Volumetric and Sedimentation Survey of RAY ROBERTS LAKE

September – October 2008 Survey

Prepared by:

The Texas Water Development Board

August 2010

Texas Water Development Board

Prepared for:

City of Dallas

With Support Provided by:

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

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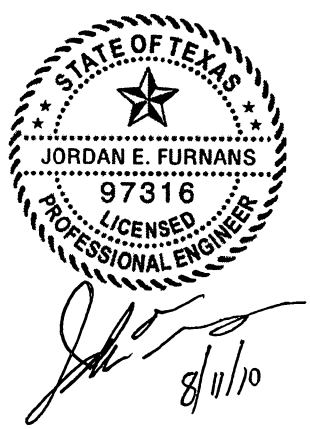

Executive summary

In April 2007, 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 Ray Roberts Lake. 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 City of Dallas 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.

Ray Roberts Dam and Ray Roberts Lake are located on the Elm Fork of the Trinity River between Sanger and Aubrey in Denton County, Texas. The conservation pool elevation of Ray Roberts Lake is 632.5 feet above mean sea level (NGVD29). TWDB collected bathymetric data collection for Ray Roberts Lake between September 11, 2008 and October 15, 2008. The water surface elevation during that time ranged between 631.70 feet and 631.12 feet above mean sea level (NGVD29).

The 2008 TWDB volumetric survey indicates that Ray Roberts Lake has a total reservoir capacity of 788,490 acre-feet and encompasses 28,646 acres at conservation pool elevation (632.5 feet above mean sea level, NGVD29). In 1985, during construction of Ray Roberts Dam, the U.S. Army Corps of Engineers estimated Ray Roberts Lake would have a total capacity of 799,600 acre-feet and would encompass 29,350 acres at conservation pool elevation. TWDB considers the methods used in the 2008 survey to be improved and more accurate than previous methods and recommends that a similar methodology be used to resurvey Ray Roberts Lake in 10 years or after a major flood event.

The 2008 TWDB sedimentation survey indicates that Ray Roberts Lake has accumulated 8,385 acre-feet of sediment since impoundment in 1987. Based on this measured sediment volume and assuming a constant sediment accumulation rate, Ray Roberts Lake loses approximately 400 acre-feet of capacity per year. Sediment accumulation is well dispersed throughout the lake, although it is nearly absent in the submerged rivers and is thickest in the submerged floodplains of the submerged rivers. The maximum sediment thickness observed in Ray Roberts Lake was 1.8 feet.

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

Introduction

The Texas Water Development Board's (TWDB) Hydrographic Survey Program was authorized by the state legislature in 1991. The Texas Water Code (Chapter 15, Subchapter M) authorizes TWDB to perform surveys to determine reservoir storage capacity, sedimentation levels, rates of sedimentation, and projected water supply availability.

In April 2007, TWDB entered into agreement with U.S. Army Corps of Engineers, Fort Worth District, to perform a volumetric and sedimentation survey of Ray Roberts Lake. 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 City of Dallas provided the remaining 50% (TWDB, 2007). 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 5], and (3) a shaded relief plot of the lake bottom [Figure 4].

Ray Roberts Lake general information

Ray Roberts Dam is located on the Elm Fork of the Trinity River between the cities of Sanger and Aubrey in Denton County, Texas, 30 miles upstream from Lewisville Dam (USACE, 2010). (Figure 1) Ray Roberts Lake inundates parts of Denton, Cooke, and Grayson Counties. Ray Roberts Lake is owned by the U.S. Government and operated by the U.S. Army Corps of Engineers, Fort Worth District. The reservoir was built primarily for water supply for the cities of Dallas and Denton (City of Denton, 2009). Construction on Ray Roberts Dam began on May 31, 1982. The dam was completed and deliberate impoundment of water began on June 30, 1987 (USACE, 2010). Additional pertinent data about Ray Roberts Dam and Ray Roberts Lake can be found in Table 1.

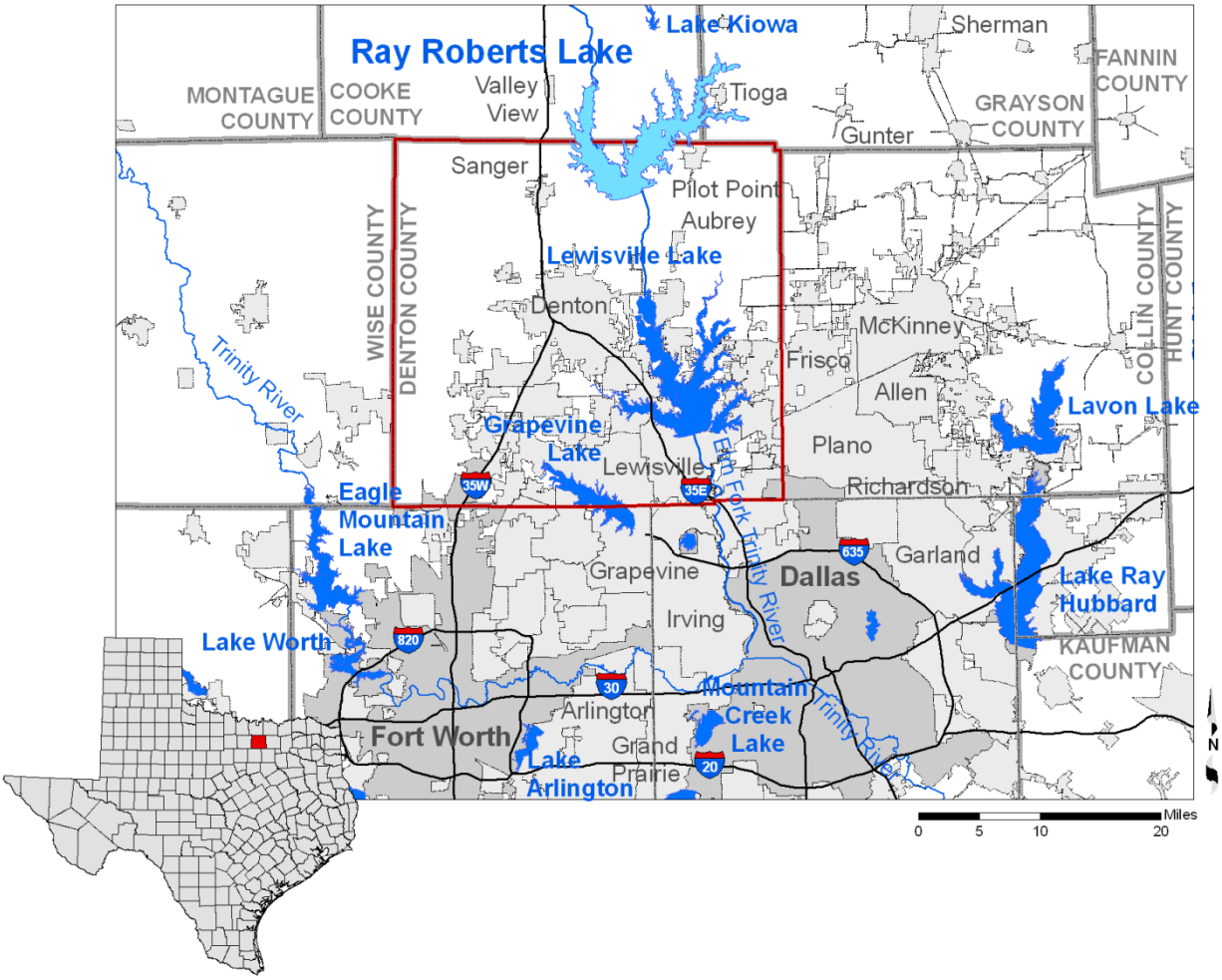

Figure 1. **Location Map – Ray Roberts Lake**

Table 1. Pertinent Data for Ray Roberts Dam and Ray Roberts Lake

Owner

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

Location of Dam

River mile 60.0 on the Elm Fork of the Trinity River, Denton County, between Sanger and Aubrey, TX, 30 miles upstream from Lewisville Dam

Drainage Area

692 square miles

Dam

Type	Rolled earth fill
Length	15,250 feet (including spillway)
Maximum height	131 feet
Top width	44 feet

Spillway

Type	Broadcrested
Length	100 feet
Crest elevation	645.5 feet NGVD29[a]
Control	None

Outlet Works

Type	1 conduit with 2 inlets
Size	13 foot diameter conduit
Invert elevation	551.0 feet NGVD29[a]
Control	Two- 6 foot x 13 foot gates

Low Flow Outlet

Type	1 concrete pipe
Size	5 foot diameter
Control	4 selector gates
Invert elevations	574.5, 588.0, 603.0, 618.0 feet NGVD29[a]

Reservoir Data (Based on 2008 TWDB volumetric survey)

Feature	**Elevation (feet NGVD29[a])**	**Capacity (acre-feet)**	**Area (acres)**
Top of concrete dam	665.0	N/A	N/A
Maximum design water surface	658.8	N/A	N/A
Spillway crest	645.5	N/A	N/A
Top of flood control pool	640.5	N/A	N/A
Top of conservation pool	632.5	788,490	28,646
Invert elevations	618.0	444,702	18,929
	603.0	221,375	11,194
	588.0	93,467	6,461
	574.5	29,933	3,045
Streambed	524.0	N/A	N/A

Source: (USACE, 2010)

[a] NGVD29 = National Geodetic Vertical Datum 1929

Water rights

Water rights for Ray Roberts Lake have been appropriated to the City of Dallas through Certificate of Adjudication No. 08-2455 and its amendments and the City of Denton through Certificate of Adjudication No. 08-2335 and its amendment. A brief summary of the certificates and amendments follow. The complete certificates are on file in the Records Division of the Texas Commission on Environmental Quality.

