Chapter 2
Hazards/Vulnerability

In FEMA/USACE comprehensive hurricane evacuation studies, the primary objective of the hazards analysis is to determine the probable worst-case effects for the various intensities of hurricanes that could strike an area. Recent studies completed include the following:

- Southeast Louisiana HES
- Southwest Louisiana HES
- Texas HES (Sabine and Valley Study Areas)
- Mississippi HES
- Bi-State (Louisiana and Mississippi) HES (being completed)

A hazards analysis quantifies the expected hurricane-caused inundation that would require emergency evacuation of the population. Historically, the hazards analysis also has assumed that mobile homes outside the surge inundation area must be evacuated due to their vulnerability to winds. The National Weather Service's SLOSH (Sea, Lake, and Overland Surge from Hurricanes) numerical storm surge prediction model was used as the basis of the hazards analysis for studies that have been completed or restudies that are ongoing in many coastal states. An example of a storm surge map can be seen in Figure 2-7, on page 2-10.

The vulnerability analysis uses the hazards analysis to identify the population potentially at risk to coastal flooding caused by the hurricane storm surge. Storm tide atlases are produced showing the inland extent of surge inundation for various hurricane intensities.

Hazards and vulnerability issues related to Isidore and Lili that were discussed with local and state officials included the following:

- What technical data/mapping was used to choose the areas to evacuate?
- Did the technical data provide a good depiction of the hazard area?

A high water mark survey for Hurricane Lili was conducted by Taylor Engineering, Inc. under contract to the FEMA Region VI, along with the surveying company, T. Baker Smith and Sons,

Inc. These firms gathered and prepared the data and then transmitted it to the National Hurricane Center for comparison with the SLOSH model. The survey was conducted from just west of Pecan Island, Louisiana to Burns Point, Louisiana. It included high water marks not only along the coastline but inland as well, where the storm tide penetrated. The highest recorded storm surge for Lili was over 11 feet at a location in St. Mary Parish, Louisiana. The following narrative and figures, provided by the National Hurricane Center, show a comparison between the observed storm tide high water marks and the SLOSH model calculated storm tide profile along the Louisiana coastline for Hurricane Lili.

Comparisons of observed and SLOSH model storm tide elevations for Hurricane Lili (Oct. 2002) provided courtesy of the Tropical Prediction Center, National Hurricane Center

The Storm Surge Group
TPC/NHC

Hurricane Lili made landfall on the Central Louisiana coastline on 3 October 2002, as a category 1 hurricane on the Saffir/Simpson scale. Lili caused storm tide flooding of two feet or greater from Pecan Island, Louisiana eastward to near Pensacola, Florida. A description of the complete history of hurricane Lili is given in a preliminary report available on the Tropical Prediction Center/National Hurricane Center web site (www.nhc.noaa.gov) under the title Hurricane History, sub title TPC Archives.

Figure 2-1 shows the landfall location and direction of hurricane Lili along the Louisiana coast.

A high water mark survey was conducted by Taylor Engineering, Inc., under contract to the FEMA. The survey was conducted from just west of Pecan Island, LA to Burns Point, LA. The survey not only included high water marks near the shoreline but inland as well, where the storm tide penetrated. In addition, numerous tide gauge maximums were collected from various agencies. These include the U.S. Army Corps of Engineers, U.S. Geological Survey, National Ocean Service, levee boards and the Louisiana Universities Marine Consortium. The surveyed high water marks and tide gauges all have various reference data. All of them were converted, if necessary, to the National Geodetic Vertical Datum of 1929 so that a direct comparison could be made to the storm tide values from the SLOSH model.

Figure 2-2 is a coastal profile, drawn from the plotted observed high water mark values and tide gauge maximums, from Pecan Island to Grand Isle LA (labeled west of the Mississippi River) and then from the Industrial Canal in New Orleans to Dauphin Island, Alabama (labeled east of the Mississippi River). Lili's track is highlighted in this figure as well as the two wind maximums. Note that the coastal profile plot does not include the inland inundation values...just those values that were near the coast. Also, the values given for

Cypremort Point and Burns Point represent an average of several observations. The profile shows that the maximum values west of the Mississippi River occurred from about Cypermort Point to Atchafalaya Bay. Also, because of the secondary wind maximum the wind field east of the Mississippi River was strong enough to generate significant surges along the Louisiana and Mississippi coastlines.

