

A Contractor's Guide to the Standards of Practice

For CPRA Contractors Performing Topographical, Construction, Monitoring Surveys, and Determining GPS Derived Orthometric Heights within the Louisiana Coastal Zone

Prepared by the
Coastal Protection and Restoration Authority of Louisiana



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Section A

Purpose and History

A.1. Introduction

In an effort to maintain quality, consistency and accuracy when performing GPS surveys on projects contracted for the Coastal Protection and Restoration Authority (CPRA), formerly the Louisiana Department of Natural Resources, Coastal Restoration Division), it is imperative that all CPRA contractors recognize and follow the recommendations and guidelines established in this booklet. The information in this booklet is not intended to be used as a standard for contractors or surveyors performing GPS surveys for other agencies, federal or local, but as a minimum standard exclusively for surveyors contracted by the CPRA. This booklet was written as a general reference guide and is not intended to be a GPS or Conventional training manual for individuals on the technical aspects of performing GPS and Conventional surveys and assumes that survey contractors performing projects for CPRA will employ personnel that possess the technical expertise and a basic understanding of geodesy and GPS technology.

For more technical information related to GPS-derived heights and in-depth guidelines related to GPS control surveys, please refer to the following government publications:

- [NOAA Technical Memorandum NOS NGS-58, "Guidelines for Establishing GPS-Derived Ellipsoid Heights", Version 4.3 dated November 1997](#)
- [NOAA Technical Memorandum NOS NGS-59, "Guidelines for Establishing GPS-Derived Orthometric Heights", Version 1.1 dated March 26, 2008](#)
- [U.S. Army Corps of Engineers Technical Letter N 1110-1-183, "Using Differential GPS Positioning for Elevation Determination" dated April 1, 1998](#)
- [USACE New Orleans District Guide for Minimum Survey Standards, Edition 2.1 dated September 2009](#)
- [National Geodetic Survey User Guidelines for Single Base Real Time GNSS Positioning, Version 1.1 dated May 2010](#)

A.2. History of the Louisiana Coastal Zone GPS Network

The Louisiana Coastal Zone (LCZ) Primary GPS Network was originally created to serve as a coast-wide GPS network adjusted to a common horizontal and vertical reference datum for the purpose of establishing accurate positions on secondary benchmark monuments to be strategically located on CPRA projects across the Louisiana drainage basins. Various projects include marsh elevation surveys, installation and calibration of staff gages and continuous automatic recording gages (sondes), coastal erosion studies, hydrographic restoration projects, construction of breakwater barriers and water control structures, just to name a few.

The LCZ GPS Network commenced in 1999 and at its inception consisted of the re-adjustment of existing GPS networks that were established on earlier CPRA projects. A coastal GPS network was initially created using an existing NGS network of High Accuracy Reference Network (HARN) monuments and encompassed the western half of coastal Louisiana. This NGS HARN network initially served as the basis for the LCZ Primary GPS Network design and included eccentric control points at HARN stations that were not suitable for GPS observations. The Louisiana Coastal Zone GPS Network covers South Louisiana from the Texas border to the Mississippi border, south of Interstate 10 and was re-adjusted in August 2001 to incorporate the Continuously Operating Reference Stations¹ (CORS). Today, the NGS CORS Stations serves as the LCZ Primary GPS Network and is used as the primary reference control to determine elevations on all benchmarks (secondary control) within the Louisiana Coastal Zone.

¹ The National Geodetic Survey (NGS), an office of NOAA's National Ocean Service, manages a network of Continuously Operating Reference Stations (CORS) that provide Global Navigation Satellite System (GNSS) data consisting of carrier phase and code range measurements in support of three dimensional positioning, meteorology, space weather, and geophysical applications throughout the United States, its territories, and a few foreign countries. Surveyors, GIS users, engineers, scientists, and the public at large that collect GPS data can use CORS data to improve the precision of their positions. CORS enhanced post-processed coordinates approach a few centimeters relative to the National Spatial Reference System, both horizontally and vertically. The CORS network is a multi-purpose cooperative endeavor involving government, academic, and private organizations. The sites are independently owned and operated. Each agency shares their data with NGS, and NGS in turn analyzes and distributes the data free of charge. As of June 2011, the CORS network contains over 1,800 stations, contributed by over 200 different organizations, and the network continues to expand.

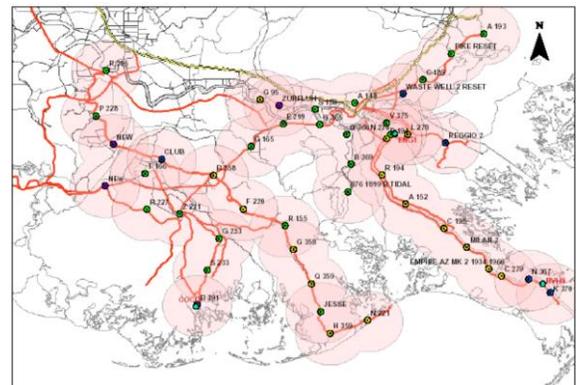
As of March 2016, efforts by the National Geodetic Survey (NGS) through the Louisiana Height Modernization Program to readjust benchmarks within the Louisiana Coastal Zone have occurred in years 2004, 2006, and most recently in 2010.

During the summer of 2003, CPRA provided task orders in support of National Geodetic Survey on the “Hurricane Evacuation Route Survey” in St. Charles Parish, which incorporated additional CORS stations to the network. A year later, CPRA again participated on a GPS campaign to update additional NGS benchmarks and to densify the GPS Network by providing task orders in support of the “NGS 2004 Louisiana Height Modernization Program”.

A.3. NGS Louisiana Height Modernization Survey Collaboration (Epoch 2004.81)

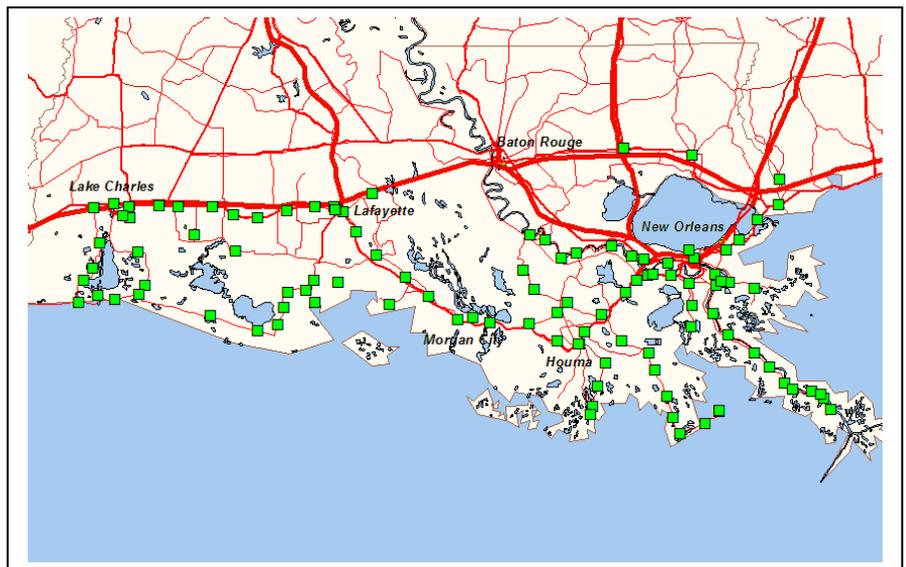
In early 2004, news was received that National Geodetic Survey (NGS) was planning to perform a static GPS campaign within the Louisiana coastal zone. The NGS project, originally titled “Southern Louisiana Evacuation Route Survey-2004”, was an ambitious ten-week survey that had a two-fold purpose, as specified on a Fact Sheet describing the Project.

1. Establish current, validated elevations on a network of monumented control points throughout the southern Parishes. The objective is to establish current elevations to within 2.5 cm (1 inch) of their correct value relative to the national vertical datum, the North American Vertical Datum (NAVD) of 1988.
2. Measure elevation profiles of key evacuation routes in southern Louisiana relative to this new vertical control framework (using NAVD88). The expectation is that these elevation profiles will be accurate to within 10 cm (4 inches) relative to NAVD 88.



An agreement was made to support the project by supplying NGS with CPRA survey contractors that were experienced with static GPS technology. CPRA benchmarks, commonly known as the Louisiana Coastal Zone Primary and Secondary GPS monuments, would be tied into this GPS Campaign and by participating in this effort, would allow the CPRA GPS Network to be tied into the NGS Height Modernization Program, benefiting both agencies. This network survey stretched from the Mississippi-Louisiana border to Hackberry, Louisiana and incorporated all CORS stations into the network adjustment. All primary GPS stations included in the network survey were re-adjusted and tied to CORS.

In October 2005, the NGS State Advisor for Louisiana, Denis Riordon, released the results of the 2004 Height Modernization Program at the Louisiana Society of Professional Surveyors District 3 meeting. The results of this effort were published on the NGS Website and read as follows:



Updated Elevations for Coastal Louisiana

NOTICE: Updated elevation information is now available for coastal Louisiana south of Interstate 10. The [GEOID03](#) (2004.65) model for this area has also been updated. This information should be incorporated into all recent, current, or planned surveying efforts in this region, which are elevation sensitive. Click on the map for updated survey information for coastal Louisiana or download a table of updated stations.

Contact [NGS](#) or the [Louisiana Spatial Reference Center](#) for updated or additional information on benchmark elevations and additional GPS sites in coastal Louisiana for the area south of Interstate 10.

Background - Subsidence affects the elevation of the land. In areas where survey marks cannot be “anchored” to an immovable mass movement occurs, and as a result, elevations change over time.

The [National Geodetic Survey](#) (NGS) and the [Louisiana Spatial Reference Center](#) (LSRC) at Louisiana State University have provided an analysis of the historic vertical control (leveling) network. NGS has validated the heights of 85 existing benchmarks using GPS, subsidence rates, and an improved geoid model. The data sheets for these Vertical Time-dependent Positioning (VTDP) stations have been updated. Furthermore, these stations will be included in the Re-adjustment of the National Spatial Reference System to be released in February 2007.

Now we need your help. The updated VTDP benchmarks MUST be used to determine VALID orthometric heights referenced to NAVD 88 for all applications of elevation information in coastal Louisiana. Failure to use this set of VTDP benchmarks with their updated elevations will result in elevations that are not consistent with the new network.

For surveys already completed - If you have recent survey data that does not use any of these stations for control purposes, additional observations between your vertical control stations and 3 (at a minimum) bench marks will allow for the transfer of the recent improved NAVD 88 heights. The more marks you use, the more confidence you build into your projects and into the network.

New projects - Design new projects to include as many VTDP benchmarks as possible, and no less than 3, in your project area. The larger the project area, the more stations you need to include. Contact NGS or LSRC for guidance.

Use National CORS data in your project as well as any other local GULFNET or temporary TIGER station in the area. This will provide a horizontal and ellipsoid height control to the project.

A.4. 2006 Southern Louisiana Post Katrina Height Modernization Project (Epoch 2006.81)

The 2006 Height Modernization project for South Louisiana was a partnership between FEMA, the Louisiana Spatial Reference Center (LSRC) at Louisiana State University (LSU), and NOAA'S National Geodetic Survey (NGS). The project involved 27 parishes in the southern portion of Louisiana. The parishes are those east of interstate I-55, those that have interstates I-10 or I-12 running through them, or are south of Interstate 10. It included a number of different components such as the re-observing of the control marks updated on the previous campaign (99 – 2004.65 marks), the update or establishment of additional control points in all 27 parishes (approx. 225 marks), a possible small amount of leveling, GPS observations, gravity observations, additional LSU/NGS established CORS, a pilot multi-base RTK network in the SE portion of the state, and the establishment of several new NOAA tide stations. There were a total of approximately 325 control marks (not counting CORS) scheduled to be observed that resulted in updated coordinate values.

This project has been loaded into the NGS Database and new position and height information is available on [NGS datasheets](#). New NAVD 88 heights from this project are given an epoch datum tag of 2006.81. To prevent the use of outdated heights within the 2006 project area, the NAVD 88 orthometric heights for stations not recently re-determined will have their values superseded and no longer published as a current & valid orthometric height.

A.5. 2010 South Louisiana Survey Control Project (Epoch 2009.55)

Beginning September 12, 2010 and continuing through October 2nd, the National Geodetic Survey (NGS) followed up on re-observing a subset of the 330 survey control marks which were updated in the NGS 2006 Height Modernization project for South Louisiana (epoch 2006.81). The field portion of this project was carried out by NGS contracted personnel. Along with this subset of marks, NGS offered the opportunity to any interested parties to update additional marks and have them published in the NGS Integrated Data Base (IDB). It was required that the interested parties collect their GPS data during the same time period as the NGS contractors, and gather the other related mark information (description, etc.). After providing this information, NGS then performed the processing and adjustment portion of the control mark publishing process (Blue Booking). To promote and encourage participation on this GPS campaign, NGS held meetings in New Orleans, Houma, Baton

Rouge, Lafayette, and Lake Charles. Final adjustment results for 120 benchmarks were updated by NGS in September 2011.

A.6. Datums used for the Louisiana Coastal Zone GPS Network

Although the horizontal and vertical datums that are to be used for Louisiana are defined below, please be aware that there are several vertical and horizontal adjustment epoch dates that have been used over time for the Louisiana Coastal Zone GPS Network.

Currently, the reference frame as determined by National Geodetic Survey (NGS) is the North American Datum of 1983 – NAD83 (2011) epoch 2010.00. NGS states on the latest revised datasheets that “*the horizontal coordinates were established by GPS observations and adjusted by National Geodetic Survey in June 2012*”. It should also be noted that the horizontal coordinates are valid at the epoch date published on the NGS datasheets.

Current NAD83 CORS coordinates were determined by re-processing all CORS data collected from January 1994 to April 2011 in the NGS initial Multi-Year CORS Solution (MYCS1) project. The resulting CORS coordinates were published by NGS in September, 2011, and constitute a new realization referred to as *NAD 83(2011/PA11/MA11) epoch 2010.00*. The realization name has two parts: the *datum tag* in parentheses after NAD 83, and the *epoch date* in decimal years. The datum tag refers to the year the realization was completed (2011) and the tectonic plate to which the coordinates are referenced (2011 refers to the North America plate, PA11 to the Pacific plate, and MA11 to the Mariana plate). The epoch date indicates that the published coordinates represent the location of the control stations on January 1, 2010 -- an important consideration in tectonically active areas (such as the western U.S.). In this way, the CORS coordinates (and thus the passive marks constrained to the CORS) are consistent across both space and time. Additional information on the MYCS1 realization of NAD83 is available on the NGS [CORS Coordinates](#) web page.

The referenced vertical datum that is to be used for determining orthometric heights is the North American Vertical Datum of 1988, NAVD88 Epoch 2009.55, computed using Geoid12A and Geoid12B. Geoid12B is identical to Geoid12A, except in Puerto Rico. Some discrepancies with respect to PRVD02 were found due to a few GPSBMs that referred to local mean sea level rather than PRVD02.

The latest geoid model to be used for calculating orthometric heights (elevations) is Geoid12A and was released in September 2012. Prior to Geoid12A, GPS users were calculating orthometric heights using Geoid09 and an “Updated” Geoid03 model (Epoch 2004.65) which was released in October of 2005.

If you are using OPUS Solutions for your adjustment results, the published reference frame is NAD83 (2011) Epoch 2010.00.

On September 6, 2011 NGS's CORS group released [revised coordinates](#) for all CORS sites. The new coordinates update both the global frame and the National Spatial Reference Frame as follows.

<u>New Frames</u>		<u>Previous Frames</u>	
IGS08	Epoch 2005.00	ITRF00	Epoch 1997.00
NAD 83(2011)	Epoch 2010.00	NAD 83(CORS96)	Epoch 2002.00
NAD 83(MA11)	Epoch 2010.00	NAD 83(MARP00)	Epoch 2002.00
NAD 83(PA11)	Epoch 2010.00	NAD 83(PACP00)	Epoch 2002.00

National Adjustment of 2011 (NA2011) NAD 83 (2011) epoch 2010.00 coordinates on passive control

The National Adjustment of 2011 (NA2011) Project is part of the National Geodetic Survey's (NGS) continuing efforts to improve the National Spatial Reference System (NSRS). The NSRS is the consistent reference system defining latitude, longitude, height, scale, gravity, and orientation throughout the United States and its territories. NGS maintains and provides access to the NSRS, the foundation for the nation's transportation, mapping, and charting infrastructure, as well as a multitude of other scientific and engineering applications.

