Terrebonne Parish
Appeal of FEMA's 2009 Preliminary DFIRMs

Prepared for the
Terrebonne Parish Consolidated Government

Michel Claudet, President

Prepared by
Shaw Coastal, Inc.

September 2009

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OFFICE OF THE PARISH PRESIDENT

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September 21, 2009

Gary Zimmerer, P.E.
FEMA Region VI
800 North Loop 288
Denton, TX 76209-3698

Re: Appeal of FEMA's 2008 Preliminary DFIRMs

Dear Mr. Zimmerer:

A thorough evaluation of FEMA's efforts to prepare the 2009 preliminary digital flood insurance maps (DFIRMs) and proposed base flood elevations (BFEs) for Terrebonne Parish has been completed. The evaluation was performed with technical assistance provided by Shaw Environmental & Infrastructure, Inc. (Shaw) and Drs. Joseph N. Suhayda and Roy Dokka. Several technical and scientific deficiencies were identified during the evaluation that warrants the submission of an appeal. The appeal is intended to enhance FEMA's work performed to date with improved data that enables a more accurate characterization of the parish's flood risk. One copy of the appeal document is provided herewith for your consideration.

Terrebonne Parish appreciates your assistance and timely response to this submittal. We would welcome the opportunity to meet with you and our consultants to discuss the appeal content. If you have any questions or require additional information regarding this appeal, do not hesitate to contact me 985-873-6401.

Very Truly Yours,

Michel H. Claudet
Parish President

Cc: Lucien Cutrera
Al J. Levron
Pat Gordon
Paul Labat

Enclosures

TERREBONNE PARISH
APPEAL OF FEMA'S 2009 PRELIMINARY DFIRMS

Prepared for the
Terrebonne Parish Consolidated Government

Michel Claudet, President

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September 2009

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Shaw Coastal, Inc.

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Acronyms and Abbreviations

ADCIRC	Advanced Circulation Model for Coastal Ocean Hydrodynamics
BFE	Base Flood Elevation
CORS	Continually Operating Reference Stations
DD	Decimal Degrees
DEM	Digital Elevation Model
DFIRM	Digital Flood Insurance Rate Map
FEMA	Federal Emergency Management Agency
FIRM	Flood Insurance Rate Map
FIS	Flood Insurance Study
GIWW	Gulf Intracoastal Waterway
GPS	Global Positioning System
LIDAR	Light Detection and Ranging
LSU	Louisiana State University
NED	National Elevation Dataset
NGS	National Geodetic Survey
NGVD	National Geodetic Vertical Datum
NASA	National Aeronautics and Space Administration
NAVD88	North American Vertical Datum of 1988
NOAA	National Oceanic and Atmospheric Administration
NRCS	Natural Resources Conservation Service
NSRS	National Spatial Reference System
QA/QC	Quality Assurance/Quality Control
SWL	Stillwater Level
TPCG	Terrebonne Parish Consolidated Government
TSDN	Technical Data Study Notebook
USACE	United States Army Corps of Engineers
USDA	United States Department of Agriculture
USGS	United States Geological Survey
WHAFIS	Wave Height Analysis for Flood Insurance Studies

Executive Summary

On June 2, 2009, the Terrebonne Parish President received correspondence from FEMA notifying the parish of upcoming milestones with regard to finalization of the preliminary digital flood insurance rate maps (DFIRMs) for both the City of Houma and the unincorporated areas of the parish. The letters explained that the parish was provided with preliminary copies of a Flood Insurance Study (FIS) report and Flood Insurance Rate Map (FIRM) on July 30, 2008. The next steps, as described in the FEMA correspondence, included two notices of proposed modifications to the base flood elevations (BFEs) in the local newspaper over a 10-day period and the beginning of a 90-day appeal period. Terrebonne Parish's 90-day appeal period began on June 24, 2009.

Following a review of FEMA's preliminary DFIRMs Terrebonne Parish procured the engineering services of Shaw Coastal, Inc. (Shaw) to provide technical assistance. The consultant's mission was to evaluate FEMA's work performed to date and, if necessary, create an appeal by identifying technical and/or scientific deficiencies, providing current and accurate data to address deficiencies, and creating new FIRM related information based on the improved data. The ultimate objective of this effort is to ensure Terrebonne Parish's future flood risks are appropriately characterized.

The following action items represent the general approach and methodology implemented during the evaluation and appeal of the preliminary DFIRMs.

- Evaluation of existing conditions
- Evaluation of Preliminary DFIRMs and analysis of data used by FEMA in the determination of new BFEs for the parish
- Identification of potential deficiencies in the FEMA data
- Collection of new data to address deficiencies
- Attempt to incorporate the new data into appropriate models
- Creation of new FIRM related data for consideration by FEMA

A comparison of the 1981/1985 FIRMs with the 2009 preliminary DFIRMs indicates that significant increases in BFEs are proposed in the preliminary DFIRMs for a large portion of Terrebonne Parish. The increased BFEs are a result of FEMA's recently completed map modernization efforts. To facilitate a proper evaluation of FEMA's previous efforts, numerous FEMA input/output files and related engineering reports were collected and reviewed.

After a careful review of the information made available by FEMA to Terrebonne Parish, it has been determined that certain areas of the preliminary DFIRMs contain BFEs which are technically deficient because of the following:

(1) The topographic data used in the creation of Terrebonne Parish's preliminary DFIRMs are of unknown quality and thus fail to meet FEMA guidelines.

(2) Critical topographic features used in FEMA's ADCIRC modeling are inaccurate and not representative of reality. The grid omits numerous coastal features and elevated roadways that act as weirs during storms. The omission of these weirs likely resulted in local overestimation of flooding risk.

(3) Errors were made in the application of the WHAFIS methodology.

(4) The WHAFIS methodology was based upon insufficient and poor quality data.

(5) The results of FEMA's WHAFIS modeling efforts were not properly transposed or mapped onto the preliminary DFIRMs.

Additional data was collected by Terrebonne Parish during the appeal period with the intent of providing improved input into the models that ultimately create the BFEs and the DFIRMs. The new data included the identification and location of weirs, the elevation of those weirs, and a structural evaluation of the weirs as coastal features. An attempt was made to incorporate the improved data into modified model runs. However, due to the complexities of the models and time limitations imposed by the 90-day appeal period, the models could not successfully be completed.

To ensure Terrebonne Parish's future flood risks are appropriately characterized, modified ADCIRC and WHAFIS model runs are necessary using the additional data provided in this appeal document as well as incorporating improved WHAFIS related data/adjustments identified herein. The new data and revised application of the ADCIRC and WHAFIS models would provide a more accurate and detailed basis for determining the BFEs and flood zones over the original FEMA results. At a minimum, FEMA should carefully review the output of their WHAFIS modeling efforts and ensure the results are accurately reflected on the preliminary DFIRMs.

1.0 INTRODUCTION AND BACKGROUND

1.1 Communication Summary

On June 2, 2009, the Terrebonne Parish President received correspondence from FEMA notifying the parish of upcoming milestones with regard to finalization of the preliminary digital flood insurance rate maps (DFIRMs) for both the City of Houma and the unincorporated areas of the parish. The letters explained that the parish was provided with preliminary copies of a Flood Insurance Study (FIS) report and Flood Insurance Rate Map (FIRM) on July 30, 2008. The next steps, as described in the FEMA correspondence, included two notices of proposed modifications to the base flood elevations (BFEs) in the local newspaper over a 10-day period and the beginning of a 90-day appeal period. The June 2, 2009, correspondence from FEMA is included as Appendix A for reference. The 90-day appeal period began on June 24, 2009.

Following a review of FEMA's preliminary DFIRMs, Terrebonne Parish procured the engineering services of Shaw Coastal, Inc. (Shaw) to provide technical assistance. The primary purpose of this report is to create a formal appeal by evaluating work performed by FEMA to date, identifying technical and/or scientific deficiencies, providing current and accurate data to address deficiencies, and creating new FIRM maps based on the improved data. The ultimate objective of this effort is to ensure Terrebonne Parish's future flood risks are appropriately characterized.

1.2 Public Comment Summary

A community coordination outreach meeting was held for Terrebonne Parish on February 2, 2009 at the Civic Center in Houma, Louisiana and the public was encouraged to attend. Members of the Parish's staff were made available at the meeting to answer questions from the public.

As directed by FEMA in correspondence dated June 2, 2009 (Appendix A), the preliminary maps have been available for public viewing at Terrebonne Parish Courthouse located in the city of Houma since they were made available to the Parish.

On June 17, 2009, and June 24, 2009, FEMA posted public notices in Terrebonne Parish's official journal, *The Courier*. The notices solicited technical information or comments regarding the BFEs shown in the preliminary FIS and on the preliminary DFIRMs for Terrebonne Parish. Confirmation of the public notices is provided as Appendix B.

According to Terrebonne Parish officials two written public comments have been received from residents of Terrebonne Parish as a result of the outreach efforts. The written comments are provided in Appendix C.

1.3 Approach and Methodology

Shaw has extensive experience in the planning, design, and construction of flood and storm protection systems in coastal settings. Since this project also incorporates a storm surge modeling component, Shaw augmented its staff by securing the services of experienced and well-respected coastal experts including: Dr. Joseph N. Suhayda, Consulting Coastal Hydrologist; Dr. Roy Dokka, Consulting Geologist and Geodesist; and the Woods Hole Group, Hydraulic and Coastal Engineering Services Consultant. These subject matter experts have experience working with other coastal communities in Louisiana on similar projects. The following action items represent the general approach and methodology implemented by the consulting team.

- Evaluation of existing conditions
- Evaluation of Preliminary DFIRMs and analysis of data used by FEMA in the determination of new BFEs for the parish
- Identification of potential deficiencies in the FEMA data
- Collection of new data to address deficiencies
- Attempt to incorporate the new data into appropriate models
- Creation of new FIRM related data for consideration by FEMA

Upon completion of the above, Terrebonne Parish is now able to provide FEMA with an objective, fact-based appeal of the preliminary DFIRMs. The appeal provides FEMA with the data necessary to modify its work completed to date and to more accurately characterize Terrebonne Parish's future flood risk.

2.0 EXISTING CONDITIONS

2.1 Topography

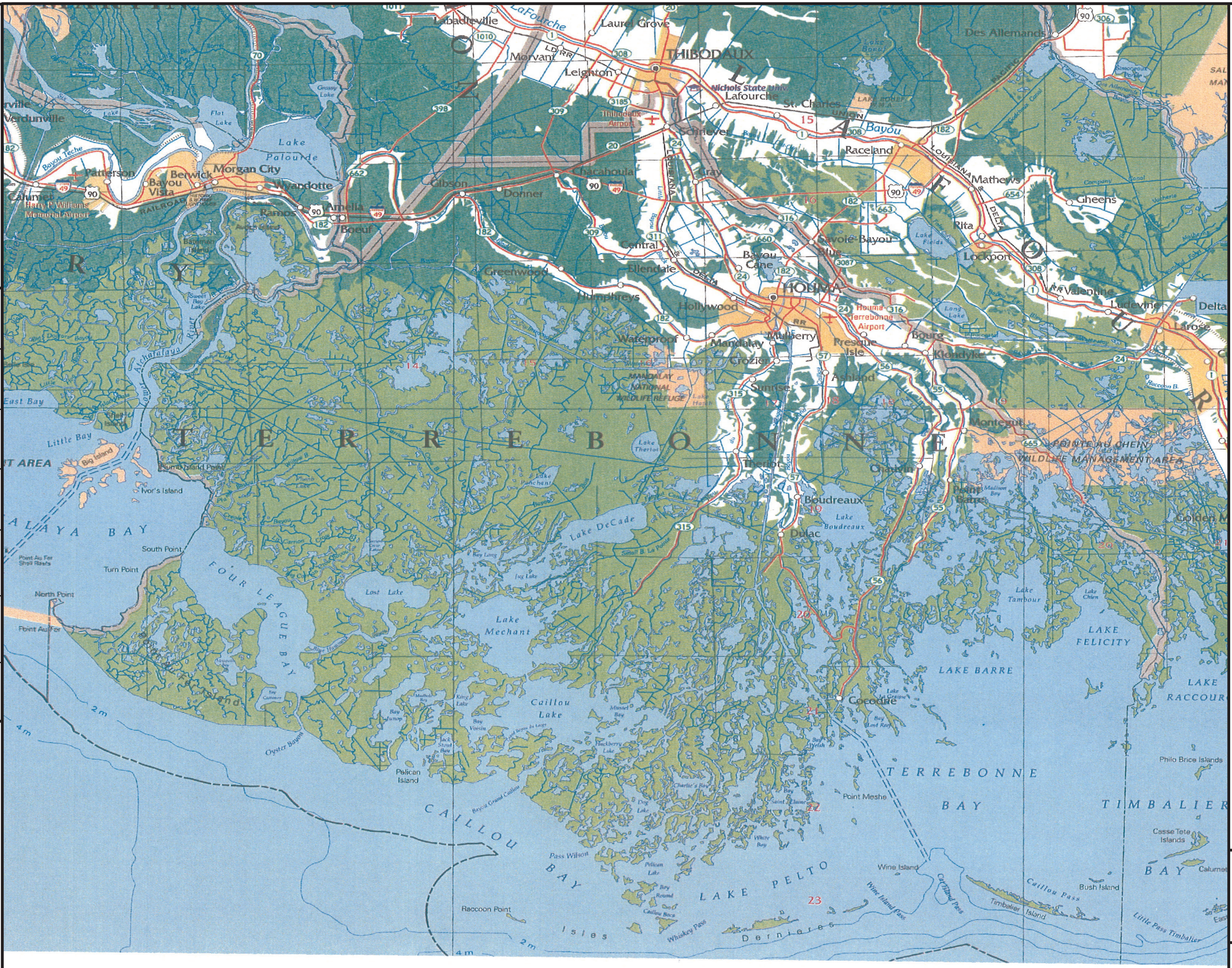
Terrebonne Parish is situated in southeast Louisiana along the state's Gulf of Mexico coastline. The population of the parish was 104,503 in 2000 and grew to 109,348 by 2006. The population is distributed such that the heaviest concentration of people and most urbanized area is in Houma. The parish includes approximately 2,100 square miles and is the second largest parish in Louisiana in terms of land area. The parish is essentially flat with a reported natural elevation ranging from zero to fourteen feet mean sea level (NAVD88). To the east is Lafourche Parish, to the west St. Mary Parish, and to the north Assumption Parish. A topographic map of the parish is included as Exhibit 2-1.

A combination of its deltaic creation, its proximity to the Gulf of Mexico, and a historical concentration of oil and gas exploration activities (construction of man-made access canals) are responsible for greater than 85% of the parish's total acreage being represented by either water or wetlands. Generally from north to south, the wetlands include fresh marsh, intermediate brackish marsh, and salt marsh near the coast line. These marshes are intertwined with hundreds of lakes, bays, bayous, and canals. Some of the more notable water bodies within the parish include:

- Bayou Black
- Bayou Dularge
- Bayou Grand Caillou
- Bayou Petit Caillou
- Bayou Terrebonne

These bayous are significant as they have historically provided the land-building sediment that created the highest areas of the parish. The sediment was deposited during annual flooding cycles of distributaries of the Mississippi River. It is upon these finger-like ridges that all urban and agriculture land exist in the parish today. The ridges become apparent when viewing Light Detection and Ranging data (LIDAR). The LIDAR map included as Exhibit 2-2 provides a graphic overview of the parish's ground elevations based on 2003 LIDAR data obtained from the United States Geological Survey (USGS) and LSU's Atlas website.

OFFICE	DRAWN BY		CHECKED BY		APPROVED BY		DRAWING NUMBER
BTR	J.Boudreaux	05/06/09	XXX	XXX	XXX	XXX	terr_136061_0001_basemap_11x17_TB



6 3 0 6
Miles

1:380,160

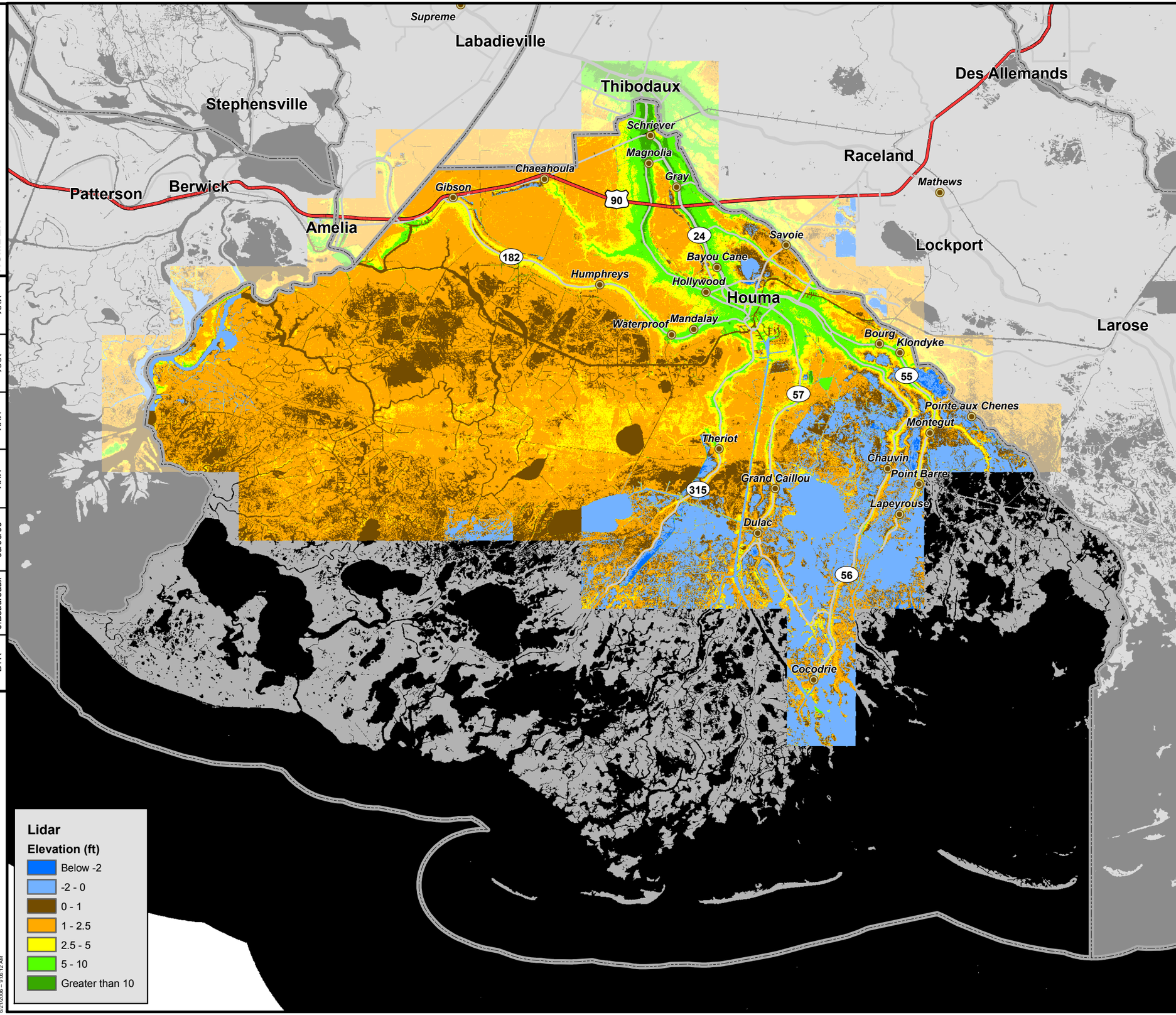
TERREBONNE PARISH
FEMA DFIRM APPEAL

EXHIBIT 2-1

TOPOGRAPHIC MAP

TERREBONNE PARISH, LOUISIANA

Map Document: (G:\GIS Data\ArcGIS\Templates\SHAW_TabloidLandscape_RightLegend.mxd.mxt)
6/21/2006 -- 9:06:12 AM



6 3 0 6 Miles

1:380,160

Legend

- Communities
- US Highway
- State/Parish Highway

REFERENCE:
LIDAR Data Obtained from LSU Atlas Website for Terrebonne Parish.

Shaw®

TERREBONNE PARISH
FEMA DFIRM APPEAL

EXHIBIT 2-2

TERREBONNE PARISH LIDAR ELEVATIONS

TERREBONNE PARISH, LOUISIANA

OFFICE	DRAWN BY		CHECKED BY		APPROVED BY		DRAWING NUMBER
BTR	J.Boudreaux	05/06/09	XXX	XXX	XXX	XXX	terr_136061_0002_lidar_11x17_TB

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2.2 Flood Protection System

Despite its location near the Gulf of Mexico and its vulnerability to hazards relative to tropical storms and hurricanes, hurricane protection levees are virtually non-existent in Terrebonne Parish. Instead, the parish relies on levees of minimal height (typically 4 to 10 feet) to force water to drain in certain patterns. Levee failure has had devastating effects on Terrebonne Parish as evidenced by past storm events—Hurricane Rita being the most recent. Levee failure essentially inundates all areas south of the Gulf Intracoastal Waterway. This hazard will persist with each passing storm until a levee system designed for true hurricane protection is constructed. All levees in the parish are maintained by the Terrebonne Levee & Conservation District. No United States Army Corps of Engineers (USACE) certified levees were noted in the parish.

Pump stations are also a major consideration in the parish. According to information provided by the Terrebonne Parish Department of Public Works (DPW), 157 individual pumps are dispersed throughout the parish. These pumps serve as critical components of the parish flood protection system as they facilitate the movement of storm water out of developed areas, over drainage levees, and into the surrounding bayous, canals, and marshes. A detailed inventory of pump stations in the parish follows. In addition, the broad range of complexity of the pump systems is graphically depicted in the following photos.

Levee and pump station D-25 in Montegut

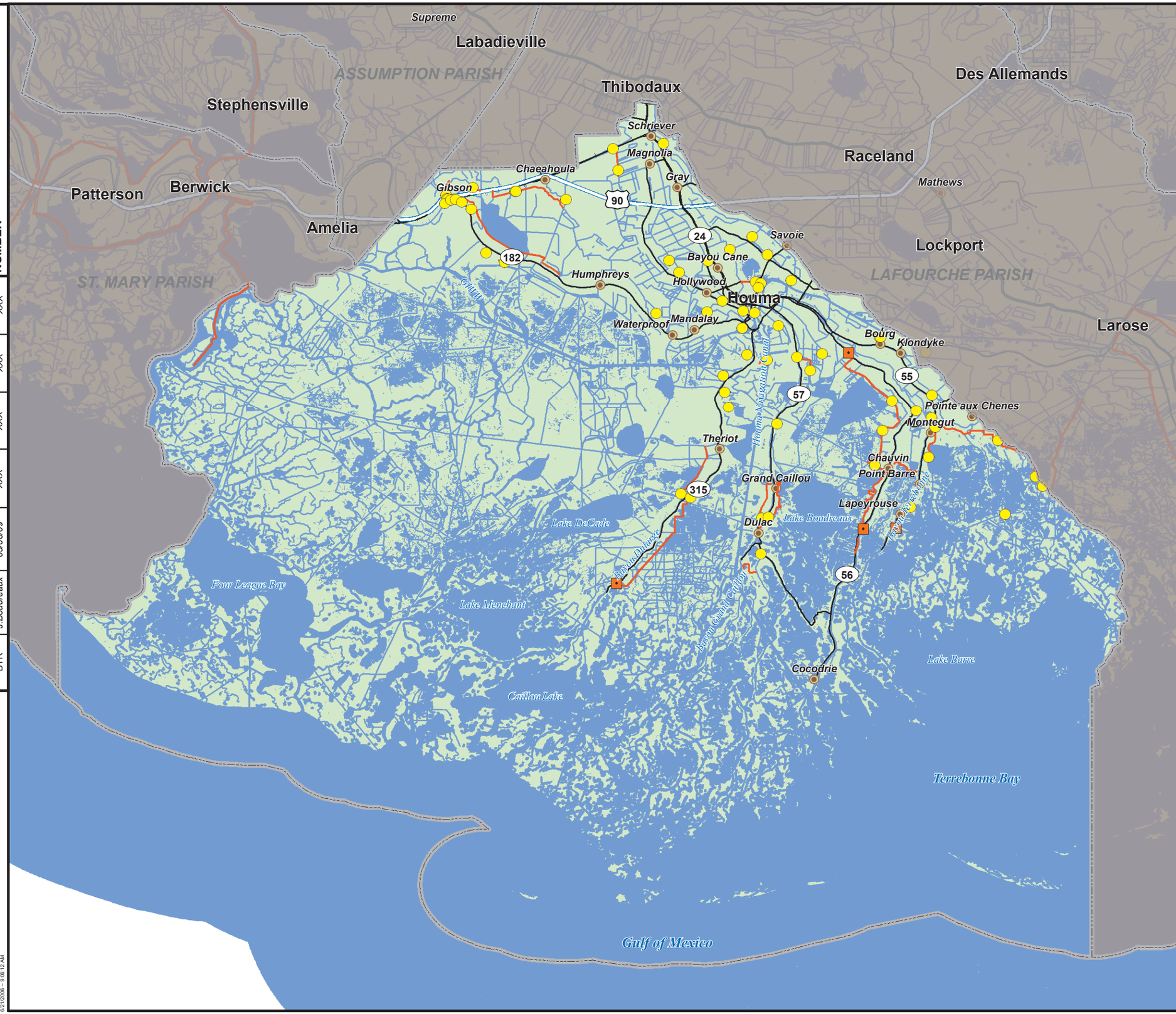
The forced drainage levees and the drainage pumps combine to form 61 individual drainage systems. These systems or areas are managed by the Terrebonne Parish Department of Public Works. The layout of levees, pump stations, and flood gates are illustrated in Exhibit 2-3.

