PLANNING FOR COASTAL AND CLIMATE TRENDS

THE IMPORTANCE OF PLANNING IN COASTAL COMMUNITIES

Ever-changing conditions and dynamics of the Great Lakes profoundly affect coastal communities. This chapter provides background information on current and anticipated conditions of the Great Lakes. Planning for coastal areas at the local level requires knowledge of both local conditions and state and federal regulations. This chapter aims to address these needs for the City of Frankfort and provide clear, well-founded recommendations for future land-use planning.

The Great Lakes are one of the most unique and important environmental systems in the world. In fact, "the Great Lakes basin contains more than 20% of the world's surface freshwater supplies and supports a population of more than 30 million people."[1] The lakes ecosystem plays a key role in the environmental, social and economic makeup of the region. Michigan is home to nearly 3,300 miles of Great Lakes shoreline, along with 36,000 miles of rivers and streams, and 11,000 inland lakes.[2] Communities across the Great Lakes shoreline haven an important role to play in ensuring the long-term sustainability of their shorelines.

Yet in general, riparian land (land adjacent to a water body) throughout Michigan is not adequately protected from development pressures.[3] This has been especially clear during high water periods, which communities across the state, including the City of Frankfort, have experienced in recent years. In 2001, the Michigan Department of Environmental Quality (DEQ; now EGLE) acknowledged "fragmentation of coastal habitats, loss of agricultural and forest lands, increased impervious surfaces and resulting stormwater runoff, and the increased development in coastal hazard areas, wetlands, and Great Lakes Islands, could be improved through better coastal land-use planning."[4]

OVERVIEW OF COASTAL DYNAMICS AND THE GREAT LAKES

The Great Lakes function differently than other inland water bodies and tidal oceans. Understanding these dynamics can help Frankfort plan for naturally occurring changes along the shoreline.

How are Great Lakes Water Levels Measured?

Great Lakes water levels are measured via the International Great Lakes Datum (IGLD), a reference system of benchmarks at various locations on the lakes that approximate sea level. Great Lakes water levels are expressed as measurements above this reference elevation.

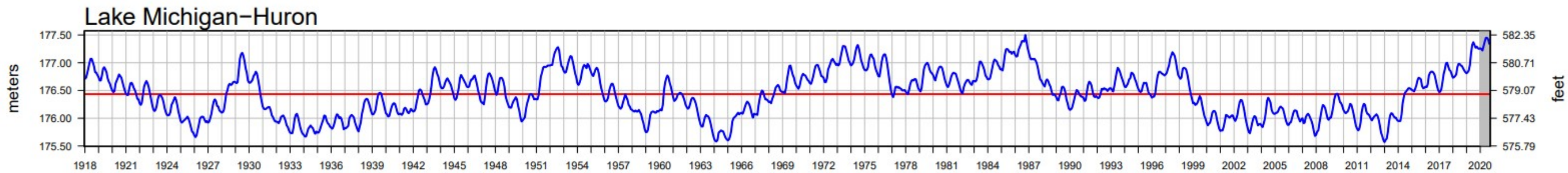
[1] Mackey, S.D. 2012: Great Lakes Nearshore and Coastal Systems. In: U.S. National Climate Assessment Midwest Technical Input Report. J. Winkler, J. Andresen, J. Hatfield, D. Bidwell, and D. Brown, coordinators

[2] Ardizone, Katherine A. and Mark A. Wyckoff, FAICP. Filling the Gaps: Environmental Protection Options for Local Governments, 2nd Edition. 2010.

[3] As cited by Norton 2007 – Michigan Department of Environmental Quality. 2001. 309 Enhancement Grants Assessment/Strategy. Lansing, MI: DEQ Coastal Management Program.

[4] Ibid

Figure 1. Lake Michigan-Huron Water Level Changes, 1918 – 2020



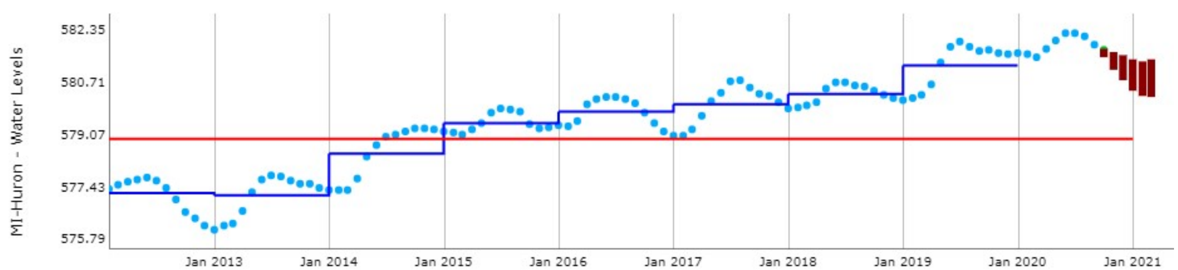
Source: http://lre-wm.usace.army.mil/ForecastData/GLBasinConditions/LTA-GLWL-Graph.pdf

Changing Water Levels of the Great Lakes

Great Lakes water level changes result not from the moon's gravitational pull, but from cyclical changes in rainfall, evaporation, and river and groundwater inflows.[5] These factors work together to raise and lower the water levels of the Great Lakes in small increments daily, and larger increments seasonally and over the course of years and decades. Long-term water levels fluctuate by multiple feet. Figure 1 illustrates the water level of Lake Michigan from 1918 to 2020 (Lake Michigan and Lake Huron are technically considered one lake). However, under certain climate conditions, water levels can dramatically fluctuate over short periods of time. For example, following the extreme winters of 2014 and 2015, water levels in Lake Michigan rose between three to four feet from an all-time low (576 feet) set just a year earlier.

The Great Lakes recently experienced a period of rising lake levels (see Figure 2). Since the early 2000s, water levels had remained low, but historical patterns over the last century indicated that higher water levels were sure to return.[6] After a period of lows in 2013, Lake Michigan's water level in July of 2020 averaged 582.2 feet, which was 34 inches above its long-term average level for the month. According to a recent U.S. Army Corps of Engineers summary, based on current

Figure 2. Lake Michigan-Huron Water Levels



Source: glerl.noaa.gov/data

[5]Norton, Richard K., Meadows, Lorelle A. and Meadows, Guy A. (2011) "Drawing Lines in Books and on Sandy Beaches; Marking Ordinary High Water on Michigan's Great Lakes Shorelines under the Public Trust Doctrine." Coastal Management, 39: 2, 133 – 157, First published on 19 February 2001 (iFirst).

[6]Meadows, Guy A., and Meadows, Lorelle, A., Wood, W.L., Hubertz, J.M., Perlin, M. "The Relationship between Great Lakes Water Levels, Wave Energies, and Shoreline Damage." Bulletin of the American Meteorological Society Series 78:4. (1997): 678-683. Print.

conditions, Lake Michigan is expected to see lake levels decline after seeing record highs throughout 2020 (see Figure 3).

It is important to note that changes in water levels are not solely responsible for the movement of the shoreline landward and lakeward over time. The velocity and height of waves, erosion of shorelines, and the pace of fluctuating water levels also contribute to coastal dynamics on the Great Lakes.

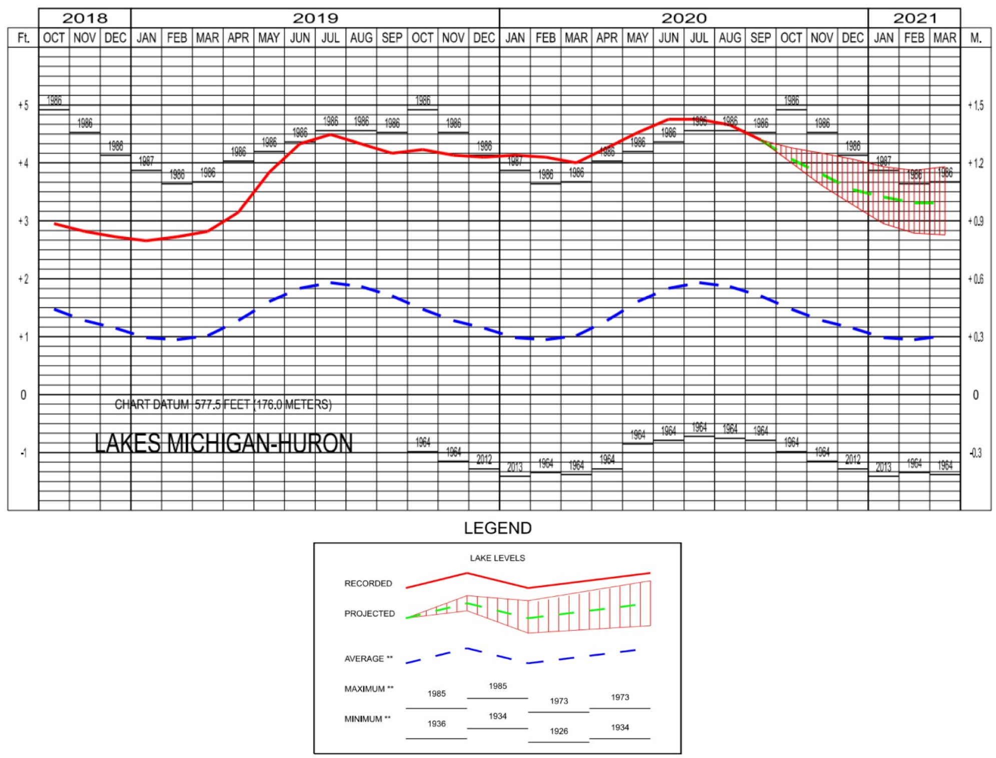
Wave Energy and Height

The Great Lakes experience high-energy waves and wave setup along the coastline. High-energy waves are high in speed and strong in intensity and are primarily created as fast winds move across the surface of the water for extended distances.[8] “Wave setup” is the height of the water as waves reach the shore. High wave setup results as regional storms create high winds on the Great Lakes.[9] Powerful and tall waves can quicken the rate of erosion and damage structures near the shoreline.[10]

Erosion

The shorelines of Lake Michigan are mostly made of gravel and sands that easily erode during times of high-energy waves.[11] Coastal erosion can cause flooding and damage infrastructure along bluffs and beaches. Erosion is caused mainly by storms and winds, and is exacerbated when lake levels are high.[12]

Figure 3. Lakes Michigan-Huron Water Levels—September 2020



[7]http://www.lre.usace.army.mil

[8]National Oceanic and Atmospheric Administration. “Coastal Currents” Ocean Services Education, NOAA, 25 March 2008. Web. Accessed July 2015.

[9]Norton, Richard K, Meadows, Lorelle A. and Meadows, Guy A. (2011) “Drawing Lines in Law Books on Sand Beaches: Marking Ordinary High Water on Michigan’s Great lakes Shorelines under the Public Trust Doctrine’, Coastal Management, 39: 2, 133 – 157, First published on: 19 February 2001 (iFirst)

[10]Ibid.

[11]Ibid.

[12]Meadows, Guy A., and Meadows, Lorelle, A., Wood, W.L., Hubertz, J.M., Perlin, M. “The Relationship between Great Lakes Water Levels, Wave Energies, and Shoreline Damage.” Bulletin of the American Meteorological Society Series 78:4. (1997): 675-683. Print.

Quickly Changing Conditions

The Great Lakes are contained in gradually shifting and tilting basins. This tilting results as the Earth slowly decompresses and rebounds from the immense weight of the glaciers that created the Great Lakes.[13] This shifting causes water levels to change more quickly in some places than others, because the shape of the water basin varies along the coast.[14] This attribute of the Great Lakes makes it difficult to predict the pace of shoreline movement. Therefore, it is safest to plan for great variability and rapid change in water levels.[15]

CLIMATE CHANGE AND THE GREAT LAKES

Each of the factors described in the previous section have implications for the Great Lakes shoreline. In addition, these processes are expected to become more dramatic in scale and effect going forward. It is therefore important to understand how communities can meet these new challenges. This section will discuss climatologist predictions of increased precipitation and storminess in the Great Lakes region, variable lake water levels, and rising water temperatures. First, it is important to understand the global context of climate disruption.

Global Changes in Climate

Climate and weather are directly related, but not the same thing. Weather refers to the day-to-day conditions in a particular place, like sunny or rainy, hot or cold. Climate refers to the long-term patterns of weather over large areas. When scientists speak of global climate change, they are referring to changes in the generalized, regional patterns of weather over months, years and decades. Climate change is the ongoing change in a region's general weather characteristics or averages. In the long-term, a changing climate will have more substantial effects on the Great Lakes than individual weather events.

Evidence collected over the last century shows a trend toward warmer global temperatures, higher sea levels, and less snow cover in the Northern Hemisphere. Scientists from many fields have observed and documented significant changes in the Earth's climate.[16] Warming of the climate system is unequivocal and is now expressed in higher air and ocean temperatures, rising sea levels, and melting ice.[17]

To help predict what the climate will be in the future, scientists use computer models of the Earth to predict large-scale changes in climate. These General Circulation Models (GCMs) have been improved and verified in recent years, resulting in relatively reliable predictions for climate changes over large regions.[18] Scientists downscale these techniques to predict climate change for smaller regions.

