Hazard Mitigation Technical Assistance Program
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Task Order 338
Hurricane Ivan Rapid Response
Alabama and Mississippi Coastal High Water Mark (CHWM) Collection
FEMA-1549-DR-AL & 1550-DR-MS

Final Report

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Introduction

Hurricane Ivan was rated as the most powerful hurricane to hit the Caribbean in 10 years. On September 7 and 8, 2004, it damaged 90 percent of the homes in Grenada and caused catastrophic damage as it swept over Grenada, Barbados, and the other islands in the area. By Thursday morning on September 9, Ivan's sustained winds reached 160 mph making it a rare Category 5 hurricane on the Saffir-Simpson scale. By Monday September 13, it had skirted western Cuba with winds clocked at 156 mph.

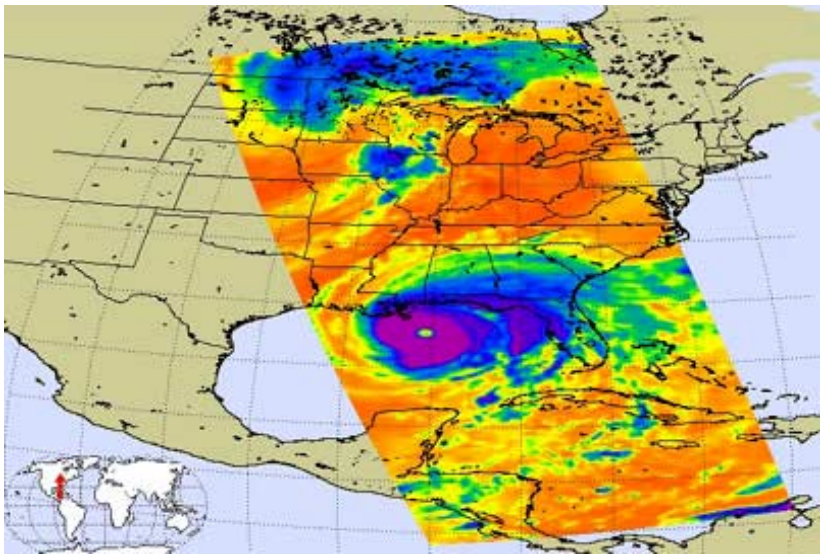


Figure 1: Hurricane Ivan Approaches

Hurricane Ivan was one of the strongest and most destructive hurricanes to hit Florida's Panhandle coast in recorded history and the most severe since Hurricane Opal in 1995. The image of Hurricane Ivan (Figure 1), was acquired by the Atmospheric Infrared Sounder (AIRS) infrared, microwave, and visible sensors on September 15 at 1:30 pm local time as the storm moved into Alabama (http://www-airs.jpl.nasa.gov/multimedia/image_releases/2004/hurricane_ivan.html). Ivan approached the Florida and Alabama area at Category 4 strength, moving north at 14 mph. Maximum sustained winds were reported to be 135 mph and extended 105 miles from the center, while tropical storm-force winds extended 290 miles from the center. Figure 1 shows how the storm looked through an AIRS Infrared window channel. It reveals a very large eye about 75 km (50 miles) across.

The storm path as it made landfall is shown in Figure 2. The hurricane began affecting Alabama and Mississippi on September 13, 2004 and made landfall on the east side of Mobile Bay, Alabama at 1:50 a.m. (2:50 a.m. ET) Thursday September 16, 2004 as a slightly weakened Category 3 hurricane with winds of 130 mph (208 kph) and storm surges over 8 feet. Storm surge with associated wave action was reported at +15 to +20 feet above mean sea level. The hurricane's strongest winds were located east-northeast of the storm center. This aspect coupled with the higher, on-shore directed winds and associated storm surge and accompanying breaking

waves resulted in much of Ivan's destructive impacts on Gulf Shores, Alabama. As the hurricane moved through Alabama and Mississippi, wind and wave action disrupted utilities, caused damage, and created localized flooding. The barrier islands exposed to Ivan's strongest winds, for example, the communities of Gulf Shores and Orange Beach, Alabama, are, in places, low lying, their dunes rising only several meters, which is insufficient to have contained Ivan's storm surge. The Gulf spilled across the islands in a strong current capable of transporting massive amounts of sand landward, undermining buildings and roads, and opening new island breaches. On top of the surge, breaking waves nearly as tall as the water was deep eroded dunes and battered structures.