			TOTAL FLOW				
PUMP #	LOCATION	ACRES	GPM	CFS	# OF ENGINES	PUMPS	PUMP SIZE
D-01	POINT-AUX-CHENE (4-3A)	34	10250	23	1 diesel engine	1	1-20"
D-02	LOWER MONTEGUT (4-8)	1120	124000	276	4 diesel engines	4	4-36"
D-03	UPPER MONTEGUT (4-1)	4526	93000	207	3 diesel	3	3-36"
D-04	LOWER LITTLE CAILLOU (5-1A)	1887	93000	207	3 diesel engines	3	3-36"
D-05	UPPER LITTLE CAILLOU (5-1B)	2567	124000	276	4 diesel engines	4	4-36"
D-06	BOUDREAUX CANAL (5-2)	26	26000	58	1 diesel and 1 electric	2	1-16" & 1- 24"
D-07	SMITHRIDGE (4-2A)	7278	204000	455	3 diesel and 1 electric	4	4-48"
D-08	UPPER GRAND CAILLOU (3-1B)	266	62000	138	1 diesel and 1 electric	2	2-36"
D-09	ASHLAND (1-2)	641	16450	37	2 diesel and 1 electric	3	2-36" & 1-20"
D-10	MAYFIELD (3-2)	1811	62000	138	2 diesel	2	2-36"
D-11	LOWER GRAND CAILLOU (3-1C)	425	62000	138	1 diesel and 1 electric	2	2-36"
D-12	WOODLAWN RANCH ROAD (1-5)	5500	510000	1136	9 diesel and 1 electiric	10	10-48"
D-13	INDUSTRIAL BLVD. (1-3)	476	123250	275	3 diesel and 1 electric	4	2-36",& 1-20" & 1-48"
D-14	SCHRIEVER (BY SCHOOL)	N/A	10250	23	1 electric motor	1	1-20"
D-15	DEADWOOD (UNDER TRACKS)	1	1500	3	1 electric motor	1	1-4"
D-16	GIBSON (6-1A)	1953	93000	207	3 diesel engines	3	3-36"
D-17	DONNER (6-2A)	940	31000	69	1 electric over diesel engine	1	1-36"
D-18	UPPER BAYOU DULARGE (8-2D)	2120	93000	207	3 diesel engines	3	3-36"
D-19	LOWER BAYOU DULARGE (8-1)	1880	93000	207	3 diesel engines	3	3-36"
D-20	GRAND BOIS	43	10250	23	1 electric motor	1	1-20"
D-21	EVEST ST. (3-1B)	204	62000	138	2 diesel engines	2	2-36"
D-22	M & L (1-8)	502	153000	341	3 diesel engines	3	3-48"
D-23	TEXAS GULF ROAD (4-6)	894	16450	37	2 diesel and 1 electric	3	2-36" & 1-20"
D-24	BAROID (1-7)	189	48000	107	2 electric over diesel	2	2-30"
D-25	MONTEGUT (4-8)	*	31000	69	1 diesel engine	1	1-36"
D-26	SUNRISE/ Tina Street (8-2A)	38	16000	36	1 diesel and 1 electric	2	2-16"
D-27	BONANZA (1-1A)	2856	184000	410	3 diesel and 1 electric	4	3-48" & 1-36"
D-28	SCHRIEVER (HWY. 20) (2-1A)	2113	184000	410	2 diesel, 1 diesel over electric, & 1 electric	4	3-48" & 1-36"
D-29	SUMMERFIELD (2-1B)	751	153000	341	3 diesel	3	3-48"
D-30	DEADWOOD (IN SUBD.) (6-1C)	38	41250	92	1 diesel engine & 1 electric	2	1-36" & 1- 20"
D-31	CHACAHOULA	234	26000	58	2 diesel engine	2	1-16"& 1 -24"
D-32	DONNER EXT. (6-2A)	*	31000	69	1 diesel over electric	1	1-36"
D-33	ST. LOUIS CANAL (1-1B)	*	5600	12	1 electric motors	1	1-14"
D-34	GIBSON WATER TOWER (6-1B)	170	8000	18	1 diesel engine	1	1-16"
D-35	GIBSON RECREATION	*	10250	23	1 diesel engine	1	1-20"
D-36	CANE BREAK	25	10250	23	1 electric motor	1	1-20"
D-37	CROZIER DRIVE (8-2A)	12	6400	14	1 diesel & 1 electric over diesel	2	2-12"
D-38	CONCORD ROAD	286	62000	138	2 diesel engines	2	2-36"
D-39	BARATARIA STREET	237	86000	192	2 diesel and 1 electric	3	2-36" & 1-30"
D-40	CENAC STREET	*	16000	36	1 electric over diesel &1electric	2	2-16"
D-41	WILLIAMS AVENUE	*	62000	138	2 diesel	2	2-36"
D-42	BAYOU BLACK MARINA	201	10250	23	1 electric motor	1	1-20"
D-43	CROZIER ROAD (8-2A)	87	18000	40	1 electric motor	1	1-24"
D-44	CAVALIER TRAILER PARK	61	8000	18	1 Diesel	1	1-16"
D-45	TIGER BAYOU	9	1500	3	1 electric motor	1	1-8"
D-46	BAYOU DULARGE (VOISIN)	1060	18000	40	1 diesel	1	1-24"
D-47	ARAGON ROAD (4-2B)	*	82000	183	2 diesel engines	2	1-48" & 1-36"
D-48	DEADWOOD "C"	14	8000	18	1 electric over diesel	1	1-16"
D-49	DEADWOOD "D"	2	1500	3	1 electric motor	1	1-8"
D-50	GREENWOOD	145	21200	47	1 diesel and 1 electric	2	1-24 & 1-12"
D-51	LIRETTE STREET (6-3)	38	3000	7	2 electric motor	2	2- 8"
D-52	KRAEMER/MAPLEWOOD (1-1B)	*	20500	46	1 electric and 1 diesel engine	2	2-20"
D-53	ELLENDALE	161	62000	138	1 electric and 1 diesel engine	2	2-36"
D-54	HIGHRIDGE	82	10250	23	1 electric motor	1	1-20"
D-55	GERALDINE ROAD	137	3200	7	1 electric motor	1	1-12"
D-56	MADISON	266	102000	227	2 diesel engines	2	2-48"
D-57	1-1B	17515	408000	909	8 diesel engines	8	8-48"
D-58	1-1B Coteau	*	510000	1136	10 diesel engines	10	10-48"
D-59	LECOMPTE LANE	10	3200	7	1 diesel engine	1	1-12"
	DULARGE WATER CONTROL		31000	69	1 diesel engine	1	1-36"
D-60	ASHLAND NORTH	296	18000	40	2 Diesel engine	1	1-24"
D-61	Hwy. 665 Point-aux-chene (4-3B)	91	36000	80	2 Diesel engines	2	2-24"
D-62	ISLE DE JEAN CHARLES (4-3C)	54	36000	80	2 Diesel engines	2	2-24"
D-63	ISLE OF CUBA ROAD (2-1A)	*	51000	114	1 Diesel engine	1	1- 48"
D-64	LAKE CRESCENT	51	6400	14	2 Hydraulic diesel	2	33
D-65	COMPANY CANAL ROAD		10250	23	1 Diesel	1	43
D-66	GIBSON POST OFFICE		3200	7	1 Electric	1	1 -12"
D-67	BUDDY'S TEXACO -PORTABLE		41000	91	1 Hydraulic diesel	1	1 -42"
D-68	HEBERT ST. - PORTABLE	*	8000	18	1 Hydraulic diesel	1	1-16"
D-69	POINTE-AUX-CHENES (4-1)	*	93000	207	3 Diesel engines	3	3-36"
		* D-25 & D-2 pump the same system					
		* D-32 & D-17 pump the same system					
		* D-33, D-40, D-41, D-52, D-57, D-58 & D-68 pump the same system					
		* D-35 & D-34 pump the same system					
		* D-63 & D-28 pump the same system					
		* D-69 & D-3 pump the same system					

Source: Terrebonne Parish Department of Public Works

Pump Station D-58 in Coteau

Pump Station D-45 in Tiger Bayou



6 3 0 6 Miles

1:380,160

Legend

- Flood Gates
- Pumping Stations
- Levees
- Communities
- US Highway
- State/Parish Highway

Shaw®

TERREBONNE PARISH
FEMA DFIRM APPEAL

EXHIBIT 2-3

LEVEES, PUMP STATIONS, AND FLOOD GATES

TERREBONNE PARISH, LOUISIANA

DRAWING NUMBER	APPROVED BY		CHECKED BY		DRAWN BY		OFFICE
terr_184_0003_levees_11x17_TB	XXX	XXX	XXX	XXX	J Boudreaux	05/06/09	BTR

Map Document: (G:\GIS Data\Arc\GIS\Templates\SHAW_Tabloid_Landscape_RightLegend.mxd)
6/21/2006 -- 9:06:12 AM

3.0 EVALUATION OF PRELIMINARY DFIRMS

3.1 Comparison of Effective FIRMs and 2009 Preliminary DFIRMs

A comparison of the 1981/1985 FIRMs with the 2009 preliminary DFIRMs is best illustrated by graphically overlaying the two maps and identifying the differences. A color coded comparison of the mapping efforts is provided in Exhibit 3-1. Shades of green represent no change or a decrease in the proposed BFEs while shades of orange and red represent an increase in the proposed BFEs. As the comparison map illustrates, increased BFEs are proposed in the preliminary DFIRMs for a large portion of Terrebonne Parish.

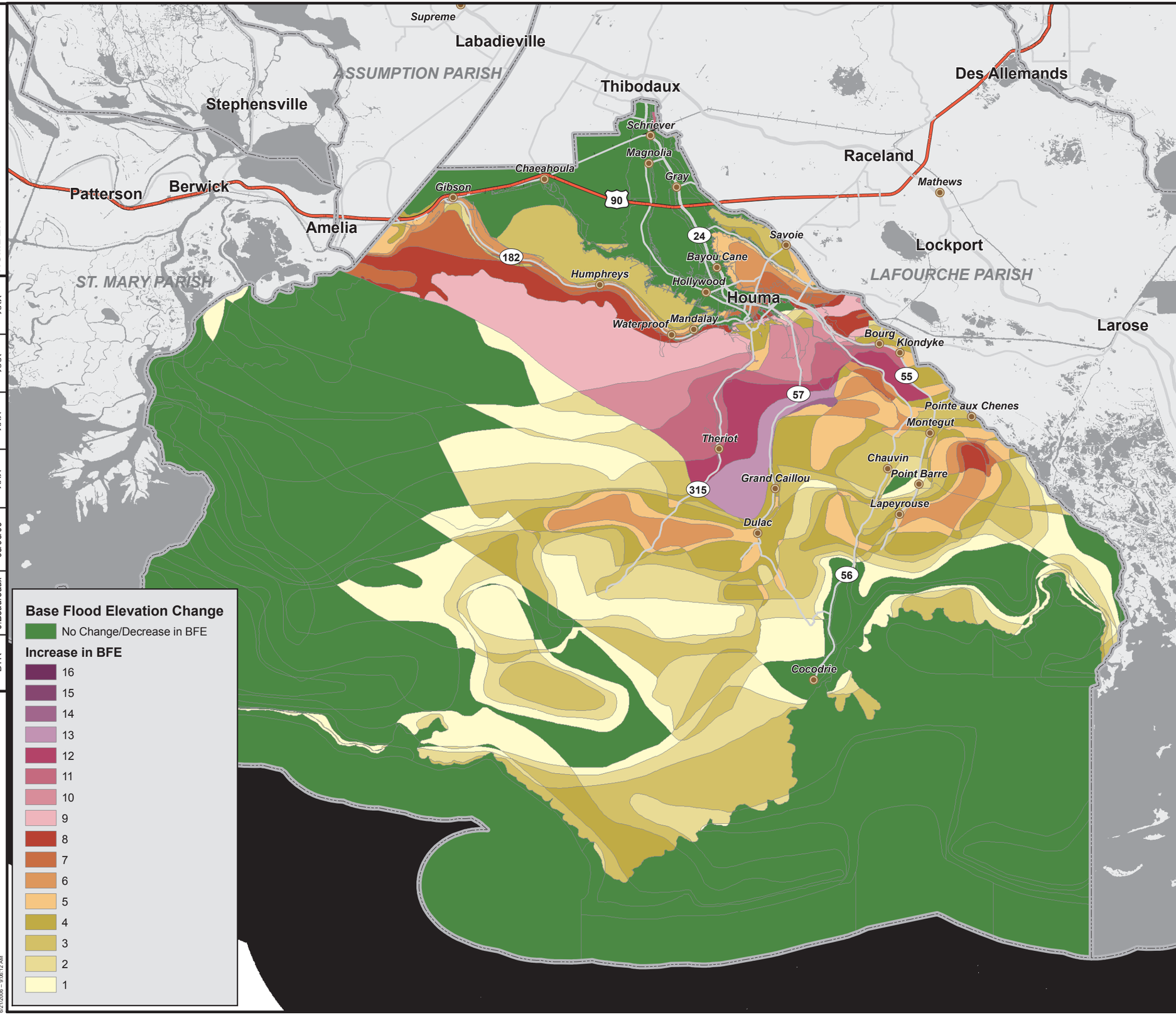
3.2 FEMA Data Requested and Reviewed

To facilitate a proper evaluation of FEMA's previous efforts, numerous input files and related engineering reports were collected and reviewed. A summary of those data sources is provided below:

- Intermediate Data Submission I
- Intermediate Data Submission 2
- Technical Support Data Notebook (TSDN)—Terrebonne Parish
- Preliminary Terrebonne Parish FIS
- DFIRM Map Panels
- Selected ADCIRC Computer Files
- WHAFIS Computer Files
- Various FEMA and USACE Publications and Guidelines Related to Levee Construction/Certification

3.3 Discussion of DFIRM Deficiencies

After a careful review of the information made available by FEMA to Terrebonne Parish, it has been found that certain areas of the preliminary DFIRMs contain BFEs which are scientifically and technically deficient. Each deficiency is discussed in the sections that follow.



6 3 0 6 Miles

1:380,160

Legend

- Communities
- US Highway
- State/Parish Highway

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TERREBONNE PARISH
FEMA DFIRM APPEAL

EXHIBIT 3-1

BASE FLOOD ELEVATION COMPARISON (EFFECTIVE FIRMS TO PRELIMINARY FIRMS)

TERREBONNE PARISH, LOUISIANA

DRAWING NUMBER	terr_136061_0007_prelim_11x17_TB
APPROVED BY	XXX
	XXX
CHECKED BY	XXX
	XXX
DRAWN BY	J Boudreaux 05/06/09
OFFICE	BTR

Map Document: (G:\GIS Data\ArcGIS\Templates\SHAW__Tablot\Landscape_RightLegend.mxd)
6/21/2008 -- 9:06:12 AM

3.3.1 Topographic Data

The topographic data used in the creation of Terrebonne Parish's preliminary DFIRMs are of unknown quality and thus fail to meet FEMA guidelines. The unknown quality of the data is a result of the following:

1. The DEM and "bare earth" LIDAR used for topography in the preparation of the DFIRMs are not in the official datum recognized and required by FEMA.
2. The accuracy of the LIDAR DEM and the "bare earth" LIDAR were never actually determined as required by FEMA because the official vertical datum was inaccessible in Louisiana when the data was acquired, i.e., 2003.
3. FEMA allowed the use of unproven individual "bare earth" LIDAR elevations as input into WHAFIS modeling that were not validated in accordance with FEMA QA/QC guidelines.
4. The assigned FEMA mapping partner failed to conduct QA/QC procedures on the DEM according to FEMA requirements and professional Standards.
5. The assigned mapping partner substituted inferior USGS National Elevation Data (NED) when LIDAR topographic data where unavailable.

A detailed analysis of the topographic data deficiency is provided in a technical report of findings provided by Dr. Dokka and included as Appendix D.

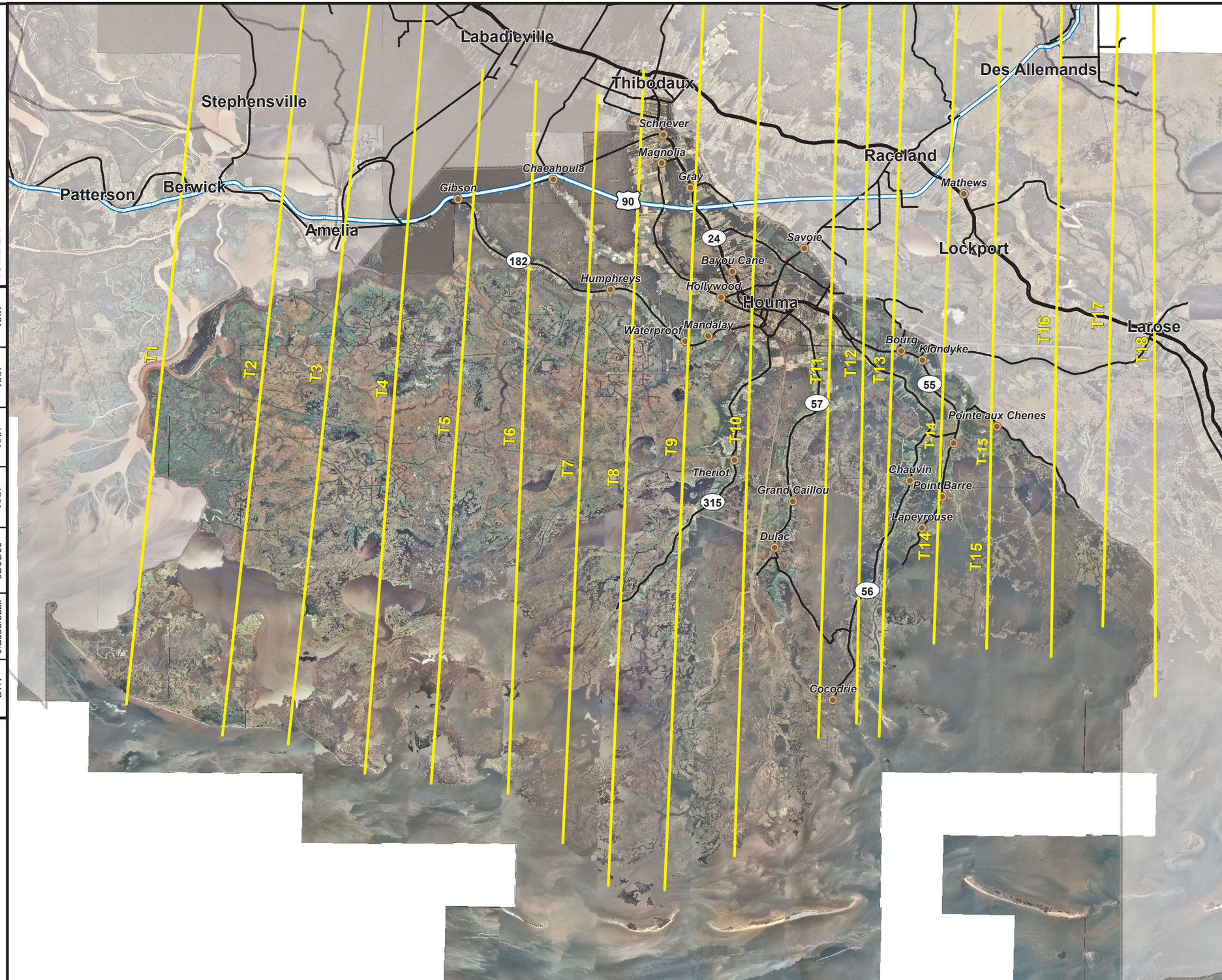
3.3.2 Topographic Features (Weirs)

Critical topographic features of the SL15 grid used in FEMA's ADCIRC modeling are inaccurate and not representative of reality. The grid omits numerous coastal features and elevated roadways that act as weirs during storms. The omission of these weirs likely resulted in local overestimation of flooding risk. A detailed analysis of the topographic feature (weir) deficiency is also provided in Appendix D.

3.3.3 WHAFIS Methodology

It has been found that certain areas of the preliminary DFIRMs contain BFEs which are technically incorrect because; (1) errors were made in the application of the WHAFIS methodology, (2) the WHAFIS methodology was based upon insufficient and poor quality data, and (3) the results of FEMA's WHAFIS modeling efforts were not properly transposed or mapped onto the preliminary DFIRMs. A detailed description of each technical deficiency is discussed below.

The WHAFIS transects used to develop the BFEs for the parish are illustrated on Exhibit 3-2. In all 18 transects were used to determine the BFEs and zones for the parish. Each transect runs in a north-south direction from the shoreline of either the Gulf of Mexico or Terrebonne Bay. Most of the transects are not perpendicular to either shoreline. A detailed summary of each transect is provided in Exhibit 3-3.



6 3 0 6 Miles

1:380,160

Legend

- Terrebonne Transects
- Communities
- US Highway
- State/Parish Highway

Shaw®

TERREBONNE PARISH
FEMA DFIRM APPEAL

EXHIBIT 3-2

2007 AERIAL PHOTOGRAPH WITH TRANSECTS

TERREBONNE PARISH, LOUISIANA

OFFICE	DRAWN BY		CHECKED BY		APPROVED BY		DRAWING NUMBER
BTR	J.Boudreaux	05/06/09	XXX	XXX	XXX	XXX	terr_136061_0013_transects_11x17_TB

Map Document: (G:\GIS Data\ArcGIS\Templates\SHAW_Tabloid_Landscape_RightLegend.mxd mxd)
6/21/2006 -- 9:06:12 AM

Exhibit 3-3: Terrebonne Parish WHAFIS Transect Summary

Community Name	Transect	Description	Latitude & at Start of Transect	Longitude WHAFIS (NAD83)	Starting Stillwater Elevations (feet NAVD 88) Range of Stillwater Elevations (feet NAVD 88)				Zone Designation and BFE (feet NAVD88)
					10% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance	
Terrebonne	T1	Located at west end of Parish, traversing south to north from Gulf Coast to northern Parish line.	29.2503	91.2830	6.1 Range Not Available	8.7 Range Not Available	10.6 8.6-10.6	13.3 11.2-15.3	AE 10-13 VE 11-16
Terrebonne	T2	Located to the east of transect 1, traversing south to north.	29.2223	91.1986	6.7	9.4	11.3 6.7-11.3	14.4 9.6-14.5	AE 7-13 VE 9-17
Terrebonne	T3	Located to the east of transect 2, traversing south to north.	29.2180	91.1405	6.7	9.3	11.3 6.6-11.4	14.7 9.4-14.9	AE 7-13 VE 10-17
Terrebonne	T4	Located to the east of transect 3, traversing south to north.	29.1885	91.0736	6.6	9.4	11.3 0-11.4	14.8 2.8-15.1	AE 0-13 VE 9-17
Terrebonne	T5	Located to the east of transect 4, traversing south to north.	29.1845	91.0151	6.5	9.6	11.3 2.1-11.4	15.0 2.6-15.5	AE 2-13 VE 9-17
Terrebonne	T6	Located to the east of transect 5, traversing south to north.	29.1767	90.9479	6.5	9.9	11.6 2.0-11.6	14.9 2.3-16.2	AE 2-13 VE 10-18
Terrebonne	T7	Located to the east of transect 6, traversing south to north.	29.1456	90.8991	6.4	9.7	11.7 2.9-11.8	14.9 2.3_16.3	AE 3-13 VE 13-18
Terrebonne	T8	Located to the east of transect 7, traversing south to north.	29.1522	90.8573	6.4	10.1	12.2 2.7-12.2	15.2 0-16.2	AE 3-14 VE 10-19
Terrebonne	T9	Located to the east of transect 8, traversing south to north.	29.1504	90.8077	6.8	10.3	12.4 0-12.6	15.3 0-18.0	AE 0-14 VE 11-19
Terrebonne	T10	Located to the east of transect 9, traversing south to north.	29.1850	90.7471	7.1	10.6	12.5 0-12.5	15.4 0-19.7	AE 0-14 VE 14-19
Terrebonne	T11	Located to the east of transect 10, traversing south to north.	29.2146	90.6758	7.2	10.4	12.3 0-12.4	15.2 0-16.8	AE 0-14 VE 14-19
Terrebonne	T12	Located to the east of transect 11, traversing south to north.	29.2343	90.6422	7.2	10.2	12.2 2.1-12.4	15.2 0-17.0	AE 2-14 VE 6-19
Terrebonne	T13	Located to the east of transect 12, traversing south to north.	29.2636	90.6207	6.8	9.8	12.2 0-12.4	15.2 0-21.5	AE 0-14 VE 6-19
Terrebonne	T14	Located to the east of transect 13, traversing south to north.	29.3251	90.5733	7.1	9.9	12.1 0-13.3	15.3 0-18.9	AE 0-14 VE 6-20
Terrebonne	T15	Located to the east of transect 14, traversing south to north.	29.3285	90.5272	6.6	9.6	11.8 0-12.4	15.0 0-16.9	AE 0-13 VE 9-18
Terrebonne	T16	Located to the east of transect 15, traversing south to north.	29.2969	90.4710	6.2	9	10.9 2.1-12.0	14.0 2.5-16.1	AE 2-13 VE 7-17
Terrebonne	T17	Located to the east of transect 16, traversing south to north.	29.3383	90.4253	6.2	9	11.1 3.7-11.6	14.2 2.2-16.5	AE 3-14 VE 7-17
Terrebonne	T18	Located to the east of transect 17, traversing south to north.	29.2880	90.3796	5.6	8.3	10.2 5.2-11.3	13.2 7.7-17.4	AE 5-12 VE 8-15

The transects of primary interest to the parish are those that pass through DFIRM panels 255, 260, 275 and 300. These panels contain WHAFIS transects 10 to 15, which will be the focus of this appeal report. This area of the parish is a "sheltered waters" as defined in Appendix D of *Atlantic Ocean and Gulf of Mexico Coastal Guidelines Update*, February, 2007. The area consists of inland waters, enclosed basins, and fetch limited waters (Appendix D, pg D.2.1-15). More specifically, "sheltered waters" are water bodies that experience diminished forces from wind and/or wave action relative to the open coast due to the presence of physical barriers, both natural and human, including tidal flats and wetlands (Appendix D, pg D.2.9-25). This condition requires special treatment of topography, wind, water level, and waves (Appendix D, pg D.2.1-16 and D.2.1-17). The primary technical deficiency contained in the preliminary DFIRMs is that the area was not treated as a "sheltered waters" environment as is required by FEMA guidelines.

3.3.3.1 Errors in the Application of the WHAFIS Methodology

3.3.3.1.1 Transect Locations

Given the complexity of the land cover and development occurring in certain areas of DFIRM panels of interest, the preliminary BFEs are not based upon a sufficient

number and location of WHAFIS transects to correctly define the BFEs. As shown on Exhibit 3-2, the parish landscape is dominated by a series of north/south trending ridges and barriers which control the location and magnitude of hurricane surge and waves. Exhibit 3-4 shows the location of WHAFIS transects and the ADCIRC weirs within the parish. The DFIRM transects parallel these linear features but are offset to the east and west, crossing areas that are primarily marsh, and are not representative of the vegetation and topography of the ridges. Therefore extrapolating BFEs from these DFIRM transects to determine BFEs on the ridges is incorrect. The DFIRM transects are not perpendicular to the local shoreline, as prescribed in FEMA guidelines. The spacing of the transects used in the producing the DFIRMs is too large. There are 18 transects spread over 60 miles of coast, giving an average spacing of about 18,000 feet, when the prescribed separation in this case should be a few hundred feet apart (Appendix D, pg D.2.7-4 and D.2.7-5).

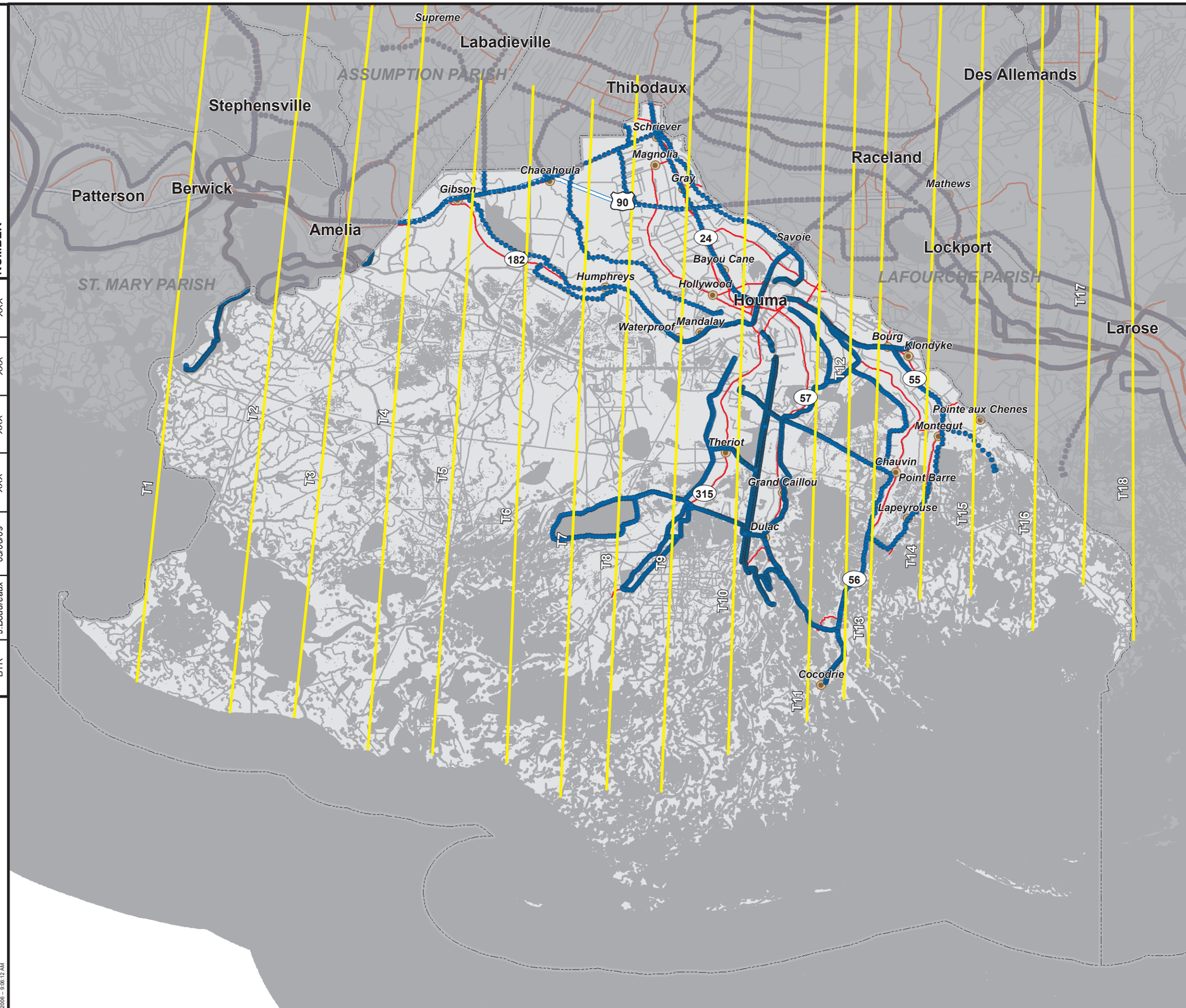
Details of the technical deficiencies contained in the DFIRMs regarding the locations of the Transects 10, 11, 12, 13, 14, and 15, are shown in Exhibit 3-5. The Figure shows the DFIRM transects on a LIDAR topographic map. Note the transects are oriented parallel to the major ridges. The transects miss ridges that lie between T9 and T10, T10 and T11, T13 and T14, and T14 and T15.

3.3.3.1.2 Use of "OF" Zones

The use of "OF" zones in the DFIRM transects is inconsistent with the inland waters contained in many the segments of these transects. These inland water bodies are shallow having a depth of less than 10 feet deep or are land areas. These segments should be treated as either "IF" zones or "VH" zones. Neglect of this factor results in controlling wave heights that are too high in some segments of the DFIRM wave transects.

3.3.3.1.3 Neglect of Muddy Bottom Sediment Effects

The calculation of the wave height component of the BFEs did not account for the effects of the presence of muddy bottom sediments in the parish. The effect of these types of sediments on the limiting the controlling wave height has been addressed by FEMA and a methodology was developed for FIS study purposes in Louisiana by Dr. Suhayda (*Attenuation of Storm Waves Over Muddy Bottom Sediments*, August 1984). Neglect of this factor results in an over estimate of the controlling wave height in water bodies along each transect. Exhibit 3-6 illustrates this issue by showing the initial wave heights along transects 10 through15. The initial wave height in each case is 0.78 of the water depth after passing over bays containing muddy bottom sediments. The correct value of this ratio should be about 0.5 to 0.6, resulting in wave heights that are over estimated by approximately 25 to 35%.



