HYDROTERRA

Survey Methodology Report

March 29, 2022

State of Louisiana
Coastal Protection and Restoration Authority (CPRA)

COASTAL PROTECTION AND RESTORATION AUTHORITY
LOST LAKE MARSH CREATION AND HYDROLOGIC RESTORATION (TE-0072)

Plaquemines Parish, Louisiana

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Section 1: General Project Description

Project Overview

The Operations Division of the Louisiana Coastal Protection and Restoration Authority (CPRA) is responsible for monitoring, maintaining, and operating projects that restore, create, enhance, and maintain coastal wetlands in Louisiana. CPRA periodically evaluates orthometric heights to determine project success and ecosystem sustainability. Analysis of elevation change is a vital tool used to evaluate geomorphic alterations in coastal environmental systems because these ephemeral environments are shaped by erosional processes. This Scope of Services will provide for topographic orthometric height surveys marsh environments inside the Lost Lake Marsh Creation and Hydrologic Restoration (TE-0072) project. Specifically, previously established cross sectional transects will be resurveyed using Real Time Kinematic (RTK) methods and the Louisiana Coastal Zone (LCZ) GPS Network. All work will be surveyed using Real Time Kinematic (RTK) methods and the Louisiana Coastal Zone (LCZ) GPS Network. HydroTerra Technologies, LLC performed the tasks highlighted in the Scope of Service as highlighted in this Report.

The Lost Lake Marsh Creation and Hydrologic Restoration (TE-0072) project is located in Terrebonne Parish, southwest of the city of Houma, beginning in Bayou Decade near Lake Pagie and extending along the northern shoreline of Lost Lake as shown in **Figure1**. Approximate coordinates for the center of the project are 29°21'21.69" N and 91°01'13.59" W (NAD 83)

Vicinity Map

Figure 1

Section 2: Project Planning

Reference Systems and Project Control

Horizontal Datum (Epoch): NAD 83 Louisiana South Zone (LA-1702) US feet.

Vertical Datum (Epoch): NAVD 88 GEOID 12B US feet.

Static monuments used as a control are tied into the CPRA - Louisiana Coastal Zone (LCZ) GPS Network. HydroTerra conducted all surveying activities using the "TE-34-SM-04" benchmark, located in the vicinity of the TE-0072 project area. This benchmark was used for horizontal and vertical control. This monument was statically surveyed into the LCZ GPS network and identified by the Louisiana State Plane Coordinate System South Zone (LSZ), the North American Horizontal Datum of 1983 (NAD 83), and the North American Vertical Datum of 1988 (NAVD88). The static logs from the base setup at the designated survey control were post-processed via OPUS. Updated data sheets are provided in this document to reflect the Geoid 12B values as observed. Survey data reported in Drawing Files and Point Files reflect values relative to this described methodology.

Preparation of Survey Transects

All survey transects described in this "Report" will be converted using AutoCAD Civil 3D© to a digital format that is compatible with the surveyor(s) task-specific data collection equipment for the use of navigation and preparation.

Section 3: RTK Topographic Survey

HydroTerra performed surveys along the cross-sectional transects provided by CPRA within the Project Area by utilizing the real-time kinematic (RTK) method. Transects provided were spaced approximately every 500ft across each designated Marsh Creation Area (**Table 1**). The points along the cross section were taken at a maximum 50 feet apart unless there was an abrupt change in elevation along the transect. Abrupt changes in elevation are greater than or equal to 6 inches. Any distinctive features that were designated in the Scope of Work were labeled in the field, real-time and labeled as such while post-processing the data.

Provided examples:

- Spoil bank or Levee (Natural or manmade "hill or levee" higher than surrounding marsh)
- Crown (for S. patens marsh tops of vegetation area where plant is above "surface")
- Natural Ground Surface (area with vegetation and mostly flat)
- Mud Flat (area with NO vegetation, only visible during very low tides)
- Pond (perceived low areas where standing water was observed)

Table 1:

Name given during Construction/AsBuilt	Alias / Notes for Cell Areas
MCA 1A	Cell 1, Area along Southern shore of Bayou Decade
MCA 1B	Cell 1, Includes the LOSCO area in NE corner (No physical separation with LOSCO)
MCA 1C	Cell 1, Southern part of MCA 1B (No physical separation with 1B)
MCA 2AD	Cell 2A, Northern area of Cell2AD
MCA 2D	ILF - DNR Area, Southern part of Cell 2AD (No physical separation with Cell A)
MCA 2B East	Cell 2B East
MCA 2B West	Cell 2B West
MCA 2C	Cell 2C
MCA 3	Cell 3
MNA West	Nourishment Cell
MCA East Mud Line *	Unconfined (Area outside and South East of MCA 1B, "no dikes")
----	LOSCO area, North East corner of MCA 1B, No physical separation with 1B)

- **MCA East Mud Line – This area will NOT be surveyed.**

Equipment

Equipment to be utilized during survey:

- One (1) Trimble Survey Grade RTK System including but not limited to R-12 Receivers (Includes Base and Rover and accessories) and/or C4G Gulfnet RTK VRS calibrated to the project control.
- One (1) Fixed Height Aluminum Rod (2-meter, 8' or 10' in length) with a 6" diameter metal plate as the base of the rod.
- One (1) Closed Cabin Survey Vessel.
- One (1) Airboat

The manufacturer's specification sheets for each item can be found in **Appendix B** at the end of this document.