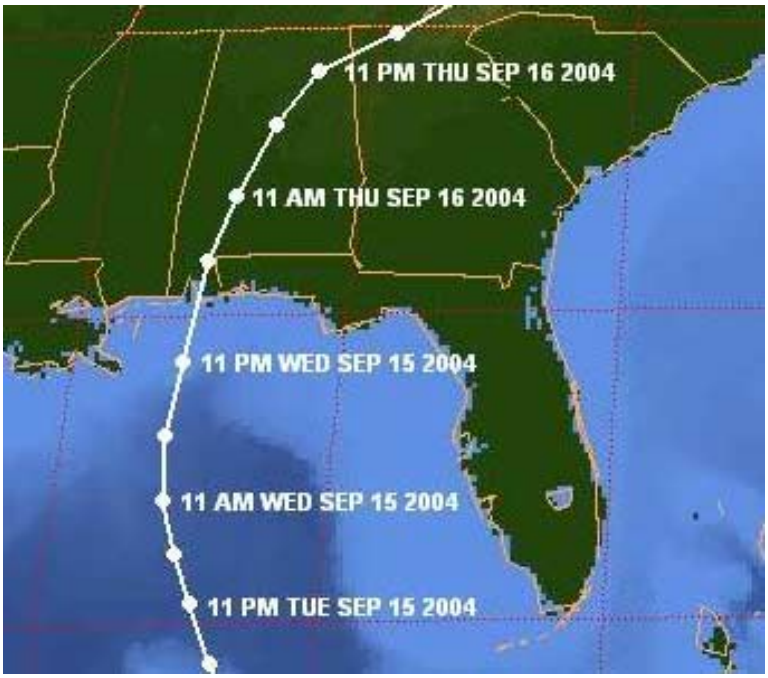


Figure 2: Hurricane Ivan Storm Path

Ivan continued inland, maintaining hurricane strength until it was over central Alabama. Late on the 16th, Ivan weakened to a tropical depression over northeastern Alabama. The hurricane continued to move toward the north-northeast and brought devastating flooding to the Appalachians and southern New England. On September 18, the remnants of Ivan drifted off the mid-Atlantic coast of the United States into the Atlantic Ocean, and the low-pressure disturbance continued to pour rain on the east coast of the United States.

Ivan reformed into a tropical depression on September 22, 2004 in the Gulf of Mexico after having traveled in a circular motion through the southeastern United States causing tremendous flooding (See Figure 3). An interesting development occurred on September 20 as a small surface low, caused by the southern remnants of Ivan, moved across the Florida peninsula. As it continued west across the northern Gulf of Mexico, the system organized and took on tropical characteristics. On September 22 the National Weather Service, determined that the low was in fact a result of the remnants of Ivan and named it accordingly.

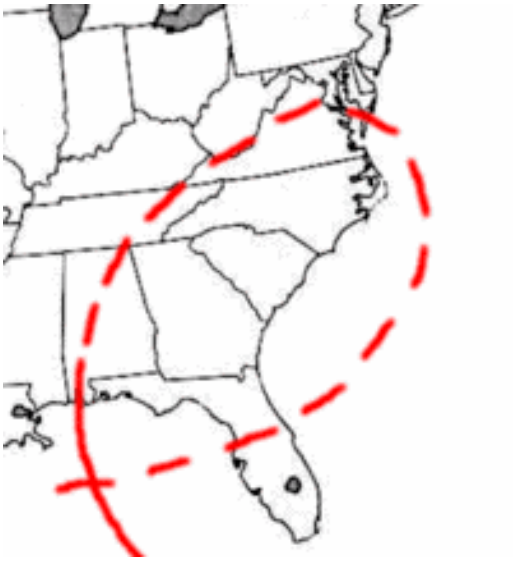


Figure 3: Hurricane Ivan Reforms and Returns

Notice was given in the Federal Register, in letters for Alabama and Mississippi, dated September 15, 2004, that the President declared a major disaster under the authority of the Robert T. Stafford Disaster Relief and Emergency Assistance Act for damage in certain areas in Alabama and Mississippi resulting from Hurricane Ivan (FEMA-1549-DR, Alabama and FEMA-1550-DR-Mississippi; http://www.fema.gov/news/dfrn.fema?id=2984, http://www.fema.gov/news/dfrn.fema?id=2983). The declaration provides the necessary Federal assistance to meet immediate needs and to help recover as quickly as possible.

