Volumetric and Sedimentation Survey of INKS LAKE

April 2007 Survey

Prepared by:

The Texas Water Development Board

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Texas Water Development Board

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Prepared for:

Lower Colorado River Authority

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Executive Summary

In March of 2007, the Texas Water Development Board (TWDB) entered into agreement with the Lower Colorado River Authority, Austin, Texas, for the purpose of performing volumetric and sediment surveys of Inks Lake. These surveys were performed simultaneously using a multi-frequency (200 kHz, 50 kHz, and 24 kHz) sub-bottom profiling depth sounder. The 200 kHz return measures the current bathymetric surface, while the combination of the three frequencies, along with core samples for correlating the pre-impoundment surface with the signal return, is analyzed for evidence of sediment accumulation throughout the reservoir.

Inks Lake, located on the Colorado River, is a part of the Lower Colorado River Authority's Highland Lakes System. Inks Lake is considered a pass-through reservoir whose main purpose is hydroelectric power generation. Inks Dam does not have floodgates, and although some floodwater can be released through hydroelectric generation, the bulk of floodwater passes over an uncontrolled spillway. While Inks Lake is considered full at elevation 888.22 feet (NGVD 29) above mean sea level, its standard operating level is 887.30 ± 0.4 feet above mean sea level (NGVD 29). TWDB completed the Inks Lake survey on April 13th and 16th of 2007, while the water surface elevation measured 887.47 and 887.32 feet (NGVD 29) above mean sea level, respectively.

To augment the survey data collected by TWDB, the Lower Colorado River Authority provided high-resolution LiDAR data, collected on January 2, 2007 when the water surface elevation in Inks Lake was approximately 887.4 feet above mean sea level (NGVD 29). Reservoir capacities were computed based on a combination of the TWDB survey data, TWDB interpolated data, and LiDAR data.

The results of the TWDB 2007 Volumetric Survey indicate Inks Lake has a total reservoir capacity of 14,074 acre-feet and encompasses 788 acres at conservation pool elevation (gauge datum 888.22 feet NGVD 29).

The results of the TWDB 2007 Sediment Survey indicate Inks Lake has accumulated approximately 338 acre-feet of sediment since impoundment. Sediment as accumulated on 64% of the lake bathymetric surface, with an average thickness of 0.7 ft. The majority of the accumulated sediment is located within the main channel of the reservoir, with the thickest deposits (Approx. 7 ft) located approximately 2,000 ft upstream from the dam.

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Inks Lake General Information

With recurring drought and devastating flooding, early-day residents of Central Texas recognized the value of building dams on the Colorado River. Through the passage of the LCRA Act by the Texas Legislature in 1934, the Lower Colorado River Authority (LCRA) was established as a “conservation and reclamation district” responsible for harnessing the Colorado River and its tributaries and making them productive for the people within its water service area. By 1951, the Lower Colorado River Authority had completed six dams on the Colorado River. The string of lakes is known as the Highland Lakes, and includes (from upstream to downstream) Lake Buchanan, Inks Lake, Lake Lyndon Baines Johnson (LBJ), Lake Marble Falls, Lake Travis, and Lake Austin. All these lakes are owned and operated by the LCRA with the exception of Lake Austin, which is owned by the City of Austin but operated by the Lower Colorado River Authority.[1] The Lower Colorado River Authority’s service area originally consisted of the ten counties that comprise the watershed of the lower Colorado River: Blanco, Burnet, Fayette, Colorado, Llano, Travis, Bastrop, Wharton, San Saba, and Matagorda. Several amendments to the LCRA Act expanded the service area to its current extent (Figure 1).

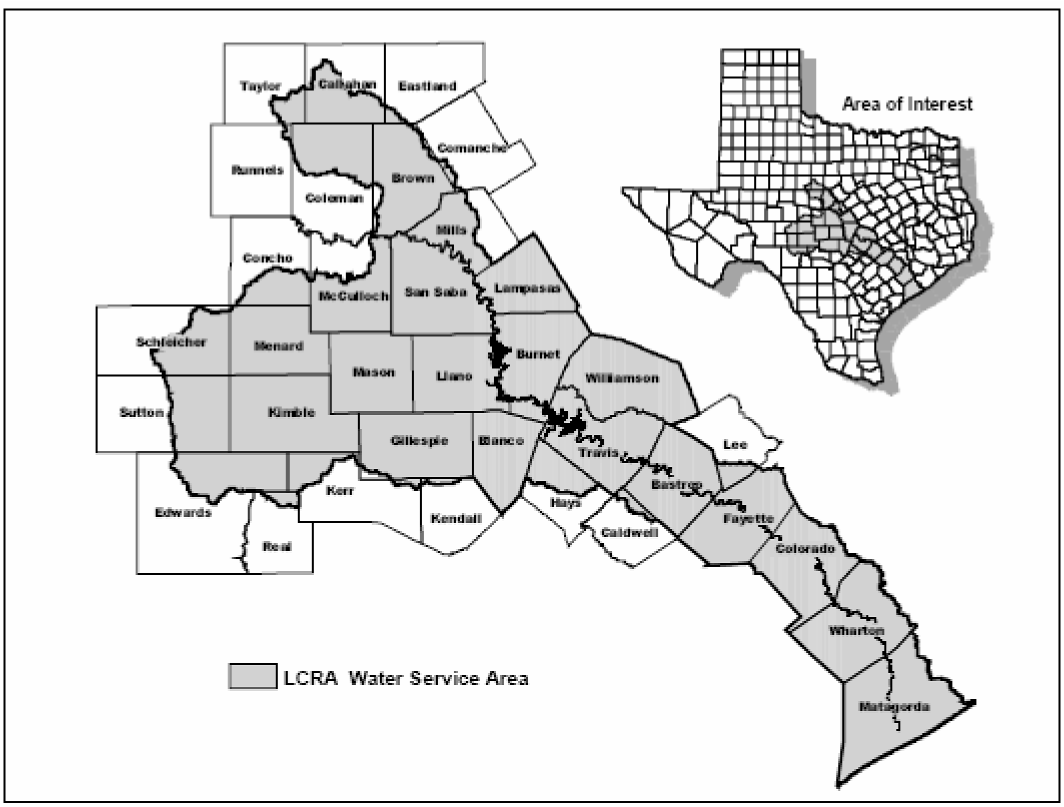


Figure 1. Lower Colorado River Authority Water Service Areas as of January 1, 2003.
Source: Lower Colorado River Authority Water Management Plan 2003.

The Lower Colorado River Authority operates the Highland Lakes as a system. Lakes Buchanan and Travis are water storage reservoirs, while Inks Lake, Lake LBJ, Lake Marble Falls, and Lake Austin are pass-through reservoirs. Lake Travis is the only lake in the system truly designed for flood control purposes. The Lower Colorado River Authority maintains a Water Management Plan as a blueprint for how it will operate the Highland Lakes System. Water availability is based on the Combined Firm Yield of Lakes Buchanan and Travis. The Combined Firm Yield is the annual dependable water supply that can be supplied from Lakes Buchanan and Travis during a repetition of the drought of record. Any water available for use in excess of the combined firm yield is considered interruptible water, used mainly for irrigation, and is sold on an interruptible basis subject to annual availability. Availability of interruptible water is projected by the Lower Colorado River Authority each November. The projected supply depends on the amount of expected combined water storage in Lakes Buchanan and Travis on January 1, anticipated inflows for the subsequent months through the irrigation season, and the current demands for firm water.[2]

The Water Management Plan and a system-operation approach to their water rights and reservoirs allows the Lower Colorado River Authority to optimize and conserve available water to meet existing and future water needs while being a steward of the water and land of the lower Colorado River.[3] The complete Lower Colorado River Authority Water Management Plan is available through the Lower Colorado River Authority website at http://www.lcra.org/water/wmp.html.

Roy Inks Dam and Inks Lake are located on the Colorado River in Llano and Burnet Counties, 12 miles west of Burnet, Texas[4] (Figure 2). The lake and dam are named after Roy B. Inks, one of the original directors on the Lower Colorado River Authority Board. Construction on Roy Inks Dam began in 1936 and was completed in June of 1938. Although the lake's primary purpose is hydroelectric power, the power plant is the smallest of the Highland Lakes chain. Roy Inks Dam does not have floodgates, and although some floodwater can be released through hydroelectric generation, the bulk of floodwater passes over an uncontrolled spillway. While Inks Lake is considered full at elevation 888.22 feet above mean sea level (NGVD 29), its standard operating level is 887.30 ± 0.4 feet (NGVD 29) above mean sea level.[5]

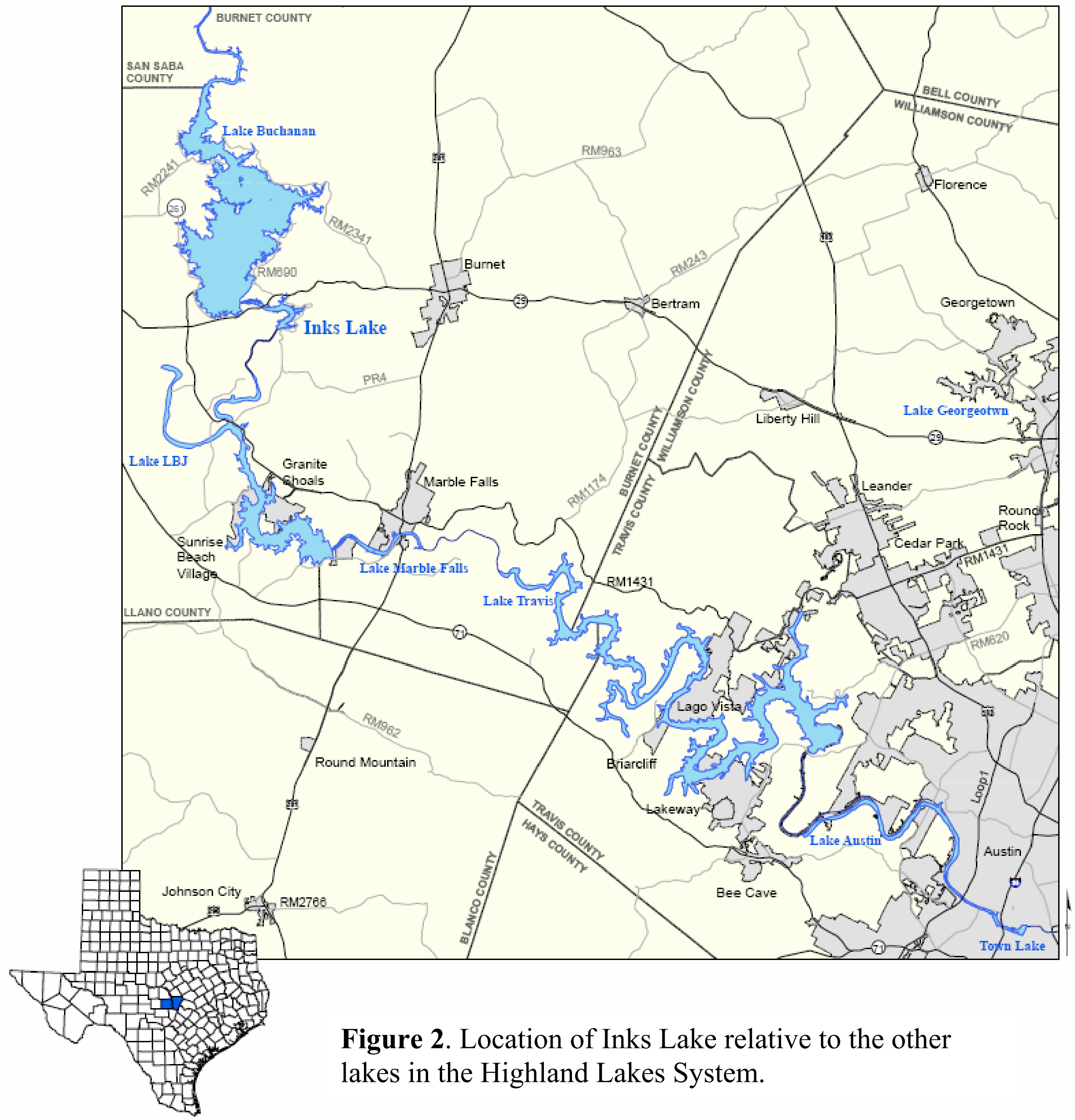


Figure 2. Location of Inks Lake relative to the other lakes in the Highland Lakes System.

Water Rights

The Lower Colorado River Authority was granted the following water rights for Inks Lake:

Certificate of Adjudication: 14-5479 Priority Date: March 29, 1926

Authorizes the Lower Colorado River Authority to maintain an existing dam and reservoir on the Colorado River (Inks Dam and Inks Lake) and impound therein not to exceed 17,545 acre-feet of water. The Lower Colorado River Authority is authorized to use the impounded water for recreation purposes with no right of diversion or release for this purpose. The Lower Colorado River Authority is authorized to divert and use water through Inks dam for the purpose of hydroelectric power generation. However, the water cannot be released solely for the purpose of hydroelectric generation, except during emergency shortages of electricity and during times that such releases will not impair Lower Colorado River Authority's ability to satisfy all existing and projected demands for water from Lakes Travis and Buchanan pursuant to all firm, uninterruptible and all non-firm, interruptible commitments. The right to release water solely for the purpose of hydroelectric generation is specifically subordinated, as to priority, to all present and future upstream rights to use the waters of the Colorado River and its tributaries for municipal, domestic, industrial, irrigation and/or mining purposes, except during emergency shortages of electricity or when the holder of any upstream right agrees otherwise. The maximum rate of release for hydroelectric power generation is 2,600 cubic feet per second.