NA2011 will yield updated North American Datum of 1983 (NAD 83) coordinates on nearly 80,000 NGS passive control marks positioned using Global Navigation Satellite System (GNSS) technology. A primary objective for

NA2011 is to ensure that NGS-published coordinates on passive GNSS marks are fully consistent with the Continuously Operating Reference Station ([CORS](#)) network. This is necessary because the CORS network is the geometric foundation of the NSRS, and it is important that NGS products and services be mutually aligned to best meet user needs. The NA2011 Project is required now because NGS recently determined a more precise set of coordinates for the CORS, and this realization is referred to as NAD 83 (2011) epoch 2010.00. Additional information on the CORS-based realization of NAD 83 is available on the NGS [CORS Coordinates](#) web page.

Since NA2011 will yield ellipsoid heights that are inconsistent with the geoid model (GEOID09), a new hybrid geoid model, GEOID12A, was developed at NGS. GEOID12A is based on NAD83 (2011) epoch 2010.00 ellipsoid heights, so its release must, therefore, occur after the completion of NA2011.

Our original goal was to complete the NA2011 Project by the end of calendar year 2011. However, completion of the project was postponed for a number of reasons (such as adding new data, re-enabling previously rejected vectors, additional analysis in subsidence areas, etc.). In addition, NA2011 results was not made available on NGS Datasheets until GEOID12 was completed.

NOTICE: NGS Update, September 11, 2012 - GEOID12A Model Released

The National Geodetic Survey has released the [GEOID12A model](#). Analysis of the underlying control data has been completed and a number of corrections were made to the original data used in making GEOID12. Changes impacted regions in the states of Alabama, Mississippi, Louisiana, Texas, Oklahoma, and Wisconsin. GEOID12A is now available for production and use.

After detecting significant defects in the control data used to create [GEOID12](#), GEOID12A was developed as a replacement. Details of these changes can be found [here](#). The final control data were effectively determined as of August 10, 2012 and can be accessed through the link to the lower right: GPS/bench mark data set for GEOID12A.

The GEOID12A model is intended to transform between NAD 83 (2011/PA11/MA11) and the respective vertical datums for the different regions, including NAVD88, GUV04, ASVD02, NMVD03, PRVD02 and VIVD09.

The regions outside of the Conterminous United States (the lower 48) were unaffected by these changes, but the name of the model for those regions was changed to GEOID12A to one consistent name (e.g., GEOID12 and GEOID12A are identical in Alaska, Hawaii, etc.).

Geoid12B is identical to Geoid12A, except in Puerto Rico. Some discrepancies with respect to PRVD02 were found due to a few GPSBMs that referred to local mean sea level rather than PRVD02.

A.7. Datasheet Access on SONRIS 2000

LCZ Secondary GPS Datasheets can be printed and downloaded from the GIS Interactive Map found on CPRA's SONRIS 2000 website at the following internet address:

<http://sonris-www.dnr.state.la.us/gis/agsweb/IE/JSViewer/index.html?TemplateID=181>

After the viewer loads, select "Coastal Protection & Restoration" to expand task bar then check the box for "Secondary GPS Network". Highlight the words "Secondary GPS Network" depending on which monument you are locating. After the GPS monuments appear on the map, select the "i" button under the layer name (for identify) then select one or box in for several monuments...your selected monuments will appear in the pop up window ...now select the datasheet...this will open a pdf file containing the Information Datasheet.

A.8. Definition of Primary and Secondary GPS

Originally, the LCZ Primary GPS Network was defined as a GPS network survey using NGS HARN as the primary reference control to establish secondary benchmarks, or readjust existing NGS benchmarks within a project area. Today, the LCZ Primary GPS Network consists of the NGS Continuously Operating Reference Stations (CORS). These referenced stations are published and maintained by NGS and the LSU Center for Geomatics (C4G). Because NGS and C4G maintains and monitors the CORS network on a regular basis in addition to providing continuous GPS data collection made available to the public at no cost, the use of the CORS network as the primary adjustment source has proven to be more accurate, up-to-date, and economical.

Section B

Standards of Practice for Determining GPS-Derived Heights on CPRA LCZ Primary & Secondary Static GPS Network Surveys

B.1. Definition of Heights

There are three types of heights involved in determining GPS-derived orthometric heights – orthometric, ellipsoid, and geoid.

Webster's dictionary defines **geoid** as the surface within or around the earth that is everywhere normal to the direction of gravity and coincides with mean sea level in the oceans.

The definition of **geoid**, as adopted by NGS, is the equipotential surface of the Earth's gravity field that best fits, in a least squares sense, global mean sea level.

Geoid height values represent the geoid-ellipsoid separation distance measured along the ellipsoid normal and are obtained by taking the difference between ellipsoidal and orthometric height values.

The current geoid model for CONUS, **GEOID12A**, is a hybrid model based on the gravimetric model but also incorporating a corrector surface.

GEOID99 – GEOID99 is a refined model of the geoid in the United States, which superseded the previous models GEOID90, GEOID93, and GEOID96.

GEOID03 – the Original Version... This original file is deprecated; its use is discouraged, but still available. Note that the GEOID03 file #7, which covers the coastal Louisiana region, has been modified. It has been updated based on the most recent VTDP model for the region to better reflect the actual orthometric heights at the bench marks.

GEOID03 – Epoch 2004.65 (the "New Realization") GEOID03 was developed by fitting the gravity geoid using the previous determined NAD 83 (HARN) set of ellipsoid heights. Applying GEOID03 to the current set of ellipsoid heights from the NSRS2007 will be different. This geoid height was determined by a new realization of GEOID03 for the epoch indicated which incorporates improved geoid heights for the Southern Louisiana Subsidence area.

GEOID09 – GEOID09 incorporates the latest ellipsoid heights from the NSRS2007 adjustment.

GEOID12 - This model was created using the GPSBM data of the [National Adjustment of 2011](#). The median change in coordinates from previously published values was approximately 2 centimeters horizontally and 1.5 centimeters vertically. However, some station coordinates changed by more than 1 meter horizontally and 60 centimeters vertically.

GEOID12A – The GEOID12A model is intended to transform between NAD83 (2011) epoch 2010.00 and the vertical datum of NAVD88: Epoch 2009.55. Geoid12A uses the same GPSBM data as Geoid12, excluding the points in southern tier states along the Gulf Coast.

GEOID12B – Geoid12B is identical to Geoid12A, except in Puerto Rico. Some discrepancies with respect to PRVD02 were found due to a few GPSBMs that referred to local mean sea level rather than PRVD02.

Ellipsoid height, or geodetic height, is the value at a given point on the Earth's surface and is based on the distance measured along the normal vector from the surface of the reference ellipsoid to the point.

The **Orthometric height** of a point on the Earth's surface is the distance from the geoidal reference surface to the point, measured along the line perpendicular (plumb line) to every equipotential surface in between, or normal to the geoid.

B.2. Determining Orthometric Heights using GPS

There are three basic rules, two control requirements, and four procedures that need to be followed when estimating GPS-derived orthometric heights.

B.3. Rules for Estimating GPS-Derived Orthometric Heights:

Rule 1: Follow CPRA's guidelines outlined in this booklet for establishing GPS-derived ellipsoid heights when performing GPS surveys.

Rule 2: Use NGS' latest National Geoid Model, e.g., GEOID12A, when computing GPS-derived orthometric heights.

Rule 3: Use the latest NGS adjusted height values for CORS found on the internet to control the project's adjusted heights.

B.4. Two Control Requirements for Estimating GPS-Derived Orthometric Heights (Data Collection):

Requirement 1: A minimum of three CORS Stations should be evenly surrounding the project area.

Requirement 2: Minimum observation time per session should be a minimum 4 hours on three separate observations is recommended. This allows for a quality control check utilizing NGS OPUS program for an independent GPS adjustment.

B.5. Four Procedures for Estimating GPS-Derived Orthometric Heights (Processing and Adjustment):

Procedure 1: Perform a 3-D minimum-constraint least squares adjustment of the GPS survey project, i.e., constrain to one latitude, one longitude, and one orthometric height value.

Procedure 2: Using the results from the adjustment in procedure 1 above, detect and remove all data outliers. The user should repeat procedures 1 and 2 until all data outliers are removed.

Procedure 3: Compute differences between the set of GPS-derived orthometric heights from the minimum constraint adjustment (using the latest National geoid model, e.g., GEOID12A²) from procedure 2 above and the CORS.

Procedure 4: Perform a fully constrained adjustment holding all latitude and longitude values, and all CORS height values fixed.

The use of GPS data and a high-resolution geoid model to estimate accurate GPS-derived orthometric heights will be a continuing part of the implementation of the CPRA-LCZ GPS Network guidelines.

² There may be occasions when the scope of services will require that elevations be adjusted using earlier geoid models for the purpose of comparing to elevations calculated with those particular geoid models. This will eliminate any possibility of bias in the elevation comparison, except for the effects of subsidence.

Section C

Pre-Planning the GPS Survey

C.1. Research Existing CPRA Control on SONRIS

LCZ Secondary GPS Datasheets can be printed and downloaded from the GIS Interactive Map found on CPRA's SONRIS 2000 website at the following internet address:

<http://sonris-www.dnr.state.la.us/gis/agsweb/IE/JSViewer/index.html?TemplateID=181>

After the viewer loads, select "Coastal Protection & Restoration" to expand task bar then check the box for "Secondary GPS Network". Highlight the words "Secondary GPS Network" depending on which monument you are locating. After the GPS monuments appear on the map, select the "i" button under the layer name (for identify) then select one or box in for several monuments...your selected monuments will appear in the pop up window ...now select the datasheet...this will open a pdf file containing the Information Datasheet.

C.2. NGS Survey Mark Datasheets Retrieval

A Datasheet is sometimes referred to as DSDATA. It is an ASCII text file which contains data for a survey control station maintained by NGS. Datasheets for horizontal control stations show precise LATITUDE and LONGITUDE. Datasheets for vertical control stations (a.k.a. Bench Marks) show precise Orthometric Heights (Elevations). Other data includes...Geoid Ht, State Plane Coordinates, UTM's, and more. A description of how to reach the mark and recovery information is also provided.

Click [here](#) to go directly to the Datasheet Retrieval Page, or go back to the [datasheet main page](#) and click on *DATASHEETS*. Input is provided for retrieving by... *PID, CORS Sited, Radius Search, Rectangular Search, Station Name, USGS Quad, Project Identifier, County, Load Date, or Map Search*. Retrieved output will consist of a list of stations from which you may choose one or more to obtain the station datasheet.

C.3. NGS OPUS-Shared Solutions Retrieval

The National Geodetic Survey has made sharing GPS survey positions easier, thanks to an upgrade to the Online Positioning User Service (OPUS) called OPUS-Shared. In addition to standard position reports, OPUS-Shared gives users an option to share their positioning results in an online NGS database. OPUS provides a comparatively streamlined and homogeneous method for computing and sharing the location of permanent features, such as tidal bench marks or other survey control. As originally designed, the OPUS solution report is distributed via e-mail to the submitting user only. By adding a database and additional Web forms to capture a description of the positioned object, NGS can now make OPUS solutions publicly available through the OPUS Shared portal. To view and retrieve published OPUS Shared Solutions go to:

<http://www.ngs.noaa.gov/OPUS/view.jsp>.

C.4. Installation of Permanent Deep Rod Monuments

Determine the locations of any proposed permanent deep-rod monuments to be installed and plot the locations on a USGS quadrangle or Google earth. Plot primary control points in addition to any other reference control points that are to be relocated from the NGS datasheet. The map will give an idea on logistics and planning for setting the monuments. Materials for the permanent deep-rod floating sleeve monument and procedures for setting the monument can be found in Section E of this booklet.

C.5. Network Design Planning

When permanent GPS Secondary monuments are required in a project area, as specified in the "Scope of Work" for a CPRA project, a GPS network plan is necessary to establish the values of those secondary monuments. The GPS network should be designed as to incorporate a minimum of three primary control monuments (CORS), one at each extreme corner that is nearest to the project area. Try to keep project areas

within a 20-kilometer radius of the primary control (CORS) points. A GPS Network Plan and Sessions Schedule will be required and must be submitted with the cost proposal to CPRA for approval prior to commencing work.

C.6. Sessions Planning and GPS Schedule

On the primary control survey, the sessions should be scheduled so that points are occupied for a minimum of 4 to 5 hours and a minimum of 3 sessions at different times. The purpose is to ensure different atmospheric conditions (different days) and significantly different satellite geometry (different times) for the two occupations. For example, if the first day occupation were made between 8:00 am to 11:00 am, the second observation would be made on the next day anytime between 1:00 pm and 5:00 pm. If the second observation is not made for a couple of days or even a week, be sure to compensate for the daily 4-minute change in the GPS satellite constellation. It has been shown that the average ellipsoid height of repeat observations is closer to the truth, with a few exceptions, than the ellipsoid height of a single observation. Some exceptions to this rule may apply due to the logistics, limited access and remote locations.

There may be an exception to this rule if access to the benchmark is difficult due to it being located in a very remote area. Static GPS can be performed at the unknown benchmark for a period of 8 hours on two separate events. Please consult with the CPRA project manager if this is the case.

In addition, it would be acceptable if Realtime kinematic (RTK) surveys are being performed concurrently with Static GPS data collection for three or more days if static is observed for more than 4 hours each day. This could provide sufficient static GPS data to post-process the base station position and meet the minimum standards.

Using the Session Schedule form (See Section J) input a proposed start time and session duration time for each session. Travel times should be calculated using a road map to compute distance and travel times between set-ups. Input the GPS operator and in the corresponding row, input the station names of the points that will be occupied by each operator.

Using Trimble's Quickplan program or other GPS planning program, determine for the planned day of survey when any PDOP/VDOP spikes may occur and make a note of the time period. Use the Session Schedule form and plan the travel times to correspond with the period of high Positional Dilution of Precision (PDOP) and high Vertical Dilution of Precision (VDOP). Sessions should be planned during times when the PDOP is less than 7.0 and VDOP is less than 5.0.

Section D

GPS Field Procedures

D.1. GPS Equipment

Fixed height tripods are mandatory for each set-up, except for locations where an adjustable tripod or fixed pole is necessary. Fixed height tripods provide a consistent station occupation method that can reduce the likelihood of antenna height measurement blunders. Please be aware not to assume that a 2 meter fixed height tripod measures 2.000 meters. The actual measurements have been known to be off and could range from 1.996 to 2.004 meters. Always verify your tripod heights and record and tag them. In the event that a setup cannot be performed with a fixed height tripod because of an obstruction such as a fence, then an adjustable tripod can be used. In this case make certain that the procedure for antenna height measurement using an adjustable tripod is used. (See D.7 Below)

The use of dual frequency receivers can correct GPS measurements for ionosphere based range errors. This will extend the feasible baseline length and resolve integer ambiguities reliably within 20 km. Dual frequency receivers should be used on all baselines longer than 10 km.

Use identical geodetic quality antennas with ground plane. Different makes and models of GPS antennas can have different reference points such as L1, L2, or antenna reference point (ARP). Mixing of different type of antennas can cause errors in the vertical component up to 100 mm. Only if the processing software can account for the phase center difference in the GPS antennas should mixing of antenna types occur. The ground plane on the antenna will reduce the amount of ground reflecting multi-path.

D.2. GPS Schedule and Log Sheet

The Session Schedule provides a guide as to start and stop times, station name set-ups for each survey technician, travel times and cell phone numbers for the crew. Once a schedule has been planned and established, it is important that any deviation from the schedule such as late start times, power failures, travel delays, etc. should be communicated to the Project Manager or Party Chief so that the schedule can be revised. It is important to remember that the processed data in a GPS session is only as good as the last person that starts collecting data on his GPS receiver and the first person to stop survey. (See Section J for a sample copy)

GPS Log Sheets (See Section J) are the field notes for the GPS survey and should be filled out in their entirety. The information on this sheet is important at the time of check-in, download and processing of the raw data. If problems are encountered with the raw data, the problem can be traced back to a particular GPS receiver that may be malfunctioning or configured incorrectly. The data required to be logged on the GPS Log Sheets by the technician include the following: Operator, Station Name, Monument Type, Julian Date, Session Number, Receiver Serial Number, GPS Antenna Number, Antenna Height, Start and Stop Times, and Session Notes. A Station sketch with reference ties is required on the back page of the sheet for future relocation and confirmation that the correct monument was used in the survey. If you are occupying an existing Secondary GPS monument, make a note on the GPS Log Sheet as to the condition of the monument. Note if the monument may have been disturbed and report to CPRA if any effort is required to re-ensure its stability.

