Volumetric and Sedimentation Survey of POSSUM KINGDOM LAKE

June – December 2016 Survey

Texas Water Development Board

February 2018

Texas Water Development Board

Prepared for:

Brazos River Authority

With Support Provided by:

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

This report was prepared by staff of the Surface Water Division:

Nathan Leber, Manager
Holly Holmquist
Khan Iqbal

Published and distributed by the

Texas Water Development Board

P.O. Box 13231, 1700 N. Congress Ave.
Austin, TX 78711-3231, www.twdb.texas.gov
Phone (512) 463-7847, Fax (512) 475-2053

Executive summary

In June 2016, the Texas Water Development Board (TWDB) entered into an agreement with the U.S. Army Corps of Engineers, Fort Worth District, to perform a volumetric and sedimentation survey of Possum Kingdom Lake (Palo Pinto County, Texas). The Brazos River Authority provided 50 percent of the funding for this survey, while the U.S. Army Corps of Engineers, Fort Worth District, provided the remaining 50 percent of the funding through their Planning Assistance to States Program. Surveying was performed using a multi-frequency (208 kHz, 50 kHz, and 24 kHz), sub-bottom profiling depth sounder. In addition, sediment core samples were collected in select locations and correlated with the multi-frequency depth sounder signal returns to estimate sediment accumulation thicknesses and sedimentation rates.

Morris Sheppard Dam and Possum Kingdom Lake are located on the Brazos River, approximately 18 miles southeast of Graham, in Palo Pinto County, Texas. The normal operating level of Possum Kingdom Lake is 999.0 feet above mean sea level (NGVD29). The TWDB collected bathymetric data for Possum Kingdom Lake between June 21, 2016, and December 21, 2016, while daily average water surface elevations measured between 998.70 and 999.21 feet above mean sea level (NGVD29).

The 2016 TWDB volumetric survey indicates that Possum Kingdom Lake has a total reservoir capacity of 538,139 acre-feet and encompasses 17,914 acres at the normal operating level (999.0 feet above mean sea level, NGVD29). The 2016 TWDB volumetric survey indicates that Possum Kingdom Lake has a total reservoir capacity of 556,340 acre-feet and encompasses 18,568 acres at top of gates elevation 1,000.0 feet. Previous capacity estimates, at elevation 1,000.0 feet, include the original design estimate of 729,985 acre-feet and two TWDB surveys in 1994 and 2005. The 1994 and 2005 TWDB surveys were re-evaluated using current processing procedures resulting in updated capacity estimates of 566,291 acre-feet and 558,489 acre-feet, respectively, at elevation 1,000.0 feet.

The 2016 TWDB sedimentation survey of Possum Kingdom Lake identified 48,149 acre feet of sediment in the reservoir below elevation 1,000.0 feet. However, the change in capacity between the original design estimate and the current capacity estimate suggests 120,000-130,000 acre-feet of sediment deposits were unidentified in the 2016 TWDB survey. Comparison of original range line data indicates much of this unidentified sediment is likely in the area upstream of Costello Island.

Evaluation of historical records indicates the rate of sedimentation occurring in Possum Kingdom Lake has been decreasing over time with a significant shift in the rate of sedimentation occurring in Possum Kingdom Lake around the time of a 1974 URS/Forrest and Cotton survey. Comparison of surveys between the original design estimate and 1974 indicate an average loss of capacity of 5,987 acre-feet per year, while comparison of surveys between 1974 and 2016 indicate an average loss of capacity of 272 acre-feet per year. The 2016 TWDB sedimentation survey indicates the distribution of sedimentation is consistent with that described by Jones and Rogers in 1949 and accumulation is mostly confined to the submerged river channels. The TWDB recommends a detailed analysis of sediment deposits - in the areas upstream of Costello Island using augured-coring techniques, as well as a volumetric survey in 10 years or after a major flood event.

Table of Contents

List of Tables

List of Figures

Appendices

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 June 2016, the TWDB entered into an agreement with the U.S. Army Corps of Engineers, Fort Worth District, to perform a volumetric and sedimentation survey of Possum Kingdom Lake. The Brazos River Authority provided 50 percent of the funding for this survey, while the U.S. Army Corps of Engineers, Fort Worth District, provided the remaining 50 percent of the funding through their Planning Assistance to States Program (Texas Water Development Board, 2016a). 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).

Possum Kingdom Lake general information

Morris Sheppard Dam and Possum Kingdom Lake are located on the Brazos River, approximately 18 miles southeast of Graham, in Palo Pinto County, Texas (Figure 1). Construction of the dam began on May 29, 1938. The dam was completed and deliberate impoundment began on March 21, 1941 (Texas Water Development Board, 1973). Possum Kingdom Lake is owned and operated by the Brazos River Authority. Possum Kingdom Lake is primarily a water supply reservoir and is a part of the Brazos River Authority's water supply system that includes eleven reservoirs throughout the Brazos River Basin (Brazos River Authority, 2017a). Although originally constructed with hydroelectric capabilities, the generating facility is no longer in use (Brazos River Authority, 2017b). Additional pertinent data about Possum Kingdom Dam and Possum Kingdom Lake can be found in Table 1.

Water rights for Possum Kingdom Lake have been appropriated to the Brazos River Authority through Certificate of Adjudication No. 12-5155 and Amendment to Certificate

of Adjudication No. 12-5155A. The complete certificates are on file in the Information Resources Division of the Texas Commission on Environmental Quality.

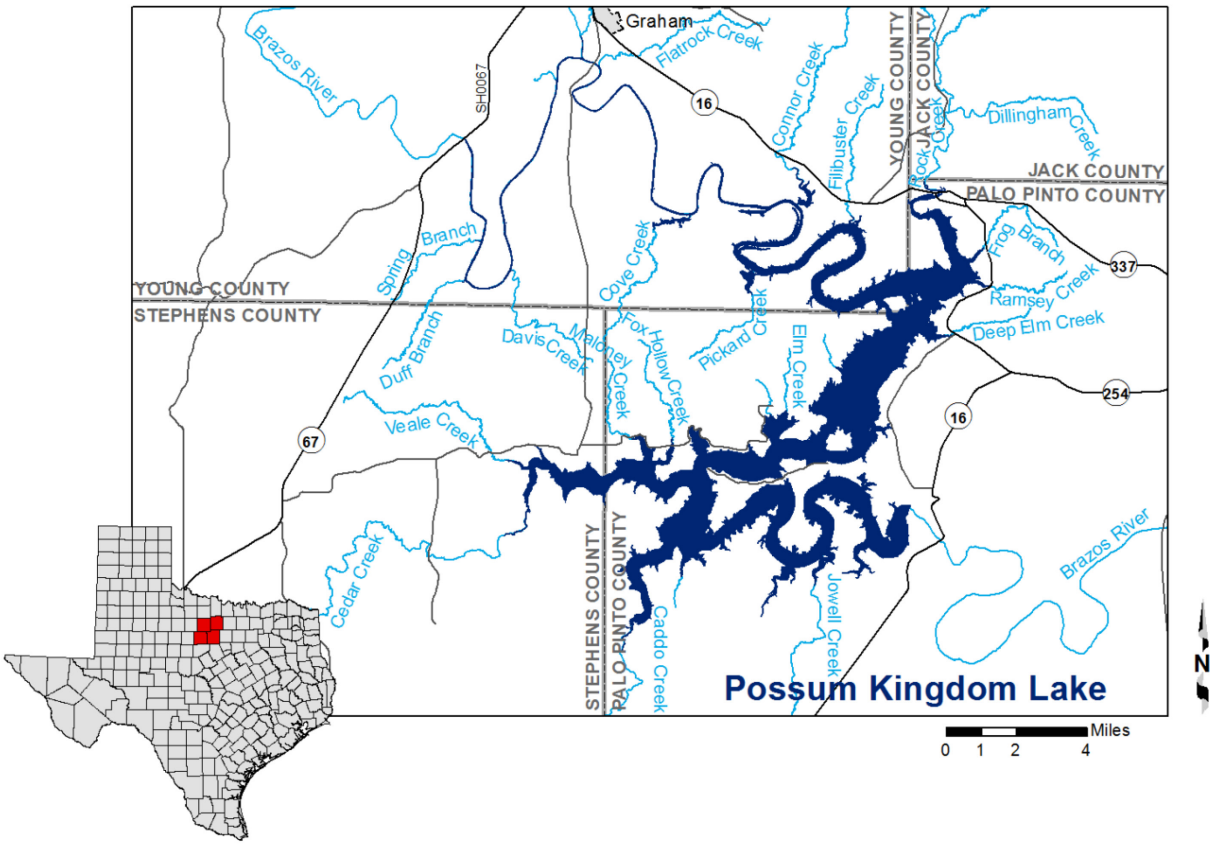


Figure 1. Location map of Possum Kingdom Lake.

Table 1. Pertinent data for Morris Sheppard Dam and Possum Kingdom Lake.

Owner	
Brazos River Authority	
Design Engineer	
Ambursen Engineering Corporation	
Location of dam	
On the Brazos River in Palo Pinto County, 18 miles southeast of Graham, Texas	
Drainage area	
22,550 square miles, of which 9,240 is probably noncontributing	
Dam	
Type	Ambursen-type, buttress with flat-slab deck and earthen dike
Length	2,740 feet
Height	189 feet
Top width	14.8 feet
Spillway	
Type	Gate-controlled ogee weir
Control	9 roof-weir gates, each 73.66 by 13 feet
Crest elevation	987.0 feet above mean sea level
Outlet Works	
Type	1 conduit, 54-inch diameter
Control	Valve
Invert	874.8 feet above mean sea level

Reservoir data (Based on 2016 TWDB survey)

Feature	Elevation (feet NGVD29[a])	Capacity (acre-feet)	Area (acres)
Top of dam	1,024.0	N/A	N/A
Top of gates	1,000.0	556,340	18,568
Normal operating level	999.0	538,139	17,914
Spillway crest	987.0	362,155	11,818
Invert of penstock	911.5	4,459	723
Invert of 54-inch outlet/ dead pool	874.8	0	0
Usable conservation storage[b]	—	538,139	—

Source: (Texas Water Development Board, 1973)

[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 Possum Kingdom Lake

Datum

The vertical datum used during this survey is the National Geodetic Vertical Datum 1929 (NGVD29). This datum also is utilized by the United States Geological Survey (USGS) for the reservoir elevation gages *USGS 08088500 Possum Kingdom Lk nr Graford, TX* (U.S. Geological Survey, 2017a)*, USGS 08088440 Possum Kingdom Lk at Sandy Beach nr Graford, TX* (U.S. Geological Survey, 2017b), and *USGS 08088435Possum Kingdom Lk abv McGinnis Pt nr Graford, TX* (U.S. Geological Survey, 2017c). 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 gages. 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 Possum Kingdom Lake between June 21, 2016 and December 21, 2016, while daily average water surface elevations measured between 998.70 and 999.21 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 24 kHz) sub-bottom profiling depth sounder integrated with differential global positioning system (DGPS) equipment. Data was collected along pre-planned survey lines oriented perpendicular to the assumed location of the original river channels and spaced approximately 500 feet apart. Many of the same survey lines also were used by the TWDB during the 1994 and 2005 surveys. The depth sounder was calibrated daily using a velocity profiler to measure the speed of sound in the water column and a weighted tape or stadia rod for depth reading verification. Figure 2 shows the data collection locations for the 2016 TWDB survey.

All sounding data was collected and reviewed before sediment core sampling sites were selected. Sediment core samples were collected at regularly spaced intervals within the reservoir or at locations where interpretation of the acoustic display would be difficult without site-specific sediment core data. After analyzing the sounding data, the TWDB selected eight locations to collect sediment core samples (Figure 2). The sediment core samples were collected on May 24, 2017, 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. The goal is to collect a sediment core sample extending from the current reservoir-bottom surface, through the accumulated sediment, and into the pre-impoundment surface. After retrieving the sample, a stadia rod is inserted into the top of the aluminum tubes to assist in locating the top of the sediment in the tube. This identifies the location of the layer corresponding to the current reservoir-bottom surface. The aluminum tube is cut to this level, capped, and transported back to TWDB headquarters for further analysis. During this time, some settling of the upper layer can occur.

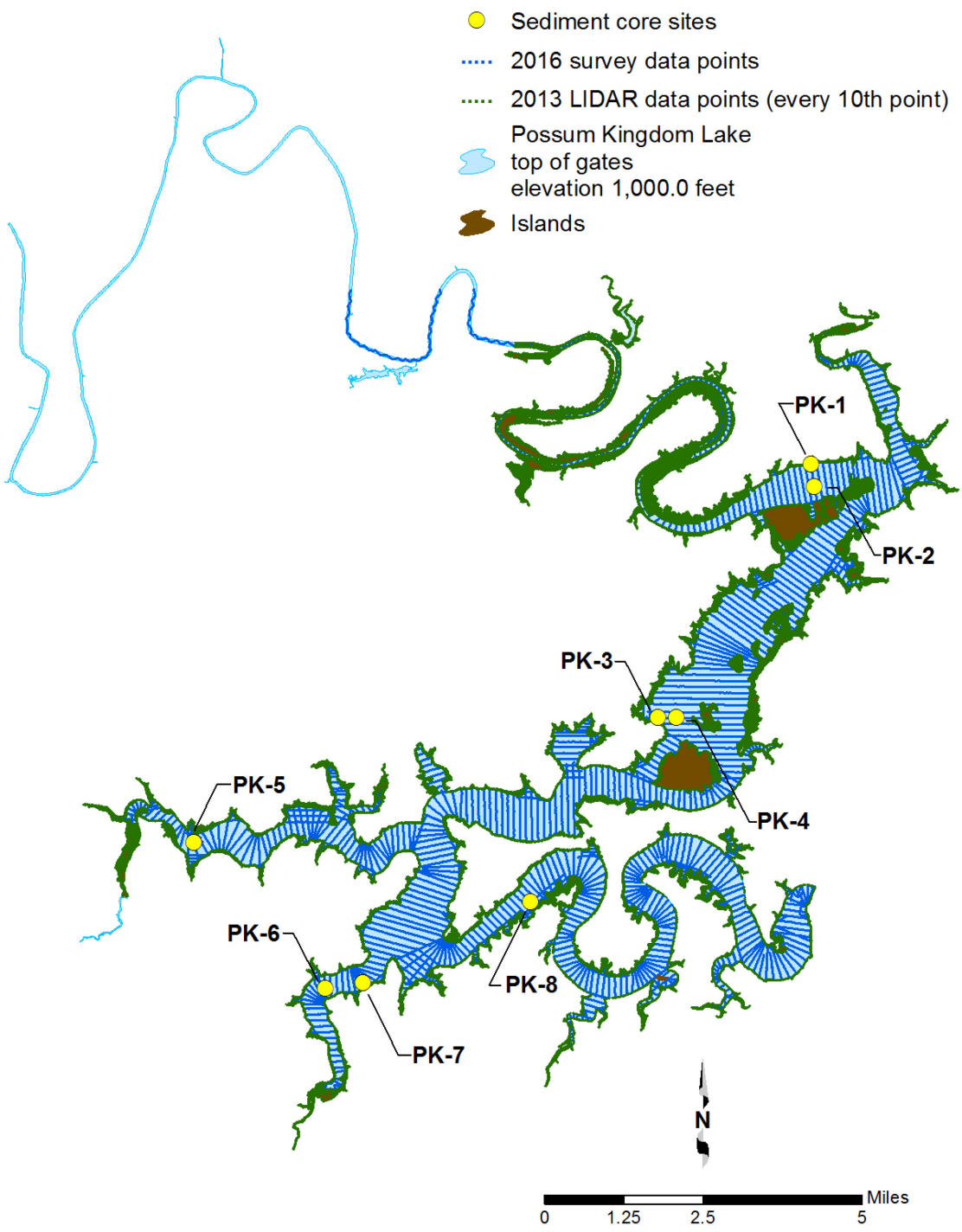


Figure 2. **2016 TWDB Possum Kingdom Lake survey data (*blue dots*) and sediment coring locations (*yellow circles*), and 2013 LIDAR data (*green dots*) between elevations 989.95 and 1,000.00 feet.**

Data processing

Model boundary

The reservoir's model boundary was generated from Light Detection and Ranging (LIDAR) Data available from the Texas Natural Resource Information System (Texas Natural Resources Information System, 2017a). LIDAR data was collected between February 8 and February 12, 2013, while daily average water surface elevation of the reservoir measured between 989.95 and 999.00 feet above mean sea level as measured by the reservoir elevation gages *USGS 08088500 Possum Kingdom Lk nr Graford, TX*. According to the associated metadata, the LIDAR data has a tested consolidated vertical accuracy of 0.228 meters at the 95th percentile in all land cover categories combined and a horizontal accuracy of 1 meter. To generate the boundary, 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 2.0 meters by 2.0 meters. 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). Therefore, a contour of 304.881 meters NAVD88, equivalent to 1,000.0 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 08088435Possum Kingdom Lk abv McGinnis Pt nr Graford, TX Latitude 32°56'09"N, Longitude 98°25'42"W NAD27*. Horizontal coordinate transformations to NAD83 State Plane Texas North Central Zone (feet) coordinates were done using the ArcGIS Project tool. Additional editing of the 1,000.0-foot contour was necessary to close the contour across the top of the dam and remove other artifacts. Where LIDAR data was insufficient to generate a proper contour and in the upper reaches that lacked LIDAR coverage, the boundary was digitized from aerial photographs, also known as digital orthophoto quarter-quadrangle images (DOQQs), taken on July 18, July 19, and August 3, 2010, while the daily average water surface elevation measured 998.43, 998.64, and 999.10, respectively, as measured at the reservoir elevation gage *USGS 08088500 Possum Kingdom Lk nr Graford, TX.* According to metadata associated with the 2010

DOQQs, the photographs have a resolution or ground sample distance of 1.0-meters and a horizontal accuracy within ± 6 meters to true ground (U.S. Department of Agriculture, 2016). The DOQQs are available at the Texas Natural Resources Information System (Texas Natural Resources Information System, 2017b).

LIDAR data points

To model the reservoir between conservation pool elevation and top of gates elevation, or model boundary elevation, the .las files were converted to text files with x, y, and z values. To reduce computational burden, the LIDAR data was filtered to include only every 10^{th} point and only data points within the reservoir boundary (Figure 2). The LIDAR data points have a nominal point spacing no greater than two points per 1 square meter; therefore, using a thinned point dataset did not significantly affect the modeled topography of the coverage area. No further interpolation of the data in the areas of LIDAR coverage was necessary. After the points were clipped to within the boundary, the shapefile was projected to NAD83 State Plane Texas North Central Zone (feet). New attribute fields were added to first convert the elevations from meters NAVD88 to meters NGVD29 by subtracting the VERTCON conversion offset of 0.081 meters, then to feet NGVD29 for compatibility with the bathymetric survey data.

While most of the overlapping LIDAR data and TWDB survey data were in agreement, some inconsistencies were found. In these areas, any LIDAR data that did not correlate well with TWDB survey data was removed from the model.

Triangulated Irregular Network model

Following completion of data collection, the raw data files collected by the TWDB were edited to remove data anomalies. The reservoir's current bottom surface is automatically determined by the data acquisition software. DepthPic© software, developed by SDI, Inc., was used to display, interpret, and edit the multi-frequency data by manually removing data anomalies in the current bottom surface and manually digitizing the reservoir-bottom surface at the time of initial impoundment (*i.e.* pre-impoundment surface). For further analysis, HydroTools, software developed by TWDB staff, was used to merge all the data into a single file including the current reservoir-bottom surface, pre-impoundment surface, and sediment thickness at each sounding location. The water surface elevation at the time of each sounding was used to convert each sounding depth to a corresponding reservoir-bottom elevation. This survey point dataset was then

preconditioned by inserting a uniform grid of artificial survey points between the actual survey lines. Bathymetric elevations at these artificial points were determined using an anisotropic spatial interpolation algorithm described in the next section. This technique creates a high resolution, uniform grid of interpolated bathymetric elevation points throughout a majority of the reservoir (McEwen and others, 2011a). Finally, the point file resulting from spatial interpolation is used in conjunction with sounding and boundary data to create volumetric and sediment Triangulated Irregular Network (TIN) models utilizing the 3D Analyst Extension of ArcGIS. The 3D Analyst algorithm uses Delaunay's criteria for triangulation to create a grid composed of triangles from non-uniformly spaced points, including the boundary vertices (Environmental Systems Research Institute, 1995).

Spatial interpolation of reservoir bathymetry

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

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

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

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

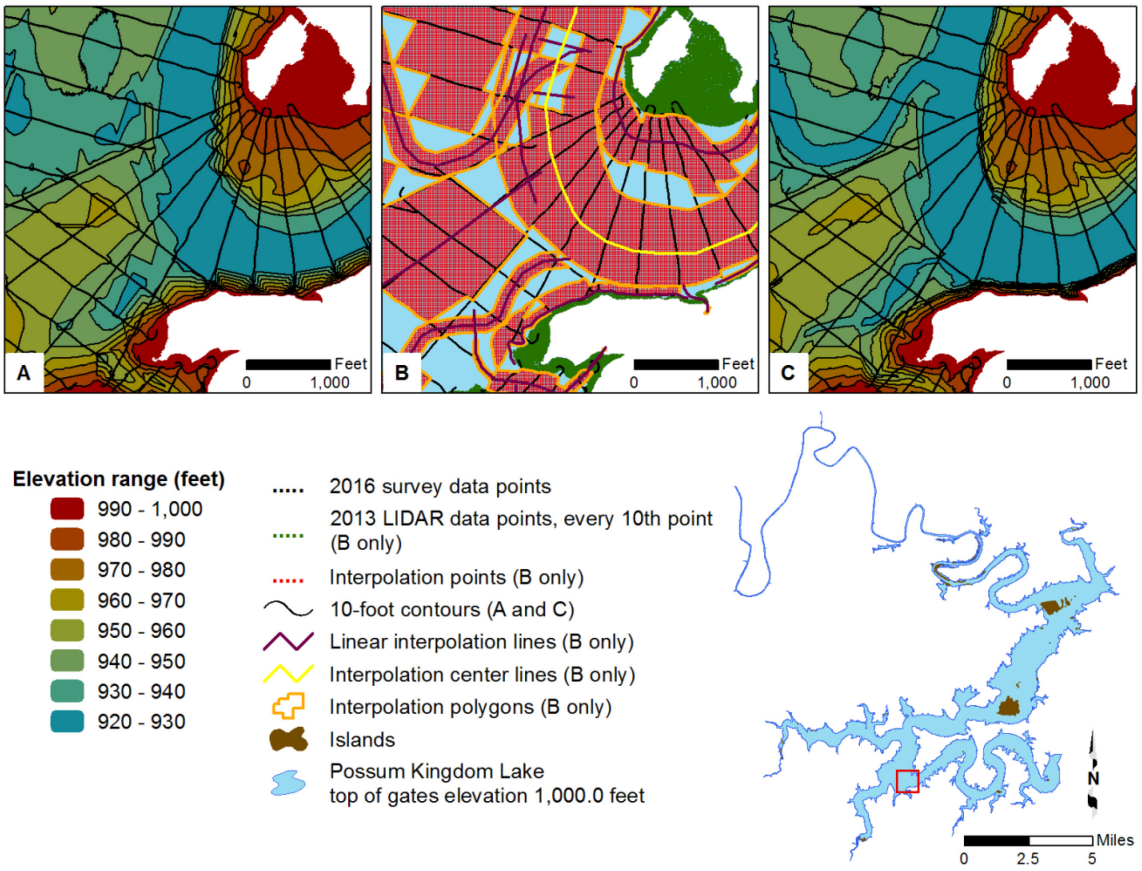


Figure 3. Anisotropic spatial interpolation and linear interpolation of Possum Kingdom Lake sounding data; A) bathymetric contours without interpolated points, B) sounding points (*black*) and interpolated points (*red*), C) bathymetric contours with interpolated points.

