Volumetric and Sedimentation Survey of RICHLAND-CHAMBERS RESERVOIR

October 2007 Survey

Prepared by:

The Texas Water Development Board

January 2009

Texas Water Development Board

J. Kevin Ward, Executive Administrator

Prepared for:

Tarrant Regional Water District

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Executive Summary

In July of 2007, the Texas Water Development Board entered into agreement with Tarrant Regional Water District, for the purpose of performing a volumetric and sedimentation survey of Richland-Chambers Reservoir. This survey was performed using a multi-frequency (200 kHz, 50 kHz, and 24 kHz) sub-bottom profiling depth sounder. In addition, sediment core samples were collected in selected locations and were used in interpreting the multi-frequency depth sounder signal returns to derive sediment accumulation estimates.

Richland-Chambers Dam and Reservoir are located on Richland and Chambers Creeks, in the Trinity River Basin approximately 20 miles southeast of the City of Corsicana, Texas. Initial Bathymetric data collection for Richland-Chambers Reservoir occurred between October 11, 2007 and January 16, 2008 with additional data collected on September 8-9, 2008. The water surface elevations during data collection ranged between 312.65 feet and 314.49 feet above mean sea level (NGVD29). The conservation pool elevation of Richland-Chambers Reservoir is 315.0 feet above mean sea level (NGVD29).

The results of the TWDB 2007 Volumetric Survey indicate Richland-Chambers Reservoir has a capacity of 1,112,763 acre-feet and encompasses 43,384 acres at conservation pool elevation (315.0 feet above mean sea level, NGVD29). In 1994 TWDB estimated the capacity of Richland-Chambers Reservoir (at conservation pool elevation) at 1,136,600 acre-feet,[1] and in 2003 Tarrant Regional Water District revised the 1994 TWDB capacity estimate to 1,137,204 acre-feet.[2] In 1987 Freese and Nichols, Consulting Engineers estimated the original reservoir capacity at 1,181,886 acre-feet.[1] Due to differences in the methodologies used in calculating areas and capacities from this and previous Richland-Chambers Reservoir surveys, comparison of these values is not recommended. The TWDB considers the 2007 survey to be a significant improvement over previous methods and recommends that a similar methodology be used to resurvey Richland-Chambers Reservoir in 10 years or after a major flood event.

The results of the TWDB 2007 Sedimentation Survey indicate Richland-Chambers Reservoir has accumulated 43,361 acre-feet of sediment since impoundment in 1987. Based on this measured sediment volume and assuming a constant sediment accumulation rate, Richland-Chambers Reservoir loses approximately 2,065 acre-feet of capacity per year. The majority of the sediment accumulation has occurred within the main body of the reservoir within four miles from the Richland-Chambers Dam. The maximum sediment thickness observed in Richland-Chambers Reservoir was 7.0 feet.

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Richland-Chambers Reservoir General Information

Richland-Chambers Dam and Reservoir are located on Richland and Chambers Creeks in the Trinity River Basin approximately 20 miles southeast of Corsicana, Texas.[1] (Figure 1) Richland-Chambers Reservoir is the third largest lake to lie entirely within the state of Texas[3], and is owned and operated by Tarrant Regional Water District. The reservoir was built primarily for water supply. Dam construction began in October of 1982. Deliberate impoundment of water began on July 14, 1987, and the facility was completed in November of 1987. Additional pertinent data about Richland-Chambers Dam and Reservoir can be found in Table 1.[1]

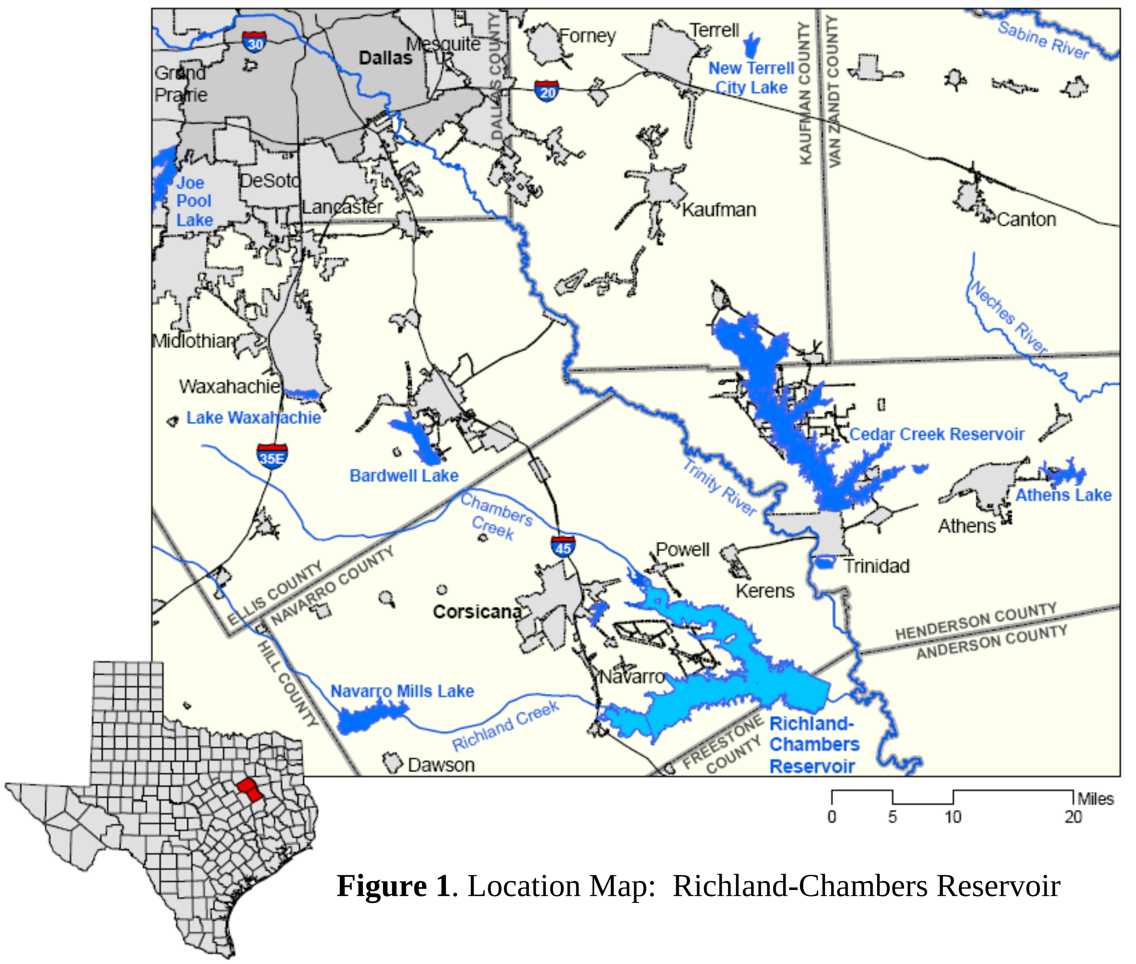


Figure 1. Location Map: Richland-Chambers Reservoir

Tarrant Regional Water District is one of the largest raw water suppliers in Texas, providing water to more than 30 customers, including the Trinity River Authority and the cities of Fort Worth, Arlington, and Mansfield. The four major water supply reservoirs owned and operated by Tarrant Regional Water District include: Richland-Chambers

Reservoir, Eagle Mountain Lake, Cedar Creek Reservoir, and Lake Bridgeport.[4] Operations of the Tarrant Regional Water District span a 10-county area and bring water to more than 1.6 million people in North Central Texas.[5,6] (Figure 2) Tarrant Regional Water District's Water Supply System features over 150 miles of pipelines to transport water from Richland-Chambers and Cedar Creek Reservoirs to southeast Tarrant County. A pipeline to carry water from Richland-Chambers and Cedar Creek Reservoirs to Eagle Mountain Lake is currently under construction and will be complete in 2008.[5,6]

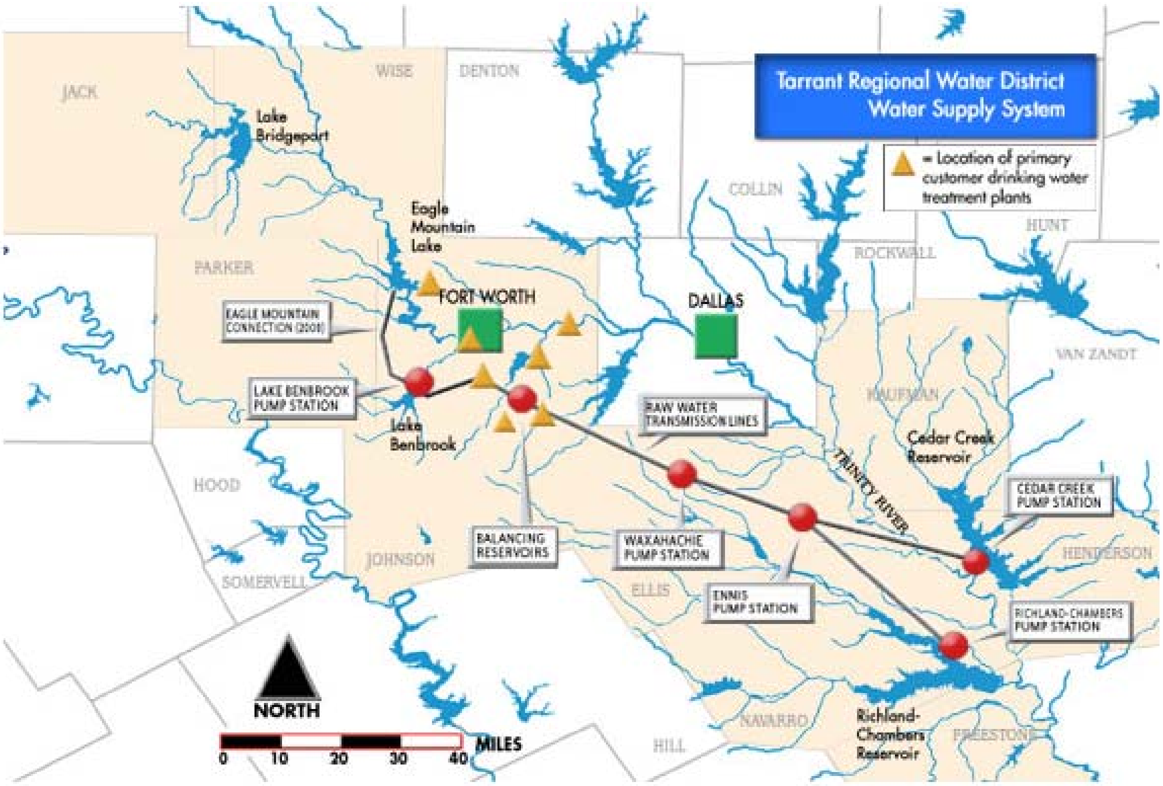


Figure 2. Tarrant Regional Water District Water Supply System and service area.