D.3. Typical Static Survey Session using a Trimble Dual Frequency 4000SSE/SSi, Trimble 5700, R7 and R8 GNSS GPS Receivers

Prior to logging a GPS session, check the configuration settings on your GPS receiver. Typically, a receiver should be set on 15-second sync rate and 10-degree elevation mask. The time zone should be confirmed and if daylight saving time is in effect. Also, check the stamping on the monument cap to confirm that you are set-up at the correct station. Sync rate and elevation mask on the Trimble 5700 Series, R7 and R8 GNSS is defaulted and only requires that a flashcard be installed.

D.4. Set-up

Upon arriving at the GPS point, connect the GPS antenna and power to the receiver and turn the receiver “**ON**”. Make sure the antenna is away from all obstructions. Set-up the tripod centered over the GPS datum point and level the tripod. Remove mounting adapter from the tripod and screw onto the base of the GPS antenna. Attach the antenna and adapter to the tripod and rotate antenna to point the arrow towards north if using the Trimble Geodetic Compact L1/L2 type. Verify that the adapter has properly seated and no gap exists. (This is important so that error in the antenna height above the datum point will not be introduced). Check the level of tripod and confirm if it’s leveled correctly over the GPS point.

D.5. Start Survey

If using a **Trimble 4000SSE/Ssi Receiver**, it should be in the “**LOG DATA**” menu. Select “**QUICK-START NOW! (SINGLE SURVEY)**”. Confirm that the GPS antenna is connected by noting the diamond shaped symbol at the bottom of the display. (Look between the PWR1 and time display). Also confirm that the data is being collected by selecting the “**MORE**” button twice. You should see which satellites the receiver is tracking and the file size increasing every 15 seconds at the beep.

If using a **Trimble 5700, R7 or R8 GPS Receiver** with Datalogger, select the RTK and Infill on the Survey Styles menu. Confirm data is being collected on the GPS receiver by observing that the light is on for the Memory storage (Blue Button) or touch the blue button to initiate. NOTE: you must have a Scandisk memory card in the receiver for it to collect GPS data.

D.6. Measuring Antenna Height If Using a Variable Height Tri-pod (Only if necessary)



Using the stainless steel meter stick, measure the antenna height by placing point of the stick into center of the GPS monument center point and read the stick at the bottom inside face of the groove beneath the antenna. Note that each division on the stainless steel measuring stick equals 2 millimeters or 0.002 meters. Record the measurement in meters on GPS log sheet and repeat procedure at 120° from previous measurement. Record and repeat until measurements have been made on three equal sides of the antenna. Add the measurements together and divide by three to get an average then record this value on the GPS Log Sheet in the box labeled “AVG Measurements”. Now re-measure the height in feet and tenths or inches using measuring tape. Record this

value on GPS Log Sheet in the box labeled “Check Measurement”. Divide the check measurement by 3.2808 and compare the answer to the average of measurements. **IMPORTANT!!! THIS IS YOUR SURVEY QUALITY CONTROL CHECK MEASUREMENT!** Make certain that the measurement is recorded properly i.e.: Inches or Feet & Tenths. If the two values differ by more than 0.016 feet or 5 mm, begin the measurement procedure all over again.

If a second session is scheduled on the same GPS Station, it would be advisable to break setup and re-measure the antenna height. This will eliminate the possibility of a wrong antenna height being used for both sessions.

D.7. Measuring Antenna Height If Using a Fixed Height Tri-pod

The fixed height tri-pods are normally measured 2.000 meters from the bottom tip of pole to the Antenna Reference Point (ARP - True Vertical to the base of the antenna mount). Always verify the true height!

D.8. Enter Antenna Height and Filename on the Trimble 4000SSE/Ssi Receiver

Select “**LOG DATA**” menu. Select “**CHANGES**” then “**ANTENNA HEIGHT**”. Confirm that the units shown in the display is in meters. Enter the antenna height. To confirm correct height, switch units to feet. Once the measurement is displayed in feet, check the GPS Log Sheet in the box labeled “Check Measurement” and confirm that the measurement is close to what was recorded previously. If so, switch the units back to meters.

Confirm the following settings

ANT HEIGHT:

(Measured Height) METERS

If using **adjustable tripod**:

OR

Confirm the following settings

If using **2 meter fixed height tripod**:

MEAS TYPE:

ANT TYPE:

ANT SERIAL:

ANT HEIGHT:

MEAS TYPE:

ANT TYPE:

ANT SERIAL:

UNCORRECTED

COMPACT L1/2 W/GRND PLANE

(See tag on bottom of antenna)

(2.000) METERS

TRUE VERTICAL

COMPACT L1/2 W/GRND PLANE

(See tag on bottom of antenna)

Select “**ACCEPT**” then “**FILENAME**”. The first four digits should be the GPS point you are currently at, i.e. “1001” or “DREU”. Change to reflect point number or name. The next three digits is today’s Julian date. Do not change this! The last digit is the current session number. Enter current session number. Now select “**ENTER**” and “**STATUS**” on keypad. Confirm the filename in the upper left corner of the display.

D.9. Complete a GPS Log Sheet

Now you are ready to complete GPS log sheet. Be aware of your scheduled stop time for this session. Also be aware not to stand near and block the GPS antenna or park a vehicle nearby, blocking the antenna view to the sky.

D.10. End Survey

To end survey at scheduled stop time on the Trimble 4000 series, select “**LOG DATA**” from keypad, then “**END SURVEY**”, then select “**YES**”. Shut off the GPS receiver by pressing down on the green POWER button. To end survey at scheduled stop time on the Trimble 5700 series, select “blue button” on the face of the receiver and confirm the blinking light has stopped.

Section E

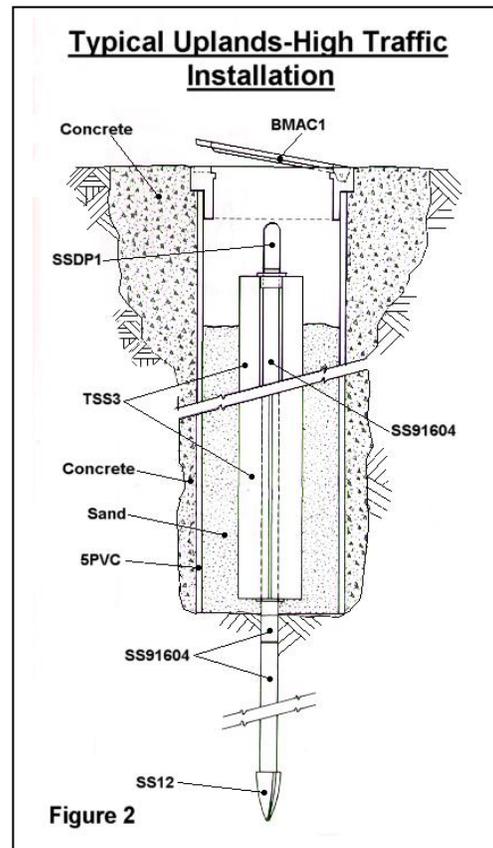
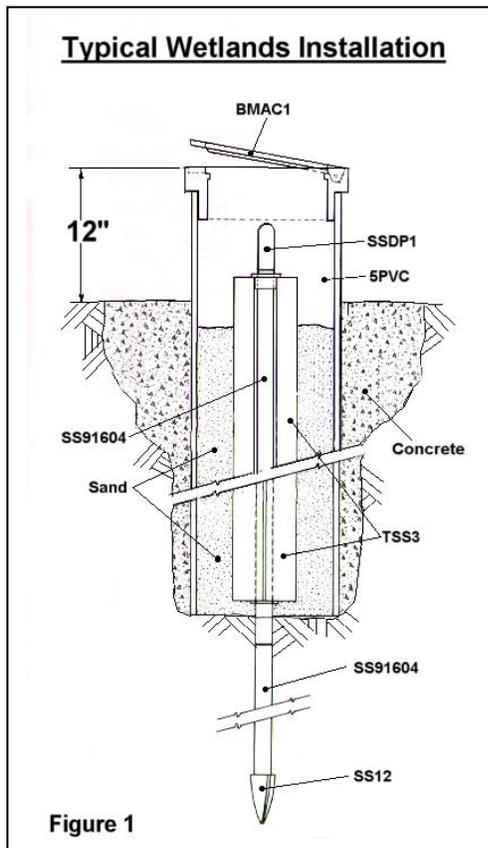
Establishing Permanent Deep Rod Monuments

E.1. Setting Monuments to Refusal

It is important to know that no monument shall be installed until all Land rights have been secured between the CPRA Contractor and the Landowner affected. A typical **Right-of-Entry/Hold Harmless Agreement** can be obtained from the LNDR point of contact. Additionally, when monuments are installed in developed urban areas or near Oil & Gas Fields, the contractor should make every effort to determine if underground pipelines or utilities exist. Please utilize the **LA One Call** system at **811** or visit their website at: <http://www.laonecall.com>

Deep Rod Monuments are required for all Secondary Control to be established in a project area as directed and requested by CPRA are to be set to refusal. The depth of refusal will vary from area to area. **"Refusal"** for a rod monument is defined by most federal agencies as *"No more than one (1) foot of further penetration of a rod monument in one (1) minute of impacting with a gasoline powered hammer"*. A Pionjar Gas Powered Breaker Drill or approved equal is required for installing the permanent monuments and can be rented from the manufacturer listed below. **Use Berntsen Monuments, Surv-Kap or approved equal.**

When selecting a location for a permanent deep rod GPS monument, be aware that this location is for GPS satellite observations and that there are minimal or no obstructions to block the satellite view. Figure 1 depicts a typical configuration and components when monuments to refusal are being installed in a wetlands area. When monuments to refusal are being installed in areas where the monument is subject to being disturbed, then the monument should be installed flush with normal ground as in Figure 2. The flush monument is typically requested by the Landowner for safety reasons.



E.2. Monument Components

The table below contains a list of components required and pricing for the installation of deep rod monuments to 48 feet. Be aware that monument depths will vary from area to area depending on the geology and therefore pricing will vary for each monument installation.

Estimated Prices for Monuments (March 2016)
Top Security Floating Sleeve Monument (9/16" Stainless Steel x 48 feet)
Pricing below does not include shipping and handling

Description	Item #	Price ea.	Quantity	Price
9/16" X 4' Stainless Steel Rod	SS91604	\$ 28.00	12	\$ 336.00
9/16" Stainless Steel Drive Point	SS12	\$ 11.00	1	\$ 11.00
Stainless Steel Spherical Datum Point	SSDP1	\$ 13.60	1	\$ 13.60
NGS Style Access Cover	BMAC1	\$ 61.75	1	\$ 61.75
5" Schedule 40 PVC x 3 foot	5PVC	\$ 30.00	1	\$ 30.00
Top Security Sleeve	TSS3	\$ 15.90	1	\$ 15.90
Adhesive for BMC to PVC Pipe	UV6800	\$ 14.95	1	\$ 14.95
NO-TOX Grease	TSSGREASE	\$ 10.65	1	\$ 10.65
5' Orange Fiberglass Post	CBM6004SM110	\$ 20.00	1	\$ 20.00
40 lb Quickcrete		\$ 3.00	1	\$ 3.00
50 lb All Purpose Sand		\$ 2.50	1	\$ 2.50

\$ 519.35

Additional Items Required to Set Monuments:

Magnet or Spike inserted into sand to assist with Magnetic locator

Gas Powered Breaker Drillrental is about \$75/Day or \$325/Week

Power Driving Adapter.....\$90 each

Steel Drive Pin for 9/16" Rods.....\$12 each

Steel Letter and Number Stamp Set.....\$40 each

Berntsen International, Inc. 800-356-7388 <http://www.berntsen.com>

E.3. Deep Rod Monument Installation Instructions

The following monument installation procedures can be obtained from the following Internet website: <http://www.berntsen.com/Portals/3/pdfs/topinst.pdf> . These instructions have been taken from:

GEOMETRIC GEODETIC ACCURACY STANDARDS AND SPECIFICATIONS FOR USING GPS RELATIVE POSITIONING TECHNIQUES (pages 46-48)

Federal Geodetic Control Committee
Rear Admiral Wesley V. Hull, Chairman
Version 5.0: May 11, 1988

Reprinted with corrections: January 5, 2000.

Berntsen International, Inc. – NGS Three Dimensional Rod Monument Installation Instructions

SPECIFICATIONS AND SETTING PROCEDURES FOR THREE DIMENSIONAL MONUMENTATION

A. MATERIALS REQUIRED FOR SETTING MONUMENT:

1. Rod, stainless steel, 4-foot (1220 mm) sections [SS91604]
2. Rod, stainless steel, one 4 inch (100 mm) [M1DPA]
3. Studs (threads), stainless steel [M13 thread]
4. Datum point, stainless steel [SSDP1]
5. Spiral (fluted) rod entry point, standard [SS-12 Point]
6. NGS logo caps, standard, aluminum [BMAC-1, -5, -6]
7. Pipe, schedule 40 PVC, 5 (or 6) inches (127 mm or 152 mm) inside diameter, 2-foot (610 mm) length [5PVC24] [6PVC24]
8. Pipe, schedule 40 PVC, 1 inch (25 mm) inside diameter, 3-foot (915 mm) length [TSS3]
9. Caps, schedule 50 PVC, (Slip-on caps centered and drilled to 0.567 inch [14 mm] ± 0.002 [.05mm]) [TSSEC-Y]
10. Cement, for making concrete
11. Cement, PVC solvent [Eclectic® UV-6800]
12. Loctite (2 oz. bottle)
13. Grease-MIL SPEC G-10924D (B15395A, Grade 7) [Bel-Ray NO TOX AA-1-1]
14. Fine-grained washed or play sand
15. Grease Gun
16. * (Vise grips or pipe wrench (2) to tighten each rod section together)



B. SETTING PROCEDURES:

1. The time required to set an average mark using the following procedures is 1 to 2 hours.
2. Using the solvent cement [Eclectic UV-6800] formulated specifically for PVC, glue the aluminum logo cap [BMAC] to a 2-foot (610 mm) section of PVC pipe [5PVC24]. This will allow the glue to set while continuing with the following setting procedures.
3. Glue the PVC cap with a drill hole [TSSEC-Y] on one end of the 3-foot (915 mm) section of schedule 40 PVC pipe 1-inch (25mm) inside diameter [TSS3]. Pump the PVC pipe full of grease. Thoroughly clean the open end of the pipe with a solvent, which will remove grease. Then glue another cap with drill hole on the remaining open end. Set aside while continuing with the next step. (**NOTE: This step can also be done in advance, prior to going into the field.*)
4. **IMPORTANT: Use proper eye and ear protection!** Using a power auger or post hole digger, drill or dig a hole in the ground 12 - 14 inches (300 mm - 350 mm) in diameter and 3-1/2 feet (1100 mm) deep.
5. Attach the standard spiral (fluted) rod entry point [SS-12 point] to one end of the 4-foot (1220 mm) section of stainless steel rod [SS-916-04] with the standard 3/8-inch (10 mm) stud [M-13 thread]. On the

opposite end, screw on a short 4 inch (100 mm) piece of rod [M-1 DPA] which will be used as the impact point for driving the rod. Drive this section of rod with a reciprocating driver such as a *Pionjar 120, Cobra 148, Wacker BHB 25* or another machine with an equivalent driving force.

6. Remove the short piece of rod used for driving [M-1-DPA] and screw in a new stud [M-13 thread]. Attach another 4-foot (1220 mm) section of rod [SS-916-04]. Tighten securely (**using vise grips or pipe wrenches*). Reattach the short piece of rod [M-1-DPA] and drive the new section into the ground.

7. Repeat step 6 until the rod refuses to drive further or until a driving rate of 60 seconds per foot (300mm) is achieved. The top of the rod should terminate about 3 inches (75 mm) below ground surface.

