Volumetric and Sedimentation Survey of LAKE TAWAKONI

June – August 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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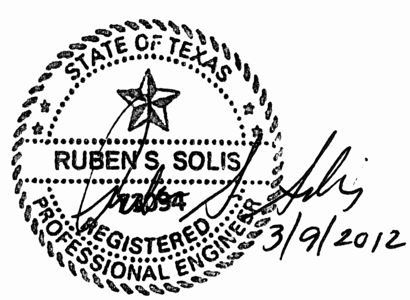

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Executive summary

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 Tawakoni. 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.

Iron Bridge Dam and Lake Tawakoni are located on the Sabine River approximately ten miles northeast of Wills Point, Texas. The conservation pool elevation of Lake Tawakoni is 437.5 feet above mean sea level (NGVD29). TWDB collected bathymetric data for Lake Tawakoni between June 10, 2009, and August 18, 2009. The daily average water surface elevation during that time ranged between 435.52 and 437.25 feet above mean sea level (NGVD29). Additional data was collected on October 15, 2009, and November 4, 2009, while the daily average water surface elevation measured 439.71 and 438.84 feet above mean sea level, respectively.

The 2009 TWDB volumetric survey indicates Lake Tawakoni has a total reservoir capacity of 871,693 acre-feet and encompasses 37,325 acres at conservation pool elevation (437.5 feet above mean sea level, NGVD29). Previous capacity estimates include the original design estimate of 936,200 acre-feet at the time of impoundment in 1960, and a re-analysis of the 1997 TWDB volumetric survey data using current processing procedures that resulted in an updated capacity estimate of 889,288 acre-feet.

Based on two methods for estimating sedimentation rates, the 2009 TWDB sedimentation survey estimates Lake Tawakoni loses between 1,316 and 2,237 acre-feet per year of capacity due to sedimentation. Sediment accumulation is greater in the lower half of the lake. The thickest sediment accumulations were found within the submerged river channels. TWDB recommends that a similar methodology be used to resurvey Lake Tawakoni 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 Tawakoni. 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 Tawakoni general information

Iron Bridge Dam and Lake Tawakoni are located on the Sabine River approximately ten miles northeast of Wills Point, Texas (Figure 1). Lake Tawakoni inundates parts of Rains, Van Zandt, and Hunt Counties. The reservoir was built primarily for water conservation and supply and is owned and operated by the Sabine River Authority (SRA, 2010). The Texas Legislature created the Sabine River Authority in 1949 to be an official agency of the State of Texas (SRA, 2010). 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.

The Sabine River Authority secured funding for the construction of Iron Bridge Dam “through a water supply agreement with the City of Dallas to provide water for municipal and industrial purposes” (SRA, 2010). Construction on Iron Bridge Dam began in January, 1958. Deliberate impoundment began in October, 1960, and the dam was completed in December, 1960 (TWDB, 1974). Conservation pool elevation was reached on

February 11, 1965 (TWDB, 2003). Additional pertinent data about Iron Bridge Dam and Lake Tawakoni can be found in Table 1.

Water rights for Lake Tawakoni have been appropriated to the Sabine River Authority through Certificate of Adjudication and amendment Nos. 05-4670 and 05-4670A. The complete certificates are on file in the Information Resources Division of the Texas Commission on Environmental Quality.

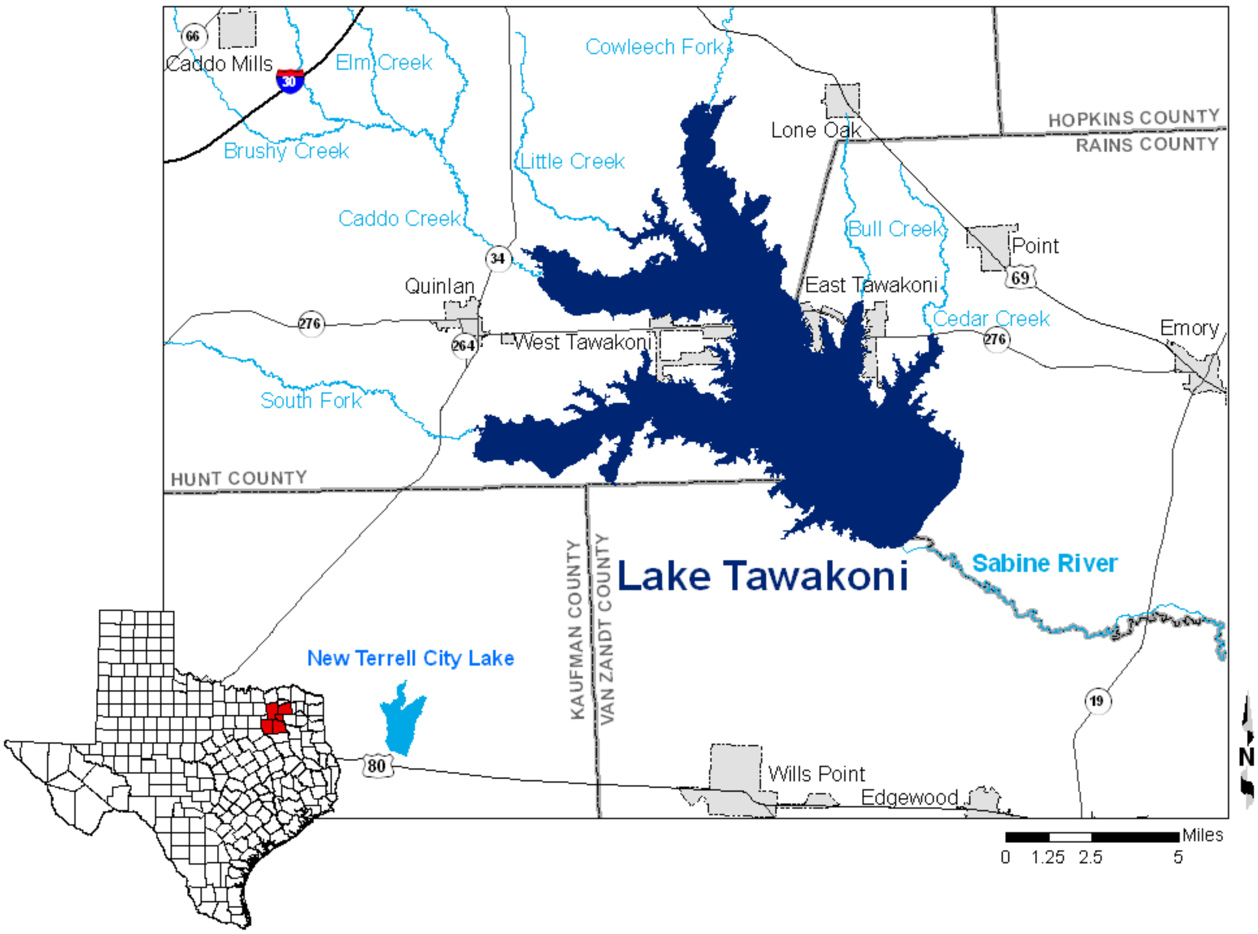

Figure 1. **Location map – Lake Tawakoni**

Table 1.	**Pertinent data for Iron Bridge Dam and Lake Tawakoni**
Owner	
Sabine River Authority	
Engineer	
Forrest and Cotton	
Location of dam	
On the Sabine River in Rains and Van Zandt Counties, 10 miles northeast of Wills Point, Texas	
Drainage area	
756 square miles	
Dam	
Type	Earthfill with concrete spillway
Length	29,560 feet (including spillway)
Maximum height	85 feet
Top width	23.33 feet
Top elevation	454.0 feet above mean sea level
Emergency spillway	
Location	Near center of river
Type	Uncontrolled concrete ogee
Crest length	480 feet
Crest elevation	437.5 feet above mean sea level
Outlet works	
Type	2 cast iron pipes, each 20-inch diameter
Control	Motor-operated valve
Invert elevation	416.5 feet above mean sea level
Type	2 conduits, each 4 by 6 feet
Control	Sluice gates
Invert elevation	378.0 feet above mean sea level

Reservoir data (based on 2009 TWDB survey)

Feature	**Elevation (feet NGVD29[a])**	**Capacity (acre-feet)**	**Area (acres)**
Top of dam	454.0	N/A	N/A
Emergency spillway/ Conservation pool elevation	437.5	871,693	37,325
Invert to 20-inch pipe	416.5	289,573	19,266
Invert to 4 by 6 foot conduit	378.0	8	5

Source: (SRA, 2010, TWDB, 1974)

[a] NGVD29 = National Geodetic Vertical Datum 1929

Volumetric and sedimentation survey of Lake Tawakoni

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 08017400Lk Tawakoni nr Wills Point, TX* (USGS, 2010). 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 Tawakoni survey between June 10, 2009, and August 18, 2009. The daily average water surface elevations during that time ranged between 435.52 and 437.25 feet above mean sea level (NGVD29). Additional data was collected on October 15, 2009, and November 4, 2009, while the daily average water surface elevation measured 439.71 and 438.84 feet above mean sea level, respectively. 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 1997 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 nearly 379,000 data points over cross-sections totaling approximately 600 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 are 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 February 2, 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.

