APPENDIX I
TIDES AND WATER LEVEL REQUIREMENT

STATEMENT OF WORK
OPR- J348-KR-2011 Approaches to Mississippi Sound, MS
(02/28/2011 HY)

1.0. TIDES AND WATER LEVELS

1.1. Specifications

Tidal data acquisition, data processing, tidal datum computation and final tidal zoning shall be performed utilizing sound engineering and oceanographic practices as specified in National Ocean Service (NOS) Hydrographic Surveys Specifications and Deliverables (April 2010).

1.2. Vertical Datums

The tidal datums for this project are Chart Datum, Mean Lower Low Water (MLLW) and Mean High Water (MHW). Soundings are referenced to MLLW and heights of overhead obstructions (bridges and cables) are referenced to MHW.

1.2.1. The operating National Water Level Observation Network (NWLON) stations at Pascagoula, MS (874-1533) serve as datum control for the short-term station 874-AAAA for the survey area. Therefore, it is critical that this station remain in operation during all periods of hydrography.

During periods of hydrography, CO-OPS is only responsible for the operation and maintenance of NWLON control stations and the contractor is responsible for the maintenance and operations of all contractor installed (tertiary) stations. The contractor is required to monitor the NWLON control water level data via the CO-OPS Web site at http://tidesandcurrents.noaa.gov/hydro.shtml or through regular communications with the OCS COTR or the OCS COTR's CO-OPS authorized point of contact (Bruce Servary at 301-713-2897 x183 or via e-mail: nos.coops.oetteam@noaa.gov) before and during operations. The OCS COTR or the COTR's CO-OPS authorized point of contact (Bruce Servary) will serve as liaison between the contractor and NOS/CO-OPS to confirm operation of this station and to ensure the acquisition of NWLON control water level data during periods of hydrography. Problems or concerns regarding the acquisition of valid water level data identified by the contractor shall be communicated with the OCS COTR or the COTR's CO-OPS authorized point of contact (Bruce Servary) to coordinate the appropriate course of action to be taken such as gauge repair and/or developing contingency plans for hydrographic survey operations.

1.3. Tide Reducer Stations

The operating water level station at Pascagoula, MS (874-1533) will also provide water level reducers for this project. Therefore it is critical that it remains in operation during the survey.

1.3.1. For this project, it will be necessary to install and continuously operate water level measurement systems (tide gauges) at one or more approved subordinate station locations. These subordinate stations identified for hydrography are required to provide tidal datums, water level reducers, refinement for final zoning, and harmonic constituents for predictions needed to meet NOS hydrographic specifications' accuracies as well as to support other NOAA objectives. The

stations listed in Section 1.2 will provide control for datum computations at subordinate stations by using the NOS method of comparison of simultaneous observations.

A 30-day minimum of continuous data acquisition is required for all required subordinate station installations. If the data is collected for less than 30 days at the required subordinate location, CO-OPS may not publish tidal datums and bench mark sheets according to the operating guidelines and business rules. This means CO-OPS may not be able to validate tidal datums for less than 30 days of valid and good data. Since all data, including water level data collected for hydrographic surveys, is used to derive products that support various NOS multipurpose applications, the collection of a minimum of 30-days of data is a crucial requirement.

For all subordinate stations, data must be collected throughout the entire survey period in specified areas for which they are applicable, from 4 hours before to 4 hours after the period of hydrography and not less than 30 continuous days. This is necessary not only to facilitate the computation of an accurate datum reference as per NOS hydrographic specifications (http://www.nauticalcharts.noaa.gov/hsd/specs/specs.htm), but also to ensure a functional data set that meets CO-OPS' multi-purpose product use and dissemination standards.

If alternative water level stations to those required by CO-OPS are necessary, then the contractor must justify the reason and coordinate with the OCS COTR to obtain CO-OPS' approval and to define the timing and location of the alternative subordinate station(s). The installation of alternative stations or any changes to the original contract documents including the hydrographic project instructions must be approved by the OCS COTR. For all subordinate stations that are approved and installed, a minimum of 30 continuous days of data must be collected throughout the entire survey period for which they are applicable. If the minimum 30-day data collection requirement is not met, CO-OPS may not be able to validate tide reducers and zoning for the survey.

All modifications to the original subordinate gauge installation requirements shall be documented by CO-OPS via an amendment to the Statement of Work. Delivery of the Statement of Work to OCS's Hydrographic Surveys Division Data Acquisitions Branch will signify CO-OPS' approval of the additions and/or modifications to the gauge installation requirements.

The following subordinate station is required:

Station Number	Station Name	Latitude(N)	Longitude(W)
874AAAA*	Horn Island	30.2419°	88.7652°

* If a station can be physically installed along the south side of Horn Island, East Ship Island, or West Ship Island along the survey area (see dashed purple boundary shown on the graphic file J348KR2011GRAPHIC.pdf), a subordinate station is required there. If no feasible location is available along the south side of those islands, re-occupation of a historical station Ship Island (874-4756) (location: 30.2133° N, 88.9717°W) is required. Conduct reconnaissance of the area to establish a suitable location for the placement of the water level gauge and provide the OCS COTR or the COTR's CO-OPS authorized representative with the proposed name and location. CO-OPS/ED will confirm this and then assign a station number. **Do not install these subordinate gauges prior to receiving assigned station numbers. If it is necessary to change the location of a gauge by more than ¼ mile from its assigned location and a station number**

has already been assigned, contact CO-OPS/Engineering Division personnel prior to the installation of the gauge.
The OCS COTR's CO-OPS authorized point of contact, Bruce Servary, will serve as liaison between the contractor and NOS/CO-OPS and can be contacted by phone at 301-713-2897 x183 or via email: nos.coops.oetteam@noaa.gov.

1.3.2 This section is not applicable for this project.

1.3.3 Water Level Records: : If subordinate water level stations are installed, submit water level data, such as leveling records, field reports, and any other relevant data/reports, including the data downloaded onto diskette/CD as specified in the latest version of the NOS Specifications and Deliverables document.

1.3.3.1. Water level records should be forwarded to the following address:

NOAA/National Ocean Service/CO-OPS
Chief, Engineering Division
N/OPS1 - SSMC4, Station 6531
1305 East-West Highway
Silver Spring, MD 20910

1.3.4. Recover all historical bench marks at each required subordinate water level station. If any bench marks are destroyed or not found, install new bench marks to replace them. In the event of a new station with no historical marks, installation of a minimum of five bench marks will be required. Third-order levels from the tide staff or sensor to a minimum of five bench marks (including the primary bench mark) are required at the beginning and end of the survey period. See Section 1.1. for clarification of requirements.

1.3.4.1. Hand held GPS latitude and longitude positions on all historical subordinate water level station bench marks are required. In addition, one of the subordinate water level station bench marks shall be selected for high accuracy static differential GPS observations to obtain ties between the tidal datums and GPS derived datums. Refer to Section 1.1 for further details on the GPS positioning requirements.

1.3.5. Operate the water level stations listed in Section 1.3.1. of this Statement of Work for the following hydrographic area(s) or zone(s):

Station Number	Hydrographic Area(s) or Zone(s)
874AAAA	Entire survey

1.4. Zoning

1.4.1. The water level station at Pascagoula, MS (874-1533) is the reference station for preliminary data for hydrography in the area of Approaches to Mississippi Sound, MS. The time and height correctors listed below for applicable zones should be applied to the preliminary data at the station indicated during the acquisition and preliminary processing phases of this project. **Preliminary data may be retrieved in one month increments over the Internet from CO-OPS SOAP web services at http://opendap.co-ops.nos.noaa.gov/axis/text.html.** The contractor

must notify the COTR or the COTR's authorized representative immediately of any problems concerning the predicted tides. Predictions are six-minute time series data relative to MLLW in metric units on Greenwich Mean Time. For the time corrections, a negative (-) time correction indicates that the time of tide in that zone is earlier than (before) the predicted tides at the reference station. A positive (+) time correction indicates that the time of tide in that zone is later than (after) the predicted tides at the reference station. For height corrections, the water level heights **relative to MLLW** at the reference station are multiplied by the range ratio to estimate the water level heights relative to MLLW in the applicable zone.

Zone	**Time Corrector(mins)**	**Range Ratio**	**Predicted Reference Station**
CGM68	+18	x1.14	8741533
CGM69	+24	x1.14	8741533
CGM118	+12	x1.14	8741533
CGM119	+6	x1.10	8741533
CGM120	-6	x1.07	8741533

1.4.2. Polygon nodes and water level corrections referencing Pascagoula, MS (874-1533) are provided. Zoning diagrams, created in MapInfo® , are provided digitally to assist with the zoning. Longitude and latitude coordinates are in decimal degrees. Negative (-) longitude is a MapInfo® representation of West longitude.

"Preliminary" data for the control water level station, Pascagoula, MS (874-1533), are available in near real-time and verified data will be available on a weekly basis for the previous week. **These water level data may be obtained from CO-OPS SOAP web services at http://opendap.co-ops.nos.noaa.gov/axis/text.html.**

Please contact the OCS COTR or designated COTR representative and CO-OPS' Hydrographic Planning Team (HPT) at nos.coops.hpt@noaa.gov and CO-OPS' Operational Engineering Team (OET) at nos.coops.oetteam@noaa.gov at least three business days before survey operations begin, and within 1 business day after survey operations are completed so that the appropriate CO-OPS National Water Level Observation Network (NWLON) control water level station(s) is/are added to or removed from the CO-OPS Hydro Hotlist (HHL) (http://tidesandcurrents.noaa.gov/hydro). Include start and end survey dates, full project number (e.g. OPR-H355-KR-10), and control and subordinate station numbers. Also the notification must go to both teams because station configuration is done by OET and addition/removal of stations to the HHL is done by HPT. NOTE: Contractor installed secondary gauges for OCS contract survey projects are not monitored through the CO-OPS Hydro Hotlist

This project requires a subordinate installation. Please follow the guidelines provided in the OCS Specifications and Deliverables for Hydrographic Surveys.

It is important to know that the addition of a water level station to the HHL ensures the station is monitored by CORMS and any problems are reported daily. In addition, stations that are on the HHL will not be taken offline for scheduled maintenance and are given priority for maintenance should a station cease normal operation during scheduled times of hydrography. CO-OPS will notify a field unit within 1 business day if a HHL water level station ceases operation during scheduled times of hydrography. This is in addition to the daily CORMS report that CORMS

sends to NOAA field units, if the field unit's e-mail address is added to the CORM's daily e-mail list. If the stations are listed on HHL, then weekly priority processing will occur and, for those water level stations, verified 6-minute water level data will be made available every week on Monday or Tuesday. If Monday happens to be a federal holiday, then the 6-minute verified water level data will be made available on the following Tuesday or Wednesday.

Final Zoning

1.5.1. For final processing, apply tidal zoning correctors to "verified" observed data of the NOS control station and/or the final processed data of the subordinate stations. The final zoning scheme in MapInfo® or ArcView® digital format and all data utilized in its development shall be documented and submitted to CO-OPS at the address referenced in section 1.3.3.1. Refer to Section 1.1. for details.

APPENDIX II
FINAL TIDE NOTE

H12353

FINAL TIDE NOTE and FINAL TIDE ZONING CHART

DATE: November 12, 2011

HYDROGRAPHIC BRANCH: Atlantic

HYDROGRAPHIC PROJECT: OPR-J348-KR-11

HYDROGRAPHIC SHEET: H12353

LOCALITY Approaches to Mississippi Sound, Mississippi

SUB-LOCALITY: SE of Ship Island Harbor

TIME PERIOD:	July	15-17, 19, 20, 22-31
	August	1-7, 17, 19, 20
	September	13, 14, 30

TIDE STATIONS USED: 8741533, Pascagoula NOAA Lab, MS
Lat. 30° 22.0 N, Lon. 88° 33.7' W

PLANE OF REFERENCE (MEAN LOWER LOW WATER): 0.000 meters

HEIGHT OF MEAN HIGH WATER (8741533) ABOVE PLANE OF REFERENCE: 0.439 meters [1]

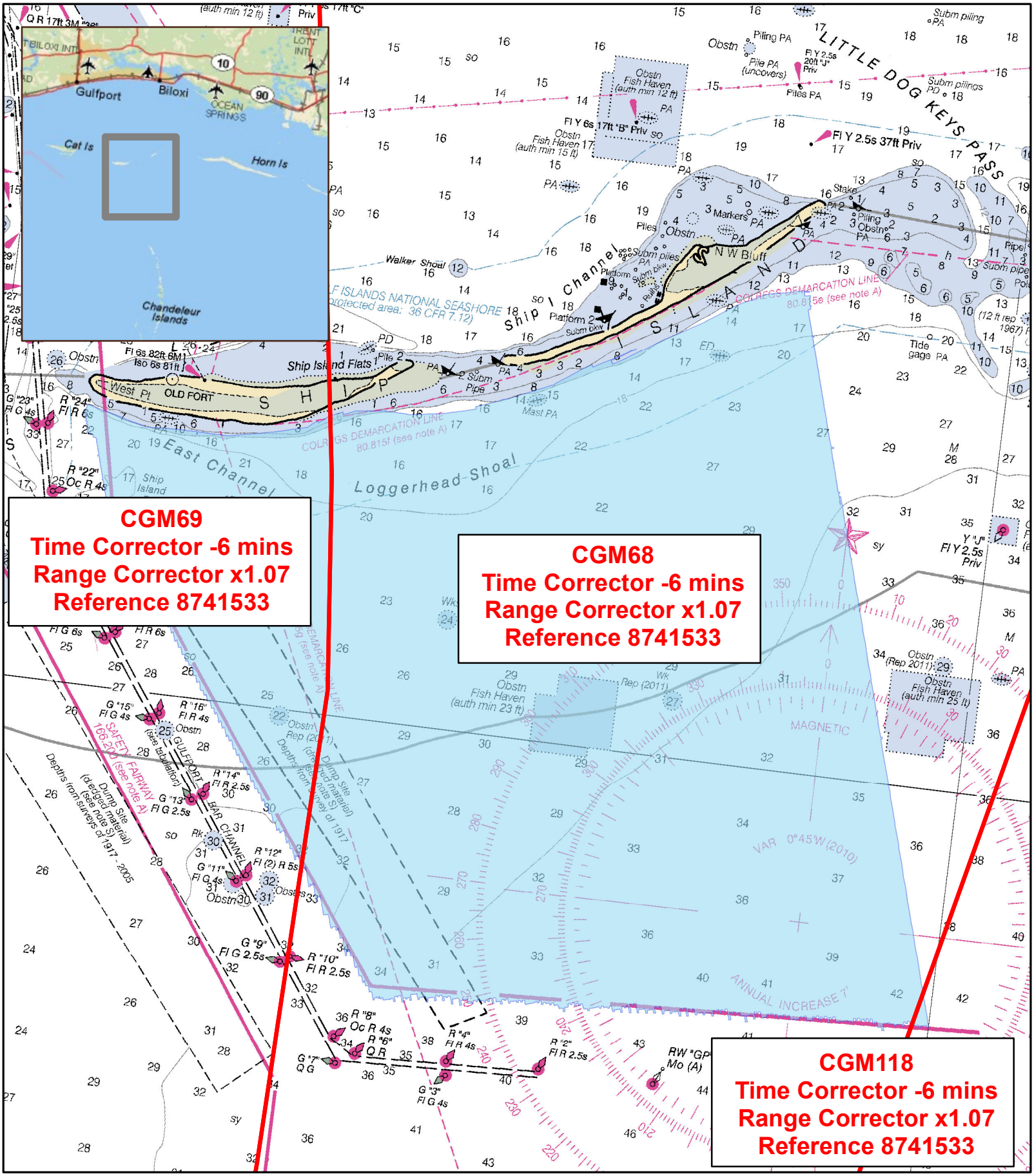
[1] MLLW 6.672m Mean Lower-Low Water
MHW 7.111m Mean High Water

http://tidesandcurrents.noaa.gov/data_menu.shtml?unit=0&format=Apply+Change&stn=8741533+Pascagoula+Noaa+Lab%2C+MS&type=Datums

FINAL TIDE ZONING
H12353
OPR-J348-KR-11

Zone	Time Corrector (Mins)	Range Ratio	Reference Station
CGM69	-6	1.07	8741533
CGM68	-6	1.07	8741533
CGM118	-6	1.07	8741533

NOTE: Final soundings were reduced to chart datum using Global Positioning System (GPS) water levels acquired directly at the vessel. The preliminary version of the zoning scheme provided with the project instructions was revised by David Evans and Associates, Inc. during analysis of ellipsoidally referenced survey transformation techniques for OPR-J348-KR-11. The revised tide zoning parameters referenced in this document are provided for information only.



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0 0.5 1
Nautical Miles

H12353
Final Tide Zoning
Reference Only

OPR-J348-KR-11
Approaches to Mississippi Sound, MS
David Evans and Associates, Inc.
Jon Dasler, Lead Hydrographer
Chart 11373_1

H12354

FINAL TIDE NOTE and FINAL TIDE ZONING CHART

DATE: November 12, 2011

HYDROGRAPHIC BRANCH: Atlantic

HYDROGRAPHIC PROJECT: OPR-J348-KR-11

HYDROGRAPHIC SHEET: H12354

LOCALITY Approaches to Mississippi Sound, Mississippi

SUB-LOCALITY: Little Dog Keys Pass

TIME PERIOD:

July	20, 31
August	1, 6-8, 11-17, 19-27, 30
September	16, 17, 22, 30
October	3, 4, 6, 11, 15
November	8, 9, 11

TIDE STATIONS USED: 8741533, Pascagoula NOAA Lab, MS
Lat. 30° 22.0 N, Lon. 88° 33.7' W

PLANE OF REFERENCE (MEAN LOWER LOW WATER): 0.000 meters

HEIGHT OF MEAN HIGH WATER (8741533) ABOVE PLANE OF REFERENCE: 0.439 meters [1]

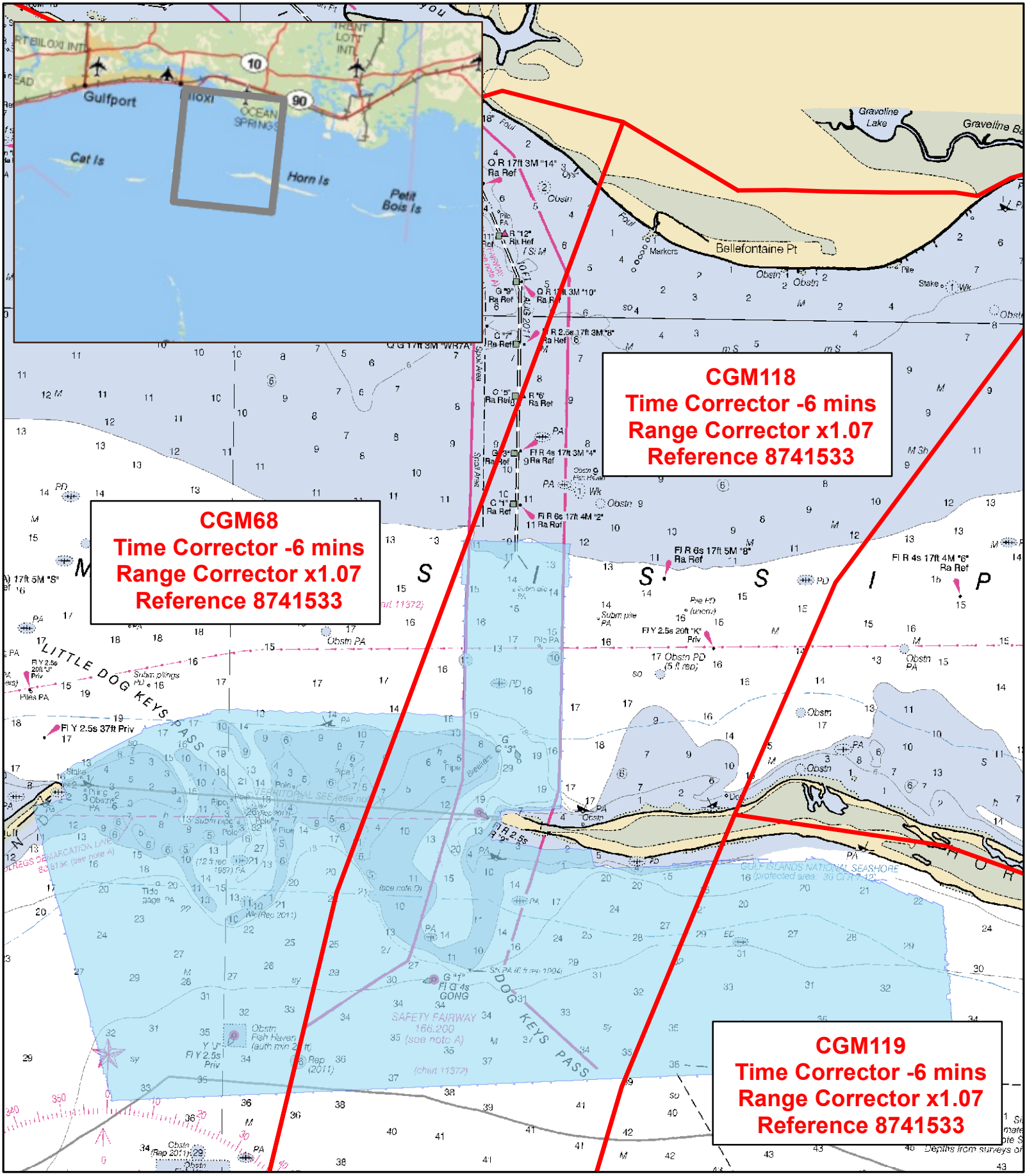
[1] MLLW 6.672m Mean Lower-Low Water
MHW 7.111m Mean High Water

http://tidesandcurrents.noaa.gov/data_menu.shtml?unit=0&format=Apply+Change&stn=8741533+Pascagoula+Noaa+Lab%2C+MS&type=Datums

FINAL TIDE ZONING
H12354
OPR-J348-KR-11

Zone	Time Corrector (Mins)	Range Ratio	Reference Station
CGM68	-6	1.07	8741533
CGM118	-6	1.07	8741533
CGM119	-6	1.07	8741533

NOTE: Final soundings were reduced to chart datum using Global Positioning System (GPS) water levels acquired directly at the vessel. The preliminary version of the zoning scheme provided with the project instructions was revised by David Evans and Associates, Inc. during analysis of ellipsoidally referenced survey transformation techniques for OPR-J348-KR-11. The revised tide zoning parameters referenced in this document are provided for information only.



