Bathymetric Survey of the West Fork San Jacinto River

June 2018 Survey

Texas Water Development Board

July 2018

Texas Water Development Board

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Jeff Walker, Executive Administrator

Prepared for:

City of Houston

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Executive summary

In March 2017, the Texas Water Development Board (TWDB) entered into an agreement with the City of Houston, to perform a bathymetric survey of the West Fork San Jacinto River (Harris County, Texas). Surveying was performed using a multi-frequency (208 kHz, 50 kHz, and 24 kHz), sub-bottom profiling depth sounder; although only data collected at the 208 kHz frequency was analyzed for this report. Additional data was collected with a Trimble® R8-Model 4 Global Navigation Satellite System (GNSS) survey system to collect singular data points either from a shallow draft boat or by walking. The GNSS system is a Real Time Kinematic with differential GPS (RTK-GPS) system that utilizes a base station with multiple rovers to collect data.

The West Fork San Jacinto River bathymetric study encompasses approximately 9 miles of the river between approximately one-half miles upstream of FM 1960 to approximately one-half mile upstream of U.S. Highway 59. The data collected during this study will be included as part of a concurrent volumetric and sedimentation study of Lake Houston per an agreement with the Coastal Water Authority. Lake Houston Dam and Lake Houston are located on the San Jacinto River, approximately 18 miles northeast of downtown Houston, in Harris County, Texas. The conservation pool elevation of Lake Houston is 41.73 feet (NAVD88). Water levels in the West Fork San Jacinto River study area are dependent on Lake Houston dam operations; therefore, water surface elevations are consistent with those for Lake Houston. The TWDB collected bathymetric data for the West Fork San Jacinto River on March 20, April 3-4, May 10-11, and June 11-13, 2018, while daily average water surface elevations measured between 42.79 and 42.06 feet (NAVD88), respectively.

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

Introduction

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

In March 2017, the TWDB entered into an agreement with the City of Houston to perform a bathymetric survey of the West Fork San Jacinto River (Texas Water Development Board, 2018a). This report provides an overview of the survey methods, analysis techniques, and associated results. Also included are the following contract deliverables: (1) a shaded relief plot of the river/reservoir bottom (Figure 4), and (2) a bottom contour map (Figure 6).

West Fork San Jacinto River general information

The West Fork San Jacinto River bathymetric study encompasses approximately 9 miles of the river between approximately one-half miles upstream of FM 1960 to approximately one-half mile upstream of U.S. Highway 59. The data collected during this study will be included as part of a concurrent volumetric and sedimentation study of Lake Houston per an agreement with the Coastal Water Authority (Texas Water Development Board, 2018b). Lake Houston Dam and Lake Houston are located on the San Jacinto River, approximately 18 miles northeast of downtown Houston, in Harris County, Texas. The conservation pool elevation of Lake Houston is 41.73 feet (NAVD88). Water levels in the West Fork San Jacinto River study area are dependent on Lake Houston dam operations; therefore, water surface elevations are consistent with those for Lake Houston.