Figure 2-3 shows a comparison of the observed and SLOSH model storm tide derived coastal profiles. Reasonable agreement is seen west of the Mississippi River and excellent agreement occurs east of the River. The differences between the observed and SLOSH model values are typical and are similar to comparisons made in other storms in other locations along the U. S. coastlines.

Figures 2-4, 2-5 and 2-6 represent comparisons between observed tide gauge hydrographs at selected locations and the SLOSH model calculated hydrograph for that same location. The LUMCON Marine Center and Golden Meadow South hydrograph maximums are shown in figure 2-2. However, the Morgan City hydrograph is inland from the coast and its maximum was not plotted in figure 2-2. Over all the results are reasonable with some discrepancies in the phasing of the SLOSH hydrographs.

In summary, comparisons between observed high water marks, tide gauge maximums and selected tide gauge hydrographs and SLOSH model calculated maximums and hydrographs are reasonable and within the normal error range.

Appendix B is the data from the Tropical Cyclone Report prepared by the National Hurricane Center. This includes the "Best Track" positions for Hurricane Lili, including positions, barometric pressure, wind speed, and storm classification by date. Also included is the "Best Track" position for Tropical Storm Isidore. The appendix also includes a table reporting selected surface observations at various localities throughout the impacted areas and a tropical cyclone watch and warning summary for Lili.

