High Water Mark Collection for Hurricane Katrina in Alabama

FEMA-1605-DR-AL, Task Orders 414 and 421

April 3, 2006 (Final)

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Alabama High Water Mark Collection
FEMA-1605-DR-AL

Final Report

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Federal Emergency Management Agency
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Prepared by:

URS

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

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Table of Contents

Figures

TABLES

APPENDICES

Abbreviations and Acronyms

Acronym	Definition
AL	State of Alabama
cfs	Cubic feet per second
FEMA	Federal Emergency Management Agency
FIRM	FEMA Flood Insurance Rate Map
GPS	Global Positioning System
HMGP	Hazard Mitigation Grant Program
HMTAP	Hazard Mitigation Technical Assistance Program
HWM	High Water Mark
HWM ID	High Water Mark Identification Number
IA	Individual Assistance
LAT	Latitude
LON	Longitude
mb	Millibar
mph	Miles Per Hour
NAD 83	North American Datum of 1983
NAVD 88	North American Vertical Datum of 1988
NFIP	National Flood Insurance Program
NGS	National Geodetic Survey
NGVD 29	National Geodetic Vertical Datum of 1929
NHC	National Hurricane Center
NOAA	National Oceanic and Atmospheric Administration
NWS	National Weather Service
PA	Public Assistance
QA	Quality Assurance
RV	Recreational Vehicle
SLOSH	Sea, Lake and Overland Surges from Hurricanes
TBM	Temporary Bench Mark
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey

Glossary of Terms

Term	Definition
Astronomical Tide	The periodic rising and falling of the earth's ocean waters resulting from the gravitational attraction of the Moon, Sun and other astronomical bodies acting upon the rotating earth.
Building Performance Assessment	The structural assessments of how buildings hold up during a storm event.
Coastal Flooding	Onshore rush of water piled higher than normal as a result of high winds on an open water body's surface.
Debris Line	Defines the extent of flooding where debris such as parts of houses, docks, cars, or other non-natural materials are carried by flood waters with some velocity and then dropped as the flood waters lose velocity and begin to recede.
Disaster declaration	The formal action by the President that makes a State eligible for major disaster or emergency assistance under the Stafford Act.
Flagging	Marking or otherwise documenting the horizontal and vertical location of a high water mark so that the high water mark data is preserved for future surveying. This data will then be available even if the homeowner cleans the property or it rains and therefore eliminates the visible high water mark.
Flood recovery map	High-resolution maps that show flood impacts, including high water mark flood elevations, flood inundation limits, the inland limit of waterborne debris (trash lines), and storm surge elevation contours based on the high water marks. The maps also show existing FEMA Flood Insurance Rate Map (FIRM) flood elevations for comparison to hurricane data.
Hazard Mitigation Grant Program	A FEMA program that 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.

Term	Definition
High Water	The maximum elevation that flood waters reach as a result of a storm event.
High Water Mark	A physical mark, such as a mud line, that designates the location and elevation of flood waters from a storm event.
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.
Inundation Maps	Maps that delineate the areas flooded during a storm.
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 reduces or eliminates 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	Used as the standard map horizontal coordinate system default by the majority of GPS devices.
North American Vertical Datum of 1988	The most widely used vertical control datum in the U.S. today. It was established by the minimum-constraint adjustment of the Canadian-Mexican-U.S. leveling observations. The general adjustment of NAVD 88 was completed in June 1991.
Point	A point associated with a discrete geographic location where data pertaining to the study were taken.
Public Assistance	Federal assistance provided to State and local governments, 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 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

Term	Definition
	share (up to 25 percent) is split with the applicants.
Riverine Flooding	Flooding that is a result of elevated levels of a river due to heavy rainfall.
SLOSH	Stands for "Sea, Lake and Overland Surges from Hurricanes," a computer model used by coastal scientists and engineers to predict the level of coastal flooding during a hurricane.
Stage	A term used by water resource professionals to indicate the elevation of the water.
Surge-only	A rise in the normal water level of a coastal body, also referred to as Stillwater flooding.
Temporary Bench Mark	A point (often a nail or stake) set near a high water mark. The vertical distance between the high water mark and temporary bench mark is measured by the personnel setting the temporary bench mark. Surveyors then survey the location and elevation of the temporary bench mark. The measured vertical distance between the high water mark and temporary bench mark is added to the temporary bench mark elevation to compute the elevation of the high water mark.
Water mark	A mark, usually on structures, left by flood waters.
Wave Height	Represents the coastal high water mark elevation due to more direct wave action.
Wave Runup	Represents the height of water rise above the surge-only level due to water rush up from a breaking wave.
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 is located along the debris line, but in some cases, inundation and flood damage extends 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 flood waters and left behind as the flood waters recede.

Executive Summary

Introduction and Purpose of the Study

The Federal Emergency Management Agency (FEMA) contracted URS Group, Inc. (URS) under Rapid Response Task Orders 414 and 421 of the Hazard Mitigation Technical Assistance Program (HMTAP) contract to assist in the disaster recovery in Alabama following Hurricane Katrina by collecting high water marks (HWMs). This study documents the HWM survey conducted along Alabama coast following Hurricane Katrina, which began affecting the area on August 29, 2005.

The purpose of this study was to document maximum flooding elevations that occurred as a result of Hurricane Katrina by collecting HWMs in affected areas. HWM data collection helps accurately document a flooding event and assists in response, recovery, and mitigation, for future disasters. These HWM data help place the event within a historical context, improve estimates of current flood risk, and enable governments to make cost-effective decisions about mitigation efforts.

Methodology

HWMs are perishable, and it was important to quickly capture HWM information before the HWMs disappeared. Consequently, field work first involved locating and flagging representative HWMs. Flagging captured information regarding the location and description of the HWM so that it could be surveyed at a later time, even if the markings had been cleaned.

URS flagged about 150 HWMs during the rapid response field assignment, which began on August 30, 2005 after receipt of a Notice to Proceed from FEMA. URS initiated data collection to determine the HWM study area on August 31, 2005. An orientation meeting was held for Alabama field staff on September 1, 2005 in Tallahassee, Florida. URS then deployed field staff to the accessible areas of Alabama on September 5, 2005, and additional crews were mobilized on September 7. By September 8, five flagging teams were in the field, and by September 10, eight flagging teams were in the field. All flagging was completed in Alabama by September 12, 2005.

By September 6, 2005, URS placed calls to all county emergency managers in Alabama to determine their priorities for HWM collection. Sixty counties indicated there was no riverine flooding in their county, and seven counties did not answer their phone or no one knowledgeable was available. The Mobile County Emergency Manager indicated the areas hardest hit by coastal flooding were the communities of Fowl River and Coden (west of Mobile Bay). Based on this data, Baldwin and Mobile Counties were identified as the study area.

Two-person flagging teams were assigned a geographic area in which to identify and flag HWMs, as indicated by mud lines, water lines, debris lines (i.e., man-made materials), or wrack lines (i.e., plant materials). The spacing of the flagged HWMs was irregular. More HWMs were flagged in areas that were significantly impacted by flooding than in areas of minor flooding. Consequently, more HWMs were flagged along the coast and bay. However, inland coastal HWMs were also flagged to determine the inland extent of flooding. Multiple HWMs were flagged in the same area to document different coastal flood types (e.g., surge-only, wave height, wave runup) or to better determine the flood elevation. Evaluation of site conditions where HWMs were flagged is based on the flaggers' best judgment of the height of flood waters. In addition, the height of flood waters can be affected by outside forces such as wind and shielding by other structures. Therefore, in significantly damaged areas, multiple HWMs were obtained in the same area to provide better flood elevation data. Fewer HWMs were flagged in areas that received less flooding or where there were fewer buildings.

URS survey crews surveyed the HWMs identified and flagged by URS flagger teams and the HWMs identified separately by USGS. The survey crews used static global position system methods and conventional leveling to determine the horizontal coordinates (latitude and longitude) and elevation for each HWM. HWMs were surveyed horizontally in the North American Datum of 1983 (NAD 83), Alabama West State Plane Coordinates, and vertically in the North American Vertical Datum of 1988 (NAVD 88); both surveys were conducted in U.S. survey feet. The HWMs were surveyed to the accuracy of 0.25 foot vertically and 10 feet horizontally with a 95% accuracy level.

Coastal HWM Observations

It should be noted that FEMA initially identified several counties to be investigated for riverine HWM collection. However, based on URS' field investigations, HWMs that may have been classified as riverine flooding were not found in Alabama. Therefore, only observations relative to coastal high water marks are discussed. Data outliers may be found in each of the areas discussed below. The outliers are anomalies that occur due to local variations in topography and/or HWMs flagged based on personal accounts of residents giving an approximation of flood heights. The following observations pertain to elevations that are referenced to NAVD 88.

Hurricane Katrina storm surge in Alabama was relatively high. The storm made landfall near the Mississippi and Louisiana state line, 65 miles west of the Alabama/Mississippi boundary. However, Katrina had a wind field that was skewed to the east, and this resulted in hurricane force winds that extended about 120 miles from the storm center. This caused a considerable storm surge at several places along the Alabama coast. As the storm approached land, storm winds in the right-front quadrant forced water from the Gulf of Mexico northward onto the western Alabama shoreline and into Mobile Bay.

HWMs along the western Alabama shoreline facing the Mississippi Sound show flooding elevations on the order of 11 to 15 feet, which are only slightly lower than the elevations that occurred along the eastern Mississippi coast. Flooding levels continued to decrease slightly to the east, along the southwestern shore of Mobile Bay, where elevations of 8 to 9 feet are found.

As the storm continued on its northeast track, the waters continued to be forced into Mobile Bay, causing higher flooding elevations farther towards the head of the bay along this shoreline. The flooding elevations slightly decreased as the flooding moved farther inland. Elevations in the vicinity of the City of Mobile were on the order of 11 to 12.5 feet, depending on local conditions. Slightly higher elevations were found along the northeastern portion of Mobile Bay, with flooding elevations reaching over 13 feet north of Fairhope. There is a bluff along much of the northern portion of this shoreline, and this limited the inland propagation of the storm surge.

South of Fairhope, along the southeastern shore of Mobile Bay, the flooding elevations diminish significantly to the south, where elevations as low as 5 feet are found on the east end of Bon Secur Bay, the very southeast corner of Mobile Bay.

The mouth of Mobile Bay is constricted on the west by Dauphin Island and on the east by West Beach, which extends from Gulf Shores westward across the mouth of the Bay. On the open gulf coast of Dauphin Island and West Beach, flooding elevations were recorded between 8.5 and 11.5 feet. Similar but lower elevations extend eastward as far as the Florida state line.

1. Introduction

1.1 General

The Federal Emergency Management Agency (FEMA) contracted URS Group, Inc. (URS) under Task Orders 414 and 421 of the Hazard Mitigation Technical Assistance Program (HMTAP) contract to assist in the disaster recovery in Alabama following Hurricane Katrina by collecting high water marks (HWMs). Consequently, this study documents the HWM survey conducted along the Alabama coast and streams following Hurricane Katrina. The effects of Hurricane Katrina were first observed on August 29, 2005, as the storm made landfall along the Gulf Coast of the United States.

This study was performed as rapid response Task Orders to help FEMA assess storm conditions for its Mitigation Program. The study was conducted in two Alabama counties: Baldwin and Mobile (Figure 1). The URS team for these Task Orders includes URS and its subconsultants PBS&J, ESP Associates, and Watershed Concepts.

Figure 1 – Alabama Coastal Counties

Although FEMA provided separate Task Orders for coastal flooding and riverine flooding, URS produced only one report because all of the significant flooding in Alabama during Hurricane Katrina occurred in the coastal counties. It was often difficult to distinguish HWMs resulting from the two flooding types; however, in Alabama it appears that all significant flooding was due to coastal flooding.

Section 1 of this report summarizes the purpose of the Task Order and provides overviews of related projects and of Hurricane Katrina. The remaining sections of the report discuss the methodology used to collect the HWMs, explain the types of flooding, summarize the FEMA Rapid Response Task Orders, and condense the results from the HWM collection efforts. The appendices include the detailed results from the HWM survey.

1.2 Purpose

After significant flooding from a hurricane, it is imperative to collect data rapidly to: document the event; assist in response, recovery, and mitigation; and improve disaster preparedness and prevention for future disasters. HWM data collection is an initial step in accurately documenting an event. These data help place the event within a historical context, improve estimates of current flood risk, and enable governments to make predictions about potential future flooding to assist with mitigation efforts.

Collection of site-specific high water data along rivers, bays, and coasts has numerous applications. The purpose of this study was to document the maximum flooding elevations that occurred as a result of Hurricane Katrina. There are a number of uses of the HWM elevation data, including:

- Estimate storm frequency and severity
- Assess accuracy of the Flood Insurance Rate Maps (FIRMs)
- Assist in preparation of Wind Water Line Maps
- Prepare Inundation Maps
- Share information for Building Performance Assessments
- Share information for calibrating models that simulate the storm
- Assist in prioritizing mitigation projects and preparing their benefit/cost analysis
- Determine depth of flooding of structures

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

- Individual Assistance – includes cash grants for housing (hotel or motel expenses reimbursement, 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).
- Public Assistance – 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 organizations. This includes emergency work and permanent work.
- Hazard Mitigation Grant Program – 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.

- National Flood Insurance Program – provides insurance claim information, floodplain management, and flood hazard identification.

This report supersedes the "Hurricane Katrina Coastal High Water Survey Preliminary Alabama Field Summary Report (Task Order 414)," dated September 29, 2005, in its entirety and subsequent submissions of preliminary HWM data. URS prepared the Preliminary Field Summary Report to provide FEMA with initial field-observed visual estimates of HWM elevations with respect to either the level of the adjacent water body at the time or their estimate of the mean tide level in this water body. These estimates are useful indicators of the overall pattern of the surge inundation. However, these estimates can be inaccurate because they are based on visual observations and were not from survey information. The HWM survey data provided in this report include actual surveyed locations and elevations. Consequently, the information in this report supersedes the visual surge estimates provided in the cited Preliminary Field Summary Report.

1.3 Overview of Related Projects

After Hurricane Katrina, FEMA issued several Task Orders under the HMTAP contract called Rapid Response Task Orders. The purpose of these Task Orders was to allow FEMA contractors to move quickly into disaster-stricken areas to collect perishable data to define the parameters of the event; these parameters can be used for future studies and flood mitigation activities. In addition to the HWM Task Orders, there were several other Rapid Response Task Orders, including Aerial Imagery Data Collection and Wind Water Line Data Collection Task Orders. HWM survey findings are used to define the extent of flooding and therefore can be used in conjunction with field findings from Wind Water Line Task Orders to determine the extent of the wind water line. Post-event aerial imagery is also used to estimate the wind water line, identify areas affected by flood damages, and approximate inland extent of storm-surge flooding. Topographic data collected with the aerial imagery was also used to evaluate the HWM elevations.

In response to Hurricane Katrina, FEMA issued several Rapid Response Task Orders. This included HMTAP Task Order 414, *Rapid Response, Hurricane Katrina Coastal High Water Mark Survey – AL*; and HMTAP Task Order 421, *Rapid Response, Hurricane Katrina Riverine High Water Mark Survey – AL* (which are the focus of this report). In addition, FEMA issued the following:

- Under HMTAP 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 Mississippi Coast.
- Under HMTAP Task Order 417, *Rapid Response*, *Hurricane Katrina*, *Wind Water Debris Line – Alabama*; visual surveys and data collection were used to determine the location of the debris line and extent of flooding to identify the wind water line.

1.4 Overview of Hurricane Katrina

Hurricane Katrina became the eleventh named tropical storm and the fourth hurricane in the 2005 Atlantic hurricane season and was one of the strongest storms to impact the coast of the United States during the last 100 years. According to the National Oceanic and Atmospheric Administration (NOAA) National Hurricane Center (NHC), the storm began as Tropical Depression 12 over the southeastern Bahamas on August 23, 2005. On August 24, 2005, the cyclone became Tropical Storm Katrina. The storm strengthened, and Katrina is estimated to have reached hurricane status on August 25, 2005. Katrina made its first landfall in the United States as a Category 1 hurricane on the Saffir-Simpson Hurricane Scale, with maximum sustained winds of 70 knots (80 mph). Katrina continued west-southwestward, spent only 6 hours over land, and weakened to a tropical storm with maximum sustained winds of 60 knots (70 mph) as it emerged into the Gulf of Mexico.

Katrina continued northward over the Gulf of Mexico, quickly regaining hurricane status and strengthening to a Category 5 hurricane on the morning of August 28, 2005. Katrina attained its peak intensity of 150 knots (173 mph) about 170 miles southeast of the mouth of the Mississippi River. Katrina remained a significantly large, sustained storm and impacted a broad area of the Gulf Coast. By the morning of August 29, Katrina weakened to a Category 3 storm, making landfall near Buras, Louisiana, with estimated maximum sustained winds of 110 knots (126 mph).[1] Heading northward, Katrina downgraded to a tropical depression near Clarksville, Tennessee, and dissipated on August 31 in southeastern Canada. The Hurricane Katrina storm track is shown in Figure 2.[2]

[1] "Tropical Cyclone Report, Hurricane Katrina, 23-30 August 2005, Richard D. Knabb, Jamie R. Rhome, and Daniel P. Brown, National Hurricane Center, 20 December 2005."
[2] http://cimss.ssec.wisc.edu/tropic/archive/2005/storms/katrina/katrina.html

Figure 2 – Hurricane Katrina Storm-Track

Figure 3 shows a composite image of Hurricane Katrina. This image is Advanced Very High Resolution Radiometer/Multi-Channel Visible and Infrared Radiometer composite imagery provided by the Cooperative Institute for Meteorological Satellite Studies as provided by NOAA and the Joint Typhoon Warning Center.[3]

[3] http://cimss.ssec.wisc.edu/tropic/archive/2005/storms/katrina/avhrr/avhrr.katrina.html

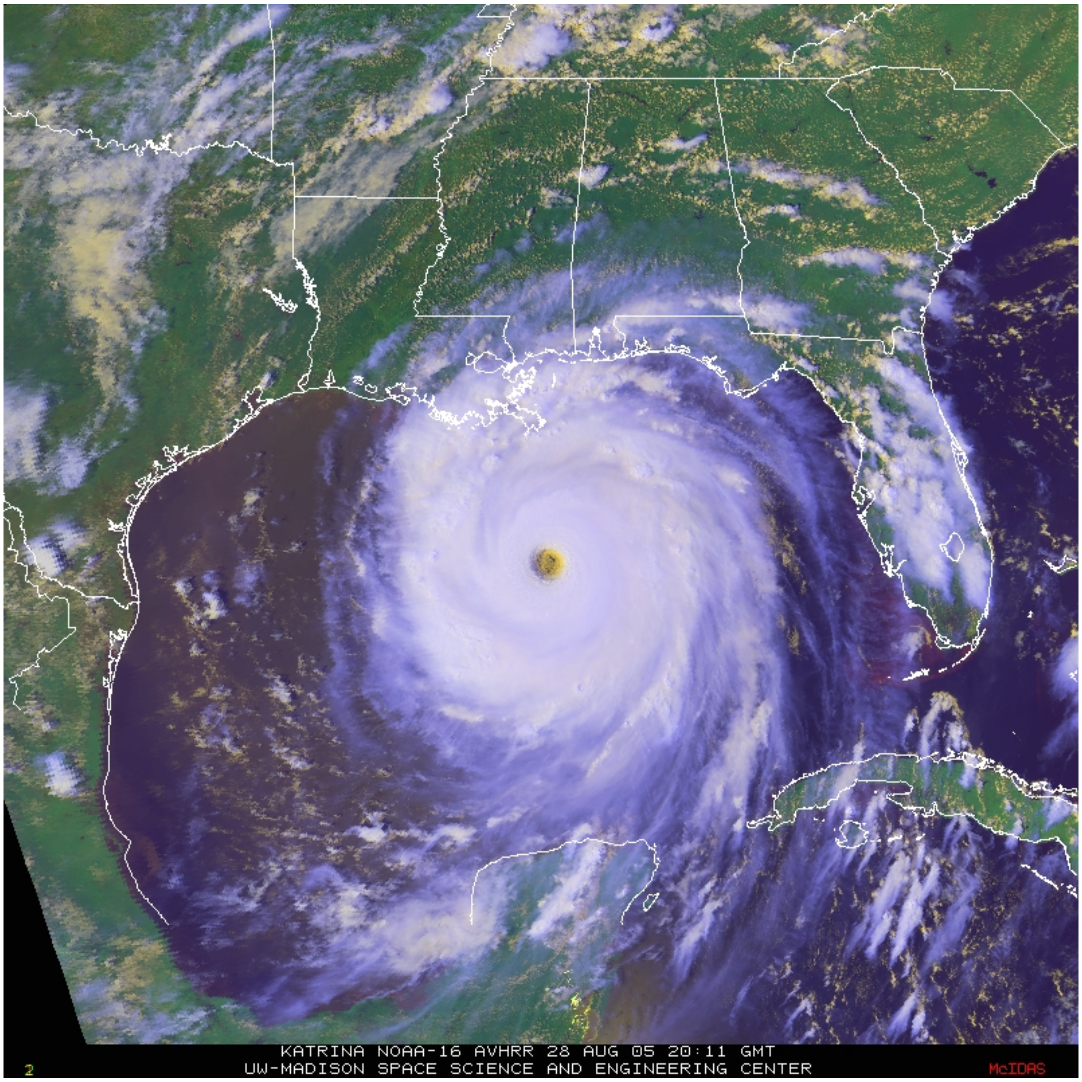


Figure 3 – Hurricane Katrina Composite Imagery

President George W. Bush issued a major disaster declaration on August 29, 2005, under the authority of the Robert T. Stafford Disaster Relief and Emergency Assistance Act (Stafford Act), for damage in certain areas of Alabama resulting from Hurricane Katrina (FEMA-1605-DR-Alabama).[4] Katrina caused widespread devastation along the central Gulf Coast states with major damage to the coastal regions of Louisiana, Mississippi, and Alabama. Katrina was the most destructive and costliest natural disaster in the history of the United States because of the extent of damage caused by the storm. According to NOAA, the storm surge along the Gulf coast was the highest storm surge ever recorded in the United States.[5]

[4] http://www.fema.gov/news/dfrn.fema?id=4504
[5] "Tropical Cyclone Report, Hurricane Katrina, 23-30 August 2005, Richard D. Knabb, Jamie R. Rhome, and Daniel P. Brown, National Hurricane Center, 20 December 2005."

