Volumetric and Sedimentation Survey of LAKE LYNDON B. JOHNSON

March – June 2020

Texas Water Development Board

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Prepared for:

Lower Colorado River Authority

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Executive summary

In May 2019, the Texas Water Development Board (TWDB) entered into an agreement with the Lower Colorado River Authority (LCRA) to perform a volumetric and sedimentation survey of Lake Lyndon B. Johnson (LBJ) (Burnet and Llano 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.

Alvin J. Wirtz Dam and Lake LBJ are located on the Colorado River in Burnet and Llano counties, 5 miles west of Marble Falls, Texas. The conservation pool elevation of Lake LBJ is 825.00 feet above mean sea level, however, the target operating range is between 824.40 and 825.00 feet. The TWDB collected bathymetric data for Lake LBJ between March 10, 2020, and June 19, 2020, while daily average water surface elevations measured between 824.67 and 824.81 feet above mean sea level.

The 2020 TWDB volumetric survey indicates Lake LBJ has a total reservoir capacity of 131,618 acre-feet and encompasses 6,432 acres at conservation pool elevation (825.00 feet above mean sea level). The 2020 TWDB volumetric survey measured 18,840 acre-feet of capacity below elevation 793.40 feet above mean sea level, or dead pool elevation. Dead pool refers to the water that cannot be drained by gravity through a dam's outlet works. The useable conservation pool storage, total reservoir capacity minus dead pool capacity, of Lake LBJ is 112,778 acre-feet. The accuracy of the TWDB survey was assessed using the root mean square error (RMSE) method. Between the axial profile points and the model surface, the RMSE equals 1.5 feet. The value 1.5 feet was added to and subtracted from the survey data and interpolated data points to find the range of uncertainty for the volumetric survey. Results at conservation pool elevation suggest the total reservoir capacity estimate is accurate to within ± 6.23 percent (± 8,201 acre-feet).

Previous capacity estimates at elevation 825.00 feet include an original design estimate of 138,500 acre-feet by the Lower Colorado River Authority, a 1995 Lower Colorado River Authority estimate revised by the Texas Water Development Board in 2007 of 135,421 acre-feet, and a 2007 TWDB estimate of 133,090 acre-feet. 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. Information from past surveys are presented here for informational purposes only.

The 2020 TWDB sedimentation survey measured 9,116 acre-feet of sediment. The sedimentation survey indicates sediment accumulation is greatest towards the dam. The TWDB sediment estimate may be a slight overestimate of accumulated sediment. Lake LBJ is a sandy reservoir, with multiple layers of sand found throughout the sediment core samples, which complicates pre-impoundment identification efforts. The TWDB recommends a similar methodology be used to resurvey Lake LBJ in 10 years or after a major high flow event. Due to the irregular bottom, riverine behavior of the reservoir, and responses to high flow events, a multibeam survey should be considered to more accurately measure capacity and identify changes in the reservoir bottom.

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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 May 2019, the TWDB entered into an agreement with the Lower Colorado River Authority (LCRA), to perform a volumetric and sedimentation survey of Lake Lyndon B. Johnson (LBJ) (Texas Water Development Board, 2019). This report provides an overview of the survey methods, analysis techniques, and associated results. Also included are the following contract deliverables: (1) an elevation-area-capacity table of the reservoir acceptable to the Texas Commission on Environmental Quality (Appendices A and B), (2) a bottom contour map (Figure 6), (3) a shaded relief plot of the reservoir bottom (Figure 4), and (4) an estimate of sediment accumulation and location (Figure 10).

Lake LBJ general information

Alvin J. Wirtz Dam and Lake LBJ are located on the Colorado River in Burnet and Llano counties, 5 miles west of Marble Falls, Texas (Figure 1). Lake LBJ is owned and operated by the LCRA. Construction of the dam began in September 1949, and the dam was completed in November 1951. Deliberate impoundment of water began in May 1951 (Texas Water Development Board, 1971). The reservoir was built primarily for hydroelectric power and is the cooling reservoir for the Thomas C. Ferguson Power Plant (Dowell, 1964; Lower Colorado River Authority, 2021; Texas Water Development Board, 1971). Additional pertinent data about Alvin J. Wirtz Dam and Lake LBJ can be found in Table 1.

Water rights for Lake LBJ have been appropriated to the Lower Colorado River Authority through Certificate of Adjudication No. 14-5480 (Texas Commission on Environmental Quality, 2021). The complete permits are on file at the Texas Commission on Environmental Quality.

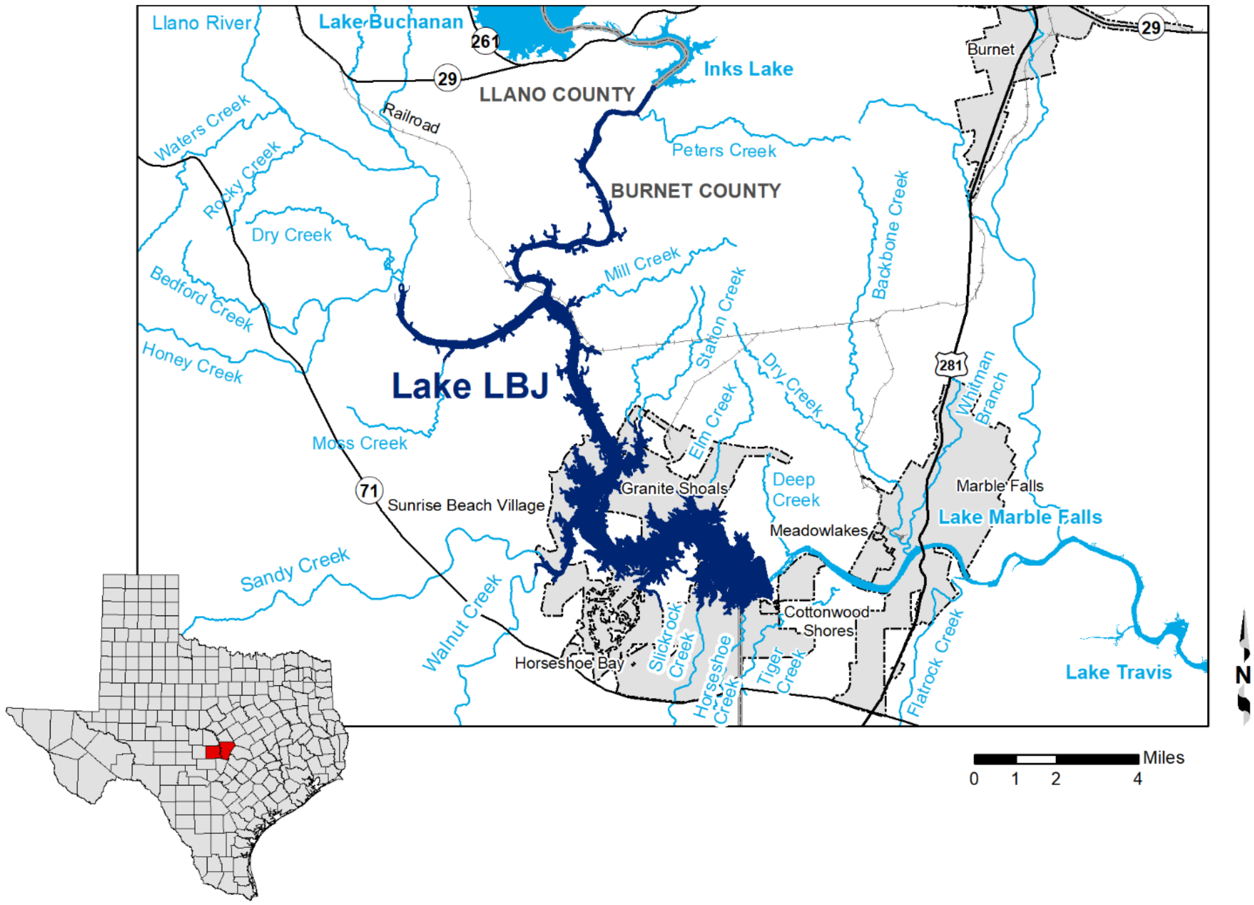


Figure 1. Location map

Table 1. Pertinent Data for Alvin J. Wirtz Dam and Lake Lyndon B. Johnson.

Owner			
Lower Colorado River Authority (LCRA)			
Engineer (Design)			
Fargo Engineering Company			
General Contractor			
Brown & Root, Inc.			
Drainage Area			
Total Drainage Area	36,290 square miles		
Contributing Area	24,390 square miles		
Non-contributing Area	11,900 square miles		
Dam			
Type	Concrete gravity, earth and rock fill		
Total Length	5,491.4		
Maximum Height	118.3 feet		
Top Width	26 feet		
Spillway			
Type	Concrete Ogee, controlled		
Total Length	450 feet		
Number of Tainter Gates	9, each 50 feet by 30 feet		
Crest Elevation	795.0 feet above mean sea level		
Outlet Works			
Number and Type	None		
Discharge Control	water releases are controlled by turbine operation		
Power Features			
Number of Hydropower units	2		
Discharge capacity	5,250 cubic feet per second each		
Number of Floodgates	10		
Discharge capacity	30,800 cubic feet per second each		
Total production capacity	60 megawatts		
Invert Elevation	793.4 feet above mean sea level		
Reservoir Data (Based on 2020 TWDB survey)			
Feature	**Elevation (feet above MSL[a])**	**Capacity (acre-feet)**	**Area (acres)**
Top of dam (concrete)	838.5	242,758	10,228
Overflow spillway	835.5	213,388	9,352
Top of Conservation Pool	825.0	131,618	6,432
Spillway Crest	795.0	21,258	1,588
Invert/dead pool elevation	793.4	18,840	1,438
Conservation storage capacity[b]	—	112,778	—

Sources: A. Dillender, written commun(s)., 2020; Lower Colorado River Authority, 2021; Texas Water Development Board, 1971; Texas Water Development Board, 2007.

[a.] Mean Sea Level (MSL) indicates a reference to the LCRA Legacy Datum for Wirtz Dam and Lake Lyndon B. Johnson. North American Vertical Datum 1988(NAVD88) equals LCRA Legacy Datum plus 0.68 feet.

[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 Lake LBJ

Datum

The vertical datum used during this survey is feet above mean sea level. This is the legacy datum used by the LCRA. The legacy datum is based on elevation benchmarks set for construction of the dams forming the Highland Lakes that have not been adjusted to a standard datum (Lower Colorado River Authority, 2020). To convert to standard datum North American Vertical Datum 1988 (NAVD88), add 0.68 to LCRA Legacy Datum. Water surface elevation data were downloaded from the United States Geological Survey (USGS) for the reservoir elevation gage *TX071 08152500 LCRA Lk LBJ nr Marble Falls, TX.* For the survey period, the reservoir elevation data provided by the USGS came directly from the LCRA Hydromet: https://hydromet.lcra.org/ (U.S. Geological Survey, 2021). Elevations herein are reported in feet relative to the legacy datum. Volume and area calculations in this report are referenced to water levels provided by the USGS as obtained from the LCRA. The horizontal datum used for this report is North American Datum 1983 (NAD83), and the horizontal coordinate system is State Plane Texas Central Zone (feet).

TWDB bathymetric and sedimentation data collection

The TWDB collected bathymetric data for Lake LBJ between March 10 and June 19, 2020, while daily average water surface elevations measured between 824.67 and 824.81 feet above mean sea level. 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 were 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 Lake Lyndon B. Johnson, May 2007 Survey* (Texas Water Development Board, 2009), therefore, data coverage in 2020 and 2007 are very similar. However, there are significant differences in data acquisition in approximately 6 river miles of the Colorado River below Inks Dam. The TWDB also extensively surveyed the canals providing residential lake access in 2020. 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 2020 TWDB survey.

All sounding data were 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 12 locations to collect sediment core samples (Figure 2). Sediment samples were collected on September 8, 2020, in the form of ten sediment cores and one grab sample using a custom-coring boat, an SDI VibeCore system, and a petite Ponar grab sampler. Sediment samples were not recovered at two locations.

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, labeled, and transported to TWDB headquarters for further analysis.