Certificate of Adjudication No. 08-2455
Priority date: November 24, 1975

This certificate authorizes the City of Dallas to store 591,704 acre-feet of water in Ray Roberts Lake at elevation 632.5 feet above mean sea level. The City is also authorized to divert and use a maximum of 591,704 acre-feet of water per year for municipal and domestic purposes.

Amendment to Certificate of Adjudication No. 08-2455A
Granted: June 27, 1990

In addition to the uses authorized under Certificate of Adjudication No. 08-2455, the City of Dallas is now authorized to use a maximum of 115,100 acre-feet of water per year of the 591,704 acre-feet for non-consumptive hydroelectric purposes on a non-priority basis. This water will be diverted through the low-flow outlet of Ray Roberts Dam at a maximum rate of 159 cubic feet per second.

Amendment to Certificate of Adjudication No. 08-2455B
Granted: April 12, 2006

This amendment authorizes the City of Dallas to change the use of the 591,704 acre-feet currently authorized for diversion and use for municipal and domestic purposes to now be used for multiple purposes including municipal, domestic, agricultural (irrigation), industrial, and recreation. The City retains the right to divert and use 115,100 acre-feet out of the total diversions for non-consumptive hydroelectric purposes on a non-priority basis.

Certificate of Adjudication No. 08-2335
Priority date: November 24, 1975

This certificate authorizes the City of Denton to store 207,896 acre-feet of water in Ray Roberts Lake at elevation 632.5 feet above mean sea level. The City is also authorized to divert and use a maximum of 207,896 acre-feet per year for municipal and domestic purposes.

Amendment to Certificate of Adjudication No. 08-2335A
Granted: July 25, 1990

In addition to the uses authorized under Certificate of Adjudication No. 08-2335, the City of Denton is now authorized to use a maximum of 115,100 acre-feet of water per year of the 207,896 acre-feet for non-consumptive hydroelectric purposes on a non-priority basis. This water will be diverted through the low-flow outlet of Ray Roberts Dam at a maximum rate of 159 cubic feet per second.

Volumetric and sedimentation survey of Ray Roberts Lake

Datum

The vertical datum used during this survey is that used by the United States Geological Survey (USGS) for the reservoir elevation gage USGS 08051100 Ray Roberts Lk nr Pilot Point, TX (USGS, 2010). The datum for this gage is reported as National Geodetic Vertical Datum 1929 (NGVD29). Elevations reported here are in feet above mean sea level. Volume and area calculations in this report are referenced to water levels provided by the USGS gage. The horizontal datum used for this report is North American Datum 1983 (NAD83), and the horizontal coordinate system is State Plane Texas North Central Zone (feet).

TWDB bathymetric data collection

TWDB collected bathymetric data for Ray Roberts Lake between September 11, 2008 and October 15, 2008. The water surface elevations during data collection ranged between 631.70 feet and 631.12 feet above mean sea level (NGVD29). 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. The depth sounder was calibrated daily using a velocity profiler to measure the speed of sound in the water column and a weighted tape or stadia rod for depth reading verification. During the 2008 survey, team members collected over 334,000 data points over cross-sections totaling approximately 530 miles in length. Figure 2 shows where data points were collected during the TWDB 2008 survey.

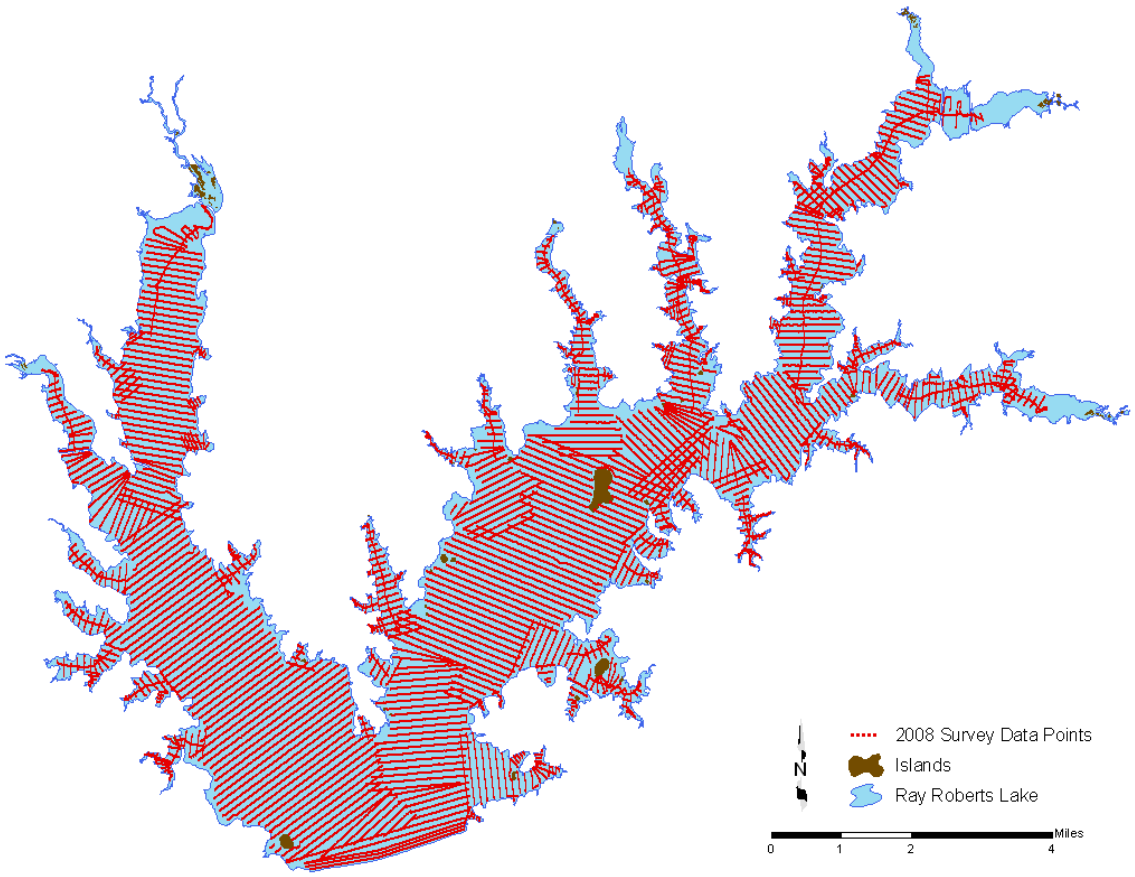

Figure 2. Map of data collected during 2008 TWDB Survey

Data processing

Model boundaries

The reservoir boundary was digitized from aerial photographs, or digital orthophoto quarter-quadrangle images (DOQQs), obtained from the Texas Natural Resources Information System (TNRIS), using Environmental Systems Research Institute's (ESRI) ArcGIS 9.1 software (NAIP, 2006, TNRIS, 2009). The DOQQs that cover Ray Roberts Lake are Mountain Springs, Pilot Point, Green Valley, Valley View, Collinsville, Woodbine, and Marilee. The majority of the DOQQs were photographed on September 10, 2004, while the water surface elevation of the lake measured 632.31 feet above mean sea level. Pilot Point NW, Pilot Point SE, and Collinsville SE were photographed on August 30, 2004, and Marilee NW was photographed on September 12, 2004, while the water surface elevation measured 632.52 and 632.27 feet above mean sea level, respectively. The water levels at the time of the photographs are within 0.19, 0.02, and 0.23 vertical feet of the conservation pool elevation, respectively. The 2004 DOQQs are of 1-meter resolution. For this analysis, the boundary digitized at the land-water interface in the 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 632.5 feet above mean sea level to facilitate calculating the area-capacity tables up to the conservation pool elevation.

Additional boundary information was available for Ray Roberts Lake from aerial photographs taken on August 2 and August 19, 2006, while the water surface elevation measured 627.64 feet and 627.17 feet. From the 2006 aerial photos, sections of 627.6 foot contours and 627.2 foot contours were digitized 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 and each section of the contours used in the model was verified for accuracy against the sounding data collected during the 2008 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 elevations at the times of each sounding were used to convert sounding depths to corresponding reservoir-bottom elevations. For processing outside of DepthPic, the sounding coordinates (X,Y,Z) were exported. TWDB also created additional mass points files of interpolated and extrapolated data based on the sounding data. Using the self-similar interpolation technique (described below), TWDB interpolated bathymetric elevation data located between surveyed cross sections. To better represent reservoir bathymetry in shallow 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 were 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 algorithms use Delaunay's criteria for triangulation to place a triangle between three non-uniformly spaced points, including the boundary vertices (ESRI, 1995).

