	17,191	17,248	17,307	17,367	17,428	17,491	17,552	17,613
389	17,674	17,735	17,796	17,855	17,914	17,974	18,033	18,093	18,152	18,211
390	18,270	18,328	18,385	18,442	18,500	18,560	18,618	18,678	18,738	18,796
391	18,855	18,916	18,978	19,050	19,122	19,192	19,261	19,328	19,396	19,460
392	19,521	19,583	19,644	19,707	19,769	19,833	19,898	19,961	20,024	20,087
393	20,151	20,214	20,276	20,338	20,401	20,462	20,522	20,583	20,646	20,707
394	20,769	20,833	20,897	20,958	21,018	21,077	21,135	21,194	21,254	21,314
395	21,374	21,435	21,495	21,555	21,614	21,673	21,733	21,794	21,854	21,914
396	21,975	22,036	22,097	22,157	22,216	22,273	22,331	22,388	22,446	22,503
397	22,559	22,616	22,672	22,727	22,783	22,838	22,894	22,951	23,007	23,063
398	23,118	23,173	23,227	23,281	23,335	23,387	23,439	23,490	23,540	23,590
399	23,640	23,690	23,741	23,792	23,844	23,896	23,949	24,001	24,055	24,109
400	24,164	24,219	24,276	24,333	24,391	24,450	24,510	24,571	24,634	24,697
401	24,761	24,827	24,894	24,963	25,033	25,106	25,180	25,257	25,336	25,418
402	25,502	25,589	25,678	25,771	25,866	25,966	26,069	26,178	26,292	26,415
403	26,889									



Lake Fork Reservoir
October 2009 Survey
Prepared by: TWDB

Appendix C: Area and Capacity Curves

Figure 6

CONTOURS
(feet above mean sea level)

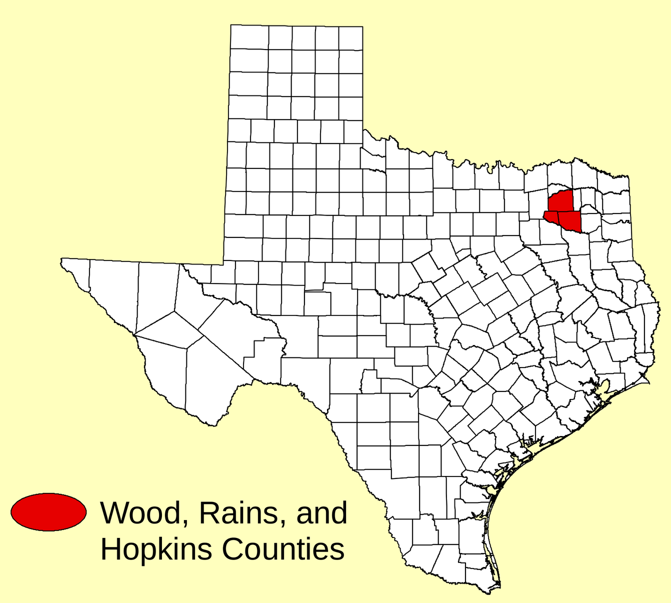
- 400
- 395
- 390
- 385
- 380
- 375
- 370
- 365
- 360
- 355
- 350
- 345
- 340
- 335
- 330

Islands

Lake Fork Reservoir

Conservation Pool Elevation:
403.0 feet above mean sea level

Projection: NAD83
State Plane
Texas North Central Zone (feet)



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 Fork Reservoir. The Texas Water Development Board makes no representations nor assumes any liability.