8. When the desired depth of rod is reached, cut off the top removing the tapped and threaded portion of the rod leaving the top about 3 inches (75 mm) below ground surface. The top of the rod must be shaped to a smooth rounded (hemispherical) top, using a portable grinding machine to produce a datum point. The datum point must then be center punched to provide a plumbing (centering) point. NOTE: For personnel that may not have the proper cutting or grinding equipment to produce the datum point, the following alternative procedure should be used if absolutely necessary. When the desired depth of the rod is obtained (an even 4-foot [1220 mm] section), thoroughly clean the thread with a solvent to remove any possible remains of grease or oil that may have been used when the rod was tapped. Coat the threads of the datum point with Loctite and screw the datum point into the rod. Tighten the point firmly with vise grips to make sure it is secure. The datum point is a stainless steel 3/8-inch (10 mm) bolt [SSDP-1] with the head precisely machined to 9/16 inch (14 mm).

9. Insert the grease filled 3-foot (915 mm) section of 1-inch (25 mm) PVC pipe sleeve [TSS3] over the rod. The rod and datum point should protrude through the sleeve about 3 inches (75 mm).

10. Backfill and pack with fine-grained washed or play sand around the sleeve [TSS3] to about 20 inches (500 mm) below surface. Place the 5-inch (127 mm) PVC [5PVC24] and logo cap [BMAC] over and around the 1-inch (25 mm) sleeve [TSS3] and rod. The datum point [SSDP-1] should be about 3 inches (75 mm) below the cover of the logo cap. **Remember to insert a magnet, rebar or spike in the sand for future aid in location since all the components are non-magnetic.**

11. Place concrete around the outside of the 5-inch (127 mm) PVC [5PVC24] and logo cap [BMAC], up to the top of logo cover. Trowel the concrete until a smooth neat finish is produced.

12. Continue to backfill and pack with sand inside the 5-inch (127 mm) PVC [5PVC24] and around the outside of the 1-inch (25 mm) sleeve [TSS3] and rod to about 1 inch (25 mm) below the top of the sleeve.

13. Remove all debris and excess dirt to leave area in original condition. Make sure all excess grease is removed and the datum point [SSDP-1] is clean.

14. Install a fiberglass witness post 2 to 3 feet adjacent to and behind the installed monument.

[SS-916-04] = Berntsen model number of material specified.

Note: These are to be used only as a guideline for geodetic surveys using GPS relative positioning techniques.

**Items in italics are added procedures recommended by Berntsen International.*

SECTION F

Downloading, Processing & GPS Network Adjustment

F.1. Downloading / Check-in Raw Data Files

Prior to downloading the raw GPS data from the receivers, organize your GPS Log Sheets by date and session times. Create a project file and connect the PC to the GPS receiver. Prior to transferring the data files, check the filenames, Julian date and session numbers are correct. Once the files have transferred, confirm that the filenames, antenna type and antenna heights are correct for each GPS occupation. Occasionally, an operator may forget to input the antenna height or numbers may have been input incorrectly. Always verify antenna height measurements to be correct. If the antenna height is in question, the observation should be removed altogether as to not affect the results of the network adjustment. Consider a re-observation of any GPS data that may be in question.

F.2. Processing the GPS Data Files using OPUS

OPUS should only be used as a quality control check and should not be used in lieu of a least squares adjustment. OPUS uses a slightly different methodology to obtain positions than the least squares adjustment method.

What is OPUS? The National Geodetic Survey operates the Online Positioning User Service (OPUS) as a means to provide GPS user's easier access to the National Spatial Reference System (NSRS).

OPUS allows users to submit their GPS data files in most formats to NGS, where the data will be processed to determine a position using NGS computers and software. Each GPS data file that is submitted will be processed with respect to a minimum of three CORS sites. The sites selected may not be the nearest to your site but are selected by distance, number of observations, site stability, etc. The position for your data will be reported back to you via e-mail in both [ITRF and NAD83 coordinates](#) as well as UTM and State Plane Coordinates (SPC) northing and easting. The current epoch date for OPUS solutions as of January 2013 is NAD83 (2011) epoch 2010.00. Check with NGS published datasheets for the most current dates.

OPUS is completely automated and requires only a minimal amount of information from the user:

Uploading

Using OPUS requires just five simple steps:

1. EMAIL

Enter the email address (e.g., your.email@domain.com) where you want OPUS to send your solution report.

2. DATA FILE

Provide OPUS a GPS observables data file in any format (for automatic conversion to [RINEX format](#) by UNAVCO's [teqc](#) converter) or convert it to RINEX yourself first. OPUS also recognizes compressed (UNIX or [Hatanaka.yyd](#)) or zipped (gzip or pkzip) files, including multiple data files in a single zip archive.

OPUS accepts receiver epoch rates of 1,2,3,5,10,15 or 30 seconds, all of which are decimated to 30 seconds for processing. Note: Though your data file may already contain survey metadata, including antenna type, height, and mark information; these are IGNORED as we have found they are inconsistently formatted.

3. ANTENNA TYPE

Select the antenna brand and model you used. This allows OPUS to determine the appropriate antenna calibration model for processing. *Please be aware that selection of an incorrect or default antenna may result in a height error as large as 10 cm.* See [antenna calibration](#) to help find an exact match.

4. ANTENNA HEIGHT

Enter the vertical height in meters of your Antenna Reference Point (ARP) above the mark you are positioning, as shown in the image above right. The ARP for your antenna type, usually the center of the base or tripod mount, is illustrated at [antenna calibration](#). If you enter a 0.0 antenna height, OPUS will return the position of

your ARP.

5. OPTIONS

Press OPTIONS to customize the way your solution is performed and/or reported. Your selections will override the optimized OPUS defaults and should therefore only be employed by experienced users.

Once this information is complete you then click the Upload button to send your data to NGS. Your results will be emailed to you in a few minutes.

Each file is submitted independently via the Internet and the final adjusted solution is returned to the user within minutes. This allows the user with an independent quality control check prior to performing an adjustment using the GPS Software.

Also, OPUS solutions uses Geoid12A model as a default for determining the elevation. The user no longer has the option of selecting prior Geoid models.

If you are processing the data within a week of data collection, the data will be processed using the rapid ephemeris. The final processed baselines should be resubmitted for adjustment when the precise ephemeris is available. The web address for submitting GPS data for processing is...

<http://www.ngs.noaa.gov/OPUS/index.html>.

If OPUS Solutions are to be used to determine current values on benchmarks or reference control, it is required that multiple observations be performed for a minimum of 4 hours, and the results averaged to determine the final result.

Although OPUS should be used as a quality assurance validation check of your post-processed and adjusted horizontal and vertical position, OPUS can also be used as a means of determining your GPS benchmark position, **IF** multiple observations are performed on the benchmark by averaging the OPUS solutions. The criteria for achieving reliable results for the average of the positions are:

1. Static is performed at the unknown benchmark for a minimum of 4 hours for three separate events, or
2. Static is performed at the unknown benchmark for 4-8 hours for two separate events, if the logistics to access the benchmarks is difficult or very remote.
3. Process the final result when Precise Ephemeris is available, usually 1 week after the GPS observation date.
4. Use a tool like MS Excel to tabulate the OPUS solutions into a spreadsheet and determine average of positions of Northing, Easting, Ellipsoid Height, and Orthometric Height.
5. If an OPUS Solution results in a vertical peak-to-peak of greater than 0.100 meters, remove this OPUS solution from the equation to obtain the best average of the positions. This may require an additional observation to be performed to achieve redundancy.

FYI...IMPORTANT CHANGES TO OPUS PROCESSING DATA RESULTS (September 14, 2011)

On September 6th 2011, the National Geodetic Survey released new CORS coordinates, velocities and absolute antenna calibration information. The new coordinates are in the IGS08 epoch 2005.00 and NAD 83 (2011, MA11, PA11) epoch 2010.00 reference frames. The Online Positioning User Service (OPUS) web tools no longer support the old (ITRF00 and NAD 83 (CORS96)) as of December 31st, 2011. Beginning on January 1st 2012, OPUS, along with the UFCORS utility will only provide coordinates in the IGS08 and NAD 83 (2011, MA11, PA11) epoch 2010.00 reference frames.

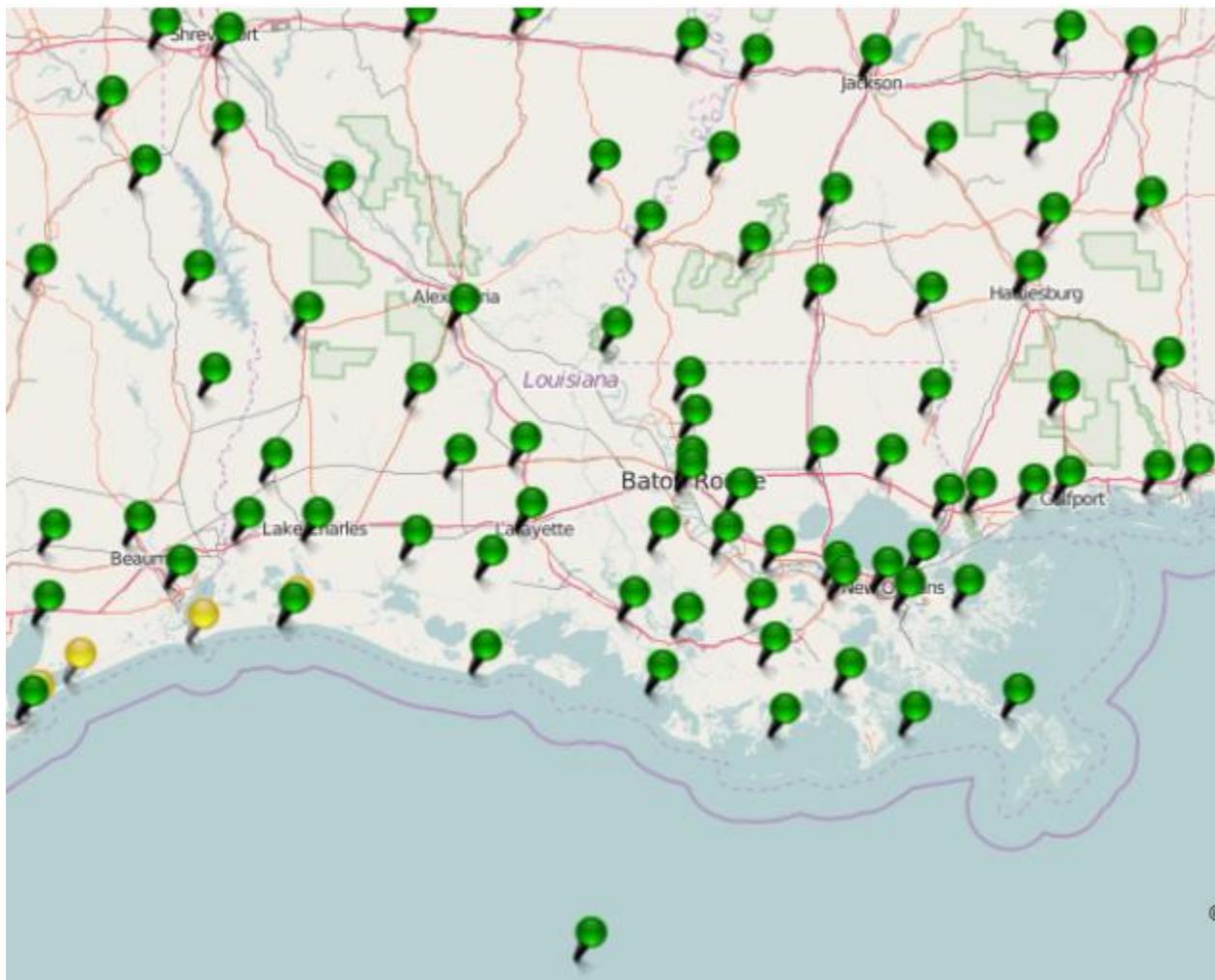
New absolute antenna calibrations have also been released in both ant_info and ANTEX formats while the older, relative antenna calibration will remain in the ant_info format.

F.3. Downloading Continuously Operating Reference Station (CORS) Data Files

Option 1: Locate the NGS National CORS stations within or adjacent to your GPS network at the following Internet web address: <http://www.ngs.noaa.gov/CORS>. Select the observation time that coincides with your GPS network observations prior to downloading.

Option 2: If you have a subscription to the LSU Center for Geoinformatics C4Gnet Real Time Network, Login to the website at <http://c4gnet.lsu.edu/>. Locate the NGS National CORS and Louisiana CORS stations within or

adjacent to your GPS network by logging into the following Internet web address: <http://c4gnet.lsu.edu/>. Select the observation time that coincides with your GPS network observations prior to downloading.



LSU C4G and LSRC have invested in the installation of CORS all across Louisiana. These CORS provide the backbone for a statewide active GNSS precise positioning network. The number of CORS will reach 67 by the end of 2011 including 27 NGS national CORS. GULFNet was built on Trimble's GPSNet infrastructure software and C4Gnet uses the next generation VRS3Net software.

F.4. Processing the GPS Data Files with Trimble Business Center (TBC v.3.4 or higher)

If you are processing the data within a week of data collection, the data will be processed using the current broadcast ephemeris (automatically downloaded with the raw data files). The final processed baselines should be re-processed using the precise ephemeris. There is 8-day latency for the precise orbit data and can be downloaded from NGS' website at the following Internet address: <http://www.ngs.noaa.gov/orbits/>

Upon completing the downloading, check-in process and confirming that all antenna heights, filenames, etc. to be correct, processing the raw data files can now begin. Select and load only the files that were observed during the same session. After the files have been loaded, verify that your elevation mask is set to 15 degrees under Project Settings. Select and process the data files one session at a time. Review the "Baseline Processing Report" and note the satellites with cycle slips and "noisy" data or short observation times. Return back to the processing menu, select the same session and remove these satellites. Re-process the session again and check the "Baseline Processing Report" once more. Check the "Final Solution Type" for each baseline and verify that it is "Fixed". If the solution type was "Float" for a baseline then review the satellite data once more and note any satellite that may be corrupting the data. Continue this procedure until the results of all the baseline solution is "Fixed".

The idea of the processing stage is to eliminate or “filter out” most of the corrupted satellite data by analyzing each processed baseline. The causes of the data becoming corrupt may vary and can be caused by a satellite being unhealthy, multi-path, obstructions from trees or buildings, etc., breaking the satellite signal to the GPS receiver.

F.5. GPS Network Adjustment

Select the network adjustment and load the all processed baselines.

Use the following procedures for determining the three dimensional values for the GPS network.

Four Procedures for Estimating GPS-Derived Orthometric Heights (Processing and Adjustment):

Procedure 1: Perform a 3-D minimum-constraint least squares adjustment of the GPS survey project, i.e., constrain to one latitude, one longitude, and one orthometric height value on one CORS Station.

Procedure 2: Using the results from the adjustment in procedure 1 above, detect and remove all data outliers. The user should repeat procedures 1 and 2 until all data outliers are removed.

Procedure 3: Compute differences between the set of GPS-derived orthometric heights from the minimum constraint adjustment (using the latest National geoid model, e.g., GEOID12A³) from procedure 2 above and the CORS.

Procedure 4: Perform a fully constrained adjustment holding all latitude and longitude values, and all CORS height values fixed.

The use of GPS data and a high-resolution geoid model to estimate accurate GPS-derived orthometric heights will be a continuing part of the implementation of the CPRA-LCZ GPS Network guidelines.

NOTE: OPUS should only be used as a quality control check and should not be used in lieu of a least squares adjustment. OPUS uses a slightly different methodology to obtain positions than the least squares adjustment method.

³ There may be occasions when the scope of services will require that elevations be adjusted using earlier geoid models for the purpose of comparing to elevations calculated with those particular geoid models. This will eliminate any possibility of bias in the elevation comparison, except for the effects of subsidence.