Climate Change on the Great Lakes

The Great Lakes Integrated Sciences and Assessments Program (GLISA) is a consortium of scientists and educators from the University of Michigan and Michigan State University

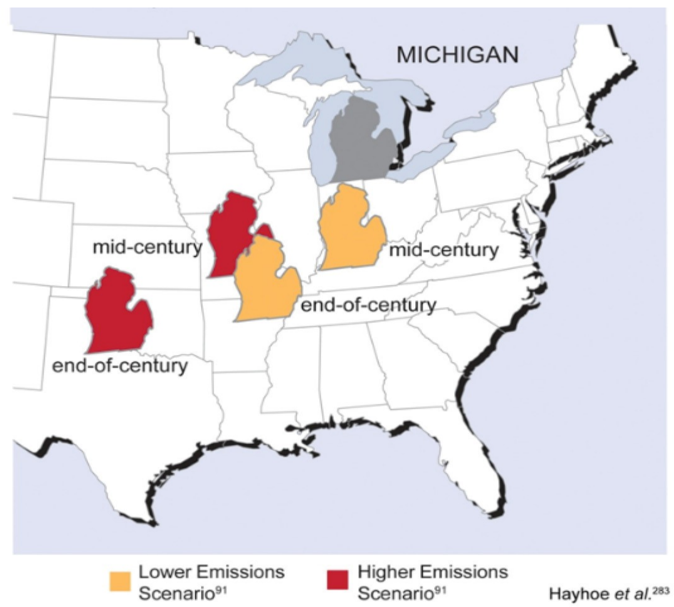
[13]Dorr, J. A. and D. F. Eschman. 1970. Geology of the Great Lakes. Ann Arbor: University of Michigan Press.
[14]Wilcox, D. A, Thompson, T.A., Booth, R.K., and Nicholas, J. R., 2007, Lake-level variability and water availability in the Great Lakes: U.S. Geological Survey Circular 1311, 25 p
[15]Ibid.
[16]Intergovernmental Panel on Climate Change. (2007). Observed changes in the climate and their effects. Eb. Accessed July 2015.
[17]Ibid.
[18]Intergovernmental Panel on Climate Change (2013). What is a GCM? Web. Access July 2015

that provides climate models for the Great Lakes region in support of community planning efforts like this Master Plan. Figure 4 illustrates the historical and predicted climate changes from GLISA for the Great Lakes region. According to GLISA, the Great Lakes region experienced a 2.3° Fahrenheit increase in average air temperatures from 1951 to 2017.[19] An additional increase of 3° to 6° F in average air temperatures is projected by 2050. Although these numbers appear relatively small, they are driving very dramatic changes in Michigan's climate and greatly impact the Great Lakes.

The National Climate Assessment for 2009 included a number of illustrations to help us understand the extent and character of anticipated climate change impacts.[20] One of these illustrations, Figure 5, shows Michigan under several emissions scenarios, each leading to changes in Michigan's climate. Just by maintaining current emission levels, Michigan's climate will feel more like present-day Arkansas or Oklahoma by the end of the century.[21]

Figure 4.

Figure 5.



Model projections of summer average temperature and precipitation changes in Illinois and Michigan for mid-century (2040-2059), and end-of-century (2080-2099), indicate that summers in these states are expected to feel progressively more like summers currently experienced in states south and west. Both states are projected to get considerably warmer and have less summer precipitation.

[19]Great Lakes Integrated Sciences and Assessments (2019) Temperature. Web. Accessed April 2019.
[20]U.S. Global Change Research Program. Global Climate Change in the United States, 2009. Cambridge University Press, Cambridge, MA.
[21]Ibid.

Increased Precipitation and Storminess

There is strong consensus among climate experts that storms greater in number and intensity will occur in the Great Lakes region as a result of climate change.[22] This is already happening as "the amount of precipitation falling in the heaviest 1% of storms increased by 35% in the Midwest from 1951 to 2017."[23] As storms drop more precipitation and generate stronger sustained winds, the Great Lakes will see stronger and higher waves. In addition to direct damage caused by storms, sustained increases in the number of storms and their intensity can both directly and indirectly pollute waters by overloading sewage and stormwater capabilities.[24] Increases in the intensity of storms also quickens the pace of erosion on Great Lakes shorelines. In fact, the Federal Emergency Management Agency (FEMA) projects approximately 28% of structures within 500 feet of a Great Lake shoreline are susceptible to erosion by 2060.[25]

Variability of Lake Water Levels

The natural ups and downs in the water levels of Lake Michigan will continue regardless of the impacts of climate change.[26] However, climate change is likely to augment this natural process, resulting in more variable water levels as warmer air temperatures result in fewer days of ice cover and faster evaporation.[27] In other words, lake levels will rise and fall faster and with less predictability than in the past. Fortunately, some of Michigan's coastal infrastructure was built in previous decades during times of high water levels.[28] However, as we recently experienced, fast-rising waters can erode shorelines, damage infrastructure, and cause extensive flooding in inland rivers.[29] When lake levels fall, access to infrastructure like docks may be restricted and navigation hazards in shallow waters may be exposed. Low lake levels pose a threat to coastal vegetation and can reduce the pumping efficiency of drinking water intake pipes.[30] Additional ramifications of changing lake levels include a drop in water supply,[31] restricted fish habitats,[32] more invasive species,[33] faster erosion, and an overall decline in beach health.[34] Climate change is likely to augment the natural highs and lows of lake levels, causing more variability and a faster rate of change, making each of these potential ramifications both more likely and less predictable.

[22]Great Lakes Integrated Sciences and Assessments (2019) Temperature. Web. Accessed December 2019.
[23]Ibid.
[24]Crice, T., & Yurkovich, E. (2011). Adapting to climate change: A planning guide for state coastal managers – a Great Lakes supplement. Silver Springs, MD: NOAA Office of Ocean and Coastal Resource Management.
[25]The Heinz Center. (2000). Evaluation of Erosion Hazards. Web. Accessed July 2015.
[26]Dinse, Keely. Preparing for extremes: The Dynamic Great Lakes. Michigan Sea Grant. Web. Accessed July 2015.
[27]Cruce, T., & Yurkovich, E. (2011). Adapting to climate change: A planning guide for state coastal managers – a Great Lakes supplement. Silver Springs, MD: NOAA Office of Ocean and Coastal Resource Management.
[28]Dinse, Keely. Preparing for extremes: The Dynamic Great Lakes. Michigan Sea Grant. Web. Accessed July 2015.
[29]Ibid.
[30]Ibid.
[31]Cruce, T., & Yurkovich, E. (2011). Adapting to climate change: A planning guide for state coastal managers – a Great Lakes supplement. Silver Springs, MD: NOAA Office of Ocean and Coastal Resource Management.
[32]Ibid.
[33]Ibid.
[34]Dinse, Keely. Preparing for extremes: The Dynamic Great Lakes. Michigan Sea Grant. Web. Accessed July 2015.

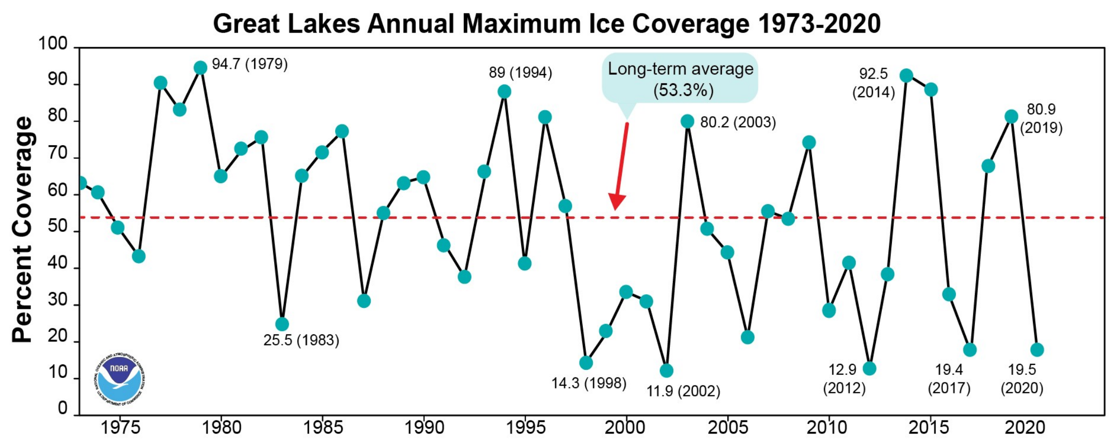
Water Temperature

Climatologists predict there will be fewer days below freezing in Michigan and other Great Lakes states. As temperatures remain warm for a greater part of the year, the winter season will shorten and the lake ice cover that accompanies winter weather will decline. In general, annual average ice cover on the Great Lakes underwent a shift from higher amounts prior to the 1990s to lower amounts in recent decades. However, there remains strong year-to-year variability, and high ice years are still possible.[35] Figure 6 illustrates the variability in ice coverage in the Great Lakes between 1973 and 2020.

Lake ice cover allows heat radiation from the sun to be reflected, so when ice declines, the surface water temperature will increase as more heat is absorbed by the water. In the Great Lakes, average summer lake surface temperatures have been increasing faster than the surrounding air temperatures, with Lake Superior surface temperatures increasing by 4.5°F between 1979 and 2006.[36]

The associated impacts of rising water temperatures include changes to where fish and other aquatic animals can live, increased vulnerability to invasive species, and increased risk of algae blooms.[37] Rising water temperatures also enable winds to travel faster across the surface of the lake, increasing the vulnerability of coastal communities to damaging waves as storms and winds increase.[38] Lastly, ice cover protects the shoreline during winter storms. With less ice cover, the shoreline is more susceptible to erosion and habitat disruption.

Figure 6.



[35]Great Lakes Integrated Sciences and Assessments (2019) Temperature. Web. Accessed April 2019.
[36]Ibid.
[37]Dinse, Keely. Preparing for extremes: The Dynamic Great Lakes. Michigan Sea Grant. Web. Accessed July 2015.
[38]Cruce, T., & Yurkovich, E. (2011). Adapting to climate change: A planning guide for state coastal managers – a Great Lakes supplement. Silver Springs, MD: NOAA Office of Ocean and Coastal Resource Management.

DEFINING VULNERABILITY IN THE COMMUNITY

The effects of climate change have been felt by everyone. With planning and preparation, communities can weather the storms and recover, becoming even better places to live and thrive. Through community-wide planning, resilient communities actively cultivate their abilities to recover from adverse situations and events, working to strengthen and diversify their local economies and communication networks, increase social capital and civic engagement, enhance ecosystem services, improve human health and social systems, and build local adaptive capacity.

Building Community Resilience

As defined by the Urban Sustainability Directors Network, community resilience is the ability of a community to anticipate, accommodate and positively adapt to or thrive amidst changing climate conditions or hazard events and enhance quality of life, reliable systems, economic vitality and conservation of resources for present and future generations.

The Rockefeller Foundation emphasizes equity as an important component of resilience, stating that community resilience is the capacity of people — particularly the poor and vulnerable — to survive and thrive no matter what stresses or shocks they encounter. Communities that are resilient are able to learn from adversity and adapt quickly to change. In general, the most important qualities of resilient communities are: (1) Reflective, (2) Flexible, (3) Integrated, (4) Robust, (5) Resourceful, (6) Redundant and (7) Inclusive.

The Rockefeller Foundation has identified 12 indicators within these qualities that make for a resilient community (see inset). However, it is important to acknowledge that the City of Frankfort is unique, and not all of these indicators or characteristics may be necessary for the community to be "resilient."

According to the Rockefeller Foundation, a Resilient Community has…

1. Minimal human vulnerability
2. Diverse livelihoods and employment
3. Effective safeguards to human life and health
4. A collective identity and mutual support
5. Comprehensive security and rule of law
6. A sustainable economy
7. Reduced exposure and fragility
8. Effective provision of critical services
9. Reliable mobility and communication
10. Effective leadership and management
11. Empowered stakeholders
12. Integrated development planning

The following is a community vulnerability assessment focused on the City of Frankfort. This assessment begins with an overview of regional climate trends and predicts societal impacts, then transitions to detailed assessments of the community's vulnerabilities to extreme heat and flooding events. Although the assessment is concentrated on these two specific types of events, many of the considerations and societal impacts identified would be present in other stresses and shocks within the community (e.g., a winter storm).

In completing the assessment, a variety of factors are considered, such as demographics, environmental conditions, locations of critical facilities and essential services, and the built environment. This assessment informs recommend-dations for reducing identified community vulnerabilities through policies, programs and projects, which will inevitably lead to a more resilient community.

Climate Variability

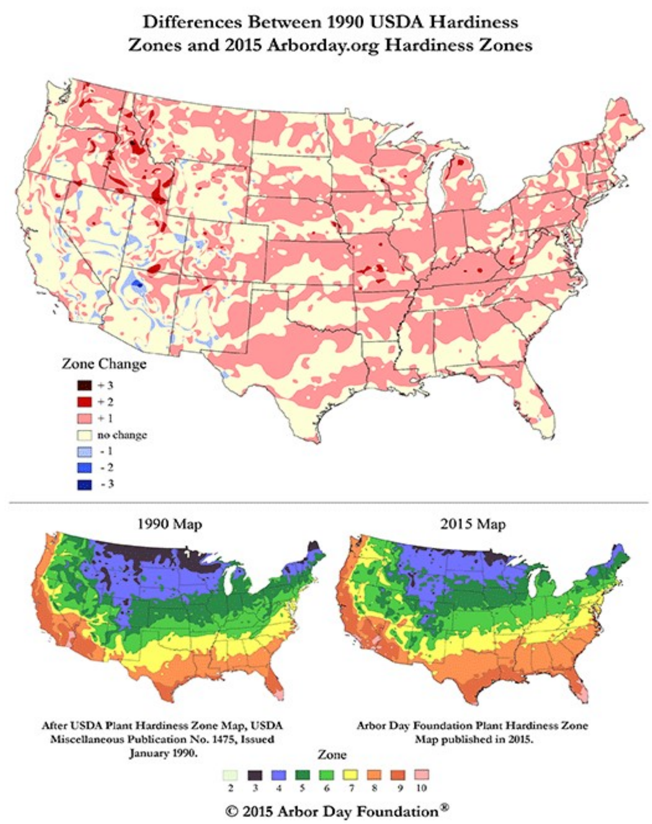
Based on the most recent models, the climate of Benzie County will continue to warm, with greater increases in average temperatures during the winter months and at night. There are a variety of weather impacts expected with this change in average temperatures. Some of the potential impacts of climate change in the community are listed below:

- Storms are expected to become more frequent and more severe
- Increases in winter and spring precipitation
- Less precipitation as snow and more as rain
- Less winter ice on lakes
- Extended growing season (earlier spring/later fall)
- More flooding events with risks of erosion
- Increases in frequency and length of severe heat events (heat waves)
- Increased risk of drought, particularly in summer

It is important to note that increased flooding and more intense drought are not mutually exclusive nor contradictory. In the Great Lakes region, scientists are predicting more intense rain events in the fall and winter along with more intense droughts in the summer months.