Area, Volume, and Contour Calculations

Using ArcInfo software, volumes and areas were calculated from the bathymetric TIN model for the entire reservoir at 0.1 feet intervals, from elevation 541.3 feet to elevation 632.5 feet. The elevation-capacity table and elevation-area table, updated for 2008, 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 3), representing the topography of the reservoir bottom, a depth range map (Figure 4), showing shaded depth ranges for Ray Roberts Lake, and a 10-foot contour map (Figure 5 - attached).

Self-similar interpolation

The 3D Analyst extension 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 is 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 Ray Roberts Lake, the application of self-similar interpolation helped represent the lake morphology near the banks and improved the representation of the submerged river channel (Figure 6). In areas where obvious geomorphic features indicate 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 Ray Roberts Lake where a high probability of change between cross-sections exists. Figure 6 illustrates typical results from the self-similar interpolation routine for Ray Roberts Lake, and the bathymetry shown in Figure 6C was used in computing

Figure 3

Ray Roberts Lake

Elevation Relief Map

2,375,000 2,400,000 2,425,000 2,450,000

7,225,000 7,200,000

Elevations

(feet above mean sea level)

- 630.1 - 632.5
- 625.1 - 630
- 620.1 - 625
- 615.1 - 620
- 610.1 - 615
- 605.1 - 610
- 600.1 - 605
- 595.1 - 600
- 590.1 - 595
- 585.1 - 590
- 580.1 - 585
- 575.1 - 580
- 570.1 - 575
- 565.1 - 570
- 560.1 - 565
- 555.1 - 560
- 550.1 - 555
- 545.1 - 550
- 541.3 - 545
- Islands

Conservation Pool Elevation:
632.5 feet above mean sea level

Projection: NAD83
State Plane
Texas North Central Zone

N

0 1 2 4 Miles

Figure 4

Ray Roberts Lake

Depth Ranges Map

2,375,000 2,400,000 2,425,000 2,450,000

7,225,000

7,200,000

Depth Ranges

(feet)

- 0 - 10'
- 10 - 20'
- 20 - 30'
- 30 - 40'
- 40 - 50'
- 50 - 60'
- 60 - 70'
- 70 - 80'
- 80 - 90'
- > 90'
- Isalnds

Conservation Pool Elevation:
632.5 feet above mean sea level

Projection: NAD83
State Plane
Texas North Central Zone

N

0 1 2 4 Miles

reservoir capacity and area tables (Appendix A, B).

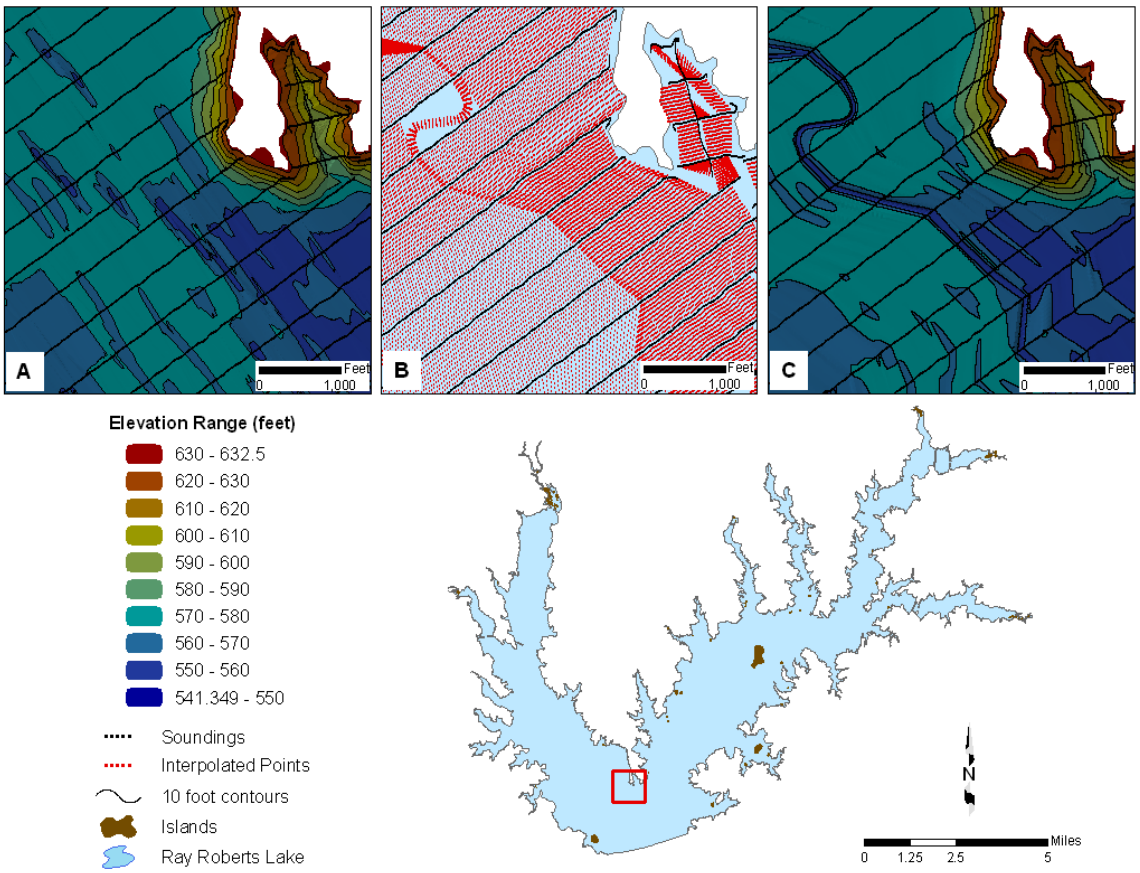

Figure 6. **Application of the self-similar interpolation technique to Ray Roberts Lake sounding data – A) bathymetric contours without interpolated points, B) sounding points (black) and interpolated points (red) with reservoir boundary shown at elevation 632.5 feet, C) bathymetric contours with the interpolated points. Note: In 6A the deeper channels indicated by the surveyed cross sections are not continuously represented in the areas in-between the cross sections. This is an artifact of the TIN generation routine, rather than an accurate representation of the physical bathymetric surface. Inclusion of self-similar points (6B) corrects and smoothes the bathymetric contours.**

Line extrapolation

In order to estimate the bathymetry within the small coves and other un-surveyed portions of Ray Roberts Lake, TWDB applied a line extrapolation method, which is similar to self-similar 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 longitudinal axis approximately bisecting the small cove, (2) the elevation at the beginning of the longitudinal axis, (3) the number of cross sections along the longitudinal axis, and (4) the number of points between the longitudinal axis and the cove boundary. The starting elevation of the longitudinal axis is

typically assumed equivalent to the elevation of the TIN model near the beginning of the longitudinal line or 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 longitudinal axis. Elevations along the longitudinal axis are linearly interpolated based on the distance along the axis from the start (nearest the reservoir interior) to the end (where the axis crosses the reservoir boundary). The elevations at points along each extrapolated cross-section are linearly interpolated from an elevation on the longitudinal axis (at the intersection with the cross-section) and the elevation at the extrapolation area boundary. Figure 7 illustrates line extrapolation as applied to Ray Roberts Lake.

