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SEWRPC Community Assistance Planning Report No. 345

MILWAUKEE COUNTY HAZARD MITIGATION PLAN UPDATE

Chapter 3

ANALYSIS OF HAZARD CONDITIONS

To evaluate various potential hazard mitigation alternatives for Milwaukee County and select the most effective and feasible hazard mitigation strategies, the existing potential natural weather hazard problems in the County must first be analyzed and the vulnerability to such hazards documented. Accordingly, this chapter provides the following:

- Identification of the hazards likely to affect Milwaukee County
- Profiles of the extent and severity of recent hazard events which occurred in the County
- Assessment of the vulnerability and risk associated with each type of hazard
- Identification of the potential for changes in hazard severity and risk under future conditions, such as climate change

The vulnerability assessment focuses on the County and community assets described in Chapter 2.

3.1 HAZARD IDENTIFICATION

The process of identifying those natural hazards that should be specifically addressed in the Milwaukee County hazard mitigation plan was based upon consideration of a number of factors. The process included input from the Milwaukee County Hazard Mitigation Local Planning Team (LPT), including a priority ranking of hazards; review of the hazard identification set forth in the State hazard mitigation plan;[1] review of documentation of past hazard events; and review of related available mapping, plans, and assessments. It is important to note that both the City of Milwaukee Hazard Mitigation Plan and the previous Milwaukee County Pre-Disaster Mitigation Plan were reviewed and utilized as a resource as part of the hazard identification and assessment in terms of the natural hazards analyses relevant to the County. As part of the updating process, the identification of hazards likely to affect Milwaukee County was reviewed and reevaluated. This reevaluation included additional input from the Milwaukee County Hazard Mitigation LPT. As such, the LPT reevaluated the hazards using a hazard and vulnerability assessment tool in the form of an online survey called "Survey123."[2] In this survey, members of the LPT indicated the likelihood of each hazard occurring in Milwaukee County and evaluated the severity of each hazard on the basis of possible impacts to people, property, and businesses. In the survey the LPT also evaluated the relative state of preparedness for each hazard. The ratings given by the LPT for each hazard were used to derive a perceived level of risk posed by each hazard which were then ranked as shown Table 3.1.

Summary of Hazard Vulnerability and Risk Assessment Survey Results

Methods

The online assessment survey was presented at the April 27, 2023 LPT online meeting, with a total of 15 surveys returned and analyzed. For each of the hazards, a risk was computed for each survey using the formula:

Risk (in weighted average) = [(Probability) x (Human impact + Property impact +
Business impact - Preparedness)]

Probability (likelihood that an event would occur), Human impact (possibility of death or injury), Property impact (physical losses and damages), Business impact (interruption of services), and Preparedness (mitigation or pre-planning) were each assigned a number from 0 to 3 by LPT members, with 0 indicating "not applicable", 1 indicating low, 2 indicating moderate, and 3 indicating high.

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[1] *Wisconsin Department of Emergency Management and Military Affairs, State of Wisconsin Hazard Mitigation Plan, December 2021.*

[2] *ArcGIS "Survey123" is an online tool that collects data through web or mobile devices which can be used to create, share, and analyze surveys.*

The interpretation of the results returned by this formula is that the perceived threat increases with increasing weighted average risk. For each hazard, an average risk was calculated using the results of all the returned surveys. The hazards were then ranked by average risk, with a rank of 1 indicating the highest perceived risk.

Results

The results from the assessment survey are summarized in Table 3.1. Hazard events are listed in order of highest perceived risk to lowest perceived risk. As listed in Table 3.1, the highest perceived risks are associated with tornado, high straight-line winds, stormwater flooding, winter events (i.e., ice storms and blizzards), and extreme temperature events with riverine flooding and coastal hazards perceived as moderate risks (middle of the ranking order).

Summary and Ranking of Hazards

There are several ways the Milwaukee County hazards can be ranked and summarized to be considered in the County hazard mitigation plan. Current guidance for all hazard mitigation plans promotes comprehensive consideration of all natural hazards. These hazards have been ranked by consideration of their frequency, amount of damage, and death and injuries incurred, as well as by concerns of, and degree of importance assigned by, the collective judgment of the Milwaukee County Hazard Mitigation LPT.

The hazards to be considered in this plan are summarized in Table 3.2,[3] along with qualitative information on the hazard severity. Natural hazard severity can be assessed and ranked in a variety of ways. The purpose of ranking hazards is to help set priorities and direct more resources to address those hazards of the greatest severity. However, the kinds of mitigation actions that will be needed and warranted depend on the type of vulnerability to be addressed. Some hazards, such as excessive heat and lightning, are unlikely to cause a disaster, but they can be fatal and, therefore, are serious hazards. Vulnerability to such hazards can best be addressed by preventative measures, such as public information to encourage hazard awareness and personal protection. Other hazards, such as flooding, are pervasive and devastating, and may require a variety of tools—mapping, building codes, zoning laws, insurance, elevation or acquisition of flood-prone

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[3] *The rankings in Table 3.2 were assigned by combining rankings of the natural hazards listed based upon the number of occurrences, number of damages, numbers of fatalities and injuries reported since 2000, and the perceived risk associated with each hazard as identified by the Local Planning Team and summarized in Table 3.1. It is important to note that some of the natural hazards listed in Table 3.2 represent combinations of hazards listed in Table 3.1. For example, while specific risks associated with thunderstorms, such as hail and lightning are listed separately in Table 3.1, they are combined into one category in Table 3.2.*

structures, and public awareness—to effectively reduce the risk of disaster. However, flooding might not result in more fatalities than a heat wave. In general, ranking hazards by the number of deaths that they cause shifts the focus away from major and largely avoidable disasters, such as floods. Weather hazards that have caused past Milwaukee County disasters are likely the hazards that will cause future disasters. However, the types of natural hazards that result in fatalities remain a public health and safety concern.

The summary listing of natural hazards in Tables 3.1 does include some hazards that have been found to have minimal chance of occurring or offer only limited applicable mitigation options. In addition, the hazards listed below will receive less emphasis in the subsequent sections of the report or are incorporated as sub-elements among existing categories, as summarized in Table 3.2.

Fog

Fog is low-level moisture caused by many contributing factors, including ice or snowmelt, moist air from Lake Michigan, or rain evaporation with light winds, which may reduce visibility levels, especially in river valleys and other low spots. Dense fog is often seen with clearing skies the day following a heavy rainstorm. Fog is a widespread natural hazard event that usually covers several counties during an episode. There have been 61 fog events reported in and around Milwaukee County from 2000 through 2022. Although no deaths or injuries were recorded during that period, fog can affect mobility. Dense fog may persist for several hours or days, reducing visibility and leading to vehicle accidents, flight delays, or cancellations at airports. This natural hazard event does not offer significant mitigation alternatives to warrant individual examination.

Wildfires

A forest fire is an uncontrolled fire occurring in forest or woodlands outside the limits of incorporated villages or cities. A wildfire is any instance of uncontrolled burning in brush, marshes, grasslands, or field lands. Such incidents are normally responded to by local fire suppression departments in accordance with established response procedures and no specific mitigation actions are deemed warranted. Wildfires in Wisconsin are primarily caused by humans burning yard debris, arson, or campfires, for example. They can also be caused by natural events like lightning. Land use, vegetation, amount of combustible materials present, and weather conditions, such as wind, low humidity, and lack of precipitation, are the chief factors determining the number of fires and acreage burned.

Less than 4 percent of the land area in Milwaukee County is woodland (see Table 2.9). Urbanization has reduced the threat of a large-scale forest or wildfire event. In addition, no wildfires are reported in the NCEI database for Milwaukee County. It should be noted that the Wisconsin Department of Natural Resources

(WDNR) online dashboard for Wisconsin wildfires indicates six reported smaller wildfire events in Milwaukee County from the period of 2012 through 2023.[4]

Based on guidance from the National Association of State Foresters, the WDNR, in conjunction with its Federal and tribal partners, developed a Statewide assessment of communities at risk from wildfires. None of the communities in Milwaukee County were determined to be a concern or at high or very high risk. Considering the low risk and lack of historical significance, forest and wildfire hazards will not be addressed in later chapters.

Dust Storms

There have been no dust storm events reported in Milwaukee County from 2000 through 2022. Natural hazard events that occurred in the past are likely to reoccur in the future, providing the opportunity to plan for them. A dust storm event in Milwaukee County would be atypical, therefore, mitigation strategies will not be recommended for this hazard in the current plan.

Land Subsidence

Land subsidence is the lowering of the land-surface elevation from changes that take place underground. Common causes of land subsidence from human activity are pumping water, oil, and gas from underground reservoirs; dissolution of limestone aquifers (sinkholes); collapse of underground utilities or mines; drainage of organic soils; and initial wetting of dry soils (hydrocompaction). Due to the limited threat from physical injury and death incidences from subsidence in Milwaukee County, this hazard will not be considered further in subsequent sections of this report.

Inland Landslide

The term "landslide" includes a wide range of ground movement, including rock falls, deep failure of slopes and shallow debris flows. The most frequent and damaging landslides in the U.S. are started by prolonged or heavy rainfall. The majority of rainfall-induced landslides are shallow, small, and move rapidly. Many rainfall-induced landslides transform into debris flows (fast-moving slurries of water, soil, and rock) as they travel down steep slopes, especially those that enter stream channels where they may mix with additional water and sediment. Due to the lack of bare (no plants or trees to hold the soil in place) hills or steep slopes in the County, inland landslides are considered to have a very low potential in Milwaukee County. As such,

[4] *dnrmaps.wi.gov/WAB.*

there have been no inland landslides reported in the County from 2000 through 2022. Thus, mitigation strategies for this hazard will not be recommended in the current plan.

Earthquake

An earthquake is a shaking or sometimes violent trembling of the earth that results from the sudden shifting of rock beneath the earth's crust. These sudden shifts release energy in the form of seismic waves or wave-like movement of the land surface. Earthquakes can strike without warning and may range in intensity from slight tremors to great shocks lasting a few seconds or over five minutes. The actual movement of the ground during earthquakes is seldom the direct cause of injury or death. Casualties may result from falling objects and debris, and disruption of communications, electrical power supplies, and gas, sewer, and water lines should be expected from earthquakes. The severity of an earthquake can be measured by comparing the peak acceleration associated with the horizontal shaking it produces to the normal acceleration a falling object experiences due to the force of gravity. This is usually expressed as a percentage of g, the acceleration due to gravity. The level of risk due to earthquake can be expressed as the percentage of g, for which there is a 2 percent probability of being exceeded in a 50-year period. Depending on location, sites in Milwaukee County have a 2 percent probability of experiencing earthquakes in a 50-year period in which the peak acceleration associated with horizontal shaking exceeds between 4 percent and 8 percent of g.[5] These are low values. While these levels of shaking can be noticeable, they are rarely associated with damage to structures. The earthquake threat to the State and Milwaukee County is considered low, therefore earthquakes will not be considered further in subsequent sections of this report.

Past Hazard Experience

Past experiences with disasters are an indication of the potential for future disasters to which Milwaukee County would be vulnerable. Accordingly, a review was made of the hazards that Milwaukee County has faced in the past. Tables 3.3 – 3.5 detail the history of estimated disaster damages caused by federally declared emergencies, the total number of weather hazard events recorded, and the severe weather history in the County.

As shown in Table 3.3, Milwaukee County has had 18 major disaster declarations and 3 emergency disaster declarations between 1969 and 2022. The total documented estimated damages of these 18 events

[5] U.S. Geological Survey, "2008 United States National Seismic Hazard Maps", USGS Fact Sheet 2008-3018, April 2008.

exceeded $380 million. It should be noted that the reported damage estimates generally underestimate the actual damage that occurred.[6]

Since 2000 (the "historical range" for this Plan update), Milwaukee County has experienced 747 weather hazard events resulting in 50 fatalities and 249 injuries reported, as shown in Table 3.4. To illustrate the broader hazard damage potential, these records indicate that nearly $220 million in property and crop damages occurred over this time period.

The historical events summarized in Table 3.4 show that thunderstorm and related high wind events were the most frequent weather hazards, closely followed by winter weather and extreme temperatures events in Milwaukee County. However, it is important to note that flooding is the most damaging weather hazard followed by tornadoes. In addition, temperature extremes have resulted in all but five of the reported 50 fatalities during this time period.

To demonstrate the potential frequency of thunderstorms, tornadoes, and flooding events a review was made of the warnings historically issued by the NWS, as shown in Table 3.5. Over the period of 2000 through 2022, there have been 46 tornado-related watches or warnings, 298 severe thunderstorm watches or warnings, and 107 flash flood and flood warnings.

3.2 DESCRIPTION OF ANALYSIS, METHODS, AND PROCEDURES

In the previous section of this Report, the natural hazards considered applicable to Milwaukee County were identified and ranked (Table 3.1). This section of the report develops a vulnerability assessment procedure for the identified hazards. This vulnerability assessment provides the basis for developing mitigation strategies that address the identified vulnerabilities.

The procedures utilized in the vulnerability analyses are based upon guidance provided by the Federal Emergency Management Agency (FEMA) and the Wisconsin Department of Military Affairs, Division of

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[6] *Major declarations are made by the President, when the President determines assistance is needed to supplement State and local efforts in providing services such as the protection of lives, property, public health, and safety, and to lessen the threat of a disaster. Agriculture-related disasters and disaster designations are quite common. A Secretarial disaster declaration occurs when the USDA Secretary of Agriculture authorizes a county (or counties) as a disaster area (or "designation") to make available emergency loans for agricultural producers that have suffered severe production losses due to a natural disaster.*

Emergency Management (WEM).[7] The analysis includes three components: 1) profile of weather hazard events, 2) inventory of assets (Chapter 2 component), and 3) estimation of losses. In addition, where applicable, potential changes in vulnerability under future conditions and the variance of vulnerability among the populations of the 19 municipalities within Milwaukee County are analyzed. The profiling of these weather hazard events was developed by utilizing the HAZUS methodology, data available on the FEMA and NOAA National Climatic web sites, USDA-RMA, data provided by the WEM, file data available from the Milwaukee County Office of Emergency Management, MMSD, and SEWRPC.

Data and estimated losses and vulnerability were developed utilizing standard risk assessment methodology as set forth in FEMA and WEM guidelines for hazard mitigation planning where hazards can be estimated spatially and by order of magnitude over a range of events. For hazards which cannot be quantified, alternative approaches have been used relying on qualitative measures. A vulnerability description has been included for each of the applicable hazards listed in Table 3.2.

3.3 HAZARD VULNERABILITY AND RISK ASSESSMENTS

Flooding and Stormwater Drainage Problems

Floods are natural events that provide many environmental benefits, such as enriching soils and recharging aquifers. Floods are only considered hazards when development occurs in the floodplain, exposing people and/or property to the risk of flood damages. Nationwide, hundreds of flood hazard events occur each year, making it one of the most common natural hazards. The type of flooding that threatens a community is dependent on a variety of factors including terrain, geologic conditions, watershed characteristics, natural features, and human interaction. The characteristics of flooding events differ significantly from a controlled engineered urban community to that of a more natural rural environment. For Milwaukee County, flooding is considered a significant hazard.

In addition to riverine (or overbank) flooding, stormwater drainage (urban flooding) problems occur throughout the County. Stormwater drainage problems are a result of a community's stormwater

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[7] *Federal Emergency Management Agency, State and Local Mitigation Planning How-to Guide, "Understanding Your Risks, Identifying Hazards and Estimating Losses," Publication No. FEMA 386-2, August 2001; Federal Emergency Management Agency, State Mitigation Planning Policy Guide, April. 2022; Federal Emergency Management Agency, Local Mitigation Planning Policy Guide, April 19, 2022.*

infrastructure capacity being exceeded by a storm or series of storms.[8] Most storm water infrastructure systems are designed to handle the amount of water expected during a 5-year or a 10-year storm. The distinction between stormwater drainage, stormwater management, and flood control is not always clear. For the purpose of this Report, flood control is defined as the prevention of damage from the overflow of natural streams and watercourses. Drainage is defined as the control of excess stormwater on the land surface before such water has entered stream channels. The term "stormwater management" encompasses both stormwater drainage and stormwater control measures. While the focus of this section of the plan is on the flooding hazard, the related stormwater drainage hazards are also considered because of the interrelationship between these two hazard conditions.

Other types of flooding concerns prone to Milwaukee County are highlighted below.

Flood Hazards Related to Dam Failure

A consideration in flood hazard mitigation is the potential for increased flooding due to dam failures. As indicated in Table 3.6 and Map 3.1, there are nine dams identified by the WDNR in Milwaukee County. Dams built according to accepted engineering principles at the time of construction and dams built without application of engineering principles can both equally fail. When a dam fails, or is subject to overtopping, large quantities of water can rush downstream with great destructive force.

The WDNR inspects and assigns hazard ratings to large dams within the State. Two factors are considered when assigning hazard ratings: existing land use and land use controls (zoning) downstream of the dam. Dams are classified, by law, in three categories that identify the potential hazard to life and property.[9]

- A **low hazard** rating is assigned to those dams that have no development beyond the allowable open space use in the hydraulic shadow where the failure or mis-operation of the dam would result. There would be no probable loss of human life, low economic losses (losses are principally limited to the owner's property), low environmental damage, and no significant disruption of lifeline facilities. Land use controls are in place to restrict future development in the hydraulic shadow.

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[8] *An urban drainage system is comprised of altered natural channels and engineered ditches, storm sewers, retention ponds, and other facilities constructed to store runoff or carry it away from residential areas to a receiving stream or lake.*

[9] Wisconsin Administrative Code*, NR 333.06.*

- A **significant hazard** rating is assigned to those dams that have no existing development in the hydraulic shadow that would be inundated to a depth greater than 2 feet and have land use controls in place to restrict future development in the hydraulic shadow. The potential for loss of human life during failure is unlikely. Failure or mis-operation of the dam would result in no probable loss of human life but may cause economic loss, environmental damage, or disruption of lifeline facilities.

- A **high hazard** rating is assigned to those dams that have existing development in the hydraulic shadow that will be inundated to a depth greater than 2 feet or do not have land use controls in place to restrict future development in the hydraulic shadow. This rating is assigned if loss of human life during failure or mis-operation of the dam is probable.

Of the nine existing (or active) dams in Milwaukee County, one dam (Milwaukee County Grounds) is listed as having a high hazard rating while the remaining are listed as low hazard (see Table 3.6).

Ice Jams

Flows that would normally be conveyed within stream and river channels with little problem can become flood hazards when an ice jam forms downstream. Likewise, ice jams can intensify flooding from streams that are already swollen from large storm events or spring melt. Ice jams occur when chunks of ice clump together to block the flow of a waterway, creating a temporary dam made of ice. The waterway backs up and floods adjacent land—often with swiftly moving water. Ice jams can develop near bends in a river, places where topography flattens, or around bridges. Jams usually occur when there are large temperature swings that cause snow melt to swell a river before the ice has a chance to thaw. The volume and speed of water released from an ice jam can be a highly destructive combination. Ice jams have been known to occur on the Milwaukee River, including a 2019 event in Ozaukee County (just north of Milwaukee County) in which 20 homes, two businesses, a fire station, and a baseball field were damaged. In total, this event caused $165,000 (2019 dollars) in damages to public facilities.

Flash Floods

Flash floods typically occur within hours of heavy rains, ice jams or dam failures. With that, flash floods usually involve a rapid rise in water level, high velocity, and large amounts of debris, which can lead to significant damage including the tearing out of trees, undermining of buildings and bridges, scouring of new channels, and creation of sink holes. The intensity of flash flooding is dependent upon the intensity and duration of rainfall, steepness of the watershed, stream gradients, watershed vegetation, natural and artificial flood storage areas, and configuration or manipulation (i.e., concrete lining) of the streambed and floodplain. Urban areas, such as Milwaukee County, are increasingly subject to flash flooding due to the removal of vegetation, installation of impermeable surfaces, and construction of drainage systems. As indicated in Table 3.7, between 2011 to 2022 of the 20 reported flood events, 14 were considered a flash flood, making this type of flooding event very common throughout Milwaukee County.

Recent Flood Events

As shown in Table 3.7, from 2011-2022 a total of 20 flood events were reported in Milwaukee County, and several have caused significant damage. These flood events ranged from one event per year up to five events per year, which demonstrates the likelihood and unpredictability of these events. In total, these flood events have resulted in three casualties, no injuries, and over $12 million (2022 dollars) in property damages within Milwaukee County. Examples of these more recent significant flood events are noted below. Note, the January 11, 2020 lakeshore flood event is described in the "Lake Michigan Coastal Hazards" section.

2018 – On August 27, 2018, there were multiple rounds of flooding and severe weather across southern Wisconsin. Significant flash flooding took place at times across parts of Milwaukee and Ozaukee Counties. Four to eight inches of rain fell over this area resulting in flash flooding in northern Milwaukee County. This event caused an estimated $30,000 in property damages (2022 dollars).

2020 – In August of 2020, three to seven inches of rain from persistent thunderstorms resulted in flash flooding of creeks, streets, parks, and residential yards in southern Milwaukee County. This mostly included the communities of West Allis, Hales Corners, Greenfield, Oak Creek, and Franklin. Many streets were impassable and closed. Numerous vehicles were stranded in 2 to 4 feet of floodwaters. Portions of I-43 were closed due to flooding. Many yards and basements were flooded especially when the floodwaters rose from the streets into the yards. Oak Creek in South Milwaukee rapidly rose and nearly reached moderate flood stage. An estimated $56,974 in property damages (2022 dollars) was reported as a result of this event.

Vulnerability and Community Impact Assessment Related to Flooding Hazards

People and property (residential structures, public facilities, and infrastructure) located within floodplains are susceptible to flood impacts. In addition, areas with poor stormwater drainage are more susceptible to short-term effects of flash flooding. To assess Milwaukee County for flooding hazards and related stormwater drainage problems, consideration was specifically given to structural assets throughout the County that would be impacted by a 100-year riverine flood event.

Damage Estimation Method: Parcel-Based Loss Analysis

SEWRPC staff conducted a parcel-based analysis to estimate the damages that would be sustained by buildings (or structures) as the result of a 1-percent-annual-probability flood event. Milwaukee Metropolitan Sewerage District (MMSD) provided a database that identified structures located within the 1-percent-annual-probability floodplain across most of the county. For these parcels, on which a principal building (structure) was located wholly or partially in the floodplain, the 2022 assessed value of improvements, when available, was obtained predominantly from the State Cartographer's Office.[10] Where tax year 2022 assessed values were not available, tax year 2023 assessed values were used. The information in the assessment along with reviewing imagery was used to classify each principal building as residential (including manufactured homes, apartments, and condominiums), commercial, parks and recreational, utility, or a critical community facility. For each principal building, the lowest elevation of the ground at the building was determined from 2015 one-foot contour topographic maps.

Standard assumptions were made as to the elevation of the first floors of the principal buildings. For a residential building, it was assumed that the first floor was 1.0 foot above the ground elevation. It was also assumed that all residential buildings had a basement unless evidence was seen to suggest otherwise. For manufactured homes it was assumed that the first floor was 2.0 feet above ground elevation. For all other building types, it was assumed that the first floor is 0.5 feet above ground elevation.

Flood elevations for the 1-percent-annual-probability flood event were derived from information in the source floodplain listed for each structure; the MMSD flooded structures dataset used a combination of the latest floodplain mapping sources across the county depending on specific location, which included FEMA effective floodplains, SEWRPC floodplains, Menomonee River and Estabrook Dam LOMRs, and WDNR Risk Map floodplains. Flood elevation values were based on the location of the structure and adjacent cross sections, linearly interpolating between water surface elevations at cross sections.

A different methodology was used to determine the flood elevation for those buildings located in floodplains that were developed using approximate methods (Zone A on the DFIRM). A transect was drawn at the building through the mapped floodplain perpendicular to the stream, and the ground elevation was noted at both edges of the floodplain along the transect. Where the two ground elevations were similar, the higher contour elevation at the floodplain edge was used to estimate the flood elevation. In cases where

[10] *For structures with no tax assessment information available, the structure value was estimated using a standard cost per square foot for the applicable building type based on construction cost reference materials.*

the difference between the elevations at the two edges of the floodplain was larger, additional methods were used to estimate the flood elevation, such as assessing overtopping elevations of adjacent stream crossings, elevations of nearby structures known to be above the floodplain, and other similar approaches to determine bounding flood elevations.

For each building, the first-floor elevation and flood elevation were compared. The extent of direct damage, such as the costs associated with cleaning, repairing, or replacing the structure, its contents, and the land for each principal building was estimated as a percent of the value of improvements based on standardized flood loss depth-damage curves prepared by FEMA, U.S. Army Corps of Engineers, and SEWRPC (see Appendix G). Indirect damages, such as the costs associated with temporary evacuations, relocations, lost wages, lost production and sales, and the incremental costs of traffic detours, were estimated to be a percentage of direct damages for residential, commercial, and industrial buildings.

Impacts of a 1-Percent-Annual-Probability Flood

As noted above, the analyses estimating the damages that would result from a 1-percent-annual-probability flood were based on the same floodplains MMSD used to develop the database of structures at risk of flooding, as shown on Map 3.2.

Based upon the initial review of the parcel-based analysis, there are currently 1,483 insurable structures estimated to be located within the 1-percent-annual-probability (100-year recurrence interval) flood hazard areas of Milwaukee County (see Tables 3.8 and 3.9), including four critical community facilities. The amount and general location of these structures are shown on Map 3.2. As indicated in Table 3.9 and Map 3.2, the Cities of Glendale and Milwaukee and the Village of Fox Point have a significant number of parcels with structures located within the flood hazard areas of Milwaukee County. The largest type of flooded structure is residential (83 percent), followed by commercial structures (13 percent). There is one manufactured home park with 16 homes in the flood hazard area in the City of Franklin. Additionally, Table 3.8 reveals that the majority of these structures are within the Kinnickinnic River and Milwaukee River watersheds, followed by the Root River watershed.

The total assessed value for the 1,483 structures, which were identified as being subject to flooding, is about $662 million. The total market value plus contents for these structures are estimated at nearly $930 million. Damages expected during a 1-percent-annual-probability flood event are estimated to be about $166 million (2022 dollars).

Repetitive or Severe Repetitive Loss Structures

As of October 2023, there are 267 structures which are considered by FEMA to be repetitive- or severe repetitive-loss properties in Milwaukee County. Repetitive-loss structures are those that have two or more flood insurance claims of at least $1,000 each. Severe repetitive-loss properties are those that either have four or more flood insurance claims for damages to building or contents of at least $5,000 each or two or more flood insurance claims for building damages that total more than the existing value of the building. All structures are listed as either single- and multi-family residential or as other-nonresidential. As indicated in Table 3.10, nearly all of these structures (231) are located in the City of Milwaukee.

Roadway Flooding

As can be seen by review of Map 3.2, the floodplain intersects a number of arterial and collector streets in the County. In some locations, this may indicate that floodwaters could potentially overtop these roads during a major flood event and potentially cause a washout or become inundated and/or covered by debris. This could disrupt portions of the transportation system, including emergency vehicle routes, in the County during flood events. Further examination on data related to water surface elevations and top-of-road elevations would need to be completed in order to identify and confirm specific roadway locations throughout Milwaukee County that continually experience flood overtopping during heavy rain events.

After review of the community assets described in Chapter 2, past flooding events, and the parcel-based analysis for Milwaukee County, the following County assets are considered a potential high risk to flooding hazard impacts: 1) a variety of flood-prone residential (including manufactured homes), commercial, and other developed land uses; 2) critical community facilities and infrastructure; 3) recreational use lands and facilities; and 4) transportation systems.

Future Changes and Conditions

Changes in land use can have a direct impact on flood flows and stages and, accordingly, can impact flooding problems. The continued increase in urban land use (i.e., impervious surfaces) through 2050 is expected to result in an increase in the amounts of impervious surface in the Milwaukee County watersheds. In the absence of mitigative measures, this could lead to increases in future flood flows and stages, especially in downstream areas. As is discussed previously in this Report, there are a number of programs in place (i.e., floodplain regulations and stormwater management best management practices) that are intended to mitigate the potential for such increases in flood flows. Nevertheless, it is important that future condition flood flows and stages be considered as mitigative actions are being determined.

Based upon the above, it may be concluded that the extent and severity of the flooding problem within the County has the potential to become more severe to a limited extent in the near future. This conclusion highlights the importance of carrying out and implementing current floodplain and related ordinances, existing and ongoing stormwater management plans, and regulations.

Changes in climate are likely to affect the potential for flooding in Milwaukee County during the 21st century. According to the Wisconsin Initiative on Climate Change 2021 Report, since 1950 average precipitation in the State has increased 17 percent (about 5 inches) with average temperatures increasing by 3°F. As previously described in Chapter 2, model projections show Wisconsin receiving more precipitation and more frequent intense precipitation events. These models suggest that by 2060 annual average temperatures in Wisconsin will increase about 4°F -5°F (see Figure 2.4) and the frequency and magnitude of extreme rainfall events will be enhanced. By the mid-21st century, Milwaukee County may receive 12 to 14 more precipitation events of two or more inches in 24 hours per decade, roughly a 10 percent increase in the frequency of heavy precipitation events.[11] This is likely to increase the frequency of high flows and high-water levels and potentially increase the frequency and severity of flooding. In particular, the expected increases in the magnitude and frequency of large rainfall events will likely increase flood magnitudes for stormwater and in streams and rivers in Wisconsin, although the amount of increase will vary from place to place. In addition, the amount of precipitation that falls as rain during winter and early spring months is expected to significantly increase by the end of the 21st century. Winter rain can create stormwater management problems due to icing and runoff over frozen ground which may also lead to an increased risk of flooding.

These changes in climate may lead to several flood and stormwater related impacts. Increased rainfall and shifting precipitation patterns that favor more rain during periods of low infiltration and evapotranspiration may lead to more frequent and severe urban, stream, and river flooding events. Increased precipitation during winter and spring may result in increased occurrence of inland lake flooding. Increased cold-weather precipitation and increased variability in frost conditions may cause a rise in water tables in some areas leading to an increase in groundwater flooding.

The projected increase in the magnitude and frequency of heavy storms could also affect the performance of existing and planned stormwater management and flood mitigation systems. This increase could also expand flood hazard areas, such as the 1-percent-annual-probability flood hazard area, beyond their

[11] *Wisconsin Initiative on Climate Change Impacts,* Trends and Projections (*wicci.wisc.edu*).

existing boundaries, potentially encompassing more existing development which could lead to an increase in the risk of flood damages and a future need for larger stormwater management facilities and updated programs.

The magnitudes of potential increases in flooding are unknown, and there is a complex interrelationship between the climatological factors that will be affected by climate change and the features of watersheds that produce runoff. In some cases, climate change-induced changes in certain climatological factors may offset the changes in other factors relative to their effects on flood flows. In other cases, the effects will reinforce one another. Thus, it is very important to continue to improve methods for downscaling climatological data, to expand the climatological parameters for which downscaled data can be developed, and to apply hydrologic and hydraulic simulation models to quantify the potential effects on flooding resulting from climate change.