2. Methodology

2.1 General

This section summarizes the methodology used to flag and survey the HWMs. It should be noted that it is important to quickly mark or flag HWMs after a disaster so that the HWMs are captured before residents clean up or it rains, thereby potentially eliminating the HWM. Every effort is made to quickly flag HWMs because they are often perishable. Once they are flagged, HWMs can be surveyed later to determine the HWM elevation.

URS received a notice to proceed for this HWM Task Order on August 30, 2005. On that same day, notices to proceed were also received for HWM collection in Mississippi and Louisiana, which were also significantly impacted by Hurricane Katrina. In addition to coastal flooding, there were reports of significant riverine flooding. In response, FEMA provided URS with Task Orders for both coastal and riverine HWM collection. These two Task Orders (Task Orders 414 and 421) have been combined into this report.

During the 2005 hurricanes, it was determined that there was a large overlap in the field work between the HWM Task Orders and the Wind Water Line Task Order. To increase efficiency and address the lack of available lodging in the affected area, it was decided to combine the field collection for the HWM Task Orders and the Wind Water Line Task Order. Additional information regarding the Wind Water Line Task Order can be found in the "*Hurricane Katrina Rapid Response Wind Water Line Report – Alabama, Task Order 417*."

2.2 Pre-Field Deployment

On August 31, 2005, URS arranged travel and lodging for field staff, modified the HWM database and forms (based on comments from FEMA regarding previous Task Orders), finalized training/orientation material, obtained equipment (e.g., hand-held Global Positioning System [GPS] units, cameras, and health and safety equipment), obtained vaccinations and blood work for field staff (due to concerns about standing water), and obtained FEMA badges for field staff.

A training/organization meeting was held for approximately 30 staff in Tallahassee, Florida on September 1, 2005. Flaggers, data collectors, quality assurance staff, and managers attended this meeting. The training was held for staff who would conduct field work in both Mississippi and Alabama. The meeting was held at URS' office in Tallahassee because it was near the affected areas and had electricity and access to available gasoline and hotel rooms. The training/orientation included discussions on selecting HWM locations, collecting wind water line data, review of field processes (including data capture, documentation, and information transfer), distribution of equipment, and a health and safety briefing.

After the training/organization meeting on September 1, 2005, FEMA agreed that mobilization of staff to the field should be postponed due to the ongoing recovery efforts in the impacted areas, the lack of lodging, and the concern for obtaining gasoline and other essential supplies. Therefore, the flagger teams were placed on standby for later deployment. On September 5, 2005, URS deployed one field team to Alabama to assess the status of the recovery efforts and availability of gasoline.

2.3 Data Sources

On August 31, 2005, URS began to collect available information on the extent of flooding to assist in identifying locations for the HWM collection. This included contacting each of the county emergency managers to determine the extent of flooding in their county as well as their priority locations for collecting high water marks. By September 6, 2005, URS placed calls to all county emergency managers in Alabama. Sixty counties indicated there was no riverine flooding in their county, and seven counties did not answer their phone or no one knowledgeable was available. The Mobile County Emergency Manager indicated the areas hardest hit by coastal flooding were the communities of Fowl River and Coden (west of Mobile Bay).

Over the next several days, URS contacted several other agencies to determine available data sources and information that could be used to determine the best HWM locations. URS contacted the Mobile District of the U.S. Army Corps of Engineers (USACE), which had no preference for HWM collection locations. The Alabama Office of Water Resources indicated that significant riverine flooding had not been reported. The Alabama Emergency Management Agency was not able to return URS' call. The NHC provided URS with 15 locations along the coast as their preferred HWM collection locations. URS also coordinated with the U.S. Geological Survey (USGS). Refer to Section 2.7 for a complete discussion of URS and USGS collaboration on HWM data collection.

URS downloaded forecasted coastal storm surge levels from Crownweather.com (Figure 4) and obtained a preliminary Sea, Lake and Overland Surges from Hurricanes (SLOSH) model prepared by the NOAA NHC. Through USGS, NHC provided output from the SLOSH model[6] dated September 9, 2005, and shown in Figure 5. This figure includes graphical, color-designated maximum surge-only levels that occurred during the modeled storm. According to NHC, the SLOSH model is generally accurate within plus or minus 20 percent. The model accounts for astronomical tides (which can add significantly to the water height) by specifying an initial tide level, but does not include rainfall amounts, river flow, or wind-driven waves.

[6] http://marine.usgs.gov/response/katrina/stormsurge/

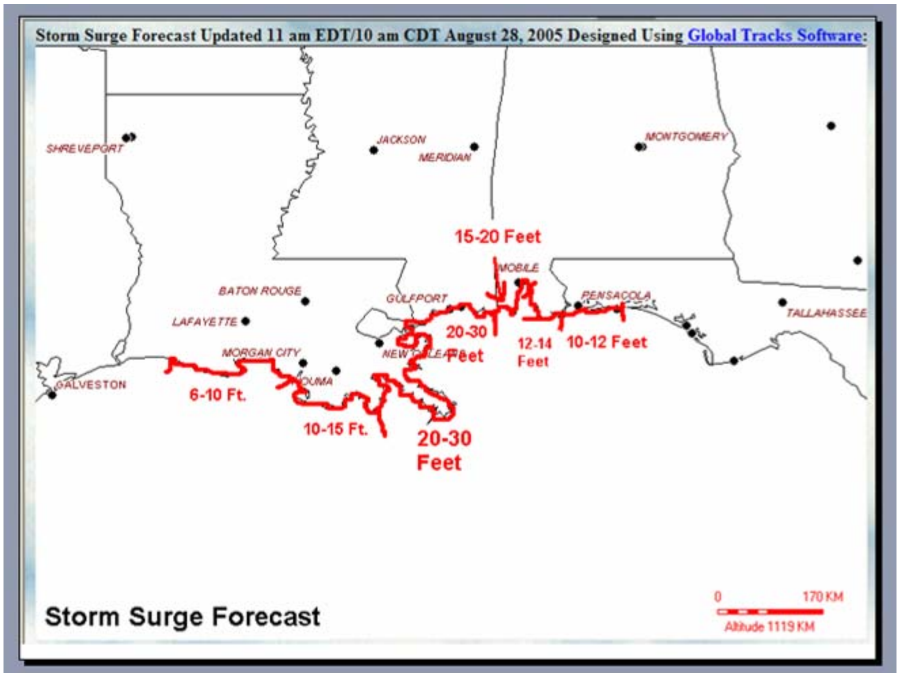


Figure 4 – Forecast Katrina Storm Surge from www.Crownweather.com

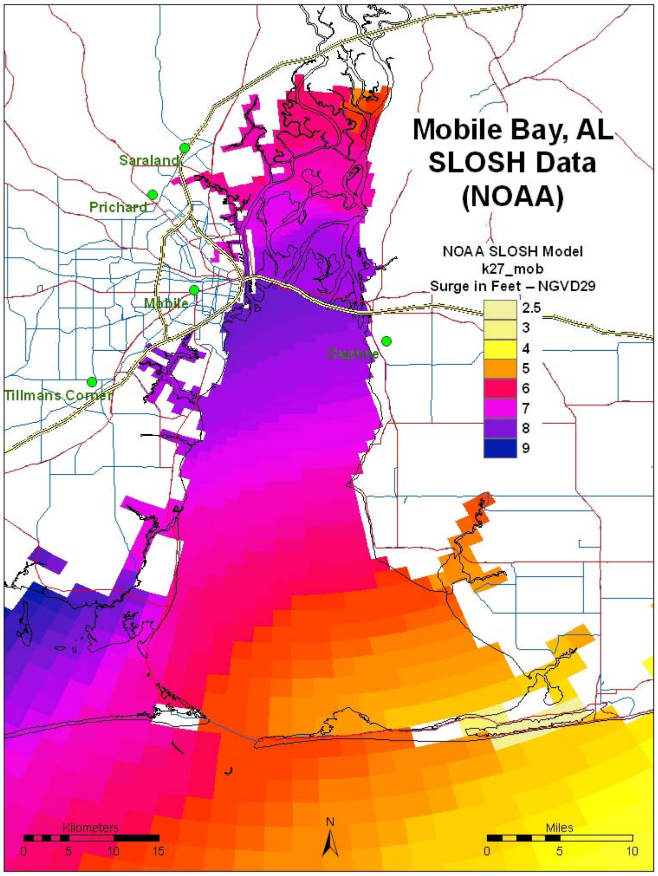


Figure 5 – NOAA Katrina Alabama Coast SLOSH Data

USGS stream gages in Alabama were also reviewed. As of September 1, 2005, only one gage recorded an elevation higher than the National Weather Service (NWS) flood stage. This gage was located near Pickensville, in Pickens County. The gage peaked at 2.6 feet above flood stage on the morning of August 31, 2005. The flooding at this gage was characterized by the NWS as minor, affecting primarily agricultural interests.

2.4 Identification of the Study Area

URS prepared a Work Plan for Hurricane Katrina Alabama HWMs, dated September 6, 2005, that was submitted to FEMA. The purpose of the Work Plan was to outline the general locations where HWMs would be collected. This plan was based on discussions with other agencies and data collected (see Section 2.3), as well as discussions with FEMA. Based on this information, URS focused the HWM collection in the coastal counties of Baldwin and Mobile where significant flooding occurred.

2.5 Flagging Field Data Collection Procedures

The field work for the Alabama HWM flagging began on September 5, 2005. Two-person teams were used to flag the HWMs. The number of two-person flagging teams in Alabama varied daily during the project. Initially one flagging team mobilized to Alabama to assess the status of the recovery efforts and availability of gasoline. Based on feedback from this first field team, additional teams were mobilized on September 7. By September 8, five flagging teams were in the field, and by September 10, eight flagging teams were in the field. All flagging was completed in Alabama by September 12, 2005.

In addition to the flagging teams, data collectors and field coordinators were in the field. The data collectors collected the data from the flagging teams and delivered it to a URS office where the data was entered into a database. Use of the data collectors was required because electricity and working phone lines in the impacted areas were intermittent. Field coordinators met daily with the flaggers to review the HWMs collected that day and to discuss the next day’s assignments. A field manager, located in the URS Tallahassee office, reviewed and mapped the compiled data daily and directed the field coordinators to the general areas of HWMs collection locations.

Each day the two-person flagging teams were given a general geographic area in which to identify and flag HWMs. The flagging teams visited these areas and searched for structures with mud or water lines and areas with debris lines (i.e., man-made materials) or wrack lines (i.e., plant materials). Upon visiting the assigned geographic area, the flaggers would first determine whether the area appeared impacted by flooding. If the area did not appear to be impacted by flooding, then the flaggers noted this for their daily briefing with the field coordinator and proceeded to the next area. If the area appeared to have been impacted by flooding, then the flagger searched for a visible HWM to be flagged.

A building is the preferred location for a HWM to be flagged. Therefore the flagger first searched for visible HWMs on buildings. The preferred HWM location is inside the building;

therefore, the flaggers searched inside for a visible HWM when access was available. If no inside HWM could be obtained, an exterior HWM was flagged. In areas where there were no visible HWMs on buildings, the flaggers searched for other signs of high water, such as debris lines or wrack lines on the ground, vegetation, bridge embankments, or fences. Visible HWMs are often difficult to find because coastal flooding typically enters and exits a site quickly, receding before a water mark is left. For illustrative purposes, examples of the typical types of HWMs collected during a HWM project are shown in Figures 6 through 9.

Figure 6 – Interior Mud Line HWM

Figure 7 – Exterior Mud Line HWM

Figure 8 – Debris Line HWM

Figure 9 – Wrack Line HWM

The spacing of the flagged HWMs was irregular. More HWMs were flagged in areas that were significantly impacted by flooding than in areas of minor flooding. Consequently, more HWMs were flagged along the coast and bay. Inland coastal HWMs were also flagged to determine the inland extent of flooding. Multiple HWMs were flagged in the same area to document different coastal flood types (e.g., surge-only, wave height, wave runup) or to better determine the flood elevation. Evaluation of site conditions where HWMs were flagged is based on the flaggers' best judgment of the height of flood waters. In addition, the height of flood waters can be affected by outside forces such as wind and shielding by other structures. Therefore, in significantly damaged areas, multiple HWMs were obtained in the same area to provide better flood elevation data. Fewer HWMs were flagged in areas that received less flooding or where there were fewer buildings.

On a daily basis, URS reviewed the areas where HWMs were flagged and sent flaggers to fill in apparent data gaps. However, there was often no access to these areas or there was no evidence of flooding.

URS flagged approximately 150 HWMs in Alabama. For each identified HWM, the flaggers completed a standardized form including detailed data about the HWM (Figure A.1 in Appendix A). The flaggers documented the HWM's approximate latitude and longitude coordinates using hand-held GPS units to help surveyors find the HWM. The flaggers used their judgment regarding the source of the flood water (coastal flooding or riverine flooding). In some instances, flaggers obtained anecdotal information from residents as to the timing of the flood. Since riverine flooding is typically delayed one or several days from the actual coastal event, this timing helped determine whether a particular HWM was classified as coastal or riverine. The flaggers used the location of the HWM in relation to other land features to estimate of the type of coastal flooding (e.g., surge-only, wave height, and wave runup). For example, a debris or wrack line on a stretch of open coast is the result of wave run-up. However, when significant amounts of vegetation block or dampen the wave effect, these marks are identified as surge-only instead.

It should be noted that FEMA initially identified several counties to be investigated for riverine HWM collection. However, based on URS' field investigations, no HWMs that URS classified as riverine flooding were found.

URS submitted the Preliminary Alabama Field Summary Report, dated September 29, 2005. This report showed the location of flagged HWMs. In addition, preliminary visually estimated HWM elevations for some points were provided to assist FEMA in its recovery efforts.

2.6 Survey Procedures

URS' surveyor, PBS&J, established the benchmark/control network and began surveying the HWMs on September 17, 2005. Due to the more extensive damage in Mississippi from Hurricane Katrina, on September 27, 2005, the surveyors were moved to Mississippi to survey the Mississippi HWMs. The surveyors remobilized to Alabama on October 13, 2005. The surveyors completed the initial surveying of over 200 points in November 2005.

URS survey crews surveyed the HWMs identified and flagged by URS flagger teams and the HWMs identified separately by USGS, as discussed in Section 2.7. The survey crews used static GPS methods and conventional leveling to determine the horizontal coordinates (latitude and longitude) and elevation for each HWM. HWMs were surveyed horizontally in the North American Datum of 1983 (NAD 83), Alabama West State Plane Coordinates, and vertically in the North American Vertical Datum of 1988 (NAVD 88); both surveys were conducted in U.S. survey feet. The HWMs were surveyed to the accuracy of 0.25 foot vertically and 10 feet horizontally with a 95% accuracy level. Inclement weather that would have adversely affected the GPS surveys was avoided to ensure this level of accuracy.

Data were recorded on standardized forms as shown in the example, Surveyor High Water Mark Data Collection Report Form (Figure A.2 in Appendix A). Static GPS was performed directly at the HWM whenever possible. The survey crews used conventional leveling techniques from a static GPS reference point when the HWM location would not support direct GPS observations. Wherever possible, a building floor elevation was surveyed on structures. These floor elevations were taken adjacent to the HWM where available and may or may not represent the first floor of the structure. This information was obtained for later use in damage assessments or HMGP applications.

2.7 USGS-Flagged HWMs

During URS' discussions with USGS in early September, USGS indicated that they were flagging HWMs in Alabama, assisted by the USACE, and requested that FEMA survey the HWMs that they flagged. FEMA agreed and tasked URS with surveying USGS/USACE-flagged HWMs. USGS flaggers did not leave physical flags at several locations situated on private property or where HWMs varied extensively, such as at bridge sections subject to drawdown. Instead they established and flagged temporary bench mark (TBMs) and did "line-of-sight" or conventional leveling from these TBMs to each of the various HWMs to establish the relative elevations of the HWMs. The USGS' intent was for the follow-on URS surveyors to level-in the TBMs to a controlled datum using GPS so that all of the elevations could be determined for multiple HWMs more efficiently and with less danger of mark destruction or disturbance.

On September 29, 2005, USGS provided URS with longitude, latitude, HWM description, and TBM descriptions for approximately 100 HWMs in Alabama. The URS surveyor visited each of the USGS-flagged HWM locations. The surveyor surveyed the HWM, when it was still visible, as well as the USGS-set TBM. The surveyor also set some TBMs for their use on this project. This information was provided to USGS.

The HWMs where the surveyor could survey the actual HWM are included in Appendix E and are sealed by a licensed surveyor. For HWMs where the URS surveyor could not find the HWM, USGS computed the HWM elevation based on the TBM elevations, when possible. These elevations are provided in Section 4, Table 5.

It should be noted that URS flaggers did not visit the USGS-flagged HWMs. Since USGS did not use the same flagger collection form as URS, several data fields were not collected (such as flooding source, flooding type, etc.), and therefore those data are not included.

2.8 Elevation Conversion from NAVD 88 to NGVD 29 Using Corpscon

As indicated, the surveyor computed the HWM elevations in the vertical datum of NAVD 88. However, since many of the FEMA FIRMs are in National Geodetic Vertical Datum of 1929 (NGVD 29), each elevation was converted and also reported in NGVD 29. This conversion was completed using the Corpscon program version 5.11.08.[7] The Corpscon program uses the VERTCON software internally. The VERTCON software was developed by the National Geodetic Survey (NGS) office to convert data between different vertical data scales. VERTCON is available as an element of the NGS Geodetic Toolkit and can be downloaded from the NGS website.[8]

The VERTCON software allows the user to compute the modeled difference, or datum shift, in orthometric height for a given location specified by its latitude and longitude. Applying the computed datum difference value to a specific elevation converts from one datum to another.

For converting elevations in the NAVD 88 datum to the NGVD 29 datum, the datum shift has to be subtracted from the NAVD 88 elevation. This can be demonstrated by two examples, one with a positive shift and one with a negative shift:

	Case 1	Case 2
NAVD 88 Elevation	5.33	5.33
Datum shift	+0.50 feet	-1.17 feet (negative shift)
NGVD 29 Elevation	5.33 – (0.50 feet) = 4.83	5.33 – (-1.17) = 6.50

2.9 Quality Assurance Review

Upon receipt of the data from the surveyor, URS began the quality assurance (QA) process. The QA process involved checking each data field in the database, including HWM elevation and flood type. URS' QA review of the data included checking the surveyed elevation for reasonableness based on other nearby HWMs and available topography. If a discrepancy was found, it was sent back to the surveyor for his/her review. If the point continued to be inconsistent, then URS made a judgment regarding continued use of the point. Based on the flaggers' information, if it appeared the surveyed point may not actually represent a valid HWM, then the point was removed from the database. Approximately two HWMs flagged and surveyed by URS were removed from the database due to concerns regarding reasonableness.

URS QA review also included examination of the flooding type. While the flaggers made their best estimate of the flooding type based on observed field conditions, sometimes the flooding

[7] http://www.cae.wisc.edu/site/software/?title=app199
[8] http://www.ngs.noaa.gov/TOOLS/Vertcon/vertcon.html

type can be better identified after the HWM locations and elevations are mapped. Therefore, the flooding type for each HWM was reviewed based on mapped locations and elevations of the surveyed HWMs.

The determination of whether a point was from coastal flooding or riverine flooding was based on review of all of the HWMs in the area and the estimated wind-water line. The wind-water line is the estimated boundary that delineates the inland extent of the area where structures were damaged as a result of flooding from coastal surge. Landward of the line, most of the damage is attributable to winds and/or wind-driven rain, and HWMs in this area would be typically designated as riverine. On the ocean-side of the line, HWMs were designated as coastal flooding. The analysis of flooding type was conducted based on the approximate location of the wind water-line because it is difficult to determine the exact location of the wind-water line. URS also considered the coastal HWM elevation at the inland extent of coastal flooding. The elevation of the coastal flooding at the inland extent should be relatively consistent in an area. Based on this analysis, all HWMs were attributed to coastal flooding.

Coastal flooding HWMs were further evaluated to determine the coastal flooding type (surge-only, wave height, and wave runup; see Section 3 for discussions of these flooding types). The QA review included evaluation of the coastal flooding types that the flaggers identified. HWMs collected inside a building or within other protected areas were designated as surge-only HWMs. URS evaluated the HWM's associated photograph, the location of the HWM relative to other land features, and other nearby HWM elevations to confirm the coastal flooding type.

Other QA checks included reviewing the flooding source, nearest municipality, county, photographs, consistency of data, and similar factors. After the QA review of the data was completed, URS prepared the Draft Report. The Draft Report was submitted to FEMA on January 31, 2006. FEMA provided comments on March 10, 2006.

3. Flood Types

3.1 General

URS was tasked with collecting HWMs associated with coastal and riverine flooding. However, based on the data collected from other sources (see Section 2.3) and field visits, it appears that all significant flooding in Alabama was a result of coastal flooding. This section discusses the conditions that surround coastal flooding and lead to specific types of coastal flooding (surge-only, wave height, and wave run-up).

3.2 Coastal Flooding

Coastal flooding is caused when coastal waters are driven inland by waves and wind. Coastal flooding conditions are more varied in their origin than those associated with riverine flooding and can be further classified as either surge-only, wave height, or wave runup. The coastal flooding types are discussed below and presented graphically in Figures 10 through 16. These figures illustrate ideal situations of coastal flooding, which will not necessarily occur in any one location or one particular storm event. Each of the three basic types of coastal HWMs—surge only, wave height, and wave runup—are often found close to each other. These HWM types can differ in elevation, and each provides information that describes the nature and behavior of the coastal flooding.

