Volumetric and Sedimentation Survey of AQUILLA LAKE

July 2014 Survey

Texas Water Development Board

June 2015

Texas Water Development Board

Prepared for:

Brazos River Authority

With Support Provided by:

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

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Executive summary

In October 2011, the Texas Water Development Board (TWDB) entered into agreement with the U.S. Army Corps of Engineers, Fort Worth District, and in November 2011, entered into agreement with the Brazos River Authority, to perform a volumetric and sedimentation survey of Aquilla Lake. The Brazos River Authority provided 50% of the funding for this survey, while the U.S. Army Corps of Engineers, Fort Worth District, provided the remaining 50% of the funding through their Texas Water Allocation Assessment Program. 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.

Aquilla Dam and Aquilla Lake are located on Aquilla and Hackberry Creeks, approximately seven miles southwest of Hillsboro, in Hill County, Texas. The conservation pool elevation of Aquilla Lake is 537.5 feet above mean sea level (NGVD29). TWDB collected bathymetric data for Aquilla Lake between July 1, 2014, and July 21, 2014. The daily average water surface elevations during the survey ranged between 538.33 and 537.83 feet above mean sea level (NGVD29). Additional bathymetric data was collected on October 30, 2014, while the daily average water surface elevation measured 535.48 feet above mean sea level.

The 2014 TWDB volumetric survey indicates that Aquilla Lake has a total reservoir capacity of 43,279 acre-feet and encompasses 3,084 acres at conservation pool elevation (537.5 feet above mean sea level, NGVD29). Previous capacity estimates include the original design estimate by the U.S. Army Corps of Engineers of 52,400 acre-feet, and volumes obtained from three TWDB surveys in 1995, 2002, and 2008. All prior TWDB volumetric surveys were re-evaluated using current processing procedures resulting in updated capacity estimates of 47,152 acre-feet, 45,824 acre-feet, and 44,568 acre-feet, respectively.

Based on two methods for estimating sedimentation rates, the 2014 TWDB sedimentation survey estimates Aquilla Lake to have an average loss of capacity between 209 and 294 acre-feet per year since impoundment due to sedimentation below conservation pool elevation (537.5 feet NGVD29). Sediment accumulation is greatest in the submerged river channels and in the low lying areas of the flood plain. Three tributaries of Aquilla Creek are no longer identifiable in the current bottom surface. TWDB recommends that a similar methodology be used to resurvey Aquilla 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. Section 15.804 of the Texas Water Code authorizes TWDB to perform surveys to determine reservoir storage capacity, sedimentation levels, rates of sedimentation, and projected water supply availability.

In October 2011, the Texas Water Development Board (TWDB) entered into agreement with the U.S. Army Corps of Engineers, Fort Worth District, and in November 2011, entered into agreement with the Brazos River Authority, to perform a volumetric and sedimentation survey of Aquilla Lake. The Brazos River Authority provided 50% of the funding for this survey, while the U.S. Army Corps of Engineers, Fort Worth District, provided the remaining 50% of the funding through their Texas Water Allocation Assessment Program (TWDB, 2011a, TWDB, 2011b). 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 Brazos River Authority and the U.S. Army Corps of Engineers, Fort Worth District, and contains as 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 10], and (4) an elevation-area-capacity table of the reservoir acceptable to the Texas Commission on Environmental Quality [Appendix A, B].

Aquilla Lake general information

Aquilla Dam and Aquilla Lake are located on Aquilla and Hackberry Creeks (tributaries of the Brazos River), approximately seven miles southwest of Hillsboro, in Hill County, Texas (Figure 1). Aquilla Dam and Aquilla Lake are owned by the United States Government and operated by the U.S. Army Corps of Engineers, Fort Worth District. Construction on Aquilla Dam began on June 14, 1978, and deliberate impoundment began on April 29, 1983. Aquilla Dam was completed on May 16, 1983 (USACE, 2002, TWDB, 2009, TWDB, 2015). Aquilla Dam and Aquilla Lake were built primarily for flood control and water supply storage. Additional pertinent data about Aquilla Dam and Aquilla Lake can be found in Table 1.

Water rights for Aquilla Lake have been appropriated to the Brazos River Authority through Certificate of Adjudication No. 12-5158 and Certificate of Adjudication No. 12-

5167. The complete certificates are on file in the Information Resources Division of the Texas Commission on Environmental Quality.

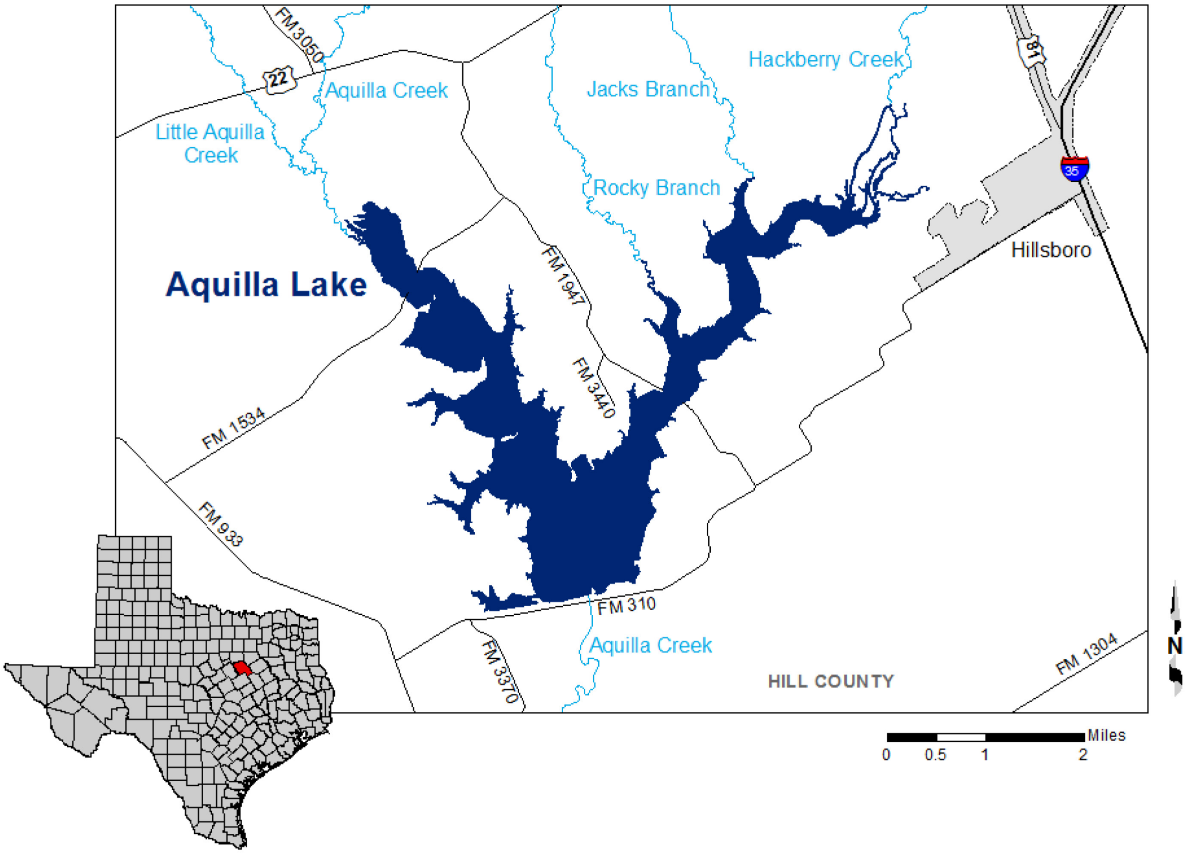


Figure 1. Location of Aquilla Lake

Table 1. Pertinent data for Aquilla Dam and Aquilla Lake

Owner
U.S. Government, operated by the U.S. Army Corps of Engineers, Fort Worth District

Engineer (design)
U.S. Army Corps of Engineers, Fort Worth District

Location of dam
At river mile 23.3 on Aquilla Creek, in the Brazos River Basin, approximately 7 miles southwest of Hillsboro and 1 mile east of Aquilla in Hill County, Texas.

Drainage area
252 square miles

Dam

Type	Rolled earthfill
Length	11,890 feet
Maximum height	104.55 feet
Top width	38 feet

Spillway

Type	Limited service
Crest elevation	564.5 feet above mean sea level
Length	1,200 feet net at crest
Control	None

Outlet works

Type	1 gate controlled conduit
Dimension	10 foot diameter
Invert elevation	503.0 feet above mean sea level
Control	2 Service and 2 Emergency 4.5 feet by 10 feet manually operated gates

Low flow outlets (discharges to flood control conduit)

Type	1-1.0 foot diameter pipe emptying into flood control conduit
Invert elevation	505.0 feet above mean sea level
Control	1.0 foot sluice gate

Reservoir data (Based on 2014 TWDB survey)

Feature	Elevation (feet NGVD29[a])	Capacity (acre-feet)	Area (acres)
Top of dam	582.5	N/A	N/A
Maximum design water surface	577.5	N/A	N/A
Spillway crest	564.5	N/A	N/A
Top of flood control pool	556.0	N/A	N/A
Top of conservation pool	537.5	43,279	3,084
Invert of outlet works/ Sediment pool	503.0	36	42
Usable conservation storage space[b]	-	43,243	-

Source: (USACE, 2002)

[a] NGVD29 = National Geodetic Vertical Datum 1929

[b] Usable conservation storage space equals total capacity at conservation pool elevation minus dead pool capacity. Dead pool refers to water that cannot be drained by gravity through a dam's outlet works.

Volumetric and sedimentation survey of Aquilla Lake

Datum

The vertical datum used during this survey is the National Geodetic Vertical Datum 1929 (NGVD29). This datum is also utilized by the United States Geological Survey (USGS) for the reservoir elevation gage *USGS 08093350 Aquilla Lk abv Aquilla, TX* (USGS, 2014). Elevations herein are reported in feet above mean sea level relative to the NGVD29 datum. Volume and area calculations in this report are referenced to water levels provided by the USGS gage. The horizontal datum used for this report is North American Datum 1983 (NAD83), and the horizontal coordinate system is State Plane Texas North Central Zone (feet).

TWDB bathymetric and sedimentation data collection

TWDB collected bathymetric data for Aquilla Lake between July 1, 2014, and July 21, 2014. The daily average water surface elevations during the survey ranged between 538.33 and 537.83 feet above mean sea level (NGVD29). Additional bathymetric data was collected on October 30, 2014, while the daily average water surface elevation measured 535.48 feet above mean sea level. For data collection, 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 were also used by TWDB during the 2008 and prior 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 where data collection occurred during the 2014 TWDB survey.

All sounding data was collected and reviewed before sediment core sampling sites were selected. Sediment core samples are 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, TWDB selected eight locations to collect sediment core samples; however, due to field conditions only seven were collected (Figure 2). The sediment core samples were collected on October 29, 2014, with a custom-coring boat and SDI VibeCore system.

Sediment cores are collected in 3-inch diameter aluminum and/or clear acrylic 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. Sediment levels in the clear acrylic tubes were measured before transport back to TWDB headquarters. During this time, some settling of the upper layer can occur.