These changes in climate could have a number of both positive and negative effects in the City of Frankfort. For example, an extended growing season could help support new crops and increase crop yields for area farmers. On the other hand, the highly variable weather conditions — such as severe storms and flooding mixed with summer droughts — present big challenges to farming. Much of the U.S. has been warmer in recent years, and that affects which plants grow best in various regions. The Arbor Day Foundation completed an extensive update of U.S. Hardiness Zones based on data from 5,000 National Climatic Data Center cooperative stations across the continental United States. As illustrated in Figure 7, zones in Lower Michigan are shifting northward. A few decades ago, the City of Frankfort was solidly in Zone 5; today, Zone 6 plants that once thrived far to the south can now successfully survive in the City of Frankfort.

Figure 7.

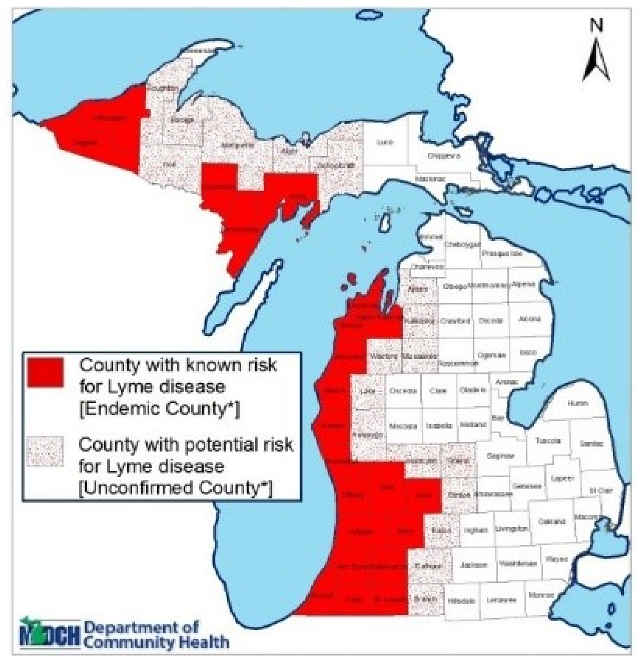


Public Health and Climate

Major health effects of long-term climatic change are predicted for the U.S. Midwest. Already, people in Michigan are experiencing higher rates of skin and eye damage from increased exposure to ultraviolet radiation, increased incidence of respiratory and cardiovascular diseases, and increased incidence of vector-borne and water-borne diseases.[39] Weather conditions and high heat events exacerbate health conditions like allergies, asthma, and obesity.

The Michigan Department of Health and Human Services (MDHHS) published the Michigan Climate and Health Adaptation Plan in 2011. The Plan indicates there is an increase in the number of illnesses and deaths as a result of extreme heat events; declining air quality as a result of increased production of ozone and particulate matter from heat and drought events; and adverse changes to water quality and availability following severe weather events. In the long term, health experts are most concerned with a rising incidence of infectious diseases and outbreaks of new diseases not currently endemic to Michigan; increasing numbers of disease vectors and the appearance of new vectors not currently established in Michigan; and a degradation of food safety, security and supply. For example, blacklegged ticks are one disease vector that has increased in recent years. According to the MDHHS, the first official reported human case of Lyme disease in Michigan was in 1985. Cases have now been reported in both the Upper and Lower Peninsula and are increasing. It is anticipated that the number of cases reported will continue to increase due to public and medical personnel education and expanding tick ranges. Figure 8 illustrates the distribution of the risk for Lyme disease in Michigan, which has increased in recent years.

Figure 8.



* Lyme disease risk in this map is based on known, field confirmed populations of infected blacklegged ticks, or laboratory confirmed human cases.

a) Counties labeled "endemic" are counties where infected tick populations have been confirmed
- and/or -
Two or more laboratory confirmed human cases have been identified with local exposure.

b) Counties labeled "unconfirmed" are conties bordering endemic counties, but which do not meet the above criteria for "endemic" counties.

MDCH Zoonotic Disease and Special Projects Section: Revised April, 2014

[39]National Research Council. Reconciling observations of global temperature change. Washington, DC: National Academy Press, 2000:86.

VULNERABILITY ASSESSMENTS

Communities interested in becoming more resilient assess their vulnerabilities and make action plans to reduce their sensitivities and exposures to hazards of all kinds. This Community Vulnerability Assessment has been compiled by the Land Information Access Association (LIAA) to provide a wide variety of useful information aimed at improving climate resilience by reducing human and community vulnerabilities.

Vulnerability = Exposure + Sensitivity

A Vulnerability Assessment is designed to identify and help prioritize adaptation strategies in the community planning process. A model that defines vulnerability as "exposure plus sensitivity" is used to complete the assessment.[40] "Exposure" refers to hazards in the natural or built environment, while "sensitivity" refers to the degree to which a community or certain segments of a community could be impacted by an event. This concept has been used in a variety of studies, such as equity and adaptation assessments conducted by the NAACP,[41] vulnerability and its relationship to adaptation,[42] and hazard-specific vulnerability assessments aimed at measuring exposure, sensitivity, and resilience.[43]

By assessing the potential for exposure to a hazard and the sensitivities of specific populations, maps are generated that identify the community's areas with relatively greater vulnerability (that is, where exposure and sensitivity overlap). This tool provides direction for community planners and public health workers in reducing risks to human health by understanding where the areas of vulnerability lie and why the vulnerability exists.

For the purposes of this tool, based on the greatest risks in Michigan and most likely predicted climate changes, the vulnerability assessment for the City of Frankfort was limited to extreme heat waves and flooding. However, climate change is predicted to result in increases of other exposures that should also be considered in community planning and development (e.g., high winds, severe winter storms).

Exposure refers to hazards in the natural or built environment, while *sensitivity* refers to the degree to which a community or certain segments of a community could be impacted by an adverse event.

Our assessment was based in part on data obtained from the American Community Survey (ACS), a continuing survey program operated by the U.S. Census Bureau. This data includes information on housing, income and education characteristics of the population in geographic areas called "Block Groups," which contain between 600 and 3,000 individuals. Data from the 2020 Census was also used, including population age and racial composition collected at the Census "Block" level, which is the smallest available geographic area for demographic data.

[40]Foundations for Community Climate Action; Definition Climate change Vulnerability in Detroit. University of Michigan. December 2012.
[41]Equity in Building Resilience in Adaptation Planning. National Association for the Advancement of Colored People (NAACP).
[42]Adger, W.N. (2006). "Vulnerability." Global Environmental Change 16 (3): 268-281. Adger, W.N., N. Arnell, and E. Tompkins (2005). "Adapting to climate change-perspectives across scales." Global Environmental Change 15(2): 77-86.
[43]Polsky, C., R. Neff, and B. Yarnal (2007). "building comparable global change vulnerability assessments: the vulnerability scoping diagram." Global Environmental Change 17(3-4): 472-485.

Heat Vulnerability

Community vulnerability to heat events varies spatially on local, regional and national scales. In Michigan communities, there are varying degrees of vulnerability to heat based on proximity to the Great Lakes, access to air conditioning, and surrounding environmental factors like tree canopy and impervious surfaces.

Studies have shown that heat-related mortality generally occurs in areas of the community that are warmer, less stable, and are home to more disadvantaged populations.[44] One study found that neighborhoods with the highest temperatures and the least amount of open space and vegetation were also likely to be the most socioeconomically disadvantaged.[45] The same study also found the strongest protective factor for residents was access to air conditioning in the home and in other places, as well as having access to transportation.

A 2012 literature review conducted by researchers at the University of Michigan indicates that children under five and persons over age 65 are highly sensitive to heat events, as are persons living in lower-income Census tracts and minority populations. Living alone, being confined to bed, having a mental illness, not leaving home daily, living on higher floors of multistory buildings, and suffering from alcoholism are additional factors that are associated with increased risk of heat-related mortality.

Many Michigan communities are rural and suburban. There have been limited studies conducted on how heat events impact rural and suburban communities, but one study notes that rural populations may exhibit patterns of vulnerability different from those of urban populations.[46]

Heat Sensitivity Assessment

To create the sensitivity and exposure maps, as well as the resulting vulnerability maps, the project team relied on methodologies developed at the University of Michigan's Taubman College of Architecture and Urban Planning in a 2012 report.[47]

To conduct the heat sensitivity assessment of the City of Frankfort, the project team used a geographic information system (GIS) for spatial data analyses to show the relative distribution of people most at risk. Five factors have been identified as primary contributors to the sensitivities and risks of people exposed to a heat wave, including: people over 65 years of age; people living alone; people over 25 with less than a high school education; minority populations; and people living below the poverty line. Using U.S. Census data, the project team identified the percentages of people living in each area (by Block Group or Block) for each sensitivity factor.

People who are older have greater sensitivity to extreme heat events. The technical literature also indicates that older age is associated with higher hospital admission rates in heat waves.

[44] Foundations for Community Climate Action: Defining Climate Change Vulnerabilities in Detroit. University of Michigan. December 2012.
[45] Semenza JC, Rubin CH, Falter KH, et al. Heat=related deaths during July 1995 heat wave in Chicago. N Engl J Med 1996; 335:84-90.
[46] Mapping Community Determinants of Heat Vulnerability. Environ Health Perspectives 117: 1730-1736 (2009). Doi:10.1289/ehp.0900683 available via http://dx.fdoi.org/[Online 10 June 2009]
[47] Foundation for Community Climate Action: Defining Climate Change Vulnerability in Detroit (December 2012) University of Michigan's Taubman College of Architecture and Urban Planning.

Table 1. Needs of Stakeholders and Participants in Disaster Recovery

	Immediate and long-term needs
Individuals and families	Housing
	Restoration of employment
	Health and welfare
	Restoration of schools and other educational facilities
Business and industry	Reconstitution of business, business recovery
	Rehiring of workers
	Insurance supplementation or coverage of uninsured losses
	Business altruistic activity
Communities and local government	Restoration of utilities and lifeline services
	Support of nonprofit charitable organizations
	Infrastructure repair and replacement
	Supervision of local recovery
	Debris removal
	Post-disaster planning
State and federal government	Repair or replacement of state-owned infrastructure or facilities
	Repair or replacement of federally-owned infrastructure or facilities

Cited in Disaster Policy & Politics (Sylves, 2008). Original source: Introduction to Emergency Management (Haddow & Bullock, 2006).

This analysis examined the relative concentration of older adults in the community by Census Block.

Another sensitivity factor is living alone, which serves as a measure of social isolation. Although living alone is not necessarily a risky thing, people who are socially isolated are at greater risk during an extreme heat event. Isolated people may not be able to recognize symptoms of heat-related illness and take proper action. In this case, the project team used the American Community Survey data for Census Block Groups, broken out into individual Census Blocks for geographic representation (Blocks with no population were not included).

Literature suggests that minorities are at greater risk during extreme heat events for various reasons, including less reliable access to health care, transportation and other social supports needed to reduce heat exposures.[48] Census Blocks were used to analyze the estimated number of non-white residents in the community.

Two socioeconomic factors associated with increased heat-related morbidity and mortality are the percentage of the people living in poverty and percentage of people without a high school diploma. In general, persons living at or below the poverty line have less access to air conditioning or cooling options for their residences. This could limit a person’s access to relief from an extreme heat event. Census Block Groups were used to analyze the relative percentages of households living below the poverty threshold in the community.

Similarly, University of Michigan researchers found studies that demonstrate a direct link between low education attainment and poor health as well as income.[49] There is also an established correlation between lower educational attainment and income. Based on these findings, Census Block Groups were used to analyze the relative percent of persons 25 years and older with less than a high school education in the community.

[48]Waugh and Tierney (eds.) Emergency Management: Principles and Practices for Local Government. Chapter 13: Identifying and addressing social vulnerabilities by Elaine Enarson.
[49]Currierp FC, Heiner KS, Samet JM, et al. Temperature and mortality in 11 cities of the eastern United States. American Journal of Epidemiology. 30 (2001): 1126-8.

To complete the heat sensitivity assessment, a cumulative score for all five sensitivity factors for each Census Block was created. In each of the sensitivity factors, the percentages were grouped into five categories (ranging from a very low percentage of people to a relatively high percentage living with the identified sensitivity). The five categorical groupings were generated by the GIS software ArcMap using natural breaks in the data (groupings). A ranking of 1 to 5 was assigned to each of the categories, ranging from 1 for the lowest percentage to 5 for the highest. Finally, the team combined the scores within each Census Block. Thus, the most sensitive Census Blocks could be scored up to 25. The sensitivity is color-coded for ease of identifying areas with the greatest sensitivity.

The Sensitivity to Excessive Heat Map (Map 1) provides a relative map of locations where the highest percentages of at-risk residents live. This does not mean these community residents are in immediate danger. Rather, the map provides planning officials a new way of identifying areas where heat waves could present serious problems for a significant number of citizens. These are populations that could be sensitive to extreme heat events.

