Volumetric and Sedimentation Survey of RICHLAND-CHAMBERS RESERVOIR

December 2018 Survey

Texas Water Development Board

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Executive summary

In March 2018, the Texas Water Development Board (TWDB) entered into an agreement with the Tarrant Regional Water District to perform a volumetric and sedimentation survey of Richland-Chambers Reservoir (Freestone and Navarro counties, Texas). Surveying was performed using a multi-frequency (208 kHz, 50 kHz, and 12 kHz), sub-bottom profiling depth sounder. Sediment core samples were collected in select locations and correlated with sub-bottom acoustic profiles to estimate sediment accumulation thicknesses and sedimentation rates.

Richland-Chambers Dam and Reservoir are located on Richland and Chambers Creeks, in the Trinity River Basin approximately 20 miles southeast of the City of Corsicana, Texas. The conservation pool elevation of Richland-Chambers Reservoir is 315.0 feet above mean sea level (NGVD29). The TWDB collected bathymetric data for Richland-Chambers Reservoir between April 9 and December 4, 2019, while daily average water surface elevations measured between 313.04 and 315.53 feet above mean sea level (NGVD29).

The 2018 TWDB volumetric survey indicates Richland-Chambers Reservoir has a total reservoir capacity of 1,125,199 acre-feet and encompasses 43,874 acres at conservation pool elevation (315.0 feet above mean sea level, NGVD29). Previous capacity estimates include the original design of 1,181,886 acre-feet and two TWDB surveys in 1994 and 2007. The 1994 and 2007 TWDB surveys were re-evaluated using current processing procedures resulting in updated capacity estimates of 1,137,204 acre-feet and 1,123,344 acre-feet, respectively.

The 2018 TWDB sedimentation survey indicates Richland-Chambers Reservoir has lost capacity at an average of 1,886 acre-feet per year since impoundment due to sedimentation below conservation pool elevation (315.0 feet above mean sea level, NGVD29). **The long-term trend based on all available surveys indicates Richland-Chambers Reservoir loses capacity at an average of 1,908 acre-feet per year due to sedimentation below conservation pool elevation (315.0 feet above mean sea level, NGVD29).** The sedimentation survey indicates sediment accumulation is occurring throughout the reservoir. The TWDB recommends that a similar methodology be used to resurvey Richland-Chambers Reservoir in 10 years or after a major flood event.

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

Introduction

The Hydrographic Survey Program of the Texas Water Development Board (TWDB) was authorized by the 72nd Texas State Legislature in 1991. 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 March 2018, the TWDB entered into an agreement with the Tarrant Regional Water District, to perform a volumetric and sedimentation survey of Richland-Chambers Reservoir (Texas Water Development Board, 2018). 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 10), and (4) an elevation-area-capacity table of the reservoir acceptable to the Texas Commission on Environmental Quality (Appendices I and J).

Richland-Chambers Reservoir general information

Richland-Chambers Dam and Richland-Chambers Reservoir are located on Richland and Chambers Creeks in the Trinity River Basin approximately 20 miles southeast of Corsicana in Freestone and Navarro Counties, Texas (Figure 1). Richland-Chambers Reservoir is the third largest lake to lie entirely within the state of Texas and is owned and operated by Tarrant Regional Water District (Tarrant Regional Water District, 2019). Deliberate impoundment of water began on July 14, 1987 (U.S. Geological Survey, 2019). The reservoir was built primarily for water supply. Additional pertinent data about Richland-Chambers Dam and Richland-Chambers Reservoir can be found in Table 1.

Water rights for Richland-Chambers Reservoir have been appropriated to the Tarrant Regional Water District through Certificate of Adjudication No. 08-5035 and Amendments to Certificate of Adjudication Nos. 08-5035A-E and the City of Corsicana through Certificate of Adjudication No. 08-5030. The complete permits are on file in the Information Resources Division of the Texas Commission on Environmental Quality.

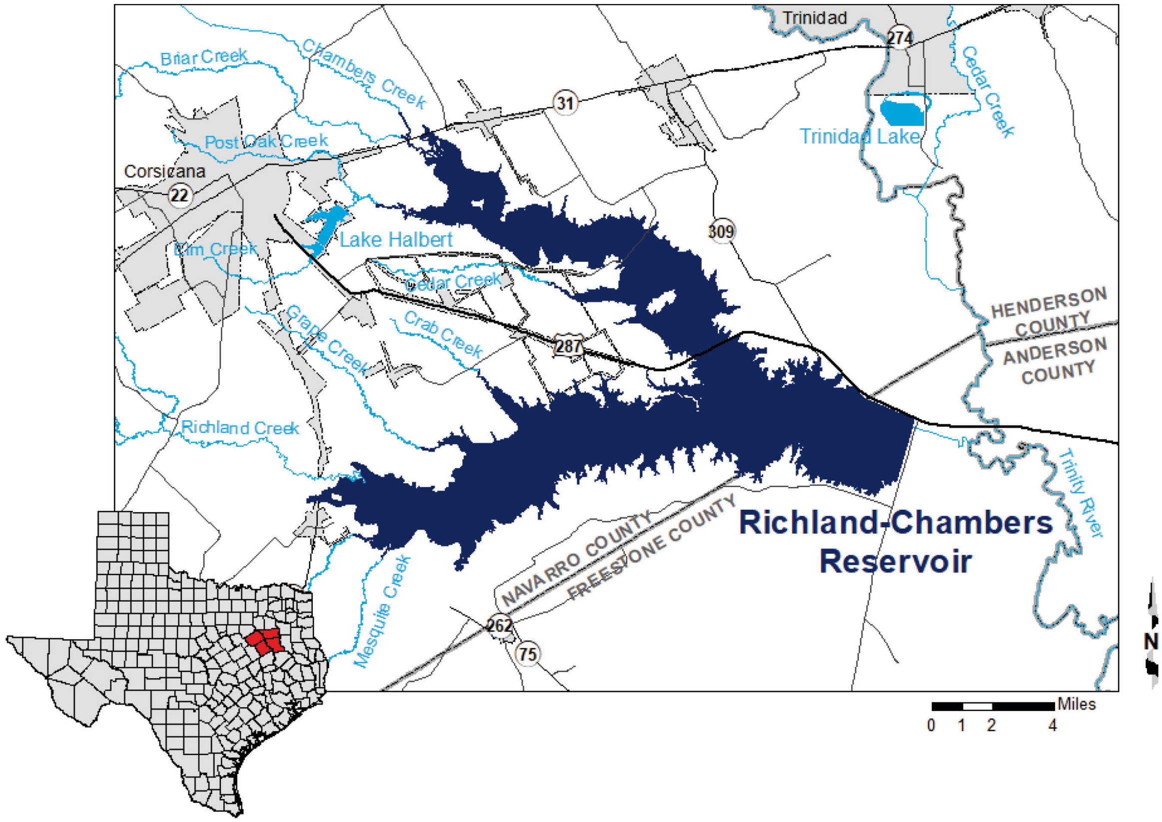


Figure 1. Location map of Richland-Chambers Reservoir.

Table 1. Pertinent Data for Richland-Chambers Dam and Reservoir

Owner	
Tarrant Regional Water District	
Engineer (Design)	
Freese and Nichols, Consulting Engineers	
Location of dam	
On Richland and Chambers Creeks in Freestone and Navarro Counties, approximately 20 miles southeast of Corsicana, Texas.	
Drainage area	
1,957 square miles (178 square miles caught by Bardwell and 320 square miles caught by Navarro Mills)	
Dam	
Type	Earthen embankment with a soil cement upstream face
Length	31,100 feet
Maximum height	120 feet
Service spillway	
Location	At station 133 of the dam, approximately 1 mile north of the original Richland Creek
Spillway type	Concrete
Total length	1,344 feet
Crest length	960 feet
Crest elevation	290.0 feet above mean sea level
Control	24 radial & 4 low flow gates
Width and Height of radial gates	40 feet by 29 feet
Low flow gates	2, each 3 feet by 5 feet at elevation 265 feet 1, each 1 foot by 1 foot at elevation 285 feet 1, each 1.5 feet by 2.5 feet at elevation 285 feet

Table 1. Pertinent Data for Richland-Chambers Dam and Reservoir (continued)

Service spillway (continued)	
Control	Sliding gates
Discharge capacity	446,000 cubic feet per second when reservoir is at elevation 315.0 feet above mean sea level

Reservoir data (Based on 2018 TWDB survey)

Feature	**Elevation (feet** NGVD29[a]**)**	**Capacity (acre-feet)**	**Area (acres)**
Height of embankment	326.0	N/A	N/A
Top of conservation pool	315.0	1,125,199	43,874
Service spillway crest	290.0	361,738	22,058
Low flow gates	285.0	261,353	18,095
Low flow gates	265.0	30,090	5,582
Usable conservation storage[b]	—	1,095,109	—

Source: (Texas Water Development Board, 1995, S. Sieja, written commun., 1995, D. Marshall, written commun., 1995)

[a] NGVD29 = National Geodetic Vertical Datum 1929

[b] Usable conservation storage 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 Richland-Chambers Reservoir

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 0864550 Richland-Chambers Res nr Kerens, TX* (U.S. Geological Survey, 2019). 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 North Central Zone (feet).

TWDB bathymetric and sedimentation data collection

The TWDB collected bathymetric data for Richland-Chambers Reservoir between April 9 and December 4, 2018, while daily average water surface elevations measured between 313.04 and 315.53 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 12 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 for the *Volumetric and Sedimentation Survey of Richland-Chambers Reservoir, October*

2007 Survey (Texas Water Development Board, 2009) and *Volumetric Survey of Richland-Chambers Reservoir, December 1994* (Texas Water Development Board, 1995). 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. Each speed of sound profile, or velocity cast, is saved for further data processing. Figure 2 shows the data collection locations for the 2018 TWDB survey.

All sounding data was collected and reviewed before sediment core sampling sites were selected. Sediment core samples are collected throughout the reservoir to assist with interpretation of the sub-bottom acoustic profiles. After analyzing the sounding data, the TWDB selected 15 locations to collect sediment core samples (Figure 2). Sediment cores were collected on December 3-5, 2018, with a custom-coring boat and an 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. A sediment core extends from the current reservoir-bottom surface, through the accumulated sediment, and into the pre-impoundment surface. After the sample is retrieved, the core tube is cut to the level of the sediment core. The tube is capped and transported to TWDB headquarters for further analysis.

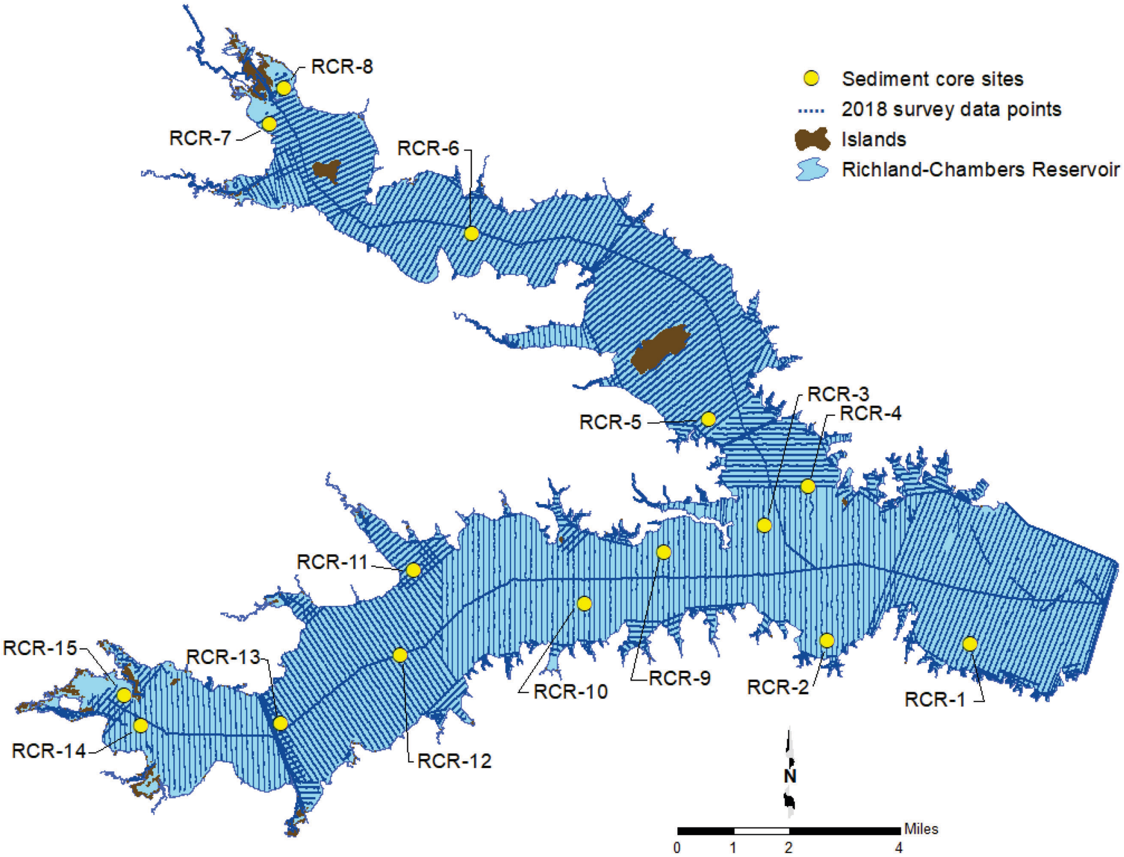


Figure 2. 2018 TWDB Richland-Chambers Reservoir survey data (*blue dots*) and sediment coring locations (*yellow circles*)

Data processing

Model boundary

The reservoir's model boundary was generated from Light Detection and Ranging (LIDAR) data provided to the TWDB by the Tarrant Regional Water District and aerial imagery obtained through the Texas Imagery Service. The LIDAR data was collected between March 12, 2015, and May 17, 2015, while daily average water surface elevations measured between 307.44 and 315.53 feet above mean sea level (NGVD29). According to the associated metadata, the classified point cloud was compiled to meet a horizontal positional accuracy of 0.770 feet at 95 percent confidence level. For vertical accuracy, the data tested 0.252 feet fundamental vertical accuracy at a 95 percent confidence level.

To generate a boundary utilizing the LIDAR data, LIDAR data with a classification equal to 2, or ground, was imported into an Environmental Systems Research Institute's ArcGIS file geodatabase from .las files. A topographical model of the data was generated and converted to a raster using a cell size of 1.0 foot by 1.0 foot. The horizontal datum used for this data is North American Datum 1983 (NAD83), and the horizontal coordinate system is State Plane Texas North Central Zone (feet). The vertical datum is North American Vertical Datum 1988 (NAVD88; feet). Therefore, a contour of 315.007 feet NAVD88, equivalent to 315.0 feet NGVD29, was extracted from the raster. The vertical datum transformation offset for the conversion from NAVD88 to NGVD29 was determined by applying the National Oceanic and Atmospheric Administration National Geodetic Survey's NADCON software (National Geodetic Survey, 2017a) and VERTCON software (National Geodetic Survey, 2017b) to a single reference point in the vicinity of the survey, the reservoir elevation gage *USGS 0864550 Richland-Chambers Res nr Kerens, TX Latitude 32º02'25"N, Longitude 96º12'23"W NAD27.* Additional editing of the 315.0-foot contour was necessary to close the contour across the top of the dam and remove other artifacts. The shoreline contour generated from the LIDAR was also unable to properly represent the shoreline where bulkheads have been constructed. These sections were digitized from aerial photographs taken on March 31, 2017, and April 3, 2017, while the daily average water surface elevation measured 315.11and 315.52, respectively. The Texas Natural Resources Information System manages the Texas Imagery Service allowing public organizations in the State of Texas to access Google Imagery as a service using Environmental Systems Research Institute's ArcGIS software (Texas Natural Resources Information System, 2018a). The imagery has a resolution of 6 inches (Texas Natural Resources Information System, 2018b).

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. The speed of sound profiles, also known as velocity casts, were used to further correct the measured depths. For each location velocity casts are collected, the harmonic mean sound speed of all the casts are calculated. From this, depths collected using one average speed of sound are corrected with an overall optimum speed of sound for each specific depth (Specialty Devices, Inc., 2018).

The TWDB developed an algorithm to automatically determine the pre-impoundment surface based on the intensity of the acoustic returns. Hydropick software, developed by TWDB staff, was used to calibrate the algorithm and manually edit the pre-impoundment surfaces in areas where the algorithm did not perform as expected. For further analysis, all data was exported 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 *et al.* 2011a). 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 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), hypsography files (the vector format of USGS 7.5 minute quadrangle map contours), and historical aerial photographs, 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, 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, the TWDB evaluated augmenting the reservoir model with LIDAR data. Below conservation pool elevation, comparison between the bathymetric survey data and the LIDAR data indicated significant elevation differences up to approximately 1.5 feet. Internal quality assurance and control measures were reviewed to ensure the accuracy of the TWDB sounding data. Upon review, no discrepancies were identified in the sounding data. The TWDB elected to exclude the LIDAR data from the reservoir model. Linear interpolation was used for volumetric and sediment accumulation estimations. Linear interpolation follows a line linking the survey points file to the lake boundary file (McEwen *et al.* 2011a). This line can intersect points along its path for consideration. 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 Richland-Chambers Reservoir. 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 I) and elevation-area (Appendix J) tables.

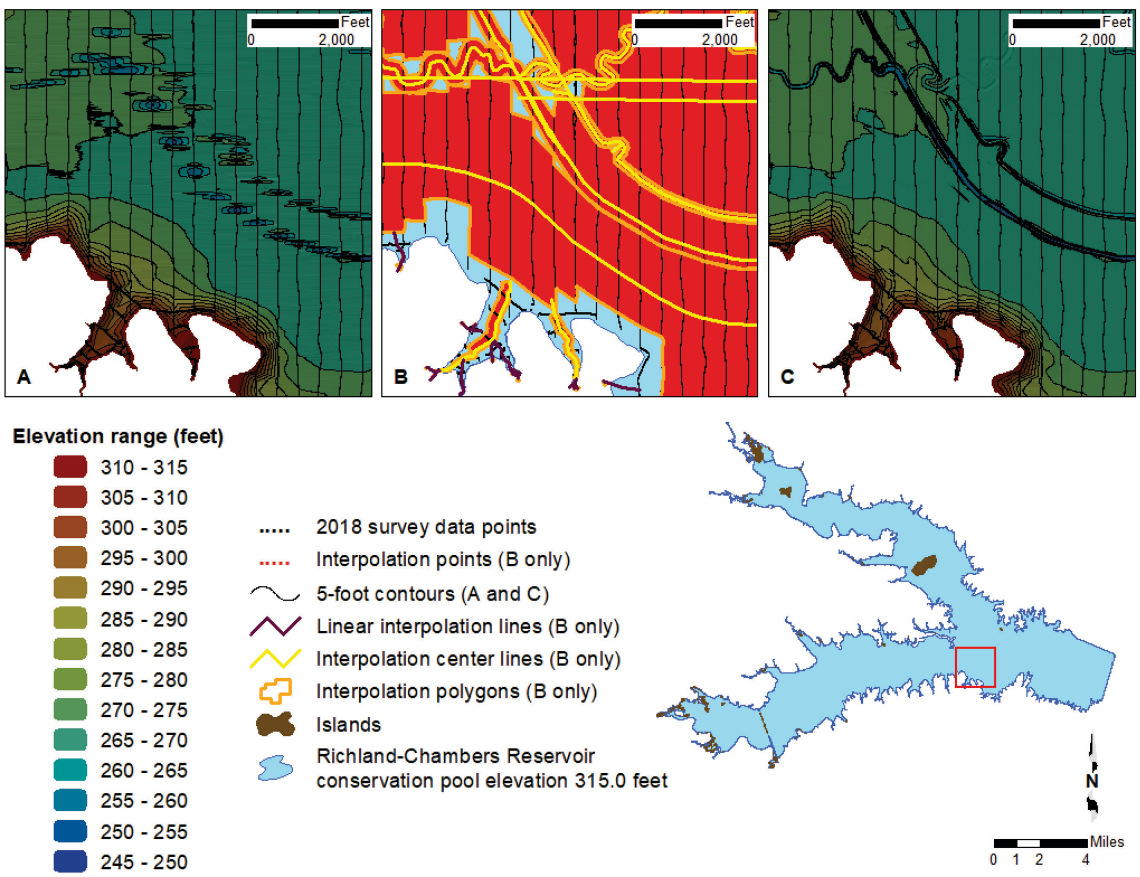


Figure 3. Anisotropic spatial interpolation and linear interpolation of Richland-Chambers Reservoir sounding data; A) bathymetric contours without interpolated points, B) sounding points (*black*) and interpolated points (*red*), C) bathymetric contours with interpolated points.

In 2016, the TWDB applied anisotropic spatial interpolation to the 1994 survey. The original 1994 survey boundary was digitized from the 315.0 foot contour from 7.5 minute USGS quadrangle maps: Goodlow Park, TX, 1960 (Photo-inspected 1978); Powell, TX, 1959; Richland, TX, 1963 (Photo-revised 1978); Roustabout Camp, TX, 1960 (Photo-revised 1982); Streetman, TX, 1960 (Photo-revised 1982); and Winkler, TX, 1960 (Photo-revised 1982), with a stated accuracy of ± ½ the contour interval (U.S. Bureau of the Budget, 1947). In 2000, Freese and Nichols, Inc. found discrepancies with this boundary and concluded it underestimated the total surface area at conservation pool elevation. As a result, in 2003, the Tarrant Regional Water District revised the 1994 TWDB estimate above elevation 309.0 feet using aerial photographs to better estimate surface area (Tarrant Regional Water District, 2003). Therefore, the TWDB re-calculation also uses TWDB surveyed estimates up to 309.0 feet and the Tarrant Regional Water District estimates above elevation 309.0 feet. Additionally, survey data points with anomalous elevations were removed from the new model (Texas Water Development Board, 2016b). The 1994 re-calculated elevation-capacity table and elevation-area table are presented in Appendices A and B, respectively. The re-calculated capacity curve is presented in Appendix C, and the re-calculated area curve is presented in Appendix D.

Before applying anisotropic spatial interpolation to the 2007 survey, the raw data files were reanalyzed using DepthPic© to remove any data anomalies. The original 2007 model boundary, digitized from aerial photographs taken between August 8, 2004, and September 9, 2004, while the daily average water surface elevations measured between 314.76 feet and 315.21 feet, was modified to include shoreline changes discovered in the 2006 aerial photographs. Many contour segments digitized from the aerial photographs taken on August 9-10, 2006, while the daily average water surface elevation measured 307.27 feet and 307.24 feet, respectively, were also used in the new model. Anisotropic spatial interpolation was applied to the 2007 survey using the same interpolation definition file as was used for the 1994 survey, with minor edits to account for differences in data coverage and boundary conditions. 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 315.0 feet. The TWDB evaluated the availability and distribution of survey data and the shape of the elevation-area curve to determine the highest accurate contour modeled by survey data was 310.8 feet. Therefore, areas between 310.8 feet and 315.0 feet were linearly interpolated between the computed values, and volumes above 310.8 feet were calculated based on the corrected areas. The 2007 re-calculated elevation-capacity table and elevation-area table are presented in Appendices E and F, respectively. The re-calculated capacity curve is presented in Appendix G, and the re-calculated area curve is presented in Appendix H.

Area, volume, and contour calculation

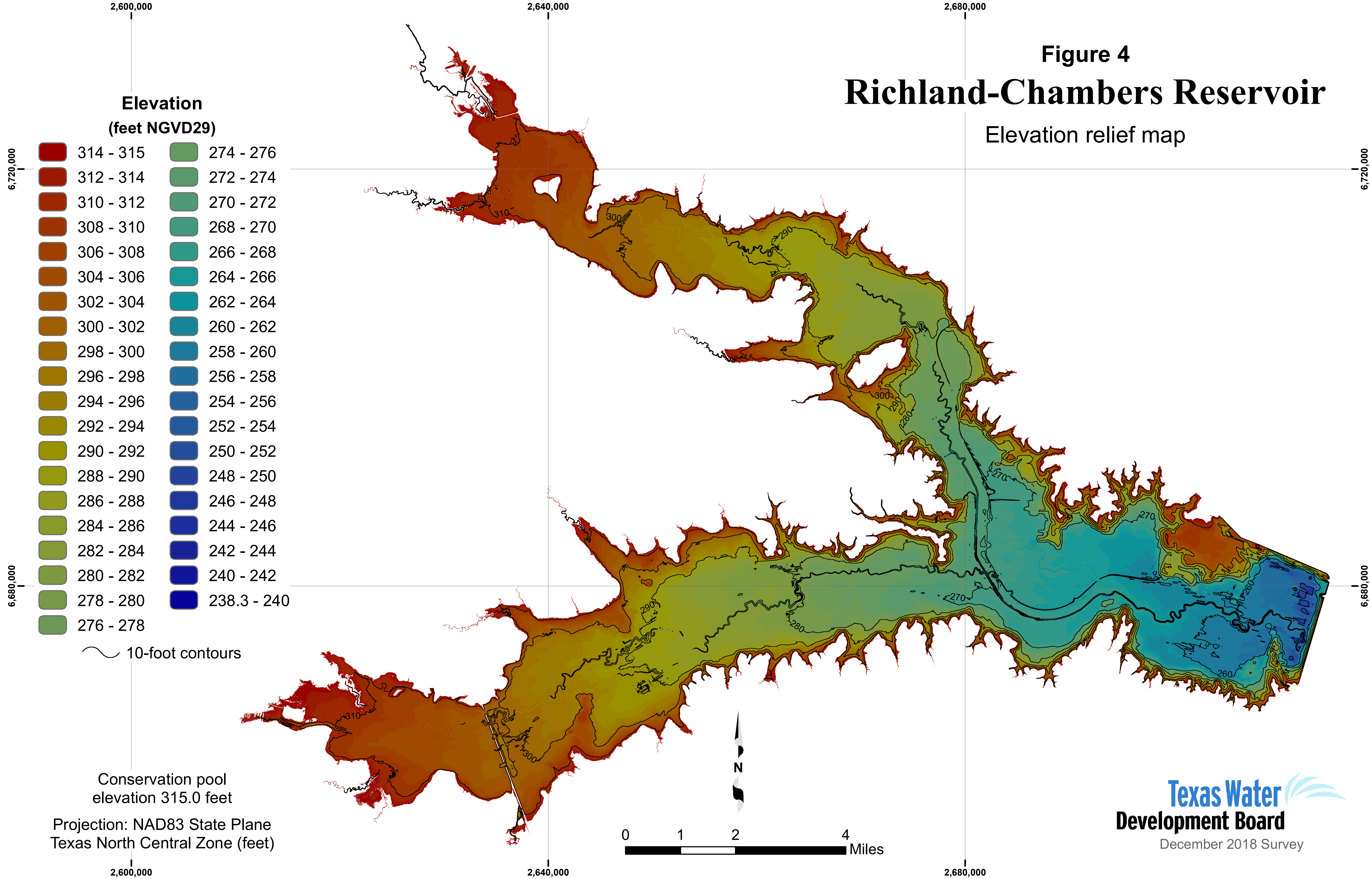
Using ArcInfo software and the volumetric TIN model, volumes and areas were computed for the entire reservoir at 0.1-foot intervals, from 238.2 to 315.0 feet. While linear interpolation was used to estimate topography in areas that were inaccessible by boat or too shallow for survey instruments to work 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 315.0 feet. The TWDB evaluated the availability and distribution of survey data and the shape of the elevation-area curve to determine the highest contour accurately modeled by survey data was 312.0 feet. To eliminate the effects of the flat triangles on area and volume calculations, areas between elevations 312.0 and 315.0 feet were linearly interpolated between the computed values, and volumes above elevation 312.0 feet were calculated from the interpolated areas. The elevation-capacity table and elevation-area table, based on the 2018 survey and analysis, are presented in Appendices I and J, respectively. The capacity curve is presented in Appendix K, and the area curve is presented in Appendix L.