The following table is a list of pertinent data about Roy Inks Dam and Inks Lake.[4,5]

Table 1: Pertinent Data for Roy Inks Dam and Inks Lake

Owner: Lower Colorado River Authority
Engineer: (Design): Fargo Engineering Company, Lower Colorado River Authority
Location: On the Colorado River in Llano County, 12 miles west of Burnet, 409 river miles from the Gulf of Mexico. Lake shoreline is in Burnet and Llano Counties.
Drainage Area: 31,290 square miles of 11,900 square miles is probably noncontributing. Flow is regulated by Buchanan Powerplant operation.
Dam:

Type	Concrete gravity
Length	1,547.5 feet
Height	96.5 feet
Top Width	16.5 feet
Width at the top of non-overflow section	16.5 feet
Base Width	75.1 feet

Spillway:

Type	Uncontrolled gravity section of dam
Crest length	871.0 feet
Crest Elevation	888.3 feet above mean sea level
Discharge Capacity	3,200 cubic feet per second 1 turbine @ 3,200 cubic feet per second

Outlet Works: None. Water is released through the turbine.
Power Features: One generating unit of 12,000 kilowatt capacity. This unit is operated by remote control from the Buchanan Plant.

Volumetric and Sedimentation Survey of Inks Lake

Introduction

The Texas Water Development Board (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, projected water supply availability.

In March of 2007, TWDB entered into agreement with the LCRA for the purpose of performing volumetric and sediment surveys of Inks Lake. These surveys were performed simultaneously using a multi-frequency (200 kHz, 50 kHz, and 24 kHz) sub-bottom profiling depth sounder. The 200 kHz return measures the current bathymetric surface, while the combination of the three frequencies, along with core samples for correlating the pre-impoundment surface with the signal return, is analyzed for evidence of sediment accumulation throughout the reservoir.

To augment the survey data collected by TWDB, the LCRA provided high-resolution LiDAR data, collected on January 2, 2007 when the water surface elevation in Inks Lake was approximately 887.41 feet above mean sea level (NGVD 29). Reservoir capacities were computed based on a combination of the TWDB survey data, TWDB interpolated data, and the LiDAR data.

Datum

The vertical datum used during this survey is that used by the United States Geological Survey for the reservoir elevation gauge TX071 08148100, named "LCRA Inks Lk nr Kingsland, TX.[6]" Capacity and area calculations in this report are referenced to water levels provided by this United States Geological Survey gauge. The datum for this gauge is reported as 890 feet above mean sea level per the National Geodetic Vertical Datum 1929 (NGVD29)[6], **thus elevations reported here are in feet above NGVD 1929, relative to the gauge**. The horizontal datum used for this report is the North American Datum of 1983 (NAD83), and the horizontal coordinate system is State Plane Texas Central Zone (feet). At the request of the LCRA, area & volume tables were created using elevations based on the gauge datum (NVGD 29) and based on the NAVD88 Datum for which LCRA provided a conversion factor of -0.31. This is for the Inks dam gauge and converting the hydromet[7] reading to NAVD88. This conversion is only valid for the Inks dam site. Volume and area tables computed from each vertical datum are included in Appendix A and B, respectively.

TWDB Bathymetric Data Collection

Bathymetric data collection for Inks Lake occurred on April 13th and April 16th of 2007, while the water surface elevation measured 887.47 and 887.32 feet, respectively. For data collection, TWDB used one boat equipped with a Specialty Devices, Inc., multi-frequency (200 kHz, 50 kHz, and 24 kHz) sub-bottom profiling depth sounder integrated with Differential Global Positioning System 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. The depth sounder was calibrated each day 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. The average speed of sound through the water column measured 4,852 feet per second on April 13th and 4,872 feet per second on April 16th. During the 2007 survey, team members collected over 26,000 data points over cross-sections totaling nearly 21 miles in length. Figure 3 shows where data points were collected during the TWDB 2007 survey.

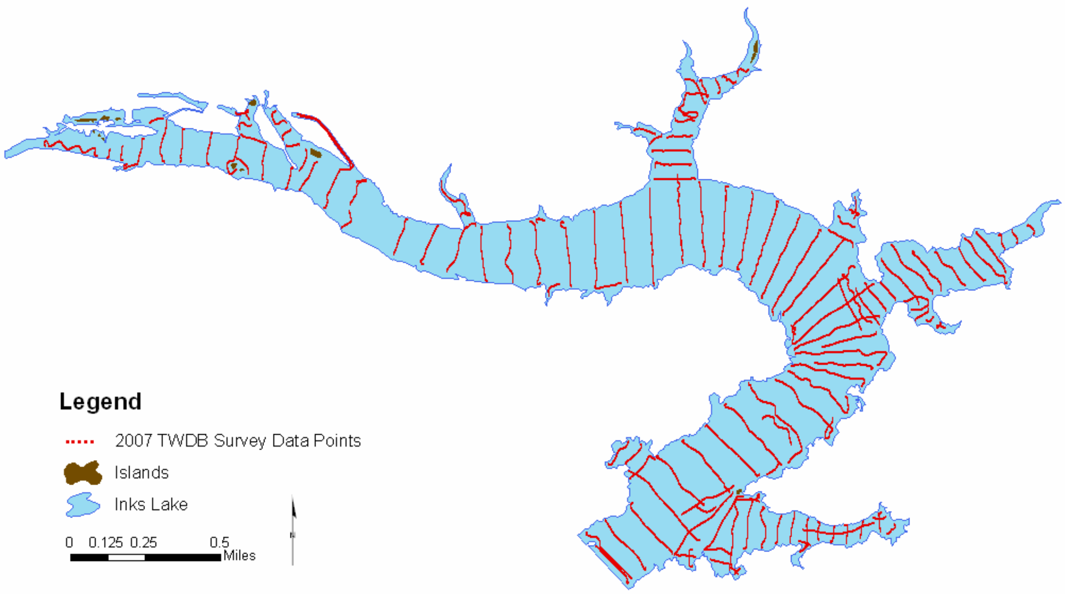


Figure 3. TWDB 2007 Survey Data Points for Inks Lake

Data Processing

Model Boundary

At the request of the LCRA, surface areas and capacities were calculated to elevation 905 ft, or 16.78 ft above CPE. In order to estimate surface areas and capacities above pool elevation 888.22 ft, an upper model boundary was developed from a combination of the 920 ft contour from the digital hypsography (1:24,000 scale)[8] and LCRA-provided LiDAR data (See Appendix F). For modeling purposes only, the 920 ft contour was closed across the top of the dam, and therefore does not reflect the true elevations near the dam crest. These incorrect elevations near the dam crest will not affect the final representation of the Inks Lake bathymetric surface, which is computed only to elevation 905 ft.

The reservoir boundary was digitized from aerial photographs using Environmental Systems Research Institute's (ESRI) ArcGIS 9.1 software. The aerial photographs, or digital orthophoto quarter-quadrangle images[9] (DOQQs), used for Inks Lake were Lake Buchanan SE, Council Creek SW, Kingsland NE, and Longhorn Cavern NW. These images were photographed on December 7, 2004, during which time the water surface elevation at Inks Lake measured 887.38 ft, within the normal operating range of Inks Lake. This boundary was used to enhance the lake boundary within the final representation of the Inks Lake bathymetric surface.

Triangular Irregular Network (TIN) Model

Upon completion of data collection, the raw data files collected by TWDB were edited using DepthPic and HypackMAX to remove any data anomalies. DepthPic is used to display, interpret, and edit the multi-frequency data, while HypackMAX is used to edit the single-frequency data collected in the shallower upper reaches of the reservoir. The water surface elevations at the times of each sounding are used to convert sounding depths to corresponding bathymetric elevations. For processing outside of DepthPic and HypackMAX, the sounding coordinates (X,Y,Z) are exported as a MASS points file. A similar MASS points file was created from the LCRA-provided LiDAR data (Appendix F). TWDB also created a MASS points file of interpolated data located in-between surveyed cross sections. This points file is described in the section entitled “Self-Similar Interpolation.”

To create a surface representation of the Inks Lake bathymetry, the 3D Analyst Extension of ArcGIS (ESRI, Inc.) is used. This extension creates a triangulated irregular network (TIN) model of the bathymetry, where each MASS point and boundary node becomes the vertex of a triangular portion of the reservoir bottom surface. [10] From the TIN model, reservoir capacities and areas are calculated at one-tenth of a foot (0.1 ft) intervals, from elevation 825.0 ft to elevation 905.0 ft. TWDB surveyed data and interpolated data were used in creating surfaces with elevations less than 887.38 ft, whereas LCRA-provided LiDAR data was used for areas with elevations greater than 887.38 ft. Figure 4 depicts the spatial extent of the various data sets used in creating the Inks Lake TIN model.

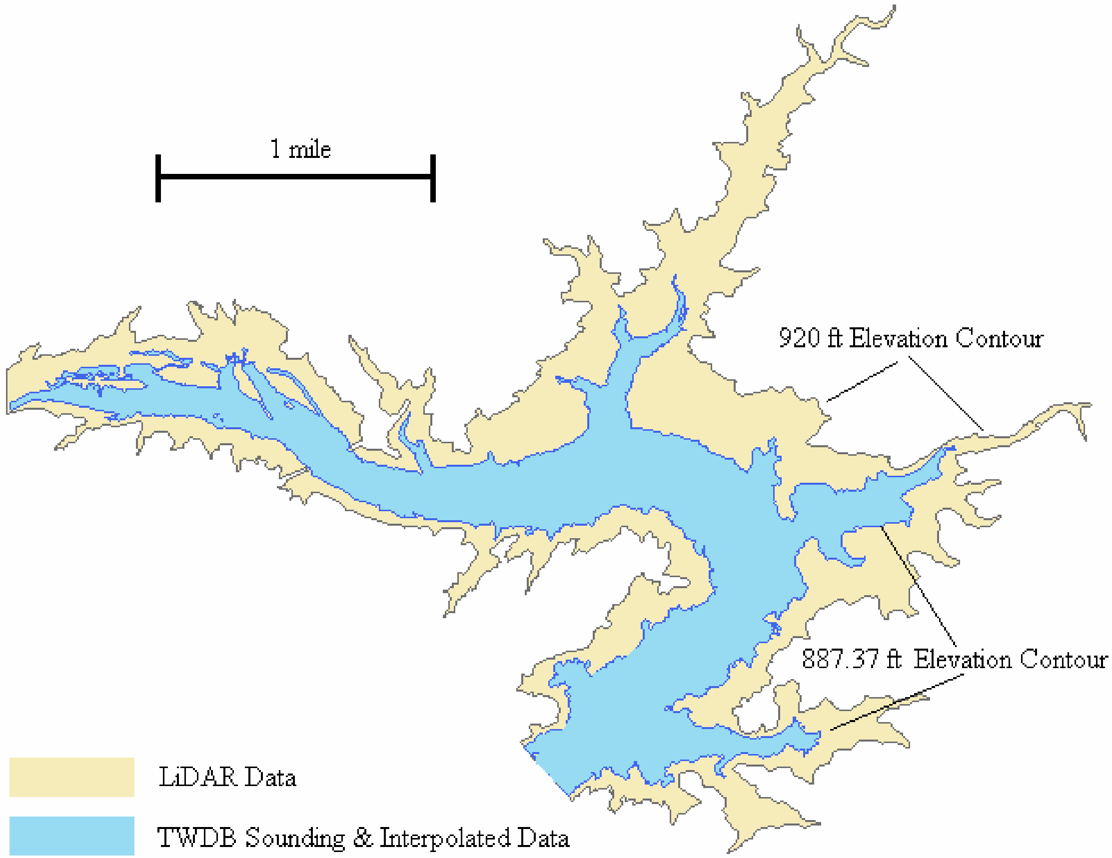
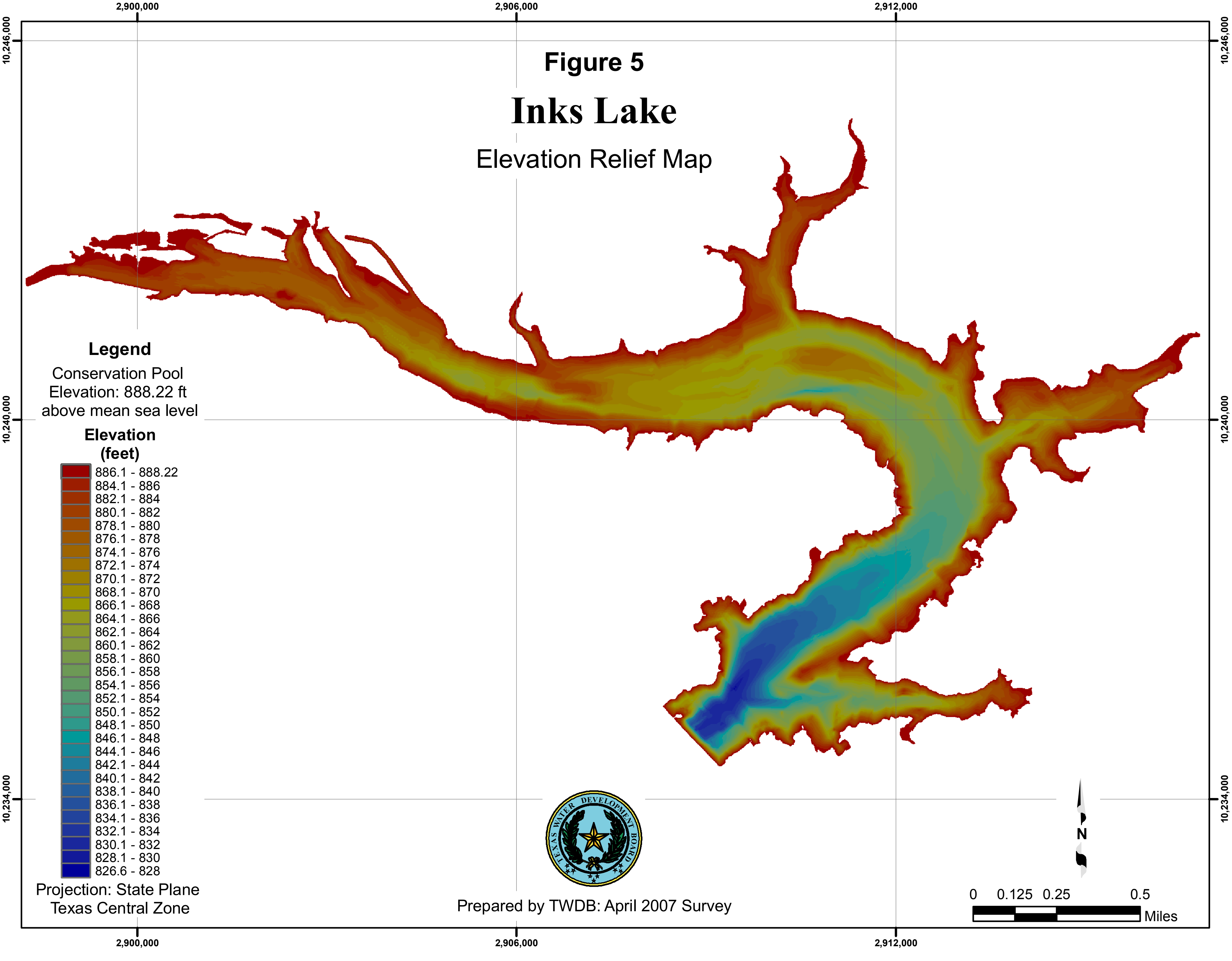


