2023 COASTAL MASTER PLAN

HISTORIC STORM RUN – ISAAC

SUPPLEMENTAL MATERIAL H6.5

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COASTAL PROTECTION AND RESTORATION AUTHORITY

This document was developed in support of the 2023 Coastal Master Plan being prepared by the Coastal Protection and Restoration Authority (CPRA). CPRA was established by the Louisiana Legislature in response to Hurricanes Katrina and Rita through Act 8 of the First Extraordinary Session of 2005. Act 8 of the First Extraordinary Session of 2005 expanded the membership, duties, and responsibilities of CPRA and charged the new authority to develop and implement a comprehensive coastal protection plan, consisting of a master plan (revised every six years) and annual plans. CPRA's mandate is to develop, implement, and enforce a comprehensive coastal protection and restoration master plan.

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LIST OF ABBREVIATIONS

ADCIRC	ADVANCED CIRCULATION (MODEL)
CLARA	COASTAL LOUISIANA RISK ASSESSMENT (MODEL)
CPRA	COASTAL PROTECTION AND RESTORATION AUTHORITY
FEMA	FEDERAL EMERGENCY MANAGEMENT AGENCY
FWA	FUTURE WITH ACTION
FWOA	FUTURE WITHOUT ACTION
HSDRRS	HURRICANE AND STORM DAMAGE RISK REDUCTION SYSTEM
SLR	SEA LEVEL RISE
SWAN	SIMULTAING WAVES NEARSHORE (MODEL)

1.0 INTRODUCTION

The historical storm analysis conducted for the 2023 Coastal Master Plan simulates and presents the potential coastal flood risk and damage that would result from five Atlantic tropical storms that directly impacted Louisiana from 2005 to 2021 were they to make landfall under current and future conditions. The simulated storms examined for this analysis include Hurricane Rita (2005), Hurricane Ike (2008), Hurricane Isaac (2012), Hurricane Barry (2019), and Hurricane Ida (2021). This document describes the current and future coastal flood risk and damage that would result from a Hurricane Isaac-like storm, a Category 1 storm that made landfall along the coast of southeast Louisiana in Plaquemines Parish in August 2012.

The Advanced Circulation (ADCIRC) and Simulating Waves Nearshore (SWAN) models were used to simulate surge and wave heights for each of the five historical hurricanes analyzed. The ADCIRC+SWAN model geometries used in this analysis and throughout Louisiana's 2023 Coastal Master Plan are derived from those used in both the 2012 and 2017 Coastal Master Plans, with incremental upgrades. As part of Louisiana's 2023 Coastal Master Plan, an extensive model validation and calibration study was conducted by Cobell and Roberts (2021) to ensure that the parameters used within these models were most appropriate from those currently found within the modeling community and available literature. ADCIRC+SWAN model version v55.00 was used in this work.

Flood depth and damage results from each of the storms described in this analysis were simulated with the Coastal Louisiana Risk Assessment (CLARA) model. An introduction to the CLARA model can be found in Johnson et al. (2021), Fischbach et al. (2012), and Johnson et al. (2013). The CLARA model uses high-resolution hydrodynamic storm surge and wave output from ADCIRC+SWAN. It estimates flood depth exceedances; direct economic damage exceedances across different asset types, including residential, commercial, and industrial structures; expected annual damage dollars; and expected annual structural damage in the Louisiana Coastal Zone. However, this analysis only considers a single storm run rather than a probabilistic storm suite, so the results are simply estimates of direct economic damage associated with the historical storm.

Results are presented for current conditions, a future without action (FWOA) in Year 50, as well as a future with action (FWA) in Year 50 that simulates the anticipated impacts of the 2023 Coastal Master Plan. Current conditions are represented with the initial conditions (Year 0) assumptions. Projected future conditions, including sea level rise (SLR), were analyzed under the lower environmental scenario (S07) developed and used in the 2023 Coastal Master Plan. Both the FWOA and FWA represent a single projected future condition with changing environmental and population conditions. This scenario represents one of many possible futures for the Louisiana coast and should be interpreted as a plausible projection rather than a likely prediction for future flood risk outcomes.

2.0 DESCRIPTION

Hurricane Isaac made landfall at Southwest Pass at the mouth of the Mississippi River on August 28, 2012, as a Category 1 storm. The slow-moving storm produced high winds, coastal flooding, and flash flooding impacts throughout the region (National Weather Service, 2012), and the highest reported sustained winds near the area of landfall in Plaquemines Parish were just over 80 mph. After this initial landfall, Hurricane Isaac moved back over open water and made a second landfall to the west of Port Fourchon in Lafourche Parish on August 29, 2012, and began to weaken as it moved inland (Berg, 2013a). The wind strength and storm surge from Isaac caused the Mississippi River to flow backwards for nearly 24 hours. In Belle Chasse, the river reached 10 ft while flowing upstream, and rose to 8 ft in Baton Rouge (Berg, 2013a). The severity of flash flooding was exacerbated by prolonged, heavy rainfall; and southeastern Louisiana received more than 10 in of rain in some places.

The most extensive storm surge during Hurricane Isaac occurred outside of the federal levee system. The storm surge around the area of landfall at Shell Beach, Louisiana was as high as 11 ft above normal levels, and many areas below sea level in Plaquemines Parish experienced inundation up to 17 ft above ground. Unprotected areas of St. Bernard, Orleans, and St. Tammany parishes also experienced major flooding. A surge of 6.3 ft in New Orleans on the southern shore of Lake Pontchartrain was recorded (Berg, 2013b). According to the tropical cyclone report, Isaac caused water from Breton Sound to overtop a back levee meant to protect the east bank of Plaquemines Parish, which led to major flooding from Braithwaite to Bel Air (Berg, 2013a).

There were no reported deaths directly associated with Hurricane Isaac in Louisiana, but over 5,000 people were rescued from the roofs of flooded homes in Plaquemines, St. John the Baptist, and Lafourche parishes. The state of Louisiana estimated that Hurricane Isaac was responsible for the damage of 59,000 homes (mostly in Jefferson, St. John the Baptist, and Plaquemines parishes).

On August 29, 2012, Louisiana Governor Bobby Jindal requested an expedited major disaster declaration for both federal public assistance and statewide hazard mitigation funds prior to completion of Preliminary Damage Assessments. On the same day, President Barack Obama declared a major disaster in Louisiana to make federal assistance available for emergency work across several Louisiana parishes (FEMA, 2012).