F.6. Expected Accuracies

<i>Table 1</i>	Horizontal	Horizontal	Horizontal	Vertical	Vertical
Spatial Accuracy Classification	0.005-0.020 meters	0.020-0.050 meters	0.050-0.500 meters	0.005-0.050 meters	0.050-0.500 meters
Network Control:					
Minimum number of stations and quadrants:	3	3	2	4	2
Maximum distance between project's outer boundary and network control stations:	50 km.	50 km.	50 km.	20 km.	20 km.
Initial Position:					
Maximum 3-D error for the NAD83 coordinates input for the initial station in any baseline solution:	10 m.	20 m.	50 m.	10 m.	20 m.
Baseline Connections:					
A baseline observation must be made between any two stations (1 and 2) where their spacing is less than (___)% of the otherwise shortest direct connection to either station:	10%	N/A	N/A	30%	20%

<i>Table 2</i>	Horizontal	Horizontal	Horizontal	Vertical	Vertical
Spatial Accuracy Classification	0.005-0.020 meters	0.020-0.050 meters	0.050-0.500 meters	0.005-0.050 meters	0.050-0.500 meters
Repeat Station Observations percent of number of stations					
Two times:	100%	100%	80%	100%	100%
Three or more times:	10%	10%	0%	50%	25%
Sidereal time displacement between occupations (start time to next start):	60 min.	45 min.	20 min.	120 min.	60 min.
Repeat Baseline Measurements					
Percent of total number of independent baselines:	5%	5%	5%	10%	10%
Satellite Constellation Mask					
Minimum mask angle, degrees above local horizon:	15	15	10	18	15
Minimum number of satellites observed during 75% of occupation:	5	5	4	5	5
Maximum PDOP during 75% of occupation:	5	5	5	4	5
Antenna Setup					
Maximum centering error (measured and phase center):	3 mm	5 mm	7 mm	5 mm	5 mm
Independent plumb point check required:	Y	Y	N	Y	N
Maximum height error (measured and phase center):	5 mm	5mm	5 mm	3 mm	5 mm
Number of independent antenna height measurements per occupation:	2	2	2	2	2
Photograph (close up) and/or pencil rubbing required for each mark occupation:	Y	Y	N	Y	N

F.7. Submitting Data to NGS OPUS Shared for Publishing.

The National Geodetic Survey has made sharing GPS survey positions easier, thanks to an upgrade to the Online Positioning User Service (OPUS) called OPUS Shared. In addition to standard position reports, OPUS Shared gives users an option to share their positioning results in an online NGS database. OPUS provides a comparatively streamlined and homogeneous method for computing and sharing the location of permanent features, such as tidal bench marks or other survey control. As originally designed, the OPUS solution report is distributed via e-mail to the submitting user only. By adding a database and additional Web forms to capture a description of the positioned object, NGS can now make OPUS solutions publicly available.

Publish Your OPUS Solutions

Publishing helps maintain local ties to the National Spatial Reference System, and, by linking observations, strengthens the models used to translate between modern and legacy mapping products.

Step 1. Follow These Requirements

Field Procedures

- GPS [data file](#) ≥ 4 hour duration
- quality [mark setting](#)
- experienced observer
- fixed height tripod recommended
- brace tripod legs with sandbags or chain
- verify [antenna height](#) and plumb
- see [HARN guidelines](#)

High-Quality OPUS Solution

- ≥ 70% observations used
- ≥ 70% ambiguities fixed
- ≤ 3 cm RMS
- ≤ 4 cm peak-to-peaks, lat. & lon.
- ≤ 8 cm peak-to-peak, el. hgt.
- properly identify [antenna type](#)
- precise or rapid orbits (avail. next day)

Mark Attributes

- photos of mark & equipment
- details (name, type, stability, etc.)
- description to aid mark recovery
- preview [mark description form](#) & [help file](#)

SECTION G

GULFNet Virtual Real Time Surveys (VRS) for Topographic and Bathymetric Surveys

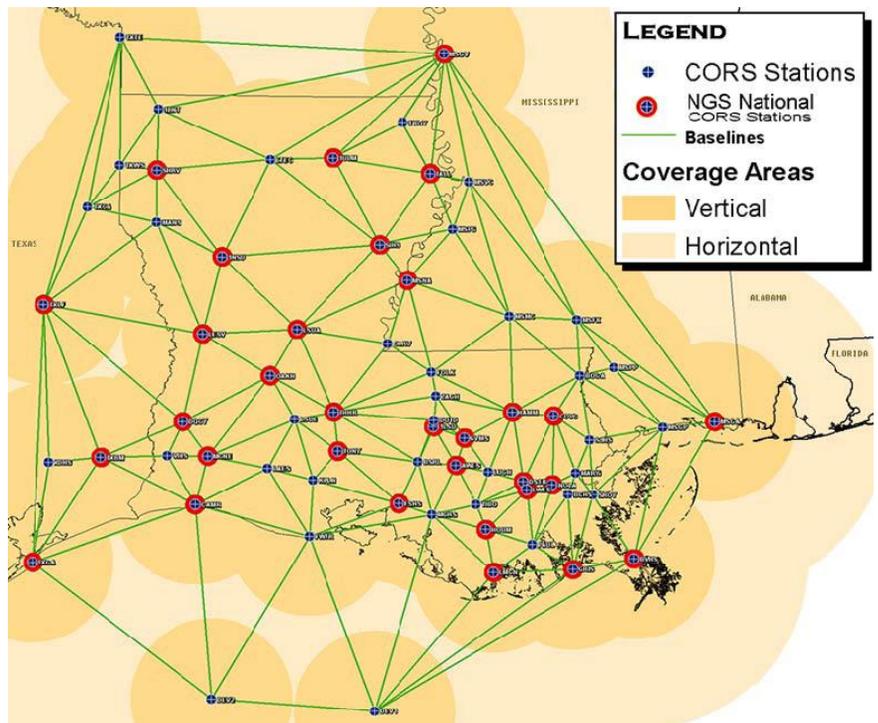
Real-Time Network (RTN) Virtual Reference Systems (VRS) like the statewide C4Gnet offered by the LSU Center for Geoinformatics can also be a useful tool for surveying on projects within the Louisiana Coastal Zone in real time where internet access is available. The horizontal precision is consistently on position with the selected datum [NAD83 (2011)]. The vertical elevations delivered on the system have the repeatability and appear to be consistent within a tenth of a foot on different days of observation. The advantages are that no base station is required and cell phone technology has replaced the radio transmission of DGPS corrections. These advantages are that the user is not limited to a three mile radius of the base and the user can carry very good positioning for miles. This reduces the time required for re-setup of the base on large project areas, not to mention radio interferences and cabling issues.

Prior to performing a topographic or bathymetric survey using GULFNet VRS, a 5-minute observation should be recorded on the project's adjusted LCZ Secondary GPS monument to validate that the system is delivering correct elevations. If the resulting elevation acquired with VRS is significantly different, wait 15 minutes and perform the observation again. If the results of the second observation is different from the GPS Adjusted elevation on the benchmark, but is consistent with first VRS observation, then there may be an elevation bust on the GPS adjusted value determined at the benchmark monument. Please review adjustment procedures in Section F.

The traditional practice that has been followed for establishing Secondary Control as per NGS technical memorandum for GPS derived orthometric heights should still be followed if you are trying to achieve the 1-5 cm relative accuracies for elevations.

The use of C4GNet RTN VRS in lieu of Real time Kinematic (RTK) surveys for topographic and bathymetric work can prove to be beneficial, not as a replacement, but as an added choice of tools in the surveyors toolbox.

For more information on C4G's Real-Time Network Virtual Reference System, visit the LSU Center for Geoinformatics at the following web address.
<http://c4g.lsu.edu>



SECTION H

Deliverables

H.1. GPS Survey Report

Upon completion of a project, a GPS Survey Report shall be provided to CPRA in a digital format and written to a compact disk (CD) attached to four (4) copies of 8 1/2" x 11" bound booklet.

The GPS Survey Report shall contain and not be limited to the following information:

H.2. Methodology Report

The Methodology Report shall be in a digital format, such as Microsoft Word, and written to the compact disk (CD) along with hard copies, signed and stamped by the Registered/Professional Land Surveyor in the State of Louisiana who was directly involved with the project. The hard copies shall be bound in the GPS Survey Report.

The report shall contain but not be limited to the following information:
(Include dates for each job task and key personnel involved)

- ***Project Description***
- ***Pre-planning the GPS Network***
- ***Information on Monument Reconnaissance***
- ***The GPS Static Survey***
- ***Equipment used for data collection***
- ***Downloading, Processing and GPS Network Adjustment procedures***
- ***GPS Network Accuracy Results***

H.3. Monument Information Datasheets

Information Datasheets shall be created for each newly established monument for the project. The Datasheet shall be in a digital format such as Microsoft Word and written to a compact disk (CD) hard copies bound in the final GPS Survey Report. (See Section J for a sample copy)

The information to be included on the Datasheet will be as follows:

- ***Location Map with monuments location plotted***
- ***Monument Name***
- ***Written directions to the monument***
- ***Monument Description/Type***
- ***Date that monument was established***
- ***Contractors Name***
- ***Adjusted NAD83 Geodetic & Lambert Coordinate (LSZ) Positions***
- ***Adjusted NAVD88/ Position***
- ***Adjusted Orthometric Height from CORS Adjustment***
- ***Adjusted Orthometric Height from OPUS Adjustment***
- ***Monument Photograph***

Monument datasheets shall be created for each newly established or revised monument for the project. Datasheets shall be in a digital format as outlined by this manual. All newly established or revised monument datasheets shall be forwarded to Mel Guidry at the address listed below:

Mel Guidry
CPRA-Lafayette Area Office
P. Box 62027
Lafayette, LA. 70596-2027

H.4. Drawing Files

A map shall be created for the project area with all monuments clearly labeled and plotted using the final adjusted coordinates. The drawing files shall be in a digital format such as AutoCAD (*.dwg or *.dxf) and written to the compact disk (CD) along with hard copies each bound in the final GPS Survey Report and folded to 8 ½" x 11".

The information to be included on the Project Map will be as follows:

- ***Project Name***
- ***Contractor Name***
- ***Digital aerial or USGS Quadrangle with monuments plotted correctly***
- ***Monument Names***
- ***Horizontal and Vertical Datum***
- ***Map Date***
- ***Map Scale***
- ***North Arrow***

H.5. Field Notebook Records

All existing and newly established GPS monuments utilized on the project shall be documented and recorded neatly and legible in a transit field book. Copies of the field notebook shall be included in the final bound GPS Survey Report. (See Section J.5 for a sample copy)

The information to be included on the field notebook will be as follows:

- ***Project name***
- ***Date of installation or survey***
- ***Crew members***
- ***Sketch of location with monument referenced to physical features such as power poles, fence posts, structures, etc.***
- ***Monument name stamping***
- ***A "Drive To" description***
- ***Monument type description***
- ***Number of rods, rod size and total depth to refusal***

H.6. Final Adjusted GPS Data

A tabulation sheet containing the final adjusted results of all CORS Stations and Secondary Control points in the project network holding to a minimum of three CORS Stations fixed shall be included in the final bound GPS Survey Report. The tabulation shall include the following information:

- ***GPS Station Name***
- ***Latitude/longitude NAD83 (2011) Epoch 2010***
- ***Geoid12A Height in meters***
- ***Ellipsoid Height in meters***
- ***Orthometric Height in meters and feet NAVD88 (2011) Epoch 2010***
- ***Published Elevation & Differences***
- ***OPUS Results and Comparisons to GPS Adjustment Results***

Also, a tabulation sheet containing the final adjusted results of all CORS Stations and Secondary Control points in the project network holding to a minimum of three CORS Stations fixed shall be included in the final bound GPS Survey Report. This sheet shall include the same information as the previous tabulation.

The final adjusted GPS project shall be archived in digital format and written to compact disk (CD) and shall be included in the final bound GPS Survey Report. Also the GPS data should be exported in "Rinex" format and shall be included in the final bound GPS Survey Report.

SECTION I

Common Errors to Avoid

I.1. Increasing Field Accuracies

Meeting the minimum standards can be difficult and sometimes impossible when errors are introduced into a survey. The cause is usually faulty equipment and/or careless field procedures. If the equipment is faulty, the errors are compounded with every set-up. Eliminating these errors will ensure meeting the minimum standards required as well as reducing the time spent trouble shooting where problems exist.

The first step to increasing field accuracies should begin with the equipment being used. Regular maintenance and calibration checks will save hours of frustration. Time is Money!

I.2. Eliminating Systematic Errors due to Faulty Equipment

- Tripods:
Ensure the stability of your tripod. Frequently check for loose screws and play in the mounting head. Check lock-down screws, pivot joints and feet.
- 2 Meter Fixed Height Tripods:
Verify center pole height. Do not assume that the tripod is 2.000 meters. Also make sure that GPS Antennas seat flush with top of tripod when attached. If a gap exists, measure and record in field book and/or GPS Log sheet. Calibrate bulls-eye bubble frequently.
- Tribrach:
Check that plumb bob aligns with optical plumb. Also check that bulls eye bubble is level with instrument.
- Prism Poles:
Bull's eye bubble should be checked for vertical accuracy. Also check that centering point is tight.

I.3. Common Errors to Avoid

These are common BAD PRACTICES that corrupt survey integrity and should be eliminated altogether!

- Set-up on the wrong station
- Setting GPS Monuments under obstructions
- Transporting tribrachs and/or instruments attached to tripod
- Leaving equipment unattended
- Unleveled Tripod
- Not tightening lock-down screws on tripod
- GPS Antenna height miss-measurement and not checked using QC procedure
- Not communicating problems such as late start time with Party Chief or Project Manager
- Hurrying up to save time

J.2. Typical GPS Log Sheet for Adjustable Tripods

USE THIS FORM IS USING ADJUSTABLE TRIPODS WITH TRIBRACHS GPS LOG SHEET

Job No. Date Operator
 Client Job Description
 Location

SESSION INFO

Station No. 4 Characters Julian Date 3 Characters Session No. 1 Character

Long Name

Monument Description

Receiver Type Receiver Serial No.

Antenna Type Ant. Serial No.

Antenna Height Measurements to Bottom Inside Notch of Ground Plate

Reading 1 Meters Average of Readings Meters

Reading 2 Meters *Check Reading Ft.Tenths or Inches

Reading 3 Meters ***Note: Record all readings on log sheet prior to key-in receiver**

Start Time Stop Time Session Time

Time	Pdop	Satellites in View

Time	Note any Power Failures, Weather Conditions, etc.

USE BACK OF THIS SHEET TO MAKE STATION SKETCH, REFERENCE TIES & DESCRIPTION

J.3. Typical GPS Log Sheet for Fixed Height Tripods

USE THIS FORM IS USING FIXED HEIGHT TRIPODS GPS LOG SHEET

Job No. Operator

Client Job Description

Location

SESSION INFO

Station No. 4 Characters Julian Date 3 Characters Session No. 1 Character

Long Name

Monument Description

Receiver Type Receiver Serial No.

Antenna Type Ant. Serial No.

Antenna Height Measurement is **TRUE VERTICAL** to Bottom of Antenna Mount if Using Fixed Height Tripod

Reading 1 *NA* Meters Fixed Hgt 2 Meter Tripod **2.000** Meters

Reading 2 *NA* Meters Check Reading **6.562** Feet/Tenths

Reading 3 *NA* Meters Note: Record all readings on log sheet prior to entering in receiver

Start Time Stop Time Session Time

Time	Pdop	Satellites in View

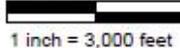
Time	Note any Power Failures, Weather Conditions, etc.

USE BACK OF THIS SHEET TO MAKE STATION SKETCH, REFERENCE TIES & DESCRIPTION

J.4. Sample Monument Datasheet



VICINITY MAP



Reproduced from NAIP Louisiana 2013 1m Aerial Imagery

Station Name: "PO29 SM 03"

Location: Monument is located approximately 4 miles west of the LaPlace exit at State Highway 3188 in the median of Interstate 10, and is approximately 6.1 miles east of State Highway 641 overpass. It is 50 feet west of the bridge crossing the Mississippi Bayou.

Monument Description: Monument is a 9/16 steel rod driven to 52 feet to refusal within a 6" PVC sleeve set in concrete with protective metal accesscover stamped 'PO29 SM 03'

Stamping: PO29 SM 03

Installation Date: 2003 **Date of Survey:** 8-Jun-14

Monument Established By: 3001, Inc.

NAD83 (2011) Epoch 2010.00 Geodetic Position

Lat: 30°06'51.58423"N

Long: 90°34'51.13441"W

NAD83 (2011) Epoch 2010.00 Datum LSZ (1702) Ft

N= 587,850.92

E= 3,518,737.04

Adjusted NAVD88 Height

Elevation = 11.86 feet (3.614 mtrs)

Ellipsoid Height (2011) = -22.850 mtrs.

Geoid12A Height = -26.464 mtrs.