6 3 0 6 Miles

1:380,160

Legend

- ADCIRC Weirs
- WHAFIS Transects
- Communities
- US Highway
- State/Parish Highway

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TERREBONNE PARISH
FEMA DFIRM APPEAL

EXHIBIT 3-4

WHAFIS TRANSECTS AND ADCIRC WEIRS

TERREBONNE PARISH, LOUISIANA

OFFICE	DRAWN BY		CHECKED BY		APPROVED BY		DRAWING NUMBER
BTR	J Boudreaux	05/06/09	XXX	XXX	XXX	XXX	terr_136061_0011_Flevees_11x17_TB

Map Document: (G:\GIS Data\ArcGIS\Templates\SHAW_TabloidLandscape_RightLegend.mxd)
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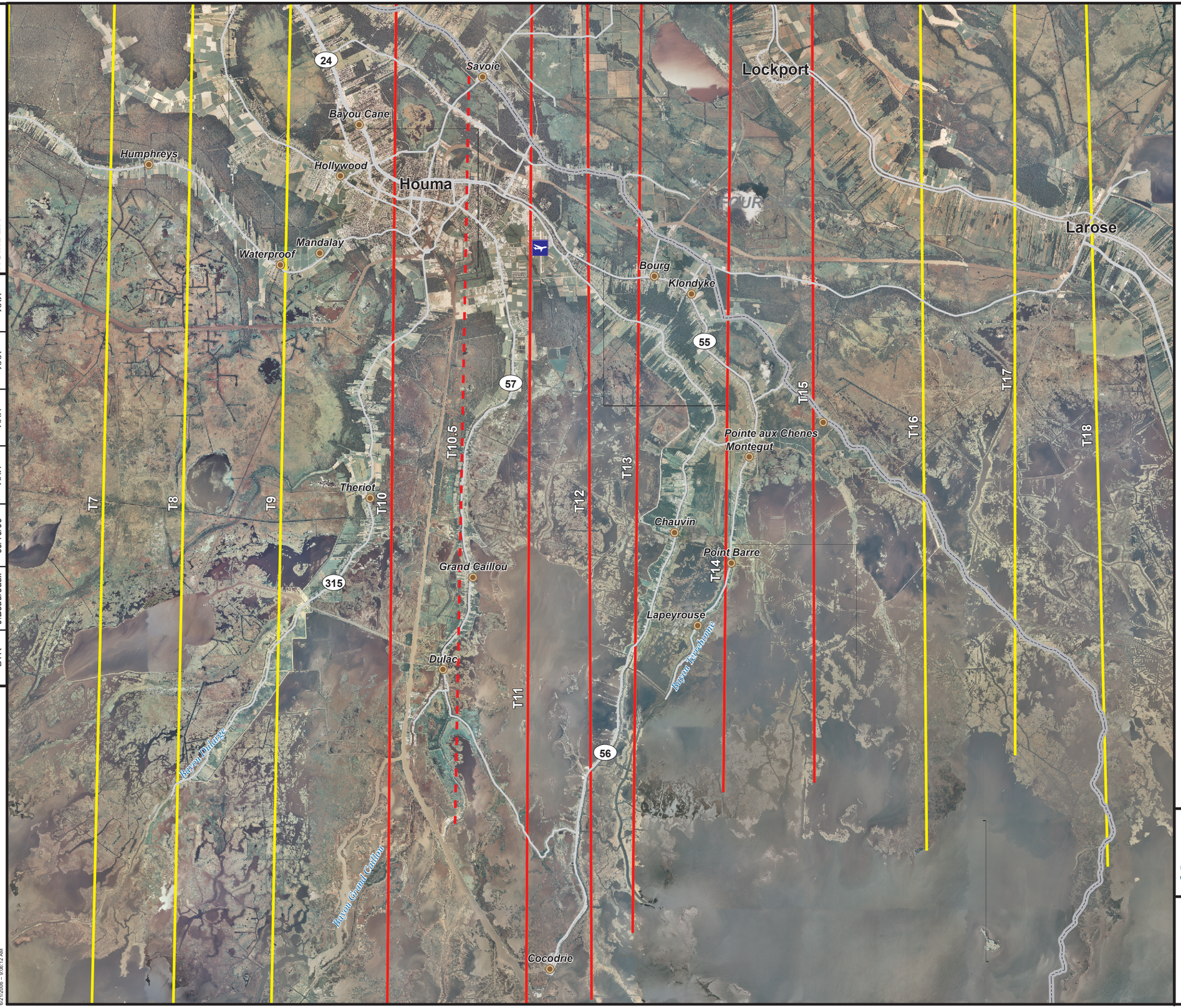


2 1 0 2 4 Miles

1:182,955
1 inch = 15,246 feet

Legend

- Proposed Additional Transect
- US Highway
- State/Parish Highway
- Transects 10 - 15
- WHAFIS Transects

TERREBONNE PARISH
FEMA DFIRM APPEAL

EXHIBIT 3-5

WHAFIS TRANSECTS 10-15

TERREBONNE PARISH, LOUISIANA

OFFICE	DRAWN BY		CHECKED BY		APPROVED BY		DRAWING NUMBER
BTR	J.Boudreaux	09/19/09	XXX	XXX	XXX	XXX	terr_136061_0022_whafis_11x17_TB

Map Document: (G:\GIS Data\ArcGIS\Templates\SHAW_Tabloid\Landscape_RightLegend.mxd.mxt)
6/21/2006 -- 9:06:12 AM

Exhibit 3-6: Terrebonne WHAFIS Transect Values

Transect No.	SWEL (ft)	Hc (ft)	Tp (sec)	Hc/SWEL	Hc/SWEL*
T10	12.51	9.76	15.1	0.78	0.5 - 0.6
T11	12.30	9.59	12.5	0.78	0.5 - 0.6
T12	12.20	9.52	12.2	0.78	0.5 - 0.6
T13	12.19	9.51	11.4	0.78	0.5 - 0.6
T14	12.10	9.44	8.10	0.78	0.5 - 0.6
T15	11.77	9.18	12.9	0.78	0.5 - 0.6

*Source: Suhayda (1984)

3.3.3.2 Insufficient and Poor Quality Data

3.3.3.2.1 Topography of Ridges and Barriers

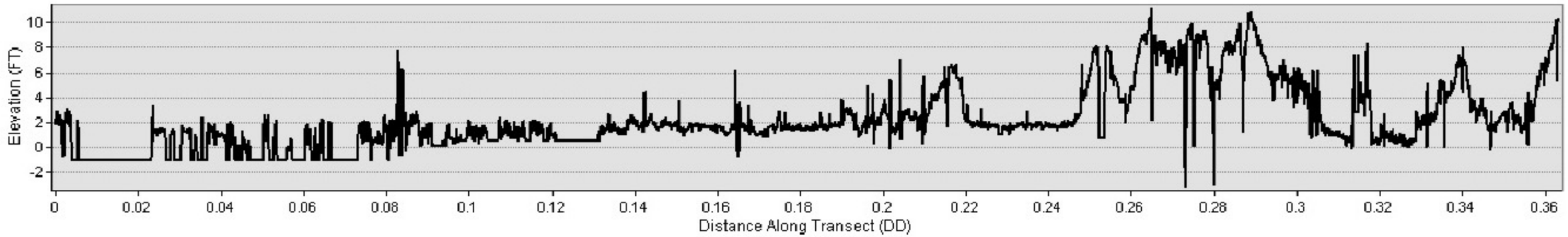
Mapping of "sheltered waters" require special treatment of the topography of the area. The location and elevation of ridges and barriers in the mapping area contained numerous errors as cited by Dr. Dokka (Appendix D). Many ridge features were either mislocated or were absent in the mapping of the BFEs.

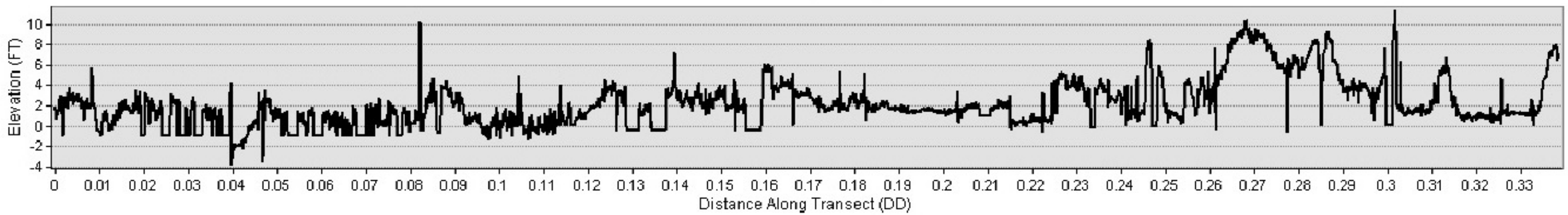
Exhibit 3-7 shows the DEM land elevation along transects 10 and 11. Note that these two profiles show major differences starting at a distance of about 0.12 decimal degrees (DD). The high topography at distance 0.26 DD in transect 10 is a different ridge system than the ridges shown in Transect 11. The BFE elevations computed for each transect cannot be cannot be correctly extrapolated to determine the BFEs for the area between these two transects. Exhibit 3-7 also shows an elevation profile along a transect midway between transects 10 and 11, identified as transect 10.5 and shown in red in Exhibit 3-5. Transect 10.5 shows a different profile than either transect 10 or 11 because it intersects a third ridge. To map the BFE for this ridge requires a WHAFIS calculation specifically for this ridge.

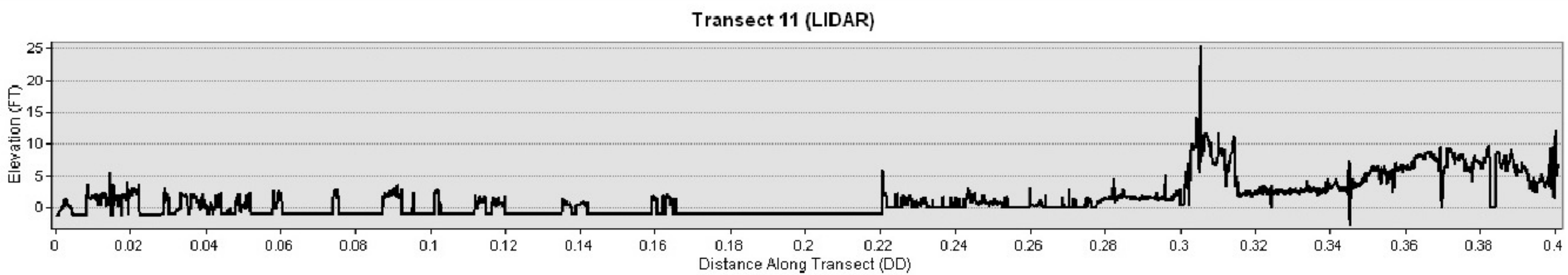
3.3.3.2.2 Bottom Sediment Data

The ability to apply the FEMA muddy bottom methodology is based upon the availability of bottom sediment data, showing sediment type and shear strength. Data concerning the bottom sediments in the parish were not collected due to time and budgetary constraints and hence the data base needed to apply the FEMA muddy bottom methodology was not available.

EXHIBIT 3-7


Transect 10 (LIDAR)
Elevation (FT)
10
8
6
4
2
0
-2
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18
0.2
0.22
0.24
0.26
0.28
0.3
0.32
0.34
0.36
Distance Along Transect (DD)


Transect 10.5 (LIDAR)
Elevation (FT)
10
8
6
4
2
0
-2
-4
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.1
0.11
0.12
0.13
0.14
0.15
0.16
0.17
0.18
0.19
0.2
0.21
0.22
0.23
0.24
0.25
0.26
0.27
0.28
0.29
0.3
0.31
0.32
0.33
Distance Along Transect (DD)
Profile Graph Subtitle


Transect 11 (LIDAR)
Elevation (FT)
25
20
15
10
5
0
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18
0.2
0.22
0.24
0.26
0.28
0.3
0.32
0.34
0.36
0.38
0.4
Distance Along Transect (DD)

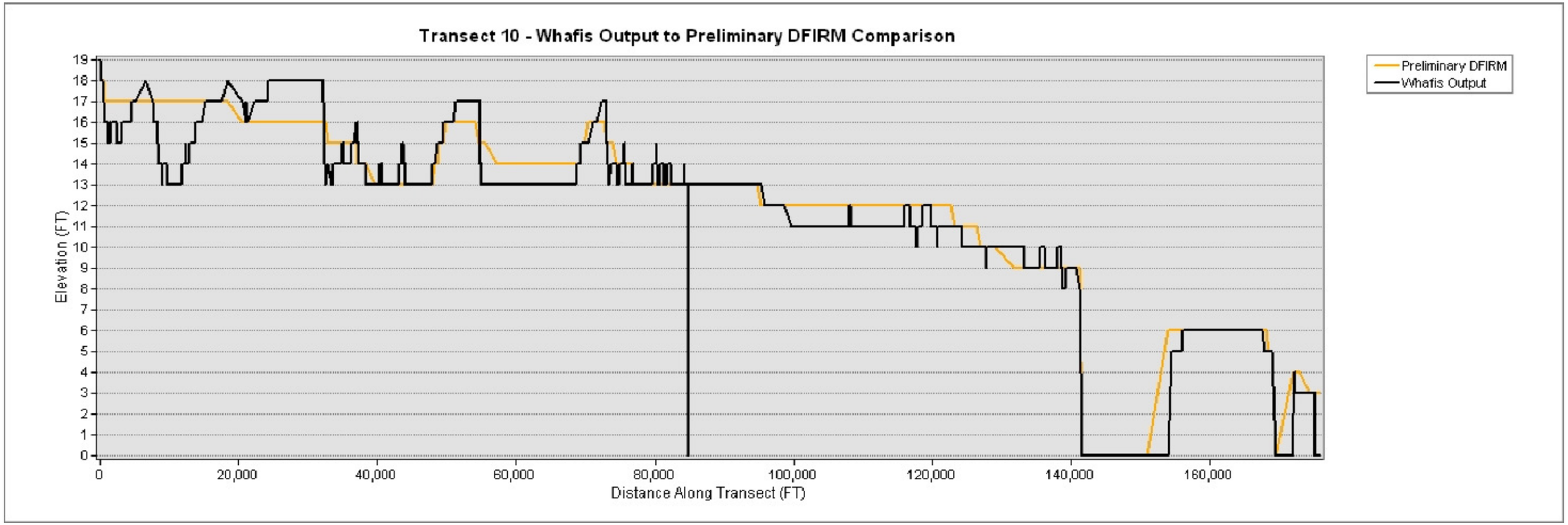
3.3.3.3 WHAFIS Results Not Properly Mapped on the Preliminary DFIRMs

The BFEs for areas contained in panels 255, 260, 275 and 300 are inconsistent with the information contained in the relevant WHAFIS transect information. The Exhibits 3-8 through 3-10 show the DFIRM BFEs and flood zones and the WHAFIS BFE output along transects 10 through 15.

A comparison of the DFIRM BFEs and the WHAFIS BFEs along transects 10, 11, and 12 (Exhibits 3-8 and 3-9), shows that the DFIRM BFEs are lower than the WHAFIS BFEs for some location, but higher in other locations. However, at the end of transect 11 (Exhibit 3-8), there is an interval where the WHAFIS BFEs drop to zero, whereas the DFIRM BFE is between 5 and 8 feet. Exhibit 3-9 shows that the DFIRM BFEs are higher than the WHAFIS BFEs by 2 feet at a distance of about 50,000 feet along transect 13. Likewise Exhibit 3-10 shows that the DFIRM BFEs are higher than the WHAFIS BFEs by 1 foot at a distance of about 52,000 feet along transect 14. Exhibit 3-10 also shows there are major discrepancies along transect 15, where the DFIRM BFEs are higher than the WHAFIS BFEs by as much as 4 feet at a distance of about 30,000 feet.

The inaccuracy of the DFIRM BFEs and zones is also illustrated in Exhibits 3-11 and 3-12. The Figures show several areas where the BFE elevations in the DFIRMs are in disagreement with the WHAFIS elevations. Along transect 10 there are locations that have a WHAFIS BFE elevation of 11 feet but are in an AE12 zone. Also, along transect 11 there are locations that have a WHAFIS BFE elevations that are 12 and 13 feet but are in a VE14 zone. Transect 12 has many locations that have a WHAFIS BFE elevation that is 12 feet but is in an AE13 zone. Along transect 13 there are locations that have a WHAFIS BFE elevation that is 8 feet but the area is in an AE9 and AE10 zones. Along transect 14 there are locations that have a WHAFIS BFE elevation that is 14 feet but is mapped as being in VE15, VE16, VE17 and VE18 zones. Finally, transect 15 has many locations that have a WHAFIS BFE elevations of 14 to 16 feet but shown in the DFIRMs as being in a VE 19 zone.

EXHIBIT 3-8


Transect 10 - Whafis Output to Preliminary DFIRM Comparison
Preliminary DFIRM
Whafis Output
Elevation (FT)
Distance Along Transect (FT)
0
20,000
40,000
60,000
80,000
100,000
120,000
140,000
160,000

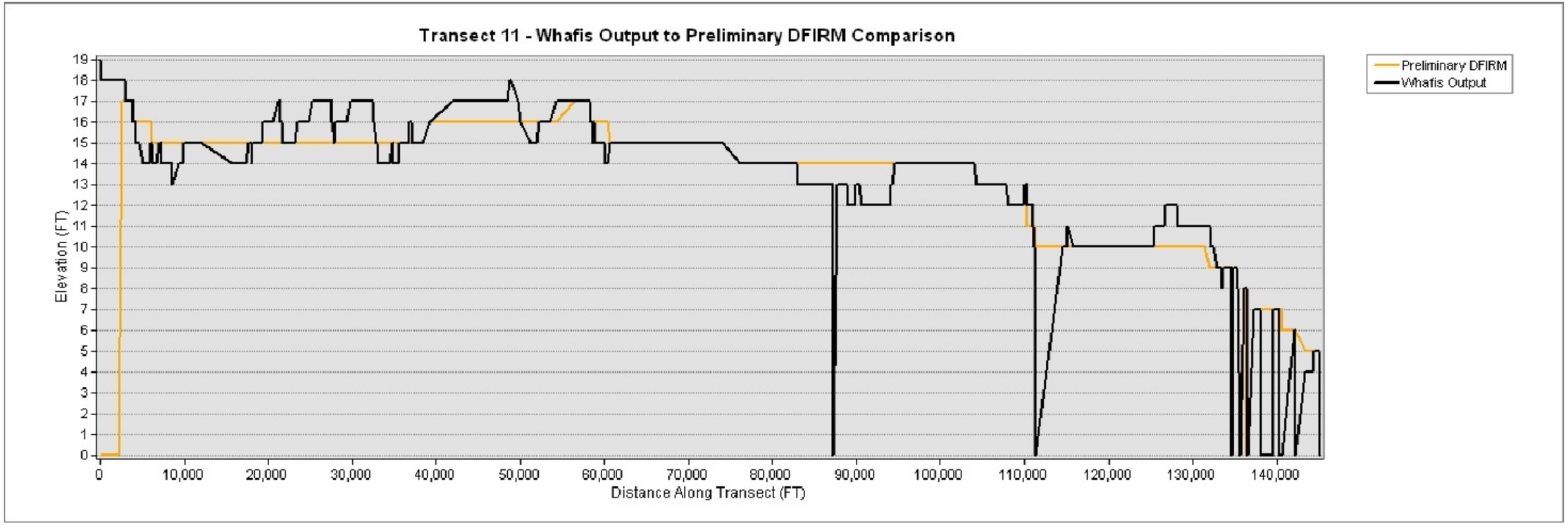
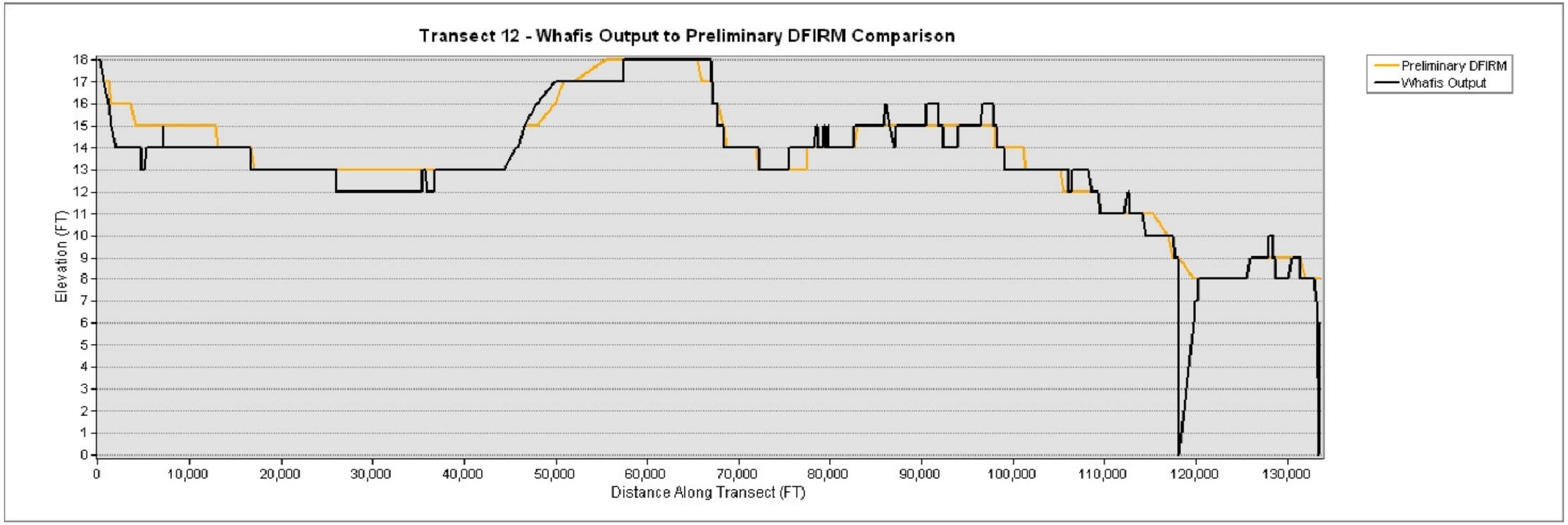

Transect 11 - Whafis Output to Preliminary DFIRM Comparison
Preliminary DFIRM
Whafis Output
Elevation (FT)
Distance Along Transect (FT)
0
10,000
20,000
30,000
40,000
50,000
60,000
70,000
80,000
90,000
100,000
110,000
120,000
130,000
140,000

EXHIBIT 3-9


Transect 12 - Whafis Output to Preliminary DFIRM Comparison
Preliminary DFIRM
Whafis Output
Elevation (FT)
Distance Along Transect (FT)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
0
10,000
20,000
30,000
40,000
50,000
60,000
70,000
80,000
90,000
100,000
110,000
120,000
130,000

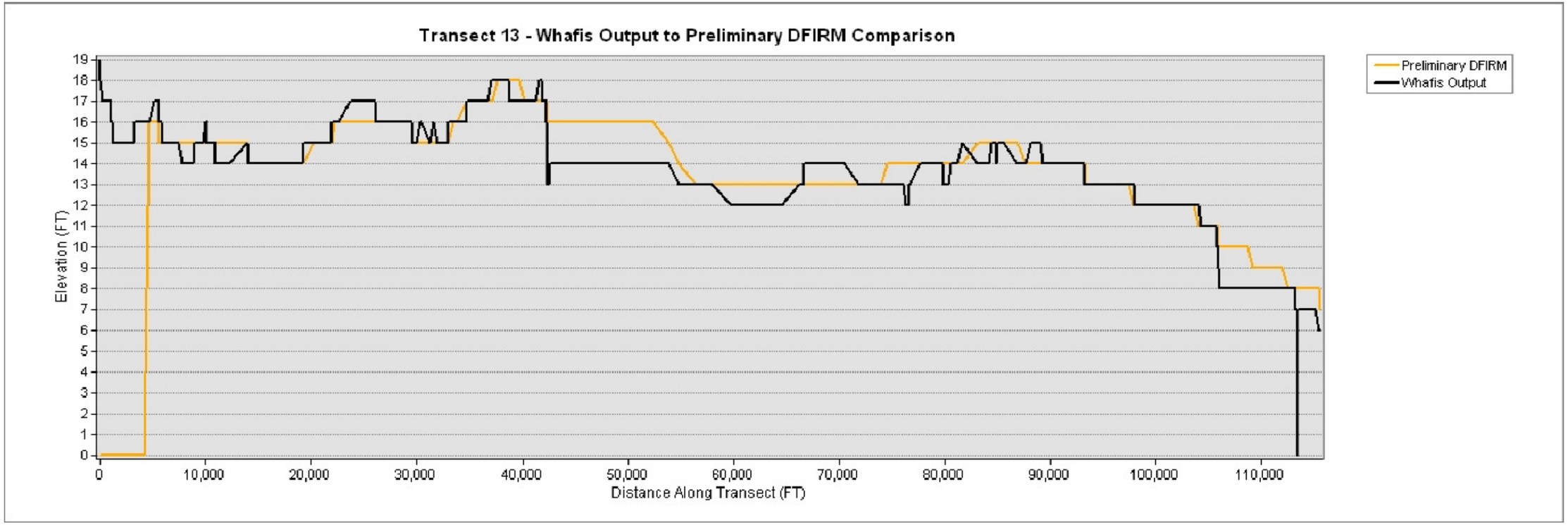
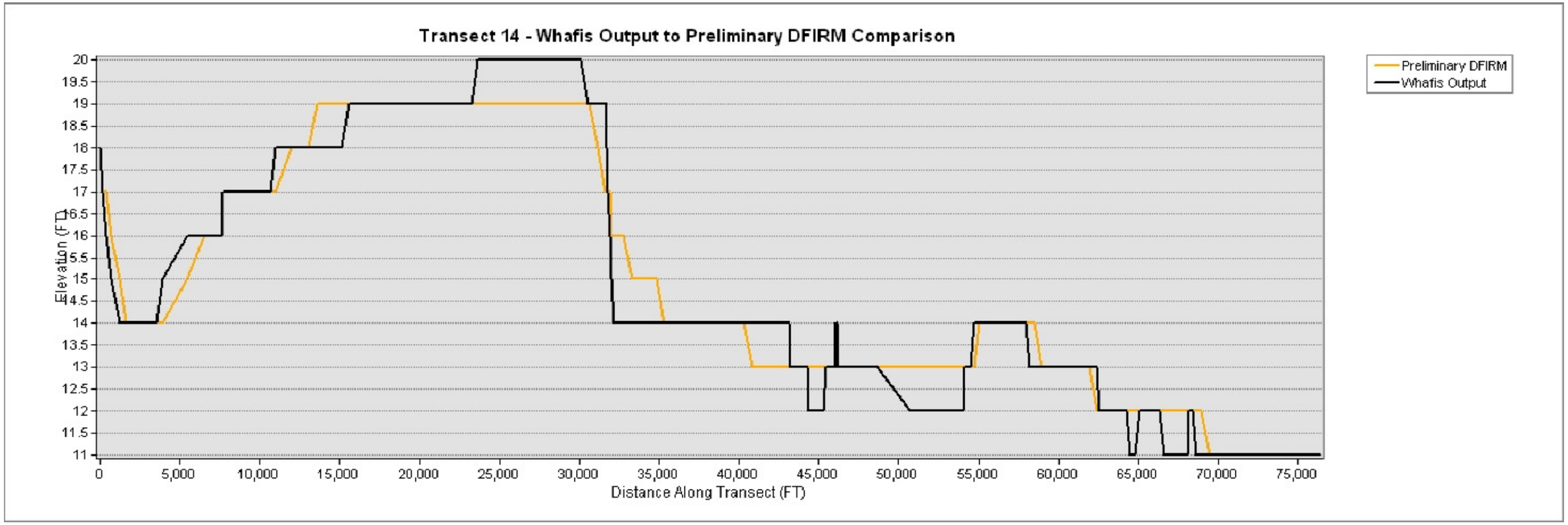
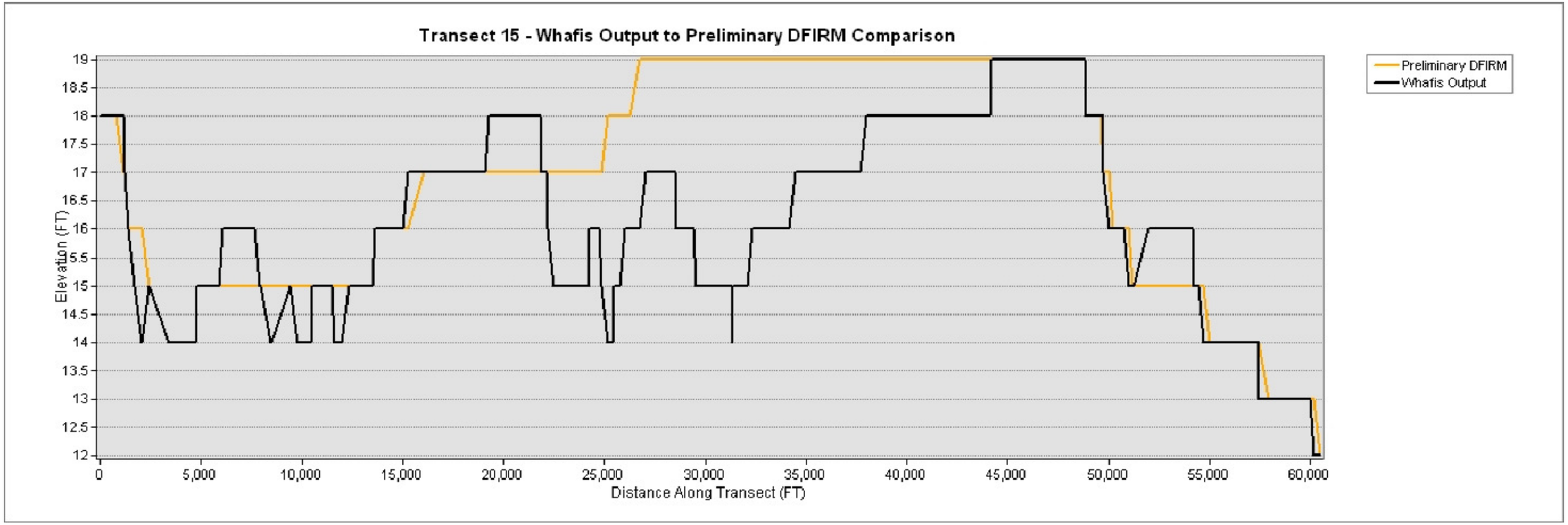
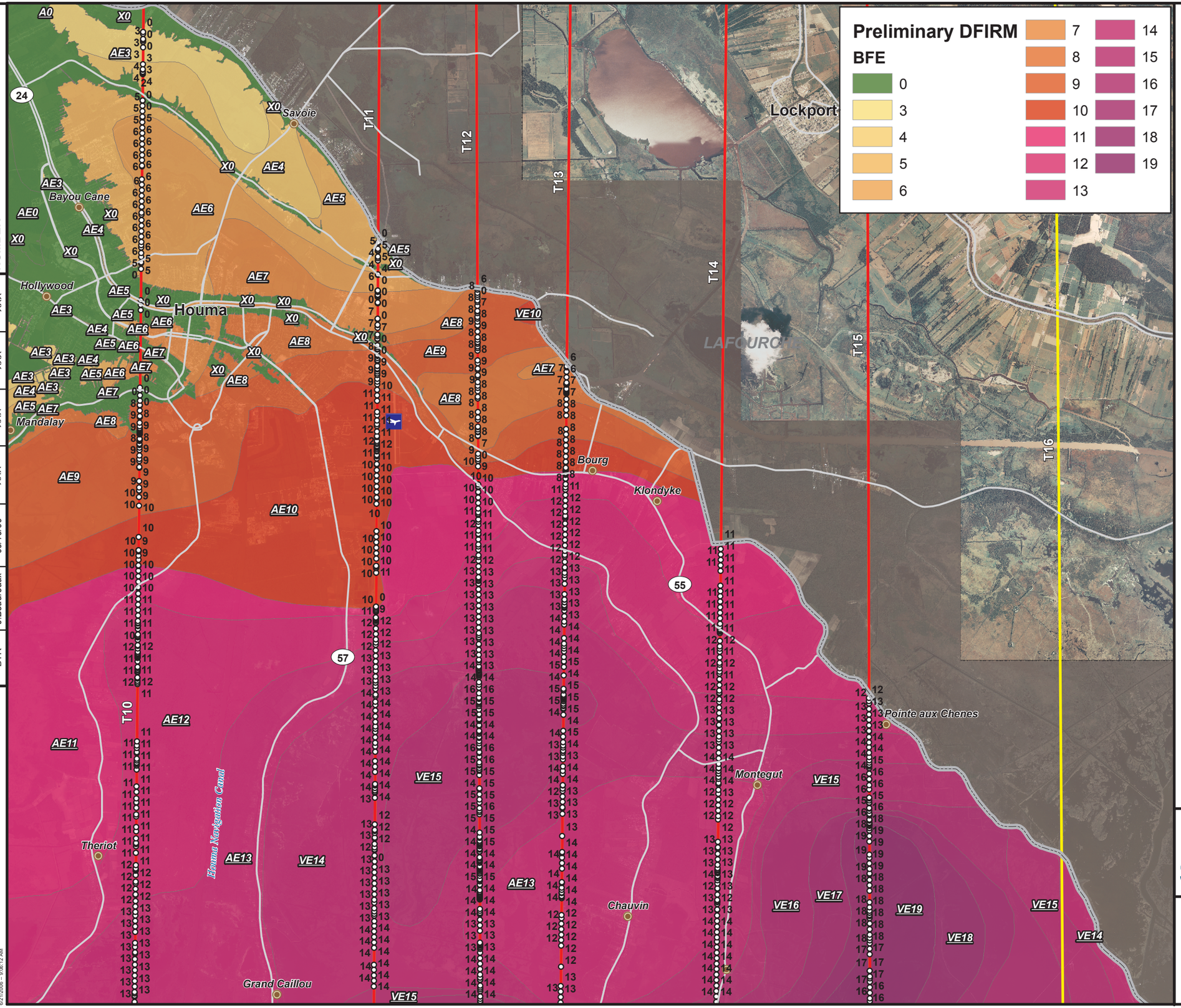