The Census data used likely double-counts some people, such as in cases where a person is both a minority and over 65; this may overestimate the severity of the sensitivities in some locations. Conversely, the sensitivity analysis may underestimate risk in some areas because it leaves out several key sensitive populations, such as those with preexisting health concerns that denote vulnerability to heat (for example, cardiovascular disease or psychiatric disorders), since such health data is not often available publicly. Emergency managers, hospitals, and community health departments may have additional data available that can be included as the community looks to better understand its sensitive populations. To further improve the analysis, additional variables could be collected through local surveys and observations, such as the degree of social connections among individuals within a community, or materials used in housing.[50]

Heat Exposure Assessment

When larger communities experience heat waves, air temperatures can vary significantly from place to place both during the day and at night. Some of these differences can be attributed to the varying types of land cover found throughout the community. For example, temperatures can be significantly lower at night in locations with a heavy tree canopy and very little pavement, versus locations with little greenery and lots of pavement.

Impervious surfaces such as paved parking lots, roadways, and buildings absorb large amounts of heat from the air and from sunshine that is then radiated back into the surroundings, and this heat continues to radiate even after the sun has set. Conversely, tree canopy and other vegetation tend to help cool an area through evaporation and transpiration of water, and by providing shade. In places with a high percentage of impervious surface and little tree canopy, the immediate surroundings can be much warmer. Urban areas typically have higher heat indexes (combinations of temperature and humidity) than surrounding suburban or rural areas. This

[50]Mapping Community Determinants of Heat Vulnerability. Environ Health Perspectives 117: 1730-1736 (2009). Doi:10.1289/ehp.0900683 available via http://dx.fdoi.org/[Online 10 June 2009]

condition has been termed the Urban Heat Island Effect.[51]

People living in settings with an Urban Heat Island Effect suffer greater exposures to heat over longer periods of time (e.g., warmer nights), making them more vulnerable to health impacts. Studies of the Urban Heat Island Effect (whereby air temperatures in an urban area are 2° to 9° F higher than in a nearby rural area) have shown that the albedo, or reflectivity, of an urban area is one of the most important determinants in reducing the magnitude of the heat island.[52] Increasing the tree canopy cover can also reduce air temperature by 2° to 5° F. Green roofs (vegetative plantings on roofs) may also decrease the Urban Heat Island Effect and decrease stormwater runoff and building energy use. Added benefits from increasing albedo and vegetation include reductions in ground level ozone pollution and reduced energy costs associated with air conditioning use.[53]

To complete a heat exposure assessment, the project team focused on the Urban Heat Island Effect, and two separate exposure maps were created. The first exposure map depicts the percentage of impervious surfaces within each Census Block, as used in the sensitivity assessment (Map 2). These percentages are divided into five categories using the GIS software's natural breaks calculation. Since exposure is lowest in areas with the lowest percentage of impervious surfaces, those scored a 1, with a rating of 5 assigned to areas with the highest percentage of impervious surfaces.

The second exposure factor is percentage of tree canopy. Here, tree canopy is mapped within each Census Block (Map 3) and scored using a similar five-category process. On Map 3, the highest percentage of tree canopy (and therefore the lowest heat exposure) received a score of 1, and the areas with the least amount of tree canopy received a 5.

FOUR PHASES OF DISASTER MANAGEMENT

Mitigation

Mitigation involves deciding what to do where a risk to the health, safety, and welfare of society has been determined to exist, and then implementing a risk reduction program.

Preparedness

Preparedness involves developing a response plan and training first responders to save lives and reduce disaster damage, identifying critical resources, and developing necessary agreements among responding agencies, both within the jurisdiction and with other jurisdictions.

Response

Response entails providing emergency aid and assistance, reducing the probability of secondary damage, and minimizing problems for recovery operations.

Recovery

Recovery involves providing the immediate support during the early post-disaster period necessary to return vital life-support systems to minimum operational levels and continuing to provide support until the community returns to normal.

From Disaster Policy & Politics (Sylves, 2008)

[51]Basu and Samet. (2002) Relation between Elevated Ambient Temperature and Mortality: A Review from the Department g Epidemiology, Bloomberg School of Public Health, John Hopkins University, Baltimore, MD.

[52]Kolokotroni M, Giridharan R. Urban heat island intensity in London: An investigation of the impact of physical characteristics on changes in outdoor air temperature during summer. Solar Energy 2008;82(11):986–998.

[53]Akbari H. Shade trees reduce building energy use and CO2 emissions from power plants. Environmental Pollution 2002;116:S119–S126. [PubMed: 11833899

The project team combined the results of the two exposure maps to provide a single Community Extreme Heat Exposure Map for the community (Map 4), which provides a reliable depiction of where the Urban Heat Island Effect would be most or least intense during a heat wave. Officials in the City of Frankfort can use this map to better assess where new vegetation and tree canopy would be helpful to reduce heat impact.

Composite Heat Vulnerability Map

The Heat Vulnerability Map is a simple additive combination of the overall sensitivity map and the overall exposures map (see Map 5). The resulting vulnerability index depicts where concentrations of exposures and sensitive populations create a higher risk for community residents. In general, those areas with a composite score of 22 to 27 (red) have residential populations that may be particularly vulnerable to extreme heat events.

HEAVY RAIN AND FLOODING

Climate scientists say that Benzie County and all of northwest Lower Michigan can expect more frequent storms of increasing severity in the decades ahead. The total amount of rainfall per year is also likely to increase. However, climate models suggest the precipitation will be more concentrated in the winter, spring and fall seasons and there will be more localized, intense storms at almost any time of year. The potential for substantially larger rain events raises concerns over the potential for harm to human health and damage to buildings and infrastructure.

In assessing vulnerability to flooding, community planners evaluate potential exposures as well as sensitivity. Buildings, roads, bridges, sewer lines and other infrastructure located in a flood zone are exposed to greater risks. Where flowing floodwaters have the greatest energy, structures may be undercut, collapse or move, and soils will erode. Even areas outside of an identified floodplain are subject to flooding from heavy downpours. Where the soils have low permeability and physical drainage is inadequate, water will accumulate and cause ponding during large storm events. Appropriate planning and land-use regulations can help reduce exposures caused by poor site selection. The sensitivity of structures can be modified to reduce risk of damage by applying flood-resistant design standards.

Exposure to Flooding Hazards

The Digital Elevation Model Map (Map 8) offers a useful view of the coastal topography of the City of Frankfort, including the most prominent drainage patterns. On this map, the darkest brown colors identify the highest elevations, while the blue-green colors identify the lowest elevations. Map 9 shows FEMA flood zones in the community.

COASTAL RECESSION

As previously discussed, Great Lakes water level fluctuations do not result from the moon's gravitational pull like oceans, but from cyclical changes in rainfall, evaporation, and riverine and groundwater inflows. These factors work together to raise and lower the water levels of the Great Lakes in small increments daily, and larger increments seasonally and over the course of years and decades.

Unlike our nation's ocean coasts (which change in shoreline level over a 24-hour tidal period), the significantly longer time spans of mean water-level change on the Great Lakes give the beach and nearshore region significant time to readjust to new water levels and wave characteristics. During multiple years of high water levels, wave base moves landward, coastal erosion (bluff and beach) is accelerated, and the nearshore profile steepens. Conversely, during prolonged years of low water levels the reverse happens, although not completely. As the wave base moves offshore, coastal erosion does not always stop completely, but it decreases and the beach area grows larger. Because the beach readjustment from high water episodes to low water episodes is not complete (due to losses of beach sediment to offshore and into longshore sediment traps), there exists a net shoreline retreat over several cycles. For most Great Lakes shoreline, this is on the order of one foot per year of coastal retreat.

Accretion is the process of coastal sediment (sand) returning to the beach from the movement of waves and currents. Over time, this sand dries out and is blown to other areas of the beach by the prevailing winds, causing the beach to appear inflated and wider. However, during periods of rising lake levels, any apparent "accretions" are quickly lost. Even worse, those short-lived beaches can be lost especially quickly because the cumulated materials are unconsolidated and easily eroded during storm events (i.e., more so than shorelands not yet attacked by erosional processes with post-glacial compaction). These issues are exacerbated in coastal regions with high glacial bluffs or unstable perched dunes. To make matters even worse during high water years in the Great Lakes, the storms that bring increased precipitation (which results in the high water within the basin) also bring more frequent and greater wind events, resulting in a 25% increase in wave energy at the shoreline. Higher water levels coupled with higher waves can produce devastating coastal results.

Unlike ocean coasts, which are now facing a steady (if accelerating) submersion from rising sea levels, Great Lakes shorelands have always eroded (and been periodically submerged) in fits and starts — taking two steps inland, then one step back, then two steps inland — as lake levels fluctuate up and down over time. Unfortunately, the decadal timeline for these fluctuations aligns with short memories, such that pressures to build in nearshore areas continually grow as lake levels stay down for extended periods. Hence, one of the big challenges for Great Lakes coastal communities is convincing shoreland property owners and public officials that the large sandy beaches they see in front of their homes are likely only temporary in their current state and require regulatory actions to prevent risky development there.

The project team used data from Michigan Technological University (MTU) to develop maps of historic shoreline and bluffline recession along Frankfort's Lake Michigan coastline, including a 30-year projection for future natural recession along bluffs (see Maps 11, 11a, 11b and 11c). These maps are only part of the available data; shoreline and bluffline recession data can be viewed in greater detail online at:

https://www.mtu.edu/greatlakes/shared-facilities/geospatial/projects/mi-coastline-czmp/

The online viewer was developed by the Great Lakes Research Center at MTU.

COASTAL HAZARD ANALYSIS

As part of this master planning process, LIAA analyzed shoreline and riverine ecosystem and physical dynamics to help the City of Frankfort manage its shoreline and riverine areas. This chapter presents a brief summary of the team's framework, results and recommendations.

Overview of Research Framework

Scenario planning, in general, identifies driving forces to inform a range of scenarios that are then analyzed and evaluated. In this context, the project team identified natural forces, especially increasing storminess and lake-level fluctuations causing increased problems with flooding. These forces informed the creation of multiple climate futures. Each climate future was tested and evaluated for impacts on the environment and land use in the community.

Climate Future Definitions

Rather than presenting a prediction of what the future will bring, each of the following "climate futures" lays out a possible future that might occur. These varying climate futures — all of which are reasonably anticipated possibilities — are arranged from a least impactful to a most impactful condition in terms of the potential for wave damage and flooding hazards they would bring. The following descriptions outline the key assumptions made in defining each of the climate futures as compared to the others. Map 6 shows the estimated land areas that would be affected by waves and flooding under these three climate futures, and Map 7 shows the same information but with building footprints displayed.

"Lucky" Future: Under the Lucky Climate Future scenario, Great Lakes water levels will stay relatively low. Although there will be wave and wind action, major storm events and wave impacts will not encroach on properties landward of current beaches. A Lucky Future projection, indicating the land areas that would be affected by high-energy waves along the shorefront and/or adjacent riverine flooding under these conditions, is shown in green on Maps 6 and 7.

"Expected" Future: Under the Expected Climate Future, Great Lakes water levels will continue to fluctuate according to long-term decadal patterns, including recent extreme storm events incorporated into the ongoing Great Lakes Coast Flood Study by the Federal Emergency Management Agency (FEMA). Given those ongoing fluctuations, this Climate Future accounts for periods when Great Lakes still-water elevations are closer to the long-term average. In addition, this Climate Future anticipates the so-called "100-year storm event" (or 1% storm) becoming more like a 20- or 50-year storm event (i.e., an expected storm within the normal community planning time horizon) because of increased storminess. The Expected Future projection is shown in orange on Maps 6 and 7.

"Perfect Storm" Future: Under the Perfect Storm Climate Future, Great Lakes water levels will continue to fluctuate according to decadal patterns, consistent with assumptions made for the Expected Future. However, for this Perfect Storm Climate Future, the estimated still-water elevation is set higher than the long-term average and closer to the long-term high (583 feet). In addition, this Climate Future anticipates the occurrence of a so-called "500-year storm event" (or 0.2% storm) occurring within the planning time horizon while lake levels are high. The Perfect Storm Future projection is shown in red on Maps 6 and 7.

MITIGATION OPTIONS: LOOKING BEYOND HARDENED SHORELINES

Communities across the Great Lakes shoreline are beginning to recognize the importance of long-range planning when it comes to their coastal development. This distinction is most recognizable during periods of high water. In many places, times of low water beckon property owners to build in beach and dune locations that appear suitable for a permanent structure, but are sure to experience inundation when high waters return. As a result, many communities have allowed risky development patterns along their shoreline. This section will briefly describe how planning processes, such as the one that took place in the City of Frankfort, can help the community make more informed and planned decisions going forward.

The first issue that comes with short-term coastal planning is that it is almost always reactive to an issue instead of proactive. Rather than restricting high-risk development when waters are low, many coastal jurisdictions are being forced to respond to shoreline erosion and flooding with engineering solutions that have demonstrated negative consequences for ecological sustainability. Perhaps the clearest example of this has been the widespread issuance of permits to harden shorelines. While this may save the property owner's infrastructure today, it is also vital to recognize the potential degradation of nearshore habitat, the potential loss of the natural Public Trust beach, the cost of cleaning up failed revetments, and the negative effects hardened shorelines can have on neighboring properties.

Thus, communities have difficult decisions to make regarding their shorelines. There is now ample evidence to suggest that shoreline hardening has detrimental consequences on shoreline ecosystems.[54, 55] In addition, as shown in Figure 9, armoring can actually increase the erosion process of neighboring beachfronts. These consequences have prompted many communities, including the City of Frankfort, to reevaluate the short-term mitigation options that are available to communities.

Short-Term Mitigation Options

In the short term, communities that face erosion and flood damage to structures are really left with three options: they can relocate structures, they can nourish (i.e., add sand to) the beach, or they can armor the shoreline. Each of these work to ease the problem in the short term, but come with a series of pros, cons and interests as illustrated in Table 2. To summarize, relocation is perhaps the best short-term solution to save both the beach and the structure, but zoning setbacks, easements and cost can all hinder this as a viable option. Beach nourishment can slow erosional processes but is often costly, especially when considering that it may take just one storm to wash away the nourished beach sand and the public's investment. Armoring can also slow erosional processes but is only a temporary solution and one that can destroy the natural beach.