FOR REFERENCE ONLY

LCZ Adjusted NAVD88 Height

Elevation (Geoid09)= N/A

Ellipsoid Height = N/A

Elevation (Geoid03)= 11.82 feet (3.603 mtrs)

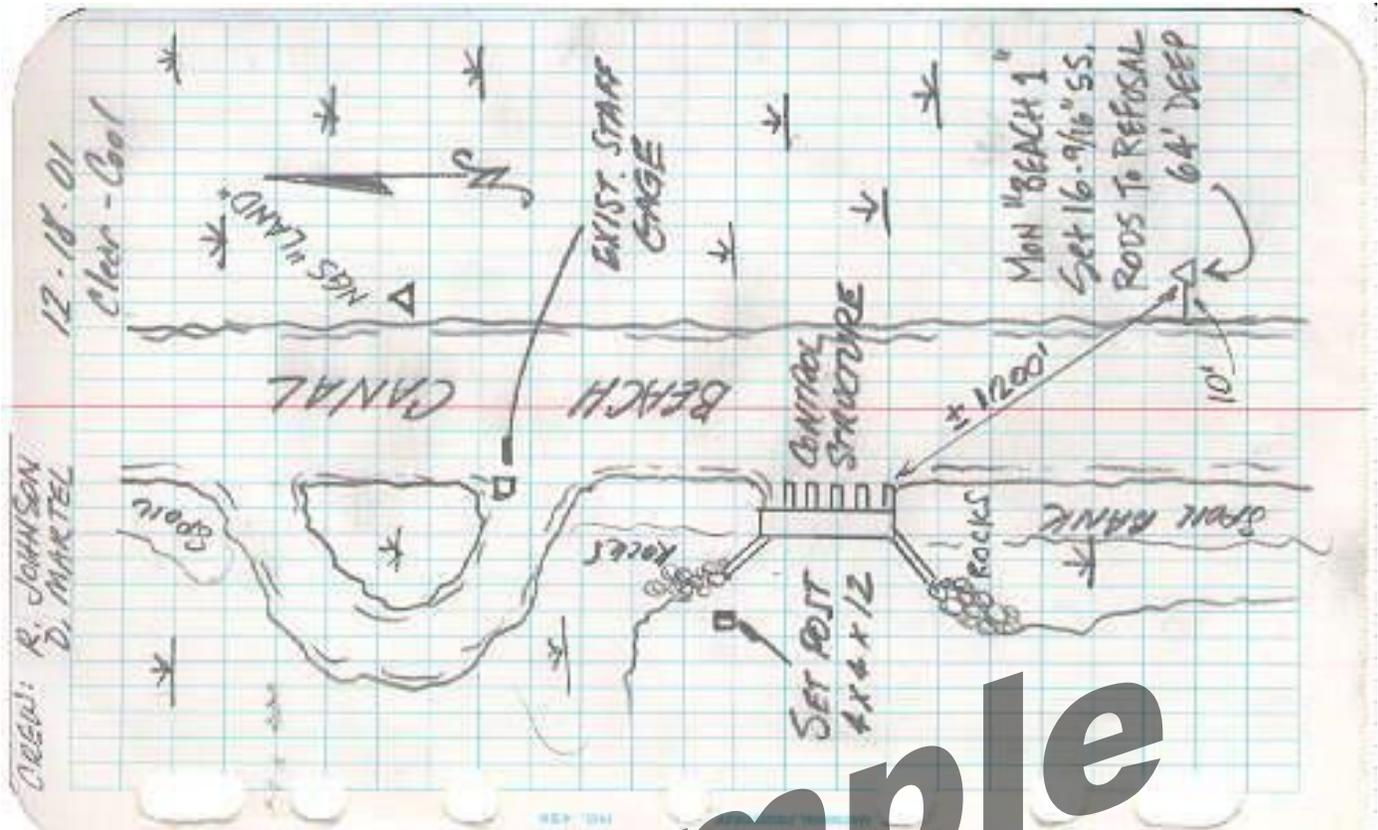
Ellipsoid Height = -22.870 mtrs.

Elevation (Geoid99)= 12.30 feet (3.749 mtrs)

Ellipsoid Height = -22.837 mtrs.

Adjusted Position Established John Chance Land Surveys, Inc. for the Coastal Protection & Restoration Authority of Louisiana

J.5. Sample Field Notes



SABINE NATIONAL WILDLIFE REFUGE

MONUMENT BEACH 1

Monument was set along the east bank of BEACH CANAL, midway between STARS NORTH CANAL & STARS CENTRAL CANAL approximately 1200 feet Southward from an existing water control structure

Monument is a standard NGS Style Floating Sleeve w/ 16 - 4 feet x 9/16" SS Rods driven to refusal total depth = 64 feet

Monument sleeve & cover projects 1 foot above normal ground.

Sample

SECTION K

Secondary Horizontal and Vertical

Control

K.1. GPS RTK

When performing Real Time Kinematic surveys (RTK), if the base station is to be occupied for 4 hours or longer, raw L1/L2 data should be collected and submitted to the National Geodetic Survey On Line Positioning User Service (OPUS) for QA purposes. Field notes shall be kept to document, at a minimum: the base station setup (control point number and ID/description antennae height (antennae reference point or antennae phase center). Checks to an established project control point shall be done at the beginning and end of each day, and/or after each base station setup and shall be logged on the data collector/controller. Control Points set with RTK should be occupied for 3 minutes and data collected at one-second epochs and averaged. The Rover Position Dilution of Precision (PDOP) should be set to 5.0 or less and the elevation mask at 15 degrees. Only coordinates that are the result of a “fixed” solution and have a horizontal and vertical precision (rms) of 2cm and 5cm respectively should be accepted. For VRS (Virtual Real Time Surveys) such as GULFNet based RTK surveys follow the procedures outlined in Section G.

K.2 Total Station

All conventional traverses in support of topographic or construction surveys shall be to Third Order Class II standards as indicated in Attachment 2 (unless otherwise specified in the Scope of Work). All traverse measurements shall be recorded in field books and or data collectors. Where short tangents (less than 800 feet) are required, a sub-traverse shall be run in which the angles shall close to no more than 10”/setup and the positional error shall be no more than 1:2500. Field notes for total station surveys shall document changes in setup, back sight, instrument height (HI), rod height (HR), cross section numbers, stationing, etc. In order to prevent the possible misidentification of occupied or back sight control points and/or to detect control point disturbances, check shots shall be performed and documented in the field book/data collector for each instrument setup. Additionally, a check shot should be made to the nearest control point and the difference in distance/coordinates and elevation should be recorded.

K.3 Leveling

All differential leveling in support of topographical or construction surveys shall be to Third Order closure standards as indicated in Attachment 2 (unless specified otherwise in The Scope of Work) from 2 existing benchmarks or a closed loop. The contractor shall strive to balance back sight/fore sight shot distances and in all cases limit them to less than 300 feet in order to reduce or eliminate typical instrumentation errors. In addition, each day, before any third-order differential leveling survey is initiated, a “PEG Test” should be performed and documented.

K.4 Secondary Survey Monuments

Newly established permanent control by the Contractor should consist of deep rod with datum point or brass disk or brass disk epoxied to a concrete foundation. P.K. fasteners in asphalt, “X”s in concrete, steel rods or pipes, railroad spikes and nails in poles or wooden stakes are to be used for temporary horizontal and vertical control only.

SECTION L

Establishing Survey Baselines/Transects

L.1 Restoration Surveys

The Contracting Party will prepare landowner notification letters using CPRA's template and shall transmit to assessed property owners prior to mobilization. At no time will the Contracting Party or its sub-consultants access private property without following proper notification procedures in accordance with state law. CPRA Landrights Division will provide the names and contact information for notifications. The Contracting Party shall notify owners in accordance with La. R.S. 49:214.6.9. Failure to adhere to the above-stated CPRA Revised Statute will be considered grounds for termination of the contract. Rights of entry to privately owned property must be respected by all CPRA contractors. Survey Transects for restoration projects should be arranged in a cross-section or grid type pattern with transect spacings ranging from 250' to 1000', and delineated along the centerline of the proposed linear feature. See Table L-1 below for guidance pertaining to typical survey transect spacing for restoration projects. These survey transect locations for restoration project features are normally defined in the project Scope of Work.

Coastal Restoration Project Feature	Pattern Type	*Typical Survey Transect Spacing (ft.)
Marsh Creation Fill Area	Cross- Section/Grid	250'/500'
Earthen Containment Dike	Cross- Section	250' - 500' (& along C.L.)
Pipeline Corridor	Cross- Section	500' - 1000' (& along C.L.)
Inland Borrow Area	Cross- Section	250' - 500'
*Offshore Borrow Area	(as per LASSARD)	(as per LASSARD)
Mississippi River Borrow Area	Cross- Section	250'
Barrier Island Beach and Dune	Cross- section/Profile	250' – 500'
Shoreline Protection	Cross- Section	500' – 1000' (& along C.L.)
Ridge Restoration	Cross- Section	250' - 500' (& along C.L.)
Earthen Terraces	Cross- Section	500' (& along C.L.)
Equipment Access Routes	Cross- Section	500' - 1000' (& along C.L.)

Table L-1: Typical Survey Transect Spacing's for the design of restoration projects.

*Survey transect spacing may be altered due to cultural resource requirements.

Survey data (position, elevation, water depth, topographic features) shall be recorded at a minimum every 25' or where elevation changes of 0.5' occur. Survey data for access routes following existing bayous and canals normally is collected along the centerline at 25' intervals with perpendicular cross-sections. An appropriate "topo

shoe” shall be attached to survey rover rods to prevent the rod from sinking. Survey transects for barrier island restorations and shoreline protection projects are normally laid out from a stationed project baseline that runs parallel to the project beach and dune feature.

Surveys shall be taken of surface features to capture infrastructure adjacent to the project areas. Surface features include, but are not limited to, pavement (including edge of pavement, pavement type, etc.) pavement markings (including type of pavement marking), driveways, parking lots, underground utilities (water, sewer, telephone, etc.) overhead utilities, utility poles, utility towers, telephone boxes, traffic signage, all other signage, trees (including type and trunk diameter) drainage channels (including invert and water surface elevations), water bodies (ditches, streams, creeks, rivers, ponds, etc.), levees (including top, toe, etc.), structures, bridges, columns, fences, gates, and all other surface features. The size and type of all surface features shall be shown.

On many restoration projects, water level measurements need to be collected for the duration of the survey. Water level data shall be collected at the beginning and end of each day. Installation and surveying techniques used for the proposed staff gauge shall follow the guidelines listed in Section O.

Average marsh elevations are normally required for marsh creation projects. The marsh elevation sites will be determined by CPRA. The average marsh elevation is defined as the point where a survey rod is resting among living vegetative stems and is supported by soil containing living vegetative roots. In order to get a consistent reading, it may be necessary to cut stems in some marsh vegetation where stem density is extremely high. A minimum of twenty (20) elevations (each one separated by 20 to 40 feet) is normally required at each site. CPRA personnel shall be present at the time of the marsh elevation survey.

L.2 Flood Protection, Control Structure Surveys

Flood protection projects such as levees, pumping stations, and water control projects require monumented, stationed baselines not only to collect topographical and elevation data but also to serve as the basis for construction layout, as built surveys and monitoring surveys. Baselines need centerline monumentation and offset monumentation if the baseline will be disturbed or destroyed during construction. Topographical surveys for proposed Levee projects generally require perpendicular transects at 200’ spacing. Construction surveys require stake outs at 100’ stationing with grades at toe top and centerline and 25’ intervals in between. Periodic levee monitoring and re-certification surveys require centerline elevations at 250’ intervals. For monitoring levees that can be vehicle driven, a useful tool is the use of truck or ATV mounted rover receiver RTK surveying techniques. In addition to proper RTK surveying methods the Rover Receiver height must be carefully determined and the receiver must be firmly mounted. RTK survey data can be collected, and tied to levee stationing, by stakeout coordinates or distance between points along the centerline.

L.3 Deliverables

Aerial Photograph Overlays

All surveys lines shall be overlaid onto 2012 or newer geo-rectified Digital Orthophoto Quarter Quadrangle (DOQQ) aerial photographs. The Contracting Party is responsible for obtaining any additional information needed to reference the surveys required by this scope to the aerial photograph.

Preliminary Submittals

In addition to the deliverables requested in this scope of services, two sets of 11” x 17” preliminary drawings shall be delivered to the CPRA Project Manager, for technical review and comment before the remaining deliverables are finalized.

Please send all preliminary and final deliverables to the following address:
Coastal Protection and Restoration Authority
P.O. Box 44027
Baton Rouge, LA 70804-4027

Three (3) copies of a report describing the survey methodology employed in the field, including but not limited to, control, any calibrations, equipment used, etc. The report should also contain the following:

- A set of half size (11" x 17") drawings including a plan view showing all survey lines and sheets showing all cross sectional diagrams. The elevations shall be referenced to NAVD 88 with the appropriate Geoid Model. The horizontal coordinates shall be referenced to the Louisiana State Plane Coordinate System South Zone, NAD83 at the appropriate Epoch.
- A hard copy of the data sets (file listing shall be stored in a comma delimited ASCII format):
 1. Baselines, including all stations and P.I.'s,
 2. Fill Site Survey Transects (by station number), including point number, northing, easting, elevation, and description.
 3. Centerline and Access Survey Transects (by station number), including point number, northing, easting, elevation, and description.
 4. Magnetometer Survey Readings, Source Information, and amplitude.
- A copy of the field notebook records.
- The results and description of the marsh elevation surveys including locations and average marsh elevation.

The drawing files shall conform to the CPRA AutoCAD Standards and shall be in **AutoCAD 2011** or later in .dwg format. The plan view(s) shall be overlaid with the Louisiana State Plane Coordinate System South Zone, NAD83. Also include a table with benchmark locations (in State Plane and Geographic coordinates) and elevations (NAVD88) on which the survey is based. Show the state project name and number on all drawings. Show the project name and number on all drawings

Two digital copies of the following files (on separate CD disks):

- 1) Complete survey report describing the survey methodology employed in the field.
- 2) Drawing files in AutoCAD 2012 (.dwg) or later format.
- 3) All data sets listed in Sections L.1 and L.2 (in .csv format)

CERTIFICATION

All deliverables shall be certified by a Professional Land Surveyor licensed by the State of Louisiana.

Section M

Hazard Surveys and Infrastructure Mapping

M.1. Research Existing Infrastructure Permits Using Available Databases

Several online GIS databases are available that display the location and supporting permitting documents of infrastructure such as oil and gas wells and pipelines, power lines, water pipelines, and communications cables that may impact a coastal project. The Louisiana Department of Natural Resources SONRIS website is specific to the state and contains pertinent data that is geo-referenced in a GIS application. The website can be accessed at the following address:

<http://sonris-www.dnr.state.la.us/gis/agsweb/IE/JSViewer/index.html?TemplateID=181>

Navigate through the appropriate tab in the “Table of Contents” window to display the GIS layer of interest. Coastal permit information is available under the “Coastal Management” tab. Information regarding other oil and gas infrastructure, such as well locations and activity status, is available under the “Oil/Gas” tab.

Another online source of information is the National Pipeline Mapping System (NPMS). This online GIS based application is similar to SONRIS and may be accessed at the following address:

<https://www.npms.phmsa.dot.gov/PublicViewer/>

It is important to note that these databases do not identify all infrastructure that may be located within a project area. The NPMS acknowledges that no gathering or distribution pipelines are available in their online database. Older infrastructure may also be absent from these mapping applications. Additionally, these mapping applications may only display the permitted location of the relevant infrastructure, which may differ significantly from the as-built location. Therefore, a robust field investigation is also required.

The results of this permitting research should be provided as a deliverable in any survey report that includes hazard and infrastructure location. Copies of relevant permits and any correspondence with operators of infrastructure located within the project area should be presented in an independent section within the final delivered survey report. Any recovered shapefiles or other mapping data showing the as-built or permitted location of project-relevant infrastructure should be included in the final survey maps delivered to CPRA.

M.2. Locate Surface Infrastructure Features

Any above-ground structures, markers, signs, or other features indicating the location of project-relevant infrastructure should be photographed and located using the prescribed positioning techniques specified in the project scope of work (i.e. RTK, DGPS, etc.). The locations of these surface features should be recorded and used to support the final determination of infrastructure location. The photographic documentation of these features should be provided in an independent section within the final survey report. Each photograph should include a brief description and the location of the feature as determined by the prescribed positioning techniques specified in the project scope of work.