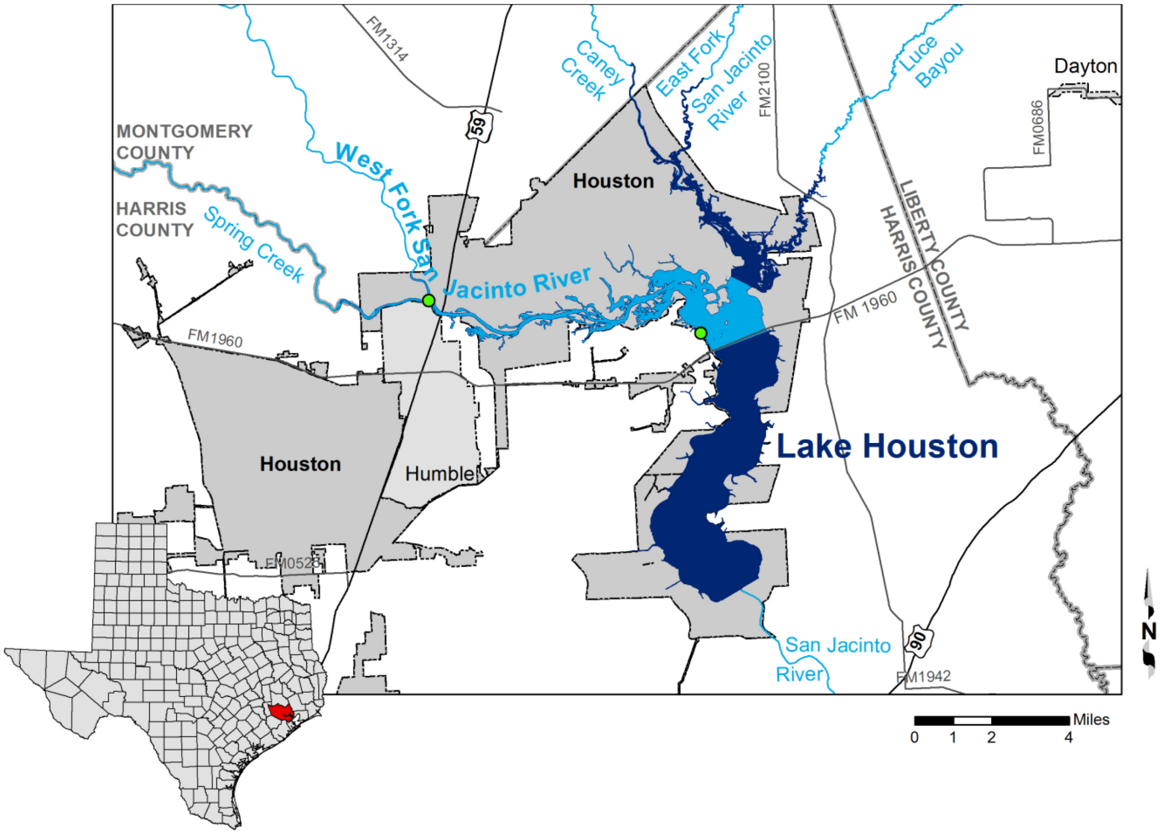


Figure 1. **Location map of the West Fork San Jacinto River study area.**

Bathymetric survey of the West Fork San Jacinto River

Datum

The vertical datum used during this survey is the North American Vertical Datum 1988 (NAVD88). This datum is also utilized by the United States Geological Survey (USGS) for the reservoir elevation gage *USGS 08072000 Lk Houston nr Sheldon, TX* (USGS, 2018). Elevations herein are reported in feet relative to the NAVD88 datum. River/reservoir bottom elevations in this report are referenced to water levels provided by the USGS gage. The horizontal datum used for this report is North American Datum 1983 (NAD83), and the horizontal coordinate system is State Plane Texas South Central Zone (feet).

TWDB bathymetric data collection

The TWDB collected bathymetric data for the West Fork San Jacinto River on March 20, April 3-4, May 10-11, and June 11-13, 2018, while daily average water surface elevations measured between 42.79 and 42.06 feet (NAVD88). For data collection, the

TWDB used a Specialty Devices, Inc. (SDI), single-beam, multi-frequency (208 kHz, 50 kHz, and 24 kHz) sub-bottom profiling depth sounder integrated with differential global positioning system (DGPS) equipment; although only data collected at the 208 kHz frequency was analyzed. Data was collected along pre-planned survey lines oriented perpendicular to the assumed location of the original river channels and spaced approximately 500 feet apart. Many of the same survey lines also were used by the TWDB for the *Volumetric and Sedimentation Survey of Lake Houston, December 2011 Survey* (Texas Water Development Board, 2013). 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.

Many areas of the river were too shallow for the depth sounder to work properly or too shallow to access by boat. For data collection in these areas, the TWDB used a Trimble® R8-Model 4 Global Navigation Satellite System (GNSS) survey system to collect singular data points either from a shallow draft boat or by walking. The GNSS system is a Real Time Kinematic with differential GPS (RTK-GPS) system that utilizes a base station with multiple rovers to collect data. Figure 2 shows the data collection locations for the 2018 TWDB survey.