Source: Tarrant Regional Water District, Pipeline, 25 April 2008, http://www.trwd.com/prod/AboutUs_Pipeline.asp, 2007.

Tarrant Regional Water District expects to provide water to 4.3 million people by 2060. To help the district meet those demands and push back the need to construct additional water supply reservoirs, a Wetlands Water Reuse Project, the first of its kind in the United States, will become a water supply alternative. The project is located on Texas Parks and Wildlife's Richland Creek Wildlife Management Area on the Navarro-Freestone County line. The wetlands system consists of a series of sedimentation ponds and wetland cells that naturally treat water diverted from the Trinity River before it moves into Richland-Chambers Reservoir.

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

Owner	
Tarrant Regional Water District	
Engineer (Design)	
Freese and Nichols, Consulting Engineers	
Location of Dam	
On Richland and Chambers Creeks in Freestone and Navarro Counties, approximately 20 miles southeast of Corsicana, Texas.	
Drainage Area	
1,957 square miles	
Dam	
Type	Earthen embankment with a soil cement upstream face
Length	6 ½ miles
Maximum height	120 feet
Service Spillway	
Location	At station 133 of the dam, approximately 1 mile north of the original Richland Creek
Spillway type	Concrete crest
Crest length	960 feet at elevation 290.0 feet above mean sea level
Control	24-forty foot wide radial gates
Discharge capacity	446,000 cubic feet per second when reservoir is at elevation 315.0 feet above mean sea level
Outlet Works	
Type	4 low flow conduits, 2-3 by 5 feet sliding gates at invert elevation and a 1 by 1 foot and 1.5 by 1.5 feet sliding gate at elevation 285.0 feet above mean sea level
Invert elevation	266.0 feet above mean sea level

Tarrant Regional Water District is currently authorized to divert 63,000 acre-feet of water per year from the Trinity River into Richland-Chambers Reservoir.[7] The water rights for Richland-Chambers Reservoir have been appropriated to the Tarrant Regional Water District (formerly the Tarrant County Water Control and Improvement District No. 1) through Certificate of Adjudication No. 08-5035 and Amendment to Certificate of Adjudication No. 08-5035A and the City of Corsicana through Certificate of Adjudication No. 08-5030. A brief summary of the certificate and amendment follow. The complete certificates are on file in the Records Division of the Texas Commission on Environmental Quality.

Certificate of Adjudication No. 08-5035 Priority date: October 18, 1954

This certificate authorizes the Tarrant County Water Control and Improvement District No. 1 to maintain an existing dam and reservoir (Richland Creek Reservoir) and impound therein up to 1,135,000 acre-feet of water. The owner is authorized to divert and use a maximum of 210,000 acre-feet of water per annum from Richland Creek Reservoir for municipal purposes.

Amendment to Certificate of Adjudication No. 08-5035A Granted: July 28, 1993

Authorizes the Tarrant County Water Control and Improvement District No. 1 to divert and use a maximum of 210,000 acre-feet of water per annum from Richland-Chambers Reservoir (previously referred to as Richland Creek Reservoir). The owner is authorized to use the 210,000 acre-feet of water per annum as follows: 205,000 acre-feet for municipal purposes, 2,500 acre-feet for irrigation purposes, and 2,500 acre-feet for industrial purposes.

Certificate of Adjudication No. 08-5030   Issued: May 5, 1987

Pursuant to Certificate of Adjudication 08-5035, the Tarrant County Water Control and Improvement District No. 1 was authorized to construct a dam on Richland Creek creating Richland Creek Reservoir (now called Richland-Chambers Reservoir) inundating Lake Corsicana. An agreement allowed the District to breach the dam and recognize the City's senior water rights to 13,650 acre-feet of water diverted directly from the District's Reservoir each year. Certificate of Adjudication No. 08-5030 sets a priority date of February 27, 1950 for the right to divert and use the first 3,650 acre-feet of water and June 23, 1952 for the right to divert and use the remaining 10,000 acre-feet of water per year from Richland-Chambers Reservoir for municipal purposes. The City of Corsicana is also authorized to store water diverted from Richland-Chambers Reservoir in Lake Halbert for subsequent diversion and use.

Volumetric and Sedimentation Survey of Richland-Chambers Reservoir

The Texas Water Development Board's (TWDB) Hydrographic Survey Program was authorized by the state legislature in 1991. 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 of 2007, TWDB entered into agreement with the Tarrant Regional Water District, for the purpose of performing a volumetric and sedimentation survey of Richland-

Chambers Reservoir. This survey was performed using a single-beam multi-frequency (200 kHz, 50 kHz, and 24 kHz) sub-bottom profiling depth sounder. The 200 kHz return indicated the current bathymetric surface, while the combination of the three frequencies was analyzed for evidence of sediment accumulation throughout the reservoir. Sediment core samples were collected in order to validate the interpretation of the multi-frequency acoustic signals and to verify the identification of the reservoir bathymetric surface at the time of initial impoundment.

Datum

The vertical datum used during this survey is that used by the United States Geological Survey (USGS) for the reservoir elevation gage USGS 08064550 Richland-Chambers Res nr Kerens, TX.[8] The datum for this gage is reported as National Geodetic Vertical Datum 1929 (NGVD29) or mean sea level, thus elevations reported here are in feet above mean sea level. 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 NAD83 State Plane Texas North Central Zone.

TWDB Bathymetric Data Collection

Initial Bathymetric data collection for Richland-Chambers Reservoir occurred between October 11, 2007 and January 16, 2008 with additional data collected on September 8-9, 2008. The water surface elevations during data collection ranged between 312.65 feet and 314.49 feet above mean sea level (NGVD29). For data collection, TWDB used a Specialty Devices, Inc., multi-frequency (200 kHz, 50 kHz, and 24 kHz) sub-bottom profiling depth sounder integrated with Differential Global Positioning System (DGPS) equipment. Data collection occurred while navigating along pre-planned range lines oriented perpendicular to the assumed location of the original river channels and spaced approximately 500 feet apart. Similar range-lines were used during the 1994 Richland-Chambers Reservoir survey conducted by TWDB.[1] 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. During the 2007 survey, team members collected over 465,000 data points over cross-sections totaling nearly 704 miles in length. Figure 3 shows where data points were collected during the TWDB 2007 survey.

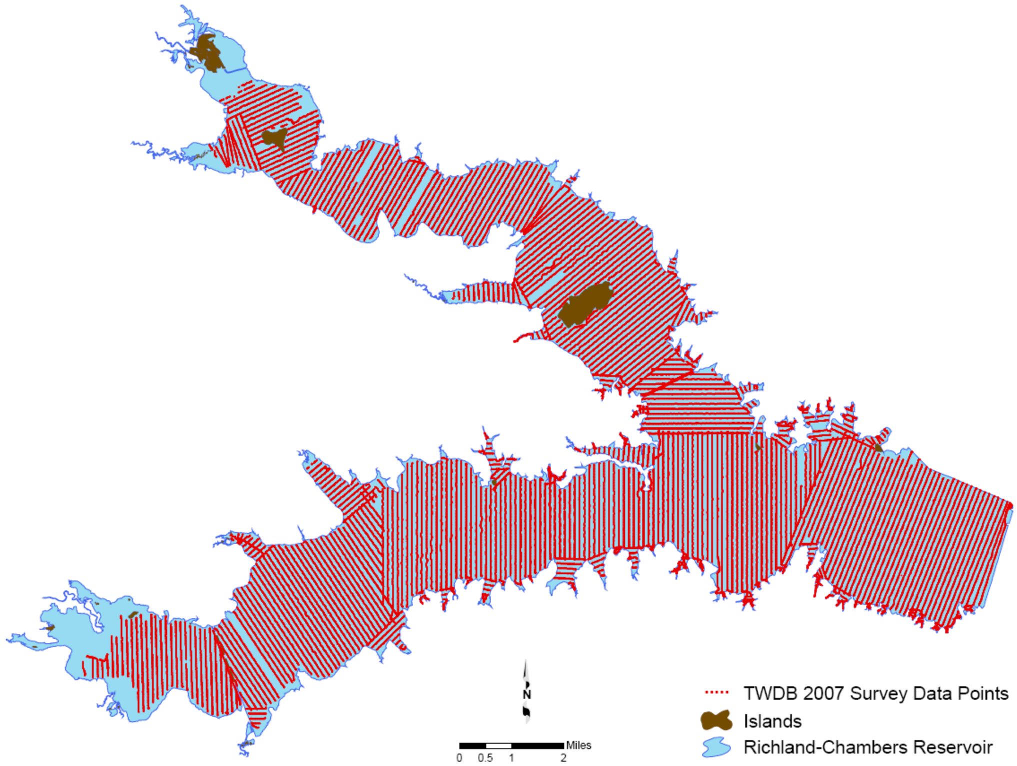


Figure 3. Data points collected during TWDB 2007 Survey

Data Processing

Model Boundaries

The reservoir boundary was digitized from aerial photographs, or digital orthophoto quarter-quadrangle images (DOQQs)[9,10], using Environmental Systems Research Institute's (ESRI) ArcGIS 9.1 software. The quarter-quadrangles that cover Richland-Chambers Reservoir are Richland NE, Richland SE, Streetman NW, Streetman NE, Streetman SW, Streetman SE, Winkler NW, Winkler NE, Roustabout Camp NW, Powell NW, Powell NE, Powell SW, Powell SE, Goodlow Park NW, Goodlow Park SW, and Goodlow Parke SE. These images were photographed between August 8, 2004 and September 9, 2004, during which time the water surface elevation at Richland-Chambers Reservoir ranged between 314.76 feet and 315.21 feet above mean sea level (NGVD29). TWDB determined that there was not a significant difference in lake area over the range of water surface elevations measured at the times of the aerial imagery given that the photographs have a 1-meter resolution. Therefore, the boundary was digitized from the land water interface in the photos and labeled 315.00 feet above mean sea level (NGVD29) to allow area and volume to be calculated to the top of conservation pool elevation.