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Nautical Miles

H12354
Final Tide Zoning
Reference Only

OPR-J348-KR-11
Approaches to Mississippi Sound, MS
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Chart 11373_1

H12355

FINAL TIDE NOTE and FINAL TIDE ZONING CHART

DATE: November 12, 2011

HYDROGRAPHIC BRANCH: Atlantic

HYDROGRAPHIC PROJECT: OPR-J348-KR-11

HYDROGRAPHIC SHEET: H12355

LOCALITY Approaches to Mississippi Sound, Mississippi

SUB-LOCALITY: South of Little Dog Keys Pass

TIME PERIOD:		
	July	20, 24, 31
	August	21-31
	September	7-11, 21
	October	5
	November	11

TIDE STATIONS USED: 8741533, Pascagoula NOAA Lab, MS
Lat. 30° 22.0 N, Lon. 88° 33.7' W

PLANE OF REFERENCE (MEAN LOWER LOW WATER): 0.000 meters

HEIGHT OF MEAN HIGH WATER (8741533) ABOVE PLANE OF REFERENCE: 0.439 meters [1]

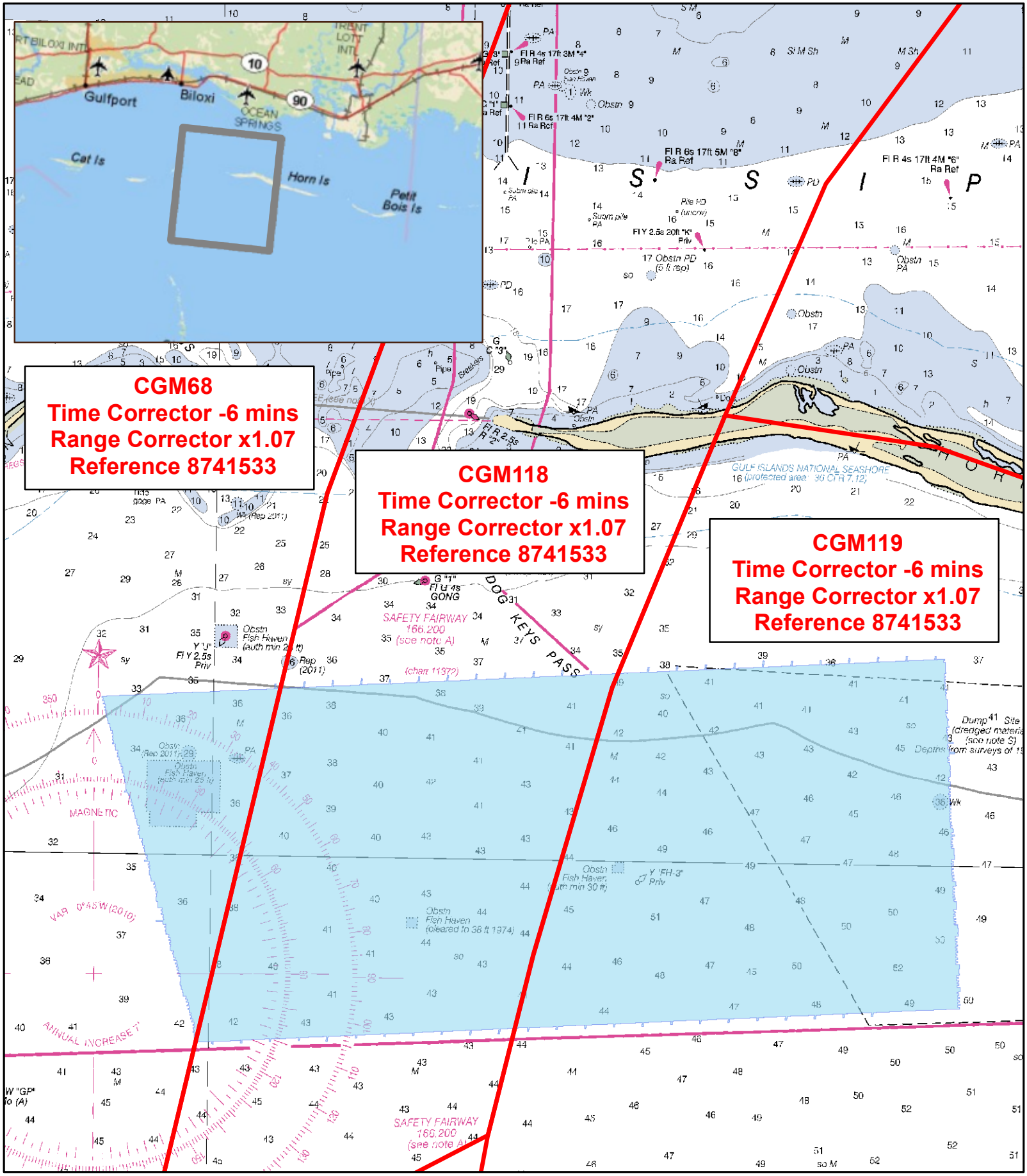
[1] MLLW 6.672m Mean Lower-Low Water
MHW 7.111m Mean High Water

http://tidesandcurrents.noaa.gov/data_menu.shtml?unit=0&format=Apply+Change&stn=8741533+Pascagoula+Noaa+Lab%2C+MS&type=Datums

FINAL TIDE ZONING
H12355
OPR-J348-KR-11

Zone	Time Corrector (Mins)	Range Ratio	Reference Station
CGM68	-6	1.07	8741533
CGM118	-6	1.07	8741533
CGM119	-6	1.07	8741533

NOTE: Final soundings were reduced to chart datum using Global Positioning System (GPS) water levels acquired directly at the vessel. The preliminary version of the zoning scheme provided with the project instructions was revised by David Evans and Associates, Inc. during analysis of ellipsoidally referenced survey transformation techniques for OPR-J348-KR-11. The revised tide zoning parameters referenced in this document are provided for information only.



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Nautical Miles

H12355
Final Tide Zoning
Reference Only

OPR-J348-KR-11
Approaches to Mississippi Sound, MS
David Evans and Associates, Inc.
Jon Dasler, Lead Hydrographer
Chart 11373_1

H12356

FINAL TIDE NOTE and FINAL TIDE ZONING CHART

DATE: November 12, 2011

HYDROGRAPHIC BRANCH: Atlantic

HYDROGRAPHIC PROJECT: OPR-J348-KR-11

HYDROGRAPHIC SHEET: H12356

LOCALITY Approaches to Mississippi Sound, Mississippi

SUB-LOCALITY: SE of Horn Island

TIME PERIOD:

July	20, 24, 31
August	27-29, 31
September	7-18, 21, 24-27, 29
October	4, 5, 14-17
November	5, 8, 9, 11

TIDE STATIONS USED: 8741533, Pascagoula NOAA Lab, MS
Lat. 30° 22.0 N, Lon. 88° 33.7' W

PLANE OF REFERENCE (MEAN LOWER LOW WATER): 0.000 meters

HEIGHT OF MEAN HIGH WATER (8741533) ABOVE PLANE OF REFERENCE: 0.439 meters [1]

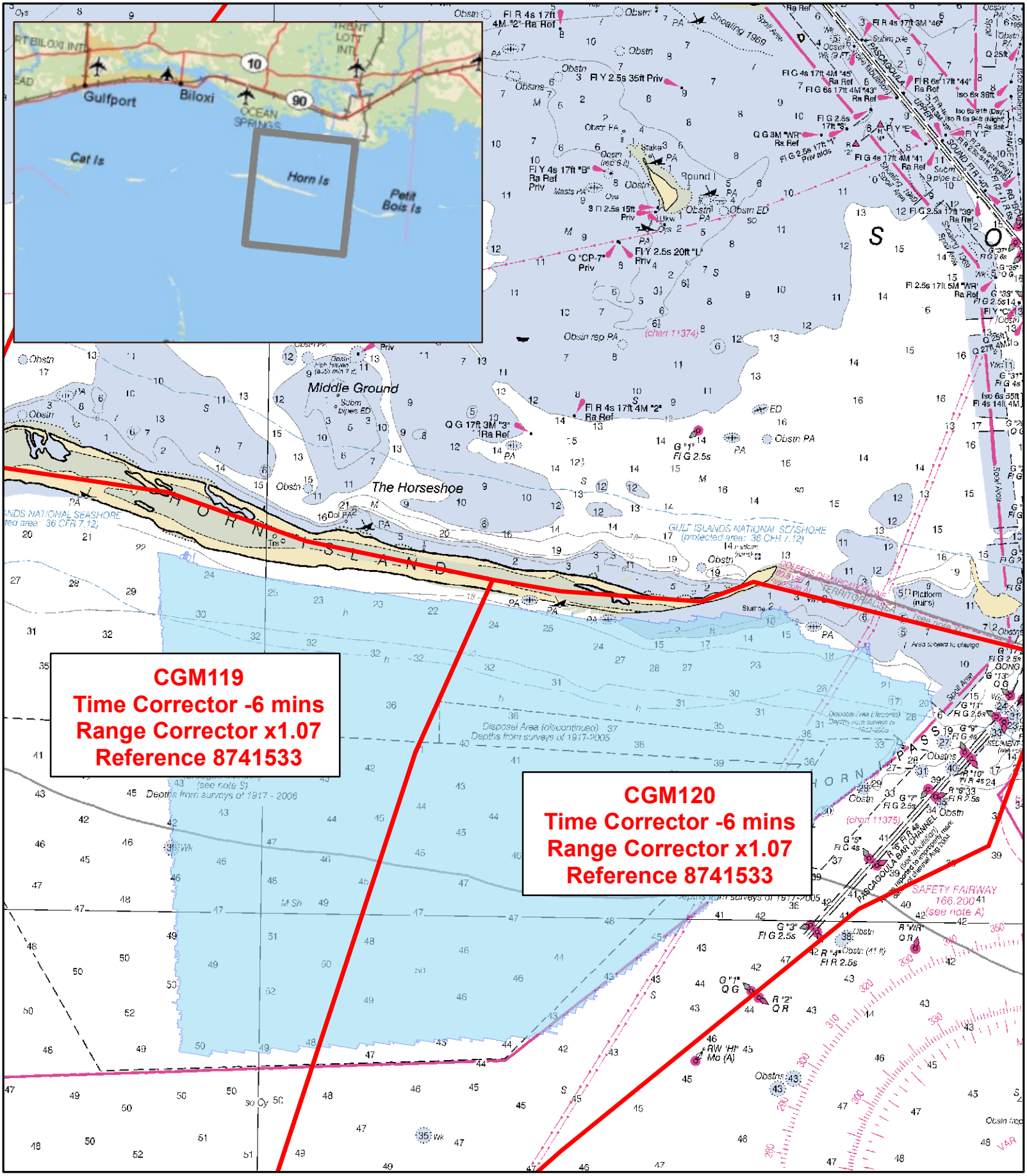
[1] MLLW 6.672m Mean Lower-Low Water
MHW 7.111m Mean High Water

http://tidesandcurrents.noaa.gov/data_menu.shtml?unit=0&format=Apply+Change&stn=8741533+Pascagoula+Noaa+Lab%2C+MS&type=Datums

FINAL TIDE ZONING
H12356
OPR-J348-KR-11

Zone	Time Corrector (Mins)	Range Ratio	Reference Station
CGM119	-6	1.07	8741533
CGM120	-6	1.07	8741533

NOTE: Final soundings were reduced to chart datum using Global Positioning System (GPS) water levels acquired directly at the vessel. The preliminary version of the zoning scheme provided with the project instructions was revised by David Evans and Associates, Inc. during analysis of ellipsoidally referenced survey transformation techniques for OPR-J348-KR-11. The revised tide zoning parameters referenced in this document are provided for information only.



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Nautical Miles

H12356
Final Tide Zoning
Reference Only

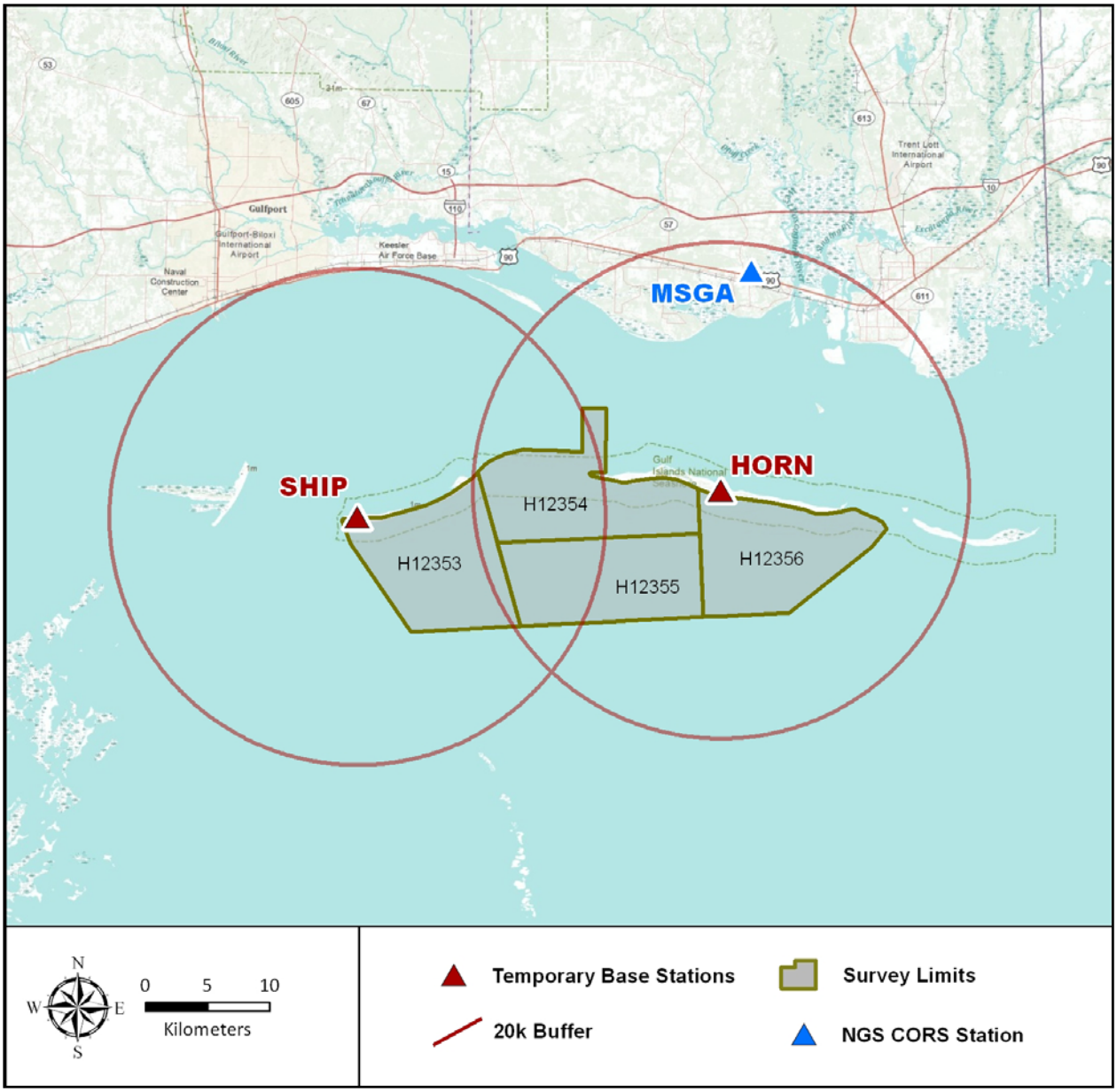
OPR-J348-KR-11
Approaches to Mississippi Sound, MS
David Evans and Associates, Inc.
Jon Dasler, Lead Hydrographer
Chart 11373_1

APPENDIX III
GPS BASE STATIONS

GPS Base Station Summary

Temporary Base Stations	Coordinates NAD83 (CORS96, Epoch 2002) D.M.S.		NAD83 Ellipsoid Heights (m)
	Latitude	Longitude	
HORN	30-14-17.35884 N	088-40-01.67123 W	-21.095*
SHIP	30-12-50.79097 N	088-58-17.34520 W	-21.222

*Adjusted height using OPUS 10-day average. The height used during POSPac processing was -21.122 meters.


MSGA
SHIP
HORN
H12353
H12354
H12355
H12356
Gulfport
Gulfport-Biloxi International Airport
Keesler Air Force Base
Naval Construction Center
Trent Lott International Airport
Gulf Islands National
N
W
E
S
0 5 10
Kilometers
Temporary Base Stations
Survey Limits
20k Buffer
NGS CORS Station

NOTE: This form intended for field use. Unsolicited data submitted to NGS must be converted to bluebook format.

GPS STATION OBSERVATION LOG
April 16, 2003

Station Designation: (check applicable: __ FBN __ CBN __ PAC __ SAC __ BM)
HORN

Station PID, if any:

Date (UTC):

General Location:
HORN ISLAND, MISSISSIPPI SOUND, MS

Airport ID, if any:

Station 4-Character ID:

Day of Year:

Project Name:
APPROACHES TO MS SOUND

Project Number:
NOAA GPS-0016

Station Serial # (SSN):

Session ID:(A,B,C etc)

NAD83 Latitude
o ' "

NAD83 Longitude
o ' "

NAD83 Ellipsoidal Height
meters

NAVD88 Orthometric Ht.
meters

GEOID99 Geoid Height
meters

Agency Full Name: DAVID EVANS AND ASSOCIATES, INC.
Operator Full Name: BEN HOCKER
Phone #: (360) 314-3200
e-mail address: bhocker@deainc.com

Observation Session Times (UTC):
Sched. Start _____ Stop _____
Actual Start _____ Stop _____

Epoch Interval= 1 Seconds
Elevation Mask = 10° Degrees

Receiver Brand & Model:
TRIMBLE NET RS
P/N: 62800-10
S/N: ~~4705~~ 4750K11589
Firmware Version: 4.19
☐ CamCorder Battery, ☐ 12V DC, ☐ 110V AC, ☐ Other

Antenna Code*, Brand & Model:
TRIMBLE ZEPHYR GEODETIC MODEL 1
P/N: 41249-00 DC 4717
S/N: 602013334
Cable Length, meters: 15 m
Vehicle is Parked _____ meters _____(direction) from antenna.

Antenna plumb before session? (Y / N)
Antenna plumb after session? (Y / N)
Antenna oriented to true North? (Y / N)
Weather observed at antenna ht. (Y / N)
Antenna ground plane used? (Y / N)
Circle Yes or No -If no, explain "

Antenna radome used? (Y / N)
Eccentric occupation (>0.5 mm)? (Y / N)
Any obstructions above 10°? (Y / N)
Radio interference source nearby (Y / N)
If yes, describe. Use Vis. form

Tripod or Antenna Mount: Check one:
☐ Fixed-Leg Tripod, ☐ Collapsible-leg tripod, ☒ Fixed Mount
Brand & Model:
P/N: N/A
S/N:
Last Adjustment date:

Psychrometer (if used) Brand & Model:
P/N: N/A
S/N:
Last Calibration or check Date:

**** ANTENNA HEIGHT ****

	Before Session Begins: Meters	Feet	After Session Ends: Meters	Feet
A= Datum point to Top of Tripod (Tripod Height)	0.000			
B= Additional offset to ARP if any (Tribrach/Spacer)	0.000			
H= Antenna Height = **A + B** = Datum Point to Antenna Reference Point (ARP)	0.000			

Meters = Feet x (0.3048)
Height Entered Into Receiver = 0.000 meters.
Note &/or sketch **ANY** unusual conditions. Be **Very Explicit** as to where and how Measured!

