Volumetric Survey
of
MARTIN LAKE

August 2014 Survey

Texas Water Development Board

April 2015

Prepared for:

Luminant Generation Company LLC

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Executive summary

In July 2014, the Texas Water Development Board entered into agreement with Luminant Generation Company LLC, to perform a volumetric survey of Martin Lake. Surveying was performed using a multi-frequency (208 kHz, 50 kHz, and 24 kHz), sub-bottom profiling depth sounder, although only the 208 kHz frequency was analyzed for this report.

Martin Lake Dam and Martin Lake are located on Martin Creek in Rusk and Panola Counties, approximately 3.0 miles southwest of Tatum, Texas. The conservation pool elevation of Martin Lake is 306.0 feet above mean sea level (NGVD29). TWDB collected bathymetric data for Martin Lake between July 30, 2014, and September 3, 2014. The daily average water surface elevation during the survey ranged between 304.98 and 305.95 feet above mean sea level.

The 2014 TWDB volumetric survey indicates that Martin Lake has a total reservoir capacity of 75,726 acre-feet and encompasses 4,954 acres at conservation pool elevation (306.0 feet above mean sea level, NGVD29). Previous capacity estimates include the original design capacity of 77,619 acre-feet, a 1984 capacity estimate by Jones and Boyd, Inc. of 69,822 acre-feet, and the volume obtained from a TWDB survey in 1999. The TWDB volumetric survey conducted in 1999 was re-evaluated using current processing procedures that resulted in an updated capacity estimate of 76,624 acre-feet.

TWDB recommends that a similar methodology be used to resurvey Martin Lake in 10 years or after a major flood event. To further improve estimates of capacity loss, TWDB recommends a volumetric and sedimentation survey. Sedimentation surveys include additional analysis of the multi-frequency data for post-impoundment sediment by correlation with sediment core samples and a map identifying the spatial distribution of sediment throughout the reservoir.

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

Introduction

The Hydrographic Survey Program of the Texas Water Development Board (TWDB) was authorized by the 72nd Texas State Legislature in 1991. Section 15.804 of the Texas Water Code authorizes TWDB to perform surveys to determine reservoir storage capacity, sedimentation levels, rates of sedimentation, and projected water supply availability.

In July 2014, the Texas Water Development Board entered into agreement with Luminant Generation Company LLC, to perform a volumetric survey of Martin Lake (TWDB, 2014). This report describes the methods used to conduct the volumetric survey, including data collection and processing techniques. This report serves as the final contract deliverable from TWDB to Luminant Generation Company LLC, and contains as deliverables: (1) a shaded relief plot of the reservoir bottom [Figure 4], (2) a bottom contour map [Figure 6], and (3) an elevation-area-capacity table of the reservoir acceptable to the Texas Commission on Environmental Quality [Appendix A, B].

Martin Lake general information

Martin Lake Dam and Martin Lake are located on Martin Creek in Rusk and Panola Counties in the Sabine River Basin, approximately three miles southwest of Tatum, Texas (Figure 1). Construction of Martin Lake Dam began on May 31, 1972, and deliberate impoundment of water began on September 30, 1974 (TWDB, 1974, TWDB, 2003). Martin Lake is owned and operated by Luminant Generation Company LLC, Texas' largest generator of electricity (Luminant, 2015a).

Martin Lake is a power plant reservoir, providing water primarily for cooling. The Martin Lake Power Plant is a lignite coal steam electric plant capable of generating 2,250 megawatts of power (Luminant, 2015b). Additional pertinent data about Martin Lake Dam and Martin Lake can be found in Table 1.

Water rights for Martin Lake have been appropriated to Luminant Generation Company LLC, formerly the Texas Utilities Electric Company, through Certificate of Adjudication No. 05-4649 and Amendments to Certificate of Adjudication Nos. 05-4649A, 05-4649B, and 05-4649C. The complete certificates are on file in the Information Resources Division of the Texas Commission on Environmental Quality.