Multi-Jurisdictional Risk Management

Flooding and associated stormwater drainage problems have been identified as a significant risk in Milwaukee County. As noted earlier and shown on Map 3.2, structures within flood hazard areas have been identified within all general-purpose local units of government in the County. In addition, there are related stormwater drainage problems in selected areas of many communities. Based upon the number of structures potentially impacted (see Map 3.2), and the impacts caused by stormwater (or urban) flooding events, the entire County is at risk to be impacted by flooding.

The Milwaukee Flood and Health Vulnerability Assessment (MFHVA) Tool

Additionally, a local organization in the City of Milwaukee known as "Groundwork Milwaukee," along with academia professionals and state partners, put together an interactive mapping (or storymap) and data tool to help identify communities across Milwaukee where exposure to urban flooding may disproportionately impact vulnerable populations due to their socioeconomic and health conditions. The project intends to provide critical information on both flood exposure and social vulnerability to support community-based advocacy and future planning to mitigate potential flood and health risks. The assessment considers two indices: 1) a **flood exposure index** that considers neighborhoods that are most likely to flood and 2) a **flood vulnerability index** that results from combining three vulnerability categories (health, socioeconomic, and housing) that predict residents' capacity to respond to a flood. By assessing exposure and vulnerability separately, the tool is able to identify locations in Milwaukee where high vulnerability and flood exposure occur at the same time. The indices are developed at the census tract level. Additionally, to assess flood exposure across Milwaukee, the flood exposure index considers two models: 1) the FEMA 100-

Year Flood Hazard Zone which models riverine or coastal flooding (known as fluvial flooding) and 2) the hydrodynamic CityCAT model which considers inland flooding during heavy rain events (known as pluvial flooding).[12] The interactive map is available online and is accessible through Groundwork Milwaukee website.

Severe Weather Events (Thunderstorms, Strong Winds, Hail, and Lightning)

NOAA's National Center for Environmental Information (NCEI) defines severe weather as "destructive storm or weather" that is "usually applied to local, intense, often damaging storms such as thunderstorms, hailstorms, and tornadoes." While this definition can cover a variety of hazards beyond what is listed, thunderstorms, tornadoes, high winds, hail, and lightning are the most prevalent in Wisconsin. Thunderstorms and their related strong or straight-line winds, lightning, hail hazards, and non-thunderstorm high winds are covered within this section. Excessive rains that cause flash flooding and tornadoes are covered separately in other sections. Figure 3.1 from WEM's 2021 State Hazard Mitigation Plan shows the amount of recorded severe weather events in Wisconsin from 1844 to 2020. The majority of the counties with more than 300 severe weather events are located in southern Wisconsin for this period.

Thunderstorms

A thunderstorm is defined as a severe and violent form of convection produced when warm, moist air is overrun by dry, cool air. As the warm air rises, thunderheads (cumulonimbus clouds) form. These thunderheads produce the strong winds, lightning, thunder, hail, and heavy rain that are associated with these storm events. The thunderheads may be a towering mass averaging 15 miles in diameter and reach up to 40,000 to 50,000 feet in height. These storm systems may contain as much as 1.5 million tons of water and enormous amounts of energy that often are released in one of several destructive forms, such as high winds, lightning, hail, excessive rains, and tornadoes. The NWS offices serving Wisconsin issue on average 5-10 Severe Thunderstorm Warnings per county per year in the southern counties where thunderstorms are more frequent.

According to the NWS, a typical thunderstorm lasts an average of 30 to 60 minutes and moves at an average velocity that ranges between 30 to 50 miles per hour.[13] Strong frontal systems may produce more than one squall line composed of many individual thunderstorm cells. In Wisconsin, these fronts can often be tracked

[12] *Groundwork Milwaukee, Wisconsin Health Professionals for Climate Action, Medical College of Wisconsin, and the City of Milwaukee*

[13] Op. cit.

across the entire State from west to east.[14] The peak season for severe thunderstorms in Wisconsin is April through August.[15] Thunderstorms may occur individually, form clusters, or as a portion of a large line of storms. Therefore, it is possible that several thunderstorms may affect one particular area in the course of a few hours, as well as larger areas of the State or County, within a relatively short period of time.

All thunderstorms are potentially dangerous. However, only about 10 percent of the thunderstorms that occur each year nationwide are classified as severe. Severe thunderstorms can cause injury or death and can also result in substantial property and crop damage. They may cause power outages, disrupt telephone service, and severely affect radio communications, as well as surface and air transportation, which may seriously impair the emergency management capabilities of the impacted areas.

The NWS monitors severe weather for 20 southern Wisconsin counties, including Milwaukee County, from its Milwaukee/Sullivan office.[16] A thunderstorm watch indicates that conditions are favorable for severe weather, and that persons within the area for which the watches are issued should remain alert for approaching storms. A severe thunderstorm warning indicates that severe weather has been sighted in an area or indicated by weather radar and persons should seek shelter immediately. These severe thunderstorms watches, warning bulletins, and advisories are disseminated throughout Milwaukee County by the NWS[17] to the general public through local television and radio stations, cable television systems, cell phone apps, and NOAA weather radios.

To convey the severity and potential impacts from thunderstorms, the NWS recently added a new "damage threat" to Severe Thunderstorm Warnings. The summary of the three damage threat classifications is below:[18]

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[14] *National Weather Service Forecast Office.*

[15] Op. cit.

[16] *National Weather Service, Milwaukee/Sullivan Weather Forecast Office.*

[17] *The NWS operates two 24-hour weather radio transmitters that serve all or portions of Milwaukee and Waukesha Counties.*

[18] *Wisconsin Department of Emergency Management and Military Affairs,* State of Wisconsin Hazard Mitigation Plan*, December 2021.*

- **Destructive** damage threat is at least 2.75-inch diameter (baseball sized) hail and/or 80 mph thunderstorm winds. Warnings with this tag will automatically activate a Wireless Emergency Alert (WEA) on smartphones within the warned area.

- **Considerable** damage threat is at least 1.75-inch diameter (golf ball-sized) hail and/or 70 mph thunderstorm winds. This will not activate a WEA.

- **Baseline** or a **"base"** severe thunderstorm warning remains unchanged with 1.00-inch (quarter-sized) hail and/or 58 mph thunderstorm winds. This will not activate a WEA.

Types of Thunderstorm-Related Problems

Thunderstorm Winds (Straight-Line Winds)

High-velocity, straight-line winds that are produced by thunderstorms and widespread non-thunderstorm high winds are one of the most destructive natural hazards in Wisconsin and are responsible for most wind-related damages to property. Thunderstorm winds can also be fatal. Damaging winds are classified as those exceeding 50-60 mph. Table 3.11 lists the recent severe weather events, including high and strong winds, in Milwaukee County from 2011 to 2022. During that period, Milwaukee County experienced three events with hurricane force winds (74 mph/64 knots or higher) and 64 thunderstorm wind events (greater than 50 mph/44 knots).

Although distinctly different from tornadoes, straight-line winds produced by thunderstorms can be very powerful, are common, and can cause damage similar to that of a tornado event. Depending upon their intensity, thunderstorm winds can uproot trees and crops, down power lines, and damage or destroy buildings and infrastructure. Flying debris can cause serious injury and death to humans, livestock, and wildlife in their path. Boats, manufactured homes, and airplanes are also extremely vulnerable to damage from thunderstorm winds. During the period from 1844 to 2020, in the State of Wisconsin, 16 fatalities and dozens of injuries were attributed to wind from severe thunderstorms.[19]

Non-Thunderstorm High Winds (or simply "High" and "Strong" Winds)

High winds are the most common form of severe weather in Wisconsin; thus, there is a high probability of an occurrence each year. Non-thunderstorm high winds tend to be less forceful than thunderstorm winds

[19] *Wisconsin Department of Emergency Management and Military Affairs,* State of Wisconsin Hazard Mitigation Plan, *December 2021.*

but are typically more sustained and widespread. These high winds can affect a region for hours, or even several days. Longer lasting windstorms have two main causes: large differences in atmospheric pressure across a region, and strong jet-stream winds overhead. Horizontal pressure differences can accelerate the surface winds substantially as air travels from a region of higher atmospheric pressure to one of lower pressure. Intense winter storms can also cause long-lasting and damaging high winds. Cold fronts associated with intense low-pressure systems can produce high winds both as they pass and for a period afterward as colder air flows overhead. High winds in the winter can produce dangerous wind chills when air temperatures are cold. Severe wind chills are discussed further in the extreme temperature section later in this Report.

Like thunderstorm winds, non-thunderstorm high winds can uproot trees and crops, cause widespread power outages, damage buildings, and make travel treacherous. Non-thunderstorm high winds tend to be more sustained and widespread, leading to more damage over a whole region, as compared to thunderstorm winds. During the period of 2011 to 2022, 32 non-thunderstorm high wind events were reported in Milwaukee County resulting in an estimated $377,168 in property damage (2022 dollars) and nearly $19,000 (2022 dollars) in crop insurance indemnities (Table 3.11).

Hail

From 2000 through 2022, 111 hailstorms and over $11.5 million (2022 dollars) in property damage and $3,500 (2022 dollars) in crop insurance indemnities were reported in Milwaukee County (Table 3.4). As indicated in Table 3.11, between the years 2011 to 2022, there have been no reported property and crop damages from the 57 hailstorm events in Milwaukee County.

Wisconsin averages between two to three hail days per year as recorded by NWS stations, although this may not be indicative of the number of hailstorms which occur within a county or larger area during any given hail season. According to the NWS, about 20 percent of all severe weather events in Wisconsin are hail events in which hailstones are at least 0.75 inches in diameter.[20] A hailstorm is a product of strong thunderstorms and unique weather condition where atmospheric water particles form into rounded or irregular masses of ice that fall to earth. Hail normally falls near the center of the moving storm along with the heaviest rain. In some instances, strong winds at high altitudes can blow the hailstones away from the storm center, causing unexpected hazards at places that otherwise might not appear threatened. Hailstones normally range from the size of a pea to the size of a golf ball, but hailstones 1.5 inches or larger in diameter

[20] *Buffalo County, Wisconsin,* Hazard Mitigation Plan*, 2021 (www.buffalocountywi.gov).*

are not uncommon in the State of Wisconsin. Hail tends to fall in swaths that may be 20 or more miles long and five or more miles wide and can fall continuously or sporadically in a series of hail strikes. Hail strikes are typically one-half mile wide and five miles long. Hail strikes may partially overlap, but often leave completely undamaged gaps between them.

Hailstorms are considered formidable among the weather and climatic hazards to property and farm crops because they dent vehicles and structures, break windows, damage roofs, and batter crops to the point that significant agricultural losses result. Falling hailstones can also cause serious injury and loss of human life and livestock, however these occurrences are rare. In addition to impact damage, thick hail combined with heavy rain can clog storm sewers and contribute to stormwater flooding. Hail sufficiently thick to cover a road will pose a traffic hazard. The peak season for hailstorms in Wisconsin is May through September with approximately 85 percent of hailstorms occurring during this period.

<u>Lightning</u>

In Wisconsin, there were 642 reported lightning events between 1996 and 2020. During this period, 22 deaths and 113 injuries from lightning were reported in the State. These numbers are likely underestimated because few people report suspected lightning deaths, injuries, and damages. More recently, from 2016 to 2021, there was 1 reported fatality and 9 injuries directly caused by lightning.[21] Lightning is a significant hazard associated with any thunderstorm and can cause extensive damage to buildings and structures, kill, or injure people and livestock, start forest fires and wildfires, and damage electrical and electronic equipment.

Lightning is defined as a sudden and violent discharge of electricity from within a thunderstorm due to a difference in electrical charges and represents a flow of electrical current from cloud to cloud or cloud to ground. Water and ice particles also affect the distribution of the electrical charge. Lightning bolts can travel 20 miles before striking the ground. The air near a lightning bolt can be heated to 50,000 degrees Fahrenheit (°F), which is five times hotter than the surface of the sun. The rapid heating and cooling of the air near the lightning channel causes a shock wave that results in thunder.

Counties in southern Wisconsin experience a higher number of lightning events than other parts of the State due to higher thunderstorm frequency and more thorough documentation by the local media. The

[21] *Wisconsin Department of Emergency Management and Military Affairs,* State of Wisconsin Hazard Mitigation Plan*, December 2021.*

high number of lightning-related injuries in southeastern Wisconsin is likely related to the higher concentration of population, coupled with higher average lightning densities in these areas. According to the NCEI storm events database, Milwaukee County reported 20 lightning events during the period of 2000 to 2022 causing a reported $1.9 million in property damage (see Table 3.4).

Recent Events

Based upon recent data published by NCEI, a total of 167 severe weather events have been recorded in Milwaukee County between 2011 and 2022 (see Table 3.11). This total includes thunderstorm winds, non-thunderstorm high winds (high, strong, or straight-line winds), hail, and lightning. During this time period, there have been no reported deaths or injuries due to these events, however there is an estimated $1.8 million (2022 dollars) in reported property and crop damages (see Table 3.11). A few notable examples of these recent events are noted below.

2011 – On June 30, 2011, a large supercell thunderstorm over Lake Michigan produced strong winds that moved into far southeast Milwaukee County and eastern sections of Racine and Kenosha counties. Wind gusts up to 82 mph felled or caused extensive damage to numerous large trees that damaged homes, garages, and vehicles as well as dropped power lines across the affected areas. At one point, 26,000 customers were without power in southeast Wisconsin. A reported $52,500 (2022 dollars) in property damages were caused by this event.

2013 – On May 14, 2013, several lines of severe thunderstorms over southern Wisconsin produced wind gusts up to 70 to 75 mph. Widespread damage was reported in swaths up to 6 miles in width, which included structural damage, including a house fire to homes and farm buildings as well as downed trees and power lines due to the powerful winds. Damage caused by these thunderstorm winds created a path from Wauwatosa to Cudahy. WE Energies reported 23,000 customers in Dodge, Jefferson, Waukesha, and Milwaukee counties were without power at the height of the storm. As a result, over $62,000 (2022 dollars) was reported in property damages.

2016 – On February 19, 2016, strong winds of 58 to 65 mph (or around 55 kts) over Southeast and Southern Wisconsin caused four semi-trucks to blow over blocking all or partial lanes on the Interstates; downed trees and branches were reported with some falling on power lines, homes, or parked vehicles; structural damage on homes and garages occurred; and power outages from the downed power lines impacted 26,000 customers. As a result, Milwaukee County reported about $120,000 (2022 dollars) in property damages.

2020 – November 10, 2020, a line of thunderstorms caused swaths of straight-line wind damage across southeast Wisconsin. As such, numerous trees and tree limbs were knocked down along with some structural damage and downed power lines. Milwaukee Mitchell International Airport measured wind gusts of 79 mph (69 kts) caused a power pole to snap, roofing material from a hangar was removed, the sliding doors to the main entrance of the airport were blown in, and several cars in an employee parking lot at the airport had windows blown in. Nearly $86,000 (2022 dollars) in property damage resulted from this thunderstorm wind event.

Vulnerability and Community Impact Assessment Related to Severe Weather Hazards

The National Weather Service can forecast and track a line of thunderstorms that may be likely to produce severe high winds, hail, lightning, and tornadoes, but where these related hazards form or touch down, and how powerful they might be, remains unpredictable.

In order to assess the vulnerability of the Milwaukee County area to these severe weather hazards, a review of the community assets (described in Chapter 2) and reported severe weather events experienced throughout Milwaukee County indicate the potential for significant thunderstorm and related hazard impacts to: 1) a variety of residential, commercial, and other developed land uses; 2) transportation systems and infrastructure; 3) telecommunications and utilities; 4) critical community facilities; and 5) historic sites. As noted in the 2018 Milwaukee County Pre-Disaster Mitigation Plan, thunderstorms and related hazards are one of the greatest risks to the population and infrastructure within Milwaukee County.

In addition, large outdoor gatherings (i.e., sporting events, concerts, campgrounds, etc.) are particularly vulnerable to lightning strikes that could result in injuries and deaths. Importantly, those who rely on the sound of thunder can oftentimes be misled as lightning can occur 20 miles away from the source thunderstorm. Additionally, individuals who are deaf or hard of hearing may have trouble identifying when to take shelter. As such, the slogan "Flash, Dash Inside," was created by and for people who are deaf and hard of hearing.[22]

Mobile and manufactured homes can also be particularly vulnerable to damage from high winds associated with severe thunderstorms. The light weight, flat-sided construction, and tenuous foundation connections of mobile and manufactured homes can make them highly vulnerable to wind damage. According to the

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[22] *Wisconsin Department of Emergency Management and Military Affairs,* State of Wisconsin Hazard Mitigation Plan*, December 2021*.

Wisconsin Department of Safety and Professional Services and shown on Map 2.1, there are 15 manufactured home parks in Milwaukee County, with the majority containing at least 50 of homes.

Future Changes and Conditions

Based upon recent data from the period 2011-2022 (Table 3.11), Milwaukee County can expect to experience averages of nine thunderstorm and related strong wind events per year, five hail events per year, and one significant lightning event per year somewhere in the County. It should be noted that the historical record shows considerable variation among years in the number of these events that occurred. While it would be expected that in some years the County will experience either fewer events or more events than the average number, the average annual number of events is not expected to change.

The likely effect of climate change on thunderstorm and high-wind events is not clear. While projections based upon downscaled climate model results indicate that the magnitude and frequency of heavy precipitation events are likely to increase by the middle of the 21st century, they do not address potential trends in wind, hail, or lightning conditions. Modeling studies utilizing the output of multiple climate models suggest that, between now and the end of the 21st century, there will be an increase in the number of days per year in which atmospheric environments will occur that are known to support the formation of severe thunderstorms.[23]

Changes in land use, such as the increase or expansion of development can have an impact on the potential for damage to occur from severe weather events. As shown in Map 2.2, the portions of the County that are less developed and have potential for growth include the Cities Franklin, Oak Creek, and Milwaukee. As such, these locations are at a potential increased risk of thunderstorm-related damage and related losses. Conversely, development within the City of Milwaukee is approaching "buildout" conditions with new development expected to be limited, indicating potential risks related to thunderstorm and related events to have similar or a slight increase of risk. In addition, it is important to note that due to the mitigation actions that have been taken by the County, local units of government, and individuals, the current vulnerability to thunderstorms and related hazards has decreased in recent years. These ongoing mitigation measures are described further in Chapter 5.

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[23] *Noah S. Diffenbaugh, Martin Scherer, and Robert J. Trapp, "*Robust Increases in Severe Thunderstorm Environments in Response to Greenhouse Forcing," *Proceedings of the National Academy of Sciences, Volume 110, pages 16,361-16366, 2013.*

Multi-Jurisdictional Risk Management

Based upon a review of the historic patterns of severe thunderstorms, along with high straight-line wind, hail, and lightning events in Milwaukee County, there are no specific municipalities that have unusual risk. Rather, the events are considered to be relatively uniform and of countywide concern.

Tornadoes

Wisconsin lies along the northern edge of an area of the United States commonly known as "tornado alley." This area extends northeasterly along an axis extending from Oklahoma and Iowa in the west, to Michigan and Ohio in the east. This corridor accounts for one-fourth of the total tornadoes in a given year. Tracks of the tornadoes that occurred nationwide between 1950 and 2015 are shown in Figure 3.2. On average, Wisconsin has 23 tornadoes that occur throughout the full year. In 2022, there were 28 reported tornadoes in Wisconsin.[24]

A tornado is defined as a violently rotating column of air extending from the ground up to the thunderstorm base. It generally lasts for only a short period. The tornado appears as a funnel-shaped column with its lower, narrower end touching the ground and upper, broader end extending into the thunderstorm cloud system. In some cases, the visible condensation cloud may not appear to reach the ground, but meanwhile tornado-force winds may be causing severe destruction (rotating winds can be nearly invisible, except for dust and debris). Similar events, not reaching the land surface, are known as funnel clouds. Funnel clouds may be a precursor to a tornado event. In Wisconsin, tornadoes usually occur in company with thunderstorms formed by eastward-moving cold fronts striking warm moist air streaming up from the south. However, it is not possible to predict tornado activity based upon the occurrence of thunderstorms. But, occasionally, multiple outbreaks of tornadoes occur along the storm frontal boundaries, affecting large areas of the State at one time. Tornadoes generally occur near the trailing edge of a thunderstorm. It is not uncommon to see clear, sunlit skies behind a tornado.

Historically, tornadoes have been categorized based upon the most intense damage along their paths using the Fujita Scale. Since February 2007, the Fujita Scale has been replaced by the Enhanced Fujita Scale, which retains the same basic design of its predecessor with six tornado strength categories. This scale is shown in Table 3.12. The newer scale reflects more refined assessments of tornado damage surveys, more standardization, and consideration of damage over a wider range of structures.

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[24] *National Weather Service (weather.gov).*

The destructive power of the tornado results primarily from its high-wind velocities, wind-driven debris, and uplifting force. These characteristics probably account for 90 percent of tornado-caused damage. Since tornadoes are generally associated with severe storm systems, hail, torrential rain, and intense lightning usually accompany tornado events. In addition, tornadoes may be accompanied by downbursts, events which are characterized by strong downdrafts initiated by a thunderstorm that manifest as straight-line winds on or near the ground. These winds can be powerful, with speeds up to 70 to 100 mph. These winds interact with tornadoes and can affect the path of the tornado event in such a manner as to make tornadoes somewhat unpredictable. Depending on their intensity, tornadoes can uproot trees and crops, down power lines, and damage or destroy buildings and infrastructure. Flying debris can cause serious injury and death to humans, livestock, and wildlife in their path. An approaching cloud of debris can mark the location of a tornado, even if the classic funnel cloud is not visible. Before a tornado hits, the wind may die down and the air may become very still.

The NWS monitors severe weather nationwide from its Norman, Oklahoma office. This office is the only entity that can issue a tornado watch. The NWS office in Milwaukee/Sullivan, and the Milwaukee County Office of Emergency Management may issue tornado warnings.[25] A tornado watch means that tornadoes are possible, and that persons within the area for which the watches are issued should remain alert for approaching storms. A tornado warning means that a tornado has been sighted in an area or indicated as likely to have occurred based on weather radar. When tornado warnings are issued for an area, people near and within that designated area are advised to move to a pre-designated place of safety. Tornado shelters are identified by appropriate signage in public buildings.

Recent Tornado Events

In the year 2000, two notable F1 tornado events occurred in Milwaukee County. The first was in March followed by another tornado in July. As indicated by Table 3.13, both these events caused an estimated $10.5 million in property damage (2022 dollars) as well as 16 reported injuries.

Vulnerability and Community Impact Related to Tornado Hazards

In order to assess the vulnerability of the Milwaukee County area to tornado hazards, a review of the community assets described in Chapter 2 was made which indicates the potential for significant tornado impacts to: 1) a variety of residential, commercial, and other developed land uses, including manufactured

[25] *All outdoor warning sirens in Milwaukee County are owned and operated by the local municipalities with the exception of the siren located on the county fairgrounds, which is owned and operated by the County.*

homes; 2) roadway transportation system; 3) utilities; 4) critical community and public safety facilities; and 5) historic sites.

Tornado prediction is not an exact science. The NWS can forecast that a line of thunderstorms may be likely to produce tornadoes, but where they form or touch down, and how powerful they might be, remains unpredictable. As can be seen from the distribution of historic F1 and F2 tornado events since 1950 in Milwaukee County, shown on Map 3.3, the locations of tornado impact points are widely scattered throughout the County.

Since 1958, a total of 19 tornadoes have been reported in Milwaukee County, or about one tornado every three years (Table 3.14). In total, these 19 tornadoes have resulted in about $22.5 million in reported property damages, about $24,000 in reported crop damages, no reported fatalities, and 176 injuries. As indicated by this Table, a single tornado event can cause significant impacts. For example, the August 11, 1969 tornado injured 153 people and the July 2, 2000 event caused over $7 million in reported property damage (2022 dollars). It should be noted that five tornado events had at least $2 million (2022 dollars) in reported property damages.

The impacts caused by a tornado can pose a signification threat to certain populations including the elderly, frail, disabled, children, infants, and foreign or out-of-state guests. Additionally, community infrastructure such as power lines, telephone lines, and radio towers are often vulnerable to damage from tornadoes and high winds. The loss of radio towers that hold public safety communications repeaters can adversely impact the ability of first responders to mount an effective response; damage to towers that hold public media equipment may adversely impact the ability to distribute adequate public information. In an extreme tornado event, such as an F4 event, the force of the wind alone can cause tremendous devastation, uprooting trees, toppling power lines, and inducing the failure of weak structural elements in homes and buildings. Due to the unpredictability of tornado events, all buildings, infrastructure, and critical facilities within the County are considered at risk.

As discussed in the section of this chapter on thunderstorms, mobile and manufactured homes can also be particularly vulnerable to high wind and tornado events. Extreme winds can displace these homes from their sites, especially if they are not properly attached to the site or if such attachment fails. In addition, these structures usually lack basements. As a result, they offer their occupants little shelter in the event of hazardous winds. As of 2022, there were 15 manufactured home parks located in Milwaukee County (see Map 2.1). The majority of these parks have around 50 manufactured homes (Table 2.6). These structures and their occupants may be particularly vulnerable to impacts from tornadoes, especially without access to a storm shelter.

It should be noted that, because of the mitigation actions that have been taken by the County and local units of government and individuals, the current vulnerability to tornadoes and related hazards has generally decreased in recent years. These ongoing mitigation measures are described further in Chapter 5.

Future Changes and Conditions

Based upon historical data, Milwaukee County can expect to experience an average of 0.31 tornado events per year or about one tornado every three years. It should be noted that the historical record shows considerable variation among years in the number of tornado events that occurred. While it would be expected that in some years the County will experience either fewer events or more events than the average number, the average annual number of events is not expected to change. Overall, the probability of Milwaukee County being struck by a tornado in the future is medium and the likelihood of damage from future tornadoes is high.

Changes in land use, such as urban development, can also have an impact on the potential for future damage impacts caused by tornado hazards. Because Milwaukee County is developed (or urbanized) with only small portions undeveloped, the impacts caused by tornado hazards are likely to only increase slightly by the additional planned land use development within the County.

The likely effects of climate change on tornado frequency and severity are not clear. The projections based upon downscaled climate model results do not address potential trends in tornado conditions. A recent study that examined the evolving contributors of risk and vulnerability for tornadoes found that growth in the human-built environment is projected to dominate the impact of future tornados. An increase in risk and exposure of tornadoes may lead to a significant increase in the magnitude and disaster impact of tornadoes on that built environment from 2010 to 2100.[26] Additionally, high-risk tornado regions may experience increased disaster probability and historically vulnerable regions may be at greater risk of tornado damages due to a combination of factors: increased tornado risk, rapidly amplified exposure, and pre-existing social and physical vulnerabilities.

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[26] *Strader, S. M., Ashley, W. S., Pingel, T. J., & Krmenec, A. J. (2017). Projected 21st Century Changes in Tornado Exposure, Risk, and Disaster Potential. Climatic Change, 141(2), 301–313. doi.org/10.1007/s10584-017-1905-4.*

Multi-Jurisdictional Risk Management

Based on the distribution of the 19 tornado events, as shown on Map 3.3, the tornado locations are widely scattered throughout the County indicating that there are no specific municipalities that have unusual or greater risks to tornado hazards. Rather, the events are considered to be relatively uniform and of a countywide concern.

Severe Winter Storms

Winter storms can vary in size and strength and include heavy snowstorms, blizzards, freezing rain, sleet, ice storms, and blowing and drifting snow conditions. Extremely cold temperatures accompanied by strong winds can result in wind chills that cause bodily injury, such as frostbite and death. A variety of weather phenomena and conditions can occur during winter storms. For clarification, the following are National Weather Service approved descriptions of winter storm elements:

- **Heavy Snowfall**—The accumulation of six or more inches of snow in a 12-hour period or eight or more inches in a 24-hour period.

- **Blizzard**—An occurrence of sustained wind or frequent gusts of 35 mph or higher accompanied by falling or blowing snow, and visibilities of one-quarter mile or less, for three or more hours.

- **Ice Storm**—An occurrence of rain falling from warmer upper layers of the atmosphere to the colder ground, freezing upon contact with the ground and exposed surfaces, resulting in ice accumulations of one-quarter inch or more within 12 hours or less.

- **Freezing Drizzle/Freezing Rain**—The effect of drizzle or rain freezing upon impact on objects that have a temperature of 32°F or below.

- **Sleet**—Solid grains or pellets of ice formed by the freezing of raindrops or the refreezing of largely melted snowflakes. This ice does not cling to surfaces.

- **Wind Chill**—An apparent temperature that describes the combined effect of wind and low air temperatures on exposed skin.

Much of the snowfall in Wisconsin occurs in small amounts of between one and three inches per occurrence. Heavy snowfalls that produce at least six inches of accumulation in one county happen on average about ten to 12 times per winter statewide.[27] The northwestern portion of Wisconsin receives most of its snow during early and late season storms, while southwestern and southeastern counties receive heavy snows more often in mid-winter. Snowfall amounts in Milwaukee County average about 50 inches per year.

Blizzard-like conditions often can occur during heavy snowstorms when gusty winds cause severe blowing and drifting of snow, even if the conditions did not last long enough to be considered a true blizzard. True blizzards are not common in Wisconsin. However, when they do occur, they tend to affect the eastern counties near Lake Michigan. This is due to less frictional drag over Lake Michigan which allow northwest windstorms to reach higher speeds. Blizzards are more likely to occur in northwestern Wisconsin than in southern portions of the State, even though heavy snowfalls are more frequent in the southeast. Blizzard-like conditions often exist during heavy snowstorms when gusty winds cause severe blowing and drifting of snow. According to NCEI, and shown in Table 3.14, the most recent blizzard event recorded in Milwaukee County occurred on February 1, 2011. Prior to 2011, there have been five other reported blizzards in the County (1996, 1997, 1999, 2006, and 2007).[28]

Freezing rain, ice, and sleet storms can occur at any time from October into April in Wisconsin. In a typical winter season, there are three to five light freezing rain events in the southeastern Wisconsin region. On average, a major ice storm occurs about once every other year somewhere in the State and once every seven years over southeastern Wisconsin. If one-half inch of rain freezes on trees and utility wires, extensive damage can occur, especially if accompanied by high winds that compound the effects of the added weight of the ice. There are also between three and five instances of glazing (less than one-quarter of an inch of ice) throughout the State during a normal winter. The most recent recorded ice storm in Milwaukee County was in 2022.

Recent Events

Table 3.14 lists recent winter hazard events that occurred in Milwaukee County from 2011 to 2022. A few examples of these recent winter storm events are described below.