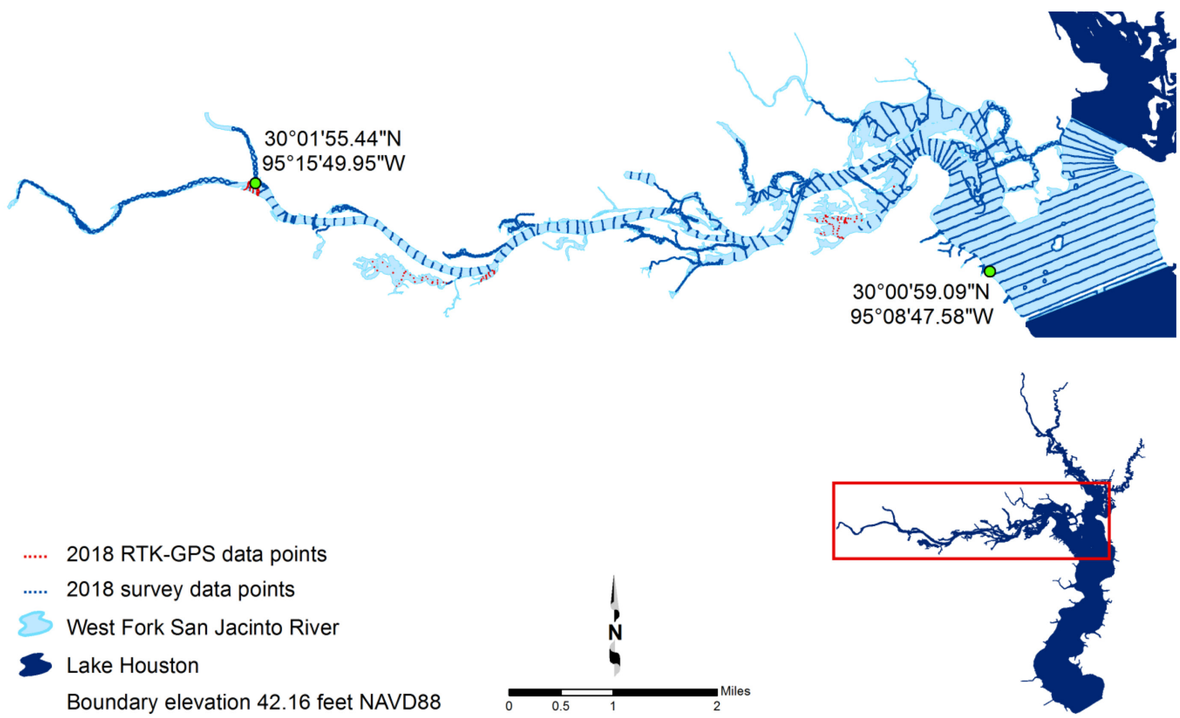


Figure 2. West Fork San Jacinto River study area coordinates (*green dots*), 2018 TWDB survey data (*blue dots*), and 2018 RTK-GPS data (*red dots*).

Data processing

Model boundary

The West Fork San Jacinto River study area's model boundary was digitized from aerial photographs, also known as digital orthophoto quarter-quadrangle images (DOQQs), obtained through the Texas Imagery Service. The Texas Natural Resources Information System manages the Texas Imagery Service allowing public organizations in the State of Texas to access Google Imagery as a service using Environmental Systems Research Institute's ArcGIS software (Texas Natural Resources Information System, 2018). The quarter-quadrangles containing the West Fork San Jacinto River are Maedan (SE) and Moonshine Hill (SW, SE). The DOQQs were photographed on October 29, 2017, while the daily average water surface elevation measured 42.16 feet (NAVD88). The DOQQs have a resolution of 6 inches (Texas Natural Resources Information System, 2018); however, Google Imagery belongs to the horizontal accuracy class for "visualization and less accurate work" (American Society for Photogrammetry and Remote Sensing, 2014). The model boundary was digitized at the land-water interface in the 2017 photographs and assigned an elevation of 42.16 feet.

RTK-GPS post-processing

Data collected using the Trimble® GPS system was downloaded from each rover's data controller (by day) and post-processed using the Trimble® Business Center (Version 4.0) software. Post-processing entails confirming project settings (e.g. vertical and horizontal datum, horizontal coordinate system) and tying the base station coordinates to Continuously Operating Reference Stations (CORS) sites to improve the precision of the project data from each rover. CORS sites are maintained by the National Geodetic Survey (NGS), an office of the National Oceanographic and Atmospheric Administration's (NOAA) National Ocean Service (National Geodetic Survey, 2014).