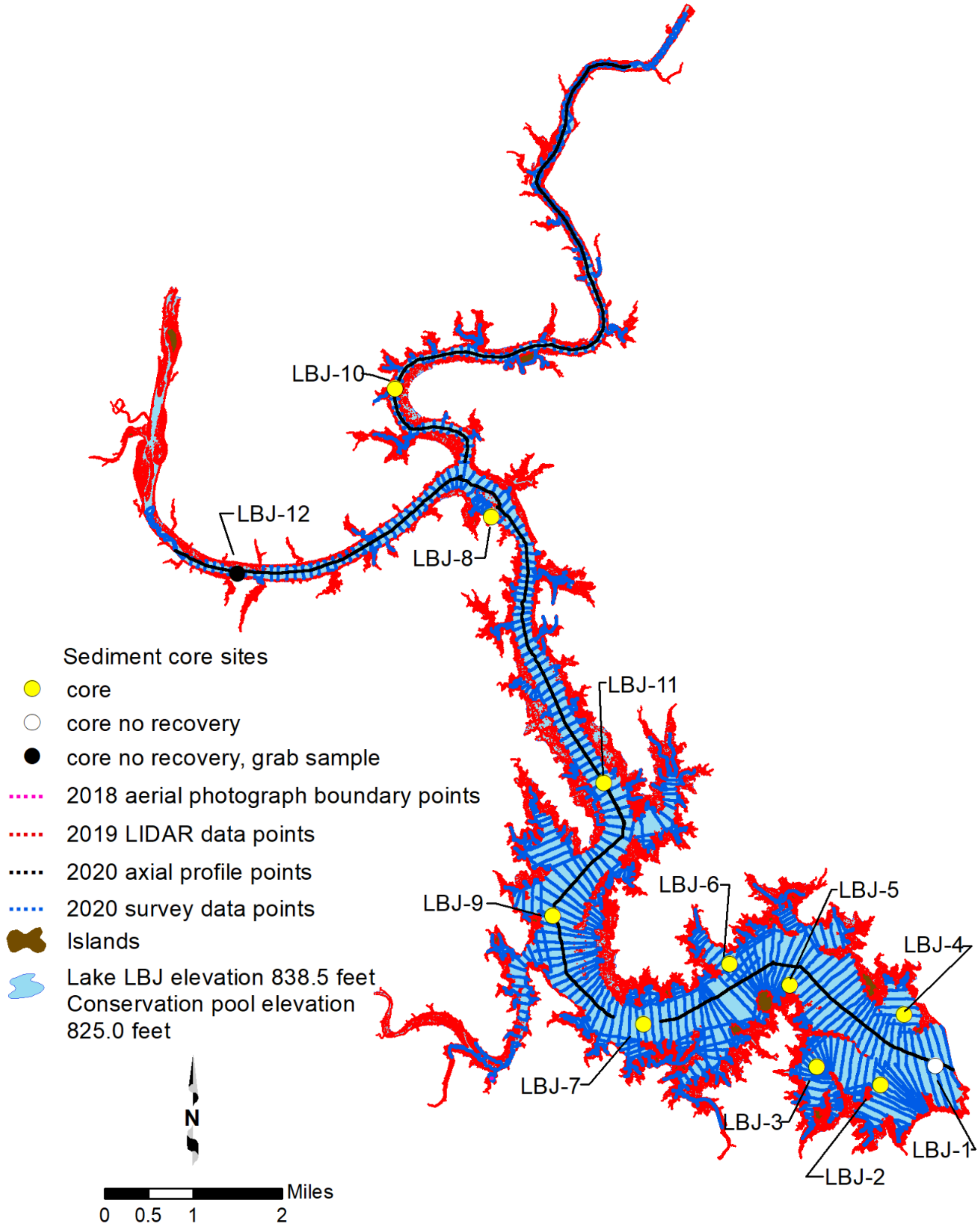


Figure 2. **2020 TWDB Lake LBJ survey data (*blue dots*), sediment coring locations (*circles*), and 2019 LIDAR data (*red dots*).**

Data processing

Model boundary

The model boundary of the reservoir was generated with Light Detection and Ranging (LIDAR) Data available from the Texas Natural Resource Information System. The LIDAR data were collected between January 4 and February 20, 2019 (Texas Water Development Board, 2021), while the daily average water surface elevation of the reservoir measured between 822.52 and 820.86 feet, respectively. The LIDAR data .las files were imported into an LAS Dataset and the dataset was converted to a raster using a cell size of 1.0 meters by 1.0 meters. A contour at 255.782064 meters equivalent to 839.18 feet NAVD88, was extracted as the upper extent of the model. The elevation of the top of the dam is 838.5 feet above mean sea level. The horizontal datum of the LIDAR data is Universal Transverse Mercator (UTM) North American Datum 1983 (NAD83; meters) Zone 14, and the vertical datum is North American Vertical Datum 1988 (NAVD88; meters). The vertical datum transformation offset of 0.68 feet was used to convert from feet NAVD88 to feet above mean sea level. The contour was edited to close the contour across the top of the dam. Horizontal coordinate transformations to NAD83 State Plane Texas Central Zone (feet) coordinates were done using the ArcGIS Project tool.

A singular island was added to the model as points in a nameless tributary of Sandy Creek just downstream of Walnut Creek. The points were digitized from aerial photography taken on August 23, 2018, while the daily average water surface elevation measured 824.7 feet above mean sea level. This imagery was obtained through the Texas Imagery Service. 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. The photographs have a resolution of 6 inches (Texas Natural Resources Information System, 2021). To make the points represent an island at conservation pool elevation when extracted from the model, the points were assigned an elevation of 825.1 feet.

Comparison of the boundary from the 2007 survey and 2020 survey show minor differences in area estimates at conservation pool elevation. These are a result of how the boundaries were generated. In 2007, the conservation pool elevation boundary was digitized from aerial photography taken on December 7, 2004, while the daily average water surface elevation of the reservoir measured 824.77 feet above mean sea level. The boundary was digitized at the land-water interface and labeled 825.0 feet above mean sea level. The 2020 boundary at conservation pool elevation is modeled from the survey data, interpolated data, and LIDAR data and was extracted from the triangular irregular network (TIN) model. Specific areas of difference include new canals added for residential lake access since the last survey and extension of the Llano River adding approximately 60 acres for the 2020 survey.

LIDAR data points

To utilize the LIDAR data in the reservoir model, the LIDAR data .las files were converted to a multipoint feature class in an Environmental Systems Research Institute's ArcGIS file geodatabase filtered to include only data classified as ground points. A topographical model of the data was generated. The ArcGIS tool Terrain to Points was used to extract points from the Terrain, or topographical model of the reservoir. The Terrain was created using the z-tolerance Pyramid Type. The points were extracted at the pyramid resolution of 0.25 meters to reduce computation burden without significantly affecting the modeled topography of the coverage area. New attribute fields were added to convert the elevations from meters to feet NAVD88 and then to feet above mean sea level for compatibility with the bathymetric survey data. LIDAR data outside of the 838.5-foot contour were deleted and the feature class projected to NAD83 State Plane Texas Central Zone (feet). Much of the LIDAR data agreed well with the TWDB survey data in areas of overlap, in areas where it did not, the LIDAR data were removed. No further interpolation of the data in the areas with only LIDAR coverage was necessary.

Triangulated Irregular Network model

Following completion of data collection, the raw data files collected by the TWDB were edited to remove data anomalies. The current bottom surface of the reservoir is automatically determined by the data acquisition software. Hydropick software, developed by TWDB staff, was used to display, interpret, and edit the multi-frequency data by manually removing data anomalies in the current bottom surface and to manually edit the pre-impoundment surfaces. The speed of sound profiles, also known as velocity casts, were used to further refine 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).

All data were 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). The resulting point file 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 (Environmental Systems Research Institute, 1995).

Spatial interpolation of reservoir bathymetry

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

To improve the accuracy of bathymetric representation between survey lines, the TWDB developed various anisotropic spatial interpolation techniques. Generally, the directionality of interpolation at different locations of a reservoir can be determined from external data sources. A basic assumption is that the reservoir profile in the vicinity of a particular location has upstream and downstream similarity. In addition, the sinuosity and directionality of submerged stream channels can be determined by directly examining the survey data, or more robustly by examining scanned USGS 7.5-minute quadrangle maps (DRGs), hypsography files (the vector format of USGS 7.5-minute quadrangle map contours), and historical aerial photographs, when available. Additionally, in the case of Lake LBJ, a multibeam survey completed on part of the lake between Wirtz Dam and the Elm Creek tributary in 2007, guided interpolation in these areas. Using the survey data, polygons are created to partition the reservoir into segments with centerlines defining the directionality of interpolation within each segment. Using the interpolation definition files and survey data, the current reservoir-bottom elevation, pre-impoundment elevation, and sediment thickness are calculated for each point in the high-resolution uniform grid of artificial survey points. The reservoir boundary, artificial survey points grid, and survey data points are used to create volumetric and sediment TIN models representing reservoir bathymetry and sediment accumulation throughout the reservoir. Specific details of this interpolation technique can be found in the HydroTools manual (McEwen and others, 2011a) and in McEwen and others (2011b).

In areas inaccessible to survey data collection, such as small coves and shallow upstream areas of the reservoir, linear interpolation is used for volumetric and sediment accumulation estimations (McEwen and others, 2011a). Although LIDAR was utilized, linear interpolation was necessary to accurately model features in the areas between survey data and LIDAR data. Linear interpolation results in improved elevation-capacity and elevation-area calculations.

Figure 3 illustrates typical results from application of the anisotropic interpolation as applied to Lake LBJ. In Figure 3A, deeper channels and steep slopes indicated by surveyed cross-sections are not continuously represented in areas between survey cross-sections. This is an artifact of the TIN generation routine rather than an accurate representation of the physical bathymetric surface. Inclusion of interpolation points in creation of the volumetric TIN model, represented in Figure 3B, directs Delaunay triangulation to better represent the reservoir bathymetry between survey cross-sections. The bathymetry shown in Figure 3C was used in computing reservoir elevation-capacity (Appendix A) and elevation-area (Appendix B) tables.

