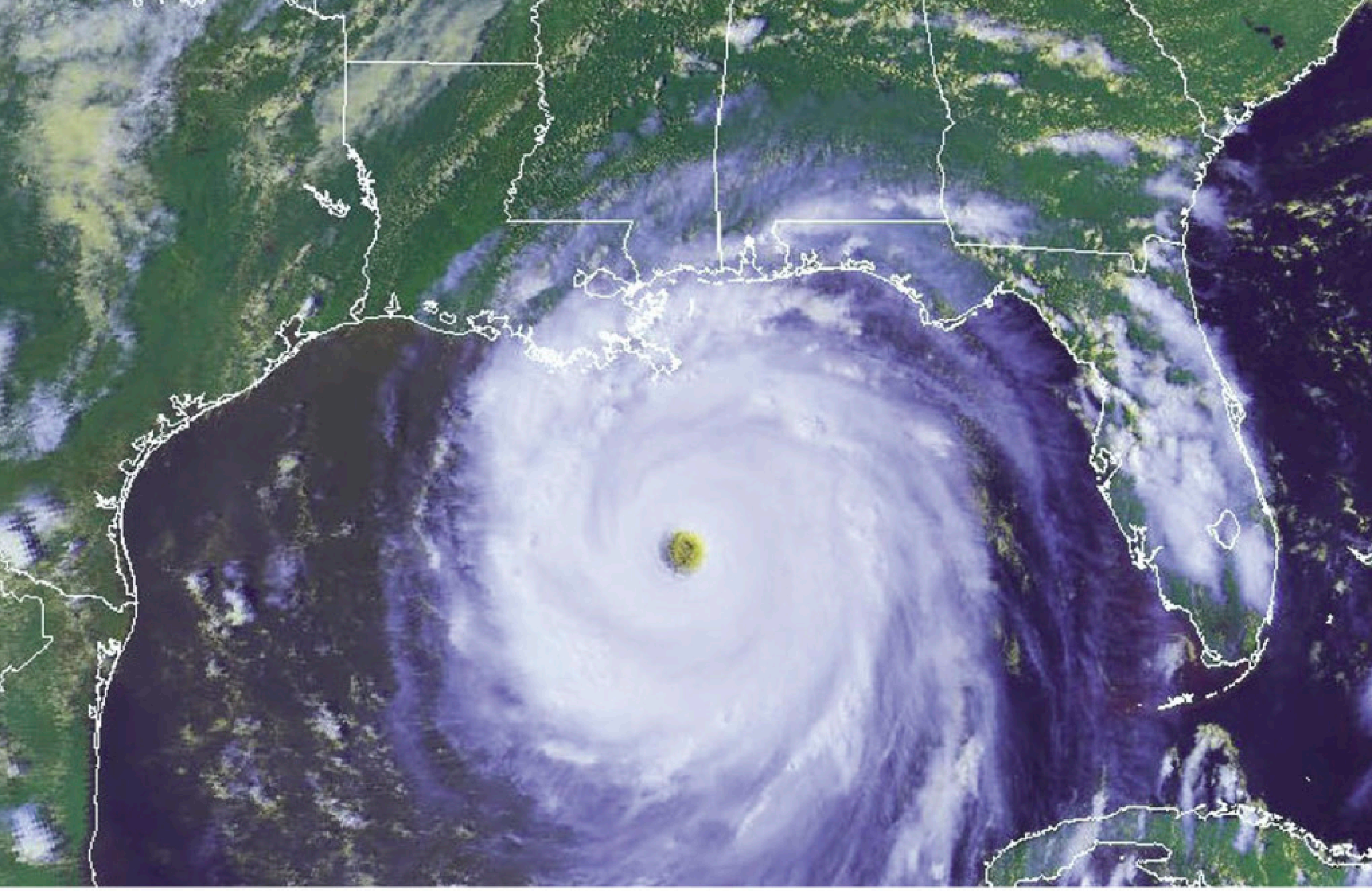

Hurricane Katrina Rapid Response Wind Water Line Report – Louisiana

Task Order 415

June 9, 2006 (Final Report)

FEMA

FOR PUBLIC RELEASE

Hazard Mitigation Technical Assistance Program
Contract No. EMW-2000-CO-0247
Task Order 415
Hurricane Katrina Rapid Response
Wind Water Line (WWL) Data Collection – Louisiana
FEMA-1603-DR-LA

Final Report

June 9, 2006

Submitted to:

Federal Emergency Management Agency
Region IV
Atlanta, GA

Prepared by:

URS Group, Inc.
200 Orchard Ridge Drive
Suite 101
Gaithersburg, MD 20878

FOR PUBLIC RELEASE

Table of Contents

List of Figures

List of Tables

Appendices

This page is intentionally left blank.

ABBREVIATIONS AND ACRONYMS

Acronyms	Explanation
CDT	Central Daylight Time (daylight savings time zone)
CHWM	Coastal High Water Mark
DEM	Digital Elevation Model
EDT	Eastern Daylight Time (daylight savings time zone)
FEMA	Federal Emergency Management Agency
FIRM	Flood Insurance Rate Map
GIS	Geographic Information System
GPS	Global Positioning System
HMGP	Hazard Mitigation Grant Program
HMTAP	Hazard Mitigation Technical Assistance Program
HWM	High Water Mark
IA	Individual Assistance
kts	Knots
LiDAR	Light Detection and Ranging or Laser Imaging Detection and Ranging
mb	Millibar
mph	Miles Per Hour
NAD 83	North American Datum of 1983
NAVD 88	North American Vertical Datum of 1988
NCDC	National Climatic Data Center
NFIP	National Flood Insurance Program
NGS	National Geodetic Survey
NGVD 29	National Geodetic Vertical Datum of 1929
NWI	National Wetlands Inventory
PA	Public Assistance
PNP	Private Non-Profit
RHWM	Riverine High Water Mark
USGS	United States Geological Survey
UTM	Universal Transverse Mercator
WWL	Wind Water Line

GLOSSARY OF TERMS

Word	Definition
ArcCatalog®	Software application from ESRI that organizes and manages all Geographic Information System (GIS) information such as maps, globes, data sets, models, metadata, and services.
ArcGIS®	The comprehensive name for the current suite of GIS products produced by ESRI that are used to create, import, edit, query, map, analyze, and publish geographic information.
ArcView®	A software application from ESRI that provides extensive mapping, data use, and analysis, along with simple editing and geoprocessing capabilities.
Base map	A map or chart showing certain fundamental information, used as a base upon which additional data of a specialized nature are compiled or overprinted.
Contour data	All the information required to create lines of equal elevation on a map. These are referred to as contour lines on topographic maps and are used to describe land forms based on elevation above a defined vertical datum.
Contour lines	Lines that connect a series of points of equal ground elevation and are used to illustrate topography, or relief, on a map.
Data point	A point associated with a discrete geographic location where data pertaining to the study were collected.
Debris line	Defines the extent of flooding where debris such as parts of houses, docks, cars, or other non-natural material is generally carried by floodwaters with some velocity and is then dropped as the floodwaters lose velocity and begin to recede.
Disaster declaration	The formal action by the President to make a state eligible for major disaster or emergency assistance under the Stafford Act.
Emergency protective measures	Actions taken by Applicants before, during, and after a disaster to save lives, protect public health and safety, and prevent damage to improved public and private property.
Flood recovery map	High-resolution maps that show flood impacts, including high water mark (HWM) flood elevations, flood inundation limits, the inland limit of waterborne debris (trash lines), and storm surge elevation contours based on the HWMs. The maps also show existing FEMA Flood Insurance Rate Map (FIRM) flood elevations for comparison to hurricane data.
Geodatabase	The geodatabase provides the common data access and management framework for ArcGIS. Geodatabases organize geographic data into a hierarchy of data objects. These objects are stored in feature classes, object classes, and feature datasets. An object class is a table in the geodatabase that stores nonspatial data. A feature class is a collection of features with the same type of geometry and the same attributes. A feature dataset is a collection of feature classes sharing the same spatial reference.

Word	Definition
Hazard Mitigation Grant Program	Provides grants to states and local government to implement long-term hazard mitigation measures after a major disaster declaration. The purpose of the program is to reduce the loss of life and property due to natural disasters and to enable mitigation measures to be implemented during the immediate recovery from a disaster.
Individual Assistance	Federal assistance provided to families or individuals following a major disaster or emergency declaration. Under a major disaster declaration, assistance to individuals and families is available through grants, loans, and other services offered by various Federal, state, local, and voluntary agencies.
Infrastructure	The basic facilities, services, and installations needed for the functioning of a community or society, such as transportation and communications systems, and water and power lines.
Inundated	Flooded or covered with water.
Inundation polygon	Aerial extent of flooding as shown by polygon feature in ArcGIS.
Knot	A unit of speed, one nautical mile per hour, approximately 1.85 kilometers (1.15 statute miles) per hour.
LiDAR	A technology that determines distance to an object or surface using laser pulses. Like the similar radar technology, which uses radio waves instead of light, the range to an object is determined by measuring the time delay between transmission of a pulse and detection of the reflected signal.
Millibar	A unit of atmospheric pressure equal to one thousandth of a bar. Standard atmospheric pressure at sea level is about 1,013 millibars.
Mitigation	Any measure that will reduce or eliminate the long-term risk to life and property from a disaster event.
National Flood Insurance Program	The Federal program created by an Act of Congress in 1968 that makes flood insurance available in communities that enact and enforce satisfactory floodplain management regulations.
National Geodetic Vertical Datum of 1929	Vertical control datum that was widely used in the U.S. prior to the establishment of NAVD 88.
North American Datum of 1983	Horizontal datum used as the standard map coordinate system default by the majority of Global Positioning System (GPS) devices.
North American Vertical Datum of 1988	The most widely used vertical control datum in the U.S. today, it was officially established in 1991 by the minimum-constraint adjustment of the Canadian-Mexican-U.S. leveling observations.
Orthorectification	Process by which the effects of relief displacement and imaging geometry are removed from aerial photographs. These adjustments are made to correct for the natural distortions caused by the perspective of the aircraft or spacecraft that took the photographs, and recreate the ground geometry in the imagery as it would appear from directly above each point in the photograph. From this process, orthophotos are created, which generally have the same geometric characteristics as topographic maps.

Word	Definition
Polygon	In ArcGIS, a shape defined by one or more rings, where a ring is a path that starts and ends at the same point. If a polygon has more than one ring, the rings may be separate from one another or they may nest inside one another, but they may not overlap.
Public Assistance	Federal assistance provided to state and local government, Native American Tribes, and certain non-profit organizations after a disaster declaration. The assistance is for the repair, replacement, or restoration of disaster-damaged, publicly owned facilities and the facilities of certain Private Non-Profit (PNP) organizations. The Federal share of assistance is not less than 75 percent of the eligible cost for emergency measures and permanent restoration. The state determines how the non-Federal share (up to 25 percent) is split with the applicants.
Riverine flooding	Occurs when rivers and streams overflow their banks.
Seed file	Used within software applications and serve as templates in which standard file parameters are set to predetermined standards.
Shapefile	Stores geographic features and their attributes. Geographic features in a shapefile can be represented by points, lines, or polygons (areas).
Storm surge	Onshore rush of water piled higher than normal as a result of high winds on an open water body's surface. It occurs primarily along the open coast and can destroy houses, wash away protective dunes, and erode soil.
Topographic quadrangle maps	A standard map size and scale used by the United States Geological Survey (USGS) to show topography, roads, and landmarks.
Water mark	A mark, usually on structures, left by floodwaters.
Wind Water Line	An approximate boundary to delineate the inland extent of the area where structures were damaged as a result of flooding from storm surge from a particular event. Landward of the line, most of the damage is attributable to winds and/or wind-driven rain. Sometimes, the Wind Water Line (WWL) is located along the debris line, but in some cases, inundation and flood damage extend beyond the area where major debris was deposited.
Wrack line	Defines the extent of flooding where organic-type debris such as grass and weeds are carried by floodwaters and then dropped as the floodwaters recede.