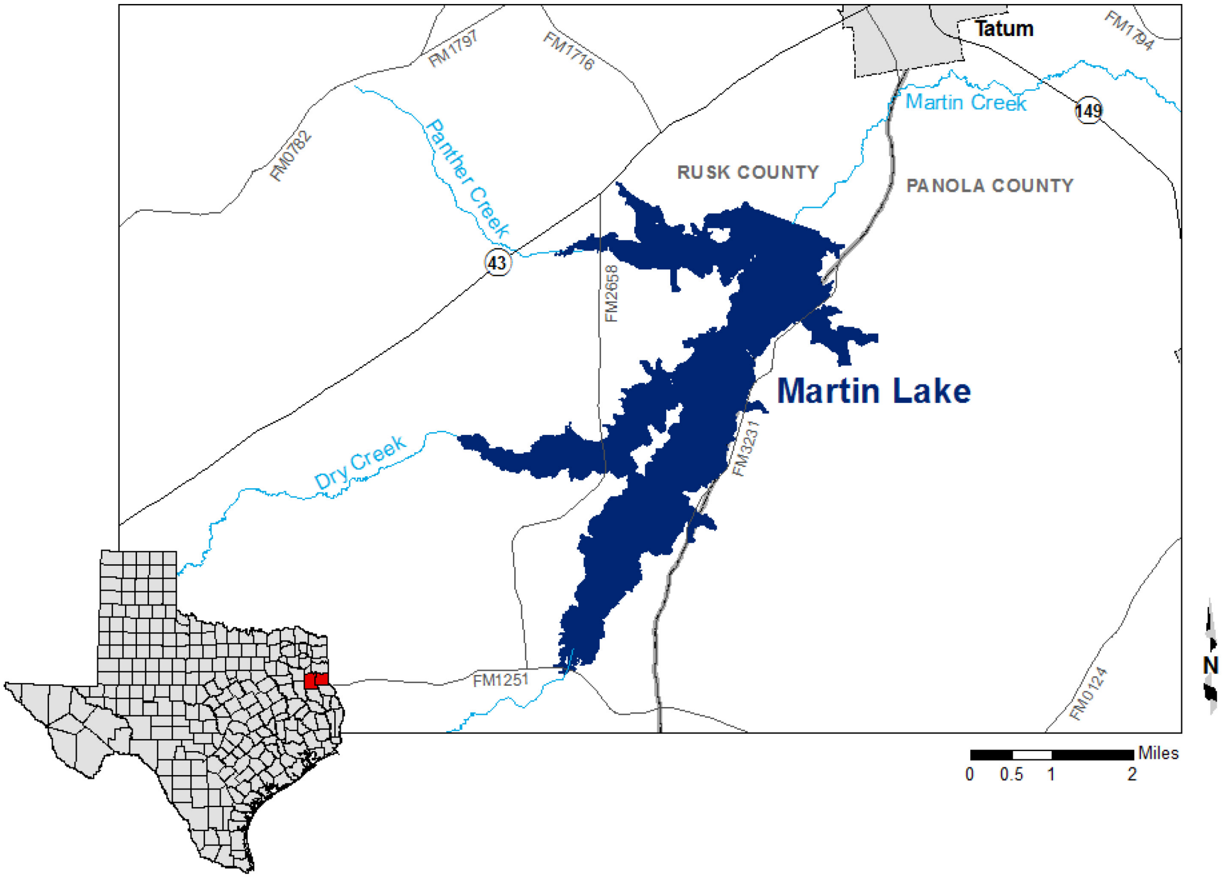


Figure 1. Location of Martin Lake

Table 1.	**Pertinent data for Martin Lake Dam and Martin Lake**		
Owner			
Luminant Generation Company LLC			
Engineer			
Forrest and Cotton, Inc.			
Location of dam			
On Martin Creek in Rusk and Panola Counties, 17 miles northeast of Henderson and 3 miles southwest of Tatum, Texas			
Drainage area			
130 square miles			
Dam			
Type	Earthfill		
Length	6,875 feet		
Height	61± feet		
Top width	20 feet		
Top elevation	321.5 feet above mean sea level		
Spillway (emergency)			
Location	Left of the dam		
Type	Uncontrolled		
Crest elevation	312.0 feet above mean sea level		
Crest length	1,000 feet		
Spillway (service)			
Location	Near left end of the dam		
Type	Concrete ogee and chute		
Control	4 tainter gates, each 40 by 14 feet		
Crest elevation	294.0 feet above mean sea level		
Crest length (net)	160 feet		
Outlet works			
One low-flow outlet is a 3 by 5 foot conduit with sluice gate control located in one of the gate piers with invert at elevation 284.0 feet above mean sea level. Additional low-flow outlet is an 8-inch pipe with invert at elevation 286.0 feet above mean sea level with a downstream sluice gate control. Water is pumped from the lake to the power plant and returned to the lake.			
Reservoir data (Based on 2014 TWDB survey)			
Feature	**Elevation (feet** NGVD29[a]**)**	**Capacity (acre-feet)**	**Area (acres)**
Top of dam	321.5	N/A	N/A
Emergency spillway crest	312.0	N/A	N/A
Conservation pool elevation	306.0	75,726	4,954
Service spillway crest	294.0	28,990	2,887
Low flow outlet	286.0	11,418	1,549
Low flow outlet	284.0	8,606	1,274
Usable conservation storage space[b]	-	67,120	-

Source: (TWDB, 1974)
[a] NGVD29 = National Geodetic Vertical Datum 1929
[b] Usable conservation storage space equals total capacity at conservation pool elevation minus dead pool capacity. Dead pool refers to water that cannot be drained by gravity through a dam's outlet works.

Volumetric survey of Martin Lake

Datum

The vertical datum used during this survey is the National Geodetic Vertical Datum 1929 (NGVD29). This datum is also utilized by the United States Geological Survey (USGS) for the reservoir elevation gage *USGS 08022060 Martin Lk nr Tatum, TX* (USGS, 2015). Elevations herein are reported in feet relative to the NGVD29 datum. Volume and area calculations in this report are referenced to water levels provided by the USGS gage. The horizontal datum used for this report is North American Datum 1983 (NAD83), and the horizontal coordinate system is State Plane Texas North Central Zone (feet).

TWDB bathymetric data collection

TWDB collected bathymetric data for Martin Lake between July 30, 2014, and September 3, 2014. The daily average water surface elevations during the survey ranged between 304.98 and 305.95 feet above mean sea level (NGVD29). For data collection, TWDB used a Specialty Devices, Inc. (SDI), single-beam, multi-frequency (208 kHz, 50 kHz, and 24 kHz) sub-bottom profiling depth sounder integrated with differential global positioning system (DGPS) equipment. Data was collected along pre-planned survey lines oriented perpendicular to the assumed location of the original river channels and spaced approximately 500 feet apart. Many of the same survey lines were also used by TWDB during the 1999 survey. The depth sounder was calibrated daily using a velocity profiler to measure the speed of sound in the water column and a weighted tape or stadia rod for depth reading verification. Figure 2 shows where data collection occurred during the 2014 TWDB survey.

