2023 COASTAL MASTER PLAN

HIGH TIDE FLOODING REPORT

ATTACHMENT H3

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This document was prepared 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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EXECUTIVE SUMMARY

The 2023 Coastal Master Plan effort defines the term *high tide flooding* (HTF) as a localized coastal flooding event that occurs as a result of meteorological conditions and tides leading to increased water levels not due solely to fluvial, pluvial, or tropical storm surge flood conditions. The focus of the analysis described in this report is prediction of future HTF in coastal Louisiana communities and evaluation of its impacts. Impacts of tropical storm surge flooding are examined in depth in other components of the 2023 Coastal Master Plan and are therefore not included in this discussion.

Water levels and water level variability are influenced by many factors in coastal Louisiana, including underlying topography as well as natural processes such as river discharge, tidal fluctuations, winds and storms, and changes in sea level and anthropogenic alterations including dredging, subsurface fluid extraction, diversions, and flood control features (Hiatt et al., 2019). HTF events in coastal Louisiana are largely driven by synoptic (e.g., tropical storm surge) and mesoscale meteorological events (Kurian et al., 2009). These scales are large enough to produce conditions that lead to sustained onshore winds for a prolonged time period.

To understand how HTF occurrence may change in the future, a number of coastal Louisiana communities were assessed for HTF events and associated impacts. Community-based analyses were performed for eight coastal communities to determine vulnerability and consequences for communities in coastal Louisiana. In conjunction, water level outputs from the Integrated Compartment Model (ICM) were analyzed in comparison to observed data and deemed to be sufficiently accurate for a coastwide analysis which occurred on parallel paths. One method of analysis compared water level output from the ICM to local landmarks in eight focus communities to study how frequently they would be flooded by HTF over time. The other method of coastwide analysis created a road network dataset linked with databases of critical and essential facilities, drive times, and population density. Future HTF events were compared against these databases to compute how communities' drive times and access to critical and essential facilities would be impacted at present and in the future by HTF events.

The focus communities selected for the 2023 Coastal Master Plan were chosen to illustrate a variety of current and future vulnerability and consequence conditions and may not be representative of the full spectrum of conditions present in coastal Louisiana.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

3DEP	3D ELEVATION PROGRAM
ADCIRC	ADVANCED CIRCULATION (MODEL)
CLARA	COASTAL LOUISIANA RISK ASSESSMENT (MODEL)
CPRA	COASTAL PROTECTION AND RESTORATION AUTHORITY
CRMS	COASTWIDE REFERENCE MONITORING SYSTEM
DEM	DIGITAL ELEVATION MODEL
EMS	EMERGENCY MEDICAL SERVICES
FWOA	FUTURE WITHOUT ACTION
GIS	GEOGRAPHIC INFORMATION SYSTEMS
HTF	HIGH TIDE FLOODING
ICM	INTEGRATED COMPARTMENT MODEL
LERN	LOUISIANA EMERGENCY RESPONSE NETWORK
MHHW	MEAN HIGHER HIGH WATER LEVEL
MWL	MEAN WATER LEVEL
NLCD	NATIONAL LAND COVER DATASET
NOAA	NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
OSM	OPEN STREET MAP
QA/QC	QUALITY ASSURANCE/QUALITY CONTROL
RMSE	ROOT MEAN SQUARE ERROR
SLR	SEA LEVEL RISE
USGS	UNITED STATES GEOLOGICAL SURVEY
WSE	WATER SURFACE ELEVATION

1.0 INTRODUCTION

This report characterizes the predicted frequencies and impacts of high tide flooding (HTF) on eight coastal communities in Louisiana using model outputs from Louisiana's 2023 Coastal Master Plan. The analysis detailed herein was performed to assess and provide information regarding the risks and impacts of HTF. The communication of risks and impacts in this manner is intended to serve as a complimentary communication tool to the 2023 Coastal Master Plan's analysis of projected coastwide land change and tropical storm flood impacts.

The term HTF has been used interchangeably with other terms such as "tidal flooding," "sunny day flooding," "chronic flooding," and "nuisance flooding" (e.g., Moftakhari et al., 2017; Dahl et al., 2017; Sweet, Dusek, et al., 2018; Spanger-Siegfried et al., 2014; Union of Concerned Scientists, 2018). HTF is associated with impacts to routines and daily life that are short-lived and less catastrophic than infrequent tropical storm impacts. In all cases, the terms above are used to describe tidal flooding events caused by phenomena other than tropical storms. The 2023 Coastal Master Plan defines the term HTF as localized coastal flooding events that occur as a result of meteorological conditions and tides leading to increased water levels not due solely to fluvial, pluvial, or tropical storm surge flood conditions. HTF in coastal Louisiana is largely driven by synoptic (e.g., tropical storm surge; ~100s to 1,000 km) and mesoscale meteorological events (~10s to 100s km; Kurian et al., 2009) such as extratropical storms, cold fronts, and mesoscale convective systems. This report focuses on mesoscale events.

The National Oceanographic and Atmospheric Administration (NOAA) has conducted HTF analysis on a national scale, and releases annual predictions of HTF frequency at a large number of its active tide gauge locations (Sweet et al., 2021). NOAA predicts HTF frequency (in days per year) at select intervals to 2050 based on sea level rise (SLR) projections. These analyses have observed increases in HTF at 80% of study locations along the Gulf and East coasts (Sweet, 2020; Sweet et al., 2017, 2019, 2021; Sweet, Marcy, et al., 2018). Since NOAA's annual analysis is intended for large areas of the coastal United States, there are local phenomena beyond SLR alone which could impact the frequency and magnitude of HTF events in Louisiana. HTF is largely dependent on both climate and the landscape topology. Thus, a change in the climate and resulting evolution of the landscape will influence water levels throughout the coastal plain. Surface processes contributing to landscape evolution include but are not limited to subsidence, surface erosion of muddy fine-grained sediments, and anthropogenic activities. The 2023 Coastal Master Plan predicts these processes will continue to degrade the Louisiana coastline and exacerbate HTF. NOAA's analysis, however, was used as a basis of comparison between three coastal communities in Louisiana (Cameron, Grand Isle, and Slidell) to establish the threshold conditions for when HTF may begin to occur.

HTF analysis for the 2023 Coastal Master Plan occurred in three phases. In Phase 1 of this analysis, predictive modeling tools used in the master plan effort were evaluated for appropriateness for predicting future conditions related to HTF. The 2017 Coastal Master Plan version of the Integrated Compartment Model (ICM) and ADvanced CIRCulation (ADCIRC) models were tested for their ability to capture selected historic events that impacted the assessed communities. Phase 2 of this analysis used the model investigation's findings to develop a simplified community-based approach using adjusted water level output data from the ICM to reflect high tide events. The simplified approach was designed as a proof-of-concept for road network analyses with hydrodynamic data from the 2017 version of the ICM since the same data types and formats were expected to be available from the 2023 Coastal Master Plan.

For the 2023 Coastal Master Plan (Phase 3 of the analysis), a hybrid approach was used in which both the frequency of exceedance of local impact thresholds and the impacts to connectivity between communities and critical and essential facilities were examined using 2023 ICM outputs. This analysis was used to project flood inundations relative to local landmarks of interest from community stakeholders and to the local road networks surrounding the eight focus communities. The document is organized into the following main sections:

- An overview of the methods used in the hydrodynamic analysis of HTF frequency versus local impact thresholds and generation of representative HTF surfaces in support of the facility access network analysis (Section 2.0).
- An overview of the methods used for the facility access network analysis (Section 3.0).
- An attachment containing all graphical and geospatial results of the network analysis, along with a vignette image for each community, noting locations of interest and predicted frequency exceedance (Attachment 1).
- A technical attachment with plots and data in support of the hydrodynamic analysis (Attachment 2).

This analysis does not include the near- or far-field signatures of tropical storms in its water surface elevation (WSE) data.

1.1 GLOSSARY OF TERMS

A series of terms are used frequently throughout this report. While these terms are defined in the text, this glossary is intended to serve as a reference to provide the reader with specific definitions for the terminology as used in this report.

Critical facilities: Facilities that are considered important for short-term response operations, including those used for public safety purposes, medical services, and infrastructure maintenance.

Disruption: A reduction of physical, social, or administrative infrastructure functioning within an affected area where normal routines will no longer be supported or maintained.

Essential facilities: Facilities that are considered important for long-term recovery, including those that provide basic necessities for residents (e.g., banks and credit unions, gas stations, and grocery stores) or serve government functions.

Focus Communities: Communities with nearby WSE data and the potential for future land loss and inundation as predicted in the 2023 Coastal Master Plan, and that together represent spatial distribution across coastal areas currently experiencing HTF.

High Tide Flooding (HTF): Localized coastal flooding that occurs because of meteorological conditions and tides leading to increased water levels not due solely to fluvial, pluvial, or tropical storm surge flood conditions.

Impact Threshold: The critical WSE at which a community will begin to be negatively impacted due to HTF (e.g., defined by the top of a levee).

Integrated Compartment Model (ICM): The master plan's hydrodynamic and geomorphologic predictive modeling suite used for HTF analysis.

Mean Water Level (MWL): Average background WSE before an event (i.e., sea level).

Metrics: Qualitative and/or quantitative measures of disruption and damage resulting from HTF events (i.e., consequences).

Water Surface Elevation (WSE): Water level relative to a reference elevation (such as NAVD88).

WSE Threshold: Water elevation from observed WSE data that is noticeably higher than the average tidal waters yet below extremes during a tropical storm surge event; used as a proxy for evaluating potential HTF.

2.0 LOCATION AND IMPACT THRESHOLD CHARACTERIZATION

To understand how HTF occurrences may change in the future, eight coastal Louisiana communities (termed *focus communities* herein) were selected for assessment of HTF occurrence and associated impacts (Figure 1).

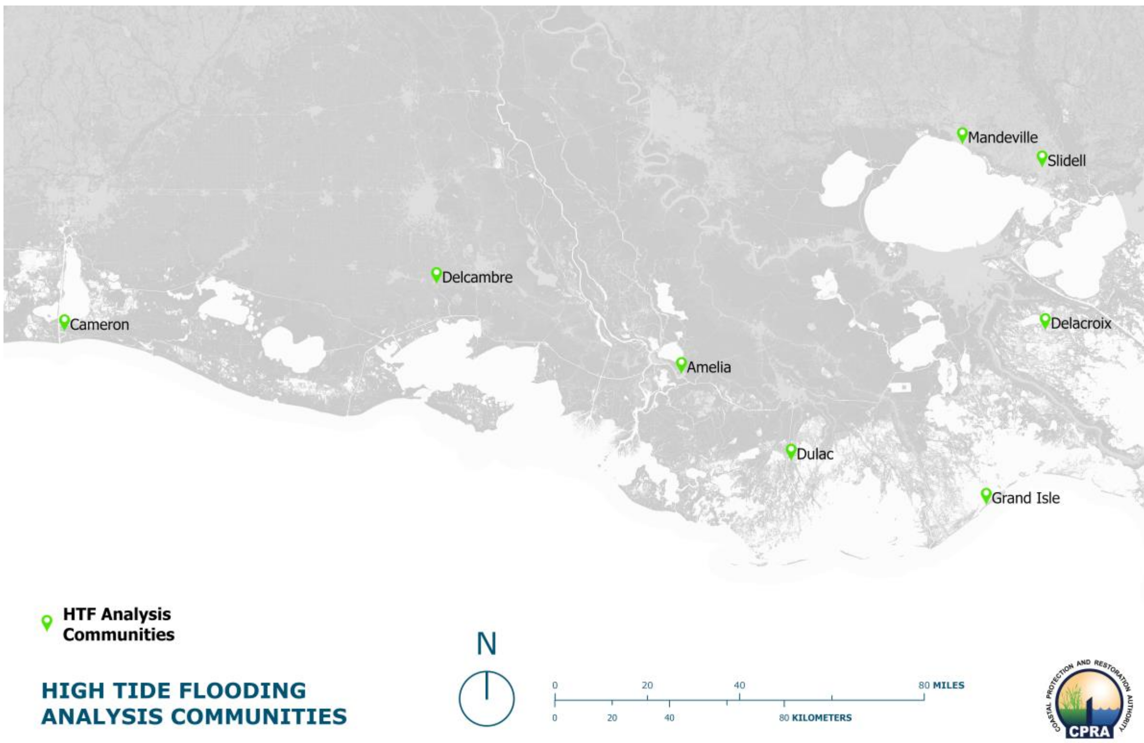

Figure 1. Eight focus communities (green markers) were selected for the master plan HTF analysis.

Focus communities were selected based on available information (Table 1) and several other factors, including:

- Spatial distribution throughout coastal Louisiana.
- Evaluation in previous or other ongoing studies (e.g., 2017 Coastal Master Plan analysis [Clipp et al., 2016; CPRA, 2017; Hemmerling & Hijuelos, 2016)], community resilience work by The Water Institute [Carruthers et al., 2017; Hemmerling et al., 2020].

- Confirmed HTF events (e.g., from analysis of coastal flood advisories, examination of feasibility and engineering design studies at CPRA, and research of news and social media outlet postings).
- Availability of nearby WSE data from continuous observation stations, which is necessary to quantitatively examine HTF events and impact thresholds.
- The potential for future land loss and future inundation within communities, based on predictive model output from the 2023 Coastal Master Plan.
- Proximity to critical and essential facilities.
- Presence of critical and essential facilities within the community.
- Number and type of roadways connecting the community to the surrounding region.

Table 1. Focus communities selected for Phase 2 of HTF community-based analysis

COMMUNITY NAME	CENSUS DATA	WSE OBSERVED DATA AVAILABILITY
AMELIA	U.S. CENSUS BUREAU (2020): • POPULATION - 2,236 • MEDIAN HOUSEHOLD INCOME - $34,957 • POVERTY RATE - 21.2%	• CRMS STATIONS (CRMS0403-H01, CRMS5035-H01) • USGS STATION AT BAYOU BOEUF AT RAILROAD BRIDGE AT AMELIA, LA (USGS 073814675) • NOAA STATION AT BERWICK, ATCHAFALAYA RIVER, LA (NOAA 8764044)
CAMERON	U.S. CENSUS BUREAU (2020): • POPULATION - 219 • MEDIAN HOUSEHOLD INCOME - $48,370 • POVERTY RATE - 29.6%	• CRMS STATIONS (CRMS0645-H01, CRMS1738-H01) • USGS AT CALCASIEU RIVER AT CAMERON, LA (USGS 08017118) • NOAA STATION AT CALCASIEU PASS, LA (NOAA 8768094)
DELACROIX	U.S. CENSUS BUREAU (2020): • POPULATION - 48 • PER CAPITA INCOME - $16,238 • POVERTY RATE - 0.0	• CRMS STATION (CRMS0146) • ICM (2023 MASTER PLAN) COMPARTMENT 110
DELCAMBRE	U.S. CENSUS BUREAU (2020): • POPULATION - 2,079 • MEDIAN HOUSEHOLD INCOME - $41,471 • POVERTY RATE - 23.3%	• CRMS STATIONS (CRMS0531-H01, CRMS0511-W01, CRMS0532-H01) • USGS STATION AT VERMILION BAY NEAR CYPREMORT POINT, LA (USGS 07387040)
DULAC	U.S. CENSUS BUREAU (2020): • POPULATION - 798 • MEDIAN HOUSEHOLD INCOME - $32,122 • POVERTY RATE - 28.1%	• CRMS STATIONS (CRMS0390-H01, CRMS0392-H01, CRMS0434-H01)

COMMUNITY NAME	CENSUS DATA	WSE OBSERVED DATA AVAILABILITY
GRAND ISLE	U.S. CENSUS BUREAU (2020): • POPULATION - 672 • MEDIAN HOUSEHOLD INCOME - $43,333 • POVERTY RATE - 25.9%	• CRMS STATION (CRMS0178-H01) • NOAA STATION AT GRAND ISLE, LA (NOAA 8761724)
MANDEVILLE	U.S. CENSUS BUREAU (2020): • POPULATION - 12,567 • MEDIAN HOUSEHOLD INCOME - $76,768 • POVERTY RATE - 9.23%	• CRMS STATION (CRMS4094-H01)
SLIDELL	U.S. CENSUS BUREAU (2019): • POPULATION - 27,633 • MEDIAN HOUSEHOLD INCOME - $42,856 • POVERTY RATE - 11.8%. • EDEN ISLE POPULATION - 7,041 • EDEN ISLE MEDIAN HOUSEHOLD INCOME - $53,811 • EDEN ISLE POVERTY RATE - 9.8%	• USGS STATION AT BAYOU LIBERTY NEAR SLIDELL, LA (USGS 07374581) • USGS STATION AT RIGOLETS AT HWY 90 NEAR SLIDELL, LA (USGS 301001089442600) • CRMS STATIONS (CRMS3667-H01, CRMS4407-H01, CRMS6088-H01, CRMS6090-H01)

2.1 PROJECTING FUTURE HTF AT SELECT LOCATIONS

Traditional flood risk analysis often uses impact thresholds — for instance, the top of a levee, dune, or critical feature protecting an area — to calculate the likelihood of overtopping of the lowest threshold elevation and project the anticipated frequency of overtopping. This process can then be used to produce statistical estimates such as annual exceedance probabilities. It can also enable projections into the future by tracking how often limits are exceeded. Over time, as subsidence, land loss, and SLR affect water levels, the frequency with which impact thresholds are crossed may increase.

DEFINITION OF IMPACT THRESHOLDS AND CONSEQUENCES

The HTF analysis focused on consequences that can be reasonably predicted when HTF events exceed impact thresholds into the future. Rather than focus on a single impact threshold per focus community (such as a berm or bulkhead low spot), the master plan team chose a twofold approach as detailed in the following two subsections.

FREQUENCY OF LOCAL THRESHOLD EXCEEDANCE

This analysis looks at how often (in days per year) WSEs modeled in the ICM would exceed or be higher than the elevations of local points of interest. Louisiana Sea Grant extension agents provided the master plan team with a list of local landmarks known to the eight focus communities. A compilation of these locations for each community can be found in Table 2 below. The list of local threshold locations was not intended to be exhaustive; rather, it was intended to be illustrative of a spectrum of locations and elevations, some of which may never have experienced HTF to date or may only expect infrequent flooding in the future. Elevations were extracted from the initial conditions digital elevation model (DEM) used by the master plan where possible. Due to the DEM's resolution, it was sometimes possible that a feature was not captured or improperly interpolated to pixel elevations. For example, some features such as narrow flood protection berms may be narrower than the minimum DEM pixel width and not represented in the DEM. As such, all features were spot checked for quality against the United States Geological Survey's (USGS's) 3D Elevation Program (3DEP) data. Elevations were adjusted based on master plan subsidence rates for Years 25 and 50, which is discussed further in Section 3.0.

FACILITY ACCESS NETWORK ANALYSIS APPROACH

A network analysis approach characterizes the consequences of HTF in the form of the community's ability to access critical and essential facilities (hospitals, emergency services, grocery stores, and pharmacies, etc.) during HTF events. In this way, all low-lying areas of the transportation network are accounted for and can be considered in the same way as impact thresholds. For this approach, DEMs and hourly WSE data from the 2023 ICM (future without action [FWOA], lower scenario [S07] simulation) were compared to published NOAA HTF data, checked to determine if adjustments were needed based on observed data from nearby stations, and then used to generate flood depths over the roadway system with Esri ArcGIS (GIS) software. Depths were generated for Years 0, 25, and 50 to predict disruption to access and drive times to critical and essential facilities. Further discussion of the approach to generate the WSE and depth information can be found in Section 3.0. Further discussion of how WSEs were applied to the landscape to investigate drive times between facilities within the road network is provided in Section 3.2.

Table 2. Local impact threshold locations across focus communities

COMMUNITY	LOCATION	PRESENT-DAY ELEVATION IN FT, NAVD88
AMELIA	LEVEE LOW POINT - SEA GRANT SURVEY	3.0
AMELIA	CASINO PARKING LOT	6.5
CAMERON	CAMERON FERRY WEST LANDING	2.9
CAMERON	EVACUATION LINK - LA27	3.0

COMMUNITY	LOCATION	PRESENT-DAY ELEVATION IN FT, NAVD88
DELACROIX	DELACROIX ISLAND PIER	6.0
DELACROIX	EVACUATION LINK - DELACROIX HWY.	2.9
DELCAMBRE	BAYOU CARLIN COVE BOAT LANDING/SEAFOOD MARKET	4.0
DELCAMBRE	LOCAL ROAD LINK - E MAIN ST. AND S PRESIDENT ST.	2.6
DULAC	DULAC COMMUNITY CENTER PARKING LOT	1.6
DULAC	LOCAL ROAD LINK - SHRIMPERS ROW AND BAYOU GUILLAUME RD.	2.0
GRAND ISLE	LOUISIANA WILDLIFE AND FISHERIES RESEARCH LAB	2.7
GRAND ISLE	EVACUATION LINK - LA1	3.8
MANDEVILLE	WOODLAKE ELEMENTARY	3.0
MANDEVILLE	MANDEVILLE SEAWALL GRAVITY DRAINAGE OUTFALLS	3.5
SLIDELL	LOCAL ROAD LINK - BAYOU LIBERTY RD. NEAR GALATAS LN.	2.0
SLIDELL	BAYOU LIBERTY MARINA	3.6

2.2 IDENTIFYING AND DEFINING METRICS AND CONSEQUENCES

For the purposes of this HTF analysis, *critical facilities* are defined as those considered important for short-term response operations, while *essential facilities* are defined as those considered important for long-term recovery of the community (Hemmerling et al., 2017). Critical facilities include those used for public safety purposes, medical services, and infrastructure maintenance, while essential facilities include those that provide for basic necessities or serve government functions (Wood, 2007).

While the categories described above can be useful for communicating the potential extents and magnitudes of HTF, the specific impact thresholds must be defined locally. For example, the analysis makes clarifying assumptions about the average height of the tailpipe or chassis of vehicles for the purpose of understanding at what point vehicles flood, but it is necessary to understand the ground elevation and elevation of infrastructure such as roads to fully understand impacts.

Here, impacts are considered a function of the disruption of access to critical essential facilities and residential locations from HTF, with a focus on two aspects of facility location that are key to examining the local impacts of HTF: access and service coverage. *Access* broadly refers to the ease of residents reaching a critical or essential facility or, in the case of emergency response, the ease of first responders reaching the place where an emergency occurs (Yao et al., 2019). The question of access becomes critical during flood events when key thoroughfares or streets may become impassable. *Service coverage* is related to the maximum influence area of a facility defined by either spatial distance or travel time. Coverage models usually involve a service standard reflecting the spatial extent that communities can be reached from at least one facility.

Travel time between residents and facilities is a critical factor in calculating accessibility. Many indicators are used to represent travel distance, such as straight-line/Euclidian distance, shortest network distance, and travel time (Gao et al., 2016). In terms of coverage standard, previous studies have indicated that straight-line distance can be a satisfactory surrogate of network travel time, and this has been commonly adopted in fire station siting (Yao et al., 2019). To assess the local impacts of HTF, however, straight line distance is not an adequate measure for service coverage of a facility due, in large part, to the local, neighborhood-scale impacts of street flooding on accessibility. This analysis therefore utilized travel time to assess both access and service coverage. Travel time is dependent on road infrastructure, transport mode, and area topography. This analysis, coupled with the frequency estimation for local landmarks, is intended to inform residents and stakeholders of the consequences and frequency of HTF that may be expected currently and in future decades.

3.0 ANALYSIS METHODOLOGY

This analysis seeks to address two questions:

1. How often could HTF occur at given points of interest in Years 0, 25, and 50 of the master plan?
2. What are the potential consequences of HTF on community access to critical and essential facilities?

To address these two questions, ICM output was mined and analyzed for utility in predicting HTF within the coastal Louisiana landscape. To answer the first of the two questions, the maximum stage from each day of the ICM's hourly outputs was extracted to create a timeseries of WSE data to compare to the elevations of local landmarks, and the number of exceedances were summed. To answer the second of these questions, WSEs were produced based on a correlation of NOAA's present day HTF frequency predictions to a statistical water level across coastal Louisiana to create coastwide HTF surfaces over time. These surfaces were overlain on the road network, and a network analysis algorithm was run in geospatial software to compute all the possible routes and drive times between locations.

A community-based analysis involves predicting HTF events, defining a small number of meaningful impact thresholds, and evaluating outcomes specific to those locations. However, a network analysis measures consequences of innumerable potential locations of threshold exceedance (via roadway flooding) within a domain. Various thresholds in proximity to a given geographic location may flood at different periods within a larger inundation event and have different frequencies of exceedance. Ideally, a larger probabilistic analysis of water levels associated with HTF could be constructed and coupled with the network analysis; however, this would require a large computational effort due to the need to avoid preemptively limiting the domain available for the network analysis to route around flooded paths by removing areas of the roadway network to increase computational speed. Thus, the number of network analysis runs was limited by computational run time and was decoupled from the frequency analysis. The frequency analysis was intended to provide residents and stakeholders with accompanying information on what flood consequences may be, but also, how often they may occur relative to local landmarks.

A generalized workflow for the complete HTF analysis for the 2023 Coastal Master Plan is shown in Figure 2. 2023 Coastal Master Plan FWOA production run data were used for the analysis. Section 3.1 summarizes the analysis which occurred in support of the left side of the workflow in Figure 2 below (establishment of frequency analysis of threshold exceedance and generation of a coastwide WSE representative of HTF to pass to the network analysis). Network analysis methods are discussed later in Section 3.2 and are described in the right side of the workflow in Figure 2.

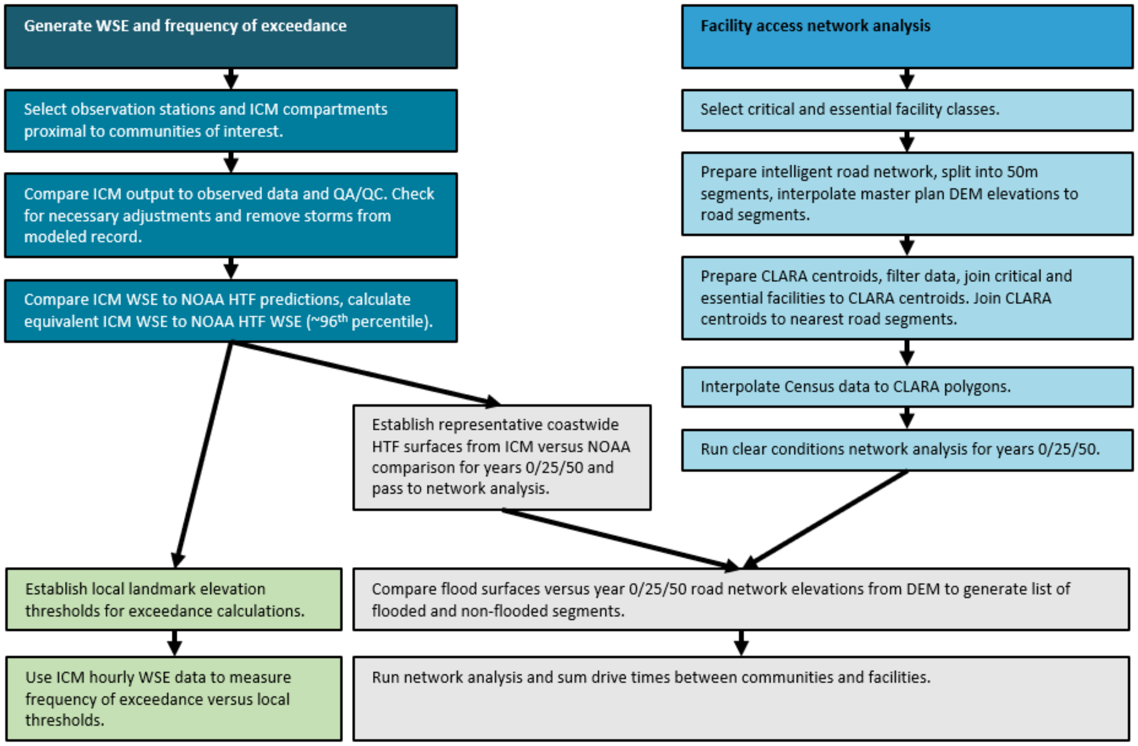

Figure 2. HTF analysis workflow.

3.1 WSE AND FREQUENCY EXCEEDANCE ANALYSIS

The present-day events that can lead to local HTF threshold exceedance consist of acute meteorological events. The ICM was intended to and is capable of modeling hydrological response to tides, sea levels, precipitation, and river hydrographs on a multi-decadal scale rather than on an acute scale over which many HTF events occur in coastal Louisiana. The effects of strong winds on water surfaces within the ICM are only captured at an offshore boundary, not interior to the model's domain in estuarine systems where communities are located (White & Reed, 2023). As HTF typically lasts hours rather than weeks or years, the resolution of the timestep used for WSE outputs was important and warranted investigation for appropriateness for use when investigating acute meteorologic phenomena. It was unknown how well the ICM would be able to represent some of the localized effects of wind, bathymetry, and topography that often combine to drive HTF in coastal Louisiana. ICM WSE outputs were compared to observed data to determine if any adjustment to WSE outputs was required (and ultimately, adjustments to outputs were deemed unnecessary). The ICM model operates on a 30-second timestep and is calibrated to daily mean WSE values; however, not every compartment is individually calibrated. Thus, the master plan team determined that an approach for generating acceptable water level predictions for HTF analysis should:

- Select a single observation station and a single ICM compartment's output as most representative of the local hydraulics and hydrology of each of the eight focus communities.
- Perform quality assurance/quality control (QA/QC) on the modeled data to ensure an appropriate ICM compartment was selected, then compare between modeled and observed data due to the lack of internal wind forcing in the model domain. ICM hourly WSE output was used to extract and create a daily maximum stage timeseries for the frequency of exceedance analysis.
- Then, if warranted, account for wind by using overlapping periods of both ICM projections and observed data to generate necessary adjustment factors for each ICM compartment's data near a community. The early years of ICM output (2019 – 2020) were used in conjunction with overlapping observed years to examine the correlation between observed water levels and ICM simulated water levels.
- Once ICM output was deemed acceptable, ICM present-day predictions for WSEs were compared to NOAA's present-day predictions for HTF to determine which statistical coastwide water level from the ICM was comparable to NOAA's threshold for the initiation of HTF (which is generally considered to be 1.75 ft above the mean higher high water level [MHHW]; Sweet et al., 2021). Coastwide, this equated to, on average, the 96th percentile WSE as predicted in the ICM for present-day conditions.
- At this stage, as shown in Figure 2, the workflow bifurcates. For threshold exceedance analysis, the WSE timeseries from hourly ICM output at Years 0, 25, and 50 of the master plan was compared to the Year 0, 25, and 50 elevations of thresholds, which were adjusted for subsidence based on 2023 Coastal Master Plan subsidence rates (Fitzpatrick et al., 2021; the ICM WSE timeseries inherently already accounted for SLR). For network analysis, a static coastwide 96th percentile WSE raster was generated to serve as a representative HTF condition upon which network analysis could be performed at Years 0, 25, and 50.

The following subsections describe each of the steps summarized above in further detail.

SELECTION OF ICM COMPARTMENTS AND OBSERVATION STATIONS PROXIMAL TO FOCUS COMMUNITIES

The initial step in the analysis was to perform reviews of community locations relative to proximal observation stations and the ICM. ICM WSEs are the basis of the analysis; however, there are certain limitations of the ICM as discussed in the *Phase I Model Improvement Plan* report (Bienn et al., 2021). Table 3 shows ICM compartment data considered for each community and lists in bold text which ICM compartment provided the WSE data used for the analysis, as well as the observation stations considered for each community. This list of compartments per community was generated by overlaying the ICM compartments on the eight focus communities. Each community was assigned a representative ICM compartment with a WSE timeseries and a representative observed WSE station.

In some cases, community polygons extend beyond the morphological domain of the ICM and into upland or inland areas where the model was not capable of predicting geomorphologic change or full water surface response. For those communities, such as Delcambre, which are located within upland ICM compartments, a proximal coastal ICM compartment was selected and its WSE timeseries data used instead. These cases were considered on an individual basis and the most appropriate ICM compartment was assigned to each community based on hydrologic behavior of the compartment, which may not have been immediately adjacent to the community. A full series of figures noting each focus community, proximal ICM compartments, and proximal observation stations can be found in Attachment 2. Figure 3 depicts ICM upland compartments relative to the focus communities (note that the locations of Mandeville, Slidell, and Delcambre are within ICM upland compartments).

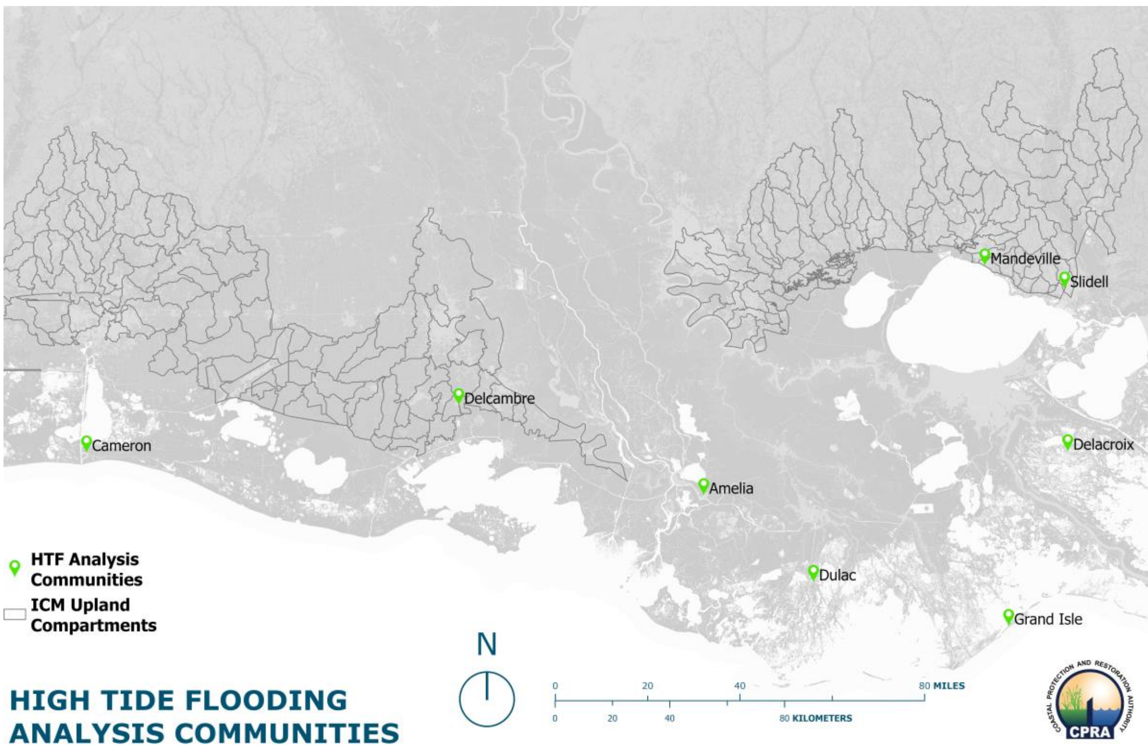

Figure 3. ICM upland compartments relative to the eight focus communities.

Table 3. Observation stations considered for the analysis (**bolded** stations used for analysis)

COMMUNITY	OBSERVED WSE DATA AVAILABILITY	ICM COMPARTMENT DATA AVAILABILITY	NOTES
AMELIA	• **CRMS 5035**, 403 USGS 073814675	526, 590, 591, **626**, 640, 890, 891, 901	RIVERINE DOMINATED, VERY LITTLE TIDAL SIGNAL
CAMERON	• USGS 08017118 (CALCASIEU RIVER AT CAMERON) • **NOAA 8768094 (CALCASIEU PASS)**	1016, 1017, 1018, 1021, 1022, 1025, 1029, 1060, 1061, 1194, **1342**, 1350, 1355, 1356, 1357	NEARBY CRMS SITES ARE IN IMPOUNDED; MARSH AREAS FAR FROM THE TOWN; WANG, 2019; WHEAT, 2016
DELACROIX	• USGS 073745257 • **CRMS 0146**	100, 101, 109, **110**, 122, 123	NOAA AND USGS COLLOCATED STATION DATA ON AVAILABLE FROM 2016-10-04 TO 2022-03-17
DELCAMBRE	• CRMS 0511, **0531** • USGS 07387040	398, 765 ,**778**, 846, 933, 951, 959, 960, 1586, 1596	RIVERINE DOMINATED, VERY LITTLE TIDAL SIGNAL
DULAC	• DISCONTINUED NOAAA • USGS 07381349 (CAILLOU LAKE SW OF DULAC, LA); USGS 07381324, 07381328 • **CRMS 0434**; 0369	464, 470, 514, 691, 695, **912**, 922	
GRAND ISLE	• NOAA 8761724 (GRAND ISLE, LA) • USGS 073802516 (BARATARIA PASS AT GRAND ISLE, LA) • **CRMS 0178**	221, **223**, 250, 315, 316	USGS STATION STAGE DATA ONLY FROM 2012-10-01 TO PRESENT
MANDEVILLE	• CRMS0006 LOCATED IN BIG BRANCH MARSH NWR • **CRMS4094** - AT MOUTH OF TCHEFUNCTE RIVER • USGS 301200090072400 L PONTCHARTRAIN AT CROSSOVER 4 NEAR MANDEVILLE, LA	**36**, 37, 38, 1507, 1619, 1653, 1620	USGS DATA ONLY AVAILABLE FROM 2016-05-04 TO PRESENT
SLIDELL	• NOAA 8761402 (THE RIGOLETS, LA) • USGS 02492700, 07374581, 301001089442600 • CRM 6090, 6088, 0035, 3626, 0002; **3667**	42, 45, 46, 47, **375**, 1516, 1645, 1646, 1625	NOAA STATION DATA NO LONGER AVAILABLE ONLINE. USGS STATION DATA ONLY AVAILABLE FROM 2016-10-04 TO PRESENT

QA/QC OF OBSERVED AND MODELED DATA

Since not every ICM compartment was calibrated, early years of each ICM compartment's timeseries output (2019 – 2020) were plotted to ensure model artifacts or unexpected behaviors, as well as local issues such as impoundments, were identified. From this process, the single representative ICM compartment was confirmed as the best representative to correspond to each of the focus communities. Figure 5 and Figure 6 below provide an example of this exercise. The remainder of these plots can be found in Attachment 2.

The timeseries obtained from the observed data were checked for data gaps (found in many cases to be a product of storm damage to the observation station) and/or datum shifts. In events where multiple observation stations were available to be used for a community, the datasets were compared for quality and completeness, and a single representative observation location was used. In general, CRMS stations were favored due to tidal and terrestrial datum reporting consistency. Figure 4 and Figure 5 depict the ICM compartment locations and observed data locations used for the example community of Delacroix. Delacroix, Louisiana is in the Breton Sound Basin, southeast of Lake Lery. The nearest observation station that records water level data is CRMS0146, approximately 5 mi southeast of Delacroix. The community and the observation station are hydrologically connected through fragmented marsh and bayous in the area, and there are no major geographic or manmade features between them. Therefore, stage data at CRMS0146 was used as the representative observed stage for Delacroix, and ICM outputs at compartment 110 were selected as the model prediction for this community. It should be noted that synthetic tropical storm events have been applied to the ICM simulations, which could produce large surges during storm events. Since the focus of this study is on HTF and not storm surge-related flooding, ICM output during these synthetic storms was removed for the analysis. Details regarding storm surge-induced flooding in the ICM outputs can be found in the separate report (Johnson et al., 2023).

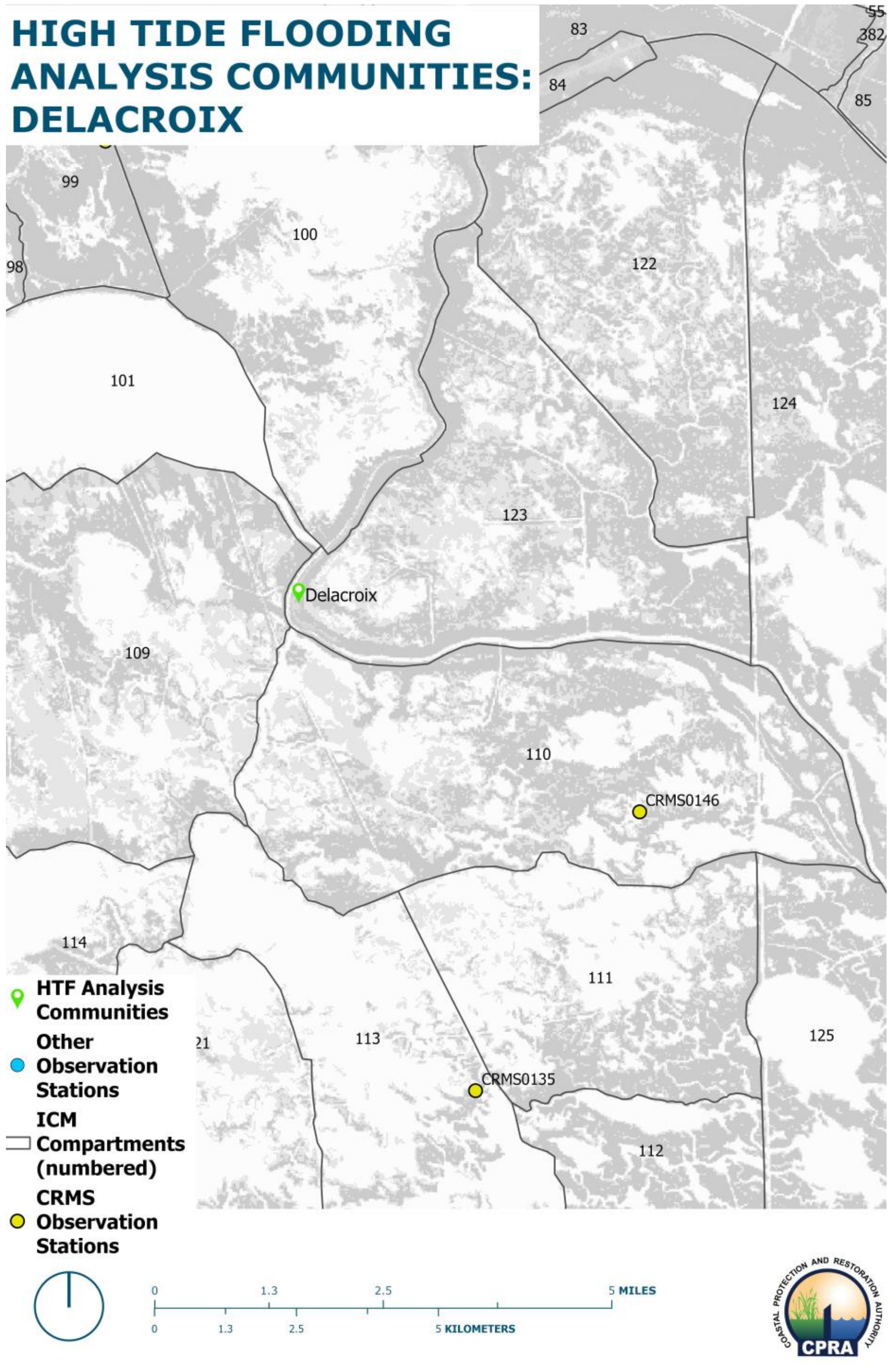

Figure 4. ICM compartments and WSE observation stations relative to Delacroix, Louisiana. ICM compartment 110 and CRMS0146 were used for the analysis.

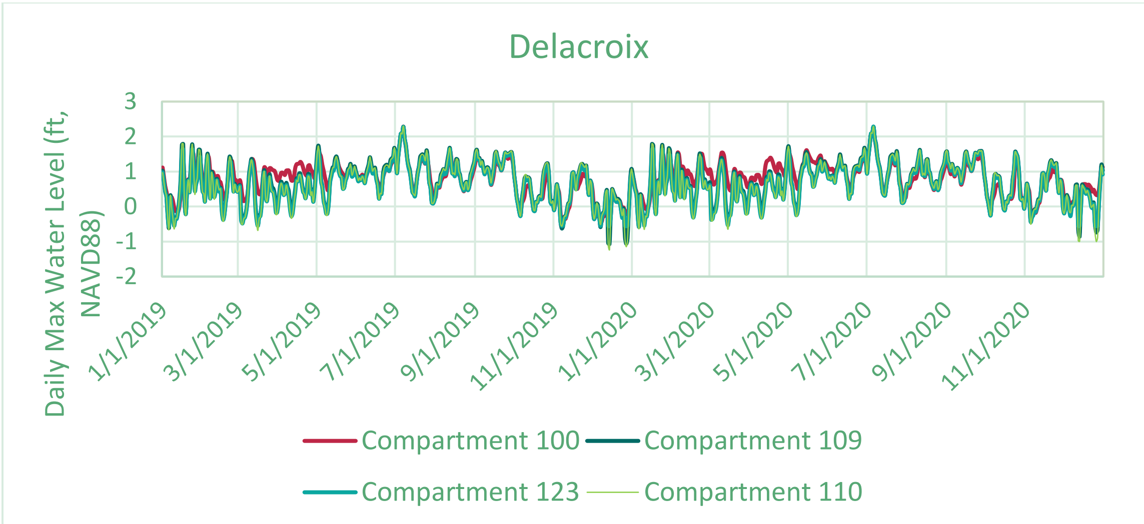

Figure 5. ICM compartments proximal to Delacroix, Louisiana and associated mean water level output for 2019 – 2020.

ANALYSIS OF ICM PERFORMANCE

Once ICM compartments (for output extraction) and observation stations (for data comparison) were selected, an analysis was conducted to determine the ICM's performance in replicating WSEs representative of HTF events.

Typically, modeled and observed data from the same time period would be compared to assess the model's ability to represent real events. During the analysis period, the full suite of the ICM's modeled stage data for the year 2010 for the entire coast was unavailable, and as such, the master plan team was required to determine an alternative means by which to validate the model for the purposes of HTF analysis.

ICM spin-up period (2019 – 2020) data from the FWOA lower scenario were the closest model output to compare to 2020 observed data, as the astronomical tide signal observed in 2010 is repeated for each of the ICM's 50 years of simulation for the 2023 Coastal Master Plan and since SLR would not yet have had a chance to accelerate and drastically change the landscape. 2019/2020 ICM output was compared against the observed data at the selected nearby station(s) for each community. The analysis was conducted for the eight focus communities, and results for one of the communities, Delacroix, are shown in this section as an example. Results for the other seven communities can be found in Attachment 2.

As the focus of this study is high-tide events, the daily maximum WSEs were extracted from the hourly observed data and ICM output and plotted against each other (Figure 6). As illustrated in this figure, the tidal signals for the years 2019 and 2020 are very similar because the astronomical tide signal at the offshore boundary is the same. When compared to the observed stage, it is evident that the model correctly reproduces the main tidal fluctuation at this location. Discrepancies between ICM output and observed data were expected due to local hydrological/hydraulic conditions that are not captured by this planning-level compartment model. More details regarding model validation and limitations can be found in the ICM documentation appendices of the master plan (White & Reed, 2023). It should also be noted that the analysis based on WSEs does not include wave setup, runup, or overtopping, as these phenomena are outside the capabilities of the ICM to calculate. For communities exposed to large open water fetch distances such as Mandeville, Cameron, and Grand Isle, it is likely that wave effects could cause HTF more frequently than those predicted by the ICM alone.

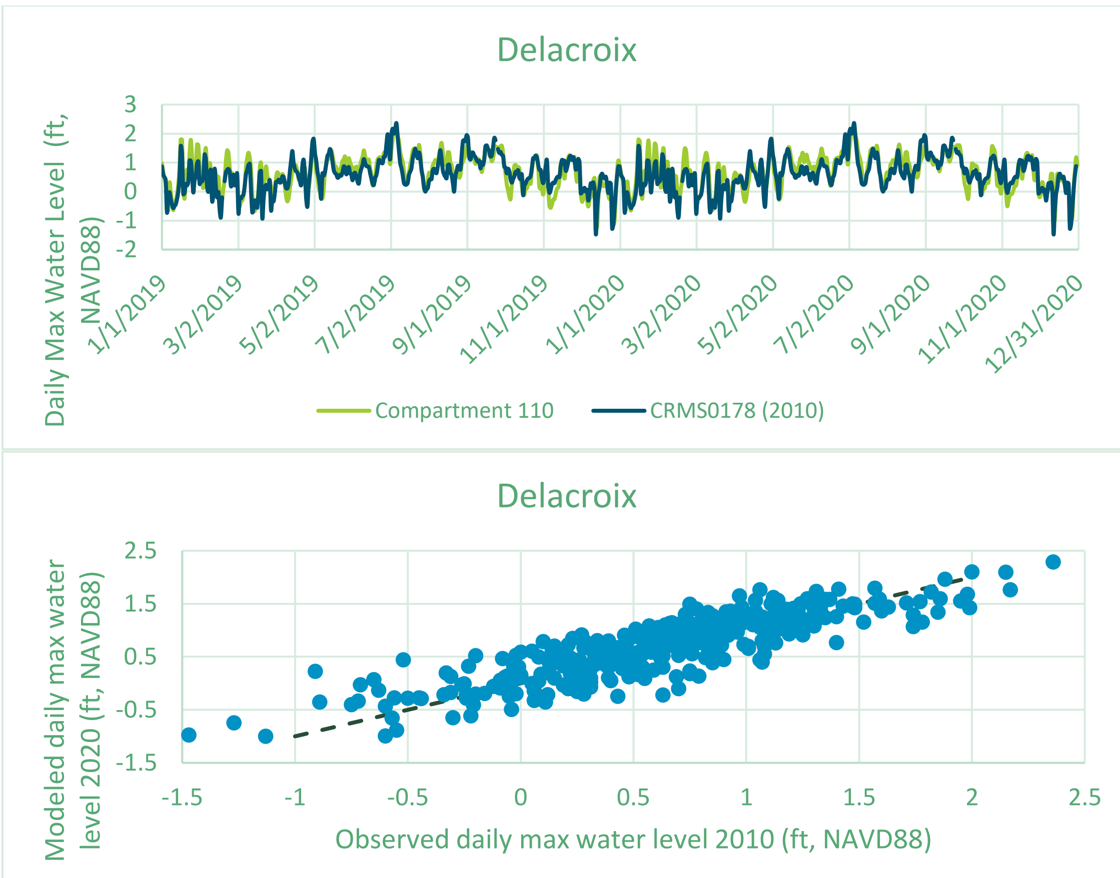

Figure 6. Modeled (ICM compartment 110) and observed (CRMS0146) daily maximum stage comparison for the ICM period of 2019-2020 versus 2010 for Delacroix, Louisiana. The top portion of the figure displays the timeseries comparison between modeled and observed data. The bottom portion of the figure displays a scatterplot of the difference in modeled and observed predictions by magnitude (in feet, NAVD88).

Figure 7 and Figure 8 show the modeled daily maximum water level versus the observed daily maximum water level for the years 2019 and 2020. As illustrated, the model and the observed stage are matched satisfactorily. The bias and Root Mean Square Error (RMSE) between the modeled and observed stage and the standard deviation are summarized in Table 4 for Delacroix. The modeled maximum daily stage was only slightly higher than the observed daily maximum stage by an average of 0.06 ft. The master plan team found the model prediction was satisfactory to perform the HTF analysis without further bias correction in this case.

The mean bias and RMSE between the modeled and observed stage and the standard deviation are summarized in Table 5 for all focus communities. Across all communities, the mean bias between the observed and modeled maximum water level was within 0.3 ft, with the exceptions of Cameron and Dulac, where the bias was slightly higher. The RMSE generally fell within the range of 0.3 to 0.5 ft. This range was within the model uncertainty generated by other sources (e.g., model inputs such as the DEM). The master plan team deemed ICM outputs satisfactory for the HTF analysis across all focus communities. Thus, the raw model outputs without any correction were used in the analysis. For any threshold exceedance analysis, results are sensitive to minor fluctuations in water level or feature elevation.

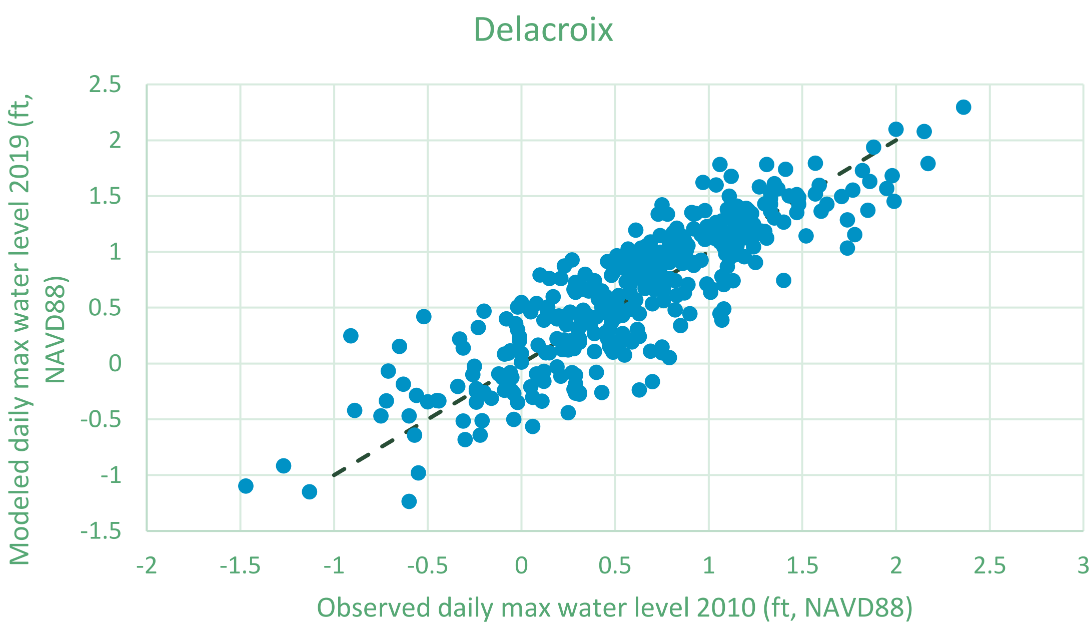

Figure 7. Modeled (ICM compartment 110) and observed (CRMS0146) daily maximum stage comparison for the ICM period of 2019 near Delacroix, Louisiana.

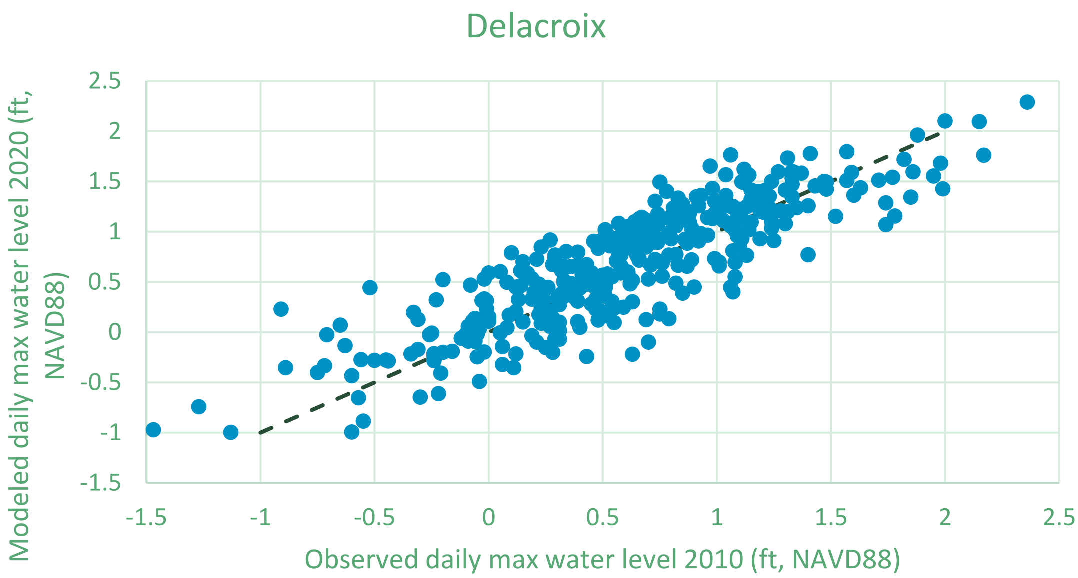

Figure 8. Modeled (ICM compartment 110) and observed (CRMS0146) daily maximum stage comparison for the ICM period of 2020 near Delacroix, Louisiana.

Table 4. Daily maximum stage bias and RMSE for the modeled (ICM compartment 110) and observed (CRMS0146) data near Delacroix, Louisiana for 2019 and 2020.

	DAILY MAX WATER LEVEL (FT, NAVD88)			
	MODELED	OBSERVED (2010)	BIAS	RMSE
2019	0.65	0.61	0.04	0.19
2020	0.69	0.61	0.08	0.18
MEAN	0.67	0.61	0.06	0.19

Table 5. Daily maximum stage bias and RMSE for the modeled and observed data for the eight focus communities.

	DAILY MAX WATER LEVEL (FT, NAVD88)			
	MODELED	OBSERVED (2010)	BIAS	RMSE
AMELIA	1.35	1.22	0.13	0.11
CAMERON	0.95	1.35	-0.40	0.15
DELACROIX	0.67	0.61	0.06	0.10
DELCAMBRE	1.21	1.19	0.02	0.10
DULAC	1.11	0.72	0.39	0.15
GRAND ISLE	0.69	0.89	-0.20	0.08
MANDEVILLE	0.54	0.74	-0.20	0.15
SLIDELL	0.57	0.58	-0.01	0.14

COMPARISON TO NOAA HTF PREDICTIONS AND ESTABLISHMENT OF REPRESENTATIVE COASTWIDE HTF SURFACES IN SUPPORT OF DRIVE TIME ANALYSIS

NOAA defines the initiation of HTF as 0.55 m (1.8 ft) above the average high tide based on nationwide analysis of hourly water level recordings at its tide observations locations (Sweet et al., 2021) for minor flooding. The minor flooding threshold is used throughout this analysis as the lower limit at which HTF may begin to occur. However, there is only one location in Louisiana which has consistently been analyzed for HTF by NOAA (Grand Isle). There are however two locations which are proximal to focus communities (Galveston, Texas, close to Cameron, Louisiana; and Bay Waveland, Mississippi, close to Slidell, Louisiana) that have been consistently analyzed since NOAA began releasing annual reports in 2016 (Figure 9). Given that the coastwide drive time analysis looks beyond local community boundaries for next nearest critical and essential facilities, some of which were located many miles away, a coastwide WSE layer representative of a HTF event at all locations was required as an input. This coastwide data layer could be considered a “snapshot” of a typical HTF event in a given year.

The network analysis was computationally intensive and precluded running network analyses on timeseries data where water level fluctuations and network access would be linked in a feedback loop. Instead, the master plan team generated the representative HTF surface, intended to capture likely flooding effects over broad areas for Years 0, 25, and 50. To create the coastwide HTF layer, rather than model distinct events at varying locations around the coast, the three NOAA HTF threshold locations proximal to Louisiana were used to back-calculate a corresponding statistical percentile WSE. For example, in Grand Isle, Louisiana the HTF threshold established by NOAA is 0.43 m (1.40 ft), which corresponds to the 98^{th} percentile WSE from the ICM across Year 0 of the analysis. NOAA has traditionally updated its predictions each year since 2016. Figure 9 summarizes the number of HTF days predicted for Slidell, Grand Isle, and Cameron from NOAA’s 2019 annual outlook report (Sweet, 2020). Table 6 summarizes NOAA’s predicted HTF days across all NOAA annual outlook reports. Note, in 2021, NOAA shifted to a web-based platform and ceased releasing data in the tabular form shown here.

Region	Tide Gauge Location	NOAA ID	HTF Height (m, MHHW)	Record HTF (days/year)	Year of Record	Typical HTF days in 2000	HTF days in 2019	2020 HTF Outlook	Peak HTF Season	2030 HTF Projection	2050 HTF Projection
Eastern Gulf	Naples, FL	8725110	0.54	3	2017	1	1	0-2	fall	2-4	9-55
	Fort Myers, FL	8725520	0.52	6	2017	1	1	1-4	fall	3-6	15-80
	St. Petersburg, FL	8726520	0.53	4	2016, 2018	1	3	2-3	fall	3-7	15-85
	Clearwater, FL	8726724	0.54	5	2018	0	4	4-6	fall	2-4	10-55
	Cedar Key, FL	8727520	0.55	11	2019	2	11	4-7	fall	5-10	20-70
	Apalachicola, FL	8728690	0.52	10	2018	2	5	2-6	fall	4-8	10-50
	Panama City, FL	8729108	0.52	7	2005	1	2	1-4	fall	4-7	10-65
	Panama City Beach, FL	8729210	0.52	8	2005	1	3	1-5	fall	4-6	10-50
	Pensacola, FL	8729840	0.52	10	2005	1	3	2-5	fall	4-8	15-70
	Dauphin Island, AL	8735180	0.52	10	2019	2	10	2-6	fall	5-10	30-95
	Bay Waveland, MS	8747437	0.52	14	2017	3	10	7-13	fall	25-40	110-205
Western Gulf	Grand Isle, LA	8761724	0.43	6	2008, 2019	1	6	2-5	fall	9-20	145-270
	Sabine Pass, TX	8770570	0.52	23	2017	0	21	9-17	fall	8-15	60-160
	Morgans Point, TX	8770613	0.52	22	2019	3	22	11-19	fall	30-45	110-215
	Eagle Point, TX	8771013	0.51	64	2019	0	64	32-48	fall	---	---
	Galveston Pier 21, TX	8771450	0.52	18	2017, 2019	3	18	7-12	fall	15-30	100-215

Figure 9. NOAA HTF predictions from its 2019 annual outlook report (Sweet, 2020).

Table 6. Present-day number of HTF days predicted across 2016-2020 NOAA HTD annual outlook reports for Bay Waveland, Mississippi (a proxy for Slidell, Louisiana); Grand Isle, Louisiana; and Galveston, Texas (a proxy for Cameron, Louisiana)

	NUMBER OF HTF DAYS PREDICTED BY NOAA					
NOAA HTF LOCATION	**2016**	**2017**	**2018**	**2019**	**2020**	**AVERAGE ACROSS YEARS**
BAY WAVELAND, MISSISSIPPI (SLIDELL, LOUISIANA)	12	14	12	14	22	15
GRAND ISLE, LOUISIANA	5	5	3	6	16	7
GALVESTON, TEXAS (CAMERON, LOUISIANA)	15	18	13	18	27	18
AVERAGE ACROSS LOCATIONS	11	12	9	13	22	13

The master plan team calculated the percentile WSE from ICM output which would equate to the average number of HTF days predicted across NOAA reports in Table 6. These results are shown in Table 7. Coastwide values (in Table 7) from Slidell to Cameron, Louisiana were averaged and equated to the 96th percentile WSE to the lower limit trigger for HTF events. Thus, three composite coastwide rasters for all ICM compartments were created (one each for Year 0, 25, and 50), for which the ICM's hourly annual data was used to calculate the 96th percentile WSE at every compartment. As noted in prior sections, some upland compartments' timeseries WSE data was replaced with proximal coastal compartment data for a more accurate result since upland compartments were not morphologically active in the ICM and lacked some key coastal processes (see Table 8 for list).

Table 7. Present-day relationship of minor HTF occurrence across 2016-2020 NOAA HTF annual outlook reports to corresponding ICM WSE percentiles required to generate the same frequency of occurrence for Bay Waveland, Mississippi (a proxy for Slidell, Louisiana); Grand Isle, Louisiana; and Galveston, Texas (a proxy for Cameron, Louisiana)

	NOAA-DEFINED MINOR HTF ELEVATION THRESHOLD (FT, NAVD88)	2016-2020 AVERAGE NUMBER OF HTF DAYS	CORRESPONDING ICM WSE PERCENTILE FOR YEAR 0 DATA
BAY WAVELAND, MISSISSIPPI (SLIDELL, LOUISIANA)	1.71	15	96
GRAND ISLE, LOUISIANA	1.41	7	98
GALVESTON, TEXAS (CAMERON, LOUISIANA)	1.71	18	95
AVERAGE	1.61	13	96

Table 8. List of upland ICM compartments replaced with corresponding coastal compartments for drive time network analysis 96th percentile WSE raster creation.

ICM UPLAND COMPARTMENT ID	REPLACEMENT ICM COASTAL COMPARTMENT
992	1136
1507	36
1508	35
1513	39
1516	1440
1556	1137
1586	398
1596	398
1617	37
1619	37
1620	38
1621	39
1623	40
1624	375
1625	1440
1634	1137
1635	1137
1653	36
1654	1440

EXCEEDANCE ANALYSIS COMPARED TO LOCAL LANDMARK ELEVATION THRESHOLDS

Understanding the impacts of disruption to community and facility access only investigates one aspect of the effects of HTF. The network analysis helps answer questions concerning what could happen if HTF occurs by examining broad areas where the entire road network contributes to a multitude of unique impact thresholds for a community. This form of analysis does not alone fully answer the question of how often those thresholds could be exceeded in the future. A general understanding of how the frequency and likelihood of HTF events may change in the future is also required to help stakeholders and communities plan and adapt.

Many communities across coastal Louisiana currently have some level of protection from daily and seasonal tidal variation and may not be negatively impacted at these levels. One example is Delacroix, which has local flood protection berms intended to fight events such as HTF, but not necessarily more infrequent tropical storm surge. Other communities may be susceptible to flooding and negatively impacted at lower WSEs than analyzed here, for example, due to local conditions not reflected in the ICM grid. Through the stakeholder input process, it became evident that many communities have informal impact thresholds widely known to the locals as important meeting places or transportation infrastructure, such as the Dulac Community Center's parking lot or the Cameron Ferry landing.

Local impact thresholds are not intended to be a universal metric for predicting loss of function since road networks and connectivity to critical and essential facilities inevitably have multiple critical thresholds within a certain geography. Rather, specific elevation exceedance thresholds for each focus community were chosen as illustrative of commonly experienced disruptions and are used within this report to inform how frequency trends of HTF may increase in coming decades. Specific impact thresholds analyzed for each community can be found in Table 9. Due to the uncertainty associated with the ground and WSE values used for calculations, exceedance frequency results should be used to inform anticipated trends rather than explicit counts of critical threshold exceedances in future years.

The 50^{th} percentile WSE represents the average water level over the course of a year. As noted in Table 9, by Year 25, the impact thresholds in many cases are within a few feet of the 50^{th} percentile water level for a given year, which is within the typical normal tidal range for most of coastal Louisiana. By Year 50, many impact thresholds are within 1 ft of the 50^{th} percentile water levels, indicating that HTF is likely to occur frequently.

As discussed in the previous section, the 96^{th} percentile WSE was used as a representative coastwide water level where HTF may reasonably be expected to initiate. For present-day conditions, HTF is expected to occur rarely; the local thresholds in Dulac and Cameron, Louisiana are most susceptible. By Year 50, the 96^{th} percentile WSE is at or above the local threshold of interest in most cases, signifying a strong likelihood of frequent HTF without further infrastructure adaptation.

When calculating the frequency of exceedance for each local threshold versus the WSE timeseries from the ICM, the maximum daily value from the ICM's hourly WSE timeseries was used. These values were then compared to the local elevation exceedance threshold values (with the local threshold values adjusted for subsidence and the ICM values including SLR in their signal). Table 10 provides a full summary of predicted frequency of exceedance by HTF at local thresholds. Community vignette figures depicting this information are provided in Attachment 1.

Table 9. Year 0, 25, and 50 projected threshold elevations used for exceedance analysis, with 50th percentile and 96th percentile (used as the initiation of HTF for this analysis) WSEs predicted by the ICM shown for comparison (Elevations do not assume facilities like roads will be improved or elevated in the future to combat subsidence and SLR)

COMMUNITY	LOCATION	YR. 0	50% WSE AT YR 0	96% (HTF) WSE AT YR 0	YR 25	50% WSE AT YR 25	96% (HTF) WSE AT YR 25	YR 50	50% WSE AT YR 50	96% (HTF) WSE AT YR 50
		ELEV. FT, NAVD88								
AMELIA	LEVEE LOW POINT - SEA GRANT SURVEY	3.0	1.3	2.0	2.8	1.8	2.4	2.7	2.6	3.3
AMELIA	CASINO PARKING LOT	6.5	1.3	2.0	6.3	1.8	2.4	6.2	2.6	3.3
CAMERON	CAMERON FERRY WEST LANDING	2.9	0.7	1.9	2.4	1.4	2.7	2.5	2.4	3.9
CAMERON	EVACUATION LINK - LA27	3.0	0.7	1.9	2.8	1.4	2.7	2.7	2.4	3.9
DELACROIX	DELACROIX ISLAND PIER	6.0	0.2	1.4	5.6	0.9	2.2	5.2	1.8	4.0
DELACROIX	EVACUATION LINK - DELACROIX HWY.	2.5	0.2	1.4	2.1	0.9	2.2	1.3	1.8	4.0
DELCAMBRE	BAYOU CARLIN COVE BOAT LANDING/SEA FOOD MARKET	4.0	0.7	1.8	3.5	1.3	2.5	3.1	2.3	3.6
DELCAMBRE	LOCAL ROAD LINK - E MAIN ST. AND S PRESIDENT ST.	2.6	0.7	1.8	2.1	1.3	2.5	1.7	2.3	3.6

COMMUNITY	LOCATION	YR. 0	50% WSE AT YR 0	96% (HTF) WSE AT YR 0	YR 25	50% WSE AT YR 25	96% (HTF) WSE AT YR 25	YR 50	50% WSE AT YR 50	96% (HTF) WSE AT YR 50
		ELEV. FT, NAVD88								
DULAC	DULAC COMMUNITY CENTER PARKING LOT	1.6	0.7	1.7	0.4	1.3	2.4	-0.7	2.2	3.6
DULAC	LOCAL ROAD LINK - SHRIMPERS ROW AND BAYOU GUILLAUME RD.	2.0	0.7	1.7	0.8	1.3	2.4	-0.3	2.2	3.6
GRAND ISLE	LOUISIANA WILDLIFE AND FISHERIES RESEARCH LAB	2.7	0.3	1.3	1.8	1.0	2.1	0.9	1.9	3.4
GRAND ISLE	EVACUATION LINK - LA1	3.8	0.3	1.3	2.9	1.0	2.1	2.1	1.9	3.4
MANDEVILLE	WOODLAKE ELEMENTARY	3.0	0.4	1.7	2.7	1.1	2.4	2.0	2.0	3.9
MANDEVILLE	MANDEVILLE SEAWALL GRAVITY DRAINAGE OUTFALLS	2.5	0.4	1.7	2.5	1.1	2.4	2.5	2.0	3.9
SLIDELL	LOCAL ROAD LINK - BAYOU LIBERTY RD. NEAR GALATAS LN.	2.0	0.4	1.8	1.8	1.1	2.4	1.5	2.0	3.8
SLIDELL	BAYOU LIBERTY MARINA	3.6	0.4	1.8	3.3	1.1	2.4	3.1	2.0	3.8

*The Mandeville seawall is pile supported and not anticipated to subside at the rates of the surrounding area.

Table 10. Year 0, 25, and 50 projected frequency of HTF at thresholds of interest. (Elevations do not assume facilities like roads will be improved or elevated in the future to combat subsidence and SLR)

COMMUNITY	LOCATION	PERCENT OF TIME HTF MAY OCCUR		
		YEAR 0	YEAR 25	YEAR 50
AMELIA	LEVEE LOW POINT - SEA GRANT SURVEY	< 5%	< 5%	53%
AMELIA	CASINO PARKING LOT	< 5%	< 5%	< 5%
CAMERON	CAMERON FERRY WEST LANDING	< 5%	12%	62%
CAMERON	EVACUATION LINK - LA27	<< 5%	< 5%	52%
DELACROIX	DELACROIX ISLAND PIER	< 5%	< 5%	< 5%
DELACROIX	EVACUATION LINK - DELACROIX HWY.	< 5%	10%	79%
DELCAMBRE	BAYOU CARLIN COVE BOAT LANDING/SEAFOOD MARKET	< 5%	< 5%	23%
DELCAMBRE	LOCAL ROAD LINK - E MAIN ST. AND S PRESIDENT ST.	< 5%	26%	93%
DULAC	DULAC COMMUNITY CENTER PARKING LOT	17%	95%	95%
DULAC	LOCAL ROAD LINK - SHRIMPERS ROW AND BAYOU GUILLAUME RD.	< 5%	92%	95%
GRAND ISLE	LOUISIANA WILDLIFE AND FISHERIES RESEARCH LAB	< 5%	22%	95%
GRAND ISLE	EVACUATION LINK - LA1	< 5%	< 5%	69%
MANDEVILLE	WOODLAKE ELEMENTARY	< 5%	< 5%	40%
MANDEVILLE	MANDEVILLE SEAWALL*	< 5%	8%	65%
SLIDELL	LOCAL ROAD LINK - BAYOU LIBERTY RD. NEAR GALATAS LN.	< 5%	23%	77%
SLIDELL	BAYOU LIBERTY MARINA	< 5%	< 5%	< 5%

3.2 NETWORK ANALYSIS APPROACH

Flooding affects transportation systems through both direct impacts and indirect impacts. Direct impacts include the physical coverage of the road with water and often includes measures of the frequency at which a road segment floods, Indirect impacts, on the other hand, can include outcomes of these direct impacts, including disruption to traffic flow, business interruption, and emergency service provision (Mitchell et al., 2023). This analysis utilized the results of the WSE and frequency exceedance analysis to create flooding impedance layers and a series of road network layers in ArcGIS Pro versions 2.9.5 and 3.0.3. Road network layers are a specific type of vector data, which is primarily composed of edges, junctions, and nodes that are commonly used to model transportation networks and travel time and distance between locations and facilities. Travel time and distance-based network analysis using GIS has been effectively utilized to carry out spatial accessibility analysis of the healthcare industry and emergency response times (Nicoară & Haidu, 2014; Silalahi et al., 2020). This analysis utilized the flooding impedance layers and road network to delineate service areas around each of the key critical and essential facilities in the study area. These services areas indicate the roads which were not impacted by any flooding and those that were not flooded under each future environmental scenario. This delineation of “accessible” roads created a network analysis layer to assess the impacts of current and future HTF events on local residents ability to access critical and essential facilities and services (Mitchell et al., 2023).

POPULATION INTERPOLATION

To assess the local impacts of HTF, it is necessary to have spatially accurate population location data. The decennial census and the American Community Survey provide the most accurate accounting of population currently available. Data at the census block level is only available in the decennial census, most recently released in 2020. Many census blocks contain broad areas of unpopulated land, particularly in rural locations, necessitating additional geospatial analysis of the census data. Utilizing dasymetric mapping techniques, this research interpolated and disaggregated the block group population counts to smaller areal units (e.g., CLARA grid cells) for each of the Phase 2 focus communities (Mitsova et al., 2012). Through dasymetric mapping, the population within each census block is distributed based on a secondary dataset, generally a land use land cover dataset. For this analysis, the census block level data from the 2020 decennial census was interpolated down to the 30 m pixel level using the 2019 National Land Cover Dataset (NLCD). The resultant dataset more clearly delineates unpopulated locations across the coast while providing a more accurate assessment of population density in coastal communities where residents often reside on the limited high ground along rivers, streams, and bayous (Figure 10).

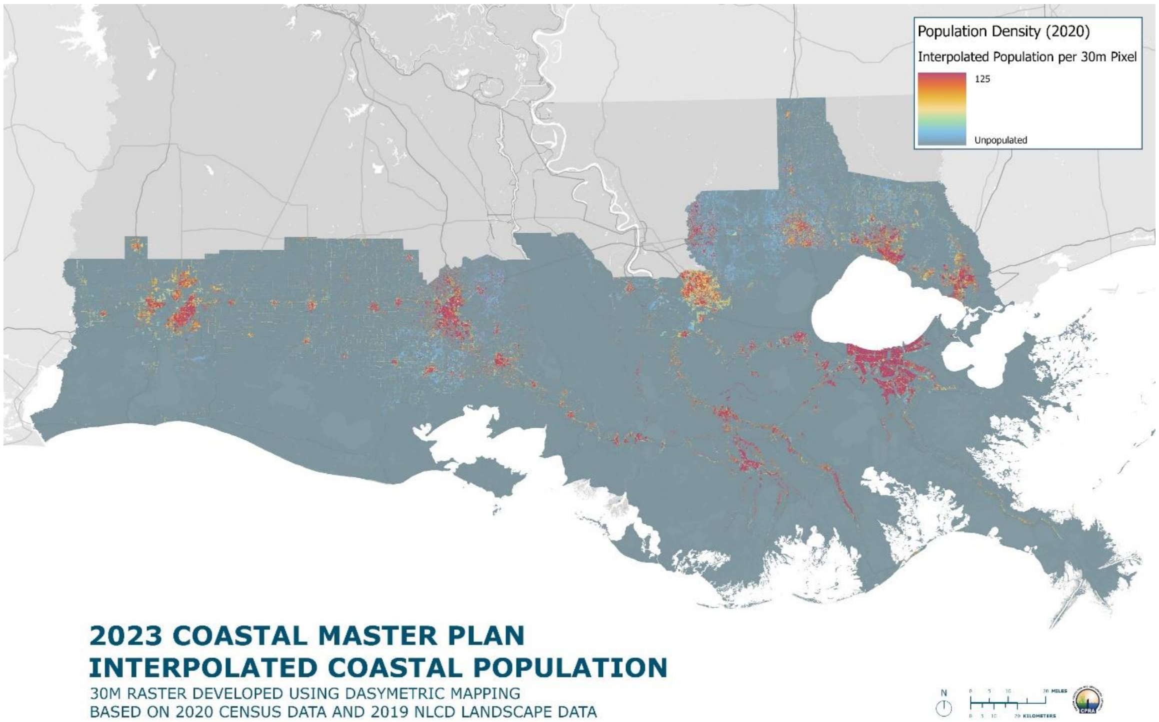

Figure 10. Dasymetric population density map of coastal Louisiana interpolated from 2020 census data and 2019 land use land cover data.

ASSIGNING WSE TO ROADWAY NETWORK

Road center line data were acquired from the Open Street Map (OSM) database (OpenStreetMap contributors, 2015) and used as the basis of the road network layer. This database was selected for use because it was already formatted in a way that allows for efficient network building. The flood depth rasters created in previous steps were used to create the flood impedance layer and were associated with the road network layer in ArcGIS Pro. Given that the base (i.e., unflooded) roadway network used to generate network datasets did not contain an elevation field, the methodology used to isolate flooded roadway segments was to identify elevated roadways as being flooded based on ICM depth outputs assigned to roadways assumed to be at ground level. This issue was mitigated in two ways, first by querying out elevated features such as bridges using tags built into the OSM dataset and then by supplementing these features through manual QA/QC of elevated roadways dataset via photogrammetric analysis.

Roadway features were assigned minimum, maximum, and mean flood depths (i.e., height of the water surface above ground level) corresponding to Years 0, 25, and 50. A bilinear interpolation method was selected to assign values from the continuous raster surface (flood depths) to the vector feature (roadway features) based on the nearest four cells in the raster. Resulting flood depth values were used to isolate flooded roadway segments based on a depth criterion.

Evaluating the potential for a vehicle to safely travel through flooded areas requires consideration of depth of inundation in the accessibility analysis (Mitchell et al., 2023). This current analysis focuses on the degree to which HTF disrupts normal physical, social, and administrative routines within potentially affected areas (Paton, 2006). A working severity scale was developed to better understand the potential range of disruptive impacts on communities from HTF. Three main categories of disruption were identified:

Minor: Impacts range from minimal water on streets (less than 6 in) to disruption of essential facilities for minutes to hours.

Moderate: Impacts range from water on streets/roads (more than 6 in) to disruption of critical facilities for minutes to hours.

Severe: Impacts range from water on state highways and interstates to disruption of critical facilities for hours. It should be noted that events within this category are likely inappropriate to consider as HTF events.

This analysis focused on moderate events; therefore, flooded roadways were isolated and restricted from the base (i.e., unflooded) roadway network based on a depth criterion of 0.5 ft (0.1524 m), which is likely to impact network connectivity. This depth criterion calculation, performed across the entire roadway network, functions as a network of impact thresholds for each focus community for determining loss of accessibility. To provide conservative estimates, the maximum flood depths were used for each ICM year. This process resulted in unique roadway datasets for each timestep (Years 0, 25, and 50). Two unique cost variables were assigned to the output network datasets: a time-dependent cost ('Minutes') and a distance-dependent cost ('Length_Miles'). A restriction was assigned that limited the flow based on real world transportation patterns along one-way highways and roads.

DRIVE TIME ANALYSIS

This analysis utilized the Make Service Area Analysis Layer function within the ArcGIS Network Analyst geoprocessing toolbox. Rather than using Euclidean distance, service areas model the movement of people or vehicles along networks. The object of this analysis was to model shortest paths along the street network from residential locations (represented by populated CLARA grid centroids) to essential facilities as well from critical facilities to all locations within each study area community. A set of service areas were generated around each facility type under four scenarios: current conditions with no HTF, current conditions with HTF, and future conditions with HTF in Years 25 and 50 (Figure 11). The directionality of each facility was established for each facility type to assure the most accuracy in drive times (e.g., distance is measured *from* a fire station but *to* a grocery store). The output geometry of each service area run is linear, resulting in each road segment being assigned a time and distance to each facility in the study area.