Background

Hurricane Katrina began as a tropical depression in the southeastern Bahamas on August 23, 2005. By the next day, the depression had developed into Tropical Storm Katrina. Moving slowly northwesterly then westerly through the Bahamas, Katrina strengthened over time. Just before landfall in South Florida on August 25, 2005, Tropical Storm Katrina developed into a Category 1 hurricane, with wind speeds of 74 miles per hour (mph)[1] (64 knots[kts]) or greater. Landfall occurred around 6:30 p.m. eastern daylight time (EDT) between Hallandale Beach and North Miami Beach, with wind speeds of approximately 80 mph (70 kts). Gusts of 90 mph (78 kts) were measured as Katrina came ashore. The storm moved southwesterly across the tip of the Florida peninsula with its winds decreasing slightly (see Figure 1). However, having spent only 7 hours on land, Katrina was not significantly diminished and regained intensity shortly after moving over the warm waters of the Gulf of Mexico.

Figure 1: Hurricane Katrina Storm Track
Source: http://cimss.ssec.wisc.edu/tropic/archive/2005/storms/katrina/katrina.html

Once over the Gulf of Mexico, Hurricane Katrina moved almost due west. A mid-level ridge from Texas weakened and moved westward, causing Katrina to gradually move northwest and then north over the next few days. Katrina attained "major hurricane" status

[1] Wind speed and central pressure data are from the National Climatic Data Center (NCDC).

on the afternoon of the August 26, 2005, due to the atmospheric and sea level conditions that rapidly intensified the storm.

Over the next 48 hours, Hurricane Katrina continued to intensify, moving in a northerly direction. The storm reached maximum sustained wind speeds of 175 mph (152 kts) with gusts of 215 mph (187 kts) on the morning of August 28, 2005, making it a Category 5 hurricane. Its minimum central pressure dropped that afternoon to 902 millibars (mb), giving it the fourth lowest recorded central pressure for an Atlantic storm at the time and the sixth lowest by the end of the 2005 hurricane season.[2] Tropical cyclones rarely stay at Category 5 strength for long; Katrina weakened slightly to a Category 4, and then became a Category 3 at its second landfall near Buras, Louisiana, on August 29, 2005, at approximately 6:10 a.m. central daylight time (CDT) (see Figure 1). Maximum sustained winds at landfall were approximately 127 mph (110 kts), making Hurricane Katrina a Category 3 storm.

After crossing over Lake Borgne (located east of New Orleans) and the Mississippi Sound, Katrina made its third landfall along the Louisiana/Mississippi border with wind speeds of approximately 121 mph (105 kts). Gusts of over 90 mph (78 kts) were recorded in Biloxi, Mississippi, while gusts reached approximately 80 mph (70 kts) in Mobile, Alabama.

Katrina's storm surge caused failure of the levee system that protects the City of New Orleans, Louisiana, from Lake Pontchartrain and, subsequently, an estimated 80 percent of the City was flooded. This and other major damage to the coastal regions of Alabama, Louisiana, and Mississippi made Katrina the most destructive natural disaster in the history of the United States.

[2] Later in the 2005 Hurricane Season, Hurricanes Rita and Wilma developed with minimum pressures of 897 mb and 882 mb, respectively. As a result, Katrina became the sixth most intense Atlantic Basin hurricane on record (Rita is now the fourth and Wilma ranks as the first).

Overview of Impacts in Louisiana

A disaster declaration in response to Hurricane Katrina was authorized by the President for several parishes in Louisiana on August 29, 2005, with the Federal Emergency Management Agency (FEMA) acting as the Federal Coordinating Agency (FEMA-1603-DR-LA). In addition, several amendments were made to the initial declaration. The declaration provided the necessary assistance to meet immediate needs and to help Louisiana recover as quickly as possible through the following means:

- Public Assistance (PA): includes supplemental Federal disaster grant assistance for the repair, replacement, or restoration of disaster-damaged publicly owned facilities, and the facilities of certain private non-profit (PNP) organizations. There are seven subcategories (A-G) within this designation under two work types: emergency work and permanent work. Unless otherwise noted, Public Assistance will include all categories under both work types. However, often only the emergency work categories are designated, which include Category A, debris removal, and Category B, emergency protective measures.

- Individual Assistance (IA): includes cash grants of up to $26,200 per individual or household for housing (reimbursement for hotel or motel expenses, rental assistance, home repair and replacement cash grants, and permanent housing construction assistance in rare circumstances) and other needs (medical, dental, and funeral costs, transportation costs, and other disaster-related needs).

- Hazard Mitigation Grant Program (HMGP): may be used to fund projects that will reduce or eliminate the losses from future disasters by providing a long-term solution to a problem. Eligible applicants include state and local government, Indian tribes or other authorized tribal organizations, and certain non-profit organizations. FEMA can fund up to 75 percent of the eligible costs of each project, and the state or grantee must provide a 25-percent match.

All Louisiana parishes were eligible for HMGP funds. Tables 1, 2, and 3 provide the designations for FEMA-assistance eligibility by parish. In all, 31 parishes received IA designations; 33 parishes received PA, Category B Only designations; 9 parishes were eligible for PA, Category A and B Only; and 22 parishes were designated for PA, All Categories. Note that all of the parishes designated for IA also received a PA designation (either Categories A and B Only or All Categories). Figure 2 shows this same information graphically.

Table 1: Parishes Designated for IA and PA

Ascension	Assumption	East Baton Rouge	Iberia
Iberville	Jefferson	Lafourche	Livingston
Orleans	Plaquemines	St. Bernard	St. Charles
St. Helena	St. James	St. John the Baptist	St. Martin
St. Mary	St. Tammany	Tangipahoa	Terrebonne
Washington	West Baton Rouge		

Table 2: Parishes Designated for IA and PA – Categories A and B Only

Acadia	Calcasieu	Cameron	East Feliciana
Jefferson Davis	Lafayette	Point Coupee	West Feliciana
Vermillion			

Table 3: Parishes Designated for PA – Category B Only

Allen	Avoyelles	Beauregard	Bienville
Bossier	Caddo	Caldwell	Catahoula
Claiborne	Concordia	De Soto	East Carroll
Evangeline	Franklin	Grant	Jackson
La Salle	Lincoln	Madison	Morehouse
Natchitoches	Ouachita	Rapides	Red River
Richland	Sabine	St. Landry	Tensas
Union	Vernon	Webster	West Carroll
Winn			

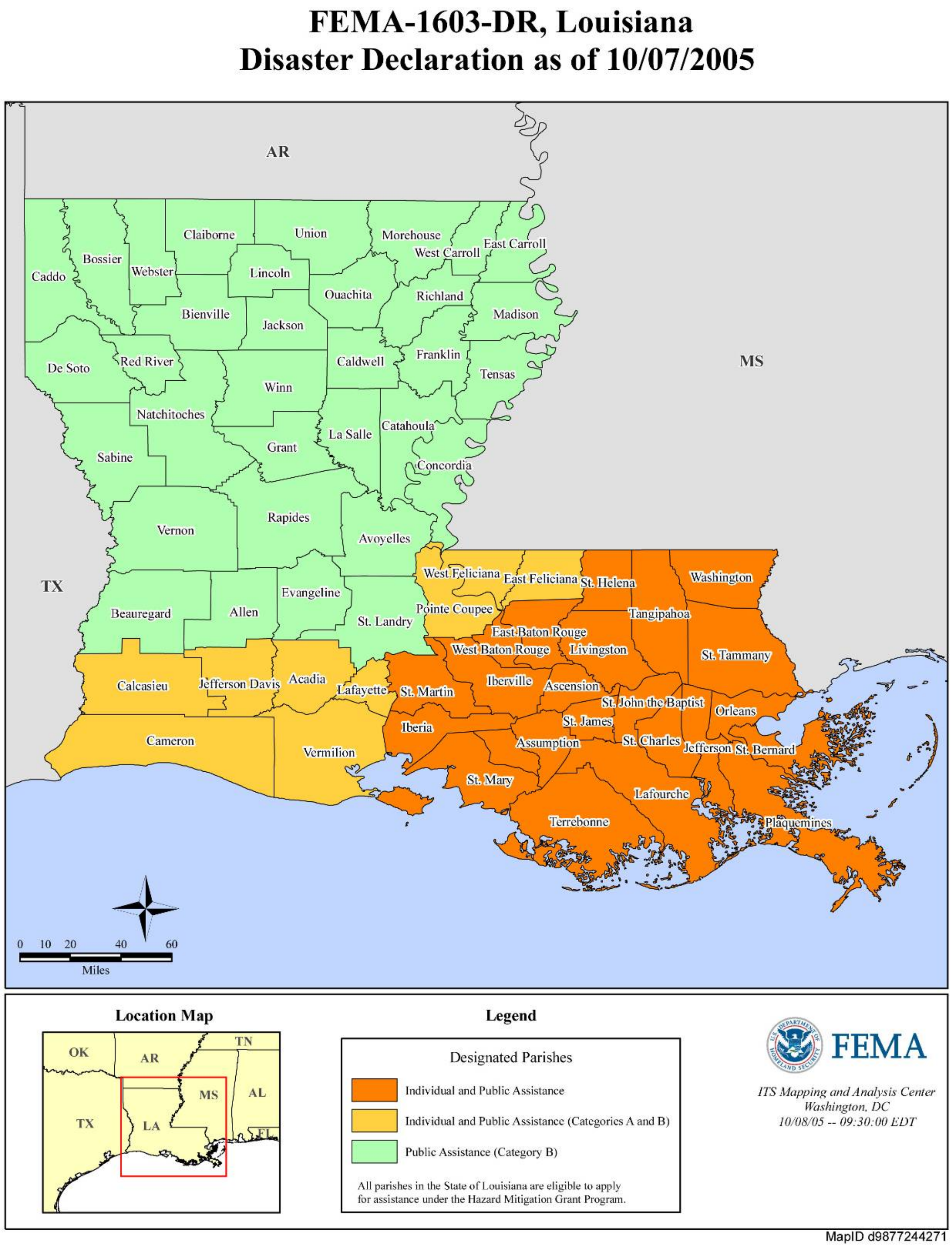

Figure 2: FEMA-1603-DR-LA Disaster Declaration

Levee Breaches

Hurricane Katrina passed just east of New Orleans shortly after 6:00 a.m. CDT on August 29, 2005. There were numerous breaches to the levee system as a result of Hurricane Katrina that affected areas in Jefferson, Orleans, Plaquemines, and St. Bernard Parishes. Figure 3 shows the location of the storm-induced breaches, as well as distressed areas and deliberate levee breaches created to help drain waters after the flooding occurred. Pump stations are also shown and are color coded based on their capacities in the days after Hurricane Katrina. The major levee breaches are described in detail in the following paragraphs.[3]

Before Hurricane Katrina made landfall, storm surge from Lake Borgne already began pounding levees along the eastern edge of St. Bernard Parish. The parish's eastern levee system began to be compromised at approximately 5:00 a.m. CDT, causing flooding of the wetland area west of this levee system. Then, surge from Lake Borgne pushed westward through the portion of the Intracoastal Waterway located between Eastern New Orleans and St. Bernard Parish. The surge overtopped and breached levees along the canal protecting eastern New Orleans. At approximately 8:30 a.m. CDT, the parish's western set of levees protecting developed communities was compromised, and floodwaters poured into these communities.