This Rapid Response Task Order required URS to quickly flag, survey, and report on the HWMs. As such, the assignment of the flooding type was based on observations made during the flagging field work and later reviewed based on mapping the data. A detailed analysis of land conditions, such as topography, bathymetry, locations of dunes, sloped water surface, overwash, or breaching, was not performed; this level of analysis was not part of the scope of work or even possible due to the time limitations. Therefore, all classifications are estimates based on the best available data at the time.

It is beneficial to collect HWM for the different types of coastal flooding because different uses of the HWM data require different coastal flooding types. Table 1 shows the typical coastal flooding type needed for each of the uses of the HWM data.

Table 1. Coastal Flooding Type Required for Various Uses of HWM Data

Coastal Flooding Type Required	HWM Data Use
Surge-Only and Wave Height	Quickly estimate event frequency and severity for different areas
Surge-Only and Wave Height	Assess Flood Insurance Rate Maps
Any type	Assist in preparation of wind-water line maps
Surge-Only (typical), Wave Height and Wave Runup	Prepare inundation maps
Wave Height	Share information for building performance assessment
Surge-Only	Share information for modeling
Wave Height	Provide public and agencies with elevations for prioritizing mitigation and benefit/cost analysis
Surge-Only	Determine depth of flooding of structures

3.2.1 Surge-Only

Figure 10 shows the simplest form of coastal flooding (surge-only). In this type of flooding, as the water level during the storm rises to a maximum level, it can leave marks on both the interior and exterior walls of a structure that are of equal elevation. Both of these water marks indicate a coastal flooding level that is not complicated by other factors, such as waves. However, these situations occur only where the structure is at a location sheltered from waves.

Ideally, surge-only flooding has maximum elevations that are either level or have a slight slope that is not easily detected visually. This is shown schematically in Figure 11. However, this is not always the case in the coastal zone. As shown in Figure 12, coastal surges can also have sloped water surfaces. High water caused by a hurricane storm surge is brought about by the combination of rapidly changing factors such as wind speed, wind direction, lowered barometric pressure and the storm track. Surge represents the rise in the water level where the location was shielded from waves. In some cases the surge develops in open water areas and spreads inland over large distances because the coastal lands have minimal topographic change. The overland flow can be retarded by inland marsh areas and other obstructions so that the flood water surface slopes downward towards the inland shore, as shown as Case A, Figure 12. Under other circumstances, a strong onshore wind can force the overland coastal flood waters further inland, forming an upward slope towards the inland shore, as shown in Case B in Figure 12.

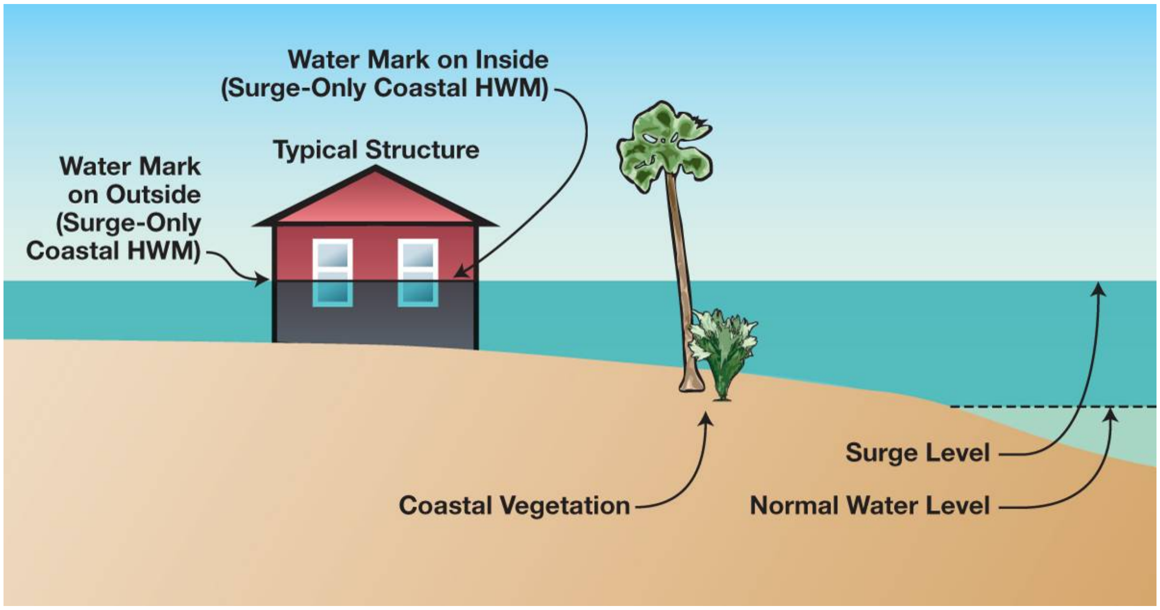


Figure 10 – Coastal HWM Resulting from Surge-Only

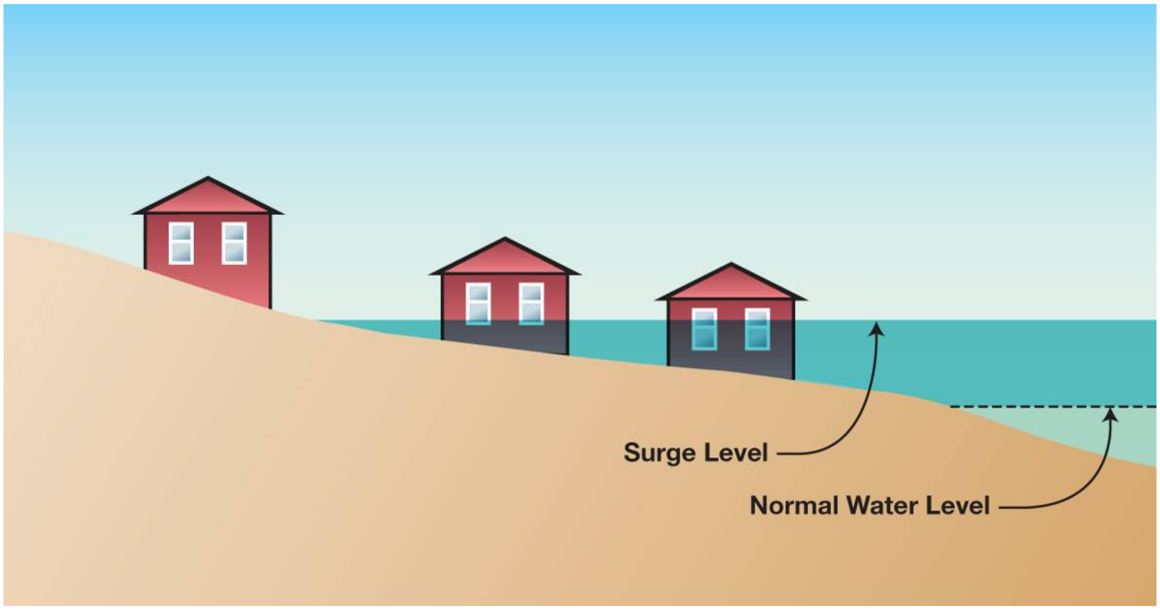


Figure 11 – A Coastal Storm Surge With a Level Water Surface

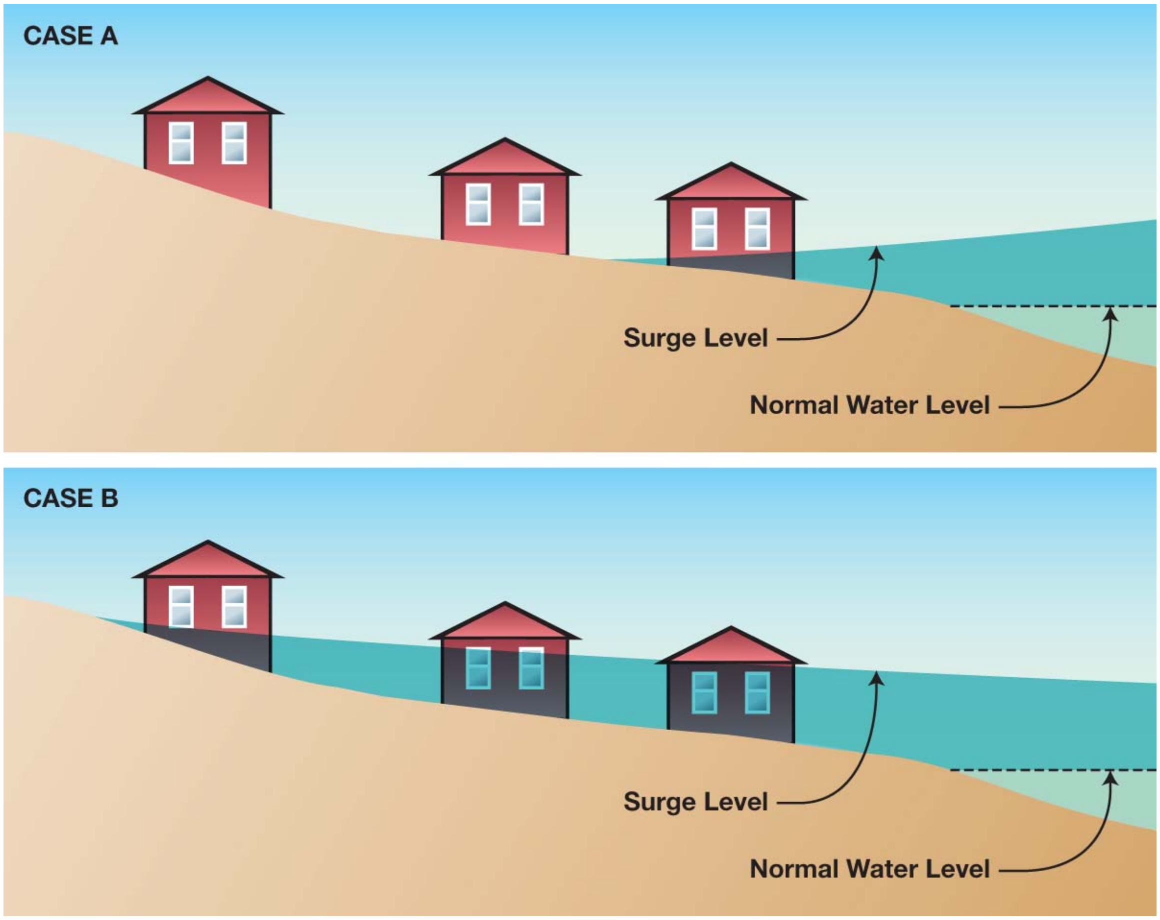


Figure 12 – Two Cases of Storm Surges With Sloped Water Surfaces

3.2.2 Wave Height

The second type of coastal flooding includes action due to waves, or coastal wave height flooding. As coastal flood waves propagate, high water conditions on structures and land vary. Coastal wave height flooding is created by the crest of the wave riding on the surge. Figure 13 shows how HWMs found inside and outside of a structure can differ considerably if they are impacted by waves. HWMs corresponding to the conditions shown on the exterior wall in Figure 13 are designated as wave height flooding because the crests of the waves that are riding on the surge leave the highest mark. HWMs corresponding to the situation shown on the interior wall in Figure 13 are designated as surge-only flooding because the whole structure acts as a stilling-well, and the HWM corresponds to a water level unaffected by the waves.

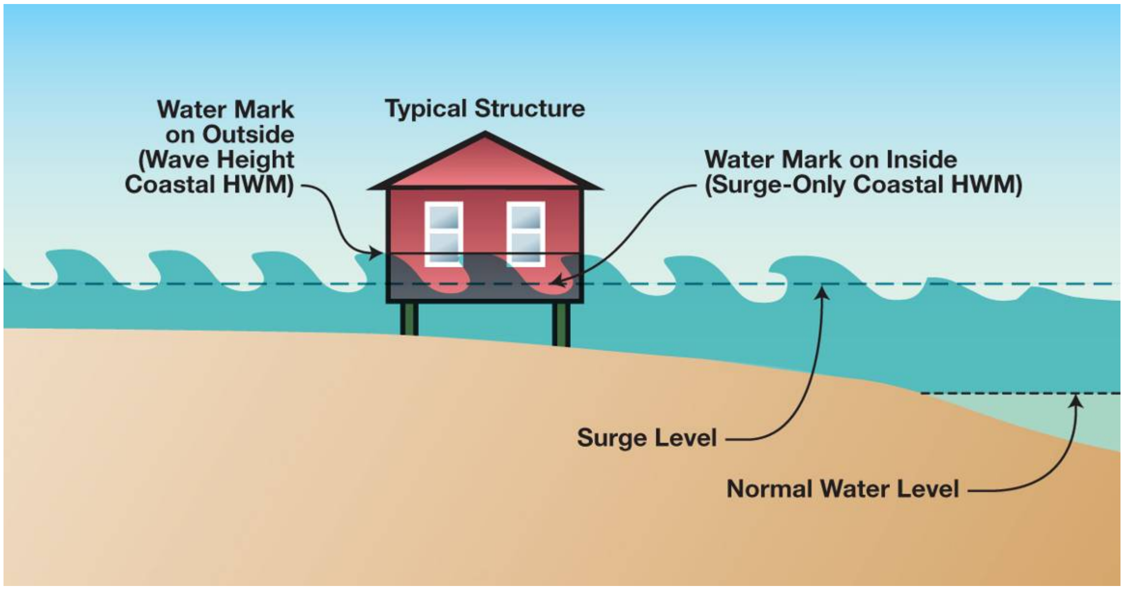


Figure 13 – Coastal HWM Resulting from Wave Height

3.2.3 Wave Runup

The third type of coastal flooding includes wave action runup, or coastal wave runup, as illustrated in Figure 14. With coastal wave runup, the situation is complicated by the presence of a surf zone, which is the broad zone of spilling and breaking waves between the open water body and the beach. At the very top of the surf zone, the remaining energy of the wave causes the waves to wash up the beach slope. The result is referred to as wave runup. Wave runup often pushes debris to its maximum limit where it is left as a wrack line. HWMs of this type are designated as wave runup flooding.

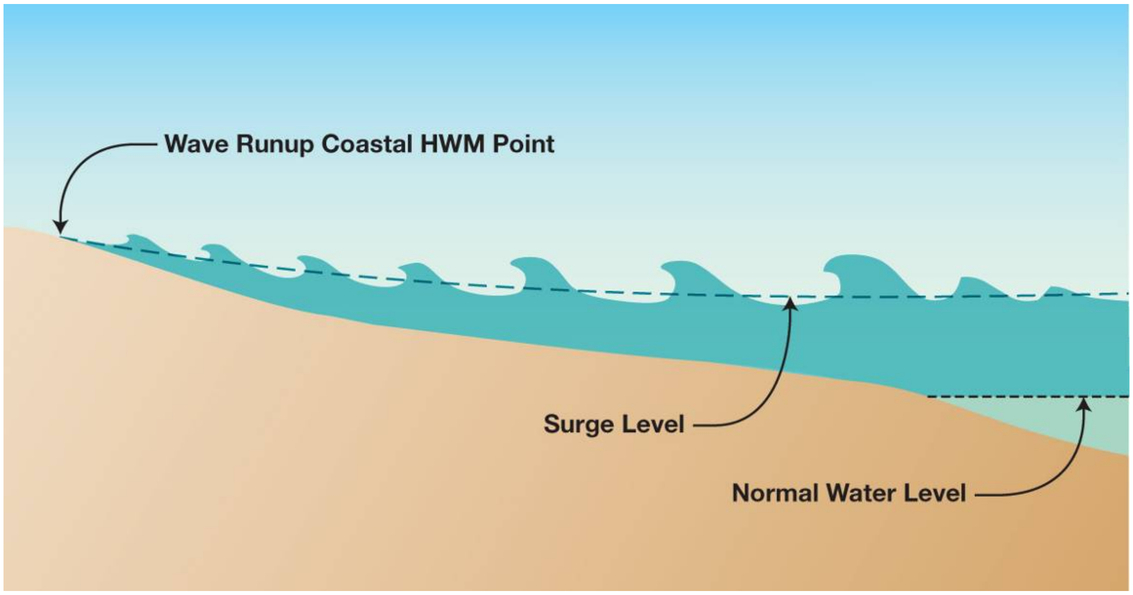


Figure 14 – Coastal HWM Resulting from Wave Runup

3.2.4 Impact of Dunes

Figure 15 shows more variable conditions of coastal flooding caused by land conditions, such as sand dunes. It is not uncommon for the wave runup in a storm to be so large that it completely crosses the beach and flows through gaps in the coastal dunes. These are called “washover channels,” and they convey the water over the dunes to low areas behind the dunes. Figure 15 shows three structures at different locations along the dune, each impacted differently by coastal flood waters during the storm. When the corresponding HWMs are found, marked, and surveyed, the elevations can differ up to several feet over a relatively short distance (e.g., 1,000 feet) due to these varying effects.

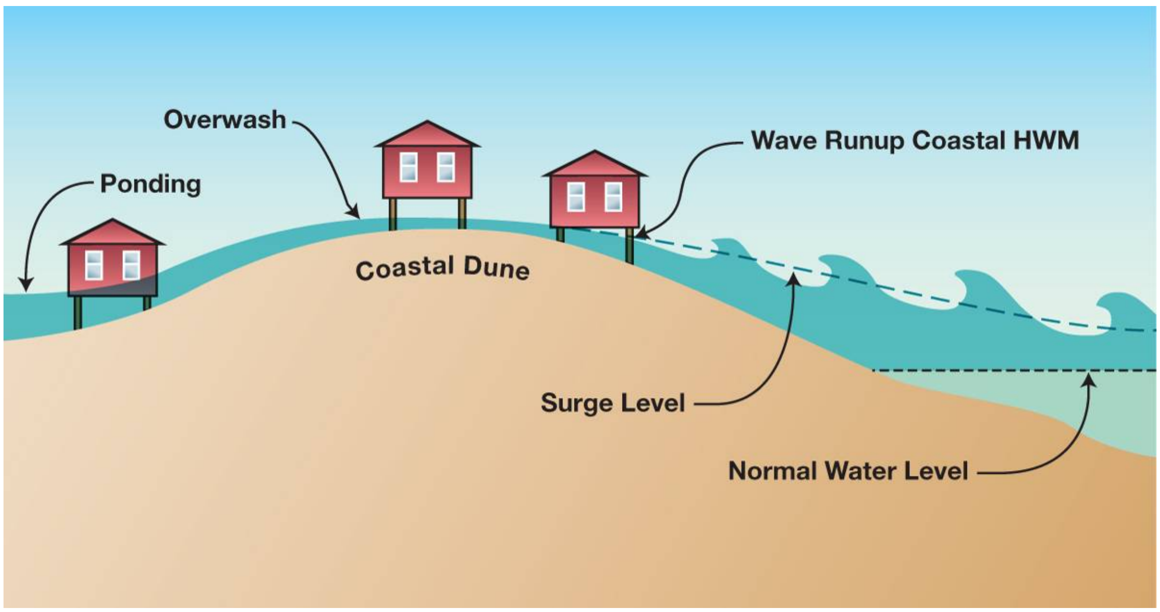


Figure 15 – Variations in Coastal Flooding Levels Due to Washover of Coastal Dunes

During some hurricanes, changes in the shape of the beach and dunes can substantially affect the elevation and extent of the coastal flood waters. Typically, storm conditions cause erosion of beaches and dunes. The combined effects of this erosion and the rise of the water levels can substantially reduce the level of coastal protection. This will inevitably result in inland inundation and flooding that would not have occurred if the coastal dunes had not eroded. These conditions are illustrated in Figure 16. Coastal flooding elevations in these areas can depend on how long the dune line held the ocean back compared to the rate at which the storm moved inland. If the dunes held back the ocean long enough, then the backshore flooding may have occurred after the maximum surge height.

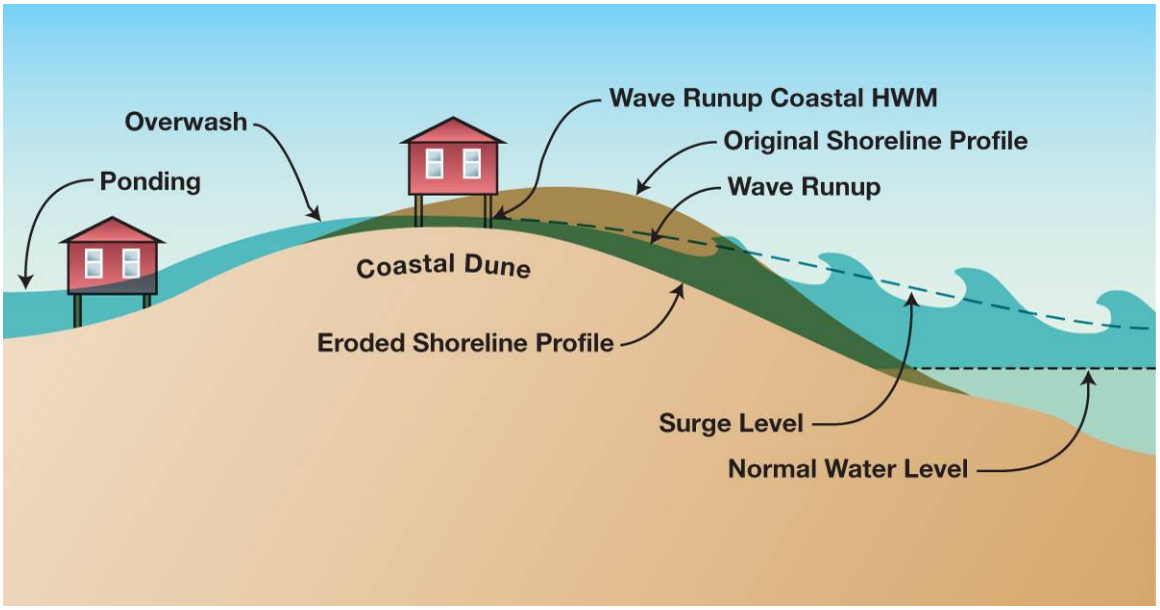


Figure 16 – Interaction of Profile Erosion and Coastal Flooding

Local conditions influence coastal flooding. On barrier islands, coastal flooding on the seaward side may differ in elevation from those on the bay side because the maximum surge levels formed at different times during the storm. Within bays, the surge may be amplified by the effect of wind acting on broad, shallow areas. In other cases, the tidal inlet may retard the flow of water into the bay so that its level cannot rise to the level of the ocean. Conversely, it is common to find a funneling action that amplifies the surge level where the shorelines of the bay converge toward the head of the bay.