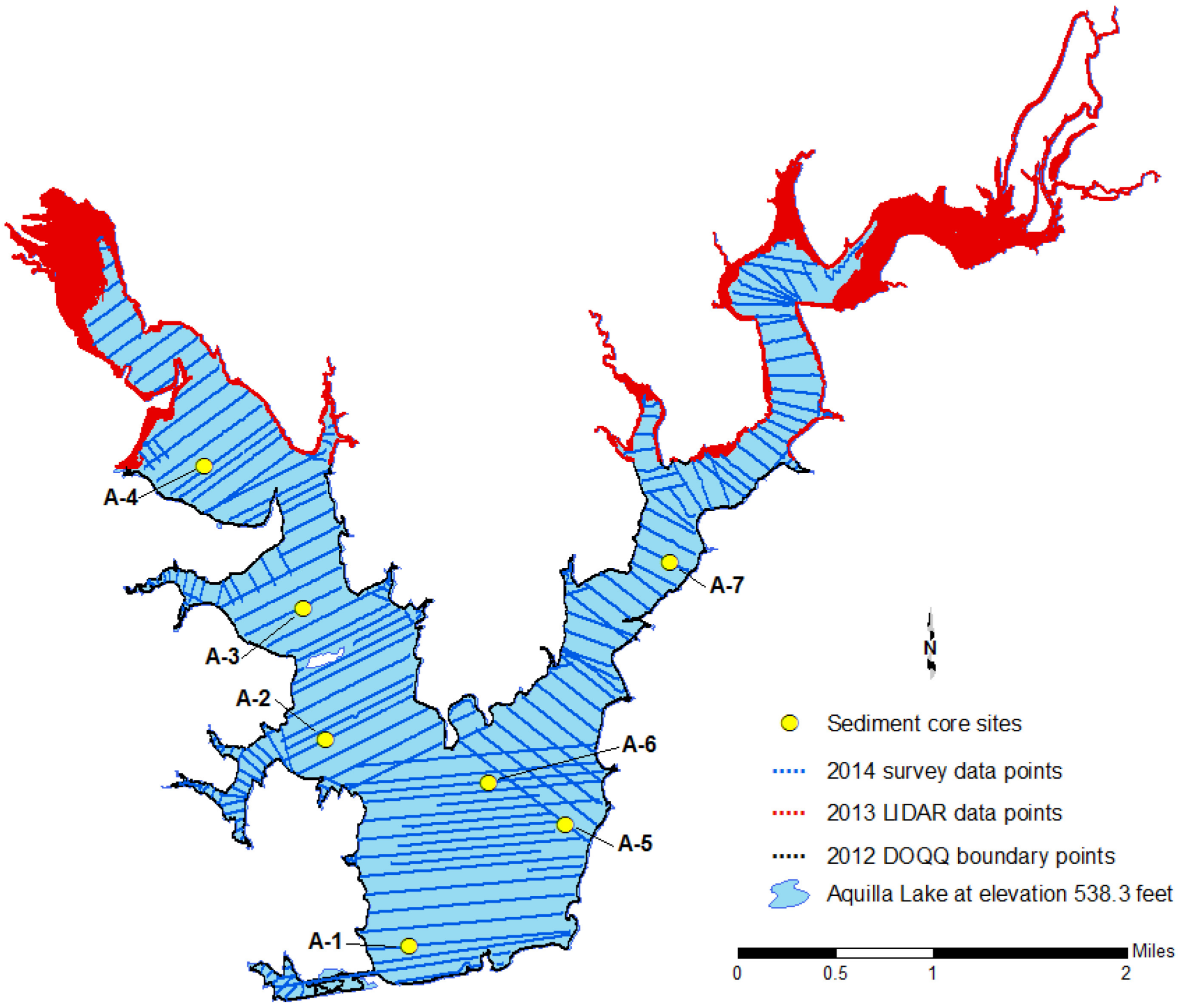


Figure 2. Data collected during 2014 TWDB Aquilla Lake survey

Data processing

Model boundaries

The reservoir boundary was digitized from aerial photographs, also known as digital orthophoto quarter-quadrangle images (DOQQs), obtained from the Texas Natural Resources Information System (TNIRIS, 2013) using Environmental Systems Research Institute's ArcGIS software. The quarter-quadrangles that cover Aquilla Lake are Peoria NW, NE, SW, and SE. The DOQQs were photographed on August 4, 2004, August 31, 2004, and December 9, 2004, while the daily average water surface elevation measured 538.31 feet, 537.90 feet, and 538.42 feet above mean sea level, respectively. According to metadata associated with the 2004 DOQQs, the photographs have a resolution or ground sample distance of 1.0 meter and a horizontal accuracy within ± 5 meters of reference

DOQQs from the National Digital Ortho Program (TNRIS, 2014, USDA, 2013). For this analysis, the boundary was digitized at the land-water interface in the 2004 photographs and assigned an elevation of 538.30 feet. In the upper reaches LIDAR data was used to define the reservoir boundary.

Additional boundary information was obtained from aerial photographs taken on July 25, 2012, and July 28, 2012, while the daily average water surface elevation measured 536.29 and 536.20 feet, respectively. The 2012 boundary information was added to the lake model as points. According to metadata associated with the 2012 DOQQs, the photographs have a resolution or ground sample distance of 1.0-meters and a horizontal accuracy within ± 6 meters to true ground (TNRIS, 2012, USDA, 2013).

LIDAR

Light Detection and Ranging Data is available from the Texas Natural Resource Information System (TNRIS, 2014). LIDAR for Hill County was collected between February 7, 2013, and March 6, 2013. The daily average water surface elevation of the reservoir during this period varied between 533.85 feet and 533.54 feet above mean sea level. The LIDAR data was used to generate a boundary for the upper reaches of the reservoir at elevation 538.30 feet and to add additional LIDAR points within the boundary. The LIDAR boundary and boundary digitized from the 2004 DOQQs were combined to make a complete boundary. To generate the LIDAR boundary, LIDAR data with a classification equal to 2, or ground, was imported into an ArcGIS file geodatabase from *.las files. A topographical model of the data was generated and converted to a raster using a cell size of 1 meter by 1 meter. The horizontal datum of the LIDAR data is Universal Transverse Mercator (UTM) North American Datum 1983 (NAD83) Zone 14 and the vertical datum is North American Vertical Datum 1988 (NAVD88). According to the associated metadata, the LIDAR data has a vertical accuracy of 6.718 centimeters.

To make the LIDAR data compatible with the bathymetric survey data, it was necessary to transform the LIDAR data to NGVD29 (vertical) and NAD83 State Plane Texas North Central (horizontal) coordinates. Horizontal coordinate transformations were done using the ArcGIS Project tool. Vertical coordinate transformations were done by applying a single vertical offset to all LIDAR data. The offset was determined by applying the National Oceanic and Atmospheric Administration National Geodetic Survey's NADCON software (NGS, 2013a) and VERTCON software (NGS, 2013b) to a single reference point in the vicinity of the survey, the reservoir elevation gage *USGS 08093350 Aquilla Lk abv Aquilla, TX, of Latitude 31º53'59", Longitude 97º12'09" NAD27.* The resulting conversion factor of 0.043 meters was subtracted from all LIDAR data elevations to obtain the transformed vertical elevations.

To reduce computational burden, the LIDAR data was filtered to include only every 20th point before clipping to include only data points within the reservoir boundary. The LIDAR data points have an average spacing of 0.5 meters; therefore, using a thinned point dataset did not significantly affect the modeled topography of the coverage area. No interpolation of the data in the areas of LIDAR coverage was necessary, however, linear interpolation was necessary to better define the river channels which had water in them during the time the LIDAR was collected. After the points were clipped to within the boundary, the shapefile was projected to NAD83 State Plane Texas North Central Zone (feet), and new attribute fields were added to first convert the elevations from meters NAVD88 to meters NGVD29, then to feet NGVD29.

Triangulated Irregular Network model

Following completion of data collection, the raw data files collected by TWDB were edited to remove data anomalies. 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 processing outside of DepthPic©, an in-house software package, HydroTools, was used to identify the current reservoir-bottom surface, pre-impoundment surface, sediment thickness at each sounding location, and output the data into a single file. 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 et al., 2014a). Finally, the point file resulting from spatial interpolation was 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 (ESRI, 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 bathymetries 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, 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 the reservoir bathymetry and sediment accumulation throughout the reservoir. Specific details of this interpolation technique can be found in the HydroTools manual (McEwen et al., 2014a) and in McEwen et al., 2014b.

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. The linear interpolation follows a linear definition file linking the survey points file to the lake boundary file (McEwen et al., 2014a). 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. It is not always possible to remove all flat triangles, and linear interpolation is only applied where adding bathymetry is deemed reasonable. For example, linear interpolation was applied throughout Aquilla Lake following channel features indicated by the 2008 TWDB survey or visible in aerial photographs taken on July 25 and July 28, 2012.

Figure 3 illustrates typical results from application of the anisotropic interpolation and linear interpolation techniques to Aquilla Lake. In Figure 3A, deeper channels 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 capacity and area tables (Appendix A, B).

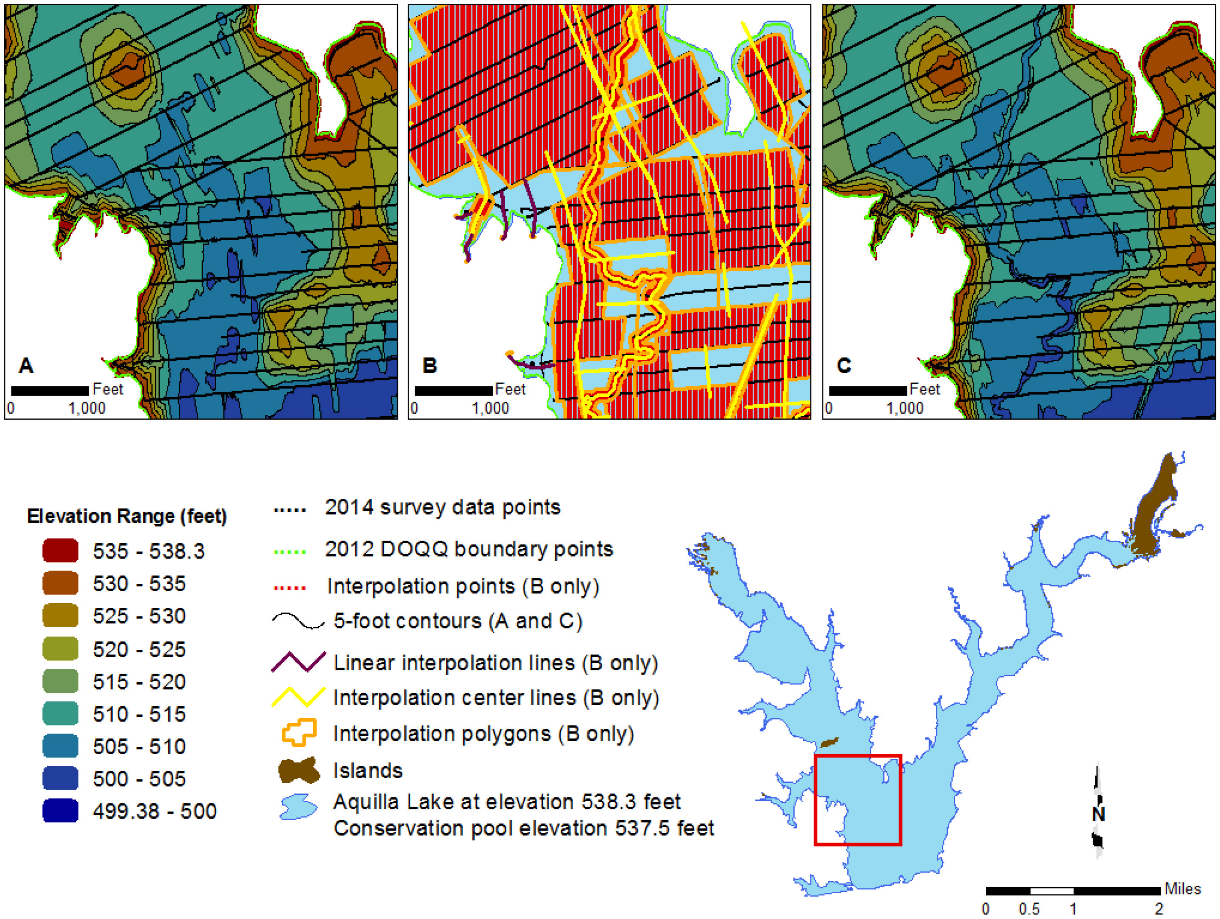


Figure 3. **Anisotropic spatial interpolation and linear interpolation of Aquilla Lake sounding data - A) bathymetric contours without interpolated points, B) sounding points (black) and interpolated points (red), C) bathymetric contours with the interpolated points**