Figure 4 – Spatial extent of data used in creating the Inks Lake TIN model

The Elevation-Capacity and Elevation-Area Tables, updated for 2007, are presented in Appendices A and B, respectively. An Elevation-Capacity graph and an Elevation-Area graph are presented in Appendices C and D, respectively.

The TIN model was interpolated and averaged using a cell size of 1 ft by 1 ft and converted to a raster. The raster was used to produce an Elevation Relief Map representing the topography of the reservoir bottom (Figure 5), a map showing shaded depth ranges for Inks Lake (Figure 6), and a 10-ft contour map (Figure 7). The reservoir extent depicted in these figures is that corresponding to the conservation-pool elevation (888.22 ft).



2,900,000
2,906,000
2,912,000
10,246,000
10,240,000
10,234,000
Figure 5
Inks Lake
Elevation Relief Map
Legend
Conservation Pool
Elevation: 888.22 ft
above mean sea level
Elevation
(feet)
886.1 - 888.22
884.1 - 886
882.1 - 884
880.1 - 882
878.1 - 880
876.1 - 878
874.1 - 876
872.1 - 874
870.1 - 872
868.1 - 870
866.1 - 868
864.1 - 866
862.1 - 864
860.1 - 862
858.1 - 860
856.1 - 858
854.1 - 856
852.1 - 854
850.1 - 852
848.1 - 850
846.1 - 848
844.1 - 846
842.1 - 844
840.1 - 842
838.1 - 840
836.1 - 838
834.1 - 836
832.1 - 834
830.1 - 832
828.1 - 830
826.6 - 828
Projection: State Plane
Texas Central Zone
TEXAS WATER DEVELOPMENT BOARD
Prepared by TWDB: April 2007 Survey
N
0
0.125
0.25
0.5
Miles

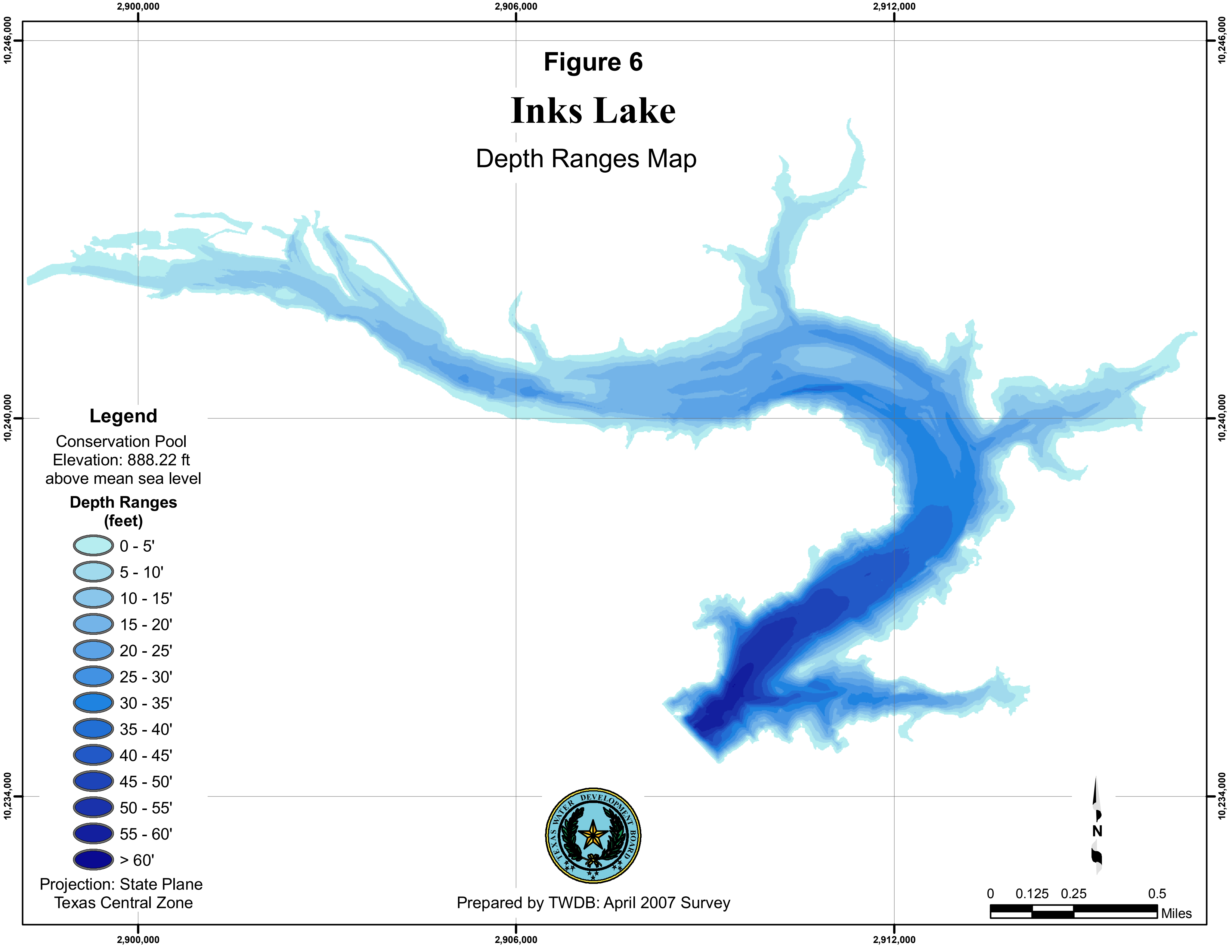


Figure 6
Inks Lake
Depth Ranges Map
Legend
Conservation Pool
Elevation: 888.22 ft
above mean sea level
Depth Ranges
(feet)
0 - 5'
5 - 10'
10 - 15'
15 - 20'
20 - 25'
25 - 30'
30 - 35'
35 - 40'
40 - 45'
45 - 50'
50 - 55'
55 - 60'
> 60'
Projection: State Plane
Texas Central Zone
Prepared by TWDB: April 2007 Survey
TEXAS WATER DEVELOPMENT BOARD
N
0
0.125
0.25
0.5
Miles
2,900,000
2,906,000
2,912,000
10,246,000
10,240,000
10,234,000

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 submerged river channel (the location of which is often unknown until after the survey), then the TIN model is not likely to represent the true channel bathymetry very well.

To ameliorate these problems, a "Self-Similar Interpolation" (SSI) routine (developed by TWDB) was used to interpolate the bathymetry in between many 500 ft-spaced survey lines. The SSI 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 Inks Lake, the application of SSI helped represent the lake morphology near the banks and improve the representation of the submerged river channel near a confluence between the main channel and a tributary (Figure 8). 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 SSI technique are not likely to be valid; therefore, s interpolation was not used in areas of Inks Lake where a high probability of change between cross-sections exists.[11] Figure 8 illustrates typical results of the application of the SSI routine in Inks Lake, and the bathymetry shown in Figure 8C was used in computing reservoir volume and area tables (Appendix A, B).

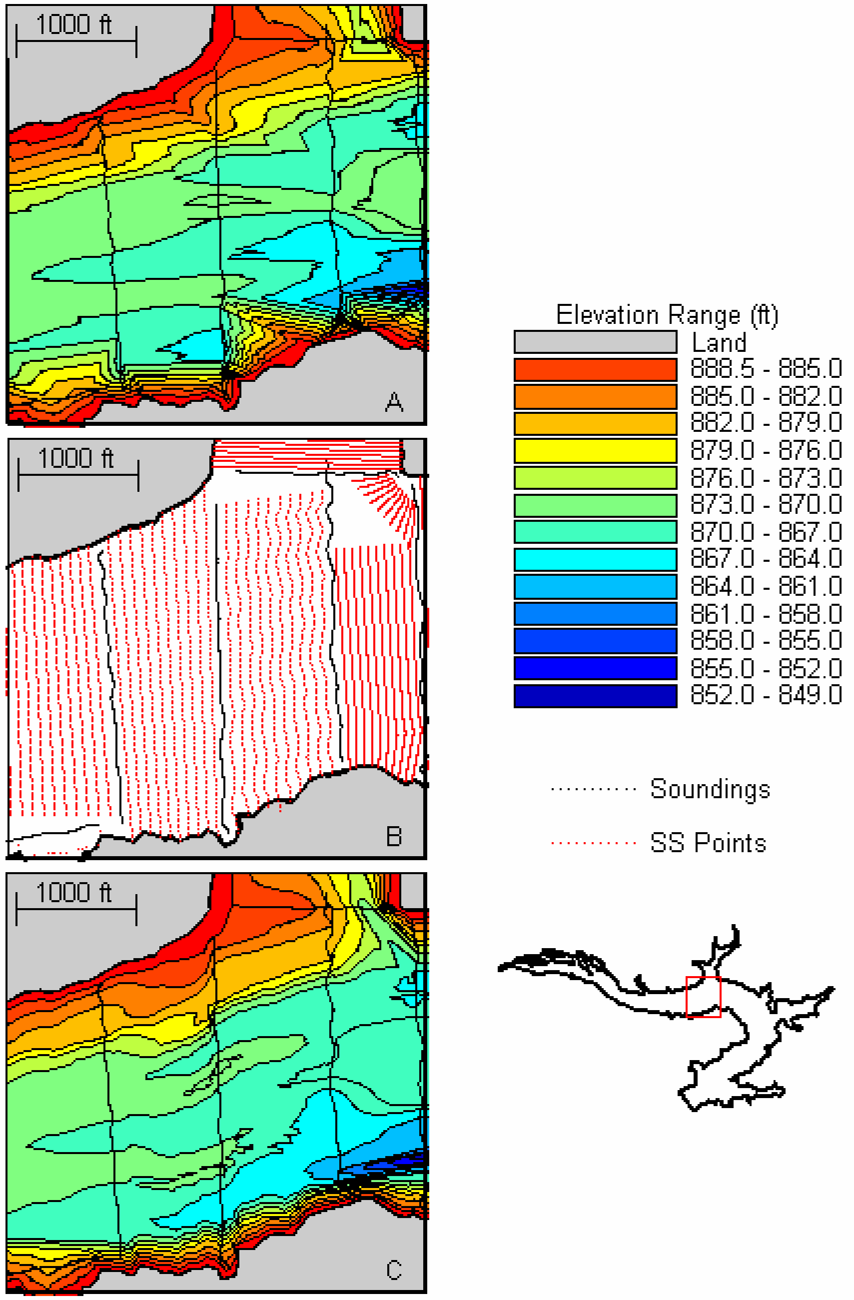


***Figure 8** - Application of the Self-Similar Interpolation technique to Inks Lake sounding data – A) bathymetric contours without interpolated points, B) Sounding points (black) and interpolated points (red) with reservoir boundary shown at elevation 887.38 (black), C) bathymetric contours with the interpolated points. Note: In 8A the contours along the southern shore are angular and extend into the lake. The incoming tributary along the northern shore is also not connected to the main channel. Both of these features are artifacts of the TIN generation routine and are eliminated through use of the SSI technique as shown in 8C.*

Volumetric Survey Results

The results of the TWDB 2007 Volumetric Survey indicate Inks Lake has a total capacity of 14,074 acre-feet and encompasses 788 acres at conservation pool elevation, (888.22 ft. above mean sea level).

Due to differences in both data collection and processing methodologies, comparisons of areas and volumes presented herein with those listed in previously published reports are not recommended.[8] The TWDB considers the methods used in this 2007 survey to be a significant improvement over previous methods and recommends that a similar methodology be used to resurvey Inks Lake in 5 to 10 years.

Sediment Survey Results

The 200 kHz, 50 kHz, and 24 kHz frequency data were used to interpret sediment distribution and accumulation throughout Inks Lake. Ancillary data was collected in the form of seven core samples to assist in the interpretation of post impoundment sediment accumulation. John Dunbar Geophysical Consulting was contracted to collect and analyze the core samples. The pre-impoundment boundaries in each core were determined by measuring the water content and penetration resistance.