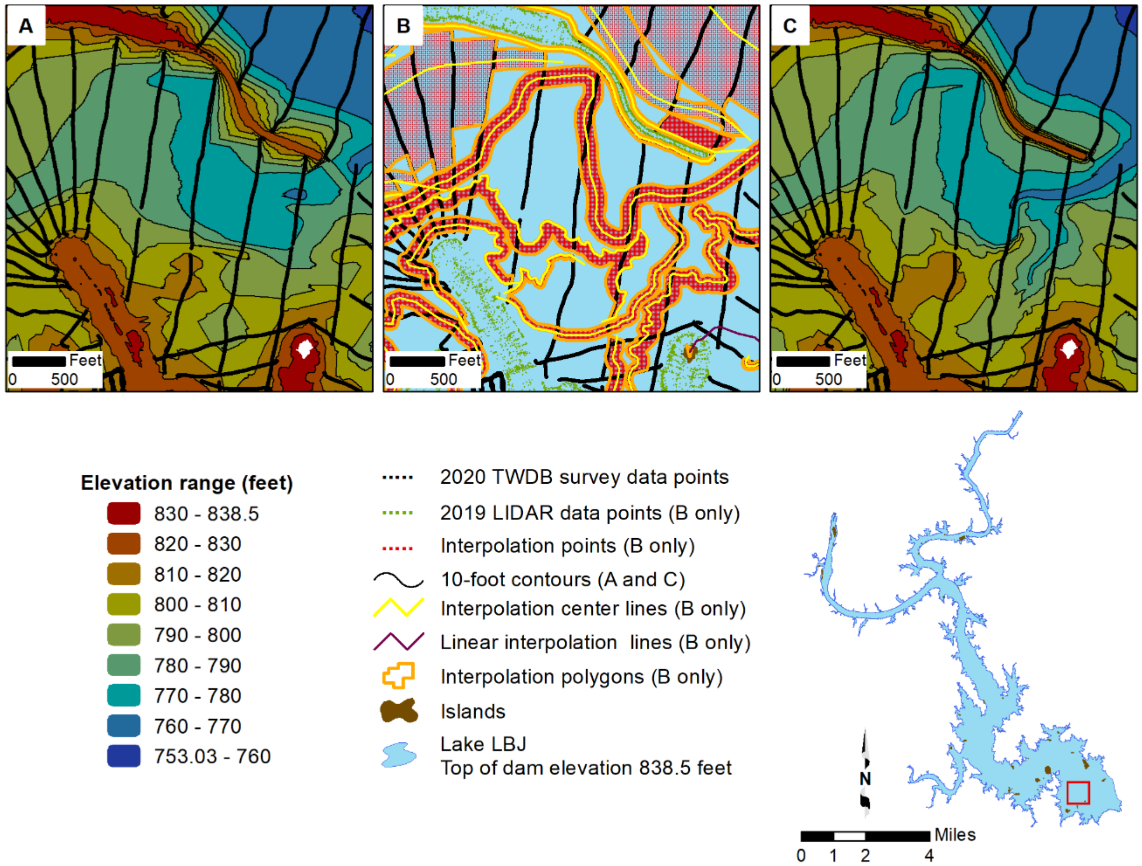
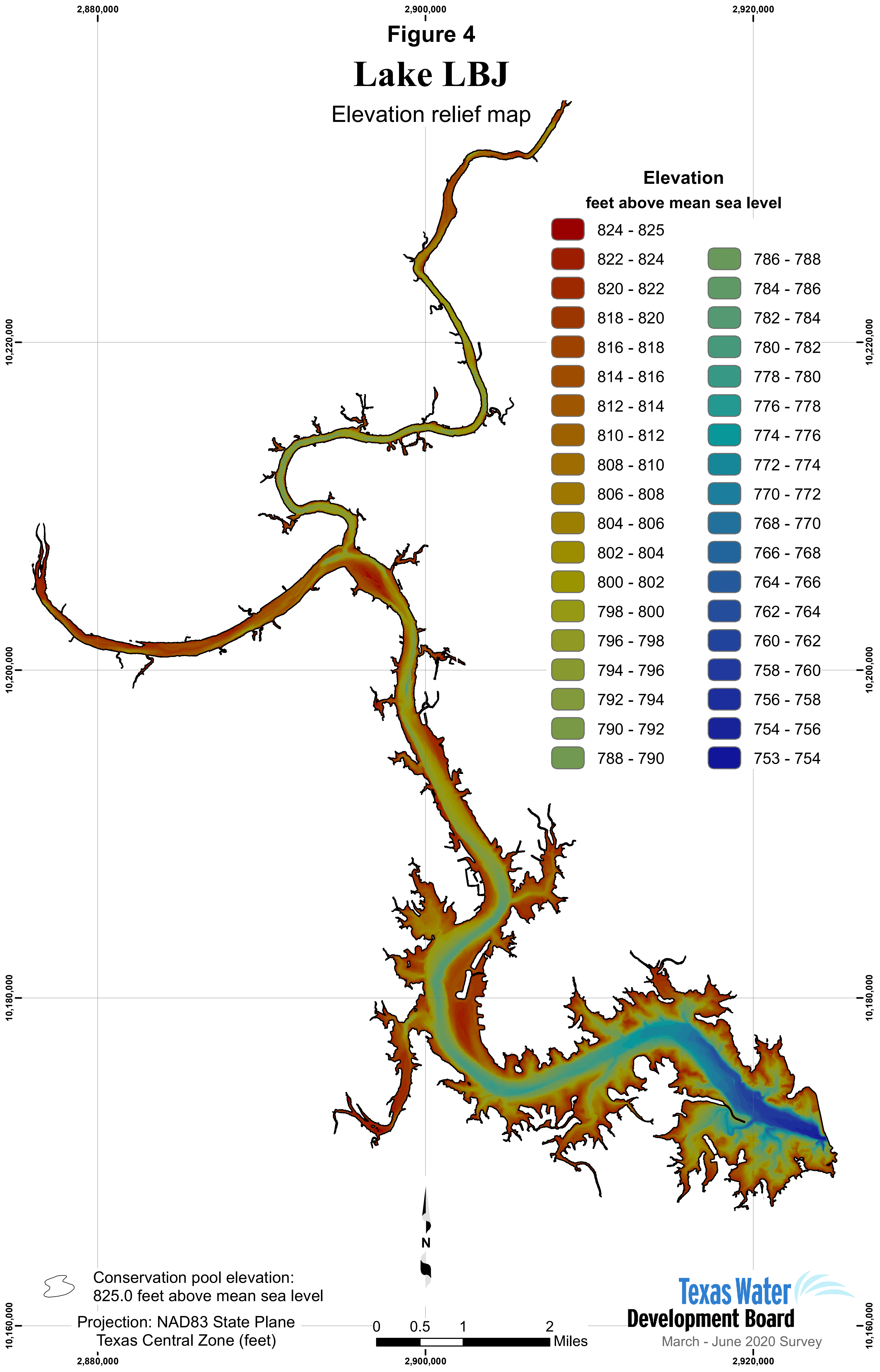


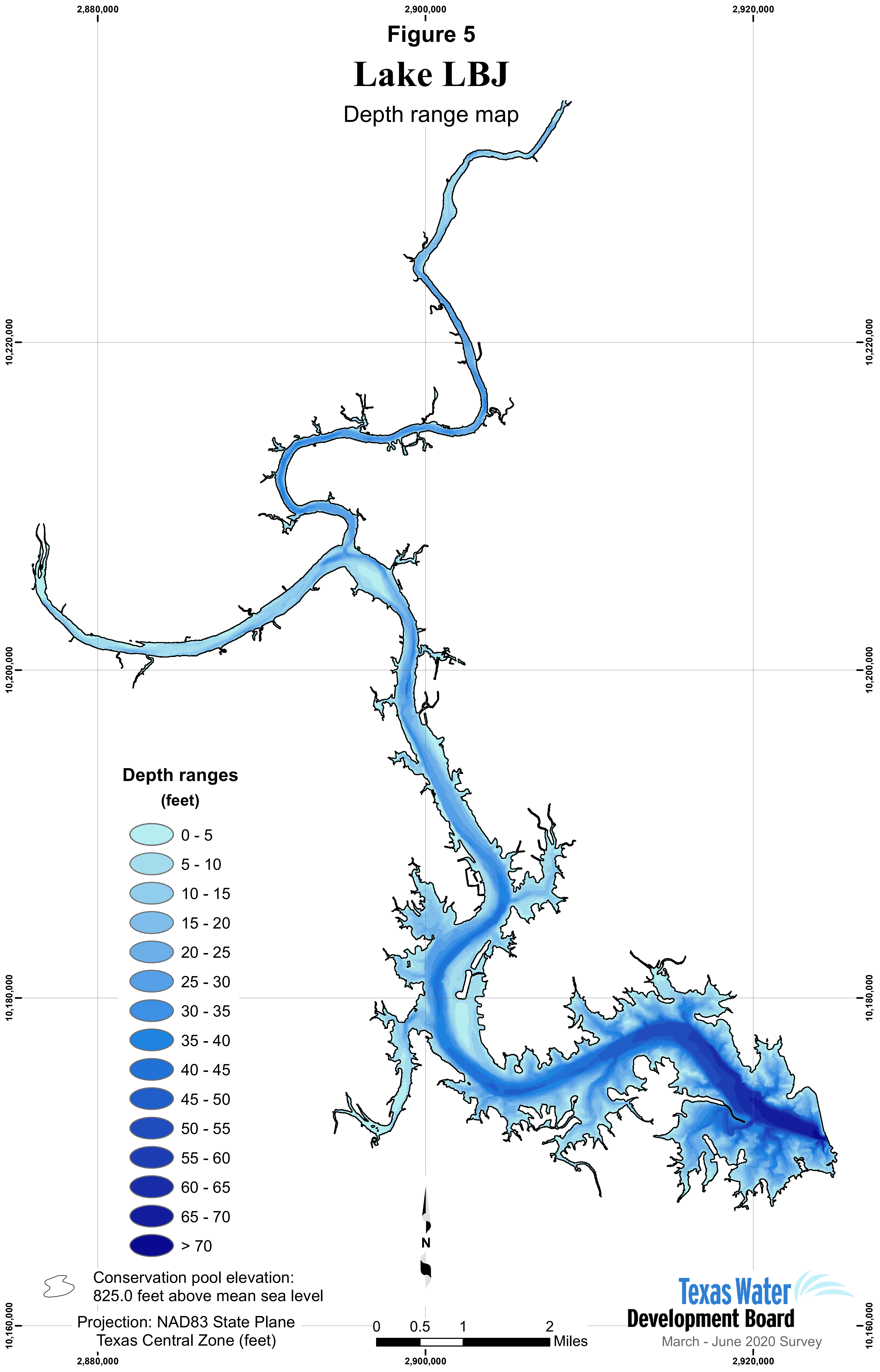
Figure 3. Anisotropic spatial interpolation as applied to Lake LBJ sounding data; A) bathymetric contours without interpolated points, B) sounding points (*black*) and interpolated points (*red*), C) bathymetric contours with interpolated points.

Area, volume, and contour calculation

Volumes and areas were computed for the entire reservoir at 0.1-foot intervals, from 753.0 to 838.5 feet above mean sea level. The elevation-capacity table and elevation-area table, based on the 2020 survey and analysis, are presented in Appendices A and B, respectively. The capacity curve is presented in Appendix C, and the area curve is presented in Appendix D.

The volumetric TIN model was converted to a raster representation using a cell size of 2 feet by 2 feet. The raster data then were 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 Lake LBJ (Figure 5); and, (3) a 10-foot contour map (Figure 6).


2,880,000
2,900,000
2,920,000
Figure 4
Lake LBJ
Elevation relief map
Elevation
feet above mean sea level
824 - 825
822 - 824
820 - 822
818 - 820
816 - 818
814 - 816
812 - 814
810 - 812
808 - 810
806 - 808
804 - 806
802 - 804
800 - 802
798 - 800
796 - 798
794 - 796
792 - 794
790 - 792
788 - 790
786 - 788
784 - 786
782 - 784
780 - 782
778 - 780
776 - 778
774 - 776
772 - 774
770 - 772
768 - 770
766 - 768
764 - 766
762 - 764
760 - 762
758 - 760
756 - 758
754 - 756
753 - 754
10,220,000
10,200,000
10,180,000
10,160,000
N
Conservation pool elevation:
825.0 feet above mean sea level
Projection: NAD83 State Plane
Texas Central Zone (feet)
0 0.5 1 2
Miles
Texas Water
Development Board
March - June 2020 Survey


2,880,000
2,900,000
2,920,000
Figure 5
Lake LBJ
Depth range map
10,220,000
10,200,000
10,180,000
10,160,000
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
Conservation pool elevation:
825.0 feet above mean sea level
Projection: NAD83 State Plane
Texas Central Zone (feet)
N
0
0.5
1
2
Miles
Texas Water
Development Board
March - June 2020 Survey

Analysis of sediment data from Lake LBJ

Sedimentation in Lake LBJ 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.

Sediment core sample	Easting[a] (feet)	Northing[a] (feet)	Total core sample / post-impoundment sediment length (inches)	Sediment core description[b]		Munsell soil color (Hue Value/Chroma)
LBJ-1	2923321.91	10171925.54	N/A	N/A	No recovery after multiple attempts	N/A
LBJ-2	2920067.83	10170788.10	79.0 / 78.0	post-impoundment	0.0-78.0" very high to moderate water content, water content decreases with depth, silty clay, smooth, pudding like, fibrous roots scattered throughout, cluster of dense roots and organic material at 45", bits of gravel at 70", organic matter present, mottled coloration	10YR 2/1 black 10 YR 3/1 very dark gray
				pre-impoundment	78.0-79.0" low water content, silty clay, very dense, fibrous roots, organic matter present	10YR 3/1 very dark gray
LBJ-3	2916294.40	10171862.63	89.0 / 81.0	post-impoundment	0.0-8.0" very high water content, silt, smooth, pudding like	10YR 2/1 black
					8.0-67.0" high to moderate water content, silty clay, smooth, pudding like	10YR 2/1 black
					67.0-75.0" low water content, sandy clay, twigs, fibrous and dendritic roots, dense, organic matter present	10YR 3/1 very dark gray
					75.0-81.0" low water content, coarse sand with clay present, dense, roots present, organic matter present	10YR 3/2 very dark grayish brown
				pre-impoundment	81.0-89.0" low water content, coarse sand with small gravel and rocks, clay present, dense, roots present, loosely packed, organic matter present	10YR 3/1 very dark gray
LBJ-4	2921479.89	10174955.75	60.0 / 58.0	post-impoundment	0.0-58.0" very high to moderate water content, water decreases with depth, silty clay, smooth, fibrous roots scattered throughout, organic matter present, mottled coloration	10YR 2/1 black 10 YR 3/1 very dark gray
				pre-impoundment	58.0-60.0" low water content, silty clay, very dense, roots throughout, bits of small rock at bottom, organic matter present	10YR 2/1 black

[a.] Coordinates are based on NAD83 State Plane Texas Central System (feet)
[b.] Sediment core samples are measured in inches with zero representing the current bottom surface

Table 2 (continued). Sediment core sample analysis data.