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 499.3 to 538.3 feet. While linear interpolation was used to estimate the topography in areas that were inaccessible by boat or too shallow for the instruments to work properly, development of anomalous "flat triangles", that is triangles whose three 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 2012 contour elevation 536.2 feet. To eliminate the effects of the flat triangles on area and volume calculations, areas between elevations 536.0 feet and 536.5feet were linearly interpolated between the computed values, and volumes above elevation 536.0 feet were calculated based on the corrected areas. The elevation-capacity table and elevation-area table, updated for 2014, 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 1 foot by 1 foot. The raster data was then used to produce: an elevation relief map (Figure 4), representing the topography of the reservoir bottom; a depth range map (Figure 5), showing shaded depth ranges for Aquilla Lake; and a 5-foot contour map (Figure 6 - attached).

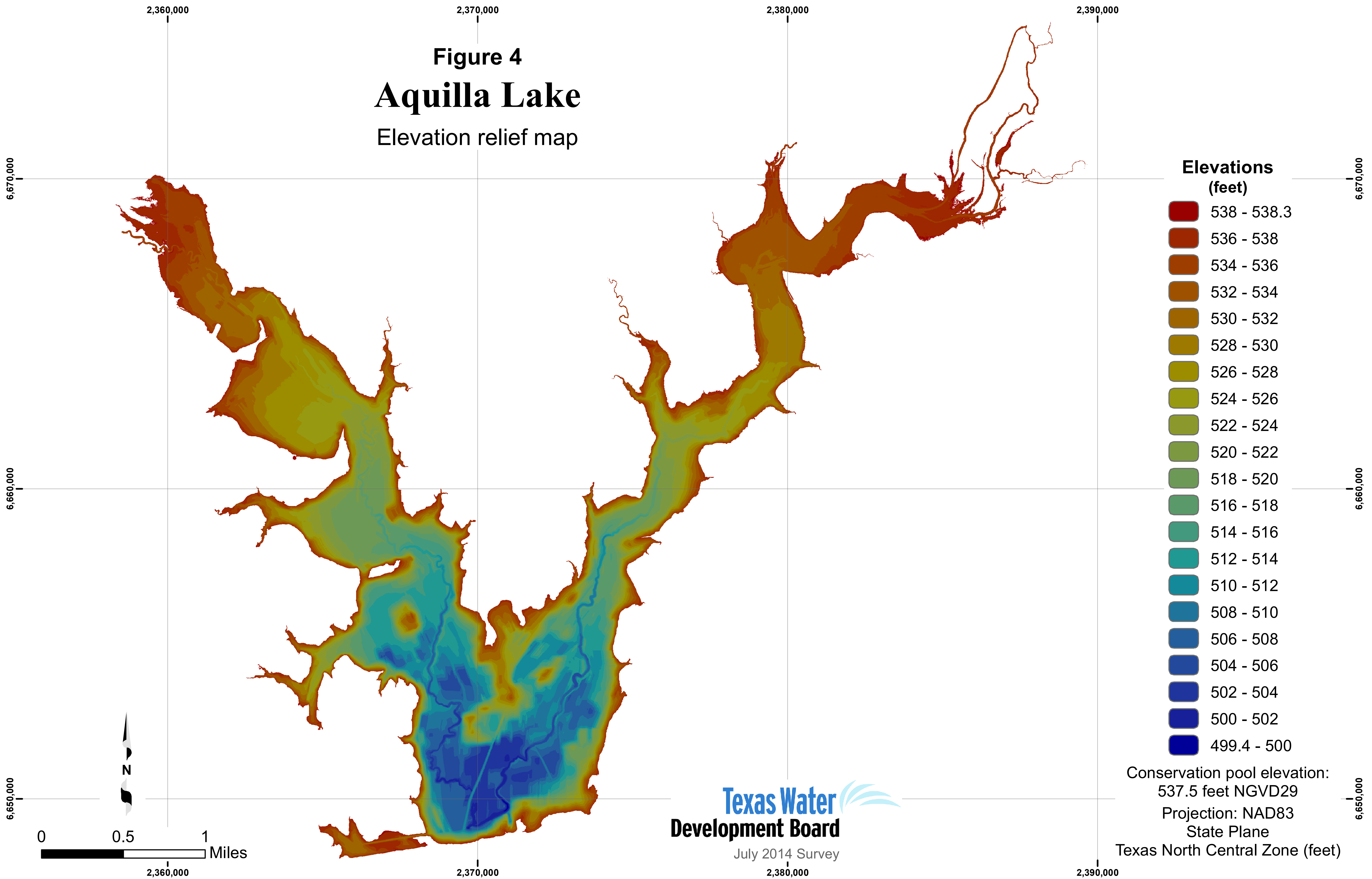


Figure 4
Aquilla Lake
Elevation relief map
2,360,000
2,370,000
2,380,000
2,390,000
6,670,000
6,660,000
6,650,000
Elevations
(feet)
538 - 538.3
536 - 538
534 - 536
532 - 534
530 - 532
528 - 530
526 - 528
524 - 526
522 - 524
520 - 522
518 - 520
516 - 518
514 - 516
512 - 514
510 - 512
508 - 510
506 - 508
504 - 506
502 - 504
500 - 502
499.4 - 500
Conservation pool elevation:
537.5 feet NGVD29
Projection: NAD83
State Plane
Texas North Central Zone (feet)
N
0
0.5
1
Miles
Texas Water
Development Board
July 2014 Survey

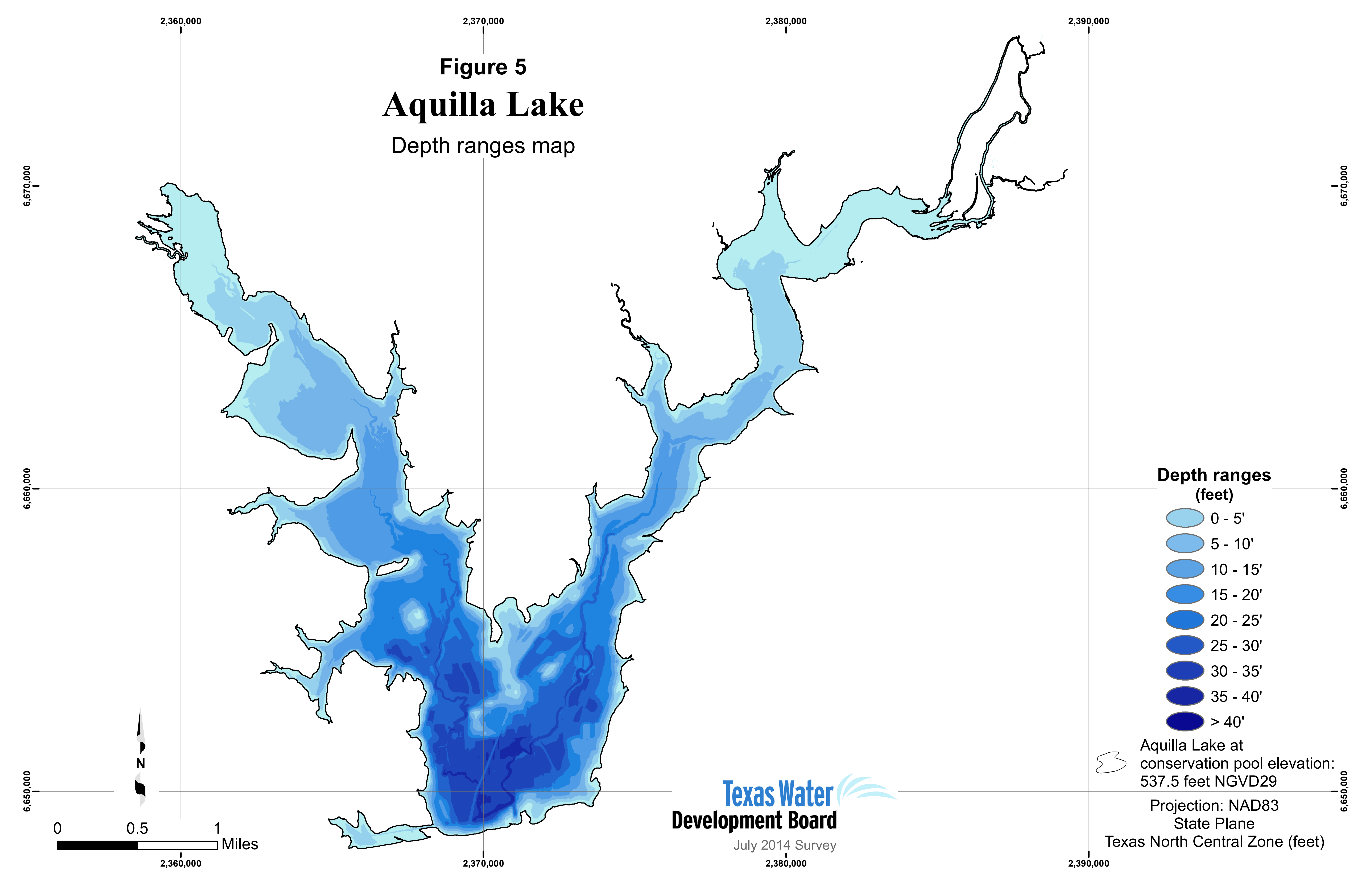


Figure 5
Aquilla Lake
Depth ranges map
2,360,000
2,370,000
2,380,000
2,390,000
6,670,000
6,660,000
6,650,000
Depth ranges
(feet)
0 - 5'
5 - 10'
10 - 15'
15 - 20'
20 - 25'
25 - 30'
30 - 35'
35 - 40'
> 40'
Aquilla Lake at conservation pool elevation: 537.5 feet NGVD29
Projection: NAD83
State Plane
Texas North Central Zone (feet)
Texas Water Development Board
July 2014 Survey
N
0
0.5
1
Miles

Analysis of sediment data from Aquilla Lake

Sedimentation in Aquilla Lake was determined by analyzing the acoustic signal returns of all three depth sounder frequencies in the DepthPic© software. The 208 kHz signal was analyzed to determine the current bathymetric surface of the reservoir, while all three frequencies, 208 kHz, 50 kHz, and 24 kHz, were 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 were used to assist in identifying the location of the pre-impoundment surface in the acoustic signals. The difference between the current surface and the pre-impoundment surface yields a sediment thickness value at each sounding location.