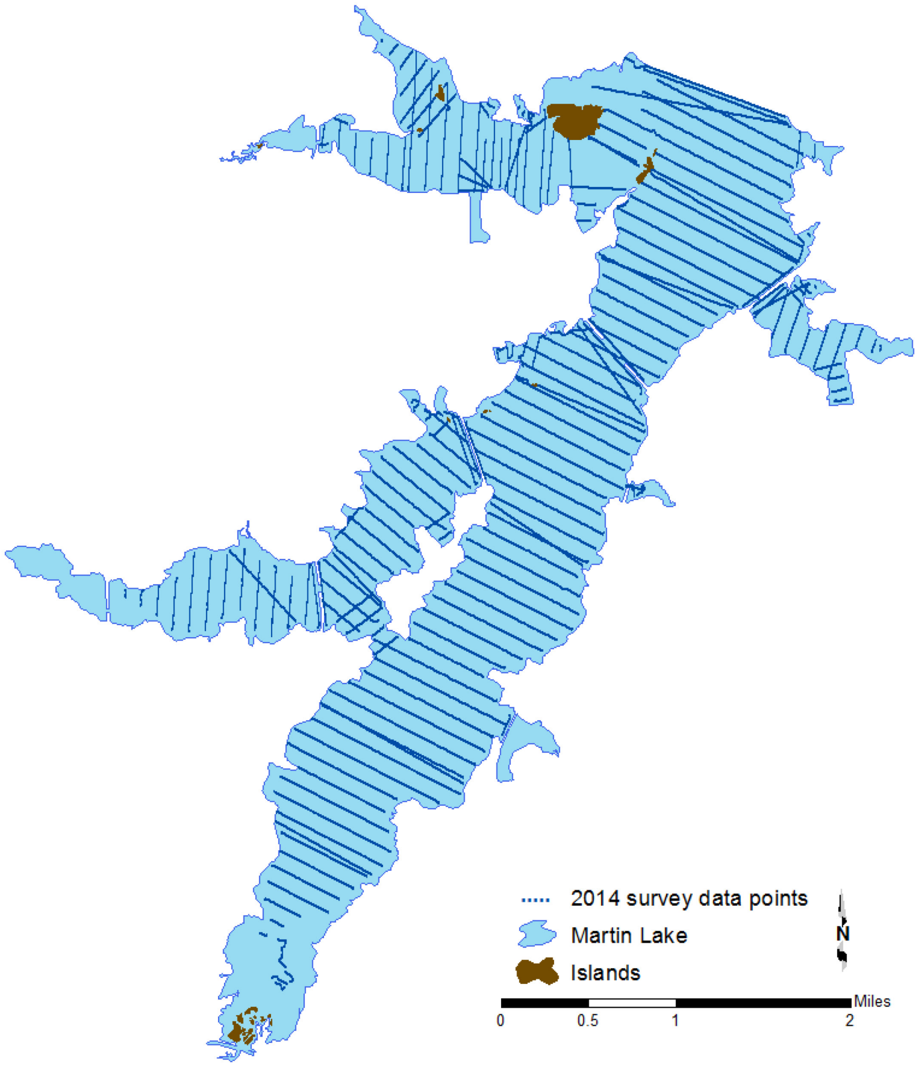


Figure 2. Data collected during 2014 TWDB Martin Lake survey

Data processing

Model boundaries

The reservoir boundary was digitized using Environmental Systems Research Institute's ArcGIS software (ArcGIS) from aerial photographs, also known as digital orthophoto quarter-quadrangle images (DOQQs), obtained from the Texas Natural Resources Information System (TNRIS, 2014). The quarter-quadrangles that cover Martin Lake are Tatum (SW, SE) and Fair Play (NW, NE). The DOQQs were photographed on September 1, 2004, while the daily average water surface elevation measured 304.49 feet (NGVD29). According to metadata associated with the 2004 DOQQs, the photographs have a resolution or ground sample distance of 1.0-meters and a horizontal accuracy within ± 5 meters of reference DOQQs from the National Digital Ortho Program (TNRIS, 2014, USDA, 2013). For this analysis, the boundary was digitized at the land-water interface in the 2004 photographs and assigned an elevation of 304.5 feet. The section titled "Area, volume, and contour calculation" describes how areas and capacities were generated up to the conservation pool elevation.

Triangulated Irregular Network model

Following completion of data collection, the raw data files were edited to remove data anomalies. DepthPic©, software developed by SDI, Inc., was used to display, interpret, and edit the multi-frequency data by manually removing data anomalies in the current bottom surface. For processing outside of DepthPic©, an in-house software package, HydroTools, was used to identify the current reservoir-bottom surface, and to output the data into a single file. The water surface elevation at the time of each sounding was used to convert each sounding depth to a corresponding reservoir-bottom elevation. This survey point dataset was then preconditioned by inserting a uniform grid of artificial survey points between the actual survey lines. Bathymetric elevations at these artificial points are determined using an anisotropic spatial interpolation algorithm described in the next section. This technique creates a high resolution, uniform grid of interpolated bathymetric elevation points throughout a majority of the reservoir (McEwen et al., 2011a). Finally, the point file resulting from spatial interpolation was used in conjunction with sounding and boundary data to create volumetric Triangulated Irregular Network (TIN) models utilizing the 3D Analyst Extension of ArcGIS. The 3D Analyst algorithm uses Delaunay's criteria for triangulation to create a grid composed of triangles from non-uniformly spaced points, including the boundary vertices (ESRI, 1995).

Spatial interpolation of reservoir bathymetry

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

To improve the accuracy of bathymetric representation between survey lines, TWDB developed various anisotropic spatial interpolation techniques. Generally, the directionality of interpolation at different locations of a reservoir can be determined from external data sources. A basic assumption is that the reservoir profile in the vicinity of a particular location has upstream and downstream similarity. In addition, the sinuosity and directionality of submerged stream channels can be determined by directly examining survey data or more robustly by examining scanned USGS 7.5 minute quadrangle maps (known as digital raster graphics or DRGs) and hypsography files (the vector format of USGS 7.5 minute quadrangle map contours), when available. Using the survey data, polygons are created to partition the reservoir into segments with centerlines defining directionality of interpolation within each segment. For surveys with similar spatial coverage, these interpolation definition files are in principle independent of the survey data and could be applied to past and future survey data of the same reservoir. In practice, however, minor revisions of the interpolation definition files may be needed to account for differences in spatial coverage and boundary conditions between surveys. Using the interpolation definition files and survey data, the current reservoir-bottom elevation, when applicable, is 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 the volumetric TIN model representing the reservoir bathymetry. Specific details of this interpolation technique can be found in the HydroTools manual (McEwen et al., 2011a) and in McEwen et al., 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 estimations. The linear interpolation follows a linear definition file linking the survey points file to the lake boundary file (McEwen et al., 2011a). Without interpolated data, the TIN model builds flat triangles. A flat triangle is defined as a triangle where all three vertices are equal in elevation, generally the elevation of the reservoir boundary. Reducing flat triangles by applying linear interpolation improves the elevation-capacity and elevation-area calculations. It is not always possible to remove all flat triangles, and linear interpolation is only applied where adding bathymetry is deemed reasonable. For example, linear interpolation was applied throughout Martin Lake following channel features indicated by the 1999 survey data or visible on aerial photographs taken on July 28 and July 29, 2012, while the water surface elevation measured 301.41 and 301.40 feet, respectively.

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

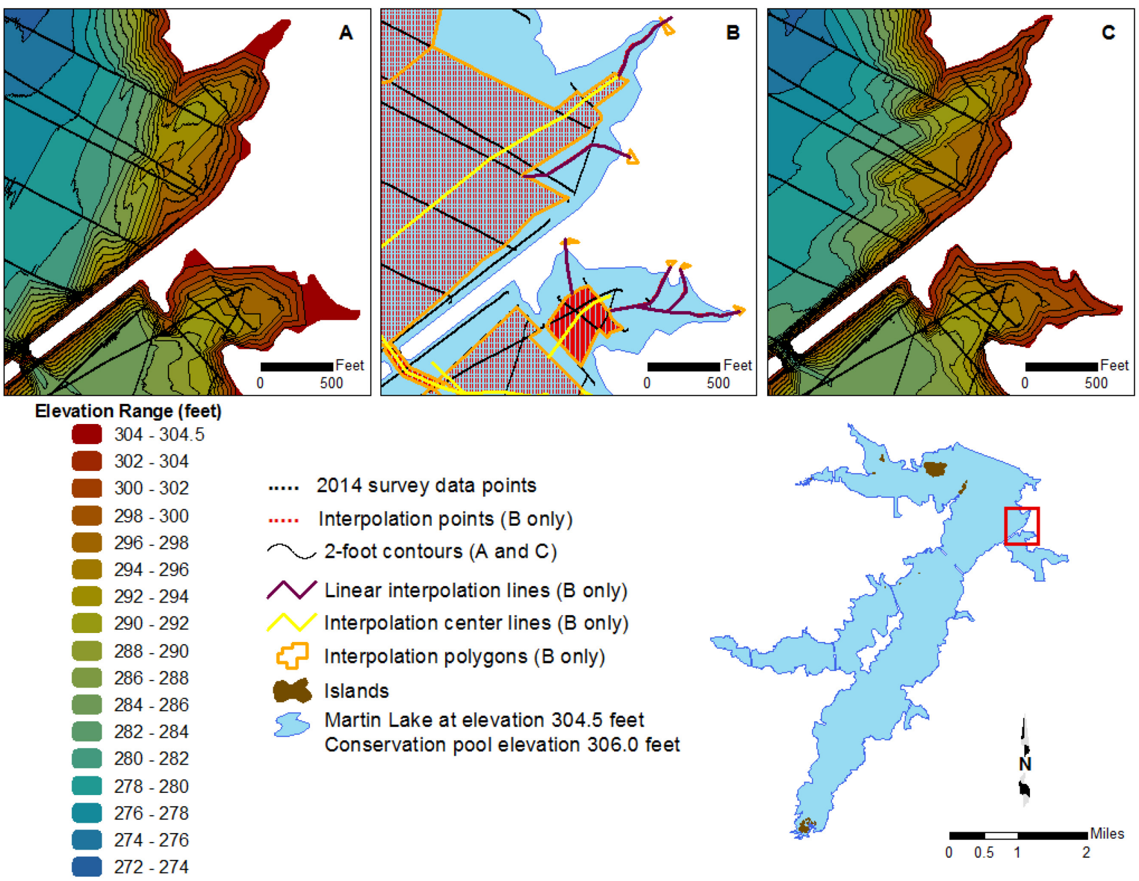


Figure 3. Anisotropic spatial interpolation and linear interpolation of Martin Lake sounding data - A) bathymetric contours without interpolated points, B) sounding points (black) and interpolated points (red), C) bathymetric contours with the interpolated points