State of Alabama

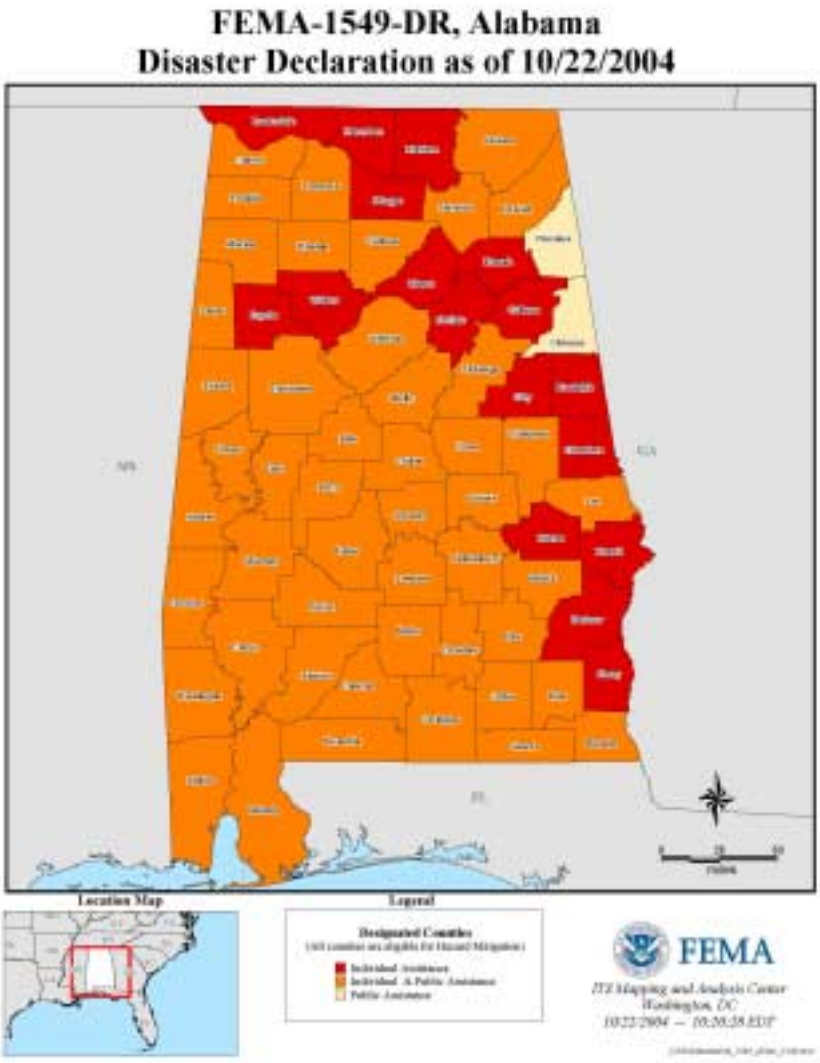
The following Alabama counties were designated for disaster declaration FEMA-1549-DR-AL. Declared Alabama counties are shown on Figure 4.

Individual Assistance was provided to: Baldwin, Butler, Clarke, Coffee, Conecuh, Covington, Crenshaw, Escambia, Geneva, Mobile, Monroe, and Washington Counties.