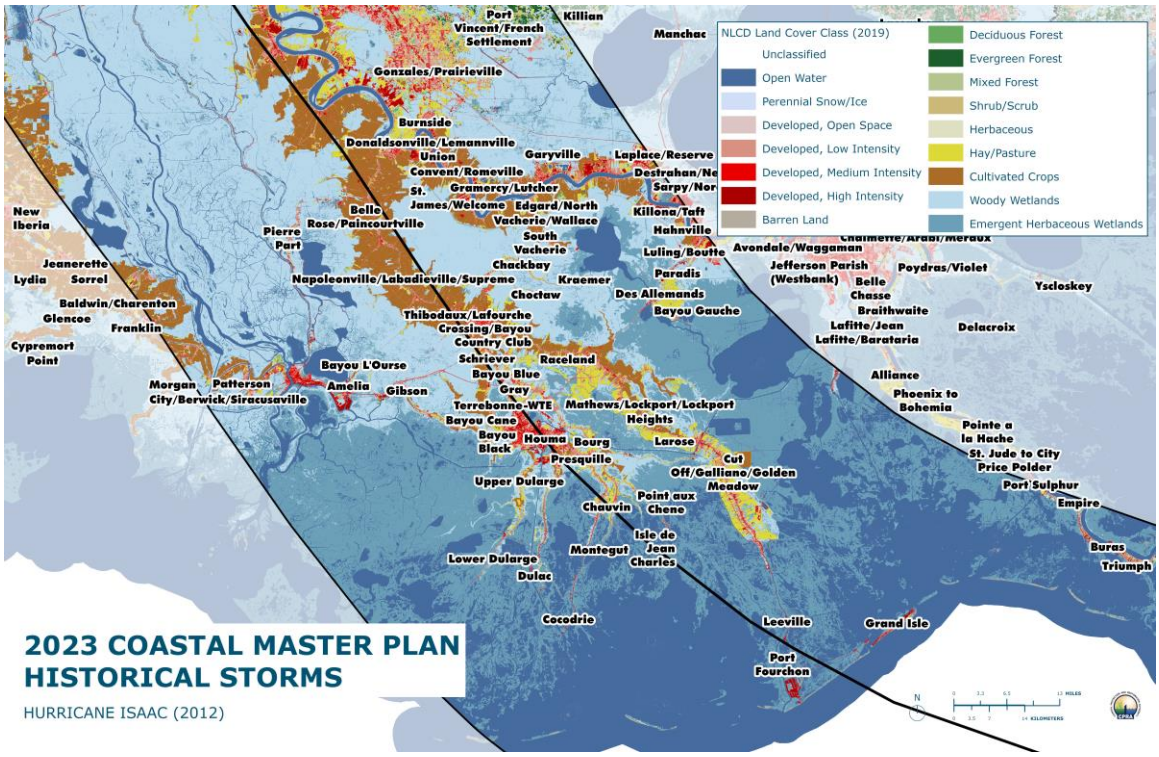

Figure 1. Storm track of Hurricane Isaac and communities within a 50 km buffer of the storm's center.

3.0 STORM SURGE AND WAVES

The ADCIRC+SWAN model was used to simulate storm surge and wave height associated with Hurricane Isaac for initial conditions, a FWOA, and a FWA, all of which assumed S07 conditions. Results for initial conditions (Year 0), a FWOA (Year 50), and a FWA (Year 50) are presented below along with localized results for several key communities/locations.

3.1 INITIAL CONDITIONS

Current sea level conditions were used to project storm impacts for initial conditions. Under these conditions, ADCIRC+SWAN simulations show that if a Hurricane Isaac-like storm were to make landfall in Year 0 following the same track, the anticipated surge would be greatest to the east of the storm (Figure 2). With the storm making a first landfall at the mouth of the Mississippi River in Plaquemines Parish and a second at Port Fourchon at the mouth of Bayou Lafourche. ADCIRC+SWAN simulations show that the highest surge levels would occur to east of the Mississippi River Bird's Foot Delta in the Pontchartrain/Breton Region. Simulations show that the greatest peak water surface elevations, estimated to be as high as 18 ft, would be in in the Breton Sound Basin between Lake Borgne and the Mississippi River, an area that includes St. Bernard Parish and the portion of Plaquemines Parish located on the east bank of the Mississippi River. In this location, the waters from a Hurricane Isaac-like storm would be concentrated against the Mississippi River levees in Plaquemines Parish and the HSDRRS levees in St. Bernard Parish, with maximum water surface elevations occurring near the community of Braithwaite near the junction of these two levee systems.

ADCIRC+SWAN simulations project lower but still notable water surface elevations ranging from 10 to 12 ft in locations throughout the Pontchartrain/Breton Region inland of the Breton and Chandeleur sounds. This includes the entirety of Lake Borgne and the broad expanse of brackish and saline marsh located south of the lake in St. Bernard Parish, an area that is home to several small unincorporated fishing communities such as Delacroix and Yscloskey. ADCIRC+SWAN simulations also show high peak water surface elevations extending northward into the lower Pearl River Valley.

Water surface elevations are also projected to be elevated along the western shore of Lake Pontchartrain and northern shore of Lake Maurepas, as well as across the land bridge between these two lakes during a Hurricane Isaac-like event in Year 0. Projected high water elevations in these locations are primarily due to hurricane winds that rotate counterclockwise, pushing water through lakes Borgne, Pontchartrain, and Maurepas, and piling it against the elevated land bounding these lakes.

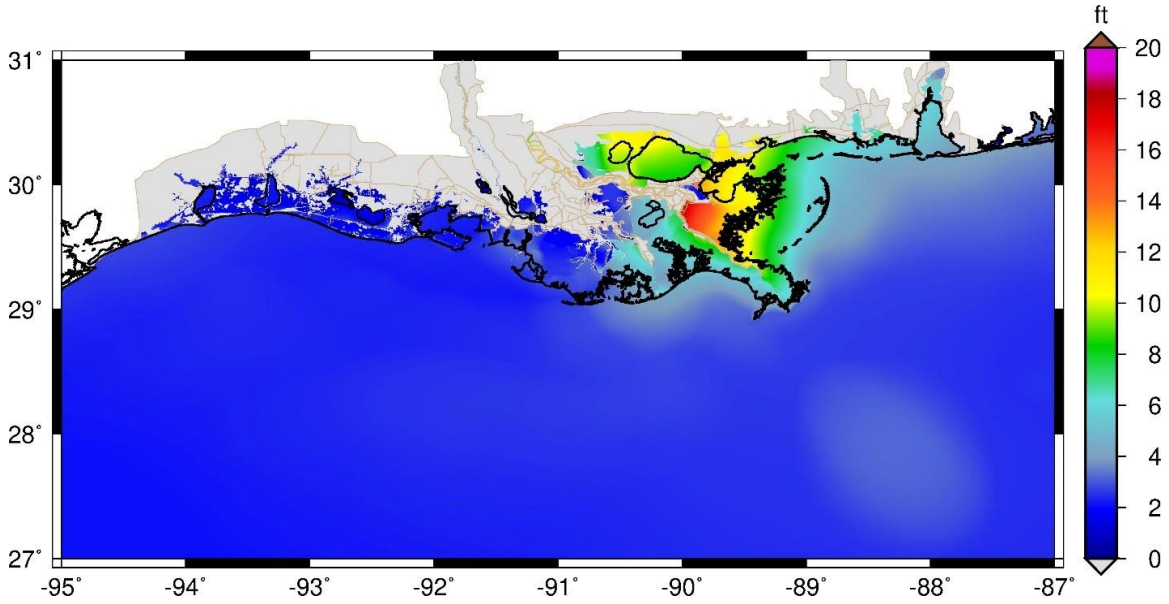

Figure 2. Peak water surface elevation (ft, NAVD88) for a Hurricane Isaac-like storm simulated in Year 0.

Between Terrebonne Bay and the Mississippi River, a Hurricane Isaac-like storm would be expected to generate surge levels of 4 to 6 ft. Lake Salvador and many of the other interior lakes and waterways between Bayou Lafourche and the Mississippi River provide direct avenues for this storm surge to push inland into the upper portion of the Barataria Region. The highest levels of storm surge anticipated west of the Mississippi River would occur immediately proximate to the river where surge is expected to pile up against the levees. This is projected to result in inundation levels of 8 ft or higher along the west bank of the river from just south of Belle Chasse to the mouth of the river. ADCIRC+SWAN results project that water levels above surface would be minimal for most of the central and southwest coast, particularly to the west of Terrebonne Bay, where model results show inundation levels of 3 ft or less from a Hurricane Isaac-like storm in Year 0.