Connecting the outputs of the service area analysis to the CLARA polygons required that the polygon layer be converted to a point layer. In GIS, this is typically accomplished through the creation of a polygon centroid file. The dasymetric mapping raster output was used to create a population weighted centroid for each of the CLARA polygons that comprised the HTF focus communities. Population weighted centroids estimate the center of population in each CLARA polygon rather than its geometric center. This conversion results in greater accuracy when mapping population centers. Once the population weighted centroid was located in GIS, it was linked to the nearest road segment in the network dataset. For unpopulated CLARA polygons, the geometric center was created and linked to the nearest road segment. By including both variables, this analysis can be used to assess both commercial and residential impacts. A visual review of the output centroids using Google Earth imagery was conducted to assure that each centroid was properly located. In commercial or industrial areas, for example, geometric centroids were adjusted to align with developed land within the polygon and manually snapped the appropriate road segment. CLARA polygons that contained no roadways or are only accessible via tracks or trails were excluded from the analysis.

Because each road segment in the service area layer was assigned a time and distance to each facility and each population weighted centroid was also assigned to a road segment, the shortest time and distance between residential areas and critical and essential facilities can be identified. By looking at both current and future conditions, this analysis can identify locations in each community where drive times or distances increase under future environmental conditions. Additionally, locations without access to these facilities can also be identified. In such cases, the service area layer cannot locate a route to these locations that does not cross at least one flooded road segment. The outputs of each of these analyses were further analyzed to estimate both the proportion of land area disrupted by flooded streets and the number of residents impacted (Attachment 1). A sample of the drive time analysis for coastwide clear conditions (no HTF) for emergency medical services (EMS) stations is presented in Figure 11.

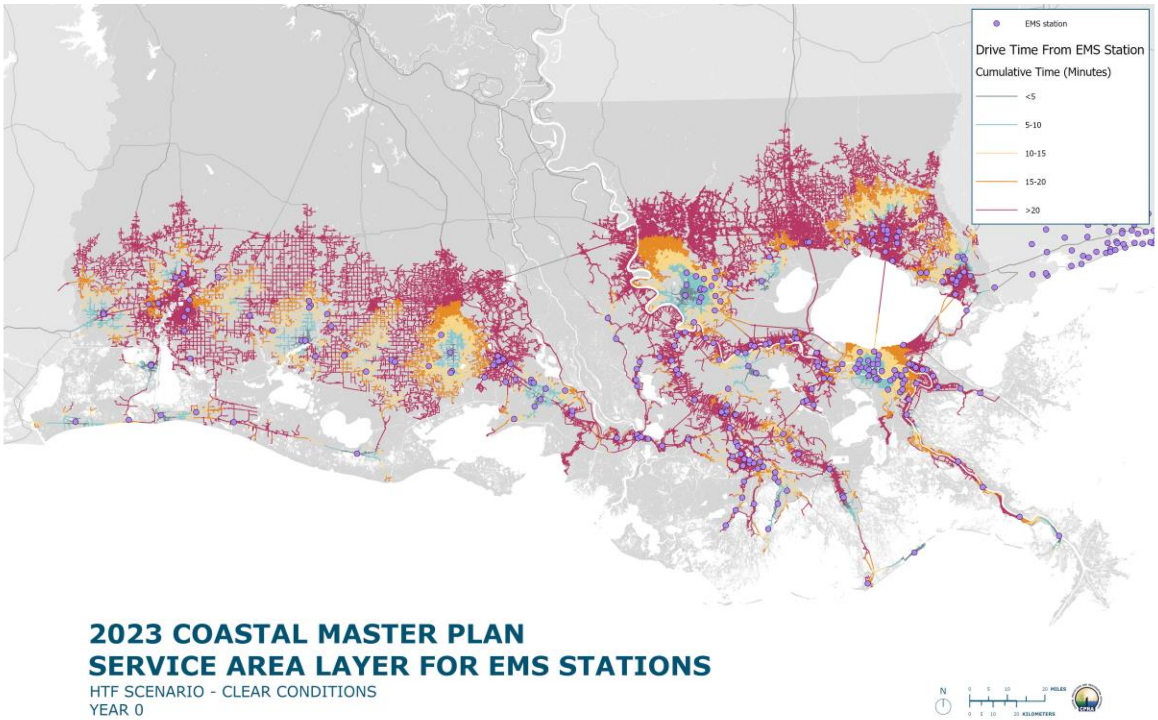

Figure 11. Example service area layer derived from the location of EMS stations in coastal Louisiana under current conditions with no HTF event.

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ATTACHMENT 1. DRIVE TIME ANALYSIS RESULTS FOR FOCUS COMMUNITIES

Community resilience is a measure of the sustained ability of a community to utilize available resources to respond to, withstand, and recover from hazard events and other adverse situations (Acosta et al., 2017). A great deal of focus has rightfully been placed on the impacts of large-scale disasters on community resilience. However, the impacts of more frequent, but less damaging, hazards events such as HTF events may have just as much influence on community resilience. This is particularly true when access to critical and essential services is disrupted. The Phase 2 analysis looks at the impacts of HTF events on street flooding and how this may impact community access to critical and essential facilities. Critical facilities include those used for public safety purposes, medical services, and infrastructure maintenance while essential facilities include those that provide for basic necessities or serve government functions (Wood, 2007). The facilities identified for this pilot study include:

- Critical Facilities
    - Hospitals
    - EMS Stations
    - Police Stations
    - Fire Stations
- Essential Facilities
    - Rural Health Clinics
    - Gas Stations
    - Retail Grocers

A drive time analysis was conducted on the CLARA grid cells in each of the focus communities under clear conditions and under HTF conditions in Years 0, 25, and 50. The results were analyzed to identify locations within each study area that were cut off from critical and essential services as well as where travel times between residents and facilities increased.

Each subsection of this attachment contains map-based and graphical representations of drive times for each facility class, as well as a stylized community cross section vignette noting the relative elevations of local points of interest versus HTF at Years 0, 25, and 50. The community cross section figures contain frequency of HTF estimates for the locations provided by Louisiana Sea Grant; however, these locations did not always align with a transect of the community and thus are sometimes not depicted. Frequency calculations from Section 3.0 are shown for general reference for each community.

Please note, often, critical and essential facilities serving a community may be far from that location (e.g., the nearest Tier 1 hospital to Cameron is not in Cameron Parish, but in Calcasieu Parish) and not within the map's frame of reference. Since the network analysis algorithm performs on a CLARA grid cell scale, it seeks the nearest facility per each cell. Thus, within a community, there could be multiple nearest facilities of the same class depending on the flooded routes, number of proximal facilities, and particular location within a community. For this reason, when the facility class is not within the map's frame of reference, arrows or labels indicating the direction of the nearest facility are not shown, since there could be numerous possibilities.

AMELIA

Amelia is in St. Mary Parish and is bounded on the north by Lake Palourde and on the west, south, and east by the Avoca Island Cutoff. Part of the Morgan City Micropolitan Statistical Area, Amelia has a total land area of 2.8 mi^2. The city's population of 2,459 is heavily dependent on Morgan City for many of its critical facilities, including the region's primary hospital and police stations. This dependency makes Amelia socially vulnerable to HTF events, which may disconnect Amelia from Morgan City on the west. When travel to Morgan City is disrupted, residents of Amelia may experience longer travel times to receive essential services from other communities further afield such as Thibodaux. See Figure 12 through Figure 28 for more information on the drive time analysis for Amelia, Louisiana.

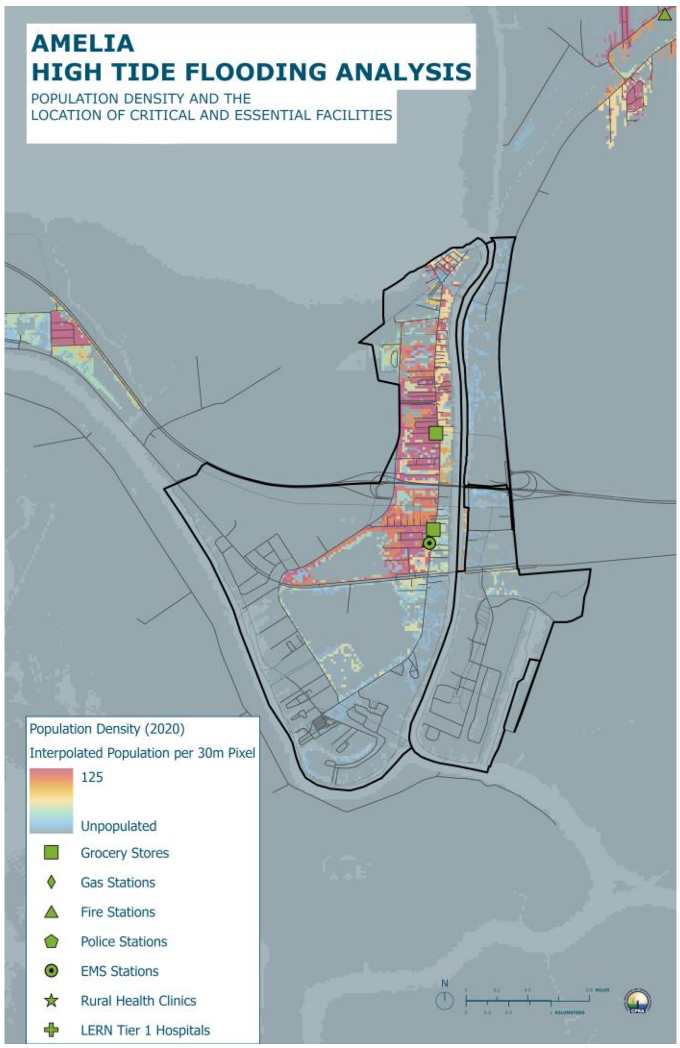


Figure 12. Dasymetric population density map of Amelia, Louisiana with locations of nearby critical and essential facilities, where applicable.

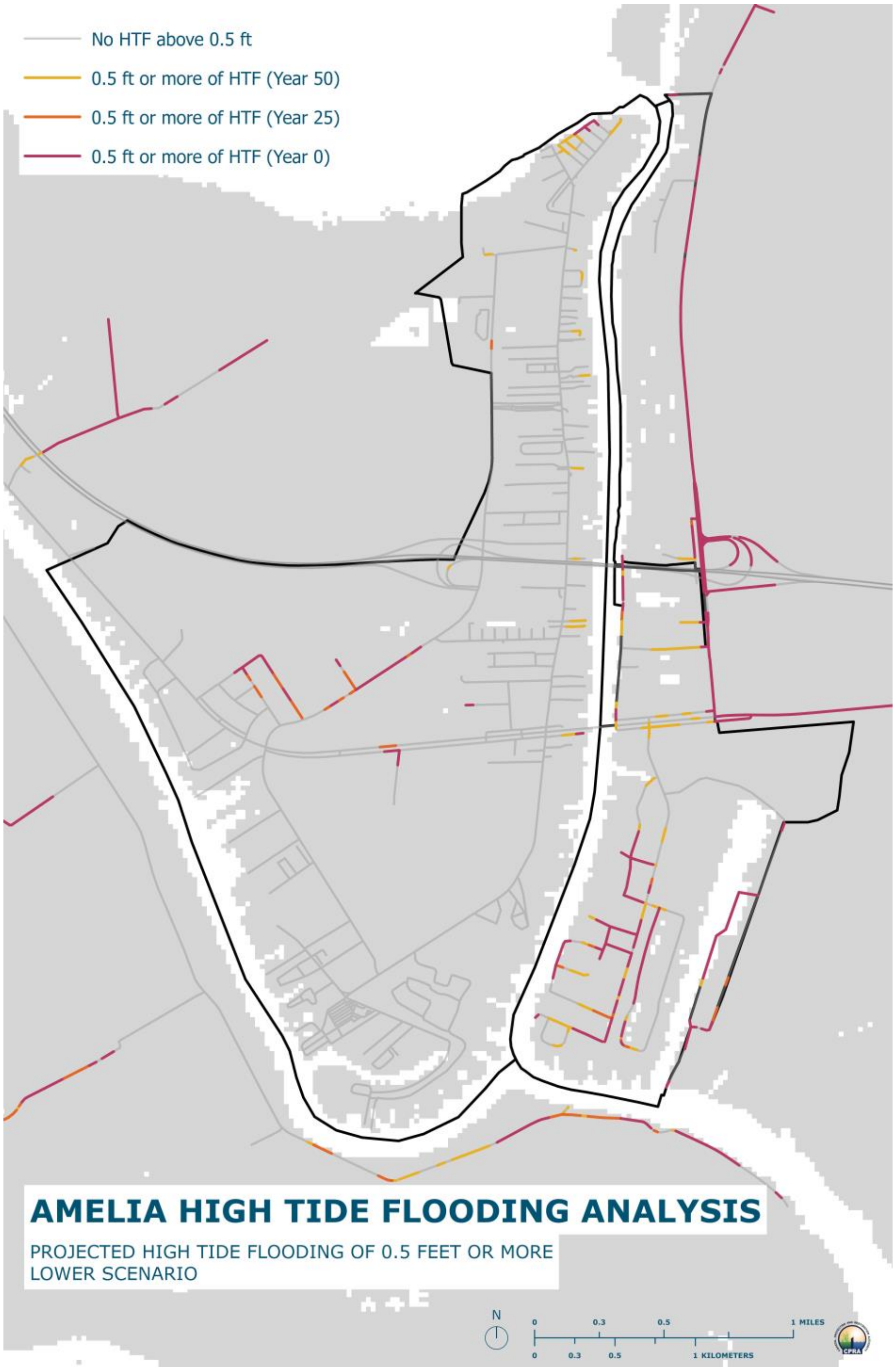


Figure 13. Road segments in Amelia, Louisiana projected to have 0.5 ft or more of HTF and considered impassable in in Year 0, Year 25, and Year 50 under the 2023 Coastal Master Plan's lower scenario

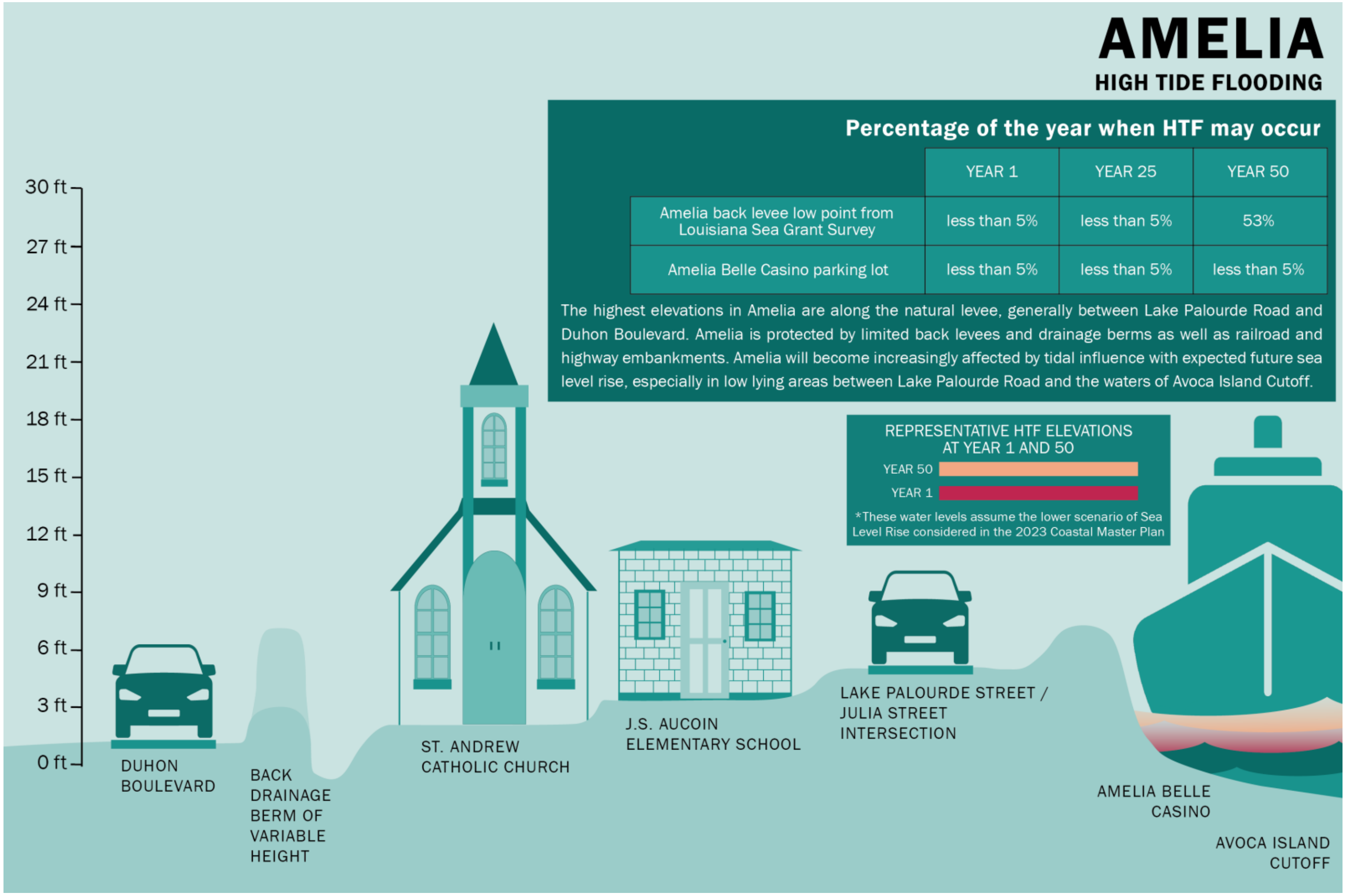
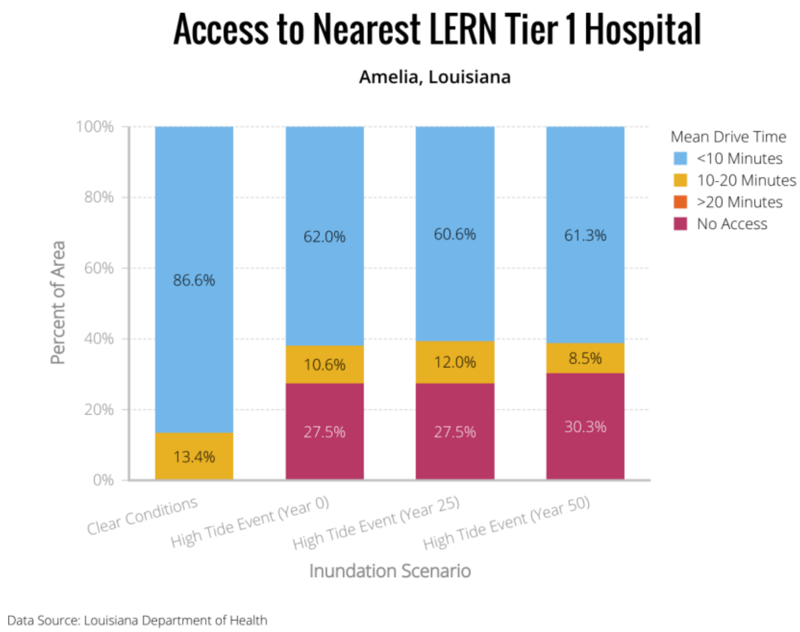


Figure 14. Modeled WSE depths for HTF events in Amelia, Louisiana at local impact threshold locations.

Figure 15. Drive time to nearest Louisiana Emergency Response Network (LERN) Tier 1 hospital in Amelia, Louisiana.



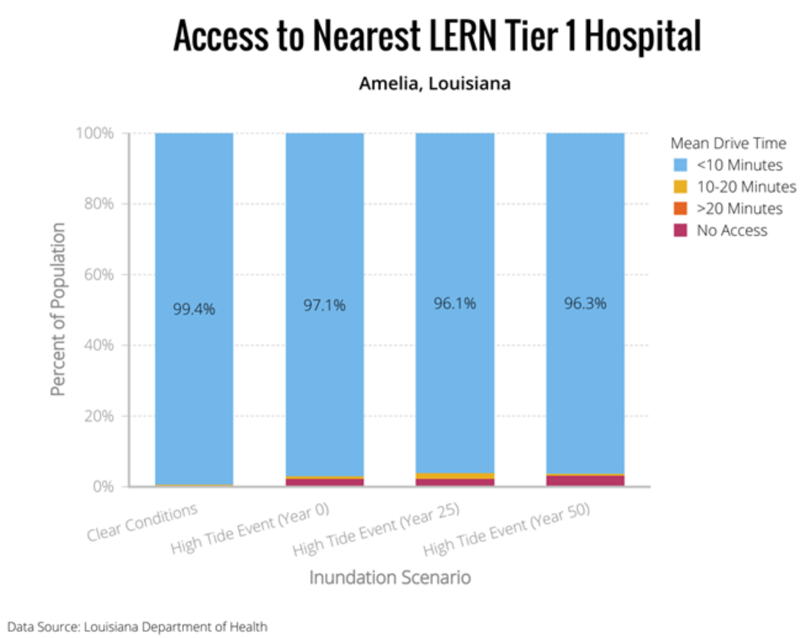


Figure 16. Drive time access to nearest LERN Tier 1 hospital by percent of area (top) and population (bottom) in Amelia, Louisiana.

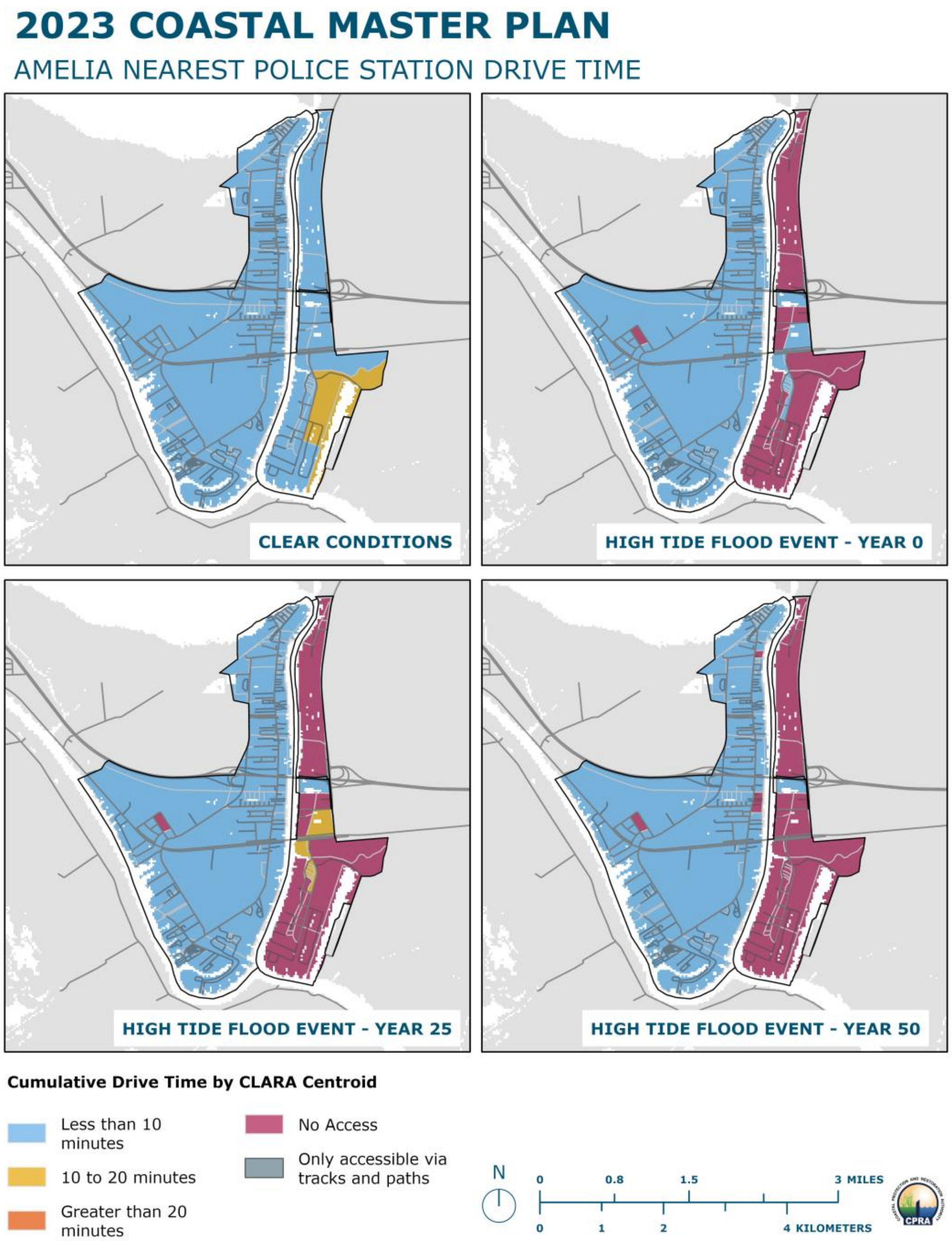
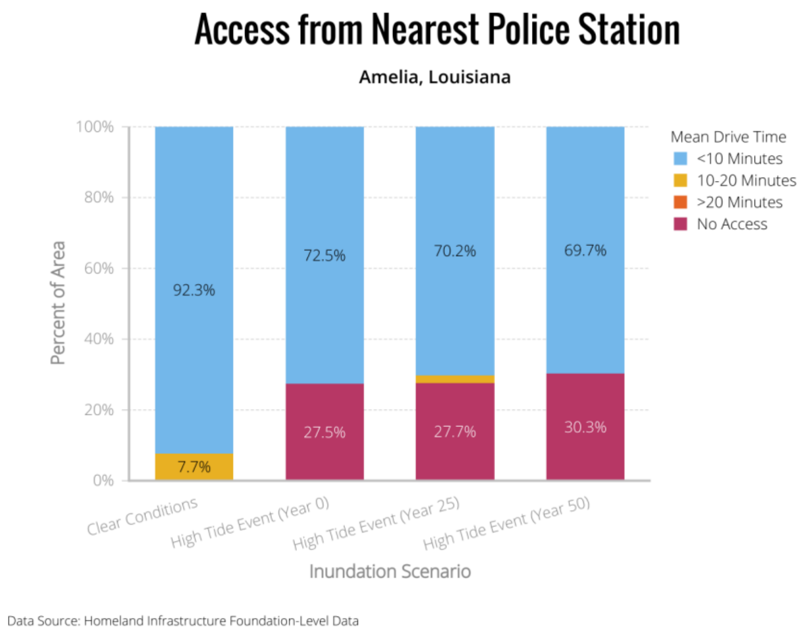


Figure 17. Drive time to nearest police station in Amelia, Louisiana.



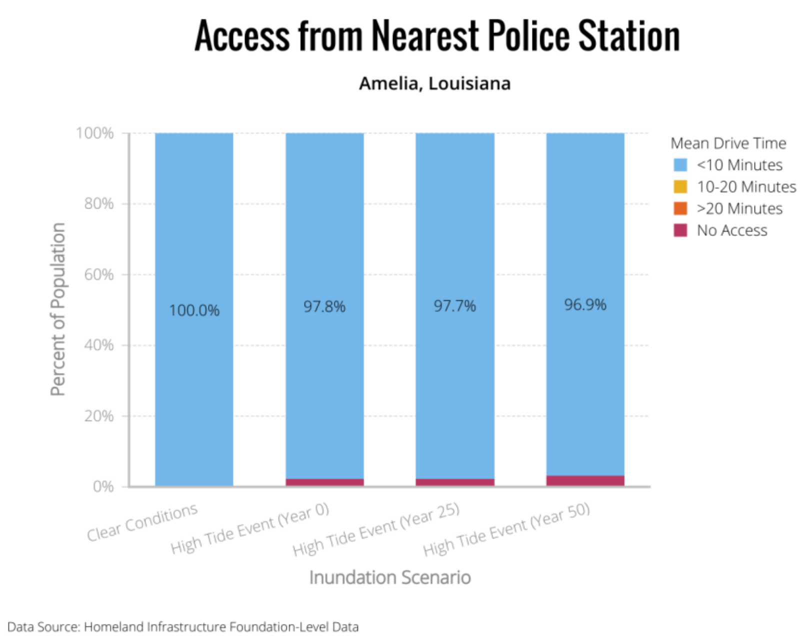


Figure 18. Drive time access to nearest police station by percent of area (top) and population (bottom) in Amelia, Louisiana.

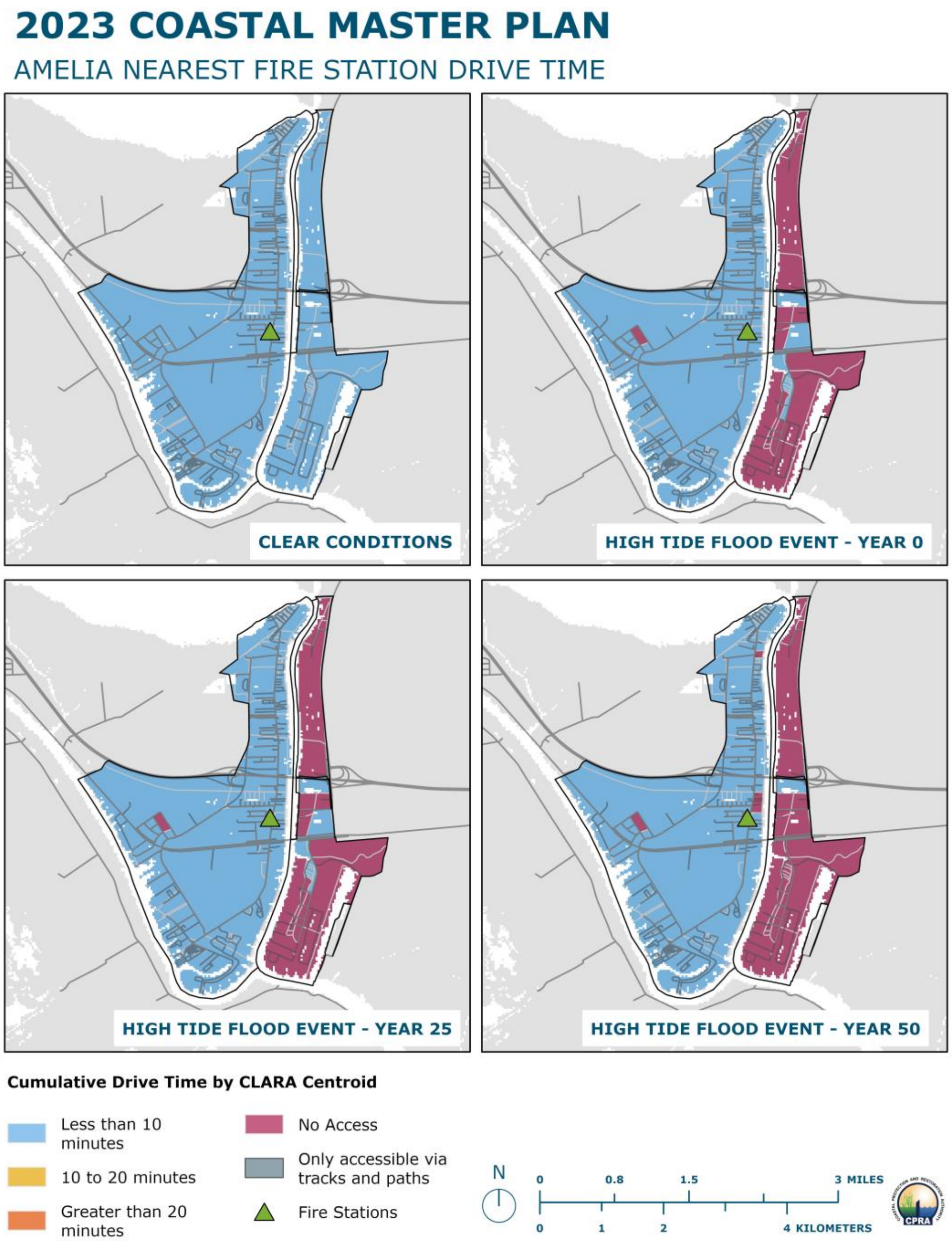
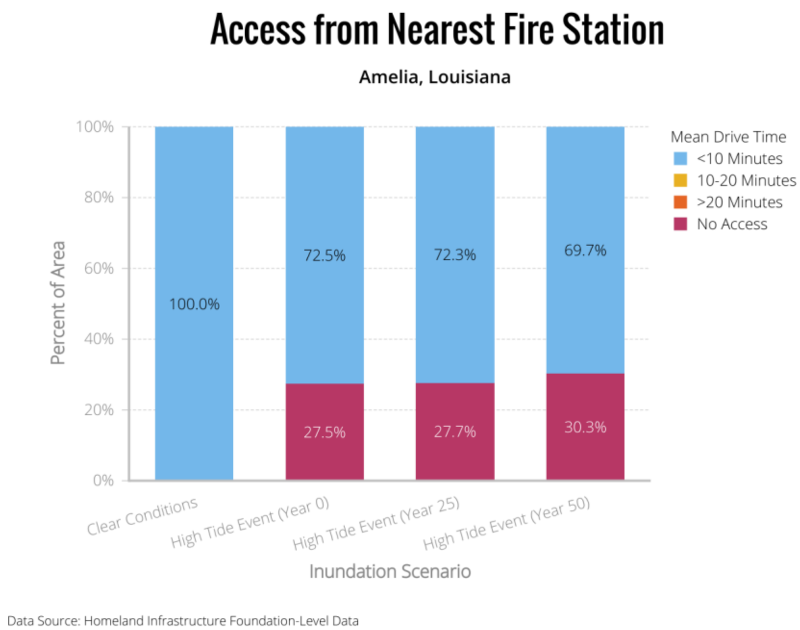


Figure 19. Drive time to nearest fire station in Amelia, Louisiana.



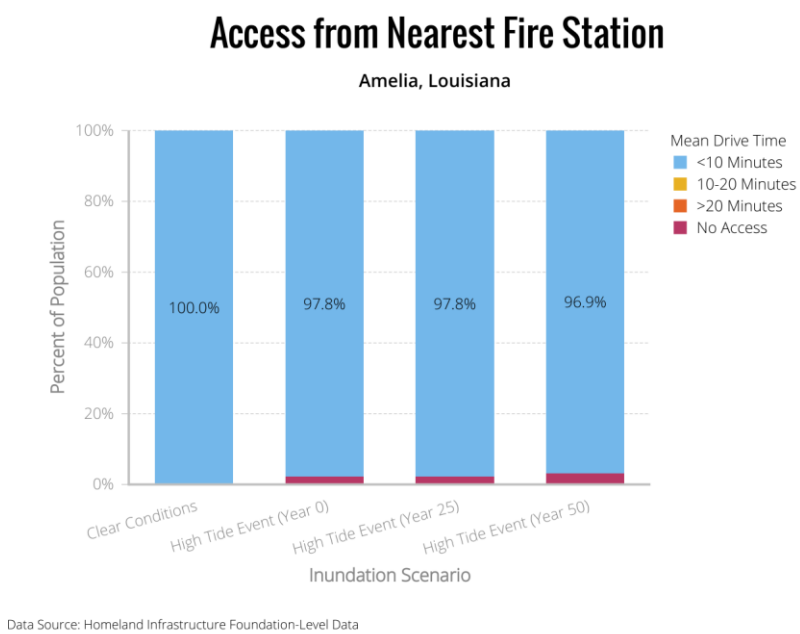
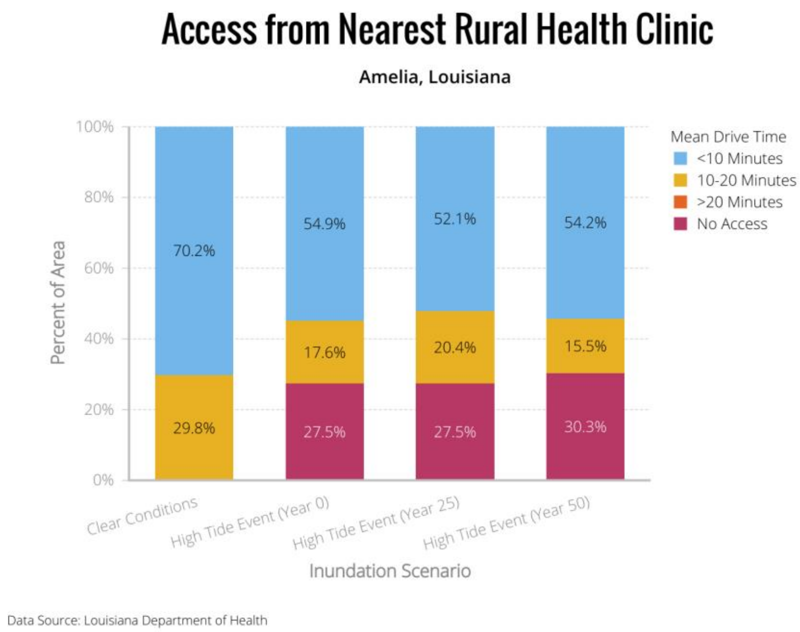


Figure 20. Drive time access to nearest fire station by percent of area (top) and population (bottom) in Amelia, Louisiana.

Figure 21. Drive time to nearest rural health clinic in Amelia, Louisiana.



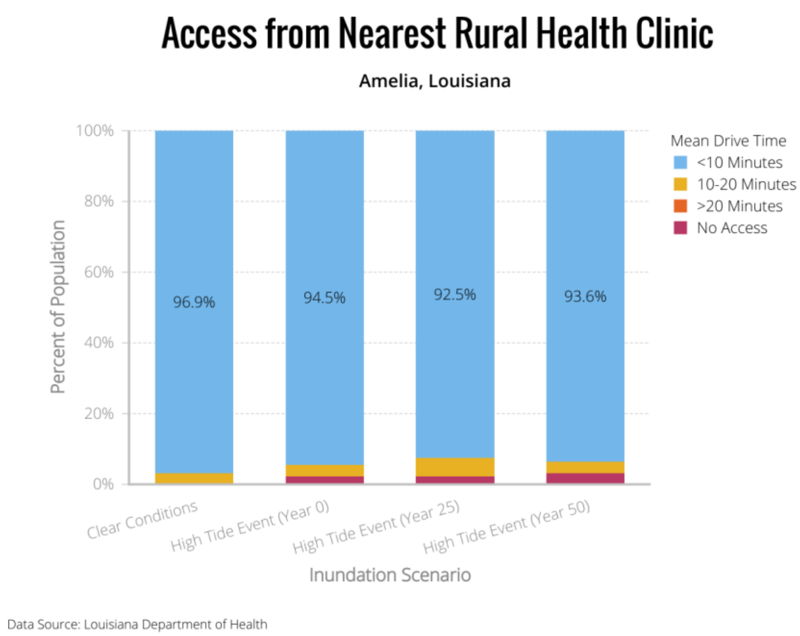


Figure 22. Drive time access to nearest rural health clinic by percent of area (top) and population (bottom) in Amelia, Louisiana.

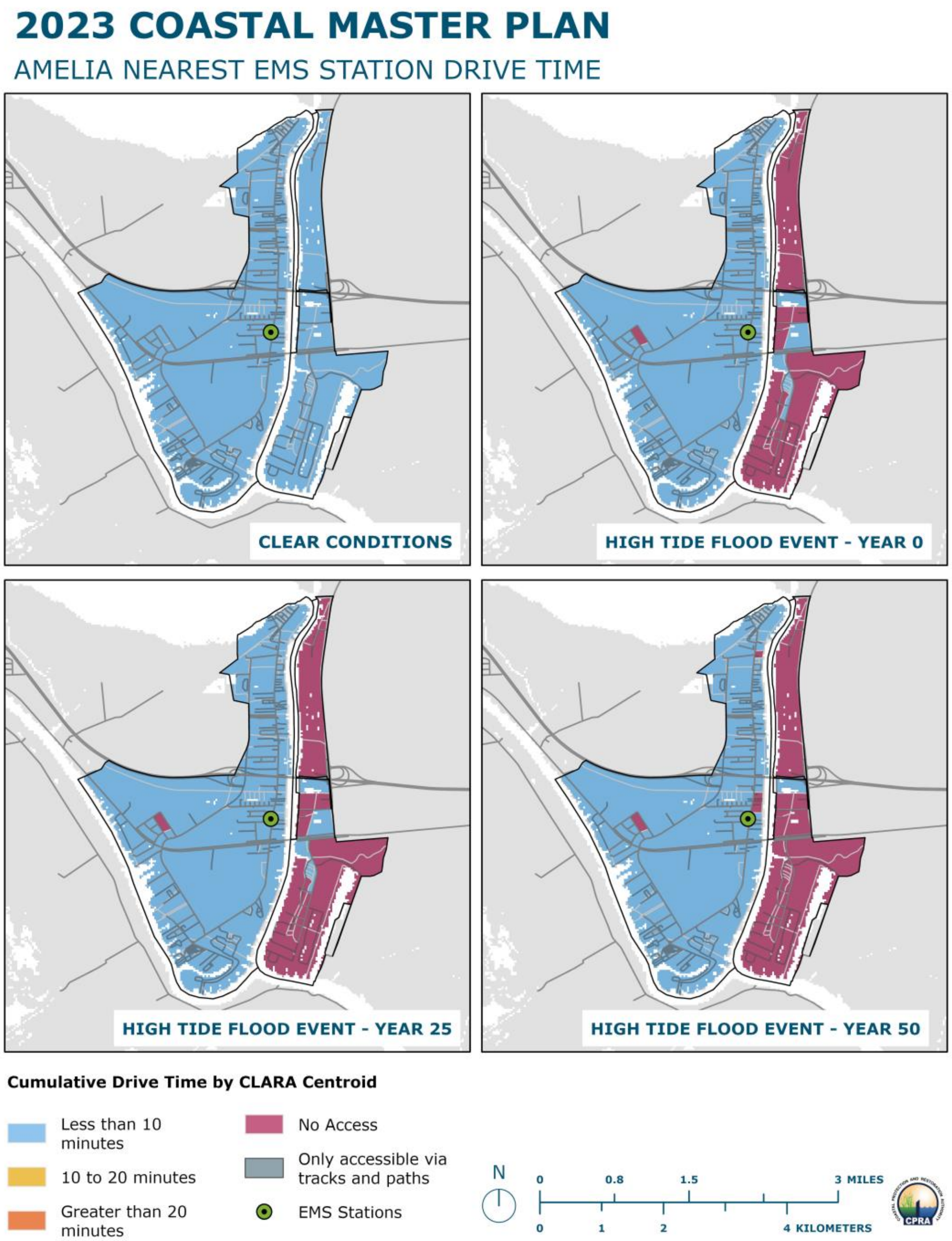
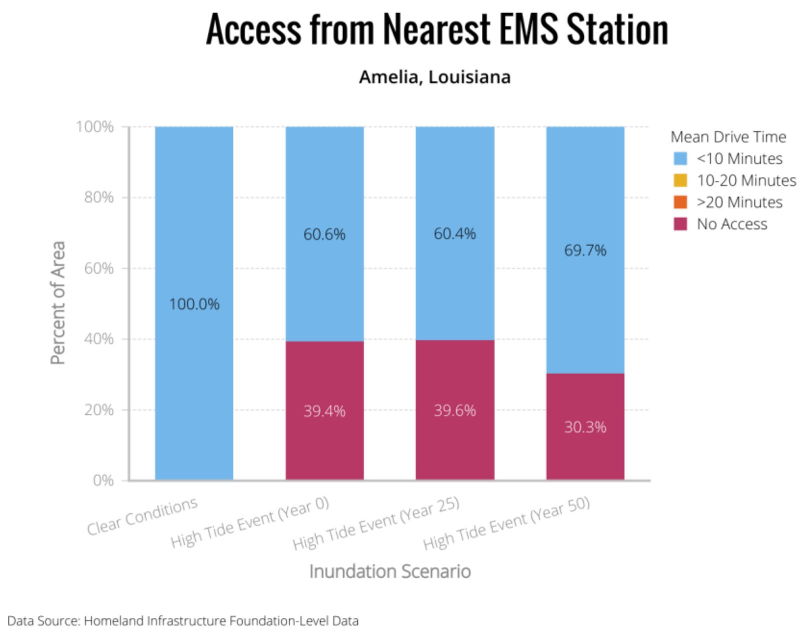


Figure 23. Drive time to nearest EMS station in Amelia, Louisiana.



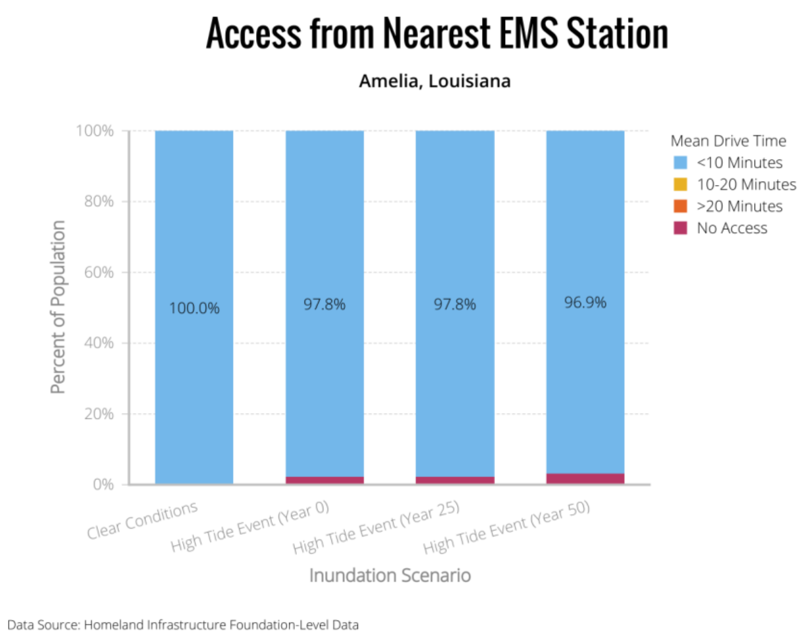
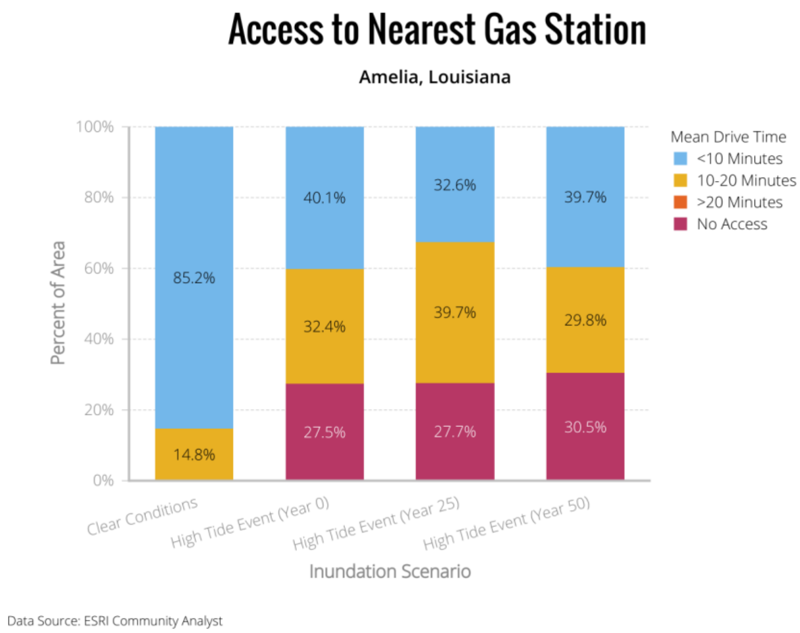


Figure 24. Drive time access to nearest EMS station by percent of area (top) and population (bottom) in Amelia, Louisiana.

Figure 25. Drive time to nearest gas station in Amelia, Louisiana.



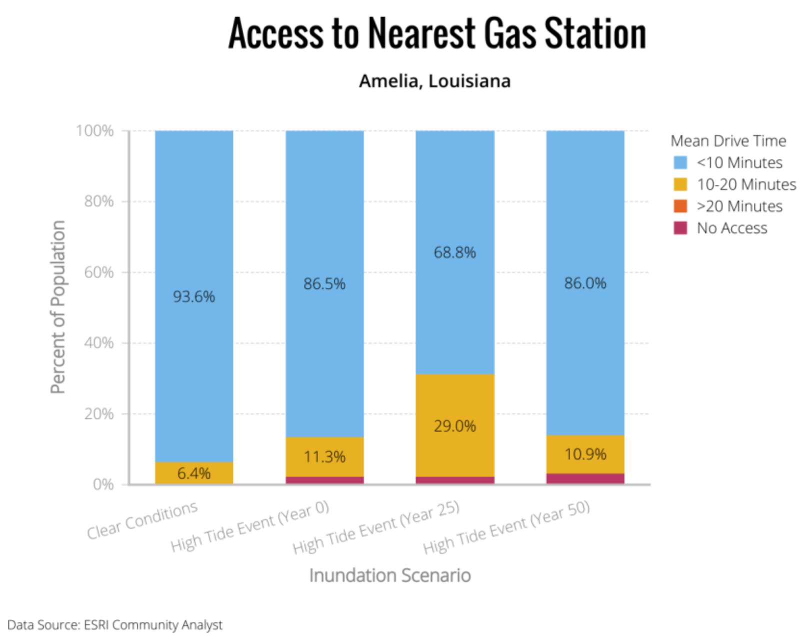


Figure 26. Drive time access to nearest gas station by percent of area (top) and population (bottom) in Amelia, Louisiana.

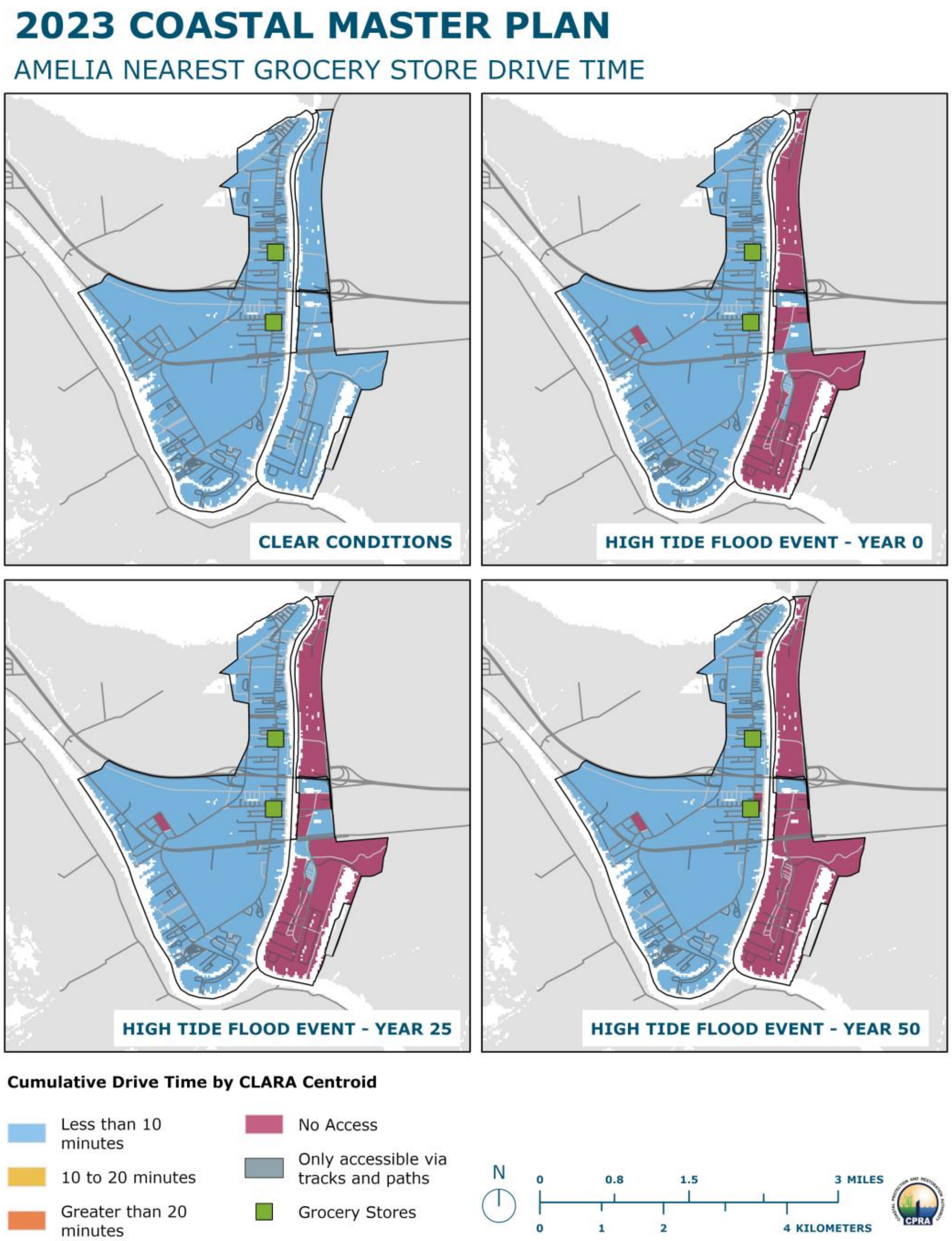
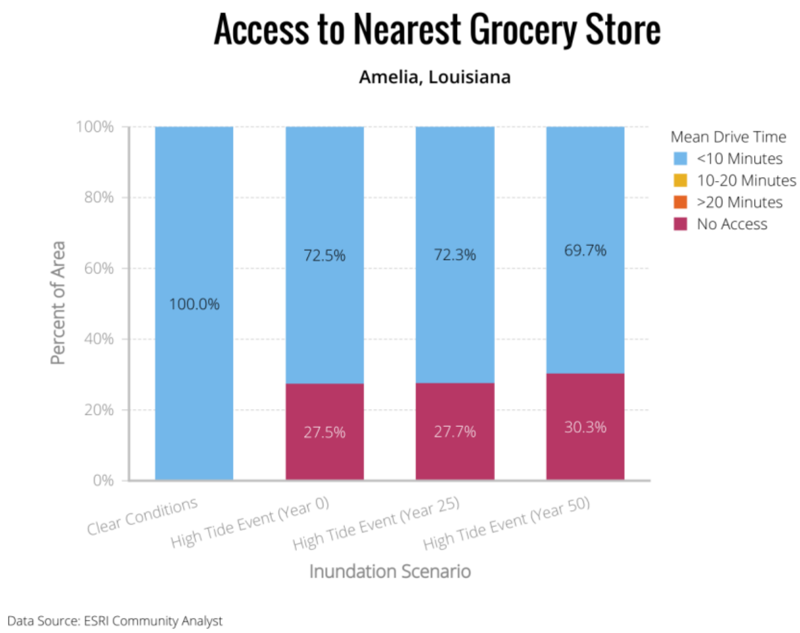


Figure 27. Drive time to nearest grocery store in Amelia, Louisiana.



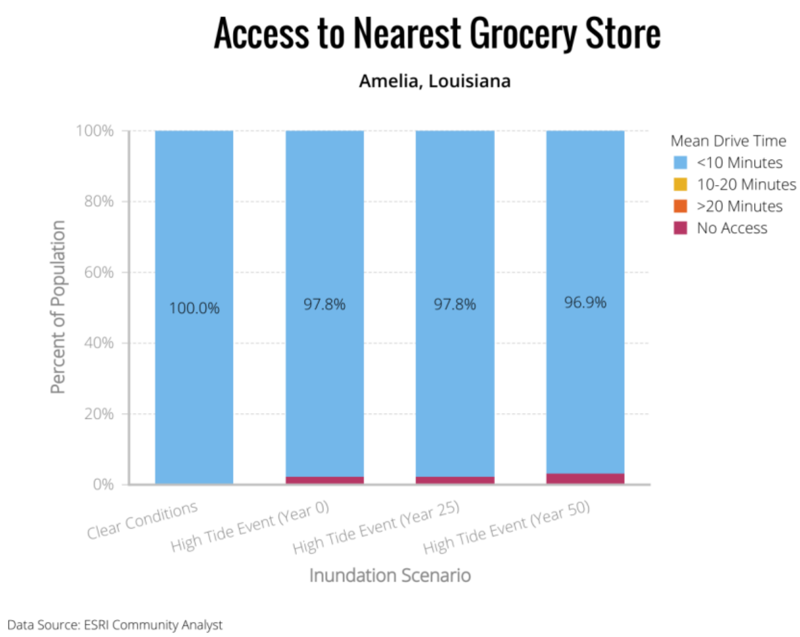


Figure 28. Drive time access to nearest grocery store by percent of area (top) and population (bottom) in Amelia, Louisiana.

CAMERON

The community of Cameron is in the southwest region of Louisiana in southcentral Cameron Parish. The city serves as the parish seat of Cameron Parish and is part of the Lake Charles Metropolitan Statistical Area. At the time of the 2020 census, 315 residents resided in Cameron. Located on the Gulf of Mexico, Cameron is serviced by highways 27 and 82, which connect its residents to many of the critical and essential facilities that they depend upon. Given the town's location, it is particularly vulnerable to HTF events which may flood a number of critical roadway segments and cut residents off from all essential services not located immediately within the town. See Figure 29 through Figure 45 for more information on the drive time analysis for Cameron, Louisiana.

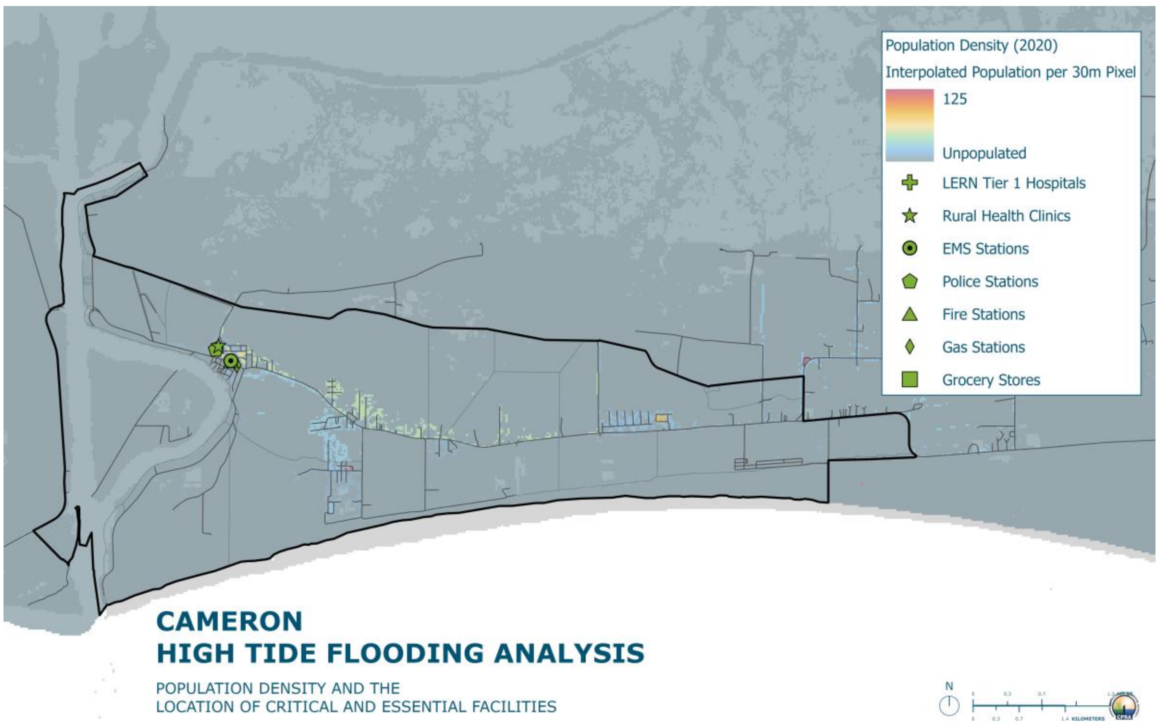


Figure 29. Dasymetric population density map of Cameron, Louisiana with locations of nearby critical and essential facilities, where applicable.

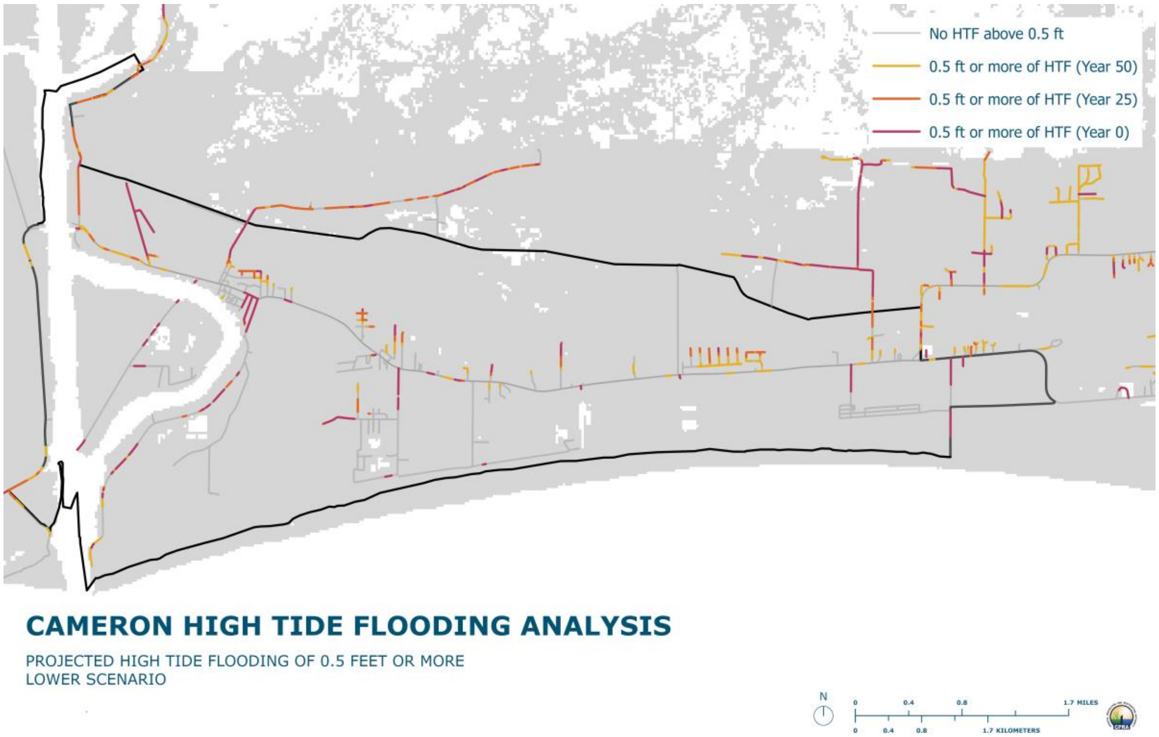


Figure 30. Road segments in Cameron, Louisiana projected to have 0.5 ft or more of HTF and considered impassable in Year 0, Year 25, and Year 50 under the 2023 Coastal Master Plan's lower scenario

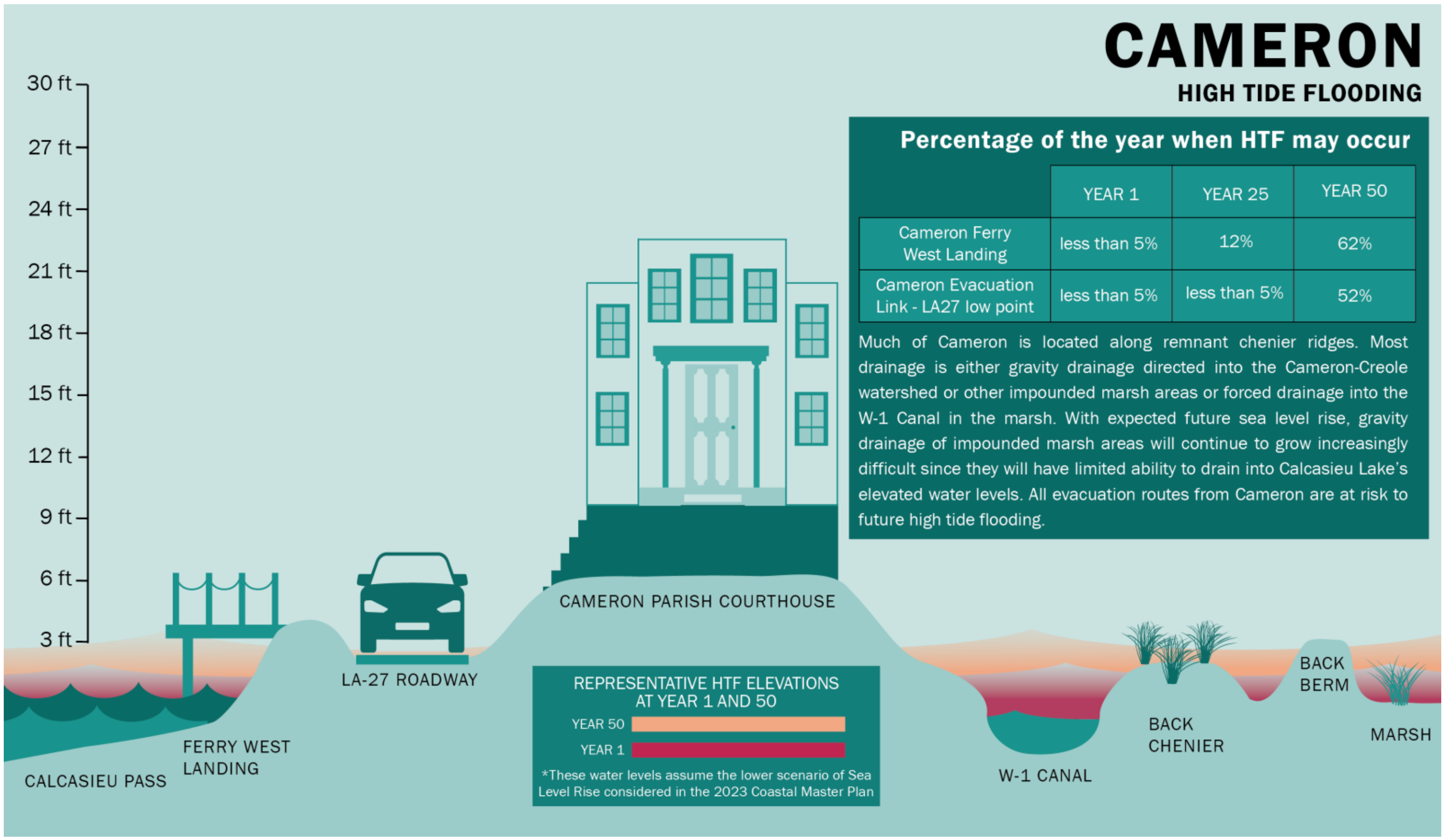


Figure 31. Modeled WSE depths for HTF events in Cameron, Louisiana at local impact threshold locations.

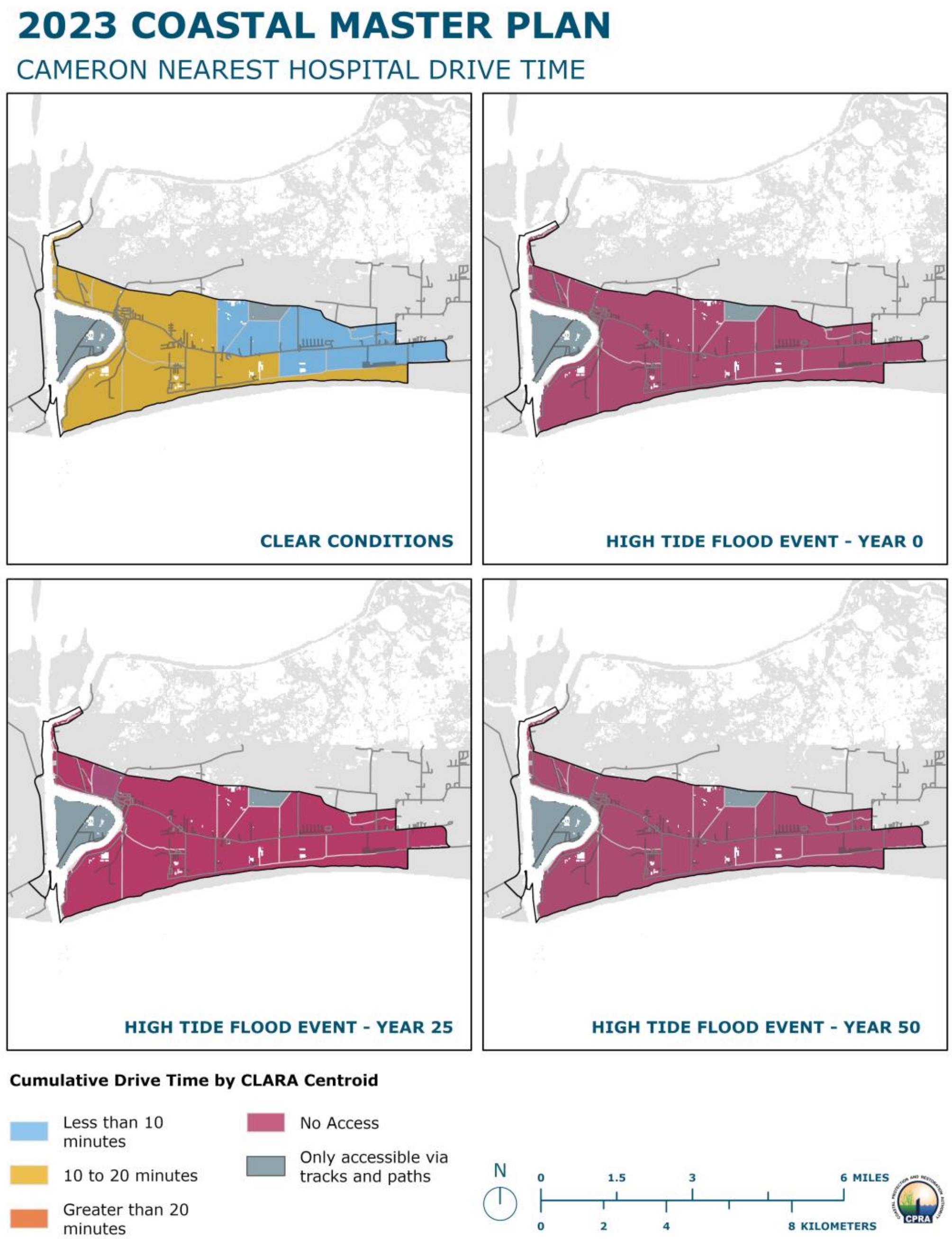
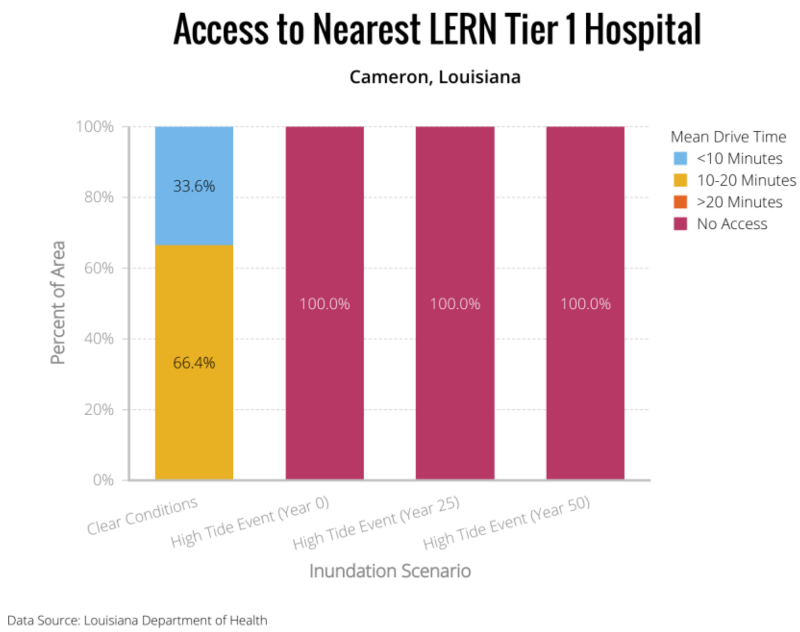


Figure 32. Drive time to nearest LERN Tier 1 hospital in Cameron, Louisiana.



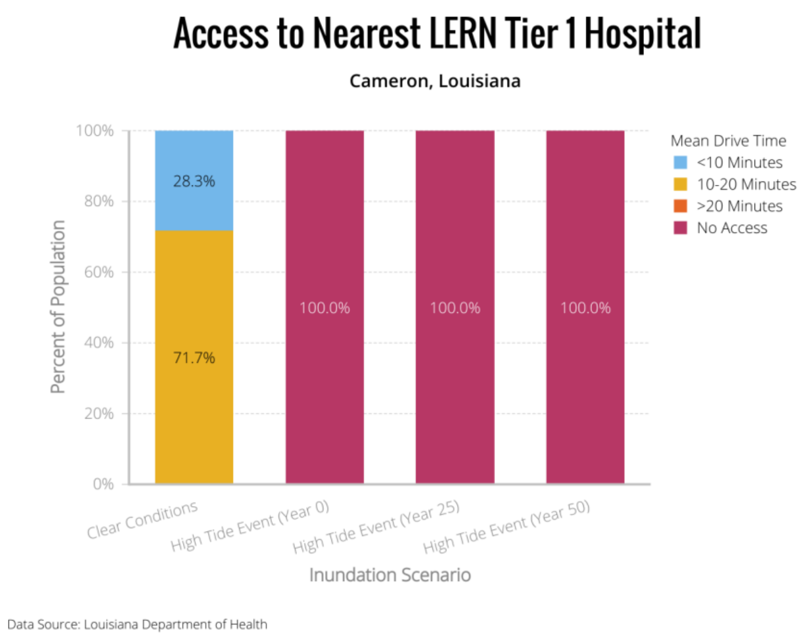


Figure 33. Drive time access to nearest LERN Tier 1 hospital by percent of area (top) and population (bottom) in Cameron, Louisiana.

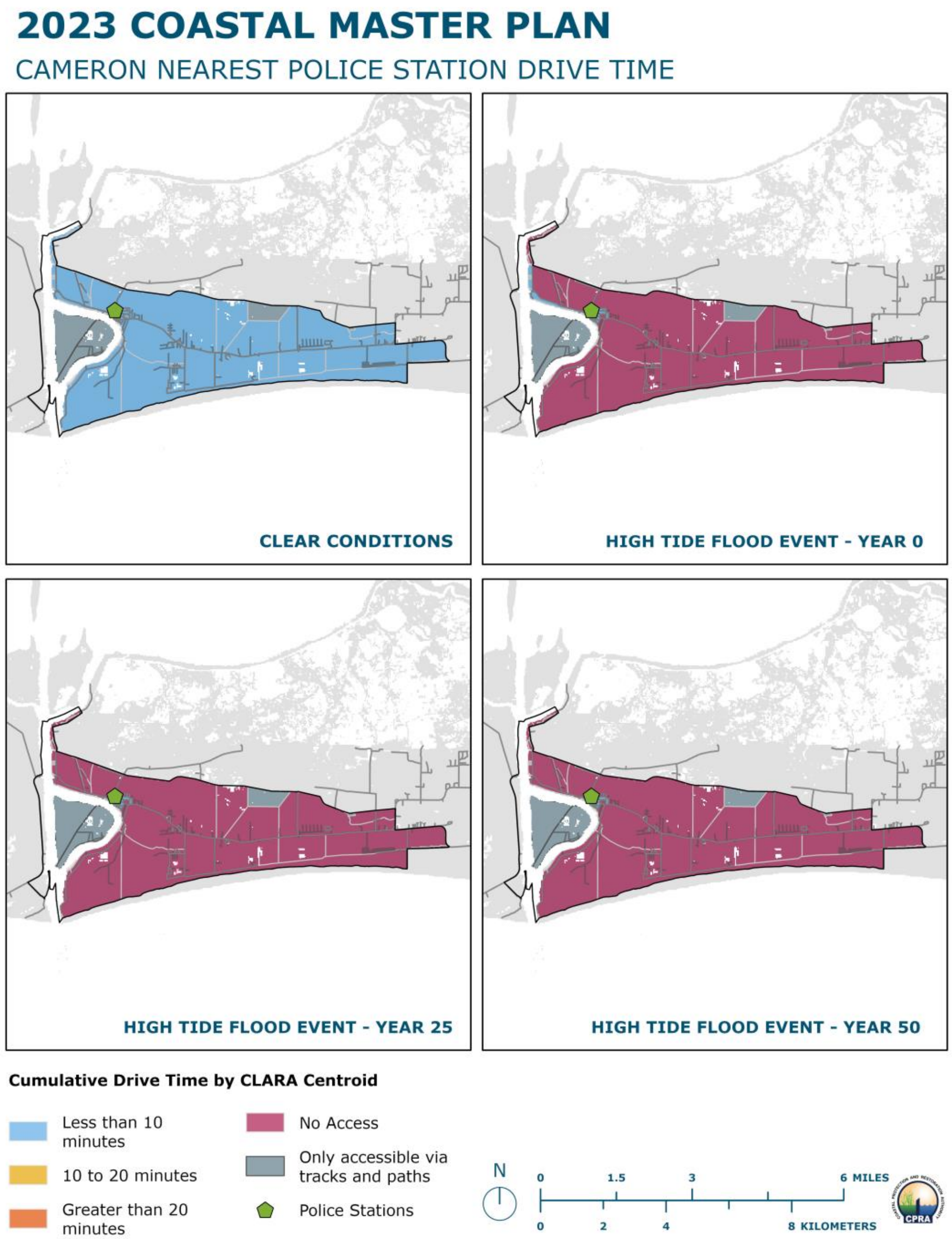
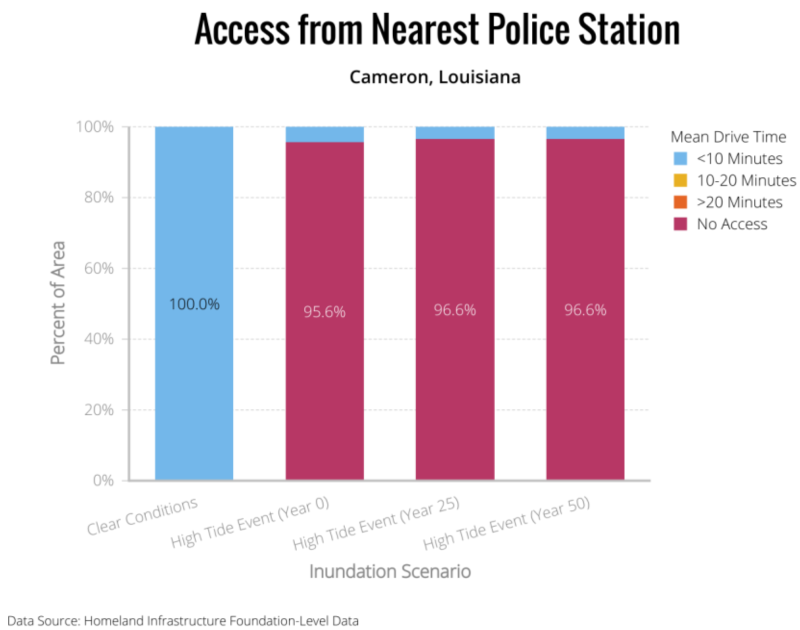


Figure 34. Drive time to nearest police station in Cameron, Louisiana.



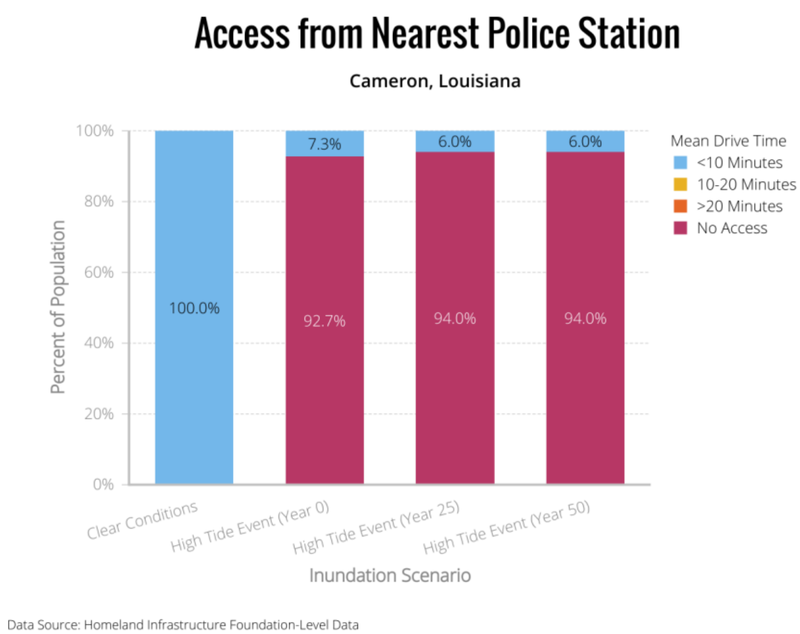


Figure 35. Drive time access to nearest police station by percent of area (top) and population (bottom) in Cameron, Louisiana.

