ALABAMA HURRICANE EVACUATION STUDY RESULTS SUMMARY REPORT – 2023 RE-STUDY

for Baldwin and Mobile Counties

PARSONS

November 2023 – Final Report

FEMA

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Definitions & Standards

Term	Definition
Bathymetry	The measurement of the depth of large bodies of water, for example, lakes, oceans, and seas.
Behavioral Analysis	Determines the expected response of the population threatened by various hurricane events in terms of the percentage expected to evacuate, probable destinations of evacuees, public shelter use, and utilization of available vehicles.
Clearance Time	The time required to clear the roadways of all evacuating vehicles measured from the time the first vehicle enters the roadway network to the time the last vehicle leaves the network to a designated point of safety.
Critical Facilities	Facilities that may need assistance or special consideration when planning evacuation, or sustained operation.
Evacuation	People leaving their residence to go from a perceived dangerous place to a perceived safer place.
Evacuation Participation Rate	The percent of the vulnerable population that evacuates under a given evacuation order.
Evacuation Zone	Designated by local officials and based on the surge inundation maps used in the transportation model. Surge inundation areas are divided up into zones for modeling purposes and evacuation notice dissemination.
Hazards Analysis	Determines the timing and magnitude of wind and storm surge hazards that can be expected from hurricanes of various categories, tracks, and forward speeds.
Hurricane Warning	An alert issued by the NHC that indicates hurricane conditions are expected in the specified area within 36 hours.
Hurricane Watch	An alert issued by the NHC that indicates hurricane conditions are possible in the specified area within 48 hours.
Response Time	The time it takes for the evacuating population to leave for an evacuation.
Shelter Demand	The number of evacuees seeking public shelter.
Shelter Capacity	The number of shelter spaces available to evacuees during a given hurricane.
Shelter Inventory	The total number of registered shelter spaces from which Shelter Capacity is selected, pending each facility's agreement to provide shelter for a given hurricane.
Shelter Participation Rate	The percentage of evacuees who seek public shelter
Saffir-Simpson Hurricane Scale	Scale developed to describe the potential storm surge generated by hurricanes:
	Category 1: Winds of 74 to 95 miles per hour
	Category 2: Winds of 96 to 110 miles per hour
	Category 3: Winds of 111 to 130 miles per hour
	Category 4: Winds of 131 to 155 miles per hour
	Category 5: Winds greater than 155 miles per hour

Term	Definition
Shelter Analysis	Presents an inventory of public shelter facilities, capacities of the shelters, vulnerability of shelters to storm surge flooding, and shelter demand for each county.
Storm Category	*See Saffir-Simpson Hurricane Scale*
Storm Surge	The abnormal rise in water level caused by wind and pressure forces of a hurricane. Storm surge produces most of the flood damage and drowning associated with tropical systems - highest surges from a hurricane usually occur on the right front quadrant of the storm's track.
Topography/Topographic Features	Features on the surface of land, including natural features such as mountains and rivers and constructed features such as highways and railroads.
Tourism Levels	Level indicating the tourism occupancy at the time of landfall, based on the occupied percentage of the region's total tourism and seasonal housing/vacation units
	Low Tourism: 21.6% occupancy
	Medium Tourism: 60.6% occupancy
	High Tourism: 92% occupancy
Traffic Analysis Zone (TAZ)	Small sub-areas of the evacuation zone used by the transportation model to determine how many vehicles will use each roadway.
Transportation Analysis	To determine the time required to evacuate the threatened population (clearance times) under a variety of hurricane situations and to evaluate traffic control measures that could improve the flow of evacuating traffic.
Tropical Cyclones	Defined by the National Weather Service as non-frontal, low-pressure synoptic scale (large-scale) systems that develop over tropical or subtropical waters and have a definite organized circulation.
	Tropical depression: Winds ≤ 38 mph
	Tropical storms: Winds 39 to 74 mph
	Hurricanes: Winds > 74 mph
	Official Atlantic hurricane season begins on June 1 and extends through November 30 of each year.
Tropical Storm Warning	An alert issued by the NHC that indicates tropical storm conditions are expected in the specified area within 36 hours
Tropical Storm Watch	An alert issued by the NHC that indicates tropical storm conditions are possible in the specified area within 48 hours.
Vulnerability Analysis	Identifies those areas, populations, and facilities that are vulnerable to specific hazards under a variety of hurricane threats.
Vulnerable Population	Persons residing or visiting (e.g. tourists) in areas subject to storm surge, freshwater flooding, and/or wind damage from tropical storms or hurricanes. This includes mobile home residents,

Term	Definition
	regardless of whether the mobile home is located in a storm surge or freshwater flooding area.

Acronym	Definition
ACS	American Community Survey
ALMS	Alabama/Mississippi
ARC	American Red Cross
DEM	Digital Elevation Model
EOC	Emergency Operations Center
FEMA	Federal Emergency Management Agency
FHWA	Federal Highway Administration
FIRM	Flood Insurance Rate Map
GIS	Geographic Information Systems
HES	Hurricane Evacuation Study
HURREVAC	HURRicane EVACuation Tracking and Analysis Software
MEOW	Maximum Envelope of Water; stores the maximum water surface elevation in each SLOSH grid cell for all the hurricane tracks in one direction for a particular forward speed, and storm intensity.
MOMs	Maximums of Maximums; represents the maximum water surface elevation for each SLOSH grid cell regardless of approach direction, forward speed or track.
NFIP	National Flood Insurance Program
NHC	National Hurricane Center
NOAA	National Oceanographic and Atmospheric Administration
NHP	National Hurricane Program
RSR	Results Summary Report (part of Hurricane Evacuation Study)
RtePM	Real Time Evacuation Planning Model
SLOSH Model	Acronym meaning Sea, Lake and Overland Surges (SLOSH) from hurricanes. SLOSH provides heights of storm surge for various combinations of hurricane strength, forward speed of storm, and direction of storm. SLOSH model is used for real-time forecasting of surges from approaching hurricanes within selected Gulf and Atlantic coastal basins.
USACE	United States Army Corps of Engineers

1 HURRICANE EVACUATION STUDIES RESULTS SUMMARY

1.1 GENERAL

The Alabama Hurricane Evacuation Study (HES) Re-Study was initiated in 2021 and completed in 2023 with the publication of this Results Summary Report (RSR). It consists of five related analyses summarizing technical data related to tropical cyclone hazards (in the Hazards Analysis), vulnerability of areas, populations, and facilities (in the Vulnerability Analysis), evacuees' response to evacuation orders (in the Behavioral Analysis), sheltering demands and available shelter capacities (in the Shelter Analysis), and ultimately clearance times (developed during the Transportation Analysis with inputs from the Behavioral Analysis and previous analyses) needed to conduct a safe and timely evacuation for various hurricane threat situations. Detailed descriptions and methodologies of the analyses are contained in separate reports for each of the five major analyses (Hazard, Vulnerability, Behavioral, Shelter, and Transportation). A summary of results from the five HES analyses with key summary data in the form of tables and figures is provided in this RSR.

In addition to this RSR, a variety of Excel spreadsheets and supporting data tables have been developed throughout the HES process. These supporting tables have been shared with the stakeholders, and are available to download on the HES ShareFile site: https://parsons.sharefile.com/home/shared/fo238ea3-1d7b-4eb3-9dc5-e980fd7e7e65. An Excel workbook titled "AL_HES_Data_Tables.xlsx" that displays high level summary information has been provided along with this report; however, for the most detailed tables and information, refer to the individual HES analyses reports and accompanying data tables. ESRI online account holders will need to request access to the FEMA MAC online group, which can be accessed here: https://arcg.is/1iWDjn.

PLANNING TOOL - ONLINE HES DASHBOARDS – INTERACTIVE STUDY RESULTS

In addition to the five HES reports, a separate planning tool called the *Online HES Dashboard* was developed. This interactive dashboard displays the GIS data and maps developed through the Hazard and Vulnerability Analyses, and can be filtered to display evacuation zones, storm surge risk areas by category storm and equivalent storm surge inundation extent groups, Federal Emergency Management Agency (FEMA) floodplains, critical facilities, storm shelters, and various population and demographic information. The dashboards are available through Esri ArcGIS online and are provided for each county. The dashboards and corresponding GIS data is hosted and managed by FEMA and can be made available to authorized users with an ESRI online account.

1.2 EVACUATION ZONES AND SCENARIOS

The approach directions of different intensity storms have varying impacts at different locations along the coastline of Alabama. Evacuation zones for the Alabama coastal counties of Baldwin and Mobile were reevaluated based on updated hazard analysis methodology in coordination

with input from local emergency management agencies, as explained in detail in the *Alabama HES Hazard Analysis – 2022 Re-Study*.

Storm surge hazards were identified through mapping of equivalent storm surge inundation extents of composited directional Maximum Envelopes of Water (MEOWs) from the 2018 New Orleans (MS8) SLOSH Super Basin model surge inundation outputs, for Baldwin and Mobile Counties. The inundation extents were sorted into 5 groups according to maximum surge depths (Group I: 0-7 feet; Group II: 0-11 feet; Group III: 0-16 feet; Group IV: 0-20 feet; Group V: 0->20 feet). Table 1 and Table 2 identify which storm intensities and approach directions produce equivalent maximum surge depths for each equivalent inundation extent group for Baldwin and Mobile Counties, respectively. This methodology differs from prior analyses (e.g. prior to the *Alabama HES Hazard Analysis – 2022 Re-Study*) which focused on identifying extents of storm surge associated with Maximums of the MEOWs (MOMs) extents for each category storm only (i.e. CAT 1-MOM, CAT 2-MOM, etc.).

Table 1 Baldwin County Equivalent Storm Surge Inundation Extent Groups and Equivalent Storms

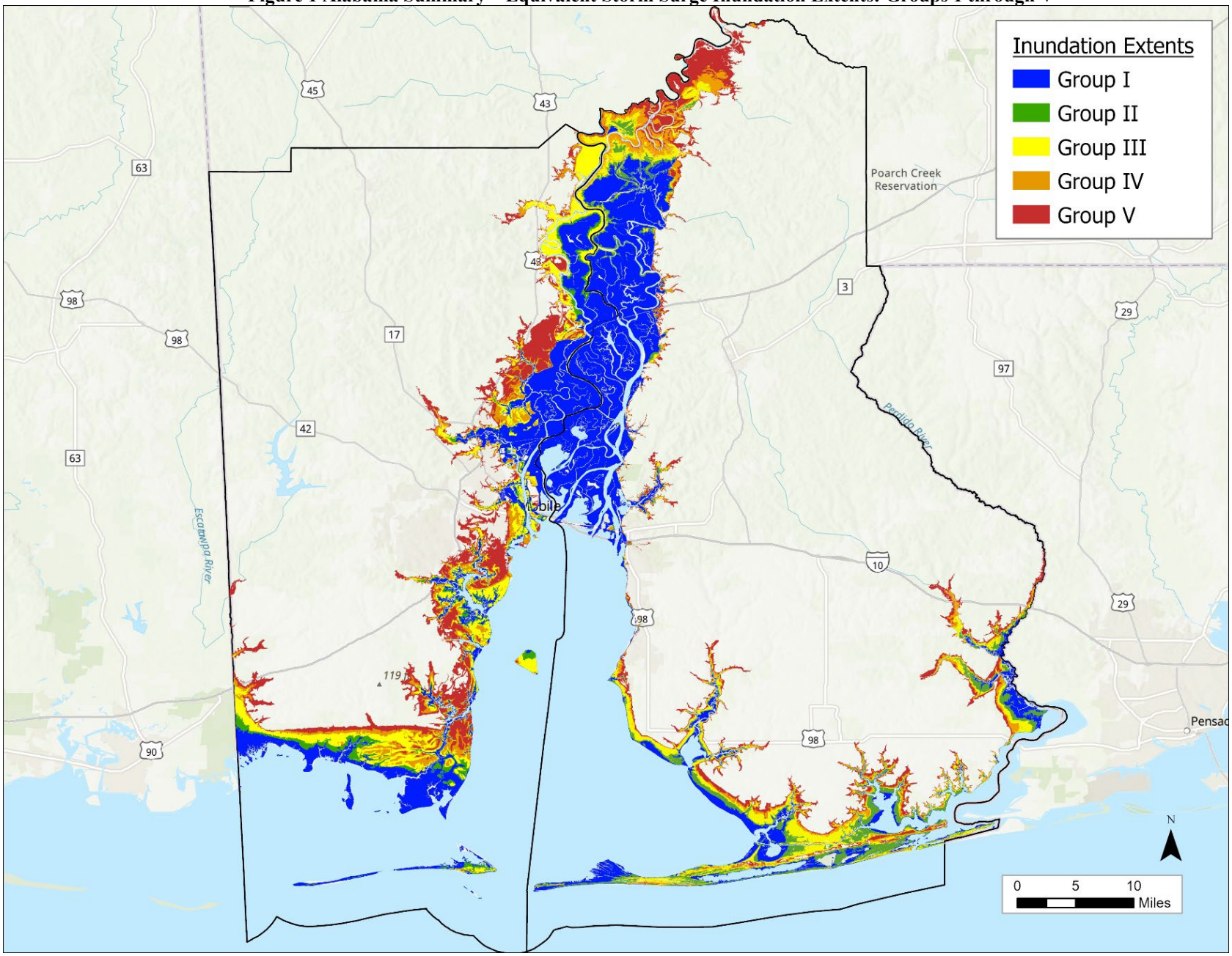
Equivalent Storm Surge Inundation Extent Groups	Maximum Depths	Equivalent Storms
I	6’	**TS:** W, ENE
	7’	**TS:** WNW, NW, NNW, N, NE, E
II	8'	**TS:** NNE, ***TS-MOM*** **CAT 1**: ENE, W
	9’	**CAT 1**: WNW, NW, NNW
	10’	**CAT 2**: ENE
	11’	**CAT 1**: N, E **CAT 2**: W, WNW
III	12'	**CAT 1**: NE **CAT 2:** NNW
	13’	**CAT 1**: NNE, ***CAT 1-MOM*** **CAT 2:** NW **CAT 3:** ENE
	14’	**CAT 2:** E
	15’	**CAT 2:** NE, N **CAT 3:** W
	16’	**CAT 4:** ENE
IV	17'	**CAT 2:** NNE, ***CAT 2-MOM*** **CAT 3:** WNW, NNW, NW, E
	18’	**CAT 3:** NE
	19’	**CAT 4:** W
	20’	**CAT 3:** NNE, N, ***CAT 3-MOM*** **CAT 5:** ENE
V	>20'	**CAT 4:** WNW, E, NW, NNW, N, NE, NNE, ***CAT 4-MOM*** **CAT 5:** W, WNW, E, NW, NE, NNW, N, NNE, ***CAT 5-MOM***

Table 2 Mobile County Equivalent Storm Surge Inundation Extent Groups and Equivalent Storms

Equivalent Storm Surge Inundation Extent Groups	Maximum Depths	Equivalent Storms
I	6’	**TS:** ENE
	7’	**TS:** W, NE
II	8'	**TS:** E, WNW
	9’	**TS:** N, NNE, NNW, NW, ***TS-MOM*** **CAT 1**: ENE
	10’	**CAT 1**: W, WNW
	11’	**CAT 2**: ENE
III	12'	**CAT 1**: NE, NW
	13’	**CAT 1**: E, N, NNE, NNW, ***CAT 1-MOM*** **CAT 2:** W, WNW
	14’	**CAT 3:** ENE
	15’	**CAT 2:** NE, NW
	16’	**CAT 2:** E, NNW
IV	17'	**CAT 2:** N, NNE, ***CAT 2-MOM*** **CAT 3:** W, WNW **CAT 4:** ENE
	19’	**CAT 3: N**W **CAT 5:** ENE
	20’	**CAT 3:** E, NE
V	>20'	**CAT 3:** N, NNE, NNW, ***CAT 3-MOM*** **CAT 4:** E, N, NE, NNE, NNW, NW, W, WNW, ***CAT 4-MOM*** **CAT 5:** E, N, NE, NNE, NNW, NW, W, WNW, ***CAT 5-MOM***

The equivalent storm surge inundation extents for all groups are presented in Figure 1, which show all of the Groups I through V in an overlapping fashion for Baldwin and Mobile Counties combined. For example, Group V is drawn underneath Groups I through IV so that the other groups can be seen.

Figure 1 Alabama Summary – Equivalent Storm Surge Inundation Extents: Groups 1 through V



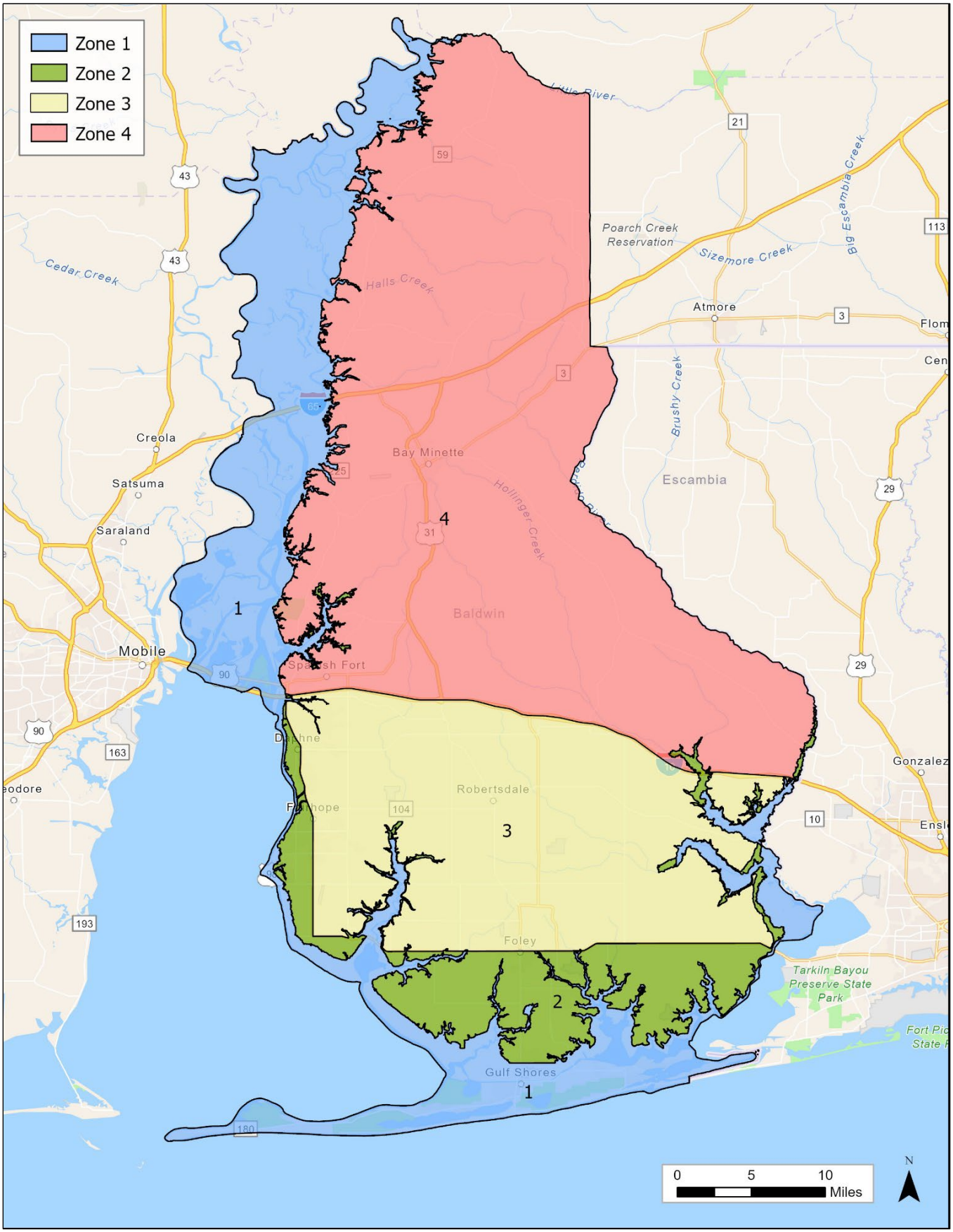
Baldwin County

Baldwin County evacuation zones were updated to better match the potential storm surge hazards for each equivalent storm surge inundation extent group. The most current evacuation zones were developed through coordination of the Mobile District USACE, FEMA, and the coastal counties' emergency management agencies as part of the *Alabama HES Vulnerability Analysis – 2022 Re-Study* process. Table 3 describes the updated 2022 evacuation zones for Baldwin County and includes the associated equivalent storm surge inundation extent groups and modeled maximum depths the evacuation zones were based on. Figure 2 displays the 2022 evacuation zones for Baldwin County. Although Zones 3 and 4 are not associated with modeled storm surge, they could be evacuated due to anticipated high winds.