3.2 FUTURE WITHOUT ACTION

ADCIRC+SWAN simulations under S07 show that were a Hurricane Isaac-like storm to make landfall in a FWOA in Year 50, the greatest expansion of the floodplain compared to Year 0 would be expected to occur in upper Barataria Basin, which sees an expansion of the floodplain across the broad expanse of forested wetlands containing Lac Des Allemands and the Lac Des Allemands Swamp. This area is home to a number of fisheries-dependent communities, including Chackbay, Choctaw, Kraemer, and South Vacherie (Figure 3). In a FWOA simulation of a Hurricane Isaac-like event occurring in Year 50, floodplain expansion is also anticipated along Bayou Lafourche north of Larose, extending beyond the

boundary of Lafourche Parish.

While expansion of the modeled floodplain for a Hurricane Isaac-like storm is not notable through visual comparison of Figure 2 and Figure 3 beyond the aforementioned locations, projected water surface elevations generated by this storm in Year 50 are expected to increase across the coast. Modeled increases in eustatic SLR and higher base water levels in the Gulf of Mexico are significant contributors to this modeled increase. Anticipated water surface elevation resulting from a Hurricane Isaac-like event in a FWOA simulation in Year 50 for Breton Sound is projected to be approximately 2 ft higher than those observed in the ADCIRC+SWAN Year 0 simulations. Similar increases are expected across the Pontchartrain Basin, most notably in areas north of lakes Borgne, Pontchartrain, and Maurepas. Similar increases are expected to occur in the forested wetlands surrounding these lakes and along the Pearl River Valley. Water surface elevations are projected to increase as much as 4 ft in some of these locations.

ADCIRC+SWAN simulations project that peak water surface elevation in locations beyond the Mississippi River levees on the west bank of the river in Plaquemines Parish are projected to increase as storm water piles against the levees. In Year 0, the water surface elevation in this location is projected to be around 8 ft. In Year 50 in a FWOA, the peak water surface elevation along the Mississippi River levees is projected to range from 10 to 12 ft. In the reach of the Mississippi River between Phoenix and Port Sulphur, these levels of flooding are much more pronounced, reaching as far west as Little Lake.

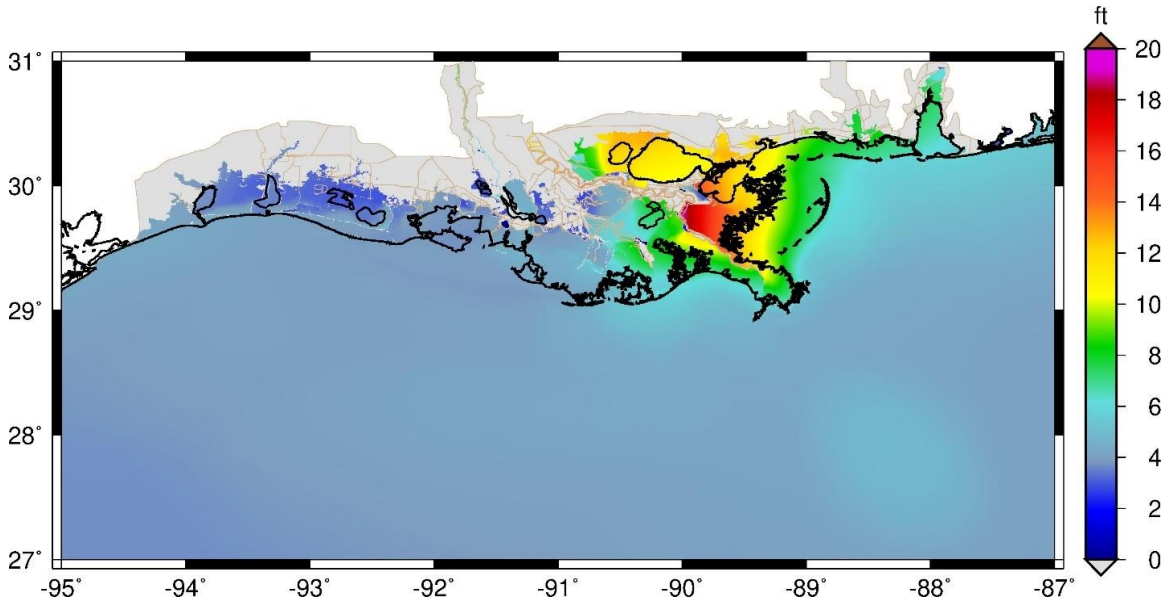

Figure 3. Peak water surface elevation (ft, NAVD88) for a Hurricane Isaac-like storm simulated in the FWOA, S07, Year 50.

3.3 FUTURE WITH ACTION

In the FWA simulation of a Hurricane Isaac-like event in Year 50, few large-scale differences from the FWOA simulation for Year 50 are observed in the Pontchartrain/Breton Region to the east of the Mississippi River (Figure 4). A reduction in peak water surface elevations is anticipated for the southern portion of Lake Pontchartrain as well as the cypress-tupelo swamp located north of lakes Pontchartrain and Maurepas. In the FWA simulation, the projected expansion of the floodplain around Lac Des Allemands and the Lac Des Allemands Swamp in a FWOA is still anticipated in a FWA. However, ADCIRC+SWAN simulations show that the expected expansion of the floodplain along Bayou Lafourche north of Larose is reduced or eliminated, most notably behind the Morganza to the Gulf project levees (Figure 5). In locations immediately outside Morganza to the Gulf, peak water surface elevations from a Hurricane Isaac-like storm are projected to increase in a FWA, as storm water piles against the levees.

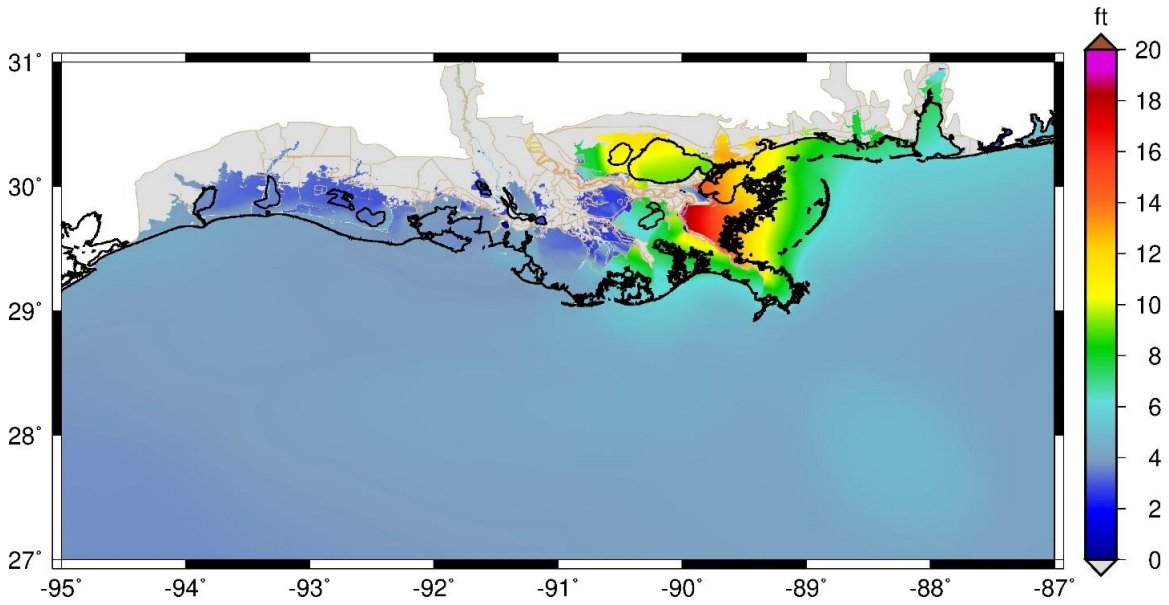

Figure 4. Peak water surface elevation (ft, NAVD88) for a Hurricane Isaac-like storm simulated in the FWA, S07, Year 50.