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 Richland-Chambers Reservoir (Figure 5); and, (3) a 5-foot contour map (Figure 6).

Figure 4

Richland-Chambers Reservoir

Elevation relief map



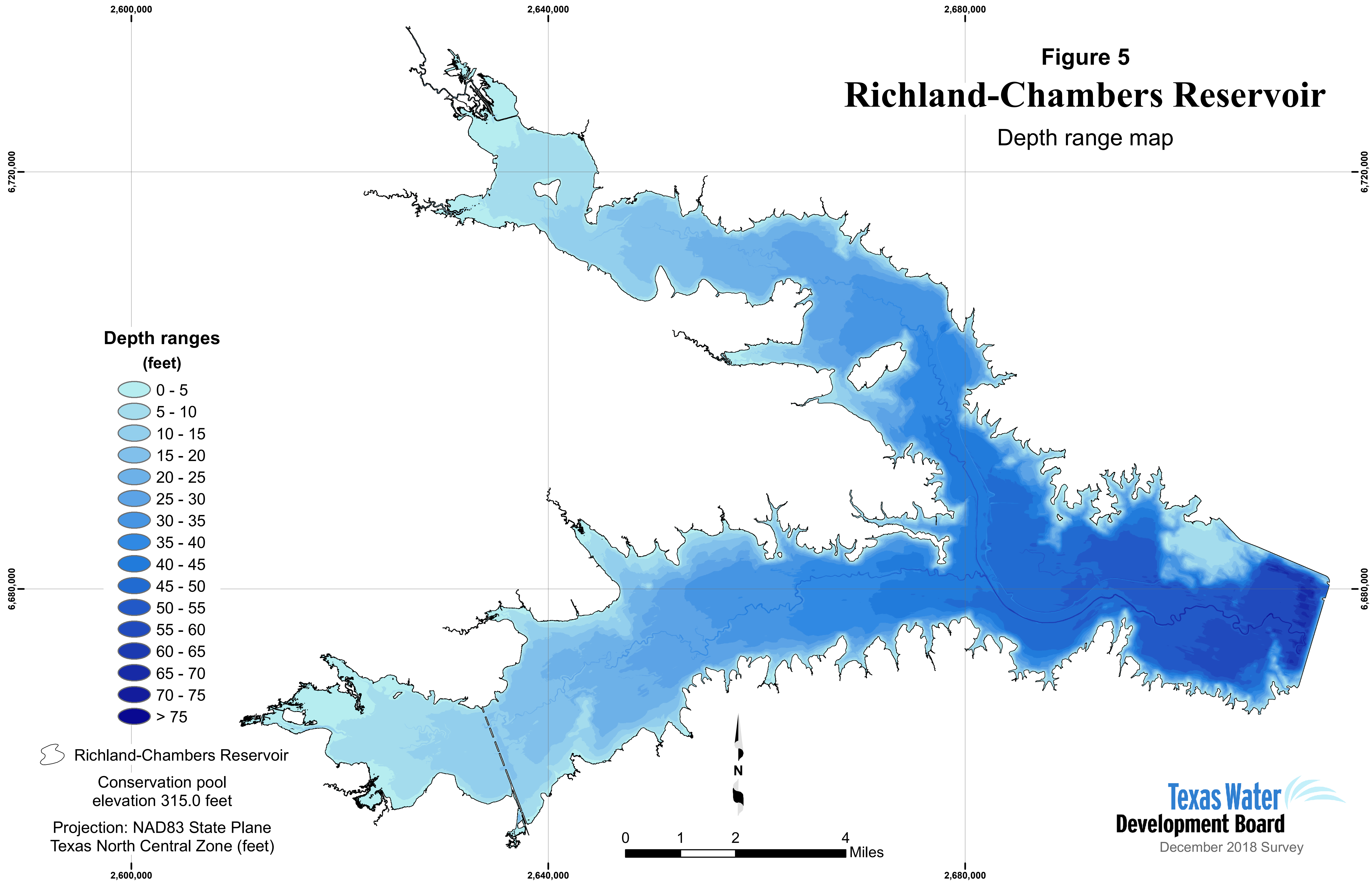


Figure 5
Richland-Chambers Reservoir
Depth range map
Depth ranges
(feet)
0 - 5
5 - 10
10 - 15
15 - 20
20 - 25
25 - 30
30 - 35
35 - 40
40 - 45
45 - 50
50 - 55
55 - 60
60 - 65
65 - 70
70 - 75
> 75
Richland-Chambers Reservoir
Conservation pool
elevation 315.0 feet
Projection: NAD83 State Plane
Texas North Central Zone (feet)
2,600,000
2,640,000
2,680,000
6,720,000
6,680,000
N
0
1
2
4
Miles
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Analysis of sediment data from Richland-Chambers Reservoir

Sedimentation in Richland-Chambers Reservoir was determined by analyzing the acoustic signal returns of all three depth sounder frequencies using customized software called Hydropick. While the 208 kHz signal is used to determine the current bathymetric surface, the 208 kHz, 50 kHz, and 12 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.

Sediment cores were analyzed at TWDB headquarters in Austin. Each core was split longitudinally and analyzed to identify the location of the pre-impoundment surface. The pre-impoundment surface was identified within the sediment core using 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) recording changes in texture from well sorted, relatively fine-grained sediment to poorly sorted mixtures of coarse and fine-grained materials; and, (3) identifying variations in the physical properties of the sediment, particularly sediment water content and penetration resistance with depth (Van Metre and others, 2004). Total sediment core 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 were recorded (Table 2).

Table 2. Sediment core sample analysis data for Richland-Chambers Reservoir.

Sediment core sample	Easting[a] (feet)	Northing[a] (feet)	Total core sample/ post-impoundment sediment	Sediment core description		Munsell soil color
RCR-1	2701029.88	6673306.91	53.0"/20"	post-impoundment	0.0–3.0" very high water content, organic material present (1/2 inch pieces of woody debris), milk shake consistency	10YR 3/1 very dark gray
					3.0–20.0" moderate to low water content, clay	10YR 2/1 black
				pre-impoundment	20.0–53.0" ow to very low water content (water content decreasing with depth), all clay, malleable, sticky, dense, organic material present (roots)	10YR 2/1 black
RCR-2	2687445.63	6673648.42	29.5"/12.0"	post-impoundment	0.0–3.0" very high water content, soupy, uniform color/texture	10YR 3/1 very dark gray
					3.0–12.0" moderate water content, milk shake consistency, sticky, predominately clay	10YR 3/1 very dark gray
				pre-impoundment	12.0–29.5" low water content, organic material present (small roots, woody debris throughout), malleable, sticky dense	10YR 2/1 black
RCR-3	2681440.49	6684534.54	44.0"/22.5"	post-impoundment	0.0–12.0" very high water content, pudding like, silty with small bits of clay, uniform color/texture throughout	2.5Y 3/2 very dark grayish brown
					12.0–22.5" moderate water content, predominately clay	10YR 2/1 black
				pre-impoundment	22.5–31.0" moderate to low water content (separated from layer below based on water content), malleable, predominately clay, sticky, dense, organic material present (roots, woody debris)	10YR 2/1 black
					31.0–44.0" very low water content, malleable, all clay, organic material throughout	10YR 2/1 black

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

Table 2. Sediment core sample analysis data for Richland-Chambers Reservoir (continued).

Sediment core sample	Easting[a] (feet)	Northing[a] (feet)	Total core sample/ post-impoundment sediment	Sediment core description		Munsell soil color
RCR-4	2685564.45	6688262.60	62.0”/16.0	post-impoundment	0.0–10.0” very high water content, pudding like, predominately silt, uniform color/texture throughout	10YR 3/1 very dark gray
					10.0–16.0” high water content, clay/silt mixture, milk shake consistency, uniform color/texture throughout	10YR 3/1 very dark gray
				pre-impoundment	16.0–51.0” moderate to low water content (separated from layer below based on water content), clay, sticky, malleable, organic material present (roots)	10YR 2/1 black
					51.0–62.0” very low water content, very dense clay, malleable (holds shape), less sticky, organic material present (roots)	no color recorded
RCR-5	2676149.58	6694650.84	59.5”/23.0”	post-impoundment	0.0–23.0” high water content, pudding like, uniform consistency throughout	10YR 3/1 very dark gray
				pre-impoundment	23.0–37.0” moderate to low water content, predominately clay, sticky, loosely packed, less dense, organic material present (large woody debris [>1.0 inches], roots)	10YR 2/1 black
					37.0–45.0” moderate to high water content, loosely packed milk shake consistency, organic material present (roots)	10YR 2/1 black
					45.0–59.5” very low water content, dense, malleable, all clay, organic material present (woody debris, roots)	10YR 2/1 black
RCR-6	2653696.67	6712188.33	45.75”/11.0”	post-impoundment	0.0–2.0” very high water content, silty, soupy, organic material present (woody debris)	10YR 3/1 very dark gray
					2.0–9.0” high water content, loosely packed, predominately clay	10YR 2/1 black
					9.0–11.0” moderate water content, predominately clay	10YR 2/1 black
				pre-impoundment	11.0–34.0” moderate to low water content (decreases with depth), loosely packed, very sticky, malleable, predominately clay, organic material present (roots)	10YR 2/1 black
					34.0–39.0” moderate to high water content, loosely packed, sticky, clay/silt mix, organic material present (roots)	10YR 3/1 very dark gray
					39.0–45.0” low water content, dense, malleable, organic material present (roots)	no color recorded

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

Table 2. Sediment core sample analysis data for Richland-Chambers Reservoir (continued).

<table>
<tr><th>Sediment core sample</th><th>Easting[a] (feet)</th><th>Northing[a] (feet)</th><th>Total core sample/ post-impoundment sediment</th><th colspan="2">Sediment core description</th><th>Munsell soil color</th></tr>
<tr><td rowspan="2">RCR-7</td><td rowspan="2">2634557.79</td><td rowspan="2">6722641.04</td><td rowspan="2">17.0”/10.0”</td><td>post-impoundment</td><td>0.0–10.0” very high water content, pudding like, high silt content, uniform texture throughout</td><td>10YR 3/1 very dark gray</td></tr>
<tr><td>pre-impoundment</td><td>10.0–17.0” low water content, predominately clay, dense, malleable, organic material present at top of layer (woody debris, leaves)</td><td>10YR 3/1 very dark gray</td></tr>
<tr><td rowspan="2">RCR-8</td><td rowspan="2">2635893.61</td><td rowspan="2">6726036.81</td><td rowspan="2">18.0”/11.0”</td><td>post-impoundment</td><td>0.0–11.0” very high water content, pudding like, bits of clay, mostly silt, organic material present (detritus)</td><td>10YR 3/1 very dark gray</td></tr>
<tr><td>pre-impoundment</td><td>11.0–18.0” low water content, clay, malleable, dense, organic material present (roots, leaves), streaks of red color</td><td>10YR 3/1 very dark gray</td></tr>
<tr><td rowspan="2">RCR-9</td><td rowspan="2">2671914.36</td><td rowspan="2">6682028.56</td><td rowspan="2">26.25”/9.0”</td><td>post-impoundment</td><td>0.0–9.0” very high water content, predominantly silt, pudding like</td><td>no color recorded</td></tr>
<tr><td>pre-impoundment</td><td>9.0–26.25” moderate to low water content (decreasing with depth), predominantly clay, malleable, dense, organic material present (woody debris, leaves, roots)</td><td>10YR 2/1 black</td></tr>
<tr><td rowspan="4">RCR-10</td><td rowspan="4">2664408.46</td><td rowspan="4">6677174.98</td><td rowspan="4">46.0”/24.0”</td><td rowspan="2">post-impoundment</td><td>0.0–8.0” very high water content, smooth, silt, soupy</td><td>10YR 3/1 very dark gray</td></tr>
<tr><td>8.0–24.0” high water content, pudding like, smooth, silt</td><td>10YR 2/1 black</td></tr>
<tr><td rowspan="2">pre-impoundment</td><td>24.0–33.0” moderate water content, loosely packed clay particle (similar to small beads), sticky, organic material present (roots)</td><td>10YR 2/1 black</td></tr>
<tr><td>33.0–46.0” very low water content, dense, clay, organic material present (fibrous roots)</td><td>10YR 2/1 black</td></tr>
</table>

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

Table 2. Sediment core sample analysis data for Richland-Chambers Reservoir (continued).

Sediment core sample	Easting[a] (feet)	Northing[a] (feet)	Total core sample/ post-impoundment sediment	Sediment core description		Munsell soil color
RCR-11	2648203.74	6680349.93	20.25"/8.0"	post-impoundment	0.0–2.0" very high water content, silt, smooth, soupy	10YR 3/1 very dark gray
					2.0–8.0" high water content, silt/clay mix (more silt), pudding like	10YR 3/1 very dark gray
				pre-impoundment	8.0–20.25" moderate water content, loosely packed clay, organic material present (roots)	10YR 2/1 black
RCR-12	2646926.01	6672315.38	47.5"/16.0"	post-impoundment	0.0–3.0" very high water content, silt, smooth, uniform color/texture throughout, organic material present (woody debris)	10YR 3/1 very dark gray
					3.0–16.0" high water content, mostly silt (small balls of clay mixed throughout), smooth, pudding like, organic material present (woody debris)	10YR 3/1 very dark gray
				pre-impoundment	16.0–30.0" high water content, pudding like, small balls of clay, more dense than previous layer, organic material present (woody debris)	10YR 2/1 black
					30.00–47.5" high to low water content (decreasing with depth), loosely packed clay, density increasing with depth, sticky, malleable, organic material present (woody debris, root fibers)	10YR 2/1 black
RCR-13	2635618.37	6665816.24	13.5"/2.0"	post-impoundment	0.0–2.0" very high water content, silt with small grains of clay, soupy	10YR 3/1 very dark gray
				pre-impoundment	2.0–13.5" moderate water content, loosely packed clay, sticky, malleable	10YR 2/1 black
RCR-14	2622325.85	6665620.16	20.5"/7.0"	post-impoundment	0.0–2.0" very high water content, silt with small grains of clay, soupy	10YR 3/1 very dark gray
					2.0–7.0" moderate to low water content, clay	10YR 2/1 black
				pre-impoundment	7.0–20.5" low to very low water content (decreases with depth), clay, density increases with depth, organic material present (roots)	10YR 2/1 black

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

Table 2. Sediment core sample analysis data for Richland-Chambers Reservoir (continued).

Sediment core sample	Easting[a] (feet)	Northing[a] (feet)	Total core sample/ post-impoundment sediment	Sediment core description		Munsell soil color
RCR-15	2620798.59	6668513.06	16.5”/10.0”	post-impoundment	0.0–1.5” high water content, silt with small grains of clay, soupy	10YR 3/1 very dark gray
					1.5–10.0” moderate to low water content, clay	10YR 3/1 very dark gray
				pre-impoundment	10.0–16.5” low water content, all clay, dense, malleable, organic material present (fibrous roots, woody debris)	10YR 3/1 very dark gray

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

A photograph of sediment core RCR-6 (for location, refer to Figure 2) is shown in Figure 7 and is representative of sediment cores sampled from Richland-Chambers Reservoir. The base of the sample is denoted by the right most blue line. The pre-impoundment boundary (right most yellow line) was evident within this sediment core sample at 11.0 inches and identified by the change in color, texture, moisture, porosity, and structure. Identification of the pre-impoundment surface for each sediment core followed a similar procedure.

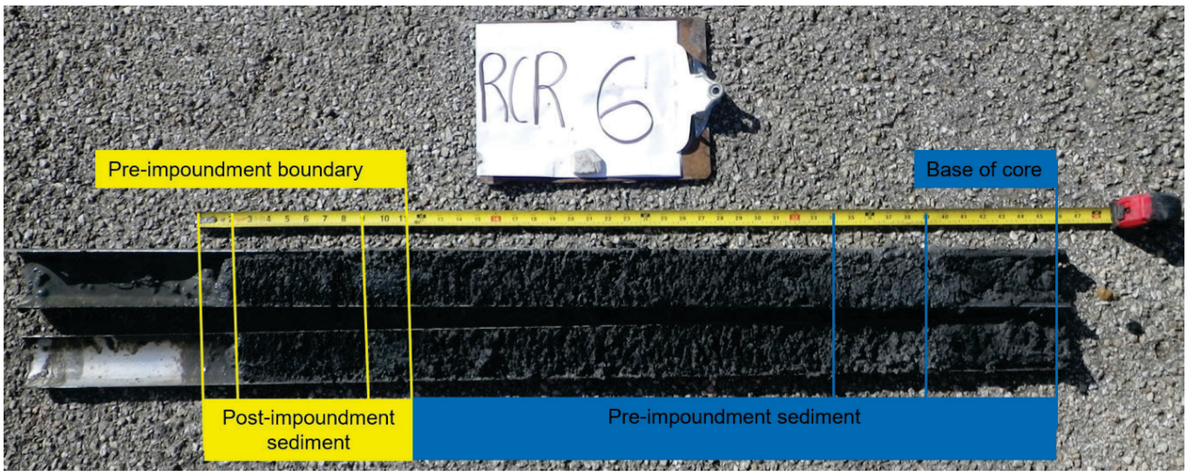

Figure 7. Sediment core RCR-6 from Richland-Chambers Reservoir. Post-impoundment sediment layers occur in the top 11.0 inches of this sediment core (identified by the yellow box). Pre-impoundment sediment layers were identified and are defined by the blue box.

Figure 8 compares sediment core sample RCR-6 with the acoustic signals as seen in Hydropick for each frequency: 208 kHz, 50 kHz, and 12 kHz. The current bathymetric surface is automatically determined based on signal returns from the 208 kHz transducer as represented by the top red line in Figure 8. The pre-impoundment surface is identified by comparing boundaries observed in the 208 kHz, 50 kHz, and 12 kHz signals to the location of the pre-impoundment surface of the sediment core sample. Many layers of sediment are identified during 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. The boundary of 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 that were identified.

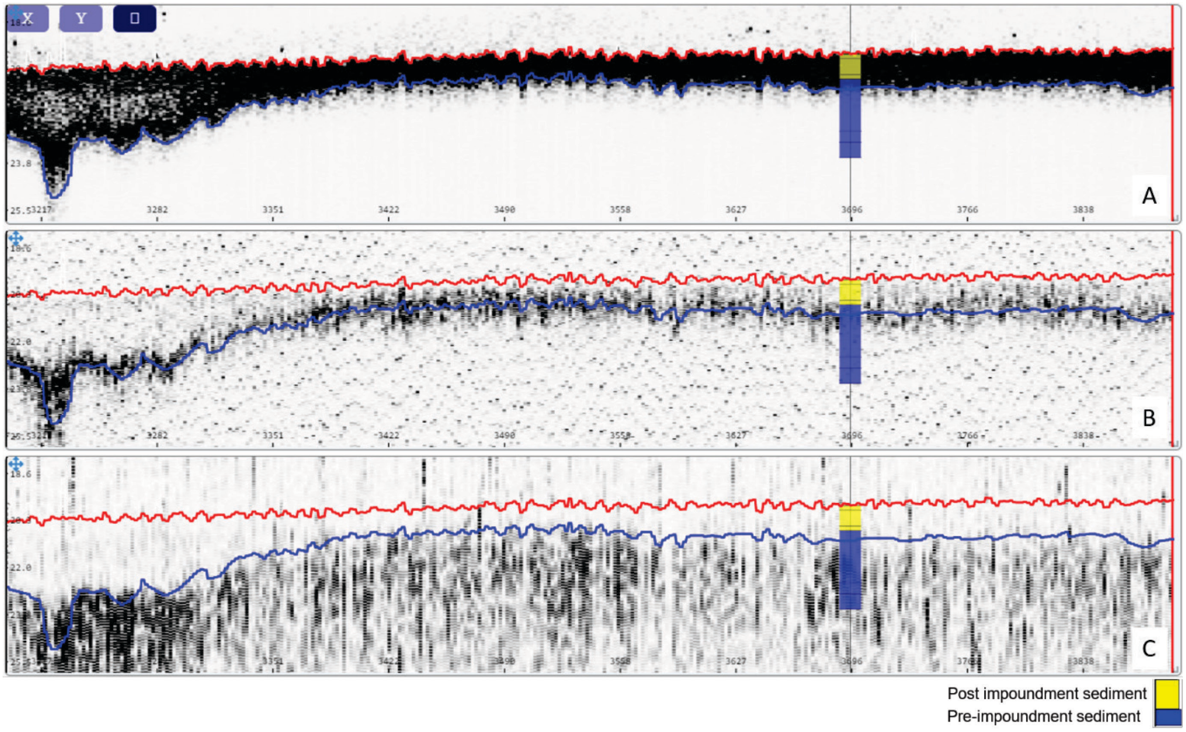

Figure 8. **Comparison of sediment core RCR-6 with acoustic signal returns. A) 208 kHz frequency, B) 50 kHz frequency, and C) 12 kHz frequency. The current surface in red and pre-impoundment surface in blue.**

In this case, the boundary in the 208 kHz signal most closely matched the pre-impoundment interface of the sediment core sample; therefore, the 208 kHz signal was used to locate the pre-impoundment surface (blue line in the top panel in Figure 8). Figure 9 shows sediment core sample RCR-6 correlated with the 208 kHz frequency of the nearest surveyed cross-section. 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.

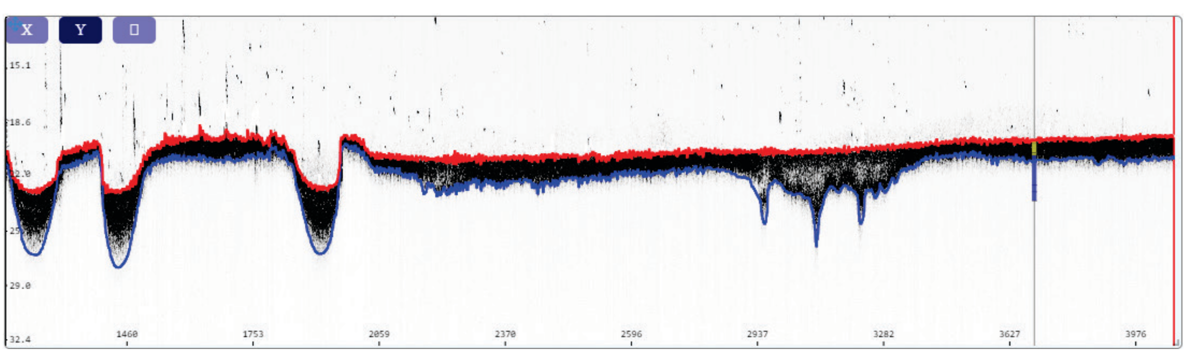

Figure 9. **Cross-section of data collected during survey, displayed in Hydropick (208 kHz frequency), correlated with sediment core sample RCR-6 and showing the current surface in red and pre-impoundment surface in blue.**

The pre-impoundment surface was automatically generated in Hydropick using Otsu's thresholding algorithm of classifying greyscale intensity images into binary (black and white) images based on maximum inter-class variance. The acoustic return images of a selected frequency from each survey line were processed using this technique and the pre-impoundment surface was identified as the bottom black/white interface (where black is the sediment layer) of the resulting binary image (D. Pothina, written commun., 2014). The pre-impoundment surface then is verified and edited manually as needed.

Identification of the pre-impoundment surface can be challenging. Richland-Chambers reservoir has periodically experienced low water levels leading to the desiccation of any exposed sediment. Upon inundation and re-saturation, exposed sediment will not return to its original high level of water content (Dunbar and Allen, 2003). Drying of sediment in exposed areas create hard surfaces that cannot be penetrated with gravity coring techniques, and compressive stresses on the sediments may also increase sediment density, inhibiting the measurement of the original, pre-impoundment surface. Density stratification in the sediment layers can also scatter and attenuate acoustic return signals of the multi-frequency depth sounder (U.S. Army Corps of Engineers, 2013).

After the pre-impoundment surface for all cross-sections is identified, a pre-impoundment TIN model and a sediment thickness TIN model are created following standard GIS techniques (Furnans and Austin, 2007). Pre-impoundment elevations and sediment thicknesses are 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 315.0-foot 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 Richland-Chambers Reservoir (Figure 10). Using ArcInfo software, the pre-impoundment TIN model was used to compute elevation-capacity and elevation-area tables for the purpose of calculating the total volume of accumulated sediment.