Analysis of the 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 et al., 2004). The total sample length, sediment thickness, and the pre-impoundment thickness were recorded. Physical characteristics of the sediment core, including Munsell soil color, texture, relative water content, and presence of organic materials, were also recorded (Table 2).

Table 2. Sediment core sampling analysis data - Aquilla Lake

Core	Easting[a] (ft)	Northing[a] (ft)	Total core sample/ post-impoundment sediment	Sediment core description	Munsell soil color
AQ-1	2369246.81	6649570.87	69"/ 59.5"	0-5.5" water and fluff	5Y 3/1
				5.5-17.0" high water content, loam	5Y 2.5/1
				17.0-31.0" slightly lower water content, loam	5Y 2.5/1
				31.0-49.0" lower water content, higher density, loam	5Y 2.5/1
				49.0-59.5" higher density, loam	GLEY1 2.5/N
				59.5-69.0" low water content, high density, thin layer of organics at top of layer, sandy clay loam	2.5Y 3/2
AQ-2	2366967.81	6655180.70	25"/12.5"	0-2.5" high water content, silty loam	5Y 2.5/1
				2.5-12.5" medium density, silty loam	5Y 2.5/1
				12.5-16.0" higher density, organics at top 1" of layer, silty clay loam	5Y 3/1
				16.0-25.0" high density, clay loam	5Y 3/2
AQ-3	2366383.47	6658740.62	0.25"/N/A"	0-0.25" fluff	5Y 4/2
AQ-4	2363696.91	6662618.57	16.25"/2.0"	0-2.0" low density, thin layer of fluff on top, silty loam	5Y 2.5/1
				2.0-9.0" higher density, thin layer of organics at top of layer, loam	5Y 4/2
				9.0-16.25" low water content, high density, loam	5Y 4/2
AQ-5	2373488.99	6652882.48	53.5"/50.0"	0-4.0" water and fluff	N/A
				4.0-18.75" high water content, low density, silty loam	5Y 3/1
				18.75-44.0" lower water content, silty loam	2.5Y 2.5/1
				44.0-50.0" higher density, silty loam	5Y 3/1
				50.0-53.5" highly dense, organics present – roots, clay	2.5Y 4/2
AQ-6	2371406.44	6653991.85	48.5"/46.5"	0-21.0" low density, silty loam	5Y 2.5/1
				21.0-32.5" higher density, silty loam	5Y 2.5/1
				32.5-41.0" lower water content, higher density, sandy loam	5Y 5/4
				41.0-46.5" lower water content, higher density, silty clay loam	5Y 3/1
				46.5-48.5" low water content, higher density, clay loam	5Y 5/4
AQ-7	2376339.63	6659986.92	12.0"/2.0"	0-2.0" high water content, silty loam	5Y 3/1
				2.0-12.0" higher density, clay loam	5Y 4/1

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

A photograph of sediment core AQ-5 is shown in Figure 7 and is representative of the sediment cores sampled from Aquilla Lake. The 208 kHz frequency measures the top layer as the current bottom surface of the reservoir. The base of the sample is denoted by the blue line. The pre-impoundment boundary (yellow line) was evident within this sediment core sample at 50.0 inches and identified by the change in color, texture, moisture, porosity, and structure. Identification of the pre-impoundment surface for the remaining sediment cores followed a similar procedure.

Figure 7. Sediment core AQ-5 from Aquilla Lake

Figures 8 and 9 illustrate how measurements from sediment core samples are used with sonar data to help identify the interface between the post- and pre-impoundment layers in the acoustic signal. Within DepthPic©, the current surface is automatically determined based on signal returns from the 208 kHz transducer and verified by TWDB staff, while the pre-impoundment surface must be determined visually. The pre-impoundment surface is first identified along cross-sections for which sediment core samples have been collected.

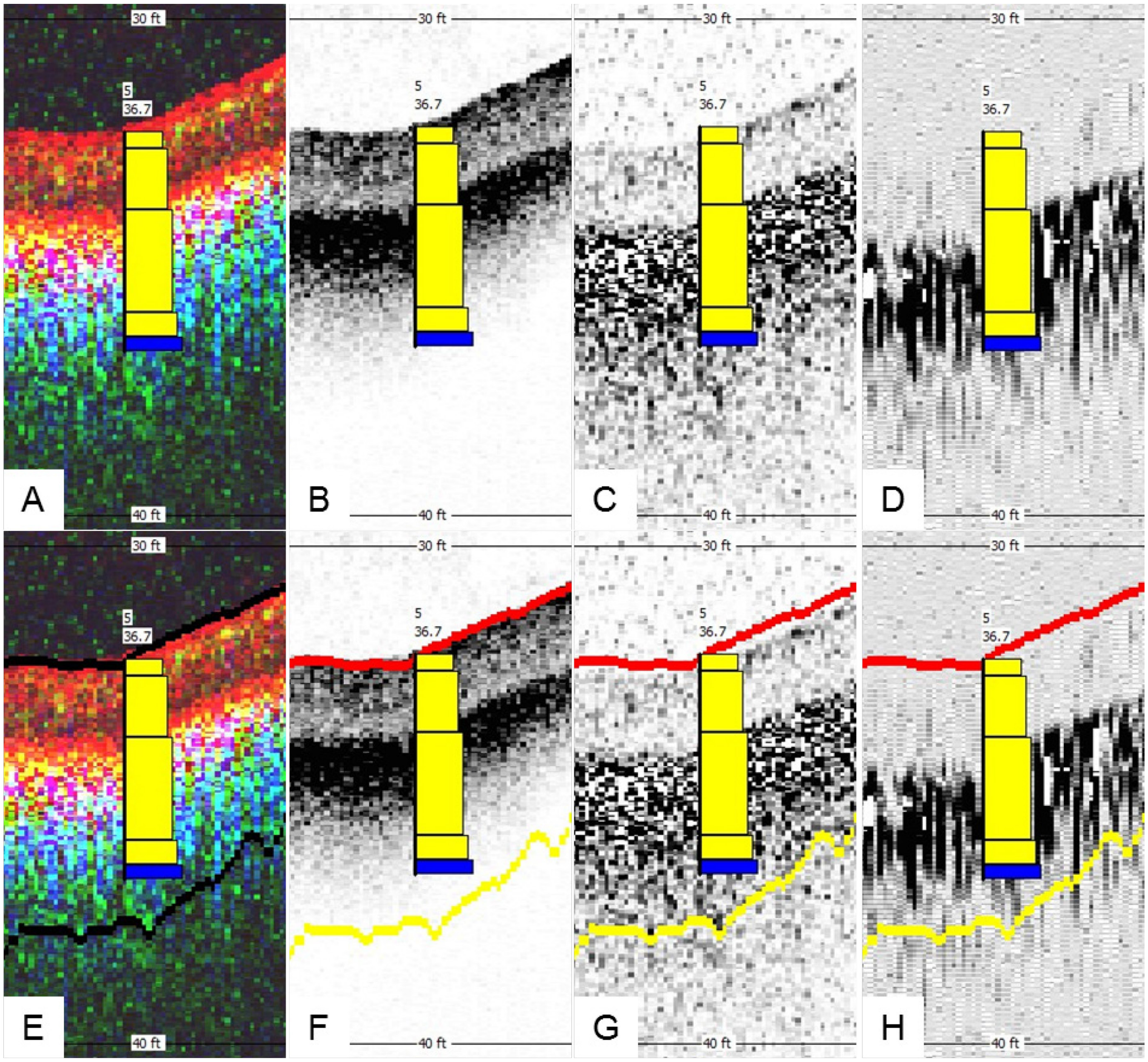


Figure 8. Comparison of sediment core AQ-5 with acoustic signal returns: A,E) combined acoustic signal returns, B,F) 208 kHz frequency, C,G) 50 kHz frequency, D,H) 24 kHz frequency

Figure 8 compares sediment core sample AQ-5 with the acoustic signals for all frequencies combined (A, E), 208 kHz (B, F), 50 kHz (C, G), and 24 kHz (D, H). The sediment core sample is represented in each figure as colored boxes. The yellow boxes represent post-impoundment sediment, and the blue box represents the pre-impoundment sediment. In Figure 8A-D, the bathymetric surfaces are not shown. In Figure 8E, the current bathymetric surface is represented as the top black line and in Figures 8 F-H as the top red line. 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 of the sediment core sample. Each sediment core sample was compared to all three frequencies and the boundary in the 50 kHz signal most closely matched the pre-impoundment interface of the sediment core samples; therefore, the 50 kHz signal was used to locate the pre-impoundment layer. The pre-impoundment surface was manually drawn and is represented by the bottom black line in Figure 8E, and by the yellow line in Figures 8F-H. Figure 9 shows sediment core sample AQ-5 correlated with the 50 kHz frequency of the nearest surveyed cross-section. The pre-impoundment surface identified along cross-sections where sediment core samples were collected is used as a guide for identifying the pre-impoundment surface along cross-sections where sediment core samples were not collected.