M.3. Magnetometer Survey

To assist in identifying and locating existing infrastructure or other hazards that may impact a coastal project, a thorough geophysical investigation of the project area should be conducted using a magnetometer. The initial magnetometer survey should consist of a grid providing maximum coverage of the project area. The spacing of the grid will be project-specific and determined by the CPRA project representative, subject to recommendations by the Contracting Party.

When surveying in channels or rivers, a minimum of three (3) survey transects oriented parallel to the shoreline, and a minimum of three (3) survey transects oriented perpendicular to the shoreline, will be collected. One parallel-oriented transect will be positioned to cover the centerline of the channel, with the remaining two positioned as close to the banks as the surveying vessel can safely navigate. Two perpendicular-oriented transects will be positioned at the points where the channel or river enters and exits the project area, with an additional transect located at the mid-point between these two termini. Additional transects may be

recommended depending on the size of the water body or specific hazards or infrastructure requiring further investigation.

Magnetometer data will be positioned using the prescribed positioning techniques specified in the project scope of work. A sketch depicting the offset distances between the GPS antenna and magnetometer will be included in the field notes. Data collected with the magnetometer will be in a recorded file format to facilitate interpretation and mapping. All data will be interpreted by qualified personnel, and magnetic anomalies will be described and mapped. A table of interpreted magnetic anomalies will be provided as a deliverable that includes, at a minimum: anomaly number, x and y coordinates, gamma signature, anomaly duration, interpreted source of anomaly, and whether or not it will impact the project. Any interpreted hazards and areas of interest will also be mapped.

M.4. Precise Horizontal and Vertical Positioning of Hazards and Infrastructure

Additional field investigations will be required if the results of the magnetometer survey indicate the presence of infrastructure or other potential hazards that may impact the project. This will involve locating the source of the anomaly and mapping it precisely using the prescribed positioning techniques specified in the project scope of work. If the object producing the anomaly is buried or submerged, a probe will be used to locate the object and determine its exact depth. If a pipeline is detected, the Contracting Party will probe the pipeline and determine depth of cover and the elevation of the top of the pipeline. Pipelines will be probed at a minimum of every 100 ft. within any area of dredging and a minimum of every 500 ft. within all adjacent areas. The results of these field investigations will be mapped and presented in plan-view on 11" x 17" layout(s).

Section N

Single Beam Echo Sounder Bathymetric Surveying

The following guidelines are based on the standards set forth in the US Army Corps of Engineers Hydrographic Surveying Manual EM 1110-2-1003. Please refer to this manual for a more detailed description of the methodology described in this guide.

N.1. Acoustic Equipment

Single beam transducers are available in a variety of configurations that balance water column penetration and resolution. In general, a high frequency (~200 kHz) transducer with a beam width not-to-exceed 5° will be used on CPRA projects. However, specific sites may require specialized dual-frequency transducers capable of recording high and low frequencies simultaneously (e.g. 24 kHz and 200 kHz). In areas known to exhibit high levels of suspended sediment, a dual-frequency transducer will be used to penetrate any fluid mud or suspended sediment and confidently measure the hard water bottom. If the digitized water bottoms measured by the high and low frequencies deviate, additional manual soundings may be requested by the CPRA project representative, and will be captured using a 13 lb. mushroom type lead.

N.2. Positioning Methods and Spatial Accuracy

Positioning for hydrographic surveying in support of CPRA projects will be accomplished using the prescribed positioning techniques specified in the project scope of work. If using Real-Time Kinematic (RTK), Post-Processed Kinematic (PPK), or other inertially-aided navigation solutions (i.e. SBET, IAPPK, IARTK), corrections will be made according to the designated benchmarks provided in the scope of work, and all hydrographic data must be recorded in a format that facilitates the calculation of adjustments according to the project datum (See Section F of this Guide). The use of a Real-Time Network (RTN), such as GULFNet, may also be acceptable if determined by the CPRA project representative (See Section G of this guide). All hydrographic data will be corrected for vessel motion using a motion sensor and software capable of accounting for, at a minimum, heave, pitch, and roll. Regardless of the positioning methods used, all hydrographic data delivered to CPRA will have a spatial accuracy of +/- 0.20 feet or better, unless otherwise specified by the scope of work.

N.3. Quality Assurance/Quality Control (QA/QC) Procedures

Hydrographic surveys employing RTK positioning techniques in support of CPRA projects will follow the RTK QA/QC procedures and best practices set forth in the previous sections of this guide. In addition, the QA/QC procedures specific to hydrographic surveying set forth in EM 1110-2-1003 Chapter 4 Table 4-6 will also be followed unless otherwise specified in the scope of work. If employing inertially-aided navigation solutions, such as those producing an SBET, IARTK, or IAPPK, dynamic draft and squat/settlement computations will not be necessary. Tidal gauges and tidal benchmarks may also be substituted with conventional monuments specified by the scope of work to be used as horizontal and vertical position checks, depending on the positioning methods employed.

N.3.1 Instrument Offset and Alignment Static Survey

All survey equipment used will be rigidly mounted to the survey vessel, and all hydrographic surveying vessels used in support of CPRA projects will undergo an instrument offset and alignment static survey to ensure lever arms and distance offsets are correctly accounted for. This is to ensure that all calculations related to motion compensation and positioning are accomplished using accurate values. This survey must be conducted while the vessel is resting on a stable platform, such as the trailer, cradle, blocks, or jack stands. If conducted on a trailer, the trailer must also be stabilized using hydraulic jacks, jack stands, blocks, etc., to ensure no movement occurs during the survey. The offset distances will then be measured using a total station, and referenced to the center-of-gravity of the vessel. The offsets determined from this static survey will be used in each subsequent hydrographic survey, and will be documented in the field notes accompanied by a sketch of the instrument layout with respect to the vessel shape in plan-view.

N.3.2 Position Check

During the field collection phase of a hydrographic survey, several QA/QC procedures must be completed and documented in the surveyor field notes. A position check confirming that the positioning equipment in use is configured and functioning correctly will be recorded prior to collecting any hydrographic data. This redundancy check is accomplished to provide confidence in the positioning of all acoustic data.

To accomplish a position check using conventional RTK techniques:

- Remove the RTK rover antenna from the survey vessel and install on a conventional range pole.
- Locate an acceptable previously adjusted project monument, as specified in the scope of work.
- Record an observation of the previously adjusted project monument for no less than 5 minutes.
- Document the results of the observation in the survey field notes.
- Rough comparisons of the positions can be accomplished real-time to assess for the presence of major position busts, incorrect datums, etc., and precise comparisons can be accomplished during post processing to assess for position quality.

Position checks using fixed navigation systems without removable antennae, such as the Applanix POS/MV, will be accomplished using a secondary independent positioning system such as GULFNet.

To accomplish a position check for fixed navigation systems:

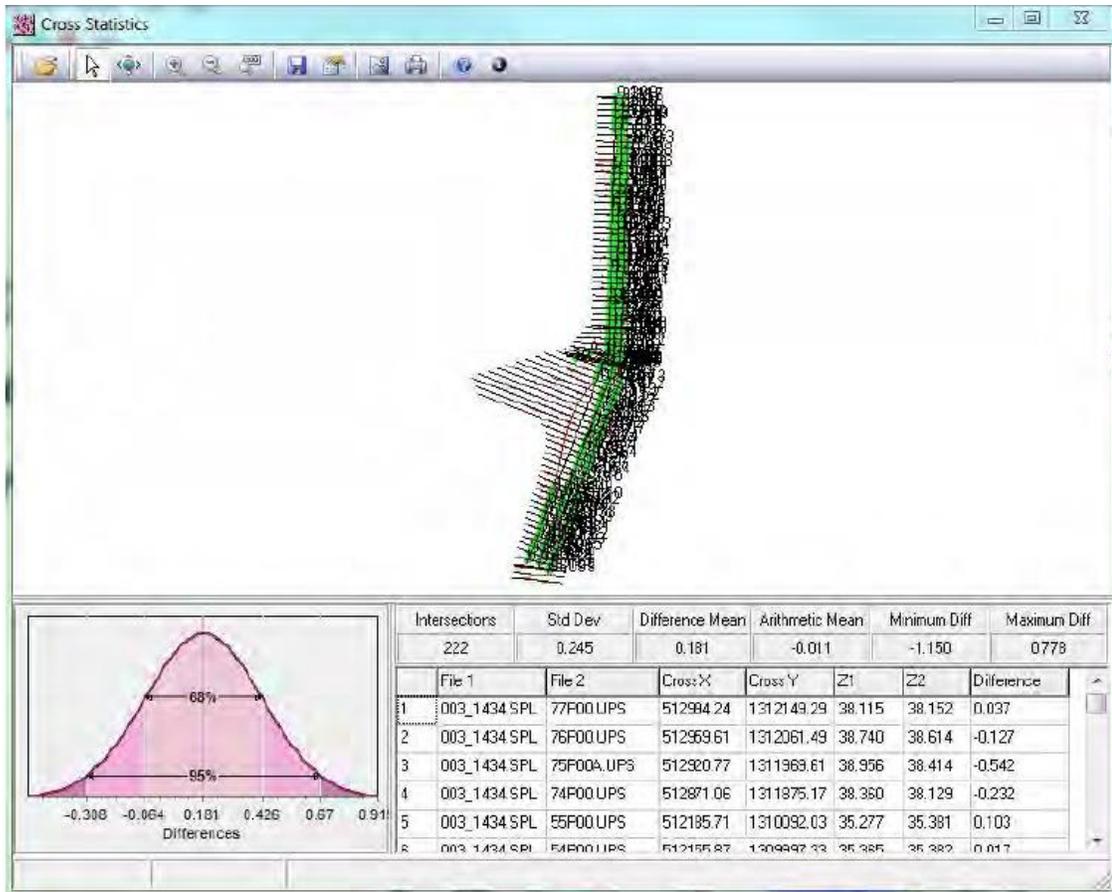
- Establish a point on the vessel that will be repeatedly used for position checks and permanently mark this with a weld, bolt, or other immovable object. The accurate position of this check point must be determined during the instrument offset and alignment static survey.
- Prior to commencing any survey, record an observation of this check point using an RTK antenna capable of receiving GULFNet corrections, mounted to a range pole. This observation should last no less than 5 minutes, and must be accomplished while the POS/MV or other navigation system is simultaneously collecting data. The vessel should be in a position to minimize motion during this observation, such as moored to a pier or on a trailer.
- Document the results of the observation in the field notes.
- Rough comparisons of the positions can be accomplished real-time to assess for the presence of major position busts, incorrect coordinate systems, etc., and precise comparisons can be accomplished during post processing to assess for position quality.

N.3.3 Sound Velocity Corrections

A bar check or sound velocity probe will also be recorded to account for sound velocity variability in the water column of the survey area. At least one method of sound velocity correction must be used and documented in the field notes. Each method must reach project depth, thus accounting for velocity variations throughout the entire water column, even in the deepest areas of the project. A minimum of two (2) sound velocity checks must be recorded daily, one prior to the survey and one immediately following the cessation of surveying activity. Additional sound velocity checks should be collected in areas of high temperature, salinity, or turbidity variability, such as in the vicinity of river mouths, plant cooling water outputs, etc. These additional checks should be spatially and temporally distributed with the goal of accounting for the potential cause of the velocity variation. For additional information on sound velocity correction methodology, please refer to EM 1110-2-1003.

N.3.4 Depth Quality Assurance Assessments

Check lines will be collected to assess the repeatability the depths measured during the survey. A minimum of three (3) survey check lines that intersect with all surveying transects will be collected. These intersections will provide the means to calculate the repeatability of the data, and to detect any potential errors resulting from vessel motion, sound velocity, positioning errors, etc. that were unaccounted for during the survey. A statistical analysis of these intersections will be accomplished and documented as a deliverable. Many commercial hydrographic software packages include automated statistics programs that will accomplish this and produce a report to provide as documentation. An example of such as report, taken from EM 1110-2-1003, is provided below. For additional information on depth quality assurance methodology, please refer to EM 1110-2-1003.



N.4. Documentation and Deliverables

The Contracting Party will provide all deliverables specific to the project scope of work, as provided by the CPRA project representative. Hydrographic survey reporting will be incorporated into the report format described in Section H of this guide. The surveying techniques, post-processing workflows, and equipment used will be described as part of the methodology report. Any other pertinent information related to the survey, such as photos, monument datasheets, and QA/QC reporting will be assimilated into the previously defined report structure.

Field notes for hydrographic surveying operations will vary from the conventional format, and include the following:

- Project Name
- Date of Survey
- Crew Members and Responsibilities
- Surveying Conditions (Sea State, Wind)
- Sketch of Surveying Vessel with Offsets Notated
- Documentation of QA/QC procedures including position and sound velocity checks
- The time each surveying line was collected
- Other pertinent information, including vessel traffic, downtime, etc.

Raw survey data may also be required for submittal at the behest of the CPRA project representative. This may include fathometer files (i.e. Hypack .RAW files), positioning files (i.e. POSPAC files), other related GPS files (i.e. Trimble DC files), and sound velocity probe files.

Section O (under development)

UAS/UAV Photogrammetry/Lidar Surveys

N.1. Overview

Definitions

N.2. Suitability

Suitability

N.3. Procedures/Data Collection

Procedures

N.4 Processing/QA/QC

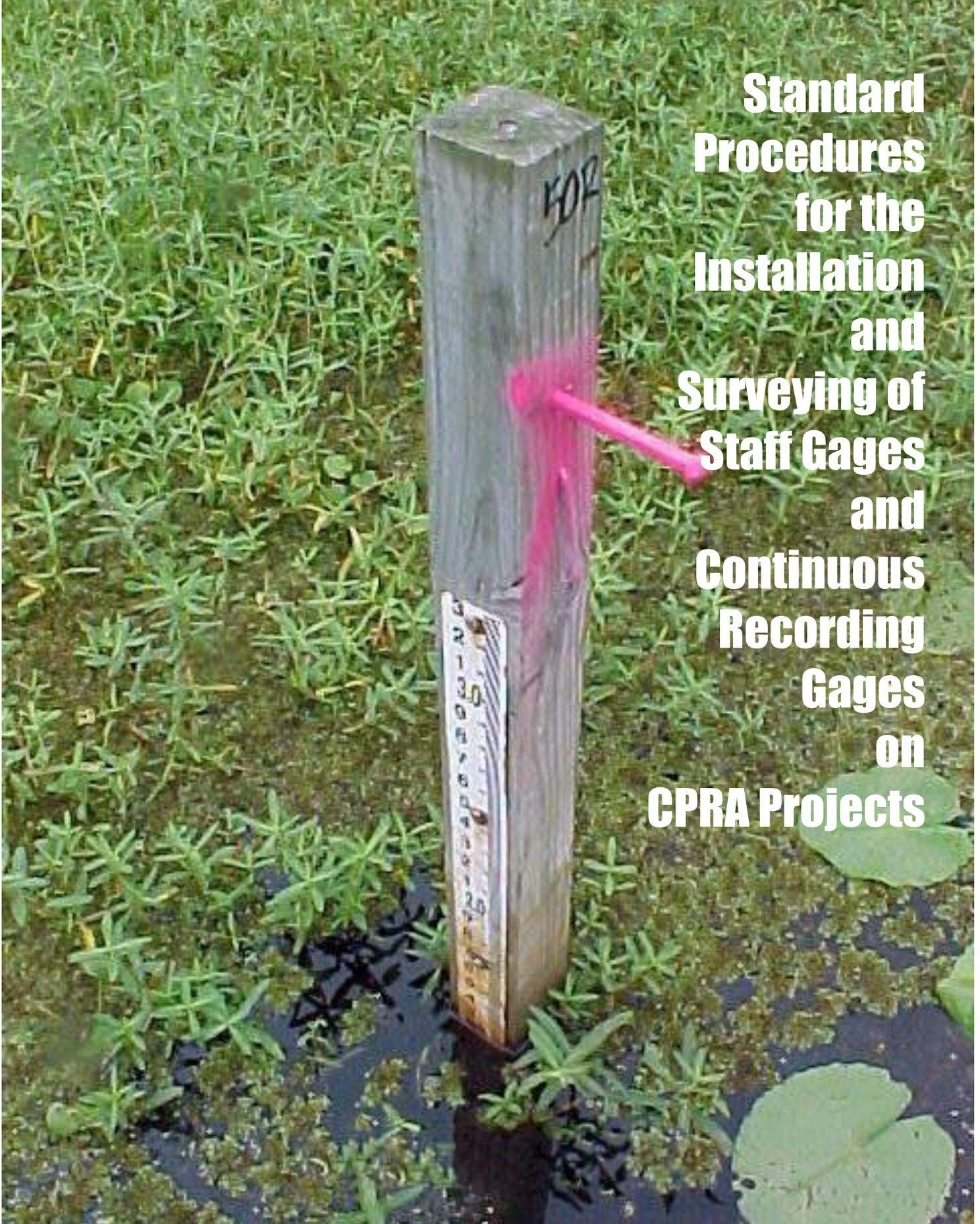
Procedures

N.5. Deliverables

Procedures

<http://sonris-www.dnr.state.la.us/gis/agsweb/IE/JSViewer/index.html?TemplateID=181>