Triangulated Irregular Network model

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

Spatial interpolation of river/reservoir bathymetry

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

To improve the accuracy of bathymetric representation between survey lines, the TWDB developed various anisotropic spatial interpolation techniques. Generally, the directionality of interpolation at different locations of a river/reservoir can be determined from external data sources. A basic assumption is that the river/reservoir profile in the vicinity of a particular location has upstream and downstream similarity. In addition, the sinuosity and directionality of submerged stream channels can be determined by directly examining the survey data, or more robustly by examining scanned USGS 7.5 minute quadrangle maps (known as digital raster graphics), hypsography files (the vector format of USGS 7.5 minute quadrangle map contours), and historical aerial photographs, when available. Using the survey data, polygons are created to partition the river/reservoir into segments with centerlines defining directionality of interpolation within each segment. For surveys with similar spatial coverage, these interpolation definition files are, in principle, independent of the survey data and could be applied to past and future survey data of the same river/reservoir. In practice, however, minor revisions of the interpolation definition files may be needed to account for differences in spatial coverage and boundary conditions between surveys. Using the interpolation definition files and survey data, the current river/reservoir-bottom elevation is calculated for each point in the high resolution uniform grid of artificial survey points. The river/reservoir boundary, artificial survey points grid, and survey data points are used to create the TIN model representing river/reservoir bathymetry. Specific details of this interpolation technique can be found in the HydroTools manual (McEwen and others, 2011a) and in McEwen and others (2011b).

In areas inaccessible to survey via depth sounder, such as small coves and shallow upstream areas of the river/reservoir, linear interpolation is used to approximate bathymetric features. Linear interpolation follows a line linking the survey points file to the river/reservoir boundary file (McEwen and others, 2011a). Without linearly interpolated data, the TIN model does not reflect actual bathymetry. Linear interpolation produces a reasonable estimate of the bathymetry in areas where data could not be collected.

Figure 3 illustrates typical results from application of the anisotropic interpolation and linear interpolation techniques to the West Fork San Jacinto River. In Figure 3A, deeper channels and steep slopes indicated by surveyed cross-sections are not continuously represented in areas between survey cross-sections. This is an artifact of the TIN generation routine rather than an accurate representation of the physical bathymetric surface. Inclusion of interpolation points in creation of the TIN model, represented in Figure 3B, directs Delaunay triangulation to better represent the river/reservoir bathymetry between survey cross-sections. The bathymetry shown in Figure 3C illustrates the final modeled bathymetry.