The results of the sedimentation analysis indicate Inks Lake has accumulated approximately **338 acre-feet** of sediment. Figure 9 shows the locations in which sediment has accumulated. A complete description of the sediment measurement & calculation process is presented in Appendix E.

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 Barney Austin, Director of Surface Water Resources, at 512-463-8856, or by email at: Barney.Austin@twdb.state.tx.us.

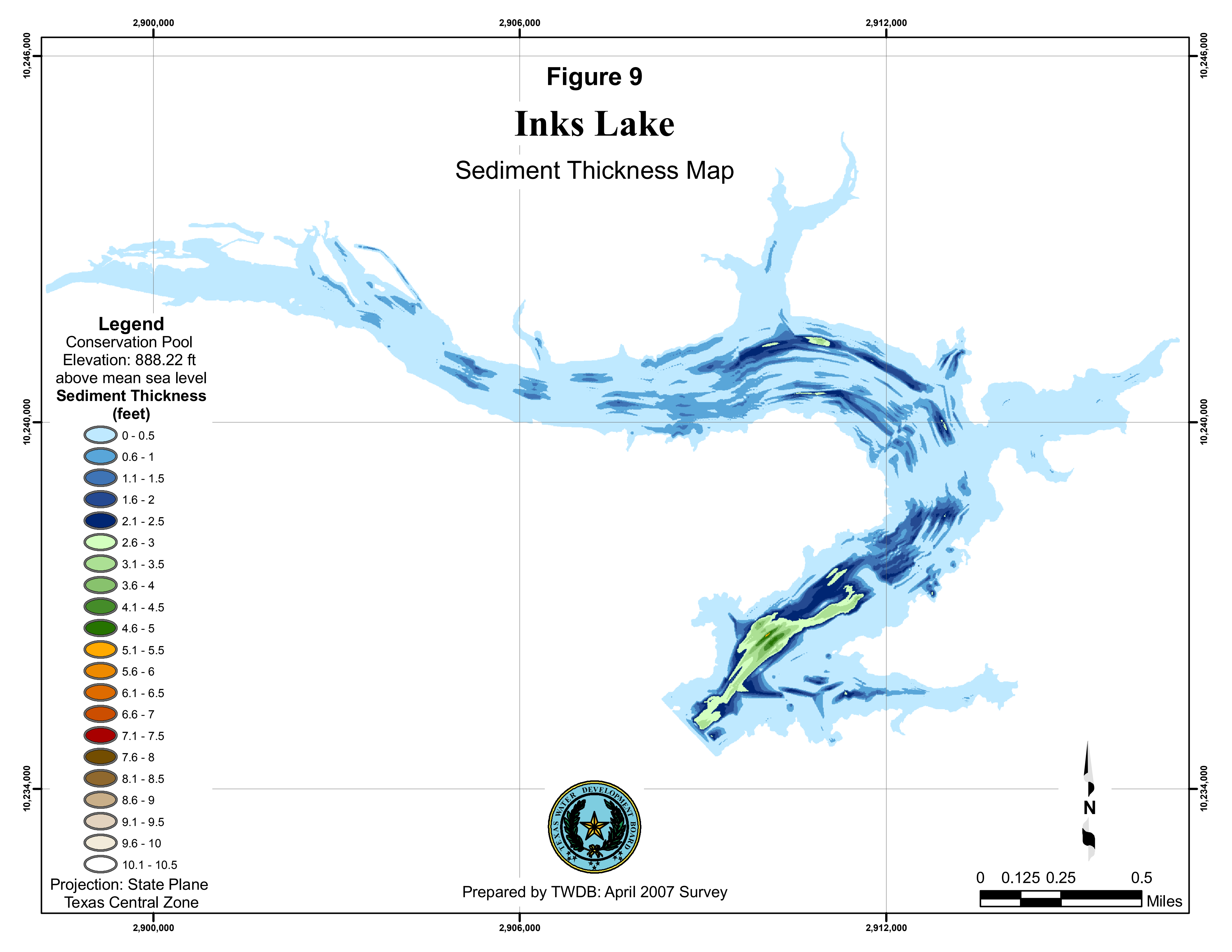


Figure 9
Inks Lake
Sediment Thickness Map
2,900,000
2,906,000
2,912,000
10,246,000
10,240,000
10,234,000
Legend
Conservation Pool
Elevation: 888.22 ft
above mean sea level
Sediment Thickness
(feet)
0 - 0.5
0.6 - 1
1.1 - 1.5
1.6 - 2
2.1 - 2.5
2.6 - 3
3.1 - 3.5
3.6 - 4
4.1 - 4.5
4.6 - 5
5.1 - 5.5
5.6 - 6
6.1 - 6.5
6.6 - 7
7.1 - 7.5
7.6 - 8
8.1 - 8.5
8.6 - 9
9.1 - 9.5
9.6 - 10
10.1 - 10.5
Projection: State Plane
Texas Central Zone
Prepared by TWDB: April 2007 Survey
TEXAS WATER DEVELOPMENT BOARD
N
0 0.125 0.25 0.5
Miles

References

1. Lower Colorado Regional Water Planning Group, Region K, 2006, LCWPG Water Plan, Chapter 3, http://www.twdb.state.tx.us/rwpg/2006_RWP/RegionK/Chapter%203.pdf.
2. Lower Colorado River Authority, Water Management Plan for the Lower Colorado River Basin, Effective September 20, 1989 Including Amendments Through May 14, 2003, http://www.lcra.org/docs/water_RevisedWMP.pdf.
3. Lower Colorado Regional Water Planning Group, Region K, 2006, LCWPG Water Plan, Chapter 4, http://www.twdb.state.tx.us/rwpg/2006_RWP/RegionK/Chapter%204.pdf.
4. Texas Water Development Board, Report 126, Engineering Data on Dams and Reservoirs in Texas, Part III, February 1971.
5. Lower Colorado River Authority, LCRA: Inks Dam, viewed 12 October 2007, http://www.lcra.org/water/dams/inks.html.
6. United States Geological Survey, http://tx.usgs.gov/ viewed 02 October 2007, http://waterdata.usgs.gov/tx/nwis/current?type=lake.
7. Lower Colorado River Authority, LCRA: Hydromet – River Operations Center Hydrologic Data, viewed 31 October 2007, http://hydromet.lcra.org/
8. Texas Natural Resources Information System (TNRIS), viewed 31 October 2007, http://www.tnris.state.tx.us/
9. U.S Department of Agriculture, Farm Service Agency, Aerial Photography Field Office, National Agriculture Imagery Program, http://www.apfo.usda.gov/NAIP.html, 2/10/06.
10. ESRI, Environmental Systems Research Institute. 1995. ARC/INFO Surface Modeling and Display, TIN Users Guide.
11. Furnans, Jordan. Texas Water Development Board. 2006. “HydroEdit User’s Manual.”

Inks Lake

RESERVOIR VOLUME TABLE - NGVD 29 DATUM

TEXAS WATER DEVELOPMENT BOARD — April 2007 SURVEY

Conservation Pool Elevation 888.22 ft

VOLUME IN ACRE-FEET — 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
825	0	0	0	0	0	0	0	0	0	0
826	0	0	0	0	0	0	0	0	0	0
827	0	0	0	0	0	0	0	0	0	0
828	0	0	0	0	0	0	0	0	0	0
829	0	0	0	0	0	0	0	0	0	0
830	0	0	0	0	0	0	1	1	1	1
831	1	1	1	1	1	2	2	2	3	3
832	3	4	4	5	5	6	7	7	8	9
833	9	10	11	12	12	13	14	15	16	17
834	18	18	19	20	21	22	24	25	26	27
835	28	29	30	32	33	34	35	37	38	39
836	41	42	44	45	47	48	50	51	53	55
837	57	58	60	62	64	66	68	70	72	74
838	76	79	81	83	85	88	90	93	95	98
839	100	103	105	108	110	113	116	119	121	124
840	127	130	133	136	139	142	145	148	151	154
841	157	161	164	167	170	174	177	181	184	188
842	191	195	199	202	206	210	214	218	221	225
843	229	233	238	242	246	250	255	259	264	268
844	273	277	282	287	292	297	302	307	312	317
845	322	327	332	338	343	348	354	359	365	370
846	376	381	387	393	399	405	411	417	423	429
847	435	441	447	454	460	467	473	480	486	493
848	500	506	513	520	527	534	541	548	555	563
849	570	577	584	592	599	607	614	622	630	638
850	645	653	661	669	677	685	693	701	710	718
851	726	735	743	752	760	769	778	787	796	805
852	814	823	832	841	850	860	869	878	888	897
853	907	917	927	936	946	956	966	976	986	997
854	1,007	1,017	1,028	1,038	1,049	1,060	1,070	1,081	1,092	1,103
855	1,114	1,125	1,136	1,147	1,158	1,169	1,181	1,192	1,204	1,216
856	1,227	1,239	1,251	1,263	1,275	1,288	1,300	1,313	1,325	1,338
857	1,351	1,364	1,377	1,390	1,404	1,417	1,431	1,444	1,458	1,473
858	1,487	1,502	1,516	1,531	1,546	1,562	1,577	1,593	1,608	1,624
859	1,640	1,656	1,672	1,689	1,705	1,722	1,738	1,755	1,772	1,789
860	1,806	1,823	1,840	1,858	1,875	1,893	1,911	1,929	1,947	1,965
861	1,983	2,001	2,019	2,038	2,057	2,075	2,094	2,113	2,132	2,151
862	2,170	2,190	2,209	2,229	2,248	2,268	2,288	2,308	2,328	2,349
863	2,369	2,390	2,410	2,431	2,452	2,473	2,495	2,516	2,537	2,559
864	2,581	2,603	2,625	2,647	2,669	2,692	2,714	2,737	2,760	2,783
865	2,806	2,829	2,853	2,876	2,900	2,924	2,948	2,972	2,997	3,021
866	3,046	3,071	3,096	3,122	3,147	3,173	3,199	3,225	3,251	3,278
867	3,304	3,331	3,358	3,385	3,413	3,440	3,468	3,496	3,525	3,553
868	3,582	3,611	3,640	3,670	3,700	3,730	3,760	3,791	3,822	3,853
869	3,884	3,916	3,948	3,980	4,012	4,045	4,077	4,110	4,143	4,176
870	4,210	4,244	4,277	4,312	4,346	4,380	4,415	4,450	4,485	4,520
871	4,556	4,591	4,627	4,663	4,700	4,736	4,773	4,809	4,846	4,884
872	4,921	4,958	4,996	5,034	5,072	5,111	5,149	5,188	5,227	5,266
873	5,305	5,345	5,384	5,424	5,464	5,504	5,545	5,585	5,626	5,667
874	5,708	5,749	5,790	5,832	5,874	5,916	5,958	6,000	6,043	6,085
875	6,128	6,171	6,214	6,258	6,301	6,345	6,388	6,432	6,477	6,521
876	6,565	6,610	6,655	6,699	6,745	6,790	6,836	6,881	6,927	6,974
877	7,020	7,067	7,114	7,161	7,209	7,257	7,305	7,354	7,403	7,452
878	7,501	7,551	7,601	7,651	7,702	7,753	7,804	7,856	7,908	7,960
879	8,013	8,065	8,119	8,172	8,226	8,279	8,334	8,388	8,443	8,498
880	8,554	8,609	8,666	8,722	8,779	8,836	8,893	8,951	9,009	9,067

Inks Lake

RESERVOIR VOLUME TABLE - NGVD 29 DATUM (Cont.)

TEXAS WATER DEVELOPMENT BOARD — April 2007 SURVEY

Conservation Pool Elevation 888.22 ft

VOLUME IN ACRE-FEET — 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
881	9,125	9,184	9,243	9,303	9,363	9,423	9,483	9,544	9,605	9,666
882	9,727	9,789	9,851	9,914	9,976	10,039	10,102	10,166	10,230	10,294
883	10,358	10,422	10,487	10,552	10,618	10,683	10,749	10,815	10,881	10,948
884	11,015	11,082	11,149	11,216	11,284	11,352	11,421	11,489	11,558	11,627
885	11,696	11,766	11,836	11,906	11,976	12,046	12,117	12,188	12,259	12,331
886	12,402	12,474	12,546	12,619	12,692	12,764	12,838	12,911	12,985	13,059
887	13,134	13,209	13,284	13,360	13,436	13,513	13,590	13,668	13,745	13,823
888	13,902	13,980	14,059	14,138	14,217	14,296	14,375	14,455	14,535	14,615
889	14,696	14,777	14,858	14,940	15,021	15,104	15,186	15,269	15,352	15,436
890	15,519	15,604	15,688	15,773	15,859	15,944	16,030	16,117	16,204	16,291
891	16,379	16,467	16,556	16,644	16,734	16,823	16,913	17,004	17,094	17,186
892	17,277	17,369	17,461	17,554	17,646	17,740	17,833	17,927	18,021	18,116
893	18,211	18,306	18,402	18,498	18,594	18,691	18,788	18,886	18,983	19,081
894	19,180	19,278	19,377	19,477	19,576	19,676	19,776	19,877	19,978	20,079
895	20,181	20,282	20,384	20,487	20,590	20,693	20,796	20,900	21,004	21,108
896	21,212	21,317	21,423	21,528	21,634	21,740	21,846	21,953	22,060	22,167
897	22,275	22,383	22,491	22,600	22,708	22,817	22,927	23,036	23,146	23,257
898	23,367	23,478	23,589	23,701	23,812	23,924	24,037	24,149	24,262	24,376
899	24,489	24,603	24,717	24,832	24,947	25,062	25,177	25,293	25,409	25,525
900	25,642	25,758	25,876	25,993	26,111	26,229	26,348	26,466	26,585	26,705
901	26,824	26,944	27,064	27,185	27,306	27,427	27,548	27,670	27,792	27,914
902	28,037	28,160	28,283	28,407	28,531	28,655	28,779	28,904	29,029	29,155
903	29,280	29,406	29,533	29,659	29,786	29,913	30,041	30,169	30,297	30,426
904	30,554	30,684	30,813	30,943	31,073	31,203	31,334	31,465	31,597	31,728
905	31,860									

