# State of Wisconsin
# Homeland Security Council
# Threat & Hazard Identification and Risk Assessment (THIRA)

Wisconsin Emergency Management
Department of Military Affairs

## December 2021

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# 1.0 INTRODUCTION

This is the 2021 State of Wisconsin Threat and Hazard Identification and Risk Assessment (THIRA) developed, promulgated, and maintained by the Wisconsin Department of Military Affairs (DMA), Division of Emergency Management (WEM). This 2021 THIRA is an update to the threats and hazards described in Wisconsin's 2020 THIRA.

## 1.1 Purpose

This THIRA serves as the foundation of the State's planning and preparedness efforts. Specific uses include, but are not limited to, the following:

## 1.2 Unified Reporting Tool

In 2016, the Federal Emergency Management Agency (FEMA) transitioned to an online Unified Reporting Tool (URT) for submittal of the THIRA. The submittal of this THIRA along with the State Preparedness Report (SPR) represents the State's contribution to the national endeavor to base preparedness efforts on data-driven decision making. This THIRA and SPR data, along with data from all other states and jurisdictions, is collected and reviewed by FEMA. This data is used by FEMA and other federal agencies to inform the development of strategic plans, goals, and priorities; develop technical assistance and support; better understand expectations related to federal support; identify areas in need of improvement; and measure progress made in making the nation more resilient.

## 1.3 Preparedness Grant Programs

This THIRA is a requirement for the Homeland Security Grant Program (HSGP) and the Emergency Management Performance Grant Program (EMPG).

## 1.4 Wisconsin Hazard Mitigation Plan

This THIRA serves as the required natural hazard risk assessment section of the 2021 update of the Wisconsin Hazard Mitigation Plan (WHMP). The WHMP establishes the state's mitigation strategy and identifies the goals, recommended actions, and initiatives that will reduce or prevent injury and damage from natural hazards. A FEMA approved state hazard mitigation plan is required for the state to be eligible for federal mitigation funds and certain other disaster assistance.

## 1.5 Confidentiality Statement

This THIRA and SPR data include jurisdiction-specific preparedness data that is FOR OFFICIAL USE ONLY (FOUO). The THIRA and SPR data shared with the Federal Government cannot be distributed outside the Federal Government and is intended for recipients with a clear disaster/emergency preparedness mission and a valid need to know. Receipt of THIRA and SPR data will be accompanied by this confidentiality statement and an interpretation guide.

# 2.0 METHODOLOGY

This 2021 Threat and Hazard Identification and Risk Assessment (THIRA) is an update to the natural hazard identification and risk assessment in the 2016 Wisconsin Hazard Mitigation Plan (WHMP) and the threats and hazards described in the 2020 THIRA. This update focused on:

- Development of the required natural hazard identification and risk assessment element for the 2021 update of the Wisconsin Hazard Mitigation Plan (WHMP).
- Development of the required risk assessment of state owned or operated critical facilities element for the 2021 update of the WHMP.
- Consultations with subject matter experts to review, revise, and update applicable content.

This THIRA update followed the process prescribed by the Department of Homeland Security (DHS) *Threat and Hazard Identification and Risk Assessment Guide, Comprehensive Preparedness Guide (CPG) 201, Third Edition, May 2018*.

## 2.1 THIRA

In 2018, FEMA began implementation of an updated THIRA/SPR methodology. At that time, FEMA required states, territories, and UASIs to complete the THIRA/SPR for the 19 core capabilities shared across mission areas and identified for the Response and Recovery mission areas. In 2019, the states, territories, and UASIs were required to compete the THIRA/SPR for all 32 core capabilities. In addition, at that time the THIRA/SPR moved to three-year reporting cycle.

The THIRA is structured around the CPG 201's three-step process depicted in Figure 2.1-1:

**Figure 2.1-1: THIRA Process**


Source: CPG 201, Third Edition

### 2.1.1 Identify Threats and Hazards of Concern

In Step 1, the state developed a list of threats and hazards based on consideration of the following:

- 2.1.2.1. The reasonable likelihood of the state experiencing a specific threat or hazard.

- 2.1.2.2. The impact of the threat of hazard to challenge at least one of the 32 core capabilities more than any other threat or hazard.

### 2.1.2 Give Threats and Hazards Context

In Step 2, the state developed context descriptions and estimates of impacts for the threats and hazards identified in Step 1.

- 2.1.3.1. Context descriptions are the details of the threat or hazard needed to identify impacts such as:
  - (1) Location
  - (2) Magnitude
  - (3) Time
- 2.1.3.2. Estimate impacts

The THIRA process uses a uniform set of impact measures (i.e., affected population, number of people requiring shelter).

### 2.1.3 Establish Capability Targets

- 2.1.4.1. In Step 3, the state described the capability targets for the 32 core capabilities. These capability targets were developed using the standardized capability target language combined with:
  - (1) Threat or hazard impacts
  - (2) Timeframe measurement
- 2.1.4.2. For the purposes of the THIRA/SPR the standardized targets cover any activity or capability contained within the geographic boundary of the community (e.g., state line).

## 2.2 Review and Ranking

Based on the THIRA process the state identified 13 threats and hazards consisting of:

- 2.2.1.1. Seven natural hazards
- 2.2.1.2. Two technological hazards
- 2.2.1.3. Four human-caused hazards

For the WHMP each of these threats and hazards was further reviewed and ranked based on a qualitative consideration of:

- 2.2.2.1. Probability

Refer to Table 2.2-1 Probability Ranking Criteria for additional information on the probability ranking criteria.

**Table 2.2-1: Probability Ranking Criteria**

| Probability | Description (in terms of frequency) |
|---|---|

| | |
|---|---|
| **Highly Likely** | • Occurs annually or assumed to occur at least once per year. Near 100% probability of occurrence each year. |
| **Likely** | • 10% to 85% probability of occurrence each year. |
| **Occasional** | • Between 1% to <10% probability of occurrence each year. |
| **Unlikely** | • <1% probability of occurrence each year. |

- 2.2.2.2. Vulnerability

Refer to Table 2.2-2 Vulnerability Ranking Criteria for additional information on the vulnerability ranking criteria

**Table 2.2-2: Vulnerability Ranking Criteria**

| Rank | Criteria |
|---|---|
| **High** | • Minimal countermeasures are in place to prevent or protect against this hazard.<br>• Countermeasures may have potential but limited demonstrated history in reducing the threat potential.<br>• The nature of the hazard may limit the availability of countermeasures. |
| **Medium** | • Multiple measures are in place to prevent or protect against this hazard.<br>• Countermeasures have been tested and have demonstrated success in reducing the threat potential. |
| **Low** | • Multiple, reliable, well-coordinated, countermeasures are in place to prevent or protect against this hazard.<br>• Countermeasures have an extensive demonstrated history of testing and success in significantly reducing the threat potential. |

- 2.2.2.3. Mitigation potential

Refer to Table 2.2-3 Mitigation Potential Ranking Criteria for additional information on the mitigation potential criteria.

**Table 2.2-3: Mitigation Potential Ranking Criteria**

| Rank | Criteria |
|---|---|
| **High** | • Methods for reducing risk from the hazard are technically reliable.<br>• The State or counties have experience in implementing mitigation measures.<br>• Mitigation measures are eligible under federal grant programs.<br>• There are multiple possible mitigation measures for the hazard. |

| | |
|---|---|
| | • The mitigation measures are known to be cost-effective.<br>• The mitigation measures protect lives and property for a long period of time or<br>are permanent risk reduction solutions. |
| **Medium** | • Mitigation methods are established.<br>• The State or counties have limited experience with the kinds of measures that<br>may be appropriate to mitigate the hazard.<br>• Some mitigation measures are eligible for federal grants.<br>• There is a limited range of effective mitigation measures for the hazard.<br>• Mitigation measures are cost-effective only in limited circumstances.<br>• Mitigation measures are effective for a reasonably long period of time. |
| **Low** | • Methods for reducing risk from the hazard are not well-established, are not<br>proven reliable, or are experimental.<br>• The State or counties have little or no experience in implementing mitigation<br>measures, and/or no technical knowledge of them.<br>• Mitigation measures are ineligible under federal grant programs.<br>• There is a very limited range of mitigation measures for the hazard, usually only<br>one feasible alternative.<br>• The mitigation measures have not been proven cost-effective and are likely to<br>be expensive compared to the magnitude of the damages caused by the hazard.<br>• The long-term effectiveness of the measure is not known or is known to be<br>relatively poor. |

## 2.3 Critical Facilities Risk Assessment

This update also includes a risk assessment of state owned or operated critical facilities. The risk assessment methodology is based on the requirements found in 44 CFR §§201.4(c)(2)(ii) and 201.4(c)(2)(iii) and further described in the 2015 State Mitigation Plan Review Guide shown in Figure 2.3-1.

**Figure 2.3-1: Risk Assessment for State Assets**

**Does the risk assessment address the vulnerability of state assets located in hazard areas and estimate the potential dollar losses to these assets?**

Intent

To understand vulnerability of assets critical for state resilience as a basis for identifying and prioritizing mitigation actions.

a. The risk assessment must include an analysis of the potential impacts of hazard events to state assets and a summary of the assets most vulnerable to the identified hazards. These assets may be located in the identified hazard areas or affected by the probability of future hazard events.

b. The risk assessment must estimate potential dollar losses to state assets located in identified hazard areas.

Vulnerability and potential losses are not a list or inventory of state facilities but the summary of the potential impacts to those assets from the identified hazards. Factors affecting vulnerability may include asset use and function as well as construction type, age, or intended use.

State assets may include state-owned or operated buildings, infrastructure, and critical facilities.

Critical facilities means structures that the state determines must continue to operate before, during, and after an emergency and/or hazard event and/or are vital to health and safety. Examples of critical facilities may include, but are not limited to:

- Emergency operations centers, police and fire stations, and storage facilities (including data storage).
- Structures that house occupants with restricted mobility or access and/or functional needs, such as hospitals, institutions, and shelters.
- Utility generating, transmission, and storage facilities and related infrastructure, such as power and/or water treatment plants.
- Transportation facilities, such as ports, airports, roads, railroads, bridges, and/or tunnels.

Source: State Mitigation Plan Review Guide, FEMA

Consistent with this guidance the following methodology was used to identify state owned or operated critical facilities and infrastructure for the purpose of developing a state critical facilities risk assessment.

### 2.3.1 Inventory of Assets

Wisconsin Emergency Management (WEM) identified the Wisconsin Department of Administration (DOA) and the University of Wisconsin (UW) System as the best available sources of information on state owned and operated assets. The DOA provided WEM with an all-agencies inventory of assets in an Excel format spreadsheet. This inventory included assets ranging from small storage sheds to large multi-story office buildings. The inventory also included a list of 268 building renovation projects and, security, energy, and life safety upgrades as separate line items, particularly within the DOC. These were not counted as facilities for this assessment. The inventory totaled 6,783 critical and non-critical state owned and buildings, infrastructure, and facilities. Each asset included data such as agency name, institution name, building (asset) name, location, and replacement cost.

The data provided by the UW-System and DOA contains three notable limitations: first, the inventory did not include the state owned and operated roads and bridges that comprise the state highway system. Second, the facility types identified in each data set did not match the categories identified in the State Hazard Mitigation Plan Review Guide. Due to this shortcoming, WEM staff had to conduct a line-by-line review of the facilities to appropriately categorize them. Finally, the DOC data included in the DOA data included building renovations, energy upgrades, security system upgrades, window replacements, and other building improvements as separate line items.

### 2.3.2 Identification of Critical Facilities

The process of identifying critical facilities involved several steps:

1. Consolidate data from the UW-System and the DOA.
2. Scrub the list to identify any building remodels, security updates, renovations, window replacements, or other non-addition improvements to ensure they are not counted as facilities.
3. Conduct a building number match between the 2016 list of critical facilities and the 2020 data set using Microsoft Excel. This match enabled staff reviewing the list to quickly identify facilities deemed critical in the 2016 plan.
4. Review facilities that matched the 2016 Hazard Mitigation Plan and ensure they are still considered “critical.” This review resulted in some differences between this version and the 2016 version.
5. Review all other data to determine which are facilities should be included as “critical” based on their function or value to the state.
6. Assign facility types to all facilities considered “critical” in the spreadsheet. The identification of critical facilities was based on the 2011 WHMP definition amended consistent with the State Mitigation Plan Review Guide 2015. The resulting definition of critical facilities is as follows:

   **Critical facilities** are state-owned [or operated][1] facilities deemed essential due to their function, size, service area, uniqueness, delivery of vital services, and for the protection of the health and safety of citizens including buildings and infrastructure that meet characteristics such as:

   - Communications facilities;
   - Correctional facilities and other custodial facilities, including facility utility services;
   - Utility services, including: electrical power generation, heating, wastewater treatment, water treatment, etc.;
   - Hospitals and other medical facilities, including: group homes, shelters, mental health facilities, etc.;
   - Major State government facilities that house key state operations;
   - Critical military facilities; and
   - Emergency response facilities, including: law enforcement, security, fire, etc.

[1] From State Mitigation Plan Review Guide, FEMA, Effective March 2016

- [Transportation facilities such as ports, airports, roads, railroads, bridges, and/or tunnels.][2]
- 2021 State Additions to Definition: State owned assets worth more than $100,000,000 dollars.

### 2.3.3 Addition of Location Information

The data provided by the DOA and the UW System did not include latitude or longitude information. The only location data included was the street address of the facilities. WEM's Geographic Information System (GIS) analyst used a geolocation tool to convert street addresses into latitude and longitude information for all 1,070 critical facilities. Further, if critical assets could be reasonably identified on aerials photographs the latitude and longitude information was added. Location information was sourced from agency information, web sources, and Google™ Maps. This type of correction was primarily applied to communications tower sites as their street address often reflected a point a significant distance from the facility itself.

### 2.3.4 Critical Facilities and Special Flood Hazard Area

The inventory of assets information was manipulated using the ESRI GIS to identify critical facilities located in a FEMA-designated special flood hazard area (SFHA). The GIS analysis sought to identify the number and value of critical facilities located in the SFHA.

### 2.3.5 Assessment

WEM used the combination of tables, charts, and GIS maps to analyze location and potential threats to the identified critical facilities

[2] From State Mitigation Plan Review Guide, FEMA, Effective March 2016

# 3.1 CLIMATE CHANGE

*"Since I took office, much of my time as lieutenant governor has been spent learning about the impact climate change has been having on our state. Extreme weather generates a costly toll on farmers and their crops. Flooding is impacting homes, infrastructure, and water quality. Deadly cold spells have shut down our state. And our Great Lakes are experiencing a period of record-high water levels, which has grave consequences for coastal ecosystems and will cost communities millions of dollars."*

--Mandela Barnes, Wisconsin's Lieutenant Governor, Governor's Task Force on Climate Change Report.

## 3.1.1 Purpose and Background

It is undeniable, Earth's climate is changing. A few lines of evidence to support this climatic change include the rise in atmospheric and ocean temperatures, shrinking glaciers and sea ice, melting permafrost, and the increase in severe weather events. Humans and their relationship to the landscape is the driving factor in climate change. The burning of fossil fuels and land use changes have accelerated any climate change that would have occurred naturally over the last 200 years. Implications of this changing climate include, but are not limited to, a decaying infrastructure, declining human health and emotional stability, landscape degradation, lower biodiversity, and increased risk of natural disasters. In this section, the nature of climate change will be examined, with special attention paid to the state of Wisconsin and the associated impacts.

Changing climate patterns are likely to have different impacts on different systems in different areas, making it difficult to generalize. In any event, emergency managers will be responsible for preparing for and responding to natural disasters. It is important to incorporate the best available climate data into hazard mitigation planning.

Most risk assessments rely on past occurrences of a given hazard to make predictions about future occurrences; if future conditions are significantly different than past conditions, this strategy will be inadequate. Considering potential changes in future conditions when developing mitigation strategies will result in projects that are resilient to increasingly severe future hazards, adaptable to variable conditions, energy efficient, and in harmony with natural systems.

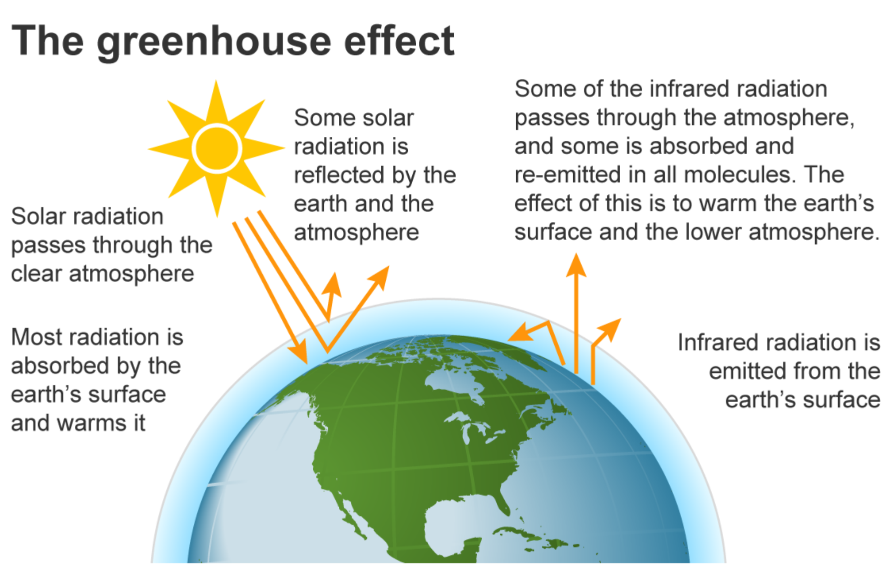
Because changes in climate patterns occur over the course of decades, mitigation plans must take a long-term approach. Mitigation plans must recognize that current best practices and existing infrastructure are based on past conditions rather than current or future trends. This may mean that they are already outdated for today's conditions, not to mention future conditions that are different than the past or present. Mitigation planners are left with the responsibility of planning for uncertain conditions, despite natural human hesitance to break from the norm.

### 3.1.2 The Science of Climate Change

The history of climate change is rooted in 19th century scientific investigations. Numerous individuals moved the needle so that a detailed understanding of climate change could be understood today. In the 1820s Joseph Fourier, a French mathematician and physicist, put forth the groundwork when he calculated that the earth would be colder than it was currently if not for the atmosphere. The mechanism of heating was still unknown, and Eunice Foote (1856) and John Tyndall (1862) are generally credited with the discovery that certain gases prevent heat from leaving earth's surface. It 1896 Svante Arrhenius suggested that the burning of fossil fuels (coal, oil, natural gas) would add carbon dioxide to the atmosphere and ultimately raise the temperature of earth. Thus, the die was cast, and human activity was anticipated to be at the forefront of future climatic changes. The scientific understanding of climate change was well underway as the 20th century began.

The term "greenhouse effect" is the process used to describe the interaction between radiation and the atmosphere. Atmospheric warming exists because the rays of the sun heat the surface of earth and cause longwave radiation to be absorbed by the atmosphere, like how a greenhouse is heated (Figure 3.1.2-1). Scientists have found that the primary gases responsible for atmospheric warming are carbon dioxide, water vapor, methane, and nitrous oxide. These four gases are typically referred to as greenhouse gases. The greater concentration of these greenhouse gases in the atmosphere, the greater the warming.

**Figure 3.1.2-1. Representation of How the Greenhouse Effect Warms Earth**




Source: U.S. Energy Information Administration

Three ways that humans have altered the climate are: (1) through the direct release of heat to the atmosphere from buildings, cars, air conditioners, etc.; (2) land use changes that include the conversion of forests to agricultural lands, urbanization, etc. and (3) altering the composition of the atmosphere through the burning of coal or the decomposition of landfill waste. Land use change and the addition of gases to the atmosphere do not occur individually, but rather systematically. A simple example is that increased population led to land clearance for urban areas, which lead to more electricity producing buildings and vehicles and ultimately the amplified release of fossil fuels.

Scientific consensus, supported by the evidence, is that humans are the driving variable in climate change. In 2021, the Intergovernmental Panel on Climate Change (IPCC) concluded that greenhouse gas emissions were responsible for an increase of 1.1°C of warming between 1850-1900. Unless there is an immediate and rapid decrease in greenhouse gas emissions there is little chance to limit warming to 2.0°C within the next 20 years.

C*limate Change Models*

Climate models rely on a well-established understanding of the physical process that drive weather and climate. The complexity of model building exists because of the delicate interaction of systematic variables at multiple spatial scales. To build a model, initial and past conditions need to be established. Once this is done a model can be established. Models are tested through a process called hindcasting. The constructed model is compared to known conditions in the past. Based on the results, variables in the model can up adjusted to refine and reduce model error.

If hindcasting proves successful, then models can begin to examine future conditions. Climate forcing variables are adjusted to expected future conditions. A few of the variables that influence future conditions include population growth, land use change, and atmospheric conditions.

*Evidence of Climate Change*

According to NASA there are numerous indicators signaling climate change. These include global temperature rise, warming ocean temperatures, shrinking ice sheets, glacial retreat, decreased snow cover, sea level rise, declining arctic sea ice, increased number of extreme events, and ocean acidification. Technical advances in monitoring and measurement devices, such as, the monitoring of greenhouse gas emissions and earth-orbiting satellites provide the tools required that align indicators to climate change. For example, atmospheric carbon dioxide measured at the Mauna Loa Observatory has risen from approximately 300 ppm in 1950 to 420 ppm in 2021 (Figures 3.1.3-1 and 3.1.3-2). This rapid increase is attributed to human induced modifications of the landscape and the burning of fossil fuels.

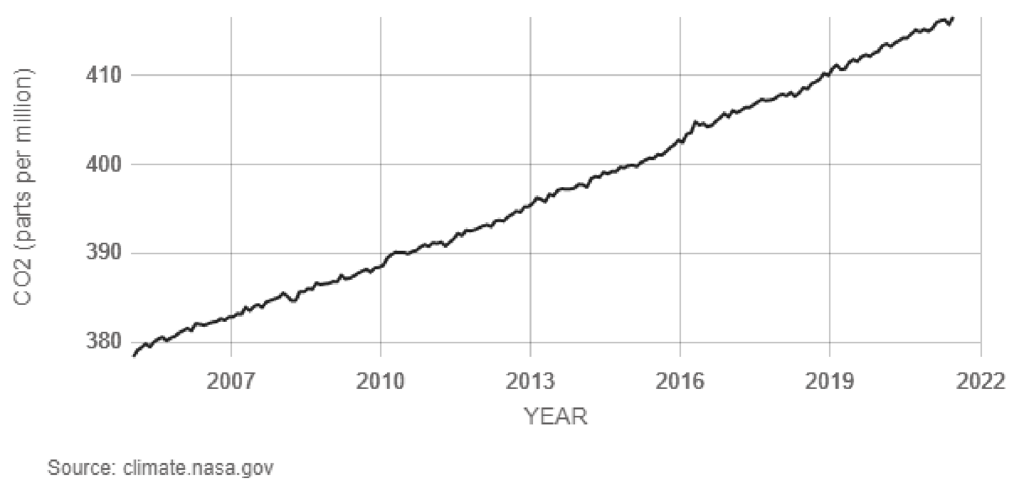
### 3.1.3 Wisconsin’s Changing Climate

For the most part, Wisconsin’s climate is getting warmer and wetter. Mean annual temperatures have increased over the last 50 years and more high magnitude precipitation events are occurring. The effects of a changing climate in Wisconsin have been documented by leading research scientists and a host of state divisions and individual organizations across the state. It is nearly impossible to acknowledge all the positive climate change work occurring in the state, but one collective body must be recognized as the climate change hub. The Wisconsin Initiative on Climate Change Impacts (WICCI) was organized in 2007 and is represented by individuals from state and federal agencies, tribal organizations, businesses and nonprofit groups, and UW System scientists. The first WICCI report was published in 2011 and listed the following goals:

- Assess and anticipate climate change impacts upon Wisconsin's natural and built environment.
- Evaluate risks and vulnerabilities within our ecosystem, infrastructure, industries, agriculture, tourism, and other human and natural systems.
- Recommend practical adaptation strategies and solutions that businesses, farmers, public health officials, municipalities, resource managers and other stakeholders can implement.

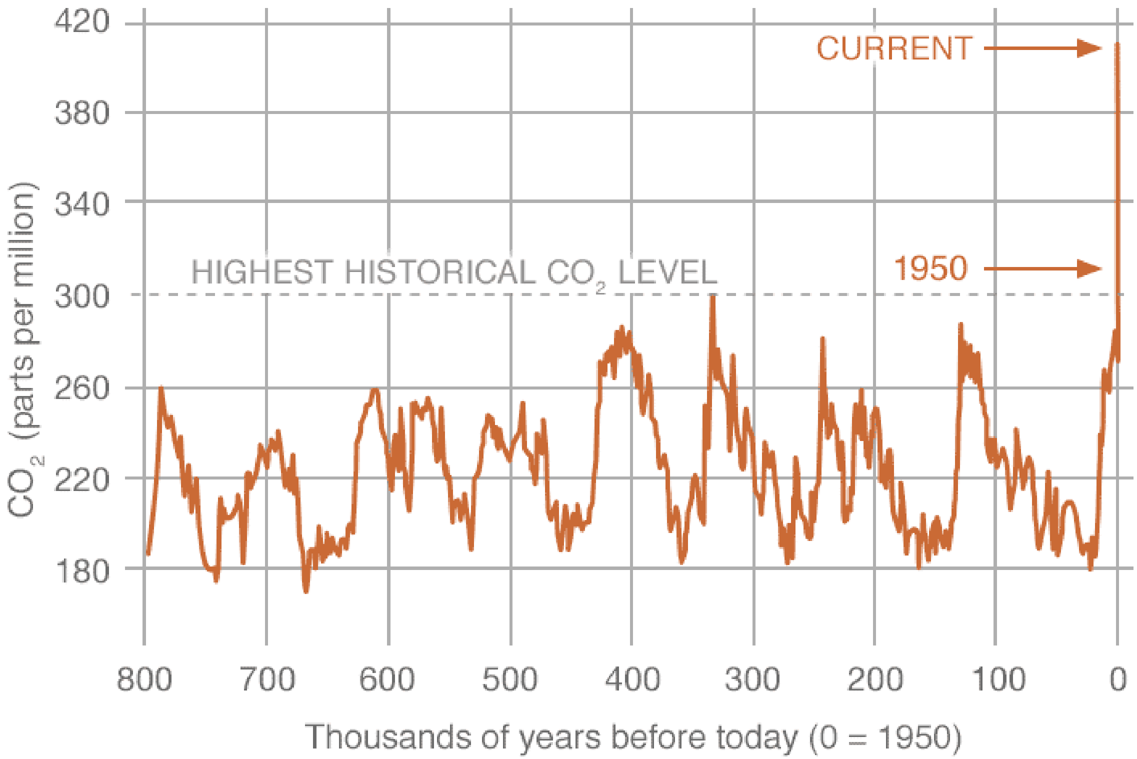
The working group is still active and updated information on climate can be found on the WICCI website (https://wicci.wisc.edu/). An updated WICCI report is scheduled for release in 2021. Much of the information in this section of the state plan on climate change finds its roots in the 2011 WICCI report, updated information in the WICCI website, and personal communications with Dan Vimont, WICCI co-director.

**Figure 3.1.3-1 Direct (2005-2020) Measures of Carbon Dioxide for Mauna Loa Observatory**




Source: NASA

**Figure 3.1.3-2: Indirect Measures of Carbon Dioxide Reconstructed from Ice Cores**



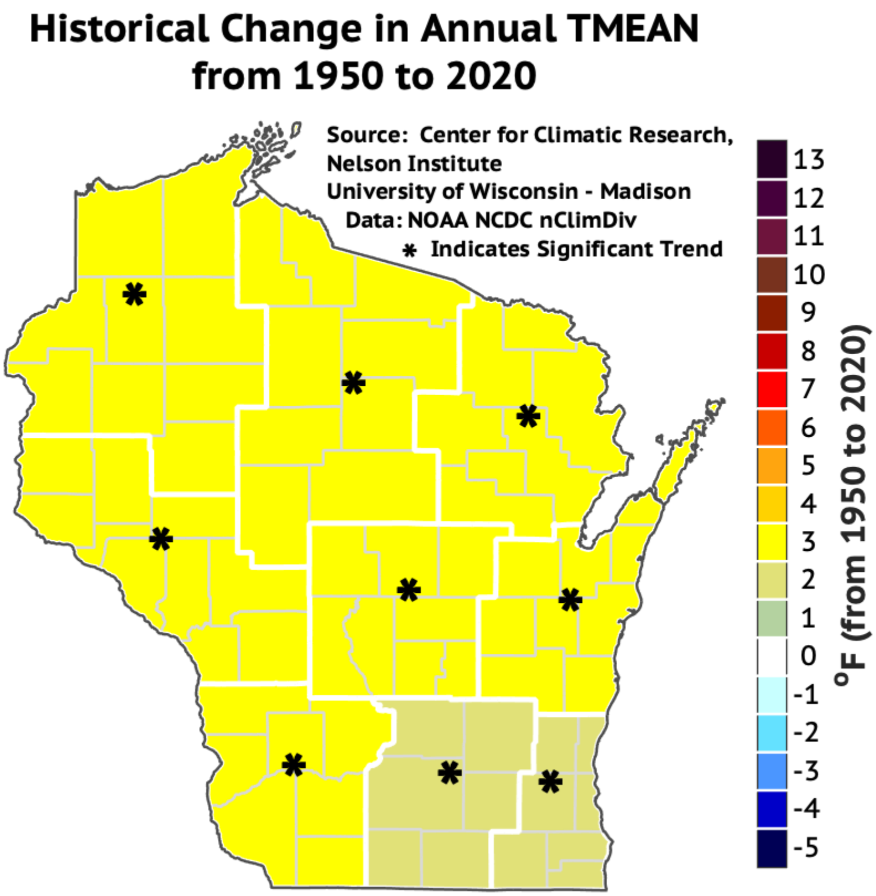

Source: NASA

### 3.1.4 Trends and Projections

*Temperature Trends (1950-2020)*

Since 1950 there has been a change in the annual daily average temperature across the state. On average this change is approximately 2.5° F (Figure 3.1.4-1). When temperature is examined by season, the greatest increase exists in the winter (Table 3.1.4-1). Winter (Dec-Feb) temperatures have increased 4-5° F with the greatest increase in the northern and central portion of the state. The least amount of change has occurred in the summer (Jun-Aug) and fall (Sept-Oct), where temperatures have increased approximately 2° F. Additional information on temperature change exists for average annual daily maximum and minimum. Perhaps the most alarming is the increase in average winter daily minimum temperature of 5-7° F (Figure 3.1.4-2).