2011 – During the overnight hours of February 1 and 2, 2011, a powerful low-pressure center produced blizzard conditions across much of southern Wisconsin. Prior to the blizzard, several inches of snow fell on

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[27] *Wisconsin Department of Emergency Management and Military Affairs, State of Wisconsin Hazard Mitigation Plan, December 2021.*

[28] *www.ncdc.noaa.gov.*

January 31st with light lake effect snow through the day on February 1. Snow associated with the system began in the mid-afternoon hours on February 1 in far southern Wisconsin and pushed northward into the State through the evening. Very strong winds were associated with the storm for an extended period of time. Two-day snowfall totals in the City of Milwaukee ranged between 12 and 20 inches, with 16.1 inches reported at MMIA. Peak wind gusts of 60 miles per hour were reported at MMIA. Snow drifts of three to 12 feet were common, with reports of some drifts reaching 12 to 15 feet in open rural areas. Drifting snow closed Interstate 94 (I-94) from the Illinois border north to Milwaukee, and I-43 from Beloit to Mukwonago, with many stranded motorists having to be rescued from vehicles buried in the drifting snow. In response to this, the Wisconsin Division of Emergency Management issued a Civil Danger Warning concerning the hazardous driving conditions. The storm, known as the Groundhog's Day blizzard, had several impacts. Most flights in and out of MMIA were canceled until later in the day on February 2. Milwaukee area law enforcement reported 24 vehicle accidents, with two injuries and 47 disabled vehicles. Emergency rooms across southeastern Wisconsin reported dozens of heart attacks and injuries from snow blower accidents. Three Milwaukee area men, two with heart problems, died while shoveling snow. Numerous businesses were closed as a result of this winter storm. At the height of the storm, We Energies reported 5,200 customers were without power across southeast Wisconsin. Wind gusts damaged at least five metal panels, siding, and a roll-down door on a large storage pole shed at the Port of Milwaukee. The Governor issued an emergency declaration for 29 counties and ordered the mobilization of about 100 National Guardsman to rescue stranded motorists and run emergency shelters at armories.

2013 – Low pressure and lake enhanced snow brought three to six inches of powdery snow to southern Wisconsin on December 8, 2013. Hundreds of vehicle accidents occurred, especially in the Milwaukee metropolitan area. These included several pile-ups, including a 41-vehicle pile-up on IH-894 at Greenfield Avenue in the City of West Allis. The weather was cited as a contributing factor in three deaths.

2015 – On December 28, 2015, a winter storm affected southern Wisconsin as strong low pressure tracked from the Mississippi River Valley to northeast Illinois and southern Michigan. Most areas received five to 10 inches of wet snow and sleet combined, with sleet accumulations of up to two inches in some areas. East to northeast wind gusts of 30 to 45 mph occurred, restricting visibility to between one-quarter and one-half mile. As a result of this storm, more than 300 accidents occurred on interstate and State highways. These occurred mostly in the Milwaukee and Madison areas. Two men collapsed and died while shoveling on the afternoon of December 29th in Milwaukee County. A golf dome was damaged by the weight of the heavy snow in Milwaukee County.

2017 – On March 12-13, 2017 a significant lake effect snowstorm occurred over eastern Wisconsin with snowfall totals of 1 to 2 feet. Hundreds of vehicles were involved in accidents and slide-offs including several large chain-reaction accidents on I-41 and I-43 on March 13th. Overall, there were 59 crash calls and 68 disabled vehicles during the daylight hours. Portions of the Interstates were closed for hours for cleanup and removal. There were five deaths in southeast Wisconsin when older men collapsed while shoveling or snow blowing. Some schools and local governments closed due to the heavy snow.

2020 – During the period of January 10-12, 2020, a severe winter storm and flooding impacted communities in Kenosha, Milwaukee, and Racine counties. On January 10th a winter storm brought a wintery mix of snow, freezing rain, and ice to much of eastern Wisconsin. On January 11th, strong onshore winds gusting at 40-50 mph developed along the coast of Lake Michigan. These winds, when combined with record high Lake Michigan water levels, flooded significant areas of the Milwaukee lakefront south to Kenosha. The lakeshore flooding was amplified by an ice-free shoreline and the winds were oriented to the maximum lake fetch. The winter storm and flooding damaged the shoreline and community infrastructure in Kenosha, Milwaukee, and Racine counties. On March 11th, 2020, a presidential disaster declaration (DR-4477) was granted for Wisconsin. The declaration made Public Assistance and Hazard Mitigation Grant Program assistance available to state and eligible local governments and select private nonprofit organizations on a cost-sharing basis for emergency and mitigation work resulting from the severe storm and flooding in Kenosha, Milwaukee, and Racine counties.

Vulnerability and Community Impact Assessment Related to Severe Winter Storm Hazards

Between 2011 and 2022, 113 winter weather events have affected Milwaukee County. Based on this, it is estimated that Milwaukee County experiences an average of 9.5 winter weather events per year. It should be noted that during this time period there has been variation around this average, with the County experiencing as few as five winter storm events in some years and as many as 14 winter storm events in other years (Table 3.14).

A review of the community assets described in Chapter 2 indicates there is a potential for winter storm hazard events to impact: 1) residents at a countywide level, 2) roadway transportation system, 3) utilities, and 4) the operation of critical community facilities. In addition, the Milwaukee County Pre-Disaster Mitigation Plan concluded that winter storm hazards are one of the greatest risks to the population and infrastructure within Milwaukee County.

The NCEI database reports only about $19,000 of property damages and no crop damage for winter storms during this eleven-year period. For Milwaukee County, records of crop insurance indemnities from the U.S. Department of Agriculture Risk Management Agency show that about $12,000 have been paid out between 2011 and 2022 due to damage caused by winter related weather, such as frost, freeze, or snow.

Winter storms present a serious threat to the health and safety of affected citizens and can result in significant damage to property. Snow and ice are the major hazards associated with winter storms and are a destructive natural hazard in Wisconsin. Snow and ice can cause traffic accidents, bring down telephone and power lines, disrupt telecommunication services, damage trees, impede transportation, burst water pipes, and can tax the public's capabilities for snow removal during heavy storms. A major winter storm can have a serious impact on a community. Loss of heat and mobility are key complications that contribute to winter storm fatalities.

Ice storms and freezing rain are less common than snow for the County but produce road conditions that can make travel hazardous. Even fog or mist on cold roads can produce a glaze of ice that makes travel slippery and dangerous. Accumulated ice can cause the structural collapse of buildings, bring down trees and power lines, causing property damage, loss of power, and isolate people from assistance or services.

Future Changes and Conditions

As discussed in Chapter 2 of the Report, changes in the 20th century and projections based on downscaled results from climate models indicate that there will likely be changes in winter storm conditions affecting Milwaukee County over the 21st century. It is projected that by 2060 the average amount of precipitation that Milwaukee County receives during the winter will increase by about 0.5 to 1.0 inch (measured as water), an increase of about 10 percent (see Figure 3.3).[29] Due to increasing winter temperatures, the amount of precipitation that falls as rain during the winter rather than as snow is projected to increase significantly. It is also projected that freezing rain will be more likely to occur.

It should also be noted that the likelihood of lake effect snow occurring could be affected by climate change. A lack of ice cover over Lake Michigan during the winter promotes the development of lake effect snow. Rising temperatures during the winter will reduce the frequency and extent of ice cover over the Lake. Because the increase in temperature may also result in some of this precipitation falling as rain, it is not clear whether this will lead to an increase in the frequency of lake effect snow events.

[29] *Wisconsin Initiative on Climate Change Impacts (wicci.wisc.edu)*

Multi-Jurisdictional Risk Management

Based upon a review of the historic patterns of winter storm events in Milwaukee County, there are no specific municipalities that have unusual risks. Rather, the events are of a uniform countywide concern.

Extreme Temperature Events

Average annual temperatures in the United States have increased by 1.3 to 1.9ºF since record keeping began in 1895. Heat waves have become more frequent and intense, and cold waves have become less frequent across the nation. Heat and cold are two of the most underrated, least understood, and deadly of all the natural hazard events that impact Milwaukee County. In contrast to the visible, destructive, and violent characteristics associated with floods and tornadoes, extreme high or low temperatures are "silent killers." Days that are hotter than the average seasonal temperature in the summer or colder than the average seasonal temperature in the winter cause increased levels of illness and death by compromising the body's ability to regulate its temperature or by inducing direct or indirect health complications. Deaths from extreme heat and cold occur quietly, without headline-making destruction.

Extreme Heat

Excessive heat has become the deadliest hazard in Wisconsin, exceeding tornado, and other storm-related deaths. The Centers for Disease Control and Prevention (CDC) reports that nationwide between 2018 and 2020 a total of 3,066 heat-related deaths occurred.[30] In Wisconsin, a total of 22 heat-related deaths were reported from 2016 to 2020.[31]

Heat and humidity together can create the most severe problems for human health. High humidity makes heat more dangerous because it slows the evaporation of perspiration, which is the body's natural cooling process. The Heat Index (HI) is a measure of discomfort and the level of risk posed to people in high-risk groups by heat and humidity. The HI is expressed in degrees Fahrenheit (ºF) and incorporates an adjustment to the air temperature for relative humidity (RH). For example, if the air temperature is 94ºF and the RH is 55 percent, the HI would equal about 106ºF (see Table 3.15). Since HI values were devised for shady, light wind conditions, exposure to full sunshine can increase HI values by up to 15ºF. The impact on people in high-risk groups associated with different levels of HI is shown in Table 3.16. The NWS will initiate alert

[30] *Merianne R. Spencer and Matthew F. Garnett., "*Quick Stats: Percentage Distribution of Heat-Related Deaths, by Age Group – National Vital Statistics System, United States, 2018-2020*". MMWR Morbidity and Mortal Weekly Rep 2022; 71:808. June 17, 2022*.

[31] Op. Cit.

procedures (advisories or warnings) when the Heat Index is expected to have a significant impact on public safety. The expected severity of a heat wave determines whether advisories or warnings are issued. High temperature periods are often also accompanied by the air quality problems related to ground-level ozone which can be harmful, especially to sensitive groups, such as active children and adults with respiratory problems.

The following heat event definitions/criteria are used for the 20 counties in south-central and southeastern Wisconsin served by the Milwaukee/Sullivan Weather Forecast Office:

- **Outlook Statement**—Issued two to seven days prior to the time that minimal Heat Advisory or Excessive Heat Warning conditions are expected. Serves as a long-term "heads-up" message.

- **Excessive Heat Watch**—Issued 24 to 72 hours in advance when Excessive Heat Warning conditions are expected.

- **Heat Advisory**— This is issued within 12 hours of the start of extremely dangerous heat conditions. The National Weather Service will issue a heat advisory for Wisconsin when the daytime heat index values are 100 to 104. A heat advisory will also be issued if heat indices are 95 to 99 for four consecutive days.

- **Excessive Heat Warning**— This is issued within 12 hours of the onset of extremely dangerous heat conditions. It will be issued by the National Weather Service when the daytime heat index is 105 or higher during the day and 75 or higher at night for at least a 48-hour period. If heat indices are 100 to 104 for four consecutive days, an excessive heat warning will be issued.

During extended periods of very high temperature, coupled with high humidity levels, individuals can suffer a variety of ailments, including heat cramps (muscular pains and spasms due to heavy exertion). Although heat cramps are the least severe heat-related ailment, they are an early signal that the body is having trouble with the heat. Heat exhaustion typically occurs when people exercise heavily or work in a hot, humid place where body fluids are lost through heavy sweating. Blood flow to the skin increases, causing blood flow to decrease to the vital organs. This results in a form of mild shock. If not treated, the victim may suffer heat stroke. Heat stroke is life threatening and requires immediate medical attention. The victim's temperature control system, which produces sweat to cool the body, stops working. The body temperature can rise so high that brain damage and death may result if the body is not cooled quickly. Sunstroke is another term for heat stroke. In addition to posing a public health hazard, periods of excessive heat usually result in high electrical consumption for air conditioning, which can cause power outages and brown outs.

Most heat-related deaths occur in cities. Large urban areas often become “heat islands.” Brick buildings, asphalt streets, and tar roofs store and radiate heat like a slow burning furnace. Heat builds up in a city during the day and cities are slower than rural areas to cool down at night. The amount of sunshine is an important contributing factor in urban heat waves. In addition, the stagnant atmospheric conditions associated with a heat wave trap ozone and other pollutants in urban areas. The worst heat disasters, in terms of loss of life, happen in large cities when a combination of high daytime temperatures, high humidity, warm nighttime temperatures, and an abundance of sunshine occurs for a period of several days. There are also socioeconomic problems that make some urban populations at greater risk. The elderly, disabled, and debilitated are especially susceptible to heat-related illness and death.

Recent Heat and Extreme Heat Events (2011-2022)

Table 3.17 lists 18 recent extreme heat events in Milwaukee County from 2011-2022, in which no property or crop damages were reported, however there were seven fatalities and 29 injuries listed during that time period. Additionally, the NWS reported 55 heat-related deaths between 1982 to 2020 in Milwaukee County. Examples of recent extreme heat events in Milwaukee County are noted below.

2012 – During the days of July 1-7, 2012, a hot air mass settled over southern Wisconsin, bringing 100-degree heat to many locations for multiple days. Maximum heat indices climbed between 100° and 115°F during the hot spell. Based on news reports, hundreds of people received medical treatment at hospitals or clinics due to heat-related illnesses. Two fatalities were reported in Milwaukee County. Numerous new daily record highs were set as well as record high minimums. The long duration of this excessive heat period likely makes this one of the most dangerous heat waves to strike southern Wisconsin in recorded history.

2016 – In mid July 2016 southeastern Wisconsin experienced maximum heat index values ranging from 90 to 110 degrees. The Wisconsin Department of Health Services designated hundreds of cooling centers across the state. In addition, the Milwaukee Health Department, and the Housing Authority of the City of Milwaukee opened cooling stations. Hospitals reported 29 people in the Milwaukee area were treated for heat related illnesses.

2018 – On June 29, 2018, hot and humid conditions produced heat index values ranging from 100° to 110°F. Numerous cooling centers were opened by local communities throughout southern Wisconsin. Some public swimming pools hours were extended due to the heat. The heatwave continued into July 1st.

2019 – On July 19, 2019, the passage of a warm front brought a heat wave to southern Wisconsin with maximum heat index values of 99° to 106°F. The Milwaukee and Madison areas did experience an influx of emergency room visits due to heat exhaustion and/or heat stroke.

High demands for electricity during extreme heat events can result in blackouts and brown outs. Loss of water pressure can result from opening of fire hydrants in urban areas. Stagnant atmospheric conditions that occur with heat waves are also favorable for trapping ozone and other pollutants in urban areas. Pets and livestock can suffer from prolonged exposure to excessive heat. On average, there are about 1.5 extreme heat events per year in Milwaukee County that can have an impact on people, pets, and other forms of life.

Extreme Cold

Like extreme heat, extreme cold is also a deadly hazard. The CDC reports that the death rate of excessive cold as the underlying cause ranges from 1 to 2.5 deaths per million people and over 19,000 people have died from exposure to cold since 1979.[32] Exposure to extreme cold temperatures can also cause a number of health conditions and can lead to loss of fingers and toes, or cause permanent kidney, pancreas, and liver injury, and even death. These health impacts often result from a combination of cold temperatures, winds, and precipitation. As a result, winter storms can pose substantial risks because they can last for several days and be accompanied by high winds, freezing rain or sleet, heavy snowfall, and cold temperatures. In addition, when deaths and injuries due to cold-related events such as vehicle accidents and fatalities, fires due to dangerous use of heaters, carbon monoxide poisoning due to use of nontraditional sources of heat such as cooking ovens, and other winter weather fatalities are considered, the impact of severe cold periods becomes even greater.

Frostbite and hypothermia are two major health risks associated with severe cold. Frostbite is an injury caused by freezing of the skin and underlying tissues. Frostbite causes a loss of feeling and a white or pale appearance in extremities. Severe frostbite can damage skin and underlying tissues and requires medical attention. Potential complications of severe frostbite include infection and nerve damage. Frostbite is most

[32] *CDC, 2018.*

common on fingers, toes, nose, ears, face, and chin. While exposed skin in cold, windy weather is most vulnerable to frostbite, this injury can also occur on skin covered by gloves or other clothing.

Hypothermia is a condition brought on when the core body temperature drops to less than 95°F. It occurs when the body loses heat more quickly than it is able to produce it. As with frostbite, wind or wetness can contribute to producing hypothermia. Symptoms of moderate to severe hypothermia include lack of coordination, slurred speech, confusion, drowsiness, progressive loss of consciousness, weak pulse, and shallow breathing. Hypothermia may cause lasting kidney, liver, and pancreas problems or death. Members of certain populations are particularly vulnerable to hypothermia. These include older adults, infants, and very young children, the homeless, persons consuming alcohol or other drugs, and persons taking certain medications.

Wind chill is an index used to evaluate the risk posed by the combination of cold temperatures and wind. It is based on temperature and wind speed. Table 3.18 shows the wind chill table used by the National Weather Service. Wind chill is not the actual temperature, but rather a measure of how the combination of wind and cold feel on exposed skin. As the wind increases, heat is carried away from the body at an accelerated rate, driving down body temperature. This combination can strongly affect the risks associated with exposure to extreme cold. For example, a wind chill of -20°F will cause frostbite on exposed skin in just 30 minutes.

The NWS issues wind chill advisories when wind chill temperatures are potentially hazardous and wind chill warnings when wind chill temperatures are life threatening. The exact criteria of a wind chill advisory and warning varies from state to state. A wind chill advisory in Wisconsin is issued when wind chill values reach -20°F to -34°F, with wind speeds of 4 mph or more. A wind chill warning in Wisconsin is issued when wind chill values reach -35°F or colder, with wind speeds of at least four mph for three hours or more. In addition, a wind chill watch is issued 12 to 48 hours before these conditions are expected to occur.

What constitutes extreme cold varies in different parts of the country. In the south, near freezing temperatures are considered extremely cold. Freezing temperatures can cause severe damage to citrus fruit crops and other vegetation. Pipes may freeze and burst in homes that are poorly insulated or without heat. In the north, extreme cold means temperatures well below zero. Winter residents in Milwaukee County may see heavy snow, strong winds/blizzards, extreme wind chill, lake-effect snow, and ice storms. The public can stay informed by listening to NOAA Weather Radio, commercial radio or television for the latest winter storm warnings and watches.

Recent Extreme Cold Events (2011-2022)

Extreme cold that affects Milwaukee County are not localized events, as they usually encompass the entire south-central to southeastern portion of the State and may continue for several days or weeks. Between 2011 and 2022, as shown in Table 3.17, there has been no reported property damage and only an estimated $920 in total crop damages that have affected Milwaukee County as a result of extreme cold temperatures. Several of the extreme cold events listed in Table 3.17 are described below.

2013 – On January 21, 2013, arctic air spread into southern Wisconsin behind deep low pressure that tracked to the north of the state. High winds combined with surface temperatures in the negative single digits to produce wind chills between -20° to -30°F. The frigid wind chills began the morning of January 21st and continued into the morning hours of January 22nd.

2014 – On January 27, 2014, an arctic cold wave affected southern Wisconsin. West to northwest winds of 10 to 20 mph with the passage of an arctic cold front brought wind chill temperatures of -20° to -38°F beginning in the early morning of January 27th. These wind chills did not end until the morning of January 29th. The coldest period was the morning of January 28th when wind chills ranged from -30° to -38°F. Widespread school and business closings occurred during this time. The Governor declared a state of emergency due to a propane shortage across the state. Numerous water main breaks and frozen laterals continued to occur throughout the entire month of January. Two cold weather deaths occurred in the southeastern Wisconsin area.

2019 – During the end of January 2019, a dangerously cold air mass settled across the upper Midwest. It was the coldest air mass since 1996 and it brought three days of sub-zero temperatures with wind chills of -30° to -60° F. At first, schools were closed only due to the snow, but by the middle of the week the Governor declared a state of emergency because of the dangerous cold. Many businesses had to close, and postal services were suspended.

Vulnerability and Community Impact Assessment Related to Extreme Temperatures

Temperature extremes are primarily a public health concern, especially for those populations considered vulnerable including young children, the elderly, underprivileged, under educated, pregnant, and those with chronic health conditions. Also, communities within large and highly urbanized areas, such the City of Milwaukee, are considered vulnerable due to the "heat island" effect which can raise the area summer temperature by 3ºF to 5ºF degrees. Also, urban communities with substantial populations of elderly, disabled, and debilitated people could face a significant medical emergency during an extended period of excessive cold and heat.

In 2014, the Building Resilience Against Climate Effects (BRACE) program in the Wisconsin Department of Health Services compiled heat vulnerability index maps for the State and each county. In addition, the Wisconsin Department of Health Services created a Milwaukee Heat Vulnerability Index report.[33] Results of the Milwaukee County heat vulnerability index are shown in Figure 3.4. The heat vulnerability index is based on multiple indicators associated with risk for heat-related illnesses and mortality including health factors, demographic and household characteristics, socioeconomic factors, natural and built environment factors, and population density. Because of its high population density, high poverty rate, and urban heat island effect, Milwaukee County has a high vulnerability to extreme heat events and has experienced many heat-related fatalities. As indicated in Figure 3.4, the largest area of high heat vulnerability identified in the Milwaukee County HVI map is the inner core of the City of Milwaukee. Areas of low heat vulnerability include the shoreline of Lake Michigan as well as the southern region of Milwaukee County.

Municipal water and electric utilities can also be impacted by extreme temperature events. Some older residents may become isolated with extreme temperatures due lack of physical strength and larger number of health problems (physically and mentally). Education, improved social awareness, and community outreach programs have likely helped to reduce the number of individuals killed or injured by extreme temperature events.

Although no property damages have been reported as a result of extreme temperature events, there have been several reported incidents of crop damages between 2011-2021, as previously noted (see Table 3.17) Based on this data, there are a total of 4.5 extreme temperature events per year in Milwaukee County with 1.5 of those events related to extreme heat and 3 events related to extreme cold.

Future Changes and Conditions

The historical record shows considerable variation among years in the numbers of extreme temperature events that occurred in Milwaukee County. While it would be expected that in some years the County will experience either fewer events or more events than the average number, the average annual number of events is not expected to change over the five-year term of this plan update.

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[33] *ww.dhs.wisconsin.gov.*

The projections based on downscaled results from climate models indicate that there will likely be substantial changes in the frequencies of extreme cold and heat events over the 21st century.[34] The frequency of extreme cold events may decrease by the middle of the century as projected warming trends are expected to be greatest during the winter. Average winter temperatures in Milwaukee County are projected to increase by about 4.0°F. This may result in a reduction of some risks associated with extreme cold.

Extreme heat events are likely to occur more frequently and to be more severe by the middle of the century. As previously described, average summertime temperatures in Milwaukee County are projected to increase by 4.0 ºF by the year 2060. Heat waves are also expected to become longer and more intense over time, with a 1.5-7.5°F minimum rise in Wisconsin summer temperatures and an increase in the number of extremely hot days. By mid-century (2041-2060), the number of days over 90 °F in Wisconsin is likely to triple.[35] A 2019 study on climate analogs for urban areas in the late 21st century predicts that in 2080, Milwaukee's climate will feel most like today's climate near Chester, Pennsylvania where the typical summer is 5.6 °F warmer and 7.8 percent wetter than summer in Milwaukee. Given that much of the documented increases in average temperature since 1950 have occurred through increases in night-time low temperatures, it is likely that there will be fewer night-time breaks in the heat during extreme heat events in the future. This could result in some extreme heat events persisting longer.

Multi-Jurisdictional Risk Management

As noted above, during extreme heat events, the City of Milwaukee can potentially be more vulnerable due to the built environment creating a heat island effect. However, during extreme cold and most extreme heat events, there are no specific municipalities that have unusual risks. Rather, the events are of a uniform countywide concern.

Drought

Drought is the result of a natural decline in the expected precipitation over an extended period of time, and occurs in virtually every climate on the planet, including areas of high and low precipitation. The severity of drought can be aggravated by other climatic factors, such as prolonged high winds, high temperatures, and low relative humidity. Drought is a complex natural hazard which is reflected in the following four definitions commonly used to describe it.

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[34] *Wisconsin Initiative on Climate Change Impacts, 2021, op. cit.*

[35] *Op. Cit.*

1. **Meteorological drought**: The degree of dryness, expressed as a departure of actual precipitation from expected average or normal amount, based on monthly, seasonal, or annual time scales

2. **Hydrological drought**: The effects of precipitation shortfalls on streamflow, reservoir, lake, and groundwater levels

3. **Agricultural drought**: Soil moisture deficiencies relative to water demands of crop life

4. **Socioeconomic drought** (or water management drought): Occurs when the demand for water exceeds the water supply, resulting in a water shortage

Drought severity depends on several factors, including its duration, its intensity, its geographic extent, and the demands for water for use by both humans and vegetation.

Drought can be difficult to define in exact terms. This is partly due to its multi-dimensional nature and partly due to the ways it differs from other natural hazards. There is no exact and universally accepted definition of what constitutes a drought. The onset and end of a drought are difficult to determine due to the slow accumulation of its impacts and the lingering effects after its apparent end. The impacts of drought are less obvious than those of some other hazards and may be spread over a larger geographic area. These characteristics have hindered the preparation of drought contingency or mitigation plans by many governments and can make it difficult to perform an accurate risk assessment analysis.

Droughts can have several impacts. They can reduce water levels and flows in surface waterbodies and groundwater. This can cause shortages of water for human and industrial consumption, hydroelectric power, recreation, and navigation. Water quality may also decline, and the number and severity of wildfires may increase during a drought. Severe droughts may result in reduced yields or the loss of agricultural crops and forest products, undernourished wildlife and livestock, and lower land values.

One method to measure the magnitude of a drought is by using the Palmer Drought Severity Index. This method considers factors like temperature, soil moisture, and precipitation, which are entered into an algorithm that returns results between -5 (extreme drought) and 4 (extremely moist) with zero being normal conditions. The U.S. Drought Monitor uses the Palmer Index, along with other indicators, to rate drought conditions into drought categories, as described in Figure 3.5.

The Crop Moisture Index was developed to measure soil moisture over shorter periods, up to four weeks, and has values between -3 (severely dry) and 3 (excessively wet), with zero as normal conditions. The NWS Climate Prediction Center publishes both Palmer Drought Severity and Crop Moisture indices for the country weekly.[36]

Wisconsin is vulnerable to agricultural drought. The State has approximately 14.2 million acres of farmland on 64,100 farms.[37] Even small droughts of limited duration can significantly reduce crop growth and yields, adversely affecting farm incomes and local economies. Droughts significantly increase the risk of forest fires and wildfires. Additionally, the loss of vegetation in the absence of sufficient water can result in flooding, even from average rainfall.

Estimates of agricultural losses experienced in Milwaukee County due to drought over the period 2011 to 2022 are shown in Table 3.19. Because there are no crop damages reported in the NCEI database, these estimates come from records of indemnities paid to agricultural operators by Federal crop insurance programs.[38] The documented loss estimates reflect several factors. First, crop losses often go unreported. Second, Federal crop insurance policies offer coverage to only certain types of crops in any particular year. Third, agricultural operators generally insure only a portion of their crops when purchasing Federal crop insurance. Thus, crop loss estimates are likely to represent underestimates of actual losses. It should be noted that indemnities for drought related losses were paid out every few years. This probably reflects variability in rainfall causing localized crop losses. Based on these sources, it is estimated that Milwaukee County experienced crop damages of just over $66,000 between 2011 and 2022. Due to the variability in crop damages paid, an average loss cannot be calculated.

Small droughts of shortened duration have occurred in Wisconsin at an interval of about every 10 years since the 1930s. Extended, widespread droughts have been infrequent in Wisconsin. The most significant droughts, in terms of severity and duration were in 1929-1934, 1948-1950, 1955-1959, 1976-1977, 1987-1989, 1995, and 2012.

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[36] *Wisconsin Department of Emergency Management and Military Affairs, State of Wisconsin Hazard Mitigation Plan, December 2021.*

[37] *State of Wisconsin Department of Agriculture, Trade and Consumer Protection, 2022 Wisconsin Agricultural Statistics.*

[38] *The U.S. Department of Agriculture Risk Management Agency report payments of crop insurance indemnities.*

Recent Events

The only recent drought event took place in 2012. A lack of rain over south-central and southeastern Wisconsin during June 2012 allowed a drought to slowly develop. The intensity of this drought increased rapidly and by June 26th the drought intensity was rated abnormally dry by the U.S. Drought Monitor. The drought continued through the month of July and by August the conditions were extremely dry across southeastern Wisconsin. Several rainfall and thunderstorm events occurred in August, but annual precipitation amounts were still below normal. The end of August ended with above normal temperatures, increasing the effects on the already stressed crops and water supply. Drought conditions improved by October with above normal precipitation. For many farmers across the region the drought conditions over the summer reduced crop yields.

Vulnerability and Community Impact Assessment Related to Drought

A review of community assets, as described in Chapter 2, indicates that Milwaukee County is less susceptible to droughts because it is very urban and positioned on Lake Michigan, which serves as the main source of drinking water. However, it is important to note that during prolonged drought conditions the depletion of groundwater reserves can impact the amount of surface water available for recreational activities (i.e., boating and fishing) and for wildlife as well as those using private wells for drinking water.

Future Changes and Conditions

The future occurrence of a drought is highly unpredictable, as it impacts the state occasionally, but not annually. Drought may also be localized, making it difficult to determine probability with any accuracy; however, the NWS and National Integrated Drought Information System (NIDIS) are improving methodologies for accurately forecasting drought conditions. The statewide historical record indicates that severe droughts can be expected to occur at roughly 10-year intervals. As can be seen in Figure 3.5, Wisconsin regularly experienced drought to at least to a moderate level two to three times every ten years from 1895 to 2021.[39] It is not expected that the probability of drought will change during the five-year term of this plan update.

Historical changes over the 20th century and projections based on downscaled results from climate models indicate that there will likely be changes in drought conditions affecting Milwaukee County over the 21st century. By mid-century, average temperatures are projected to rise, leading to longer summers and shorter winters. The temperature increase will also lead to a longer growing season and increased rates of

[39] *University of Wisconsin-Madison, Atmospheric and Oceanic Sciences, www.aos.wisc.edu.*

evapotranspiration during summer and early fall months. While the amount of rain during the summer is not projected to change, a greater proportion of precipitation is projected to fall in heavy rainfall events. This will result in a greater number of dry days during the summer. More dry days, coupled with higher summer temperatures and increases in evapotranspiration rates, may increase the likelihood of summer droughts occurring.[40]

Multi-Jurisdictional Risk Management

Because Milwaukee County has little agricultural lands and the communities are served by public water supply that use Lake Michigan water as a source of supply, there are no areas of the County that are likely to experience unusual risks or major debilitating impacts of drought. Impacts from drought would be limited to a few individual farms and residents that may rely on private wells. Drought impacts to surface vegetation that is not irrigated may occur during a drought, but this result would be uniform across the County.

Lake Michigan Coastal Hazards

For the purposes of this Report, coastal hazard mitigation can be defined as a means by which the County may mitigate coastline impacts, such as coastal flooding, wave runup, shoreline and beach erosion or bluff recession and failure. Coastal mitigation measures may incorporate structural or nonstructural measures. Examples of structural coastline management measures include retaining walls within a bluff slope, shoreline revetments, and breakwaters. Examples of nonstructural coastline management measures include regulations or guidelines for land uses or development, such as promoting landscape management techniques that are appropriate for bluffs. Whether located on-shore or near off-shore, structural and nonstructural coastline management techniques are intended to mitigate or prevent damage from the impacts of coastal hazards on life and property.