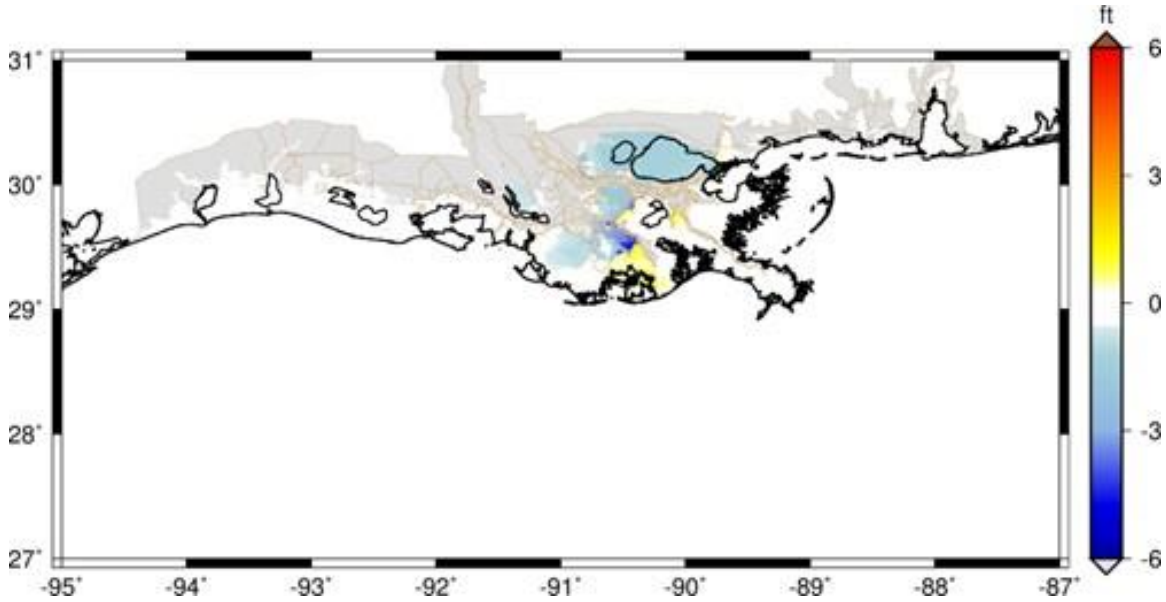

Figure 5. Change in peak water surface elevation (ft, NAVD88) between FWOA and FWA for a Hurricane Isaac-like storm simulated in S07, Year 50.

3.4 LOCAL STORM SURGE AND WAVE IMPACTS

A more granular analysis of the anticipated local impacts of a Hurricane Isaac-like event in Year 50, in both FWA and FWOA simulations, reveals the impacts of local landscape features on exacerbating or reducing the impacts of storm surge and waves. Several communities across coastal Louisiana were analyzed for high tide flooding impacts (see Attachment H3: High Tide Flooding). Within each community, a number of key locations of community importance were identified and verified by local stakeholders. To assess the local impacts of a Hurricane Isaac-like storm, water surface elevations were projected under initial conditions as well as into the future under both FWOA and FWA.

On average, hurricane-force winds tend to extend forward and to the right about 50 to 100 km from the eye and 25 to 50 km to the left of the storm track (Keim et al., 2007). Of the communities examined for this analysis, three were located within 50 km of the center line of the storm, one on the eastern side (Grand Isle) and two on the western side (Amelia and Dulac). ADCIRC+SWAN analysis of a Hurricane Isaac-like storm in Year 50 for Grand Isle, the only barrier island in Louisiana that is human occupied, shows an increase of approximately 0.5 ft at all key locations examined in a FWOA compared to Year 0 (Table 1). This includes flooding along the transportation network, both on the island and on the mainland, across the causeway over Caminada Pass. The implementation of planned master plan projects would not be expected to significantly alter these flood depths.

Table 1. Peak water surface elevation (ft, NAVD88) for a Hurricane Isaac-like storm at key locations in Grand Isle, Louisiana

Community	Name	Initial Conditions (Year 0)	FWOA (Year 50)	FWA (Year 50)
Grand Isle	Grand Isle Community Center	1.06	1.57	1.64
Grand Isle	Grand Isle Evacuation Link - LA1	1.31	1.77	1.82
Grand Isle	Grand Isle Local Road Link - Oak Ln at Louisiana Ave	1.41	1.92	1.94
Grand Isle	Grand Isle State Park	1.04	1.67	1.69

Further to the east of storm track in the Pontchartrain/Breton Region, ADCIRC+ SWAN simulations show much greater peak water surface elevations than those experienced on Grand Isle. In Delacroix, an Isleño fishing community located along Bayou Terre-aux-Boeufs to the east of the Mississippi River, water surface elevations are projected to exceed 4 ft at all key locations in the community in Year 0 (Table 2). This includes flooding along the town's transportation network, including roadways and boat docks. This value is expected to approach 5 ft in Year 50 in a FWOA. ADCIRC+SWAN simulations show implementation of planned protection and restoration projects in a FWA would not be expected to significantly alter these peak water surface elevations.

Table 2. Peak water surface elevation (ft, NAVD88) for a Hurricane Isaac-like storm at key locations in Delacroix, Louisiana

Community	Name	Initial Conditions (Year 0)	FWOA (Year 50)	FWA (Year 50)
Delacroix	Delacroix Evacuation Link - Delacroix Hwy	4.38	4.84	4.78
Delacroix	Delacroix Island Pier	4.45	4.94	4.87
Delacroix	Delacroix Local Road Link - Delacroix Hwy	4.43	4.90	4.84

The projected peak water surface elevations resulting from a Hurricane Isaac-like storm event for communities located on the north shore of Lake Pontchartrain, including Slidell and Mandeville, is approximately 3 ft at all key locations analyzed (Table 3). In Slidell, ADCIRC+SWAN results project that peak water surface elevations will increase by nearly 0.5 ft in Year 50 in a FWOA at all key locations analyzed. However, under a FWA in Year 50, the projected peak water surface elevations resulting from a Hurricane Isaac-like event are notably diminished or even eliminated in the case of the local high school, one local church, and a local marina. The high school and church exist in the downtown area of Slidell, away from Bayou Bonfouca and Bayou Liberty, each of which connect to the wetlands fringing Lake Pontchartrain.

Table 3. Peak water surface elevation (ft, NAVD88) for a Hurricane Isaac-like storm at key locations in Slidell, Louisiana

Community	Name	Initial Conditions (Year 0)	FWOA (Year 50)	FWA (Year 50)
Slidell	Bayou Liberty Marina	2.87	3.42	0.89
Slidell	Our Lady of Lourdes Church	2.89	3.34	N/A
Slidell	Salmen High School	2.86	3.34	N/A
Slidell	Slidell Local Road Link - Bayou Liberty Rd near Galatas Ln	2.86	3.40	0.98
Slidell	Slidell Municipal Marina at Heritage Park	2.85	3.40	N/A
Slidell	St Genevieve Church	2.89	3.44	0.89

As with Slidell, the ADCIRC+SWAN simulations for Mandeville from a Hurricane Isaac-like storm in Year 0 project peak water surface elevations of around 3 ft at all key locations examined (Table 4). This value is projected to jump nearly 0.5 ft by Year 50 in a FWOA. Under FWA conditions in Year 50, simulations show slight declines in peak water surface elevations relative to a FWOA.