Table 3 Baldwin County 2022 Evacuation Zones

Zone	Description	Scenario Group	Max Depth	Storms
1	Designated based on Groups I, II, II; FEMA 1% Annual Chance Storm; and roadway networks when possible.	**I**	7'	**TS:** W, WNW, NW, NNW, N, NE, ENE, E
		II	11'	**TS:** NNE **CAT 1**: ENE, W, WNW, NW, NNW, N, E **CAT 2**: ENE, W, WNW
		III	16'	**CAT 1**: NE, NNE, ***CAT 1-MOM*** **CAT 2:** NNW, NW, E, NE, N **CAT 3:** ENE, W **CAT 4:** ENE
2	Based on Groups IV and V; FEMA 0.2 % Annual Chance Storm; and roadway networks when possible.	**IV**	20'	**CAT 2:** NNE, ***CAT 2-MOM*** **CAT 3:** WNW, NNW, NW, E, NE, NNE, N, ***CAT 3-MOM*** **CAT 4:** W **CAT 5:** ENE
		V	>20'	**CAT 4:** WNW, E, NW, NNW, N, NE, NNE, ***CAT 4-MOM*** **CAT 5:** W, WNW, E, NW, NE, NNW, N, NNE, ***CAT 5-MOM***
3	Based on existing Zone 4, with small portions of new Zones 1 and 2 removed.	N/A	N/A	N/A
4	Based on existing Zone 5, with small portions of new Zones 1 and 2 removed.	N/A	N/A	N/A

Figure 2 Baldwin County Evacuation Zones



Mobile County

After reviewing the 2018 New Orleans SLOSH model surge inundation outputs, Mobile County Emergency Management Agency (EMA) decided to keep the same four main evacuation zones that they have been using without any alterations, with the exception of Dauphine Island. The Mobile County EMA has split Dauphin Island into four subzones labeled A, B, C, and D to provide a tool for the mayor to evacuate Dauphin Island when no other areas of Mobile County need to be evacuated. Table 4 includes the description of the previous 2012 evacuation zones for Mobile County, which were based on category storms, along with the description of the four subzones for Dauphin Island. Figure 3 and Figure 4 display the 2022 evacuation zones for Mobile County.

Table 4 Mobile County 2022 Evacuation Zones

Evacuation Zone	Associated Storm	Description
1	Category 1 & 2	Consists of all areas of Mobile County south of Interstate 10. This includes Dauphin Island, residents of manufactured homes, low lying areas and flood prone areas anywhere in the County.
2	Category 1 & 2	Consists of all areas of Mobile County north of Interstate 10 and east of a line formed by Interstate 65 north to US. Highway 43 then north to the county line.
3	Category 3, 4 & 5	Consists of all areas of Mobile County north of Interstate 10 but south of U.S. Highway 98/Moffatt Road and west of Interstate 65.
4	Category 3, 4 & 5	Consists of all areas of Mobile County north of U.S. Highway 98/Moffatt Road and west of a line formed by Interstate 65 north to U.S. Highway 43 then north to the County line.
1A	Category TS, 1 through 5 OR Dauphin Island specific events called by the Mayor	Consists of Dauphin Island west end to St. Stephens Street. Dauphin Island will always evacuate during a TS or when any of the numbered evacuation zones 1-4 are called to evacuate. Certain storms and coastal events that do not affect the rest of Mobile County will cause problems on Dauphin Island.
1B	Category TS, 1 through 5 OR Dauphin Island specific events called by the Mayor	Consists of St. Stevens Street to Pelican Street on Dauphin Island. Dauphin Island will always evacuate during a TS or when any of the numbered evacuation zones 1-4 are called to evacuate. Certain storms and coastal events that do not affect the rest of Mobile County will cause problems on Dauphin Island.
1C	Category TS, 1 through 5 OR Dauphin Island specific events called by the Mayor	Consists of Pelican Street to Lemoyne Drive on Dauphin Island. Dauphin Island will always evacuate during a TS or when any of the numbered evacuation zones 1-4 are called to evacuate. Certain storms and coastal events that do not affect the rest of Mobile County will cause problems on Dauphin Island.
1D	Category TS, 1 through 5 OR Dauphin Island specific events called by the Mayor	Consists of east of Lemoyne Drive to the east end of Dauphin Island. Dauphin Island will always evacuate during a TS or when any of the numbered evacuation zones 1-4 are called to evacuate. Certain storms and coastal events that do not affect the rest of Mobile County will cause problems on Dauphin Island.

Figure 3 Mobile County Evacuation Zones

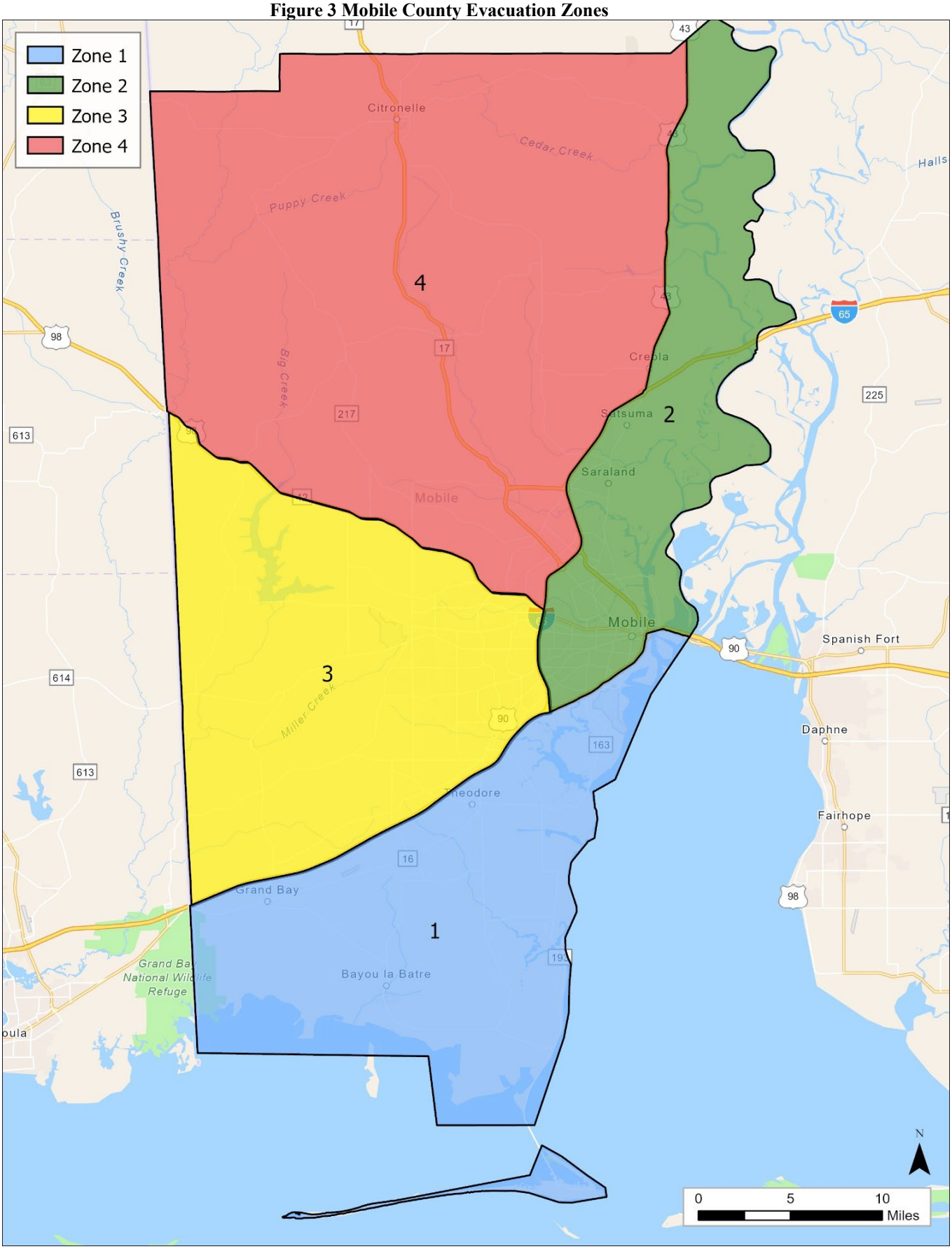
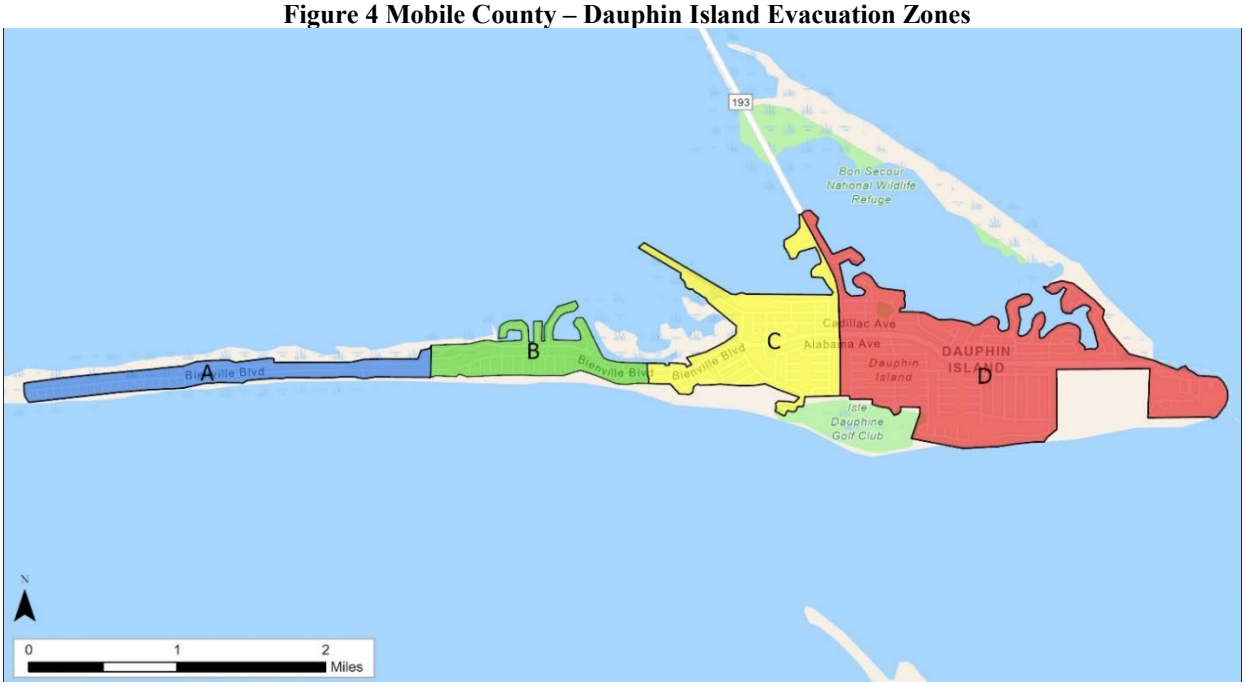


Figure 4 Mobile County – Dauphin Island Evacuation Zones



1.3 VULNERABLE POPULATIONS, STRUCTURES, CRITICAL FACILITIES, AND INFRASTRUCTURE KEY RESOURCES

Baldwin County

From 2010 to 2020, Baldwin County has had significant population growth, increasing overall by 24%, with senior populations 65 and older seeing a 54% increase.

Table 5 shows approximately 5% of Baldwin County's total population is estimated to be at risk of storm surge from the lowest strength tropical storms and hurricanes, as defined by equivalent storm surge inundation extent Group I. Conversely, an estimated 17% of the total population of Baldwin County would be impacted by storm surge from the highest strength hurricanes, as defined by equivalent storm surge inundation extent Group V, which can produce maximum surge depths of more than 20 feet. High, medium, and low tourist population scenarios were also calculated for the county, with the estimated high-occupancy tourist population, using a 92% occupancy rate, included in the tables below.

Table 5 Baldwin County Estimated Population within Equivalent Storm Surge Inundation Extent Groups

Equivalent Storm Surge Inundation Extent Groups	Total Population[1]	Est. Mobile Home Population[2]	Non-Mobile Home Population	Total Mobile Home Population[3]	High (92%) Tourist Population[4]	Vulnerable Population with High Tourist Occ
Countywide	218,289	21,918	196,371	21,918	9,902	228,191
I	10,840	1,135	9,705	21,918	9,902	41,525
II	19,373	2,007	17,366	21,918	9,902	49,186
III	27,829	2,720	25,109	21,918	9,902	56,929
IV	31,400	3,132	28,268	21,918	9,902	60,088
V	38,087	3,908	34,179	21,918	9,902	65,999
Non-Surge Area	180,202	18,010	162,192	0	0	162,192

[1]Total population is the number of residents (not tourists) living within each equivalent storm surge inundation group or in a non-surge area.
[2]Mobile home population is the number of residents living in mobile homes within each equivalent storm surge inundation group or in a non-surge area.
[3] Assumes the total countywide mobile home population will be evacuated regardless of which evacuation zone is called.
[4]Assumes that the total tourist population will be evacuated regardless of which evacuation zone is evacuated.
Source: U.S. Census Bureau, American Community Survey (ACS) 5-Year Estimates (2016-2020)

As shown in Table 6, in Baldwin County, over one third (37%) of the county's population is located within evacuation zones 1 and 2, while evacuation zone 3 has almost half of the county's population (45%).

Table 6 Baldwin County Estimated Population within Evacuation Zones

Evacuation Zones	Total Population[1]	Est. Mobile Home Population[2]	Non-Mobile Home Population	Total Mobile Home Population[3]	High (92%) Tourist Population[4]	Vulnerable Population with High Tourist Occ
Countywide	218,289	21,918	196,371	21,918	9,902	228,191
1	34,014	3,216	30,798	21,918	9,902	62,618
2	46,222	5,037	41,185	21,918	9,902	73,005
3	98,230	8,837	89,393	21,918	9,902	121,213
4	39,823	4,828	34,995	21,918	9,902	66,815

[1]Total population is the number of residents (not tourists) living within each evacuation zone.
[2]Mobile home population is the number of residents living in mobile homes within each evacuation zone.
[3] Assumes the total countywide mobile home population will be evacuated regardless of which evacuation zone is called.
[4]Assumes that the total tourist population will be evacuated regardless of which evacuation zone is evacuated.
Source: U.S. Census Bureau, ACS 5-Year Estimates (2016-2020)

According to spatial analysis using GIS, most structures (residential, commercial, and industrial) within Baldwin County (79%) are not impacted by storm surge inundation, as shown in Table 7.

Table 7 Baldwin County Vulnerable Structures within Equivalent Storm Surge Inundation Extents

Equivalent Storm Surge Inundation Extent Groups	Residential	Commercial	Industrial	Total	Percent
I	1,985	146	39	2,170	2%
II	7,178	407	113	7,698	9%
III	11,799	674	180	12,653	14%
IV	13,992	767	201	14,960	17%
V	17,088	927	240	18,255	21%
Not in Storm Surge	65,097	4,185	1,062	70,344	79%
TOTAL	**82,185**	**5,112**	**1,302**	**88,599**	

Source: USACE National Structure Inventory (2022).

In Table 8, evacuation zone 4 has the lowest overall concentration of structures (18%), with the highest concentration of structures in evacuation zone 3, with 38% of all residential structures and 36% of all commercial and industrial structures. The strongest intensity storms, or those within equivalent storm surge inundation extent Group V, are estimated to impact a little over one fifth (21%) of the residential housing units in the county and 18% of commercial and industrial structures. However, structures not impacted by storm surge are still vulnerable from the impacts of wind.

Table 8 Baldwin County Vulnerable Structures within Evacuation Zones

Zone	Residential	Commercial	Industrial	Total	Percent
1	15,435	887	222	16,544	19%
2	20,148	1,484	303	21,935	25%
3	31,450	1,837	463	33,750	38%
4	15,152	904	314	16,370	18%
TOTAL	**82,185**	**5,112**	**1,302**	**88,599**	**100%**

Source: USACE National Structure Inventory (2022).

The critical facilities and infrastructure key resources within Baldwin County were compiled and a GIS spatial analysis was performed to associate each facility's location with respect to evacuation zones and equivalent storm surge inundation extents. This analysis is summarized in Table 9.