To properly compare results from previous TWDB surveys of Possum Kingdom Lake, the TWDB applied anisotropic spatial interpolation to the survey data collected in 1994 and 2005 using the same interpolation definition file as was used for the 2016 survey, with minor edits to account for differences in data coverage and boundary conditions.

The original 1994 survey boundary was digitized from the 1,000.0 foot contour from 7.5 minute USGS quadrangle maps: Fortune Bend, Texas, (Provisional Edition) 1984; Costello Island, TX, (Provisional) 1984; Cove Creek, TX, 1967 (Photorevised 1981); Brad, TX, 1967 (Photoinspected 1979); Ross Mountain, TX, 1967 (Photorevised 1981); and Graham, TX, (Photorevised 1981), with a stated accuracy of ± ½ the contour interval (U.S. Bureau of the Budget, 1947). However, the 1994 survey was recalculated using the 2005 survey boundary. The 2005 survey boundary was digitized from aerial photographs taken on January 23, January 27, and January 30, 1995, while the daily average water surface elevation of the reservoir measured 997.34 feet, 997.30 feet, and 997.19 feet above mean sea level, respectively. The boundary was assigned an elevation of 1,000.0 feet for

modeling purposes. According to the associated metadata, the 1995-1996 DOQQs have a resolution of 1-meter, with a horizontal positional accuracy that meets the National Map Accuracy Standards (NMAS) for 1:12,000-scale products. Additionally, survey data points with anomalous elevations from both surveys were removed from the new models. While linear interpolation was used to estimate the topography in areas without data, flat triangles led to anomalous area and volume calculations at the boundary elevation of 1,000.0 feet. Therefore, areas between 996.2 feet and 1,000.0 feet were linearly interpolated between the computed values, and volumes above 996.2 feet were calculated based on the corrected areas for the 1994 survey and areas between 997.2 feet and 1,000.0 feet were linearly interpolated between the computed values, and volumes above 997.2 feet were calculated based on the corrected areas for the 2005 survey (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. The 2005 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

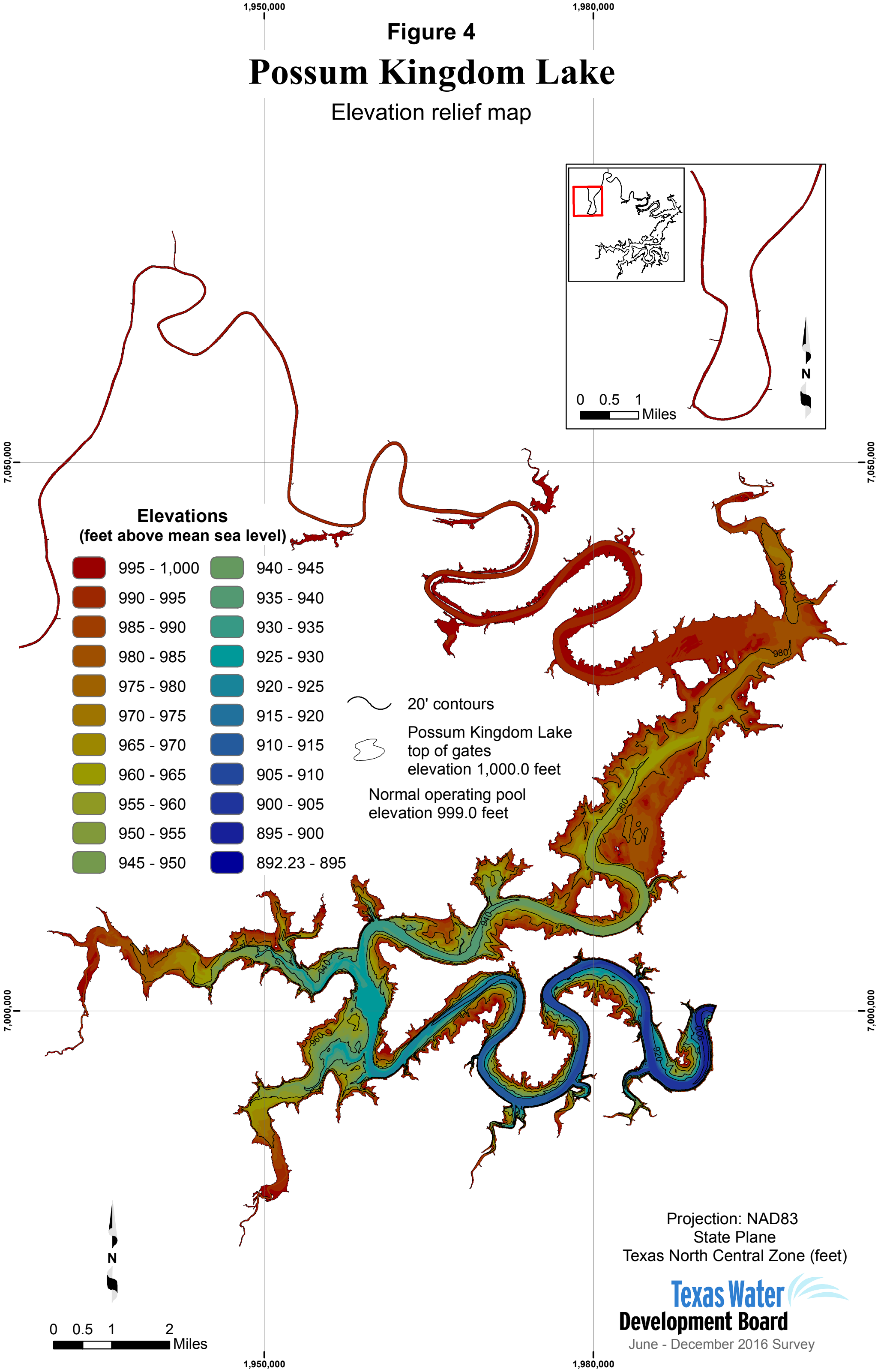
Using ArcInfo software and the volumetric TIN model, volumes and areas were computed for the entire reservoir at 0.1-foot intervals, from 892.2 to 1,000 feet. The elevation-capacity table and elevation-area table, based on the 2016 survey and analysis, are presented in Appendices I and J, respectively. 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 Possum Kingdom Lake (Figure 5); and, (3) a 5-foot contour map (Figure 6).

Figure 4

Possum Kingdom Lake

Elevation relief map



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

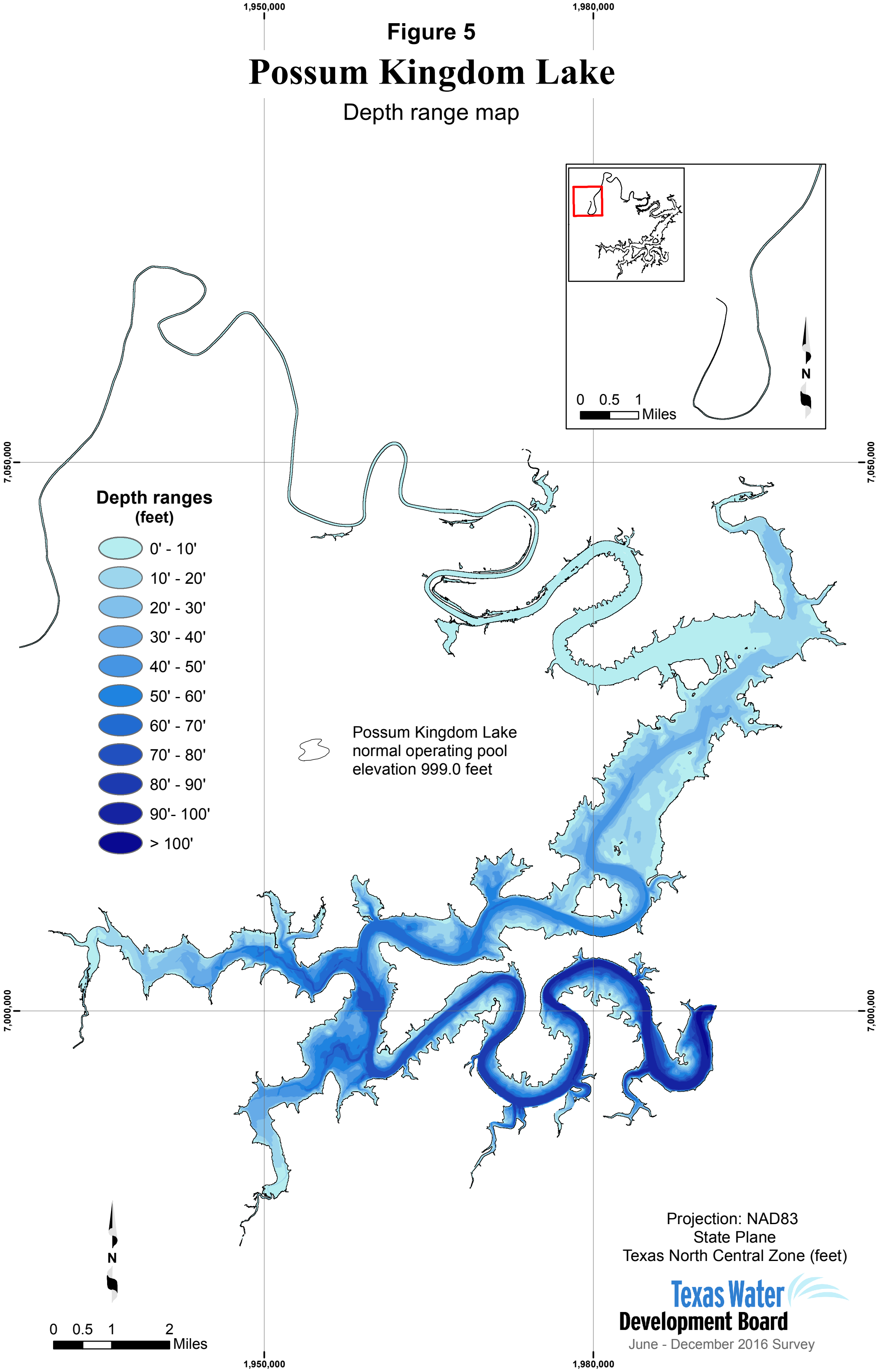
Texas Water Development Board

June - December 2016 Survey

Figure 5

Possum Kingdom Lake

Depth range map



Analysis of sediment data from Possum Kingdom Lake

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

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

Table 2. Sediment core sample analysis data for Possum Kingdom Lake.

Sediment core sample	Easting[a] (feet)	Northing[a] (feet)	Total core sample/ post-impoundment sediment	Sediment core description		Munsell soil color
PK-1	1990854.12	7035558.23	43.25”/N/A	post-impoundment	0.0–1.0” water and fluff	N/A
					1.0–4.0” high water content, silt, small chunks of clay (<0.2” diameter)	7.5YR 4/2 brown
					4.0–12.5” significant decrease in water content, color and soil type change, clay, very dense at upper boundary, water content increasing with depth	7.5YR 4/4 brown
					12.5–43.25” high water content, silt loam or silty clay loam	7.5YR 4/4 brown with layers of 7.5YR 4/2 brown
PK-2	1991156.93	7033720.81	18.25”/N/A	post-impoundment	0.0–0.2” very dark thin layer, high water content, silt	7.5YR 2.5/1 black
					0.2–12.75” very similar to bottom layer of PK-1, silt loam or silty clay loam, high water content	7.5YR 4/4 brown with streaks (<30%) of 7.5YR 4/2 brown
				post-impoundment (likely false pre-impoundment)	12.75–13.75” very well-defined transition, significant drop in water content, clay, with organics (leaf litter, very small pieces), material not smooth, creates ribbons when worked	7.5YR 4/4 brown
					13.75–18.25” extremely dense, clay, low water content, smooth texture	7.5YR 4/4 brown
PK-3	1978104.90	7014488.07	68.0”/57.0”	post-impoundment	0–2.0” water and fluff	N/A
					2.0–28.25” silt loam, high water content, similar to post-impoundment layers in PK-1 and PK-2	7.5YR 4/2 with streaks of 7.5YR 4/3 brown and 7.5YR 4/4 brown
					28.25–43.25” texture similar to above layer, color change to darker hue, silt loam	7.5YR 3/1 very dark gray
					43.25–57.0” high water content, similar texture as above 2 layers, colors mottled, silt loam	7.5YR 3/1 very dark gray, 7.5YR 4/4 brown, and 7.5YR 2.5/1 black
				pre-impoundment	57.0–68.0” significant texture and color change, much more dense than above layer, increased sand content, loam or sandy clay loam	10YR 4/1 dark gray

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

Table 2. Sediment core sample analysis data for Possum Kingdom Lake (continued).

Sediment core sample	Easting[a] (feet)	Northing[a] (feet)	Total core sample/ post-impoundment sediment	Sediment core description		Munsell soil color
PK-4	1979684.01	7014482.57	120.0”/N/A	post-impoundment	0–2.0” water and fluff	N/A
					2.0–6.5” high water content, silt	7.5YR 3/1 very dark gray
					6.5–33.0” high water content, silt loam	7.5YR 4/2 brown mottled 50% with 7.5YR 4/1 brown
					33.0–45.0” same as above, high water content, silt loam, homogeneous color	10YR 4/2 dark grayish brown
					45.0–75.0” same texture as above, high water content, silt loam	7.5YR 4/2 brown mottled 50% with 7.5YR 4/1 brown
					75.0–89.5” same texture as above 3 layers, high water content, silt loam	5YR 4/3 reddish brown
					89.5–111.5” same texture as above, high water content, silt loam	5YR 4/5 mottled 50% with 7.5YR 2.5/1 black
					111.5–120.0” same texture as above, high water content, silt loam, color same as layer at 75-89.5”	5YR 4/3 reddish brown
PK-5	1939529.72	7004085.28	70.0”/N/A	post-impoundment	0–70.0” homogeneous core, very dark, silt, silt loam, high water content	2.5Y 3/1 very dark gray
PK-6	1950456.26	6991942.11	36.0”/27.5”	post-impoundment	0–27.5” high water content, silt	50% mottling 7.5YR 2.5/1 black with 10YR 4/1 dark gray
				pre-impoundment	27.5–36.0” significant texture and color change, much more dense than above layer, small roots and rocks throughout, increased sand content, loam or sandy clay loam	10YR 4/1 dark gray
PK-7	1953569.63	6992400.93	48.0”/33.0”	post-impoundment	0–33.0” high water content, very dark, silt	2.5Y 3/1 very dark gray mottled 25% with 10YR 4/1 dark gray
				pre-impoundment	33.0–48.0” similar to PK-6 27.5-36.0” layer, significant texture change, sandy clay loam or loam, roots and small pebbles throughout, much lower water content, much more dense	10YR 4/1 dark gray

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

Table 2. Sediment core sample analysis data for Possum Kingdom Lake (continued).

Sediment core sample	Easting[a] (feet)	Northing[a] (feet)	Total core sample/ post-impoundment sediment	Sediment core description		Munsell soil color
PK-8	1967529.97	6999175.66	25.25”/3.0”	post-impoundment	0.0–0.5” loamy sand, high water content, dense	10YR 4/2 dark grayish brown
					0.5–1.5” loamy sand, small pebbles (<0.2” diameter) throughout, darker than above layer	2.5Y 4/1 dark gray
					1.5–3.0” color change, small pebbles present in lower quantities than above layer	2.5Y 5/1 gray
				pre-impoundment	3.0–25.25” transition to clay, significant color, texture, water content drop, small pebbles throughout	5YR 3/2 dark reddish brown

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

A photograph of sediment core PK-6 (for location, refer to Figure 2) is shown in Figure 7 and is representative of sediment cores sampled from Possum Kingdom Lake. The base of the sample is denoted by the blue line. The pre-impoundment boundary (right most yellow line) was evident within this sediment core sample at 27.5 inches and identified by the change in color, texture, moisture, porosity, and structure. Identification of the pre-impoundment surface for the other three sediment cores followed a similar procedure.

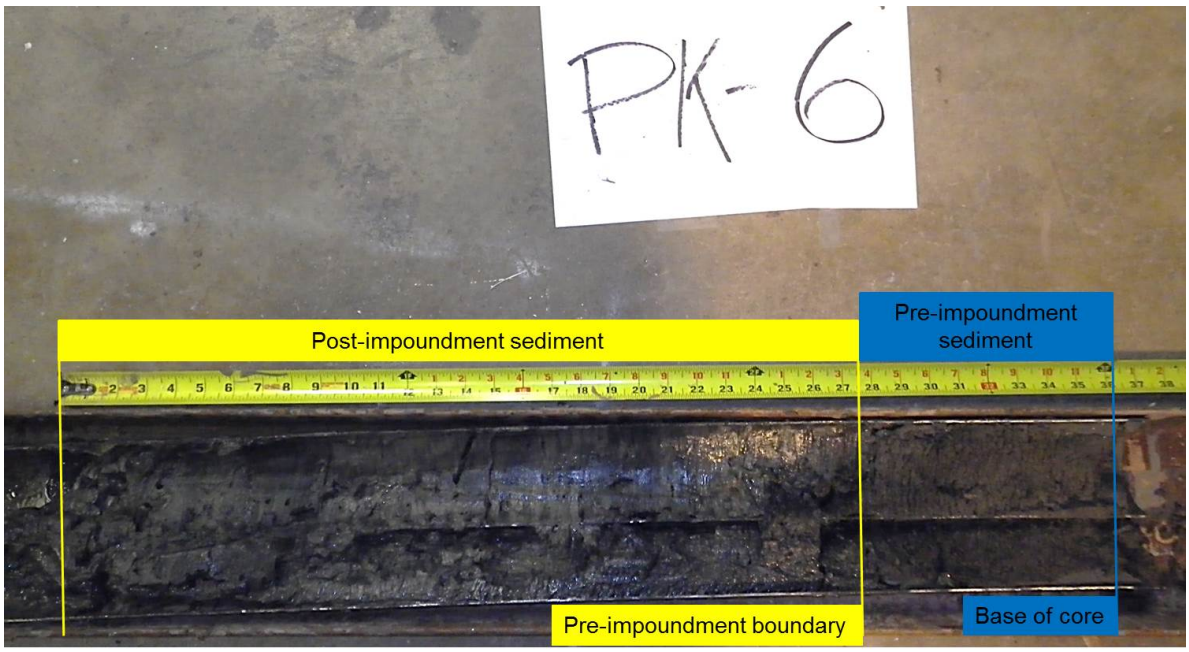


Figure 7. Sediment core PK-6 from Possum Kingdom Lake. Post-impoundment sediment layers occur in the top 27.5 inches of this sediment core (identified by the yellow box). Pre-impoundment sediment layers were identified and are defined by the blue box.

Figures 8 and 9 illustrate how measurements from sediment core samples are used with sonar data to help identify the post- and pre-impoundment layers in the acoustic signal. Figure 8 compares sediment core sample PK-6 with the acoustic signals for each frequency combined (8A, 8A'), and the individual frequencies: 208 kHz (8B, 8B'), and 50 kHz (8C, 8C'). Within DepthPic©, the current bathymetric surface is automatically determined based on signal returns from the 208 kHz transducer as represented by the top black line in Figure 8A' and red line in Figures 8B' and 8C'. The pre-impoundment surface is identified by comparing boundaries observed in the 208 kHz, 50 kHz, and 24 kHz signals to the location of the pre-impoundment surface as determined by the sediment core sample analysis. Many layers of sediment may be identified during core analysis based on changes in observed characteristics, such as water content, organic matter content, and sediment particle size, and each layer is classified as either post-impoundment or pre-impoundment. Each layer of

sediment identified in the sediment core sample during analysis (Table 2) is represented in Figures 8 and 9 by a yellow or blue box. A yellow box represents post-impoundment sediments. A blue box indicates pre-impoundment sediments.