Methodology

Survey Control

Before the survey will began the location and verification of the survey control point provided in the Scope of Work "TE-34-SM-04" was be completed. Once the project monument was located, visually inspected for integrity, and deemed undisturbed and suitable for use, a base receiver was set on the monument. Static data was collected at the base station each day that surveys were performed and were processed with NGS-OPUS to derive updated horizontal and vertical coordinates. An additional temporary benchmark was established (011722MHB1R) to be used as additional check for the accuracy of positioning.

In lieu of using a base station, the C4G Gulfnet (http://c4g.lsu.edu/) was utilized to verify the initial horizontal and vertical positioning of "TE-34-SM-04." The Center for GeoInformatics

(C4G) at Louisiana State University is a science and technology unit focused on high precision 3-D and 4-D Earth positioning. At its heart is a state-wide infrastructure of instruments linked to the Global Positioning System (GPS) and other Global Navigational Satellite Systems (GNSS) that allows scientific and professional users to measure their exact position anywhere in Louisiana to the millimeter scale. This infrastructure is the largest university-owned and operated positioning network in the world. This state-of-the-art system, termed GULFNet, has proven scientific, practical, and legal applications that are recognized by the United States and Louisiana as the official positioning reference system within the State (R.S. 50:173.1).

Data Acquisition

Pole Soundings were recorded along transects provided by CPRA with the use of an airboat and by method of RTK pole sounding (An R12 GPS Antenna mounted on a fixed height pole with a 6-inch plate at the bottom). Transects provided were spaced approximately every 500ft across each designated Marsh Creation Area. The points along the transect were taken at a maximum 50 feet apart unless there was an abrupt change in elevation along the transect. Abrupt changes in elevation are greater than or equal to 6 inches. Any distinctive features that were designated in the Scope of Work were labeled in the field, real-time and labeled as such while post-processing the data. (Descriptions previously described) The Trimble Survey Grade RTK system has a minimum horizontal and vertical accuracy of 0.01m / 0.10 ft. as required is TS-2 5.1 (See specification sheet Appendix B).

Real Time Kinematic surveying
Single Baseline <30 km
Horizontal - 8 mm + 1 ppm RMS
Vertical - 15 mm + 1 ppm RMS

Network RTK
Horizontal - 8 mm + 0.5 ppm RMS
Vertical - 15 mm + 0.5 ppm RMS
Initialization time - typically <8 seconds
Initialization reliability - typically >99.9%

Survey transects will be provided digitally to the field surveyor(s) for acquisition of data along the transects.

Data Processing

Field Crews submitted raw data, field notes, and any additional information pertinent to the specific tasks highlighted in this Report at the end of each date of survey. Survey data was then post-processed in office by a qualified project manager/data processer. All topographic data was processed using the latest Trimble Business Center (TBC) software version to determine the quality of survey performed for each day's task. All data will be collected and processed using Geoid 12B.

All processed data will be represented visually using AutoCAD Civil 3D 2022 software for analysis. Processed data was then mapped along provided survey transect to check for any gaps or missing data. A "lines remaining" file was provided to the Field Crew to perform remaining tasks for the next survey day.

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Section 4: Deliverables

One set of deliverables shall/will follow the agency's Louisiana Sand Resources Database (LASARD)/Coastal Information Management System (CIMS) formats and naming conventions for upload to the agency's public access database. This dataset will be delivered in the horizontal datum of NAD83, LSP U.S. Feet and the vertical datum NAVD88 Feet, GEOID12B and include the *.csv files, metadata, survey cross-section and tracklines in ESRI shapefile formats. Data file formatting was provided in the Scope of Work. (See RTK Data Formats **Appendix C**)

Drawing Files:

A plan view drawing and an elevation contour drawing of each designated Survey Area was created.

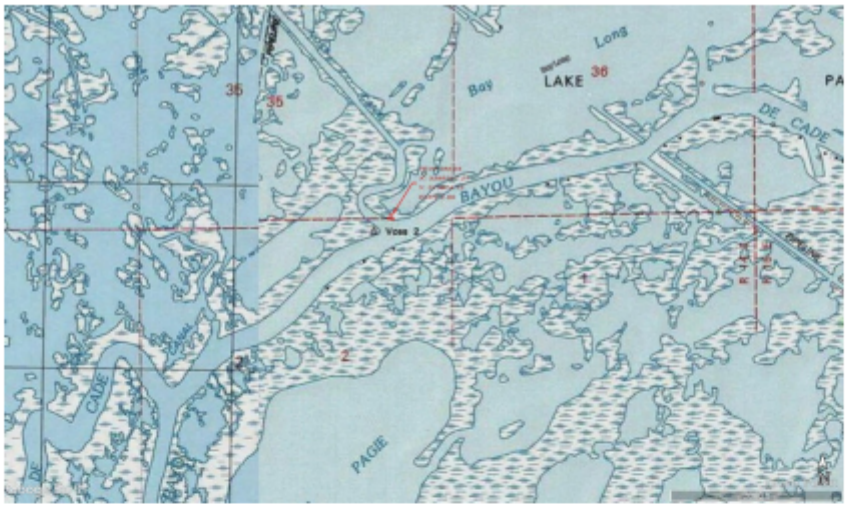
- Plan view drawing shall include a project area aerial image, the transects surveyed, the "TE34-SM-04" benchmark used to conduct the survey.
- The contour drawing will topographically illustrate the elevation contour results from the survey.
- The elevation contour drawing shall include a project area (TE-0072) image, the contour lines, and the TE34-SM-02 benchmark.