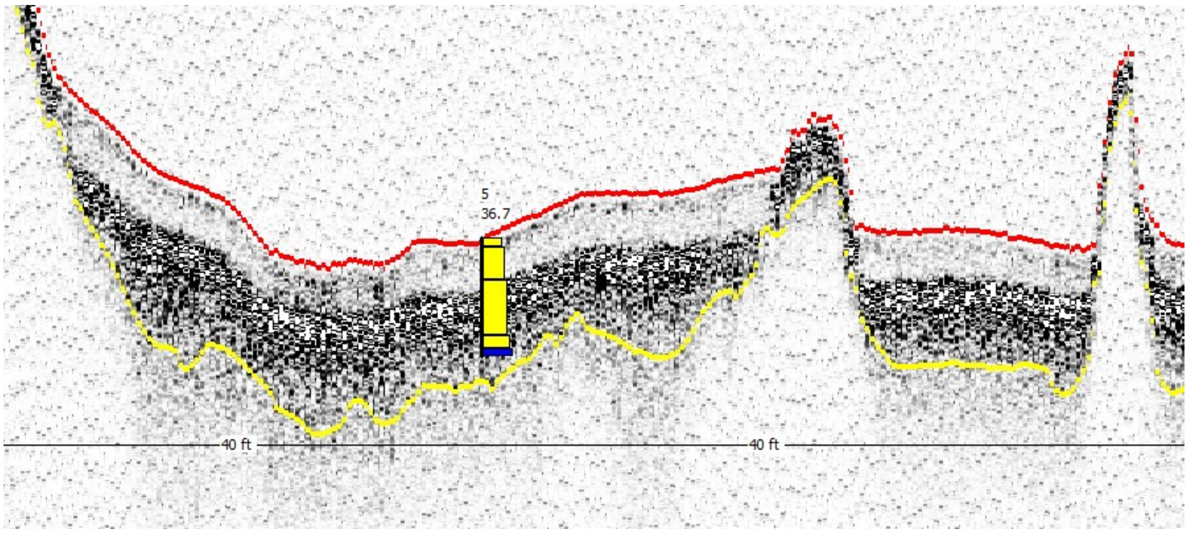
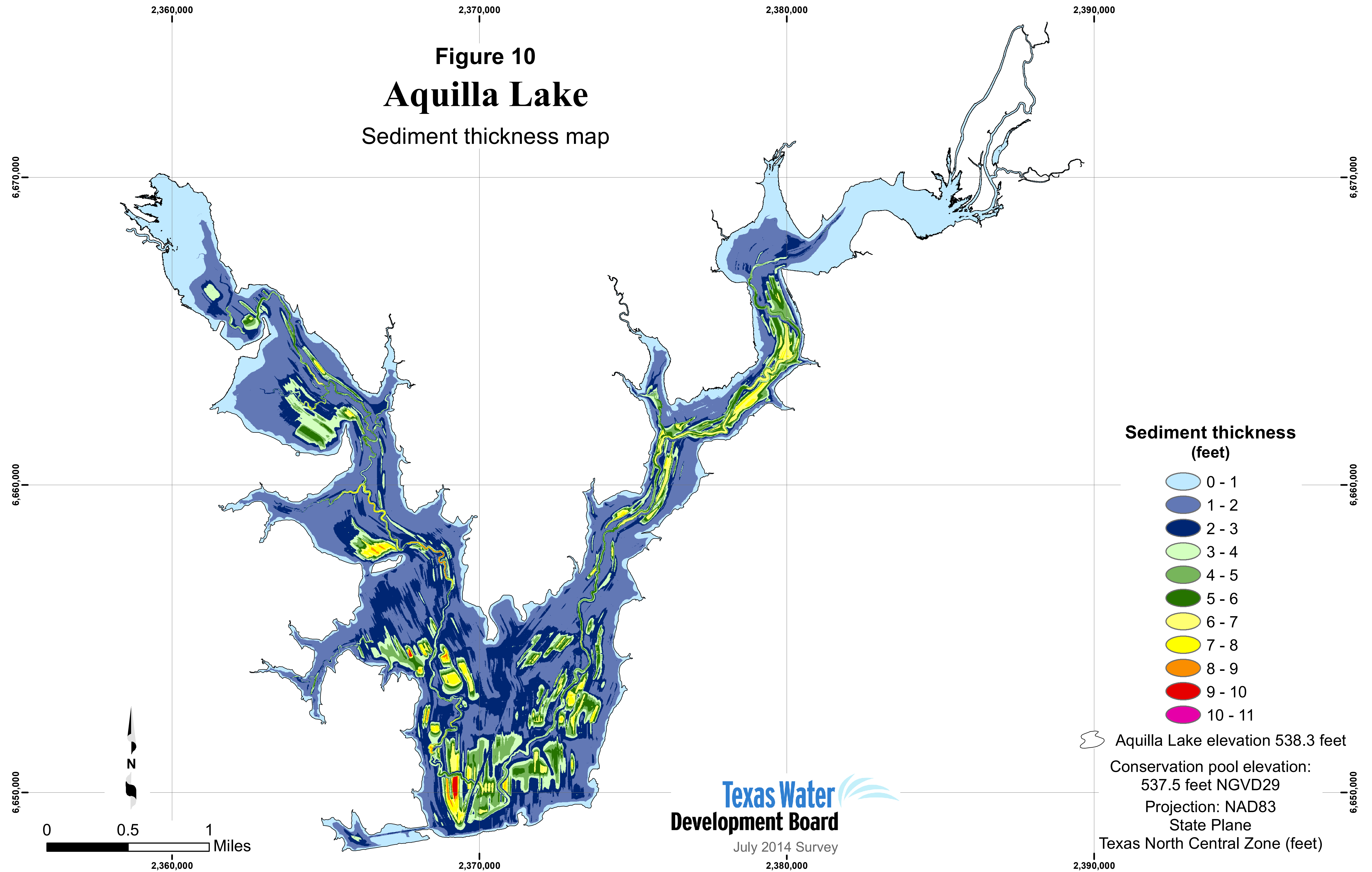


Figure 9. Cross-section of data collected during survey, displayed in DepthPic© (50 kHz frequency), correlated with sediment core sample AQ-5 and showing the current surface in red and pre-impoundment surface in yellow

After the pre-impoundment surface from all cross-sections is identified, a sediment thickness TIN model is created following standard GIS techniques (Furnans, 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 the TIN model creation, TWDB assumed sediment thickness at the reservoir boundary was zero feet (defined as the 538.30 foot NGVD29 elevation contour). The sediment thickness at each LIDAR point and 2012 DOQQ boundary point was also assumed to be zero. The sediment thickness TIN model was converted to a raster representation using a cell size of 1 foot by 1 foot and used to produce a sediment thickness map of Aquilla Lake (Figure 10).

Figure 10
Aquilla Lake
Sediment thickness map



Survey results

Volumetric survey

The results of the 2014 TWDB volumetric survey indicate Aquilla Lake has a total reservoir capacity of 43,279 acre-feet and encompasses 3,084 acres at conservation pool elevation (537.5 feet above mean sea level, NGVD29). The original design estimate by the U.S. Army Corps of Engineers indicates Aquilla Lake encompassed 3,280 acres with a total reservoir capacity of 52,400 acre-feet. Because of differences in past and present survey methodologies, direct comparison of volumetric surveys to estimate loss of capacity is difficult and can be unreliable.

To properly compare results from TWDB surveys of Aquilla Lake, TWDB applied the 2014 data processing techniques to the survey data collected in 1995, 2002, and 2008. Specifically, TWDB applied anisotropic spatial interpolation to the survey data collected in 1995, 2002, and 2008 using the same interpolation definition file as was used for the 2014 survey, with minor edits to account for differences in data coverage and boundary conditions. The 1995 survey boundary came from 1:100,000 scale 1990 Census TIGER line files. 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 537.5 feet. Therefore, areas between 533.0 feet and 537.5 feet were linearly interpolated between the computed values, and volumes above 533.0 feet were calculated based on the corrected areas. The 2002 survey boundary was digitized from aerial photographs taken on January 31, 1995, while the water surface elevation of the reservoir measured 537.87 feet above mean sea level. The boundary was assigned an elevation of 537.9 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. The 2008 survey boundary was digitized from aerial photographs taken on March 21, 2008, while the water surface elevation of the reservoir measured 542.1 feet above mean sea level. However, due to the difficulty in identifying the land-water interface from the photos at this elevation, LIDAR data in the upper reaches was used to update this boundary to use a combination of the digitized shoreline and LIDAR contour. LIDAR points below elevation 542.1 feet were also added to the model, see the section titled “LIDAR”. Additionally, select sections of the boundaries digitized from aerial photographs dated August 4, 2004, August 31, 2004, and December 9, 2004, while the daily average water surface elevation measured 538.31 feet, 537.90 feet, and 538.42 feet, respectively, and August 19, 2006, while the daily average water surface elevation measured 531.34 feet, were added to the TIN model as hard lines. The 2008 recalculated elevation-capacity table and elevation-area table are presented in Appendices E and F, respectively. The capacity curve is presented in Appendix G, and the area curve is presented in Appendix H. Re-evaluation of the 1995, 2002, and 2008 surveys resulted in a 2.6 percent, 1.1 percent and 0.004 percent increase, respectively, in total capacity estimates at conservation pool elevation 537.5 feet (Table 3). Re-evaluation of the 2008 survey at elevation 542.1 feet resulted in a total capacity estimate of 60,665 acre-feet encompassing 3,933 acres, a 1.1 percent increase in capacity and a 7.8 percent increase in area from the original 2008 estimate.

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

Survey	Surface area (acres)	Total capacity (acre-feet)
Original[a]	3,280	52,400
TWDB 1995[b]	3,266	45,962
TWDB 1995 (re-calculated)	3,266	47,152
TWDB 2002[c]	3,020	45,319
TWDB 2002 (re-calculated)	3,056	45,824
TWDB 2008[d]	3,066	44,566
TWDB 2008 (re-calculated)	3,098	44,568
TWDB 2014	3,084	43,279

[a] Source: (USACE, 2002)
[b] Source: (TWDB, 2003a)
[c] Source: (TWDB, 2003b)
[d] Source: (TWDB, 2009)

Sedimentation survey

Based on two methods for estimating sedimentation rates, the 2014 TWDB sedimentation survey estimates Aquilla Lake to have an average loss of capacity between 209 and 294 acre-feet per year since impoundment due to sedimentation below conservation pool elevation (537.5 feet NGVD29). The sedimentation survey indicates sediment accumulation varies throughout the reservoir. Sediment accumulation is greatest in the submerged river channels and in the low lying areas of the flood plain. Three tributaries of Aquilla Creek are no longer identifiable in the current bottom surface. Comparison of capacity estimates of Aquilla Lake derived using differing methodologies are provided in Table 4 for sedimentation rate calculation.

Original design information (USACE, 2015) for Aquilla Lake indicates 18,800 acre-feet of the total capacity of the reservoir below elevation 537.5 feet was designated as sediment reserve. With an estimated design life for the sediment reserve of 100 years, the sediment reserve of 18,800 acre-feet would be depleted at an average sedimentation rate of 188 acre-feet per year. Based on the sedimentation rates estimated from this study (Table 4), the sediment reserve in Aquilla Lake could be depleted as early as 2047.

Table 4. Capacity loss comparisons for Aquilla Lake

Survey	Volume comparisons at conservation pool elevation (acre-feet)				Pre-impoundment (acre-feet)
Original design[a]	52,400	<>	<>	<>	<>
TWDB 1995 (re-calculated)	<>	47,152	<>	<>	
TWDB 2002 (re-calculated)	<>	<>	45,824	<>	<>
TWDB 2008 (re-calculated)	<>	<>	<>	44,568	<>
TWDB pre-impoundment estimate based on 2014 survey	<>	<>	<>	<>	49,760[b]
2014 volumetric survey	43,279	43,279	43,279	43,279	43,279
Volume difference (acre-feet)	9,121 (17.4%)	3,873 (8.2%)	2,545 (5.6%)	1,289 (2.9%)	6,481 (13.0%)
Number of years	31	19	12	6	31
Capacity loss rate (acre-feet/year)	294	204	212	215	209

[a] Source: (USACE, 2002), note: Deliberate impoundment began on April 29,1983 and Aquilla Dam was completed on May 16, 1983.
[b] 2014 TWDB surveyed capacity of 43,279 acre-feet plus 2014 TWDB surveyed sediment volume of 6,481 acre-feet