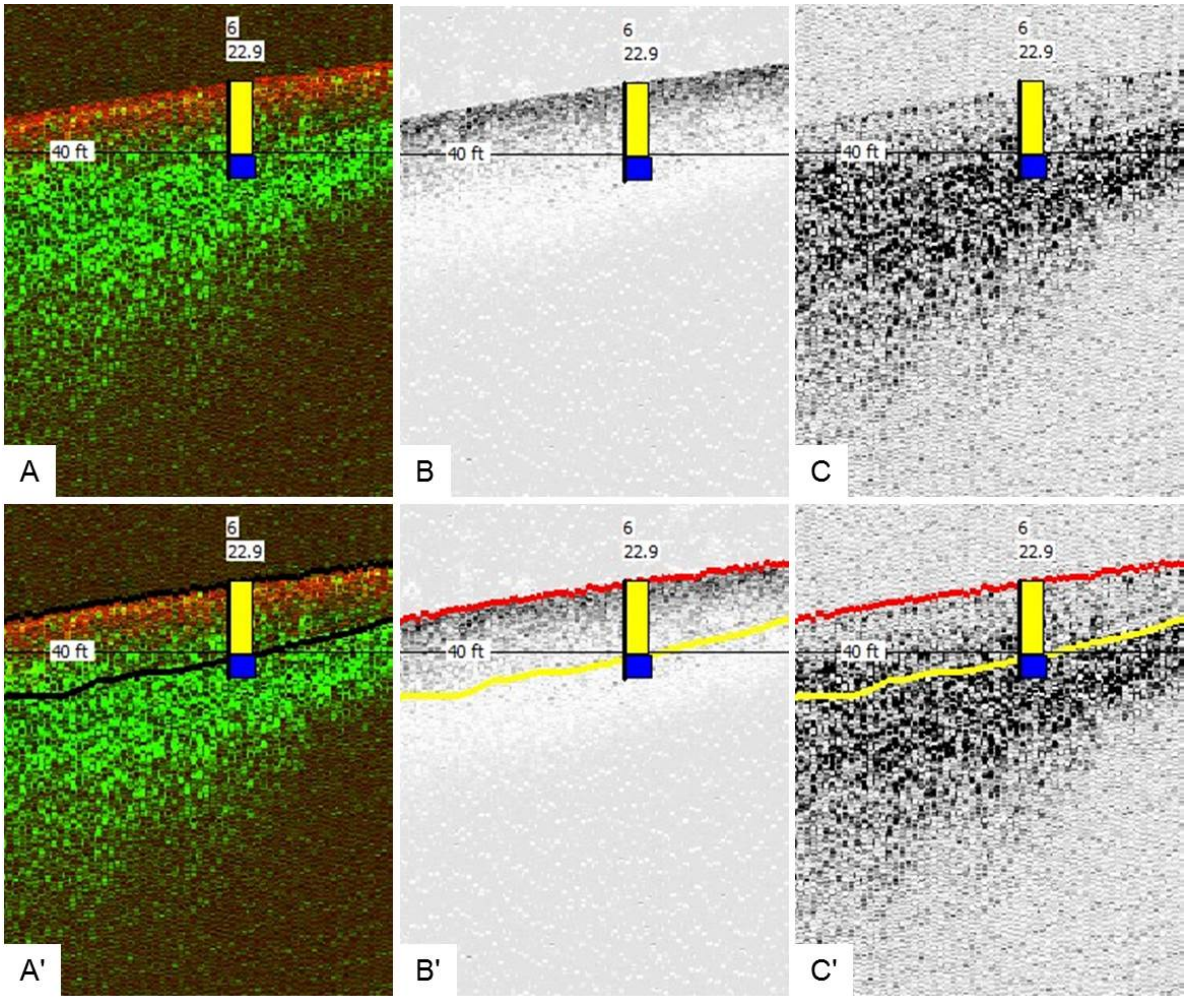


Figure 8. Comparison of sediment core PK-6 with acoustic signal returns A, A') combined acoustic signal returns, B, B') 208 kHz frequency, and C, C') 50 kHz frequency.

In this case, the pre-impoundment boundary was most visible in the 50 kHz acoustic signal returns; therefore, the 50 kHz acoustic signal returns were used to locate the pre-impoundment surface (yellow line in Figure 8). Figure 9 shows sediment core sample PK-6 correlated with the 50 kHz acoustic signal returns of the nearest surveyed cross-section. The pre-impoundment surface was first identified along cross-sections for which sediment core samples have been collected. This information was then used as a guide for identifying the pre-impoundment surface along cross-sections where sediment core samples were not collected. Comparison of the 2016 TWDB survey data to historical aerial photographs dated March 31, 1953, April 13, 1953, December 28, 1958, and January 2, 1959, taken

while the daily average water surface elevation of the lake measured 967.4 feet, 967.5 feet, 989.3 feet and 989.3 feet, respectively, and to U.S. Geological Survey 1:48,000 scale contour maps dated 1924 titled Palo Pinto 2-b, Palo Pinto 2-c, Breckenridge 1-a, and Breckenridge 1-d provided additional support for identifying the pre-impoundment boundaries.

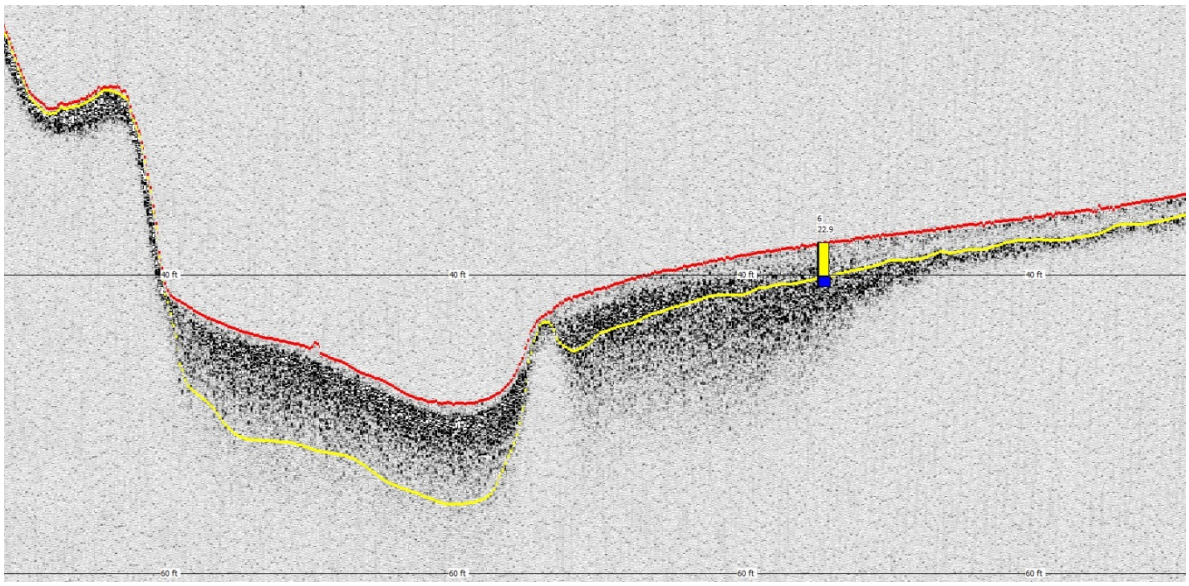


Figure 9. Cross-section of data collected during the 2016 survey, displayed in DepthPic© (50 KHz acoustic signal returns), correlated with sediment core sample PK-6 and showing the current surface as the top red line, and pre-impoundment surface as the bottom yellow line.

After the pre-impoundment surface for all cross-sections was identified, a pre-impoundment TIN model and a sediment thickness TIN model were created following standard GIS techniques (Furnans and Austin, 2007). Pre-impoundment elevations and sediment thicknesses were interpolated between surveyed cross-sections using HydroTools after modifying the interpolation definition file used for bathymetric interpolation for modeling without the LIDAR data points. For the purposes of TIN model creation, the TWDB assumed the sediment thickness at the reservoir boundary was 0 feet (defined as the 1,000.0 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 Possum Kingdom Lake (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 total sediment capacity.

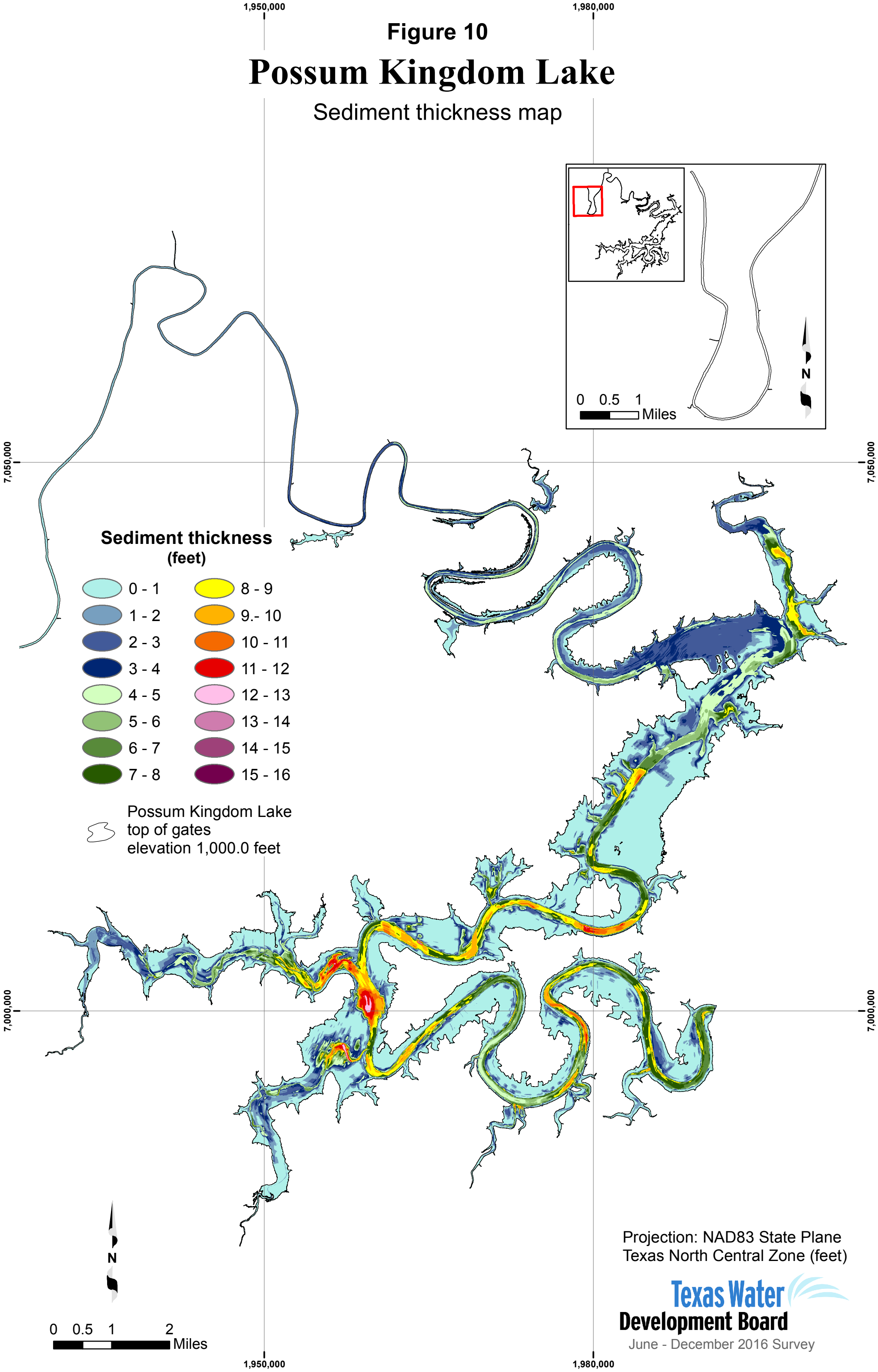
Although linear interpolation was used to estimate topography in areas inaccessible by boat or too shallow for the instruments to work properly, including those areas that were

no longer represented when the LIDAR data was removed, 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 1,000.0 feet. To eliminate the effects of the flat triangles on area and volume calculations, area between elevations 993.5 and 1,000.0 feet were linearly interpolated between the computed values, and volumes above elevation 993.5 feet were calculated based on the corrected areas.

Figure 10

Possum Kingdom Lake

Sediment thickness map



Survey results

Volumetric survey

The 2016 TWDB volumetric survey indicates that Possum Kingdom Lake has a total reservoir capacity of 538,139 acre-feet and encompasses 17,914 acres at normal operating level (999.0 feet above mean sea level, NGVD29). The 2016 TWDB volumetric survey indicates that Possum Kingdom Lake has a total reservoir capacity of 556,340 acre-feet and encompasses 18,568 acres at top of gates elevation 1,000.0 feet. Previous capacity estimates, at elevation 1,000.0 feet, include the original design estimate of 729,985 acre-feet, a 1949 estimate of 672,420 acre-feet (Jones and Rogers, 1949), and a 1974 estimate of 569,379 acre-feet (URS/Forrest and Cotton, 1975) Re-evaluation of the 1994 and 2005 surveys resulted in updated capacity estimates of 566,291 acre-feet and 558,489 acre-feet, respectively, or a 1.8 and 3.4 percent increase in total capacity estimates at top of gates elevation 1,000.0 feet, respectively (Table 3). Differences in surface area are most likely attributable to differences in reservoir boundary delineation methods. The total capacity estimates found in Table 3 are plotted in Figure 11. 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.

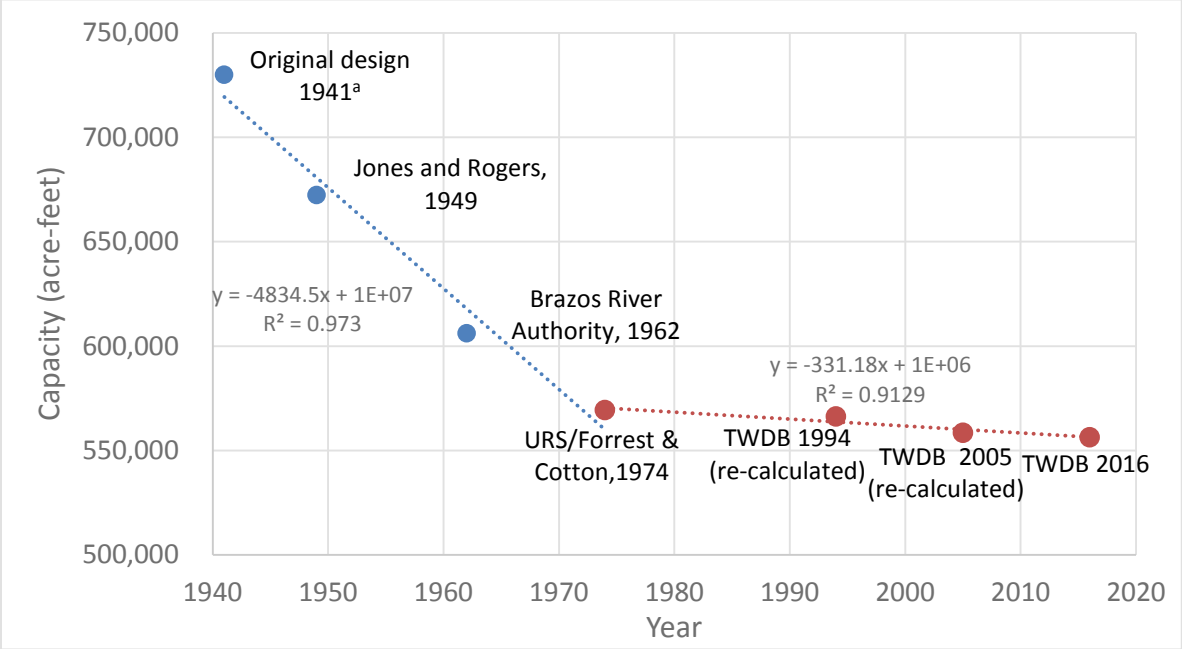


Figure 11. Plot of total capacity estimates at elevation 1,000.0 feet for Possum Kingdom Lake. Capacity estimates before 1974 shown as blue dots, and capacity estimates since 1974 shown as red dots. Blue and red trend lines illustrate a shift in rate of capacity changes before and after 1974.

Table 3. Current and previous survey capacity and surface area estimates for Possum Kingdom Lake.

Top of gates elevation (1,000 feet, NGVD29)			
Survey	**Surface area (acres)**	**Total capacity (acre-feet)**	**Source**
Original design	20,600	729,985	Jones and Rogers, 1949
Soil Conservation Service 1949	20,600	672,420	Jones and Rogers, 1949
Brazos River Authority, 1962	19,960	606,100	C. Higgins, personal commun., November 16, 2017
1974	17,621	569,379	URS/Forrest and Cotton, 1974
TWDB 1994	17,624	556,220	Texas Water Development Board, 1994
TWDB 1994 (re-calculated)	16,713	566,291	Texas Water Development Board, 2016b
TWDB 2005	16,716	540,340	Texas Water Development Board, 2006
TWDB 2005 (re-calculated)	16,713	558,489	Texas Water Development Board, 2016b
TWDB 2016	18,568	556,340	
Normal operating level (999 feet, NGVD29)			
Survey	**Surface area** (acres)	**Total capacity** (acre-feet)	**Source**
Original design	N/A	711,728	Jones and Rogers, 1949
Brazos River Authority, 1962	19,540	588,500	C. Higgins, personal commun., November 16, 2017
1974	17,039	552,049	URS/Forrest and Cotton, 1974
TWDB 1994	17,100	538,950	Texas Water Development Board, 1994
TWDB 1994 (re-calculated)	16,470	549,699	Texas Water Development Board, 2016b
TWDB 2005	16,340	523,873	Texas Water Development Board, 2006
TWDB 2005 (re-calculated)	16,472	541,897	Texas Water Development Board, 2016b
TWDB 2016	17,914	538,139	

Sedimentation survey

The 2016 TWDB sedimentation survey identified a pre-impoundment capacity of 604,489 acre-feet at elevation 1,000.0 feet, or 48,149 acre-feet of sediment in the reservoir below elevation 1,000.0 feet. Comparison of the 2016 TWDB sedimentation survey data and results with historical records suggest the amount of sediment measured in 2016 significantly underestimates the total sediment that has accumulated in the reservoir upstream of Costello Island since impoundment. However, the TWDB sedimentation

survey indicates the distribution of sedimentation is consistent with that described by Jones and Rogers in 1949 and accumulation is mostly confined to the submerged river channels.

Evaluation of historical records indicates the rate of sedimentation occurring in Possum Kingdom Lake has been decreasing over time with a significant shift in the rate of sedimentation occurring around the time of a 1974 URS/Forrest and Cotton survey (Tables 4-5 and Figures 15-16). Comparison of surveys between 1941 and 1974 indicate an average loss of capacity of 5,987 acre-feet per year, while comparison of surveys between 1974 and 2016 indicate an average loss of capacity of 272 acre-feet per year (Table 5).

Comparison of prior surveys of Possum Kingdom Lake provides substantial evidence to support a decreasing rate of sedimentation over time (Tables 4 and 5). Sediment studies by the Soil Conservation Service provide additional evidence sedimentation has decreased over time. Bulletin 5912, published in 1959 estimated an annual sediment rate as high as 7,384 acre-feet per year (Soil Conservation Service, 1959). Using the drainage area of 13,310 square miles, this equates to approximately 0.55 acre-feet per square mile of drainage area per year. A sediment study completed by URS/Forrest and Cotton, Inc. in 1974 indicated the current sediment rate at the time was 4,696 acre-feet per year, or 0.35 acre-feet per square mile per year and predicted that future improvements to the watershed would reduce the rate of sedimentation (URS/Forrest and Cotton, 1975). Report 268, Erosion and Sedimentation by Water in Texas, estimated that in 1979 Possum Kingdom Lake was losing capacity at 0.11 acre-feet per square mile per year (Greiner, 1982)). Comparison of the 2005 TWDB survey with the 2016 TWDB survey indicate Possum Kingdom Lake may currently be losing capacity at 0.01 acre-feet per square mile per year (Table 4).

Table 4. Average annual capacity loss comparisons for Possum Kingdom Lake.

Survey	Volume comparisons at top of gates elevation 1,000.0 feet (acre-feet)					
Original design 1941[a]	729,985	<>	<>	<>	<>	<>
Jones and Rogers, 1949	<>	672,420	<>	<>	<>	<>
Brazos River Authority, 1962	<>	<>	606,100	<>	<>	<>
URS/Forrest and Cotton, 1974	<>	<>	<>	569,379	<>	<>
TWDB 1994 (re-calculated)	<>	<>	<>	<>	566,291	<>
TWDB 2005 (re-calculated)	<>	<>	<>	<>	<>	558,489
2016 volumetric survey	556,340	556,340	556,340	556,340	556,340	556,340
Volume difference (acre-feet)	173,645 (23.8%)	116,080 (17.3%)	49,760 (8.2%)	13,039 (2.3%)	9,951 (1.8%)	2,149 (0.4%)
Number of years	75	67	54	42	21	11
Capacity loss rate (acre-feet/year)	2,315	1733	921	310	474	195
Capacity loss rate (acre-feet/square mile of drainage area of 13,310[b] square miles /year)	0.17	0.13	0.07	0.02	0.04	0.01

[a] Source: (Jones and Rogers, 1949), note: Morris Sheppard Dam was completed and deliberate impoundment began on March 21, 1941.
[b]Source: (TWDB, 1973)

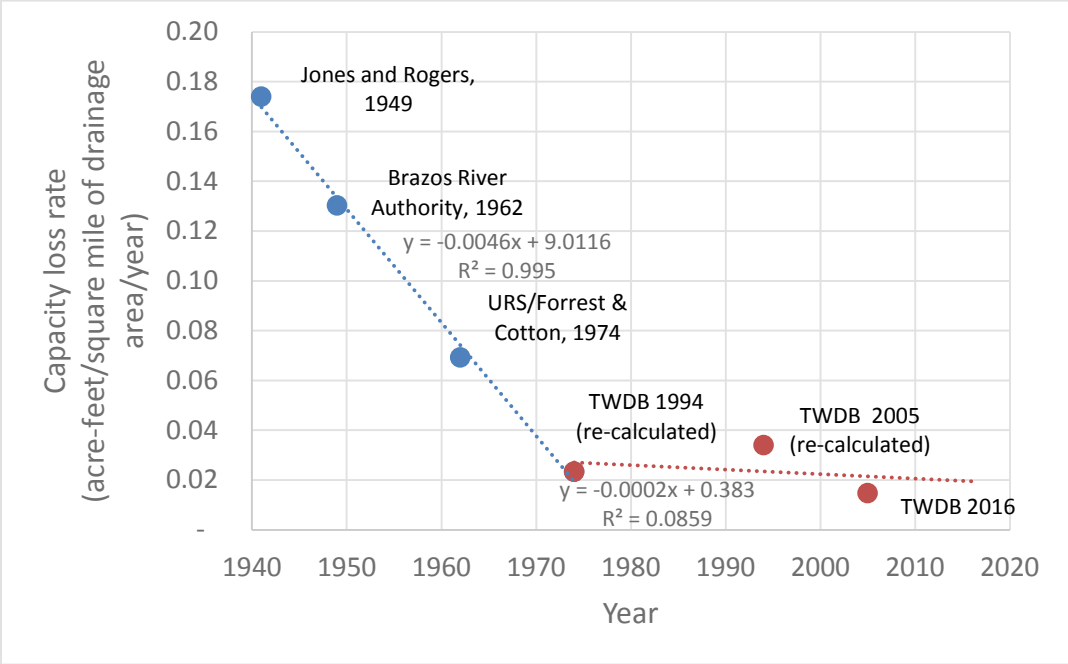


Figure 12. Plot of average annual capacity loss rates (acre-feet per square mile of drainage per year) for Possum Kingdom Lake. Capacity loss rates 1974 and earlier shown as blue dots, and capacity loss rates since 1974 shown as red dots. Blue and red trend lines illustrate a shift in rates of capacity loss before and after 1974.

Table 5. Capacity loss trends before and after 1974 for Possum Kingdom Lake.