More recent aerial photographs of Richland-Chambers Reservoir were taken on August 9-10, 2006, while the water surface elevation measured 307.27 feet and 307.24 feet. From these, a 307.3 foot contour was digitized to supplement the TWDB survey data in locations where the survey data alone was insufficient to properly represent the reservoir bathymetry. The 307.3 contour was verified for accuracy against the sounding data collected during the 2007 survey.

Triangulated Irregular Network (TIN) Model

Upon completion of data collection, the raw data files collected by TWDB were edited using DepthPic to remove any data anomalies. DepthPic is used to display, interpret, and edit the multi-frequency data. The water surface elevations at the times of each sounding were used to convert sounding depths to corresponding bathymetric elevations. For processing outside of DepthPic, the sounding coordinates (X,Y,Z) were exported as a MASS points file. TWDB also created additional MASS points files of interpolated and extrapolated data based on the sounding data. Using the “Self-Similar Interpolation” technique (described below), TWDB interpolated bathymetric elevation data located in-between surveyed cross sections. To better represent reservoir bathymetry in shallow regions, TWDB used the “Line Extrapolation” technique.[11] The point files resulting from both the data interpolation and extrapolation were exported as MASS points files, and were used in conjunction with the sounding and boundary files in creating a Triangulated Irregular Network (TIN) model with the 3D Analyst Extension of ArcGIS. The 3D Analyst algorithms use Delaunay’s criteria for triangulation to place a triangle between three non-uniformly spaced points, including the boundary vertices.[12]

Using Arc/Info software, volumes and areas were calculated from the TIN model for the entire reservoir at one-tenth of a foot intervals, from elevation 237.0 feet to elevation 315.0 feet. The Elevation-Capacity Table and Elevation-Area Table, updated for 2007, are presented in Appendix A and B, respectively. The Area-Capacity Curves are presented in Appendix C.

The TIN model was interpolated and averaged using a cell size of 2 feet by 2 feet and converted to a raster. The raster was used to produce Figure 4, an Elevation Relief Map representing the topography of the reservoir bottom, Figure 5, a map showing shaded depth ranges for Richland-Chambers Reservoir, and Figure 6, a 5-foot contour map (attached).

Self-Similar Interpolation

A limitation of the Delaunay method for triangulation when creating TIN models results in artificially-curved contour lines extending into the reservoir where the reservoir walls are steep and the reservoir is relatively narrow. These curved contours are likely a poor representation of the true reservoir bathymetry in these areas. Also, if the surveyed cross sections are not perpendicular to the centerline of the submerged river channel (the location of which is often unknown until after the survey), then the TIN model is not likely to well-represent the true channel bathymetry.

To ameliorate these problems, a Self-Similar Interpolation routine (developed by TWDB) was used to interpolate the bathymetry in between many survey lines. The Self-Similar Interpolation technique effectively increases the density of points input into the TIN model, and directs the TIN interpolation to better represent the reservoir topography.[11] In the case of Richland-Chambers Reservoir, the application of Self-Similar Interpolation helped represent the lake morphology near the banks and improved the representation of the submerged river channel (Figure 7). In areas where obvious geomorphic features indicate a high-probability of cross-section shape changes (e.g. incoming tributaries, significant widening/narrowing of channel, etc.), the assumptions used in applying the Self-Similar Interpolation technique are not likely to be valid; therefore, Self-Similar Interpolation was not used in areas of Richland-Chambers Reservoir where a high probability of change between cross-sections exists.[11] Figure 7 illustrates typical results of the application of the Self-Similar Interpolation routine in Richland-Chambers Reservoir, and the bathymetry shown in Figure 7C was used in computing reservoir capacity and area tables (Appendix A, B).

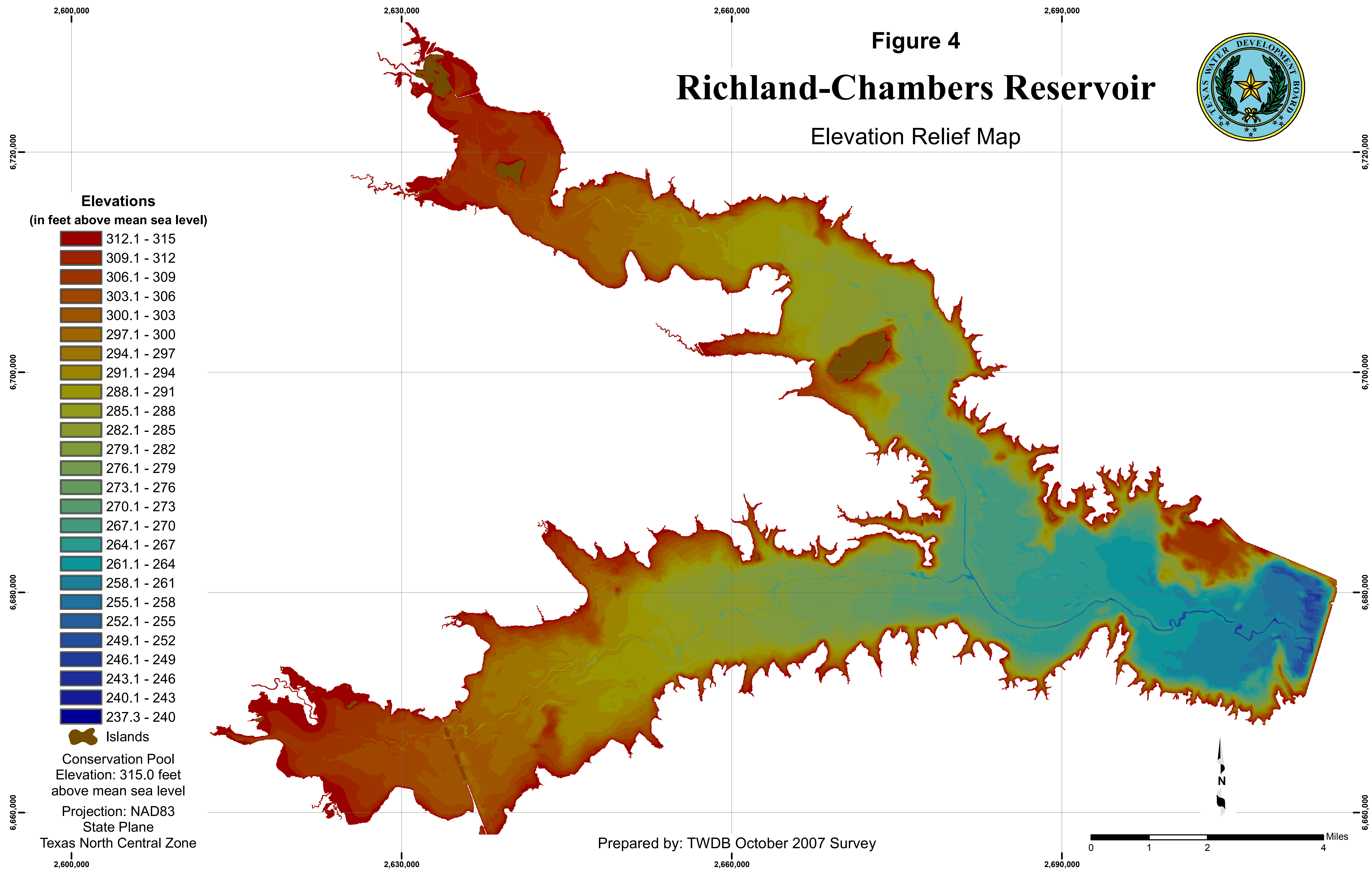


Figure 4
Richland-Chambers Reservoir
Elevation Relief Map
Elevations
(in feet above mean sea level)
312.1 - 315
309.1 - 312
306.1 - 309
303.1 - 306
300.1 - 303
297.1 - 300
294.1 - 297
291.1 - 294
288.1 - 291
285.1 - 288
282.1 - 285
279.1 - 282
276.1 - 279
273.1 - 276
270.1 - 273
267.1 - 270
264.1 - 267
261.1 - 264
258.1 - 261
255.1 - 258
252.1 - 255
249.1 - 252
246.1 - 249
243.1 - 246
240.1 - 243
237.3 - 240
Islands
Conservation Pool
Elevation: 315.0 feet
above mean sea level
Projection: NAD83
State Plane
Texas North Central Zone
Prepared by: TWDB October 2007 Survey
N
0
1
2
4
Miles
2,600,000
2,630,000
2,660,000
2,690,000
6,720,000
6,700,000
6,680,000
6,660,000
TEXAS WATER DEVELOPMENT BOARD

