Volumetric and Sedimentation Survey of STILLHOUSE HOLLOW LAKE

September – December 2015 Survey

Texas Water Development Board

June 2017

Texas Water Development Board

Prepared for:

Brazos River Authority

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Executive summary

In September 2015, the Texas Water Development Board (TWDB) entered into an agreement with the Brazos River Authority, to perform a volumetric and sedimentation survey of Stillhouse Hollow Lake (Bell County, Texas). Surveying was performed using a multi-frequency (208 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.

Stillhouse Hollow Dam and Stillhouse Hollow Lake are located on the Lampasas River, a tributary of the Little River which is a tributary of the Brazos River, approximately 5 miles southwest of the City of Belton, in Bell County, Texas. The conservation pool elevation of Stillhouse Hollow Lake is 622.0 feet above mean sea level (NGVD29). The TWDB collected bathymetric data for Stillhouse Hollow Lake between September 1 and December 1, 2015, while daily average water surface elevations measured between 621.36 and 626.16 feet above mean sea level (NGVD29).

The 2015 TWDB volumetric survey indicates that Stillhouse Hollow Lake has a total reservoir capacity of 229,881 acre-feet and encompasses 6,429 acres at conservation pool elevation (622.0 feet above mean sea level, NGVD29). The original design estimate by the U.S. Army Corps of Engineers indicates Stillhouse Hollow Lake encompassed 6,430 acres with a total reservoir capacity of 235,703 acre-feet. The U.S. Army Corps of Engineers resurvey of Stillhouse Hollow Lake in 1987 indicates the lake encompassed 6,408 acres with a total reservoir capacity of 228,533 acre-feet. The TWDB previously surveyed Stillhouse Hollow Lake in 1995 and 2005. The 1995 and 2005 TWDB surveys were re-evaluated using current processing procedures resulting in updated capacity estimates of 231,050 acre-feet and 232,807 acre-feet, respectively.

The 2015 TWDB sedimentation survey indicates Stillhouse Hollow Lake has lost capacity at an average of 119 acre-feet per year since impoundment due to sedimentation below conservation pool elevation (622.0 feet NGVD29). The sedimentation survey indicates sediment accumulation varies throughout the reservoir. Sediment accumulation is greatest throughout the main river channel with additional heavy deposits in the floodplains south and west of Dana Peak Park. The TWDB recommends that a similar methodology be used to resurvey Stillhouse Hollow Lake 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. Texas Water Code Section 15.804 authorizes the TWDB to perform surveys to determine reservoir storage capacity, sedimentation levels, rates of sedimentation, and projected water supply availability.

In September 2015, the TWDB entered into an agreement with the Brazos River Authority, to perform a volumetric and sedimentation survey of Stillhouse Hollow Lake (Texas Water Development Board, 2015). This report provides an overview of the survey methods, analysis techniques, and associated results. Also included are the following contract deliverables: (1) a shaded relief plot of the reservoir bottom (Figure 4), (2) a bottom contour map (Figure 6), (3) an estimate of sediment accumulation and location (Figure 11), and (4) an elevation-area-capacity table of the reservoir acceptable to the Texas Commission on Environmental Quality (Appendices A and B).

Stillhouse Hollow Lake general information

Stillhouse Hollow Dam (formerly Lampasas Dam) and Stillhouse Hollow Lake are located on the Lampasas River, a tributary of the Little River which is a tributary of the Brazos River, approximately 5 miles north of the City of Belton, in Bell County, Texas (Figure 1). Stillhouse Hollow Dam and Stillhouse Hollow Lake are owned by the U.S. Government and operated by the U.S. Army Corps of Engineers, Fort Worth District (Texas Water Development Board, 1973). The U.S. Congress authorized the construction of Stillhouse Hollow Lake for flood control, water conservation, and other multipurpose uses with the passage of the Flood Control Act approved September 3, 1954 (U.S. Army Corps of Engineers, 2014). Construction on Stillhouse Hollow Dam began on June 11, 1962, and deliberate impoundment began on February 19, 1968. Stillhouse Hollow was completed on May 10, 1968 (Texas Water Development Board, 1973; U.S. Army Corps of Engineers, 1988). Additional pertinent data about Stillhouse Hollow Dam and Stillhouse Hollow Lake can be found in Table 1.

Water rights for Stillhouse Hollow Lake have been appropriated to the Brazos River Authority through Certificate of Adjudication No. 12-5161. The complete certificate is on file in the Information Resources Division of the Texas Commission on Environmental Quality.

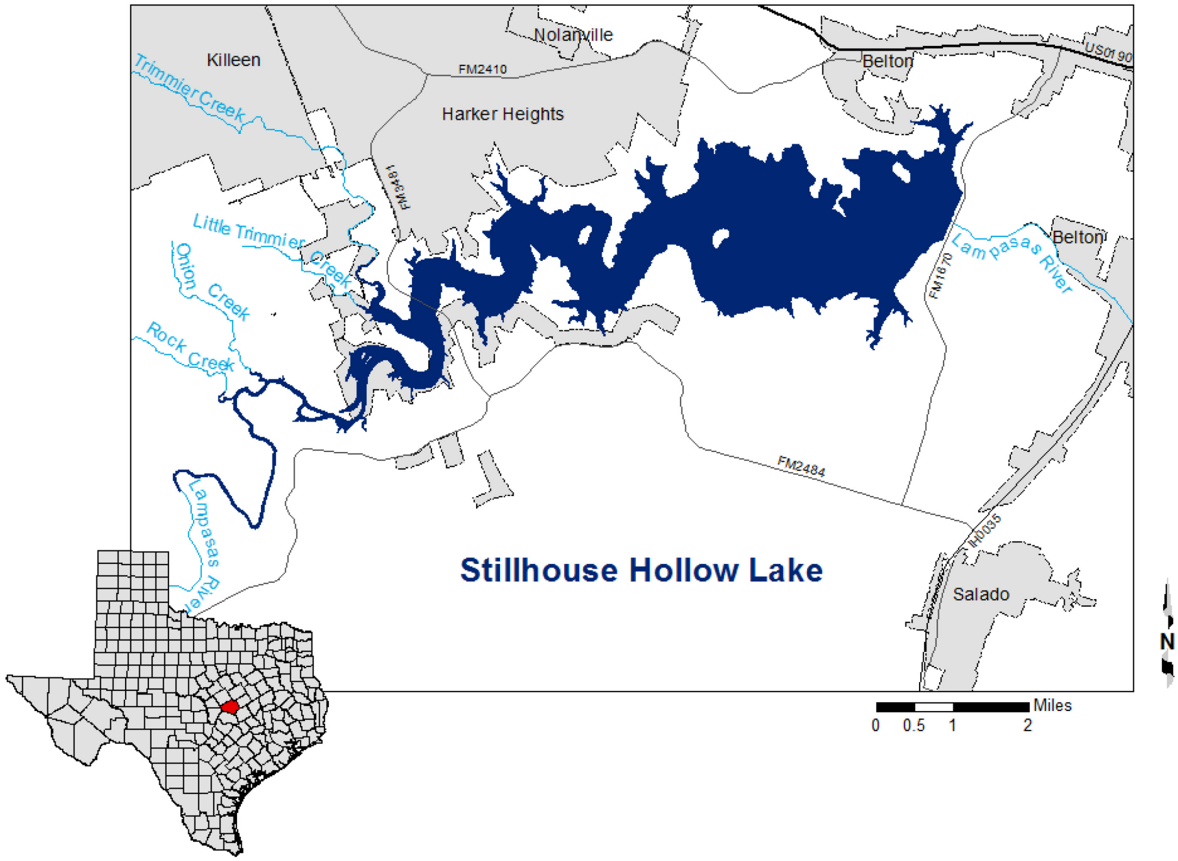


Figure 1. **Location map of Stillhouse Hollow Lake.**

Table 1. Pertinent data for Stillhouse Hollow Dam and Stillhouse Hollow Lake.

Owner

The U.S. Government
Operated by the U.S. Army Corps of Engineers, Fort Worth District

Design Engineer

U.S. Army Corps of Engineers

Location of dam

On the Lampasas River in Bell County, 5 miles southwest of the City of Belton

Drainage area

1,318 square miles

Dam

Type	Rolled earth fill
Length	15,624 feet (including spillway and dike)
Maximum height	200 feet
Top width	42 feet (dike 10 feet)

Spillway

Type	Broad-crested weir
Control	None
Length	1,650 feet net at crest
Crest elevation	666.0 feet above mean sea level

Outlet Works

Type	1 gate controlled conduit
Dimension	12 feet diameter
Control	2 - 5.67 feet by 12 feet, hydraulically operated slide gates
Invert elevation	515.0 feet above mean sea level

Reservoir data (Based on 2015 TWDB survey)

Feature	**Elevation (feet** NGVD29[a]**)**	**Capacity (acre-feet)**	**Area (acres)**
Top of dam	698.0	N/A	N/A
Top of flood control pool and spillway crest elevation	666.0	N/A	N/A
Top of conservation pool	622.0	229,881	6,429
Invert outlet works	515.0	86	26

Source: (Texas Water Development Board, 1973; U.S. Army Corps of Engineers, 1988; U.S. Army Corps of Engineers, 2000)
[a] NGVD29 = National Geodetic Vertical Datum 1929

Volumetric and sedimentation survey of Stillhouse Hollow Lake

Datum

The vertical datum used during this survey is the National Geodetic Vertical Datum 1929 (NGVD29). This datum also is utilized by the United States Geological Survey (USGS) for the reservoir elevation gage *USGS 08104050 Stillhouse Hollow Lk nr Belton, TX* (U.S. Geological Survey, 2016). Elevations herein are reported in feet 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 Central Zone (feet).

TWDB data collection

The TWDB collected bathymetric data for Stillhouse Hollow Lake between September 1 and December 1, 2015, while the daily average water surface elevations measured between 621.36 and 626.16 feet above mean sea level (NGVD29). For data collection, the TWDB used a Specialty Devices, Inc. (SDI), single-beam, multi-frequency (208 kHz, 50 kHz, and 24 kHz) sub-bottom profiling depth sounder integrated with differential global positioning system (DGPS) equipment. Data was collected along pre-planned survey lines oriented perpendicular to the assumed location of the original river channels and spaced approximately 500 feet apart. Many of the same survey lines also were used by the TWDB during the 1995 and 2005 surveys. 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. Figure 2 shows the data collection locations for the 2015 TWDB survey.

All sounding data was collected and reviewed before sediment core sampling sites were selected. Sediment core samples were collected at regularly spaced intervals within the reservoir or at locations where interpretation of the acoustic display would be difficult without site-specific sediment core data. After analyzing the sounding data, the TWDB selected nine locations to collect sediment core samples; however, sediment core sample 1 was not recoverable (Figure 2). The sediment core samples were collected on March 16, 2016, with a custom-coring boat and SDI VibeCore system.

Sediment cores are collected in 3-inch diameter aluminum tubes. Analysis of the acoustic data collected during the bathymetric survey assists in determining the depth of penetration the tube must be driven during sediment sampling. The goal is to collect a sediment core sample extending from the current reservoir-bottom surface, through the accumulated sediment, and to the pre-impoundment surface. After retrieving the sample, a stadia rod is inserted into the top of the aluminum tubes to assist in locating the top of the sediment in the tube. This identifies the location of the layer corresponding to the current reservoir-bottom 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.

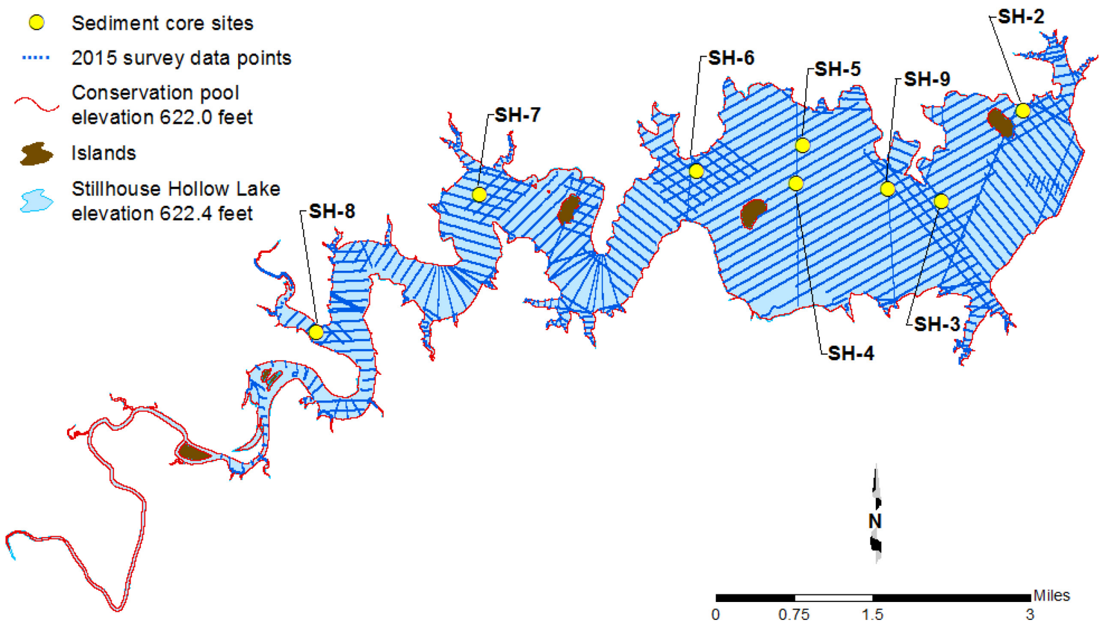


Figure 2. 2015 TWDB Stillhouse Hollow Lake survey data (*blue dots*) and sediment coring locations (*yellow circles*).

Data processing

Model boundaries

The reservoir's boundary was digitized from aerial photographs, also known as digital orthophoto quarter-quadrangle images (DOQQs), obtained from the Texas Natural Resources Information System (Texas Natural Resources Information System, 2016a) using Environmental Systems Research Institute's ArcGIS software. The quarter-quadrangles that cover Stillhouse Hollow Lake are Killeen (SE), Nolanville (SE, SW), and Youngsport (NE, NW). The DOQQs were photographed on July 31 and August 1, 2010, while daily average water surface elevation measured 622.38 feet, and 622.36 feet above mean sea level, respectively. According to metadata associated with the 2010 DOQQs, the photographs have a resolution or ground sample distance of 1.0 meters and a horizontal accuracy within ± 6 meters to true ground (Texas Natural Resources Information System, 2016b; U.S. Department of Agriculture, 2016). The boundary was digitized at the land-water interface in the 2010 photographs and assigned an elevation of 622.4 feet.

Triangulated Irregular Network model

Following completion of data collection, the raw data files collected by the TWDB were edited to remove data anomalies. The reservoir's current bottom surface is automatically determined by the data acquisition software. DepthPic© software, developed by SDI, Inc., was used to display, interpret, and edit the multi-frequency data by manually removing data anomalies in the current bottom surface and manually digitizing the reservoir-bottom surface at the time of initial impoundment (*i.e.* pre-impoundment surface). For further analysis, HydroTools software, developed by TWDB staff, was used to merge all the data into a single file, including the current reservoir-bottom surface, pre-impoundment surface, and sediment thickness at each sounding location. The water surface elevation at the time of each sounding was used to convert each sounding depth to a corresponding reservoir-bottom elevation. This survey point dataset was then preconditioned by inserting a uniform grid of artificial survey points between the actual survey lines. Bathymetric elevations at these artificial points were determined using an anisotropic spatial interpolation algorithm described in the next section. This technique creates a high resolution, uniform grid of interpolated bathymetric elevation points throughout a majority of the reservoir (McEwen and others, 2011a). Finally, the point file resulting from spatial interpolation is used in conjunction with sounding and boundary data to create volumetric and sediment Triangulated Irregular Network (TIN) models 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 (Environmental Systems Research Institute, 1995).

Spatial interpolation of reservoir bathymetry

Isotropic spatial interpolation techniques such as the Delaunay triangulation used by the 3D Analyst extension of ArcGIS are, in many instances, unable to suitably interpolate bathymetry between survey lines common to reservoir surveys. Reservoirs and stream channels are anisotropic morphological features where bathymetry at any particular location is more similar to upstream and downstream locations than to transverse locations. Interpolation schemes that do not consider this anisotropy lead to the creation of several types of artifacts in the final representation of the reservoir bottom surface and hence to errors in volume. These include artificially-curved contour lines extending into the reservoir where the reservoir walls are steep or the reservoir is relatively narrow, intermittent representation of submerged stream channel connectivity, and oscillations of contour lines in between survey lines. These artifacts reduce the accuracy of the resulting volumetric and sediment TIN models in areas between actual survey data.

To improve the accuracy of bathymetric representation between survey lines, the TWDB developed various anisotropic spatial interpolation techniques. Generally, the directionality of interpolation at different locations of a reservoir can be determined from external data sources. A basic assumption is that the reservoir profile in the vicinity of a particular location has upstream and downstream similarity. In addition, the sinuosity and directionality of submerged stream channels can be determined by directly examining the survey data, or more robustly by examining scanned USGS 7.5 minute quadrangle maps (known as digital raster graphics) and hypsography files (the vector format of USGS 7.5 minute quadrangle map contours) when available. Using the survey data, polygons are created to partition the reservoir into segments with centerlines defining directionality of interpolation within each segment. For surveys with similar spatial coverage, these interpolation definition files are, in principle, independent of the survey data and could be applied to past and future survey data of the same reservoir. In practice, however, minor revisions of the interpolation definition files may be needed to account for differences in spatial coverage and boundary conditions between surveys. Using the interpolation definition files and survey data, the current reservoir-bottom elevation, pre-impoundment elevation, and sediment thickness are calculated for each point in the high resolution uniform grid of artificial survey points. The reservoir boundary, artificial survey points grid, and survey data points are used to create volumetric and sediment TIN models representing reservoir bathymetry and sediment accumulation throughout the reservoir. Specific details of this interpolation technique can be found in the HydroTools manual (McEwen and others, 2011a) and in McEwen and others, 2011b.