Survey	Volume comparisons at top of gates elevation 1,000.0 feet (acre-feet)					
Original design 1941[a]	729,985	729,985	729,985	<>	<>	<>
Jones and Rogers, 1949	672,420	<>	<>	<>	<>	<>
Brazos River Authority, 1962	<>	606,100	<>	<>	<>	<>
URS/Forrest and Cotton, 1974	<>	<>	569,379	569,379	569,379	569,379
TWDB 1994 (re-calculated)	<>	<>	<>	566,291	<>	<>
TWDB 2005 (re-calculated)	<>	<>	<>	<>	558,489	<>
2016 volumetric survey	<>	<>	<>	<>	<>	556,340
Volume difference (acre-feet)	57,565 (7.9%)	123,885 (17.0%)	160,606 (22.0%)	3,088 (0.5%)	10,890 (1.9%)	13,039 (2.3%)
Number of years	8	21	33	20	31	42
Capacity loss rate (acre-feet/year)	7,196	5,899	4,867	154	351	310
Capacity loss rate (acre-feet/square mile of drainage area of 13,310[b] square miles /year)	0.54	0..44	0.37	0.01	0.03	0.02

[a] Source: (Jones and Rogers, 1949), note: Morris Sheppard Dam was completed and deliberate impoundment began on March 21, 1941.
[b] Source: (TWDB, 1973)

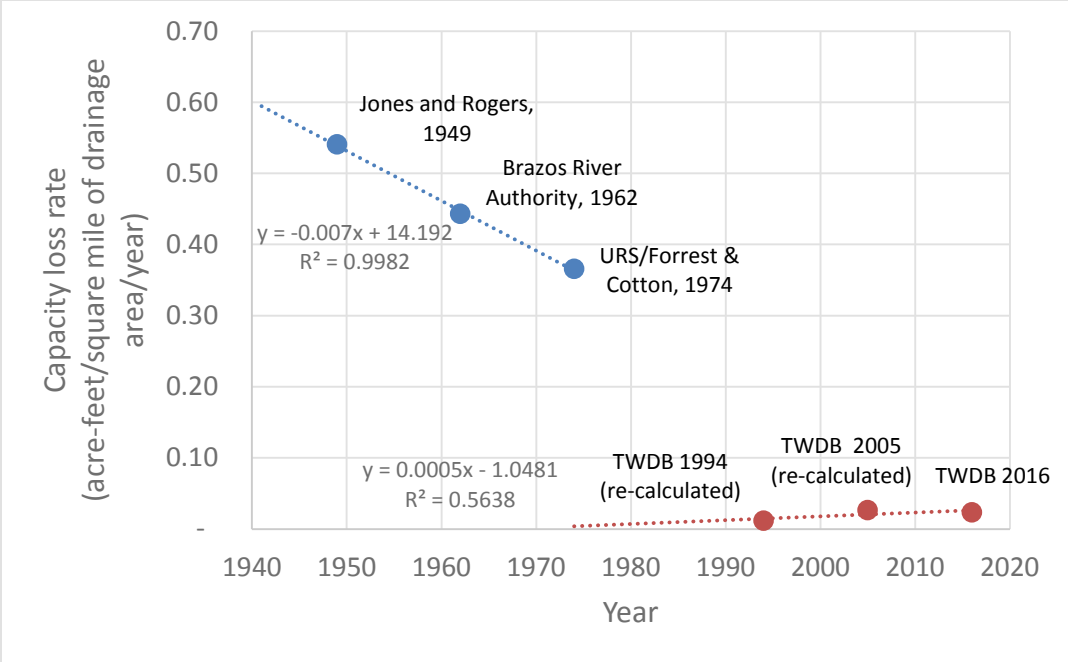


Figure 13. Plot of capacity loss rates (acre-feet per square mile of drainage per year) before and after 1974 for Possum Kingdom Lake. Capacity loss rates dated 1974 and earlier shown as blue dots, and capacity loss rates after1974 shown as red dots. Blue and red trend lines illustrate a shift in rates of capacity loss before and after 1974.

Analysis of historical records

Significant differences between the 2016 pre-impoundment estimate and original capacity estimate led the TWDB to conduct additional analysis of available historical records. U.S. Geological Survey contours from 1924 and aerial photographs from 1953 and 1958 were evaluated to assess inconsistencies. In addition, detailed notes on the original capacity estimate computed by the Brazos River Conservation and Reclamation District and the 1949 survey conducted by the Soil Conservation Service were evaluated.

Photos and Contours

Comparison of historical elevation measurements from a 1924 1:48,000 scale U.S. Geological Survey map titled Palo Pinto 2-b, Texas, and aerial photos dated March 31, 1953, and April 13, 1953, taken while the daily average water surface elevation of the reservoir measured 967.4 and 967.5 feet, respectively, with measured data from this survey and the sediment core samples (See Table 2, sediment core samples PK-1 and PK-2), indicate the pre-impoundment surface in the upper reaches of the reservoir was not well identified. These photos support the lack of pre-impoundment sediments identified in sediment core PK-1, collected in the main channel. Contours generated from the pre-impoundment TIN model at various elevations correlate well with the 1924 map and 1953 aerial photos, except for the areas near and upstream of Carter Bend and the bottom of the main river channel. Figures 12 and 13 illustrate this correlation.

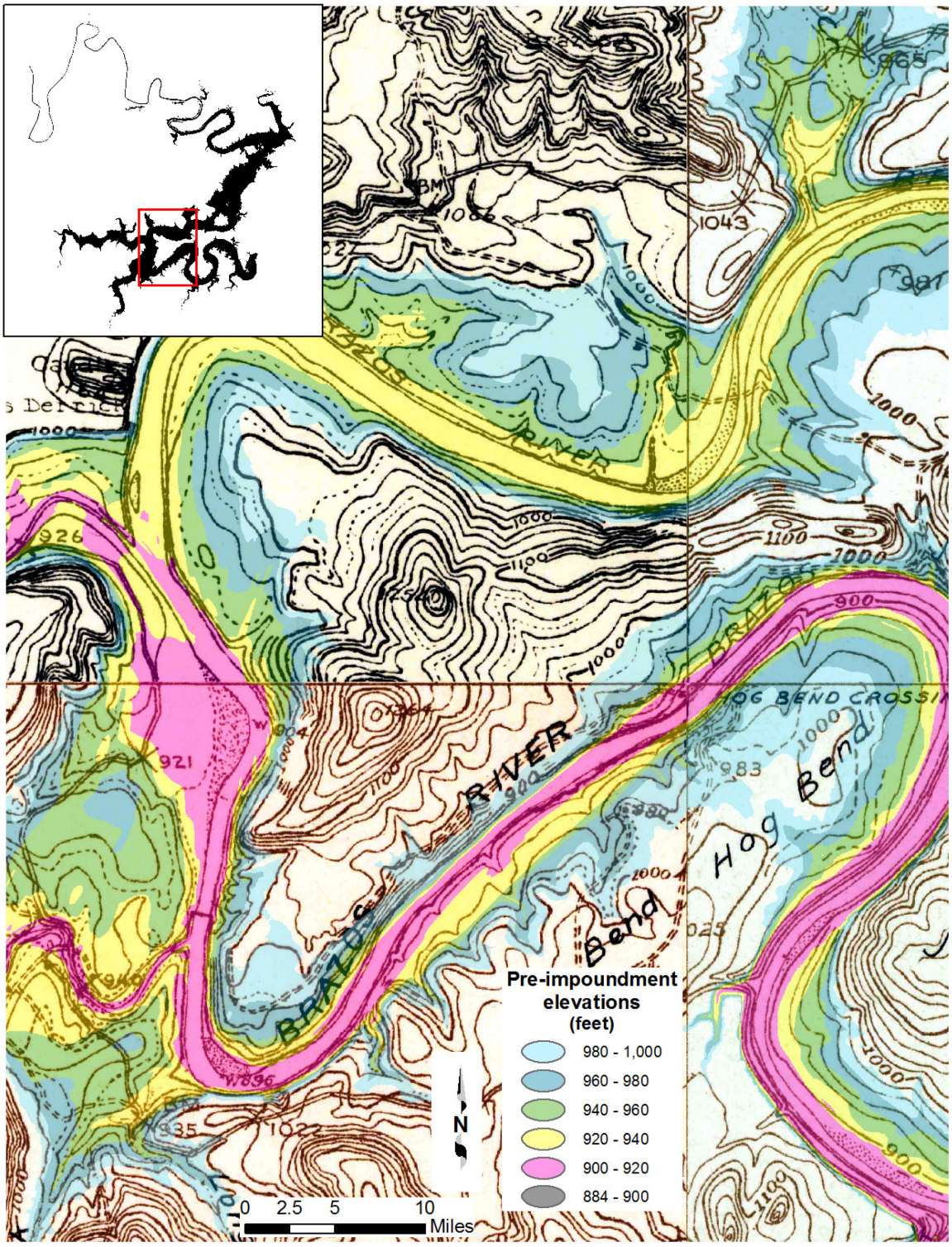


Figure 14. The TWDB surveyed pre-impoundment surface at 20-foot increments overlain on the USGS 1924 contour maps with a contour interval of 20 feet (solid lines, with some 10-foot contours shown as dashed lines).

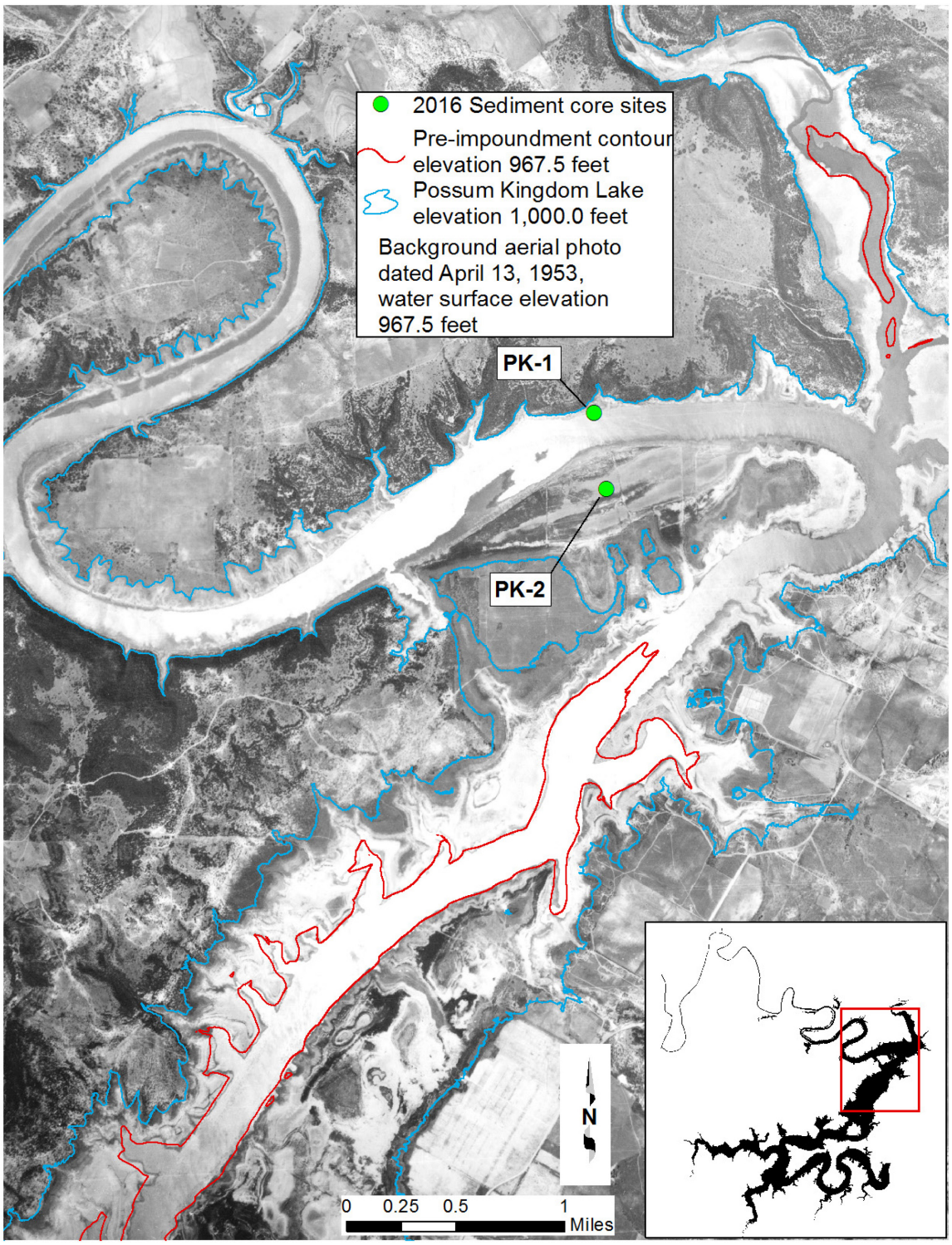


Figure 15. **The TWDB surveyed pre-impoundment contour at elevation 967.5 feet (*red line*) overlain on an aerial photograph taken on April 13, 1953, while the daily average water surface elevation measured 967.5 feet. The current 1,000-foot contour is shown in blue. The TWDB sediment core samples PK-1 and PK-2 (*green dots*) were collected in this part of the lake.**

Sediment core sample PK-8 was collected at an elevation of approximately 987.0 feet, or 12 feet below the normal operating level. Analysis of sediment core PK-8 indicates little to no sediment. Examination of historical aerial photos collected on December 28, 1958, taken while the daily average water surface elevation of the reservoir measured 989.3 feet, also indicate very little sediment has been deposited at higher elevations. This was determined by comparing the 989.3-foot contour generated from the current bottom measurements and comparing it to the land-water interface visible in the photos. A pre-impoundment contour was created for comparison to verify the pre-impoundment surface had been reasonably identified at this elevation (Figure 14).

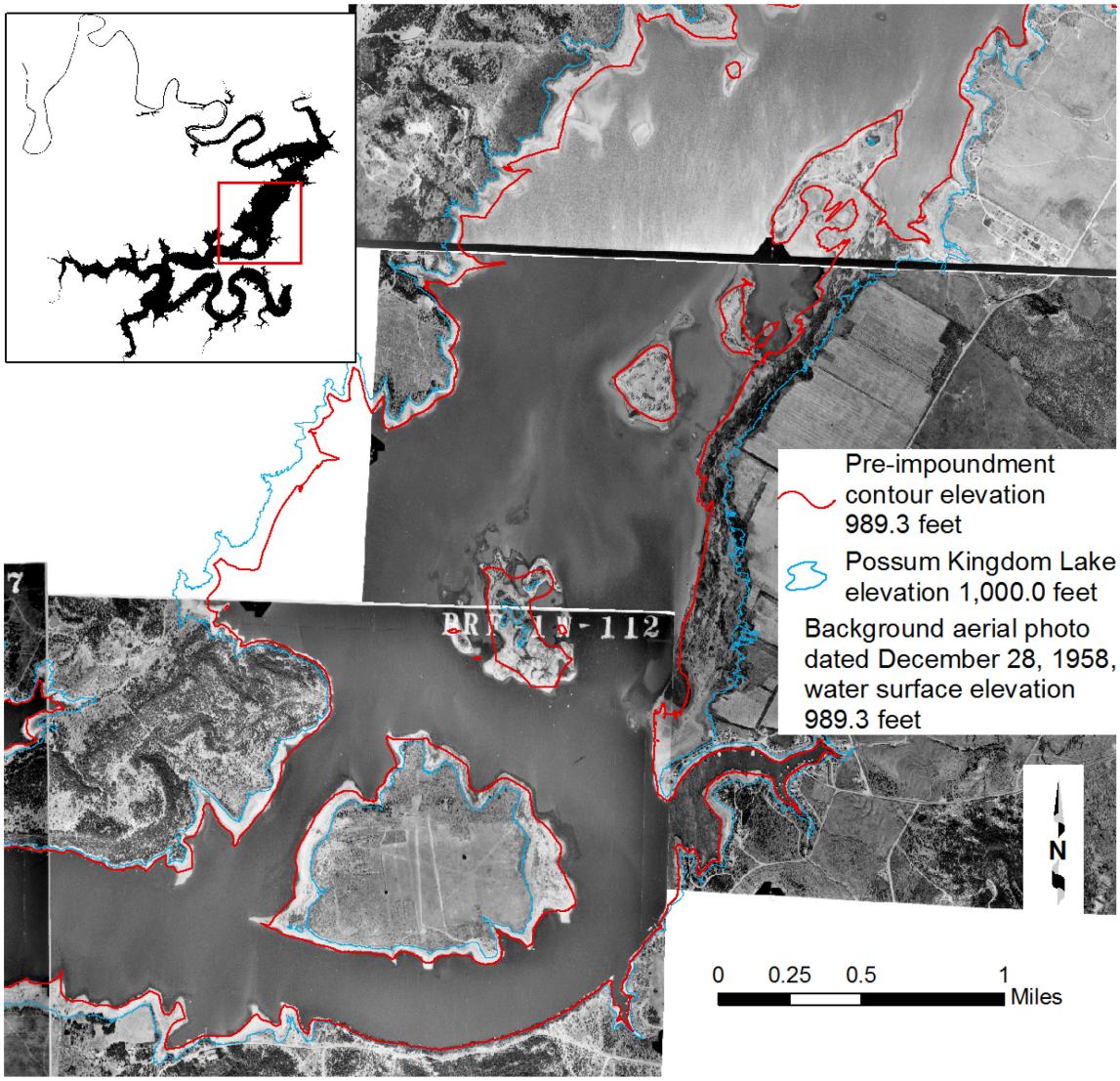


Figure 16. The TWDB surveyed pre-impoundment contour at elevation 989.3 feet (*red line*) overlain on an aerial photograph taken on December 28, 1958, while the daily average water surface elevation measured 989.3 feet. The current 1,000-foot contour is shown in blue.

Range line comparison

In 1949, Jones and Rogers used the range line method (Eakin and Brown, 1939) to estimate a current capacity of Possum Kingdom Lake. Water depths and sediment thicknesses were collected along thirty-three range lines in the reservoir. The reservoir was divided into segments bounded by sediment range lines. The surface area of each segment was multiplied by the average depths of the bounding range lines to estimate a capacity for each segment. Comparison of average depths across the 1949 range lines to average depths of similar cross-sections of the 2016 TIN models confirm that sediment depths in the area upstream of Carter Island were substantially greater than found by the TWDB survey. In the area upstream of Carter Island, current average range line depths suggest sediment deposits averaging over 25 feet thick.

Original capacity estimates in the area upstream of Costello Island total 235,304 acre-feet (Jones and Rogers, 1949). The 2016 TIN model of the pre-impoundment surface estimates the same area contained 114,855 acre-feet at impoundment. This value suggests 120,449 acre-feet of sediment exists in the area upstream of Costello Island that was not identified in the TWDB survey. The TWDB's estimated pre-impoundment capacity of 604,489 acre-feet in addition to the 120,449 acre-feet not identified in the area upstream of Costello Island aligns well with the original capacity estimate.

Impediments to sedimentation identification

Distribution of the unidentified sediment in the upper reaches suggests identification was likely impeded due to desiccation of sediment caused during exposure. Possum Kingdom Lake has gone through several dry periods, most recently in late 2014, during which water levels reached at least twenty-five feet below normal operating pool. 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).

Recommendations

The TWDB recommends a detailed analysis of sediment deposits in the areas upstream of Costello Island using augured-coring techniques, as well as a volumetric 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

References

Brazos River Authority, 2017a, Reservoirs, accessed September 21, 2017, http://www.brazos.org/About-Us/Reservoirs.

Brazos River Authority, 2017b, Possum Kingdom Lake – Morris Sheppard Dam, accessed September 21, 2017, http://www.brazos.org/About-Us/Reservoirs/Possum-Kingdom-Lake.

Dunbar, J.A. and Allen, P.M., 2003, Sediment Thickness from Coring and Acoustics within Lakes Aquilla, Granger, Limestone, and Proctor: Brazos River Watershed, TX: Baylor University, Department of Geology.

Eakin, H. M. and Brown, C. B., 1939, Silting of Reservoirs, United States Soil Conservation Service, Technical Bulletin No. 524.

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

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

Greiner, J. H. Jr., 1982, Erosion and Sedimentation by Water in Texas, Average Annual Rates Estimated in 1979, Texas Department of Water Resources Report 268, accessed November 19, 2017, at https://www.twdb.texas.gov/publications/reports/numbered_reports/doc/R268/R268_opt.pdf.

Jones, V.H. and Rogers, R.E., 1949, Reconnaissance Investigation of Sedimentation in Possum Kingdom Lake, United States Department of Agriculture, Soil Conservation Service, SCS-TP-87, accessed November 1, 2017, at https://archive.org/details/reconnaissancein87jone.

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

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

National Geodetic Survey, 2017a, NADCON computations, accessed July 2017, http://www.ngs.noaa.gov/cgi-bin/nadcon.prl.

National Geodetic Survey, 2017b, Orthometric Height Conversion, accessed July 2017, http://www.ngs.noaa.gov/cgi-bin/VERTCON/vert_con.prl.

Soil Conservation Service, 1959, Inventory and Use of Sedimentation Data in Texas. Bulletin 5912, accessed November 19, 2017, at http://www.twdb.texas.gov/publications/reports/bulletins/doc/B5912.pdf.

Texas Natural Resources Information System, 2017a, FEMA 2013 60cm Middle Brazos-Palo Pinto Lidar, accessed May 10, 2017, at https://www.tnris.org/data-catalog/entry/fema-2013-60cm-middle-brazos-palo-pinto/.

Texas Natural Resources Information System, 2017b, Maps & Data, accessed May 10, 2017, at http://www.tnris.org/maps-and-data/.

Texas Water Development Board, 1973, Morris Sheppard Dam and Possum Kingdom Lake, Report 126: Engineering Data on Dams and Reservoirs in Texas, Part II.

Texas Water Development Board, 1994, Volumetric Survey of Possum Kingdom Lake, accessed September 21, 2017, at http://www.twdb.texas.gov/hydro_survey/PossumKingdom/1994-06/PossumKingdom1994_FinalReport.PDF.

Texas Water Development Board, 2006, Volumetric Survey of Possum Kingdom Lake, accessed September 21, 2017, at http://www.twdb.texas.gov/hydro_survey/PossumKingdom/2005-01/PK2005_FinalReport.pdf.

Texas Water Development Board, 2016a, Contract No. R1648011985 with U.S. Army Corps of Engineers, Fort Worth District.

Texas Water Development Board, 2016b, Application of new procedures to re-assess reservoir capacity, accessed November 15, 2017, at http://www.twdb.texas.gov/hydro_survey/Re-assessment/.

URS/Forrest and Cotton, Inc., 1975, Report on Possum Kingdom Reservoir Yield Study.