Although linear interpolation was used to estimate topography in areas 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 pre-impoundment TIN model are unavoidable. The flat triangles in turn lead to anomalous calculations of surface area and volume at the boundary elevation 315.0 feet. The TWDB evaluated the availability and distribution of survey data and the shape of the elevation-area curve to determine the highest accurate contour modeled by survey data was 311.5 feet. To eliminate the effects of the flat triangles on area and volume calculations, areas between elevations 311.5 and 315.0 feet were linearly interpolated between the computed values, and volumes above elevation 311.5 feet were calculated based on the corrected areas.

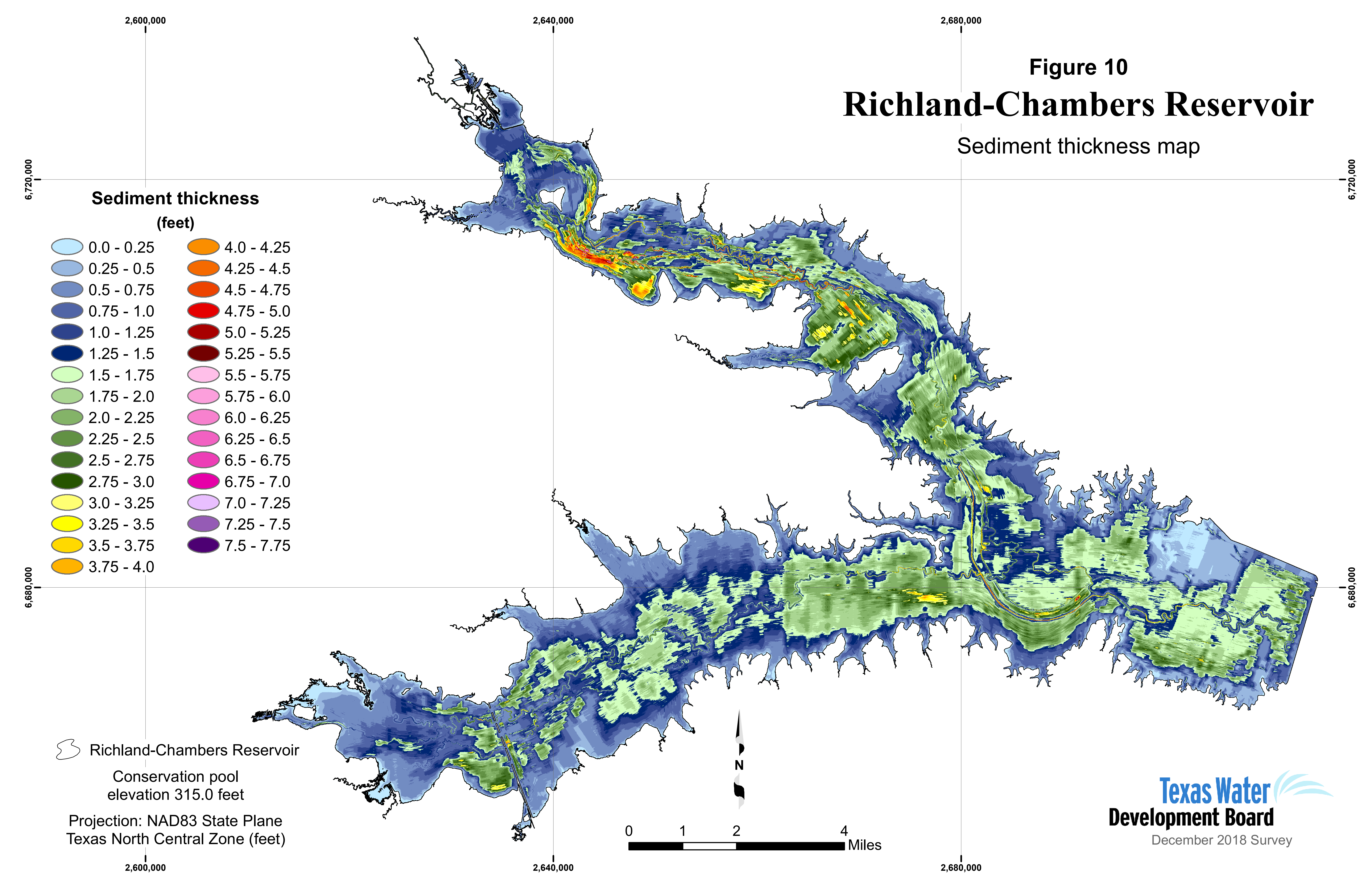

Figure 10
Richland-Chambers Reservoir
Sediment thickness map
Sediment thickness
(feet)
0.0 - 0.25
0.25 - 0.5
0.5 - 0.75
0.75 - 1.0
1.0 - 1.25
1.25 - 1.5
1.5 - 1.75
1.75 - 2.0
2.0 - 2.25
2.25 - 2.5
2.5 - 2.75
2.75 - 3.0
3.0 - 3.25
3.25 - 3.5
3.5 - 3.75
3.75 - 4.0
4.0 - 4.25
4.25 - 4.5
4.5 - 4.75
4.75 - 5.0
5.0 - 5.25
5.25 - 5.5
5.5 - 5.75
5.75 - 6.0
6.0 - 6.25
6.25 - 6.5
6.5 - 6.75
6.75 - 7.0
7.0 - 7.25
7.25 - 7.5
7.5 - 7.75
Richland-Chambers Reservoir
Conservation pool
elevation 315.0 feet
Projection: NAD83 State Plane
Texas North Central Zone (feet)
N
0 1 2 4 Miles
Texas Water
Development Board
December 2018 Survey
2,600,000
2,640,000
2,680,000
6,720,000
6,680,000

Survey results

Volumetric survey

The 2018 TWDB volumetric survey indicates that Richland-Chambers Reservoir has a total reservoir capacity of 1,125,199 acre-feet and encompasses 43,874 acres at conservation pool elevation (315.0 feet above mean sea level, NGVD29). The original design capacity was estimated at 1,181,886 acre-feet. Re-evaluation of the 1994 and 2007 surveys resulted in updated capacity estimates of 1,137,204 acre-feet and 1,123,344 acre-feet (Table 3). Differences in surface area are most likely attributable to differences in reservoir boundary delineation methods. Because of differences in past and present survey methodologies, direct comparison of volumetric surveys to others to estimate loss of area and capacity can be unreliable.

Table 3. Current and previous survey capacity and surface area estimates for Richland-Chambers Reservoir.

Top of conservation pool elevation (315.0 feet NGVD29)			
Survey	**Surface area (acres)**	**Total capacity (acre-feet)**	**Source**
Original design	44,752	1,181,886	S. Sieja, written commun., 1995
TWDB 1994	41,356	1,136,600	Texas Water Development Board, 1995
TWDB 1994 (re-calculated)	45,365	1,137,204	Texas Water Development Board, 2016
TWDB 2007	43,384	1,112,763	Texas Water Development Board, 2009
TWDB 2007 (re-calculated)	43,385	1,123,344	
TWDB 2017	43,874	1,125,199	

Sedimentation survey

The 2018 TWDB sedimentation survey indicates Richland-Chambers Reservoir has lost capacity at an average of 1,886 acre-feet per year since impoundment due to sedimentation below conservation pool elevation (315.0 feet above mean sea level, NGVD29). The long-term trend based on all available surveys indicates Richland-Chambers Reservoir loses capacity at an average of 1,908 acre-feet per year due to sedimentation below conservation pool elevation (315.0 feet above mean sea level, NGVD29). The sedimentation survey indicates sediment accumulation is occurring throughout the reservoir. Comparison of capacity estimates of Richland-

Chambers Reservoir derived using differing methodologies are provided in Table 4 for sedimentation rate calculation.

Table 4. Average annual capacity loss comparisons for Richland-Chambers Reservoir.

Survey	**Volume comparisons at top of conservation pool elevation 315.0 feet (acre-feet)**			
Original design[a]	1,181,886	<>	<>	<>
TWDB 1994 (re-calculated)	<>	1,137,204	<>	<>
TWDB 2007 (re-calculated)	<>	<>	1,123,344	<>
TWDB pre-impoundment estimate based on 2018 survey	<>	<>	<>	1,183,651
2018 volumetric survey	1,125,199	1,125,199	1,125,199	1,125,199
Volume difference (acre-feet)	56,687 (4.8%)	12,005 (1.1%)	-1,855 (0.2%)	58,452 (4.9%)
Number of years	31	24	11	31
Capacity loss rate (acre-feet/year)	1,829	500	-169	1,886
Capacity loss rate (acre-feet/square mile of drainage area of 1,957[a] square miles /year)	0.93	0.26	-0.09	0.96

[a] Source: (S. Sieja, written commun., 1995), note: Deliberate impoundment at Richland-Chambers Dam began on July 14, 1987.

While the results of the 2018 TWDB survey indicate an increase in volume of 1,855 acre-feet since the 2007 TWDB survey, it is highly unlikely that the reservoir is gaining capacity. The difference, 0.2 percent, is within the error margins of both reservoir surveys and is likely a result of differences in survey data coverage, reservoir boundary delineation, and TIN model generation.

To account for short-term variances in sedimentation rate, the TWDB generated a trend line utilizing the pre-impoundment value identified in the 2018 survey and the previous volumetric estimates generated in 1987, 1994, 2007, and 2018 to show the sedimentation rate trend since impoundment. Results show a 1,908 acre-feet per year sedimentation rate and are shown in Figure 11.

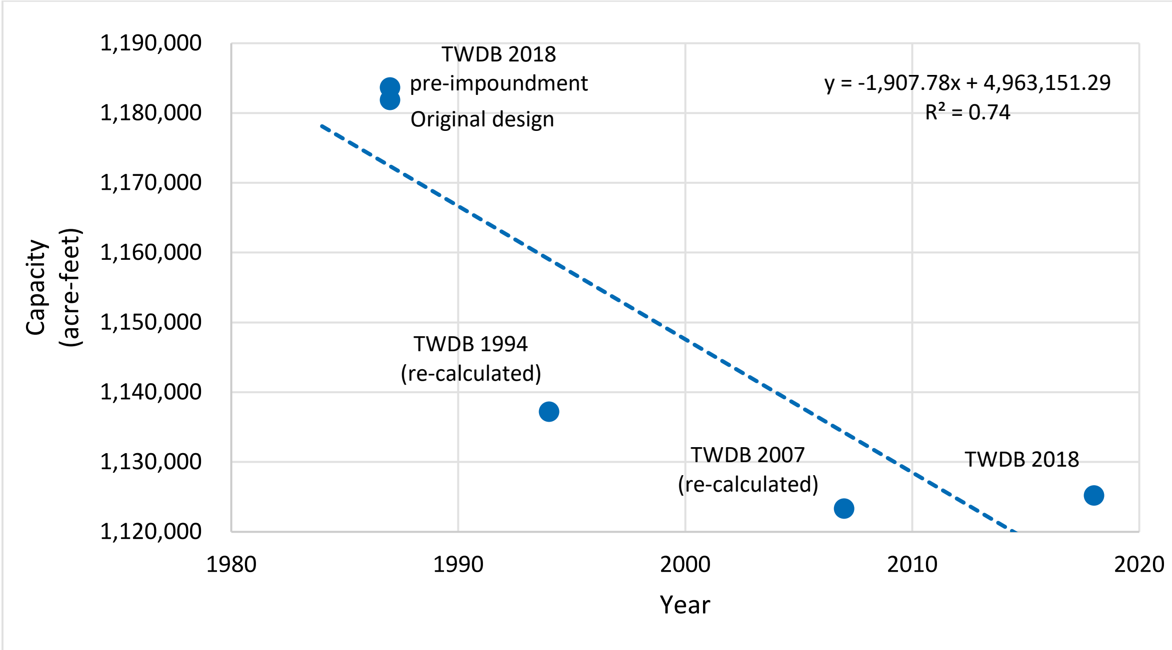

Figure 11. Plot of current and previous capacity estimates (acre-feet) for Richland-Chambers Reservoir. Capacity estimates for each survey plotted as blue dots. The blue trend line illustrates the average loss of capacity through 2018 based on all available survey data.

Sediment range lines

In 2019, the TWDB established fourteen sediment range lines throughout Richland-Chambers Reservoir to measure sediment accumulation over time. A cross-sectional comparison of the fourteen sediment range lines comparing the current bottom surface from the 2018 TWDB survey, the 2007 TWDB re-calculated survey, and the 1994 TWDB re-calculated survey is presented in Appendix M. Also presented in Appendix M are a map, depicting the locations of the sediment range lines and Table M1, 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.

Axial profile

At the request of the Tarrant Regional Water District, the TWDB surveyed the axial profile of the reservoir. This profile showing both the 2018 current and pre-impoundment surfaces is plotted in Appendix N. Also presented in Appendix N are a map, depicting the TWDB location of the axial profile, and a table listing the coordinates of each vertex defining the axial line.

Identification of the pre-impoundment surface on the axial profile was based on the acoustic returns identified in the cross-sections where sediment cores were collected. Sediment core sites were selected to recollect cores where previously collected by the TWDB in 2007 and Specialty Devices, Inc. in 2016 and to correlate with unique acoustic returns throughout the reservoir. Axial profile data points within 1.5 feet of survey data points were compared to refine identification of the pre-impoundment surface along survey transects. Pre-impoundment acoustic signature interpretation was refined based on the agreement between intersecting data and applied during pre-impoundment identifications throughout the reservoir.

Recommendations

The TWDB recommends a detailed analysis of sediment deposits in the areas where exposure of the lake bottom may have led to identification of a false pre-impoundment using augured-coring techniques, as well as a volumetric and sedimentation survey in 10 years or after a major flood event 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

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Appendix A

Richland-Chambers Reservoir

RESERVOIR CAPACITY TABLE

TEXAS WATER DEVELOPMENT BOARD — December 1994 Survey re-calculated November 2016

CAPACITY IN ACRE-FEET — Conservation Pool Elevation 315.0 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
229	0	0	0	0	0	0	0	0	0	0
230	0	0	0	0	0	0	0	0	0	0
231	0	0	0	0	0	0	0	0	0	0
232	0	0	1	1	1	1	1	1	1	1
233	1	1	1	1	1	1	1	1	1	2
234	2	2	2	2	2	2	2	2	2	2
235	3	3	3	3	3	3	3	3	3	4
236	4	4	4	4	4	4	5	5	5	5
237	5	5	6	6	6	6	6	7	7	7
238	7	7	8	8	8	8	8	9	9	9
239	9	10	10	10	10	11	11	11	12	12
240	12	13	13	13	14	14	15	15	15	16
241	16	17	18	18	19	20	20	21	22	23
242	23	24	25	26	27	28	29	30	31	33
243	34	35	37	38	40	41	43	45	47	49
244	51	53	55	57	60	62	65	68	70	73
245	76	79	82	86	89	92	96	100	104	109
246	113	118	123	128	133	139	145	151	157	163
247	170	177	184	192	200	208	217	225	234	244
248	254	264	274	285	296	308	320	332	345	358
249	372	386	400	415	430	446	462	478	495	512
250	530	548	566	585	604	624	644	664	685	706
251	727	749	771	794	817	840	864	888	913	939
252	964	990	1,017	1,044	1,072	1,100	1,129	1,158	1,188	1,218
253	1,250	1,281	1,314	1,347	1,381	1,416	1,451	1,488	1,525	1,563
254	1,602	1,641	1,682	1,723	1,765	1,809	1,853	1,898	1,944	1,991
255	2,039	2,088	2,138	2,189	2,241	2,294	2,349	2,406	2,466	2,528
256	2,594	2,662	2,733	2,808	2,886	2,968	3,052	3,140	3,231	3,326
257	3,424	3,526	3,632	3,742	3,856	3,974	4,095	4,221	4,350	4,484
258	4,622	4,764	4,909	5,059	5,214	5,372	5,535	5,702	5,875	6,054
259	6,238	6,426	6,620	6,819	7,024	7,233	7,448	7,667	7,892	8,122
260	8,356	8,596	8,839	9,088	9,342	9,601	9,867	10,139	10,418	10,703
261	10,994	11,290	11,591	11,898	12,210	12,526	12,848	13,173	13,503	13,837
262	14,177	14,521	14,870	15,223	15,581	15,943	16,310	16,681	17,057	17,438
263	17,824	18,215	18,612	19,015	19,423	19,836	20,255	20,680	21,111	21,548
264	21,991	22,441	22,898	23,362	23,834	24,313	24,799	25,294	25,797	26,307
265	26,823	27,346	27,876	28,413	28,957	29,509	30,067	30,631	31,201	31,777
266	32,360	32,948	33,542	34,142	34,748	35,359	35,976	36,600	37,229	37,865
267	38,506	39,153	39,806	40,466	41,132	41,804	42,483	43,168	43,859	44,558
268	45,264	45,976	46,693	47,417	48,147	48,883	49,627	50,379	51,138	51,904
269	52,677	53,456	54,239	55,027	55,820	56,619	57,424	58,235	59,051	59,873
270	60,701	61,534	62,372	63,216	64,066	64,921	65,781	66,647	67,517	68,393
271	69,273	70,158	71,049	71,946	72,849	73,759	74,675	75,597	76,524	77,457
272	78,395	79,339	80,288	81,241	82,200	83,164	84,133	85,108	86,088	87,074
273	88,063	89,058	90,056	91,059	92,067	93,079	94,097	95,120	96,148	97,181
274	98,219	99,262	100,310	101,364	102,424	103,489	104,561	105,639	106,722	107,812
275	108,908	110,010	111,117	112,231	113,350	114,477	115,610	116,749	117,895	119,049
276	120,211	121,379	122,554	123,736	124,925	126,120	127,322	128,530	129,745	130,966
277	132,196	133,432	134,676	135,925	137,180	138,441	139,707	140,979	142,254	143,535
278	144,820	146,110	147,404	148,702	150,004	151,311	152,621	153,936	155,254	156,578
279	157,905	159,238	160,575	161,917	163,265	164,619	165,980	167,348	168,723	170,104
280	171,493	172,888	174,291	175,702	177,120	178,546	179,979	181,420	182,869	184,325
281	185,788	187,259	188,736	190,220	191,711	193,210	194,715	196,228	197,747	199,274
282	200,809	202,352	203,904	205,464	207,032	208,608	210,192	211,784	213,382	214,987
283	216,601	218,222	219,851	221,486	223,128	224,776	226,431	228,092	229,760	231,436
284	233,119	234,809	236,505	238,207	239,916	241,632	243,354	245,083	246,819	248,562

Appendix A

Richland-Chambers Reservoir

RESERVOIR CAPACITY TABLE (Continued)

TEXAS WATER DEVELOPMENT BOARD — December 1994 Survey re-calculated November 2016

CAPACITY IN ACRE-FEET — Conservation Pool Elevation 315.0 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
285	250,311	252,066	253,826	255,592	257,365	259,144	260,930	262,721	264,519	266,325
286	268,138	269,960	271,790	273,628	275,475	277,329	279,191	281,059	282,934	284,818
287	286,709	288,608	290,513	292,426	294,346	296,273	298,207	300,149	302,097	304,052
288	306,016	307,986	309,963	311,948	313,940	315,939	317,946	319,961	321,983	324,012
289	326,047	328,090	330,139	332,195	334,259	336,330	338,409	340,495	342,588	344,689
290	346,799	348,917	351,044	353,178	355,322	357,474	359,635	361,805	363,981	366,165
291	368,356	370,555	372,762	374,974	377,194	379,422	381,658	383,902	386,153	388,413
292	390,681	392,958	395,242	397,532	399,832	402,140	404,455	406,777	409,105	411,440
293	413,781	416,130	418,484	420,845	423,213	425,588	427,971	430,361	432,758	435,163
294	437,576	439,997	442,427	444,865	447,311	449,766	452,230	454,701	457,179	459,667
295	462,163	464,667	467,179	469,700	472,229	474,767	477,314	479,868	482,431	485,003
296	487,583	490,173	492,771	495,377	497,992	500,615	503,247	505,888	508,537	511,195
297	513,863	516,541	519,228	521,923	524,628	527,342	530,065	532,796	535,535	538,284
298	541,042	543,809	546,585	549,369	552,163	554,966	557,778	560,598	563,426	566,264
299	569,111	571,967	574,832	577,706	580,589	583,482	586,385	589,296	592,217	595,148
300	598,087	601,035	603,993	606,959	609,935	612,921	615,914	618,917	621,928	624,948
301	627,978	631,017	634,065	637,124	640,193	643,273	646,362	649,461	652,569	655,687
302	658,815	661,952	665,098	668,251	671,413	674,584	677,763	680,950	684,145	687,348
303	690,560	693,780	697,007	700,241	703,485	706,735	709,994	713,261	716,534	719,816
304	723,107	726,405	729,712	733,027	736,351	739,685	743,028	746,379	749,739	753,110
305	756,489	759,878	763,276	766,683	770,100	773,526	776,961	780,405	783,857	787,320
306	790,792	794,273	797,764	801,263	804,771	808,289	811,816	815,352	818,895	822,449
307	826,012	829,585	833,169	836,764	840,371	843,989	847,617	851,255	854,901	858,558
308	862,224	865,900	869,585	873,279	876,984	880,699	884,424	888,159	891,904	895,662
309	897,384	900,934	904,497	908,074	911,666	915,272	918,892	922,526	926,175	929,838
310	933,516	937,208	940,915	944,637	948,373	952,124	955,890	959,670	963,466	967,277
311	971,103	974,944	978,800	982,671	986,558	990,460	994,377	998,310	1,002,259	1,006,223
312	1,010,203	1,014,198	1,018,209	1,022,237	1,026,280	1,030,339	1,034,414	1,038,505	1,042,613	1,046,737
313	1,050,877	1,055,033	1,059,206	1,063,395	1,067,601	1,071,824	1,076,063	1,080,319	1,084,592	1,088,882
314	1,093,189	1,097,512	1,101,853	1,106,211	1,110,587	1,114,979	1,119,389	1,123,817	1,128,262	1,132,724
315	1,137,204									

Note: Capacities from elevation 309.0 to 315.0 feet from Blaylock, L., 2003, Richland Chambers Surface Area/Capacity Table Analysis: Tarrant Regional Water District Memorandum, p. 19-32.