**Figure 3.1.4-1: Mean Annual Temperature Change in Wisconsin, 1950-2020**



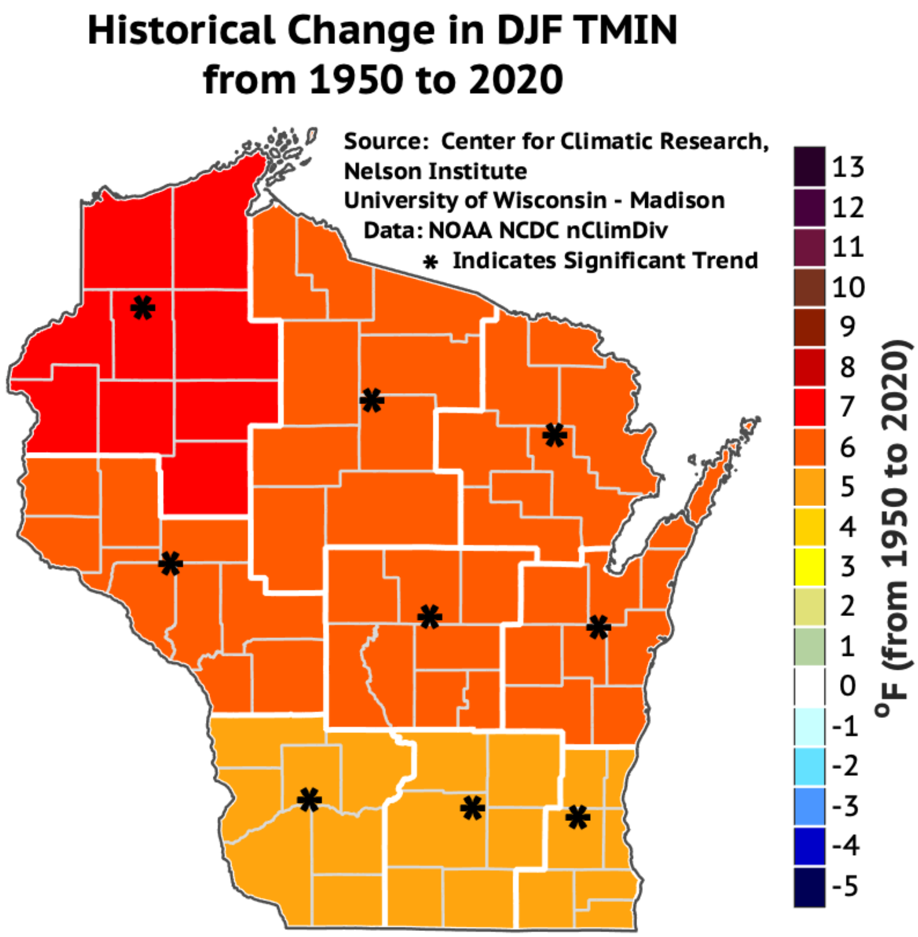

Source: WICCI

**Table 3.1.4-1: Change in annual daily mean temperature (1950-2020) by season.**

| Region | Change in Winter Daily Ave. Temp. | Change in Summer Daily Ave. Temp | Change in Spring Daily Ave. Temp. | Change in Fall Daily Ave. Temp. |
|---|---|---|---|---|
| Northwest | + 5° F | + 2° F | + 3° F | + 2° F |
| Northcentral | + 5° F | + 2° F | + 3° F | + 2° F |
| Northeast | + 5° F | + 2° F | + 3° F | + 2° F |
| West central | + 5° F | + 2° F | + 3° F | + 2° F |
| Central | + 5° F | + 2° F | + 3° F | + 2° F |
| East central | + 5° F | + 2° F | + 3° F | + 2° F |
| Southwest | + 4° F | + 2° F | + 3° F | + 2° F |
| Southcentral | + 4° F | + 2° F | + 2° F | + 2° F |
| Southeast | + 4° F | + 1° F | + 2° F | + 2° F |

Source: WICCI

**Figure 3.1.4-2: Change in Winter Minimum Temperatures, 1950-2020**




Source: WICCI

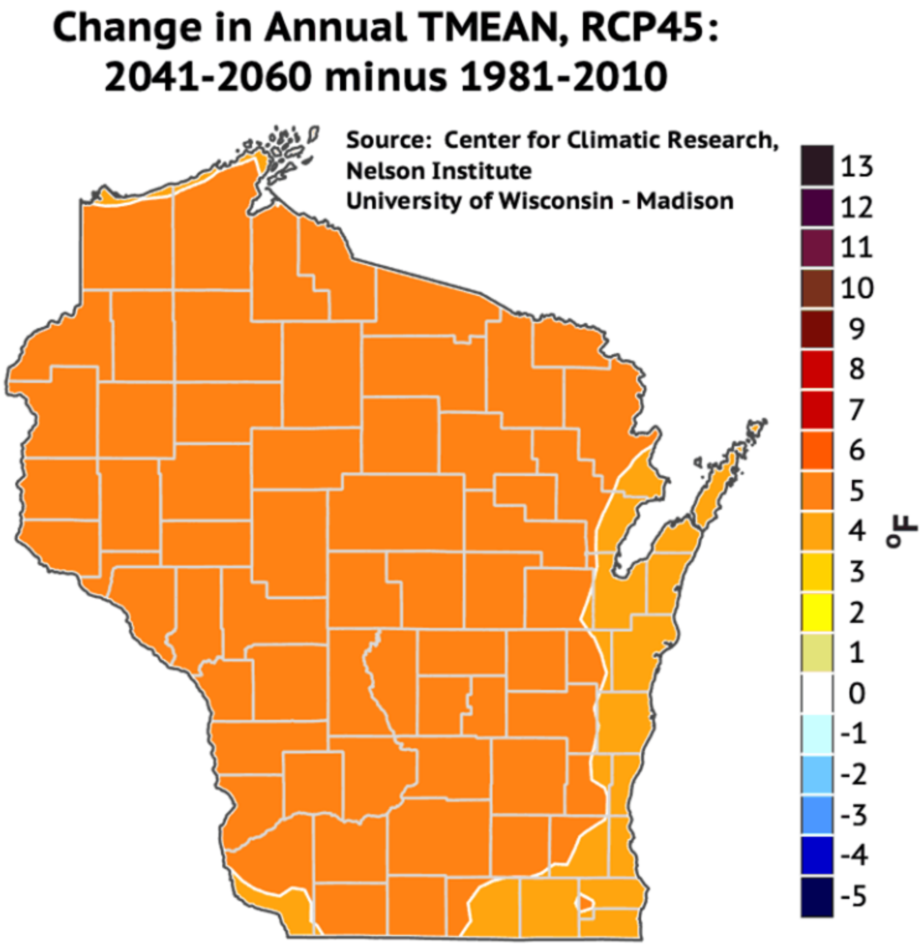
*Climate Projections (2041-2060)*

The climate is projected to get warmer in Wisconsin over the next few decades (Figure 3.1.4-3). Much of the state will see a 4-5° F increase in mean daily temperature. Winter temperatures are expected to rise the most. It is estimated that an increase of 6-7° F is likely. Other likely changes will include a decrease in the nights per year that temperature is <32° F. Northern Wisconsin is projected to see the greatest reduction in the <32° F with a decrease of 40 days from the 1981-2010 historical average. Days per year with temperatures over 90° F will increase. It is projected that southern Wisconsin will have the greatest number of days over 90° F, but it is likely that the rest of the state will see 20 more days of these high temperatures (Figure 3.1.4-4). A few implications for this increased warming are listed below:

- Increased health risk associated with extreme heating events, especially for the elderly and young without access to air conditioning.
- Winter recreation activities will be shortened or removed altogether. These include ice fishing, snowmobiling, skiing.

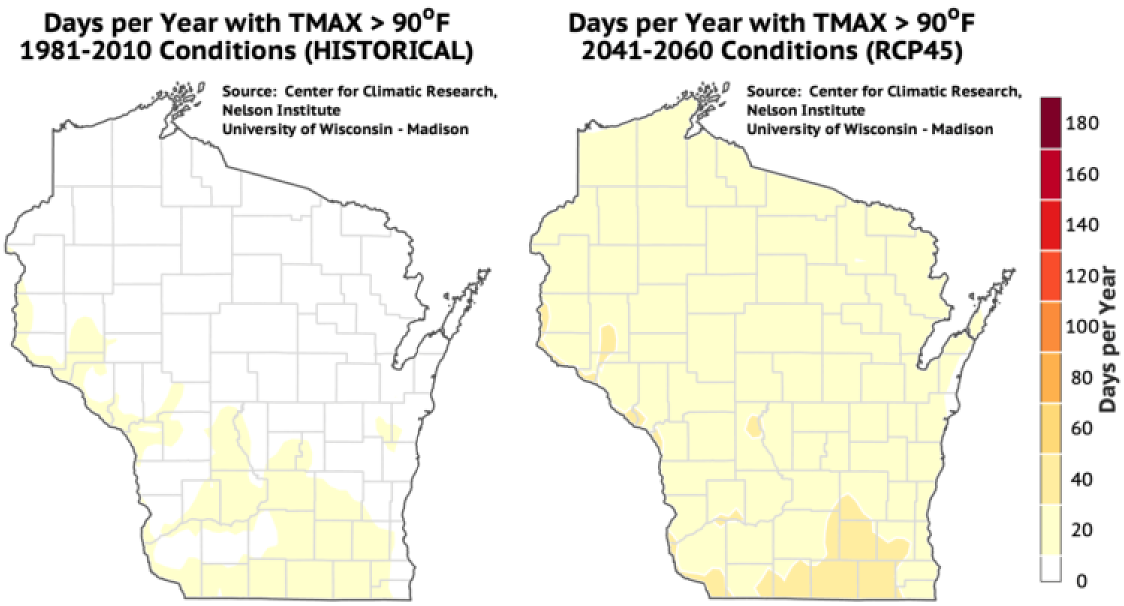
- Extreme temperatures could decrease crop yields, especially if these temperatures are accompanied by severe droughts.
- Increased water temperatures in lakes and rivers will change the composition of fish species. Cold water species like trout are easily stressed and will face an uncertain future.
- The duration of ice cover on lake will be reduced.

**Figure 3.1.4-3 Change in Modeled Mean Annual Temperature**




Source: WICCI

**Figure 3.1.4-4: Change in Days Over 90°F**

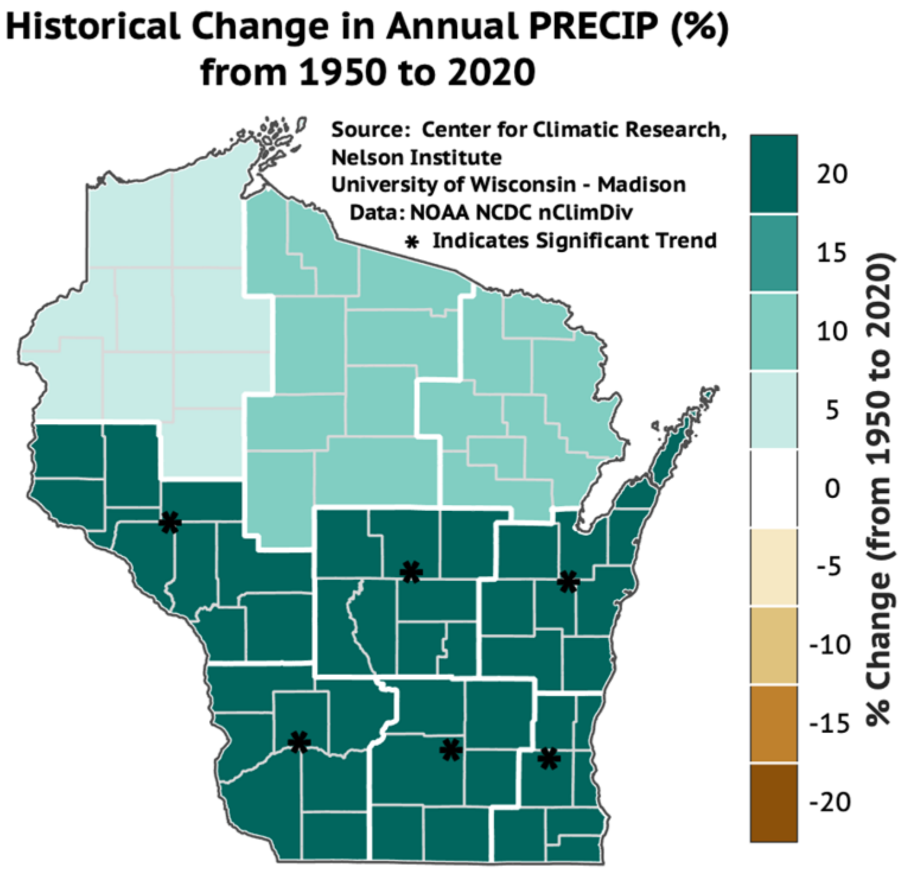



Source: WICCI

*Precipitation Trends (1950-2020)*

Like temperature, there has been a positive trend in annual precipitation across the state (Figure 3.1.4-5). The southern two-thirds have seen a much greater increase than the northern third. The lower two-thirds of Wisconsin witnessed an increase of 20 percent in annual precipitation, whereas the northern third increased 5-10 percent. Seasonal changes are most pronounced in the fall (Sept-Nov) and winter (Dec-Feb) (Table 3.1.4-2). During fall a 10-20 percent increase occurred, with the great percentages bordering central Wisconsin. The winter months accrued an increase in 20 percent. Summer (June-Aug) precipitation remain unchanged or decreased in northern Wisconsin and substantially increased in most of the lower two-thirds of the state. Spring (Mar-May) precipitation remined unchanged or slightly increased in much of northern Wisconsin and the lower two-thirds of the state. The slight change in summer and spring in the northern third of the state is most likely attributed to lower precipitation during two multi-level droughts that occurred in the 1990s and 2000s.

**Figure 3.1.4-5: Historical Changes in Annual Precipitation Between 1950-2020**




Source: WICCI

**Table 3.1.4-2: Change in season precipitation (1950-2020) by season.**

| Region | Change in Winter Precipitation | Change in Summer Precipitation | Change in Spring Precipitation | Change in Fall Precipitation |
|---|---|---|---|---|
| Northwest | +20% | -10% | +5% | + 20% |
| Northcentral | +20% | -5% | +5% | + 20% |
| Northeast | +20% | 0% | 0% | + 20% |
| West central | +20% | +10% | +20% | + 20% |
| Central | +20% | +20% | +20% | + 10% |
| East central | +20% | +20% | +20% | + 20% |
| Southwest | +20% | +20% | +20% | + 20% |
| Southcentral | +20% | +20% | +20% | + 20% |
| Southeast | +20% | +5% | +20% | + 20% |

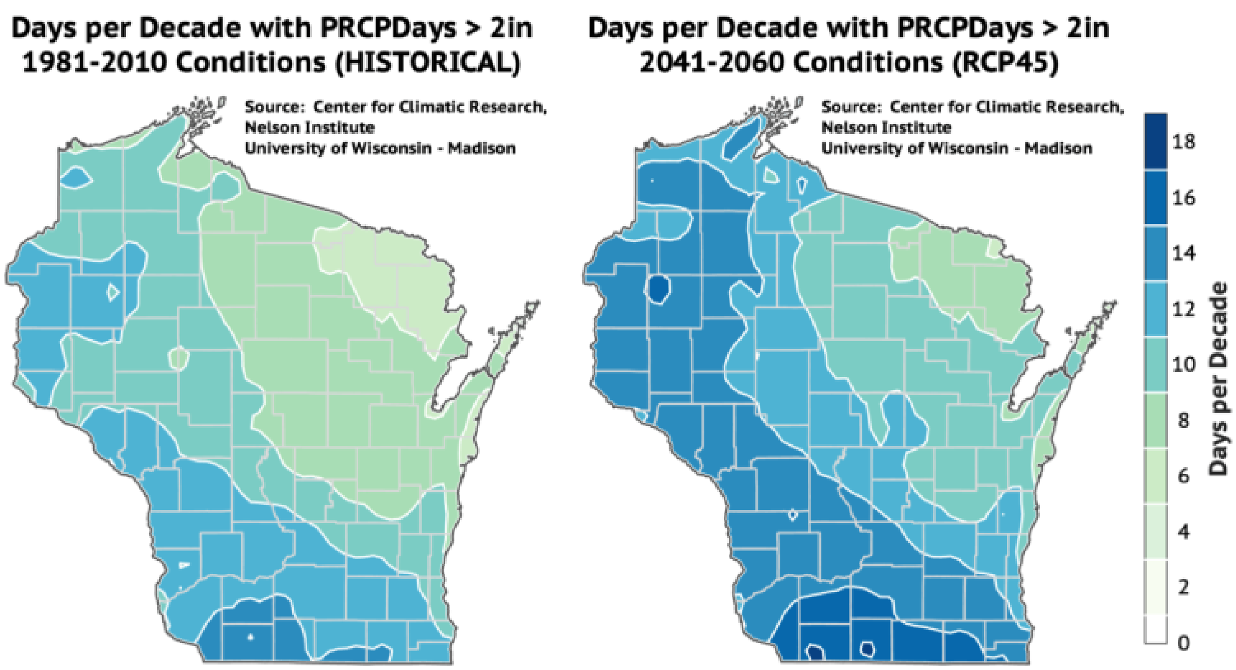
Source: WICCI

*Precipitation Projections (2041-2060)*

Projected changes suggest a statewide average increase in precipitation of 5 percent. The greatest increases will occur in the winter and spring. Projections suggest that much of the state will witness an increase of 10 percent during these two seasons. Summer precipitation will remain unchanged in the southern portion of the state, but a slight 5 percent increase is projected in the central and northwest. Fall precipitation is projected to increase around 5 percent statewide. Higher magnitude events (1-5 inches) have been modeled and are expected to increase statewide (Figures 3.1.4-6; Figure 3.1.4-7). The greatest increase in these high magnitude events is projected to occur along a southeast-to-northwest transect. The frequency increase projected in the southwest portion of the state is especially alarming because the watershed characteristics of this region allow for extreme flash flooding. A few implications for precipitation changes are listed below:

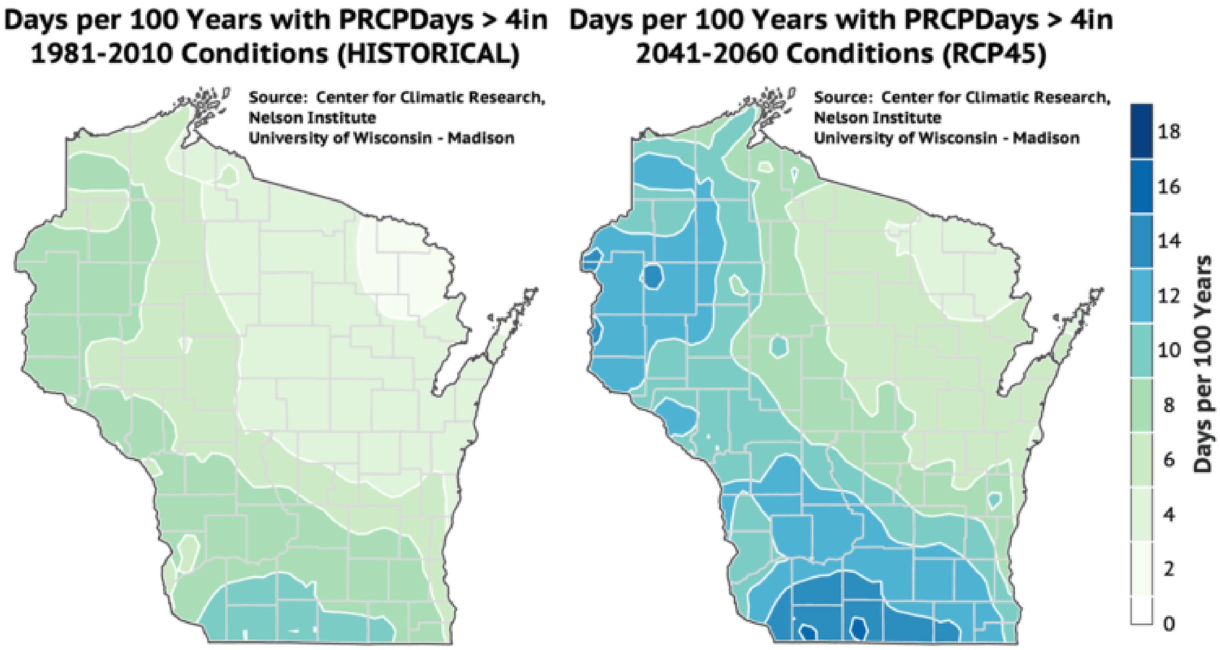
- Heavy precipitation events will increase the amount of runoff to lakes – increasing nutrients, sediment, and other pollutants.
- Increased flooding is likely across the state.
- Surface water levels – lakes and rivers – will change.
- Increased groundwater recharge is likely across certain regions of the state.

**Figure 3.1.4-6: Days Per Decade of >2-inch Precipitation Event.**




Source: WICCI

**Figure 3.1.4-7: Days Per Century of >4-inch Precipitation Event.**




Source: WICCI

*Climate Change and Mitigation and Adaptation*

The climate of Wisconsin is changing. The spatial and temporal distribution of this change is based on geography. Because the natural system is complex and interrelated, it is critical that structures of government and non-government organizations work together to adapt to circumstances brought on by deviations in temperature and precipitation. Recognizing and preparing for risk is extremely valuable, even when the consequences are not yet known. Aligning climate change to mitigation and adaptation strategies should be at the forefront of all hazard risk assessments in Wisconsin. Incorporated throughout the 2021 state hazard mitigation plan are strategies to reduce the risk associated with disasters in a changing climate. Table 3.1.4-3 provides links to websites on climate change for multi levels of governments, organizations, and Tribal Nations.

**Table 3.1.4-3: Climate Change Resources**

| Organizational Level | Organization | Link to Website |
|---|---|---|
| Global | United Nations | http://www.ipcc.ch/<br>https://www.un.org/en/climatechange<br>https://public.wmo.int/en |
| United States | Environmental Protection Agency (EPA) | https://www.epa.gov/climate-change |
| | National Oceanic and Atmospheric Association (NOAA) | https://www.ncdc.noaa.gov/rcsd |
| | National Aeronautics and Space Administration (NASA) | http://climate.nasa.gov/ |
| | Federal Emergency Management Administration (FEMA) | www.fema.gov/climate-change |
| | U.S. Global Change Research Program | www.globalchange.gov |
| | U.S. Climate Resilience Toolkit | http://toolkit.climate.gov/ |
| | 2018 National Climate Assessment (USGCRP) | https://nca2018.globalchange.gov/<br>https://nca2018.globalchange.gov/chapter/21/ |
| Wisconsin | Wisconsin DNR | https://dnr.wisconsin.gov/climatechange |
| | Nelson Institute for Environmental Studies | https://nelson.wisc.edu/ccr/index.php |
| | Wisconsin Initiative on Climate Change Impacts (WICCI) | http://www.wicci.wisc.edu/<br>http://www.wicci.wisc.edu/climate-change.php |
| | Climate Wisconsin | www.climatewisconsin.org |
| Tribal Nations | National Congress of American Indians | https://www.ncai.org/policy-issues/land-natural-resources/climate-change |
| | U.S. Climate Resilience Toolkit | https://toolkit.climate.gov/topics/tribal-nations |
| County Examples | Dane and Milwaukee | https://daneclimateaction.org/<br>https://city.milwaukee.gov/climate/Climate-Plan |

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# 3.2 SEVERE WEATHER

**(including thunderstorms, high winds and tornadoes, hail, and lightning)**

## 3.2.1 Nature of the Hazard

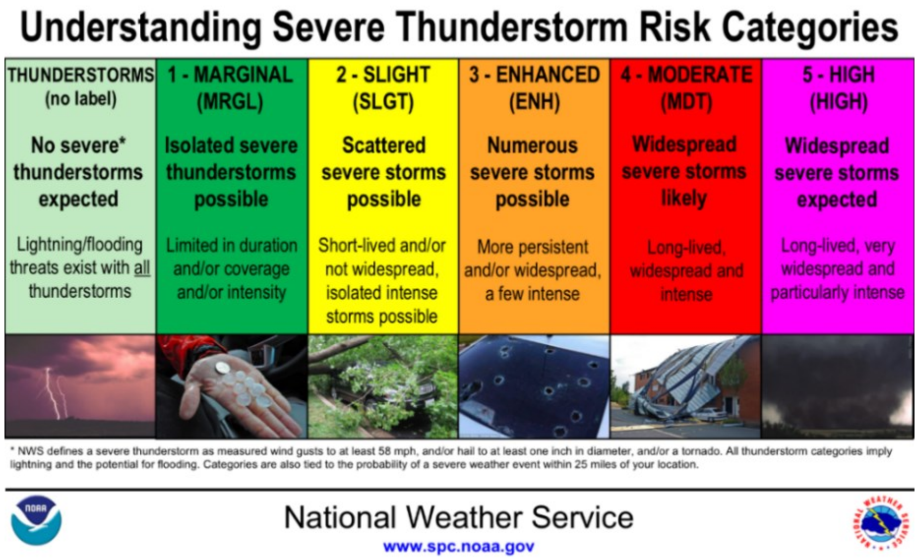
NOAA's National Center for Environmental Information (NCEI) defines severe weather as "destructive storm or weather" that is "usually applied to local, intense, often damaging storms such as thunderstorms, hailstorms, and tornadoes." While this definition can cover a variety of hazards beyond the previously listed ones, thunderstorms, tornadoes, high winds, hail, and lightning are the most prevalent in Wisconsin. Thus, these five are the focus for the following section. Although related to severe weather, flooding, drought and extreme heat, and winter storms and extreme cold all have their own sections in the state hazard mitigation plan.

**Thunderstorms** are generated by an upward motion of unstable air (convection) that contains a high amount of moisture. They are characterized by heavy rain, high winds, downbursts, tornadoes, hail, and lightning. Occasionally, thunderstorms occur in winter during heavy snow events. Although, more typically, Wisconsin experiences the most thunderstorms during the summer months. Wisconsin thunderstorms are approximately 15 miles across and last for about 30 minutes, but events of longer duration or with high rates of precipitation can lead to flooding. The National Weather Service (NWS) classifies a thunderstorm as severe if one or more of the following conditions are met:

1. Winds reach or exceed 58 mph
2. The storm produces a tornado
3. The storm produces hail at least one inch in diameter
4. Flash flooding occurs

Severe thunderstorms can also be categorized according to the levels in Figure 3.2.1-1 below.

**Figure 3.2.1-1: Severe Thunderstorm Risk Categories**




Source: NOAA, Storm Prediction Center (SPC)

**High winds** can occur during severe thunderstorms or with a strong weather system. Figure 3.2.1-2 gives the threat levels to life and property based on the windspeed. The National Severe Storms Laboratory (NSSL) classifies damaging winds using the following terms:

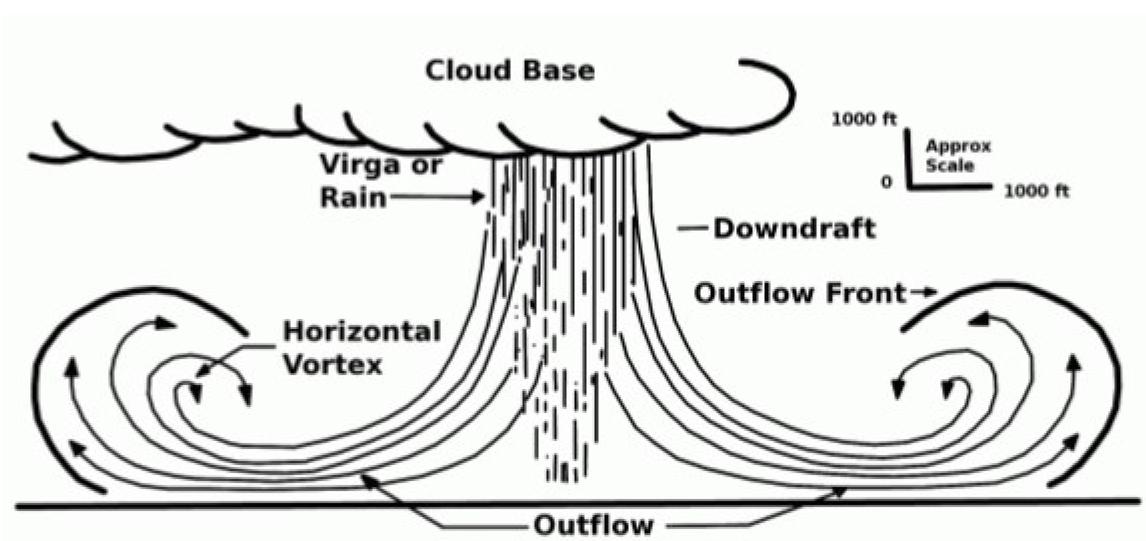
1. **Straight-line winds** are associated with thunderstorms, but do not have rotations. This term is used to differentiate straight-line from tornadic winds.
2. A **downdraft** (Figure 3.2.1-3) is a small-scale column of air that rapidly sinks toward the ground.
3. A **downburst** is a burst of strong winds that occur when a downdraft reaches the ground. Downbursts can be separated into microbursts and macrobursts.
    a. A **microburst** is a small, concentrated downburst that produces an outward burst of strong winds at or near the surface of the earth with horizontal dimensions less than 2.5 miles across. Microbursts are short-lived (2-5 minutes) and can have windspeeds up to 168 mph.
    b. A **macroburst** is an outward burst of strong winds at or near ground with horizontal dimensions larger than 2.5 miles. Compared to microbursts, macroburst winds are not as strong, but are spread out over a larger area and last longer (5-20 minutes).
4. A **gust front** is the leading edge of rain-cooled air that clashes with warmer thunderstorm inflow.
5. A **derecho** is a widespread, long-lived windstorm that is associated with a band of rapidly moving showers or thunderstorms.
6. A **haboob** is a wall of dust that is pushed out along the ground from a thunderstorm downdraft at high speeds.

**Figure 3.2.1-2: High Wind Threat Level Descriptions**

| High Wind Threat Level | Threat Level Descriptions |
|---|---|
| **Extreme** | **"An Extreme Threat to Life and Property from High Wind."** "Damaging high wind" with sustained speeds greater than 58 mph, or frequent wind gusts greater than 58 mph. Damaging wind conditions are consistent with a high wind warning. |
| **High** | **"A High Threat to Life and Property from High Wind."** "High wind" with sustained speeds of 40 to 57 mph. Wind conditions consistent with a high wind warning. |
| **Moderate** | **"A Moderate Threat to Life and Property from High Wind."** "Very windy" with sustained speeds of 26 to 39 mph, or frequent wind gusts of 35 to 57 mph. Wind conditions consistent with a wind advisory. |
| **Low** | **"A Low Threat to Life and Property from High Wind."** "Windy" conditions. Sustained wind speeds of 21 to 25 mph, or frequent wind gusts of 30 to 35 mph. |
| **Very Low** | **" A Very Low Threat to Life and Property from High Wind."** "Breezy" to "Windy" conditions. Sustained wind speeds around 20 mph, or frequent gusts of 25 to 30 mph. |
| **Non-Threatening** | **" No Discernable Threat to Life and Property from High Wind."** The sustain wind speeds are non-threatening; "breezy" conditions may still be present. |

Source: NOAA, NWS, Melbourne

**Figure 3.2.1-3: Downdraft Diagram**



Source: NOAA, NWS, Norman

A **tornado** is a violently rotating column of air (vortex) extending from the base of a convective cloud (usually cumulonimbus) to the ground. Tornadoes form in many parts of the world under many types of conditions; however, the most common conditions in Wisconsin are intense squall lines and supercell thunderstorms. Tornadoes can be classified as supercell or non-supercell:

1. **Supercell tornadoes** are derived from supercell thunderstorms of which a key component is a rotating updraft. These tornadoes can be devastating.
2. **Non-supercell tornadoes** are formed by a spinning column of air near the ground and tend to be short-lived and weaker than supercell tornadoes. Non-supercell tornadoes include gustnadoes, land spouts, and waterspouts.

Most tornadoes in the U.S. last less than ten minutes but can exist for more than an hour. The path of a tornado can range from a few hundred feet to miles and tornado widths may range from tens of yards to a mile or two.

In 1971, researchers Tetsuya Fujita and Allen Pearson developed the Fujita-Pearson Scale (F-Scale) for measuring tornado intensity. In 2007, the US National Weather Service created the refined Enhanced Fujita Tornado Scale (EF-Scale) based on empirical data (Table 3.2.1-1). Both scales indicate damage only – associated wind speeds are only estimations.

**Table 3.2.1-1: Enhanced Fujita Tornado Scale (EF-Scale)**

| Category | F-Scale Wind Speed (mph) | EF-Scale Wind Speed (mph) |
|---|---|---|
| EF0 (weak) | 40-72 | 65-85 |
| EF1 (weak) | 73-112 | 86-110 |
| EF2 (strong) | 113-157 | 111-135 |
| EF3 (strong) | 158-206 | 136-165 |
| EF4 (violent) | 207-260 | 166-200 |
| EF5 (violent) | 261-318 | >200 |

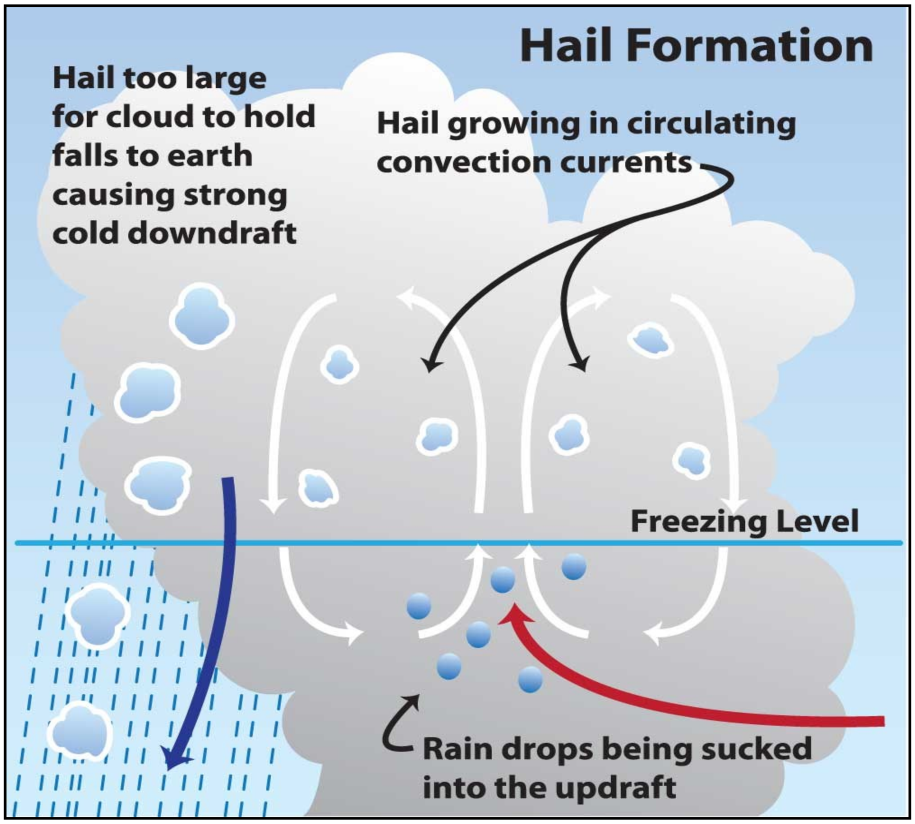
Source: NOAA, NWS

The new EF-Scale keeps the previous numerical values of zero to five from the old F-Scale and maintains the same degree of damage associated with each rating value. However, the estimated wind speed values associated with the higher numerical ratings were lowered in the EF-Scale based on engineering studies and meteorological research. Consequently, the damage inflicted by an F-4 tornado will be comparable to that of an EF-4 tornado, even though the estimated wind speed of the EF-4 tornado is lower. Tornadoes occurring prior to 2007 were assigned F-Scale values while those after February 1, 2007 have been assigned EF-Scale values. A detailed description of the EF-Scale can be found online at the NWS SPC website.