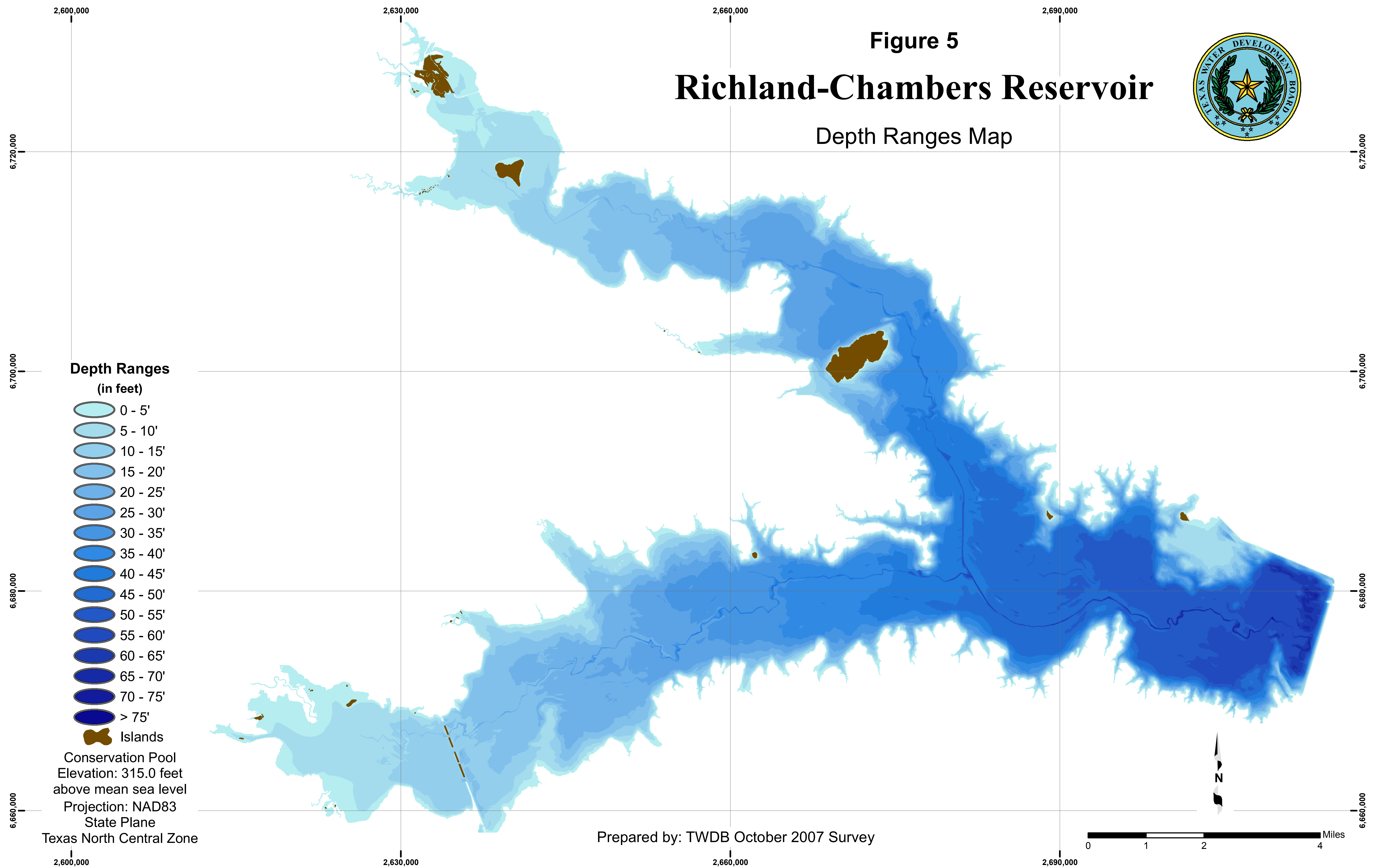


Figure 5
Richland-Chambers Reservoir
Depth Ranges Map
TEXAS WATER DEVELOPMENT BOARD
Depth Ranges
(in feet)
0 - 5'
5 - 10'
10 - 15'
15 - 20'
20 - 25'
25 - 30'
30 - 35'
35 - 40'
40 - 45'
45 - 50'
50 - 55'
55 - 60'
60 - 65'
65 - 70'
70 - 75'
> 75'
Islands
Conservation Pool
Elevation: 315.0 feet
above mean sea level
Projection: NAD83
State Plane
Texas North Central Zone
Prepared by: TWDB October 2007 Survey
N
Miles
0
1
2
4
2,600,000
2,630,000
2,660,000
2,690,000
6,720,000
6,700,000
6,680,000
6,660,000

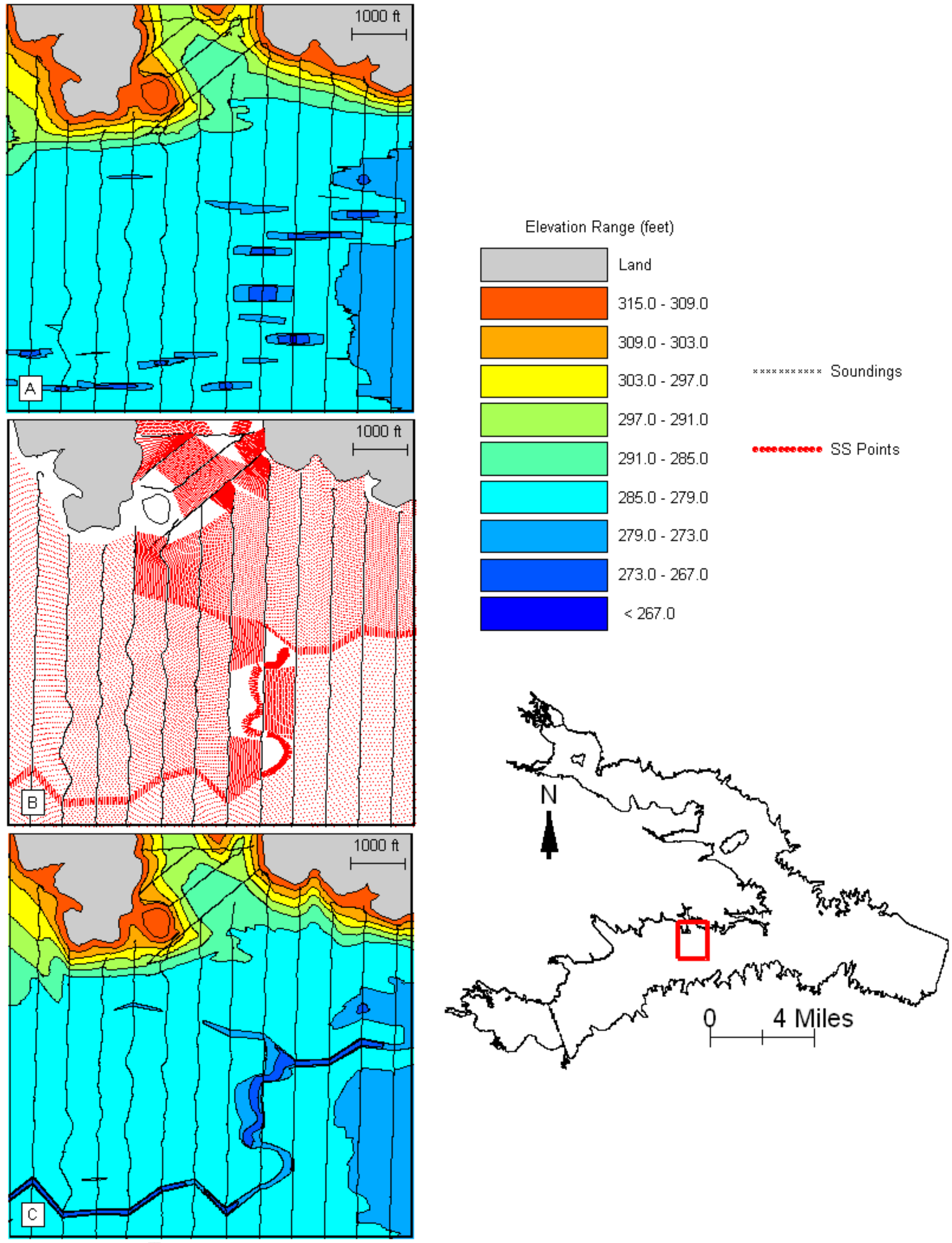


Figure 7. Application of the Self-Similar Interpolation technique to Richland-Chambers sounding data – A) bathymetric contours without interpolated points, B) Sounding points (black) and interpolated points (red) with reservoir boundary shown at elevation 315.0 feet (black), C) bathymetric contours with the interpolated points. Note: In 7A the deeper channels indicated by the surveyed cross sections are not continuously represented in the areas in-between the cross sections. This is an artifact of the TIN generation routine, rather than an accurate representation of the physical bathymetric surface. Inclusion of the interpolated points (7C) corrects this and smoothes the bathymetric contours.

Survey Results

Volumetric Survey

The results of the TWDB 2007 Volumetric Survey indicate Richland-Chambers Reservoir has a capacity of 1,112,763 acre-feet and encompasses 43,384 acres at conservation pool elevation (315.0 feet above mean sea level, NGVD29). In 1987 Freese and Nichols, Consulting Engineers estimated the original reservoir capacity at 1,181,886 acre-feet.[1] Based on 1994 survey data, TWDB estimated the capacity of Richland-Chambers Reservoir (at conservation pool elevation) at 1,136,600 acre-feet.[1] This estimate was further revised, in 2003, by the Tarrant Regional Water District to 1,137,204 acre-feet[2] through the use of aerial photography to define the reservoir boundary. Due to differences in the methodologies used in calculating areas and capacities from this 2007 survey and previous Richland-Chambers Reservoir surveys, comparison of these values is not recommended. The TWDB considers the 2007 survey to be a significant improvement over previous methods and recommends that a similar methodology be used to resurvey Richland-Chambers Reservoir in 10 years or after a major flood event.