As Katrina made landfall at Buras shortly after 6:00 a.m. CDT, water from the Breton Sound surged onto land overtopping the Mississippi River levees from the east side and flooding Plaquemines Parish (south of area shown on Figure 3).

Water began to overtop flood walls and levees shortly before 7:00 a.m. CDT along the Industrial Canal. Between 7:30 and 8:00 a.m. CDT, first the west side and then the east side of the Industrial Canal was breached (see Figure 4). There were actually two breaches on the east side of the Industrial Canal. Both of them were located to the north of the lock separating the canal from the Mississippi River, between the Florida Avenue and Claiborne Avenue Bridges.

Surge from Lake Pontchartrain also began straining the levee and floodwall system along the London Avenue Canal. At approximately 9:00 a.m. CDT, walls on both sides of the levee began showing signs of weakening. At approximately 9:30 a.m., the east side of the canal began to fail north of the Mirabeau Avenue Bridge, followed by the west side at approximately 10:30 a.m. CDT. Also, at approximately 9:00 a.m. CDT, flooding occurred east of the New Orleans Avenue Canal as water reached the foot of the canal and overtopped the embankment.

[3] Levee breach approximate times and some details are taken from the Times-Picayune *Flash Flood* graphic published in print on May 14, 2006, and online at http://www.nola.com/katrina/graphics/flashflood.swf.

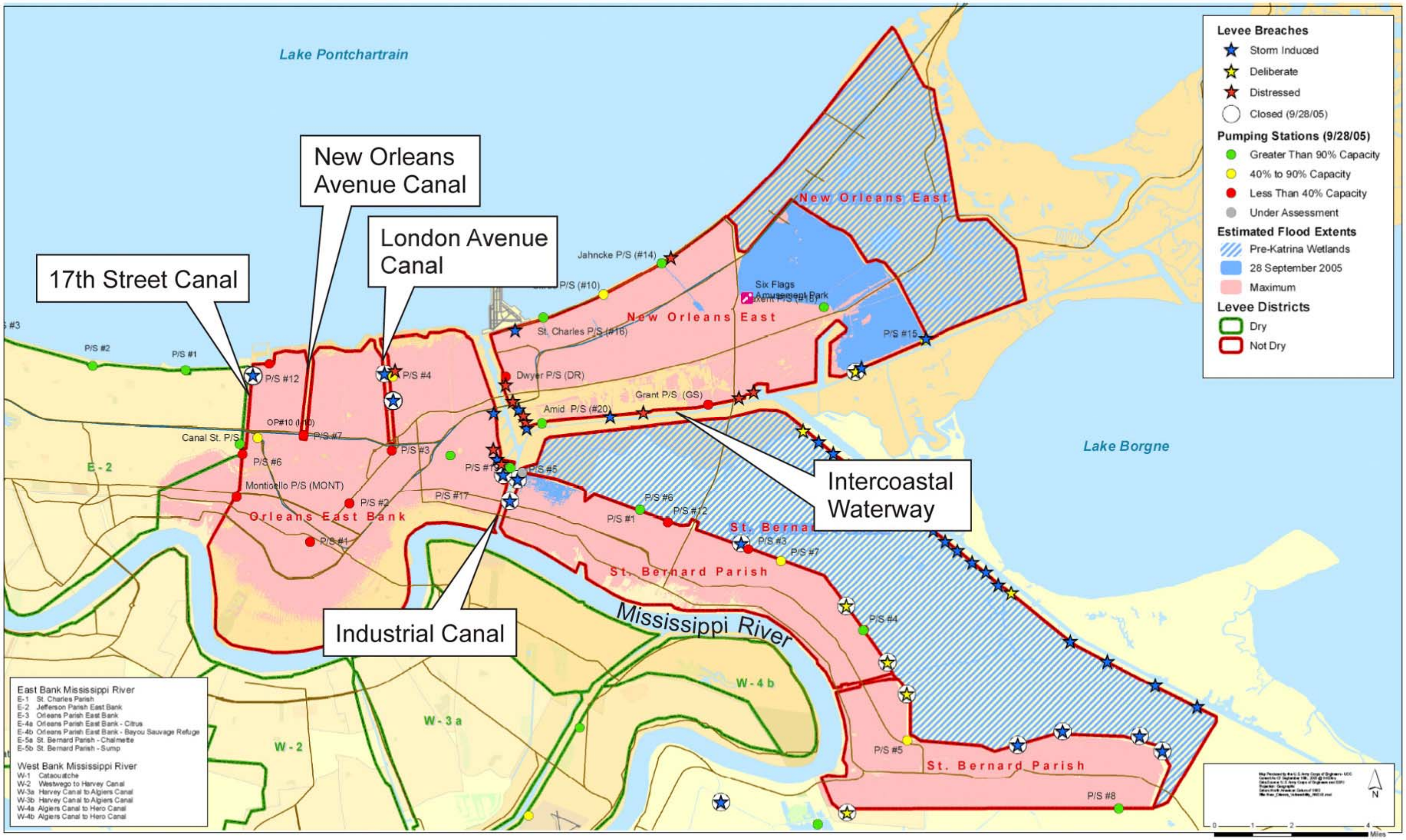

Figure 3: New Orleans Area Levee Breaches
Source: U.S. Army Corps of Engineers

Figure 4: Southern Breach in the East Floodwall and Levee of the Industrial Canal
Source: http://homepage.ntlworld.com/c.mcmahon4/nola/industrial.htm

At approximately 9:45 a.m. CDT, the vital 17th Street Canal levee (see Figure 5) began to be breached where it connects to the new "hurricane proof" Old Hammond Highway Bridge. This breach sent water from Lake Pontchartrain coursing across Lakeview and into Mid-City, Carrollton, Gentilly, City Park, and neighborhoods farther south and east. The breach was an estimated 200 feet in length.

Figure 5: New Orleans 17th Street Canal at Old Hammond Highway Bridge
Source: http://en.wikinews.org/wiki/Image:New_Orleans_USACE-17th_Canal-A-09-04-05_0004.JPG

At least 80 percent of New Orleans was under water by August 31, 2005, as a result of the levee failures (see Figure 6). The flooding also caused a water line main in New Orleans to break, leaving the City without drinking water.

Figure 6: Photograph of Flooded Homes along New Orleans Levee
Source: http://homepage.ntlworld.com/c.mcmahon4/nola/london.htm

Reported Damage[4]

More than 1.7 million people lost power as a direct result of Hurricane Katrina. According to the FEMA Public Information Officer for Louisiana, over 200,000 structures in Louisiana were destroyed due to Hurricane Katrina. According to the Louisiana Economic Development Office, an estimated 71,000 of those structures were businesses. Infrastructure also suffered heavy losses; a preliminary estimate of $5.5 billion in damage to infrastructure, including roads and bridges, was reported. Approximately 300,000 to 350,000 vehicles were destroyed, and approximately 2,400 ships and vessels were wrecked. An estimated 46 million cubic yards of debris has been generated due to hurricane damage. The number of people displaced is estimated to be 450,000, and 800,000 Louisiana citizens have requested assistance from various Federal and state relief programs and agencies.

As of December 5, 2005, the Small Business Administration reported that requests for $229 million in home and small business loans have been submitted. The insurance industry has reported loss payouts in the amount of $20.8 million, while the National Flood Insurance Program (NFIP) reported losses totaling $17 billion. As of December 3, 2005, the Federal government had provided $3.6 billion in assistance to Louisiana. In January 2006, IA projections were at $7.7 billion, while the PA program had already allocated $1.2 billion.

Hurricane Katrina also caused major business disruptions. The financial impact on the tourism industry is estimated to be approximately $11 billion. For the retail fishing

[4] Damage estimates are from an interview with FEMA Public Information Officer for Louisiana in mid-December 2005 and information provided by FEMA Jackson, Mississippi, Disaster Field Office personnel in January 2006.

industry, losses are estimated at $1.29 billion, and for the recreational fishing industry a loss of approximately $400 million was estimated.

The oil industry has estimated that 15 percent of the Gulf oil production was lost between August 26 and November 10, 2005. Approximately 12 percent of natural gas production along the Gulf Coast was lost during that same period.

Purpose

After a hurricane impacts a coastal area with significant flooding, it is imperative that data be collected to document the event to assist in response, recovery, and mitigation efforts, and to improve disaster preparedness and prevention efforts for future disasters. Wind Water Line (WWL) data collection is an initial step in accurately documenting an event. These data help place the event in historical perspective and improve the ability to estimate current flood risk and future event prediction.

Collection of site-specific flood inundation data along rivers, bays, and coasts has numerous applications. The purpose of this particular data collection effort was to document the extent of flooding caused by storm surge that occurred as a result of Hurricane Katrina in southeast Louisiana. There are several potential uses for these data, including:

- Estimating storm frequency and severity
- Assessing accuracy of Flood Insurance Rate Maps (FIRMs)
- Providing information for use with other studies, including FEMA Building Performance Assessments
- Assisting with the prioritization of mitigation projects and providing data for use in benefit/cost analyses
- Sharing information for calibrating models that simulate the storm (for example, HAZUS and other coastal storm-surge models)
- Helping to create flood recovery maps when coupled with sufficient data density and observational information; building officials can use the maps to update guidance for both reconstruction and future construction by local citizens, developers, and contractors

Specific FEMA programs that directly benefit from post-disaster flood data collection include:

- IA Program – advises individuals on how to use Federal grants to increase their homes' flood resistance
- PA Program – identifies appropriate flood mitigation measures to pursue when providing Federal grants to repair infrastructure
- HMGP – ensures that accurate benefit/cost analysis is performed
- NFIP – provides insurance claim information, floodplain management, repetitive loss classification, and flood hazard identification

The purpose of WWL data collection is to determine the inland extent of damages caused by storm-surge-induced flooding, and differentiate this area from those areas farther inland where damages were primarily the result of wind forces. By delineating the WWL, an approximate boundary is created to distinguish areas where both storm-surge-induced flooding and wind forces caused damage to structures from those areas where wind forces were the primary cause of damages to structures, and storm-surge flooding did not have a significant impact. Sometimes, the WWL is located along the debris line, but in some cases, inundation and flood damages extend beyond the area where major debris was deposited.

Overview of Related Projects

URS Group, Inc. (URS), with support from Government Services Integrated Process Team, LLC, was tasked by FEMA under their existing Hazard Mitigation Technical Assistance Program (HMTAP) contract to assist in disaster recovery efforts for Hurricane Katrina. Assistance provided by this Task Order included data collection and visual survey of the debris line and the extent of flooding to identify the WWL in the New Orleans area.

After Hurricane Katrina, FEMA issued several task orders under the HMTAP contract called Rapid Response Task Orders. Generally, the purpose of these task orders is to allow FEMA contractors to move quickly into disaster-stricken areas to collect perishable data for use in defining the parameters of the event that can be used for future studies and flood mitigation activities. In addition to the WWL Task Order, there were several other Rapid Response Task Orders issued including Aerial Imagery Data Collection, Coastal High Water Mark (CHWM) Surveys, and Riverine High Water Mark (RHWM) Surveys. HWM Survey findings are used to define the extent of flooding, and therefore can be used in conjunction with field findings from the WWL Task Order to determine the extent of the WWL. Aerial imagery is also used to estimate the WWL; post-event imagery can be used to identify areas affected by flood damages as well as the approximate inland extent of storm surge flooding.