Transect 13 - Whafis Output to Preliminary DFIRM Comparison
Preliminary DFIRM
Whafis Output
Elevation (FT)
Distance Along Transect (FT)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
0
10,000
20,000
30,000
40,000
50,000
60,000
70,000
80,000
90,000
100,000
110,000

EXHIBIT 3-10


Transect 14 - Whafis Output to Preliminary DFIRM Comparison
Preliminary DFIRM
Whafis Output
Elevation (FT)
Distance Along Transect (FT)


Transect 15 - Whafis Output to Preliminary DFIRM Comparison
Preliminary DFIRM
Whafis Output
Elevation (FT)
Distance Along Transect (FT)



2 1 0 2 Miles

1:105,190
1 inch = 8,766 feet

Legend

- US Highway
- State/Parish Highway
- Transects 10 - 15
- WHAFIS Transects

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TERREBONNE PARISH
FEMA DFIRM APPEAL

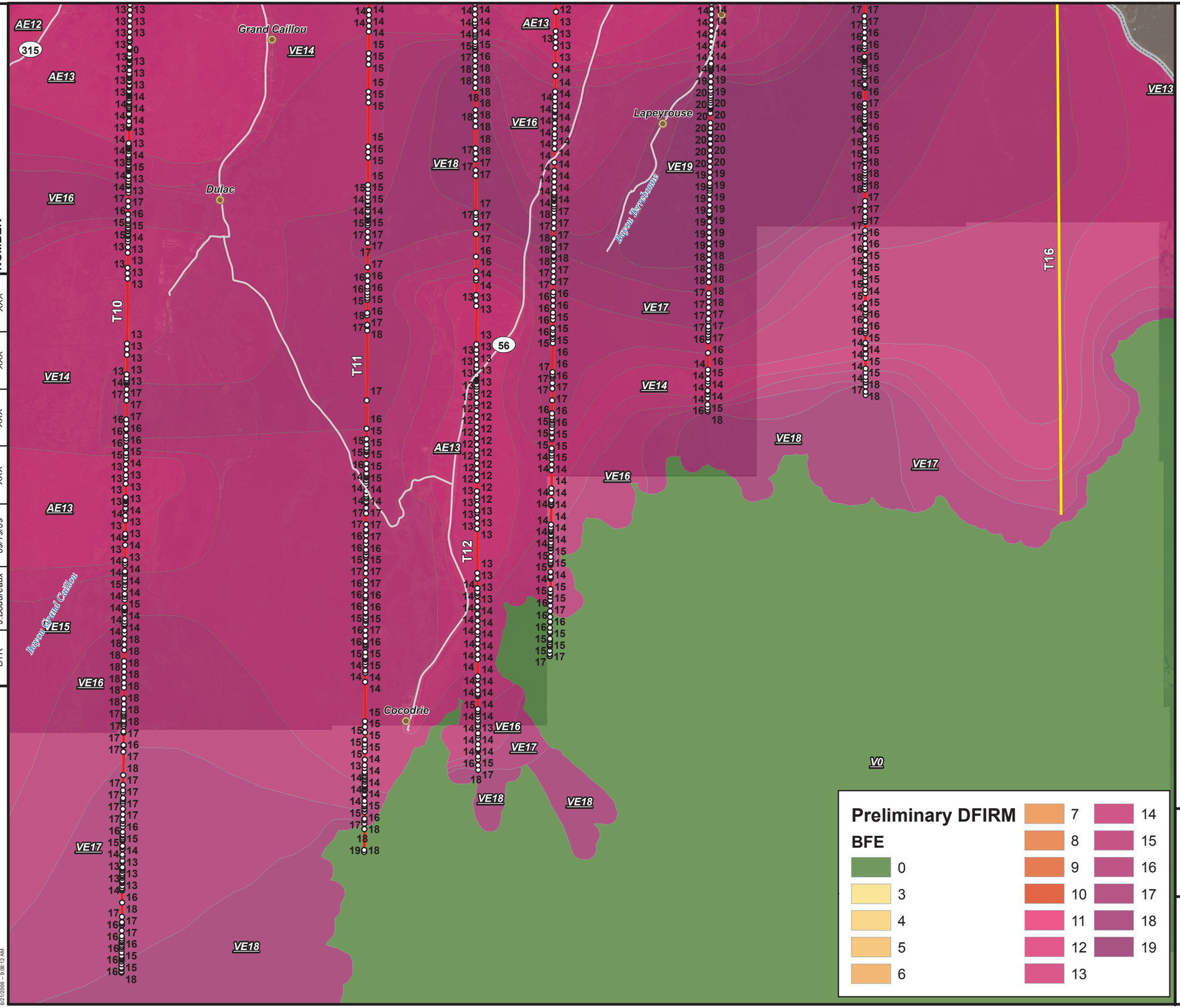
EXHIBIT 3-11

COMPARISON OF DFIRM ZONES AND WHAFIS TRANSECT ZONES (NORTH)

TERREBONNE PARISH, LOUISIANA

OFFICE	DRAWN BY		CHECKED BY		APPROVED BY		DRAWING NUMBER
BTR	J.Boudreaux	09/19/09	XXX	XXX	XXX	XXX	terr_136061_0024_whafis_11x17_TB

Map Document: (G:\GIS Data\ArcGIS\Templates\SHAW_Tablor\Landscape_RightLegend.mxd mxd)
8/21/2008 -- 9:06:12 AM



2 1 0 2 Miles

1:105,190
1 inch = 8,766 feet

Legend

- US Highway
- State/Parish Highway
- Transects 10 - 15
- WHAFIS Transects

Preliminary DFIRM

BFE

0	7	14
3	8	15
4	9	16
5	10	17
6	11	18
	12	19
	13	

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TERREBONNE PARISH
FEMA DFIRM APPEAL

EXHIBIT 3-12

COMPARISON OF DFIRM ZONES AND WHAFIS TRANSECT ZONES (SOUTH)

TERREBONNE PARISH, LOUISIANA

DRAWING NUMBER	APPROVED BY	CHECKED BY	DRAWN BY	OFFICE
terr_136061_0025_whafis_11x17_TB	XXX	XXX	09/19/09	BTR
	XXX	XXX	J.Boudreaux	

Map Document: (G:\GIS Data\ArcGIS\Templates\SHAW_Tabloid_Landscape_Right_legend.mxd.mxd)
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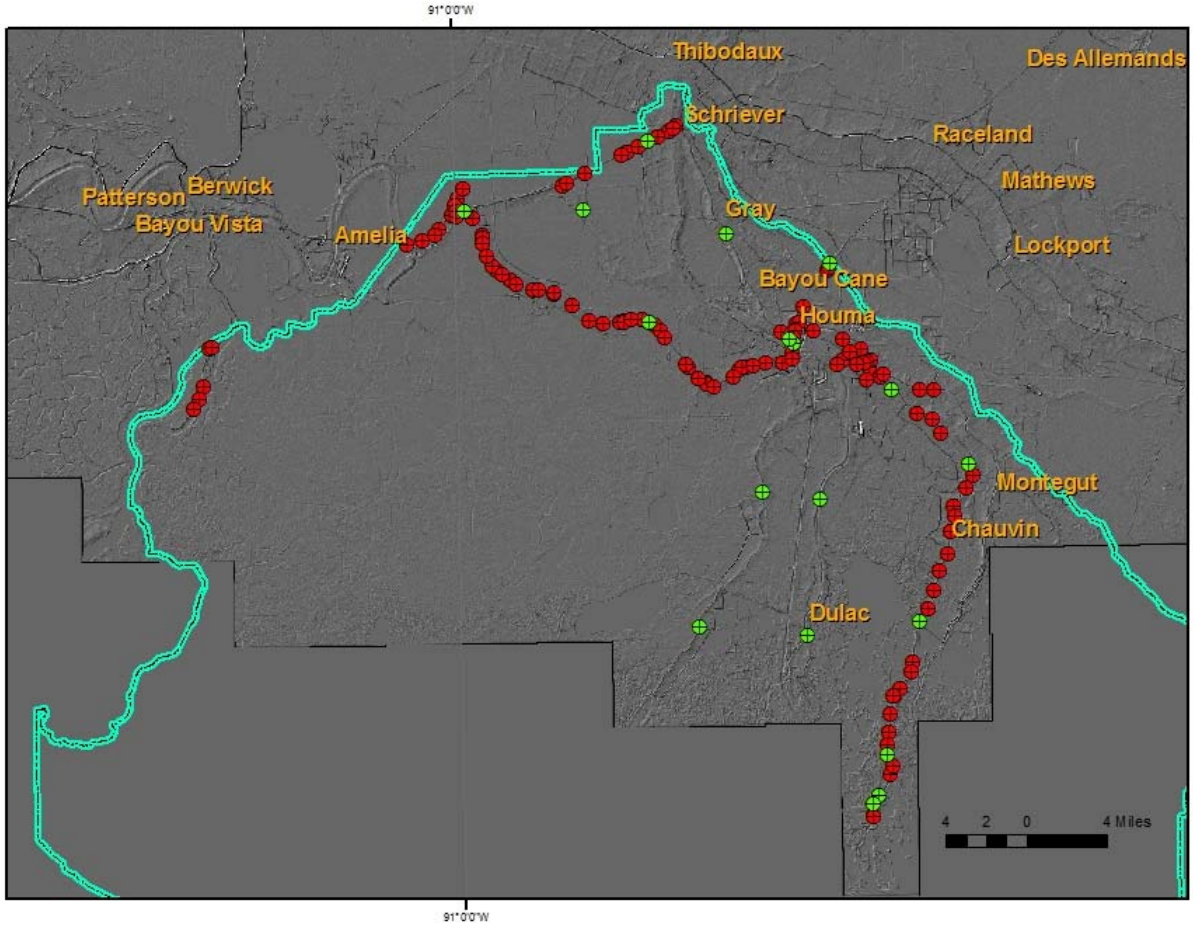
3.4 Protest Issues

A thorough review of the DFIRMs has identified one protest issue—benchmarks identified on Terrebonne Parish's preliminary DFIRMs. On page 24 of FEMA's *Guidelines and Specifications for Flood Hazard Mapping Partners*, April 2003, it states "The only ground control points printed on DFIRMs are those that are included in the NSRS." FEMA's preliminary DFIRMs include 130 benchmarks in Terrebonne Parish. However, only five of the benchmarks are deemed valid according to the National Geodetic Survey (NGS)/NOAA database. The current realization of NAVD88 in Louisiana, termed the 2006.81 epoch, includes benchmarks from the 2004.65 realization. According to Louisiana's NGS Advisor, Terrebonne Parish actually has 17 benchmarks and two Continually Operating Reference Stations (CORS) that are part of the NSRS. Electronic files created by Dr. Dokka and referenced herein are available upon request. Vertical control in Terrebonne Parish is illustrated in the following exhibit.

Exhibit 3-13: Vertical Control in Terrebonne Parish. Green symbols are valid control (NAVD88 – 2006.81 & 2004.65). Red symbols are benchmarks on FEMA DFIRMs.



4.0 IMPROVING THE DFIRMS

Additional data was collected with the intention of incorporating into the ADCIRC and WHAFIS models to correct the deficiencies in the preliminary DFIRMs. The additional data will provide the opportunity to perform modified model runs based upon the new data which is believed to be more accurate and/or better suited than that used in the original analysis. The new data is described in the following sections.

4.1 Data Collection and Analysis

4.1.1 Topographic

To produce better topographic data for Terrebonne Parish, Dr. Dokka conducted an extensive sampling of height measurements in the parish using real-time GPS technology. The measurements were made on major roads in the parish and are relative to NAVD88 (2004.65 & 2006.81). Dr. Dokka details his collection of more accurate topographic data in the parish on pages 13 through 23 of his report included in Appendix D. The newly collected topographic data was provided to Dr. Suhayda and the Woods Hole Group as improved input for modified ADCIRC and WHAFIS model runs.

4.1.2 Terrebonne Parish Soils Data

Due to time constraints created by the 90-day DFIRM appeal period, it was not possible to collect soil samples from coastal features located in the parish. The following is a general discussion of predominate soil types found within the parish.

The soils of Terrebonne Parish are a direct result of the Mississippi River deltaic plain depositional environment. According to *Recent Deltaic deposits of the Mississippi River: Their Chronology and Development. Trans. Gulf Coast Assoc. Geol. Soc. 17:287-315* (Frazier, D.E. 1967), the recent geomorphic history of the Mississippi River is a cycle of various delta lobe building and abandonment stretching from south central to southeast Louisiana. The delta building sequence is characterized by a main distributary channel with natural levees with back slopes, swamps, marshes, and interdistributary lakes and bays. Through channel bifurcation in the seaward, lower delta lobe area, a new main distributary channel develops producing similar depositional environments.

Terrebonne Parish has been predominantly affected by the Lafourche Delta sequence. During the Lafourche period, Bayou Lafourche served as the main channel of the Mississippi River. A bifurcation in the channel near the present location of Thibodaux, La. produced a new main channel which became Bayou Terrebonne. Numerous channel bifurcations and occupations by the main channel created the existing network of bayous of Terrebonne Parish. The addition of minor secondary channel bifurcations and crevasses with splay deposits resulted in an extensive, complex network of landforms, with subsequent soil types that comprise Terrebonne Parish. Landforms

include bayous, natural ridges with back slopes, and interdistributary areas of swamps, marshes and open water

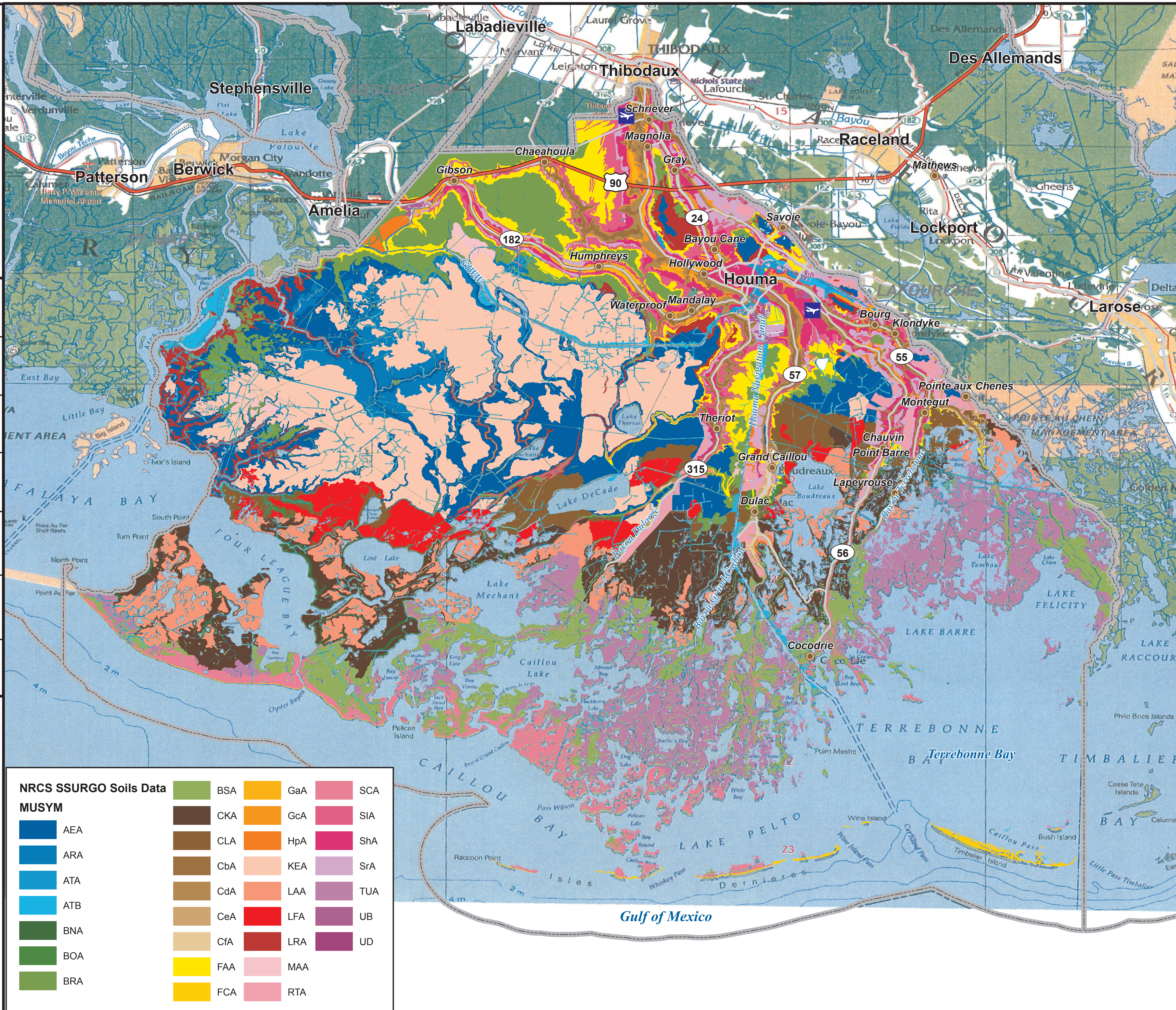
The existing levees of Terrebonne Parish are predominantly parallel to the natural distributary ridges. A few levee alignments traverse the interdistributary areas to provide linkage to the various natural ridges. The organic matter of Terrebonne's soils closely follows the geomorphic positioning from natural distributary ridge with lesser organics to the interdistributary areas with greater organics. Naturally, the upper layers of the soils tend to have greater amount of organics with less present in the lower layers. The natural distributary ridge soils have a loamy or clayey surface layer with clayey subsoil, loamy throughout, or a clayey surface layer and subsoil. Organic matter is generally less than 1% below a surface layer of 0-8". Swamp soils have a mucky or clayey surface and clayey subsoil. Organic matter for swamp soils generally range from less than 1-25% below a surface layer of 0-5". Marsh soils have a mucky surface with a mucky or clayey underlying material. Organic matter for marsh soils is more complex. Surface layers can range from 0-8" to 0-80" with organic percentages ranging from 20-85%. Drained former marshes and swamps have a clayey or mucky surface with clayey or loamy subsoil. Organic matter ranges from 2-70% at a surface layer of 0-9", less than 10% at an intermediate layer of 4-30", and less than 1% from 24-80". Soils data was provided by the USDA/NRCS *Soil Survey of Terrebonne Parish, Louisiana*, 2007. Predominate soil types located in the Terrebonne Parish are illustrated on Exhibit 4-1.

4.2 Coastal Features Structural Analysis

A variety of manmade elevation features affect hydrology in the parish, including levees and roadways. The information that follows is intended to substantiate these features as "coastal features" that should be accounted for in WHAFIS and ADCIRC modeling efforts.

Levee elevations range from +4 to +10 feet NAVD 88. Some are as old as 35 years. These levees are typically constructed by using earthen material excavated from an adjacent borrow canal. The borrow canal typically serves as the collection basin for the forced drainage system. These forced drainage networks are either closed, or tie into an elevation feature such as roads or highways.

Most of the roads, streets and highways in Terrebonne Parish are built of concrete on a compacted limestone base. The majority of the state highways follow natural bayou ridges. The road surfaces range from +4 to +8 ft NAVD 88 south of the GIWW, and higher to the north.



6 3 0 6 Miles

1:387,993

Legend

US Highway

State/Parish Highway

REFERENCE:
SSURGO Soils Dataset Obtained from NRCS.

Shaw®

TERREBONNE PARISH
FEMA DFIRM APPEAL

EXHIBIT 4-1

TERRENBONNE PARISH SOILS MAP

TERREBONNE PARISH, LOUISIANA

DRAWING NUMBER: terr_xxxxxx_0021_soils_11x17_TB

APPROVED BY: XXX

CHECKED BY: XXX

DRAWN BY: J.Boudreaux 05/06/09

OFFICE: BTR

Map Document: (G:\GIS Data\ArcGIS\Templates\SHAW_TabloidLandscape_RightLegend.mxd.mxt)
6/21/2006 -- 9:06:12 AM

4.2.1 Geotechnical and Construction Evaluation

The levees in Terrebonne Parish help protect lives and properties during a major storm event. These levees are made up of mostly clay material, which leads to strong, sturdy levees. Levees are built by hauling dirt to the site and shaped and compacted. Material may be hauled in from a dirt pit or it may be dredged from a canal running adjacent to the current levee construction. An excavator is used to load material into the haul trucks. A dredge or an excavator is used if canal borrow is used as levee material; the excavator or dredge lays the material on the slopes and allowed to dry. Bulldozers are used to move material around on the slopes during levee construction.

Organic material, such as roots, is unsuitable and removed from fill material. Track-wheeled tractors and rollers are used to shape and compact levees. Levees are typically reinforced with a berm on the protected side to provide for additional strength. The side slopes of a levee play an important part of its strength. Side slopes are typically at 1 vertical to 2.5 or 3 horizontal, while the crown width is approximately 10 feet, varying to up to 15 feet. Levee heights vary anywhere from +4 to +10 feet NAVD 88 in elevation.

Recent levee construction involves compacted levees, which increases the strength of the levees. Compaction helps achieve the required shear strengths for a levee design. Moisture content plays a part in the compaction of the levee as well. Prior to compaction, material is disked so that it obtains acceptable in situ moisture content.

In any case, recent levee construction or older levees, consolidation over time of underlying soils does occur. A compacted levee, whether it be compacted at the time of construction or consolidated over time, leads to a durable levee that has less chance of seepage or breakage during a major storm event.

In addition to compaction, subsidence is a factor. To account for subsidence, the Parish does maintain its levees by periodically adding more clay material to build the levees up to grade. Levees are periodically maintained to remove trees, roots and other large plants. They are covered with grasses to prevent erosion, and either mowed or chemically controlled.

4.2.2 Description of Overtopping Calculations and Inputs

The volume of water overtopping a levee is a function of the relative freeboard (levee crest compared to still water elevation), flood side slope and incident wave characteristics. With a freeboard greater than zero (i.e. levee crest higher than SWL), the overtopping is periodic, only occurring during the higher waves of the spectrum. The actual instantaneous discharge rate, therefore, is much higher than the average during the actual overtopping wave peak, and much less for all other moments.

As the SWL approaches and exceeds the levee crest elevation (relative freeboard less than or equal to zero), the overtopping discharge rate increases greatly. Two methods have been proposed for estimating the overtopping discharge rate. The first is for relative freeboard greater than zero. This method (Hughes, 2008a) is based on irregular wave analysis methods in the Coastal Engineering Manual. The second is applicable for relative freeboard less than zero (i.e. SWL exceeds the levee elevation). This method (Hughes, 2008b) was developed based on an empirical study using a single levee geometry. Though the levee geometries in Terrebonne Parish vary, we believe that the accuracy of this equation is close enough given the purpose of this analysis.

Both methods produce results in units of volume per time per linear foot of levee. We use the results of these methods here to conceptually evaluate the relative resiliency of earthen features under overtopping conditions.

4.2.3 Levee Resiliency During Overtopping Conditions

Levee resiliency under overtopping conditions is still a developing science. Typical design guidelines call for a maximum permissible overtopping volume rate of 0.1 $ft^3\ s^{-1}ft^{-1}$ (Hughes, 2008). At this rate, vegetated clay levees suffer no damage. The Dutch (Van der Meer, 2008) found that test sections could withstand 0.3 $ft^3\ s^{-1}ft^{-1}$ for as long as six hours with no damage. Increasing degrees of damage were observed from 0.3 $ft^3\ s^{-1}ft^{-1}$ to 0.8 $ft^3\ s^{-1}ft^{-1}$, though not all of their test sections suffered damage. Anecdotal descriptions of levee overtopping in Terrebonne Parish indicate that levee crowns don't lose elevation at up to half a foot of overtopping (relative freeboard equal to -0.5 ft), though the protected side toe of the levee suffers scour.

The overtopping discharge value of 0.3 $ft^3\ s^{-1}ft^{-1}$ corresponds to about +1.8 ft of freeboard; 0.8 $ft^3\ s^{-1}ft^{-1}$ corresponds to about +1 ft of freeboard. At -0.5 ft of freeboard, a discharge value of about 5 $ft^3\ s^{-1}ft^{-1}$ is expected. *Note that FEMA typically requires 3 ft of freeboard in order for a levee to be included in their models.*

When levees do breach, the breach is caused by failure at a localized weak point. The weak point begins to scour out, with the rate of scour increasing non-linearly. The breach may expand with time, though complete loss of an entire levee reach has never been encountered in Terrebonne Parish.

The roads and highways in Terrebonne typically survive storm surge overtopping with almost no loss of grade. The flood slide shoulder of an overtopped road may need repair, but this does not impair its function as a hydrologic barrier. Overtopped levees, roads and other "weirs" may suffer scour damage during overtopping conditions; however, it is highly unlikely that complete loss of section will occur, unless the overtopping is sustained for a long period of time.

Data included in this section was gathered from the following sources:

Hughes, S. A. 2008a. CHETN-III-77 Estimation of Overtopping Flow Velocities on Earthen Levees Due to Irregular Waves. U.S. Army Corps of Engineers. January, 2008.

Hughes, S. A. 2008b. CHETN-III-78 Estimation of Combined Wave and Storm Surge Overtopping at Earthen Levees. USACE. May, 2008.

Van der Meer, J. 2008. Erosion strength of inner slopes of dikes against wave overtopping: Preliminary conclusions after two years of testing with the Wave Overtopping Simulator. Version 1.1. August.

4.3 Modified ADCIRC and WHAFIS Modeling

The consulting team intended to incorporate the previously described missing and misrepresented weir locations and relevant elevations into the ADCIRC model to improve the output of the model. However, due to technical difficulties encountered while inputting and modeling the improved data and time constraints imposed by the 90 day appeal period, the modified ADCIRC runs could not be completed prior to the termination of the 90-day appeal period.

Likewise, the consulting team intended to perform modified WHAFIS modeling based on a revised still water level produced by the modified ADCIRC model. The modified WHAFIS modeling was not possible since the ADCIRC model could not be successfully modified for inclusion in this appeal.

4.4 WHAFIS Related Data/Adjustments Necessary to Create Improved DFIRMs

In order to be consistent with the WHAFIS methodology requirements several improvements to the DFIRM are needed. These improvements include new data, new transects and revision of existing transects. These improvements will provide a more consistent, accurate, detailed and representative basis for the determination of the BFEs in the parish than were used in developing the preliminary BFEs, and hence the newly computed BFEs will be superior.

4.4.1 New Bottom Sediment Data

A field study is needed to determine of the type of the bottom sediments contained the inland water bodies in Terrebonne Parish, and thus provide a quantified basis for applying the muddy bottom methodology. Samples of bottom sediment should be obtained in random locations in the bays and lakes in the parish. The samples should be analyzed for grain size and shear strength, to a depth of greater than 10 feet below the mud line. Based on this information, the muddy bottom sediment methodology can be employed.