Updated Monument Data Sheets: **See Appendix A for updated sheet**

Survey Data:

The point data results shall be reported in .csv format per the CPRA LASARD data standard format and named per the LASARD file naming conventions. An Excel template file will be provided to the contracting party with the scope of work for reference in formatting, naming, and gridding. A shapefile in LASARD format with completed survey transects will also be provided in UTM NAD83 Zone15N. In addition to the Geoid12B elevations, the RTK survey data results will be provided in comma delimited text format (.csv) as specified in the Scope of Work. (See RTK Data Formats **Appendix C**) RINEX files for all Static GPS observations will be provided.

APPENDIX A: Updated Data Sheet (TE34-SM-04)



VICINITY MAP

Station Name: TE34-SM-04

Location: From the intersection of LA Hwy 3219 and Hwy 3127 south of Lagan, Louisiana, proceed westerly on Hwy 3127 for approximately 0.7 miles to the monument on the left. Located approximately 382 feet westerly of a gravel oilfield road leading south to Cut Grass Coulee Oilfield. The monument is 43.3 feet southerly from the centerline of the Highway and 25.8 feet northerly from the north edge of a canal. Permission is required for Right of Entry from Burlington Resources, POC: Jeff Deblieux at (985)853-3009 or (985)879-1517.

Description: NGS style floating sleeve monument; 9/16" stainless steel rod driven 60 feet to refusal, set in a sand-filled 6" PVC pipe with access cover set flush with the ground.

Stamping: **TE34-SM-04**

Installation Date: N/A Date of Survey: N/A

Monument Established By: N/A

NAD83 (2011) Geodetic Position:

Lat: 29°21'45.47778"N
Long: 90°59'34.13004"W

NAD83 (2011) Louisiana South Zone (1702) UsFt:

Northing: 313,874.132'
Easting: 3,389,307.291'

Adjusted NAVD88 Height (OPUS Adjusted Geoid12B):

Elevation: 2.424' (0.739m)
Ellipsoid Hgt: -23.989m

Adjusted Position Established by HydroTerra Technologies, LLC for the Coastal Protection & Restoration Authority of Louisiana

APPENDIX B

Manufacturer's Specification Sheets

DATASHEET

Trimble R12

GNSS SYSTEM

KEY FEATURES

- Next generation Trimble® ProPoint™ GNSS positioning engine. Engineered for improved accuracy and productivity in challenging GNSS conditions.
- 672-channel solution with Trimble 360 satellite tracking technology
- Trimble SurePoint™ tilt compensation and precise position capture
- Trimble xFill® correction outage technology
- Support for RTK level precision Trimble CenterPoint® RTX corrections technology
- Optimized for Trimble Access™ field software
- Android™ and iOS platform support
- Cellular, Bluetooth®, Wi-Fi data connectivity
- Military-spec rugged design and IP-67 rating
- Ergonomic form factor
- All day battery with built-in status indicator
- 6 GB internal memory