Barometer (if used) Brand & Model:
S/N: N/A

Weather Data	Weather Codes	Time (UTC)	Dry-Bulb Temp Fahrenheit	Dry-Bulb Temp Celsius	WetBulb Temp Fahrenheit	WetBulb Temp Celsius	Rel. % Humidity	Atm. Pressure inches Hg	Atm. Pressure millibar
Before	00100								
Middle									
After									

Remarks, Comments on Problems, Sketches, Pencil Rubbing, etc:

- MICROWAVE TOWER APPROXIMATELY 1/2 MILE SOUTH OF STATION
- CELLULAR MODEM ANTENNA LOCATED 4/M NE AND 4/1.5m BELOW GPS ANTENNA.

Weather codes are required. Weather data are optional but encouraged. *Antenna code comes from ant_info file furnished by project coordinator.

Data File Name(s):
(Standard NGS Format = aaaaddds.xxx)
where aaaa=4-Character ID, ddd=Day of Year, s=Session ID, xxx=file dependant extension

Updated Station Description: ☐ Attached ☐ Submitted earlier
Visibility Obstruction Form: ☐ Attached ☐ Submitted earlier
Photographs of Station: ☐ Attached ☐ Submitted earlier
Pencil Rubbing of Mark: ☐ Attached

LOG CHECKED BY:

Table of Weather Codes

CODE	PROBLEM	VISIBILITY	TEMPERATURE	CLOUD COVER	WIND
0	did not occur	Good, over 15 miles	Normal, 32° F- 80° F	Clear, below 20%	Calm, under 5mph (8km/h)
1	did occur	Fair, 7-15 miles	Hot, over 80°F (27 C)	Cloudy, 20% to 70%	Moderate, 5 to 15 mph
2	- not used -	Poor, under 7 miles	Cold, below 32° F (0 C)	Overcast, over 70%	Strong, over15 mph (24km/h)

Examples: 00000 = No problem, good visibility, normal temp, clear, calm wind 12121 = Problems, poor visibility, hot, overcast, moderate wind

Station Location Sketch and Visibility Diagram

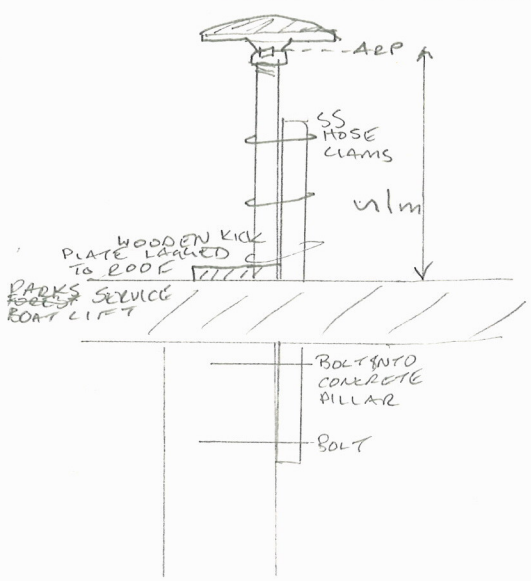
Location / Airport Name and ID: HORN ISLAND, MS Project: NOAA0016

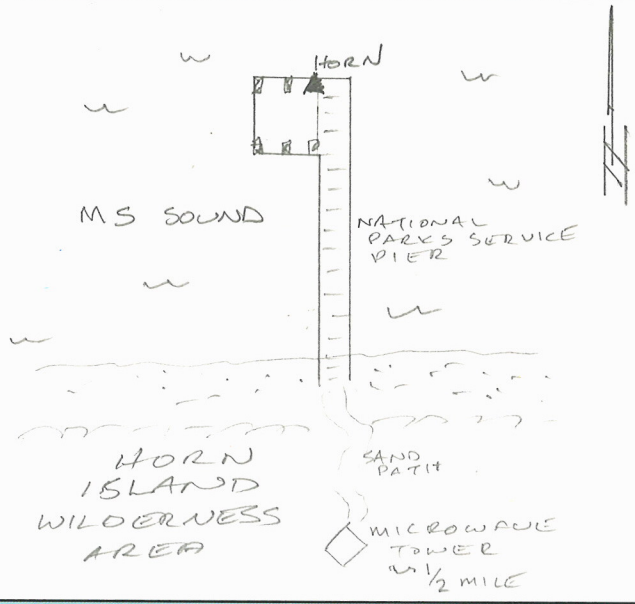
Station Designation: HORN PID: _____ Date: _____

Circle all applicable:
PACS SACS BM FBN CBN OTHER_____

Observer & Organization: BEN HOCKOR, DEA INC.

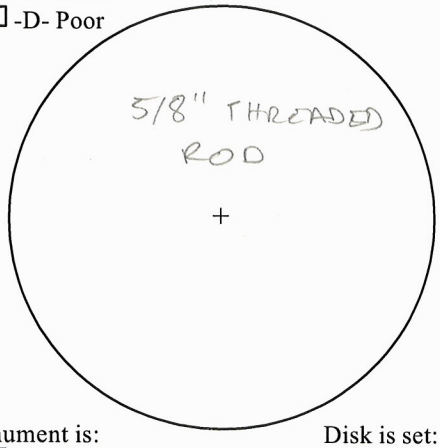
Station Location Sketch





Sketch of Disk

Monument Stability Quality: ☒ Photos Available
- ☐ -A- Most stable
- ☐ -B- Excellent
- ☒ -C- Good
- ☐ -D- Poor

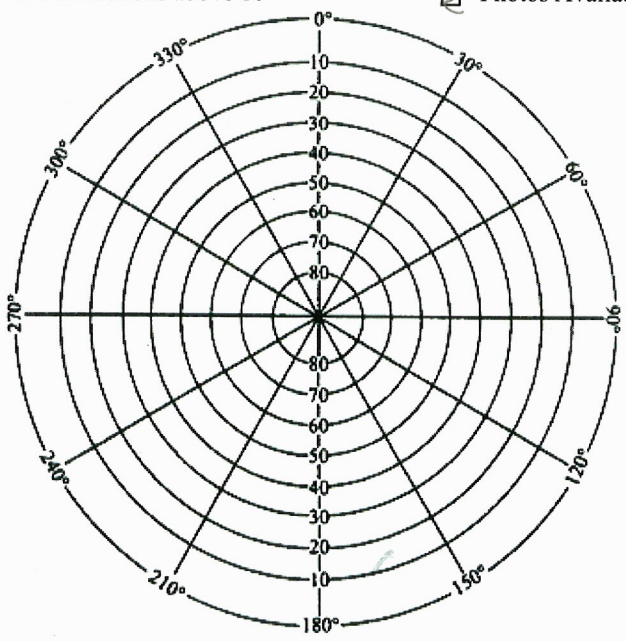


Monument is:
- ☐ Recessed ___ cm
- ☐ Flush with ground surface
- ☐ Projecting ___ cm

Disk is set:
- ☐ in bedrock.
- ☐ in concrete.
- ☒ in structure.

Visibility Diagram

☒ No Obstructions above 10° ☐ Photos Available



All computed coordinate accuracies are listed as peak-to-peak values.
For additional information: http://www.ngs.noaa.gov/OPUS/about.html#accuracy

USER: gpb@deainc.com DATE: July 19, 2011
RINEX FILE: 15891990.11o TIME: 22:31:36 UTC

SOFTWARE: page5 1106.16 master2.pl 0620113 START: 2011/07/18 00:00:00
EPHEMERIS: igr16451.eph [rapid] STOP: 2011/07/18 23:59:00
NAV FILE: brdc1990.11n OBS USED: 59663 / 63044 : 95%
ANT NAME: TRM41249.00 NONE # FIXED AMB: 242 / 274 : 88%
ARP HEIGHT: 0.0 OVERALL RMS: 0.020(m)

REF FRAME:	NAD_83(CORS96)(EPOCH:2002.0000)		ITRF00 (EPOCH:2011.5438)	
X:	128283.404(m)	0.017(m)	128282.679(m)	0.017(m)
Y:	-5513498.435(m)	0.009(m)	-5513496.939(m)	0.009(m)
Z:	3193199.161(m)	0.008(m)	3193198.957(m)	0.008(m)
LAT:	30 14 17.35884	0.002(m)	30 14 17.37785	0.002(m)
E LON:	271 19 58.32877	0.017(m)	271 19 58.30296	0.017(m)
W LON:	88 40 1.67123	0.017(m)	88 40 1.69704	0.017(m)
EL HGT:	-21.122(m)	0.012(m)	-22.531(m)	0.012(m)
ORTHO HGT:	6.615(m)	0.028(m)	[NAVD88 (Computed using GEOID09)]	

	UTM COORDINATES (UTM (Zone 16))	STATE PLANE COORDINATES (SPC (2301 MS E))
Northing (Y) [meters]	3346350.869	81832.283
Easting (X) [meters]	339583.160	315997.037
Convergence [degrees]	-0.83973899	0.08369896
Point Scale	0.99991748	0.99995316
Combined Factor	0.99992080	0.99995647

US NATIONAL GRID DESIGNATOR: 16RCU3958346350(NAD 83)

BASE STATIONS USED

PID	DESIGNATION	LATITUDE	LONGITUDE	DISTANCE(m)
DL3486	ALDI DAUPHIN ISLAND CORS ARP	N301456.988	W0880440.689	56719.3
DK3340	MSPK PERKINSTON CORS ARP	N304644.796	W0890835.937	75403.8
DH3836	MSSC STENNIS SPACE CTR CORS ARP	N302230.794	W0893649.903	92322.0

NEAREST NGS PUBLISHED CONTROL POINT

BH1897	MID	N301429.015	W0884036.159	989.3

This position and the above vector components were computed without any knowledge by the National Geodetic Survey regarding the equipment or field operating procedures used.

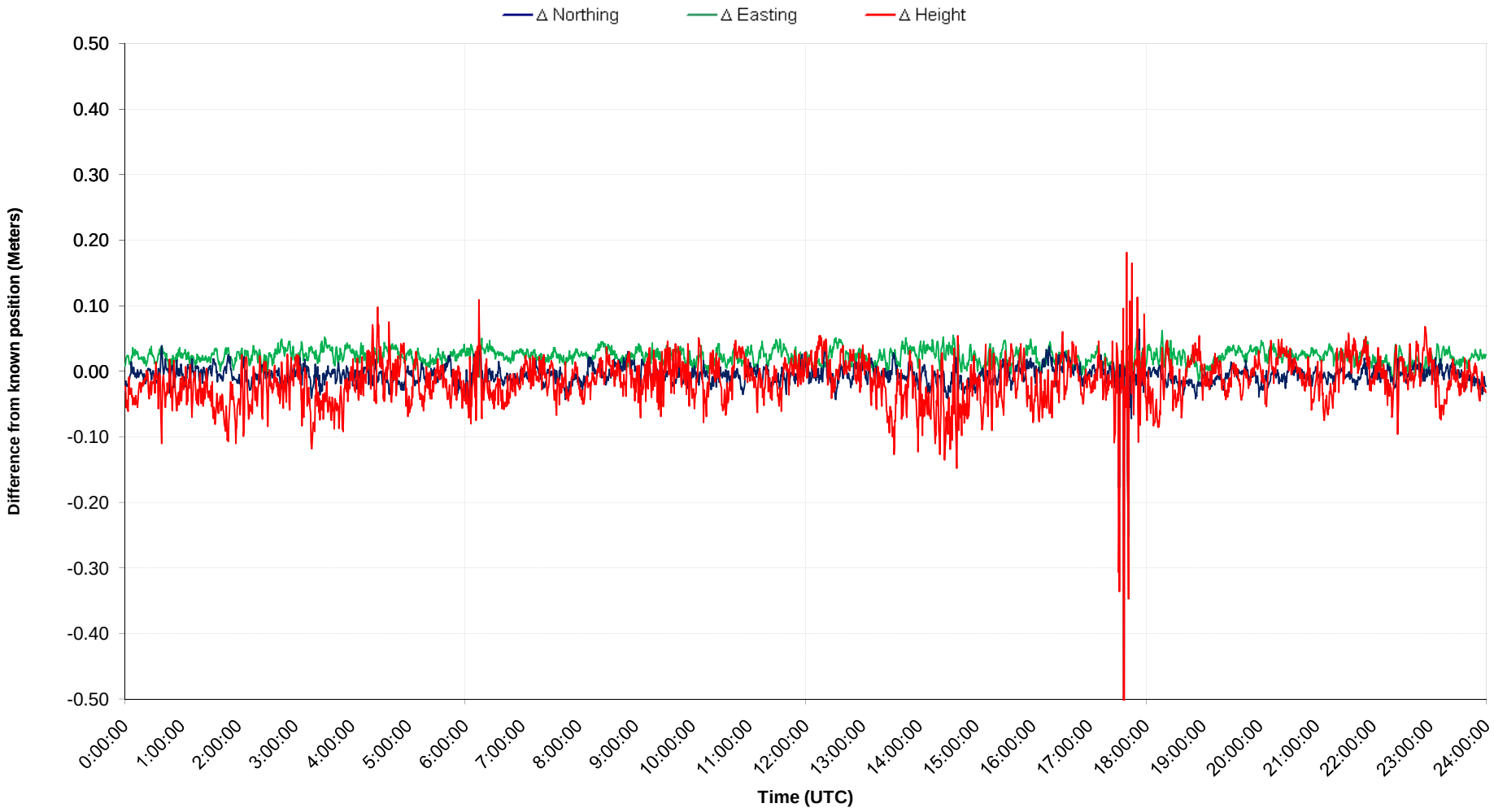
David Evans and Associates, Inc.
2801 SE Columbia Way, Suite 130
Vancouver, WA 98661
Phone: 360-314-3200
Fax: 360-314-3250

"HORN"
GPS Base Station Site Verification
24 Hour PPK Solution Relative to Base Station Position

Date 7/29/2011
Locality Approaches to Mississippi Sound, MS
Project OPR-J348-KR-11
Version GrafNav Version 8.30.2105
Datum NAD-83 (CORS96, Epoch 2002)
Projection UTM Zone 16 North, Meters

Base Station held for PPK processing MSGA (DN210) - CORS

Station Latitude 30°14' 17.35884" N
Station Longitude 88° 40' 01.67123" W
Station Ellipsoid Height -21.095
Receiver Trimble NetR5
Antenna Type Trimble Zephyr-Geodetic 41249-00



OPR-J348-KR-11
WEEKLY BASE STATION CHECKS
"1589 HORN"

David Evans and Associates, Inc.
2801 SE Columbia Way, Ste 130
Vancouver, WA 98661
Phone: 360-314-3200
Fax: 360-314-3250

Reference Frame NAD83 (CORS96) Epoch 2002.0
Latitude 30°14' 17.35884" (N)
Longitude 88° 40' 01.67123" (W)
Ellipsoid Height (m) -21.095
*Ellipsoid height = -21.122 + 0.027 Adjustment

Datum NAD-83 UTM Zone 16 North, Meters
Northing (Y) 3346350.869
Easting (X) 339583.160
Derived from 24hr OPUS with rapid orbit 15891990.11o

INFORMATION			Base Station: HORN OPUS Position			Quality Check						Comments
Week of	DN	RINEX File	Northing	Easting	Ellipsoid Height (m)	Northing Measured Separation	Northing 95% CI	Easting Measured Separation	Easting 95% CI	Ellipsoid Height Measured Separation	Ellipsoid Height 95% CI	
07/24/2011	205	15892050.11o	3346350.859	339583.166	-21.101	-0.010	PASS	0.006	PASS	-0.006	PASS	rapid
07/31/2011	212	15892120.11o	3346350.868	339583.166	-21.089	-0.001	PASS	0.006	PASS	0.006	PASS	rapid
08/07/2011	219	15892190.11o	3346350.875	339583.166	-21.093	0.006	PASS	0.006	PASS	0.002	PASS	rapid
08/14/2011	226	15892260.11o	3346350.868	339583.163	-21.091	-0.001	PASS	0.003	PASS	0.004	PASS	rapid
08/21/2011	233	15892330.11o	3346350.874	339583.174	-21.094	0.005	PASS	0.014	PASS	0.001	PASS	rapid
08/28/2011	240	15892400.11o	3346350.870	339583.166	-21.090	0.001	PASS	0.006	PASS	0.005	PASS	rapid
09/04/2011	247	15892470.11o	3346350.870	339583.151	-21.091	0.001	PASS	-0.009	PASS	0.004	PASS	rapid, Tropical Storm Lee, no survey operations
09/11/2011	254	15892540.11o	3346350.866	339583.162	-21.099	-0.003	PASS	0.002	PASS	-0.004	PASS	rapid
09/18/2011	261	15892610.11o	3346350.866	339583.164	-21.098	-0.003	PASS	0.004	PASS	-0.003	PASS	rapid
09/25/2011	268	15892680.11o	3346350.87	339583.161	-21.095	0.001	PASS	0.001	PASS	0.000	PASS	rapid
10/02/2011	275	15892750.11o	3346350.869	339583.164	-21.099	0.000	PASS	0.004	PASS	-0.004	PASS	rapid
10/09/2011	282	15892820.11o	3346350.863	339583.166	-21.106	-0.006	PASS	0.006	PASS	-0.011	PASS	rapid
10/16/2011	289	15892890.11o	3346350.870	339583.163	-21.098	0.001	PASS	0.003	PASS	-0.003	PASS	rapid
10/23/2011	296	15892960.11o	3346350.867	339583.162	-21.099	-0.002	PASS	0.002	PASS	-0.004	PASS	rapid
10/30/2011	303	15893030.11o	3346350.865	339583.164	-21.095	-0.004	PASS	0.004	PASS	0.000	PASS	rapid
11/06/2011	310	15893100.11o	3346350.868	339583.165	-21.097	-0.001	PASS	0.005	PASS	-0.002	PASS	rapid
11/13/2011	317	15893170.11o	3346350.865	339583.165	-21.105	-0.004	PASS	0.005	PASS	-0.010	PASS	rapid
				Mean		-0.001		0.004		-0.001		
				Std Deviation		0.004		0.004		0.005		

Established Position Peak to Peak Values		95% Confidence
Northing	0.020	0.039
Easting	0.020	0.039
Ellipsoid Height	0.020	0.039

NOTE: This form intended for field use. Unsolicited data submitted to NGS must be converted to bluebook format.

GPS STATION OBSERVATION LOG
April 16, 2003

Station Designation: (check applicable: __ FBN __ CBN __ PAC __ SAC __ BM) SHIP		Station PID, if any:	Date (UTC):
General Location: SHIP ISLAND, MISSISSIPPI SOUND, MS	Airport ID, if any:	Station 4-Character ID:	Day of Year:
Project Name: APPROACHES TO MS SOUND	Project Number: NOAA GPS- 0016	Station Serial # (SSN):	Session ID:(A,B,C etc)

NAD83 Latitude ° ' "	NAD83 Longitude ° ' "	NAD83 Ellipsoidal Height meters NAVD88 Orthometric Ht. meters GEOID99 Geoid Height meters
Observation Session Times (UTC): Sched. Start _____ Stop _____ Actual Start _____ Stop _____	Epoch Interval= 1 Seconds Elevation Mask = 10 Degrees	Agency Full Name: DAVID EVANS AND ASSOCIATES INC. Operator Full Name: BEN HOOKER Phone #: (360) 314-3203 e-mail address: bkho@dea.inc.com

Receiver Brand & Model:
TRIMBLE NET R5
P/N: 62800-10
S/N: 4750K11594
Firmware Version: 4.19
☐ CamCorder Battery, ☒ 12V DC, ☐ 110V AC, ☐ Other

Antenna Code*, Brand & Model:
TRIMBLE ZEPHYR GEODETIC MODEL 1
P/N: 41249-00 DC 4218
S/N: 12338039
Cable Length, meters: 15m
Vehicle is Parked _____ meters ____(direction) from antenna.

		Circle Yes or No -If no, explain
Antenna plumb before session?	(Y / N)	
Antenna plumb after session?	(Y / N)	
Antenna oriented to true North?	(Y / N)	
Weather observed at antenna ht.	(Y / N)	
Antenna ground plane used?	(Y / N)	
Antenna radome used?	(Y / N)	If yes, describe. Use Vis. form
Eccentric occupation (>0.5 mm)?	(Y / N)	
Any obstructions above 10°?	(Y / N)	
Radio interference source nearby	(Y / N)	

Tripod or Antenna Mount: Check one:
☐ Fixed-Leg Tripod, ☐ Collapsible-leg tripod ☒ Fixed Mount
Brand & Model:
P/N:
S/N: N/A
Last Adjustment date:

Psychrometer (if used) Brand & Model:
P/N:
S/N:
Last Calibration or check Date:

**** ANTENNA HEIGHT ****

	Before Session Begins: Meters	Feet	After Session Ends: Meters	Feet
A= Datum point to Top of Tripod (Tripod Height)	0.000			
B= Additional offset to ARP if any (Tribrach/Spacer)	0.000			
H= Antenna Height **= A + B** = Datum Point to Antenna Reference Point (ARP)	0.000			

Meters = Feet x (0.3048)
Height Entered Into Receiver = 0.000 meters.
Note &/or sketch **ANY** unusual conditions. Be **Very Explicit** as to where and how Measured!