Sediment core sample	Easting[a] (feet)	Northing[a] (feet)	Total core sample / post-impoundment sediment length (inches)	Sediment core description[b]		Munsell soil color (Hue Value/Chroma)
LBJ-5	2914669.23	10176718.10	30.0 / 20.0	post-impoundment	0.0-17.0” very high to high water content, water decreases with depth, silt, smooth and pudding like, fibrous roots and large amount of organic matter present between 12 to 14 inches, organic matter present	10YR 3/1 very dark gray
					17.0-20.0” moderate water content, silt with small gravel, organic matter present	10YR 2/1 black
				pre-impoundment	20.0-26.0” moderate water content, coarse sand with silt and small gravel, some clay throughout, organic matter present	10YR 3/1 very dark gray
					26.0-30.0” low water content, loose, coarse sand, gravel, silt present, fibrous roots, organic matter present	10YR 2/1 black
LBJ-6	2911095.03	10177978.13	75.0 / 72.0	post-impoundment	0.0-38.0” very high to moderate water content, water content decreases with depth, silty clay, uniform, smooth, fibrous roots throughout, organic matter present, mottled coloration	10YR 2/1 black 10YR 3/1 very dark gray
					38.0-72.0” moderate water content, silty clay, smooth, very dense, fibrous root and twigs throughout, organic matter present, mottled coloration	10YR 2/1 black 10YR 3/1 very dark gray
				pre-impoundment	72.0-75.0” low water content, clay, large amounts of fibrous roots throughout, organic matter present	10YR 2/2 very dark brown
LBJ-7	2905976.04	10174413.30	68.0 / 50.0	post-impoundment	0.0-4.0” very high water content, silt, smooth, soupy, fibrous roots throughout, organic matter present	10YR 2/1 black
					4.0-24.0” moderate water content, silty clay, dense, pudding like, fibrous roots throughout, organic matter present, mottled coloration	10YR 2/1 black 10YR 3/1 very dark gray
					24.0-28.0” moderate water content, silty clay, dense, pudding like, some fine sand present, fibrous roots throughout, thick layer of organic matter present	10YR 2/1 black
					28.0-43.0” moderate water content, silty clay, smooth, pudding like, organic matter throughout, twigs and small woody debris scattered throughout, mottled coloration	10YR 2/1 black 10YR 3/1 very dark gray
					43.0-47.0” moderate water content, layer of organic matter with silty clay mixed in	10YR 2/1 black

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

[b] Sediment core samples are measured in inches with zero representing the current bottom surface

Table 2 (continued). Sediment core sample analysis data.

Sediment core sample	Easting[a] (feet)	Northing[a] (feet)	Total core sample / post-impoundment sediment length (inches)	Sediment core description[b]		Munsell soil color (Hue Value/Chroma)
LBJ-7 (continued)	2905976.04	10174413.30	68.0 / 50.0	post-impoundment	47.0-50.0" low water content, sand dense, small roots present	10YR 3/2 very dark grayish brown
				pre-impoundment	50.0-68.0" low water content, silty clay, roots and leaves present, mottled coloration	10YR 2/1 black 10YR 3/1 very dark gray
LBJ-8	2896908.85	1204556.85	74.0 / 71.0	post-impoundment	0.0-2.0" very high water content, sandy silt, smooth, soupy	10YR 2/2 very dark brown
					2.0-4.0" moderate water content, dense silty sand, coarse sand	10YR 2/1 black
					4.0-12.0" moderate water content, silty clay, pudding like	10YR 2/1 black
					12.0-17.0" moderate water content, silty clay, pudding like, dense	10YR 2/1 black
					17.0-20.0" moderate water content, layer of organic matter with silty clay mixed in	10YR 2/1 black
					20.0-71.0" moderate to low water content, water decreases with depth, silty clay, malleable, roots and leaf litter present, organic matter present throughout	10YR 2/1 black
				pre-impoundment	71.0-74.0" low water content, very dense clay, roots throughout	10YR 2/1 black
LBJ-9	2900585.56	10180844.53	110.0 / 96.0	post-impoundment	0-18.0" very high water content, silt, smooth, pudding like	10YR 5/1 gray
					18.0-21.0" moderate water content, silty sand, dense, organic matter present	10YR 2/2 very dark brown
					21.0-39.0" moderate water content, silty clay, smooth, pudding like, fibrous roots, minimal organic matter at bottom of layer	10YR 3/2 very dark grayish brown
					39.0-46.0" low water content, fine sand, dense, distinct leaf litter, bark and small twigs, dense roots at 46 inches	2.5Y 3/2 very dark grayish brown

a. Coordinates are based on NAD83 State Plane Texas Central System (feet)
b. Sediment core samples are measured in inches with zero representing the current bottom surface

Table 2 (continued). Sediment core sample analysis data.

Sediment core sample	Easting[a] (feet)	Northing[a] (feet)	Total core sample / post-impoundment sediment length (inches)	Sediment core description[b]		Munsell soil color (Hue Value/Chroma)
LBJ-9 (continued)	2900585.56	10180844.53	110.0 / 96.0	post-impoundment	46.0-94.0" moderate to low water content, water decreases with depth, silty clay, malleable, peanut butter consistency, uniform consistency throughout, no organic matter present	10YR 2/1 black
					94.0-96.0" low water content, sandy clay, malleable, uniform consistency, no organic matter present	10YR 3/3 dark brown
				pre-impoundment	96.0-110.0" low water content, clay, very dense, fibrous roots throughout	10YR 2/1 black
LBJ-10	2891205.34	10212213.54	21.0 / 21.0	post-impoundment	0.0-5.0" very high water content, silty clay, soupy, no organic matter present	10YR 2/2 very dark brown
					5.0-21.0" moderate water content, water decreases with depth, silty clay, pudding like, smooth, woody debris present, mottled coloration	10YR 2/1 black 10YR 2/2 very dark brown
LBJ-11	2903619.15	10188770.47	80.0 / 78.0	post-impoundment	0.0-23.0" low water content, thin layer of soupy silt at top, dense fine sand, uniform sugar textured sand, no organic matter present	10YR 4/4 dark yellowish brown
					23.0-54.0" low water content, silty clay, dense, small roots throughout, band of sand present at 48-50 inches	10YR 3/1 very dark gray
					54.0-63.0" very low water content, fine sand, very dense, uniform consistency, no organic matter present	10YR 4/4 dark yellowish brown
					63.0-78.0" low water content, silty clay, smooth, dense, uniform consistency, organic matter present	10YR 3/1 very dark gray
				pre-impoundment	78.0-80.0" low water content, silty clay, very dense, lots of organic material present	10YR 2/1 black
LBJ-12	2881797.92	10201188.93	Grab[c]	post-impoundment	fine to coarse sand	N/A
			N/A	N/A	No recovery after multiple attempts	N/A

[a.] Coordinates are based on NAD83 State Plane Texas Central System (feet)
[b.] Sediment core samples are measured in inches with zero representing the current bottom surface
[c.] Grab samples were collected using a petite Ponar dredge sampler

A photograph of sediment core LBJ-11 (for location, refer to Figure 2) is shown in Figure 7. The base, or deepest part of the sample is denoted by the blue line. The pre-impoundment boundary (yellow line closest to the base) was evident within this sediment core sample at 78.0 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.

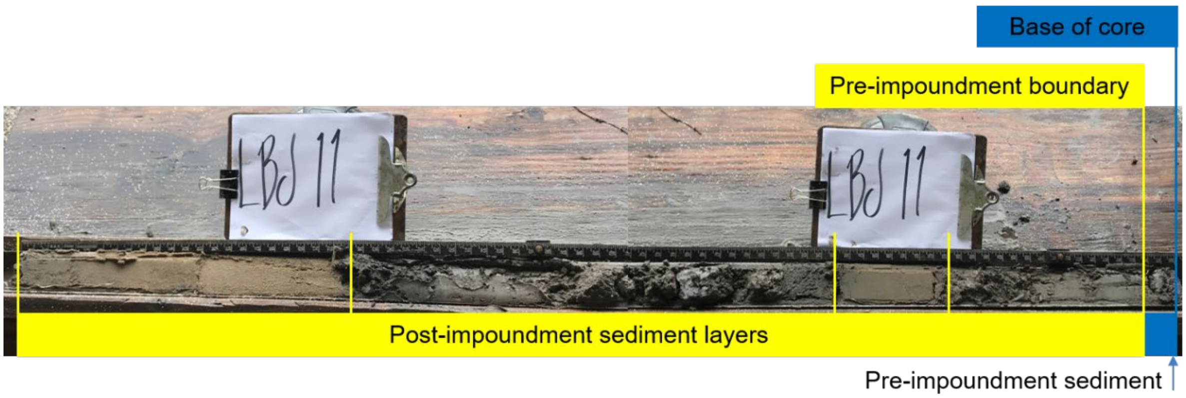


Figure 7. Sediment core LBJ-11 from Lake LBJ. Post-impoundment sediment layers occur in the top 50.0 inches of this sediment core (identified by the yellow box). Pre-impoundment sediment layers were identified and are defined by the blue box.

Figure 8 illustrates the relationships between acoustic signal returns and the depositional layering seen in sediment cores. In this example, sediment core LBJ-11 is shown correlated with each frequency: 208 kHz, 50 kHz, and 12 kHz. The current bathymetric surface is 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 were 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. Yellow boxes represent post-impoundment sediments identified in the sediment core. Blue boxes indicate pre-impoundment sediments.

The pre-impoundment boundary in sediment core LBJ-11 most closely aligned with the different layers picked up by the 12 kHz acoustic returns (Figure 8). The pre-impoundment surface is first identified along cross-sections for which sediment core samples were 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.

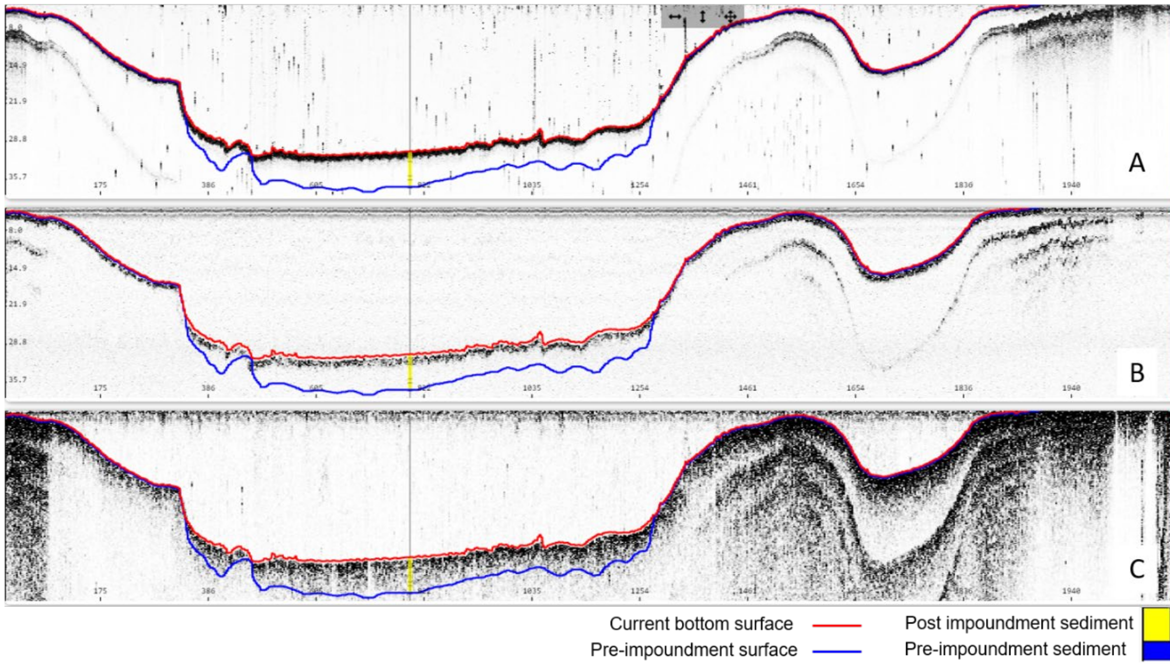
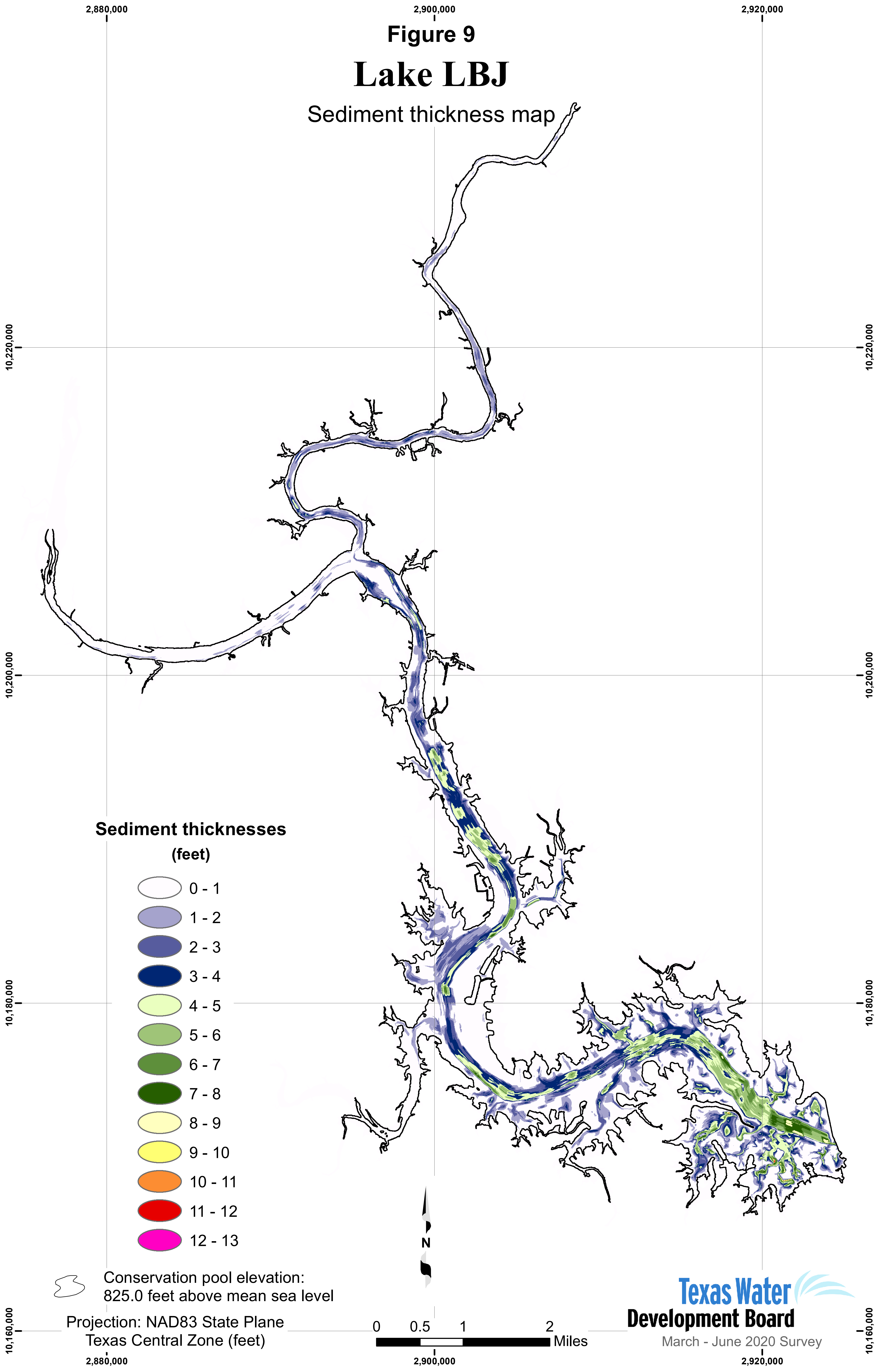