**Standard
Procedures
for the
Installation
and
Surveying of
Staff Gages
and
Continuous
Recording
Gages
on
CPRA Projects**



SECTION P

New Staff Gage Installation

P.1. Materials Required

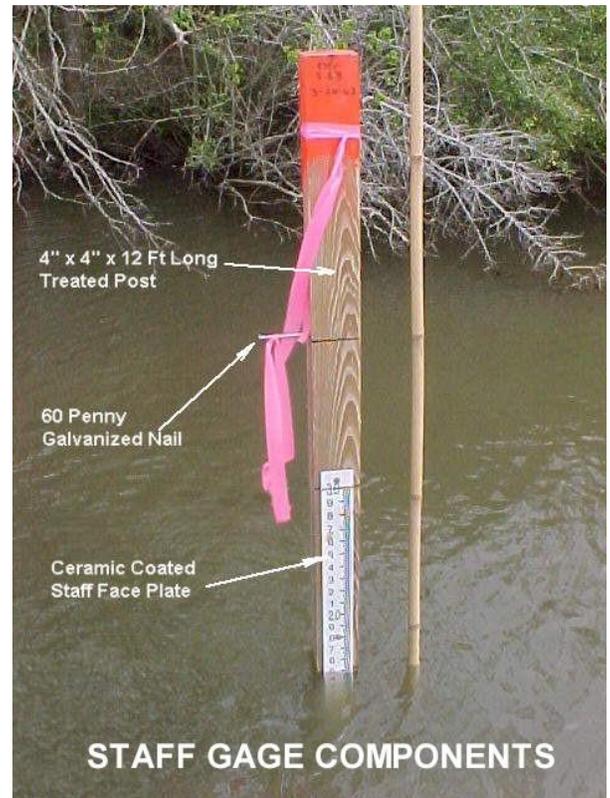
The standard components that are required by CPRA for a typical new staff gage installation are as follows:

- 4" x 4" x 12 foot long treated post
- Galvanized 60d Nail (TBM)
- 1/4" x 3" long Stainless Steel Screws
- Ceramic Coated Staff Gage Plate

P.2. Tools Required for the Installation

Tools required to install the new staff gage on site are as follows:

- Post Driver (Man-Killer)
- Cordless Drill with 1" Drill Bit
- Carpenter's Hand Level
- Ratchet with 3/8" Socket
- Vise Grip
- Combination Square
- Permanent Marker
- Tape Measure
- Hand Saw



P.3. Installation

The first step for installing a new staff gage is to find a suitable site. Considerations for finding the proper location are maximum protection from boat traffic, proper water depth for the post length to be installed, proximity of a GPS monument or bench mark to be referenced from for differential leveling procedures and satellite visibility if Real-Time Kinematic (RTK) procedures are to be used for elevation determination.

Using the handsaw, saw cut a "V" at the base of the 4 x 4 post. This makes for easier installation while driving the post into the water bottom. Once a location has been selected, place the post driver over the top end of the post and the bottom point in the water bottom (approximately 2-3 feet deep) while a helper keeps vertical plumb using the hand level. The Post should be driven until the top of the post is about 4 to 5 feet above the top of water, occasionally checking plumb.

P.4. Top of Post Measurements With RTK

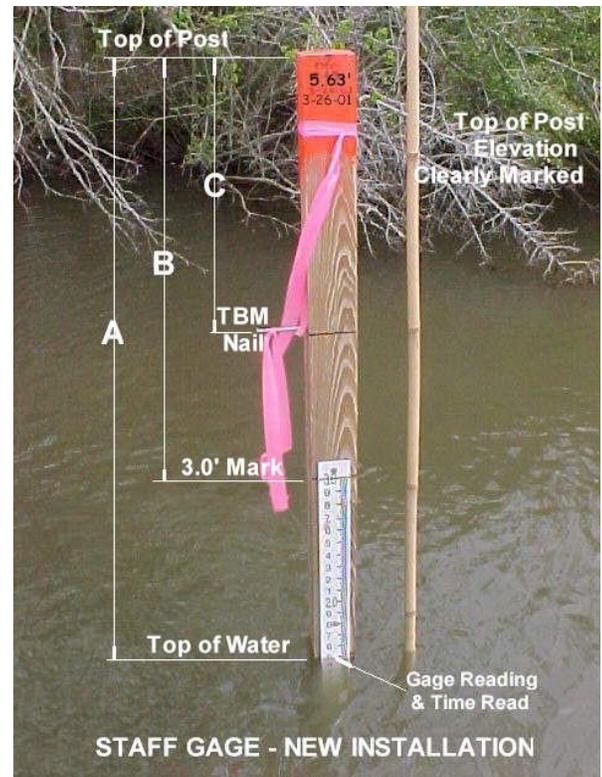
After setup of RTK Base Station on a known GPS bench mark and the Rover unit is in fixed mode and receiving differential corrections, perform a quality assurance check near the base station to confirm positions are being correctly delivered. Upon confirmation, carefully measure the Rover's GPS antenna pole from the Base of the antenna mount to the base of

the bracket of the bulls-eye bubble and make a note of this value. Use value as the measured rover antenna height. The base of the bulls-eye bubble is more stable for performing shots on the gage versus using the point of the pole.

Place the base of the bulls-eye bracket of the RTK Pole flush with the Top of the 4 x 4 Post and enter the "Point Number" and Feature Code (Top of 4x4 Post), then select "Measure" in the "Topo Mode" on the Data Controller (should be about a 3-5 second measurement). Switch the measurement mode to "Observed Control" and enter the same point number adding the letter "A" after it and select "Measure". Once the measurement has been taken (about 3 minutes), compare the elevation to the previous shot. If the elevation differs by more than 0.04 feet, retake the measurement until a satisfactory tolerance is attained.

P.5. Installation of TBM Nail

Using the permanent marker, write the elevation and the date at the top of the post. Subtract 4.00 from the top of post elevation and note the number...Example: $5.63 - 4.00 = 1.63$. (See measurement "C" in photo at right). Use this value to measure down from the top of the post and place a mark on the side of the post. Use the combination square to draw a line at this point. Drill a $\frac{1}{4}$ " hole with the drill, aligning the top of the hole with the bottom of the line and install TBM at the 4.00 foot mark using a 60d galvanized nail. Place the base of the bulls-eye bracket of the RTK Pole flush with the top shank of the 60d galvanized nail and enter the "Point Number" and Feature Code (60d Nail), then select "Measure" in the "Topo Mode" on the Data Controller (should be about a 3-5 second measurement).



P.6. Installation of the Staff Plate

Subtract 3.00 from the top of post elevation and note the number...Example: $5.63 - 3.00 = 2.63$. (See measurement "B" in photo at right). Use this value to measure down from the top of the post and place a mark on the side of the post. Use the combination square to draw a line at this point. Place the Staff plate on the 4x4 post and align the 3.00-foot gage reading with the 3.00' MarO. While holding the staff plate in place, drill into the post through the top hole of the plate, about $\frac{1}{2}$ " deep. Attach the plate to the post using a $\frac{1}{4}$ " stainless steel bolt leaving about $\frac{1}{16}$ " of the bolt away from the brass washer on the plate. Note: Compressing the screw to the plate will cause the ceramic coating to chip and premature corrosion to the staff plate. Attach 2 more screws to the plate to complete installation of staff plate.

P.7. Record Measurements and Sketch in Field Notes

All measurements should be recorded in the field book. Included should be date of survey, names of crew members, name of gage, RTK Base location, gage reading and time read, measurements A, B and C after installation, RTK point numbers and elevations observed with check shots included, and a front view sketch with measurements shown. (See Section J.8)

P.8. Example of Field Notes Required

SABINE NATIONAL WILDLIFE REFUGE

BASE @ "SOC3"

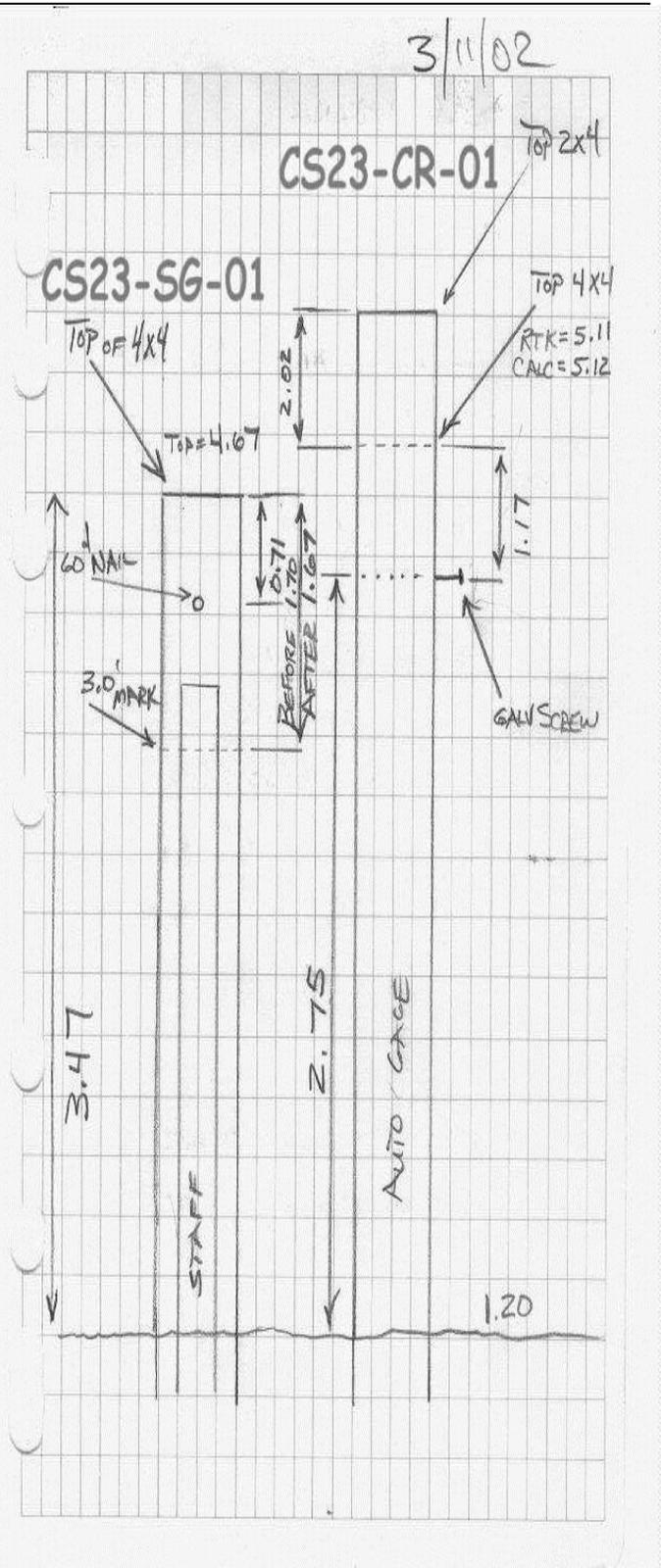
STAFF GAGE AND AUTO GAGE
@ HUMPBACK LANDING

STAFF GAGE READING PRE-ADJUSTMENT
1.22 @ 1:00 P.M.

STAFF GAGE READING POST-ADJUSTMENT
1.20 @ 1:20 P.M.

STAFF GAGE RAISED 0.03 FT

105	TOP AUTO GAGE POST 4x4	5.11
104	TOP STAFF GAGE POST CHECK	4.65
103	TOP STAFF GAGE POST	4.67



P.9. Examples of Types of Staff Gage Installations



Example 1

Photo at left is an example of a new ceramic staff gage plate attached to a home-made wooden staff gage at a revised elevation. Note the reset date and elevation marked on the top of the old gage and 60d galvanized reference nail installed.

Example 2

Photo at right is an example of a new ceramic staff gage plate attached to a timber piling at a revised elevation. Note the homemade wooden staff gage attached to the timber piling in the rear of the phot





Example 3

Photo at left is an example of a new ceramic staff gage plate attached to a timber piling at a floodgate. Note the TBM using a PK nail with flagging at the top of the post and at the 4 foot marO.

Example 4

Photo at the right is RTK being performed on a staff gage post at the reference 60d nail. The bottom of the bulls-eye bubble is set on the shank of the nail. To the left is a continuous recorder gage.



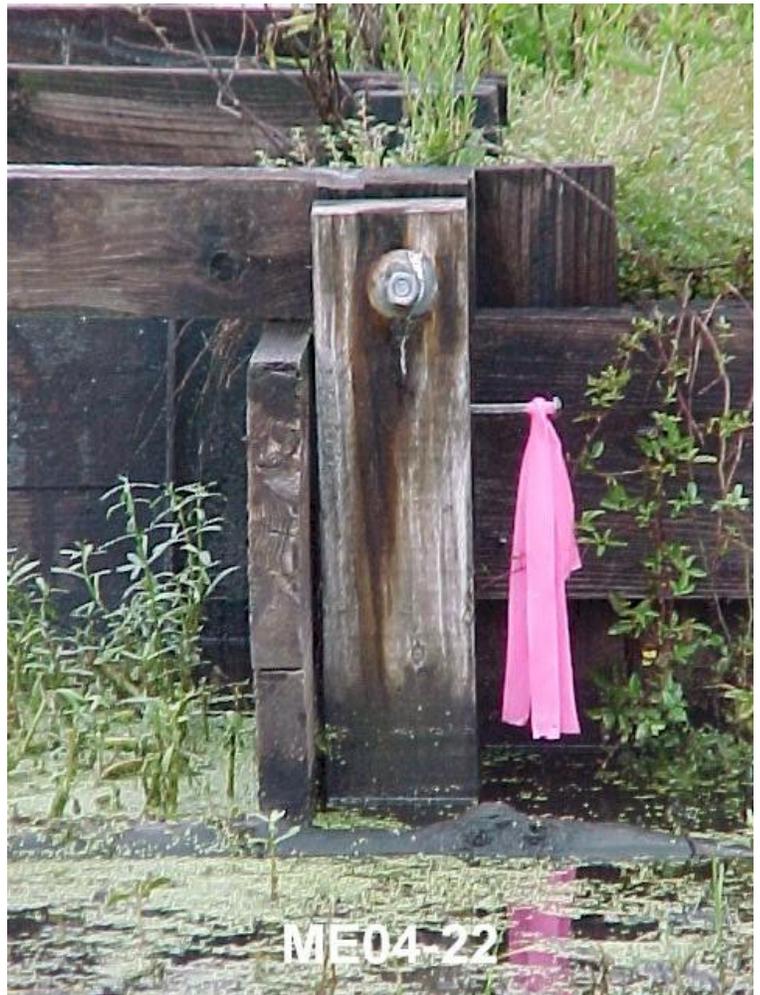


Example 5

Photo at left is an example of a new ceramic staff gage plate attached to a 4x4 post. To the left is a continuous recorder gage tied to a transmitter.

Example 6

Photo at the right shows a TBM boatspike installed into a timber post at a water control structure. This TBM was used to set a staff gage at the structure by measuring down to the top of water.





Example 7

Photo at left is an example of a new gage installation in the Terrebone and Barataria Basins. A ceramic staff gage plate attached to a 2x4 treated board which is attached to a 2" galvanized pipe that is driven into firm bottom.

Example 6

Photo at the right shows RTK Survey being performed to determine the elevation at the top of a 4x4 treated post at a continuous recorder. Once the elevation was determined, measurements were taken from the top of the post to the reference nail and top of water to determine those elevations, as noted.