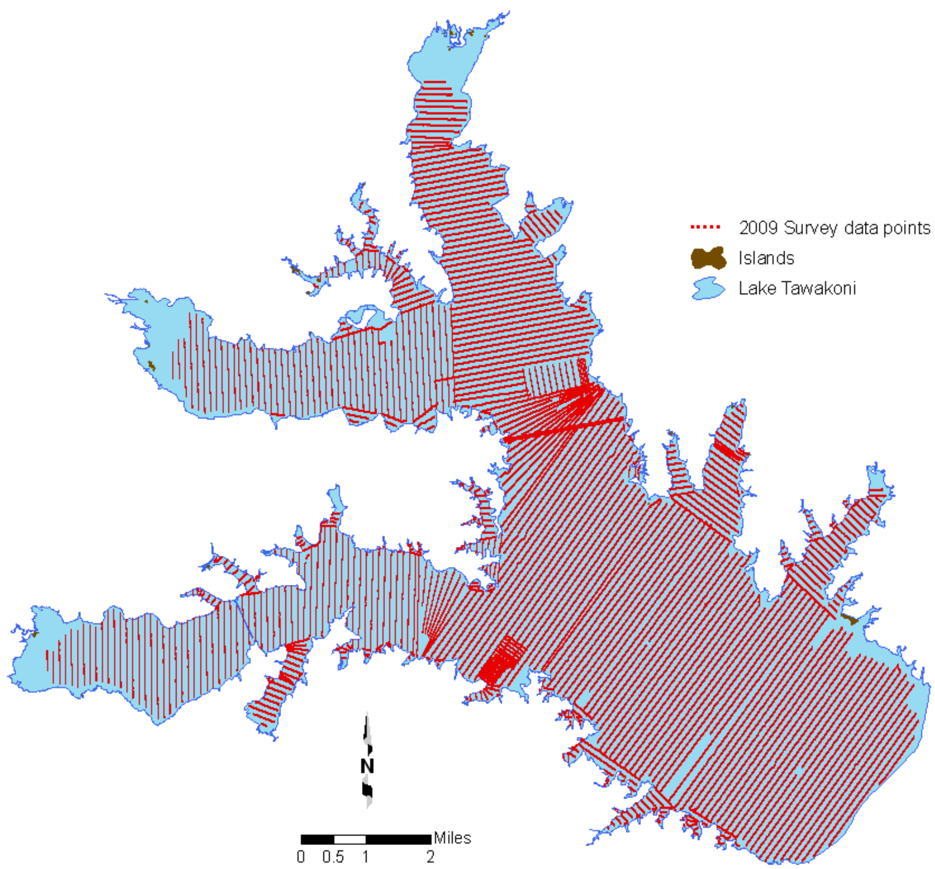

Figure 2. **Data collected during 2009 TWDB Lake Tawakoni survey**

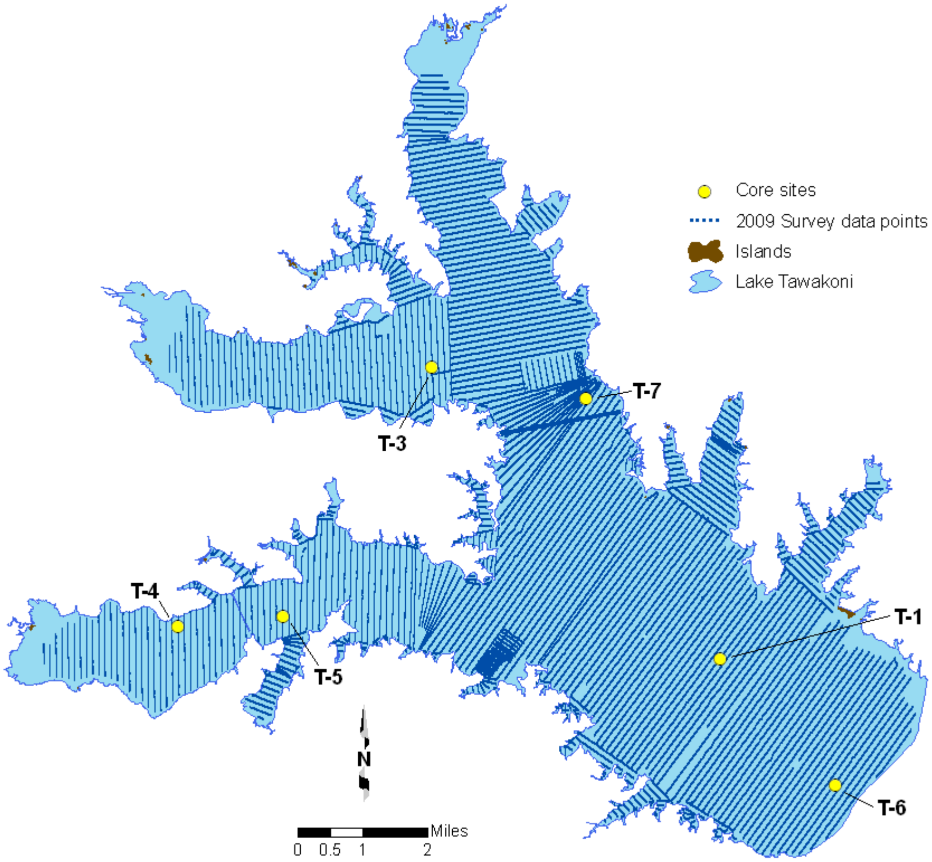

Figure 3. **Locations of sediment core samples relative to the 2009 TWDB survey data (Note: Sample T-2 was unrecoverable due to field conditions and is not shown)**

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 Tawakoni are West Tawakoni (NW, NE, SW, SE), Lone Oak South (NW, NE, SW, SE), Iron Bridge Dam (NW, NE, SW, SE), Able Springs (NW, NE), and Poetry (NE). The DOQQs were photographed on July 19 and 22, 2008, and January 11 and 12, 2009, while the daily average water surface elevation measured 436.77, 436.67, 432.72 and 432.70 feet above mean sea level, respectively. The majority of the lake was photographed in 2008 when the daily average water surface elevation was 0.73 and 0.83 vertical feet below conservation pool elevation, respectively. The 2008 and 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 2008 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 437.5 feet above mean sea level to facilitate calculating the area-capacity tables up to the conservation pool elevation. For the area of the lake photographed in 2009, the conservation pool boundary was digitized at the tree line. This was considered a good approximation of the boundary in these areas because the boundary digitized from the 2008 photos correlated well to the tree line in the 2009 photos where overlap occurred.

The land water interface visible in the 2009 aerial photos was also digitized to create a 432.72-foot contour line. Additional boundary information was available for Lake Tawakoni from aerial photographs taken on August 9, 2006, while the daily average water surface elevation measured 428.74 feet above mean sea level. Sections of 432.72 and 428.74-foot contour lines were used to supplement TWDB survey data in locations where the survey data alone was insufficient to properly represent the reservoir bathymetry. The 2006 aerial photos have a 2-meter resolution. The contour lines incorporated into the Triangulated Irregular Network (TIN) model were verified for accuracy against the sounding data collected during the 2009 survey.

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 each sounding depth to a corresponding reservoir-bottom elevation. 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, unsurveyed regions, TWDB used the line extrapolation technique described below (Furnans, 2006). The point files resulting from both the data interpolation and extrapolation were used in conjunction with the sounding and boundary data to create a TIN model utilizing 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 374.4 to 437.5 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 Tawakoni, and a 5-foot contour map (Figure 6 - attached).

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 near the boundary of the reservoir between surveyed cross sections. 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 Tawakoni, application of self-similar interpolation improved representation of 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