Table 4. Peak water surface elevation (ft, NAVD88) for a Hurricane Isaac-like storm at key locations in Mandeville, Louisiana

Community	Name	Initial Conditions (Year 0)	FWOA (Year 50)	FWA (Year 50)
Mandeville	Fontainebleau State Park Visitors Center	3.08	3.64	3.28
Mandeville	Lakeshore Dr	3.11	3.67	3.30
Mandeville	Mandeville Evacuation Link - Florida St and Jackson Ave	3.11	3.67	3.30
Mandeville	Mandeville Local Road Link - Monroe St and Ramon St	3.17	3.72	3.36
Mandeville	West Lakefront Children's Park	3.11	3.67	3.30

To the west of the storm track within the 50 km buffer, ADCIRC+SWAN results show much lower peak water surface elevations than those expected to the east. In coastal Terrebonne Parish, most of the communities, including Dulac, Dularge, Chauvin, and Montegut, are located atop a number of distributary ridges. A Hurricane Isaac-like storm would be expected to generate between 1 to 2 ft of water surface elevation in Dulac at each of the key locations examined, including the Dulac Community Center (Table 5). Similar water surface levels would be expected to occur along the two roadways analyzed in Dulac, Grand Caillou Road and Shrimpers Row. However, ADCIRC+SWAN results

show that the Morganza to the Gulf project and other restoration and protection measures would reduce hurricane storm surge levels for all the key locations examined in Dulac (though some reductions are generally less than 3 in).

Table 5. Peak water surface elevation (ft, NAVD88) for a Hurricane Isaac-like storm at key locations in Dulac, Louisiana

Community	Name	Initial Conditions (Year 0)	FWOA (Year 50)	FWA (Year 50)
Dulac	Dulac Community Center	0.79	1.50	1.44
Dulac	Dulac Evacuation Link - Grand Caillou Rd	N/A	1.30	1.22
Dulac	Dulac Local Road Link - Shrimpers Row and Bayou Guillaume Rd	0.77	1.24	1.03
Dulac	Holy Family Catholic Church	0.75	1.24	1.05

Further west, lower peak water surface elevations than those expected in Dulac are projected for Amelia at all key locations examined in this analysis. In Year 0 and Year 50, ADCIRC+SWAN simulations show no water above surface in both key locations examined, the local library and elementary school (Table 6). At the one local road link examined, a water surface elevation of 0.4 ft at Year 0 is projected. In both a FWOA and a FWA, this value is projected to climb to approximately 0.9 ft at this location.

Table 6. Peak water surface elevation (ft, NAVD88) for a Hurricane Isaac-like storm at key locations in Amelia, Louisiana

Community	Name	Initial Conditions (Year 0)	FWOA (Year 50)	FWA (Year 50)
Amelia	Amelia Branch Library	N/A	N/A	N/A
Amelia	Amelia Local Road Link - Duhon Blvd	0.36	0.86	0.86
Amelia	J S Aucoin Elementary School	N/A	N/A	N/A

In the community of Delcambre, located west of the storm track beyond the 50 km buffer, ADCIRC+SWAN results project that the impacts of a Hurricane Isaac-like storm in Year 0 would be limited to the Bayou Carlin Cove, located on the Delcambre Canal, a location expected to experience less than 0.7 ft of water above surface (Table 7). Beyond the canal, model results show no anticipated flooding. By Year 50 in a FWOA, this value is projected to climb to just over 1 ft. In addition, ADCIRC+SWAN results indicate that a local road link located along East Main Street will experience a similar peak water surface elevation during a Hurricane Isaac-like storm in Year 50. In a FWA for Year

50, ADCIRC+SWAN simulations show that master plan actions would not be projected to notably reduce the water surface elevations that a Hurricane Isaac-like storm could generate in Delcambre.

Table 7. Peak water surface elevation (ft, NAVD88) for a Hurricane Isaac-like storm at key locations in Delcambre, Louisiana

Community	Name	Initial Conditions (Year 0)	FWOA (Year 50)	FWA (Year 50)
Delcambre	Bayou Carlin Cove Boat Landing	0.68	1.18	0.91
Delcambre	Delcambre High School	N/A	N/A	N/A
Delcambre	Delcambre Local Road Link - E Main St and S President St	N/A	1.18	0.90
Delcambre	Vermilion Parish Library - Delcambre Branch	N/A	N/A	N/A

Finally, in the community of Cameron, located in southwestern corner of the state, ADCIRC+SWAN results project that areas located atop the elevated chenier ridges, such as the local recreational facility, would not be expected to experience any flooding as the result of a Hurricane Isaac-like event in Year 0 (Table 8). Locations off the chenier ridges and along the local waterways are projected to experience less than 0.7 ft of water above surface as the result of a Hurricane Isaac-like storm in Year 0 (Table 8). By Year 50 in a FWOA, however, ADCIRC+SWAN simulations show that all key locations examined are projected to experience approximately 1 ft of water above surface. In a FWA in Year 50, planned protection and restoration actions in the 2023 Coastal Master Plan are not projected to alter these patterns.

Table 8. Peak water surface elevation (ft, NAVD88) for a Hurricane Isaac-like storm at key locations in Cameron, Louisiana

Community	Name	Initial Conditions (Year 0)	FWOA (Year 50)	FWA (Year 50)
Cameron	Cameron Clerk of Court	N/A	1.30	1.25
Cameron	Cameron Evacuation Link - LA27	N/A	0.95	0.94
Cameron	Cameron Ferry West Landing	0.67	1.13	1.13
Cameron	Cameron Parish Library	0.68	1.17	1.18
Cameron	Cameron Parish Recreation District No. 6 Facility	N/A	1.19	1.19

4.0 FLOOD DEPTH

The CLARA model was used to estimate flood depths associated with a Hurricane Isaac-like storm for initial conditions, a FWOA, and a FWA, all of which assumed S07 conditions. Results for initial conditions (Year 0), a FWOA (Year 50), and a FWA (Year 50) are presented below.

4.1 INITIAL CONDITIONS

CLARA simulations modeling the impacts of a Hurricane Isaac-like storm across the Louisiana coast largely follow the results of the storm surge and wave results, with impacts concentrated in communities in the Pontchartrain/Breton Region (Figure 6). Whereas the surge and wave results show inundation and water levels over both land and water, the CLARA results focus on flood depth over land surfaces. Isaac first made landfall over Plaquemines Parish, and CLARA results project that the greatest flood depths from a Hurricane Isaac-like storm in Year 0 will be centered on this parish. The expected flood depths are highest on the coastal side of the levee protecting the Braithwaite community, where expected depths are projected to exceed 20 ft. However, CLARA results also project that the community of Braithwaite will experience substantial flooding inside the levee system, with expected depths exceeding 10 ft. Many of the communities surrounding Lake Pontchartrain and Lake Maurepas are also projected to experience flood depths of greater than 10 ft, including parts of St. Tammany, Orleans, St. John the Baptist, and Tangipahoa parishes. Notably, CLARA results do not suggest overtopping of the HSDRRS levee system in these areas. Outside of the Plaquemines levee system, CLARA simulations show extensive expected flooding with parts of Plaquemines and Jefferson parishes projected to experience greater than 10 ft of expected flooding. To the west in the Barataria and Terrebonne regions, CLARA results show that parts of Lafourche and St. Charles parishes are projected to experience flood depths greater than 5 ft.