4.4.2 WHAFIS Transects

4.4.2.1 New Transect Data

An initial result of the WHAFIS analysis indicates that several new WHAFIS transects would be needed to provide better resolution of the zones and elevation in the affected area of the Parish. The new transects should be placed between transects 9 and 10, 10 and 11, and 13 and 14, and 14 and 15. The topography along these new transects is substantially different from those on either side. The land cover designations used in each new transect can be the same as used in the DFIRM transects.

4.4.2.2 Revise Existing Transects

Transects 10 through 15 should be revised and the WHAFIS program re-run to address the errors in the original transect set-ups. The transects should be changed in two ways. The initial wave heights used on the “IE” card for each transect need to be changed to the correct values as given in the information provided by FEMA (Suhayda, 1984). Also, segments along each transect that contained “OF” designations should be changed to “IF” or “VH” segments, as appropriate.

5.0 CONCLUSION

After a careful review of the information made available by FEMA to Terrebonne Parish, it has been determined that certain areas of the preliminary DFIRMs contain BFEs which are scientifically and technically deficient because of the following:

(1) The topographic data used in the creation of Terrebonne Parish's preliminary DFIRMs are of unknown quality and thus fail to meet FEMA guidelines.

(2) Critical topographic features used in FEMA's ADCIRC modeling are inaccurate and not representative of reality. The grid omits numerous coastal features and elevated roadways that act as weirs during storms. The omission of these weirs likely resulted in local overestimation of flooding risk.

(3) Errors were made in the application of the WHAFIS methodology.

(4) The WHAFIS methodology was based upon insufficient and poor quality data.

(5) The results of FEMA's WHAFIS modeling efforts were not properly transposed or mapped onto the preliminary DFIRMs.

Additional data was collected by Terrebonne Parish during the appeal period with the intent of providing improved input into the models that ultimately create the BFEs and the DFIRMs. The new data included the identification and location of weirs, the elevation of those weirs, and a structural evaluation of the weirs as coastal features. An attempt was made to incorporate the improved data into modified model runs. However, due to the complexities of the models and time limitations imposed by the 90-day appeal period, the models could not successfully be completed.

To ensure Terrebonne Parish's future flood risks are appropriately characterized, modified ADCIRC and WHAFIS model runs are necessary using the additional data provided in this appeal document as well as incorporating improved WHAFIS related data/adjustments identified herein. The new data and revised application of the ADCIRC and WHAFIS models would provide a more accurate and detailed basis for determining the BFEs and flood zones over the original FEMA results. At a minimum, FEMA should carefully review the output of their WHAFIS modeling efforts and ensure the results are accurately reflected on the preliminary DFIRMs.

Appendix A

FEMA Correspondence
June 2, 2009

Federal Emergency Management Agency

Washington, D.C. 20472

June 2, 2009

CERTIFIED MAIL
RETURN RECEIPT REQUESTED

IN REPLY REFER TO:
101/155

The Honorable Michel Claudet
Parish President, Terrebonne Parish
8026 Main Street
Houma, LA

Community: Unincorporated Areas, Terrebonne Parish, Louisiana
Community No.: 225206

Dear President Claudet:

On July 30, 2008, the Department of Homeland Security's Federal Emergency Management Agency (FEMA) provided your community with Preliminary copies of a Flood Insurance Study (FIS) report and Flood Insurance Rate Map (FIRM). The FIS report and FIRM for your community were prepared in our countywide format, which means that flood hazard information for the entire geographic area of the county, including your community and all incorporated areas, was presented. This information makes it appropriate to modify the elevations of the flood having a 1-percent chance of being equaled or exceeded in any given year (base flood) for certain locations in the Unincorporated Areas, Terrebonne Parish, Louisiana. Public notification by way of a Standard Newspaper Notice that the proposed modifications in Base Flood Elevations (BFEs) are posted in the BFE Notice for Studies on the FEMA Website http://www.fema.gov/plan/prevent/fhm/bfe will be given in *The Courier* on or about June 17, 2009 and June 24, 2009. The BFEs for the flooding sources are listed in the table at the end of the BFE Notice for Studies. Also, the proposed BFE determinations can be obtained by calling the FEMA Map Assistance Center toll free at 1-877-FEMA MAP (1-877-336-2627). A copy of the Standard Newspaper Notice and a copy of the Notice of Proposed Flood Elevation Determinations published in the *Federal Register*, on May 18, 2009 in Vol. 74 No. 94 page 23145 are enclosed for your information.

These proposed BFEs, if finalized, will become the basis for the floodplain management measures that your community must adopt or show evidence of having in effect in order to qualify or remain qualified for participation in the National Flood Insurance Program (NFIP). However, before any revised BFEs are effective for floodplain management purposes, you will be provided an opportunity to appeal the proposed BFEs.

Section 110 of the Flood Disaster Protection Act of 1973 (Public Law 93-234) is intended to ensure an equitable balancing of all interests involved in the setting of BFE determinations. The legislation provides for an explicit process of notification and appeals for your community and for private persons prior to this office making the BFE determinations final. The appeal procedure is outlined below for your information. The regulations FEMA developed to implement Section 110 are listed in Title 44, Chapter I, Part 67, Code of Federal Regulations. A copy of the NFIP regulations is enclosed.

During the 90-day appeal period following the second publication in the referenced newspaper, any owner or lessee of real property in your community who believes his or her property rights will be adversely affected by the BFE determinations may appeal to you, or to an agency that you publicly designate. You must send copies of the individual appeals to the FEMA Region as soon as you receive them. Note that the 90-day appeal period is statutory and cannot be extended or shortened for any reason. It is important to know, however, that the sole basis for the appeals is having knowledge or information indicating that the proposed BFE determinations are scientifically or technically incorrect. However, inquiries regarding data other than the proposed BFE determinations (e.g., incorrect street names, typographical errors, omissions) will be considered as comments and not appeals. Any applicable changes will be made before the revised FIS report and FIRM become effective.

During the appeal period, private citizens who want to appeal should present to you the scientific or technical data (*preferably in shapefile format*) intended to negate or contradict FEMA's findings in any form, as you specify. FEMA requests that you review and consolidate all appeals by private persons, and issue a written opinion stating whether the evidence presented is sufficient to justify an official appeal by your community on behalf of such persons. Your decision on whether an appeal by the community, in its own name, will be made, and must be sent to the following office within the 90-day appeal period.

Frank Pagano
Director, FEMA Mitigation Division
800 N. Loop 288
Denton, TX 76209

Any documents submitted to you without evidence that they were sent within 90 days of the second publication in the local newspaper will be considered comments. Your community may find it appropriate to call further attention to the proposed BFE determinations and to the appeal procedure by using a press release or other public notice.

If the FEMA Region does not receive an appeal from your community on behalf of individuals within the 90 days provided, FEMA shall consolidate and review on their own merits the individual appeals, which you have on file and forwarded to us. FEMA's final decision will be in writing, and copies will be sent to each individual appellant and the State coordinating agency.

The appeal resolution process will consider any scientific or technical data (preferably in shapefile format) submitted by your community intended to negate or contradict the information upon which the proposed BFE determinations are based. The appeal will be resolved by consultation with officials of the local government involved, an administrative hearing, or submission of the conflicting data to an independent scientific body or appropriate Federal agency for a determination. FEMA will determine the method for resolution.

If your community cannot submit scientific or technical data before the end of the 90-day appeal period, you may nevertheless submit data at any time as specified in Part 65 of the NFIP Regulations. If warranted, FEMA will revise the FIRM again after the effective date.

The reports and other information used for the final determination will be made available for public inspection. Until the conflict of data is resolved and the **[**revised**]** FIRM becomes effective, flood insurance available within your community shall continue to be available in accordance with the effective FIRM dated April 2, 1992.

If warranted by substantive changes, during the appeal period, FEMA will send to you revised copies of the FIS report and FIRM. At the end of the 90-day appeal period and following the resolution of any appeals, FEMA will send you a letter of final BFE determinations.

The FIRM panels for Terrebonne Parish, Louisiana, and Incorporated Areas have been computer-generated. Once the FIS report and FIRM are printed and distributed, the digital files containing the flood hazard data for the entire county can be provided to your community for use in a computer mapping system. In the mean time, if you have any questions about the digital files please contact Scott Stone, CDM, the designated mapping partner for preparing digital mapping files. These files can be used in conjunction with other thematic data for purposes of floodplain management, insurance determinations, and many other planning applications. In addition, your community may be eligible for additional credits under the NFIP Community Rating System if you implement your activities using digital mapping files.

If you have any questions regarding the proposed BFE determinations, revised FIS report, or revised FIRM for your community, please contact the FEMA Map Assistance Center, toll free, at 1-877-FEMA MAP (1-877-336-2627).

Sincerely,

William R Blanton Jr

William R. Blanton Jr., CFM, Chief
Engineering Management Branch
Mitigation Directorate

Enclosures:

1) Newspaper Notice
2) *Federal Register Notice*
3) National Flood Insurance Program Regulations - Part 67

cc: Community Map Repository

Mitch McDonald
Floodplain Administrator, Terrebonne Parish

Cindy O'Neal
Louisiana State NFIP Coordinator

Durund Elzey
U.S. Army Corps of Engineers
New Orleans District

Mike Hunnicutt
Louisiana TRO

Vicki Munn
Michael Baker Corp.

Scott Stone
CF3R/ (CDM)

Regional Director R6-MT

MBJ Case File/NRS/KKR
MBJ Project File
FEDD File

U.S. Department of Homeland Security
FEMA Region 6
800 N. Loop 288
Denton, TX 76209-3698

FEMA

June 2, 2009

IN REPLY REFER TO:
101-155wo BFE

The Honorable Michel Claudet
Parish President, Terrebonne Parish
8026 Main Street
Houma, LA

Community: City of Houma, Louisiana
Community No.: 220220

Dear President Claudet:

On July 30, 2008, the Department of Homeland Security's Federal Emergency Management Agency (FEMA) provided your community with Revised Preliminary copies of the Flood Insurance Study (FIS) report and Digital Flood Insurance Rate Map (DFIRM) for your community. That material makes it appropriate to modify the elevations of the flood having a 1-percent chance of being equaled or exceeded in any given year (base flood) for certain locations in Terrebonne Parish, Louisiana and the Incorporated Areas. No substantial changes in the Base Flood Elevation (BFE) occurred in your community; however, you may still submit comments during the period of June 24, 2009 through September 22, 2009. This 90 day comment period will allow for comments and concerns to be addressed concerning the new DFIRM and FIS report. Please ensure that the Preliminary Maps can be viewed at your community's map repository located at the *Terrebonne Parish Courthouse, 7856 Main Street, Houma, Louisiana 70360*. Please forward any comments or concerns to the following:

Frank Pagano
Director, FEMA Mitigation Division
800 N. Loop 288
Denton, Texas 76209

During this 90-day comment period, any owner or lessee of real property in your community who believes his or her property rights will be adversely affected by the DFIRM determinations may comment to you, or to an agency that you publicly designate. It is important to note, however, that only inquiries regarding data other than the BFEs, e.g., incorrect street names, typographical errors, omissions, floodplain delineations, will be considered by FEMA, and any applicable changes will be made before the FIS report and DFIRM become effective.

If you have any questions regarding the proposed BFE determinations, FIS or FIRM, please contact Jack Quarles at (940) 898-5156 for assistance. If you have any questions concerning mapping issues in general, please call our Map Assistance Center, toll free, at 1-877-FEMA MAP (1-877-336-2627).

Sincerely,

Frank Pagano
Director, Mitigation Division
Mitigation Division

cc: Community Map Repository

Mitch McDonald
Floodplain Administrator

Cindy O'Neal
Louisiana State NFIP Coordinator

Durund Elzey
U.S. Army Corps of Engineers
New Orleans District

Mike Hunnicutt
Louisiana TRO

Vicki Munn
Michael Baker Corp.

Scott Stone
CF3R/ (CDM)

Regional Director RVI-MT
NSP Case File
FEDD File

Appendix B

Confirmation of FEMA Public Notices
June 17 & 24, 2009

The newspapers of **Louisiana** make public notices from their printed pages available electronically in a single database for the benefit of the public. This enhances the legislative intent of public notice - keeping a free and independent public informed about activities of their government and business activities that may affect them. Importantly, Public Notices now are in one place on the web (www.PublicNoticeAds.com), not scattered among thousands of government web pages.

County: Terrebonne
Printed In: The Courier
Printed On: 2009/06/24

13570 Publication dates June 17 and 24, 2009
"Notice of Proposed Flood Elevation Determintations"
DEPARTMENT OF HOMELAND SECURITY
FEDERAL EMERGENCY MANAGEMENT AGENCY
Proposed Base Flood Elevation Determination for the Unincorporated Areas, Terrebonne Parish, Louisiana: The Department of Homeland Security's Federal Emergency Management Agency solicits technical information or comments on the proposed Base (1-percent-annual-chance) Flood Elevations (BFEs) shown in the Preliminary Flood Insurance Study (FIS) and on the Preliminary Flood Insurance Rate Map (FIRM) for your community. These proposed BFEs are the basis for the floodplain management measures that your community is required to either adopt or show evidence of having in effect in order to qualify or remain qualified for participation in the National Flood Insurance Program (NFIP). For a detailed listing of the proposed BFEs and information on the statutory period provided for appeals, please visit FEMA's website at http://www.fema.gov/plan/prevent/fhm/bfe, or call the FEMA Map Assistance Center toll free at 1-877-FEMA MAP.

Public Notice ID: 10232415

Appendix C

Public Comments
June 22, 2009

Robert "Bobby" Bergeron
4119 Bayou Estates Drive
Bourg, LA 70343

RECEIVED
JUN 22 2009
PLANNING & ZONING

Terrebonne Parish Consolidated Government
Office of Parish President
PO Box 2768
Houma, LA 70361

Dear Michel Claudet:

Due to the impacts the FEMA flood maps will have on our communities, the best professional data should be used to determine flood zones. I believe it is unfair to the people living north of the Intracoastal Waterway for the Intracoastal to be used as "the line" determining flood zones. Using this line gives them an unrealistic idea that they will not flood when in reality they are more likely to flood than some properties in the Bourg and Little Caillou areas which are below the Intracoastal.

The transect lines shot flying from the Gulf of Mexico to the North through Terrebonne Parish skipped the Upper Little Caillou and Bourg areas. The topography of this area is absent and does not take into account the natural ridges and other obstructions that would act as a barrier to flooding in the Bourg and Upper Little Caillou areas. Without all the information for the entire parish, these requirements are using incomplete data to determine elevation requirements.

For example, Lake Long which is a couple miles east northeast of my home in Bourg and north of the Intracoastal Waterway is at an 8ft elevation requirement on the proposed FEMA Advisory Base Flood Elevation map and my home is at an 11 foot base flood elevation. This is just one example of how inaccurate these maps are for the complex topography of Terrebonne Parish.

I urge Terrebonne Parish Government to work with FEMA to make sure that the topography of lower Terrebonne Parish is taken into account to provide a more

accurate depiction of our parish when determining FEMA Base Flood map elevation requirements.

To properly introduce myself I am a 70 year old lifetime resident of Terrebonne Parish. I am a principal owner and President of an Oil Field Services company that provides many tax dollars to both Terrebonne Parish and the State of Louisiana. I have served the public in Terrebonne Parish as a Police Juror, Parish Councilman, State Representative, and Parish President. Please contact me if you would like to discuss this in further detail. I can be reached at (985)872-6764, and also (985)223-1922. Or by E-mail at Bobby@surbo.com

Respectfully,

Robert "Bobby" Bergeron

CC: Al Levron – Parish Manager
Pat Gordon – Planning Director
Paul Labat – Council Clerk
Council Reading File

Nolan J. Bergeron Jr.
100 Lecompte Dr. Drive
Bourg, LA 70343

RECEIVED
JUN 22 2009
PLANNING & ZONING

Terrebonne Parish Government
PO Box 2768
Houma, LA. 70361
Mr. Pat Gordon
Director Planning Dept.

Dear Mr. Gordon

I have lived, worked and played in Terrebonne Parish for 71 Years and worked onshore and offshore for the greater part of my life. I have served the people of this community as a Terrebonne Parish Councilman from 1984 to 1996, presently serving as a member and past chairman of the Coastal Zone Management and Coastal Restoration Advisory Committee, still presently serving as a member and chairman of the projects committee. I also serve as Chairman of the Bourg Fire District 5 Board.

I have spent a great deal of time looking at the FEMA proposed maps for Terrebonne. It is quite obvious to me that the best available professional data has not been used to determine proper flood zones in my area of Bourg or in the whole of Terrebonne Parish.

The natural ridges were not considered in the Bourg or Little Caillou areas. An example of this is that my home and the site of the new Bourg Fire Station are being put in higher flood zones than the immediate adjacent land although we are at a higher elevation. I cannot visualize my home being in a 10ft. flood zone and my immediate neighbors will be at a 9ft. flood zone even though they are at a lower elevation then I am.

I would also like to bring forth the land that the new Fire Protection District # 5 fire station will be built on. The proposed flood line that separates the 11ft flood zone from the 10 ft flood zone divides our property with the proposed lower flood elevation of 10ft. being in the lowest land elevation. As the land falls north to the Gulf Intracoastal Waterways the proposed flood zones drop to 9ft. and less. This all happens within a half mile or less. The land in the past near the GIWW has always flooded from the GIWW and adjacent company canal and never over the Terrebonne Bayou and upper Little Caillou Bayou ridges. This is the reason that putting the proposed 100 year flood zone at the top of the ridges makes no sense.

Before these new proposed flood elevations can be allowed to be adopted by FEMA there must be some proven technical justifications.

I believe it is unfair to the people living north and south of the GIWW to be told that the Intracoastal will be used as "the line" determining flood zones. Using this line gives the people north of this line an unrealistic idea that they will not flood and simply stops all development and increase flood insurance to the south. The reality is that people to the north are more likely to flood than some higher elevation properties in the Bourg and Little Caillou areas which are located south of the Intracoastal.

The transect lines shot flying from the Gulf of Mexico to the North through Terrebonne Parish skipped the Upper Little Caillou and Bourg areas. The topography of this area is absent and does not take into account the natural ridges and other obstructions that would act as a barrier to flooding in the Bourg and Upper Little Caillou areas. Without all the information for the entire parish, these requirements are using incomplete and/or technically deficient data to determine 100 year Base Flood Elevation (BFE) requirements.

For example, Lake Long which is just a short distance northeast of Bourg and north of the GIWW is at an 8ft elevation requirement on the proposed FEMA Advisory Base Flood Elevation map. Lake Boudreaux to the south has 3 different flood zones. This is unreal.

I thank the Terrebonne Parish Government for appealing the proposed DFIRM maps and ask that you continue to insist that the topography of upper and lower Terrebonne Parish is taken into account to provide a more accurate depiction of our parish when determining FEMA Base Flood map elevation requirements in order to properly protect any new future construction from being improperly elevated and to insure that all the people of Terrebonne Parish are treated fairly and evenly across the parish.

I am available and knowledgeable enough to drive or show anyone the problems with the new proposed flood maps. The samples I have included in my letter are only a small number of the unjustified proposal that may be forced on our people and our parish.

Sincerely,

Nolan J. Bergeron Jr.

Cc;
Council's reading file

Appendix D

Evaluation of Elevation Issues Related to FEMA DFIRMs in Terrebonne Parish

Roy K. Dokka, PhD

EVALUATION OF ELEVATION ISSUES RELATED TO FEMA DFIRMS IN TERREBONNE PARISH

BY

ROY K. DOKKA, PH.D.
5790 Creekside Ln.
St. Francisville, LA 70775

For

Shaw Coastal, Inc.
Baton Rouge, LA
Submitted September 3, 2009

EXECUTIVE SUMMARY

Materials pertaining to the accuracy of elevation data used by FEMA and its mapping partner in preparation, validation, and production of FEMA DFIRMS for Terrebonne Parish were examined and analyzed. Particular attention was paid to LiDAR DEM elevation data used in the creation of DFIRMs and the data used in modeling. The study revealed several deficiencies that severely impact the quality of DFIRMs. New data that was collect were forwarded to other members of the team to assist in modeling.

The following deficiencies were noted:

- The derivative products of the LIDAR data, i.e., DEM and "bare earth" LIDAR, used for topography in the preparation of the DFIRMs are not in the official datum recognized and required by FEMA. The accuracy assessment conducted in 2003 by the assigned mapping partner is also invalid because it too was performed when the vertical datum was not available. Both activities occurred after the National Geodetic Survey reported to Congress that vertical control was absent in south Louisiana, i.e., 2001, but before vertical control was officially reestablished with the introduction of NAVD88 (2004.65) in late 2005. This invalidates the ADCIRC and WHAFIS modeling conducted for FEMA as these models require valid NAVD88 topographic data.
- Records demonstrate that the accuracy of the LiDAR DEM and "bare earth" LIDAR were never actually determined as required by FEMA because the official vertical datum was inaccessible in Louisiana when the data were acquired, i.e., 2003. This finding can be verified by a comparison of the FEMA production timeline with notes of the National Geodetic Survey/NOAA. Because they were of unknown accuracy at the time of DFIRM construction, FEMA violated its own rules by allowing the use of the LiDAR DEM and "bare earth" LIDAR in the DFIRM study.
- FEMA and its mapping partners have violated professional standards by allowing the use of individual "bare earth" LIDAR elevations as input into WHAFIS modeling. FEMA provides standards in its guidelines for the QA/QC of a DEM and TIN based on "bare earth" LIDAR points. However, FEMA provides no requirements for QA/QC of individual "bare earth" points and the mapping partner has not provided any independent

test of their validity. Because the vertical accuracy of individual "bare earth" points are unproven, FEMA should have not allowed its use for the WHAFIS.

- The Assigned Mapping Partner has provided adequate data and records that prove that he failed to conduct QA/QC procedures on the DEM according to FEMA requirements and professional standards. Specifically, the Assigned Mapping Partner failed to obtain the requisite observations for the accuracy assessment of the DEM. Samples were clumped and not randomly distributed as required by professional standards. The Assigned Mapping Partner also violated professional standards by rejecting data without sufficient cause in an apparent attempt to improve the results. These shortcomings invalidate the application of the RMSE statistic to this project.
- Where LiDAR topographic data were unavailable, the Assigned Mapping Partner substituted in its place inferior U.S. Geologic Survey National Elevation Data. It is acknowledged by FEMA that these data clearly do not meet FEMA requirements. No accuracy assessment of these data was done.
- In order to establish accuracy of the LIDAR DEM per FEMA requirements, an independent accuracy assessment using up-to-date NAVD88 (2004.65) elevation data was performed. Analysis proved that the 98.4% of DEM pixels agreed to within +/- 1.2 ft of 6832 NAVD88 (2004.65) test points; it was also noted that that a significant ~-0.5 ft bias exists in the data. Unfortunately, the accuracy assessment data fail a statistical test for normality, a key requirement for the application of the RMSE statistic. I have created a new and improved DEM by removing most of the bias and tested it against a new and independent elevation data set. While an improvement over the FEMA DEM, the new DEM also fails the test for normality. It is my professional judgment that this lack of normality is likely related to two factors. First, it is obvious that the LIDAR is too old to characterize present-day Terrebonne Parish, one of Louisiana fastest growing and developing areas. The LIDAR was collected almost a decade ago and cannot accurately account for substantial changes to the current topography by coastal erosion [negative effect] and coastal restoration [positive effect], and most importantly, the construction of man-made weirs (roads, new levees and new lifts on existing levees). These coastal features control water flow in Terrebonne Parish. Second, the errors in our road/lidar comparison are skewed towards higher elevations, an effect consonant with the high degree of new road building and road height enhancement throughout this decade after the LIDAR data acquisition (personal communication, A. Levron, Terrebonne Parish Manager, 2009).
- An accuracy assessment of weir locations and heights was also performed and showed that many weirs of Terrebonne Parish defined by FEMA are mis-located and/or have inaccurate heights. FEMA modelers include some roads as weirs in Terrebonne Parish but inexplicitly disregard others with similar characteristics. FEMA has also failed to include old and new levees in the parish that act as substantial coastal barriers that retard storm surge. We have identified many miles of new weirs with elevations well above 3 feet NAVD88 (2004.65).
- One hundred twenty-five out of 130 benchmarks included in the parish DFIRMs are not recognized as currently accurate by National Geodetic Survey/NOAA. The DFIRMs have also omitted 14 benchmarks or National CORS stations that serve as connecting points to the National Spatial Reference System.

INTRODUCTION

This report describes the results of an analysis of the original topographic, related data, and procedures used by FEMA to create DFIRMs of Terrebonne Parish, Louisiana. It examines these issues in light of the requirements established by FEMA and reports on deficiencies. This report also includes new topographic data that was collected specifically to test the validity of the digital elevation model (DEM), as well as the "grid" that was used in storm surge computer models used in the FIS. Additional topographic data were also collected on coastal barriers and roads that serve as weirs during storms. These additions have resulted in a better dataset that can significantly improve the DFIRMs of Terrebonne Parish. The report is organized into five parts and is presented in the following order:

- Analysis of Topographic Datum Issues.
- Analysis of Datum Conversion Techniques.
- Analysis of Accuracy Claims Regarding LiDAR Digital Elevation Models (DEMs).
- Analysis of FEMA's Contention that the LIDAR DEM is Accurate and Constitute the "Best Available".
- Better Topographic Data for Terrebonne Parish
  - ✓ Independent Testing of the Accuracy of Terrebonne Parish LiDAR DEM.
  - ✓ Improvement of the Terrebonne LiDAR DEM.
- Assessment of the Spatial Accuracy of the Weirs Used in FEMA ADCIRC Models.
- Assessment of Elevation Data Used in Wave Modeling.

ANALYSIS OF TOPOGRAPHIC DATUM ISSUES

Topographic Data Used in DFIRM Preparation

Terrebonne Parish LiDAR data was produced from two Louisiana/Federal Emergency Management Agency (FEMA) sponsored and managed projects:

- Phase 2 (Task Areas 6 and 7) (3001, Inc., delivery date unknown). QA/QC work proceeded under the Louisiana LIDAR Data Development: Terrebonne and Vermilion Parishes, Louisiana under the Watershed Concepts contract number EMT-2002-CO-0048. The results of Task Area 6 were submitted to FEMA on September 15, 2003; Task Area 7 was submitted on August 19, 2003. The surveying work was submitted by J. Hendricks.
- Phase 3 (Task Area 11) (3001, Inc., delivery date unknown). QA/QC work proceeded under the Louisiana LIDAR Data Development: Cameron, Terrebonne and St. Bernard Parishes, Louisiana under the Watershed Concepts contract number EMT-2002-CO-0048. The results of QA/QC Task Area 11 were submitted to FEMA on April 15, 2004. The report was submitted by M. Leonard of Watershed Concepts (Appendix 1 of TA-11).

A Review of FEMA Vertical Datum Requirements Topographic Data

The requirements for vertical datums are spelled out on page A-25 of the "*Guidelines and Specifications for Flood Hazard Mapping Partners" [April 2003]*. It states: ***"The assigned Mapping Partner must perform necessary field surveys to maintain vertical control, with all elevations referenced to the National Geodetic Vertical Datum of 1929 (NGVD29) or to the North American Vertical Datum of 1988 (NAVD88). The vertical datum may be either***

NGVD29 or NAVD88, but not mixed within a single Flood Map Project. FEMA recommends that all new Flood Map Projects be referenced to NAVD88."

Statement of Deficiency.

Access to the NGVD29 datum has not possible in Louisiana for over a decade. The FIS claims that all work related to FEMA DFIRM preparation was related to NAVD88. The record shows that it was impossible to obtain true NAVD88 during any phase of this project. The National Geodetic Survey, a division of the National Oceanic and Atmospheric Administration, and the agency responsible for maintaining geodetic control, reported to the U.S. Congress in 2001 that vertical control in Louisiana was unreliable and obsolete (www.ngs.noaa.gov/PUBS_LIB/NGS**report**_823.pdf). The ability of surveyors to again obtain NAVD88 heights did not become possible until the release of the local realization of NAVD88 (2004.65) in late 2005 (www.ngs.noaa.gov). In other words, timing relations demonstrate that it was impossible to access the National Spatial Reference System (NAVD88) in Louisiana at the time of the creation or QA-QC work of the LiDAR DEM. The timing of the accuracy assessment of the Terrebonne Parish LiDAR DEM occurred 2-3 years BEFORE NGS approved NAVD88 heights were possible in south Louisiana. NAVD88 was unavailable in the entire state during the accuracy assessment phase of the project. The effect of bad vertical control on the collection of LiDAR was pointed out in the Interagency Performance Review Team (IPET) report that examined the factors contributing to the flooding associated with Hurricane Katrina. Quoting from Chapter *III "Geodetic Vertical and Water Level Datum", p. III-56 III: "Finding: Various LIDAR mapping projects covering the region were not independently ground-truthed for absolute accuracy."* This section of the IPET report was penned by Mr. David Zilkoski, Director of the National Geodetic Survey. The IPET report can be located at:

https://ipet.wes.army.mil/NOHPP/_Post-Katrina/(IPET)%20Interagency%20Performance%20Evaluation%20TaskForce/Reports/IPET%20Report%202/Report%20by%20chapter/03%20III.%20Geodetic%20Vertical%20and%20Water%20Level%20Datum%20-%20IPET%20Report%202.pdf

To summarize, the LIDAR data and its derivatives as well as the QA/QC observations made by the assigned mapping partner was NEVER referenced to NAVD88 or NAVD88 (2004.65 or 2006.81). This is a clear violation of FEMA requirements. This also calls into question the validity of both the ADCIRC and wave modeling, activities that assume that topographic data are referenced to NAVD88.

ANALYSIS OF DATUM CONVERSION TECHNIQUES

Vertical Datum Conversion Tools Used in DFIRM Preparation

FEMA states on p. A-26 of the "*Guidelines and Specifications for Flood Hazard Mapping Partners"* [April 2003] that users can convert elevations referenced in NGVD29 to NAVD88 using the National Geodetic Survey program, VERTCON. FEMA's mapping partner followed this guideline in Terrebonne Parish. Quoting from page 14 of the FIS: ***"Some of the data used in this revision were taken from the prior effective FIS reports and FIRMs and adjusted to NAVD 88.The datum conversion factor from NGVD 29 to NAVD 88 in Terrebonne Parish is +0.06 feet."***

Statement of Deficiency.