Amendment No. 1 to a Notice of a Major Disaster Declaration included Barbour, Blount, Bullock, Calhoun, Clay, Cullman, Dale, Etowah, Fayette, Franklin, Lamar, Lawrence, Lee, Macon, Marshall, Marion, Pike, St. Clair, Tallapoosa, Walker, and Winston Counties for Individual Assistance. Autauga, Bibb, Chilton, Choctaw, Coosa, Dallas, Elmore, Greene, Hale, Jefferson, Lowndes, Marengo, Montgomery, Perry, Pickens, Shelby, Sumter, Talladega, Tuscaloosa, and Wilcox Counties were included for Individual Assistance. These counties were already designated for debris removal and emergency protective measures (Categories A & B) under the Public Assistance Program including direct Federal assistance, at 100 percent Federal funding of the total eligible costs for a period of up to 72 hours.

Amendment No. 4 included Chambers, DeKalb, Henry, Houston, Jackson, Lauderdale, Limestone, Morgan, and Russell Counties for Individual Assistance.

Amendment No. 5 included Colbert, Madison, and Randolph Counties for Individual Assistance.



Source: http://www.gismaps.fema.gov/2004graphics/dr1549/dec_1549.pdf

Figure 4: Disaster Declaration Map - Alabama

Public Assistance was provided to: Autauga, Baldwin, Bibb, Butler, Chilton, Choctaw, Clarke, Coffee, Conecuh, Coosa, Covington, Crenshaw, Dallas, Elmore, Escambia, Geneva, Greene, Hale, Jefferson, Lowndes, Marengo, Mobile, Monroe, Montgomery, Perry, Pickens, Shelby, Sumter, Talladega, Tuscaloosa, Washington, and Wilcox Counties for Public Assistance Categories A and B, including direct Federal assistance, at 100 percent of the total eligible costs for a period of up to 72 hours.

Amendment No. 2 included Autauga, Baldwin, Bibb, Butler, Chilton, Choctaw, Clarke, Coffee, Conecuh, Coosa, Covington, Crenshaw, Dallas, Elmore, Escambia, Geneva, Greene, Hale, Jefferson, Lowndes, Marengo, Mobile, Monroe, Montgomery, Perry, Pickens, Shelby, Sumter, Talladega, Tuscaloosa, Washington, and Wilcox Counties for Public Assistance (Categories C through G) which were already designated for Public Assistance (Categories A and B), including direct Federal assistance, at 100 percent Federal funding of the total eligible costs for a period of up to 72 hours, and Individual Assistance.

Amendment No. 6 included Cleburne, Colbert, Cullman, Dale, DeKalb, Franklin, Lamar, Lawrence, Lee, Marion, Marshall, Pike, Tallapoosa, and Winston Counties for Public Assistance.

Amendment No. 7 included Cherokee, Bullock, Houston, and Jackson Counties for Public Assistance.

Hazard Mitigation Grant Program (HMGP). All counties in the State of Alabama are eligible to apply for assistance under the HMGP.

State of Mississippi

The following Mississippi counties were designated for disaster declaration FEMA-1550-DR-MS. Declared Mississippi counties are shown on Figure 5.

Individual Assistance was provided to: George, Hancock, Harrison, Jackson, Perry, Stone, and Wayne Counties. Amendment No. 1 included Greene County. Amendment No. 2 included Clarke and Lauderdale Counties.

Public Assistance was provided to*:* Clarke, Covington, Forrest, George, Greene, Hancock, Harrison, Jackson, Jefferson Davis, Jones, Kemper, Lamar, Lauderdale, Lowndes, Marion, Neshoba, Newton, Noxubee, Pearl River, Perry, Smith, Stone, and Walthall Counties for Public Assistance Categories A and B, including direct Federal assistance, at 100 percent of the total eligible costs for a period of up to 72 hours.

Amendment No. 1 to a Notice of a Major Disaster Declaration included Jasper County for Public Assistance Categories A and B, including direct Federal assistance, at 100 percent of the total eligible costs for a period of up to 72 hours, and Wayne County for Public Assistance Categories A and B, including direct Federal assistance, at 100 percent of the total eligible costs for a period of up to 72 hours (already designated for Individual Assistance).

Amendment No. 4 included Clay, Monroe, Oktibbeha, and Winston Counties for Public Assistance and Clarke, Forrest, George, Greene, Hancock, Harrison, Jackson, Jasper, Jones, Kemper, Lamar, Lauderdale, Lowndes, Neshoba, Newton, Noxubee, Perry, Stone, and Wayne Counties for Public Assistance Categories C through G.