Figure 2-4

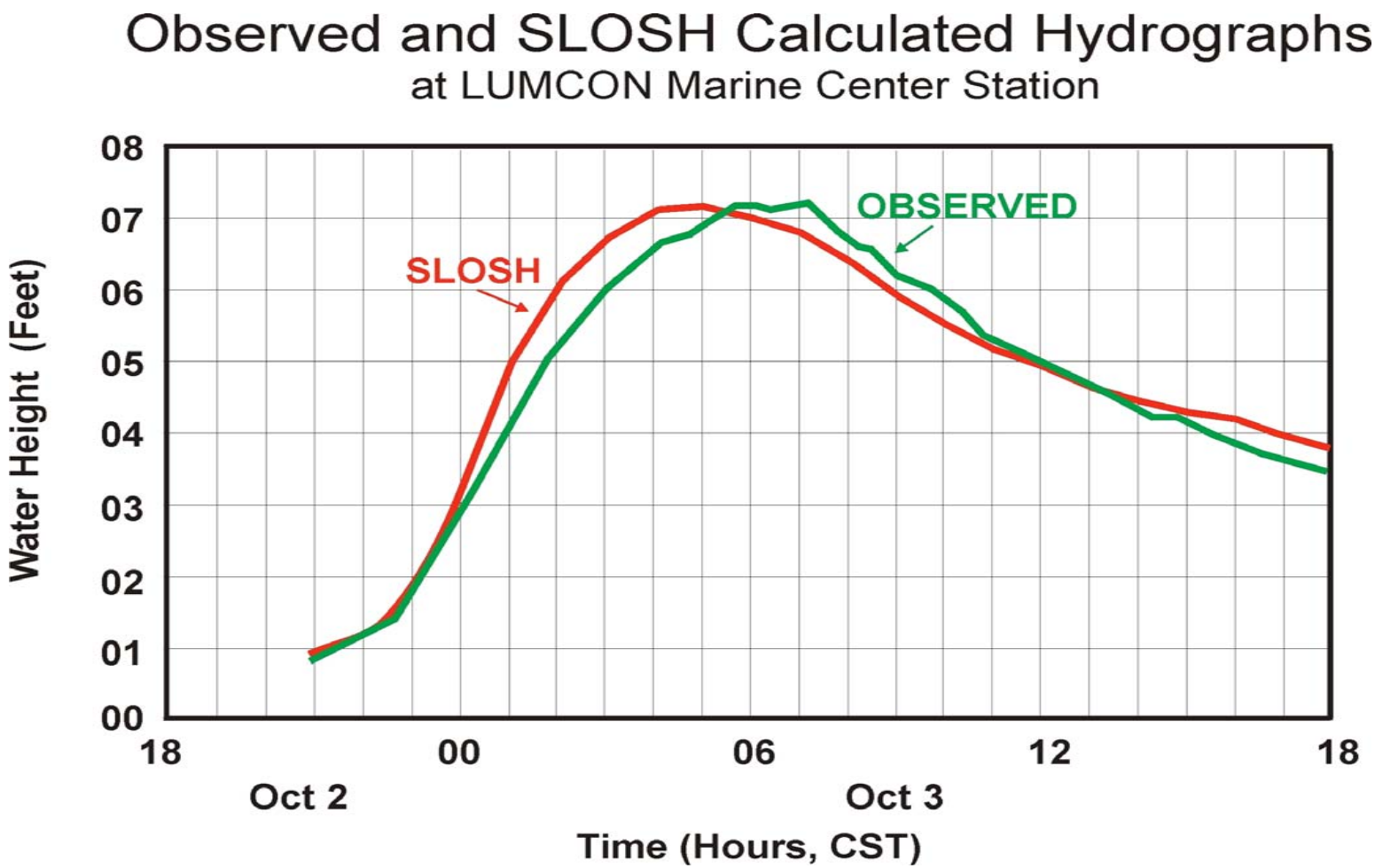


Figure provided courtesy of Tropical Prediction Center/National Hurricane Center and NOAA