In areas inaccessible to survey data collection, such as small coves and shallow upstream areas of the reservoir, linear interpolation is used for volumetric and sediment accumulation estimations. Linear interpolation follows a line linking the survey points file to the lake boundary file (McEwen and others, 2011a). Without linearly interpolated data, the TIN model builds flat triangles. A flat triangle is defined as a triangle where all three vertices are equal in elevation, generally the elevation of the reservoir boundary. Reducing flat triangles by applying linear interpolation improves the elevation-capacity and elevation-area calculations, although it is not always possible to remove all flat triangles.

Figure 3 illustrates typical results from application of the anisotropic interpolation and linear interpolation techniques to Stillhouse Hollow Lake. In Figure 3A, deeper channels and steep slopes indicated by surveyed cross-sections are not continuously represented in 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 in creation of the volumetric TIN model, represented in Figure 3B, directs Delaunay triangulation to better represent the reservoir bathymetry between survey cross-sections. The bathymetry shown in Figure 3C was used in computing reservoir elevation-capacity (Appendix A) and elevation-area (Appendix B) tables.

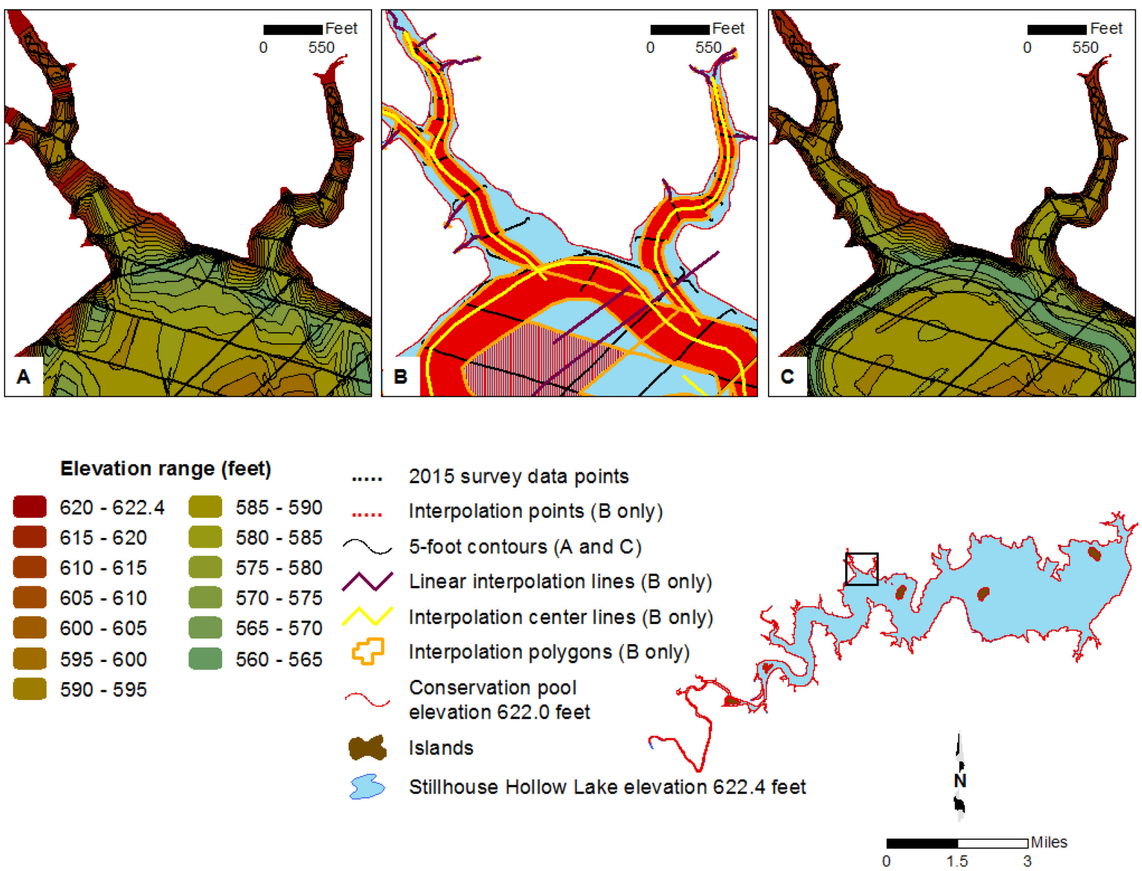


Figure 3. Anisotropic spatial interpolation and linear interpolation of Stillhouse Hollow Lake sounding data; A) bathymetric contours without interpolated points, B) sounding points (*black*) and interpolated points (*red*), C) bathymetric contours with interpolated points.

Area, volume, and contour calculation

Using ArcInfo software and the volumetric TIN model, volumes and areas were calculated for the entire reservoir at 0.1-foot intervals, from 505.2 to 622.4 feet. While linear interpolation was used to estimate topography in areas that were inaccessible by boat or too shallow for the instruments to work properly, development of some flat triangles (triangles whose vertices all have the same elevation) in the TIN model are unavoidable. The flat triangles in turn lead to anomalous calculations of surface area and volume at the boundary elevation 622.4 feet. To eliminate the effects of the flat triangles on area and volume calculations, areas between elevations 621.0 feet and 622.4 feet were linearly interpolated between the computed values, and volumes above elevation 621.0 feet were calculated based on the corrected areas. The elevation-capacity table and elevation-area table, based on the 2015 survey and analysis, are presented in Appendices A and B, respectively. The capacity curve is presented in Appendix C, and the area curve is presented in Appendix D.

The volumetric TIN model was converted to a raster representation using a cell size of 2 feet by 2 feet. The raster data then was used to produce three figures: (1) an elevation relief map representing the topography of the reservoir bottom (Figure 4); (2) a depth range map showing shaded depth ranges for Stillhouse Hollow Lake (Figure 5); and, (3) a 10-foot contour map (Figure 6).

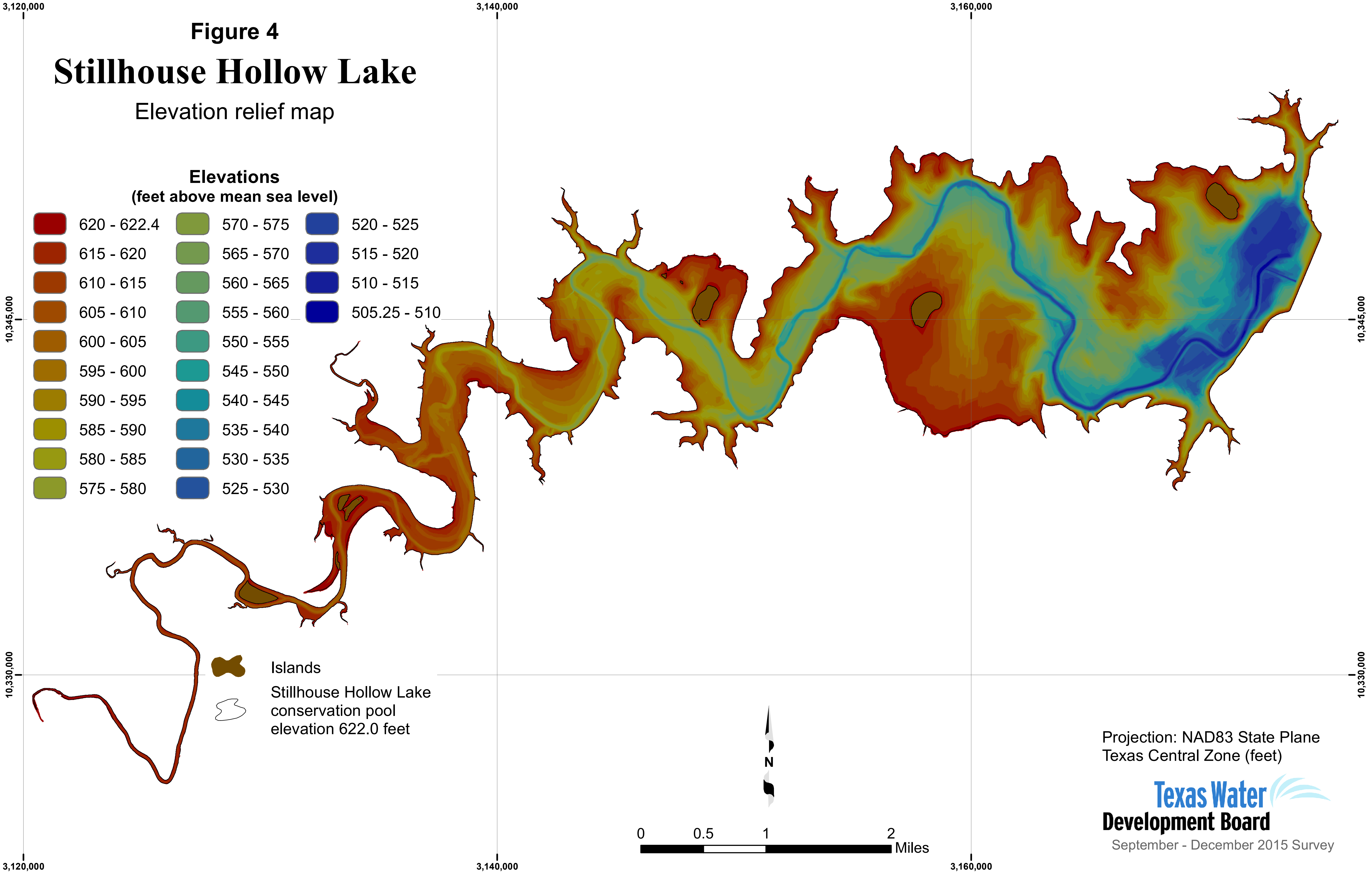
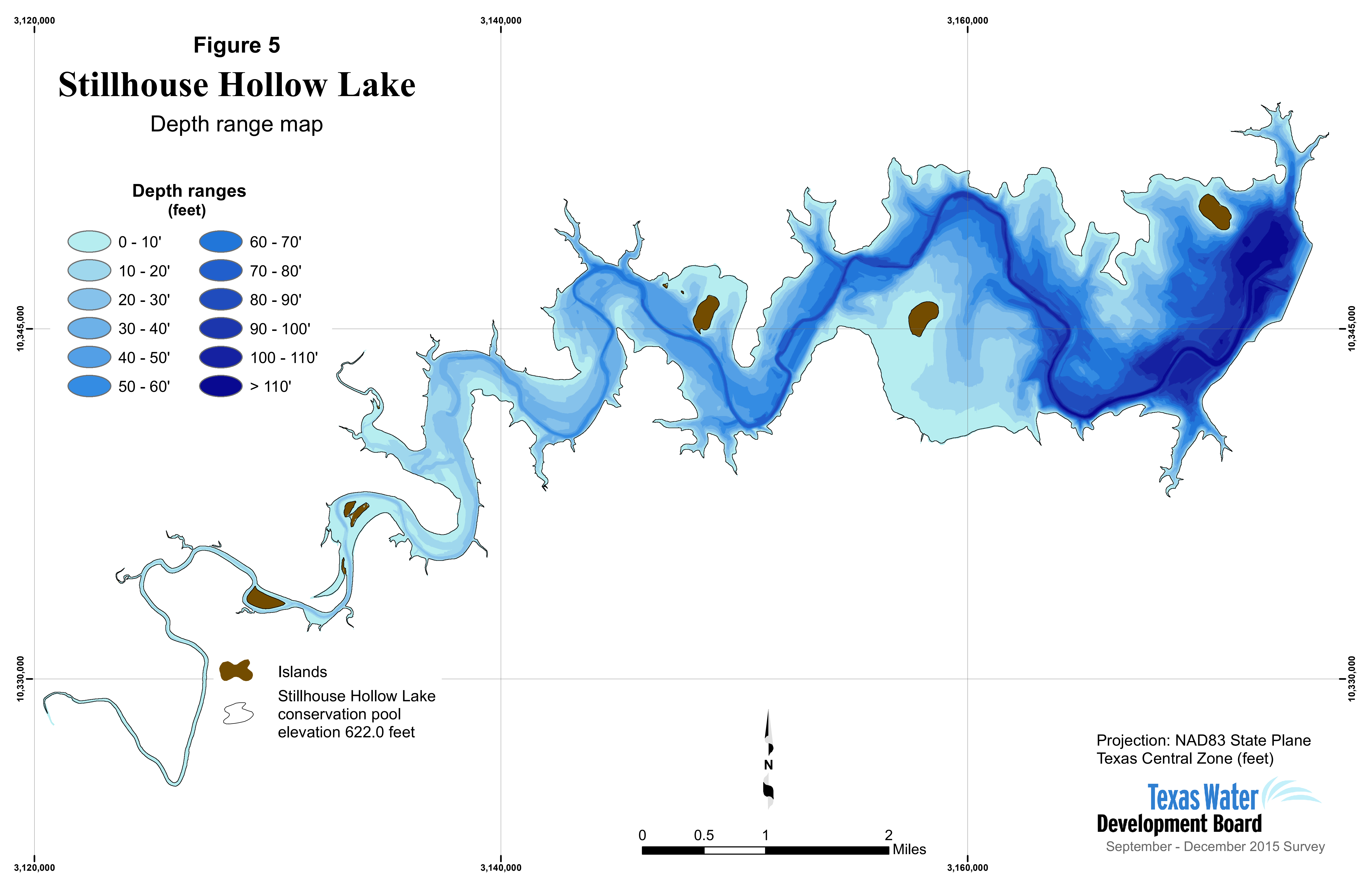


Figure 4

Stillhouse Hollow Lake

Elevation relief map



3,120,000
3,140,000
3,160,000
10,345,000
10,330,000
Figure 5
Stillhouse Hollow Lake
Depth range map
Depth ranges
(feet)
0 - 10'
10 - 20'
20 - 30'
30 - 40'
40 - 50'
50 - 60'
60 - 70'
70 - 80'
80 - 90'
90 - 100'
100 - 110'
> 110'
Islands
Stillhouse Hollow Lake
conservation pool
elevation 622.0 feet
N
0
0.5
1
2
Miles
Projection: NAD83 State Plane
Texas Central Zone (feet)
Texas Water
Development Board
September - December 2015 Survey

Analysis of sediment data from Stillhouse Hollow Lake

Sedimentation in Stillhouse Hollow Lake was determined by analyzing the acoustic signal returns of all three depth sounder frequencies in the DepthPic© software. While the 208 kHz signal is used to determine the current bathymetric surface, all three frequencies, 208 kHz, 50 kHz, and 24 kHz, are analyzed to determine the reservoir bathymetric surface at the time of initial impoundment, *i.e.*, pre-impoundment surface. Sediment core samples collected in the reservoir are correlated with the acoustic signals in each frequency to assist in identifying the pre-impoundment surface. The difference between the current surface bathymetry and the pre-impoundment surface bathymetry yields a sediment thickness value at each sounding location.

Analysis of the sediment core samples was conducted at TWDB headquarters in Austin. Each sample was split longitudinally and analyzed to identify the location of the pre-impoundment surface. The pre-impoundment surface is identified within the sediment core sample by one or more of the following methods: (1) a visual examination of the sediment core for terrestrial materials, such as leaf litter, tree bark, twigs, intact roots, *etc.*, concentrations of which tend to occur on or just below the pre-impoundment surface; (2) changes in texture from well sorted, relatively fine-grained sediment to poorly sorted mixtures of coarse and fine-grained materials; and, (3) variations in the physical properties of the sediment, particularly sediment water content and penetration resistance with depth (Van Metre and others, 2004). The total sample length, post impoundment sediment thickness, and pre-impoundment thickness were recorded. Physical characteristics of the sediment core, such as Munsell soil color, texture, relative water content, and presence of organic materials also were recorded (Table 2).

Table 2. Sediment core sampling analysis data for Stillhouse Hollow Lake.

Sediment core sample	Easting[a] (feet)	Northing[a] (feet)	Total core sample/ post-impoundment sediment	Sediment core description		Munsell soil color
SH-2	3171726.94	10350607.39	11.0”/5.5”	post-impoundment	0.0–2.0” water and fluff	N/A
					2.0–5.5” high water content, silty loam	2.5Y 4/2 dark greyish brown
				pre-impoundment	5.5–11.0” clay with assorted rocks and pebbles up to 2” diameter	2.5Y 6/3 light yellowish brown
SH-3	3167612.70	10346035.37	15.0”/4.5”	post-impoundment	0.0–1.0” water and fluff	N/A
					1.0–4.5” high water content, organics (small shells) at 4.5”, silt, 30% mottled	2.5Y 3/2 very dark greyish brown
				pre-impoundment	4.5–15.0” lower water content, clay loam with small pebbles (0.5” diameter) throughout layer, loose but not saturated soil	2.5Y 3/2 very dark greyish brown
SH-4	3160263.44	10346930.10	16.75”/12.25”	post-impoundment	0.0–3.0” water and fluff	N/A
					3.0–12.25” high water content, silt, mottling up to 30%	2.5Y 3/2 very dark greyish brown
				pre-impoundment	12.25–16.75” lower water content, clay loam, small roots and pebbles throughout, similar to lowest layer in SH-3 in color and texture	2.5Y 3/2 very dark greyish brown
SH-5	3160623.01	10348844.72	23.0”/17.5”	post-impoundment	0.0–2.25” water and fluff	N/A
					2.25–17.5” high water content, silt, up to 30% mottling	2.5Y 2.5/1 black
				pre-impoundment	17.5–23.0” lower water content, clay loam with small roots and pebbles (0.5" diameter) throughout	10YR 2/1 black

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

Table 2. Sediment core sampling analysis data for Stillhouse Hollow Lake (continued).