Area, volume, and contour calculation

Using ArcInfo software and the volumetric TIN model, volumes and areas were calculated for the entire reservoir at 0.1 feet intervals, from 264.6 to 304.5 feet. While linear interpolation was used to estimate the topography in areas that were inaccessible by boat or too shallow for the instruments to work properly, development of anomalous “flat triangles”, that is triangles whose three vertices all have the same elevation, in the TIN model are unavoidable. The flat triangles in turn lead to anomalous calculations of surface area and volume at the boundary elevation 304.5feet. To eliminate the effects of the flat triangles on area and volume calculations, areas between elevations 300.0 feet and 304.5feet were linearly interpolated between the computed values, and volumes above elevation 300.0 feet were calculated based on the corrected areas. Areas above elevation 304.5 feet were linearly extrapolated and capacities were calculated from the extrapolated areas. The elevation-capacity table and elevation-area table, updated for 2014, are presented in Appendices A and B, respectively. The capacity curve is presented in Appendix C, and the area curve is presented in Appendix D.

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

Figure 4
Martin Lake
Elevation relief map

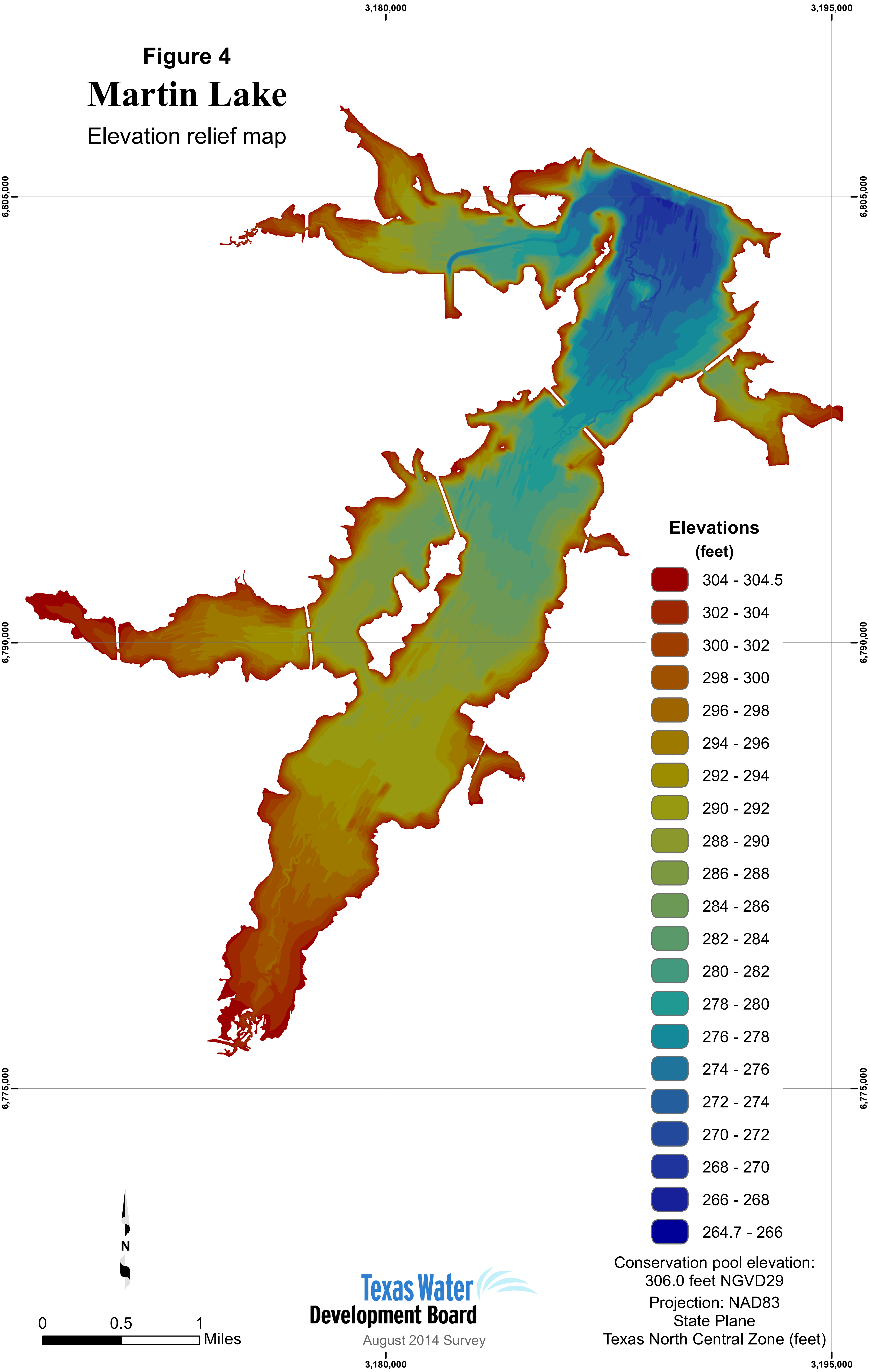
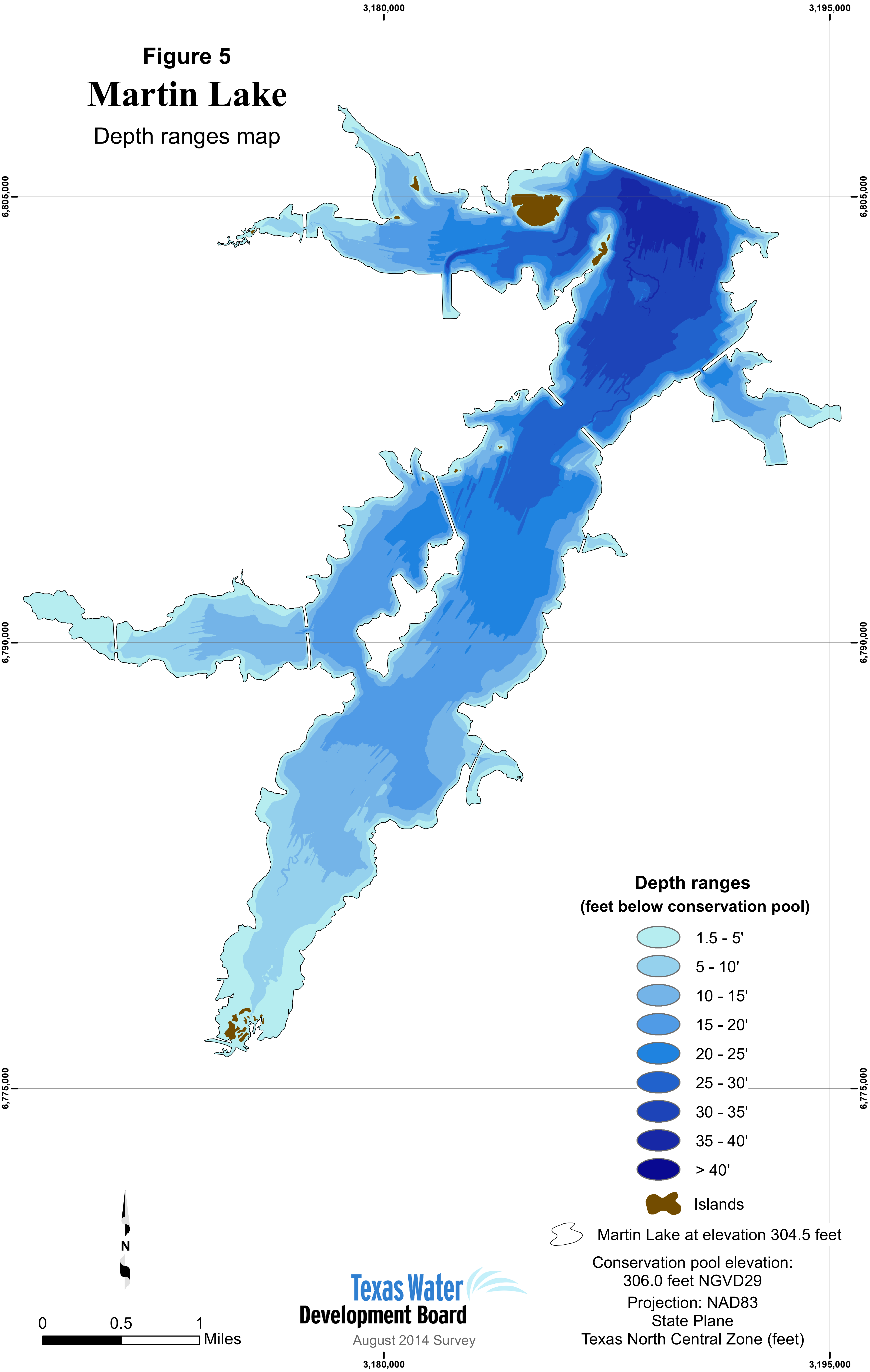