Sedimentation Survey

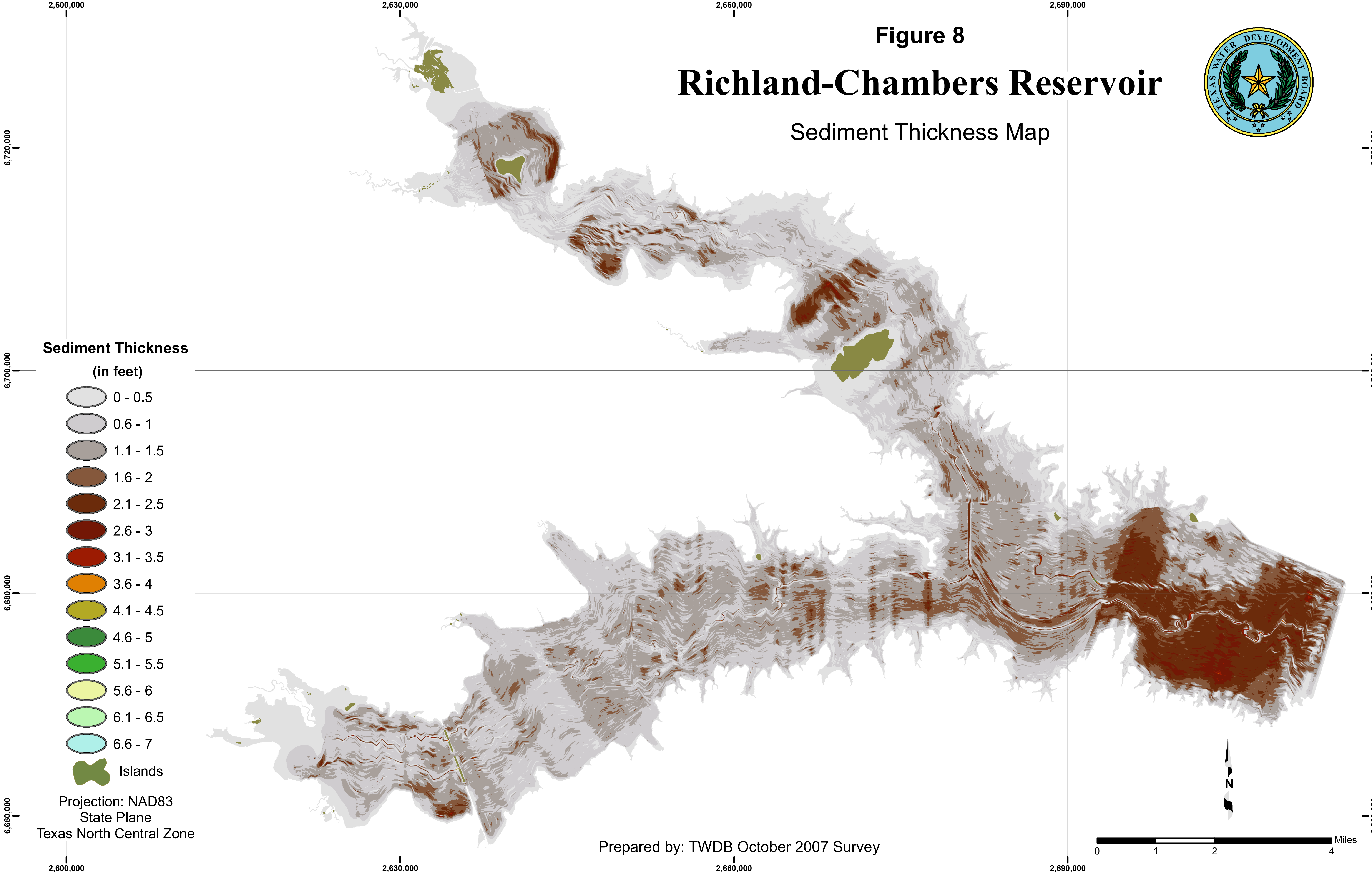
The 200 kHz, 50 kHz, and 24 kHz frequency data were used to interpret sediment distribution and accumulation throughout Richland-Chambers Reservoir. Figure 8 shows the thickness of sediment throughout the reservoir. To assist in the interpretation of post-impoundment sediment accumulation, ancillary data was collected in the form of six core samples. Sediment cores were collected on September 16-17, 2008 using a Specialty Devices, Inc. VibraCore system.

The results of the TWDB 2007 Sedimentation Survey indicate Richland-Chambers Reservoir has accumulated 43,361 acre-feet of sediment since impoundment in 1987. Based on this measured sediment volume and assuming a constant sediment accumulation rate, Richland-Chambers Reservoir loses approximately 2,065 acre-feet of capacity per year. The majority of the sediment accumulation has occurred within the main body of the reservoir within four miles from the Richland-Chambers Dam. The maximum sediment thickness observed in Richland-Chambers Reservoir was 7.0 feet. A complete description of the sediment measurement methodology and sample results is presented in Appendix D.

Figure 8

Richland-Chambers Reservoir

Sediment Thickness Map



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TWDB Contact Information

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

http://www.twdb.state.tx.us/assistance/lakesurveys/volumetricindex.asp

Any questions regarding the TWDB Hydrographic Survey Program may be addressed to:

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Or

Jason Kemp
Team Leader, TWDB Hydrographic Survey Program
Phone: (512) 463-2465
Email: Jason.Kemp@twdb.state.tx.us

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Appendix A

Richland-Chambers Reservoir

RESERVOIR CAPACITY TABLE

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

October 2007 Survey
Conservation Pool Elevation 315.0 feet NGVD29

ELEVATION in Feet	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
237	0	0	0	0	0	0	0	0	0	0
238	0	0	0	0	0	0	0	0	0	0
239	0	0	0	0	0	0	0	0	0	0
240	0	0	0	1	1	1	1	1	1	1
241	1	1	1	1	1	1	1	1	1	1
242	2	2	2	2	2	2	2	2	2	2
243	3	3	3	3	3	3	3	3	4	4
244	4	4	4	5	5	5	5	6	6	6
245	7	7	8	8	9	10	10	11	12	13
246	14	15	16	17	19	20	21	23	25	26
247	28	30	33	35	37	40	43	46	49	53
248	56	60	64	68	72	77	82	87	92	98
249	105	111	119	127	136	145	154	164	174	185
250	195	207	218	231	243	256	269	283	297	312
251	327	342	358	374	391	408	426	444	463	482
252	502	522	542	563	585	606	629	651	675	698
253	722	747	772	798	824	851	879	907	935	965
254	995	1,025	1,057	1,089	1,121	1,155	1,189	1,223	1,259	1,295
255	1,331	1,369	1,407	1,446	1,486	1,526	1,567	1,609	1,651	1,695
256	1,739	1,785	1,832	1,879	1,928	1,978	2,030	2,083	2,137	2,194
257	2,253	2,315	2,380	2,448	2,520	2,596	2,675	2,758	2,844	2,933
258	3,025	3,120	3,218	3,319	3,424	3,532	3,643	3,759	3,878	4,003
259	4,132	4,267	4,405	4,547	4,693	4,841	4,995	5,152	5,314	5,480
260	5,650	5,826	6,006	6,190	6,379	6,572	6,770	6,973	7,182	7,397
261	7,616	7,841	8,070	8,304	8,543	8,787	9,035	9,289	9,548	9,813
262	10,086	10,365	10,648	10,937	11,229	11,527	11,830	12,138	12,451	12,769
263	13,092	13,421	13,755	14,093	14,436	14,783	15,134	15,488	15,847	16,210
264	16,576	16,946	17,320	17,697	18,078	18,464	18,855	19,250	19,650	20,056
265	20,467	20,884	21,308	21,736	22,171	22,613	23,061	23,516	23,978	24,447
266	24,924	25,409	25,901	26,402	26,911	27,427	27,950	28,482	29,021	29,570
267	30,126	30,690	31,260	31,835	32,416	33,002	33,594	34,193	34,798	35,410
268	36,030	36,658	37,292	37,933	38,580	39,234	39,895	40,561	41,235	41,917
269	42,606	43,302	44,005	44,716	45,435	46,161	46,893	47,632	48,377	49,128
270	49,884	50,645	51,412	52,185	52,964	53,749	54,539	55,334	56,135	56,943
271	57,756	58,576	59,402	60,235	61,074	61,918	62,768	63,624	64,483	65,348
272	66,218	67,093	67,973	68,857	69,746	70,641	71,541	72,445	73,354	74,268
273	75,187	76,110	77,038	77,971	78,909	79,851	80,797	81,748	82,704	83,665
274	84,631	85,602	86,579	87,560	88,547	89,540	90,537	91,538	92,543	93,552
275	94,566	95,584	96,607	97,634	98,667	99,705	100,748	101,797	102,850	103,910
276	104,974	106,044	107,119	108,199	109,285	110,376	111,475	112,581	113,695	114,820
277	115,954	117,099	118,252	119,413	120,581	121,757	122,939	124,127	125,319	126,518
278	127,723	128,933	130,150	131,373	132,604	133,842	135,085	136,333	137,586	138,845
279	140,109	141,379	142,654	143,934	145,221	146,513	147,810	149,112	150,420	151,732
280	153,049	154,371	155,699	157,032	158,370	159,714	161,063	162,418	163,779	165,146
281	166,518	167,897	169,282	170,673	172,072	173,478	174,891	176,311	177,739	179,175
282	180,619	182,071	183,530	184,998	186,475	187,960	189,451	190,951	192,458	193,973
283	195,495	197,024	198,561	200,106	201,659	203,222	204,793	206,374	207,962	209,558
284	211,161	212,772	214,390	216,016	217,650	219,292	220,941	222,597	224,259	225,930
285	227,607	229,292	230,985	232,684	234,392	236,107	237,829	239,558	241,294	243,037

Appendix A (Continued)

Richland-Chambers Reservoir

RESERVOIR CAPACITY TABLE

TEXAS WATER DEVELOPMENT BOARD

October 2007 Survey

CAPACITY IN ACRE-FEET

Conservation Pool Elevation 315.0 feet NGVD29

ELEVATION INCREMENT IS ONE TENTH FOOT

ELEVATION in Feet	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
286	244,786	246,543	248,307	250,077	251,854	253,639	255,431	257,231	259,038	260,854
287	262,677	264,508	266,345	268,189	270,041	271,899	273,764	275,637	277,517	279,406
288	281,303	283,208	285,121	287,041	288,969	290,905	292,849	294,800	296,757	298,722
289	300,695	302,674	304,661	306,655	308,657	310,666	312,682	314,707	316,741	318,784
290	320,836	322,897	324,967	327,046	329,135	331,233	333,341	335,458	337,584	339,718
291	341,861	344,012	346,171	348,336	350,511	352,694	354,887	357,089	359,299	361,518
292	363,747	365,986	368,233	370,487	372,750	375,022	377,301	379,588	381,881	384,184
293	386,494	388,813	391,139	393,472	395,813	398,161	400,517	402,880	405,249	407,626
294	410,011	412,403	414,803	417,209	419,624	422,047	424,477	426,917	429,364	431,819
295	434,283	436,755	439,235	441,723	444,219	446,723	449,234	451,753	454,279	456,813
296	459,356	461,906	464,464	467,031	469,608	472,195	474,792	477,398	480,012	482,636
297	485,270	487,913	490,566	493,227	495,899	498,580	501,269	503,966	506,670	509,383
298	512,104	514,834	517,572	520,318	523,075	525,842	528,618	531,403	534,196	536,997
299	539,808	542,627	545,455	548,292	551,139	553,996	556,861	559,736	562,618	565,512
300	568,416	571,328	574,251	577,181	580,122	583,072	586,031	588,999	591,975	594,961
301	597,956	600,959	603,971	606,989	610,015	613,050	616,093	619,144	622,204	625,273
302	628,354	631,445	634,547	637,658	640,780	643,912	647,054	650,205	653,364	656,534
303	659,713	662,904	666,103	669,311	672,528	675,753	678,987	682,230	685,481	688,742
304	692,012	695,290	698,576	701,870	705,173	708,484	711,804	715,133	718,470	721,817
305	725,174	728,539	731,915	735,300	738,696	742,104	745,523	748,956	752,400	755,857
306	759,325	762,804	766,294	769,792	773,303	776,825	780,358	783,901	787,454	791,019
307	794,594	798,181	801,781	805,404	809,040	812,690	816,355	820,035	823,727	827,432
308	831,149	834,877	838,616	842,364	846,124	849,895	853,677	857,470	861,272	865,088
309	868,915	872,753	876,604	880,464	884,336	888,219	892,111	896,012	899,921	903,839
310	907,766	911,702	915,645	919,594	923,552	927,516	931,488	935,467	939,451	943,443
311	947,443	951,448	955,460	959,477	963,501	967,531	971,567	975,609	979,656	983,711
312	987,772	991,839	995,912	999,991	1,004,077	1,008,170	1,012,269	1,016,374	1,020,485	1,024,604
313	1,028,730	1,032,862	1,037,001	1,041,146	1,045,299	1,049,459	1,053,626	1,057,799	1,061,979	1,066,168
314	1,070,363	1,074,566	1,078,777	1,082,995	1,087,221	1,091,456	1,095,699	1,099,951	1,104,211	1,108,482
315	1,112,763									