U.S. Army Corps of Engineers, 2013, Engineering and Design, Hydrographic Surveying - Engineer Manual, EM 1100-2-1003 (30 Nov 13): U.S. Army Corps of Engineers, Appendix P.

U.S. Department of Agriculture, 2016, National Agricultural Imagery Program (NAIP) Information Sheet, accessed September 21, 2017, at http://www.fsa.usda.gov/Assets/USDA-FSA-Public/usdafiles/APFO/support-documents/pdfs/naip_infosheet_2016.pdf.

U.S. Geological Survey, 2017a, U.S. Geological Survey National Water Information System: Web Interface, *USGS 08088500 Possum Kingdom Lk nr Graford, TX*, accessed September 15, 2017, at https://waterdata.usgs.gov/tx/nwis/uv/?site_no=08088500&PARAmeter_cd=00054,62614,62615,62619.

U.S. Geological Survey, 2017b, U.S. Geological Survey National Water Information System: Web Interface, *USGS 08088440 Possum Kingdom Lk at Sandy Beach nr*

Graford, TX, accessed September 15, 2017, at https://waterdata.usgs.gov/tx/nwis/uv/?site_no=08088440&PARAmeter_cd=00054,62614,62615,62619.

U.S. Geological Survey, 2017c, U.S. Geological Survey National Water Information System: Web Interface, *USGS Possum Kingdom Lk abv McGinnis Pt nr Graford, TX*, accessed September 15, 2017, at https://waterdata.usgs.gov/tx/nwis/uv/?site_no=08088435&PARAmeter_cd=00054,62614,62615,62619.

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

Appendix A

Possum Kingdom Lake

RESERVOIR CAPACITY TABLE

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

June 1994 Survey re-calculated November 2016
Normal operating level 999.0 feet NGVD29
Top of gates/Emergency spillway elevation 1,000.0 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
893	0	0	0	0	0	0	0	0	0	0
894	0	0	0	0	0	0	0	0	0	0
895	0	0	0	0	0	1	1	1	1	2
896	2	2	3	3	4	4	5	6	7	8
897	10	11	13	16	18	21	24	28	31	35
898	40	44	49	54	60	65	72	78	85	92
899	99	107	115	124	132	142	151	162	172	184
900	196	208	221	234	248	262	276	290	305	321
901	336	352	369	386	403	420	438	457	476	496
902	517	537	559	581	604	627	651	675	700	726
903	752	778	805	833	862	891	921	951	982	1,014
904	1,046	1,079	1,113	1,147	1,181	1,216	1,251	1,286	1,322	1,359
905	1,396	1,434	1,472	1,511	1,551	1,591	1,633	1,675	1,718	1,762
906	1,807	1,852	1,898	1,944	1,992	2,039	2,088	2,137	2,187	2,238
907	2,289	2,341	2,393	2,446	2,500	2,554	2,609	2,664	2,720	2,777
908	2,834	2,891	2,950	3,009	3,070	3,131	3,192	3,254	3,317	3,380
909	3,444	3,509	3,575	3,641	3,708	3,776	3,844	3,912	3,981	4,051
910	4,122	4,192	4,264	4,336	4,409	4,483	4,557	4,632	4,707	4,784
911	4,861	4,938	5,017	5,096	5,175	5,255	5,336	5,418	5,500	5,583
912	5,667	5,751	5,835	5,920	6,006	6,092	6,179	6,267	6,354	6,443
913	6,532	6,621	6,711	6,802	6,893	6,985	7,077	7,170	7,263	7,357
914	7,451	7,547	7,642	7,739	7,836	7,933	8,032	8,131	8,230	8,331
915	8,431	8,533	8,635	8,737	8,840	8,943	9,047	9,151	9,256	9,362
916	9,469	9,576	9,684	9,792	9,901	10,011	10,121	10,232	10,343	10,456
917	10,568	10,681	10,795	10,909	11,024	11,139	11,255	11,372	11,490	11,607
918	11,726	11,845	11,964	12,084	12,205	12,326	12,447	12,570	12,692	12,815
919	12,939	13,063	13,188	13,314	13,440	13,566	13,693	13,821	13,949	14,078
920	14,207	14,337	14,467	14,598	14,729	14,861	14,994	15,127	15,260	15,394
921	15,529	15,664	15,801	15,938	16,075	16,214	16,352	16,492	16,632	16,772
922	16,913	17,055	17,197	17,340	17,483	17,627	17,772	17,917	18,062	18,209
923	18,356	18,503	18,652	18,800	18,950	19,100	19,251	19,402	19,554	19,706
924	19,859	20,013	20,167	20,322	20,478	20,635	20,792	20,949	21,108	21,267
925	21,427	21,588	21,750	21,914	22,078	22,244	22,412	22,582	22,753	22,925
926	23,099	23,274	23,450	23,628	23,807	23,987	24,167	24,349	24,532	24,717
927	24,902	25,089	25,276	25,465	25,655	25,845	26,037	26,230	26,424	26,619
928	26,815	27,012	27,211	27,410	27,611	27,813	28,016	28,219	28,424	28,630
929	28,837	29,045	29,254	29,464	29,675	29,887	30,099	30,313	30,528	30,743
930	30,960	31,177	31,396	31,615	31,836	32,058	32,280	32,504	32,729	32,955
931	33,181	33,409	33,638	33,867	34,098	34,329	34,561	34,795	35,029	35,264
932	35,500	35,737	35,976	36,215	36,456	36,698	36,941	37,185	37,430	37,676
933	37,923	38,171	38,420	38,670	38,921	39,173	39,426	39,680	39,935	40,191
934	40,448	40,706	40,964	41,224	41,485	41,746	42,008	42,272	42,537	42,802
935	43,069	43,336	43,605	43,875	44,146	44,417	44,690	44,965	45,240	45,517
936	45,795	46,073	46,354	46,635	46,917	47,201	47,486	47,771	48,058	48,346
937	48,635	48,925	49,216	49,508	49,802	50,097	50,393	50,690	50,989	51,289
938	51,590	51,893	52,197	52,502	52,809	53,117	53,427	53,738	54,050	54,363
939	54,678	54,994	55,312	55,630	55,950	56,271	56,593	56,917	57,242	57,568
940	57,896	58,224	58,554	58,885	59,218	59,551	59,886	60,222	60,559	60,897
941	61,236	61,577	61,918	62,261	62,605	62,950	63,296	63,644	63,993	64,343
942	64,694	65,046	65,400	65,754	66,110	66,467	66,825	67,184	67,544	67,906
943	68,269	68,632	68,997	69,363	69,730	70,099	70,468	70,838	71,210	71,582
944	71,956	72,331	72,707	73,084	73,463	73,843	74,223	74,606	74,989	75,373
945	75,759	76,145	76,533	76,922	77,313	77,704	78,097	78,491	78,887	79,284
946	79,682	80,081	80,482	80,885	81,288	81,693	82,099	82,507	82,915	83,325
947	83,736	84,148	84,562	84,976	85,392	85,809	86,228	86,647	87,067	87,489
948	87,912	88,336	88,761	89,188	89,616	90,045	90,476	90,908	91,342	91,777
949	92,213	92,651	93,091	93,532	93,974	94,417	94,862	95,308	95,755	96,203

Appendix A (Continued)

Possum Kingdom Lake

RESERVOIR CAPACITY TABLE

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

CAPACITY IN ACRE-FEET — Normal operating level 999.0 feet NGVD29

ELEVATION INCREMENT IS ONE TENTH FOOT — Top of gates/Emergency spillway elevation 1,000.0 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
950	96,653	97,104	97,556	98,010	98,466	98,922	99,380	99,839	100,300	100,762
951	101,225	101,689	102,155	102,622	103,091	103,560	104,031	104,504	104,977	105,452
952	105,928	106,405	106,884	107,364	107,845	108,327	108,810	109,295	109,781	110,268
953	110,757	111,246	111,738	112,230	112,724	113,220	113,716	114,215	114,714	115,215
954	115,717	116,220	116,725	117,230	117,738	118,246	118,756	119,267	119,779	120,293
955	120,807	121,323	121,841	122,359	122,880	123,401	123,924	124,448	124,973	125,500
956	126,027	126,556	127,087	127,618	128,152	128,686	129,221	129,758	130,296	130,836
957	131,377	131,919	132,462	133,007	133,553	134,100	134,648	135,198	135,750	136,302
958	136,856	137,412	137,969	138,527	139,088	139,650	140,213	140,778	141,344	141,912
959	142,482	143,052	143,624	144,198	144,773	145,350	145,928	146,508	147,088	147,671
960	148,255	148,840	149,426	150,014	150,604	151,195	151,787	152,381	152,976	153,573
961	154,170	154,769	155,370	155,972	156,575	157,179	157,785	158,393	159,002	159,612
962	160,224	160,838	161,453	162,069	162,688	163,307	163,928	164,551	165,175	165,801
963	166,428	167,056	167,686	168,318	168,951	169,586	170,222	170,860	171,500	172,141
964	172,784	173,428	174,074	174,721	175,370	176,021	176,673	177,327	177,982	178,639
965	179,298	179,958	180,620	181,283	181,949	182,615	183,283	183,954	184,626	185,300
966	185,975	186,652	187,331	188,012	188,695	189,379	190,065	190,753	191,443	192,135
967	192,828	193,523	194,221	194,920	195,621	196,323	197,028	197,734	198,442	199,152
968	199,863	200,576	201,291	202,008	202,726	203,446	204,167	204,891	205,615	206,342
969	207,070	207,800	208,532	209,266	210,001	210,738	211,477	212,218	212,960	213,704
970	214,450	215,197	215,947	216,698	217,451	218,206	218,963	219,722	220,482	221,245
971	222,009	222,775	223,544	224,314	225,087	225,861	226,638	227,417	228,198	228,981
972	229,766	230,553	231,343	232,135	232,928	233,724	234,522	235,323	236,125	236,930
973	237,737	238,546	239,358	240,172	240,989	241,808	242,629	243,453	244,279	245,108
974	245,938	246,771	247,607	248,445	249,285	250,127	250,972	251,819	252,669	253,521
975	254,375	255,231	256,090	256,950	257,814	258,679	259,546	260,416	261,288	262,163
976	263,040	263,919	264,802	265,687	266,574	267,464	268,357	269,252	270,150	271,051
977	271,955	272,861	273,770	274,681	275,596	276,513	277,432	278,355	279,280	280,208
978	281,138	282,070	283,006	283,943	284,884	285,827	286,773	287,722	288,673	289,627
979	290,584	291,543	292,506	293,471	294,440	295,412	296,388	297,368	298,350	299,336
980	300,325	301,316	302,311	303,309	304,310	305,313	306,319	307,329	308,341	309,356
981	310,374	311,395	312,419	313,446	314,476	315,509	316,545	317,585	318,627	319,673
982	320,722	321,774	322,830	323,888	324,950	326,014	327,082	328,153	329,227	330,304
983	331,384	332,467	333,554	334,643	335,736	336,832	337,930	339,033	340,138	341,246
984	342,357	343,471	344,588	345,709	346,833	347,959	349,088	350,222	351,358	352,497
985	353,640	354,785	355,933	357,084	358,239	359,396	360,555	361,718	362,884	364,052
986	365,223	366,397	367,574	368,754	369,937	371,121	372,309	373,500	374,693	375,889
987	377,088	378,289	379,494	380,701	381,912	383,124	384,340	385,559	386,780	388,005
988	389,233	390,463	391,698	392,935	394,176	395,420	396,668	397,920	399,175	400,435
989	401,697	402,964	404,235	405,508	406,786	408,067	409,352	410,641	411,933	413,230
990	414,529	415,832	417,139	418,449	419,764	421,082	422,404	423,731	425,061	426,397
991	427,737	429,081	430,432	431,787	433,148	434,513	435,884	437,262	438,645	440,036
992	441,432	442,834	444,242	445,655	447,075	448,501	449,933	451,373	452,818	454,270
993	455,727	457,188	458,656	460,127	461,603	463,082	464,566	466,055	467,548	469,047
994	470,549	472,056	473,568	475,083	476,602	478,125	479,651	481,182	482,716	484,254
995	485,794	487,338	488,886	490,436	491,991	493,548	495,109	496,673	498,240	499,811
996	501,383	502,958	504,536	506,116	507,699	509,284	510,871	512,461	514,053	515,648
997	517,245	518,845	520,447	522,051	523,658	525,268	526,879	528,494	530,110	531,729
998	533,351	534,975	536,601	538,230	539,861	541,495	543,131	544,769	546,410	548,054
999	549,699	551,348	552,998	554,651	556,307	557,965	559,625	561,288	562,953	564,621
1,000	566,291									

Note: Capacities above elevation 996.2 feet calculated from interpolated areas

Appendix B

Possum Kingdom Lake

RESERVOIR AREA TABLE

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

AREA IN ACRES — Normal operating level 999.0 feet NGVD29

ELEVATION INCREMENT IS ONE TENTH FOOT — Top of gates/Emergency spillway elevation 1,000.0 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
893	0	0	0	0	0	0	0	0	0	0
894	0	0	0	0	0	0	0	0	0	0
895	0	0	1	1	1	1	2	3	3	4
896	4	4	5	5	6	6	9	10	11	13
897	15	18	20	23	27	30	34	37	39	41
898	43	46	51	54	57	60	63	67	70	72
899	75	78	82	87	91	95	99	105	112	117
900	122	126	130	134	137	141	144	147	151	155
901	159	163	166	170	174	177	182	190	195	201
902	206	212	219	225	230	234	241	247	253	258
903	263	268	274	281	288	295	303	309	315	320
904	326	332	337	341	345	349	354	358	363	369
905	374	380	387	393	400	408	419	429	436	442
906	449	455	462	469	476	482	489	496	503	509
907	515	522	528	534	539	545	551	556	561	566
908	573	582	590	598	605	612	619	625	631	638
909	644	652	659	666	673	678	683	689	695	700
910	706	713	719	725	732	739	745	752	759	768
911	774	780	786	792	799	807	814	820	826	832
912	838	843	848	854	860	866	871	876	881	887
913	893	898	903	908	913	918	925	931	937	943
914	949	954	960	966	973	981	988	994	1,000	1,005
915	1,010	1,015	1,020	1,025	1,030	1,036	1,042	1,049	1,056	1,063
916	1,069	1,075	1,081	1,087	1,093	1,099	1,105	1,111	1,117	1,122
917	1,127	1,134	1,140	1,147	1,152	1,157	1,164	1,171	1,176	1,181
918	1,186	1,191	1,196	1,202	1,209	1,215	1,220	1,224	1,229	1,233
919	1,239	1,246	1,252	1,257	1,262	1,267	1,273	1,279	1,285	1,290
920	1,296	1,301	1,306	1,311	1,317	1,322	1,327	1,333	1,338	1,343
921	1,351	1,359	1,367	1,373	1,378	1,385	1,391	1,396	1,402	1,408
922	1,413	1,419	1,425	1,431	1,437	1,442	1,448	1,454	1,460	1,466
923	1,473	1,479	1,485	1,492	1,498	1,504	1,510	1,515	1,521	1,527
924	1,534	1,541	1,547	1,554	1,561	1,568	1,575	1,582	1,588	1,596
925	1,605	1,614	1,627	1,640	1,654	1,670	1,688	1,702	1,716	1,731
926	1,745	1,758	1,771	1,782	1,792	1,803	1,814	1,825	1,836	1,849
927	1,860	1,871	1,882	1,892	1,902	1,912	1,922	1,934	1,945	1,957
928	1,968	1,979	1,990	2,001	2,012	2,023	2,033	2,043	2,054	2,064
929	2,074	2,085	2,095	2,105	2,114	2,123	2,132	2,141	2,150	2,161
930	2,171	2,181	2,191	2,200	2,210	2,222	2,233	2,243	2,253	2,263
931	2,272	2,282	2,291	2,300	2,309	2,318	2,327	2,336	2,346	2,356
932	2,368	2,379	2,390	2,402	2,413	2,424	2,434	2,444	2,454	2,465
933	2,476	2,486	2,496	2,506	2,515	2,525	2,535	2,545	2,555	2,564
934	2,574	2,583	2,592	2,601	2,610	2,619	2,629	2,640	2,651	2,661
935	2,672	2,682	2,692	2,702	2,712	2,723	2,737	2,749	2,761	2,772
936	2,783	2,794	2,806	2,819	2,831	2,842	2,852	2,863	2,873	2,883
937	2,894	2,905	2,917	2,929	2,942	2,955	2,968	2,980	2,993	3,006
938	3,020	3,034	3,048	3,060	3,074	3,087	3,102	3,116	3,129	3,142
939	3,154	3,167	3,179	3,192	3,205	3,217	3,230	3,243	3,255	3,268
940	3,280	3,293	3,305	3,317	3,329	3,341	3,353	3,366	3,377	3,388
941	3,399	3,410	3,420	3,432	3,444	3,458	3,470	3,482	3,494	3,506
942	3,518	3,529	3,541	3,552	3,563	3,575	3,586	3,598	3,610	3,621
943	3,632	3,643	3,654	3,665	3,676	3,687	3,698	3,709	3,720	3,732
944	3,744	3,756	3,768	3,779	3,791	3,803	3,814	3,826	3,838	3,850
945	3,861	3,874	3,886	3,898	3,909	3,921	3,934	3,948	3,962	3,975
946	3,989	4,002	4,016	4,030	4,043	4,055	4,068	4,080	4,092	4,104
947	4,116	4,128	4,141	4,153	4,165	4,177	4,188	4,199	4,211	4,222
948	4,234	4,245	4,259	4,272	4,288	4,302	4,315	4,328	4,342	4,358
949	4,372	4,388	4,402	4,416	4,428	4,440	4,453	4,465	4,477	4,489

Appendix B (Continued)

Possum Kingdom Lake

RESERVOIR AREA TABLE

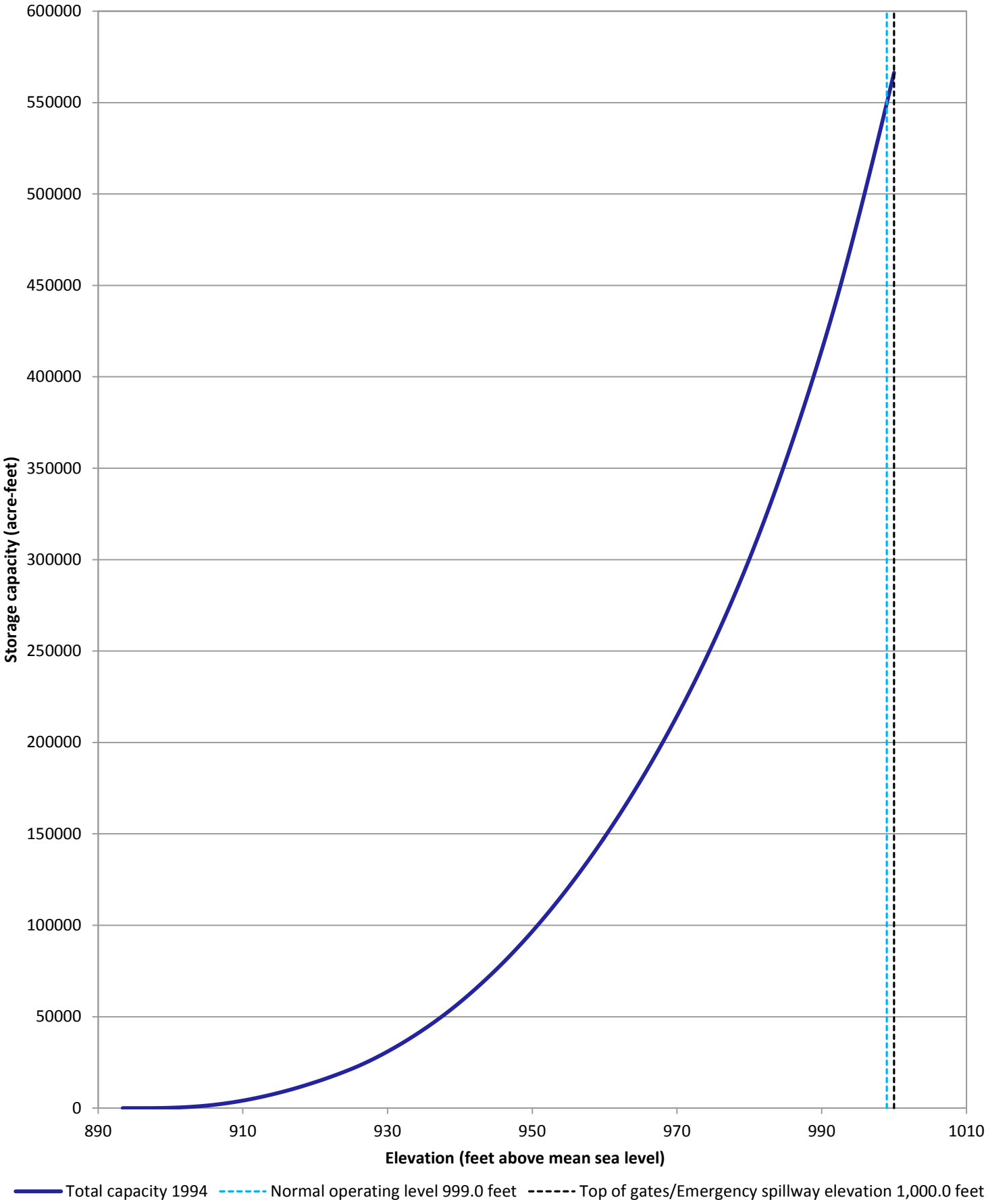
TEXAS WATER DEVELOPMENT BOARD — June 1994 Survey re-calculated November 2016

AREA IN ACRES — Normal operating level 999.0 feet NGVD29

ELEVATION INCREMENT IS ONE TENTH FOOT — Top of gates/Emergency spillway elevation 1,000.0 feet NGVD29