Inks Lake

RESERVOIR VOLUME TABLE - NAVD 88 DATUM

TEXAS WATER DEVELOPMENT BOARD — April 2007 SURVEY

Conservation Pool Elevation 888.53 ft

VOLUME IN ACRE-FEET — 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
825	0	0	0	0	0	0	0	0	0	0
826	0	0	0	0	0	0	0	0	0	0
827	0	0	0	0	0	0	0	0	0	0
828	0	0	0	0	0	0	0	0	0	0
829	0	0	0	0	0	0	0	0	0	0
830	0	0	0	0	0	0	0	0	0	1
831	1	1	1	1	1	1	1	1	2	2
832	2	3	3	3	4	4	5	5	6	7
833	7	8	9	9	10	11	11	12	13	14
834	15	16	17	17	18	19	20	21	22	23
835	24	26	27	28	29	30	31	33	34	35
836	37	38	39	41	42	44	45	47	48	50
837	51	53	55	56	58	60	62	64	66	68
838	70	72	74	76	78	81	83	85	88	90
839	92	95	97	100	102	105	108	110	113	116
840	118	121	124	127	130	133	136	138	142	145
841	148	151	154	157	160	164	167	170	174	177
842	180	184	187	191	195	198	202	206	209	213
843	217	221	225	229	233	237	241	246	250	254
844	259	263	268	272	277	282	286	291	296	301
845	306	311	316	321	326	332	337	342	348	353
846	359	364	370	375	381	387	392	398	404	410
847	416	422	428	434	440	447	453	459	466	472
848	479	486	492	499	506	512	519	526	533	540
849	547	555	562	569	576	584	591	599	606	614
850	621	629	637	644	652	660	668	676	684	692
851	701	709	717	725	734	742	751	760	768	777
852	786	795	804	813	822	831	840	849	859	868
853	877	887	896	906	916	926	935	945	955	965
854	975	985	996	1,006	1,016	1,027	1,037	1,048	1,058	1,069
855	1,080	1,091	1,102	1,113	1,124	1,135	1,146	1,157	1,168	1,180
856	1,191	1,203	1,214	1,226	1,238	1,250	1,262	1,274	1,287	1,299
857	1,311	1,324	1,337	1,350	1,363	1,376	1,389	1,402	1,416	1,429
858	1,443	1,457	1,471	1,485	1,500	1,515	1,530	1,545	1,560	1,576
859	1,591	1,607	1,623	1,638	1,655	1,671	1,687	1,703	1,720	1,737
860	1,753	1,770	1,787	1,804	1,821	1,839	1,856	1,874	1,891	1,909
861	1,927	1,945	1,963	1,981	1,999	2,018	2,036	2,055	2,073	2,092
862	2,111	2,130	2,149	2,168	2,188	2,207	2,227	2,246	2,266	2,286
863	2,306	2,326	2,347	2,367	2,388	2,408	2,429	2,450	2,471	2,493
864	2,514	2,535	2,557	2,579	2,600	2,622	2,645	2,667	2,689	2,712
865	2,735	2,757	2,780	2,804	2,827	2,850	2,874	2,898	2,922	2,946
866	2,970	2,994	3,019	3,044	3,069	3,094	3,119	3,145	3,170	3,196
867	3,222	3,248	3,275	3,302	3,328	3,355	3,383	3,410	3,438	3,465
868	3,494	3,522	3,550	3,579	3,608	3,637	3,667	3,697	3,727	3,757
869	3,788	3,819	3,850	3,881	3,913	3,945	3,977	4,009	4,041	4,074
870	4,107	4,140	4,173	4,207	4,240	4,274	4,308	4,343	4,377	4,412
871	4,447	4,482	4,517	4,552	4,588	4,624	4,660	4,696	4,733	4,769
872	4,806	4,843	4,880	4,917	4,955	4,993	5,031	5,069	5,107	5,146
873	5,184	5,223	5,262	5,301	5,341	5,381	5,420	5,460	5,501	5,541
874	5,581	5,622	5,663	5,704	5,745	5,787	5,828	5,870	5,912	5,954
875	5,996	6,039	6,081	6,124	6,167	6,210	6,254	6,297	6,341	6,384
876	6,428	6,472	6,517	6,561	6,606	6,650	6,695	6,740	6,786	6,831
877	6,877	6,923	6,969	7,016	7,062	7,109	7,157	7,204	7,252	7,301
878	7,349	7,398	7,447	7,497	7,546	7,596	7,647	7,697	7,748	7,800
879	7,851	7,903	7,955	8,008	8,060	8,113	8,167	8,220	8,274	8,328
880	8,383	8,438	8,493	8,548	8,604	8,660	8,716	8,773	8,830	8,888

Inks Lake

RESERVOIR VOLUME TABLE - NAVD 88 DATUM (Cont.)

TEXAS WATER DEVELOPMENT BOARD — April 2007 SURVEY

Conservation Pool Elevation 888.53 ft

VOLUME IN ACRE-FEET — 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
881	8,945	9,003	9,061	9,120	9,179	9,238	9,297	9,357	9,417	9,477
882	9,538	9,599	9,660	9,722	9,783	9,845	9,908	9,970	10,033	10,097
883	10,160	10,224	10,288	10,352	10,416	10,481	10,546	10,612	10,677	10,743
884	10,809	10,875	10,942	11,008	11,076	11,143	11,210	11,278	11,346	11,415
885	11,483	11,552	11,621	11,690	11,760	11,830	11,900	11,970	12,040	12,111
886	12,182	12,253	12,325	12,397	12,469	12,541	12,613	12,686	12,759	12,833
887	12,906	12,980	13,054	13,129	13,204	13,280	13,355	13,432	13,509	13,586
888	13,664	13,742	13,820	13,899	13,978	14,057	14,136	14,216	14,295	14,376
889	14,456	14,537	14,618	14,700	14,781	14,863	14,946	15,029	15,112	15,195
890	15,279	15,363	15,448	15,533	15,618	15,704	15,790	15,877	15,964	16,051
891	16,139	16,227	16,315	16,404	16,493	16,583	16,673	16,763	16,854	16,945
892	17,037	17,128	17,221	17,313	17,406	17,499	17,593	17,687	17,781	17,876
893	17,971	18,066	18,162	18,258	18,354	18,451	18,548	18,645	18,743	18,841
894	18,939	19,038	19,137	19,236	19,336	19,436	19,536	19,637	19,737	19,839
895	19,940	20,042	20,144	20,246	20,349	20,452	20,556	20,659	20,763	20,867
896	20,972	21,077	21,182	21,288	21,393	21,500	21,606	21,713	21,820	21,927
897	22,035	22,142	22,251	22,359	22,468	22,577	22,686	22,796	22,906	23,016
898	23,127	23,238	23,349	23,460	23,572	23,684	23,796	23,909	24,022	24,135
899	24,249	24,363	24,477	24,591	24,706	24,821	24,937	25,052	25,168	25,285
900	25,401	25,518	25,635	25,753	25,871	25,989	26,107	26,226	26,345	26,464
901	26,584	26,704	26,824	26,945	27,065	27,186	27,308	27,430	27,552	27,674
902	27,797	27,920	28,043	28,166	28,290	28,414	28,539	28,664	28,789	28,914
903	29,040	29,166	29,292	29,419	29,546	29,673	29,801	29,929	30,057	30,185
904	30,314	30,443	30,573	30,702	30,833	30,963	31,094	31,225	31,356	31,488
905	31,620									

Inks Lake

RESERVOIR AREA TABLE - NGVD 29 DATUM

TEXAS WATER DEVELOPMENT BOARD — April 2007 SURVEY

Conservation Pool Elevation 888.22 ft

AREA IN ACRES — 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
825	0	0	0	0	0	0	0	0	0	0
826	0	0	0	0	0	0	0	0	0	0
827	0	0	0	0	0	0	0	0	0	0
828	0	0	0	0	0	0	0	0	0	0
829	0	0	0	0	0	0	0	0	0	0
830	0	0	0	0	0	0	1	1	1	1
831	1	1	1	2	2	3	3	3	4	4
832	4	5	5	5	6	6	6	6	7	7
833	7	7	8	8	8	8	8	9	9	9
834	9	10	10	10	10	10	11	11	11	11
835	12	12	12	12	13	13	13	13	14	14
836	14	14	15	15	15	16	16	16	17	17
837	18	18	18	19	19	20	20	21	21	21
838	22	22	23	23	23	24	24	24	25	25
839	25	26	26	26	27	27	27	28	28	28
840	29	29	29	30	30	30	31	31	31	32
841	32	32	33	33	33	34	34	35	35	35
842	36	36	37	37	38	38	39	39	39	40
843	40	41	42	42	43	43	44	45	45	46
844	46	47	48	48	49	49	50	50	51	51
845	52	52	52	53	53	54	54	55	55	56
846	56	57	57	58	59	59	60	60	61	61
847	62	62	63	64	64	65	65	66	66	67
848	68	68	69	69	70	70	71	71	72	72
849	73	73	74	74	75	75	76	77	77	78
850	78	79	79	80	80	81	82	82	83	83
851	84	85	85	86	87	87	88	88	89	90
852	90	91	92	92	93	94	94	95	95	96
853	97	97	98	98	99	100	101	101	102	103
854	103	104	105	105	106	107	107	108	109	109
855	110	111	111	112	113	113	114	115	116	117
856	118	119	120	122	123	124	125	126	127	128
857	129	130	132	133	134	136	137	138	140	143
858	145	147	149	150	152	153	155	156	158	159
859	160	161	162	163	165	166	167	168	169	170
860	172	173	174	175	176	177	178	179	180	181
861	182	183	184	185	186	187	188	190	191	192
862	193	194	195	196	197	199	200	201	203	204
863	205	207	208	209	210	212	213	214	215	217
864	218	219	221	222	224	225	226	228	229	231
865	232	234	235	237	239	240	242	243	245	247
866	249	251	252	254	256	258	260	262	264	265
867	267	269	271	273	275	278	280	282	284	287
868	289	292	294	297	300	303	306	308	311	313
869	315	317	319	321	323	326	328	330	332	334
870	336	338	340	342	344	346	348	350	352	354
871	356	358	360	361	363	365	367	369	371	373
872	374	376	378	380	382	384	386	388	390	392
873	394	396	397	399	401	403	404	406	408	410
874	412	413	415	417	419	421	422	424	426	427
875	429	431	432	434	435	437	438	440	442	443
876	445	447	449	450	452	455	457	459	461	464
877	466	469	472	475	478	481	484	487	490	493
878	496	499	502	505	508	512	515	518	521	524
879	526	529	532	535	538	541	544	547	550	553
880	556	559	563	566	569	572	575	578	581	584

Inks Lake

RESERVOIR AREA TABLE - NGVD 29 DATUM (Cont.)

TEXAS WATER DEVELOPMENT BOARD

April 2007 SURVEY

Conservation Pool Elevation 888.22 ft

AREA IN ACRES

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
881	587	590	593	596	599	602	605	608	611	614
882	617	620	622	625	628	631	633	636	639	641
883	644	646	649	652	654	657	659	662	664	667
884	669	672	674	677	679	682	684	687	689	692
885	694	696	699	701	704	706	708	711	713	716
886	718	721	723	726	728	731	734	737	740	743
887	747	751	755	760	768	771	774	777	779	781
888	783	785	787	789	791	793	796	799	802	805
889	808	811	814	817	820	823	827	830	833	837
890	840	844	848	851	855	859	863	867	871	875
891	879	883	887	891	894	898	902	906	909	913
892	916	920	924	927	931	934	938	941	945	948
893	952	955	958	962	965	969	972	975	979	982
894	985	988	992	995	998	1,001	1,004	1,007	1,010	1,013
895	1,017	1,020	1,023	1,026	1,029	1,032	1,035	1,038	1,041	1,044
896	1,047	1,051	1,054	1,057	1,060	1,063	1,066	1,069	1,072	1,075
897	1,078	1,080	1,083	1,086	1,089	1,092	1,095	1,098	1,101	1,104
898	1,107	1,110	1,113	1,116	1,119	1,122	1,125	1,128	1,131	1,134
899	1,137	1,140	1,143	1,146	1,149	1,152	1,155	1,158	1,161	1,164
900	1,168	1,171	1,174	1,177	1,180	1,183	1,186	1,189	1,192	1,195
901	1,198	1,201	1,204	1,207	1,210	1,213	1,216	1,219	1,222	1,225
902	1,228	1,231	1,234	1,237	1,240	1,243	1,246	1,249	1,252	1,255
903	1,259	1,262	1,265	1,268	1,271	1,274	1,277	1,281	1,284	1,287
904	1,290	1,293	1,296	1,300	1,303	1,306	1,309	1,312	1,316	1,319
905	1,322									