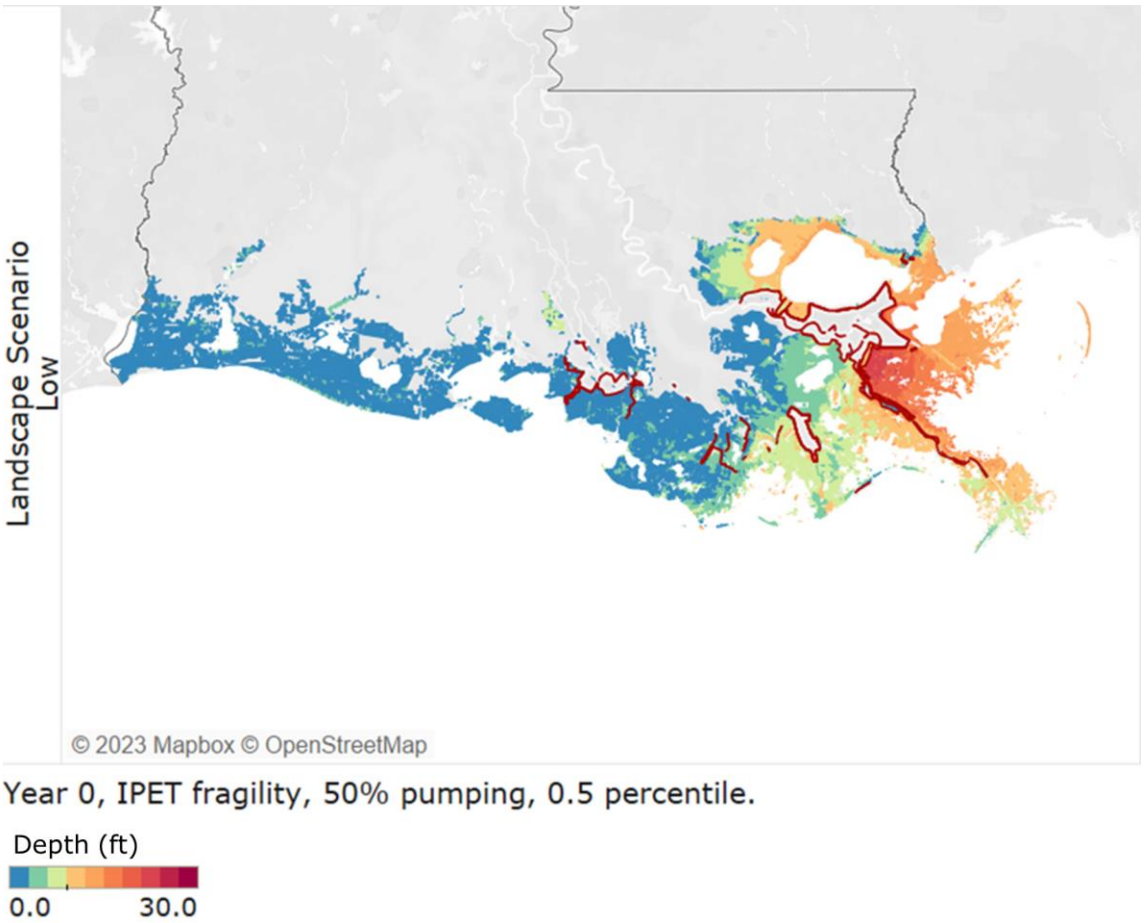

Figure 6. Modeled maximum future flood depth for a Hurricane Isaac-like storm simulated under initial conditions.

4.2 FUTURE WITHOUT ACTION

By Year 50 in a FWOA, CLARA results show that the water elevation patterns observed in Year 0 are expected to intensify, with maximum flood depths projected to increase throughout the Year 0 floodplain. These results mirror those observed in the ADCIRC+SWAN analysis. Most of the areas projected to experience flooding during a Hurricane Isaac-like storm event in Year 0 are expected to experience 1 to 2 ft increases in flood depth in Year 50 in a FWOA. Locations within the lower Terrebonne and lower Barataria regions around the location of the storm's second landfall are expected to see the greatest increases in flood depths, although the highest overall depths are expected to occur in the Pontchartrain/Breton Region to the east of the location of the storm's first landfall (Figure 7). In addition to increasing flood depths across the coast, CLARA simulations show

that the anticipated floodplain in a Hurricane Isaac-like storm in Year 50 in a FWOA is expected to expand more inland, encompassing much of the low-lying locations to the south and west of Lac Des Allemands. In this simulation, notable floodplain expansion is also anticipated to the west of the storm track, including locations in Iberia Parish to the northwest of Lake Verret and inland from the coast in Cameron and Vermilion parishes.

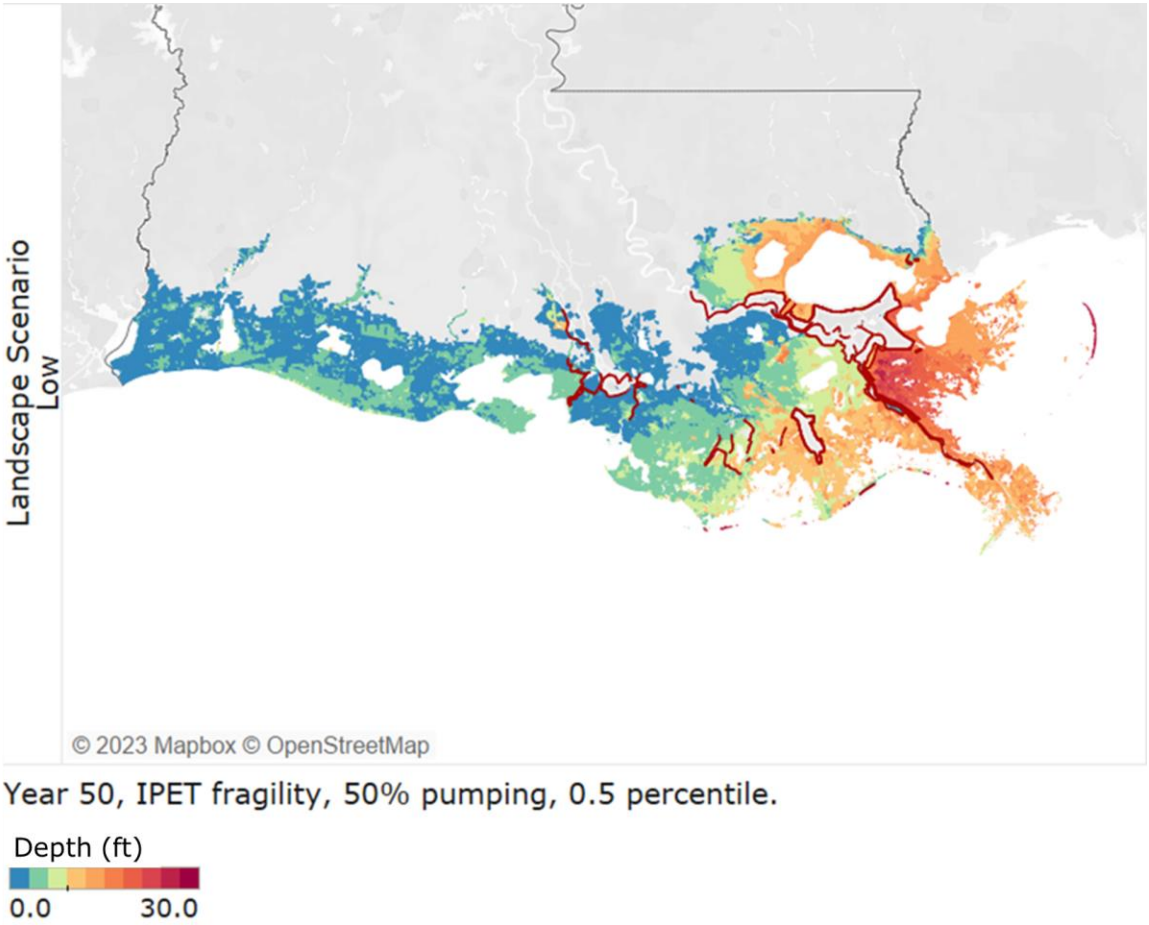

Figure 7. Modeled maximum future flood depth for a Hurricane Isaac-like storm simulated in the FWOA, S07, Year 50 with current levee alignments.