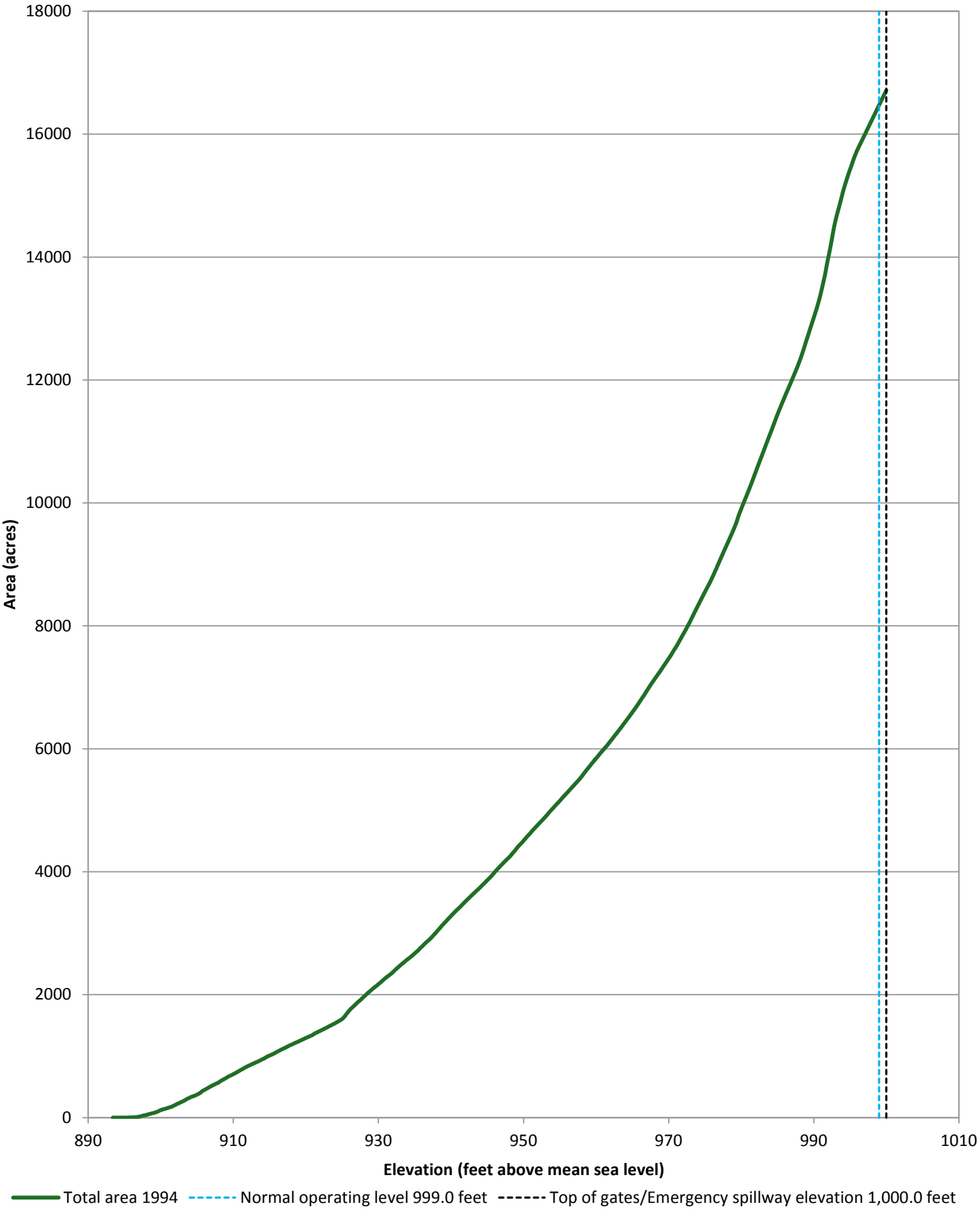
ELEVATION in Feet	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
950	4,504	4,519	4,532	4,545	4,560	4,573	4,586	4,598	4,611	4,624
951	4,637	4,652	4,665	4,678	4,691	4,704	4,717	4,729	4,741	4,754
952	4,767	4,780	4,792	4,804	4,816	4,828	4,841	4,853	4,866	4,879
953	4,892	4,904	4,918	4,932	4,947	4,961	4,975	4,988	5,001	5,014
954	5,026	5,039	5,052	5,065	5,079	5,091	5,103	5,116	5,129	5,141
955	5,154	5,167	5,181	5,195	5,209	5,221	5,234	5,247	5,259	5,271
956	5,284	5,297	5,310	5,323	5,336	5,350	5,363	5,375	5,388	5,401
957	5,414	5,427	5,440	5,453	5,466	5,478	5,492	5,505	5,519	5,533
958	5,547	5,562	5,579	5,595	5,611	5,627	5,642	5,657	5,671	5,685
959	5,699	5,714	5,729	5,745	5,759	5,774	5,788	5,802	5,817	5,831
960	5,845	5,858	5,873	5,887	5,902	5,916	5,931	5,944	5,958	5,971
961	5,985	5,998	6,012	6,025	6,039	6,053	6,067	6,082	6,097	6,112
962	6,127	6,142	6,157	6,173	6,188	6,204	6,219	6,234	6,249	6,263
963	6,278	6,294	6,309	6,325	6,340	6,355	6,372	6,388	6,404	6,419
964	6,434	6,450	6,466	6,482	6,498	6,514	6,530	6,546	6,561	6,578
965	6,594	6,611	6,627	6,643	6,660	6,676	6,694	6,711	6,728	6,745
966	6,763	6,781	6,800	6,818	6,835	6,852	6,870	6,888	6,907	6,926
967	6,945	6,963	6,982	7,000	7,018	7,037	7,055	7,071	7,088	7,105
968	7,122	7,140	7,157	7,174	7,191	7,207	7,223	7,240	7,257	7,274
969	7,292	7,310	7,327	7,345	7,362	7,380	7,397	7,415	7,432	7,449
970	7,467	7,484	7,502	7,520	7,539	7,559	7,579	7,598	7,616	7,634
971	7,653	7,673	7,693	7,714	7,735	7,757	7,779	7,800	7,821	7,842
972	7,863	7,884	7,905	7,926	7,947	7,970	7,992	8,014	8,036	8,058
973	8,082	8,106	8,130	8,154	8,178	8,202	8,226	8,249	8,273	8,296
974	8,320	8,343	8,366	8,390	8,413	8,437	8,460	8,483	8,506	8,529
975	8,553	8,575	8,598	8,620	8,642	8,664	8,686	8,709	8,733	8,758
976	8,784	8,809	8,835	8,862	8,888	8,913	8,940	8,967	8,995	9,023
977	9,049	9,076	9,102	9,129	9,156	9,183	9,211	9,237	9,263	9,288
978	9,314	9,340	9,366	9,393	9,419	9,446	9,473	9,499	9,526	9,553
979	9,581	9,610	9,639	9,669	9,704	9,741	9,778	9,811	9,842	9,872
980	9,902	9,933	9,963	9,991	10,021	10,050	10,078	10,106	10,136	10,165
981	10,195	10,225	10,255	10,285	10,316	10,347	10,378	10,410	10,442	10,474
982	10,506	10,538	10,569	10,600	10,631	10,662	10,694	10,724	10,755	10,786
983	10,817	10,848	10,879	10,911	10,942	10,974	11,005	11,036	11,067	11,096
984	11,126	11,157	11,188	11,220	11,251	11,282	11,314	11,346	11,377	11,408
985	11,439	11,469	11,498	11,527	11,555	11,584	11,613	11,642	11,670	11,698
986	11,727	11,755	11,782	11,810	11,837	11,864	11,892	11,919	11,947	11,975
987	12,003	12,031	12,059	12,087	12,115	12,143	12,171	12,201	12,231	12,262
988	12,292	12,324	12,357	12,391	12,427	12,462	12,498	12,535	12,573	12,612
989	12,648	12,685	12,721	12,758	12,794	12,832	12,869	12,905	12,941	12,977
990	13,013	13,050	13,088	13,124	13,162	13,203	13,243	13,286	13,331	13,376
991	13,425	13,476	13,527	13,579	13,630	13,682	13,741	13,807	13,872	13,934
992	13,991	14,048	14,105	14,165	14,227	14,292	14,362	14,424	14,487	14,544
993	14,595	14,644	14,690	14,735	14,777	14,821	14,865	14,911	14,957	15,003
994	15,049	15,093	15,133	15,172	15,210	15,248	15,285	15,322	15,357	15,390
995	15,424	15,458	15,490	15,525	15,560	15,594	15,626	15,655	15,685	15,714
996	15,741	15,766	15,789	15,814	15,838	15,862	15,887	15,911	15,935	15,960
997	15,984	16,008	16,032	16,057	16,081	16,105	16,130	16,154	16,178	16,203
998	16,227	16,251	16,276	16,300	16,324	16,349	16,373	16,397	16,422	16,446
999	16,470	16,495	16,519	16,543	16,568	16,592	16,616	16,640	16,665	16,689
1,000	16,713									

Note: Areas between elevations 996.2 and 1,000.0 feet linearly interpolated



Possum Kingdom Lake
June 1994 Survey
re-calculated November 2016
Prepared by: TWDB

Appendix C: Capacity curve



Possum Kingdom Lake
June 1994 Survey
re-calculated November 2016
Prepared by: TWDB

Appendix D: Area curve

Appendix E

Possum Kingdom Lake

RESERVOIR CAPACITY TABLE

TEXAS WATER DEVELOPMENT BOARD — December 2004 - January 2005 Survey re-calculated October 2016

CAPACITY IN ACRE-FEET — Normal operating level 999.0 feet NGVD29

ELEVATION INCREMENT IS ONE TENTH FOOT — Top of gates/Emergency spillway elevation 1,000.0 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
893	0	0	0	0	0	0	0	0	0	0
894	0	0	0	0	0	0	1	1	1	1
895	1	1	1	1	1	1	1	2	2	2
896	2	2	2	2	2	2	3	3	3	3
897	3	3	4	4	4	5	5	6	6	7
898	8	9	10	12	13	15	17	20	22	25
899	29	32	36	40	45	49	55	60	66	71
900	77	84	90	97	105	112	120	128	137	146
901	155	165	175	186	198	210	222	235	249	262
902	276	290	305	320	336	353	370	388	406	426
903	445	466	486	507	529	551	574	597	620	645
904	670	696	723	750	777	805	834	862	892	922
905	952	984	1,016	1,049	1,083	1,117	1,152	1,187	1,223	1,260
906	1,297	1,335	1,373	1,411	1,451	1,490	1,531	1,572	1,615	1,658
907	1,703	1,748	1,794	1,841	1,889	1,937	1,986	2,036	2,087	2,138
908	2,190	2,242	2,296	2,349	2,404	2,459	2,514	2,570	2,627	2,684
909	2,742	2,800	2,859	2,919	2,979	3,039	3,101	3,162	3,225	3,287
910	3,351	3,414	3,478	3,543	3,608	3,673	3,739	3,805	3,872	3,939
911	4,007	4,075	4,144	4,214	4,284	4,355	4,427	4,499	4,572	4,646
912	4,720	4,794	4,870	4,945	5,022	5,100	5,178	5,256	5,336	5,416
913	5,496	5,577	5,659	5,741	5,823	5,906	5,990	6,073	6,158	6,243
914	6,328	6,415	6,501	6,588	6,676	6,764	6,852	6,941	7,031	7,121
915	7,211	7,302	7,394	7,487	7,580	7,674	7,769	7,864	7,959	8,056
916	8,152	8,250	8,348	8,446	8,546	8,645	8,746	8,847	8,948	9,050
917	9,152	9,255	9,359	9,463	9,567	9,672	9,778	9,885	9,991	10,099
918	10,207	10,315	10,424	10,534	10,644	10,755	10,866	10,978	11,090	11,203
919	11,317	11,431	11,546	11,661	11,777	11,893	12,010	12,128	12,246	12,364
920	12,483	12,603	12,723	12,844	12,966	13,088	13,211	13,334	13,459	13,583
921	13,709	13,834	13,961	14,088	14,215	14,343	14,471	14,599	14,729	14,858
922	14,988	15,119	15,250	15,381	15,513	15,645	15,778	15,912	16,046	16,182
923	16,318	16,454	16,592	16,730	16,870	17,010	17,150	17,292	17,434	17,577
924	17,720	17,865	18,009	18,155	18,301	18,448	18,596	18,744	18,893	19,043
925	19,194	19,345	19,497	19,649	19,802	19,956	20,110	20,265	20,421	20,577
926	20,735	20,893	21,052	21,213	21,375	21,538	21,703	21,870	22,038	22,208
927	22,379	22,550	22,723	22,897	23,072	23,248	23,425	23,603	23,782	23,962
928	24,142	24,324	24,507	24,692	24,878	25,065	25,254	25,443	25,634	25,826
929	26,020	26,214	26,409	26,605	26,803	27,001	27,201	27,401	27,603	27,806
930	28,010	28,215	28,421	28,629	28,837	29,047	29,257	29,469	29,682	29,896
931	30,110	30,326	30,544	30,762	30,981	31,202	31,423	31,646	31,870	32,095
932	32,321	32,548	32,776	33,004	33,235	33,466	33,698	33,931	34,165	34,400
933	34,636	34,873	35,112	35,351	35,592	35,834	36,076	36,320	36,565	36,811
934	37,058	37,306	37,556	37,806	38,057	38,309	38,563	38,817	39,072	39,329
935	39,586	39,844	40,103	40,364	40,625	40,887	41,150	41,415	41,680	41,947
936	42,215	42,483	42,753	43,024	43,296	43,569	43,844	44,120	44,398	44,676
937	44,956	45,237	45,519	45,802	46,087	46,372	46,659	46,947	47,236	47,527
938	47,819	48,112	48,406	48,702	48,998	49,296	49,595	49,895	50,196	50,499
939	50,802	51,107	51,412	51,719	52,027	52,336	52,647	52,958	53,271	53,585
940	53,900	54,217	54,534	54,854	55,174	55,496	55,820	56,144	56,470	56,797
941	57,125	57,455	57,786	58,118	58,452	58,787	59,123	59,460	59,799	60,139
942	60,480	60,822	61,166	61,511	61,857	62,204	62,553	62,904	63,255	63,609
943	63,963	64,318	64,675	65,034	65,393	65,754	66,116	66,479	66,844	67,210
944	67,577	67,945	68,314	68,685	69,057	69,430	69,805	70,181	70,558	70,936
945	71,316	71,697	72,079	72,462	72,847	73,233	73,621	74,010	74,400	74,792
946	75,185	75,579	75,974	76,371	76,769	77,168	77,569	77,971	78,374	78,779
947	79,185	79,593	80,002	80,413	80,825	81,238	81,653	82,069	82,486	82,904
948	83,323	83,744	84,166	84,589	85,013	85,439	85,866	86,294	86,724	87,154
949	87,586	88,019	88,453	88,888	89,324	89,762	90,201	90,641	91,082	91,525

Appendix E (Continued)

Possum Kingdom Lake

RESERVOIR CAPACITY TABLE

TEXAS WATER DEVELOPMENT BOARD — December 2004 - January 2005 Survey re-calculated October 2016

CAPACITY IN ACRE-FEET — Normal operating level 999.0 feet NGVD29

ELEVATION INCREMENT IS ONE TENTH FOOT — Top of gates/Emergency spillway elevation 1,000.0 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
950	91,969	92,414	92,861	93,309	93,759	94,211	94,663	95,118	95,574	96,032
951	96,490	96,950	97,412	97,874	98,338	98,803	99,269	99,737	100,206	100,677
952	101,148	101,621	102,095	102,571	103,048	103,526	104,005	104,486	104,968	105,452
953	105,937	106,423	106,911	107,400	107,890	108,382	108,874	109,369	109,864	110,362
954	110,860	111,359	111,860	112,362	112,866	113,371	113,877	114,385	114,894	115,405
955	115,917	116,430	116,945	117,462	117,979	118,498	119,019	119,541	120,064	120,588
956	121,114	121,641	122,170	122,699	123,231	123,763	124,297	124,832	125,369	125,906
957	126,445	126,986	127,528	128,071	128,615	129,161	129,708	130,257	130,807	131,358
958	131,910	132,464	133,019	133,576	134,134	134,693	135,254	135,817	136,380	136,946
959	137,512	138,080	138,650	139,220	139,793	140,367	140,942	141,519	142,097	142,677
960	143,258	143,841	144,425	145,011	145,598	146,186	146,776	147,368	147,960	148,555
961	149,150	149,747	150,345	150,945	151,546	152,148	152,751	153,356	153,962	154,570
962	155,178	155,789	156,400	157,013	157,628	158,244	158,861	159,479	160,099	160,720
963	161,343	161,967	162,592	163,219	163,847	164,477	165,107	165,740	166,373	167,009
964	167,645	168,282	168,922	169,562	170,204	170,847	171,492	172,139	172,786	173,436
965	174,086	174,738	175,393	176,048	176,706	177,365	178,026	178,689	179,354	180,021
966	180,689	181,360	182,032	182,706	183,383	184,060	184,740	185,423	186,107	186,793
967	187,481	188,170	188,862	189,555	190,251	190,947	191,645	192,346	193,047	193,751
968	194,456	195,163	195,872	196,582	197,295	198,009	198,725	199,443	200,162	200,884
969	201,607	202,331	203,059	203,787	204,518	205,251	205,985	206,722	207,460	208,200
970	208,942	209,685	210,431	211,178	211,928	212,678	213,431	214,186	214,942	215,701
971	216,461	217,223	217,987	218,753	219,522	220,292	221,064	221,838	222,614	223,393
972	224,173	224,955	225,740	226,526	227,316	228,106	228,900	229,696	230,494	231,295
973	232,097	232,902	233,710	234,519	235,331	236,145	236,961	237,781	238,602	239,426
974	240,252	241,080	241,911	242,744	243,580	244,417	245,257	246,100	246,944	247,791
975	248,640	249,492	250,346	251,202	252,061	252,921	253,784	254,650	255,518	256,389
976	257,261	258,137	259,015	259,896	260,779	261,665	262,554	263,445	264,339	265,236
977	266,135	267,037	267,942	268,849	269,760	270,672	271,587	272,505	273,425	274,349
978	275,274	276,202	277,133	278,065	279,001	279,939	280,880	281,824	282,770	283,720
979	284,673	285,629	286,588	287,551	288,517	289,486	290,458	291,434	292,413	293,396
980	294,382	295,371	296,363	297,358	298,356	299,357	300,361	301,368	302,377	303,389
981	304,404	305,421	306,442	307,466	308,493	309,523	310,556	311,593	312,633	313,677
982	314,724	315,773	316,826	317,882	318,941	320,003	321,068	322,137	323,208	324,283
983	325,360	326,440	327,524	328,611	329,701	330,794	331,889	332,989	334,090	335,196
984	336,303	337,413	338,528	339,644	340,764	341,886	343,012	344,141	345,273	346,408
985	347,546	348,687	349,831	350,978	352,129	353,282	354,438	355,597	356,759	357,925
986	359,093	360,263	361,437	362,614	363,794	364,976	366,161	367,349	368,540	369,734
987	370,930	372,129	373,332	374,536	375,744	376,955	378,168	379,384	380,603	381,825
988	383,050	384,277	385,508	386,741	387,978	389,218	390,460	391,705	392,953	394,205
989	395,458	396,714	397,974	399,237	400,503	401,771	403,042	404,317	405,594	406,875
990	408,159	409,445	410,735	412,027	413,323	414,622	415,923	417,229	418,537	419,849
991	421,164	422,483	423,805	425,131	426,460	427,792	429,128	430,469	431,812	433,161
992	434,514	435,872	437,235	438,602	439,975	441,353	442,737	444,127	445,523	446,927
993	448,336	449,752	451,175	452,604	454,040	455,482	456,931	458,389	459,853	461,326
994	462,805	464,291	465,786	467,288	468,798	470,313	471,834	473,361	474,891	476,427
995	477,967	479,510	481,059	482,610	484,166	485,723	487,284	488,848	490,415	491,986
996	493,559	495,134	496,714	498,295	499,880	501,466	503,055	504,647	506,240	507,837
997	509,435	511,035	512,638	514,243	515,851	517,460	519,072	520,687	522,304	523,924
998	525,545	527,170	528,796	530,425	532,057	533,691	535,327	536,966	538,607	540,251
999	541,897	543,545	545,196	546,849	548,505	550,163	551,823	553,486	555,152	556,819
1,000	558,489									

Note: Capacities above elevation 997.2 feet calculated from interpolated areas

Appendix F

Possum Kingdom Lake

RESERVOIR AREA TABLE

TEXAS WATER DEVELOPMENT BOARD — December 2004 - January 2005 Survey re-calculated October 2016

AREA IN ACRES — Normal operating level 999.0 feet NGVD29

ELEVATION INCREMENT IS ONE TENTH FOOT — Top of gates/Emergency spillway elevation 1,000.0 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
893	0	0	0	0	0	0	0	0	0	0
894	0	1	1	1	1	1	1	1	1	1
895	1	1	1	1	1	1	1	1	1	1
896	1	1	1	1	1	1	1	1	1	1
897	2	2	2	3	4	5	5	5	7	8
898	9	12	14	16	18	20	22	25	29	31
899	33	37	40	43	47	50	52	55	57	59
900	62	65	68	71	74	78	81	84	87	91
901	96	101	106	113	119	123	127	131	134	137
902	141	144	150	157	164	169	175	182	189	195
903	199	204	209	214	219	223	228	233	241	248
904	257	264	268	273	277	281	285	290	297	303
905	311	317	325	332	340	346	353	358	363	369
906	374	378	383	389	394	401	409	419	430	440
907	449	458	466	473	480	488	495	501	508	516
908	523	529	535	540	546	551	557	564	570	576
909	581	587	592	597	604	610	615	620	625	630
910	634	639	643	646	650	655	661	666	670	675
911	681	687	694	700	707	713	719	725	731	738
912	743	749	756	763	771	778	785	791	797	802
913	807	812	817	823	828	832	837	842	847	853
914	859	864	868	873	877	883	888	893	898	903
915	909	915	922	930	936	942	948	954	960	965
916	971	977	983	989	995	1,000	1,006	1,011	1,016	1,021
917	1,026	1,032	1,038	1,043	1,049	1,055	1,061	1,067	1,072	1,077
918	1,082	1,087	1,093	1,099	1,105	1,110	1,116	1,121	1,127	1,133
919	1,138	1,144	1,149	1,155	1,161	1,167	1,172	1,178	1,183	1,189
920	1,194	1,200	1,206	1,211	1,219	1,226	1,233	1,239	1,245	1,251
921	1,256	1,261	1,265	1,270	1,275	1,280	1,284	1,289	1,293	1,298
922	1,302	1,307	1,312	1,317	1,322	1,328	1,333	1,340	1,347	1,355
923	1,363	1,372	1,380	1,389	1,397	1,404	1,411	1,418	1,424	1,432
924	1,439	1,445	1,452	1,458	1,465	1,473	1,481	1,488	1,495	1,502
925	1,508	1,515	1,521	1,527	1,533	1,539	1,547	1,554	1,562	1,569
926	1,579	1,589	1,600	1,611	1,625	1,642	1,662	1,676	1,689	1,701
927	1,712	1,723	1,734	1,744	1,755	1,765	1,775	1,784	1,792	1,802
928	1,812	1,825	1,839	1,853	1,866	1,879	1,893	1,904	1,915	1,926
929	1,936	1,947	1,957	1,968	1,979	1,991	2,001	2,011	2,021	2,034
930	2,046	2,058	2,069	2,080	2,091	2,101	2,112	2,122	2,132	2,142
931	2,153	2,167	2,178	2,188	2,199	2,211	2,223	2,233	2,243	2,254
932	2,265	2,275	2,284	2,295	2,305	2,315	2,325	2,335	2,345	2,357
933	2,368	2,379	2,390	2,401	2,412	2,423	2,433	2,443	2,454	2,465
934	2,476	2,487	2,497	2,507	2,518	2,528	2,538	2,548	2,558	2,568
935	2,578	2,588	2,598	2,607	2,618	2,628	2,638	2,649	2,661	2,671
936	2,682	2,693	2,703	2,714	2,726	2,740	2,755	2,769	2,780	2,792
937	2,804	2,815	2,826	2,838	2,850	2,862	2,874	2,886	2,898	2,911
938	2,925	2,938	2,950	2,962	2,973	2,984	2,995	3,006	3,017	3,028
939	3,040	3,051	3,062	3,075	3,086	3,098	3,110	3,121	3,134	3,146
940	3,158	3,171	3,185	3,200	3,214	3,226	3,239	3,251	3,264	3,277
941	3,290	3,304	3,317	3,330	3,342	3,355	3,367	3,380	3,392	3,405
942	3,418	3,431	3,443	3,455	3,468	3,482	3,497	3,510	3,524	3,537
943	3,550	3,563	3,576	3,588	3,601	3,614	3,627	3,640	3,652	3,664
944	3,676	3,687	3,701	3,714	3,727	3,739	3,752	3,764	3,777	3,791
945	3,803	3,816	3,829	3,841	3,855	3,869	3,883	3,896	3,909	3,922
946	3,935	3,948	3,961	3,974	3,987	4,000	4,012	4,026	4,039	4,053
947	4,070	4,084	4,100	4,115	4,127	4,140	4,152	4,165	4,177	4,189
948	4,201	4,213	4,225	4,237	4,251	4,264	4,276	4,288	4,299	4,311
949	4,322	4,334	4,346	4,359	4,371	4,383	4,395	4,406	4,418	4,431