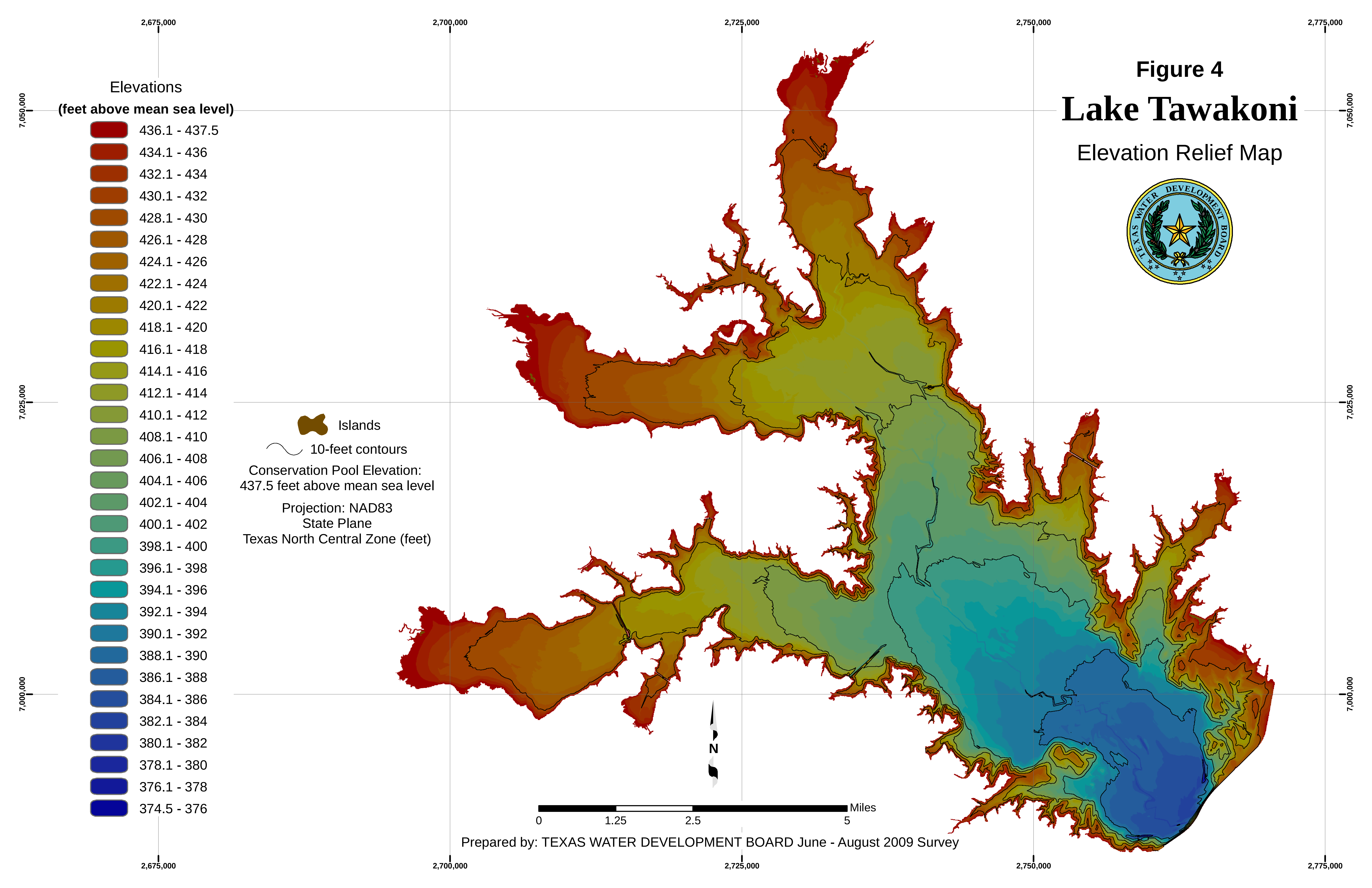
Figure 4
Lake Tawakoni
Elevation Relief Map
TEXAS WATER DEVELOPMENT BOARD
Elevations
(feet above mean sea level)
436.1 - 437.5
434.1 - 436
432.1 - 434
430.1 - 432
428.1 - 430
426.1 - 428
424.1 - 426
422.1 - 424
420.1 - 422
418.1 - 420
416.1 - 418
414.1 - 416
412.1 - 414
410.1 - 412
408.1 - 410
406.1 - 408
404.1 - 406
402.1 - 404
400.1 - 402
398.1 - 400
396.1 - 398
394.1 - 396
392.1 - 394
390.1 - 392
388.1 - 390
386.1 - 388
384.1 - 386
382.1 - 384
380.1 - 382
378.1 - 380
376.1 - 378
374.5 - 376
Islands
10-feet contours
Conservation Pool Elevation:
437.5 feet above mean sea level
Projection: NAD83
State Plane
Texas North Central Zone (feet)
N
0
1.25
2.5
5
Miles
2,675,000
2,700,000
2,725,000
2,750,000
2,775,000
7,050,000
7,025,000
7,000,000
Prepared by: TEXAS WATER DEVELOPMENT BOARD June - August 2009 Survey

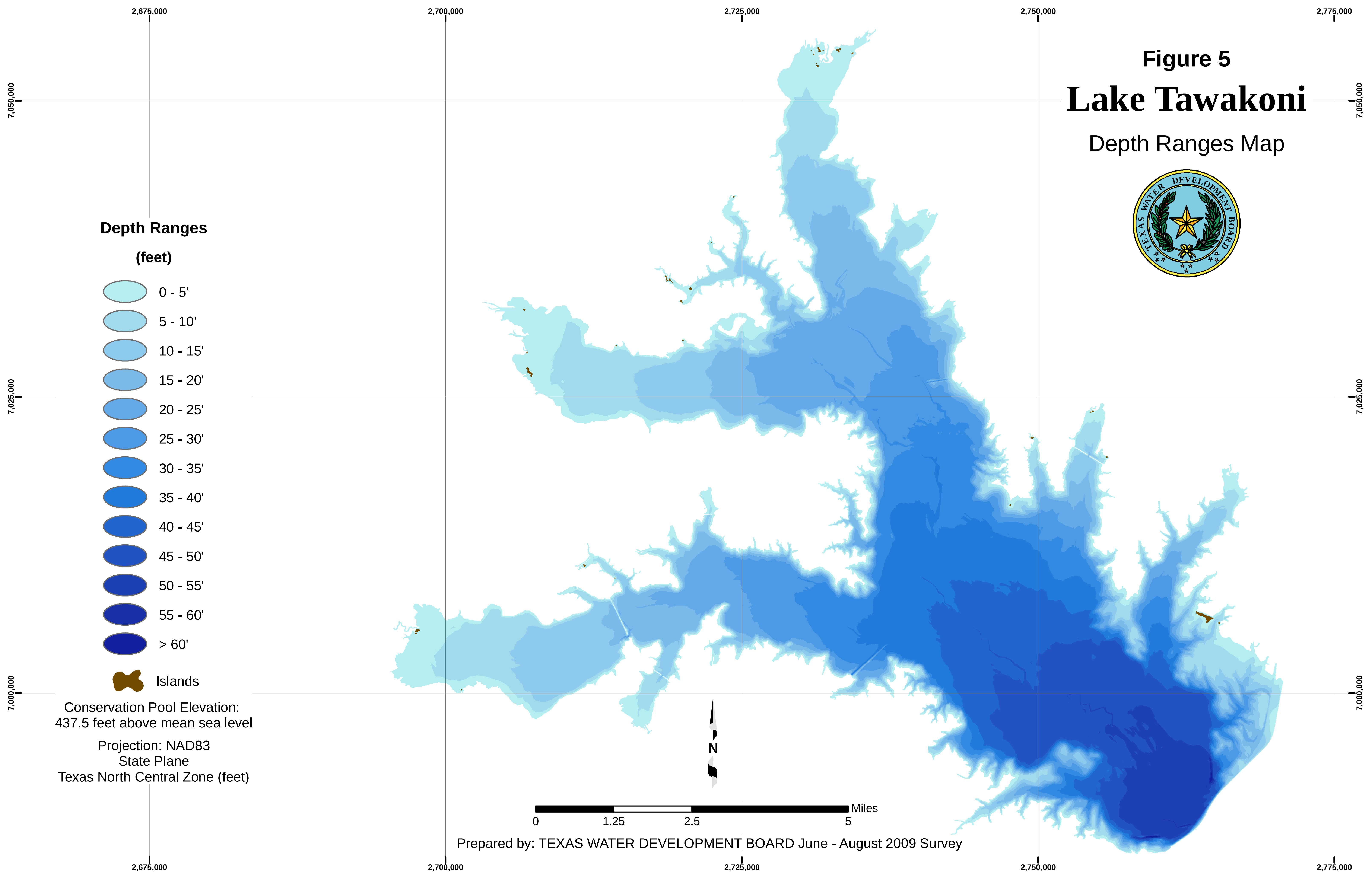
Figure 5
Lake Tawakoni
Depth Ranges Map
TEXAS WATER DEVELOPMENT BOARD
Depth Ranges
(feet)
0 - 5'
5 - 10'
10 - 15'
15 - 20'
20 - 25'
25 - 30'
30 - 35'
35 - 40'
40 - 45'
45 - 50'
50 - 55'
55 - 60'
> 60'
Islands
Conservation Pool Elevation:
437.5 feet above mean sea level
Projection: NAD83
State Plane
Texas North Central Zone (feet)
N
Miles
0
1.25
2.5
5
Prepared by: TEXAS WATER DEVELOPMENT BOARD June - August 2009 Survey
2,675,000
2,700,000
2,725,000
2,750,000
2,775,000
7,050,000
7,025,000
7,000,000

be valid. Therefore, interpolation was not used in areas of Lake Tawakoni where a high probability of change between cross-sections exists. Figure 7 illustrates typical results from the self-similar interpolation routine for Lake Tawakoni. 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.