Barometer (if used) Brand & Model:
S/N:

Weather Data	Weather Codes	Time (UTC)	Dry-Bulb Temp Fahrenheit	Dry-Bulb Temp Celsius	WetBulb Temp Fahrenheit	WetBulb Temp Celsius	Rel. % Humidity	Atm. Pressure inches Hg	Atm. Pressure millibar
Before	00100								
Middle									
After									

Remarks, Comments on Problems, Sketches, Pencil Rubbing, etc:

- GOES ANTENNAS LOCATED 2 m FROM ANTENNA (POINTED AWAY FROM ANTENNA).
- CELLULAR MODEM ANTENNA LOCATED ON SAME POLE 2m BELOW GPS ANTENNA

Weather codes are required. Weather data are optional but encouraged. *Antenna code comes from ant_info file furnished by project coordinator.

Data File Name(s):
(Standard NGS Format = aaaaddds.xxx)
where aaaa=4-Character ID, ddd=Day of Year, s=Session ID, xxx=file dependant extension

Updated Station Description: ☐ Attached ☐ Submitted earlier
Visibility Obstruction Form: ☐ Attached ☐ Submitted earlier
Photographs of Station: ☐ Attached ☐ Submitted earlier
Pencil Rubbing of Mark: ☐ Attached

LOG CHECKED BY:

Table of Weather Codes

CODE	PROBLEM	VISIBILITY	TEMPERATURE	CLOUD COVER	WIND
0	did not occur	Good, over 15 miles	Normal, 32° F- 80° F	Clear, below 20%	Calm, under 5mph (8km/h)
1	did occur	Fair, 7-15 miles	Hot, over 80°F (27 C)	Cloudy, 20% to 70%	Moderate, 5 to 15 mph
2	- not used -	Poor, under 7 miles	Cold, below 32° F (0 C)	Overcast, over 70%	Strong, over15 mph (24km/h)

Examples: 00000 = No problem, good visibility, normal temp, clear, calm wind 12121 = Problems, poor visibility, hot, overcast, moderate wind

Station Location Sketch and Visibility Diagram

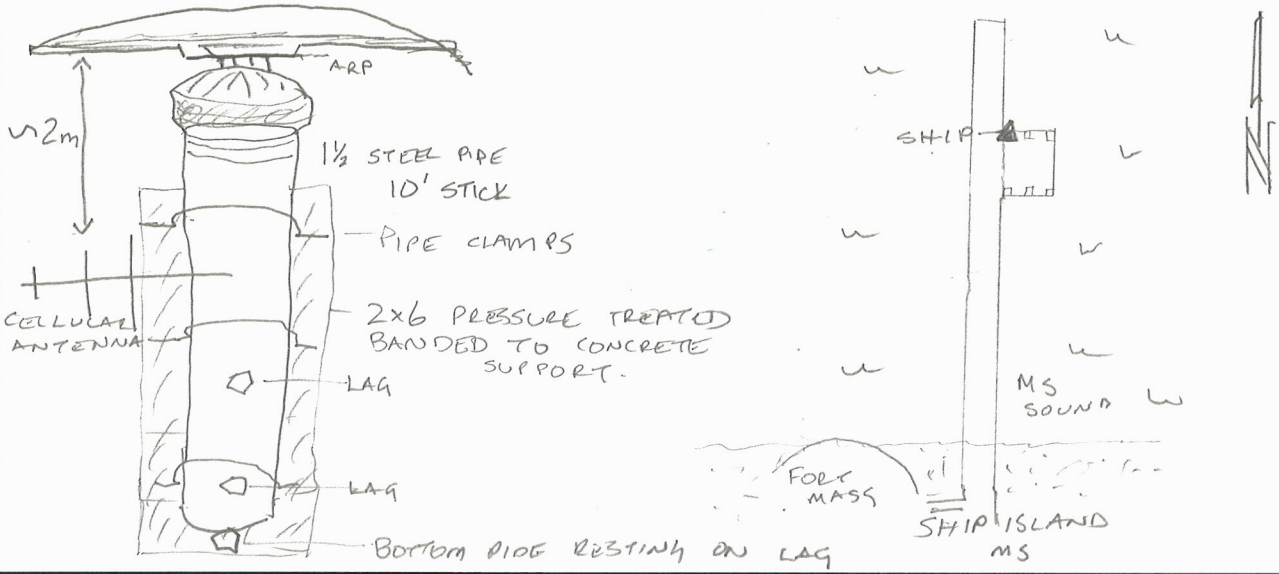
Location / Airport Name and ID: SHIP ISLAND, MS Project: NOAA0016

Station Designation: SHIP PID: Date:

Circle all applicable: PACS SACS BM FBN CBN OTHER_____

Observer & Organization: BEN HOCKER, DEA INC.

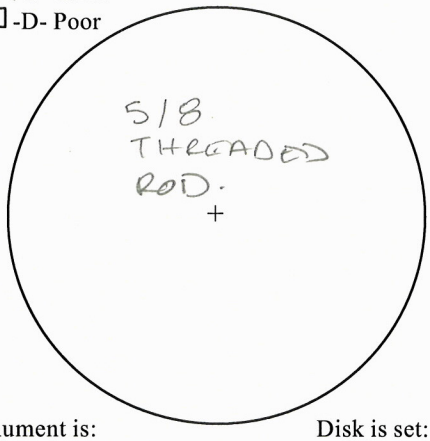
Station Location Sketch



Sketch of Disk

Monument Stability Quality: ☒ Photos Available

- ☐ -A- Most stable
- ☐ -B- Excellent
- ☒ -C- Good
- ☐ -D- Poor

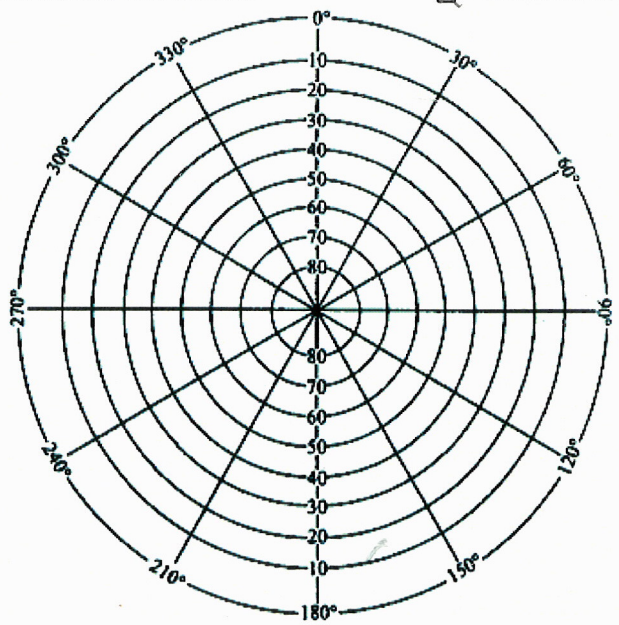


Monument is:
- ☐ Recessed ___ cm
- ☐ Flush with ground surface
- ☐ Projecting ___ cm

Disk is set:
- ☐ in bedrock.
- ☐ in concrete.
- ☒ in structure.

Visibility Diagram

☒ No Obstructions above 10° ☒ Photos Available



1594SHIP_OPUS_0713.txt

USER: gpb@deainc.com DATE: July 14, 2011
RINEX FILE: 15941940.11o TIME: 19:07:07 UTC

SOFTWARE: page5 1106.16 master28.pl 062011 START: 2011/07/13 00:00:00
EPHEMERIS: igr16443.eph [rapid] STOP: 2011/07/13 23:59:00
NAV FILE: brdc1940.11n OBS USED: 59465 / 62878 : 95%
ANT NAME: TRM41249.00 NONE # FIXED AMB: 243 / 279 : 87%
ARP HEIGHT: 0.0 OVERALL RMS: 0.018(m)

REF FRAME:	NAD_83(CORS96)(EPOCH:2002.0000)		ITRF00 (EPOCH:2011.5301)	
X:	99018.240(m)	0.007(m)	99017.515(m)	0.007(m)
Y:	-5515443.737(m)	0.015(m)	-5515442.243(m)	0.015(m)
Z:	3190895.816(m)	0.012(m)	3190895.612(m)	0.012(m)
LAT:	30 12 50.79097	0.011(m)	30 12 50.80987	0.011(m)
E LON:	271 1 42.65480	0.008(m)	271 1 42.62870	0.008(m)
W LON:	88 58 17.34520	0.008(m)	88 58 17.37130	0.008(m)
EL HGT:	-21.222(m)	0.016(m)	-22.626(m)	0.016(m)
ORTHO HGT:	6.308(m)	0.032(m)	[NAVD88 (Computed using GEOID09)]	

	UTM COORDINATES UTM (Zone 16)	STATE PLANE COORDINATES SPC (2301 MS E)
Northing (Y) [meters]	3344153.978	79163.082
Easting (X) [meters]	310245.741	286699.647
Convergence [degrees]	-0.99241261	-0.06952243
Point Scale	1.00004424	0.99995218
Combined Factor	1.00004757	0.99995551

US NATIONAL GRID DESIGNATOR: 16RCU1024544153(NAD 83)

BASE STATIONS USED

PID	DESIGNATION	LATITUDE	LONGITUDE	DISTANCE(m)
DK3577	ENG5 ENGLISH TURN 5 CORS ARP	N295244.246	W0895630.197	100674.9
DL3486	ALDI DAUPHIN ISLAND CORS ARP	N301456.988	W0880440.689	86097.7
DJ8941	MSGA GAUTIER CORS ARP	N302340.464	W0883842.490	37224.4

NEAREST NGS PUBLISHED CONTROL POINT

BH1894	FORT	N301243.691	W0885819.471	226.8

This position and the above vector components were computed without any knowledge by the National Geodetic Survey regarding the equipment or field operating procedures used.

David Evans and Associates, Inc.
2801 SE Columbia Way, Suite 130
Vancouver, WA 98661
Phone: 360-314-3200
Fax: 360-314-3250

"SHIP"
GPS Base Station Site Verification
24 Hour PPK Solution Relative to Base Station Position

Date 7/29/2011
Locality Approaches to Mississippi Sound, MS
Project OPR-J348-KR-11
Version GrafNav Version 8.30.2105
Datum NAD-83 (CORS96, Epoch 2002)
Projection UTM Zone 16 North, Meters

Base Station held for PPK processing HORN (DN210) - precise

Station Latitude 30° 12' 50.79097" N
Station Longitude 88° 58' 17.34520" W
Station Ellipsoid Height -21.222
Receiver Trimble NetR5
Antenna Type Trimble Zephyr-Geodetic 41249-00

DAVID EVANS AND ASSOCIATES INC.

OPR-J348-KR-11
WEEKLY BASE STATION CHECKS
"1594 SHIP "

David Evans and Associates, Inc.
2801 SE Columbia Way, Ste 130
Vancouver, WA 98661
Phone: 360-314-3200
Fax: 360-314-3250

Reference Frame NAD83 (CORS96) Epoch 2002.0
Latitude 30°12' 50.79097" (N)
Longitude 88° 58' 17.34520" (W)
Ellipsoid Height (m) -21.222

Datum NAD-83 UTM Zone 16 North, Meters
Northing (Y) 3344153.978
Easting (X) 310245.741
Derived from 24hr OPUS with rapid orbit 15941940.11o

INFORMATION			Base Station: SHIP OPUS Position			Quality Check						Comments
Week of	DN	RINEX File	Northing	Easting	Ellipsoid Height (m)	Northing Measured Separation	Northing 95% CI	Easting Measured Separation	Easting 95% CI	Ellipsoid Height Measured Separation	Ellipsoid Height 95% CI	
07/24/2011	205	15942050.11o	3344153.979	310245.747	-21.237	0.001	PASS	0.006	PASS	-0.015	PASS	rapid
07/31/2011	212	15942120.11o	3344153.979	310245.739	-21.229	0.001	PASS	-0.002	PASS	-0.007	PASS	rapid
08/07/2011	219	15942190.11o	3344153.982	310245.746	-21.211	0.004	PASS	0.005	PASS	0.011	PASS	rapid
08/14/2011	226	15942260.11o	3344153.985	310245.744	-21.221	0.007	PASS	0.003	PASS	0.001	PASS	rapid
08/21/2011	233	15942330.11o	3344153.981	310245.748	-21.219	0.003	PASS	0.007	PASS	0.003	PASS	rapid
08/28/2011	240	15942400.11o	3344153.977	310245.745	-21.221	-0.001	PASS	0.004	PASS	0.001	PASS	rapid
09/04/2011	247	15942470.11o	3344153.982	310245.741	-21.189	0.004	PASS	0.000	PASS	0.033	PASS	rapid, Tropical Storm Lee, no survey operations
09/11/2011	254	15942540.11o	3344153.982	310245.746	-21.219	0.004	PASS	0.005	PASS	0.003	PASS	rapid
09/18/2011	261	15942610.11o	3344153.984	310245.745	-21.214	0.006	PASS	0.004	PASS	0.008	PASS	rapid
09/25/2011	268	15942680.11o	3344153.98	310245.753	-21.225	0.002	PASS	0.012	PASS	-0.003	PASS	rapid
10/02/2011	275	15942750.11o	3344153.976	310245.742	-21.208	-0.002	PASS	0.001	PASS	0.014	PASS	rapid
10/09/2011	282	15942820.11o	3344153.975	310245.741	-21.229	-0.003	PASS	0.000	PASS	-0.007	PASS	rapid
10/16/2011	289	15942890.11o	3344153.979	310245.744	-21.216	0.001	PASS	0.003	PASS	0.006	PASS	rapid
10/23/2011	296	15942960.11o	3344153.980	310245.749	-21.212	0.002	PASS	0.008	PASS	0.010	PASS	rapid
10/30/2011	303	15943030.11o	3344153.976	310245.744	-21.219	-0.002	PASS	0.003	PASS	0.003	PASS	rapid
11/06/2011	310	15943100.11o	3344153.979	310245.743	-21.220	0.001	PASS	0.002	PASS	0.002	PASS	rapid
11/13/2011	317	15943170.11o	3344153.983	310245.749	-21.218	0.005	PASS	0.008	PASS	0.004	PASS	rapid
				Mean		0.002		0.004		0.004		
				Std Deviation		0.003		0.003		0.010		

Established Position Peak to Peak Values		95% Confidence
Northing	0.020	0.039
Easting	0.020	0.039
Ellipsoid Height	0.020	0.039

```
The NGS Data Sheet
See file dsdata.txt for more information about the datasheet.
DATABASE = NGSIDB , PROGRAM = datasheet95, VERSION = 7.87.4.2
1        National Geodetic Survey,   Retrieval Date = DECEMBER  6, 2011
 DJ8941
 ***********************************************************************
 DJ8941  CORS        -  This is a GPS Continuously Operating Reference
 Station.
 DJ8941  DESIGNATION -  GAUTIER CORS ARP
 DJ8941  CORS_ID     -  MSGA
 DJ8941  PID         -  DJ8941
 DJ8941  STATE/COUNTY-  MS/JACKSON
 DJ8941  USGS QUAD   -  GAUTIER NORTH (1982)
 DJ8941
 DJ8941                          *CURRENT SURVEY CONTROL
 DJ8941
 DJ8941* NAD 83(CORS)-  30 23 40.46429(N)     088 38 42.49027(W)      ADJUSTED
 DJ8941* NAVD 88     -              **(meters)            **(feet)
 DJ8941
 DJ8941  EPOCH DATE  -         2002.00
 DJ8941  X           -     130,193.229 (meters)                       COMP
 DJ8941  Y           -  -5,504,709.806 (meters)                       COMP
 DJ8941  Z           -   3,208,174.735 (meters)                       COMP
 DJ8941  ELLIP HEIGHT-          -7.883 (meters)          (01/??/08) ADJUSTED
 DJ8941  GEOID HEIGHT-         -28.24  (meters)                       GEOID09
 DJ8941  HORZ ORDER  -  SPECIAL (CORS)
 DJ8941  ELLP ORDER  -  SPECIAL (CORS)
 DJ8941
 DJ8941.ITRF positions are available for this station.
 DJ8941.The coordinates were established by GPS observations
 DJ8941.and adjusted by the National Geodetic Survey in January 2008.
 DJ8941.The coordinates are valid at the epoch date displayed above.
 DJ8941.The epoch date for horizontal control is a decimal equivalence
 DJ8941.of Year/Month/Day.
 DJ8941
 DJ8941
 DJ8941.The PID for the CORS L1 Phase Center is DJ8942.
 DJ8941
 DJ8941.The XYZ, and position/ellipsoidal ht. are equivalent.
 DJ8941
 DJ8941.The ellipsoidal height was determined by GPS observations
 DJ8941.and is referenced to NAD 83.
 DJ8941
 DJ8941.The geoid height was determined by GEOID09.
 DJ8941
 DJ8941;                    North         East     Units Scale Factor Converg.
 DJ8941;SPC MS E     -    99,174.933   318,085.290   MT  0.99995403   +0 05
 42.8
 DJ8941;SPC MS E     -   325,376.43  1,043,584.82   sFT  0.99995403   +0 05
 42.8
 DJ8941
 DJ8941!             -  Elev Factor  x  Scale Factor =   Combined Factor
 DJ8941!SPC MS E     -   1.00000124  x   0.99995403  =   0.99995527
 DJ8941
 DJ8941                           SUPERSEDED SURVEY CONTROL
 DJ8941
 DJ8941.No superseded survey control is available for this station.
 DJ8941
 DJ8941 U.S. NATIONAL GRID SPATIAL ADDRESS: 16RCU4195163656(NAD 83)
 DJ8941_MARKER: STATION IS THE ANTENNA REFERENCE POINT OF THE GPS ANTENNA
 DJ8941
 DJ8941                           STATION DESCRIPTION
 DJ8941
 DJ8941'DESCRIBED BY NATIONAL GEODETIC SURVEY 2008
 DJ8941'STATION IS A GPS CORS.  LATEST INFORMATION INCLUDING POSITIONS AND
 DJ8941'VELOCITIES ARE AVAILABLE IN THE COORDINATE AND LOG FILES ACCESSIBLE
 DJ8941'BY ANONYMOUS FTP OR THE WORLDWIDE WEB.
 DJ8941'   ftp cors.ngs.noaa.gov: cors/coord  and  cors/station_log
```

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Vancouver, WA 98661
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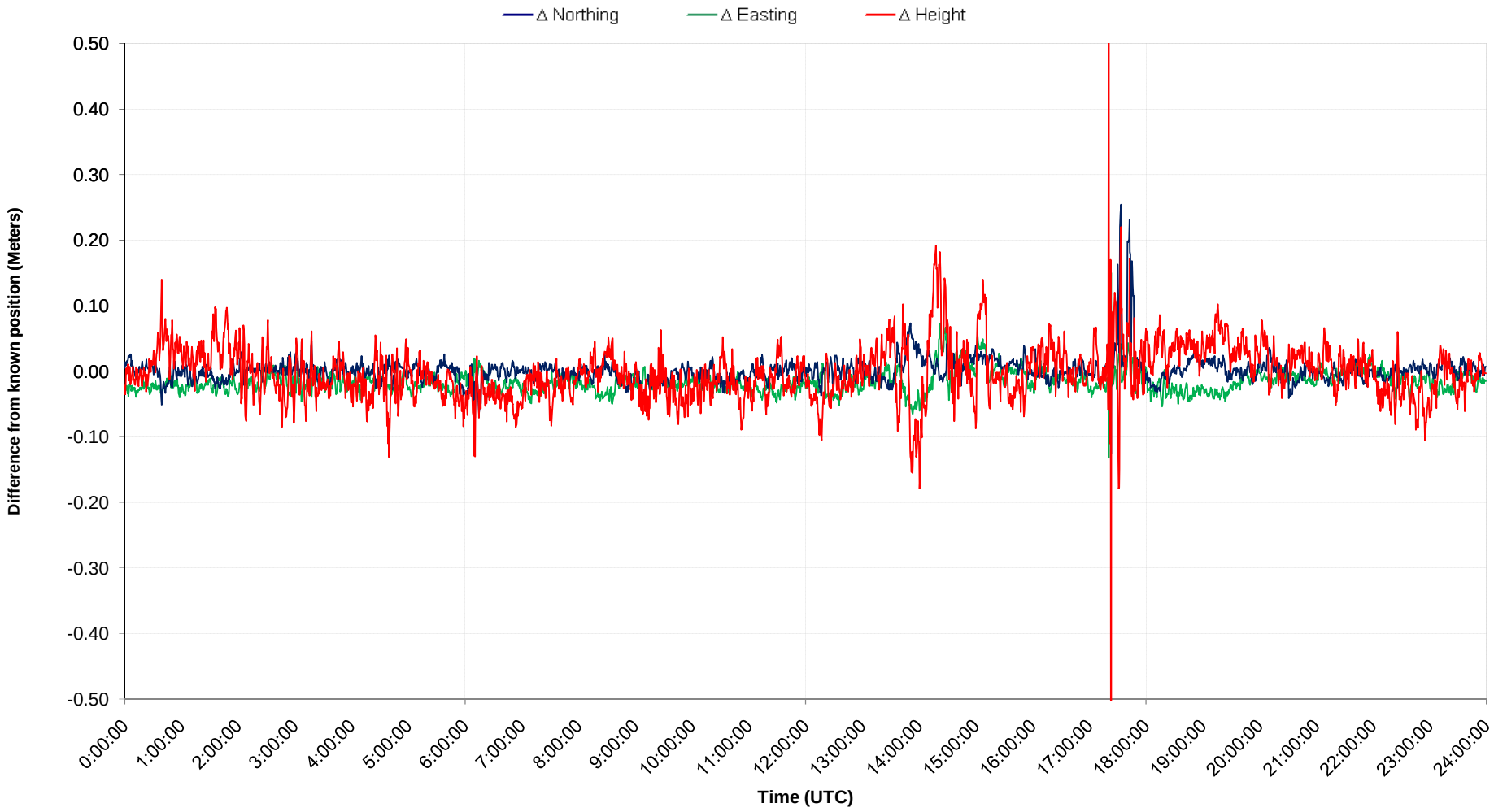
"MSGA"
GPS Base Station Site Verification