Figure 8. Comparison of sediment core LBJ-11 with acoustic signal returns. A) 208 kHz frequency, B) 50 kHz frequency, and C) 12 kHz frequency. The current surface in red and pre-impoundment surface in blue.

After the pre-impoundment surface for all cross-sections is identified, a pre-impoundment TIN model and a sediment thickness TIN model are created. 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 each LIDAR data point and the reservoir boundary was 0 feet (defined as the 740.0-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 (Figure 9). Elevation-capacity and elevation-area tables were computed from the pre-impoundment TIN model for the purpose of calculating the total volume of accumulated sediment.



2,880,000
2,900,000
2,920,000
Figure 9
Lake LBJ
Sediment thickness map
10,220,000
10,200,000
10,180,000
10,160,000
Sediment thicknesses
(feet)
0 - 1
1 - 2
2 - 3
3 - 4
4 - 5
5 - 6
6 - 7
7 - 8
8 - 9
9 - 10
10 - 11
11 - 12
12 - 13
Conservation pool elevation:
825.0 feet above mean sea level
Projection: NAD83 State Plane
Texas Central Zone (feet)
N
0
0.5
1
2
Miles
Texas Water
Development Board
March - June 2020 Survey

Survey results

Volumetric survey

The 2020 TWDB volumetric survey indicates that Lake LBJ has a total reservoir capacity of 131,618 acre-feet and encompasses 6,432 acres at conservation pool elevation (825.00 feet above mean sea level). Current area and capacity estimates are compared to previous area and capacity estimates at different elevations in Table 3. 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.

Survey	Surface Area (acres)	Total Capacity (acre-feet)	Conservation Pool Elevation[a]	Source(s)
Original design LCRA 1949	6,375	138,500	825.00	Texas Water Development Board, 1971
LCRA 1995 TWDB revised[b]	6,289	135,421	825.00	Texas Water Development Board, 2007
TWDB 2007	6,273	133,090	825.00	Texas Water Development Board, 2007
TWDB 2020	6,432	131,618	825.00	

[a] Feet above mean sea level, LCRA legacy datum.

[b] Developed from a combination of 1995 LCRA survey data, 1995 aerial photographs, and TWDB self-similar and line extrapolation techniques (Texas Water Development Board, 2009).

Volumetric survey accuracy assessment

Axial profile data were collected to evaluate the accuracy of the volumetric survey. For location of the axial profile points see Figure 2. For other uses of the axial profile data see the section below titled "Axial profile". First, the accuracy of the survey data was assessed by calculating the root mean square error (RMSE) of the differences between the axial profile points and the survey data points within 1.5 feet. Second, the accuracy of the interpolated data was assessed by calculating the RMSE of the differences between the axial profile points and the model surface. The RMSE of the survey data points is 0.56 feet and the RMSE of the model surface is 1.50 feet. Using the RMSE value of 1.50 as the range of uncertainty for the volumetric survey, 1.50 feet was added to and subtracted from only the survey data and interpolated data points. Elevation-area-capacity tables of the resulting models provide the range of potential error throughout the survey. Results at conservation pool elevation suggest the total reservoir capacity estimate is accurate to within ± 6.23 percent (± 8,201 acre-feet). As depth increases the percent of uncertainty increases as a small change in elevation can lead to a much larger percent change in area, and therefore, capacity.

Sedimentation survey

The 2020 TWDB sedimentation survey measured 9,116 acre-feet of sediment. The sedimentation survey indicates sediment accumulation is greatest near the dam. Comparison of capacity estimates of Lake LBJ derived using differing methodologies are provided in Table 4 for sedimentation rate calculation. The 2020 TWDB sedimentation survey indicates Lake LBJ has lost capacity at an average of 132 acre-feet per year since impoundment due to sedimentation below flood gate elevation (825.00 feet above mean sea level). Long-term trends indicate Lake LBJ loses capacity at an average of 111 acre-feet per year since impoundment due to sedimentation below flood gate elevation (825.00 feet above mean sea level) (Figure 10). Differences in methodology may also contribute to differences between these surveys.

The TWDB sedimentation estimate may be a slight overestimate of accumulated sediment. Lake LBJ is a sandy reservoir, with multiple layers of sand found throughout the sediment core samples, which complicates pre-impoundment identification efforts. Density stratification in the sediment layers can scatter and attenuate acoustic return signals of the multi-frequency depth sounder (U.S. Army Corps of Engineers, 2013). Lake LBJ, on the confluence of the Llano River with the Colorado River has been historically susceptible to major flooding. Some sediment identified as post-impoundment in 2020 may be sediment that has shifted downstream in the reservoir due to high flow events, particularly a record setting flood in October of 2018.

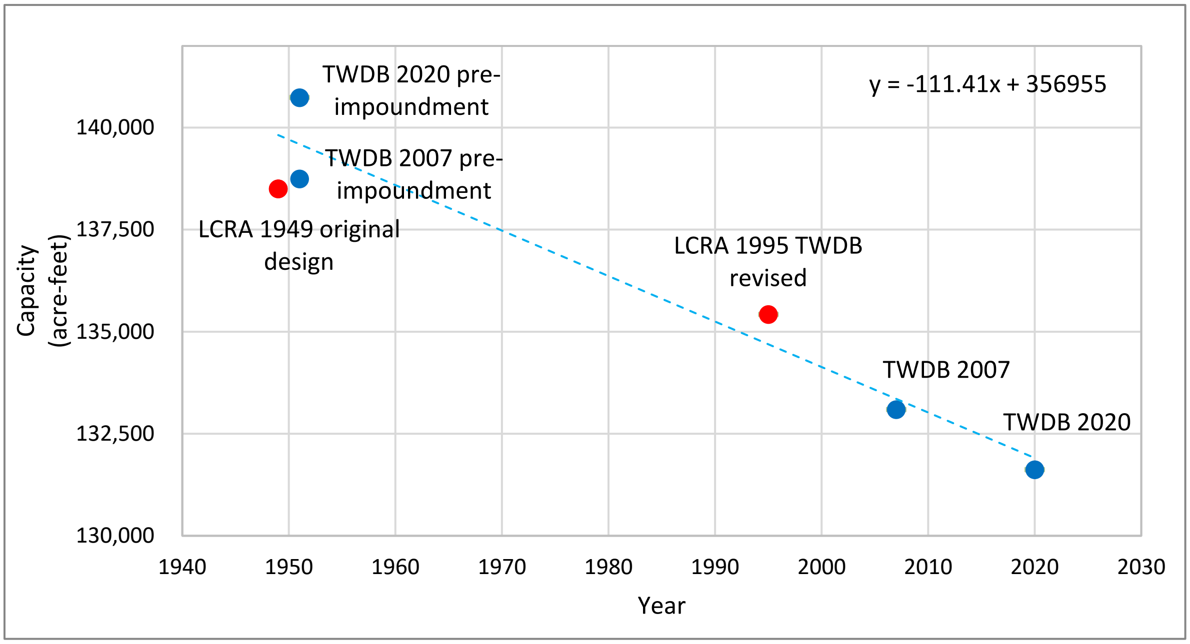


Figure 10. Plot of current and previous capacity estimates (acre-feet) at elevation 825.0 feet for Lake LBJ. Capacity estimates for each TWDB survey plotted as blue dots and other surveys as red dots. The blue trend line illustrates the total average loss of capacity through 2020. The 2007 TWDB pre-impoundment estimate is not included in the trendline calculation and is for informational purposes only.

Table 4. Average annual capacity loss comparisons

Survey	Top of conservation pool elevation (825.0 feet above mean sea level)			
Original design LCRA 1949[a]	138,500	<>	<>	<>
LCRA 1995 TWDB revised[b]	<>	135,421	<>	<>
TWDB 2007	<>	<>	133,090	<>
TWDB pre-impoundment estimate based on 2020 survey[c]	<>	<>	<>	140,734
2020 volumetric survey	131,618	131,618	131,618	131,618
Volume difference (acre-feet) Percent change	6,882 5.0	3,803 2.8	1,472 1.1	9,116 6.5
Number of years	71	25	13	69
Capacity loss rate (acre-feet/year)	97	152	113	132
Capacity loss rate (acre-feet/square mile of drainage area of 24,390 square miles /year)	0.004	0.006	0.005	0.005

[a] Source(s): M. Luna, P.E., written commun(s)., 2006; Texas Water Development Board, 1971.

[b] Source: Texas Water Development Board, 2009. Developed from a combination of 1995 LCRA survey data, 1995 aerial photographs, and TWDB self-similar and line extrapolation techniques.

[c] Alvin J. Wirtz Dam was completed on June 27,1951, and the deliberate impoundment began in May 1951.

Axial profile

The axial profile of the reservoir, showing both the 2020 current and pre-impoundment surfaces, is plotted in Appendix E. Also presented in Appendix E 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 in 2007 and to correlate with unique acoustic returns throughout the reservoir. 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 volumetric survey of Lake LBJ within a 10-year timeframe or after a major high flow event to assess changes in reservoir capacity and to further improve estimates of sediment accumulation rates. As technology improves, a volumetric and sedimentation survey may better define the pre-impoundment surface further improving estimates of sediment accumulation rates. Due to the irregular bottom, riverine behavior of the reservoir, and responses to high flow events, a multibeam survey should be considered to more accurately measure capacity and identify changes in the reservoir bottom.

TWDB contact information

For more information about the TWDB Hydrographic Survey Program, visit www.twdb.texas.gov/surfacewater/surveys. Any questions regarding the TWDB Hydrographic Survey Program or this report may be addressed to: Hydrosurvey@twdb.texas.gov.