It is important to note that shoreline protection structures (i.e., seawalls, revetments, breakwater structures) have been known to contribute to coastal problems by decreasing, or preventing, natural erosion of littoral material (lake bottom near shore) such as sand and gravel from existing shorelines. Additionally, these structures can disrupt the natural flow and deposition of those sediments along the lake shore, affecting beach ecosystems. Some shoreline protection structures may redirect wave energy to adjacent shorelines, which can increase the potential for erosion at neighboring sites.[41]

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[40] *Wisconsin Initiative on Climate Change Impacts, 2021,* op. cit.

[41] *University of Wisconsin Sea Grant, Great Lakes Coastal Shore Protection Structures and Their Effects on Coastal Processes, 2013.*

There are five types of Lake Michigan coastal hazards of concern that pose risk to Milwaukee County:

- **Shoreline Recession and Bluff Failure**
- **Beach Erosion**
- **Coastal Flooding**
- **Damage and failure of shoreline protection structures** (revetments,[42] seawalls, and groins[43]) from wave action, storm surge, and varying lake levels
- **Damage to shoreline structures** (residences, businesses, and public facilities) from storm waves, including wave runup)

Nearly 80 percent of Wisconsin's Lake Michigan shoreline is affected by coastal erosion and bluff recession to some degree, and recurring erosion presents a significant risk in almost every coastal county. The terms recession and erosion are often used interchangeably. Recession is the landward movement of a land feature, such as a bluff crest, while erosion is the wearing away of land. Recession is expressed as distance or a change in distance, while erosion is expressed as a volume or change in volume. Recession can be thought of as a consequence of erosion. Shoreline recession rates are usually determined by comparing aerial photographs taken on different dates.

The rate at which coastal erosion occurs is dependent on a variety of factors including Lake Michigan level fluctuations, disruption of the transport of beach-building sediments, elevated groundwater levels, storms, and surface stormwater runoff. Additional contributing factors to coastal erosion can include soil composition, vertical cracks in the upper slope of the soil, shoreline ice cover, freezing and thawing cycles, shoreline orientation, beach composition, beach width and slope, the presence or absence of shore

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[42] *Revetments are sloping structures placed on banks or cliffs in such a way as to absorb the energy of incoming water (i.e., wave impact). Many materials may be used such as wooden piles, loose-piled boulders (i.e., riprap), concrete shapes, or geotextile fabric sandbags.*

[43] *A groin is a narrow structure (i.e., breakwater and/or jetty) built out into the water from a beach in order to prevent beach erosion or to trap and accumulate sediments that would otherwise drift along the beach face. A groin can be successful in stabilizing a beach on the up-drift side, but erosion tends to be aggravated on the down-drift side.*

protection, and the type of shore protection. Shores that have cohesive materials, such as clay, till, and bedrock have strong binding forces. Shores that have noncohesive materials, such as sand and/or gravel have weak or no binding forces. Like most of the Great Lakes Region, the soils in Milwaukee County are composed of sand, gravel, clay, and clay-like material known as glacial till. The bluffs along Milwaukee County's Lake Michigan coastline exhibit a variety of height, slope, composition, vegetative cover, and groundwater conditions, which affect the degree and rate of bluff recession. Much of the bluff heights along the Milwaukee County coastline ranged from approximately 25 feet to 140 feet. Bluffs within the northern and southern extents of the County were higher than the central portion of the County, where conditions ranged from the absence of natural bluffs to bluffs of up to 25 feet in height.

A portion of the Milwaukee County bluff in the City of Milwaukee is set back from Lake Michigan by fill placed for Lincoln Memorial Drive, various County parks, and facilities including the Jones Island and South Shore Water Reclamation Facilities, Milwaukee Water Works, and the Port of Milwaukee. The southernmost section of the Milwaukee County bluff in the City of Oak Creek is set back from Lake Michigan by fill placed for the We Energies Oak Creek Power Plant. Thus, these two coastal areas are not directly impacted by Lake Michigan processes and will not be discussed in as great a detail as the rest of the Milwaukee County coastline.

Lake Level Fluctuations

Lake level can be a significant factor in determining the rate of erosion along Wisconsin's coasts. As mentioned above, high Lake levels and increased wave action can worsen both coastal erosion and coastal flooding issues. As lake levels rise, bluff recession rates can also increase. Major storm events can also lead to high erosion rates because of increased wave action on the shoreline. The effects of wave-induced erosion are usually greater during periods of high Lake levels. Conversely, low Lake levels pose problems for facilities that are dependent on water depth, such as ports, marinas, and nearshore water utility intakes. Low water levels can also cause problems with shore protection structures, such as normally submerged timber pilings being exposed to air.

The Great Lakes have experienced a period of both low and high-water levels over the past 25 years. Water levels in the Great Lakes fluctuate seasonally, annually, and over multi-decade cycles. Seasonally, the lakes are at their lowest levels during the winter, when much of the precipitation is held on land in the form of snow and ice, and evaporation occurs over open water. The highest seasonal levels are typically during the summer when snowmelt from the spring thaw and summer rains contribute to the Lake water supply. For Lake Michigan in the 30-year-period between 1992-2022, the average difference between summer high water levels and winter low water levels has been about one foot. Long-term variations in Lake levels (over multi decades) depend on climatic factors such as precipitation, the presence or absence of ice cover on the Lake during the winter, and evaporation of water from the Lake.

Coastal hazard problems have been most evident in southeastern Wisconsin and Milwaukee County during high water periods. As indicated in Figure 3.6, these have occurred in recent history on Lake Michigan in the early 1950s, the early 1970s, the mid-1980s and late 1990s, and again in 2020 with water levels reaching record highs. As of November 2021, Lake Michigan water levels continued their seasonal decline, decreasing by about 3 inches from October to November. Though Lake Michigan is about 25 inches below the highest monthly water level recorded for November in 1986, the Lake is still about 13 inches above the long-term average water level as of November 2021. Water levels are expected to continue their seasonal decline through the early winter but remain above the long-term average.[44]

Beach, Coastal, and Shoreline Erosion and Bluff Stability Conditions

Shoreline erosion and bluff stability conditions can change over time since they are related, in part, to changes in climate, water levels, the geometry of the onshore beach and nearshore areas, the extent and condition of shore protection measures, the type and extent of vegetation, and the type of land uses in shoreland areas, among other related factors. Bluff and beach erosion are the primary forms of erosion occurring along the Milwaukee County Lake Michigan coastline. Additionally, bluff slope failure along the Milwaukee County Lake Michigan coastline can occur. The most common forms of bluff slope failure in the County are translational slides, rotational slides, and creeping.[45] Beaches along the Milwaukee County coastline are also subject to erosion via littoral drift, where coastline sediment is transported via longshore currents.

As noted in Chapter 2, the reports below are studies and assessments on bluff stability and shoreline conditions along the Lake Michigan Milwaukee County coastline.

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[44] *Collaborative Action for Lake Michigan (CALM) Coastal Resilience Monthly Newsletter, November 2021.*

[45] ***Translational slides*** *occur when a single mass or a few closely related masses of soil or rock move quickly downslope in a planar manner.* ***Rotational slides*** *(or slumps) are classified as a soil mass with a curved rupture surface moving slowly downslope.*

- *SEWRPC Technical Report No. 36. SEWRPC* Lake Michigan Shoreline Recession and Bluff Stability in Southeastern Wisconsin: 1995 and December 1997.

  An inventory of the shoreline conditions and bluff stability within the entire Southeastern Wisconsin Region was conducted in 1977 by a number of coastal technical consultants under the Wisconsin Coastal Management Program (WCMP) and again in 1995 for a study published in 1997 by SEWRPC in conjunction with the WCMP. Information from the later study is summarized in Table 3.20 and includes bluff heights, bluff stability, shoreline recession, and beach width for each associated reach area.[46] Bluff stability, bluff recession rates, and beach width from that study are shown on Map 3.4. Within northern Milwaukee County, many bluffs were generally found to be stable based upon conditions during the 1995 survey; however, bluffs in two areas were found to be unstable. One of these areas was located along the shoreline in the Village of Bayside. The other was located along the shoreline in the Villages of Fox Point and Whitefish Bay. In central Milwaukee County, the 1995 survey found that bluffs were generally stable. The 1995 survey found that bluffs in several areas in the southern part of the County were unstable. These areas are located along the shoreline in the Cities of Cudahy, South Milwaukee, and Oak Creek.

- Shoreline Erosion Study for Warnimont Park in the City of Cudahy, STS Consultants, 2001

  In 2001, bluff stability and erosion conditions were assessed along approximately 2,000 linear feet of bluff in Warnimont Park.[47] This study found visible evidence of erosion along the toe of the bluffs; evidence of recent bluff failures, including translational slides and rotational slumps; and visible water seeps at mid bluff levels, some exhibiting relatively rapid discharge of water during field investigation.

- Lake Park Bluff Stability and Plant Community Assessment, 2003. *Memorandum Report No 156, SEWRPC, September 2004*

  Bluff stability conditions were assessed within Lake Park in the City of Milwaukee.[48] While the bluff stability analysis conducted as part of this study found that most bluffs in the park were stable, it concluded that bluffs in the southern portion of the park were marginally stable and less stable than bluffs in the other portions of the park. In addition, this study found evidence of active recession of the bluffs in the southern portion of the park, including evidence of top recession.

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[46] *A safety factor against sliding of less than 1.0 is considered unstable, a factor of 1.0 to 1.1 considered marginally stable, and a factor of greater than 1.1 is considered stable.*

[47] *STS Consultants*, op. cit.

[48] Ibid.

- Integrated Assessment on Water Level Variability and Coastal Bluff Erosion, 2015

  In 2015, coastal bluff conditions were analyzed along communities in northern Milwaukee County. While the bluff analysis conducted as part of this assessment found that most bluffs in this area of the County were stable prior to 2013, it concluded that there were some areas of continued bluff failure. The assessment found new bluff toe failures have occurred due to decreased beach widths and bluffs that were initially stable were failing because an adjacent property owner-built shoreline/bluff protection structures to stabilize their property, thus adversely affecting a neighboring property owner that didn't have protection structures in place. In addition, the assessment indicated that about 63 percent of the northern Milwaukee County shoreline was armored with a form of protection.

Wisconsin Shoreline and Oblique Photo Viewer

WCMP, the Association of State Floodplain Managers (ASFPM), and Geo-Professional Consultants, LLC have developed a web mapping tool to view shoreline conditions along most of Wisconsin's Great Lakes coast. The Wisconsin Shoreline Inventory and Oblique Photo Viewer (shoreline viewer tool) can be used to view and compare assessments on shoreline protection and shore and bluff conditions. Shoreline characteristics and conditions were derived from interpretation of oblique aerial photography of the Lake Michigan coastline taken in 1976-78, 2007-08, and 2018-19, and the analysis was performed by David M. Mickelson. It should be noted that these interpretations represent conditions on the date that these photographs were taken and are limited by what can be seen in the photos.

In addition, geotagged oblique images can be viewed and compared on the shoreline viewer tool from 2012, 2016, 2017, 2018, 2019, 2020, 2021, 2022, and 2023. These images can be used with the interactive mapping tool to understand and evaluate how bluffs along the Milwaukee County coast have changed over time.

Map 3.5 and Table 3.21 summarizes an assessment of the types of shore protection in the County in 2018-2019, as provided on the shoreline viewer tool. In 2018, about 36 percent of the shoreline in Milwaukee County was unprotected. The most common type of shore protection in the County was revetment (37 percent); followed by other armored areas (docks or marinas) (14 percent); seawall or bulkhead (9 percent); poorly organized riprap or rubble (3 percent); and offshore breakwater (1 percent).

The shoreline viewer tool also provides insight into the general conditions of Lake Michigan bluffs in 2018, as shown in Map 3.6. In 2018, about 17 percent of Milwaukee County's shoreline was considered to have moderately unstable to unstable or failing bluffs (as shown in black and red on Map 3.6). According to the dataset, some bluff areas considered to be unstable or failing were located in the same municipalities as the 1995-1997 assessment, especially in the southern portion of the County, which includes the Cities of Oak Creek, South Milwaukee, and Cudahy. As shown on Map 3.6, areas identified as having unstable or failing bluff conditions were located in the areas of three County-owned parks—Grant Park in the City of South Milwaukee and Sheridan and Warnimont Parks in the City of Cudahy. An area in the Village of Fox Point that was considered unstable or failing in the 1995-1997 assessment is now considered moderately unstable in the 2018 dataset and an area in the Village of Bayside that was also considered unstable or failing in the 1995-1997 assessment has been upgraded to moderately stable. However, an area along Bay View Park in the City of St. Francis was considered stable in the 1995-1997 assessment is now considered unstable or failing in the 2018 dataset. As shown on Map 3.6, the majority of bluff areas in Milwaukee County that are the most vulnerable to the effects of extreme weather conditions and are considered moderately unstable or unstable or failing are located in the southern portion of the County.

Map 3.7 specifies the types of bluff failure that was occurring at the time of the 2018 dataset. Shallow slides were the most observed type of bluff failure, occurring at 16 percent of the assessed County shoreline, followed by creep failure (10 percent), and deep-seated slumps (2 percent). As shown on Map 3.7, about 70 percent of the County’s bluff shoreline was observed as having minimal or no obvious failures.

Long-Term (1956-2015) and Short-Term (1995-2015) Bluff Toe and Bluff Crest Recession

A recent analysis by the University of Wisconsin-Madison Coastal Sustainability and Environmental Fluid Mechanics Laboratory is also available to view on the shoreline viewer tool. The study measured long-term (1956-2015) and short term (1995-2015) bluff toe recession, bluff crest recession, and general shoreline recession along the shores of Kenosha, Milwaukee, Ozaukee, and Racine Counties. It should be noted that the analyses discussed below were for bluff conditions through 2015, thus do not include the higher water levels and storm events experienced in later years. Bluff recession distances were measured from historical aerial photos in Geographic Information Systems (GIS) software. The bluff crest, bluff toe, and shoreline were carefully traced on each aerial photo. The bluff crest is identified as the break in slope between the upland and the bluff slope; the bluff toe is identified as the break in slope between the bluff slope and the beach; and the shoreline is defined as the location that appears as the interface between the water and land at the time the photo was taken (see Figure 3.7). Once each feature was digitized, the Digital Shoreline Analysis System (DSAS) software was used to measure the location of each digitized feature along transect lines spaced at 10-meter intervals along the shoreline. Data in Maps 3.8 through 3.11 show recession distances that have been spatially averaged along 300-foot sections of coast. The data therefore represent average recession over a distance wider than a typical parcel or shoreline frontage and should not be interpreted as recession at a specific property.

This recession analysis can provide useful insights into the historic migration of the Lake Michigan coast in Milwaukee County. It should be noted that bluff recession can be sporadic. A bluff crest that remained unchanged for decades can recede many feet almost instantly due to a bluff collapse. This analysis represents how the bluffs have responded to historical environmental conditions and human actions over a specific time period. There will always be uncertainty in how bluff and shoreline recession will respond to future conditions.

Long-Term Bluff Toe and Crest Recession

As shown in Map 3.8, about 47 percent of the bluff toe in Milwaukee County has experienced at least some recession in the 59-year long term period from 1956 to 2015. Furthermore, about 9 percent of the County's bluff toe was estimated to have experienced significant recession of more than 60 feet. The most severe long term bluff toe recession has occurred in Whitefish Bay, St. Francis, South Milwaukee, and Oak Creek (see Map 3.8). It is estimated that about 53 percent of the bluff toe in the County has either experienced no recession or has moved towards the Lake (accretion). It should be noted that accretion or small bluff toe recession distances may represent areas where the bluff crest has slumped towards the shoreline or where the construction of shore protection structures has advanced the bluff toe lakeward.

Map 3.9 shows long term bluff crest recession distances in the County. About 27 percent of the bluff crest in Milwaukee County has experienced at least some recession through 2015, with 7 percent experiencing at least 20 feet of retreat, and 4.5 percent experiencing more than 60 feet of recession. The largest bluff crest recession distances have occurred In the City of Milwaukee, St. Francis, Whitefish Bay, and Oak Creek. About 73 percent of the bluff crest in the County have had no recession or has experienced accretion, possibly due to fill added to the bluff in a slope stabilization project.

Short-Term Bluff Toe and Crest Recession

As shown in Map 3.10, about 31 percent of the bluff toe in Milwaukee County has experienced at least some recession in the 27-year short term period from 1995 to 2015, with most of that percentage experiencing 0 to 10 feet of bluff toe retreat. A few reaches in Oak Creek, South Milwaukee, City of Milwaukee, and Bayside have experienced bluff toe recession distances greater than 20 feet. It is estimated that 12 percent of bluff toe in the County has not seen any recession and 56 percent has experienced accretion. Again, it should be noted that bluff toe accretion may represent areas where material has slumped from the bluff crest above.

Map 3.11 shows short term bluff crest recession distances in Milwaukee County. Only about 4 percent of bluff crest data collected in the County has shown at least some recession in the 27-year short term period. Of those 4 percent, 2.6 percent has seen retreat of the bluff crest of more than 20 feet. Bluff crest recession distances greater than 20 feet have occurred in St. Francis and Oak Creek. Conversely, 96 percent of the bluff crest in Milwaukee County has either experienced no recession or accretion during this short-term period.

Because shoreline and beach erosion and bluff instability occur along the County's Lake Michigan coastline, hazard mitigation planning on coastal and bluff conditions should be considered important for the protection, sound development, and redevelopment on the lands located along the Lake Michigan shoreline.

Coastal Flooding

Coastal communities face flood risks from a combination of increased water levels and/or high-energy waves. Coastal flooding tends to be the most serious in the low-lying areas.[49] The risk of coastal flooding is reduced when lake levels are low, however other factors such as storm-induced winds and wave run-up can cause or exacerbate coastal flooding. Likewise, when lake levels are high, storm surge, wave height, and wave run-up also influence the severity of coastal flooding. Communities positioned on low terraces, including portions of the City of Milwaukee and Villages of Bayside and Fox Point are at a medium risk of flooding, whereas communities in the County located on high bluff areas are not vulnerable to coastal flooding.[50]

As indicated in Table 3.7, there have been two recent reported lakeshore flood events along the Milwaukee County shoreline, including the January 11, 2020, event, which was reported with an estimated $12 million (2022 dollars) in property damage. Details of this event are described under the "Recent Events" subsection. Because there are low-lying terraces along the Milwaukee County coastline and coastal flooding has occurred, coastal flooding is an important element in hazard mitigation planning.[51]

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[49] *Wisconsin Emergency Management,* Hazard Mitigation Plan*, December 2016, op. cit.*

[50] Ibid.

[51] *Wisconsin Emergency Management,* Hazard Mitigation Plan*, 2021*

Potential Flood Damage for Coastal Areas

Based on SEWRPC's parcel-based analysis, as described earlier in this Chapter, an estimated 15 structures (mainly residential in the Village of Fox Point) were identified within Lake Michigan's 1-percent annual probability floodplain (special flood hazard area), including a large parcel in the Port of Milwaukee. The assessed value of these structures in 2022 was estimated at about $9.9 million and more than $12.4 million when the value of contents is considered. The location of the parcels with structures within the flood hazard areas are shown on Map 3.12 (and also included in Map 3.2). Because of their proximity to the Lake and low lying position, these identified structures are vulnerable to coastal flooding and its associated hazards such as storm-induced winds or wave run-up. It is estimated that for the 1-percent-annual probability flood event, these structures would sustain about $325,000 in damages.

The Great Lakes Coastal Flood Study (GLCFS)—an on-going collaboration between FEMA and the U.S. Army Corps of Engineers (USACE)—have produced preliminary FEMA maps for coastal flood velocity zones (V Zones) for the Great Lakes. The current FEMA maps include flood Zones A or AE along the Milwaukee County coast, including Milwaukee County. Zones A and AE are typically inland (i.e., lakes and rivers) flood zones that do not account for wave action greater than 3 feet or storm surge. Zones V and VE represent the area along the coast that is subject to inundation by the one-percent-annual-probability flood with additional hazards associated to wave run-up greater than 3 feet above the base flood elevation (BFE). Note, Zones AE and VE have detailed hydraulic studies to determine the BFE (i.e., elevation data), while Zones A and V do not and are approximate flood Zones. Digital Flood Insurance Rate Maps (DFIRMs) showing the new coastal V and VE Zones for the Great Lakes should move from preliminary to effective within the life span of this plan.

Recent Coastal Hazard Events

2019 – Water levels in the Great Lakes rose significantly in 2019, as water levels approached the lake's highest measured level, sections of bluffs along Milwaukee County's coastline collapsed. Bluff sloughs in Sheridan and Warnimont Parks carried away several trees and infrastructure in the County-owned parks near the new bluff edge. These properties and others along Milwaukee County's lakefront are becoming increasingly vulnerable to coastline impacts. As indicated by the aforementioned studies and reports,[52]

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[52] *Including Community Assistance Planning Report (CAPR) No. 155,* A Lake Michigan Shoreline Erosion Management Plan for Northern Milwaukee County, Wisconsin, *1988; CAPR No. 163,* A Lake Michigan Shoreline Erosion Management Plan for Milwaukee County, Wisconsin, *1989*; *and Memorandum Report No. 156,* Lake Park Bluff Stability and Plant Community Assessment: 2003, Milwaukee County, Wisconsin*, 2004*.

lakefront property may be best protected from future coastline impacts through the implementation of coastline management guidelines based upon best practices.

2020 – On January 11, 2020, strong onshore winds combined with near record high Lake Michigan water levels to produce severe lakeshore flooding and erosion at the Port of Milwaukee. Maximum wave heights were estimated to be between 10 to 18 feet. Flood waters due to high waves estimated 6 to 8 feet high caused flooding to spread across the Port of Milwaukee, causing the Port and Car Ferry to close for two days. About 60 to 70 percent of Jones Island, where the Port of Milwaukee is located, was flooded. The floodwater stripped dock wall material and covered railroad tracks with a foot of ice. Flood erosion damage took place at other locations along the Milwaukee County shore, including South Shore Yacht Club and the Oak Leaf walking trail along South Shore Drive. Damage also occurred at the Riverfront boat launch, Veterans Park, McKinley Marina gas dock, Warnimont Golf Course, North Point Lighthouse, and portions of bluff collapse at Bay View Park and Lake Park. Damage as a result of this event was estimated at $12 million (2022 dollars)

It should be noted that numerous improvements were made to the City of Milwaukee lakefront as part of the creation of Lakeshore State Park and integration with Pier Wisconsin, Discovery World, and the Quadracci Pavilion, in addition to the Milwaukee Art Museum. The first phase of planned improvements was completed in 2007 for the 17-acre park at a cost of $17 million. Detailed coastal analyses were completed with physical models to assess water levels, wave conditions, design storm events, and water circulation. Improvements to the lakefront included reconstruction of the eastern shore of Lakeshore State Park and two new breakwalls. One 180 linear foot breakwater protects the Quadracci Pavilion addition from wave runup, and a 1,200 linear foot breakwater minimizes wave heights in a maritime basin just north of the State Park.[53]

Vulnerability and Community Impact Assessment Related to Lake Michigan Coastal Hazards

<u>Wisconsin Emergency Management (WEM) Coastal Erosion Risk and Vulnerability Assessment</u>

In 2021, Wisconsin Emergency Management (WEM) conducted a county-level coastal erosion risk and vulnerability assessment for the State as part of the Threat and Hazard Identification and Risk Assessment (THIRA). WEM used the statewide parcel inventory (Wisconsin Statewide Parcel Database) as the basis for estimating the existing potential losses from Lake Michigan coastal erosion. Each parcel contained information such as total parcel value, improvement value, and property class. A GIS buffer analysis was

[53] *Fred Klancnik and William Brose,* "Lakefront Renaissance," Civil Engineering—ASCE, *Volume 80, July 2010.*

conducted to identify parcels within one-quarter and one-half mile of the Lake Michigan coastline. Parcels within one-quarter of a mile from the coast were considered to be in a High-Risk Erosion Zone, while parcels within one-half mile were considered to be in a Low-Risk Erosion Zone. As a result, a total of 23,869 parcels in Milwaukee County were determined to be within the coastal risk erosion zones (see Table 3.22). Of those 23,869 total identified parcels, 22,950 were classified as residential, 902 as commercial, and 17 as manufacturing. The low-risk zone has an estimated value of improvements of $7.2 billion, while the high-risk zone has a value of improvements of about $3.3 billion, for a combined total value of improvements around $10.5 billion. It should be noted that the high and low risk coastal zones are solely based on distance from the Lake Michigan shoreline. Location above a bluff as well as steps already taken, such as shoreline protection structures, likely have reduced the coastal hazard risk to many of these structures.

Milwaukee County Coastal Resources Inventory Report, 2020

As noted in Chapter 2, Milwaukee County recently completed a comprehensive study identifying its coastal resources, including facilities, assets, and infrastructure, to assess their vulnerability to extreme weather. Shoreline protection structures and erosion control measures intended to reduce coastal erosion, are among the County's assets inventoried in the study including breakwaters, bulkheads, groins, and revetments (or riprap). It was found that Grant and Warnimont Parks have the least structural shoreline protection. However, while numerous groins adorn the Sheridan Park shoreline, Sheridan and Warnimont Parks suffered extensive damage in 2019. This contrast can be attributed, at least in part, to the potential for shore protection structures to adversely affect nearby coastline areas or to otherwise fail during extreme weather events or high lake levels.

Overall, the study found that approximately 13 percent of County assets were in poor condition and 22 percent were deemed highly vulnerable to further damage. The assets with the highest risk were the beaches, groins, and parking lots. The infiltration basins, revetment, and parking lots by McKinley Marina all appeared at the top for risk. The total asset valuation for Milwaukee County coastal assets was almost $3 billion, with approximately 50 percent of the value due to bluff stabilization.[54]

After review of Milwaukee County community and County-owned coastal assets, there is indication for potential coastal hazards to impact 1) flood prone residential, commercial, and other developed land uses, including the Port of Milwaukee's multi-modal transportation and distribution center, 3) roadway systems near the shoreline; 4) utilities and stormwater infrastructure located along the lakeshore, 5) County-owned

[54] *Milwaukee County, Environmental Services Unit, Milwaukee County Coastal Resources Inventory, October 7, 2020*

recreational lands and facilities along the shorelines, and 6) shoreline protection structures deemed to be in fair or poor condition.

Future Changes and Conditions

Changes in land use can have an impact on the potential for coastal erosion hazards to occur. Such changes relate to the potential future increase in development within the erosion hazard areas, particularly when not accompanied by proper shore protection measures. Enforcement of the current zoning procedures that are in place in the coastal communities of Milwaukee County call for the use of shoreline protection, bluff stabilization structural measures, and bluff setbacks for new development along portions of the Lake Michigan shoreline where urban shoreline development exists, or is envisioned, and for areas of limited development where no structural protection measures are envisioned (Chapter 5 will detail current Milwaukee County shoreline communities' coastal ordinances).

As discussed in the sections above, Lake Michigan is about 13 inches above the long-term average water level as of November 2021, causing some residents to experience significant erosion and bluff recession issues. In addition, climate change may lead to more drastic fluctuations in Lake Michigan water levels. Over the five-year period covered by this plan update, Lake Michigan water levels are expected to continue to fluctuate. Potential future fluctuations in Lake Michigan water levels could lead to continued bluff failures, particularly in areas that have no shoreline protection, where shoreline protection structures are not maintained adequately, or where shoreline protection structures are not built to sufficient specifications to protect against fluctuating water levels. Mitigation measures to protect areas along the Lake Michigan coast are described further in Chapter 5.

Changes over the 20th century and projections based on downscaled results from climate models indicate that there will likely be changes affecting coastal conditions over the 21st century. Coastal areas have experienced, and are projected to experience, increases in air temperatures, increases in precipitation, especially during fall, winter, and spring months, and increases in the frequency of heavy precipitation events. Wind strengths have increased over the Great Lakes and are expected to continue increasing into the future. In addition, wind patterns over Lake Michigan have altered. Prevailing winds during summer months have shifted from predominantly coming from the southwest during the 1980s to coming from the east after 1990. These climatic changes are expected to influence lake levels, coastal erosion, flooding, and shoreline stability, sometimes in complex ways. According to the NOAA Office for Coastal Management in 2015, "recent climate studies, along with the large spread in existing modeling results, indicate that projections of Great Lakes water levels represent evolving research and are still subject to considerable uncertainty."

For example, Lake Michigan is likely to be impacted by trends that act both to increase and to decrease water levels. Increased precipitation will increase water contributions to the Lake. At the same time, increases in temperatures will lead to increases in evaporation of water from the Lake. The projected temperature increase will also result in reduced ice cover over the winter. This affects evaporation because ice cover on the Lake acts as a cap, reducing evaporation by preventing water vapor from escaping into the air. As a result of both of these processes, evaporation from the Lake is projected to increase. It should be noted that water levels in the Lake vary widely around their average, with high-water and low-water decades occurring. This variability is expected to continue.

While the hazard impacts associated with water level variations should be similar in type to those impacts currently resulting from water level variations, there may be some increase in the magnitude of these impacts. While low water levels may allow beaches and beach ridges to build and beach-anchoring vegetation to move toward the Lake, they may also adversely impact shipping, power generation, and tourism. It should be noted that long periods of low water levels may lead to erosion of the lakebed, which may allow storm-generated waves to reach farther inland when water levels rise. While high water levels may benefit communities, businesses, and industries that depend upon Great Lakes waters for commercial shipping, hydropower, recreational boating, and tourism, higher water levels with increased storm frequency and intensity could increase shoreline and bank erosion. This could increase damages to lakefront property and reduce the area of beaches.

Several other elements of climate change may also act to intensify shoreline erosional processes. Increases in wind strength over the Lake and changes in prevailing wind direction would be likely to lead to greater offshore wave development. This would produce higher waves along the coast. Changes in several elements of climate may affect the stability of bluffs along the lakeshore. The amount of water contained in bluff soils is an important factor determining their stability. Friction between soil particles hold them in place. As water fills the spaces between these particles the friction between soil particles decreases, causing the soil to become more fluid and less stable. Higher lake levels and increases in 1) precipitation, 2) the frequency of heavy storms, and 3) the number of freeze-thaw cycles may all contribute to shoreline bluffs becoming less stable and more susceptible to slumping. Prolonged dry periods and droughts may also contribute to reduced stability of coastal bluffs. As bluff soils dry out, cracks in the soil can form, weakening the surface soil. During long-term droughts, these cracks can develop into deep fractures. Such fractures can allow surface water to penetrate deep into bluff soils. If heavy rainfall events occur following a drought, they may cause rapid saturation of dry, fractured bluff soils which could cause a major bluff slope failure.

Multi-Jurisdictional Risk Management

Shoreline erosion, bluff failure, and coastal flooding, when combined, present a moderate risk in Milwaukee County. Similarly, the Milwaukee County Pre-Disaster Mitigation Plan identified that several coastal communities are at risk from coastal erosion, but coastal erosion was not considered a primary concern relative to the potential damages to population and infrastructure within Milwaukee County.[55] As discussed above, coastal hazard risks are present in all nine local units of government in Milwaukee County along Lake Michigan. Those coastal risk communities include the Cities of Cudahy, Milwaukee, Oak Creek, South Milwaukee, and St. Francis and the Villages of Bayside, Fox Point, Shorewood, and Whitefish Bay.