4. Observations and Conclusions

The HWM data collected for this study demonstrate that the Hurricane Katrina affected a significant portion of the Alabama coast. This section discusses the data that was collected as well as characteristics of the HWM elevations.

4.1 High Water Mark Data Collected

High water marks were collected in Baldwin and Mobile Counties, which are the two Alabama coastal counties that lie between the Mississippi/Alabama border and the Mississippi/Florida border. As shown in Tables 2 and 3, over 200 HWMs were surveyed in Baldwin and Mobile Counties. In addition, the USGS flagged some additional points in adjacent Escambia County, Florida, which were also surveyed by URS.

Table 2. URS Team HWMs Surveyed by County

County	Number of HWMs Surveyed
Baldwin	80
Mobile	79
Total	159

Table 3. USGS-Located HWMs Surveyed by County

County	Number of HWMs Surveyed
Baldwin	50
Mobile	14
Total	64

HWMs are based on the flagger teams' best judgment of the flood waters' height. In addition, the height of flood waters can be impacted by outside forces such as wind and shielding by other structures. Therefore, HWMs should be used to identify trends and not to extrapolate exact height of water throughout the area.

HWMs flagged and surveyed by the URS team and USGS are shown graphically in Figure 17.

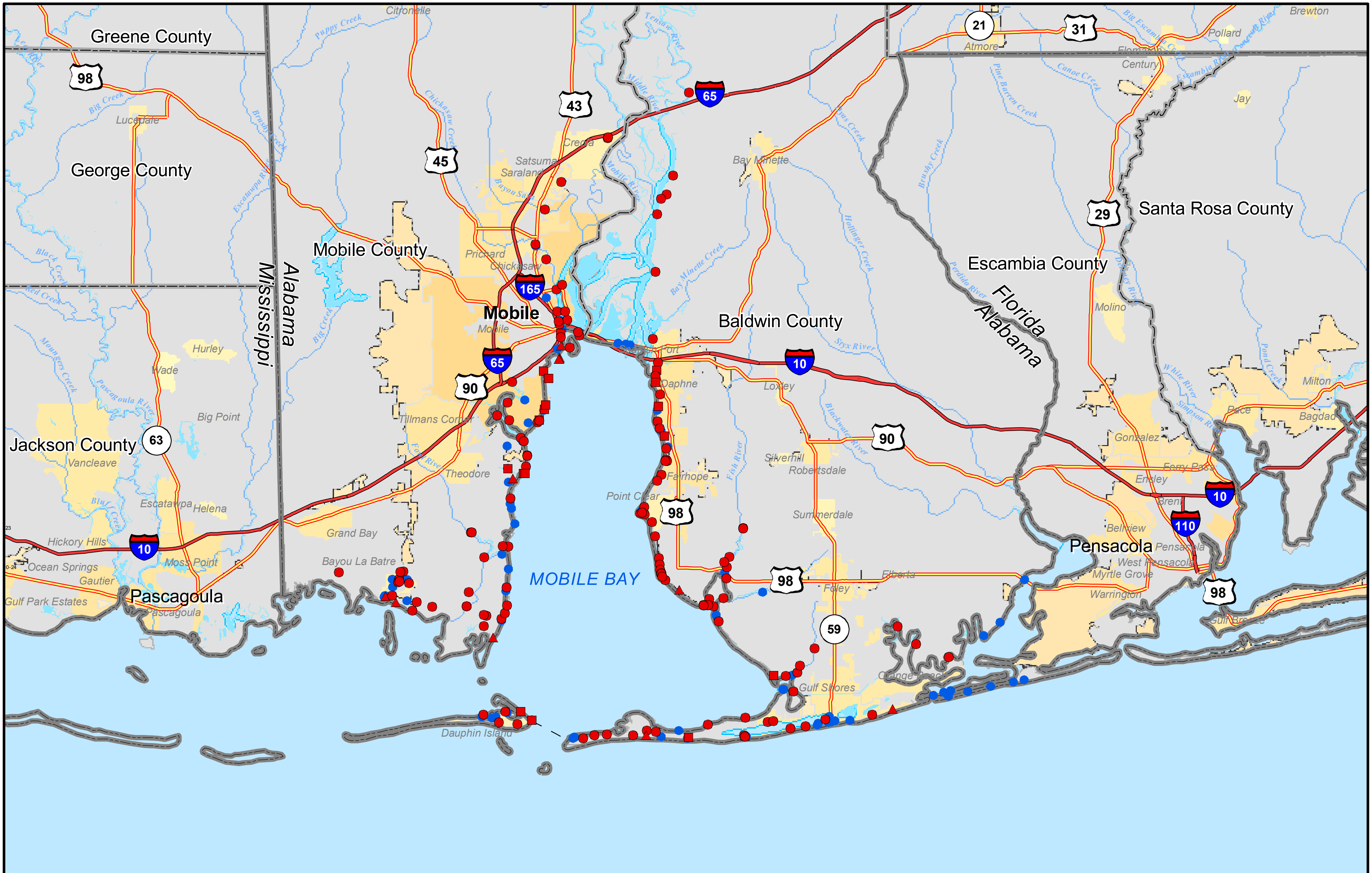
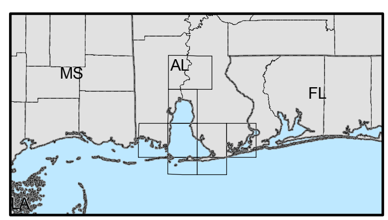


Figure 17: Alabama Overview
Hurricane Katrina, Alabama
Surveyed High Water Mark (HWM) Elevations

Flooding Type
- Coastal - Surge Only
- Coastal - Wave Height
- Coastal - Wave Runup
- USGS High Water Marks

County
CITY

Road Classification
- Limited Access Highway
- Highway



N
0 5 10 20
Miles
0 5 10 20
Kilometers
FEMA

Data collected for the HWMs are stored in a digital database and presented on one-page forms that are sorted by county in the appendices of this report. Forms for HWMs that were flagged and surveyed by URS are included as Appendices C through D. Points investigated and located by USGS are shown on forms in Appendix E. The HWMs are identified with a unique point number, the High Water Mark Identifier (HWM ID), as shown on the one-page HWM form. The one-page HWM forms include data for the storm event, flood type, location, point description, surveyed point coordinates (LAT/LON), and elevations. A summary of basic data for all HWMs collected are sorted by county and HWM sheet number and presented in Table 4. A second summary table with HWM data sorted by HWM ID is provided in Appendix B as Table B-2.

HWM location maps (see Figure B.1) and a second summary table of HWM data are provided in Appendix B. HWMs collected for Hurricane Katrina in Alabama, including URS Team and USGS flagged points, are shown spatially on HWM location maps, Figures B.1 through B.9. These figures present the location, HWM ID, and the field-surveyed HWM elevation in feet referenced in NAVD 88. The symbol representing the HWM point on the map is graphically coded and designates whether the HWM is a URS Team or USGS point, and the type of coastal flooding (i.e., surge-only, wave height, or wave runup). Table B-1 lists Counties in which the data were collected and the corresponding figures on which they are shown. Table B-2 provides the HWM summary data provided in Table 4, however, the data is sorted by the HWM ID value for referencing convenience.

Table 4. Hurricane Katrina Alabama HWM Data Summary

HWM ID	County	Flooding Type	HWM Flood Elevation - Feet NAVD 88	Survey Latitude	Survey Longitude	HWM Report Sheet No.
URS Team Flagged Points						
KALC-02-18	Baldwin	Coastal - Surge Only	6.0	30.356229	-87.601063	Bald-1
KALC-02-19	Baldwin	Coastal - Surge Only	5.1	30.321809	-87.534673	Bald-2
KALC-02-20	Baldwin	Coastal - Surge Only	6.0	30.336035	-87.577146	Bald-3
KALC-02-21	Baldwin	Coastal - Surge Only	8.6	30.386607	-87.845388	Bald-4
KALC-02-22	Baldwin	Coastal - Surge Only	9.0	30.240890	-87.739675	Bald-5
KALC-02-23	Baldwin	Coastal - Surge Only	9.4	30.243475	-87.720007	Bald-6
KALC-02-24	Baldwin	Coastal - Surge Only	8.8	30.251457	-87.694753	Bald-7
KALC-02-25	Baldwin	Coastal - Surge Only	5.2	30.233736	-87.977785	Bald-8
KALC-02-26	Baldwin	Coastal - Surge Only	8.6	30.248250	-87.769211	Bald-9
KALC-03-16	Baldwin	Coastal - Surge Only	8.6	30.387662	-87.826893	Bald-10
KALC-03-17	Baldwin	Coastal - Surge Only	7.2	30.331168	-87.708448	Bald-11
KALC-03-18	Baldwin	Coastal - Surge Only	7.4	30.304067	-87.730858	Bald-12
KALC-03-19	Baldwin	Coastal - Surge Only	9.0	30.409938	-87.823535	Bald-13
KALC-04-08	Baldwin	Coastal - Surge Only	11.4	30.652731	-87.913060	Bald-14
KALC-04-09	Baldwin	Coastal - Wave Runup	13.6	30.643702	-87.915591	Bald-15
KALC-04-10	Baldwin	Coastal - Surge Only	11.2	30.637664	-87.916574	Bald-16
KALC-04-11	Baldwin	Coastal - Wave Runup	11.0	30.630239	-87.916188	Bald-17
KALC-04-13	Baldwin	Coastal - Wave Runup	9.6	30.614936	-87.911995	Bald-18
KALC-04-14	Baldwin	Coastal - Wave Runup	13.2	30.603361	-87.912641	Bald-19

HWM ID	County	Flooding Type	HWM Flood Elevation - Feet NAVD 88	Survey Latitude	Survey Longitude	HWM Report Sheet No.
KALC-04-16	Baldwin	Coastal - Surge Only	10.8	30.586513	-87.913308	Bald-20
KALC-04-17	Baldwin	Coastal - Surge Only	11.8	30.578519	-87.910763	Bald-21
KALC-04-18	Baldwin	Coastal - Wave Runup	13.7	30.569867	-87.905101	Bald-22
KALC-04-19	Baldwin	Coastal - Wave Runup	5.2	30.300829	-87.761910	Bald-23
KALC-04-20	Baldwin	Coastal - Surge Only	9.2	30.361238	-87.833448	Bald-24
KALC-04-21	Baldwin	Coastal - Surge Only	9.5	30.484048	-87.931595	Bald-25
KALC-04-22	Baldwin	Coastal - Surge Only	10.3	30.481645	-87.929825	Bald-26
KALC-04-23	Baldwin	Coastal - Surge Only	9.8	30.457092	-87.916419	Bald-27
KALC-04-24	Baldwin	Coastal - Surge Only	10.2	30.473224	-87.920188	Bald-28
KALC-04-25	Baldwin	Coastal - Surge Only	9.4	30.432541	-87.911293	Bald-29
KALC-05-10	Baldwin	Coastal - Surge Only	5.9	30.311908	-87.727556	Bald-30
KALC-05-11	Baldwin	Coastal - Surge Only	5.6	30.300327	-87.745703	Bald-31
KALC-05-12	Baldwin	Coastal - Surge Only	6.9	30.282972	-87.735947	Bald-32
KALC-06-01	Baldwin	Coastal - Surge Only	9.4	30.229377	-88.008609	Bald-33
KALC-06-02	Baldwin	Coastal - Surge Only	5.6	30.232636	-87.993963	Bald-34
KALC-06-03	Baldwin	Coastal - Surge Only	8.2	30.232726	-87.943612	Bald-35
KALC-06-04	Baldwin	Coastal - Surge Only	5.3	30.238188	-87.925684	Bald-36
KALC-06-05	Baldwin	Coastal - Wave Height	12.2	30.233108	-87.927181	Bald-37
KALC-06-06	Baldwin	Coastal - Surge Only	10.4	30.236696	-87.914444	Bald-38
KALC-06-07	Baldwin	Coastal - Wave Runup	11.0	30.230697	-87.872584	Bald-39
KALC-06-08	Baldwin	Coastal - Surge Only	6.6	30.245169	-87.846709	Bald-40
KALC-06-09	Baldwin	Coastal - Surge Only	6.5	30.253069	-87.798418	Bald-41
KALC-06-10	Baldwin	Coastal - Surge Only	9.1	30.249512	-87.762118	Bald-42
KALC-07-01	Baldwin	Coastal - Surge Only	11.3	30.256873	-87.633672	Bald-43
KALC-07-02	Baldwin	Coastal - Wave Height	11.4	30.263113	-87.607466	Bald-44
KALC-08-01	Baldwin	Coastal - Surge Only	9.5	30.425327	-87.909699	Bald-45
KALC-08-02	Baldwin	Coastal - Surge Only	9.6	30.419541	-87.909101	Bald-46
KALC-08-03	Baldwin	Coastal - Surge Only	9.5	30.415125	-87.908286	Bald-47
KALC-08-04	Baldwin	Coastal - Surge Only	9.4	30.415230	-87.907854	Bald-48
KALC-08-05	Baldwin	Coastal - Surge Only	9.2	30.415000	-87.907793	Bald-49
KALC-08-06	Baldwin	Coastal - Surge Only	7.2	30.379138	-87.852952	Bald-50
KALC-08-07	Baldwin	Coastal - Surge Only	6.3	30.379690	-87.852605	Bald-51
KALC-08-08	Baldwin	Coastal - Surge Only	9.0	30.378253	-87.840121	Bald-52
KALC-09-01	Baldwin	Coastal - Surge Only	10.2	30.555943	-87.902009	Bald-53
KALC-09-02	Baldwin	Coastal - Surge Only	10.5	30.543086	-87.902038	Bald-54
KALC-09-03	Baldwin	Coastal - Surge Only	9.7	30.541570	-87.900657	Bald-55
KALC-09-04	Baldwin	Coastal - Surge Only	10.7	30.541551	-87.903199	Bald-56
KALC-09-06	Baldwin	Coastal - Wave Runup	12.4	30.512861	-87.920338	Bald-57
KALC-09-07	Baldwin	Coastal - Surge Only	10.0	30.512116	-87.919439	Bald-58
KALC-09-08	Baldwin	Coastal - Surge Only	9.6	30.489872	-87.930166	Bald-59
KALC-09-09	Baldwin	Coastal - Surge Only	9.6	30.482843	-87.935296	Bald-60
KALC-09-10	Baldwin	Coastal - Surge Only	9.6	30.483762	-87.933143	Bald-61
KALC-09-11	Baldwin	Coastal - Surge Only	9.0	30.434026	-87.819440	Bald-62
KALC-09-12	Baldwin	Coastal - Surge Only	9.9	30.422684	-87.822556	Bald-63
KALC-09-13	Baldwin	Coastal - Wave Height	11.0	30.396753	-87.884944	Bald-64
KALC-09-14	Baldwin	Coastal - Surge Only	11.0	30.407740	-87.902586	Bald-65
KALC-09-15	Baldwin	Coastal - Surge Only	6.6	30.379876	-87.846653	Bald-66

HWM ID	County	Flooding Type	HWM Flood Elevation - Feet NAVD 88	Survey Latitude	Survey Longitude	HWM Report Sheet No.
KALC-09-21	Baldwin	Coastal - Surge Only	9.0	30.466616	-87.801442	Bald-67
KALC-09-22	Baldwin	Coastal - Surge Only	9.1	30.465898	-87.801620	Bald-68
KALC-09-23	Baldwin	Coastal - Surge Only	11.2	30.411647	-87.906800	Bald-69
KALC-09-24	Baldwin	Coastal - Surge Only	9.0	30.428385	-87.826406	Bald-70
KALC-10-01	Baldwin	Coastal - Surge Only	9.2	30.233113	-87.799649	Bald-71
KALC-10-02	Baldwin	Coastal - Wave Height	8.5	30.232372	-87.798811	Bald-72
KALC-10-03	Baldwin	Coastal - Surge Only	9.2	30.231934	-87.798608	Bald-73
KALR-04-01	Baldwin	Coastal - Surge Only	9.0	30.841757	-87.902804	Bald-74
KALR-04-02	Baldwin	Coastal - Surge Only	10.6	30.836882	-87.910127	Bald-75
KALR-04-03	Baldwin	Coastal - Surge Only	8.5	30.956541	-87.873829	Bald-76
KALR-04-04	Baldwin	Coastal - Surge Only	8.8	30.863050	-87.894579	Bald-77
KALR-04-05	Baldwin	Coastal - Surge Only	7.6	30.819433	-87.914795	Bald-78
KALR-04-06	Baldwin	Coastal - Surge Only	7.9	30.754847	-87.916899	Bald-79
KALR-04-07	Baldwin	Coastal - Surge Only	7.1	30.679313	-87.919746	Bald-80
KALC-01-01	Mobile	Coastal - Surge Only	11.5	30.415636	-88.246662	Mobi-1
KALC-01-02	Mobile	Coastal - Surge Only	13.8	30.376339	-88.204941	Mobi-2
KALC-01-03	Mobile	Coastal - Surge Only	10.8	30.377094	-88.160194	Mobi-3
KALC-01-04	Mobile	Coastal - Surge Only	11.0	30.377056	-88.160604	Mobi-4
KALC-01-05	Mobile	Coastal - Surge Only	12.7	30.355212	-88.137934	Mobi-5
KALC-01-06	Mobile	Coastal - Wave Height	15.0	30.381055	-88.252562	Mobi-6
KALC-01-07	Mobile	Coastal - Wave Height	12.2	30.387486	-88.266179	Mobi-7
KALC-01-08	Mobile	Coastal - Surge Only	12.4	30.682765	-88.015711	Mobi-8
KALC-01-09	Mobile	Coastal - Surge Only	11.1	30.567405	-88.091335	Mobi-9
KALC-01-10	Mobile	Coastal - Wave Runup	11.3	30.527069	-88.088024	Mobi-10
KALC-01-11	Mobile	Coastal - Wave Runup	9.4	30.532156	-88.108309	Mobi-11
KALC-02-01	Mobile	Coastal - Surge Only	11.0	30.414319	-88.326508	Mobi-12
KALC-02-03	Mobile	Coastal - Surge Only	11.0	30.407259	-88.248347	Mobi-13
KALC-02-04	Mobile	Coastal - Surge Only	13.0	30.388546	-88.256883	Mobi-14
KALC-02-06	Mobile	Coastal - Surge Only	11.9	30.444559	-88.106675	Mobi-15
KALC-02-07	Mobile	Coastal - Surge Only	9.2	30.444931	-88.113647	Mobi-16
KALC-02-08	Mobile	Coastal - Surge Only	11.3	30.403672	-88.249339	Mobi-17
KALC-02-09	Mobile	Coastal - Surge Only	11.2	30.371828	-88.230447	Mobi-18
KALC-02-10	Mobile	Coastal - Surge Only	9.4	30.432537	-88.137748	Mobi-19
KALC-02-11	Mobile	Coastal - Surge Only	12.6	30.402962	-88.235230	Mobi-20
KALC-02-12	Mobile	Coastal - Wave Height	14.3	30.521355	-88.101540	Mobi-21
KALC-02-13	Mobile	Coastal - Surge Only	12.7	30.415749	-88.242463	Mobi-22
KALC-02-14	Mobile	Coastal - Surge Only	13.2	30.381664	-88.225424	Mobi-23
KALC-02-15	Mobile	Coastal - Surge Only	11.7	30.592093	-88.121901	Mobi-24
KALC-02-16	Mobile	Coastal - Surge Only	11.3	30.630111	-88.102496	Mobi-25
KALC-03-01	Mobile	Coastal - Surge Only	9.9	30.824292	-88.061436	Mobi-26
KALC-03-02	Mobile	Coastal - Surge Only	10.8	30.785112	-88.073196	Mobi-27
KALC-03-03	Mobile	Coastal - Surge Only	11.1	30.768333	-88.059505	Mobi-28
KALC-03-04	Mobile	Coastal - Surge Only	10.7	30.734343	-88.045763	Mobi-29
KALC-03-05	Mobile	Coastal - Surge Only	11.1	30.709701	-88.044482	Mobi-30
KALC-03-06	Mobile	Coastal - Wave Runup	10.9	30.685253	-88.040267	Mobi-31
KALC-03-07	Mobile	Coastal - Surge Only	10.4	30.739842	-88.038381	Mobi-32
KALC-03-08	Mobile	Coastal - Surge Only	11.7	30.699870	-88.031509	Mobi-33