Appendix F (Continued)

Possum Kingdom Lake

RESERVOIR AREA TABLE

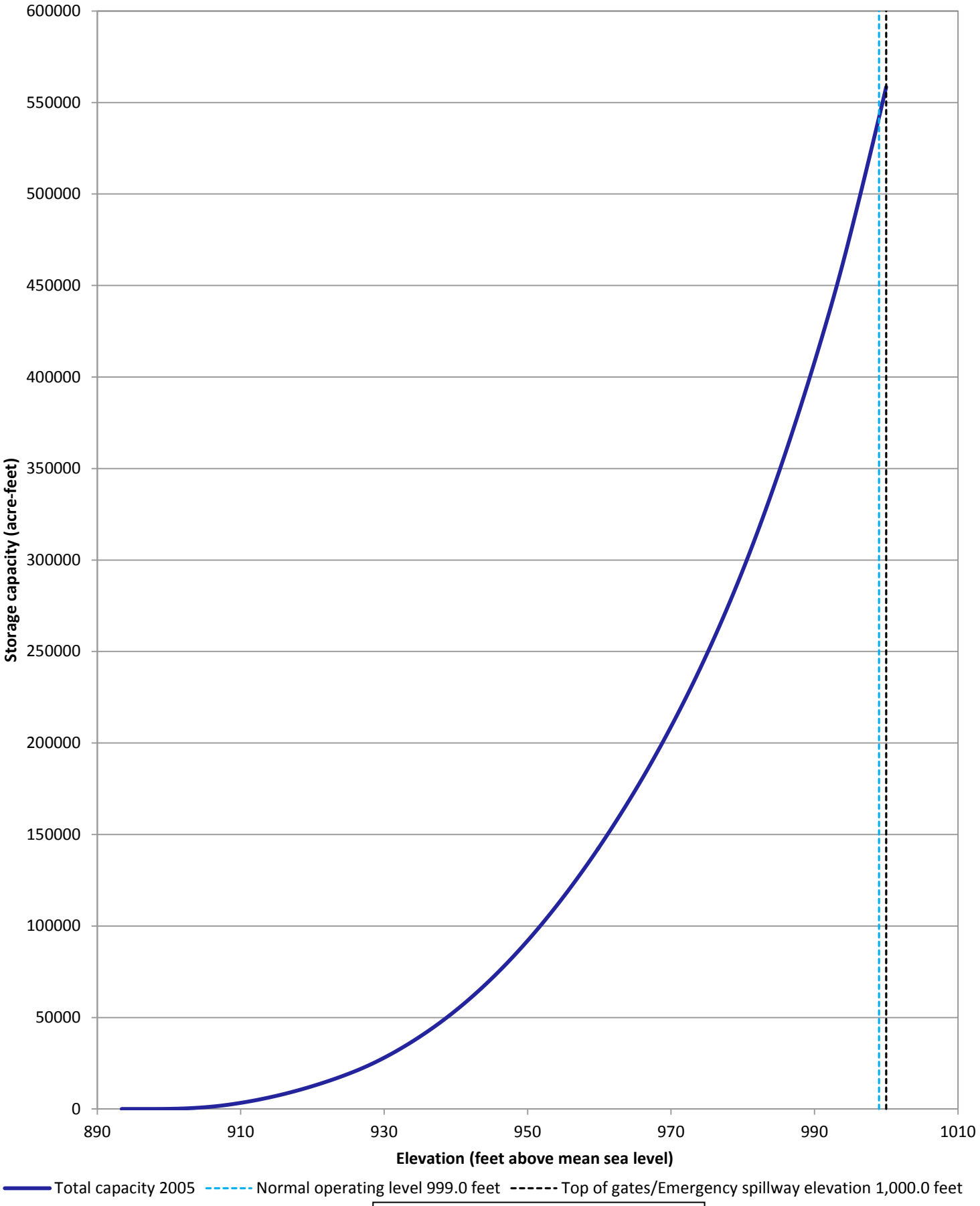
TEXAS WATER DEVELOPMENT BOARD — December 2004 - January 2005 Survey re-calculated October 2016

AREA IN ACRES — Normal operating level 999.0 feet NGVD29

ELEVATION INCREMENT IS ONE TENTH FOOT — Top of gates/Emergency spillway elevation 1,000.0 feet NGVD29

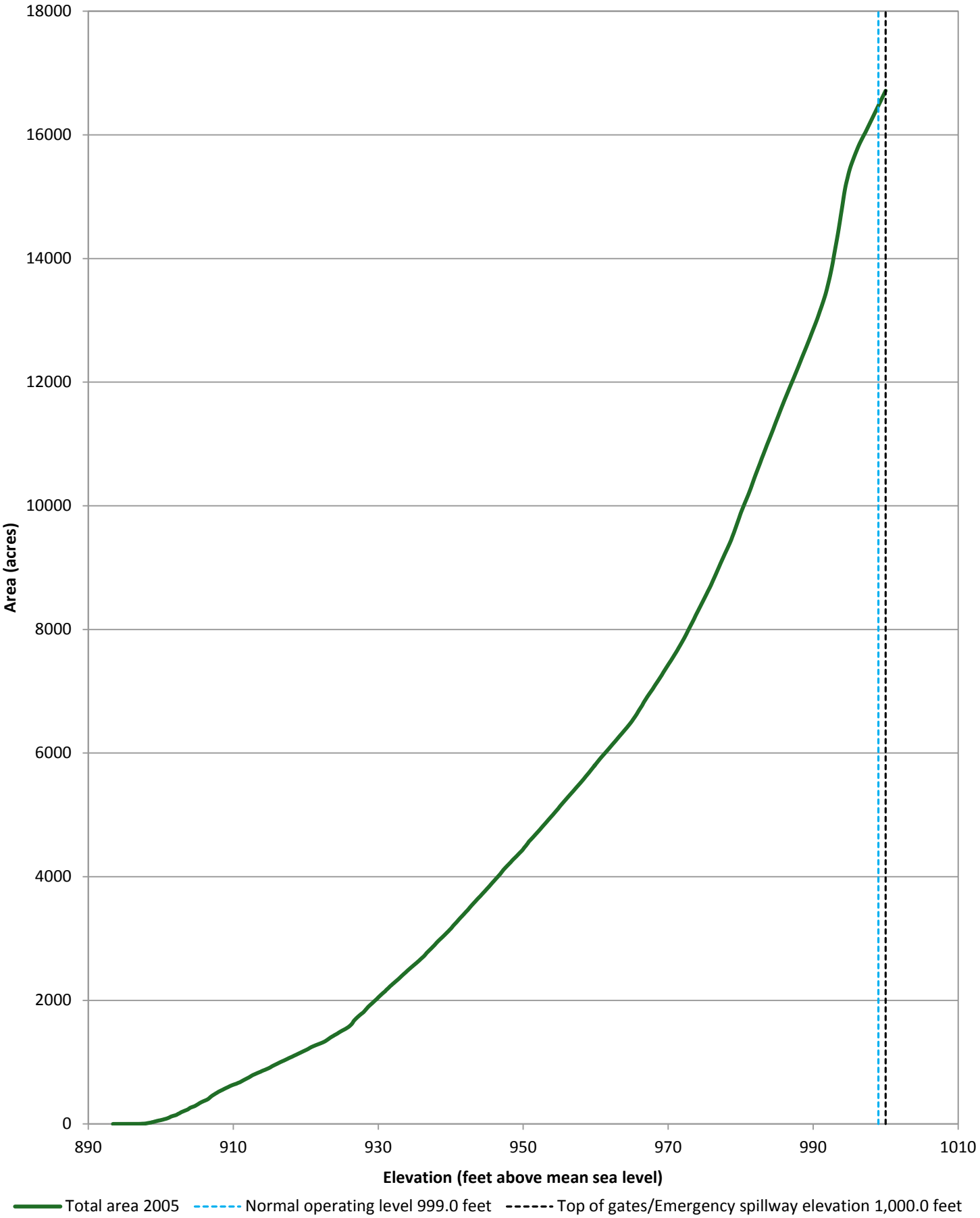
ELEVATION in Feet	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
950	4,446	4,463	4,477	4,491	4,505	4,521	4,535	4,553	4,570	4,582
951	4,594	4,607	4,619	4,632	4,644	4,657	4,671	4,684	4,696	4,709
952	4,722	4,735	4,748	4,761	4,775	4,789	4,803	4,816	4,830	4,843
953	4,855	4,869	4,882	4,896	4,910	4,923	4,936	4,950	4,963	4,976
954	4,989	5,002	5,016	5,030	5,043	5,057	5,071	5,084	5,097	5,112
955	5,129	5,143	5,157	5,170	5,184	5,198	5,211	5,224	5,238	5,251
956	5,265	5,278	5,292	5,305	5,318	5,332	5,345	5,358	5,371	5,384
957	5,397	5,411	5,425	5,439	5,452	5,465	5,478	5,491	5,505	5,518
958	5,531	5,545	5,559	5,573	5,587	5,602	5,617	5,631	5,645	5,659
959	5,673	5,687	5,702	5,717	5,732	5,746	5,761	5,776	5,790	5,805
960	5,820	5,834	5,849	5,864	5,878	5,893	5,908	5,921	5,935	5,948
961	5,962	5,975	5,988	6,001	6,015	6,028	6,041	6,055	6,068	6,082
962	6,096	6,110	6,124	6,138	6,151	6,164	6,178	6,191	6,205	6,219
963	6,233	6,247	6,261	6,275	6,289	6,302	6,315	6,329	6,343	6,357
964	6,371	6,385	6,398	6,412	6,426	6,441	6,455	6,470	6,485	6,500
965	6,515	6,533	6,550	6,567	6,584	6,601	6,619	6,637	6,658	6,678
966	6,697	6,715	6,733	6,751	6,769	6,791	6,813	6,833	6,851	6,869
967	6,888	6,907	6,924	6,941	6,958	6,975	6,992	7,008	7,025	7,042
968	7,061	7,080	7,098	7,116	7,133	7,151	7,169	7,186	7,204	7,222
969	7,240	7,258	7,278	7,299	7,318	7,336	7,354	7,373	7,392	7,410
970	7,428	7,446	7,464	7,481	7,499	7,518	7,537	7,556	7,575	7,594
971	7,613	7,632	7,651	7,671	7,692	7,712	7,732	7,752	7,773	7,793
972	7,814	7,835	7,856	7,878	7,900	7,922	7,946	7,970	7,994	8,017
973	8,039	8,062	8,085	8,107	8,130	8,153	8,177	8,202	8,227	8,250
974	8,273	8,295	8,319	8,342	8,365	8,388	8,411	8,434	8,457	8,481
975	8,504	8,527	8,550	8,574	8,598	8,622	8,644	8,667	8,691	8,715
976	8,742	8,769	8,795	8,821	8,847	8,873	8,899	8,926	8,954	8,980
977	9,007	9,034	9,062	9,088	9,114	9,139	9,165	9,191	9,217	9,242
978	9,267	9,292	9,317	9,343	9,369	9,395	9,422	9,450	9,483	9,514
979	9,544	9,575	9,609	9,642	9,675	9,708	9,742	9,775	9,808	9,843
980	9,877	9,907	9,937	9,966	9,994	10,023	10,052	10,079	10,107	10,135
981	10,163	10,192	10,223	10,254	10,285	10,317	10,351	10,385	10,418	10,451
982	10,482	10,514	10,544	10,575	10,606	10,636	10,666	10,697	10,729	10,762
983	10,792	10,821	10,852	10,883	10,913	10,944	10,975	11,004	11,034	11,062
984	11,092	11,122	11,152	11,181	11,211	11,241	11,273	11,305	11,336	11,366
985	11,396	11,426	11,456	11,486	11,517	11,547	11,577	11,607	11,636	11,666
986	11,695	11,724	11,752	11,781	11,809	11,837	11,866	11,895	11,923	11,952
987	11,979	12,007	12,034	12,062	12,090	12,119	12,148	12,176	12,204	12,233
988	12,262	12,291	12,321	12,350	12,380	12,410	12,438	12,467	12,495	12,524
989	12,552	12,581	12,611	12,640	12,669	12,699	12,730	12,761	12,791	12,821
990	12,851	12,881	12,911	12,941	12,971	13,002	13,034	13,068	13,102	13,138
991	13,171	13,204	13,238	13,272	13,308	13,344	13,381	13,419	13,462	13,507
992	13,555	13,603	13,652	13,701	13,755	13,811	13,868	13,929	13,997	14,065
993	14,129	14,195	14,258	14,323	14,390	14,459	14,533	14,606	14,684	14,757
994	14,830	14,907	14,985	15,060	15,125	15,185	15,236	15,282	15,331	15,379
995	15,422	15,462	15,498	15,531	15,564	15,595	15,626	15,657	15,687	15,716
996	15,745	15,774	15,802	15,829	15,855	15,880	15,903	15,926	15,950	15,972
997	15,995	16,017	16,037	16,062	16,086	16,110	16,134	16,158	16,182	16,206
998	16,231	16,255	16,279	16,303	16,327	16,351	16,375	16,400	16,424	16,448
999	16,472	16,496	16,520	16,544	16,569	16,593	16,617	16,641	16,665	16,689
1,000	16,713									

Note: Areas between elevations 997.2 and 1,000.0 feet linearly interpolated



Possum Kingdom Lake
December 2004 - January 2005 Survey
re-calculated October 2016
Prepared by: TWDB

Appendix G: Capacity curve



Possum Kingdom Lake
December 2004 - January 2005 Survey
re-calculated October 2016
Prepared by: TWDB

Appendix H: Area curve

Appendix I

Possum Kingdom Lake

RESERVOIR CAPACITY TABLE

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

June - December 2016 Survey
Normal operating level 999.0 feet NGVD29
Top of gates elevation 1,000.0 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
892	0	0	0	0	0	0	0	0	0	0
893	0	0	0	0	0	0	0	0	0	0
894	0	0	0	0	0	0	0	0	0	0
895	0	0	0	0	0	0	1	1	1	1
896	1	1	1	1	2	2	2	2	2	3
897	3	3	3	4	4	5	6	7	8	10
898	11	13	15	17	20	23	26	30	34	38
899	43	48	53	58	64	70	76	83	90	97
900	105	112	120	129	137	146	155	165	176	187
901	198	210	223	235	249	262	276	290	305	320
902	335	351	368	385	402	419	437	456	475	495
903	516	537	559	581	603	626	650	673	698	724
904	750	777	804	832	860	889	918	948	978	1,009
905	1,041	1,073	1,106	1,140	1,175	1,210	1,246	1,282	1,319	1,357
906	1,395	1,433	1,472	1,511	1,550	1,590	1,631	1,672	1,714	1,757
907	1,801	1,846	1,892	1,939	1,986	2,034	2,083	2,133	2,182	2,233
908	2,284	2,336	2,388	2,442	2,496	2,550	2,606	2,661	2,718	2,775
909	2,833	2,891	2,950	3,009	3,069	3,129	3,190	3,252	3,314	3,377
910	3,441	3,505	3,569	3,634	3,700	3,766	3,833	3,900	3,967	4,036
911	4,105	4,175	4,245	4,315	4,387	4,459	4,531	4,605	4,679	4,754
912	4,829	4,905	4,982	5,060	5,138	5,217	5,296	5,376	5,457	5,538
913	5,620	5,703	5,786	5,870	5,954	6,039	6,124	6,210	6,297	6,384
914	6,471	6,560	6,648	6,738	6,828	6,918	7,009	7,100	7,192	7,285
915	7,379	7,473	7,568	7,663	7,759	7,856	7,954	8,052	8,151	8,251
916	8,351	8,451	8,553	8,654	8,756	8,859	8,961	9,065	9,169	9,273
917	9,379	9,485	9,591	9,698	9,806	9,914	10,022	10,131	10,241	10,351
918	10,462	10,573	10,684	10,796	10,909	11,022	11,135	11,249	11,363	11,479
919	11,594	11,710	11,827	11,945	12,063	12,182	12,301	12,421	12,542	12,663
920	12,785	12,907	13,030	13,153	13,277	13,401	13,526	13,652	13,778	13,904
921	14,031	14,159	14,287	14,415	14,544	14,673	14,803	14,934	15,065	15,197
922	15,329	15,462	15,595	15,729	15,864	15,999	16,134	16,271	16,407	16,544
923	16,682	16,820	16,959	17,098	17,238	17,378	17,519	17,660	17,802	17,945
924	18,088	18,232	18,377	18,522	18,669	18,815	18,962	19,110	19,259	19,408
925	19,558	19,708	19,860	20,011	20,164	20,317	20,471	20,626	20,781	20,937
926	21,094	21,251	21,409	21,568	21,727	21,887	22,047	22,209	22,370	22,533
927	22,696	22,860	23,025	23,191	23,358	23,525	23,695	23,865	24,038	24,212
928	24,388	24,566	24,745	24,925	25,107	25,289	25,473	25,658	25,844	26,031
929	26,220	26,410	26,601	26,794	26,987	27,182	27,379	27,576	27,775	27,975
930	28,176	28,379	28,583	28,788	28,994	29,201	29,409	29,619	29,829	30,041
931	30,253	30,467	30,681	30,896	31,112	31,329	31,547	31,766	31,985	32,206
932	32,427	32,650	32,873	33,097	33,322	33,547	33,774	34,002	34,230	34,460
933	34,691	34,922	35,155	35,389	35,623	35,859	36,095	36,333	36,571	36,811
934	37,051	37,293	37,536	37,779	38,024	38,270	38,517	38,764	39,013	39,262
935	39,513	39,765	40,017	40,271	40,525	40,780	41,037	41,294	41,552	41,811
936	42,071	42,332	42,593	42,856	43,119	43,384	43,649	43,915	44,183	44,451
937	44,720	44,990	45,261	45,532	45,805	46,079	46,353	46,629	46,906	47,185
938	47,464	47,745	48,027	48,310	48,595	48,881	49,167	49,455	49,744	50,034
939	50,325	50,618	50,912	51,207	51,503	51,800	52,099	52,399	52,700	53,002
940	53,305	53,610	53,916	54,223	54,531	54,841	55,152	55,464	55,777	56,092
941	56,407	56,724	57,042	57,362	57,683	58,005	58,329	58,654	58,981	59,308
942	59,637	59,967	60,298	60,631	60,965	61,300	61,636	61,974	62,312	62,652
943	62,993	63,335	63,678	64,023	64,368	64,716	65,064	65,414	65,765	66,118
944	66,472	66,827	67,184	67,541	67,900	68,260	68,621	68,984	69,348	69,713
945	70,079	70,447	70,815	71,185	71,557	71,929	72,303	72,678	73,054	73,432
946	73,811	74,190	74,571	74,954	75,337	75,722	76,108	76,495	76,883	77,273
947	77,664	78,056	78,450	78,844	79,240	79,638	80,036	80,436	80,838	81,240
948	81,644	82,049	82,455	82,862	83,271	83,681	84,092	84,505	84,919	85,335

Appendix I (Continued)