Appendix B

Richland-Chambers Reservoir

RESERVOIR AREA TABLE

TEXAS WATER DEVELOPMENT BOARD — December 1994 Survey re-calculated November 2016

AREA IN ACRES — Conservation Pool Elevation 315.0 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
229	0	0	0	0	0	0	0	0	0	0
230	0	0	0	0	0	0	0	0	0	0
231	0	0	0	0	0	0	0	0	0	0
232	0	0	0	0	0	0	0	1	1	1
233	1	1	1	1	1	1	1	1	1	1
234	1	1	1	1	1	1	1	1	1	1
235	1	1	1	1	1	1	1	1	1	1
236	1	1	1	1	1	2	2	2	2	2
237	2	2	2	2	2	2	2	2	2	2
238	2	2	2	2	2	2	2	2	2	2
239	2	3	3	3	3	3	3	3	3	3
240	3	3	4	4	4	4	4	5	5	5
241	5	6	6	6	7	7	7	7	8	8
242	8	9	9	10	10	11	11	11	12	12
243	13	14	14	15	16	17	18	19	19	20
244	21	22	23	23	24	25	26	27	28	29
245	30	31	32	33	35	36	38	40	42	44
246	47	49	51	53	55	56	58	61	63	66
247	68	72	75	78	80	83	86	90	93	96
248	100	103	107	110	114	117	121	125	130	134
249	138	142	146	150	154	158	162	166	170	174
250	178	182	186	189	193	197	201	205	209	213
251	216	220	224	228	233	237	241	246	250	255
252	259	264	269	274	279	284	290	296	302	308
253	315	322	329	336	344	351	359	367	376	384
254	393	401	409	417	426	436	446	456	465	475
255	485	494	505	515	528	541	560	584	609	638
256	668	697	732	765	798	828	863	896	928	965
257	1,000	1,039	1,082	1,120	1,157	1,195	1,234	1,274	1,316	1,359
258	1,399	1,437	1,479	1,521	1,563	1,604	1,651	1,705	1,759	1,811
259	1,862	1,913	1,966	2,017	2,067	2,119	2,172	2,225	2,271	2,320
260	2,369	2,416	2,463	2,513	2,566	2,622	2,689	2,758	2,817	2,878
261	2,935	2,988	3,041	3,093	3,143	3,189	3,233	3,277	3,322	3,368
262	3,417	3,464	3,512	3,557	3,600	3,643	3,690	3,736	3,782	3,834
263	3,888	3,942	3,996	4,052	4,107	4,164	4,220	4,279	4,339	4,402
264	4,467	4,532	4,604	4,681	4,751	4,824	4,905	4,992	5,068	5,131
265	5,194	5,261	5,333	5,409	5,482	5,548	5,612	5,670	5,730	5,793
266	5,856	5,914	5,971	6,027	6,084	6,143	6,205	6,266	6,323	6,381
267	6,441	6,499	6,565	6,631	6,693	6,754	6,815	6,884	6,953	7,023
268	7,089	7,148	7,208	7,266	7,330	7,399	7,476	7,559	7,630	7,699
269	7,756	7,806	7,856	7,906	7,961	8,021	8,081	8,137	8,191	8,245
270	8,300	8,359	8,415	8,467	8,521	8,575	8,629	8,683	8,731	8,778
271	8,827	8,881	8,941	9,000	9,064	9,132	9,191	9,244	9,298	9,356
272	9,410	9,462	9,514	9,563	9,612	9,664	9,721	9,777	9,829	9,875
273	9,919	9,964	10,009	10,053	10,100	10,151	10,202	10,255	10,306	10,354
274	10,405	10,457	10,511	10,567	10,625	10,685	10,747	10,809	10,868	10,927
275	10,985	11,045	11,106	11,166	11,232	11,297	11,359	11,427	11,501	11,576
276	11,651	11,719	11,786	11,854	11,921	11,985	12,049	12,115	12,179	12,253
277	12,331	12,400	12,462	12,523	12,583	12,636	12,688	12,735	12,782	12,829
278	12,875	12,919	12,961	13,003	13,043	13,084	13,126	13,168	13,209	13,253
279	13,298	13,346	13,397	13,453	13,511	13,576	13,644	13,712	13,780	13,850
280	13,919	13,991	14,070	14,144	14,217	14,294	14,373	14,452	14,525	14,596
281	14,669	14,740	14,808	14,876	14,946	15,017	15,089	15,160	15,231	15,308
282	15,388	15,474	15,560	15,643	15,722	15,800	15,878	15,949	16,019	16,093
283	16,173	16,250	16,320	16,388	16,451	16,514	16,581	16,649	16,722	16,794
284	16,862	16,928	16,991	17,055	17,122	17,192	17,257	17,327	17,394	17,458

Appendix B

Richland-Chambers Reservoir

RESERVOIR AREA TABLE (Continued)

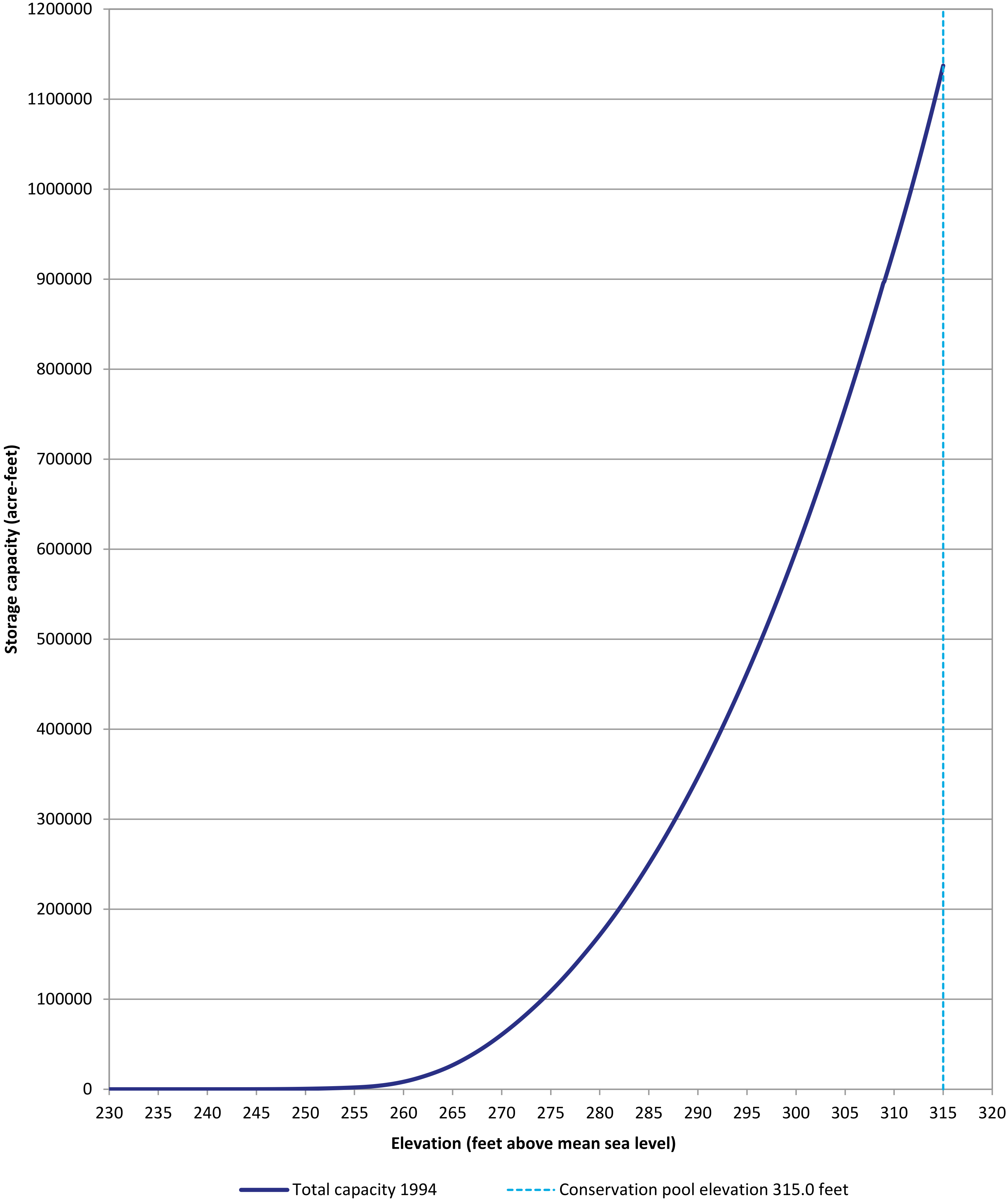
TEXAS WATER DEVELOPMENT BOARD | December 1994 Survey re-calculated November 2016

AREA IN ACRES | Conservation Pool Elevation 315.0 feet NGVD29

ELEVATION INCREMENT IS ONE TENTH FOOT

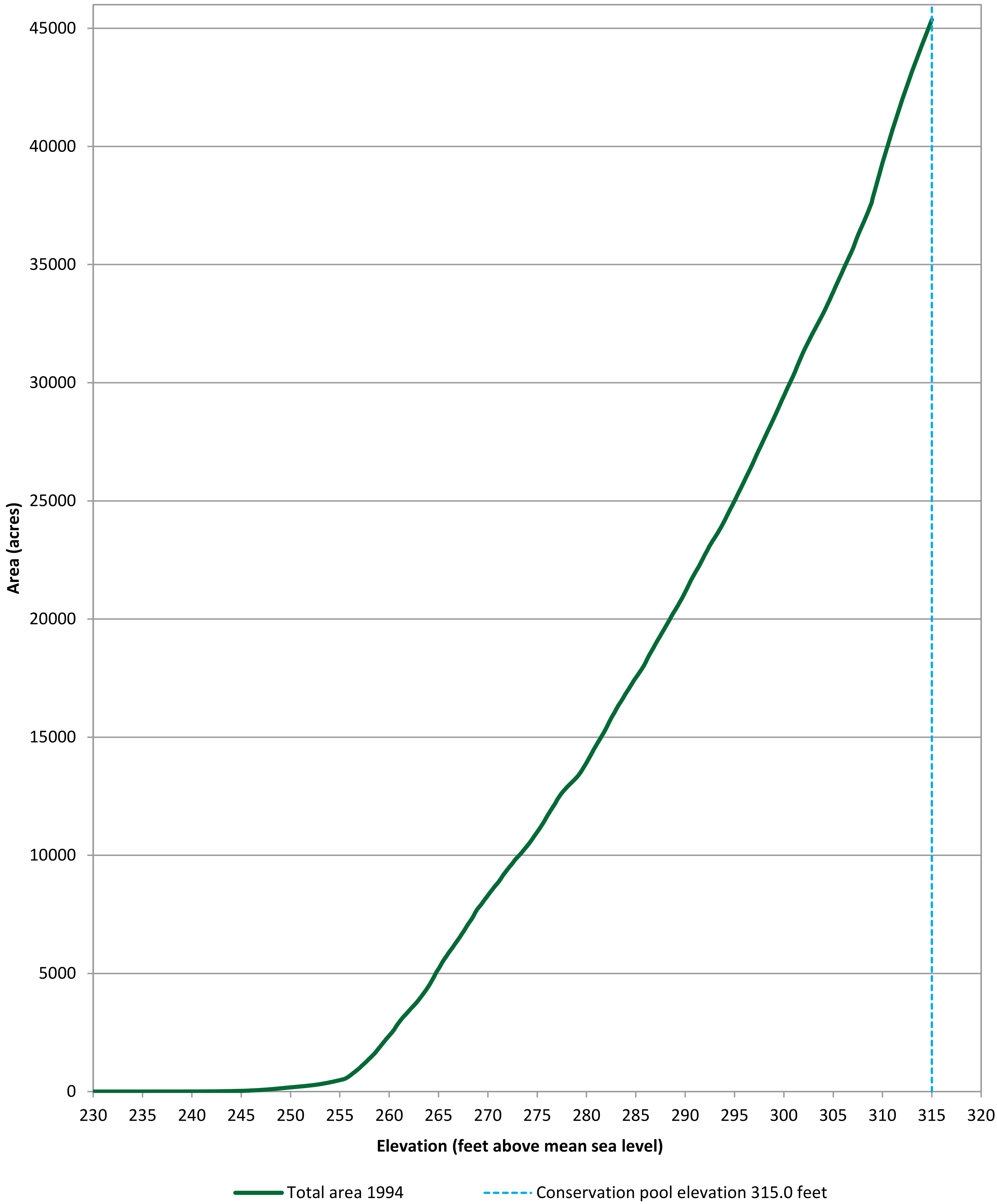
ELEVATION in Feet	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
285	17,518	17,576	17,635	17,697	17,760	17,821	17,882	17,948	18,019	18,091
286	18,172	18,262	18,346	18,427	18,504	18,577	18,649	18,719	18,793	18,873
287	18,949	19,022	19,094	19,163	19,232	19,306	19,380	19,450	19,522	19,593
288	19,666	19,739	19,810	19,883	19,954	20,034	20,111	20,185	20,256	20,322
289	20,388	20,459	20,528	20,599	20,673	20,748	20,821	20,895	20,974	21,056
290	21,139	21,223	21,305	21,390	21,479	21,568	21,651	21,728	21,802	21,877
291	21,954	22,026	22,095	22,163	22,238	22,315	22,398	22,477	22,558	22,643
292	22,723	22,801	22,874	22,953	23,040	23,113	23,182	23,250	23,319	23,382
293	23,447	23,513	23,578	23,645	23,716	23,789	23,860	23,934	24,012	24,091
294	24,171	24,253	24,340	24,424	24,508	24,591	24,673	24,749	24,830	24,916
295	24,998	25,081	25,166	25,253	25,339	25,420	25,502	25,588	25,676	25,761
296	25,847	25,936	26,023	26,107	26,192	26,276	26,363	26,449	26,538	26,629
297	26,724	26,820	26,914	27,005	27,093	27,182	27,268	27,354	27,445	27,534
298	27,625	27,715	27,801	27,893	27,985	28,071	28,156	28,242	28,335	28,422
299	28,514	28,605	28,695	28,787	28,882	28,973	29,069	29,163	29,260	29,349
300	29,434	29,526	29,624	29,715	29,808	29,894	29,979	30,071	30,159	30,245
301	30,339	30,434	30,538	30,644	30,744	30,840	30,940	31,039	31,135	31,231
302	31,324	31,412	31,496	31,579	31,662	31,745	31,829	31,914	31,994	32,075
303	32,155	32,234	32,311	32,390	32,468	32,546	32,624	32,702	32,781	32,860
304	32,943	33,027	33,110	33,199	33,290	33,380	33,467	33,560	33,656	33,747
305	33,839	33,933	34,027	34,121	34,213	34,303	34,396	34,486	34,576	34,669
306	34,767	34,859	34,951	35,040	35,131	35,219	35,312	35,400	35,487	35,579
307	35,678	35,782	35,899	36,013	36,123	36,230	36,328	36,427	36,520	36,613
308	36,707	36,802	36,899	36,997	37,095	37,195	37,301	37,406	37,516	37,625
309	37,808	37,956	38,104	38,253	38,403	38,553	38,703	38,855	39,007	39,159
310	39,312	39,448	39,585	39,722	39,859	39,998	40,136	40,275	40,414	40,554
311	40,695	40,822	40,950	41,078	41,207	41,336	41,465	41,595	41,725	41,855
312	41,986	42,105	42,224	42,343	42,462	42,582	42,702	42,823	42,944	43,065
313	43,187	43,296	43,406	43,516	43,627	43,738	43,849	43,960	44,072	44,183
314	44,296	44,401	44,508	44,614	44,720	44,827	44,934	45,042	45,149	45,257
315	45,365									

Note: Areas from elevation 309.0 to 315.0 feet from Blaylock, L., 2003, Richland Chambers Surface Area/Capacity Table Analysis: Tarrant Regional Water District Memorandum, p. 19-32.



Richland-Chambers Reservoir
December 1994 Survey
re-calculated November 2016
Prepared by: TWDB

Appendix C: Capacity curve



Richland-Chambers Reservoir
December 1994 Survey
re-calculated November 2016
Prepared by: TWDB

Appendix D: Area curve

Appendix E

Richland-Chambers Reservoir

RESERVOIR CAPACITY TABLE

TEXAS WATER DEVELOPMENT BOARD | October 2007 Survey re-calculated December 2018

CAPACITY IN ACRE-FEET | Conservation Pool Elevation 315.0 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
235	0	0	0	0	0	0	0	0	0	0
236	0	0	0	0	0	0	0	0	1	1
237	1	1	1	1	1	1	1	1	1	1
238	2	2	2	2	2	2	2	2	2	3
239	3	3	3	3	3	3	4	4	4	4
240	4	4	4	5	5	5	5	5	5	6
241	6	6	6	6	7	7	7	7	8	8
242	8	8	9	9	10	10	10	11	11	12
243	12	13	13	14	15	15	16	17	18	18
244	19	20	21	22	24	25	26	27	29	30
245	32	34	35	37	39	41	44	46	48	51
246	54	56	59	62	65	68	72	75	79	83
247	87	91	95	99	103	108	113	117	122	127
248	133	138	144	149	155	162	168	175	182	190
249	198	207	216	226	236	246	258	269	281	293
250	305	318	332	345	359	374	389	404	420	436
251	453	470	487	505	523	542	561	580	600	620
252	641	662	683	705	728	751	774	798	822	846
253	872	897	923	949	976	1,004	1,032	1,060	1,089	1,119
254	1,149	1,180	1,211	1,243	1,276	1,309	1,343	1,378	1,413	1,449
255	1,486	1,524	1,562	1,602	1,641	1,682	1,723	1,765	1,807	1,851
256	1,895	1,940	1,987	2,034	2,082	2,132	2,183	2,236	2,290	2,347
257	2,406	2,468	2,532	2,600	2,670	2,745	2,823	2,905	2,991	3,079
258	3,170	3,265	3,362	3,463	3,568	3,677	3,789	3,905	4,025	4,150
259	4,279	4,413	4,552	4,694	4,840	4,989	5,143	5,300	5,462	5,628
260	5,799	5,975	6,156	6,342	6,532	6,727	6,927	7,132	7,342	7,557
261	7,777	8,003	8,233	8,468	8,708	8,953	9,202	9,457	9,717	9,983
262	10,256	10,536	10,820	11,109	11,402	11,700	12,003	12,311	12,625	12,943
263	13,266	13,594	13,927	14,265	14,607	14,954	15,305	15,661	16,020	16,383
264	16,750	17,121	17,496	17,876	18,260	18,649	19,042	19,440	19,843	20,253
265	20,669	21,092	21,521	21,956	22,397	22,845	23,299	23,760	24,227	24,701
266	25,183	25,671	26,168	26,672	27,184	27,703	28,231	28,766	29,310	29,862
267	30,422	30,989	31,562	32,142	32,727	33,318	33,915	34,518	35,128	35,745
268	36,369	37,000	37,638	38,282	38,933	39,590	40,255	40,926	41,605	42,291
269	42,983	43,683	44,389	45,103	45,825	46,553	47,288	48,029	48,776	49,528
270	50,286	51,049	51,817	52,590	53,368	54,152	54,942	55,738	56,539	57,346
271	58,159	58,978	59,804	60,635	61,472	62,315	63,165	64,020	64,882	65,749
272	66,621	67,500	68,384	69,276	70,174	71,079	71,990	72,907	73,830	74,759
273	75,694	76,635	77,582	78,534	79,492	80,455	81,425	82,400	83,380	84,367
274	85,360	86,358	87,362	88,370	89,385	90,405	91,431	92,461	93,496	94,537
275	95,585	96,639	97,700	98,768	99,844	100,926	102,016	103,111	104,211	105,317
276	106,429	107,545	108,668	109,797	110,933	112,076	113,227	114,386	115,552	116,727
277	117,909	119,101	120,301	121,510	122,726	123,950	125,181	126,419	127,663	128,913
278	130,167	131,427	132,692	133,962	135,237	136,518	137,802	139,092	140,386	141,685
279	142,989	144,297	145,610	146,928	148,252	149,581	150,917	152,258	153,605	154,958
280	156,318	157,684	159,058	160,440	161,829	163,226	164,630	166,042	167,462	168,890
281	170,325	171,768	173,218	174,674	176,138	177,608	179,085	180,570	182,061	183,561
282	185,069	186,583	188,106	189,636	191,174	192,719	194,271	195,832	197,399	198,974
283	200,555	202,144	203,739	205,342	206,954	208,574	210,203	211,839	213,483	215,133
284	216,791	218,455	220,126	221,803	223,488	225,178	226,875	228,578	230,288	232,006
285	233,730	235,461	237,199	238,942	240,693	242,451	244,215	245,986	247,764	249,549
286	251,342	253,143	254,952	256,768	258,593	260,427	262,268	264,117	265,974	267,840
287	269,714	271,596	273,485	275,382	277,286	279,197	281,115	283,040	284,972	286,912
288	288,860	290,816	292,779	294,750	296,729	298,716	300,710	302,711	304,719	306,734
289	308,757	310,786	312,823	314,867	316,917	318,974	321,038	323,111	325,192	327,280
290	329,377	331,482	333,595	335,715	337,843	339,979	342,123	344,274	346,432	348,598

Appendix E

Richland-Chambers Reservoir

RESERVOIR CAPACITY TABLE (Continued)

TEXAS WATER DEVELOPMENT BOARD — October 2007 Survey re-calculated December 2018

CAPACITY IN ACRE-FEET — Conservation Pool Elevation 315.0 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
291	350,772	352,952	355,140	357,335	359,538	361,748	363,965	366,190	368,422	370,664
292	372,913	375,171	377,437	379,710	381,990	384,278	386,574	388,876	391,186	393,504
293	395,830	398,164	400,505	402,852	405,208	407,570	409,940	412,318	414,702	417,093
294	419,492	421,899	424,313	426,734	429,165	431,602	434,048	436,501	438,962	441,430
295	443,906	446,390	448,882	451,382	453,890	456,407	458,931	461,464	464,005	466,553
296	469,110	471,674	474,246	476,826	479,416	482,016	484,624	487,242	489,868	492,505
297	495,150	497,805	500,468	503,140	505,822	508,513	511,212	513,919	516,634	519,357
298	522,089	524,829	527,578	530,334	533,101	535,878	538,663	541,456	544,256	547,065
299	549,882	552,708	555,543	558,386	561,240	564,103	566,974	569,855	572,744	575,644
300	578,553	581,471	584,399	587,334	590,280	593,234	596,198	599,170	602,150	605,139
301	608,137	611,143	614,157	617,178	620,208	623,245	626,291	629,345	632,406	635,478
302	638,560	641,652	644,755	647,867	650,990	654,123	657,266	660,418	663,579	666,751
303	669,932	673,124	676,325	679,534	682,752	685,978	689,214	692,458	695,710	698,972
304	702,242	705,521	708,808	712,102	715,405	718,716	722,037	725,366	728,703	732,051
305	735,407	738,773	742,149	745,535	748,932	752,341	755,762	759,196	762,641	766,099
306	769,568	773,047	776,536	780,035	783,546	787,068	790,600	794,144	797,696	801,259
307	804,832	808,417	812,014	815,622	819,245	822,880	826,527	830,186	833,855	837,538
308	841,231	844,934	848,647	852,369	856,102	859,846	863,601	867,367	871,144	874,935
309	878,738	882,554	886,380	890,217	894,064	897,921	901,788	905,664	909,548	913,443
310	917,347	921,260	925,181	929,108	933,045	936,989	940,940	944,899	948,864	952,839
311	956,822	960,814	964,815	968,824	972,843	976,870	980,906	984,950	989,004	993,066
312	997,137	1,001,217	1,005,305	1,009,402	1,013,508	1,017,623	1,021,747	1,025,879	1,030,020	1,034,170
313	1,038,329	1,042,496	1,046,672	1,050,857	1,055,051	1,059,254	1,063,465	1,067,685	1,071,914	1,076,152
314	1,080,398	1,084,653	1,088,917	1,093,190	1,097,471	1,101,761	1,106,061	1,110,368	1,114,685	1,119,010
315	1,123,344									

Note: Capacities above elevation 310.8 feet calculated from interpolated areas

Appendix F

Richland-Chambers Reservoir

RESERVOIR AREA TABLE

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

October 2007 Survey re-calculated December 2018
Conservation Pool Elevation 315.0 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
235	0	0	0	0	0	0	0	0	0	0
236	0	0	0	0	1	1	1	1	1	1
237	1	1	1	1	1	1	1	1	1	1
238	1	1	1	1	1	1	1	1	1	1
239	1	1	1	1	1	1	1	1	2	2
240	2	2	2	2	2	2	2	2	2	2
241	2	2	2	2	2	2	2	2	3	3
242	3	3	4	4	4	4	4	5	5	5
243	5	6	6	6	6	7	7	8	8	9
244	9	10	10	11	12	12	13	14	15	15
245	16	17	18	19	20	22	23	24	25	26
246	27	28	29	30	32	33	34	36	37	38
247	39	41	42	43	45	46	48	49	50	52
248	53	55	56	59	61	64	67	70	74	78
249	84	89	95	100	104	108	112	116	120	123
250	127	131	135	139	143	147	151	155	159	164
251	168	172	176	180	184	188	192	196	201	205
252	209	213	218	222	226	231	235	239	244	248
253	253	257	262	267	272	277	282	288	294	299
254	305	311	317	323	329	336	343	350	358	366
255	374	381	388	395	401	408	415	422	430	438
256	447	457	467	478	490	504	519	537	558	579
257	602	629	659	691	727	764	803	839	869	898
258	929	960	992	1,028	1,066	1,104	1,141	1,180	1,224	1,272
259	1,319	1,364	1,402	1,439	1,476	1,515	1,555	1,595	1,636	1,684
260	1,736	1,791	1,836	1,877	1,923	1,972	2,026	2,077	2,126	2,176
261	2,228	2,280	2,329	2,374	2,421	2,469	2,519	2,572	2,632	2,699
262	2,763	2,818	2,866	2,913	2,957	3,004	3,055	3,108	3,158	3,206
263	3,256	3,305	3,356	3,401	3,445	3,490	3,534	3,573	3,611	3,650
264	3,689	3,730	3,776	3,819	3,864	3,907	3,953	4,010	4,067	4,130
265	4,193	4,256	4,318	4,383	4,446	4,511	4,575	4,639	4,706	4,777
266	4,850	4,927	5,005	5,081	5,155	5,231	5,317	5,398	5,481	5,556
267	5,633	5,703	5,765	5,824	5,881	5,939	5,999	6,065	6,133	6,202
268	6,277	6,344	6,411	6,474	6,545	6,608	6,676	6,753	6,824	6,891
269	6,961	7,029	7,104	7,177	7,244	7,316	7,381	7,443	7,498	7,553
270	7,603	7,653	7,705	7,756	7,812	7,869	7,927	7,983	8,040	8,100
271	8,162	8,226	8,287	8,345	8,399	8,459	8,525	8,587	8,642	8,698
272	8,754	8,814	8,878	8,948	9,015	9,081	9,143	9,203	9,260	9,318
273	9,380	9,439	9,495	9,548	9,605	9,665	9,722	9,781	9,837	9,895
274	9,953	10,010	10,065	10,117	10,175	10,228	10,278	10,326	10,381	10,444
275	10,506	10,576	10,648	10,720	10,791	10,859	10,922	10,981	11,032	11,086
276	11,139	11,195	11,259	11,327	11,395	11,468	11,545	11,625	11,706	11,789
277	11,866	11,959	12,047	12,129	12,202	12,274	12,346	12,411	12,468	12,522
278	12,574	12,624	12,674	12,727	12,776	12,824	12,872	12,919	12,965	13,014
279	13,059	13,106	13,157	13,209	13,265	13,323	13,382	13,440	13,502	13,563
280	13,629	13,702	13,780	13,855	13,928	14,004	14,081	14,161	14,241	14,316
281	14,390	14,463	14,532	14,601	14,668	14,736	14,806	14,880	14,959	15,036
282	15,110	15,186	15,263	15,340	15,414	15,487	15,564	15,641	15,713	15,781
283	15,848	15,917	15,994	16,077	16,158	16,243	16,324	16,402	16,472	16,539
284	16,606	16,675	16,743	16,811	16,875	16,937	16,999	17,067	17,139	17,209
285	17,276	17,342	17,407	17,476	17,541	17,606	17,676	17,744	17,817	17,891
286	17,967	18,047	18,128	18,209	18,290	18,373	18,453	18,534	18,614	18,698
287	18,779	18,857	18,931	19,003	19,075	19,145	19,217	19,289	19,360	19,438
288	19,515	19,593	19,674	19,752	19,831	19,905	19,973	20,044	20,120	20,189
289	20,257	20,331	20,405	20,470	20,534	20,605	20,685	20,768	20,848	20,926
290	21,008	21,088	21,168	21,242	21,317	21,395	21,475	21,552	21,622	21,696

Appendix F

Richland-Chambers Reservoir

RESERVOIR AREA TABLE (Continued)