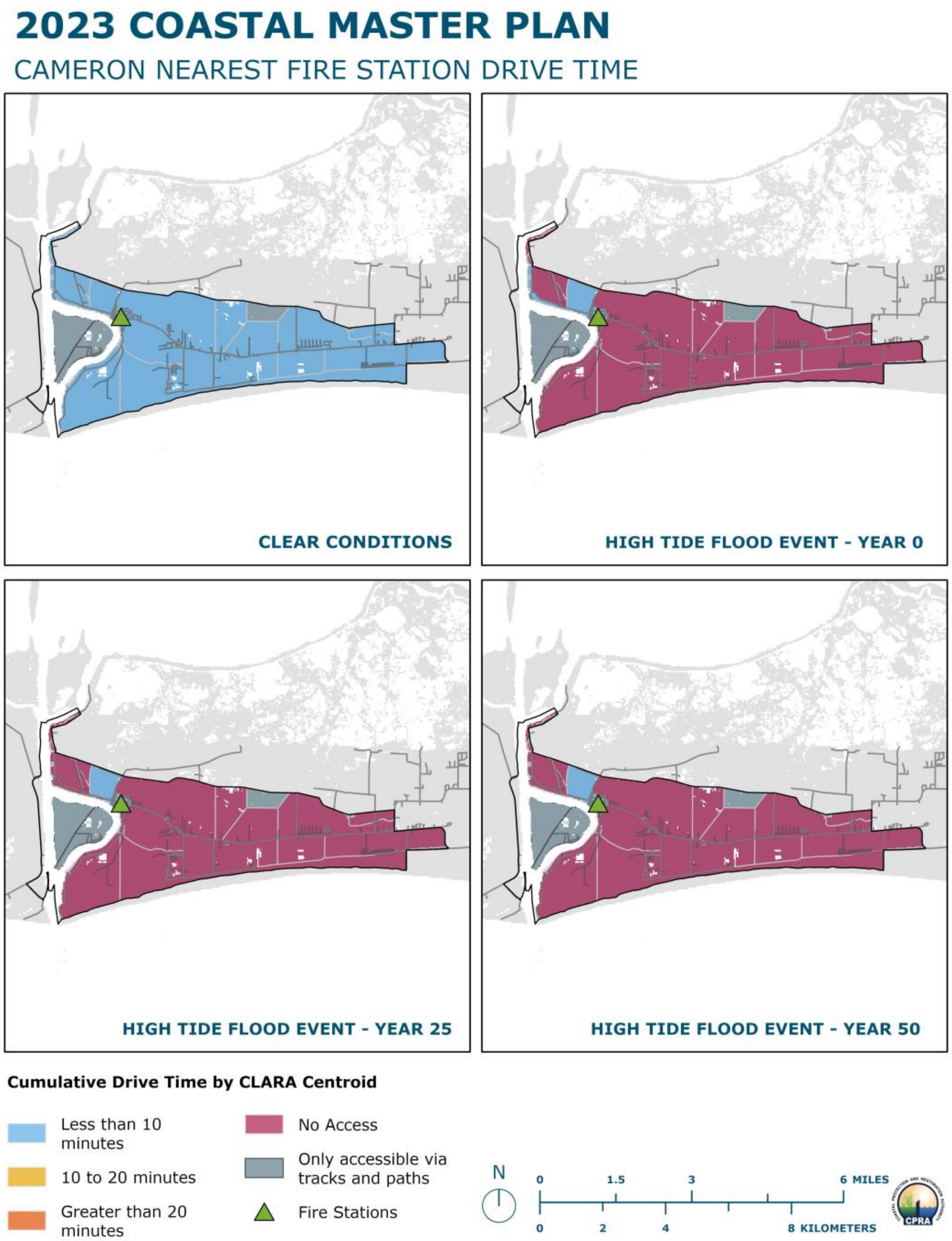
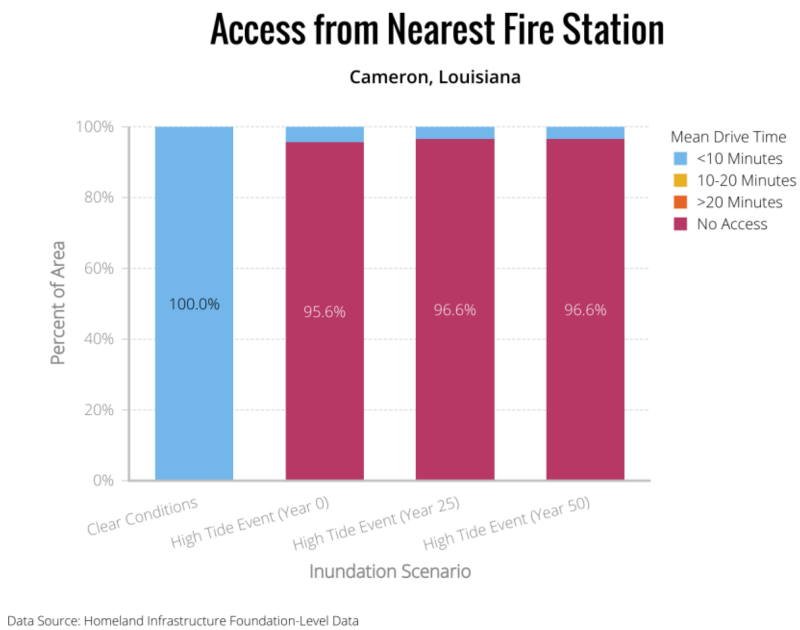


Figure 36. Drive time to nearest fire station in Cameron, Louisiana.



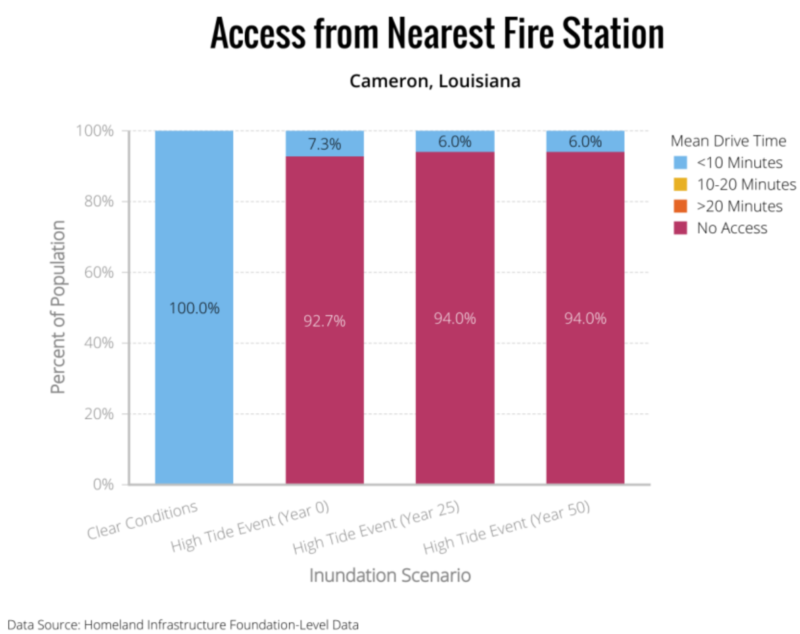


Figure 37. Drive time access to nearest fire station by percent of area (top) and population (bottom) in Cameron, Louisiana.

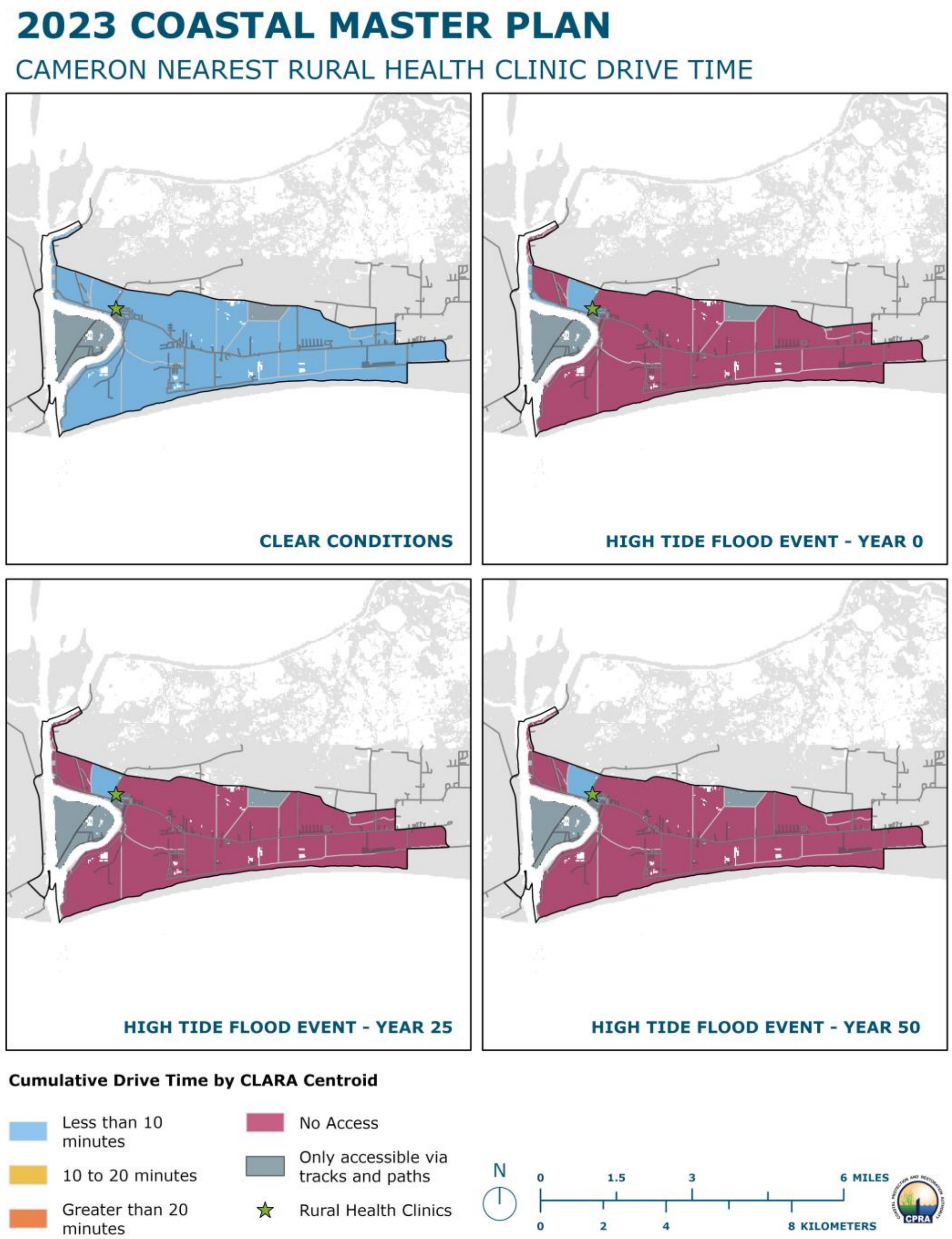
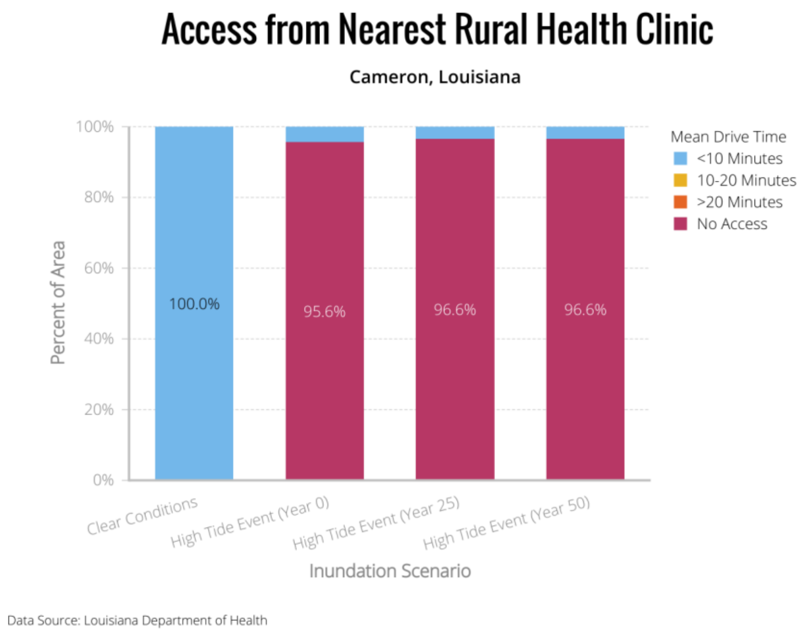


Figure 38. Drive time to nearest rural health clinic in Cameron, Louisiana.



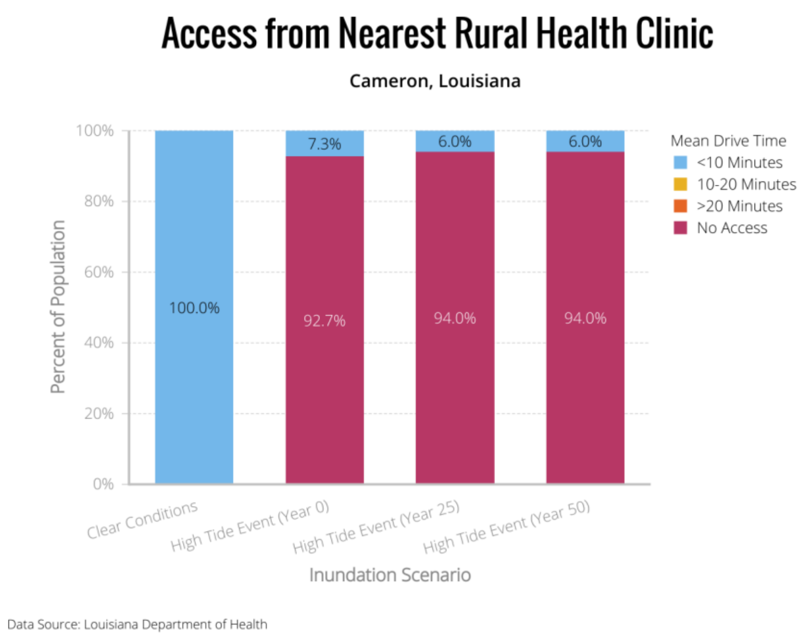


Figure 39. Drive time access to nearest rural health clinic by percent of area (top) and population (bottom) in Cameron, Louisiana.

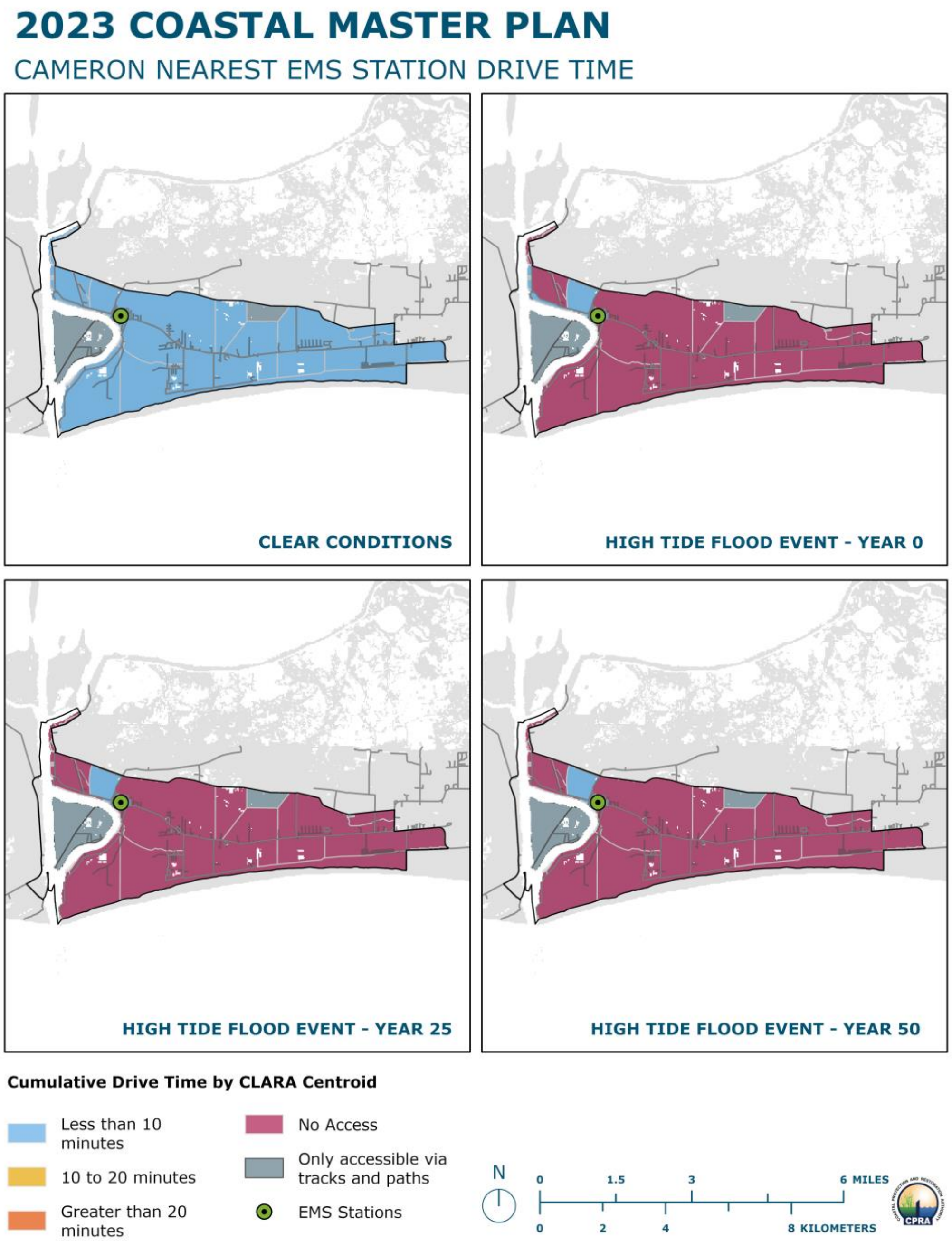
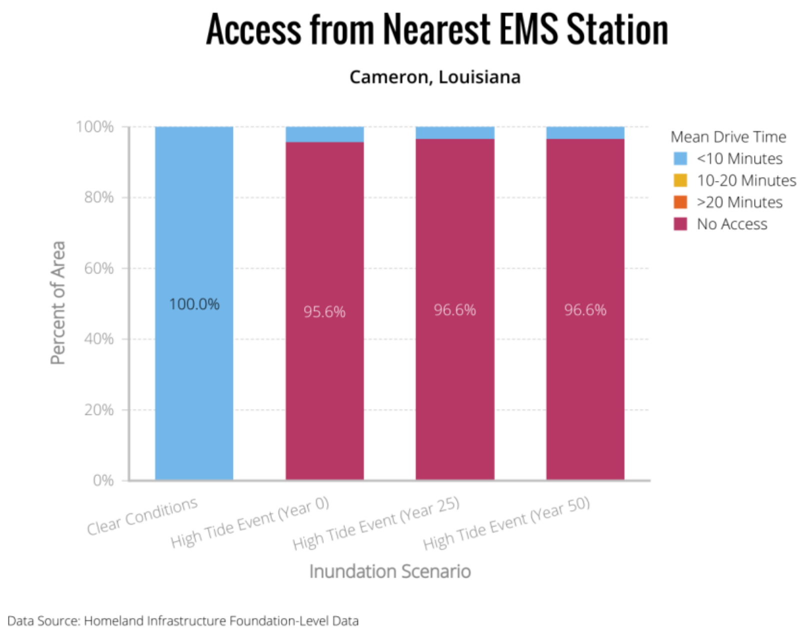


Figure 40. Drive time to nearest EMS station in Cameron, Louisiana.



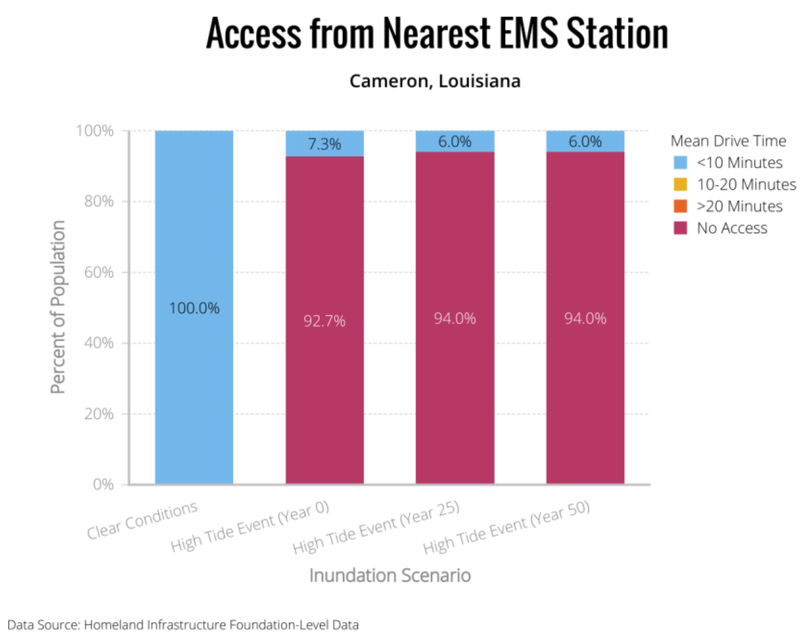


Figure 41. Drive time access to nearest EMS station by percent of area (top) and population (bottom) in Cameron, Louisiana.

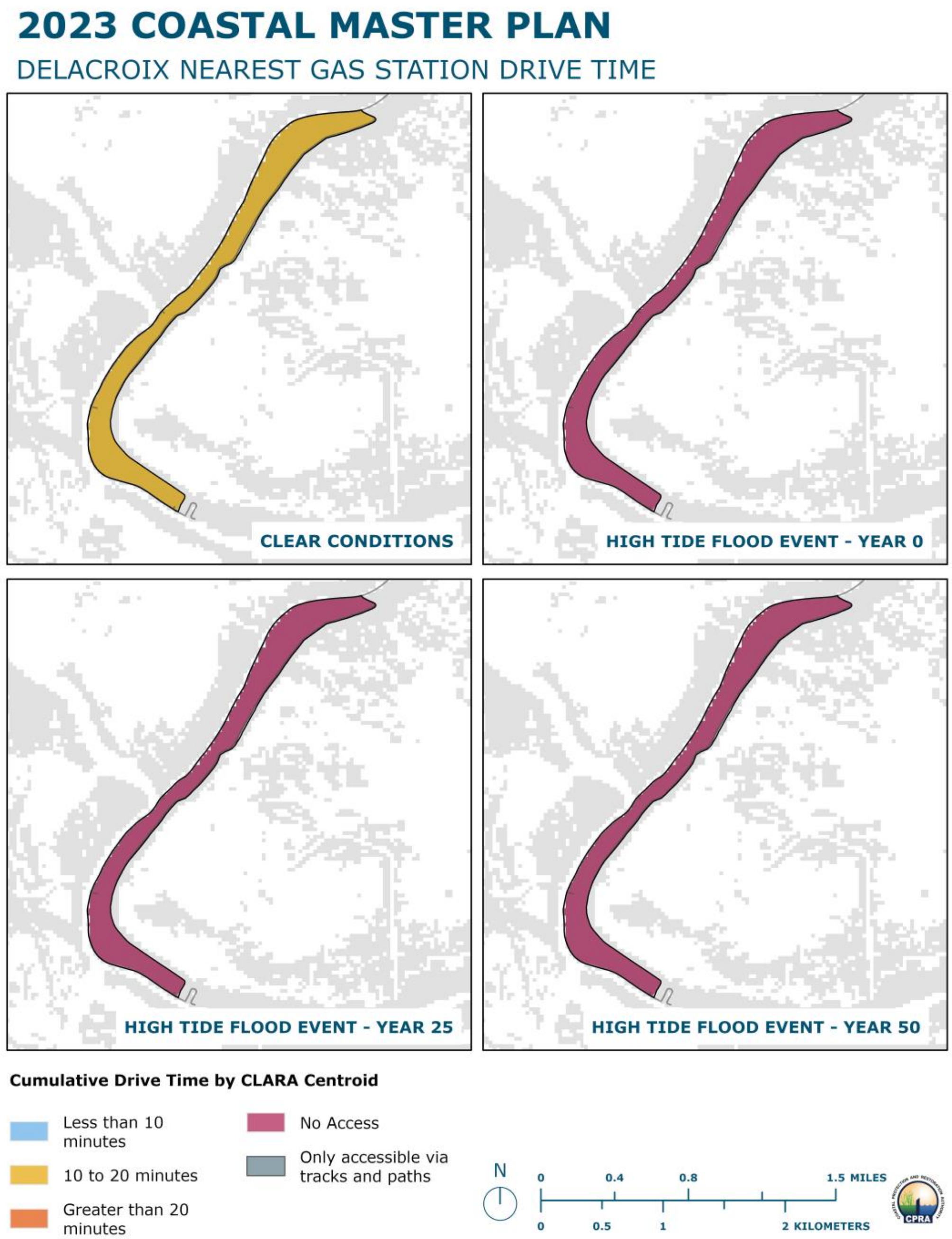
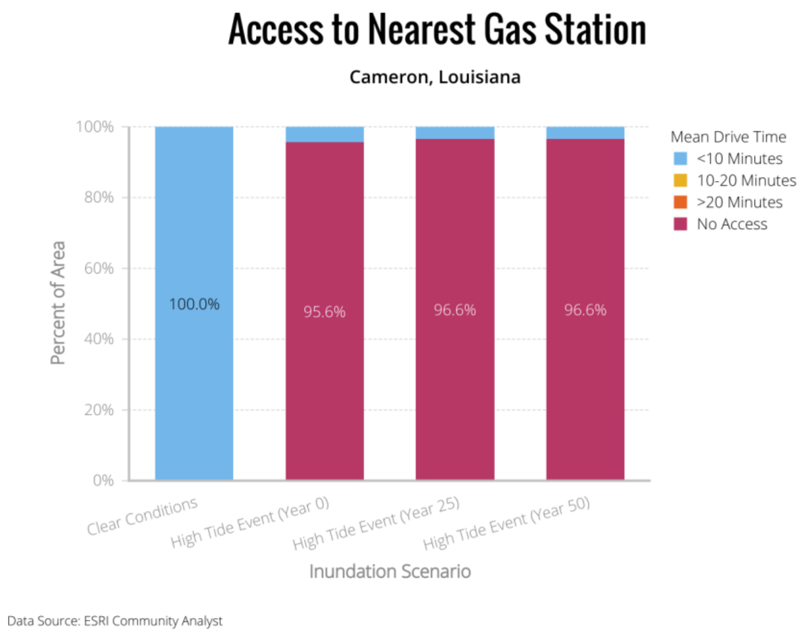


Figure 42. Drive time to nearest gas station in Cameron, Louisiana.



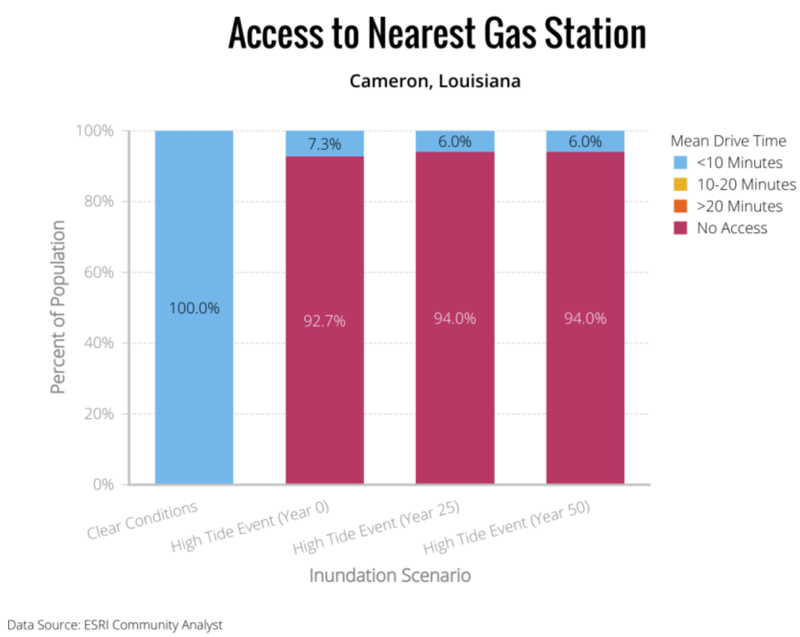


Figure 43. Drive time access to nearest gas station by percent of area (top) and population (bottom) in Cameron, Louisiana.

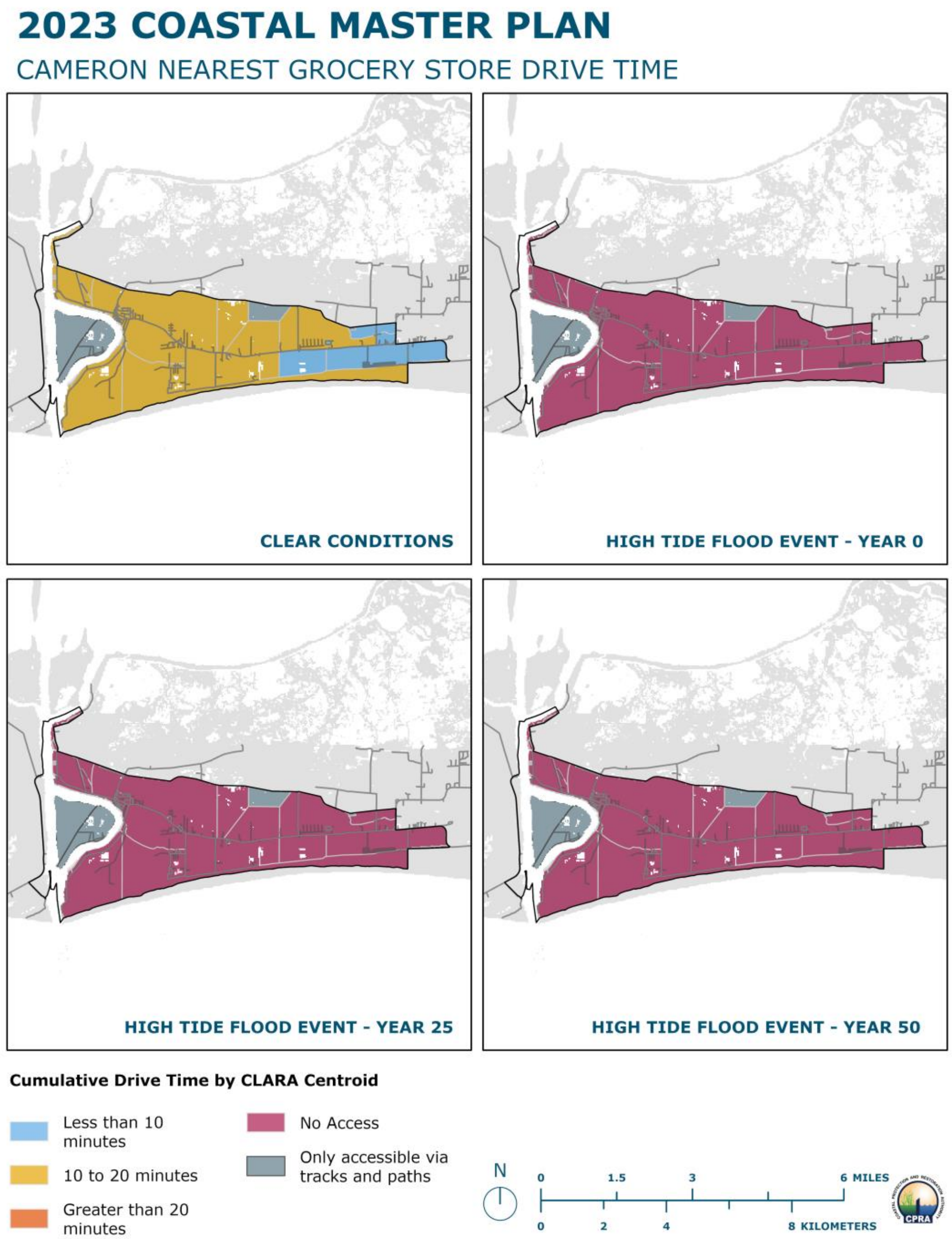
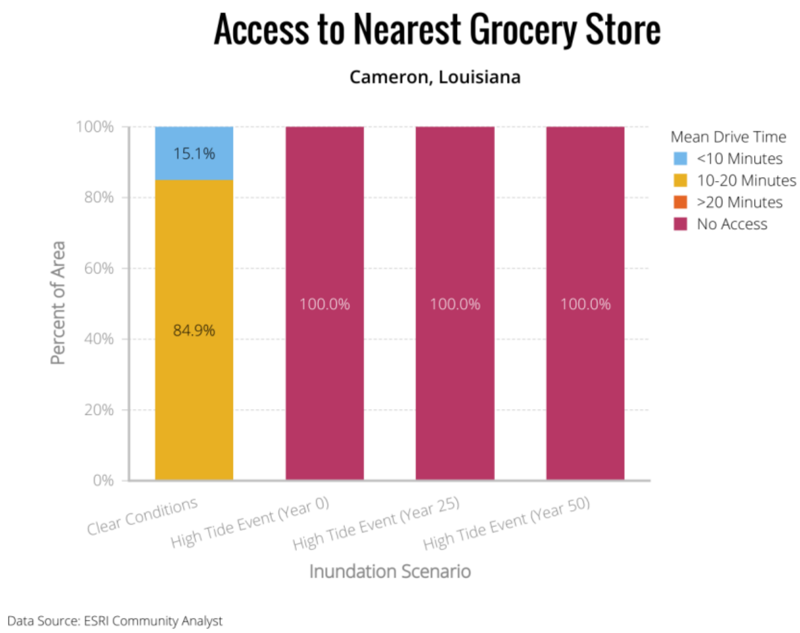


Figure 44. Drive time to nearest grocery store in Cameron, Louisiana.



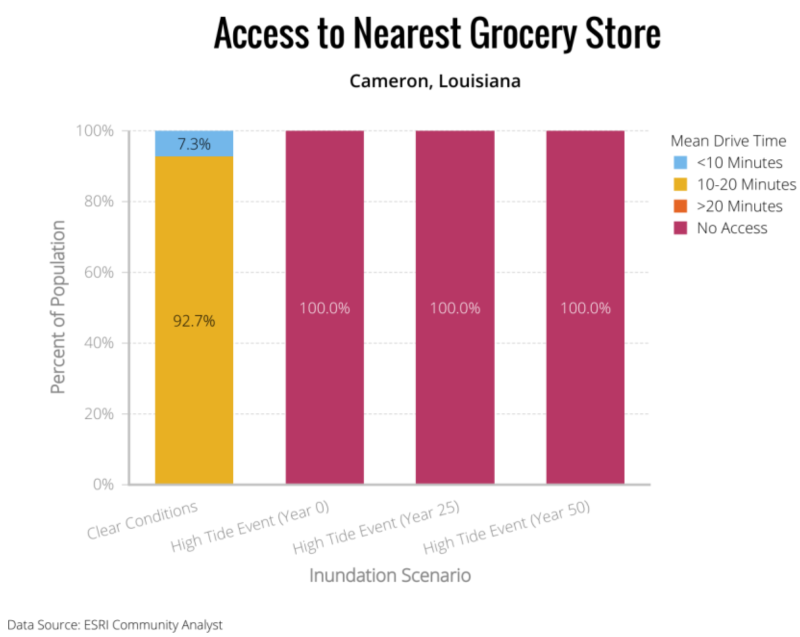


Figure 45. Drive time access to nearest grocery store by percent of area (top) and population (bottom) in Cameron, Louisiana.

DELACROIX

The small unincorporated fishing community of Delacroix is in St. Bernard Parish along Bayou Terre aux Bouefs, surrounded on all sides by bayous and wetlands. The majority of the critical and essential facilities that service the community are located further inland within the federal levee system or along the Delacroix Highway, which is the only road in or out of Delacroix. During HTF events, ICM output indicates that segments of the highway are expected to flood, potentially disrupting the ability of residents to access critical and essential facilities. See Figure 46 through Figure 62 for more information on the drive time analysis for Delacroix, Louisiana.

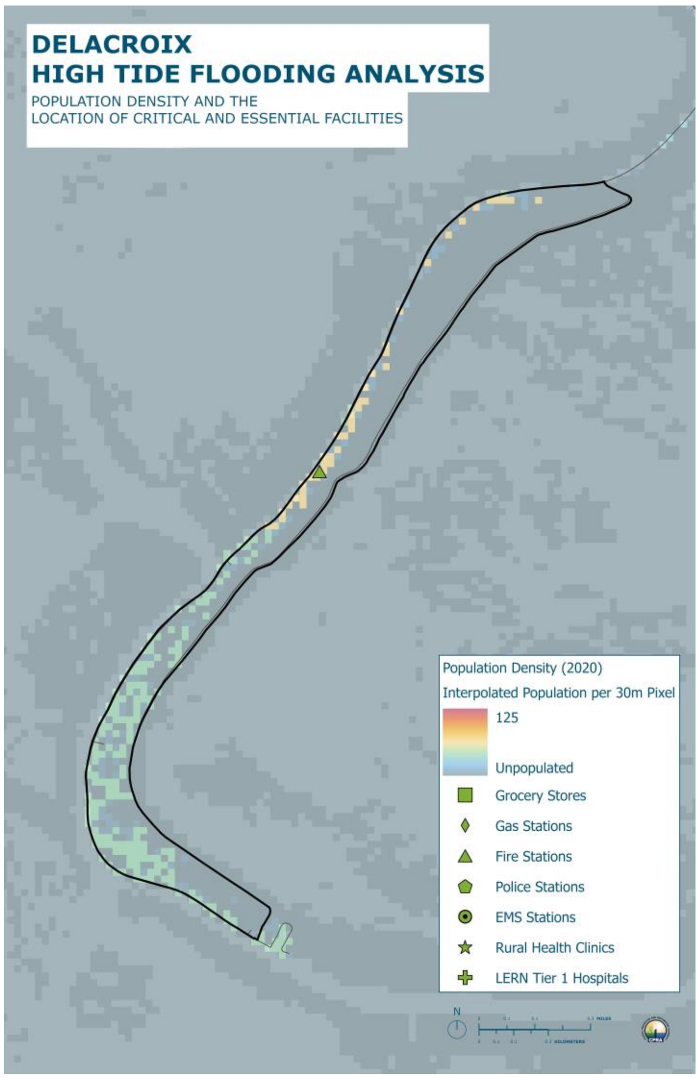


Figure 46. Dasymetric population density map of Delacroix, Louisiana with locations of nearby critical and essential facilities, where applicable.

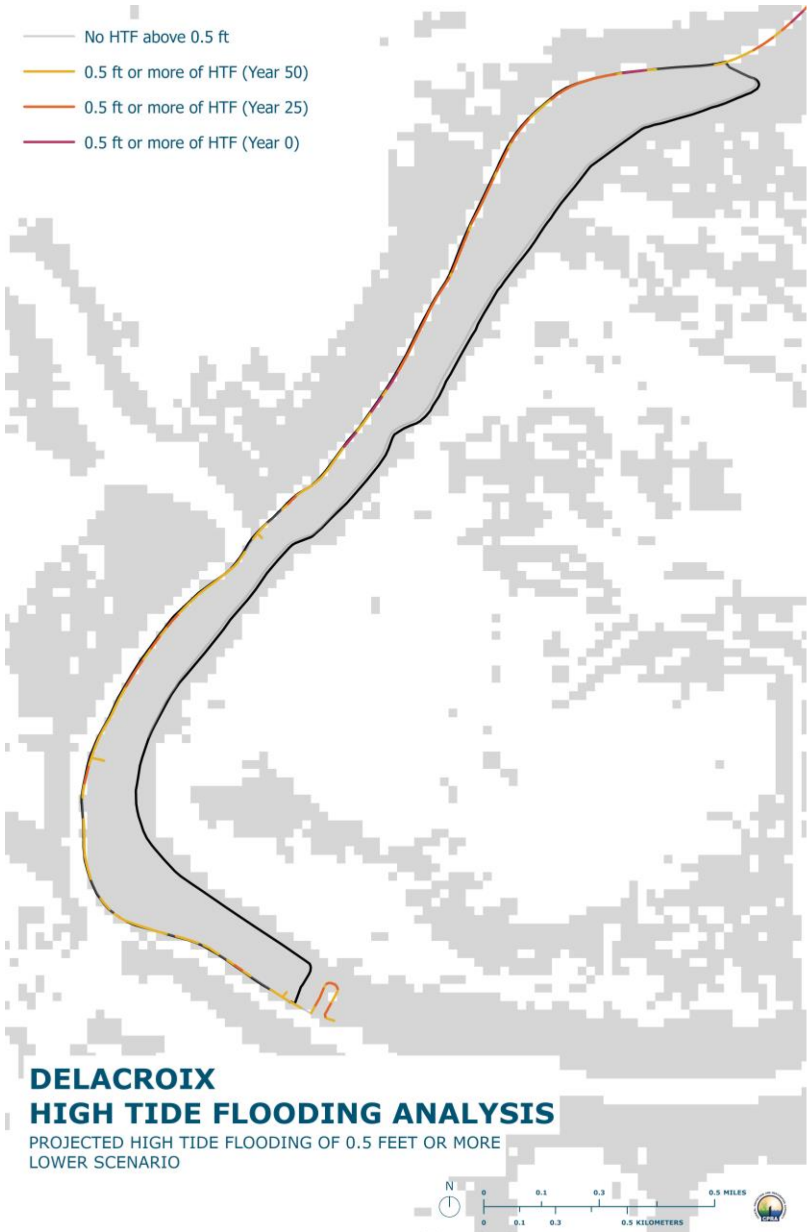


Figure 47. Road segments in Delacroix, Louisiana projected to have 0.5 ft or more of HTF and considered impassable in Year 0, Year 25, and Year 50 under the 2023 Coastal Master Plan's lower scenario

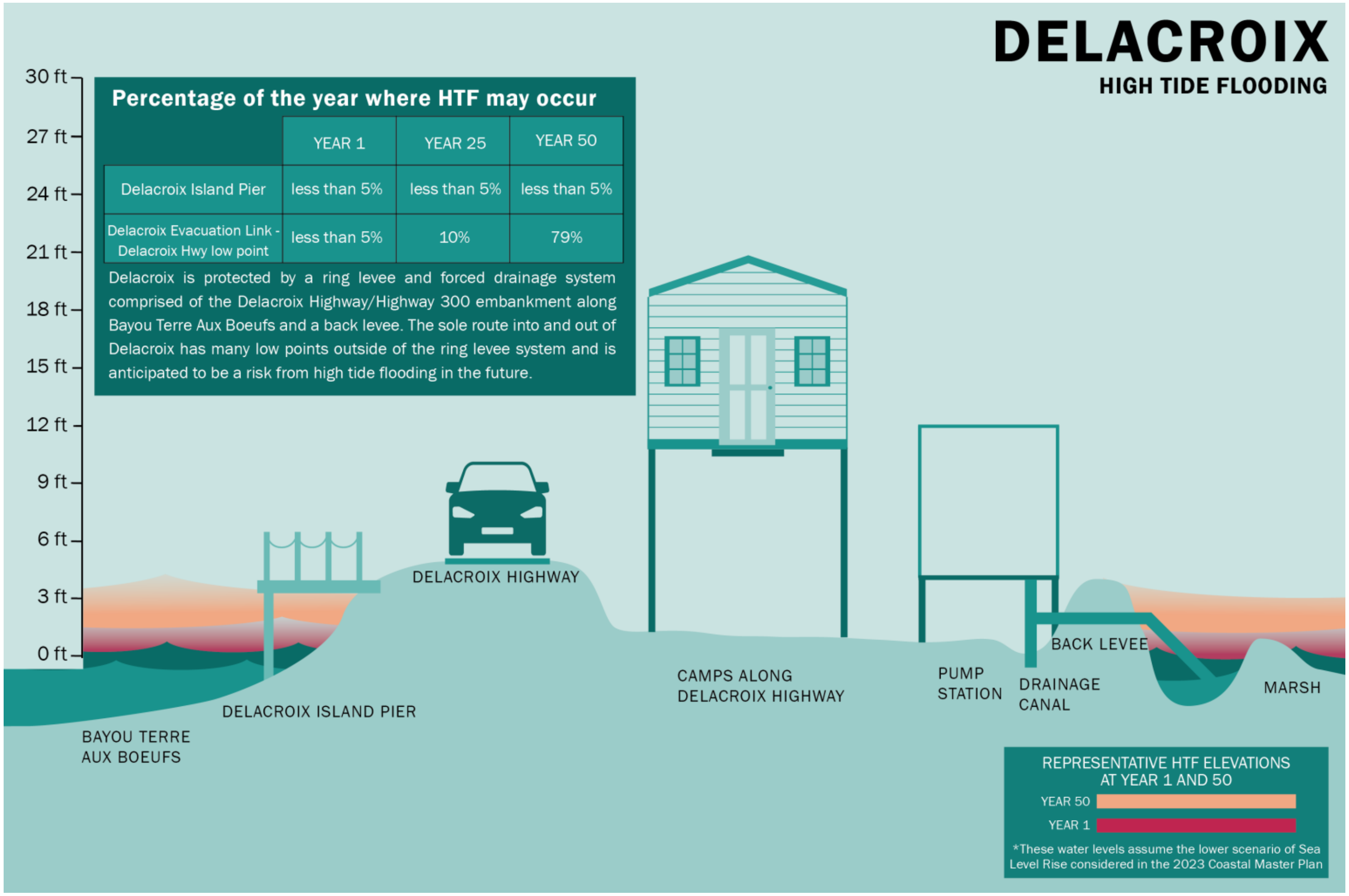


Figure 48. Modeled WSE depths for HTF events in Delacroix, Louisiana at local impact threshold locations.

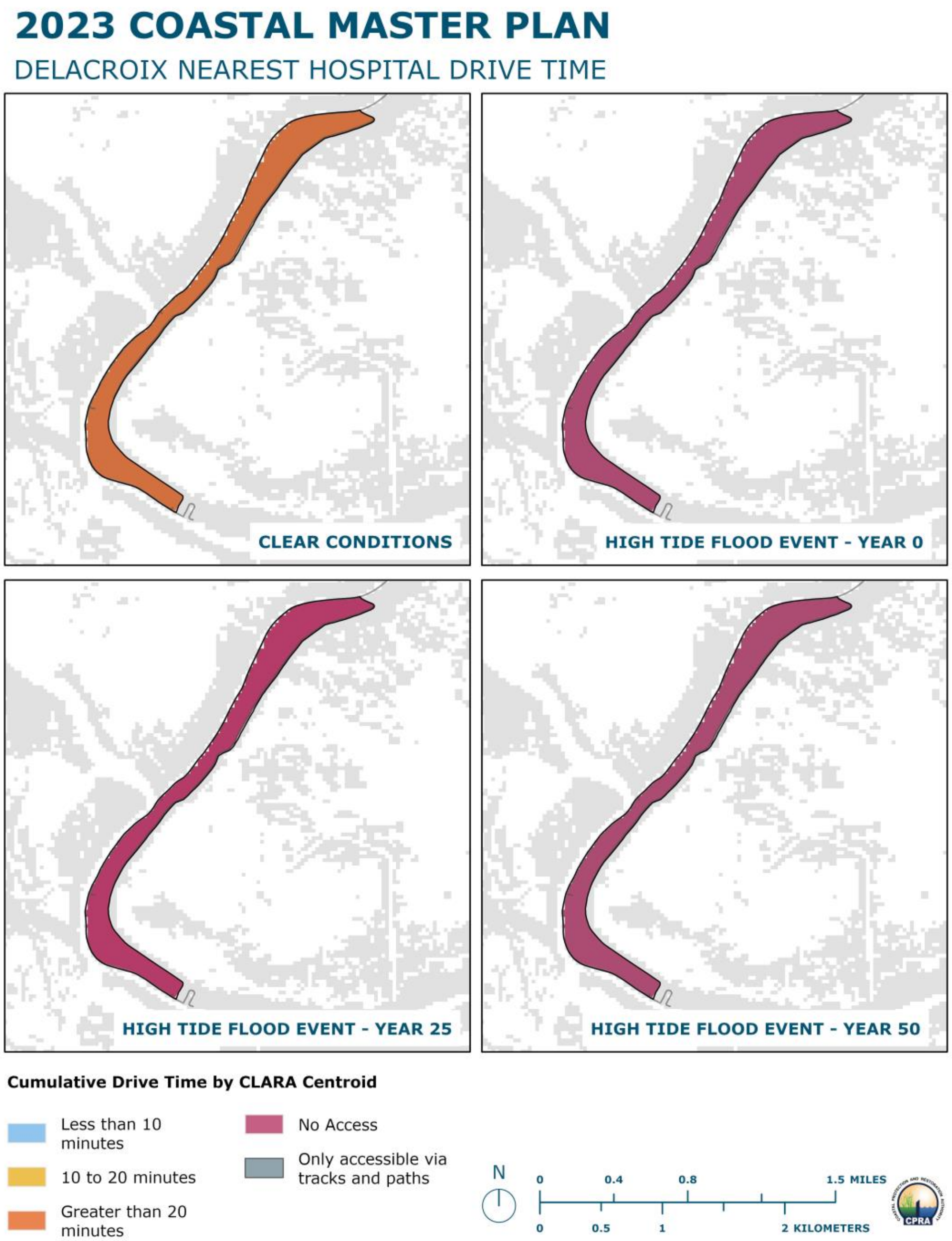
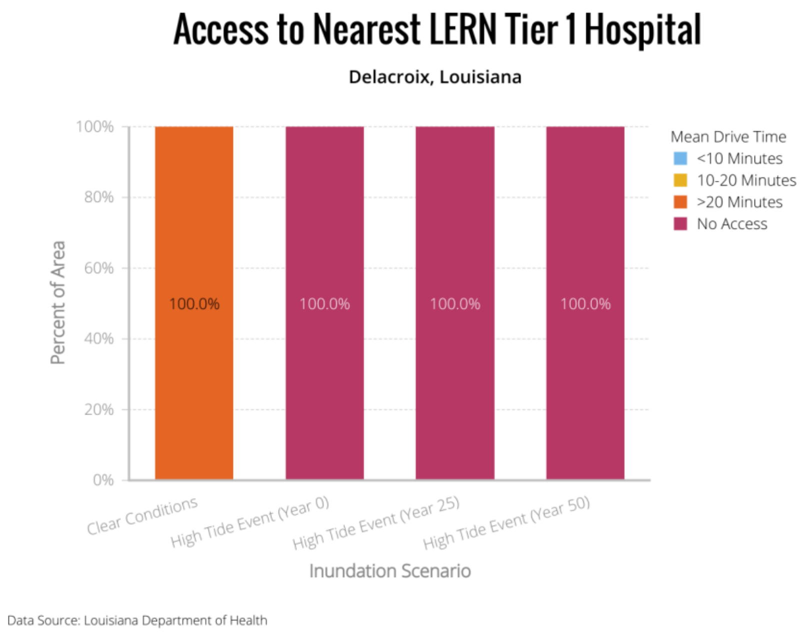


Figure 49. Drive time to nearest LERN Tier 1 hospital in Delacroix, Louisiana.



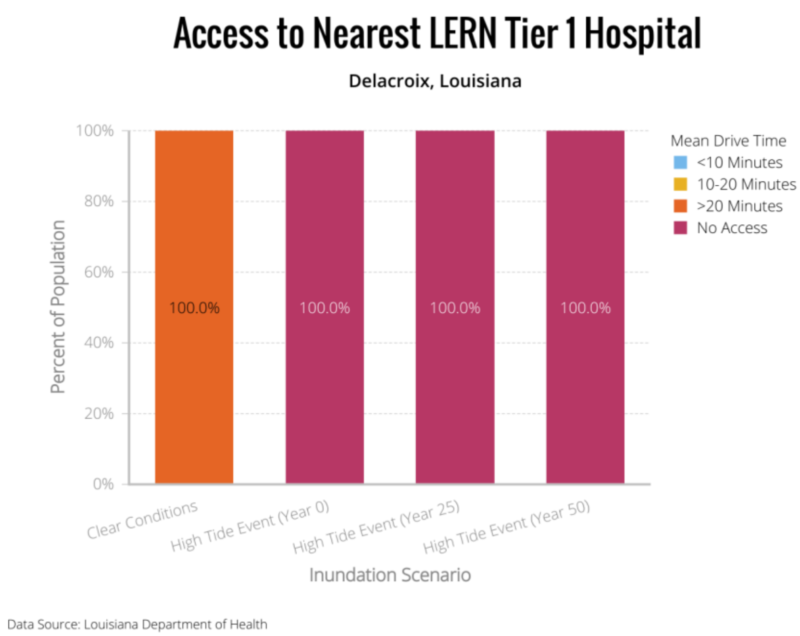


Figure 50. Drive time access to nearest LERN Tier 1 hospital by percent of area (top) and population (bottom) in Delacroix, Louisiana.

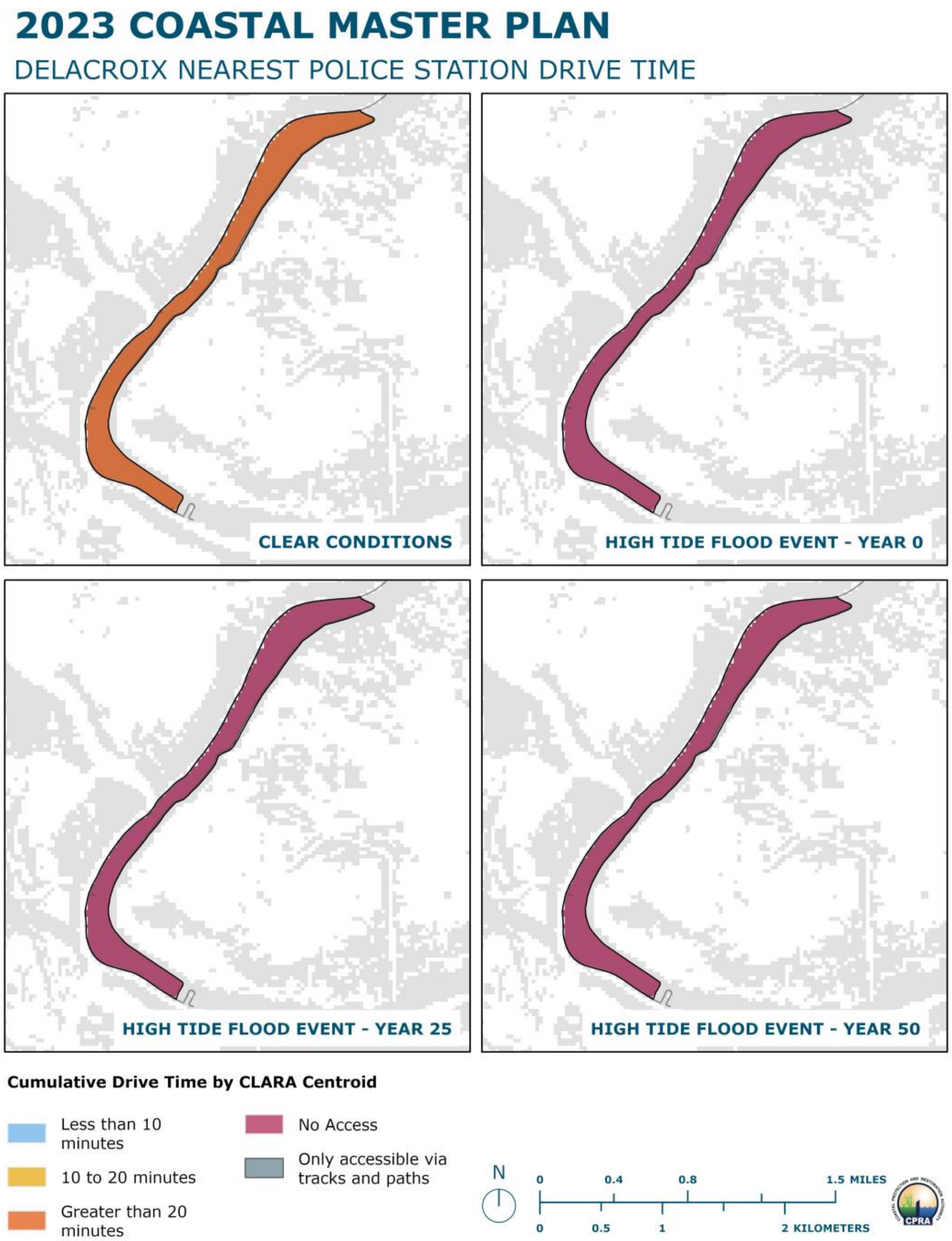
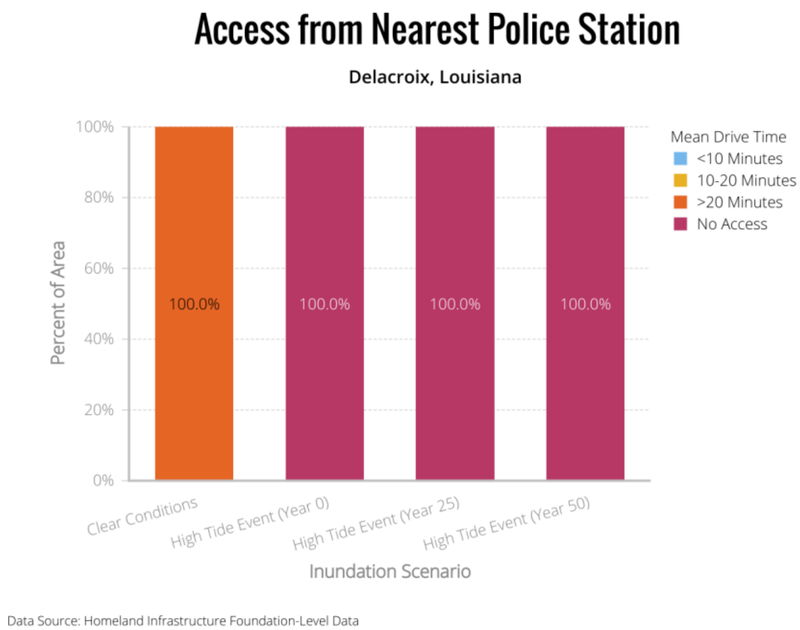


Figure 51. Drive time to nearest police station in Delacroix, Louisiana.



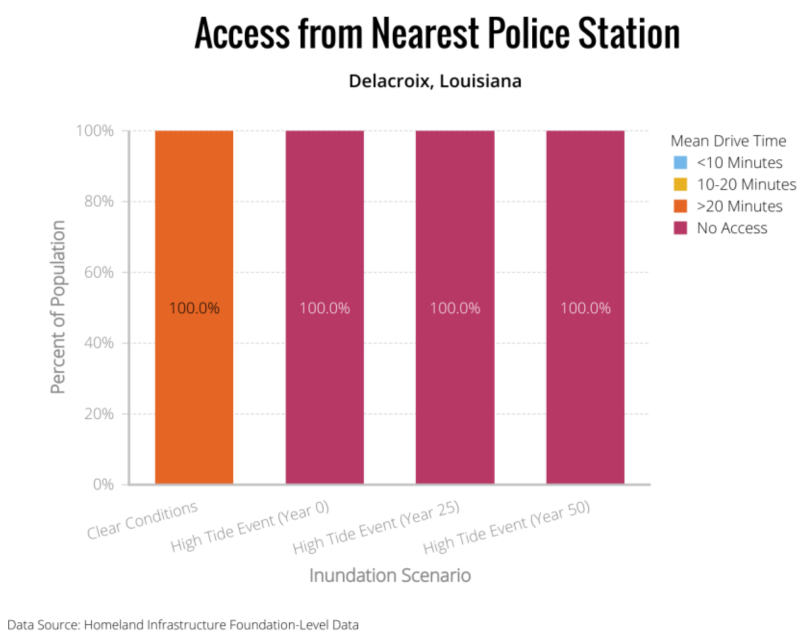


Figure 52. Drive time access to nearest police station by percent of area (top) and population (bottom) in Delacroix, Louisiana.

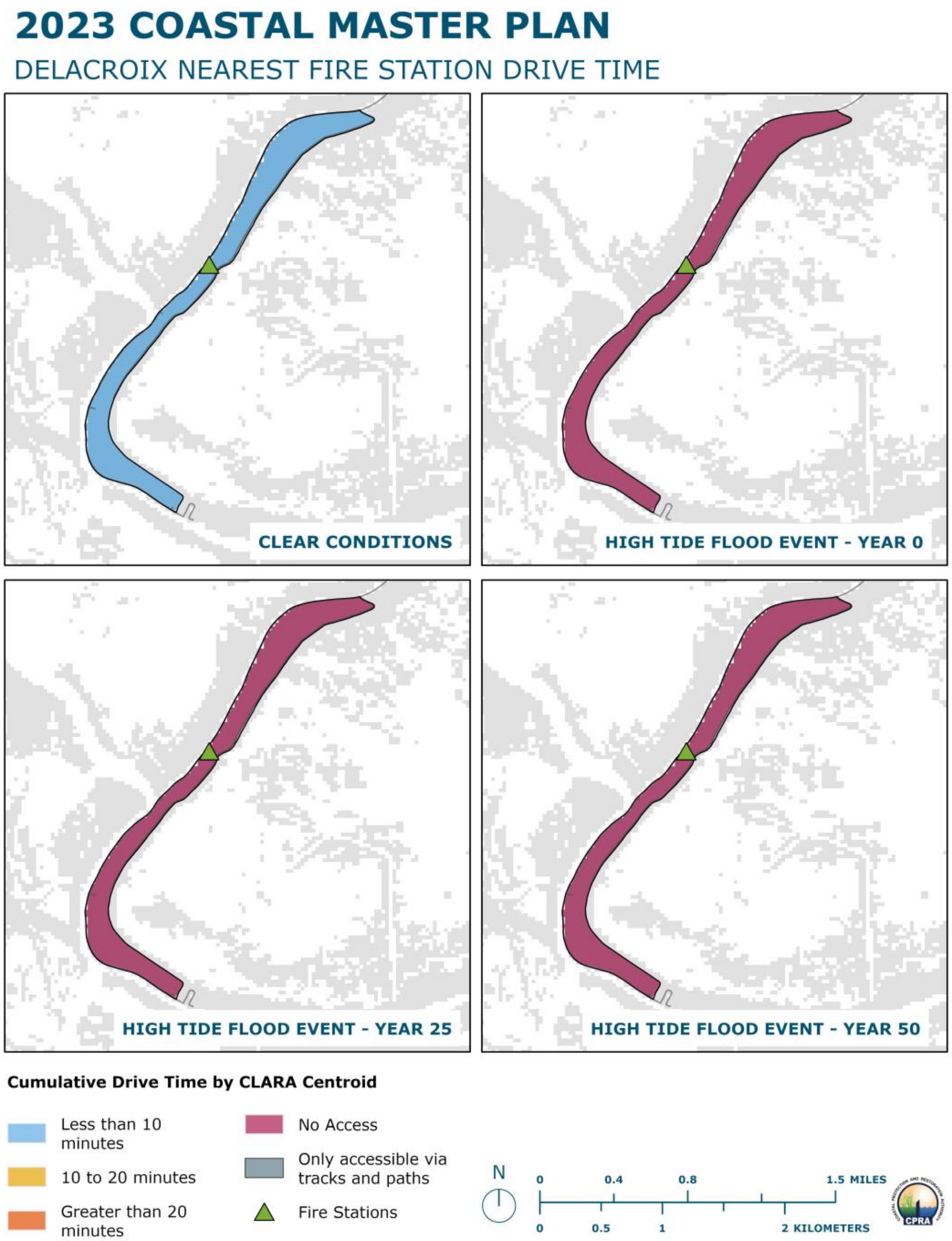
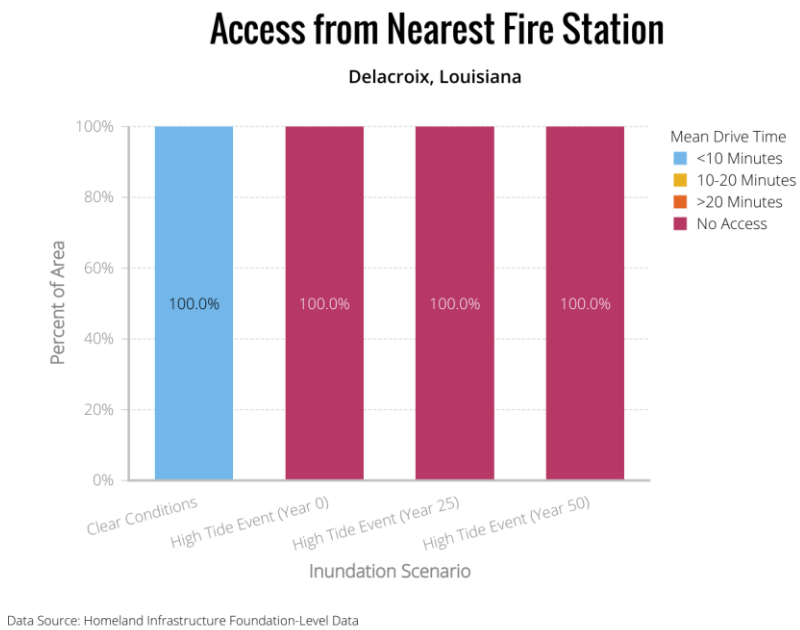


Figure 53. Drive time to nearest fire station in Delacroix, Louisiana.



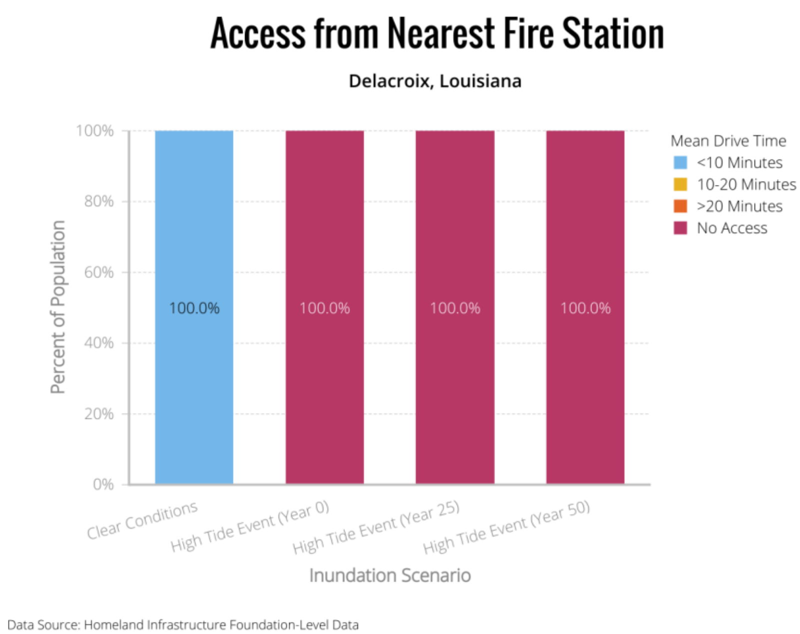


Figure 54. Drive time access to nearest fire station by percent of area (top) and population (bottom) in Delacroix, Louisiana.

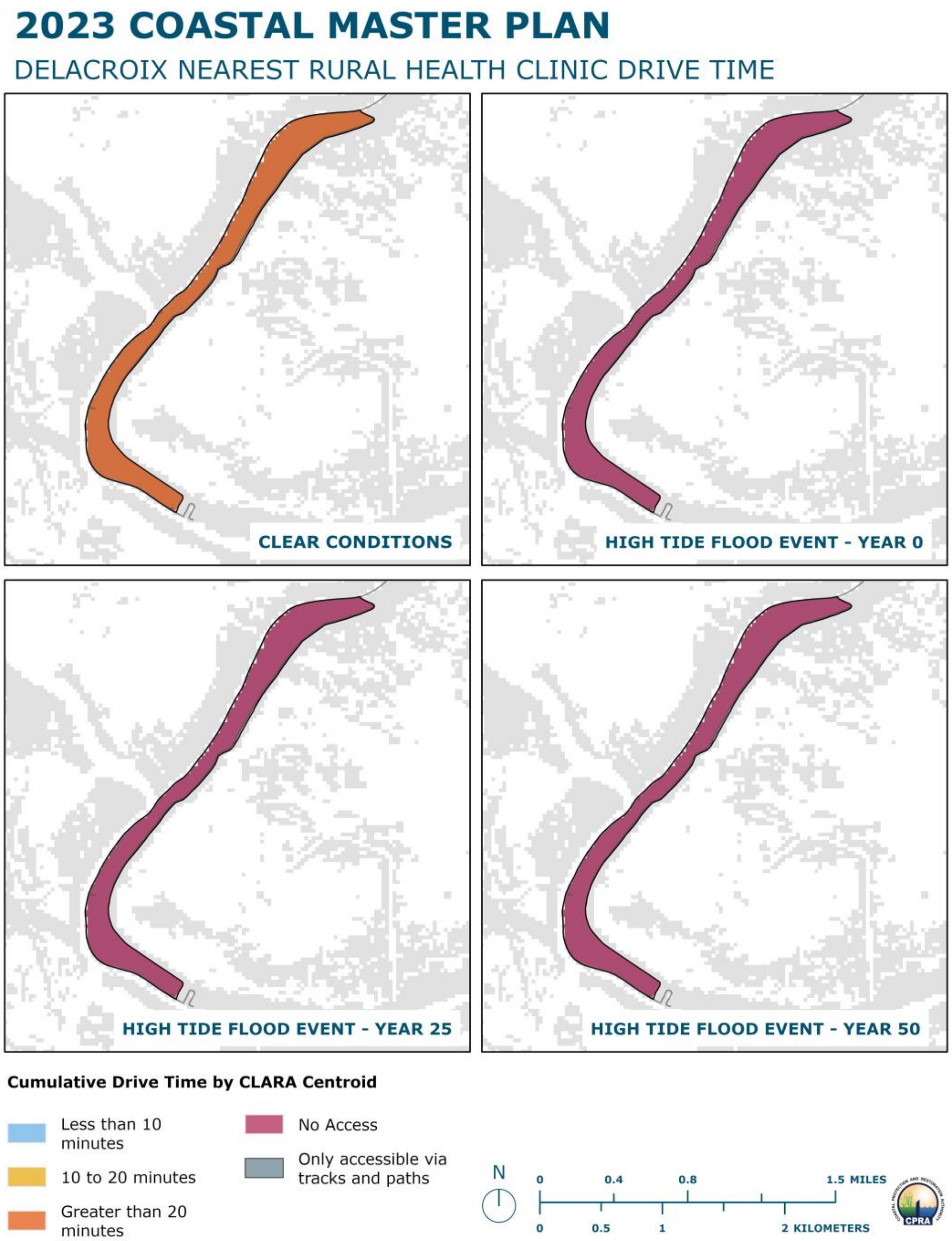
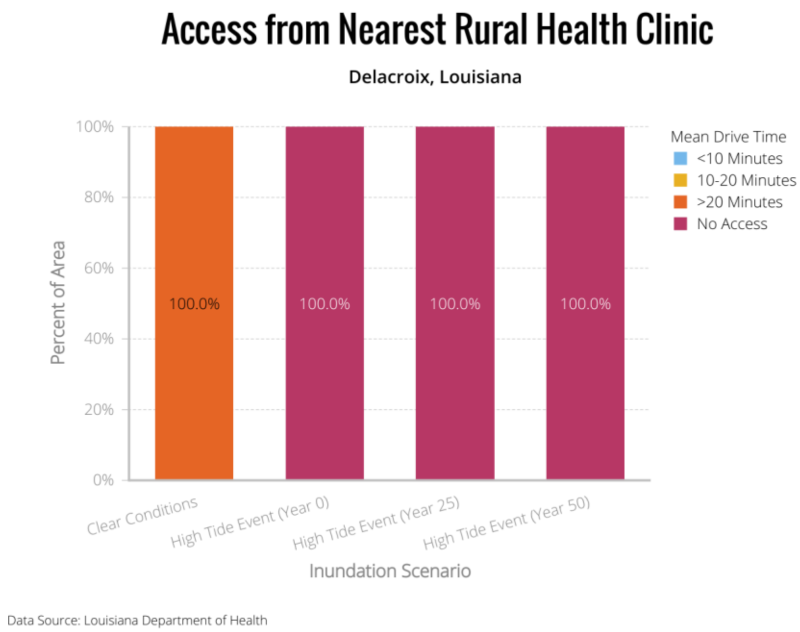


Figure 55. Drive time to nearest rural health clinic in Delacroix, Louisiana.



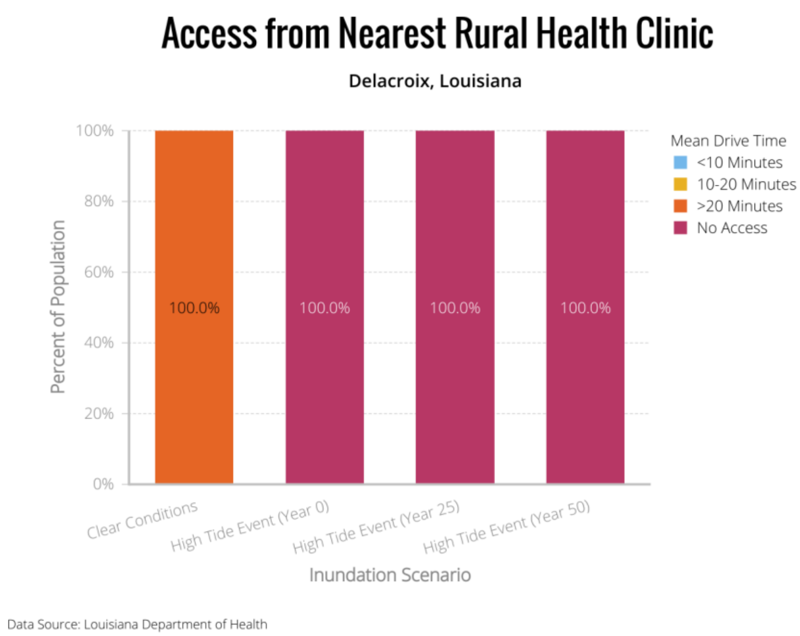


Figure 56. Drive time access to nearest rural health clinic by percent of area (top) and population (bottom) in Delacroix, Louisiana.

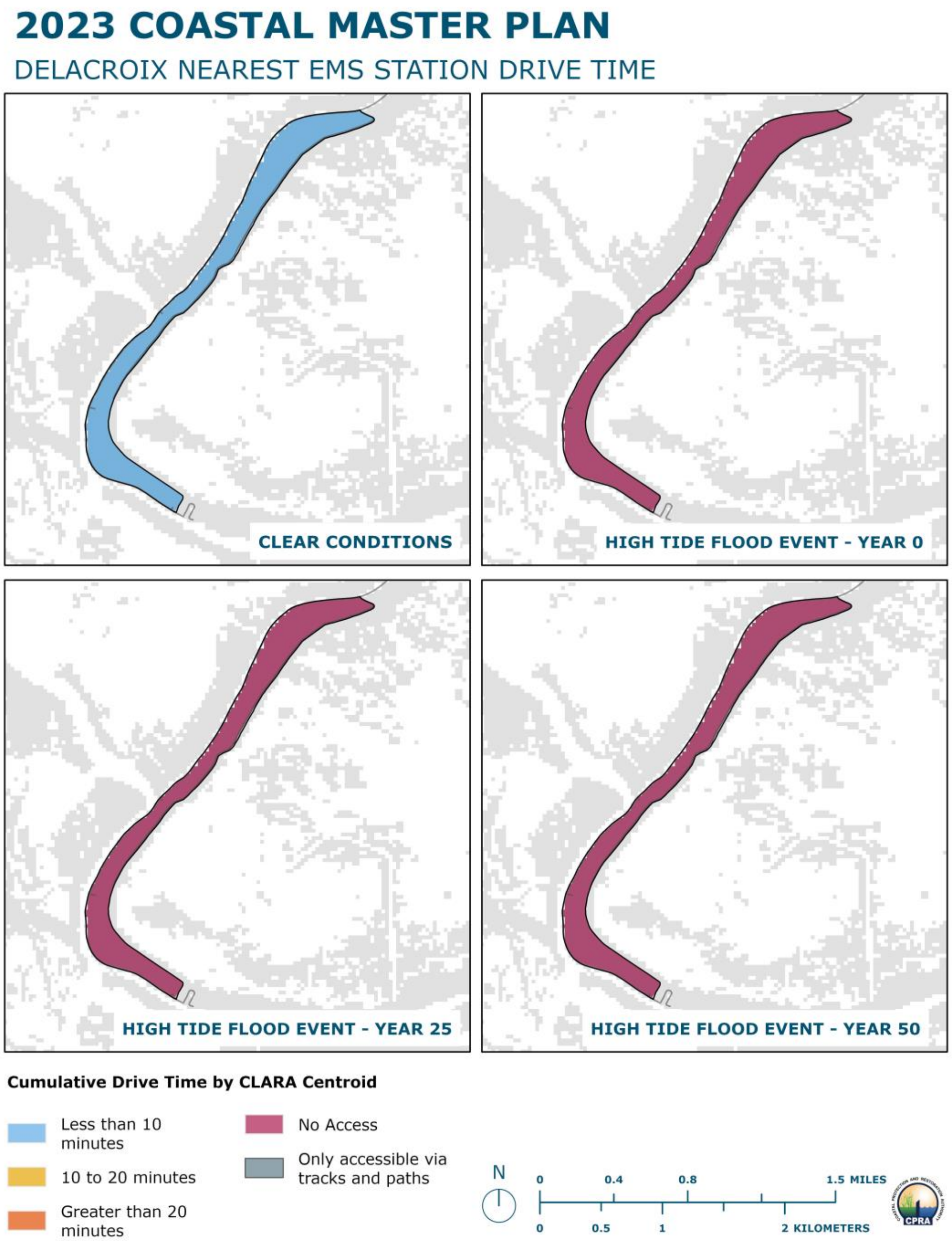
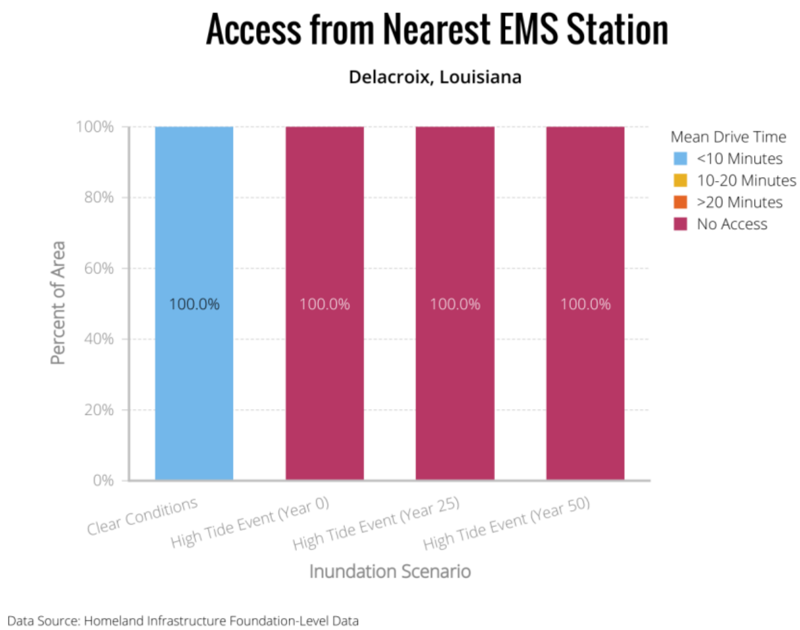


Figure 57. Drive time to nearest EMS station in Delacroix, Louisiana.



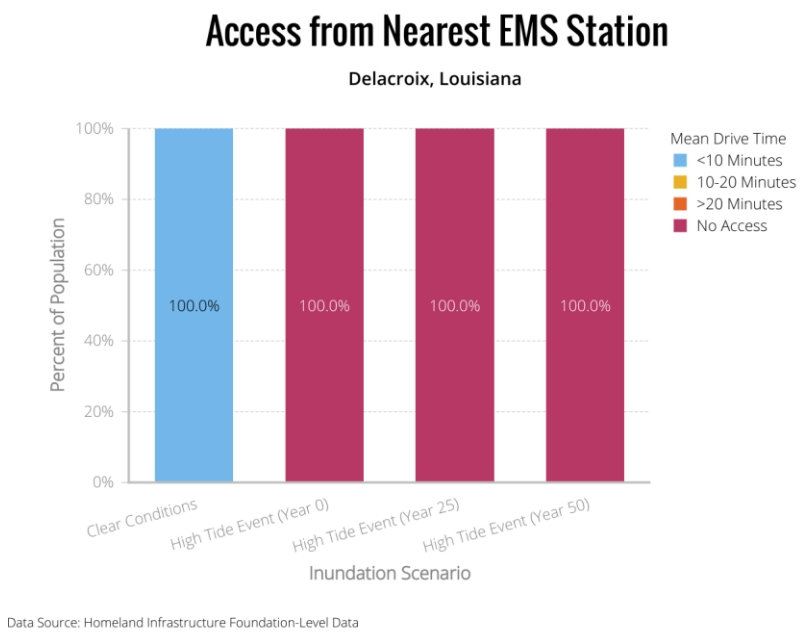


Figure 58. Drive time access to nearest EMS station by percent of area (top) and population (bottom) in Delacroix, Louisiana.