HWM ID	County	Flooding Type	HWM Flood Elevation - Feet NAVD 88	Survey Latitude	Survey Longitude	HWM Report Sheet No.
KALC-03-09	Mobile	Coastal - Surge Only	11.9	30.686813	-88.017473	Mobi-34
KALC-03-10	Mobile	Coastal - Surge Only	11.9	30.668907	-88.027868	Mobi-35
KALC-03-12	Mobile	Coastal - Surge Only	8.3	30.905147	-87.980126	Mobi-36
KALC-03-13	Mobile	Coastal - Surge Only	8.1	30.905831	-87.979489	Mobi-37
KALC-03-14	Mobile	Coastal - Surge Only	9.0	30.855205	-88.040197	Mobi-38
KALC-03-15	Mobile	Coastal - Surge Only	11.7	30.709865	-88.034325	Mobi-39
KALC-03-20	Mobile	Coastal - Surge Only	9.2	30.366495	-88.134455	Mobi-40
KALC-05-01	Mobile	Coastal - Wave Runup	8.4	30.249403	-88.075257	Mobi-41
KALC-05-02	Mobile	Coastal - Wave Runup	6.9	30.258657	-88.089674	Mobi-42
KALC-05-03	Mobile	Coastal - Surge Only	9.8	30.244703	-88.093654	Mobi-43
KALC-05-04	Mobile	Coastal - Surge Only	11.1	30.246608	-88.117518	Mobi-44
KALC-05-05	Mobile	Coastal - Surge Only	7.3	30.258859	-88.109650	Mobi-45
KALC-05-06	Mobile	Coastal - Surge Only	8.6	30.255389	-88.137606	Mobi-46
KALC-05-08	Mobile	Coastal - Surge Only	8.5	30.460511	-88.155163	Mobi-47
KALC-05-09	Mobile	Coastal - Surge Only	7.2	30.460378	-88.154324	Mobi-48
KALC-06-11	Mobile	Coastal - Surge Only	11.6	30.563544	-88.087073	Mobi-49
KALC-06-12	Mobile	Coastal - Surge Only	12.5	30.584594	-88.069404	Mobi-50
KALC-06-13	Mobile	Coastal - Surge Only	11.5	30.587107	-88.106695	Mobi-51
KALC-06-14	Mobile	Coastal - Surge Only	11.6	30.606740	-88.108938	Mobi-52
KALC-06-16	Mobile	Coastal - Surge Only	8.8	30.363243	-88.114863	Mobi-53
KALC-06-17	Mobile	Coastal - Wave Height	8.1	30.341828	-88.126036	Mobi-54
KALC-06-18	Mobile	Coastal - Surge Only	10.1	30.393140	-88.157686	Mobi-55
KALC-06-19	Mobile	Coastal - Surge Only	9.9	30.367573	-88.137803	Mobi-56
KALC-06-21	Mobile	Coastal - Surge Only	12.7	30.404586	-88.247459	Mobi-57
KALC-07-03	Mobile	Coastal - Wave Height	11.6	30.671136	-88.039965	Mobi-58
KALC-07-04	Mobile	Coastal - Surge Only	9.8	30.680772	-88.039544	Mobi-59
KALC-07-05	Mobile	Coastal - Wave Height	12.5	30.657634	-88.041627	Mobi-60
KALC-07-06	Mobile	Coastal - Wave Height	12.3	30.656006	-88.042278	Mobi-61
KALC-07-07	Mobile	Coastal - Wave Height	12.4	30.655856	-88.042664	Mobi-62
KALC-07-08	Mobile	Coastal - Surge Only	10.2	30.695116	-88.041489	Mobi-63
KALC-07-09	Mobile	Coastal - Surge Only	11.1	30.698683	-88.042539	Mobi-64
KALC-07-10	Mobile	Coastal - Wave Runup	12.0	30.642543	-88.062563	Mobi-65
KALC-07-11	Mobile	Coastal - Wave Runup	12.0	30.634089	-88.055503	Mobi-66
KALC-07-12	Mobile	Coastal - Wave Runup	11.4	30.586939	-88.067673	Mobi-67
KALC-07-13	Mobile	Coastal - Surge Only	11.5	30.586561	-88.067362	Mobi-68
KALC-07-14	Mobile	Coastal - Wave Runup	11.2	30.599291	-88.061115	Mobi-69
KALC-07-15	Mobile	Coastal - Wave Runup	11.6	30.604260	-88.059762	Mobi-70
KALC-08-09	Mobile	Coastal - Surge Only	11.9	30.547221	-88.082740	Mobi-71
KALC-08-10	Mobile	Coastal - Surge Only	10.2	30.547146	-88.082941	Mobi-72
KALC-08-11	Mobile	Coastal - Surge Only	12.0	30.534639	-88.084202	Mobi-73
KALC-08-12	Mobile	Coastal - Wave Runup	9.3	30.527138	-88.086080	Mobi-74
KALC-08-14	Mobile	Coastal - Surge Only	12.0	30.498843	-88.104187	Mobi-75
KALC-09-16	Mobile	Coastal - Surge Only	8.9	30.369778	-88.110617	Mobi-76
KALC-09-17	Mobile	Coastal - Surge Only	9.2	30.378212	-88.107983	Mobi-77
KALC-09-18	Mobile	Coastal - Surge Only	8.4	30.398486	-88.108368	Mobi-78
KALC-09-19	Mobile	Coastal - Surge Only	9.2	30.444931	-88.113647	Mobi-79

HWM ID	County	Flooding Type	HWM Flood Elevation - Feet NAVD 88	Survey Latitude	Survey Longitude	HWM Report Sheet No.
USGS Flagged Points						
KAL_USGS_02	Baldwin	N/A	12.1	30.575624	-87.909159	Bald-1
KAL_USGS_03	Baldwin	N/A	10.3	30.557654	-87.900046	Bald-2
KAL_USGS_04	Baldwin	N/A	9.7	30.486471	-87.932864	Bald-3
KAL_USGS_05	Baldwin	N/A	9.7	30.486458	-87.932922	Bald-4
KAL_USGS_06	Baldwin	N/A	10.0	30.416105	-87.907936	Bald-5
KAL_USGS_07	Baldwin	N/A	7.2	30.416105	-87.907936	Bald-6
KAL_USGS_08	Baldwin	N/A	8.8	30.416501	-87.825330	Bald-7
KAL_USGS_09	Baldwin	N/A	8.8	30.416501	-87.825330	Bald-8
KAL_USGS_10	Baldwin	N/A	9.2	30.378927	-87.852837	Bald-9
KAL_USGS_12	Baldwin	N/A	8.6	30.394625	-87.776232	Bald-10
KAL_USGS_20	Baldwin	N/A	8.5	30.246850	-87.703794	Bald-11
KAL_USGS_21	Baldwin	N/A	9.2	30.245114	-87.704994	Bald-12
KAL_USGS_22	Baldwin	N/A	5.7	30.232539	-87.993966	Bald-13
KAL_USGS_23	Baldwin	N/A	5.7	30.232451	-87.994115	Bald-14
KAL_USGS_24	Baldwin	N/A	8.5	30.232860	-87.943154	Bald-15
KAL_USGS_25	Baldwin	N/A	8.5	30.232850	-87.943178	Bald-16
KAL_USGS_26	Baldwin	N/A	11.6	30.231620	-87.907422	Bald-17
KAL_USGS_27	Baldwin	N/A	11.9	30.231613	-87.907413	Bald-18
KAL_USGS_28	Baldwin	N/A	11.0	30.229892	-87.873245	Bald-19
KAL_USGS_29	Baldwin	N/A	11.2	30.238555	-87.884403	Bald-20
KAL_USGS_30	Baldwin	N/A	8.6	30.232101	-87.797253	Bald-21
KAL_USGS_68	Baldwin	N/A	8.4	30.368732	-87.836576	Bald-22
KAL_USGS_69	Baldwin	N/A	7.9	30.301325	-87.737611	Bald-23
KAL_USGS_70	Baldwin	N/A	7.6	30.285006	-87.749857	Bald-24
KAL_USGS_71	Baldwin	N/A	6.9	30.284928	-87.748950	Bald-25
KAL_USGS_72	Baldwin	N/A	7.1	30.284897	-87.749164	Bald-26
KAL_USGS_73	Baldwin	N/A	10.2	30.250536	-87.662649	Bald-27
KAL_USGS_74	Baldwin	N/A	7.0	30.249729	-87.682237	Bald-28
KAL_USGS_75	Baldwin	N/A	8.6	30.248005	-87.690407	Bald-29
KAL_USGS_76	Baldwin	N/A	7.9	30.249573	-87.687102	Bald-30
KAL_USGS_78	Baldwin	N/A	8.2	30.254745	-87.689327	Bald-31
KAL_USGS_79	Baldwin	N/A	8.2	30.254745	-87.689327	Bald-32
KAL_USGS_80	Baldwin	N/A	8.2	30.254745	-87.689327	Bald-33
KAL_USGS_81	Baldwin	N/A	6.6	30.278586	-87.554729	Bald-34
KAL_USGS_83	Baldwin	N/A	4.8	30.281940	-87.541473	Bald-35
KAL_USGS_84	Baldwin	N/A	5.5	30.281147	-87.536269	Bald-36
KAL_USGS_85	Baldwin	N/A	7.9	30.284080	-87.532170	Bald-37
KAL_USGS_86	Baldwin	N/A	10.3	30.277592	-87.535139	Bald-38
KAL_USGS_87	Baldwin	N/A	10.3	30.277592	-87.535139	Bald-39
KAL_USGS_88	Baldwin	N/A	5.4	30.408743	-87.436536	Bald-40
KAL_USGS_89	Baldwin	N/A	5.2	30.360855	-87.468139	Bald-41
KAL_USGS_90	Baldwin	N/A	4.1	30.345840	-87.489601	Bald-42
KAL_USGS_91	Baldwin	N/A	16.6	30.674402	-87.965202	Bald-43
KAL_USGS_92	Baldwin	N/A	16.0	30.674402	-87.965202	Bald-44
KAL_USGS_93	Baldwin	N/A	16.0	30.674402	-87.965202	Bald-45
KAL_USGS_94	Baldwin	N/A	13.0	30.673077	-87.955025	Bald-46

HWM ID	County	Flooding Type	HWM Flood Elevation - Feet NAVD 88	Survey Latitude	Survey Longitude	HWM Report Sheet No.
KAL_USGS_95	Baldwin	N/A	10.6	30.672215	-87.949782	Bald-47
KAL_USGS_103	Baldwin	N/A	5.9	30.230618	-88.020226	Bald-48
KAL_USGS_104	Baldwin	N/A	5.6	30.229404	-88.021645	Bald-49
KAL_USGS_105	Baldwin	N/A	5.6	30.229952	-88.019602	Bald-50
KAL_USGS_16	Mobile	N/A	12.8	30.382890	-88.237984	Mobi-1
KAL_USGS_33	Mobile	N/A	10.3	30.610018	-88.086693	Mobi-2
KAL_USGS_34	Mobile	N/A	10.8	30.598484	-88.061909	Mobi-3
KAL_USGS_36	Mobile	N/A	9.9	30.563287	-88.088848	Mobi-4
KAL_USGS_37	Mobile	N/A	9.8	30.557933	-88.108926	Mobi-5
KAL_USGS_39	Mobile	N/A	10.0	30.532578	-88.108094	Mobi-6
KAL_USGS_40	Mobile	N/A	10.2	30.517425	-88.107072	Mobi-7
KAL_USGS_41	Mobile	N/A	10.7	30.493242	-88.104488	Mobi-8
KAL_USGS_42	Mobile	N/A	11.0	30.487823	-88.102783	Mobi-9
KAL_USGS_51	Mobile	N/A	8.2	30.252760	-88.121735	Mobi-10
KAL_USGS_64	Mobile	N/A	11.4	30.699619	-88.040700	Mobi-11
KAL_USGS_65	Mobile	N/A	11.4	30.725192	-88.059273	Mobi-12
KAL_USGS_99	Mobile	N/A	8.4	30.419584	-88.106537	Mobi-13
KAL_USGS_100	Mobile	N/A	8.3	30.399023	-88.108640	Mobi-14

As discussed in Section 2.7, USGS also conducted HWM flagging in Alabama. The USGS-flagged HWMs surveyed by URS are included in Appendix E and are sealed by a licensed surveyor certifying that the HWM location is accurate to 0.25 feet vertically and 10 feet horizontally, with a 95 percent accuracy. For those locations where the URS surveyor could not find the HWM, the nearby TBM set by the USGS was surveyed. The USGS then computed the HWM elevation based on line-of-sight surveys between the TBM and the HWM. The USGS' computed elevations for these HWMs are provided in Table 5.

Table 5. USGS HWMs Not Surveyed by URS

HWM ID	County	USGS Elevation - Feet, NAVD88[a]	Surveyed Latitude [b]	Surveyed Longitude [b]
KAL_USGS_01	Baldwin	11.6	30.599016	-87.913999
KAL_USGS_11	Baldwin	8.3	30.391372	-87.806816
KAL_USGS_13	Mobile	12.3	30.406922	-88.245683
KAL_USGS_14	Mobile	12.4	30.406979	-88.237663
KAL_USGS_15	Mobile	11.3	30.377254	-88.159556
KAL_USGS_17	Mobile	12.6	30.409776	-88.244925
KAL_USGS_18	Mobile	13.1 [c]	30.404250	-88.247982
KAL_USGS_19	Baldwin	8.7	30.242564	-87.738404
KAL_USGS_31	Mobile	12.0	30.687249	-88.017085
KAL_USGS_32	Mobile	12.1	30.667696	-88.044416

HWM ID	County	USGS Elevation - Feet, NAVD88[a]	Surveyed Latitude [b]	Surveyed Longitude [b]
KAL_USGS_35	Mobile	9.8 [d]	30.584356	-88.081936
KAL_USGS_38	Mobile	11.2	30.549608	-88.083089
KAL_USGS_43	Mobile	10.3	30.470401	-88.098407
KAL_USGS_44	Mobile	9.7	30.445237	-88.113889
KAL_USGS_45	Mobile	9.0	30.435998	-88.115153
KAL_USGS_46	Mobile	9.0	30.435998	-88.115153
KAL_USGS_52	Mobile	8.4 [e]	30.253083	-88.140025
KAL_USGS_53	Mobile	6.7	30.249582	-88.075489
KAL_USGS_54	Mobile	7.4	30.257928	-88.106931
KAL_USGS_55	Mobile	8.3	30.251582	-88.126708
KAL_USGS_56	Mobile	10.4	30.367307	-88.136919
KAL_USGS_57	Mobile	9.7	30.361381	-88.115056
KAL_USGS_58	Mobile	13.8	30.387347	-88.267412
KAL_USGS_59	Mobile	12.5 [f]	30.406892	-88.257113
KAL_USGS_60	Mobile	13.5	30.388878	-88.266338
KAL_USGS_61	Mobile	13.3	30.388878	-88.266338
KAL_USGS_62	Mobile	13.1	30.398407	-88.256373
KAL_USGS_63	Mobile	11.6	30.689853	-88.038306
KAL_USGS_66	Mobile	10.7	30.783199	-88.072844
KAL_USGS_77	Baldwin	12.4	30.248281	-87.687529
KAL_USGS_82	Baldwin	6.6	30.278398	-88.554987
KAL_USGS_97	Baldwin	12.8	30.670699	-88.939027
KAL_USGS_99	Mobile	8.2 [g]	30.394613	-88.109415
KAL_USGS_102	Mobile	9.0	30.374480	-88.108369

Notes:
[a] Elevation computed by USGS based on elevation of nearby TBM
[b] Latitude and longitude denote the location of the nearby TBM
[c] Elevation is based on nearby National Geodetic Survey Bench Mark because USGS could not locate TBM set by surveyor
[d] Based on nearby USACE bench mark, elevation may be 11.6 ft.
[e] Based on nearby USACE bench mark, elevation may be 7.4 ft.
[f] Elevation is based on nearby USACE bench mark because USGS could not locate TBM set by surveyor.
[g] Based on nearby USACE bench mark, elevation may be 8.7 ft.

The USGS also conducted quality-assurance checks for 10 HWMs flagged by the USGS, but surveyed by URS. For these sites, the USGS leveled the HWMs, using line-of-sight surveying, from benchmarks previously established by the USACE or other agencies, and compared those elevations to URS' surveyed elevations. The comparisons are presented in Table 6. The differences in elevation may be a result of different interpretations of the line representing the HWM or variations in the benchmarks that were used. The differences are summarized as:

- 4 were less than or equal to 0.25 foot;
- 2 were greater than 0.25 and less than or equal to 0.50 foot;
- 1 was greater than 0.50 feet and less than or equal to 0.75 foot;
- 3 were greater than 0.75 and less than 1.25 feet.

Table 6: Comparison of HWM Surveyed by URS and Surveyed by USGS

HWM ID	County	URS Surveyed Elevation (feet, NAVD88)	USGS Computed Elevation (feet, NAVD88)[a]	Elevation Difference (feet)	Surveyed Latitude	Surveyed Longitude
KAL_USGS_16	Mobile	12.8	13.0	-0.2	30.382890	-88.237984
KAL_USGS_31	Mobile	12.0	11.9	0.1	30.687249	-88.017085
KAL_USGS_34	Mobile	10.8	11.9	-1.1	30.598484	-88.061909
KAL_USGS_36	Mobile	9.9	11.1	-1.2	30.563287	-88.088848
KAL_USGS_37	Mobile	9.8	11.0	-1.2	30.557933	-88.108926
KAL_USGS_51	Mobile	8.2	8.3	-0.1	30.252760	-88.121735
KAL_USGS_64	Mobile	11.4	11.0	0.4	30.699619	-88.040700
KAL_USGS_65	Mobile	11.4	11.6	-0.2	30.725192	-88.059273
KAL_USGS_99	Mobile	8.4	9.1	-0.7	30.419584	-88.106537
KAL_USGS_100	Mobile	8.3	8.8	-0.5	30.399023	-88.108640

The USGS also conducted quality-assurance checks for eight HWMs flagged by the USGS, but the URS surveyor could not find the HWM, so only the nearby TBM was surveyed. For these HWMs, the USGS computed the HWM elevations, using line-of-sight surveying, based on two different types of benchmarks: TBMs surveyed by URS and benchmarks set by USACE or other agency. The comparisons are presented in Table 7. The differences in elevation may be a result of variations in the benchmarks that were used. The differences are summarized as:

- 3 were less than or equal to 0.25 foot;
- 3 were greater than 0.25 and less than or equal to 0.50 foot;
- 1 was greater than 0.50 and less than or equal to 1.0 foot;
- 1 was greater than 1.0 and less than 2.0 feet.

Table 7. Comparison of USGS Computed HWMs From URS Surveyed TBMs and USACE Benchmark

HWM ID	County	Elevation Based on URS TBM (feet, NAVD88)	Elevation Based on USACE Benchmark (feet, NAVD88)	Elevation Difference (feet)	Surveyed Latitude	Surveyed Longitude
KAL_USGS_35	Mobile	9.8	11.6	-1.8	30.584356	-88.081936
KAL_USGS_52	Mobile	8.4	7.4	1.0	30.253083	-88.140025
KAL_USGS_53	Mobile	6.7	6.6	0.1	30.249582	-88.075489
KAL_USGS_54	Mobile	7.4	7.6	-0.3	30.257928	-88.106931
KAL_USGS_57	Mobile	9.7	9.7	0.0	30.361381	-88.115056
KAL_USGS_63	Mobile	11.6	12.0	-0.4	30.689853	-88.038306
KAL_USGS_66	Mobile	10.7	10.8	-0.1	30.783199	-88.072844
KAL_USGS_101	Mobile	8.2	8.7	-0.5	30.394613	-88.109415

In addition to the HWMs flagged in Baldwin and Mobile Counties, USGS flagged some HWMs in Escambia County which URS also surveyed. Since these points are not located in Alabama, HWM sheets for these points are not included in the appendices. Information on these points is provided in Table 8.

Table 8. USGS-Flagged HWMs Surveyed by URS In Escambia, Florida

HWM ID	County	URS Surveyed Elevation (feet, NAVD88)	Surveyed Latitude	Surveyed Longitude
KAL_USGS_47	Escambia, FL	7.0	30.2887	-87.4804
KAL_USGS_48	Escambia, FL	12.3	30.2960	-87.4369
KAL_USGS_49	Escambia, FL	11.5	30.2831	-87.5101
KAL_USGS_50	Escambia, FL	12.9	30.2937	-87.4510

4.2 Coastal HWM Observations

This section discusses observations regarding the HWMs. The observations pertain to elevations that are referenced to NAVD 88. It should be noted that data outliers may be found in each of the areas discussed below. The outliers are anomalies that occur due to local variations in topography and/or HWMs flagged based on personal accounts of residents giving an approximation of flood heights.

Hurricane Katrina storm surge in Alabama was relatively high. The storm made landfall near the Mississippi and Louisiana state line, 65 miles west of the Alabama/Mississippi boundary. However, Katrina had a wind field that was skewed to the east and this resulted in hurricane force winds that extended about 120 miles from the storm center. This caused a considerable storm surge at several places along the Alabama coast. As the storm approached land, storm winds in the right-front quadrant forced water from the Gulf of Mexico northward onto the western Alabama shoreline and into Mobile Bay.

HWMs along the western Alabama shoreline facing the Mississippi Sound shows flooding elevations on the order of 11 to 15 feet (Figure B.2), which are only slightly lower than the elevations that occurred along the eastern Mississippi coast. Flooding levels continued to decrease slightly to the east, along the southwestern shore of Mobile Bay (Figure B.3) where elevations of 8 to 9 feet are found.

As the storm continued on its northeast track the waters continued to be forced into Mobile Bay causing higher flooding elevations farther towards the head of the bay along this shoreline (Figure B.4). The flooding elevations slightly decreased as the flooding moved farther inland (Figure B.5). Elevations in the vicinity of the City of Mobile were on the order of 11 to 12.5 feet, depending on local conditions. Slightly higher elevations were found along the northeastern portion of Mobile Bay, with flooding elevations reaching over 13 feet north of Fairhope. There is a bluff along much of the northern portion of this shoreline, and this limited the inland propagation of the storm surge.

South of Fairhope, along the southeastern shore of Mobile Bay (Figure B.6), the flooding elevations diminish significantly to the south where elevations as low as 5 feet are found on the east end of Bon Secur Bay, the very southeast corner of Mobile Bay.

The mouth of Mobile Bay is constricted on the west by Dauphin Island and on the east by West Beach, which extends from Gulf Shores westward across the mouth of the Bay. On the open Gulf Coast of Dauphin Island and West Beach, flooding elevations were recorded between 8.5 and 11.5 feet (Figures B.8 and B.9). Similar, but lower elevations extend eastward as far as the Florida state line (Figure B.7).