Sedimet core sample	Easting[a] (feet)	Northing[a] (feet)	Total core sample/ post-impoundment sediment	Sediment core description		Munsell soil color
SH-6	3155244.76	10347564.38	34.5"/23.25"	post-impoundment	0.0–2.0" water and fluff	N/A
					2.0–23.25" high water content, silt, up to 25% mottling	2.5Y 3/1 very dark grey
				pre-impoundment	23.25–34.5" lower water content decreasing with depth, clay loam, small roots throughout	2.5Y 3/2 very dark greyish brown
SH-7	3144287.27	10346389.81	45.0"/28.0"	post-impoundment	0.0–1.0" water and fluff	N/A
					1.0–28.0" high water content, silt, up to 25% mottling	2.5Y 3/1 very dark grey
				pre-impoundment	28.0–45.0" lower water content, sandy loam, roots and small pebbles (up to 0.25") throughout	2.5Y 3/2 very dark greyish brown
SH-8	3136102.39	10339429.26	17.0"/13.75"	post-impoundment	0.0–0.25" water and fluff	N/A
					0.25–5.0" med-high water content, silty clay loam with some organic material (leaf litter, sticks)	2.5Y 5/2 greyish brown
					5.0–6.25" med-high water content, silty clay loam, same parent material as layer above and below, very dense organic debris present	2.5Y 5/2 greyish brown
					6.25–13.75" med-high water content, silty clay loam with some organic material	2.5Y 5/2 greyish brown
				pre-impoundment	13.75–17.0" lower water content, clay, darker color than above layer	2.5Y 3/2 very dark brown

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

Table 2. Sediment core sampling analysis data for Stillhouse Hollow Lake (continued).

Sedimet core sample	Easting[a] (feet)	Northing[a] (feet)	Total core sample/ post-impoundment sediment	Sediment core description		Munsell soil color
SH-9	3164903.16	10346649.10	32.25”/27.0”	post-impoundment	0.0–3.0” water and fluff	N/A
					3.0–27.0” high water content, silt, up to 25% mottling	2.5Y 3/2 very dark greyish brown
				pre-impoundment	27.0–32.25” lower water content, silty clay loam with small pebbles throughout, organics (leaf litter, sticks) at top boundary of layer	2.5Y 3/1 very dark grey

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

A photograph of sediment cores SH-7 and SH-4 (for location, refer to Figure 2) are shown in Figure 7 and are representative of sediment cores sampled from Stillhouse Hollow Lake. The base of the sample is denoted by the blue line. The pre-impoundment boundary (yellow line) was evident within sediment core sample SH-7 at 28.0 inches and SH-4 at 12.25 inches as identified by the change in color, texture, moisture, porosity, and structure. Identification of the pre-impoundment surface for the other six sediment cores followed a similar procedure.

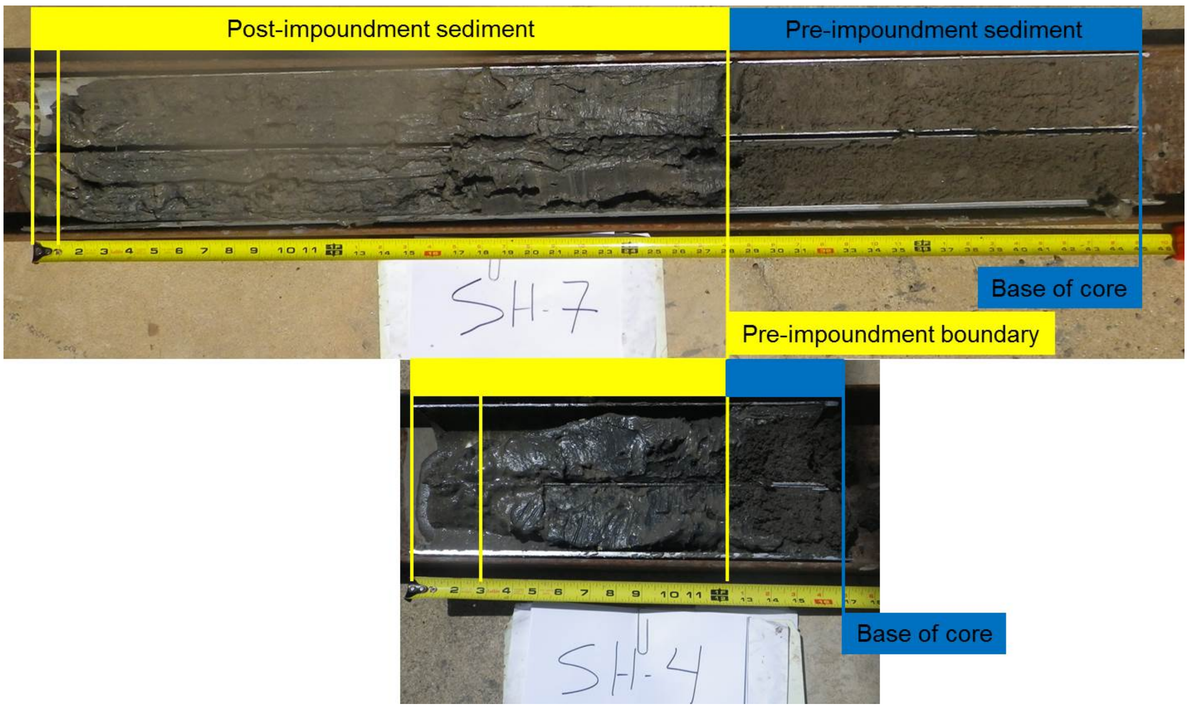


Figure 7. Sediment cores SH-7 and SH-4 from Stillhouse Hollow Lake. Post-impoundment sediment layers occur in the top 28 inches of sediment core SH-7 and top 12.25 inches in sediment core SH-4 (identified by yellow boxes). Pre-impoundment sediment layers were identified and are defined by the blue box.

Figures 8 through 10 illustrate how measurements from sediment core samples are used with sonar data to help identify the post- and pre-impoundment layers in the acoustic signal. Figure 8 compares sediment core sample SH-7 with the acoustic signals for all frequencies combined (8A, 8E), and each individual frequency: 208 kHz (8B, 8F), 50 kHz (8C, 8G), and 24 kHz (8D, 8H). Figure 9 compares sediment core sample SH-4 with the acoustic signals for all frequencies combined (9A, 9E), and each individual frequency: 208 kHz (9B, 9F), 50 kHz (9C, 9G), and 24 kHz (9D, 9H). Within DepthPic©, the current bathymetric surface is automatically determined based on signal returns from the 208 kHz transducer as represented by the top black line in Figures 8E and 9E and red line in Figures

8F–8H and 9F–9H. The pre-impoundment surface is identified by comparing boundaries observed in the 208 kHz, 50 kHz, and 24 kHz signals to the location of the pre-impoundment surface as determined by the sediment core sample analysis. Many layers of sediment may be identified during core analysis based on changes in observed characteristics, such as water content, organic matter content, and sediment particle size, and each layer is classified as either post-impoundment or pre-impoundment. Each layer of sediment identified in the sediment core sample during analysis (Table 2) is represented in Figures 8 and 9 by a yellow or blue box. A yellow box represents post-impoundment sediments. A blue box indicates pre-impoundment sediments.

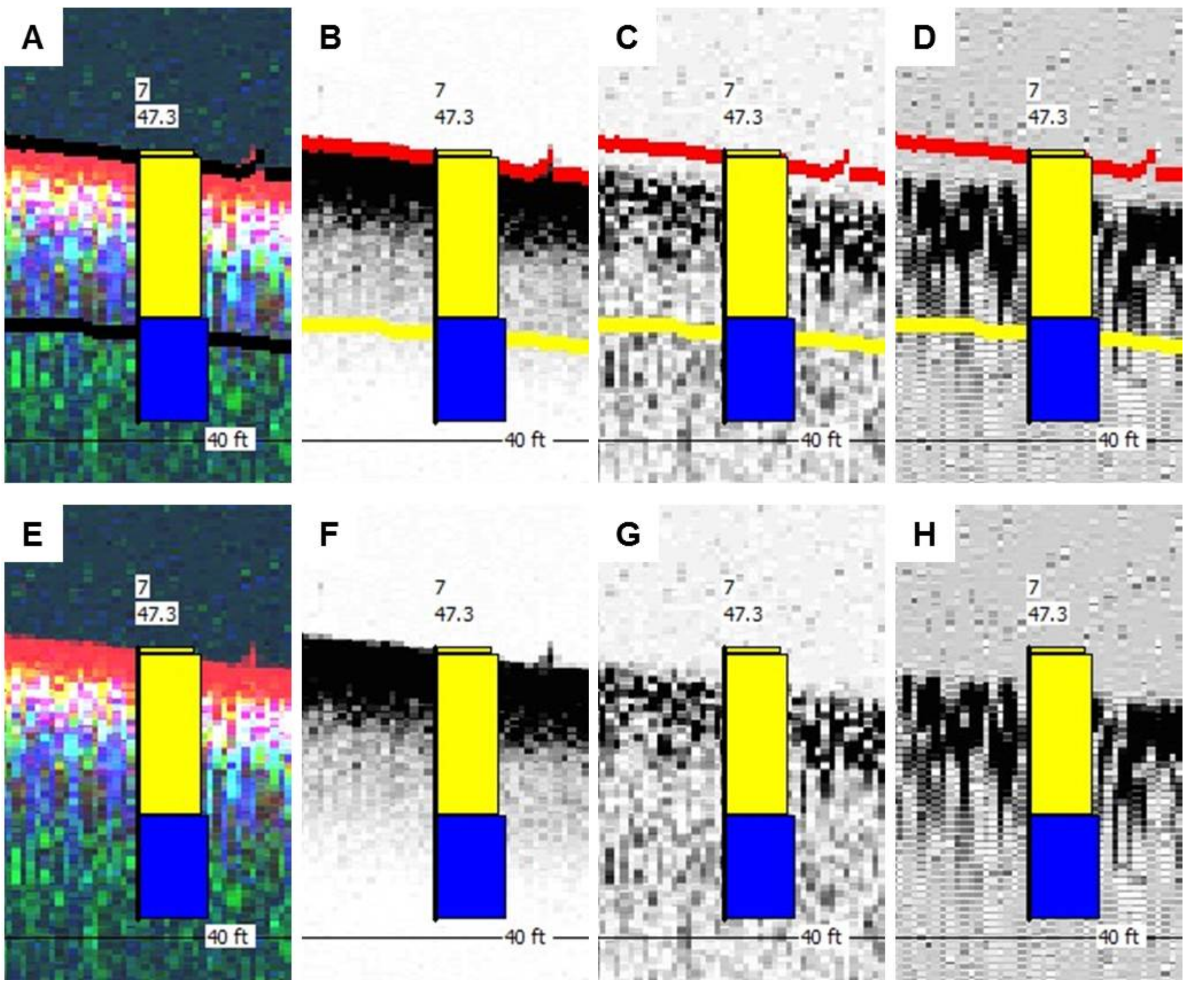


Figure 8. Comparison of sediment core SH-7 with acoustic signal returns A,E) combined acoustic signal returns, B,F) 208 kHz frequency, C,G) 50 kHz frequency, and D,H) 24 kHz frequency.

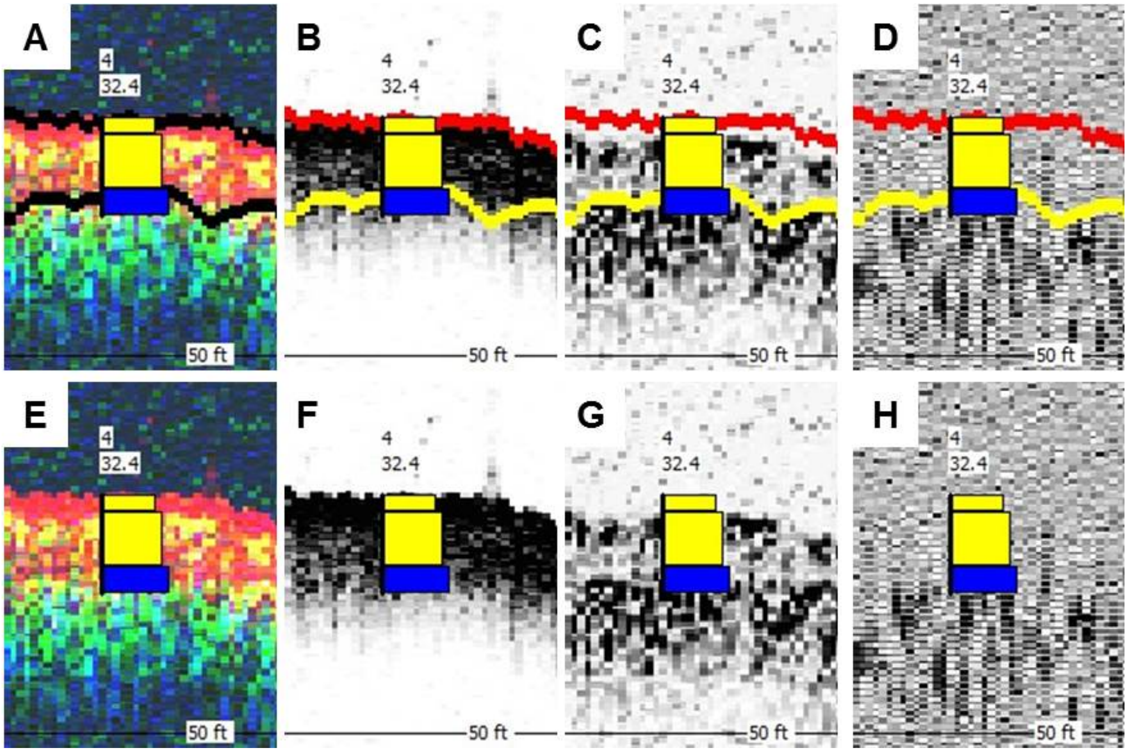


Figure 9. Comparison of sediment core SH-4 with acoustic signal returns A,E) combined acoustic signal returns, B,F) 208 kHz frequency, C,G) 50 kHz frequency, and D,H) 24 kHz frequency.

In this case, the pre-impoundment boundary as identified from the pre-impoundment interface of sediment core sample SH-4 was most visible in the 50 kHz acoustic signal returns. However, the pre-impoundment boundary as identified from the pre-impoundment interface of sediment core sample SH-7 was most visible in the 208 kHz acoustic signals. Therefore, the 50 kHz acoustic signal returns were used to locate the pre-impoundment surface for the main body of the reservoir and the 208 kHz acoustic signal returns were used to locate the pre-impoundment surface for the upper half of the reservoir or more riverine area with the transition area at the eastern edge of Dana Peak Park (yellow line in Figures 8 and 9). Figures 10a and 10b show sediment core sample SH-7 correlated with the 208 kHz acoustic signal returns and SH-4 correlated with the 50 kHz acoustic signal returns of the nearest surveyed cross-sections. The pre-impoundment surface is first identified along cross-sections for which sediment core samples have been collected. This information then is used as a guide for identifying the pre-impoundment surface along cross-sections where sediment core samples were not collected.