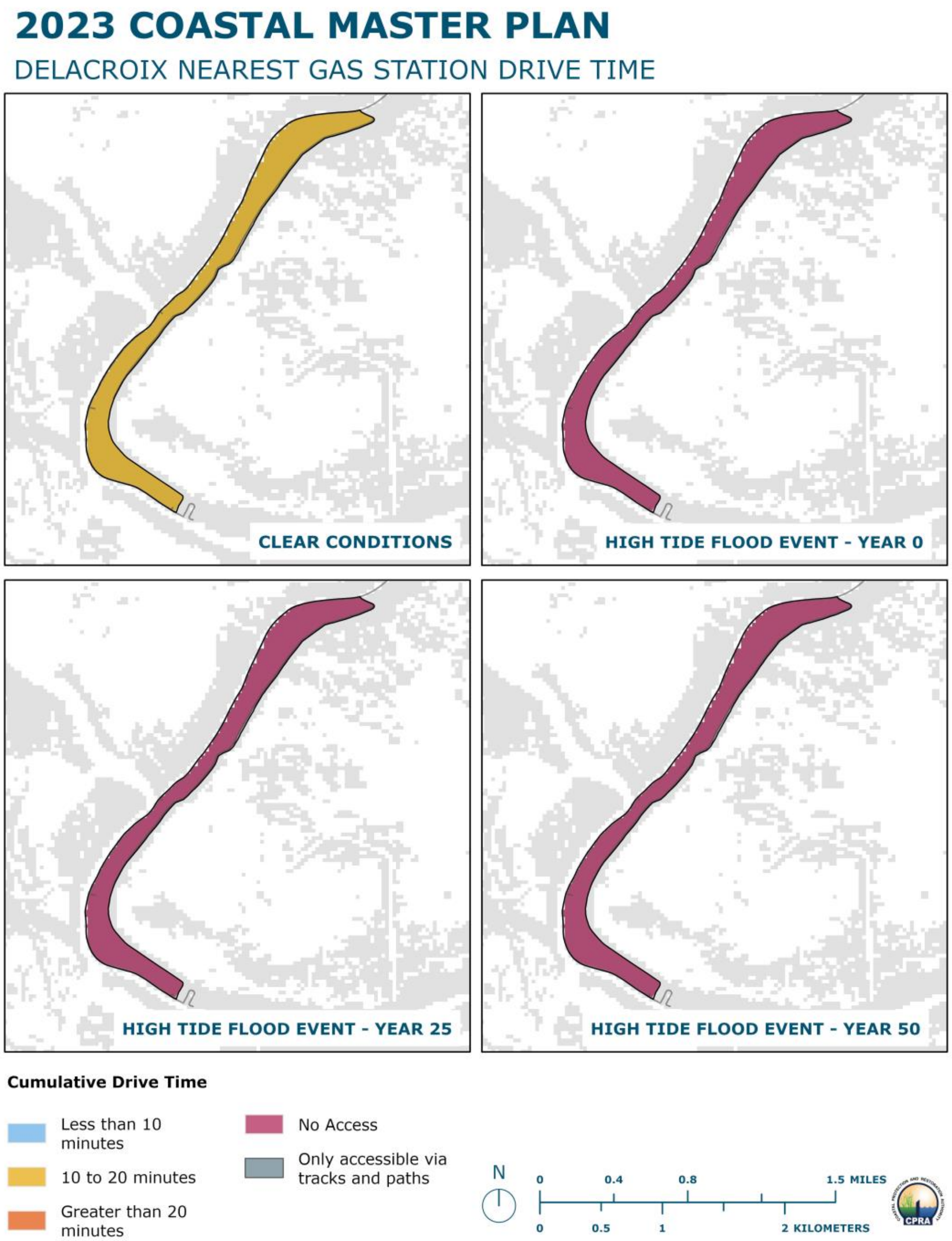
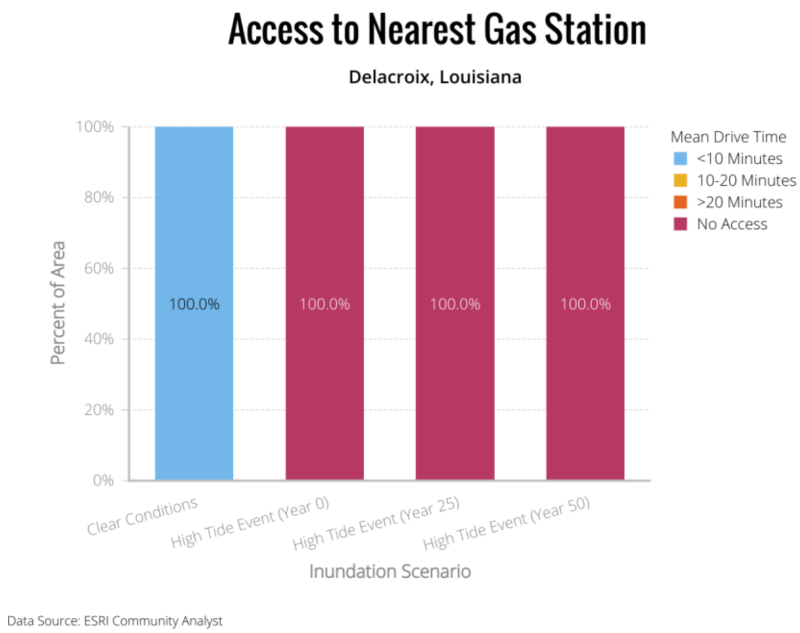


Figure 59. Drive time to nearest gas station in Delacroix, Louisiana.



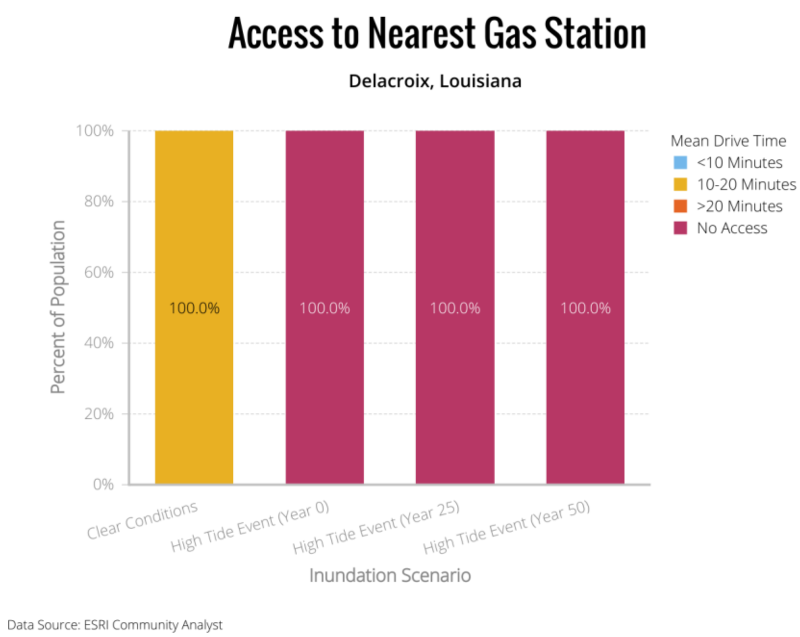


Figure 60. Drive time access to nearest gas station by percent of area (top) and population (bottom) in Delacroix, Louisiana.

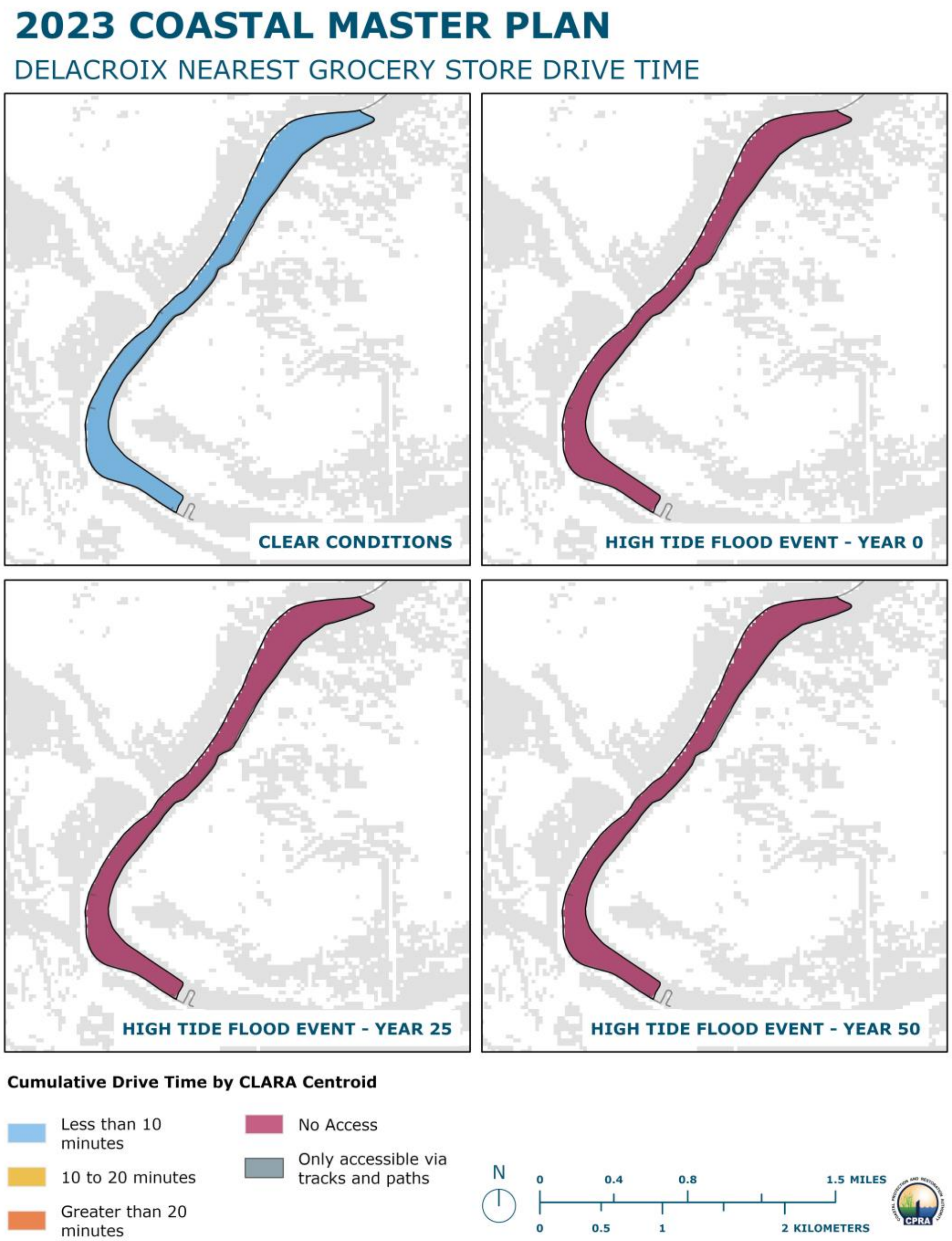
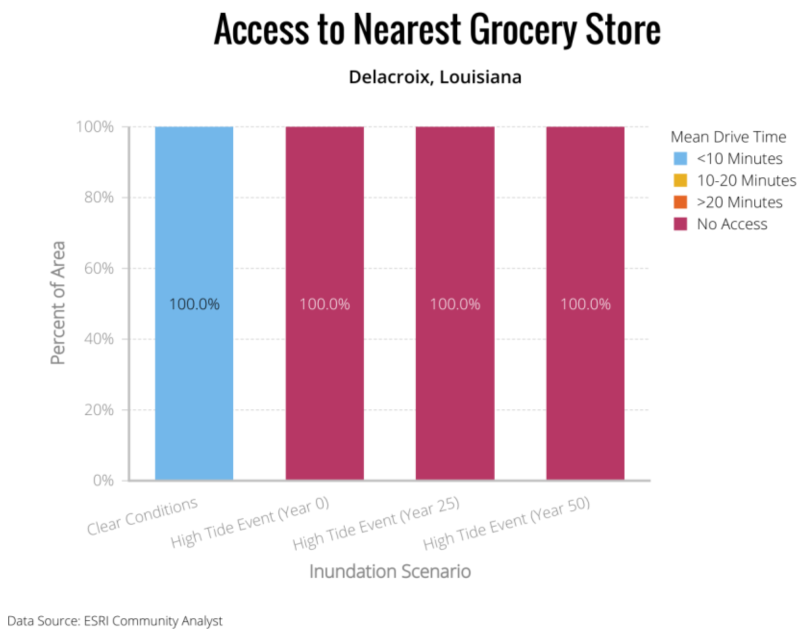


Figure 61. Drive time to nearest grocery store in Delacroix, Louisiana.



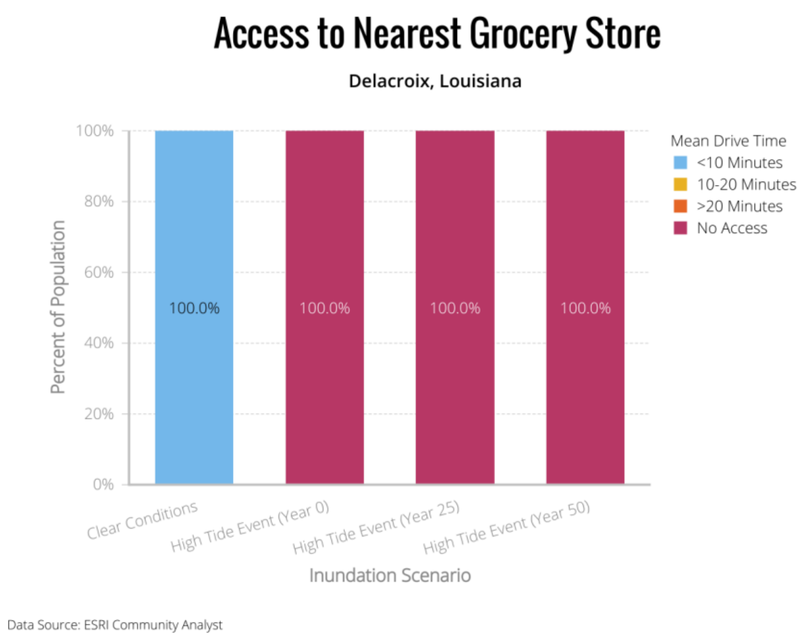


Figure 62. Drive time access to nearest grocery store by percent of area (top) and population (bottom) in Delacroix, Louisiana.

DELCAMBRE

The town of Delcambre is located in southcentral Louisiana, west of the Atchafalaya River and north of Vermilion Bay. The Delcambre Canal runs through the middle of the town, connecting Vermilion Bay and the Gulf of Mexico to the inland communities of the region. During HTF events, ICM outputs indicate that notable roadway flooding would not be expected to occur until Years 25 and 50. The majority of the impacts are expected to occur to the east of the Delcambre Canal, away from the residential center of the town. See Figure 63 through Figure 79 for more information on the drive time analysis for Delcambre, Louisiana.

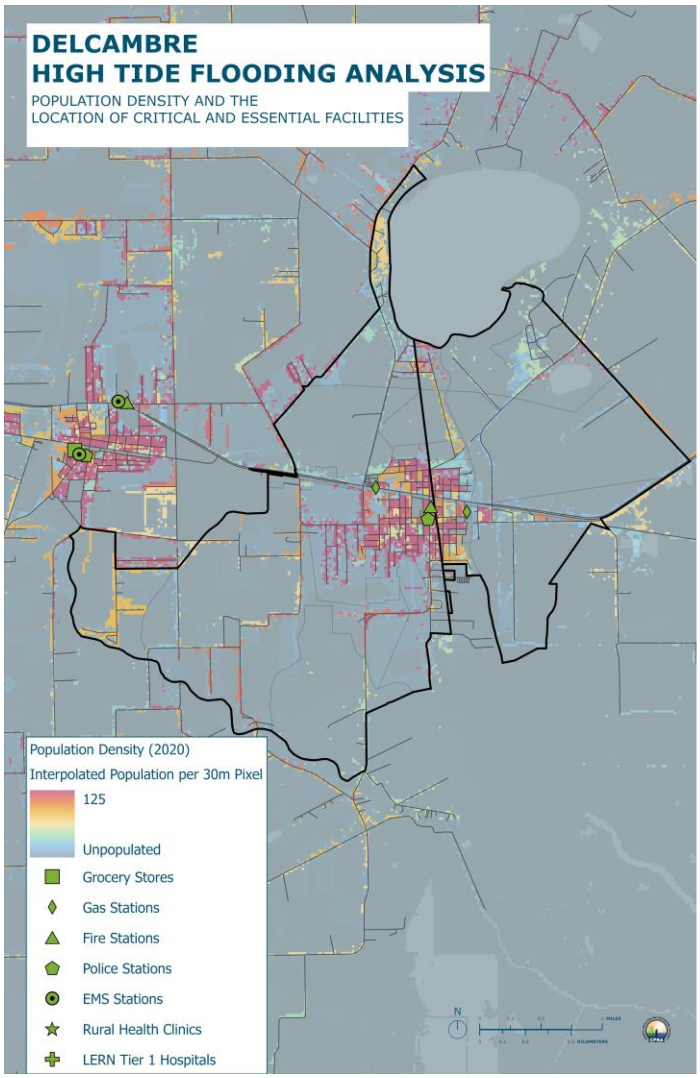


Figure 63. Dasymetric population density map of Delcambre, Louisiana with locations of nearby critical and essential facilities, where applicable.

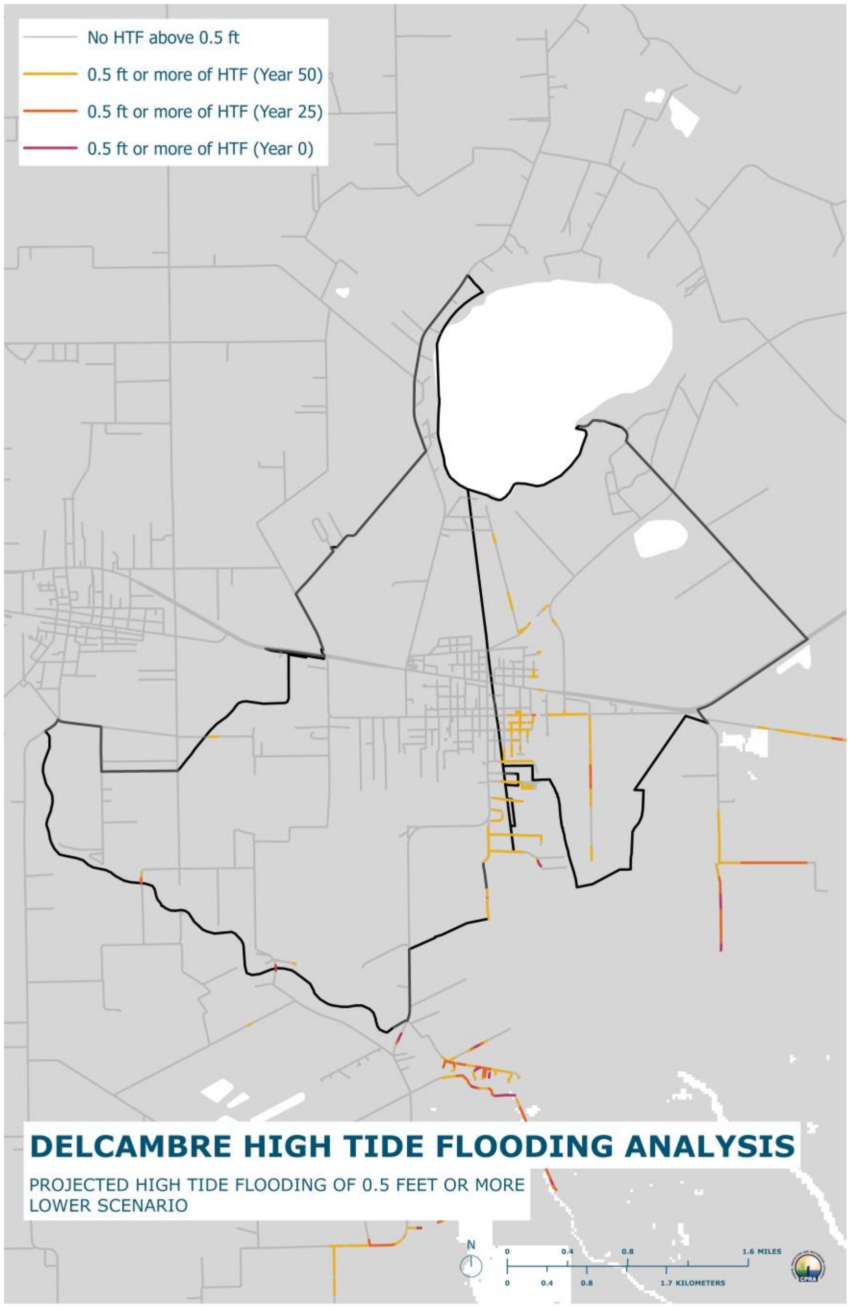


Figure 64. Road segments in Delcambre, Louisiana projected to have 0.5 ft or more of HTF and considered impassable in Year 0, Year 25, and Year 50 under the 2023 Coastal Master Plan's lower scenario

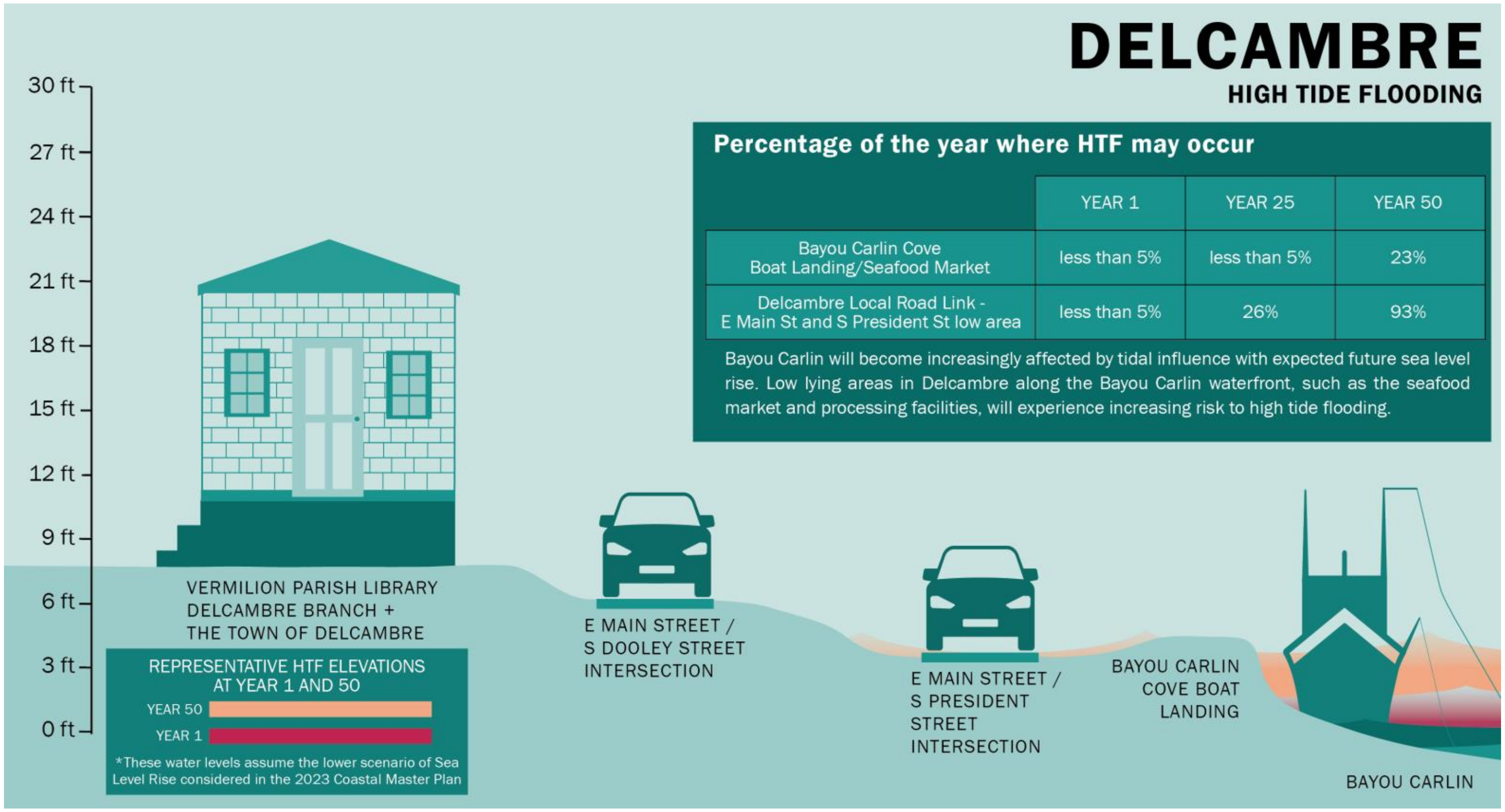


Figure 65. Modeled WSE depths for HTF events in Delcambre, Louisiana at local impact threshold locations.

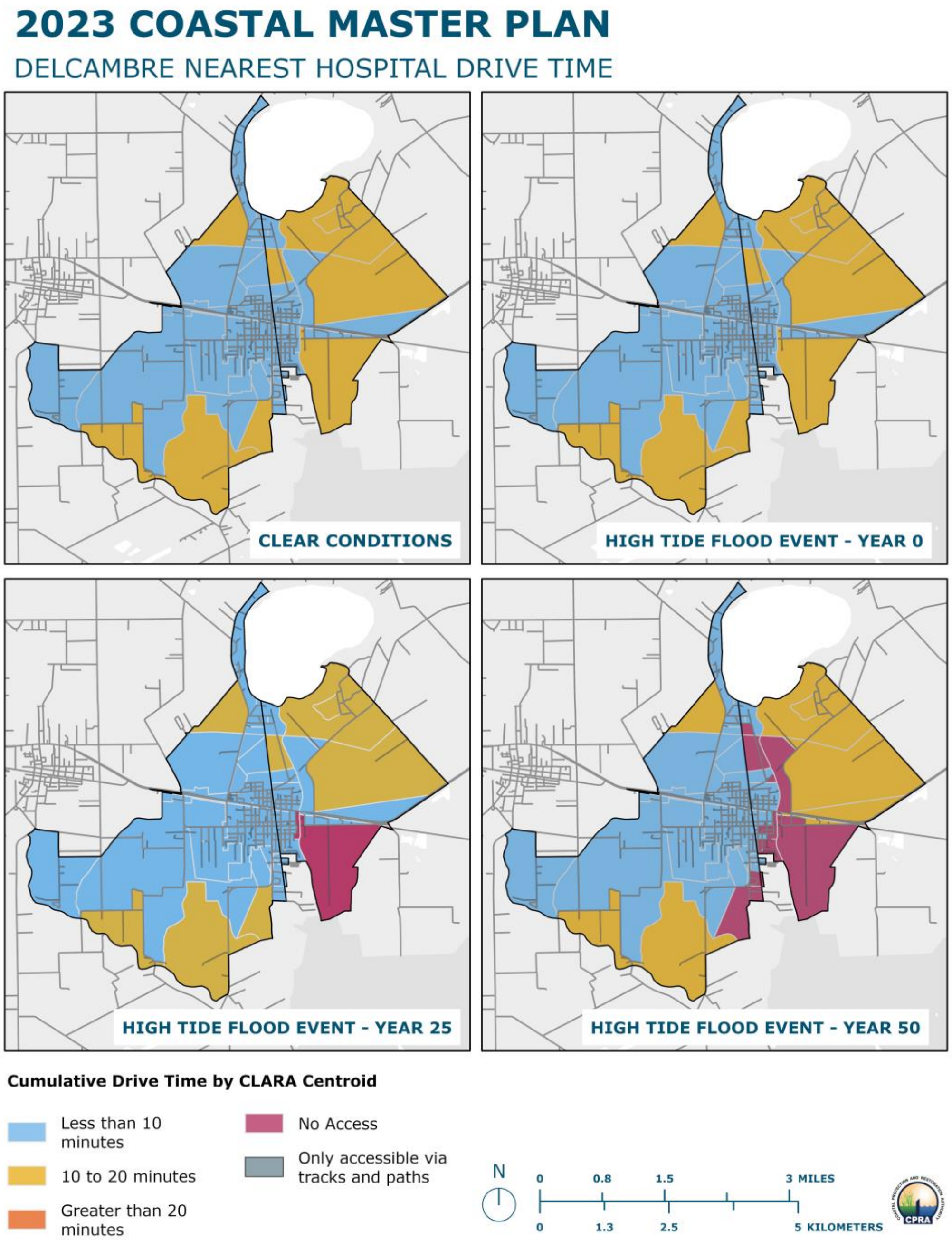
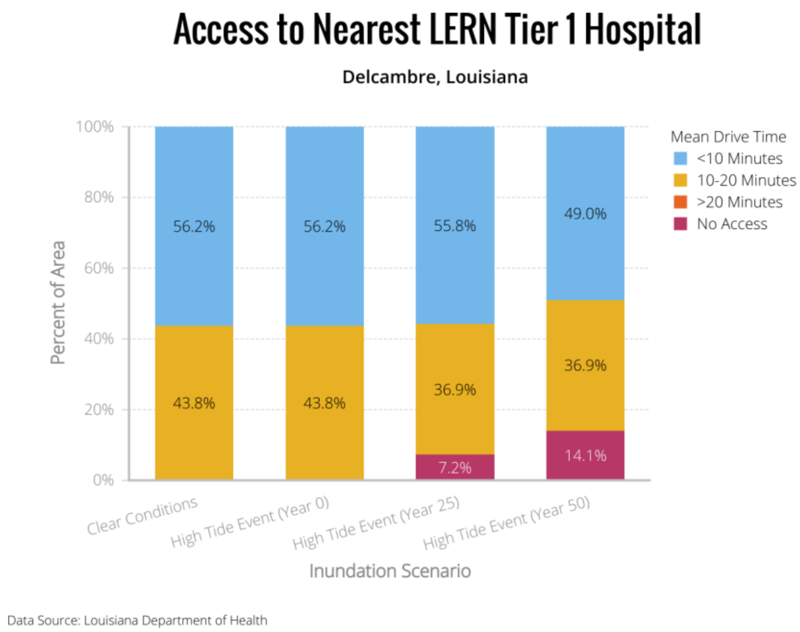


Figure 66. Drive time to nearest LERN Tier 1 hospital in Delcambre, Louisiana.



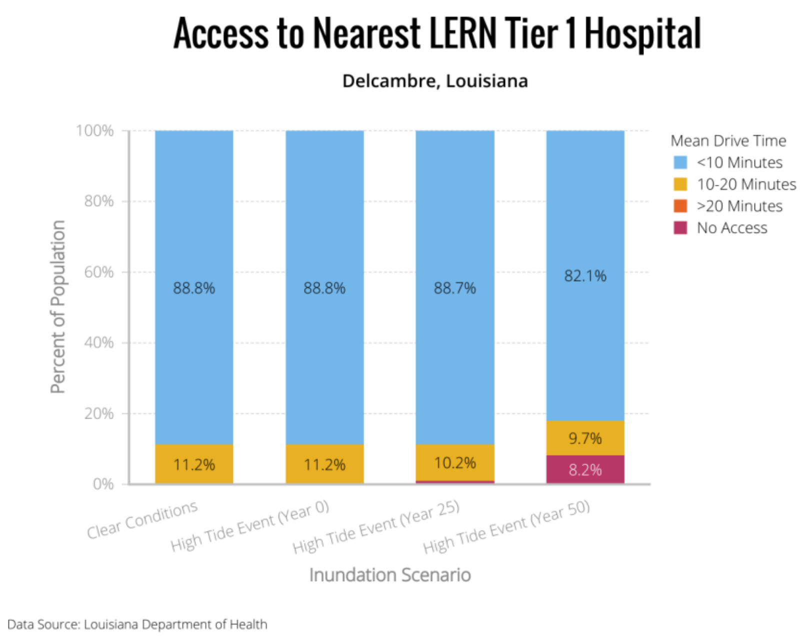


Figure 67. Drive time access to nearest LERN Tier 1 hospital by percent of area (top) and population (bottom) in Delcambre, Louisiana.

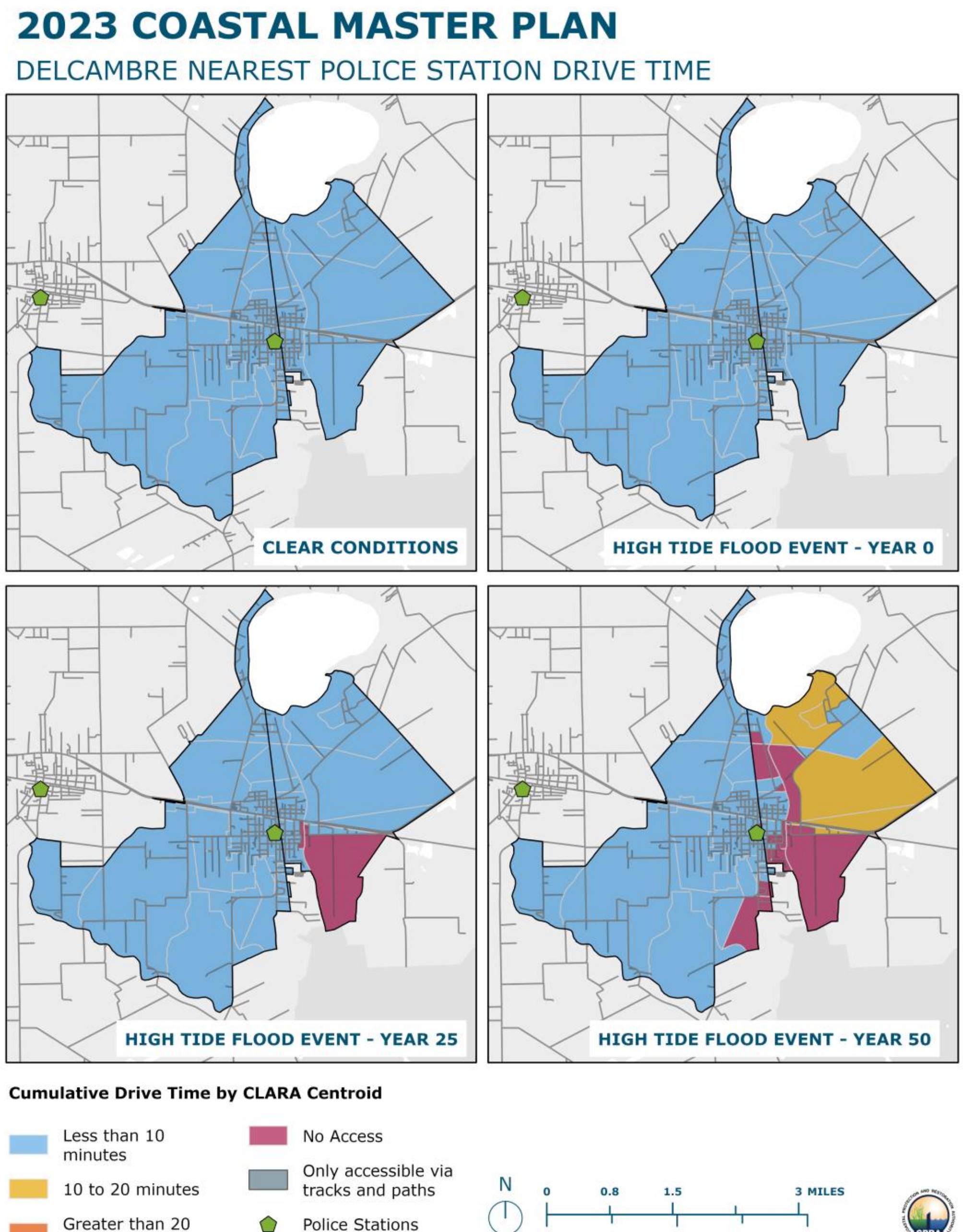
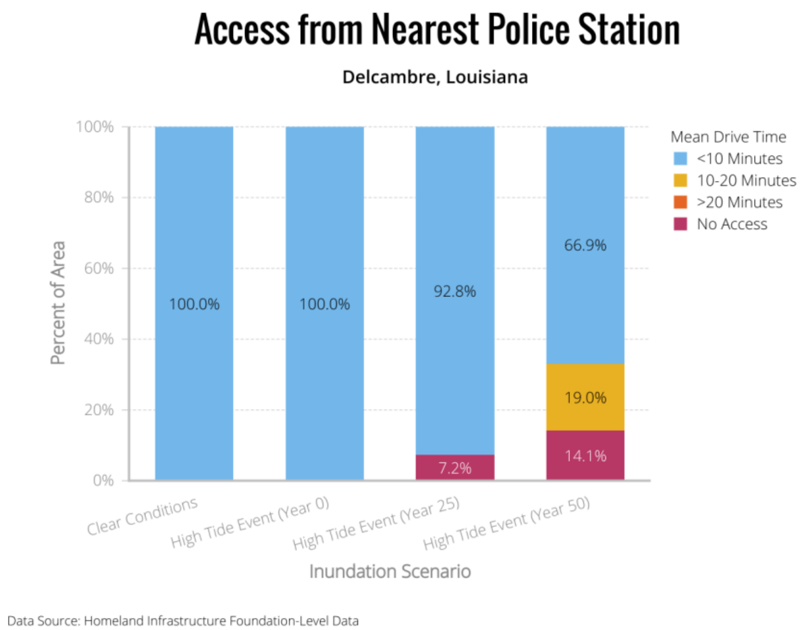


Figure 68. Drive time to nearest police station in Delcambre, Louisiana.



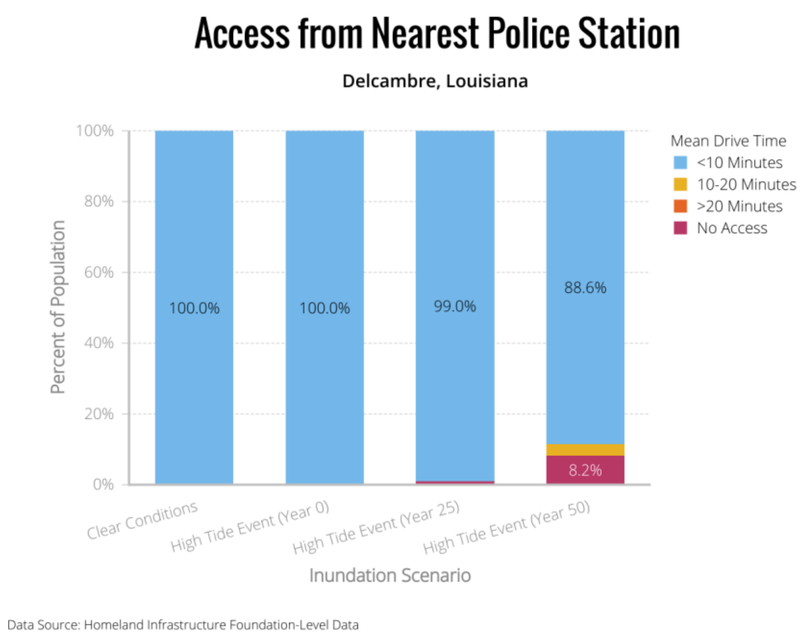


Figure 69. Drive time access to nearest police station by percent of area (top) and population (bottom) in Delcambre, Louisiana.

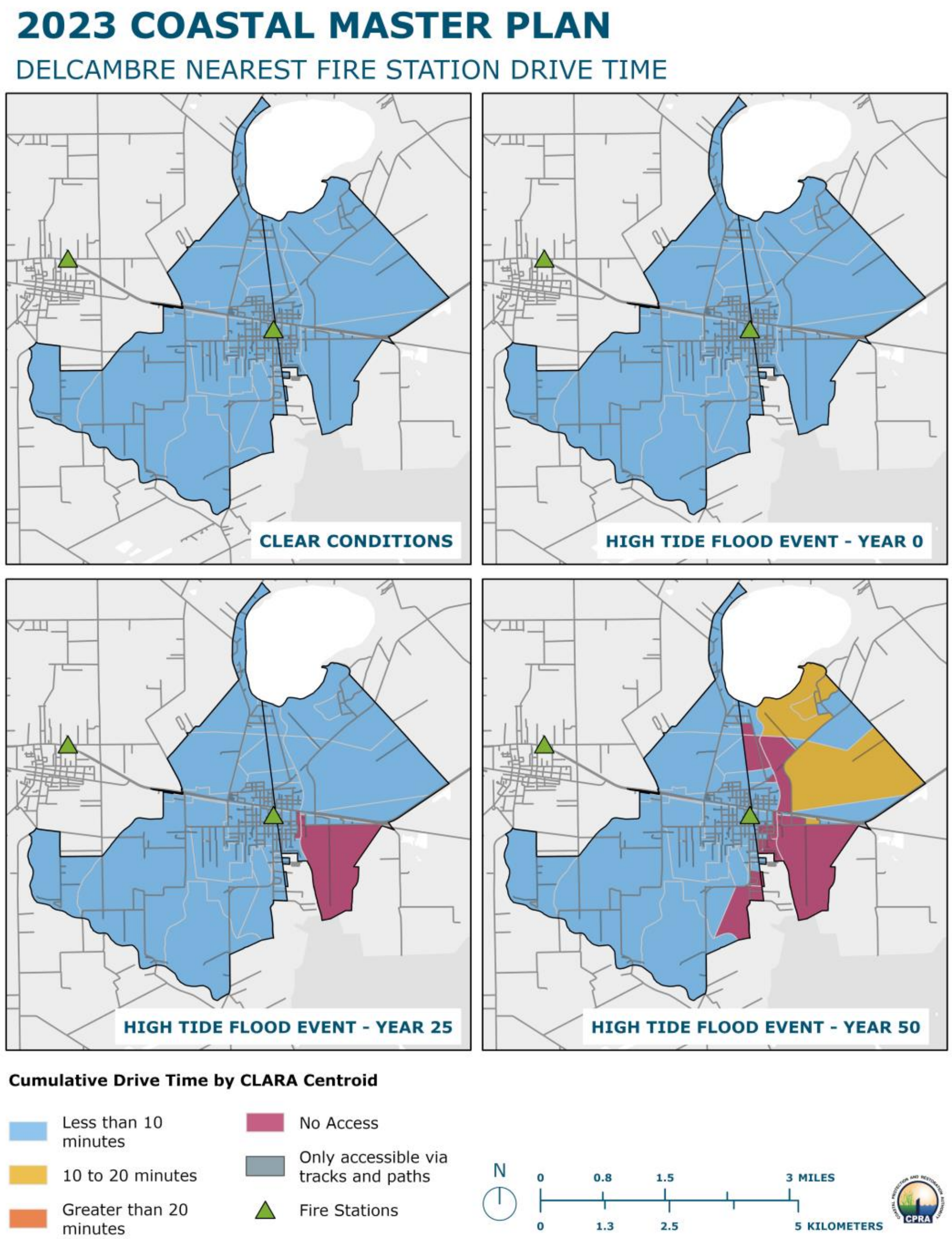
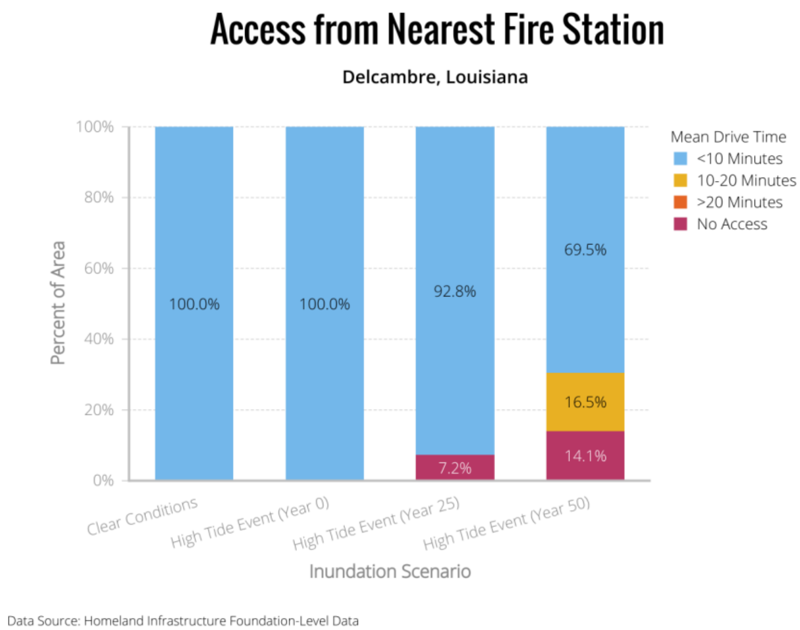


Figure 70. Drive time to nearest fire station in Delcambre, Louisiana.



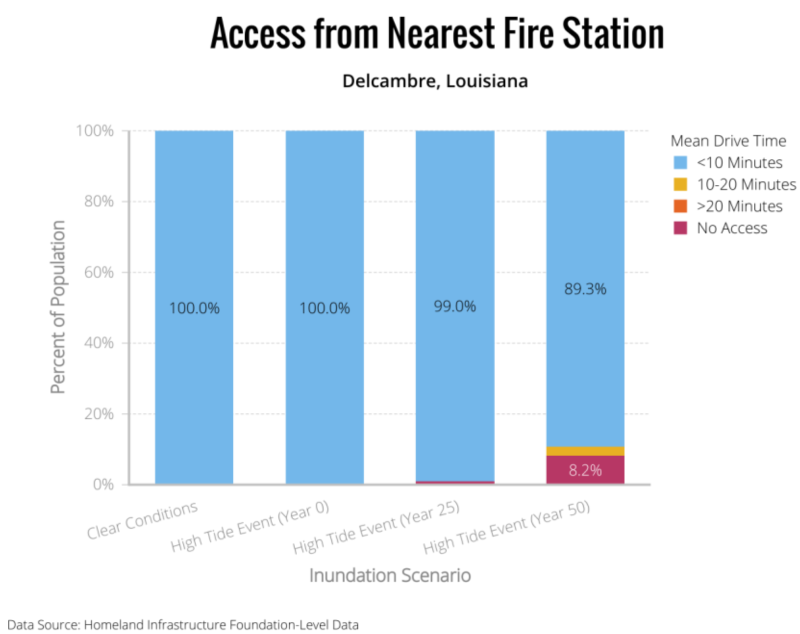


Figure 71. Drive time access to nearest fire station by percent of area (top) and population (bottom) in Delcambre, Louisiana.

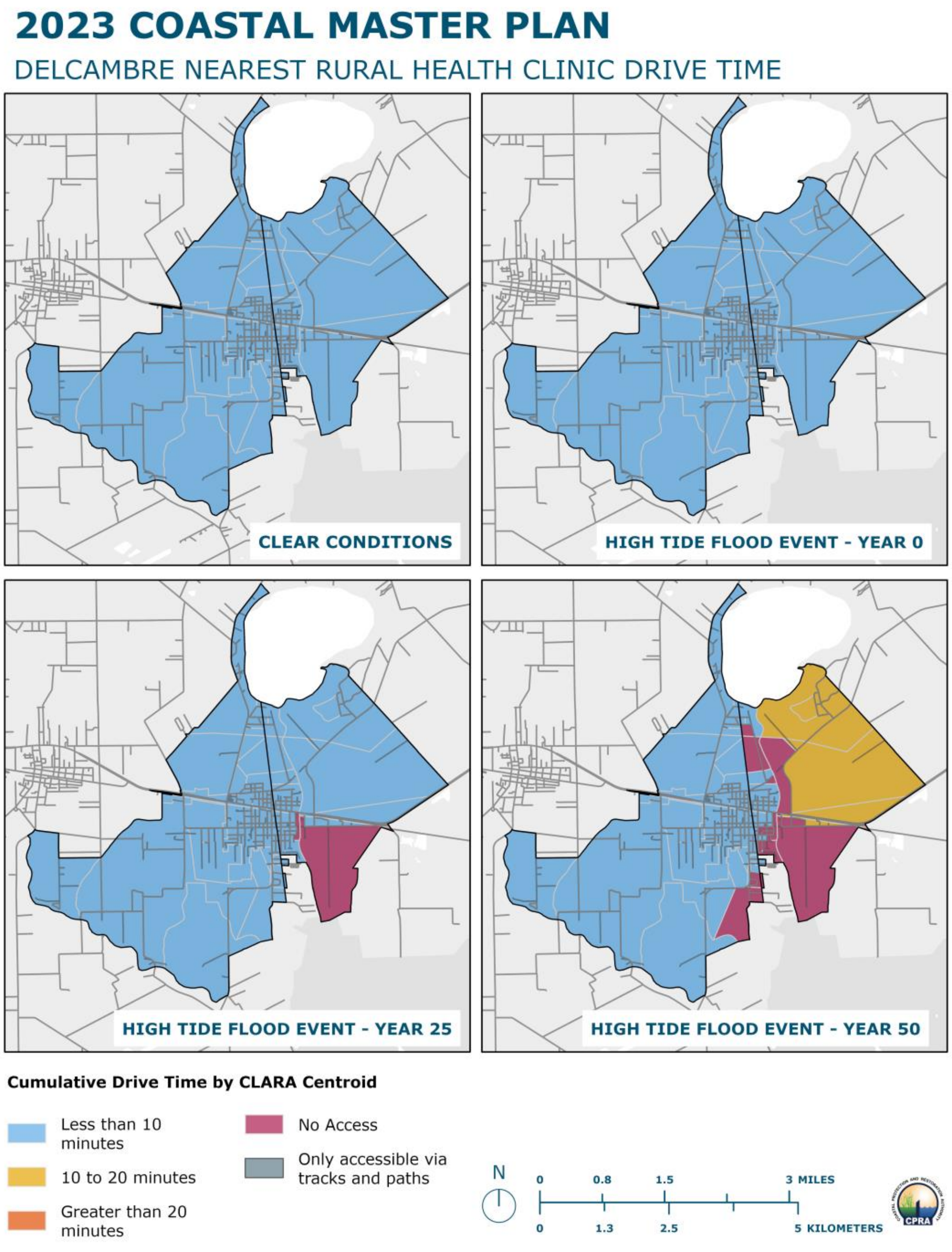
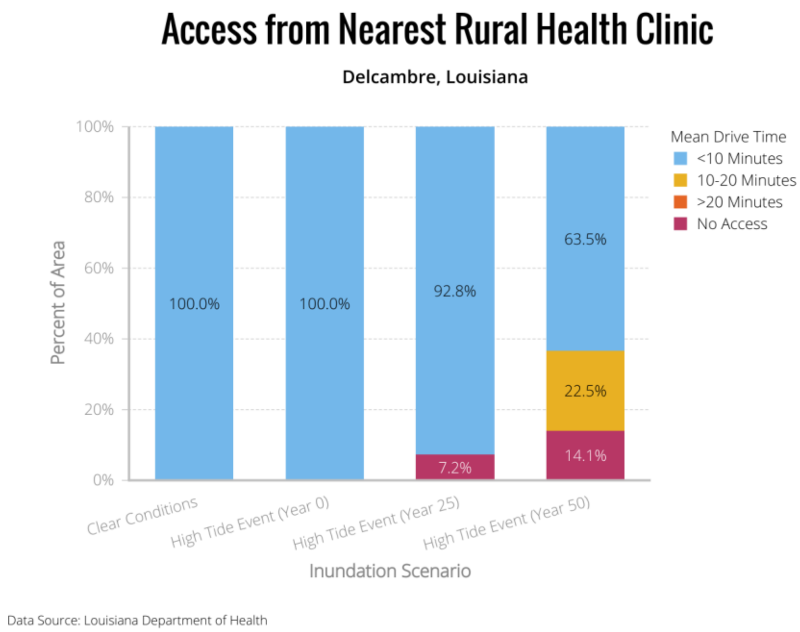


Figure 72. Drive time to nearest rural health clinic in Delcambre, Louisiana.



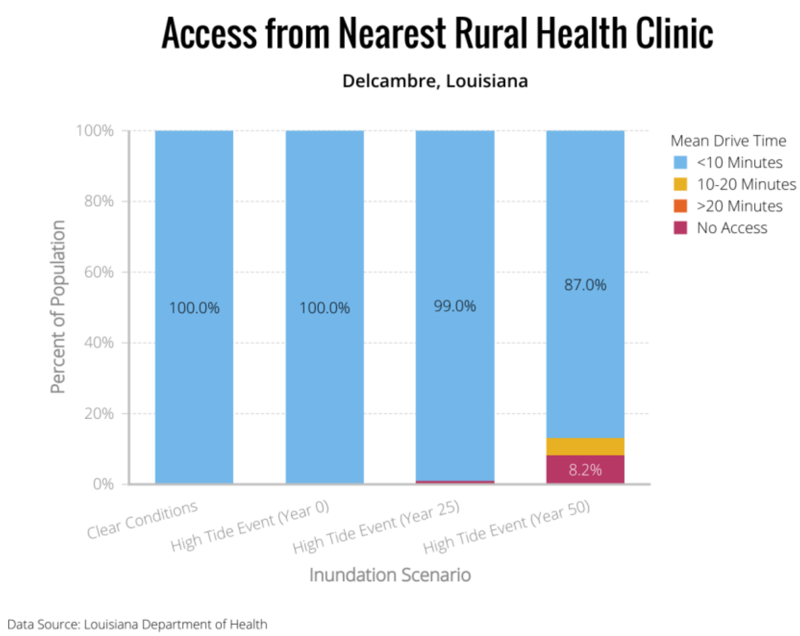


Figure 73. Drive time access to nearest rural health clinic by percent of area (top) and population (bottom) in Delcambre, Louisiana.

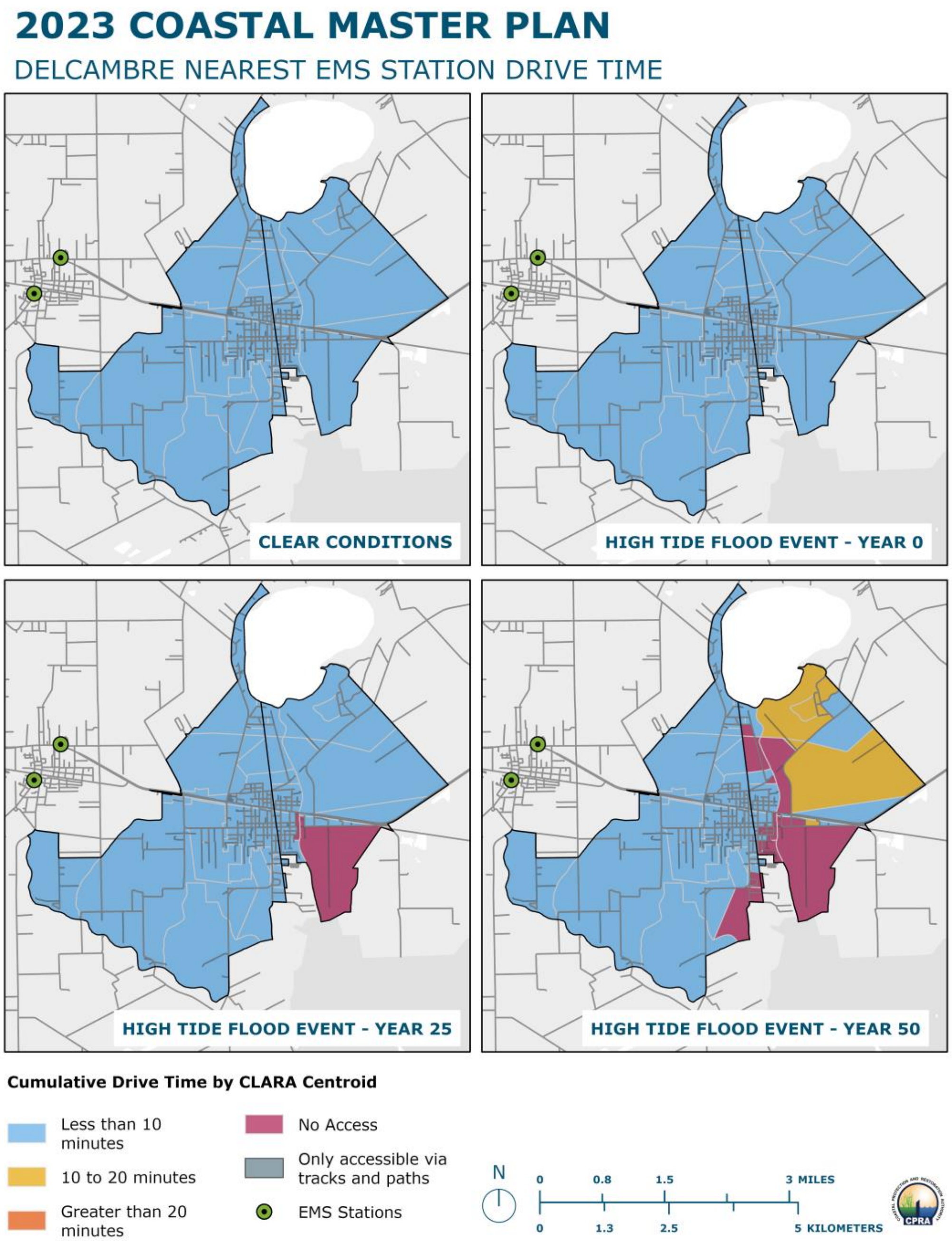


Figure 74. Drive time to nearest EMS station in Delcambre, Louisiana.

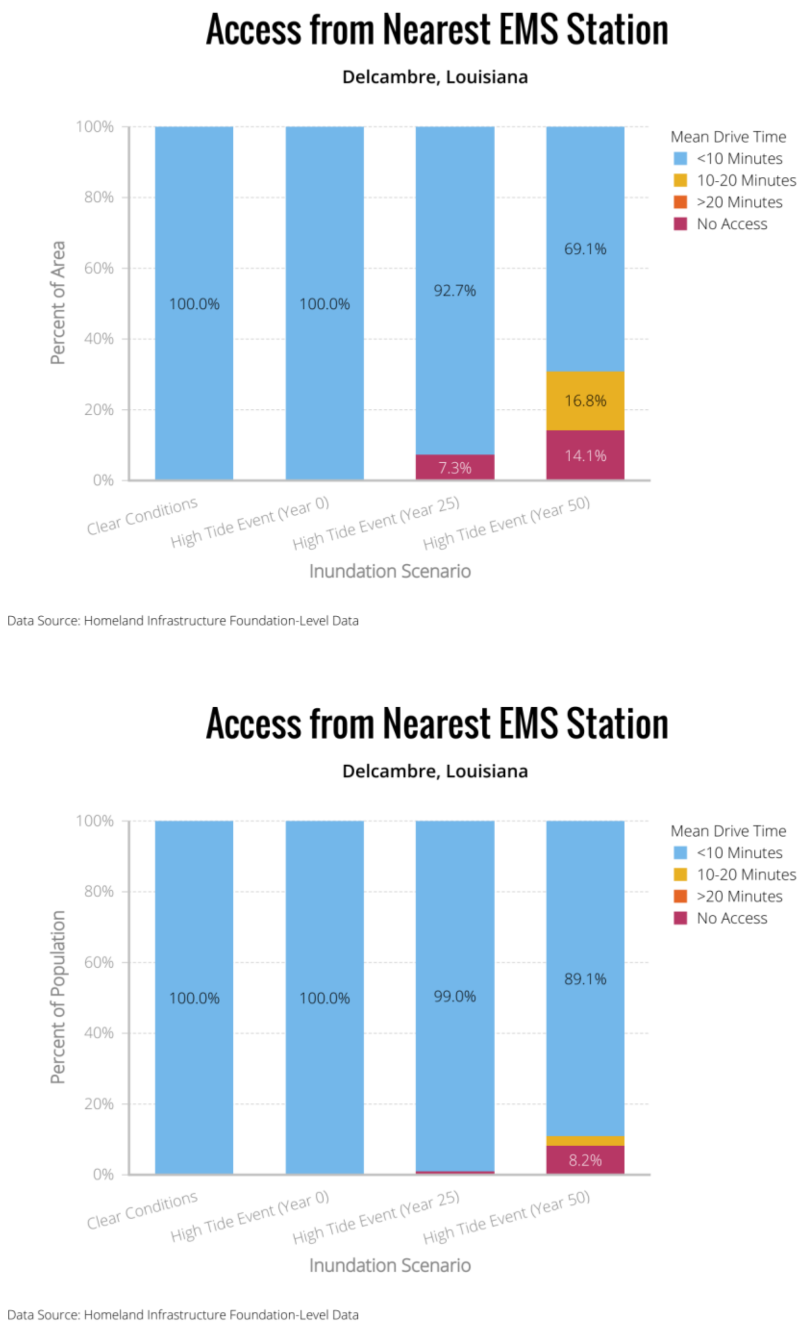


Figure 75. Drive time access to nearest EMS station by percent of area (top) and population (bottom) in Delcambre, Louisiana.

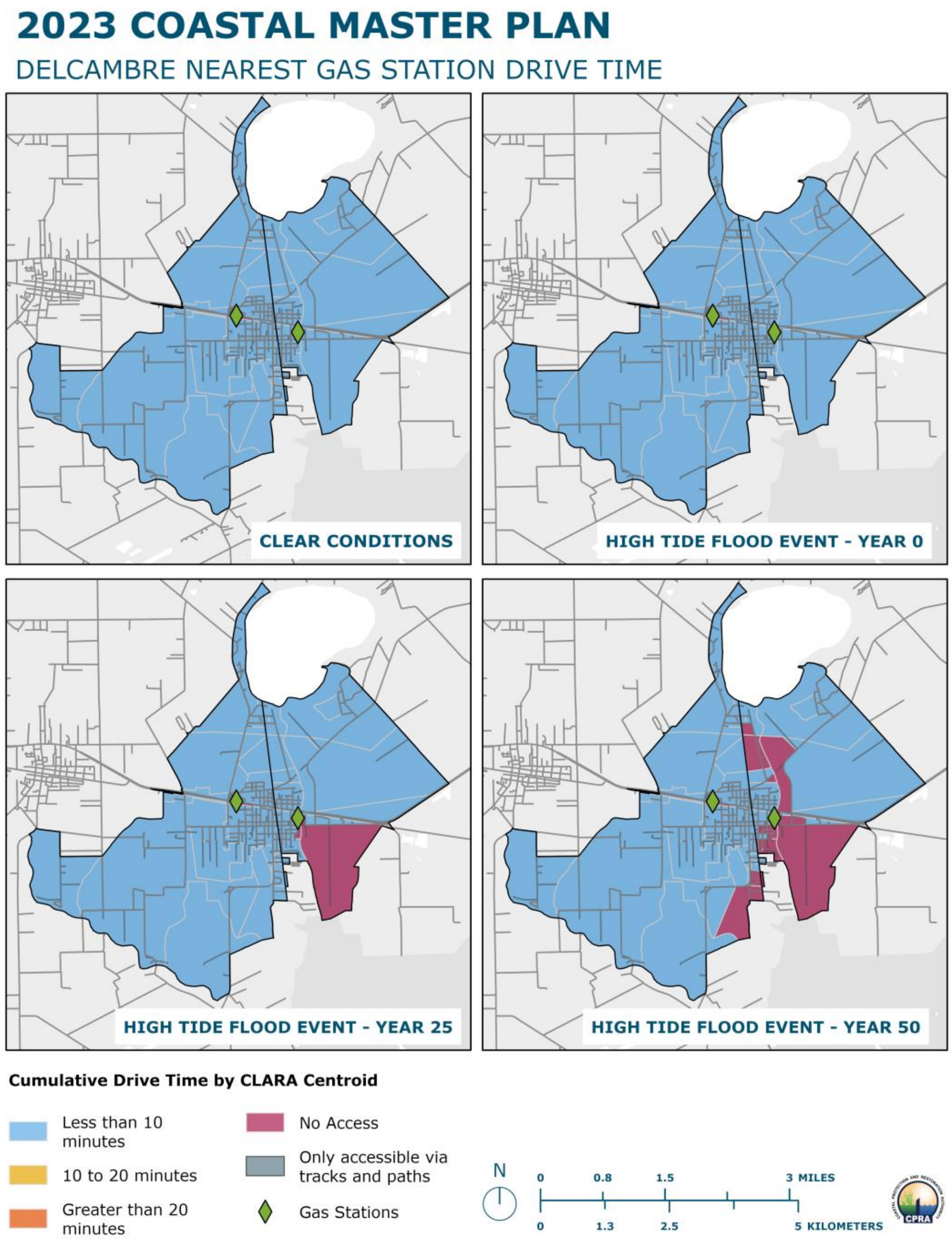
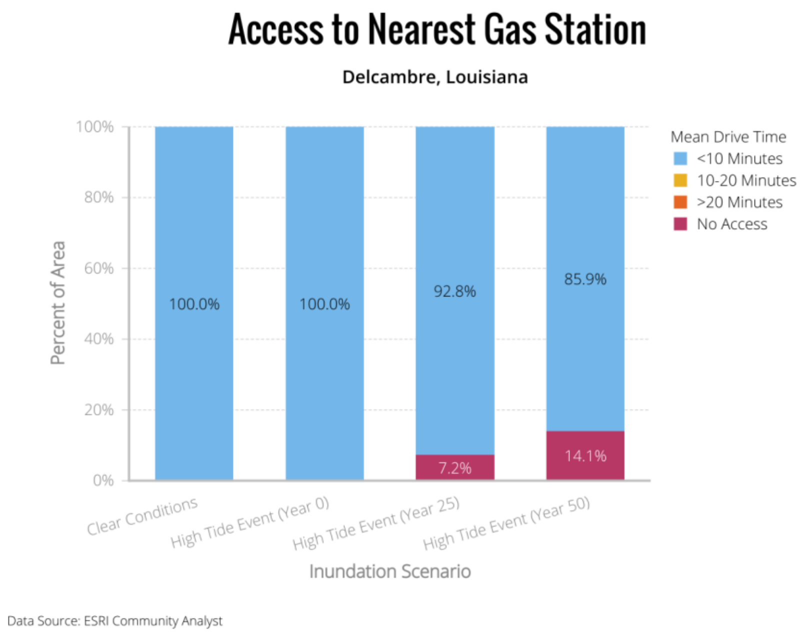


Figure 76. Drive time to nearest gas station in Delcambre, Louisiana.



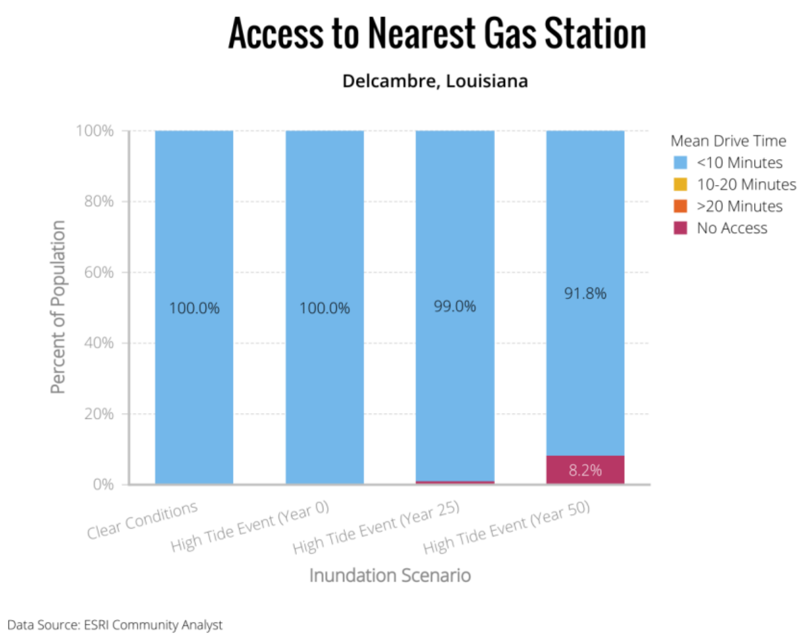


Figure 77. Drive time access to nearest gas station by percent of area (top) and population (bottom) in Delcambre, Louisiana.

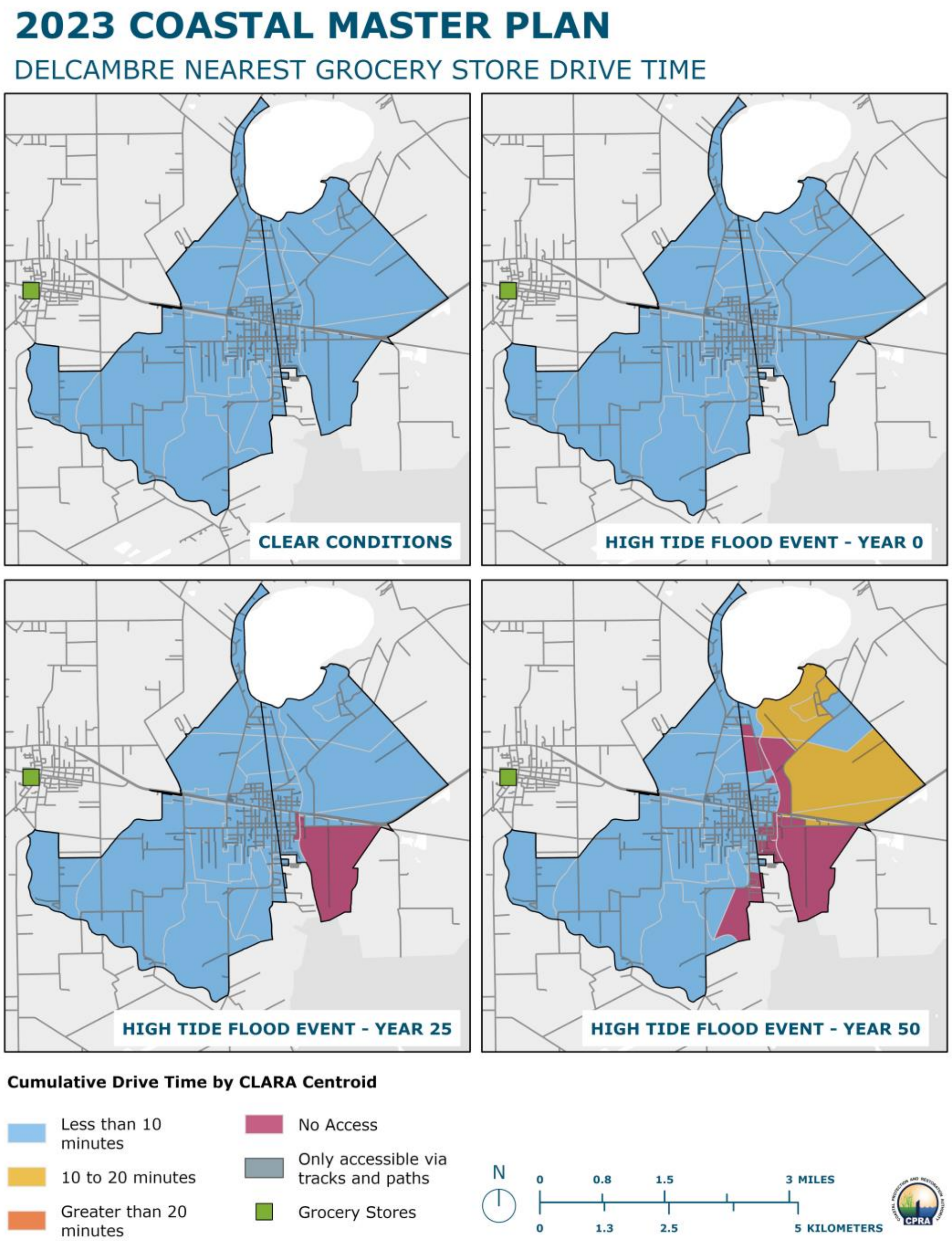
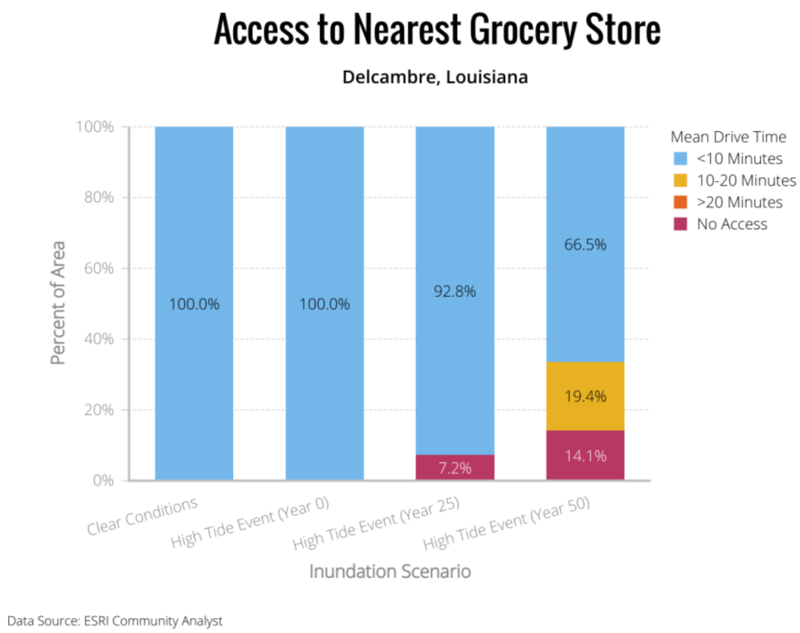


Figure 78. Drive time to nearest grocery store in Delcambre, Louisiana.



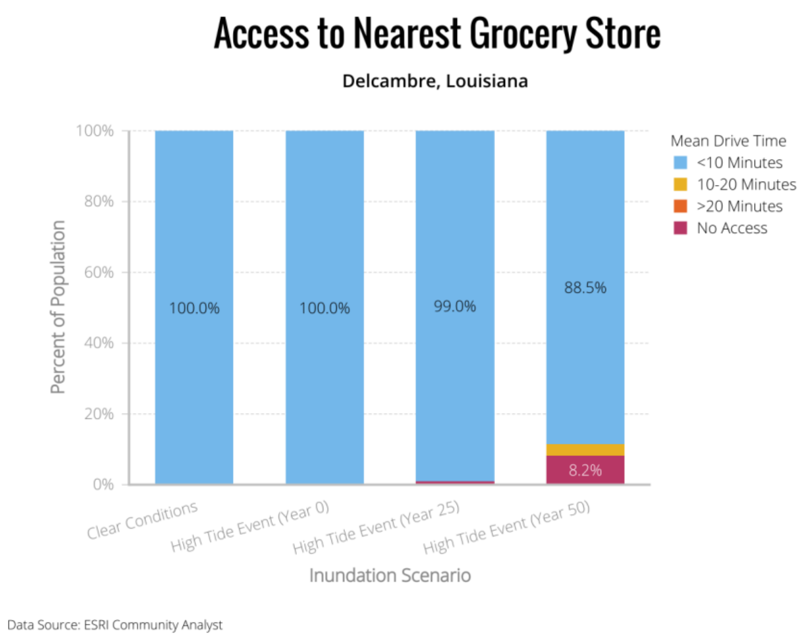


Figure 79. Drive time access to nearest grocery store by percent of area (top) and population (bottom) in Delcambre, Louisiana.

DULAC

The community of Dulac is located in southern Terrebonne Parish on a narrow thread of higher elevation along Bayou Grand Caillou. Part of the Houma–Bayou Cane–Thibodaux Metropolitan Statistical Area, many residents of Dulac are dependent upon the city of Houma for critical and essential services. Bisected by the Falgout Canal, the community is divided into an upper and lower portion. During HTF events, many streets within the lower portion of the community become flooded, potentially isolating and cutting them off from the rest of the community. See Figure 80 through Figure 96 for more information on the drive time analysis for Dulac, Louisiana.

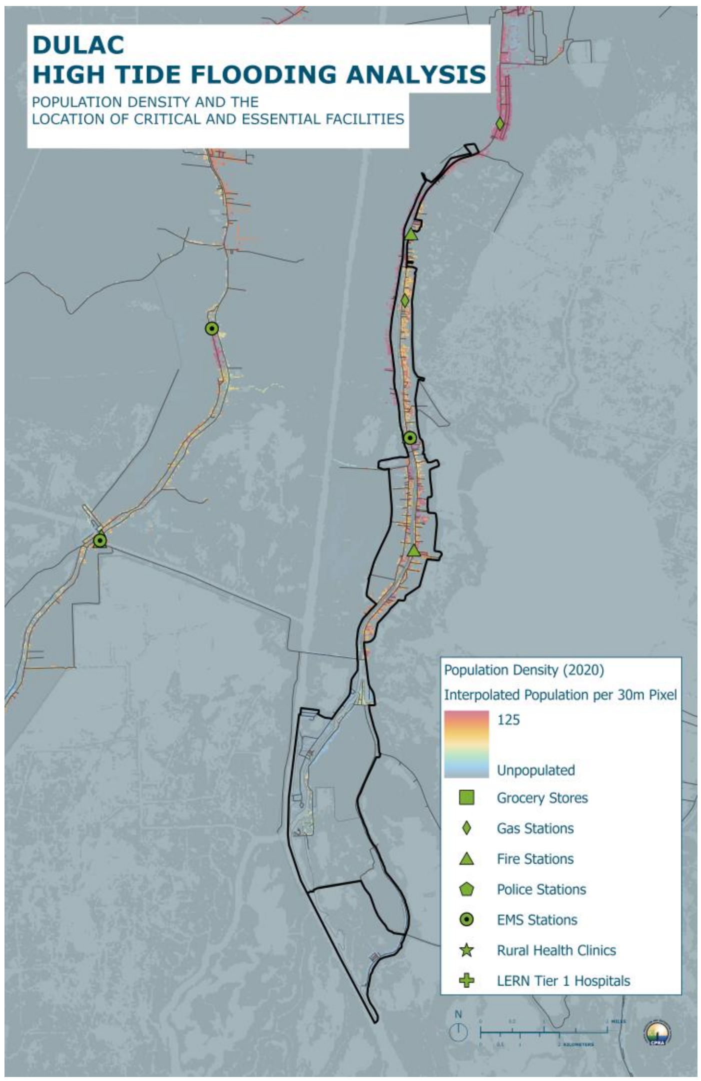


Figure 80. Dasymetric population density map of Dulac, Louisiana with locations of nearby critical and essential facilities, where applicable.

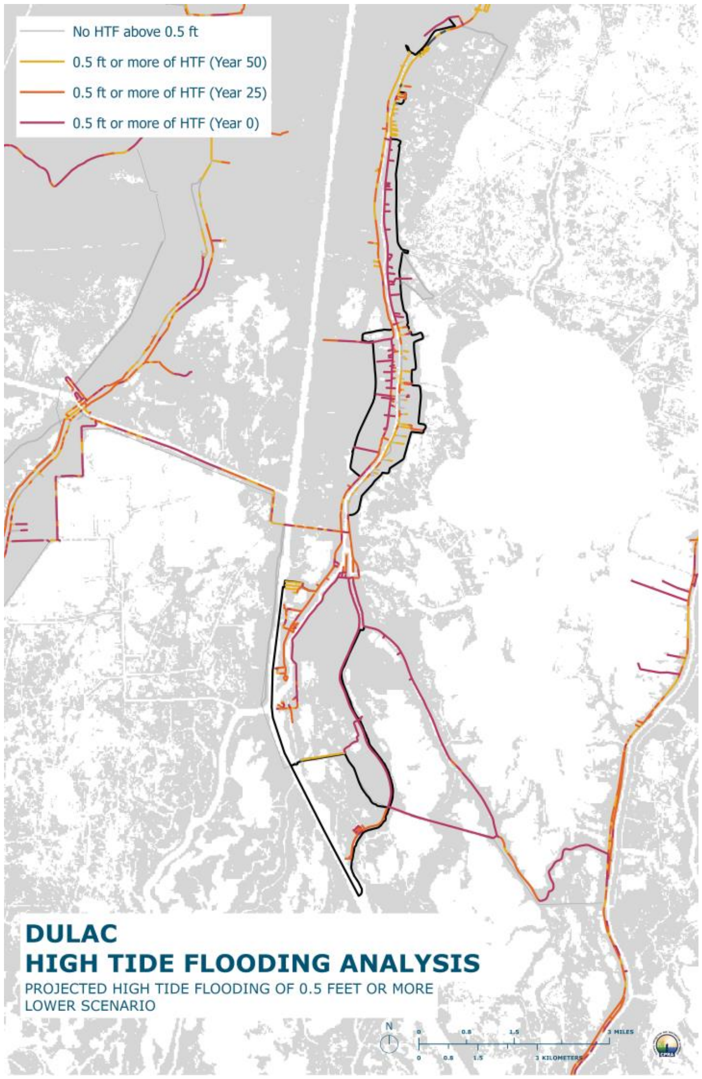


Figure 81. Road segments in Dulac, Louisiana projected to have 0.5 ft or more of HTF and considered impassable in Year 0, Year 25, and Year 50 under the 2023 Coastal Master Plan's lower scenario

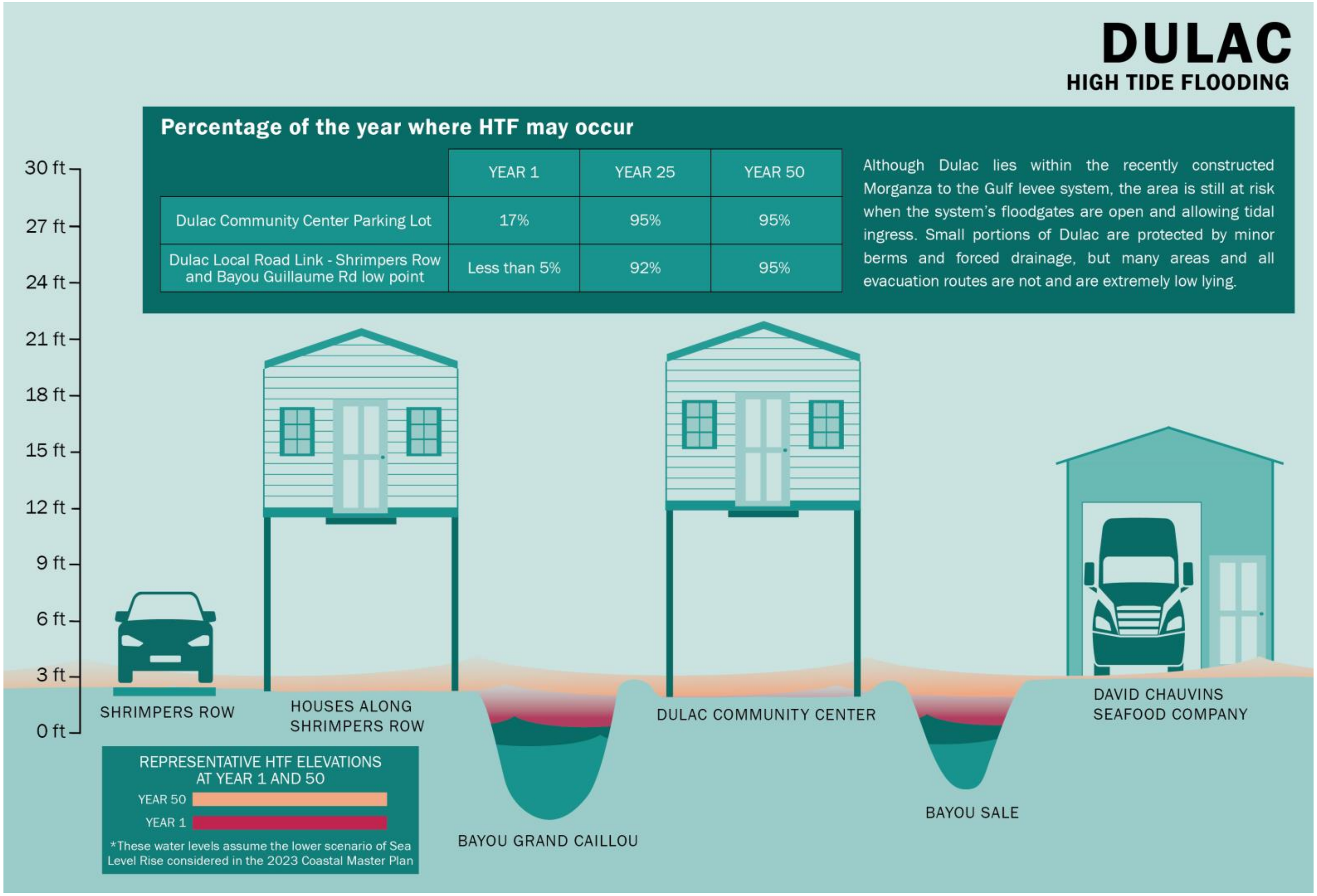


Figure 82. Modeled WSE depths for HTF events in Dulac, Louisiana at local impact threshold locations.