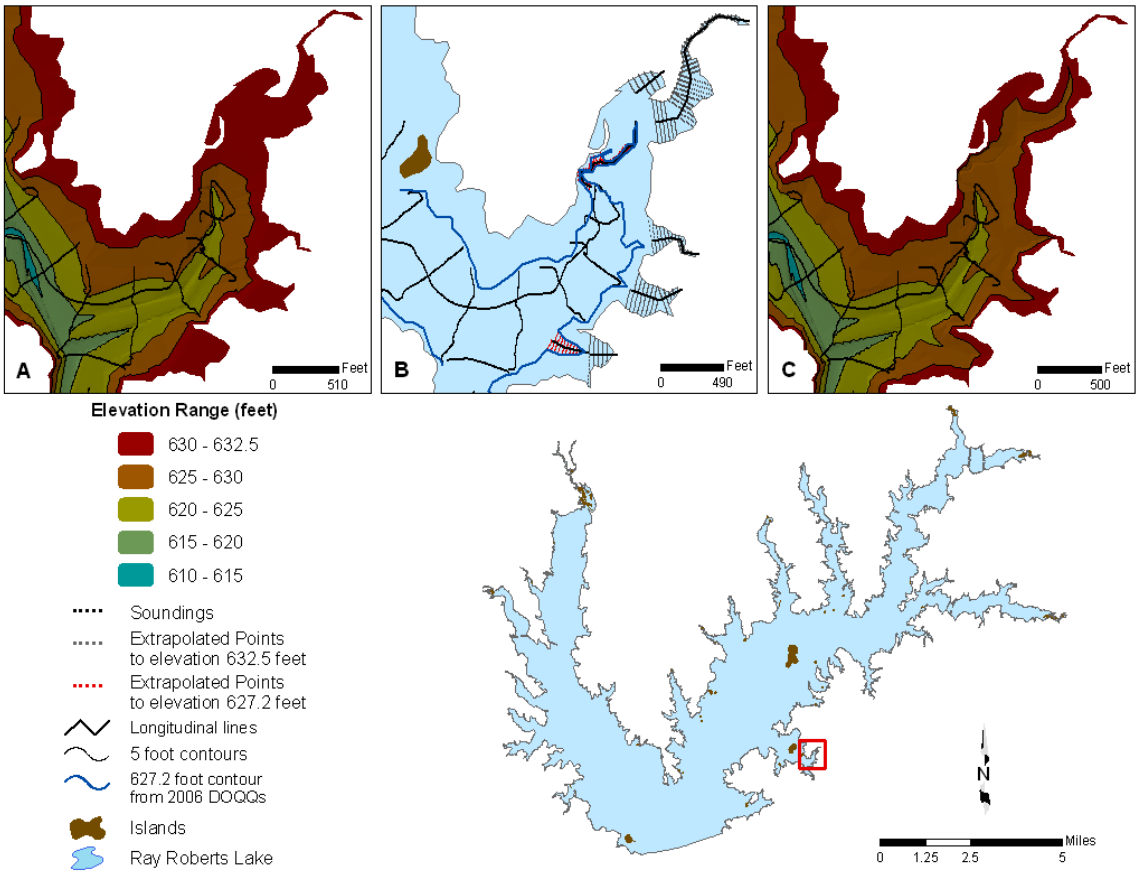

Figure 7. **Application of the line extrapolation technique to Ray Roberts Lake sounding data – A) bathymetric contours without extrapolated points, B) Sounding points (black), 627.2 foot contour digitized from 2006 DOQQs (blue), and extrapolated points to 627.2 feet (red) and to 632.5 feet (grey), with reservoir boundary shown at elevation 632.5 feet, and C) bathymetric contours with the 627.2 foot contour and extrapolated points.**

As shown in Figure 7, the line extrapolation method for Ray Roberts Lake was implemented using the 627.6 foot and 627.2 foot contours (derived from the 2006 DOQQs) as the bounding extent of many 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 632.5 feet was used as the bounding extent. In Figure 7A the bathymetric contours do not extend into the un-surveyed area and "flat" triangles are formed connecting the nodes of the reservoir boundary. This is an artifact of the TIN generation routine when data points are too far apart or are absent from portions of the reservoir. Inclusion of the extrapolated points (7C) corrects this and smoothes the bathymetric contours.

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. TWDB has not yet been able to test this assumption, and therefore can only assume that the results of the usage of line extrapolation are more accurate than those derived without line extrapolation. 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 Ray Roberts Lake had shapes more similar to U-profiles than to V-profiles. The V-profiles are thus conservative in that a greater volume of water is implied by a U-profile than a V-profile. Further information on line extrapolation is provided in the HydroEdit User's Manual (Furnans, 2006).

Analysis of sediment data from Ray Roberts Lake

Sedimentation in Ray Roberts Lake 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). Core samples collected throughout the lake were correlated with the multi-frequency acoustic signals to verify the location of the pre-impoundment surface. The difference between the current surface and the pre-impoundment surface yields a sediment thickness value at each sounding location.

TWDB collected four sediment cores from Ray Roberts Lake on January 21, 2009. Core samples were collected at locations where sounding data had been previously collected (Figure 8). All cores were collected with a custom-coring boat and SDI VibraCore system. Cores were analyzed by TWDB and both the sediment thickness and the distance the core penetrated into the pre-impoundment boundary were recorded (Table 2). The pre-impoundment surface is identified within the core sample by one of the following methods:

(1) a visual examination of the core for in-place terrestrial materials, such as leaf litter, tree bark, twigs, intact roots, etc., concentrations of which tend to occur on or just below the pre-impoundment surface, (2) changes in texture from well sorted, relatively fine-grained sediment to poorly sorted mixtures of coarse and fine-grained materials, and (3) variations in the physical properties of the sediment, particularly sediment water content and penetration resistance with depth.

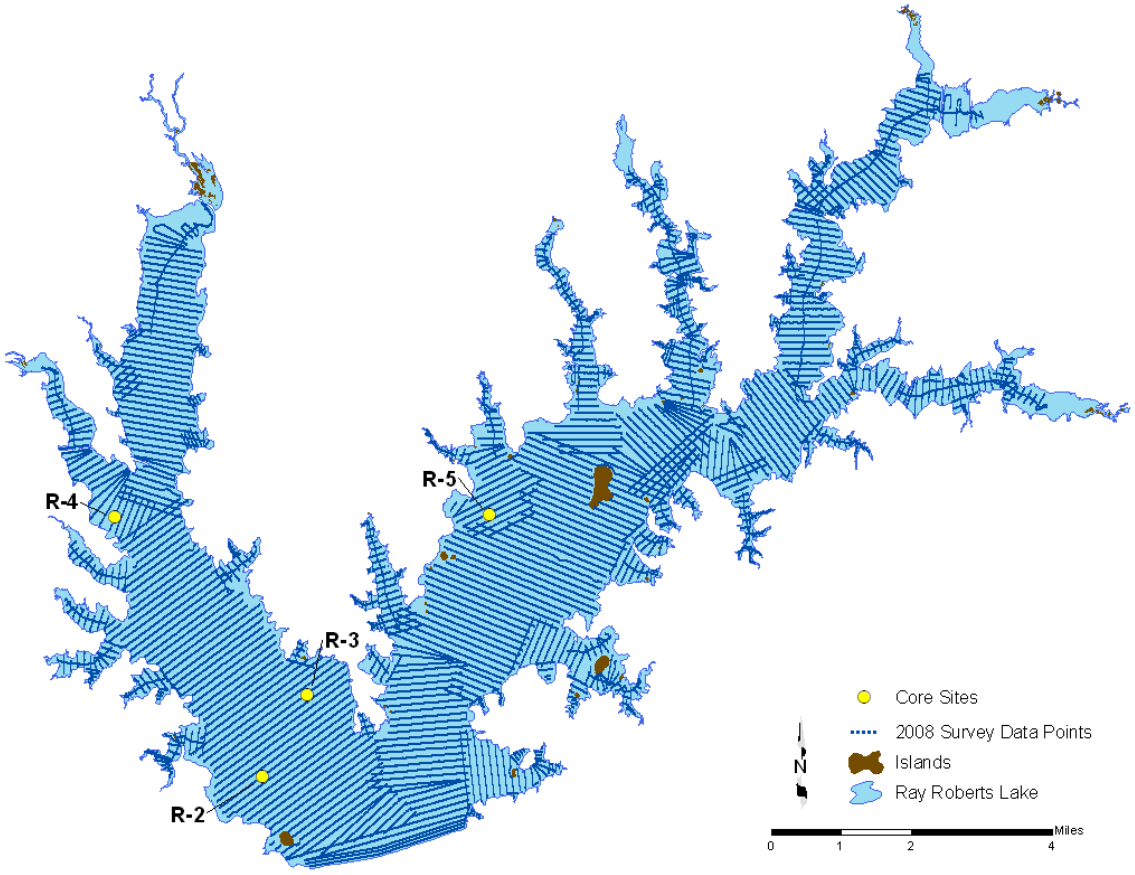

Figure 8. **Locations of core samples relative to the 2008 TWDB survey data. Note: Core sample R-1 was unrecoverable due to field conditions and is not shown.**

Table 2. Core sampling analysis data – Ray Roberts Lake

Core	Easting[a] (ft)	Northing[a](ft)	Total core sediment	Post impoundment sediment thickness - Description
R-2	240606.16	7184219.63	4.5”	2” -sandy loam, reddish brown in color, high water content, organics present in remaining core
R-3	2403963.64	7190348.44	16”	9” - brownish grey sediment, high water content, soil structure present in remaining core
R-4	2417656.54	7203864.05	13.5”	5” - brownish sediment, high water content, organics and soil structure in remaining core
R-5	2389507.63	7203686.67	16.5”	5” - sandy loam, reddish brown in color, high moisture content, soil density rapidly increases to base of core, organics at 8” deep

[a] Coordinates are based on NAD 1983 State Plane Texas North Central System

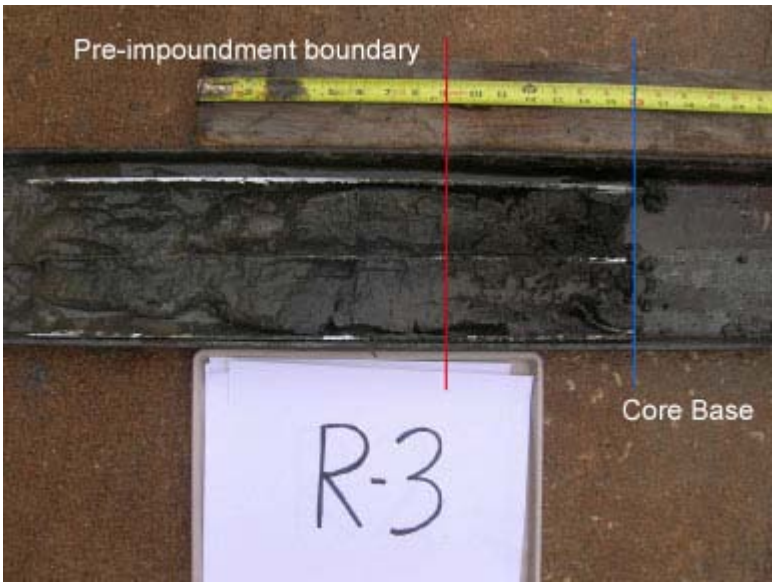

Figure 9. Sediment Core R-3 from Ray Roberts Lake

Sediment core R-3 consisted of 16 inches of sediment. The start of the tape measure (left) indicates the sediment level before bisecting the core tube for analysis. The upper sediment layer, from 0 – 9 inches, had high water content and consisted of sandy-loam material. The pre-impoundment boundary was evident from this core at nine inches and is identified by the change in soil structure at 9 inches on the ruler (red line in Figure 9). Between nine inches and the base of the core (blue line in Figure 9), soil structure was present and organics were found at 12 inches.

