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Development of storm surge which led to flooding in St. Bernard Polder during Hurricane Katrina

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ABSTRACT

Hurricane Katrina caused devastating flooding in St. Bernard Parish, Louisiana. Storm surge surrounded the polder that comprises heavily populated sections of the Parish in addition to the Lower 9th Ward section of Orleans Parish. Surge propagated along several pathways to reach levees and walls around the polder's periphery. Extreme water levels led to breaches in the levee/wall system which, along with wave overtopping and steady overflow, led to considerable flood water entering the polder. Generation and evolution of the storm surge as it propagated into the region is examined using results from the SL15 regional application of the ADCIRC storm surge model. Fluxes of water into the region through navigation channels are compared to fluxes which entered through Lake Borgne and over inundated wetlands surrounding the lake. Fluxes through Lake Borgne and adjacent wetlands were found to be the predominant source of water reaching the region. Various sources of flood water along the polder periphery are examined. Flood water primarily entered through the east and west sides of the polder. Different peak surges and hydrograph shapes were experienced along the polder boundaries, and reasons for the spatial variability in surge conditions are discussed.

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1. Introduction

In August 2005, extremely high storm surge and energetic waves during Hurricane Katrina caused massive flooding, devastating loss of life, and widespread damage throughout south-eastern Louisiana and Mississippi. The immense size of Hurricane Katrina, in relation to the entire northern Gulf of Mexico coastline from western Louisiana (left side of the figure) to the Florida panhandle (right side), is shown in Fig. 1. The Interagency Performance Evaluation Task Force (IPET) thoroughly investigated and documented this extraordinary event and its consequences (IPET, 2008). Flooding caused by Katrina was particularly severe in the polder that comprises part of St. Bernard and Orleans Parishes in New Orleans, Louisiana, referred to here as the St. Bernard Polder (see Fig. 2). This polder is located within the small rectangular box shown in Fig. 1.

The St. Bernard Polder is surrounded by a perimeter of levees and floodwalls. There was considerable variability in levee/wall crest elevation along each of the various segments that form the perimeter. A small segment of the western boundary of the polder extends along the Inner Harbor Navigation Canal (IHNC); this section of levee/wall had crest elevations that ranged from approximately 3.7 to 4.6 m NAVD88 2004.65, with a few isolated low spots having crests of 3.5–3.7 m. NAVD88 2004.65 is the vertical datum that was developed for the region as part of the IPET investigation. The rest of the western boundary of the polder is formed by the much higher Mississippi River levee. The northern polder boundary runs along the south side of the co-located Gulf Intracoastal Waterway (GIWW) and Mississippi River Gulf Outlet (MRGO) channels, referred to as the GIWW/MRGO Reach 1; levee/walls along this segment had crest elevations in the range of 4.6–5.5 m, with a few isolated low spots of 3.5–4.6 m. The eastern polder boundary parallels the MRGO Reach 2 navigation channel from Bayou Bienvenue to a point southeast of Bayou Dupre; wall/levee crest elevations generally ranged from 4.6 to 5.8 m with isolated low spots of 4.3–4.6 m. The southern boundary of the polder, the Chalmette Extension Levee, extends from the MRGO Reach 2 to the Mississippi River levee at Caernarvon and is fronted by the extensive Caernarvon marsh. Levee/wall crest elevations along this section ranged from 4.6 to 5.8 m, with isolated low spots of 4.0–4.6 m.

Unique dynamics of storm surge development and propagation into the region caused different surge conditions to occur along the polder's periphery. Spatial differences in the surge hydrograph and variability in levee/wall crest elevation led to highly complex and variable (in space and time) overtopping and overflow conditions. This paper examines the development of the storm surge in this local region, causes for its temporal

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and spatial variability, and it discusses how that variability contributed to different sources of floodwater that entered the polder.

High surge levels led to two breaches in the floodwall located just north of the IHNC lock along the western boundary of the polder (IPET, 2007b). Both led to early inundation of the Lower 9th Ward, the heavily populated western most portion of the polder, with interior water elevations initially rising to approximately +0.6 to +1.2 m NAVD88 2004.65 (IPET, 2007a). Along the MRGO Reach 2 channel, high storm surge and energetic waves led to widespread overtopping and overflow, which caused erosion and degradation of much of the levee immediately adjacent to the waterway (IPET, 2007b). As this levee degraded, a large volume of water entered the Central Wetlands which lie within the polder, fully inundating them. The advancing surge overwhelmed the much lower local interior 40 Arpent levee (see Fig. 2) within the polder, which separates the wetlands from most of the population. Crest elevations along the 40 Arpent levee generally ranged from 1.8 to 3 m. Flow over this interior levee caused substantial inundation throughout the populated areas of the polder, raising water levels everywhere to elevations of approximately +3.3 m NAVD88 2004.65. The northern and southern boundaries of the polder experienced less overtopping and overflow. Levees and walls had crest elevations that generally exceeded peak surge levels along these two segments.