**Hail** can also develop in thunderstorms when strong currents of rising air, known as updrafts, carry water droplets high within the storm, exposing these droplets to cold air and freezing them. As the frozen droplets begin to fall toward the ground, rising currents within the storm lift them again. The hailstones gain an ice layer and grow increasingly larger with each ascent.

Eventually the hailstones become too heavy for the updraft to support, and they fall to the ground. Figure 3.2.1-4 depicts this process.

**Figure 3.2.1-4: Hail Formation Process**




Source: NOAA SciJinks

Though hail typically accompanies severe thunderstorms, all strong thunderstorms have the potential to produce hailstones of small diameter (less than one inch). The size of hailstones varies (Table 3.2.1-2) and is a direct consequence of the severity and size of the thunderstorm; greater instability in the atmosphere causes stronger updrafts. Stronger updrafts can keep hailstones suspended for longer periods of time, resulting in larger hailstones at ground level. Trained volunteer storm spotters and the NWS officially report severe hail, which are hailstones considered one inch in diameter or greater.[3]

[3] Prior to 2010, hail greater than 0.75 inches was considered severe. Unless otherwise noted, all statistics prior to 2010 reflect the 0.75 inch threshold and all statistics from 2010 to the present reflect the one inch threshold.

**Table 3.2.1-2: Estimating Hail Size**

| Hailstone size | Measurement | | Updraft Speed | |
|---|---|---|---|---|
| | in. | cm. | mph | km/h |
| bb | < 1/4 | < 0.64 | < 24 | < 39 |
| pea | 1/4 | 0.64 | 24 | 39 |
| marble | 1/2 | 1.3 | 35 | 56 |
| dime | 7/10 | 1.8 | 38 | 61 |
| penny | 3/4 | 1.9 | 40 | 64 |
| nickel | 7/8 | 2.2 | 46 | 74 |
| quarter | 1 | 2.5 | 49 | 79 |
| half dollar | 1.25 | 3.2 | 54 | 87 |
| walnut | 1.5 | 3.8 | 60 | 97 |
| golf ball | 1.75 | 4.4 | 64 | 103 |
| hen egg | 2 | 5.1 | 69 | 111 |
| tennis ball | 2.5 | 6.4 | 77 | 124 |
| baseball | 2.75 | 7 | 81 | 130 |
| tea cup | 3 | 7.6 | 84 | 135 |
| grapefruit | 4 | 10.1 | 98 | 158 |
| softball | 4.5 | 11.4 | 103 | 166 |

Source: NOAA, NSL

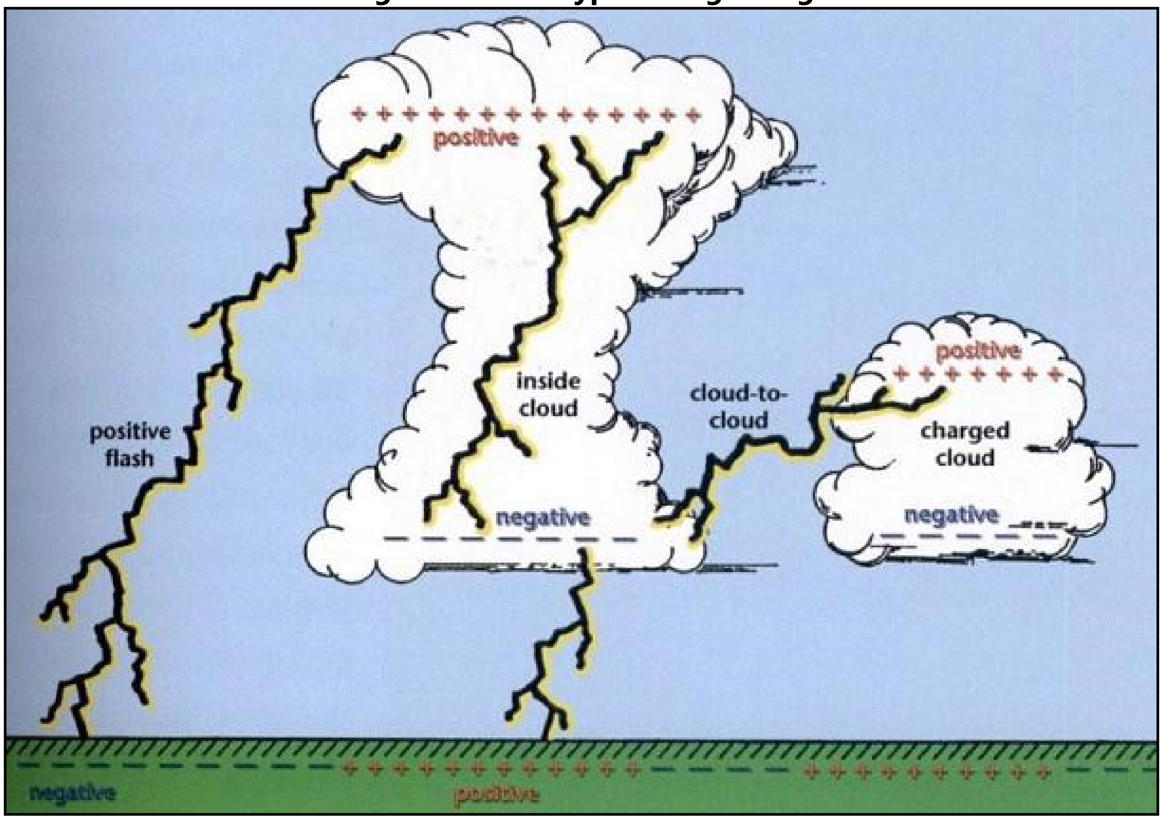
Another byproduct of a thunderstorm is **lightning.** The action of rising and descending air in a thunderstorm separates positive and negative charges, with lightning the result of the buildup and discharge of energy between positive and negative charge areas. Water and ice particles may also affect the distribution of the electrical charge. In only a few millionths of a second, the air in a lightning strike is heated to 50,000°F, a temperature five times hotter than the surface of the sun. The heated air expands so rapidly that it causes a shock wave which can be heard as thunder.

Lightning can travel between clouds (cloud-to-cloud), from one point to another within one cloud (intra-cloud), from a cloud to the air surrounding the storm (cloud-to-air), from a cloud to the ground (cloud-to-ground), or from the ground to a cloud (ground-to-cloud). The first four types are considered natural lightning because they occur naturally in the environment. Ground-to-cloud lightning is considered artificially initiated or triggered lightning because it strikes human-made objects like airplanes, very tall buildings, and structures on mountains.

According to the NWS, on average, about 25 million cloud-to-ground strikes are detected in the continental US annually, with about half of all flashes contacting more than one ground point. In addition, there are roughly five to ten times as many cloud-to-cloud flashes as there are cloud-to-ground flashes.

Over 95% of cloud-to-ground lightning is negative lightning, which means the lightning transfers a negative charge from the lower portion of a cloud to the ground. However, positive lighting can occur too, transferring a net positive charge from the upper portion of a cloud to the ground. Although much less common, positive lightning can be more dangerous. Because lightning must travel a longer distance to reach the ground, the electrical field is stronger which means the strike can have a longer duration with a charge ten times that of a negative lightning strike.

**Figure 3.2.1-5: Types of Lightning**




Source: Crondall Weather

The hazard posed by lightning is significantly underrated. After floods, lightning kills the most people on average each year. Nationally, lightning has the highest total fatalities since 1940 out of all the severe weather hazards. However, in Wisconsin, there were no reported lightning fatalities since 2017. High winds, rainfall, and a darkening cloud cover are warning signs for possible cloud-to-ground lightning strikes. While many casualties of lightning occur at the onset of a storm, more than half of lightning related deaths transpire after a thunderstorm has passed. The lightning threat diminishes after the last sound of thunder but may persist for more than 30 minutes. When thunderstorms are in the area, but not overhead, the lightning threat can still exist. Lightning has been known to strike ten miles or more from the storm in an area with clear skies. Large outdoor gatherings are particularly vulnerable to lightning strikes that could result in injuries and deaths. This vulnerability underscores the importance of developing site-specific emergency procedures for large events with particular emphasis on adequate early warning.

### 3.2.2 History

Severe storms occur regularly in Wisconsin, especially in warmer months. Table 3.2.2-1 shows some of the statewide record-breaking impacts of these storms. Several notable severe weather events are described below. Emphasis is placed on severe weather events that have occurred since the 2016 state plan update. The 1998 and 2006 storms are also highlighted because of their magnitude and impacts on Wisconsin communities.

**Table 3.2.2-1: Wisconsin Record-Breaking Storm Facts**

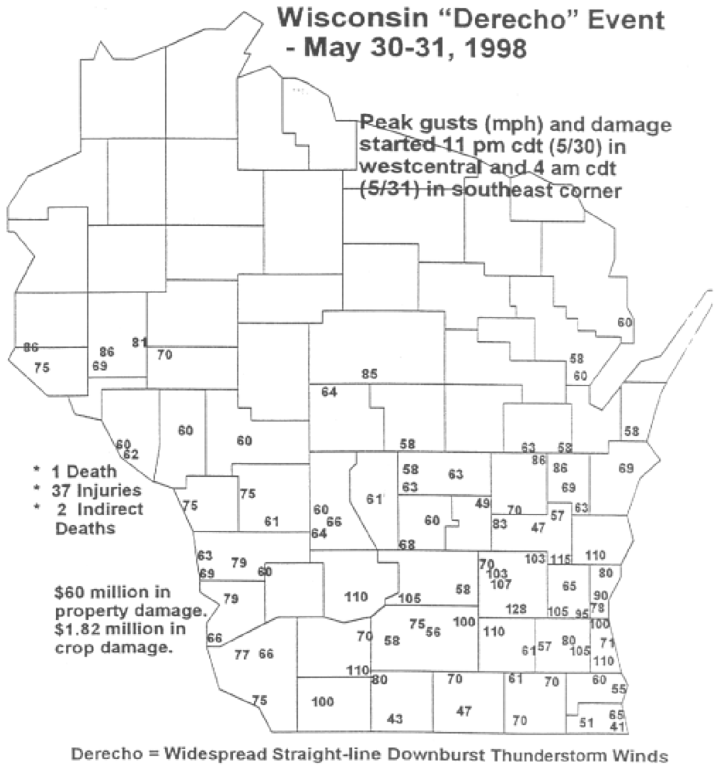
| Record | Location(s) | County/-ies | Date | Magnitude |
|---|---|---|---|---|
| Deadliest Tornado | New Richmond | St. Croix | June 12, 1899 | 117 killed |
| Longest-Track Tornado | River Falls to Van Buskirk | Pierce to Iron | April 5, 1929 | 187 miles |
| Most Tornadoes in One Day | Central Wisconsin | Dane, Jefferson, others | August 18, 2005 | 27 tornadoes |
| Costliest Tornado | Barneveld | Iowa | June 8, 1984 | $40.4 m ($82.1 m adjusted) |
| Largest Hailstone | Wausau | Marathon | May 22, 1921 | 5.7 inch diameter |
| Costliest Hailstorm | Southern Wisconsin | Iowa to Milwaukee | April 13, 2006 | $420 m |

Source: WEM

<u>May 31, 1998</u>

During the early morning hours of Sunday, May 31, 1998, south-central and southeast Wisconsin experienced a derecho (Figure 3.2.2-1). Incredibly powerful, hurricane-force high winds, with peak gusts of 100 to 128 mph tore through 12 counties, while another eight counties had peak gusts of 30 to 80 mph. Utility companies and Emergency Managers stated that the May 31, 1998 event was the most damaging, widespread, straight-line thunderstorm wind event to affect southern Wisconsin in the past 100 years. Estimated monetary damage for all twenty counties was $55.85 million. This includes damages to homes, businesses, utility and agriculture buildings, signs, streetlights, billboards, campers, and boats. An additional $1.48 million in damages occurred in crop and livestock losses.

**Figure 3.2.2-1: Wisconsin Derecho Event, May 30-31**




Source: NOAA, NWS, Milwaukee/Sullivan

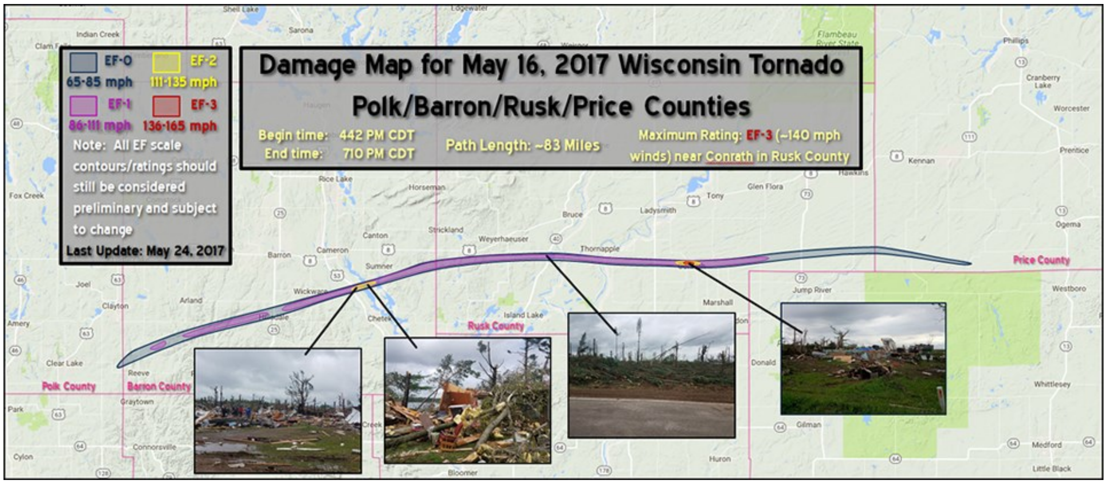
<u>April 13, 2006</u>

Three supercell thunderstorms moved across the southern part of the state on April 13, 2006. These storms produced hail up to 4.25 inches in diameter in a large swath from Mineral Point in Iowa County to north of Milwaukee. Based on insurance claims information, these hailstorms resulted in total damage of about $420 million, making it the costliest hailstorm day in Wisconsin weather history.

<u>May 16, 2017</u>

An 83-mile-long tornado tracked across northwest Wisconsin in the late afternoon of May 16, 2017. The 4 affected counties were Polk, Barron, Rusk, and Price. This was Wisconsin's longest tornado since modern tornado documentation began in 1950. It was rated an EF3 (140 mph) and resulted in one fatality and 25 injuries. Figure 3.2.2-2 has the damage map for this event.

**Figure 3.2.2-2: Damage Map for 83-Mile-Long Tornado**




Source: NOAA, NWS, Twin Cities

August 28, 2018

19 tornadoes stretched from Marquette county through Sheboygan county on August 28, 2018. There were no injuries or deaths reported with this event, but the damage to trees and agriculture in the areas varied. The following list provides the rating for each of the 19 tornadoes:

- 1 EF2 Tornado
- 13 EF1 Tornadoes
- 5 EF0 Tornadoes

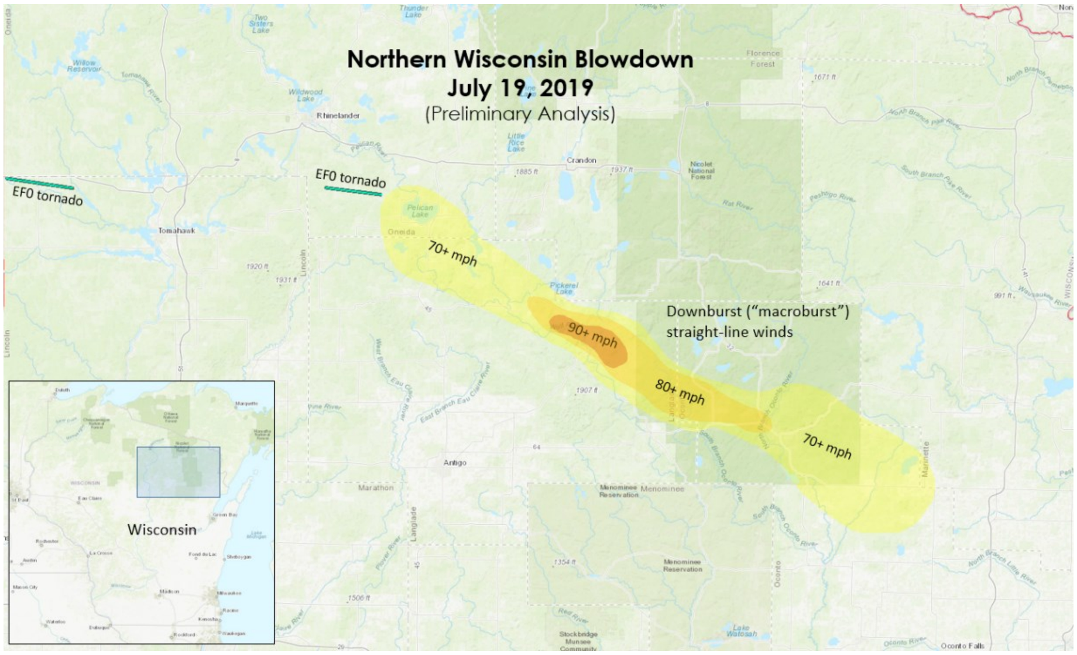
September 24, 2019

Supercell thunderstorms in Elk Mound, WI produced an EF3 tornado on the evening of September 24, 2019. The tornado lasted five minutes and damaged trees, barns, and silos along its path. This was the first September EF3 tornado in Wisconsin since 2002. While uncharacteristic for the typical timing of Wisconsin tornadoes, this event shows how unpredictable they can be.

July 19, 2019

Multiple thunderstorms moved across central, north central, and eastern Wisconsin on the evening of July 19, 2019. During the height of the storm, Wisconsin Public Service reported over 50,000 power outages. The worst of the damage came from a macroburst that snapped or uprooted hundreds of thousands of trees. Winds reached upwards of 100 mph in Lily near northeast Langlade County. Figure 3.2.2-3 shows the damage path of the macroburst and the associated EF0 tornadoes.

**Figure 3.2.2-3: Northern Wisconsin Blowdown**




Source: NOAA, NWS, Green Bay

October 1-2, 2019

Severe weather including heavy rainfall, thunderstorms, high winds, and two confirmed tornadoes impacted southern Wisconsin starting on October 1, 2019 through October 2, 2019. As a result of the tornadoes and intense weather, there was damage to residential homes and farms in Jefferson County, as well as Waukesha County.

July 19, 2020

Between midnight and 4 a.m. on July 19, 2020, a storm moved through western and central Wisconsin. Hail, damaging winds, and a tornado caused damaged to outbuildings, trees, and crops.

June 17, 2021

Two supercells brought severe weather – including baseball-sized hailstones and ample rainfalls – to southwest Wisconsin on the evening of June 17, 2021. Figure 3.2.2-4 shows the size of one of the hailstones compared to a playing card.

**Figure 3.2.2-4: Hailstone Reported in Buffalo City, WI**

Source: NOAA. NWS, La Crosse

Significant Tornado Events

Because tornadoes are violent and can be extremely devastating, in terms of both damages and loss of life, it's worth noting significant tornadoes experienced in the state. Table 3.2.2-2 lists the event dates, EF-ratings, locations, reported damages (property and crops), and deaths. The number of deaths has dropped off dramatically since the 19th century and the early part of the 20th century. This is likely due to the prevalence of improved construction materials and practices, more accurate forecasting models, and more effective warning systems.

**Table 3.2.2-2: Significant Tornado Events in Wisconsin, 1865-2019**

| Date | EF-Rating | Location (County/-ies) | Reported Damage | Number of Deaths |
|---|---|---|---|---|
| June 29, 1865 | | Vernon | Not Available | 24 |
| May 23, 1878 | EF4 (est.) | Dane, Iowa, Jefferson, Milwaukee, Waukesha (may have been three tornadoes) | Not Available | 19 |
| May 18, 1898 | EF5 (est.) | Clark, Eau Claire, Langlade, Lincoln, Marathon | Not Available | 17 |
| June 12, 1899 | | St. Croix | Not Available | 117 |
| September 21, 1924 | | Eau Claire to Oneida | Not Available | 26 |
| September 21, 1924 | | Barron to Ashland | Not Available | 10 |
| April 5, 1929 | EF4 (est.) | Barron, Pierce, St. Croix | $4,000,000 | 7 |
| April 3, 1956 | EF4 (est.) | Green Lake, Waushara, Winnebago | $1,000,000 | 7 |
| June 4, 1958 | | Chippewa, Clark, Dunn (three tornadoes) | $27,750,000 | 27 |
| April 11, 1965 | EF2 (est.) | Dodge, Jefferson | $2,500,000 | 3 |

| Date | EF-Rating | Location (County/-ies) | Reported Damage | Number of Deaths |
|---|---|---|---|---|
| April 21, 1974 | EF4 (est.) | Winnebago | $4,000,000 | 0 |
| April 21, 1974 | EF3 (est.) | Dodge, Fond du Lac | $5,000,000 | 2 |
| July 15, 1980 | | Chippewa, Dunn, Eau Claire (nine tornadoes) | $150,000,000 | 0 |
| April 27, 1984 | EF3 | Oneida, Vilas | $52,500,000 | 1 |
| April 27, 1984 | EF3 | Menominee, Shawano, Waupaca | $2,624,000 | 0 |
| April 27, 1984 | EF4 | Outagamie, Winnebago | $3,600,000 | 1 |
| April 27, 1984 | EF4 | Waukesha | $1,300,000 | 1 |
| June 8, 1984 | EF5 | Columbia, Dane, Iowa | $40,000,000 | 9 |
| August 29, 1992 | EF3 | Waushara | $10,100,000 | 1 |
| July 5, 1994 | EF4 | Manitowoc | $2,100,000 | 0 |
| August 27, 1994 | EF3 | Adams | $4,600,000 | 2 |
| July 18, 1996 | EF5 | Fond du Lac | $40,400,000 | 0 |
| August 23, 1998 | EF3 | Door | $7,000,000 | 0 |
| March 8, 2000 | EF1 | Milwaukee | $4,181,000 | 0 |
| June 18, 2001 | EF3 | Burnett, Washburn | $10,000,000 | 3 |
| September 2, 2002 | EF3 | Rusk | $25,000,000 | 0 |
| June 23, 2004 | EF3 | Dodge, Fond du Lac, Green (two tornadoes merged) | $20,000,000 | 1 |
| August 18, 2005 | EF3 | Dane, Jefferson | $35,052,000 | 1 |
| August 18, 2005 | EF2 | Richland, Vernon | $3,570,000 | 0 |
| June 7, 2006 | EF3 | Langlade, Menominee, Oconto, Shawano | $15,400,000 | 0 |
| January 7, 2008 | EF3 | Kenosha, Walworth | $13,810,000 | 0 |
| June 21, 2010 | EF2 | Waukesha | $20,600,000 | 0 |
| June 16, 2014 | EF2 | Grant | $20,500,000 | 0 |
| June 16, 2014 | EF3 | Dane | $14,000,000 | 0 |
| June 16, 2014 | EF2 | Dane | $5,000,000 | 0 |
| June 29, 2014 | EF2 | Iowa | $3,500,000 | 0 |
| June 29, 2014 | EF2 | Iowa | $400,000 | 0 |
| May 16, 2017 | EF2 | Barron | $10,100,000 | 1 |
| May 16, 2017 | EF3 | Rusk | $420,000 | 0 |
| August 28, 2018 | EF2 | Dodge | $169,000 | 0 |
| September 24, 2019 | EF3 | Chippewa | $3,000,000 | 0 |

Source: NOAA, NWS, Milwaukee/Sullivan

### 3.2.3 Probability, Vulnerability, and Mitigation Potential

***3.2.3 Thunderstorms***

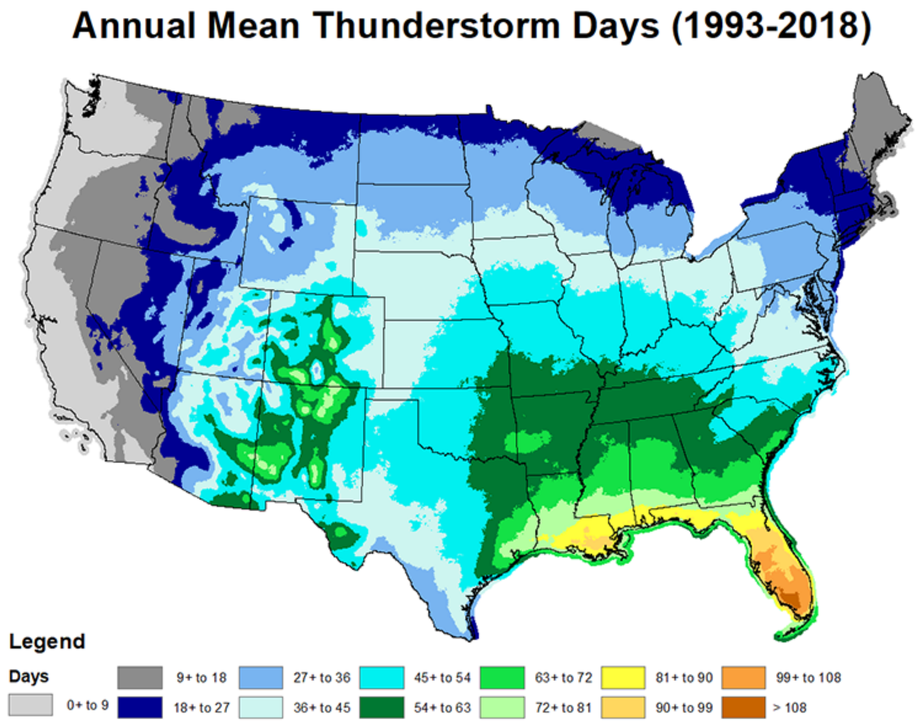
**Table 3.2.3-1: Hazard Ranking**

| Evaluation Criteria | Description | Ranking |
|---|---|---|
| Probability | • Occurs annually or assumed to occur at least once per year. Near 100% probability of occurrence each year. | Highly Likely |
| Vulnerability | • Multiple measures are in place to prevent or protect against this hazard.<br>• Countermeasures have been tested and have demonstrated success in reducing the threat potential. | Medium |
| Mitigation Potential | • Mitigation methods are established<br>• The State or counties have limited experience with the kinds of measures that may be appropriate to mitigate the hazard<br>• Some mitigation measures are eligible for federal grants<br>• There is a limited range of effective mitigation measures for the hazard<br>• Mitigation measures are cost-effective only in limited circumstances<br>• Mitigation measures are effective for a reasonably long period of time | Medium |

This section provides an examination of severe thunderstorms and their probability of occurrence and vulnerability posed. Since severe thunderstorms are often associated with other severe weather, there are limited statistics for only severe thunderstorms in Wisconsin. High winds/tornadoes, hail, and lightning will all be discussed at length in separate sections. Regardless, severe thunderstorms are an important hazard to highlight since they only need one of the severe storm characteristics to be classified as such.

While most thunderstorms do not become severe, the small percent that do can have devasting impacts on the communities they affect. According to the NWS, “a typical storm is usually 15 miles in diameter lasting an average of 30 to 60 minutes. Every thunderstorm produces lightning, which usually kills more people each year than tornadoes.” As shown in Figure 3.2.3-1, Wisconsin lies in the 18 to 45 range for annual mean thunderstorm days. Further south, the states closer to the Gulf of Mexico experience 90+ annual mean thunderstorm days.

**Figure 3.2.3-1: Annual Mean Thunderstorm Days, U.S.**




Source: NWS, JetStream

It is important to know the difference between a severe thunderstorm watch and warning. The National Severe Storms Laboratory (NSSL) provides the following distinction:

- A **Severe Thunderstorm WATCH** is issued by the NOAA Storm Prediction Center meteorologists who are watching the weather 24/7 across the entire U.S. for weather conditions that are favorable for severe thunderstorms. A watch can cover parts of a state or several states. **Watch** and **prepare** for severe weather and stay tuned to NOAA Weather Radio to know when warnings are issued.
- A **Severe Thunderstorm WARNING** is issued by your local NOAA National Weather Service Forecast Office meteorologists who watch a designated area 24/7 for severe weather that has been reported by spotters or indicated by radar. Warnings mean there is a serious threat to life and property to those in the path of the storm. **ACT** now to find safe shelter! A warning can cover parts of counties or several counties in the path of danger.

The NWS offices servicing Wisconsin issue, on average, 5-10 Severe Thunderstorm Warnings per county per year in the southern counties where thunderstorms are more frequent. Comparatively, the SPC issues, on average, about 29 Severe Thunderstorm Watches per year that cover at least a part of Wisconsin. To convey the severity and potential impacts from thunderstorm winds, the NWS will add a new "damage threat" tag to Severe Thunderstorm

Warnings. This will go into effect on August 2, 2021. The summary of the three classifications is below:

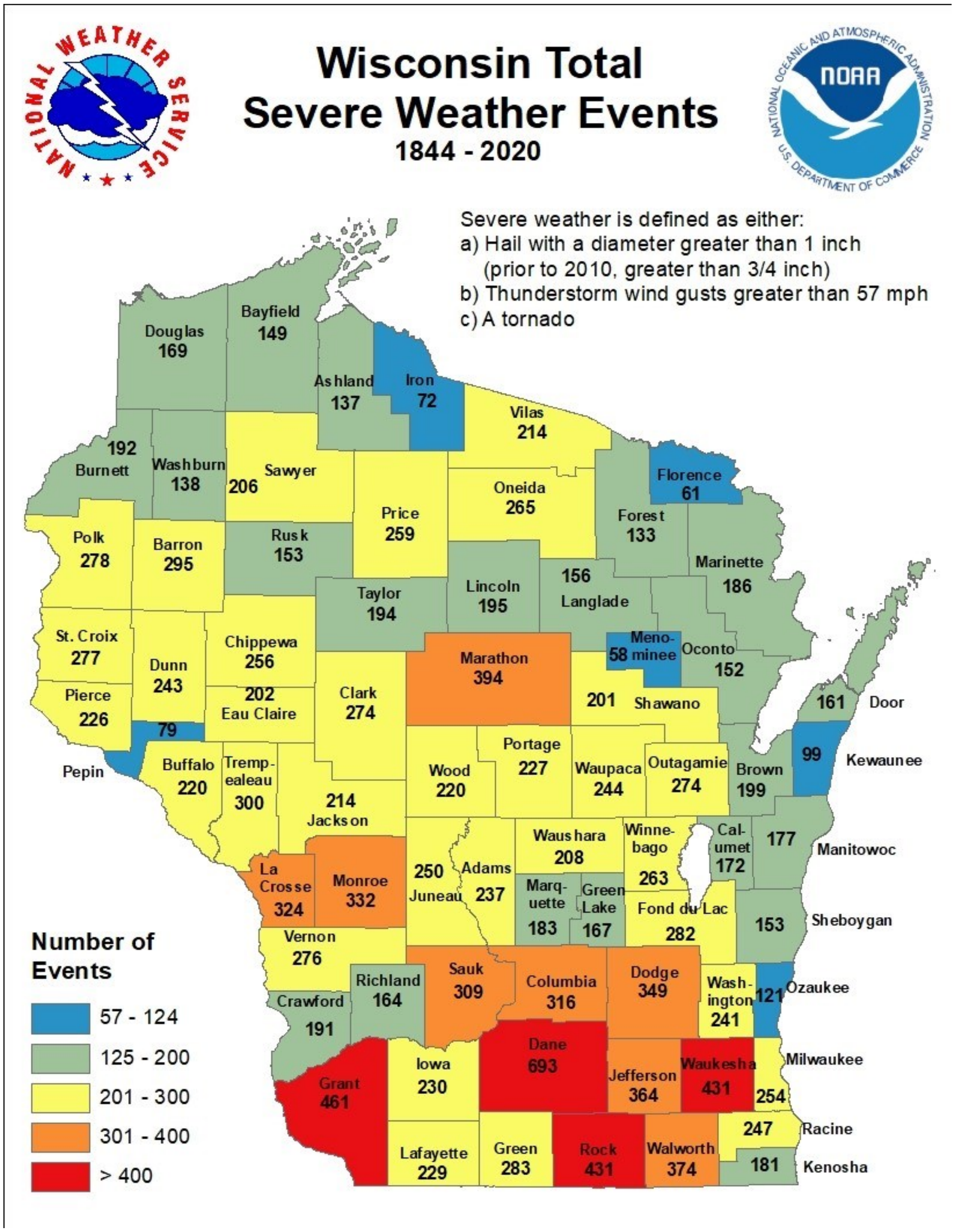
- The criteria for a **destructive** damage threat is at least 2.75 inch diameter (baseball-sized) hail and/or 80 mph thunderstorm winds. Warnings with this tag will automatically activate a Wireless Emergency Alert (WEA) on smartphones within the warned area.
- The criteria for a **considerable** damage threat is at least 1.75 inch diameter (golf ball-sized) hail and/or 70 mph thunderstorm winds. This will not activate a WEA.
- The criteria for a **baseline** or **"base"** severe thunderstorm warning remains unchanged, 1.00 inch (quarter-sized) hail and/or 58 mph thunderstorm winds. This will not activate a WEA. When no damage threat tag is present, damage is expected to be at the base level.