Table 9 Baldwin County Vulnerable Critical Facilities and Infrastructure Key Resources within Evacuation Zones and Equivalent Storm Surge Inundation Extent Groups

Description	Facility	Total	Evacuation Zone				Extent Group					
			1	2	3	4	I	II	III	IV	V	N/A
First Responders	Police Stations	**20**	3	2	12	3	0	1	2	3	3	17
	Fire Stations	**62**	9	15	17	21	1	2	5	9	13	49
	Hospitals	**5**	0	1	3	1	0	0	0	0	0	5
Emergency Response	EOC's	**1**	0	0	1	0	0	0	0	0	0	1
	Emergency Shelters	**31**	0	7	13	11	0	0	0	0	0	31
	Government Offices	**52**	7	4	24	17	0	0	4	5	8	44
Services	Large Supply Outlets	**32**	5	11	12	4	0	1	3	4	4	28
	Mail/Shipping	**96**	26	29	29	12	1	13	18	26	27	69
	Pharmacies	**60**	8	16	26	10	0	1	5	5	7	53
	Banks	**89**	17	27	31	14	1	5	11	12	16	73
Transportation	EV Charging Stations	**21**	9	4	8	0	0	1	7	8	8	13
	Gas Stations	**127**	17	26	55	29	2	6	11	13	19	108
Supportive	Homeless Shelters	**2**	2	0	0	2	0	0	0	0	0	2
	Nursing Homes	**32**	32	0	6	18	0	0	0	0	0	32
	Senior Centers	**9**	9	1	2	4	0	0	1	1	1	8
	Schools	**59**	59	5	14	26	0	0	1	1	2	57
Tourism	Airports	**4**	1	0	2	1	0	0	1	1	1	3
	Hotels/Motels	**60**	22	22	6	10	1	10	14	17	24	36
	Boat Ramps	**13**	13	0	0	0	12	13	13	13	13	0
Utilities	Potable or WW Treatment	**12**	2	4	3	3	0	0	0	1	2	10
	Public Water Wells	**62**	15	22	17	8	1	6	12	16	21	41
	Electric Substations	**88**	12	24	31	21	1	4	9	12	12	76
	Cell Towers	**19**	7	4	3	5	0	0	4	5	7	12
Other	Dams	**23**	0	3	13	7	0	0	0	0	1	22

Mobile County

From 2010 to 2020, Mobile County's population has stayed relatively static, increasing by 1%. However, the county's population has been growing older, with the population aged 65 and older increasing 30% during this same time.

Table 10 shows approximately 3% of Mobile County's total population would be at risk of storm surge inundation from the lowest strength tropical storms and hurricanes, as defined by equivalent storm surge inundation extent Group I. Conversely, an estimated 21% of the total population of Mobile County would be impacted by storm surge inundation from the highest strength hurricanes, as defined by equivalent storm surge inundation extent Group V, which can produce maximum surge depths of more than 20 feet. High, medium, and low tourist population scenarios were also calculated for the county, with the estimated high-occupancy tourist population, using a 92% occupancy rate, included in the tables below.

Table 10 Mobile County Estimated Population within Equivalent Storm Surge Inundation Extent Groups

Equivalent Storm Surge Inundation Extent Groups	Total Population[1]	Est. Mobile Home Population[2]	Non-Mobile Home Population	Total Mobile Home Population[3]	High (92%) Tourist Population[4]	Vulnerable Population with High Tourist Occ
Countywide	413,977	29,340	384,637	29,340	8,643	422,620
I	13,682	182	13,500	29,340	8,643	51,483
II	19,314	368	18,946	29,340	8,643	56,929
III	35,974	1,331	34,643	29,340	8,643	72,626
IV	50,237	1,920	48,317	29,340	8,643	86,300
V	85,004	2,974	82,030	29,340	8,643	120,013
Non-Surge Area	328,973	26,366	302,607	0	0	302,607

[1]Total population is the number of residents (not tourists) living within each equivalent storm surge inundation group or in a non-surge area.
[2]Mobile home population is the number of residents living in mobile homes within each equivalent storm surge inundation group or in a non-surge area.
[3] Assumes the total mobile home population will be evacuated regardless of which evacuation zone is called.
[4]Assumes that the total tourist population will be evacuated regardless of which evacuation zone is evacuated.
Source: U.S. Census Bureau, ACS 5-Year Estimates (2016-2020)

In Table 11, evacuation zone 1 has the smallest percentage of Mobile County's population (13%), while evacuation zone 3 has the largest percentage, with nearly half (47%) of the county's population.

Table 11 Mobile County Estimated Population within Evacuation Zones

Evacuation Zones	Total Population[1]	Est. Mobile Home Population[2]	Non-Mobile Home Population	Total Mobile Home Population[3]	High (92%) Tourist Population[4]	Vulnerable Population with High Tourist Occ
Countywide	413,977	29,340	384,637	29,340	8,643	422,620
1	53,817	7,073	46,744	29,340	8,643	84,727
2	103,494	1,203	102,291	29,340	8,643	140,274
3	194,569	13,910	180,659	29,340	8,643	218,642
4	62,097	7,154	54,943	29,340	8,643	92,925

[1]Total population is the number of residents (not tourists) living within each evacuation zone.
[2]Mobile home population is the number of residents living in mobile homes within each evacuation zone.
[3] Assumed that the total mobile home population in Mobile County will be evacuated regardless of which evacuation zone is evacuated.
[4] Assumed that the total tourist population will be evacuated regardless of which evacuation zone is evacuated.
Source: U.S. Census Bureau, ACS 5-Year Estimates (2016-2020)

According to spatial analysis using GIS, most structures (79%) within Mobile County are not impacted by storm surge inundation. As shown in Table 12, the strongest intensity storms, as defined by equivalent storm surge inundation extent Group V, are estimated to impact 21% of the county's structures. Mobile homes/trailers are least at risk of storm surge, with just 10% of all structures estimated to be impacted by equivalent storm surge inundation extent Group V. However, structures not impacted by storm surge are still vulnerable from the impacts of wind.

Table 12 Mobile County Vulnerable Structures within Equivalent Storm Surge Inundation Extent Groups

Equivalent Storm Surge Inundation Extent Groups	Residential	Mobile Homes/ Trailers	Commercial	Industrial	Total	Percent
I	3,207	52	165	147	3,571	2%
II	6,446	105	333	257	7,141	4%
III	12,799	380	1,138	616	14,933	8%
IV	18,573	548	1,613	823	21,557	11%
V	35,525	849	2,588	1,212	40,174	21%
Not in Storm Surge	134,266	7,527	6,087	867	148,747	79%
TOTAL	**169,791**	**8,376**	**8,675**	**2,079**	**188,921**	**100%**

As shown in Table 13, in Mobile County, evacuation zone 1 has the lowest overall concentration of structures (16%); however, it has a large number of industrial structures (41%). The highest concentration of structures is in evacuation zone 3 with 37% of residential structures and 42% of commercial structures.

Table 13 Mobile County Vulnerable Structures within Evacuation Zones

Zone	Residential	Mobile Homes/ Trailers	Commercial	Industrial	Total	Percent
1	25,915	2,012	1,509	848	30,284	16%
2	47,420	345	3,216	971	51,952	28%
3	62,491	3,968	3,637	221	70,317	37%
4	33,965	2,051	313	39	36,368	19%
TOTAL	**169,791**	**8,376**	**8,675**	**2,079**	**188,921**	**100%**

The critical facilities and infrastructure key resources within Mobile County were compiled and a GIS spatial analysis was performed to associate each facility's location with respect to evacuation zones and equivalent storm surge inundation extents. This analysis is summarized in Table 14.

Table 14 Mobile County Vulnerable Critical Facilities and Infrastructure Key Resources within Evacuation Zones and Equivalent Storm Surge Inundation Extent Groups

Description	Facility	Total	Evacuation Zone				Extent Group					
			1	2	3	4	I	II	III	IV	V	N/A
First Responders	Police Stations	**35**	7	21	6	1	0	2	7	10	16	19
	Fire Stations	**65**	13	19	20	13	0	2	6	9	15	50
	Hospitals	**8**	0	3	5	0	0	0	0	2	2	6
Emergency Response	EOC	**1**	0	0	1	0	0	0	0	0	0	1
	EMA Distribution	**39**	10	13	12	4	1	2	6	6	9	30
	Emergency Shelters	**21**	1	4	12	4	0	0	0	0	0	21
	Government Offices	**41**	6	25	8	2	0	5	15	18	22	19
Services	Large Supply Outlets	**59**	7	19	27	6	0	1	3	7	10	49
	Mail/Shipping	**161**	6	63	88	4	2	4	21	30	45	116
	Pharmacies	**106**	5	44	48	9	0	2	6	14	26	80
	Banks	**113**	8	42	58	5	3	6	16	18	29	84
Transportation	EV Charging Stations	**27**	1	18	8	0	4	5	10	12	14	13
	Gas Stations	**329**	51	110	112	56	1	6	21	39	62	267
Supportive	Homeless Shelters	**8**	1	5	2	0	0	1	3	4	4	4
	Nursing Homes	**43**	1	13	25	4	0	0	1	3	7	36
	Senior Centers	**6**	1	2	2	1	0	0	1	1	1	5
	Schools	**194**	24	74	73	23	0	1	6	15	32	162
Tourism	Airports	**5**	4	0	1	0	0	0	0	0	2	3
	Hotels/Motels	**74**	4	30	34	6	1	3	12	16	20	54
	Boat Ramps	**14**	14	0	0	0	13	14	14	14	14	0
Utilities	Potable or WW Treatment	**12***	2	5	2	2	0	1	2	3	7	5
	Public Water Wells	**102**	20	6	59	17	2	3	5	5	9	93
	Electric Substations	**173***	57	35	56	24	3	4	18	29	52	121
	Power Plants	**7**	3	4	0	0	0	0	0	2	6	1
	Cell Towers	**13**	5	0	3	5	1	3	3	3	3	10
Other	HAZMAT	**2**	0	2	0	0	0	0	0	0	0	2
	Dams	**33**	2	0	13	18	0	0	0	0	1	32

**Clifton C. Williams Wastewater Treatment Plant and one substation riser are not within defined evacuation zones.*

1.4 BEHAVIORAL ANALYSIS - EVACUATION PARTICIPATION

Evacuation participation rates are the percentage of the population within each evacuation zone that are expected to evacuate for tropical cyclones, including shadow evacuees who evacuate even when they are not ordered to. The evacuation participation rates were developed through comparison of prior demographic data collected during the *2012 Alabama HES Behavioral Analysis* and updated U.S. Census Bureau [2016-2020, American Community Survey (ACS) 5-Year estimates] demographic data. Based on socio-demographic changes and assumptions about the population, responses from the prior *2012 Alabama HES Behavioral Analysis* on evacuation likelihood were adjusted to provide an updated prediction of the current evacuation participation rates. These adjusted evacuation participation rates were then presented to county and state EMAs stakeholders for validation and refinement to match local knowledge and previously observed evacuation behaviors.

Table 15 and Table 16 display the updated estimated evacuation participation over a range of low, medium, and high scenarios for Baldwin and Mobile Counties, respectively. As no storm is the same, scenarios for low, medium, and high evacuation participation rates were identified to allow for greater flexibility in evaluating and assessing the possible impacts of a hurricane event. The evacuation participation rates represent the proportion of the population, including shadow evacuees, which are expected to evacuate outside of the county during a given storm intensity.

Table 15 Baldwin County Evacuation Participation Rates

HIGH Evacuation Participation Rate – Baldwin						
Zone	TS	Cat 1	Cat 2	Cat 3	Cat 4	Cat 5
1	70%	70%	70%	90%	100%	100%
2	65%	65%	65%	85%	95%	95%
3	60%	60%	60%	80%	90%	90%
4	55%	55%	55%	75%	85%	85%

MEDIUM Evacuation Participation Rate – Baldwin						
Zone	TS	Cat 1	Cat 2	Cat 3	Cat 4	Cat 5
1	20%	20%	25%	50%	65%	70%
2	15%	15%	20%	45%	60%	65%
3	10%	10%	15%	35%	50%	55%
4	5%	5%	5%	20%	35%	40%

LOW Evacuation Participation Rate – Baldwin						
Zone	TS	Cat 1	Cat 2	Cat 3	Cat 4	Cat 5
1	10%	15%	15%	50%	50%	55%
2	5%	10%	10%	35%	40%	50%
3	5%	5%	10%	20%	25%	25%
4	5%	5%	5%	10%	10%	15%

Table 16 Mobile County Evacuation Participation Rates

HIGH Evacuation Participation Rate – Mobile						
Zone	TS	Cat 1	Cat 2	Cat 3	Cat 4	Cat 5
1	55%	55%	55%	65%	75%	80%
2	50%	50%	50%	60%	70%	75%
3	45%	45%	45%	55%	65%	70%
4	40%	40%	40%	50%	55%	60%

MEDIUM Evacuation Participation Rate – Mobile						
Zone	TS	Cat 1	Cat 2	Cat 3	Cat 4	Cat 5
1	15%	20%	25%	40%	55%	60%
2	10%	15%	20%	35%	50%	55%
3	5%	10%	15%	30%	45%	50%
4	5%	5%	10%	15%	25%	30%

LOW Evacuation Participation Rate – Mobile						
Zone	TS	Cat 1	Cat 2	Cat 3	Cat 4	Cat 5
1	5%	10%	15%	35%	35%	40%
2	5%	10%	10%	20%	25%	30%
3	5%	5%	5%	5%	10%	10%
4	5%	5%	5%	5%	5%	5%

From 2010 to 2020, Baldwin County has experienced a population increase of 24%, or 42,498 people, as shown in Table 17. Most of this population growth has occurred in inland areas away from the coast, with Zone 3 gaining over half (57%) of the new population and Evacuation Zone 1 experiencing a population decline of 9%.

Table 17 Baldwin County Population Change

Evacuation Zone	2010 Population	2020 Population	Change	% Change
Zone 1	37,175	34,014	-3,161	-9%
Zone 2	34,709	46,222	11,513	33%
Zone 3	74,204	98,230	24,026	32%
Zone 4	29,702	39,823	10,121	34%
Total	**175,791**	**218,289**	**42,498**	**24%**

Source: U.S. Census Bureau, 2016-2020 ACS 5-Year Estimates

Mobile County's population has remained generally consistent from 2010 to 2020, increasing a moderate 1%, or 5,357 people, as shown in Table 18. This growth has occurred in Zones 3 and 4, with Zone 1 and 2 both experiencing population loss.

Table 18 Mobile County Population Change

Evacuation Zone	2010 Population	2020 Population	Change	% Change
Zone 1	55,542	54,183	-1,359	-2%
Zone 2	115,862	104,622	-11,240	-10%
Zone 3	179,410	192,147	12,737	7%
Zone 4	57,805	63,025	5,220	9%
Total	**408,620**	**413,977**	**5,357**	**1%**

Source: U.S. Census Bureau, 2016-2020 ACS 5-Year Estimates

The updated evacuation participation rates are multiplied by the U.S. Census population data (shown in Table 17 and Table 18) for each evacuation zone to determine the estimated number of people expected to evacuate for different intensity tropical cyclones.

1.5 TRANSPORTATION ANALYSIS - EVACUATION CLEARANCE TIMES

A notable change compared to previous Transportation Analyses studies is the use of the Real Time Evacuation Planning Model (RtePM), a free, web-based transportation modeling tool with updated population and transportation network data sources. The primary outputs of RtePM are the clearance times from an evacuation. A clearance time represents the time it takes to clear the roadway of all evacuating vehicles, measured from the moment an evacuation order is issued until the time when the final evacuating vehicle reaches its point of safety. RtePM also graphically shows the overall evacuation traffic control flow on an hourly timestep. However, it is a macro-scale transportation model; therefore, it is not designed to model the exact traffic flow, does not contain the entire roadway network, and approximates population, behavior, and traffic. 265 different evacuation scenarios were run to provide Alabama and Mississippi emergency managers with an array of parameters and a range of clearance times to better plan for an evacuation. Input that was coordinated with local, state, and federal agencies included, but was not limited to the following:

- Combinations of zones to be evacuated during local vs. regional evacuations
- Overall evacuation participation rates
- Public shelter participation rates
- Road modifications (i.e., contraflow)
- Evacuation destinations
- Evacuation routing
- Evacuation response rates
- Background traffic conditions
- Seasonal (tourist) populations.

Some evacuation scenarios modeled during the *Alabama/Mississippi (ALMS) HES Transportation Analysis- 2023 Re-Study* include Louisiana and Florida evacuees. However, the results from the *ALMS HES Transportation Analysis - 2023 Re-Study* do not supersede and nor dictate any changes to the recently completed *Southeast Louisiana HES and Emerald Coast Regional Council Regional Evacuation Study* in Florida (which encompasses the Pensacola area in Escambia County, Florida).

The inputs and results of the Southeast Louisiana and the Emerald Coast evacuation studies were reviewed to inform the *ALMS HES Transportation Analysis – 2023 Re-Study* only.

Table 19 summarizes the range of clearance times given four evacuating geographies: Alabama only; Mississippi only; Mobile County, Alabama and Jackson County, Mississippi; and the ALMS region, which includes combined Alabama and Mississippi counties and neighboring states. The range of clearance times also represents the implementation of high, medium, and low, evacuation participation rates. Countywide scenarios with progressive zone evacuation (zone A, zone A+, zone B, etc.) were modeled and documented as a sensitivity analysis but are not considered scenarios for overall regional evacuation planning.

Table 19 Range of Clearance Times by Participation Rates

Region	Evacuation Participation Rate[1]	Evacuation Clearance Time (Hours)
Alabama Scenarios (includes scenarios with and without Florida)	High	24-43
	Medium	9-36
	Low	7-32
Mississippi Scenarios (includes scenarios with and without Louisiana)	High	14-44
	Medium	8-32
	Low	7-32
ALMS Regional Scenarios (includes scenarios with and without Louisiana and with and without Florida)	High	22-43
	Medium	17-35
	Low	12-31

[1] *Low, Medium, and High participation rates are referenced from Alabama Hurricane Evacuation Study Behavioral Analysis – 2022 Re-Study and Mississippi Hurricane Evacuation Study Behavioral Analysis – 2022 Re-Study.*

Although this report and the figures, appendices, and charts related to the HES are static, the results from the newly updated SLOSH model and RtePM are best leveraged in a dynamic mapping environment and are intended to be integrated into the National Hurricane Program's web-based platform, HURRicane EVACuation Tracking and Analysis Software (HURREVAC), a widely used hurricane decision-support tool. In addition, the ability to use RtePM allows users to test many different evacuation scenarios, which makes this macro-scale model a useful tool in the decision-making toolbox. Geographic information system databases containing data and maps are included in the Online county-specific HES Dashboards (discussed in Section 1.1 of this report) associated with each state's Vulnerability Analysis. The results and information can be shared between federal, state, tribal, and local levels of government to quickly make decisions and to better inform the general public when a storm approaches.

The most critical evacuation scenarios involve evacuating the most people, which are shown in Table 20. The clearance times, evacuating vehicles, and evacuating population are included for each scenario. All of these scenarios are for Category 4 or Category 5 storm events without contraflow and with high participation from evacuating population and seasonal population. Also, the most critical evacuation scenarios include Louisiana and Florida population.