Learn more:
geospatial.trimble.com/R12

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Trimble R12 GNSS SYSTEM

HARDWARE		
PHYSICAL		
Dimensions (W×H)	11.9 cm x 13.6 cm (4.6 in x 5.4 in)	
Weight	1.12 kg (2.49 lb) with internal battery, internal radio with UHF antenna, 3.95 kg (8.71 lb) items above plus range pole, Trimble TSC7 controller & bracket	
Temperature[10]		
	Operating	–40 °C to +65 °C (–40 °F to +149 °F)
	Storage	–40 °C to +75 °C (–40 °F to +167 °F)
Humidity		100%, condensing
Ingress protection		IP67 dustproof, protected from temporary immersion to depth of 1 m (3.28 ft)
Shock and vibration (Tested and meets the following environmental standards)		
	Shock	Non operating: Designed to survive a 2 m (6.6 ft) pole drop onto concrete. Operating: to 40 G, 10 msec, sawtooth
	Vibration	MIL STD 810F, FIG.514.5C 1
ELECTRICAL		
	Power 11 to 24 V DC external power input with over voltage protection on Port 1 and Port 2 (7 pin Lemo)	
	Rechargeable, removable 7.4 V, 3.7 Ah Lithium ion smart battery with LED status indicators	
	Power consumption is 4.2 W in RTK rover mode with internal radio[11]	
Operating times on internal battery[12]		
	450 MHz receive only option	6.5 hours
	450 MHz receive/transmit option (0.5 W)	6.0 hours
	450 MHz receive/transmit option (2.0 W)	5.5 hours
	Cellular receive option	6.5 hours
COMMUNICATIONS AND DATA STORAGE		
Serial	3 wire serial (7 pin Lemo)	
USB v2.0	Supports data download and high speed communications	
Radio modem	Fully Integrated, sealed 450 MHz wide band receiver/transmitter with frequency range of 403 MHz to 473 MHz, support of Trimble, Pacific Crest, and SATEL radio protocols:	
	Transmit power	2 W
	Range	3–5 km typical / 10 km optimal[13]
Cellular[14]	Integrated, 3.5 G modem, HSDPA 7.2 Mbps (download), GPRS multi slot class 12, EDGE multi slot class 12, Penta band UMTS/HSDPA (WCDMA/FDD) 800/850/900/1900/2100 MHz, Quad band EGSM 850/900/1800/1900 MHz, GSM CSD, 3GPP LTE	
Bluetooth	Version 4.1[15]	
Wi Fi	802.11 b,g, access point and client mode, WPA/WPA2/WEP64/WEP128 encryption	
I/O ports	Serial, USB, TCP/IP, IBSS/NTRIP, Bluetooth	
Data storage	6 GB internal memory	
Data format	CMR+, CMRx, RTCM 2.1, RTCM 2.3, RTCM 3.0, RTCM 3.1, RTCM 3.2 input and output	
	24 NMEA outputs, GSOF, RT17 and RT27 outputs, 1 PPS output	
WEBUI		
	Offers simple configuration, operation, status, and data transfer	
	Accessible via Wi Fi, Serial, USB, and Bluetooth	
SUPPORTED CONTROLLERS & FIELD SOFTWARE		
	Trimble TSC7, Trimble T10, Trimble T7, Android and iOS devices running supported apps	
	Trimble Access 2019.10 or later	
CERTIFICATIONS		
	FCC Part 15 (Class B device), 24, 32; CE Mark; RCM; PTCRB; BT SIG	

Trimble.

DATASHEET

PERFORMANCE SPECIFICATIONS		
GNSS MEASUREMENTS		
	Constellation agnostic, flexible signal tracking and improved positioning[1] in challenging environments with Trimble ProPoint GNSS technology	
	Increased measurement productivity and traceability with Trimble SurePoint eBubble tilt compensation	
	Advanced Trimble Custom Survey GNSS chips with 672 channels	
	Reduced downtime due to loss of radio signal or cellular connectivity with Trimble xFill technology	
	Signals tracked simultaneously	GPS: L1C, L1C/A, L2C, L2E, L5 GLONASS: L1C/A, L1P, L2C/A, L2P, L3 SBAS (WAAS, EGNOS, GAGAN, MSAS): L1C/A, L5 Galileo: E1, E5A, E5B, E5 AltBOC, E6[2] BeiDou: B1, B1C, B2, B2A, B3 QZSS: L1C/A, L1S, L1C, L2C, L5, L6 NavIC (IRNSS): L5 L band: CenterPoint RTX
	Iridium filtering above 1616 MHz allows antenna to be used up to 20 m away from iridium transmitter	
	Japanese LTE filtering below 1510 MHz allows antenna to be used up to 100 m away from Japanese LTE cell tower	
	Digital Signal Processor (DSP) techniques to detect and recover from spoofed GNSS signals	
	Advanced Receiver Autonomous Integrity Monitoring (RAIM) algorithm to detect and reject problem satellite measurements to improve position quality Improved protection from erroneous ephemeris data	
	Positioning Rates	1 Hz, 2 Hz, 5 Hz, 10 Hz, and 20 Hz
POSITIONING PERFORMANCE[3]		
CODE DIFFERENTIAL GNSS POSITIONING		
	Horizontal	0.25 m + 1 ppm RMS
	Vertical	0.50 m + 1 ppm RMS
	SBAS[4]	typically <5 m 3DRMS
STATIC GNSS SURVEYING		
High-Precision Static		
	Horizontal	3 mm + 0.1 ppm RMS
	Vertical	3.5 mm + 0.4 ppm RMS
Static and Fast Static		
	Horizontal	3 mm + 0.5 ppm RMS
	Vertical	5 mm + 0.5 ppm RMS
REAL TIME KINEMATIC SURVEYING		
Single Baseline <30 km		
	Horizontal	8 mm + 1 ppm RMS
	Vertical	15 mm + 1 ppm RMS
Network RTK[5]		
	Horizontal	8 mm + 0.5 ppm RMS
	Vertical	15 mm + 0.5 ppm RMS
RTK start-up time for specified precisions[6]		2 to 8 seconds
TRIMBLE RTX™ TECHNOLOGY (SATELLITE AND CELLULAR/INTERNET (IP))		
CenterPoint RTX[7]		
	Horizontal	2 cm RMS
	Vertical	5 cm RMS
	RTX convergence time for specified precisions Worldwide	< 15 min
	RTX QuickStart convergence time for specified precisions	< 1 min
	RTX convergence time for specified precisions in select regions (Trimble RTX Fast Regions)	< 1 min
TRIMBLE XFILL[8]		
	Horizontal	RTK[9] + 10 mm/minute RMS
	Vertical	RTK[9] + 20 mm/minute RMS