[55] *Milwaukee County Office of Emergency Management,* Milwaukee County Hazard Mitigation Plan, *2016*

SEWRPC Community Assistance Planning Report No. 345

MILWAUKEE COUNTY HAZARD MITIGATION PLAN UPDATE

Chapter 3

ANALYSIS OF HAZARD CONDITIONS

TABLES

Table 3.1
Perceived Risks of Hazards as Determined by the Milwaukee County Hazard Vulnerability and Risk Assessment Survey: 2022

Hazard	Probability[a] Likelihood this will occur	Human Impact[a] Possibility of death or injury	Property Impact[a] Physical losses and damages	Business & Agency Impact[a] Interruption of services	Preparedness[a] Mitigation or pre-planning	Total Risk[b] Relative threat	Rank[c]
Tornado	2.133	2.667	2.733	2.533	1.933	12.798	1
Straight-Lined Winds	2.800	2.333	2.333	1.933	2.133	12.505	2
Ice Storm	2.667	2.400	2.000	2.267	2.133	12.092	3
Blizzard	2.733	2.733	1.667	2.267	2.267	12.025	4
Stormwater Flooding	2.667	2.133	2.067	1.733	1.733	11.201	5
Extreme Cold	2.933	2.467	1.533	1.667	2.200	10.169	6
Heavy Snowstorm	3.000	2.133	1.533	2.067	2.400	9.999	7
Extreme Heat	2.667	2.333	1.533	1.667	2.067	9.244	8
Hail	2.733	1.867	2.000	1.400	2.067	8.746	9
Thunderstorm	2.933	1.867	1.800	1.467	2.400	8.019	10
Lightning	2.733	2.000	1.800	1.467	2.400	7.836	11
Riverine Flooding	2.067	1.333	1.733	1.400	1.333	6.476	12
Fog	2.600	1.667	1.333	1.000	1.800	5.720	13
Lake Michigan Bluff Failure	1.733	1.467	1.533	1.000	1.067	5.083	14
Drought	2.067	1.667	1.067	1.000	1.467	4.686	15
Lake Michigan Erosion	1.800	1.200	1.400	0.933	1.133	4.320	16
Earthquake	0.733	1.200	1.200	1.200	0.800	2.052	17
Land Slide	0.867	1.133	1.133	0.800	0.867	1.907	18
Wildfire	1.000	0.933	1.000	0.933	1.000	1.866	19
Land Subsidence	1.000	1.000	0.933	0.800	1.000	1.733	20
Coastal Flooding	0.667	0.933	1.133	0.733	0.667	1.422	21
Dam Failure	0.600	0.800	0.733	0.800	0.733	0.960	22
Inland Lake Flooding	0.600	0.733	0.933	0.533	0.800	0.839	23
Dust Storm	0.600	0.600	0.533	0.533	0.600	0.640	24

Note: Value is based on the weighted average of the number of votes received for each score of No Available information (NA), low (1), moderate (2), or high (3).

[a] *Severity = Sum of Impact – Preparedness*

[b] *Total Risk = Probability x Severity*

[c] *Perceived threat/rank is based on Total Risk score.*

Source: Southeastern Wisconsin Regional Planning Commission

Table 3.2
Summary of Hazards to be Considered in the Milwaukee County Hazard Mitigation Plan

Hazard	Risk of Occurrence[a]	Damage to Property[a]	Threat to Life Safety[a]	Duration of Impact[b]	Size of Area Affected[c]
Flooding and Stormwater Drainage Problems	Medium	High	High	Moderate	Large
Thunderstorm, High Winds, Hail, Lightning	High	Medium	High	Long	Large
Tornadoes	Medium	High	High	Short	Small
Winter Storms	High	Medium	High	Medium	Large
Temperature Extremes	High	Medium	High	Long	Large
Drought	Low	Low	Low	Long	Large
Coastal Hazards	Medium	Medium	Medium	Short	Medium

Note: Some of the natural hazards listed in this table represent combinations of hazards listed in Table 3.1. For example, while specific risks associated with thunderstorms, such as hail and lightning are listed separately in Table 3.1, here they are combined into one category.

[a] *High, medium, or low*

[b] *Long, moderate, or short*

[c] *Large, medium, or small*

Source: Milwaukee County LPT and SEWRPC

#270975 –Milwaukee Co HMP Table 3.3 Federally Declared Disasters Emergencies
500-1151
MLP/MAS/nkk
01/12/2024

Table 3.3
Summary of Estimated Disaster Damages and Assistance in Milwaukee County for Federally Declared Disaster Emergencies: 1969-2022

Date of Disaster and Event(s)	Event	Fatalities	Estimated Damages ($)[a]
1969 – July (DR-264)	Severe Storms, Flooding	--	--
1973 – April (DR-376)	Flooding	0	--
1976 – March (DR-496)	Ice Storm	--	--
1979 – January (EM-3069)	Snow Emergency	0	--
1986 – August (DR-770)	Flooding	2	36,387,696
1986 – September (DR-775)	Flooding and Wind Damage	0	10,852,489
1993 – April-May (DR-994)	Flooding, Severe Storms	0	--
1996 – August (DR-1131)	Flooding	0	--
1997 – July-June (DR-1180)	Flooding and High Winds	0	139,645,725
1998 – August 12 (DR-1238)	Flooding, Severe Storms	0	19,470,567
2000 – June (DR-1332)	Flooding, Severe Storms	0	11,331,235
2001 – January (EM-3163)	Snow Emergency	0	--
2004 – May (DR-1526)	Severe Storms, Tornadoes, and Flooding	2	1,554,612
2008 – February (EM-3285)	Severe Storms, Tornadoes, and Flooding	0	--
2008 – June (DR-1768)	Severe Winter Storm and Snowstorm	0	107,306,625
2010 – July (DR-1933)	Severe Storms, Flooding	1	46,745,603
2011 – January-February (DR-1966)	Flooding	0	13,882
2020 – January (DR-4477-WI)	Severe Winter Storm and Flooding	0	10,036,467
	Total – 18 Disaster Events	5	383,344,901

[a] *Dollar values are adjusted to year 2022 by using the annual Consumer Price Index (CPI) values from the U.S. Department of Labor, Bureau of Labor Statistics.*

Source: Milwaukee County Pre-Disaster Mitigation Plan, National Climate Data Center, Wisconsin Emergency Management, Federal Emergency Management Agency, and SEWRPC

Table 3.4
Natural Hazard Events Recorded in Milwaukee County: 2000-2022

Event	Number of Events	Average Number per Year	Deaths	Injuries	Property Damages ($)[a]	Crop Damages ($)[a]
Dust Storms	0	0.00	0	0	0	0
Wildfires/Forest Fires	0	0.00	0	0	0	0
Drought	14	0.61	0	0	0	322,369
Tornadoes/Waterspouts	18	0.78	0	176	22,458,481	9,310
Lightning	20	0.87	0	2	1,964,126	0
Flood	45	1.96	4	0	170,829,985	155,615
Fog	61	2.65	0	0	0	0
Temperature Extremes	83	3.61	45	69	29,169	2,043
Hail	111	4.83	0	0	11,481,820	3,516
Winter Weather	187	8.13	0	0	144,418	22,548
Thunderstorms/High Winds	208	9.04	1	2	10,752,089	771,986
Total	747	2.95	50	249	217,660,088	1,287,387

[a] *Dollar values were adjusted to year 2022 by using the average Consumer Price Index (CPI) values from the U.S. Department of Labor, Bureau of Labor Statistics.*

Source: The National Climatic Data Center (NCDC), National Oceanic and Atmospheric Administration (NOAA), and the National Environmental Satellite, Data and Information Service (NESDIS), and the U.S. Department of Agriculture Risk Management Agency

#270967 – CAPR-345 Table 3.5 Severe Weather History
500-1151
MLP/MAS/nkk
01/24/2024

Table 3.5
Milwaukee County Severe Weather Warning History: 2000-2022

Year	Flash Flood Warning	Flood Warning	Severe Thunderstorm		Tornado	
			Watch	Warning	Watch	Warning
2000	4	0	14	0	0	2
2001	0	0	4	0	0	1
2002	1	0	5	0	0	0
2003	0	0	4	0	0	0
2004	0	0	9	0	0	0
2005	1	0	9	0	0	0
2006	3	0	16	17	2	0
2007	2	2	9	5	3	0
2008	6	20	14	9	6	3
2009	3	8	3	7	1	2
2010	5	7	8	6	7	3
2011	1	1	11	12	1	0
2012	0	0	12	7	0	0
2013	1	5	7	5	2	2
2014	3	1	10	8	1	0
2015	0	2	9	5	2	0
2016	2	0	2	8	0	0
2017	0	0	6	8	2	0
2018	1	5	8	4	1	0
2019	2	4	3	7	0	0
2020	2	8	0	0	2	0
2021	1	1	8	4	0	1
2022	2	3	10	5	1	1
Total	40	67	181	117	31	15

Source: Iowa State University, Iowa Environmental Mesonet

Table 3.6
WDNR Dam Inventory for Milwaukee County: 2023

Map ID	Official Name	Owner Type	Water Feature	Size	Hazard Potential	Structure Type
1	Milwaukee General Hospital 3	County	Honey Creek	Small	Low	Earth
2	Milwaukee General Hospital 2	County	Honey Creek	Small	Low	Concrete, Earth
3	Milwaukee General Hospital 1	County	Honey Creek	Small	Low	Earth
4	Kurtze Lake	Private	Kurtze Lake Outlet	Small	Low	Gravity, Earth
5	Tuckaway Country Club	Private	Legend Creek	Small	Low	Earth
6	Kletzsch Park	County	Milwaukee River	Large	Low	Gravity, Concrete, Masonry
7	South Milwaukee Mill	County	Oak Creek	Small	Low	Gravity, Earth, Other
8	Milwaukee County Grounds	Sanitary District	Underwood Creek	Large	High	Earth, Concrete
9	Northridge Lakes Residential Development	Private	Unnamed	Large	Low	Concrete, Gravity, Other

Source: Wisconsin Department of Natural Resources

#270717- Table 3.7 Recent Flood Events in Milwaukee County
500-1151
MLP/MAS/nkk
01/16/2024

Table 3.7
Recent Flood Events in Milwaukee County: 2011-2022

Date	Location	Type[a]	Deaths	Injuries	Property Damages ($)[a]	Crop Damages ($)[a]
June 21, 2011	Franklin	Flash Flood	0	0	656	--
October 5, 2013	St Martins	Flash Flood	0	0	0	--
May 12, 2014	Butler	Flash Flood	0	0	0	--
August 30, 2016	West Milwaukee	Flash Flood	0	0	61,485	--
September 7, 2016	West Allis	Flash Flood	0	0	12,294	--
February 19, 2018	Granville	Flood	0	0	1,139	--
August 26, 2018	Milwaukee Hoan Bridge	Flash Flood	0	0	29,365	--
May 28, 2019	Milwaukee Hoan Bridge	Flood	0	0	11,414	--
September 12, 2019	Franklin	Flash Flood	0	0	28,899	--
September 13, 2019	Franklin	Flood	0	0	0	--
January 11, 2020	Milwaukee Shoreline	Lakeshore Flood	0	0	12,099,213	--
May 17, 2020	Fox Pt	Flood	0	0	34,201	--
May 18, 2020	Franklin	Flood	0	0	11,400	--
August 2, 2020	Hales Corners	Flash Flood	0	0	56,974	--
August 8, 2021	Fox Point	Flash Flood	0	0	1,083	--
October 24, 2021	Milwaukee Shoreline	Lakeshore Flood	0	0	0	--
June 13, 2022	West Allis	Flood	3	0	0	--
July 5, 2022	Greenfield	Flash Flood	0	0	10,000	--
July 23, 2022	Brown Deer	Flash Flood	0	0	5,000	--
September 11, 2022	Franklin	Flood	0	0	15,000	--
		Total – 20 Events	3	0	12,378,123	--

Note: Dollar Values were adjusted to year 2022 by the average annual Consumer Price Index (CPI) values from the U.S. Department of Labor, Bureau of Labor Statistics.

[a] *National Weather Service determines the type of event bason on report narratives from local officials.*

Source: The National Climatic Data Center (NCDC), National Oceanic and Atmospheric Administration (NOAA)

Table 3.8
Estimated Flood Damages for a 1-Percent-Annual-Probability Flood in Milwaukee County by Watershed: 2023

Watershed	Structures	Flood Damages[a]		
		Direct ($)	Indirect ($)	Total ($)
Kinnickinnic River	624	50,069,660	16,159,260	66,228,920
Lake Michigan Drainage Basin	28	853,790	128,070	981,860
Menomonee River	86	10,872,120	4,096,910	14,969,030
Milwaukee River	541	45,870,310	12,380,720	58,251,030
Oak Creek	10	4,234,470	1,681,310	5,915,780
Root River	194	14,506,190	5,103,920	19,610,110
Total	1,483	126,406,540	39,550,190	165,956,730

Note: Estimated damages are based on assessed improvement values in 2022.

[a] *Dollar values were adjusted to year 2022 by using the average annual Consumer Price Index (CPI) values from the U.S. Department of Labor, Bureau of Labor Statistics.*

Source: Federal Emergency Management Agency, Wisconsin Department of Natural Resources, Milwaukee County, Milwaukee Metropolitan Sewerage District, and SEWRPC

#271782 – CAPR-345 Table 3.9 Number of Structures in the 1-Percent-Annual-Probability Floodplain in Milwaukee County by Structure Type: 2023
500-1151
JMM/LKH/nkk
1/30/2024

Table 3.9
Number of Structures in the 1-Percent-Annual-Probability Floodplain in Milwaukee County by Structure Type: 2023

	Number of Flooded Structures								Total Number of Flooded Structures
Civil Division	Apartment	Condominium	Residential	Commercial	Critical Facility	Mobile Home	Parks	Utility	
Cities									
Cudahy	0	0	0	0	0	0	0	0	0
Franklin	1	0	8	2	0	16[d]	0	0	27
Glendale	0	0	350	3	0	0	0	0	353
Greenfield	0	4	11	5	0	0	0	0	20
Milwaukee	12	7	538	123	3[b]	0	1	1	685
Oak Creek	1	0	11	4	0	0	0	0	16
St. Francis	0	0	0	0	0	0	0	0	0
South Milwaukee	0	0	2	0	0	0	0	0	2
Wauwatosa	0	0	14	24	0	0	0	0	38
West Allis	8	0	48	16	0	0	0	0	72
Villages									
Bayside[a]	0	0	60	0	0	0	0	0	60
Brown Deer	0	0	3	10	0	0	0	0	13
Fox Point	0	0	109	0	0	0	0	0	109
Greendale	0	0	25	7	1[c]	0	2	0	35
Hales Corners	0	2	36	3	0	0	0	0	41
River Hills	0	0	10	2	0	0	0	0	12
Shorewood	0	0	0	0	0	0	0	0	0
West Milwaukee	0	0	0	0	0	0	0	0	0
Whitefish Bay	0	0	0	0	0	0	0	0	0
Total	22	13	1,225	199	4	16	3	1	1,483

[a] *Milwaukee County portion only.*

[b] *The three critical facilities in the City of Milwaukee are St. Luke's Medical Center; Adult Day Services of Wisconsin, LLC; and the Lake Express High-Speed Ferry.*

[c] *The critical facility in the Village of Greendale is College Park Elementary School.*

[d] *The mobile (manufactured) home community in the City of Franklin is the Franklin Mobile Estates property.*

Source: Milwaukee Metropolitan Sewerage District (MMSD) and SEWRPC

#271521 – CAPR-345 Table 3.10 Repetitive Loss Properties
500-1151
MAS/nkk
1/7/2023

Table 3.10
Repetitive or Severe Repetitive Loss Properties in Milwaukee County: 2023

Civil Division	Number of Properties	Property Types Listed
City of Glendale	13	Single Family
City of Milwaukee	231	Single Family, Multi-Residential, and Other
City of Oak Creek	2	Single Family
City of Wauwatosa	4	Single Family
City of West Allis	2	Single Family
Village of Bayside	2	Single Family
Village of Brown Deer	8	Single Family
Village of River Hills	5	Single Family
Total	267	--

Source: SEWRPC

#269563 – CAPR-345 Table 3.11
500-1151
MAS/nkk
10/23/2023

Table 3.11
Recent Severe Weather Events in Milwaukee County: 2011-2022

Date	Event Type	Magnitude	Reported Damages			
			Deaths	Injuries	Property Damages ($)	Crop Damages ($)
January 1, 2011	Strong Wind	43 kts.	0	0	5,391	--
February 18, 2011	Strong Wind	39 kts.	0	0	2,564	--
April 10, 2011	Thunderstorm Wind	61 kts.	0	0	--	--
April 10, 2011	Thunderstorm Wind	57 kts.	0	0	--	--
April 15, 2011	Strong Wind	39 kts.	0	0	6,427	--
May 15, 2011	Strong Wind	41 kts.	0	0	6,468	5,479
May 22, 2011	Thunderstorm Wind	53 kts.	0	0	--	5,479
June 8, 2011	Hail	1 in.	0	0	--	--
June 8, 2011	Thunderstorm Wind	57 kts.	0	0	--	--
June 8, 2011	Thunderstorm Wind	56 kts.	0	0	--	--
June 30, 2011	Thunderstorm Wind	55 kts.	0	0	52,509	--
September 3, 2011	Thunderstorm Wind	56 kts.	0	0	--	--
September 29, 2011	Strong Wind	39 kts.	0	0	2,616	--
October 19, 2011	High Wind	50 kts.	0	0	19,622	--
November 13, 2011	Strong Wind	39 kts.	0	0	1,316	--
November 29, 2011	Strong Wind	49 kts.	0	0	1,316	--
January 1, 2012	Strong Wind	39 kts.	0	0	3,721	--
March 10, 2012	Strong Wind	29 kts.	0	0	2,507	--
April 15, 2012	Strong Wind	40 kts.	0	0	1,257	--
April 16, 2012	Strong Wind	26 kts.	0	0	1,257	--
April 16, 2012	Strong Wind	43 kts.	0	0	1,257	--
April 16, 2012	Strong Wind	39 kts.	0	0	1,256	--
May 1, 2012	Thunderstorm Wind	57 kts.	0	0	2,544	3,178
June 18, 2012	Strong Wind	39 kts.	0	0	19,369	--
September 17, 2012	Hail	0.75 in.	0	0	--	--
September 17, 2012	Hail	1.25 in.	0	0	--	--
September 17, 2012	Hail	0.75 in.	0	0	--	--
September 17, 2012	Thunderstorm Wind	52 kts.	0	0	2,565	--
November 11, 2012	Strong Wind	43 kts.	0	0	6,466	--
January 18, 2013	Strong Wind	43 kts.	0	0	9,767	--
January 19, 2013	Strong Wind	42 kts.	0	0	6,104	--

Table continued on next page.

Table 3.11 (Continued)

Date	Event Type	Magnitude	Reported Damages			
			Deaths	Injuries	Property Damages ($)	Crop Damages ($)
April 11, 2013	Strong Wind	42 kts.	0	0	14,920	3,102
May 14, 2013	Thunderstorm Wind	61 kts.	0	0	62,739	2,740
June 27, 2013	Hail	0.75 in.	0	0	--	--
November 17, 2013	Hail	1 in.	0	0	--	--
November 17, 2013	Hail	1.5 in.	0	0	--	--
November 17, 2013	Hail	1 in.	0	0	--	--
November 17, 2013	Heavy Rain	--	0	0	--	--
April 12, 2014	Hail	1 in.	0	0	--	--
April 12, 2014	Hail	0.75 in.	0	0	--	--
April 12, 2014	Hail	0.75 in.	0	0	--	--
May 7, 2014	Hail	0.88 in.	0	0	--	--
May 12, 2014	Hail	0.75 in.	0	0	--	--
May 12, 2014	Hail	2 in.	0	0	--	--
May 12, 2014	Hail	0.75 in.	0	0	--	--
May 12, 2014	Thunderstorm Wind	52 kts.	0	0	--	--
June 17, 2014	Hail	1.25 in.	0	0	--	--
June 17, 2014	Hail	0.88 in.	0	0	--	--
June 17, 2014	Hail	1 in.	0	0	--	--
June 17, 2014	Thunderstorm Wind	65 kts.	0	0	37,296	6,763
June 18, 2014	Hail	1 in.	0	0	--	--
June 18, 2014	Hail	0.88 in.	0	0	--	--
June 28, 2014	Thunderstorm Wind	55 kts.	0	0	2,486	3,243
June 30, 2014	Thunderstorm Wind	53 kts.	0	0	6,216	3,243
June 30, 2014	Thunderstorm Wind	51 kts.	0	0	8,702	3,243
August 1, 2014	Hail	0.75 in.	0	0	--	--
August 1, 2014	Hail	1 in.	0	0	--	--
August 1, 2014	Hail	1 in.	0	0	--	--
June 22, 2015	Thunderstorm Wind	52 kts.	0	0	1,242	202
June 22, 2015	Thunderstorm Wind	52 kts.	0	0	1,242	202
June 22, 2015	Thunderstorm Wind	50 kts.	0	0	621	202
July 18, 2015	Thunderstorm Wind	55 kts.	0	0	1,241	--
August 2, 2015	Hail	1 in.	0	0	--	--
August 2, 2015	Hail	1 in.	0	0	--	--
August 2, 2015	Hail	1.25 in.	0	0	--	--
August 2, 2015	Hail	1 in.	0	0	--	--
August 2, 2015	Hail	1 in.	0	0	--	--
August 2, 2015	Hail	1.25 in.	0	0	--	--

Table continued on next page.

Table 3.11 (Continued)

Date	Event Type	Magnitude	Reported Damages			
			Deaths	Injuries	Property Damages ($)	Crop Damages ($)
August 2, 2015	Hail	1 in.	0	0	--	--
August 2, 2015	Hail	3 in.	0	0	--	--
August 10, 2015	Hail	1 in.	0	0	--	--
August 14, 2015	Hail	1 in.	0	0	--	--
December 23, 2015	Strong Wind	50 kts.	0	0	2,510	--
February 19, 2016	High Wind	55 kts.	0	0	119,655	--
March 16, 2016	High Wind	50 kts.	0	0	36,220	--
April 25, 2016	Hail	0.75 in	0	0	--	--
April 25, 2016	Hail	0.75 in	0	0	--	--
April 25, 2016	Hail	0.75 in	0	0	--	--
April 25, 2016	Hail	0.75 in	0	0	--	--
April 25, 2016	Hail	1 in.	0	0	--	--
June 5, 2016	Thunderstorm Wind	50 kts.	0	0	1,229	--
August 3, 2016	Thunderstorm Wind	50 kts.	0	0	6,148	--
August 3, 2016	Thunderstorm Wind	50 kts.	0	0	6,148	--
September 7, 2016	Thunderstorm Wind	50 kts.	0	0	3,688	--
September 7, 2016	Thunderstorm Wind	52 kts.	0	0	1,229	--
September 21, 2016	Hail	1 in.	0	0	--	--
March 8, 2017	High Wind	51 kts.	0	0	47,170	--
April 10, 2017	Hail	0.75 in.	0	0	--	--
April 10, 2017	Hail	0.75 in.	0	0	--	--
April 10, 2017	Hail	0.75 in.	0	0	--	--
April 20, 2017	Thunderstorm Wind	52 kts.	0	0	1,182	4,240
April 20, 2017	Thunderstorm Wind	52 kts.	0	0	5,912	4,240
May 15, 2017	Thunderstorm Wind	50 kts.	0	0	2,389	60,079
July 12, 2017	Heavy Rain	--	0	0	--	1,094
July 15, 2017	Hail	0.75 in.	0	0	--	--
July 15, 2017	Thunderstorm Wind	56 kts.	0	0	12,103	1,094
August 3, 2017	Hail	1 in.	0	0	--	--
August 3, 2017	Hail	0.88	0	0	--	--
December 4, 2017	High Wind	52 kts.	0	0	8,427	--
March 31, 2018	Strong Wind	39 kts.	0	0	1,152	--
May 9, 2018	Hail	0.75 in.	0	0	--	--
May 14, 2018	Lightning	--	0	0	34,854	--
June 18, 2018	Heavy Rain	--	0	0	--	--
June 18, 2018	Lightning	--	0	0	3,528	--
July 1, 2018	Thunderstorm Wind	61 kts.	0	0	5,878	--

Table continued on next page.

Table 3.11 (Continued)

Date	Event Type	Magnitude	Reported Damages			
			Deaths	Injuries	Property Damages ($)	Crop Damages ($)
July 1, 2018	Thunderstorm Wind	50 kts.	0	0	588	--
July 1, 2018	Thunderstorm Wind	50 kts.	0	0	2,351	--
August 17, 2018	Heavy Rain	--	0	0	70,476	1,197
September 4, 2018	Lightning		0	0	476,183	--
September 4, 2018	Thunderstorm Wind	50 kts.	0	0	11,758	833
September 4, 2018	Thunderstorm Wind	50 kts.	0	0	2,352	833
September 25, 2018	Lightning	--	0	0	11,758	--
October 20, 2018	Strong Wind	47 kts.	0	0	1,178	98
February 24, 2019	High Wind	55 kts.	0	0	2,245	--
May 19, 2019	Thunderstorm Wind	50 kts.	0	0	--	104,801
May 19, 2019	Thunderstorm Wind	50 kts.	0	0	--	104,801
June 27, 2019	Thunderstorm Wind	50 kts.	0	0	1,157	15,658
June 27, 2019	Thunderstorm Wind	50 kts.	0	0	2,314	15,658
June 27, 2019	Thunderstorm Wind	50 kts.	0	0	1,157	15,658
July 2, 2019	Thunderstorm Wind	50 kts.	0	0	577	--
July 2, 2019	Thunderstorm Wind	50 kts.	0	0	3,464	--
September 11, 2019	Thunderstorm Wind	61 kts.	0	0	8,092	--
October 1, 2019	Heavy Rain	--	0	0	--	--
October 21, 2019	Strong Wind	45 kts.	0	0	5,790	--
November 27, 2019	Strong Wind	46 kts.	0	0	11,575	4,470
April 7, 2020	Hail	1 in.	0	0	--	--
April 7, 2020	Hail	1 in.	0	0	--	--
April 20, 2020	Thunderstorm Wind	51 kts.	0	0	--	--
April 20, 2020	Thunderstorm Wind	60 kts.	0	0	--	--
June 20, 2020	Thunderstorm Wind	50 kts.	0	0	3,448	8,887
June 20, 2020	Thunderstorm Wind	50 kts.	0	0	3,448	8,887
June 20, 2020	Thunderstorm Wind	50 kts.	0	0	2,299	8,887
July 7, 2020	Heavy Rain	--	0	0	--	--
July 18, 2020	Thunderstorm Wind	56 kts.	0	0	5,717	--
August 10, 2020	Heavy Rain	--	0	0	--	--
November 10, 2020	Thunderstorm Wind	69 kts.	0	0	85,803	--
August 10, 2021	Thunderstorm Wind	52 kts.	0	0	5,697	5,697
August 24, 2021	Thunderstorm Wind	50 kts.	0	0	5,697	--
August 28, 2021	Heavy Rain	--	0	0	--	--
September 12, 2021	Hail	0.75 in.	0	0	--	--
September 13, 2021	Hail	0.88 in.	0	0	--	--
December 15, 2021	High Wind	55 kts.	0	0	10,645	--

Table continued on next page.

Table 3.11 (Continued)

Date	Event Type	Magnitude	Reported Damages			
			Deaths	Injuries	Property Damages ($)	Crop Damages ($)
April 14, 2022	Strong Wind	49 kts.	0	0	7,000	276
June 10, 2022	Hail	0.75 in.	0	0	--	--
June 10, 2022	Hail	0.75 in.	0	0	--	--
June 13, 2022	Hail	1.25 in.	0	0	--	--
June 13, 2022	Hail	1.25 in.	0	0	--	--
June 13, 2022	Thunderstorm Wind	50 kts.	0	0	4,000	--
June 13, 2022	Thunderstorm Wind	56 kts.	0	0	10,000	--
June 13, 2022	Thunderstorm Wind	56 kts.	0	0	12,000	--
June 13, 2022	Thunderstorm Wind	51 kts.	0	0	--	--
July 23, 2022	Hail	0.75 in.	0	0	--	--
July 23, 2022	Thunderstorm Wind	50 kts.	0	0	500	--
September 25, 2022	Thunderstorm Wind	50 kts.	0	0	8,000	--
September 25, 2022	Thunderstorm Wind	52 kts.	0	0	--	--
September 25, 2022	Thunderstorm Wind	52 kts.	0	0	8,000	--
September 25, 2022	Thunderstorm Wind	50 kts.	0	0	7,000	--
September 25, 2022	Thunderstorm Wind	50 kts.	0	0	1,000	--
October 12, 2022	Thunderstorm Wind	64 kts.	0	0	7,000	--
October 12, 2022	Thunderstorm Wind	50 kts.	0	0	8,000	--
October 12, 2022	Thunderstorm Wind	51 kts.	0	0	--	--
November 4, 2022	Hail	1 in.	0	0	--	--
November 4, 2022	Hail	1 in.	0	0	--	--
November 5, 2022	High Wind	53 kts.	0	0	10,000	--
November 5, 2022	Thunderstorm Wind	50 kts.	0	0	1,000	--
November 5, 2022	Thunderstorm Wind	50 kts.	0	0	--	--
November 5, 2022	Thunderstorm Wind	50 kts.	0	0	3,000	--
		Total	0	0	1,414,699	403,370

[a] Deaths, injuries, and property damages reported were based upon a geographic area impacted by the hazard event, which affected Milwaukee County and, in some cases, a larger area of impact than the County itself, generally within the southeast regional area of Wisconsin.

[b] Dollar values were adjusted to year 2022 by using the average annual Consumer Price Index (CPI) values from the U.S. Department of Labor, Bureau of Labor Statistics.