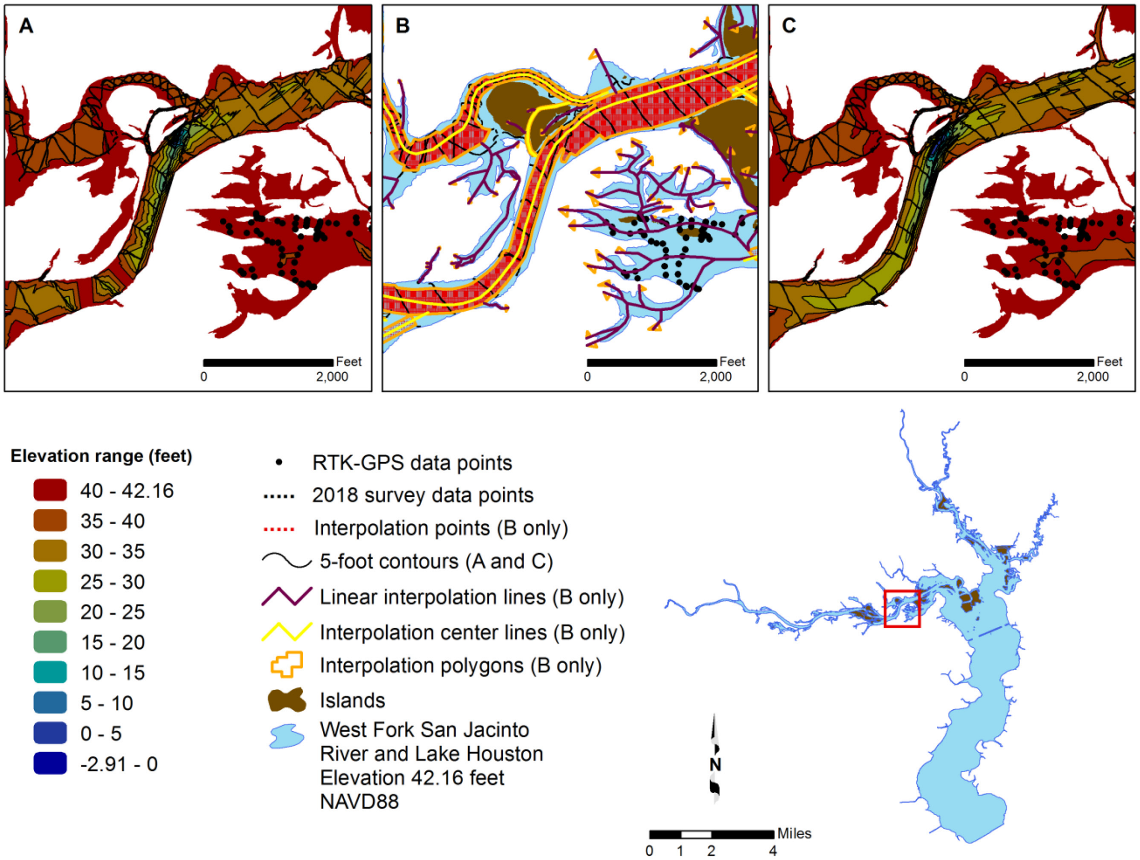


Figure 3. Anisotropic spatial interpolation and linear interpolation of the West Fork San Jacinto River sounding data; A) bathymetric contours without interpolated points, B) sounding points (*black*) and interpolated points (*red*), C) bathymetric contours with interpolated points.

Contour calculation

The TIN model is converted to a raster representation using a cell size of 2 feet by 2 feet. The raster data is then used to produce three figures: (1) an elevation relief map representing the topography of the river/reservoir bottom (Figure 4); (2) a depth range map showing shaded depth ranges for the West Fork San Jacinto River (Figure 5); and, (3) a 5-foot contour map (Figure 6).