In response to Katrina, HMTAP Task Order 415, Rapid Response, Hurricane Katrina Wind Water Line Data Collection – Louisiana was issued and is the focus of this report. In addition, HMTAP Task Order 411, Rapid Response, Aerial Radar – Louisiana, Mississippi, and Alabama; HMTAP Task Order 412, Rapid Response, Hurricane Katrina Coastal High Water Mark Survey – Louisiana; and HMTAP Task Order 419, Rapid Response, Hurricane Katrina Riverine High Water Mark Survey – Louisiana were also issued. An overview of these task orders is provided below.

- Under Task Order 411, Rapid Response, Aerial Radar – Louisiana, Mississippi, and Alabama, cartographic analysts were tasked with using post-event aerial imagery to delineate areas affected by flooding along the Louisiana Coast, with a focus on New Orleans. Uses of post-event aerial imagery for Mississippi and Alabama are discussed in the HMTAP task orders contracted for those states.

- Through Task Order 412, Rapid Response, Hurricane Katrina Coastal High Water Mark Survey – Louisiana, field crews collected perishable HWM data at field-observed point locations. The crews looked for evidence of the peak elevation of flooding caused by storm surge, then inventoried and surveyed these elevations. Peak flood elevations in southeastern Louisiana were recorded at several locations as part of this task order. These data can be used to help determine the extent of flooding.

- For Task Order 419, Rapid Response, Hurricane Katrina Riverine High Water Mark Survey – Louisiana, field crews also collected HWM data at field-observed point locations. Field crews for RHWMs focused on areas of overbank flooding where heavy and/or prolonged precipitation resulted in an exceedance of the capacity of rivers and streams to keep floodwaters within their banks. Peak flood elevations for riverine-type flooding were surveyed and recorded as part of this task order.

This report focuses on the results of data collected in Louisiana to determine the WWL. Figure 7 shows the WWL Study Area within Louisiana; parishes included in the study area are highlighted in yellow. The study area comprises parishes in southern coastal Louisiana, including Jefferson, Lafourche, Orleans, Plaquemines, St. Bernard, and Terrebonne Parishes. The study area also encompasses the parishes affected by the flooding of Lake Pontchartrain and Lake Maurepas, including Ascension, Livingston, St. John the Baptist, St. Tammany, and Tangipahoa Parishes, and two additional parishes along the Mississippi River, St. Charles and St. James Parishes.

Figure 7: WWL Study Area within Louisiana

This page is intentionally left blank.

Methodology

There were two basic elements to this project: field data collection and WWL mapping. While field crews worked to collect data in the weeks following Hurricane Katrina, the WWL mapping process occurred after the data had been collected and involved interpretation and analysis of data from several sources.

Data Collection Methodology

URS field crews collected WWL data for Hurricane Katrina in Louisiana. The teams met in Baton Rouge, Louisiana, on September 8, 2005, to be briefed on the project and form field crews. On September 9, 2005, field data collection began. However, access to the New Orleans area was restricted because floodwaters still covered much of the City. Efforts were initially focused on areas outside of the City. By September 14, 2005, field crews began to gain access to New Orleans, and data collection within the City was underway.

Data collection for Task Order 415, Rapid Response, Hurricane Katrina Wind Water Line Data Collection – Louisiana was performed in conjunction with data collection for Task Order 412, Rapid Response, Hurricane Katrina Coastal High Water Mark Survey – Louisiana and Task Order 419, Rapid Response, Hurricane Katrina Riverine High Water Mark Survey – Louisiana. Under Task Orders 412 and 419, field crews collected perishable HWM data at field-observed, point locations. Under Task Order 412, they looked for evidence of the peak elevation of flooding caused by storm surge, then inventoried and surveyed these elevations. CHWM points are taken where surge directly affects flood levels, including the shoreline of open coasts, bays, and tidally influenced rivers. CHWMs are formed when the water level during a storm rises to a maximum elevation and leaves marks on the interior and/or exterior walls of a structure, or debris or wrack lines along the ground. CHWM field crews are responsible for identifying these marks and recording basic information about the data point. Survey crews then use these initial records to later relocate the points and survey them to determine the peak elevation of flooding.

The WWL points, which are also located by identifying water marks on structures or debris or wrack lines, doubled as HWMs. WWL points are used to define the inland extent of damage to structures caused by surge flooding. Thus, the points generally form a line showing the approximate inland limit of surge flooding. The WWL is so called because landward of the line in coastal areas, damage to structures is usually limited to wind damage, which includes direct rain damage, where the envelope of the structure may have been compromised. Seaward of the line, damage to structures is the result of surge-induced flooding with wind forces contributing as well (see Figure 8).

URS field crews were tasked with identifying data points for a WWL for southeast Louisiana with a focus along the open coasts of the Gulf of Mexico, the shores of Lake Pontchartrain, and areas affected by the breached levees. Parish emergency managers were contacted prior to field work within each parish to inform them of the crews' work and site investigations and to acquire any available information about the location and extent of damages to structures within the parish. Priority was given to areas of known damage to structures and significant flooding as identified by parish emergency managers.

The presence of low swampy ground made determination of the limit of the coastal storm surge difficult to establish along coastlines (i.e., southern areas in Lafourche, Plaquemines, and Terrebonne Parishes and eastern St. Bernard Parish), inland swamps/marshes (i.e., Lake Maurepas area and the southern portion of Tangipahoa Parish), and up river courses affected by surge. Where access was available and a determination as to the approximate location of the WWL was possible, data points were taken. Ideally, these points were taken every 2 to 4 miles along coastlines and at denser intervals in more populated areas, including the City of New Orleans. Field crews' data were sent to a central processing unit in a local URS office each night and data points were plotted to ensure adequate spatial coverage. Figure 9 shows the WWL data point distribution, which illustrates the overall coverage of WWL points and highlights areas where there was a lack of data points due to swampy or marshy land areas or inaccessibility.

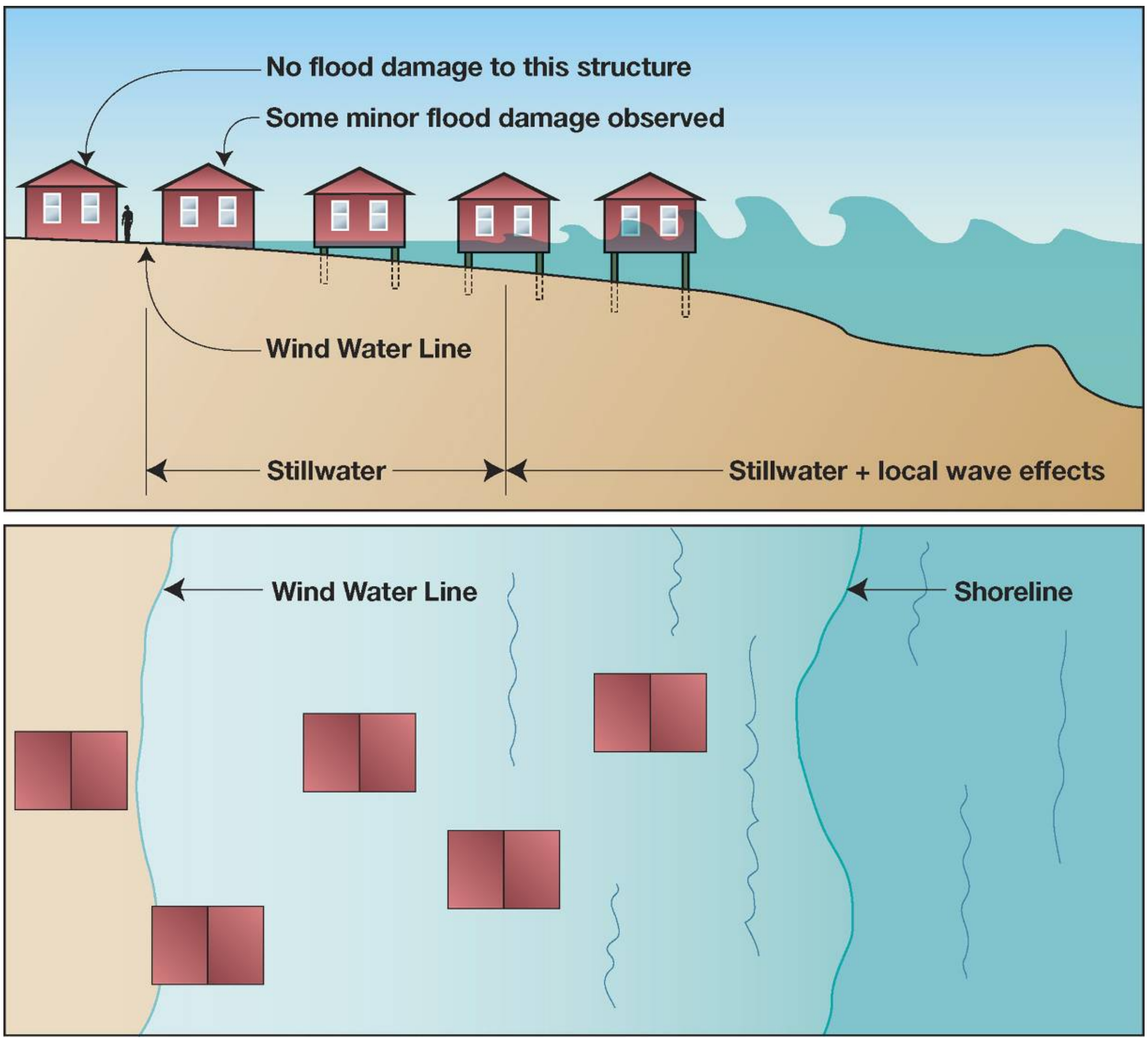

Figure 8: WWL Illustration (Profile View/Plan View)

The area highlighted by a pale blue-green overlay on Figure 9 shows coastal swamps/marshes (developed from ESRI open water coverage) where access was limited and the WWL points were difficult to find. The hatched green area by Lake Maurepas shows one of the larger inland wetland areas where the land use/vegetation and lack of roads prevented access and WWL points were difficult to distinguish.

Each field team was tasked with identifying the WWL and collecting data points. The WWL was located by observing wrack lines, debris lines, or by locating water marks close to the ground and tracing them along topographic features to determine the extent of flooding. Generally, when these features were observed within 1.5 feet of the ground and the field crews could validate through field observations or interviews with local citizens that these features were near the edge of inundation, these points were marked as WWL data points.

Figure 9: WWL Data Point Distribution

Data collection had to be completed quickly given the perishable nature of the data; as community cleanup efforts progressed, valuable debris line (see Figure 10) and HWM (see Figure 11) data were being destroyed. The field crews collected raw data for both WWLs and HWMs from September 9 through September 19, 2005. The data for each data point were stored in a database (see Appendix A). In fact, as previously mentioned, the WWL points doubled as HWM points since a flood elevation could be determined at each of the WWL data points. Therefore, the WWL data points are actually a subset of the HWM data points. WWL data points are assigned a HWM identification number that is also used as their WWL identifier. It is a three-part alphanumeric label. For example, a point might be labeled KLAC-05-16. The leading ‘K’ indicates that the HWM/WWL data point is a Hurricane Katrina data point, the middle ‘LA’ stands for Louisiana, and the last letter can be either a ‘C’ or an ‘R’ indicating coastal or riverine flooding. The middle two-digit number identifies the field crew that gathered the data, and the final two-digit number identifies the sequential data points collected by the field crew.

At each observed WWL point, the following data were collected:

- Address (if the point was near an addressable structure)
- Latitude/longitude reading, taken in North American Datum of 1983 (NAD83), which is used as the standard map coordinate system default by the majority of Global Positioning System (GPS) devices
- Location description (e.g., neighborhood or other descriptive name)
- Date data point was taken
- Type of data point, including debris line, water mark, wrack line (indicates the high tide mark), etc.
- Type and severity of observed wind damage
- Flood source
- Approximate flood depth (if a water mark data point)
- Digital photographs (named according to the WWL point identification number; see Appendix B)[5]

[5] The SD memory cards containing some of the images became corrupt, and, as such, the images on them were unrecoverable. For this reason, images for 10 of the WWL points are not available.