Figure 5

Martin Lake

Depth ranges map



Survey results

Volumetric survey

The results of the 2014 TWDB volumetric survey indicate Martin Lake has a total reservoir capacity of 75,726 acre-feet and encompasses 4,954 acres at conservation pool elevation (306.0 feet above mean sea level, NGVD29). Previous capacity estimates include the original design capacity of 77,619 acre-feet, a 1984 capacity estimate by Jones and Boyd, Inc. of 69,822 acre-feet, and the recalculated volume obtained from a TWDB survey in 1999 of 76,624 acre-feet. Because of differences in past and present survey methodologies, direct comparison of volumetric surveys to estimate loss of capacity is difficult and can be unreliable.

To properly compare results of TWDB surveys, TWDB applied the 2015 data processing techniques to the data collected in 1999. Specifically, TWDB applied anisotropic spatial interpolation to the survey data collected in 1999 using the same interpolation definition file as was used for the 2014 survey with minor edits to account for differences in data coverage and boundary conditions. The 1999 survey boundary at conservation pool elevation was digitized from the digital USGS 7.5 minute quadrangle maps, or DRGs. The USGS quadrangle maps have a stated accuracy of ± ½ the contour interval (USBB, 1947). To eliminate the effects of the flat triangles on area and volume calculations, areas between elevations 302.0 feet and 306.0 feet were linearly interpolated between the computed values, and volumes above elevation 302.0 feet were calculated based on the corrected areas. Re-evaluation of the 1999 survey resulted in a 2.0 percent increase in the total capacity estimate (Table 2). Comparison of capacity estimates of Martin Lake derived using differing methodologies are provided in Table 3 for capacity loss rate calculation.

Table 2. Current and previous survey capacity and surface area data

Survey	Surface area (acres)	Total capacity (acre-feet)
1974[a]	5,020	77,619
Jones and Boyd, Inc. 1984[b]	5,010	69,822
TWDB 1999[c]	4,981	75,116
TWDB 1999 (re-calculated)	4,960	76,624
TWDB 2014	4,954	75,726

[a] Source: (TWDB, 1974)
[b] Source: (TXU, 1985)
[c] Source: (TWDB, 2003)

Table 3. Capacity loss comparisons for Martin Lake

Survey	Volume comparisons at conservation pool elevation (acre-feet)	
1974[a]	77,619	<>
TWDB 1999 (re-calculated)	<>	76,624
2014 volumetric survey	75,726	75,726
Volume difference (acre-feet)	1,893 (2.4%)	898 (1.2%)
Number of years	40	15
Capacity loss rate (acre-feet/year)	47	60

[a] Source: (TWDB, 2003). Note: Impoundment of Martin Lake began September 30, 1974.

Recommendations

To improve estimates of sediment accumulation rates, TWDB recommends resurveying Martin Lake in approximately 10 years or after a major flood event. To further improve estimates of capacity loss, TWDB recommends a volumetric and sedimentation survey. Sedimentation surveys include additional analysis of the multi-frequency data for post-impoundment sediment by correlation with sediment core samples and a map identifying the spatial distribution of sediment throughout the reservoir.