Figures 10 and 11 illustrate how a core sample is correlated with the sounding data to verify post-impoundment sediment in the acoustic signal. Within DepthPic, the current surface is automatically determined based on the signal returns from the 200 kHz transducer, while the pre-impoundment surface must be determined visually. The pre-impoundment surface is first identified along cross-sections for which core samples have

been collected. When analyzing data from cross-sections where core samples were not collected, it is assumed that the pre-impoundment layer may be identified by similar acoustic patterns as were identified when core sample data was available. To improve the validity of this assumption, core samples are collected at regularly spaced intervals within the lake, or at locations where interpretation of the DepthPic display would be difficult without site-specific core data. For this reason, all sounding data is collected and reviewed before core sites are selected and cores are collected. For shallow areas of the lake where soundings have not been collected, sediment thicknesses are assumed negligible. This assumption may lead to underestimating the calculated sediment volume compared to the physical sediment volume present within the lake. In Ray Roberts Lake, the physical characteristics of all the cores matched well with the 24 kHz frequency, which was used to digitize the pre-impoundment surface in all the data.

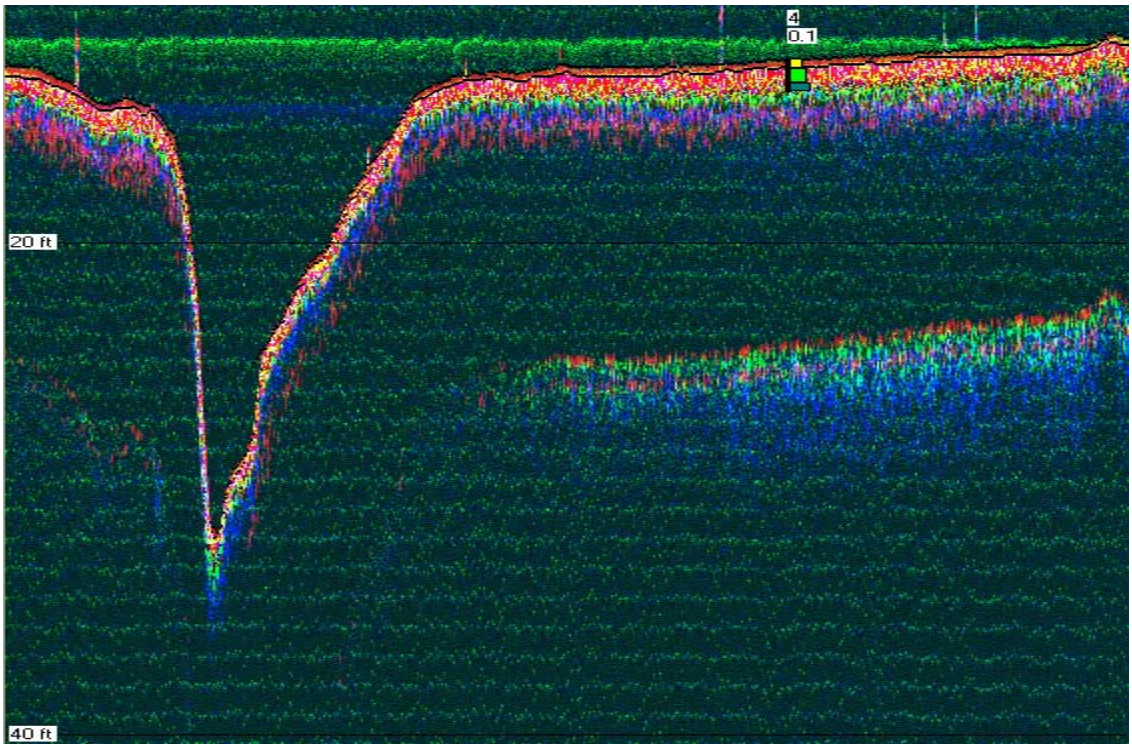

Figure 10. **Cross-section of data collected during 2008 survey, displayed in DepthPic with all three frequencies on and correlated with core sample R-5.**

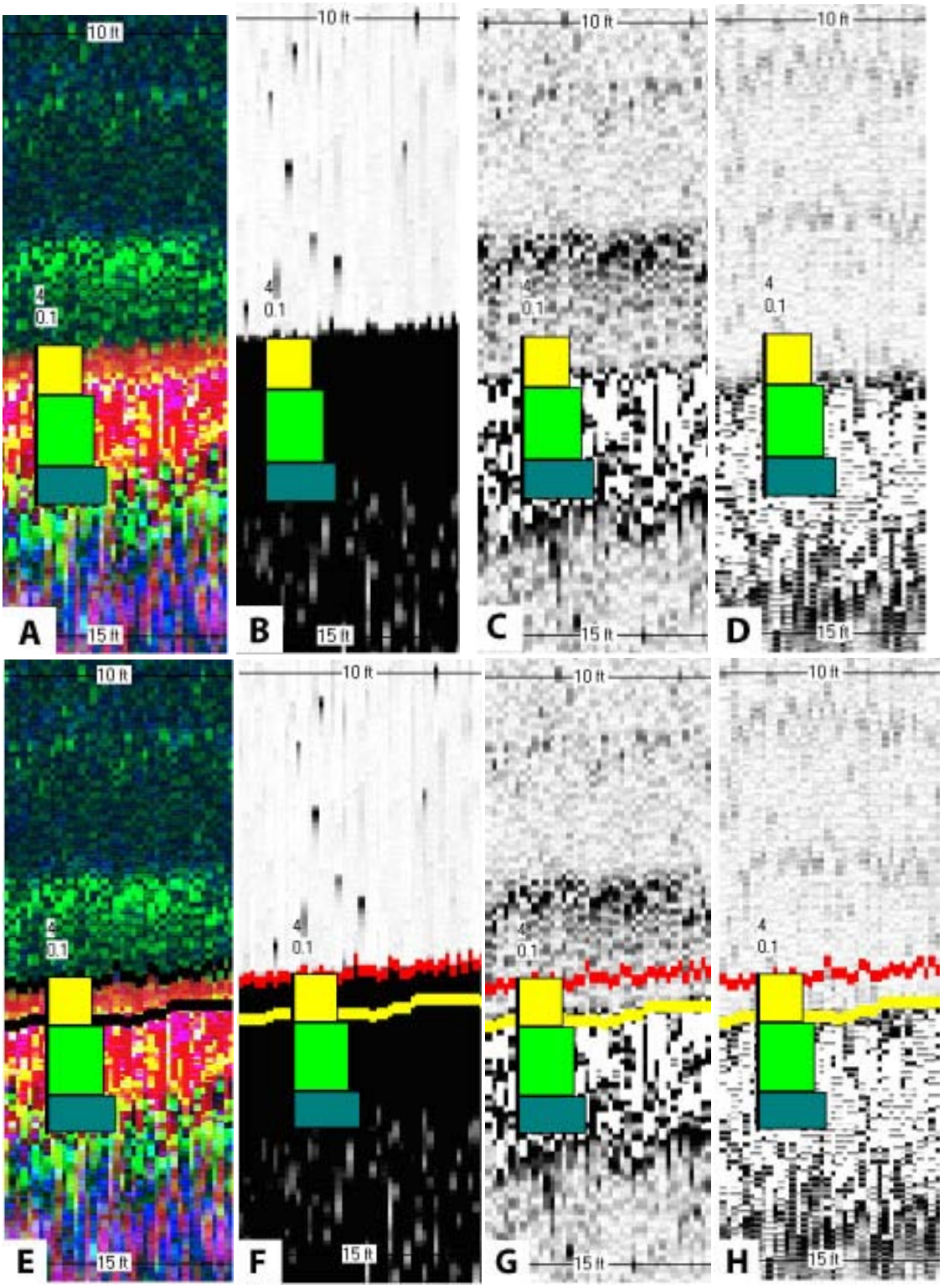

Figure 11. **A,E) Close up of combined acoustic signal returns shown in Figure 10 correlated with core sample R-5, B,F) 200 kHz frequency, C,G) 50 kHz frequency, D,H) 24 kHz frequency.**

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 the pre-impoundment surface is represented by the bottom black line. In figures 11F-H, the red line represents the current surface and the yellow line represents the pre-impoundment surface. The core sample is represented in DepthPic as colored boxes, where yellow represents post-impoundment sediment, identified as the 5 inches of sandy loam with a high water content (Table 2), the green box represents the denser soil from 5 inches to 12 inches, and the blue box represents the very dense dark soil found from 12 inches to the base of the core at 16.5 inches.