FEMA inappropriately advocates the use of discredited tools to convert old and inaccurate NGVD29 data for inclusion in the DFIRM of Terrebonne Parish. The use of old and demonstrably inaccurate elevation data and tools in flood projects where public safety and property are involved is wrong both professionally and ethically. The method used by FEMA to "adjust" this outdated and bad data has been soundly rejected by Louisiana's largest professional group of surveyors and federal agency responsible for flood protection in the United States of America. Both the United States Corps of Engineers and the Louisiana Society of Professional Surveyors do not consider VERTCON and it derivative CORPSCON to be accurate enough to support engineering and design applications. United States Corps of Engineers states the following:

> *"Corpscon performs vertical conversions to and from the National Geodetic Vertical Datum of 1929 (NGVD 29) and the North American Vertical Datum of 1988 (NAVD 88). Vertical conversions are based on the NGS program Vertcon. However, use of Corpscon for vertical datum transformations in NOT AUTHORIZED for any work in south Louisiana"* --http://www.mvn.usace.army.mil/ed/edss/software.asp . The National Geodetic Survey explains that this is due to subsidence (see IPET report).

References to their exact positions can be found at:

- http://www.lapels.com/PDF/Journal1106.pdf
- http://www.mvn.usace.army.mil/ed/edss/faq.asp

ANALYSIS OF ACCURACY CLAIMS REGARDING TOPOGRAPHIC DATA

A Review of the Role and FEMA requirements of Lidar digital elevation models for ground elevations in the creation of DFIRMs.

Topographic data, specifically digital elevation data, are required by FEMA to facilitate hydrologic and hydraulic (H&H) modeling of watersheds and floodplains so that accurate Flood Insurance Rate Maps (FIRMs) can be produced for the National Flood Insurance Program (NFIP). These data are also essential for storm surge (ADCIRC) and wave modeling (STWAVE and WHAFIS) employed by FEMA in DFIRM preparation. The NFIP has specific requirements for digital elevation data produced by both ground- and aerial-survey methods. To this end, FEMA has set out specific requirements for accuracy and precision of DEMs in their document entitled, "Guidelines and Specifications for Flood Hazard Partners (Appendix A: Guidance for Aerial Mapping and Surveying (http://www.fema.gov/fhm/dl_cgs.shtm).

Review of FEMA Position Regarding the Quality of LiDAR DEM.

The most recent summary of FEMA's position is embodied in a January 12, 2009 letter to Mr. Paul Rainwater (Louisiana Recovery Authority, herein LRA). The letter states that, ***"LiDAR data collected as part of the Louisiana Statewide LiDAR Project was used as the elevation data for the FIS. This project is being funded by FEMA with matching funds and deliverables distribution provided by the State of Louisiana. The LiDAR systems being used in the Louisiana project are accurate to 15-30 cm RMSE, depending upon land cover, and support contours of 1'·2' vertical map accuracy standards. A previous review performed by the Louisiana State University and the Louisiana Oil Spill Coordinators Office of the Governor's Office concluded that the RMSE of checked points to be 11.51 cm. which is well within the***

project scope and FEMA G&S. The elevation dataset used for the FIS is the best available data for use in the parish wide analyses."

Statement of Deficiency.

The LiDAR elevation data used in the creation of DFIRMs are inaccurate and fail FEMA's own quality requirements. Furthermore, the accuracy of the LiDAR data was never actually determined and documented in Terrebonne Parish as is claimed by FEMA. The further claim made in the January 12, 2009 letter by FEMA is that Louisiana State University and the Louisiana Oil Spill Coordinators Office of the Governor's Office conducted an accuracy assessment of the data that prove the accuracy of the LiDAR data. The letter is in reality a misinterpretation of a poorly prepared, non-peer reviewed paper that contains no data that can support its conclusions. In fact, the cited report discussed the results of only one task order (out of 55 task orders in the state). The FEMA letter implies that it is representative of the entire state of Louisiana. This task order (Calcasieu Parish) was the ONLY area that passed FEMA requirements in the state. Examination of the record also shows that the LiDAR data collected for Terrebonne Parish were obtained during a time interval when the National Geodetic Survey had officially determined that it was impossible in Louisiana to make elevation measurements relative to NAVD88; the 2004.65 realization of NAVD88 is the datum currently required by FEMA. Furthermore, the accuracy assessment quoted by FEMA was from a different parish with different land cover characteristics and were obtained during a different year than the data collection for Terrebonne Parish. Thus, the LiDAR digital elevation model (DEM) used by FEMA as its primary source of ground elevation does not meet FEMA's own requirements for accuracy. It follows, therefore, that all derivative products such as the surge and wave modeling and mapping based on the LiDAR DEM must also be unreliable. It is concluded, therefore, that, because the LiDAR data are of unknown accuracy, they cannot logically be considered the "best available data."

Description of Deficiencies*:*

FEMA requires that the topographic data used in creation of DFIRMs be accurate. To that end, FEMA has described specific requirements to achieve that goal. To review, accuracy is defined as the closeness of a sample measurement to a valid reference standard or datum. FEMA requires that accuracy be determined relative to the current federal datums, i.e., NAVD88 (vertical) and NAD83 (horizontal). The current realizations of NAVD88 in Louisiana that are recognized by NGS/NOAA are designated 2004.65 and 2006.81.

The deficiency with regards to the accuracy of topographic data is manifest in several ways in materials put forth by FEMA to support the DFIRMs. Below, I cite numerous examples of how the Assigned Mapping Partner has violated FEMA's own requirements and basic professional standards in this matter:

- Lidar DEM used in ADCIRC models of DFIRM development do not pass QA/QC standards (described in FEMA Guidelines, Appendix A). The root of this problem is that insufficient sampling was performed and thus accuracy has NOT been proven (Fig.1). Because the uncertainty is not known, the LiDAR cannot be considered the "best available" but instead should be considered to be an "unknown quantity". The result is that the data should have never been accepted by FEMA. This deficiency is systemic

throughout the entire state of Louisiana. FEMA has violated its guidelines in every task order it has delivered as follows:

- ✓ From page A-46. ***"The Mapping Partner shall distribute sample points throughout each category area being evaluated and not group the sample points of the same type in a small sub-area."*** Figure 1 shows that sample points are clumped and not distributed as required. No samples from Terrebonne Parish were taken in the QA/QC study for Task Area 11.
- ✓ From page A-46. ***"The assigned Mapping Partner shall select a minimum of 20 test points for <u>each</u> major vegetation category identified. Therefore, a minimum of 60 test points shall be selected for three (minimum) major land cover categories, 80 test points for four major categories, and so on."*** LiDAR data of Terrebonne Parish are composed of data collected as part of Task Orders 6, 7, and 11. Table 1 summarizes these data.

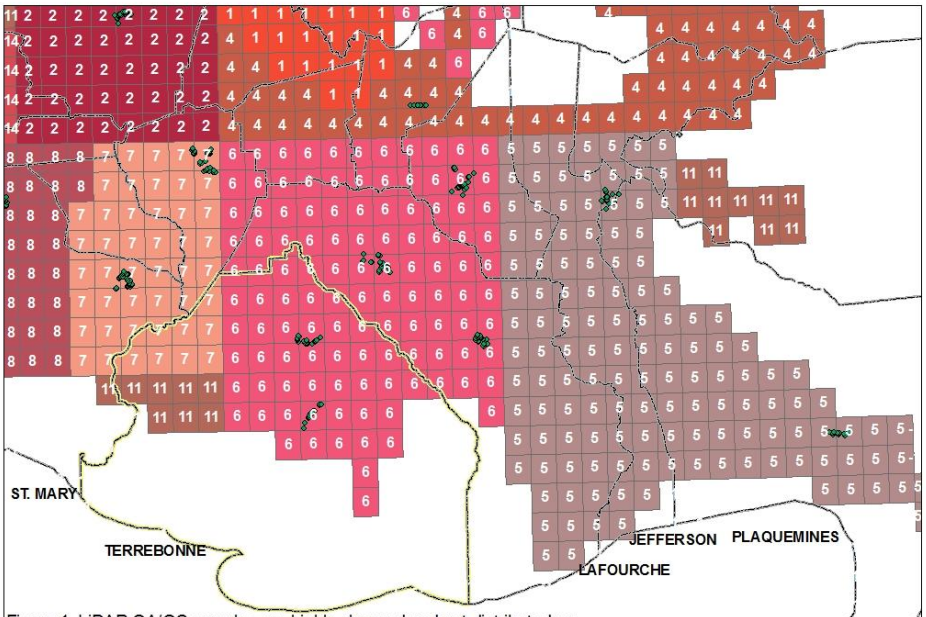


Figure 1. LiDAR QA/QC samples are highly clumped and not distributed as required by FEMA Guidelines Appendix A. White numbers identify specific task order. Clumping indicates that the samples are not random, a condition that must met if RMSE statistics are to be applied.

Task Order 6				
Category	*Number of Points*	*Average Error*	*RSME Feet*	*RSME CM*
Open Terrain	*64*	*0.27*	*0.53*	*16.03*
High Grass	*29*	*0.30*	*0.55*	*16.8*
Brush & low trees	*15*	*0.55*	*0.74*	*22.49*
Urban	*23*	*0.25*	*0.5*	*15.31*
Task Order 7				
Category	*Number of Points*	*Average Error*	*RSME Feet*	*RSME CM*
Open Terrain	*28*	*0.18*	*0.42*	*12.8*
High Grass	*13*	*0.17*	*0.41*	*12.5*

Brush & low trees	*9*	*1.09*	*1.04*	*31.84*
Forested	*12*	*0.47*	*0.68*	*20.99*
Urban	*16*	*0.1*	*0.03*	*9.44*
Task Order 11				
Category	*Number of Points*	*Average Error*	*RSME Feet*	*RSME CM*
Open Terrain	*21*	*0.2*	*0.45*	*13.8*
High Grass	*12*	*0.18*	*0.18*	*12.9*
Brush	*13*	*0.38*	*0.62*	*18.8*
Urban	*14*	*0.09*	*0.3*	*9.1*

Red = fails FEMA requirements for sample size

Table 1. Summary of Terrebonne Parish LiDAR QA/QC QA/QC Reports (Louisiana Oil Spill Coordinator's Office, 2003-2008; http:www.atlas.lsu.edu).

This table clearly shows that FEMA's assigned mapping partner did not collect the minimum 20 samples per category in Task Orders 6, 7, and 11 to satisfy FEMA's requirements. The lack of sufficient samples undermines FEMA application of the RMSE statistic.

- The assigned mapping partner has improved the accuracy statistics by inappropriately deleting data claimed to be outliers. FEMA guidelines (p. A-43) contend that any data that lies beyond errors exceeding the "3-sigma" level are outliers. To quote the FEMA guidelines," Statisticians almost unanimously agree that errors exceeding the "3-sigma" level are outliers; the "3-sigma" level provides confidence at the 99.75-percent confidence level, enabling only the worst 0.25percent of a dataset to be discarded as outliers." In Terrebonne Parish, FEMA has instead inexplicitly removed all data greater than 1.96-sigma. Without adequate proof that the offending observation is an outlier, deletion of outliers is not acceptable professional practice. In Terrebonne Parish, no explanation was provided. It is quite possible that the deleted data are likely not outliers, but instead the unintended result of insufficient sampling by FEMA. To remove an outlier, FEMA should have provided adequate reasons prompting deletion of data.
- It is common knowledge among scientists and statisticians that to apply the RSME statistic, errors, i.e., differences between "truth" and the LIDAR DEM pixel value, must be normally distributed. In my professional opinion, the Assigned Mapping Partners QA/QC analysis is so flawed that data collected are inadequate to test for normality. A properly designed accuracy assessment conducted for the protest demonstrates that the LIDAR DEM fails the test for normality and thus, invalidates FEMA claim regarding the use of the RSME statistic.
- FEMA and its mapping partners have also violated professional standards by allowing the use of unproven individual "bare earth" LIDAR elevations as input into WHAFIS modeling. FEMA requires ALL data to be proven. FEMA provides standards in its guidelines for the QA/QC of a DEM and TIN based on "bare earth" LIDAR points. However, FEMA provides no requirements for QA/QC of individual "bare earth" points and the mapping partner has not provided any independent test of their validity. Because the vertical accuracy of individual "bare earth" points are unproven, FEMA should have not allowed its use for the WHAFIS.

ANALYSIS OF FEMA'S CONTENTION THAT THE TOPOGRAPHIC DATA USED IN THE DFIRM PREPARATION ARE ACCURATE AND CONSTITUTE THE "BEST AVAILABLE".

FEMA contends that the LiDAR and USGS GAP and National Elevation Database (NED) topography for south Louisiana is accurate and constitutes the "best available" data. This is demonstrably NOT the case for Terrebonne Parish. For reasons stated above, FEMA has NOT proven that the original LIDAR DEM is accurate. In fact, the FIS points out that questions regarding the LIDAR were raised by federal agencies (NGS/NOAA) and FEMA-paid consultants; FEMA acknowledged in the FIS that the USGS NED data are substandard. To satisfy appeal requirements, better data has been generated and forwarded to Shaw Coastal, Inc. Its use will result in significant improvement of the FEMA DFIRMS. This is described below.

To meet FEMA requirements AND be considered the "best available", topographic data would have the following characteristics:

- Properly referred to the official, FEMA-sanctioned local realization of NAVD88 in Terrebonne Parish. This would be the 2004.65 realization of NAVD88 released by NGS. The 2006.81 realization could be used if FEMA had that requirement.
- The product used in the DFIRM modeling and mapping, e.g., DEM or TIN, would be validated using data tied to NAVD88 (2004.65) vertical control.
- The data would be sufficiently accurate to meet FEMA specifications.

The topographic data used by the Assigned Mapping Partner in Terrebonne Parish lack all of these characteristics. Above, I have proven that the LiDAR DEM used by FEMA is not referenced to NAVD88 (2004.65). In actuality, the original LiDAR data (please note distinction between "LIDAR DEM" and "LIDAR data") is not even referenced to NAVD88 because access to NAVD88 was unavailable to ALL users during the time when the collection and accuracy assessment of the LiDAR were performed. Instead, the FIS and the January 12, 2009 letter to Mr. Paul Rainwater (LRA) from FEMA make unsubstantiated claims regarding the accuracy of the LiDAR. Accuracy assessment study presented for Terrebonne Parish clearly does not meet FEMA requirements. Furthermore, the regional topographic data that support storm surge modeling of the parish is based on data of variable quality. The latter statement can be substantiated in a report issued in 2007 by FEMA and the USACE entitled, *"Flood Insurance Study: Southeastern Parishes, Louisiana (DRAFT) Intermediate Submission 1: Scoping and Data Review".*

The FEMA/USACE report explicitly points out that topographic and bathymetric data used by FEMA in all of southern Louisiana is not uniformly referenced to the NAVD88 datum realization for south Louisiana currently used by FEMA and USACE to assess flood risk and build hurricane protection, i.e., NAVD88 (2004.65). FEMA/USACE also implies that the existing topographic data cannot be improved. Quoting from p. 7 of the document:

"This study will reference water level data to NAVD88 (2004.65) and incorporate vertical data referenced to NAVD88 (2004.65) when feasible. Note that the topographic lidar data in Louisiana (http://atlas.lsu.edu/lidar/) and Mississippi (URS, 2006c) are available relative to NAVD88. Although some of these data have been mapped to NAVD88 (2004.65) in portions of Louisiana, the warping surface used to perform the transformation appears to be of insufficient quality to apply throughout Southern Louisiana. This is related to the fact that the

density of control points defined in the Interagency Performance Evaluation Taskforce (IPET) geodetic study (Garster et al., 2007) is not sufficient to reliably apply throughout the entire southern portion of the state (J. Suhayda, personal communication, 2007). Therefore, topographic values are applied using NAVD88 as the vertical reference throughout Louisiana and Mississippi. However differences between the NAVD88 and NAVD88 (2004.65) should be no more than 1.06 feet throughout Southern Louisiana (Garster et al., 2007). Applying current warping surfaces available for Southern Louisiana will lead to errors larger than this. Federal levees were incorporated using NAVD88 (2004.65) as the vertical datum because these were resurveyed and/or were adjusted to the new NAVD88 (2004.65) as part of the IPET study using reliable and sufficiently dense control points (Garster et al., 2007)."

Thus, FEMA admits that only the features of the south Louisiana landscape that are actually NAVD88 (2004.65) are the federal levees of the southeast part of the state. In Terrebonne Parish, FEMA has not certified any federal levees. FEMA effectively admits that topographic used for all aspects of DFIRM preparation in Terrebonne Parish are NOT NAVD88 (2004.65). Furthermore, the same report states that FEMA/USACE inserted data of unknown accuracy into areas of southwestern Louisiana where LiDAR were not available. I quote from p. 7 of that 2007 report,

"Note that at the time of this study, Atlas lidar coverage was not available for all of Southern Louisiana. These regions are shown on Figure 3-1. In small portions of western Southern Louisiana, east Texas, and to the west of Simmesport, Louisiana, 30-meter by 30-meter USGS NED data were used to fill the voids left by the Atlas lidar (http://gisdata.usgs.net/ned/). Though not as high resolution as the lidar data and with unknown accuracy, the NED data were the most comprehensive data available in these areas."

FEMA has also substituted non-orthometric, low-grade GIS height estimates based on USGS GAP land use maps. The This FEMA/USACE report states this clearly on their p. 7 that,

"Furthermore, Atlas lidar does not generally extend into many of the marshes and wetlands within Southern Louisiana as is detailed on Figure 3-1. In these regions, estimates of topographic and bathymetric depths have been applied based on USGS GAP land use maps which clearly define the coastal marshes (USGS, 2000). The land use maps were coupled with controlled marsh elevation approximations and adjacent water depth estimates relative to NAVD88 (2004.65). Marsh topography and water bathymetry was approximated based on nearby marshes where lidar data were available. The base of the marshland was assumed to be 0.80 meter above the NAVD88 (2004.65) geoid and the depth in water areas within the marsh was assumed to be 0.40 meter below the NAVD88 (2004.65) geoid. Nodal elevations were then set by tallying the number of marsh pixels and water pixels within the elements surrounding each node and finding an average value based on the elevation assumptions. Any errors created by assuming marsh elevations should not greatly affect the results due to the fact that the marshes have small elevation gradients, thus small inaccuracies in elevation data should not affect surge results considerably when the surge is large."

Aside from the obvious substitution of assumed bathymetry and topography data where real data are REQUIRED, the USGS has expressly stated that it does not stand behind the accuracy of the data for general or scientific purposes beyond the objectives of **their** project. Quoting from the June 2000 Final Report issued by the U.S. Department of the Interior, U.S. Geological Survey report entitled, A GAP ANALYSIS OF LOUISIANA (http://sabdata.cr.usgs.gov/sabnet/priv/net_pub_products/DOC/2000-02-0139.PDF),

"The major objectives of the project were to (1) produce GIS databases describing actual land cover type, terrestrial vertebrate species distributions, land stewardship, and land management status at a scale of 1:100,000, (2) identify land cover types and terrestrial vertebrate species that currently are not represented or are under-represented in areas managed for long-term maintenance of biodiversity, i.e., "gaps," and (3) facilitate cooperative development and use of information so that institutions, agencies, and private land owners may be more effective stewards of Louisiana's natural resources. The LA-GAP Project is a planning for biodiversity conservation in Louisiana."

To quote further from the official USGS metadata supplied with the product,

"Although these data have been processed successfully on a computer system at the BRD, no warranty expressed or implied is made regarding the accuracy or utility of the data on any other system or for general or scientific purposes, nor shall the act of distribution constitute any such warranty".

By using the Louisiana Gap data to infer marshes and wetlands topography of south Louisiana, the assigned mapping partners of FEMA may have introduced seriously deficient data into their DFIRM analysis of Terrebonne Parish. This was done despite published warnings by the USGS to avoid using their data in a manner for which it was never intended. In my professional opinion, it seems inescapable to conclude that elevation data that has gone into such important aspects of the DFIRM analysis have done so without the direct involvement or overview of a professional licensed surveyor or geodesist.

Conclusion Regarding the FEMA's Contention That Their Topographic Data are the "Best Available"

In my professional opinion based on the paper trail left by their own assigned mapping partners, FEMA has not met their own fundamental requirements for data accuracy that underpin DFIRM preparation. Because ALL topographic data pertaining to Terrebonne Parish were never properly related to NAVD88, the accuracy of the topographic products utilized by the assigned mapping partners are effectively unknown. Therefore, because the data are of unknown accuracy, the concept of "Best" available cannot be applied in this context. This is because:

- The word "best" implies that a comparison with something else has taken place and that a known reference was used in the comparison; and
- No other data of better quality are known to exist or that could be reasonably obtained to support the project.

On the last topic of whether data of better quality could have been reasonably obtained to support the FEMA project, the above quotations clearly state the FEMA/USACE position that

the topographic products could not/cannot be improved. Their justification was apparently three-fold:

- A purported quote from Dr. Suhayda where he is said to have claimed that vertical control in south Louisiana was inadequate to re-adjust the LiDAR to their correct positions relative to NAVD88. Dr. Suhayda has read this passage and has denied to me that he explicitly or implicitly advised FEMA or the USACE regarding the feasibility that any particular remedy could make the LiDAR more accurate. According to Dr. Suhayda (personal communication, March 15, 2009), what he did say said at the time was that the LiDAR topography was too inaccurate to be used for realistic ADCIRC modeling for the assessment of flood risk. He advocated the collection of new ground control points using GPS derived orthometric heights tied to the then newly calibrated NAVD88 (2004.65) benchmarks and new CORS stations so that an adjustment and improvement of the LiDAR could occur. He also stated to me that he warned the ADCIRC team at the time that the topographic issue would greatly impair the projects dealing with upcoming DFIRMs and 100-year flood protection.
- The unsupported argument regarding the feasibility of improving the Lidar products based on the density of accurate vertical control. This is absurd. Such an improvement of the LiDAR topographic data for Terrebonne Parish has been accomplished in support of this appeal (see below).
- Again quoting from report issued in 2007 by FEMA and the USACE entitled, *"Flood Insurance Study: Southeastern Parishes, Louisiana (DRAFT) Intermediate Submission 1: Scoping and Data Review".*

  "There are, however, some regions of southern Louisiana that have been identified as possibly having larger errors. Dokka (2006a and 2006b) found that less than 90 percent of the sampled points were accurate within +/- 0.8 foot. These areas, which are located throughout the state, especially in the Atchafalaya flood basin, were discovered using preliminary analyses which compare the lidar data to high precision Global Positioning System (GPS) measurements including portions of the Atchafalaya flood basin (Dokka, 2006a and 2006b). In addition, questions remain as to whether additional errors are occurring due to the lack of consistency of the vertical datum used as well as because of the ever-changing datum itself over time. The Atlas lidar data were referenced to NAVD88 which has changed in time. The IPET study established NAVD88 (2004.65) and made localized adjustments to the Atlas data in the New Orleans metropolitan region and for Plaquemines Parish. Control points that were established have been applied for this and a mapping or so-called warping surface for Southern Louisiana as a whole has been developed. It was found that the density of the control points was such that the warping surface was based extensively on either poorly interpolated regions or regions that were extrapolated. The resulting adjusted topography showed unrealistic features with extensive regions having errors that were larger than the differences between NAVD88 and NAVD88 (2004.65) at the control points themselves. Therefore, the original NAVD88 datum for the Atlas lidar data was retained".

- The addition of better, more accurate data caused their model to malfunction. Instead of working the problem, it was declared that testing and transformation of the LiDAR data

would not be attempted and declared the existing LiDAR to be the "best available" data and quickly moved on even though concerns raised by the review team remained. It is indeed strange that FEMA/USACE never considered obvious alternative explanations such as:

- ✓ Their proposed transformation of the LiDAR data was wrong.
- ✓ The ADCIRC model has problems.
- ✓ Something else is awry.

In short, all topographic data used in the creation of DFIRMs in Terrebonne Parish are of unknown quality and thus fail to meet FEMA guidelines. Next, I present the results of an assessment to test accuracy of the LiDAR DEM in Terrebonne Parish.

BETTER TOPOGRAPHIC DATA FOR TERREBONNE PARISH

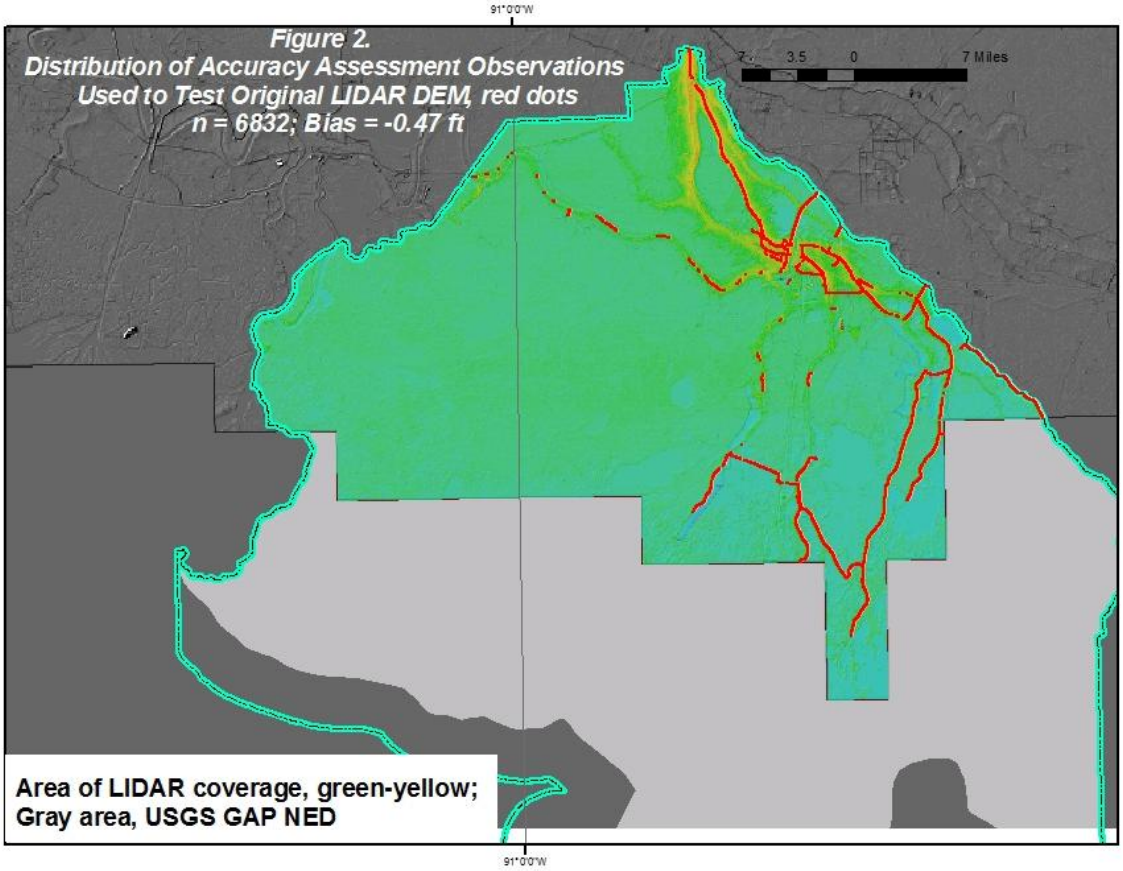
Independent Testing of the Accuracy of Terrebonne Parish LiDAR DEM

Independent height measurements of the ground in Terrebonne Parish were made with respect to NAVD88 (2004.65 and 2006.81) were made using real-time GPS technology. All measurements were made using the LSU Center for Geoinformatics Network RTN System. The system is based on Trimble's VRS™ (Virtual Reference Station) system technology and uses the RTK solutions from the Trimble® RTKNet software to provide high-accuracy, real-time kinematic (RTK) GPS positioning for south Louisiana. The foundation of the system is the LSU GULFNet, a group of GPS-based reference stations that are recognized by the National Geodetic Survey as National CORS sites. Calibration of the system shows that the horizontal error is ~1 cm and vertical error is 2 cm vertical anywhere in the network. The VRS system is made up of the latest in GPS hardware, modeling and networking software, plus communications interfacing. Survey-grade GPS receivers operating in RTK roving mode were used in the field. Samples included asphalt and concrete roads composed of materials of unequivocal LiDAR return characteristics. All work was checked and validated by a professional land surveyor licensed in the State of Louisiana (see Appendix).

Field measurements were made using a vehicle-mounted configuration. A magnetic roof mount centered between all four tires was used. The HI, i.e., the vertical distance from the base of the antenna to the ground, was measured using a tape, level, and plumb-bob. Samples were taken every 50 ft. where possible.

Measurement uncertainties estimated using static surveys, i.e., no motion, where sampling conditions comparable to actual measurements were simulated. However, instead of kinematic sampling, the antenna remained stationary for an extended period. Repeated static testing shows that the accuracy of the measurements is within ±3/10ths of a foot of its true value. The lateral coordinates are within ±1/10th of a foot of its true value.

Over 6832 height observations were made on major roads of Terrebonne Parish (Fig. 2). All data were adjusted with measurements from all NAVD88 (2004.65) benchmarks in Terrebonne Parish. The data were then compared to the original LiDAR DEM of Terrebonne Parish. The DEM was obtained from the official public access site for the Louisiana Oil Spill Coordinator's Office (FEMA's partner in the Louisiana LiDAR project) at www.atlas.lsu.edu. The panels were first mosaiked and edge-matched. The elevation values for each LiDAR pixel that was coextensive with our observations were extracted and compared with our NAVD88 (2004.65) value.