TWDB contact information

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

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

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Appendix A

Martin Lake

RESERVOIR CAPACITY TABLE

TEXAS WATER DEVELOPMENT BOARD — August 2014 Survey

CAPACITY IN ACRE-FEET — Conservation Pool Elevation 306.0 feet NGVD29

ELEVATION INCREMENT IS ONE TENTH FOOT

ELEVATION in Feet	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
264	0	0	0	0	0	0	0	0	0	0
265	0	0	0	0	0	0	0	0	0	0
266	0	0	0	0	0	0	0	0	0	0
267	0	0	0	1	1	1	1	1	2	2
268	2	3	3	3	4	5	5	6	7	8
269	9	10	11	13	15	17	19	22	26	30
270	34	39	44	50	57	64	72	80	89	99
271	109	121	133	146	160	174	189	205	222	240
272	258	278	298	319	341	364	387	412	437	462
273	488	515	542	570	599	629	659	690	722	755
274	789	823	858	894	930	966	1,004	1,042	1,081	1,121
275	1,162	1,204	1,247	1,291	1,336	1,382	1,429	1,478	1,527	1,578
276	1,629	1,682	1,736	1,790	1,846	1,902	1,959	2,018	2,077	2,136
277	2,197	2,258	2,320	2,383	2,447	2,511	2,576	2,642	2,708	2,776
278	2,844	2,912	2,981	3,051	3,121	3,191	3,263	3,335	3,408	3,482
279	3,556	3,632	3,708	3,785	3,863	3,941	4,021	4,102	4,183	4,266
280	4,351	4,436	4,523	4,611	4,700	4,790	4,881	4,973	5,066	5,161
281	5,257	5,353	5,451	5,550	5,650	5,751	5,853	5,956	6,060	6,166
282	6,272	6,379	6,487	6,596	6,707	6,818	6,930	7,043	7,157	7,272
283	7,389	7,506	7,624	7,743	7,863	7,984	8,106	8,230	8,354	8,480
284	8,606	8,734	8,864	8,994	9,126	9,259	9,393	9,529	9,666	9,804
285	9,944	10,085	10,227	10,370	10,516	10,662	10,811	10,960	11,111	11,264
286	11,418	11,574	11,731	11,889	12,049	12,209	12,371	12,535	12,700	12,866
287	13,034	13,203	13,373	13,545	13,718	13,893	14,069	14,247	14,425	14,606
288	14,788	14,971	15,155	15,340	15,527	15,715	15,905	16,097	16,289	16,484
289	16,681	16,879	17,078	17,280	17,482	17,687	17,893	18,100	18,310	18,521
290	18,734	18,950	19,167	19,388	19,613	19,841	20,071	20,304	20,540	20,777
291	21,017	21,259	21,502	21,748	21,995	22,244	22,495	22,748	23,002	23,258
292	23,515	23,774	24,035	24,297	24,560	24,826	25,092	25,361	25,631	25,903
293	26,176	26,451	26,727	27,004	27,284	27,565	27,847	28,130	28,415	28,702
294	28,990	29,279	29,570	29,862	30,156	30,452	30,749	31,047	31,348	31,649
295	31,952	32,257	32,564	32,872	33,182	33,494	33,808	34,124	34,442	34,761
296	35,082	35,406	35,730	36,057	36,385	36,716	37,048	37,382	37,717	38,054
297	38,393	38,733	39,074	39,417	39,762	40,108	40,456	40,806	41,157	41,509
298	41,864	42,219	42,577	42,936	43,297	43,659	44,023	44,388	44,755	45,124
299	45,494	45,865	46,238	46,613	46,989	47,367	47,746	48,127	48,509	48,893
300	49,278	49,665	50,054	50,445	50,837	51,232	51,628	52,026	52,426	52,827
301	53,231	53,636	54,043	54,452	54,863	55,275	55,690	56,106	56,524	56,944
302	57,366	57,789	58,214	58,642	59,071	59,501	59,934	60,368	60,805	61,243
303	61,683	62,124	62,568	63,013	63,460	63,909	64,360	64,813	65,267	65,724
304	66,182	66,642	67,103	67,567	68,032	68,499	68,968	69,439	69,912	70,386
305	70,863	71,341	71,821	72,303	72,786	73,272	73,759	74,248	74,739	75,232
306	75,726									

Note: Capacities above elevation 300.0 calculated from interpolated and extrapolated areas

Appendix B

Martin Lake

RESERVOIR AREA TABLE

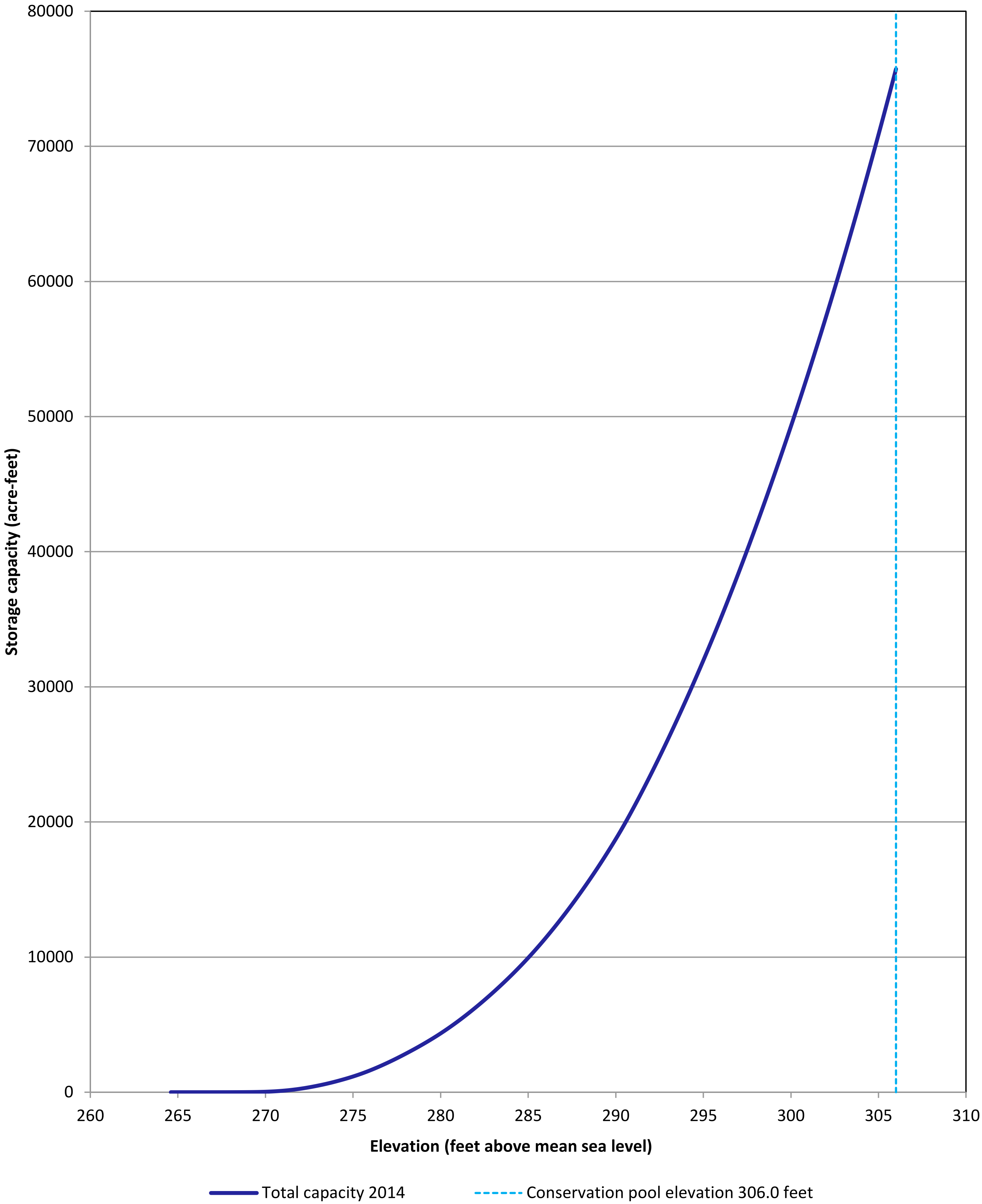
TEXAS WATER DEVELOPMENT BOARD — August 2014 Survey