Table 20 Critical Evacuation Scenarios

Scenario	Clearance Time (hours)	Evacuating Vehicles	Evacuating Population
ALMS-169	30	668,538	1,318,083
ALMS-170	35	790,346	1,558,939
ALMS-171	40	905,296	1,784,425
ALMS-172	31	687,171	1,352,170
ALMS-173	35	813,708	1,602,265
ALMS-174	40	916,192	1,805,130
ALMS-193	31	668,538	1,318,083
ALMS-194	35	790,346	1,558,939
ALMS-195	40	905,296	1,784,425
ALMS-196	31	687,171	1,352,170
ALMS-197	35	813,708	1,602,265
ALMS-198	40	916,192	1,805,130

Evacuation clearance times data has been included in the HES Data Tables template provided by USACE, but the transportation scenarios companion spreadsheet developed for the *ALMS HES Transportation Analysis – 2023 Re-Study* has more detailed inputs and outputs for each scenario and is more easily sortable than the HES Data Tables. There were no factors added to increase evacuation clearance times for a simultaneous evacuation of a neighboring state. The evacuating population and roadway network from those states were incorporated into the relevant evacuation scenarios. The RtePM default value of 80% for contraflow/lane reversal efficiency was used for the portions of the roadway network where contraflow was applied.

1.6 SHELTER DEMAND

Shelter demand (the number of evacuees seeking public shelter during hurricane evacuations) were estimated for different hurricane events at a range of high, medium, and low evacuation participation rates using the estimated population (from the ACS 5-Year Estimates 2016-2020) for each evacuation zone. The evacuating population for each scenario was then multiplied by the same shelter usage rate of 5%, which was agreed upon by both Baldwin and Mobile Counties and state EMA stakeholders. Table 21 and Table 22 display the estimated evacuating resident population seeking shelter for various storm and shelter participation scenarios (e.g. low, medium, and high) in Baldwin and Mobile Counties, respectively. The estimated shelter demands vary per evacuation zone since population varies between evacuation zones.

Table 21 Baldwin County Estimated Shelter Demands

Estimated Resident Population Seeking Shelters (Shelter Demand Rounded to Nearest 10)						
HIGH Shelter Participation						
Zone	TS	Cat 1	Cat 2	Cat 3	Cat 4	Cat 5
1	1,200	1,200	1,200	1,540	1,710	1,710
2	1,510	1,510	1,510	1,970	2,200	2,200
3	2,950	2,950	2,950	3,930	4,430	4,430
4	1,100	1,100	1,100	1,500	1,700	1,700
TOTAL	**6,760**	**6,760**	**6,760**	**8,940**	**10,040**	**10,040**
MEDIUM Shelter Participation						
Zone	TS	Cat 1	Cat 2	Cat 3	Cat 4	Cat 5
1	350	350	450	900	1,150	1,200
2	350	350	500	1,050	1,400	1,550
3	500	500	750	1,750	2,500	2,750
4	100	100	100	400	700	800
TOTAL	**1,300**	**1,300**	**1,800**	**4,100**	**5,750**	**6,300**
LOW Shelter Participation						
Zone	TS	Cat 1	Cat 2	Cat 3	Cat 4	Cat 5
1	200	300	300	900	900	950
2	150	250	250	850	950	1,200
3	250	250	500	1,000	1,250	1,250
4	100	100	100	200	200	300
TOTAL	**700**	**900**	**1,150**	**2,950**	**3,300**	**3,700**

Table 22 Mobile County Estimated Shelter Demands

Estimated Resident Population Seeking Shelters (Shelter Demand Rounded to Nearest 10)						
HIGH Shelter Participation						
Zone	TS	Cat 1	Cat 2	Cat 3	Cat 4	Cat 5
1	1,480	1,480	1,480	1,750	2,020	2,160
2	2,590	2,590	2,590	3,110	3,630	3,890
3	4,380	4,380	4,380	5,360	6,330	6,810
4	1,250	1,250	1,250	1,560	1,710	1,870
TOTAL	**9,700**	**9,700**	**9,700**	**11,780**	**13,690**	**14,730**

MEDIUM Shelter Participation						
Zone	TS	Cat 1	Cat 2	Cat 3	Cat 4	Cat 5
1	410	540	680	1,080	1,480	1,620
2	520	780	1,040	1,820	2,590	2,850
3	490	980	1,460	2,920	4,380	4,870
4	160	160	320	470	780	940
TOTAL	**1,580**	**2,460**	**3,500**	**6,290**	**9,230**	**10,280**

LOW Shelter Participation						
Zone	TS	Cat 1	Cat 2	Cat 3	Cat 4	Cat 5
1	140	270	410	950	950	1,080
2	260	520	520	1,040	1,300	1,560
3	490	490	490	490	980	980
4	160	160	160	160	160	160
TOTAL	**1,050**	**1,440**	**1,580**	**2,640**	**3,390**	**3,780**

1.7 SHELTER CAPACITY

The sheltering population was compared against general storm shelter capacities to determine surplus or deficit space for various storm and participation scenarios. Using ArcGIS, the vulnerability of shelters due to both storm surge and freshwater flooding represented by the FEMA Flood Insurance Rate Map (FIRM) 1% and 0.2% annual chance events was analyzed. None of the current storm shelters within Baldwin or Mobile Counties are located within a storm surge or FEMA floodplain risk area.

According to evacuation zone boundaries, the distribution of shelters within evacuation zones for Baldwin and Mobile Counties is shown in Table 23.

Table 23 Alabama Shelters within Evacuation Zones

County	Zone 1	Zone 2	Zone 3	Zone 4	Total
Baldwin	0	2	9	6	17
Mobile	1	4	12	4	21

Baldwin County

Baldwin County has shelter capacity deficits under high evacuation participation rate scenarios for Category 3, 4 and 5 storms. Table 24 displays the resulting county evacuation shelter capacity surplus or deficit after accounting for the estimated sheltering demand in the various scenarios with green indicating shelter capacity surplus and red indicating a capacity deficit.

Table 24 Baldwin County Shelter Capacity Surplus/Deficit

	Low	Med	High
TS	7,372	6,772	1,312
CAT 1	7,172	6,772	1,312
CAT 2	6,922	6,272	1,312
CAT 3	4,872	3,722	-1,118
CAT 4	4,522	2,072	-2,218
CAT 5	4,122	1,522	-2,218

Mobile County

Mobile County has shelter capacity deficits under high evacuation participation rate scenarios for Category 4 and 5 storms. Table 25 displays the resulting county evacuation shelter capacity surplus or deficit after accounting for the estimated sheltering demand in the various scenarios with green indicating shelter capacity surplus and red indicating a capacity deficit.

Table 25 Mobile County Shelter Capacity Surplus/Deficit

	Low	Med	High
TS	12,150	11,620	3,500
CAT 1	11,760	10,740	3,500
CAT 2	11,620	9,700	3,500
CAT 3	10,560	6,910	1,420
CAT 4	9,810	3,970	-490
CAT 5	9,420	2,920	-1,530

Important to note is that while Craighead Elementary School and Eichold-Mertz Magnet School shelters were included in the total capacity, during a Category 5 storm these areas can potentially become isolated. While these shelters are still assumed to be useable during all storm events, the choice of opening public shelters for a specific evacuation is determined by state and county authorities and changes based on a variety of circumstances including storm intensity, storm direction, and availability of qualified shelter operators.

2 BACKGROUND AND COMMENTARY

2.1 EVACUATION ZONES AND STORM SCENARIOS

National Hurricane Center (NHC) 2018 MS8 Basin for SLOSH Model was used for the updated Hazard Analysis. A comparison was made between the estimated storm surge inundation covering land areas from the 2008 Mobile Bay (MO2) SLOSH Basin modeled MOMs and from the 2018 MS8 SLOSH Basin modeled MOMs for the five categories of hurricanes. All of the modeled inundation land area coverage increased between the 2008 MO2 and 2018 MS8 SLOSH models, with higher percentages of change occurring in Mobile County than Baldwin County. Also, higher percentages of change in inundation areas occurred with Category 1 MOMs than other category storms, with percentages of change decreasing with increasing storm intensities. For example, in Baldwin County for a Category 5 MOM, storm surge inundation only increased 0.3% between the 2008 MO2 and 2018 MS8 SLOSH models, but increased 3% for the Category 4 MOM, 6% for the Category 3 MOM, 9% for the Category 2 MOM, and 25% for the Category 1 MOM.

A new methodology utilizing directional MEOW output data was developed for this updated Hazard Analysis. Previous hazard mapping of MOMs was only according to storm intensity. The new analysis included effects from intensity, directional approach, and forward speed. Directional MEOW maps show the influence that approach direction has on storm surge. Equivalent inundation extent maps were developed from directional MEOWs of different intensities and forward speeds which produced similar maximum surge depths. The intent of this new methodology is to provide emergency planners with a more detailed look into which storms produce similar risks.

For somewhat protected areas such as Mobile Bay, it was noted the storm intensity (storm category) and the approach direction typically have the most influence on surge height, with forward speed having less influence. The higher the intensity, generally the larger the storm size and the wider the wind field, which pushes more water further inland. However, when there is a wide open fetch in the direction of the hurricane approach to land, the inundation depths produced are more sensitive to the forward speed. In addition, storms that are moving parallel to the coast, east to west, also exhibit a larger influence from forward speed than storms moving west to east, due to the additive relative velocity forces produced from forward speed and counter clockwise rotation of the winds in the upper right quadrant of the storm.

Considering all storm categories (e.g., Tropical Storm through Category 5 Hurricane) and forward speeds (e.g., 2, 5, 10, 15, and 25 mph), the maximum inundation depths were plotted for all 9 storm approach directions to determine the worst and best cases. The north approach direction produced the most areas inundated with the highest surge heights due to water pushing into Mobile Bay and up the Mobile River. The east northeast approach direction produced the least areas inundated with the lowest surge heights due to the storm moving nearly parallel to the coastline and not pushing as much water into Mobile Bay and up the Mobile River.

The inundation extents for composited directional MEOWs for Baldwin and Mobile Counties were sorted into 5 groups (I through V) according to maximum surge depths. This new approach

enabled comparison of similar surge impacts from 6 different intensity storms (e.g., Categories 0 through 5) and 9 approach directions resulting in 54 storm scenarios. Figure 5 to Figure 9 (Baldwin County) and Figure 10 to Figure 14 (Mobile County) depict the equivalent inundation extents for each maximum surge depth group for directional MEOWs for the coastal counties. The associated tables in the figures show which storm intensities and directions produce equivalent maximum surge depths within groups. For instance, in Figure 7, Baldwin County Group III shows extents of surge inundation flooding up to 16 feet in depth for various Category 1, 2, 3, or 4 storms of varying approach directions that produce maximum depths of 12 – 16 feet.

Included in the associated tables are the MOMs for each category storm (e.g., 6 storms with Categories 0 through 5) that produced similar equivalent inundation depths to the directional MEOW Groups I through V. For instance, Group III is also associated with a Category 1 MOM storm as indicated in Figure 7.

The *Alabama HES Hazard Analysis – 2022 Re-Study* for the Alabama coastal counties of Baldwin and Mobile provided additional resources including the following:

- Freshwater flooding information regarding the latest FEMA Flood Insurance Rate Map (FIRM) floodplain mapping.

- Wind Extent Maps (WEMs) produced from directional Maximum Envelopes of Wind that were developed for 5 forward speeds (8, 12, 16, 20, and 24 knots) using the 2021 National Oceanic and Atmospheric Administration (NOAA) Wind Speed Decay Modeling polygons based on the Saffir-Simpson Hurricane Wind Scale. WEMs depict the estimated furthest inland wind extents for sustained wind speeds for representative tropical cyclones making landfall from the Gulf of Mexico.

Figure 5 Baldwin County – Equivalent Storm Surge Inundation Extent Map: Group I

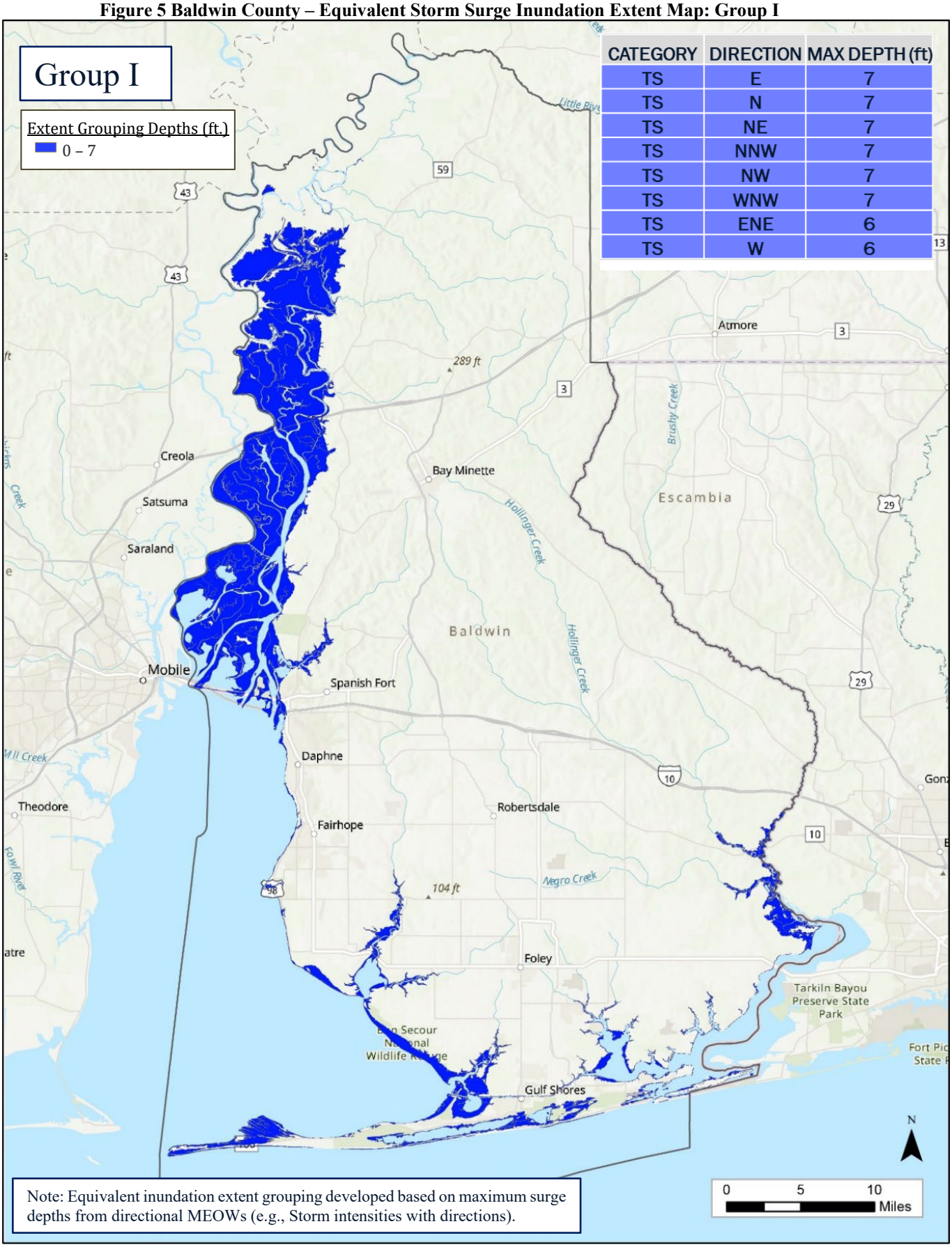


Figure 6 Baldwin County – Equivalent Storm Surge Inundation Extent Map: Group II

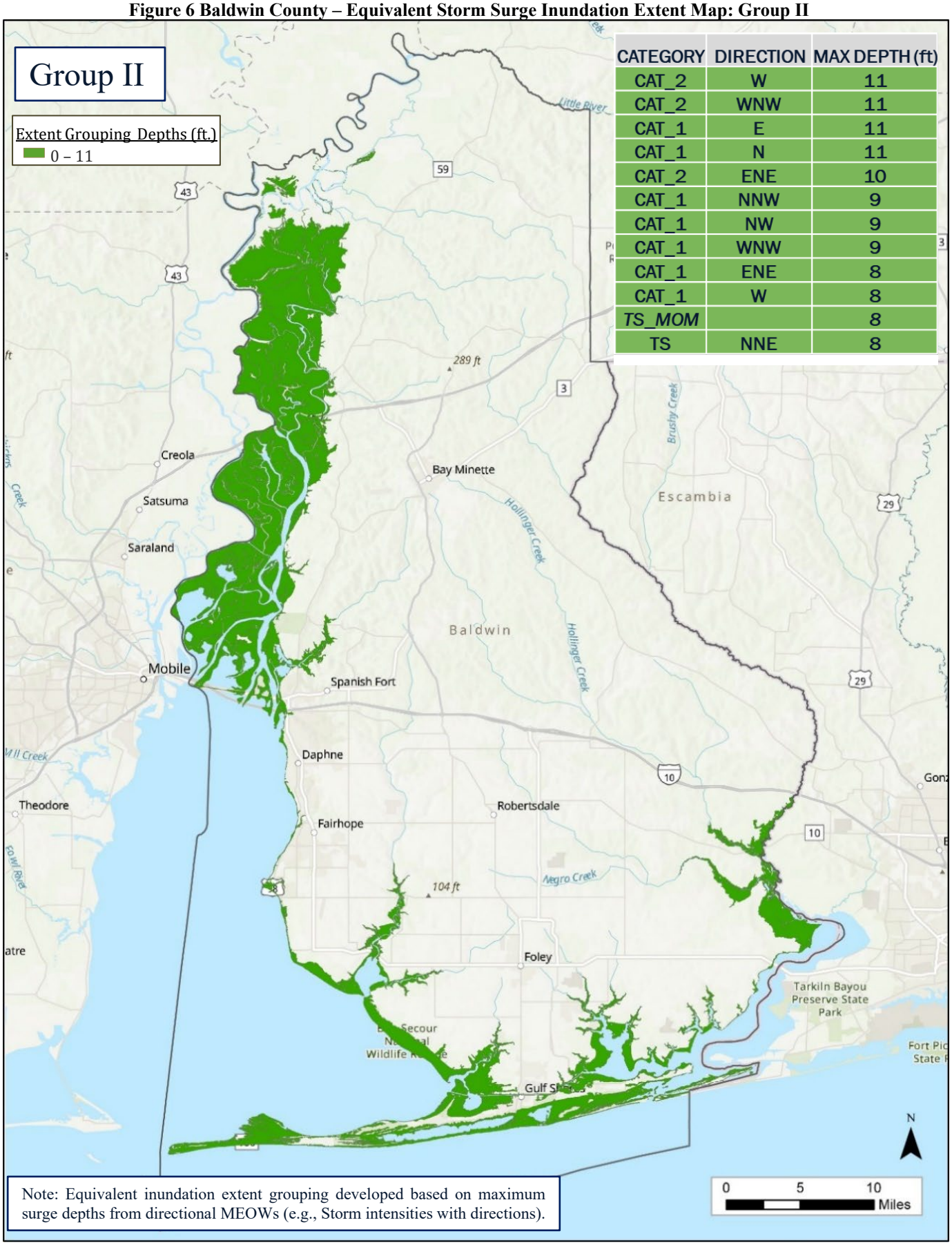


Figure 7 Baldwin County – Equivalent Storm Surge Inundation Extent Map: Group III