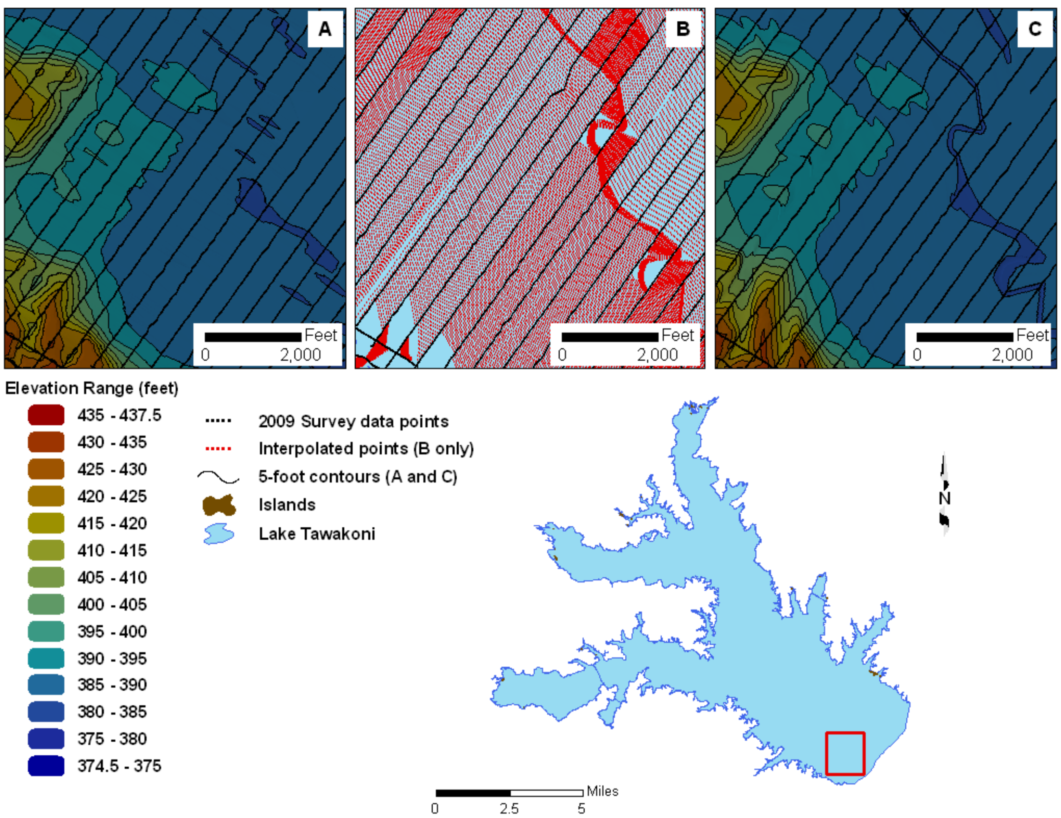

Figure 7. **Application of the self-similar interpolation technique to Lake Tawakoni sounding data – A) bathymetric contours without interpolated points, B) sounding points (black) and interpolated points (red), C) bathymetric contours with the interpolated points**

Line extrapolation

In order to estimate the bathymetry within the small coves and other un-surveyed portions of Lake Tawakoni, TWDB applied a line extrapolation technique similar to the interpolation discussed above. TWDB uses line extrapolation to project bathymetries in small coves 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 Tawakoni.

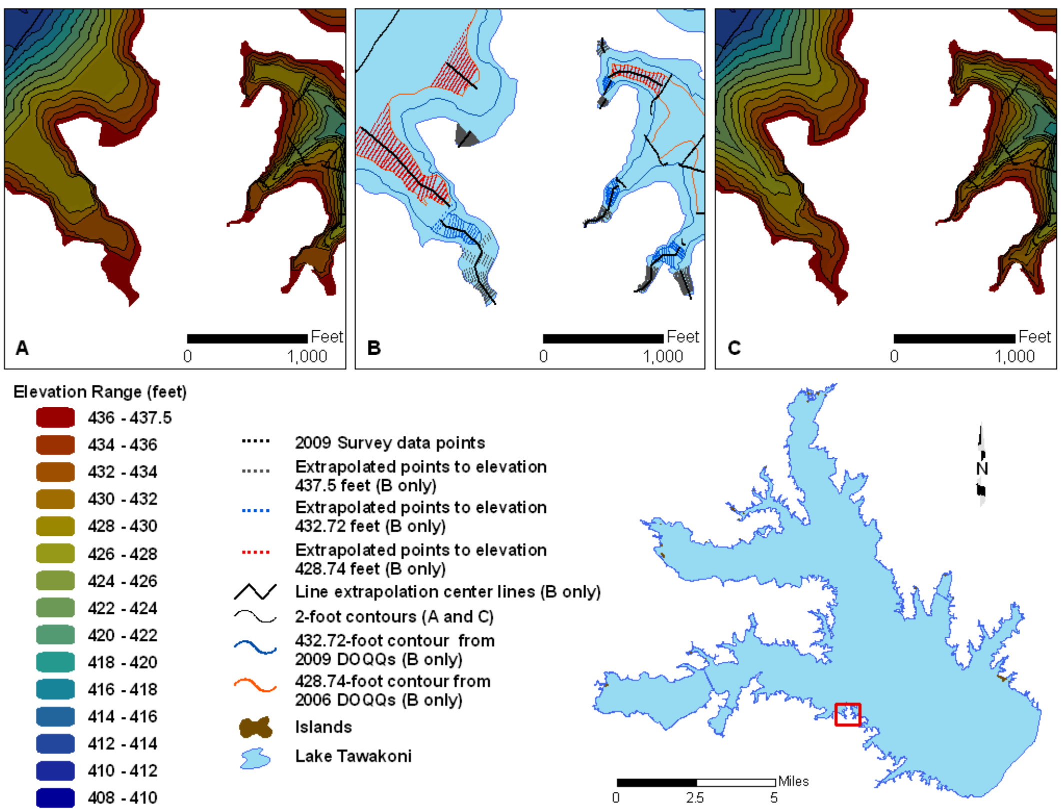

Figure 8. **Application of the line extrapolation technique to Lake Tawakoni sounding data – A) bathymetric contours without extrapolated points, B) Sounding points (black), 432.72-foot contour digitized from 2009 DOQQs (blue), 428.74-foot contour digitized from 2006 DOQQs (orange), and extrapolated points to 437.5 feet (grey), 432.72 feet (blue), and 428.74 feet (red), with reservoir boundary shown at elevation 437.5 feet, and C) bathymetric contours with extrapolated points**

As shown in Figure 8, the line extrapolation method for Lake Tawakoni was implemented using the 428.74 and 432.72-foot contours (derived from the 2006 and 2009 DOQQs, respectively) as the bounding extents of the extrapolation areas. In areas where it was not necessary to use the contours to define the bathymetry and in the areas of the lake between the contours and the outer boundary, the reservoir boundary at 437.5 feet was used as the bounding extent. 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 generation routine when data points are too far apart or are absent from portions of the reservoir.

The inherent assumption of line extrapolation is 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 Tawakoni 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 Tawakoni

Sedimentation in Lake Tawakoni 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 sample by one of the following methods: (1) a visual examination of the sediment core for organic 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 Tawakoni

Core	Easting[a] (ft)	Northing[a] (ft)	Total core sample/ post-impoundment sediment	Core description	Munsell soil color
T-1	2753775.21	7002587.81	54"/32"	0-32" Grey colored sandy loam, high water content, little to no soil structure	10YR 5/1
				32-39" darker loamy clay, increased soil structure, organics at 34"	10YR 4/1
				39-54" lower water content, well defined soil structure	10YR 3/1
T-3	2730282.36	7026377.40	33"/22.5"	0-22.5" fine sandy loam, high water content, no soil structure, organics at 17" and 19"	2.5Y 4/1
				22.5-33" sandy clay loam, low water content, well defined soil structure	2.5Y 2.5/1
T-4	2709491.57	7005212.62	65"/57.5"	0-57.5" fine sandy loam, high water content, no soil structure	2.5Y 5/1
				57.5-65" clay loam, lower water content, well defined soil structure	10YR 2/1
T-5	2718118.92	7006092.93	40.5"/27.5"	0-27.5" fine sandy loam, high water content, no soil structure	5Y 4/1
				27.5-40.5" clay loam, lower water content, well defined soil structure	5Y 3/1
T-6	2763202.96	6992250.51	64.5"/50"	0-42" fine sandy loam, high water content, no soil structure	5Y 4/1
				42-50" increased soil structure in parts with 5Y 2/1 Munsell soil color and parts of less soil structure with 5Y 4/1 Munsell soil color	5Y 2/1 and 5Y 4/1
				50-64.5" lower water content, high soil structure, organics throughout	5Y 2/1
T-7	2742822.66	7023817.07	41.5"/24"	0-24" fine sandy loam, high water content, low soil structure	5Y 4/1
				24-35" high water content, increased soil structure, organics at 26"	5Y 2/1
				35-41.5" decreased water content, high soil structure	5Y 2/1

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

A photograph of sediment core T-4 is shown in Figure 9 and is representative of the sediment cores sampled from Lake Tawakoni. The 200 kHz frequency measures the top layer as the current bottom surface of the reservoir.