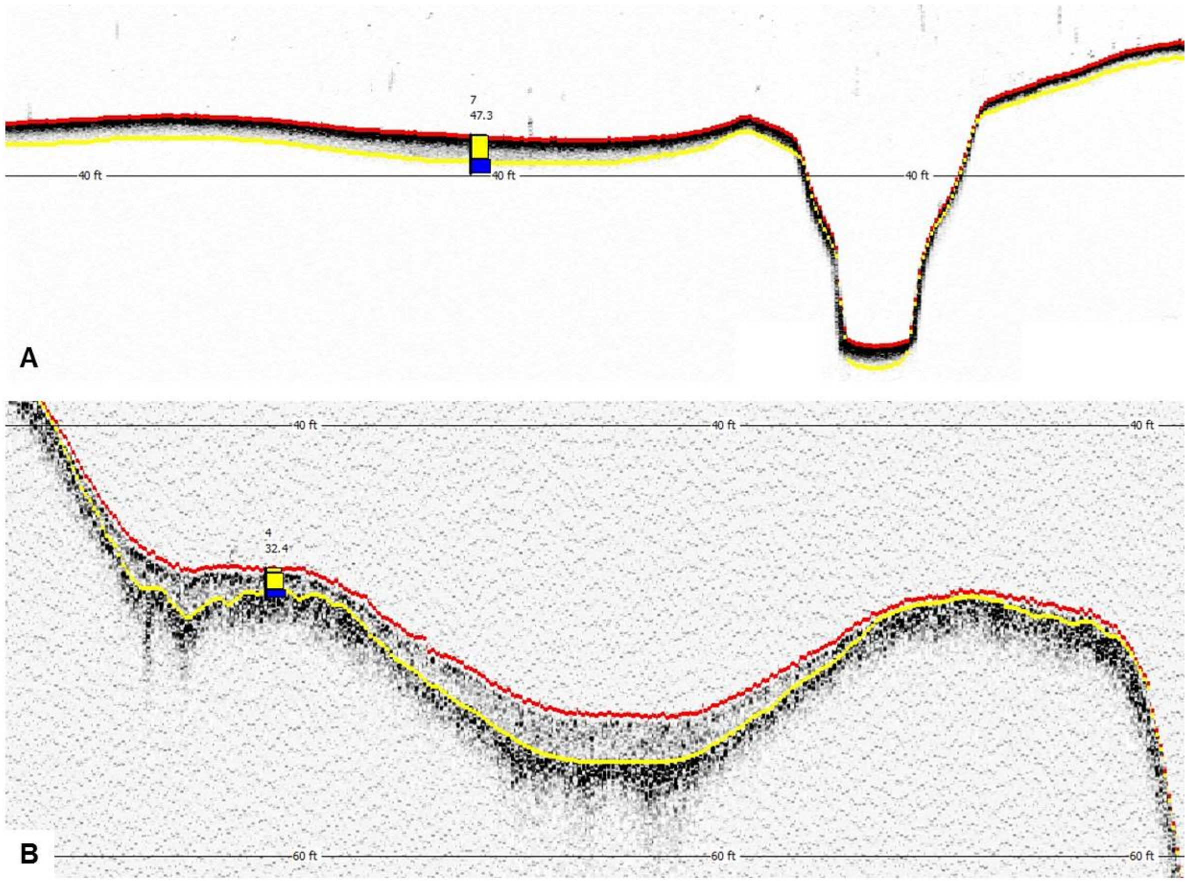


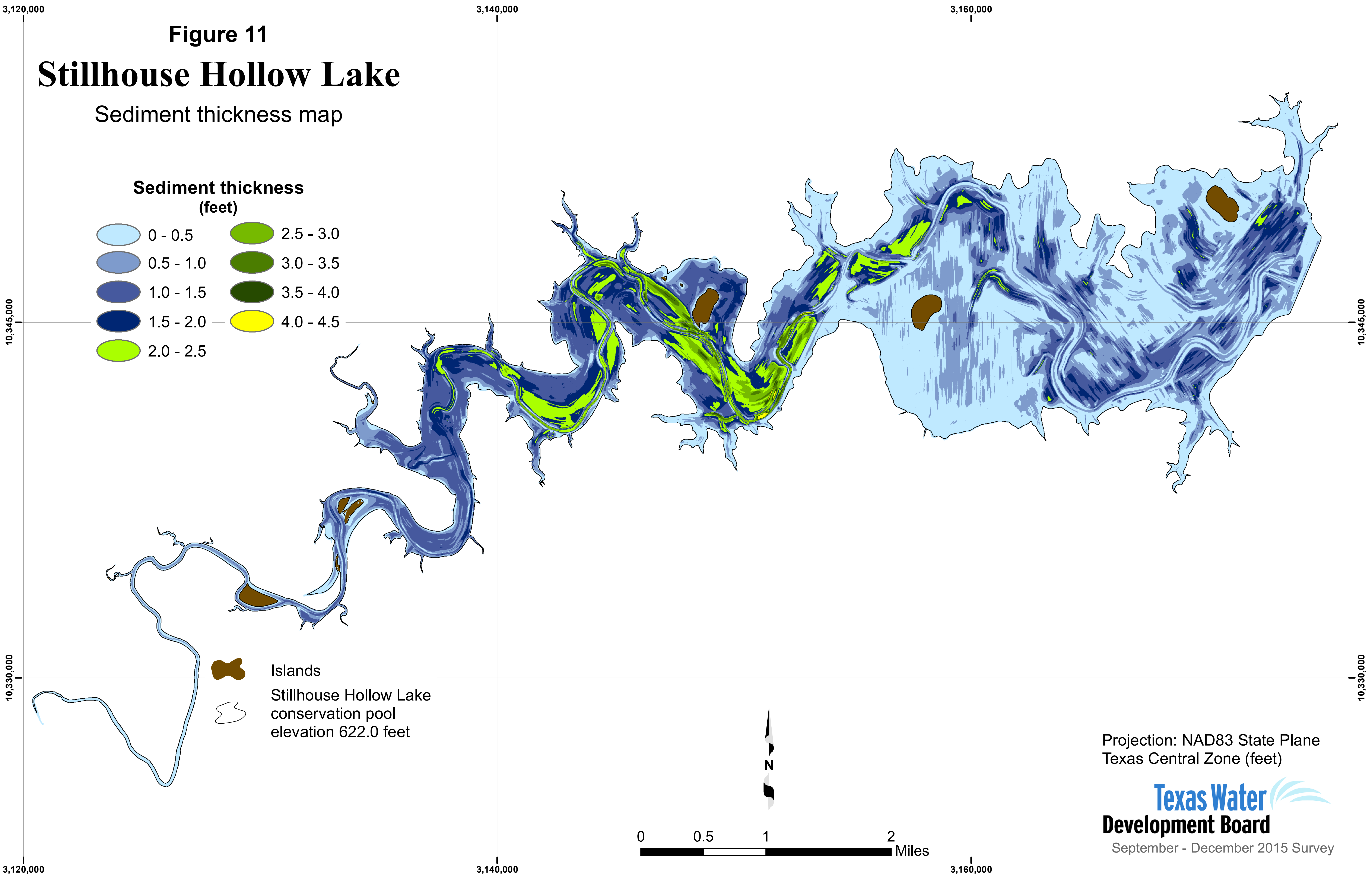
Figure 10. (A) Cross-section of data collected during the 2015 survey, displayed in DepthPic© (208 kHz), correlated with sediment core sample SH-7 and showing the current surface as the red line, and pre-impoundment surface as the yellow line and (B) cross-section of data collected during the 2015 survey, displayed in DepthPic© (50 kHz), correlated with sediment core sample SH-4 and showing the current surface as the red line, and pre-impoundment surface as the yellow line.

After the pre-impoundment surface for all cross-sections was identified, a sediment thickness TIN model was created following standard GIS techniques (Furnans and Austin, 2007). Sediment thicknesses were interpolated between surveyed cross-sections using HydroTools with the same interpolation definition file used for bathymetric interpolation. For the purposes of TIN model creation, the TWDB assumed the sediment thickness at the reservoir boundary was 0 feet (defined as the 622.4 foot NGVD29 elevation contour). The sediment thickness TIN model was converted to a raster representation using a cell size of 5 feet by 5 feet and was used to produce a sediment thickness map of Stillhouse Hollow Lake (Figure 11).

Figure 11

Stillhouse Hollow Lake

Sediment thickness map



Survey results

Volumetric survey

The 2015 TWDB volumetric survey indicates that Stillhouse Hollow Lake has a total reservoir capacity of 229,881 acre-feet and encompasses 6,429 acres at conservation pool elevation (622.0 feet above mean sea level, NGVD29). The original design estimate by the U.S. Army Corps of Engineers indicates Stillhouse Hollow Lake encompassed 6,430 acres with a total reservoir capacity of 235,703 acre-feet. The U.S. Army Corps of Engineers' resurvey of Stillhouse Hollow Lake in 1987 indicates the lake encompassed 6,408 acres with a total reservoir capacity of 228,533 acre-feet (U.S. Army Corps of Engineers, 1988). TWDB previously surveyed Stillhouse Hollow Lake in 1995 and 2005. Because of differences in past and present survey methodologies, direct comparison of volumetric surveys to others to estimate loss of capacity can be unreliable. To properly compare results from the TWDB surveys of Stillhouse Hollow Lake, the TWDB applied the 2015 data processing techniques to the survey data collected in 1995 and 2005. Specifically, the TWDB applied anisotropic spatial interpolation to the survey data collected in 1995 and 2005 using the same interpolation definition file as was used for the 2015 survey, with minor edits to account for differences in data coverage and boundary conditions.

The original 1995 survey boundary was digitized from the 622.0 foot contour from 7.5 minute USGS quadrangle maps: Nolanville 1958 (Photo revised 1974); Killeen 1958 (Photo revised 1974); and Youngsport 1958 (Photo revised 1979), with a stated accuracy of ± ½ the contour interval (U.S. Bureau of the Budget, 1947). While linear interpolation was used to estimate the topography in areas without data, flat triangles led to anomalous area and volume calculations at the boundary elevation of 622.0 feet. Therefore, areas between 620.0 feet and 622.0 feet were linearly interpolated between the computed values, and volumes above 620.0 feet were calculated based on the corrected areas. The 2005 survey boundary was digitized from aerial photographs taken on January 19, January 28, and February 2, 1995, while the daily average water surface elevation of the reservoir measured 622.31 feet, 622.13 feet, and 622.08 feet above mean sea level, respectively. The boundary was assigned an elevation of 622.0 feet for modeling purposes. According to the associated metadata, the 1995-1996 DOQQs have a resolution of 1-meter, with a horizontal positional accuracy that meets the National Map Accuracy Standards (NMAS) for 1:12,000-scale products. Additionally, survey data points with anomalous elevations from both surveys were removed from the new models. While linear interpolation was used to estimate the topography in areas without data, flat triangles led to anomalous area and volume calculations at the boundary elevation of 622.0 feet. Therefore, areas between 620.4 feet and 622.0 feet were linearly interpolated between the computed values, and volumes above 620.4 feet were calculated based on the corrected areas. Re-evaluation of the 1995 and 2005 surveys resulted in a 2.2 percent increase in total capacity estimates at conservation pool elevation 622.0 feet (Table 3).

Table 3. Current and previous survey capacity and surface area estimates for Stillhouse Hollow Lake.

Survey	Surface area (acres)	Capacity (acre-feet)
Original design 1967 [a,b]	6,430	235,703
USACE 1987 Resurvey [b]	6,408	228,533
TWDB 1995 [c]	6,429	226,063
TWDB 1995 (re-calculated)[d]	6,429	231,050
TWDB 2005[e]	6,484	227,825
TWDB 2005 (re-calculated)[d]	6,484	232,807
TWDB 2015	6,429	229,881

[a] Source: (Texas Water Development Board, 1973)
[b] Source: (U.S. Army Corps of Engineers, 1988)
[c] Source: (Texas Water Development Board, 2003)
[d] Source: (Texas Water Development Board, 2016)
[e] Source: (Texas Water Development Board, 2006)

Sedimentation survey

The 2015 TWDB sedimentation survey indicates Stillhouse Hollow Lake has lost capacity at an average of 119 acre-feet per year since impoundment due to sedimentation below conservation pool elevation (622.0 feet NGVD29). The sedimentation survey indicates sediment accumulation varies throughout the reservoir. Sediment accumulation is greatest throughout the main river channel with additional heavy deposits in the floodplains south and west of Dana Peak Park. The sediment core samples indicate silt and silty clay type sediments are being deposited in the main body of the reservoir. Comparison of the 2015 current surface with prior surveys completed by the TWDB indicate larger sediments are being moved and deposited in the upper riverine parts of the reservoir. Comparison of capacity estimates of Stillhouse Hollow Lake derived using differing methodologies are provided in Table 4 for sedimentation rate calculation.

Table 4. Capacity loss comparisons for Stillhouse Hollow Lake

Survey	Volume comparisons at conservation pool elevation (acre-feet)			
Revised original design[a]	235,703	<>	<>	<>
TWDB 1995 (re-calculated)	<>	231,050	<>	<>
TWDB 2005 (re-calculated)	<>	<>	232,807	<>
TWDB pre-impoundment estimate based on 2015 survey	<>	<>	<>	235,493[b]
2015 volumetric survey	229,881	229,881	229,881	229,881
Volume difference (acre-feet)	5,822 (2.5%)	1,169 (0.5%)	2,926 (1.3%)	5,612 (2.4%)
Number of years	47	20	10	47
Capacity loss rate (acre-feet/year)	124	58	293	119

[a] Source: (Texas Water Development Board, 1973; U.S. Army Corps of Engineers, 1988), note: Deliberate impoundment began on February 19, 1968, and Stillhouse Hollow Dam was completed on May 10, 1968.
[b] 2015 TWDB surveyed capacity of 229,881 acre-feet plus 2015 TWDB surveyed sediment volume of 5,612 acre-feet below elevation 622.0 feet

Sediment range lines

In 1967, the U.S. Army Corps of Engineers established 25 sediment range lines throughout Stillhouse Hollow Lake to measure sediment accumulation over time. In 1987, the U.S. Army Corps of Engineers resurveyed these range lines. A cross-sectional comparison of nine of these sediment range lines with the TWDB 2015 survey, 2005 re-calculated survey, and the TWDB 1995 re-calculated survey is presented in Appendix E. Also presented in Appendix E is a map depicting the historical locations of the sediment range lines which includes Table E1, a list of the endpoint coordinates for each line. Some differences in the cross-sections may be a result of spatial interpolation and the interpolation routine of the TIN Model.

Recommendations

The TWDB recommends a volumetric and sedimentation survey of Stillhouse Hollow Lake within a 10 year time-frame or after a major flood event to assess changes in lake capacity and to further improve estimates of sediment accumulation rates.

TWDB contact information

More information about the Hydrographic Survey Program can be found at:
http://www.twdb.texas.gov/surfacewater/surveys/index.asp
Any questions regarding the TWDB Hydrographic Survey Program may be addressed to:
Hydrosurvey@twdb.texas.gov

References

Environmental Systems Research Institute, 1995, ARC/INFO Surface Modeling and Display, TIN Users Guide: ESRI, California.

Furnans, J. and Austin, B., 2007, Hydrographic survey methods for determining reservoir volume, Environmental Modeling & Software, v. 23, no. 2: Amsterdam, The Netherlands, Elsevier Science Publishers B.V., p. 139-146. doi: 10.1016/j.envsoft.2007.05.011

McEwen, T., Brock, N., Kemp, J., Pothina, D. and Weyant, H., 2011a, HydroTools User's Manual: Texas Water Development Board.

McEwen, T., Pothina, D. and Negusse, S., 2011b, Improving efficiency and repeatability of lake volume estimates using Python: Proceedings of the 10th Python for Scientific Computing Conference.

Texas Natural Resources Information System, 2016a, Maps & Data, accessed November 1, 2016, at http://www.tnris.org/maps-and-data/.

Texas Natural Resources Information System, 2016b, National Agriculture Imagery Program (NAIP) 2010 1m NC\CIR, accessed November 1, 2016, at https://tnris.org/data-catalog/entry/national-agriculture-imagery-program-naip-2010-1m-nc-cir/.

Texas Water Development Board, 1973, Stillhouse Hollow Dam and Stillhouse Hollow Lake, Report 126: Engineering Data on Dams and Reservoirs in Texas, Part II.

Texas Water Development Board, 2006, Volumetric Survey of Stillhouse Hollow Lake, accessed November 1, 2016, at http://www.twdb.texas.gov/surfacewater/surveys/completed/files/StillhouseHollow/2005-05/STH2005_FinalReport.pdf.

Texas Water Development Board, 2003, Volumetric Survey of Stillhouse Hollow Lake, accessed November 1, 2016, at http://www.twdb.texas.gov/surfacewater/surveys/completed/files/StillhouseHollow/1995-05/Stillhouse1995_FinalReport.pdf.

Texas Water Development Board, 2015, Contract No. R1648011904 with Brazos River Authority.

Texas Water Development Board, 2016, Application of new procedures to re-assess reservoir capacity, accessed March 31, 2017, at http://www.twdb.texas.gov/hydro_survey/Re-assessment/

U.S. Army Corps of Engineers, 1988, Report on Sedimentation, Stillhouse Hollow Lake, Lampasas River, Brazos River Basin, Texas, Resurvey of December 1987: U.S. Army Corps of Engineers, Fort Worth District.

U.S. Army Corps of Engineers, 2014, History of Stillhouse Hollow Lake, accessed December 12, 2016, at http://www.swf-wc.usace.army.mil/stillhouse/Information/History.asp.

U.S. Army Corps of Engineers, 2000, Pertinent Data – Stillhouse Hollow Dam and Lake, accessed December 12, 2016, at http://www.swf-wc.usace.army.mil/pertdata/stit2.pdf.

U.S. Bureau of the Budget, 1947, United States National Map Accuracy Standards, accessed December 12, 2016, at http://nationalmap.gov/standards/pdf/NMAS647.PDF.

U.S. Department of Agriculture, 2016, National Agricultural Imagery Program (NAIP) Information Sheet, accessed November 1, 2016, at http://www.fsa.usda.gov/Assets/USDA-FSA-Public/usdafiles/APFO/support-documents/pdfs/naip_infosheet_2016.pdf.

U.S. Geological Survey, 2016, U.S. Geological Survey National Water Information System: Web Interface, USGS 08104050 Stillhouse Hollow Lk nr Belton, TX, accessed November 1, 2016, at http://nwis.waterdata.usgs.gov/nwis/uv?cb_62614=on&format=rdb&site_no=08104050&period=&begin_date=2015-08-31&end_date=2015-12-02.

Van Metre, P.C., Wilson, J.T., Fuller, C.C., Callender, E., and Mahler, B.J., 2004, Collection, analysis, and age-dating of sediment cores from 56 U.S. lakes and reservoirs sampled by the U.S. Geological Survey, 1992-2001: U.S. Geological Survey Scientific Investigations Report 2004-5184, 180 p.