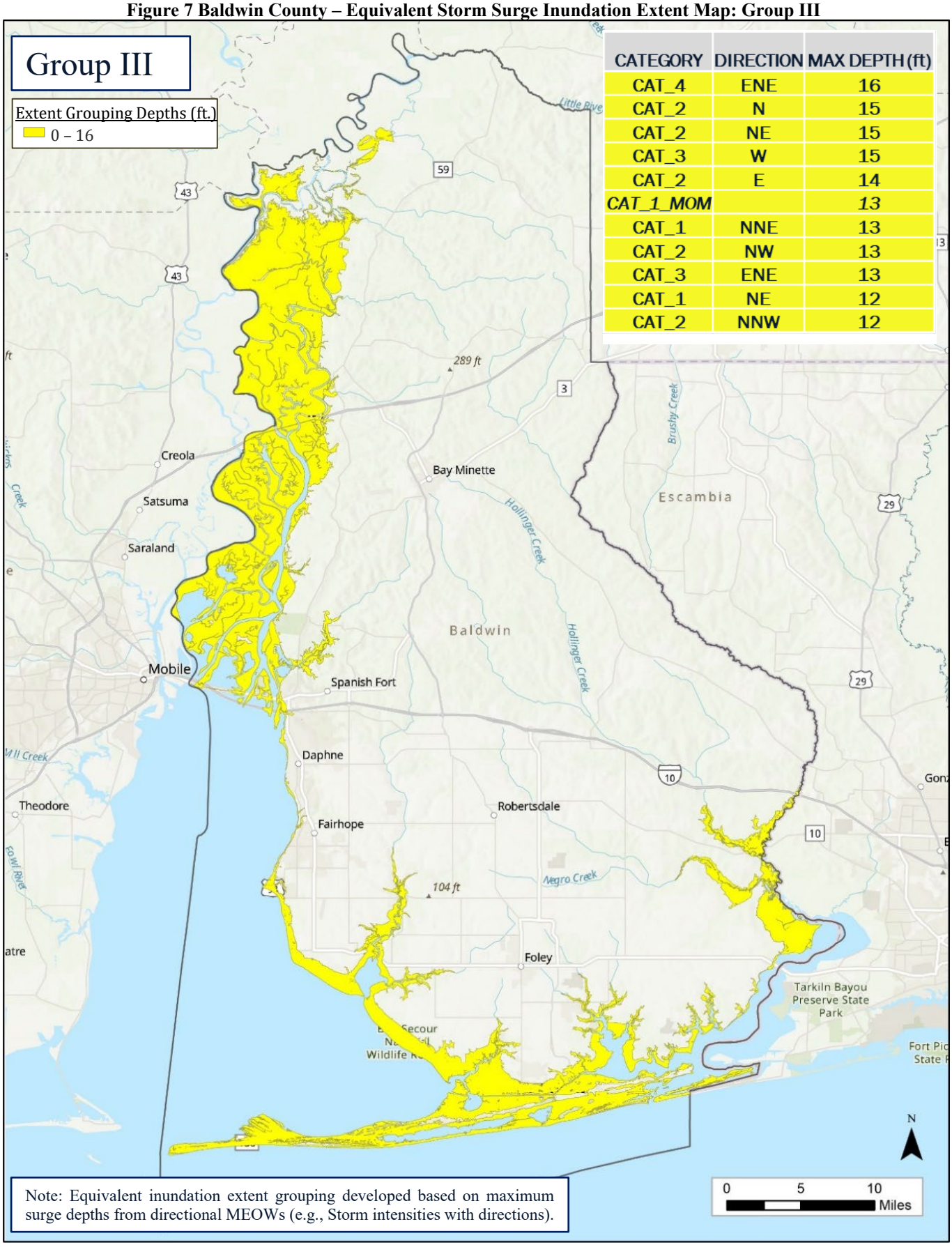
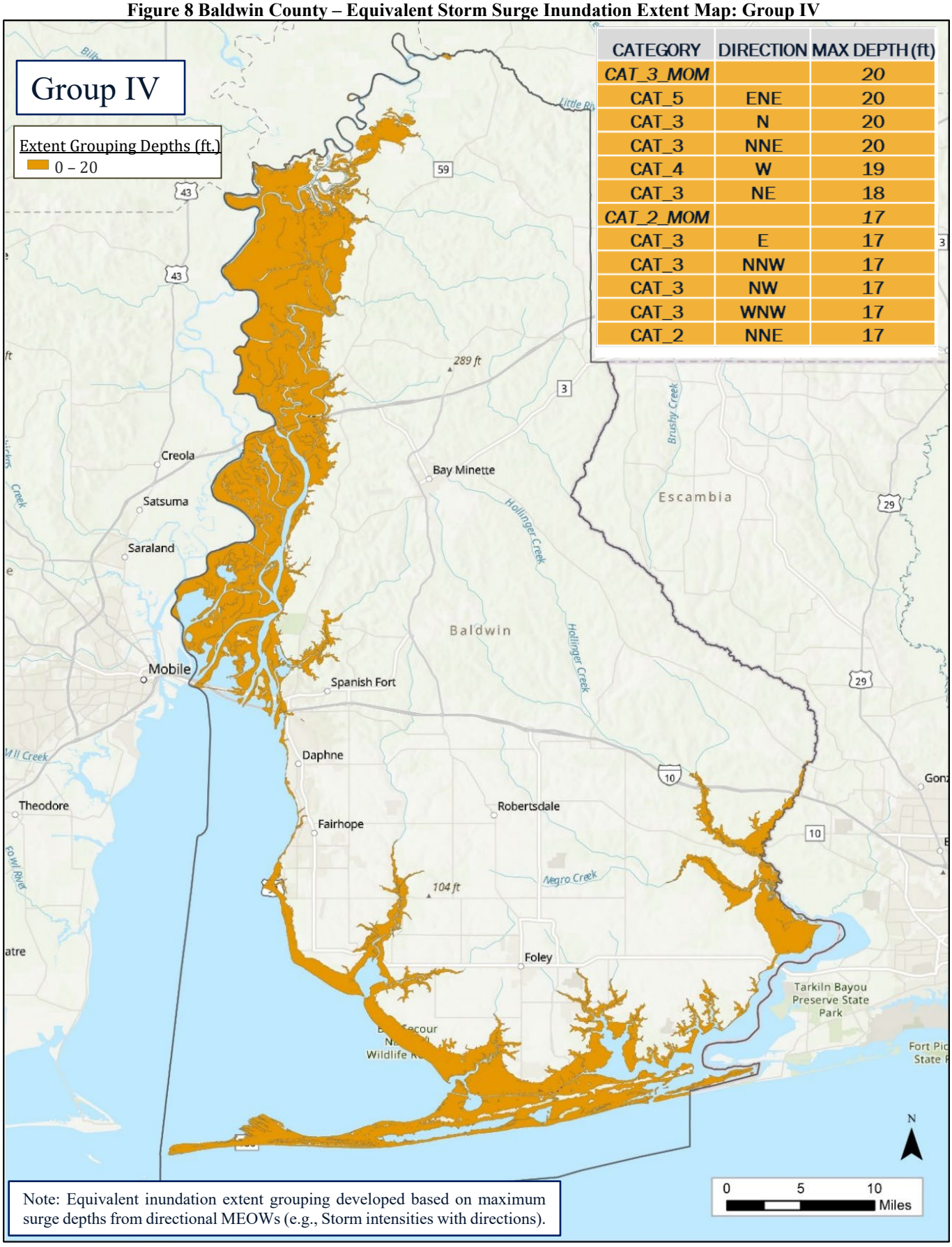


Figure 8 Baldwin County – Equivalent Storm Surge Inundation Extent Map: Group IV



Note: Equivalent inundation extent grouping developed based on maximum surge depths from directional MEOWs (e.g., Storm intensities with directions).