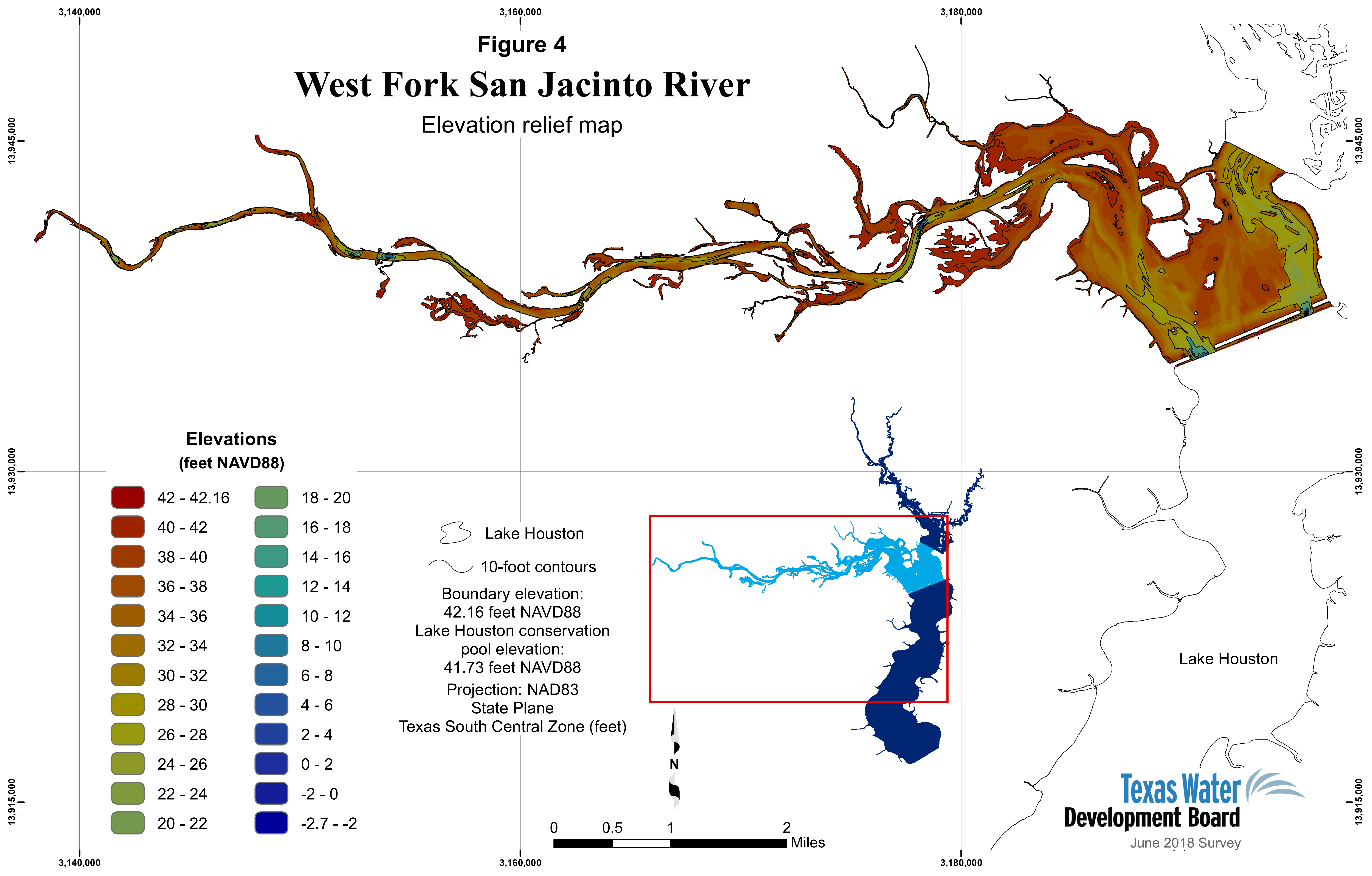
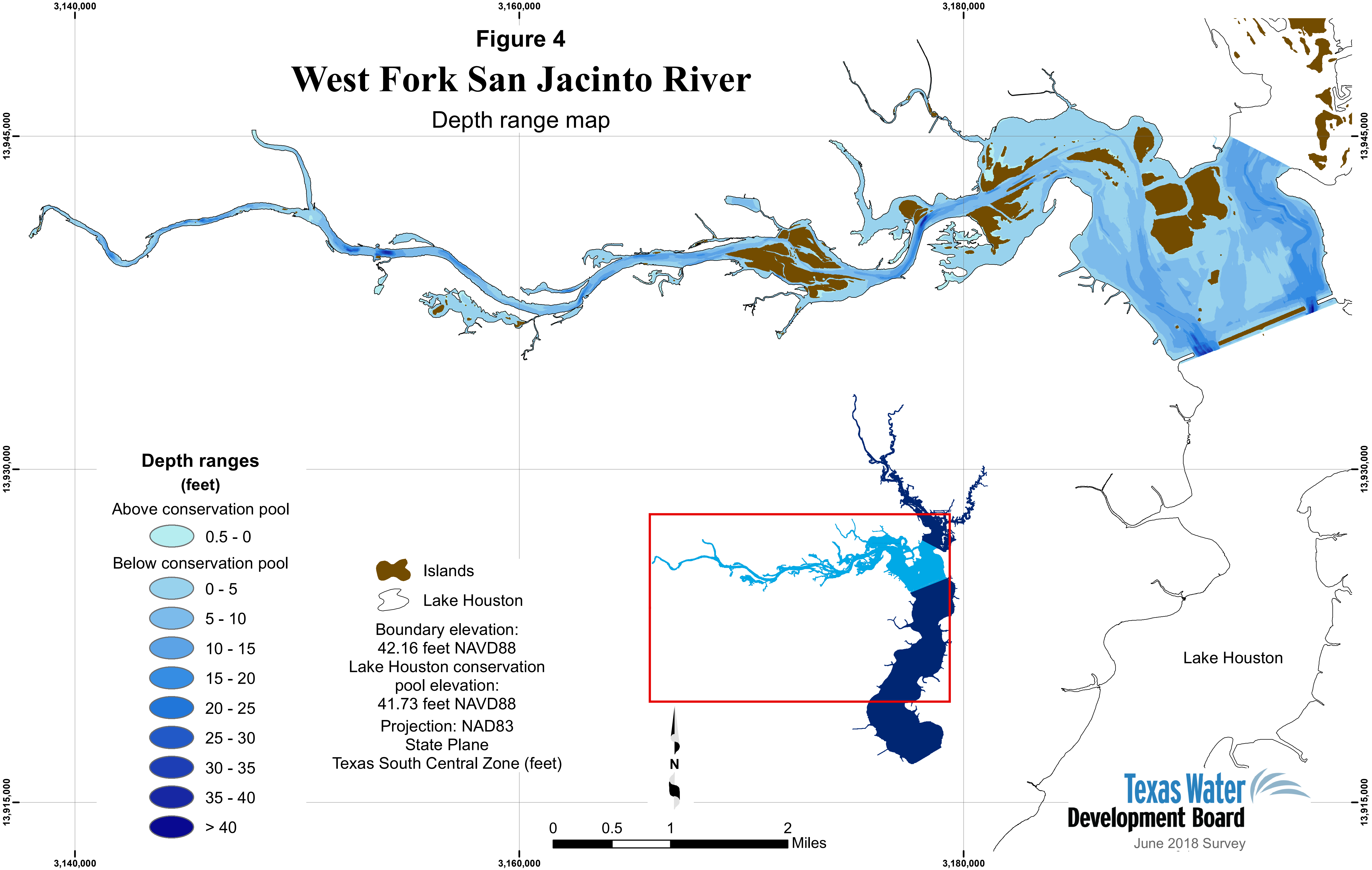