4.3 FUTURE WITH ACTION

In a FWA, CLARA results show that a Hurricane Isaac-like storm making landfall in Year 50 will result in lower flood depths than those observed in the FWOA simulation (Figure 8). While much of the anticipated expansion of the floodplain to the north of lakes Pontchartrain and Maurepas in a FWOA is

still observed in a FWA, the anticipated flood depths are projected to be reduced to levels observed in Year 0. Relative to the FWOA, CLARA results show reductions of 1 to 2 ft in expected flooding throughout parts of St. Charles and Lafourche parishes. However, simulations show that much of the western part of the coastline will see minimal to no difference in a FWA relative to a FWOA.

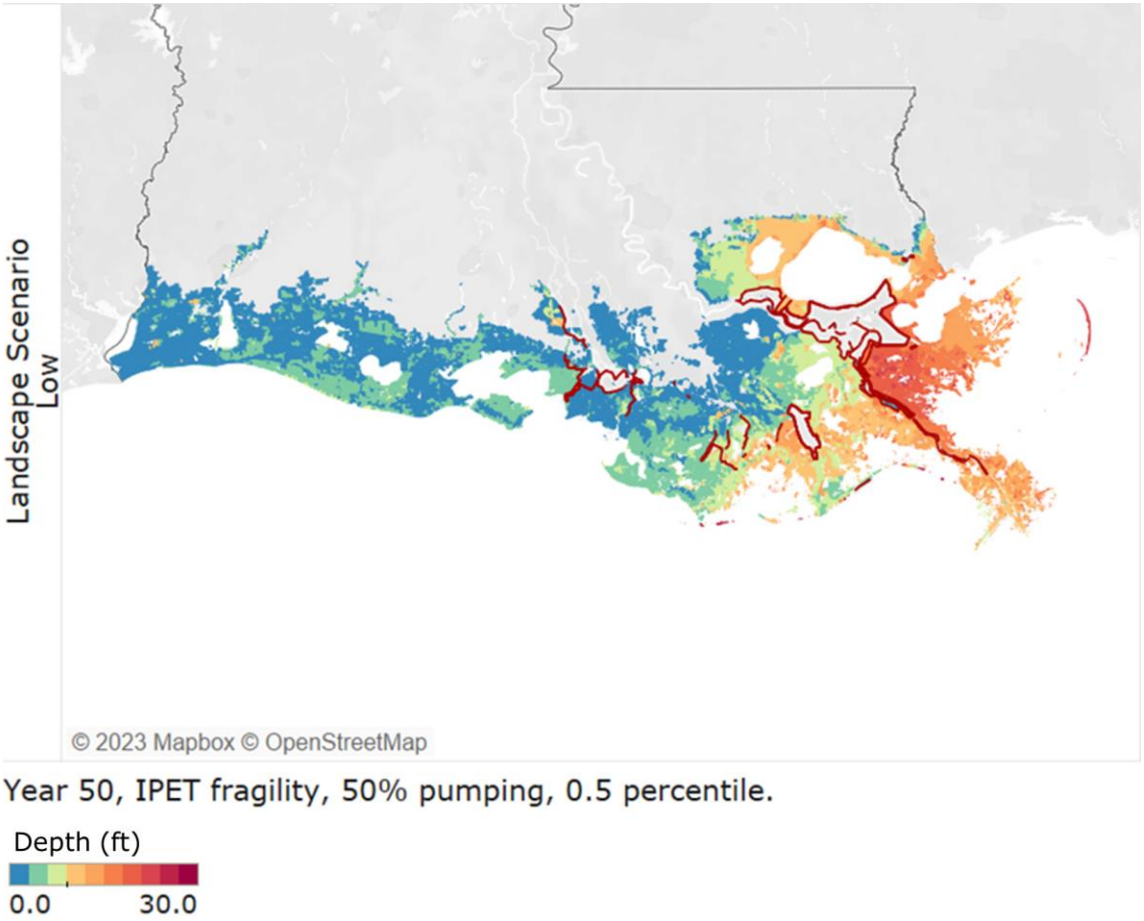

Figure 8. Modeled maximum future flood depth for a Hurricane Isaac-like storm simulated in the FWA, S07, Year 50.

5.0 DAMAGES

The CLARA model was used to estimate direct economic damage associated with a Hurricane Isaac-like storm for a FWOA and a FWA under S07 conditions. Results for Year 50 are presented below.

5.1 FUTURE WITHOUT ACTION

CLARA simulations for a Hurricane Isaac-like storm generally show that the distribution of economic damage is tied to the density of population and residential structures. Most future direct economic damage from flooding resulting from a Hurricane Isaac-like storm in Year 50 would be expected to be concentrated in the areas around lakes Pontchartrain and Maurepas (Figure 9). This includes New Orleans and New Orleans East, where flood depths are expected to be relatively minimal but in areas with a high density of development. It also includes communities like Slidell/Eden Isle/Pearl River and Mandeville/Covington/Madisonville/Abita Springs, where high expected flood depths combined with high property values can lead to extremely high damage estimates.

Additionally, CLARA results project high damage values from a Hurricane Isaac-like storm in Year 50 in a FWOA in both the upper Barataria Basin and the Terrebonne Region, with communities in the vicinity of Luling/Boutte and Houma expected to experience the highest damage values. High projected damages are expected in many communities around Terrebonne Bay, including the communities on the west bank of Bayou Lafourche in Lafourche Parish and many of the bayou communities south of Houma in Terrebonne Parish. CLARA simulations also project high expected damage at Port Fourchon due to the combination of flood depth and the high value of industrial infrastructure in the area.

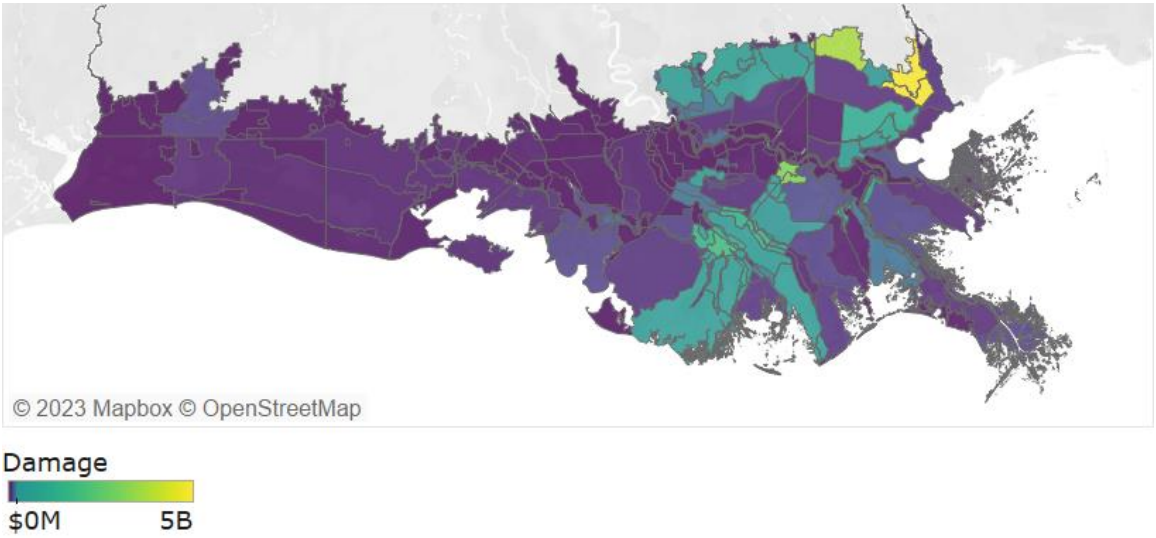

Figure 9. Modeled future economic damage for a Hurricane Isaac-like storm simulated in the FWOA, S07, Year 50.