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 for locations 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 632.5 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 Ray Roberts Lake.

Survey results

Volumetric survey

The results of the 2008 TWDB volumetric survey indicate Ray Roberts Lake has a total reservoir capacity of 788,490 acre-feet and encompasses 28,646 acres at conservation pool elevation (632.5 feet above mean sea level, NGVD29). In 1985, during construction of Ray Roberts Dam, the U.S. Army Corps of Engineers estimated Ray Roberts Lake would have a total capacity of 799,600 acre-feet and would encompass 29,350 acres at conservation pool elevation. (USACE, 2010). This indicates the capacity of Ray Roberts Lake has decreased by 11,110 acre-feet, or approximately 1.4% since impoundment. Differences in past and present survey methodologies makes direct comparison of volumetric surveys difficult and potentially unreliable.

Figure 12

Ray Roberts Lake

Sediment Thickness Map

2,375,000 2,400,000 2,425,000 2,450,000

7,225,000

7,200,000

Sediment Thickness

(in feet)

- 0 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.4
- 0.4 - 0.5
- 0.5 - 0.6
- 0.6 - 0.7
- 0.7 - 0.8
- 0.8 - 0.9
- 0.9 - 1.0
- 1.0 - 1.1
- 1.1 - 1.2
- 1.2 - 1.3
- 1.3 - 1.4
- 1.4 - 1.5
- 1.5 - 1.6
- 1.6 - 1.7

Islands

Ray Roberts Lake

Conservation Pool Elevation:
632.5 feet above mean sea level

Projection: NAD83
State Plane
Texas North Central Zone

N

0 1 2 4 Miles

Sedimentation survey

The 2008 TWDB sedimentation survey indicates that Ray Roberts Lake has accumulated 8,385 acre-feet of sediment since impoundment in 1987. Sediment accumulation is well dispersed throughout the lake, though nearly absent in the submerged rivers and thickest in the submerged floodplains of the submerged rivers. The maximum sediment thickness observed in Ray Roberts Lake was 1.8 feet.

Theoretically, 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. Comparing results from multiple volumetric surveys, however, would also yield sediment accumulation rate estimates as long as similar methodologies were used when generating each capacity estimate.

For informational purposes only, a capacity loss rate, i.e. sedimentation rate, was calculated for both the measured sediment volume and the difference between the current volumetric survey and 1985 survey (Table 3). Based on the measured sediment volume and assuming a constant sediment accumulation rate, Ray Roberts Lake loses approximately 400 acre-feet of capacity per year. Comparison #3 in the table compares the original, mid-construction 1985 survey capacity to the pre-impoundment capacity measured during the 2008 survey. The difference between the two surveys is 0.3%.

Table 3. Capacity loss comparisons for Ray Roberts Lake

Survey	Volume comparisons @ CPE (acre-ft)		Pre-impoundment (acre-ft)
	Comparison #1	**Comparison #2**	**Comparison #3**
1985[a]	799,600	<>	799,600
TWDB pre-impoundment estimate based on 2008 survey	<>	796,875[b]	796,875[b]
2008 volumetric survey	788,490	788,490	<>
Volume difference (acre-feet)	11,110 (1.4%)	8,385 (1.05%)	2,725 (0.3%)
Number of years	21[a]	21	21[a]
Capacity loss rate (acre-feet/year)	483	399	130

[a] 1985 capacity estimation completed during construction of dam and impoundment began in 1987, therefore number of years calculated based on impoundment date of 1987.
[b] 2008 TWDB surveyed capacity of 788,490 acre-feet plus 2008 TWDB surveyed sediment volume of 8,385 acre-feet.

Recommendations

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

TWDB contact information

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

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Or

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Appendix A

Ray Roberts Lake

RESERVOIR CAPACITY TABLE

TEXAS WATER DEVELOPMENT BOARD — September - October 2008 Survey

CAPACITY IN ACRE-FEET — Conservation Pool Elevation 632.5 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
541	0	0	0	0	0	0	0	0	0	0
542	0	0	0	1	1	1	1	1	2	2
543	2	3	3	3	4	4	5	5	6	7
544	7	8	8	9	10	10	11	12	13	14
545	14	15	16	17	18	20	21	22	24	25
546	27	28	30	32	34	36	38	40	43	45
547	48	51	54	57	60	64	68	72	76	80
548	84	89	94	99	104	109	115	121	128	134
549	141	148	155	162	170	178	186	195	203	212
550	221	230	240	249	259	269	279	290	300	311
551	323	334	346	358	370	383	396	409	423	437
552	451	466	482	498	514	531	549	567	586	605
553	625	647	669	692	716	741	766	793	820	848
554	877	907	938	970	1,002	1,035	1,069	1,104	1,140	1,176
555	1,213	1,251	1,289	1,329	1,368	1,409	1,450	1,492	1,534	1,578
556	1,622	1,667	1,712	1,759	1,806	1,855	1,904	1,954	2,005	2,057
557	2,110	2,164	2,219	2,275	2,331	2,389	2,448	2,508	2,568	2,630
558	2,693	2,756	2,821	2,886	2,953	3,020	3,089	3,159	3,229	3,301
559	3,374	3,448	3,523	3,599	3,676	3,754	3,833	3,912	3,993	4,074
560	4,157	4,240	4,325	4,410	4,497	4,585	4,673	4,763	4,853	4,944
561	5,036	5,130	5,224	5,319	5,415	5,511	5,609	5,708	5,808	5,909
562	6,010	6,113	6,217	6,322	6,428	6,535	6,643	6,752	6,862	6,973
563	7,086	7,199	7,314	7,430	7,547	7,665	7,785	7,906	8,029	8,153
564	8,278	8,405	8,534	8,664	8,795	8,928	9,062	9,198	9,335	9,474
565	9,614	9,755	9,898	10,042	10,187	10,334	10,483	10,632	10,783	10,936
566	11,090	11,245	11,402	11,560	11,720	11,881	12,044	12,208	12,373	12,540
567	12,709	12,879	13,051	13,224	13,398	13,574	13,750	13,929	14,108	14,289
568	14,471	14,654	14,839	15,025	15,212	15,400	15,589	15,780	15,972	16,166
569	16,361	16,557	16,755	16,954	17,154	17,356	17,560	17,765	17,972	18,181
570	18,392	18,605	18,820	19,037	19,256	19,477	19,700	19,925	20,152	20,382
571	20,613	20,846	21,081	21,318	21,556	21,797	22,039	22,283	22,528	22,776
572	23,025	23,277	23,530	23,785	24,043	24,302	24,563	24,826	25,091	25,358
573	25,628	25,899	26,172	26,448	26,726	27,006	27,288	27,573	27,860	28,149
574	28,441	28,734	29,031	29,329	29,630	29,933	30,239	30,547	30,857	31,169
575	31,484	31,800	32,119	32,439	32,762	33,088	33,416	33,746	34,079	34,414
576	34,752	35,092	35,435	35,779	36,126	36,476	36,827	37,181	37,536	37,894
577	38,254	38,616	38,979	39,345	39,713	40,082	40,454	40,829	41,205	41,585
578	41,966	42,350	42,737	43,127	43,519	43,913	44,310	44,709	45,111	45,516
579	45,922	46,331	46,743	47,157	47,574	47,993	48,415	48,840	49,266	49,696
580	50,128	50,562	50,998	51,437	51,878	52,322	52,768	53,217	53,668	54,123
581	54,580	55,039	55,502	55,967	56,434	56,905	57,378	57,854	58,332	58,814
582	59,298	59,785	60,275	60,768	61,265	61,764	62,266	62,771	63,278	63,789
583	64,301	64,817	65,335	65,855	66,379	66,905	67,434	67,966	68,501	69,039
584	69,581	70,125	70,673	71,224	71,778	72,335	72,895	73,458	74,023	74,592
585	75,163	75,737	76,314	76,893	77,476	78,061	78,648	79,239	79,831	80,427
586	81,024	81,624	82,227	82,831	83,438	84,048	84,659	85,273	85,889	86,508
587	87,129	87,752	88,377	89,005	89,635	90,268	90,903	91,540	92,180	92,823
588	93,467	94,114	94,764	95,416	96,071	96,729	97,388	98,051	98,716	99,383
589	100,053	100,725	101,400	102,078	102,758	103,440	104,124	104,811	105,500	106,192
590	106,886	107,583	108,282	108,983	109,687	110,393	111,101	111,812	112,525	113,241
591	113,959	114,679	115,402	116,128	116,856	117,586	118,318	119,053	119,791	120,530
592	121,272	122,016	122,763	123,511	124,262	125,015	125,771	126,529	127,289	128,052
593	128,817	129,584	130,354	131,126	131,901	132,678	133,458	134,241	135,026	135,814
594	136,604	137,396	138,192	138,990	139,791	140,594	141,400	142,209	143,021	143,835
595	144,652	145,472	146,295	147,120	147,949	148,781	149,615	150,453	151,294	152,138