24 Hour PPK Solution Relative to Base Station Position

Date 7/29/2011
Locality Approaches to Mississippi Sound, MS
Project OPR-J348-KR-11
Version GrafNav Version 8.30.2105
Datum NAD-83 (CORS96, Epoch 2002)
Projection UTM Zone 16 North, Meters

Base Station held for PPK processing SHIP (DN210) - precise

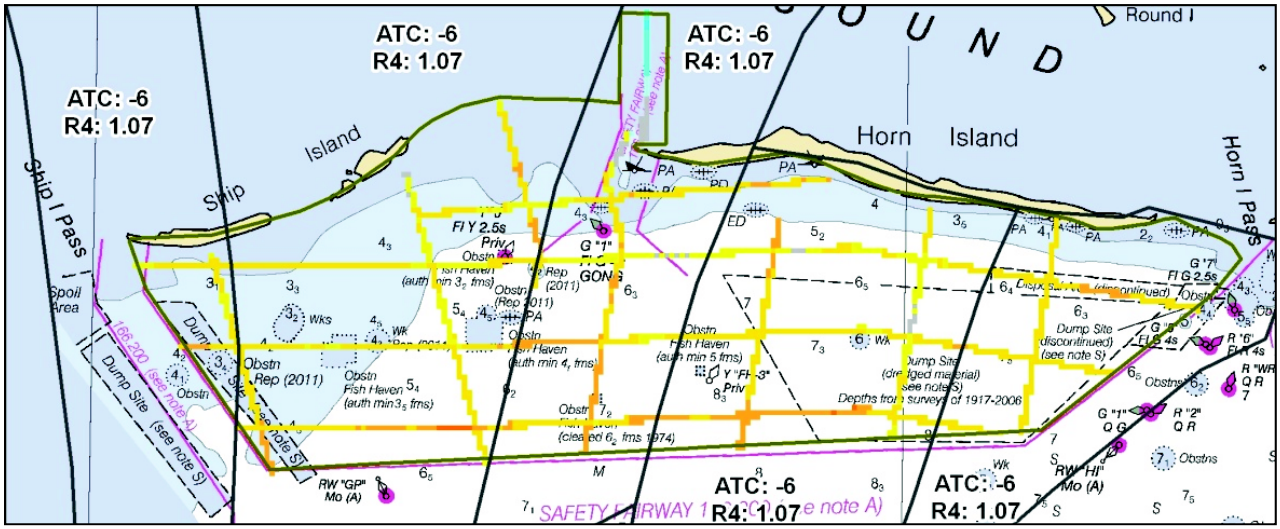
Station Latitude 30° 23' 40.46429" N
Station Longitude 88° 38' 42.49027" W
Station Ellipsoid Height -7.883
Receiver Trimble NetR5
Antenna Type Trimble Zephyr-Geodetic 41249-00



APPENDIX IV
INTERIM VDATUM REPORT

OPR-J348-KR-11 Approaches to Mississippi Sound
Interim VDatum Report

November 2011



Prepared For:

US Department of Commerce
National Oceanic and Atmospheric Administration
National Ocean Service

Prepared By:

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OPR-J348-KR-11 Approaches to Mississippi Sound
Interim VDatum Report

November 2011

This report and the accompanying data are respectfully submitted.

Field operations contributing to the accomplishment of OPR-J348-KR-11 were conducted under my direct supervision with frequent personal checks of progress and adequacy. This report and associated data have been closely reviewed and are considered complete and adequate for an interim deliverable as per the OPR-J348-KR-11 *Project Instructions* (June 2011).

Digitally signed by Jon Dasler
DN: cn=Jon Dasler, email=jld@deainc.com, o=David Evans and Associates, Inc., c=US
Date: 2011.11.01 15:23:33 -07'00'

Jonathan L. Dasler, PE (OR), PLS (OR,CA)
ACSM/THSOA Certified Hydrographer
Chief of Party

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Date: 2011.11.01 15:23:14 -07'00'

Jason Creech
Lead Hydrographer

Digitally signed by Ben Hocker
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Date: 2011.11.01 15:22:42 -07'00'

Ben Hocker
Lead Hydrographer
Tides and Water Levels Specialist

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Appendix A: Ship Island, Mississippi Sound, MS Datum Computation Results

Acronyms and Abbreviations

ARP	Antenna Reference Point
ASCII	American Standard Code for Information Interchange
CO-OPS	Center for Operational Oceanographic Products and Services
CORS	Continuously Operating Reference Station
CUBE	Combined Uncertainty and Bathymetry Estimator
DAA	Design Analysis and Associates, Inc.
DEA	David Evans and Associates, Inc.
DN	Day Number
ERS	Ellipsoidal Referenced Survey
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HIPS	Hydrographic Information Processing System
HVF	HIPS Vessel Files
HSSD	Hydrographic Surveys Specifications and Deliverables
IAKAR	Inertially Aided Kinematic Ambiguity Resolution
JOA	John Oswald and Associates
LMSL	Local Mean Sea Level
MHHW	Mean Higher High Water
MHW	Mean High Water
MLLW	Mean Lower Low Water
MN	Mean Range
NAD83	North American Datum of 1983
NAVD88	North American Vertical Datum of 1988
NGS	National Geodetic Survey
NGVD29	National Geodetic Vertical Datum of 1929
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Service
NTDE	National Tidal Datum Epoch
NWLON	National Water Level Observation Network
OPUS	Online Positioning User Service
PPK	Post-Processed Kinematic
RMS	Root Mean Square
SBET	Smoothed Best Estimate Trajectory
STND	Station Datum
TPVU	Total Propagated Vertical Uncertainty
UTC	Universal Time Coordinated
VDATUM	Vertical Datum
ZDF	Zone Definition File

1.0 Executive Summary

This document is an interim report describing preliminary methods and results of an ongoing Vertical Datum (VDatum) analysis component of project OPR-J348-KR-11. The project, which is being performed by David Evans and Associates, Inc. (DEA), is located in the vicinity of the Approaches to Mississippi Sound and encompasses hydrographic surveys H12353, H12354, H12355, and H12356. DEA was contracted to perform an analysis of the reliability of Mean Lower Low Water (MLLW) estimates from the current Louisiana/Mississippi VDatum release and the ability to use those estimates to compute a North American Datum of 1983 (NAD83) ellipsoid to MLLW separation model for use with Global Positioning System (GPS) water levels following guidelines for ERS/Zoned Hydrography Comparisons set in the 2011 National Ocean Service (NOS) Hydrographic Surveys Specifications and Deliverables. This interim report and supporting data will be used by National Oceanic and Atmospheric Administration (NOAA) to support a decision on whether to use (ERS) (Ellipsoidal Referenced Survey) methods in lieu of traditional tides for final water level correctors for the OPR-J348-KR-11 surveys.

Based on preliminary tidal datum computations at Ship Island, Mississippi Sound, MS (874-4756), computed MLLW relative to heights determined using GPS is approximately 3.9 centimeters lower when compared to the NAD83 ellipsoid height of MLLW using VDatum. Vessel float observations at Ship Island supported this finding (gauge observations reduced to MLLW were 2.2 centimeters lower than MLLW determined from vessel floats using VDatum).

The results of the test line analysis show no significant difference between crossline ties with mainscheme data when using either GPS or traditional tidal correctors. As shown by the lowest standard deviation of crossing differences, the use of GPS water levels does offer a general improvement in the agreement of the VDatum test lines. It should be noted that these test lines were run under near optimum conditions for using traditional tidal zoning (calm seas, light winds, relatively low tide ranges, etc.). One would expect comparable results when using GPS methods as sea and weather patterns degrade while the traditional tidal zoning would not perform nearly as well. Further, the application of zoned tides does not adequately correct multibeam data for large kinematic waves, wind driven water level changes and other small scale transient water levels typical to the survey area. Last, ERS eliminates errors resulting from vessel loading and inadequate compensation for vessel squat by using speed over ground lookup tables. For this project, the implementation of ERS will result in the application of slightly lower water levels that more accurately reflect dynamic water levels in the survey area. The resultant soundings will be slightly deeper than soundings corrected through the application of zoned tides.

Based on the analysis performed to date, DEA recommends moving forward with ERS deliverables for this project.

2.0 GPS Base Stations

Two temporary GPS base stations were installed by DEA to post-process GPS and inertial data collected on the survey vessels by the Applanix POS/MV. Each station was strategically located near the project site in order to meet the 20-kilometer maximum baseline length for single base post-processed kinematic (PPK) mode using Applanix POSPac MMS software. The stations were designated SHIP and HORN and were installed on existing piers at Ship and Horn Islands respectively. Both GPS stations were located within the boundaries of the Gulf Islands National Seashore and as such, a permit was required from the National Park Service. The base station HORN was located along the east side of the project area while SHIP was located on the west at the tertiary tide station (Figure 1).

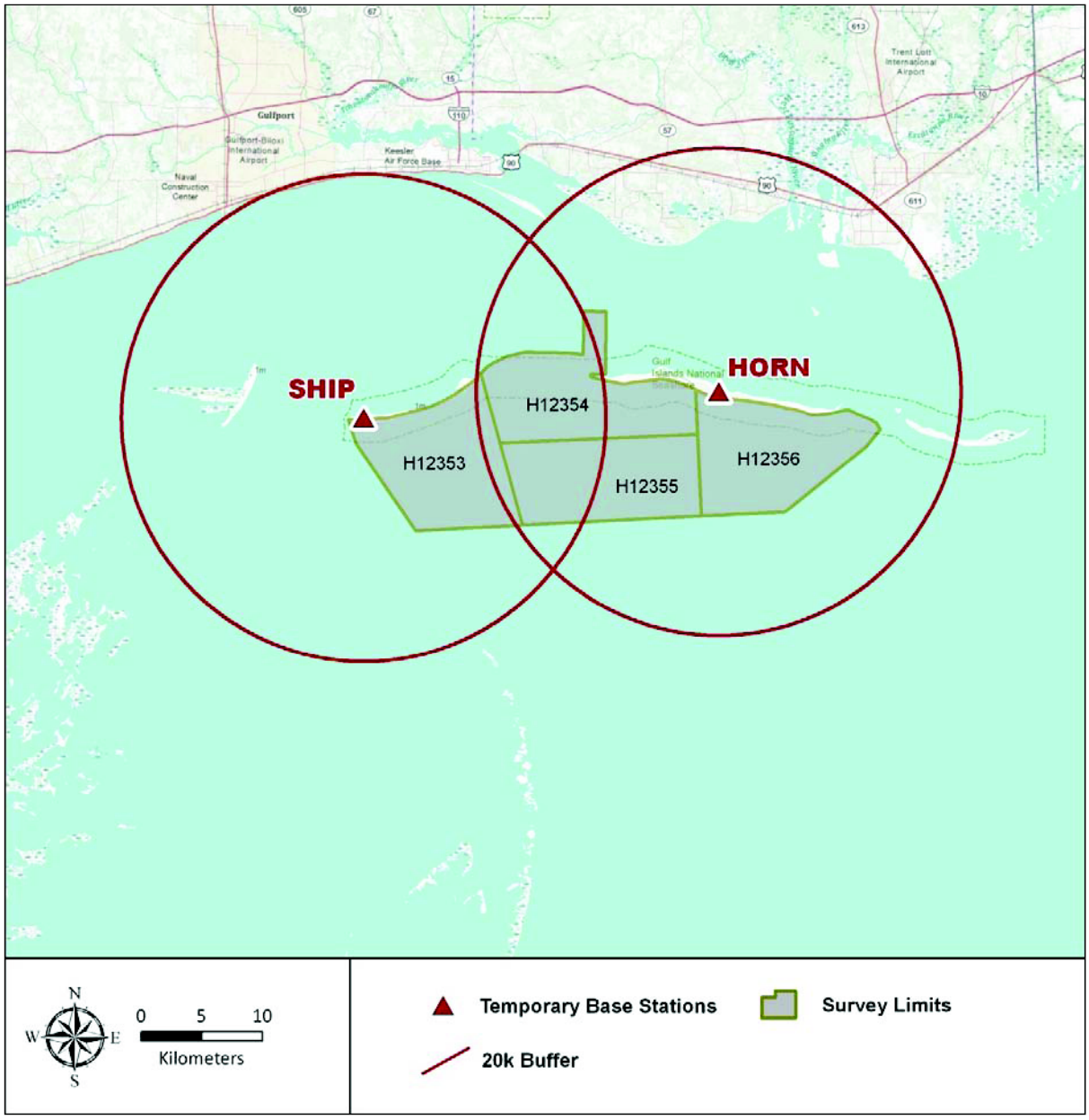

Figure 1: Temporary GPS Base Stations used for OPR-E349-KR-11

Data from existing Continually Operating Reference Station (CORS) sites could not be used in a multi-base solution in POSPac MMS due to the geometry of the network. The distances between the existing stations forming the southern baseline (needed to capture the offshore sides of the project area) exceeded the maximum length of 100 km specified in Section 9.1.1.1 of the NOS Hydrographic Surveys Specifications and Deliverables (HSSD) dated April 2011.

Each temporary GPS base station consists of a Trimble Net-R5 GPS dual frequency (L1/L2) receiver with Trimble Zephyr Geodetic GPS antenna. The station location was selected to provide clear satellite visibility with the GPS antennas installed on a rigid steel pole securely attached to a stable structure. The receivers were configured to log raw GPS observables at 1 Hz. Data logged included: L1 phase, C/A code, L2 phase, P(Y) code and L2C (CM+CL). Internally logged data were stored in Trimble T01 format and segmented into 24-hour files that were automatically uploaded to the DEA FTP site daily. The network connection was provided by a cellular modem with a directional antenna to increase signal strength. Files were manually downloaded from the FTP site and quality controlled daily. Table 1 lists the GPS equipment used on the project.

Table 1: GPS Base Station Equipment

GPS Base Station Equipment					
Item/ Manufacturer	**Model**	**P/N**	**S/N**	**Firmware Version**	**Location**
Receiver					
Trimble	NetR5	62800-10	4750K11594	4.19	SHIP
Trimble	NetR5	62800-10	4750K11589	4.19	HORN
Antenna					
Trimble	Zephyr-Geodetic	41249-00	12338039	N/A	SHIP
Trimble	Zephyr-Geodetic	41249-00	60201334	N/A	HORN

The coordinates were derived at each site from the GPS receiver logging one second epochs for a 24-hour static occupation. The data files recorded at each site were submitted to the Online Positioning User Service (OPUS), operated by the National Geodetic Survey (NGS). The solutions derived from OPUS were processed using a rapid GPS ephemeris and later checked against a precise orbit. This was done to expedite processing and meet the interim deliverables deadline. All solutions were in accordance with the passing criteria for the solution statistics established in the NOAA publication *User's Guide for GPS Observations (March 2007).* The coordinates for each site were derived at the Antenna Reference Point (ARP) of the Trimble Zephyr Geodetic antennas. The coordinates derived from the OPUS solutions at the temporary base stations are shown in Table 2, referenced to NAD83 (CORS96, Epoch 2002).

Table 2: Antenna Reference Point (ARP) Station Coordinates

Coordinates NAD83(CORS96, Epoch 2002) ARP (24 Hour OPUS Solution)			
Temporary Station	Latitude	Longitude	Ellipsoid Height (m)
SHIP	30° 12' 50.79097" N	088° 58' 17.34520" W	-21.222
HORN	30° 14' 17.35884" N	088° 40' 01.67123" W	-21.095[1]

[1] Adjusted height using OPUS 10-day average. The height used during POSPac processing was -21.122 meters.

Weekly OPUS solutions were obtained and compared to the initial base station position to verify the stability of the base station over the course of the project. Similar to the technique used to establish the base station coordinates, these weekly solutions were computed using a rapid GPS ephemeris. A total of 13 weekly comparisons were made between July 24, 2011 and October 16, 2011. For the base station on Ship Island, the average vertical deviation between the weekly check position and the original reference position was 0.004 meters, with a standard deviation of 0.012 meters. Horizontal deviation was also on average 0.004 meters or less, indicating the base station was stable over the course of the project. For the base station on Horn Island, the average vertical deviation between the weekly check position and the original reference position was 0.026 meters, with a standard deviation of 0.005 meters. Similar to the Ship island station, the average horizontal deviation was 0.004 meters or less. The 0.026-meter vertical deviation between the weekly check positions and initial base position, which was well in excess of the corresponding standard deviation, suggested that either the Horn island station had moved vertically since the initial derived position, or the initial derived position was in error.

To further evaluate base station stability for the station on Horn Island, OPUS solutions using final ephemeris were derived for a 24-hour period prior to and another following the day used to derive the initial position. Both of these solutions deviated from the derived initial position in the same direction, with the prior day 0.042 meters higher, and the following day 0.034 meters higher. This suggests that the observed deviation was attributable to error in the estimation of the original base station position, not to a physical change in the vertical location of the base station. To derive a more reliable estimate of the vertical position of the Horn Island base station, additional OPUS solutions using final ephemeris were derived for 10 days and averaged. The majority of the days used to compute the 10-day average did not coincide with days used for weekly checks, and included days prior to and following the day used to derive the initial position. The resulting position was 0.027 meters higher than the original base station position, with a standard deviation of 0.009 meters. Comparing the weekly check vertical positions to this new Horn Island vertical position yields an average difference of 0.001 meters, with a standard deviation of 0.005 meters. These results indicated that the rapid ephemeris OPUS solution used to compute the initial base position was in error by approximately 0.027 meters. The 0.027 meter shift in the vertical position of the Horn Island base station was applied to the bathymetric data as a static offset during the computation of GPS Tide in Caris Hydrographic Information Processing System (HIPS) rather than reprocessing all of the POSPac sessions using the Horn Island base station.

To tie the GPS observations to MLLW, optical leveling was performed between the GPS base station ARP and the tidal bench marks. Optical levels were run between the Horn Island GPS station HORN and bench mark 8742221 J in order to tie the NAD83 antenna reference position (ARP) height of HORN to Center for Operational Oceanographic Products and Services (CO-OPS) published MLLW; and to verify the historic NAD83 height of the tidal bench mark 8742221 H (PID: BBBG92) obtained by NGS in 2009 (Table 3). It was not possible to occupy tidal bench mark 8742221 H or any other bench marks due to access restrictions mandated by the National Park Service. GPS observation were collected on 8742221 H by the NGS on February 12, 2009 and published by OPUS-DB. CO-OPS provided station datum elevations of 8742221 H and 8742221 J which were adjusted to MLLW using published values for (874-2221). The Horn Island GPS observations when comparing the ten-day average height for HORN ARP to the NGS GPS observations do not agree by 0.028 meters. This is most likely the result of a questionable OPUS solution from 8742221 H acquired on February 12, 2009 which has a published height accuracy of ±0.078 meters. Vertical peak-to-peak errors of this magnitude typically signify a questionable OPUS solution from the 2009 GPS observation by NGS.

Table 3: Horn Island, MS (874-2221) VDatum Check

Horn Island, Mississippi Sound, MS (874-2221)	
Bench Mark	**HORN ARP**
MLLW (CO-OPS Published / transferred from 8742221 H)	6.779 m
MLLW (VDatum GEOID09)	6.691 m
MLLW Difference	**-0.088 m**
NAD83 OPUS (CORS96, 2002 Epoch) / 10 day average	-21.095 m
NAD83 Published (CORS96, 2002 Epoch) transferred from 8742221 H	-21.123 m
NAD83 Difference	**-0.028 m**

The SHIP GPS station included optical leveling from the GPS ARP to tidal bench marks during the installation of the tertiary gauge at Ship Island (874-4756). Results comparing observations to VDatum are listed in Table 4.