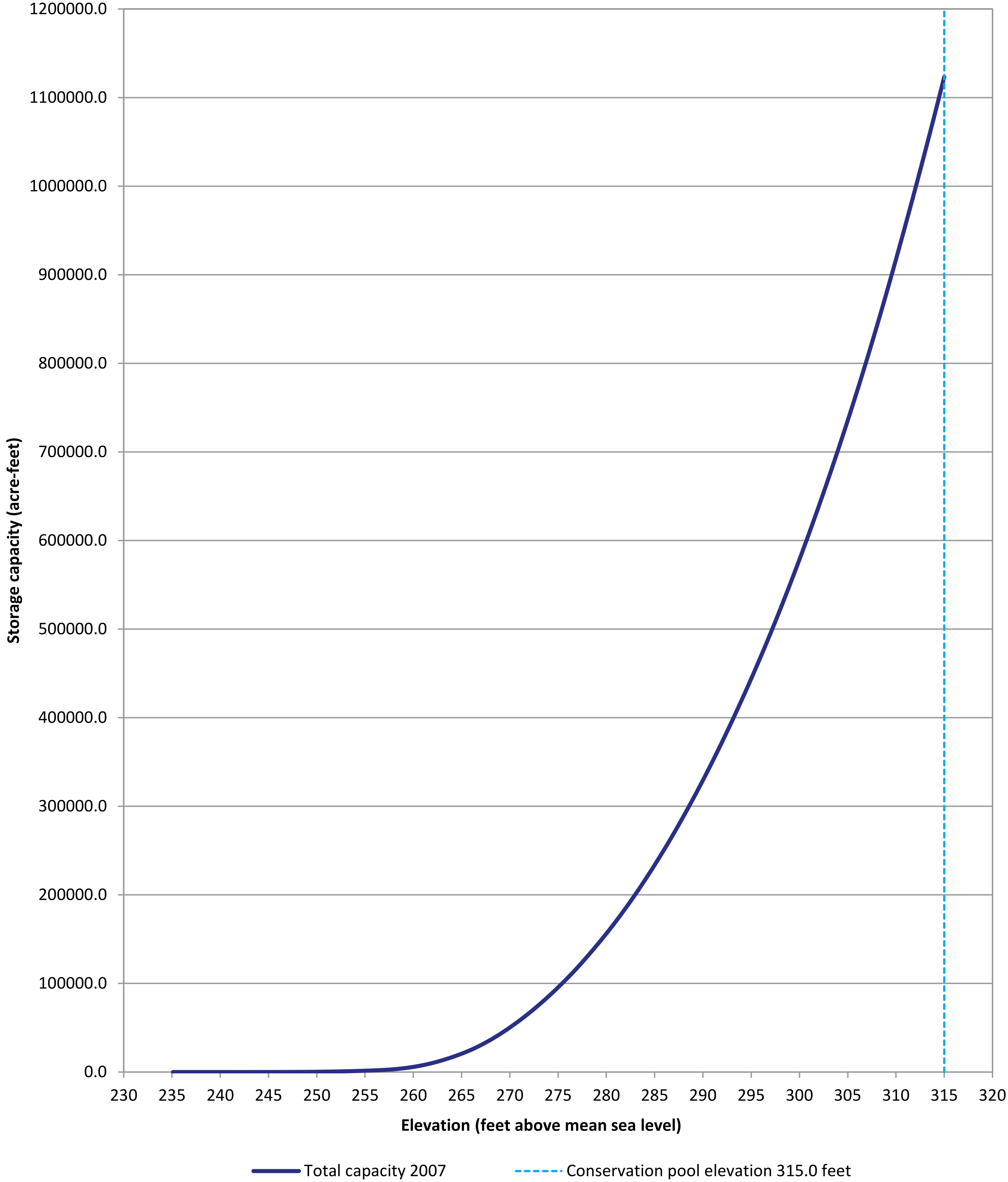
TEXAS WATER DEVELOPMENT BOARD — October 2007 Survey re-calculated December 2018

AREA IN ACRES — Conservation Pool Elevation 315.0 feet NGVD29

ELEVATION INCREMENT IS ONE TENTH FOOT

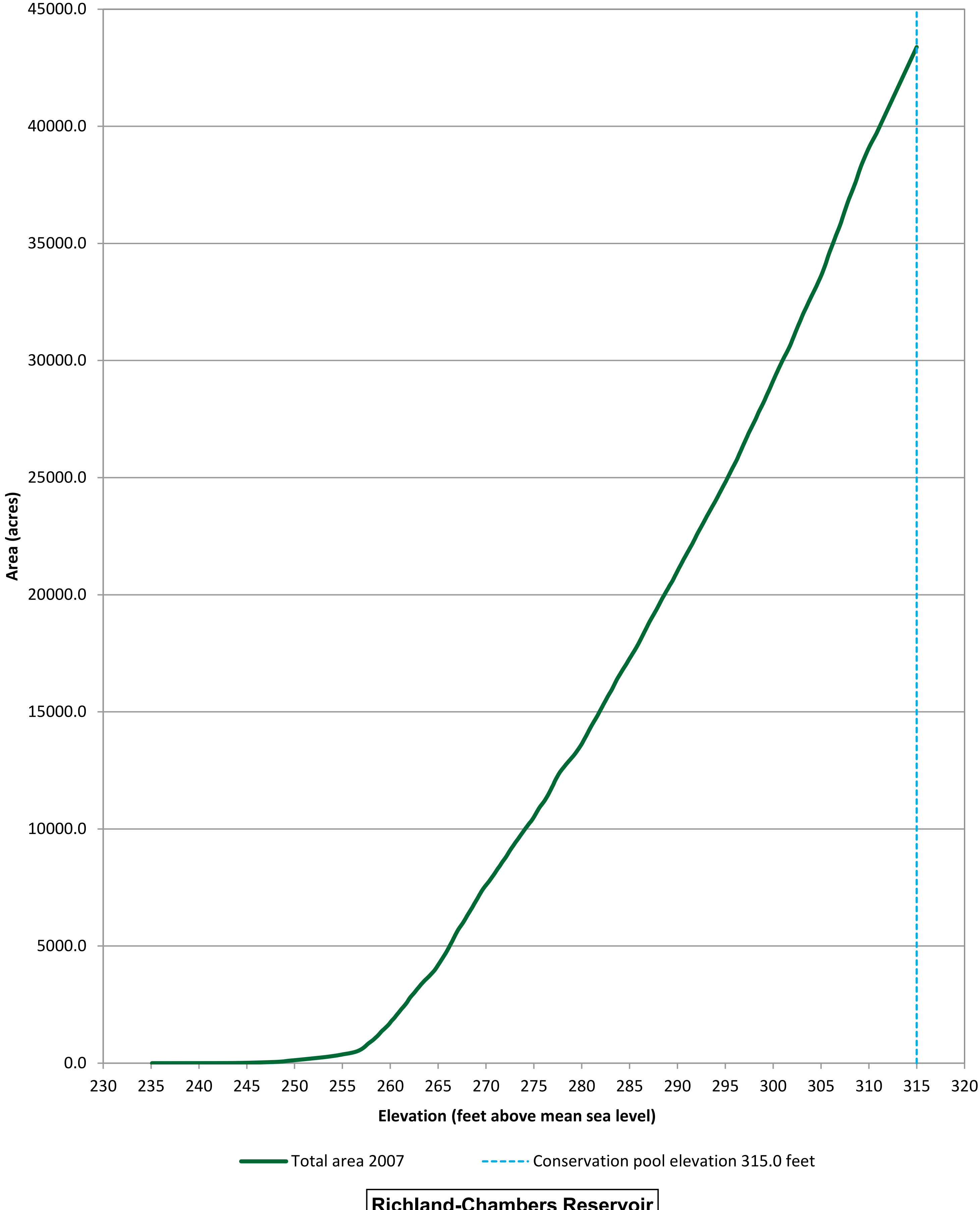
ELEVATION in Feet	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
291	21,769	21,844	21,915	21,989	22,061	22,132	22,209	22,291	22,370	22,453
292	22,538	22,619	22,694	22,768	22,841	22,914	22,990	23,063	23,141	23,219
293	23,295	23,373	23,444	23,516	23,591	23,663	23,737	23,809	23,879	23,951
294	24,025	24,103	24,179	24,261	24,339	24,416	24,492	24,571	24,648	24,723
295	24,797	24,877	24,961	25,042	25,122	25,204	25,287	25,370	25,448	25,523
296	25,602	25,679	25,761	25,850	25,947	26,040	26,130	26,222	26,316	26,409
297	26,498	26,589	26,679	26,768	26,864	26,949	27,031	27,111	27,194	27,277
298	27,358	27,441	27,524	27,620	27,716	27,808	27,889	27,969	28,048	28,130
299	28,214	28,300	28,394	28,491	28,581	28,668	28,757	28,849	28,947	29,042
300	29,136	29,227	29,320	29,411	29,496	29,588	29,678	29,763	29,848	29,936
301	30,019	30,099	30,179	30,255	30,331	30,411	30,495	30,579	30,668	30,765
302	30,873	30,973	31,072	31,179	31,278	31,379	31,478	31,572	31,666	31,762
303	31,864	31,962	32,054	32,138	32,220	32,306	32,397	32,487	32,572	32,657
304	32,742	32,825	32,906	32,989	33,072	33,155	33,246	33,338	33,426	33,515
305	33,609	33,706	33,812	33,922	34,029	34,145	34,268	34,399	34,519	34,633
306	34,738	34,841	34,945	35,052	35,160	35,271	35,378	35,479	35,578	35,680
307	35,791	35,903	36,035	36,160	36,285	36,407	36,526	36,647	36,763	36,877
308	36,978	37,078	37,178	37,281	37,387	37,492	37,599	37,715	37,842	37,971
309	38,093	38,209	38,318	38,422	38,520	38,616	38,713	38,807	38,902	38,993
310	39,081	39,167	39,246	39,324	39,399	39,474	39,550	39,625	39,701	39,788
311	39,876	39,964	40,052	40,139	40,227	40,315	40,402	40,490	40,578	40,666
312	40,753	40,841	40,929	41,016	41,104	41,192	41,280	41,367	41,455	41,543
313	41,631	41,718	41,806	41,894	41,981	42,069	42,157	42,245	42,332	42,420
314	42,508	42,596	42,683	42,771	42,859	42,946	43,034	43,122	43,210	43,297
315	43,385									

Note: Areas between elevations 310.8 and 315.0 feet linearly interpolated



Richland-Chambers Reservoir
October 2007 Survey
re-calculated December 2018
Prepared by: TWDB

Appendix G: Capacity curve



Richland-Chambers Reservoir
October 2007 Survey
re-calculated December 2018
Prepared by: TWDB

Appendix H: Area curve

Appendix I

Richland-Chambers Reservoir

RESERVOIR CAPACITY TABLE

TEXAS WATER DEVELOPMENT BOARD — December 2018 Survey

CAPACITY IN ACRE-FEET — Conservation Pool Elevation 315.0 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
238	0	0	0	0	0	0	0	0	0	0
239	0	0	0	0	0	0	0	0	0	0
240	0	1	1	1	1	1	1	1	1	1
241	1	1	1	2	2	2	2	2	2	2
242	2	2	3	3	3	3	3	3	4	4
243	4	5	5	5	6	6	7	7	8	8
244	9	9	10	11	11	12	13	14	15	16
245	17	18	19	20	22	23	25	27	29	31
246	33	35	37	40	42	45	48	51	54	57
247	60	64	67	71	75	79	83	88	92	97
248	101	107	112	117	123	129	134	141	147	154
249	161	168	176	184	193	202	212	222	233	244
250	256	268	280	294	307	321	335	350	365	381
251	397	413	430	448	466	484	503	522	542	561
252	582	603	624	646	668	690	713	737	761	785
253	810	835	860	887	913	940	968	996	1,025	1,055
254	1,085	1,116	1,147	1,179	1,212	1,245	1,279	1,314	1,349	1,385
255	1,422	1,460	1,498	1,537	1,576	1,616	1,658	1,699	1,742	1,785
256	1,830	1,875	1,922	1,970	2,019	2,069	2,121	2,175	2,231	2,289
257	2,349	2,412	2,477	2,547	2,620	2,697	2,778	2,862	2,948	3,038
258	3,130	3,226	3,324	3,425	3,530	3,638	3,750	3,866	3,987	4,112
259	4,242	4,377	4,517	4,661	4,811	4,966	5,127	5,294	5,466	5,643
260	5,826	6,015	6,208	6,407	6,610	6,819	7,032	7,251	7,475	7,703
261	7,937	8,176	8,419	8,667	8,921	9,180	9,445	9,715	9,991	10,272
262	10,558	10,849	11,145	11,444	11,748	12,056	12,367	12,682	13,002	13,326
263	13,655	13,989	14,328	14,672	15,021	15,374	15,731	16,092	16,457	16,827
264	17,199	17,576	17,957	18,341	18,730	19,123	19,521	19,923	20,332	20,748
265	21,172	21,602	22,039	22,482	22,933	23,390	23,853	24,325	24,803	25,289
266	25,783	26,285	26,794	27,308	27,830	28,360	28,897	29,443	29,998	30,560
267	31,129	31,705	32,286	32,874	33,467	34,068	34,675	35,290	35,911	36,539
268	37,174	37,815	38,462	39,116	39,775	40,441	41,113	41,791	42,475	43,165
269	43,861	44,562	45,268	45,980	46,697	47,421	48,151	48,887	49,630	50,378
270	51,131	51,889	52,651	53,419	54,193	54,973	55,758	56,549	57,345	58,147
271	58,955	59,769	60,589	61,416	62,249	63,089	63,934	64,785	65,639	66,500
272	67,364	68,233	69,108	69,987	70,871	71,762	72,657	73,557	74,461	75,371
273	76,288	77,210	78,139	79,073	80,014	80,962	81,916	82,877	83,843	84,815
274	85,793	86,775	87,763	88,756	89,755	90,759	91,769	92,784	93,804	94,829
275	95,858	96,893	97,932	98,976	100,026	101,082	102,143	103,211	104,286	105,368
276	106,458	107,553	108,656	109,764	110,879	112,001	113,129	114,262	115,401	116,547
277	117,700	118,860	120,028	121,204	122,387	123,578	124,776	125,982	127,195	128,414
278	129,640	130,872	132,111	133,354	134,603	135,858	137,119	138,386	139,659	140,938
279	142,222	143,511	144,805	146,103	147,405	148,713	150,025	151,341	152,662	153,988
280	155,318	156,653	157,993	159,339	160,691	162,049	163,413	164,785	166,164	167,551
281	168,947	170,349	171,759	173,177	174,603	176,037	177,480	178,932	180,390	181,855
282	183,329	184,809	186,298	187,792	189,295	190,804	192,321	193,846	195,377	196,917
283	198,465	200,020	201,583	203,155	204,735	206,325	207,923	209,529	211,144	212,767
284	214,398	216,037	217,684	219,338	221,001	222,671	224,349	226,034	227,725	229,422
285	231,125	232,835	234,550	236,272	238,001	239,738	241,481	243,230	244,985	246,747
286	248,515	250,289	252,070	253,859	255,655	257,461	259,274	261,096	262,926	264,765
287	266,611	268,465	270,326	272,193	274,068	275,951	277,841	279,739	281,643	283,555
288	285,475	287,401	289,335	291,278	293,229	295,190	297,158	299,134	301,118	303,111
289	305,111	307,120	309,136	311,159	313,190	315,229	317,277	319,333	321,398	323,474
290	325,558	327,651	329,752	331,861	333,978	336,104	338,237	340,379	342,529	344,688

Appendix I

Richland-Chambers Reservoir

RESERVOIR CAPACITY TABLE (Continued)

TEXAS WATER DEVELOPMENT BOARD — December 2018 Survey

CAPACITY IN ACRE-FEET — Conservation Pool Elevation 315.0 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
291	346,855	349,028	351,209	353,396	355,592	357,795	360,006	362,225	364,451	366,684
292	368,926	371,174	373,430	375,692	377,963	380,240	382,525	384,818	387,118	389,426
293	391,741	394,065	396,397	398,736	401,085	403,441	405,806	408,178	410,557	412,946
294	415,342	417,746	420,159	422,578	425,006	427,443	429,889	432,342	434,804	437,275
295	439,754	442,242	444,738	447,241	449,754	452,274	454,803	457,340	459,883	462,436
296	464,997	467,567	470,145	472,731	475,327	477,932	480,547	483,171	485,803	488,445
297	491,096	493,756	496,425	499,102	501,788	504,483	507,186	509,896	512,613	515,339
298	518,074	520,816	523,569	526,330	529,101	531,882	534,671	537,469	540,274	543,089
299	545,914	548,748	551,590	554,439	557,298	560,165	563,041	565,927	568,823	571,728
300	574,644	577,569	580,504	583,448	586,402	589,366	592,339	595,320	598,307	601,304
301	604,307	607,319	610,338	613,364	616,398	619,441	622,492	625,552	628,621	631,700
302	634,790	637,889	640,998	644,117	647,247	650,387	653,538	656,699	659,870	663,052
303	666,244	669,445	672,655	675,872	679,099	682,336	685,581	688,836	692,099	695,372
304	698,654	701,946	705,248	708,560	711,882	715,215	718,558	721,912	725,274	728,649
305	732,035	735,431	738,840	742,259	745,691	749,134	752,588	756,054	759,530	763,018
306	766,517	770,027	773,549	777,080	780,623	784,177	787,743	791,319	794,905	798,504
307	802,114	805,736	809,371	813,016	816,673	820,342	824,021	827,712	831,413	835,127
308	838,854	842,593	846,345	850,108	853,884	857,672	861,475	865,291	869,119	872,963
309	876,820	880,690	884,571	888,462	892,365	896,278	900,200	904,132	908,073	912,025
310	915,987	919,957	923,937	927,925	931,924	935,933	939,952	943,980	948,016	952,062
311	956,118	960,183	964,257	968,339	972,432	976,533	980,644	984,764	988,892	993,029
312	997,174	1,001,325	1,005,485	1,009,652	1,013,828	1,018,012	1,022,203	1,026,403	1,030,610	1,034,826
313	1,039,049	1,043,281	1,047,520	1,051,768	1,056,024	1,060,287	1,064,559	1,068,838	1,073,126	1,077,421
314	1,081,725	1,086,036	1,090,356	1,094,683	1,099,019	1,103,362	1,107,714	1,112,073	1,116,440	1,120,816
315	1,125,199									

Note: Capacities above elevation 312.0 feet calculated from interpolated areas

Appendix J

Richland-Chambers Reservoir

RESERVOIR AREA TABLE

TEXAS WATER DEVELOPMENT BOARD — December 2018 Survey

AREA IN ACRES — Conservation Pool Elevation 315.0 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
238	0	0	0	0	0	0	0	0	0	0
239	0	0	0	0	0	0	0	0	0	1
240	1	1	1	1	1	1	1	1	1	1
241	1	1	1	1	1	1	1	1	1	1
242	1	1	1	2	2	2	2	2	2	3
243	3	3	4	4	4	4	5	5	5	6
244	6	6	7	7	7	8	8	9	10	10
245	11	12	13	14	15	16	17	18	19	20
246	22	23	24	26	27	28	29	30	31	33
247	34	35	36	38	39	41	42	44	46	47
248	50	51	53	55	57	58	60	63	66	69
249	72	76	80	84	89	94	99	105	110	115
250	120	124	128	133	138	142	145	149	153	158
251	163	168	173	177	181	185	189	193	198	202
252	206	210	215	219	223	228	232	236	241	245
253	250	254	259	263	268	273	279	285	292	299
254	306	312	318	324	330	337	343	350	357	364
255	371	378	385	392	399	407	414	422	430	439
256	450	461	472	483	496	511	528	548	569	591
257	615	641	674	713	751	791	824	853	881	910
258	939	968	999	1,029	1,062	1,100	1,138	1,183	1,229	1,277
259	1,324	1,372	1,423	1,473	1,524	1,579	1,637	1,695	1,746	1,802
260	1,857	1,911	1,961	2,009	2,061	2,110	2,161	2,213	2,262	2,313
261	2,362	2,409	2,458	2,506	2,562	2,619	2,676	2,735	2,786	2,837
262	2,886	2,930	2,974	3,017	3,058	3,095	3,133	3,173	3,217	3,265
263	3,315	3,367	3,419	3,463	3,507	3,549	3,592	3,633	3,674	3,709
264	3,747	3,784	3,825	3,867	3,908	3,953	4,001	4,057	4,126	4,196
265	4,266	4,336	4,404	4,470	4,536	4,602	4,674	4,749	4,821	4,897
266	4,981	5,056	5,118	5,183	5,255	5,334	5,419	5,504	5,583	5,660
267	5,726	5,784	5,842	5,906	5,971	6,035	6,112	6,179	6,248	6,313
268	6,379	6,442	6,505	6,567	6,626	6,686	6,753	6,812	6,871	6,928
269	6,982	7,033	7,090	7,149	7,207	7,268	7,330	7,396	7,454	7,506
270	7,555	7,601	7,652	7,712	7,767	7,825	7,881	7,937	7,989	8,045
271	8,105	8,173	8,236	8,301	8,365	8,425	8,480	8,528	8,576	8,623
272	8,669	8,716	8,766	8,819	8,878	8,928	8,974	9,023	9,073	9,129
273	9,191	9,254	9,318	9,379	9,441	9,512	9,575	9,636	9,692	9,747
274	9,798	9,850	9,904	9,962	10,018	10,072	10,123	10,175	10,223	10,273
275	10,321	10,367	10,419	10,471	10,523	10,583	10,645	10,716	10,788	10,857
276	10,924	10,990	11,055	11,119	11,183	11,249	11,308	11,363	11,423	11,492
277	11,565	11,640	11,719	11,796	11,867	11,945	12,024	12,094	12,160	12,224
278	12,293	12,354	12,408	12,463	12,523	12,580	12,638	12,698	12,761	12,816
279	12,867	12,914	12,957	13,001	13,049	13,095	13,143	13,189	13,234	13,277
280	13,323	13,377	13,434	13,490	13,549	13,608	13,678	13,752	13,831	13,917
281	13,990	14,063	14,137	14,219	14,302	14,386	14,473	14,549	14,619	14,693
282	14,770	14,844	14,916	14,987	15,059	15,132	15,203	15,281	15,360	15,439
283	15,512	15,591	15,675	15,759	15,849	15,938	16,024	16,106	16,188	16,270
284	16,352	16,428	16,506	16,589	16,666	16,743	16,813	16,879	16,940	17,003
285	17,065	17,124	17,186	17,254	17,329	17,396	17,462	17,524	17,586	17,647
286	17,707	17,776	17,851	17,928	18,006	18,092	18,177	18,261	18,344	18,425
287	18,499	18,573	18,645	18,715	18,787	18,860	18,938	19,016	19,085	19,155
288	19,226	19,301	19,386	19,471	19,556	19,643	19,720	19,804	19,886	19,964
289	20,043	20,121	20,197	20,274	20,353	20,433	20,516	20,608	20,704	20,796
290	20,886	20,970	21,054	21,132	21,211	21,294	21,376	21,463	21,550	21,627

Appendix J

Richland-Chambers Reservoir

RESERVOIR AREA TABLE (Continued)

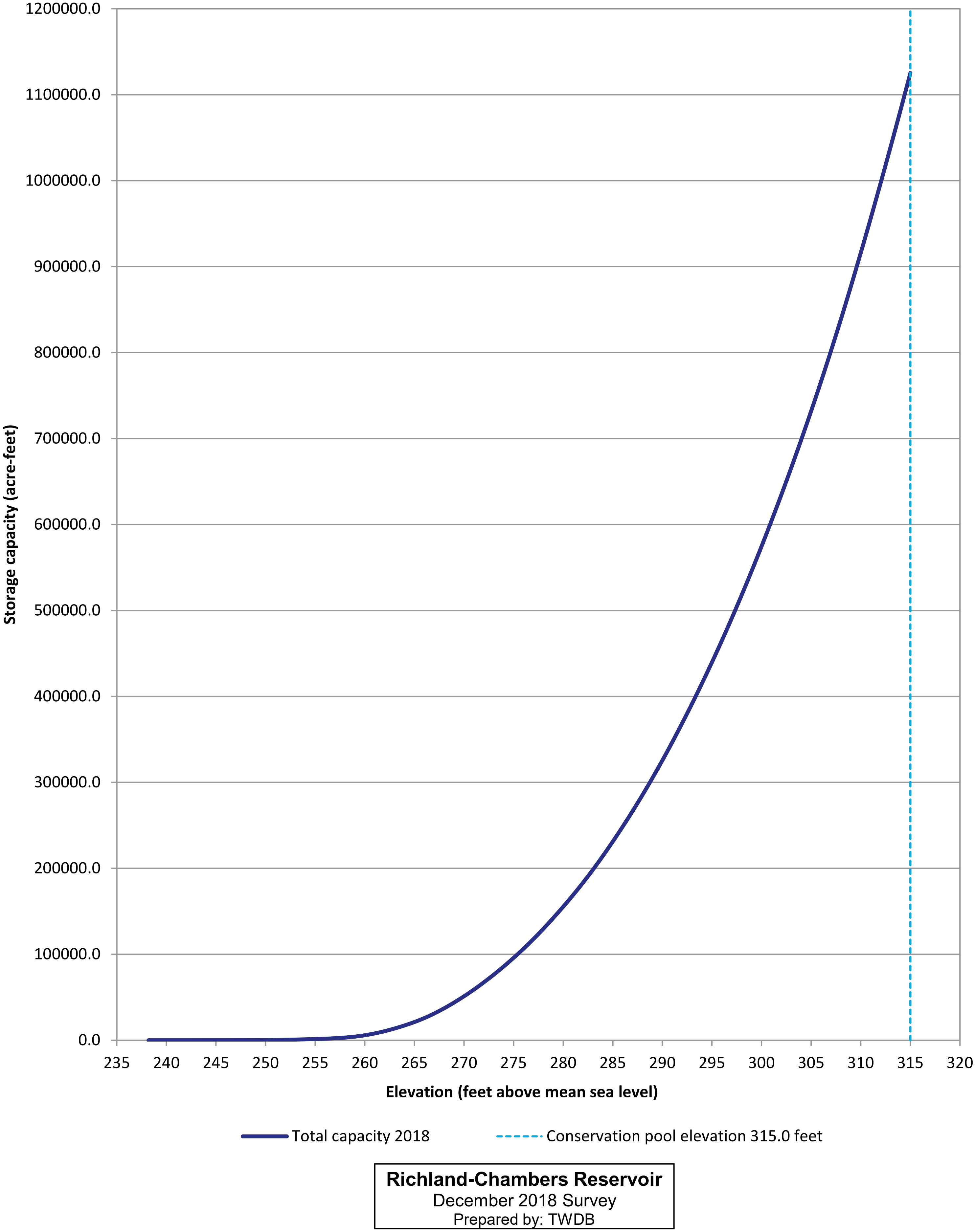
TEXAS WATER DEVELOPMENT BOARD | December 2018 Survey