Appendix A (Continued)

Ray Roberts Lake

RESERVOIR CAPACITY TABLE

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

September - October 2008 Survey
Conservation Pool Elevation 632.5 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
596	152,985	153,835	154,689	155,546	156,406	157,269	158,134	159,004	159,875	160,751
597	161,629	162,511	163,397	164,286	165,178	166,074	166,974	167,877	168,784	169,694
598	170,608	171,525	172,447	173,372	174,302	175,234	176,170	177,111	178,055	179,003
599	179,954	180,910	181,869	182,833	183,801	184,772	185,747	186,727	187,711	188,699
600	189,691	190,686	191,687	192,691	193,700	194,712	195,728	196,749	197,773	198,803
601	199,835	200,872	201,914	202,959	204,009	205,063	206,121	207,183	208,249	209,320
602	210,394	211,473	212,556	213,643	214,736	215,831	216,931	218,036	219,145	220,258
603	221,375	222,497	223,623	224,753	225,889	227,028	228,172	229,320	230,473	231,630
604	232,792	233,958	235,130	236,305	237,486	238,670	239,860	241,054	242,253	243,458
605	244,666	245,879	247,098	248,320	249,548	250,779	252,015	253,257	254,502	255,752
606	257,007	258,266	259,530	260,798	262,072	263,350	264,632	265,920	267,212	268,510
607	269,811	271,118	272,430	273,746	275,068	276,394	277,724	279,060	280,400	281,746
608	283,096	284,452	285,813	287,178	288,549	289,925	291,305	292,691	294,082	295,478
609	296,879	298,285	299,698	301,115	302,539	303,968	305,402	306,842	308,287	309,738
610	311,192	312,652	314,118	315,587	317,063	318,542	320,027	321,518	323,013	324,513
611	326,019	327,529	329,045	330,566	332,093	333,626	335,163	336,706	338,255	339,809
612	341,367	342,931	344,501	346,074	347,654	349,238	350,828	352,423	354,022	355,628
613	357,237	358,852	360,473	362,098	363,730	365,365	367,005	368,652	370,302	371,959
614	373,620	375,286	376,958	378,635	380,318	382,005	383,698	385,398	387,103	388,814
615	390,531	392,252	393,981	395,714	397,454	399,198	400,948	402,705	404,466	406,234
616	408,006	409,784	411,570	413,360	415,156	416,958	418,766	420,581	422,401	424,227
617	426,059	427,897	429,741	431,591	433,447	435,308	437,175	439,049	440,927	442,812
618	444,702	446,597	448,499	450,406	452,320	454,239	456,163	458,095	460,032	461,977
619	463,927	465,883	467,847	469,815	471,791	473,772	475,759	477,754	479,754	481,761
620	483,773	485,793	487,820	489,853	491,894	493,940	495,994	498,056	500,124	502,201
621	504,283	506,372	508,470	510,572	512,683	514,798	516,920	519,050	521,185	523,329
622	525,477	527,632	529,794	531,963	534,139	536,320	538,508	540,704	542,904	545,113
623	547,327	549,548	551,777	554,011	556,254	558,502	560,757	563,021	565,290	567,568
624	569,851	572,142	574,442	576,747	579,061	581,381	583,708	586,044	588,385	590,735
625	593,090	595,451	597,821	600,195	602,578	604,965	607,358	609,758	612,163	614,575
626	616,992	619,414	621,844	624,278	626,720	629,167	631,620	634,081	636,546	639,020
627	641,499	643,986	646,482	648,995	651,518	654,045	656,581	659,142	661,707	664,279
628	666,856	669,437	672,026	674,618	677,218	679,821	682,429	685,045	687,664	690,290
629	692,919	695,554	698,196	700,842	703,494	706,150	708,812	711,481	714,153	716,833
630	719,516	722,205	724,901	727,601	730,308	733,019	735,736	738,460	741,188	743,923
631	746,663	749,408	752,161	754,917	757,682	760,451	763,226	766,008	768,795	771,590
632	774,389	777,195	780,009	782,829	785,656	788,490				

Appendix B

Ray Roberts Lake

RESERVOIR AREA TABLE

TEXAS WATER DEVELOPMENT BOARD — September - October 2008 Survey

AREA IN ACRES — Conservation Pool Elevation 632.5 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
541	0	0	0	0	0	0	0	0	1	1
542	1	1	1	1	2	2	2	2	3	3
543	3	4	4	4	5	5	5	5	6	6
544	6	6	6	7	7	7	7	8	8	8
545	9	9	10	11	12	13	13	14	14	15
546	16	17	18	19	20	21	22	23	25	26
547	28	30	31	33	35	36	38	40	42	44
548	45	47	49	51	53	56	59	61	64	66
549	69	71	74	76	78	80	82	85	87	89
550	91	93	95	97	99	102	104	106	108	111
551	113	116	119	122	125	128	132	135	139	143
552	147	152	156	161	166	172	178	185	192	200
553	208	217	226	235	244	252	261	269	278	287
554	295	303	311	319	327	335	344	352	361	368
555	375	381	388	395	401	408	415	422	429	436
556	444	453	461	470	479	488	497	506	515	524
557	534	544	554	563	573	583	592	602	612	621
558	631	640	650	660	671	681	692	702	713	724
559	735	745	755	764	774	783	792	801	810	820
560	830	840	850	860	871	881	890	899	908	917
561	926	936	945	954	964	974	983	993	1,002	1,012
562	1,023	1,033	1,043	1,053	1,064	1,075	1,086	1,097	1,107	1,118
563	1,129	1,141	1,153	1,165	1,177	1,191	1,205	1,219	1,233	1,248
564	1,263	1,278	1,293	1,307	1,321	1,336	1,350	1,364	1,378	1,392
565	1,406	1,420	1,433	1,447	1,462	1,477	1,491	1,504	1,517	1,531
566	1,545	1,560	1,576	1,591	1,605	1,619	1,634	1,649	1,664	1,679
567	1,695	1,709	1,723	1,736	1,749	1,761	1,775	1,788	1,801	1,814
568	1,827	1,840	1,852	1,864	1,877	1,889	1,902	1,915	1,928	1,942
569	1,956	1,969	1,983	1,998	2,013	2,029	2,045	2,061	2,079	2,098
570	2,119	2,139	2,159	2,180	2,200	2,220	2,241	2,262	2,284	2,304
571	2,322	2,340	2,358	2,376	2,394	2,412	2,430	2,449	2,467	2,485
572	2,504	2,524	2,543	2,563	2,583	2,602	2,621	2,640	2,660	2,681
573	2,702	2,724	2,746	2,768	2,790	2,812	2,835	2,858	2,880	2,903
574	2,926	2,950	2,974	2,997	3,020	3,045	3,069	3,091	3,112	3,133
575	3,154	3,174	3,196	3,218	3,242	3,267	3,292	3,316	3,340	3,365
576	3,389	3,413	3,437	3,459	3,482	3,504	3,526	3,546	3,567	3,587
577	3,607	3,627	3,647	3,667	3,687	3,708	3,731	3,755	3,779	3,804
578	3,829	3,855	3,883	3,909	3,933	3,957	3,980	4,004	4,030	4,055
579	4,080	4,105	4,130	4,155	4,181	4,205	4,230	4,256	4,282	4,306
580	4,329	4,352	4,375	4,399	4,425	4,450	4,476	4,502	4,529	4,555
581	4,583	4,610	4,637	4,664	4,691	4,718	4,745	4,772	4,799	4,827
582	4,857	4,887	4,918	4,947	4,977	5,006	5,035	5,062	5,089	5,115
583	5,141	5,167	5,194	5,220	5,247	5,275	5,304	5,336	5,368	5,400
584	5,431	5,463	5,494	5,524	5,554	5,583	5,613	5,642	5,670	5,698
585	5,726	5,755	5,782	5,810	5,837	5,864	5,889	5,915	5,940	5,965
586	5,989	6,013	6,036	6,058	6,081	6,104	6,127	6,150	6,173	6,197
587	6,220	6,243	6,266	6,290	6,314	6,338	6,362	6,387	6,411	6,436
588	6,461	6,485	6,510	6,535	6,560	6,586	6,612	6,636	6,661	6,687
589	6,712	6,737	6,761	6,785	6,810	6,834	6,857	6,881	6,905	6,929
590	6,954	6,977	7,000	7,025	7,049	7,073	7,096	7,120	7,144	7,168
591	7,193	7,217	7,242	7,266	7,290	7,314	7,337	7,361	7,385	7,408
592	7,430	7,452	7,475	7,498	7,521	7,544	7,567	7,591	7,614	7,638
593	7,662	7,686	7,711	7,736	7,760	7,786	7,812	7,837	7,863	7,890
594	7,916	7,942	7,968	7,994	8,021	8,048	8,075	8,102	8,130	8,157
595	8,185	8,213	8,242	8,271	8,301	8,331	8,362	8,393	8,424	8,455