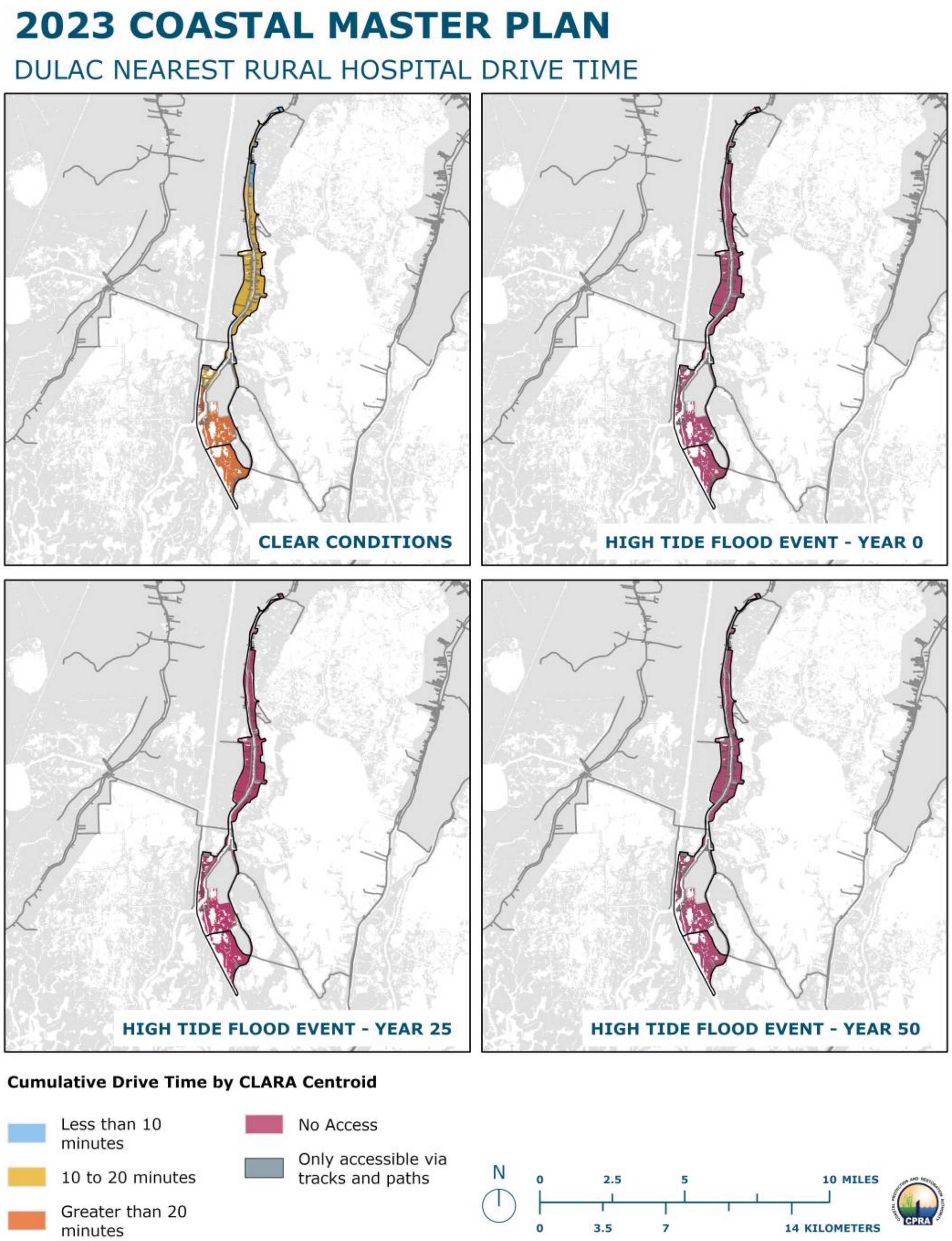
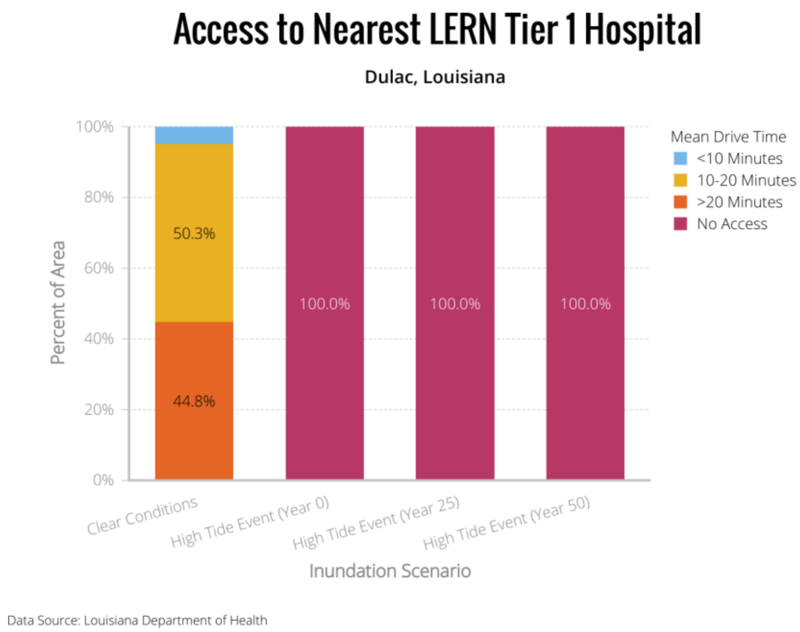


Figure 83. Drive time to nearest LERN Tier 1 hospital in Dulac, Louisiana.



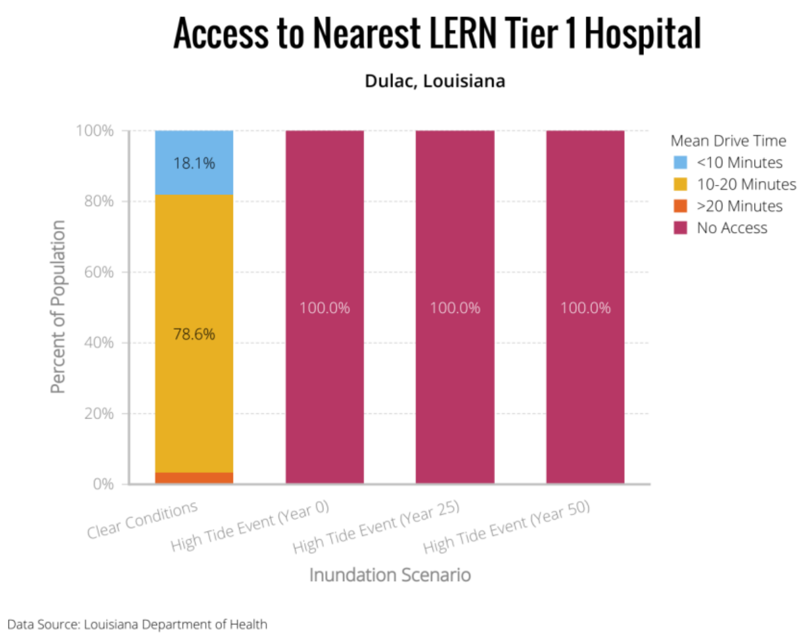


Figure 84. Drive time access to nearest LERN Tier 1 hospital by percent of area (top) and population (bottom) in Dulac, Louisiana.

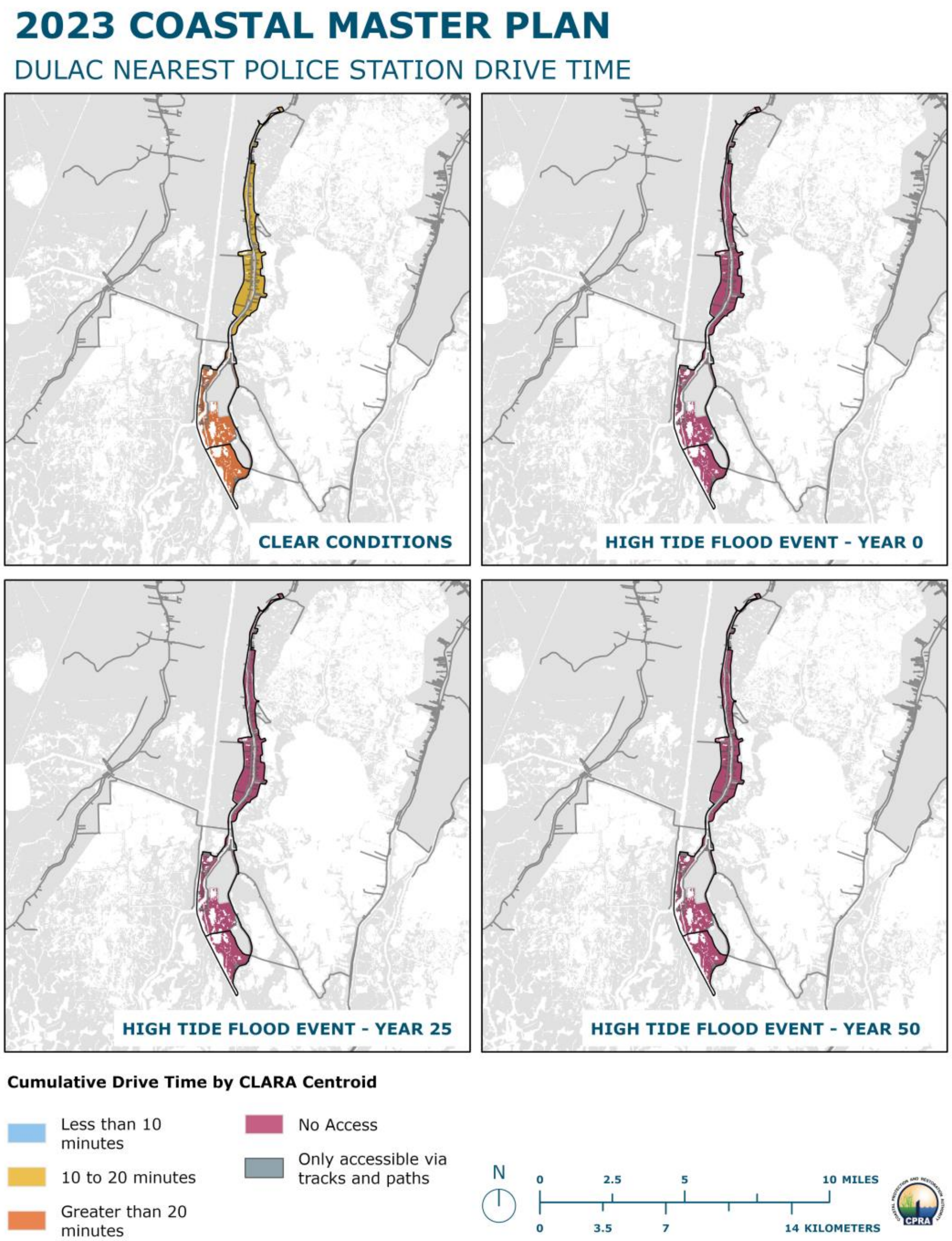
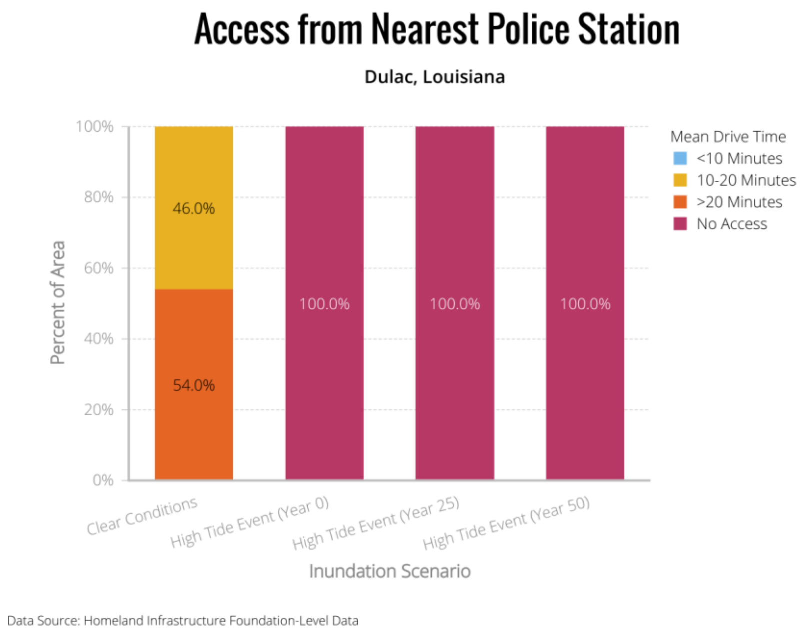


Figure 85. Drive time to nearest police station in Dulac, Louisiana.



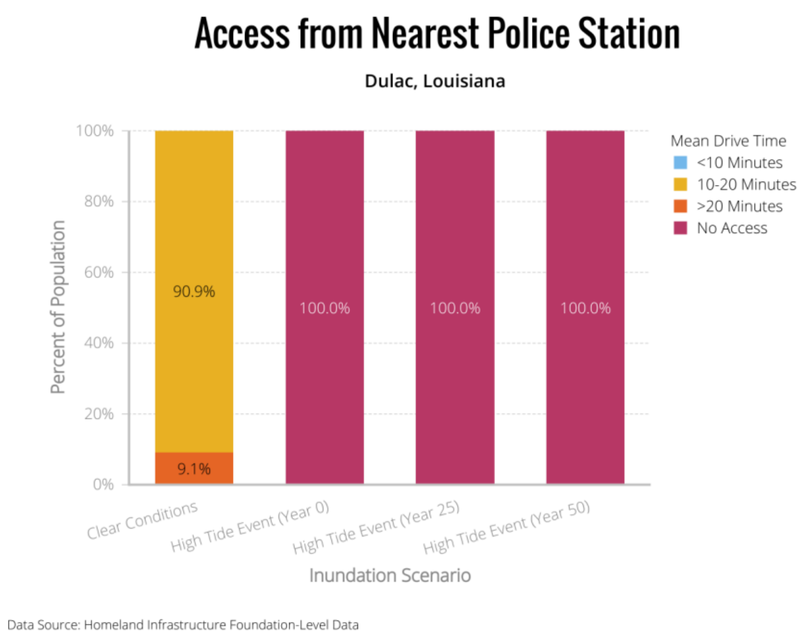


Figure 86. Drive time access to nearest police station by percent of area (top) and population (bottom) in Dulac, Louisiana.

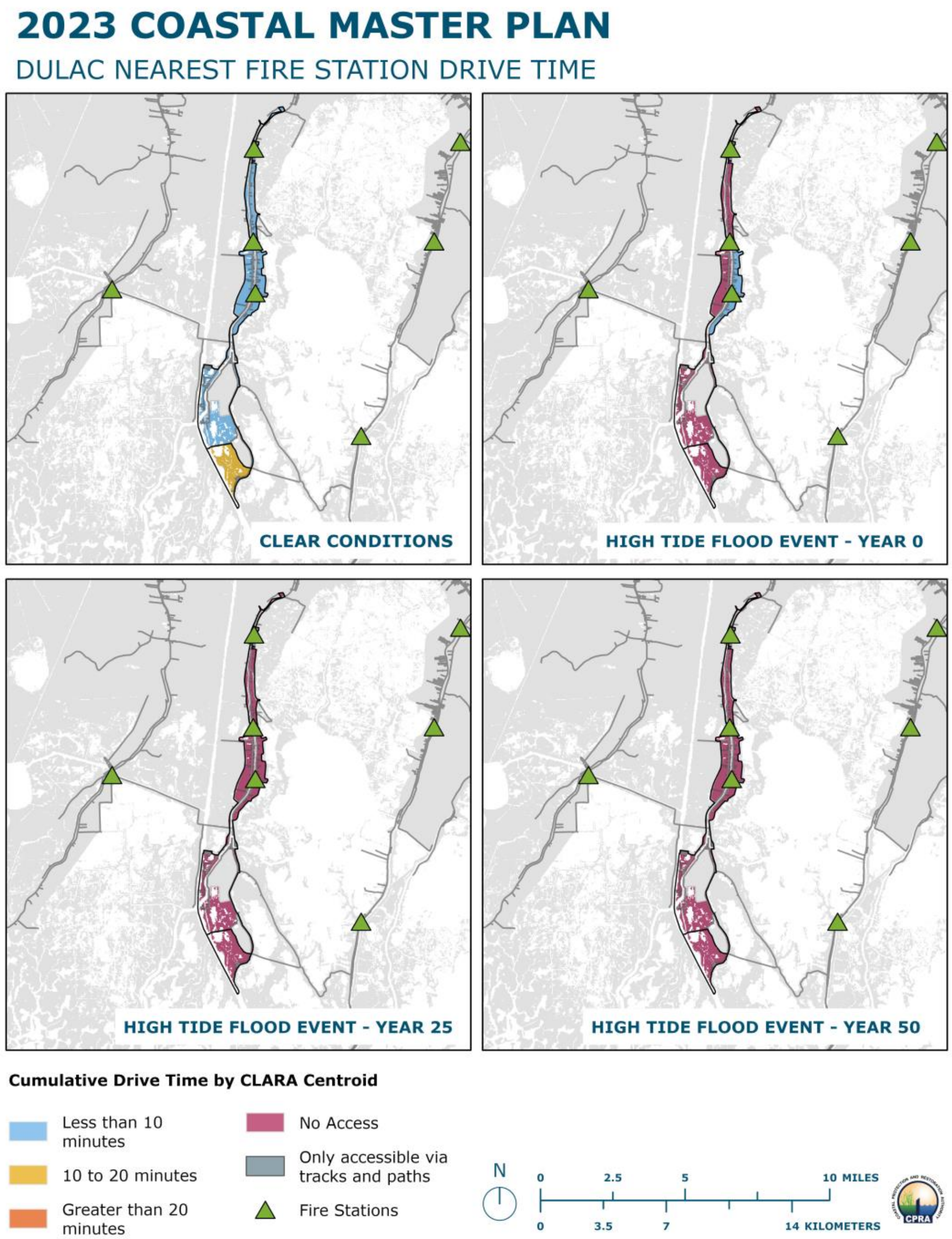
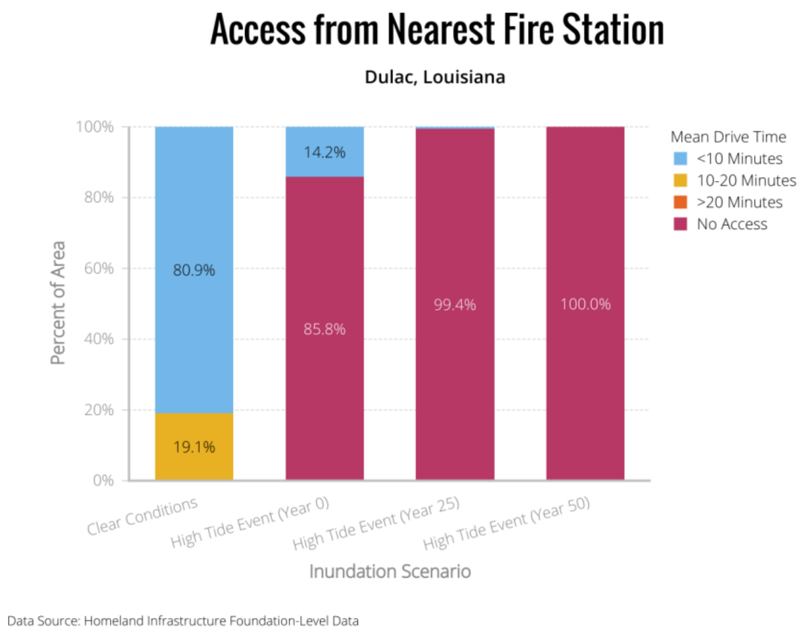


Figure 87. Drive time to nearest fire station in Dulac, Louisiana.



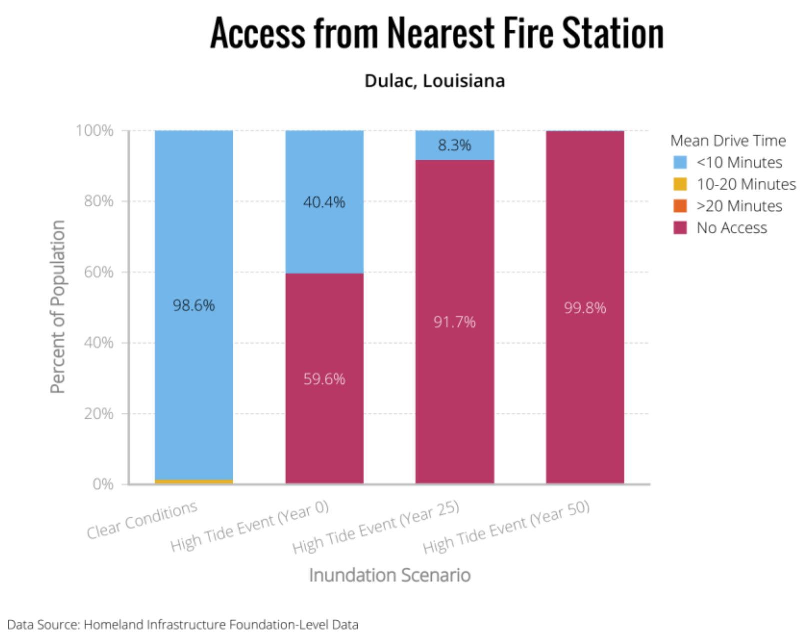


Figure 88. Drive time access to nearest fire station by percent of area (top) and population (bottom) in Dulac, Louisiana.

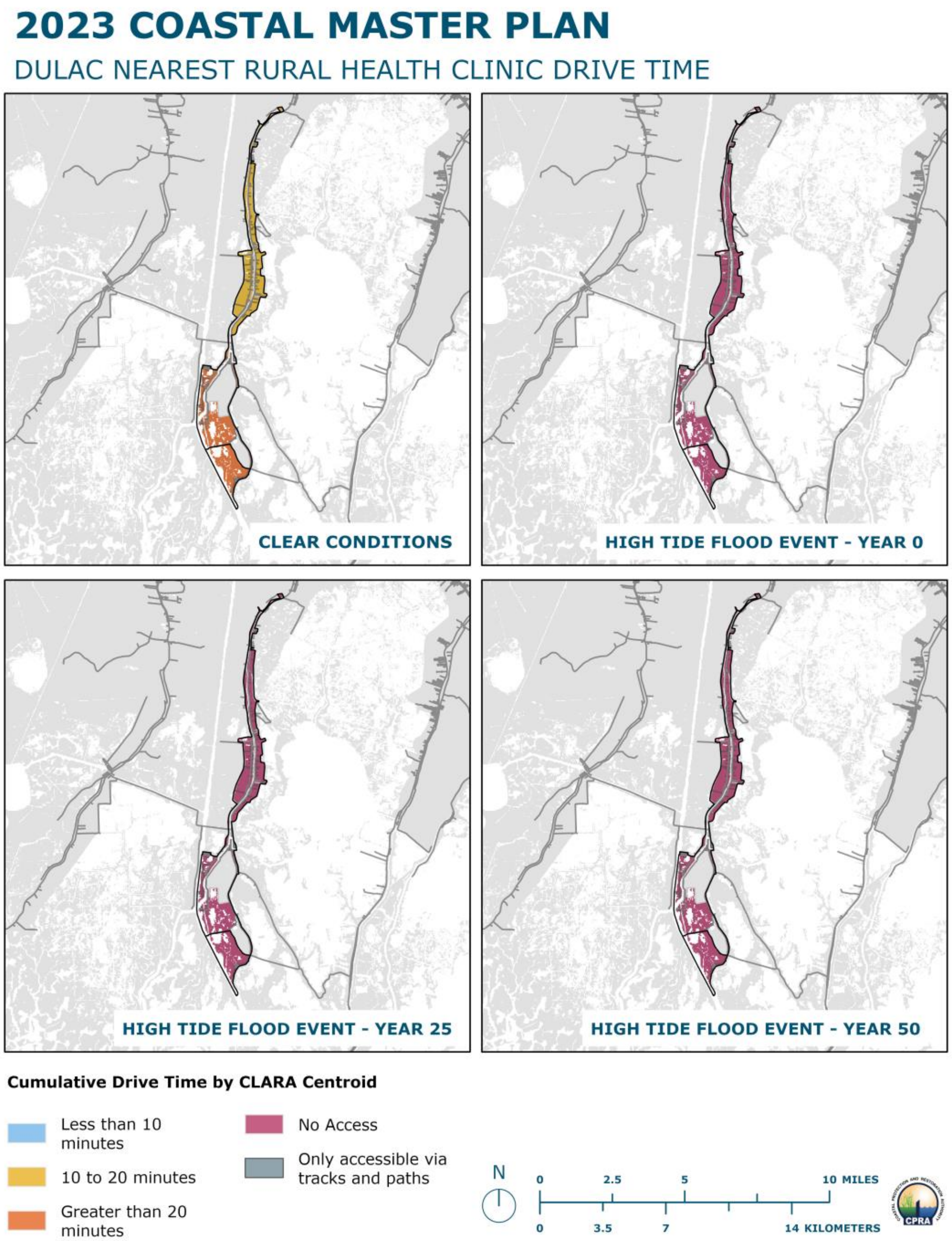
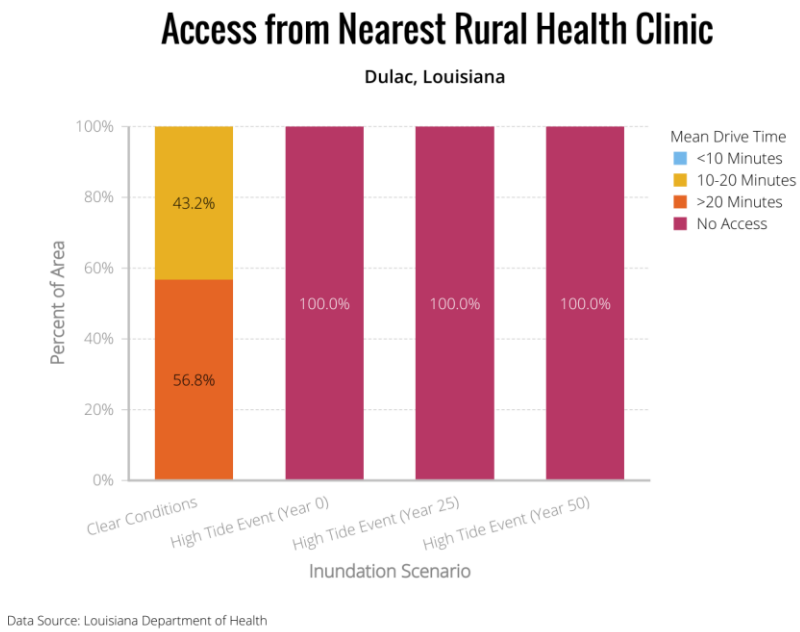


Figure 89. Drive time to nearest rural health clinic in Dulac, Louisiana.



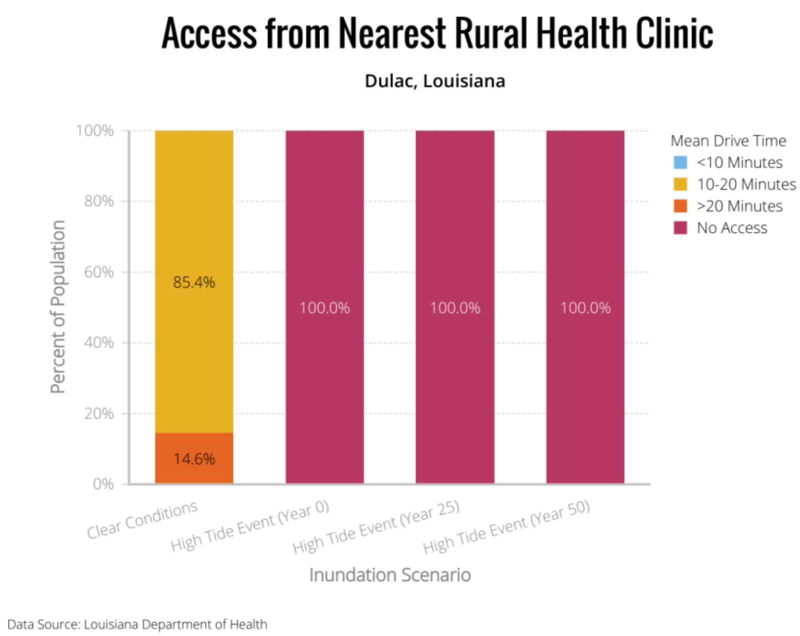


Figure 90. Drive time access to nearest rural health clinic by percent of area (top) and population (bottom) in Dulac, Louisiana.

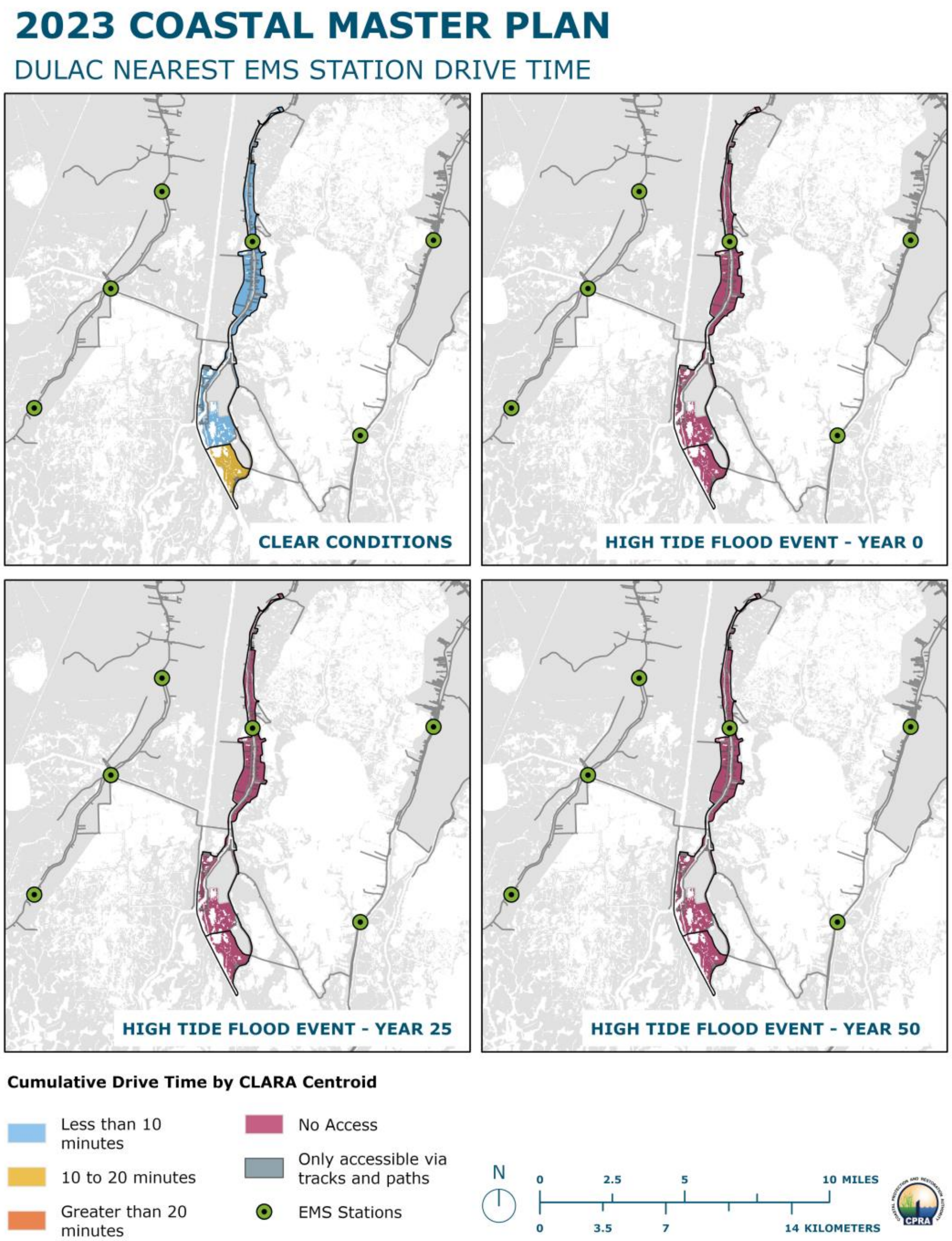
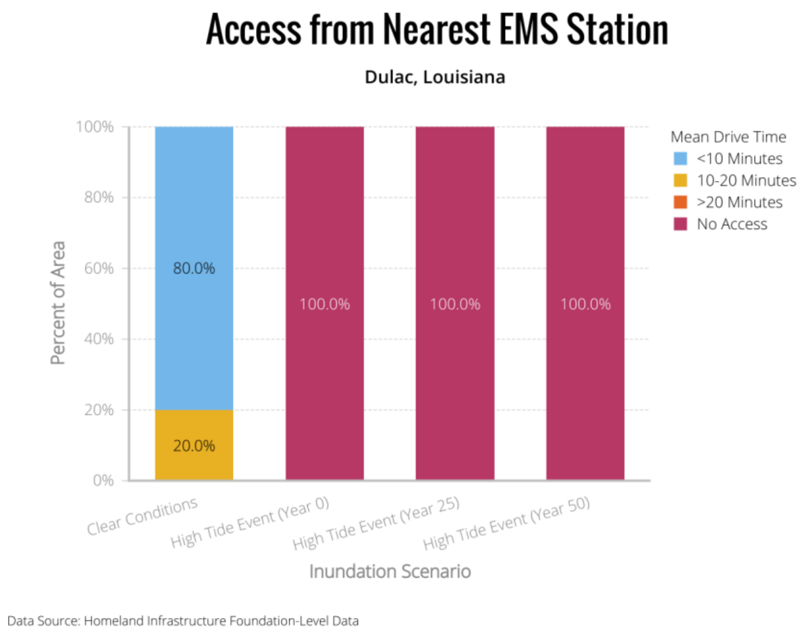


Figure 91. Drive time to nearest EMS station in Dulac, Louisiana.



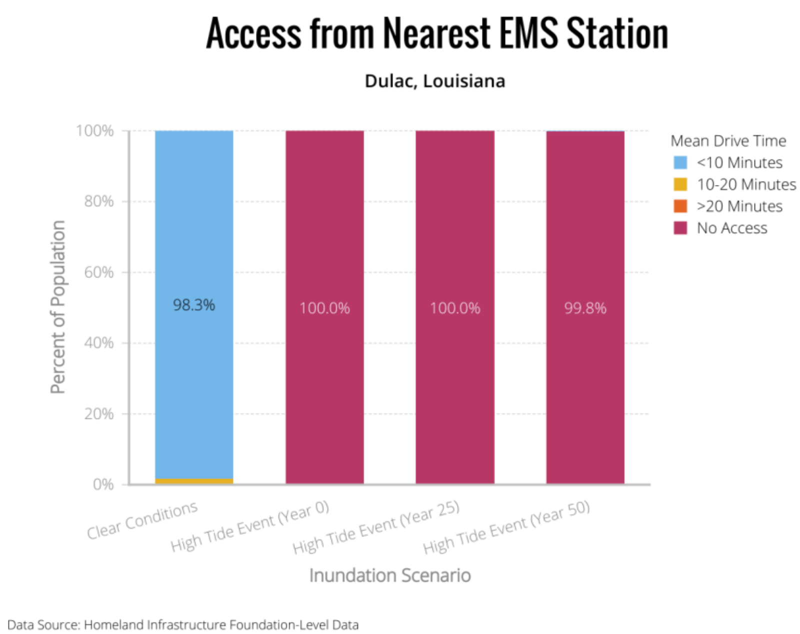


Figure 92. Drive time access to nearest EMS station by percent of area (top) and population (bottom) in Dulac, Louisiana.

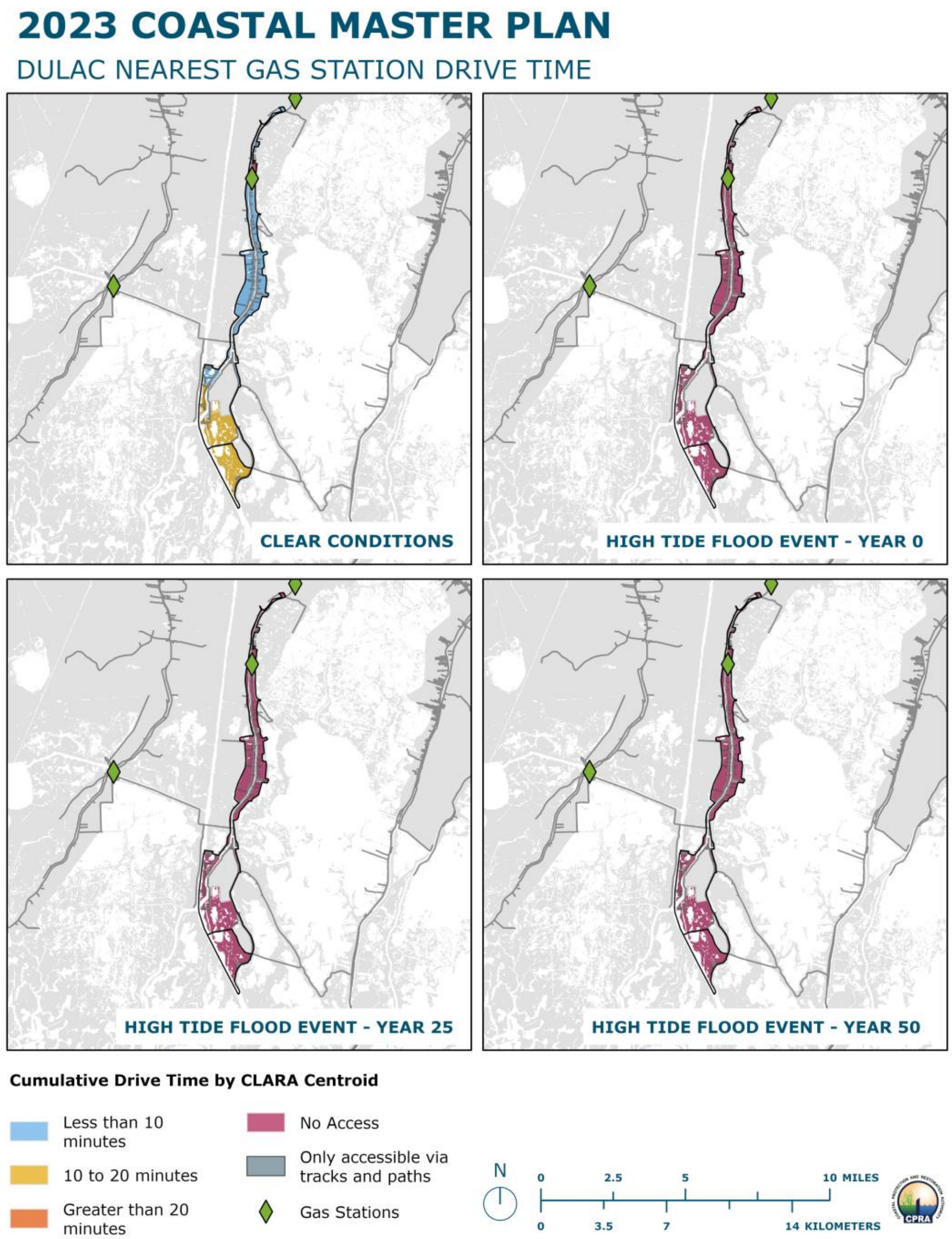
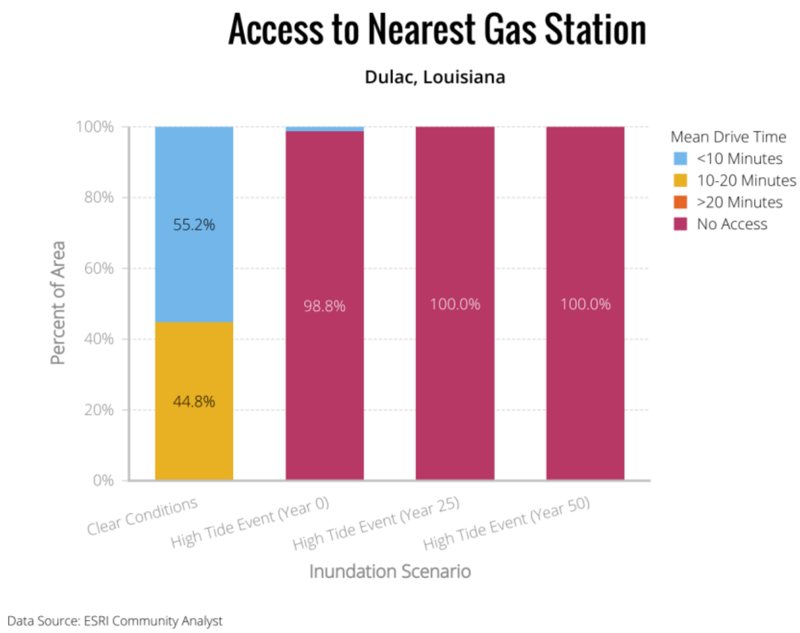


Figure 93. Drive time to nearest gas station in Dulac, Louisiana.



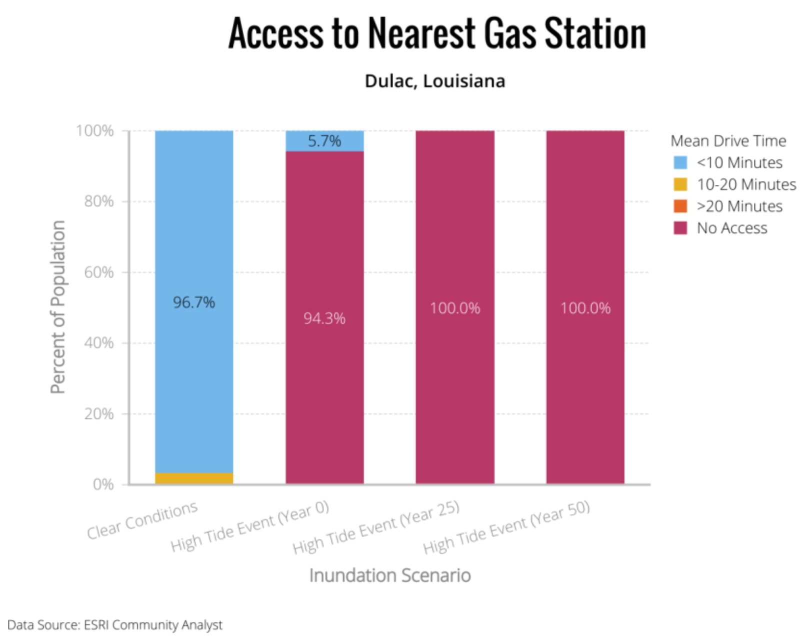


Figure 94. Drive time access to nearest gas station by percent of area (top) and population (bottom) in Dulac, Louisiana.

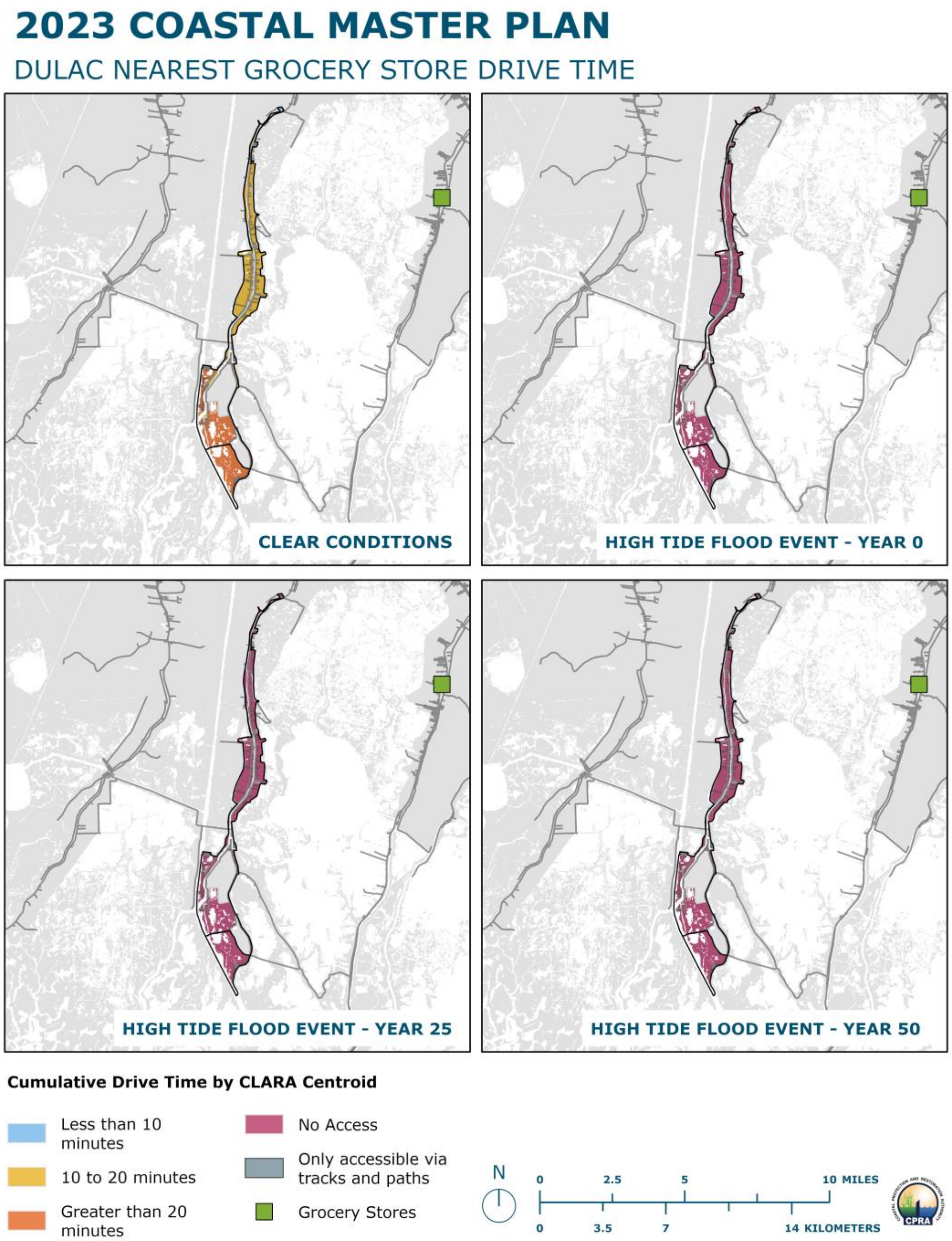
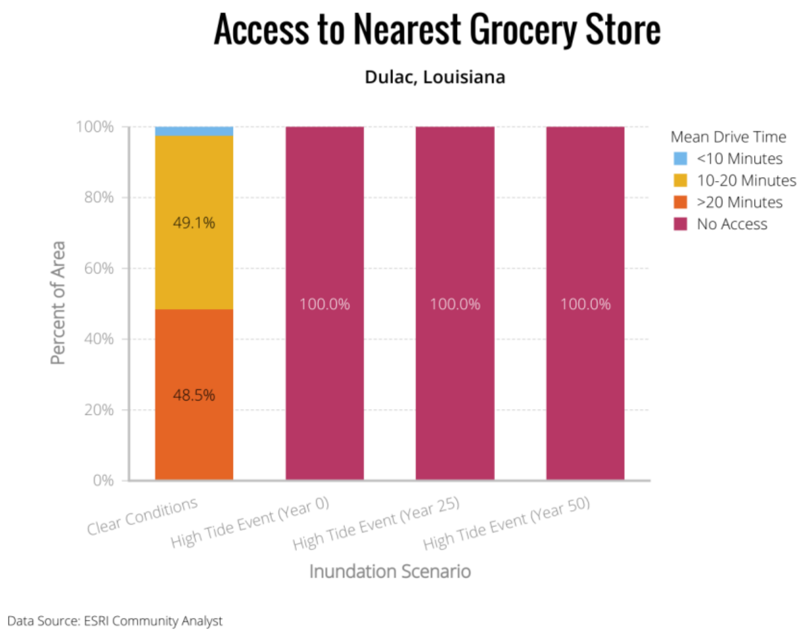


Figure 95. Drive time to nearest grocery store in Dulac, Louisiana.



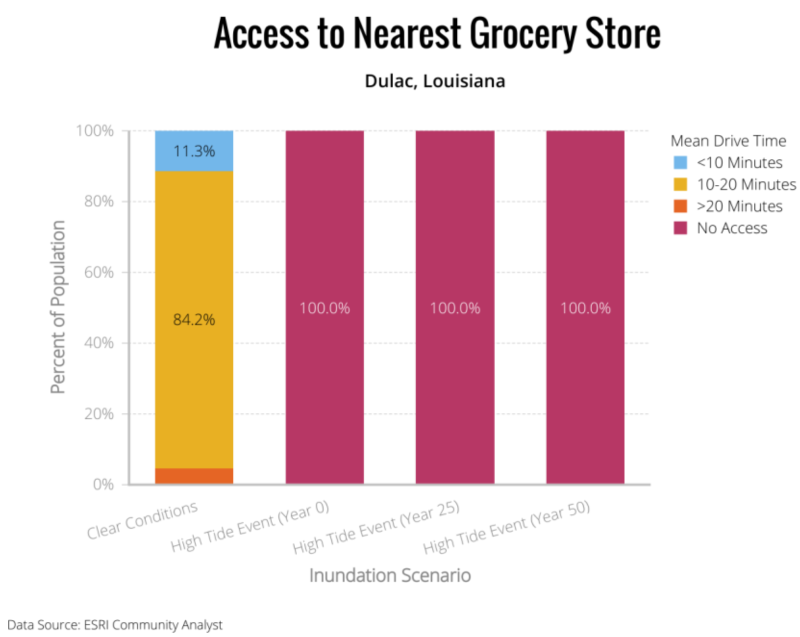


Figure 96. Drive time access to nearest grocery store by percent of area (top) and population (bottom) in Dulac, Louisiana.

GRAND ISLE

Located at the southern edge of the Barataria Basin, Grand Isle is one of a chain of barrier islands separating the basin from the Gulf of Mexico. Grand Isle is the only barrier island in Louisiana that is human-occupied, and it is a focal point of regional tourism. Located just to the east of Port Fourchon, Grand Isle is accessible by a single road that runs through Lafourche Parish. Although the community is protected by a 13-foot-high levee constructed by the U.S. Army Corps of Engineers in 2010ICM output indicates that that residents are susceptible to street flooding from high tide events, cutting them off from critical and essential facilities, both on and off the island. See Figure 97 through Figure 113 for more information on the drive time analysis for Grand Isle, Louisiana.

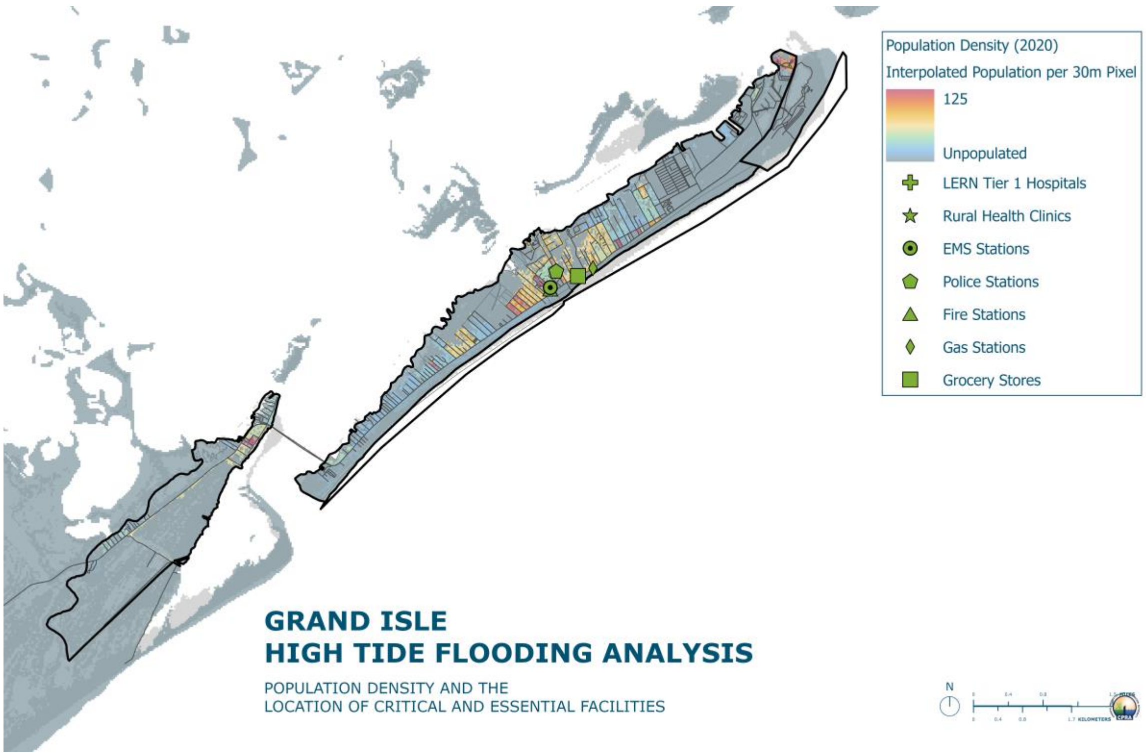


Figure 97. Dasymetric population density map of Grand Isle, Louisiana with locations of nearby critical and essential facilities, where applicable.

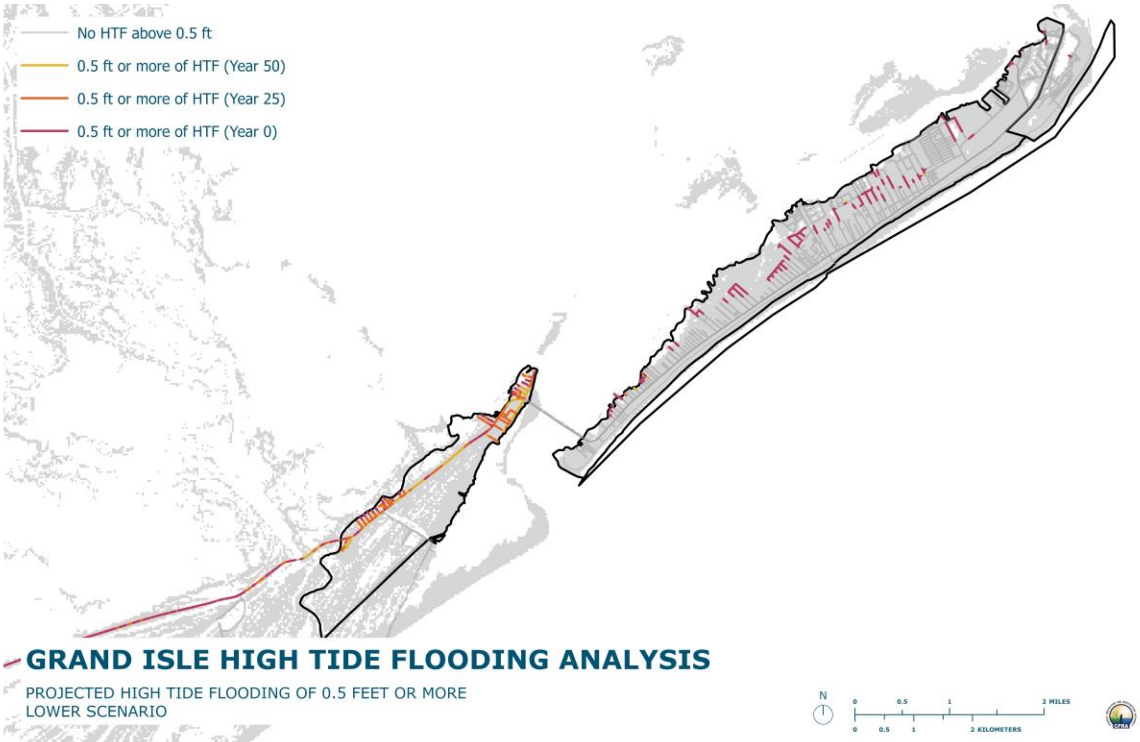


Figure 98. Road segments in Grand Isle, Louisiana projected to have 0.5 ft or more of HTF and considered impassable in Year 0, Year 25, and Year 50 under the 2023 Coastal Master Plan’s lower scenario

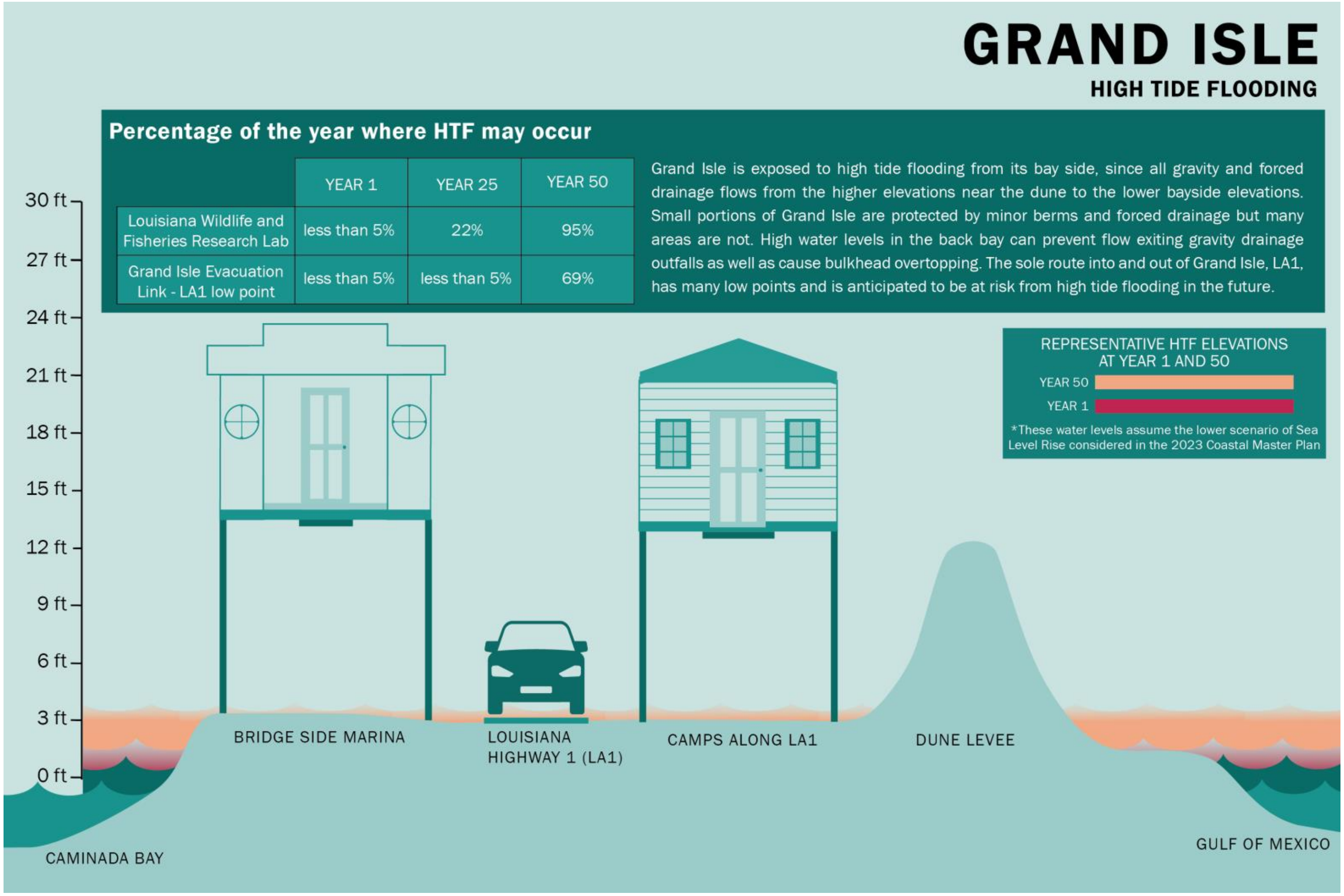


Figure 99. Modeled WSE depths for HTF events in Grand Isle, Louisiana at local impact threshold locations.

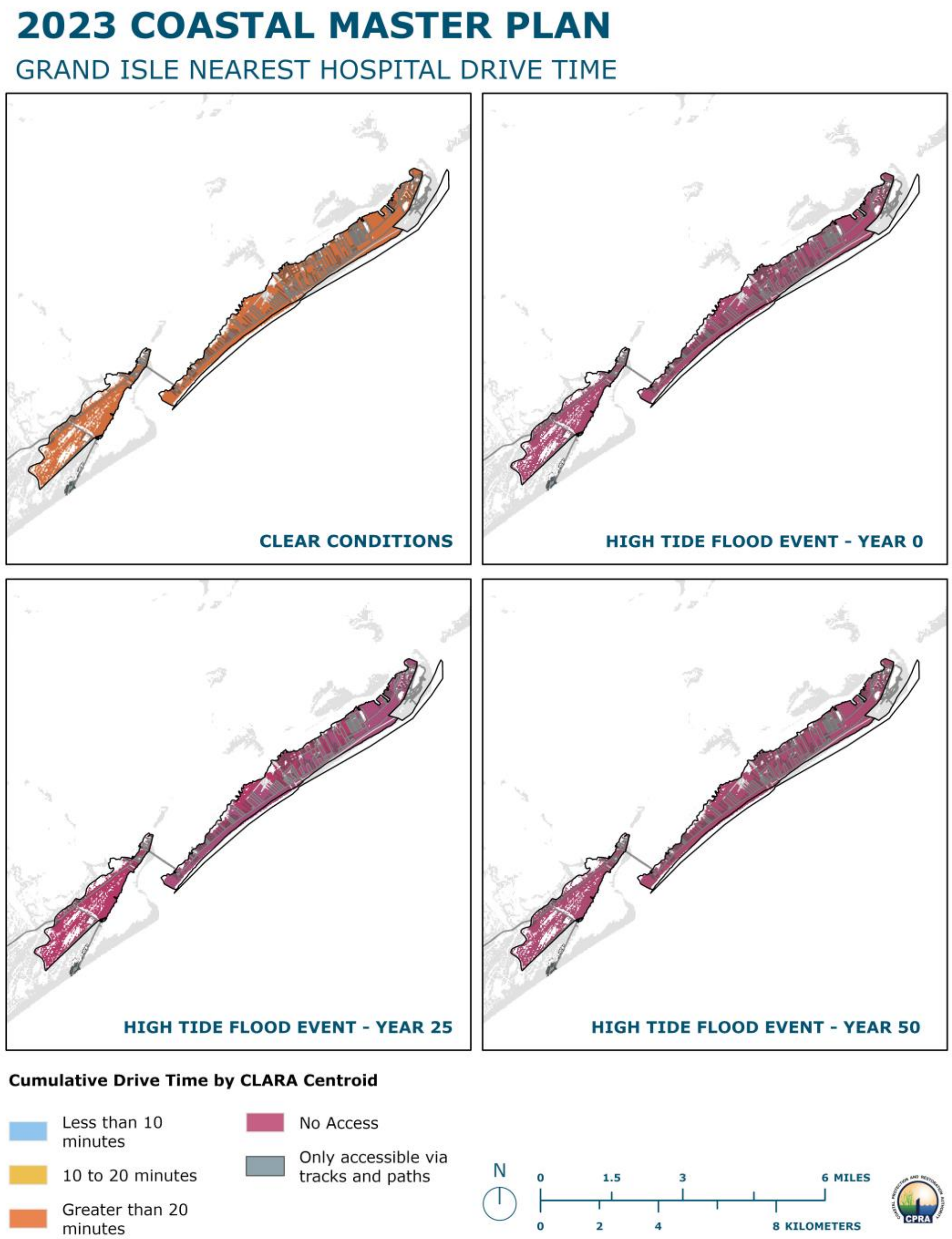
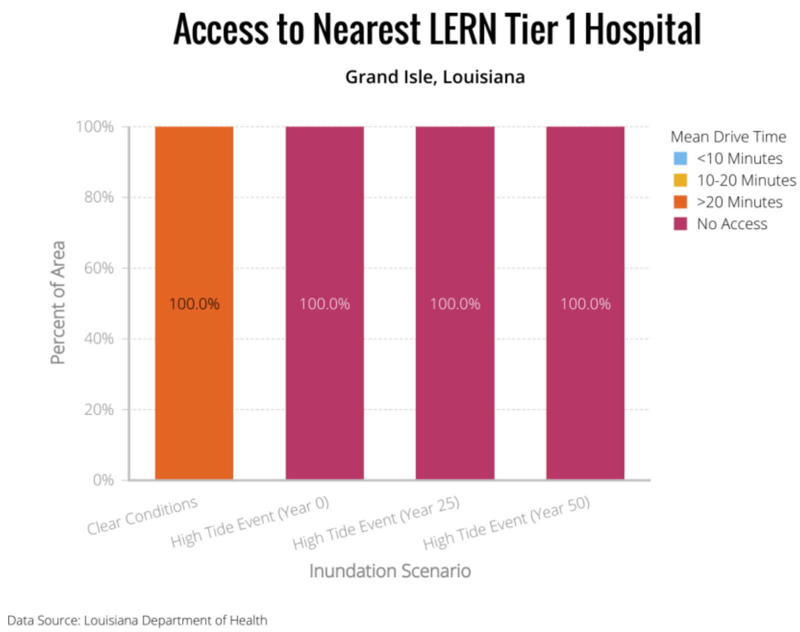


Figure 100. Drive time to nearest LERN Tier 1 hospital in Grand Isle, LA.



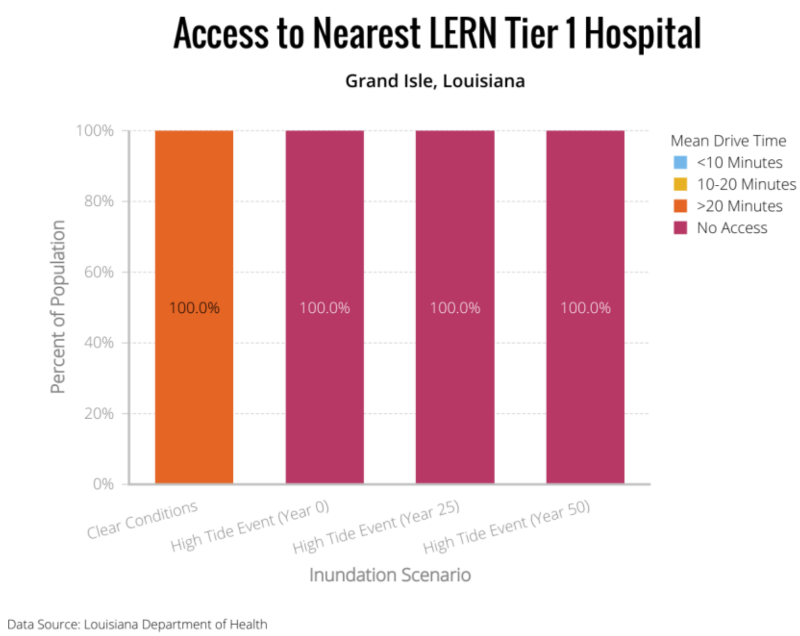


Figure 101. Drive time access to nearest LERN Tier 1 hospital by percent of area (top) and population (bottom) in Grand Isle, Louisiana.

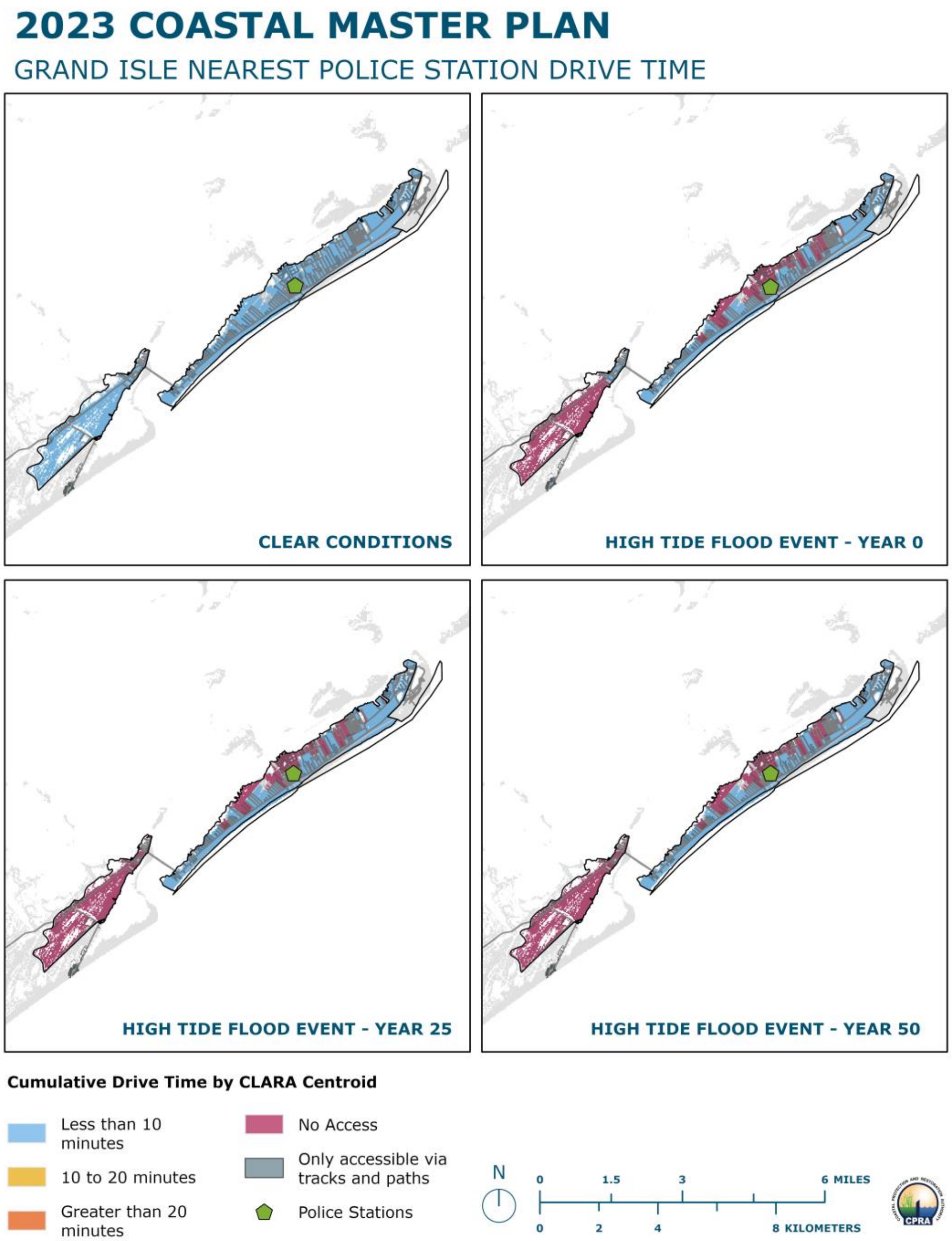
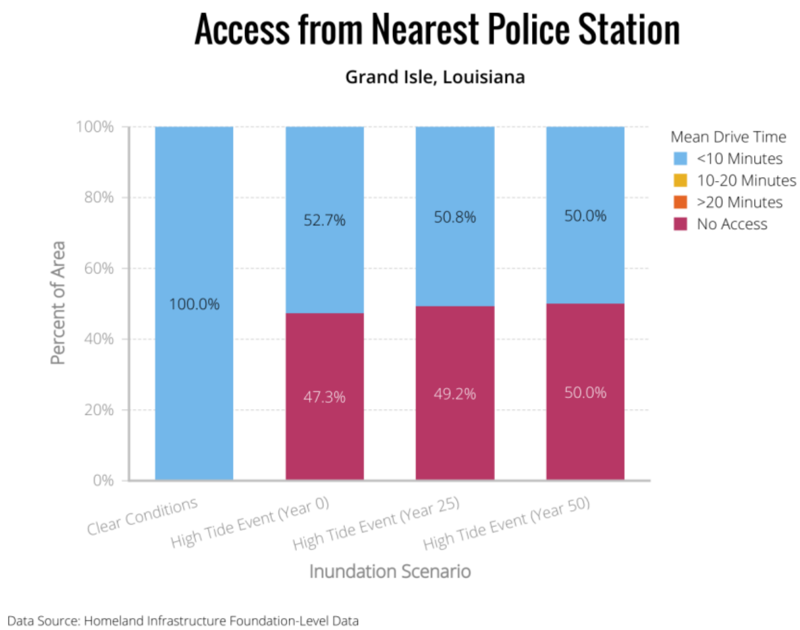


Figure 102. Drive time to nearest police station in Grand Isle, Louisiana.



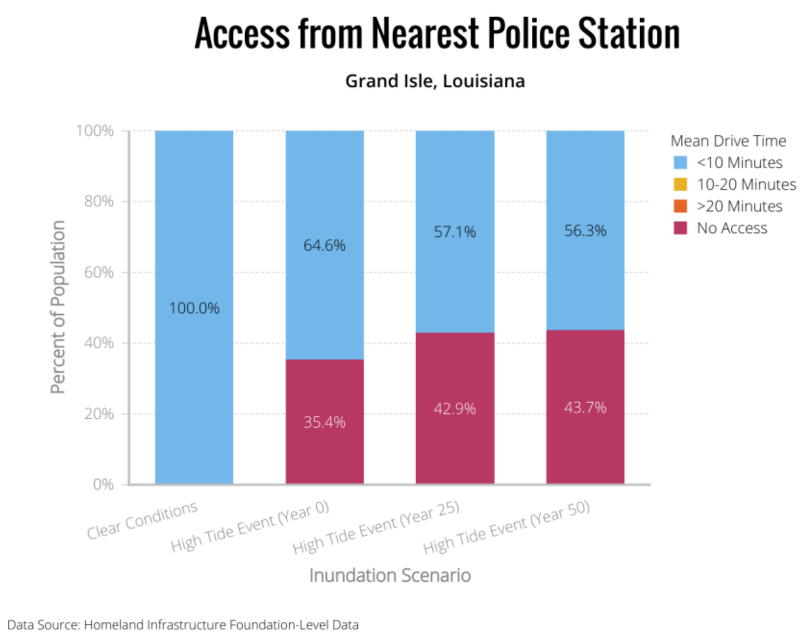


Figure 103. Drive time access to nearest police station by percent of area (top) and population (bottom) in Grand Isle, Louisiana.

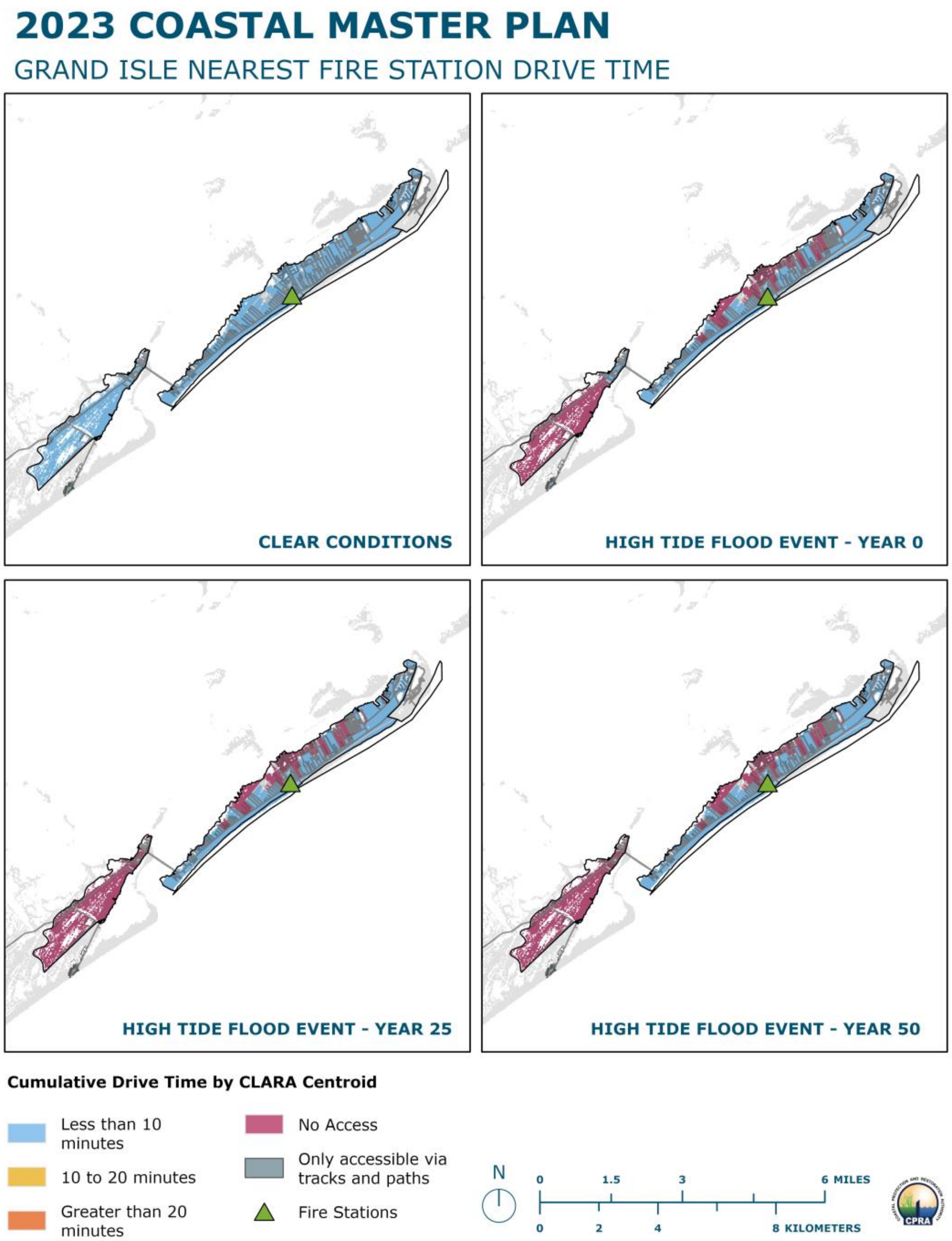
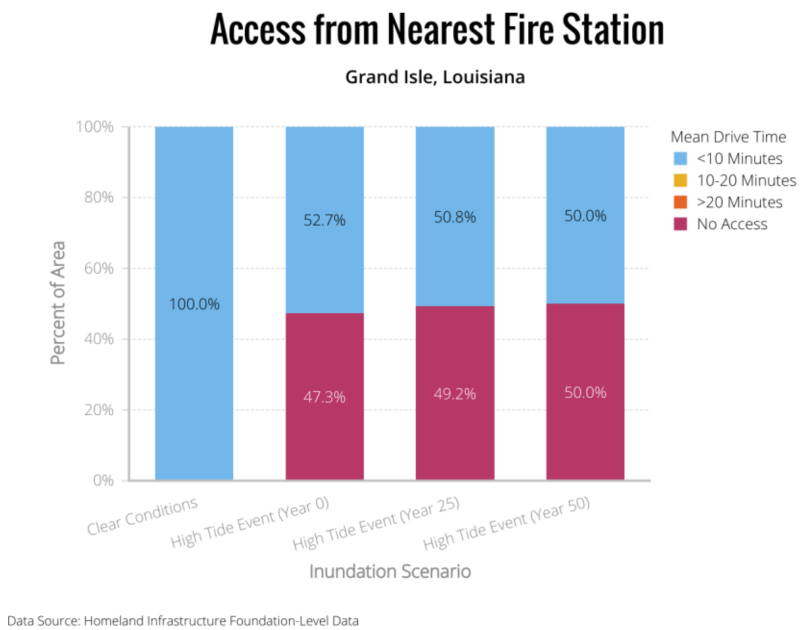


Figure 104. Drive time to nearest fire station in Grand Isle, Louisiana.