Probability

The probability of severe thunderstorms in Wisconsin is highly likely as there is a 100% chance of the hazard occurring in any given year. Thunderstorms can occur throughout the state during any month of the year, but the peak season is from April through August. Most will start in the afternoons and early evenings.

According to the NWS, Wisconsin experiences 15 severe storms each summer that produce hail 1.5 inches in diameter or larger. Northern Wisconsin experiences, on average, approximately 30 thunderstorm days per year. In southern Wisconsin, the average is about 40 annual thunderstorm days. This notable difference is also highlighted in Figure 3.2.3-2 which shows the total severe weather events that occurred in each county from 1844-2020. Evidently, many of the southern counties like Grant, Dane, Rock, and Waukesha have had more than 400 severe weather events. The northern counties of Bayfield, Ashland, Iron, and Florence have had less than 150.

**Figure 3.2.3-2: Wisconsin Total Severe Weather Events by County, 1844-2020**




Source: NOAA, NWS, Milwaukee/Sullivan

Vulnerability

As the number of severe weather events in Wisconsin increases over time, so does the negative health impacts resulting from these storms. Severe thunderstorms can cause damage to building infrastructure and crops, injure, and even kill people.

According to NCEI, since 1980, Wisconsin has experienced 22 severe storms where overall costs/damages exceed $1 billion dollars (including CPI adjustment to 2021). Beyond monetary consequences, the aftermath affects the mental health of individuals, families, and communities who must deal with the storm damage and destruction. People who work outdoors and large gatherings are particularly susceptible to the impacts of severe thunderstorms. Anytime there is limited access to buildings or covered areas, people are at risk of injury.

Depending on the characteristics of the storm, the damage can vary. Heavy rainfalls cause flash flooding, killing more people each year than hurricanes. Under dry conditions, lightning is responsible for many fires around the world and causes fatalities. Large hail damages windows and cars and can kill livestock that is out in the open. Strong winds associated with thunderstorms are likely to knock down trees, powerlines, and mobile homes. Each of the impacts of these hazards will be explored in more detail in the next three sections.

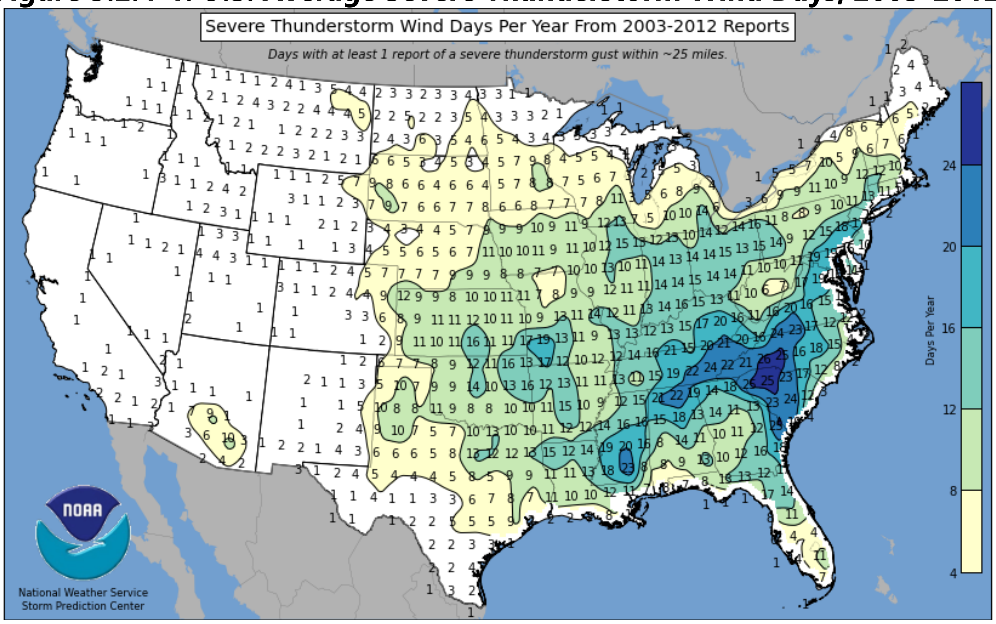
### *3.2.4 High Winds and Tornadoes*

**Table 3.2.4-1: Hazard Ranking**

| Evaluation Criteria | Description | Ranking |
|---|---|---|
| Probability: High Winds and Tornadoes | • Occurs annually or assumed to occur at least once per year. Near 100% probability of occurrence each year. | Highly Likely |
| Vulnerability: High Winds | • Multiple measures are in place to prevent or protect against this hazard.<br>• Countermeasures have been tested and have demonstrated success in reducing the threat potential. | Medium |
| Vulnerability: Tornadoes | • Multiple measures are in place to prevent or protect against this hazard.<br>• Countermeasures have been tested and have demonstrated success in reducing the threat potential. | Medium |
| Mitigation Potential: High Winds and Tornadoes | • Methods for reducing risk from the hazard are technically reliable.<br>• The State or counties have experience in implementing mitigation measures.<br>• Mitigation measures are eligible under federal grant programs.<br>• There are multiple possible mitigation measures for the hazard.<br>• The mitigation measures are known to be cost-effective.<br>• The mitigation measures protect lives and property for a long period of time or are permanent risk reduction solutions. | High |

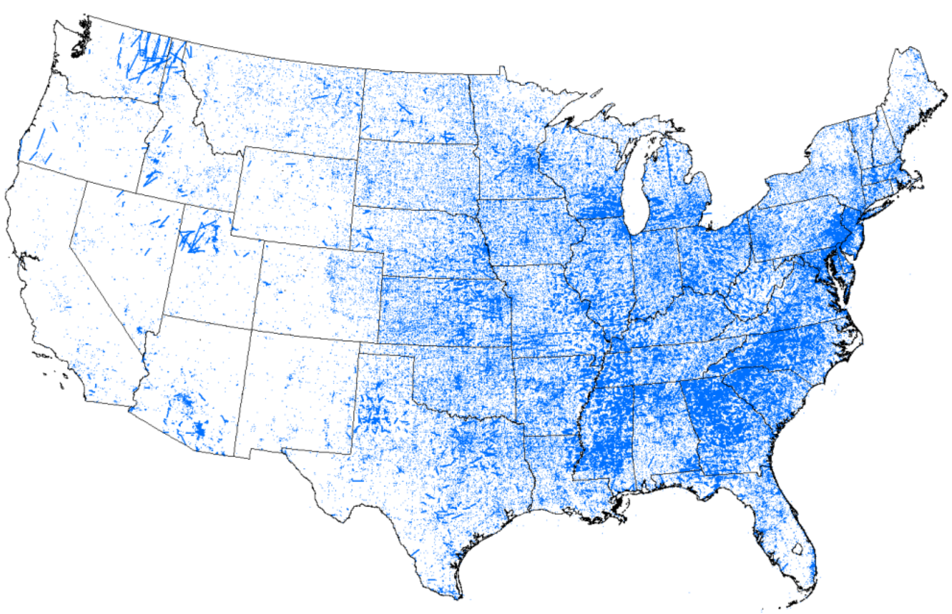
This section will examine the impacts of high winds (58 mph and greater) as well as tornadoes in Wisconsin. Figure 3.2.4-1 depicts the annual number of days with high winds that can be expected throughout the U.S. The highest concentration of annual thunderstorm wind days is in the southeastern part of the country. Parts of North and South Carolina, Tennessee, and Virginia experience upwards of 20 severe thunderstorm wind events per year on average. Portions of Wisconsin range from an average of three to 13 events per year. Figure 3.2.4-2 also depicts these trends with the wind tracks for the country.

**Figure 3.2.4-1: U.S. Average Severe Thunderstorm Wind Days, 2003-2012**




Source: NOAA, NWS, SPC

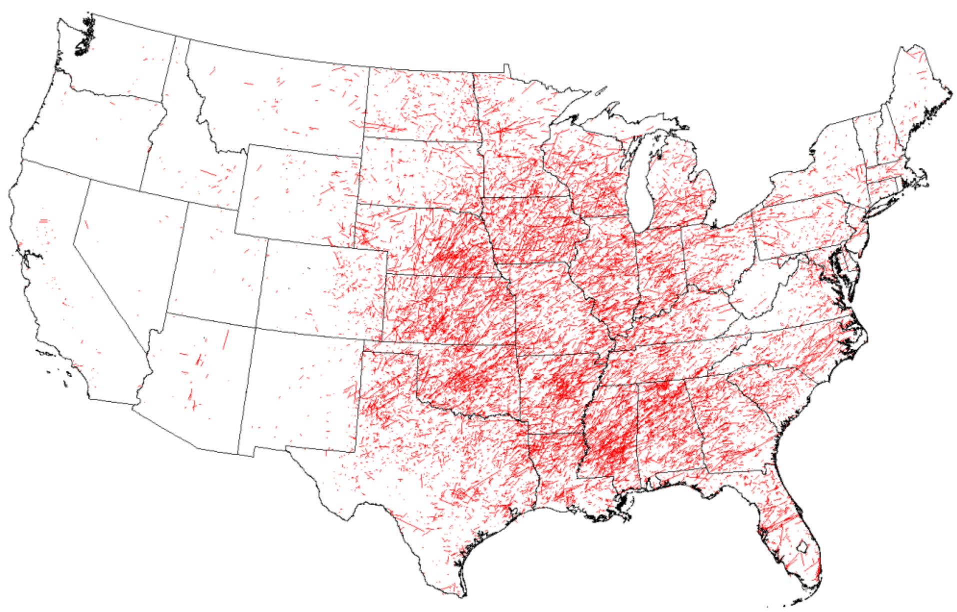
**Figure 3.2.4-2: U.S. Wind Tracks, 1950-2019**



Source: NOAA, NWS, SPC

With even higher wind speeds, tornadoes also occur regularly in Wisconsin. The state lies along the northern edge of the nation's maximum frequency belt for tornadoes, called "Tornado Alley." In Tornado Alley, the region is susceptible to supercell thunderstorms which can produce violent tornadoes (EF-2 or greater). 77% of tornadoes in the U.S. are weak (EF-0 or EF-1) and 95% are below EF-3. However, NOAA estimates that around 1,000 tornadoes hit the U.S. each year. This means that roughly 20 of these tornadoes may become violent. Since 2017 – and up until May 19, 2021 – there have been 183 tornado-related fatalities. Only one of these deaths occurred in Wisconsin. Tracks of the tornadoes that occurred nationwide between 1950 and 2019 are shown in Figure 3.2.4-3.

**Figure 3.2.4-3: U.S. Tornado Tracks, 1950-2019**



Source: NOAA, NWS, SPC

The NSSL has the following distinctions for a tornado watch versus a tornado warning:

- A **Tornado WATCH** is issued by the NOAA Storm Prediction Center meteorologists who watch the weather 24/7 across the entire U.S. for weather conditions that are favorable for tornadoes and severe weather. A watch can cover parts of a state or several states. Watch and prepare for severe weather and stay tuned to NOAA Weather Radio to know when warnings are issued.
- A **Tornado WARNING** is issued by your local NOAA National Weather Service Forecast Office meteorologists who watch the weather 24/7 over a designated area. This means a tornado has been reported by spotters or indicated by radar and there is a serious threat to life and property to those in the path of the tornado. **A tornado warning indicates that you should ACT NOW** to find safe shelter! A warning can cover parts of counties or several counties in the path of danger.

The NWS offices servicing Wisconsin issue, on average, 1 to 2 tornado warnings per county per year in the southern counties. The averages are lower for the northern counties. Comparatively, the SPC issues, on average, 11 tornado watches per year that cover at least a part of Wisconsin.

All the data comes from NWS, but due to changes in data collection and processing procedures over time, there are multiple formats and potential for lost data. The breakdown of how the data will be used in the frequency and probability section is listed below:

- High winds: data became available in 1955. For 1955-2019, a comma separate value (CSV) text file was compiled for high winds. Because of the accessibility and ease of searching this file, the downloaded version of it is used for 1955-2019. For 2020 and 2021, the Storm Events Database (containing records through April 2021) is used. Unfortunately, due to the sheer number of records in the Storm Events Database, we cannot use it for the entire period that it covers – from January 1950 to April 2021 for high winds. However, when numbers from the SPC are referenced in the frequency and probability analysis, it will be a compilation of these two data formats (i.e., January 1955 through April 2021).
- Tornadoes: data became available in 1950, but any data prior to 1953 is likely underreported. For 1950-2021, the Storm Events Database (containing records through April 2021) is used.

Probability

High winds are the most common form of severe weather in Wisconsin; thus, there is a highly likely probability of occurrence each year. As with severe thunderstorms, the peak season for severe thunderstorm winds is April through August. Most severe thunderstorms will also start in the afternoons; although, they can occur during any month or time. According to the SPC, from 1955 until 2021, there have been 2,040 accounts of high winds. While less likely, straight-line thunderstorm winds with hurricane-force winds of 75 to 100 mph can also occur – especially during the warm months. The SPC has 178 records of these intense winds between 1955 and 2021. For hurricane-force winds, a Severe Thunderstorm Warning is issued rather than a Tornado Warning. Table 3.2.4-2 summarizes Wisconsin's severe thunderstorm wind events that occurred in the last five years.

**Table 3.2.4-2: Wisconsin Severe Thunderstorm Winds, 2016-2020**

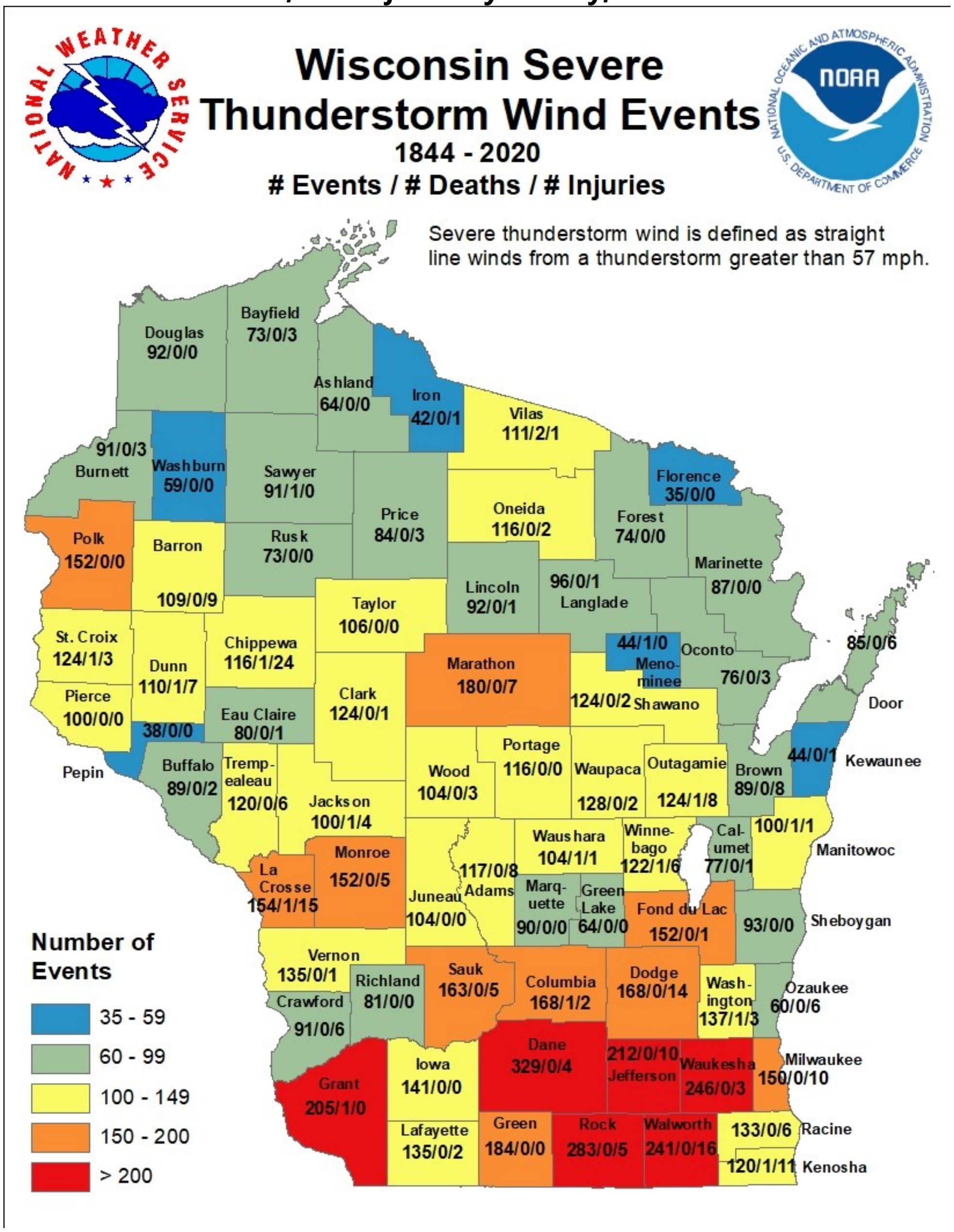
| Year | # of Events | Average Wind Speed (Kts) |
|---|---|---|
| **2016** | 293 | 54.64 kts |
| **2017** | 364 | 54.26 kts |

| | | |
|---|---|---|
| **2018** | 162 | 52.78 kts |
| **2019** | 198 | 53.51 kts |
| **2020** | 144 | 51.48 kts |

Source: SPC, WEM

The frequency of high wind events is important to be aware of because they can result in damages, injuries, and deaths. Figure 3.2.4-4 shows the distribution of severe thunderstorm wind events between 1844 and 2020 by county. Six counties – Grant, Dane, Jefferson, Rock, Walworth, and Waukesha – in the south-central to southeast part of the state each experienced over 200 events in that time, with Dane County recording over 300. This is alarming due, in part, to the recent development of land in these counties and the projected population growth. Only five counties experienced fewer than 50 severe thunderstorm wind events in that time. As shown, 16 fatalities and dozens of injuries in Wisconsin were attributed to severe thunderstorm winds between 1844 and 2020.

**Figure 3.2.4-4: Wisconsin Severe Thunderstorm Wind Events, Deaths, and Injuries by County, 1844-2020**

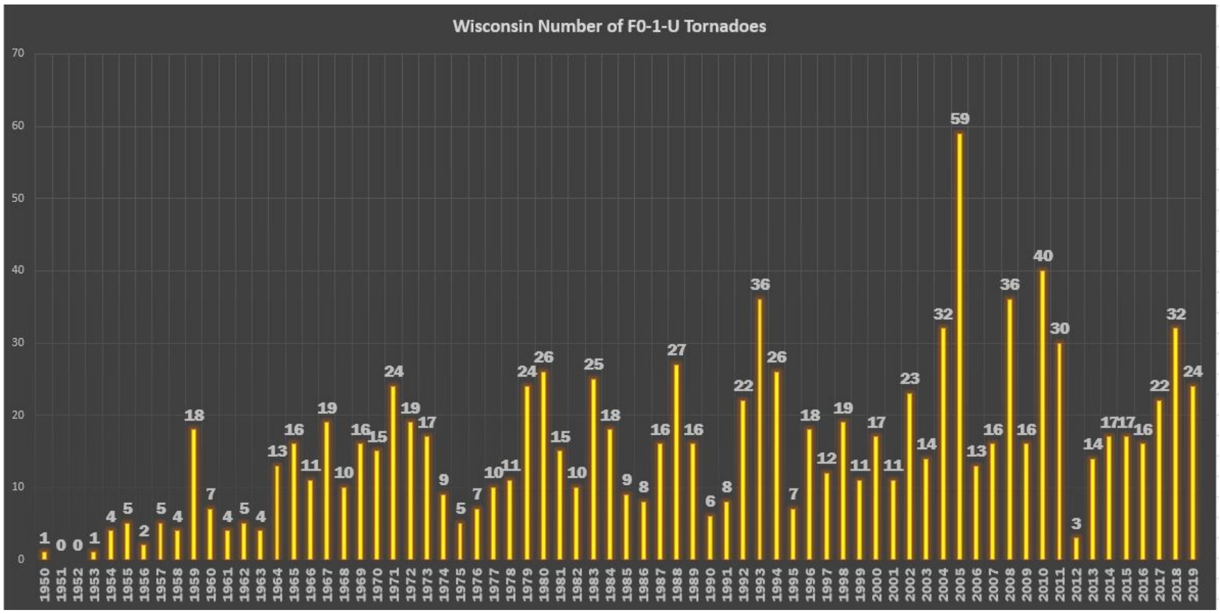



Source: NOAA, NWS, Milwaukee/Sullivan

As for tornadoes, the probably in Wisconsin is highly likely with an average of 23 tornadoes each year. Like high winds, tornadoes can occur during any month. In Wisconsin, the tornado season tends to pick up in June (peak), July, and August. Most tornadoes have struck during mid-afternoon or early evening (3 p.m. to 7 p.m.). The "average" Wisconsin tornado between 1982 and 2007 had a lifespan of 7.1 minutes, a path length of 3.7 miles, a path width of 118 yards, and an EF rating of 0.7 (between EF0 and EF1). Despite the averages, strong year-to-year variations occur, and many tornadoes can come without warnings.

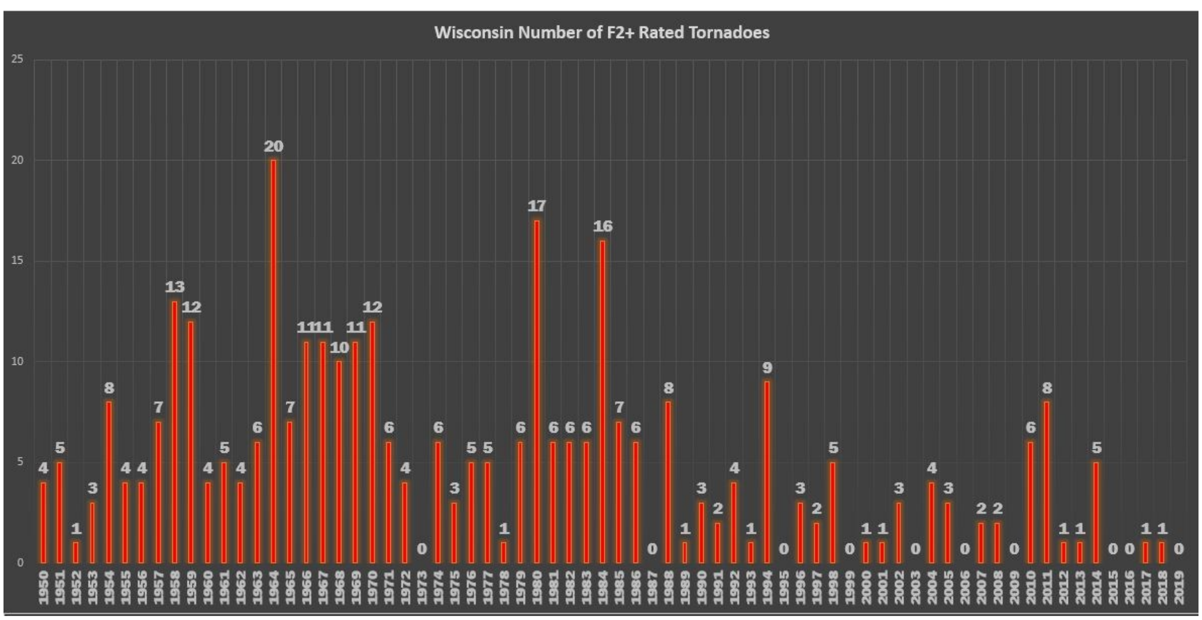
For simplicity, the frequency of tornadoes in the state from 1950 through 2021 has been divided into weak and violent occurrences. The SPC has 1,058 records of weak tornadoes (F0, F1, EF-0, and EF-1). For violent tornadoes (F2-F5 and EF-2+), there are 422 records. These counts for 1950-2019 are also portrayed in Figures 3.2.4-5 and 3.2.4-6 below.

**Figure 3.2.4-5: Number of F0-1-U Tornadoes, 1950-2019**




Source: NOAA, Milwaukee/Sullivan

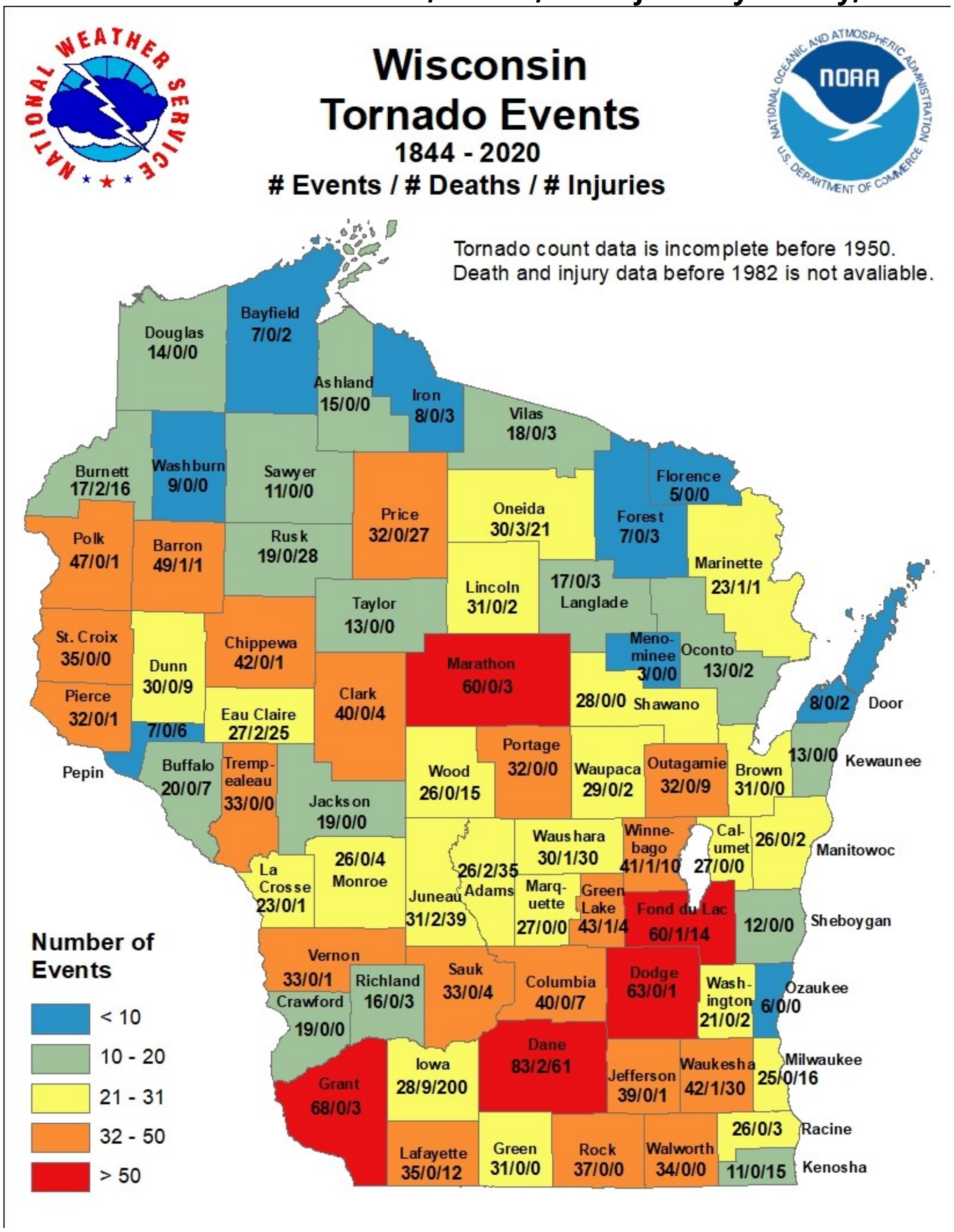
**Figure 3.2.4-6: Number of F2+ Rated Tornadoes, 1950-2019**




Source: NOAA, Milwaukee/Sullivan

Even though all Wisconsin counties have recorded at least three tornadoes between 1844 and 2020, five counties – Dane, Grant, Dodge, Fond du Lac, and Marathon – have each recorded over 50 tornadoes as shown in Figure 3.2.4-7. Dane and Grant counties had the most with 83 and 68 respectively. Counties in the southern part of Wisconsin had more recorded tornadoes than the rest of the state, with a concentration of 30 or more per county in the south-central area.

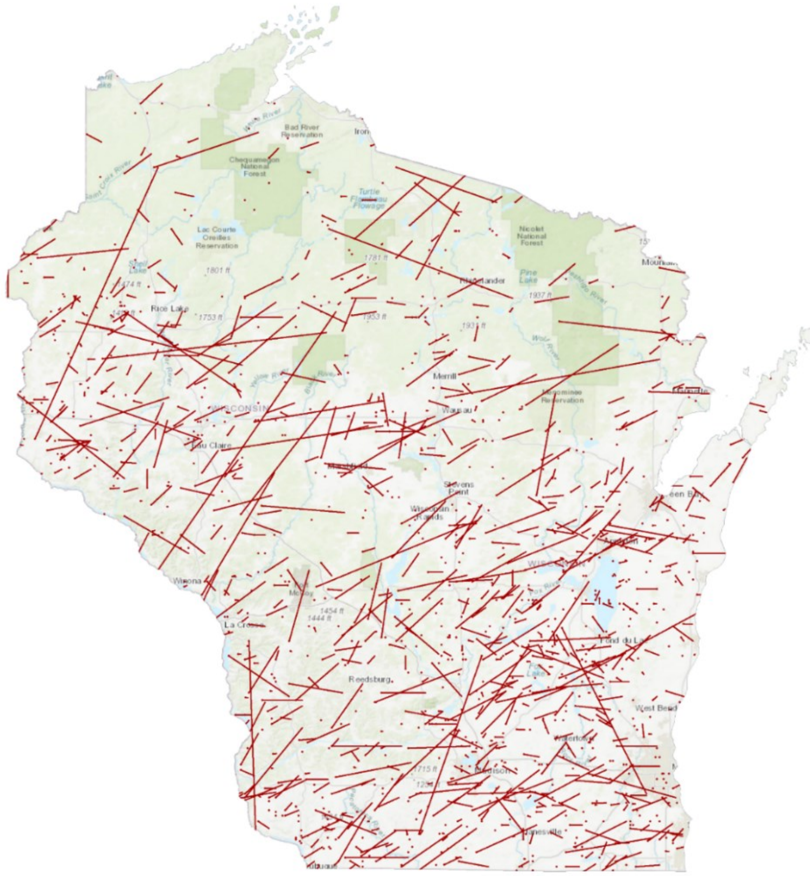
**Figure 3.2.4-7: Wisconsin Tornadoes, Deaths, and Injuries by County, 1844-2020**




Source: NOAA, NWS, Milwaukee/Sullivan

Figure 3.2.4-8 is a plot of Wisconsin's short-track and long-track tornadoes for the period 1950 through 2019. This map indicates that most long-track tornadoes in the state travel southwest to northeast; however, several of the tornadoes moved west to east as well as northwest to southeast.

**Figure 3.2.4-8: Wisconsin Tornado Tracks, 1950-2019**




Source: NOAA SPC, WEM

Speculation suggests that the concentration of tornadoes between Madison and Lake Winnebago may be related to the fact that the terrain in that area is flatter than in the southwestern counties. Additionally, an interaction between a lake breeze front generated by Lake Winnebago and outflow boundaries (gust fronts) generated by individual thunderstorms may enhance the spin-up of tornado rotation below the cloud base. The absence of tornadoes along the coasts (both Lake Michigan and Lake Superior) is due, in part, to the cold air from the lakes stabilizing the atmosphere and suppressing the formation of deep thunderstorm convection. Notably, there will be more records for minor tornadoes in areas that have higher populations since more people will see and report them.