AREA IN ACRES — Conservation Pool Elevation 306.0 feet NGVD29

ELEVATION INCREMENT IS ONE TENTH FOOT

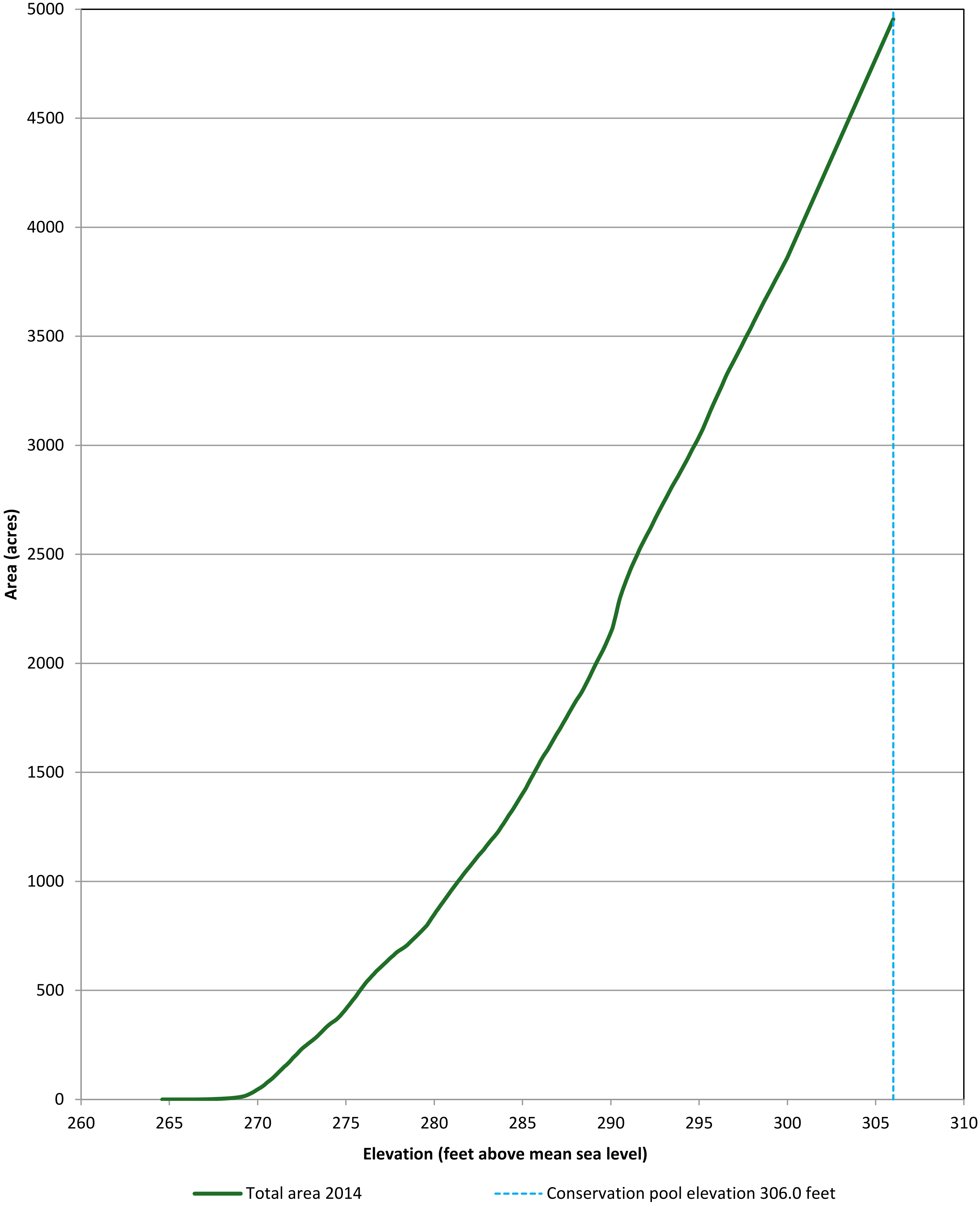
ELEVATION in Feet	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
264	0	0	0	0	0	0	0	0	0	0
265	0	0	0	0	0	0	0	0	0	0
266	0	0	0	0	0	0	0	0	0	1
267	1	1	1	1	2	2	2	3	3	3
268	4	4	5	5	6	6	7	8	9	10
269	11	13	14	17	20	23	27	31	36	41
270	46	51	56	62	68	75	82	88	94	101
271	110	117	126	133	141	150	156	164	172	181
272	191	199	206	215	224	232	239	245	252	258
273	265	271	277	284	292	300	308	316	324	332
274	339	346	352	357	363	370	378	386	396	405
275	415	425	435	446	457	466	477	489	500	511
276	522	532	542	551	560	569	577	586	594	602
277	609	617	624	632	640	647	655	661	669	676
278	682	687	692	698	703	710	719	726	734	742
279	750	758	766	774	783	791	800	812	825	837
280	848	861	872	883	895	906	917	928	939	951
281	962	973	984	994	1,005	1,015	1,027	1,037	1,047	1,057
282	1,067	1,077	1,087	1,097	1,108	1,118	1,127	1,136	1,145	1,156
283	1,167	1,177	1,187	1,197	1,206	1,216	1,226	1,238	1,250	1,262
284	1,274	1,287	1,300	1,312	1,323	1,336	1,349	1,363	1,376	1,389
285	1,402	1,415	1,428	1,444	1,460	1,475	1,489	1,504	1,519	1,534
286	1,549	1,563	1,577	1,589	1,600	1,614	1,628	1,643	1,657	1,671
287	1,684	1,697	1,711	1,725	1,739	1,753	1,768	1,782	1,796	1,810
288	1,824	1,837	1,848	1,861	1,875	1,890	1,906	1,922	1,938	1,955
289	1,972	1,989	2,005	2,021	2,036	2,051	2,068	2,085	2,104	2,122
290	2,142	2,163	2,194	2,226	2,262	2,294	2,319	2,343	2,365	2,386
291	2,406	2,427	2,446	2,464	2,482	2,499	2,518	2,535	2,550	2,566
292	2,582	2,597	2,612	2,628	2,645	2,662	2,678	2,693	2,709	2,724
293	2,739	2,754	2,769	2,785	2,800	2,815	2,829	2,843	2,857	2,872
294	2,887	2,901	2,916	2,931	2,947	2,963	2,979	2,994	3,008	3,023
295	3,040	3,056	3,073	3,092	3,111	3,130	3,150	3,169	3,187	3,205
296	3,222	3,240	3,257	3,275	3,294	3,313	3,330	3,346	3,362	3,377
297	3,392	3,408	3,423	3,439	3,455	3,471	3,488	3,503	3,518	3,534
298	3,550	3,567	3,583	3,599	3,614	3,630	3,647	3,662	3,677	3,693
299	3,708	3,723	3,738	3,754	3,769	3,784	3,799	3,814	3,830	3,846
300	3,862	3,880	3,898	3,916	3,935	3,953	3,971	3,989	4,007	4,026
301	4,044	4,062	4,080	4,098	4,117	4,135	4,153	4,171	4,189	4,208
302	4,226	4,244	4,262	4,281	4,299	4,317	4,335	4,353	4,372	4,390
303	4,408	4,426	4,444	4,463	4,481	4,499	4,517	4,535	4,554	4,572
304	4,590	4,608	4,627	4,645	4,663	4,681	4,699	4,718	4,736	4,754
305	4,772	4,790	4,809	4,827	4,845	4,863	4,881	4,900	4,918	4,936
306	4,954									