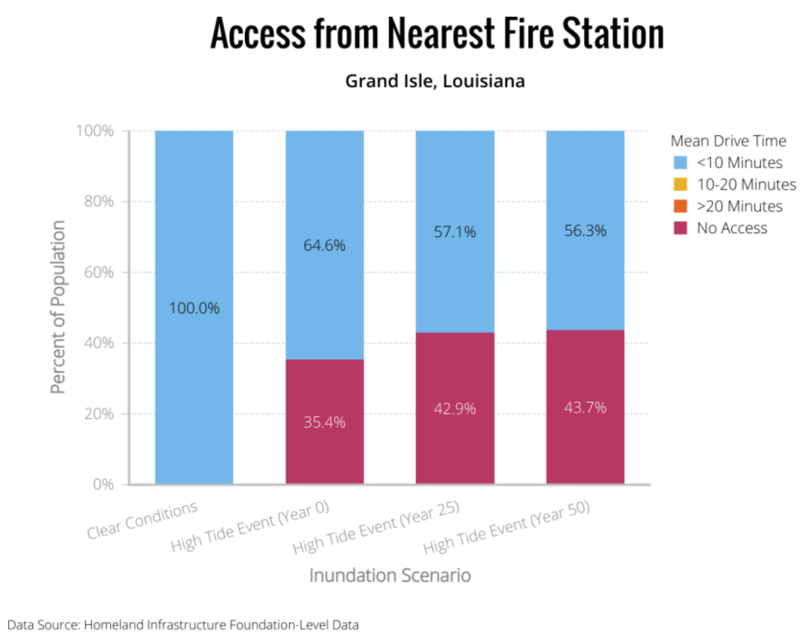


Figure 105. Drive time access to nearest fire station by percent of area (top) and population (bottom) in Grand Isle, Louisiana.

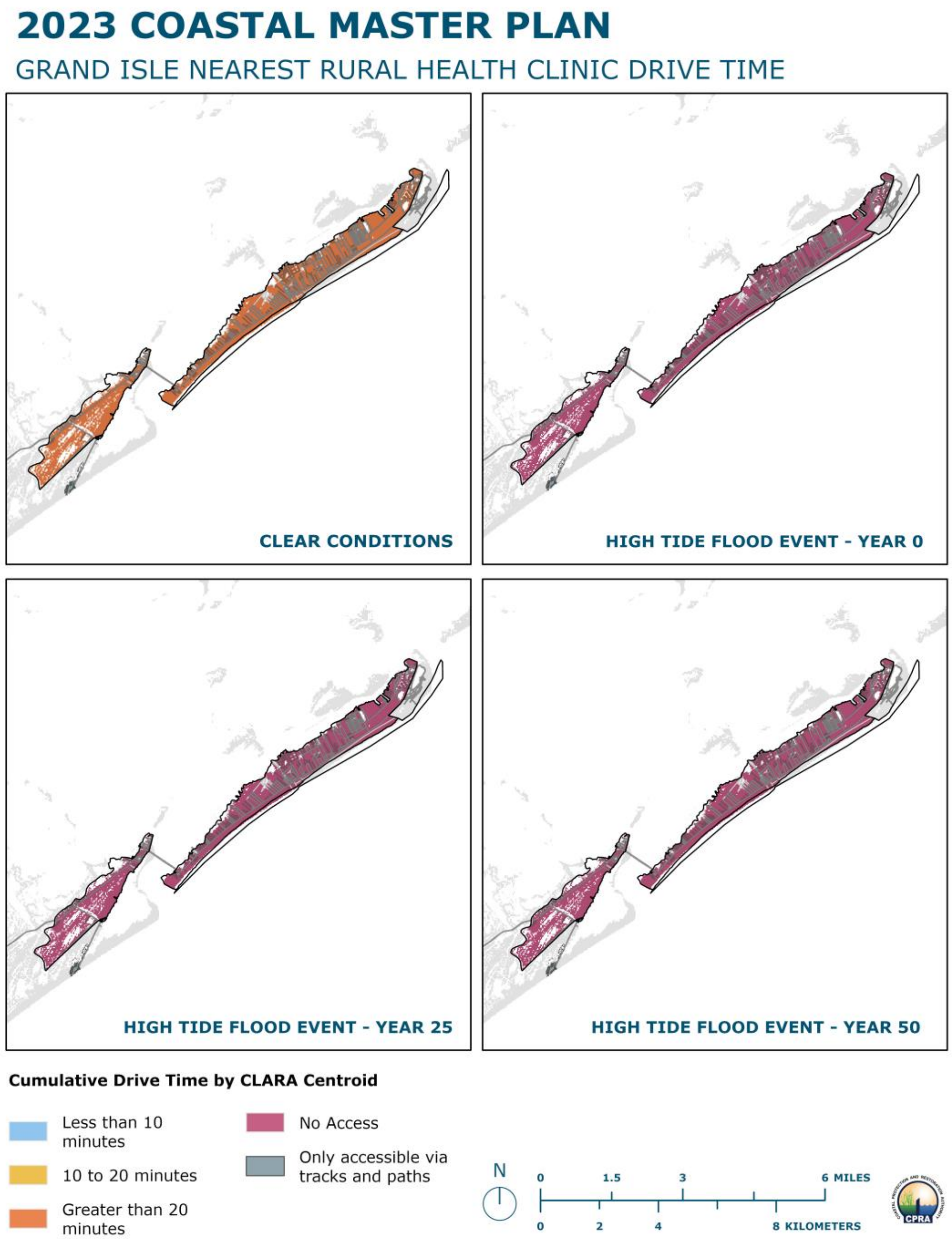
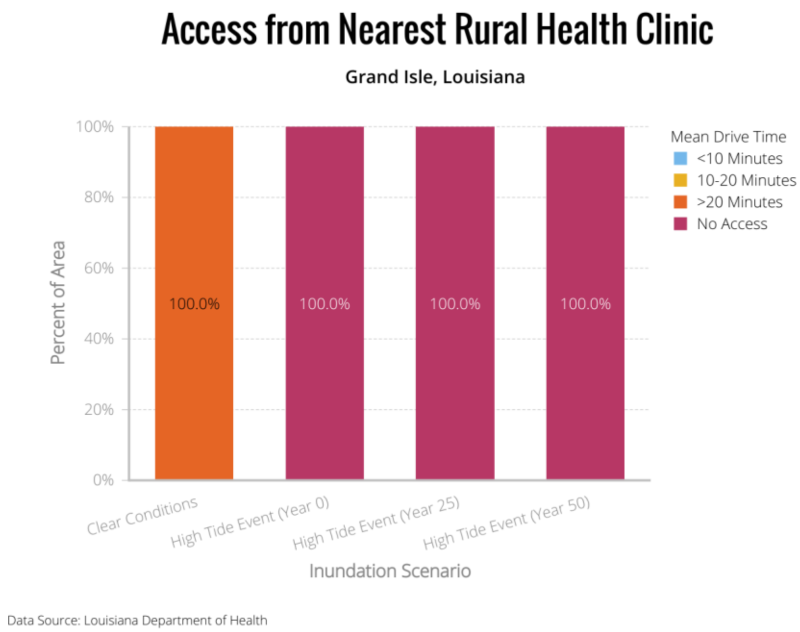


Figure 106. Drive time to nearest rural health clinic in Grand Isle, Louisiana.



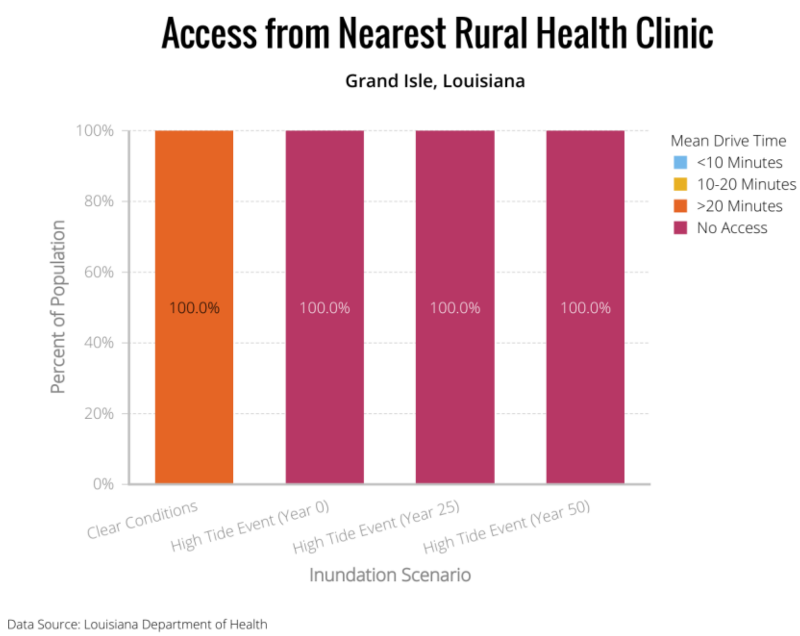


Figure 107. Drive time access to nearest rural health clinic by percent of area (top) and population (bottom) in Grand Isle, Louisiana.

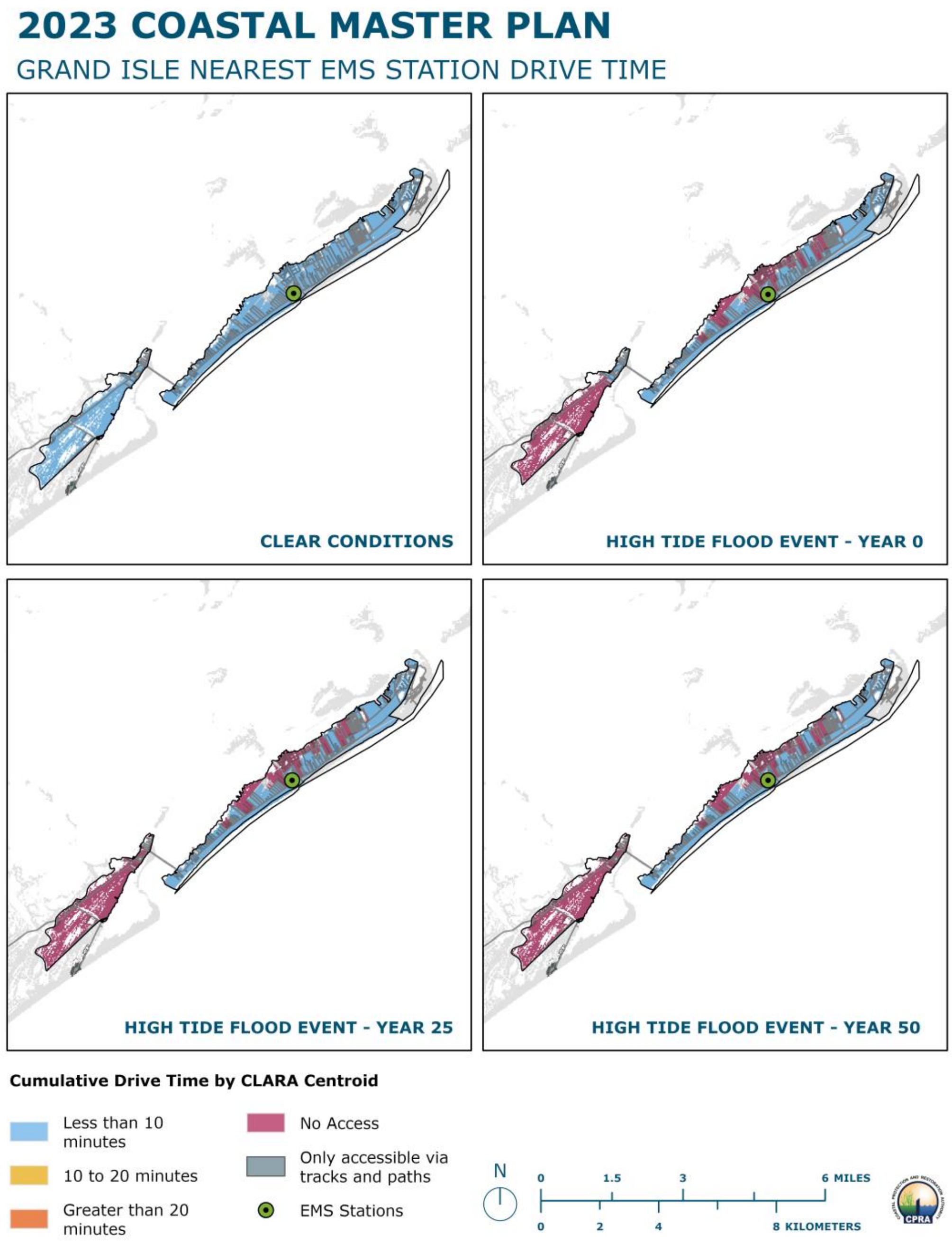
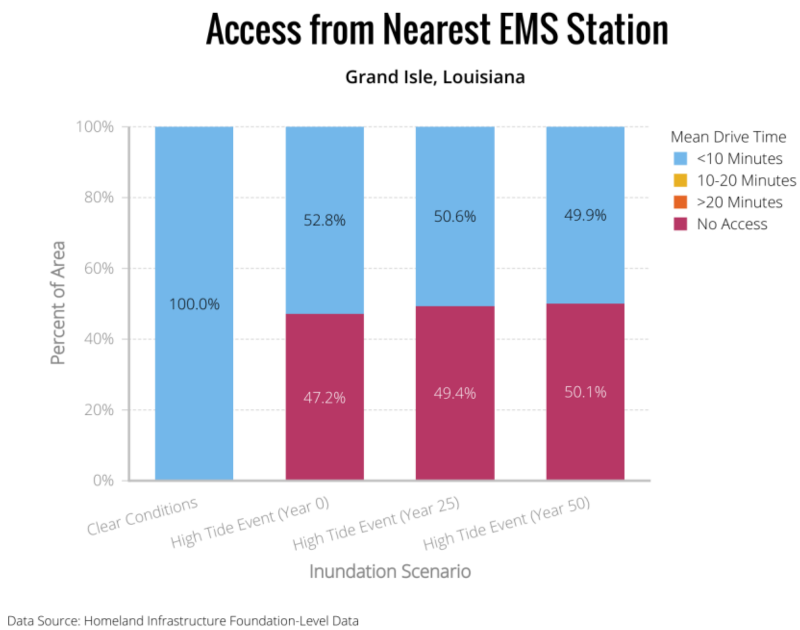


Figure 108. Drive time to nearest EMS station in Grand Isle, Louisiana.



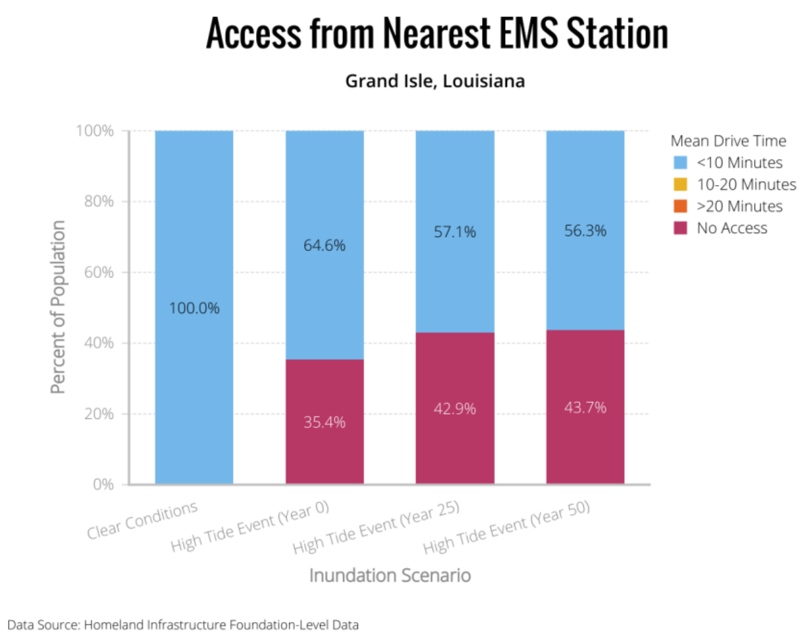


Figure 109. Drive time access to nearest EMS station by percent of area (top) and population (bottom) in Grand Isle, Louisiana.

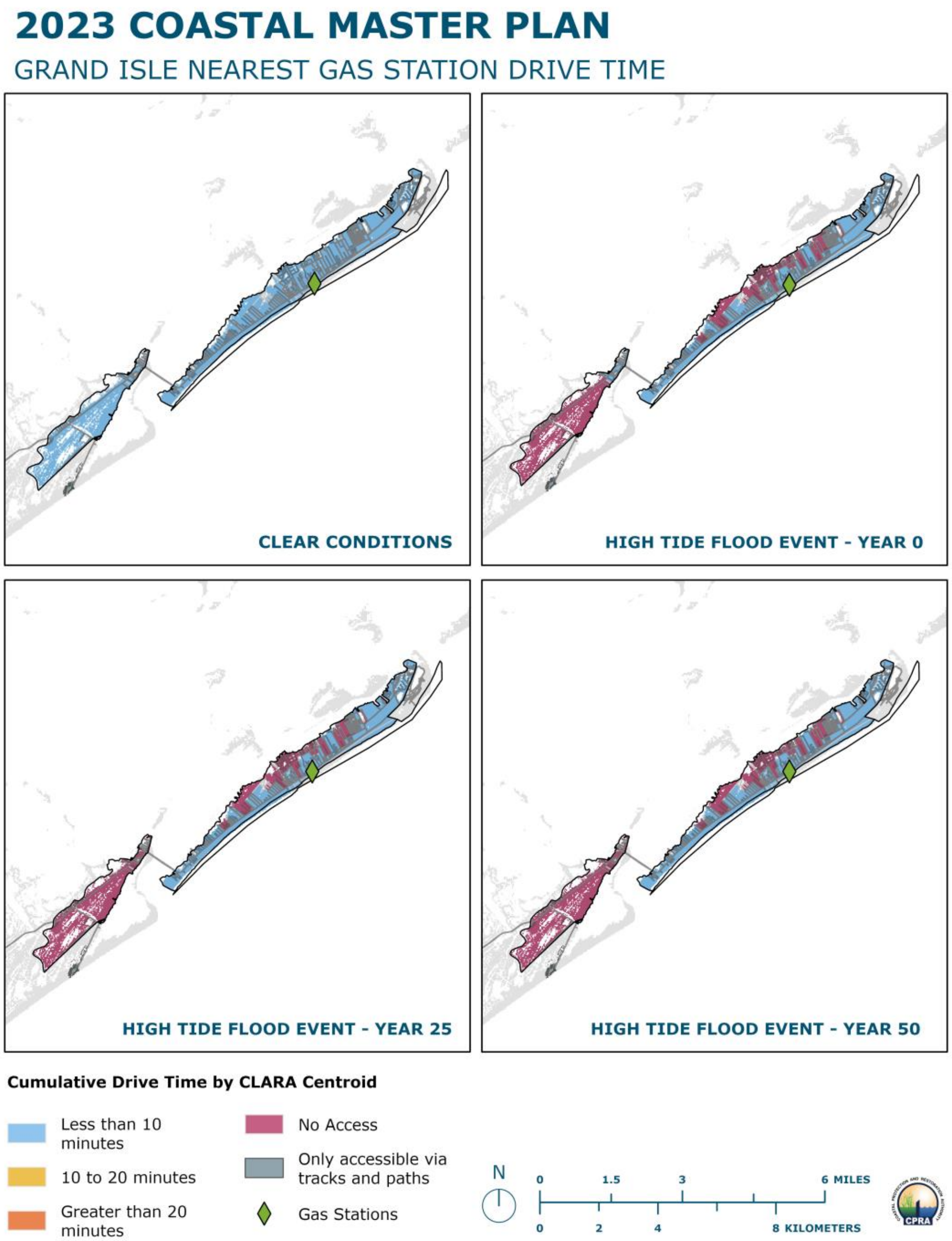
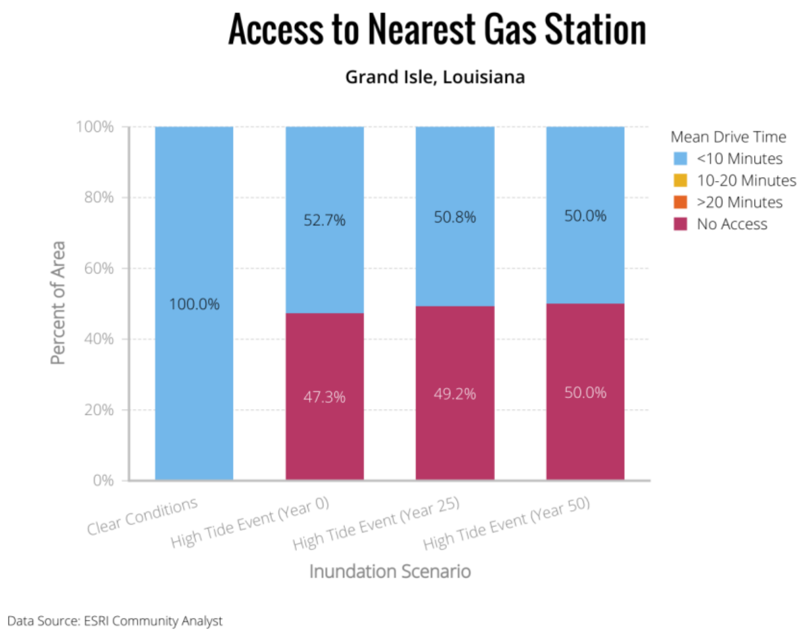


Figure 110. Drive time to nearest gas station in Grand Isle, Louisiana.



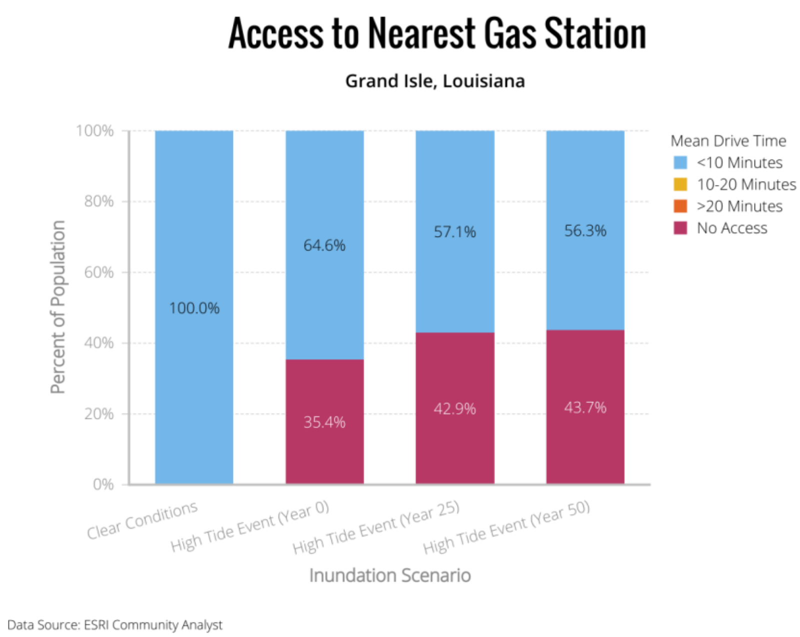


Figure 111. Drive time access to nearest gas station by percent of area (top) and population (bottom) in Grand Isle, Louisiana.

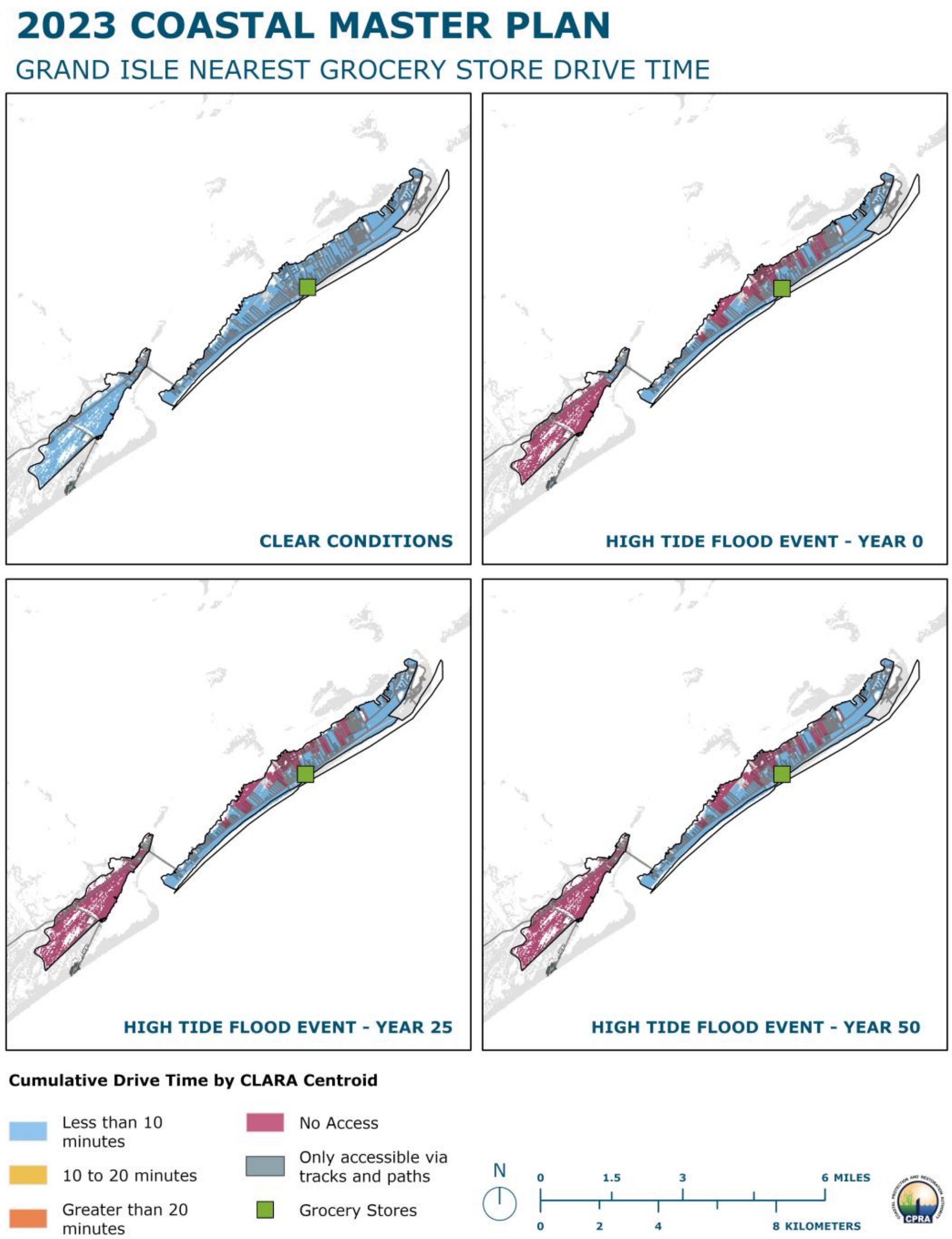
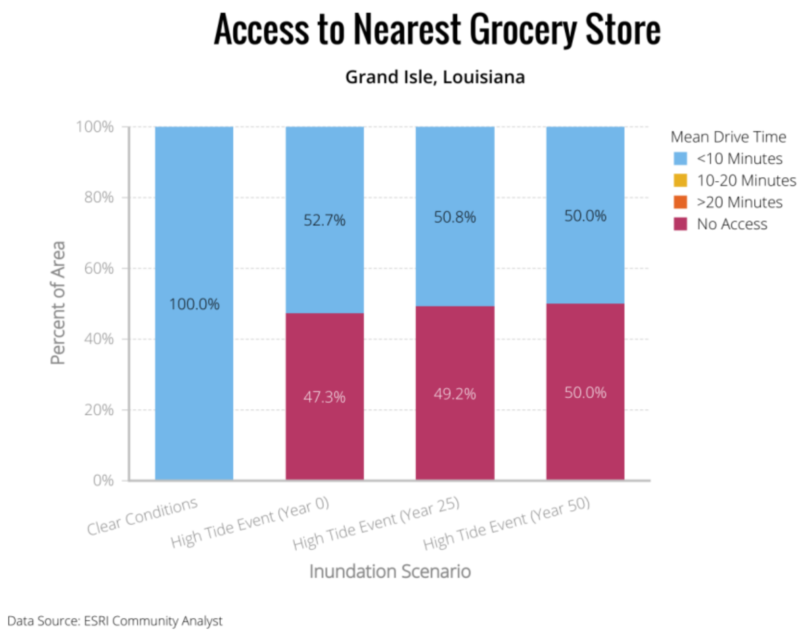


Figure 112. Drive time to nearest grocery store in Grand Isle, Louisiana.



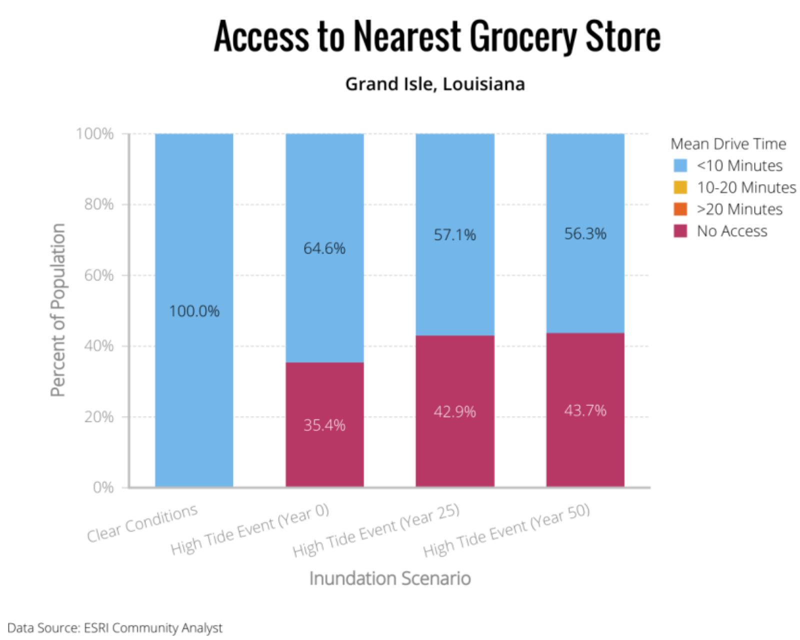


Figure 113. Drive time access to nearest grocery store by percent of area (top) and population (bottom) in Grand Isle, Louisiana.

MANDEVILLE

Mandeville is a city located on the North Shore of Lake Pontchartrain adjacent to the communities of Covington, Abita Springs, and Madisonville. Much of the development in this region occurs along a series of elevated Pleistocene terraces. The lowest elevation in the community consists largely of brackish marsh along the Lake Pontchartrain shoreline. The impacts of high tide events are expected within the wetland fringe separating Mandeville from Lake Pontchartrain with other impacts likely to occur to the west along the Tchefuncte River in Madisonville. See Figure 114 through Figure 130 for more information on the drive time analysis for Mandeville, Louisiana.

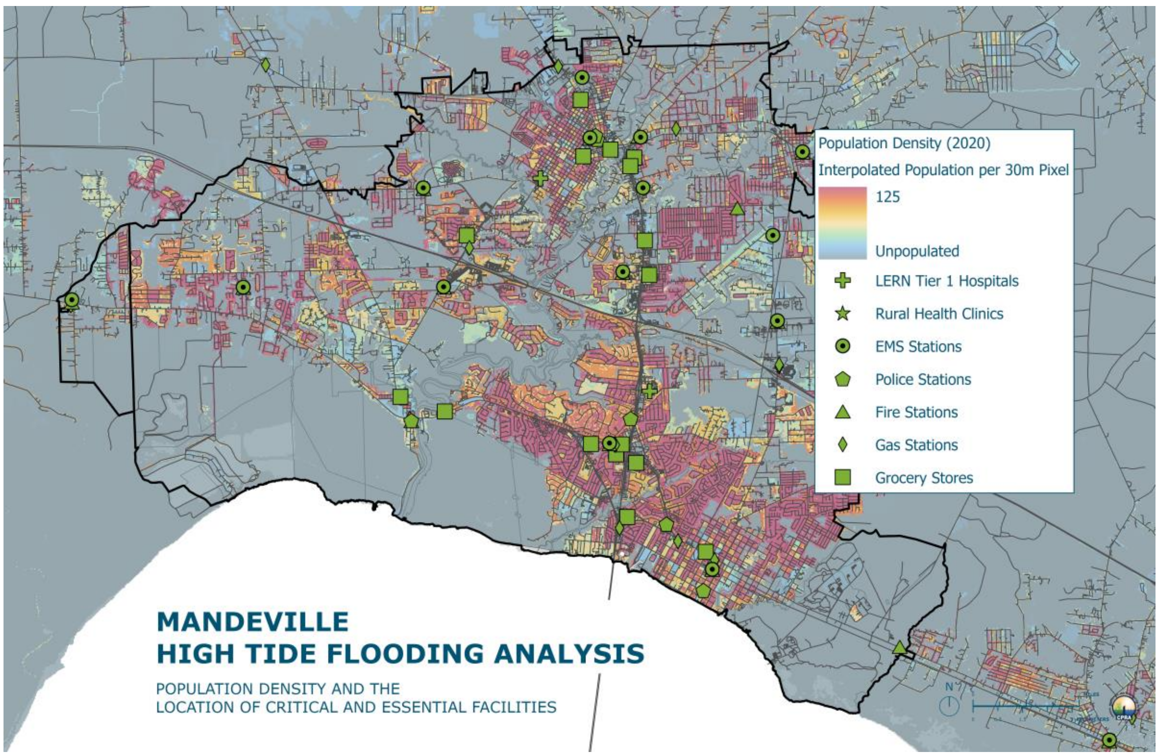


Figure 114. Dasymetric population density map of Mandeville, Louisiana with locations of nearby critical and essential facilities, where applicable.

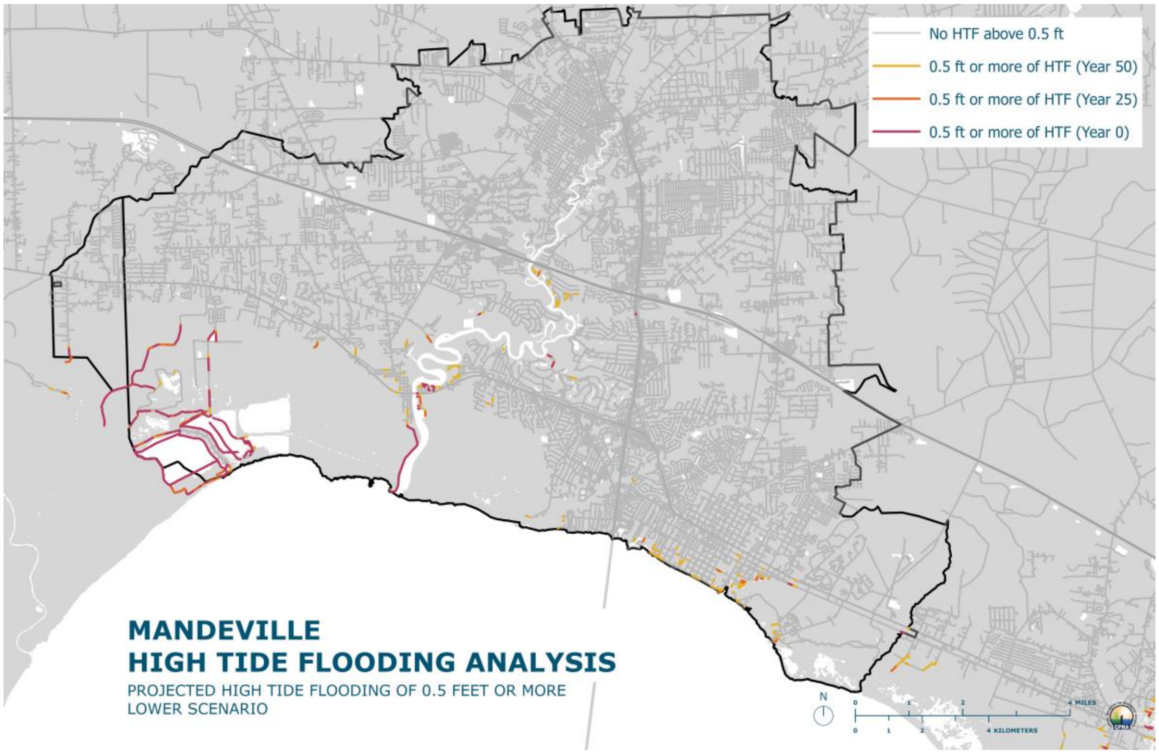


Figure 115. Road segments in Mandeville, Louisiana projected to have 0.5 ft or more of HTF and considered impassable in Year 0, Year 25, and Year 50 under the 2023 Coastal Master Plan's lower scenario

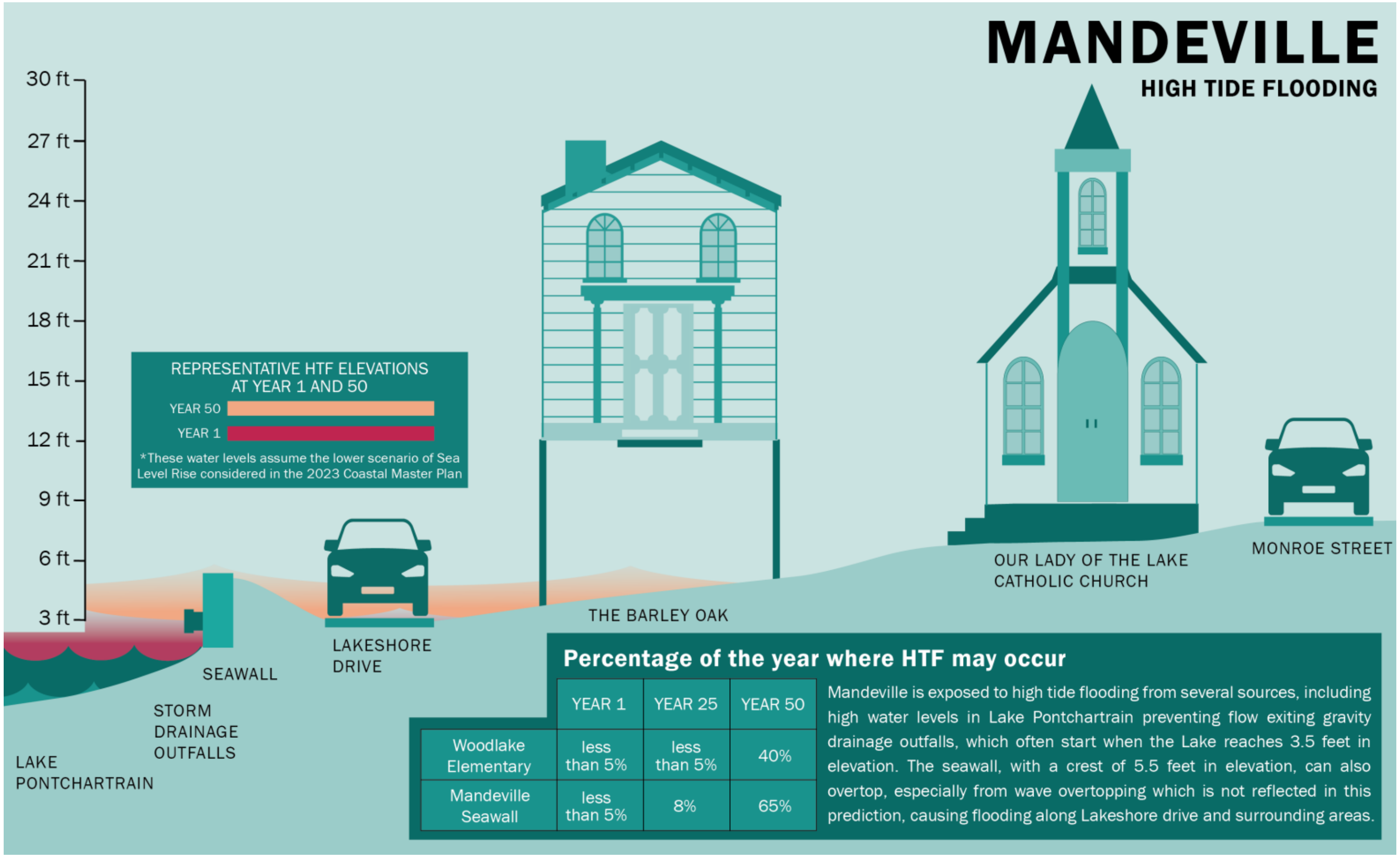


Figure 116. Modeled WSE depths for HTF events in Mandeville, Louisiana at local impact threshold locations.

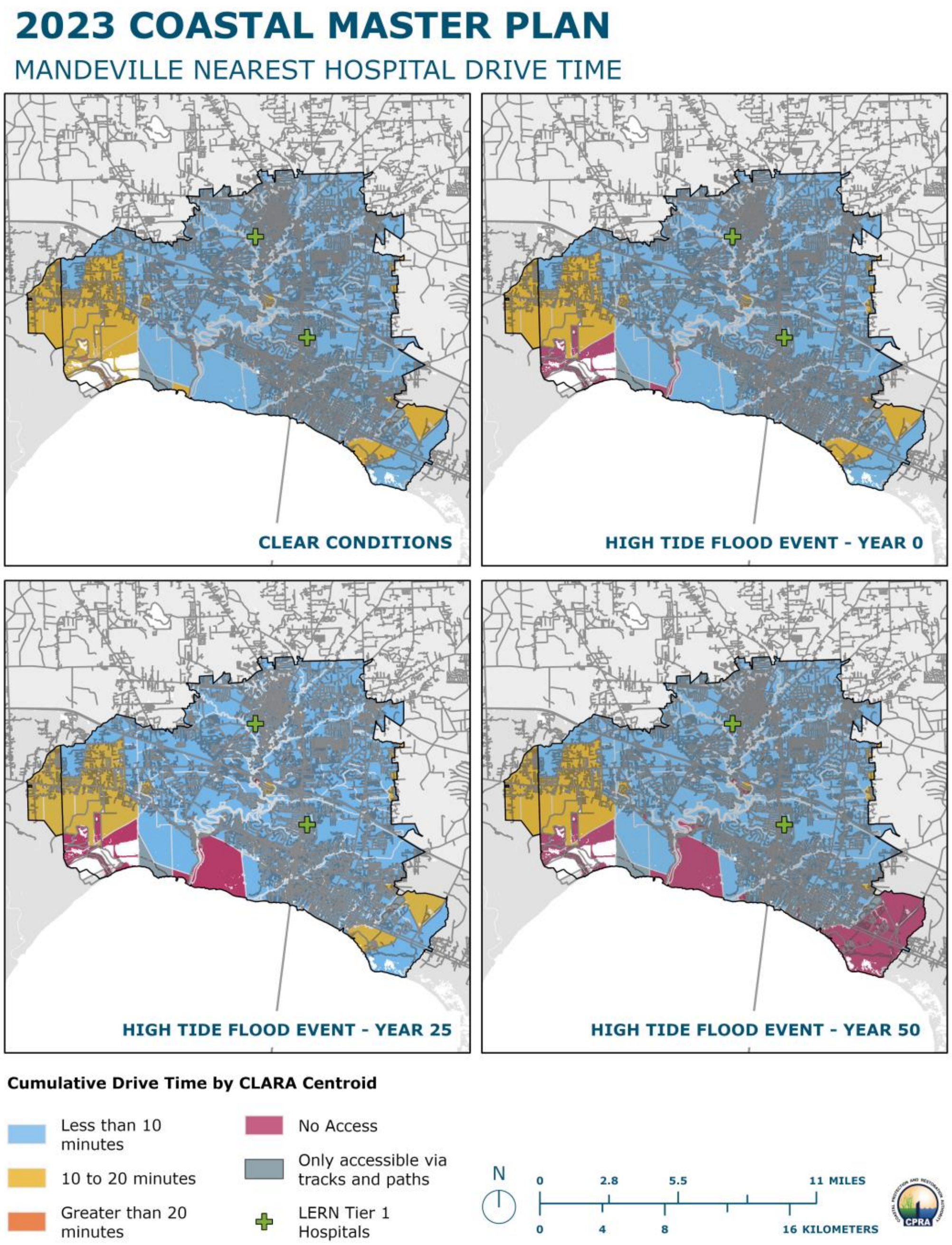
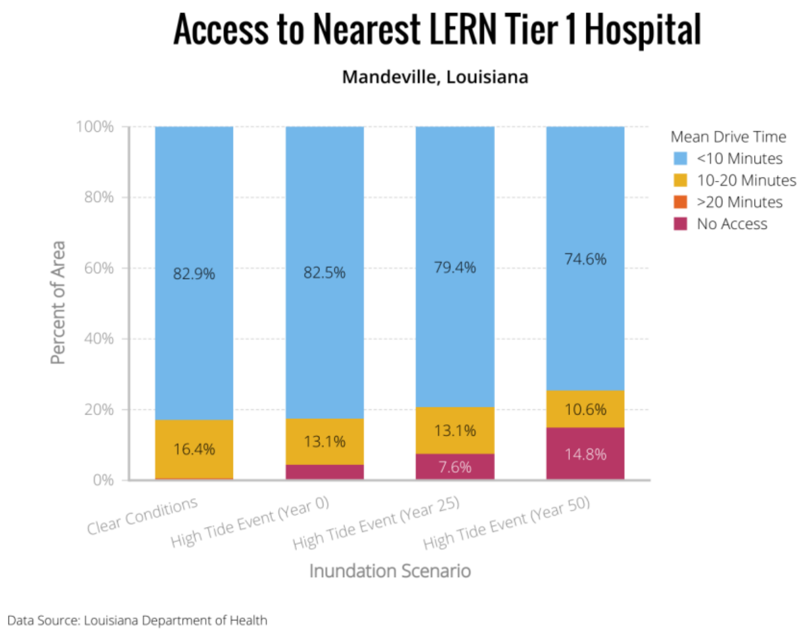


Figure 117. Drive time to nearest LERN Tier 1 hospital in Mandeville, Louisiana.



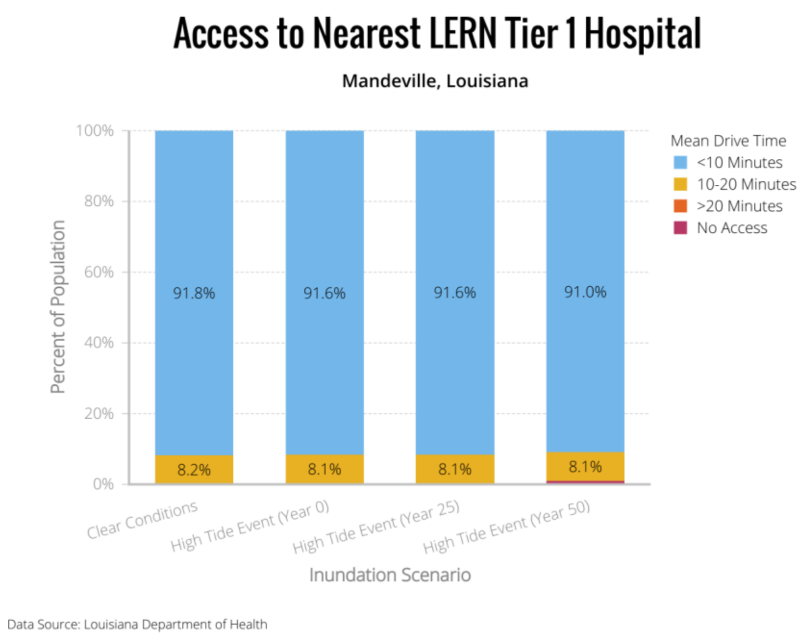


Figure 118. Drive time access to nearest LERN Tier 1 hospital by percent of area (top) and population (bottom) in Mandeville, Louisiana.

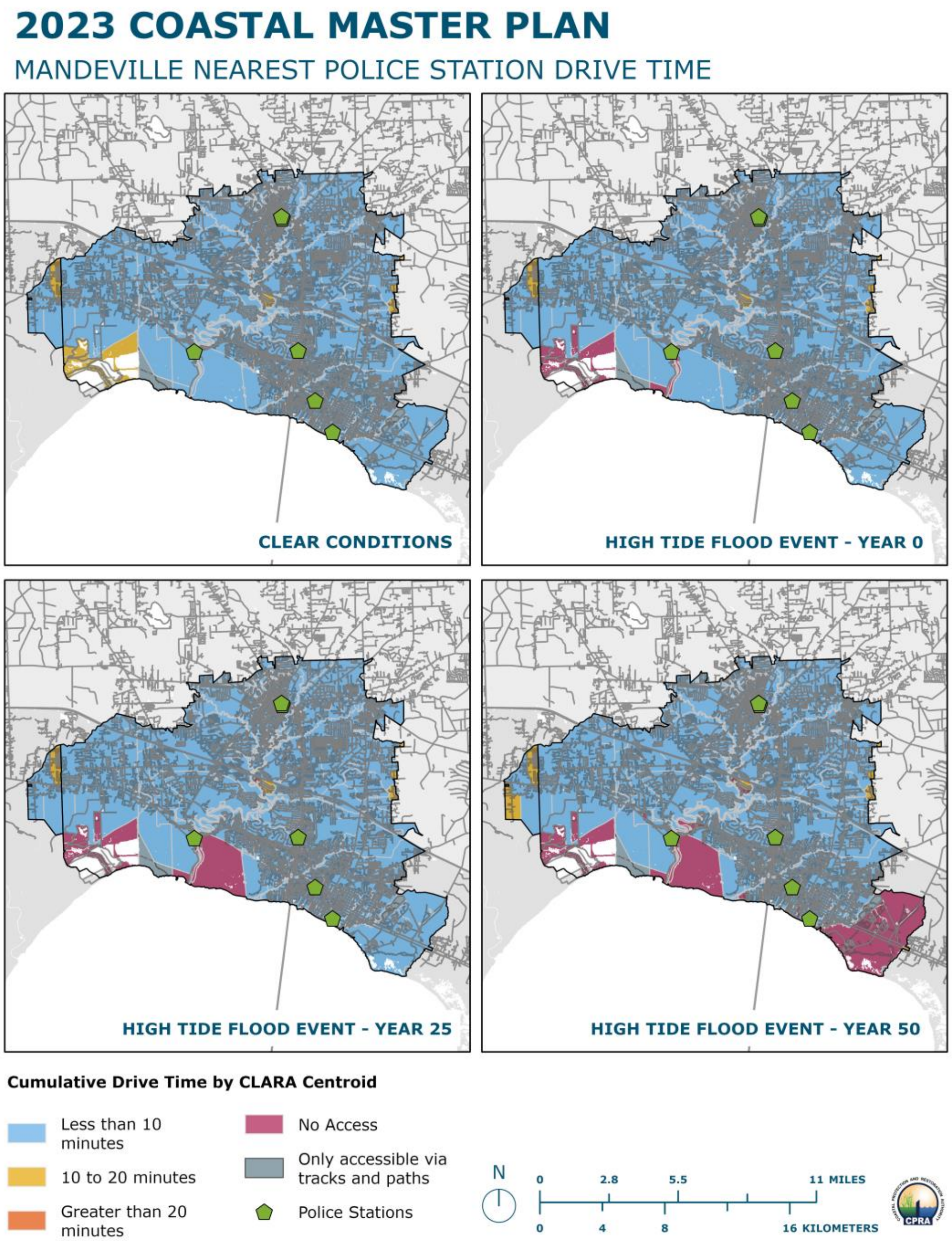
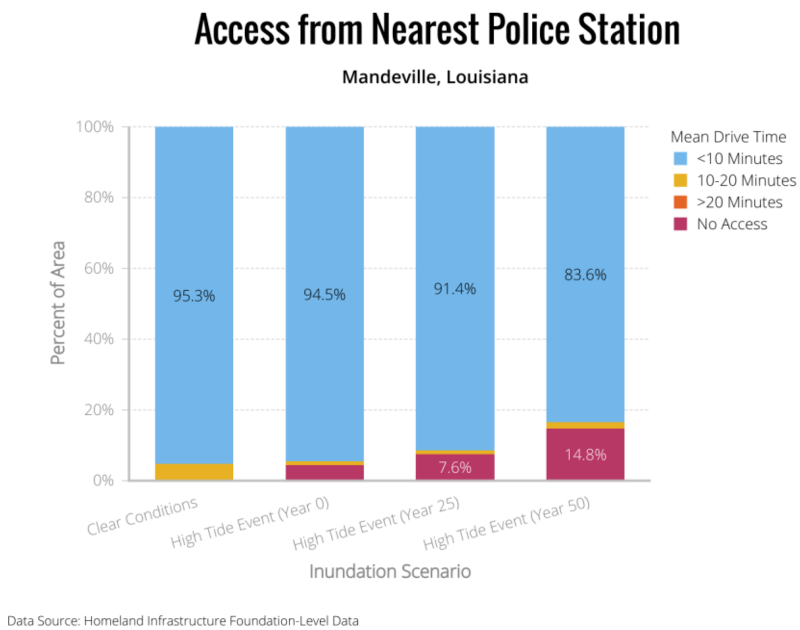


Figure 119. Drive time to nearest police station in Mandeville, Louisiana.



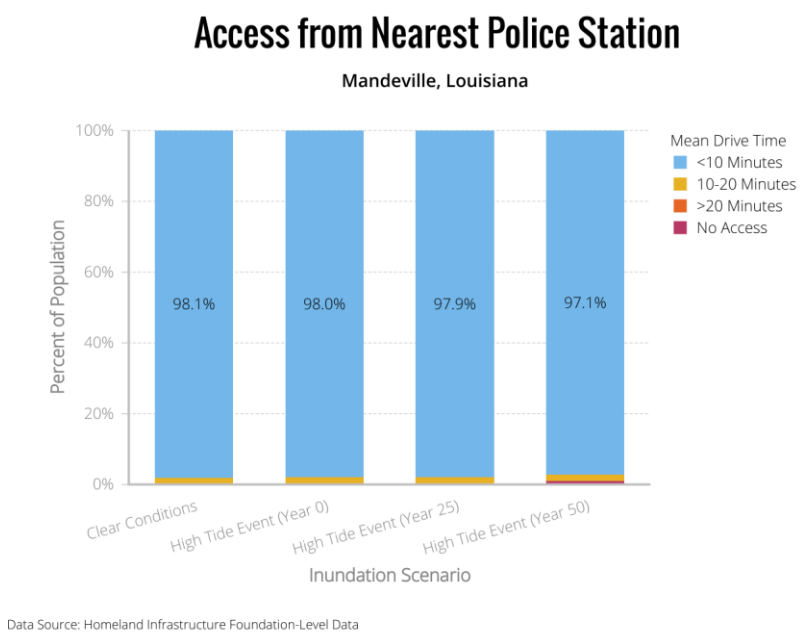


Figure 120. Drive time access to nearest police station by percent of area (top) and population (bottom) in Mandeville, Louisiana.

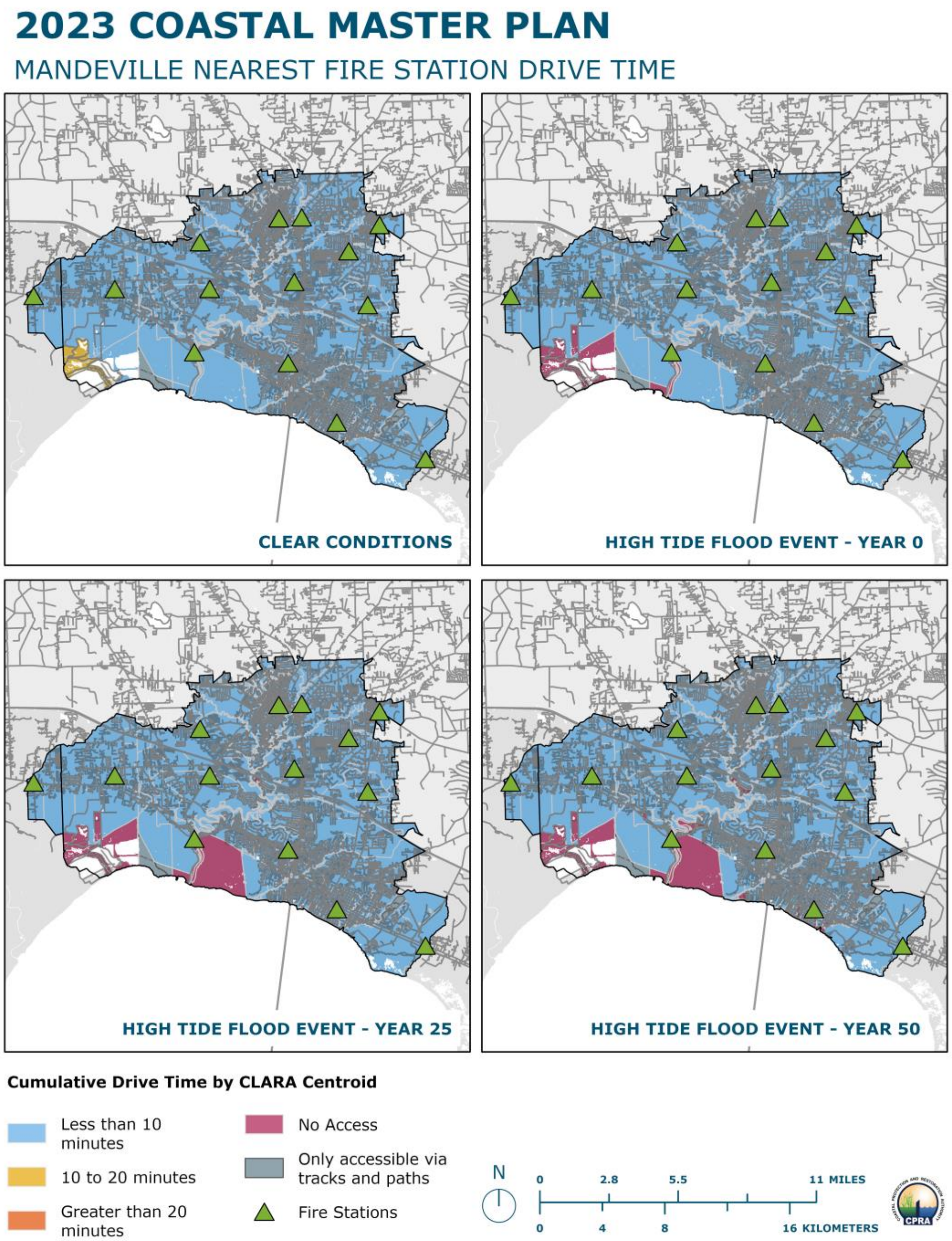
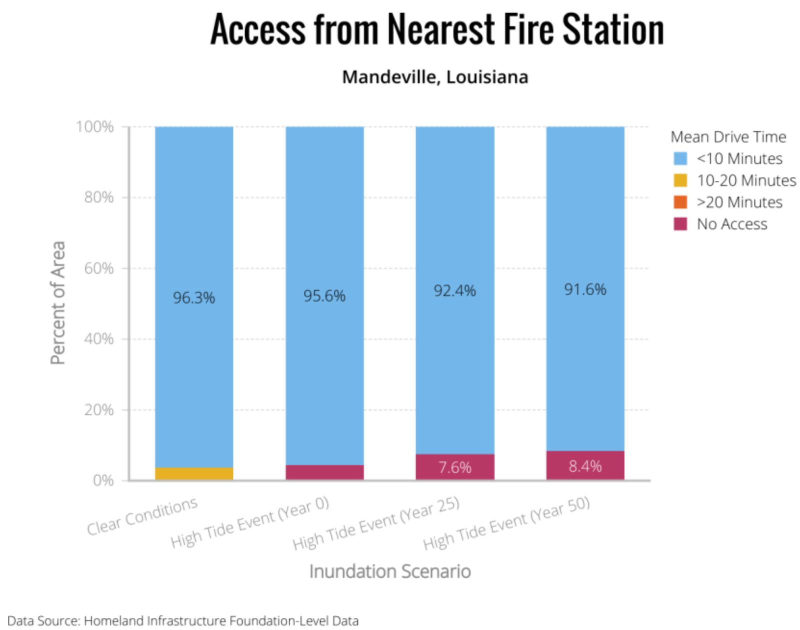


Figure 121. Drive time to nearest fire station in Mandeville, Louisiana.



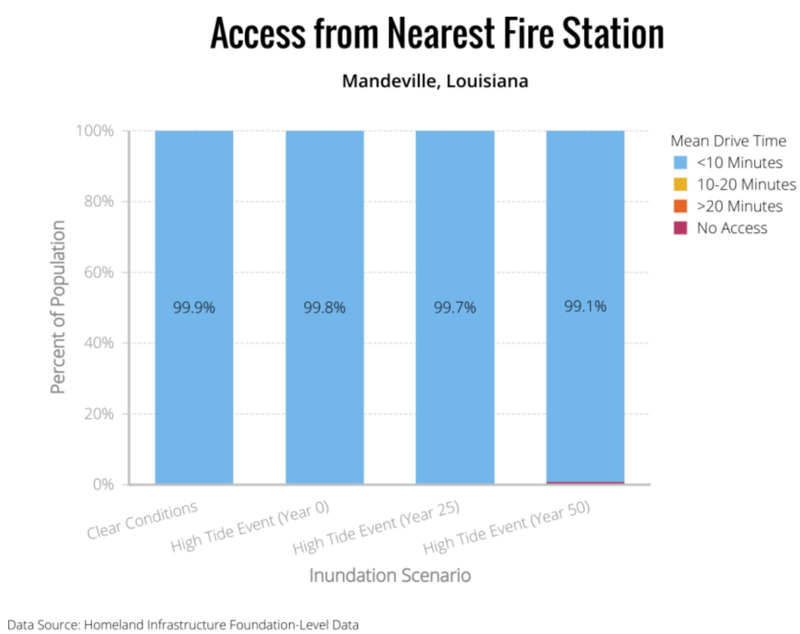


Figure 122. Drive time access to nearest fire station by percent of area (top) and population (bottom) in Mandeville, Louisiana.

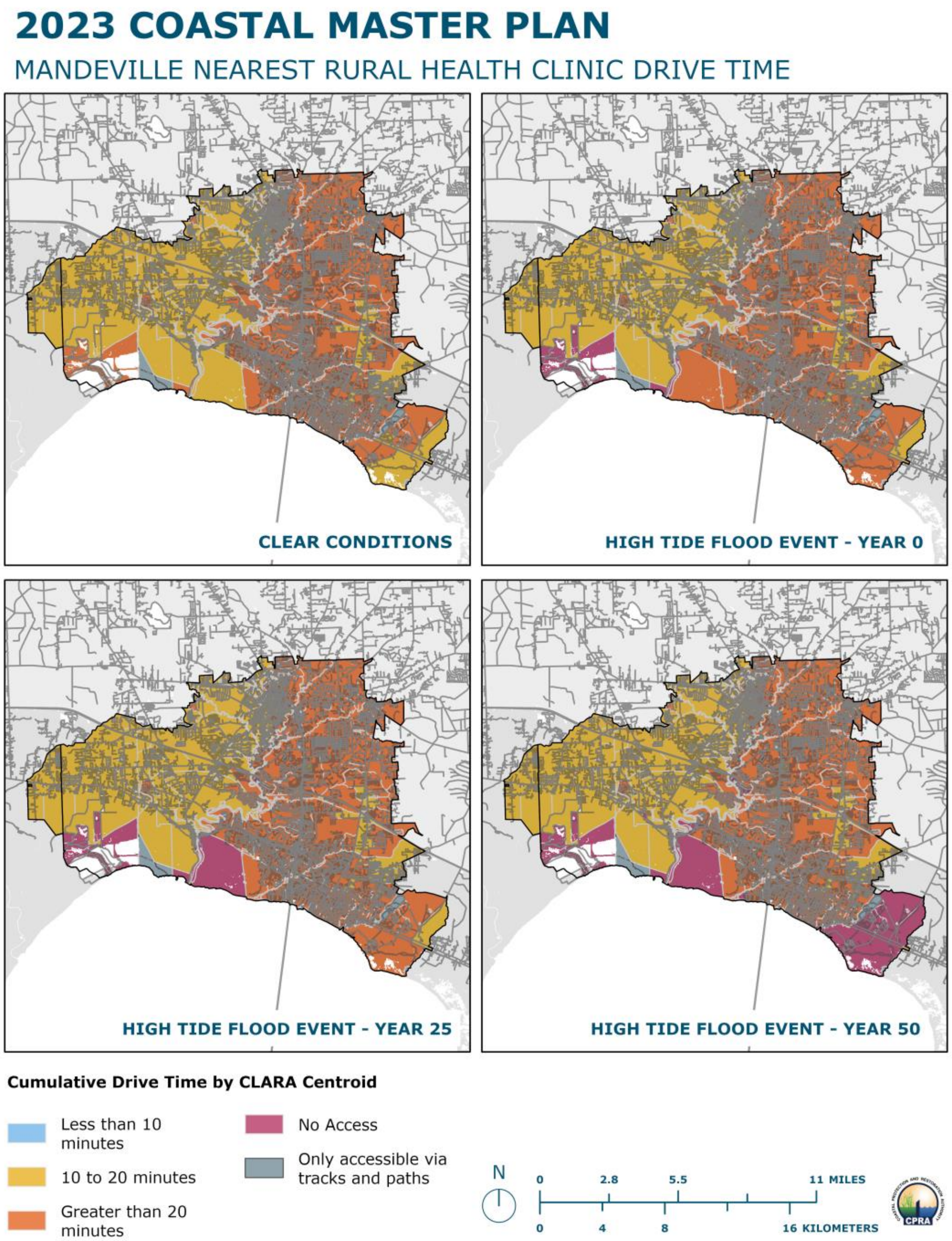
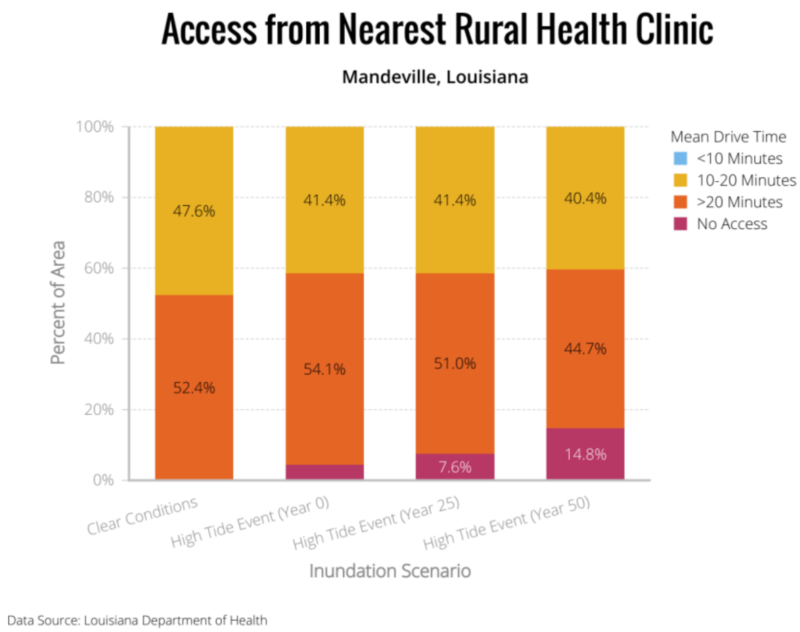


Figure 123. Drive time to nearest rural health clinic in Mandeville, Louisiana.



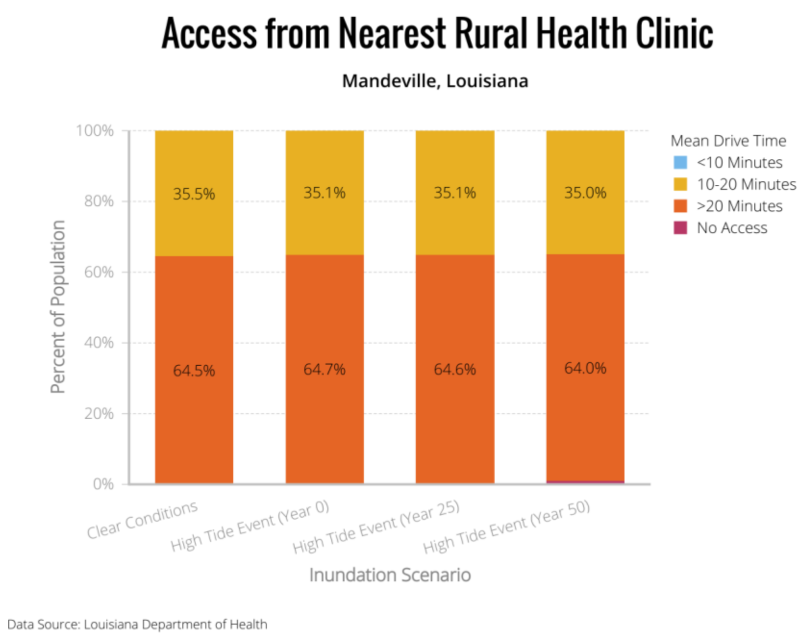


Figure 124. Drive time access to nearest rural health clinic by percent of area (top) and population (bottom) in Mandeville, Louisiana.

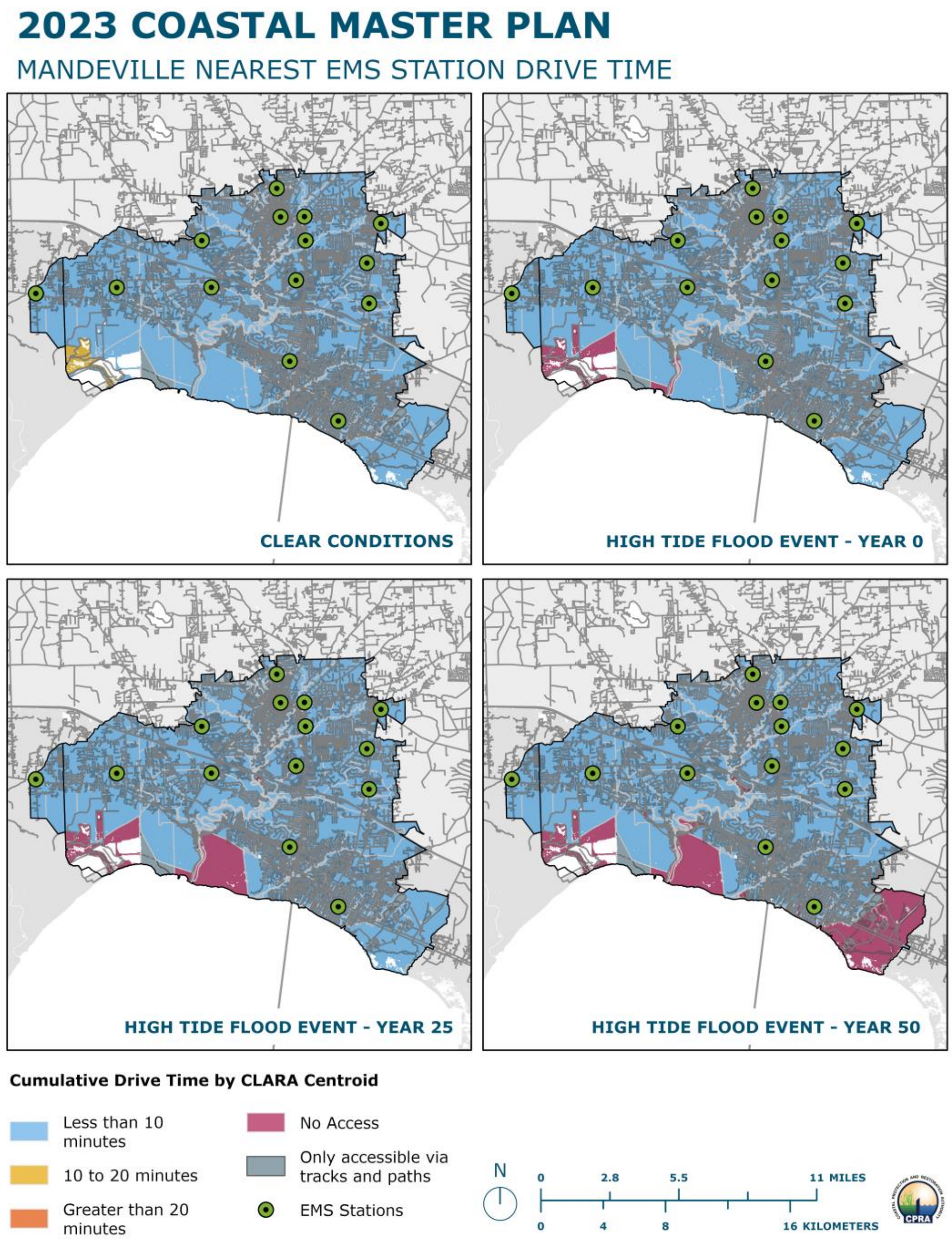
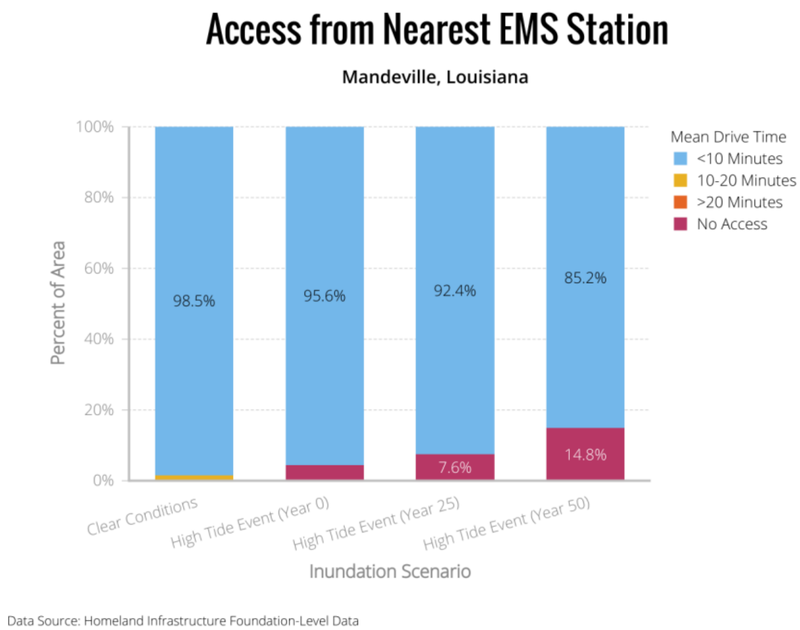


Figure 125. Drive time to nearest EMS station in Mandeville, Louisiana.



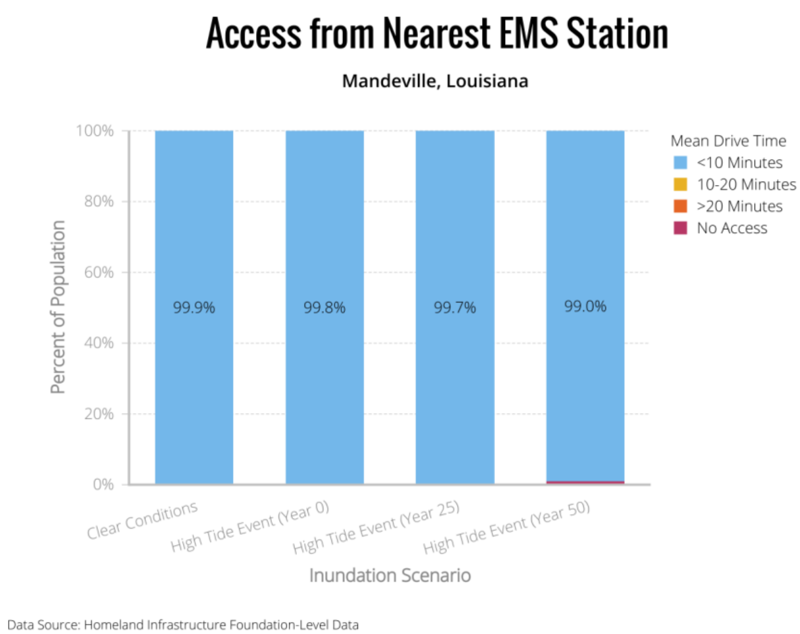


Figure 126. Drive time access to nearest EMS station by percent of area (top) and population (bottom) in Mandeville, Louisiana.

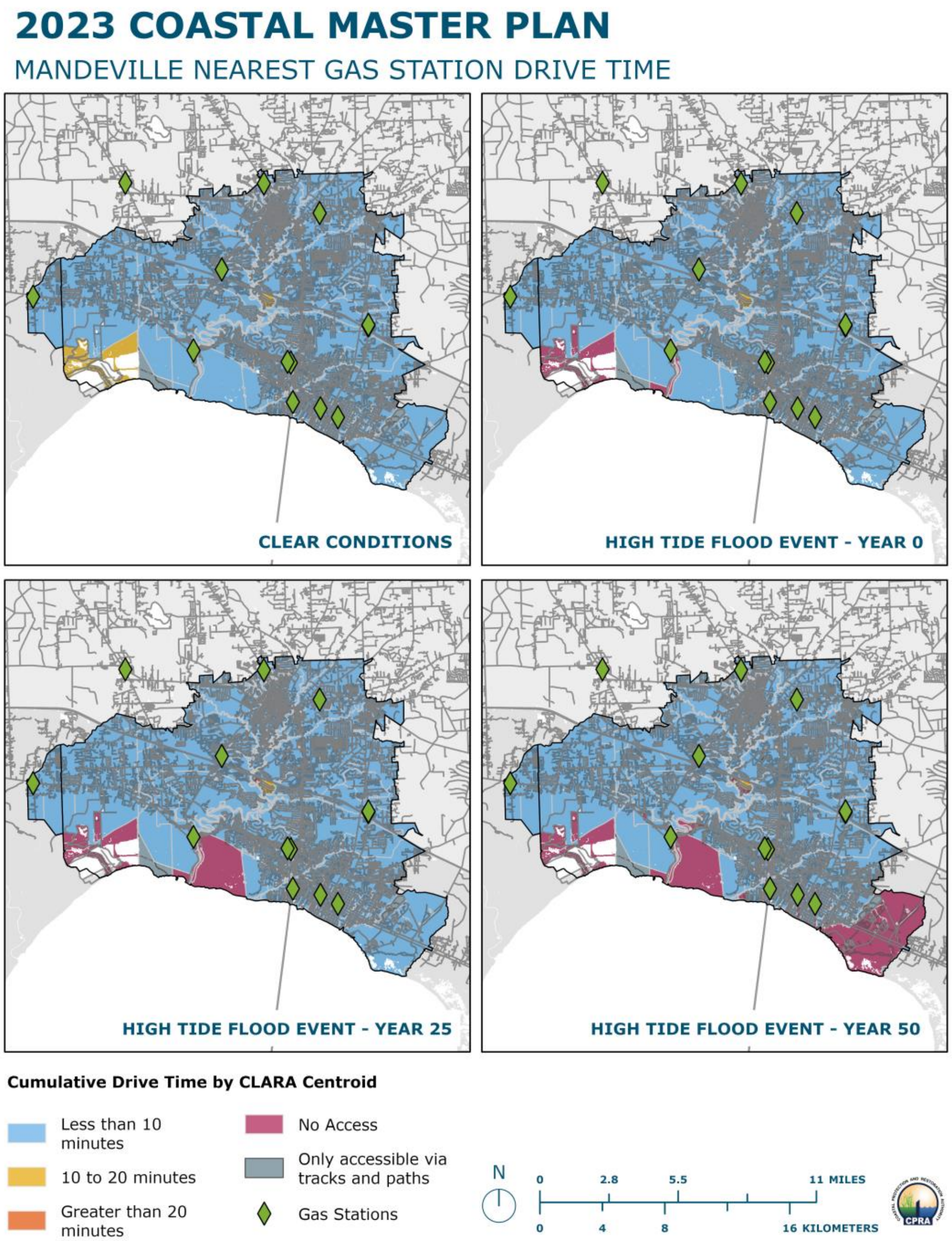
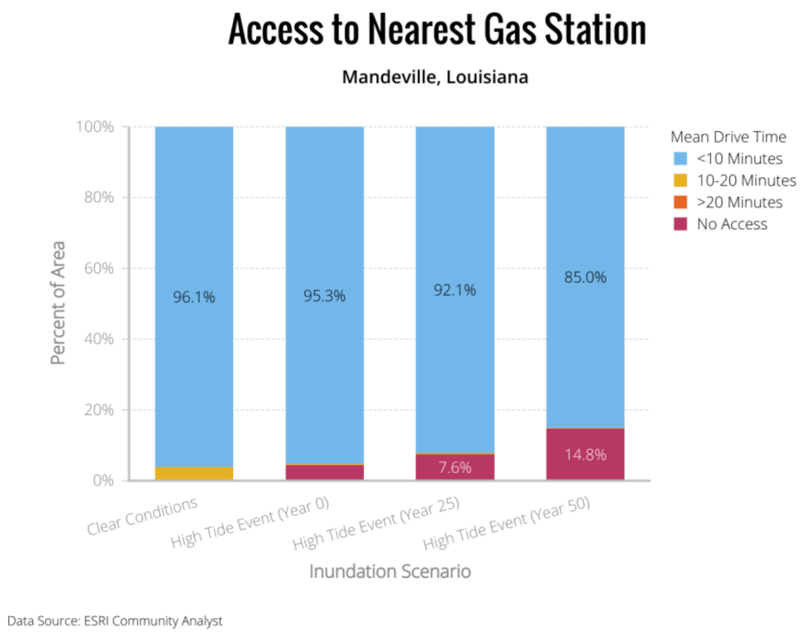


Figure 127. Drive time to nearest gas station in Mandeville, Louisiana.