Figure 10: Example of a Debris Line

Figure 11: Example of an HWM

Mapping Methodology

To create the WWL maps, the project team relied heavily on data supplied from both HMTAP Task Order 411, Rapid Response, Aerial Radar – Louisiana, Mississippi, and Alabama, and HMTAP Task Order 412, Rapid Response, Hurricane Katrina Coastal High Water Mark Survey – Louisiana.

Under Task Order 411, Rapid Response, Aerial Radar – Louisiana, Mississippi, and Alabama, cartographic analysts used post-event aerial imagery to delineate areas affected by flooding along the Louisiana coast, with a focus on New Orleans. The analysts used natural color orthorectified imagery acquired between September 4 and September 17, 2005, by the firm 3001, Inc. The analysts studied the imagery to locate the extent to which high-velocity floodwaters, including coastal surge, pushed debris inland, and to delineate areas beyond these debris lines where floodwaters had continued to push inland causing additional flood inundation without leaving behind major debris. Contour data were created using U.S. Geological Survey (USGS) Digital Elevation Models (DEMs) to perform checks as needed of the analysts' interpretations against elevation data. A Geographic Information System (GIS) coverage showing the approximate extent of flooding was created as part of this task order. Appendix C includes a summary report prepared by the cartographic analysts summarizing their methodology and product.

Under this task order, Task Order 415 Rapid Response, Hurricane Katrina Wind Water Line Data Collection – Louisiana, field WWL data points were used together with the information about the extent of flooding determined as part of the aerial imagery task order (Task Order 411, Rapid Response, Aerial Radar – Louisiana, Mississippi, and Alabama) to finalize the aerial measure of inundation based on both photointerpretation and field ground-truthed data. The inundation areas defined under Task Order 411, Rapid Response, Aerial Radar – Louisiana, Mississippi, and Alabama, served as the base data for determining the WWL, and the field data collected under this Task Order 415 Rapid Response, Hurricane Katrina Wind Water Line Data Collection – Louisiana were compared to this base data to determine if the two data sets were in agreement. A geodatabase with the WWL data points was created. Where WWL field data point locations varied from the photointerpreted flood area delineation by more than 200 feet, analyses using information about the depth of flooding and flood elevation for the WWL (and potentially for nearby HWM points) were conducted. If the flood elevation data and supporting documentation, including comments and photographs from the field crews, confirmed that the WWL point was correct, the inundation coverage was modified to agree with the field-collected data, and topography[6] was used to delineate the boundaries for these modifications. Notes from these comparisons are included in tabular format in Appendix D.

[6] Topography was obtained from the Louisiana State University website at http://atlas.lsu.edu/. It is 2-foot contour data provided to the University by the Louisiana Oil Spill Coordinator's Office and was generated from Light Detection and Ranging (LiDAR) data processed by 3001, Inc. The elevation data were developed in five phases between 2000 and 2003. Error measurements for the data were derived by surveying elevations at check points and comparing them to the LiDAR-developed elevation data. This comparison showed that the mean elevation difference for all points ranged from -6.41 centimeters (phases 3 and 4) to 0.64 centimeters (phase 5). The greatest Vertical Root Mean Square Error reported was 11.65 centimeters (phase 1).

The extent of flooding was defined not only by the WWL points, but also from data collected as part of the HWM Surveys (Task Orders 412 and 419). In some areas, it was difficult to locate WWL points, either because areas could not be accessed by field crews (no roads, undeveloped areas, etc.) or because there was no clear physical evidence to define a WWL point. This happened particularly in swampy/marshy areas where it was not clear how far inland the surge had moved through the swamps and marshes. In these cases, the elevation data from the HWM surveys were used to complement the data. The HWM is a measure of the peak flood elevation and, when used along with reliable topography data, can help to determine an approximate WWL boundary. In these cases, HWM points that appear to be near the edge of inundation (based on interpolation from other WWL points or boundary estimates) should be used, as surge-induced flood elevations will generally increase towards the coastline. Information about these HWMs and how they were used is provided in Table 4, and an overview map of their locations is shown in Figure 12.

Table 4. HWMs Used to Help Delineate the WWL

CHWM ID	ELEVATION (feet NAVD 88[a])	LOCATION	ISSUE	ACTION
KLAC-02-06	3.1	West of Lake Maurepas	Only one WWL point in this area and post-event imagery ends approximately 10,000 feet west of Lake Maurepas, so there were no photointerpreted inundation boundaries here either.	Elevation of 4 feet was used as a guide in this area to estimate the extent of flooding.
KLAC 02-07	2.8			
KLAC 02-08	3.3			
KLAC 02-09[b]	5.4			
KLAC 07-01	4.0			

[a] NAVD 88 = North American Vertical Datum of 1988
[b] A WWL point, but the surveyed elevation was used to help determine the extent of flooding in surrounding areas.

Figure 12. HWMs Used to Help Delineate the WWL

The complicated flooding patterns that occurred within the City of New Orleans due to the levee breaches made the field identification of WWL data points more challenging. Some CHWMs were determined to actually be WWL data points when data were reviewed after crews returned from the field. These data points are presented in Table 5.

Table 5. HWM Data Points Used as WWL Data Points

CHWM ID	LOCATION	REASONING
KLAC 06-28	New Orleans, along Lake Pontchartrain	Aerial imagery indicated that this was the boundary of flooding, and field crew personnel noted that, along Lake Pontchartrain by the levee east of the Lakefront Airport, there was some dry ground as land sloped upward.
KLAC 06-29		
KLAC 06-30		
KLAC 06-31		
KLAC 07-47	New Orleans, north of Mississippi River west of confluence with Industrial Canal	Aerial imagery indicated that this was the boundary of flooding, and field crew personnel noted that on the western side of the Industrial Canal, in New Orleans east, there was a dry area. St. Claude Avenue seemed to be the WWL line. On the east side of the Industrial Canal, the water got closer to the levee.
KLAC 07-48		

The GIS maps also show a general coastal wetland coverage based on National Wetlands Inventory (NWI) data to illustrate why WWL data points could not be located along much of the southern coast of southeast Louisiana.

HWMs were used to determine the inland limit of surge along coastal rivers. Because HWMs are grouped into two types, coastal and riverine, they serve as a good tool to help distinguish these two types of flooding. Therefore, the first general indication of the extent of surge was the 'boundary' between CHWMs and RHWMs along a given watercourse. After finding this boundary area, surge elevations for the closest CHWMs were identified, and the inland limit of surge was mapped by following the topography along these elevations.

In Louisiana, this method was used along the Pearl River and the Mississippi River. Along the Pearl River, two CHWMs were used to make the determination. However, one point was located in Louisiana, and the other was across the state line along the river in Mississippi. KLAC 06-05, the point in Louisiana, was located approximately 18.5 miles inland of the river's mouth at Lake Borgne and the Mississippi Sound. The other point, which was in Mississippi, was named KMS USGS-105 and located about 14 miles inland. As shown in Table 6, using these two points, an elevation of 15 feet NAVD 88 was determined to be the maximum elevation along the river where surge effects occurred.

Table 6. CHWM Points Used to Determine the Inland Extent of Surge Flooding along the Pearl River

POINT	DISTANCE INLAND FROM RIVER MOUTH (linear miles)	ELEVATION (feet NAVD 88)	ELEVATION USED (feet NAVD 88)
KLAC 06-05	18.5	15.2	15
KMS-USGS-105[a]	13.8	14.8	

[a] Some HWM points from USGS field teams were also available.

Along the Mississippi River, two points were used, KLAC 02-04 and KLAC 06-10, that are located well inland in western Jefferson Parish. These points provided the surge elevation used to determine the extent of the WWL along the river. This elevation was determined to be 18 feet NAVD 88 as shown in Table 7.

Table 7. CHWM Points Used to Determine the Inland Extent of Surge Flooding along the Mississippi River

POINT	ELEVATION (ft NAVD 88)	ELEVATION USED (ft NAVD 88)
KLAC 02-04	17.8	18
KLAC 06-10	17.9	18

GIS maps of the WWL were produced at a scale of 1:24,000 (see Appendix E). The maps depict the location of each WWL data point and the WWL. Additionally, they show the debris line and inundation located inland of the debris line. The GIS maps are based on USGS 7.5-minute topographic quadrangle maps.

Recommendations

The use of post-event imagery analyzed through photointerpretation, combined with field data and observations, allowed for a balanced interpretation of the WWL and extent of flooding, as shown on the maps in Appendix E. The post-event imagery provided an overview of the extent of flooding within the area and a basis for determining the general flood boundaries. The field data, including field crews' damage observations, pictures, notes about flood depths, etc., provided true ground observations to compare to the WWL developed through the use of the debris line and flood extent created via photointerpretation of the post-event imagery.

One potential area for improvement in the field data collection methodology would be the use of teams with a more specific focus on WWL data collection. While HWM data and field crew observations were helpful in interpreting the WWL locations, field crews with a more narrow focus aimed solely at determining the WWL would probably have allowed for more specific and/or descriptive data about WWL indicators and damages at sites, as well as better visual documentation (photographs) illustrating evidence of the WWL.

Much of southeastern Louisiana consists of swampy wetlands, which presented a major impediment to field data collection and prevented access to coastal areas in several of the affected parishes. While development in these areas is limited (along with the potential for damage), being able to collect data here would have allowed for a more continuous WWL to be delineated along the entire coastline. One possible solution would be to perform a flyover by renting time on a helicopter or small plane to observe conditions along these swampy coastal areas that would help to define the WWL.

Also, a better log or record of field crews' attempts to access areas where no data points were identified would help to create a clearer picture of the efforts made and the ground covered when there are no WWL data points to illustrate the crews' findings. One possible solution would be to make better use of mapping/navigational software to record crews' movements each day. Crews can note directly on a map what hindrances or problems kept them from collecting data in specific areas.

Findings and Observations

The WWL is shown as the inland extent of coastal flooding on the maps in Appendix E. Many of the WWL data points were taken around Lake Ponchartrain where there is the highest concentration of development in the affected area, which includes the City of New Orleans. Table 8 shows locations affected by flooding, their corresponding flood sources, and the map sheet names and numbers contained in Appendix E.