Source: National Centers for Environmental Information (NCEI), National Oceanic and Atmospheric Administration (NOAA), and the National Environmental Satellite, Data and Information Service (NESDIS), and the U.S. Department of Agriculture Risk Management Agency

Table 3.12
Enhanced Fujita Scale Characteristics

F-Scale	Wind Speed (miles per hour)[a]	Character of Damage	Relative Frequency (percent)
FO (weak)	65-85	Light	53
F1 (weak)	86-110	Moderate	32
F2 (strong)	111-135	Considerable	11
F3 (strong)	136-165	Severe	3
F4 (violent)	166-200	Devastating	1
F5 (violent)	>200	Incredible (rare)	<1

[a] *Equivalent wind speeds associated with the Enhanced Fujita Scale represent a three-second gust of wind.*

Source: National Oceanic and Atmospheric Administration

#271091 – CAPR-345 Table 3.13
500-1151
MLP/MAS/mid
01/16/2024

Table 3.13
Tornado Events in Milwaukee County: 1958-2022

Number on Map 3.3	Date	Location	Magnitude (Fujita)	Deaths	Injuries	Property Damage ($)	Crop Damage ($)
1	August 7, 1958	City of Milwaukee	F2	0	4	256,745	--
2	September 26, 1959	Milwaukee County	F2	0	3	2,532,398	--
3	July 22, 1962	City of Milwaukee	F2	0	0	244,882	--
4	October 4, 1962	Milwaukee County	F1	0	0	244,076	--
5	August 22, 1964	Milwaukee County	F1	0	0	2,393,524	--
6	September 3, 1964	City of Milwaukee	F2	0	0	2,385,828	--
7	August 11, 1969	Milwaukee County	F1	0	153	2,005,385	--
8	August 25, 1975	City of Milwaukee	F1	0	0	13,665	--
9	August 25, 1975	City of Milwaukee	F2	0	0	136,647	--
10	April 2, 1977	Milwaukee County	F2	0	0	123,665	--
11	August 4, 1977	City of Milwaukee	F1	0	0	--	--
12	August 4, 1980	City of Milwaukee	F2	0	0	890,747	--
13	July 20, 1981	City of Milwaukee	F1	0	0	81,004	--
14	August 17, 1985	City of Milwaukee	F1	0	0	--	--
15	May 24, 1989	City of Milwaukee	F0	0	0	599,348	3,565
16	March 8, 2000	Milwaukee County	F1	0	16	7,922,677	--
17	July 2, 2000	City of Milwaukee	F1	0	0	2,627,890	20,715
18	October 12, 2022	City of West Allis	EF0	0	0	--	--
			Total	0	176	22,458,481	24,280

Note: Dollar Values were adjusted to year 2022 by the average annual Consumer Price Index (CPI) values from the U.S. Department of Labor, Bureau of Labor Statistics. N/A indicates data not available. Also, "--" indicates data was not available.

Source: National Centers for Environmental Information and U.S. Department of Agriculture Risk Management Agency

#269576 – CAPR-345 Table 3.14
500-1151
MAS/mid
10/23/2023

Table 3.14
Recent Winter Events in Milwaukee County: 2011-2022

Date	Type[a]	Deaths	Injuries	Property Damages ($)	Crop Damages ($)
January 17, 2011	Winter Weather	0	0	--	--
February 1, 2011	Blizzard	0	0	12,820	--
February 6, 2011	Winter Weather	0	0	--	--
February 20, 2011	Winter Storm	0	0	--	--
February 21, 2011	Winter Weather	0	0	--	--
March 9, 2011	Winter Weather	0	0	--	--
December 29, 2011	Winter Weather	0	0	--	--
January 12, 2012	Winter Weather	0	0	--	--
January 17, 2012	Winter Weather	0	0	--	--
February 23, 2012	Winter Weather	0	0	--	--
March 2, 2012	Winter Storm	0	0	--	--
December 20, 2012	Winter Storm	0	0	--	--
January 27, 2013	Winter Weather	0	0	--	--
January 30, 2013	Winter Weather	0	0	--	--
February 7, 2013	Winter Storm	0	0	--	--
February 22, 2013	Winter Weather	0	0	--	--
February 26, 2013	Winter Storm	0	0	--	--
March 5, 2013	Winter Weather	0	0	--	--
March 18, 2013	Winter Weather	0	0	--	--
November 25, 2013	Winter Weather	0	0	--	--
December 8, 2013	Winter Weather	0	0	--	--
December 19, 2013	Winter Weather	0	0	--	--
December 22, 2013	Winter Storm	0	0	--	--
December 31, 2013	Winter Weather	0	0	--	--
January 1, 2014	Winter Weather	0	0	--	--
January 10, 2014	Winter Weather	0	0	--	--
January 14, 2014	Winter Weather	0	0	--	--
January 24, 2014	Winter Weather	0	0	--	--
January 26, 2014	Winter Weather	0	0	--	--
January 26, 2014	Winter Weather	0	0	--	--
February 4, 2014	Winter Weather	0	0	--	1,753
February 13, 2014	Winter Weather	0	0	--	1,753
February 17, 2014	Winter Storm	0	0	--	1,753
March 4, 2014	Winter Weather	0	0	--	--
April 14, 2014	Winter Weather	0	0	--	--
November 22, 2014	Winter Weather	0	0	--	--
November 28, 2014	Winter Weather	0	0	--	--
December 18, 2014	Winter Weather	0	0	--	--
January 8, 2015	Winter Weather	0	0	--	--
February 1, 2015	Winter Storm	0	0	--	495
February 25, 2015	Winter Weather	0	0	--	495
March 3, 2015	Winter Weather	0	0	--	--
November 20, 2015	Winter Storm	0	0	--	--
December 28, 2015	Winter Storm	0	0	6,274	--
February 8, 2016	Winter Weather	0	0	--	--
February 29, 2016	Winter Weather	0	0	--	--
March 1, 2016	Winter Weather	0	0	--	--
March 24, 2016	Winter Weather	0	0	--	--

Table continued on next page.

Table 3.14 (Continued)

Date	Type[a]	Deaths	Injuries	Property Damages ($)	Crop Damages ($)
April 2, 2016	Winter Weather	0	0	--	--
April 8, 2016	Winter Weather	0	0	--	--
December 4, 2016	Winter Weather	0	0	--	--
December 10, 2016	Winter Storm	0	0	--	--
December 16, 2016	Winter Storm	0	0	--	--
December 19, 2016	Winter Weather	0	0	--	--
January 10, 2017	Winter Weather	0	0	--	--
January 11, 2017	Winter Weather	0	0	--	--
January 16, 2017	Winter Weather	0	0	--	--
February 24, 2017	Winter Weather	0	0	--	--
March 12, 2017	Lake-Effect Snow	0	0	--	--
January 12, 2018	Winter Weather	0	0	--	--
January 14, 2018	Winter Weather	0	0	--	--
January 22, 2018	Winter Weather	0	0	--	--
February 3, 2018	Winter Weather	0	0	--	--
February 5, 2018	Winter Weather	0	0	--	--
February 8, 2018	Winter Storm	0	0	--	--
February 11, 2018	Winter Weather	0	0	--	--
March 5, 2018	Winter Weather	0	0	--	--
April 3, 2018	Winter Weather	0	0	--	--
April 14, 2018	Winter Weather	0	0	--	--
April 18, 2018	Winter Weather	0	0	--	--
November 25, 2018	Winter Weather	0	0	--	2,309
December 28, 2018	Winter Weather	0	0	--	--
December 29, 2018	Winter Weather	0	0	--	--
January 18, 2019	Winter Storm	0	0	--	--
January 22, 2019	Winter Storm	0	0	--	--
January 27, 2019	Winter Storm	0	0	--	--
February 5, 2019	Winter Weather	0	0	--	--
February 7, 2019	Winter Weather	0	0	--	--
February 11, 2019	Winter Storm	0	0	--	--
February 17, 2019	Winter Weather	0	0	--	--
February 26, 2019	Winter Weather	0	0	--	--
April 14, 2019	Winter Weather	0	0	--	1,193
April 27, 2019	Winter Weather	0	0	--	1,193
October 30, 2019	Winter Weather	0	0	--	--
November 6, 2019	Winter Weather	0	0	--	--
November 10, 2019	Winter Weather	0	0	--	--
January 10, 2020	Winter Weather	0	0	--	--
January 17, 2020	Winter Weather	0	0	--	--
January 31, 2020	Winter Weather	0	0	--	--
February 9, 2020	Winter Weather	0	0	--	--
February 12, 2020	Winter Weather	0	0	--	--
December 12, 2020	Winter Weather	0	0	--	--
December 29, 2020	Winter Storm	0	0	--	--
January 1, 2021	Winter Weather	0	0	--	--
January 25, 2021	Winter Storm	0	0	--	--
January 30, 2021	Winter Storm	0	0	--	--
February 4, 2021	Winter Weather	0	0	--	--
February 11, 2021	Winter Weather	0	0	--	--
February 13, 2021	Winter Weather	0	0	--	--
February 15, 2021	Winter Storm	0	0	--	--
December 6, 2021	Winter Weather	0	0	--	--
December 28, 2021	Winter Weather	0	0	--	--
January 1, 2022	Winter Weather	0	0	--	264

Table continued on next page.

Table 3.14 (Continued)

Date	Type[a]	Deaths	Injuries	Property Damages ($)	Crop Damages ($)
January 22, 2022	Winter Weather	0	0	--	264
January 24, 2022	Winter Weather	0	0	--	264
February 6, 2022	Winter Weather	0	0	--	--
February 18, 2022	Winter Weather	0	0	--	--
February 22, 2022	Winter Weather	0	0	--	--
February 24, 2022	Winter Weather	0	0	--	--
March 6, 2022	Winter Weather	0	0	--	--
March 31, 2022	Winter Weather	0	0	--	--
December 9, 2022	Winter Weather	0	0	--	--
December 22, 2022	Winter Weather	0	0	--	--
Total		0	0	19,094	11,736

Note: The data presented in this table only accounts for damages, injuries, and deaths that are directly caused by each winter storm event. Damages, injuries, and deaths that occur indirectly as the result of traffic accidents, slips and falls, or health issues associated with winter storms are not included in this table.

Dollar values were adjusted to year 2022 by the average annual Consumer Price Index (CPI) values from the U.S. Department of Labor, Bureau of Labor Statistics

[a] *NWS defines the following types of events:*

- *Blizzard as a winter storm which produces the following conditions for three consecutive hours or longer: (1) sustained winds or frequent gusts 30 knots (35 mph) or greater, and (2) falling and/or blowing snow reducing visibility frequently to less than 1/4 mile.*
- *Winter Storm is an event that has more than one significant hazard (i.e., heavy snow and blowing snow; snow and ice; snow and sleet; sleet and ice; or snow, sleet, and ice) and meets or exceeds locally/regionally defined 12 and/or 24-hour warning criteria for at least one of the precipitation elements.*
- *Winter Weather as an event that causes a death, injury, or a significant impact to commerce or transportation, but does not meet locally/regionally defined warning criteria. Such an event could result from one or more winter precipitation types (snow, or blowing/drifting snow, or freezing rain/drizzle). The Winter Weather event can also be used to document out-of-season and other unusual or rare occurrences of snow, or blowing/drifting snow, or freezing rain/drizzle.*

Source: National Centers for Environmental Information and U.S. Department of Agriculture Risk Management Agency

271802- Table 3.15- Heat Index Chart
500-1151
MAS/mid
1/31/2024

Table 3.15
Heat Index Chart

	Relative Humidity (percent)												
	100	95	90	85	80	75	70	65	60	55	50	45	40
Temperature (°F)	**Heat Index (°F)**												
80	87.2	86.4	85.6	84.9	84.2	83.6	83.0	82.4	81.8	81.3	80.8	80.3	79.9
82	94.5	93.0	91.5	90.1	88.8	87.6	86.4	85.4	84.4	83.6	82.8	82.5	81.5
84	102.7	100.3	98.0	95.9	94.0	92.2	90.5	88.9	87.5	86.3	85.1	84.1	83.3
86	111.5	108.3	105.3	102.5	99.8	97.3	95.1	93.0	91.1	89.4	87.9	86.6	85.4
88	121.2	117.1	113.2	109.6	106.3	103.1	100.2	97.6	95.1	93.0	91.0	89.4	87.4
90	131.6	126.6	121.9	117.5	113.3	109.5	105.9	102.7	99.7	97.0	94.6	92.5	90.7
92	142.8	136.9	131.3	126.0	121.0	116.4	112.2	108.3	104.7	101.4	98.5	96.0	93.8
94	154.8	147.9	141.3	135.2	129.4	124.0	119.0	114.4	110.2	106.3	102.9	99.8	97.2
96	167.5	159.6	152.1	145.0	138.3	132.1	126.4	121.0	116.1	111.7	107.6	104.0	100.9
98	181.0	172.0	163.5	155.5	147.9	140.9	134.3	128.2	122.6	117.4	112.8	108.6	104.9
100	195.3	185.2	175.7	166.7	158.2	150.2	142.8	135.9	129.5	123.6	118.3	113.5	109.3
102	210.4	199.2	188.5	178.5	169.0	160.1	151.8	144.1	136.9	130.3	124.3	118.8	113.9
104	226.2	213.8	202.1	191.0	180.5	170.7	161.4	152.8	144.8	137.4	130.6	124.4	118.9
106	242.7	229.2	216.4	204.2	192.6	181.8	171.6	162.0	153.1	144.9	137.3	130.4	124.2
108	260.1	245.4	231.3	218.0	205.4	193.5	182.3	171.1	161.9	152.8	144.4	136.7	129.8
110	278.2	262.2	247.0	232.5	218.8	205.8	193.5	182.0	171.2	161.2	152.0	143.4	135.7

Source: National Weather Service

#270719 Milwaukee Co HMP Table 3.16
500-1151
MAS/mid
10/2023

Table 3.16
Level of Risk for Persons in High-Risk Groups Associated with the Heat Index

Heat Index (°F)	Category	Possible Heat Disorders for Persons in High-Risk Groups
80-90	Caution	Fatigue possible with prolonged exposure and/or physical activity
90-105	Extreme Caution	Sunstroke, muscle cramps, and/or heat exhaustion possible with prolonged exposure and/or physical activity
105-129	Danger	Sunstroke, muscle cramps and/or heat exhaustion likely. Heatstroke possible with prolonged exposure and/or physical activity
130 or above	Extreme Danger	Heat stroke or sunstroke likely

Source: National Weather Service

Table 3.17
Recent Extreme Temperature Events in Milwaukee County: 2011-2022

Date	Type	Deaths	Injuries[a]	Property Damage ($)	Crop Damage ($)
January 21, 2011	Cold/Wind Chill	0	0	--	--
July 20, 2011	Heat	0	0	--	--
June 18, 2012	Heat	2	0	--	--
June 28, 2012	Heat	0	0	--	--
July 3, 2012	Excessive Heat	2	0	--	--
July 16, 2012	Heat	0	0	--	--
July 23, 2012	Heat	0	0	--	--
July 25, 2012	Heat	0	0	--	--
January 21, 2013	Cold/Wind Chill	0	0	--	--
July 16, 2013	Excessive Heat	0	0	--	--
August 30, 2013	Heat	0	0	--	--
January 3, 2014	Cold/Wind Chill	1	0	--	--
January 6, 2014	Extreme Cold/Wind Chill	0	0	--	--
January 27, 2014	Cold/Wind Chill	1	0	--	--
February 5, 2014	Cold/Wind Chill	1	0	--	--
March 16, 2014	Cold/Wind Chill	1	0	--	--
December 3, 2014	Cold/Wind Chill	1	0	--	--
December 5, 2014	Cold/Wind Chill	1	0	--	--
January 1, 2015	Cold/Wind Chill	1	0	--	--
January 7, 2015	Cold/Wind Chill	0	0	--	--
January 9, 2015	Cold/Wind Chill	0	0	--	--
January 8, 2016	Cold/Wind Chill	1	0	--	--
January 17, 2016	Cold/Wind Chill	1	0	--	--
July 21, 2016	Heat	0	29	--	561
July 27, 2016	Heat	1	0	--	561
December 10, 2016	Cold/Wind Chill	1	0	--	--
December 14, 2016	Cold/Wind Chill	0	0	--	--
December 18, 2016	Cold/Wind Chill	1	0	--	--
January 4, 2017	Cold/Wind Chill	1	0	--	--
January 5, 2017	Cold/Wind Chill	1	0	--	--
December 25, 2017	Cold/Wind Chill	2	0	--	--
January 1, 2018	Cold/Wind Chill	1	0	--	--
June 17, 2018	Heat	0	0	--	--
June 29, 2018	Excessive Heat	0	0	--	--
July 1, 2018	Excessive Heat	0	0	--	--
July 4, 2018	Heat	0	0	--	--
November 29, 2018	Cold/Wind Chill	1	0	--	--
December 28, 2018	Cold/Wind Chill	1	0	--	--
January 29, 2019	Extreme Cold/Wind Chill	1	0	--	--
February 1, 2019	Cold/Wind Chill	1	0	--	--
February 3, 2019	Cold/Wind Chill	1	0	--	--
March 3, 2019	Cold/Wind Chill	1	0	--	--
March 5, 2019	Cold/Wind Chill	1	0	--	--
July 19, 2019	Excessive Heat	0	0	--	--
November 6, 2019	Cold/Wind Chill	1	0	--	--
November 10, 2019	Cold/Wind Chill	1	0	--	--
February 11, 2020	Cold/Wind Chill	1	0	--	307
February 14, 2020	Cold/Wind Chill	1	0	--	307

Table continued on next page.

Table 3.17 (Continued)

Date	Type	Deaths	Injuries[a]	Property Damage ($)	Crop Damage ($)
February 17, 2020	Cold/Wind Chill	1	0	--	307
February 7, 2021	Cold/Wind Chill	0	0	--	--
February 13, 2021	Cold/Wind Chill	0	0	--	--
June 14, 2022	Excessive Heat	2	0	--	--
June 21, 2022	Excessive Heat	0	0	--	--
December 22, 2022	Extreme Cold/Wind Chill	0	0	--	--
	Total	35	29	--	2,043

Note: Dollar Values were adjusted to year 2021 by the average annual Consumer Price Index (CPI) values from the U.S. Department of Labor, Bureau of Labor Statistics.

[a] *No injuries were reported to NCEI or USDA RMA, but injuries may have occurred.*

Source: National Centers for Environmental Information and U.S. Department of Agriculture Risk Management Agency

#270212 – CAPR-345 Table 3.18
500-1151
MAS/mid
01/16/2024

Table 3.18
Wind Chill Temperatures[a]

Wind (mph)	Temperature (°F)																	
	40	35	30	25	20	15	10	5	0	-5	-10	-15	-20	-25	-30	-35	-40	-45
5																		
10																		
15																		
20																		
25																		
30																		
35																		
40																		
45																		
50																		
55																		
60																		

[a] *Wind Chill (°F) = $35.74 + 0.6215T - 35.75(V^{0.16}) + 0.4275T(V^{0.16})$, where T = air temperature (°F) and V = wind speed (mph). The wind chill temperature is only defined for temperatures at or below 50°F and wind speeds above 3 mph. Bright sunshine may increase wind chill temperature by 10°F to 18°F.*

Frostbite times associated with wind chills:

30 minutes

10 minutes

5 minutes

Source: National Weather Service

#271108 – CAPR-345 Table 3.19
500-1151
MAS/mid
12/8/23

Table 3.19
Estimates of Recent Crop Losses Due to Drought in Milwaukee County: 2011-2022

Year	Crop Insurance Indemnity Paid ($)[a]
2011	5,369
2012	14,518
2013	--
2014	337
2015	16,083
2016	8,348
2017	--
2018	--
2019	--
2020	--
2021	11,500
2022	10,129
Total	66,284

[a] *Dollar values were adjusted to year 2022 by using the average Consumer Price Index (CPI) values from the U.S. Department of Labor, Bureau of Labor Statistics.*

Source: National Climatic Data Center (NCDC), the U.S. Department of Agriculture Risk Management Agency, and SEWRPC

#271147- CAPR-345 Table 3.20 1995 Bluff Stability Study
500-1151
MAS/mid
10/04/2023

Table 3.20
Bluff Stability and Shoreline Recession Along Lake Michigan Shoreline of Milwaukee County: 1995

Shoreline Analysis (see Map 3.4)	Bluff Heights (feet)	Deterministic Bluff Stability Safety Factor		Shoreline Recession Data 1963-1995		Estimated Beach Width (feet)	
		1995 Conditions	1977 Conditions	Total (feet)	Annual Average (feet per year)	1995 Conditions	1977 Conditions
Reach 7	60-125	0.80-1.59 (Unstable to Stable)	0.54-1.38 (Unstable to Stable)	10-400	0.3-12.5	0-150	0-20
Reach 8	25-100	0.74-1.95 (Unstable to Stable)	0.33-1.69 (Unstable to Stable)	10-330	0.3-10.3	0-600	0-20
Reach 9	0-25	2.40 (Stable)	1.21 (Stable)	20-70	0.6-2.2	0-170	0-20
Reach 10	70-120	0.95-1.62 (Unstable to Stable)	0.45-2.97 (Unstable to Stable)	-90-50	-2.8-1.6	0-150	0-50
Reach 11[a]	80-140	1.07-2.34 (Unstable to Stable)	0.85-1.71 (Unstable to Stable)	10-50	0.3-1.6	5-170	15-30

[a] *Includes a portion of Milwaukee County.*

Source: Wisconsin Coastal Management Program and SEWRPC Technical Report No. 36, Lake Michigan Shoreline Recession and Bluff Stability in Southeastern Wisconsin: 1995, *December 1997*

Table 3.21
Shore Protection in Milwaukee County: 2018

Type of Shore Protection	Percent of County Shoreline
Public Marina	9.1
Private Marina	0.3
Seawall/Bulkhead	8.8
Revetment	36.7
Poorly Organized Rip-Rap/Rubble	2.8
Commercial/Industrial Dock	5.0
Offshore Breakwater	1.4
No Protection	35.9
Total	100.0

Source: Wisconsin Shoreline Inventory and Oblique Photo Viewer

#271669 – Milwaukee Co HMP Table 3.22
500-1151
MAS/mid
12/18/23

Table 3.22
Parcels Within the Low- and High-Risk Coastal Erosion Zones in Milwaukee County: 2021

	Improved Parcels in Erosion Risk Zone				Value of Improvements ($)[a]			
Milwaukee County	Residential	Commercial	Manufacturing	Total	Residential	Commercial	Manufacturing	Total
Low-Risk Zone (within 0.5 miles)	16,633	764	15	17,412	5,542,023,107	1,661,681,300	10,981,800	7,214,686,207
High-Risk Zone (within 0.25 miles)	6,317	138	2	6,457	2,538,426,743	788,641,000	2,171,000	3,329,238,743
Total	22,950	902	17	23,869	8,080,449,850	2,450,322,300	13,152,800	10,543,924,950

[a] *2021 dollars.*

Source: Wisconsin Land Information Program and Wisconsin Emergency Management

#271671 – Milwaukee Co HMP Table 3.23
500-1151
MAS/mid
1/19/24

Table 3.23
Communities and in Milwaukee County with Special Coastal Hazard Conditions (Working on)

Community	Reason for Special Consideration
Cities	
Milwaukee	The port of Milwaukee is a critical facility considered to be within the 100-year Lake Michigan floodplain.
Oak Creek	The City of Oak Creek has two critical facilities (We Energies Power Plant and a wastewater treatment plant) on the shores of Lake Michigan.
St. Francis	Several residential structures on S. Lake Drive are observed to be near the bluff coastline.
South Milwaukee	The city wastewater treatment plant, a critical facility, is located near the shores of Lake Michigan.
Villages	
Fox Point	15 residential parcels along N. Beach Drive are considered to be within the 100-year Lake Michigan floodplain.
Whitefish Bay	N. Lake Drive has re residential structures observed to be near the bluff coastline.
Milwaukee County	Bluff conditions along the Warnimont Park shoreline are considered poor or unstable and failing. This area also has reported poor groin shoreline protection structures. The shoreline along Sheridan Park also has unstable/failing bluff conditions and groin structures considered to be in poor condition. McKinley Marina and the War Memorial and Art Center have revetments that are reported to be in poor condition. Shorelines along Bay View Park and South Shore Park have reported unstable/failing bluffs. South Shore Park also has breakwater structures considered to be in fair condition, however still a risk to coastal hazard impacts. Grant Park shoreline has bluffs considered to be unstable/failing as well as revetment and groin structures in fair condition but still at high risk to coastal hazard impacts. Bluff conditions within Big Bay Park are fair but still considered a high risk to coastal hazard impacts. McKinley Marina and the War Memorial and Art Center have revetments that are reported to be in poor condition.

Source: Milwaukee County, Coastal Resources Inventory Report*, October 2020, Wisconsin Shoreline Inventory and Oblique Photo Viewer, and SEWRPC*

SEWRPC Community Assistance Planning Report No. 345

MILWAUKEE COUNTY HAZARD MITIGATION PLAN UPDATE

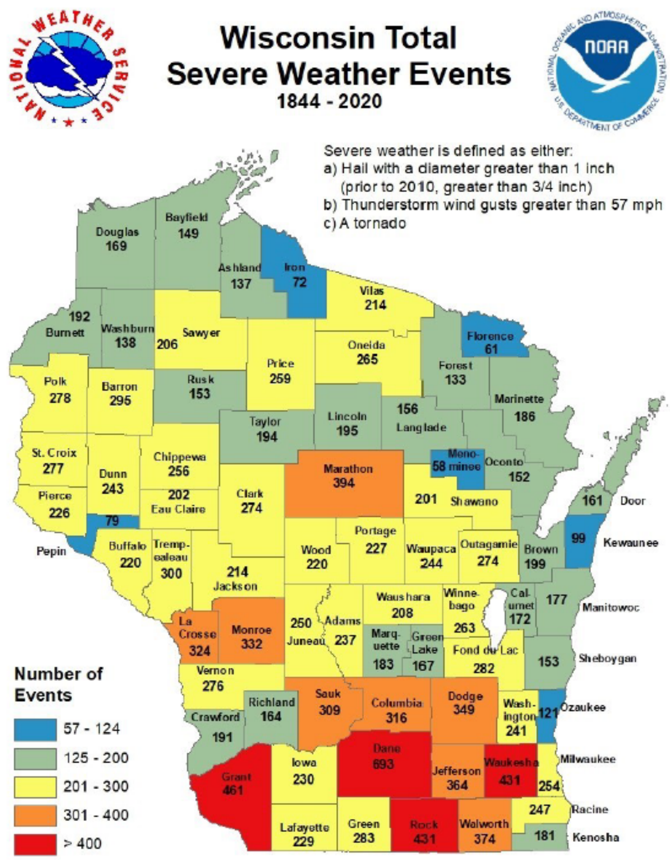
Chapter 3

ANALYSIS OF HAZARD CONDITIONS

FIGURES

#271726 – CAPR-345 Figure 3.1 Severe Weather Events in WI 1844-2020
500-1149
MAS/mid
1/23/2024

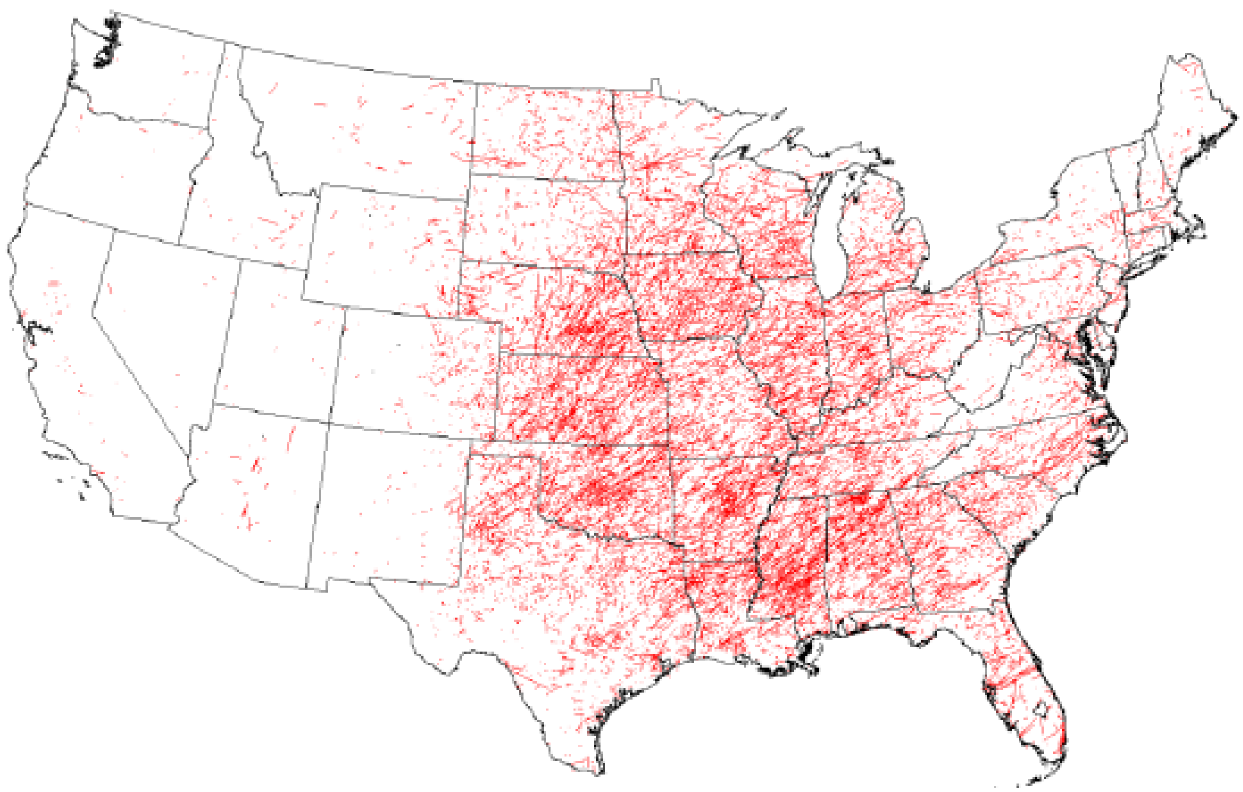
Figure 3.1
Severe Weather Events
in Wisconsin: 1844 to 2020



Source: National Oceanic and Atmospheric Administration, National Weather Service, and Wisconsin Emergency Management

#271518 – CAPR-345 Figure 3.2 Tornado Tracks in US
500-1151
MAS/mid
1/6/2023

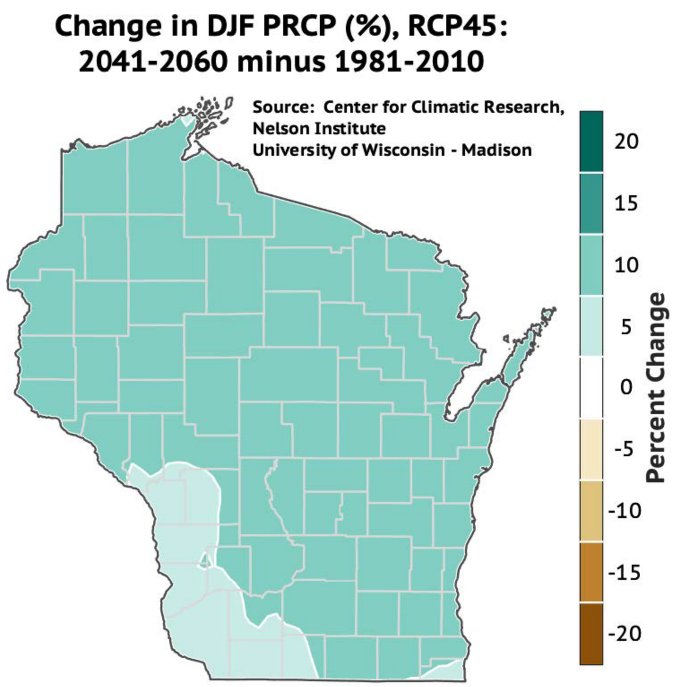
Figure 3.2
Recorded Tracks of Tornados Occurring in the United States: 1950-2015