Nature-Based Solutions

Throughout the planning process, the City expressed interest in incorporating nature-based approaches for shoreline management whenever possible. The high wave energy of Lake Michigan sometimes makes for different approaches from inland lakes, though the nature-based philosophy remains the same: balancing lake access and views with aesthetics, shoreline stabilization, water quality, and habitat for fish and wildlife populations. Siting development as far from the lakeshore as possible, minimizing impervious surfaces in the community, and retaining native shoreline vegetation are all examples of approaches that can help strike these balances.

The Michigan Natural Shoreline Partnership's website (https://www.shorelinepartnership.org) includes extensive information about different approaches to natural shorelines. The U.S. Army Corps of Engineers (USACE) Engineering With Nature (EWN) Initiative seeks to combine engineering and ecology in cost-effective approaches for infrastructure development and environmental management (https://ewn.erdc.dren.mil/).

In essence, the Frankfort community recognizes that there is no one-size-fits-all short-term solution to promote a resilient coastline. These findings have prompted communities across the Great Lakes to adopt a long-term vision for the shoreline. In this way, the community will be better prepared to address the issues that arise from living on the shoreline, and to make decisions that balance the interests of property owners with the public interest in maintaining a healthy shoreline. The next section describes the data that was collected, as well as the City of Frankfort's preliminary efforts to plan long-term for the changing coast.

Figure 9.

Table 2. Short-Term Mitigation Options, Pros and Cons

	Relocate	Nourish	Armor
Pros	Conserves natural Public Trust beach and shoreline	Slows erosional processes	Slows erosional processes
Cons	Cost of relocation, loss of land	Short-term solution (e.g., one storm may destroy the investment)	Loss of natural shoreline and Public Trust beach; damage to neighboring shoreline
Owner's Interest	Preservation of infrastructure and natural shoreline prioritized over cost of relocation	Safeguarding property and structures prioritized over cost and feasibility	Safeguarding infrastructure prioritized over the cost of armor, loss of Public Trust beach, and damage elsewhere
Public Interest	Preservation of natural beach prioritized over cost of relocation and loss of land	Safeguarding property and structures prioritized over cost and feasibility	Owner's interest prioritized over loss of natural beach and potential future public cost of cleanup when armor fails

[54]Prosser, D.J., Jordan, T.E., Nagel, J.L., Seitz, R.D., Weller, D.E., Whigham, D.F. (2018). Impacts of Coastal Land Use and Shoreline Armoring on Estuarine Ecosystems: an Introduction to a Special Issue. Estuaries and Coasts 41 (S1).
[55]Wensink, S.M. & Tiegs, S.D. (2016). Shoreline hardening alters freshwater shoreline ecosystems. Freshwater Science 35 (3).

LAND USE RESULTS FOR THE CITY OF FRANKFORT

Total Acres

The total acres of land impacted by flooding (see Table 3) increases from the Lucky Climate Future to the Perfect Storm Climate Future in the community. Under the Lucky climate scenario, the city would likely see 2.7 acres of land inundated with water. In the Perfect Storm scenario, we see a nearly tenfold increase up to 26.7 acres impacted.

Parcels

Table 4 displays the number of parcels that the city could expect to be affected in each of the flood scenarios. It is important to note that affected parcels are different from affected structures. In other words, some of the parcels impacted in a certain flood scenario may not indicate that a structure is at risk or that additional setbacks are needed, per se. However, the total number of affected parcels in each flood scenario can give the community a better idea of how many people and properties are at risk, helping to better frame the issue.

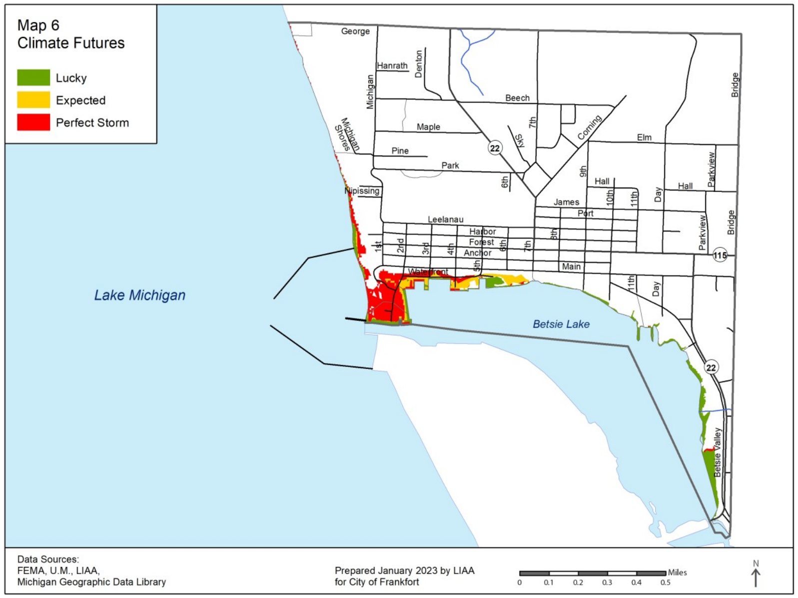
The number of affected parcels increases in each flood scenario. However, even in the Lucky scenario when lake levels are low and major storms are relatively small, the city would still expect to see 43 parcels impacted by flooding.

Table 3. Total Land Acres Impacted by Flooding

	Lucky	Expected	Perfect Storm
City of Frankfort	2.7	8.9	26.7

Table 4. Number of Parcels Impacted by Flooding

	Lucky	Expected	Perfect Storm
City of Frankfort	43	83	222



Map: excerpt from Vulnerability Map 6—Future Climate Scenarios

Residential Parcels

Breaking down the parcel data further, Table 5 distinguishes between residential and non-residential areas. Across all scenarios, between 46.3%-71.8% of the affected parcels have been assessed as residential. This highlights the city's need to work with property owners to implement best practices to make the community more resilient to flooding and shoreline erosion.

State Equalized Value (SEV)

Table 6 shows the SEV of the parcels that could be impacted in each of the three flood scenarios. Over $6 million worth of property would be affected in each scenario, and over $29 million in the Perfect Storm climate future. While this data does not necessarily project the cost of damages, it does provide an insight into the potential economic consequences if a major storm event were to occur.

Table 5. Parcels Affected in the City of Frankfort

		Lucky	Expected	Perfect Storm
City of Frankfort	Residential Parcels Affected	19 (46.3%)	41 (50%)	155 (71.8%)
	Non-residential Parcels Affected	22 (53.7%)	41 (50%)	61 (28.2%)

Note: the entries for Table 5 came from LIAA's shapefile downloaded on 2/16/2023 from Benzie's online web mapping application Benzie County uploaded the data in August 2022.

Table 6. SEV* of Properties in the City of Frankfort Flood Scenarios

	Lucky	Expected	Perfect Storm
City of Frankfort	$6,431,481	$14,430,766	$29,228,627

*2022 Benzie County SEV

Regulating At-Risk Areas

In pursuing greater coastal resilience and reducing risks from storm events, the city may consider implementing greater setbacks or additional site requirements than those already established locally and at the state level.

Table 7 assumes that the municipality would seek to implement best practices for land use within the boundaries established by the three flood scenarios, or extended further to reduce risk even more. For example, if 83 City of Frankfort parcels are currently estimated to be impacted by flooding in the Expected future, the municipality may want to consider additional setback requirements. Table 7 demonstrates that increased setbacks would correspondingly increase the number of parcels under regulation. If the community is willing to accept more risk, it may seek to use the areas affected in the Lucky scenario as a starting point.

This information, along with Maps 6 and 7, can help the city, as well as members of the community, to decide how much risk is acceptable, understanding that avoiding all risk is impossible.

Table 7. Number of Parcels Regulated in Flood Scenarios

		Flood Scenario		
		Lucky	**Expected**	**Perfect Storm**
City of Frankfort	**Number of Parcels Regulated**	43	83	222
	+10-ft Setback	58	103	245
	+50-ft Setback	93	152	254
	+100-ft Setback	118	180	274

Note: Parcels that overlap each other is likely the reason that the Expected and Perfect Storm "Current Affected" produce different results when running the top portion method. The method used in this section is the "Select By Location" and then using the "Apply a search distance" for each setback.

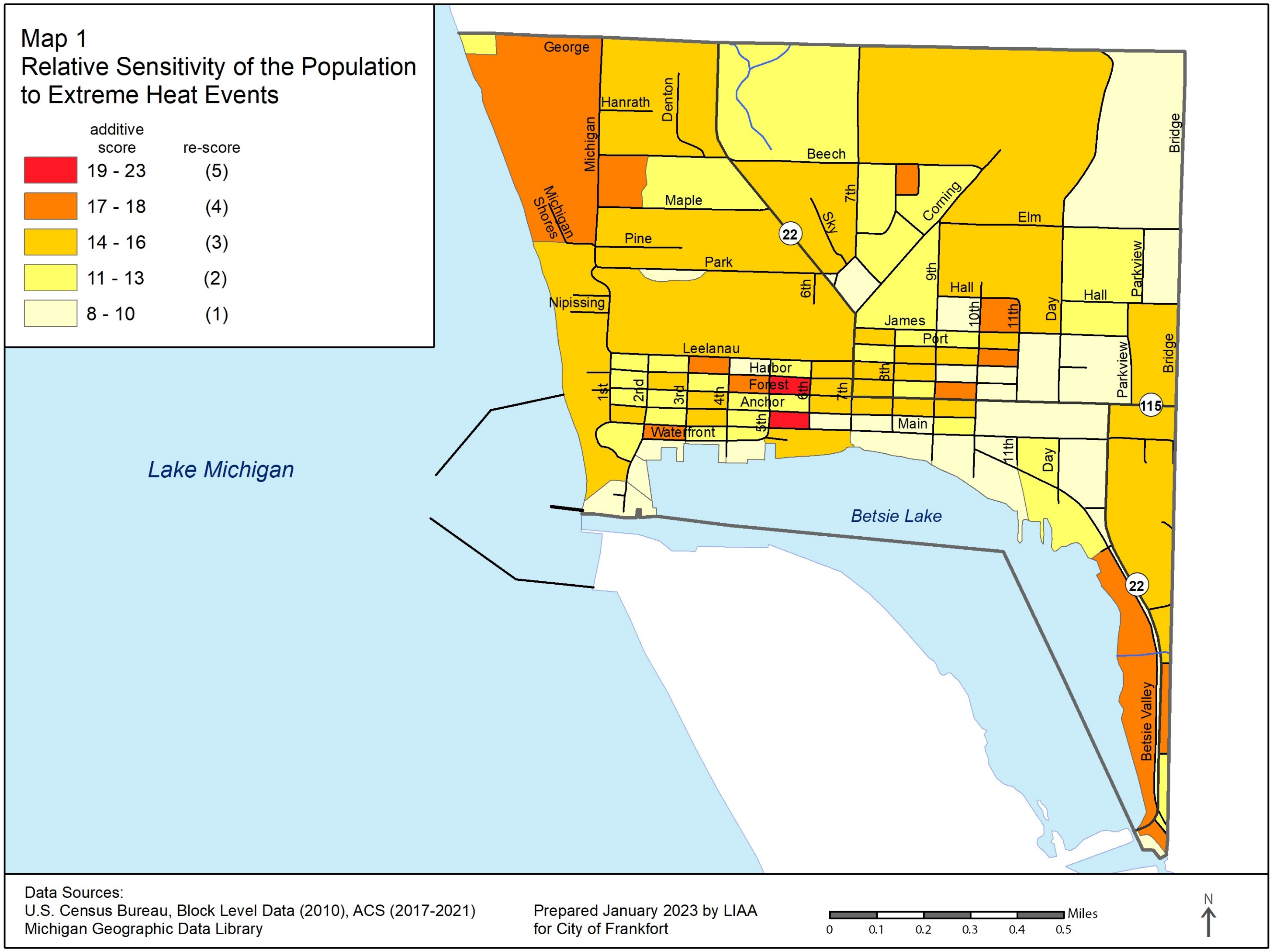
PUBLIC INPUT

The following summarizes the input received regarding coastal resilience during the public meeting held February 14, 2023.

What we heard...
The City Superintendent asked, “What are other communities doing to preserve their coastlines?”
Commissioners appreciated the vulnerability maps.
The City of Frankfort is looking to be proactive for when the next high-water level comes, as opposed to reactive.