Figure 2-5

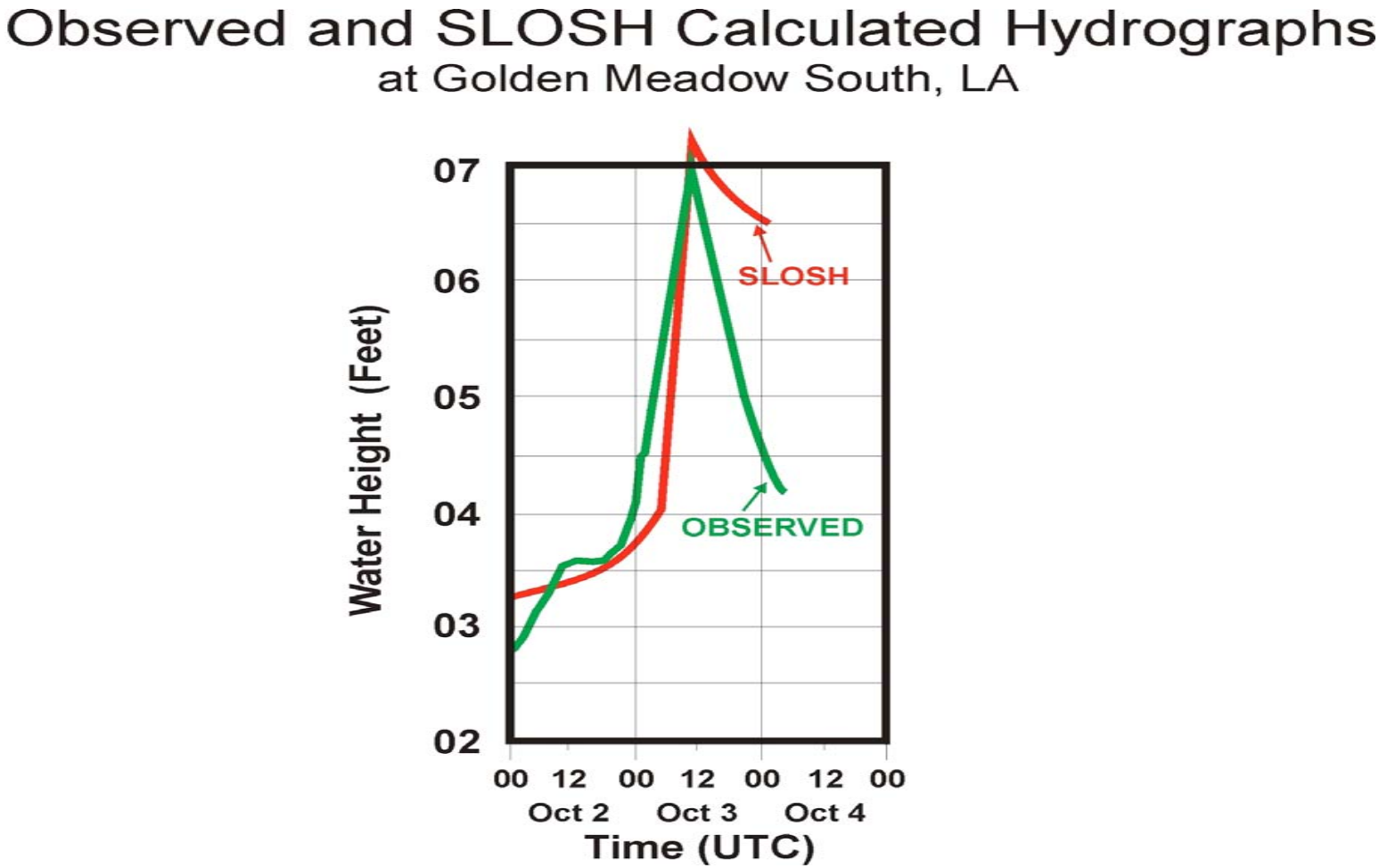


Figure provided courtesy of Tropical Prediction Center/National Hurricane Center and NOAA

Figure 2-6

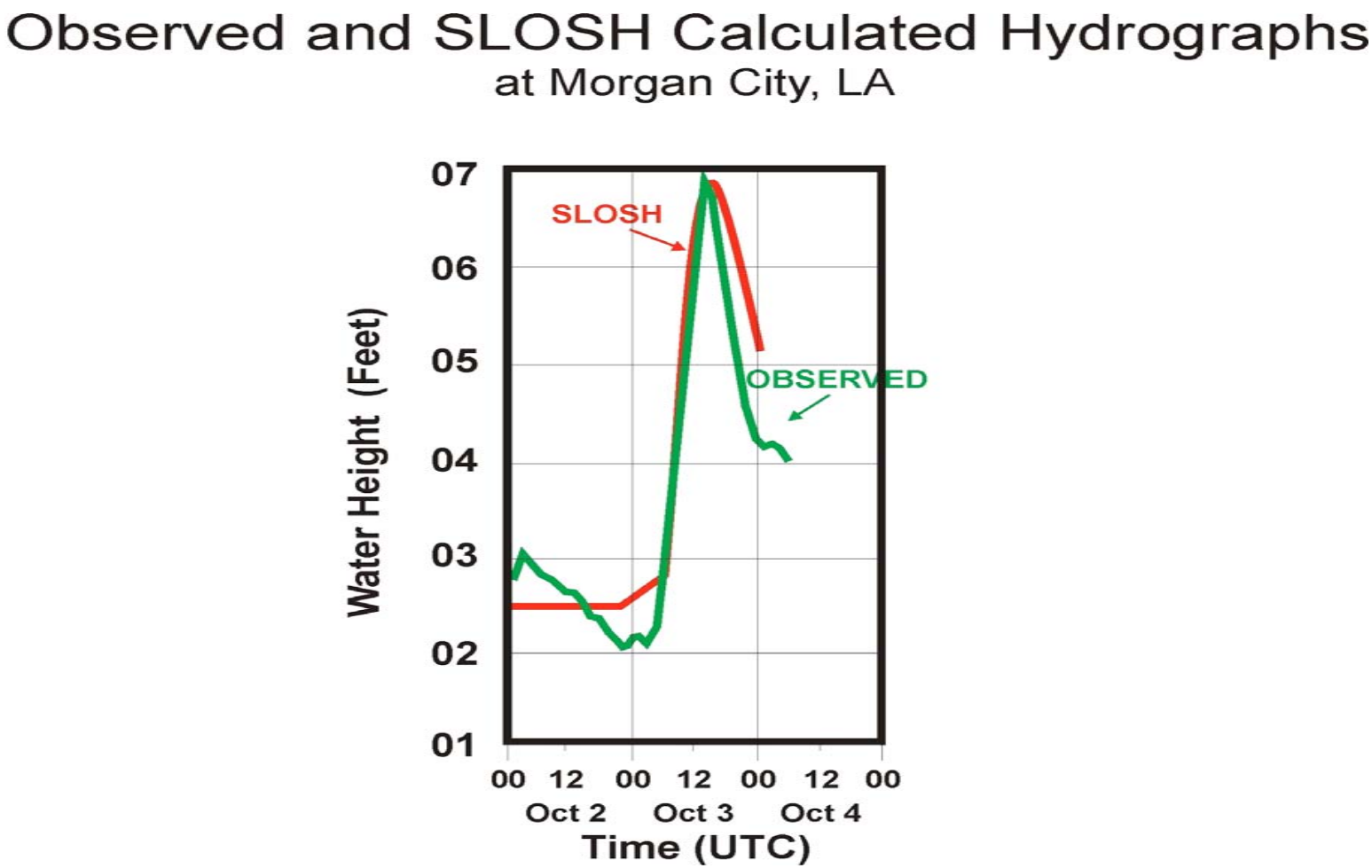


Figure provided courtesy of Tropical Prediction Center/National Hurricane Center and NOAA