Appendix A

Stillhouse Hollow Lake

RESERVOIR CAPACITY TABLE

TEXAS WATER DEVELOPMENT BOARD — September - December 2015 Survey

CAPACITY IN ACRE-FEET — Conservation Pool Elevation 622.0 feet NGVD29

ELEVATION INCREMENT IS ONE TENTH FOOT

ELEVATION in Feet	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
505	0	0	0	0	0	0	0	0	0	0
506	0	0	0	0	0	0	0	1	1	1
507	1	1	1	1	2	2	2	2	3	3
508	3	3	4	4	4	4	5	5	6	6
509	6	7	7	7	8	8	9	9	10	10
510	11	11	12	13	13	14	14	15	16	17
511	17	18	19	20	21	22	23	24	25	26
512	27	28	29	31	32	33	35	36	38	40
513	41	43	45	47	49	51	53	55	57	59
514	61	64	66	68	71	73	75	78	80	83
515	86	88	91	94	96	99	102	104	107	110
516	113	116	119	122	125	128	131	134	138	141
517	144	148	152	156	160	164	169	174	179	184
518	190	196	202	208	215	222	229	236	244	252
519	260	268	277	286	295	304	314	324	333	344
520	354	365	376	387	398	410	421	433	445	458
521	470	483	496	509	522	536	550	564	578	593
522	607	622	638	653	669	685	701	718	734	751
523	769	787	805	823	842	862	882	902	922	944
524	965	987	1,009	1,032	1,055	1,078	1,102	1,126	1,150	1,174
525	1,199	1,224	1,249	1,274	1,300	1,326	1,352	1,379	1,405	1,432
526	1,459	1,487	1,515	1,543	1,571	1,599	1,628	1,657	1,686	1,715
527	1,745	1,775	1,805	1,835	1,865	1,896	1,927	1,958	1,989	2,020
528	2,052	2,084	2,115	2,148	2,180	2,212	2,245	2,278	2,311	2,344
529	2,377	2,411	2,445	2,479	2,513	2,548	2,582	2,617	2,652	2,687
530	2,722	2,758	2,794	2,830	2,866	2,903	2,939	2,976	3,014	3,051
531	3,089	3,127	3,165	3,203	3,242	3,281	3,320	3,359	3,399	3,439
532	3,479	3,519	3,560	3,600	3,642	3,683	3,724	3,766	3,808	3,850
533	3,893	3,936	3,979	4,022	4,066	4,109	4,153	4,197	4,242	4,286
534	4,331	4,376	4,421	4,467	4,513	4,558	4,604	4,651	4,697	4,744
535	4,790	4,837	4,885	4,932	4,979	5,027	5,075	5,123	5,171	5,220
536	5,268	5,317	5,366	5,415	5,464	5,514	5,563	5,613	5,663	5,714
537	5,764	5,814	5,865	5,916	5,967	6,018	6,070	6,121	6,173	6,225
538	6,277	6,329	6,382	6,435	6,487	6,540	6,594	6,647	6,701	6,754
539	6,808	6,862	6,917	6,971	7,026	7,081	7,136	7,191	7,246	7,302
540	7,357	7,413	7,470	7,526	7,582	7,639	7,696	7,753	7,811	7,868
541	7,926	7,984	8,042	8,101	8,159	8,218	8,277	8,337	8,396	8,456
542	8,516	8,576	8,637	8,697	8,759	8,820	8,882	8,944	9,006	9,068
543	9,131	9,194	9,258	9,322	9,386	9,450	9,515	9,580	9,645	9,711
544	9,777	9,843	9,910	9,976	10,044	10,111	10,179	10,247	10,315	10,384
545	10,453	10,522	10,591	10,661	10,731	10,802	10,872	10,943	11,015	11,086
546	11,158	11,231	11,303	11,376	11,449	11,523	11,596	11,670	11,745	11,819
547	11,894	11,970	12,045	12,121	12,197	12,273	12,350	12,427	12,504	12,581
548	12,659	12,737	12,815	12,894	12,973	13,052	13,132	13,212	13,292	13,373
549	13,454	13,536	13,617	13,699	13,782	13,865	13,948	14,031	14,115	14,199
550	14,284	14,369	14,454	14,539	14,625	14,711	14,798	14,884	14,972	15,059
551	15,147	15,235	15,324	15,413	15,502	15,592	15,682	15,773	15,864	15,955
552	16,047	16,139	16,231	16,324	16,418	16,511	16,605	16,700	16,795	16,890
553	16,986	17,082	17,179	17,275	17,373	17,470	17,568	17,666	17,765	17,864
554	17,963	18,063	18,163	18,263	18,364	18,465	18,567	18,669	18,772	18,875
555	18,978	19,081	19,185	19,290	19,394	19,499	19,605	19,711	19,817	19,924
556	20,031	20,139	20,247	20,356	20,465	20,574	20,684	20,795	20,906	21,017
557	21,129	21,242	21,355	21,468	21,582	21,696	21,811	21,926	22,042	22,158
558	22,274	22,391	22,509	22,627	22,745	22,863	22,982	23,102	23,222	23,342
559	23,463	23,584	23,706	23,828	23,950	24,073	24,196	24,320	24,444	24,569
560	24,694	24,819	24,944	25,070	25,197	25,324	25,451	25,578	25,706	25,835
561	25,964	26,093	26,223	26,353	26,484	26,615	26,747	26,879	27,012	27,145
562	27,279	27,412	27,547	27,681	27,817	27,952	28,088	28,225	28,362	28,499
563	28,637	28,775	28,913	29,052	29,192	29,332	29,472	29,614	29,755	29,897
564	30,040	30,183	30,327	30,471	30,616	30,761	30,906	31,052	31,199	31,346
565	31,494	31,642	31,792	31,941	32,092	32,243	32,394	32,546	32,699	32,852

Appendix A (Continued)

Stillhouse Hollow Lake

RESERVOIR CAPACITY TABLE

TEXAS WATER DEVELOPMENT BOARD — September - December 2015 Survey

CAPACITY IN ACRE-FEET — Conservation Pool Elevation 622.0 feet NGVD29

ELEVATION INCREMENT IS ONE TENTH FOOT

ELEVATION in Feet	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
566	33,006	33,160	33,315	33,471	33,627	33,783	33,940	34,098	34,256	34,415
567	34,575	34,735	34,896	35,058	35,220	35,382	35,545	35,709	35,873	36,037
568	36,202	36,367	36,533	36,700	36,867	37,034	37,202	37,370	37,539	37,709
569	37,879	38,049	38,220	38,392	38,564	38,737	38,910	39,084	39,258	39,433
570	39,608	39,784	39,960	40,137	40,315	40,493	40,671	40,850	41,029	41,209
571	41,389	41,570	41,751	41,933	42,115	42,298	42,481	42,665	42,849	43,034
572	43,219	43,405	43,591	43,778	43,965	44,153	44,342	44,531	44,720	44,910
573	45,101	45,292	45,483	45,675	45,868	46,061	46,255	46,450	46,644	46,840
574	47,036	47,232	47,430	47,627	47,825	48,024	48,223	48,423	48,624	48,825
575	49,026	49,228	49,431	49,634	49,838	50,042	50,247	50,452	50,658	50,865
576	51,072	51,279	51,488	51,697	51,906	52,116	52,327	52,538	52,749	52,961
577	53,174	53,387	53,600	53,814	54,029	54,244	54,460	54,676	54,893	55,111
578	55,329	55,547	55,767	55,987	56,208	56,429	56,651	56,874	57,097	57,321
579	57,545	57,770	57,996	58,222	58,449	58,677	58,905	59,134	59,364	59,595
580	59,826	60,058	60,290	60,523	60,757	60,992	61,227	61,462	61,699	61,936
581	62,174	62,412	62,651	62,891	63,131	63,372	63,613	63,855	64,098	64,341
582	64,585	64,829	65,075	65,321	65,567	65,815	66,063	66,311	66,561	66,811
583	67,061	67,312	67,564	67,817	68,070	68,323	68,577	68,832	69,087	69,343
584	69,600	69,857	70,115	70,373	70,632	70,892	71,152	71,413	71,675	71,937
585	72,200	72,464	72,728	72,993	73,259	73,526	73,793	74,061	74,330	74,599
586	74,869	75,140	75,411	75,683	75,956	76,229	76,503	76,778	77,053	77,329
587	77,605	77,882	78,160	78,438	78,718	78,997	79,277	79,558	79,840	80,122
588	80,405	80,689	80,973	81,258	81,543	81,829	82,116	82,404	82,692	82,980
589	83,270	83,560	83,852	84,144	84,436	84,730	85,024	85,320	85,615	85,912
590	86,209	86,508	86,806	87,106	87,406	87,707	88,009	88,312	88,615	88,919
591	89,224	89,529	89,835	90,141	90,449	90,757	91,066	91,375	91,685	91,996
592	92,308	92,620	92,933	93,247	93,561	93,876	94,192	94,509	94,826	95,144
593	95,462	95,781	96,101	96,422	96,743	97,065	97,388	97,712	98,036	98,361
594	98,687	99,013	99,341	99,669	99,998	100,328	100,658	100,990	101,322	101,654
595	101,988	102,322	102,658	102,994	103,331	103,669	104,008	104,348	104,688	105,030
596	105,372	105,714	106,058	106,402	106,747	107,093	107,439	107,786	108,134	108,483
597	108,832	109,182	109,533	109,885	110,238	110,591	110,945	111,300	111,656	112,013
598	112,370	112,728	113,087	113,446	113,807	114,168	114,530	114,893	115,257	115,621
599	115,987	116,353	116,720	117,088	117,457	117,827	118,198	118,570	118,943	119,316
600	119,691	120,066	120,443	120,820	121,198	121,578	121,958	122,339	122,721	123,104
601	123,489	123,874	124,260	124,647	125,035	125,424	125,814	126,205	126,597	126,990
602	127,384	127,779	128,175	128,572	128,971	129,370	129,770	130,172	130,575	130,979
603	131,384	131,790	132,198	132,606	133,016	133,426	133,838	134,251	134,665	135,080
604	135,497	135,914	136,333	136,752	137,173	137,595	138,018	138,442	138,867	139,294
605	139,721	140,150	140,580	141,011	141,443	141,877	142,311	142,748	143,184	143,623
606	144,062	144,502	144,944	145,386	145,830	146,274	146,720	147,167	147,615	148,064
607	148,514	148,966	149,418	149,872	150,327	150,783	151,240	151,698	152,158	152,619
608	153,081	153,544	154,009	154,474	154,941	155,408	155,877	156,347	156,818	157,291
609	157,764	158,239	158,715	159,192	159,671	160,150	160,631	161,113	161,597	162,082
610	162,567	163,054	163,542	164,031	164,522	165,013	165,506	166,000	166,495	166,991
611	167,488	167,986	168,485	168,986	169,487	169,990	170,494	170,999	171,504	172,012
612	172,520	173,029	173,540	174,052	174,565	175,079	175,595	176,111	176,629	177,148
613	177,669	178,190	178,713	179,237	179,762	180,288	180,816	181,345	181,874	182,406
614	182,938	183,471	184,006	184,542	185,079	185,618	186,157	186,698	187,240	187,784
615	188,328	188,874	189,421	189,969	190,518	191,068	191,620	192,173	192,727	193,283
616	193,840	194,398	194,958	195,518	196,081	196,645	197,209	197,776	198,344	198,913
617	199,484	200,056	200,630	201,205	201,781	202,359	202,938	203,519	204,102	204,686
618	205,272	205,859	206,448	207,038	207,631	208,224	208,819	209,416	210,014	210,613
619	211,214	211,817	212,421	213,026	213,633	214,242	214,851	215,463	216,075	216,689
620	217,304	217,920	218,538	219,156	219,777	220,398	221,021	221,645	222,270	222,897
621	223,524	224,154	224,784	225,416	226,050	226,685	227,321	227,959	228,598	229,239
622	229,881	230,525	231,170	231,817	232,465					

Note: Capacities above elevation 621.0 feet calculated from interpolated areas

Appendix B

Stillhouse Hollow Lake

RESERVOIR AREA TABLE

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

September - December 2015 Survey
Conservation Pool Elevation 622.0 feet NGVD29

ELEVATION in Feet	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
505	0	0	0	0	0	0	0	0	0	0
506	0	0	1	1	1	1	1	1	1	1
507	2	2	2	2	2	2	2	2	2	2
508	3	3	3	3	3	3	3	3	4	4
509	4	4	4	4	4	5	5	5	5	5
510	5	6	6	6	6	6	7	7	7	7
511	8	8	9	9	9	10	10	10	11	11
512	11	12	12	13	13	14	15	16	16	17
513	17	18	18	19	19	20	20	21	21	22
514	22	23	23	24	24	24	25	25	25	26
515	26	26	27	27	27	27	28	28	28	29
516	29	29	30	30	31	31	32	32	33	34
517	35	37	38	40	43	45	48	50	52	54
518	57	60	62	65	68	70	73	75	78	80
519	83	86	88	90	92	94	96	98	100	103
520	105	108	110	112	114	117	119	120	122	124
521	126	128	130	132	134	137	140	142	145	147
522	149	151	154	156	158	161	164	166	169	173
523	176	180	184	188	192	196	200	204	209	214
524	218	221	225	228	231	234	237	240	243	245
525	248	250	253	255	258	260	263	266	268	271
526	274	276	278	281	283	285	288	290	292	295
527	297	299	301	303	305	307	309	311	313	315
528	316	318	320	322	324	326	327	329	331	333
529	335	337	339	341	343	345	347	349	351	353
530	355	357	359	361	364	366	369	371	373	376
531	378	380	383	386	388	390	393	395	397	400
532	402	404	406	409	412	414	417	419	422	424
533	427	429	432	434	436	438	440	442	445	447
534	449	451	453	455	457	459	461	463	465	467
535	469	471	473	474	476	478	480	481	483	485
536	487	488	490	492	494	496	497	499	501	503
537	504	506	508	510	511	513	515	517	519	521
538	522	524	526	528	529	531	533	535	537	538
539	540	542	544	546	547	549	551	553	554	556
540	558	560	562	564	567	569	571	573	575	577
541	579	581	583	585	587	590	592	594	596	599
542	601	604	607	610	612	615	618	621	624	627
543	630	633	637	640	643	646	649	652	655	658
544	661	664	667	670	673	676	679	682	685	688
545	691	693	696	699	702	705	708	712	715	718
546	721	724	727	730	733	736	739	742	745	748
547	751	754	756	759	762	764	767	770	773	776
548	779	782	785	789	792	795	798	802	805	809
549	812	816	819	823	826	829	833	837	840	844
550	847	850	853	857	860	863	866	870	873	877
551	880	884	888	892	896	900	904	908	912	915
552	919	923	927	931	935	939	944	948	952	955
553	959	962	966	970	973	977	980	984	988	992
554	995	999	1,003	1,007	1,011	1,015	1,019	1,023	1,027	1,030
555	1,034	1,038	1,041	1,045	1,049	1,053	1,057	1,061	1,065	1,070
556	1,075	1,080	1,084	1,089	1,094	1,098	1,103	1,107	1,112	1,117
557	1,122	1,127	1,132	1,136	1,141	1,145	1,149	1,154	1,158	1,163
558	1,168	1,172	1,176	1,180	1,184	1,188	1,193	1,197	1,202	1,206
559	1,210	1,214	1,218	1,222	1,226	1,230	1,235	1,239	1,243	1,247
560	1,250	1,254	1,258	1,262	1,266	1,270	1,274	1,278	1,282	1,287
561	1,291	1,296	1,300	1,305	1,310	1,316	1,320	1,324	1,329	1,333
562	1,337	1,341	1,345	1,349	1,353	1,358	1,362	1,367	1,371	1,375
563	1,379	1,384	1,388	1,393	1,398	1,403	1,409	1,414	1,419	1,424
564	1,429	1,434	1,439	1,443	1,448	1,453	1,458	1,464	1,470	1,475
565	1,482	1,488	1,494	1,500	1,507	1,513	1,518	1,524	1,530	1,535

Appendix B (Continued)

Stillhouse Hollow Lake

RESERVOIR AREA TABLE

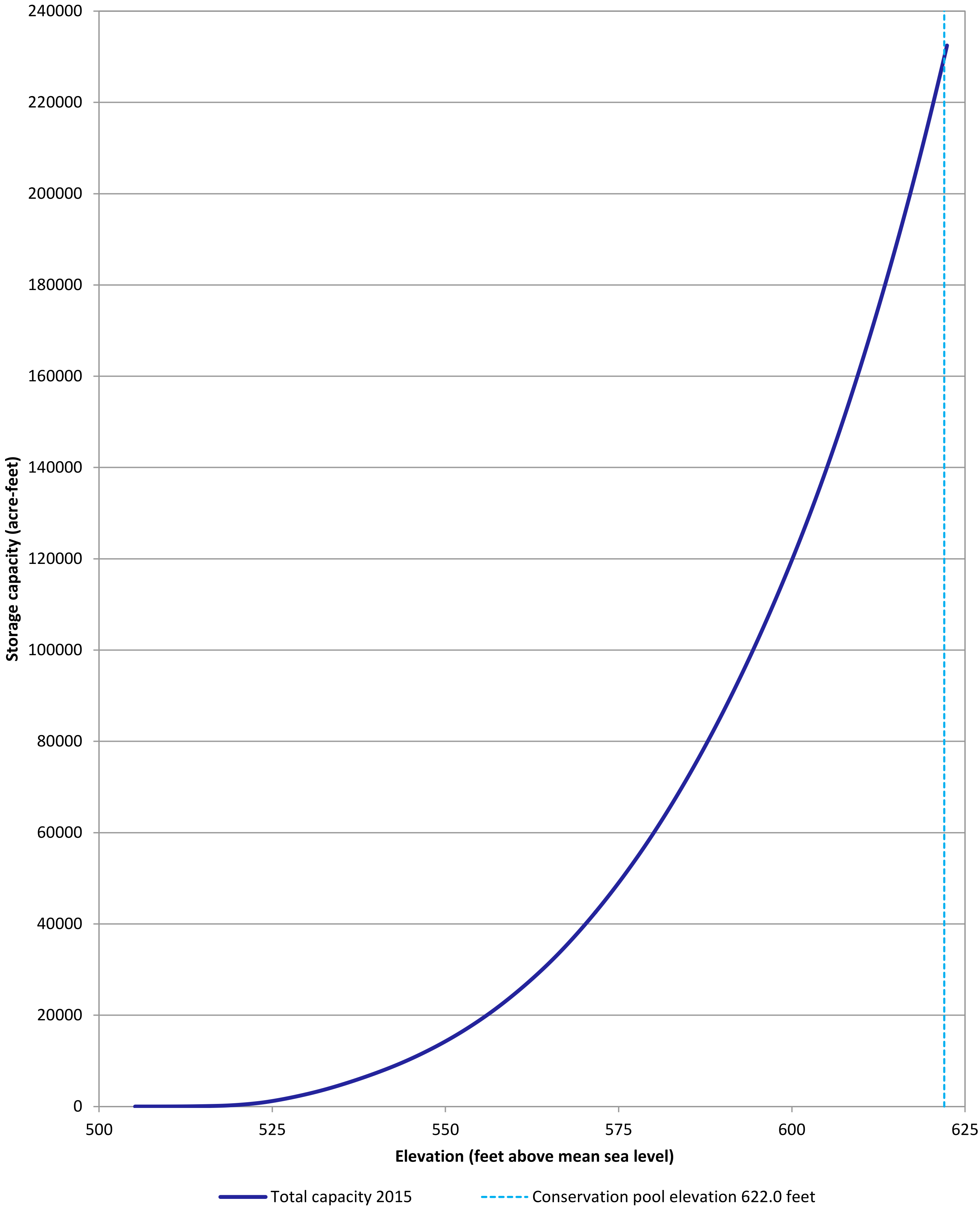
TEXAS WATER DEVELOPMENT BOARD — September - December 2015 Survey