Map 1

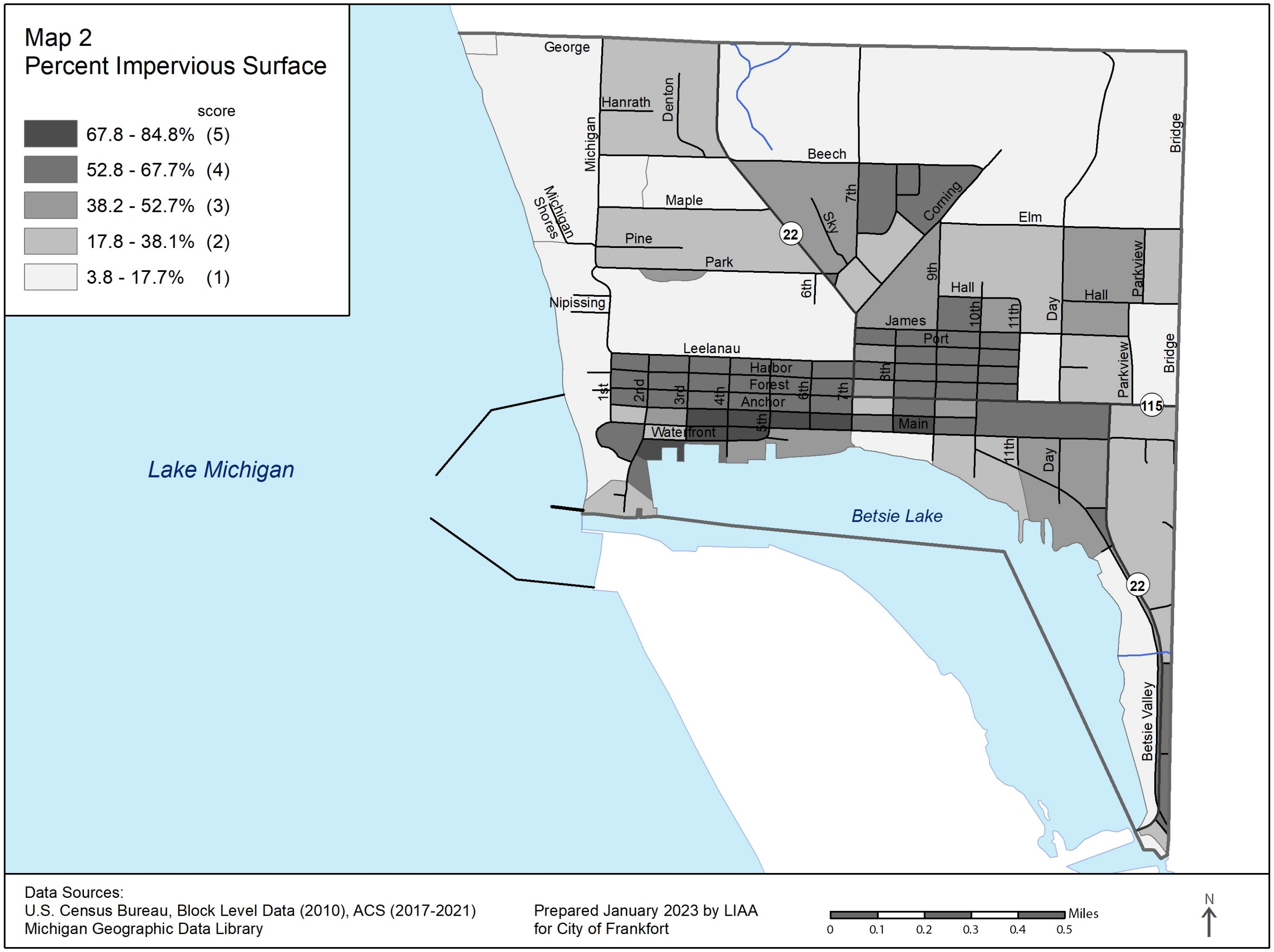
Relative Sensitivity of Populations to Extreme Heat Events