Appendix B

Richland-Chambers Reservoir

RESERVOIR AREA TABLE

TEXAS WATER DEVELOPMENT BOARD — October 2007 Survey

AREA IN ACRES — Conservation Pool Elevation 315.0 feet NGVD29

ELEVATION INCREMENT IS ONE TENTH FOOT

ELEVATION in Feet	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
237	0	0	0	0	0	0	0	0	0	0
238	0	0	0	0	0	0	0	0	0	0
239	0	0	0	0	0	0	0	0	0	0
240	0	0	0	0	0	0	0	1	1	1
241	1	1	1	1	1	1	1	1	1	1
242	1	1	1	1	1	1	1	1	1	1
243	1	1	1	1	1	1	1	2	2	2
244	2	2	2	2	3	3	3	3	4	4
245	4	5	5	6	6	7	7	8	9	10
246	10	11	12	13	14	14	15	16	17	19
247	20	21	23	24	26	27	29	31	33	35
248	37	38	40	42	44	47	50	53	57	61
249	66	73	79	83	88	91	95	100	104	107
250	111	115	119	123	127	131	135	139	144	148
251	152	157	161	165	170	175	180	184	189	194
252	198	203	207	212	216	221	225	230	234	239
253	244	249	255	260	266	272	277	283	290	296
254	304	311	317	324	330	336	343	350	357	364
255	372	379	385	392	398	406	414	422	430	440
256	451	461	472	483	494	507	521	539	558	579
257	603	630	666	702	739	776	809	843	877	906
258	935	963	998	1,029	1,063	1,098	1,135	1,175	1,217	1,269
259	1,324	1,365	1,403	1,437	1,469	1,512	1,555	1,593	1,635	1,683
260	1,729	1,778	1,823	1,865	1,908	1,954	2,008	2,063	2,117	2,167
261	2,220	2,273	2,318	2,365	2,414	2,459	2,509	2,563	2,622	2,689
262	2,761	2,814	2,859	2,905	2,950	3,002	3,054	3,104	3,154	3,208
263	3,266	3,314	3,360	3,405	3,447	3,487	3,527	3,568	3,606	3,645
264	3,681	3,717	3,756	3,792	3,836	3,881	3,928	3,981	4,031	4,082
265	4,142	4,202	4,261	4,319	4,379	4,445	4,516	4,588	4,656	4,729
266	4,806	4,886	4,966	5,053	5,122	5,192	5,274	5,355	5,446	5,522
267	5,602	5,671	5,729	5,781	5,834	5,890	5,952	6,018	6,088	6,160
268	6,237	6,312	6,377	6,442	6,505	6,570	6,634	6,703	6,775	6,854
269	6,926	6,996	7,072	7,149	7,222	7,293	7,357	7,418	7,481	7,536
270	7,588	7,641	7,698	7,761	7,817	7,872	7,928	7,984	8,043	8,103
271	8,165	8,229	8,295	8,360	8,421	8,474	8,524	8,578	8,625	8,674
272	8,723	8,772	8,818	8,869	8,919	8,971	9,023	9,069	9,115	9,160
273	9,211	9,258	9,307	9,354	9,396	9,439	9,487	9,537	9,584	9,634
274	9,687	9,737	9,790	9,844	9,896	9,947	9,991	10,032	10,074	10,114
275	10,158	10,203	10,250	10,300	10,355	10,405	10,457	10,512	10,566	10,619
276	10,674	10,724	10,775	10,831	10,884	10,943	11,020	11,104	11,197	11,295
277	11,390	11,489	11,573	11,648	11,723	11,788	11,847	11,904	11,959	12,016
278	12,072	12,134	12,203	12,273	12,343	12,402	12,456	12,507	12,561	12,616
279	12,671	12,723	12,778	12,834	12,892	12,945	12,998	13,050	13,099	13,144
280	13,194	13,250	13,309	13,358	13,408	13,464	13,519	13,580	13,641	13,695
281	13,753	13,819	13,883	13,951	14,024	14,095	14,164	14,237	14,319	14,402
282	14,480	14,555	14,637	14,725	14,807	14,881	14,956	15,035	15,108	15,183
283	15,256	15,330	15,411	15,493	15,577	15,671	15,763	15,843	15,918	15,996
284	16,069	16,145	16,222	16,301	16,382	16,452	16,520	16,594	16,667	16,740
285	16,811	16,884	16,963	17,039	17,113	17,183	17,255	17,325	17,395	17,463

Appendix B (Continued)