Table 8. Summary of Flood Sources and Map Sheets by Parish

PARISH	LOCATION (City or Area)	MAJOR FLOOD SOURCES	MAP SHEET NAMES AND NUMBERS
Ascension	Eastern portion of parish	Lake Maurepas and surrounding swamps and rivers, including the Petit Amite and Amite Rivers	French Settlement – 7 Mount Airy NW – 18 Sorrento –17
Jefferson	Coast along Lake Pontchartrain	Lake Pontchartrain and canal system	Indian Beach – 28 La Branche – 27 Luling – 33 New Orleans East – 35 New Orleans West – 34
Jefferson	Central portion of parish	Intercoastal Waterway, Lake Cataouatche, and Lake Salvador	Barataria – 44 Bertandville – 40 Lafitte – 45 Lake Cataouatche East – 39
Lafourche	Central eastern border of parish at Lake Salvador	Lake Salvador	Barataria – 44 Catahoula Bay – 43 Des Allemands – 37
Lafourche	Gulf Coast	Gulf of Mexico	No sheets printed for Gulf Coast area
Livingston	Southern portion of parish	Lake Maurepas, Amite River, Blind River, Natalbany River, Petit Amite River, and Tickfaw River	French Settlement – 7 Killian – 9 Mount Airy NE – 19 Mount Airy NW – 18 Springfield – 2 Whitehall – 8
Orleans	City of New Orleans	Lake Pontchartrain and canal system including Industrial Canal, London Avenue Canal, and 17th Street Canal	Chalmette – 36 Chef Menteur – 31 Little Woods – 30 New Orleans East – 35 North Shore – 21 Rigolets – 22 Spanish Fort – 29
Plaquemines	Gulf Coast	Gulf of Mexico	No sheets printed for Gulf Coast area
Plaquemines	Along Mississippi River	Mississippi River	Belle Chasse – 41 Bertandville – 40 Buras – 52 Chalmette – 36 Empire – 51 Happy Jack – 49 Lafitte – 45 Lake Laurier – 47 New Orleans East – 35 Phoenix – 46 Pilottown – 55 Point a la Hache – 48 Port Sulphur – 50

PARISH	LOCATION (City or Area)	MAJOR FLOOD SOURCES	MAP SHEET NAMES AND NUMBERS
Plaquemines	Along Mississippi River (con't)	Mississippi River (con't)	Triumph – 53 Venice – 54
St. Bernard	Western portion of parish	Industrial Canal, Intercoastal Waterway, and Lake Borgne	Belle Chasse – 41 Chalmette – 36 Delacroix – 42
St. Charles	Entire parish	Lake Pontchartrain, Lake Salvador, Lake Cataouatche, and the Mississippi River	Barataria – 44 Catahoula Bay – 43 Des Allemands – 37 Hahnville – 32 Lake Cataouatche East – 39 Lake Cataouatche West – 38 Laplace – 26 La Branche – 27 Luling – 33
St. James	Northeast corner of parish	Lake Maurepas and the Mississippi River	Convent – 23 Lutcher – 24 Mount Airy NW – 18 Sorrento – 17
St. John the Baptist	Parish coastline along Lake Pontchartrain and Mississippi River	Lake Maurepas, Lake Pontchartrain, Mississippi River, and Pass Manchac	Laplace – 26 Lutcher – 24 Manchac – 10 Mount Airy NE – 19 Mount Airy NW – 18 Ponchatoula SE – 11 Reserve – 25 Ruddock – 20
St. Tammany	Southern parish along Lake Pontchartrain and eastern parish bordering Lake Borgne and the Pearl River[1]	Lake Borgne, Lake Pontchartrain, Pearl River, and West Pearl River	Covington – 4 Covington SW – 12 Haaswood – 16 Hickory – 5 Madisonville – 3 Mandeville – 13 Nicholson – 6 North Shore – 21 Lacombe – 14 Rigolets – 22 Slidell – 15
Tangipahoa	Southern parish along Lake Pontchartrain	Lake Maurepas, Lake Ponchartrain, Natalbany River, Pass Manchac and Tangipahoa River	Manchac – 10 Ponchatoula SE – 11 Springfield – 2
Terrebonne	Gulf Coast	Gulf of Mexico	No sheets printed for this parish

[1] Most of eastern coast is not shown on maps. Focus is on surge flooding along coastlines of lakes.

Following is a brief summary of the extent of surge-related flooding in each of the parishes included as part of the study. It is suggested that the reader view the maps included in Appendix E while reading these summaries.

Ascension Parish

In Ascension Parish, flooding occurred in the eastern portion of the parish in an area that is mapped as a swamp/marsh. The WWL is located an estimated 3 to 3.5 miles inside of

Ascension Parish from its eastern border with St. John the Baptist Parish, westward to near State Highway 22 on the north side and to U.S. Highway 61 on the south side (see map sheets 7, 17, and 18). The WWL in this area was developed based on HWMs and topography. Aerial imagery was not available, and WWL data points were not taken because of the swampy nature of the area.

Jefferson Parish

Flooding in Jefferson Parish is attributed to the canal and pumping system being overwhelmed (see map sheets 27, 28, 33, 34, and 35). Unlike Orleans and St. Bernard Parishes, flood water was pumped out relatively quickly. Aerial imagery did not show clear signs of flooding in this area; however, field data collection for both WWL data points and CHWM data points showed that flood elevations were approximately -4 feet (NAVD 88) for much of the parish near Lake Pontchartrain; much of the parish lies below 0 feet (NAVD 88).

In the central and southern portions of the parish, some flooding occurred along the eastern edges of Lake Cataouatche and Lake Salvador. This flooding is shown on map sheets 39 and 44. The central portion of the parish is also shown on map sheets 40 and 45.

Lafourche Parish

In Lafourche Parish, the WWL was not delineated along the Gulf Coast. No field data points were collected for this parish, and post-event imagery did not include this area. WWL data points were not taken in most of this parish because surge effects occurred only in the undeveloped, largely inaccessible swampy areas along the southern coast. The wetlands coverage shown on the Appendix E map sheets (see map sheets 37, 43, and 44) shows the extent of NWI wetland areas where surge effects were difficult to identify. Along the eastern border of the parish, a WWL is shown along Lake Salvador (see map sheets 43 and 44) and extends from 150 feet landward of the lake in some areas to as much as approximately 3,000 feet landward.

Livingston Parish

The WWL is located north and west of Lake Maurepas, as much as 2 miles inland in some areas (see map sheets 2, 7, 8, 9, 18, and 19). State Highway 22 borders the low wetland areas near Lake Maurepas, and the WWL follows the roadway for much of the length of the parish.

Orleans Parish

The WWL in Orleans Parish is complicated; all three of the major levee breaches associated with Hurricane Katrina occurred in this parish in the New Orleans area (see map sheets 29 and 35). The New Orleans' Uptown Area, Garden District, and most of the French Quarter were spared from major flooding, but most of the rest of the City was flooded, as evidenced by the WWL. The WWL extends inland from the Lake Pontchartrain coast about 3.5 to 7.5 miles (see map sheets 29, 30, 35, and 36). However, much of the Lakeshore area just behind the lake's levees west of the Industrial Canal was spared. The portion of the parish south of the Mississippi River was also spared from flooding (see map sheets 34 and 35). East of the Industrial Canal (see map sheets 35 and 36), most areas were affected by flooding, but there are some pockets of high ground here, including areas along Gentilly Road and areas just behind the lake's levees.

Plaquemines Parish

Most development in Plaquemines Parish is located along the Mississippi River where there is a system of levees. Beyond the river, most of the parish consists of low, wetland areas. The levees were overtopped during Katrina, and developed areas along the levees were flooded. The east bank was hit particularly hard, and several communities in the parish sustained severe damage (see map sheets 40, 41, and 45-56). The WWL shows where flooding occurred just outside of the levees. Wetland areas are shown as such, indicating that surge effects occurred in these areas along the eastern and southern coasts.

St. Bernard Parish

There is considerable information that surge flooding occurred in St. Bernard Parish from Lake Borgne. The extent of wetlands in the parish, particularly in its eastern portion, made delineation of a WWL difficult (see Figure 3 and the pre-Katrina wetlands in St. Bernard Parish). Field crews could not gain access to this wetland area to obtain data points, nor could imagery analysts identify flooded wetlands. Therefore, although the WWL does not show flooding in this area (eastern part of panel 36 and points eastward), the NWI wetlands coverage is included to highlight this and other wetland areas where constant 'wet' conditions persist.

Field crews and imagery analysts were able to collect and assess data for western St. Bernard Parish (see map sheets 36, 41, and 42). However, it's important to note that the eastern border of the WWL in this area ends at one of the parish's levee systems, which is also the border of the NWI wetlands. According to recent reports, however, the surge affecting even this western portion of the parish came largely from Lake Borgne and breached this levee system. Therefore, although the eastern area is shown as wetlands, surge from Lake Borgne did travel through this area, reached the western portion of the parish via levee breaches, and caused flooding.

St. Charles Parish

In St. Charles Parish, the WWL along Lake Pontchartrain extends inland for approximately 3 to 5 miles, with U.S. Highway 61 forming the border for most of the WWL. Flooding along the Mississippi was contained within the levees in this parish (see map sheets 26, 32, and 33). Further south along Lake Salvador and Lake Cataouatche, some relatively minor flooding resulted in a WWL around and between the lakes (see map sheets 38 and 39). Generally, this WWL stays within 500-1,500 feet of the lakes' coastlines in wetland areas.

St. James Parish

St. James Parish's northeast corner was affected by flooding from Lake Maurepas; however, this area consists primarily of wetlands. Areas south and west of U.S. Highway 61, where development begins, are beyond the WWL. Flooding along the Mississippi River was contained within the levee system.

St. John the Baptist Parish

Much of the parish north of I-10 is composed of swamp/marsh areas and portions of lakes Pontchartrain and Maurepas. Between I-10 and U.S. Highway 61, most areas were inundated with flooding from Lake Pontchartrain (see map sheets 25 and 26). This area includes the cities of Garyville, Reserve, and Laplace. However, developed areas south of I-10 and between State Highway 3188 and Highway 51 (a portion of the City of Laplace) were an exception and were not inundated. In this parish, flooding along the Mississippi River was contained within the levee system (see map sheets 17, 18, 23, and 24).

St. Tammany Parish

Along Lake Pontchartrain, the WWL is located from approximately 3,000 feet inland of the shore (west of Lacombe Bayou and south of U.S. Highway 190 as shown on map sheets 3, 4, 12, 13, and 14) to as much as 4 miles inland along Lacombe Bayou (see map sheet 14). East of Lake Pontchartrain at the Pearl River's confluence with Lake Borgne, a debris line is shown approximately 3.5 to 5.5 miles inland (see map sheets 21 and 22).

Tangipahoa Parish

WWL data points were not taken in this area, so the WWL is based on data from HWMs and aerial imagery. The WWL ended in swampy, undeveloped areas that make up the southern portion of the parish (see map sheets 2, 10, and 11).

Terrebonne Parish

In Terrebonne Parish (as in Lafourche Parish), a WWL was not drawn because only one field data point was collected and imagery did not include this area. WWL data points were not taken in most of this parish because surge effects occurred only in the undeveloped, largely inaccessible swamp/marsh areas along the southern coast. The NWI wetlands coverage shown on the Appendix E index sheet indicates areas where surge effects were difficult to determine given the land cover.

This page is intentionally left blank.

Conclusion

Although field crews attempted to visit coastal areas along the Gulf of Mexico in Terrebonne, Lafourche, Plaquemines, and St. Bernard Parishes, the swampy characteristics of the Louisiana coast prevented access to and clear identification of WWL points in many of these areas. However, coverage was developed to show these swamp/marsh areas by using information such as the land cover shown in aerial imagery (post-event imagery obtained under HMTAP Task Order 411) and other sources of GIS land and water cover data, including NWI data. Effects from surge in these areas were partially absorbed by the swamps, but the swamps did not fully buffer the effects of the storm, particularly in Plaquemines and St. Bernard Parishes where there was extensive damage farther inland.

Similarly, low-lying swamp/marsh areas west of Lake Pontchartrain near Lake Maurepas were difficult to access, and thus estimates of the WWL in these areas are based on elevations of CHWMs and topography. The WWL in this area extends several miles west of Lake Maurepas where swamp/marsh areas can be found. Field crews noted that much of this area lacks significant development due to the land cover.

A total of 45 WWL data points were identified in southeast Louisiana by the field crews. Of these, 23 data points were located in Orleans Parish, 6 were in Jefferson Parish, 5 were in both St. Tammany and St. Charles Parishes, 2 were in Plaquemines Parish, and 1 data point each was in the remaining parishes of Livingston, St. James, Terrebonne, and St. John the Baptist.