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Appendix A

Lake Lyndon B Johnson

RESERVOIR CAPACITY TABLE

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

March - June 2020 Survey
Top of flood dam elevation 838.5 feet
Conservation pool elevation 825.0 feet

ELEVATION (Feet MSL)	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
753	0	0	0	0	0	0	0	0	0	0
754	0	1	1	1	1	2	2	2	3	3
755	4	4	5	5	6	7	8	9	10	11
756	12	14	15	17	18	20	22	24	26	29
757	31	34	36	39	42	45	48	52	55	59
758	63	67	71	75	80	84	89	95	100	106
759	112	118	124	130	137	144	151	158	166	173
760	181	188	196	204	213	221	230	239	247	256
761	265	275	284	293	303	313	323	333	343	353
762	364	375	385	396	407	419	430	442	454	466
763	478	491	503	516	530	543	557	571	586	600
764	615	630	645	660	675	691	706	722	737	753
765	769	786	802	819	835	852	869	886	904	921
766	939	957	975	993	1,011	1,030	1,049	1,068	1,087	1,107
767	1,126	1,146	1,166	1,186	1,206	1,227	1,247	1,268	1,289	1,310
768	1,331	1,353	1,374	1,396	1,419	1,441	1,464	1,487	1,510	1,533
769	1,557	1,581	1,605	1,629	1,654	1,678	1,703	1,728	1,754	1,779
770	1,805	1,831	1,858	1,884	1,911	1,938	1,965	1,993	2,021	2,049
771	2,078	2,106	2,136	2,165	2,194	2,224	2,255	2,285	2,316	2,346
772	2,378	2,409	2,441	2,473	2,505	2,538	2,571	2,604	2,637	2,671
773	2,705	2,739	2,774	2,809	2,844	2,879	2,916	2,952	2,989	3,026
774	3,064	3,103	3,141	3,180	3,219	3,258	3,298	3,338	3,378	3,419
775	3,460	3,501	3,542	3,584	3,626	3,668	3,710	3,753	3,796	3,839
776	3,883	3,926	3,970	4,015	4,059	4,104	4,149	4,194	4,240	4,286
777	4,332	4,378	4,425	4,472	4,519	4,567	4,614	4,662	4,710	4,758
778	4,807	4,856	4,905	4,955	5,004	5,055	5,105	5,156	5,207	5,258
779	5,310	5,362	5,414	5,467	5,520	5,574	5,628	5,682	5,737	5,793
780	5,849	5,905	5,963	6,021	6,080	6,139	6,199	6,260	6,321	6,382
781	6,445	6,508	6,571	6,635	6,699	6,763	6,828	6,894	6,960	7,026
782	7,093	7,160	7,228	7,296	7,364	7,433	7,502	7,572	7,643	7,714
783	7,786	7,858	7,932	8,006	8,081	8,156	8,232	8,309	8,386	8,464
784	8,543	8,622	8,702	8,782	8,863	8,945	9,027	9,110	9,193	9,277
785	9,362	9,447	9,532	9,619	9,705	9,793	9,881	9,969	10,058	10,148
786	10,238	10,329	10,420	10,513	10,606	10,699	10,793	10,888	10,983	11,080
787	11,177	11,274	11,373	11,472	11,571	11,672	11,773	11,875	11,977	12,080
788	12,184	12,289	12,394	12,500	12,606	12,713	12,821	12,929	13,038	13,148
789	13,258	13,369	13,480	13,593	13,706	13,820	13,934	14,049	14,165	14,281
790	14,399	14,517	14,636	14,756	14,876	14,997	15,119	15,242	15,366	15,490
791	15,616	15,742	15,868	15,996	16,124	16,253	16,382	16,513	16,644	16,775
792	16,908	17,041	17,174	17,309	17,444	17,580	17,717	17,854	17,993	18,132
793	18,272	18,413	18,554	18,697	18,840	18,985	19,130	19,276	19,422	19,570
794	19,719	19,868	20,019	20,170	20,323	20,476	20,631	20,786	20,943	21,100
795	21,258	21,417	21,578	21,739	21,901	22,065	22,229	22,394	22,561	22,729
796	22,897	23,067	23,238	23,410	23,583	23,758	23,934	24,111	24,289	24,469
797	24,649	24,831	25,014	25,198	25,383	25,570	25,757	25,946	26,135	26,326
798	26,518	26,712	26,906	27,102	27,299	27,497	27,696	27,897	28,099	28,302
799	28,506	28,712	28,919	29,128	29,337	29,548	29,761	29,975	30,190	30,406
800	30,624	30,843	31,064	31,285	31,508	31,732	31,958	32,184	32,412	32,641
801	32,872	33,103	33,336	33,571	33,806	34,043	34,281	34,520	34,760	35,002
802	35,245	35,489	35,734	35,980	36,228	36,476	36,726	36,977	37,228	37,481
803	37,735	37,991	38,247	38,504	38,763	39,022	39,283	39,545	39,808	40,072
804	40,338	40,605	40,873	41,142	41,413	41,685	41,958	42,232	42,507	42,784
805	43,061	43,340	43,620	43,902	44,184	44,468	44,753	45,040	45,327	45,616
806	45,907	46,198	46,492	46,786	47,082	47,380	47,678	47,978	48,279	48,582
807	48,885	49,190	49,497	49,804	50,113	50,424	50,735	51,048	51,362	51,678
808	51,995	52,313	52,632	52,953	53,275	53,599	53,923	54,249	54,577	54,905
809	55,235	55,567	55,900	56,234	56,569	56,906	57,245	57,584	57,926	58,268
810	58,612	58,958	59,305	59,654	60,004	60,355	60,708	61,062	61,418	61,775
811	62,133	62,493	62,855	63,218	63,582	63,948	64,316	64,685	65,056	65,428
812	65,802	66,178	66,555	66,933	67,314	67,695	68,078	68,463	68,850	69,237

Appendix A

Lake Lyndon B Johnson

RESERVOIR CAPACITY TABLE continued

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

March - June 2020 Survey
Top of flood dam elevation 838.5 feet
Conservation pool elevation 825.0 feet

ELEVATION (Feet MSL)	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
813	69,627	70,018	70,411	70,805	71,201	71,599	71,998	72,399	72,802	73,207
814	73,613	74,021	74,431	74,843	75,257	75,672	76,089	76,509	76,930	77,353
815	77,778	78,205	78,634	79,065	79,498	79,933	80,370	80,810	81,251	81,694
816	82,139	82,587	83,036	83,487	83,941	84,396	84,853	85,312	85,774	86,237
817	86,702	87,168	87,637	88,108	88,581	89,055	89,532	90,011	90,491	90,974
818	91,458	91,944	92,433	92,923	93,416	93,911	94,408	94,907	95,408	95,912
819	96,417	96,926	97,436	97,949	98,464	98,982	99,502	100,025	100,550	101,078
820	101,609	102,142	102,678	103,216	103,757	104,302	104,849	105,400	105,955	106,514
821	107,077	107,643	108,214	108,788	109,365	109,946	110,530	111,117	111,707	112,299
822	112,895	113,493	114,094	114,697	115,303	115,911	116,520	117,132	117,745	118,360
823	118,977	119,596	120,216	120,838	121,462	122,087	122,713	123,341	123,971	124,602
824	125,234	125,868	126,503	127,139	127,776	128,414	129,053	129,693	130,333	130,975
825	131,618	132,261	132,906	133,552	134,199	134,847	135,496	136,146	136,798	137,451
826	138,105	138,761	139,419	140,078	140,739	141,403	142,069	142,738	143,409	144,084
827	144,761	145,442	146,125	146,812	147,502	148,194	148,890	149,589	150,290	150,995
828	151,702	152,412	153,126	153,842	154,561	155,284	156,010	156,738	157,470	158,205
829	158,943	159,684	160,428	161,176	161,926	162,680	163,437	164,196	164,959	165,725
830	166,494	167,267	168,042	168,820	169,602	170,386	171,174	171,964	172,758	173,554
831	174,353	175,156	175,961	176,769	177,580	178,393	179,210	180,029	180,851	181,677
832	182,505	183,336	184,170	185,007	185,847	186,690	187,536	188,385	189,237	190,092
833	190,950	191,811	192,675	193,542	194,413	195,286	196,163	197,042	197,925	198,811
834	199,699	200,591	201,486	202,383	203,284	204,187	205,094	206,003	206,916	207,831
835	208,750	209,671	210,596	211,523	212,454	213,388	214,324	215,264	216,206	217,152
836	218,101	219,052	220,006	220,964	221,924	222,887	223,853	224,822	225,794	226,769
837	227,747	228,728	229,711	230,698	231,687	232,679	233,675	234,672	235,673	236,677
838	237,683	238,692	239,704	240,719	241,737	242,758				

Appendix B

Lake Lyndon B Johnson

RESERVOIR AREA TABLE

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

March - June 2020 Survey
Top of flood dam elevation 838.5 feet
Conservation pool elevation 825.0 feet

ELEVATION (Feet MSL)	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
753	0	0	0	0	0	0	0	1	1	1
754	1	2	3	3	3	4	4	4	4	5
755	5	5	6	6	7	9	9	10	11	12
756	13	14	15	16	17	19	21	22	23	24
757	25	26	27	28	29	31	33	35	36	37
758	39	40	43	44	46	49	52	54	56	58
759	60	61	63	66	67	70	71	73	74	76
760	77	78	80	82	84	85	87	88	89	90
761	91	92	94	95	96	98	100	101	103	105
762	106	108	109	110	112	114	115	117	120	122
763	124	127	129	132	135	138	140	142	144	146
764	148	149	151	152	153	154	156	157	158	160
765	161	163	165	166	168	169	171	173	174	176
766	178	180	181	184	186	188	190	192	194	195
767	197	198	200	201	203	204	206	208	210	212
768	214	217	219	221	224	226	228	230	232	234
769	237	239	242	244	247	249	251	253	255	257
770	260	262	264	267	269	272	275	277	280	284
771	287	290	292	295	298	300	303	305	308	310
772	313	316	319	322	325	328	330	333	335	338
773	342	344	347	350	354	359	363	367	372	377
774	380	384	387	390	393	396	399	401	404	407
775	409	412	415	417	420	423	425	428	431	434
776	436	439	442	444	447	450	452	455	457	460
777	463	465	468	470	472	475	477	480	483	485
778	488	491	493	496	499	502	505	508	512	516
779	519	523	526	530	534	538	542	547	552	558
780	564	571	577	584	590	597	603	609	615	621
781	626	630	635	639	643	648	653	657	661	665
782	669	674	678	683	687	692	697	702	707	714
783	723	731	737	744	750	757	763	770	776	783
784	789	795	801	807	813	819	825	831	837	843
785	848	854	860	865	871	876	882	888	894	900
786	906	912	919	925	932	938	945	951	958	966
787	973	980	987	994	1,001	1,008	1,015	1,022	1,028	1,035
788	1,041	1,048	1,054	1,061	1,067	1,073	1,080	1,086	1,093	1,100
789	1,106	1,113	1,120	1,127	1,134	1,141	1,147	1,154	1,162	1,169
790	1,178	1,186	1,193	1,201	1,208	1,216	1,224	1,232	1,241	1,248
791	1,256	1,263	1,271	1,278	1,285	1,292	1,299	1,306	1,313	1,320
792	1,327	1,334	1,341	1,349	1,356	1,363	1,371	1,379	1,388	1,396
793	1,404	1,413	1,421	1,429	1,438	1,447	1,455	1,464	1,473	1,482
794	1,491	1,500	1,510	1,520	1,530	1,539	1,549	1,559	1,569	1,578
795	1,588	1,597	1,608	1,618	1,628	1,639	1,649	1,660	1,671	1,681
796	1,692	1,704	1,715	1,727	1,740	1,752	1,765	1,777	1,789	1,801
797	1,812	1,823	1,835	1,846	1,857	1,869	1,880	1,892	1,904	1,915
798	1,927	1,939	1,951	1,963	1,975	1,988	2,000	2,012	2,025	2,038
799	2,051	2,064	2,077	2,090	2,104	2,117	2,131	2,145	2,158	2,172
800	2,185	2,198	2,211	2,223	2,236	2,248	2,259	2,272	2,285	2,297
801	2,310	2,323	2,336	2,349	2,362	2,374	2,386	2,398	2,410	2,422
802	2,434	2,446	2,457	2,468	2,480	2,491	2,502	2,513	2,524	2,535
803	2,546	2,557	2,568	2,580	2,591	2,602	2,613	2,625	2,637	2,649
804	2,662	2,674	2,687	2,700	2,712	2,724	2,736	2,748	2,759	2,771
805	2,783	2,795	2,807	2,820	2,832	2,845	2,857	2,870	2,883	2,897
806	2,911	2,925	2,939	2,953	2,966	2,980	2,993	3,005	3,018	3,031
807	3,044	3,057	3,070	3,083	3,096	3,109	3,123	3,136	3,149	3,162
808	3,175	3,188	3,201	3,214	3,227	3,240	3,253	3,267	3,280	3,294
809	3,308	3,321	3,335	3,348	3,362	3,376	3,391	3,405	3,420	3,434
810	3,449	3,464	3,478	3,492	3,507	3,521	3,535	3,549	3,564	3,578
811	3,593	3,608	3,623	3,638	3,653	3,668	3,684	3,700	3,717	3,732
812	3,747	3,763	3,778	3,794	3,809	3,824	3,840	3,855	3,871	3,887