Figure 9 Baldwin County – Equivalent Storm Surge Inundation Extent Map: Group V

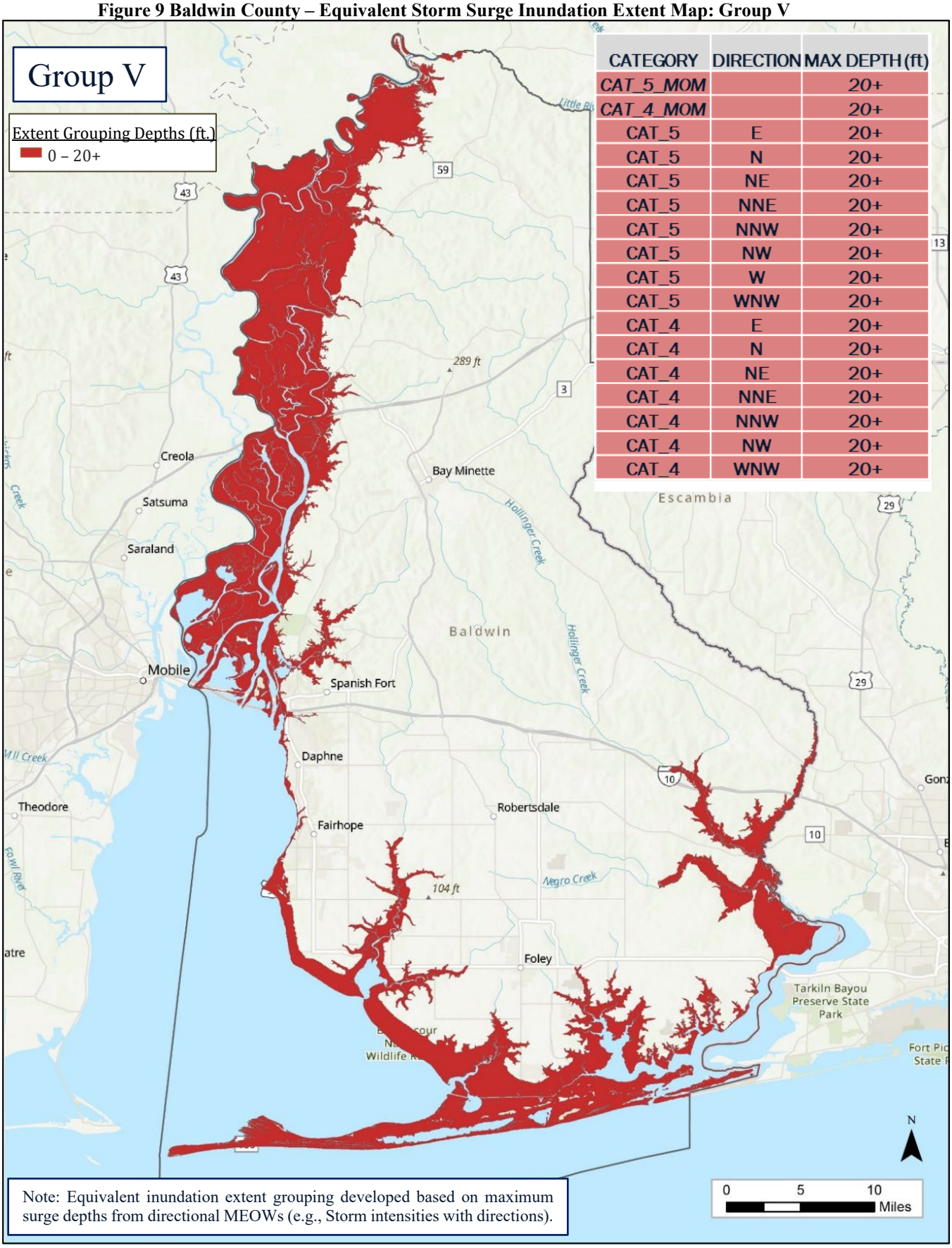


Figure 10 Mobile County – Equivalent Storm Surge Inundation Extent Map: Group I

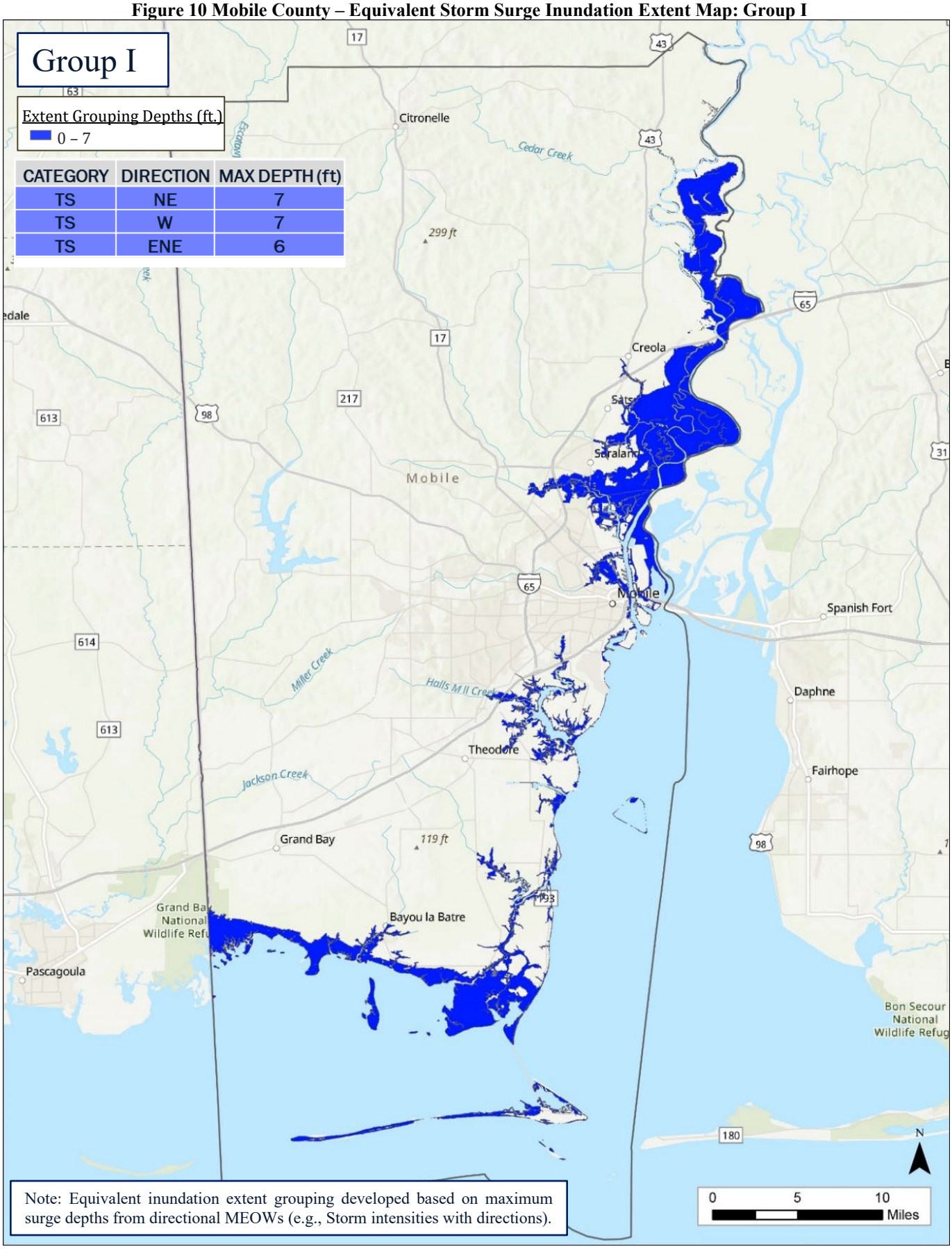


Figure 11 Mobile County – Equivalent Storm Surge Inundation Extent Map: Group II

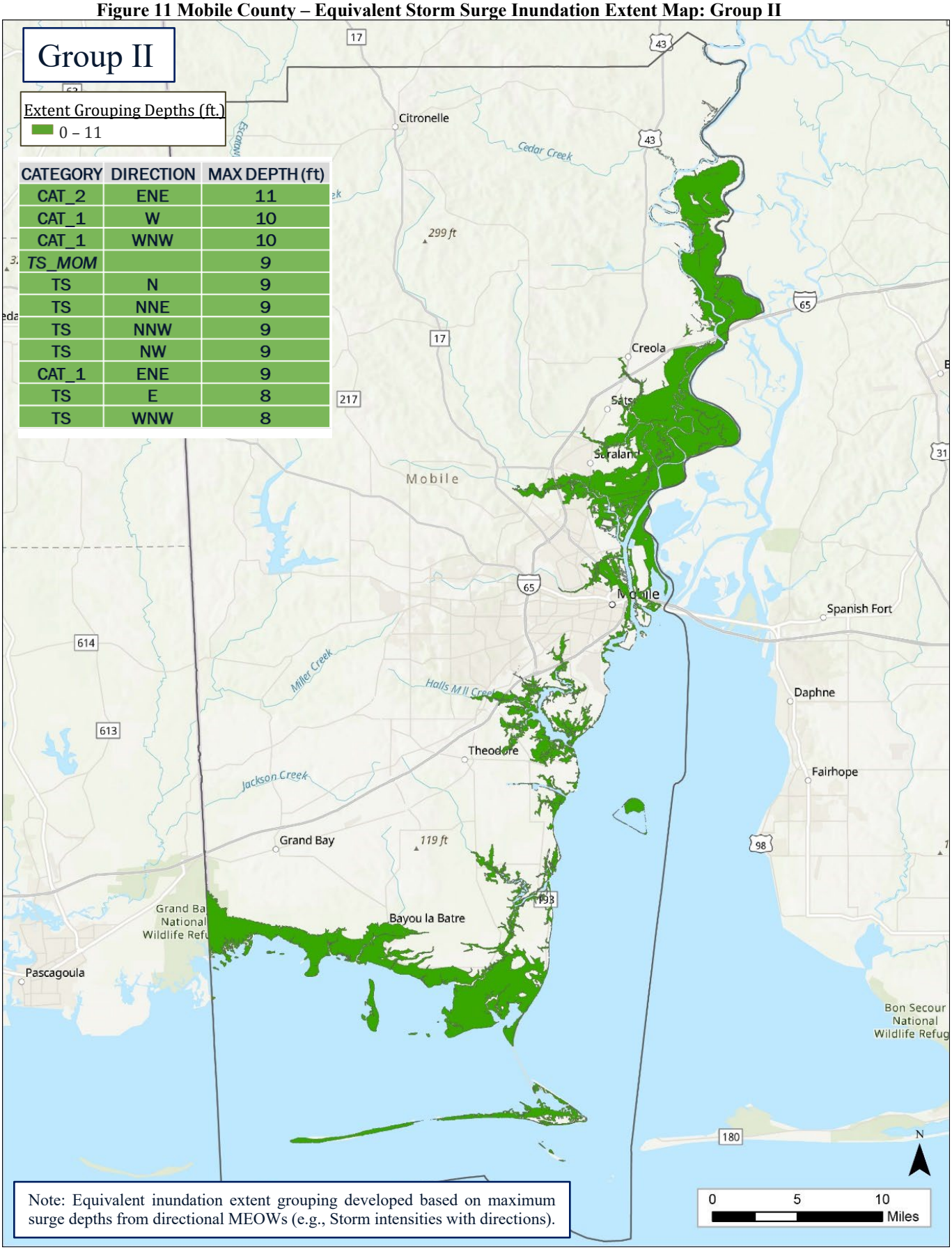
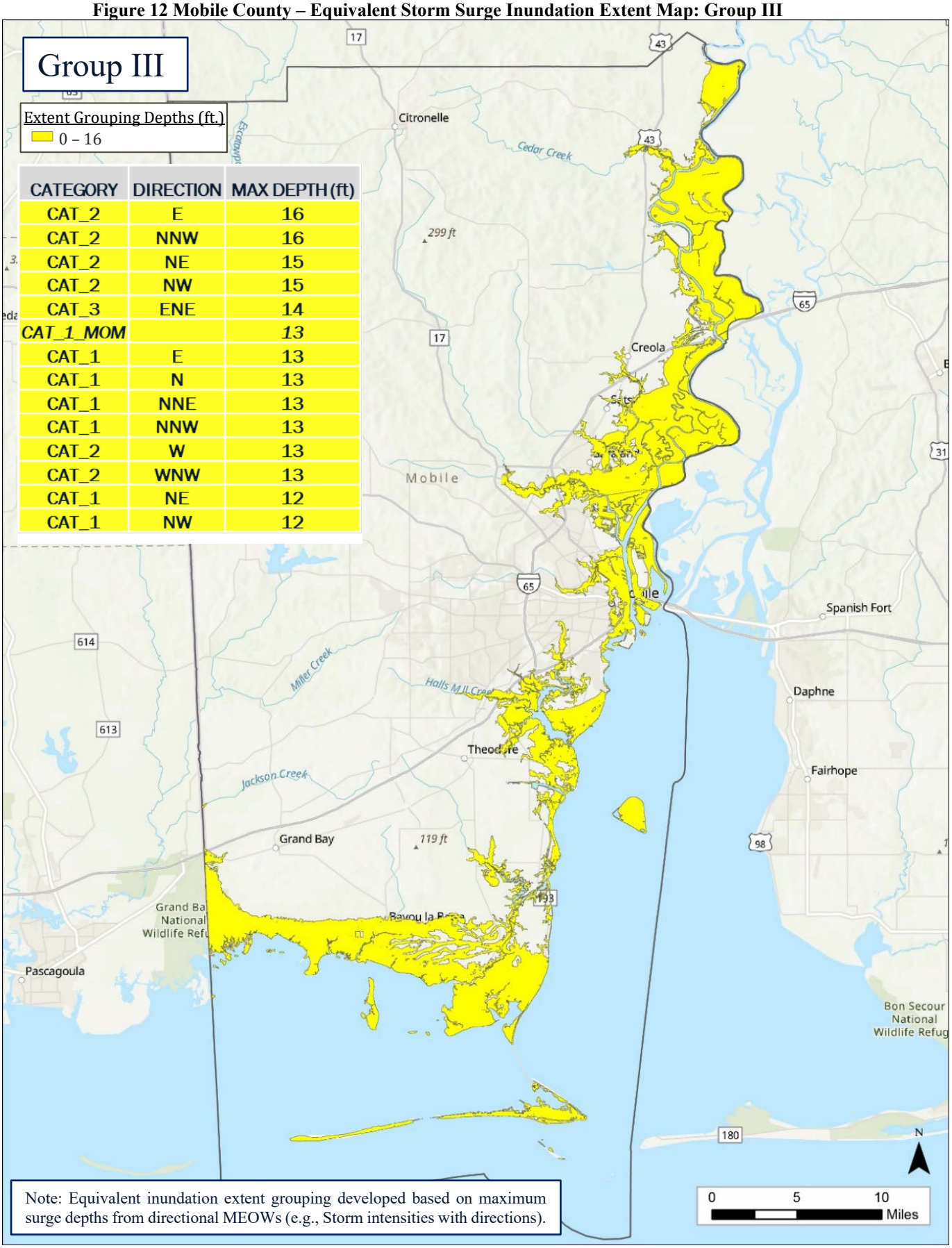


Figure 12 Mobile County – Equivalent Storm Surge Inundation Extent Map: Group III



CATEGORY	DIRECTION	MAX DEPTH (ft)
CAT_2	E	16
CAT_2	NNW	16
CAT_2	NE	15
CAT_2	NW	15
CAT_3	ENE	14
CAT_1_MOM		*13*
CAT_1	E	13
CAT_1	N	13
CAT_1	NNE	13
CAT_1	NNW	13
CAT_2	W	13
CAT_2	WNW	13
CAT_1	NE	12
CAT_1	NW	12

Figure 13 Mobile County – Equivalent Storm Surge Inundation Extent Map: Group IV

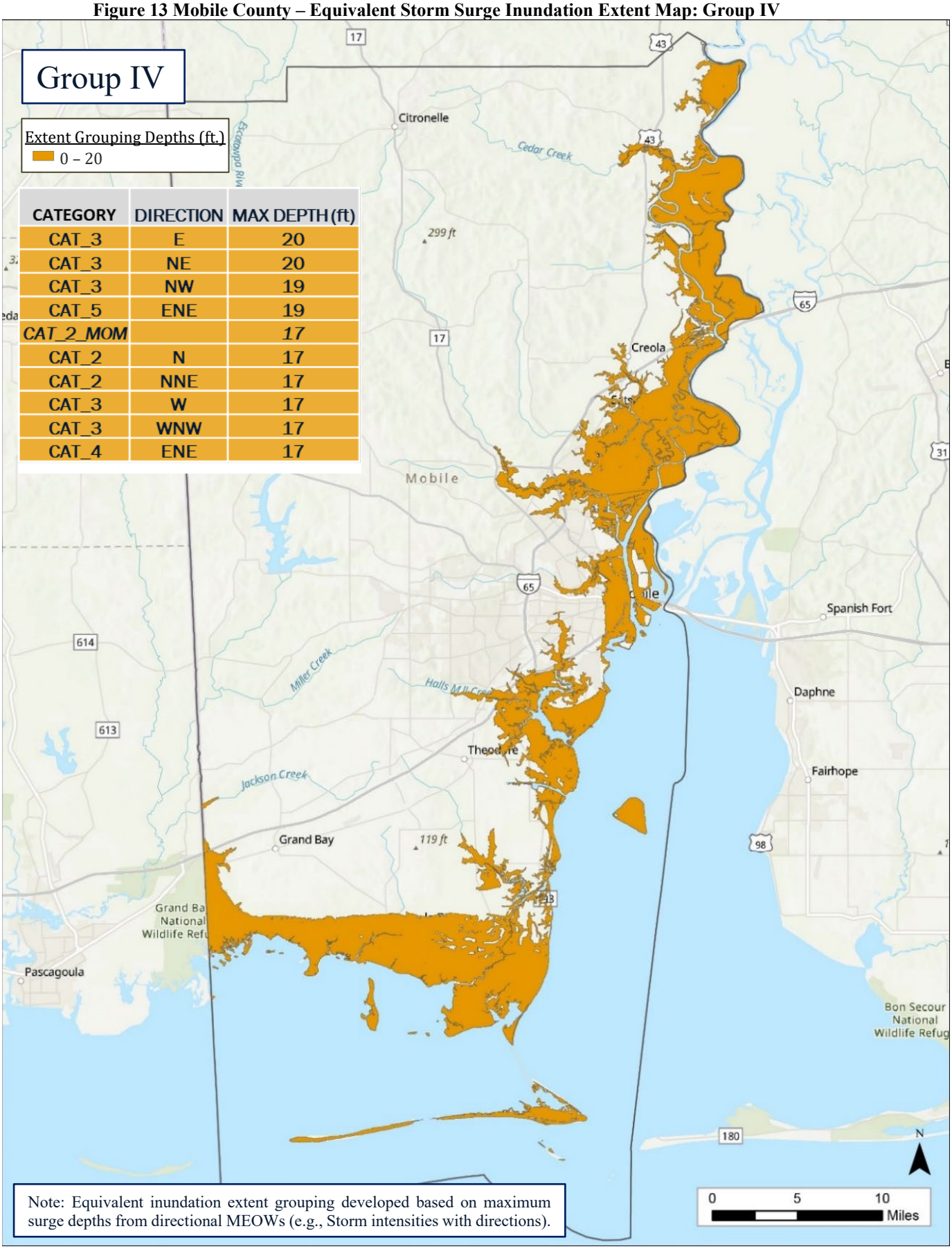
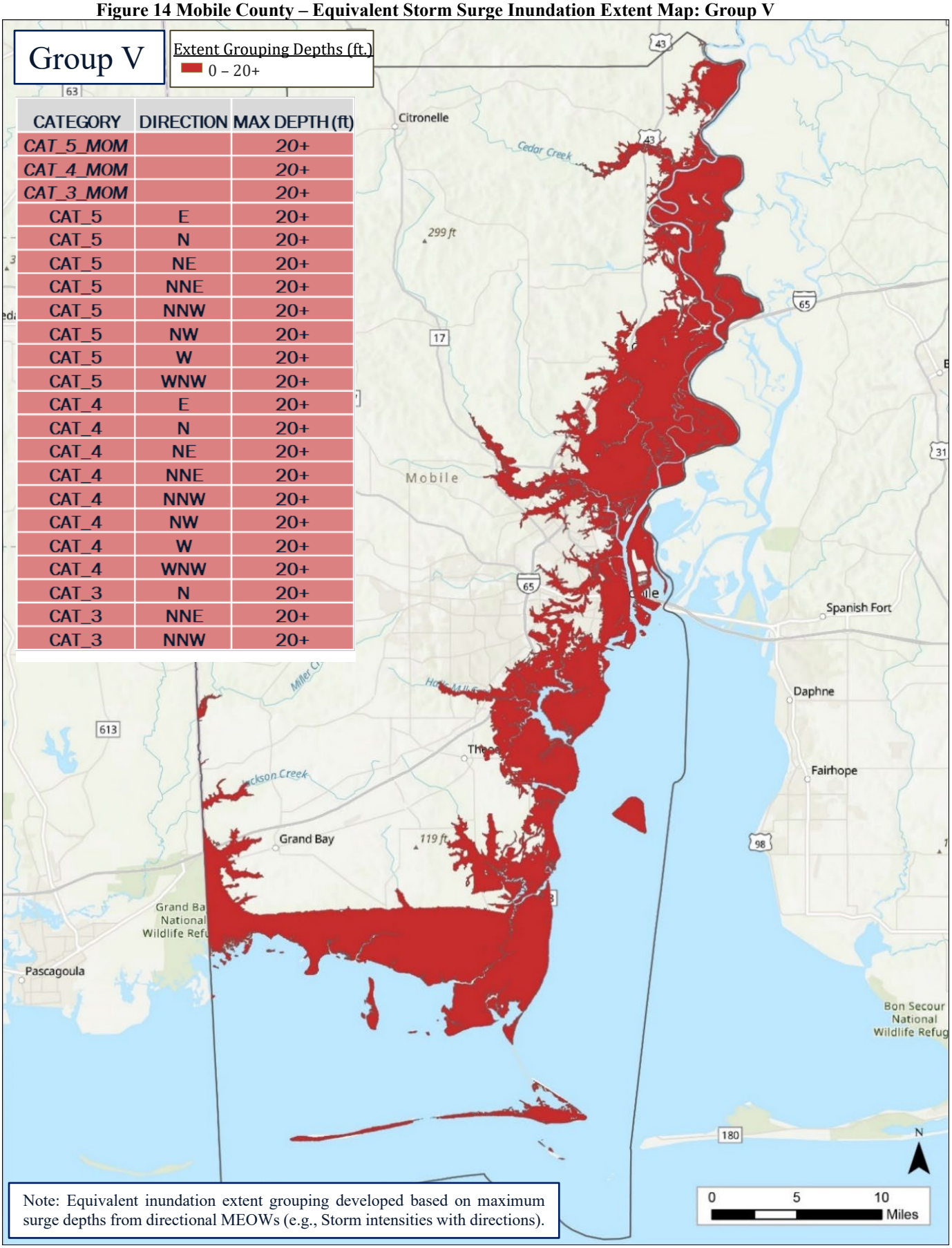


Figure 14 Mobile County – Equivalent Storm Surge Inundation Extent Map: Group V



CATEGORY	DIRECTION	MAX DEPTH (ft)
CAT_5_MOM		20+
CAT_4_MOM		20+
CAT_3_MOM		20+
CAT_5	E	20+
CAT_5	N	20+
CAT_5	NE	20+
CAT_5	NNE	20+
CAT_5	NNW	20+
CAT_5	NW	20+
CAT_5	W	20+
CAT_5	WNW	20+
CAT_4	E	20+
CAT_4	N	20+
CAT_4	NE	20+
CAT_4	NNE	20+
CAT_4	NNW	20+
CAT_4	NW	20+
CAT_4	W	20+
CAT_4	WNW	20+
CAT_3	N	20+
CAT_3	NNE	20+
CAT_3	NNW	20+

The most current evacuation zones were developed for Baldwin County through coordination of the Mobile District United States Army Corps of Engineers (USACE), FEMA, and the coastal counties' emergency management agencies as part of the *Alabama HES Vulnerability Analysis – 2022 Restudy* process. Coordination stakeholders' meetings were held to develop the Baldwin County evacuation zones on Oct. 12, 2021, Oct. 26, 2021, Oct. 29, 2021, Nov. 12, 2021, and Dec. 13, 2021. For Baldwin County, the current four evacuation zones are largely based on equivalent storm surge inundation extent groups developed from directional MEOWs maximum surge depths as mapped in the *Alabama HES Hazard Analysis – 2022 Restudy*.

For Mobile County, coordination stakeholders' meetings were held on October 12, 2021 and October 26, 2021, but after reviewing equivalent storm surge inundation extent maps and data tables, the Mobile County Emergency Management Agency (MCEMA) decided to keep the same four main evacuation zones that they had been using prior to the *Alabama HES Vulnerability Analysis -2022 Restudy*, without any alterations, with the exception of the Dauphin Island area of Zone 1.

In Alabama, the evacuation zone boundaries in the coastal areas are based on a combination of flooding risk and prominent community features such as major highways.

2.2 VULNERABLE POPULATIONS, STRUCTURES, CRITICAL FACILITIES, AND INFRASTRUCTURE KEY RESOURCES

The most recently available population data from the U.S. Census Bureau ACS 5-Year Estimates 2016-2020 was used to identify vulnerable populations. The vulnerable population is defined as all persons residing within the area subject to storm surge or wind damage and all the residents of mobile homes within the entire study area, even located above the estimated storm surge and freshwater flooding inundation levels.

Due to the impact of the COVID-19 pandemic restrictions on tourism in 2020, only 2019 tourist information was analyzed as best available information. Data was obtained from the Alabama Tourism Department and Gulf Shoes & Orange Beach Tourism.

Baldwin County

Vulnerable Populations

The vulnerable population within equivalent storm surge inundation extent group areas and evacuation zones was estimated using census block group data. The vulnerable population that could be subject to evacuation for each separate equivalent storm surge inundation extent group or evacuation zone is calculated as the sum of the non-mobile home population plus the countywide mobile home and tourist population (Mobile home residents are vulnerable to winds from any storm, and tourists are assumed to evacuate during any event). The Mobile home population was estimated by multiplying the number of mobile housing units by the average household size and occupancy rate of the county, according to 2020 U.S. Census Bureau data.

The tourist population was estimated according to tourism data obtained from the 2020 Alabama Tourism Industry Economic Impact Report prepared by The Alabama Tourism Department.[1] The report included 2019 and 2020 numbers of visitors staying in hotel and motel accommodations, average hotel occupancy rates, and annual monthly average number of hotel rooms in Baldwin County as shown in Table 26. However, due to the impact of the COVID-19 pandemic restrictions on tourism in 2020, only 2019 tourist information is used in this analysis.

Table 26 Baldwin County Tourism Data for 2019

Avg. Tourists in Hotel/Motel per Month[a]	Avg. Occupancy Rates	Hotel Room Count[b]	Average Travel Party Size[c]
156,392	60.6%	6,453	3.8

[a] Total tourists staying in hotel/motels divided by 12.
[b] Room supply divided by average number of days in a month.
[c] Gulf Shores & Orange Beach Tourism Visitor Profile Research Spring 2019[2].

The 2020 Alabama Tourism Industry Economic Impact Report also provides the ratio of counties' quarterly annual lodging tax contributions, which highlights the seasonal fluctuations in tourist populations. The second and third quarters (April through end of September) account for nearly three quarters of Baldwin County's lodging tax collection, as shown in Table 27.

Table 27 Baldwin County Lodging Tax Collection in 2019

	Q1	Q2	Q3	Q4
Baldwin	16%	37%	36%	12%

To better estimate the tourist population while accounting for seasonal fluctuations, the average number of tourists per month was weighted by the lodging tax ratio for the quarter (divided evenly among the three months in the quarter). The weighted average was then divided by the average number of days in a month to find the average number of tourists in a day. This population was then used to estimate high, median, and low tourist scenarios. The high tourist population occurred in the second quarter, the low tourist population occurred in the fourth quarter, and the median tourist population was calculated from the yearly average.

As the 2020 report only tracks travelers staying in hotels/motels, the number of tourists staying in short term rentals (STR), such as from Airbnb or Vrbo, was estimated by multiplying the number of hotel rooms by the national STR average supply penetration rate to hotel rooms of 10.4%[3]. This value was then multiplied by the average travel party size to estimate the population staying at short term rentals. This population was then multiplied by high (92%), median (60.6%), and low (21.6%) occupancy rate scenarios (obtained from the Mississippi Hotel and Lodging

[1]Source: Alabama Tourism Department. (2020). Alabama Tourism Industry Economic Impact 2020 Report. https://tourism.alabama.gov/app/uploads/2021-2020-Annual-Tourism-Economic-Impact-Report-Master-Copy.pdf
[2] Source: Gulf Shores & Orange Beach Tourism & Strategic Marketing & Research Insights, LLC. (2019). GSOBT Spring 2019 Visitor Profile. https://www.gulfshores.com/partners/resources/statistics/research/
[3]Source: CBRE, Inc. (2020). Short Term Rentals: A Maturing U.S. Market & Its Impact on Traditional Hotels. https://www.cbre.us/research-and-reports/Short-Term-Rentals-A-Maturing-US-Market--Its-Impact-on-Traditional-Hotels-January-2020

Association's *2019 Tourism Economic Contribution Report*[4] since this data was not readily available for the Alabama coastal counties) and added to the hotel/motel tourist population to get the total estimated tourist population as shown in Table 28. Note that estimated tourist population is countywide, since spatial data was not available.