Vulnerability and Mitigation Potential

Both severe thunderstorm winds and tornadoes can lead to loss of life, injury, and damage to property, infrastructure, crops, and forested areas. Wind and tornadoes often create excessive amounts of debris that then needs to be cleaned up and managed properly. Securing the workforce and equipment to clean up after a large event can be problematic and expensive. Additionally, disposing of the debris properly requires knowledge of local disposal requirements and permitting, which may also be costly.

Areas that are heavily developed and contain higher populations are more vulnerable to the negative impacts of high winds and tornadoes. The damage of an EF-3 or greater tornado to cities such as Milwaukee, Madison, Green Bay, or Kenosha would have lasting impacts on the metropolitan and surrounding areas. A lack of adequate safe rooms, people who do not quickly seek shelter, or those who try to "out drive" a tornado in their car can led to more injuries and deaths during an event. Individuals and families that live in manufactured homes are particularly at risk of increased impact due to the weak structural integrity of their homes.

Preparing, understanding how to stay safe, and recovering from high winds and tornadoes are all important aspects of mitigating their outcomes. The NWS outlines how to accomplish each of these steps below:

*Prepare for a Tornado*

- **Be Weather-Ready:** Check the forecast regularly to see if you're at risk for tornadoes. Listen to local news or a NOAA Weather Radio to stay informed about tornado watches and warnings. Check the Weather-Ready Nation for tips.
- **Sign Up for Notifications**: Know how your community sends warnings. Some communities have outdoor sirens. Others depend on media and smart phones to alert residents of severe storms capable of producing tornadoes.
- **Create a Communications Plan**: Have a family plan that includes an emergency meeting place and related information. If you live in a mobile home or home without a basement, identify a nearby safe building you can get too quickly, such as a church or family member.
- **Pick a safe area** in your home, such as a basement, storm cellar, an interior room on the lowest floor with no windows or other areas that can serve as a Best Available Refuge Area. Check more ideas for your family plan at: ready.gov
- **Practice Your Plan:** Conduct a family severe thunderstorm drill regularly so everyone knows what to do if a tornado is approaching. Make sure all members of your family know to go there when tornado warnings are issued. Don't forget pets if time allows.
- **Prepare Your Home:** Consider having your safe room reinforced. You can find plans for reinforcing an interior room to provide better protection on the Federal Emergency Management Agency website.
- **Help Your Neighbor**: Encourage your loved ones to prepare for the possibility of tornadoes. Take CPR training so you can help if someone is hurt.

*During a Tornado*

- **Stay Weather-Ready**: Continue to listen to local news or a NOAA Weather Radio to stay updated about tornado watches and warnings.
- **At Your House**: If you are in a tornado warning, go to your basement, safe room, or an interior room away from windows (Figure 3.2.4-9). Don't forget pets if time allows.
- **At Your Workplace or School**: Follow your tornado drill and proceed to your tornado shelter location quickly and calmly. Stay away from windows and do not go to large open rooms such as cafeterias, gymnasiums, or auditoriums.
  - **Outside**: Seek shelter inside a sturdy building immediately if a tornado is approaching. Sheds and storage facilities are not safe. Neither is a mobile home or tent. If you have time, get to a safe building.
  - **In a vehicle**: Being in a vehicle during a tornado is not safe. The best course of action is to drive to the closest safe room. If you are unable to make it to a safe room, either get down in your car and cover your head, or abandon your car and seek shelter in a low lying area such as a ditch or ravine.

**Figure 3.2.4-9: Where to Go When Sheltering from a Tornado**


Source: NOAA, NWS

*After a Tornado*

- **Stay Informed:** Continue to listen to local news or a NOAA Weather Radio to stay updated about tornado watches and warnings. Multiple rounds of thunderstorms capable of producing tornadoes are possible during severe weather outbreaks.
- **Contact Your Family and Loved Ones**: Let your family and close friends know that you're okay so they can help spread the word. Text messages or social media are more reliable forms of communication than phone calls.

- **Assess the Damage:** After the threat for tornadoes has ended, check to see if your property has been damaged. When walking through storm damage, wear long pants, a long-sleeved shirt, and sturdy shoes. Contact local authorities if you see power lines down. Stay out of damaged buildings. Be aware of insurance scammers if your property has been damaged.
- **Help Your Neighbor**: If you come across people that are injured and you are properly trained, provide first aid to victims if needed until emergency response teams arrive.

Potential Losses

In Table 3.2.4-3 below, the past four years of tornado damage in Wisconsin is listed. As shown, there is a wide range of variability in the impacts of each tornado. For example, an EF-0 in Rusk County cost more in property damage ($500,000.00) than an EF-3 in Rusk County ($420,000.00) a few years prior. The costliest damage occurred in Barron County during an EF-2 tornado with $10.1 million in property damages. Total property damages were $19.684 million and total crop damages were $37,000 for the four-year-period. As a general trend, there is a positive correlation between the property damage and the number of deaths/injuries associated with each event.

**Table 3.2.4-3: Wisconsin Tornado Damage, 2016-2020**

| County | Begin Date | Magnitude | Deaths | Injuries | Property Damage | Crop Damage |
|---|---|---|---|---|---|---|
| Fond Du Lac Co. | 5/27/2016 | EF1 | 0 | 0 | $100,000.00 | $- |
| Waupaca Co. | 6/26/2016 | EF1 | 0 | 0 | $200,000.00 | $- |
| Marathon Co. | 6/30/2016 | EF0 | 0 | 0 | $5,000.00 | $- |
| Pepin Co. | 7/5/2016 | EF1 | 0 | 0 | $500,000.00 | $- |
| Buffalo Co. | 7/5/2016 | EF1 | 0 | 0 | $260,000.00 | $- |
| Buffalo Co. | 7/5/2016 | EF1 | 0 | 0 | $235,000.00 | $- |
| Vernon Co. | 7/5/2016 | EF0 | 0 | 0 | $5,000.00 | $- |
| Chippewa Co. | 7/12/2016 | EF0 | 0 | 0 | $25,000.00 | $- |
| Barron Co. | 7/27/2016 | EF0 | 0 | 0 | $50,000.00 | $- |
| Marathon Co. | 8/4/2016 | EF1 | 0 | 0 | $100,000.00 | $5,000.00 |
| Kewaunee Co. | 8/20/2016 | EF0 | 0 | 0 | $25,000.00 | $- |
| La Crosse Co. | 3/6/2017 | EF1 | 0 | 0 | $290,000.00 | $- |
| Barron Co. | 5/16/2017 | EF2 | 1 | 25 | $10,100,000.00 | $- |
| Rusk Co. | 5/16/2017 | EF3 | 0 | 0 | $420,000.00 | $- |
| Trempealeau Co. | 5/17/2017 | EF1 | 0 | 0 | $60,000.00 | $- |
| Fond Du Lac Co. | 6/12/2017 | EF0 | 0 | 0 | $7,000.00 | $- |
| Waushara Co. | 6/14/2017 | EF1 | 0 | 0 | $100,000.00 | $- |
| Winnebago Co. | 6/14/2017 | EF0 | 0 | 0 | $5,000.00 | $- |
| Outagamie Co. | 6/14/2017 | EF1 | 0 | 0 | $250,000.00 | $- |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Outagamie Co. | 6/14/2017 | EF0 | 0 | 0 | $2,500.00 | $- |
| Shawano Co. | 6/14/2017 | EF1 | 0 | 0 | $75,000.00 | $- |
| Shawano Co. | 6/14/2017 | EF0 | 0 | 0 | $25,000.00 | $- |
| Green Co. | 6/28/2017 | EF1 | 0 | 0 | $145,000.00 | $- |
| Green Co. | 6/28/2017 | EF1 | 0 | 0 | $325,000.00 | $- |
| Rock Co. | 6/28/2017 | EF0 | 0 | 0 | $60,000.00 | $- |
| Portage Co. | 7/12/2017 | EF0 | 0 | 0 | $5,000.00 | $- |
| Dane Co. | 10/7/2017 | EF0 | 0 | 0 | $250,000.00 | $- |
| Grant Co. | 5/9/2018 | EF0 | 0 | 0 | $25,000.00 | $- |
| Washington Co. | 5/9/2018 | EF0 | 0 | 0 | $15,000.00 | $- |
| Columbia Co. | 6/16/2018 | EF0 | 0 | 0 | $2,000.00 | $- |
| Lafayette Co. | 6/26/2018 | EF0 | 0 | 0 | $1,000.00 | $- |
| Lafayette Co. | 6/26/2018 | EF0 | 0 | 0 | $15,000.00 | $- |
| Dane Co. | 8/9/2018 | EF0 | 0 | 0 | $50,000.00 | $- |
| Walworth Co. | 8/20/2018 | EF0 | 0 | 0 | $15,000.00 | $- |
| Monroe Co. | 8/27/2018 | EF1 | 0 | 0 | $25,000.00 | $- |
| Dodge Co. | 8/28/2018 | EF2 | 0 | 0 | $169,000.00 | $5,000.00 |
| Manitowoc Co. | 8/28/2018 | EF1 | 0 | 0 | $75,000.00 | $- |
| Vernon Co. | 5/24/2019 | EF0 | 0 | 0 | $1,000.00 | $4,000.00 |
| Rusk Co. | 7/4/2019 | EF0 | 0 | 0 | $500,000.00 | $- |
| Vernon Co. | 7/18/2019 | EF0 | 0 | 0 | $40,000.00 | $- |
| Clark Co. | 7/19/2019 | EF0 | 0 | 0 | $30,000.00 | $- |
| Clark Co. | 7/19/2019 | EF1 | 0 | 0 | $30,000.00 | $- |
| Oneida Co. | 7/19/2019 | EF0 | 0 | 0 | $400,000.00 | $- |
| Marathon Co. | 7/19/2019 | EF1 | 0 | 0 | $25,000.00 | $- |
| Trempealeau Co. | 7/20/2019 | EF0 | 0 | 0 | $0.00 | $10,000.00 |
| Jackson Co. | 7/20/2019 | EF0 | 0 | 0 | $0.00 | $10,000.00 |
| Waupaca Co. | 7/20/2019 | EF1 | 0 | 0 | $150,000.00 | $- |
| Waupaca Co. | 7/20/2019 | EF0 | 0 | 0 | $150,000.00 | $- |
| Waupaca Co. | 7/20/2019 | EF0 | 0 | 0 | $100,000.00 | $- |
| Outagamie Co. | 7/20/2019 | EF1 | 0 | 0 | $25,000.00 | $- |
| Outagamie Co. | 7/20/2019 | EF1 | 0 | 0 | $75,000.00 | $- |
| Outagamie Co. | 7/20/2019 | EF0 | 0 | 0 | $10,000.00 | $- |
| Brown Co. | 8/7/2019 | EF0 | 0 | 0 | $50,000.00 | $- |
| Dunn Co. | 9/24/2019 | EF0 | 0 | 0 | $250,000.00 | $- |
| Chippewa Co. | 9/24/2019 | EF3 | 0 | 3 | $3,000,000.00 | $- |
| Clark Co. | 9/24/2019 | EF1 | 0 | 0 | $255,000.00 | $- |
| Grant Co. | 3/28/2020 | EF1 | 0 | 0 | $180,000.00 | $- |
| Trempealeau Co. | 7/18/2020 | EF1 | 0 | 0 | $120,000.00 | $3,000.00 |
| Grant Co. | 8/10/2020 | EF0 | 0 | 0 | $15,000.00 | $- |
| Walworth Co. | 8/10/2020 | EF0 | 0 | 0 | $12,000.00 | $- |
| Kenosha Co. | 8/10/2020 | EF1 | 0 | 0 | $250,000.00 | $- |

| Total | | | 1 | 28 | $19,684,500.00 | $37,000.00 |
|---|---|---|---|---|---|---|

Source: SPC, WEM

### *3.2.5 Hail*

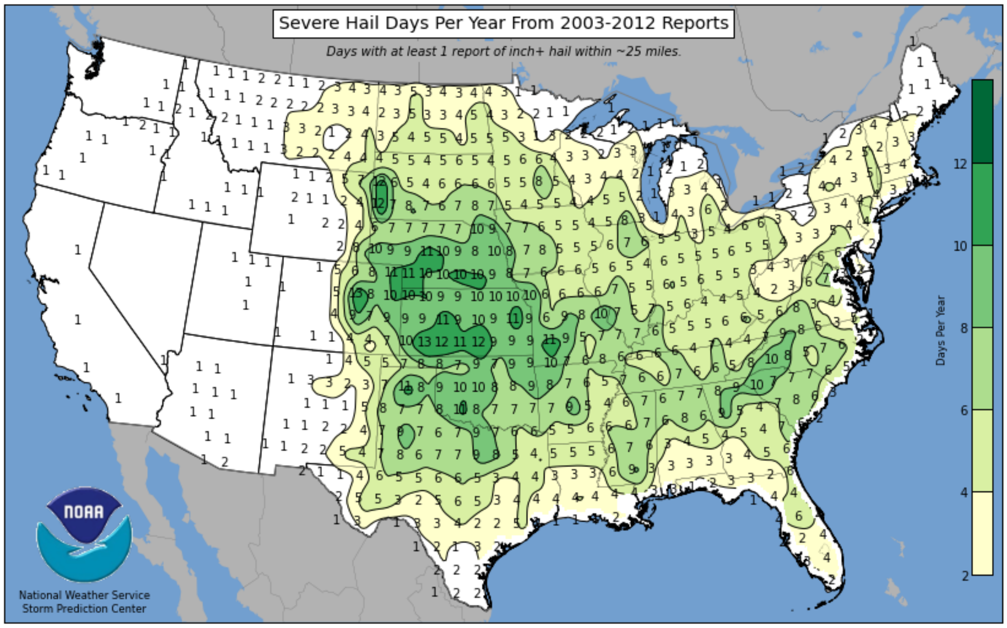
**Table 3.2.5-1: Hazard Ranking**

| Evaluation Criteria | Description | Ranking |
|---|---|---|
| Probability | • Occurs annually or assumed to occur at least once per year. Near 100% probability of occurrence each year. | Highly Likely |
| Vulnerability | • Minimal countermeasures are in place to prevent or protect against this hazard.<br>• Countermeasures may have potential but limited demonstrated history in reducing the threat potential.<br>• The nature of the hazard may limit the availability of countermeasures. | High |
| Mitigation Potential | • Methods for reducing risk from the hazard are not well-established, are not proven reliable, or are experimental.<br>• The State or counties have little or no experience in implementing mitigation measures, and/or no technical knowledge of them.<br>• Mitigation measures are ineligible under federal grant programs.<br>• There is a very limited range of mitigation measures for the hazard, usually only one feasible alternative.<br>• The mitigation measures have not been proven cost-effective and are likely to be expensive compared to the magnitude of the damages caused by the hazard.<br>• The long-term effectiveness of the measure is not known or is known to be relatively poor. | Low |

Section 3.2.5 looks at the frequency and impacts for hail events in Wisconsin. Severe hail is one inch or larger in diameter, which is equal to the size of a quarter. Hailstorms are relatively frequent across the United States. Figure 3.2.5-1 depicts the annual number of days with severe hail per 100 square miles in the U.S. Although they can occur in any state, the states with the highest average number of annual hail days are in the Great Plains. Nebraska, Colorado, and Wyoming usually have the most hailstorms and the area where these three states meet has been dubbed "hail alley." Here, there are an average of seven to nine hail days per year. As shown in Figure 3.2.5-2, Mississippi and Georgia have also had a historically large concentration of hail paths in their time.

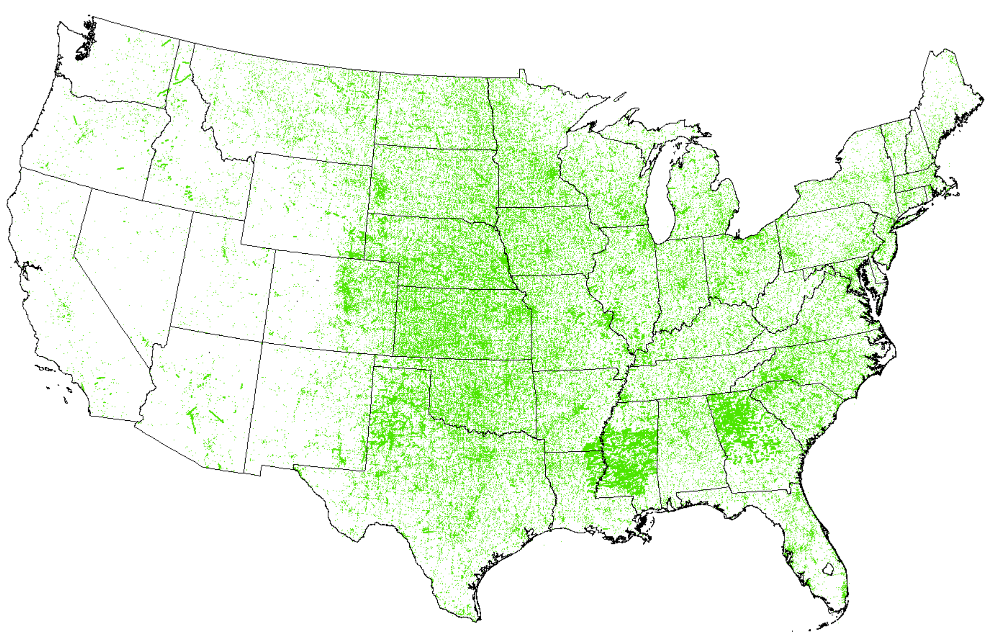
Though hail-related fatalities are rare, hail can cause tremendous amounts of crop and property damage. The costliest hailstorms in the U.S. occurred in Dallas/Fort Worth, Texas, on May 5, 1995, and in St. Louis, Missouri, on April 10, 2001. Both storms had reported damages of over $2 billion. The largest hailstone ever recorded fell in Vivian, South Dakota, on July 23, 2010, with a diameter of eight inches and weighing almost two pounds.

**Figure 3.2.5-1: U.S. Average Hail Days, 2003-2012**




Source: NOAA, SPC

**Figure 3.2.5-2: U.S. Hail Paths, 1950-2019**



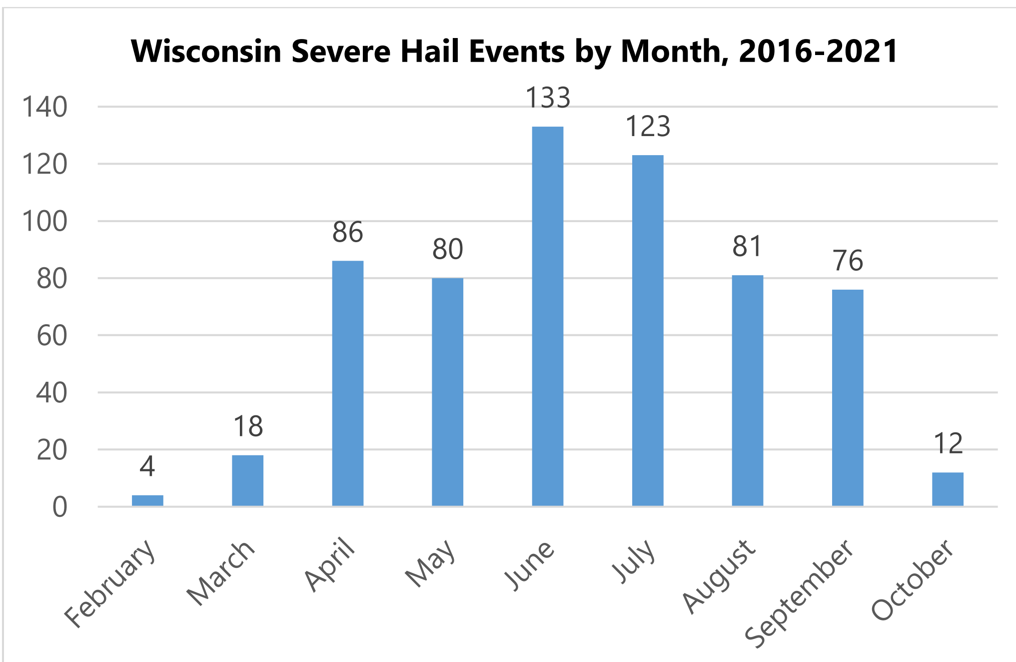
Source: NOAA, SPC

Probability

The probability of severe hail in Wisconsin is highly likely as hailstorms occur every year. As of recently, June and July have the highest frequency of hail events. Although, there are still many occurrences during April, May, August, and September. Between 1955 and 2021, there were 4,266 hail events that produced hailstones one inch or greater. Of these 4,266 events, 613 have been within the last five and a half years – from 2016 to 2021. Figure 3.2.5-3 shows these counts by month.

According to local experts at NWS, the average land area affected by an individual hail event is about 225 square miles. In other words, on average, an area within an 8.5-mile radius of the center of the storm is affected in a hail event. Hail risk at a single point or over an area is a function of the target at risk (crop or property) and the hail frequency and intensity.[4] The qualitative annual probability of hail occurring somewhere in the state is quite high. However, the site-specific incidence of hail is lower due to the localized nature of the hazard.

**Figure 3.2.5-3: Wisconsin Severe Hail Events by Month, 2016-2021**



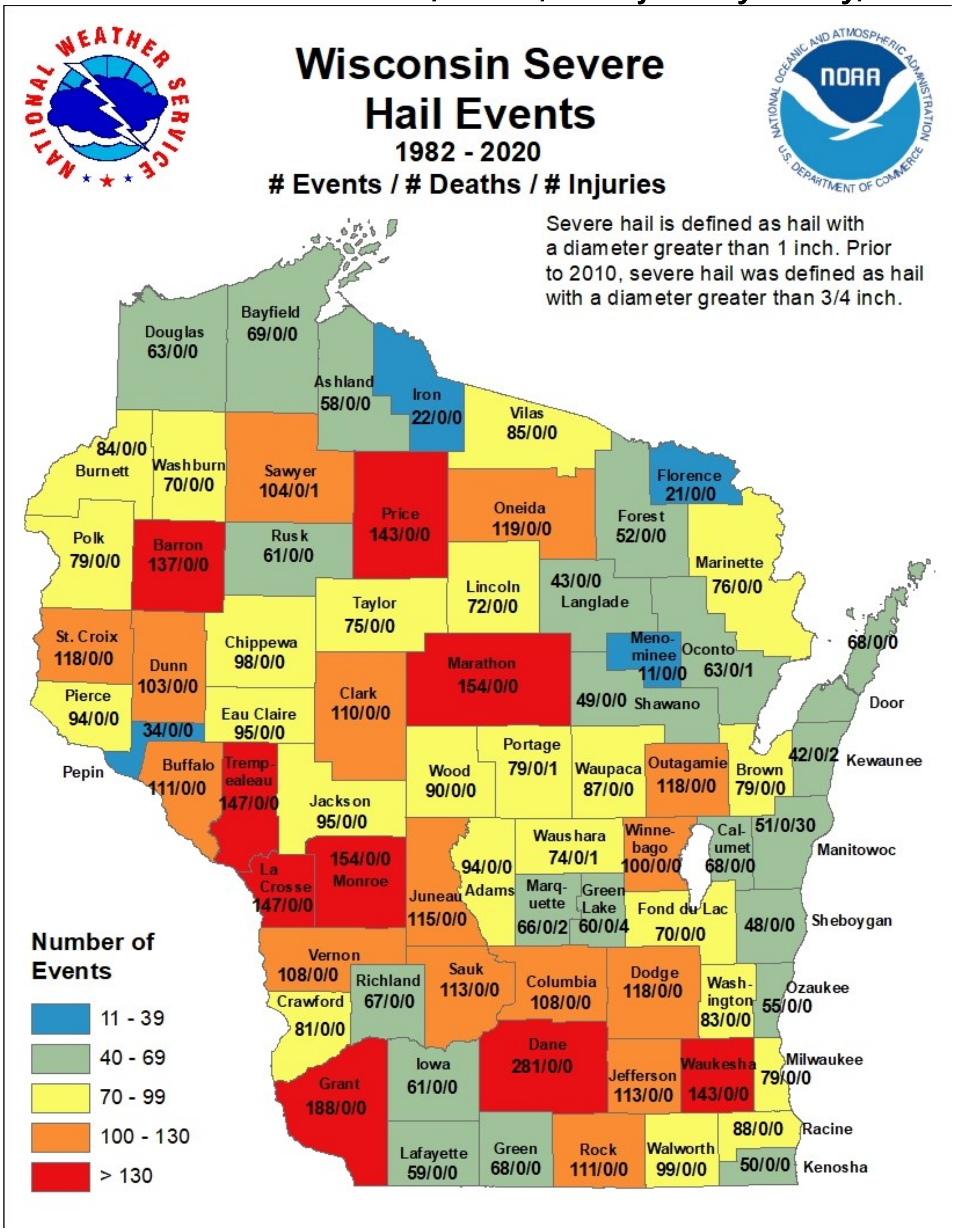

Source: NOAA, SPC, WEM

Figure 3.2.5-4 highlights the severe hailstorm events that occurred in each Wisconsin county between 1982 and 2020, including the numbers of deaths and injuries attributed to those events. Only one county, Menominee, has experienced fewer than 20 hail events during the 39-year period shown. Conversely, Dane county encountered nearly 100 more hail events than any other county in Wisconsin. Unlike other severe weather, high counts of severe hail are not only

[4] This estimate was provided by a meteorologist at the NWS Milwaukee/Sullivan Office specializing in storm statistics in 2011.

in the southern counties. The northern areas of Barron, Sawyer, Price, and Oneida all have over 100 severe hail events.

**Figure 3.2.5-4: Wisconsin Hail Events, Deaths, and Injuries by County, 1982-2020**




Source: NWS, Milwaukee/Sullivan

<u>Vulnerability</u>

Both agricultural and urban land uses are susceptible to costly hail damage. Many Wisconsin counties, such as Dane and Grant, have large proportions of their land area devoted to agricultural uses. Accounting for roughly 80% of Wisconsin's hailstorms, May through September are the months of maximum hailstorm frequency in Wisconsin. Unfortunately, those months also correspond to the growing and harvesting season for most of the state's crops. Crop damage from hail can devastate an agricultural region's economy. In the past five and a half years, there was just under $7 million in crop damage. Although, to put this number to scale, severe hailstorms have caused $62 million in crop damages since 1955.

Counties like Milwaukee, Waukesha, Dane, and St. Croix have high concentrations of development and dense population centers. Property damage to structures, vehicles, and occasionally infrastructure, from hail is relatively common. Total property damages since 2016 were $55.3 million.

Surprisingly, very few injuries resulting from hail have occurred in the more densely populated areas of the state. Manitowoc County has seen the highest number of reported injuries from hail, 30, all of which stemmed from a single severe hailstorm event on May 12, 2000. Between 2016 and 2021, there were zero injuries reported in the state because of hail. There have been no fatalities in Wisconsin due to hail, but there have been a few nationwide.

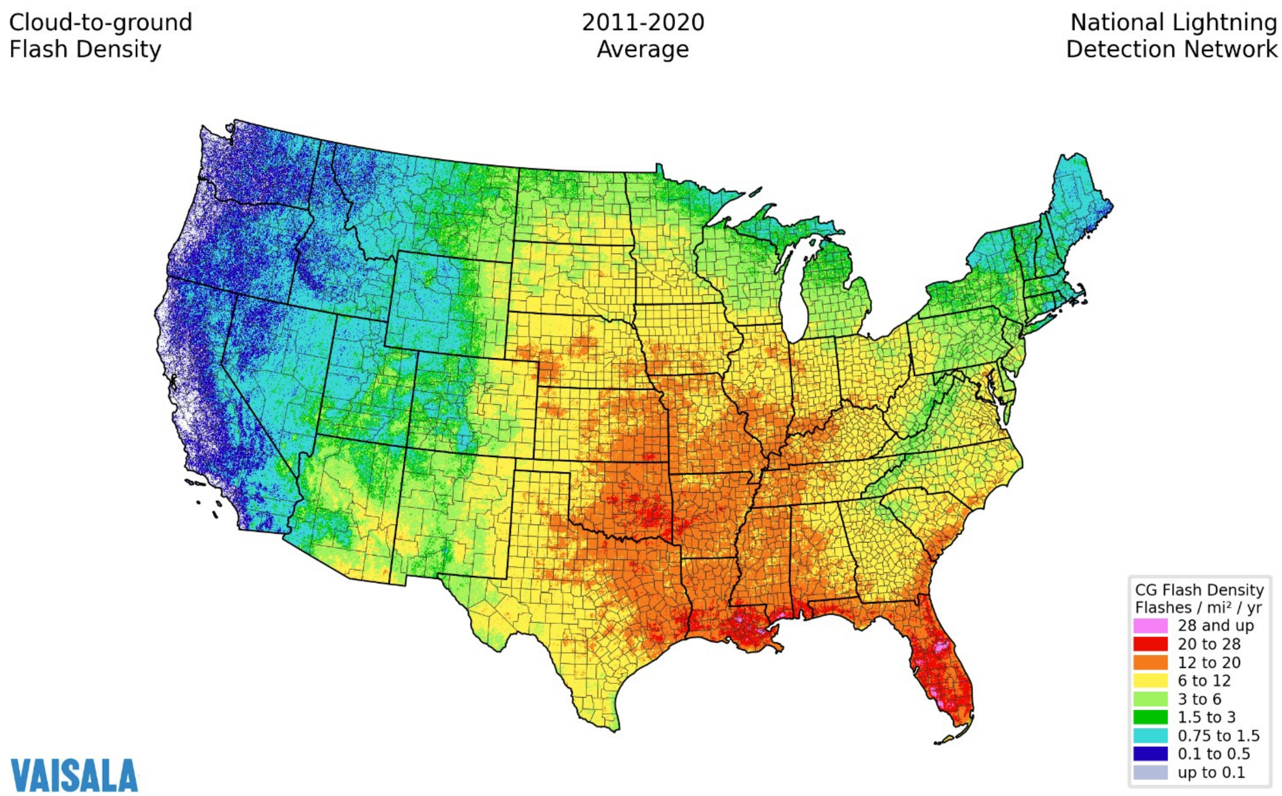
### *3.2.6 Lightning*

**Table 3.2.6-1: Hazard Ranking**

| Evaluation Criteria | Description | Ranking |
|---|---|---|
| Probability | • Occurs annually or assumed to occur at least once per year. Near 100% probability of occurrence each year. | Highly Likely |
| Vulnerability | • Multiple measures are in place to prevent or protect against this hazard.<br>• Countermeasures have been tested and have demonstrated success in reducing the threat potential. | Medium |
| Mitigation Potential | • Methods for reducing risk from the hazard are not well-established, are not proven reliable, or are experimental.<br>• The State or counties have little or no experience in implementing mitigation measures, and/or no technical knowledge of them.<br>• Mitigation measures are ineligible under federal grant programs.<br>• There is a very limited range of mitigation measures for the hazard, usually only one feasible alternative.<br>• The mitigation measures have not been proven cost-effective and are likely to be expensive compared to the magnitude of the damages caused by the hazard.<br>• The long-term effectiveness of the measure is not known or is known to be relatively poor. | Low |

This section will detail the final severe weather category – lightning. According the NWS, lightning strikes the United States about 25 million times each year. Figure 3.2.6-1 shows the density of cloud-to-ground flashes in the United States. As shown, there is a high concentration of these flashes in the southern coastal states where tropical thunderstorms are prevalent. The west coast, as well as the upper east coast, experience significantly less cloud-to-ground flashes each year. A typical lightning flash is about 300 million Volts and about 30,000 Amps. Comparatively, a household current is 120 Volts and 15 Amps.