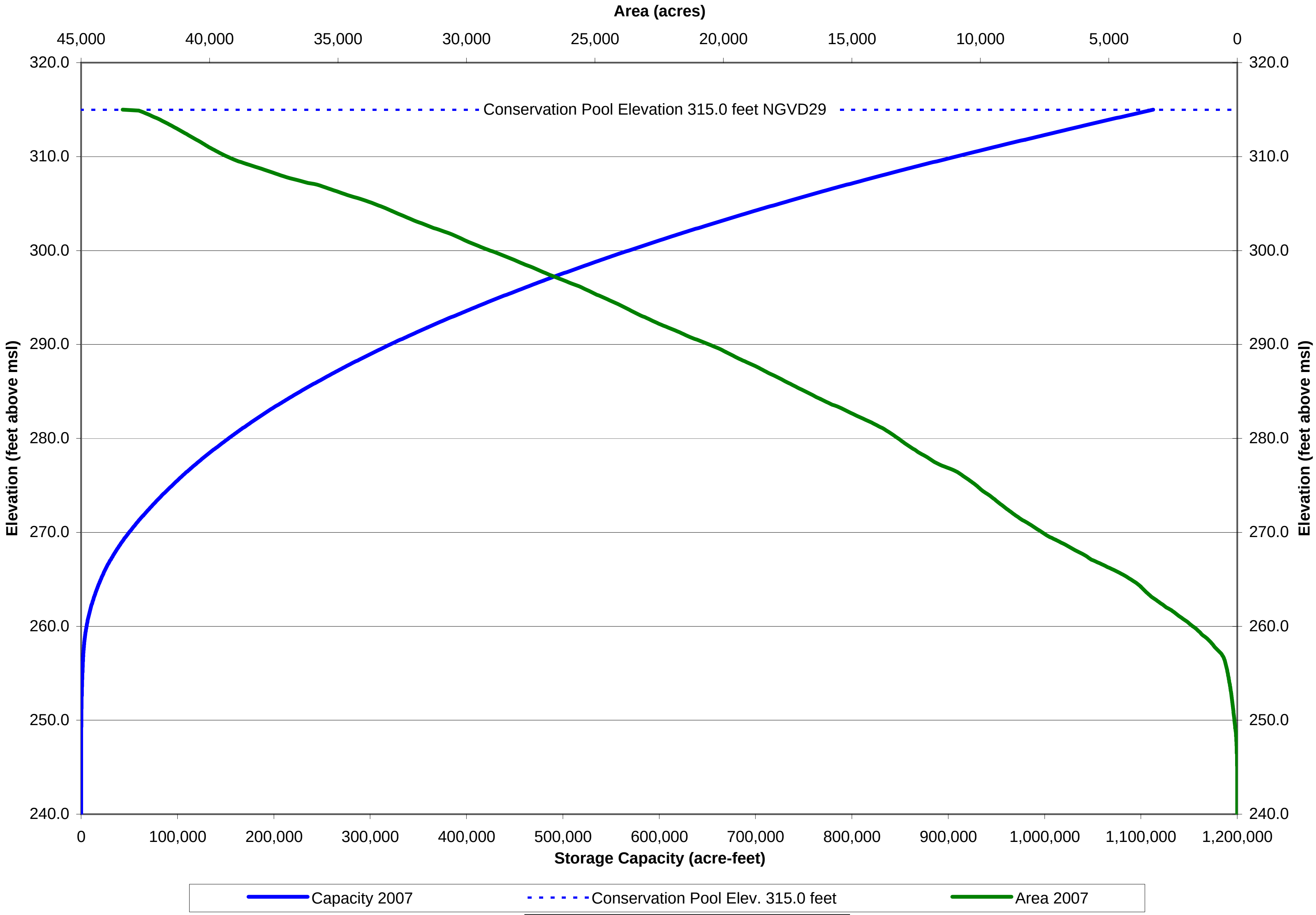
Richland-Chambers Reservoir

RESERVOIR AREA TABLE

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

October 2007 Survey
Conservation Pool Elevation 315.0 feet NGVD29

ELEVATION in Feet	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
286	17,531	17,603	17,671	17,737	17,807	17,883	17,958	18,036	18,114	18,198
287	18,270	18,338	18,410	18,479	18,548	18,615	18,687	18,764	18,848	18,932
288	19,011	19,090	19,166	19,244	19,317	19,397	19,471	19,544	19,614	19,686
289	19,760	19,832	19,905	19,982	20,050	20,124	20,207	20,294	20,387	20,473
290	20,561	20,653	20,749	20,842	20,936	21,028	21,123	21,214	21,305	21,386
291	21,468	21,545	21,623	21,700	21,789	21,878	21,969	22,064	22,151	22,240
292	22,336	22,426	22,512	22,591	22,671	22,753	22,828	22,904	22,984	23,063
293	23,142	23,223	23,299	23,373	23,446	23,521	23,591	23,661	23,733	23,809
294	23,883	23,960	24,033	24,106	24,183	24,266	24,349	24,435	24,514	24,594
295	24,675	24,756	24,844	24,927	25,001	25,073	25,147	25,225	25,304	25,384
296	25,461	25,540	25,622	25,720	25,822	25,920	26,012	26,104	26,195	26,287
297	26,382	26,478	26,574	26,665	26,762	26,848	26,929	27,007	27,092	27,172
298	27,251	27,335	27,425	27,516	27,618	27,716	27,804	27,889	27,973	28,058
299	28,145	28,235	28,329	28,423	28,517	28,608	28,697	28,790	28,886	28,985
300	29,079	29,172	29,268	29,362	29,452	29,540	29,631	29,724	29,816	29,905
301	29,991	30,071	30,148	30,225	30,305	30,386	30,470	30,555	30,648	30,748
302	30,855	30,965	31,065	31,170	31,273	31,368	31,461	31,555	31,647	31,740
303	31,848	31,951	32,039	32,125	32,212	32,297	32,381	32,471	32,563	32,654
304	32,739	32,821	32,901	32,984	33,069	33,156	33,245	33,333	33,423	33,514
305	33,606	33,700	33,803	33,911	34,018	34,134	34,254	34,390	34,509	34,628
306	34,735	34,839	34,944	35,050	35,162	35,270	35,380	35,485	35,590	35,696
307	35,811	35,935	36,160	36,299	36,429	36,569	36,723	36,865	36,993	37,110
308	37,223	37,331	37,438	37,545	37,655	37,762	37,872	37,978	38,092	38,212
309	38,325	38,442	38,559	38,668	38,771	38,869	38,964	39,055	39,142	39,226
310	39,309	39,391	39,466	39,538	39,609	39,679	39,749	39,817	39,887	39,958
311	40,025	40,086	40,147	40,207	40,267	40,328	40,389	40,450	40,512	40,574
312	40,637	40,700	40,763	40,827	40,892	40,957	41,022	41,088	41,154	41,220
313	41,287	41,354	41,423	41,491	41,560	41,630	41,701	41,772	41,844	41,917
314	41,992	42,067	42,144	42,223	42,304	42,387	42,473	42,562	42,657	42,759
315	43,384									



Richland-Chambers Reservoir
October 2007 Survey
Prepared by: TWDB

Appendix C: Area and Capacity Curves

Appendix D

Analysis of Sediment Accumulation Data from Richland-Chambers Reservoir

Executive Summary

The results of the TWDB 2007 Sedimentation Survey indicate Richland-Chambers Reservoir has accumulated 43,361 acre-feet of sediment since impoundment in 1987. Based on this measured sediment volume and assuming a constant sediment accumulation rate, Richland-Chambers Reservoir loses approximately 2,065 acre-feet of capacity per year. The majority of the sediment accumulation has occurred within the main body of the reservoir within four miles from the Richland-Chambers Dam. The maximum sediment thickness observed in Richland-Chambers Reservoir was 7.0 feet.

Introduction

This appendix includes the results of the sediment investigation using multi-frequency depth sounder and sediment core data collected by the Texas Water Development Board (TWDB). Through careful analysis and interpretation of the multi-frequency signal returns, it is possible to discern the pre-impoundment bathymetric surface, as well as the current surface and sediment thickness. Such interpretations are aided and validated through comparisons with sediment core samples which provide independent measurements of sediment thickness. The remainder of this appendix presents a discussion of the results from and methodology used in the core sampling and multi-frequency data collection efforts, followed by a composite analysis of sediment measured in Richland-Chambers Reservoir.

Data Collection & Processing Methodology

TWDB conducted the initial bathymetric survey for Richland-Chambers Reservoir between October 11, 2007 and January 16, 2008. Additional data were collected on September 8-9, 2008. For all data collection efforts, TWDB used a Specialty Devices, Inc. (SDI), multi-frequency (200 kHz, 50 kHz, and 24 kHz) sub-bottom profiling depth sounder integrated with Differential Global Positioning System (DGPS) equipment. Data collection occurred while navigating along pre-planned range lines oriented perpendicular to the assumed location of the original river channels and spaced approximately 500 feet apart. For all data collection efforts, 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. During the 2007 survey, team members collected over 465,000 data points over cross-sections totaling nearly 704 miles in length. Figure D1 shows where data points were collected during the TWDB 2007 survey.

TWDB collected six sediment cores on September 16-17, 2008. Core samples were collected at locations where sounding data had been previously collected (Figure D1). All cores were collected with a custom-coring boat and SDI VibraCore system. Cores were analyzed by TWDB, and both the sediment thickness and the distance the core penetrated the pre-impoundment boundary were recorded. The coordinates and a description of each core sample are provided in Table D1. Figure D2 shows the cross-section of sediment core R-3. At this location, TWDB collected 14.5 inches of sediment, with the upper sediment layers (Figure D2) having a high water content, consisting of clay material and lacking in vegetation. The pre-impoundment boundary was evident from this core at a distance of 3.5 inches above the core base. Below this location, the sediment moisture content is extremely low, yet above this location, the moisture content in the sediment greatly increases until a distance of 8.5 inches above the core base (Figure D2). At distances above 8.5 inches from the core base, the sediment moisture content is extremely high.

Table D1 – Core Sampling Analysis Data – Richland-Chambers Reservoir

Core	Easting** (ft)	Northing** (ft)	Description
R-1	2701080.30	6673287.03	19" of muddy sediment with plant material visible
R-2	2676148.35	6694657.66	8" of sediment with plant material, high moisture content. High clay content.
R-3	2653694.17	6712195.36	14.5" of clay sediment, with plant material/roots visible
R-4	2671893.73	6682015.32	18.5" of wet, fine grained sediment (clay), some plant material visible
R-5	2646916.99	6672308.99	15" gelatinous, clay-rich sediment with some plant material
R-6	2635822.64	6665958.22	8" of sediment with high clay content and plant material

** Coordinates are based on NAD 1983 State Plane Texas North Central system

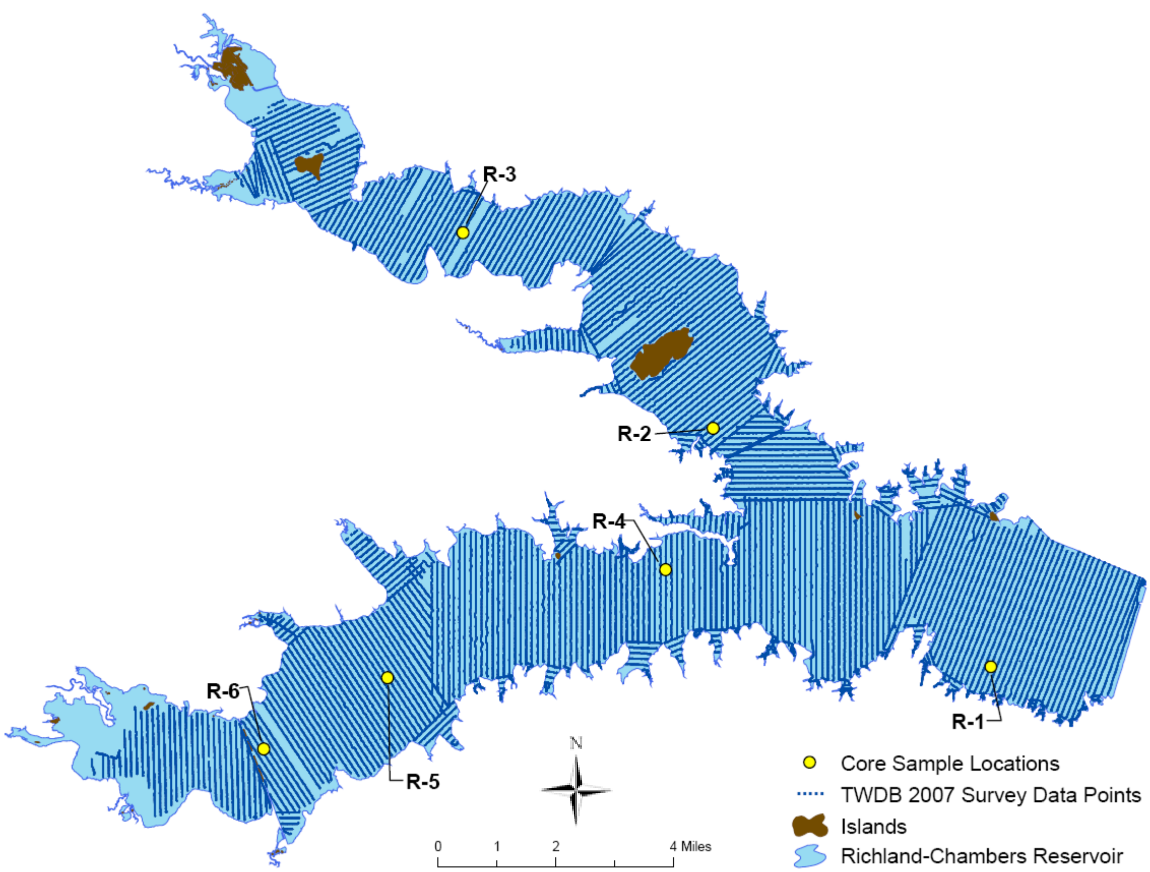


Figure D1 – TWDB 2007 survey data points for Richland-Chambers Reservoir

Figure D2 – Sediment Core R-3 from Richland-Chambers Reservoir, showing the pre-impoundment boundary 3.5 inches above the base of the core (left). The pre-impoundment boundary is marked by the change in sediment moisture content below and above the area 3.5 inches up from the core base. Above 8.5 inches from the core base, the sediment moisture content is extremely high.

All sounding data is processed using the DepthPic software, within which both the pre-impoundment and current bathymetric surfaces are identified and digitized manually. These surfaces are first identified along cross-sections for which core samples have been collected – thereby allowing the user to identify color bands in the DepthPic display that correspond to the sediment layer(s) observed in the core samples. This process is illustrated in Figure D3 where core sample R-3 is shown with its corresponding sounding data. The 14.5 inches of sediment in core sample R-3 is represented by the yellow, red, and green boxes in the core sample shown in Figure D3. The yellow box shows the extent of the high-moisture content sediment shown in Figure D2, while the red box represents the 5 inches of gradually changing moisture content just above the pre-impoundment boundary. The green box represents the 3.5 inches of pre-impoundment sediment. The pre-impoundment surface is usually identified within the core sample by one of the following methods: (1) a visual examination of the core for in-place 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.