Amendment No. 5 included Adams, Amite, Claiborne, Copiah, Franklin, Hinds, Jefferson, Lawrence, Lincoln, Pike, Rankin, Scott, Simpson, Warren, and Wilkinson Counties for emergency protective measures (Category B) under the Public Assistance Program, including

direct Federal assistance, at 100 percent Federal funding of the total eligible costs for a period of up to 72 hours.

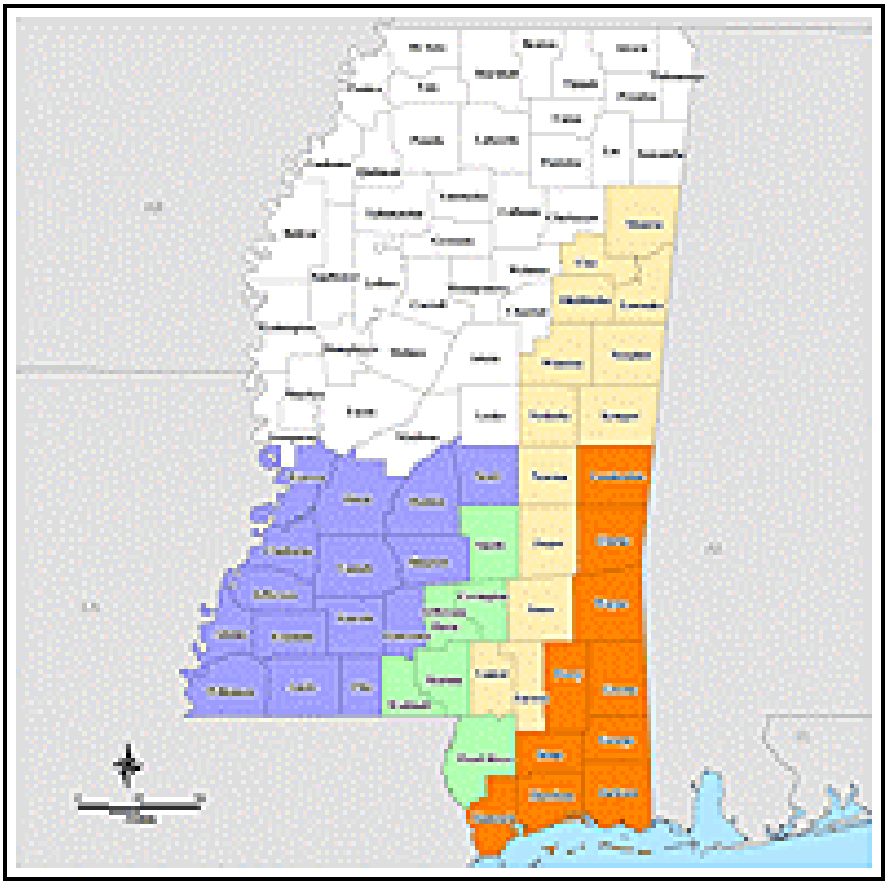


Figure 5: Disaster Declaration Map - Mississippi

HMGP. All counties in the State of Mississippi are eligible to apply for assistance under the HMGP.

URS Group, Inc. was contracted by the Federal Emergency Management Agency (FEMA) under the Hazard Mitigation Technical Assistance Program (HMTAP) to assist in the Hurricane Ivan disaster recovery. Assistance provided by this Task Order includes flagging, surveying, and reporting of Coastal High Water Marks (CHWMs). This report summarizes the methodologies used to flag the CHWM locations and survey the locations and elevations of the marks. This is an important step in assisting communities in establishing high water marks, which will be used in flood hazard mitigation.

Hurricane Ivan caused both coastal and riverine flooding. The resulting high water marks were flagged and surveyed along coastal locations. The purpose of this report is to document the flagging and surveying of the CHWMs, estimate the storm surge at each location, and discriminate between storm surge and wave action.

The data collected is invaluable to Federal, state, and local recovery efforts. The data assists in identifying areas of significant damage in order to target resources needed for disaster recovery.