Appendix B

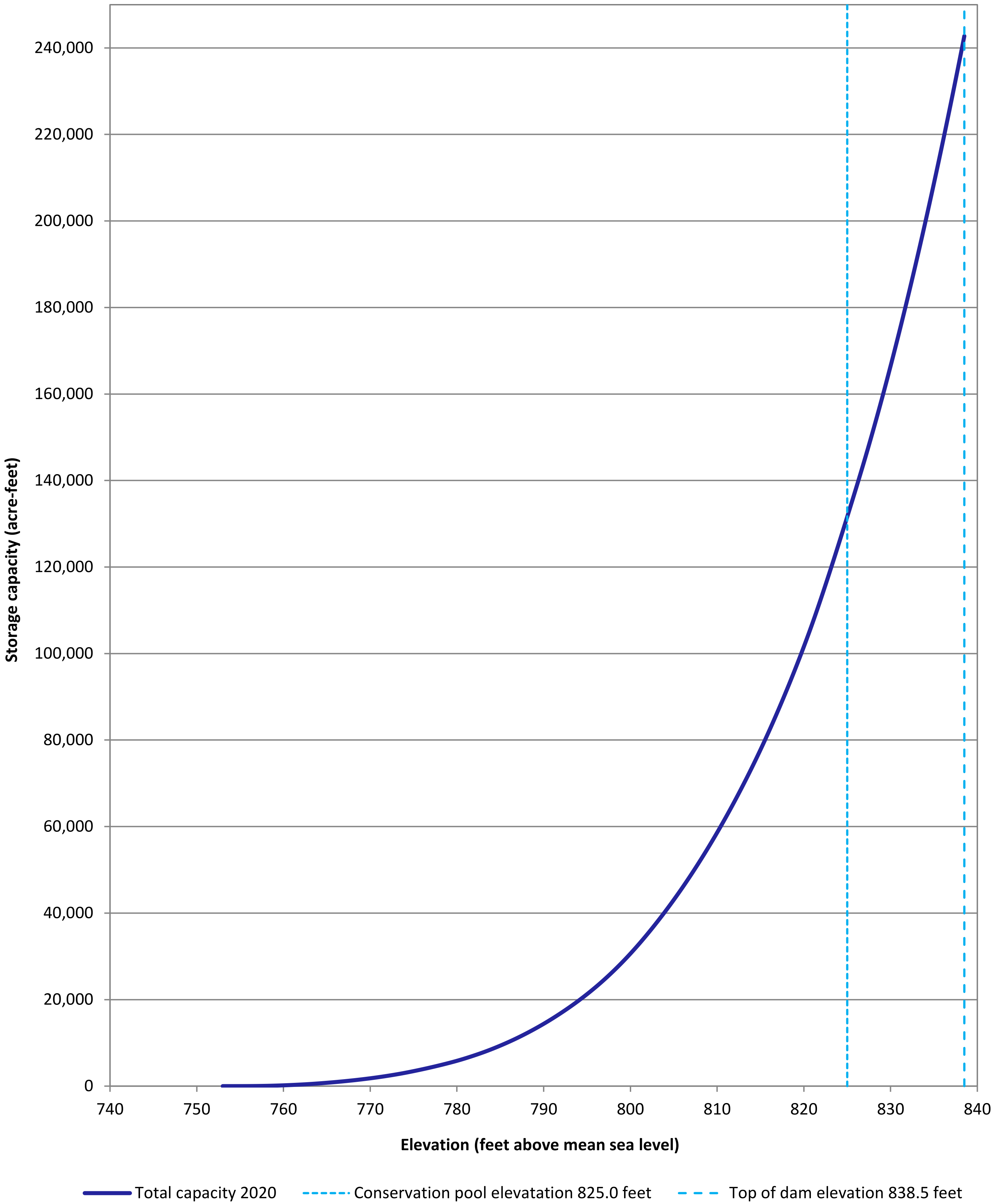
Lake Lyndon B Johnson

RESERVOIR AREA TABLE continued

TEXAS WATER DEVELOPMENT BOARD
AREA IN ACRES
CAPACITY IN ACRE-FEET

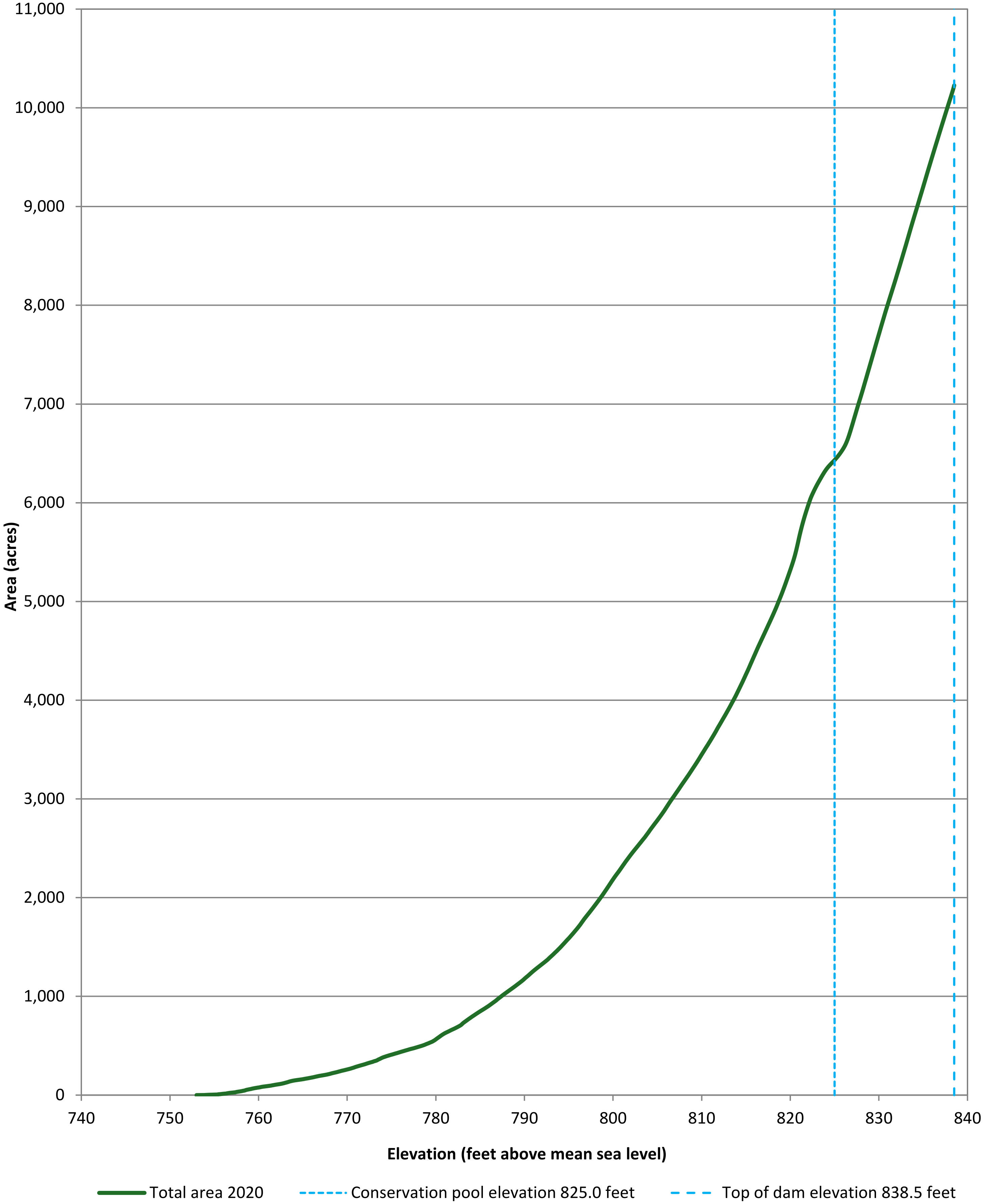
March - June 2020 Survey
Top of flood dam elevation 838.5 feet
Conservation pool elevation 825.0 feet

ELEVATION (Feet MSL)	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
813	3,903	3,919	3,936	3,952	3,969	3,986	4,002	4,019	4,036	4,054
814	4,072	4,090	4,109	4,127	4,146	4,164	4,183	4,202	4,222	4,242
815	4,261	4,280	4,300	4,320	4,340	4,361	4,381	4,402	4,422	4,443
816	4,463	4,483	4,504	4,524	4,544	4,563	4,582	4,602	4,621	4,640
817	4,659	4,679	4,698	4,717	4,737	4,756	4,776	4,795	4,815	4,834
818	4,854	4,874	4,895	4,915	4,936	4,958	4,981	5,003	5,025	5,047
819	5,069	5,093	5,116	5,141	5,165	5,190	5,216	5,241	5,266	5,292
820	5,318	5,344	5,371	5,399	5,428	5,459	5,493	5,529	5,567	5,607
821	5,648	5,686	5,723	5,758	5,791	5,823	5,854	5,884	5,913	5,941
822	5,968	5,995	6,020	6,046	6,067	6,087	6,106	6,125	6,143	6,161
823	6,178	6,195	6,211	6,226	6,242	6,258	6,273	6,288	6,303	6,317
824	6,330	6,342	6,354	6,365	6,375	6,385	6,394	6,404	6,413	6,422
825	6,432	6,442	6,452	6,463	6,474	6,485	6,497	6,510	6,523	6,537
826	6,551	6,567	6,584	6,603	6,625	6,648	6,674	6,701	6,730	6,760
827	6,790	6,820	6,851	6,881	6,911	6,942	6,972	7,001	7,030	7,059
828	7,089	7,118	7,148	7,179	7,210	7,241	7,272	7,303	7,334	7,365
829	7,396	7,427	7,458	7,489	7,520	7,551	7,583	7,614	7,645	7,676
830	7,706	7,737	7,768	7,799	7,829	7,860	7,890	7,920	7,950	7,979
831	8,008	8,037	8,065	8,094	8,123	8,151	8,180	8,208	8,237	8,266
832	8,296	8,325	8,355	8,385	8,415	8,444	8,475	8,505	8,535	8,565
833	8,596	8,626	8,657	8,688	8,719	8,750	8,781	8,812	8,842	8,872
834	8,902	8,931	8,961	8,990	9,020	9,050	9,081	9,110	9,140	9,170
835	9,200	9,230	9,260	9,291	9,321	9,352	9,381	9,411	9,441	9,470
836	9,500	9,529	9,559	9,588	9,618	9,647	9,676	9,705	9,735	9,764
837	9,793	9,821	9,850	9,879	9,908	9,936	9,965	9,993	10,022	10,050
838	10,078	10,106	10,135	10,164	10,194	10,228				