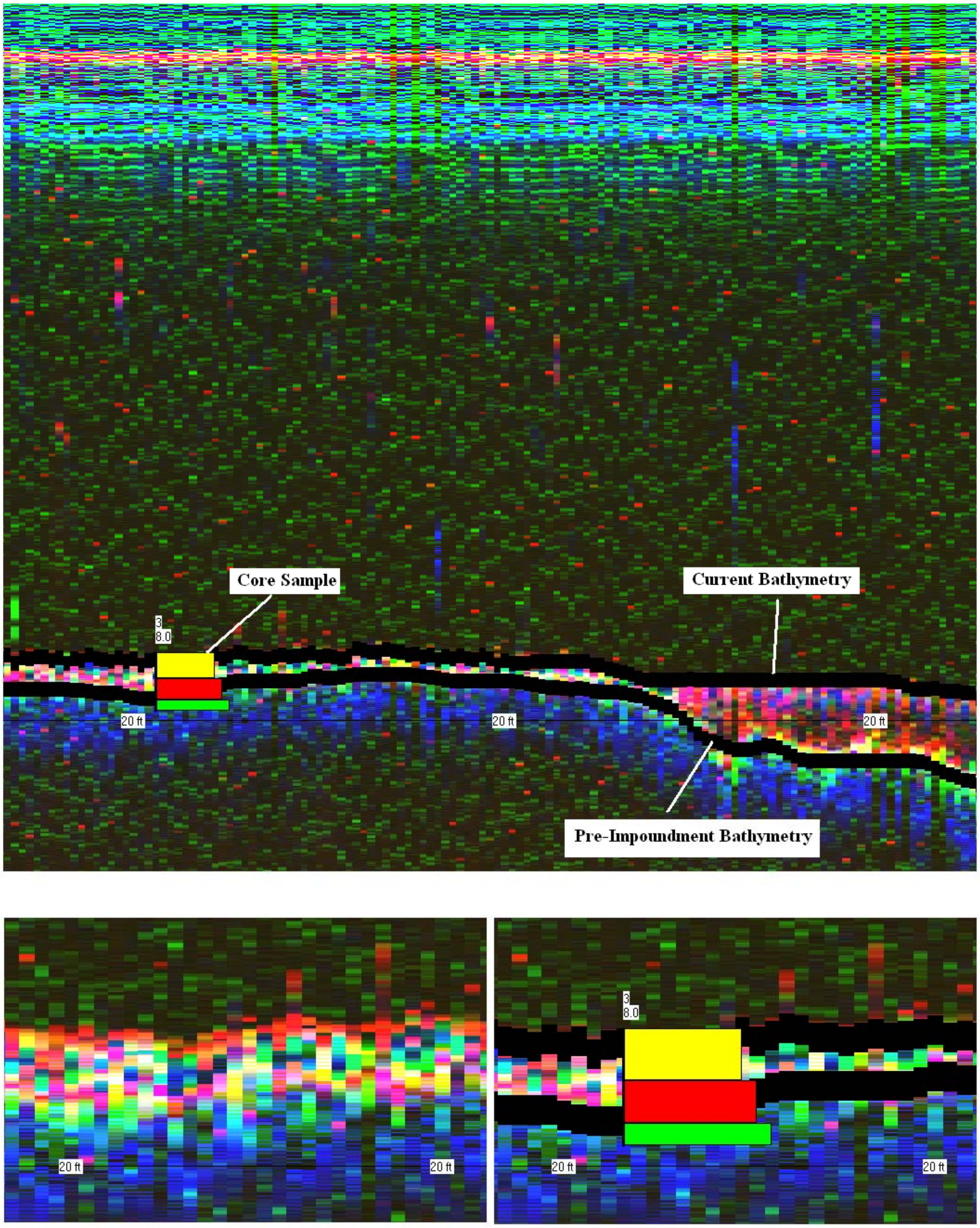


Figure D3 – DepthPic and core sample use in identifying the pre-impoundment bathymetry.

Within DepthPic, the current surface is automatically determined based on the signal returns from the 200 kHz transducer. The pre-impoundment surface must be determined visually based on the pixel color display and any available core sample data. Based on core sample R-3, it is clear that the sediment layer is indicated by the bright pink, white, and red pixels. The pre-impoundment bathymetric surface for this cross-section is therefore identified as the base of the bright pixels in the DepthPic display, which also corresponds generally with the interface between the bright pixels and dark blue pixels located slightly below the bright pixels. The current bathymetric surface is located at the top of the band of bright pixels. (Figure D3).

In analyzing data from cross-sections where core samples were not collected, the assumption is made that sediment layers may be identified in a similar manner as when core sample data is available. To improve the validity of this assumption, core samples are collected at regularly spaced intervals within the lake, or at locations where interpretation of the DepthPic display would be difficult without site-specific core data. For this reason, all sounding data is collected and reviewed before core sites are selected and cores are collected.

After manually digitizing the pre-impoundment surface from all cross-sections, both the pre-impoundment and current bathymetric surfaces are exported as X-,Y-,Z-coordinates from DepthPic into text files suitable for use in ArcGIS. Within ArcGIS, the sounding points are then processed into TIN models following standard GIS techniques[1]. The accumulated sediment volume for Richland-Chambers Reservoir was calculated from a sediment thickness TIN model created in ArcGIS. Sediment thicknesses were computed as the difference in elevations between the current and pre-impoundment bathymetric surfaces as determined with the DepthPic software. Sediment thicknesses were interpolated for locations between surveyed cross-sections using the TWDB Self-Similar Interpolation technique[2]. For the purposes of the TIN model creation, TWDB assumed 0-feet sediment thicknesses at the model boundaries (defined as the 315.0 foot NGVD29 elevation contour).

Results

The results of the TWDB 2007 Sediment Survey indicate Richland-Chambers Reservoir has accumulated 43,361 acre-feet of sediment since impoundment in 1987. Figure D4 depicts the sediment thickness in Richland-Chambers Reservoir. The majority of the sediment accumulation has occurred within the main body of the reservoir within four miles from the Richland-Chambers Dam. The maximum sediment thickness observed in Richland-Chambers Reservoir was 7.0 feet. Thicker sediment deposits tended to form upstream of flow constrictions or impediments.

Based on this measured sediment volume and assuming a constant sediment accumulation rate from 2007 to 1987 (21 years), Richland-Chambers Reservoir loses approximately 2,065 acre-feet of capacity per year. To improve the sediment accumulation rate estimates, TWDB recommends Richland-Chambers Reservoir be re-surveyed using similar methods in approximately 10 years or after a major flood event.

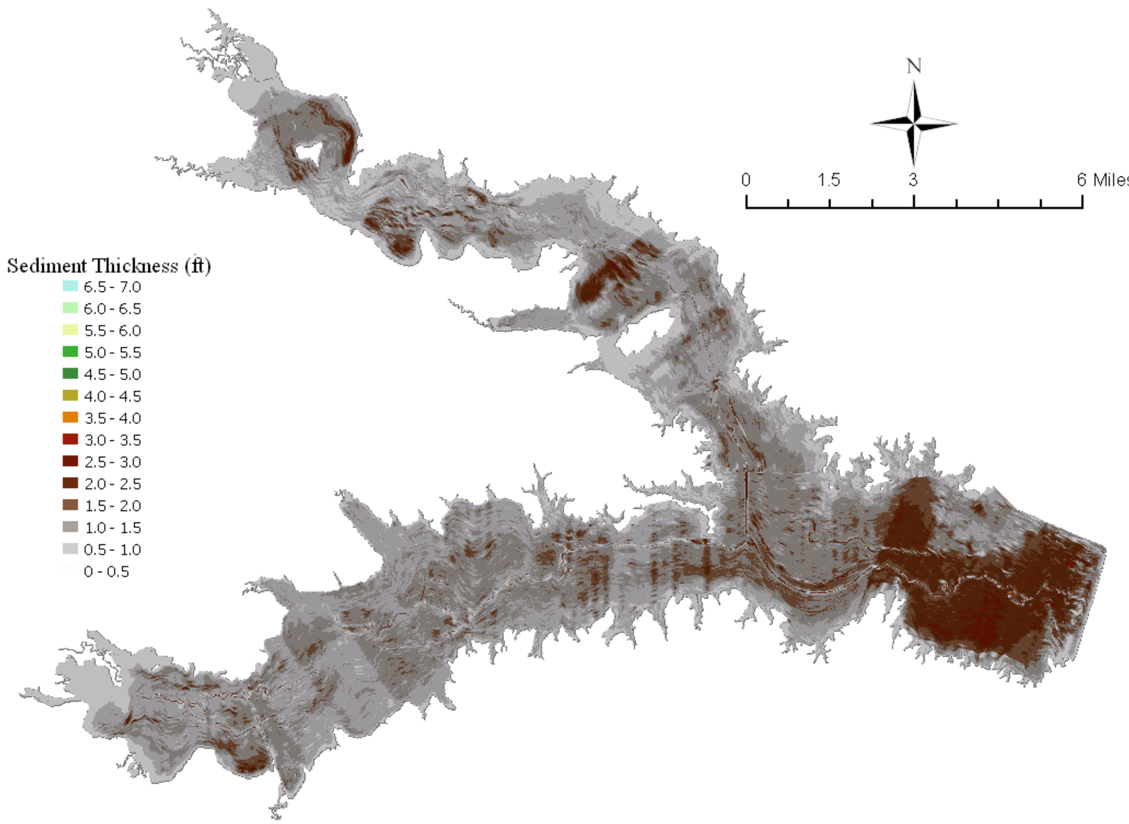


Figure D4 - Sediment thicknesses in Richland-Chambers Reservoir derived from multi-frequency sounding data.

References

1. Furnans, J., Austin, B., Hydrographic survey methods for determining reservoir volume, Environmental Modelling & Software (2007), doi: 10.1016/j.envsoft.2007.05.011
2. Furnans, Jordan. Texas Water Development Board. 2006. "HydroEdit User's Manual."

Figure 6

CONTOURS

(in feet above mean sea level)

240
245
250
255
260
265
270
275
280
285
290
295
300
305
310

Richland-Chambers Reservoir

Islands

Conservation Pool Elevation
315.0 feet above mean sea level

Projection: NAD83
State Plane
Texas North Central Zone

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