5.2 FUTURE WITH ACTION

CLARA simulations show that planned protection and restoration actions in Year 50 in a FWA are expected to have minimal impact on reducing damage for the majority of communities affected by a Hurricane Isaac-like storm in a FWOA (Figure 10). However, these simulations project notable reductions in damage on the order of multiple billions of dollars in certain densely populated and highly developed North Shore communities. These communities include Slidell/Eden Isle/Pearl River and Mandeville/Covington/Madisonville/Abita Springs, as well as the River Parish community of Luling/Boutte on the west bank of the Mississippi River in the upper Barataria Basin (Figure 11). Lesser but notable reductions in damage are projected for Houma and the surrounding communities.

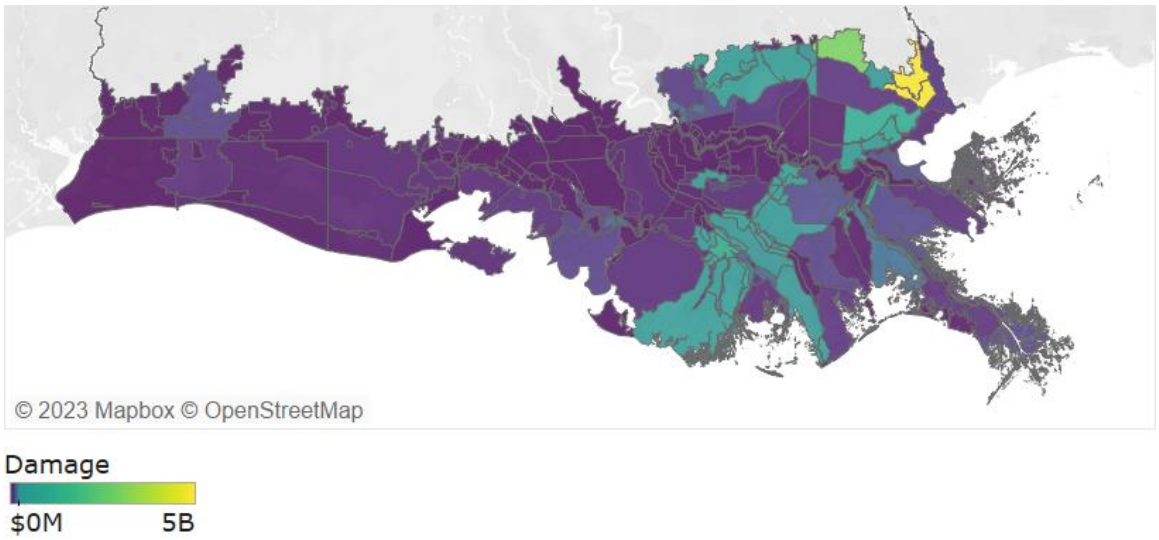

Figure 10. Modeled future economic damage for a Hurricane Isaac-like storm simulated in the FWA, S07, Year 50.

Figure 11. Change in modeled future economic damage between FWOA and FWA for a Hurricane Isaac-like storm simulated in S07, Year 50.

Coastwide, CLARA results show that planned protection and restoration actions would effectively reduce the total amount of future economic damage from a Hurricane Isaac-like storm by over $17.4 billion were a Hurricane Isaac-like storm to make landfall in Year 50 (Table 9). Reflecting the social and economic profile of the potentially impacted areas, the highest level of both damage and damage

reduction is expected to be in single family and other small residential units (e.g., manufactured homes and duplexes), followed by commercial and industrial structures.

Table 9. Modeled future asset damage and damage reduction from a Hurricane Isaac-like storm in S07, Year 50

	Small Residential	Large Residential	Commercial and Industrial	Public and Educational	Grand Total
FWOA (Year 50)	$29,457M	$599M	$9,025M	$1,703M	$40,784M
FWA (Year 50)	$16,579M	$321M	$5,744M	$716M	$23,360M
Reduction in Damage Between FWOA and FWA (Year 50)	$12,879M	$278M	$3,280M	$987M	$17,423M

Similar to the ADCIRC+SWAN results, CLARA simulations project that flood depth and damage resulting from a Hurricane Isaac-like storm event will show a large amount of spatial variation in community impacts across the coast (Table 10). Unlike the ADCIRC+SWAN results, however, CLARA damage projections show that the amount of expected economic damage is not purely a function of biogeophysical factors. The exposure of assets and associated economic damage is directly tied to the degree of human development and population exposed to flood impacts. Because the track of a Hurricane Isaac-like storm would first bring the storm onshore in the Mississippi River Bird's Foot Delta region of Plaquemines Parish, high damage levels would be expected to occur in communities along the large lakes to the east, including the North Shore communities of Mandeville/Covington/ Madisonville/Abita Springs and Slidell/Eden Isle/Pearl River. These are densely developed, resulting in high levels of expected damage in both Year 0 and in Year 50 in a FWOA. While CLARA results still project high overall damage values for these communities in Year 50 in a FWA, the presence of planned projection and restoration projects is expected to reduce the expected damage from a Hurricane Isaac-like storm by hundreds of millions to billions of dollars.

Beyond the highly developed North Shore area, CLARA simulations project lower damage levels, particularly in the more sparsely populated areas of the coast. In these locations, projected damages are generally lower due to a combination of reduced flood depths and less development. For example, the smaller communities of Amelia, Delacroix, and Dulac, located to the west of the storm track, are projected to experience flood damages that are multiple orders of magnitude below what is expected in the affected parts of St. Tammany Parish closer to where the storm made landfall. Planned protection and restoration measures implemented by Year 50 in a FWA are expected to have much smaller effects on reducing damage from a Hurricane Isaac-like storm in many of these smaller communities to the west.

Table 10. Modeled total damage and change in damage to select coastal communities from a Hurricane Isaac-like storm in S07

Community	Initial Conditions (Year 0)	FWOA (Year 50)	FWA (Year 50)	Delta Damage Between FWOA and FWA (Year 50)
Amelia	$6M	$6M	$6M	2%
Cameron	$43M	$60M	$59M	-1%
Delacroix	$31M	$8M	$8M	0%
Delcambre	$0M	$24M	$4M	-83%
Dulac	$41M	$183M	$166M	-9%
Grand Isle	$86M	$93M	$85M	-8%
Mandeville/Covington/Madisonville/ Abita Springs	$1,942M	$3,720M	$2,961M	-20%
Slidell/Eden Isle/Pearl River	$2,451M	$11,197M	$5,446M	-51%

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