AREA IN ACRES — Conservation Pool Elevation 622.0 feet NGVD29

ELEVATION INCREMENT IS ONE TENTH FOOT

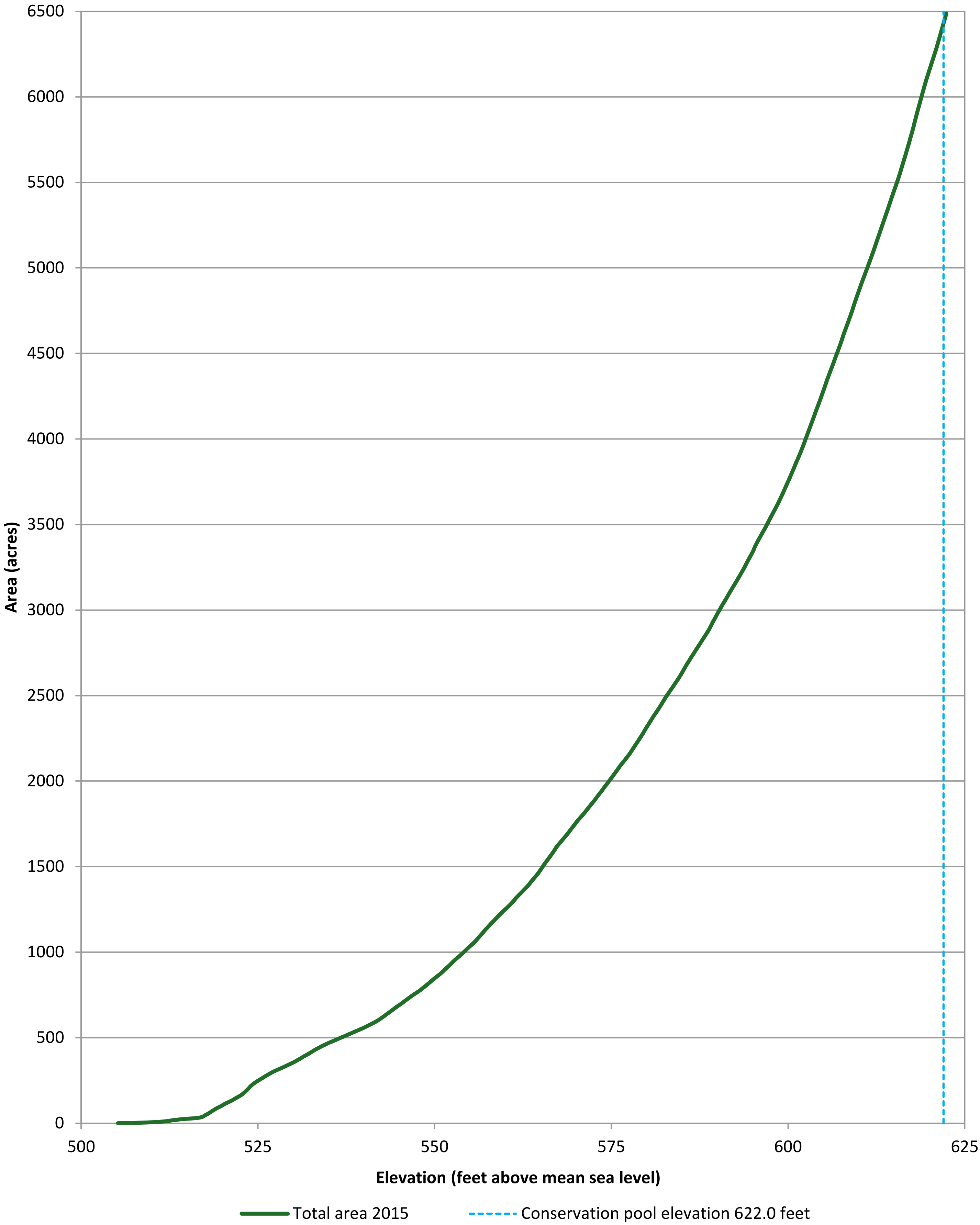
ELEVATION in Feet	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
566	1,540	1,546	1,552	1,557	1,563	1,569	1,574	1,580	1,587	1,592
567	1,598	1,606	1,612	1,617	1,623	1,628	1,633	1,637	1,642	1,647
568	1,652	1,657	1,662	1,667	1,672	1,677	1,682	1,686	1,691	1,697
569	1,702	1,708	1,713	1,719	1,724	1,729	1,735	1,740	1,745	1,751
570	1,756	1,762	1,767	1,772	1,777	1,781	1,786	1,791	1,795	1,800
571	1,805	1,809	1,814	1,819	1,825	1,830	1,835	1,840	1,845	1,850
572	1,855	1,861	1,866	1,871	1,876	1,881	1,886	1,892	1,897	1,903
573	1,909	1,914	1,919	1,924	1,930	1,935	1,940	1,946	1,951	1,957
574	1,963	1,969	1,974	1,979	1,984	1,990	1,995	2,001	2,007	2,012
575	2,018	2,023	2,029	2,034	2,040	2,045	2,051	2,057	2,063	2,069
576	2,075	2,081	2,086	2,092	2,097	2,102	2,107	2,112	2,117	2,122
577	2,127	2,133	2,138	2,143	2,149	2,154	2,160	2,166	2,172	2,179
578	2,185	2,191	2,198	2,204	2,210	2,217	2,223	2,229	2,235	2,241
579	2,248	2,254	2,261	2,267	2,273	2,280	2,287	2,294	2,302	2,309
580	2,315	2,322	2,328	2,334	2,341	2,348	2,354	2,361	2,368	2,374
581	2,381	2,387	2,393	2,399	2,405	2,411	2,417	2,423	2,430	2,436
582	2,443	2,449	2,456	2,463	2,470	2,477	2,484	2,490	2,497	2,503
583	2,509	2,515	2,521	2,527	2,533	2,539	2,544	2,550	2,557	2,563
584	2,569	2,575	2,581	2,587	2,593	2,600	2,606	2,613	2,619	2,626
585	2,633	2,640	2,648	2,655	2,662	2,670	2,677	2,684	2,690	2,697
586	2,703	2,710	2,717	2,723	2,730	2,736	2,742	2,749	2,755	2,762
587	2,768	2,775	2,781	2,787	2,794	2,800	2,806	2,813	2,819	2,826
588	2,832	2,839	2,845	2,851	2,858	2,864	2,871	2,878	2,884	2,892
589	2,900	2,908	2,916	2,925	2,932	2,940	2,947	2,955	2,963	2,971
590	2,978	2,985	2,992	3,000	3,007	3,014	3,022	3,029	3,036	3,043
591	3,049	3,056	3,063	3,070	3,077	3,085	3,092	3,099	3,106	3,113
592	3,120	3,127	3,133	3,140	3,147	3,154	3,161	3,168	3,174	3,181
593	3,189	3,196	3,203	3,210	3,217	3,224	3,232	3,239	3,246	3,254
594	3,262	3,271	3,279	3,286	3,294	3,301	3,309	3,316	3,324	3,331
595	3,339	3,348	3,358	3,368	3,377	3,385	3,393	3,401	3,409	3,416
596	3,424	3,431	3,438	3,446	3,453	3,460	3,468	3,475	3,482	3,490
597	3,498	3,506	3,514	3,522	3,530	3,538	3,546	3,554	3,561	3,569
598	3,577	3,585	3,592	3,600	3,608	3,616	3,624	3,633	3,641	3,650
599	3,659	3,667	3,676	3,685	3,695	3,704	3,714	3,723	3,732	3,741
600	3,750	3,759	3,769	3,778	3,788	3,798	3,807	3,817	3,826	3,836
601	3,847	3,857	3,867	3,876	3,885	3,895	3,904	3,914	3,924	3,935
602	3,945	3,956	3,967	3,978	3,989	4,000	4,011	4,023	4,035	4,046
603	4,057	4,067	4,078	4,090	4,101	4,112	4,123	4,135	4,146	4,158
604	4,169	4,180	4,191	4,202	4,213	4,224	4,235	4,247	4,259	4,270
605	4,282	4,293	4,305	4,318	4,330	4,342	4,353	4,364	4,376	4,387
606	4,398	4,408	4,419	4,430	4,441	4,452	4,464	4,475	4,486	4,497
607	4,508	4,519	4,531	4,542	4,554	4,565	4,578	4,591	4,603	4,615
608	4,626	4,638	4,649	4,660	4,672	4,683	4,694	4,706	4,717	4,729
609	4,741	4,753	4,766	4,779	4,792	4,804	4,816	4,828	4,840	4,852
610	4,863	4,875	4,886	4,898	4,910	4,921	4,932	4,943	4,955	4,966
611	4,977	4,988	4,999	5,010	5,021	5,032	5,043	5,054	5,066	5,077
612	5,089	5,100	5,112	5,125	5,137	5,149	5,161	5,173	5,185	5,196
613	5,209	5,221	5,233	5,245	5,257	5,270	5,282	5,293	5,305	5,317
614	5,329	5,341	5,353	5,366	5,378	5,391	5,403	5,415	5,427	5,439
615	5,451	5,463	5,474	5,486	5,498	5,510	5,523	5,535	5,548	5,562
616	5,576	5,590	5,603	5,617	5,630	5,644	5,657	5,672	5,686	5,700
617	5,714	5,728	5,743	5,758	5,772	5,786	5,801	5,816	5,832	5,850
618	5,865	5,882	5,897	5,913	5,928	5,943	5,958	5,973	5,988	6,003
619	6,018	6,033	6,048	6,063	6,077	6,091	6,104	6,118	6,131	6,144
620	6,156	6,169	6,182	6,195	6,208	6,221	6,233	6,246	6,259	6,272
621	6,285	6,299	6,314	6,328	6,343	6,357	6,372	6,386	6,400	6,415
622	6,429	6,444	6,458	6,473	6,487					

Note: Areas between elevations 621.0 and 622.4 feet linearly interpolated



Stillhouse Hollow Lake
September - December 2015 Survey
Prepared by: TWDB

Appendix C: Capacity curve



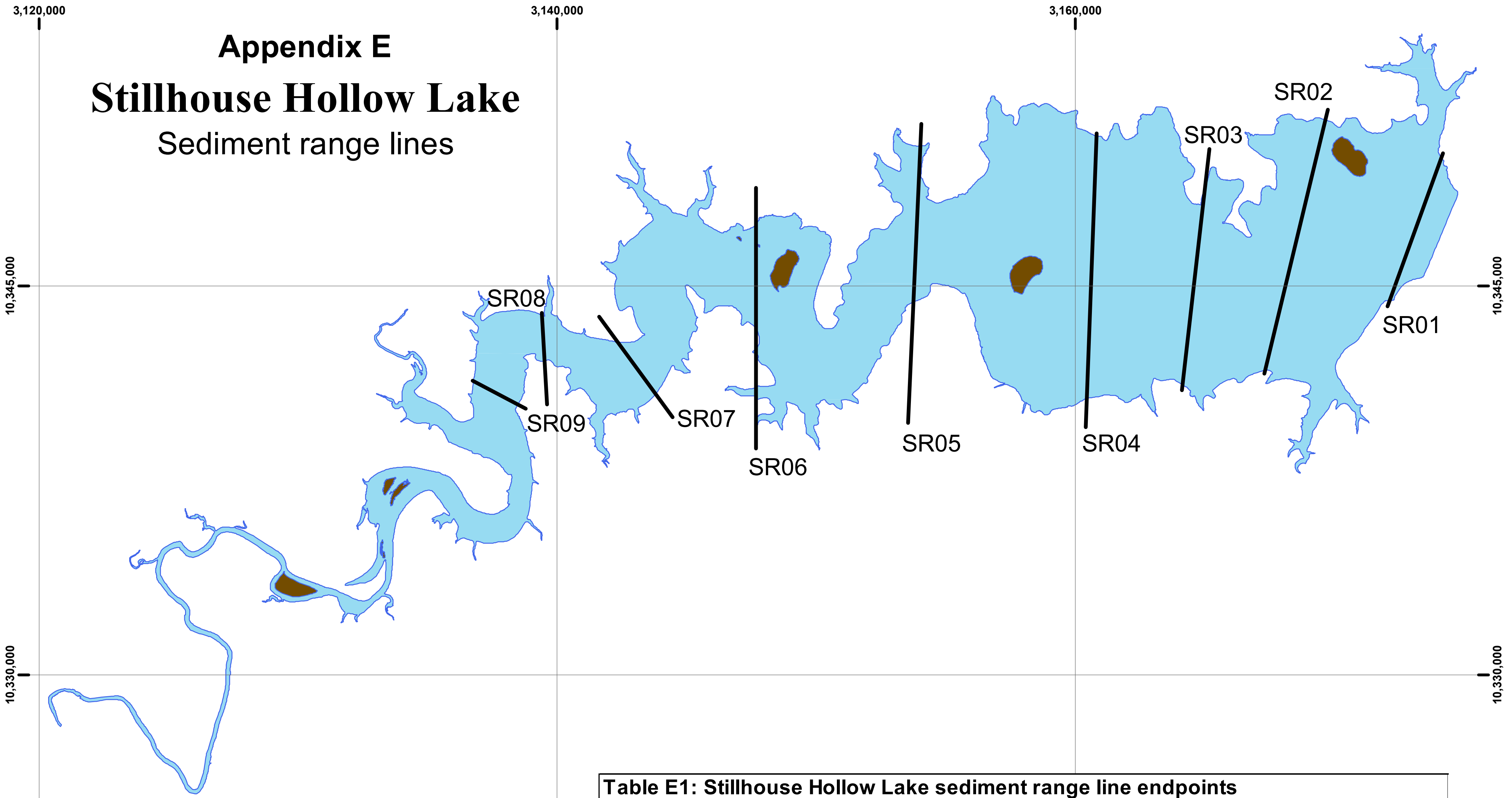
Stillhouse Hollow Lake
September - December 2015 Survey
Prepared by: TWDB