Of these 45 points, 11 were within a range of approximately 200 feet from either the debris line or inundation polygon developed by photointerpretation of the post-event imagery. Using the remaining 34 points, including the field crews' observations, photographs, post-event imagery, local topography, and base mapping, engineers analyzed the photointerpreted debris line and inundation area and decided that 18 of these points would be used to actually edit the photointerpreted data.

Appendix A: WWL Data Points

Appendix A contains a table with field-collected data for each WWL data point. These data are first referenced in the Data Collection Methodology section of this report and were collected between September 9 and September 22, 2005. As described in the Mapping Methodology section, the data points were used together with the information about the debris line and the extent of flooding determined through photointerpretation of post-event imagery to delineate the WWL as presented on the maps in Appendix E. A description of how the data points were used to edit the debris line and limits of inundation defined through photointerpretation of the imagery can be found in Appendix D.

APPENDIX A IS NOT INCLUDED IN THE REPORT VERSION FOR PUBLIC RELEASE DUE TO PRIVACY ISSUES.

Appendix B: WWL Photographs

Appendix B contains an index and thumbnails of the photographs that correspond to each WWL data point presented in Appendix A. The naming convention for the photographs uses the data point ID Number (KLAC-XX-XX) and then a sequential number for the photographs(s) associated with that ID Number (KLAC-XX-XX-1, KLAC-XX-XX-2). In most instances, two photographs were taken for each data point; however, when additional information was needed, three photographs were taken.

NOTE: The SD memory cards containing some of the images became corrupt and the images on them were unrecoverable. For this reason, images for some of the data points are not available.

APPENDIX B IS NOT INCLUDED IN THE REPORT VERSION FOR PUBLIC RELEASE DUE TO PRIVACY ISSUES.

Appendix C: Debris Line and Inundation Mapping Report:

HMTAP Task Order 411, Rapid Response, Aerial Radar – Louisiana, Mississippi, and Alabama

Appendix C contains a summary report of the debris line and inundation mapping performed under HMTAP Task Order 411: Rapid Response, Aerial Radar – Louisiana, Mississippi, and Alabama. Photoanalysts used the post-event aerial imagery to estimate the location of the debris line and the extent of inundation from Hurricane Katrina. As described in the Mapping Methodology section of the report, this information developed by the photoanalysts was used as the initial estimate of the WWL delineation, which was further edited based on the field-collected data presented in Appendices A and B.

Hurricane Katrina Rapid Response:
Debris Line and Inundation Mapping
20 January 2006

Background

As part of the Hurricane Katrina Rapid Response disaster relief efforts performed for the Federal Emergency Management Agency (FEMA), EarthData International, LLC (EarthData) supported URS Group, Inc. (URS) in its effort to identify areas of storm damage through mapping procedures. EarthData produced and delivered mapping in ESRI shapefile (SHP) format containing delineation of debris lines caused by ocean surge and polygons surrounding areas inundated by floodwaters from both surge and freshwater flooding from Hurricane Katrina. The areas mapped include the storm-struck areas along the Gulf Coast of Alabama, Mississippi, and Louisiana.

The primary purpose of this mapping effort was to provide a comprehensive, region-wide inventory of areas damaged by Hurricane Katrina with as quick a turnaround as possible. More specifically, the mapping products distinguished between areas damaged by high velocity floodwaters from surge along the coast (debris line), comparably slower moving floodwaters from surge and riverine flooding (inundation polygons), and high winds. FEMA's National Flood Insurance Program (NFIP) requires this type of data to ensure that Flood Insurance Studies (FISs) and Flood Insurance Rate Maps (FIRMs) provide reasonable risk information.

Area of Interest

Mapping coverage extended along the entire Gulf Coast region of Louisiana, Mississippi, and Alabama. The area mapped was approximately 12,000 square miles and included portions of or all of the following counties:

1. **Alabama Counties:** Baldwin and Mobile
2. **Mississippi Counties:** Forrest, George, Greene, Hancock, Harrison, Jackson, Lamar, Marion, Pearl River, Perry, and Stone
3. **Louisiana Parishes:** Jefferson, Livingston, Orleans, Plaquemines, Saint Bernard, Saint Charles, Saint John the Baptist, Saint Tammany, Tangipahoa, and Washington

Imagery Source

EarthData used natural color digital aerial orthophotographs acquired between September 4 and September 17, 2005. The 3001, Inc. source imagery was acquired under an unrelated disaster response contract issued by the U.S. Army Corps of Engineers (USACE) to support their "blue tarp" task. The imagery was made available to URS for use in Hazard Mitigation Technical Assistance Program (HMTAP)-related work. Questions related to the imagery acquisition scope of work and technical specifications should be addressed to the USACE (Kevin Carlock, USACE, Rock Island District, 309-794-5249). The 3001, Inc. imagery provided to EarthData by URS covered approximately 3,600 tiles (4,077 x 4,092 pixels) and was projected in latitude/longitude coordinates.

Accuracy Standards

Digital orthophotography is normally created from aerial photographs combined in an aerotriangulation adjustment with ground and airborne positional control, which is rectified using a digital elevation model

(DEM). In the Hurricane Katrina response, USACE and their contractor, 3001, eliminated some of rigorous photogrammetric processing steps to expedite delivery of the imagery within 24 hours of acquisition. No ground control was acquired. Airborne Global Positioning System (GPS) and inertial measurement unit (IMU) data were used to provide an absolute orientation solution; however, a rigorous aerotriangulation block adjustment was not performed. Due to the flatness of the terrain, it was also decided that planar rectification (using a flat surface) would be performed, rather than rectification to an actual DEM. The resulting orthophotography, therefore, does not meet National Map Accuracy Standards or Federal Geographic Data Committee (FGDC) standards for the final map scale. No rigorous positional accuracy assessment was performed either by the USACE or URS due to 1) lack of extensive ground control check points and 2) turnaround time required for response and recovery products. Based on observations of positional displacements of distinguishable linear features between adjacent flight lines and comparisons of existing geographical information system (GIS) data layers overlaid on the orthophotographs, EarthData estimates the horizontal accuracy of the 3001, Inc. orthophotography to be on the order of ±10 meters. Again, this is not a rigorous accuracy assessment, but rather a subjective estimate of error based on the internal consistency of the image dataset. When using derived mapping products, such as the debris line and inundation mapping described in this report, the end user should be cognizant of the magnitude of the potential spatial errors.

Mapping Products

EarthData used a production staff of eight professional cartographic analysts to produce and deliver mapping products for the above-mentioned areas stricken by Hurricane Katrina. EarthData's project manager and cartographic team leader/supervisor managed all of the day-to-day project functions throughout the life of the project. This mapping effort began on September 9, 2005 and was completed on October 7, 2005.

The final deliverable products consisted of polygon shapefiles in units of meters projected to Universal Transverse Mercator (UTM) Zone 16, North American Datum of 1983 (NAD83). A separate shapefile was produced for each of the mapping features—one for the debris line and one for inundation polygons.

Mapping analysts used 3001, Inc. imagery to interpret areas of storm surge damage along the coast marked by debris lines as well as inland areas that experienced surge and/or riverine flooding. As a secondary source, analysts used 10-foot contours produced from Light Detection and Ranging (LiDAR) and U.S. Geological Survey (USGS) DEM datasets covering the areas of interest. The contours were referenced with the imagery to locate low-lying areas where the potential for flooding was high and debris would likely collect. EarthData's staff used preliminary high water mark points provided by URS as another ancillary reference to locate areas field surveyors identified as flooded.

Using the imagery source provided along with the ancillary sources listed above, EarthData mapped the debris line where visual evidence of the high velocity ocean surge was present. For instance, significant debris from man-made structures, sand, mud, and other biomass would collect along lines where the surge carried it over land.

Additional indications of ocean surge extended along the coast, where trees and vegetation had turned brown due to salt water inundation. Flooding further inland was determined by visual evidence of standing water or deposited debris and mud along bays, rivers, lakes, and other water bodies farther inland; receding floodwaters left the debris behind. In areas where the imagery was either void, corrupt, or covered by clouds, a polygon was digitized around the area and labeled as "obscured."

Software Applications

EarthData used a combination of ESRI ArcCatalog and ArcView software to create the working file templates. These templates, or "seed files," set all of the parameters and applicable attribution that was later populated in the compilation stage, ensuring consistency in the file structure across the entire project. Digitizing of the debris lines and flood polygons was performed using both ESRI ArcView and ArcMap software packages. All final data were merged to create a single file in ESRI shapefile format for each of the two separate featured themes: the debris line and inundation polygons. All shapefiles were reprojected from latitude/longitude to the UTM Zone 16, NAD83 using ArcCatalog.

Interpretation Obstacles

EarthData's analysts used professional interpretation and judgment in identifying areas damaged from ocean surge and inland flooding based on the sources of information provided. Due to the urgency associated with the hurricane response, some scattered areas of the aerial imagery contained cloud cover. Lighting conditions were often less than optimal for interpretation, and it was not physically possible to photograph the entire project area coincident with actual storm surge and peak inundation conditions. Mapping analysts were confronted with the need to make subjective decisions in interpretation.

Figure 1 shows a case of inland flooding along a river, where the high water had partially receded by the time the photograph was taken. In such cases, analysts designated any areas covered with mud, sand, or silt, as well as areas where the color of the ground or vegetation indicated a high level of moisture due to recent inundation, as "flooded."

Figure 1

When flood waters recede quickly before the photographs are taken, analysts are confronted with a more complex interpretation assessment. In these cases, analysts look for signatures in the photographs, such as leaning trees, standing water, deposited debris (mud, silt, vegetation, etc.) and other features, that indicate the presence of inland flood waters. Figure 2 depicts an area which was interpreted to have been entirely inundated with water that receded before the photo was taken. This was determined by the presence of mud, fallen trees and saturated ground indicated by brown coloration throughout the image.

Figure 2

Figure 3 represents an area where the presence of marsh results in a unique situation whereby debris no longer collects as it would typically do on dry land. What is normally a visible debris line on dry land becomes less obvious for photo-interpretation when over marsh and other standing water bodies. In such cases, analysts may use contour lines, the presence of high water marks, deposited mud and silt, and/or any damage to vegetation that has been submerged by flood waters. The marsh in Figure 3 is evident in the lower left and lower right sectors of the image. URS engineers judged final placement of the wind/water line in such areas where photo interpretation alone was not conclusive.

Figure 3

Figure 4 depicts the presence of multiple debris lines. In such cases, the analyst must decide whether all debris was deposited by the ocean surge or some debris was later swept up by inland flooding caused by heavy rain. If tide waters are present along the coast, it can result in multiple debris lines being left behind. Typically, the analyst will place the debris line at the most evident and consistent debris line or along the furthest inland point (high water mark).

Figure 4

Coastal areas containing salt marshes and other low-lying areas such as that represented in Figure 5 can pose a challenge to photo-interpreters delineating flood waters. An analyst must determine whether or not to represent an area as flooded. There are many cases in which land appears to be flooded, but the area is really a marsh and always has saturated characteristics. In these cases analysts often review other sources such as secondary maps, historical data, and field surveyed conditions. Analysts also look for deposited mud and the condition of nearby vegetation to determine whether an area has been flooded or whether it is simply a marsh.

Figure 5

Appendix D: Notes on Analysis of WWL Data Points

Appendix D contains a record of the comparison of the photointerpreted data to the field data and the actions taken to resolve any differences between the two. The Mapping Methodology section of the report provides a description of how the field-collected data presented in Appendices A and B were used to edit the photointerpreted debris line and inundation limit, which were developed as explained in Appendix C. Appendix D provides detailed descriptions of how each WWL data point was used to either confirm the proper delineation of the WWL based on the photointerpreted data, or to edit this initial delineation of the WWL where the two data sets did not agree.