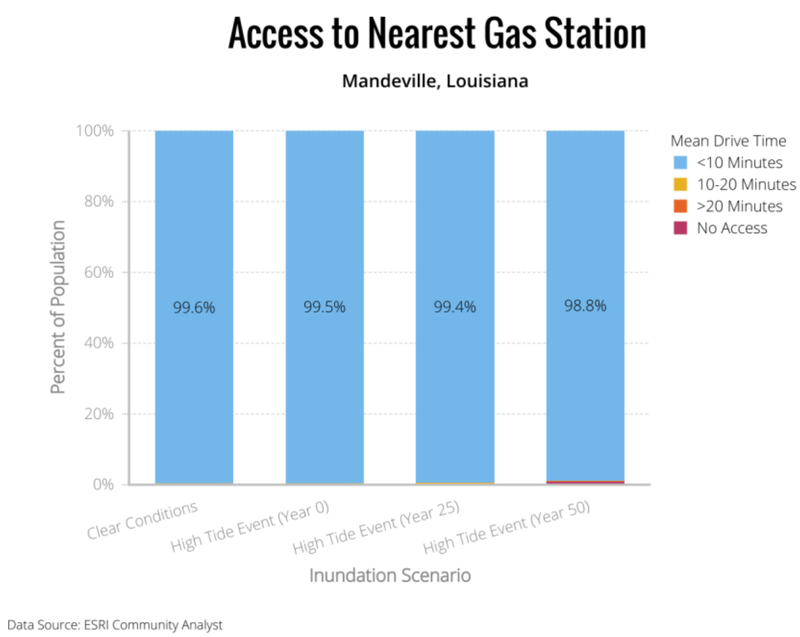


Figure 128. Drive time access to nearest gas station by percent of area (top) and population (bottom) in Mandeville, Louisiana.

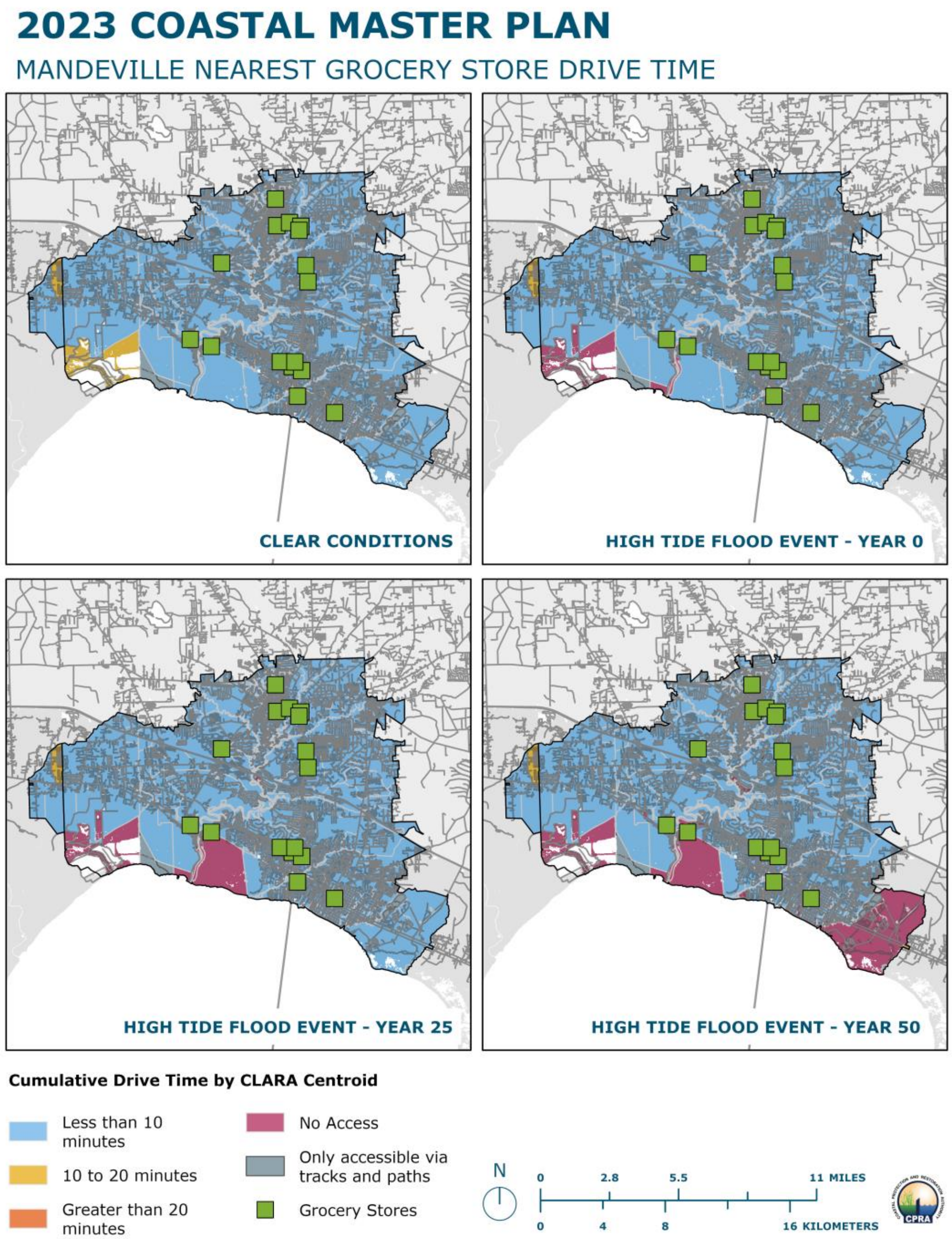
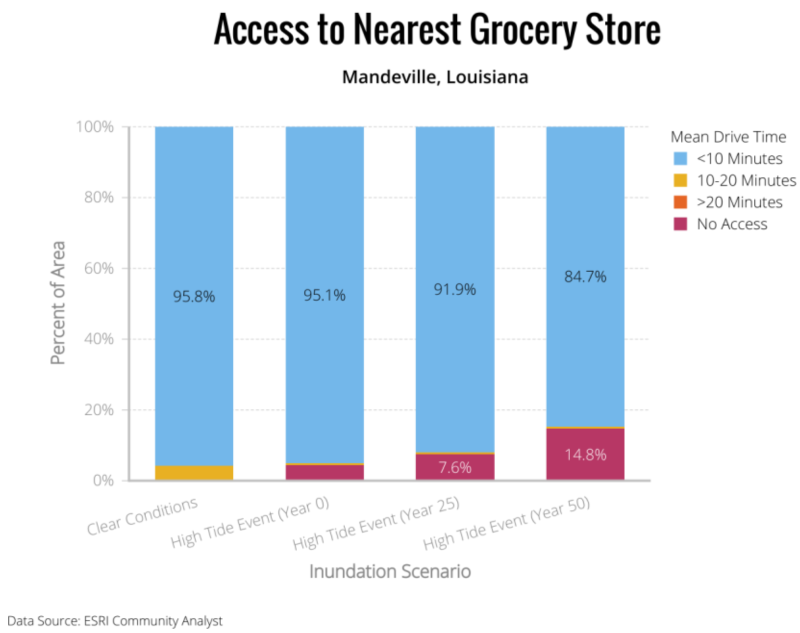


Figure 129. Drive time to nearest grocery store in Mandeville, Louisiana.



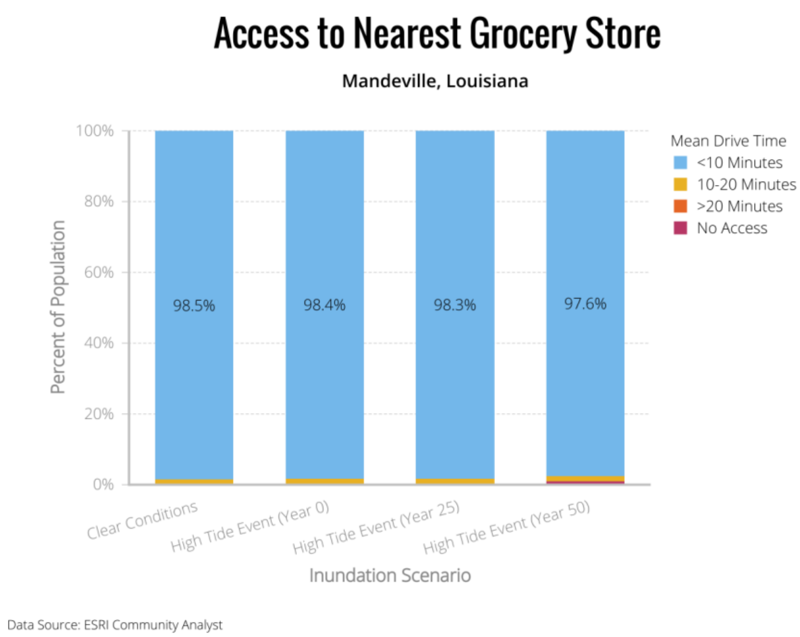


Figure 130. Drive time access to nearest grocery store by percent of area (top) and population (bottom) in Mandeville, Louisiana.

SLIDELL

Slidell and Eden Isle are located in St. Tammany Parish on the northeast shore of Lake Pontchartrain. Part of the New Orleans–Metairie–Kenner Metropolitan Statistical Area, the region is heavily developed and largely urbanized. The city of Slidell has a total area of 15.2 mi^2 and is home to over 27,000 residents. Eden Isle, located directly on the shore of Lake Pontchartrain, is a census designated place with a total area of 4.2 mi^2 and is home to over 7,000 residents. Most of Slidell is buffered from HTF events by the Big Branch Marsh National Wildlife Refuge, which encompasses some 15,000 acres of land along the shores of Lake Pontchartrain, while Eden Isle is vulnerable to these events. See Figure 131 through Figure 147 for more information on the drive time analysis for Slidell, Louisiana.

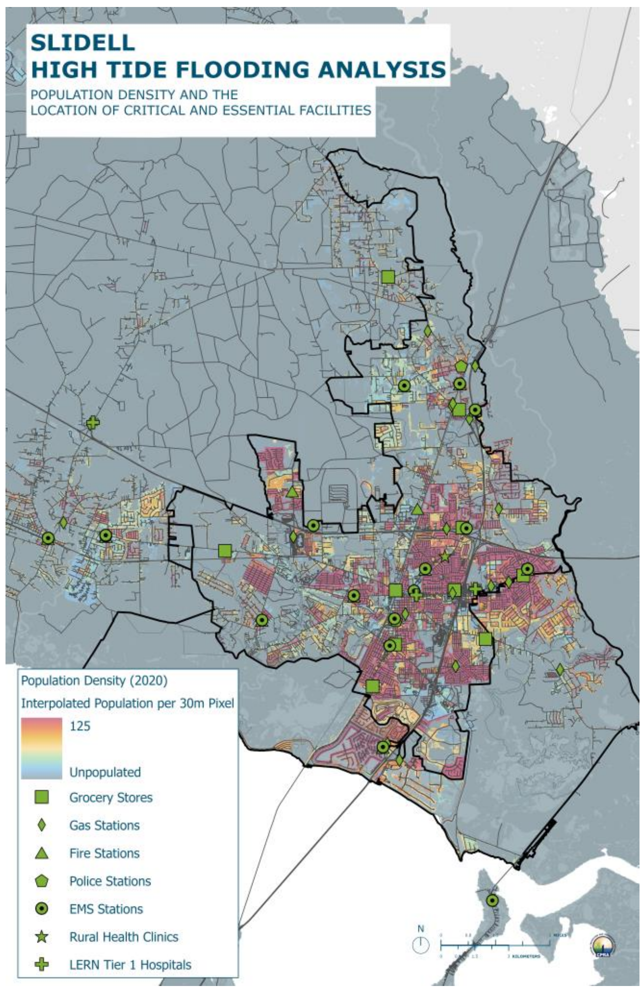


Figure 131. Dasymetric population density map of Slidell, Louisiana with locations of nearby critical and essential facilities, where applicable.

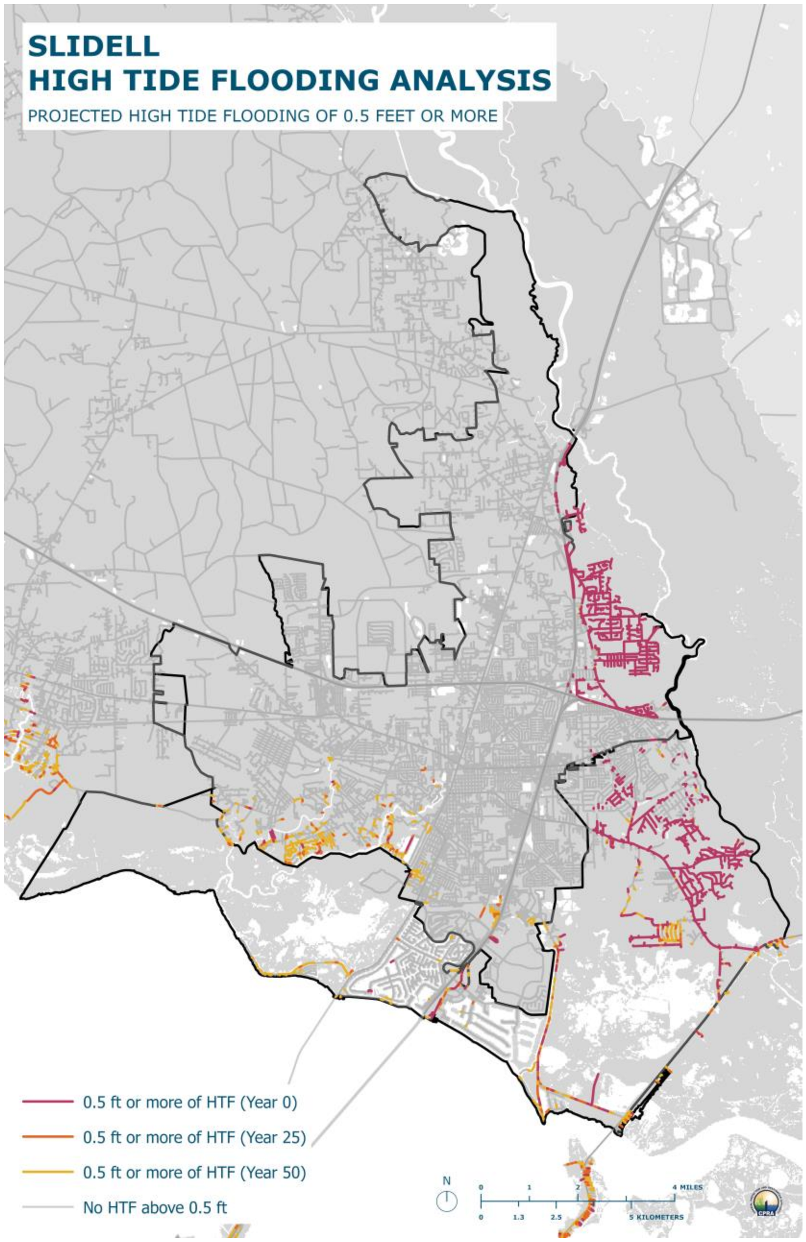


Figure 132. Road segments in Slidell, Louisiana projected to have 0.5 ft or more of HTF and considered impassable in Year 0, Year 25, and Year 50 under the 2023 Coastal Master Plan's lower scenario

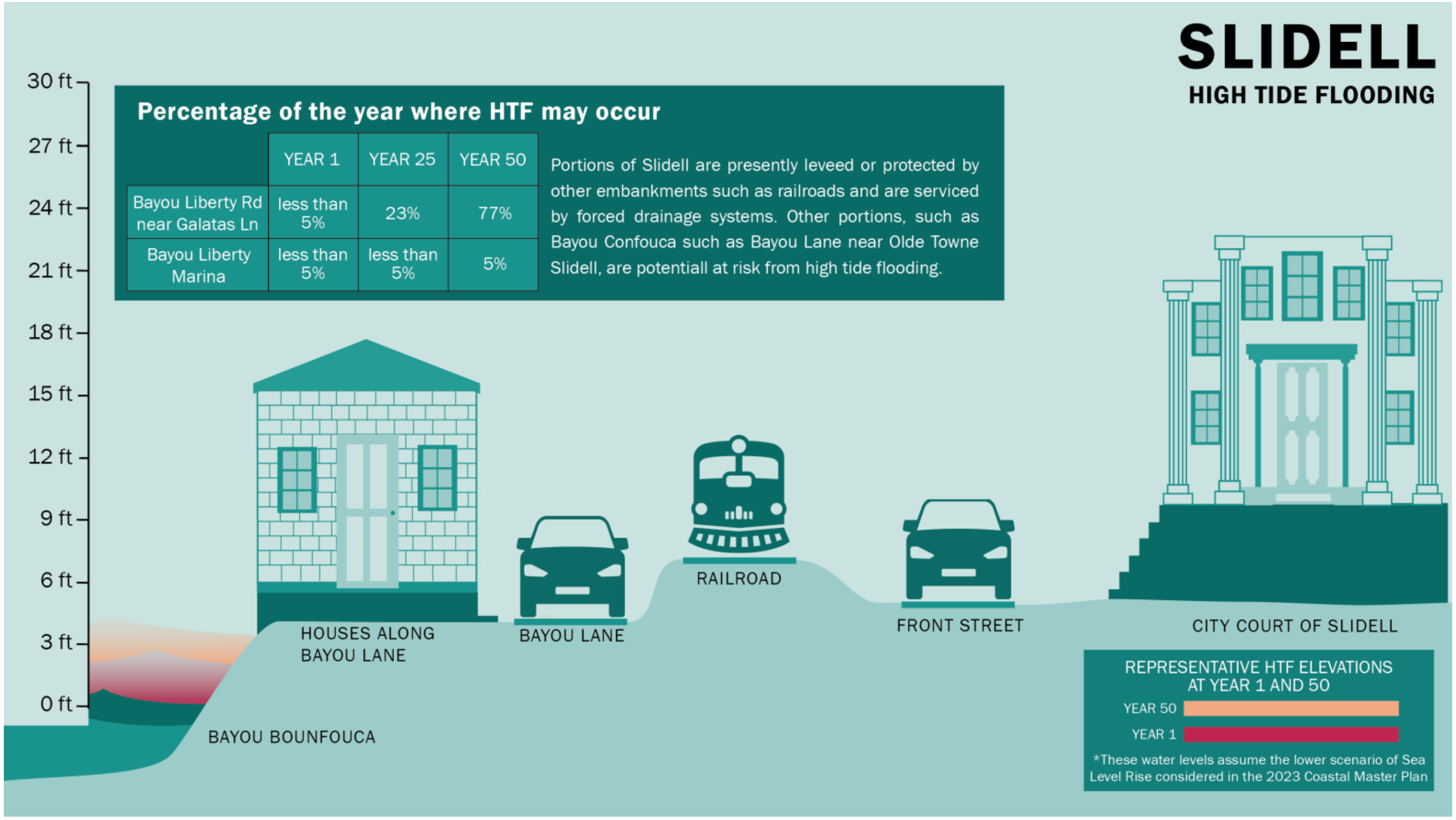


Figure 133. Modeled WSE depths for HTF events in Slidell, Louisiana at local impact threshold locations.

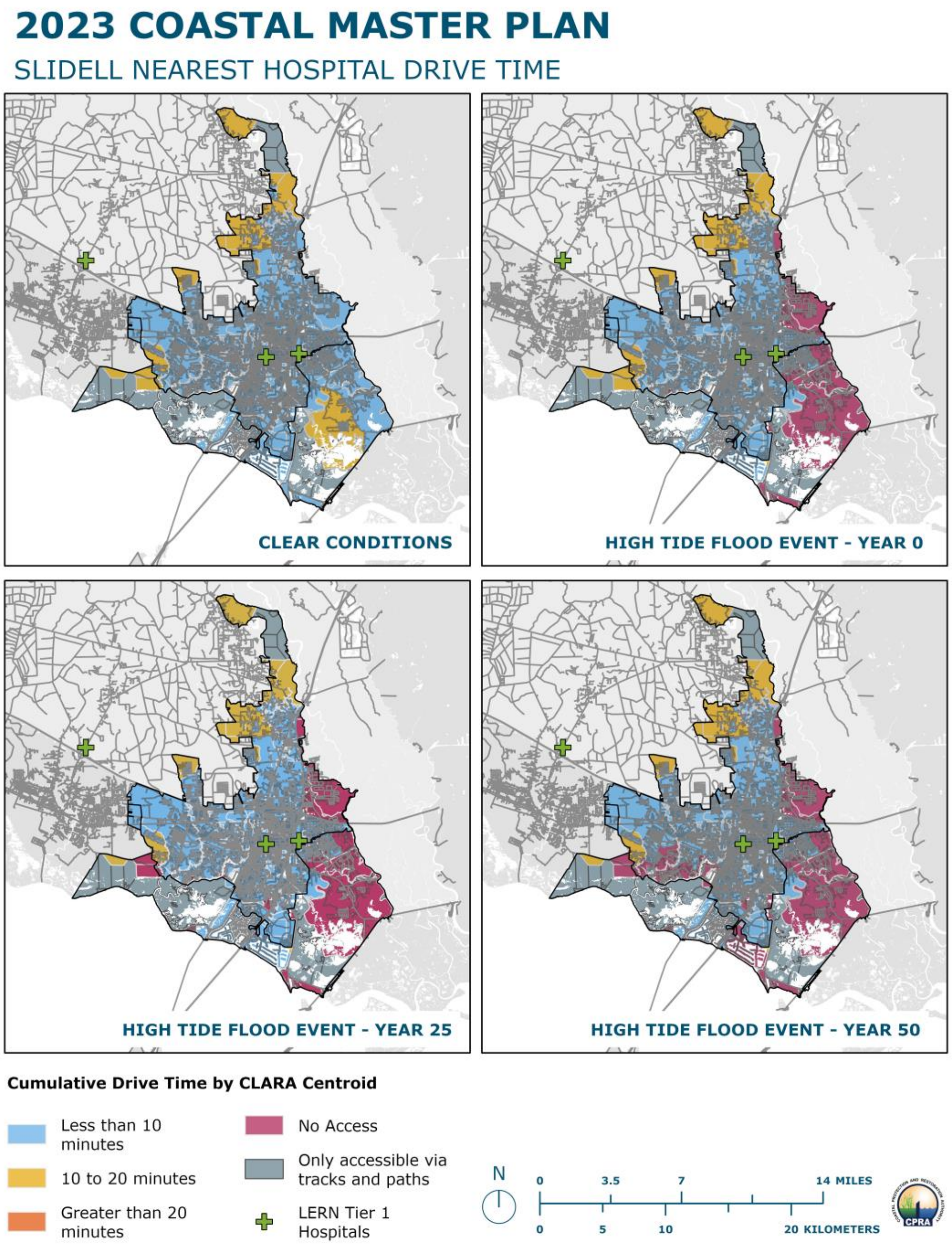
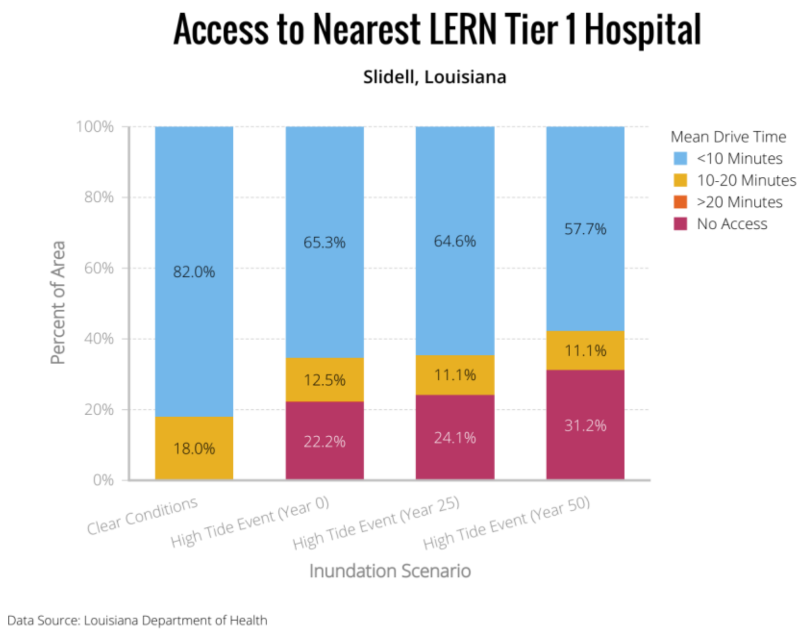


Figure 134. Drive time to nearest LERN Tier 1 hospital in Slidell, Louisiana.



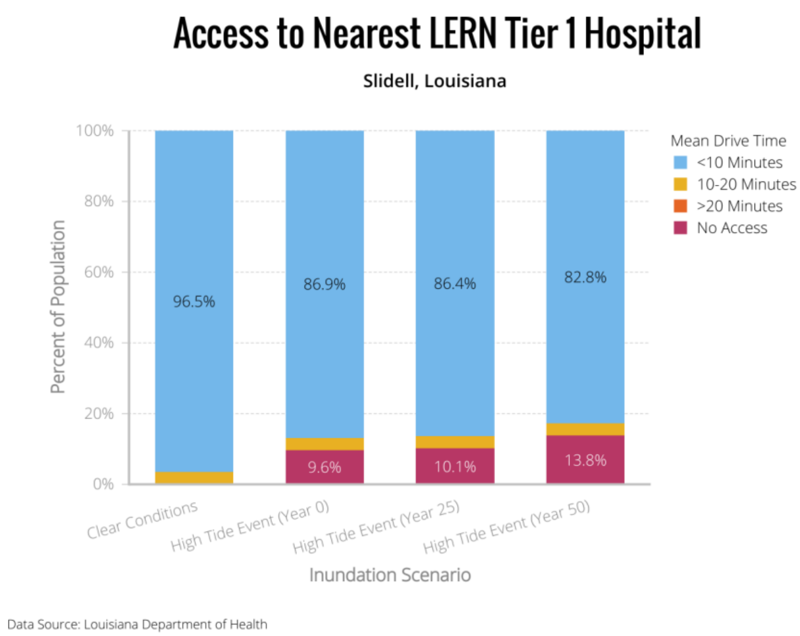


Figure 135. Drive time access to nearest LERN Tier 1 hospital by percent of area (top) and population (bottom) in Slidell, Louisiana.

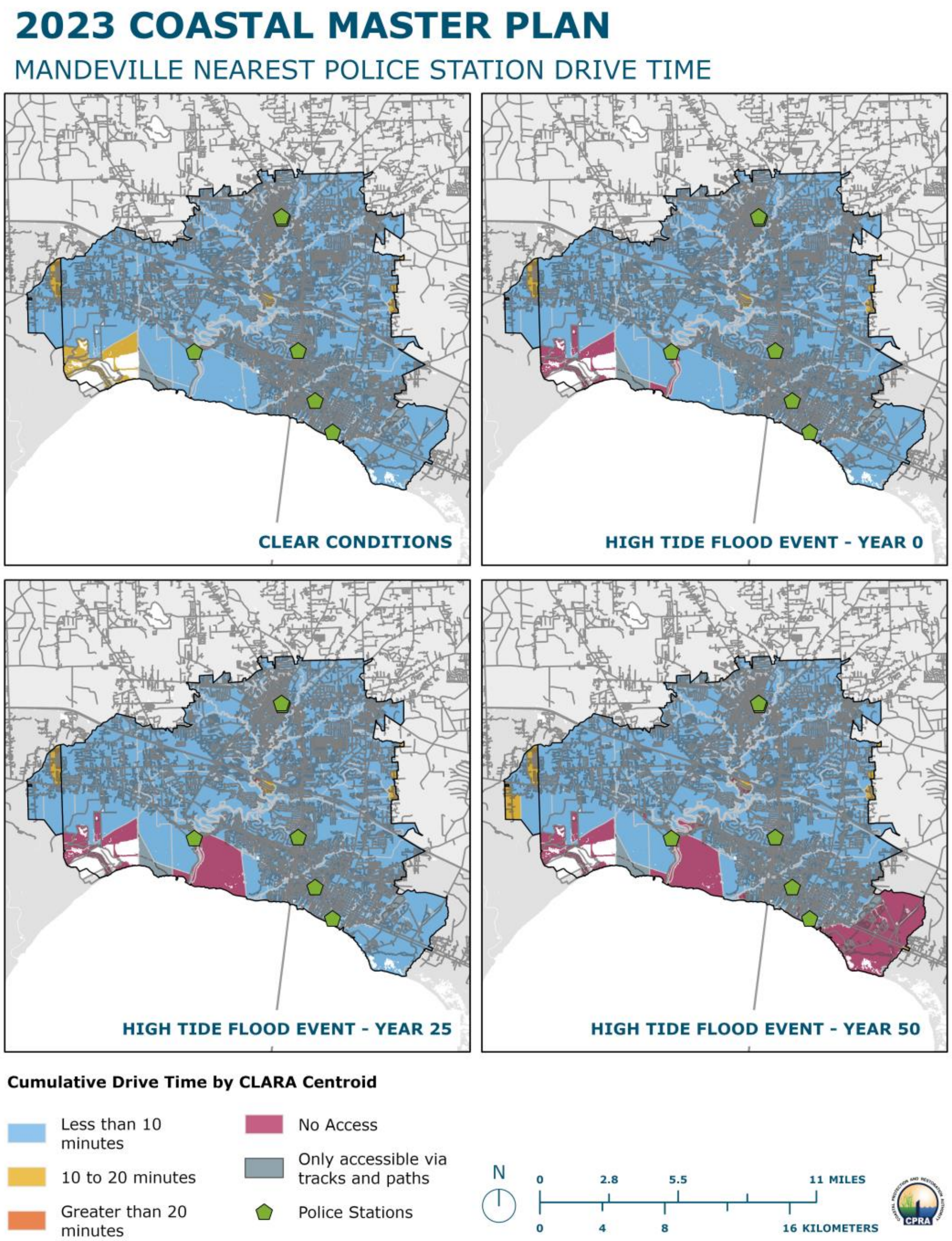
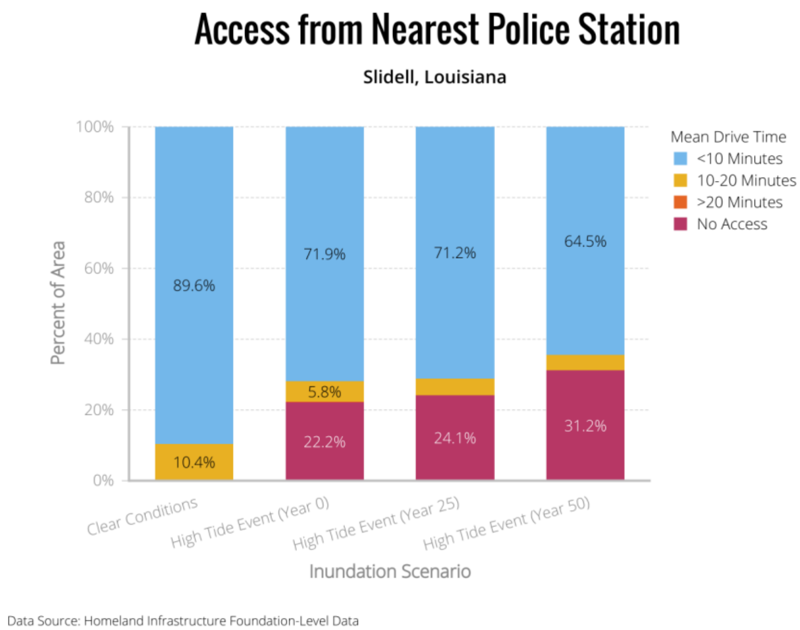


Figure 136. Drive time to nearest police station in Slidell, Louisiana.



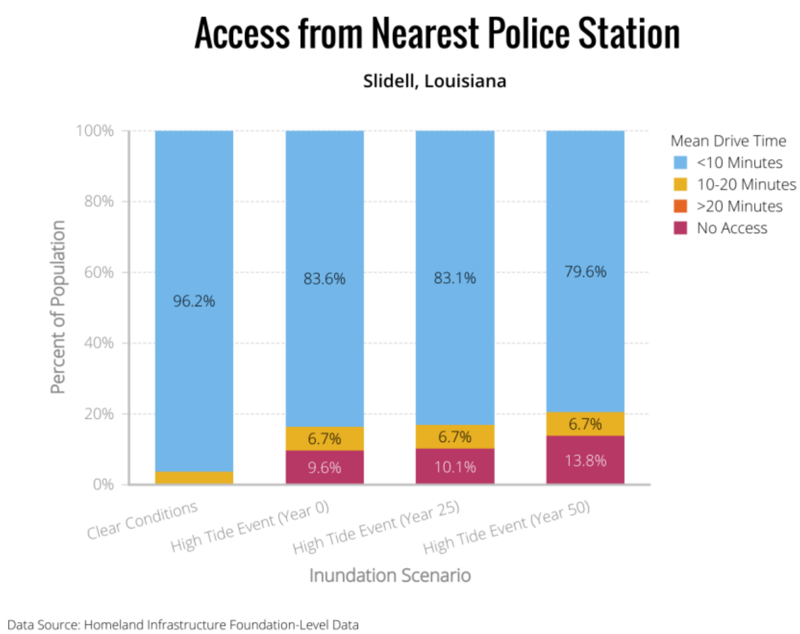


Figure 137. Drive time access to nearest police station by percent of area (top) and population (bottom) in Slidell, Louisiana.

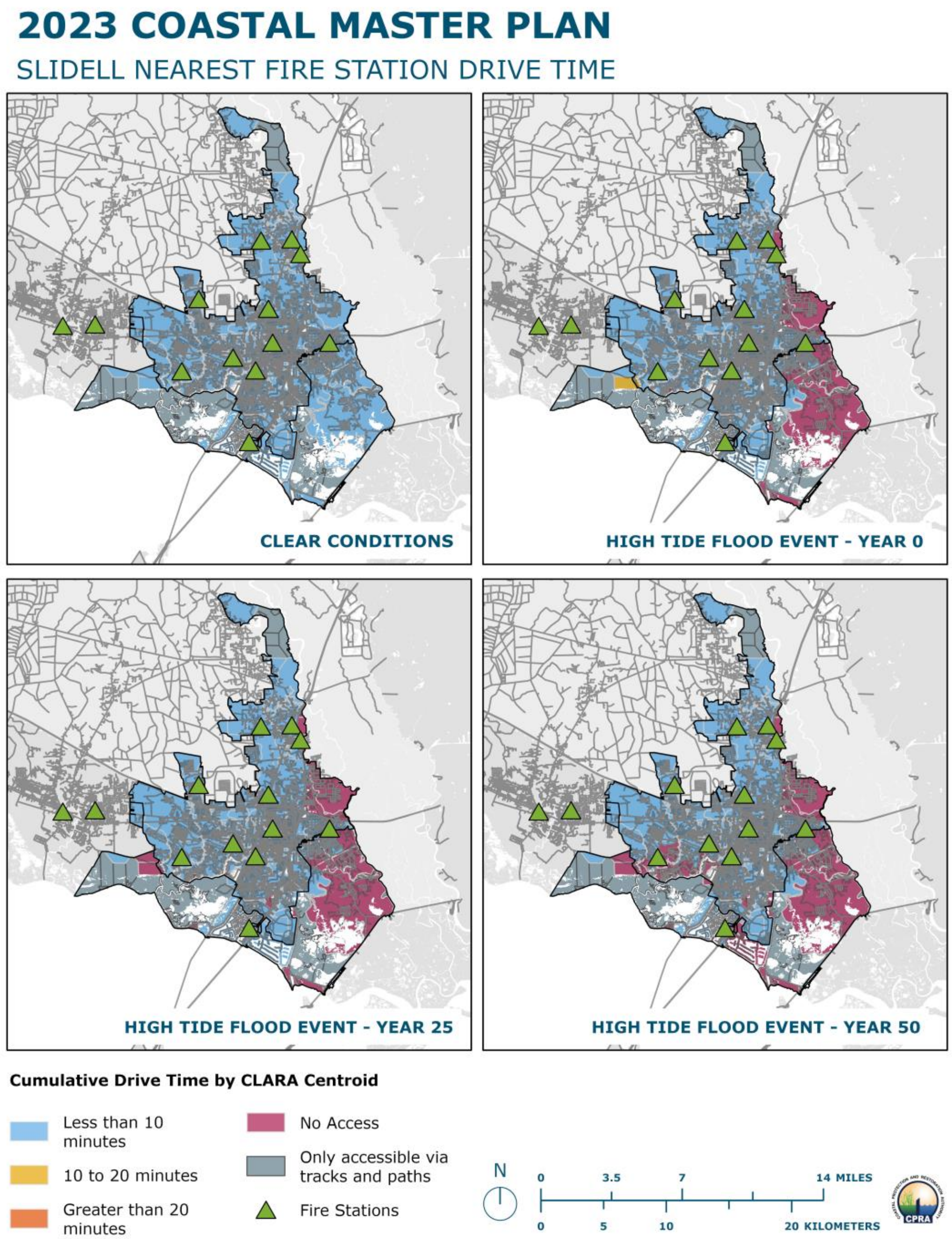
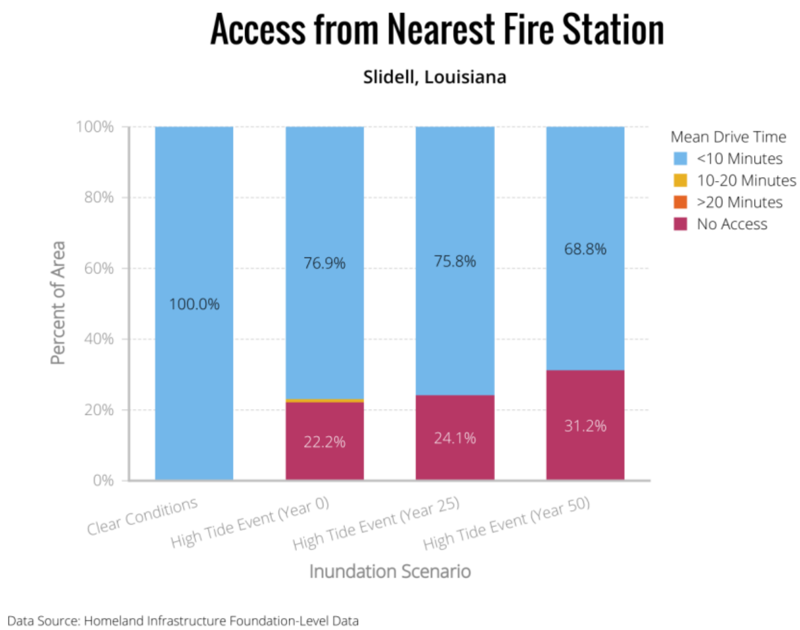


Figure 138. Drive time to nearest fire station in Slidell, Louisiana.



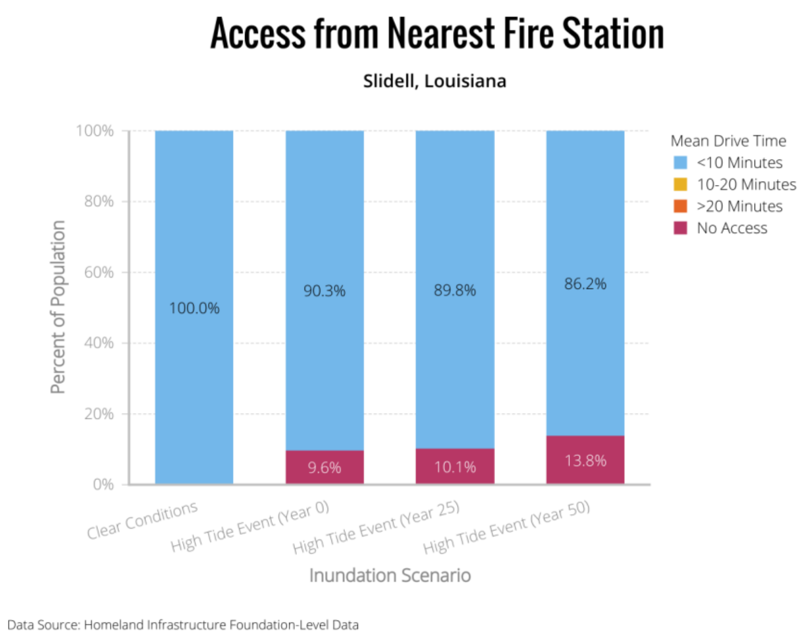


Figure 139. Drive time access to nearest fire station by percent of area (top) and population (bottom) in Slidell, Louisiana.

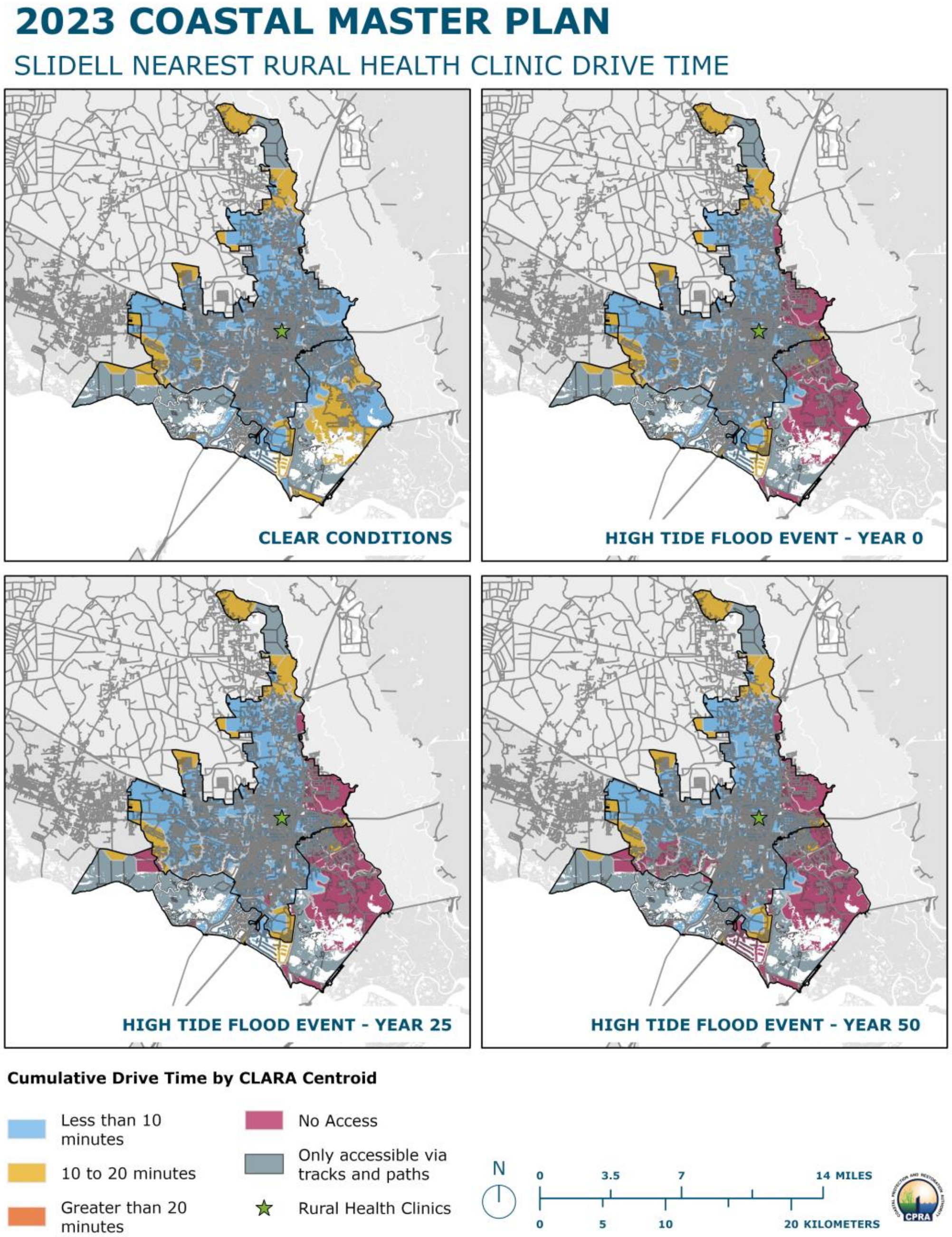
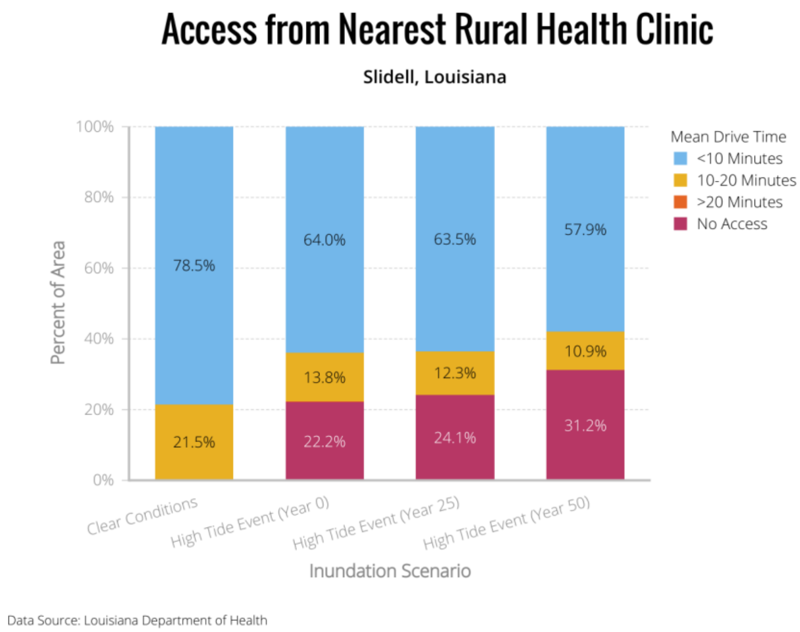


Figure 140. Drive time to nearest rural health clinic in Slidell, Louisiana.



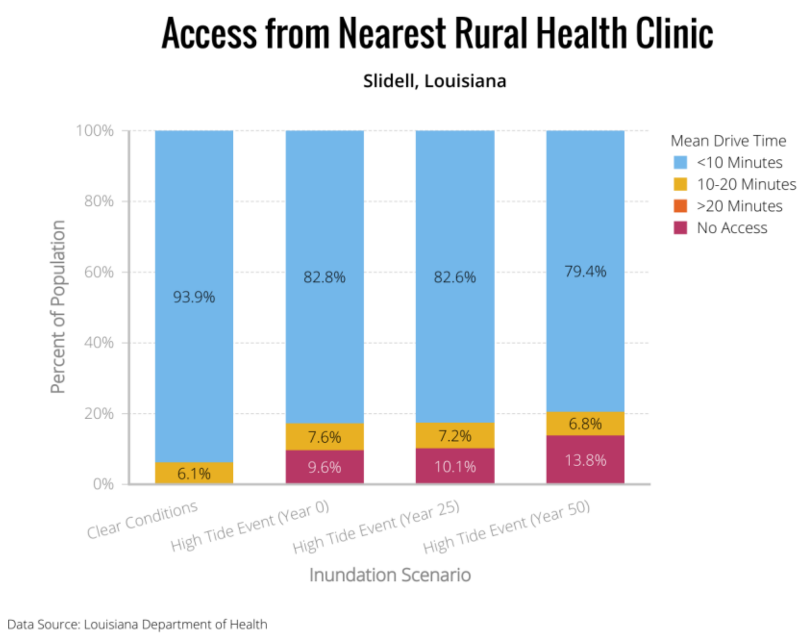


Figure 141. Drive time access to nearest rural health clinic by percent of area (top) and population (bottom) in Slidell, Louisiana.

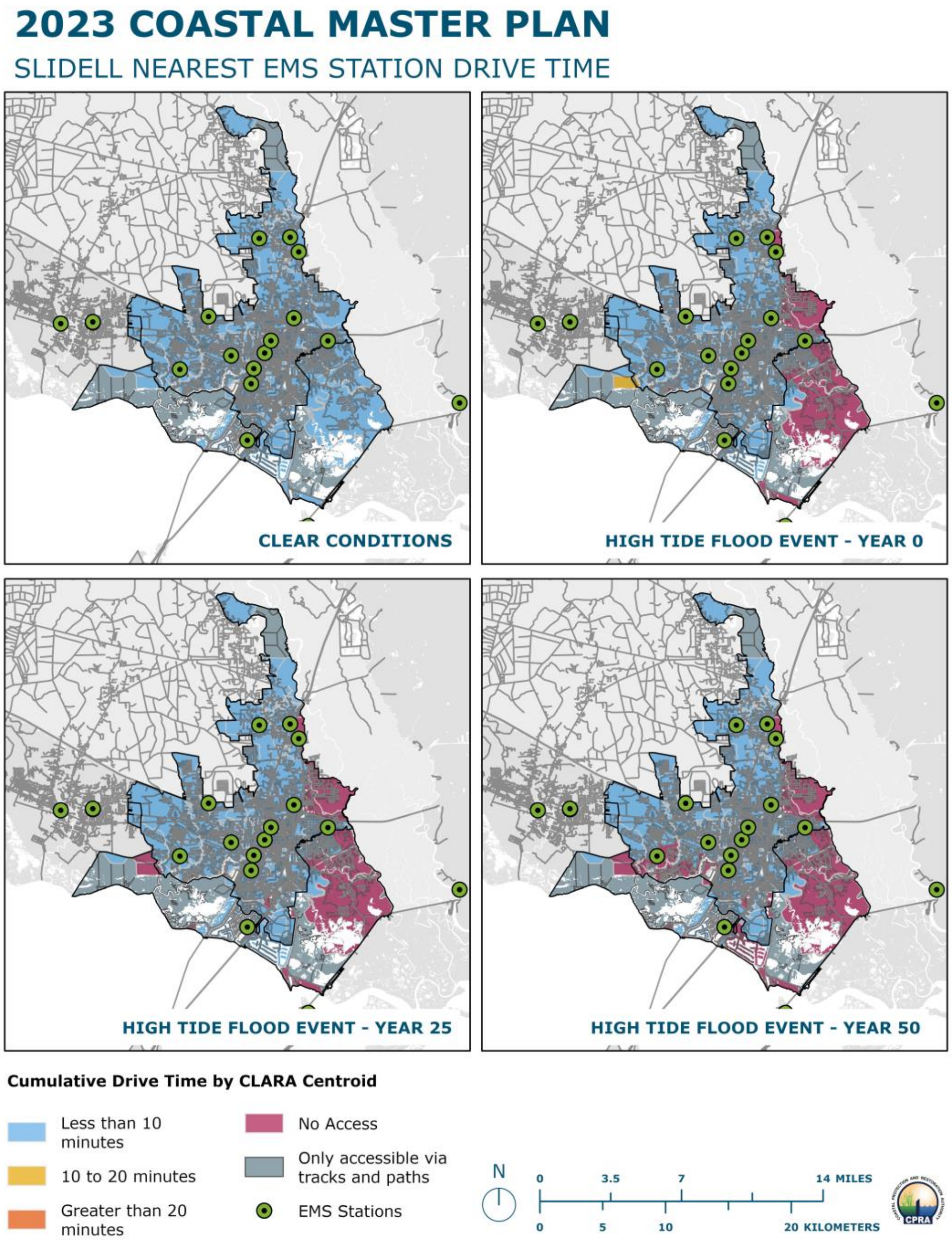
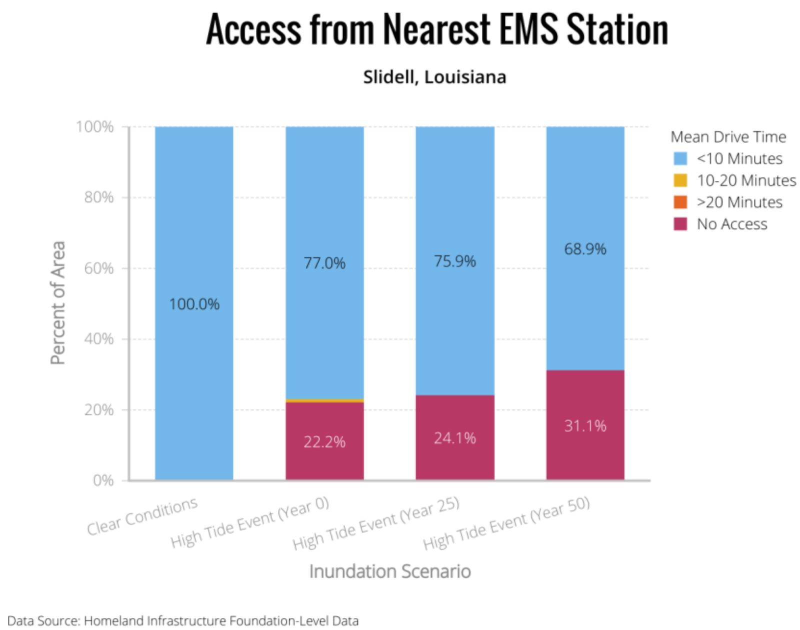


Figure 142. Drive time to nearest EMS station in Slidell, Louisiana.



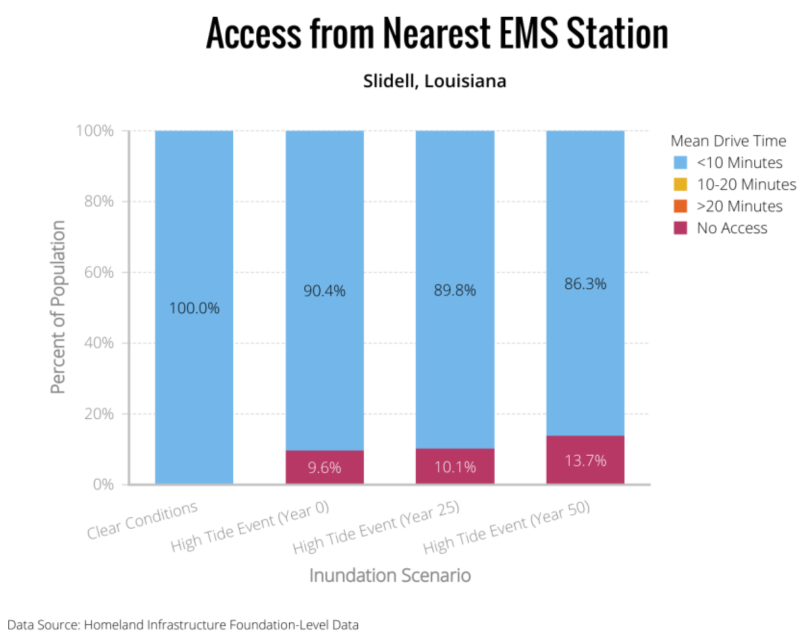


Figure 143. Drive time access to nearest EMS station by percent of area (top) and population (bottom) in Slidell, Louisiana.

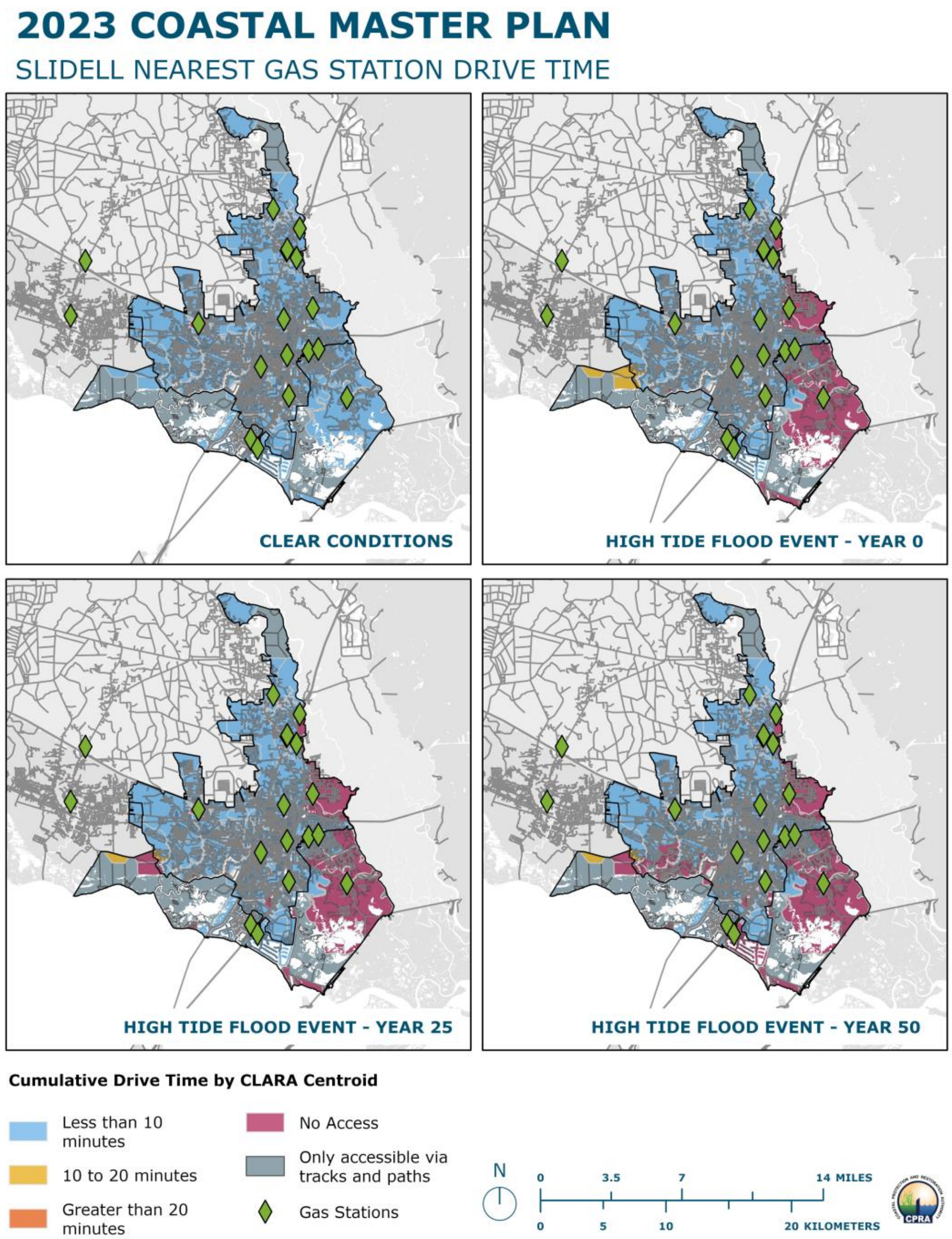
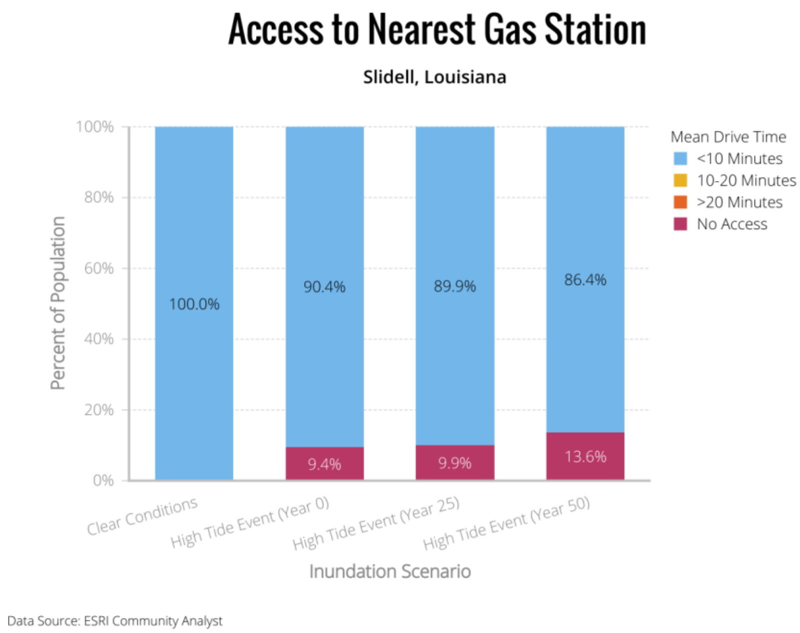


Figure 144. Drive time to nearest fire station in Slidell, Louisiana.



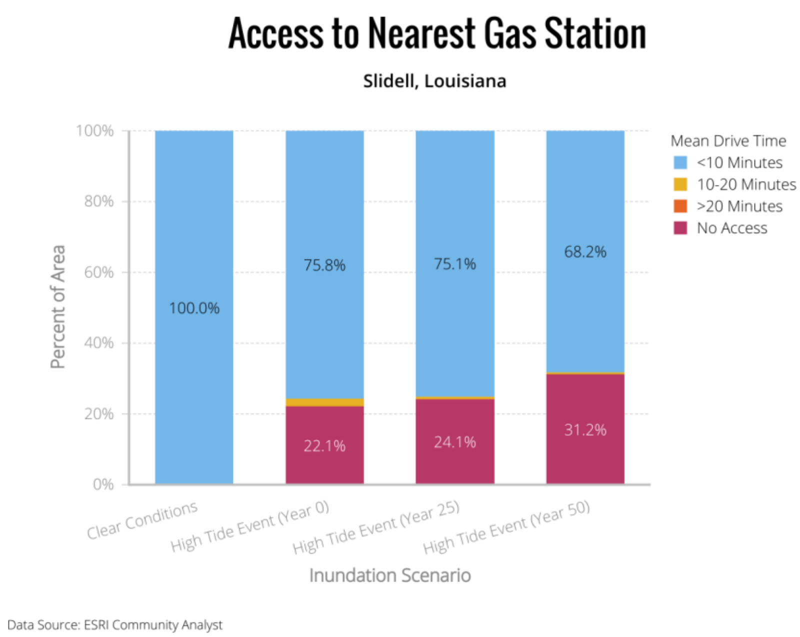


Figure 145. Drive time access to nearest gas station by percent of area (top) and population (bottom) in Slidell, Louisiana.

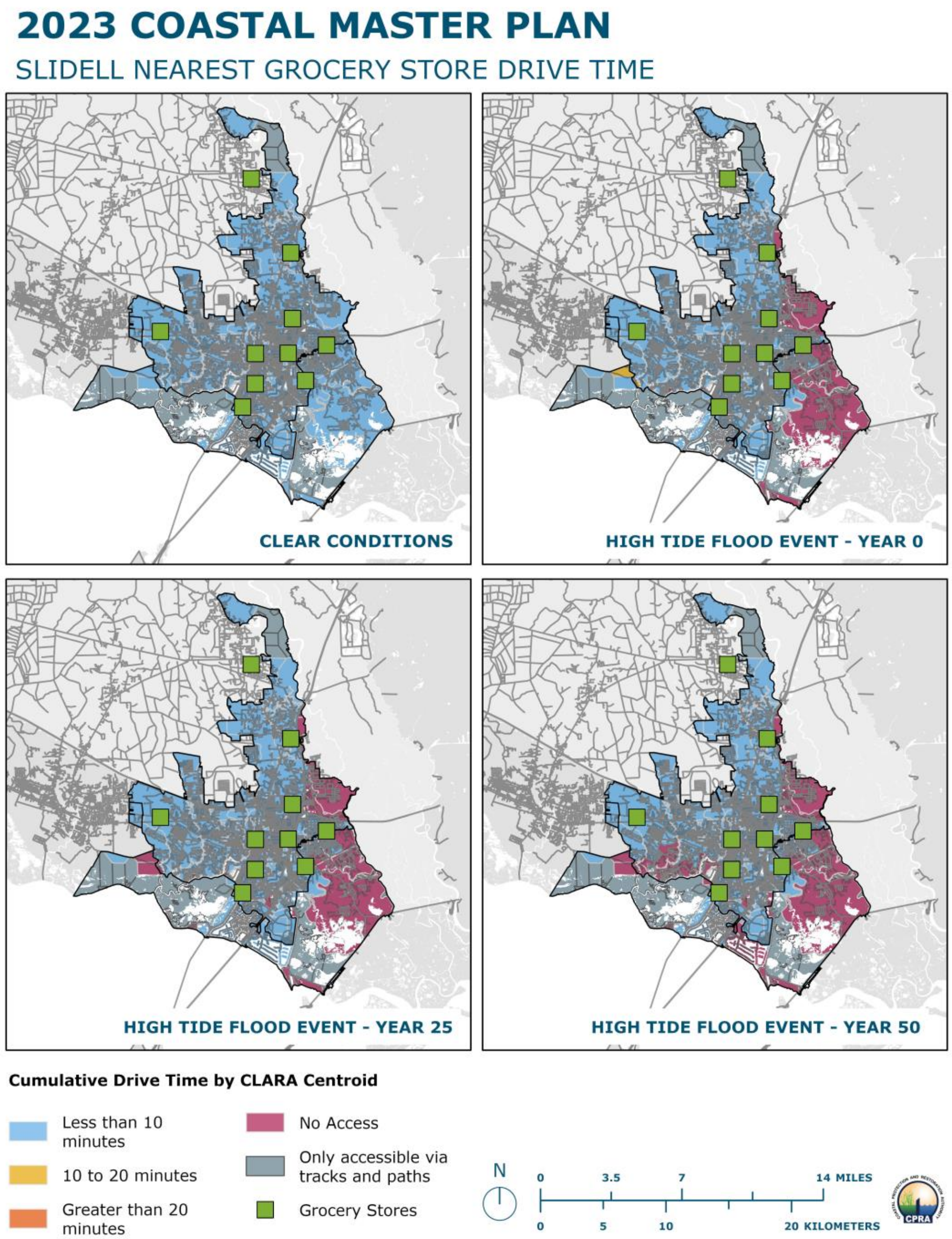
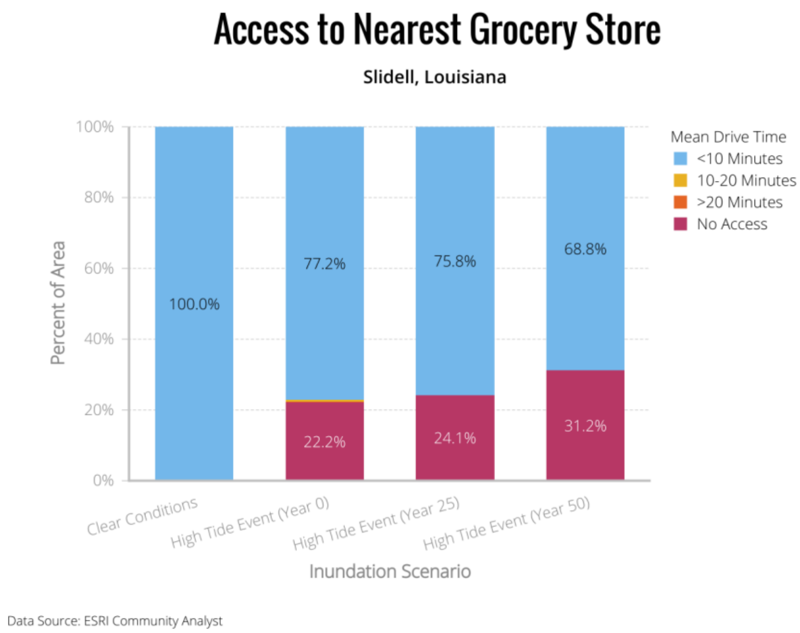


Figure 146. Drive time to nearest grocery store in Slidell, Louisiana.



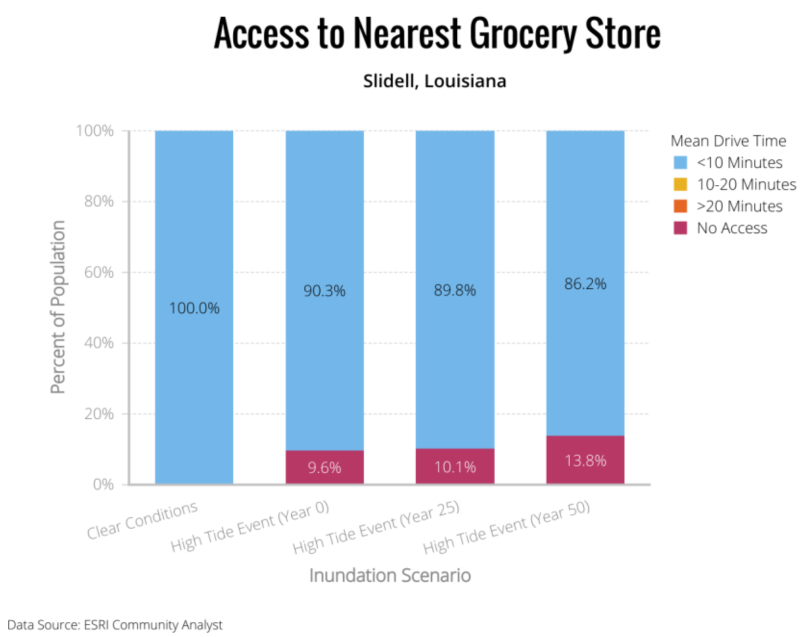


Figure 147. Drive time access to nearest grocery store by percent of area (top) and population (bottom) in Slidell, Louisiana.

ATTACHMENT 2. ICM WATER SURFACE ELEVATION ANALYSIS

In this attachment, a series of figures and plots are provided for each of the eight focus communities:

- A figure noting the community location, ICM compartment numbers, and proximal observation stations considered in the analysis, as discussed in Table 3.
- A comparison WSE timeseries plot of all the compartments considered when selecting a representative ICM compartment's data for each community.
- A comparison WSE timeseries plot of the representative ICM compartment versus the local observed data for each community.
- Comparison scatter plots of observed versus modeled data from the selected compartment for each community which were used to determine if WSE adjustment factors were required.

AMELIA

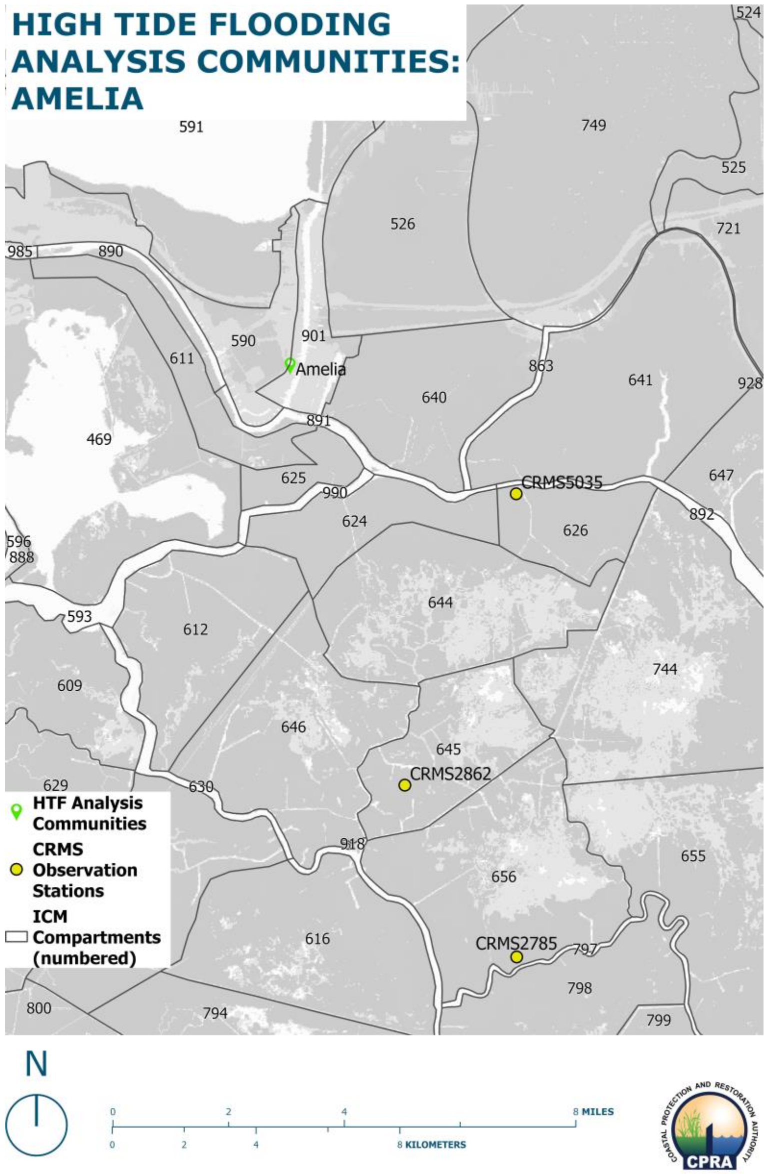


Figure 148. ICM compartments and WSE observation stations relative to Amelia, Louisiana. ICM compartment 626 and CRMS5035 were used for the analysis.

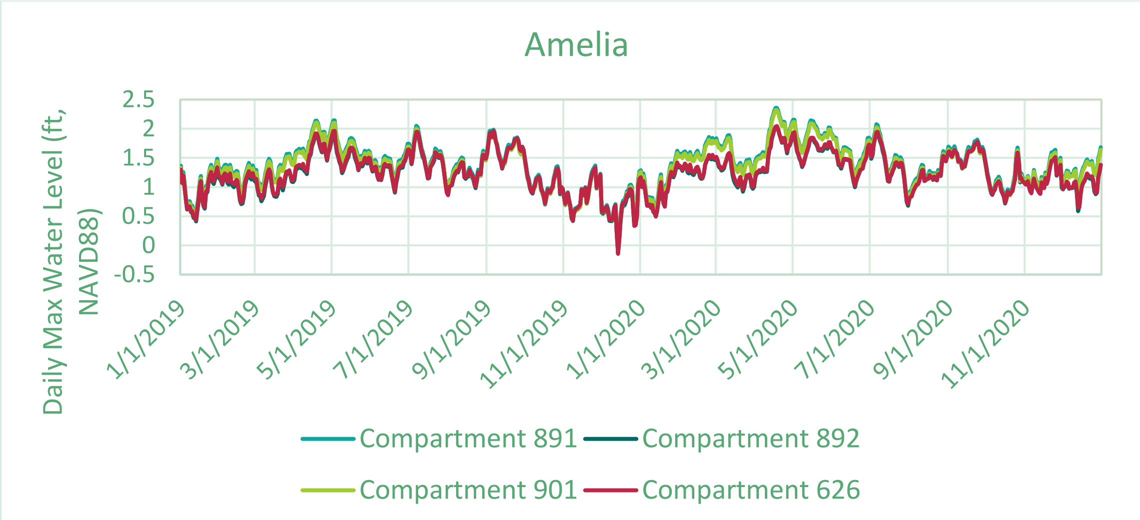


Figure 149. ICM compartments proximal to Amelia, Louisiana and associated mean water level output for 2019 – 2020.

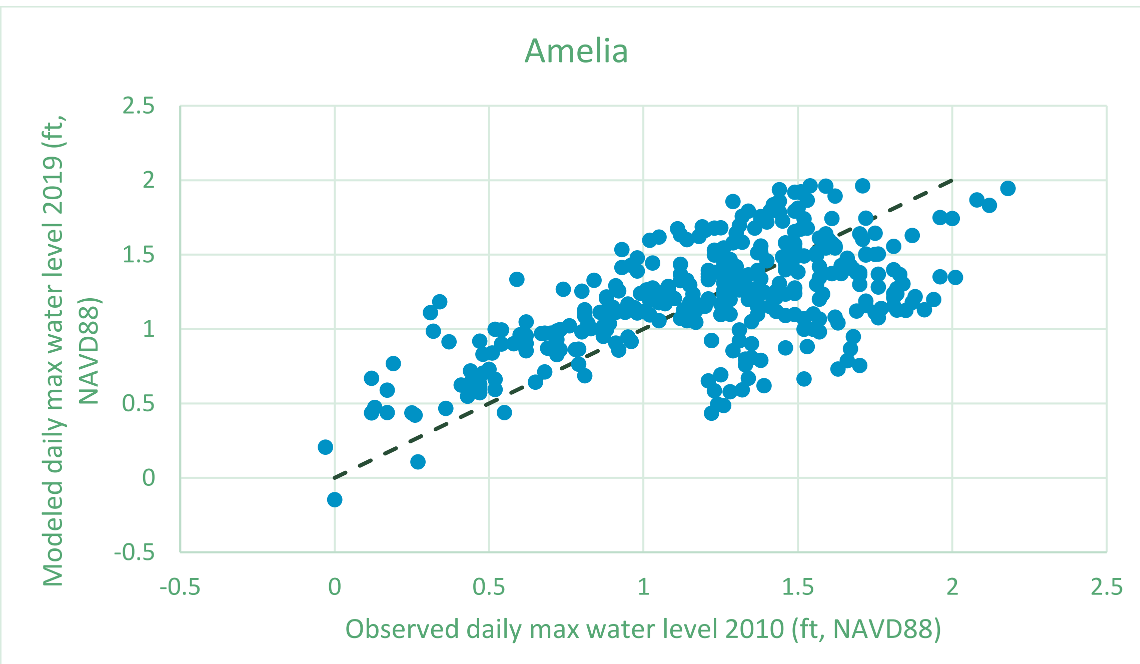


Figure 150. ICM compartment 626 versus observed data scatter plot comparison for Amelia, Louisiana for 2019.

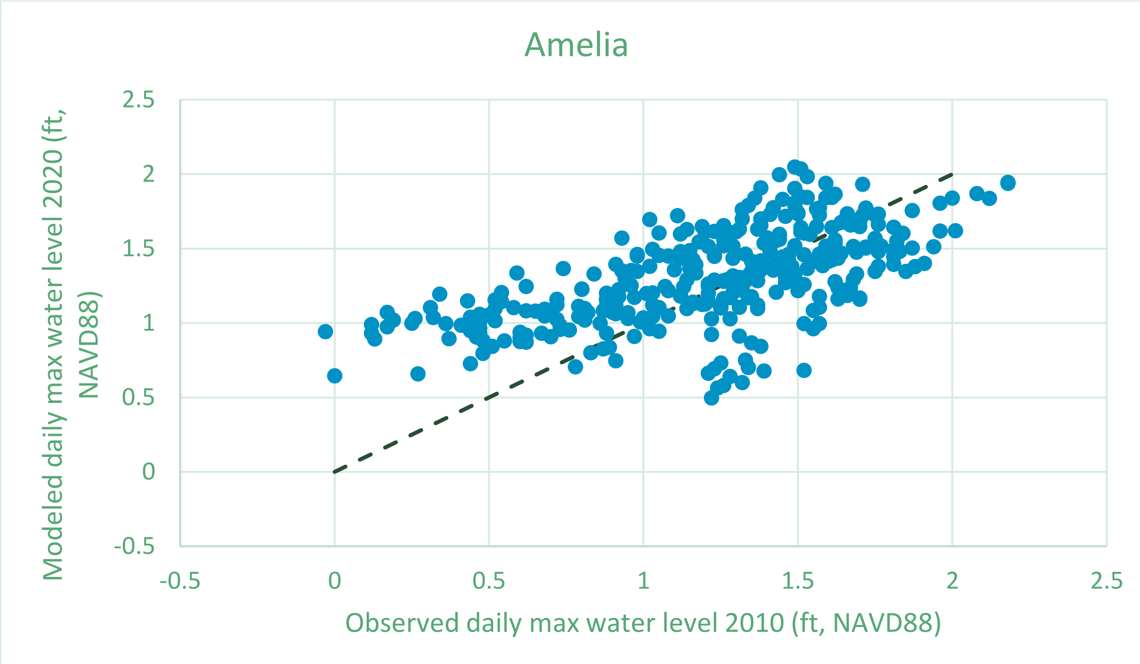


Figure 151. ICM compartment 626 versus observed data scatter plot comparison for Amelia, Louisiana for 2020.