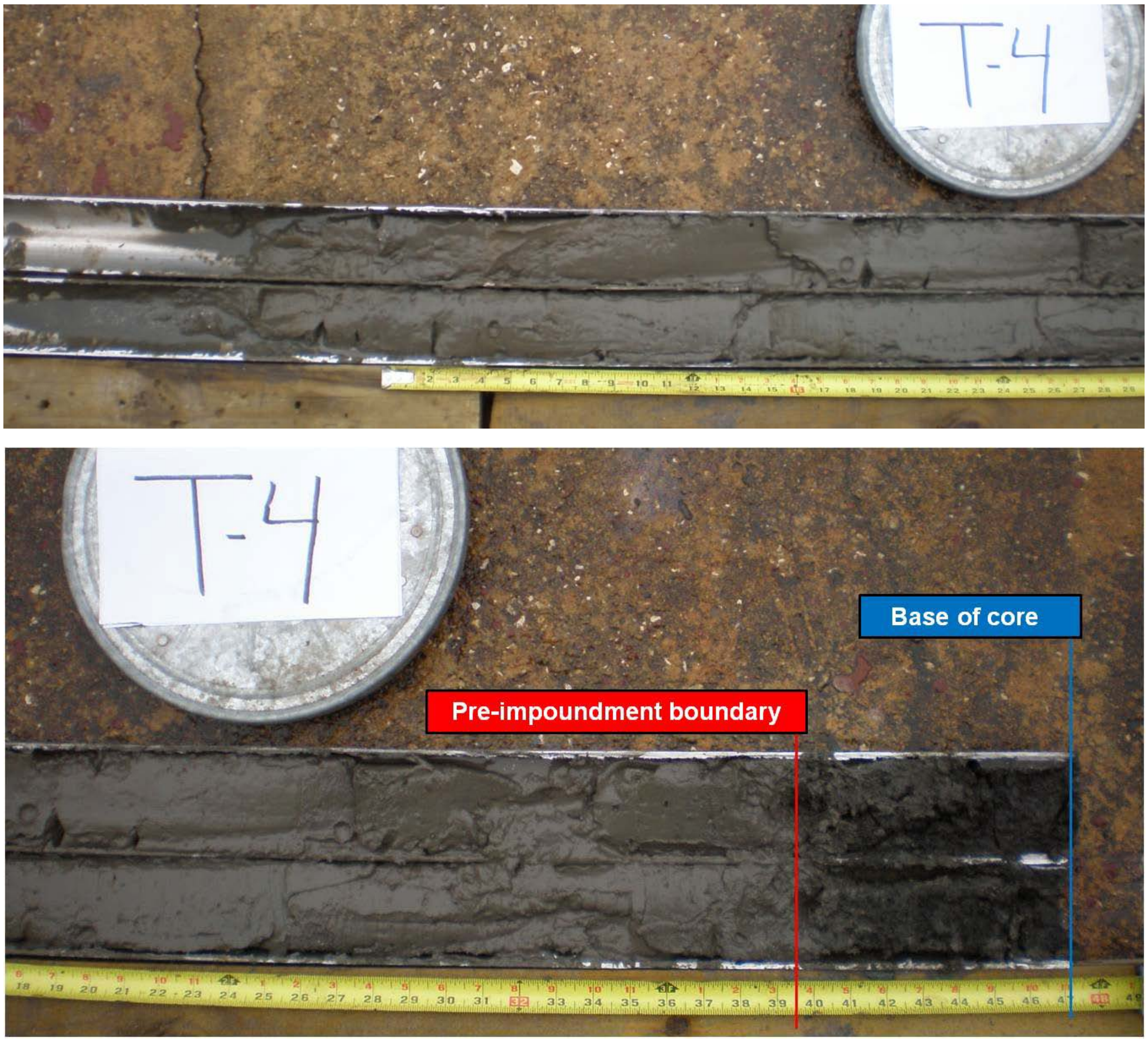

Figure 9. Sediment core sample T-4 from Lake Tawakoni

Sediment core sample T-4 consisted of 65 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 – 57.5 inches, had high water content, no soil structure, consisted of fine sandy loam soil, and was a 2.5Y 5/1 color on the Munsell soil color chart. The second horizon, beginning at 57.5 inches and extending to 65 inches below the surface, consisted of a 10 Y 2/1 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 57.5 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.

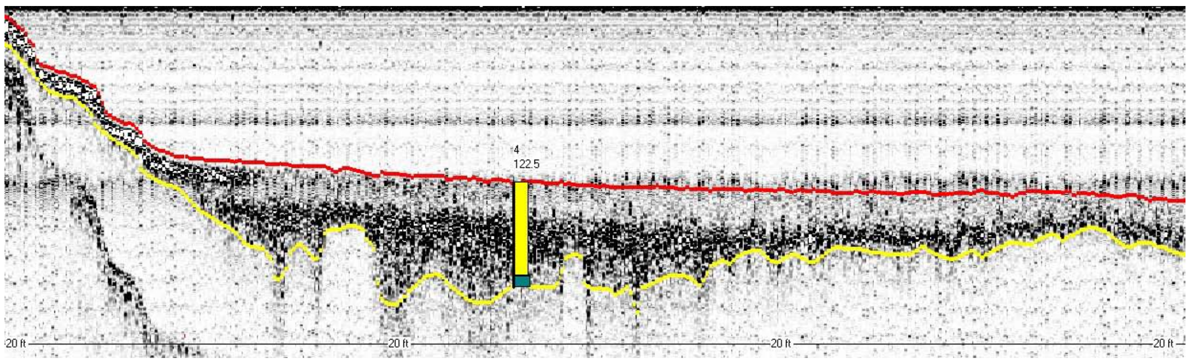

Figure 10. **Cross-section of data collected during 2009 survey, displayed in DepthPic (50 kHz frequency), correlated with sediment core sample T-4 and showing the current surface in red and pre-impoundment surface in yellow**

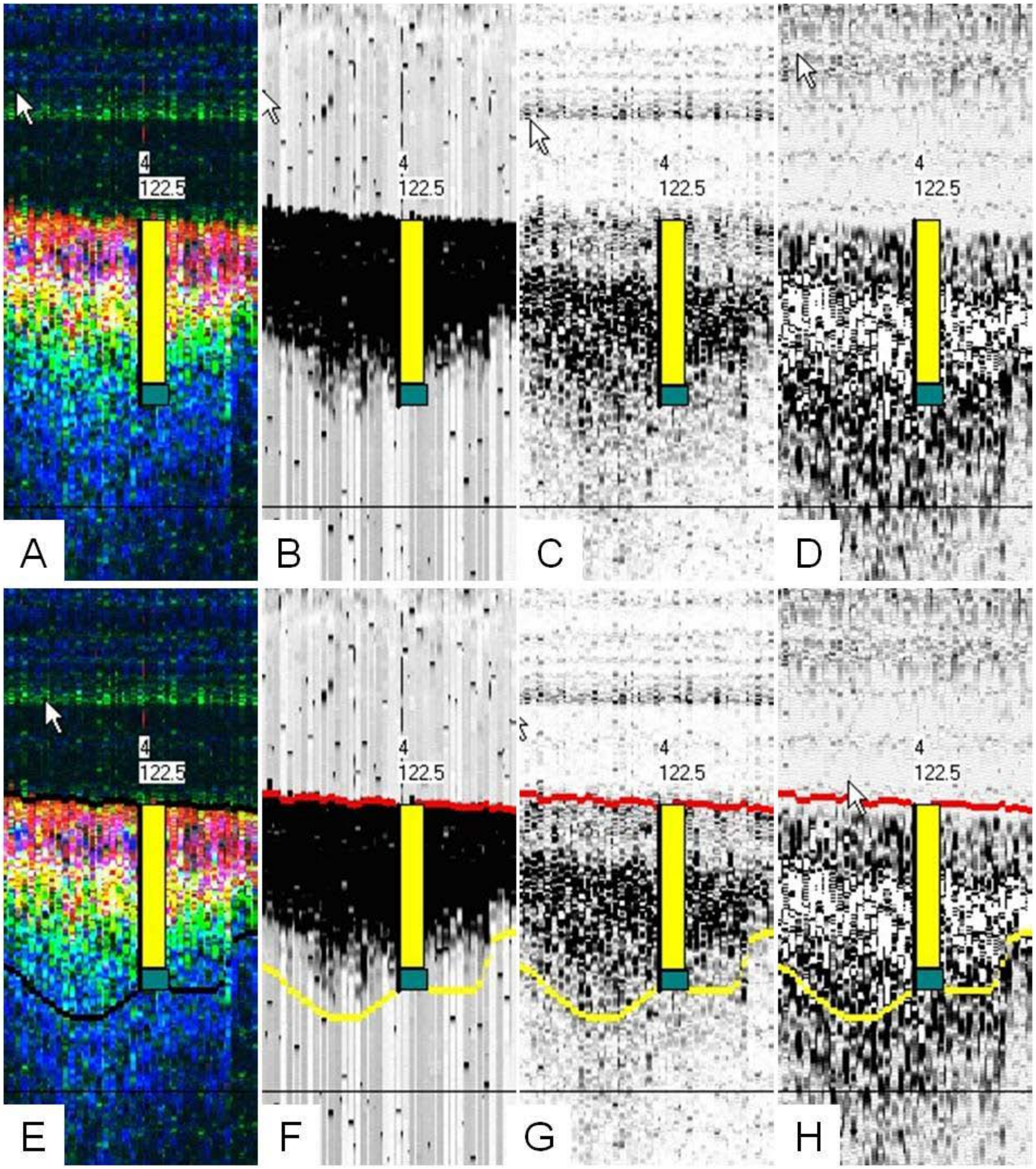

Figure 11. Comparison of sediment core T-4 with acoustic signal returns A,E) combined acoustic signal returns, B,F) 200 kHz frequency, C,G) 50 kHz frequency, D,H) 24 kHz frequency

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 57.5 inches in length based on analysis of Sample T-4 (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 437.5-foot 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 Tawakoni.