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Trimble R12 GNSS SYSTEM

1 Challenging GNSS environments are locations where the receiver has sufficient satellite availability to achieve minimum accuracy requirements, but where the signal may be partly obstructed by and/or reflected off of trees, buildings, and other objects. Actual results may vary based on user's geographic location and atmospheric activity, scintillation levels, GNSS constellation health and availability, and level of multipath and signal occlusion.
2 The current capability in the receivers is based on publicly available information. As such, Trimble cannot guarantee that these receivers will be fully compatible with a future generation of Galileo satellites or signals.
3 Precision and reliability may be subject to anomalies due to multipath, obstructions, satellite geometry, and atmospheric conditions. The specifications stated recommend the use of stable mounts in an open sky view, EMI and multipath clean environment, optimal GNSS constellation configurations, along with the use of survey practices that are generally accepted for performing the highest order surveys for the applicable application including occupation times appropriate for baseline length. Baselines longer than 30 km require precise ephemeris and occupations up to 24 hours may be required to achieve the high precision static specification.
4 Depends on SBAS system performance.
5 Network RTK PPM values are referenced to the closest physical base station.
6 May be affected by atmospheric conditions, signal multipath, obstructions and satellite geometry. Initialization reliability is continuously monitored to ensure highest quality.
7 RMS performance based on repeatable in field measurements. Achievable accuracy and initialization time may vary based on type and capability of receiver and antenna, user's geographic location and atmospheric activity, scintillation levels, GNSS constellation health and availability and level of multipath including obstructions such as large trees and buildings.
8 Accuracies are dependent on GNSS satellite availability. xFill positioning without a Trimble CenterPoint RTX subscription ends after 5 minutes of radio downtime. xFill positioning with a CenterPoint RTX subscription will continue beyond 5 minutes providing the Trimble RTX solution has converged, with typical precisions not exceeding 6 cm horizontal, 14 cm vertical or 3 cm horizontal, 7 cm vertical in Trimble RTX Fast regions. xFill is not available in all regions, check with your local sales representative for more information.
9 RTK refers to the last reported precision before the correction source was lost and xFill started.
10 Receiver will operate normally to –40 °C, internal batteries are rated from –20 °C to +60 °C (ambient +50 °C).
11 Tracking GPS, GLONASS and SBAS satellites.
12 Varies with temperature and wireless data rate. When using a receiver and internal radio in the transmit mode, it is recommended that an external 6 Ah or higher battery is used.
13 Varies with terrain and operating conditions.
14 Due to local regulations, the integrated cellular modem cannot be enabled in China, Taiwan, or Brazil. A Trimble controller integrated cellular modem or external cellular modem can be used to obtain GNSS corrections via an IP (Internet Protocol) connection.
15 Bluetooth type approvals are country specific.

Specifications subject to change without notice.

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Bluetooth

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ENABLING FIELD TO FINISH WORKFLOWS WITH CONFIDENCE

Harness the power of geospatial data reliably. Trimble® Business Center enables you to efficiently edit, process, adjust and create deliverables with confidence.

Complete Software Solution

Comprehensive workflows for Survey, GIS, and specialist service providers creating deliverables from traditional data types or expanding to the latest point cloud and imagery data from terrestrial, mobile and aerial sensors. One software does it all: eliminating historically disjointed workflows, supporting the needs and flexibility of multi-disciplined businesses and reducing costs of software purchases and training.

Data Integration

Combine data from GNSS, total stations, and levels to achieve the most accurate horizontal and vertical results. Enhance visualization and data richness with points clouds, imagery, BIM and CAD models as well as PDFs to create the ultimate in complete project deliverables. Market leading data integration allows users to easily adopt new sensor technology to respond to evolving customer needs.

Confidence Inspiring Results

TBC is loaded with all the necessary tools to control, manage and check your data – ensuring the most accurate and precise results. Don't put up with fragmented data sets or questionable data that causes costly mistakes and jeopardizes your business reputation. TBC provides the confidence to ensure every project is correct.

Rich Deliverables

TBC enables you to deliver a multitude of application based deliverables such as QA reports, surfaces, CAD plans and complex alignment/corridor designs. Strong partnerships with major CAD and GIS packages ensure that data transactions with TBC are seamless and highly productive.

Key Features

A customizable user interface enhances the Trimble Business Center experience. For users who wish to maximize their efficiency, the Trimble Business Center ribbon interface makes functions easy to find and understand.