**Figure 3.2.6-1: Cloud-to-ground Flash Density, 2011-2020**

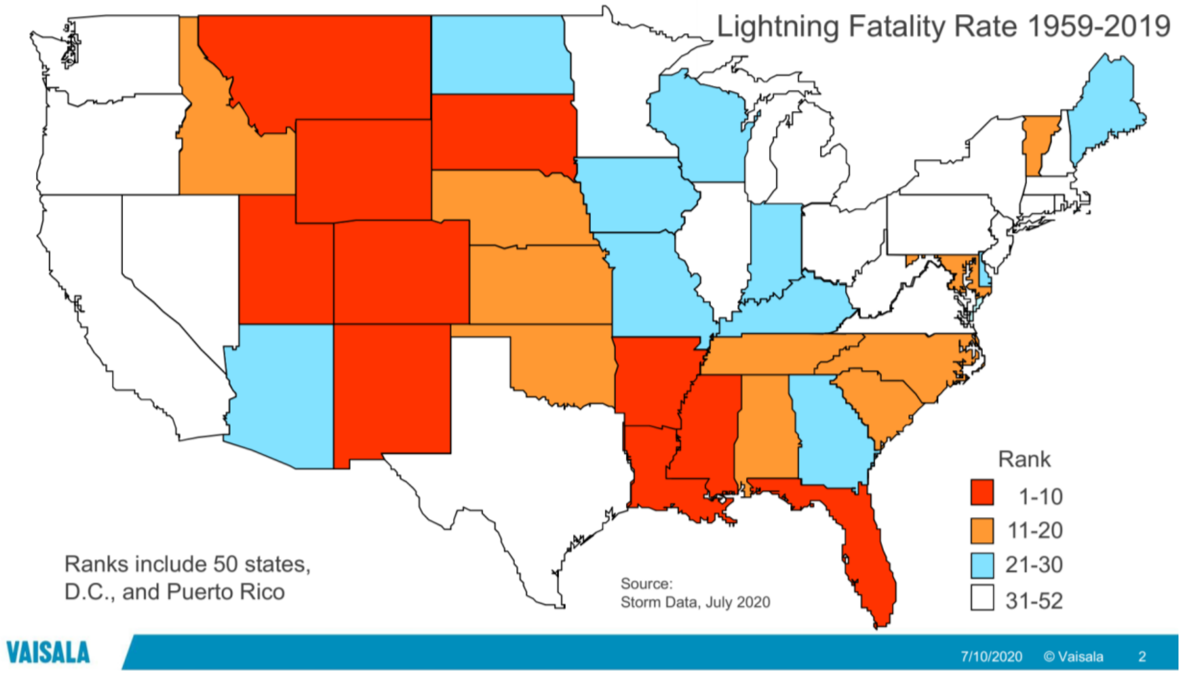



Source: National Lightning Detection Network (NLSN)

According to NOAA, there were 9,422 lightning fatalities in the United States from 1940 until 2020. In Figure 3.2.6-2, the lightning fatality rates for 1959 through 2019 are shown by ranking. The states in red have the highest number of lightning deaths (ranks 1-10), followed by those in orange (ranks 11-20). Wisconsin falls in the blue (ranks 21-30) range for its ranking. The states remaining in white (ranks 31-52), have the least lightning fatalities in the country.

While there is some correlation between the density of lightning (Figure 3.2.6-1) and location of lightning fatalities (Figure 3.2.6-2), there are areas where lightning is very dense, and a low number of deaths occurred; Texas is a good example of this. Vice versa, in Utah, there is a low density of strikes, yet they in the top ten for number of lightning fatalities. This goes to show that the impacts of lightning can be unpredictable; more about those impacted and the vulnerability of certain groups is in the last paragraph of this section.

**Figure 3.2.6-2: Lightning Fatality Rate, 1959-2019**

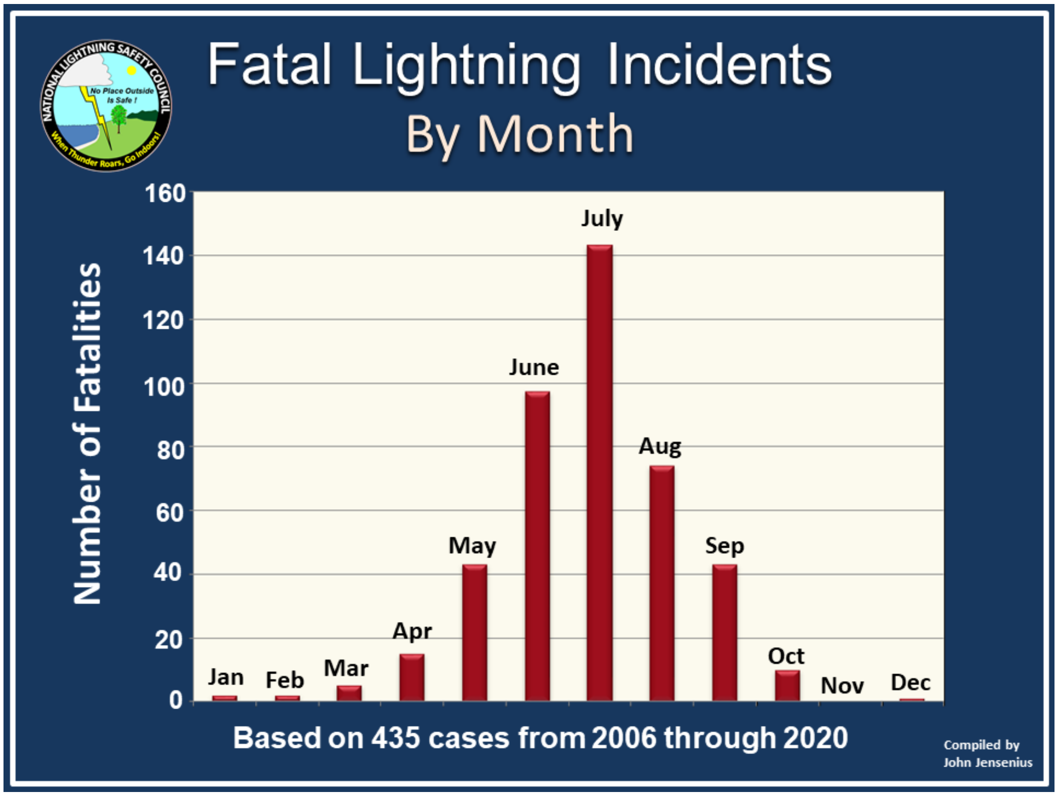



Source: National Lightning Safety Council (NLSC), NOAA

<u>Probability</u>

Since lightning occurs with most severe thunderstorms, the probability of occurrence is highly likely in Wisconsin. As with the other severe weather patterns, lightning can occur during any season and at any time, but it is most frequent in the summer months between the afternoons and early evenings. Figure 3.2.6-3 highlights how most fatal lightning incidents occur during July; June and August are close seconds.

**Figure 3.2.6-3: Fatal Lightning Incidents by Month, 2006-2020**

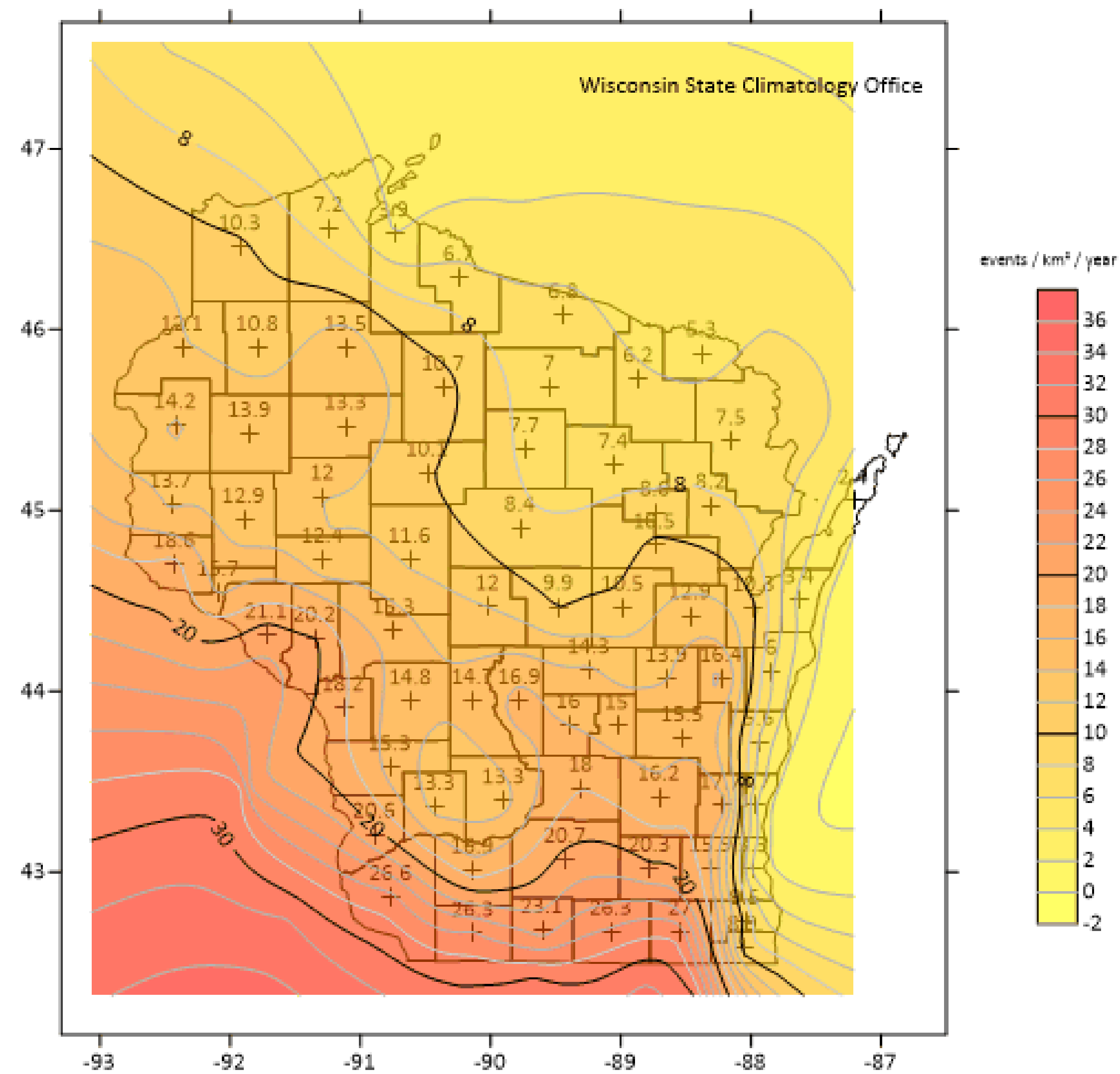



Source: NLSC

In Wisconsin, there were 642 reported lightning events between 1996 and 2020 according to the SPC. 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.

Figure 3.2.6-4 is a map of the average lightning densities throughout the state. Like severe thunderstorms, there are few lightning events along the coasts where cold air from the lakes can potentially suppress thunderstorm formation. The southern counties experience the most lightning, and these numbers gradually decrease as you move north. Please note that the units for this map are lightning events / $km^2$ / year.

**Figure 3.2.6-4: Wisconsin Average Lightning Density, 2016-2020**

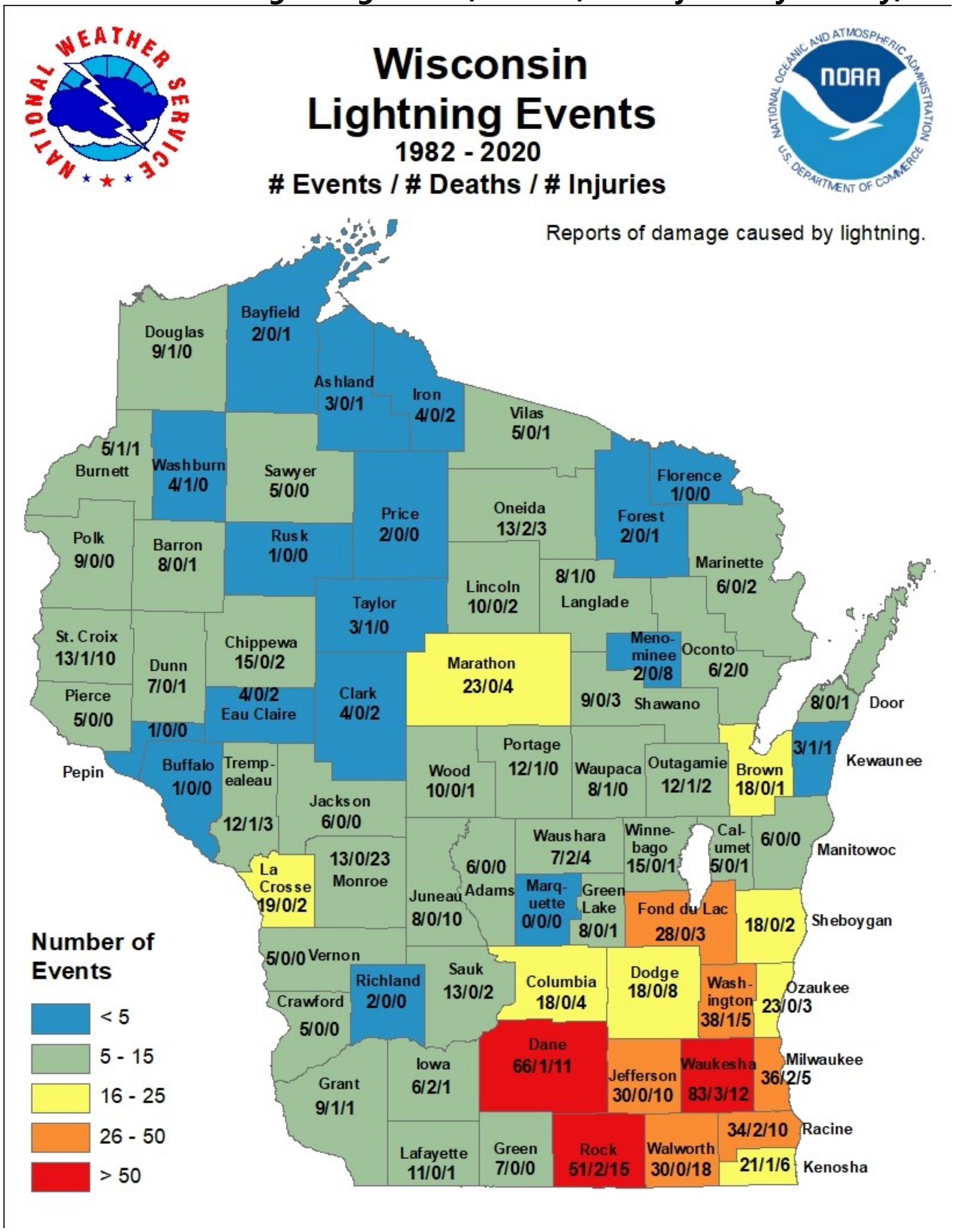



Average lightning density (2016-2020)
Units: lightning events / km² / year
Source: Vaisala Interactive Global Lightning Density Map, 2021

Source: Vaisala Interactive Global Lightning Density Map, Wisconsin State Climatology Office

Figure 3.2.6-5 shows the damaging lightning events by county from 1982 to 2020. The number of reported deaths and injuries are also presented on the map. Note the high concentration of damaging lightning events in the southeastern part of the state. Waukesha County leads Wisconsin in the number of lightning events with 83 occurring since 1982. Walworth and Rock counties have experienced the most reported injuries with 18 and 15, respectively. The 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. Notably, Figures 3.2.6-4 and 3.2.6-5 show different information due to different data collection methods. Figure 3.2.6-4 uses Vaisala's GLD360 lightning detection network to pick up on nearly every lightning strike in the state. Comparatively, Figure 3.2.6-5 relies on reports of damage caused by lightning, which does not include smaller lightning strikes that produce no damage.

**Figure 3.2.6-5: Wisconsin Lightning Events, Deaths, and Injuries by County, 1982-2020**




Source: NWS, Milwaukee/Sullivan

Vulnerability and Mitigation Potential

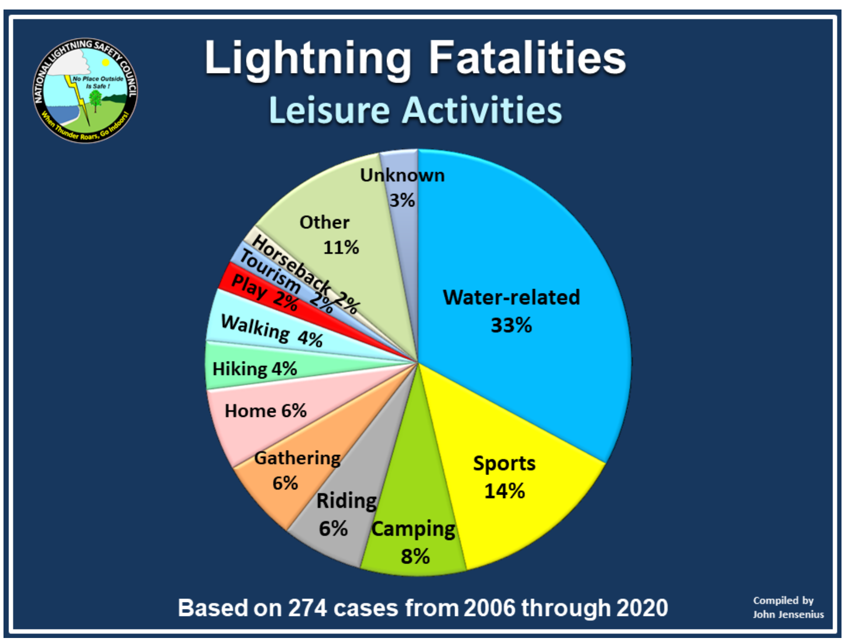
Large outdoor gatherings (sporting events, concerts, campgrounds, etc.) are particularly vulnerable to lightning strikes that could result in injuries and deaths. While some states have warning sirens for severe thunderstorm and lightning events, others do not. Counties, tribes, and cities own the sirens and therefore decide how and when to activate them. Activation policies vary by location; some will activate them for tornado warnings only, others will activate them for tornado warnings and severe thunderstorm warnings. Similarly, the type of sirens may not be the same across the state. Some counties have lightning sirens in addition to their other severe weather sirens. Many counties may not have warning sirens purely for severe thunderstorm and lightning events.

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. The slogan "Flash, Dash Inside," was created by and for people who are deaf and hard of hearing. Regardless of the safety measures taken, media reports from past lightning fatalities describe how the victims were either headed to safety at the time of the strike or just steps away from safety.

According to NWS Storm Data from 1989-2018, approximately 10% of persons struck by lightning are killed, leaving 90% of lightning strike survivors with various degrees of disability. With lightning strikes, cardiac arrest and/or injuries to the nervous system can occur. Furthermore, lightning strike survivors can experience delayed symptoms like personality changes, irritability, difficulty carrying on conversations, depression, chronic pain, and headaches.

John Jensenius, a Lightning Safety Specialist for NLSC has identified patterns in lightning fatality cases. Between 2006 and 2020, 79% of lightning fatalities were male, 21% female. Additionally, the majority, 63%, occurred during leisure activities, while 16% occurred during daily routines, and 19% during work-related activities. 3% of activities were unknown. Figure 3.2.6-6 shows the breakdown of leisure activities associated with lightning fatalities, followed by Table 3.2.6-2 with Wisconsin's lightning fatalities in the last 15 years.

**Figure 3.2.6-6: Lightning Fatalities During Leisure Activities, 2006-2020**



Source: NLSC, NOAA

**Table 3.2.6-2: Wisconsin Lightning Fatalities, 2006-2020**

| Date | Day of Week | State | City | Age | Sex | Location | Activity |
|---|---|---|---|---|---|---|---|
| 9/6/2016 | Tuesday | WI | Minocqua | 66 | M | Outside home | Walking dog |
| 8/3/2014 | Sunday | WI | Morgan | 27 | M | In tree | Building tree house |
| 8/3/2014 | Sunday | WI | Morgan | 31 | M | Under tree | Building tree house |
| 6/30/2014 | Monday | WI | Janesville | 63 | M | Roadway | Fixing windshield wiper |
| 7/1/2011 | Friday | WI | Burnett Cnty | 11 | F | Under tree | Camping |
| 7/7/2008 | Monday | WI | Watertown | 16 | M | Under tree in yard | |
| 8/27/2007 | Monday | WI | Madison | 75 | M | Under tree | Golf |
| 10/2/2006 | Monday | WI | Preston | 46 | M | Field | Surveying |
| 7/24/2006 | Monday | WI | Antigo | 24 | M | Under Tree | ------ |

Source: NLSC

Wisconsin also has a high frequency of property loss due to lightning. During the 5-year period from 2016 to 2020, there was $6.425 million in property damages from lightning reported in Wisconsin. One of the most damaging lightning events occurred in downtown Waukesha in 2019. Lightning struck and caused a fire in a 42-unit apartment building causing 100 people to be displaced and the building to be totaled.

While lightning detection capabilities have improved over the past several years, the mitigation potential remains low due to the unpredictability of lightning strikes. Additionally, many people and events do not act quickly enough when thunderstorms begin. In general, the willingness to cancel or postpone plans due to weather is low. The safest option when lightning is present is to move indoors. The CDC provides guidance on how to stay safe during each of the follow scenarios:

*Safety Precautions Outdoors*

- If the weather forecast calls for thunderstorms, postpone your trip or activity.
- Remember this slogan, "**When thunder roars, go indoors**." Find a safe, enclosed shelter. Safe shelters include homes, offices, shopping centers, and hard-top vehicles with the windows rolled up.

- Don’t forget the **30-30 rule.** After you see lightning, start counting to 30. If you hear thunder before you reach 30, go indoors. Suspend activities for at least 30 minutes after the last clap of thunder.
- If you are caught in an open area, act quickly to find adequate shelter. The most important action is to remove yourself from danger. Crouching or getting low to the ground can reduce your chances of being struck but does not remove you from danger. If you are caught outside with no safe shelter nearby, the following actions may reduce your risk:
    - Immediately get off elevated areas such as hills, mountain ridges, or peaks.
    - Never lie flat on the ground. Crouch down in a ball-like position with your head tucked and hands over your ears so that you are down low with minimal contact with the ground.
    - Never shelter under an isolated tree.
    - Never use a cliff or rocky overhang for shelter.
    - Immediately get out of and away from ponds, lakes, and other bodies of water.
    - Stay away from objects that conduct electricity (such as barbed wire fences, power lines, or windmills).
- Stay away from concrete floors or walls. Lightning can travel through any metal wires or bars in concrete walls or flooring.

*Safety Precautions Indoors*

- Avoid contact with water during a thunderstorm. Do NOT bathe, shower, wash dishes, or have any other contact with water during a thunderstorm. Lightning can travel through plumbing.
- Avoid using electronic equipment of all types. Lightning can travel through electrical systems and radio and television reception systems.
- Avoid using corded phones. Corded phones are NOT safe to use during a thunderstorm. However, cordless or cellular phones are safe to use during a storm.
- Avoid concrete floors and walls. Do NOT lie on concrete floors during a thunderstorm. Also, avoid leaning on concrete walls. Lightning can travel through any metal wires or bars in concrete walls or flooring.

### 3.2.7 Climate Change Impacts

According to the Climate Science Special Report (CSSR) as part of the Fourth National Climate Assessment, "quantifying how broad-scale average climate influences the behavior of extreme storms is particularly challenging, in part because extreme storms are comparatively rare short-lived events and occur within an environment of largely random variability." As touched on above, many of the correlations between climate change and its effect on thunderstorms, high winds, tornadoes, hail, and lightning are somewhat inconclusive. However, it is still important to identify the risks of a changing climate in Wisconsin as it relates to each of these hazards. Since confidence levels are frequently used in the NCA4 report, their descriptions are listed below in Table 3.2.7-1

**Table 3.2.7-1: Confidence Levels from NCA4 Report**

| Low | Medium | High | Very High |
|---|---|---|---|
| Inconclusive evidence (limited sources, extrapolations, inconsistent findings, poor documentation and/or methods not tested, etc.), disagreement or lack of opinions among experts | Suggestive evidence (a few sources, limited consistency, models incomplete, methods emerging, etc.), competing schools of thought | Moderate evidence (several sources, some consistency, methods vary and/or documentation limited, etc.), medium consensus | Strong evidence (established theory, multiple sources, consistent results, well documented and accepted methods, etc.), high consensus |

Source: U.S. Global Change Research Program (USGCRP), Intergovernmental Panel on Climate Change (IPCC)

*Thunderstorms*

As more robust climate models are developed, their ability to predict future severe storm activity will also increase. Currently, the models in place suggest an increase in the frequency and intensity of severe thunderstorms – especially in the Midwest and Southern Great Plains during the spring months. Unfortunately, there is low confidence in these models and limited data to support this finding. Regardless, Wisconsin is *likely* to experience an increase in both the frequency and severity of thunderstorms since the state is prone to this hazard.

*High Winds*

Many climate studies and models do not include wind in their calculations, despite its ability to accelerate climate disruptions. For example, an increase in high winds can lead to a small wildfire quickly spreading into a larger one. Despite its potential impacts, the available models are unreliable as there is little tangible visual evidence for damaging winds. Although, since high winds are oftentimes associated with severe thunderstorms, it is *possible* that their frequency and speed will increase in Wisconsin.

*Tornadoes*

The general impact of climate change on tornadoes is an increase in the variability of the hazard. That is, the models show that the United States has experienced a decrease in the number of days per year on which tornadoes occur, but an increase in the number of tornadoes that form on these days. This means that the likelihood of tornado outbreaks appears to be increasing. There is a medium amount of confidence in the models that point to this finding. In Wisconsin, it is *likely* that the number of tornado events will increase – especially on each of the days during the peak season.

*Hail*

Hail is like high wind in that there is unreliable evidence regarding how climate change will affect it. This is largely to the fact that hail size is hard to report and oftentimes people will overestimate it. Since there is conflicting information on how hailstorms will change with our warming climate, there is no definite outcome for Wisconsin at this time.

*Lightning*

While there is little information regarding the impacts of climate change on lightning, one study in the Environment Journal claimed that an increase in CO2 emissions means stronger updrafts are more likely to produce lightning. If there is double the amount of CO2 as there is now, we may see fewer lightning storms overall, but 25% stronger storms with a 5% increase in lightning. There is low confidence in the models and studies supporting this finding. However, for Wisconsin, we can assume that it is *possible* the state will see an increase in the amount of lightning associated with severe thunderstorms.

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# 3.3 FLOODING

## 3.3.1 Nature of the Hazard

**Flooding**, as defined by the National Flood Insurance Program (NFIP), is "a general and temporary condition where two or more acres of normally dry land, or two or more properties, are inundated by water or mudflow." 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. Flooding is the most widespread natural disaster in the U.S.

Floods specifically affect **floodplains**, lowland areas adjacent to lakes or rivers that are periodically covered with water. In Wisconsin, riverine floodplains range from narrow, confined channels in the steep valleys of hilly regions, to wide, flat areas in plains and coastal regions. The amount of water that inundates a floodplain is a function of the size and topography of the contributing watershed, the regional and local climate, geological characteristics, and land use attributes.

The U.S. experiences several different types of floods, the most common of which is riverine flooding, also known as overbank flooding. Wisconsin is also prone to experiencing flash floods, ice jam floods, local drainage floods, and high groundwater floods. Flash floods are notable for their rapid escalation, which typically occurs with little or no warning and tends to be accompanied by other problems.

**Flash floods** occur within six hours of a causative event such as heavy rains, rain combined with snowmelt, ice jams, or dam failures. They usually involve a rapid rise in water level, high velocity discharge, and large amounts of debris. Flash floods can cause significant damage, including the toppling of trees, undermining of buildings and bridges, scouring of channels, and the creation of sink holes. The intensity of flash flooding is a function of the intensity and duration of rainfall, steepness of the watershed, stream gradients, watershed vegetation, natural and artificial flood storage areas, and configuration of the streambed and floodplain. Urban areas are increasingly subject to flash flooding due to the removal of vegetation, installation of impermeable surfaces, and construction of manmade drainage systems.

Much of the flooding on Wisconsin's larger rivers occurs more than six hours after a causative event. This kind of flooding can ultimately affect larger rivers, but also small streams and low-lying areas outside of the floodplains of larger rivers. In Wisconsin, it is not uncommon for flash flooding on larger rivers to transition into general river flooding that persists for days. Prolonged periods of rainfall from weather systems covering large areas represent the most common cause of flooding in Wisconsin's large rivers. These systems may saturate the ground and overload the rivers and/or reservoirs in numerous smaller basins that drain into larger rivers. Localized weather systems, such as thunderstorms, may cause intense rainfall over smaller areas, leading to flooding in smaller rivers and streams. These events may also lead to flooding in larger waterways, as smaller rivers, and streams feed into larger systems. Annual spring floods caused by the melting of snowpack may affect both large and small rivers and areas.

*Floodplain Regulation and Mapping*

Humans have settled on the edges of lakes, rivers, and other waterbodies since the earliest civilizations. This innate attraction to water has unfortunately resulted in widespread, costly, and repetitive flood damages where development encroaches upon the natural floodplain. Regulatory measures have thus been enacted to reduce flood risk, prevent loss of life and damage to property, and maintain the natural value of undeveloped floodplains. The successful regulation of development in floodplains relies on collaboration between multiple levels of government.

At the Federal level, floodplain regulation primarily falls to FEMA and the National Flood Insurance Program. The NFIP, established in 1968, administers the nationwide flood insurance program and sets standards for floodplain management as part of the requirements for participating in the program. NFIP requirements are outlined in 44 Code of Federal Regulations 59-72. Communities that elect to participate in the NFIP ensure the availability of federally backed flood insurance policies for the homeowners, renters, and businesses in their jurisdiction. As of August 2021, 561 Wisconsin communities participate in the NFIP; 65 additional communities have mapped floodplains but are not currently in the program.

FEMA produces **Flood Insurance Rate Maps** (FIRMs), which show areas at risk of flooding and provide a basis for regulatory decisions and insurance requirements. FIRMs are generated using data from Flood Insurance Studies (FISs), engineering studies that examine records of river flow, rainfall, hydrologic and hydraulic analyses, topographic surveys, and community information. FIRMs were first distributed as printed paper maps, but in recent years FEMA has switched to Digital Flood Insurance Rate Maps (DFIRMs).

FIRMs show the **Special Flood Hazard Area** (SFHA), defined as the area that is inundated during the **base flood**, also known as the 1-percent-annual-chance or "100-year" flood. In Wisconsin, the base flood is also referred to as the regional flood. In areas where the **Base Flood Elevation** (BFE) has been calculated through engineering studies, it serves as the regulatory benchmark for structure elevation or floodproofing. Flood insurance premiums are determined by a structure's elevation in relation to the BFE. State statutes refer to the BFE as the **regional flood elevation**; in Wisconsin, the **flood protection elevation** (FPE) is two feet above the regional flood elevation.

Floodplain regulation activities in Wisconsin are administered by the Wisconsin Department of Natural Resources (DNR) Floodplain Management Section. The State of Wisconsin has required communities to regulate floodplains since 1968 through Chapter NR 116 of the Wisconsin Administrative Code. The standards established in Ch. NR 116 exceed the minimum standards set by the NFIP to provide a higher level of protection to Wisconsin residents. Some of the higher standards set by Wisconsin include the prohibition of structures in the floodway, the requirement that elevated structures be at least two feet above the regional flood elevation, and the requirement that structures have dryland access even during flooding.

State floodplain managers also support FEMA's flood mapping efforts. DNR engineers often conduct the engineering studies and hydraulic analyses used to create FISs and DFIRMs under FEMA's Risk MAP program. DNR staff reviews and approves these studies to ensure compliance with Ch. NR 116.

Local governments are responsible for regulating new construction in mapped flood hazard areas and are typically the first point of contact for community members regarding floodplain management issues. Communities manage floodplain development through their local floodplain ordinances. Wisconsin state statutes require communities to adopt a reasonable and effective floodplain ordinance if adequate hydraulic and engineering data is available in their area. Local ordinances are required to comply with both Ch. NR 116 and 44 CFR 59-72 if the community wishes to participate in the NFIP. The DNR provides two model ordinances that communities can use to achieve compliance.

Communities must enforce federal, state, and local floodplain ordinances and make FIRMs and FISs available to the public to remain in good standing with the NFIP. FEMA can penalize communities that fail to meet these requirements through probation or suspension from the NFIP. The DNR can take enforcement action if communities violate the minimum requirements of NR 116.

*Flood Mitigation*

Attempts to reduce flood risk usually take one of two approaches: those that focus on controlling the flood through structural means, and those that aim to reduce vulnerabilities through smaller-scale projects such as elevations and acquisitions. Large structural projects may provide significant short-term benefits but tend to be costly and often have unpredictable secondary effects. In contrast, smaller projects tend to be more cost-effective, work with rather than against the system's natural tendency to flood, and often provide additional flood storage capacity.

Many historically flood-prone urban areas have been removed from the regulatory floodplain through the application of two structural flood mitigation measures: 1) flood control dams, which reduce peak discharges; and 2) levees, which redirect floods away from areas that would otherwise be inundated. As Wisconsin develops, however, urbanization decreases the abilities of natural systems to absorb rainfall due to the increased number of impervious surfaces and subsequent increase in runoff. Structural flood mitigation projects may not be able to provide protection during increasingly severe flood events if they are designed based on pre-urbanization conditions.