It also helps to establish the magnitude and recurrence interval of the flood and erosion events caused by hurricanes along various areas of the coast. This data collection is also beneficial for future use in (a) accurately assessing the benefits to be expected from flood mitigation efforts, (b) prioritizing the flood mitigation efforts pursued following the hurricane, and (c) making HMGP decisions.

Area of Study

The area FEMA identified to be covered by the Coastal High Water Study Team extended west from the Alabama-Florida state line. At the time of the study's mobilization, it was known that the Gulf Shore to Perdido Key section of the coast was most impacted by the surge. The western extent of surge impact was not known, but the broad and shallow region off the Mississippi coast suggested that effects could be noted that far west. Therefore, URS was directed to cover the area from the Alabama-Florida state line to Bay St. Louis, Mississippi. The distribution of effort was concentrated in the higher impacted eastern areas and progressively sparser to the west. Two counties were covered in Alabama and two in Mississippi as listed in the following tables:

Table 1: Number of Alabama CHWMs Surveyed by County

County	Number of CHWMs Surveyed
Baldwin	38
Mobile	13
TOTAL	51

Table 2: Number of Mississippi CHWMs Surveyed by County

County	Number of CHWMs Surveyed
Harrison	6
Jackson	3
TOTAL	9

The National Oceanic and Atmospheric Administration (NOAA), U.S. Army Corps of Engineers (USACE), U.S. Geological Survey (USGS) and U.S. Coast Guard (USCG) tide and river gages that were operating in the area during the time of the hurricane and their peak elevations during the Hurricane are shown in Table 3.

Table 3: Peak Water Elevations during Hurricane Ivan Reported in USACE-Mobile, September 2004 Report

Name	Longitude (West)	Latitude (North)	Hurricane Ivan Peak Elevation (Ft) NGVD 29
Mississippi Sound at Waveland, MS (USGS)	89.364722	30.280556	4.56
Gulfport Harbor at Gulfport, MS (540)	89.090833	30.360278	4.63
Mississippi Sound at Ship Island	88.971944	30.211944	5.15
Biloxi Bay at Point Cadet	88.857222	30.389722	4.23
West Pascagoula River at Hwy 90 at Gautier, MS	88.608889	30.382778	4.10
Pascagoula River (NOAA) at Pascagoula, MS	88.563333	30.366944	6.72
Mississippi Sound at Pascagoula PI-Rear Range	88.514444	30.298889	5.83
Mississippi Sound at Petit Bois Island	88.505556	30.214444	4.83
Escatawpa River at I-10 near Orange Grove, MS	88.451389	30.458611	3.93
Middle Gage at Bayou LaBatre	88.256944	30.398611	4.66
Mobile Bay at Cedar Point, AL	88.138333	30.310556	6.90
Dauphin Island Bay at Dauphin Island	88.107778	30.258333	7.80
Mobile Bay at Dauphin Island (USCG)	88.079444	30.251111	8.0
Mobile River at Mobile, AL	88.039444	30.704444	4.87
Mobile River at Bucks, AL (Barry Steam Plant)	88.011111	30.004444	6.82
Mobile Bay at Ft. Morgan Front Range	88.033333	30.233333	7.85
Perdido Pass Orange Beach, AL	87.555000	30.278611	8.81

NGVD = National Geodetic Vertical Datum

Marking and Survey Methodology

Field and survey crews from URS and their subconsultants, Dewberry and PBS&J, were deployed to interview residents, find evidence of coastal high water levels, take digital photographs, and survey CHWMs from Hurricane Ivan. Figures 6 and 7 show an example of both the flaggers' form and the surveyors' form used to record field information. During the flagging, field crews entered estimates of surge heights in the comments field on the flagger forms. These were visual estimates and were referenced to the normal range of the tides as best estimated by the observers. The purpose of these observations was to initially estimate water levels well before the surveyors' work was completed. The CHWM flagging crews were deployed on Tuesday, September 28, 2004, shortly followed by the survey crews.