City of Frankfort

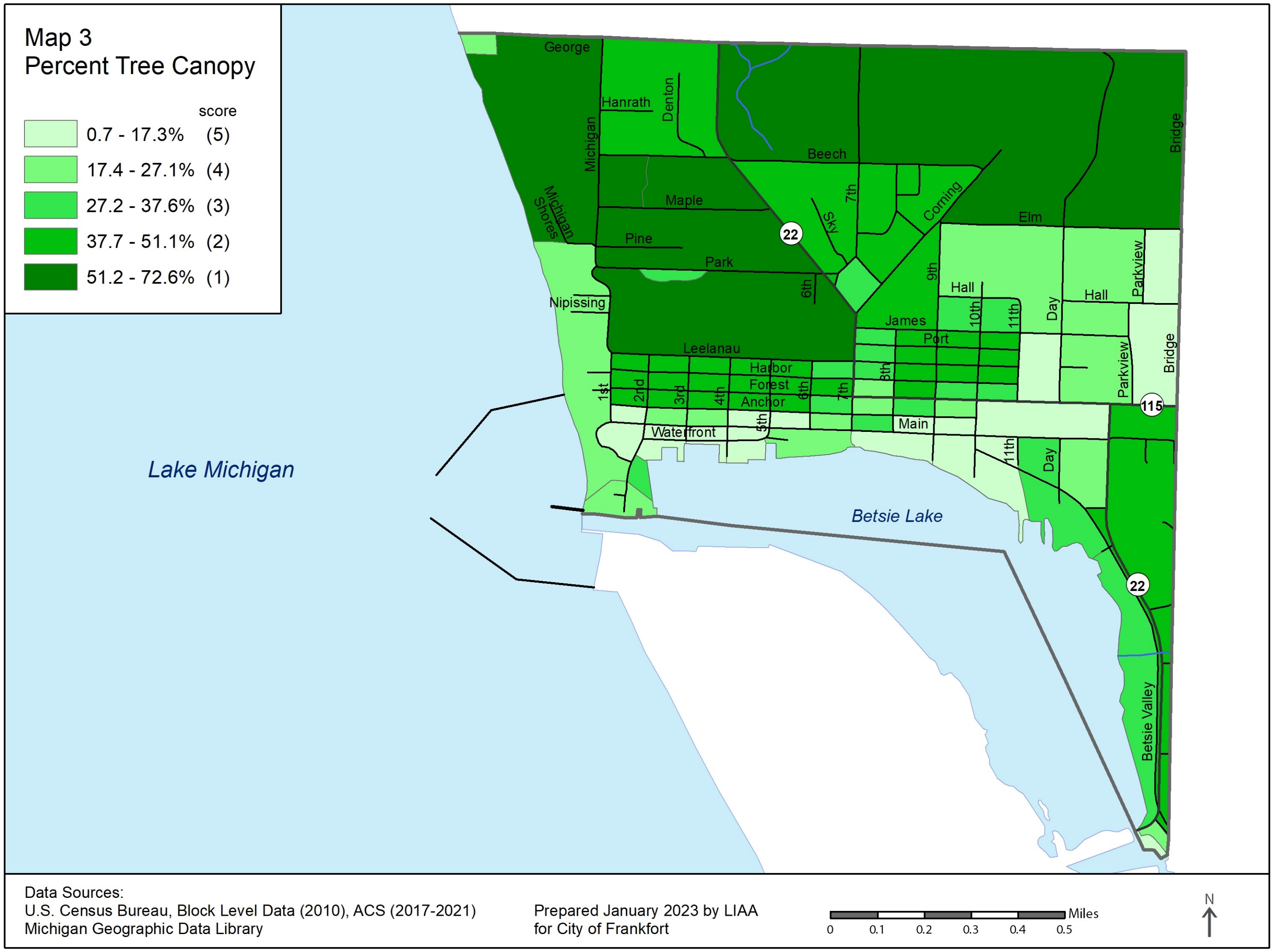
Map 2

Percent Impervious Surface



Map 3

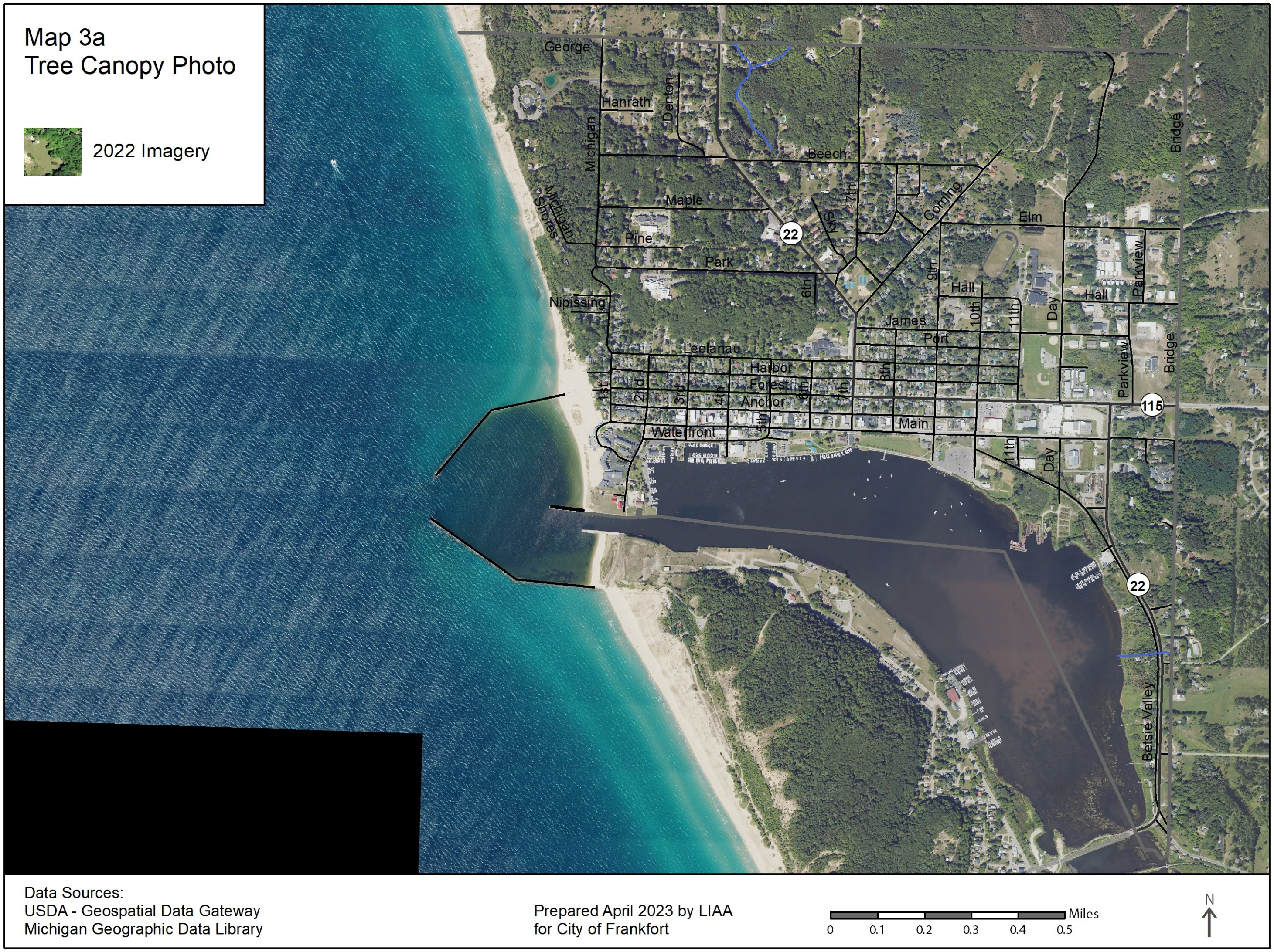
Percent Tree Canopy



City of Frankfort

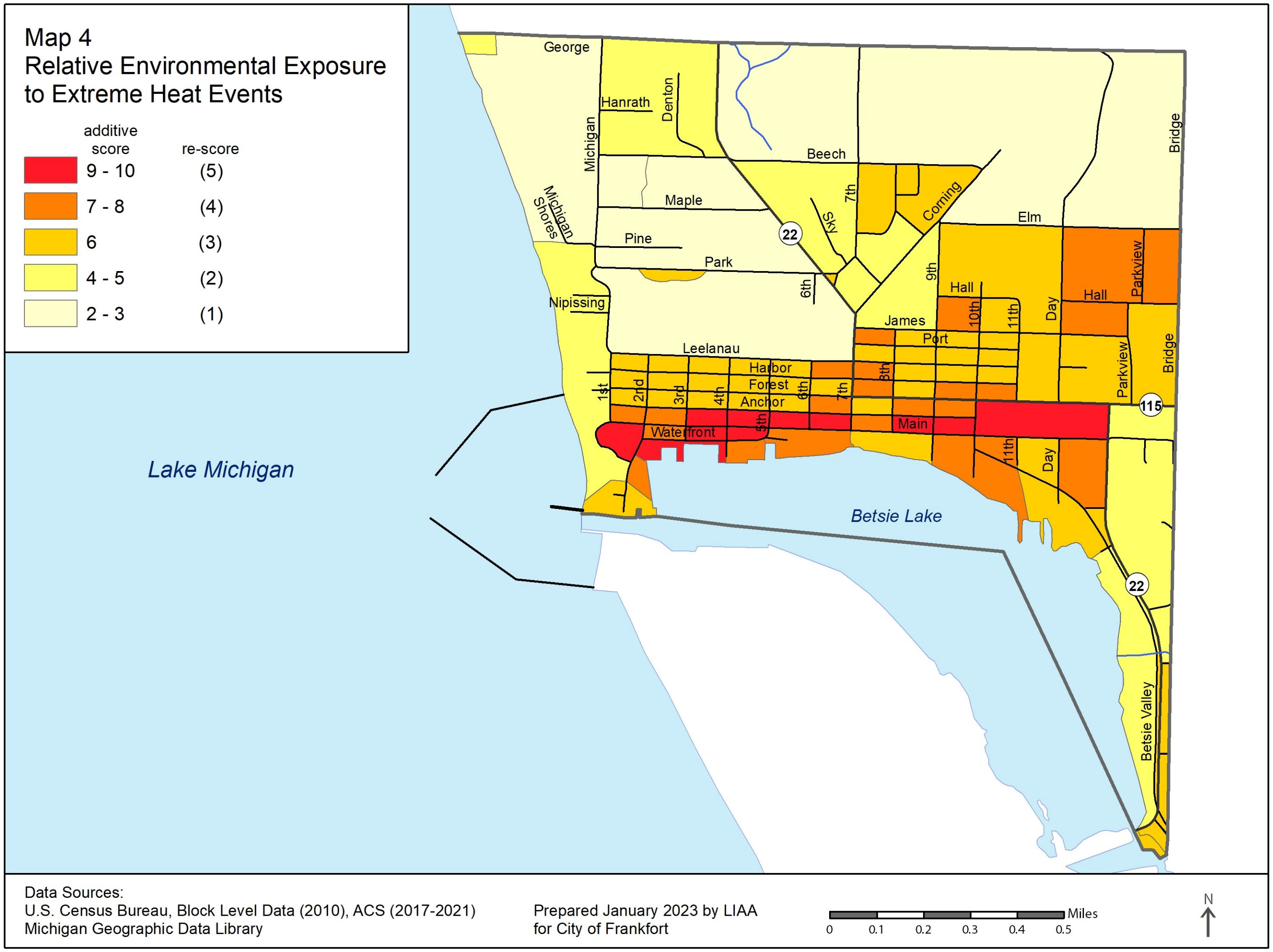
Map 3a

Tree Canopy Photo



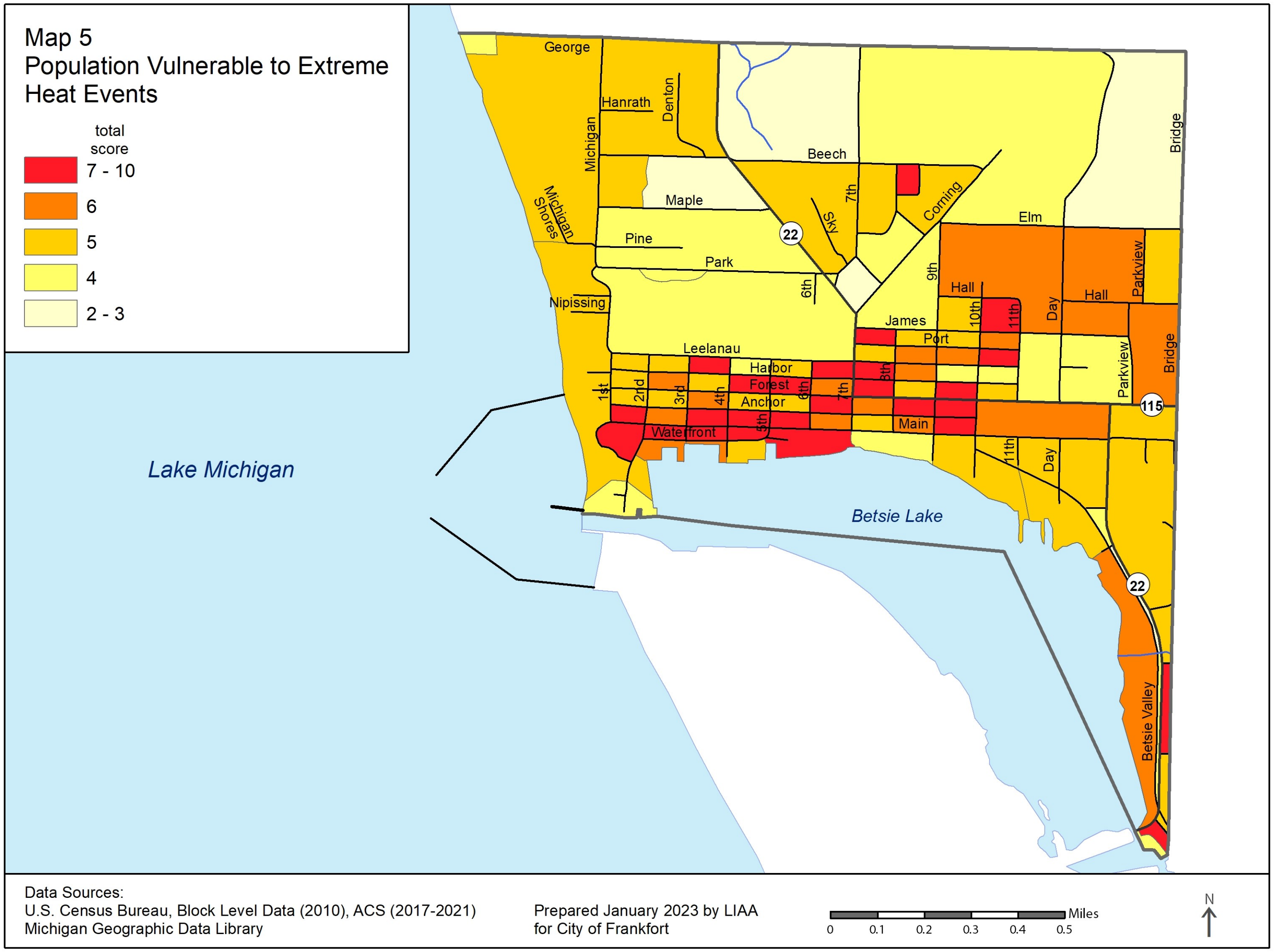
Map 4

Relative Exposure of Populations to Extreme Heat Events



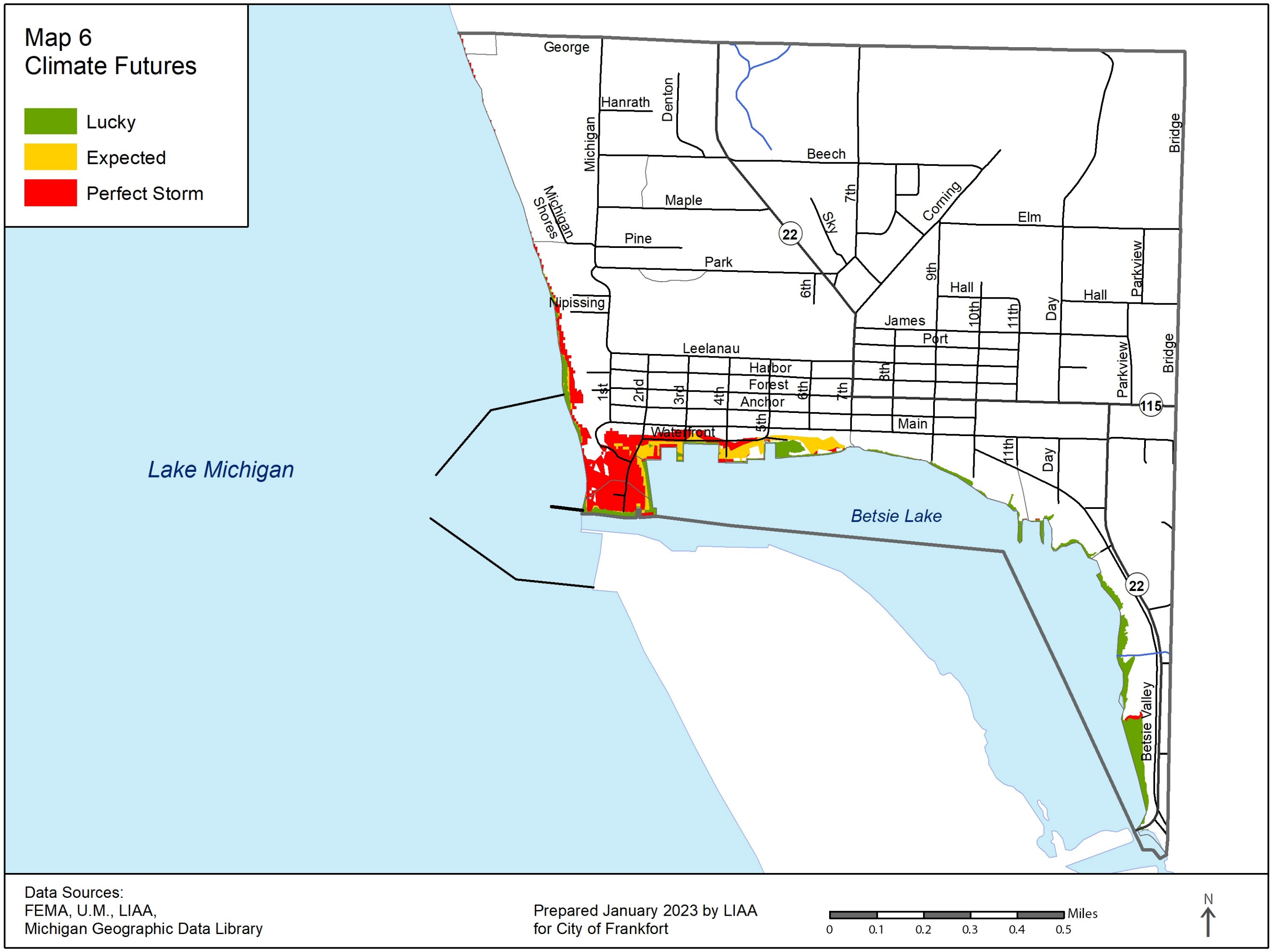
Map 5

Population Vulnerable to Extreme Heat Events



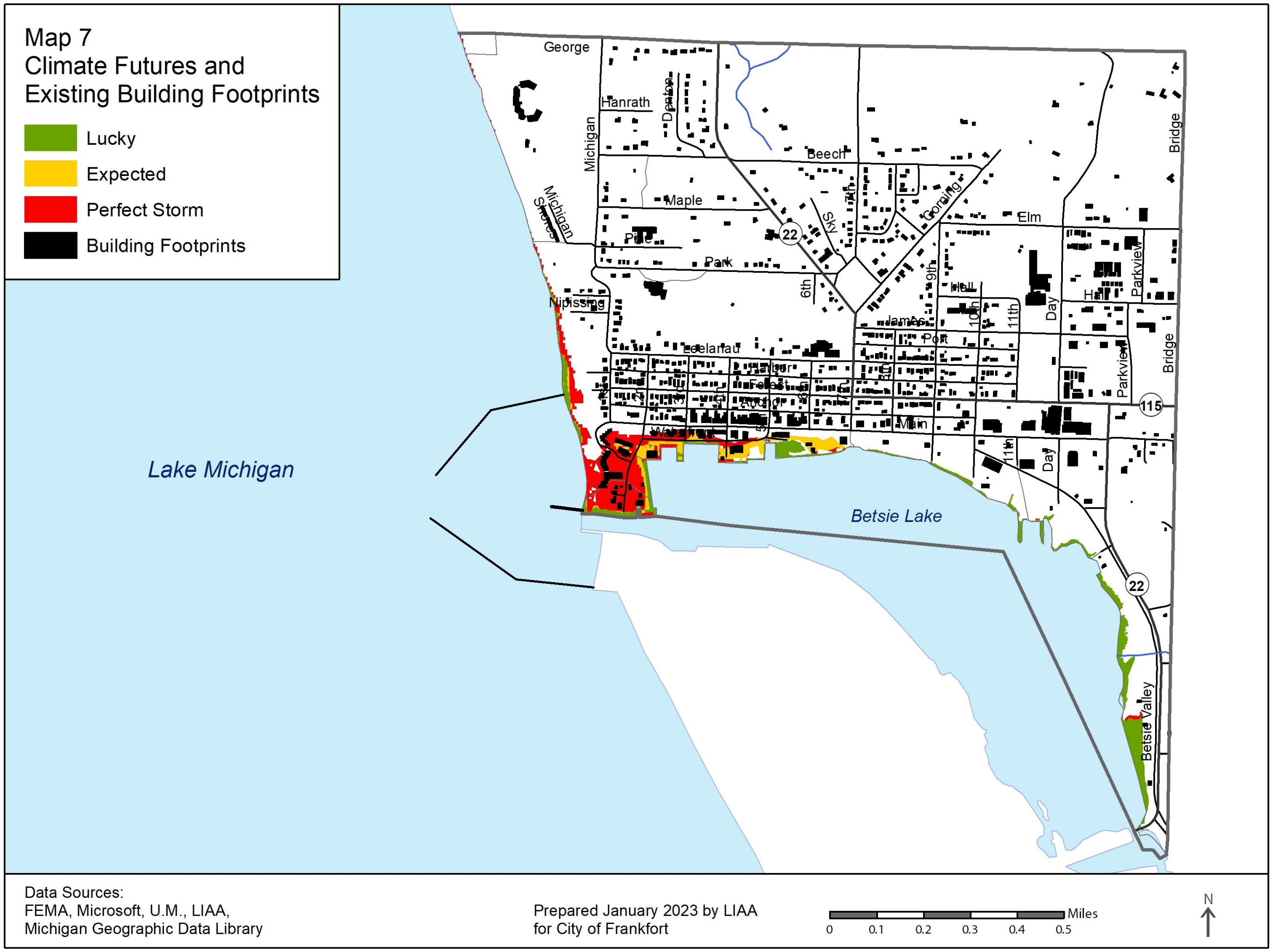
Map 6

Future Climate Scenarios