Recommendations

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

TWDB contact information

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

http://www.twdb.texas.gov/surfacewater/surveys/index.asp

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Appendix A

Aquilla Lake

RESERVOIR CAPACITY TABLE

TEXAS WATER DEVELOPMENT BOARD — July 2014 Survey

CAPACITY IN ACRE-FEET — Conservation Pool Elevation 537.5 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
499	0	0	0	0	0	0	0	0	0	0
500	0	0	0	0	0	1	1	1	1	2
501	2	3	3	4	5	5	6	7	8	9
502	10	11	13	14	16	19	21	25	28	32
503	36	40	45	50	55	60	66	72	79	85
504	93	100	108	116	125	134	143	152	162	172
505	182	193	205	216	228	241	254	268	282	297
506	311	327	343	359	376	393	412	430	450	470
507	490	512	533	556	579	603	627	652	677	703
508	730	757	785	813	842	871	901	932	963	995
509	1,027	1,060	1,094	1,128	1,163	1,199	1,234	1,271	1,308	1,346
510	1,385	1,424	1,464	1,504	1,545	1,587	1,629	1,672	1,715	1,760
511	1,804	1,850	1,896	1,943	1,991	2,039	2,088	2,137	2,187	2,238
512	2,289	2,341	2,393	2,446	2,499	2,553	2,608	2,663	2,719	2,776
513	2,834	2,892	2,952	3,012	3,074	3,137	3,200	3,265	3,330	3,396
514	3,463	3,531	3,600	3,669	3,739	3,810	3,881	3,953	4,026	4,099
515	4,173	4,247	4,322	4,398	4,475	4,552	4,630	4,708	4,788	4,868
516	4,949	5,030	5,112	5,195	5,278	5,362	5,447	5,532	5,618	5,704
517	5,791	5,879	5,968	6,057	6,147	6,238	6,329	6,421	6,513	6,607
518	6,700	6,795	6,891	6,987	7,085	7,183	7,283	7,383	7,485	7,587
519	7,691	7,795	7,900	8,006	8,113	8,221	8,330	8,440	8,550	8,661
520	8,773	8,885	8,999	9,113	9,228	9,344	9,460	9,577	9,695	9,814
521	9,934	10,054	10,175	10,297	10,419	10,542	10,666	10,790	10,916	11,041
522	11,168	11,295	11,424	11,553	11,682	11,813	11,943	12,075	12,208	12,341
523	12,475	12,609	12,744	12,880	13,016	13,154	13,292	13,430	13,570	13,710
524	13,852	13,994	14,136	14,280	14,424	14,569	14,715	14,862	15,010	15,158
525	15,308	15,458	15,610	15,762	15,915	16,070	16,225	16,382	16,539	16,697
526	16,857	17,017	17,179	17,343	17,508	17,674	17,841	18,010	18,180	18,350
527	18,522	18,695	18,869	19,043	19,219	19,395	19,573	19,752	19,932	20,112
528	20,294	20,477	20,661	20,846	21,032	21,219	21,408	21,598	21,789	21,981
529	22,175	22,370	22,567	22,764	22,962	23,161	23,361	23,562	23,764	23,967
530	24,171	24,376	24,582	24,790	24,999	25,209	25,420	25,632	25,845	26,059
531	26,274	26,491	26,709	26,928	27,148	27,370	27,593	27,817	28,042	28,269
532	28,497	28,726	28,957	29,189	29,422	29,655	29,891	30,127	30,365	30,605
533	30,846	31,089	31,333	31,578	31,825	32,073	32,323	32,575	32,827	33,082
534	33,338	33,597	33,857	34,118	34,381	34,645	34,911	35,178	35,446	35,716
535	35,987	36,260	36,534	36,809	37,087	37,365	37,645	37,928	38,212	38,499
536	38,787	39,077	39,368	39,661	39,956	40,252	40,549	40,848	41,148	41,449
537	41,751	42,054	42,358	42,664	42,971	43,279	43,588	43,898	44,209	44,522
538	44,835	45,150	45,466	45,784						

Note: Capacities above elevation 536.0 feet calculated from areas

Appendix B

Aquilla Lake

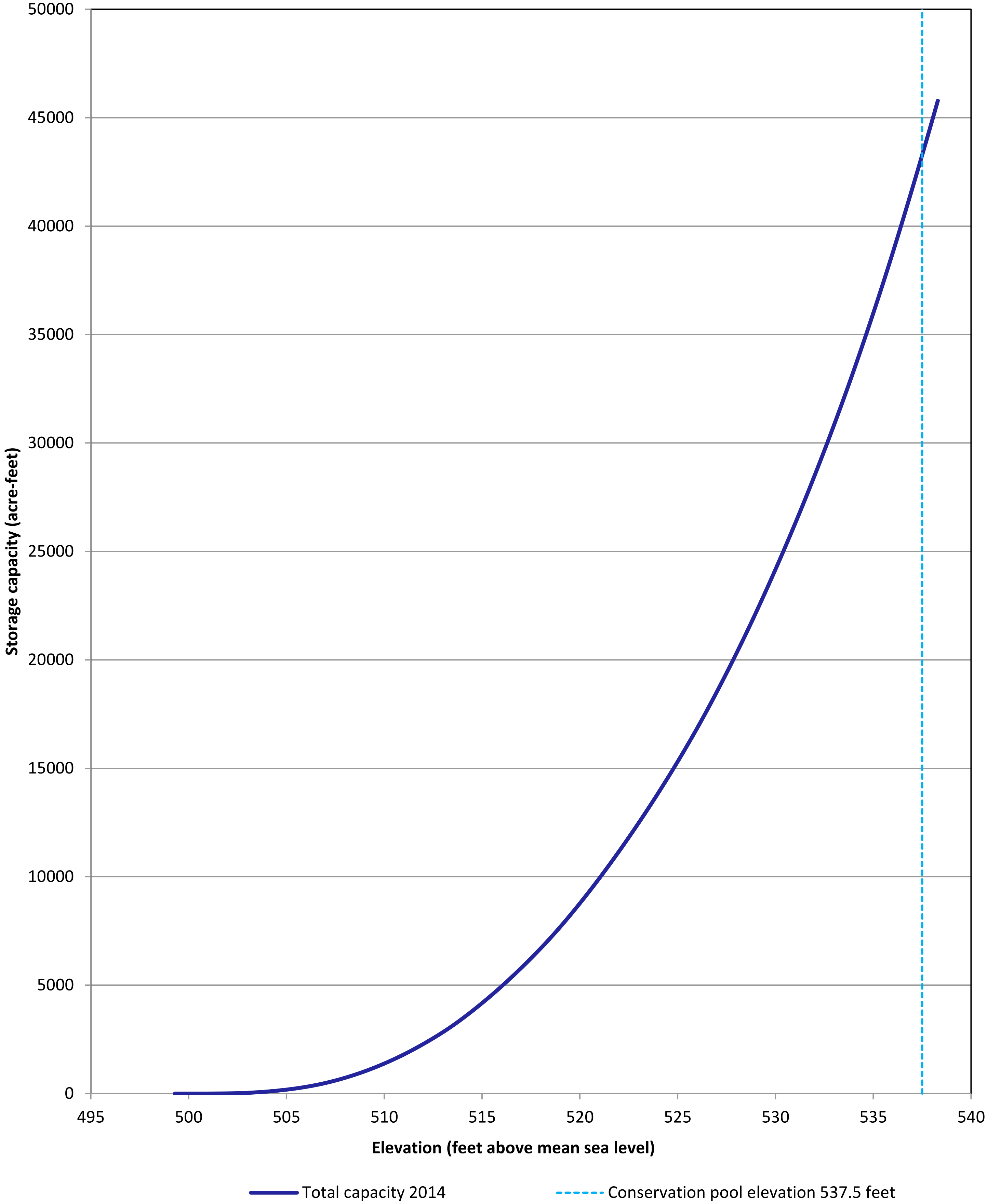
RESERVOIR AREA TABLE

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

July 2014 Survey
Conservation Pool Elevation 537.5 feet NGVD29

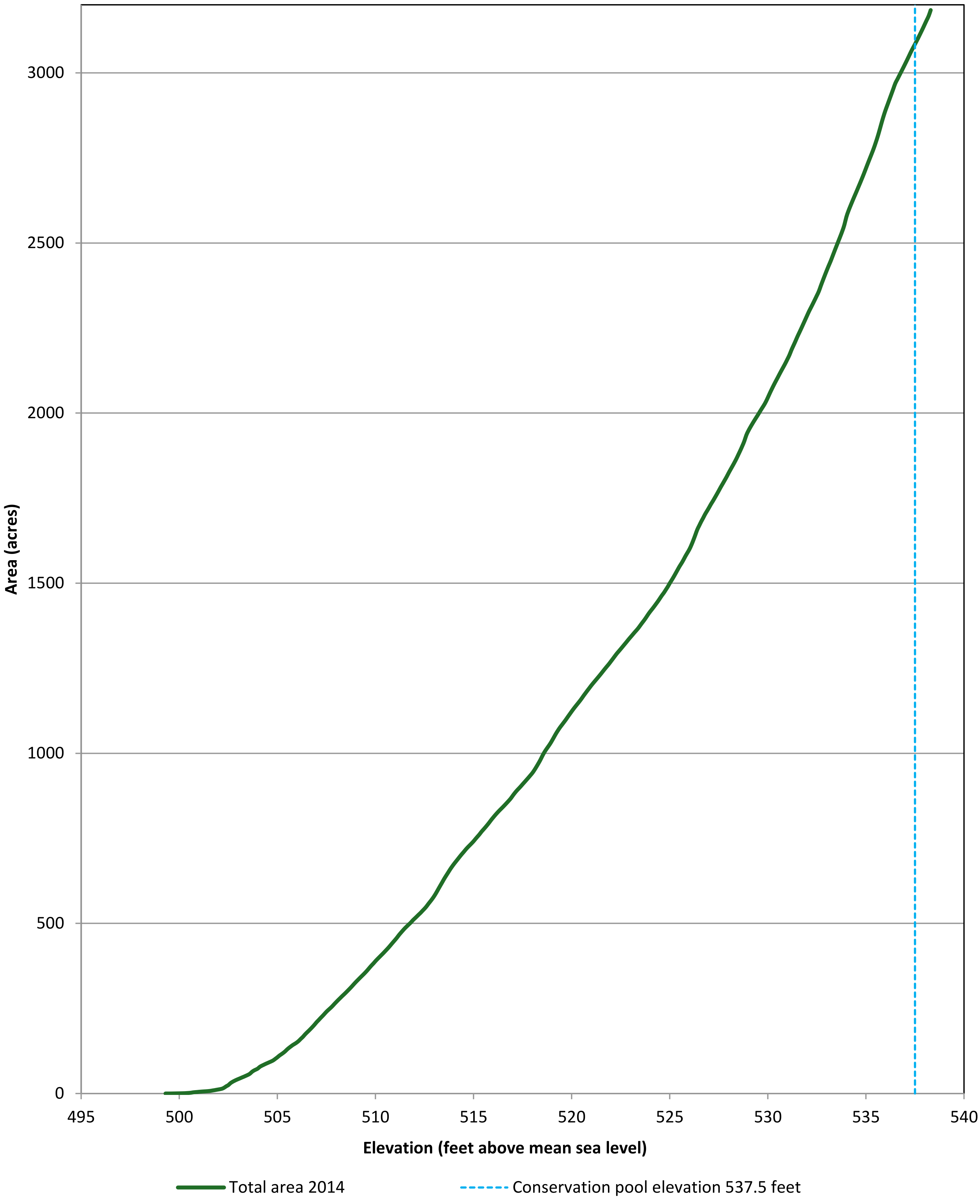
ELEVATION in Feet	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
499	0	0	0	0	0	0	0	0	0	0
500	1	1	1	1	1	2	2	3	4	4
501	5	5	6	6	7	7	8	9	10	11
502	12	13	15	18	21	25	30	34	37	40
503	42	45	47	50	52	55	58	63	67	70
504	73	78	81	84	87	90	92	95	98	102
505	106	111	115	119	124	130	135	139	143	147
506	150	155	161	166	173	179	184	190	196	203
507	210	216	222	228	234	240	246	251	257	263
508	269	275	280	286	292	297	303	309	315	321
509	328	334	339	345	351	357	363	370	376	383
510	389	395	401	407	413	419	425	431	438	445
511	451	458	466	473	479	486	491	497	502	509
512	514	520	526	531	537	543	550	558	565	572
513	581	590	600	611	621	631	640	649	658	667
514	675	682	689	696	704	710	717	724	729	735
515	741	748	755	762	769	776	782	789	797	804
516	811	818	825	831	837	842	848	855	861	868
517	876	883	890	896	902	909	915	922	929	935
518	942	951	960	970	980	991	1,002	1,011	1,019	1,028
519	1,037	1,048	1,058	1,067	1,076	1,083	1,091	1,099	1,107	1,115
520	1,123	1,131	1,138	1,145	1,153	1,160	1,169	1,176	1,184	1,192
521	1,199	1,206	1,213	1,220	1,227	1,234	1,241	1,249	1,256	1,262
522	1,270	1,278	1,285	1,293	1,300	1,307	1,314	1,321	1,327	1,335
523	1,341	1,348	1,355	1,361	1,368	1,376	1,384	1,391	1,400	1,408
524	1,416	1,424	1,431	1,439	1,447	1,455	1,464	1,472	1,481	1,490
525	1,500	1,509	1,519	1,529	1,539	1,550	1,559	1,569	1,580	1,589
526	1,599	1,612	1,626	1,641	1,657	1,669	1,681	1,691	1,703	1,712
527	1,722	1,732	1,742	1,751	1,762	1,772	1,782	1,792	1,803	1,813
528	1,824	1,834	1,845	1,855	1,866	1,878	1,891	1,904	1,917	1,935
529	1,947	1,958	1,968	1,977	1,986	1,995	2,005	2,014	2,023	2,033
530	2,046	2,058	2,070	2,082	2,093	2,104	2,115	2,126	2,136	2,147
531	2,159	2,171	2,185	2,198	2,210	2,224	2,236	2,248	2,261	2,274
532	2,287	2,299	2,311	2,322	2,334	2,346	2,358	2,374	2,389	2,404
533	2,419	2,433	2,446	2,461	2,476	2,491	2,506	2,520	2,536	2,553
534	2,576	2,593	2,608	2,622	2,635	2,649	2,662	2,676	2,690	2,704
535	2,719	2,734	2,749	2,763	2,779	2,795	2,813	2,833	2,854	2,873
536	2,891	2,906	2,922	2,938	2,954	2,970	2,981	2,992	3,004	3,015
537	3,027	3,038	3,050	3,062	3,074	3,084	3,095	3,107	3,119	3,131
538	3,143	3,155	3,168	3,184						