Table 4: Ship Island, MS (874-4756) VDatum Check

Ship Island, Mississippi Sound, MS (874-4756)	
Bench Mark	**SHIP ARP**
MLLW (CO-OPS Published / transferred from 8744756 F)	1.425 m
MLLW (VDatum GEOID09)	1.310 m
MLLW Difference	**-0.115 m**
NAD83 OPUS (CORS96, 2002 Epoch)	-21.222 m
NAD83 (CORS96, 2002 Epoch) transferred from 8744756 F	-21.228 m
NAD83 Difference	**-0.006 m**

3.0 Ship Island Tertiary Gauge

A tertiary gauge was established at the historic CO-OPS site at Ship Island, Mississippi Sound, MS (874-4756). This station was last occupied by CO-OPS in 1980. DEA incorporated this station in the permit acquired from the National Park Service and worked jointly with John Oswald and Associates, Inc. (JOA) to install two bubbler gauges to collect data for datum determination and possible sounding reduction. The primary gauge was based on a ParoScientific pressure sensor while the backup gauge consisted of a Design Analysis and Associates (DAA) H-350XL. Complete details of the installation, which was established to CO-OPS specifications as required by the Tides and Water Levels component of the project instructions, were submitted to CO-OPS in the Installation Report dated September 1, 2011. The location of the Ship Island tertiary station relative to the project area is shown in Figure 2.

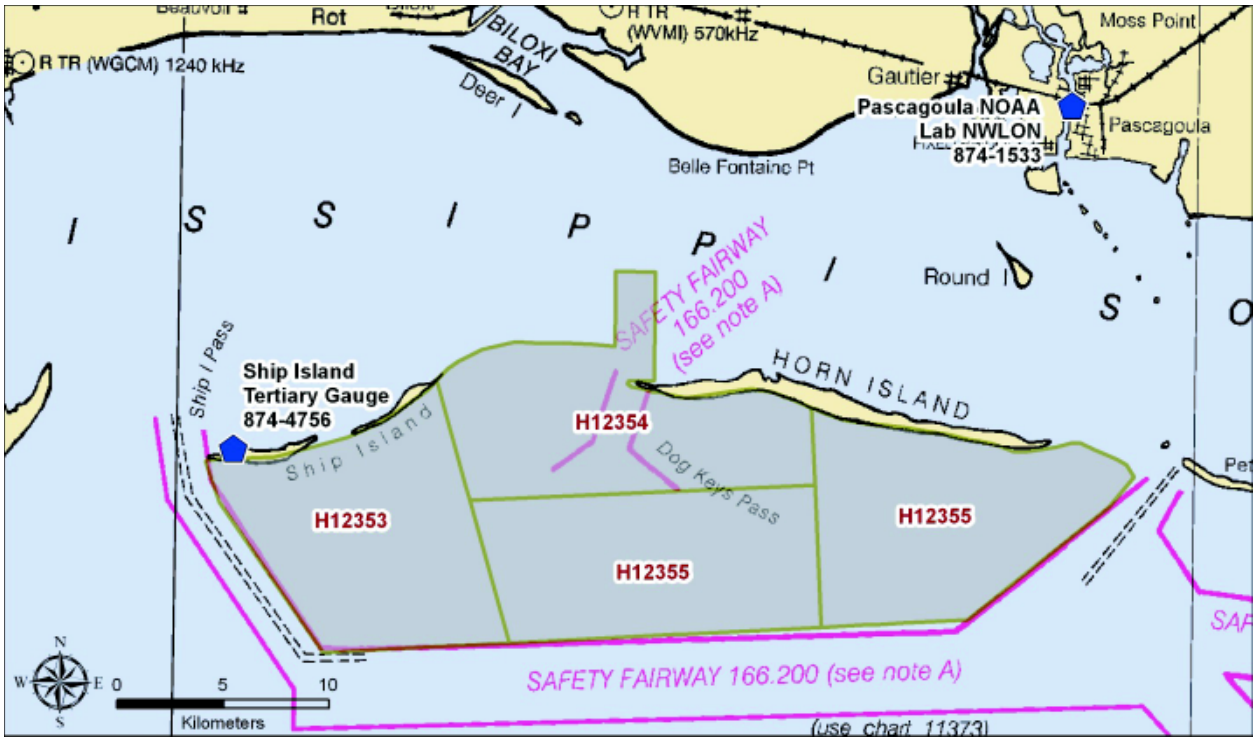

Figure 2: Water level gauging sites for OPR-E349-KR-11

3.1 Preliminary Tidal Datum at Ship Island

A preliminary datum was computed from the first set of data using the modified range ratio method. One calendar month of data was used from August, 2011 with Pascagoula NOAA Lab, MS (874-1533) as the control station. The modified range ratio method was used to correct the datums to the current National Tidal Datum Epoch (NTDE). By using this method, the Mean Higher High Water (MHHW) datum computes to a value lower than Mean High Water (MHW). Using the other computation methods this is not the case; however the modified range ratio method is the recommended method for the Gulf Coast. Datum planes are presented in Table 4

while the tabulations are given in *Appendix A. Ship Island, Mississippi Sound, MS Datum Computation Results*.

To compare the results to the published historic datum and VDatum values, the elevation of MLLW on station datum (STND) was used. The results from this preliminary datum computation are 7.6 centimeters higher than the published CO-OPS datum from 1980 that was based on four months of data (Table 5).

Table 5: Ship Island, Mississippi Sound, MS (874-4756) Datum Planes

	Preliminary Datum Planes Relative to STND (m)	Historic Datum Planes Relative to STND (m)
MHHW	1.631	1.582
MHW	1.638	1.545
DTL	1.388	1.326
MTL	1.398	1.325
MSL	1.386	1.326
MLW	1.157	1.104
MLLW	1.145	1.069
GT	0.486	0.512
MN	0.481	0.441
DHQ	-0.008	0.037
DLQ	0.012	0.035

The Computational Techniques for Tidal Datums Handbook estimates the uncertainty of a tidal datum computed from one month of data collected on the Gulf Coast is 5.49 centimeters while a datum computed from four months of data has an associated uncertainty of 4.57 centimeters at 1 sigma. Thus, in general, the differences between the 1980 published datums and the computed 2011 preliminary datums are within the estimated uncertainties, particularly when sea level trends and subsidence are taken into account.

The closest station to Ship Island with published sea level trends is Dauphin Island, AL (873-5180). Dauphin Island is approximately 86 kilometers (46 nautical miles) east of Ship Island and likely experiences similar sea level trends. The published long term trend, with regular seasonal fluctuations due to coastal ocean temperatures, salinities, winds, atmospheric pressures and ocean currents removed, is 2.98 millimeters per year with an uncertainty of 0.87 millimeters at 2 sigma. Projecting this out 31 years, yields a corrected historic MLLW datum of 1.161 meters relative to STND with a sea level correction uncertainty of 0.027 meters at 2 sigma. This compares very well to the preliminary MLLW datum relative to STND (1.145 meters) with a difference of 0.016 meters.

3.2 Preliminary VDatum Comparison at Ship Island

To compare the VDatum model to the preliminary datum, the ellipsoid height of bench mark 8744756 F determined by static GPS observations during the station installation was input to the VDatum software and the MLLW elevation was computed. It was found that the VDatum determined MLLW elevation was 3.9 centimeters below the preliminary MLLW datum computed from the observed water levels (Table 6).

Table 6: Ship Island, Mississippi Sound, MS MLLW Datum Plane Comparison

Ship Island, Mississippi Sound, MS (874-4756)	
Bench Mark	**8744756 F (GPS bench mark)**
MLLW (Preliminary)	1.349 m
MLLW (CO-OPS Published, installation levels)	1.425 m
MLLW Difference between Preliminary & CO-OPS	**0.076 m**
MLLW (VDatum GEOID09)	1.310 m
MLLW Difference between Preliminary & VDatum	**-0.039 m**
NAD83 (CORS96, 2002 Epoch)	-26.321 m

The adjusted VDatum model file for Louisiana/Mississippi - Eastern Louisiana to Mississippi Sound, released August 10, 2011 was used for the conversion.

3.3 Vessel Float Observation at Ship Island

To compare the gauge results with GPS water levels, a one-hour vessel float observation was acquired adjacent to the tertiary gauge at Ship Island during a maintenance visit. GPS data acquired during the vessel float observation was logged and processed using the combined separation model generated from the VDatum model and GEOID09. The resulting water elevations on MLLW were then compared to the tertiary gauge measured values, which were also adjusted to MLLW using a preliminary datum computed from the first month of data. The vessel measurements were averaged using the same interval as the gauge (three minutes centered on the six-minute interval). The average difference between the two methodologies was 2.2 centimeters with a standard deviation of 1.2 centimeters (Table 7 and Figure 9).

Table 7: Ship Island, Mississippi Sound, MS (874-4756) GPS to Tertiary Water Levels Comparison

Ship Island, Mississippi Sound, MS (874-4756), September 6, 2011			
Time (UTC)	GPS Water Level (VDATUM MLLW m)	Gauge Water Level (Preliminary MLLW m)	Difference (m)
19:42	0.259	0.268	-0.009
19:48	0.247	0.260	-0.013
19:54	0.256	0.258	-0.002
20:00	0.234	0.253	-0.019
20:06	0.225	0.243	-0.018
20:12	0.226	0.238	-0.012
20:18	0.217	0.238	-0.021
20:24	0.192	0.228	-0.036
20:30	0.185	0.220	-0.035
20:36	0.191	0.217	-0.026
20:42	0.167	0.205	-0.038
20:48	0.164	0.201	-0.037
		Mean	-0.022
		Standard Deviation	0.012

The direction of the difference is consistent with the differences observed by static GPS discussed in section 3.2.

4.0 Analysis of VDatum Test Lines

A series of VDatum test lines have been processed and reduced to MLLW using both ERS methods and traditional discrete zoning. The intent of these lines, which are required by the Project Instructions, is to provide a baseline in which to compare results of the two sounding reduction techniques. The VDatum test lines (Figure 3) consist of a subset of preplanned mainscheme and crosslines which run perpendicular to the maximum slopes of both the Geoid and the zoning range correctors. These lines were approved for use by NOAA Hydrographic Surveys Division by email on June 29, 2011.

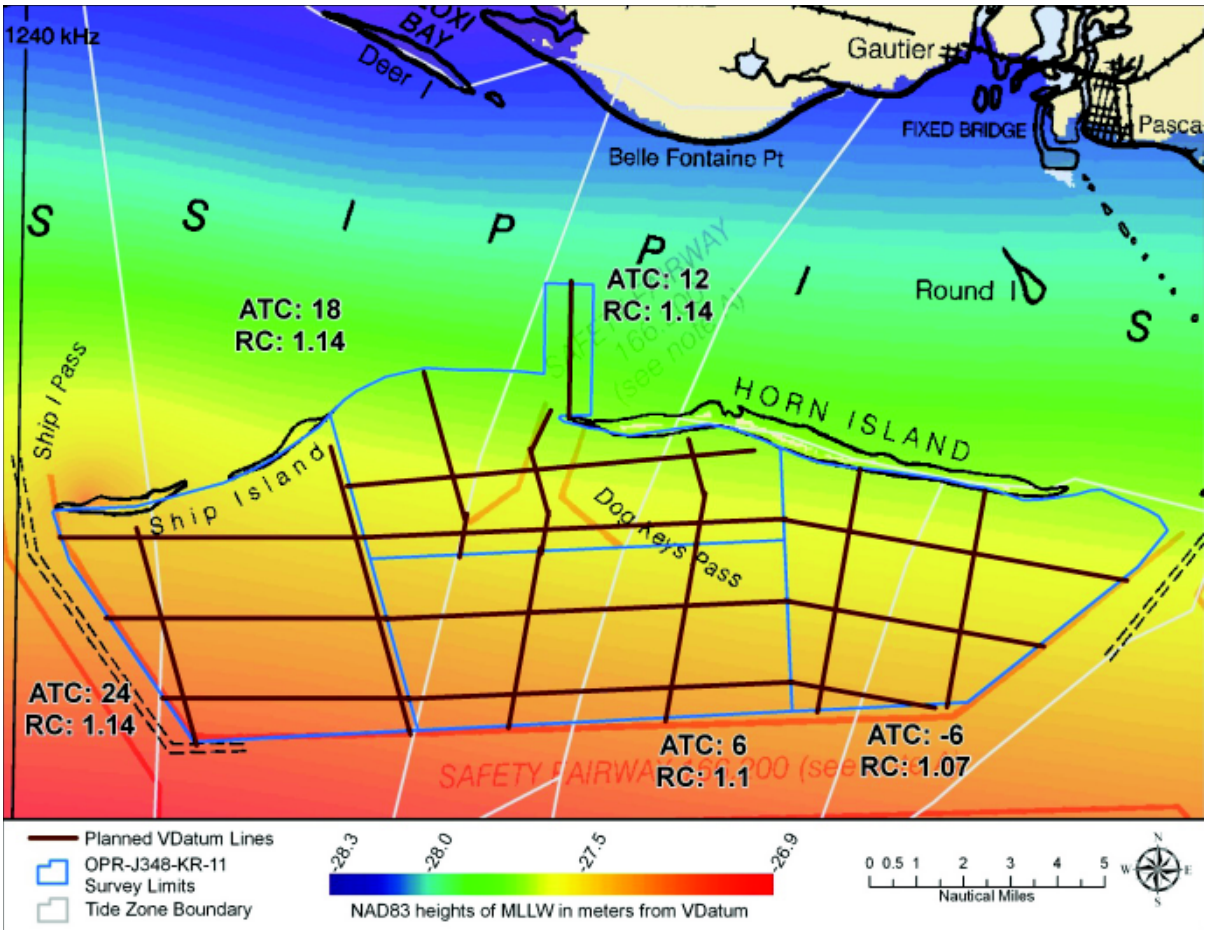

Figure 3: VDatum test lines for OPR-E349-KR-11 and preliminary zoning correctors

4.1 Processing Methods

The VDatum test lines approved for this project required the collection of 29 individual survey lines that were converted into Caris HIPS for processing and analysis. Integrated vessel attitude and Global Satellite Navigation System (GNSS) data were post-processed using the Applanix POSPac MMS Single Base option. DEA installed two base stations, SHIP and HORN, on Ship and Horn Islands to support the post processing effort. Post-processing using a SmartBase network was not possible for this project due to the inability to create a network from existing

and new GPS infrastructure without exceeding the 100 kilometer tolerance for adjacent base stations as defined in the 2011 NOS HSSD.

For both datasets (ERS and discrete zoning) data processing followed the typical Caris HIPS (CUBE) Combined Uncertainty Bathymetric Estimator workflow with integration of Smoothed Best Estimate Trajectory (SBET) data through the HIPS load Attitude and Navigation tool. Applanix POSPac MMS was used to produce an Inertially Aided Kinematic Ambiguity Resolution (IAKAR) navigation solution relative to NAD83 (CORS96, Epoch 2002) and well as real time error estimates. All available post-processed navigation, attitude, and error parameters (Navigation/Position, Gyro, Pitch, Roll, and GPS Height/Down) were applied to the ERS versions of the survey lines. All parameters except Down Root Mean Square (RMS) were applied to the zoned version of the survey lines. Down RMS was excluded in order to facilitate the proper computation of total propagated vertical uncertainty (TPVU).

The file name convention of all delivered HIPS survey lines follows the Hypack CHS format which uses a thirteen character structure incorporating year, the first two letters of the survey vessel name, Julian day number, and year (e.g. 2011WE1971724_XL_VD_ERS). Several suffixes have been appended to each survey line to indicate they are Vdatum test lines (_VD), they are also crosslines in the original survey dataset (_XL), and the method of datum reduction. The suffix _ERS indicates that the survey line uses ERS methods with SingleBase post-processing while the suffix _Zoned indicated that the survey line uses discrete zoning with NOS verified water levels.

GPS water levels from the POSPac SBET solutions were computed for the ERS version using the HIPS Compute GPS Tide dialogue. During this step the NAD83 to MLLW model file (MS_Sound.bin) created by DEA was selected as well as options necessary to apply HIPS water line offsets and to remove heave and dynamic draft from the GPS signal. The bin file was created with the aid of VDatum using GEOID09 and the Eastern Louisiana to Mississippi Sound, Version 01 transformation grids (LAMobile01_8301). During the HIPS Merge process GPS Tides are applied and the waterline, heave, and dynamic draft correctors applied during the GPS tide computation are backed out. With all correctors applied, depths were reduced to MLLW. Figure 4 shows the basic ERS processing workflow. This same methodology will be used for all project OPR-J348-KR-11 survey deliverables if permission is granted to use ERS methods in place of traditional discrete zoning.

The adjustment of the Horn Island GPS base station height previously discussed in Section 2.0 was performed with the Caris HIPS Compute GPS Tide dialogue using the Apply Height Correction option. This adjustment was not performed for survey lines collected within the H12353 survey area since they used the Ship Island base during post-processing.

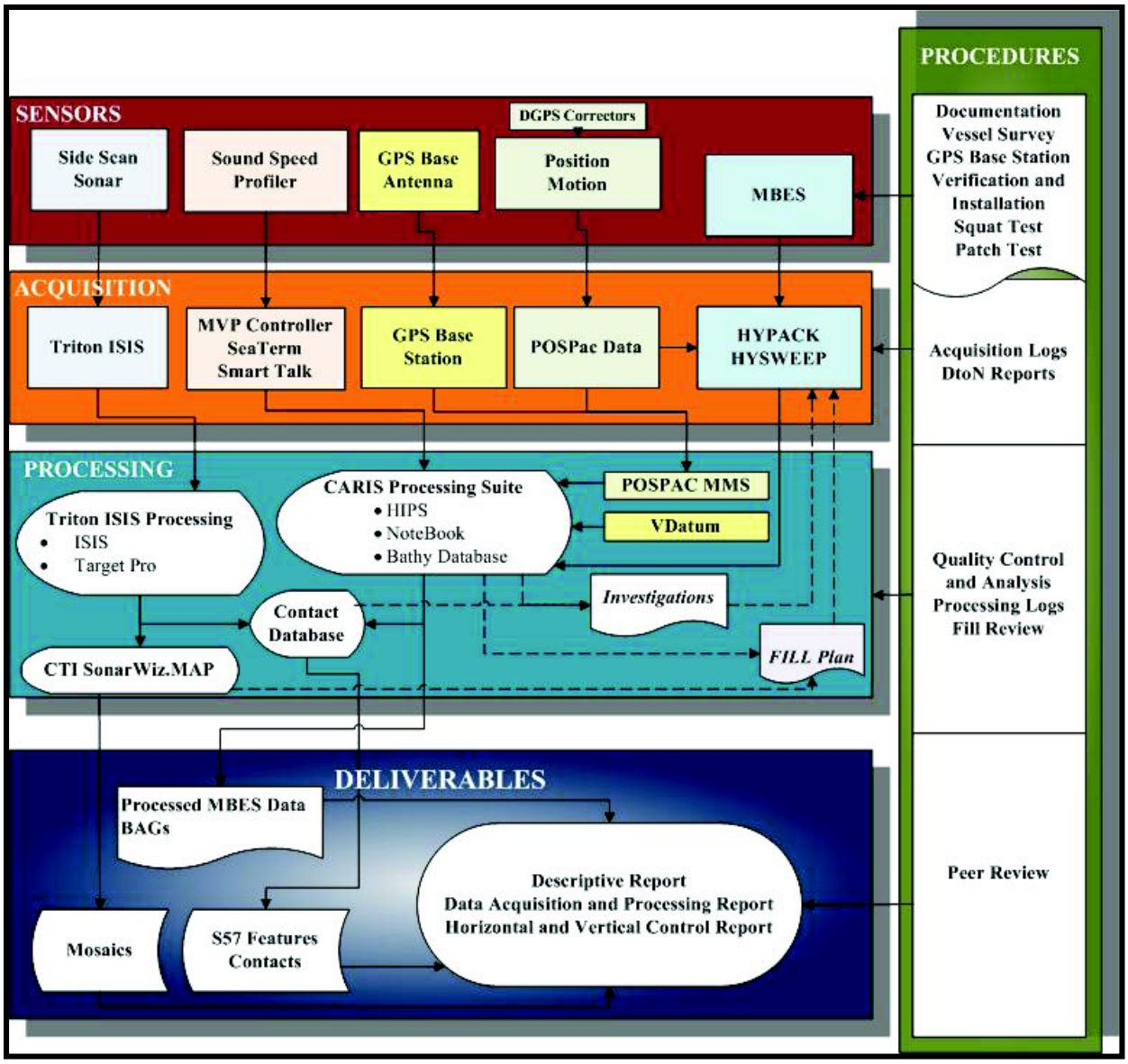

Figure 4: Workflow for GPS Water Levels

The zoned version of the survey lines followed a similar workflow. Data were reduced to MLLW using a HIPS Zone Definition File (ZDF) rather than the VDatum model file. The zoning schemes used to correct the data for this analysis are a modified version of the scheme supplied with the project instructions (J348KR2011CORP_Rev). The modified files used a HIPS Interval value of one second rather than the default value of 360 seconds which was used in the file received by DEA. The interval value controls the frequency of tide zoning interpolation. The default value of 360 seconds is too infrequent to properly correct for the assigned zoning boundaries where it would be possible for the survey vessel to pass through a zone without a zoned tide corrector being applied if the vessel was not within the zone boundary for longer than 359 seconds. Using a 1 second interval value is also more appropriate when evaluating the

performance of zoning correctors since the longer default interval has the potential to mask zoning artifacts at zone boundaries.