Although flooding resulting from inadequate man-made or "gray" infrastructure presents serious issues that communities must address, this type of flooding has not typically been mapped by the NFIP. Because the NFIP only requires local governments to impose land use regulations in a mapped floodplain, there is little regulatory incentive for communities to act. The NFIP standard flood insurance policy, however, often pays claims for flood losses in areas with inadequate infrastructure.

### 3.3.2 History

One of the first documented accounts of flooding in Wisconsin dates back to 1785 along the Mississippi River in Prairie du Chien. Since that time, flooding has been documented across variable landscape regions of Wisconsin and within all the major watersheds. As Wisconsin has become warmer and wetter over the last couple of decades, the frequency of high magnitude precipitation events has increased, resulting in increased flooding across the state. Because flood events tend to cause the most widespread damages of all Wisconsin's natural hazards, it is critical that managing flood risk is a top priority.

Typically, locations most susceptible to flooding include:

- Low-lying areas in the central and western part of the state that border Wisconsin's largest rivers, the Mississippi and the Wisconsin.
- Streams flowing through watersheds with high relief. These include rivers and streams in the Driftless Area watersheds.
- Streams flowing through predominantly urban centers. These streams are not confined solely to urban centers but have sections that flow through highly developed areas. Stormwater management plans in these urban areas have been developed to help mitigate against flooding.

Understanding flood risk in Wisconsin is important, especially as many communities develop lands previously dedicated to agricultural or preservation uses. Throughout recent years, flooding in Wisconsin has changed in scale and scope. This is due largely to the increasing demand for housing along Wisconsin's waterfronts, land use changes that reduce natural flood storage capacity and alter the characteristics of stream channels, and recent trends toward increasing precipitation amounts.

Flood events in recent decades tend to affect a greater number of counties and result in increasingly costly damages. For example, the July-August 2018 floods that resulted from high magnitude precipitation events impacted 14 counties and caused over 50 million dollars in damages. Historically, the two largest flood hazards in Wisconsin occurred in 1993 and 2008. These two events caused approximately 1.5 billion dollars of damage. Major flood events occurring in Wisconsin since 1973 are listed in Table 3.3.2-1. Fatalities were only listed in the table if they were directly attributed to floodwater drowning. The number of fatalities listed in Table 3.3.2-1 differs from separate online sources because of the way the death classification occurred.

**Table 3.3.2-1: Major Flood Events in Wisconsin, 1973-2021**

| Date of Flood Event | Disaster Number | Area Affected (County/ies) | Damages | Fatalities |
|---|---|---|---|---|
| 1973 | 376 | Adams, Brown, Buffalo, Chippewa, Clark, Crawford, Door, Dunn, Eau Claire, Green Lake, Jefferson, Kenosha, Kewaunee, La Crosse, Langlade, Lincoln, Manitowoc, Marathon, Marinette, Marquette, Milwaukee, Oconto, Outagamie, Ozaukee, Pepin, Portage, Racine, Rock, Rusk, Sheboygan, Walworth, Waukesha, Waupaca, Waushara, Wood | $24,000,000 | 0 |
| 1975 | 482 | Buffalo, Pepin, Pierce, Trempealeau | $5,200,000 | 0 |
| 1978 | 559 | 16 counties in southern and southwestern Wisconsin; the Kickapoo River Valley was the most severely affected area | $51,000,000 | 0 |
| June & Sept. 1980 | 626 | 6 northwestern and west-central counties including Chippewa, Dunn, Eau Claire, and Pierce | $6,000,000 | 0 |
| July 1984 | 3091 | Vernon | $1,000,000 | 0 |
| Sept. 1985 | - | Ashland, Bayfield, Douglas | $3,000,000 | 0 |
| Aug. 1986 | 770 | Milwaukee, Waukesha | $20,000,000 | 2 |
| Sept. 1986 | 775 | Dodge, Fond du Lac, Kenosha, Milwaukee, Ozaukee, Sheboygan, Washington, Waukesha | $6,000,000 | 0 |
| June 1990 | 874 | East-central and southwestern counties, including Brown (including City of Green Bay), Kewaunee, Calumet, Manitowoc, Outagamie, Winnebago, Dane, Green, Rock, Grant, Iowa, Lafayette (including City of Darlington), Crawford, Richland, Sauk, Juneau, and Vernon | $21,000,000 | 0 |
| Aug. 1990 | 877 | City of Tomah and surrounding areas of Monroe County | $6,200,000 | 2 |
| Sept. 1992 | 964 | Brown, Calumet, Crawford, Dane, Grant, Green, Iowa, Juneau, Kewaunee, Lafayette, Manitowoc, Monroe, Outagamie, Richland, Rock, Sauk, Vernon, Winnebago | $17,000,000 | 0 |
| June - Aug. 1993 | 994 | Adams, Brown, Buffalo, Calumet, Chippewa, Clark, Columbia, Crawford, Dane, Dodge, Dunn, Eau Claire, Fond du Lac, Grant, Greene, Green Lake, Iowa, Jackson, Jefferson, Juneau, Kenosha, La Crosse, Lafayette, Lincoln, Marathon, Marquette, Menominee, Milwaukee, Monroe, Outagamie, Pepin, Pierce, Portage, Price, Racine, Richland, Rock, Rusk, Sauk, Shawano, St. Croix, Trempealeau, Vernon, Waupaca, Waushara, Winnebago, Wood | $740,000,000 | 2 |
| July 1996 | 1131 | Fond du Lac, Green (including City of Monroe and the Village of Monticello) | $6,000,000 | 2 |
| June 1997 | 1180 | Milwaukee, Ozaukee, Washington, Waukesha | $87,700,000 | 0 |
| Aug. 1998 | 1238 | Milwaukee, Waukesha, Sheboygan, Racine, Rock | $55,000,000 | 2 |
| July 1999 | 1284 | Ashland, Bayfield, Douglas, Florence, Iron, Oneida, Price, Rusk, Sawyer, Vilas | $31,000,000 | 0 |

| Date of Flood Event | Disaster Number | Area Affected (County/ies) | Damages | Fatalities |
|---|---|---|---|---|
| May–July 2000 | 1332 | Columbia, Crawford, Dane, Grant, Iowa, Juneau, Kenosha, Lafayette, Milwaukee, Richland, Sauk, Vernon, Walworth, Adams, Ashland, Barron, Burnett, Forest, Green, Iron, Jackson, Monroe, Oneida, Polk, Rusk, Sawyer, Washburn, Dodge, Racine, Waukesha | $74,000,000 | 0 |
| April 2001 | 1369 | Adams, Ashland, Barron, Bayfield, Buffalo, Burnett, Calumet, Chippewa, Clark, Crawford, Douglas, Dunn, Grant, Iron, Jackson, Juneau, La Crosse, Outagamie, Pepin, Pierce, Polk, Portage, Rusk, St. Croix, Taylor, Trempealeau, Vernon, Washburn, Waupaca, Waushara, Winnebago, Wood | $84,200,000 | 0 |
| June 2002 | 1429 | Adams, Clark, Dunn, Marathon, Marinette, Portage, Waushara, Wood | $14,300,000 | 0 |
| Sept. 2002 | 1432 | Polk | $3,000,000 | 0 |
| May-June 2004 | 1526 | Clark, Columbia, Crawford, Dodge, Fond du Lac, Grant, Green Lake, Jefferson, Kenosha, Ozaukee, Vernon, Winnebago | $268,425,000 | 1 |
| July 2006 | - | Waukesha County and City of Madison | $13,000,000 | 0 |
| Aug. 2007 | 1719 | Columbia, Crawford, Dane, Grant, Green, Iowa, Jefferson, Kenosha, La Crosse, Racine, Richland, Rock, Sauk, Vernon | $116,400,000 | 1 |
| June 2008 | 1768 | Adams, Calumet, Crawford, Columbia, Dane, Dodge, Fond du Lac, Grant, Green, Green Lake, Iowa, Jefferson, Juneau, Kenosha, La Crosse, Lafayette, Marquette, Manitowoc, Milwaukee, Monroe, Ozaukee, Racine, Richland, Rock,, Sauk, Sheboygan, Vernon, Walworth, Washington, Waukesha, Winnebago | $763,618,860 | 1 |
| July 2010 | 1933 | Calumet, Grant, Milwaukee | $45,000,000 | 1 |
| Sept. 2010 | 1944 | Buffalo, Clark, Jackson, Juneau, Marathon, Portage, Taylor, Trempealeau, Wood | $4,600,000 | 0 |
| June 2012 | 4076 | Ashland, Bayfield, Douglas | $8,620,700 | 0 |
| June 2013 | 4141 | Ashland, Bayfield, Crawford, Grant, Iowa, Richland, St. Croix, Vernon | $9,290,000 | 0 |
| July 2016 | 4276 | Ashland, Bayfield, Burnett, Douglas, Florence, Iron, Sawyer, and Washburn | $26,000,000 | 4 |
| Sept. 2016 | 4288 | Adams, Chippewa, Clark, Crawford, Jackson, Juneau, La Crosse, Monroe, Richland, Vernon | $11,340,000 (Ongoing) | 2 |
| July 2017 | 4343 | Buffalo, Crawford, Grant, Iowa, Jackson, La Crosse, Lafayette, Monroe, Richland, Trempealeau, Vernon | $10,000, 000 | 0 |
| June 2018 | 4383 | Ashland, Bayfield, Burnett, Clark, Douglas, Iron | 13,000,000 | 1 |
| July-Aug. 2018 | 4402 | Adams, Crawford, Dane, Fond du Lac, Green Lake, Iron, Juneau, La Crosse, Marquette, Monroe, Ozaukee, Richland, Sauk, Vernon | 37,000,000 | 1 |
| July 2019 | 4459 | Barron, Clark, Forest, La Crosse, Langlade, Marinette, Menominee, Monroe, Oconto, Oneida, Outagamie, Polk, Portage, Rusk, Shawano, Vernon, Waupaca, Wood | 19,000,000 | 0 |
| Jan. 2020 | 4477 | Kenosha, Milwaukee, Racine | 10,000, 000 | 0 |

| Date of Flood Event | Disaster Number | Area Affected (County/ies) | Damages | Fatalities |
|---|---|---|---|---|

Sources: Wisconsin Emergency Management (WEM); National Oceanic and Atmospheric Administration (NOAA), National Weather Service (NWS) Milwaukee/Sullivan

Examining Prior (1993-2016) Flood Events

Significant flooding exists each year across the state of Wisconsin. While it is not possible to reconstruct all the flood events since 1785, it is possible to highlight a few of the most substantial events having occurred over the last three decades. For brevity, six significant floods occurring between 1993 and 2016 are documented.

June – August 1993

Major flooding impacted nine Midwestern states during the summer of 1993. Generating more than $15 billion in damages and resulting in 50 fatalities across the region, the 1993 flood remains one of the most severe and damaging floods in US history. The severe damages experienced during the 1993 floods, including the failure of hundreds of levees across the region and challenged traditional approaches to flood control first developed in the 1940s. The resulting shift in national policy focus toward non-structural mitigation strategies, such as reducing flood risk through acquisition and demolition of flood-prone properties and increasing natural flood storage capacity, continues today.

In Wisconsin, extremely heavy rainfall resulted in a Presidential Disaster Declaration for 47 counties with total associated damage exceeding $740 million ($1.38 billion in 2021 dollars). Forty of the counties received both Public and Individual Assistance declarations, while the other seven were declared for Individual Assistance only. Though Wisconsin was not affected as severely as other states in the Midwest, the 1993 floods were one of the state's most significant disasters in terms of both damages and funds received through disaster relief programs. The total amount of disaster relief funds Wisconsin received from all declarations prior to 1993 was $352 million. Approximately $300 million ($480 million in 2012 dollars) in disaster relief was received for the 1993 Presidential Disaster Declaration alone.

June 1997

A rainstorm dumped more than seven inches of rain in a 30-hour period in Milwaukee and surrounding counties on June 20-21. The intense rainfall overwhelmed creeks and rivers, as well as storm and sanitary sewers. Hundreds of local roads and highways were filled with water, as deep as 23 feet in some areas. Thousands of homes were damaged, many of which had six to seven feet of water in their basement. The flood also damaged hundreds of businesses, many of which were forced to close temporarily or permanently. Some of the damaged businesses that provide critical services included Bayshore Clinical Labs, St. Michael's Hospital Health Center, St. Luke's South Shore Hospital, and the dialysis center in the City of Brown Deer.

The initial damage losses from the 1997 floods amounted to almost $55 million for the public and private sectors, with most of the $44 million in private sector losses being uninsured. The severity of the storm and significance of the uninsured losses prompted a request for a Presidential Disaster Declaration for four Wisconsin counties. The declaration was granted for both Public and Individual Assistance. A fifth county was added later for Public Assistance only.

August 2007

In August 2007, a series of thunderstorm clusters moved east-southeast through the southern third of Wisconsin, dumping record-setting rains. Many locations set new all- time daily and monthly August rainfall records. Much of the rain fell on August 19-20, when six to 12 inches were measured (150% to 300% of the August monthly average). One person perished in a flash flood event in southern Richland County. Alongside unofficial reports of 22 to 25 inches of water, Viroqua (Vernon County) picked up 21.74 inches of rain for the month, a new all-time monthly record for Wisconsin. Total flood damages were about $116.4 million. A record flood crest was reported at the Root River Canal near Raymond (Racine County), and major flood levels were observed at New Munster on the Fox River (Kenosha County) and at Newville on the Rock River (Rock County). Some locations along the Kickapoo River came within one to two inches of establishing a new record crest.

June 2008

In June 2008 a severe flooding/flash flooding event, consisting of two rounds of heavy rains, ravaged an already saturated part of the state south of a line from La Crosse (La Crosse County) to Manitowoc (Manitowoc County). The first round of heavy rains occurred June 5 through 8, 2008, followed by a second round during the overnight hours of June 12 through 13, 2008. Collectively, amounts ranged from six to over 15 inches. In many locations, 24-hour and monthly rainfall records were established. Milwaukee would eventually measure 12.27 inches, which was a new record monthly rainfall.

The intense and extensive flooding necessitated rescues, evacuations, road closures, and sandbagging. Thousands of homes sustained damages, and many people were left homeless. Hundreds of small businesses were damaged and temporarily closed. Damage to public facilities was estimated to be in the tens of millions of dollars. Both the agriculture and tourism industries, the heart of state and local economies, suffered significantly. Many of the communities were still recovering from the flooding that occurred ten months earlier, which also resulted in a federal disaster declaration.

In some cases, rivers remained in flood stage into late July 2008, and some low spots in farm fields still had standing water into September 2008 due to a high-water table. Most of the flooding was of the "100-year" magnitude, and some was probably of the "200- or 300-year" type. Numerous roads were closed, damaged, or washed-out in river valleys and other low spots, and some bridges were significantly damaged. The worst river flooding occurred on the Baraboo, Kickapoo, Rock, Northern and Southeastern Fox, and Crawfish Rivers. In some areas, the June 2008 flooding in Wisconsin was worse than the 1993 flooding. On June 14th, President Bush declared Disaster Declaration 1768 in the state. Eventually the declaration included 31 counties with estimated damages totaling roughly $763 million.

July 2010

Parts of south-central and southeast Wisconsin experienced several rounds of record-setting torrential rains during the afternoon and evening hours of July 22, 2010 that led to flash flooding. During the afternoon, a persistent band of strong to severe thunderstorms developed and moved very slowly over the region throughout the evening hours. The individual storms were moving quite fast, at about 40 to 50 mph, but the slow southward movement of the boundary of these storms resulted in storms repeatedly moving over the same area. Widespread three-to-four-inch rainfall amounts were reported along and on either side of the I-94 corridor, with locally higher amounts of five to eight inches. The greatest rain amounts fell in Milwaukee County, where the most damage occurred. Mitchell Field recorded 5.61 inches for the day, setting a record for the date. The previous record was 1.26 inches set in 1948.

Massive flooding shut down streets and the freeway system in parts of Milwaukee County at rush hour with up to four feet of rushing water. There was one fatality in Milwaukee. The Milwaukee Fire Department logged 50 rescues from homes and streets. The Milwaukee Metropolitan Sewerage District reported that the storm resulted in a combined sewer overflow of around two billion gallons. All Lake Michigan beaches in Milwaukee were closed through the following weekend of July 24 and 25 because of sewer contamination. The City of Milwaukee received at least 2,000 calls for sewer backups into basements of homes, with the northern half of the city hit hardest. Flooding rains created a massive 20-foot-deep sink hole in the City of Milwaukee, swallowing a sport utility vehicle and a streetlight. The driver of the SUV was injured and treated at a hospital. Electrical power cables and other cable lines were also damaged.

General Mitchell International Airport (Milwaukee County) was closed late Thursday night, July 22, through 2 p.m. Friday, July 23 because of flooded runways. Over 4,400 homes reported water-filled basements in the city of Milwaukee. 11,764 homes received some sort of impact from the flooding, with six homes destroyed; 57 homes receiving major damage; 1,859 home receiving minor damage; and 9,842 homes minimally affected by the flood waters. 68 businesses were affected, with nine having major damage and 59 having minor damage. About 32,000 WE Energy utility customers lost electricity through- out southeast Wisconsin due to the flooding and lightning.

September 2016

Beginning on September 21 and extending through September 22, 2016, multiple rounds of severe thunderstorms impacted much of west central and southwestern Wisconsin. The area received over 10 inches of precipitation during this two-day period, resulting in flash flooding in the areas with the heaviest rainfall. Saturated soils and vegetative conditions due to high rainfalls over the preceding month caused stream, riverine, and urban flooding to develop faster than normal, resulting in mudslides, washouts, and flooding on roadways. Numerous road closures were enacted, including a multiple-day closure of State Highway 35, a major transportation corridor along the Mississippi River. With travel severely limited, many communities experienced economic impacts due to reduced tourism and cancellation of annual events.

Over 485 homes were impacted in addition to the extensive road damage and large amounts of debris generated by this event. In Crawford County, more than 60 households reported over $1,475,000 in damages. Sadly, the dangerous conditions caused by the flooding resulted in the loss of two lives.

Examining Most Recent (2017-2021) Flood Events

Over the last five years there has been significant flooding across the state of Wisconsin. High magnitude precipitation events are driving the flooding. While all regions of Wisconsin are susceptible to flooding, the southwest has been extremely vulnerable over the last five years. A few of the largest floods are documented below.

2017

Two major storms occurred in a one-week period in southern Wisconsin. The first occurred in southeast Wisconsin on July 12 when 6-8 inches of rain fell over a 48-hour period in Racine, Kenosha, and Walworth counties. The area hardest hit was Burlington. The Fox River, which flows through Burlington overflowed its banks and flooded much of the city (Figure 3.3.2-1). Stream gage data at New Munster, south of Burlington, recoded the highest stream discharge on record. The maximum discharge recorded at New Munster on July 13 was more than twice the yearly peak. Thousands of individuals were left without power because a WE Energies substation was flooded. Additional impacts included, but are not limited to, road closures, flooded homes, and crop failure.

**Figure 3.3.2-1: Flooding in Burlington, WI**

Source: Wisconsin Public Radio

The second July event occurred when a line of thunderstorms advanced into southwest Wisconsin between July 19-20 triggering severe winds, mudslides, and flooding in 11 counties. The 24-hour rainfall total for parts of southwest Wisconsin totaled 6-8 inches of rain on July 20. Additional thunderstorms on July 21-22 brought an additional 2-3 inches of rain to the region. Many streams in the region exceeded major flood height and many were close to record highs. The National Weather Service reported flooded towns and cities, road washouts, flooded basements, and fire team rescues of individuals stranded in homes (Figure 3.3.2-2). A Presidential Disaster Declaration (DR 4343) was declared for southwest Wisconsin on October 7. The primary impact was to roads and bridges. The estimated total public assistance cost estimate was $10,000,000.

**Figure 3.3.2-2: Flooding in the Village of Gays Mills**

Source: WI Air Coordination Group

<u>2018</u>

Heavy rains occurred in northwest Wisconsin on June 14-17. Substantial precipitation totals were received in the counties of Bayfield, Douglas, Ashland, Iron, Price, Sawyer, and the Bad River Nation. The highest rainfall totals exceeded 15 inches in Bayfield County. Record crests occurred on the Nemadji River at Superior, Whittlesy Creek at Ashland, White River at Ashland, and the St. Croix River at Danbury. A 75-year-old man was found dead in a ditch 60 feet away from his vehicle south of Ashland and near the Bad River. A Presidential Disaster Declaration (DR 4383) was declared for Ashland, Bayfield, Burnett, Clark, Douglas, and Iron counties. The primary impact was to roads and bridges (Figure 3.3.2-3). The estimated total public assistance cost estimate was $13,000,000.

**Figure 3.3.2-3: US Highway 2 in Bayfield County at North Fish Creek**

Source: Wisconsin Department of Transportation

In October 2018, Presidential Disaster Declaration (DR 4402) was declared for 14 counties primarily in central and southern Wisconsin. The total individual and public assistance was estimated at $50,000,000. From late August and into early September much of Wisconsin was stricken with severe thunderstorms that lead to major flooding. As classified by NOAA, four of the top 10 weather events were related to flooding that occurred during this timeframe. These include: (1) Dane County flooding on August 20-21; (2) east central flooding on August 26-27; (3) southwest/central flooding on August 27-28; and (4) southwest flooding on September 3-5.

On August 20-21 parts of western Dane County received over 11 inches of rain in 24-hours (Figure 3.3.2-4). This rain triggered flash flooding throughout the region, including the Yahara chain of lakes. Black Earth Creek exceeded its highest recorded flood level. Residents in Black Earth, Mazomanie, and Cross Plains had to be evacuated. Millions of dollars in damages occurred in Dane County. The body of one individual was recovered in a retention pond after being swept away in the current.

**Figure 3.3.2-4: Flooding in Madison, WI**


Source: WEM

Thunderstorms and associated flooding impacted east central and southwestern Wisconsin on August 26-27. Four-10 inches of rain occurred in Ozaukee and Washington counties. Impacts of the rainfall were stream flooding, road closures, and flooded basements.

On August 27-28 rainfall totals exceeded 10 inches in numerous locations of southwest/central Wisconsin. Highest rainfall totals were in Adams, Juneau, La Crosse, Monroe, and Vernon Counties. Record flooding occurred along sections of the Kickapoo River. The stream discharge on the Kickapoo River at La Farge exceeded the previous high that was set in 1978. Record setting river flooding occurred across the region (Figure 3.3.2-5). Impacts of the flooding included mass evacuations and millions of dollars in economic damages.

A second round of heavy rains (4-6 inches) occurred on September 3-5. The heaviest rains were in Adams, Crawford, Juneau, and Vernon Counties. This rainfall exacerbated the already wet and saturated landscape. Streams that were at or near flood stage were most susceptible to reoccurring flooding. Areas across the central and northern portions of the state also witnessed extreme precipitation events.

**Figure 3.3.2-5: Flooding at La Farge, WI**

Source: WI Air Coordination Group

<u>2019</u>

The New York Times called the spring Midwest flooding "The Great Flood of 2019." Conditions in Wisconsin were not as bad as other states, but severe flooding occurred. In March, Governor Tony Evers declared a state of emergency across much of Wisconsin. The flooding was attributed, in part, to above average snowfall cover in January and February and heavy rainfall on frozen ground. Locations with extreme to record flooding include Lodi, Sheboygan, Kewaunee, Martintown, and near Cedarburg. The flooding triggered numerous evacuations in Brown, Columbia, Trempealeau, and Ozaukee counties.

A series of severe storms, tornadoes, straight-line winds, and flooding battered Wisconsin on July 18-20 prompting Presidential Disaster Declaration (DR 4459) for 17 counties and the Menominee Indian Tribe of Wisconsin and the St. Croix Chippewa Indians of Wisconsin. A serve line of storms moved from Iowa and Minnesota into central Wisconsin producing 4-6 inches of rain. The precipitation led to flash floods and mudslides that damaged roads (Figure 3.3.2-6). Moderate to major flood stage occurred in the region, including the Kickapoo, Middle Fork Whitewater, and La Crosse rivers.

**Figure 3.3.2-6: A washed-out road section east of Mount Prairie, WI**

Source: NWS La Crosse

2020

On June 28-29 severe rainfall produced approximately 9 inches of rainfall in the hardest hit region of western Wisconsin, Baldwin. Over 50 roads were closed in the region and stranded motorists were rescued from floodwaters. The Rush River was flowing well beyond normal capacity. U.S. Highway 63 north of Baldwin was washed out by the Rush River (Figure 3.3.2-7) and it was reported 3 feet over a bridge in Martell. Evacuations from apartments and assisted living complexes were reported. Localized flooding occurred at culverts, as they did not have the capacity to move the amount of water quickly enough from the system. A 70-year-old man died when his vehicle entered a flooded area and became submerged.

Two significant flooding events occurred in August. The first occurred on August 2 when upward of 5 inches of rain triggered flash flooding in parts of eastern Wisconsin. The most significant flooding occurred in southern Milwaukee County where the storm stalled out and dropped 0.76 inches of rain in 10 minutes. Reports of 2.56 inches of rain fell north of Greenfield in 30 minutes. The rainfall event led to flooded backyards and basements, closed roads, and stalled vehicles.

On August 27-28 serve storms brought 4-9 inches of precipitation to southwest and central Wisconsin. Counties with the highest rainfall totals were Juneau and Monroe. Reports of flooded and washed-out roads were common.

**Figure 3.3.2-7: A washed-out road section at the intersection of Highways 63 and E**

Source: WQOW ABC News Affiliate – Eau Claire, WI

2021

Localized weather systems moved into southwest Wisconsin dropping 8-10 inches of precipitation in Crawford County over a 24-hour period on June 25-26. The greatest amount of precipitation fell around Mt. Sterling and Gays Mills. The county declared a state of emergency as road crews worked to repair roads and remove falling trees across the region. Many streams overtopped their banks and the Kickapoo River reached minor flood stage.

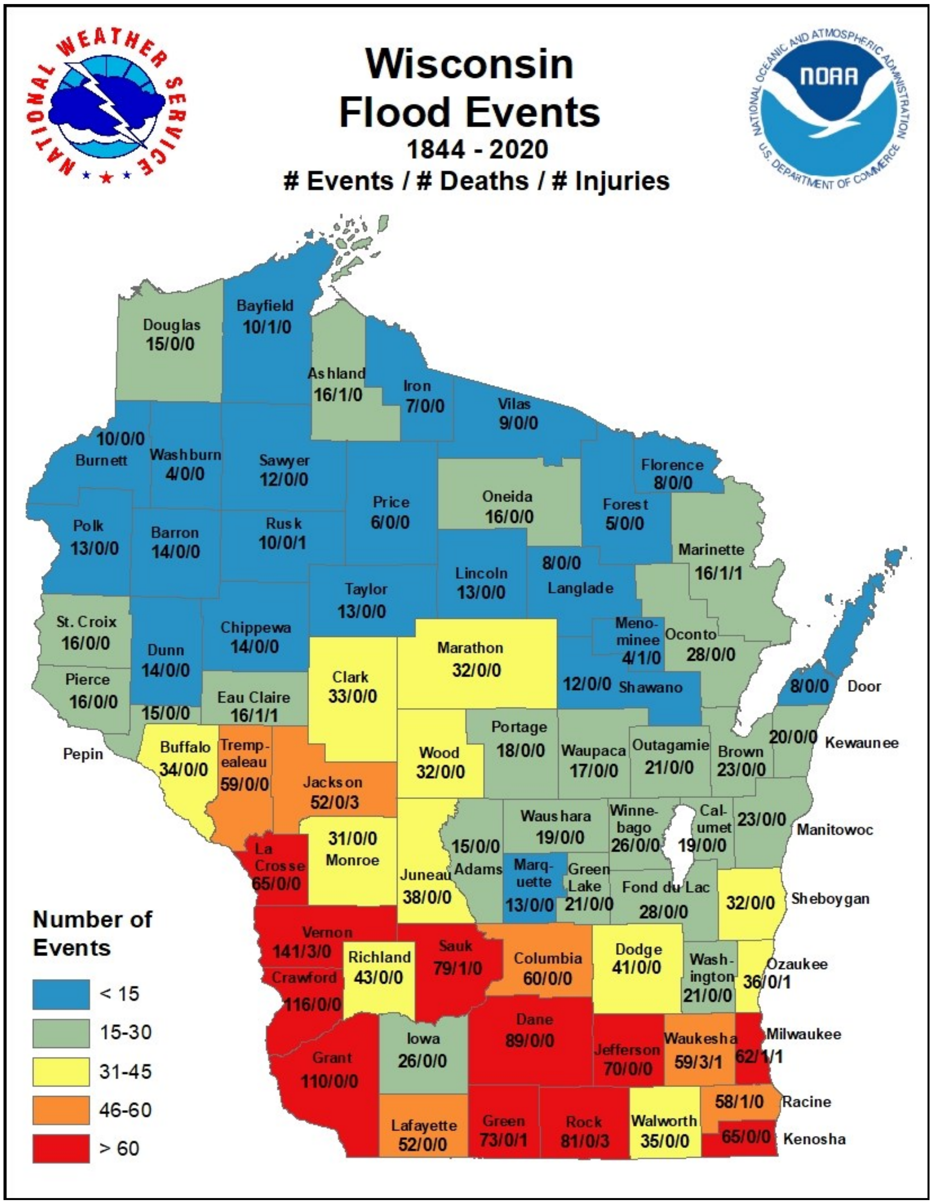
Distribution and Fatality Statistics of Flood Events

Figure 3.3.2-8 shows the county-by-county distribution of flood events across Wisconsin for the period of 1884-2020. The map also shows the number of flood events, the number of directly related fatalities, and the number of directly related injuries. The death totals represented on Figure 3.3.2-8 differs from the information from NOAA/National Weather Service (Table 3.3.2-1). The death toll totals in Figure 3.3.2-8 show 9 incidents over a 137-year period and those in Table 3.3.2-1 report 11 incidents between 2021-2011. The discrepancy in the data is a result of how flood related deaths are classified and reported.

The southern part of the state has most of the flood events. Hilly terrain in the southwestern counties and the built-up urban areas in the southeast are factors that increase the chances of flooding. Noteworthy is the fact that Vernon, Crawford, and Grant Counties have the most flooding events during the time, with 141, 116 and 110, respectively. This region of southeast

Wisconsin was included in 3 of 5 Presidential Disaster Declarations related to flooding in the last 5 years.

**Figure 3.3.2-8: Flood Events by County, 1844-2020**




Source: NOAA, NWS Milwaukee/Sullivan

**Table 3.3.2-1: Flood Fatalities Reported in Wisconsin Between 2021-2011**

| | 2021 | 2020 | 2019 | 2018 | 2017 | 2016 | 2015 | 2014 | 2013 | 2012 | 2011 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Fatalities | 0 | 1 | 3 | 2 | 0 | 5 | 0 | 0 | 0 | 0 | 1 |

Source: NWS La Crosse

### 3.3.3 Flooding: Probability, Vulnerability, and Mitigation Potential

**Table 3.3.3-1: Hazard Ranking for Flooding**

| Evaluation Criteria | Description | Ranking |
|---|---|---|
| **Probability** | • Occurs annually or assumed to occur at least once per year. Near 100% probability of occurrence each year. | Highly Likely |
| **Vulnerability** | • Minimal countermeasures are in place to prevent or protect against this hazard.<br>• Countermeasures may have potential but limited demonstrated history in reducing the threat potential.<br>• The nature of the hazard may limit the availability of countermeasures. | High |
| **Mitigation Potential** | • Methods for reducing risk from the hazard are technically reliable.<br>• The State or counties have experience in implementing mitigation measures.<br>• Mitigation measures are eligible under federal grant programs.<br>• There are multiple possible mitigation measures for the hazard.<br>• The mitigation measures are known to be cost-effective.<br>• The mitigation measures protect lives and property for a long period of time or are permanent risk reduction solutions. | High |

Flooding is Wisconsin's most costly natural disaster, generating direct costs such as rescue and relief efforts, clean-up operations, and rebuilding public and private structures, as well as indirect costs, such as business interruptions, loss of wages, tax base declines in flood blighted areas, and subsidies for flood insurance. The statewide flood risk assessment is an initial step in identifying and quantifying vulnerability to flood damage throughout Wisconsin. This assessment estimates the potential direct costs of damage to structures located in or near the 100-year/one-percent annual chance floodplain. The results of this analysis can serve as a starting point for highlighting areas at risk to flood damage.

Probability

Floods are described in terms of their extent and the related probability of occurrence. Flood studies use historical records to determine the probability of occurrence for different extents of flooding. From these records, a probability of occurrence is determined and expressed in a percentage. The percentage describes the chance that the level of flood water exceeds a certain height, on average in any given year.

The most widely adopted design and regulatory standard for floods in the US is the one-percent annual chance flood (base flood), which has been formally adopted by FEMA. The base flood, or "100-year flood," has a one-percent chance of occurring in any particular year. This measure is a simple and general way to express the statistical likelihood of a flood; actual recurrence periods vary from place to place. The area that is inundated during the base flood is called the Special Flood Hazard Area (SFHA).