AREA IN ACRES | Conservation Pool Elevation 315.0 feet NGVD29

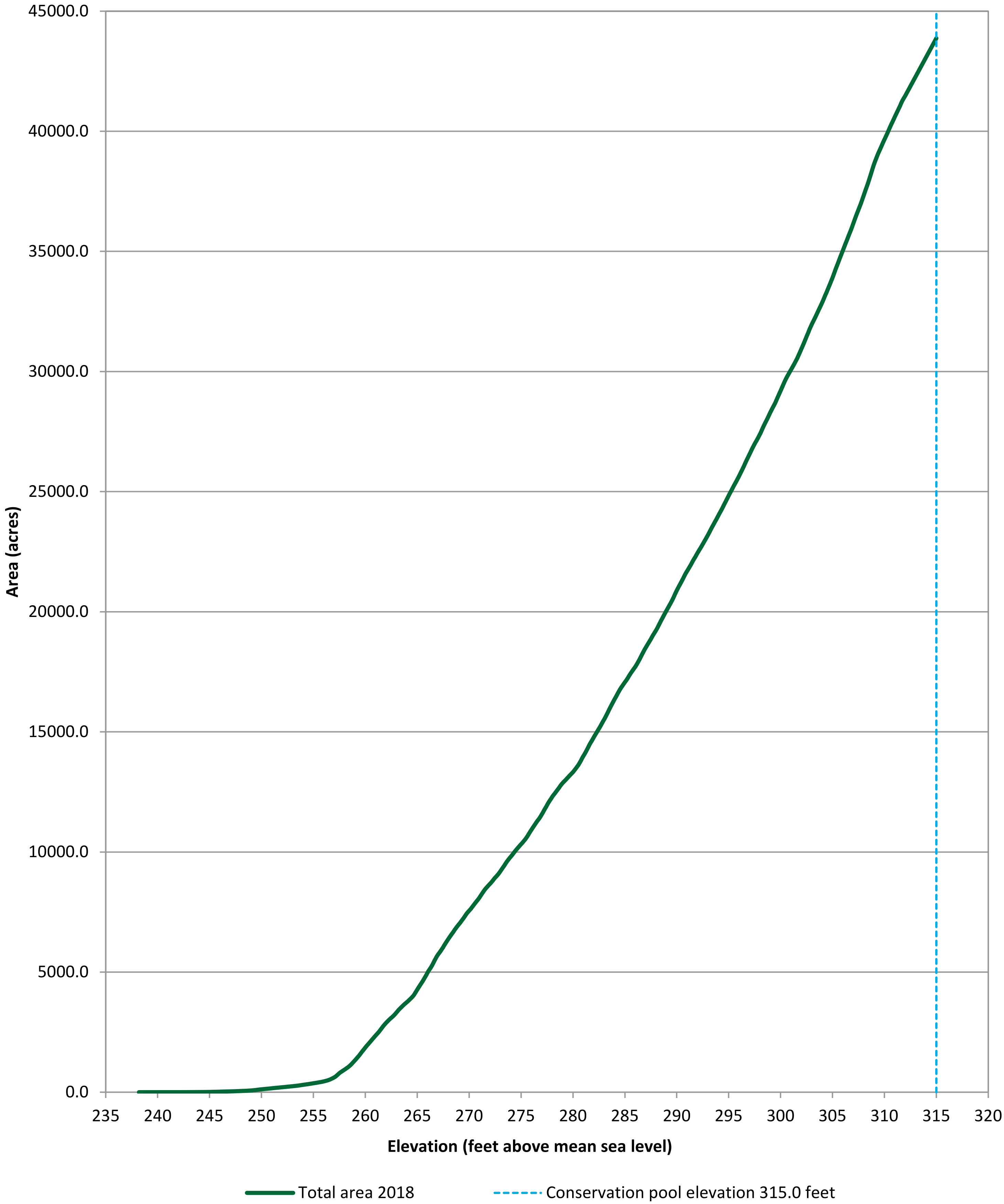
ELEVATION INCREMENT IS ONE TENTH FOOT

ELEVATION in Feet	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
291	21,698	21,768	21,843	21,915	21,992	22,075	22,152	22,225	22,293	22,375
292	22,450	22,522	22,593	22,663	22,738	22,811	22,889	22,963	23,039	23,116
293	23,195	23,275	23,360	23,444	23,524	23,602	23,682	23,762	23,837	23,921
294	24,001	24,084	24,161	24,239	24,322	24,411	24,496	24,578	24,666	24,748
295	24,836	24,919	25,000	25,078	25,164	25,247	25,324	25,403	25,485	25,567
296	25,651	25,738	25,825	25,913	26,003	26,095	26,193	26,284	26,374	26,462
297	26,552	26,641	26,733	26,822	26,906	26,988	27,064	27,138	27,217	27,300
298	27,383	27,471	27,572	27,665	27,760	27,847	27,931	28,017	28,105	28,199
299	28,291	28,376	28,462	28,543	28,626	28,711	28,811	28,911	29,006	29,105
300	29,200	29,297	29,397	29,498	29,593	29,682	29,768	29,846	29,922	29,998
301	30,072	30,150	30,226	30,305	30,385	30,467	30,552	30,648	30,744	30,842
302	30,941	31,040	31,140	31,246	31,349	31,457	31,557	31,662	31,773	31,867
303	31,962	32,052	32,137	32,224	32,316	32,408	32,500	32,593	32,682	32,774
304	32,868	32,966	33,072	33,177	33,272	33,375	33,482	33,584	33,691	33,798
305	33,906	34,022	34,144	34,261	34,374	34,484	34,598	34,711	34,824	34,933
306	35,044	35,156	35,267	35,377	35,483	35,597	35,708	35,813	35,924	36,042
307	36,162	36,282	36,400	36,516	36,628	36,738	36,849	36,959	37,078	37,203
308	37,325	37,453	37,578	37,698	37,819	37,953	38,088	38,226	38,366	38,504
309	38,634	38,751	38,863	38,974	39,079	39,175	39,271	39,368	39,468	39,565
310	39,658	39,750	39,842	39,937	40,036	40,136	40,234	40,325	40,416	40,509
311	40,603	40,695	40,785	40,875	40,965	41,053	41,159	41,250	41,331	41,404
312	41,476	41,556	41,636	41,716	41,796	41,876	41,956	42,036	42,116	42,196
313	42,275	42,355	42,435	42,515	42,595	42,675	42,755	42,835	42,915	42,995
314	43,075	43,155	43,235	43,315	43,395	43,475	43,555	43,635	43,715	43,795
315	43,874									

Note: Areas between elevations 312.0 and 315.0 feet linearly interpolated



Appendix K: Capacity curve



Richland-Chambers Reservoir
December 2018 Survey
Prepared by: TWDB

Appendix L: Area curve

Appendix M Sediment Range Lines

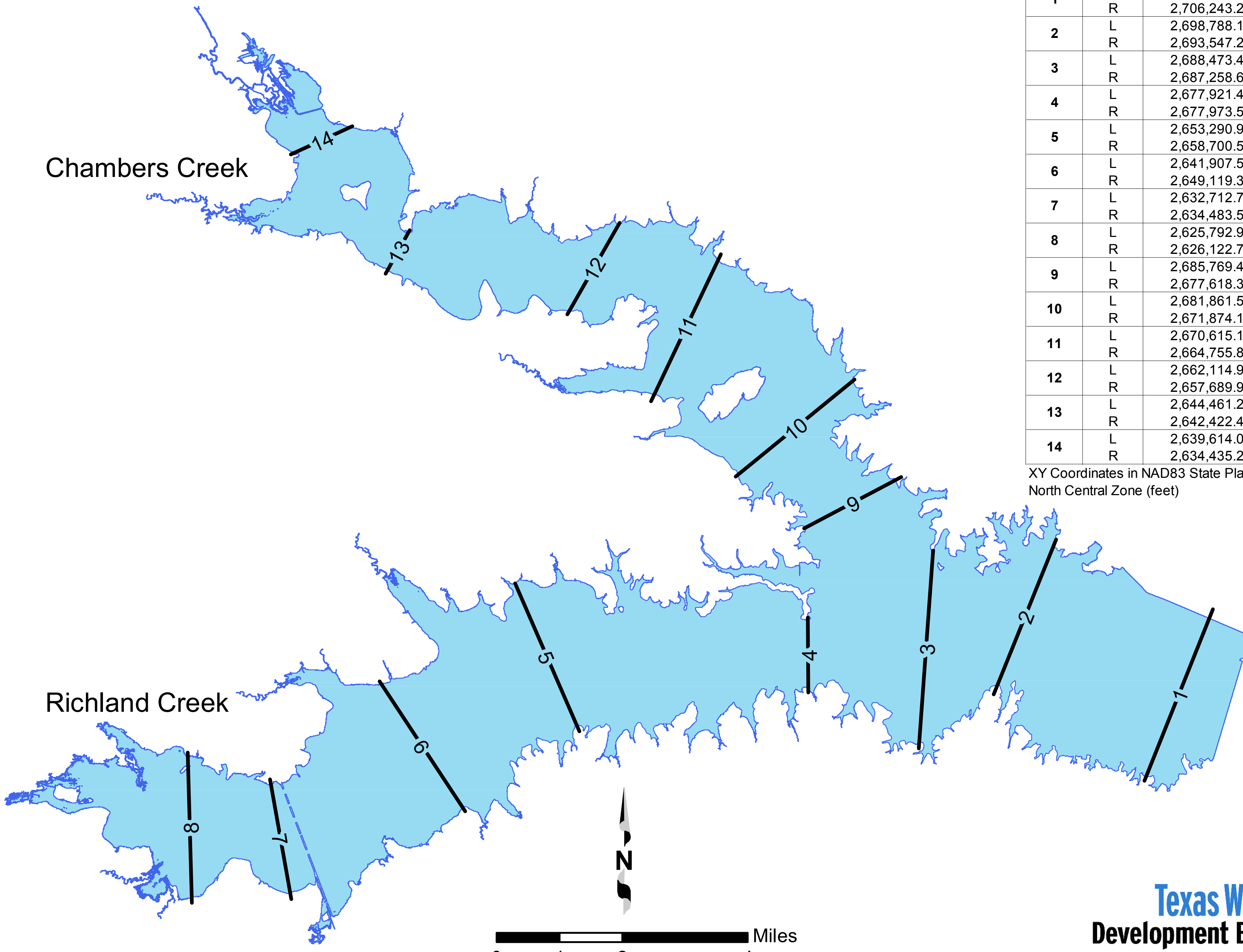


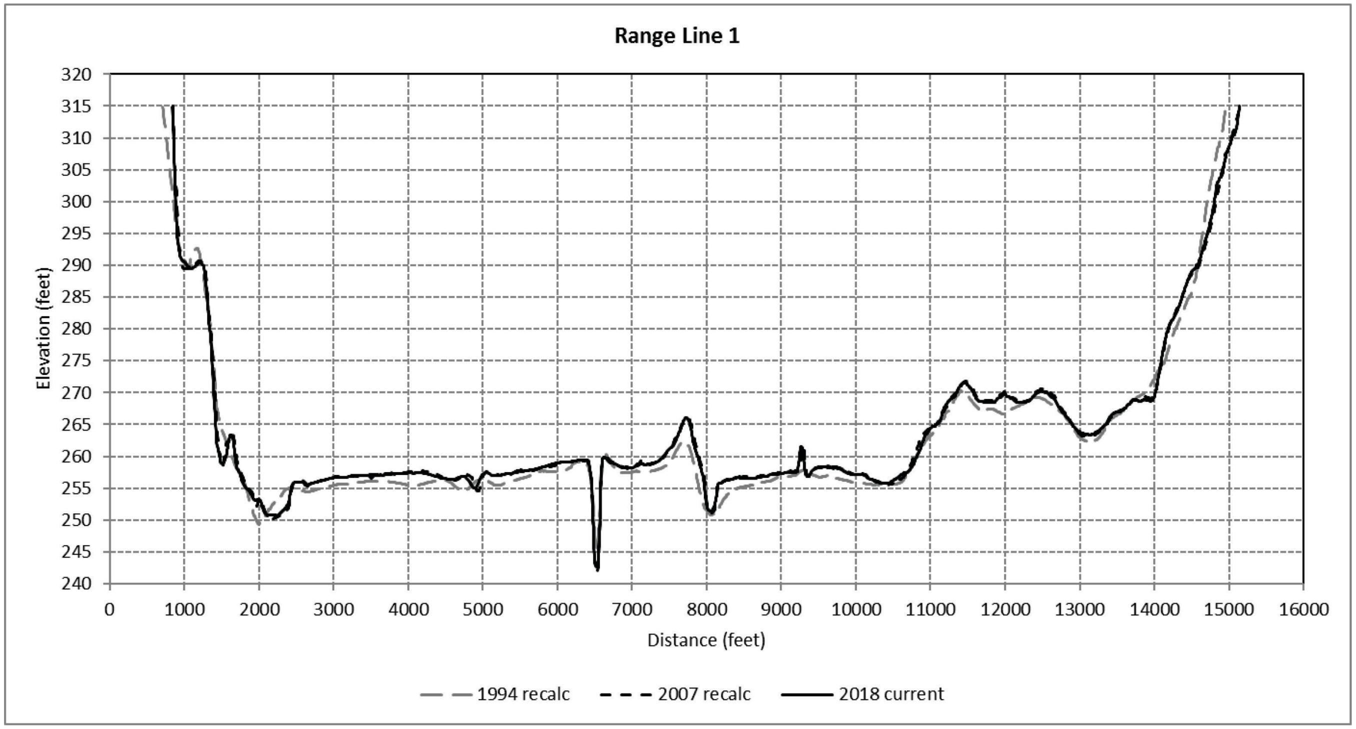
Table M1. Endpoint Coordinates for Richland-Chambers Reservoir Sediment Range Lines

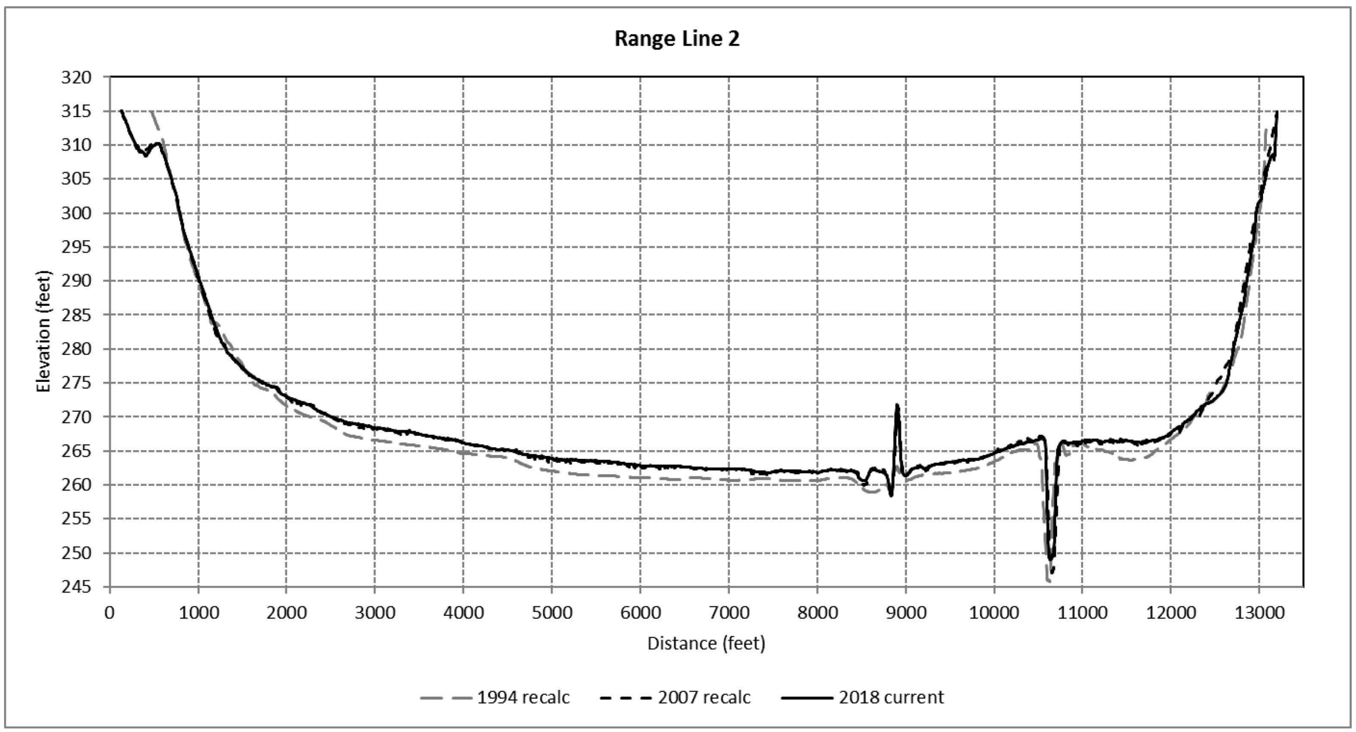
Range	L=Left R=Right	X	Y
1	L	2,711,979.76	6,683,291.71
	R	2,706,243.22	6,668,835.12
2	L	2,698,788.10	6,689,138.07
	R	2,693,547.21	6,676,128.09
3	L	2,688,473.49	6,688,196.96
	R	2,687,258.64	6,671,589.64
4	L	2,677,921.49	6,682,568.99
	R	2,677,973.57	6,676,274.28
5	L	2,653,290.90	6,685,467.15
	R	2,658,700.56	6,673,022.66
6	L	2,641,907.51	6,677,216.05
	R	2,649,119.31	6,666,292.44
7	L	2,632,712.71	6,668,979.25
	R	2,634,483.54	6,658,892.45
8	L	2,625,792.93	6,671,212.29
	R	2,626,122.79	6,658,590.76
9	L	2,685,769.41	6,694,391.22
	R	2,677,618.37	6,690,068.30
10	L	2,681,861.57	6,702,597.09
	R	2,671,874.10	6,694,415.67
11	L	2,670,615.19	6,713,138.90
	R	2,664,755.81	6,700,790.81
12	L	2,662,114.90	6,715,772.78
	R	2,657,689.98	6,708,077.47
13	L	2,644,461.25	6,715,156.01
	R	2,642,422.40	6,711,520.31
14	L	2,639,614.02	6,723,926.85
	R	2,634,435.20	6,721,521.46

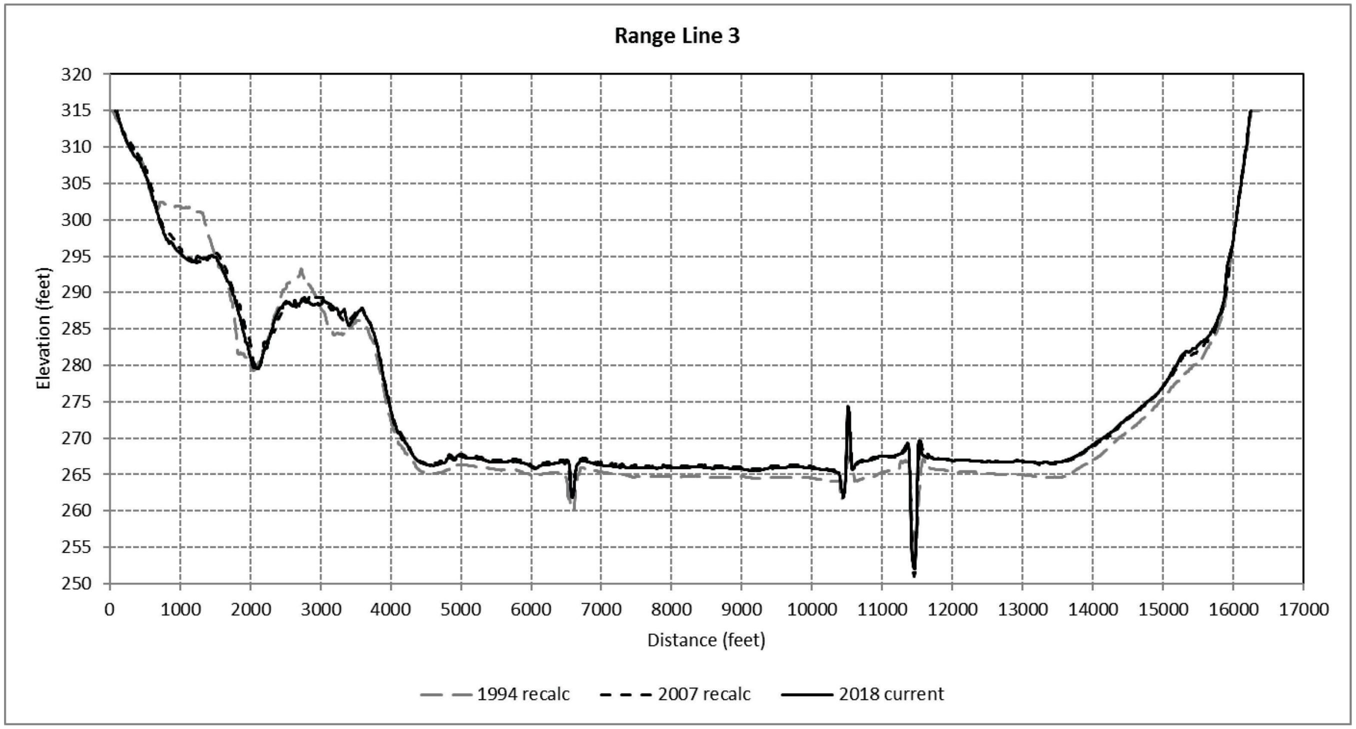
XY Coordinates in NAD83 State Plane Texas North Central Zone (feet)

Texas Water Development Board

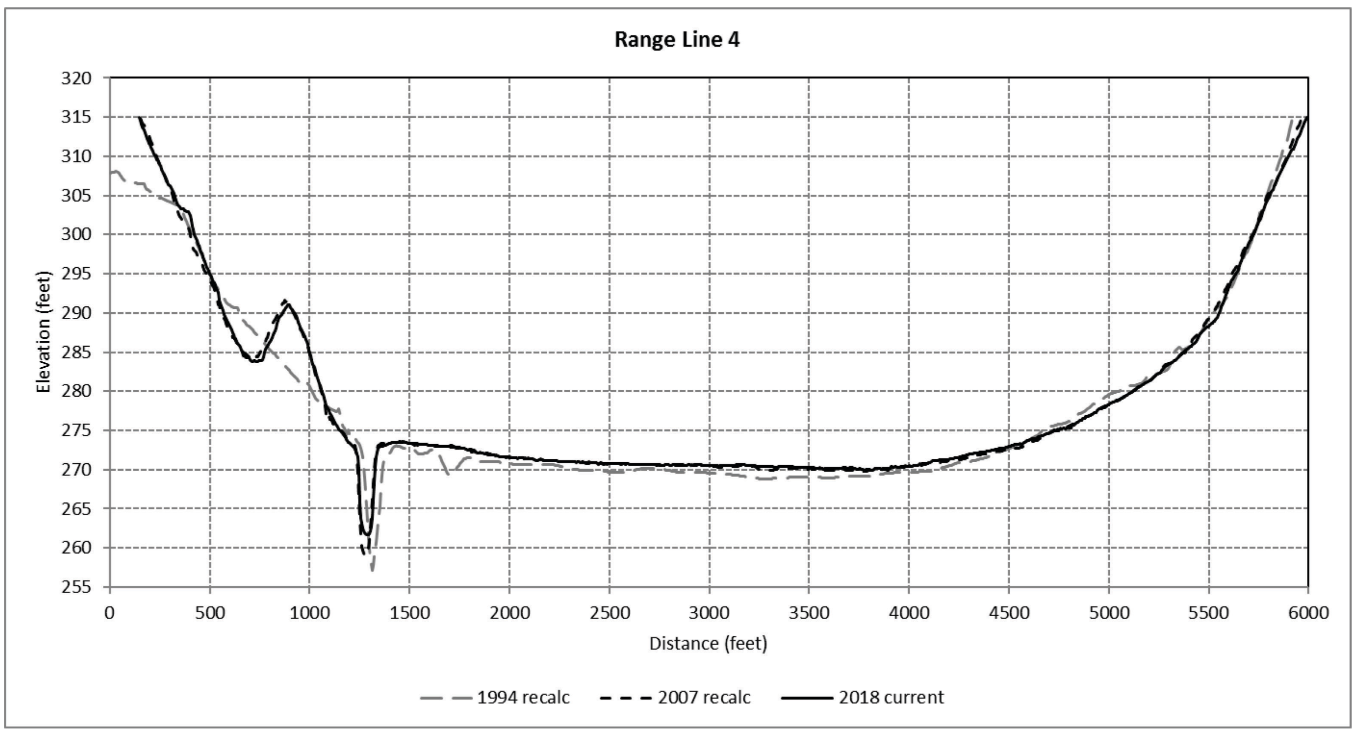
December 2018 Survey


Range Line 1
Elevation (feet)
Distance (feet)
1994 recalc
2007 recalc
2018 current