Note: Areas between elevations 536.0 and 536.5 feet linearly interpolated



Aquilla Lake
July 2014 Survey
Prepared by: TWDB

Appendix C: Capacity curve



Aquilla Lake
July 2014 Survey
Prepared by: TWDB

Appendix D: Area curve

Appendix E

Aquilla Lake

RESERVOIR CAPACITY TABLE

TEXAS WATER DEVELOPMENT BOARD — March 2008 Survey recalculated July 2014

CAPACITY IN ACRE-FEET — Conservation Pool Elevation 537.5 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
497	0	0	0	0	0	0	0	0	0	0
498	0	0	0	0	0	0	0	0	1	1
499	1	1	1	2	2	2	3	3	4	4
500	5	5	6	7	8	8	9	10	11	12
501	14	16	17	19	22	24	27	30	33	37
502	41	45	49	53	58	62	68	73	79	85
503	91	98	106	113	122	130	139	148	158	168
504	179	190	202	214	226	239	253	266	281	295
505	310	326	342	358	375	393	411	429	448	467
506	487	508	529	550	572	595	618	641	665	690
507	715	740	766	793	820	847	875	903	932	961
508	991	1,022	1,053	1,084	1,116	1,149	1,182	1,216	1,250	1,285
509	1,320	1,356	1,392	1,429	1,467	1,505	1,543	1,583	1,622	1,663
510	1,704	1,745	1,787	1,830	1,874	1,918	1,963	2,008	2,055	2,102
511	2,149	2,197	2,246	2,296	2,346	2,396	2,447	2,499	2,552	2,605
512	2,658	2,713	2,768	2,823	2,880	2,937	2,995	3,054	3,113	3,174
513	3,235	3,297	3,361	3,425	3,491	3,557	3,624	3,693	3,762	3,832
514	3,903	3,975	4,047	4,120	4,194	4,269	4,344	4,419	4,496	4,573
515	4,650	4,729	4,808	4,887	4,967	5,048	5,130	5,212	5,295	5,378
516	5,462	5,547	5,633	5,719	5,806	5,893	5,981	6,070	6,159	6,249
517	6,340	6,432	6,524	6,618	6,711	6,806	6,902	6,998	7,095	7,193
518	7,292	7,392	7,493	7,595	7,698	7,802	7,906	8,012	8,118	8,226
519	8,334	8,443	8,553	8,663	8,775	8,887	9,000	9,114	9,229	9,345
520	9,461	9,578	9,696	9,815	9,934	10,054	10,174	10,295	10,417	10,539
521	10,662	10,786	10,911	11,036	11,162	11,289	11,416	11,544	11,673	11,803
522	11,933	12,064	12,195	12,327	12,461	12,594	12,729	12,864	13,000	13,137
523	13,274	13,412	13,551	13,691	13,831	13,972	14,113	14,256	14,398	14,542
524	14,686	14,831	14,978	15,125	15,273	15,422	15,572	15,723	15,876	16,029
525	16,184	16,340	16,496	16,654	16,813	16,973	17,133	17,295	17,458	17,623
526	17,788	17,955	18,123	18,292	18,461	18,632	18,803	18,976	19,149	19,323
527	19,497	19,673	19,850	20,028	20,207	20,387	20,569	20,751	20,935	21,120
528	21,305	21,492	21,681	21,870	22,061	22,253	22,446	22,641	22,837	23,033
529	23,230	23,429	23,628	23,829	24,030	24,233	24,436	24,641	24,847	25,054
530	25,262	25,470	25,680	25,891	26,103	26,316	26,531	26,746	26,962	27,180
531	27,399	27,619	27,840	28,062	28,286	28,510	28,736	28,964	29,192	29,422
532	29,654	29,886	30,120	30,355	30,591	30,829	31,068	31,310	31,552	31,797
533	32,042	32,289	32,538	32,787	33,039	33,291	33,545	33,800	34,056	34,313
534	34,572	34,833	35,095	35,358	35,623	35,889	36,156	36,425	36,695	36,967
535	37,241	37,516	37,792	38,070	38,350	38,631	38,914	39,198	39,485	39,773
536	40,062	40,353	40,646	40,940	41,235	41,532	41,830	42,129	42,430	42,732
537	43,035	43,339	43,644	43,951	44,259	44,568	44,878	45,190	45,503	45,817
538	46,132	46,449	46,767	47,087	47,409	47,732	48,058	48,385	48,714	49,046
539	49,379	49,715	50,052	50,392	50,734	51,078	51,423	51,771	52,121	52,473
540	52,826	53,181	53,539	53,898	54,259	54,621	54,985	55,352	55,719	56,089
541	56,459	56,832	57,207	57,584	57,962	58,343	58,725	59,110	59,496	59,884
542	60,273	60,665								