- The results of the study show that 97.9% of the samples fall within +/-1.2 ft. of the true NAVD88 (2004.65) value. The mean error is -0.47 ft (12.4 cm) and is interpreted as the bias in the LiDAR DEM. In other words, the LiDAR DEM is about 0.47 ft (14.3 cm) too high everywhere in Terrebonne Parish; this likely reflects the error in the vertical control in the parish at the time when original LiDAR data was collected. Although the average error of the LiDAR DEM passes the minimum 95% requirement, the DEM unfortunately fails the variance requirement spelled out by FEMA. Analysis of the errors ("truth" minus the LiDAR DEM value) shows that the errors are not normally distributed as also required by FEMA. Analysis of the errors is provided below and shows that the errors fail the common test for normality (Kolmogorov-Smirnov). This is a requirement for the application of the RMSE statistic that FEMA requires to prove accuracy. In other words, the average error may be modest, but the variability of the errors are too large to be explained by the statistical model used by FEMA. Thus, the RMSE statistics computed by the Assigned Mapping Partner are invalid measures of the quality of the LIDAR DEM. The data should not have been accepted by FEMA and offered to its contractors for use in the construction of DFIRMs of Terrebonne Parish.

Normality Test (Kolmogorov-Smirnov) Sunday, September 06, 2009, 10:22:37 AM

Data source: Excel1 in Extract_TerrebonneRDS.xls

Column S: K-S Dist. = 0.115 P < 0.001 Failed

A test that fails indicates that the data varies significantly from the pattern expected if the data was drawn from a population with a normal distribution.
A test that passes indicates that the data matches the pattern expected if the data was drawn from a population with a normal distribution.

Improvement of the Terrebonne LiDAR DEM

A strategy for improving the LiDAR data for Terrebonne Parish by removing the -0.47 ft (-14.3 cm) bias resulted in a product that is significantly improved over the original DEM. **This strategy also allowed the LiDAR data to finally be referenced to NAVD88 (2004.65).** The procedure removed the bias by adding -0.47 ft (-14.3 cm) to each pixel of the original DEM. This improved DEM is named Terr_impDEM. In effect, I moved the error distribution -0.47 ft, and if correct, the difference between the improved LiDAR and new test points collected during the validation step should have a mean near zero. To validate the new DEM, an extensive sampling schema was developed that resulted in the collection of 18,390 new samples (Fig. 3). Only new data were included in the new accuracy assessment. The mean error associated with the improved DEM is +0.13 ft (4 cm). In contrast to the FEMA study where data were deleted, no outliers of any magnitude were removed in our effort. The accuracy assessment showed that 97.4% of the improved LiDAR DEM is accurate. Unfortunately, analysis showed that the distribution of the errors was not normally distributed. However, a plausible explanation for this emerges by noting that the distribution of errors is skewed toward lower numbers; such a skewed distribution is due to an over abundance of positively-signed errors.

Normality Test (Kolmogorov-Smirnov) Sunday, September 06, 2009, 2:42:53 PM

Data source: Excel1 in Extr_TerVAL.xls

Column S: K-S Dist. = 0.064 P < 0.001 Failed

A test that fails indicates that the data varies significantly from the pattern expected if the data was drawn from a population with a normal distribution.
A test that passes indicates that the data matches the pattern expected if the data was drawn from a population with a normal distribution.

It is proposed that our elevation data are skewed due to sampling bias. Road improvements in Terrebonne Parish during the last several years resulted in raising the elevations of many miles of major roadways in the parish while other lesser roads were not improved (personal communication, Al Levron, 2009, Parish Manager). Because my sampling focused on major roadways where greater positive elevation change occurred, the resulting error distribution contains an inordinately high number of positively-signed errors. Such a situation would be expected if test sampling emphasized improved (raised) roads over unimproved roads.

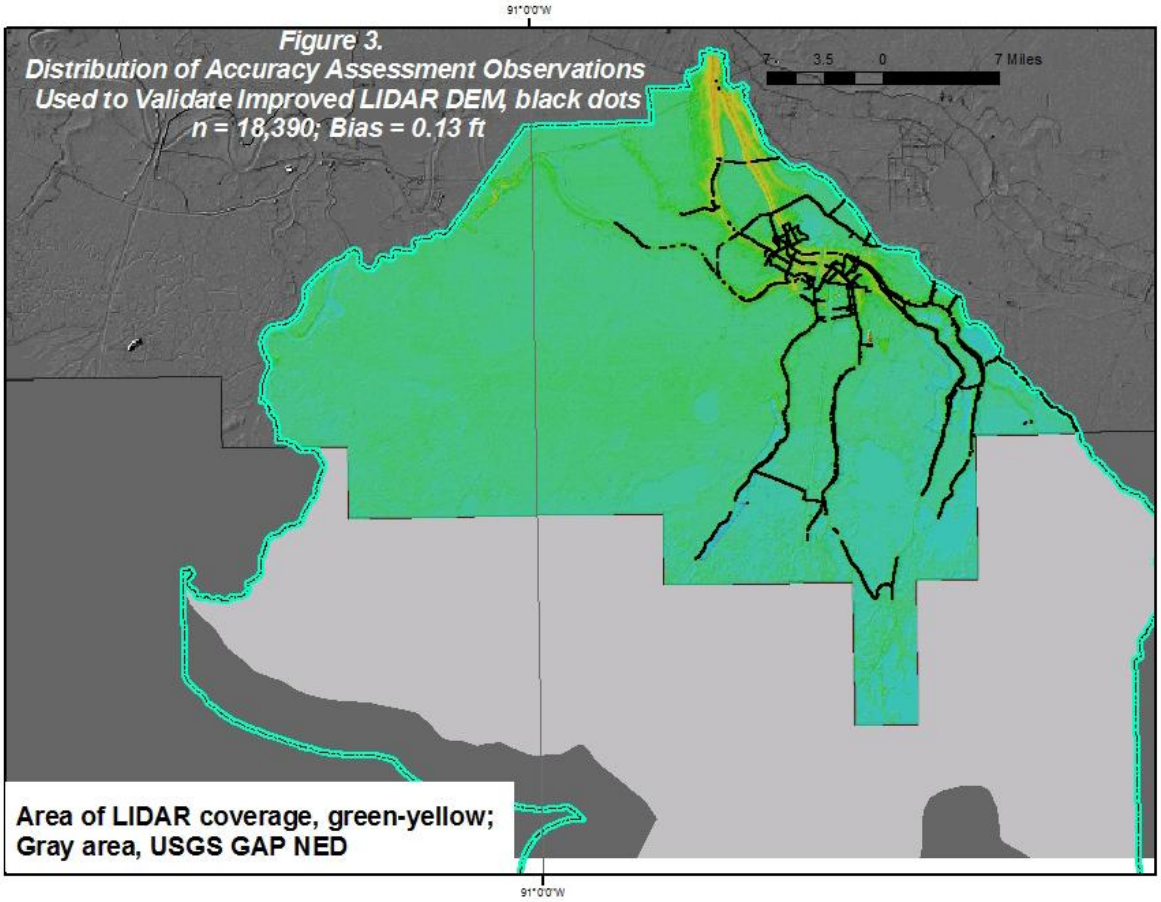


Figure 3. Map showing location of samples used to test the improved LiDAR DEM of Terrebonne Parish, LA. The number of observation was 18,390. See text for explanation.

ASSESSMENT OF THE SPATIAL ACCURACY OF THE WEIRS USED IN FEMA ADCIRC MODELS

FEMA has in part based its DFIRMs on a series of numerical models that attempt to simulate flooding and waves under specified conditions, i.e., hurricanes. The models are based on equations that require inputs of topography, bathymetry, surface friction, barriers, etc. in order to estimate desired physical parameters. The model utilized by FEMA for storm surge simulation is the Advanced Circulation (ADCIRC). ADCIRC requires a topo/bathy dataset commonly called, a "grid" to function. The grid is supposed to depict the true shape and height of the surface of the Earth, both on the land (topography) and below the oceans and lakes. The grid must also accurately render the location, geometry, and height of man-made structures that help control the flow of water during floods. These features are often referred to as weirs and include levees, floodwalls, sheetpiles, spoil banks, roads, railroad beds, etc. For this project, FEMA's modelers used a dataset that is commonly called the "SL15" grid. Unfortunately, comparison of spatial location and height of the weirs, i.e., barriers to the flow of water, used by FEMA in their models with actual measurements tied directly to NAVD88 (2004.65) in Terrebonne Parish shows that critical features of the SL15 grid are grossly inaccurate and not representative of reality.

Furthermore, the grid has also omitted a number of coastal features and elevated roadways that act as weirs during storms. Below, these features are described.

Coastal Features and Elevated Roadways That Should be Included in Models

Figure 4 shows the location of coastal features and elevated roadways that should be included in ADCIRC grid for storm surge modeling. Please refer to the section of the protest document on new ADCIRC modeling for specific locations of proposed new weirs as well as their effect.

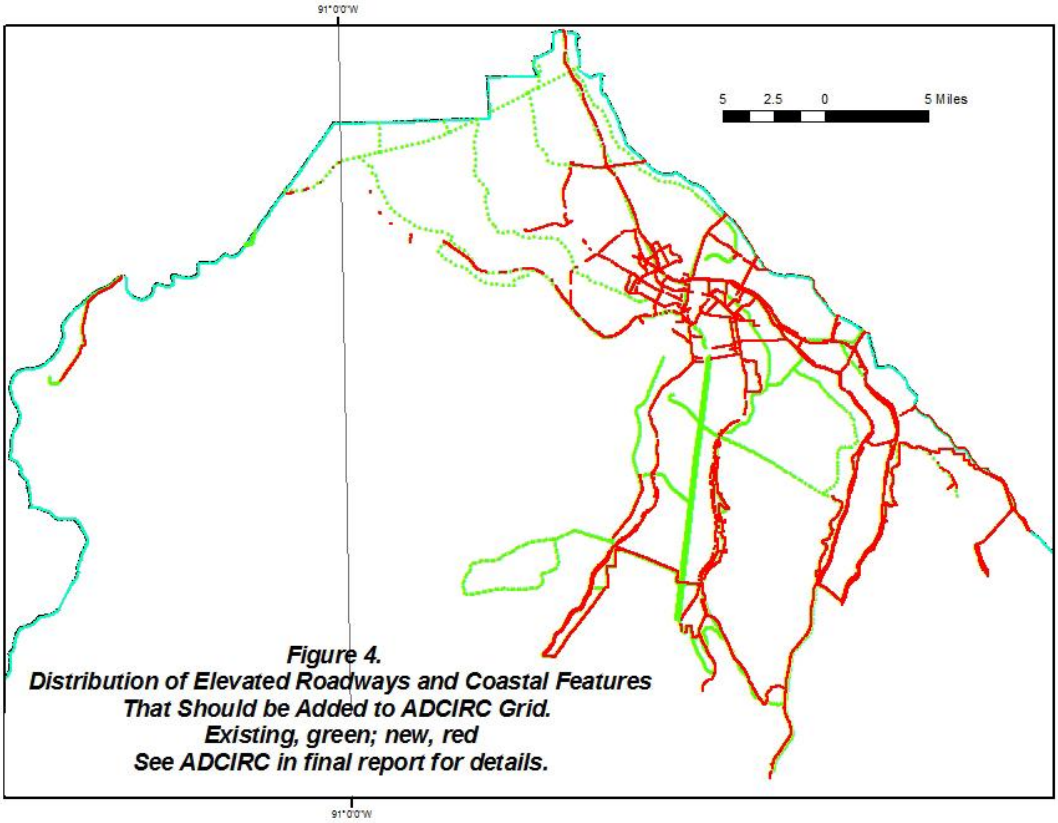


Figure 4.
Distribution of Elevated Roadways and Coastal Features
That Should be Added to ADCIRC Grid.
Existing, green; new, red
See ADCIRC in final report for details.

Examples of Mis-Located Weirs in the ADCIRC Grid

In several places, FEMA does not include or accurately depict features that function as weirs during storm surges. These include weirs within the Parish as well as in adjacent areas that impact surge effects in the parish. The latter includes the levees of the South Lafourche Levee District that offer substantial mitigation of surges coming from the east.

Examples of localities where the FEMA weirs are mis-located in the ADCIRC grid are provided below in Figure 5. Where place names are lacking, streets are shown to help in location.

Figure 5. Examples of mislocated weirs in the ADCIRC grid of Terrebonne Parish.

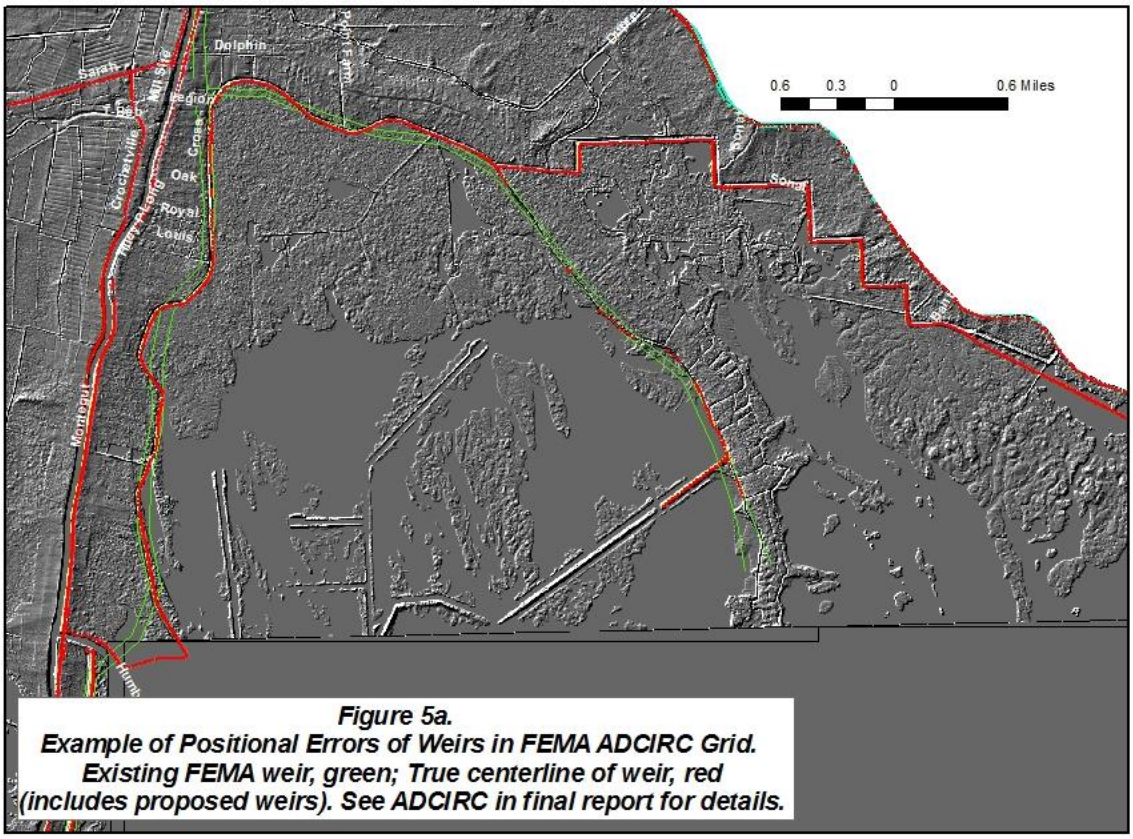


Figure 5a.
Example of Positional Errors of Weirs in FEMA ADCIRC Grid.
Existing FEMA weir, green; True centerline of weir, red
(includes proposed weirs). See ADCIRC in final report for details.

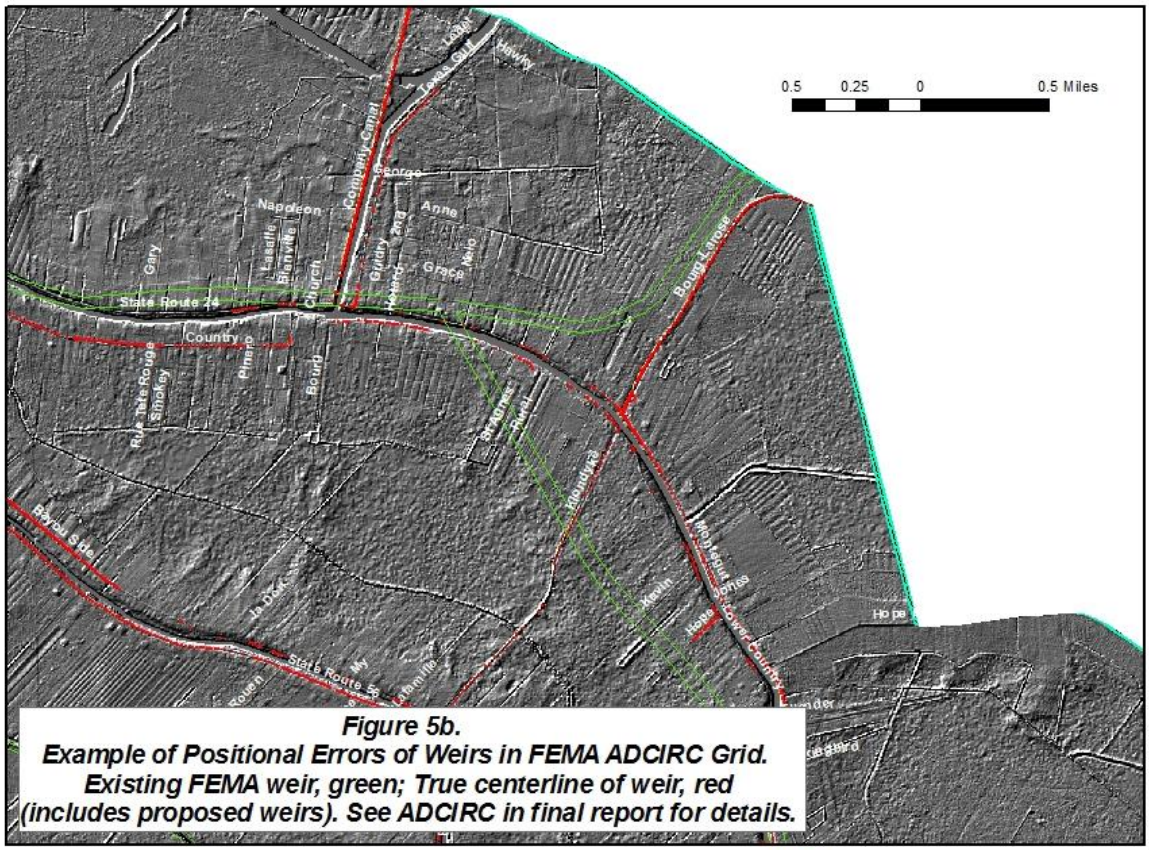


Figure 5b.
Example of Positional Errors of Weirs in FEMA ADCIRC Grid.
Existing FEMA weir, green; True centerline of weir, red
(includes proposed weirs). See ADCIRC in final report for details.

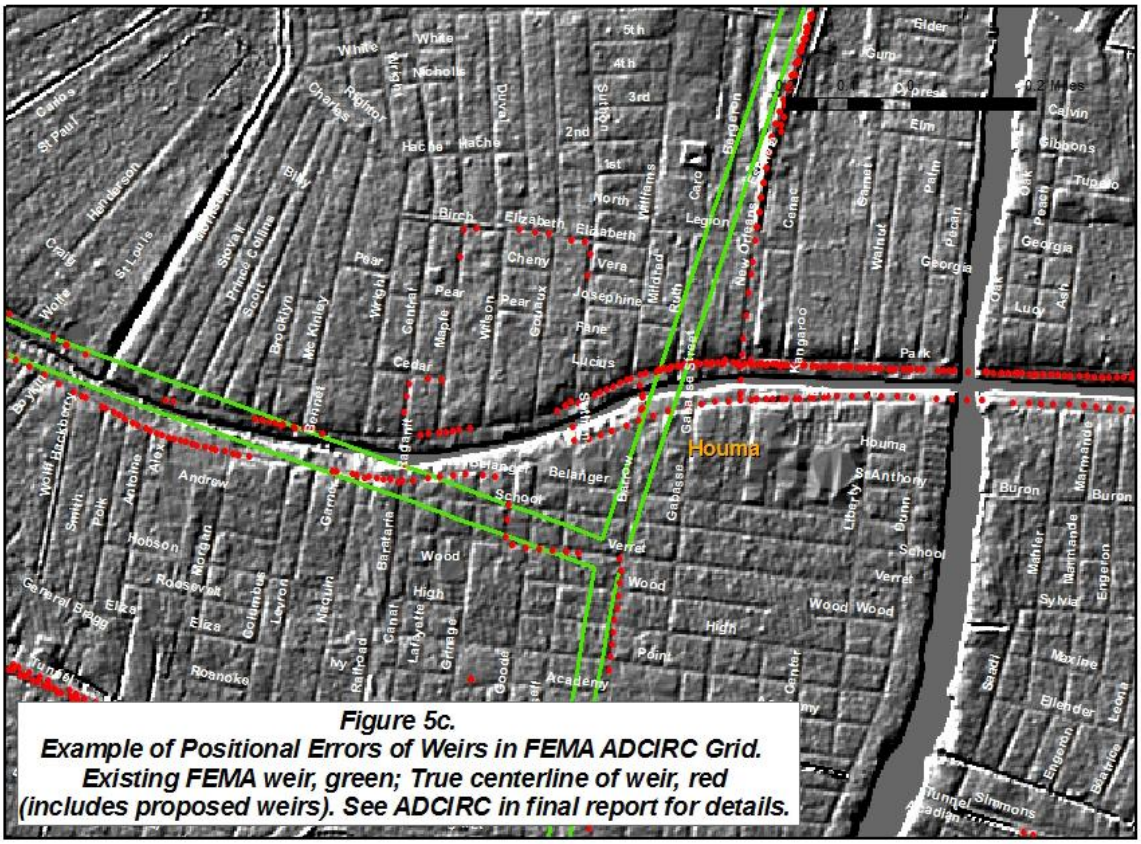


Figure 5c.
Example of Positional Errors of Weirs in FEMA ADCIRC Grid.
Existing FEMA weir, green; True centerline of weir, red
(includes proposed weirs). See ADCIRC in final report for details.

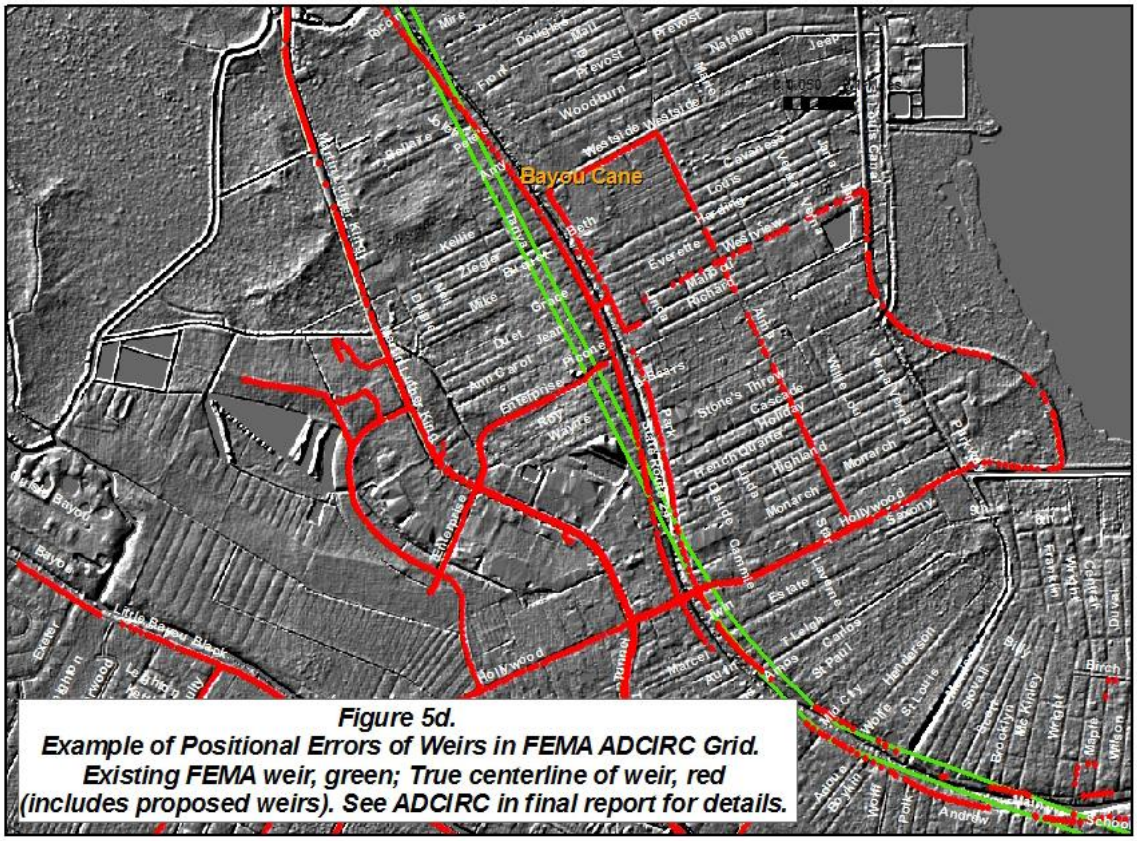


Figure 5d.
Example of Positional Errors of Weirs in FEMA ADCIRC Grid.
Existing FEMA weir, green; True centerline of weir, red
(includes proposed weirs). See ADCIRC in final report for details.

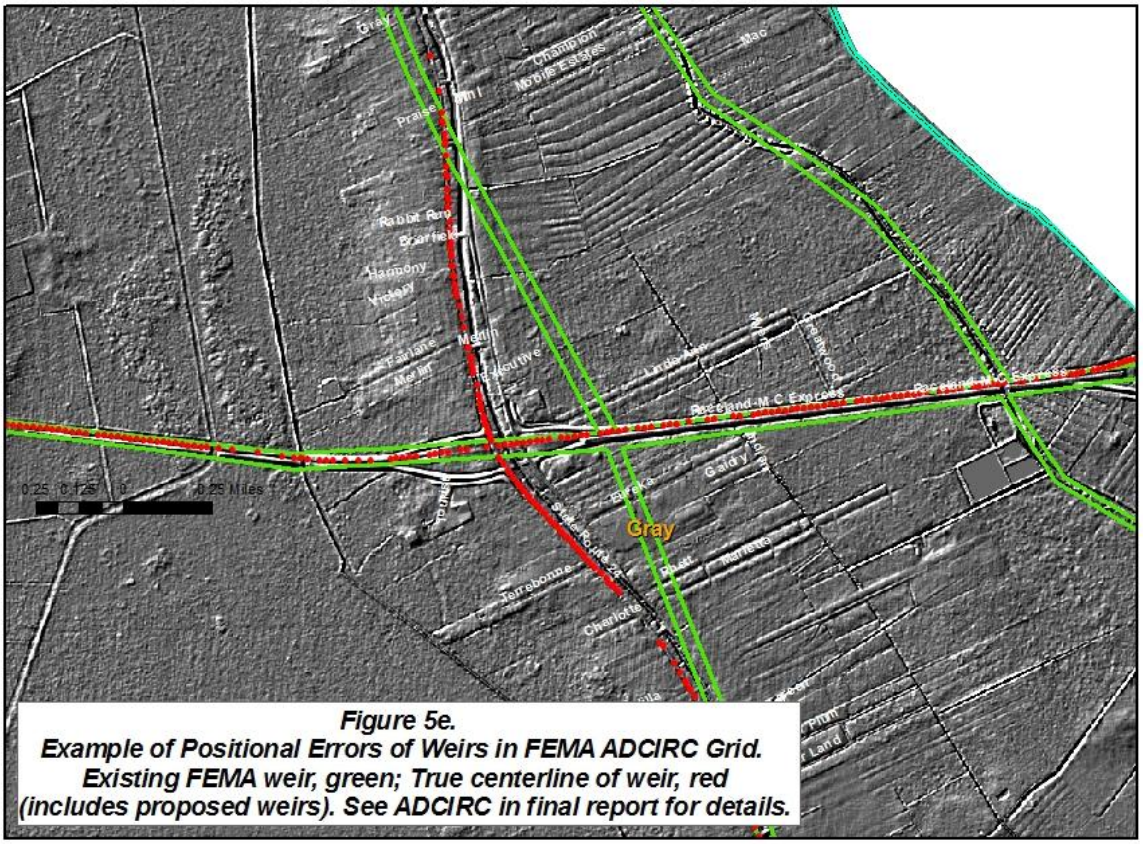


Figure 5e.
Example of Positional Errors of Weirs in FEMA ADCIRC Grid.
Existing FEMA weir, green; True centerline of weir, red
(includes proposed weirs). See ADCIRC in final report for details.