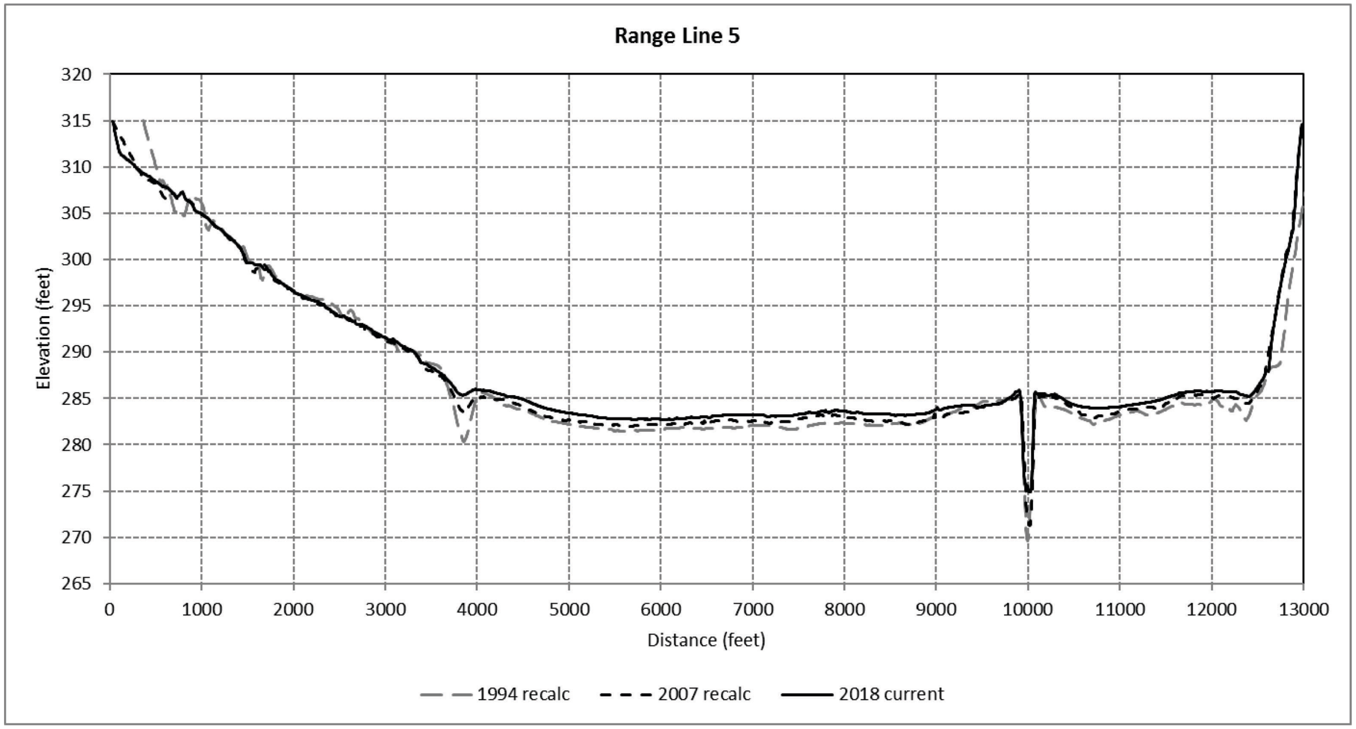

Range Line 2
Elevation (feet)
Distance (feet)
1994 recalc
2007 recalc
2018 current

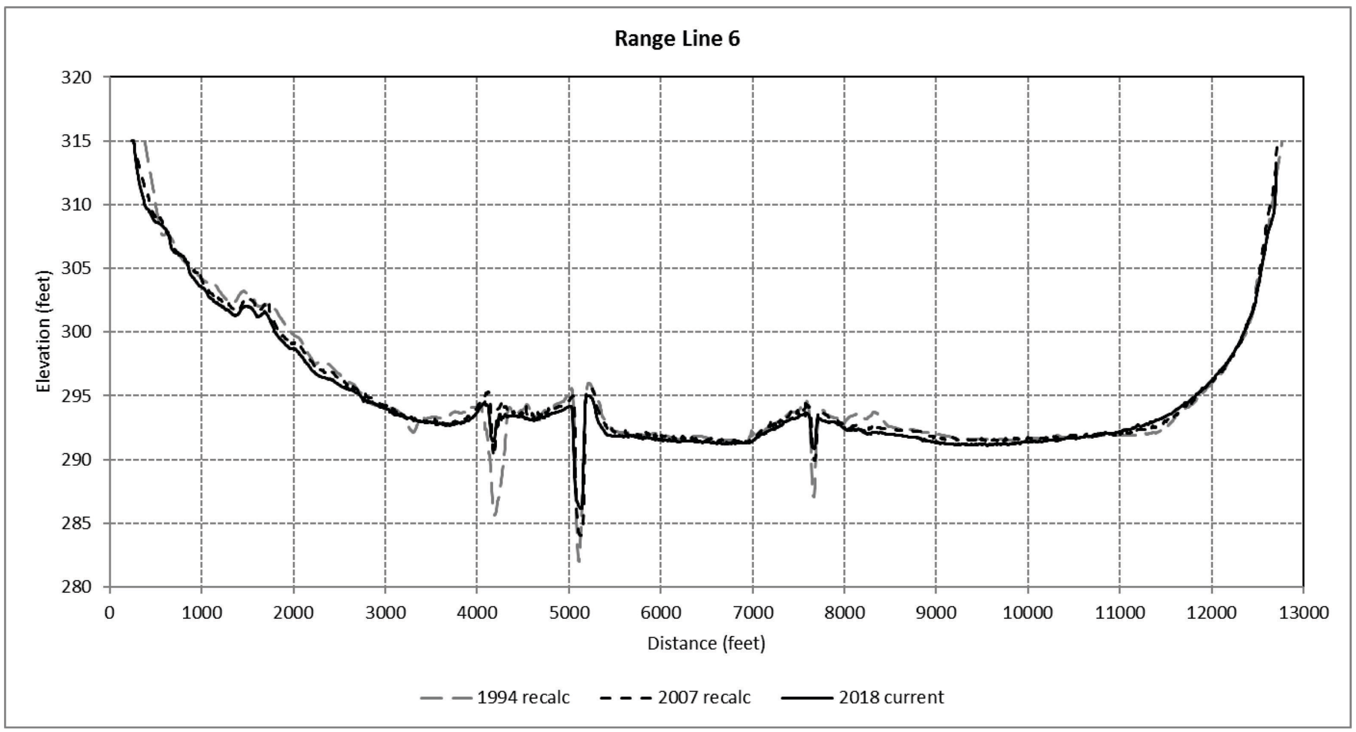


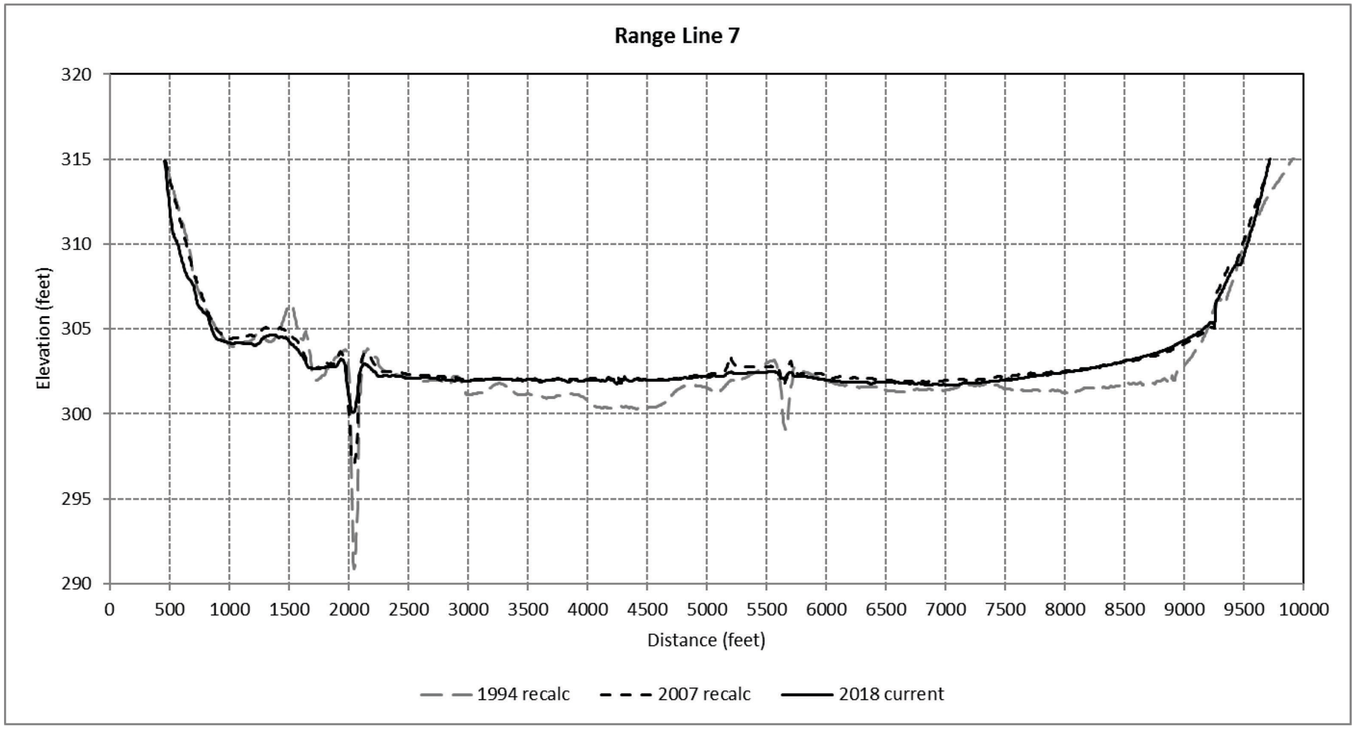
Range Line 3
Elevation (feet)
320
315
310
305
300
295
290
285
280
275
270
265
260
255
250
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
12000
13000
14000
15000
16000
17000
Distance (feet)
1994 recalc
2007 recalc
2018 current

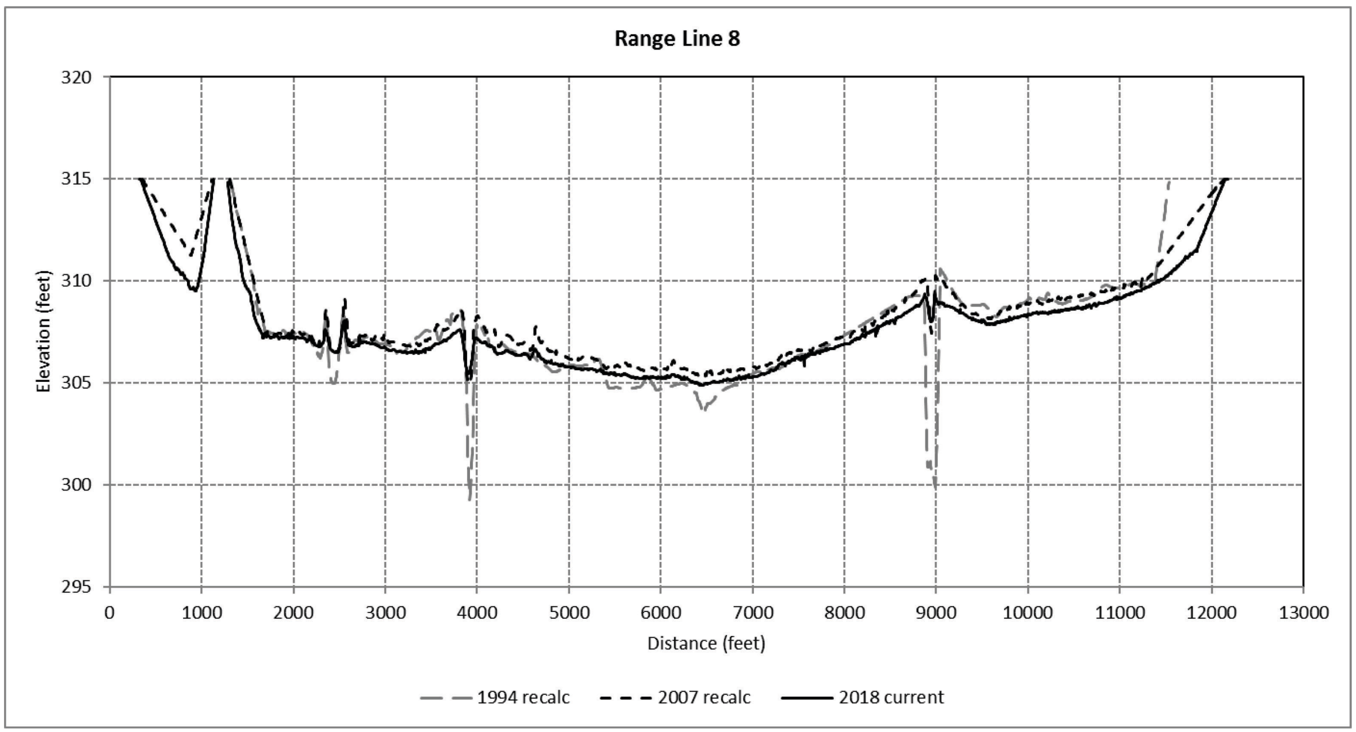


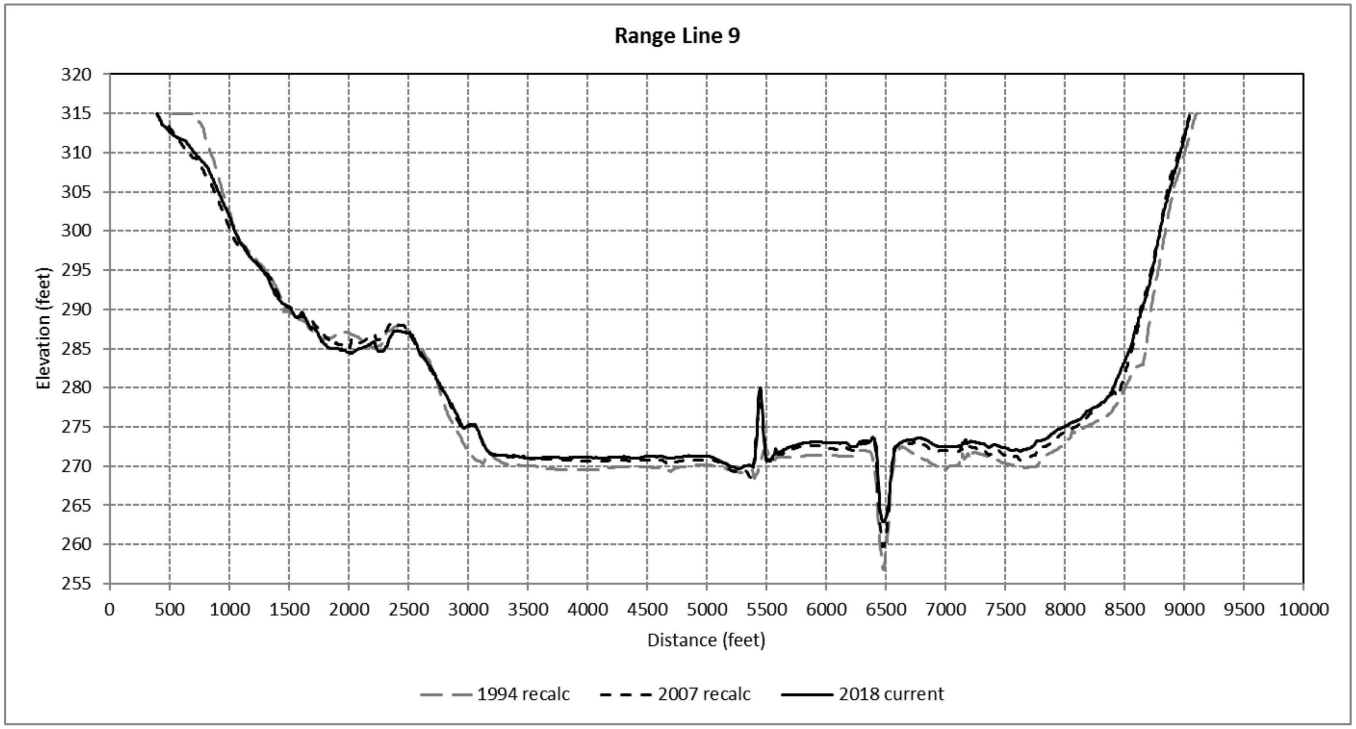
Range Line 4
Elevation (feet)
320
315
310
305
300
295
290
285
280
275
270
265
260
255
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
Distance (feet)
1994 recalc
2007 recalc
2018 current

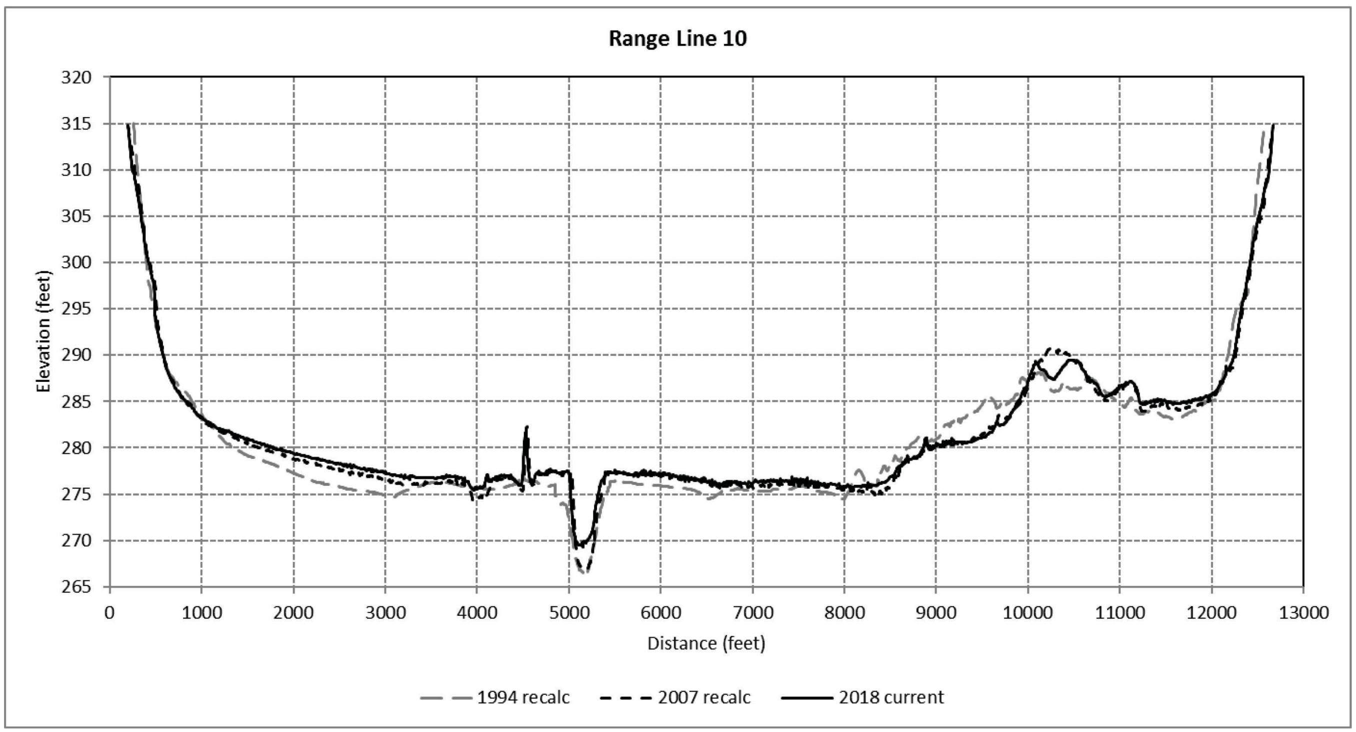

Range Line 5
Elevation (feet)
320
315
310
305
300
295
290
285
280
275
270
265
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
12000
13000
Distance (feet)
1994 recalc
2007 recalc
2018 current

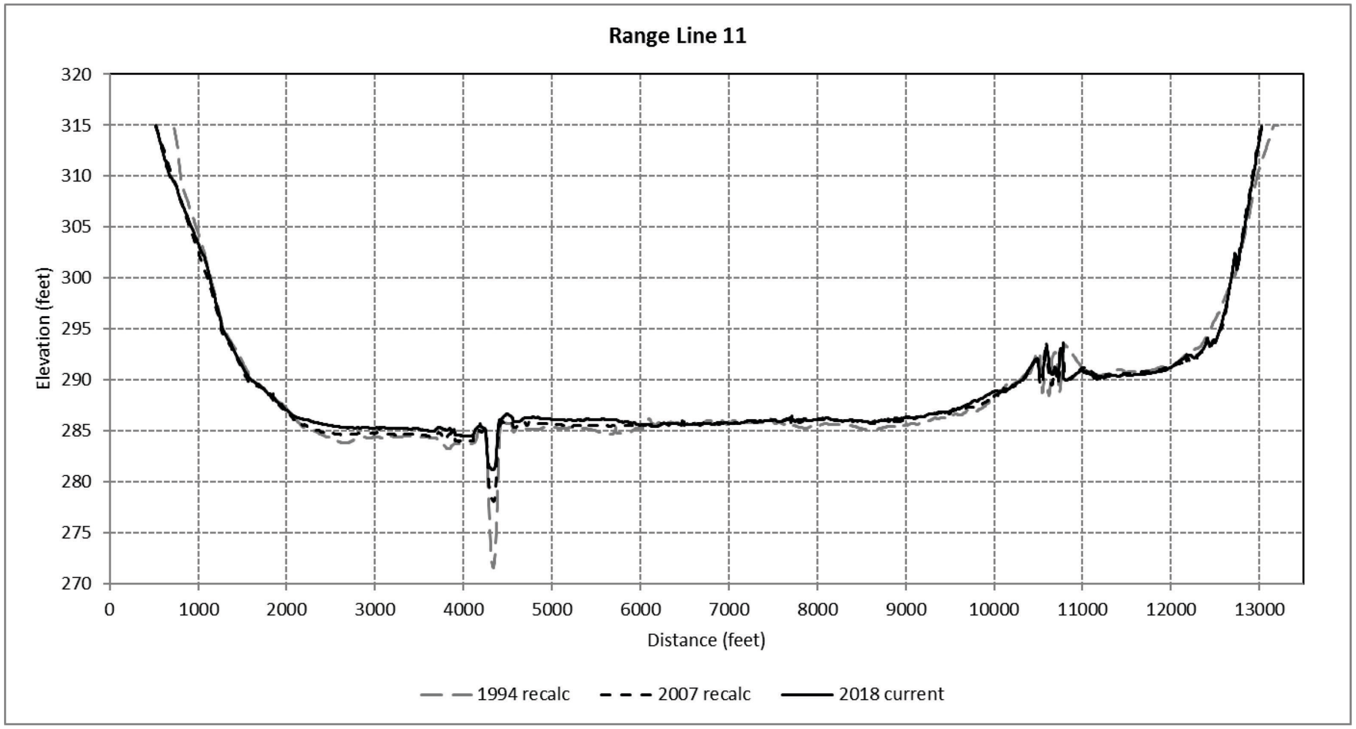

Range Line 6
Elevation (feet)
320
315
310
305
300
295
290
285
280
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
12000
13000
Distance (feet)
1994 recalc
2007 recalc
2018 current

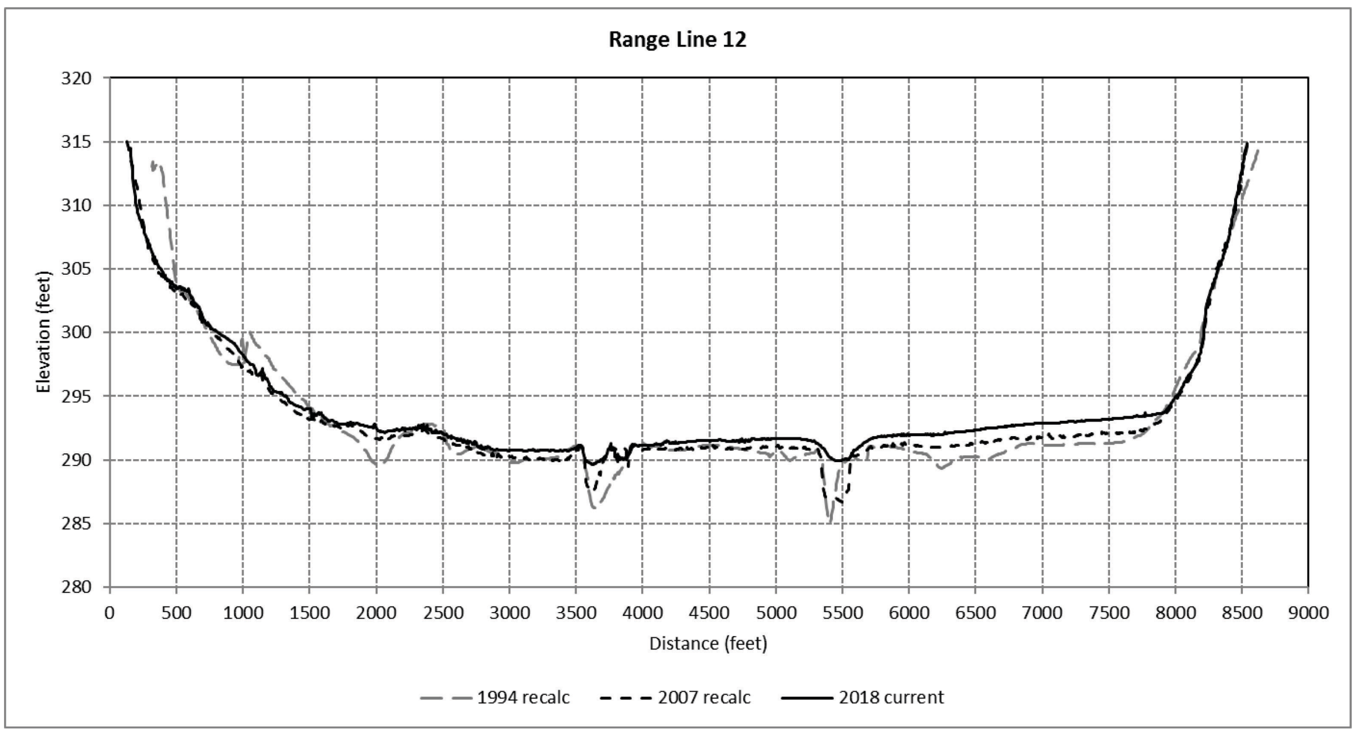

Range Line 7
320
315
310
305
300
295
290
Elevation (feet)
0 500 1000 1500 2000 2500 3000 3500 4000 4500 5000 5500 6000 6500 7000 7500 8000 8500 9000 9500 10000
Distance (feet)
1994 recalc
2007 recalc
2018 current