Appendix A. Field Data Collection Forms

Figure A.1

FLAGGER HIGH WATER MARK – COASTAL and RIVERINE
DATA COLLECTION REPORT FORM
(For Use By Flaggers) **HMTAP TO No.____________________**

HWM ID (e.g. DFLC-07-01) (Repeat in case forms are separated)		
HWM Street Address		
Rep Loss Number		
Multiple HWM	**(Circle One)**: Yes No	
HWM Area Identifier		
Subdivision / Industrial Park		
Date of Flagging/Interview		
Date of Flood Event		
Type/Name of Storm Event	**(Circle One)**: Hurricane, Tropical Storm, Tropical Depression, Other:	Name of storm event (e.g., Dennis)
Disaster Number (e.g.: DR-1539-FL)		
Date of Peak		
Source for Date of Peak		
Stream Name/Flood Source (Closest/responsible water body)		
Municipality, City or Town (Circle One: Known, closest)		
County		
State		
Type of HWM – **(Circle One)** **If Personal Account or Other, you MUST provide comment**	Mud Line Wrack Line Debris Line Water Line Personal Account Other Comment	
Wind Water Debris Line	**(Circle One)**: Yes No	
HWM Object, Surface (What object, surface is the HWM on? An interior/exterior wall, tree, fence, etc…)		

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Storm: ____________________
FLAGGER FORM Page 1 of 4

Figure A.1 (continued)

FLAGGER HIGH WATER MARK – COASTAL and RIVERINE
DATA COLLECTION REPORT FORM
(For Use By Flaggers) **HMTAP TO No.____________________**

HWM ID (e.g. DFLC-07-01) (Repeat in case forms are separated)			
Location/Directions to HWM Object			
Was a Vertical Offset Measurement used for HWM **(Circle Yes, No. If Yes, enter data)**	Yes No	If Yes: Measurement: Description of offset point:	
Vertical Distance HWM to existing ground (feet) (Required			
HWM Quality – **(Circle One)**	GOOD	FAIR	POOR
Description of Marker Used To Flag HWM **(e.g. red paint, tape. NOTE: HWM IS LINE AT BOTTOM OF TAPE OR PAINT. UNLESS the Flagger indicates that there is a vertical offset from the marked point)**			
Survey of HWM Needed	YES	NO	
Flagger HWM Latitude (Decimal Degrees ex: 29.12345 (5 places))	N		DECIMAL DEGREES
Flagger HWM Longitude (Decimal Degrees ex: 84.12345 (5 places))	W		DECIMAL DEGREES
Flooding Type – **(Circle One)**	**Riverine Choices are**: - Riverine - Heavy Rain - Riverine - Hurricane	**Coastal Choices are:** - Coastal - surge only - Coastal - wave height - Coastal - wave runup	**Breached Levee**
Estimated HWM Surge Level and what is this based on (Coastal HWM Only)	Elevation (Feet) Based On:		
Timestamp of Surge Estimate (Coastal HWM Only)	____ : ____ AM / PM CENTRAL / EASTERN		
Photo ID (HWM ID)-(Photo file name from camera)	Photo 1 (HWM mark from 20 feet away)	Photo 2 (Structure / Area from 50 feet away)	
Photos Location/Orientation			
Photos Description/Subject			
Unit Number (2-digit number)			

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Storm: ____________________
FLAGGER FORM Page 2 of 4

Figure A.1 (continued)

FLAGGER HIGH WATER MARK – COASTAL and RIVERINE
DATA COLLECTION REPORT FORM
(For Use By Flaggers) **HMTAP TO No.____________________**

HWM ID (e.g. DFLC-07-01) (Repeat in case forms are separated)		
Name of Flagger 1/Flagger 2	1	2
Flagger 1 Company/Flagger 2 Company	1	2
Flagger's Comments		
Resident/Eyewitness Information		
Name		
Address		
Obtained Permission to Survey	Yes	No
Phone		
Length of residence or familiarity with area		
Relevant witness Information (Document only if witness is willing to have personal information included in record)		
Wind Damage Data		
Structure Damage **(Circle as applicable)**	1) No Damage; 2) Structure type (use): residential, commercial, agricultural, mobile home; 3) Cause: wind, fallen objects, blown debris; 4) Severity (subjective): light, moderate, severe	
Tree Damage **(Circle as applicable)**	1) No Damage; 2) Tree Species: oak, pine, palm, other; 3) Damage: uprooted, snapped, twisted; 4) Severity (subjective): light (single tree), moderate, severe	
Overhead Utility Damage **(Circle as applicable)**	1) No Damage; 2) Materials: wood, metal, concrete; 3) Utility Type: power, telephone, cable; 4) Cause: wind, fallen objects, blown debris; 5) Severity (subjective): light, moderate, sever	

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Storm: ____________________
FLAGGER FORM Page 3 of 4

Figure A.1 (continued)

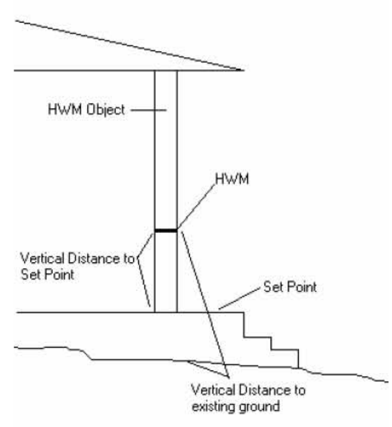
FLAGGER HIGH WATER MARK – COASTAL and RIVERINE
DATA COLLECTION REPORT FORM
(For Use By Flaggers) **HMTAP TO No.**____________________

HWM ID (e.g. DFLC-07-01) (Repeat in case forms are separated)	
Other Damage/Comments	

<u>Required Plan/ Elevation View Sketches (use back if needed)</u>

<u>Required</u>: 1) Sketch/Plan of nearest cross roads, directions to get to the HWM
2) Plan and Elevation views of the HWM

<u>Example Measurements</u>



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Storm: ____________________________
FLAGGER FORM Page 4 of 4

Figure A.2

SURVEYOR'S
HIGH WATER MARK (HWM) – COASTAL AND RIVERINE
DATA COLLECTION REPORT FORM HMTAP TO No.________________

HWM ID (Repeat in case forms are separated)		
HWM Street Address		
Municipality, City or Town (Known, closest)		
County		
State		
Exact Mark To Survey		
HWM Flood Elevation (NAVD 88 Datum) (1)		
HWM Flood Elevation (NGVD 29) (1)		
Was Flagger's Vertical Offset Measurement used to survey HWM Elevation (1)		No Yes
If Yes, then:	Flagger Vertical Offset Distance	
	Surveyed Elevation of Reference Point (NAVD 88)	
Survey Latitude **Must Use Decimal Degrees (6 Decimal places)**		N
Survey Longitude **Must Use Decimal Degrees (6 Decimal places)**		W
Northing (feet)		
Easting (feet)		
Approx. First Floor Elevation (NAVD 88)		
Map Projection Used During Survey		
Vertical Datum		NAVD 88 NGVD 29 OTHER:
Horizontal Datum		NAD 83 OTHER:
Survey Crew		
Responsible Licensed Professional Land Surveyor Name and Number		PLS Name:
Survey Company / Office Location		

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Storm________________
SURVEY FORM Page 1 of 2

Figure A.2 (continued)

SURVEYOR'S
HIGH WATER MARK (HWM) – COASTAL AND RIVERINE
DATA COLLECTION REPORT FORM HMTAP TO No.________________

HWM ID (Repeat in case forms are separated)	
Survey Date (e.g. 07/15/2005)	
Surveyor's Comments	

(1) note that the HWM is the line at the bottom of the tape or paint **UNLESS the Flagger indicates that there is a vertical offset from the marked point**

Surveyor Plan/ Elevation View Sketches (if needed)

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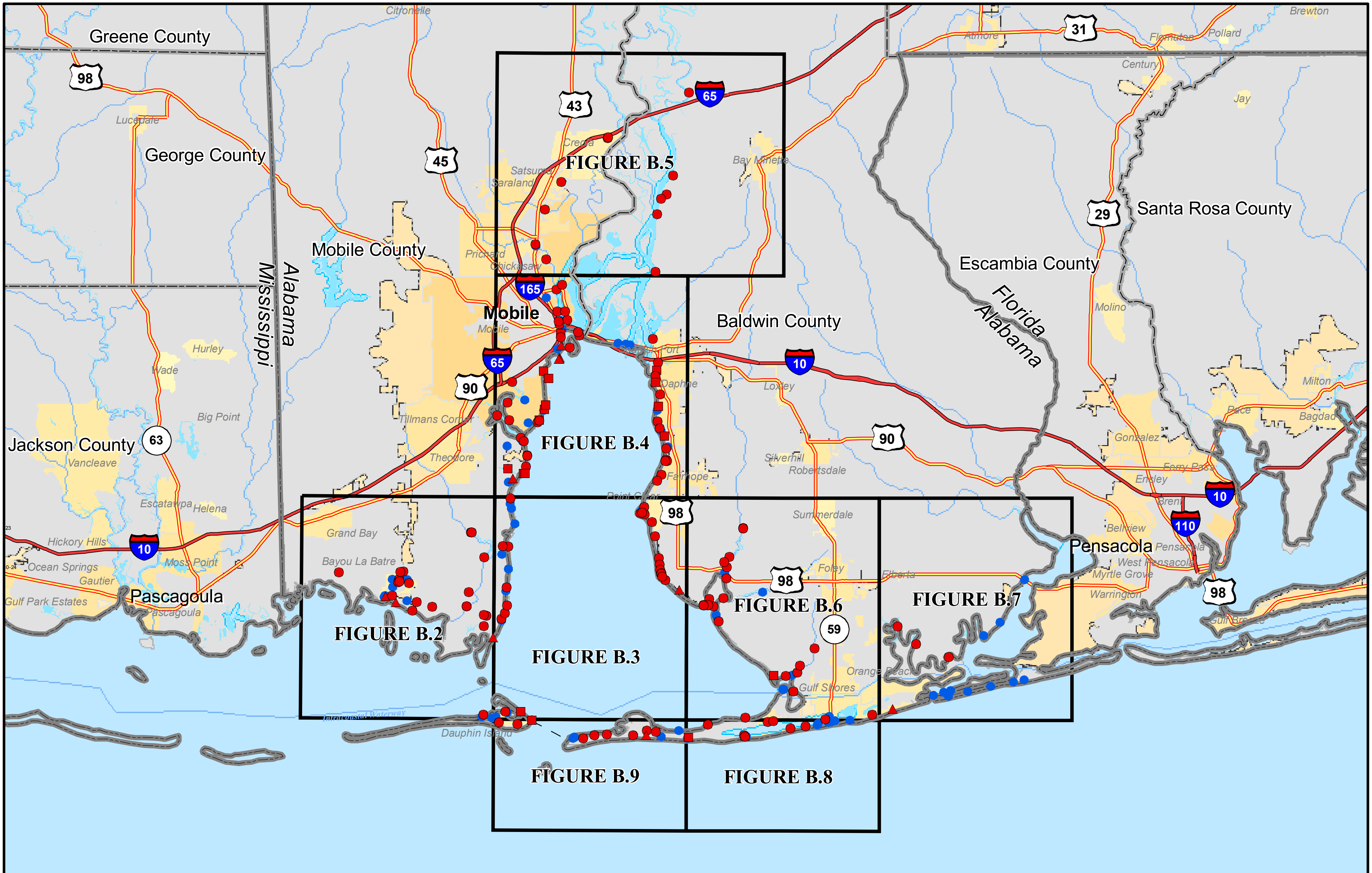
Storm__________________
SURVEY FORM Page 2 of 2

APPENDICES

Appendix B. HWM Location Maps and Summary Table

Table B.1 Appendix B Figures



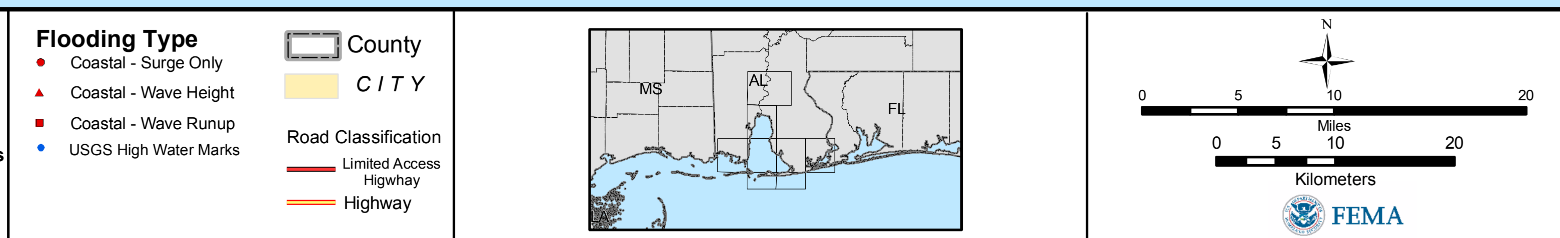
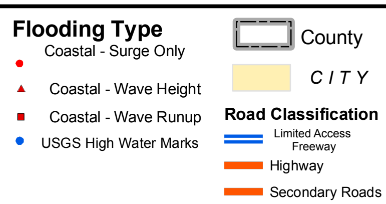
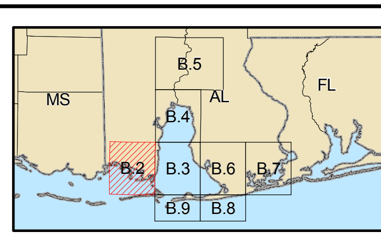
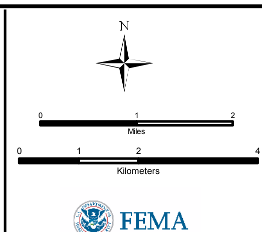


Figure B.1: Overview Map Index
Hurricane Katrina, Alabama
Surveyed High Water Mark (HWM) Elevations

Figure B.2: Hurricane Katrina, Alabama
Mobile County, Alabama
Surveyed High Water Mark (HWM) Elevations







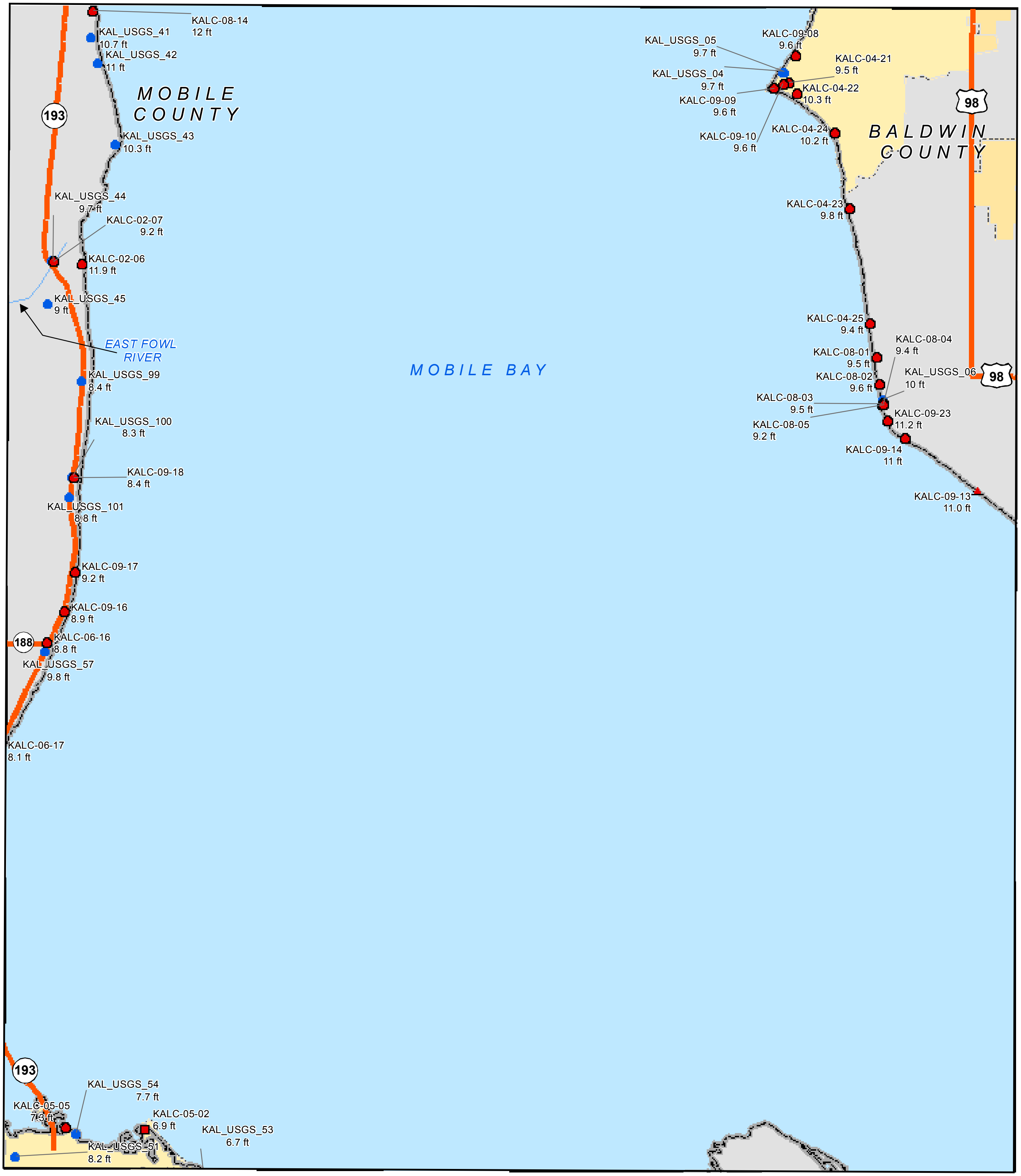
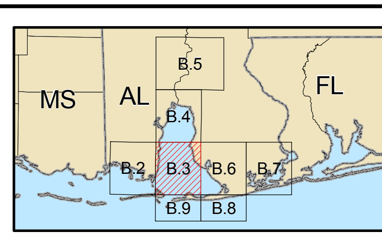


Figure B.3: Hurricane Katrina, Alabama
Mobile & Baldwin Counties
Surveyed High Water Mark (HWM) Elevations

Flooding Type
- Coastal - Surge Only
- Coastal - Wave Height
- Coastal - Wave Runup
- USGS High Water Marks

County
CITY

Road Classification
- Limited Access Freeway
- Highway
- Secondary Roads



N
0 1 2
Miles
0 1 2 4
Kilometers

FEMA

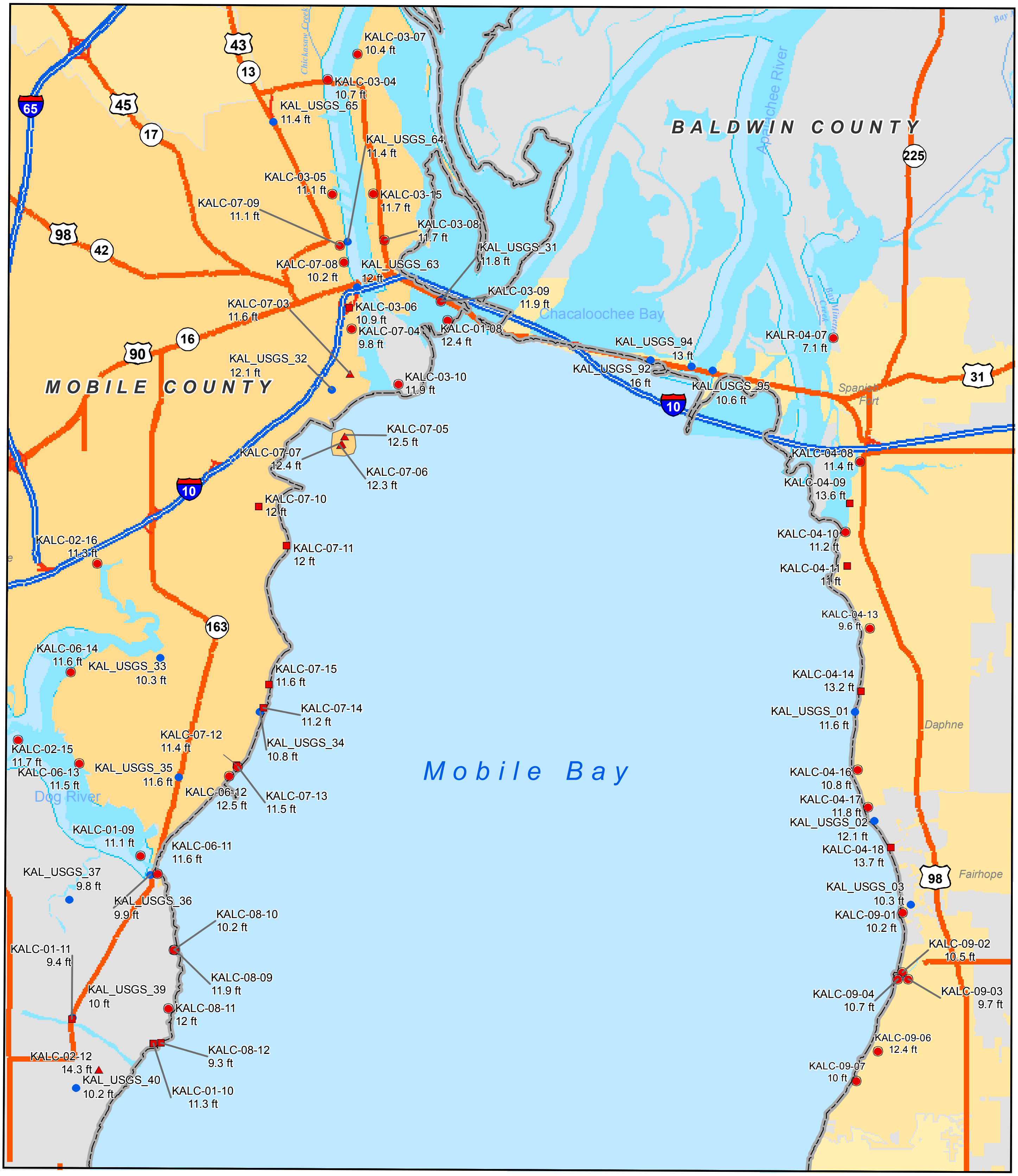


Figure B.4: Hurricane Katrina, Alabama Mobile & Baldwin Counties Surveyed High Water Mark (HWM) Elevations

Flooding Type

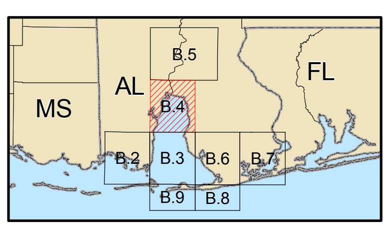
- Coastal - Surge Only
- Coastal - Wave Height
- Coastal - Wave Runup
- USGS High Water Marks