- Add frequently used functions to the quick access toolbar
- Create ribbon tabs with streamlined workflows
- Specify any website as the start page

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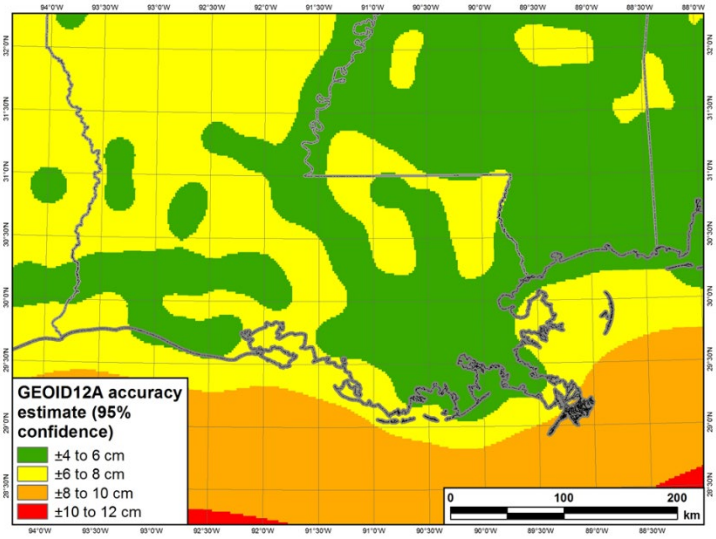
C4G Gulfnet

The Center for GeoInformatics (C4G) at Louisiana State University is a science and technology unit focused on high precision 3-D and 4-D Earth positioning. At its heart is a state-wide infrastructure of instruments linked to the Global Positioning System (GPS) and other Global Navigational Satellite Systems (GNSS) that allows scientific and professional users to measure their exact position anywhere in Louisiana to the millimeter scale. This infrastructure is the largest university-owned and operated positioning network in the world. This state-of-the-art system, termed GULFNet, has proven scientific, practical, and legal applications that are recognized by the United States and Louisiana as the official positioning reference system within the State (R.S. 50:173.1).

GULFNet was established as a statewide network of Continuously Operating Reference Stations (CORS), 31 of which are currently recognized National CORS that tie Louisiana into the National Spatial Reference System (NSRS), defined and managed by the National Geodetic Survey (NGS) @NOAA. The NSRS is a consistent national coordinate system that specifies latitude, longitude, height, scale, gravity, and orientation throughout the nation, as well as showing how these values change with time. C4G provides raw data hourly from all of its GULFNet CORS, free of charge to the public. The NGS also redistributes raw data from each of the 31 C4G GULFNet sites that they have accepted into their NSRS CORS program. Long-term data collection from an analysis of the data collected by the GULFNet CORS infrastructure is used to improve modeling of weather, geoids, storm surge, flooding, subsidence and other scientific models as well as Height Modernization efforts along the entire Northern Gulf Coast.



The NGS stated that the current geoid model produces only 95% confidence at ± 4 to 8 cm in Louisiana, they concluded that the geoid problem in Louisiana is too large for NGS to handle alone and only by feeding well-distributed vertical control data into future GEOID models will we be able to improve the accuracy of future GEOID models. In 2013 C4G started actively pursuing the funding necessary to do the terrestrial gravity surveys and control work needed to create better GEOID models in Louisiana. Through funding from Height Modernization and Board of Regent grants, C4G acquired two relative gravity meters and then self-funded an absolute gravity meter with the intention of capturing the data needed to feed future GEOID models and help NGS reach their 2 cm GRAV-D goals in Louisiana.

One non-positioning related scientific modeling application of the data collected by GULFNet is the way NOAA's Earth System Research Laboratory (ESRL) uses raw GPS data to improve weather forecasts and climate monitoring. Much of the error or noise in GPS data is caused by water vapor that slows and bends GPS radio signals as they pass through the Earth's lower atmosphere. The operational use of this new and heretofore unavailable water vapor information by the National Centers for Environmental Prediction has resulted in substantial improvement in the accuracy of U.S. weather forecasts in recent years.

The GULFNet infrastructure is currently the backbone for surveying in Louisiana, as well as supporting all GIS development, detailed topographic mapping, precision farming, navigation, and other location-based applications. To sustain the GULFNet infrastructure and help clients access the NSRS easier, C4G created C4GNet, which is a Real-Time Network featuring value-added services. C4G makes C4GNet services available by subscription to those in three different fields, surveying, agriculture and GIS/Mapping.

C4G researchers use these systems in their research focusing on identifying the location of subsidence and measuring how fast the coast is sinking from place to place. Subsidence in Louisiana makes the roads more likely to flood. C4G's efforts in Height Modernization help to predict how much flooding specific areas will experience before a storm even begins. Accurate heights alert safety planners to storm evacuation routes that are slowly sinking and susceptible to storm surges.

Committed to making transportation and navigation safer, C4G assists NGS in conducting aerial photography surveys and elevation surveys of Hurricane Evacuation routes. C4G also assists NGS in mapping the coastal regions of Louisiana and provides data for navigational charts. Accurate heights also provide ships with safe under-keel and overhead clearance to avoid dangerous collisions. Data from this infrastructure also provides the needed information to support present and future coastal restoration efforts.