Lake Lyndon B Johnson
March - June 2020 Survey
Prepared by: TWDB

Appendix C: Capacity curve



Lake Lyndon B Johnson
March - June 2020 Survey
Prepared by: TWDB

Appendix D: Area curve

Appendix E Axial profile

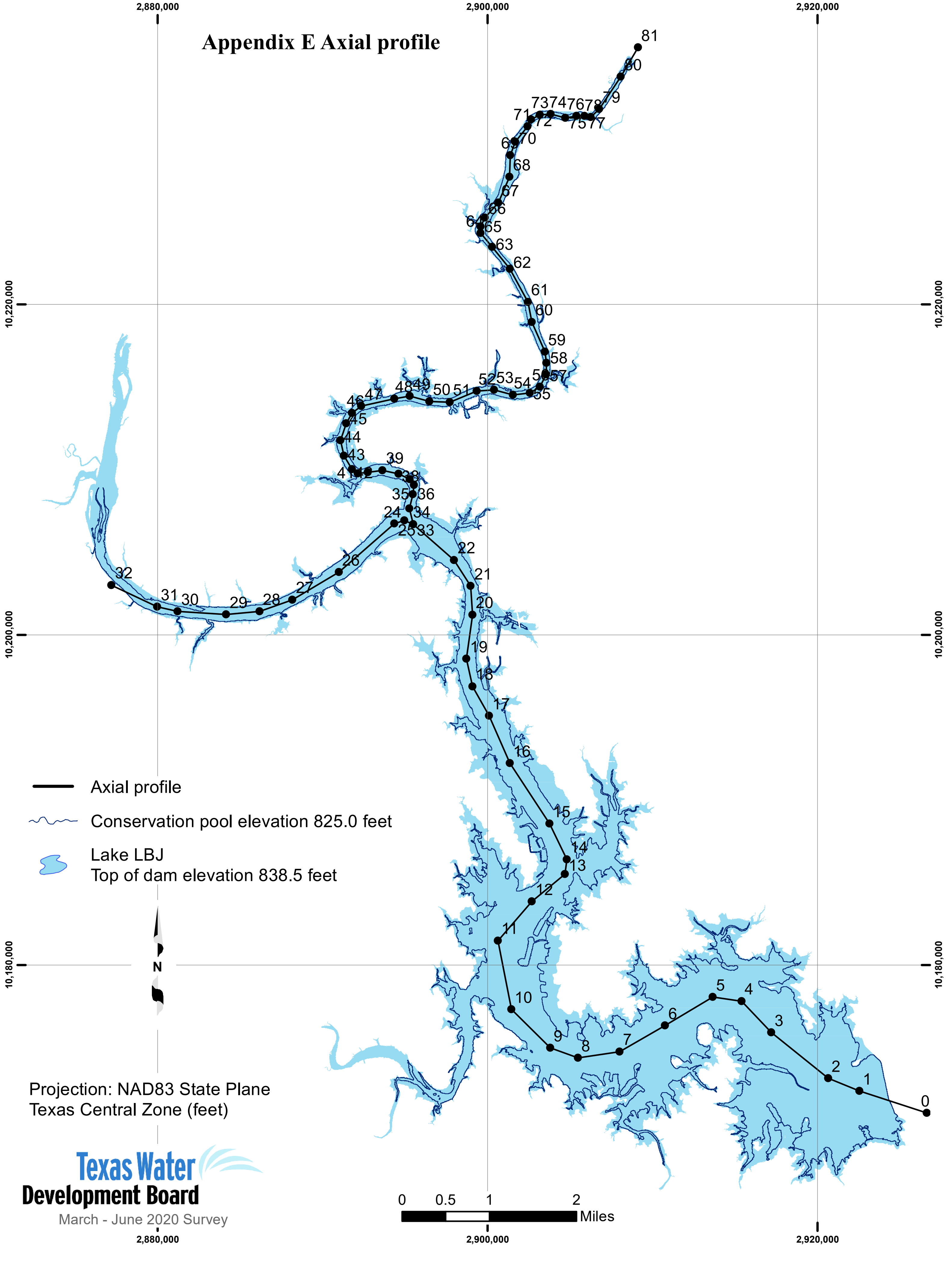


Table E1. Lake LBJ axial profile vertice coordinates

Point ID	x	y	Point ID	x	y
Llano River to Wirtz Dam			**Colorado River to intersection with Llano River (cont)**		
0	2926615.27	10171031.27	41	2892132.656	10209769.55
1	2922544.089	10172361.57	42	2891768.073	10210029.97
2	2920634.367	10173121.12	43	2891299.323	10210845.94
3	2917183.846	10175898.89	44	2891073.628	10211766.08
4	2915382.631	10177808.62	45	2891420.85	10212790.38
5	2913646.52	10178047.33	46	2891785.434	10213432.74
6	2910755.895	10176317.73	47	2892340.989	10213849.41
7	2908004.159	10174748.72	48	2894337.517	10214283.44
8	2905482.457	10174362.43	49	2895275.017	10214457.05
9	2903789.749	10174970.07	50	2896472.934	10214127.19
10	2901432.978	10177307.31	51	2897705.573	10214092.47
11	2900625.686	10181473.98	52	2899337.517	10214752.19
12	2902682.978	10183845.94	53	2900379.184	10214838.99
13	2904688.186	10185510.44	54	2901525.017	10214526.49
14	2904792.353	10186395.85	55	2902549.323	10214648.02
15	2903746.346	10188555.14	56	2903156.961	10215012.6
16	2901337.492	10192222.68	57	2903549.757	10215773.96
17	2900078.811	10195087.26	58	2903571.458	10216457.56
18	2899080.548	10196866.78	59	2903462.951	10217130.3
19	2898711.624	10198537.78	60	2902681.701	10218942.36
20	2899080.548	10201207.05	61	2902432.135	10220157.64
21	2898972.041	10202943.16	62	2901347.066	10222154.17
22	2897973.777	10204527.37	63	2900272.847	10223477.96
23	2895499.818	10206697.5	64	2899578.402	10224324.31
24	2894957.284	10206914.52	65	2899578.402	10224725.78
25	2894349.645	10206740.91	66	2899838.819	10225257.47
26	2890985.93	10203789.52	67	2900641.771	10226168.93
27	2888164.749	10202118.51	68	2901325.364	10227731.43
28	2886168.221	10201402.37	69	2901379.618	10229044.36
29	2884149.992	10201228.75	70	2901683.437	10229847.31
30	2881220.305	10201402.37	71	2902421.284	10230780.47
31	2879983.325	10201684.48	72	2902638.298	10231214.5
32	2877205.548	10203008.27	73	2903159.132	10231496.62
Colorado River to intersection with Llano River			74	2903810.173	10231529.17
33	2895499.818	10206697.5	75	2904710.781	10231312.16
34	2895266.336	10207648.02	76	2905394.375	10231420.66
35	2895465.989	10208502.19	77	2905877.278	10231410.48
36	2895535.434	10209075.1	78	2906251.58	10231344.71
37	2895275.017	10209404.97	79	2906761.562	10231832.99
38	2894597.934	10209752.19	80	2908074.496	10233796.97
39	2893625.711	10209960.52	81	2909105.312	10235565.63
40	2892740.295	10209838.99			

XY coordinates in NAD83 State Plane Texas Central Zone (feet)

Lake LBJ axial profile plot Llano River to Wirtz Dam
840
830
820
810
800
790
780
770
760
750
740
Elevation (feet above mean sea level)
0
10000
20000
30000
40000
50000
60000
70000
80000
Distance (feet)
2020 TWDB current bottom surface
2020 TWDB pre-impoundment surface
Conservation pool elevation 825.0 feet
Top of dam elevation 838.5 feet
Llano River intersection with Colorado River

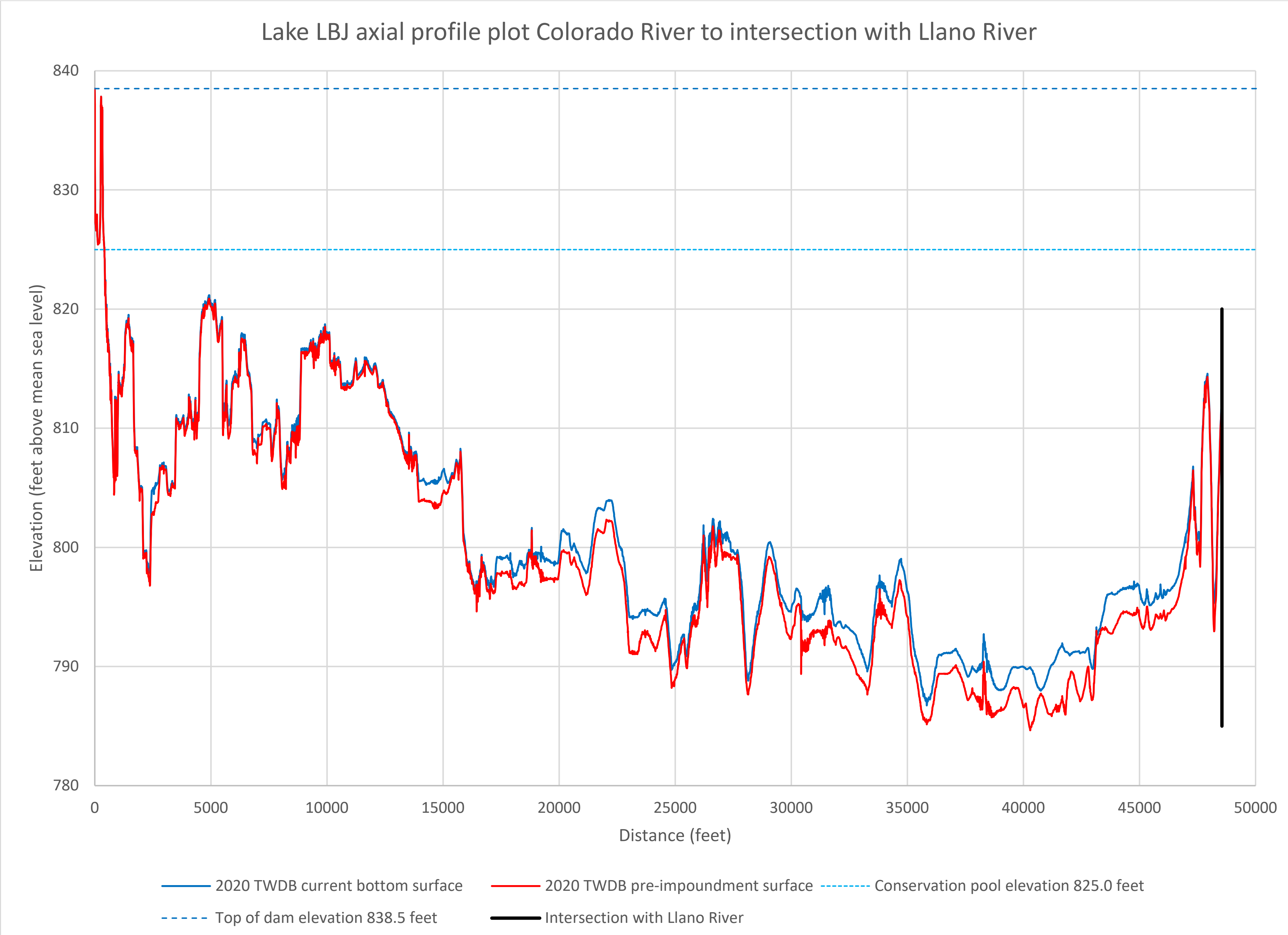

Lake LBJ axial profile plot Colorado River to intersection with Llano River
Elevation (feet above mean sea level)
840
830
820
810
800
790
780
0
5000
10000
15000
20000
25000
30000
35000
40000
45000
50000
Distance (feet)
2020 TWDB current bottom surface
2020 TWDB pre-impoundment surface
Conservation pool elevation 825.0 feet
Top of dam elevation 838.5 feet
Intersection with Llano River

Figure 6

Contours
feet above mean sea level

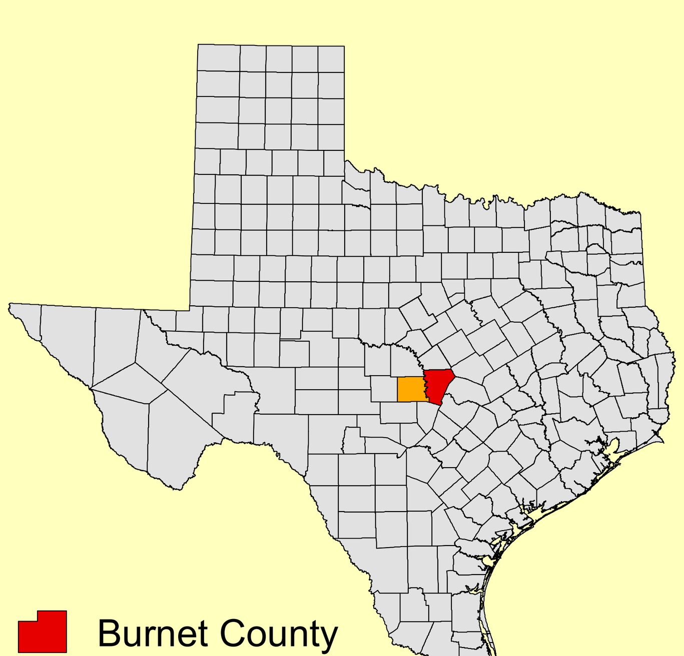
830
825
820
810
800
790
780
770
760

Lake LBJ
Top of dam elevation
838.5 feet

Conservation pool elevation
825.0 feet

Islands
elevation 838.5 feet

Projection: NAD83
State Plane Texas
Central Zone (feet)



Burnet County
Llano 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 Lake LBJ. The Texas Water Development Board makes no representations nor assumes any liability.