Table 8 lists the inputs entered into the Caris HIPS Compute Total Propagated Error (TPE) dialogue for each version of the data.

Table 8: Differences between GPS Water Levels and Zoned Tide Uncertainties

Parameter	ERS	Zoned
Tide Value Measured (m)	0.000	0.000
Tide Value Zoning (m)	0.170[1]	0.070[2]
Sound Speed Measured (m/s)	1.000	1.000
Surface Sound Speed (m/s)	0.500	0.500

[1] Computed from published values (http://vdatum.noaa.gov/docs/est_uncertainties.html)
[2] Computed from values supplied by CO-OPS and conditionally approved by HSD for use in this report

4.2 Analysis Methods

Difference surfaces of the VDatum test lines were created over the project area in order to quantify the differences between the two tide correction methods and to evaluate the effectiveness of each method. These quality control checks follow the ERS / Zoned Hydrography Comparisons guidelines set in the 2012 NOS Hydrographic Specification and Deliverables. VDatum test line mainscheme to crossline differences statistics were computed for ERS methods as well as several different zoning schemes in order to determine the most effective tide correction method for the project.

The preliminary version of the zoning scheme (noted as "Zoned" during the analysis) provided with the project instructions was evaluated alongside several new schemes created by DEA using analytical methods as well as unempirical interpretation of the local tidal dynamics. Two other zoning schemes were created after discovering that the time correction for the Ship Island (874-4756) short term datum computed specifically for the Interim Deliverables differs from the preliminary zoning value by 24 minutes. Both of these schemes were based on assumptions about the tidal dynamics for the area and held the zoning parameters from zone CGM120 for the entire project area. The first of these zones ("CGM120") used Pascagoula, NOAA Lab, MS (874-1533) water levels and the preliminary time and range correctors for CMG120 for all zones. The other ("SHIP_CGM120") used Ship Island water levels and preliminary zoning CGM120 back zoned from Ship Island.

In addition, a completely new zoning scheme was created after generating new co-phase and co-range lines for the area. New zoning parameters were created for multiple stations in the vicinity of the survey area, including the Ship Island (874-4756) subordinate gauge. Predictions were made for each of these sites using published tidal harmonics for Pascagoula, NOAA Lab, MS (874-1533) and then fitting these predictions to observed data using least squares techniques.

Revised co-range and co-phase lines were generated from the results of the analysis and used to create a new zoning scheme for the project area. This scheme was tagged as "DEA_Mod" during the analysis.

Difference surfaces were created using one meter HIPS swath angle surfaces. HIPS swath angle surfaces were generated using the 1x1 maximum footprint setting to prevent depth interpolation beyond the boundary of each one meter node. The surface differencing analysis used swath angle surfaces in lieu of CUBE surfaces to remove the impact of uncertainty weighting on the final depth estimates of each node. Total propagated uncertainty was computed for both datasets using the appropriate a priori and real-time uncertainties to enable the comparison of both depth and uncertainly differences resulting from the two tide correction techniques. This required the use of two HIPS Vessel Files (HVF) which used the same sensor offset information, but with standard deviation values specific to the water level correction technique. Loading, draft, and dynamic draft error estimates were used in the Zoned version of the vessel files while these parameters were zeroed out in the ERS version.

Difference surfaces between crossings of the VDatum test lines were created to evaluate the performance of each tide correction method. VDatum test lines included both mainscheme and crosslines from the OPR-J348-KR-11 data set. This analysis excluded VDatum lines run on September 13, 2011 (DN 256) because water levels reduced to MLLW at the Ship Island subordinate gauge were not available when the analysis was performed. The difference surfaces were created in HIPS 7.1 using the GPS water levels version of a surface as Input Surface 1 and the zoned version as Input Surface 2. The output grid was then exported to American Standard Code for Information Interchange (ASCII) to enable computation of descriptive statistics (Table 9). Positive differences indicate that the zoned tide was greater than the GPS water level.

The results from the project-wide crossline analysis are presented in Table 9 and Figure 5.

Table 9: Crossline Differences at VDatum Test Line Crossings

	ERS	Zoned (CO-OPS preliminary)	Zoned (CGM120)	Ship Island (DEA mod)	Zoned (SHIP_CGM120)
Mean (m)	-0.022	-0.004	-0.002	0.010	0.010
Median (m)	-0.022	-0.005	-0.002	0.008	0.011
Standard Deviation (m)	0.030	0.048	0.039	0.041	0.041
Range (m)	0.279	0.269	0.238	0.250	0.247
Minimum (m)	-0.190	-0.133	-0.115	-0.103	-0.114
Maximum (m)	0.089	0.137	0.124	0.148	0.134

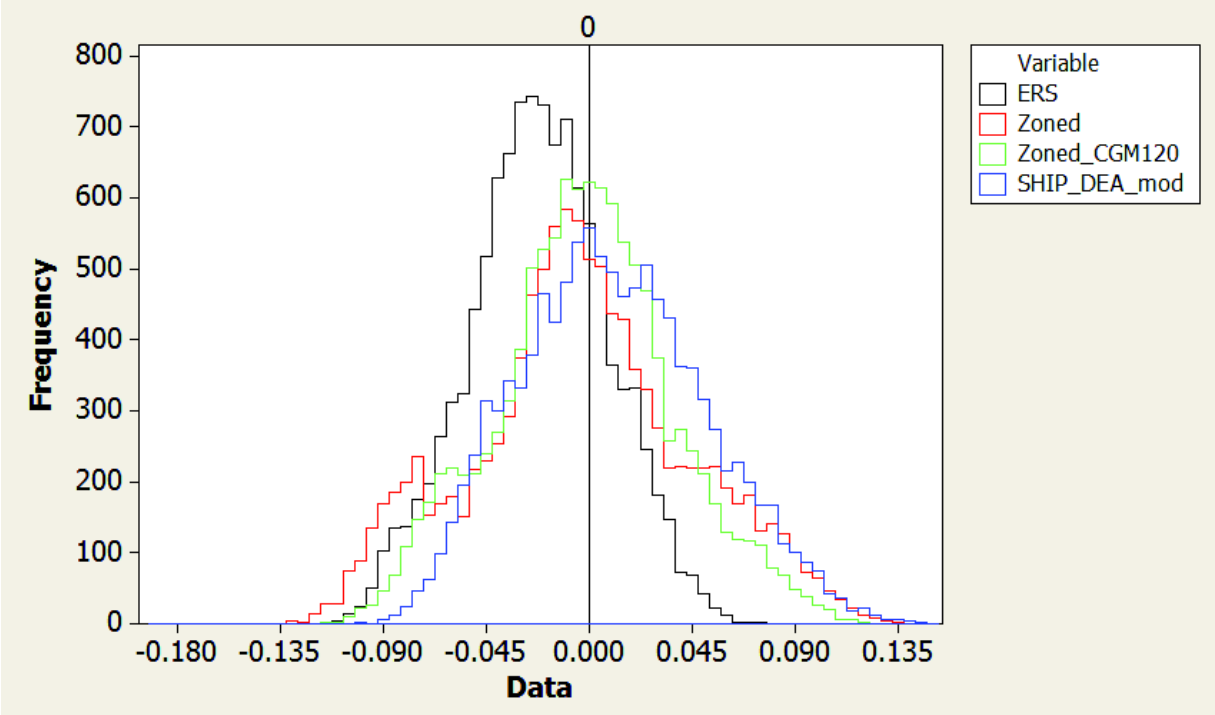

Figure 5: Histogram of difference results from crossing analysis

Outliers in the difference statistics, including those represented by the minimum and maximum statistics result from errors in water level correction techniques, other contributors to vertical errors such as refraction, actual changes in the seafloor, and gridding errors.

The best performing zoning scheme was the scheme "CGM120" which used Pascagoula, NOAA Lab, MS (874-1533) water levels and the preliminary time and range correctors for CMG120 for all zones. After this determination was made difference surfaces were generated using the ERS VDatum test lines and the duplicate version corrected with zoned water levels using "CGM120". As with the crossing analysis the GPS water levels version of a surface was used as Input Surface 1 and the zoned version entered as Input Surface 2. Input surfaces included survey lines for the entire project area. Statistics for individual survey areas were created by spatially selecting differences within each survey area polygon.

Table 10: Depth Differences between GPS Water Levels and Zoned Tides (CMG_120)

Survey	Minimum (m)	Maximum (m)	Mean (m)	Standard Deviation (m)
H12353	0.005	0.172	0.076	0.029
H12354	-0.166	0.176	0.053	0.040
H12355	0.007	0.158	0.093	0.027
H12356	-0.003	0.137	0.069	0.022

Figures 6 and 7 display difference surfaces for each of the four survey sheets overlaid on the zoning scheme and the GEOID09 model. A standard difference color map was applied to all of the surfaces in order to aid in the visual comparison of differences. Areas where soundings corrected with zoned water levels are deeper than those corrected with ERS water levels are depicted in yellows and reds and areas where soundings corrected with ERS water levels are deeper than those corrected with zoned water levels are depicted in shades of blues. Conversely, yellow and red shadings also indicate areas where zoned tide values were greater than GPS water level values and areas shaded with blue indicate areas where the zoned tide values were less than the GPS water level values.

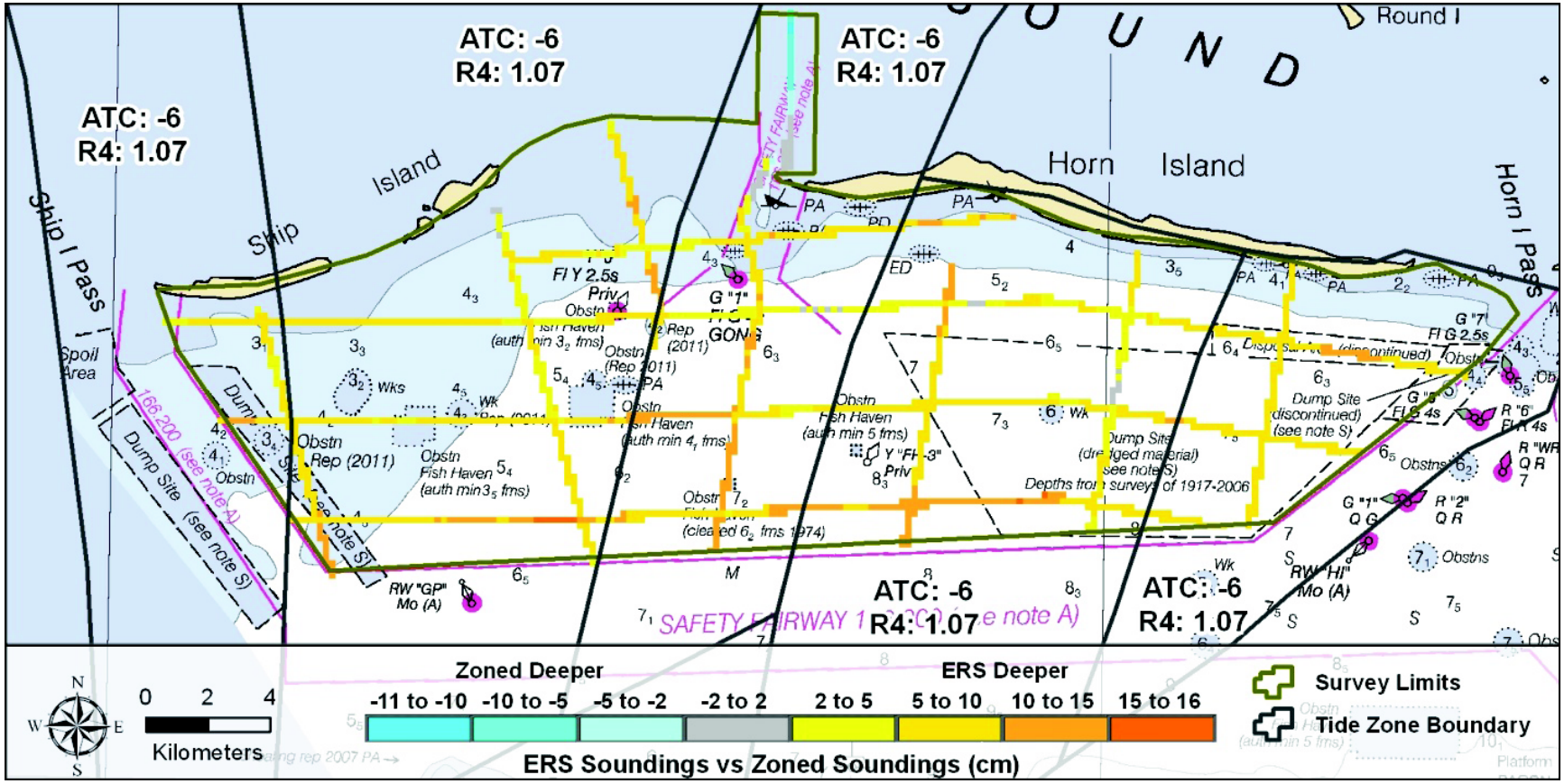

Figure 6: Depth Difference Surface between GPS Water Levels and Zoned Tides with Zoning Scheme Overlay

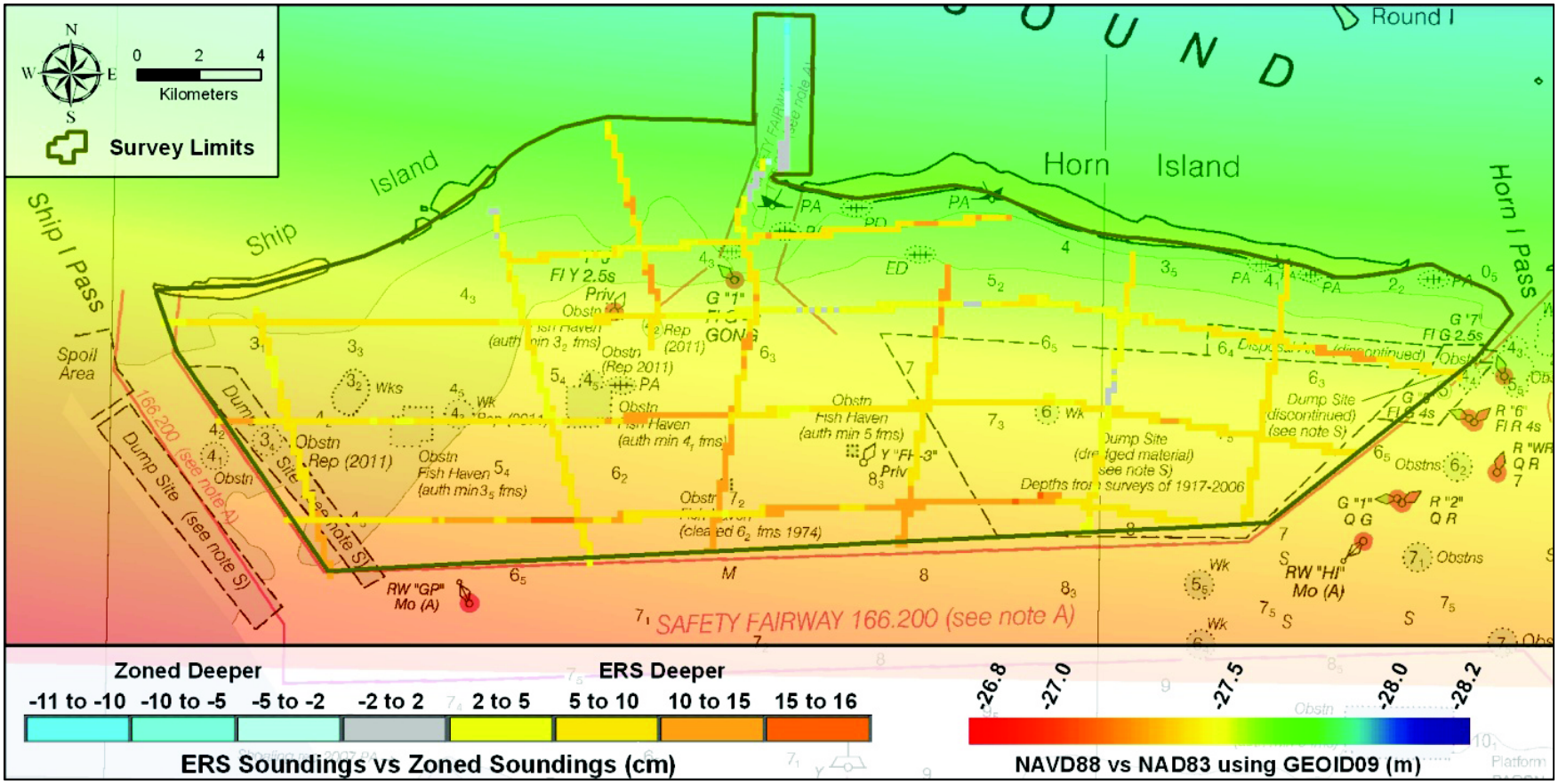

Figure 7: Depth Difference Surface between GPS Water Levels and Zoned Tides with GEOID09 Overlay

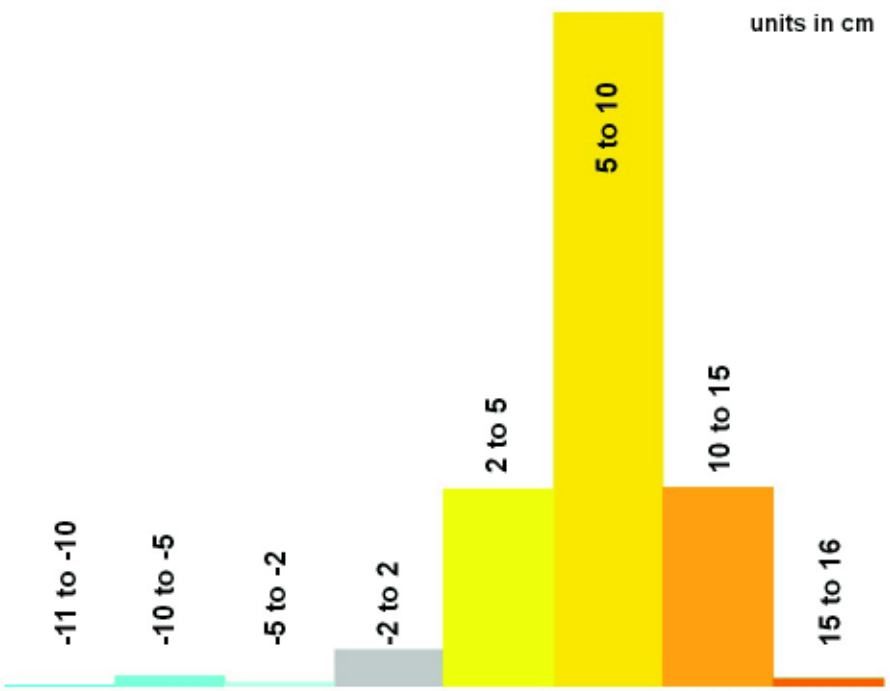

Figure 8: Histogram of GPS Water Levels and Zoned Tides Depth Difference Surface

4.3 Ship Island Comparisons to Zone CGM69

The Ship Island tertiary gauge (874-4756) lies within zone CGM69 of the preliminary zoning scheme provided by CO-OPS as part of the project instructions. The primary gauge for this zone is the National Water Level Observation Network (NWLON) station at Pascagoula NOAA Lab (874-1533), located approximately 44 kilometers (24 nautical miles) from the tertiary gauge.

Water level data from the tertiary gauge was used with zoned data from the primary gauge at Pascagoula NOAA Lab (874-153) to analyze the uncertainty of the zone time and range correctors. Water levels for the tertiary gauge were corrected to MLLW using the preliminary datum planes. An iterative least squares approach was used to correlate the time and range differences between the two stations. The results from this computation should approximate the zoning parameters for this location. The comparison between the preliminary zoning parameters and least squares determined fit factors are presented in Table 11.

Table 11: Zoning correctors for CGM69

	CGM69	
	Time Corrector	Range Corrector
Preliminary CO-OPS Tidal Zoning Scheme	00:24:00	x1.14
Least Squares Computation Results	00:00:00	x1.07

The least squares results were verified during the tide float done by the survey vessel at the Ship Island gauge on September 9, 2011. The average difference between the observed water level by the tertiary gauge and the GPS determined water levels on MLLW was -2.2 centimeters (Table 6). The average difference between the tertiary gauge and the CO-OPS zoned Pascagoula NOAA Lab data was 6.6 centimeters during the same time period. When the least squares determined zoning values were applied, this difference drops to 2.0 centimeters (Figure 9).