Possum Kingdom Lake

RESERVOIR CAPACITY TABLE

TEXAS WATER DEVELOPMENT BOARD — June - December 2016 Survey

CAPACITY IN ACRE-FEET — Normal operating level 999.0 feet NGVD29

ELEVATION INCREMENT IS ONE TENTH FOOT — Top of gates elevation 1,000.0 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
949	85,751	86,169	86,589	87,009	87,431	87,853	88,277	88,703	89,129	89,557
950	89,986	90,416	90,847	91,280	91,714	92,149	92,585	93,023	93,461	93,902
951	94,343	94,786	95,230	95,675	96,122	96,570	97,019	97,469	97,921	98,374
952	98,829	99,285	99,742	100,201	100,661	101,123	101,586	102,052	102,518	102,985
953	103,454	103,924	104,395	104,868	105,342	105,817	106,293	106,771	107,251	107,731
954	108,213	108,697	109,182	109,668	110,155	110,644	111,134	111,625	112,118	112,612
955	113,107	113,603	114,101	114,601	115,102	115,603	116,107	116,611	117,117	117,625
956	118,133	118,643	119,154	119,667	120,181	120,696	121,213	121,731	122,250	122,771
957	123,293	123,817	124,342	124,868	125,396	125,925	126,456	126,988	127,521	128,056
958	128,593	129,130	129,669	130,209	130,751	131,294	131,839	132,385	132,932	133,481
959	134,030	134,582	135,134	135,688	136,244	136,800	137,358	137,918	138,479	139,042
960	139,606	140,171	140,738	141,307	141,877	142,448	143,021	143,595	144,171	144,748
961	145,326	145,906	146,488	147,071	147,656	148,242	148,830	149,420	150,010	150,603
962	151,197	151,793	152,391	152,990	153,591	154,193	154,796	155,402	156,009	156,617
963	157,227	157,839	158,452	159,067	159,683	160,300	160,919	161,539	162,161	162,785
964	163,410	164,036	164,664	165,294	165,925	166,558	167,192	167,827	168,464	169,103
965	169,743	170,384	171,028	171,672	172,319	172,966	173,616	174,267	174,920	175,574
966	176,230	176,887	177,547	178,207	178,870	179,533	180,198	180,865	181,534	182,204
967	182,875	183,548	184,223	184,899	185,577	186,256	186,937	187,620	188,303	188,989
968	189,677	190,366	191,057	191,750	192,445	193,142	193,840	194,540	195,242	195,946
969	196,652	197,359	198,069	198,780	199,493	200,208	200,924	201,643	202,364	203,086
970	203,811	204,537	205,266	205,996	206,729	207,463	208,200	208,938	209,678	210,421
971	211,165	211,911	212,660	213,410	214,162	214,916	215,672	216,431	217,191	217,953
972	218,717	219,483	220,252	221,023	221,796	222,570	223,347	224,126	224,907	225,690
973	226,474	227,261	228,049	228,840	229,632	230,426	231,222	232,020	232,820	233,623
974	234,428	235,235	236,044	236,856	237,671	238,487	239,307	240,129	240,953	241,780
975	242,609	243,440	244,274	245,110	245,949	246,789	247,632	248,479	249,327	250,178
976	251,030	251,885	252,743	253,603	254,466	255,331	256,197	257,067	257,939	258,813
977	259,689	260,568	261,450	262,334	263,220	264,109	265,001	265,895	266,792	267,691
978	268,593	269,497	270,404	271,314	272,226	273,141	274,059	274,979	275,902	276,828
979	277,756	278,687	279,621	280,557	281,496	282,437	283,381	284,329	285,278	286,232
980	287,187	288,146	289,108	290,073	291,042	292,014	292,990	293,970	294,952	295,939
981	296,928	297,921	298,917	299,917	300,920	301,927	302,936	303,949	304,965	305,985
982	307,006	308,031	309,059	310,090	311,124	312,161	313,201	314,245	315,292	316,343
983	317,398	318,455	319,516	320,580	321,647	322,717	323,790	324,866	325,945	327,028
984	328,113	329,201	330,294	331,388	332,486	333,587	334,692	335,800	336,910	338,025
985	339,142	340,262	341,386	342,513	343,644	344,777	345,914	347,054	348,197	349,344
986	350,492	351,644	352,800	353,958	355,120	356,284	357,452	358,624	359,798	360,975
987	362,155	363,338	364,525	365,715	366,908	368,104	369,303	370,507	371,713	372,923
988	374,135	375,351	376,571	377,793	379,018	380,247	381,478	382,713	383,950	385,191
989	386,435	387,681	388,931	390,184	391,440	392,699	393,962	395,228	396,497	397,771
990	399,047	400,327	401,612	402,899	404,192	405,488	406,788	408,094	409,403	410,717
991	412,036	413,360	414,690	416,024	417,365	418,710	420,061	421,419	422,781	424,150
992	425,524	426,904	428,293	429,688	431,091	432,502	433,920	435,348	436,784	438,229
993	439,682	441,143	442,614	444,092	445,579	447,071	448,569	450,075	451,586	453,104
994	454,628	456,160	457,700	459,245	460,798	462,356	463,920	465,491	467,068	468,652
995	470,242	471,838	473,442	475,050	476,665	478,285	479,911	481,543	483,180	484,824
996	486,471	488,124	489,783	491,446	493,116	494,789	496,467	498,151	499,838	501,531
997	503,227	504,928	506,635	508,346	510,062	511,782	513,507	515,238	516,972	518,712
998	520,455	522,203	523,956	525,713	527,475	529,240	531,010	532,786	534,565	536,350
999	538,139	539,932	541,732	543,536	545,347	547,162	548,984	550,813	552,648	554,491
1,000	556,340									

Appendix J

Possum Kingdom Lake

RESERVOIR AREA TABLE

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

June - December 2016 Survey
Normal operating level 999.0 feet NGVD29
Top of gates elevation 1,000.0 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
892	0	0	0	0	0	0	0	0	0	0
893	0	0	0	0	0	0	0	0	0	0
894	0	0	0	0	0	0	0	0	0	0
895	0	0	0	1	1	1	1	1	1	1
896	1	1	1	2	2	2	2	2	2	2
897	3	3	3	4	6	8	10	12	14	16
898	17	19	22	25	28	31	35	39	41	44
899	47	49	53	56	59	62	65	68	71	73
900	76	78	81	84	88	91	95	100	108	114
901	118	122	126	129	132	136	139	144	149	154
902	158	162	166	170	173	177	182	191	198	203
903	209	214	219	223	227	232	236	242	250	260
904	266	271	276	280	285	290	296	302	307	313
905	320	327	333	341	349	356	362	367	372	377
906	381	385	389	393	397	403	409	416	425	436
907	445	454	464	471	478	485	491	496	502	508
908	514	522	530	537	543	549	555	561	568	574
909	580	586	591	596	601	607	613	619	626	632
910	638	643	648	653	658	663	668	675	681	687
911	693	699	704	710	717	723	730	737	743	751
912	758	765	772	779	785	792	798	804	811	817
913	823	829	834	840	846	852	857	862	867	873
914	879	885	890	896	901	906	911	919	925	932
915	938	944	952	959	966	973	980	986	992	998
916	1,004	1,009	1,013	1,018	1,022	1,027	1,031	1,037	1,043	1,050
917	1,056	1,062	1,067	1,073	1,078	1,083	1,089	1,094	1,099	1,104
918	1,108	1,113	1,118	1,122	1,127	1,132	1,136	1,142	1,147	1,153
919	1,159	1,165	1,173	1,179	1,186	1,191	1,197	1,204	1,209	1,215
920	1,220	1,225	1,230	1,235	1,240	1,246	1,252	1,257	1,263	1,267
921	1,272	1,276	1,281	1,285	1,292	1,298	1,304	1,309	1,315	1,321
922	1,326	1,331	1,337	1,342	1,347	1,353	1,359	1,364	1,369	1,374
923	1,380	1,385	1,390	1,394	1,399	1,403	1,409	1,416	1,424	1,431
924	1,438	1,444	1,451	1,458	1,464	1,470	1,476	1,482	1,488	1,494
925	1,502	1,509	1,515	1,522	1,529	1,536	1,542	1,549	1,557	1,563
926	1,570	1,577	1,583	1,590	1,596	1,602	1,608	1,616	1,622	1,629
927	1,636	1,643	1,652	1,663	1,674	1,686	1,699	1,715	1,732	1,753
928	1,769	1,783	1,796	1,809	1,822	1,833	1,844	1,854	1,865	1,877
929	1,893	1,907	1,921	1,932	1,944	1,956	1,969	1,982	1,993	2,005
930	2,021	2,034	2,045	2,055	2,066	2,077	2,088	2,100	2,110	2,120
931	2,129	2,138	2,148	2,157	2,165	2,174	2,183	2,191	2,202	2,210
932	2,218	2,226	2,235	2,244	2,253	2,262	2,272	2,282	2,292	2,301
933	2,311	2,322	2,332	2,341	2,351	2,360	2,369	2,380	2,390	2,401
934	2,411	2,422	2,432	2,442	2,452	2,462	2,471	2,481	2,491	2,501
935	2,511	2,521	2,530	2,539	2,549	2,558	2,567	2,576	2,586	2,595
936	2,604	2,613	2,622	2,630	2,640	2,649	2,658	2,668	2,677	2,686
937	2,695	2,704	2,713	2,722	2,731	2,741	2,754	2,765	2,778	2,790
938	2,802	2,814	2,826	2,840	2,851	2,861	2,871	2,883	2,895	2,907
939	2,920	2,932	2,944	2,957	2,969	2,980	2,992	3,003	3,015	3,027
940	3,040	3,053	3,066	3,078	3,090	3,102	3,114	3,126	3,138	3,150
941	3,163	3,176	3,191	3,204	3,217	3,231	3,244	3,257	3,270	3,282
942	3,295	3,307	3,319	3,332	3,344	3,357	3,369	3,381	3,392	3,403
943	3,415	3,426	3,438	3,451	3,464	3,479	3,493	3,506	3,520	3,533
944	3,546	3,558	3,570	3,582	3,595	3,607	3,619	3,632	3,644	3,657
945	3,669	3,681	3,694	3,707	3,720	3,732	3,744	3,756	3,768	3,780
946	3,792	3,804	3,816	3,829	3,840	3,853	3,866	3,878	3,891	3,903
947	3,915	3,928	3,941	3,953	3,968	3,981	3,994	4,006	4,018	4,031
948	4,043	4,056	4,068	4,080	4,093	4,108	4,121	4,135	4,148	4,160

Appendix J (Continued)

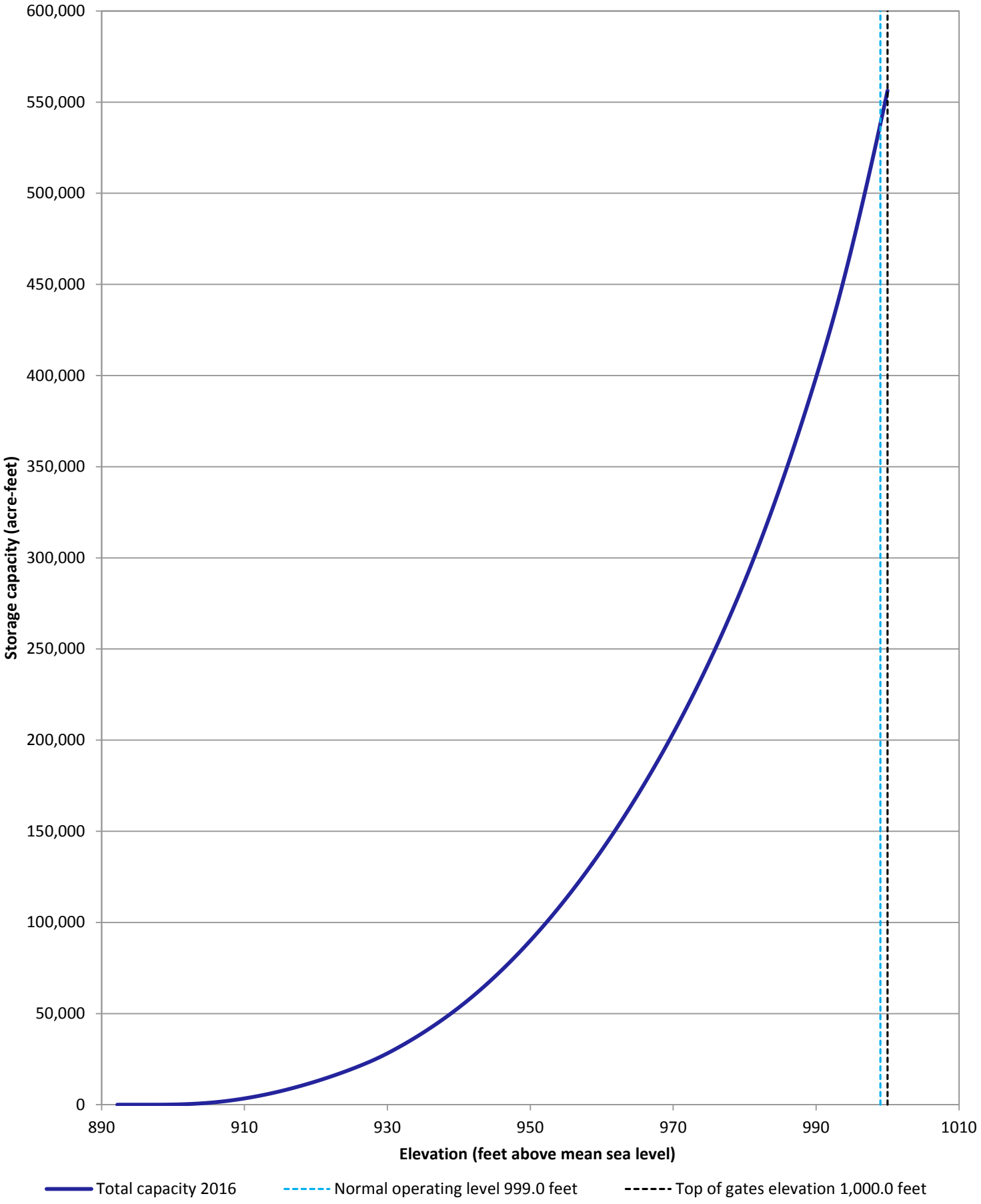
Possum Kingdom Lake

RESERVOIR AREA TABLE

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

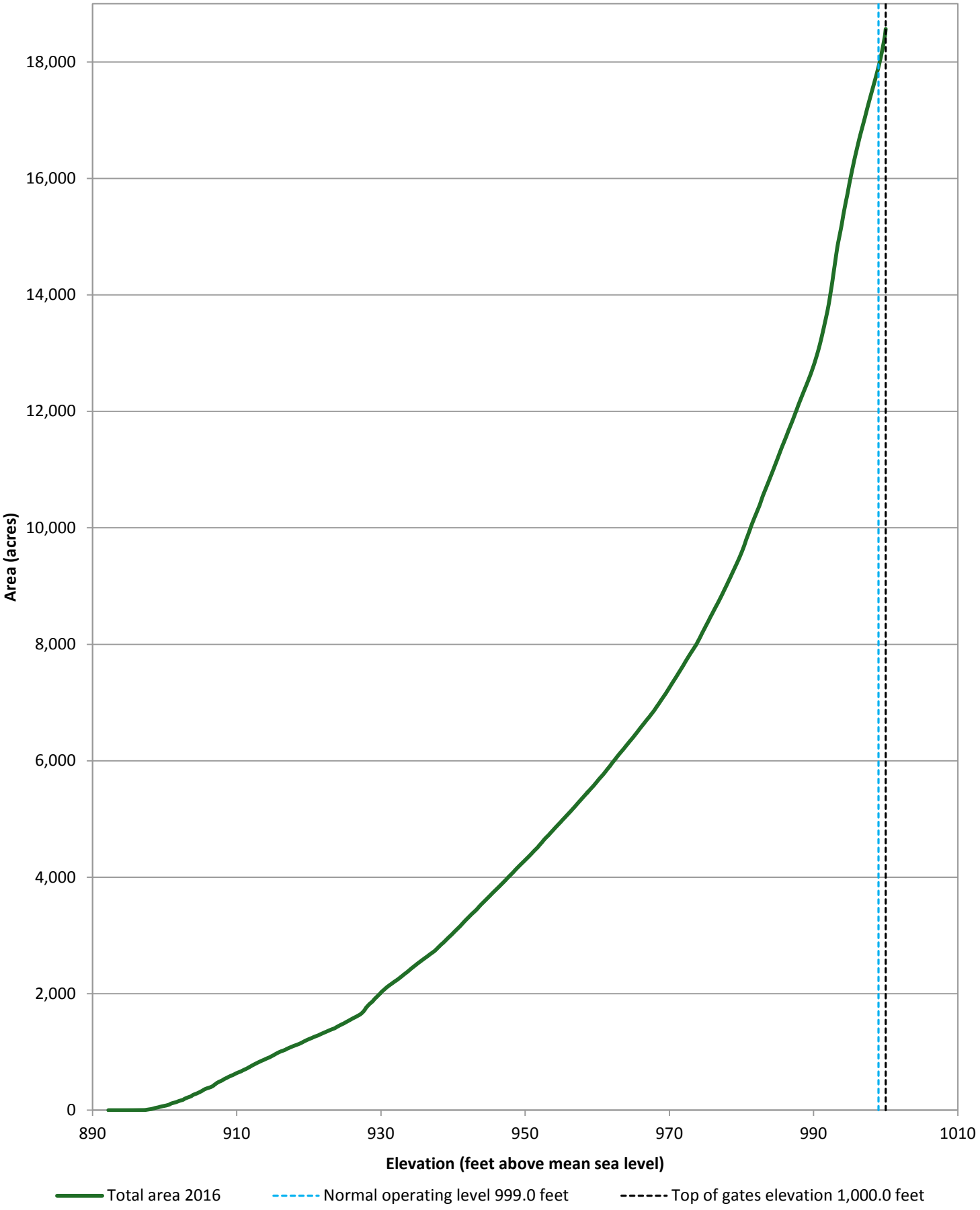
June - December 2016 Survey
Normal operating level 999.0 feet NGVD29
Top of gates elevation 1,000.0 feet NGVD29

ELEVATION in Feet	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
949	4,173	4,185	4,198	4,210	4,222	4,235	4,247	4,259	4,271	4,282
950	4,295	4,308	4,320	4,332	4,344	4,357	4,369	4,382	4,395	4,408
951	4,421	4,435	4,448	4,461	4,473	4,485	4,497	4,510	4,523	4,540
952	4,554	4,567	4,582	4,596	4,611	4,626	4,642	4,656	4,669	4,682
953	4,694	4,706	4,718	4,731	4,745	4,760	4,773	4,786	4,800	4,813
954	4,827	4,841	4,854	4,867	4,880	4,894	4,907	4,920	4,932	4,945
955	4,959	4,974	4,987	5,000	5,013	5,026	5,040	5,053	5,066	5,079
956	5,093	5,106	5,119	5,132	5,146	5,160	5,174	5,187	5,201	5,215
957	5,229	5,243	5,258	5,272	5,286	5,300	5,313	5,327	5,341	5,355
958	5,369	5,383	5,397	5,411	5,424	5,438	5,451	5,465	5,479	5,492
959	5,506	5,520	5,533	5,547	5,560	5,574	5,588	5,603	5,618	5,633
960	5,648	5,664	5,679	5,693	5,707	5,721	5,735	5,748	5,763	5,777
961	5,793	5,808	5,824	5,840	5,856	5,871	5,886	5,901	5,917	5,935
962	5,952	5,968	5,983	5,998	6,014	6,029	6,046	6,062	6,077	6,093
963	6,109	6,123	6,138	6,153	6,167	6,182	6,196	6,211	6,226	6,243
964	6,258	6,273	6,288	6,304	6,319	6,334	6,349	6,363	6,378	6,392
965	6,408	6,424	6,439	6,455	6,471	6,487	6,502	6,519	6,535	6,552
966	6,568	6,583	6,599	6,614	6,630	6,645	6,661	6,677	6,693	6,708
967	6,723	6,737	6,752	6,768	6,785	6,802	6,817	6,833	6,849	6,866
968	6,884	6,903	6,921	6,939	6,957	6,974	6,993	7,011	7,030	7,049
969	7,067	7,085	7,103	7,120	7,139	7,157	7,176	7,196	7,216	7,235
970	7,256	7,275	7,295	7,315	7,335	7,355	7,374	7,394	7,413	7,432
971	7,452	7,472	7,492	7,512	7,532	7,552	7,572	7,592	7,612	7,632
972	7,653	7,675	7,696	7,717	7,738	7,758	7,778	7,798	7,818	7,837
973	7,857	7,876	7,895	7,914	7,933	7,952	7,971	7,990	8,012	8,037
974	8,060	8,083	8,107	8,131	8,156	8,183	8,207	8,230	8,254	8,278
975	8,302	8,326	8,349	8,373	8,397	8,421	8,447	8,471	8,494	8,517
976	8,541	8,565	8,589	8,613	8,636	8,659	8,682	8,705	8,729	8,753
977	8,778	8,802	8,827	8,852	8,878	8,903	8,929	8,955	8,980	9,005
978	9,030	9,058	9,084	9,110	9,136	9,163	9,190	9,217	9,243	9,269
979	9,296	9,323	9,349	9,375	9,402	9,430	9,457	9,485	9,514	9,544
980	9,574	9,604	9,636	9,669	9,703	9,739	9,778	9,814	9,846	9,878
981	9,912	9,945	9,980	10,014	10,050	10,082	10,112	10,144	10,175	10,204
982	10,233	10,264	10,294	10,324	10,354	10,385	10,419	10,456	10,492	10,529
983	10,562	10,593	10,624	10,654	10,685	10,715	10,746	10,776	10,807	10,839
984	10,870	10,902	10,933	10,964	10,996	11,028	11,061	11,093	11,124	11,156
985	11,189	11,222	11,255	11,288	11,320	11,353	11,385	11,416	11,445	11,475
986	11,506	11,536	11,568	11,600	11,633	11,665	11,696	11,726	11,757	11,787
987	11,818	11,849	11,881	11,914	11,947	11,980	12,012	12,045	12,079	12,113
988	12,145	12,176	12,207	12,238	12,269	12,300	12,331	12,361	12,391	12,422
989	12,452	12,482	12,514	12,545	12,577	12,609	12,642	12,677	12,713	12,749
990	12,784	12,821	12,861	12,902	12,942	12,983	13,027	13,071	13,117	13,166
991	13,217	13,267	13,321	13,375	13,429	13,485	13,542	13,597	13,655	13,712
992	13,775	13,842	13,915	13,994	14,071	14,146	14,228	14,317	14,404	14,488
993	14,574	14,661	14,746	14,825	14,895	14,957	15,018	15,080	15,144	15,210
994	15,282	15,356	15,426	15,489	15,554	15,618	15,675	15,737	15,803	15,871
995	15,935	15,997	16,056	16,117	16,175	16,232	16,291	16,347	16,401	16,453
996	16,506	16,559	16,610	16,662	16,712	16,760	16,807	16,853	16,899	16,945
997	16,991	17,038	17,086	17,136	17,184	17,231	17,277	17,323	17,369	17,414
998	17,459	17,503	17,548	17,592	17,637	17,682	17,727	17,773	17,819	17,866
999	17,914	17,965	18,018	18,073	18,130	18,191	18,254	18,320	18,387	18,458
1,000	18,568									



Possum Kingdom Lake
June - December 2016 Survey
Prepared by: TWDB

Appendix K: Capacity curve



Possum Kingdom Lake
June - December 2016 Survey
Prepared by: TWDB

Appendix L: Area curve

Figure 6

Possum Kingdom Lake

10' - contour map

Possum Kingdom Lake normal operating pool elevation 999.0 feet

Possum Kingdom Lake top of gates elevation 1,000.0 feet

Islands

Contours

(feet above mean sea level)

1,000

990

980

970

960

950

940

930

920

910

900

Jack County

Palo Pinto County

Stephens County

Young 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 Possum Kingdom Lake. The Texas Water Development Board makes no representations nor assumes any liability.

1,950,000

1,975,000

2,000,000

7,000,000

N

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

Texas Water Development Board

June - December 2016 Survey

0 0.5 1 2 Miles