Figure 4
West Fork San Jacinto River
Elevation relief map
Elevations
(feet NAVD88)
42 - 42.16
40 - 42
38 - 40
36 - 38
34 - 36
32 - 34
30 - 32
28 - 30
26 - 28
24 - 26
22 - 24
20 - 22
18 - 20
16 - 18
14 - 16
12 - 14
10 - 12
8 - 10
6 - 8
4 - 6
2 - 4
0 - 2
-2 - 0
-2.7 - -2
Lake Houston
10-foot contours
Boundary elevation:
42.16 feet NAVD88
Lake Houston conservation
pool elevation:
41.73 feet NAVD88
Projection: NAD83
State Plane
Texas South Central Zone (feet)
N
0
0.5
1
2
Miles
Lake Houston
Texas Water
Development Board
June 2018 Survey
3,140,000
3,160,000
3,180,000
13,945,000
13,930,000
13,915,000

Figure 4

West Fork San Jacinto River

Depth range map



TWDB contact information

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

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

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

Hydrosurvey@twdb.texas.gov

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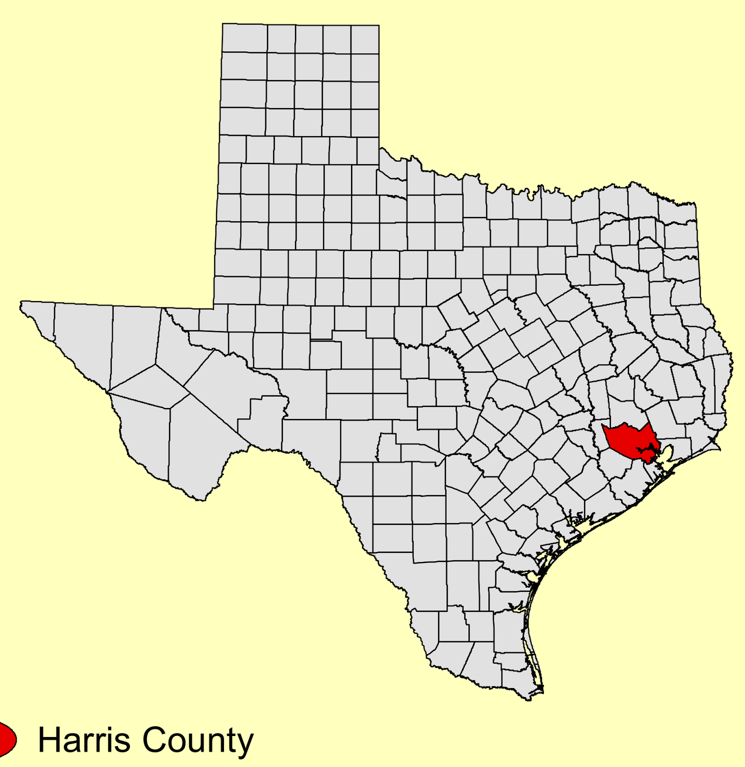
Figure 6

Contours
(feet NAVD88)

40
35
30
25
20
15
10
5
0

Islands
West Fork San Jacinto River
Lake Houston

Boundary elevation:
42.16 feet NAVD88
Conservation pool elevation:
41.73 feet NAVD88



This map is the product of a survey conducted by the Texas Water Development Board's Hydrographic Survey Program to determine the bathymetry of the West Fork San Jacinto River. The Texas Water Development Board makes no representations nor assumes any liability.