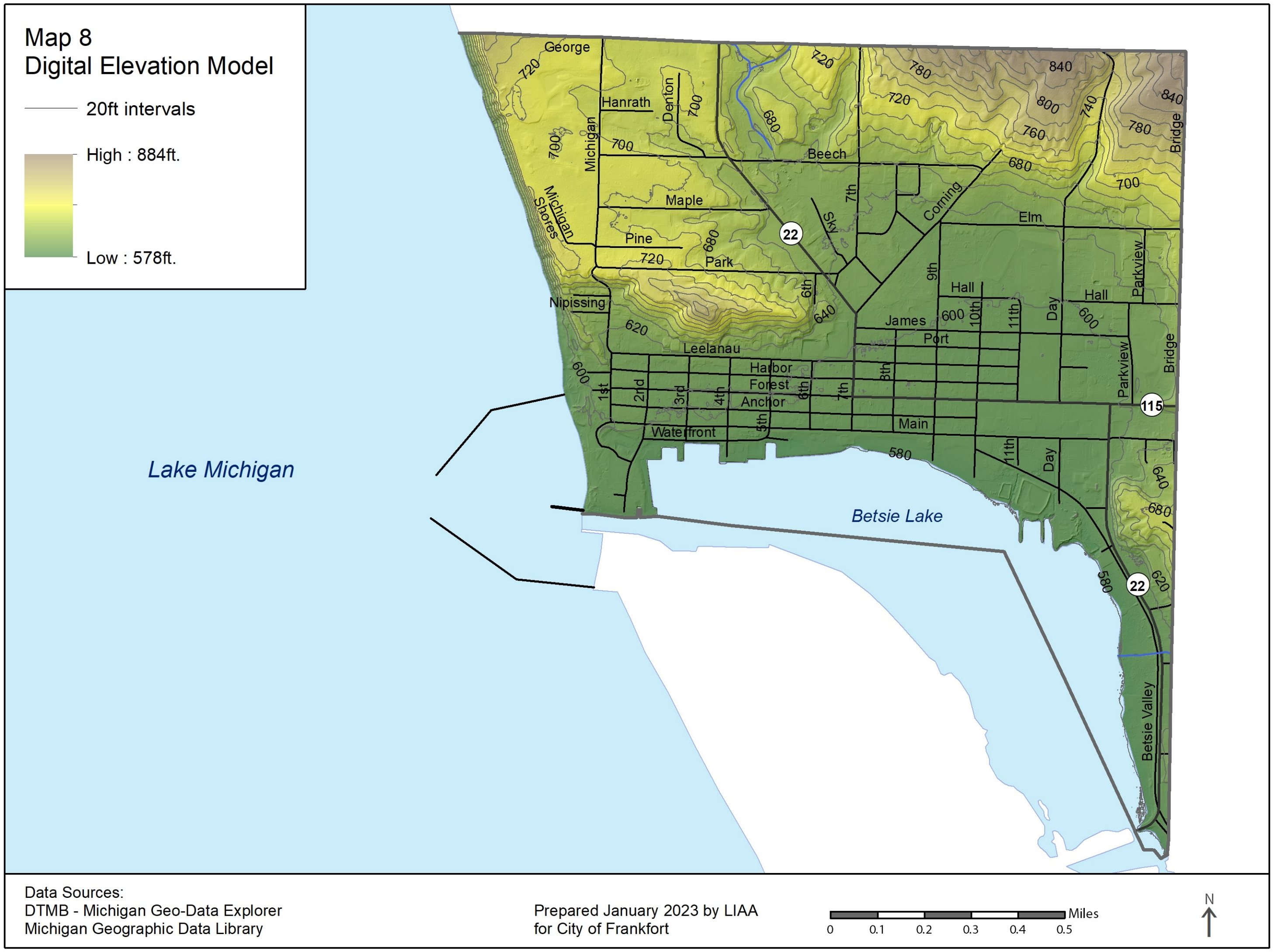
Map 7

Future Climate Scenarios with Building Footprints



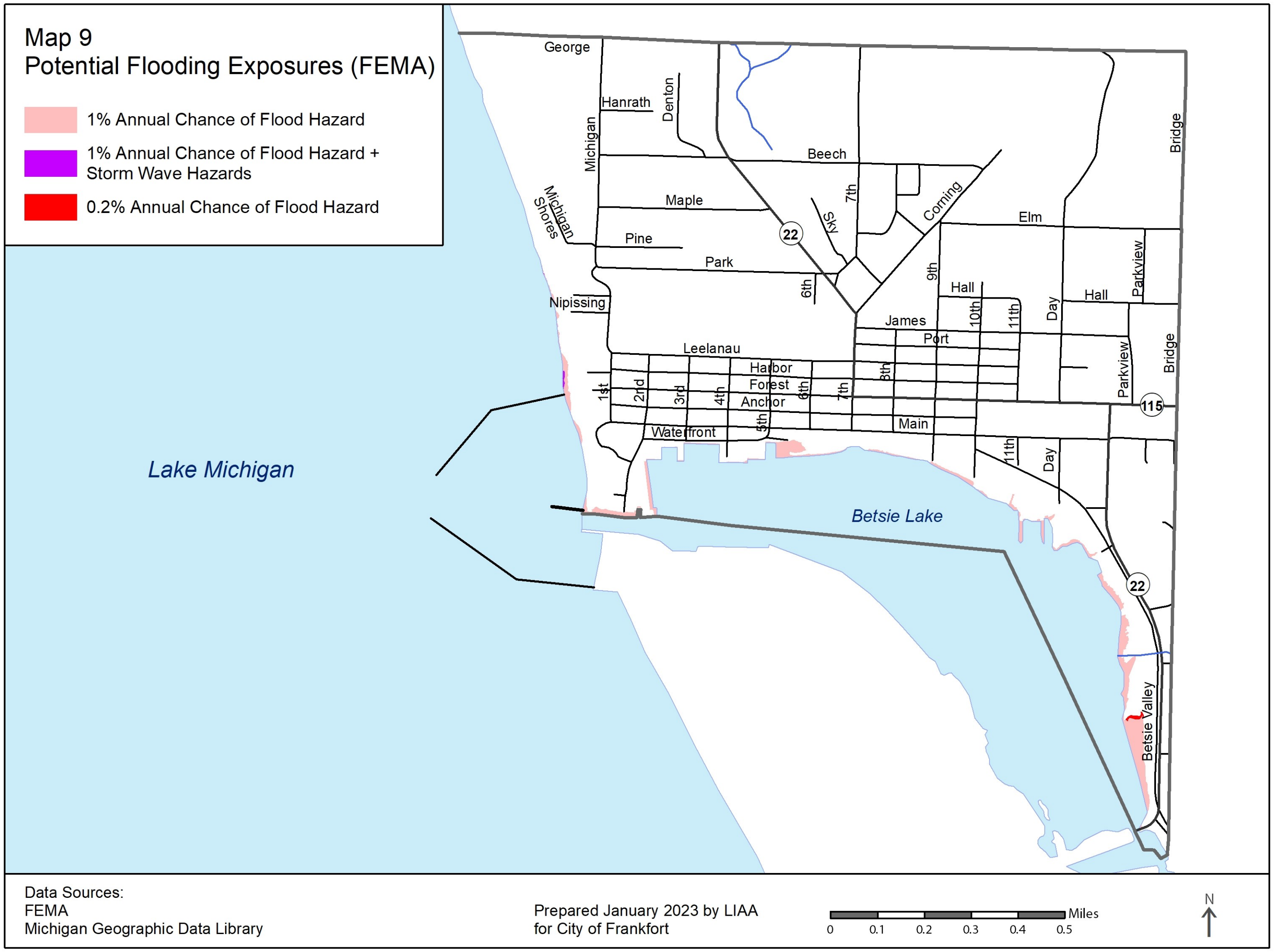
Map 8

Digital Elevation Model



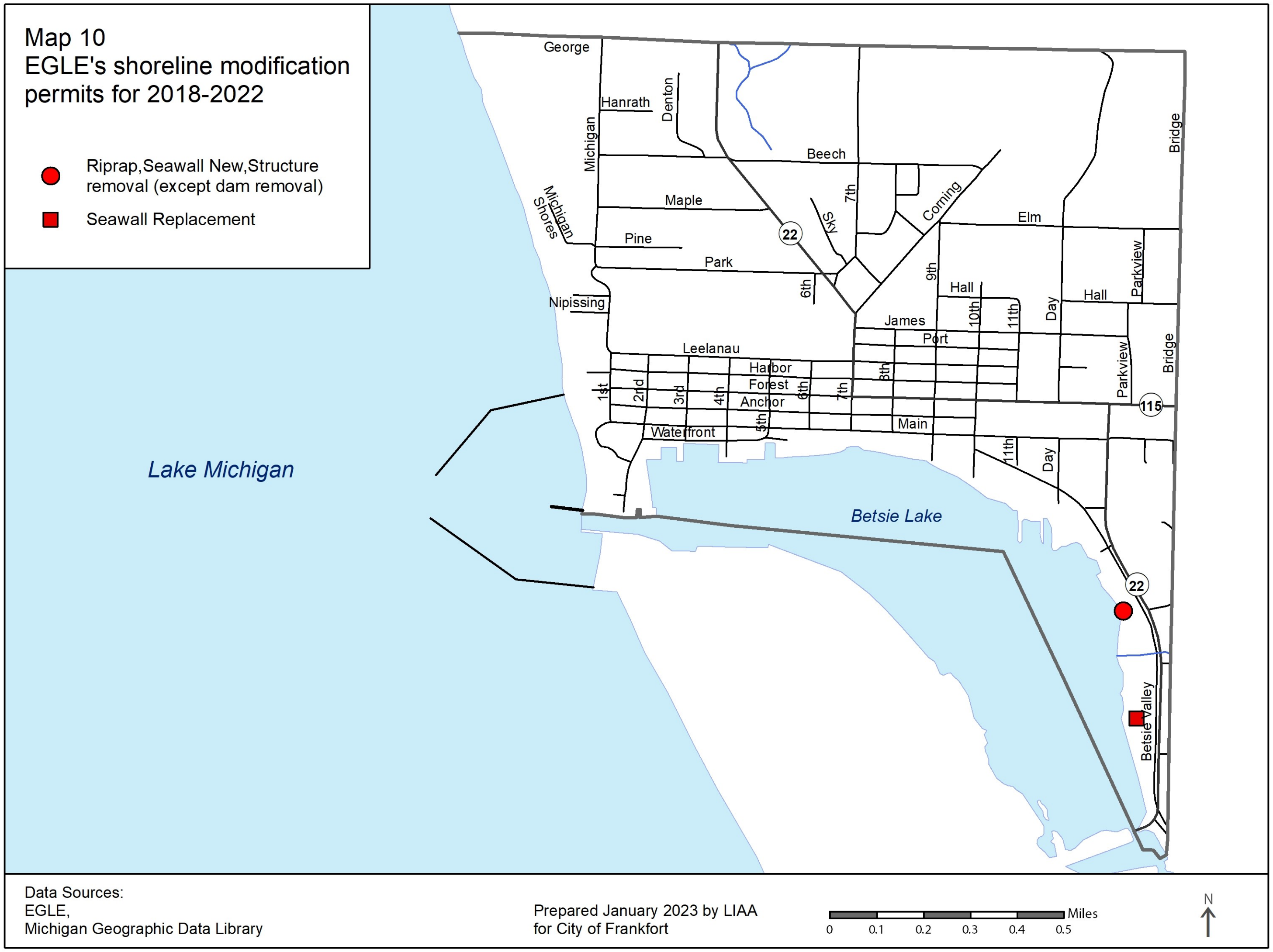
Map 9

Potential Flooding Exposures (FEMA)



Map 10

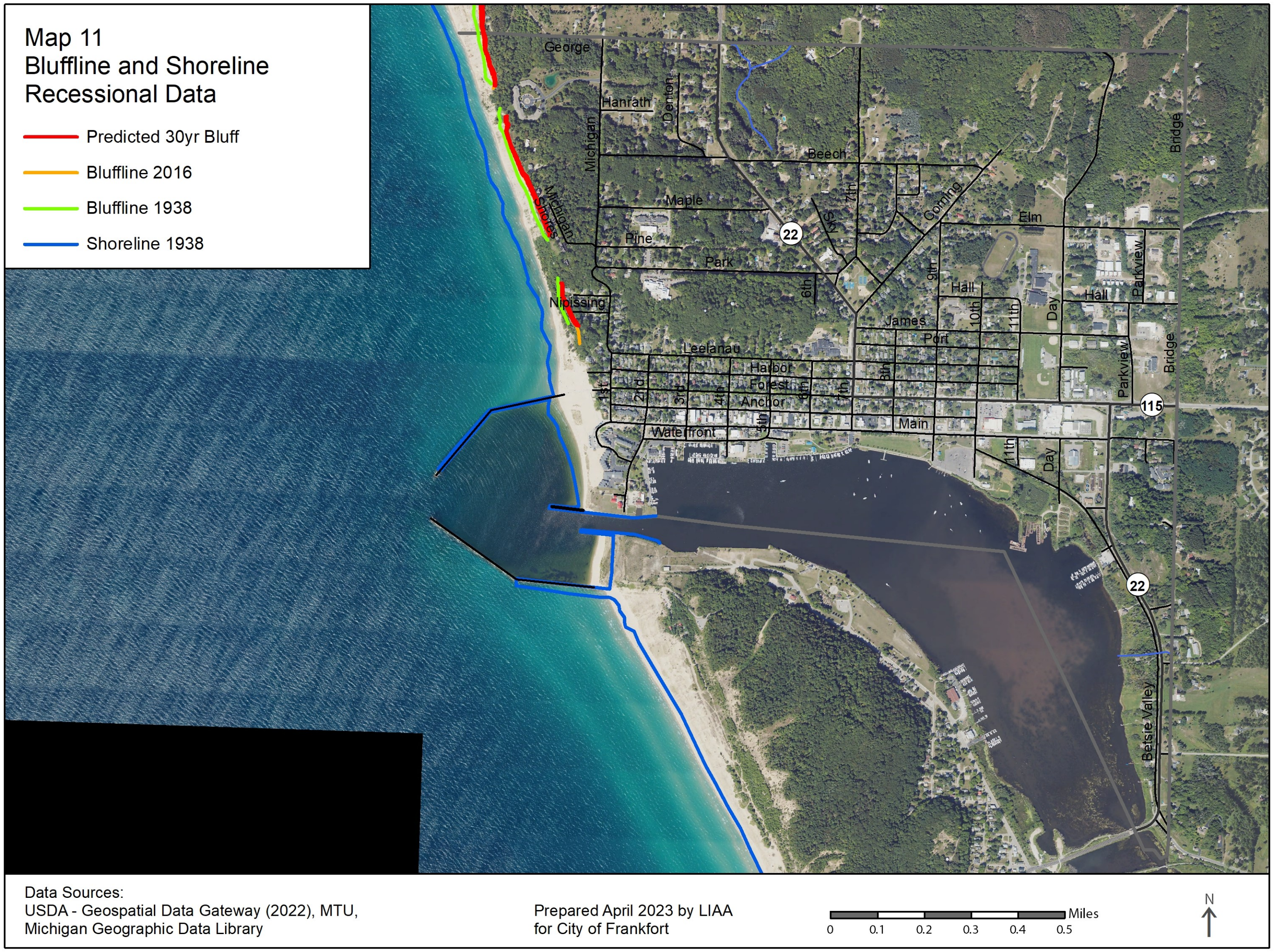
EGLE Shoreline Modification Permits for 2018 — 2022



City of Frankfort

Map 11

Coastal Recession



Map 11a

Coastal Recession Detail

Map 11b

Coastal Recession Detail

Map 11c

Coastal Recession Detail