Source: National Oceanic and Atmospheric Administration

#271729 – CAPR-345 Figure 3.3 Projected Change in Winter Precipitation
500-1151
MAS/mid
1/23/2023; 8/2/2022

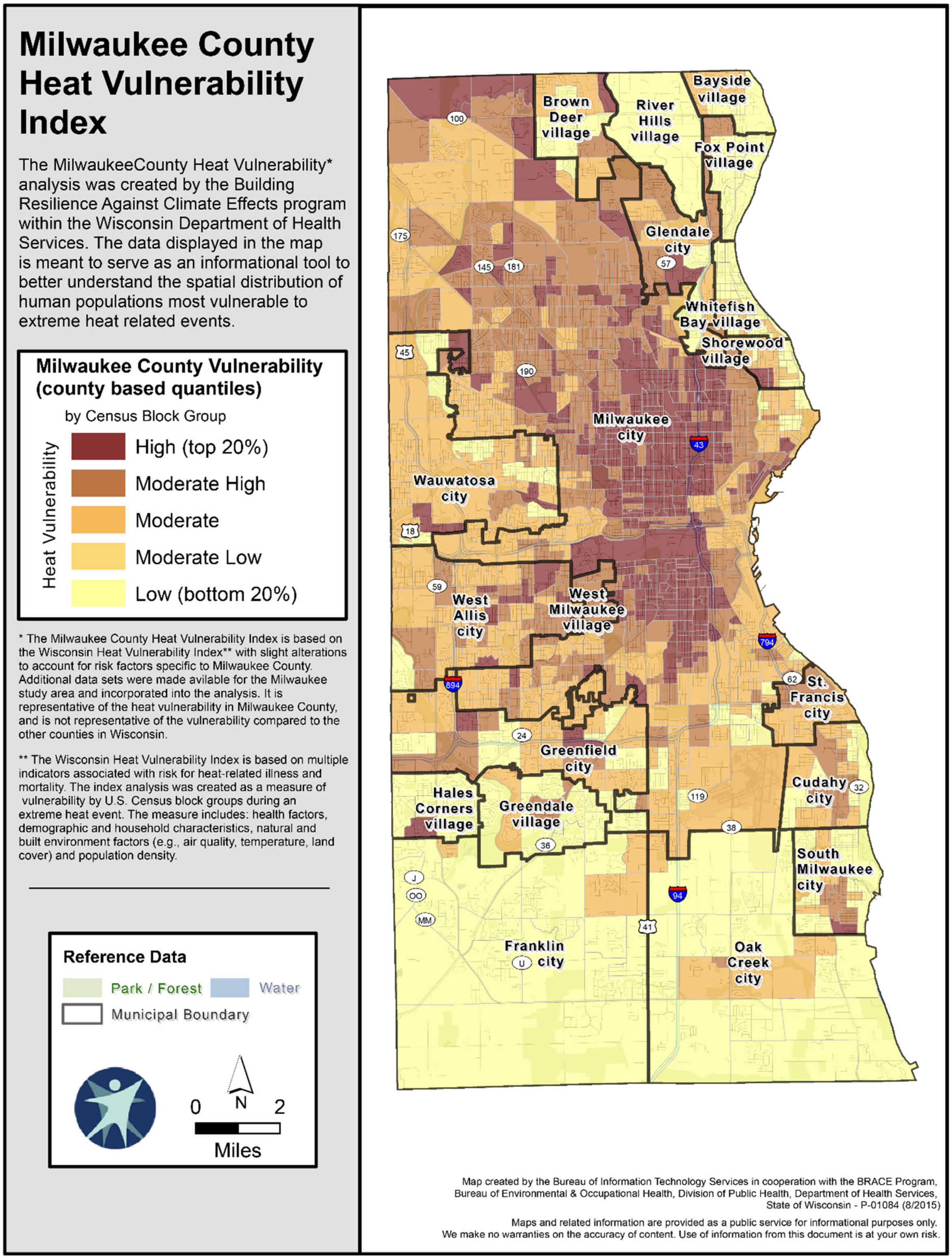
Figure 3.3
Projected Percent Change in Average Winter Precipitation: 2040-2060



Source: Wisconsin Initiative on Climate Change Impacts, Trends and Projections, wicci.wisc.edu

#271732 – Milwaukee Co HMP Figure 3.4
500-1151
MAS/mid
1/20/24

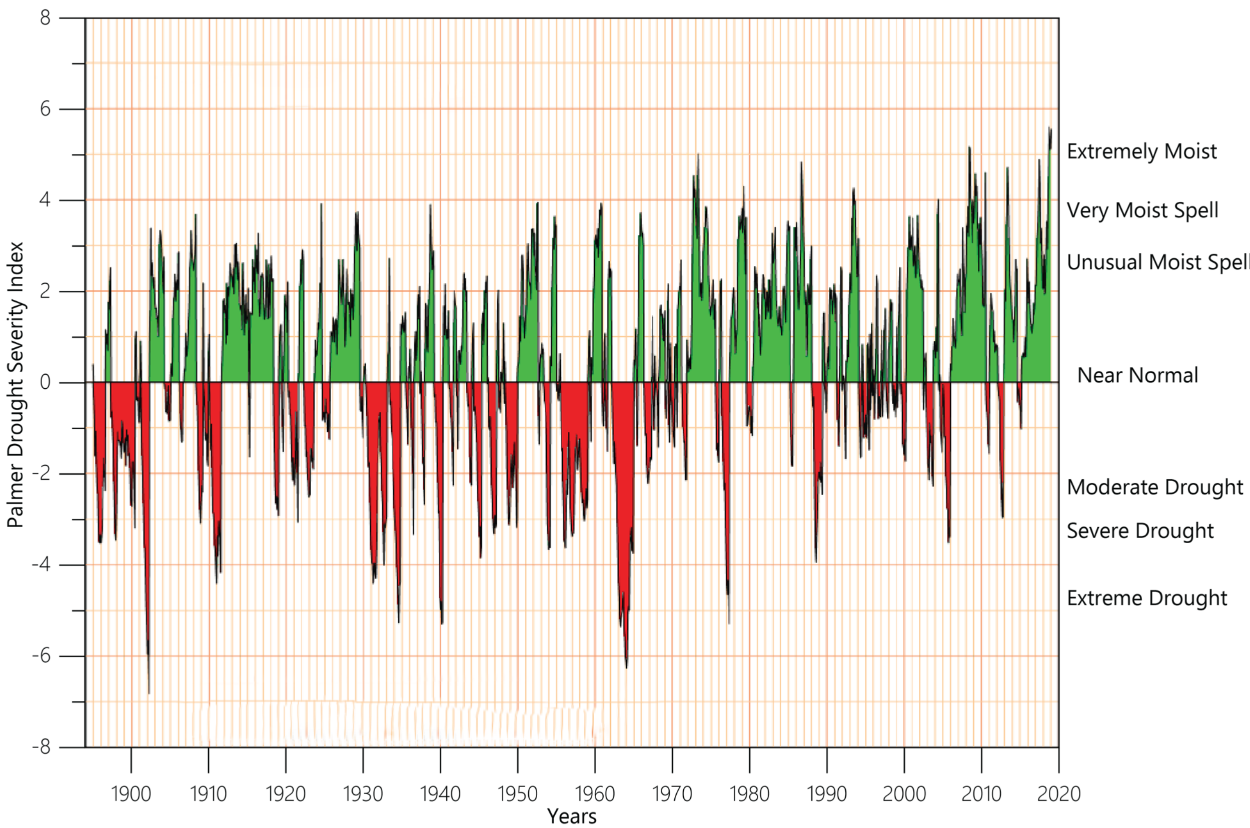
Figure 3.4
Milwaukee County Heat Vulnerability Index: 2014



Source: Wisconsin Department of Health Services

#271726 – CAPR-345 Figure 3.5 Palmer Drought Index in WI:1900-2020, WEM
500-1151
MAS/mid
1/23/2024

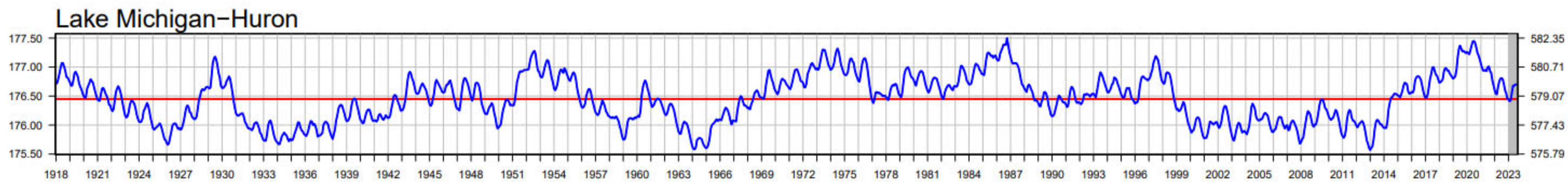
Figure 3.5
Wisconsin Statewide Average Palmer Drought Severity Index: 1895-2021



Source: University of Wisconsin Atmospheric and Oceanic Sciences, Wisconsin State Climatology Office

#271727 – CAPR-345 Figure 3.6 Lake Michigan Water Levels
500-1151
MAS/mid
1/23/2024

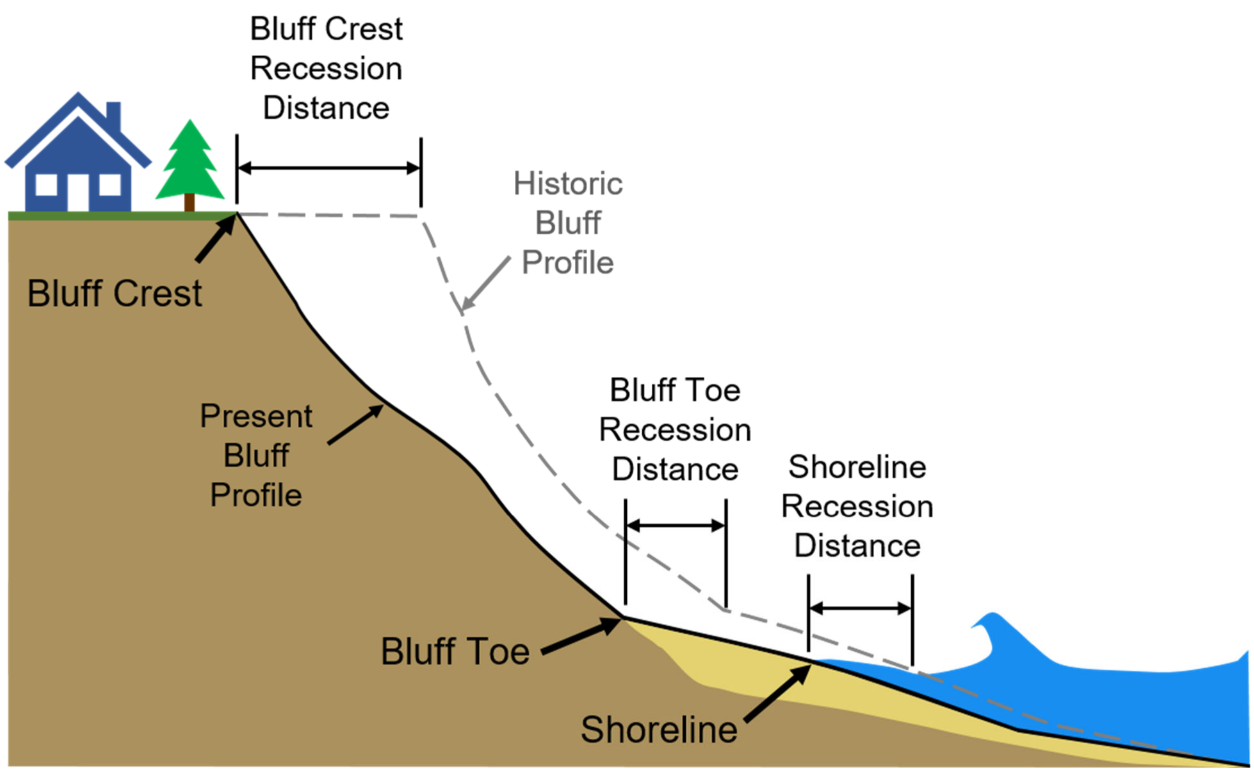
Figure 3.6
Lake Michigan-Huron Water Levels: 1918 to 2023



Source: United States Army Corps of Engineers

#271226 – Milwaukee Co HMP Figure 3.7
500-1151
MAS/mid
12/7/2023

Figure 3.7
Bluff Recession Schematic



Source: Wisconsin Coastal Management Program and SEWRPC

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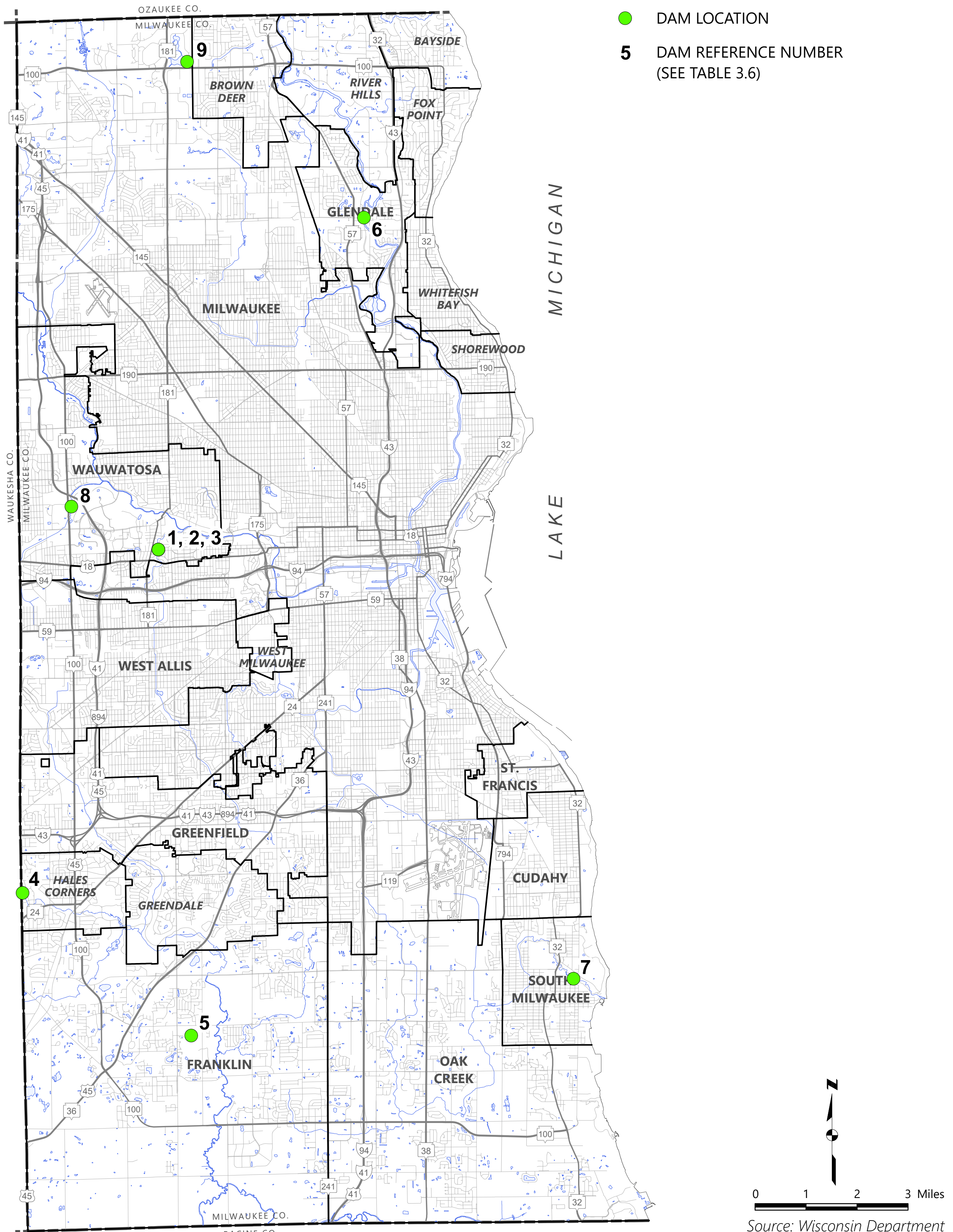
MILWAUKEE COUNTY HAZARD MITIGATION PLAN UPDATE

Chapter 3

ANALYSIS OF HAZARD CONDITIONS

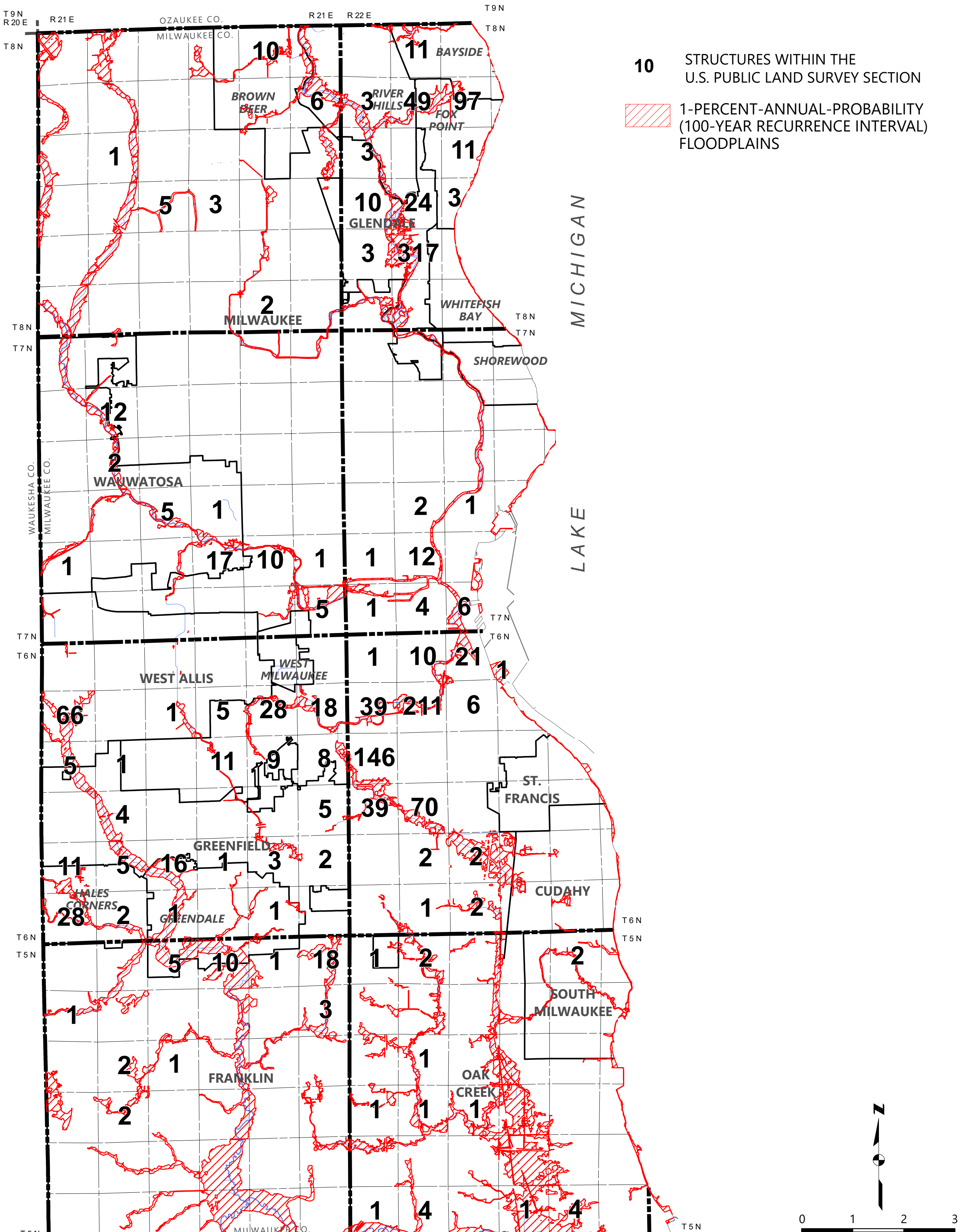
MAPS

Map 3.1
Dam Locations in Milwaukee County: 2023



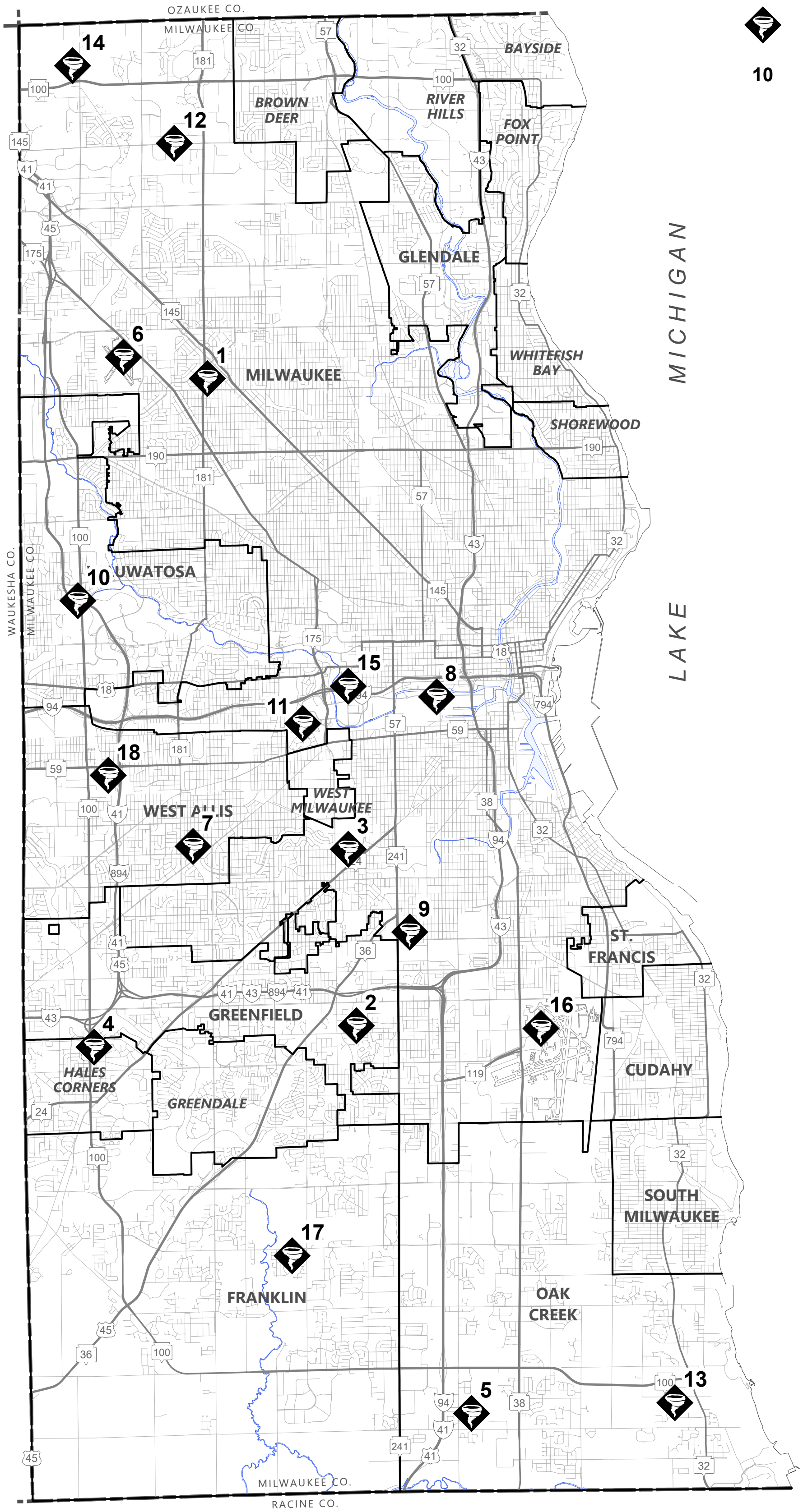
Source: Wisconsin Department of Natural Resources and SEWRPC

Map 3.2
Structures Located within the 1-Percent-Annual-Probability Floodplain: 2023



Source: Federal Emergency Management Agency, Milwaukee County, and SEWRPC

Map 3.3
Tornado Events Reported within Milwaukee County 1950 - 2022



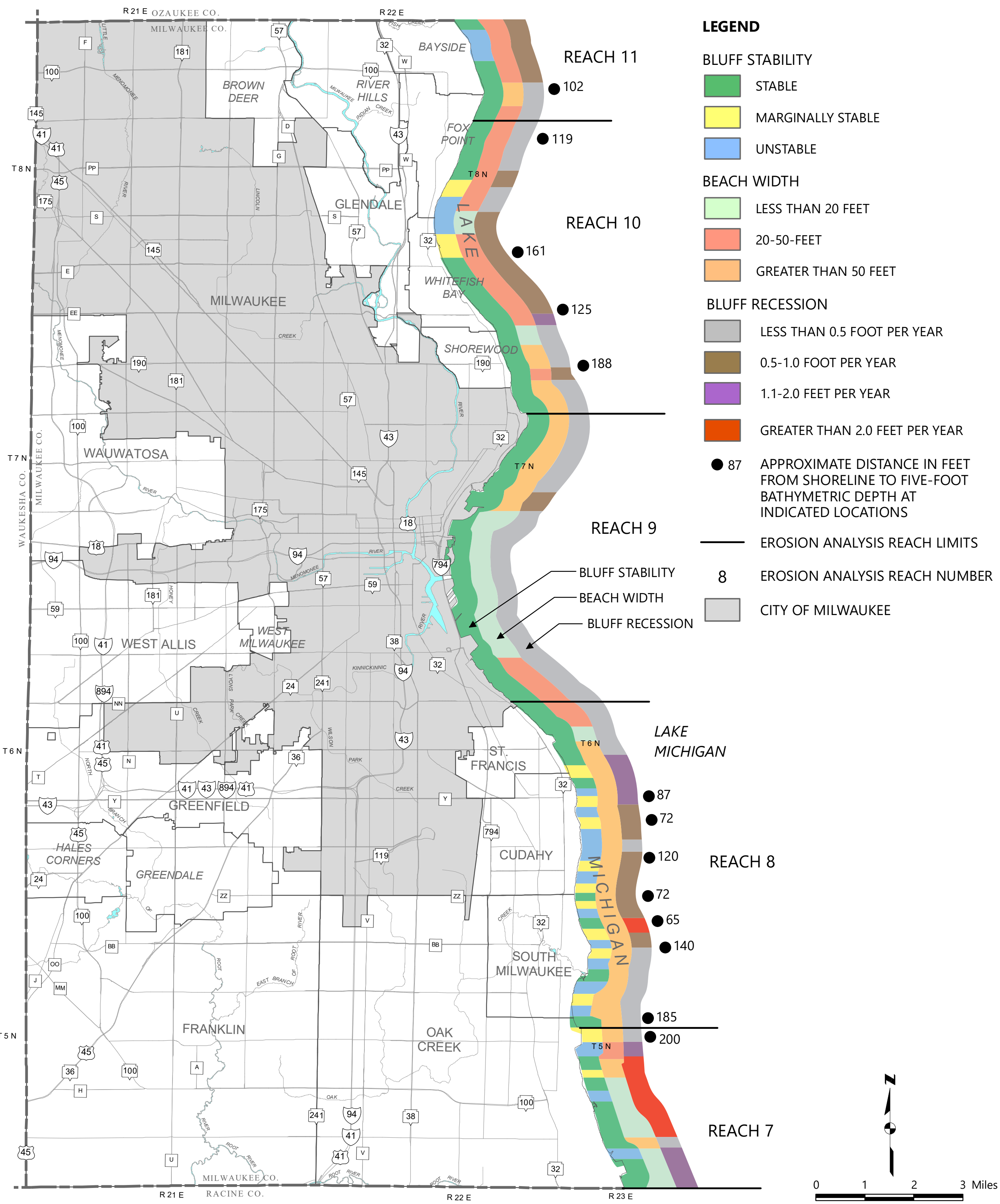
REPORTED TORNADO SIGHTING

10 TORNADO REFERENCE NUMBER (SEE TABLE 3.xx)

0 1 2 3 Miles

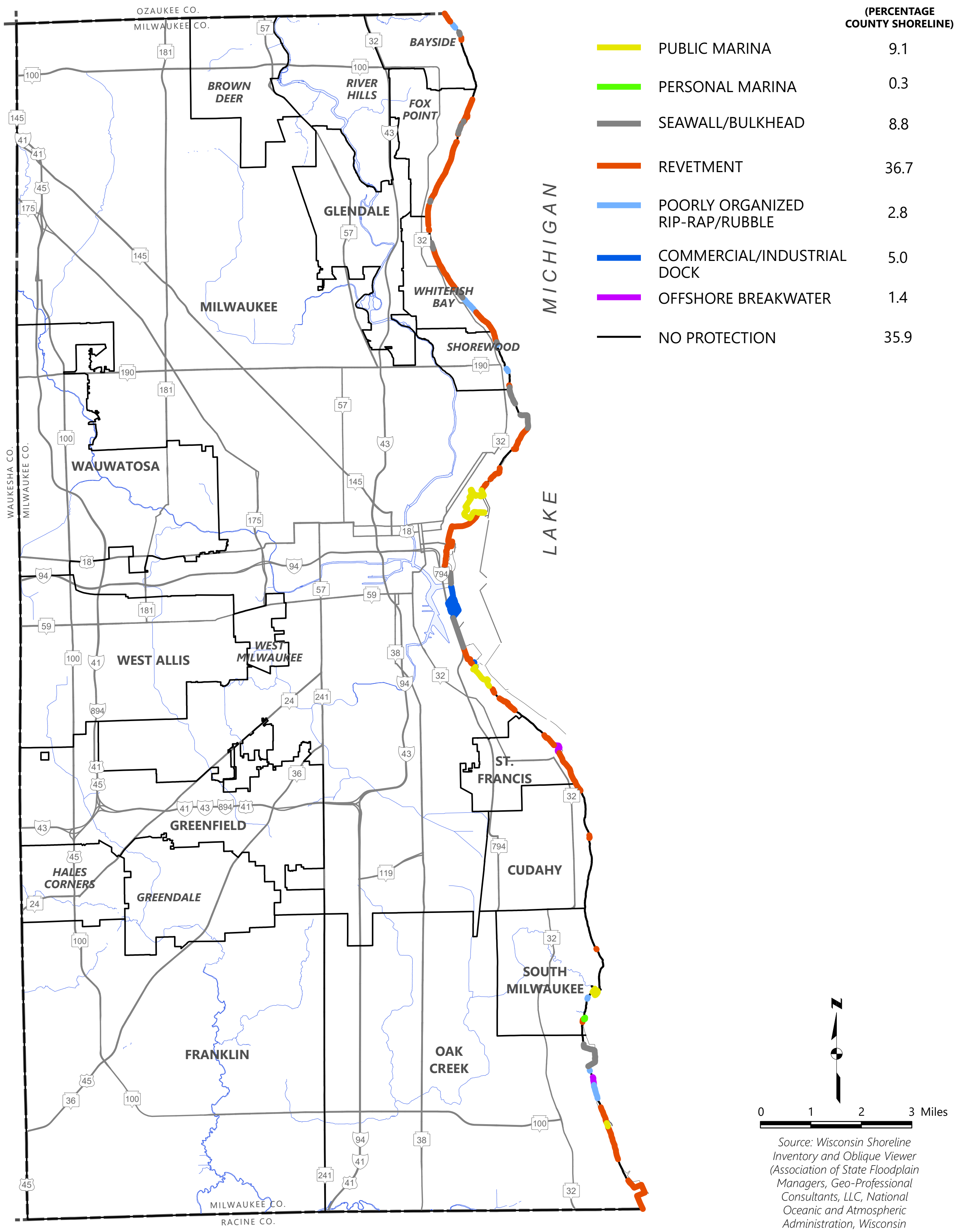
Source: SEWRPC

Map 2.8
Summary of Lake Michigan Shoreline Erosion and Bluff Stability Analyses in Milwaukee County: 1995