Note: Areas between elevations 300.0 and 304.5 feet linearly interpolated, areas above elevation 304.5 feet linearly extrapolated



Martin Lake
August 2014 Survey
Prepared by: TWDB

Appendix C: Capacity curve



Martin Lake
August 2014 Survey
Prepared by: TWDB

Appendix D: Area curve

Figure 6

Contours (feet)

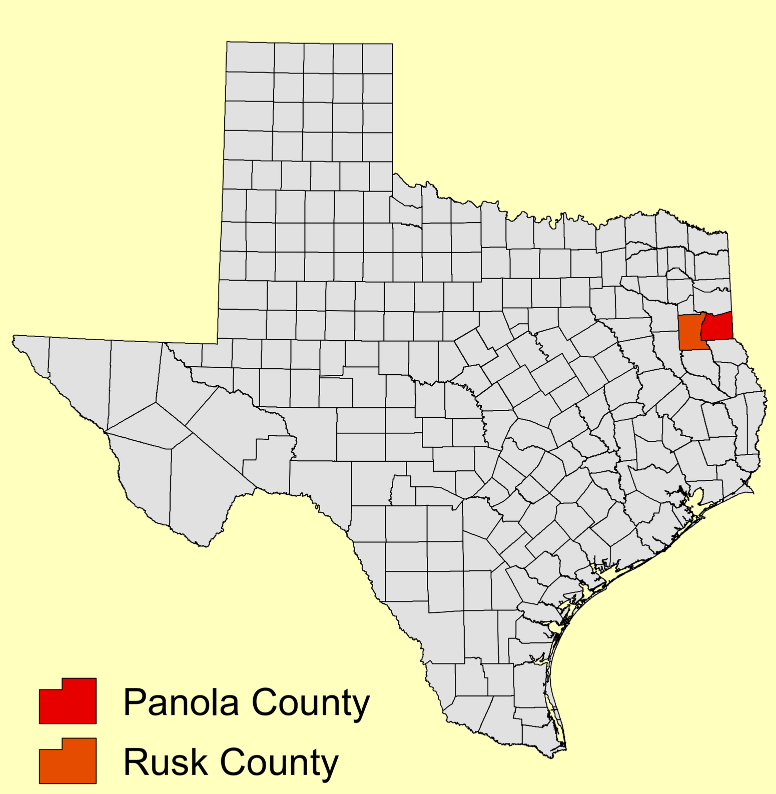
304
302
300
298
296
294
292
290
288
286
284
282
280
278
276
274
272
270
268
266

Martin Lake at elevation 304.5 feet

Islands

Conservation pool elevation 306.0 feet NGVD29

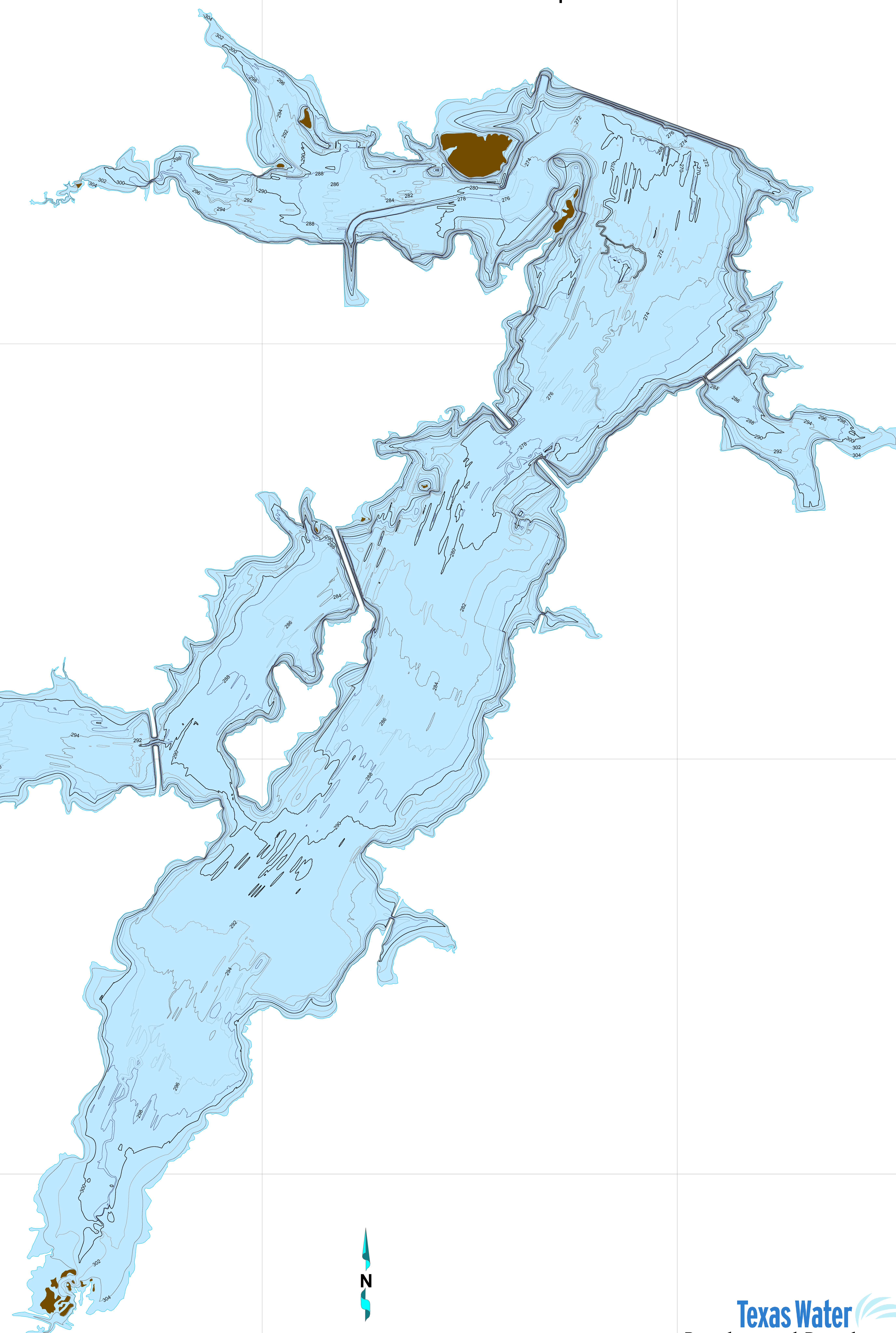
Projection: NAD83 State Plane Texas North Central Zone (feet)



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

Martin Lake

2' - contour map



0 0.5 1 2 Miles

Texas Water Development Board

August 2014 Survey