Appendix F

Aquilla Lake

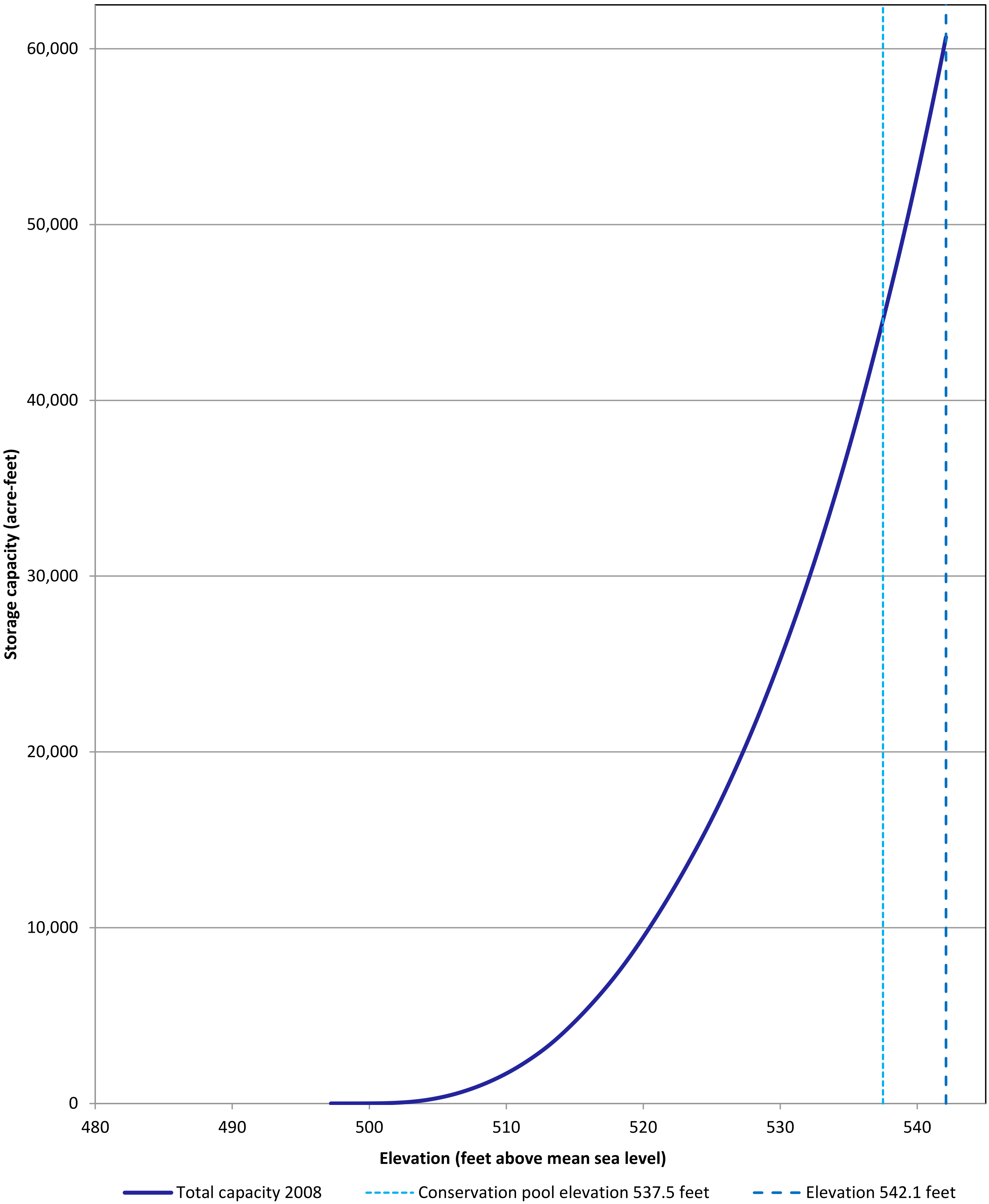
RESERVOIR AREA TABLE

TEXAS WATER DEVELOPMENT BOARD — March 2008 Survey recalculated July 2014

AREA IN ACRES — Conservation Pool Elevation 537.5 feet NGVD29

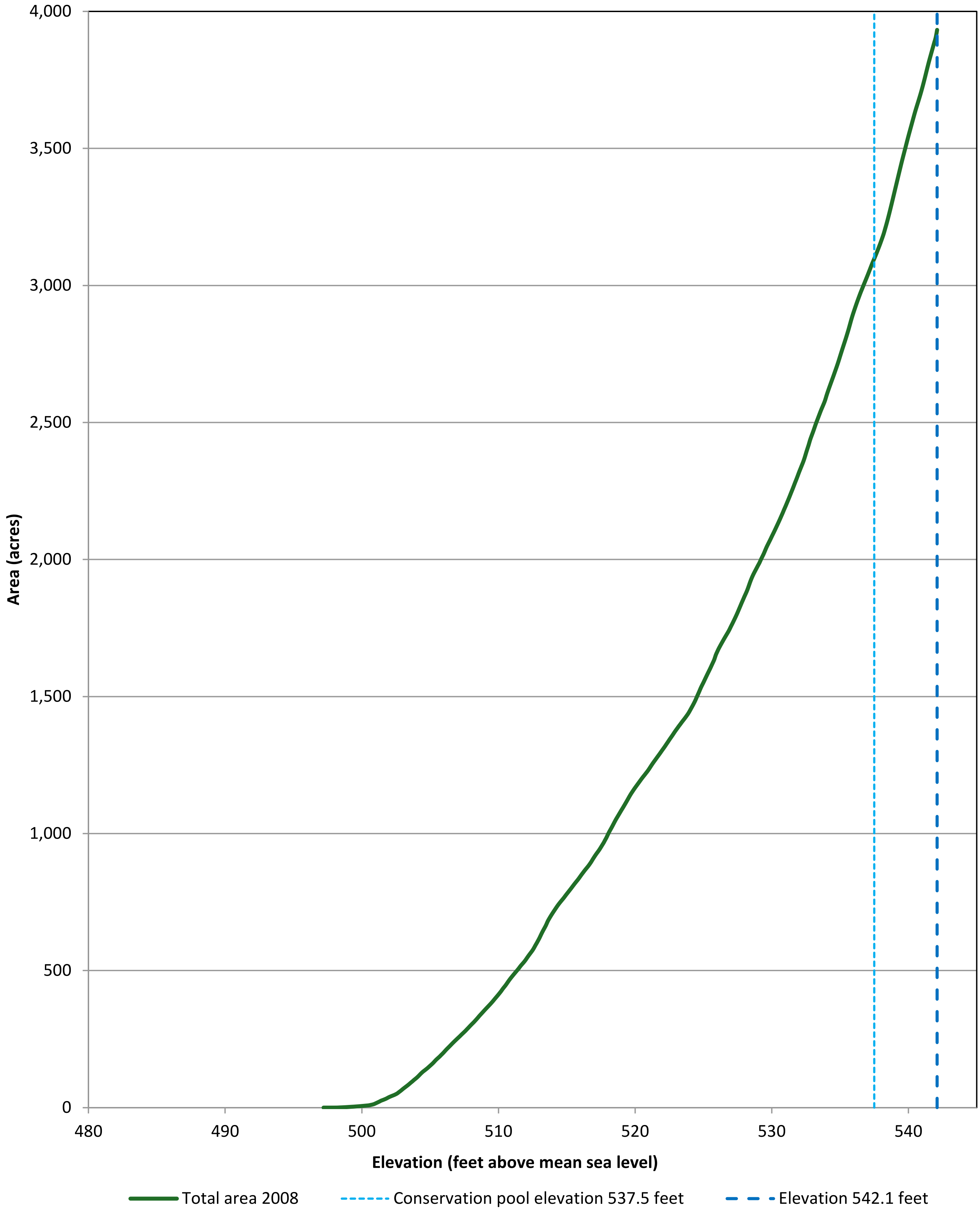
ELEVATION INCREMENT IS ONE TENTH FOOT

ELEVATION in Feet	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
497	0	0	0	0	0	0	0	0	0	0
498	0	0	0	0	1	1	1	1	2	2
499	2	3	3	3	3	4	4	5	5	5
500	6	6	7	7	8	8	9	10	11	13
501	15	18	20	22	25	27	29	31	33	36
502	38	41	43	45	47	49	52	56	60	63
503	68	72	75	79	83	87	92	96	100	104
504	108	113	118	123	128	132	136	140	144	148
505	153	157	162	167	173	177	182	186	192	196
506	202	207	213	218	223	228	233	238	243	248
507	252	257	262	267	271	276	281	286	291	297
508	302	307	312	317	323	329	334	340	345	351
509	356	362	367	372	377	383	389	395	401	407
510	413	419	425	432	439	445	452	459	466	473
511	479	485	491	497	503	509	516	522	527	533
512	540	547	554	561	568	574	583	592	600	610
513	619	629	640	649	658	668	679	688	697	705
514	713	720	728	735	742	748	754	760	767	773
515	780	786	792	799	805	812	819	825	831	838
516	845	851	858	865	871	877	883	890	898	906
517	914	921	928	935	942	950	959	967	976	985
518	996	1,006	1,015	1,024	1,033	1,043	1,052	1,060	1,069	1,077
519	1,085	1,094	1,102	1,111	1,119	1,128	1,137	1,145	1,153	1,160
520	1,167	1,174	1,181	1,188	1,195	1,202	1,208	1,214	1,221	1,227
521	1,234	1,242	1,249	1,257	1,264	1,271	1,278	1,284	1,291	1,298
522	1,305	1,312	1,319	1,327	1,334	1,342	1,349	1,356	1,364	1,371
523	1,378	1,385	1,392	1,398	1,405	1,412	1,418	1,425	1,432	1,439
524	1,448	1,457	1,466	1,475	1,485	1,497	1,508	1,519	1,531	1,541
525	1,551	1,562	1,572	1,583	1,593	1,603	1,614	1,625	1,636	1,651
526	1,662	1,673	1,683	1,692	1,701	1,710	1,718	1,727	1,735	1,744
527	1,755	1,764	1,775	1,785	1,796	1,807	1,818	1,830	1,842	1,853
528	1,865	1,876	1,887	1,901	1,915	1,928	1,940	1,950	1,960	1,969
529	1,979	1,988	1,999	2,009	2,020	2,031	2,043	2,053	2,063	2,073
530	2,084	2,094	2,104	2,115	2,126	2,136	2,147	2,159	2,170	2,182
531	2,193	2,205	2,217	2,229	2,242	2,254	2,267	2,280	2,292	2,305
532	2,319	2,331	2,344	2,356	2,371	2,387	2,403	2,418	2,435	2,450
533	2,463	2,477	2,492	2,505	2,518	2,531	2,544	2,556	2,568	2,581
534	2,597	2,612	2,626	2,640	2,654	2,668	2,682	2,696	2,710	2,726
535	2,742	2,758	2,773	2,788	2,804	2,820	2,836	2,854	2,872	2,889
536	2,904	2,919	2,933	2,947	2,961	2,974	2,986	2,999	3,011	3,023
537	3,035	3,048	3,061	3,074	3,086	3,098	3,109	3,122	3,135	3,148
538	3,161	3,175	3,190	3,208	3,225	3,244	3,263	3,283	3,304	3,324
539	3,345	3,366	3,387	3,407	3,428	3,448	3,468	3,487	3,506	3,526
540	3,545	3,563	3,581	3,600	3,618	3,635	3,652	3,668	3,684	3,701
541	3,719	3,737	3,757	3,777	3,797	3,816	3,834	3,852	3,870	3,888
542	3,905	3,933								



Aquilla Lake
March 2008 Survey
recalculated July 2014
Prepared by: TWDB

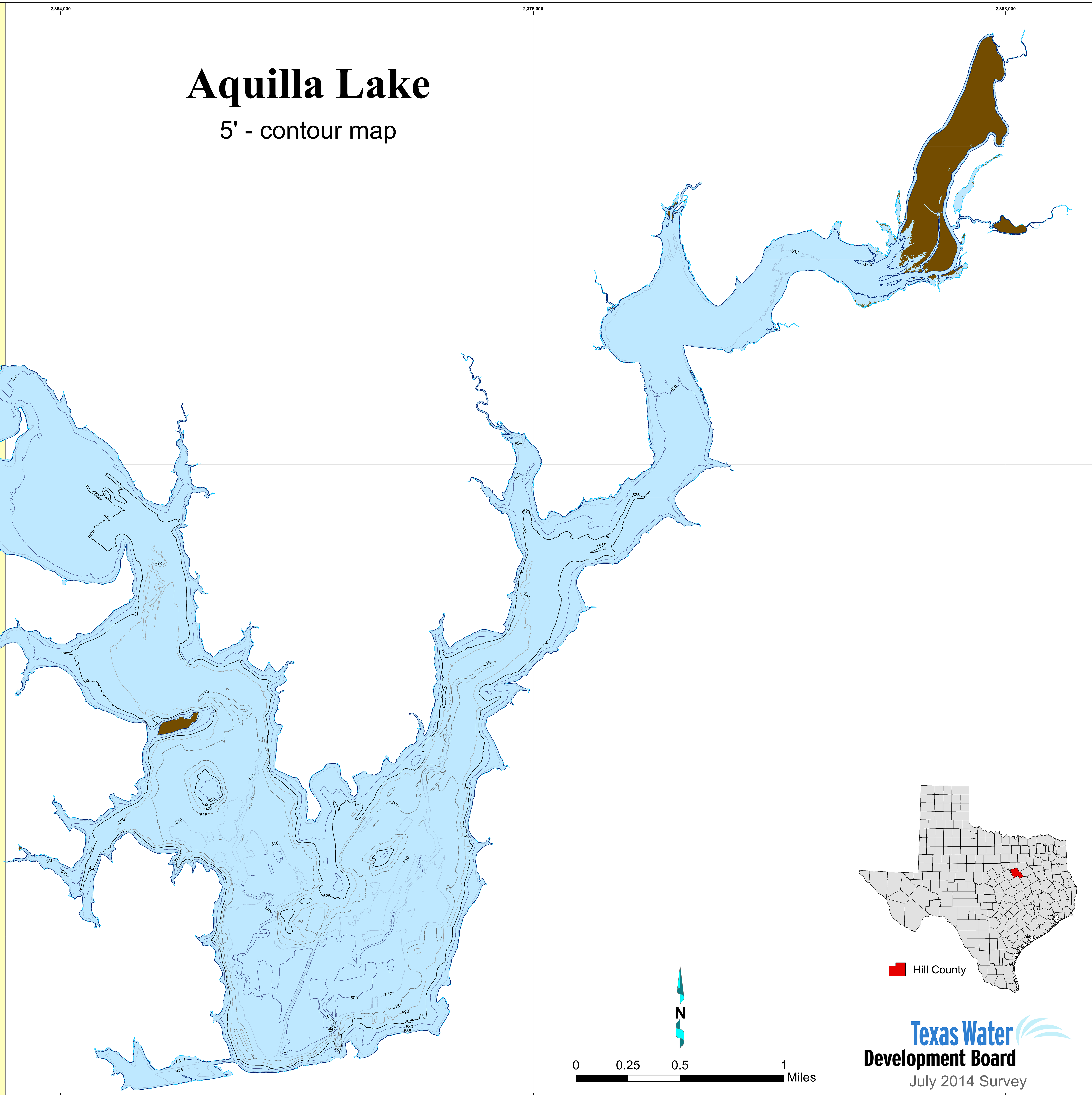
Appendix G: Capacity curve



Aquilla Lake
March 2008 Survey
recalculated July 2014
Prepared by: TWDB

Appendix H: Area curve

Figure 6



Contours
(feet)

- 537.5
- 535
- 530
- 525
- 520
- 515
- 510
- 505
- 500

Aquilla Lake at elevation 538.3 feet

Islands

Conservation pool elevation 537.5 feet NGVD29

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

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