Survey results

Volumetric survey

The results of the 2009 TWDB volumetric survey indicate Lake Tawakoni has a total reservoir capacity of 871,693 acre-feet and encompasses 37,325 acres at conservation pool elevation (437.5 feet above mean sea level, NGVD29). The Sabine River Authority in 1956 estimated that Lake Tawakoni had a total capacity of 936,200 acre-feet and encompassed 36,700 acres at conservation pool elevation (TWDB, 1974).

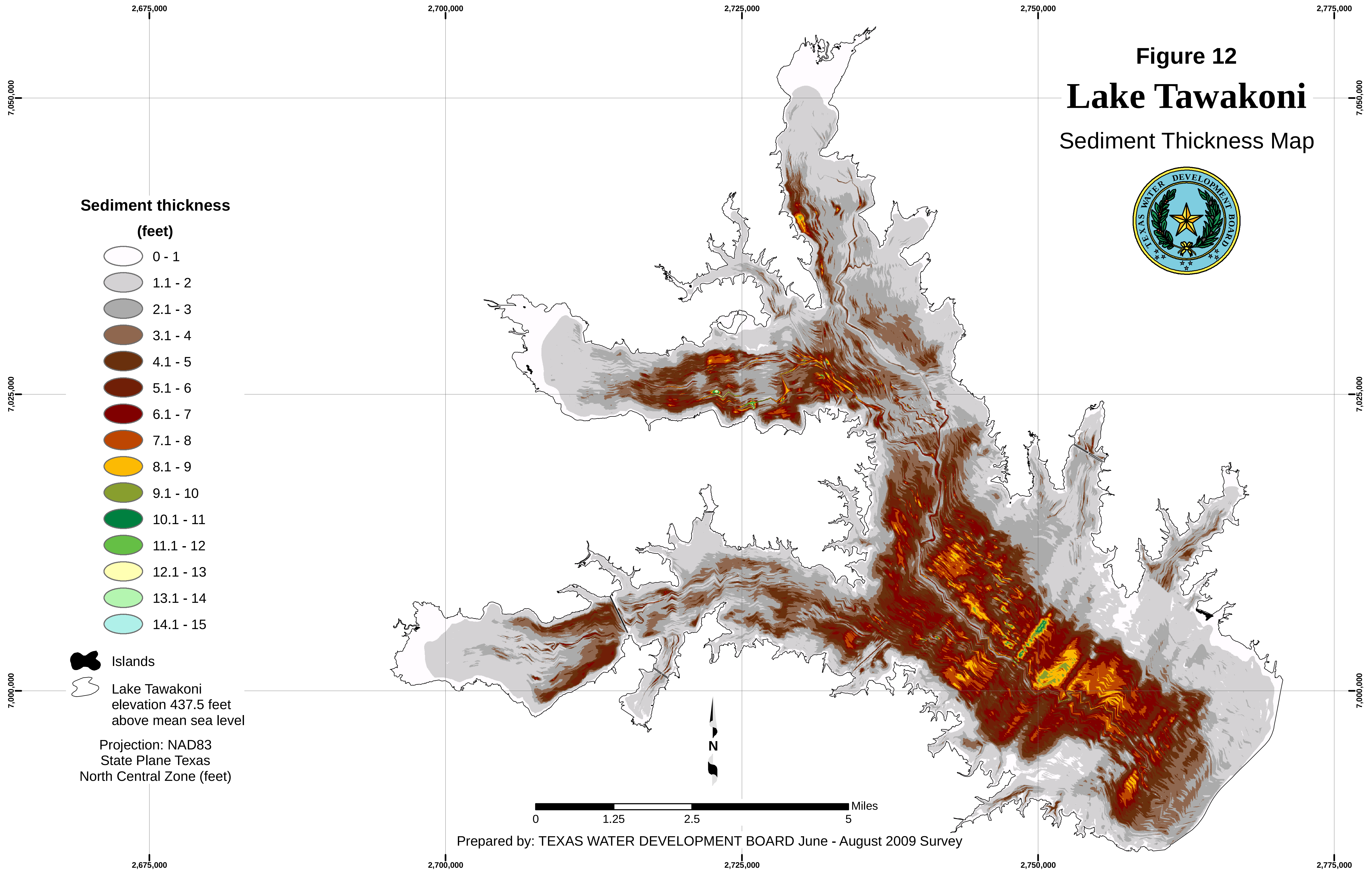

Figure 12
Lake Tawakoni
Sediment Thickness Map
TEXAS WATER DEVELOPMENT BOARD
Sediment thickness
(feet)
0 - 1
1.1 - 2
2.1 - 3
3.1 - 4
4.1 - 5
5.1 - 6
6.1 - 7
7.1 - 8
8.1 - 9
9.1 - 10
10.1 - 11
11.1 - 12
12.1 - 13
13.1 - 14
14.1 - 15
Islands
Lake Tawakoni elevation 437.5 feet above mean sea level
Projection: NAD83
State Plane Texas
North Central Zone (feet)
N
0
1.25
2.5
5
Miles
Prepared by: TEXAS WATER DEVELOPMENT BOARD June - August 2009 Survey
2,675,000
2,700,000
2,725,000
2,750,000
2,775,000
7,050,000
7,025,000
7,000,000

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 Tawakoni, TWDB applied the 2009 data processing techniques to the survey data collected in 1997. Specifically, TWDB applied the self-similar interpolation and line extrapolation techniques to the 1997 survey dataset (Furnans, 2006). A revised TIN model was created using the original 1997 survey boundary. The 1997 survey boundary was created from 7.5 minute USGS quadrangle maps, with a stated accuracy of ± 1/2 the contour interval (USBB, 1947). Revision of the 1997 survey using current TWDB data processing methods resulted in a 1,151 acre-feet (0.13%) 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 1956[a]	36,700	936,200
TWDB 1997	37,879	888,137
TWDB 1997 revised	38,054	889,288
TWDB 2009	37,325	871,693

[a]Source: (TWDB, 1974)

Sedimentation survey

Based on two methods for estimating sedimentation rates, the 2009 TWDB sedimentation survey estimates Lake Tawakoni loses between 1,316 and 2,237 acre-feet per year of capacity due to sedimentation (Table 4). Sediment accumulation is dispersed throughout the lake, though the majority of sediment is in the lower half of the lake. 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 for the difference between the current volumetric survey and the original design estimate; the current capacity estimation and the 2009 pre-impoundment capacity estimation; as well as the current volumetric capacity estimation and the revised 1997 volumetric capacity estimation (Table 4). Based on the 2009 estimated sediment volume, Lake Tawakoni lost an average of approximately 2,237 acre-feet of capacity per year from 1960 to 2009. Comparison 3 in the Table 4 compares the current volumetric survey to the 1997 revised volumetric survey. This comparison suggests the current rate of sedimentation in Lake Tawakoni is approximately 1,466 acre-feet per year. Comparison of capacity estimates of Lake Tawakoni 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 Tawakoni

Survey	Volume comparisons @ CPE (acre-ft)		Pre-impoundment (acre-ft)
	Comparison #1	**Comparison #2**	**Comparison #3**
Original design estimate[a]	936,200	<>	<>
TWDB pre-impoundment volumetric estimate based on 2009 sedimentation survey	<>	<>	981,303[b]
1997 TWDB volumetric survey (revised)	<>	889,288	<>
2009 volumetric survey	871,693	871,693	871,693
Volume difference (acre-feet)	64,507 (6.9%)	17,595 (2.0%)	109,610 (11.2%)
Number of years	49	12	49
Capacity loss rate (acre-feet/year)	1,316	1,466	2,237

[a] Source: (TWDB, 1974), note: original design estimate based on 1956 survey and deliberate impoundment began in October, 1960.
[b] 2009 TWDB surveyed capacity of 871,693 acre-feet plus 2009 TWDB surveyed sediment volume of 109,610 acre-feet

Recommendations

To improve estimates of sediment accumulation rates, TWDB recommends resurveying Lake Tawakoni 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 Tawakoni.