Comments from Field Crew Reviewers

Comment	Map Panel	HWM/WWL Points Nearby	Action
Lakefront Airport was flooded - shown as outside inundation area on map	Spanish Fort	KLAC 88-20	Expanded inundation polygon to include the airport.
Points near levee in St. Bernard Parish do seem to be pretty accurate in showing the limit of flooding. There was some dry area there.	Chalmette	KLAC 01-34, 01-35, 01-40, 01-38	If anything, the HWM data supports that the flooding went all the way up to the levee in this area [01-40 (4 ft), 01-34 (5.8 ft), 01-35 (6.3 ft), 01-38 (4.4 ft)]. Leave as shown on photointerpreted inundation limits.
Along Lake Pontchartrain by the levee east of the Lakefront Airport, there was some dry ground as land sloped upwards	Spanish Fort and Little Woods	KLAC 08-19, 06-25, 06-28, 06-29, 06-30, 06-31	Made these points into WWL points 06-28 (0.8), 06-29 (0.9), 06-30 (1.2), 06-31 (1.5) and looked at topo to confirm that existing boundary made sense with topo.
Swampy areas of St. Bernard Parish east of inundation polygon was flooded - limited access to this area. Swampy areas of Plaquemines between the coast and the river are also thought to have been affected by surge.	north, east, and south of Delacroix. Happy Jack, Port Sulphur, etc.		Made a separate polygon coverage to highlight marshy areas where there were likely surge affects including coastal areas in St. Bernard, Plaquemines, LaFourche and Terrebonne.
Flooding was mostly limited to river floodplains west of Pontchartrain and in the Lake Maurepas area	Killian, Mt. Airy, Reserve	KLAC 03-05, 03-06, 03-07, 03-08, 03-09, and 03-10.	Used the topo and HWM data to delineate flooding/WWL here
On the western side of the industrial canal, in New Orleans east, points 07-47, 07-48 likely do define the WWL. The street St. Claude Ave seemed to have been the WWL line for the most part. On the east side of the Industrial Canal, the water got closer to the levee than on the New Orleans side if not all the way to the levee.	New Orleans East	KLAC 07-47 and 07-48	Made these points WWL points

Hurricane Katrina
Louisiana
Notes on Analysis of Wind Water Line Data Points

Parish/ WWL Data Point	Source of Flooding	Map Panel	Surveyed Elev (ft NAVD 88)	Elev (from 2-ft contours)	Flood Elev (from 2-ft contours)	Distance to Flood Boundary (ft)	Action	Reasoning
Jefferson								
KLAC-04-10	Coastal	Indian Beach SW	9.4	*Elevation Data not available for this topo quad*		320	No action.	Point along levee on Lake Pontchartrain that held.
KLAC-04-11	Coastal	Indian Beach SW	11.6			0	No action.	Point along levee on Lake Pontchartrain that held.
KLAC-04-13	Canal/Coastal	New Orleans West NW	-3.9	-4	*Along inland canals where enough flood inundation is mapped*		Used contour data to create WWL with boundary at elevation -2 to -4.	No inundation polygon was shown in Jefferson Parish along Lake Pontchartrain from aerial imagery photointerpretation. Reports and comments from field crews and the number of coastal HWMs taken in this area clearly indicate there was significant flooding here. Unlike other nearby parishes in the New Orleans area, flooding in Jefferson Parish was drained relatively quickly and many areas experienced only shallow flooding. Therefore, there may not have been obvious signs of flooding on the imagery. There were enough datapoints (both WWL and coastal HWM) and comments from field crews to confirm there was widespread flooding here.
KLAC-04-14	Coastal	New Orleans West NW	-3.7	-4			Used contour data to create WWL with boundary at elevation -2 to -4.	
KLAC-04-15	Coastal	New Orleans West NW	-3.8	-4			Used contour data to create WWL with boundary at elevation -2 to -4.	
KLAC-04-34	Coastal	Indian Beach SW	9.4	*Elevation Data not available for this topo quad*		140	No action.	Point along levee on Lake Pontchartrain that held.
Lafourche (0)								
Livingston (NIS)								
KLAC-02-09	Coastal	Killian	5.4	6	N/A	N/A	Went up canals with inundation polygon.	Inundation line seems to match with surveyed elevations through here, except for canals where WWL datapoint was taken.
Orleans								
KLAC-01-20	Breached Levee	New Orleans East NW	0.7	0	-12	7100	Mapped as 'islands' of high ground.	Small area that appears to be high ground, according to imagery and WWL datapoints.
KLAC-01-33	Breached Levee	New Orleans East	2.3	2	4	500	Moved inundation boundary out to this point - use topo as guide.	Imagery and flagger observations support that flooding went further inland here.
KLAC-02-13	Breached Levee	Spanish Fort SW	1.6	2	-2	7700	No action.	Looks like levee along this canal worked ok and kept water out, but areas are flooded from other canal break where water has come back up into these areas.
KLAC-02-14	Breached Levee	Spanish Fort SW	1.4	2	-2	7900	Left inundation polygon as is.	Looks like levee along this canal worked ok and kept water out, but areas are flooded from other canal break where water has come back up into these areas.

Parish/ WWL Data Point	Source of Flooding	Map Panel	Surveyed Elev (ft NAVD 88)	Elev (from 2-ft contours)	Flood Elev (from 2-ft contours)	Distance to Flood Boundary (ft)	Action	Reasoning
Orleans (cont'd.)								
KLAC-02-16	Coastal	Spanish Fort SE	10.7	8	-2	3067	Edited inundation polygon to show portions of elevated area of levee as outside of flooding.	Levee worked in this area.
KLAC-02-17	Coastal	Spanish Fort SE	14.5	12	-2	5000	Edited inundation polygon to show portions of elevated area of levee as outside of flooding.	Levee worked in this area.
KLAC-02-18	Coastal	Spanish Fort SE	12.9	14	-2	7900	Edited inundation polygon to show portions of elevated area of levee as outside of flooding.	Levee worked in this area.
KLAC-02-21	Breached Levee	Spanish Fort SW	1.7	2	-2	7400	Left inundation polygon as is.	Looks like levee along this canal worked ok and kept water out, but areas are flooded from other canal break where water has come back up into these areas.
KLAC-02-22	Coastal	Spanish Fort SW	12.6	14	-2	4900	Edited inundation polygon to show portions of elevated area of levee as outside of flooding.	Levee worked in this area.
east of KALC-02-22		Spanish Fort SW	*not an actual WWL point*				From imagery, area shown as inundated actually stayed dry. Adjusted inundation polygon to show this area outside of flooded area.	Imagery supports that this area did not flood.
KLAC-04-16	Riverine	Spanish Fort	1.3	2	2	0	No action.	Very near existing boundary. No action.
KLAC-04-17	Riverine	Spanish Fort	7.7	8	6	230	No action.	Point on levee, but areas on both sides of levee in this vicinity were dry.
KLAC-04-18	Riverine	Spanish Fort	16.6	14	6	330	No action.	Point on levee, but areas on both sides of levee in this vicinity were dry.
KLAC-04-21	Coastal	New Orleans East NW	1.5	0	-12	1750	Mapped as 'islands' of high ground.	Small area that appears to be high ground, according to imagery and WWL datapoints.
KLAC-04-25	Breached Levee	New Orleans East	1	2	2	75	No action.	Right near existing boundary.
KLAC-04-26	Breached Levee	New Orleans East	1.73	4	2	1000	Moved inundation boundary out to this point - use topo as guide.	Imagery and flagger observations support that flooding went further inland here.
East New Orleans		Little Woods & Chef Menteur	note that there are not HWMs or WWL points here. Swampy, undeveloped area without access					
Plaquemines								
KLAC 05-18	Riverine	Bertrandville	16.3	14	8	260	No action.	Point is close to inundation boundary. Polygon is contained within levee and point is on top of levee.
KLAC 08-06	Riverine	Port Sulphur	1.4	2	12	0	No action. Point is right along inundation border.	Point is along border
St. Bernard (0)								
St. Charles								
KLAC-02-02	Coastal	Luling	13.6	14	14	10	Along levee. No action	Flooding contained in levee system in this area along MS River.
KLAC-02-03	Coastal	Luling	15.7	14	16	0	Along levee. No action	Flooding contained in levee system in this area along MS River.
KLAC-02-04	Coastal	Luling	17.8	18	16	87	Along levee. No action	Flooding contained in levee system in this area along MS River.
KLAC-02-05	Coastal	Des Allemands	3.5	3	4		No inundation mapped here - left as it was.	Only point for area along Bayou des Allemands. Not enough info for mapping WWL.
KLAC-20-01	Coastal	Hahnville	13.5	10	2	65	Along levee. No action	Flooding contained in levee system in this area along MS River.

Parish/ WWL Data Point	Source of Flooding	Map Panel	Surveyed Elev (ft NAVD 88)	Elev (from 2-ft contours)	Flood Elev (from 2-ft contours)	Distance to Flood Boundary (ft)	Action	Reasoning
St. James								
KLAC-20-03	Coastal	Lutcher	13.6	14	4	90	Brought inundation border out to point along levee from 20-02.	Inundation border follows levee through this area. Point taken on levee.
St. John the Baptist								
KLAC-03-09	Coastal	Laplace	3.9	6	4	4100	No action.	Flat area through here that appears to be highly vegetated, undeveloped swamp, shown as being inundated according to photointerpretation. Would seem that much of this swampy area would have been flooded, but there is not much access or structures for finding HWMs with the swamp, so left inundation boundary as it was.
KLAC-03-10	Coastal	Laplace	5.7	6	4	4100	No action.	
KLAC-20-02	Coastal	Reserve	12.9	14	20	175	Along levee. No action	Flooding contained in levee system in this area along MS River.
St. Tammany								
KLAC-01-03	Coastal	Lacombe SW	7.57	6	4	730	Moved line out to 8-ft contour in this area, about 8,000-ft long stretch.	Imagery shows discoloration of vegetation from flooding beyond current inundation boundary. Inland polygon doesn't make sense with topo.
KLAC-01-13	Coastal	Lacombe NW	10.85	10	4	500	Moved line out to 10-ft contour line.	Imagery shows discoloration of vegetation from flooding beyond current inundation boundary and point supports that inundation went further inland.
St. Tammany (con't)								
KLAC-07-08	Coastal	Mandeville NW	9.23	8	10	450	No action.	Flaggers estimate flood depth is 1.3 ft at this point and area is relatively flat, so inundation could have spread farther inland, as indicated by inundation polygons.
KLAC-07-09	Coastal	Mandeville NW	10.32	8	8	480	Moved line to follow 10-ft contour closer east of point.	Imagery shows discoloration of vegetation in this area beyond flood inundation. HWMs through here (07-02, 07-03) show elevation of 9 to 10 ft.
KLAC-07-11	Coastal	Covington	7.8	6	2	3500	Moved flooding inland using imagery, topo (~8ft) and point as guide.	Based on imagery and point, need to move flooding further inland. Flaggers went into subdivision to find point where there was an estimated 1.3-ft depth.
Terrebonne								
KLAC-02-01	Coastal	Montegut	2.1	3	*no inundation mapped here*		Kept for reference, but noting that this area is swampy, with limited access. Do not have enough points for full WWL or inundation polygon here.	Keep for reference, but we're not going to use with WWL or inundation polygon since there is only one point.
Tangipahoa								
Undeveloped swampy area. No WWL points. HWMs are concentrated in small areas along highways/roadways.								

Appendix E: WWL Maps

Appendix E contains the WWL Maps illustrating the location of the WWL. Summaries of the WWL by parish are found in Table 8, which also highlights which of the following map sheets correspond to each parish.