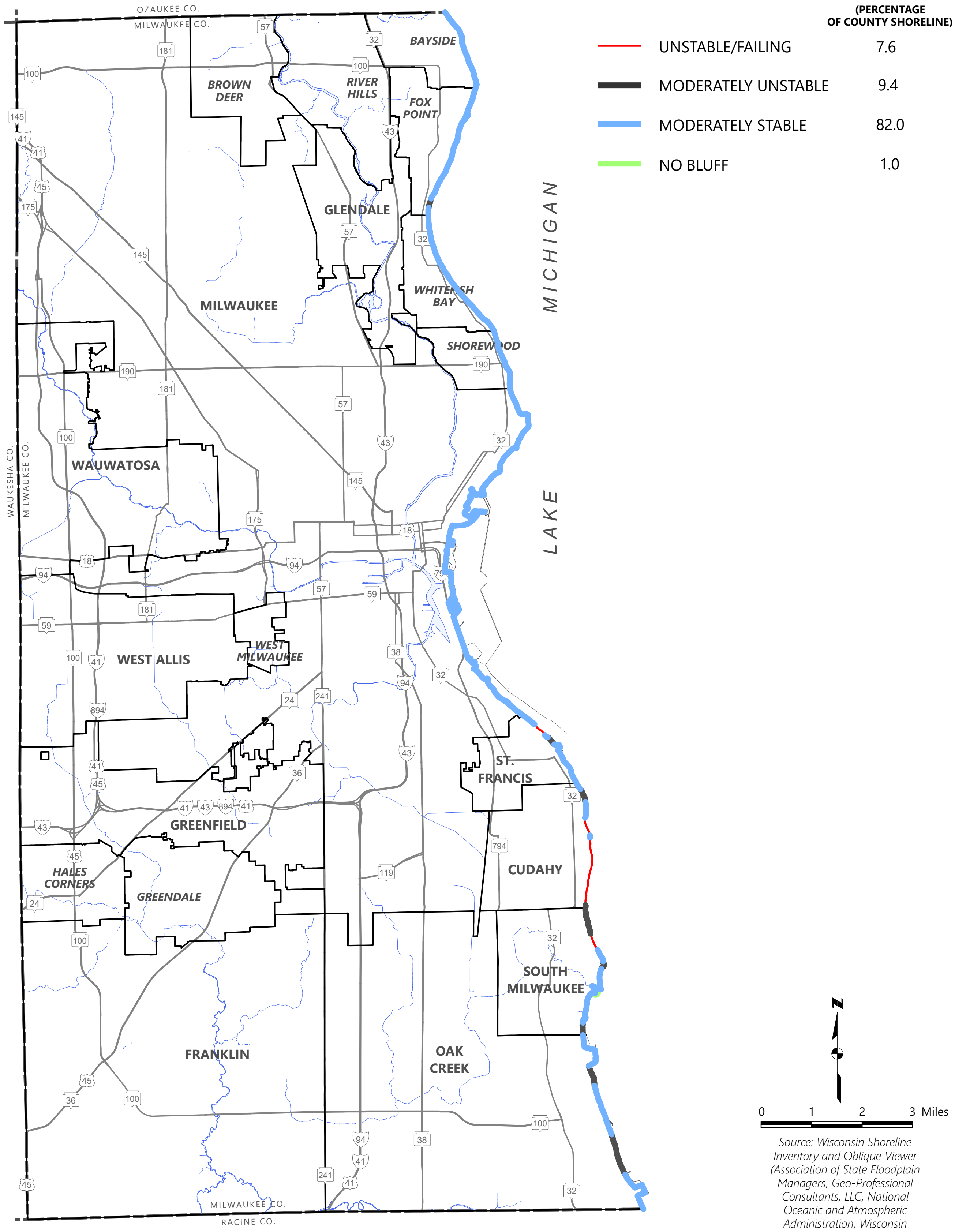
Source: T.B. Edil, D.M. Mickelson, J.A. Chapman, and SEWRPC

Map 3.5
Types of Shore Protection in Milwaukee County: 2018-2019



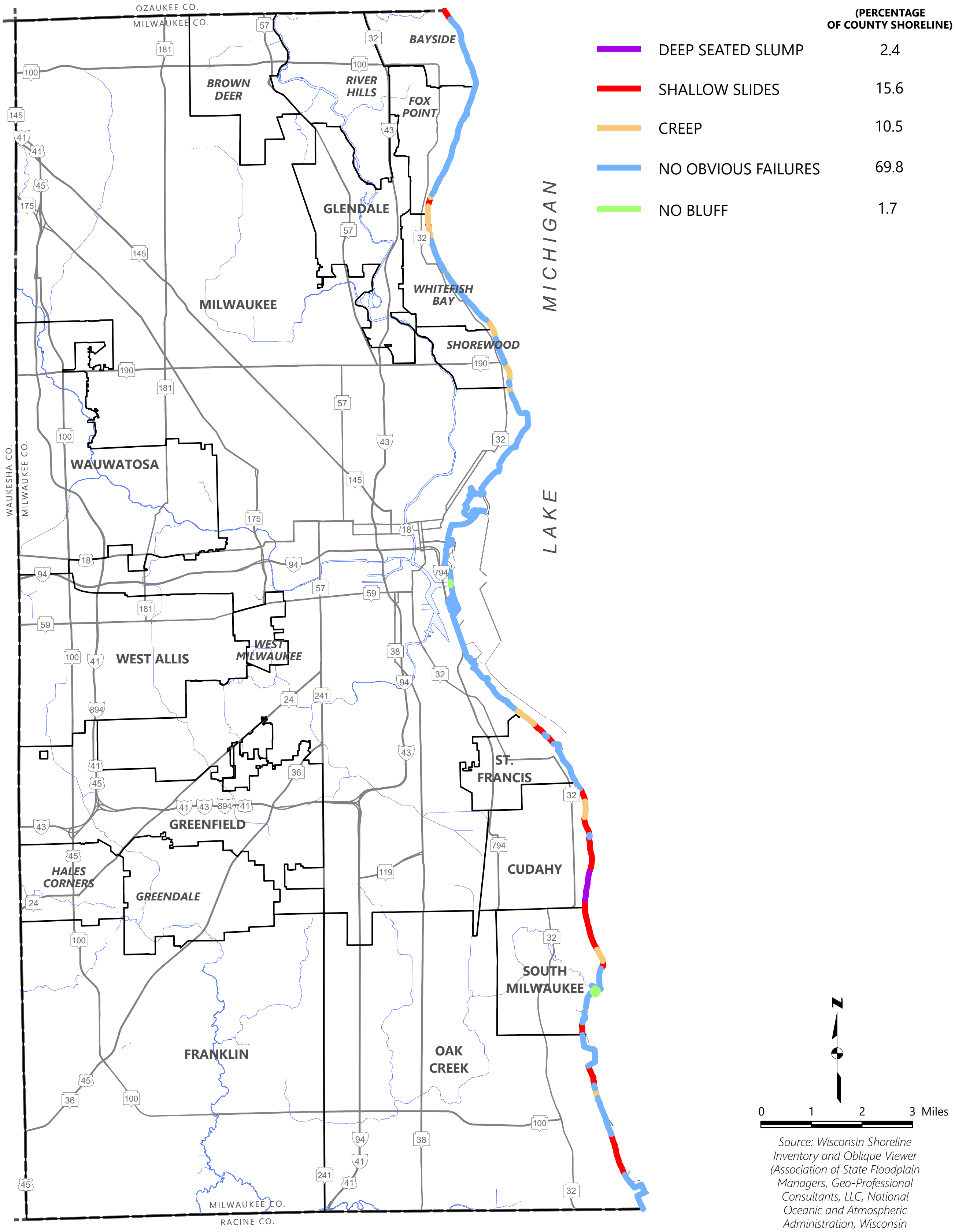
Source: Wisconsin Shoreline Inventory and Oblique Viewer (Association of State Floodplain Managers, Geo-Professional Consultants, LLC, National Oceanic and Atmospheric Administration, Wisconsin Coastal Management Program) and SEWRPC

Map 3.6
General Bluff Conditions in Milwaukee County: 2018



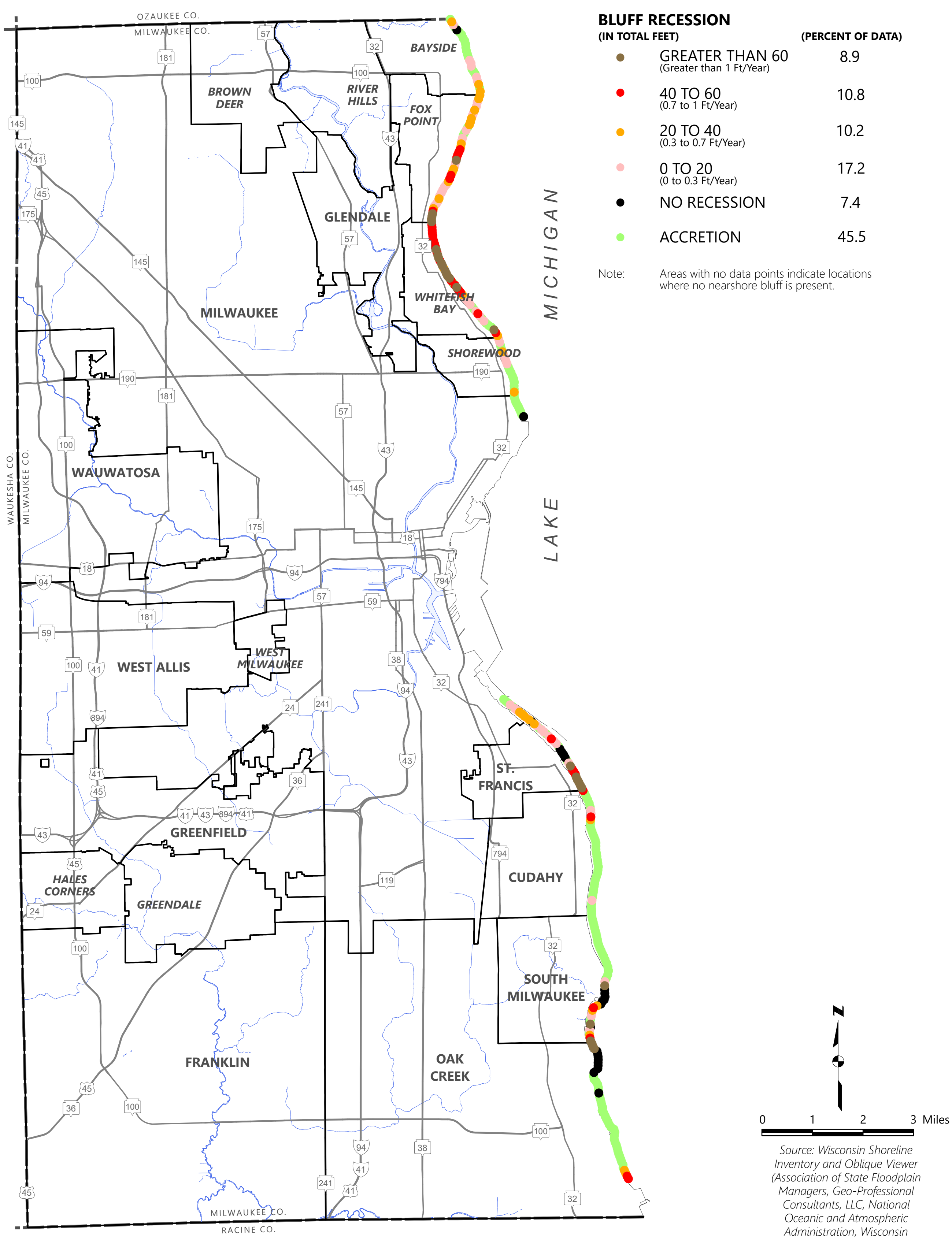
Source: Wisconsin Shoreline Inventory and Oblique Viewer (Association of State Floodplain Managers, Geo-Professional Consultants, LLC, National Oceanic and Atmospheric Administration, Wisconsin Coastal Management Program) and SEWRPC

Map 3.7
Types of Bluff Failure in Milwaukee County: 2018-2019



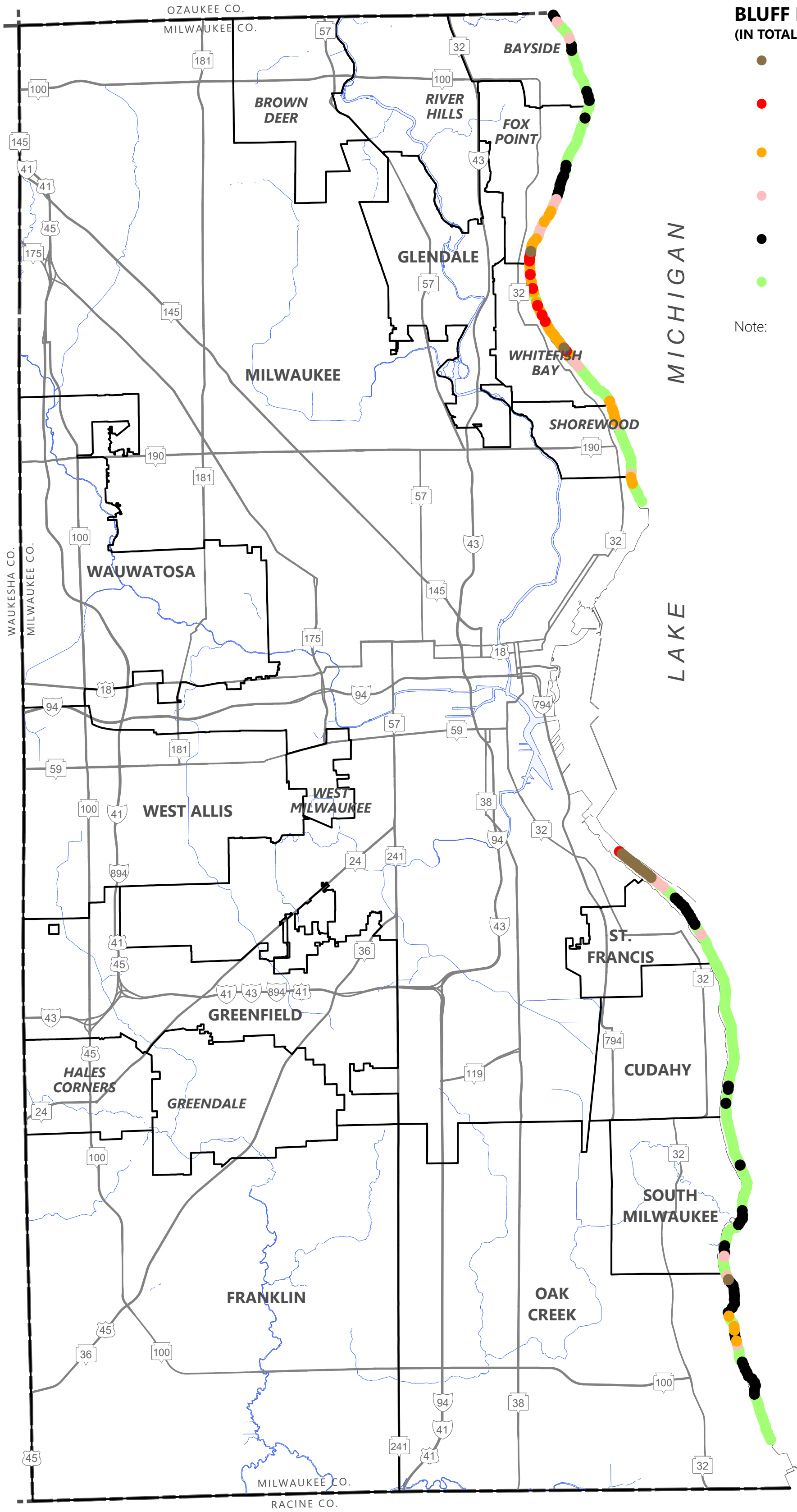
Source: Wisconsin Shoreline Inventory and Oblique Viewer (Association of State Floodplain Managers, Geo-Professional Consultants, LLC, National Oceanic and Atmospheric Administration, Wisconsin Coastal Management Program) and SEWRPC

Map 3.8
Long Term Bluff Toe Recession in Milwaukee County: 1956-2015



Source: Wisconsin Shoreline Inventory and Oblique Viewer (Association of State Floodplain Managers, Geo-Professional Consultants, LLC, National Oceanic and Atmospheric Administration, Wisconsin Coastal Management Program) and SEWRPC

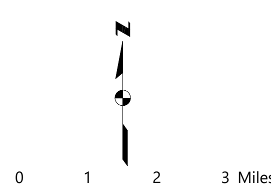
Map 3.9
Long Term Bluff Crest Recession in Milwaukee County: 1956-2015



BLUFF RECESSION

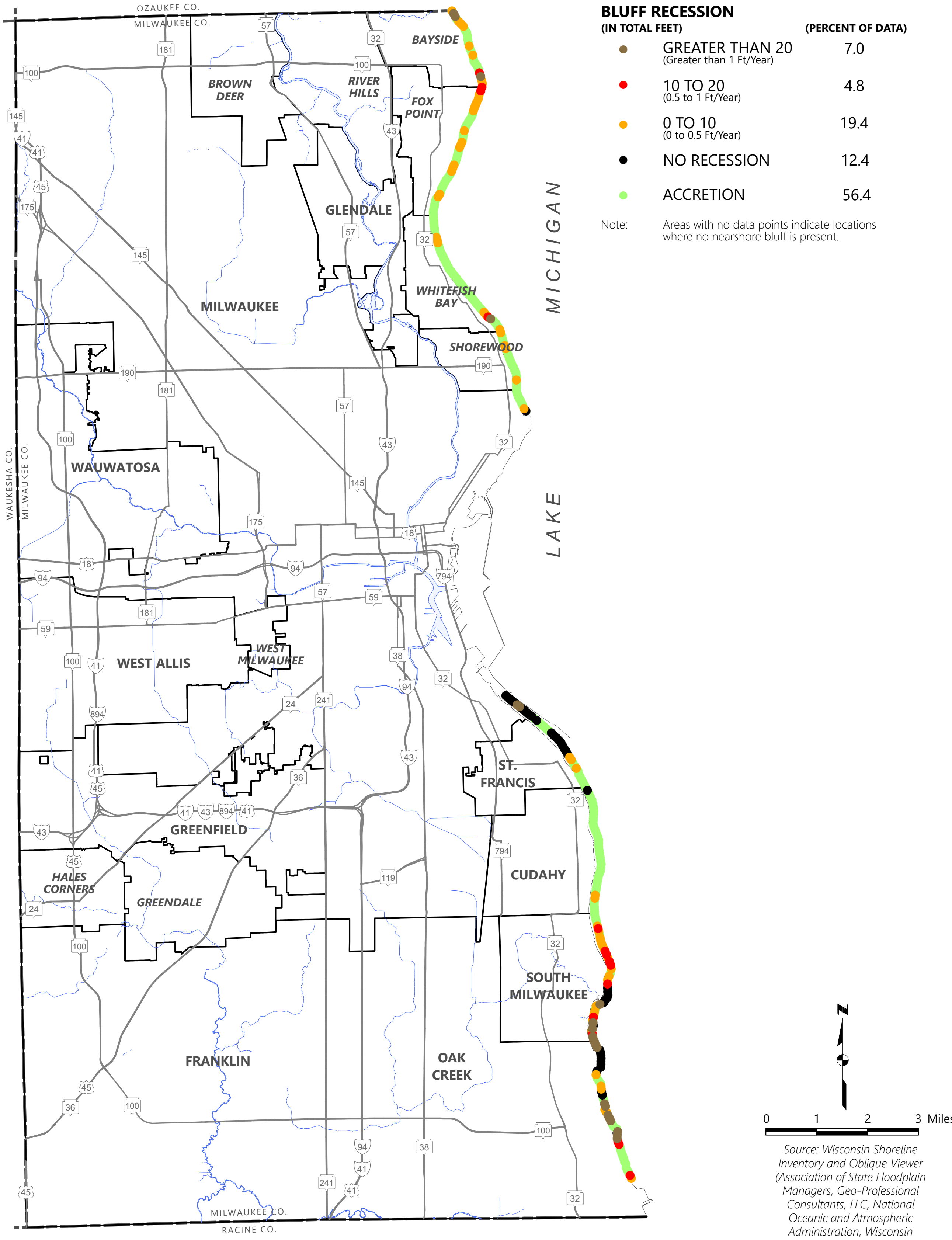
(IN TOTAL FEET)	(PERCENT OF DATA)
GREATER THAN 60 (Greater than 1 Ft/Year)	4.5
40 TO 60 (0.7 to 1 Ft/Year)	3.2
20 TO 40 (0.3 to 0.7 Ft/Year)	11.5
0 TO 20 (0 to 0.3 Ft/Year)	7.4
NO RECESSION	18.9
ACCRETION	54.5

Note: Areas with no data points indicate locations where no nearshore bluff is present.



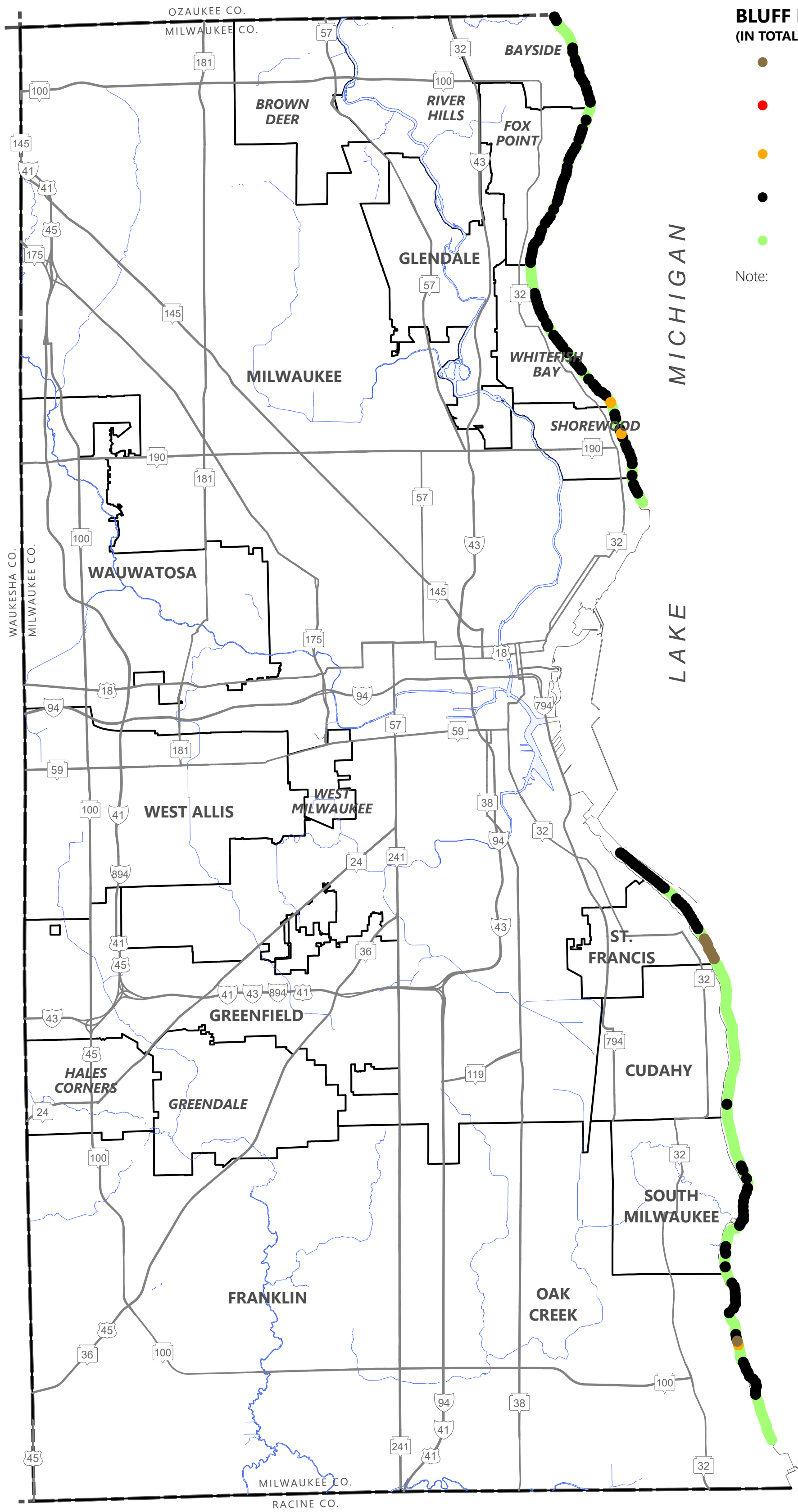
Source: Wisconsin Shoreline Inventory and Oblique Viewer (Association of State Floodplain Managers, Geo-Professional Consultants, LLC, National Oceanic and Atmospheric Administration, Wisconsin Coastal Management Program) and SEWRPC

Map 3.10
Short Term Bluff Toe Recession in Milwaukee County: 1995-2015



Source: Wisconsin Shoreline Inventory and Oblique Viewer (Association of State Floodplain Managers, Geo-Professional Consultants, LLC, National Oceanic and Atmospheric Administration, Wisconsin Coastal Management Program) and SEWRPC

Map 3.11
Short Term Bluff Crest Recession in Milwaukee County: 1995-2015



BLUFF RECESSION

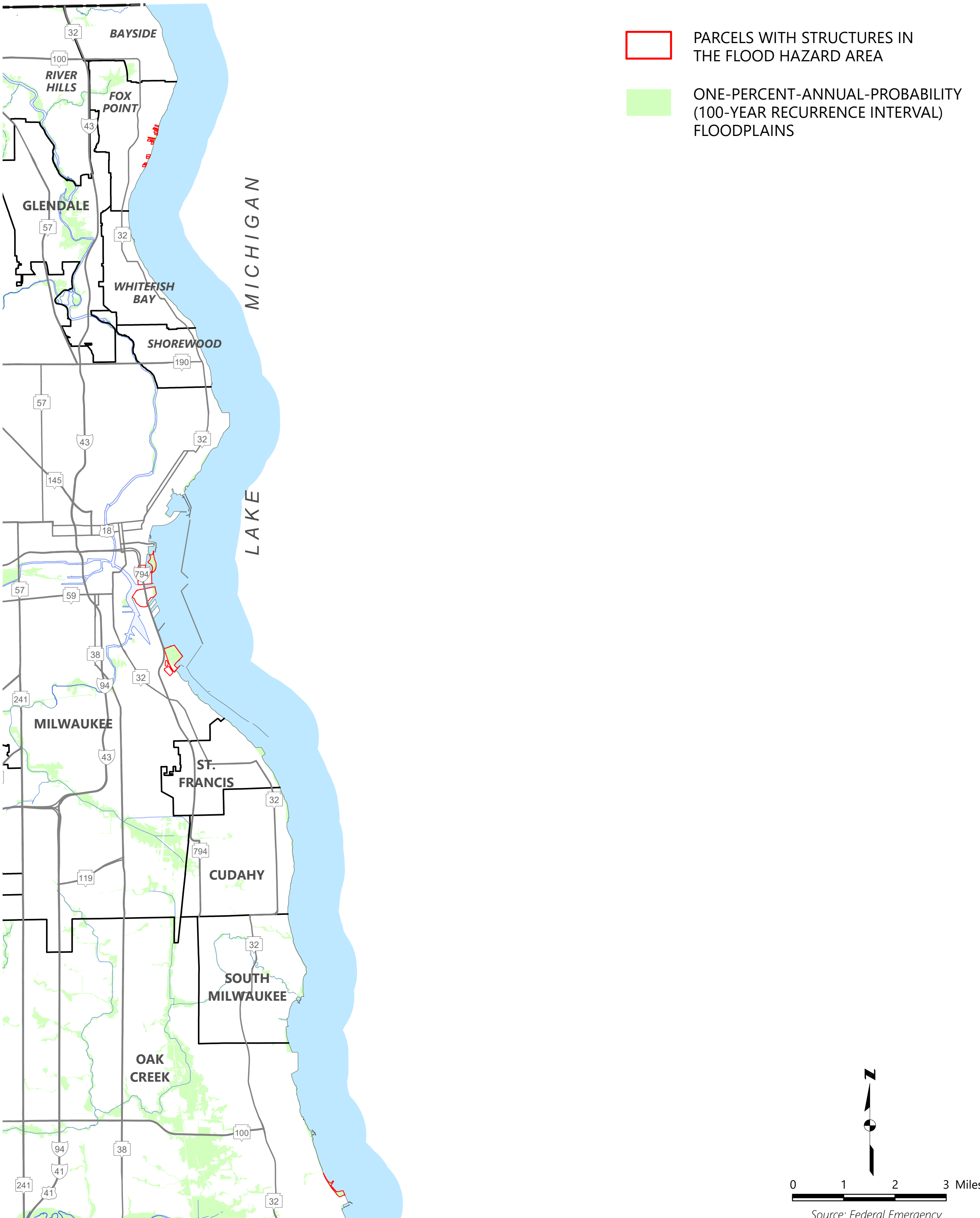
(IN TOTAL FEET)	(PERCENT OF DATA)
GREATER THAN 20 (Greater than 1 Ft/Year)	2.6
10 TO 20 (0.5 to 1 Ft/Year)	0.0
0 TO 10 (0 to 0.5 Ft/Year)	1.0
NO RECESSION	50.6
ACCRETION	45.8

Note: Areas with no data points indicate locations where no nearshore bluff is present.

0 1 2 3 Miles

Source: Wisconsin Shoreline Inventory and Oblique Viewer (Association of State Floodplain Managers, Geo-Professional Consultants, LLC, National Oceanic and Atmospheric Administration, Wisconsin Coastal Management Program) and SEWRPC

Map 3.12
Location of Structures Along the Lake Michigan Coast that are within the One-Percent-Annual-Probability Flood Hazard Area: 2023



Source: Federal Emergency Management Administration, Wisconein Department of Natural Resources, and SEWRPC