Appendix D: Area curve

Appendix E

Stillhouse Hollow Lake

Sediment range lines



Islands

Stillhouse Hollow Lake conservation pool elevation 622.0 feet

Texas Water Development Board

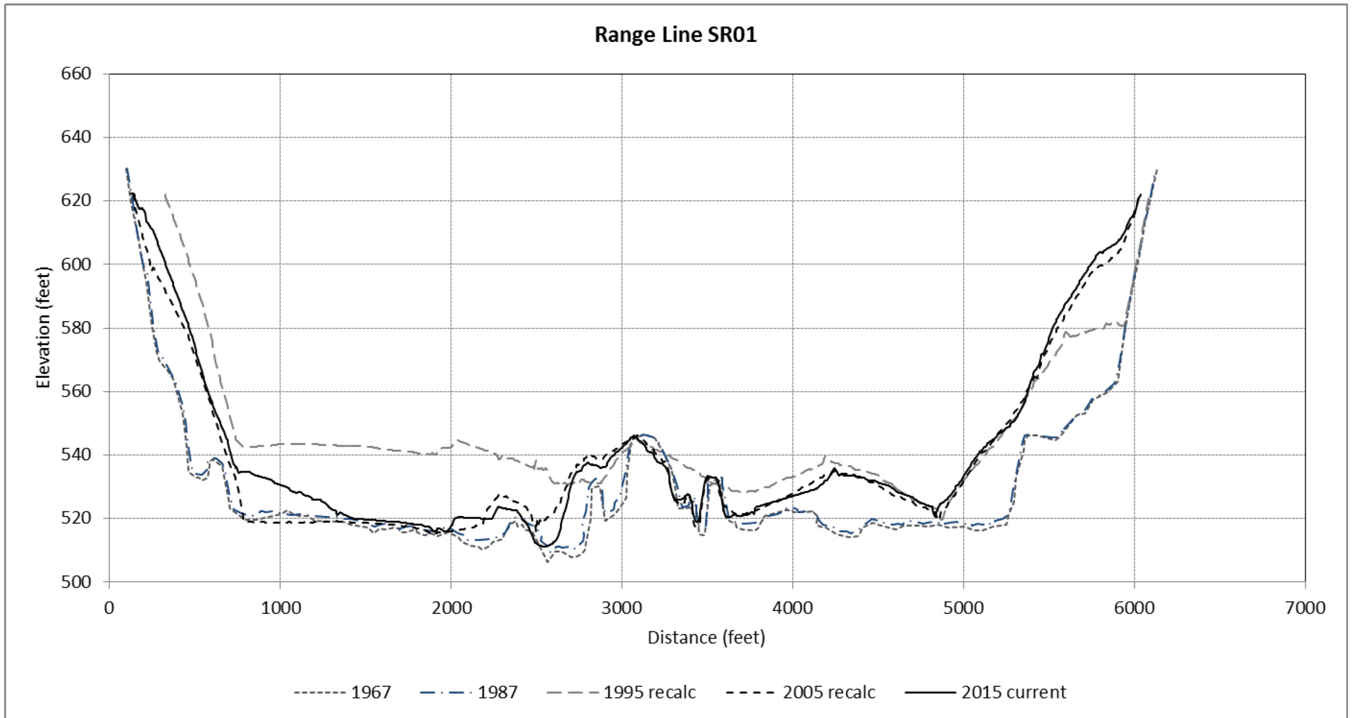
September - December 2015 Survey

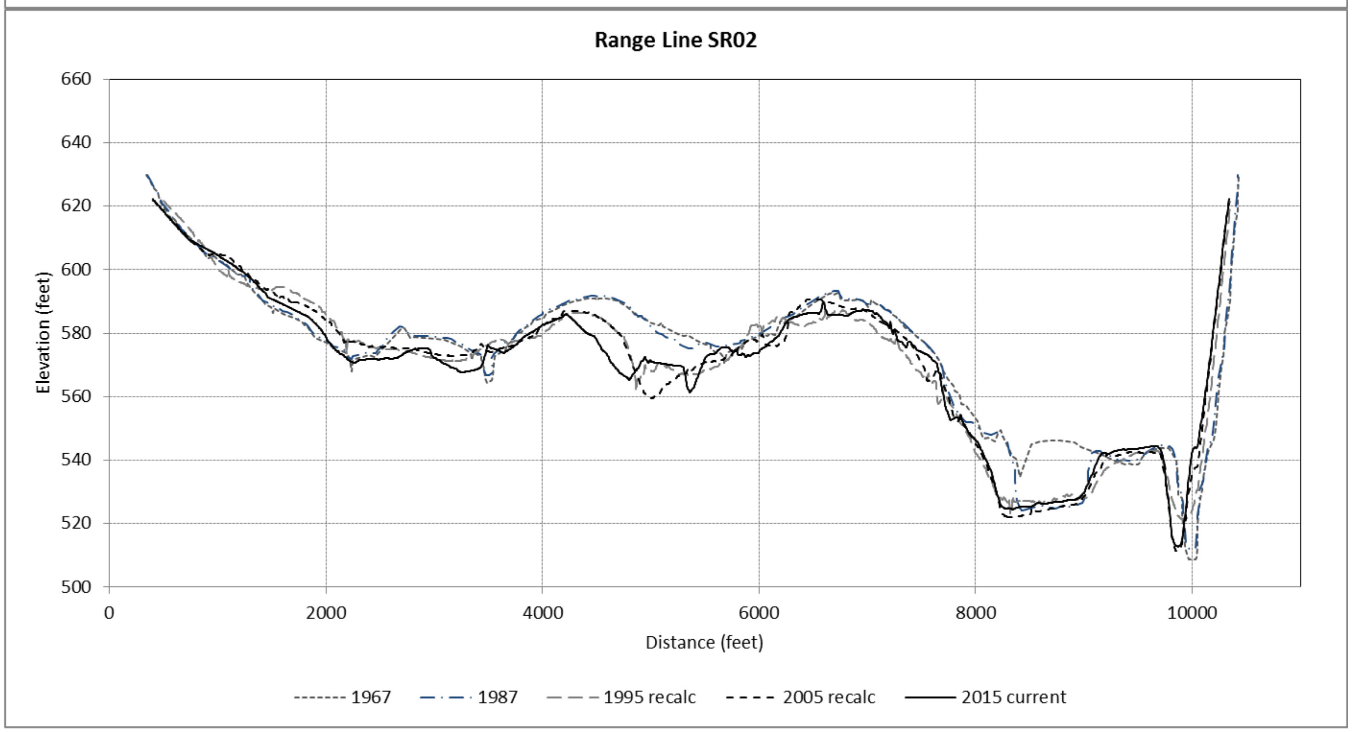
0 0.5 1 2 Miles

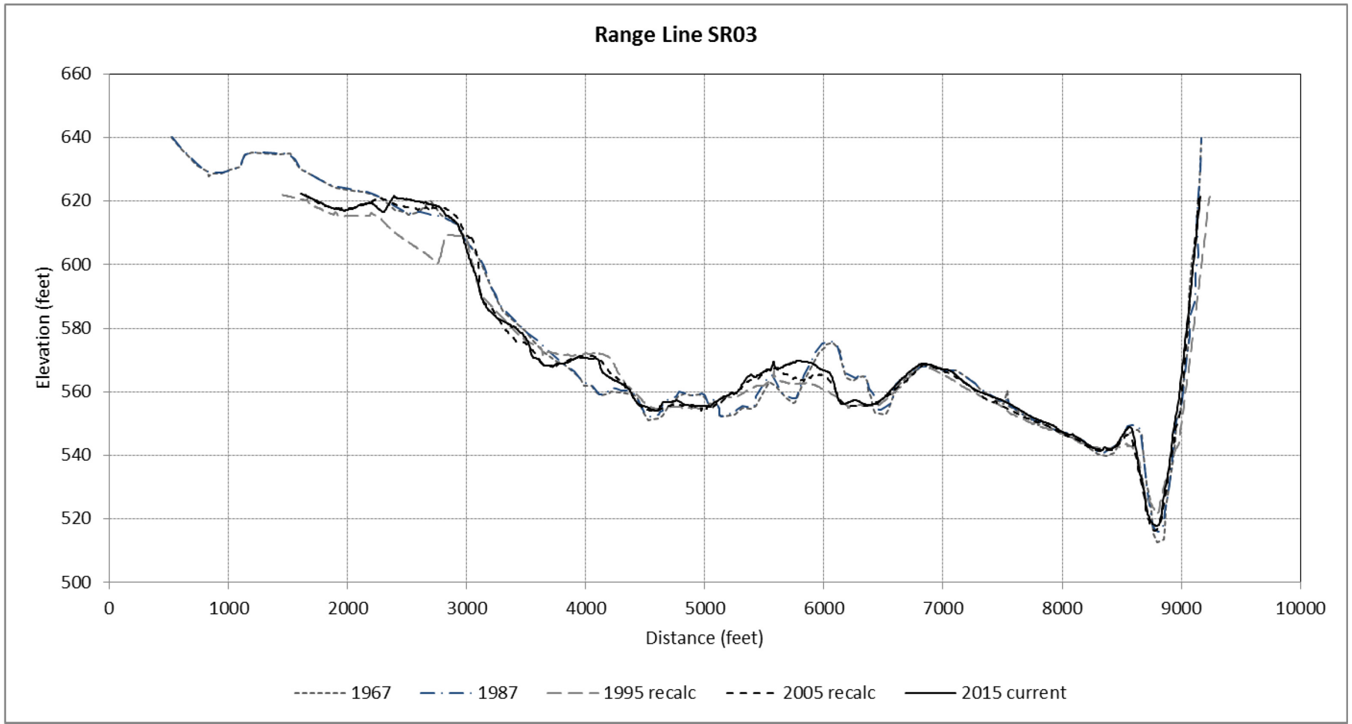
N

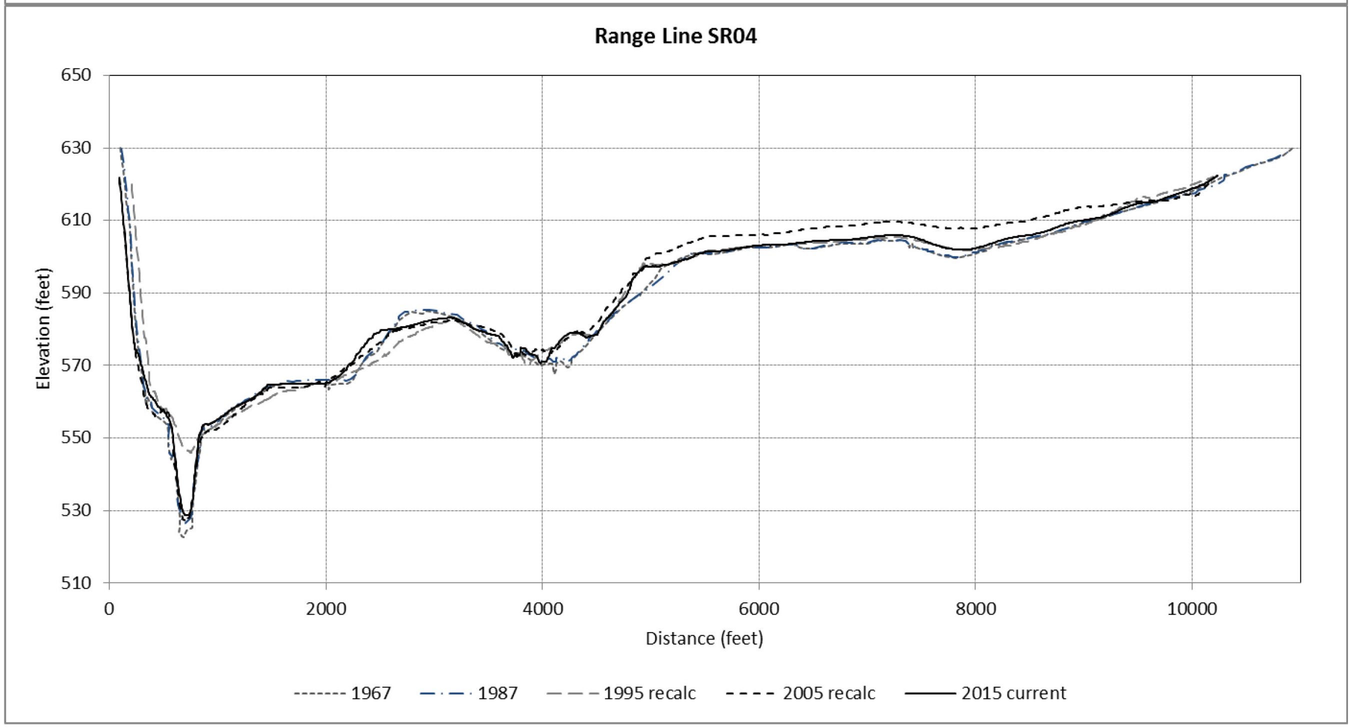
Table E1: Stillhouse Hollow Lake sediment range line endpoints				
Sediment Range Line	**X_L**	**Y_L**	**X_R**	**Y_R**
SR01	2,877,623.75	507,601.68	2,875,483.83	501,709.83
SR02	2,873,190.99	509,284.71	2,870,728.15	499,101.66
SR03	2,868,610.67	507,774.88	2,867,551.71	498,475.82
SR04	2,864,256.30	508,376.65	2,863,838.47	497,037.30
SR05	2,857,494.77	508,737.01	2,856,978.92	497,213.29
SR06	2,851,115.22	506,275.28	2,851,105.76	496,222.59
SR07	2,845,059.38	501,299.03	2,847,900.03	497,423.79
SR08	2,842,842.16	501,441.14	2,843,048.93	497,913.36
SR09	2,840,174.95	498,840.09	2,842,217.54	497,762.46

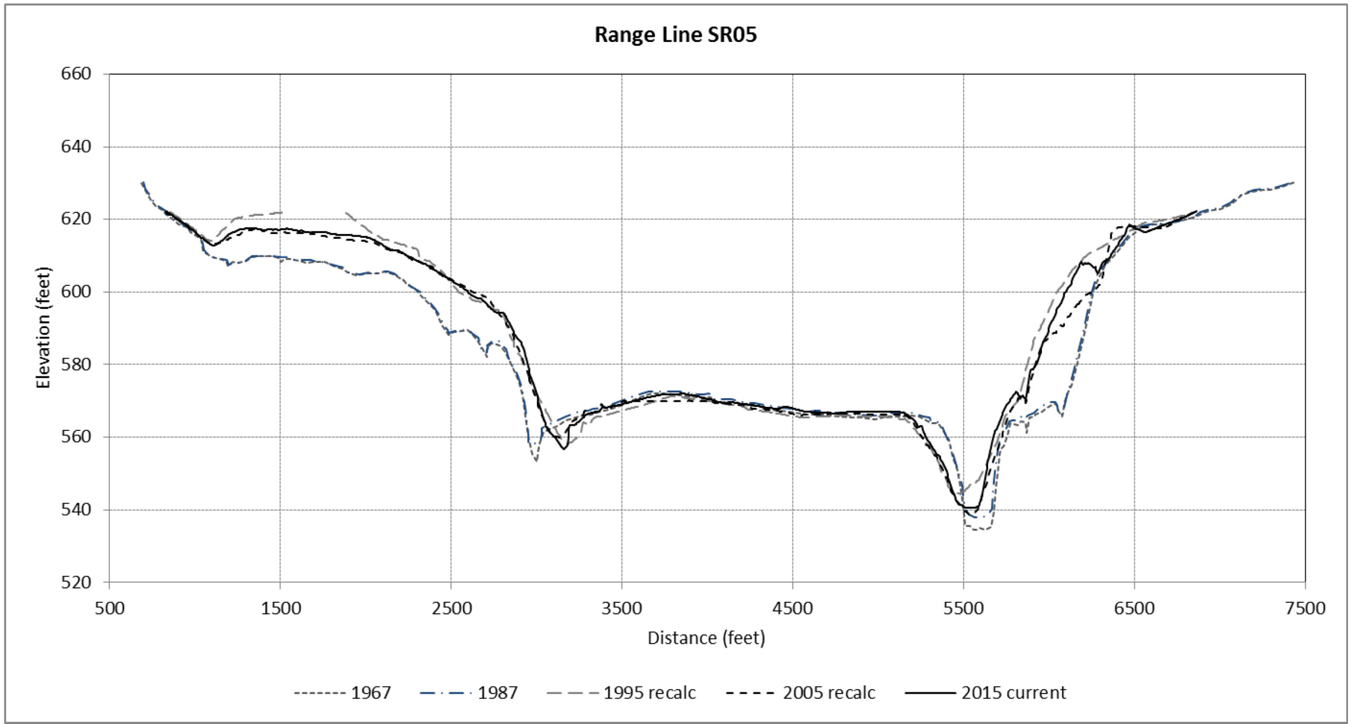
XY: Lambert Grid Coordinates North American Datum 1927 — L= Left End Point R= Right End Point

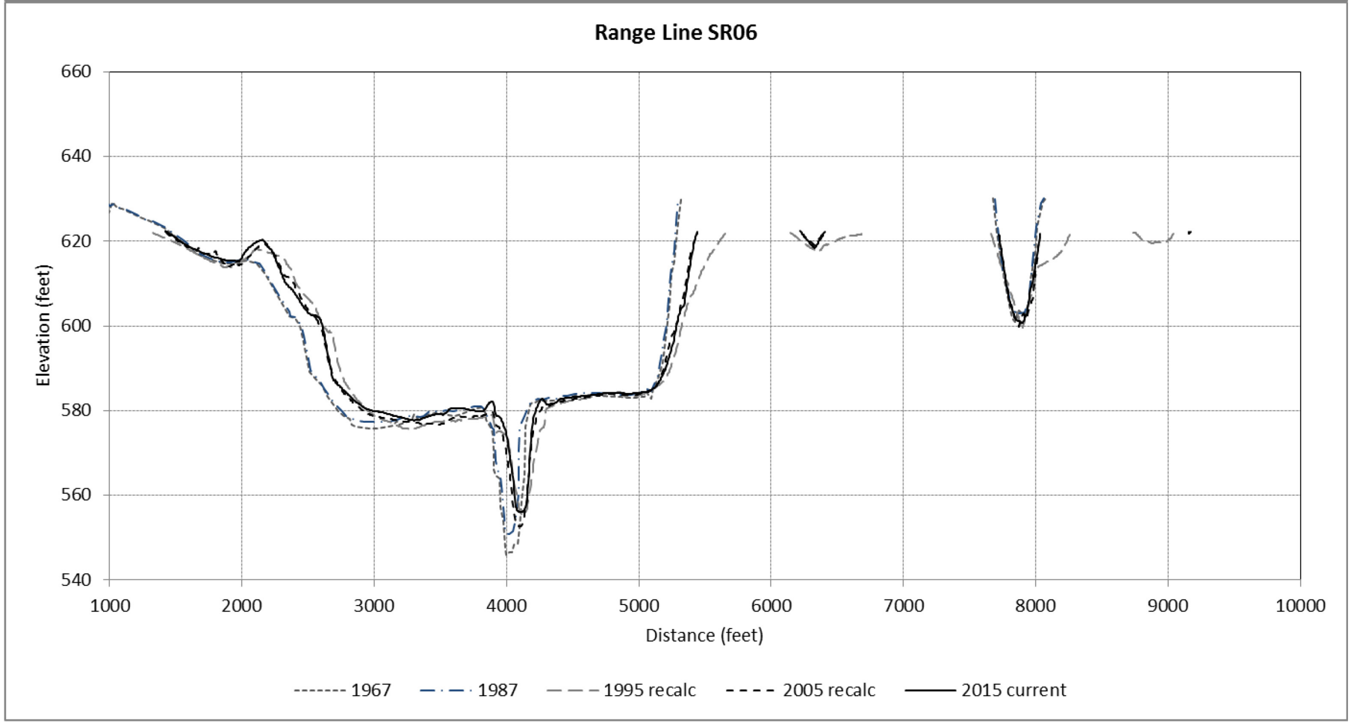

Range Line SR01
660
640
620
600
580
560
540
520
500
Elevation (feet)
0
1000
2000
3000
4000
5000
6000
7000
Distance (feet)
1967
1987
1995 recalc
2005 recalc
2015 current

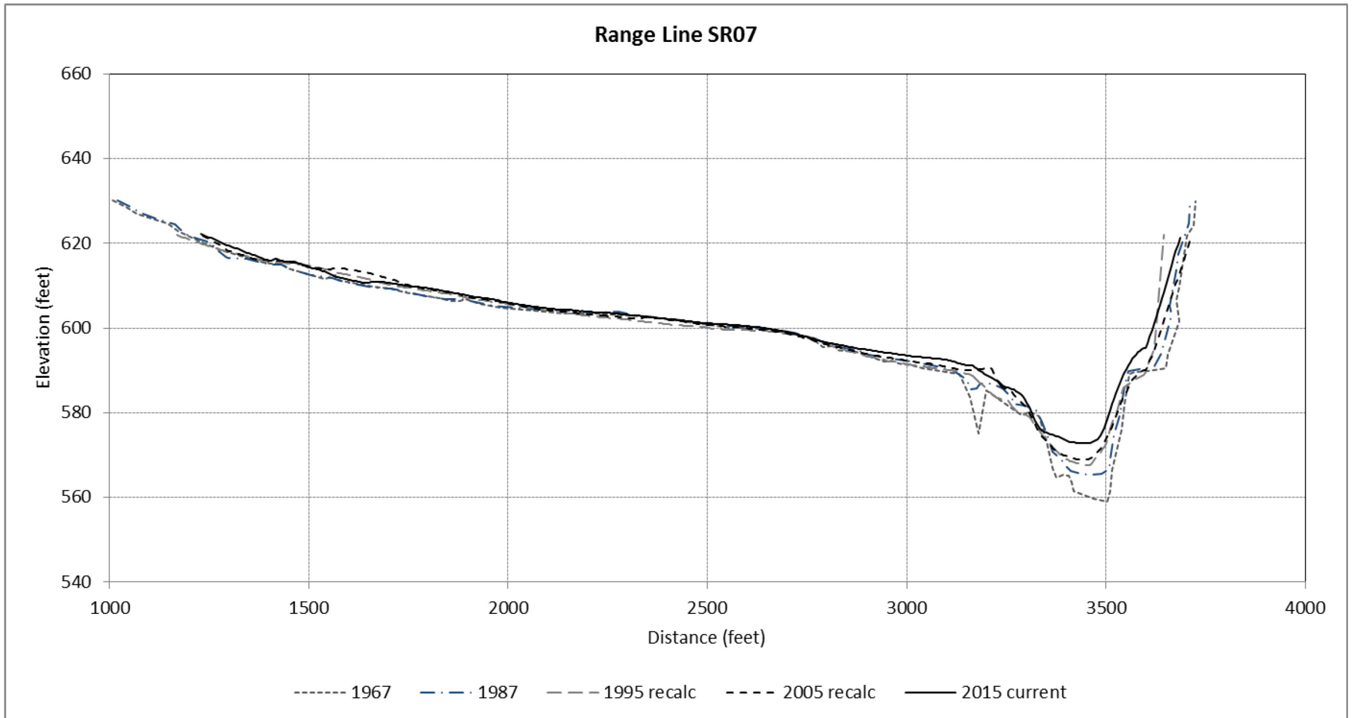

Range Line SR02
660
640
620
600
580
560
540
520
500
Elevation (feet)
0
2000
4000
6000
8000
10000
Distance (feet)
1967
1987
1995 recalc
2005 recalc
2015 current