The primary scientific research pursued by the Center is concentrated on monitoring and modeling land subsidence across the Louisiana coast, as well as neighboring sites in Texas, Mississippi, Alabama, Florida and an offshore platform in the Gulf of Mexico. This research is broadening our understanding of the physics that explain subsidence along the Gulf Coast. By virtue of its unique geology, geography, and cultural heritage, Louisiana represents one of the most rewarding and worthwhile "natural laboratories" for subsidence research in the world. The Center provides the technological, intellectual, and practical leadership for contemporary subsidence research in Louisiana.

APPENDIX C

RTK Data Formats

(Sheets 19-20 Scope of Work)

Table 1. Example spreadsheet showing required survey data formats for State Plane Coordinates.

Date	Point_num	X_LSP1702_ft	Y_LSP1702_ft	Z_NAVD88_GEOID12A_ft	Description	Station	Benchmark_ID
4/5/2016	1	3564559.770	181331.470	-37.55	BOTTOM	T-1	BICM2-MPH-04
4/5/2016	2	3564559.980	181332.520	-37.55	BOTTOM	T-1	BICM2-MPH-04
4/5/2016	3	3564560.070	181333.020	-37.54	BOTTOM	T-1	BICM2-MPH-04
4/5/2016	4	3564560.210	181333.900	-37.54	BOTTOM	T-1	BICM2-MPH-04
4/5/2016	5	3564560.390	181334.950	-37.54	BOTTOM	T-1	BICM2-MPH-04
4/5/2016	6	3564560.650	181336.280	-37.43	BOTTOM	T-1	BICM2-MPH-04
4/5/2016	7	3564560.760	181336.830	-37.43	BOTTOM	T-1	BICM2-MPH-04
4/5/2016	8	3564560.970	181337.770	-37.43	BOTTOM	T-1	BICM2-MPH-04
4/5/2016	9	3564561.170	181338.630	-37.42	BOTTOM	T-1	BICM2-MPH-04
4/5/2016	10	3564561.300	181339.170	-37.42	BOTTOM	T-1	BICM2-MPH-04
4/5/2016	11	3564561.530	181340.110	-37.42	BOTTOM	T-1	BICM2-MPH-04
4/5/2016	12	3564561.740	181340.960	-37.42	BOTTOM	T-1	BICM2-MPH-04
4/5/2016	13	3564561.880	181341.530	-37.43	BOTTOM	T-1	BICM2-MPH-04
4/5/2016	14	3564562.120	181342.480	-37.53	BOTTOM	T-1	BICM2-MPH-04
4/5/2016	15	3564562.330	181343.360	-37.43	BOTTOM	T-1	BICM2-MPH-04
4/5/2016	16	3564562.480	181343.930	-37.43	BOTTOM	T-1	BICM2-MPH-04
4/5/2016	17	3564562.730	181344.890	-37.54	BOTTOM	T-1	BICM2-MPH-04
4/5/2016	18	3564562.990	181345.780	-37.54	BOTTOM	T-1	BICM2-MPH-04
4/5/2016	19	3564563.160	181346.340	-37.64	BOTTOM	T-1	BICM2-MPH-04
4/5/2016	20	3564563.300	181346.830	-37.64	BOTTOM	T-1	BICM2-MPH-04
4/5/2016	21	3564563.450	181347.320	-37.64	BOTTOM	T-1	BICM2-MPH-04
4/5/2016	22	3564563.590	181347.810	-37.74	BOTTOM	T-1	BICM2-MPH-04
4/5/2016	23	3564563.880	181348.790	-37.64	BOTTOM	T-1	BICM2-MPH-04
4/5/2016	24	3564564.020	181349.280	-37.64	BOTTOM	T-1	BICM2-MPH-04
4/5/2016	25	3564564.160	181349.780	-37.54	BOTTOM	T-1	BICM2-MPH-04
4/5/2016	26	3564564.390	181350.670	-37.74	BOTTOM	T-1	BICM2-MPH-04
4/5/2016	27	3564564.540	181351.260	-37.74	BOTTOM	T-1	BICM2-MPH-04
4/5/2016	28	3564564.660	181351.750	-37.63	BOTTOM	T-1	BICM2-MPH-04
4/5/2016	29	3564564.760	181352.240	-37.63	BOTTOM	T-1	BICM2-MPH-04
4/5/2016	30	3564564.960	181353.150	-37.53	BOTTOM	T-1	BICM2-MPH-04

Where

Date (MM/DD/YYYY) is the date the point was collected,
Point_num is the Survey Point Number,
X_LSP1702_ft is the easting coordinate in State Plane, NAD83 – LA South 1702 in Feet,
Y_LSP1702_ft is the northing coordinate in State Plane, NAD83 – LA South 1702 in **Feet,**
Z_NAVD88_GEOID12A_ft is the orthometric height at a specific coordinate referenced to the NAVD88 and the Geoid12A Model – in Feet,
Description describes the location where the point was taken,
Station is the Transect Number (T-1 to T-10; S-1 to S-7; M-1 to M-10),, and
Benchmark_ID is the name of the benchmark referenced during the survey.