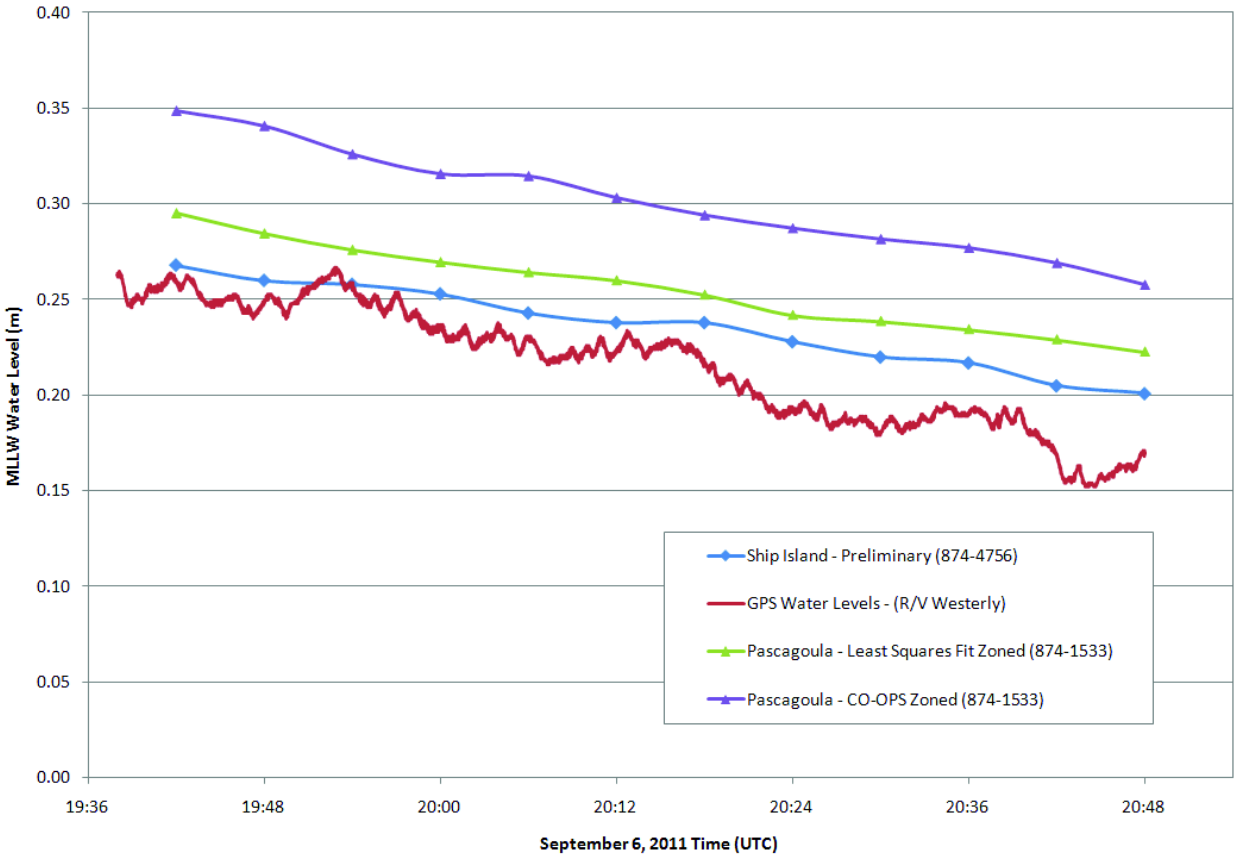

Figure 9: Zoned, observed and GPS water levels at Ship Island on September 6, 2011

Larger differences were observed during weather events as strong winds drive the Gulf coast water levels. During the approach of tropical storm Lee, differences between the zoned and measured water levels at Ship Island approached 30 centimeters, as shown in Figure 10.

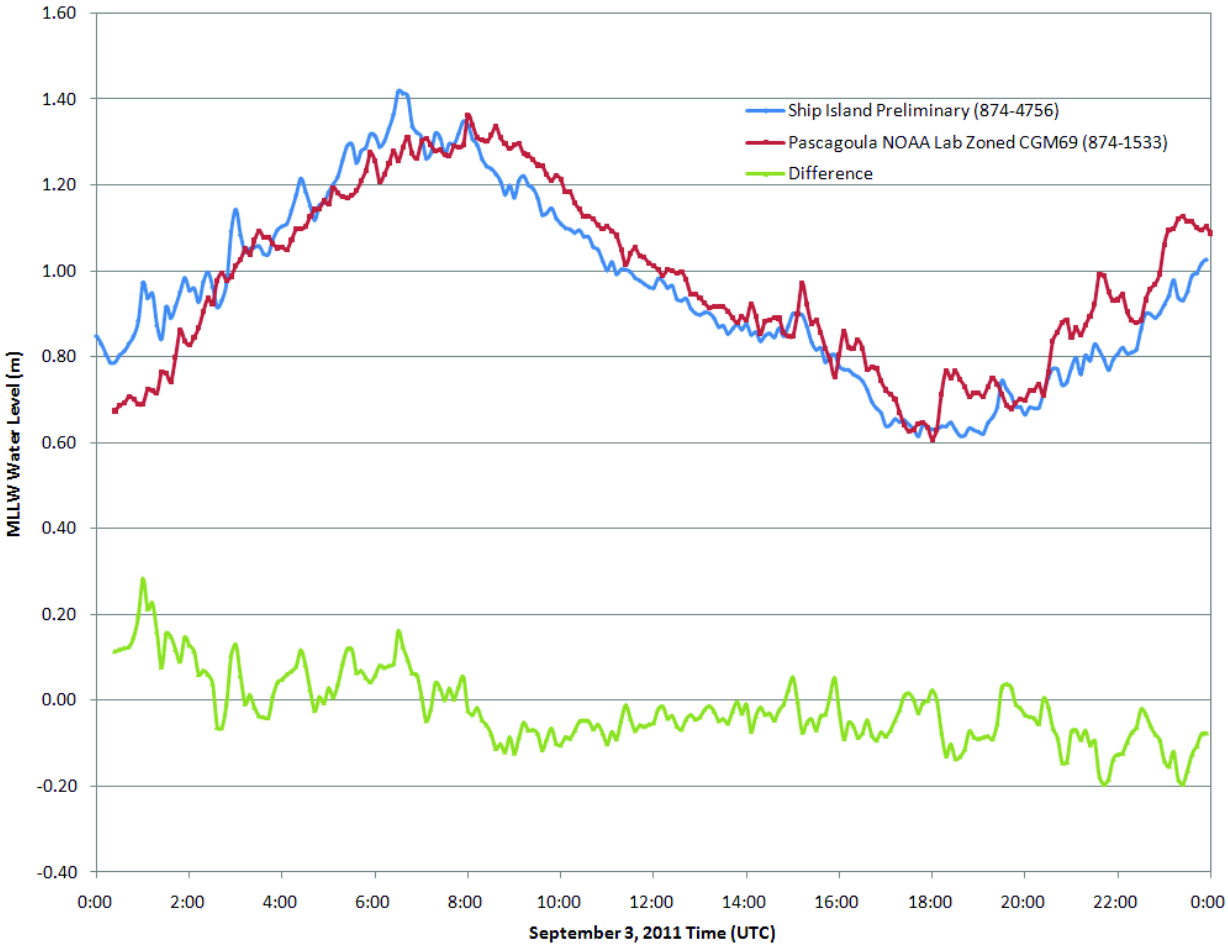

Figure 10: Zoned and observed water levels at Ship Island on September 3, 2011

The tertiary station at Ship Island is the only active water level station in the zoning scheme. No water level observations were available in other zones to conduct comparisons.

5.0 VDatum Grid Analysis

Prior to the start of the project DEA reviewed the VDatam transformation grids (LAmobile01_8301_03) in order to evaluate VDatum suitability for use in supporting ERS for the OPR-J348-KR-11 project. During this pre-analysis DEA gridded and contoured all component transformation grids required to convert a NAD83 ellipsoid height to MLLW and discovered significant artifacts in the North American Vertical Datum of 1988 (NAVD88) to Local Mean sea level transformation surface. These artifacts were brought to the attention of NOAA HSD and they were later removed prior to the release of updated VDatum surfaces on August 10, 2011. The previously discussed VDatum test line analysis used the revised VDatum products.

As shown is Figure 11, bulls-eye artifacts discovered during the VDatum pre-analysis were centered on historic CO-OPS tide gauge sites on Cat and Ship Islands. DEA discovered that the artifacts were caused by the use of inaccurate NAVD88 heights on tidal bench marks when creating the VDatum model of the area. The published NAVD88 heights of the Cat Island bench mark (ARMY 1966 RM 2) and the Ship Island bench mark (SIGNAL AZ MK) were computed by using VERTCON to shift superseded National Geodetic Vertical Datum of 1929 (NGVD29) orthometric heights computed from vertical angle observations out to the islands and rounded to zero decimal places.

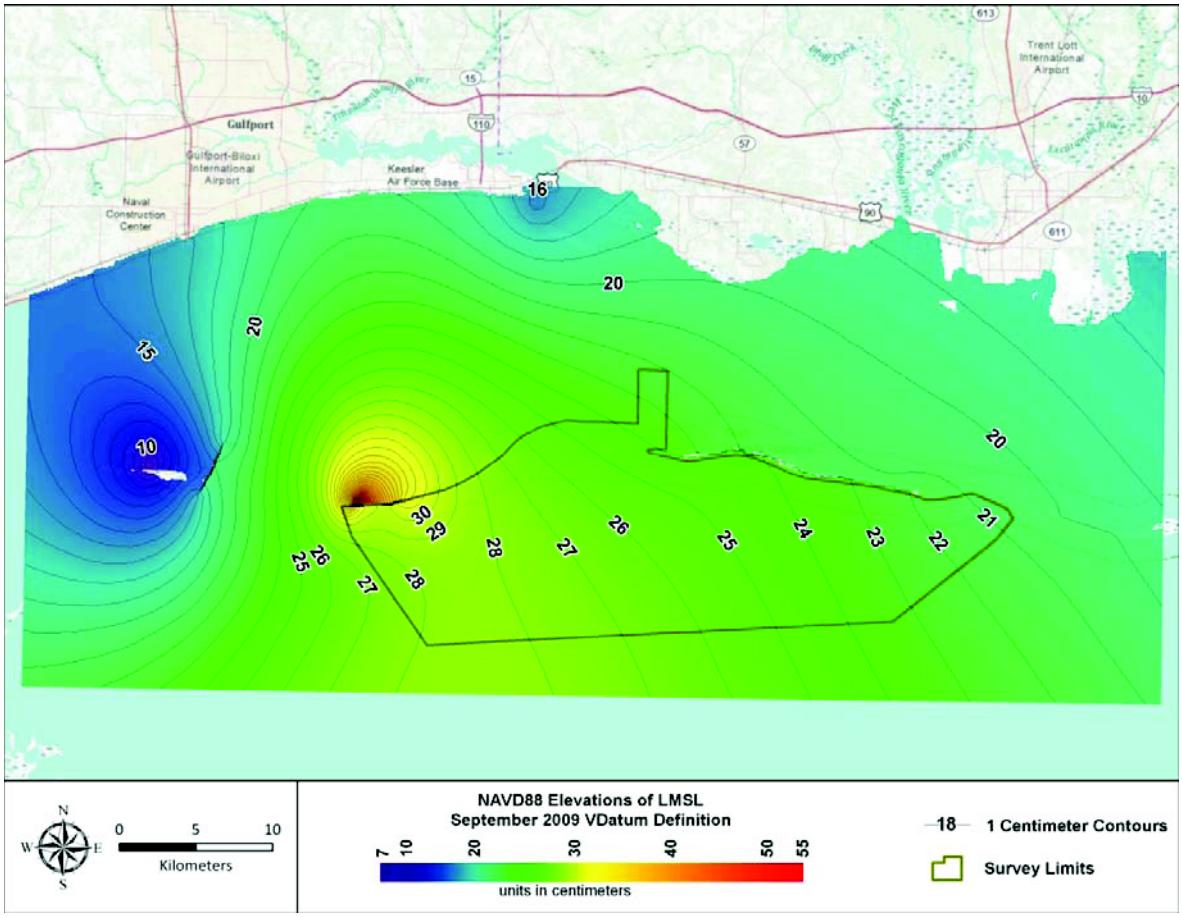

Figure 11: NAVD88 to Local Mean sea level transformation surface, Version 01

During additional investigation of the bulls-eye artifacts DEA discovered that a 2009 GPS occupation of SIGNAL AZ MK by the National Geodetic Survey was posted on the OPUS website. The NAVD88 height on the OPUS site was 1.531 meters while the published height of the mark, which was used in VDatum, was 2.0 meters. These differences confirmed that the published height of SIGNAL AZ MK was incorrect.

Since notifying HSD about the anomalies in the LAmobile01_8301_03 transformation grids NOAA has released a revision. According to documentation included with its release, the Version 02 grids were generated with updated tidal datums and in some cases entirely different tidal stations. Visual interpretation of a grid and contours of the revised NAVD88 to Local Mean sea level transformation surface (Figure 12) leads one to believe that the Ship Island station was removed from the revised grid, that the Cat Island Station was retained, and that a Horn Island station was added. It is also apparent from Figures 11 and 12, which use the same color ramp to display differences between Local Mean Sea Level (LMSL) to NAVD88, that differences up to 20 centimeters have been incorporated in the vicinity of the OPR-J348-KR-11 project area as a result of this revision.

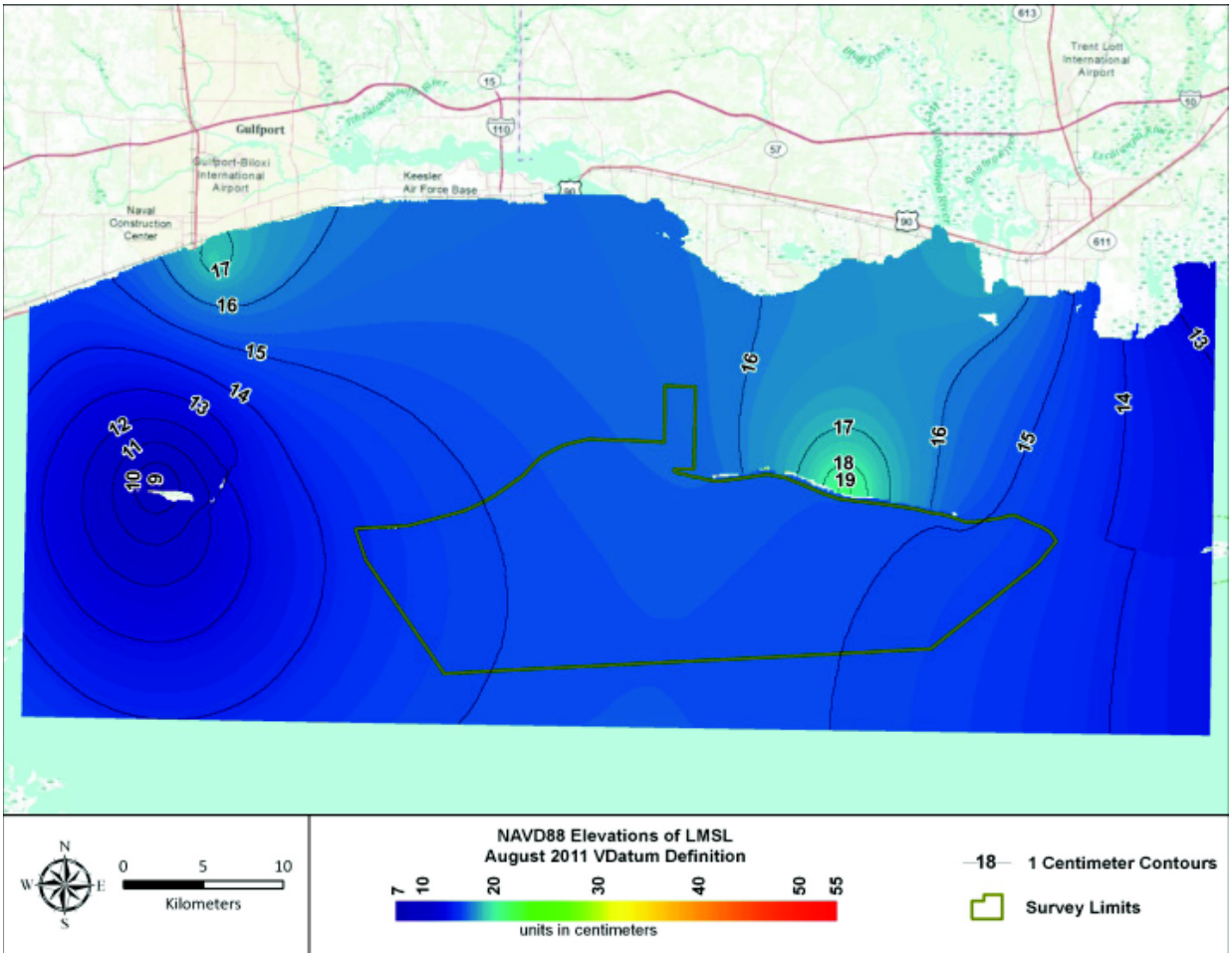

Figure 12: NAVD88 to Local Mean sea level transformation surface, Version 02

6.0 Recommendations

Based on the analysis performed to date DEA recommends moving forward with ERS deliverables for this project. The results of the test line analysis show no significant difference between crossline ties with mainscheme data when using either GPS or traditional tidal correctors. It should be noted that these test lines were run under near optimum conditions for using traditional tidal zoning (calm seas, light winds, relatively low tide ranges, etc.). One would expect comparable results when using GPS methods as sea and weather patterns degrade while the traditional tidal zoning would not perform nearly as well. Further, the application of zoned tides does not adequately correct multibeam data for wind driven water level changes and other small scale transient water levels typical to the survey area. Last, ERS eliminates errors resulting from vessel loading and inadequate compensation for vessel squat by using speed over ground lookup tables. For this project, the implementation of ERS will result in the application of slightly lower water levels that more accurately reflect dynamic water levels in the survey area. The resultant soundings will be slightly deeper than soundings corrected through the application of zoned tides.

APPENDIX A

Ship Island, Mississippi Sound, MS
Datum Computation Result

COMPARISON OF MONTHLY MEANS (Aug 2011 - Aug 2011)
1983-2001 TIDAL EPOCH

File Created: Sep 08 2011 00:47

Sub Contractor: JOA Surveys, LLC
Prime Contractor: David Evans & Associates
Processor: N. Wardwell

Subordinate Station: Ship Island, MS
Control Station: Pascagoula Noaa Lab, MS

		MTL			MSL			DTL	
MONTH	(A)	(B)	(A-B)	(A)	(B)	(A-B)	(A)	(B)	(A-B)
		Meter			Meter			Meter	
Aug	1.450	6.958	-5.508	1.446	6.961	-5.515	1.449	6.967	-5.518
Sums			-5.508			-5.515			-5.518
Count			1			1			1
Means			-5.508			-5.515			-5.518
Accepted(B)			6.906			6.901			6.906
Corrected(A)			1.398			1.386			1.388

		MN			DHQ			DLQ			GT	
MONTH	(A)	(B)	(A/B)	(A)	(B)	(A/B)	(A)	(B)	(A/B)	(A)	(B)	(A/B)
		Meter			Meter			Meter			Meter	
Aug	0.383	0.327	1.170	0.021	0.050	0.410	0.022	0.033	0.678	0.425	0.410	1.038
Sums			1.170			0.410			0.678			1.038
Count			1			1			1			1
Means			1.170			0.410			0.678			1.038
Accepted(B)			0.411			0.029			0.028			0.468
Corrected(A)			0.481			0.012			0.019			0.486

MODIFIED

1.631 = MHHW(A) = MLLW(A) + GT(A)
1.638 = MHW(A) = MLW(A) + MN(A)
1.157 = MLW(A) = MTL(A) - 0.5*MN(A)
1.145 = MLLW(A) = DTL(A) - 0.5*GT(A)

STANDARD

1.650 = MHHW(A) = MHW(A) + DHQ(A)
1.638 = MHW(A) = MLW(A) + MN(A)
1.157 = MLW(A) = MTL(A) + 0.5*MN(A)
1.138 = MLLW(A) = MLW(A) - DLQ(A)
1.394 = DTL(A) = 0.5*(MHHW(A) + MLLW(A))
0.512 = GT(A) = MHHW(A) - MLLW(A)

FINAL DATUMS (modified)

1.631 = MHHW = MLLW(A) + GT(A)
1.638 = MHW = MLW(A) + MN(A)
1.388 = DTL = Corrected for (A)
1.398 = MTL = Corrected for (A)
1.386 = MSL = Corrected for (A)
1.157 = MLW = MTL(A) - 0.5*MN(A)
1.145 = MLLW = DTL(A) - 0.5*GT
0.486 = GT = Corrected for (A)
0.481 = MN = Corrected for (A)
-0.008 = DHQ = MHHW(A) - MHW(A)
0.012 = DLQ = MLW(A) - MLLW(A)