The survey crews followed the field crews and used static global positioning system (GPS) methods to determine an accurate elevation for each CHWM. Since static GPS requires an area with no tree cover to return an accurate result, in some cases it was necessary to perform a short level loop survey from the GPS point to the CHWM. Wherever possible, finished floor elevations of structures adjacent to the CHWM were collected. This information may be used at a later date for possible damage assessments or HMGP applications. CHWM locations were surveyed horizontally in North American Datum of 1983 (NAD 83), State Plane feet, and vertically in North American Vertical Datum of 1988 (NAVD 88), US survey feet. CHWM locations have been surveyed to within accuracies of 0.25 foot vertically and 10 feet horizontally with a 95% confidence level.

Figure 6: Sample CHWM Flagger Form

HIGH WATER MARK (HWM) REPORT – FLAGGERS

HWM ID	
HWM Address	
Date of Flagging/ Interview	
Date of Flood Event	
Name of Storm Event	
Stream Name/Flood Source	
Closest Municipality	
County	
State	

HWM Type	
HWM Object	
Location of HWM Object	
HWM Quality	
Type of Mark	
Directions to Flagger's Mark	
Vertical Dist from set point & description of set point	
Survey Needed	
Flagger HWM Latitude	
Flagger HWM Longitude	
Flooding Type	
Photo ID	
Photo Location/ Orientation	
Photo Description/Subject	
Comments	
Name of Flagger/Interviewer	
Unit Number	
Flagger Company	
Resident/Eyewitness Information	
Name	
Address	
Phone	
How Long Lived There	
Obtained Permission to Survey	

Figure 7: Sample CHWM Surveyor Form

HWM ID	
HWM Address	
HWM/Flood Elevation (1)	
Survey Crew	
Survey Company	
Survey Date	
Survey Latitude	
Survey Longitude	
Northing	
Easting	
Vertical Datum	NAVD 88
Horizontal Datum	NAD 83
Survey Project	
Approx. First Floor Elevation	
Survey Comments	

Field crews flagged CHWMs with characteristics such as surge, wave runup, and wave height. These designations on the survey sheets in the appendices represent the flaggers' estimates of this characteristic based on a combination of physical flood evidence and interviews with witnesses at the time of collection. Surge represents the rise in the normal water level, wave runup indicates the height of water rise above the stillwater level due to water runup from a breaking wave, and wave height indicates CHWM elevation due to more direct wave action. Typically, surge CHWMs are associated with a slow rising flood that causes more water damage than structural damage. Wave height usually results in a higher elevation. All attempts were

made to flag storm surge elevations, but in areas where surge characteristics were not obvious, wave runup or wave height was flagged.

Elevation Conversion from NAVD 88 to NGVD 29 Using VERTCON

The elevations shown in the 1929 NGVD were derived from the VERTCON program and the existing 1988 NAVD elevation. The VERTCON software was developed by the National Geodetic Survey (NGS) Office to allow the conversion of 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: http://www.ngs.noaa.gov/TOOLS/Vertcon/vertcon.html.

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

For example, a NAVD 88 elevation is 5.33 feet. Using the latitude and longitude, VERTCON computes a datum shift of (-)1.171 feet; to convert to the NGVD 29 elevation, SUBTRACT the datum shift from the NAVD 88 height. NAVD EL=5.33’ minus (-)1.171 feet equals NGVD 29 elevation of 6.50 feet.

Findings and Observations

The results of this survey are presented as a series of six maps that are shown on Figures 8-13 (Appendix A). The individual points are coded to differentiate between surge data (taken in places protected from the effects of waves), wave runup data (where the water line resulted from waves rushing up a slope) and wave height data (where wave crests caused the water mark). The relative quality of each data point is also represented. Further information about each point is given on CHWM forms in Appendices B through E.

Results from the NOAA National Hurricane Center Sea, Lake and Overland Surges from Hurricanes (SLOSH) computer model were used to plan the locations of the collected CHWMs. Damage was so extensive over the eastern portion of the area that it was possible to designate general locations where data points would be most useful. Almost without exception, places with distinct water marks could be found within these general locations. One result is that the great majority of the data points represent water marks from protected locations such as interior walls. On the other hand, the storm damage was so extensive that coastal roads were washed out or entirely buried with sand. These areas are shown as being inaccessible on the figures. Some of the Gulf beaches in this area are within parks or National Seashores. These natural areas contained scant record of the coastal storm surge compared to the built-up areas.