Appendix B (Continued)

Ray Roberts Lake

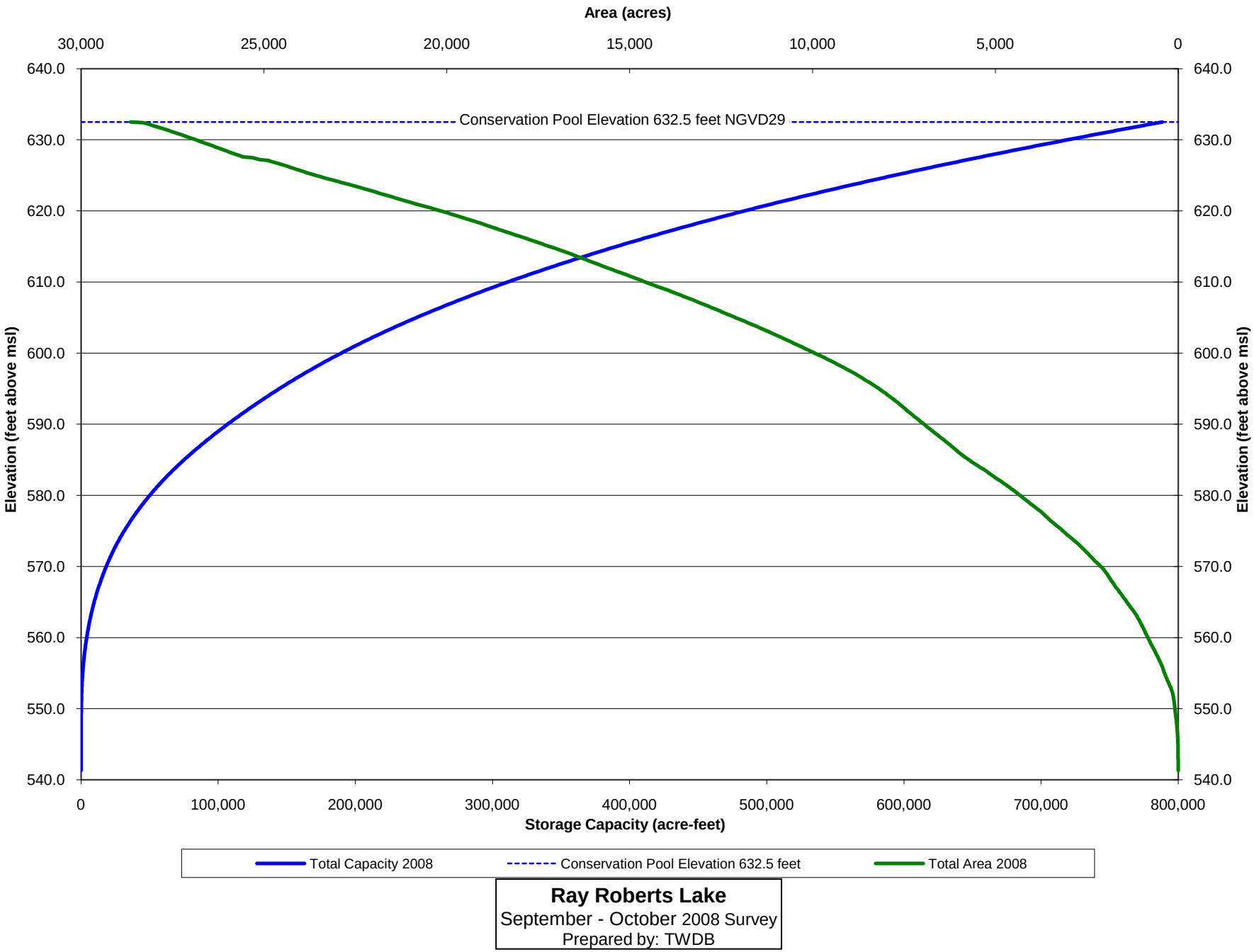
RESERVOIR AREA TABLE

TEXAS WATER DEVELOPMENT BOARD — September - October 2008 Survey

AREA IN ACRES — Conservation Pool Elevation 632.5 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
596	8,487	8,520	8,552	8,583	8,614	8,644	8,674	8,705	8,737	8,769
597	8,802	8,836	8,872	8,908	8,943	8,978	9,014	9,050	9,085	9,121
598	9,159	9,196	9,235	9,272	9,309	9,346	9,383	9,421	9,459	9,497
599	9,535	9,574	9,616	9,656	9,696	9,735	9,776	9,817	9,858	9,899
600	9,939	9,981	10,023	10,064	10,104	10,144	10,184	10,225	10,267	10,309
601	10,351	10,394	10,435	10,476	10,517	10,559	10,599	10,641	10,683	10,725
602	10,768	10,810	10,853	10,896	10,939	10,982	11,024	11,066	11,109	11,151
603	11,194	11,238	11,284	11,328	11,373	11,417	11,461	11,505	11,550	11,594
604	11,640	11,687	11,734	11,781	11,826	11,872	11,919	11,967	12,015	12,063
605	12,110	12,158	12,204	12,250	12,296	12,341	12,386	12,431	12,478	12,524
606	12,570	12,616	12,662	12,708	12,755	12,803	12,851	12,899	12,949	12,997
607	13,045	13,093	13,141	13,188	13,235	13,284	13,332	13,380	13,430	13,479
608	13,529	13,580	13,632	13,683	13,734	13,783	13,831	13,881	13,932	13,986
609	14,039	14,093	14,150	14,207	14,263	14,317	14,371	14,423	14,476	14,527
610	14,576	14,625	14,673	14,724	14,776	14,827	14,877	14,926	14,976	15,029
611	15,081	15,133	15,185	15,239	15,296	15,351	15,404	15,457	15,511	15,563
612	15,614	15,666	15,717	15,768	15,819	15,870	15,921	15,972	16,023	16,074
613	16,127	16,179	16,230	16,282	16,333	16,383	16,433	16,484	16,534	16,586
614	16,638	16,691	16,743	16,797	16,852	16,907	16,965	17,022	17,079	17,137
615	17,194	17,251	17,306	17,362	17,420	17,476	17,532	17,588	17,644	17,701
616	17,758	17,816	17,875	17,934	17,992	18,053	18,112	18,171	18,231	18,291
617	18,351	18,410	18,469	18,527	18,585	18,643	18,702	18,759	18,817	18,873
618	18,929	18,986	19,043	19,102	19,161	19,222	19,283	19,345	19,407	19,470
619	19,534	19,598	19,662	19,724	19,785	19,845	19,906	19,969	20,032	20,098
620	20,165	20,233	20,299	20,366	20,436	20,508	20,578	20,650	20,722	20,794
621	20,862	20,930	20,998	21,064	21,130	21,194	21,258	21,324	21,391	21,456
622	21,521	21,587	21,653	21,721	21,786	21,851	21,916	21,980	22,046	22,113
623	22,179	22,246	22,315	22,385	22,454	22,522	22,591	22,662	22,732	22,805
624	22,880	22,953	23,024	23,096	23,168	23,241	23,313	23,383	23,453	23,522
625	23,589	23,653	23,718	23,782	23,845	23,907	23,966	24,026	24,084	24,142
626	24,200	24,259	24,319	24,380	24,442	24,504	24,567	24,631	24,696	24,764
627	24,834	24,908	25,110	25,179	25,248	25,320	25,573	25,630	25,686	25,742
628	25,796	25,851	25,905	25,958	26,011	26,064	26,117	26,170	26,223	26,276
629	26,329	26,382	26,436	26,489	26,543	26,596	26,650	26,704	26,759	26,813
630	26,868	26,923	26,978	27,033	27,089	27,145	27,201	27,258	27,315	27,372
631	27,430	27,488	27,546	27,605	27,664	27,724	27,785	27,846	27,907	27,970
632	28,034	28,098	28,164	28,232	28,303	28,646				



Ray Roberts Lake
September - October 2008 Survey
Prepared by: TWDB

Appendix C: Area and Capacity Curves

Figure 5

Ray Roberts Lake

10' - Contour Map

CONTOURS

(feet above mean sea level)

630
620
610
600
590
580
570
560
550

Islands

Ray Roberts Lake

Conservation Pool Elevation:
632.5 feet above mean sea level

Projection: NAD83
State Plane
Texas North Central Zone

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

2,400,000
2,420,000
2,440,000
2,460,000
7,240,000
7,220,000
7,200,000
7,180,000

N

0 1 2 4 Miles

Denton County

Prepared by: TEXAS WATER DEVELOPMENT BOARD September - October 2008 Survey