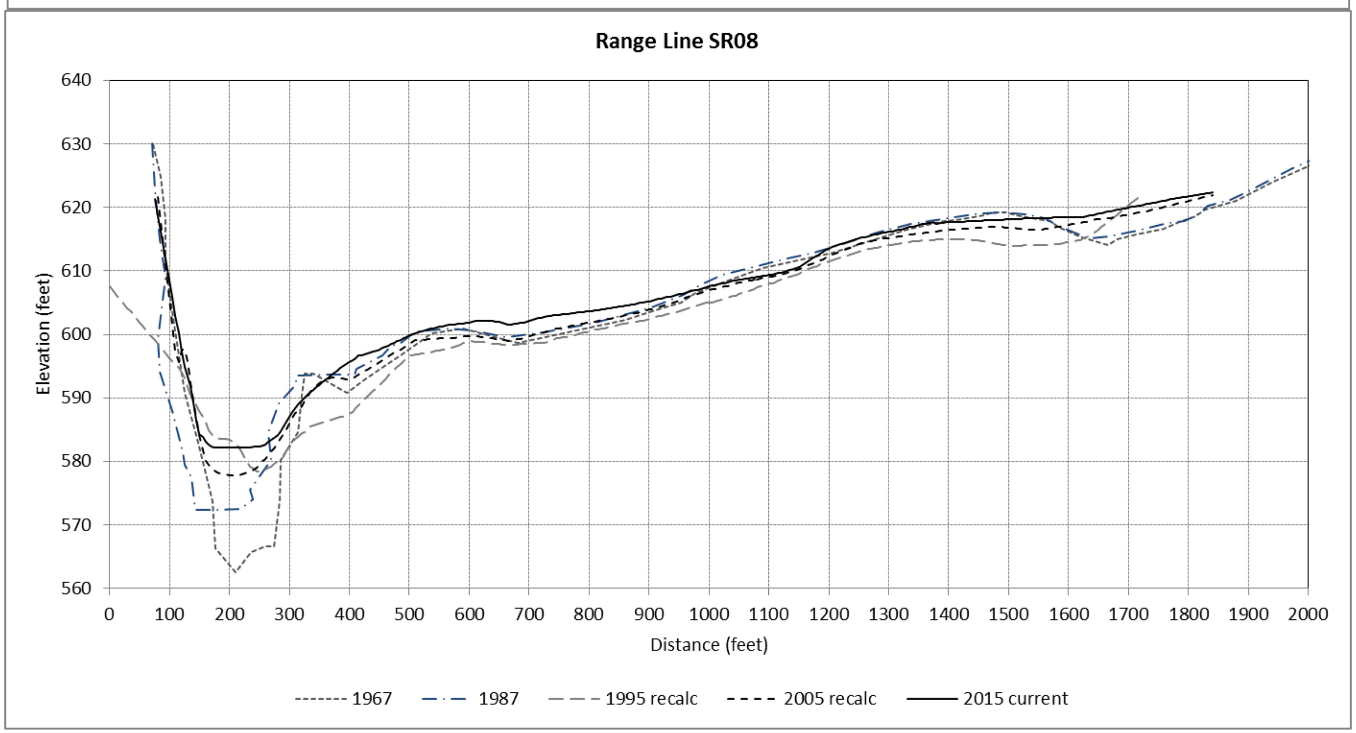

Range Line SR03
660
640
620
600
580
560
540
520
500
Elevation (feet)
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
Distance (feet)
1967
1987
1995 recalc
2005 recalc
2015 current


Range Line SR04
650
630
610
590
570
550
530
510
Elevation (feet)
0
2000
4000
6000
8000
10000
Distance (feet)
1967
1987
1995 recalc
2005 recalc
2015 current


Range Line SR05
660
640
620
600
580
560
540
520
Elevation (feet)
500
1500
2500
3500
4500
5500
6500
7500
Distance (feet)
1967
1987
1995 recalc
2005 recalc
2015 current


Range Line SR06
660
640
620
600
580
560
540
Elevation (feet)
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
Distance (feet)
1967
1987
1995 recalc
2005 recalc
2015 current


Range Line SR07
Elevation (feet)
660
640
620
600
580
560
540
1000
1500
2000
2500
3000
3500
4000
Distance (feet)
1967
1987
1995 recalc
2005 recalc
2015 current


Range Line SR08
Elevation (feet)
640
630
620
610
600
590
580
570
560
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
Distance (feet)
1967
1987
1995 recalc
2005 recalc
2015 current

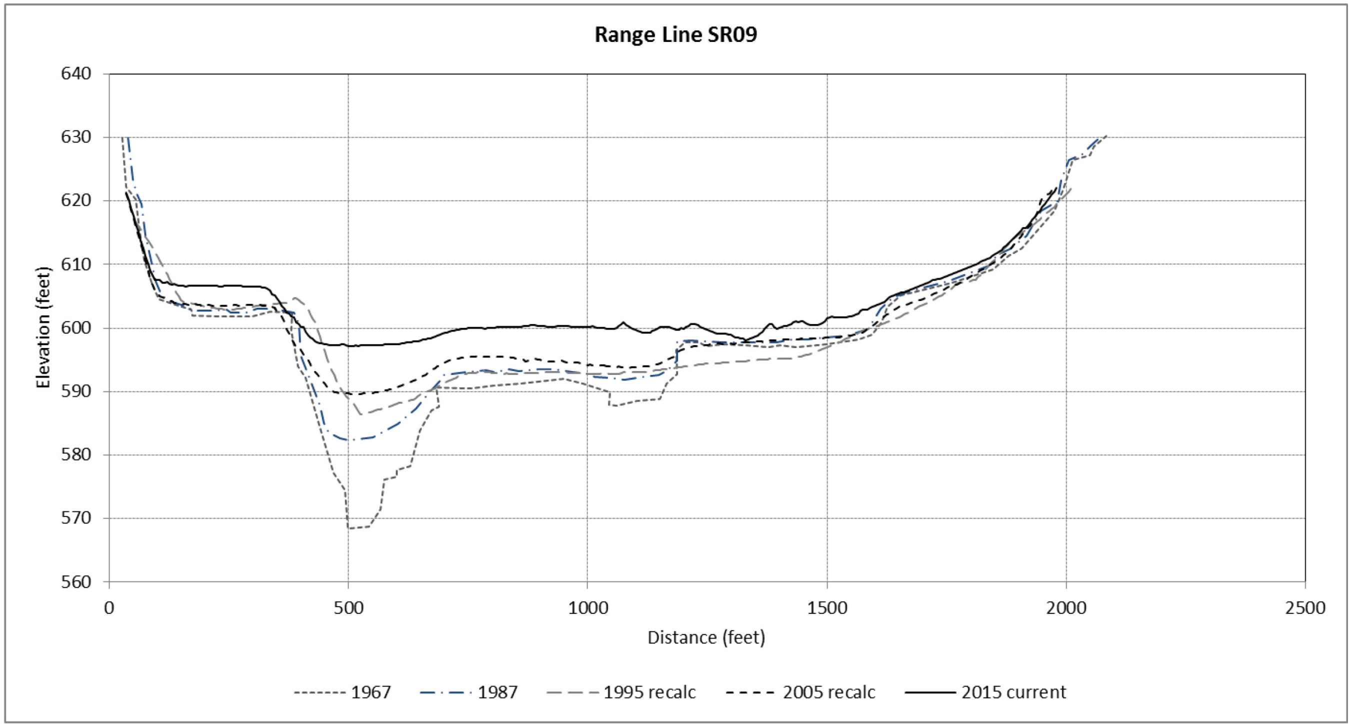

Range Line SR09
640
630
620
610
600
590
580
570
560
Elevation (feet)
0
500
1000
1500
2000
2500
Distance (feet)
1967
1987
1995 recalc
2005 recalc
2015 current

Figure 6

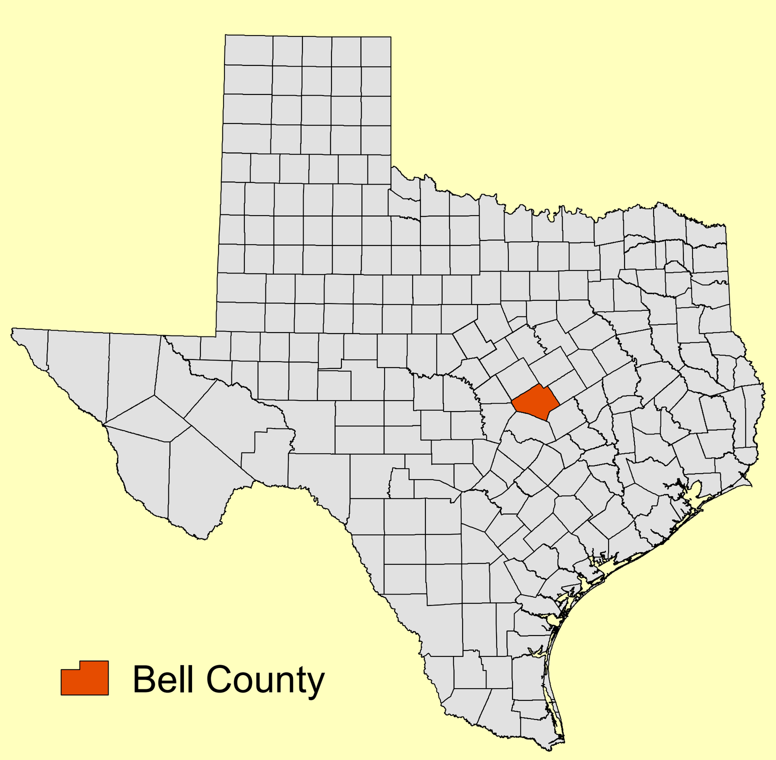
CONTOURS
(feet above mean sea level)

- 622
- 620
- 610
- 600
- 590
- 580
- 570
- 560
- 550
- 540
- 530
- 520
- 510

Stillhouse Hollow Lake elevation 622.4 feet NGVD29

Islands

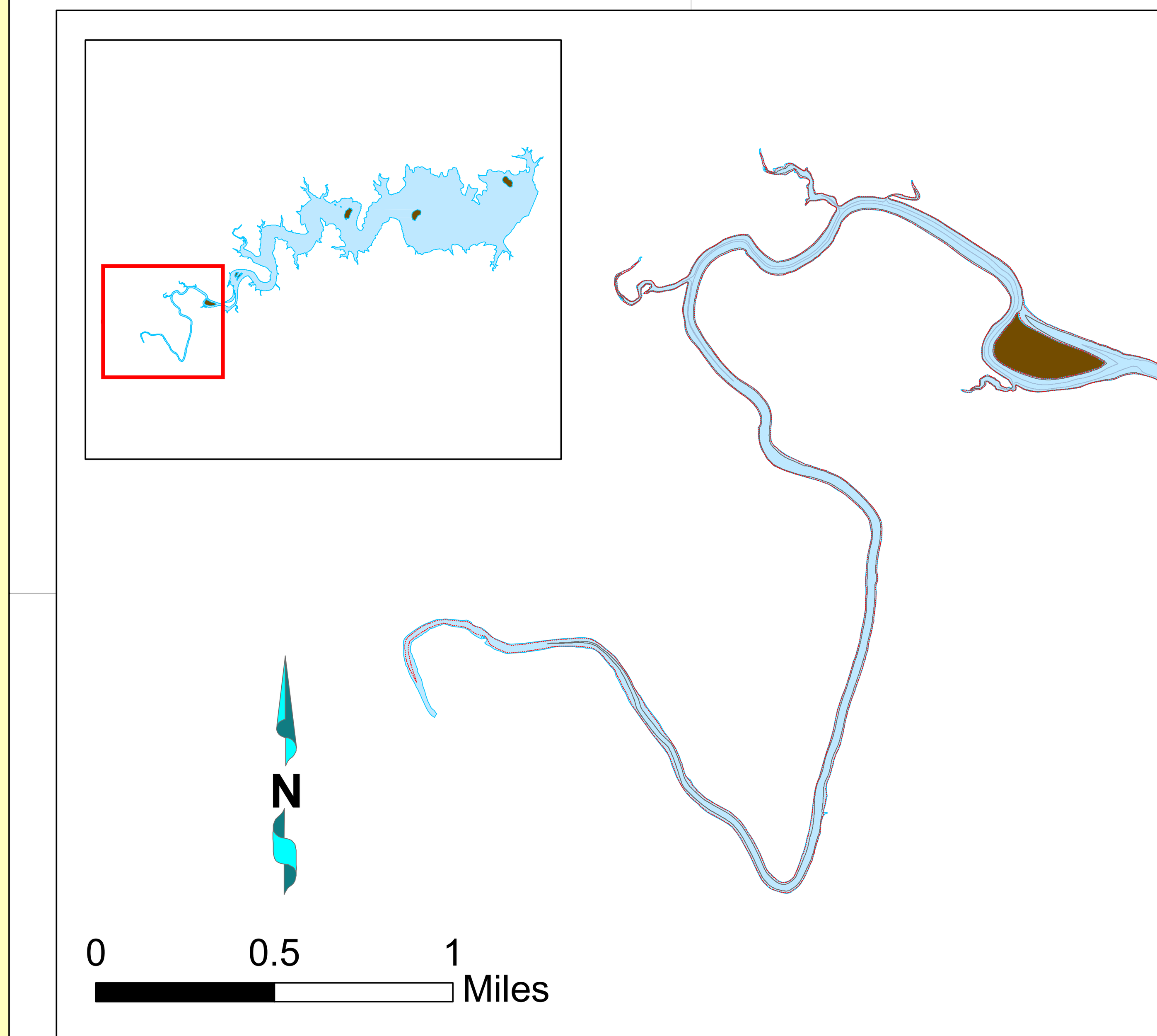
Projection: NAD83
State Plane Texas
Central Zone

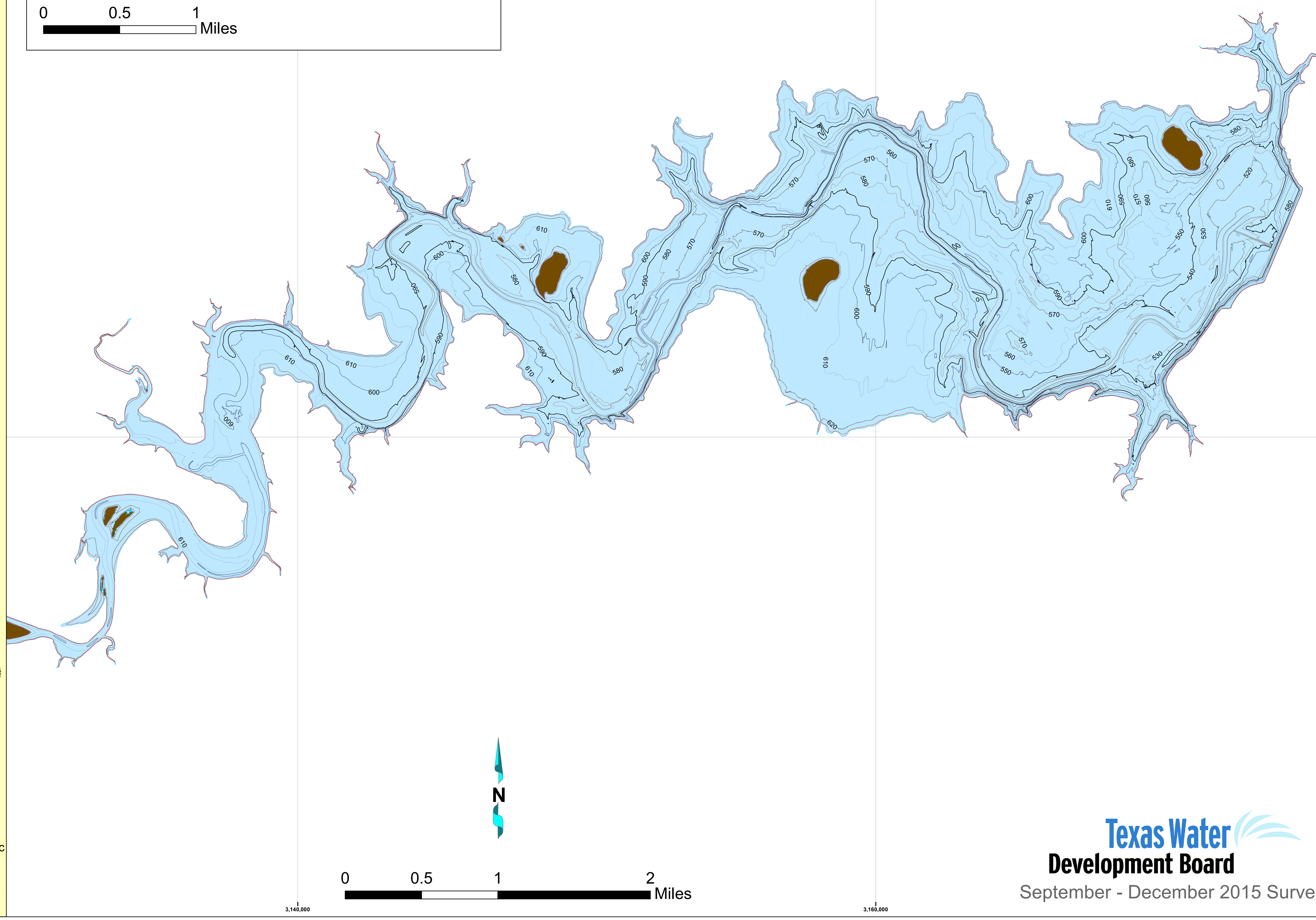


This map is the product of a survey conducted by the Texas Water Development Board's Hydrographic Survey Program to determine the capacity of Stillhouse Hollow Lake. The Texas Water Development Board makes no representations nor assumes any liability.

Stillhouse Hollow Lake

10' - contour map





Texas Water Development Board

September - December 2015 Survey