Table 28 Estimated Baldwin County Tourist Population

Scenario	Hotel/ Motel Tourists per Day	STR Tourists per Day	Total Tourists per Day
High	7,553	2,349	**9,902**
Med	5,292	1,547	**6,840**
Low	2,415	552	**2,967**

Vulnerable Structures, Critical Facilities, and Infrastructure Key Resources

In Baldwin County, structures were identified and related to equivalent storm surge inundation extent groups of directional MEOWs, FEMA special flood areas, as well as wind hazard areas estimated from tropical cyclones. Baldwin County does not maintain any GIS structure data with land use related information. USACE provided structure data points, which are classified as residential, industrial, commercial, or public. For the structure analysis, the public land use points were grouped with the commercial ones. GIS database containing data and maps is included in the online ***Baldwin County HES Dashboard*** associated with the *Alabama HES Vulnerability Analysis – 2022 Restudy*.

Mobile County

Vulnerable Populations

The population within equivalent storm surge inundation extent group areas and evacuation zones were estimated using census block group data. The vulnerable population for each separate storm surge extent group or evacuation zone is calculated as the sum of the non-mobile home population plus the countywide mobile home and tourist population (Mobile home residents are vulnerable to winds from any storm, and tourists are assumed to evacuate during any event). Mobile home populations were estimated by multiplying the number of mobile housing units by the average household size and occupancy rate of the county, according to 2020 U.S. Census Bureau data.

The tourist population was estimated according to tourism data obtained from the 2020 Alabama Tourism Industry Economic Impact Report prepared by The Alabama Tourism Department[5]. The report included 2019 and 2020 numbers of visitors staying in hotel and motel accommodations,

[4] Source: https://visitmississippi.org/wp-content/uploads/2020/06/Economic-Impact-Record-2019.pdf
[5] Source: Alabama Tourism Department. (2020). Alabama Tourism Industry Economic Impact 2020 Report. https://tourism.alabama.gov/app/uploads/2021-2020-Annual-Tourism-Economic-Impact-Report-Master-Copy.pdf

average hotel occupancy rates, and annual monthly average number of hotel rooms in Mobile County as shown in Table 29. However, due to the impact if the COVID-19 pandemic restrictions on tourism, only 2019 tourist information is used in this analysis.

Table 29 Mobile County, AL Tourism Data for 2019

Avg. Tourists in Hotel/Motel per Month[a]	Avg. Occupancy Rates	Hotel Room Count[b]	Average Travel Party Size[c]
161,837	61%	5,321	3.8

[a] Total tourists staying in hotel/motels divided by 12; [b] Room supply divided by average number of days in a month; [c] Gulf Shores & Orange Beach Tourism Visitor Profile Research Spring 2019[6].

The 2020 Alabama Tourism Industry Economic Impact Report also provides the ratio of counties' quarterly annual lodging tax contributions, which highlights the seasonal fluctuations in tourist populations. The first, second, and third quarters (January through end of September) each have approximately the same lodging tax collections, as shown in Table 30.

Table 30 Mobile County Lodging Tax Collection in 2019

	Q1	Q2	Q3	Q4
Mobile	26%	27%	26%	20%

To better estimate the tourist population while accounting for seasonal fluctuations, the average number of tourists per month was weighted by the lodging tax ratio for the quarter (divided evenly among the three months in the quarter). The weighted average was then divided by the average number of days in a month to find the average number of tourists in a day. This population was then used to estimate high, median, and low tourist scenarios. The high tourist population occurred in the second quarter, the low tourist population occurred in the fourth quarter, and the median tourist population was calculated from the yearly average.

As the 2020 report only tracks travelers staying in hotels/motels, the number of tourists staying in short term rentals (STR), such as from Airbnb or Vrbo, was estimated by multiplying the number of hotel rooms by the national STR average supply penetration rate to hotel rooms of 10.4%[7]. This value was then multiplied by the average travel party size to estimate the population staying at short term rentals. This population was then multiplied by high (92%), median (61%), and low (21.6%) occupancy rate scenarios (obtained from the Mississippi Hotel and Lodging Association's *2019 Tourism Economic Contribution Report*[8] since this data was not readily available for the Alabama coastal counties) and added to the hotel/motel tourist population to get the total estimated tourist population as shown in Table 31. Note that estimated tourist population is countywide, since spatial data was not available.

[6] Source: Gulf Shores & Orange Beach Tourism & Strategic Marketing & Research Insights, LLC. (2019). GSOBT Spring 2019 Visitor Profile. https://www.gulfshores.com/partners/resources/statistics/research/
[7] Source: CBRE, Inc. (2020). Short Term Rentals: A Maturing U.S. Market & Its Impact on Traditional Hotels. https://www.cbre.us/research-and-reports/Short-Term-Rentals-A-Maturing-US-Market--Its-Impact-on-Traditional-Hotels-January-2020
[8] Source: https://visitmississippi.org/wp-content/uploads/2020/06/Economic-Impact-Record-2019.pdf

Table 31 Estimated Mobile County Tourist Population

Scenario	Hotel/ Motel Tourists per Day	STR Tourists per Day	Total Tourists per Day
High	5,796	2,847	**8,643**
Med	5,583	1,888	**7,471**
Low	4,307	668	**4,975**

Vulnerable Structures, Critical Facilities, and Infrastructure Key Resources

In Mobile County, structures were identified and related to equivalent storm surge inundation extent groups of directional MEOWs, FEMA special flood areas, as well as wind hazard areas estimated from tropical cyclones. Mobile County provided 2020 GIS planimetric data of structures and a spreadsheet of land use descriptions. The vulnerable structures data was grouped according to the descriptions that best represented commercial, industrial, residential, and mobile home/trailers. GIS database containing data and maps is included in the online ***Mobile County HES Dashboard*** associated with the *Alabama HES Vulnerability Analysis – 2022 Restudy*.

2.3 BEHAVIORAL ANALYSIS - EVACUATION PARTICIPATION

The *Alabama HES Behavioral Analysis – 2022 Re-Study* for the coastal counties of Baldwin and Mobile did not use a new phone survey instrument to gather evacuation behavior data. Instead, prior behavioral survey results, most recent U.S. Census Bureau demographic data (ACS, 2016-2020 5-Year Estimates), and coastal counties and state EMAs stakeholders' input was leveraged to develop estimates and assumptions of evacuation behavior.

To determine the hurricane evacuation participation rates, demographic changes since the last study were measured and weighted against the regression analysis conducted in the prior study, which relates demographic characteristics of survey respondents to evacuation likelihood. Based on the demographic changes, evacuation responses for each county were adjusted. The methodology and adjusted rates were then presented to county stakeholders for approval. Based on stakeholder feedback, the participation rates were then further adjusted to align with stakeholder's expected results and prior experiences for a given storm scenario. A range of low, medium, and high rates were decided upon to provide the most flexibility in evaluating evacuation participation. (Appendix A of the HES Behavioral Analysis Report provides a detailed technical approach for how the participation rates were calculated).

2.4 TRANSPORTATION ANALYSIS - EVACUATION CLEARANCE TIMES

Evacuation Modeling/Simulation Methods and Assumptions

Software Concept and Methodology

The software used for the *ALMS HES Transportation Analysis – 2023 Re-Study* simulations is RtePM (accessible at https://RtePM.hurrevac.com/). RtePM is a free, web-based transportation model designed to capture the impacts of traffic flow along a regional roadway network to calculate clearance times and represents the time it takes to clear the roadway of all evacuating vehicles, measured from the moment the evacuation order is issued until the time when the final evacuating vehicle reaches its point of safety.

RtePM allows users to set parameters and conditions including the area to be evacuated by specifying roadways, the number of evacuees and vehicles involved in the evacuation, the speed at which evacuees respond to evacuation orders (e.g. response times), and the destinations that evacuees travel to.

Evacuation Scenarios

In total, 265 evacuation scenarios were developed for the *ALMS HES Transportation Analysis – 2023 Re-Study*. Evacuation scenarios may be different based on the assumptions below:

- Evacuation participation rates (low, medium, or high)
- Include areas outside of Alabama and Mississippi (i.e., with or without Escambia County, FL, with or without Southeast Louisiana evacuation zones)
- Evacuation zones
  - Alabama: Zones 1, 2, 3, and 4
  - Mississippi: Zones A, B, and C
  - Louisiana: Zones Phase 1 Central, Phase 1 East, Phase 2 East, and Phase 3
  - Florida: Zones A, B, C, D and E
- Contraflow lane operations
- Response curves (slow, medium, or fast)
- Background traffic (low or high)
- Shelter capacity

The 265 scenarios were broken down into the following categories:

- Alabama Only (Baldwin and Mobile Counties): 66 scenarios
- Baldwin County and Escambia County, FL: 18 scenarios
- Mississippi Only (Hancock, Harrison, and Jackson Counties): 93 scenarios
- Mobile County and Jackson County: 21 scenarios
- Regional (Alabama and Mississippi): 24 scenarios
- Regional with Other States (Alabama, Mississippi, Florida, Louisiana): 26 scenarios
- Countywide (progressive evacuation of each zone within each county): 17 scenarios

See Section 6 of the *ALMS HES Transportation Analysis – 2023 Re-Study* for a detailed description of all scenarios. Refer to the transportation scenarios companion spreadsheet developed for the *ALMS HES Transportation Analysis – 2023 Re-Study* for the complete list of scenarios, inputs, and outputs.

Input Data to Define Population Distribution and Behavioral Patterns

The source of the population data is the U.S. Census Bureau, ACS 5-Year Estimates (2016-2020). Population distribution within each evacuation zone as shown in Table 32 is from the Vulnerability Analyses (*Alabama HES Vulnerability Analysis – 2022 Re-Study* for Baldwin and Mobile Counties and *Mississippi HES Vulnerability Analysis – 2022 Re-Study* for Hancock, Harrison, and Jackson Counties).

Table 32 Population Distribution Data for Each Evacuation Zone

State	County	Zone	Population in RtePM
Alabama	Baldwin	1	34,014
Alabama	Baldwin	2	46,222
Alabama	Baldwin	3	98,230
Alabama	Baldwin	4	39,823
Alabama	Mobile	1	53,817
Alabama	Mobile	2	103,494
Alabama	Mobile	3	194,569
Alabama	Mobile	4	62,097
Mississippi	Hancock	A	15,300
Mississippi	Hancock	B	17,160
Mississippi	Hancock	C	4,774
Mississippi	Harrison	A	22,621
Mississippi	Harrison	B	22,183
Mississippi	Harrison	C	95,823
Mississippi	Jackson	A	53,207
Mississippi	Jackson	B	50,051
Mississippi	Jackson	C	12,939

The sources of the evacuation participation rates are the Behavioral Analyses (*Alabama HES Behavioral Analysis – 2022 Re-Study* for Baldwin and Mobile Counties and the *Mississippi HES Behavioral Analysis – 2022 Re-Study* for Hancock, Harrison, and Jackson Counties). The Alabama evacuation participation rates are included in Section 1.4 of this report.
The sources of the response curve times for Alabama and Mississippi are the 2012 Alabama and Mississippi Hurricane Evacuation Study Technical Data Reports. For Florida and Louisiana, the response curve times are from their respective studies. The response curve information is included in Table 33.

Table 33 Response Curves for Evacuation Scenarios

Response Curve	Alabama Response Time (Hours)	Mississippi Response Time (Hours)	Florida Response Time (Hours)	Louisiana Response Time (Hours)
Fast	-	4	-	-
Medium	3	7	-	-
Slow	5	9	-	-
Constant	-	-	12	8

The sources of the number of people per vehicle for Alabama and Mississippi are the *Alabama HES Behavioral Analysis – 2022 Re-Study* for Baldwin and Mobile Counties and *Mississippi HES Behavioral Analysis – 2022 Re-Study* for Hancock, Harrison, and Jackson Counties. The number of people per vehicle for Florida and Louisiana evacuation zones is derived from their respective studies with an assumed average of 2.0 people per vehicle. Table 34 includes the average number of people per vehicle for the states included in the evacuation scenarios.

Table 34 Average Number of People Per Vehicle by County

State	County	Average Number of People Per Vehicle
Alabama	Baldwin	1.90
	Mobile	1.78
Mississippi	Hancock	1.57
	Harrison	1.90
	Jackson	1.80
Florida	Escambia	2.00
Louisiana	Multiple Parishes	2.00

The sources of the vehicle towing rate for Alabama and Mississippi is the *Alabama HES Behavioral Analysis – 2022 Re-Study* for Baldwin and Mobile Counties and *Mississippi HES Behavioral Analysis – 2022 Re-Study* for Hancock, Harrison, and Jackson Counties. The *2020 Southeast Louisiana Hurricane Evacuation Study Transportation Analysis Report* defines a vehicle towing rate of 24%. The *2021 Emerald Coast Regional Council Evacuation Study* does not define a rate for trailered vehicles. The vehicle towing rates are listed in Table 35.

Table 35 Vehicle Towing Rates by State

State	Vehicle Towing Rate
Alabama	10%
Mississippi	15%
Florida	Not Applicable
Louisiana	24%

The sources of the destination rates are the *Alabama HES Behavioral Analysis – 2022 Re-Study* for Baldwin and Mobile Counties and *Mississippi HES Behavioral Analysis – 2022 Re-Study* for Hancock, Harrison, and Jackson Counties. The shelter usage rate for both states is 5 percent of the evacuating population. For the transportation scenarios that include Florida and Louisiana,

the evacuating population from the two states do not use ALMS public shelters, and the public shelter usage rates are set to zero percent.

Transportation Model Links, Transportation Network, and Modeling Assumptions

RtePM uses the HERE[9] transportation network data, which includes highways, major arterials, minor arterials, and smaller roadways. Existing roads can be modified, and new roads can be added within RtePM. RtePM provides the option of selecting and modifying roads and road networks when defining evacuation routes. The *ALMS HES Transportation Analysis – 2023 Re-Study* uses highways, major arterials, minor arterials, and ramps as the roadway network.

The evacuation zones are imported into RtePM, which then selects the 2010 Census Block Groups that are the base model inputs. A population change percentage is applied to update the evacuating population to the 2020 Census population for each evacuation zone.

In RtePM, background traffic is selected as Low or High depending on the scenario. The percentage using public transit and the percentage as pedestrians are assumed as zero for all scenarios. Updated tourist population totals for each county are from the Vulnerability Analyses (*Alabama HES Vulnerability Analysis – 2022 Re-Study* for Baldwin and Mobile Counties and *Mississippi HES Vulnerability Analysis – 2022 Re-Study* for Hancock, Harrison, and Jackson Counties).

Tourist population distribution within each evacuation zone is from the 2012 Alabama and Mississippi Hurricane Evacuation Technical Data Reports. The tourist occupancy is paired with the evacuation participation rate (i.e., high seasonal population with high evacuation participation) to streamline the scenario assumptions, as shown in Table 36. The *Mississippi HES Behavioral Analysis – 2022 Re-Study* documents 3.24 tourists per vehicle and the *Alabama HES Behavioral Analysis – 2022 Re-Study* documents 4 tourists per vehicle in Alabama.

The transportation scenarios companion spreadsheet developed for the *ALMS HES Transportation Analysis – 2023 Re-Study* has more detailed inputs and outputs for the 265 scenarios including clearance times, evacuating population, and evacuating vehicles.

[9] HERE Technologies (previously NAVTEQ, Inc.) is a company that provides mapping, networks, location data, and related services.

Table 36 Distribution of Total Tourist Population within Each Evacuation Zone

State	County	Evacuation Zone	Distribution of Total Tourist Population	High Occupancy	Medium Occupancy	Low Occupancy
Alabama	Baldwin	1	60%	19,948	13,133	6,825
		2	30%	9,936	6,541	3,399
		3	1%	438	288	150
		4	9%	3,129	2,060	1,070
	Mobile	1	10%	1,149	935	701
		2	26%	2,917	2,373	1,779
		3	46%	5,046	4,105	3,077
		4	18%	1,961	1,595	1,196
Mississippi	Hancock	A	68%	1,158	757	272
		B	27%	457	299	107
		C	5%	77	50	18
	Harrison	A	55%	23,981	15,692	5,630
		B	36%	15,987	10,461	3,754
		C	9%	4,026	2,634	945
	Jackson	A	34%	2,025	1,325	475
		B	46%	2,701	1,767	634
		C	20%	1,153	755	271

Special Circumstances

Emergency Lane Reversals

Implementing contraflow lane operations (also referred to as "lane reversal" operations) is a common method adopted during hurricane evacuations. By reversing the incoming traffic lanes, the highway capacity available for evacuation traffic is increased though not doubled. RtePM allows the ability to assess contraflow operations within evacuation scenarios by specifying roadways with this capability. Therefore, for the *ALMS HES Transportation Analysis – 2023 Re-Study*, several scenarios are identified to evaluate the impacts of contraflow operations. Table 37 summarizes the specific locations where contraflow is implemented by state. According to the *Mississippi Department of Transportation 2021 Hurricane Evacuation Guide*, "Category 3, 4, or 5 hurricanes in the Gulf of Mexico might cause a mandatory evacuation of the greater New Orleans area." Therefore, contraflow operations for Mississippi scenarios are simulated for Category 3 or higher scenarios.

Table 37 Contraflow Locations for Evacuation Scenarios

State	Route Name	Specific Location
Alabama	Interstate 65	The southbound lanes of I-65 are reversed toward northbound. Contraflow operations begin in Baldwin County just south of Exit 31 (State Road 225) and end in Montgomery just north of Exit 167 (U.S. 80)
Mississippi	Interstate 59	The I-59 North contraflow operations begin at I-10 West in Louisiana, extend into Mississippi, and end just south of Hattiesburg.
	Interstate 55	The I-55 North contraflow operations begin at I-12 West in Louisiana, extend into Mississippi, and end just south of Brookhaven.
Louisiana	Interstate 10	The I-10 West contraflow operations begin at US 190 (Causeway) and ends just east of I-55.

Special Evacuation Routes

The RtePM evacuation roadway network that is used for Alabama, Mississippi, Escambia County (Florida), and Southeast Louisiana is shown in Figure 15, Figure 16, and Figure 17. The RtePM roadway network in the *ALMS HES Transportation Analysis – 2023 Re-Study* includes roadways in addition to the designated, state-specific evacuation routes.