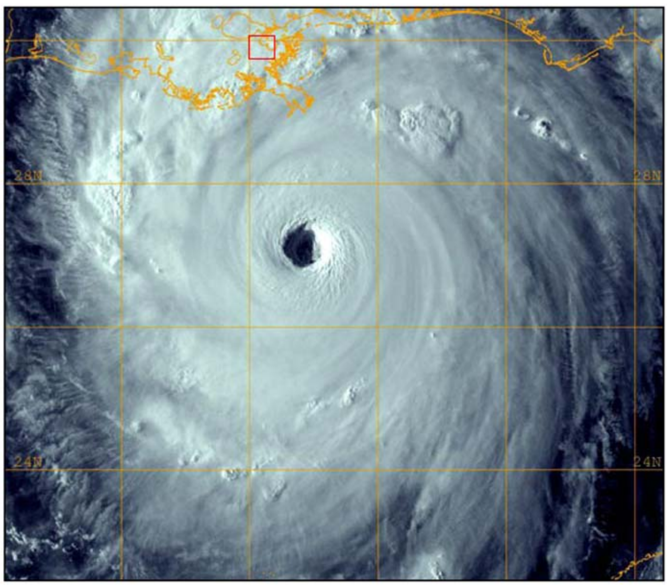

Fig. 1. Satellite image of Hurricane Katrina cloud cover as the storm approaches landfall along the northern Gulf of Mexico coastline.

2. The storm surge model

The regional storm surge and waves team of the IPET performed extensive technical analyses of measured data and applied state-of-the art computer models of hurricane winds, storm surge using ADCIRC (Blain et al., 1994, 1998; Westerink et al., 1994; Luettich and Westerink, 2004; Dawson et al., 2006; Westerink et al., 2008) and waves using WAM (Komen et al., 1994; Gunther, 2005) and STWAVE (Smith, 2000; Smith et al., 2001; Smith and Smith, 2001), to examine the regional-scale hydrodynamic conditions that developed during Katrina. Wave and surge models were coupled over a large regional area. Subsequent to the IPET work (IPET, 2007a), further advancements led to development of the even more detailed SL15 ADCIRC storm surge model application. Dietrich et al. (2009) describe the regional-scale characteristics of storm surge and waves during Hurricanes Katrina and Rita, based on results from the SL15 application.

A highly detailed representation of the complex bathymetry and topography that characterizes the southeastern Louisiana and Mississippi coasts is incorporated into the SL15 application, as shown in Fig. 3. Grid mesh resolution adopted in creating this

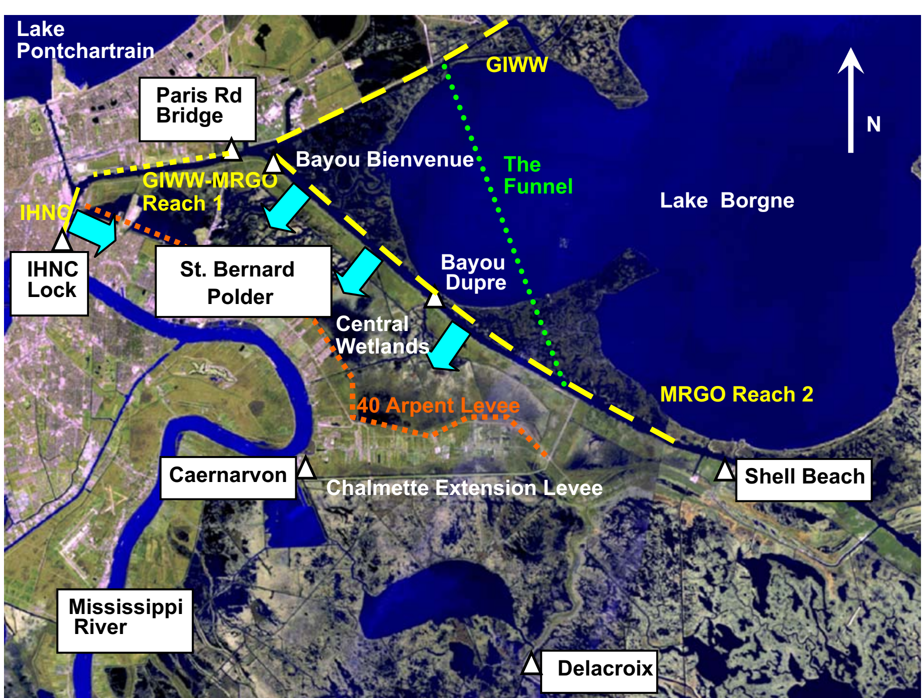

Fig. 2. Location map for the region of interest. Blue arrows indicate major flooding paths into the St. Bernard Polder during Hurricane Katrina.