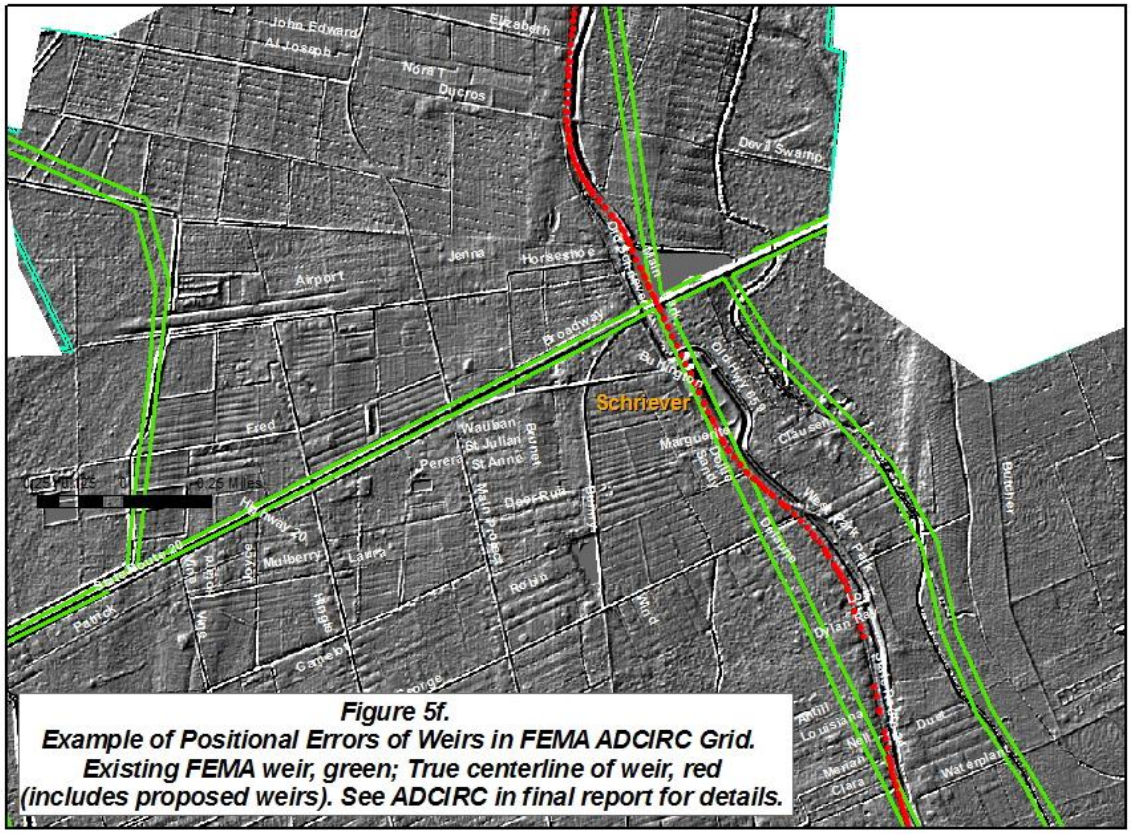


Figure 5f.
Example of Positional Errors of Weirs in FEMA ADCIRC Grid.
Existing FEMA weir, green; True centerline of weir, red
(includes proposed weirs). See ADCIRC in final report for details.

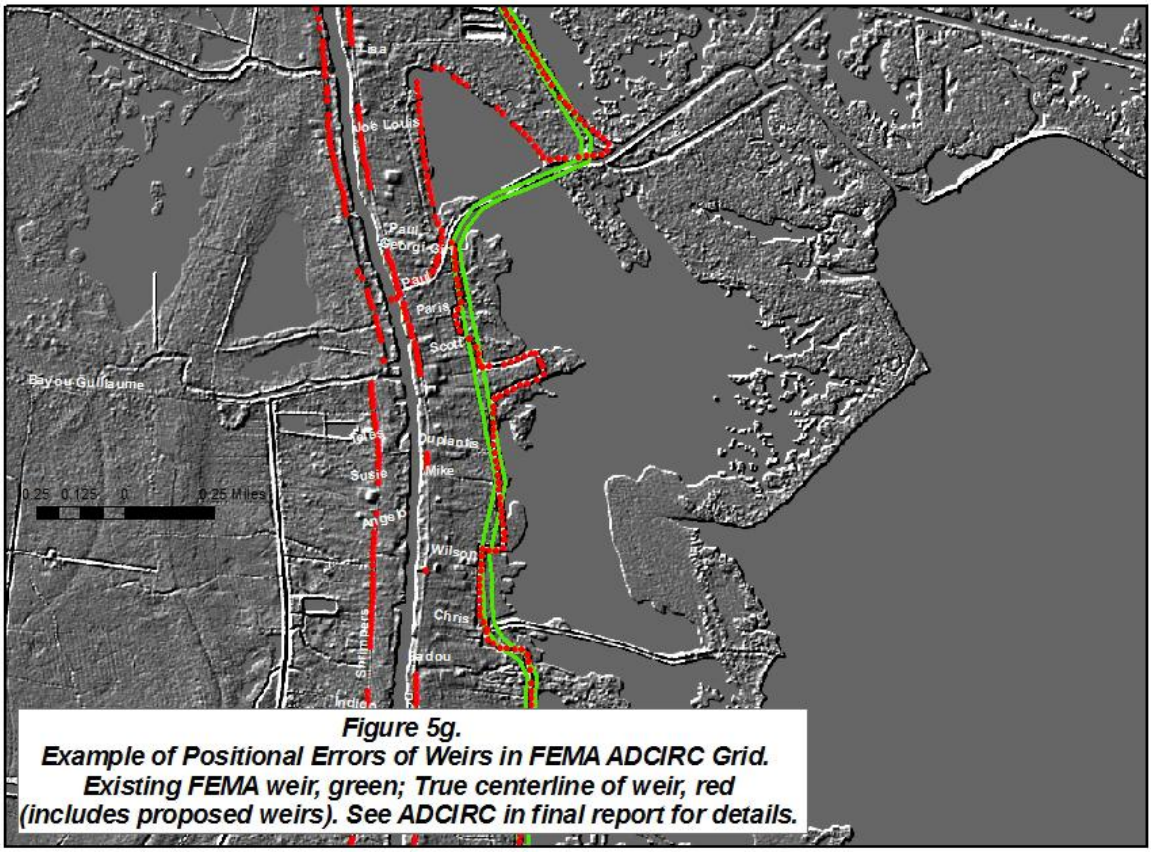


Figure 5g.
Example of Positional Errors of Weirs in FEMA ADCIRC Grid.
Existing FEMA weir, green; True centerline of weir, red
(includes proposed weirs). See ADCIRC in final report for details.

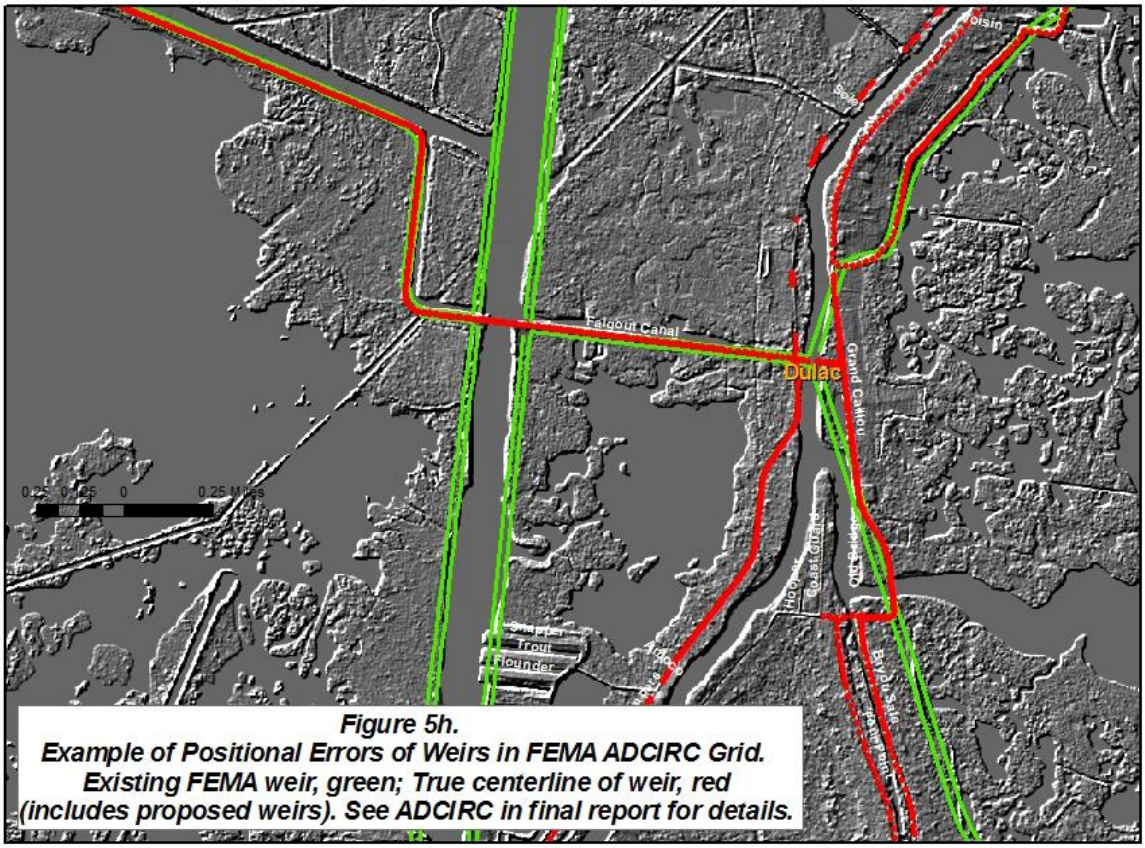


Figure 5h.
Example of Positional Errors of Weirs in FEMA ADCIRC Grid.
Existing FEMA weir, green; True centerline of weir, red
(includes proposed weirs). See ADCIRC in final report for details.

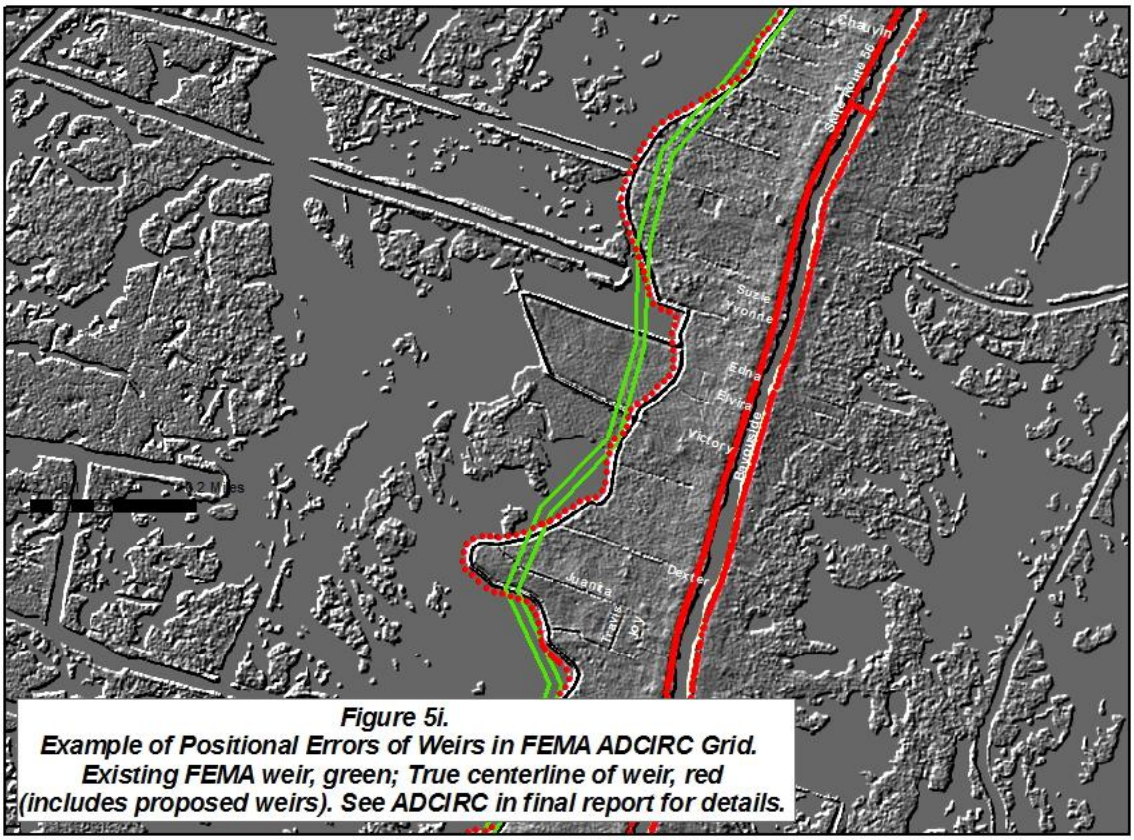


Figure 5i.
Example of Positional Errors of Weirs in FEMA ADCIRC Grid.
Existing FEMA weir, green; True centerline of weir, red
(includes proposed weirs). See ADCIRC in final report for details.

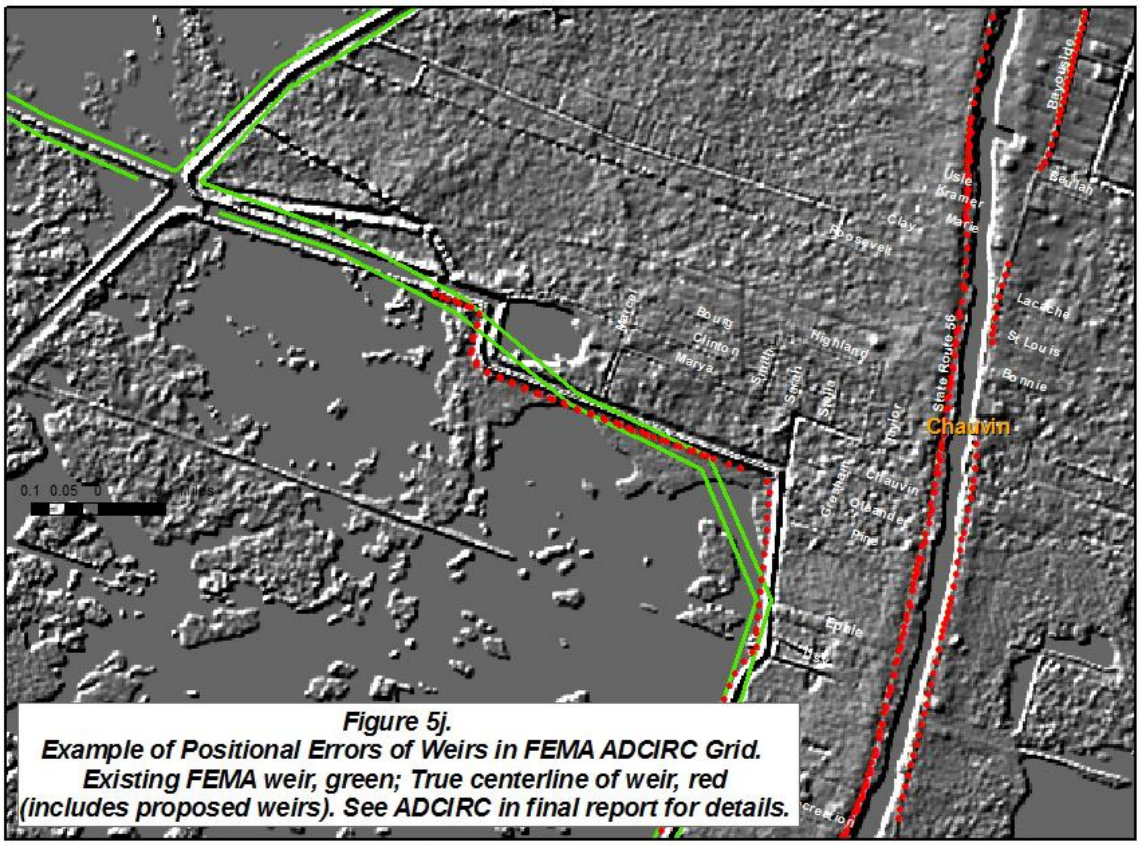


Figure 5j.
Example of Positional Errors of Weirs in FEMA ADCIRC Grid.
Existing FEMA weir, green; True centerline of weir, red
(includes proposed weirs). See ADCIRC in final report for details.

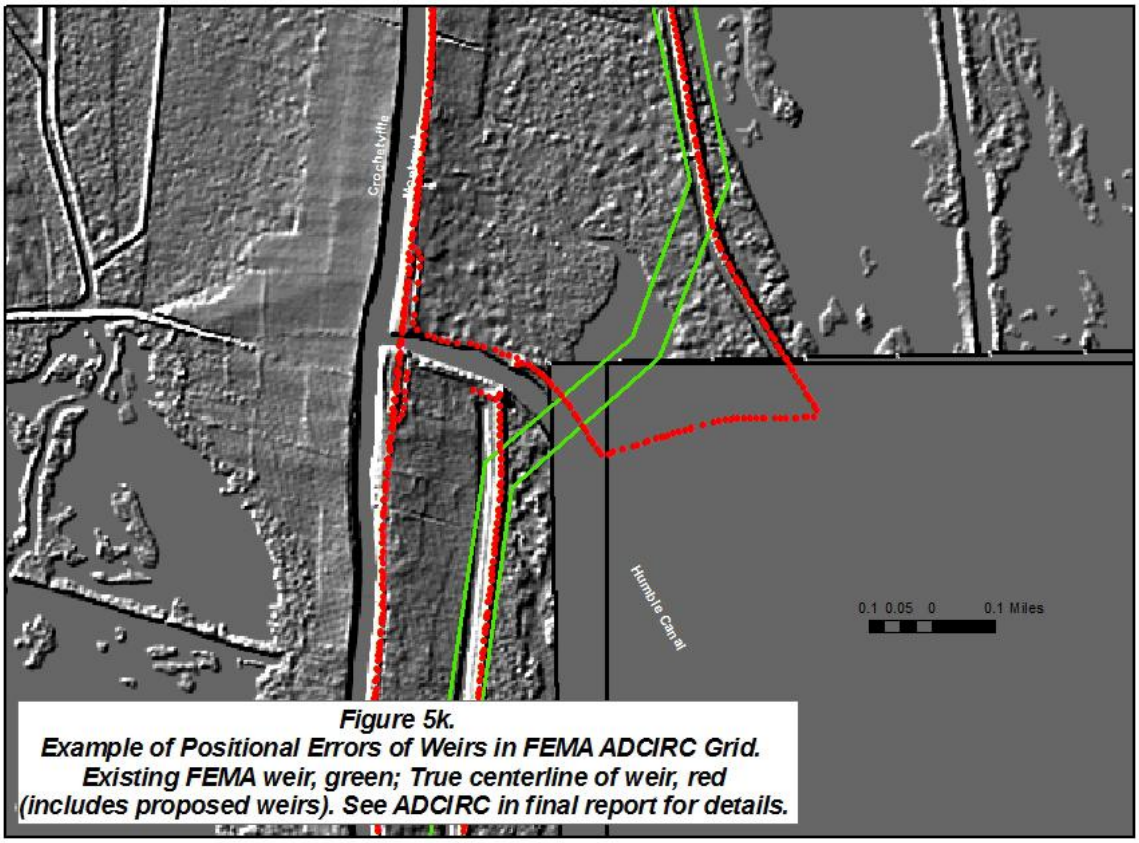


Figure 5k.
Example of Positional Errors of Weirs in FEMA ADCIRC Grid.
Existing FEMA weir, green; True centerline of weir, red
(includes proposed weirs). See ADCIRC in final report for details.

APPENDIX A. List of GIS files supplied to Shaw Coastal, Inc. under this report.

- TerrebonneDEM -- Obtained from www.atlas.lsu.edu
- Extract_TerrebonneRDS -- Data collected to test original LIDAR DEM (Terr_impDEM) of Terrebonne Parish.
- Terr_impDEM -- Improved LIDAR DEM of Terrebonne Parish.
- Extr_TerVAL -- Data collected to test improved LIDAR DEM (Terr_impDEM) of Terrebonne Parish.
- BM_Terre_2006_81_UTM -- Current inventory of valid NAVD88 vertical control in Terrebonne Parish.
- TerrebonneFEMA_BMs – Benchmarks included in Terrebonne Parish DFIRMs.
- LafourcheTerrebonneNATE -- Data on proposed weirs of Terrebonne and Lafourche Parishes.

APPENDIX B. Surveyors Report.

J. Anthony Cavell, PLS, CFedS

Terrebonne Parish Benchmarks Calibration

I was asked by Roy K. Dokka, Ph. D. to establish horizontal translation and vertical adjustment to be used for expressing, in the 2006.81 realization of the North American Vertical Datum of 1988 (NAVD88) by the National Geodetic Survey (NGS), the results of a study that utilized the LSU C4G GULFNet Real-Time System (GRTS). The GRTS uses a Virtual Reference System (VRS) process to provide Real-Time Kinematic (RTK) base data to "rover" users over the Internet, typically using a cellular phone connection. The desired vertical precision of the study is better than 5 cm.

Current best practices for measuring a VRS RTK observed control point include the use of a single averaged window solution, which can significantly improve the levels of accuracy compared with a single epoch network RTK solution. Testing has determined that RMS errors can be reduced by about 5 mm, particularly in the Up component, through the adoption of the mean of two 3-minute averaged windows separated by 20 minutes and not to yield significant improvement beyond 45 minutes.

Shortly after the 2005 hurricanes, NGS validated a few benchmarks in southern Louisiana. The realization was labeled 2004.65. Later in 2006 FEMA paid for revalidating about 300 benchmarks several of which are located in Terrebonne Parish. This realization is labeled 2006.81

In general, I found about a one cm vertical difference with a slight slope in the difference from southeast to northwest. The 2006.81 results are lower than the GRTS results. Details of the calculations are contained in the appended report. Consistency of the calibration/localization was about 24 mm horizontally and 35 mm vertically. Additionally the accuracy of the geoid model, Geoid03 (2.4 cm RMS) must also be considered. The geoid model is required to derive orthometric height (elevation) values from GPS observations. Application of the calibration/localization permits expression of GRTS data in the parish in terms of the 2006.81 realization of NAVD88 with the desired precision.

Horizontal Parameters

Northing coordinate of center	113396.686m
Easting coordinate of center	1057544.574m
Rotation about the center point	0°00'00"
Translation north	-0.006m
Translation east	-0.004m
Scale factor	1.00000000

Vertical Parameters

Northing coordinate of origin	129763.600m
Easting coordinate of origin	1054128.473m
Vertical separation at origin	0.007m
Slope north	-0.489ppm
Slope east	0.400ppm

J. Anthony Cavell, PLS, CFedS
September 7, 2009

GPS Calibration Report

Project : 681Terrebonne

User name	JA Cavell	**Date & Time**	8:20:04 PM 9/9/2009
Coordinate System	Site	**Zone**	Louisiana South 1702
Project Datum	NAD 1983 (Conus)		
Vertical Datum	NAVD 1988	**Geoid Model**	GEOID03 Map7 (Rev 2005)(2)
Coordinate Units	Meters		
Distance Units	Meters		
Height Units	Meters		

Contents

- Datum Transformation Parameters
- Updated Default Projection Definition
- Horizontal Adjustment Parameters
- Vertical Adjustment Parameters
- Geoid Model Definition
- Residual Differences Between GPS And Known Coordinates

Datum Transformation Parameters

Datum Transformation computation not requested

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Updated Default Projection (Transverse Mercator) Definition

Updated default projection not requested

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Horizontal Adjustment Parameters

Northing coordinate of rotation center	113396.686m
Easting coordinate of rotation center	1057544.574m
Rotation about the center point	0°00'00"
Translation north	-0.006m
Translation east	-0.004m
Scale factor	1.00000000

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Vertical Adjustment Parameters

Northing coordinate of origin point	129763.600m
Easting coordinate of origin point	1054128.473m
Vertical separation at origin	0.007m
Slope north	-0.489ppm
Slope east	0.400ppm

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Geoid Model Definition

GEOID03 Map7 (Rev 2005)(2)

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Residual Differences Between GPS And Known Coordinates

Summary

	Maximum error	Root Mean Square error	Point
Horizontal	0.041m	0.024	S 233-a
Vertical	0.065m	0.035	DUB 11-a
Three-dimensional	0.074m	0.043	DUB 11-a

Point Residuals

GPS point		Calculated point		Control point	
Point	NBTB 11-a	Northing	129763.600m	Point	NBTB 11
Latitude	29°40'10.14867"N	Easting	1054128.473m	Northing	129763.622m
Longitude	90°46'26.92460"W	Elevation	2.780m	Easting	1054128.449m
Height	-22.681m	Horizontal error	0.033m	Elevation	2.770m
		Vertical error	0.009m	Type	Horz and Vert
		3D error	0.034m	Point quality	Control quality
Point	BRB 11-a	Northing	131786.558m	Point	BRB 11
Latitude	29°41'17.47994"N	Easting	1042639.649m	Northing	131786.562m
Longitude	90°53'33.90770"W	Elevation	1.283m	Easting	1042639.665m
Height	-24.229m	Horizontal error	0.017m	Elevation	1.253m
		Vertical error	0.030m	Type	Horz and Vert
		3D error	0.034m	Point quality	Control quality
Point	X 276-a	Northing	137223.743m	Point	X 276
Latitude	29°44'13.36814"N	Easting	1047950.441m	Northing	137223.705m
Longitude	90°50'15.48639"W	Elevation	1.601m	Easting	1047950.454m
Height	-24.009m	Horizontal error	0.040m	Elevation	1.642m
		Vertical error	0.041m	Type	Horz and Vert
		3D error	0.058m	Point quality	Control quality
Point	DOKKA-a	Northing	131809.909m	Point	DOKKA
Latitude	29°41'19.29666"N	Easting	1033099.360m	Northing	131809.904m
Longitude	90°59'28.77834"W	Elevation	2.340m	Easting	1033099.363m
Height	-23.178m	Horizontal error	0.006m	Elevation	2.305m
		Vertical error	0.035m	Type	Horz and Vert
		3D error	0.035m	Point quality	Control quality
Point	R 227-a	Northing	122658.978m	Point	R 227
Latitude	29°36'20.32932"N	Easting	1047899.707m	Northing	122658.990m
Longitude	90°50'19.71406"W	Elevation	1.459m	Easting	1047899.702m
Height	-23.882m	Horizontal error	0.013m	Elevation	1.497m
		Vertical error	0.038m	Type	Horz and Vert
		3D error	0.040m	Point quality	Control quality
Point	Z 221-a	Northing	120867.259m	Point	Z 221
Latitude	29°35'20.33476"N	Easting	1059377.495m	Northing	120867.253m
Longitude	90°43'13.48339"W	Elevation	1.483m	Easting	1059377.507m
Height	-23.809m	Horizontal error	0.013m	Elevation	1.497m
		Vertical error	0.014m	Type	Horz and Vert
		3D error	0.019m	Point quality	Control quality
Point	A 233-a	Northing	116985.379m	Point	A 233

Longitude	90°38'19.78058"W	**Elevation**	2.142m	**Easting**	1067304.767m
Height	-23.065m	**Horizontal error**	0.008m	**Elevation**	2.078m
		Vertical error	0.064m	**Type**	Horz and Vert
		3D error	0.065m	**Point quality**	Control quality

Point	G 233-a	**Northing**	111017.297m	**Point**	G 233
Latitude	29°29'57.71607"N	**Easting**	1073318.403m	**Northing**	111017.311m
Longitude	90°34'37.85707"W	**Elevation**	1.047m	**Easting**	1073318.399m
Height	-24.029m	**Horizontal error**	0.014m	**Elevation**	1.043m
		Vertical error	0.003m	**Type**	Horz and Vert
		3D error	0.015m	**Point quality**	Control quality

Point	GCB 11-a	**Northing**	108323.012m	**Point**	GCB 11
Latitude	29°28'32.56624"N	**Easting**	1061343.447m	**Northing**	108323.015m
Longitude	90°42'03.00179"W	**Elevation**	0.765m	**Easting**	1061343.458m
Height	-24.292m	**Horizontal error**	0.012m	**Elevation**	0.742m
		Vertical error	0.022m	**Type**	Horz and Vert
		3D error	0.025m	**Point quality**	Control quality

Point	DUMOND-a	**Northing**	?	**Point**	DUMOND
Latitude	29°23'04.95588"N	**Easting**	?	**Northing**	98186.282m
Longitude	90°48'08.94948"W	**Elevation**	?	**Easting**	1051531.415m
Height	-24.711m	**Horizontal error**	?	**Elevation**	0.379m
		Vertical error	?	**Type**	(Ignored)
		3D error	?	**Point quality**	Control quality

Point	GC 3-a	**Northing**	97400.536m	**Point**	GC 3
Latitude	29°22'38.01732"N	**Easting**	1060222.170m	**Northing**	97400.545m
Longitude	90°42'46.81653"W	**Elevation**	1.062m	**Easting**	1060222.170m
Height	-23.779m	**Horizontal error**	0.009m	**Elevation**	1.057m
		Vertical error	0.006m	**Type**	Horz and Vert
		3D error	0.011m	**Point quality**	Control quality

Point	S 233-a	**Northing**	98398.780m	**Point**	S 233
Latitude	29°23'08.73484"N	**Easting**	1069237.651m	**Northing**	98398.813m
Longitude	90°37'12.27832"W	**Elevation**	2.917m	**Easting**	1069237.677m
Height	-21.911m	**Horizontal error**	**0.041m**	**Elevation**	2.954m
		Vertical error	**0.037m**	**Type**	Horz and Vert
		3D error	**0.055m**	**Point quality**	Control quality

Point	DREUX 2-a	**Northing**	87766.614m	**Point**	DREUX 2
Latitude	29°17'23.95022"N	**Easting**	1066552.306m	**Northing**	87766.589m
Longitude	90°38'54.22073"W	**Elevation**	0.585m	**Easting**	1066552.306m
Height	-24.026m	**Horizontal error**	0.025m	**Elevation**	0.598m
		Vertical error	0.013m	**Type**	Horz and Vert

		3D error	0.028m	**Point quality**	Control quality
Point	B 391-a	**Northing**	84543.358m	**Point**	B 391
Latitude	29°15'39.41448"N	**Easting**	1065772.544m	**Northing**	84543.337m
Longitude	90°39'23.81575"W	**Elevation**	0.345m	**Easting**	1065772.531m
Height	-24.206m	**Horizontal error**	0.025m	**Elevation**	0.306m
		Vertical error	0.038m	**Type**	Horz and Vert
		3D error	0.046m	**Point quality**	Control quality
Point	DUB 11-a	**Northing**	109008.492m	**Point**	DUB 11
Latitude	29°28'55.61803"N	**Easting**	1056777.560m	**Northing**	109008.499m
Longitude	90°44'52.34916"W	**Elevation**	1.105m	**Easting**	1056777.527m
Height	-23.977m	**Horizontal error**	**0.034m**	**Elevation**	1.170m
		Vertical error	**0.065m**	**Type**	Horz and Vert
		3D error	**0.074m**	**Point quality**	Control quality

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