Inks Lake

RESERVOIR AREA TABLE - NAVD 88 DATUM

TEXAS WATER DEVELOPMENT BOARD — April 2007 SURVEY

Conservation Pool Elevation 888.53 ft

AREA IN ACRES — 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
825	0	0	0	0	0	0	0	0	0	0
826	0	0	0	0	0	0	0	0	0	0
827	0	0	0	0	0	0	0	0	0	0
828	0	0	0	0	0	0	0	0	0	0
829	0	0	0	0	0	0	0	0	0	0
830	0	0	0	0	0	0	0	0	0	1
831	1	1	1	1	1	1	2	2	3	3
832	3	4	4	4	5	5	5	6	6	6
833	6	7	7	7	7	8	8	8	8	8
834	9	9	9	9	10	10	10	10	10	11
835	11	11	11	12	12	12	12	13	13	13
836	13	14	14	14	14	15	15	15	16	16
837	16	17	17	18	18	18	19	19	20	20
838	21	21	21	22	22	23	23	23	24	24
839	24	25	25	25	26	26	26	27	27	27
840	28	28	28	29	29	29	30	30	30	31
841	31	31	32	32	32	33	33	33	34	34
842	35	35	35	36	36	37	37	38	38	39
843	39	39	40	40	41	42	42	43	43	44
844	45	45	46	46	47	47	48	48	49	49
845	50	50	51	51	52	52	53	53	54	54
846	55	55	56	56	57	57	58	58	59	60
847	60	61	61	62	62	63	64	64	65	65
848	66	66	67	67	68	69	69	70	70	71
849	71	72	72	73	73	74	74	75	75	76
850	76	77	78	78	79	79	80	80	81	81
851	82	83	83	84	85	85	86	86	87	88
852	88	89	90	90	91	92	92	93	94	94
853	95	95	96	96	97	98	98	99	100	101
854	101	102	103	103	104	105	105	106	107	107
855	108	109	109	110	110	111	112	112	113	114
856	115	116	117	118	119	120	121	123	124	125
857	126	127	128	129	130	131	133	134	135	137
858	138	140	142	145	147	149	150	152	153	155
859	156	157	159	160	161	162	163	165	166	167
860	168	169	170	171	172	174	175	176	177	178
861	179	180	181	182	183	184	185	186	187	188
862	189	191	192	193	194	195	196	197	199	200
863	201	202	204	205	206	208	209	210	212	213
864	214	215	217	218	219	221	222	224	225	226
865	228	229	231	232	234	235	237	238	240	242
866	243	245	247	249	250	252	254	256	258	260
867	262	263	265	267	269	271	273	275	277	280
868	282	284	286	289	292	294	297	300	303	305
869	308	310	313	315	317	319	321	323	325	327
870	329	331	333	335	337	339	342	344	346	348
871	350	352	354	356	358	359	361	363	365	367
872	369	371	372	374	376	378	380	382	384	386
873	388	390	392	394	395	397	399	401	403	404
874	406	408	410	411	413	415	417	418	420	422
875	424	426	427	429	430	432	434	435	437	438
876	440	442	443	445	447	448	450	452	454	456
877	459	461	463	466	469	472	475	478	481	484
878	487	490	493	496	499	502	505	508	511	514
879	517	520	523	526	529	532	535	538	540	543
880	546	550	553	556	559	562	565	569	572	575

Inks Lake

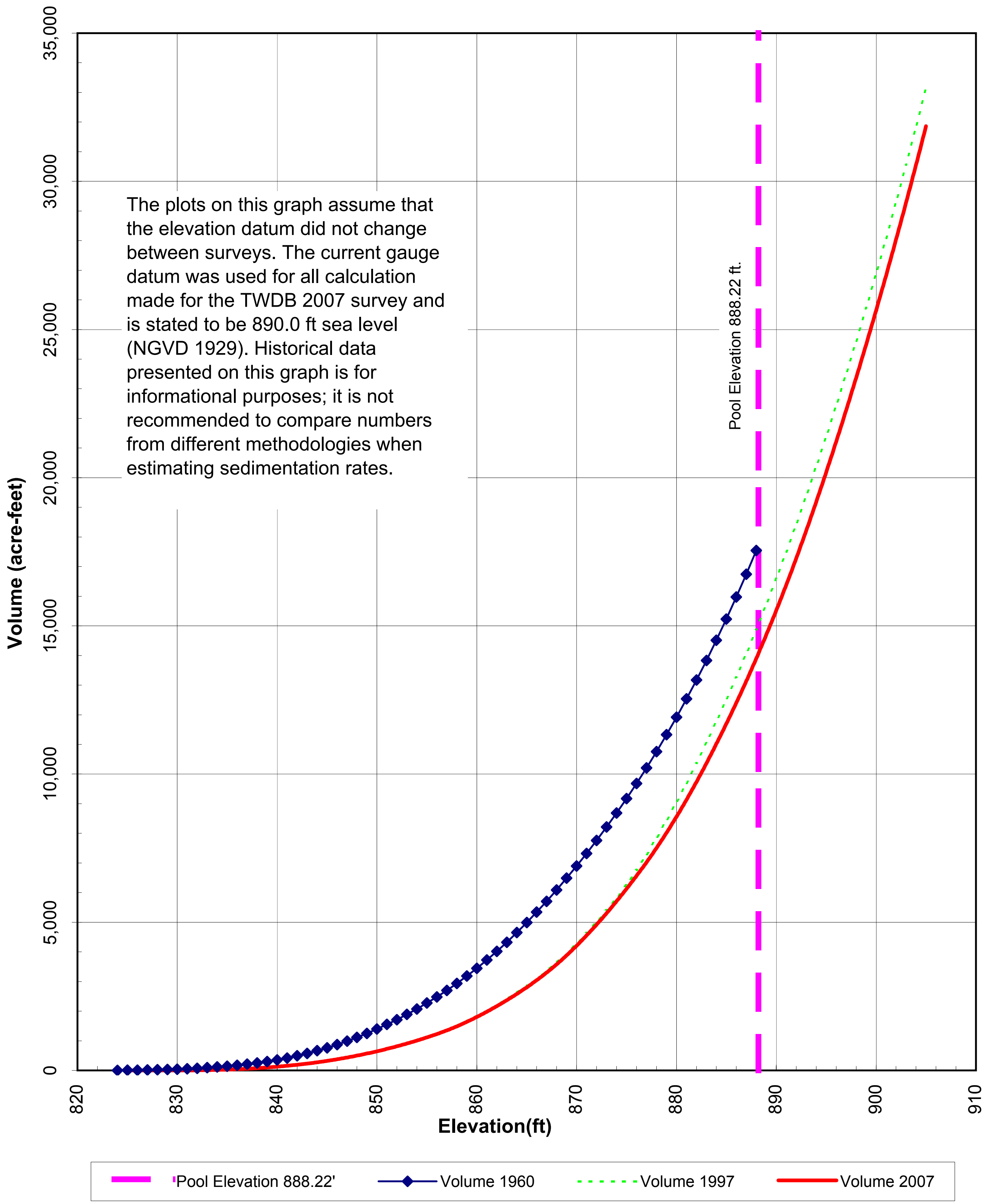
RESERVOIR AREA TABLE - NAVD 88 DATUM (Cont.)

TEXAS WATER DEVELOPMENT BOARD — April 2007 SURVEY

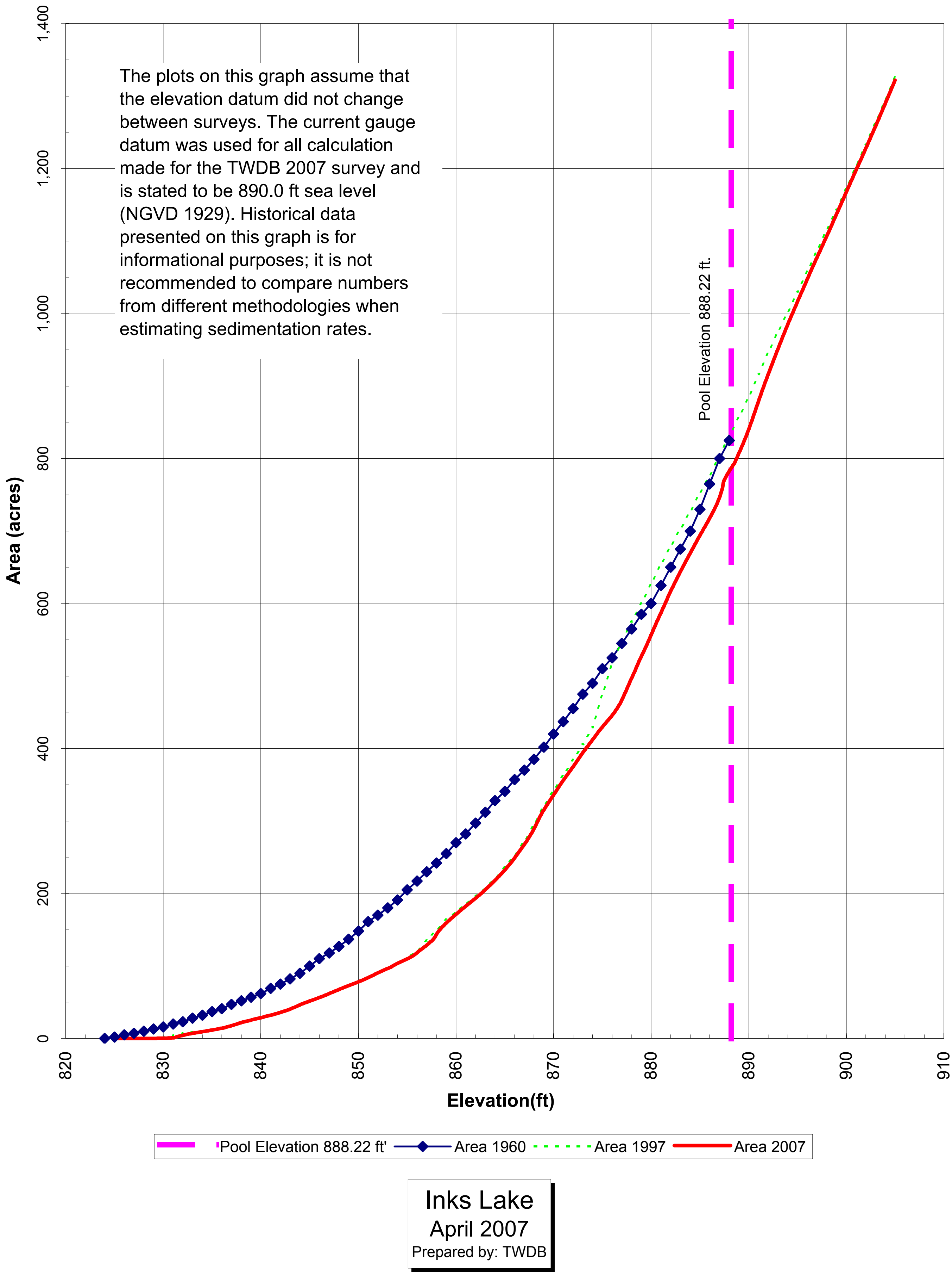
Conservation Pool Elevation 888.53 ft

AREA IN ACRES — 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
881	578	581	584	587	590	593	596	599	602	605
882	608	611	614	617	619	622	625	628	630	633
883	636	639	641	644	646	649	652	654	657	659
884	662	664	667	669	672	674	677	679	682	684
885	687	689	692	694	697	699	701	704	706	709
886	711	714	716	719	721	724	726	729	732	735
887	738	741	745	748	752	756	761	769	773	776
888	779	781	784	786	789	791	794	797	801	804
889	807	810	813	816	820	823	826	830	833	837
890	840	844	848	851	855	859	863	867	871	875
891	879	883	887	891	894	898	902	906	909	913
892	916	920	923	927	931	934	938	941	945	948
893	952	955	958	962	965	969	972	975	979	982
894	985	988	992	995	998	1,001	1,004	1,007	1,010	1,013
895	1,017	1,020	1,023	1,026	1,029	1,032	1,035	1,038	1,041	1,044
896	1,047	1,051	1,054	1,057	1,060	1,063	1,066	1,069	1,072	1,075
897	1,078	1,080	1,083	1,086	1,089	1,092	1,095	1,098	1,101	1,104
898	1,107	1,110	1,113	1,116	1,119	1,122	1,125	1,128	1,131	1,134
899	1,137	1,140	1,143	1,146	1,149	1,152	1,155	1,158	1,161	1,164
900	1,168	1,171	1,174	1,177	1,180	1,183	1,186	1,189	1,192	1,195
901	1,198	1,201	1,204	1,207	1,210	1,213	1,216	1,219	1,222	1,225
902	1,228	1,231	1,234	1,237	1,240	1,243	1,246	1,249	1,252	1,256
903	1,259	1,262	1,265	1,268	1,271	1,274	1,277	1,281	1,284	1,287
904	1,290	1,293	1,296	1,300	1,303	1,306	1,309	1,312	1,316	1,319
905	1,322									



Inks Lake
April 2007
Prepared by: TWDB



Appendix D Elevation vs. Area

Appendix E

Analysis of Sedimentation Data from Inks Lake

Executive Summary

The measured sediment volume in Inks Lake is 338 acre-feet, with most of the sediment located in the main body of the lake upstream from the dam. Sediment was measured on 64% of the lake bathymetric surface, with an average thickness of 0.7 feet. To better assess sedimentation in Inks Lake, a complete re-survey of the lake is suggested in 5-10 years or after 3 to 4 major flood events (similar to the flood events in the summer of 2007). Any re-survey should occur at a time when the water level is at or above the conservation pool elevation.

Introduction

This appendix includes the results of the sediment investigation using multi-frequency depth sounder data collected on April 13, 2007 and April 16, 2007 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 and spud-bar samples which provide independent measurements of sediment thickness. On July 30, 2007 John Dunbar Geophysical Consulting (JDGC), a subcontractor of the Board, collected seven core samples of the impoundment bottom throughout the reservoir. On April 13, 2007 TWDB recorded nine spud bar measurements. The remainder of this appendix presents a discussion of the results from and methodology used in the core sampling, spud bar sampling, and multi-frequency data collection efforts, followed by a composite analysis of sediment measured in Inks Lake. Rudimentary error estimates in the reported sediment values are also presented.