TWDB contact information

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

http://www.twdb.texas.gov/assistance/lakesurveys/volumetricindex.asp

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Appendix A

Lake Tawakoni

RESERVOIR CAPACITY TABLE

TEXAS WATER DEVELOPMENT BOARD — June - August 2009 Survey

CAPACITY IN ACRE-FEET — Conservation Pool Elevation 437.5 feet NGVD29

ELEVATION INCREMENT IS ONE TENTH FOOT

ELEVATION in Feet	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
374	0	0	0	0	0	0	0	0	0	0
375	0	0	0	0	0	1	1	1	1	1
376	1	1	2	2	2	2	2	3	3	3
377	4	4	4	5	5	5	6	6	7	7
378	8	8	9	10	10	11	12	12	13	14
379	14	15	16	17	18	19	19	20	21	22
380	23	24	25	26	28	29	30	31	32	33
381	35	36	37	39	40	41	43	44	46	47
382	49	50	52	53	55	57	59	61	63	65
383	68	70	73	77	80	85	90	97	105	115
384	126	138	151	166	182	199	219	241	264	291
385	321	355	392	434	480	530	584	642	704	769
386	837	909	985	1,064	1,146	1,233	1,324	1,420	1,522	1,628
387	1,738	1,852	1,971	2,095	2,224	2,357	2,496	2,638	2,786	2,937
388	3,094	3,255	3,422	3,593	3,772	3,957	4,149	4,347	4,552	4,763
389	4,982	5,209	5,442	5,682	5,928	6,180	6,439	6,704	6,975	7,250
390	7,532	7,818	8,110	8,407	8,709	9,018	9,334	9,656	9,984	10,318
391	10,658	11,005	11,358	11,718	12,085	12,459	12,841	13,228	13,622	14,022
392	14,427	14,838	15,254	15,674	16,100	16,532	16,970	17,413	17,862	18,317
393	18,779	19,247	19,721	20,201	20,686	21,178	21,676	22,179	22,688	23,203
394	23,724	24,250	24,783	25,321	25,864	26,412	26,963	27,519	28,079	28,644
395	29,213	29,788	30,367	30,951	31,539	32,133	32,732	33,336	33,945	34,559
396	35,177	35,801	36,430	37,064	37,702	38,345	38,993	39,646	40,302	40,964
397	41,630	42,301	42,976	43,656	44,343	45,035	45,733	46,437	47,147	47,861
398	48,581	49,305	50,034	50,767	51,507	52,252	53,002	53,758	54,520	55,288
399	56,062	56,842	57,628	58,419	59,217	60,022	60,834	61,652	62,477	63,308
400	64,145	64,989	65,840	66,697	67,560	68,431	69,309	70,194	71,086	71,985
401	72,890	73,803	74,725	75,654	76,590	77,534	78,483	79,440	80,404	81,375
402	82,352	83,337	84,327	85,324	86,329	87,341	88,360	89,387	90,420	91,462
403	92,511	93,568	94,632	95,704	96,784	97,871	98,964	100,064	101,171	102,284
404	103,402	104,526	105,657	106,793	107,935	109,084	110,238	111,397	112,561	113,731
405	114,906	116,086	117,272	118,462	119,659	120,860	122,067	123,279	124,496	125,718
406	126,945	128,177	129,414	130,656	131,904	133,158	134,416	135,680	136,949	138,224
407	139,504	140,790	142,081	143,376	144,677	145,984	147,296	148,614	149,938	151,268
408	152,604	153,945	155,292	156,643	158,001	159,364	160,733	162,107	163,487	164,873
409	166,265	167,664	169,068	170,478	171,893	173,314	174,740	176,172	177,608	179,051
410	180,498	181,950	183,408	184,871	186,340	187,816	189,298	190,786	192,280	193,780
411	195,286	196,799	198,318	199,843	201,376	202,916	204,462	206,014	207,572	209,136
412	210,706	212,282	213,865	215,454	217,051	218,656	220,269	221,891	223,521	225,161
413	226,810	228,468	230,134	231,809	233,493	235,185	236,884	238,592	240,306	242,030
414	243,763	245,504	247,253	249,010	250,774	252,546	254,325	256,112	257,905	259,707
415	261,516	263,332	265,156	266,986	268,825	270,673	272,528	274,392	276,263	278,142
416	280,029	281,923	283,825	285,733	287,650	289,573	291,503	293,440	295,384	297,335
417	299,294	301,261	303,234	305,214	307,203	309,199	311,202	313,213	315,231	317,257
418	319,290	321,329	323,375	325,426	327,486	329,552	331,626	333,705	335,791	337,885
419	339,986	342,093	344,208	346,329	348,460	350,597	352,742	354,893	357,049	359,212
420	361,382	363,557	365,740	367,929	370,126	372,329	374,540	376,757	378,981	381,212
421	383,450	385,695	387,947	390,204	392,469	394,741	397,019	399,304	401,595	403,893
422	406,199	408,510	410,829	413,154	415,486	417,826	420,173	422,527	424,888	427,257
423	429,635	432,021	434,414	436,814	439,223	441,640	444,066	446,499	448,940	451,390
424	453,847	456,312	458,785	461,265	463,754	466,250	468,755	471,268	473,789	476,319
425	478,858	481,406	483,963	486,528	489,103	491,688	494,282	496,885	499,499	502,123
426	504,758	507,403	510,057	512,720	515,393	518,075	520,767	523,468	526,178	528,898
427	531,627	534,365	537,113	539,869	542,636	545,412	548,198	550,993	553,796	556,610
428	559,433	562,267	565,109	567,962	570,825	573,698	576,582	579,477	582,385	585,307
429	588,242	591,187	594,143	597,108	600,084	603,070	606,066	609,072	612,088	615,115
430	618,152	621,201	624,260	627,330	630,413	633,506	636,610	639,725	642,850	645,985
431	649,132	652,289	655,456	658,632	661,819	665,016	668,223	671,438	674,663	677,898
432	681,143	684,398	687,662	690,935	694,219	697,512	700,813	704,123	707,443	710,773
433	714,110	717,453	720,804	724,160	727,524	730,895	734,273	737,657	741,046	744,443
434	747,847	751,258	754,675	758,098	761,528	764,966	768,410	771,862	775,319	778,784
435	782,256	785,736	789,222	792,715	796,216	799,725	803,241	806,765	810,296	813,835
436	817,383	820,939	824,503	828,075	831,656	835,246	838,846	842,454	846,071	849,699
437	853,337	856,985	860,644	864,313	867,996	871,693				