Figure 15 Alabama/Mississippi Evacuation Roadway Networks

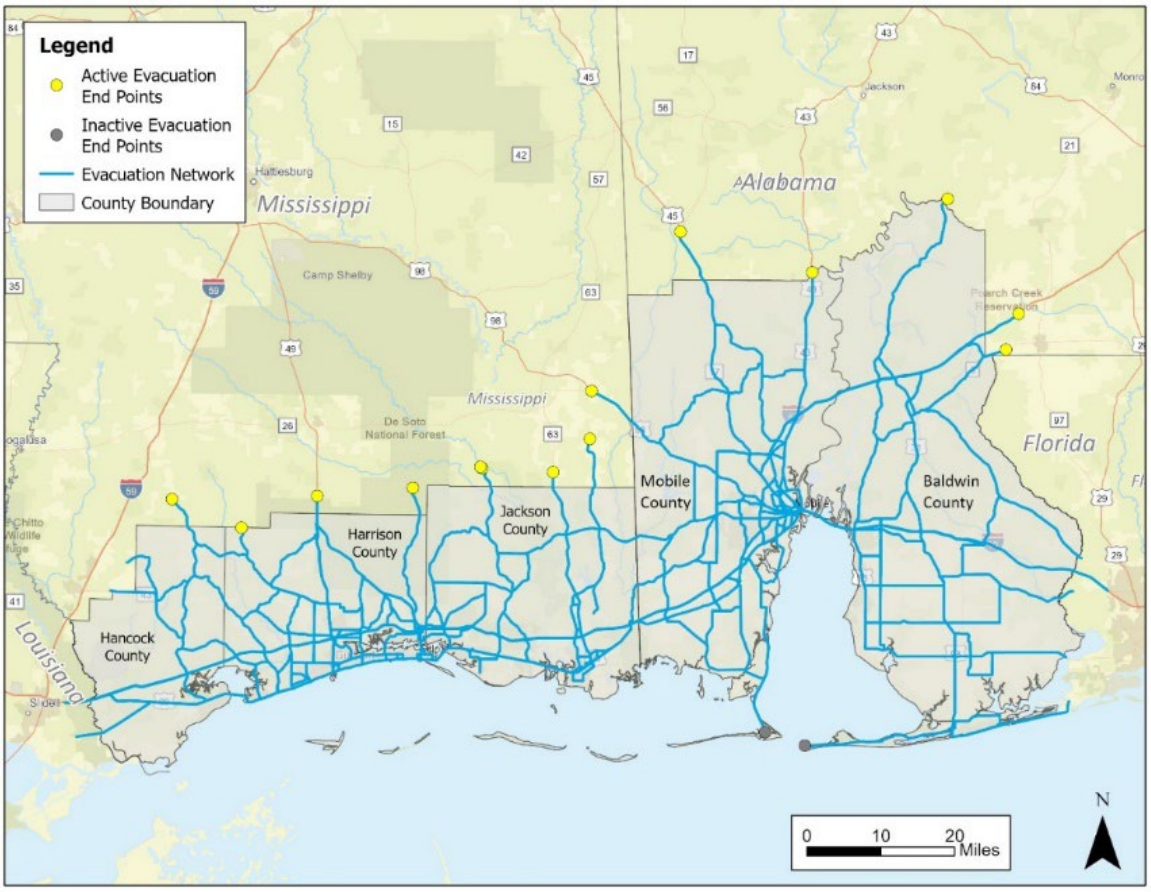


Figure 16 Escambia County, Florida Evacuation Network

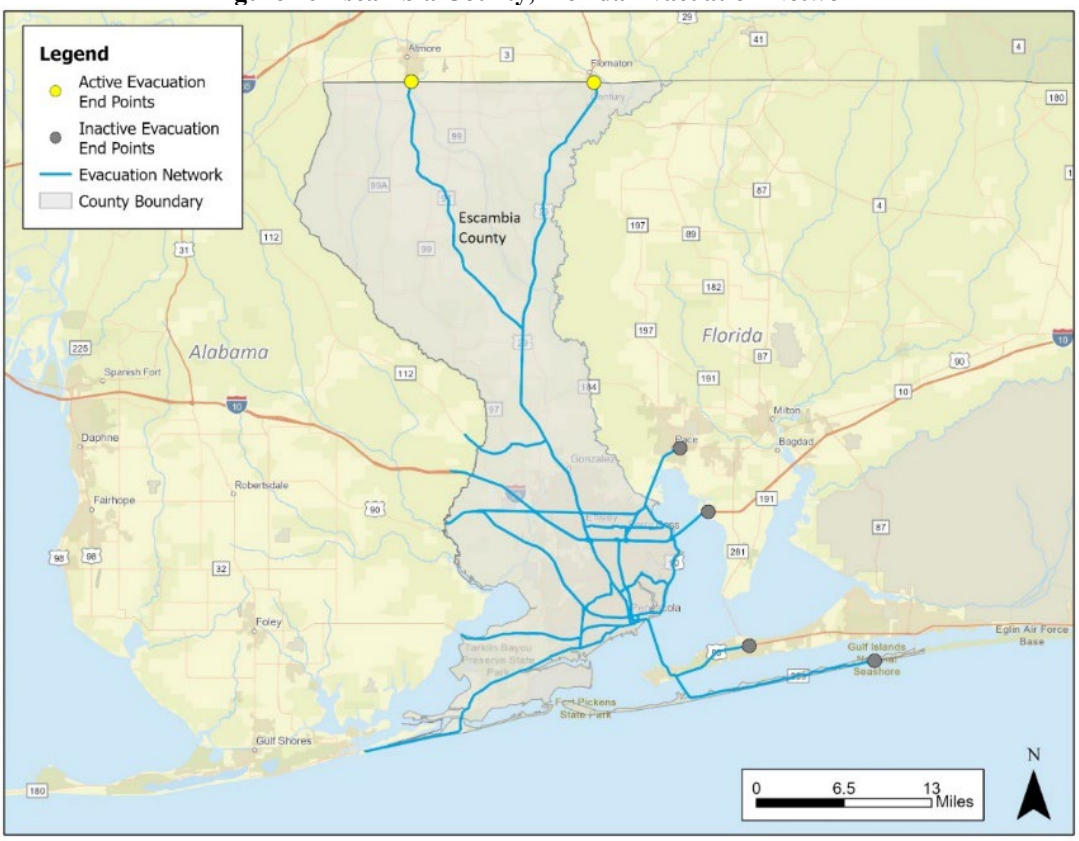
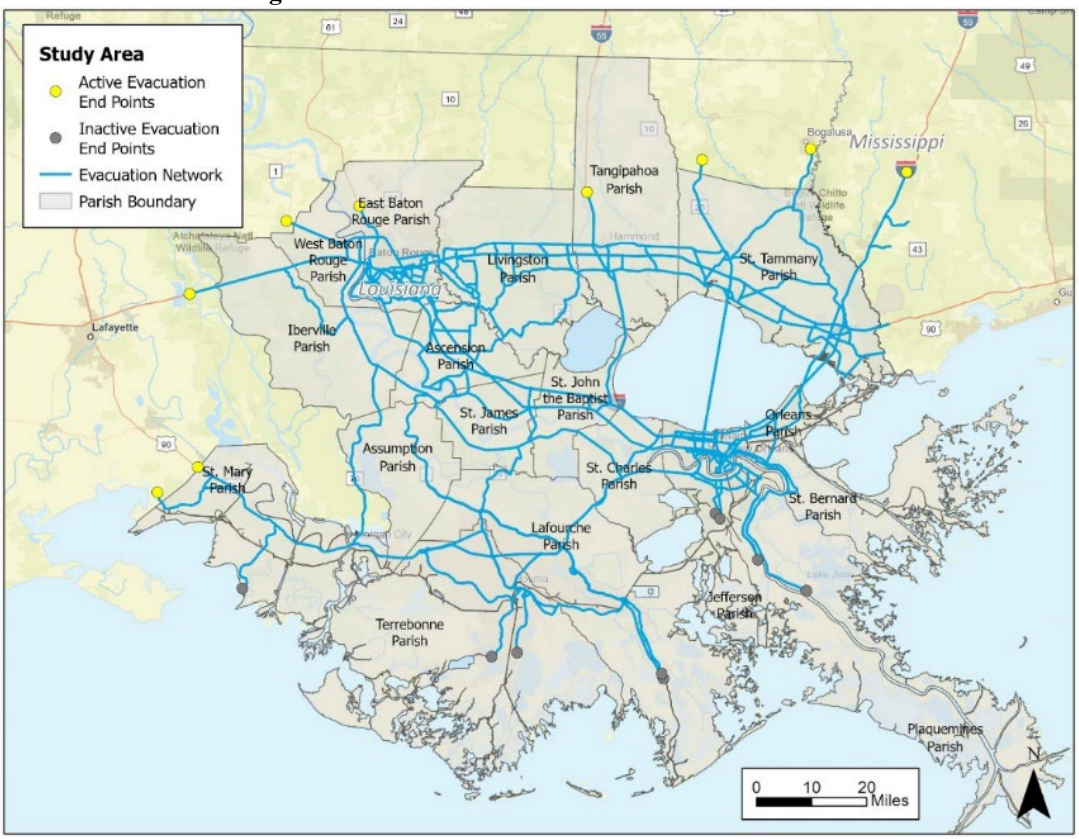


Figure 17 Southeast Louisiana Evacuation Network



Multi-State Evacuations

There are 50 regional scenarios simulated for Category 4 or Category 5 events with the expectation that a storm large or intense enough to impact the region will cause widespread evacuations across multiple states. Out of the 50 regional scenarios, 26 of them involve both Florida and Louisiana in addition to Alabama and Mississippi. The remaining 24 regional scenarios involve evacuations from Alabama and Mississippi only.

2.5 SHELTER DEMAND

Public shelter demand is the number of evacuees anticipated to seek public shelter for a given hurricane evacuation event. As American Red Cross (ARC) records of actual shelter use during hurricane evacuations were not available, sheltering demand was instead estimated. Participation rates (for a range of low, medium, and high scenarios) were converted into an estimated evacuee population using the most recently available population data from the U.S. Census ACS 5-Year Estimates (2016-2020). A shelter usage rate of 5% is then applied to the evacuee population in each evacuation zone to determine the total shelter demand for various storm scenarios. This range provides emergency planners greater flexibility when assessing the possible impacts of a hurricane event.

2.6 SHELTER CAPACITY

The current list of shelters for Baldwin and Mobile Counties was provided by the counties' EMAs in 2022. Selected shelter inventory information including addresses, capacities, facility types, use constraints, and location in Evacuation Zones are shown in Table 39 and Table 41. As agreed upon at coordination meetings with counties and state EMAs held on 8/18/2022 and 9/1/2022, shelters with restricted use constraints (highlighted in red in Table 39 and Table 41) are not available to the general public. Therefore, the capacities are totaled separately, as the restricted use capacities are not accounted for in the transportation model used in the *ALMS HES Transportation Analysis – 2023 Re-Study*.

The *Alabama HES Shelter Analysis - 2023 Re-Study* includes a detailed summary of shelter inventory information for Baldwin and Mobile Counties including location, operators (local or AMC staff), facility type, size, normal shelter capacity and shelter capacity with COVID-19 pandemic restrictions (if available), amenities, ADA compliance, user constraints, and pet accommodation information.

The calculated shelter demand was compared to the latest shelter inventories to identify deficiencies in shelter capacity.

Baldwin County

In total, Baldwin County has 17 designated storm shelters. Of these shelters, 11 are open for general public use with a capacity to support 8,072 people, and six are restricted for first responders, special needs, or electrical life support patients and caregivers with a capacity to support 3,170 people.

Table 38 Baldwin County Shelter Summary

Shelter Type	Count	Capacity
General Public	11	8,072
Restricted	6	3,170
Total	**17**	**11,242**

Table 39 Shelters in Baldwin County, AL

Shelter Name	Address	Capacity (# of People)	Facility Type	Use Constraints	Within Which Evacuation Zone?
ARC-BC[1]	22860 McAuliffe Dr., Robertsdale, AL 36567	373	Restricted	Only for ARC-BC or Lighthouse clients and pre-registered clients	3
Baldwin County Coliseum	19477 Fairground Rd., Robertsdale, AL 36567	1,900	General Public	General Public (Mass Care)/ ADPH Medical Needs	3
Baldwin County High School	1 Tiger Dr., Bay Minette, AL 36507	866	General Public	General Public (Mass Care)	4
Baldwin County Level II Shelter[2]	207N White Ave., Bay Minette, AL 36507	50	Restricted	Electrical Support Shelter for Life Support (25 patients & 25 caregivers)	4
Bay Minette Middle School	1311 W 13th St., Bay Minette, AL 36507	700	General Public	Mass Care (Secondary)	4
Central Baldwin Middle School	24545 State Hwy 59, Robertsdale, AL 36567	543	General Public	NA	3
Daphne Civic Center	2603 Highway 98, Daphne, AL, 36526	250	General Public	NA	2
Daphne East Elementary School	26551 County Rd 13, Daphne, AL 36526	388	General Public	Mass Care (Secondary)	3
Daphne Middle School	1 Jodie Davis Circle, Daphne, AL 36526	850	General Public	NA	3
Fairhope High School	1 Pirate Drive, Fairhope, AL 36532	905	General Public	NA	3
Fairhope Satellite Courthouse	1100 Fairhope Ave., Fairhope, AL 36532	40	Restricted	Electrical Support Shelter for Life Support (20 patients & 20 caregivers)	3

Shelter Name	Address	Capacity (# of People)	Facility Type	Use Constraints	Within Which Evacuation Zone?
Faulkner State Community College	1900 US Hwy 31 S, Bay Minette, AL 36507	250	General Public	Intended for CAT 1 or CAT 2 Storms only	4
Florence B. Mathis Elementary	600 9th Ave., Foley, AL 36535	1,330	Restricted	First Responders pre-storm (from Orange Beach, Gulf Shores, Bon Secour, Fort Morgan & National Guard)	4
Foley High School	1 Pride Dr., Foley, AL 36535	1,337	Restricted	First Responders pre-storm (from Orange Beach, Gulf Shores, Bon Secour, Fort Morgan & National Guard)	2
Foley Satellite Courthouse	201 E Section St., Foley, AL 36535	40	Restricted	Electrical Support Shelter for Life Support (20 patients & 20 caregivers)	3
Robertsdale High School	1 Golden Bear Dr., Robertsdale, AL 36567	573	General Public	NA	3
Spanish Fort High School	1 Plaza de Toros Dr., Spanish Fort, AL 36527	847	General Public	NA	4

General Public Total	8,072
Restricted Total	**3,170**
OVERALL TOTAL	**11,242**

NOTES:
[1] ARC-BC is ARC Baldwin County which is an organization that ensures that appropriate and quality services are available and accessible to persons with intellectual disabilities and/or developmental disabilities throughout their life.
[2] The Baldwin County Level II shelter is for Public Health Medical Needs and only operates during the daytime.

In addition to the storm shelters summarized in Table 39, Baldwin County also has post-storm shelters. These shelters are not included in the shelter demand calculations, as they support the population after an evacuation rather than during one. These shelters are opened within 72 hours after storm landfall and provide sleeping support items, meals, shower facilities, medical services, and other support services for evacuees who are unable to return to their homes.

Mobile County

In total, Mobile County has 21 designated storm shelters. All but one of these shelters are designated for public general use. The 20 general public use shelters can accommodate a total capacity of 13,200 people, while the one restricted shelter, reserved for the sheriff's office, has a total capacity of 800 people.

Table 40 Mobile County Shelter Summary

Shelter Type	Count	Capacity
General Public	20	13,200
Restricted	1	800
Total	**21**	**14,000**

Table 41 Shelters in Mobile County, AL

Shelter Name	Address	Capacity (# of People)	Facility Type	Use Constraints	Within Which Evacuation Zone?
Baker High School	8901 Airport Blvd., Mobile, AL 36608	1500	General Public	Primary	3
Bernice Causey Middle School	2205 McFarland Rd., Mobile, AL 36695	400	General Public	Secondary	3
Craighead Elementary School	1000 S Ann St., Mobile, AL 36605	400	General Public	Overflow	2
Cranford H Burns Middle School	6175 Girby Rd., Mobile, AL 36693	600	General Public	Secondary (General & Special Needs)	3
Collier Elementary School	601 Snow Rd. N, Mobile, AL 36608	400	General Public	Overflow Only	3
Collins-Rhodes Elementary School	5110 St. Stephens Rd., Eight Mile, AL 36613	600	General Public	Primary	4
Dawes Intermediate	10451 West Lake Rd., Mobile, AL 36695	400	General Public	Overflow	3
E R Dickson Elementary School	4645 Bit and Spur Rd., Mobile, AL 36608	400	General Public	Secondary	3
Eichold-Mertz Magnet School	2815 Government St., Mobile, AL 36606	600	General Public	Secondary	2
Ella Grant Elementary School	535 Easterling St., Prichard, AL 36610	400	General Public	Secondary	2
Forest Hill Elementary School	4501 Moffett Rd., Mobile, AL 36618	400	General Public	Overflow	3
Haskew, Pearl Elementary School	7001 White Oak Dr., Irvington, AL 36544	400	General Public	Secondary	3
Jeremiah A Denton Middle School	3800 Pleasant Valley Rd., Mobile, AL 36609	1500	General Public	Secondary	3

Shelter Name	Address	Capacity (# of People)	Facility Type	Use Constraints	Within Which Evacuation Zone?
John L Leflore Magnet High School	700 Donald St., Mobile, AL 36617	1000	General Public	Primary	2
Kate Shepard Elementary School	3980-B Burma Rd., Mobile, AL 36693	400	General Public	Secondary	3
McDavid Jones Elementary School	16250 Ushy 45 S, Citronelle, AL 36522	1000	General Public	Secondary	4
North Mobile Middle	1950 Salco Rd., Axis, AL 36505	600	General Public	Primary	4
Semmes Middle School	4566 Ed George Rd., Semmes, AL 36575	600	General Public	Primary	3
Theodore High School	6201 Swedetown Rd. N, Theodore, AL 36582	1000	General Public	Primary	1
W P Davidson High School[1]	3900 Pleasant Valley Rd., Mobile, AL 36609	800	Restricted	Sheriff's Office	3
Wilmer Elementary School	7456 Wilmer Georgetown Rd., Wilmer, AL 36587	600	General Public	Secondary	4
	General Public Total	13,200			
	Restricted Total	**800**			
	OVERALL TOTAL	**14,000**			

NOTES:

[1] The whole campus of W.P. Davidson High School is used by the Sheriff's office. It is not clear which buildings they actually use. Main building is 147,510 sq. ft.; Gym/classrooms is 52,345 sq. ft.; Locker room is 13,432 sq. ft.; Auditorium is 27,395 sq. ft.