NOAA's Center for Operational Oceanographic Products and Services (CO-OPS) maintains a network of tide gauges along the Gulf Coast from Brownsville, Texas to Key West, Florida. During hurricane season, CO-OPS maintain and monitor these gauges providing information regarding water levels along the coastline during storm events. Table 2-1 summarizes peak observed, predicted and storm surge water levels for five of these gauges. The data was calculated from six-minute acoustic data referenced to Mean Lower Low Water (MLLW).

Table 2-1 - Tide Gauge Data

Tide Gauge Location	Date/Time (GMT)	Elevation above MLLW (ft)		Storm Surge (ft)	Latitude	Longitude
		Observed	Predicted			
Mobile Channel, AL	10/03/02 17:30	4.19	1.79	2.40	30° 42.5' N	88° 2.6' W
Pilot Station SW Pass, LA	10/03/02 12:06	4.34	1.70	2.64	28° 55.6' N	89° 25.1' W
Grand Isle, LA	10/03/02 12:48	4.48	1.45	3.03	29° 15.8' N	89° 57.4' W
Lake Charles, LA	10/04/02 23:24	2.69	1.21	1.48	30° 13.5' N	93° 20.6' W
East Jetty Calcasieu Pass, LA	10/03/02 17:18	3.51	1.79	1.72	29° 45.9' N	93° 20.6' W

*Data taken from Taylor Engineering, Inc. Hurricane Lili Coastal High Water Mark Collection Report

The United States Geological Survey (USGS) provided the real-time water surface elevation information. Mobile Channel and Grand Isle gauges are referenced to NAVD88 heights based on benchmark data. The others have no benchmark data to establish NAVD referenced heights.

As part of the survey of high water marks, 40 points were surveyed in Iberia, St. Mary and Vermilion Parishes. Table 2-2 presents this data showing three points in Iberia Parish, four points in Vermilion Parish and six points in St. Mary Parish.

The following procedure established the horizontal locations and vertical elevations:

1) Transfer High Water Marks, transferred with a convention level, to an offset point, to an easily accessible location
2) Record the elevation of the High Water Mark above general land surface
3) Record the latitude and longitude of the offset point location
4) Use the recently update Department of Natural Resources (DNR) Louisiana Coastal Zone Primary Global Positioning System (GPS) Network for benchmark control. Note: The DNR established this network to overcome problems in elevation datum due to subsidence. This network is the best available benchmark system and provides a consistent benchmark network for the parishes surveyed.
   (a) Horizontal Datum: North American Datum of 1983 (NAD83)[1] State Plane Louisiana South Zone Coordinates
   (b) Vertical Datum: NAVD 88 (The North American Vertical Datum of 1988)[2] (GEOID 99)
5) Survey the elevation with a 4700/5700 GPS Total Station

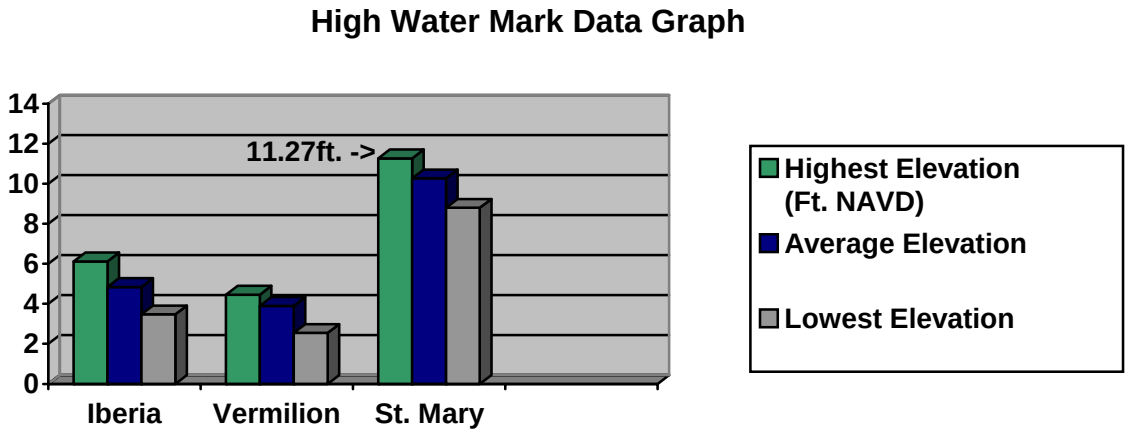
[1] North American Datum of 1983 (NAD83) is an earth-centered datum based on the Geodetic Reference System of 1980. The size and shape of the earth was determined through measurements made by satellites and other sophisticated electronic equipment; the measurements accurately represent the earth to within two meters.