Appendix B

Lake Tawakoni

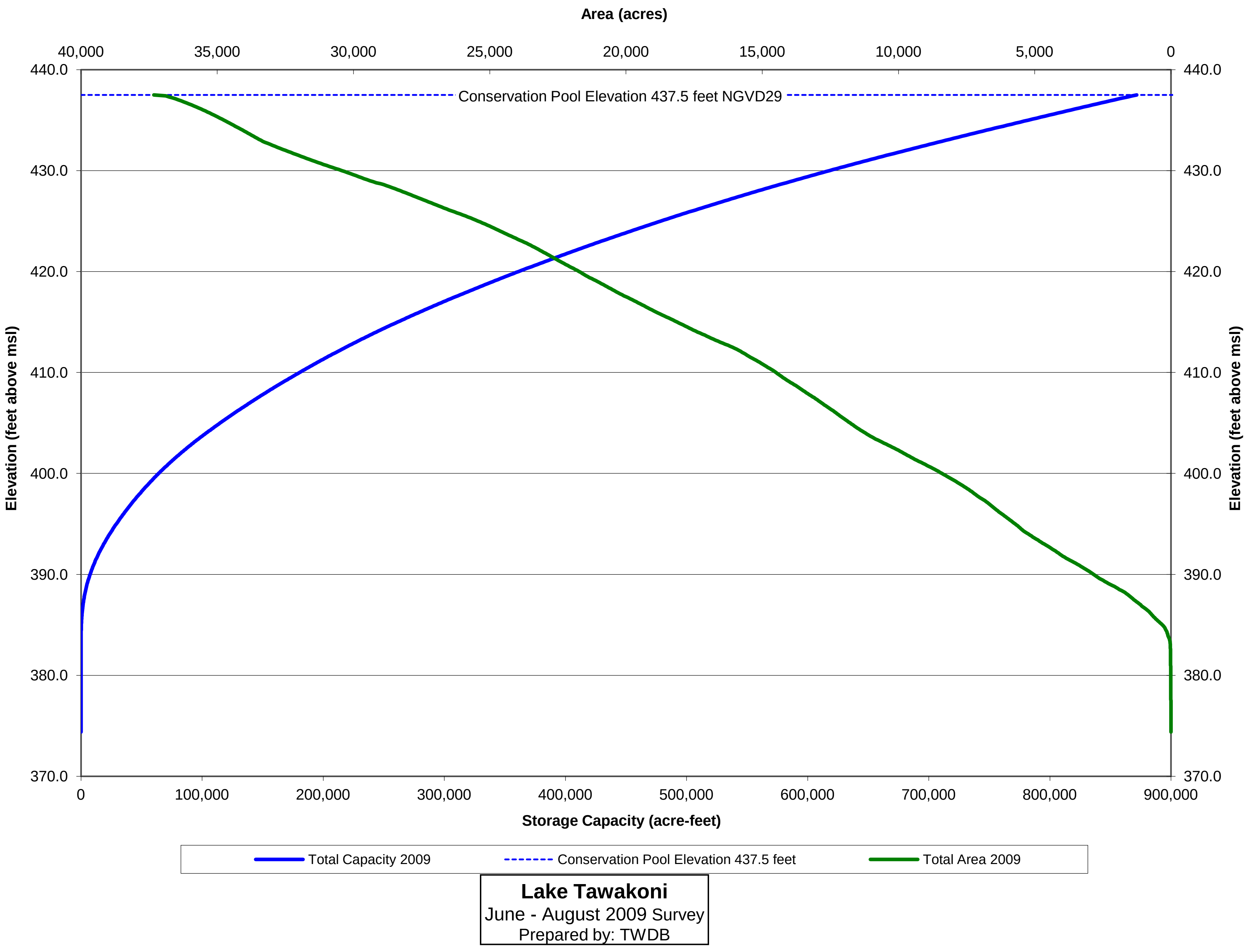
RESERVOIR AREA TABLE

TEXAS WATER DEVELOPMENT BOARD — June - August 2009 Survey

AREA IN ACRES — Conservation Pool Elevation 437.5 feet NGVD29

ELEVATION INCREMENT IS ONE TENTH FOOT

ELEVATION in Feet	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
374	0	0	0	0	0	0	0	0	0	1
375	1	1	1	1	1	1	1	1	1	1
376	2	2	2	2	2	2	3	3	3	3
377	3	3	4	4	4	4	4	5	5	5
378	5	6	6	6	6	7	7	7	7	8
379	8	8	8	8	9	9	9	9	10	10
380	10	10	11	11	11	11	12	12	12	12
381	13	13	13	13	14	14	14	14	15	15
382	15	16	16	17	18	18	20	21	23	24
383	26	28	30	34	39	47	60	74	91	104
384	115	127	139	153	169	187	206	226	252	282
385	317	355	398	439	481	520	560	598	634	669
386	703	737	771	805	846	891	935	988	1,042	1,081
387	1,120	1,167	1,213	1,262	1,312	1,362	1,405	1,450	1,494	1,542
388	1,590	1,637	1,688	1,748	1,819	1,890	1,951	2,011	2,076	2,150
389	2,229	2,302	2,368	2,428	2,491	2,559	2,621	2,675	2,731	2,785
390	2,838	2,891	2,944	2,998	3,058	3,124	3,187	3,250	3,309	3,369
391	3,435	3,500	3,567	3,636	3,703	3,777	3,846	3,907	3,970	4,027
392	4,080	4,130	4,180	4,232	4,292	4,348	4,405	4,460	4,519	4,582
393	4,649	4,711	4,771	4,826	4,883	4,948	5,007	5,065	5,120	5,177
394	5,234	5,292	5,356	5,410	5,454	5,495	5,536	5,578	5,624	5,674
395	5,721	5,768	5,814	5,862	5,913	5,965	6,015	6,063	6,112	6,162
396	6,212	6,265	6,314	6,360	6,406	6,454	6,501	6,547	6,593	6,639
397	6,683	6,728	6,778	6,832	6,891	6,953	7,015	7,067	7,122	7,170
398	7,217	7,264	7,313	7,365	7,420	7,475	7,532	7,590	7,649	7,708
399	7,771	7,828	7,885	7,948	8,017	8,082	8,151	8,215	8,280	8,342
400	8,407	8,472	8,537	8,600	8,671	8,744	8,815	8,886	8,952	9,021
401	9,093	9,171	9,256	9,328	9,398	9,464	9,530	9,603	9,675	9,744
402	9,810	9,874	9,937	10,007	10,082	10,156	10,229	10,303	10,377	10,452
403	10,530	10,605	10,678	10,759	10,837	10,903	10,968	11,033	11,098	11,157
404	11,212	11,270	11,334	11,395	11,454	11,511	11,566	11,617	11,671	11,724
405	11,776	11,829	11,882	11,935	11,990	12,042	12,093	12,144	12,195	12,245
406	12,294	12,346	12,398	12,453	12,506	12,558	12,610	12,666	12,722	12,775
407	12,828	12,881	12,933	12,985	13,036	13,091	13,151	13,210	13,270	13,329
408	13,384	13,439	13,493	13,549	13,601	13,657	13,713	13,771	13,831	13,893
409	13,955	14,014	14,071	14,126	14,181	14,235	14,290	14,341	14,394	14,447
410	14,499	14,548	14,602	14,660	14,725	14,789	14,851	14,912	14,971	15,030
411	15,093	15,159	15,226	15,291	15,361	15,428	15,491	15,551	15,610	15,669
412	15,732	15,796	15,861	15,932	16,008	16,087	16,171	16,260	16,353	16,443
413	16,535	16,620	16,708	16,794	16,879	16,956	17,034	17,110	17,196	17,281
414	17,369	17,450	17,531	17,606	17,679	17,753	17,829	17,903	17,976	18,050
415	18,124	18,198	18,274	18,351	18,431	18,514	18,594	18,673	18,752	18,832
416	18,908	18,980	19,051	19,124	19,196	19,266	19,336	19,406	19,477	19,553
417	19,625	19,696	19,770	19,845	19,919	19,997	20,074	20,146	20,221	20,292
418	20,358	20,423	20,489	20,557	20,630	20,697	20,763	20,831	20,903	20,971
419	21,038	21,107	21,182	21,262	21,340	21,410	21,477	21,540	21,599	21,659
420	21,722	21,790	21,860	21,932	22,002	22,069	22,139	22,209	22,277	22,344
421	22,413	22,482	22,548	22,614	22,682	22,749	22,814	22,881	22,948	23,016
422	23,083	23,151	23,220	23,289	23,360	23,431	23,504	23,578	23,651	23,730
423	23,816	23,897	23,971	24,046	24,127	24,212	24,294	24,374	24,454	24,533
424	24,609	24,688	24,768	24,847	24,926	25,005	25,087	25,171	25,257	25,345
425	25,434	25,524	25,612	25,701	25,795	25,889	25,987	26,089	26,192	26,295
426	26,394	26,492	26,588	26,684	26,777	26,869	26,963	27,056	27,149	27,243
427	27,336	27,429	27,523	27,619	27,715	27,807	27,899	27,992	28,091	28,186
428	28,280	28,378	28,477	28,579	28,682	28,785	28,893	29,003	29,161	29,283
429	29,398	29,504	29,607	29,709	29,808	29,908	30,009	30,112	30,215	30,320
430	30,428	30,538	30,653	30,765	30,876	30,987	31,095	31,198	31,303	31,409
431	31,516	31,618	31,719	31,821	31,919	32,015	32,109	32,203	32,301	32,400
432	32,497	32,595	32,692	32,787	32,881	32,968	33,055	33,143	33,255	33,329
433	33,400	33,470	33,539	33,606	33,673	33,739	33,804	33,870	33,936	34,003
434	34,070	34,137	34,204	34,271	34,339	34,407	34,476	34,546	34,616	34,686
435	34,757	34,828	34,900	34,973	35,047	35,122	35,198	35,275	35,353	35,433
436	35,515	35,598	35,683	35,769	35,856	35,946	36,038	36,131	36,227	36,326
437	36,427	36,532	36,642	36,761	36,890	37,325				



Appendix C: Area and Capacity Curves

Figure 6

CONTOURS

(feet above mean sea level)

435

430

425

420

415

410

405

400

395

390

385

380

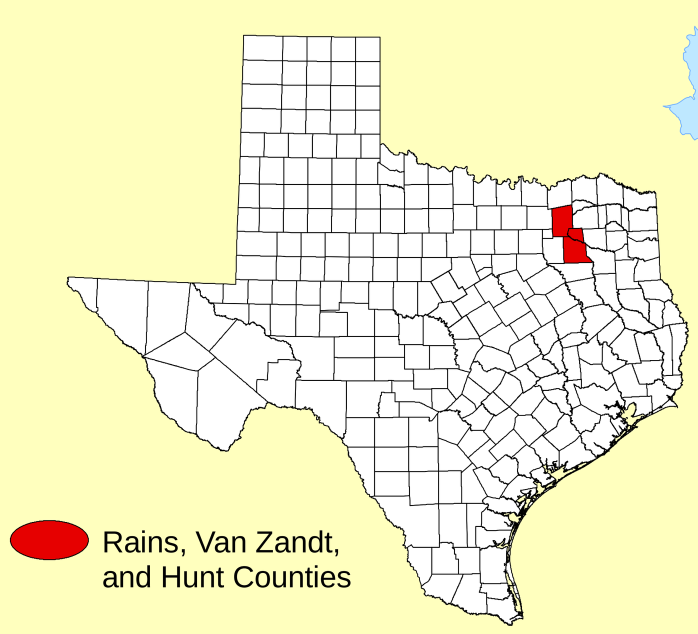
375

Islands

Lake Tawakoni

Conservation Pool Elevation:
437.5 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 Tawakoni. The Texas Water Development Board makes no representations nor assumes any liability.