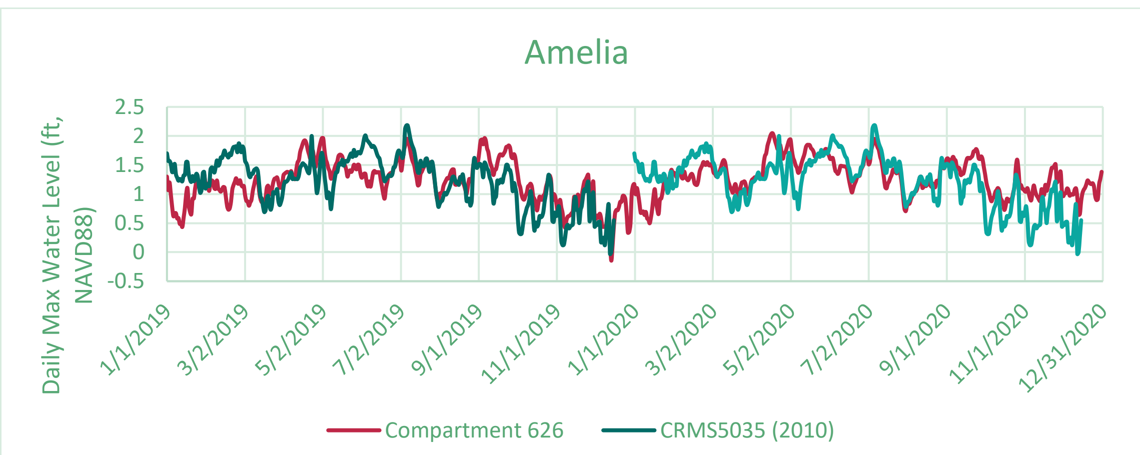


Figure 152. ICM compartment 626 versus observed data comparison for Amelia, Louisiana for 2019 – 2020.

CAMERON

Figure 153. ICM compartments and WSE observation stations relative to Cameron, Louisiana. ICM compartment 1342 and NOAA 8768094 (blue marker in image) were used for the analysis.

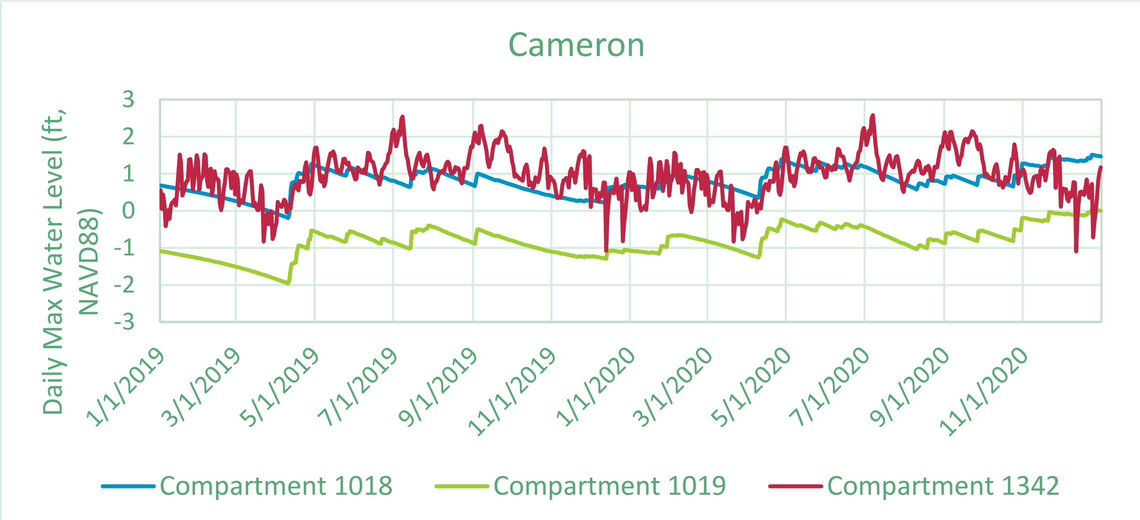


Figure 154. ICM compartments proximal to Cameron, Louisiana and associated mean water level output for 2019 – 2020. Note, ICM compartments 1018 and 1019 are partially wetland or fast land areas, and thus returned WSE signals lacking full hydrodynamic and tidal response.

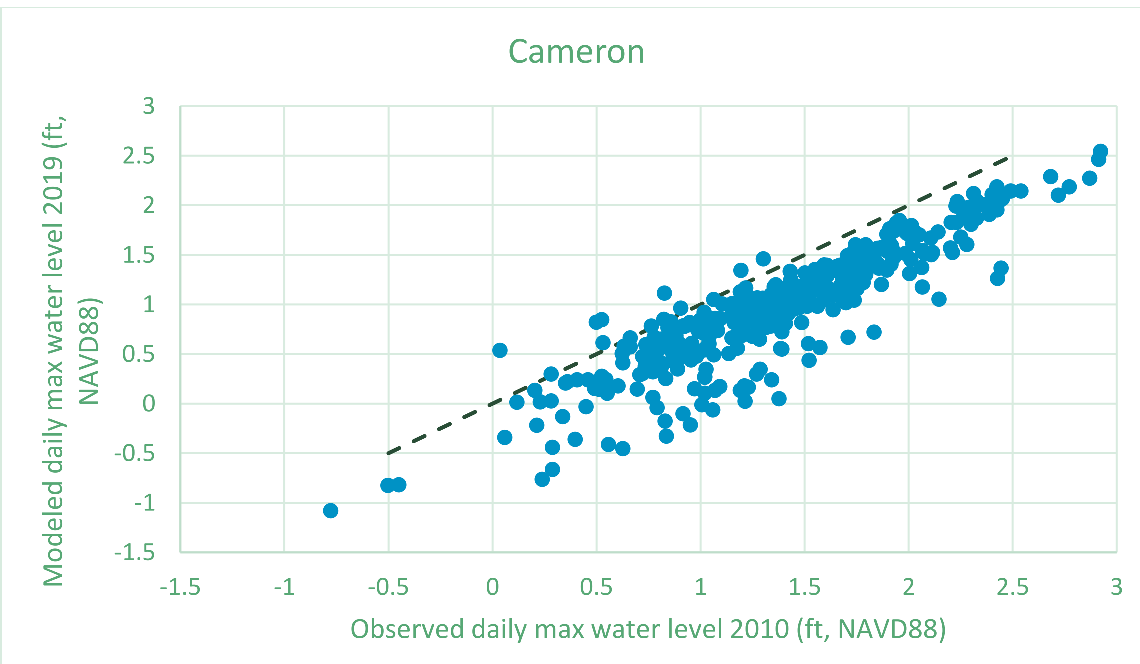


Figure 155. ICM compartment 1342 versus observed data scatter plot comparison for Cameron, Louisiana for 2019.

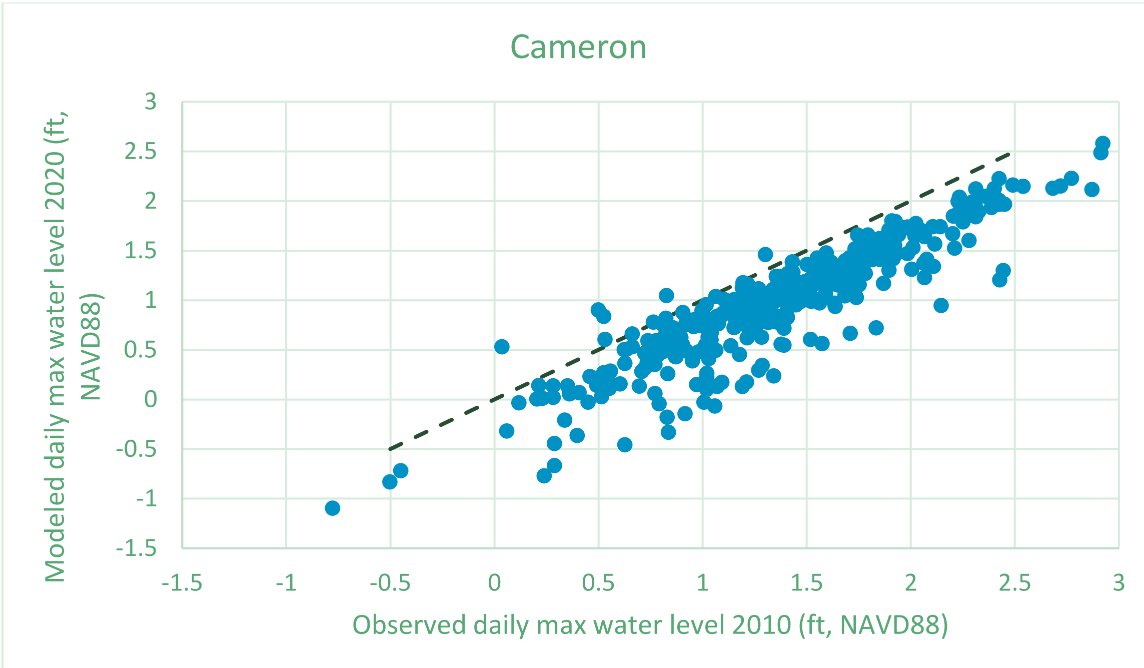


Figure 156. ICM compartment 1342 versus observed data scatter plot comparison for Cameron, Louisiana for 2020.

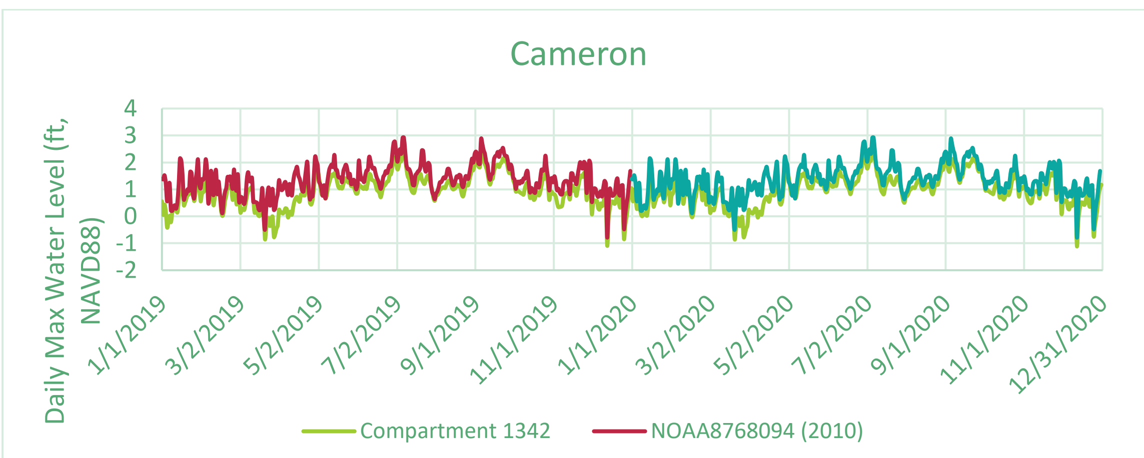


Figure 157. ICM compartment 1342 versus observed data comparison for Cameron, Louisiana for 2019 – 2020.

DELACROIX

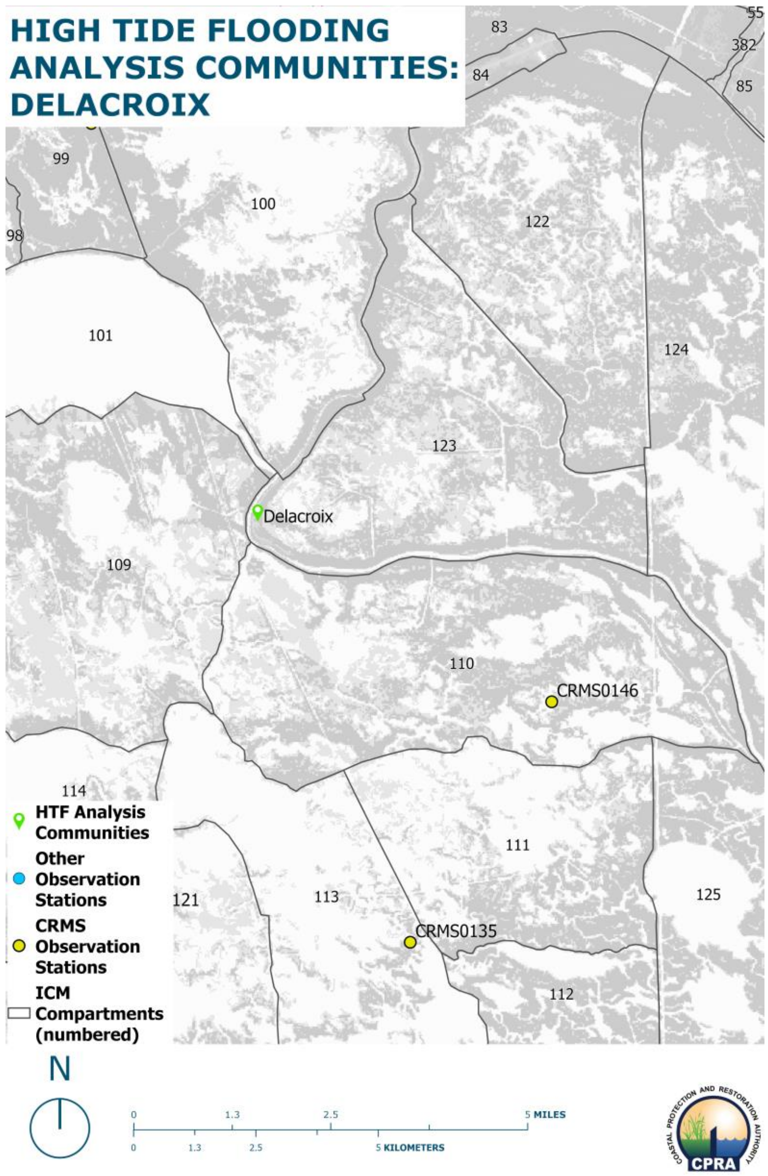


Figure 158. ICM compartments and WSE observation stations relative to Delacroix, Louisiana. ICM compartment 110 and CRMS0146 were used for the analysis.

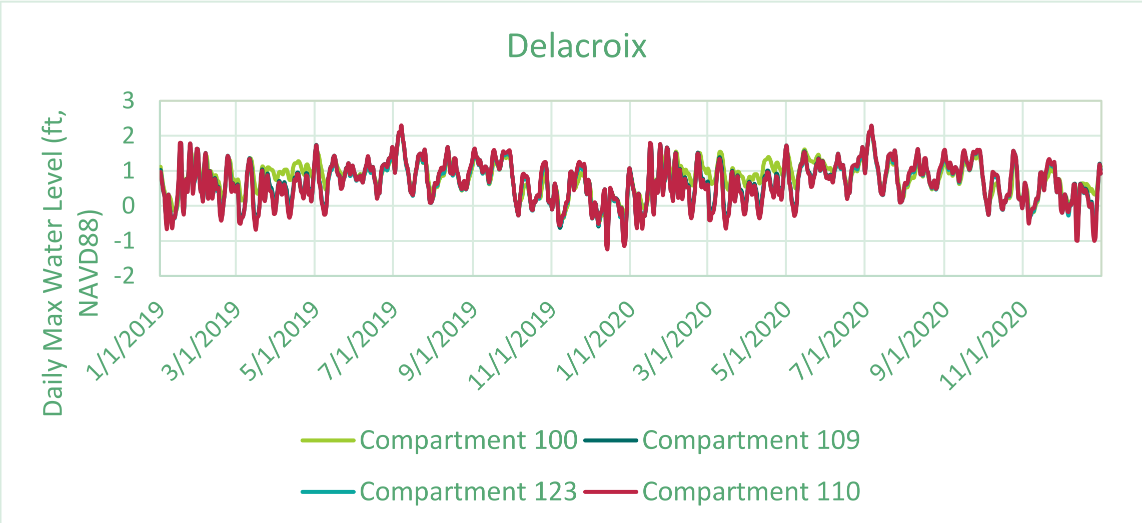


Figure 159. ICM compartments proximal to Delacroix, Louisiana and associated mean water level output for 2019 – 2020.

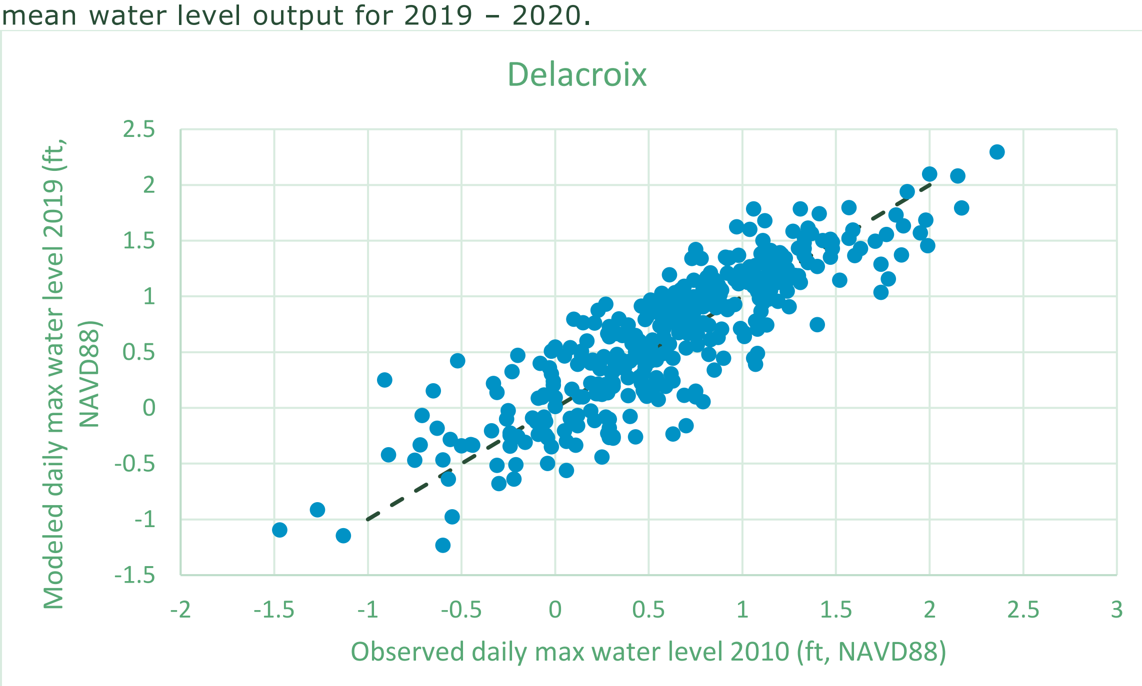


Figure 160. ICM compartment 110 versus observed data scatter plot comparison for Delacroix, Louisiana for 2019.

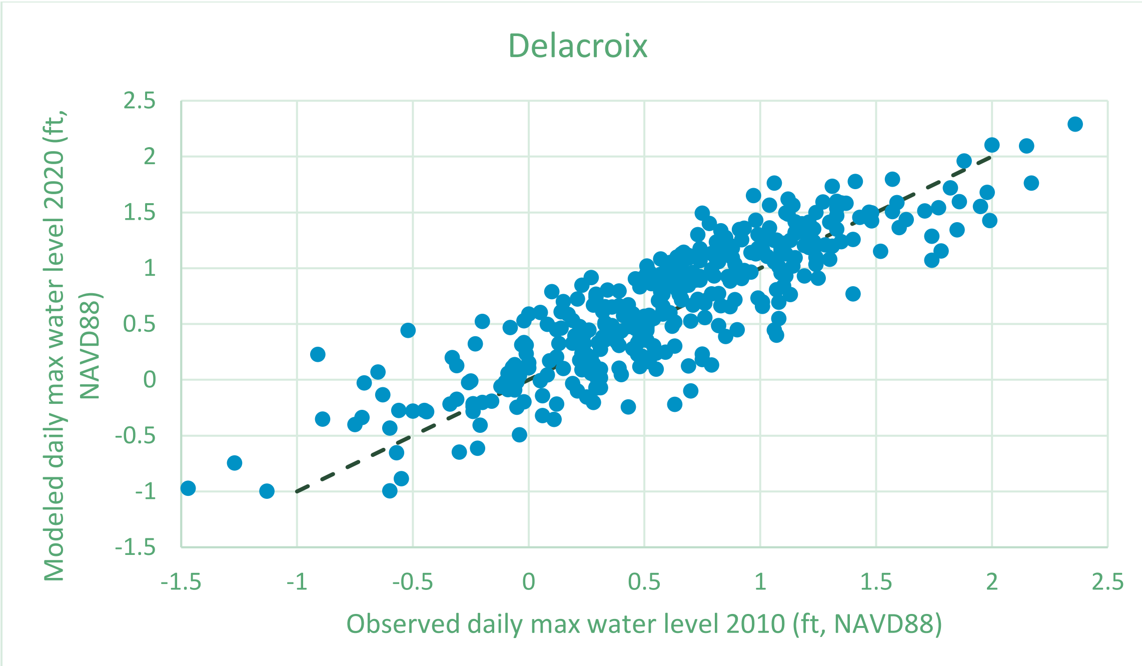


Figure 161. ICM compartment 110 versus observed data scatter plot comparison for Delacroix, Louisiana for 2020.

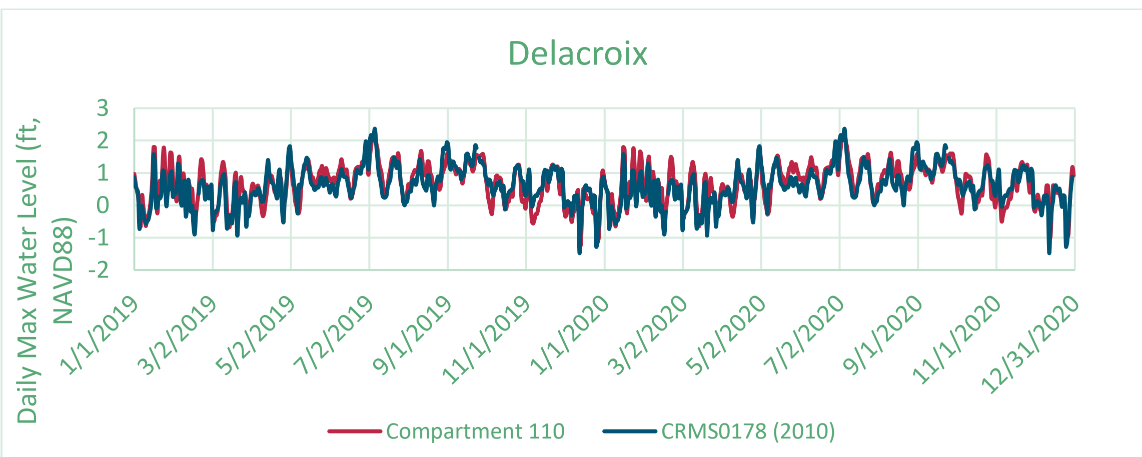


Figure 162. ICM compartment 110 versus observed data comparison for Cameron, Louisiana for 2019 – 2020.

DELCAMBRE

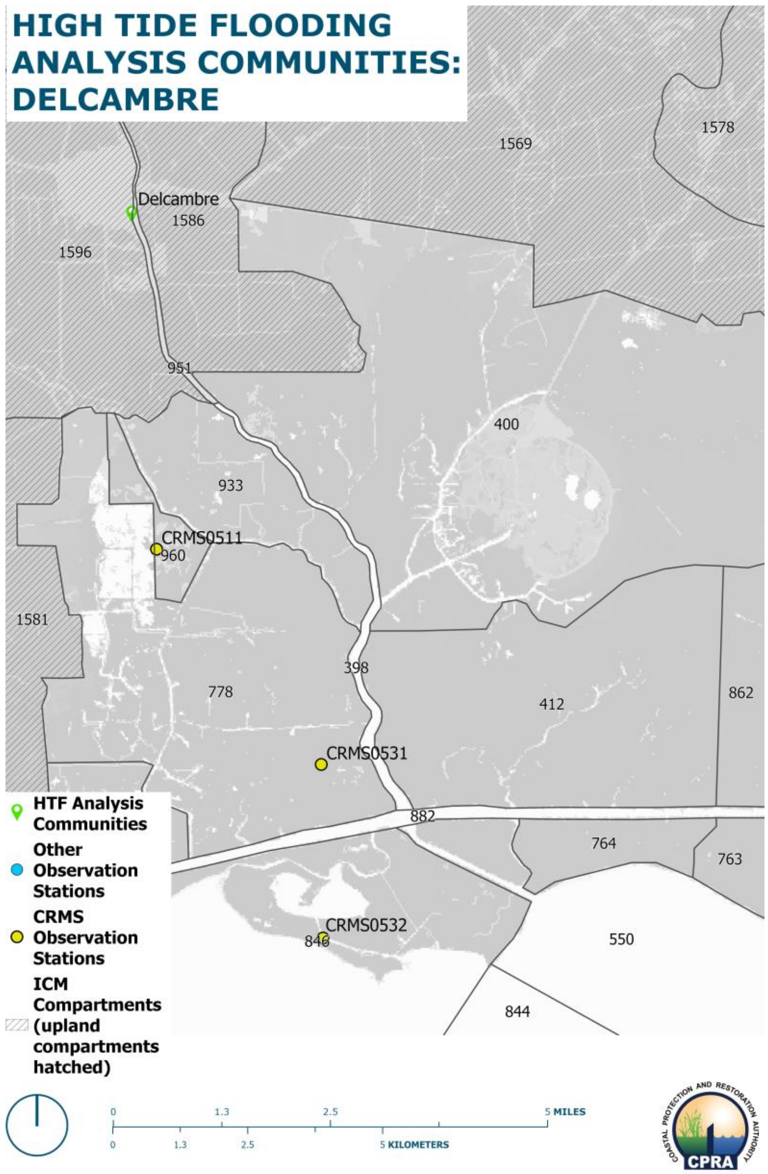


Figure 163. ICM compartments and WSE observation stations relative to Delcambre, Louisiana. ICM compartment 778 and CRMS0531 were used for the analysis.

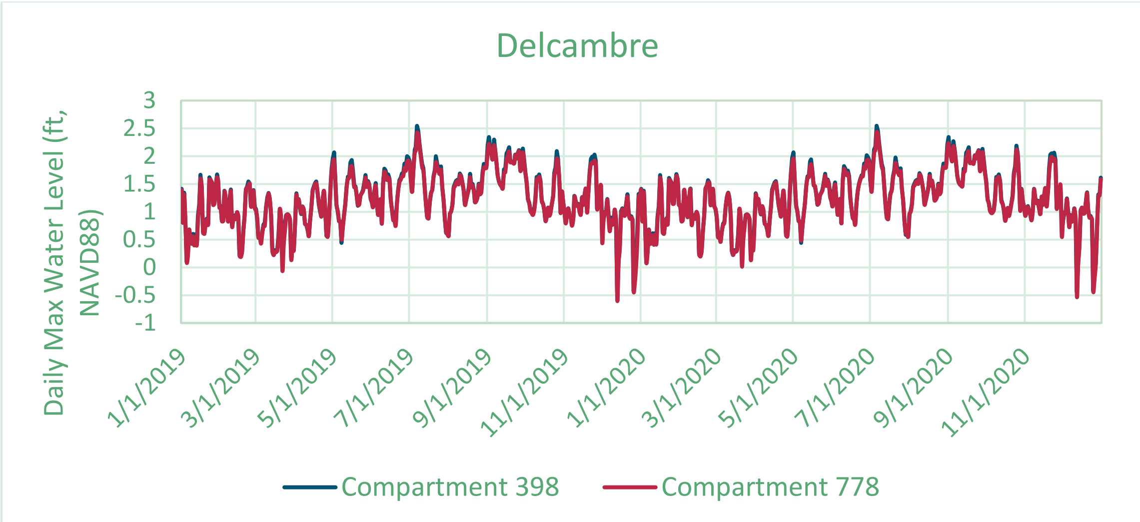


Figure 164. ICM compartments proximal to Delcambre, Louisiana and associated mean water level output for 2019 – 2020.

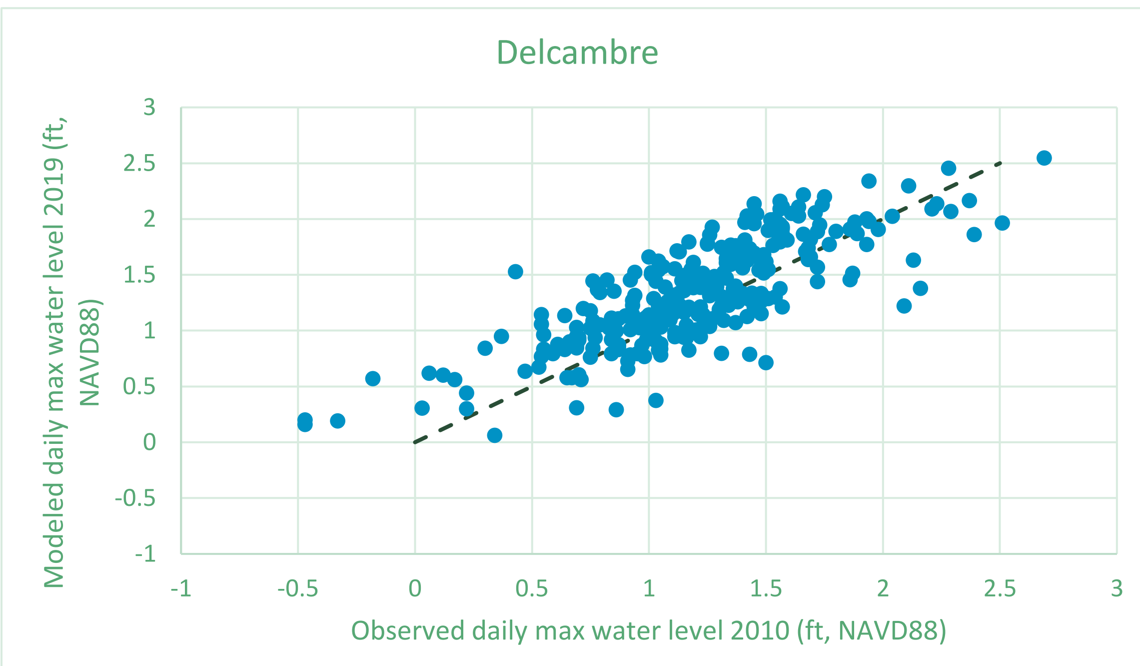


Figure 165. ICM compartment 110 versus observed data scatter plot comparison for Delcambre, Louisiana for 2019.

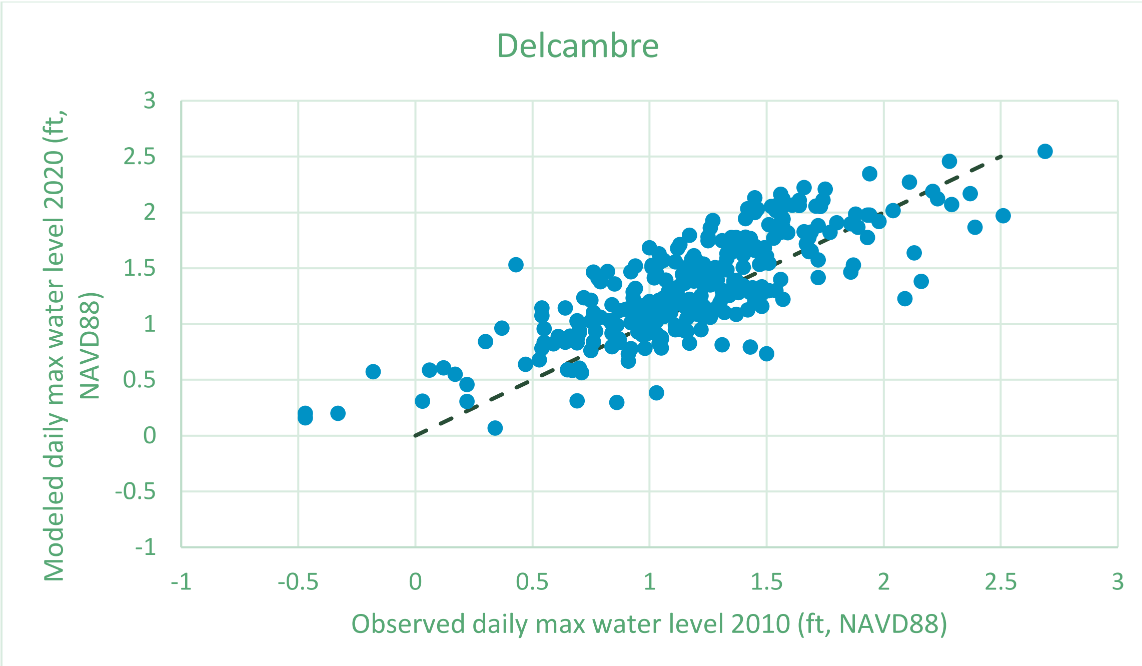


Figure 166. ICM compartment 110 versus observed data scatter plot comparison for Delcambre, Louisiana for 2020.

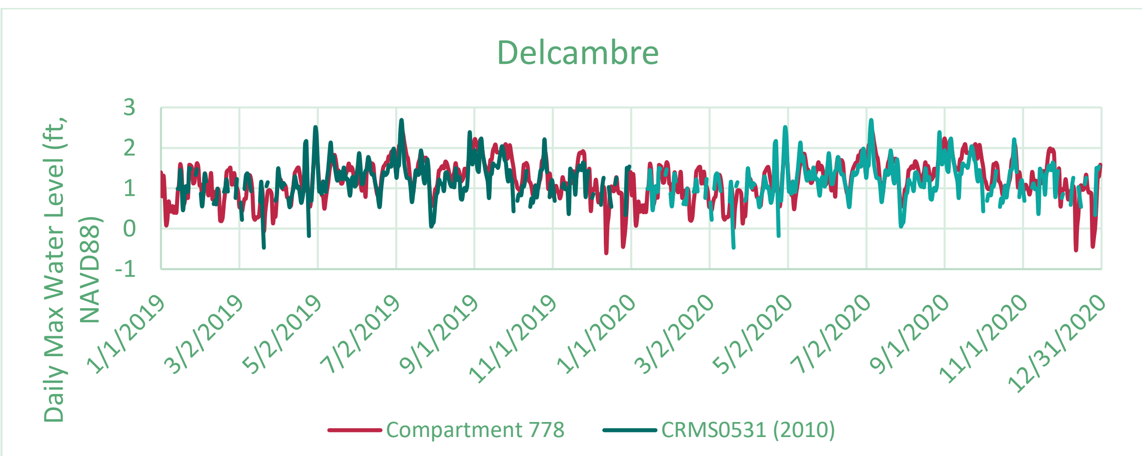


Figure 167. ICM compartment 778 versus observed data comparison for Delcambre, Louisiana for 2019 – 2020.

DULAC

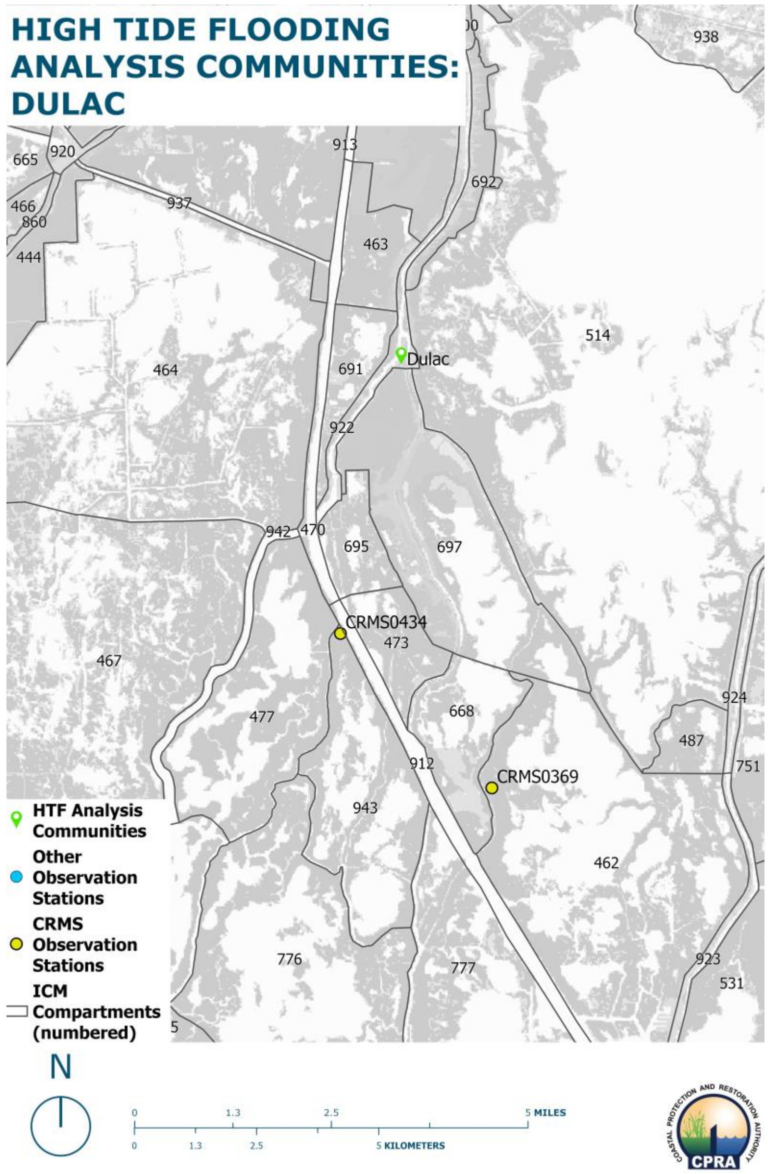


Figure 168. ICM compartments and WSE observation stations relative to Dulac, Louisiana. ICM compartment 912 and CRMS0434 were used for the analysis.

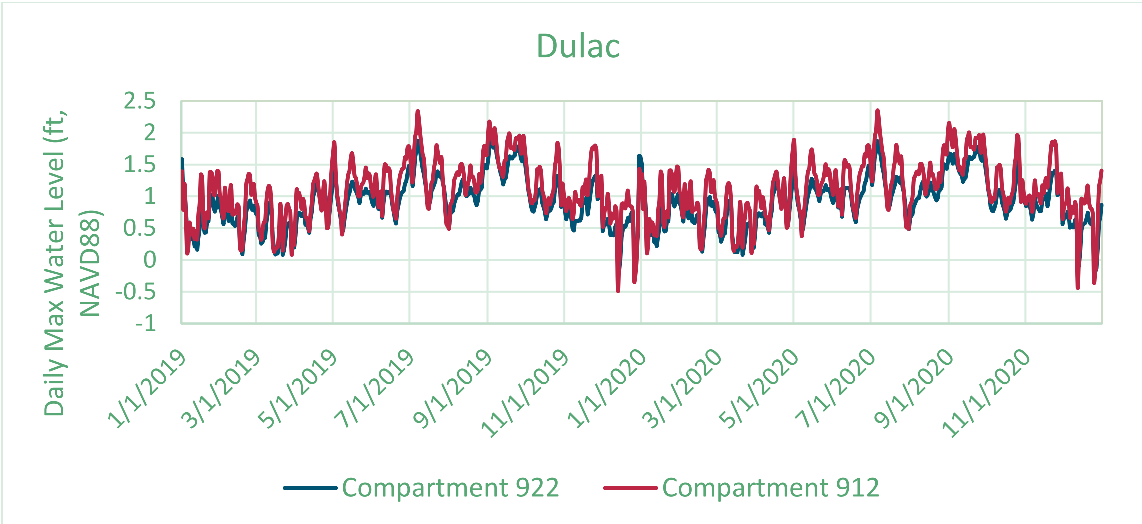


Figure 169. ICM compartments proximal to Dulac, Louisiana and associated mean water level output for 2019 – 2020.

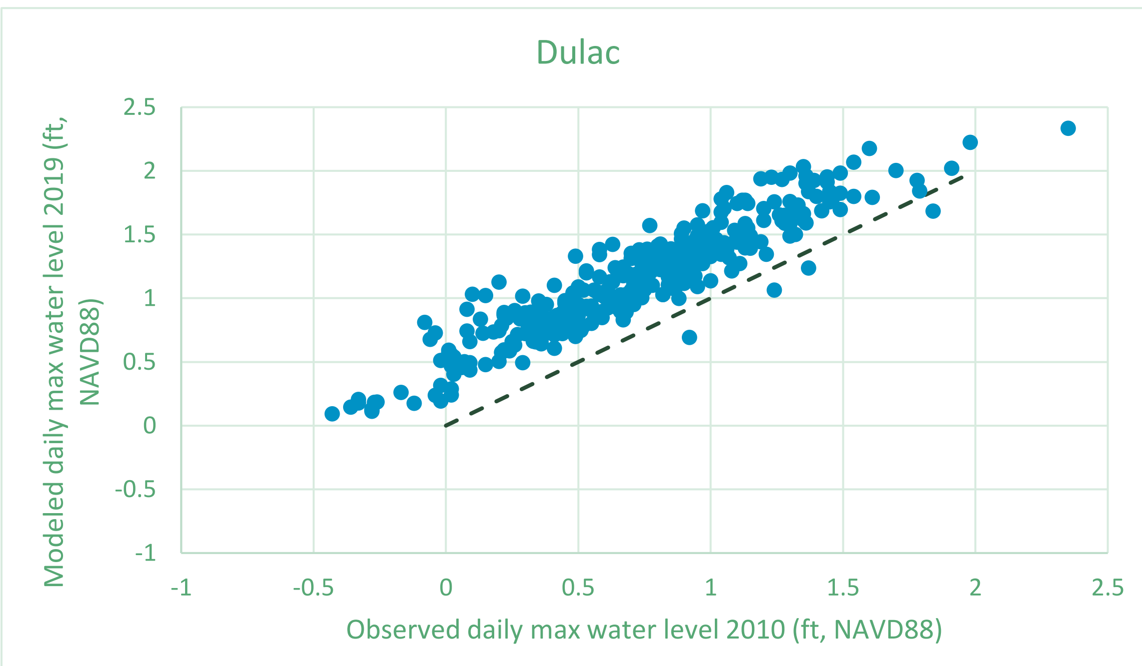


Figure 170. ICM compartment 912 versus observed data scatter plot comparison for Dulac, Louisiana for 2019.

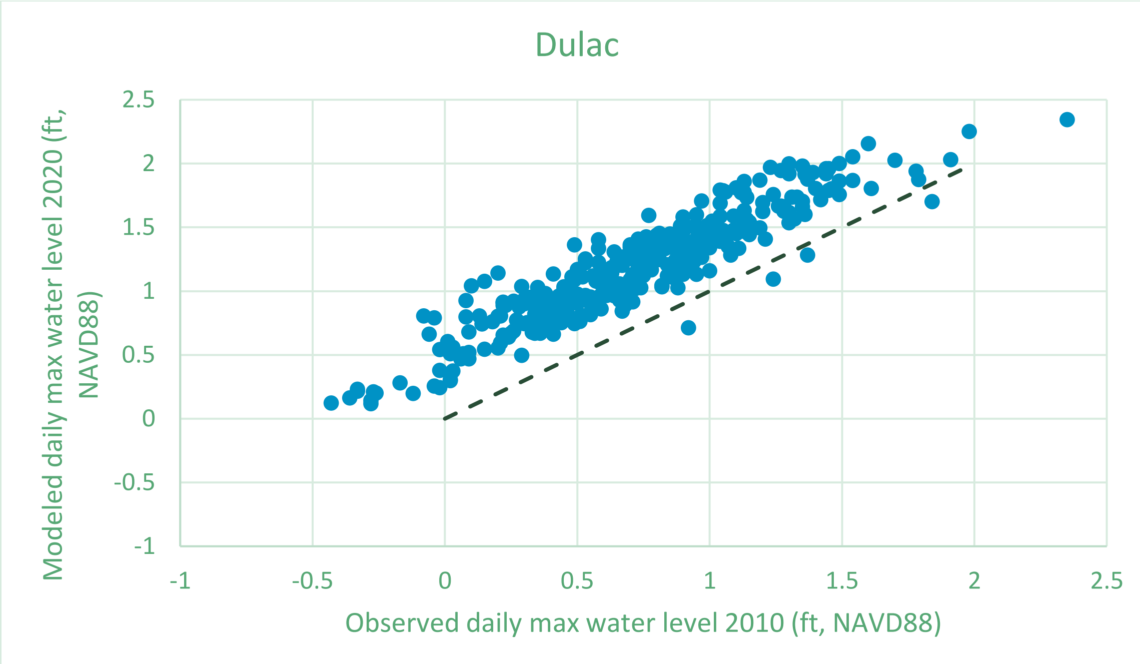


Figure 171. ICM compartment 912 versus observed data scatter plot comparison for Dulac, Louisiana for 2020.

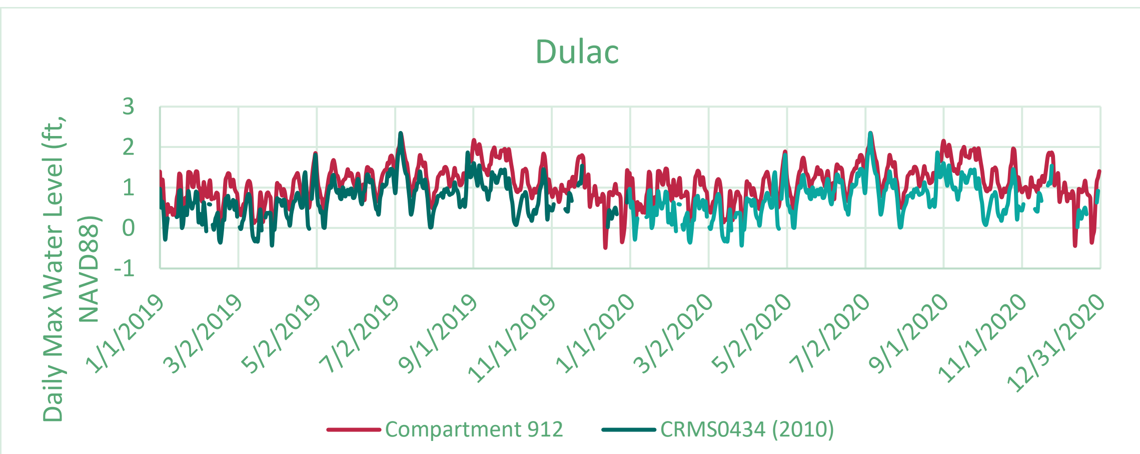


Figure 172. ICM compartment 912 versus observed data comparison for Dulac, Louisiana for 2019 – 2020.

GRAND ISLE

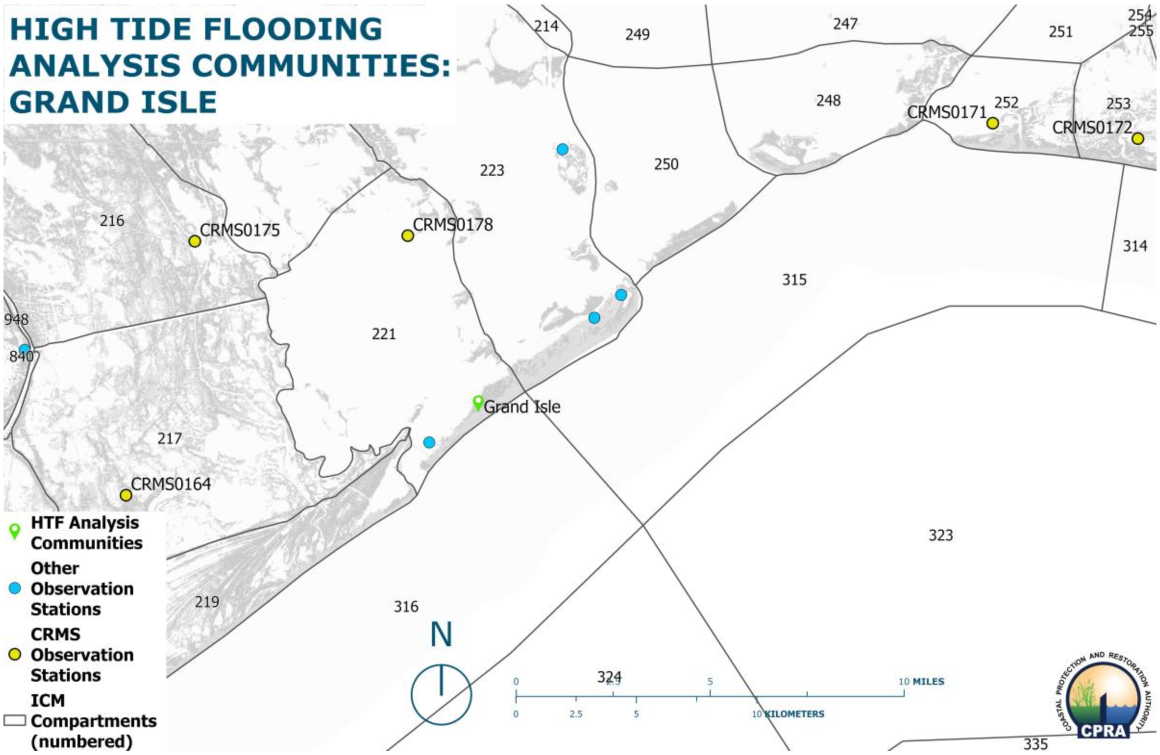


Figure 173. ICM compartments and WSE observation stations relative to Grand Isle, Louisiana. ICM compartment 223 and CRMS0178 were used for the analysis.

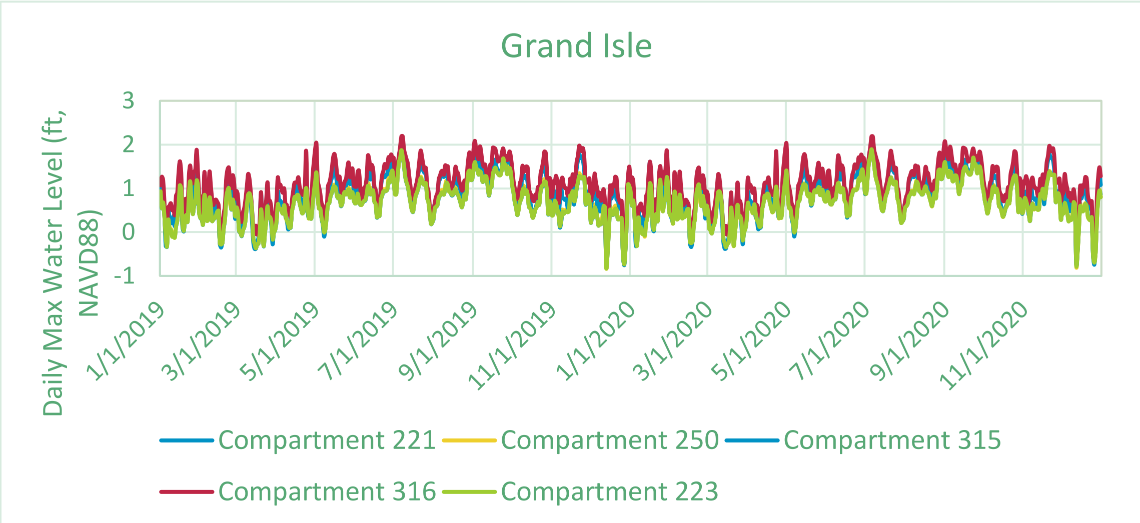


Figure 174. ICM compartments proximal to Grand Isle, Louisiana and associated mean water level output for 2019 – 2020.

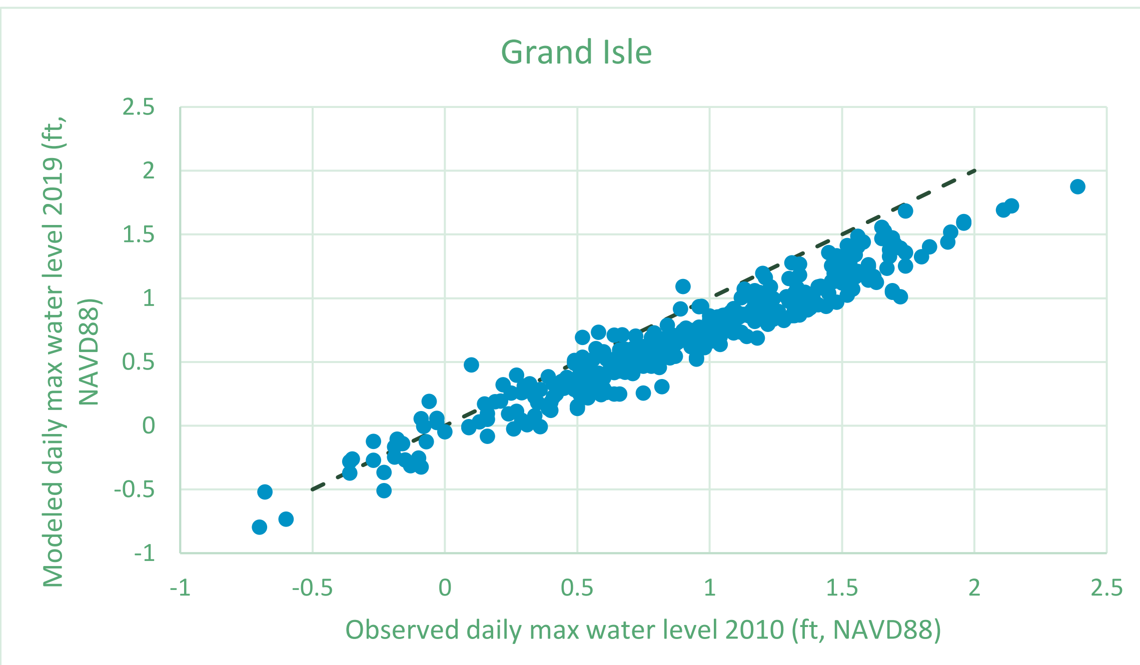


Figure 175. ICM compartment 223 versus observed data scatter plot comparison for Grand Isle, Louisiana for 2019.

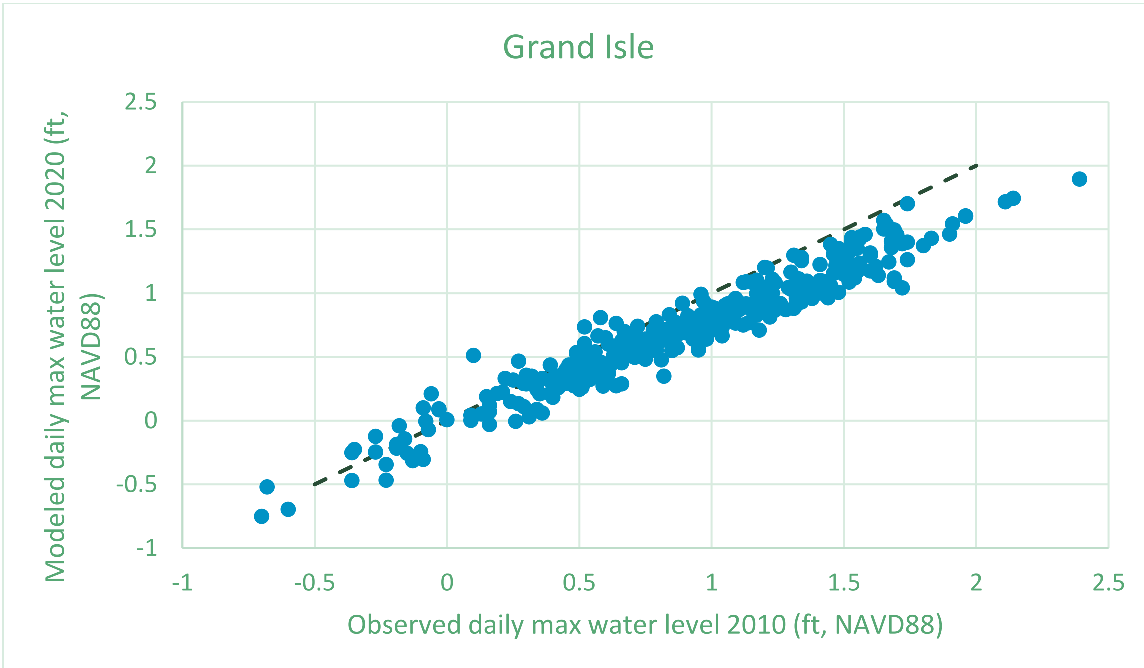


Figure 176. ICM compartment 223 versus observed data scatter plot comparison for Grand Isle, Louisiana for 2020.

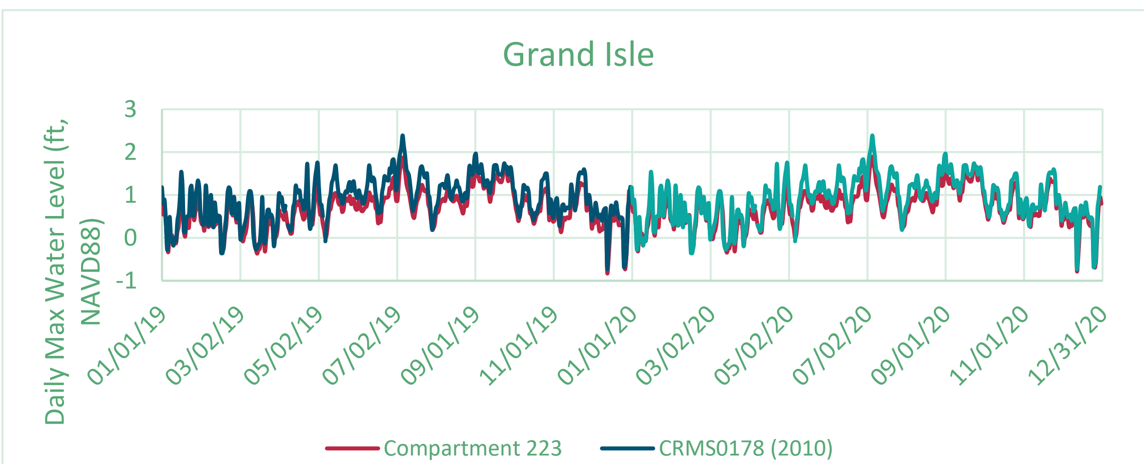


Figure 177. ICM compartment 223 versus observed data comparison for Grand Isle, Louisiana for 2019 – 2020.

MANDEVILLE

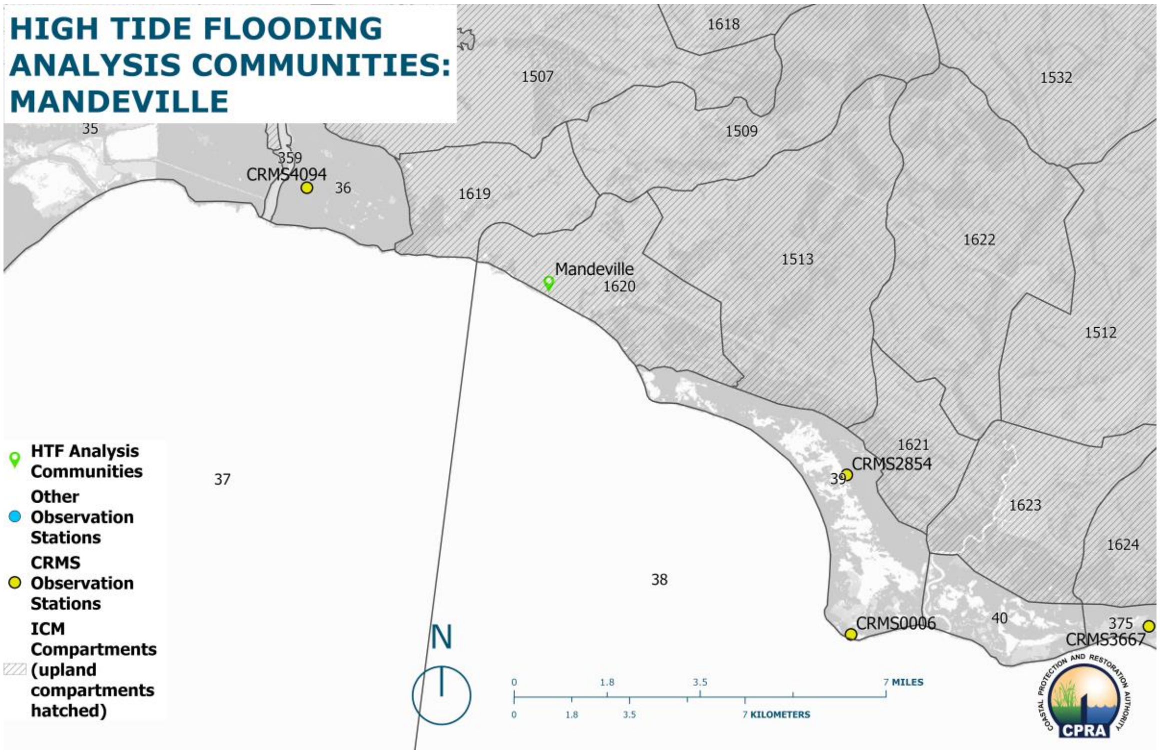


Figure 178. ICM compartments and WSE observation stations relative to Mandeville, Louisiana. ICM compartment 36 and CRMS4094 were used for the analysis.

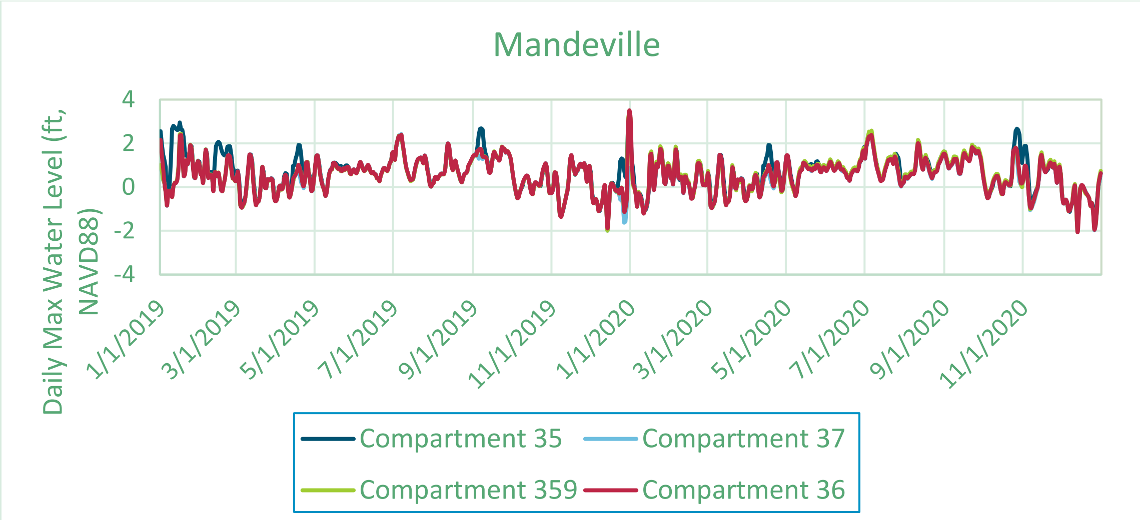


Figure 179. ICM compartments proximal to Mandeville, Louisiana and associated mean water level output for 2019 – 2020.

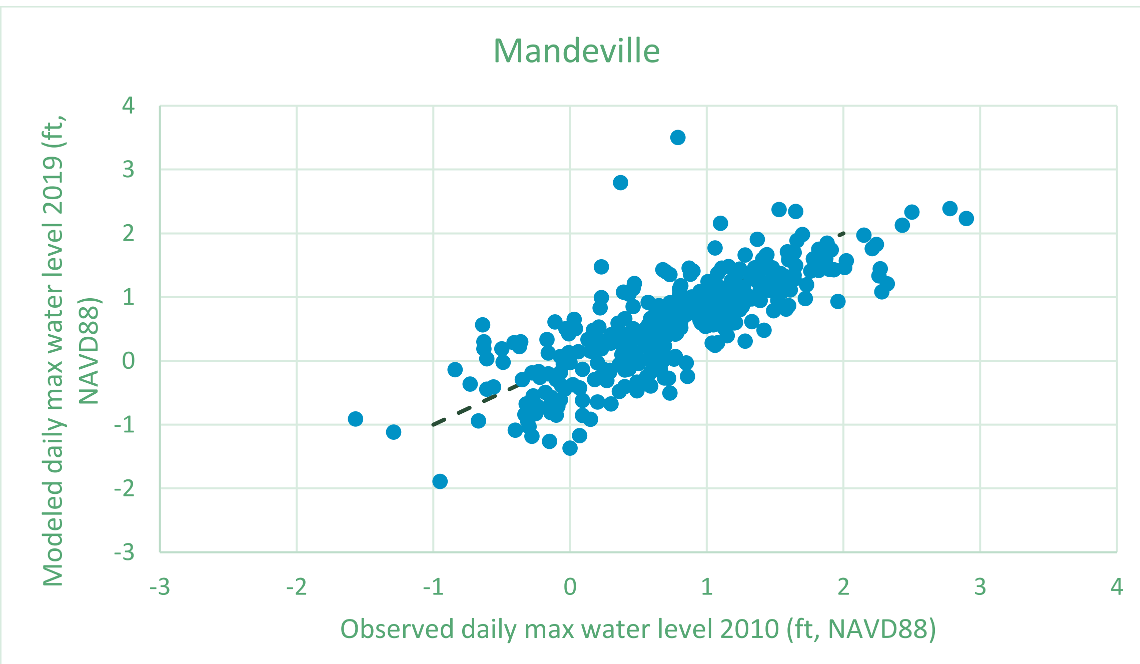


Figure 180. ICM compartment 36 versus observed data scatter plot comparison for Mandeville, Louisiana for 2019.

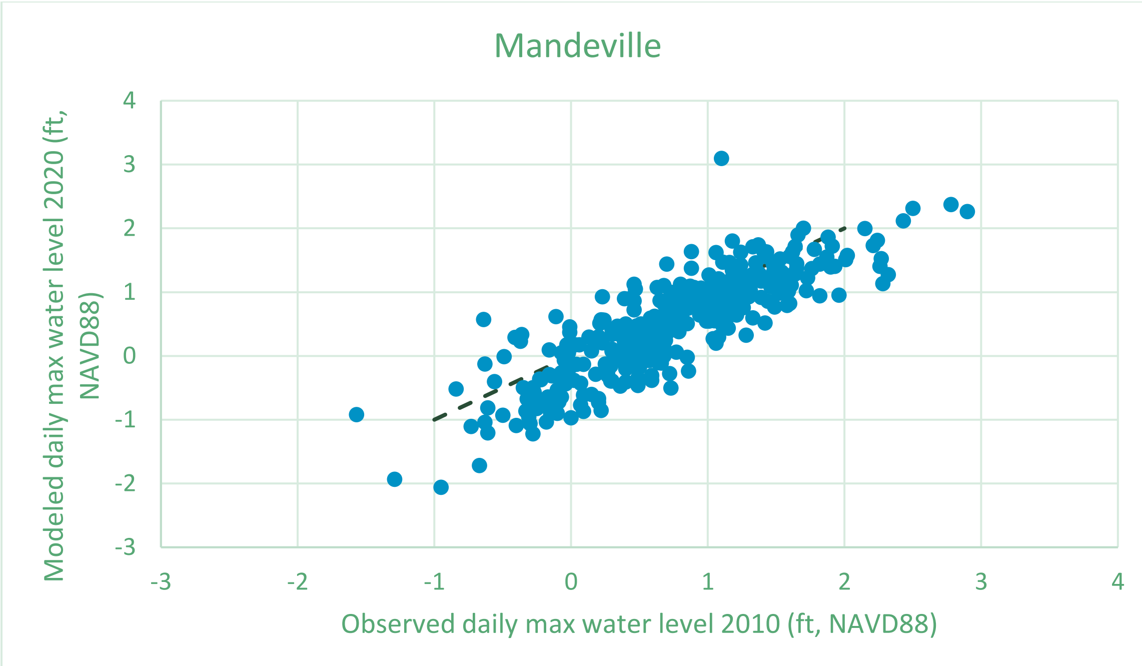


Figure 181. ICM compartment 36 versus observed data scatter plot comparison for Mandeville, Louisiana for 2020.

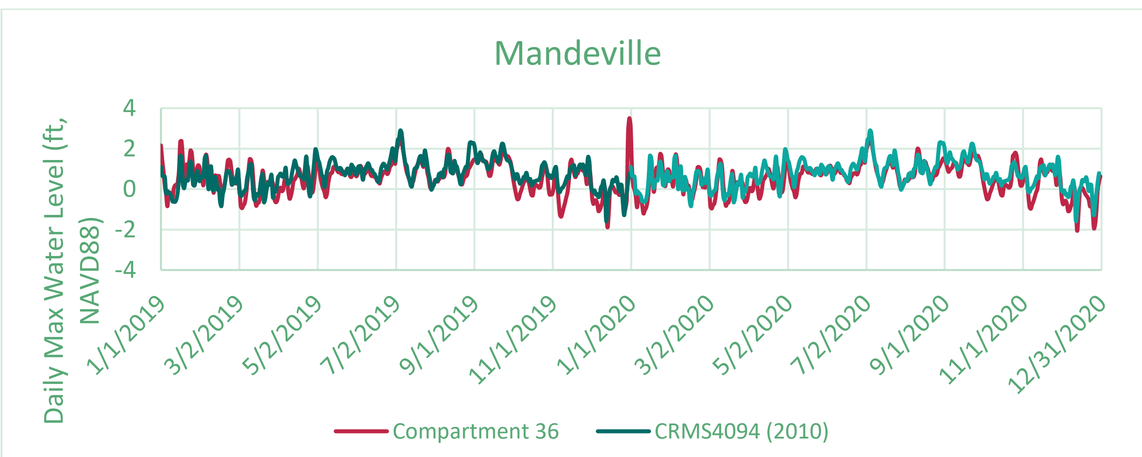


Figure 182. ICM compartment 36 versus observed data comparison for Mandeville, Louisiana for 2019 – 2020.

SLIDELL

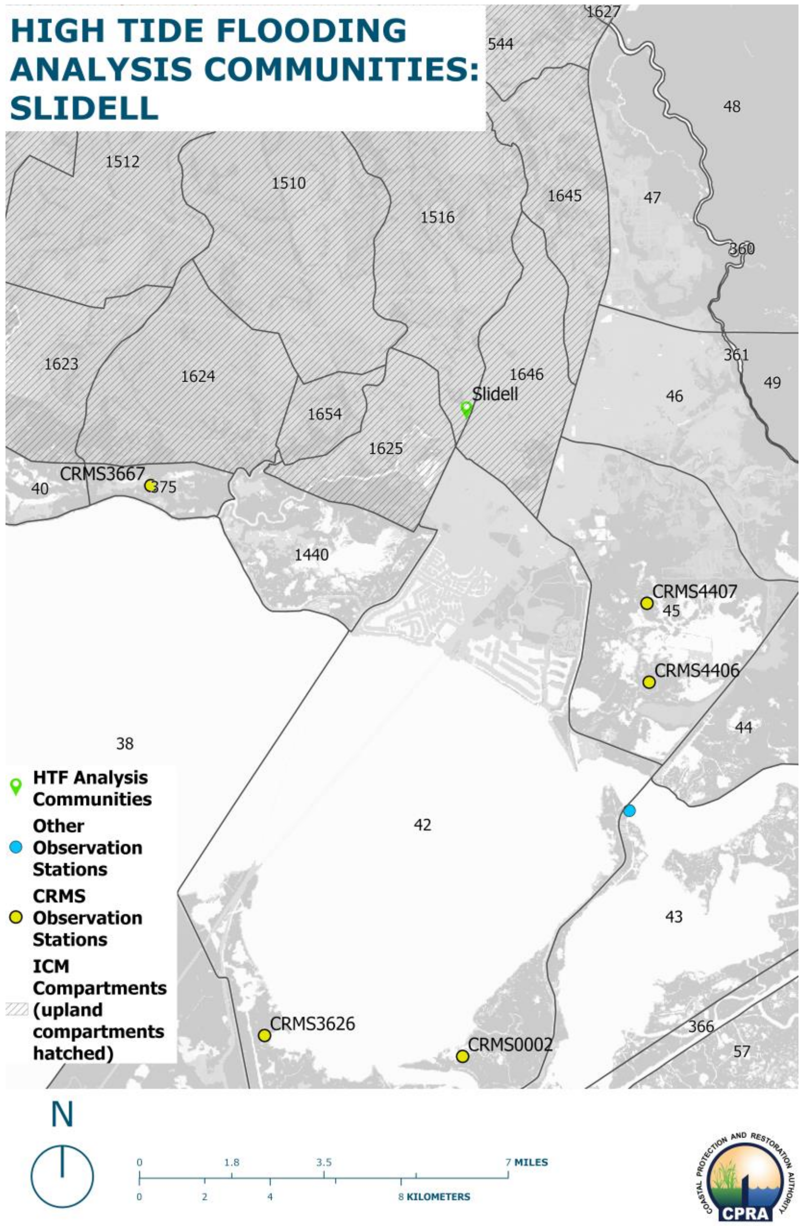


Figure 183. ICM compartments and WSE observation stations relative to Slidell, Louisiana. ICM compartment 75 and CRMS3667 were used for the analysis.

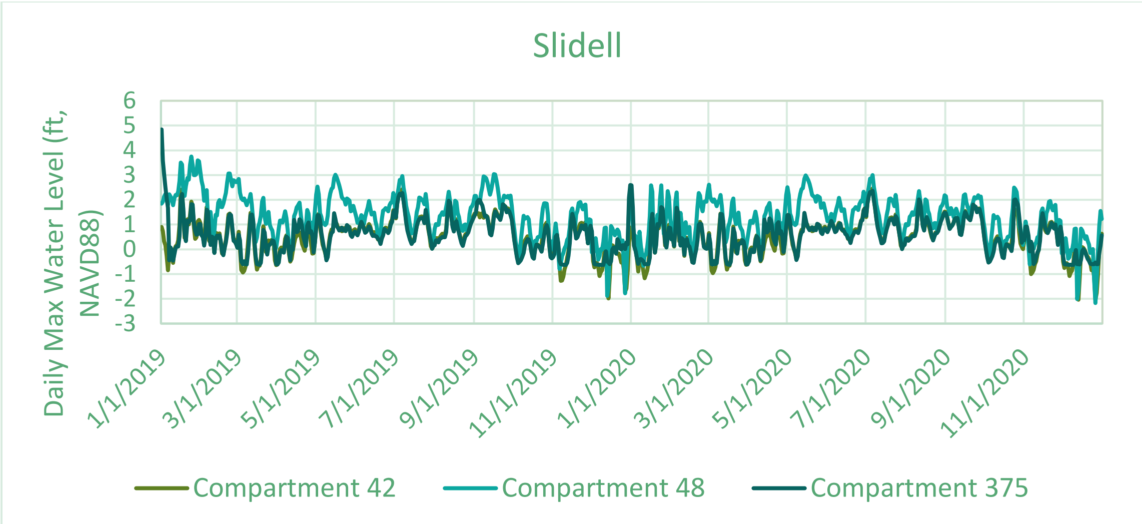


Figure 184. ICM compartments proximal to Slidell, Louisiana and associated mean water level output for 2019 – 2020.

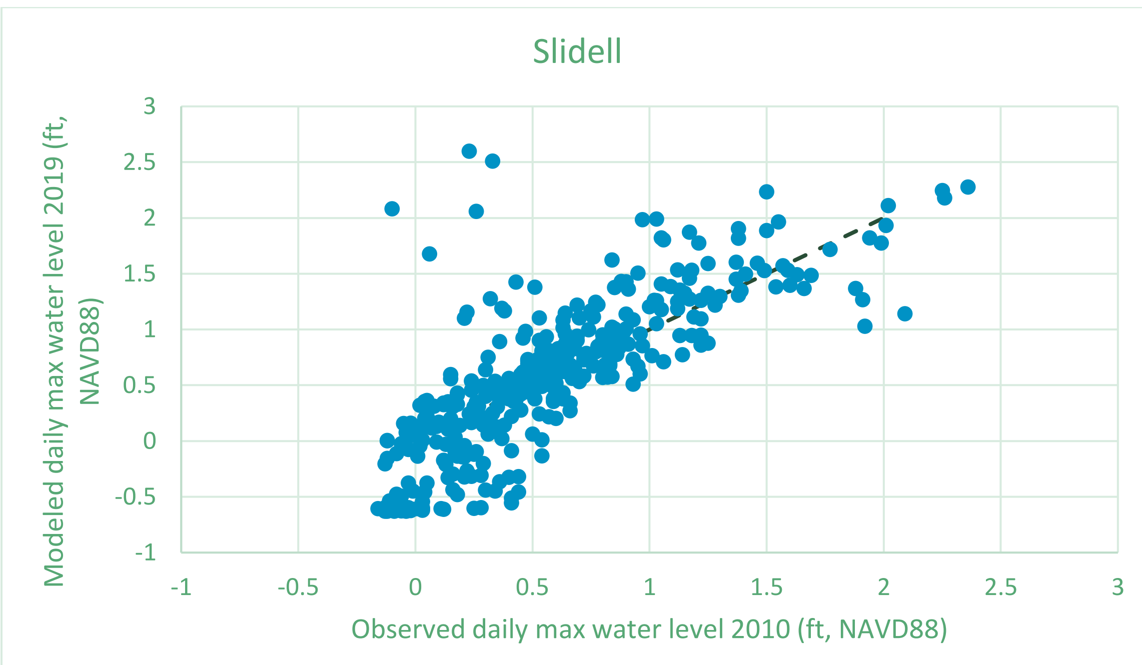


Figure 185. ICM compartment 75 versus observed data scatter plot comparison for Slidell, Louisiana for 2019.

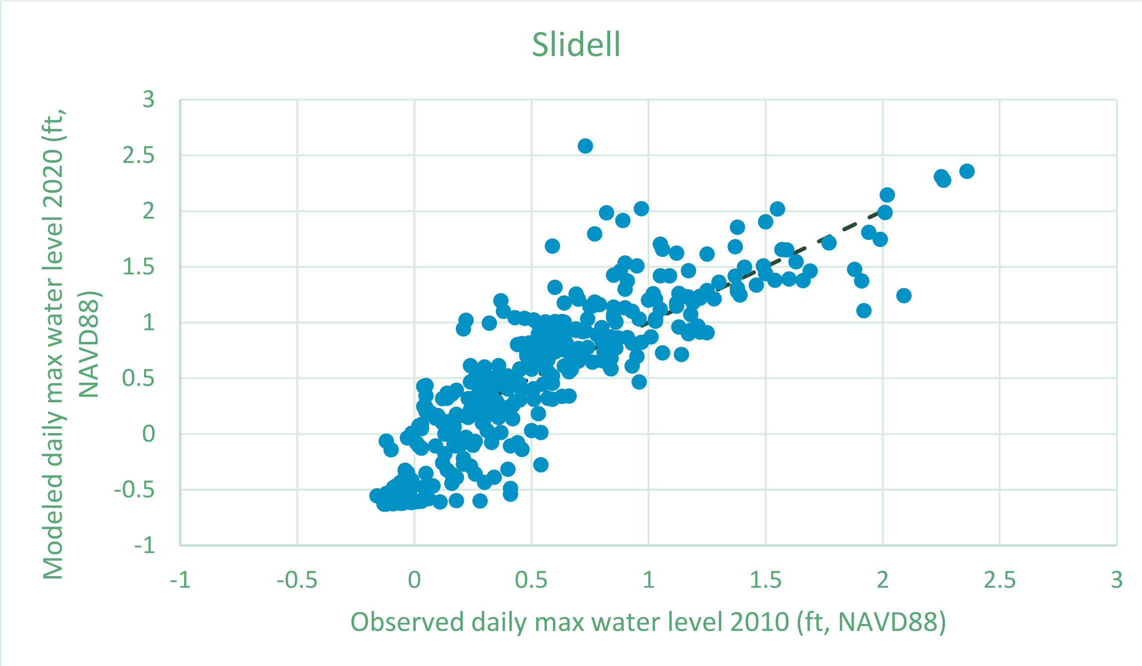


Figure 186. ICM compartment 75 versus observed data scatter plot comparison for Slidell, Louisiana for 2020.

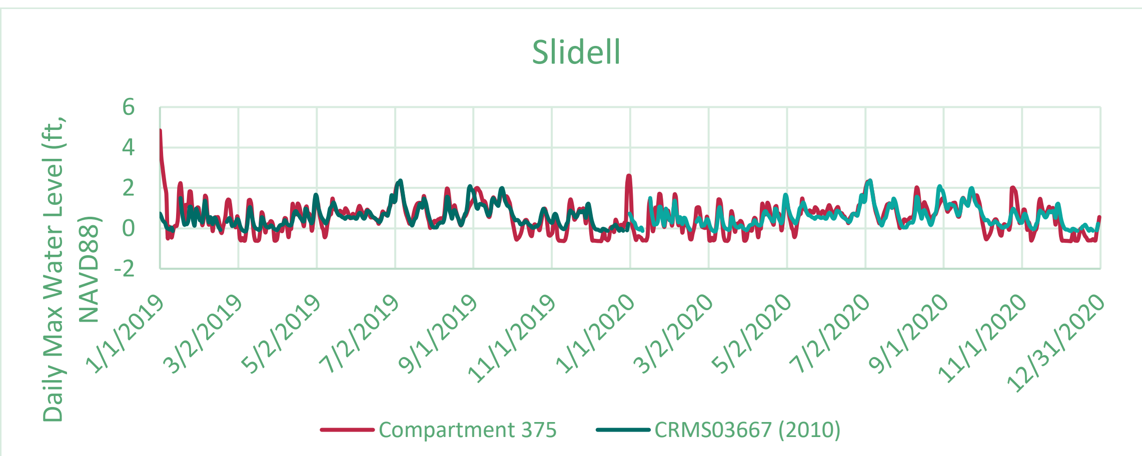


Figure 187. ICM compartment 75 versus observed data comparison for Slidell, Louisiana for 2019 – 2020.