Data Collection & Processing Methodology

Bathymetric data collection for Inks Lake occurred on April 13th and April 16th of 2007, while the water surface elevation measured 887.47 and 887.32 feet, respectively. For data collection, TWDB used one boat equipped with a Specialty Devices, Inc, multi-frequency (200 kHz, 50 kHz, and 24 kHz) sub-bottom profiling depth sounder integrated with Differential Global Positioning System equipment while navigating along pre-planned range lines. The pre-planned range lines were oriented in a perpendicular fashion to the original stream channels and spaced approximately 500 feet apart. The depth sounders were calibrated each day using a velocity profiler to measure the speed of sound in the water column and a modified bar check using a weighted tape or stadia rod to verify the depth reading. During the 2007 survey, team members collected over 26,000 data points. Figure E1 shows where data points were collected during the TWDB 2007 survey. Core samples collected by John Dunbar Geophysical Consulting (JDGC) were collected at locations where sounding data had been previously collected (Figure E1). All cores were collected with a custom-coring boat and SDI Vibracorer system. Cores were analyzed by JDGC, who reported the sediment thickness sampled as well as the distance the core penetrated the pre-impoundment boundary. Spud bar measurements were collected by TWDB at all coring locations and at two other locations of interest in the lake (Figure E1). Spud bar measurements provide an estimate of sediment thickness, though less accurate than the core sample estimates.

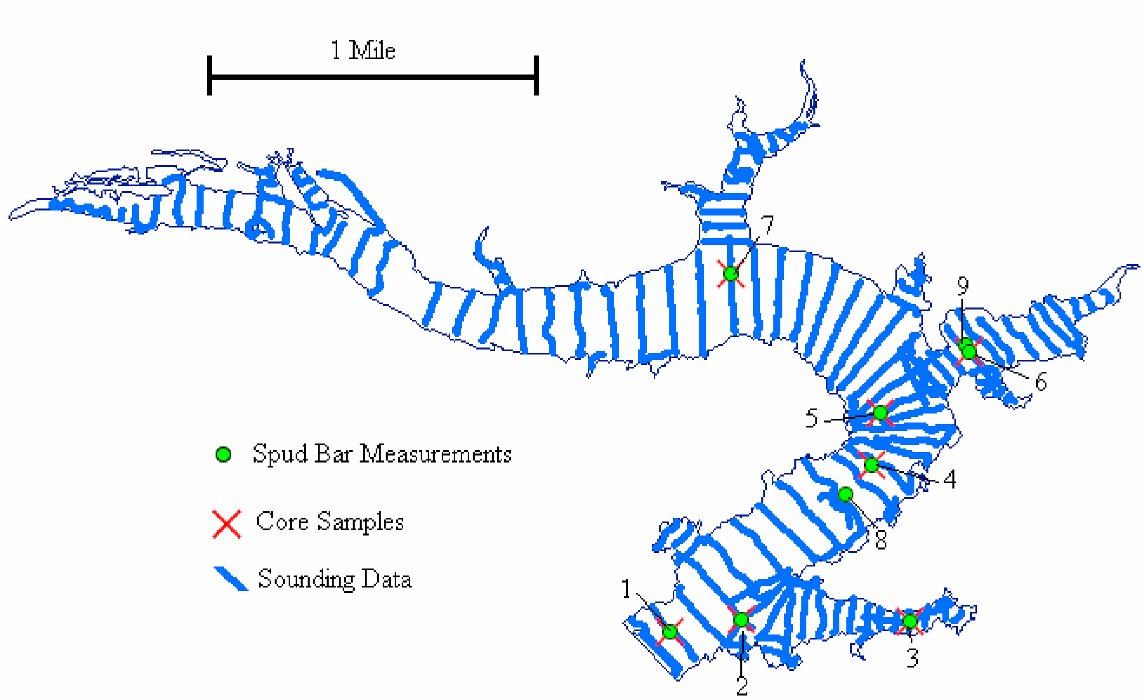


Figure E1 – Map of data collection effort for Inks Lake

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 E2 where the core sample #1 is shown with its corresponding sounding data. Core sample #1 contained 3.6 feet of sediment above the pre-impoundment bathymetry, as indicated by the yellow & green boxes, respectively, representing the core sample in Figure E2. 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.

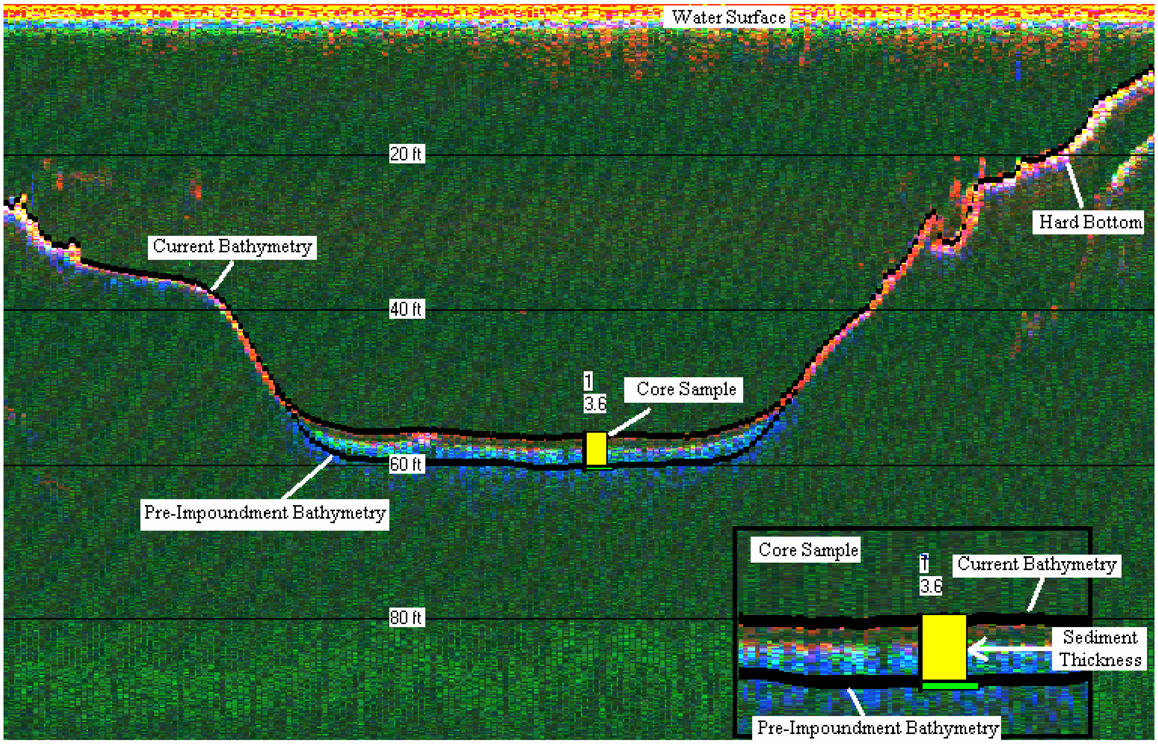


Figure E2 – DepthPic & core sample use in identifying the pre-impoundment bathymetry.

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 #1, it is clear that the pre-impoundment bathymetric surface for this cross-section may be identified as the base of the blue pixels in the DepthPic display. As the extent of the blue pixels is that of the main submerged river channel, it can be concluded that only the submerged river channel in this portion of the lake contains sediment.

Outside of the river channel in Figure E2, the DepthPic display shows stark red-white pixels immediately below the current bathymetry for most of the cross-section width. These colors correspond to sounding returns off of hard granite, as have been verified on previously sampled lakes by John Dunbar Geophysical Consulting. The blue pixels adjacent to the “Current Bathymetry” label on Figure E2 may be mistakenly considered as evidence of sediment as seen in the submerged river channel portion of the cross section. This mistake is easily identified when zooming in on the DepthPic display, where the sharp red pixel returns (indicating a hard granite/rock surface) become visible between the current surface line and the blue pixels beneath.

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.

Spud bar measurements are similar in principle to core sample measurements in that they provide a spot-indication of the sediment thickness above a pre-impoundment surface. As shown in Figure E3, a spud bar is a cylindrical metal bar with upward facing barbs. After the heavy bar is dropped into the sediment, the barbs collect the sediment as the bar is retrieved. Sediment thickness is then measured from the base of the bar upward to where the last bits of sediment are visible on the bar. This method of measuring sediment thickness assumes that 1) the spud bar penetrates the pre-impoundment boundary, 2) the pre-impoundment boundary is discernible upon inspection of the spud bar, and 3) the sediment on the spud bar is not washed away as the spud bar is retrieved. These assumptions combine to make spud bar results a less reliable form of sediment thickness measurement. The results are, however, useful in properly characterizing displayed sounding results in DepthPic, even if the thicknesses between the datasets are not exactly identical. For spud bar measurements 1-7 collected during the Inks Lake survey, the measured sediment thicknesses agreed well with the core samples collected at the same location.

Figure E3 – Sediment thickness measurements using a spud bar.

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].

Results

The total estimated volume of sediment measured during the survey is **338 acre-feet**. This value was obtained with two related methods for computing sediment volume:

1) Subtracting the current surface volume from the pre-impoundment surface volume, and
2) Computing a sediment thickness surface and volume

An explanation of the two methods is provided below. In theory, the results from each method should be identical. In practice, however, each method involves sediment volume determinations over different spatial scales, and the summations over all scales affect the computed sediment volumes. A small difference in volume between the two methods, therefore, indicates that either method of sediment volume computation is valid and provides confidence in the TIN model representation of the sediment data.

For the first method, two separate TIN models were constructed from the multi-frequency data and data interpolated using the self-similar interpolation technique[1]. The first surface was a representation of the current bathymetric bottom of the reservoir, and the second surface was an estimated pre-impoundment bottom derived from analyses of the multi-frequency data, spud bar measurements, and core samples. Each TIN model was created using the elevation 888.5 feet as the TIN model boundary (This boundary was derived from 1995 aerial photographs and is the boundary to which the self-similar interpolation routine was applied). Reservoir volumes were computed for each TIN (at elevation 888.22 feet), and subtracting the volumes yielded a sediment volume estimate of 338 acre-feet.

For the second method, a TIN model was created based on sediment thickness data, assuming a 0-feet sediment thickness at the TIN model boundary (defined as the 888.22 foot elevation contour). Sediment thickness at each sounding location was computed as the difference between the current bathymetric surface and the pre-impoundment bathymetric surface. Using the self-similar interpolation technique,[2] sediment thicknesses between measured survey lines were also computed. The sediment thickness TIN model, therefore, was created using the 888.5 foot boundary (assigned a 0-feet thickness), and both the surveyed and interpolated thickness values. The effect of this would be to invert the reservoir and pile the sediment as if on a flat plane. From this TIN model, the volume of sediment was estimated to be 338 acre-feet.

As the volumes computed from each method are identical, the TIN model representation of the sediment data is likely to be highly accurate. Figure E4 depicts the sediment thickness in Inks Lake up to the 888.22 feet contour elevation. The thickest sediment deposits occur in the main body of the reservoir approximately 2,000 feet upstream from the dam. Sediment was measured over 64% of the pre-impoundment surface, with an average sediment thickness of 0.7 feet.

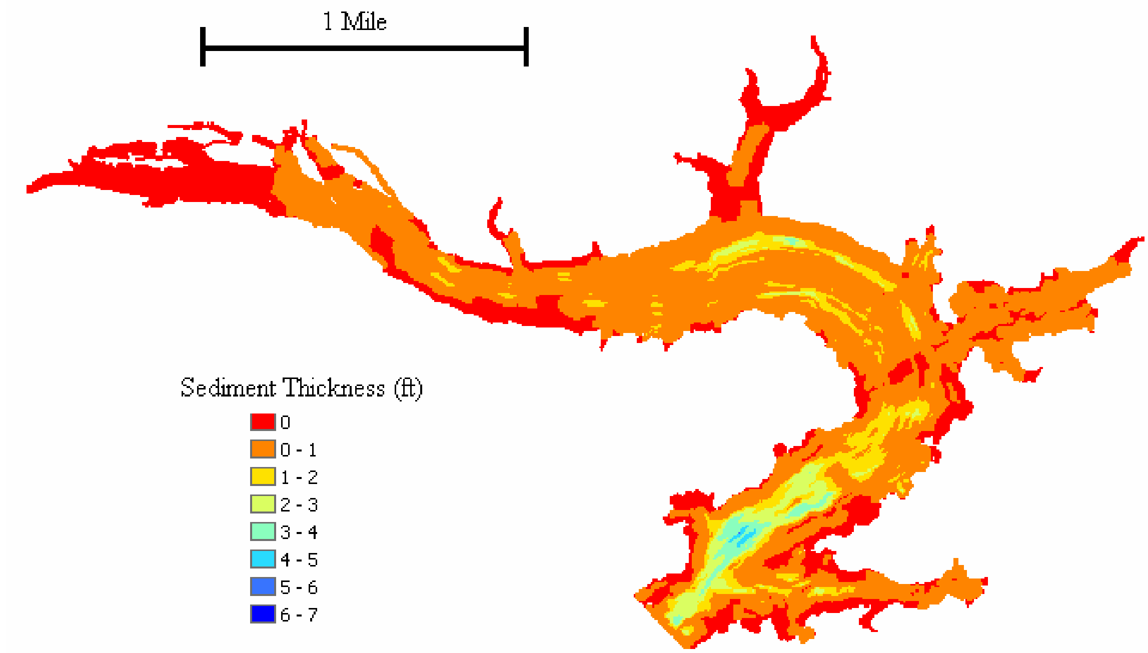


Figure E4 - Sediment Thicknesses in Inks Lake derived from multi-frequency sounding data up to the 888.5 feet elevation.