The NOAA SLOSH model prediction run output shows that the maximum surge conditions moved across the area as the storm tracked across the coast. Hurricane Ivan crossed the coast in the general area of Gulf Shores and Orange Beach. Because it tracked north-northeast from there, Mobile Bay and most of the Alabama coast was exposed to the weaker “left-front” storm quadrant. The major storm surge struck Orange Beach, Gulf Shores, and the peninsula between Bon Secour Bay (the southeastern corner of Mobile Bay) and the open Gulf. Figures 8 and 9 show the CHWM elevations in these areas. The surge height, determined from water marks in sheltered locations such as interior rooms, ranged between 12 and 14½ feet along this portion of the open Alabama shore. Much of the beach system was overtopped or overwashed. Little Lagoon filled with water but the effects of wave set-up may have been smaller than on the open coast, accounting for slightly lower CHWM elevations along its north shore.

The open Gulf coastal CHWM elevations decrease slightly near Perdido Pass, possibly because of the flow into Perdido Bay. Figure 8 shows that CHWM elevations in the lower Perdido Bay were on the order of 6 to 7 feet. Data from the Florida side of upper Perdido Bay (not shown) indicated that the water level increased towards the head of the bay with values in the range of 8½ to 9 feet at its northern end. The surge was then amplified as it propagated up the lower Perdido River such that the USGS gage at Barrineau Park indicated a level of 14 feet above the preceding river level. A similar effect appears to have affected the head of Wolf Bay as shown on Figure 8.

Figure 9 shows that the CHWM elevations were much lower along the eastern shore of Mobile Bay compared to the open coast. Data on Figures 9 and 10 show that elevations on the order of 6½ feet were characteristic of this eastern shore.

Figure 11 shows the effect of the storm on Dauphin Island and the lower western part of Mobile County. Along the open coast, CHWM elevations reached 12 feet and ranged between 3 and 6.8 feet on the landward side of the island and the more protected coastline of lower Mobile County.

Figures 12 and 13 show the CHWM locations and elevations along the Mississippi coast from Pascagoula west to Bay St. Louis. CHWMs recorded at these points show a general decrease in elevation from east to west along this coast with a height range between 6½ and 4 feet.

Recommendations

The following recommendations discuss how FEMA can use the CHWM information to assist in the recovery effort from Hurricane Ivan:

- Compare the Hurricane Ivan CHWMs to the flood elevation data on the effective or preliminary Flood Insurance Rate Maps. These comparisons can help FEMA determine where the updated flood hazard data was supported by the flooding that occurred or where new detailed studies should be performed to update the maps, and can help illustrate deficiencies on the existing maps.

- An evaluation is needed of the recurrence intervals of the surge conditions across the area. This will vary from place to place owing to distance from the storm track and local geographic effects. Preliminary evidence suggests that much of the area that experienced the most severe surge conditions was exposed to more than 100-year conditions.

- Compare the Ivan CHWMs to CHWMs from other significant flood events. This will identify areas of repetitive flooding that can assist FEMA in determining locations that would make good flood mitigation projects.

- Complete detail-engineering analyses to determine flood elevations in the areas where deficiencies have been identified on the existing FEMA maps, or on areas where property loss occurred where no previous studies have been prepared.

- The locations and severity of the Ivan CHWMs can help FEMA identify areas of concern for future mitigation projects when funding for such projects becomes available.

- Use these CHWMs to evaluate the success of completed mitigation projects. The flood depths that occurred during Ivan can be used to estimate potential damage that could have occurred to structures that have been bought out and removed as part of mitigation projects already completed. Documentation of the “damages avoided” can be used as success stories to further support the mitigation efforts.

- The CHWMs can be used to create inundation mapping for Hurricane Ivan. The inundation maps would provide a plan-view of the extent of flooding from Hurricane Ivan and can assist in determining the accuracy of existing FEMA flood maps. The inundation mapping would be a spatially correct Geographic Information System (GIS) coverage that can be provided to community officials to assist in disaster recovery. Note that under HMTAP Task Order 352, the CHWMs for Baldwin County are being used for flood inundation maps.

- Provide this report on the Internet to aid public officials and the community in the recovery effort.