County

CITY

Road Classification

- Limited Access Freeway
- Highway
- Secondary Roads



N

0 1 Miles

0 1 2 4 Kilometers

FEMA

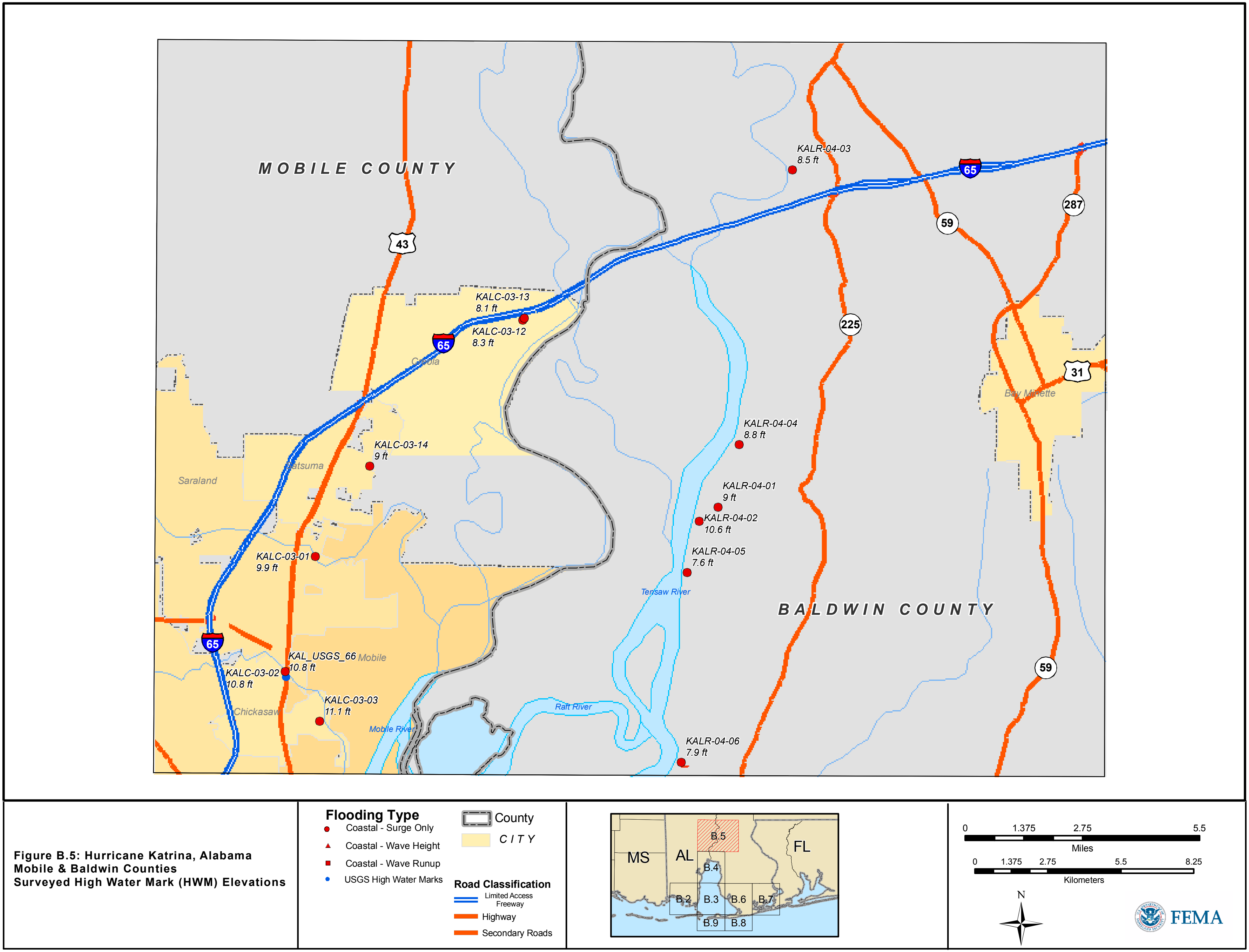


Figure B.5: Hurricane Katrina, Alabama
Mobile & Baldwin Counties
Surveyed High Water Mark (HWM) Elevations

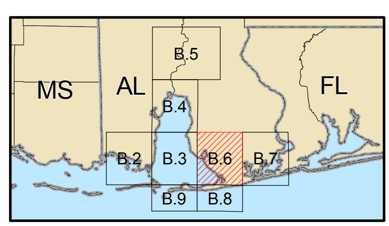
Figure B.6: Hurricane Katrina, Alabama
Baldwin County
Surveyed High Water Mark (HWM) Elevations

Flooding Type
- Coastal - Surge Only
- Coastal - Wave Height
- Coastal - Wave Runup
- USGS High Water Marks

County

CITY

Road Classification
- Limited Access Freeway
- Highway
- Secondary Roads



N

0 1 2
Miles

0 1 2 4
Kilometers

FEMA

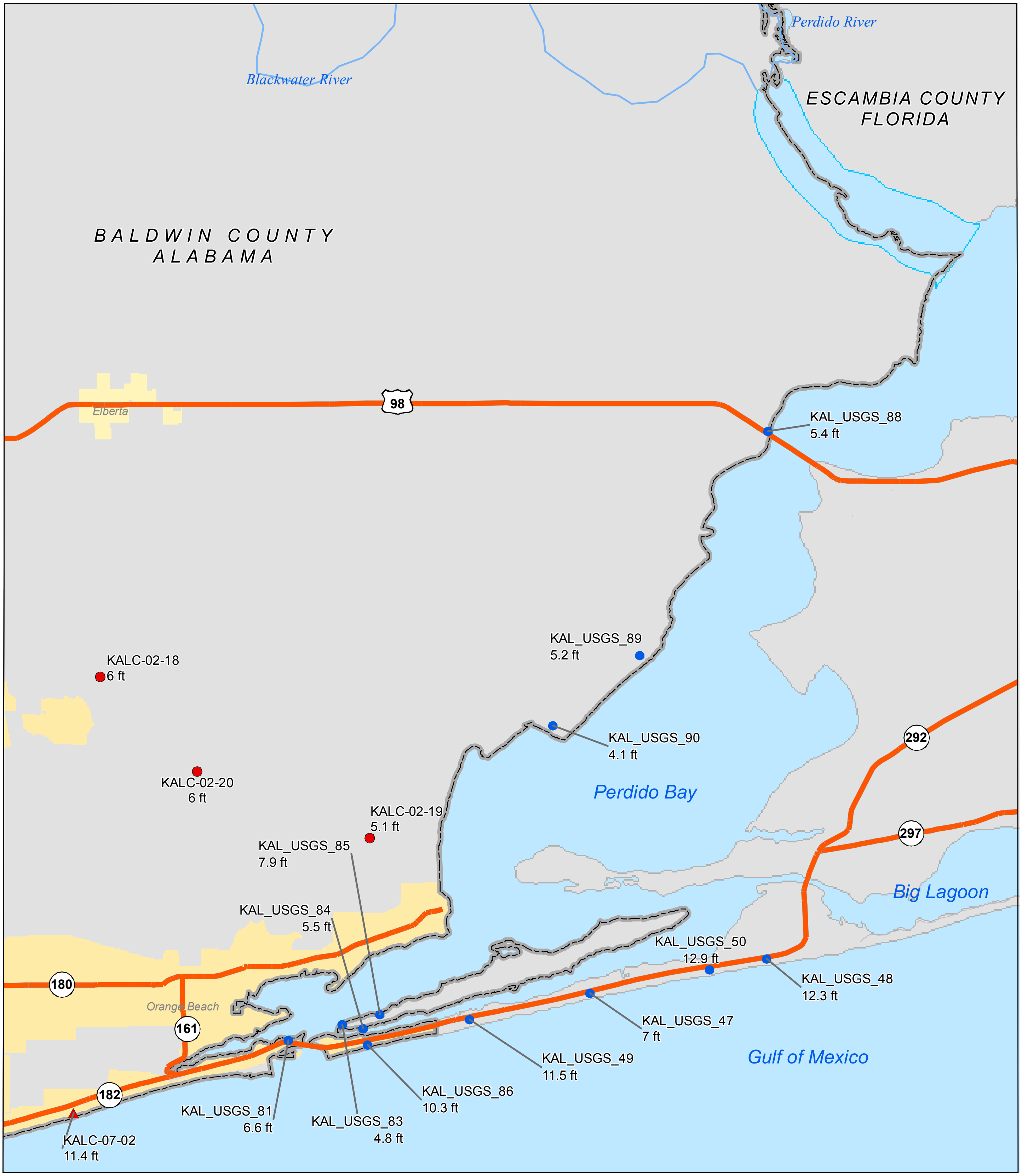


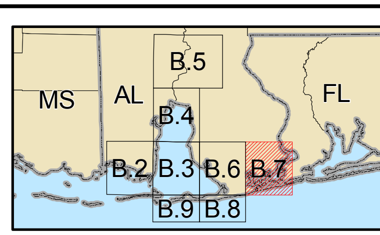
Figure B.7: Hurricane Katrina, Alabama Baldwin County, AL & Escambia County, FL Surveyed High Water Mark (HWM) Elevations

Flooding Type
- Coastal - Surge Only
- Coastal - Wave Height
- Coastal - Wave Runup
- USGS High Water Marks

County

CITY

Road Classification
- Limited Access Freeway
- Highway
- Secondary Roads



N

0 0.25 0.5 1 1.5 2
Miles

0 0.5 1 2 3 4
Kilometers

FEMA

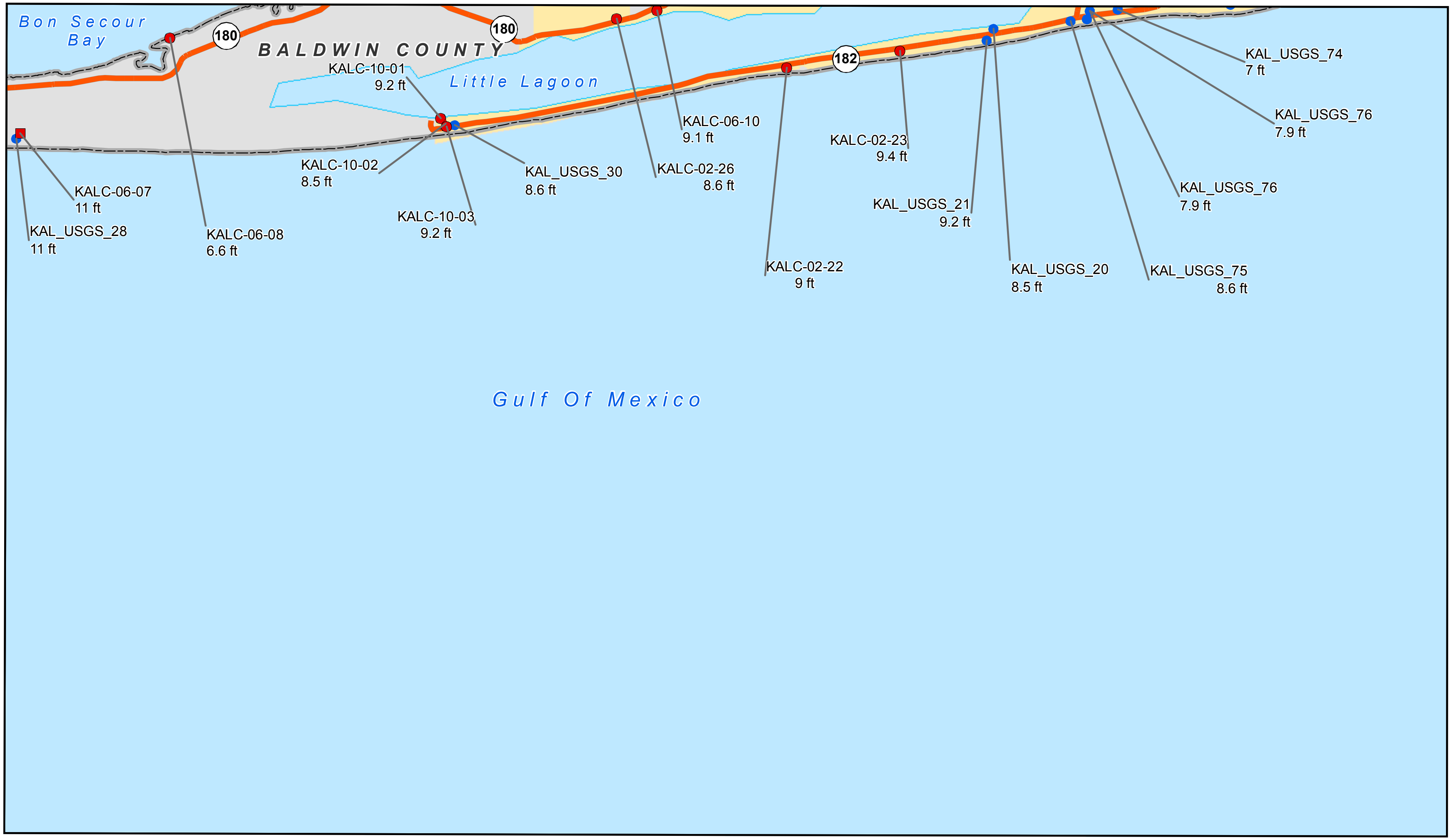


Figure B.8: Hurricane Katrina, Alabama
Baldwin County
Surveyed High Water Mark (HWM) Elevations

Flooding Type

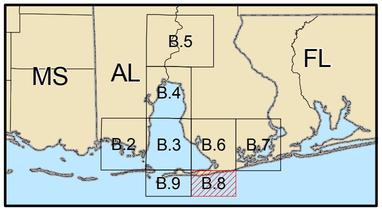
- Coastal - Surge Only
- Coastal - Wave Height
- Coastal - Wave Runup
- USGS High Water Marks

County

CITY

Road Classification

- Limited Access Freeway
- Highway
- Secondary Roads



0 0.75 1.5 3
Miles

0 0.75 1.5 3 4.5
Kilometers

N

FEMA

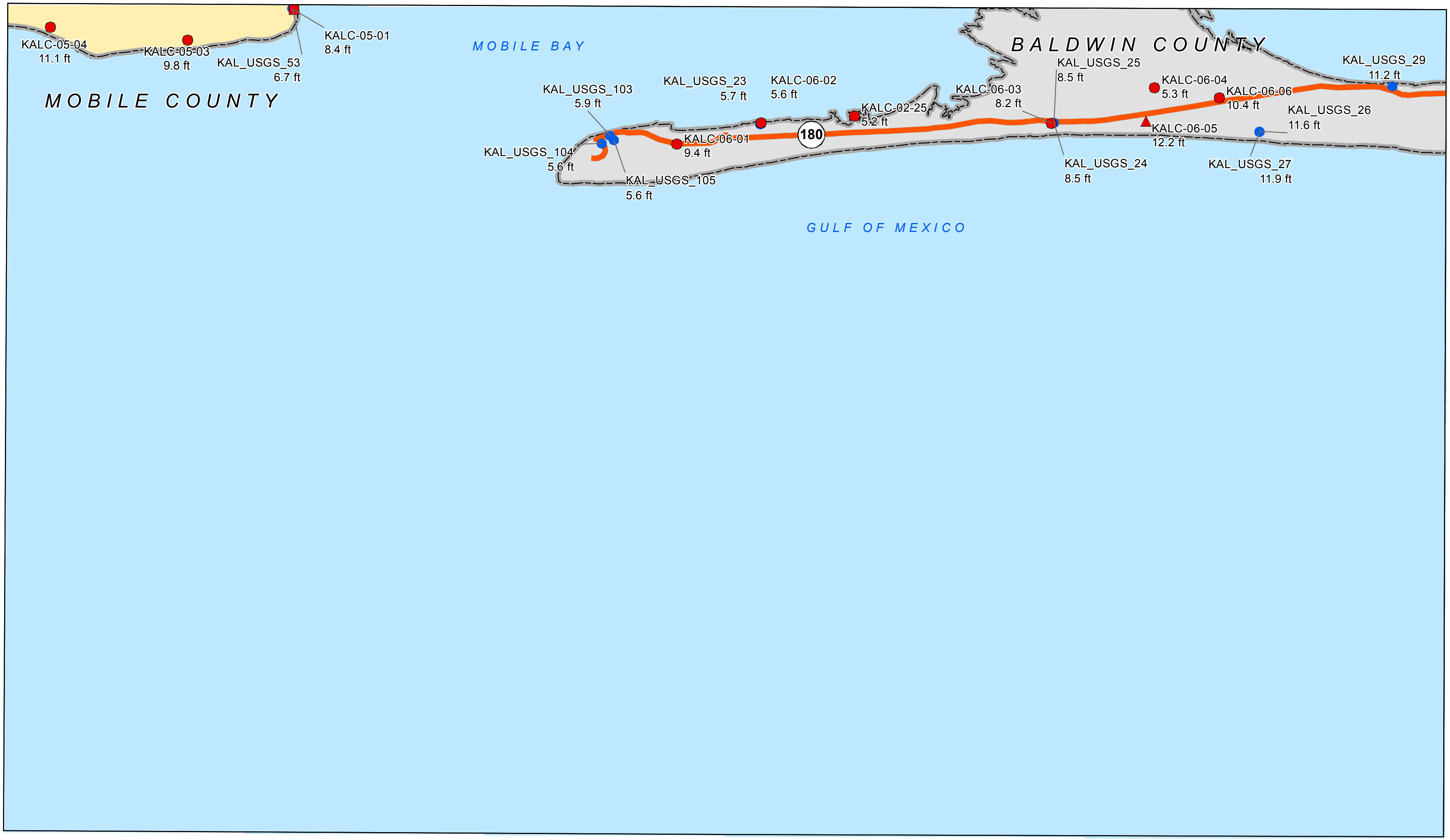


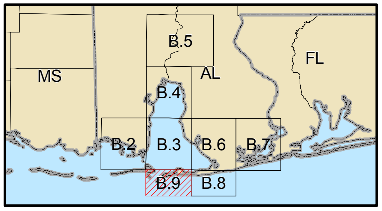
Figure B.9: Hurricane Katrina, Alabama Mobile & Baldwin Counties Surveyed High Water Mark (HWM) Elevations

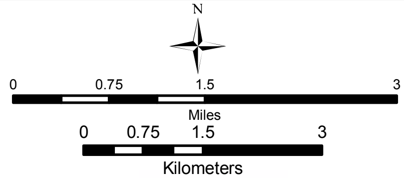
Flooding Type
- Coastal - Surge Only
- Coastal - Wave Height
- Coastal - Wave Runup
- USGS High Water Marks

County

CITY

Road Classification
- Limited Access Freeway
- Highway
- Secondary Roads





FEMA

Table B.2 Hurricane Katrina Alabama HWM Data Summary (same as Table 4, sorted by HWM-ID)[9]

HWM ID	County	Flooding Type	HWM Flood Elevation - Feet NAVD 88	Survey Latitude	Survey Longitude	HWM Report Sheet No.
URS Team Surveyed Points						
KALC-01-01	Mobile	Coastal - Surge Only	11.5	30.415636	-88.246662	Mobi-1
KALC-01-02	Mobile	Coastal - Surge Only	13.8	30.376339	-88.204941	Mobi-2
KALC-01-03	Mobile	Coastal - Surge Only	10.8	30.377094	-88.160194	Mobi-3
KALC-01-04	Mobile	Coastal - Surge Only	11.0	30.377056	-88.160604	Mobi-4
KALC-01-05	Mobile	Coastal - Surge Only	12.7	30.355212	-88.137934	Mobi-5
KALC-01-06	Mobile	Coastal - Wave Height	15.0	30.381055	-88.252562	Mobi-6
KALC-01-07	Mobile	Coastal - Wave Height	12.2	30.387486	-88.266179	Mobi-7
KALC-01-08	Mobile	Coastal - Surge Only	12.4	30.682765	-88.015711	Mobi-8
KALC-01-09	Mobile	Coastal - Surge Only	11.1	30.567405	-88.091335	Mobi-9
KALC-01-10	Mobile	Coastal - Wave Runup	11.3	30.527069	-88.088024	Mobi-10
KALC-01-11	Mobile	Coastal - Wave Runup	9.4	30.532156	-88.108309	Mobi-11
KALC-02-01	Mobile	Coastal - Surge Only	11.0	30.414319	-88.326508	Mobi-12
KALC-02-03	Mobile	Coastal - Surge Only	11.0	30.407259	-88.248347	Mobi-13
KALC-02-04	Mobile	Coastal - Surge Only	13.0	30.388546	-88.256883	Mobi-14
KALC-02-06	Mobile	Coastal - Surge Only	11.9	30.444559	-88.106675	Mobi-15
KALC-02-07	Mobile	Coastal - Surge Only	9.2	30.444931	-88.113647	Mobi-16
KALC-02-08	Mobile	Coastal - Surge Only	11.3	30.403672	-88.249339	Mobi-17
KALC-02-09	Mobile	Coastal - Surge Only	11.2	30.371828	-88.230447	Mobi-18
KALC-02-10	Mobile	Coastal - Surge Only	9.4	30.432537	-88.137748	Mobi-19
KALC-02-11	Mobile	Coastal - Surge Only	12.6	30.402962	-88.235230	Mobi-20
KALC-02-12	Mobile	Coastal - Wave Height	14.3	30.521355	-88.101540	Mobi-21
KALC-02-13	Mobile	Coastal - Surge Only	12.7	30.415749	-88.242463	Mobi-22
KALC-02-14	Mobile	Coastal - Surge Only	13.2	30.381664	-88.225424	Mobi-23
KALC-02-15	Mobile	Coastal - Surge Only	11.7	30.592093	-88.121901	Mobi-24
KALC-02-16	Mobile	Coastal - Surge Only	11.3	30.630111	-88.102496	Mobi-25
KALC-02-18	Baldwin	Coastal - Surge Only	6.0	30.356229	-87.601063	Bald-1
KALC-02-19	Baldwin	Coastal - Surge Only	5.1	30.321809	-87.534673	Bald-2
KALC-02-20	Baldwin	Coastal - Surge Only	6.0	30.336035	-87.577146	Bald-3
KALC-02-21	Baldwin	Coastal - Surge Only	8.6	30.386607	-87.845388	Bald-4
KALC-02-22	Baldwin	Coastal - Surge Only	9.0	30.240890	-87.739675	Bald-5
KALC-02-23	Baldwin	Coastal - Surge Only	9.4	30.243475	-87.720007	Bald-6
KALC-02-24	Baldwin	Coastal - Surge Only	8.8	30.251457	-87.694753	Bald-7
KALC-02-25	Baldwin	Coastal - Surge Only	5.2	30.233736	-87.977785	Bald-8
KALC-02-26	Baldwin	Coastal - Surge Only	8.6	30.248250	-87.769211	Bald-9
KALC-03-01	Mobile	Coastal - Surge Only	9.9	30.824292	-88.061436	Mobi-26
KALC-03-02	Mobile	Coastal - Surge Only	10.8	30.785112	-88.073196	Mobi-27
KALC-03-03	Mobile	Coastal - Surge Only	11.1	30.768333	-88.059505	Mobi-28
KALC-03-04	Mobile	Coastal - Surge Only	10.7	30.734343	-88.045763	Mobi-29
KALC-03-05	Mobile	Coastal - Surge Only	11.1	30.709701	-88.044482	Mobi-30
KALC-03-06	Mobile	Coastal - Wave Runup	10.9	30.685253	-88.040267	Mobi-31
KALC-03-07	Mobile	Coastal - Surge Only	10.4	30.739842	-88.038381	Mobi-32