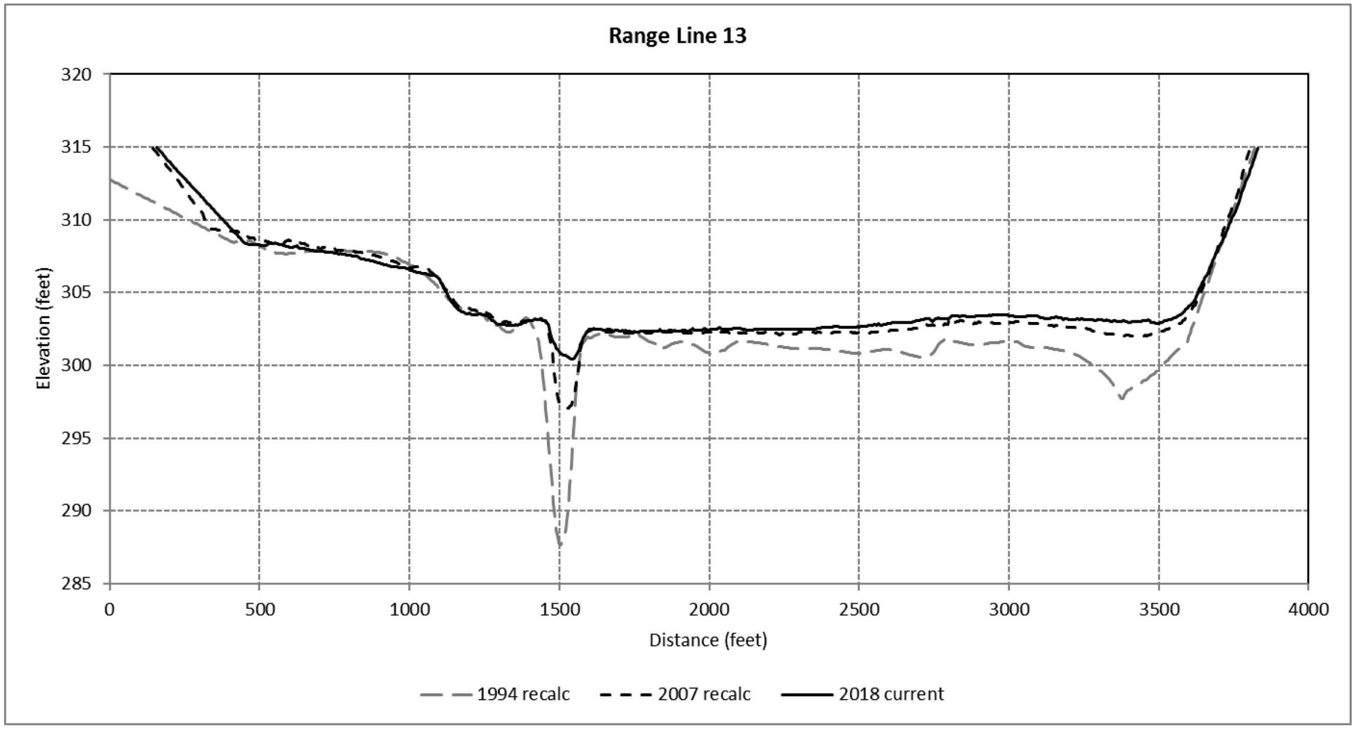

Range Line 8
320
315
310
305
300
295
Elevation (feet)
0 1000 2000 3000 4000 5000 6000 7000 8000 9000 10000 11000 12000 13000
Distance (feet)
1994 recalc
2007 recalc
2018 current

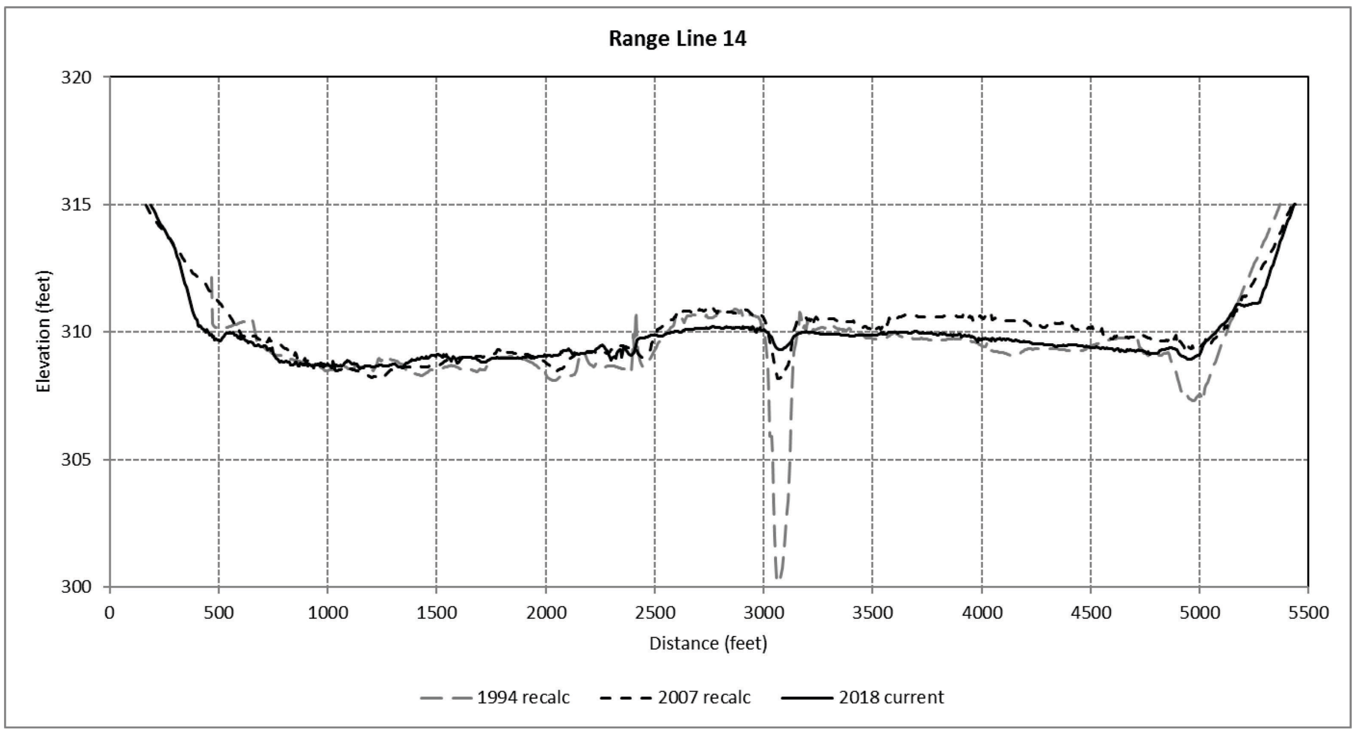

Range Line 9
Elevation (feet)
320
315
310
305
300
295
290
285
280
275
270
265
260
255
0 500 1000 1500 2000 2500 3000 3500 4000 4500 5000 5500 6000 6500 7000 7500 8000 8500 9000 9500 10000
Distance (feet)
1994 recalc
2007 recalc
2018 current


Range Line 10
Elevation (feet)
320
315
310
305
300
295
290
285
280
275
270
265
0 1000 2000 3000 4000 5000 6000 7000 8000 9000 10000 11000 12000 13000
Distance (feet)
1994 recalc
2007 recalc
2018 current


Range Line 11
320
315
310
305
300
295
290
285
280
275
270
Elevation (feet)
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
12000
13000
Distance (feet)
1994 recalc
2007 recalc
2018 current


Range Line 12
320
315
310
305
300
295
290
285
280
Elevation (feet)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
6500
7000
7500
8000
8500
9000
Distance (feet)
1994 recalc
2007 recalc
2018 current


Range Line 13
Elevation (feet)
320
315
310
305
300
295
290
285
0
500
1000
1500
2000
2500
3000
3500
4000
Distance (feet)
1994 recalc
2007 recalc
2018 current


Range Line 14
Elevation (feet)
320
315
310
305
300
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
Distance (feet)
1994 recalc
2007 recalc
2018 current

Appendix N Axial profile

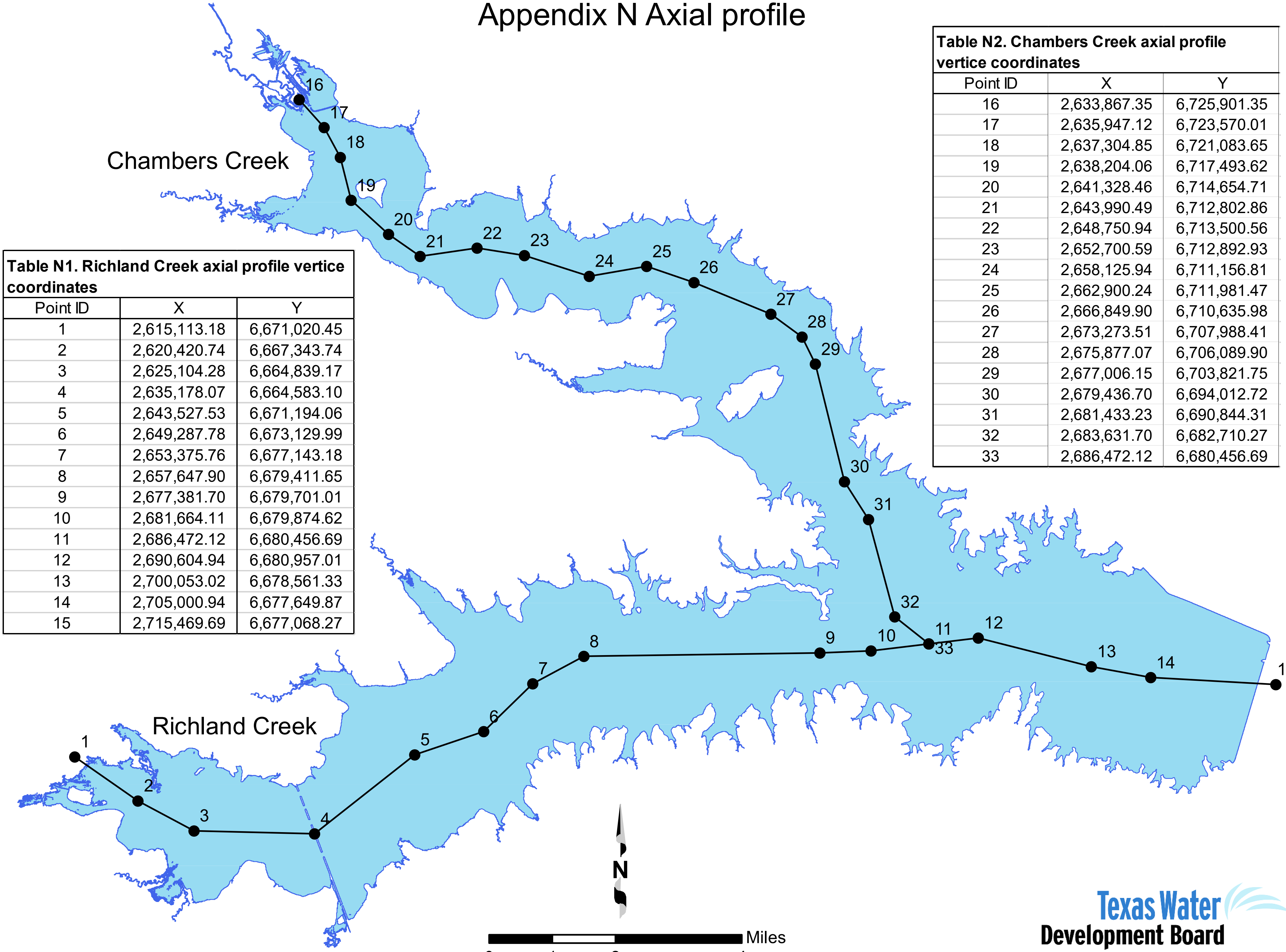


Table N1. Richland Creek axial profile vertice coordinates		
Point ID	X	Y
1	2,615,113.18	6,671,020.45
2	2,620,420.74	6,667,343.74
3	2,625,104.28	6,664,839.17
4	2,635,178.07	6,664,583.10
5	2,643,527.53	6,671,194.06
6	2,649,287.78	6,673,129.99
7	2,653,375.76	6,677,143.18
8	2,657,647.90	6,679,411.65
9	2,677,381.70	6,679,701.01
10	2,681,664.11	6,679,874.62
11	2,686,472.12	6,680,456.69
12	2,690,604.94	6,680,957.01
13	2,700,053.02	6,678,561.33
14	2,705,000.94	6,677,649.87
15	2,715,469.69	6,677,068.27

Table N2. Chambers Creek axial profile vertice coordinates		
Point ID	X	Y
16	2,633,867.35	6,725,901.35
17	2,635,947.12	6,723,570.01
18	2,637,304.85	6,721,083.65
19	2,638,204.06	6,717,493.62
20	2,641,328.46	6,714,654.71
21	2,643,990.49	6,712,802.86
22	2,648,750.94	6,713,500.56
23	2,652,700.59	6,712,892.93
24	2,658,125.94	6,711,156.81
25	2,662,900.24	6,711,981.47
26	2,666,849.90	6,710,635.98
27	2,673,273.51	6,707,988.41
28	2,675,877.07	6,706,089.90
29	2,677,006.15	6,703,821.75
30	2,679,436.70	6,694,012.72
31	2,681,433.23	6,690,844.31
32	2,683,631.70	6,682,710.27
33	2,686,472.12	6,680,456.69

Texas Water Development Board

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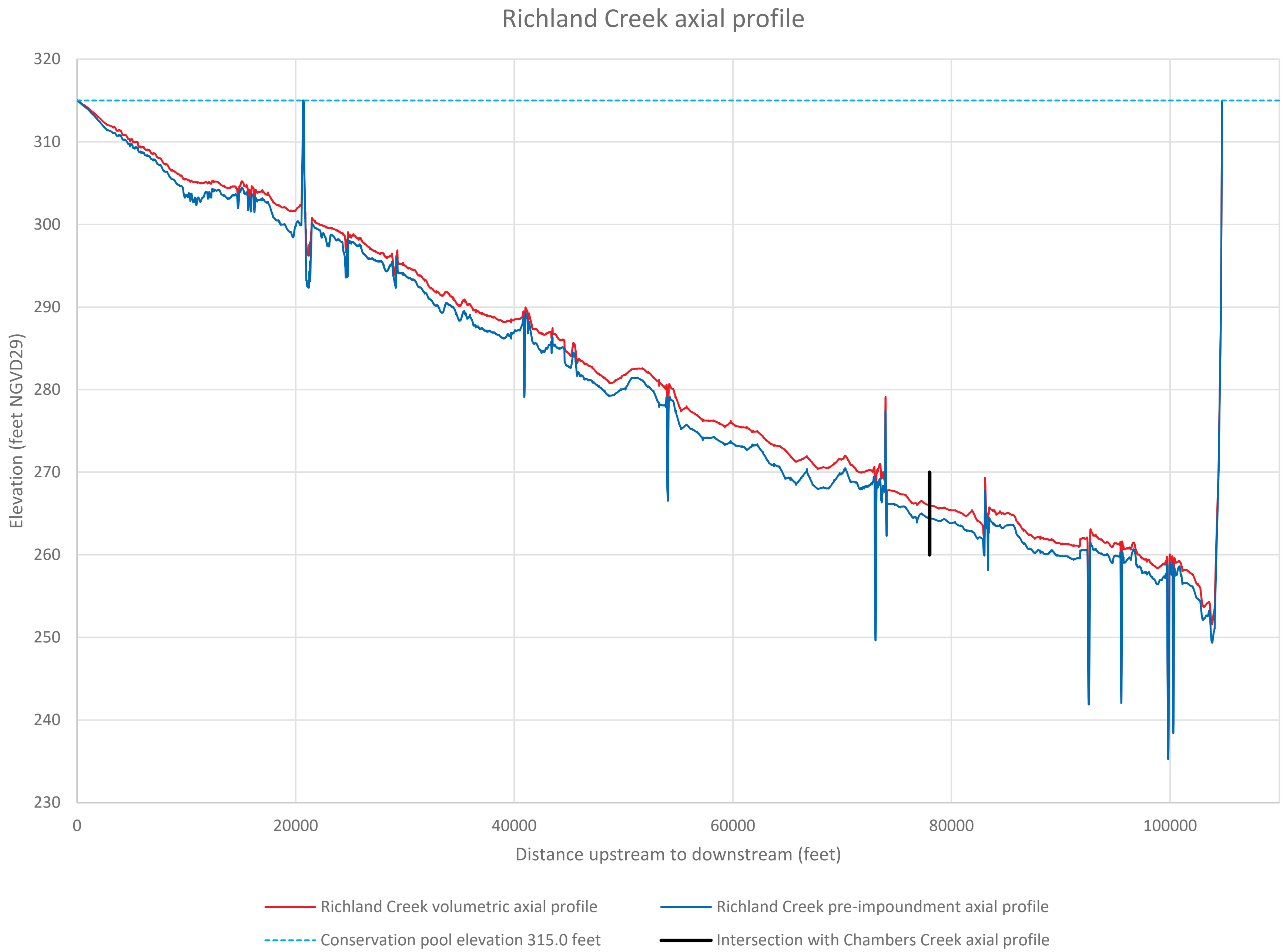
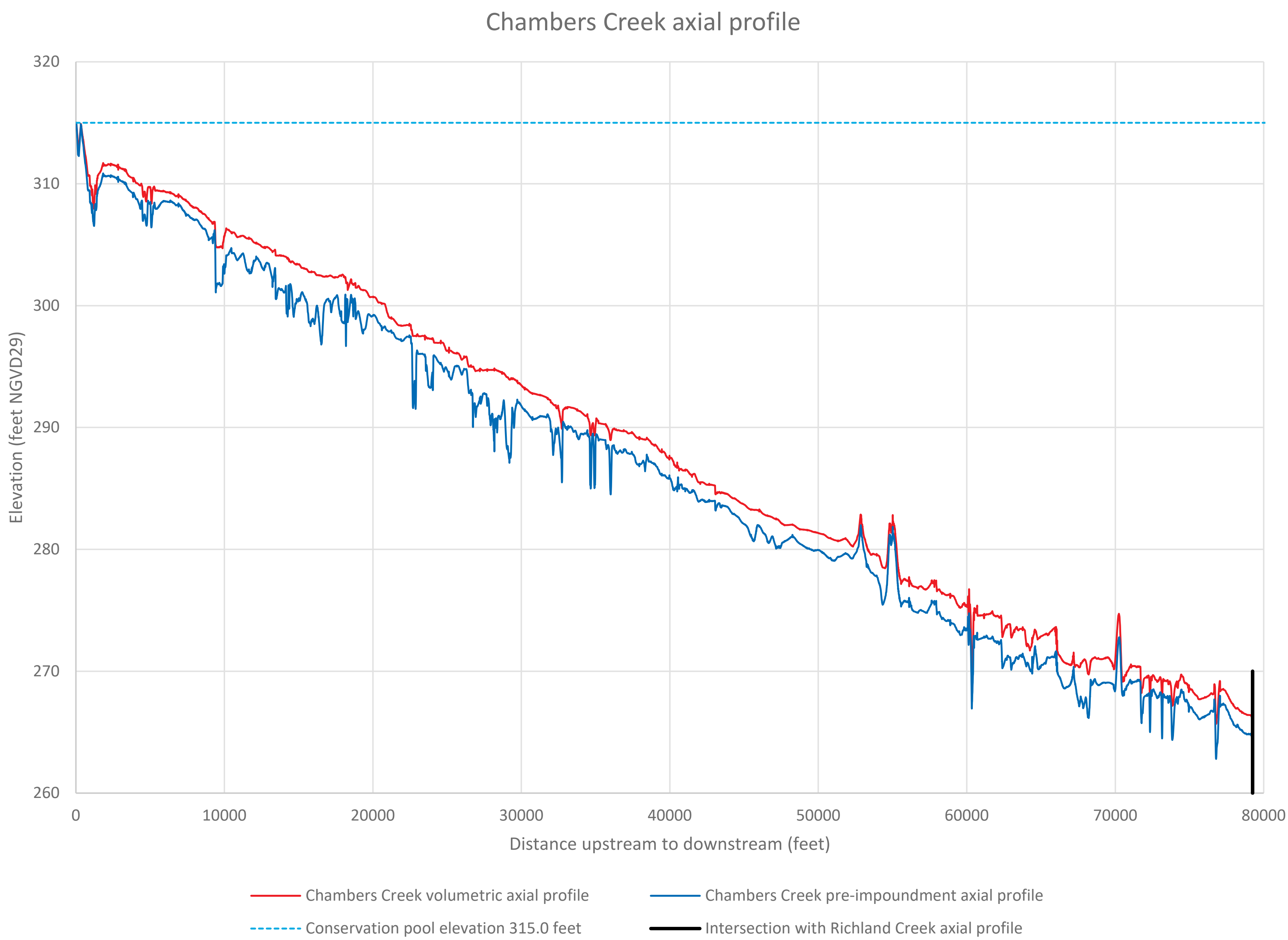

Richland Creek axial profile
Elevation (feet NGVD29)
320
310
300
290
280
270
260
250
240
230
0
20000
40000
60000
80000
100000
Distance upstream to downstream (feet)
Richland Creek volumetric axial profile
Richland Creek pre-impoundment axial profile
Conservation pool elevation 315.0 feet
Intersection with Chambers Creek axial profile



Chambers Creek axial profile
Elevation (feet NGVD29)
320
310
300
290
280
270
260
0
10000
20000
30000
40000
50000
60000
70000
80000
Distance upstream to downstream (feet)
Chambers Creek volumetric axial profile
Chambers Creek pre-impoundment axial profile
Conservation pool elevation 315.0 feet
Intersection with Richland Creek axial profile

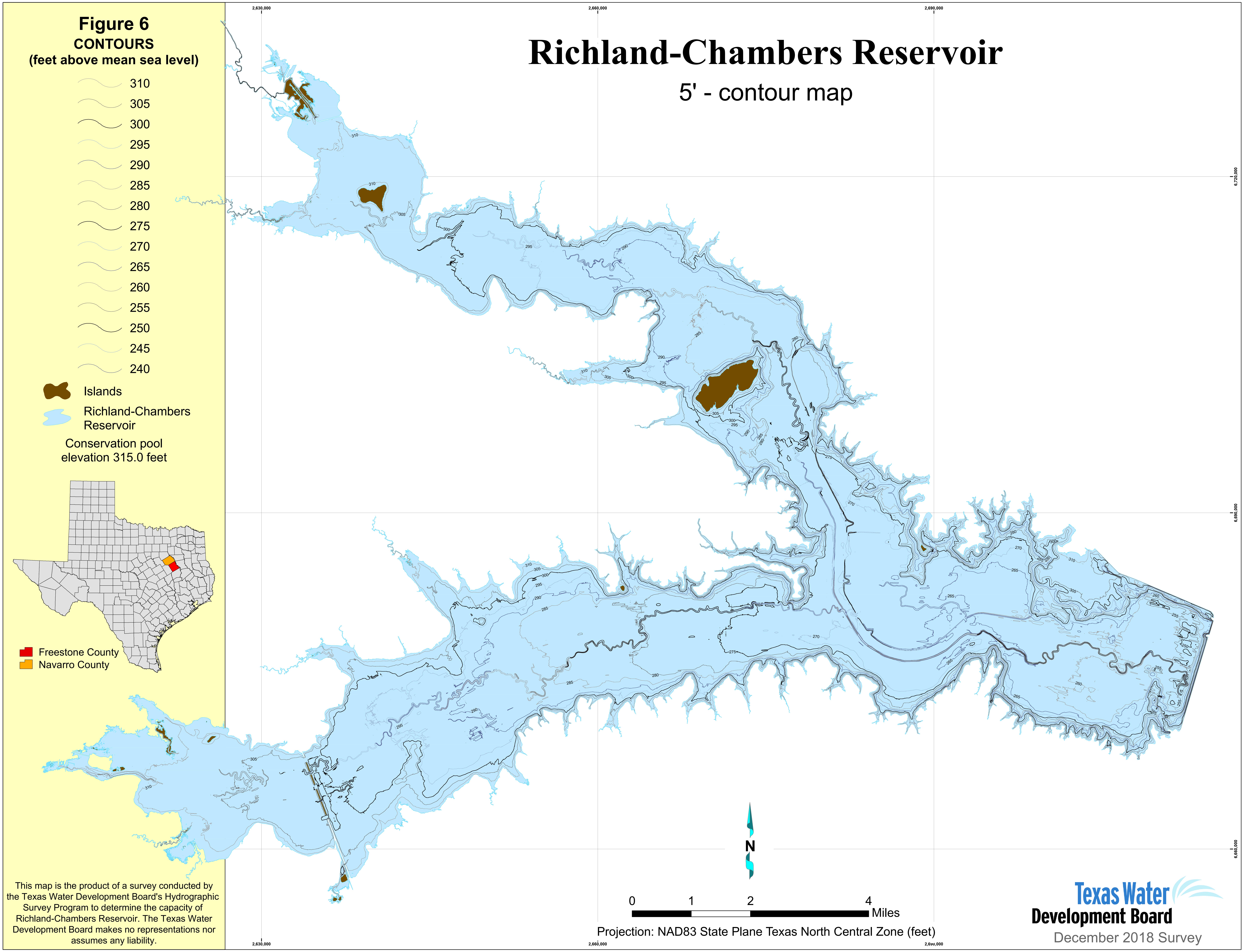


Figure 6
CONTOURS
(feet above mean sea level)
310
305
300
295
290
285
280
275
270
265
260
255
250
245
240
Islands
Richland-Chambers Reservoir
Conservation pool elevation 315.0 feet
Freestone County
Navarro County
This map is the product of a survey conducted by the Texas Water Development Board's Hydrographic Survey Program to determine the capacity of Richland-Chambers Reservoir. The Texas Water Development Board makes no representations nor assumes any liability.
Richland-Chambers Reservoir
5' - contour map
N
0 1 2 4 Miles
Projection: NAD83 State Plane Texas North Central Zone (feet)
Texas Water Development Board
December 2018 Survey