(RTK Data Format Cont.)

Table 2. Example spreadsheet showing required survey data formats for Universal Transverse Mercator Coordinates.

Date	Point_num	Easting_utm15N_m	Northing_utm15N_m	Elevation_NAVD88_GEOID12A_m	Description	Station	Benchmark_ID	Ellp_hgt_m
4/5/2016	1	748823.611	3210185.447	-11.45	BOTTOM	T-1	BICM2-MPH-04	-35.086
4/5/2016	2	748823.670	3210185.768	-11.45	BOTTOM	T-1	BICM2-MPH-04	-35.086
4/5/2016	3	748823.695	3210185.921	-11.44	BOTTOM	T-1	BICM2-MPH-04	-35.083
4/5/2016	4	748823.734	3210186.190	-11.44	BOTTOM	T-1	BICM2-MPH-04	-35.083
4/5/2016	5	748823.785	3210186.511	-11.44	BOTTOM	T-1	BICM2-MPH-04	-35.083
4/5/2016	6	748823.858	3210186.917	-11.41	BOTTOM	T-1	BICM2-MPH-04	-35.049
4/5/2016	7	748823.890	3210187.086	-11.41	BOTTOM	T-1	BICM2-MPH-04	-35.049
4/5/2016	8	748823.950	3210187.373	-11.41	BOTTOM	T-1	BICM2-MPH-04	-35.049
4/5/2016	9	748824.007	3210187.636	-11.41	BOTTOM	T-1	BICM2-MPH-04	-35.046
4/5/2016	10	748824.044	3210187.801	-11.41	BOTTOM	T-1	BICM2-MPH-04	-35.046
4/5/2016	11	748824.110	3210188.089	-11.41	BOTTOM	T-1	BICM2-MPH-04	-35.046
4/5/2016	12	748824.171	3210188.349	-11.41	BOTTOM	T-1	BICM2-MPH-04	-35.046
4/5/2016	13	748824.211	3210188.523	-11.41	BOTTOM	T-1	BICM2-MPH-04	-35.049
4/5/2016	14	748824.280	3210188.814	-11.44	BOTTOM	T-1	BICM2-MPH-04	-35.08
4/5/2016	15	748824.341	3210189.083	-11.41	BOTTOM	T-1	BICM2-MPH-04	-35.049
4/5/2016	16	748824.384	3210189.257	-11.41	BOTTOM	T-1	BICM2-MPH-04	-35.049
4/5/2016	17	748824.456	3210189.551	-11.44	BOTTOM	T-1	BICM2-MPH-04	-35.083
4/5/2016	18	748824.532	3210189.824	-11.44	BOTTOM	T-1	BICM2-MPH-04	-35.083
4/5/2016	19	748824.581	3210189.995	-11.47	BOTTOM	T-1	BICM2-MPH-04	-35.113
4/5/2016	20	748824.622	3210190.145	-11.47	BOTTOM	T-1	BICM2-MPH-04	-35.113
4/5/2016	21	748824.665	3210190.295	-11.47	BOTTOM	T-1	BICM2-MPH-04	-35.113
4/5/2016	22	748824.706	3210190.445	-11.50	BOTTOM	T-1	BICM2-MPH-04	-35.144
4/5/2016	23	748824.790	3210190.745	-11.47	BOTTOM	T-1	BICM2-MPH-04	-35.113
4/5/2016	24	748824.831	3210190.895	-11.47	BOTTOM	T-1	BICM2-MPH-04	-35.113
4/5/2016	25	748824.871	3210191.048	-11.44	BOTTOM	T-1	BICM2-MPH-04	-35.083
4/5/2016	26	748824.938	3210191.320	-11.50	BOTTOM	T-1	BICM2-MPH-04	-35.144
4/5/2016	27	748824.981	3210191.501	-11.50	BOTTOM	T-1	BICM2-MPH-04	-35.144
4/5/2016	28	748825.015	3210191.651	-11.47	BOTTOM	T-1	BICM2-MPH-04	-35.11
4/5/2016	29	748825.044	3210191.800	-11.47	BOTTOM	T-1	BICM2-MPH-04	-35.11
4/5/2016	30	748825.101	3210192.079	-11.44	BOTTOM	T-1	BICM2-MPH-04	-35.08

Where

Date (MM/DD/YYYY) is the date the point was collected,
Point_num is the Survey Point Number,
Easting_utm15N_m is the easting coordinate in Universal Transverse Mercator Zone 15, NAD83 – in Meters,
Northing_utm15N_m is the northing coordinate in Universal Transverse Mercator Zone 15, NAD83 – in Meters,
Elevation_NAVD88_GEOID12A_m is the orthometric height at a specific coordinate referenced to the NAVD88 and the Geoid12A Model – in Meters,
Description describes the location where the point was taken,
Station is the Transect Number (T-1 to T-10; S-1 to S-7; M-1 to M-10),
Benchmark_ID is the name of the benchmark referenced during the survey,
Ellp_hgt_m is the height of the ellipsoid at a specific coordinate – in Meters.