[9] Note – For HWM data summary listing sorted by County and HWM sheet number, refer to Table 6

HWM ID	County	Flooding Type	HWM Flood Elevation - Feet NAVD 88	Survey Latitude	Survey Longitude	HWM Report Sheet No.
KALC-03-08	Mobile	Coastal - Surge Only	11.7	30.699870	-88.031509	Mobi-33
KALC-03-09	Mobile	Coastal - Surge Only	11.9	30.686813	-88.017473	Mobi-34
KALC-03-10	Mobile	Coastal - Surge Only	11.9	30.668907	-88.027868	Mobi-35
KALC-03-12	Mobile	Coastal - Surge Only	8.3	30.905147	-87.980126	Mobi-36
KALC-03-13	Mobile	Coastal - Surge Only	8.1	30.905831	-87.979489	Mobi-37
KALC-03-14	Mobile	Coastal - Surge Only	9.0	30.855205	-88.040197	Mobi-38
KALC-03-15	Mobile	Coastal - Surge Only	11.7	30.709865	-88.034325	Mobi-39
KALC-03-16	Baldwin	Coastal - Surge Only	8.6	30.387662	-87.826893	Bald-10
KALC-03-17	Baldwin	Coastal - Surge Only	7.2	30.331168	-87.708448	Bald-11
KALC-03-18	Baldwin	Coastal - Surge Only	7.4	30.304067	-87.730858	Bald-12
KALC-03-19	Baldwin	Coastal - Surge Only	9.0	30.409938	-87.823535	Bald-13
KALC-03-20	Mobile	Coastal - Surge Only	9.2	30.366495	-88.134455	Mobi-40
KALR-04-01	Baldwin	Coastal - Surge Only	9.0	30.841757	-87.902804	Bald-74
KALR-04-02	Baldwin	Coastal - Surge Only	10.6	30.836882	-87.910127	Bald-75
KALR-04-03	Baldwin	Coastal - Surge Only	8.5	30.956541	-87.873829	Bald-76
KALR-04-04	Baldwin	Coastal - Surge Only	8.8	30.863050	-87.894579	Bald-77
KALR-04-05	Baldwin	Coastal - Surge Only	7.6	30.819433	-87.914795	Bald-78
KALR-04-06	Baldwin	Coastal - Surge Only	7.9	30.754847	-87.916899	Bald-79
KALR-04-07	Baldwin	Coastal - Surge Only	7.1	30.679313	-87.919746	Bald-80
KALC-04-08	Baldwin	Coastal - Surge Only	11.4	30.652731	-87.913060	Bald-14
KALC-04-09	Baldwin	Coastal - Wave Runup	13.6	30.643702	-87.915591	Bald-15
KALC-04-10	Baldwin	Coastal - Surge Only	11.2	30.637664	-87.916574	Bald-16
KALC-04-11	Baldwin	Coastal - Wave Runup	11.0	30.630239	-87.916188	Bald-17
KALC-04-13	Baldwin	Coastal - Wave Runup	9.6	30.614936	-87.911995	Bald-18
KALC-04-14	Baldwin	Coastal - Wave Runup	13.2	30.603361	-87.912641	Bald-19
KALC-04-16	Baldwin	Coastal - Surge Only	10.8	30.586513	-87.913308	Bald-20
KALC-04-17	Baldwin	Coastal - Surge Only	11.8	30.578519	-87.910763	Bald-21
KALC-04-18	Baldwin	Coastal - Wave Runup	13.7	30.569867	-87.905101	Bald-22
KALC-04-19	Baldwin	Coastal - Wave Runup	5.2	30.300829	-87.761910	Bald-23
KALC-04-20	Baldwin	Coastal - Surge Only	9.2	30.361238	-87.833448	Bald-24
KALC-04-21	Baldwin	Coastal - Surge Only	9.5	30.484048	-87.931595	Bald-25
KALC-04-22	Baldwin	Coastal - Surge Only	10.3	30.481645	-87.929825	Bald-26
KALC-04-23	Baldwin	Coastal - Surge Only	9.8	30.457092	-87.916419	Bald-27
KALC-04-24	Baldwin	Coastal - Surge Only	10.2	30.473224	-87.920188	Bald-28
KALC-04-25	Baldwin	Coastal - Surge Only	9.4	30.432541	-87.911293	Bald-29
KALC-05-01	Mobile	Coastal - Wave Runup	8.4	30.249403	-88.075257	Mobi-41
KALC-05-02	Mobile	Coastal - Wave Runup	6.9	30.258657	-88.089674	Mobi-42
KALC-05-03	Mobile	Coastal - Surge Only	9.8	30.244703	-88.093654	Mobi-43
KALC-05-04	Mobile	Coastal - Surge Only	11.1	30.246608	-88.117518	Mobi-44
KALC-05-05	Mobile	Coastal - Surge Only	7.3	30.258859	-88.109650	Mobi-45
KALC-05-06	Mobile	Coastal - Surge Only	8.6	30.255389	-88.137606	Mobi-46
KALC-05-08	Mobile	Coastal - Surge Only	8.5	30.460511	-88.155163	Mobi-47
KALC-05-09	Mobile	Coastal - Surge Only	7.2	30.460378	-88.154324	Mobi-48
KALC-05-10	Baldwin	Coastal - Surge Only	5.9	30.311908	-87.727556	Bald-30
KALC-05-11	Baldwin	Coastal - Surge Only	5.6	30.300327	-87.745703	Bald-31
KALC-05-12	Baldwin	Coastal - Surge Only	6.9	30.282972	-87.735947	Bald-32
KALC-06-01	Baldwin	Coastal - Surge Only	9.4	30.229377	-88.008609	Bald-33

HWM ID	County	Flooding Type	HWM Flood Elevation - Feet NAVD 88	Survey Latitude	Survey Longitude	HWM Report Sheet No.
KALC-06-02	Baldwin	Coastal - Surge Only	5.6	30.232636	-87.993963	Bald-34
KALC-06-03	Baldwin	Coastal - Surge Only	8.2	30.232726	-87.943612	Bald-35
KALC-06-04	Baldwin	Coastal - Surge Only	5.3	30.238188	-87.925684	Bald-36
KALC-06-05	Baldwin	Coastal - Wave Height	12.2	30.233108	-87.927181	Bald-37
KALC-06-06	Baldwin	Coastal - Surge Only	10.4	30.236696	-87.914444	Bald-38
KALC-06-07	Baldwin	Coastal - Wave Runup	11.0	30.230697	-87.872584	Bald-39
KALC-06-08	Baldwin	Coastal - Surge Only	6.6	30.245169	-87.846709	Bald-40
KALC-06-09	Baldwin	Coastal - Surge Only	6.5	30.253069	-87.798418	Bald-41
KALC-06-10	Baldwin	Coastal - Surge Only	9.1	30.249512	-87.762118	Bald-42
KALC-06-11	Mobile	Coastal - Surge Only	11.6	30.563544	-88.087073	Mobi-49
KALC-06-12	Mobile	Coastal - Surge Only	12.5	30.584594	-88.069404	Mobi-50
KALC-06-13	Mobile	Coastal - Surge Only	11.5	30.587107	-88.106695	Mobi-51
KALC-06-14	Mobile	Coastal - Surge Only	11.6	30.606740	-88.108938	Mobi-52
KALC-06-16	Mobile	Coastal - Surge Only	8.8	30.363243	-88.114863	Mobi-53
KALC-06-17	Mobile	Coastal - Wave Height	8.1	30.341828	-88.126036	Mobi-54
KALC-06-18	Mobile	Coastal - Surge Only	10.1	30.393140	-88.157686	Mobi-55
KALC-06-19	Mobile	Coastal - Surge Only	9.9	30.367573	-88.137803	Mobi-56
KALC-06-21	Mobile	Coastal - Surge Only	12.7	30.404586	-88.247459	Mobi-57
KALC-07-01	Baldwin	Coastal - Surge Only	11.3	30.256873	-87.633672	Bald-43
KALC-07-02	Baldwin	Coastal - Wave Height	11.4	30.263113	-87.607466	Bald-44
KALC-07-03	Mobile	Coastal - Wave Height	11.6	30.671136	-88.039965	Mobi-58
KALC-07-04	Mobile	Coastal - Surge Only	9.8	30.680772	-88.039544	Mobi-59
KALC-07-05	Mobile	Coastal - Wave Height	12.5	30.657634	-88.041627	Mobi-60
KALC-07-06	Mobile	Coastal - Wave Height	12.3	30.656006	-88.042278	Mobi-61
KALC-07-07	Mobile	Coastal - Wave Height	12.4	30.655856	-88.042664	Mobi-62
KALC-07-08	Mobile	Coastal - Surge Only	10.2	30.695116	-88.041489	Mobi-63
KALC-07-09	Mobile	Coastal - Surge Only	11.1	30.698683	-88.042539	Mobi-64
KALC-07-10	Mobile	Coastal - Wave Runup	12.0	30.642543	-88.062563	Mobi-65
KALC-07-11	Mobile	Coastal - Wave Runup	12.0	30.634089	-88.055503	Mobi-66
KALC-07-12	Mobile	Coastal - Wave Runup	11.4	30.586939	-88.067673	Mobi-67
KALC-07-13	Mobile	Coastal - Surge Only	11.5	30.586561	-88.067362	Mobi-68
KALC-07-14	Mobile	Coastal - Wave Runup	11.2	30.599291	-88.061115	Mobi-69
KALC-07-15	Mobile	Coastal - Wave Runup	11.6	30.604260	-88.059762	Mobi-70
KALC-08-01	Baldwin	Coastal - Surge Only	9.5	30.425327	-87.909699	Bald-45
KALC-08-02	Baldwin	Coastal - Surge Only	9.6	30.419541	-87.909101	Bald-46
KALC-08-03	Baldwin	Coastal - Surge Only	9.5	30.415125	-87.908286	Bald-47
KALC-08-04	Baldwin	Coastal - Surge Only	9.4	30.415230	-87.907854	Bald-48
KALC-08-05	Baldwin	Coastal - Surge Only	9.2	30.415000	-87.907793	Bald-49
KALC-08-06	Baldwin	Coastal - Surge Only	7.2	30.379138	-87.852952	Bald-50
KALC-08-07	Baldwin	Coastal - Surge Only	6.3	30.379690	-87.852605	Bald-51
KALC-08-08	Baldwin	Coastal - Surge Only	9.0	30.378253	-87.840121	Bald-52
KALC-08-09	Mobile	Coastal - Surge Only	11.9	30.547221	-88.082740	Mobi-71
KALC-08-10	Mobile	Coastal - Surge Only	10.2	30.547146	-88.082941	Mobi-72
KALC-08-11	Mobile	Coastal - Surge Only	12.0	30.534639	-88.084202	Mobi-73
KALC-08-12	Mobile	Coastal - Wave Runup	9.3	30.527138	-88.086080	Mobi-74
KALC-08-14	Mobile	Coastal - Surge Only	12.0	30.498843	-88.104187	Mobi-75
KALC-09-01	Baldwin	Coastal - Surge Only	10.2	30.555943	-87.902009	Bald-53

HWM ID	County	Flooding Type	HWM Flood Elevation - Feet NAVD 88	Survey Latitude	Survey Longitude	HWM Report Sheet No.
KALC-09-02	Baldwin	Coastal - Surge Only	10.5	30.543086	-87.902038	Bald-54
KALC-09-03	Baldwin	Coastal - Surge Only	9.7	30.541570	-87.900657	Bald-55
KALC-09-04	Baldwin	Coastal - Surge Only	10.7	30.541551	-87.903199	Bald-56
KALC-09-06	Baldwin	Coastal - Wave Runup	12.4	30.512861	-87.920338	Bald-57
KALC-09-07	Baldwin	Coastal - Surge Only	10.0	30.512116	-87.919439	Bald-58
KALC-09-08	Baldwin	Coastal - Surge Only	9.6	30.489872	-87.930166	Bald-59
KALC-09-09	Baldwin	Coastal - Surge Only	9.6	30.482843	-87.935296	Bald-60
KALC-09-10	Baldwin	Coastal - Surge Only	9.6	30.483762	-87.933143	Bald-61
KALC-09-11	Baldwin	Coastal - Surge Only	9.0	30.434026	-87.819440	Bald-62
KALC-09-12	Baldwin	Coastal - Surge Only	9.9	30.422684	-87.822556	Bald-63
KALC-09-13	Baldwin	Coastal - Wave Height	11.0	30.396753	-87.884944	Bald-64
KALC-09-14	Baldwin	Coastal - Surge Only	11.0	30.407740	-87.902586	Bald-65
KALC-09-15	Baldwin	Coastal - Surge Only	6.6	30.379876	-87.846653	Bald-66
KALC-09-16	Mobile	Coastal - Surge Only	8.9	30.369778	-88.110617	Mobi-76
KALC-09-17	Mobile	Coastal - Surge Only	9.2	30.378212	-88.107983	Mobi-77
KALC-09-18	Mobile	Coastal - Surge Only	8.4	30.398486	-88.108368	Mobi-78
KALC-09-19	Mobile	Coastal - Surge Only	9.2	30.444931	-88.113647	Mobi-79
KALC-09-21	Baldwin	Coastal - Surge Only	9.0	30.466616	-87.801442	Bald-67
KALC-09-22	Baldwin	Coastal - Surge Only	9.1	30.465898	-87.801620	Bald-68
KALC-09-23	Baldwin	Coastal - Surge Only	11.2	30.411647	-87.906800	Bald-69
KALC-09-24	Baldwin	Coastal - Surge Only	9.0	30.428385	-87.826406	Bald-70
KALC-10-01	Baldwin	Coastal - Surge Only	9.2	30.233113	-87.799649	Bald-71
KALC-10-02	Baldwin	Coastal - Wave Height	8.5	30.232372	-87.798811	Bald-72
KALC-10-03	Baldwin	Coastal - Surge Only	9.2	30.231934	-87.798608	Bald-73
USGS Flagged Points						
KAL_USGS_02	Baldwin	N/A	12.1	30.575624	-87.909159	Bald-1
KAL_USGS_03	Baldwin	N/A	10.3	30.557654	-87.900046	Bald-2
KAL_USGS_04	Baldwin	N/A	9.7	30.486471	-87.932864	Bald-3
KAL_USGS_05	Baldwin	N/A	9.7	30.486458	-87.932922	Bald-4
KAL_USGS_06	Baldwin	N/A	10.0	30.416105	-87.907936	Bald-5
KAL_USGS_07	Baldwin	N/A	7.2	30.416105	-87.907936	Bald-6
KAL_USGS_08	Baldwin	N/A	8.8	30.416501	-87.825330	Bald-7
KAL_USGS_09	Baldwin	N/A	8.8	30.416501	-87.825330	Bald-8
KAL_USGS_10	Baldwin	N/A	9.2	30.378927	-87.852837	Bald-9
KAL_USGS_12	Baldwin	N/A	8.6	30.394625	-87.776232	Bald-10
KAL_USGS_16	Mobile	N/A	12.8	30.382890	-88.237984	Mobi-1
KAL_USGS_20	Baldwin	N/A	8.5	30.246850	-87.703794	Bald-11
KAL_USGS_21	Baldwin	N/A	9.2	30.245114	-87.704994	Bald-12
KAL_USGS_22	Baldwin	N/A	5.7	30.232539	-87.993966	Bald-13
KAL_USGS_23	Baldwin	N/A	5.7	30.232451	-87.994115	Bald-14
KAL_USGS_24	Baldwin	N/A	8.5	30.232860	-87.943154	Bald-15
KAL_USGS_25	Baldwin	N/A	8.5	30.232850	-87.943178	Bald-16
KAL_USGS_26	Baldwin	N/A	11.6	30.231620	-87.907422	Bald-17
KAL_USGS_27	Baldwin	N/A	11.9	30.231613	-87.907413	Bald-18
KAL_USGS_28	Baldwin	N/A	11.0	30.229892	-87.873245	Bald-19
KAL_USGS_29	Baldwin	N/A	11.2	30.238555	-87.884403	Bald-20
KAL_USGS_30	Baldwin	N/A	8.6	30.232101	-87.797253	Bald-21

HWM ID	County	Flooding Type	HWM Flood Elevation - Feet NAVD 88	Survey Latitude	Survey Longitude	HWM Report Sheet No.
KAL_USGS_33	Mobile	N/A	10.3	30.610018	-88.086693	Mobi-2
KAL_USGS_34	Mobile	N/A	10.8	30.598484	-88.061909	Mobi-3
KAL_USGS_36	Mobile	N/A	9.9	30.563287	-88.088848	Mobi-4
KAL_USGS_37	Mobile	N/A	9.8	30.557933	-88.108926	Mobi-5
KAL_USGS_39	Mobile	N/A	10.0	30.532578	-88.108094	Mobi-6
KAL_USGS_40	Mobile	N/A	10.2	30.517425	-88.107072	Mobi-7
KAL_USGS_41	Mobile	N/A	10.7	30.493242	-88.104488	Mobi-8
KAL_USGS_42	Mobile	N/A	11.0	30.487823	-88.102783	Mobi-9
KAL_USGS_51	Mobile	N/A	8.2	30.252760	-88.121735	Mobi-10
KAL_USGS_64	Mobile	N/A	11.4	30.699619	-88.040700	Mobi-11
KAL_USGS_65	Mobile	N/A	11.4	30.725192	-88.059273	Mobi-12
KAL_USGS_68	Baldwin	N/A	8.4	30.368732	-87.836576	Bald-22
KAL_USGS_69	Baldwin	N/A	7.9	30.301325	-87.737611	Bald-23
KAL_USGS_70	Baldwin	N/A	7.6	30.285006	-87.749857	Bald-24
KAL_USGS_71	Baldwin	N/A	6.9	30.284928	-87.748950	Bald-25
KAL_USGS_72	Baldwin	N/A	7.1	30.284897	-87.749164	Bald-26
KAL_USGS_73	Baldwin	N/A	10.2	30.250536	-87.662649	Bald-27
KAL_USGS_74	Baldwin	N/A	7.0	30.249729	-87.682237	Bald-28
KAL_USGS_75	Baldwin	N/A	8.6	30.248005	-87.690407	Bald-29
KAL_USGS_76	Baldwin	N/A	7.9	30.249573	-87.687102	Bald-30
KAL_USGS_78	Baldwin	N/A	8.2	30.254745	-87.689327	Bald-31
KAL_USGS_79	Baldwin	N/A	8.2	30.254745	-87.689327	Bald-32
KAL_USGS_80	Baldwin	N/A	8.2	30.254745	-87.689327	Bald-33
KAL_USGS_81	Baldwin	N/A	6.6	30.278586	-87.554729	Bald-34
KAL_USGS_83	Baldwin	N/A	4.8	30.281940	-87.541473	Bald-35
KAL_USGS_84	Baldwin	N/A	5.5	30.281147	-87.536269	Bald-36
KAL_USGS_85	Baldwin	N/A	7.9	30.284080	-87.532170	Bald-37
KAL_USGS_86	Baldwin	N/A	10.3	30.277592	-87.535139	Bald-38
KAL_USGS_87	Baldwin	N/A	10.3	30.277592	-87.535139	Bald-39
KAL_USGS_88	Baldwin	N/A	5.4	30.408743	-87.436536	Bald-40
KAL_USGS_89	Baldwin	N/A	5.2	30.360855	-87.468139	Bald-41
KAL_USGS_90	Baldwin	N/A	4.1	30.345840	-87.489601	Bald-42
KAL_USGS_91	Baldwin	N/A	16.6	30.674402	-87.965202	Bald-43
KAL_USGS_92	Baldwin	N/A	16.0	30.674402	-87.965202	Bald-44
KAL_USGS_93	Baldwin	N/A	16.0	30.674402	-87.965202	Bald-45
KAL_USGS_94	Baldwin	N/A	13.0	30.673077	-87.955025	Bald-46
KAL_USGS_95	Baldwin	N/A	10.6	30.672215	-87.949782	Bald-47
KAL_USGS_99	Mobile	N/A	8.4	30.419584	-88.106537	Mobi-13
KAL_USGS_100	Mobile	N/A	8.3	30.399023	-88.108640	Mobi-14
KAL_USGS_103	Baldwin	N/A	5.9	30.230618	-88.020226	Bald-48
KAL_USGS_104	Baldwin	N/A	5.6	30.229404	-88.021645	Bald-49
KAL_USGS_105	Baldwin	N/A	5.6	30.229952	-88.019602	Bald-50

Appendices

Appendices C through E are not included due to privacy issues.