[2] NAVD 88 (The North American Vertical Datum of 1988) is a vertical geodetic datum created in 1991 from measurements in Mexico, the US, and Canada

Table 2-2 – High Water Mark Data

Latitude (NAD 83)	Longitude (NAD 83)	High Water Mark Elevation (FT NAVD)	Natural Grade Elevation (FT NAVD)
Iberia Parish			
29° 56' 30.25"	91° 50' 26.82"	6.12	3.38
29° 56' 14.36"	91° 54' 34.7"	3.47	2.70
29° 54' 17.44"	91° 49' 02.58"	4.93	3.02
Vermilion Parish			
29° 48' 14.60"	92° 08' 17.58"	4.11	1.84
29° 47' 00.27"	92° 09' 44.35"	4.5	1.28
29° 47' 41.96"	92° 08' 32.83"	4.46	2.34
29° 39' 28.11"	92° 31' 13.29"	2.55	0.99
St. Mary Parish			
29° 37' 40.02"	91° 32' 13.82"	10.02	5.50
29° 36' 36.97"	91° 32' 22.41"	11.27	4.70
29° 44' 15.05"	91° 49' 47.38"	8.80	3.21
29° 43' 55.59"	91° 50' 21.09"	10.33	4.22
29° 36' 15.83"	91° 32' 04.51"	10.55	4.86
29° 33' 33.34"	91° 31' 32.69"	10.65	3.46

*Data taken from Taylor Engineering, Inc. Hurricane Lili Coastal High Water Mark Collection Report



Recommendations:

Storm Surge: Many of the areas interviewed for Isidore and Lili are waiting for updated surge mapping. Most should have received it through the recently completed SW Louisiana HES. There is still a wide variety of technology being used to produce the mapping around the country and within the interviewed areas. The various agencies of ICCOH should continue to review past and present methodologies and technologies on a regular basis to determine the most cost-effective and user-friendly formats that state and local agencies should consider. FEMA and other federal and state agencies, including NOAA and the USACE, are securing and incorporating new data from LIDAR (Light Identification and Detection and Ranging) systems to increase as well as improve quality of maps. FEMA's multi-million dollar Map Modernization program should benefit not only floodplain mapping efforts but also storm surge maps. **Storm surge maps are based on SLOSH Models. Maps vary from one study to another based on existing map technology at the time that the Hazards and Vulnerability Analyses were conducted. Maps also vary based on the preference of the customers.** Figure 2-8 shows the predicted maximum envelope of water (MEOW) for Hurricane Lili using the SLOSH Model.

Wind: Additionally, researchers from Clemson University, Louisiana State University, Texas Tech University, University of Florida, University of Oklahoma and the Hurricane Research Division of NOAA collaborated to collect meteorological data from Lili at landfall about maximum sustained winds. Clemson and Florida also collected data for Isidore. These organizations collected data from a variety of surfaces including deployment of mobile teams and instruments. The research revealed that Tropical Storm Isidore made landfall with winds of 63 mph just west of Grand Isle in Jefferson Parish, Louisiana on September 26. Hurricane Lili made landfall farther west near Marsh Island in Iberia Parish on October 3 with maximum sustained winds of 92 miles per hour.

Rain: As usual, hurricanes bring rain but Lili moved very rapidly upon landfall and the highest rainfall was about 9 inches. For more detailed information about wind data from Isidore or Lili, see the following web site. http://www.ce.ufl.edu/~fcmp/pubs/pubs.htm