Sediment Error Estimation

To determine the possible extent by which the accumulated sediment value reported herein (338 acre-feet) may be either an underestimate or overestimate of the total accumulated sediment within Inks Lake, a sensitivity analysis was performed. In this sensitivity analysis, 6 alternative sediment thickness TIN models were created, with each model differing from the "base" model due to the addition of uniform or random adjustments of the individual measured sediment thickness values. The thickness adjustments were selected to approximate potential data interpretation errors possibly derived when processing the multi-frequency depth sounder data within the DepthPic software package. In this analysis, sediment thickness values were adjusted by up to either 0.1 feet or 0.5 feet, with the former value representing the likely error in interpretation in DepthPic and the later value (0.5 feet) representing an extreme error which is unlikely to occur. In each alternative sediment thickness dataset, the original sediment thickness value was adjusted either by one of these values or a random fraction of these values, and the adjustments could be up or down. The random adjustments are most likely to approximate the actual error in the DepthPic processing, as the signal digitizing is performed manually and errors in interpretation are not likely to be consistent. Note: sediment thickness values of “0” were left unchanged throughout this analysis, and any negative thickness values resulting from the thickness adjustments were also set to “0.” Table E1 presents the sensitivity analysis results.

Table E1: Sediment Thickness Sensitivity Analysis Results

Sediment Thickness Surface	Sediment Volume (acre-feet)	% Difference
BASE	338	N/A
BASE ± 0.1 ft (Random)	338	0.0%
BASE ± 0.5 ft (Random)	338	0.0%
BASE - 0.1 ft	307	-9.3%
BASE + 0.1 ft	370	9.5%
BASE - 0.5 ft	202	-40.2%
BASE + 0.5 ft	497	47%

As indicated in Table E1, the percentage differences in sediment volume between the BASE surface and the randomly adjusted surfaces was negligible. This provides confidence in the accuracy of the sediment volume reported herein as such random errors are expected to have occurred when processing the multi-frequency data in DepthPic. Larger percentage errors were obtained when the measured sediment thicknesses were uniformly adjusted. This result was also expected and these results should only be interpreted as unlikely error bounds to the sediment volume reported herein.

Conclusions & Recommendations

While there remains some uncertainty in the total amount of sediment, the multi-data collected during this survey indicates that a 338 acre-feet of sediment has been delivered to Inks Lake since impoundment. Figure E4 shows that the majority of sediment remains confined to the original river channel, with the thickest sediment deposits located approximately 2,000 feet upstream from the dam.

In order to improve sedimentation rate estimates for Inks Lake, TWDB recommends the following:

1. Repeat the multi-frequency survey in 5-10 years or after 3-4 large flooding events
2. Conduct the next survey at a time when the reservoir water surface elevation is at or above the 888.22 ft conservation pool elevation

Following each of these recommendations should produce a survey from which a second full assessment of Inks Lake sediment accumulation rates may be obtained. Also, comparing such a survey with the results from this survey would provide further confidence in the sediment assessment technique.

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.”

Appendix F

LiDAR Data Processing Methods

Summary

To supplement the data collected by TWDB during the 2007 volumetric and sedimentation survey of Inks Lake, LCRA provided high-resolution LiDAR data for the land areas adjacent to each of the Highland Lakes. This appendix outlines how TWDB processed the LiDAR data provided by LCRA, and describes how this data was incorporated into the TIN models used in representing the bathymetric surface of Inks Lake and its immediate surroundings.

The LCRA LiDAR data discussed herein was collected on January 2, 2007 when the approximate water surface elevation in Inks Lake was 887.4 feet above mean sea level. LiDAR points were processed in a series of steps in order to reduce the number of points used in creating bathymetric TIN models. The processing steps used in dataset reduction were:

1. Excluding any point more than 1000 ft outside the 920 ft elevation contour boundary about Inks Lake, obtained from available hypsography datasets.
2. Excluding any point with an elevation greater than elevation 920 ft, including those points within the boundaries of Lake Buchanan immediately upstream of Inks Lake.
3. Excluding any point with an elevation less than elevation 888.5 ft.
4. Removing any wayward points located in the lake interior where elevations are known not to exceed 888.5 ft. Such points were often reflections off of boat docks or other man-made structures on the water surface as identified from aerial photos.
5. Adjusting the LiDAR point elevations by -0.36 ft to convert from the NAVD88 datum to the NGVD 29 datum used by TWDB in this report. The conversion factor used herein was provided by LCRA and is only valid for use in the immediate vicinity of Inks Lake.

The resulting LiDAR dataset contained 1,896,041 data points with elevations ranging from 888.14 ft (slightly below the Inks Lake CPE) to 920 ft. TWDB soundings and interpolated points were added to the LiDAR data set in order to create the Inks Lake bathymetric TIN model. The lake boundary (digitized from aerial photos) at elevation 888.38 ft was also included in the TIN model as a hard-line.

Introduction

The LiDAR data provided by LCRA to TWDB for were used in assessing the volume of Inks Lake at elevations greater than the Inks Lake conservation pool elevation. The data were obtained in the form of LAS text files. Each file contained numerous lines of data, with each individual line containing an X coordinate, a Y coordinate, an elevation above mean sea level, and an unknown data value (This value was not readily identifiable and LCRA did not provide metadata describing this value). The X- and Y- coordinates were in the UTM Zone 14N coordinate system, and the elevation value was given in feet above mean sea level. TWDB was provided with 157 LAS files covering all of the Highland Lakes area (including the vicinity of Lakes Buchanan, Inks, LBJ, Marble Falls, and Travis), and consisting of 23.3 GB.

LIDAR Data Processing

To process the LAS text files, TWDB created the program "read_lidar.exe" using the FORTAN computer programming language and the Lahey Fujitsu Fortran (V5.6) compiler. This program performed the following operations:

1. Opened each individual LAS file and read the file contents
2. Removed any line of data that corresponded to a point more than 1000 ft outside the 920 ft contour line around Inks Lake (as defined by the 920-ft contour from available hypsography datasets, artificially closed at the Inks and Buchanan dam locations).
3. Removed any line of data with elevations less than 888.5 ft or greater than 920.0 ft.
4. Output the data in CSV format, suitable for importation as a shapefile in the ArcGIS software system.

The output was then converted into ArcGIS shapefiles and manually reviewed to assure data quality. In this step, wayward points (i.e. those with incorrectly edited coordinates) were manually removed. Points within the boundary of Inks Lake (as determined in ArcGIS using aerial photos) were reviewed and removed if determined to correspond with boat docks or other man-made structures on the lake surface. Points corresponding to visible rock outcrops were not removed. The spatial extent of the LiDAR data used in creating the Inks Lake bathymetric TIN model is shown in Figure F1. LiDAR data was used in representing 1100.4 acres about Inks Lake, with an average point density of 1 point per 25 square-ft. Due to the high resolution of the LiDAR data, small features such as road surfaces and stream channels become evident in the TIN model (Figure F2).

To create the elevation relief (Figure 5), Depth Range (Figure 6), and 10-ft contour maps (Figure 7), the Inks Lake TIN model was converted into a raster gird with elevations assigned at the centers of 1 ft x 1 ft grid cells. The raster grid was masked to elevation 888.22 ft (conservation pool elevation), with all cells containing elevations greater than this value converted to NODATA cells.

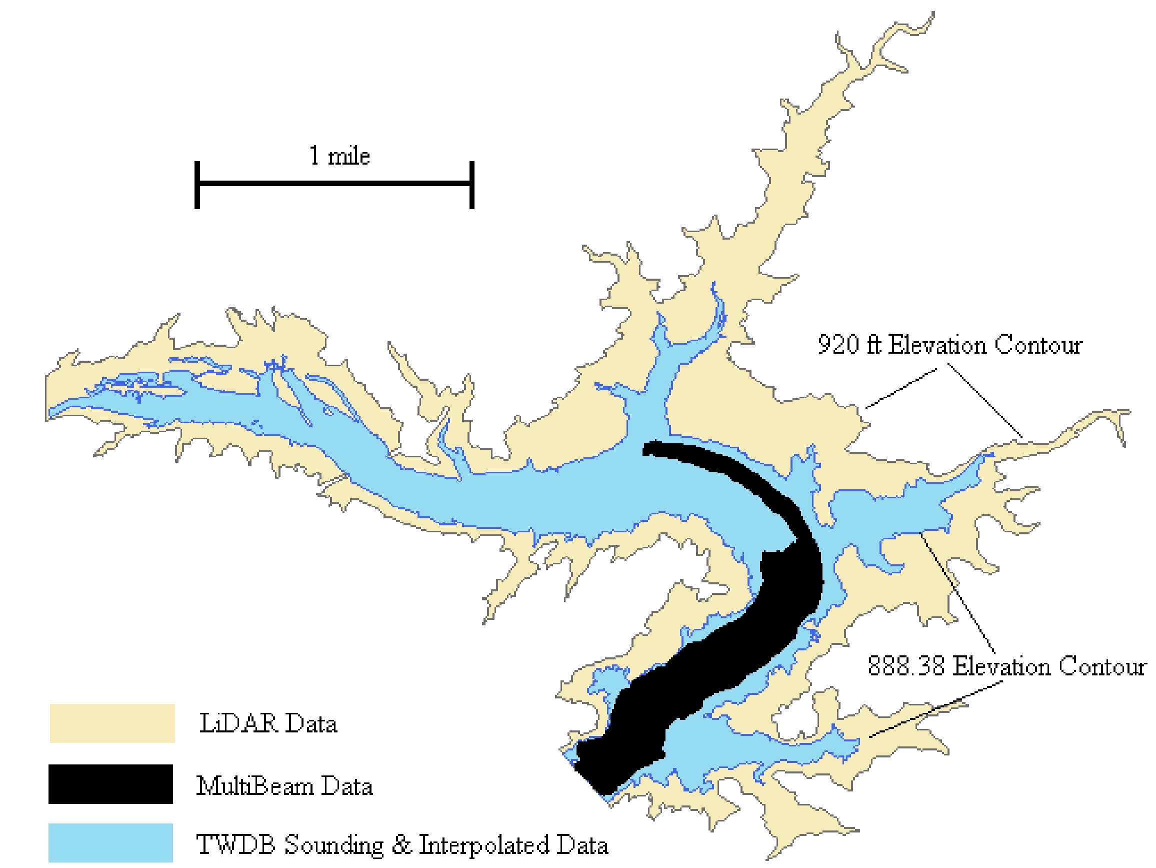


Figure F1 – Spatial extent of data used in creating the Inks Lake TIN model (Reproduced from Figure 4).

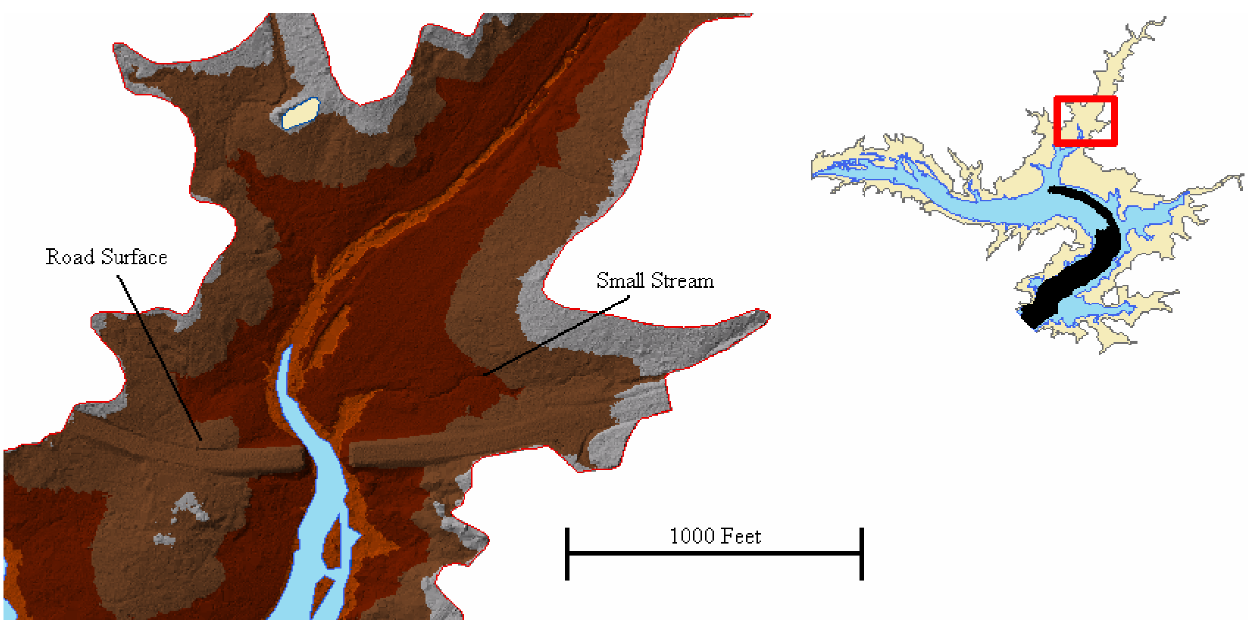


Figure F2 – TIN model of Inks Lake area derived from LiDAR data. Road surfaces and small steams are easily defined.

Figure 7

Prepared by: TEXAS WATER DEVELOPMENT BOARD APRIL 2007 SURVEY

This map is the product of a surey conducted by the Texas Water Development Board's Hydrographic Survey Program to determine the capacity of Inks Lake. The Texas Water Development Board makes no representation or assumes any liability.