Smaller floods occur more often than larger, deeper, and more widespread floods. Thus, a "10-year" flood has a greater likelihood of occurring than a "100- year" flood. Table 3.3.3-2 shows a range of flood recurrence intervals and their probabilities of occurrence.

**Table 3.3.3-2: Flood Probability Terms**

| Flood Recurrence Intervals | Annual Percent Chance of Occurrence |
|---|---|
| 10-year | 10.0% |
| 25-year | 4.0% |
| 50-year | 2.0% |
| 100-year | 1.0% |
| 500-year | 0.2% |

Source: Wisconsin Emergency Management

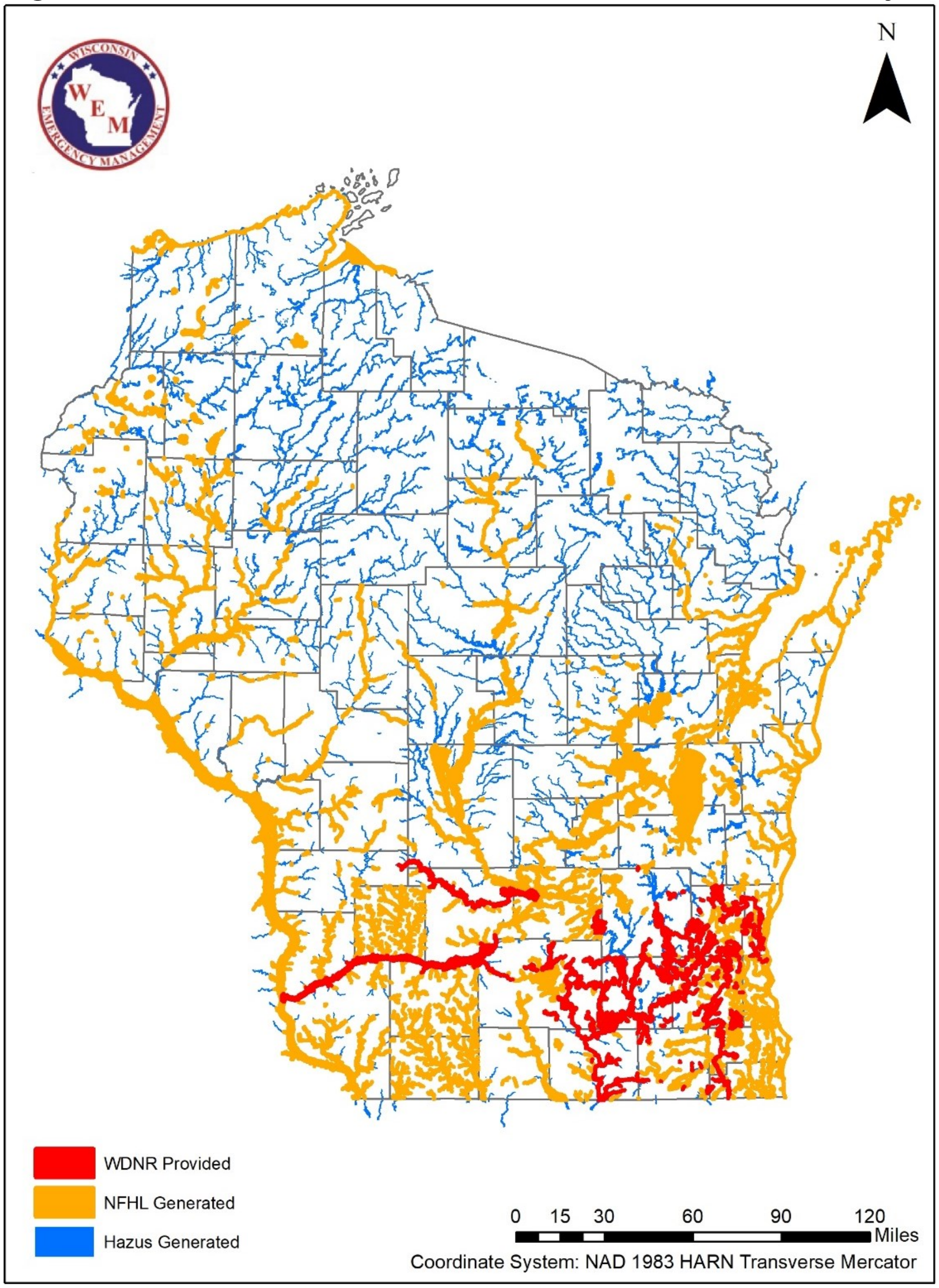
It is important to note that the risk of a flood event occurring changes over time. Since natural hazards do not affect a particular location every single year, the focus is on the overall probability of the event occurring over a selected time horizon. Assuming that most hazard events are independent outcomes, the probability of a 100-year flood occurring at any given time is 1/100 or 0.01 (one-percent annual chance). However, the probability of a 100-year flood occurring at least once over the next 100 years is 1-(0.99)^100=0.63 (63-percent chance).

This plan considers hazards over the entire State of Wisconsin; however, flood probability and magnitude are highly location-specific, so it is not possible to characterize these generally across the state in a meaningful way. The State Plan includes flood risk assessments that implicitly include probability and magnitude determinations on a state and county basis. However, truly accurate determinations of flood probability and magnitude require site-specific engineering studies and data-gathering that is beyond the scope of this hazard profile.

*Data Sources*

The modeling team leveraged the best available flood hazard data from three sources. These include the Wisconsin Department of Natural Resources floodplain models, FEMA's National Flood Hazard Layer, and FEMA's HAZUS-MH Program. The Wisconsin's Department of Natural Resources (WDNR) is responsible for most of the modeling of floodplains in Wisconsin. They were able to provide detailed flood depth grids for the Baraboo River, the Middle Rock River watershed, Milwaukee River watershed, Upper Fox River watershed, Upper Rock River watershed, and the Wisconsin River (in red in Figure 3.3.3-1). This data covered parts of 19 counties, all in southern Wisconsin. The data covered the majority of 3 counties, but for 16 counties the data did not cover all the streams and rivers in the county.

**Figure 3.3.3-1: Sources of Data Used in Wisconsin's Flood Risk Analysis**




Sources: Hazus-MH, 2021; FEMA Map Service Center, 2021; Wisconsin Emergency Management, 2021; Wisconsin Department of Natural Resources 2021

FEMA provides flood hazard products as a part of the National Flood Insurance Program and can be downloaded from FEMA's Map Service Center's (MSC) website. Sixty-one of Wisconsin's 72 counties have flood hazard layer data (in orange in Figure 3.3.3-1) available. The modeling team used the base flood elevations and flood polygons in ArcGIS to produce flood depth grids for the streams and rivers not captured in the data from the WDNR. Finally, the remaining streams were modeled using HAZUS-MH version 4.2.3. The National Elevation Dataset was used in HAZUS-MH and the best resolution for each county was chosen. For some counties, HAZUS-MH could not process a 1/3 arcsecond DEM and a 1 arcsecond DEM was used instead. In most cases a 10 square mile drainage area was chosen (to determine the size of the streams that were modeled), but in some cases HAZUS-MH could not complete the analysis at 10 square miles and 20 square miles were chosen. Documentation on the parameters used can be provided upon request to WEM. HAZUS-MH could not process the streams and rivers in northern Vilas County and therefore no flood hazard or impact data exists in that region.

*Data Analysis and Flood Risk Results*

To determine the risks from riverine and coastal flooding in Wisconsin, three approaches were utilized. In the first approach, HAZUS-MH in combination with the flood depth grids was used to determine the risks and impacts to each County. HAZUS-MH can compute the impacts on a building-by-building analysis or can model at the US Census' census block boundaries. For this project, census block boundaries were used due to a lack of statewide building points. While this approach has been proven to be accurate at county and regional levels, it does have limitations. Due to the limitations, a second approached was used. An intersection analysis was completed by intersecting land parcels that contain buildings with the modeled floodplains (Table 3.3.3-3). Parcels were selected as having a building if the 'improvements' value was greater than $5,000. We considered buildings with a value under $5,000 as buildings that were not 'primary' buildings and represented structures like sheds, barns, and recreational facilities.

While this captures all the parcels that intersect the floodplain, it does not capture how many buildings are going to be exposed to flood waters, which lead to a third approach. One way to approximate the building count is to intersect the parcel centroid with the floodplain. This assumes the building is in the middle of the parcel, which is true for many parcel types (e.g., residential) and it eliminates parcels where floodwater may be on the edge of the parcel and not intersect the main structure. The parcel centroid analysis is provided in Table 3.3.3-3. Like with the intersection analysis, this only provides the possible structure 'exposed' to flooding but does not provide the risk or vulnerability.

**Table 3.3.3-3: Parcels and Parcel Points with Improvements Intersecting the Floodplain**

| County | Parcels with Improvements in the Floodplain | Improvements Value | Parcel Points with Improvements in the Floodplain | Improvements Value |
|---|---|---|---|---|
| Adams County | 1,824 | $189,335,800 | 279 | $20,042,700 |
| Ashland County | 712 | $75,330,200 | 178 | $10,515,400 |
| Barron County | 4,304 | $610,844,400 | 499 | $61,118,600 |
| Bayfield County | 2,011 | $283,226,400 | 212 | $22,406,400 |
| Brown County | 7,987 | $2,249,812,150 | 2,708 | $456,408,500 |
| Buffalo County | 959 | $104,725,200 | 359 | $31,152,100 |

| County | Parcels with Improvements in the Floodplain | Improvements Value | Parcel Points with Improvements in the Floodplain | Improvements Value |
|---|---|---|---|---|
| Burnett County | 2,670 | $303,234,600 | 582 | $56,436,500 |
| Calumet County | 956 | $203,874,000 | 144 | $18,868,400 |
| Chippewa County | 3,173 | $550,290,100 | 1,007 | $143,384,700 |
| Clark County | 1,006 | $114,862,100 | 194 | $17,988,700 |
| Columbia County | 3,137 | $489,702,300 | 783 | $89,775,300 |
| Crawford County | 829 | $72,692,100 | 463 | $37,161,500 |
| Dane County | 6,104 | $1,987,223,500 | 634 | $134,660,200 |
| Dodge County | 3,320 | $568,652,400 | 606 | $90,379,400 |
| Door County | 4,491 | $1,042,928,600 | 538 | $89,572,300 |
| Douglas County | 2,146 | $367,236,400 | 251 | $29,367,000 |
| Dunn County | 1,898 | $253,926,600 | 433 | $48,581,000 |
| Eau Claire County | 1,737 | $495,602,100 | 409 | $211,811,900 |
| Florence County | 392 | $32,951,800 | 132 | $9,737,600 |
| Fond du Lac County | 4,160 | $709,728,800 | 1,017 | $109,003,500 |
| Forest County | 954 | $77,286,090 | 298 | $17,890,660 |
| Grant County | 1,475 | $138,923,800 | 563 | $38,623,200 |
| Green County | 801 | $151,097,500 | 244 | $33,700,200 |
| Green Lake County | 2,003 | $348,524,700 | 302 | $21,297,200 |
| Iowa County | 776 | $103,033,400 | 181 | $19,303,200 |
| Iron County | 657 | $80,559,900 | 55 | $4,913,400 |
| Jackson County | 690 | $86,946,300 | 226 | $21,648,000 |
| Jefferson County | 3,267 | $640,532,523 | 1,070 | $159,068,000 |
| Juneau County | 1,581 | $160,035,000 | 683 | $54,252,900 |
| Kenosha County | 2,069 | $1,015,960,000 | 328 | $172,762,800 |
| Kewaunee County | 715 | $117,586,600 | 189 | $24,320,600 |
| La Crosse County | 4,551 | $1,029,495,100 | 2,072 | $291,672,000 |
| Lafayette County | 736 | $87,225,200 | 136 | $13,128,300 |
| Langlade County | 1,127 | $97,456,850 | 336 | $25,257,400 |
| Lincoln County | 2,603 | $312,716,400 | 407 | $34,862,800 |
| Manitowoc County | 1,695 | $279,986,200 | 286 | $34,380,900 |
| Marathon County | 3,058 | $607,105,100 | 998 | $135,309,800 |
| Marinette County | 2,757 | $341,779,500 | 976 | $96,970,400 |
| Marquette County | 1,568 | $159,156,864 | 233 | $19,094,125 |
| Menominee County | 294 | $38,917,400 | 12 | $633,200 |
| Milwaukee County | 5,224 | $2,445,925,468 | 1,016 | $224,565,895 |
| Monroe County | 1,207 | $168,960,400 | 533 | $51,902,100 |
| Oconto County | 3,442 | $374,193,400 | 933 | $83,899,400 |
| Oneida County | 4,415 | $657,107,400 | 370 | $34,930,500 |

| County | Parcels with Improvements in the Floodplain | Improvements Value | Parcel Points with Improvements in the Floodplain | Improvements Value |
|---|---|---|---|---|
| Outagamie County | 2,704 | $935,976,800 | 605 | $94,055,100 |
| Ozaukee County | 3,770 | $1,062,535,100 | 1,258 | $267,670,000 |
| Pepin County | 303 | $33,264,600 | 172 | $17,337,400 |
| Pierce County | 973 | $165,660,700 | 291 | $34,187,700 |
| Polk County | 2,386 | $341,584,400 | 521 | $58,895,600 |
| Portage County | 1,733 | $347,069,200 | 391 | $59,156,200 |
| Price County | 1,725 | $174,864,000 | 295 | $22,124,500 |
| Racine County | 4,715 | $1,171,368,300 | 1,319 | $234,850,900 |
| Richland County | 1,559 | $176,664,300 | 517 | $47,471,900 |
| Rock County | 3,547 | $688,005,800 | 1,313 | $223,203,100 |
| Rusk County | 1,981 | $183,291,200 | 498 | $41,275,400 |
| Sauk County | 2,458 | $457,279,600 | 573 | $76,742,000 |
| Sawyer County | 3,084 | $390,283,600 | 848 | $88,772,300 |
| Shawano County | 1,534 | $184,967,523 | 252 | $24,563,467 |
| Sheboygan County | 1,806 | $419,342,700 | 318 | $57,577,100 |
| St. Croix County | 1,777 | $400,260,100 | 410 | $69,399,500 |
| Taylor County | 644 | $60,851,800 | 160 | $13,747,600 |
| Trempealeau County | 1,051 | $120,801,500 | 565 | $51,822,300 |
| Vernon County | 935 | $102,739,300 | 360 | $35,139,200 |
| Vilas County | 2,778 | $422,146,500 | 333 | $41,355,700 |
| Walworth County | 3,808 | $1,041,147,650 | 236 | $81,352,600 |
| Washburn County | 2,926 | $393,207,900 | 362 | $38,890,000 |
| Washington County | 5,683 | $1,277,316,100 | 1,189 | $224,968,300 |
| Waukesha County | 13,144 | $4,499,636,320 | 2,568 | $646,295,900 |
| Waupaca County | 2,836 | $350,996,900 | 1,021 | $91,100,300 |
| Waushara County | 1,112 | $111,002,620 | 272 | $23,856,750 |
| Winnebago County | 5,584 | $1,177,076,350 | 1,402 | $172,001,550 |
| Wood County | 1,406 | $251,507,800 | 504 | $69,435,400 |
| **Total** | **179,443** | **$37,167,539,308** | **42,428** | **6,210,006,447** |

The State of Wisconsin does not have a geospatial layer that tracks the exact location of every building it owns. Wisconsin's State Cartographer's office maintains a statewide land parcel layer. This layer tracks parcels that are owned by the State of Wisconsin but provides little information on the value of the parcel or the type of building on the parcel. To determine if a building is on the parcel the parcel layer was intersected with Microsoft's building footprints layer and if a building was found on a state-owned parcel, the building footprint was then intersected with the flood hazard layer. The Microsoft building layer does have limitations and may not accurately capture every building in the State. Table 3.3.3-4 and Table 3.3.3-5 provide a building count for each agency that has a building in the floodplain and by county.

**Table 3.3.3-4: State-Owned buildings Intersecting the Floodplain**

| State Agency | State-Owned Buildings in Floodplain |
|---|---|
| Board of Regents - University of Wisconsin | 1 |
| Board of Regents - University of Wisconsin System | 16 |
| Wisconsin Conservation Commission | 13 |
| Wisconsin Department of Natural Resources | 164 |
| Wisconsin Department of Transportation | 50 |
| Wisconsin Historical Society | 24 |
| Wisconsin Department of Development | 1 |
| State of Wisconsin - Unknown | 25 |
| Wisconsin Department of Military Affairs | 5 |
| Wisconsin Soil and Water Conservation | 2 |
| Wisconsin Public Service Corporation | 3 |
| **Total** | **304** |

A HAZUS-MH analysis was completed for each county. There were no changes to the default building inventory, but updates were made to the essential facilities (fire stations, police stations, medical care facilities, schools, and emergency operations centers). The estimated damage and loss to essential facilities is given in Table 3.3.3-6 and the estimated damages to buildings by building occupancy is provided in Tables 3.3.3-7 through 3.3.3-9. Appendix C provides a full summary of building damages and losses by county.

**Table 3.3.3-5: State-Owned Buildings Intersecting the Floodplain by County**

| County | State-Owned Buildings in Floodplain | County | State-Owned Buildings in Floodplain |
|---|---|---|---|
| Adams County | 1 | Menominee County | 0 |
| Ashland County | 1 | Milwaukee County | 3 |
| Barron County | 0 | Monroe County | 3 |
| Bayfield County | 5 | Oconto County | 2 |
| Brown County | 1 | Oneida County | 4 |
| Buffalo County | 1 | Outagamie County | 2 |
| Burnett County | 3 | Ozaukee County | 0 |
| Calumet County | 0 | Pepin County | 1 |
| Chippewa County | 2 | Pierce County | 6 |
| Clark County | 0 | Polk County | 1 |
| Columbia County | 7 | Portage County | 4 |
| Crawford County | 19 | Price County | 0 |
| Dane County | 8 | Racine County | 0 |
| Dodge County | 2 | Richland County | 8 |

| County | State-Owned Buildings in Floodplain | County | State-Owned Buildings in Floodplain |
|---|---|---|---|
| Door County | 2 | Rock County | 5 |
| Douglas County | 7 | Rusk County | 3 |
| Dunn County | 10 | Sauk County | 18 |
| Eau Claire County | 2 | Sawyer County | 7 |
| Florence County | 4 | Shawano County | 0 |
| Fond du Lac County | 5 | Sheboygan County | 3 |
| Forest County | 2 | St. Croix County | 7 |
| Grant County | 36 | Taylor County | 1 |
| Green County | 2 | Trempealeau County | 4 |
| Green Lake County | 6 | Vernon County | 5 |
| Iowa County | 3 | Vilas County | 2 |
| Iron County | 2 | Walworth County | 1 |
| Jackson County | 3 | Washburn County | 1 |
| Jefferson County | 5 | Washington County | 1 |
| Juneau County | 3 | Waukesha County | 9 |
| Kenosha County | 1 | Waupaca County | 1 |
| Kewaunee County | 2 | Waushara County | 1 |
| La Crosse County | 9 | Winnebago County | 8 |
| Lafayette County | 2 | Wood County | 3 |
| Langlade County | 3 | | |
| Lincoln County | 3 | Total | 304 |
| Manitowoc County | 0 | | |
| Marathon County | 10 | | |

**Table 3.3.3-6: Estimated Essential Facilities Damages from HAZUS-MH**

| County Name | Essential Facility Type | Facility Name | Estimated Building Dollar Loss | Estimated Building Contents Loss | Estimated Total Loss |
|---|---|---|---|---|---|
| Brown | Fire Station | GREEN BAY FIRE DEPARTMENT STATION 3 | $120,900 | $207,100 | $327,900 |
| Buffalo | Fire Station | ALMA VOLUNTEER FIRE DEPARTMENT | $109,400 | $187,400 | $296,800 |
| Buffalo | Police Station | ALMA POLICE DEPARTMENT | $29,900 | $51,300 | $81,100 |
| Buffalo | School | BUFFALO LUTHERAN SCHOOL | $9,100 | $48,800 | $57,800 |
| Clark | School | PLEASANT VALLEY MENNONITE SCHOOL | $29,600 | $160,100 | $189,700 |
| Columbia | Fire Station | Lodi Area Fire | $137,100 | $235,000 | $372,000 |

| County Name | Essential Facility Type | Facility Name | Estimated Building Dollar Loss | Estimated Building Contents Loss | Estimated Total Loss |
|---|---|---|---|---|---|
| | | Department | | | |
| Columbia | Police Station | CITY OF LODI POLICE DEPARTMENT | $171,800 | $294,400 | $466,100 |
| Crawford | Police Station | GAYS MILLS POLICE DEPARTMENT | $263,700 | $776,800 | $1,040,400 |
| Dunn | School | BOYCEVILLE MIDDLE SCH | $31,700 | $171,200 | $202,800 |
| Dunn | School | BOYCEVILLE HIGH | $68,900 | $372,100 | $441,000 |
| Eau Claire | Police Station | EAU CLAIRE POLICE DEPARTMENT | $282,000 | $1,034,400 | $1,316,300 |
| Forest | Police Station | LAONA POLICE DEPARTMENT | $288,100 | $1,402,300 | $1,690,400 |
| Grant | Fire Station | Bagley Volunteer Fire Department | $246,700 | $674,300 | $920,900 |
| Lafayette | Fire Station | Blanchardville Fire Department | $218,800 | $490,600 | $709,400 |
| Lafayette | Police Station | BLANCHARDVILLE POLICE DEPARTMENT | $218,800 | $490,600 | $709,400 |
| Marathon | School | EVERGREEN ELEMENTARY | $479,700 | $2,603,200 | $3,082,800 |
| Marathon | School | DCE 4K COMMUNITY PARTNERSHIP | $331,500 | $1,799,100 | $2,130,600 |
| Marquette | Fire Station | Montello Fire Department | $141,600 | $242,700 | $384,200 |
| Marquette | Police Station | MONTELLO POLICE DEPARTMENT | $141,600 | $242,700 | $384,200 |
| Monroe | Fire Station | Sparta Rural Fire Department | $538,500 | $3,590,800 | $4,129,200 |
| Monroe | Fire Station | Sparta City Fire Department | $318,400 | $2,117,700 | $2,436,000 |
| Monroe | Fire Station | Norwalk Area Fire District | $188,000 | $322,400 | $510,300 |
| Outagamie | School | RIVER VIEW SCHOOL | $1,416,100 | $9,619,500 | $11,035,600 |
| Ozaukee | Fire Station | WAUBEKA FIRE DEPARTMENT | $38,400 | $65,900 | $104,300 |
| Ozaukee | Fire Station | THIENSVILLE VOLUNTEER FIRE DEPARTMENT | $160,500 | $275,100 | $435,500 |
| Ozaukee | Police Station | THIENSVILLE VILLAGE POLICE DEPARTMENT | $92,900 | $159,200 | $252,000 |
| Ozaukee | School | SAUKVILLE ELEMENTARY | $34,600 | $186,600 | $221,200 |
| Pierce | Fire Station | Spring Valley Fire Department | $310,800 | $1,986,900 | $2,297,700 |

| County Name | Essential Facility Type | Facility Name | Estimated Building Dollar Loss | Estimated Building Contents Loss | Estimated Total Loss |
|---|---|---|---|---|---|
| Pierce | Police Station | SPRING VALLEY POLICE DEPARTMENT | $266,600 | $821,100 | $1,087,700 |
| Pierce | School | SPRING VALLEY ELEMENTARY | $516,400 | $3,655,400 | $4,171,800 |
| Richland | Police Station | RICHLAND CENTER POLICE DEPARTMENT | $304,700 | $1,704,900 | $2,009,500 |
| Richland | School | BUCK CREEK MENNONITE SCHOOL | $28,100 | $194,300 | $222,300 |
| Richland | School | RICHLAND CHRISTIAN ACADEMY | $21,100 | $114,000 | $135,100 |
| Richland | School | DOUDNA ELEMENTARY | $338,500 | $1,832,800 | $2,171,200 |
| Rock | Medical Care Facility | JANESVILLE VETERAN AFFAIRS CLINIC | $3,889,400 | $4,259,800 | $8,149,100 |
| Rock | School | ROCK RIVER CHARTER SCHOOL | $382,900 | $2,166,300 | $2,549,100 |
| Rock | School | PRESCHOOL 4 JANESVILLE | $371,800 | $2,008,600 | $2,380,300 |
| Rock | School | TAGOS LEADERSHIP ACADEMY | $44,100 | $238,200 | $282,300 |
| Rock | School | FIRST CLASS COSMETOLOGY SCHOOL | $73,700 | $693,700 | $767,400 |
| Sauk | Fire Station | La Valle Fire Department | $277,400 | $1,046,600 | $1,324,000 |
| Shawano | Fire Station | Gresham Area Fire Department | $308,800 | $1,873,400 | $2,182,200 |
| Sheboygan | Fire Station | Johnsonville Fire Department | $449,200 | $3,165,100 | $3,614,200 |
| Vernon | Fire Station | La Farge Fire Department | $177,400 | $304,000 | $481,400 |
| Washburn | School | SHELL LAKE JR/SR HIGH | $294,500 | $1,598,000 | $1,892,400 |
| Washburn | School | SHELL LAKE ELEMENTARY (3-6) | $226,800 | $1,251,600 | $1,478,300 |
| Washburn | School | SHELL LAKE PRIMARY (K-2) | $189,500 | $1,028,000 | $1,217,400 |
| Washington | Emergency Operations Center | HARTFORD EMERGENCY OPERATIONS CENTER | $486,400 | $3,472,800 | $3,959,200 |
| Washington | Fire Station | Kewaskum Fire Department | $71,200 | $122,100 | $193,300 |
| Washington | Fire Station | Hartford Fire and Rescue Department | $231,200 | $523,100 | $754,300 |
| Washington | Police Station | HARTFORD POLICE DEPARTMENT | $486,400 | $3,472,800 | $3,959,200 |

| County Name | Essential Facility Type | Facility Name | Estimated Building Dollar Loss | Estimated Building Contents Loss | Estimated Total Loss |
|---|---|---|---|---|---|
| Waukesha | Fire Station | Menomonee Falls Fire Department Station | $29,400 | $50,400 | $79,700 |
| Waukesha | Fire Station | Waukesha Fire Department Station 1 | $480,200 | $3,426,200 | $3,906,300 |
| Waukesha | Police Station | VILLAGE OF PEWAUKEE POLICE DEPARTMENT | $118,000 | $202,200 | $320,100 |
| Waupaca | Fire Station | FREMONT-WOLF RIVER FIRE DEPARTMENT | $196,100 | $396,300 | $592,400 |
| Waupaca | Police Station | FREMONT POLICE DEPARTMENT | $152,800 | $261,900 | $414,600 |

**Table 3.3.3-7: Statewide Estimated Building Damages and Losses**

| State of Wisconsin | | | | |
|---|---|---|---|---|
| **Occupancy** | **Number of Damaged Buildings** | **Building Loss ($)** | **Content Loss ($)** | **Inventory Loss ($)** |
| Residential | 14,740 | $1,974,371,000 | $978,198,000 | 0 |
| Commercial | 174 | $407,405,000 | $1,225,884,000 | $29,606,000 |
| Industrial | 74 | $246,242,000 | $620,732,000 | $100,396,000 |
| Agricultural | 2 | $21,618,000 | $63,165,000 | $7,216,000 |
| Education | 4 | $18,473,000 | $111,599,000 | 0 |
| Government | 10 | $13,060,000 | $70,942,000 | 0 |
| Religion | 1 | $21,679,000 | $149,489,000 | 0 |
| **Total** | **15,005** | **$2,702,848,000** | **$3,220,009,000** | **$137,218,000** |

Source: HAZUS-MH analysis conducted in 2021

**Table 3.3.3-8: Summarized HAZUS-MH Building Loss**

| County | Residential | Commercial | Industrial | Other | Total |
|---|---|---|---|---|---|
| Adams County | $8,508,000 | $256,000 | $64,000 | $123,000 | $8,951,000 |
| Ashland County | $2,445,000 | $386,000 | $122,000 | $118,000 | $3,071,000 |
| Barron County | $12,207,000 | $1,979,000 | $1,394,000 | $531,000 | $16,111,000 |
| Bayfield County | $3,521,000 | $207,000 | $59,000 | $155,000 | $3,942,000 |
| Brown County | $152,585,000 | $51,426,000 | $20,589,000 | $2,813,000 | $227,413,000 |
| Buffalo County | $16,213,000 | $2,562,000 | $609,000 | $800,000 | $20,184,000 |
| Burnett County | $9,671,000 | $366,000 | $233,000 | $315,000 | $10,585,000 |
| Calumet County | $7,402,000 | $740,000 | $598,000 | $393,000 | $9,133,000 |
| Chippewa County | $42,356,000 | $12,000,000 | $3,760,000 | $2,643,000 | $60,759,000 |
| Clark County | $4,608,000 | $243,000 | $208,000 | $238,000 | $5,297,000 |
| Columbia County | $36,237,000 | $6,380,000 | $1,496,000 | $2,120,000 | $46,233,000 |
| Crawford County | $42,176,000 | $10,644,000 | $1,583,000 | $1,871,000 | $56,274,000 |

| County | Residential | Commercial | Industrial | Other | Total |
|---|---|---|---|---|---|
| Dane County | $69,085,000 | $13,083,000 | $8,889,000 | $2,377,000 | $93,434,000 |
| Dodge County | $26,228,000 | $2,441,000 | $2,805,000 | $656,000 | $32,130,000 |
| Door County | $19,623,000 | $537,000 | $77,000 | $127,000 | $20,364,000 |
| Douglas County | $6,457,000 | $821,000 | $243,000 | $159,000 | $7,680,000 |
| Dunn County | $21,347,000 | $1,121,000 | $2,757,000 | $1,023,000 | $26,248,000 |
| Eau Claire County | $21,019,000 | $10,317,000 | $2,016,000 | $2,387,000 | $35,739,000 |
| Florence County | $2,493,000 | $13,000 | $2,000 | $2,000 | $2,510,000 |
| Fond du Lac County | $24,303,000 | $4,539,000 | $1,407,000 | $1,166,000 | $31,415,000 |
| Forest County | $4,642,000 | $321,000 | $78,000 | $76,000 | $5,117,000 |
| Grant County | $32,203,000 | $5,144,000 | $2,146,000 | $2,027,000 | $41,520,000 |
| Green County | $23,015,000 | $2,816,000 | $971,000 | $791,000 | $27,593,000 |
| Green Lake County | $5,857,000 | $1,226,000 | $1,217,000 | $201,000 | $8,501,000 |
| Iowa County | $14,354,000 | $685,000 | $565,000 | $564,000 | $16,168,000 |
| Iron County | $848,000 | $107,000 | $74,000 | $27,000 | $1,056,000 |
| Jackson County | $10,273,000 | $842,000 | $2,624,000 | $523,000 | $14,262,000 |
| Jefferson County | $47,142,000 | $6,948,000 | $9,804,000 | $1,640,000 | $65,534,000 |
| Juneau County | $20,140,000 | $1,638,000 | $2,680,000 | $1,048,000 | $25,506,000 |
| Kenosha County | $37,456,000 | $5,329,000 | $2,326,000 | $2,977,000 | $48,088,000 |
| Kewaunee County | $3,169,000 | $252,000 | $79,000 | $66,000 | $3,566,000 |
| La Crosse County | $106,581,000 | $23,694,000 | $9,490,000 | $1,870,000 | $141,635,000 |
| Lafayette County | $20,061,000 | $2,865,000 | $1,157,000 | $1,395,000 | $25,478,000 |
| Langlade County | $3,684,000 | $885,000 | $145,000 | $81,000 | $4,795,000 |
| Lincoln County | $8,574,000 | $458,000 | $474,000 | $198,000 | $9,704,000 |
| Manitowoc County | $28,292,000 | $3,233,000 | $1,588,000 | $931,000 | $34,044,000 |
| Marathon County | $41,054,000 | $6,522,000 | $8,195,000 | $3,362,000 | $59,133,000 |
| Marinette County | $15,822,000 | $1,692,000 | $2,365,000 | $262,000 | $20,141,000 |
| Marquette County | $4,882,000 | $1,050,000 | $763,000 | $346,000 | $7,041,000 |
| Menominee County | $814,000 | $17,000 | $3,000 | $349,000 | $1,183,000 |
| Milwaukee County | $109,358,000 | $30,832,000 | $31,963,000 | $3,094,000 | $175,247,000 |
| Monroe County | $22,526,000 | $5,290,000 | $1,790,000 | $744,000 | $30,350,000 |
| Oconto County | $17,203,000 | $1,291,000 | $3,260,000 | $282,000 | $22,036,000 |
| Oneida County | $8,079,000 | $2,166,000 | $167,000 | $32,000 | $10,444,000 |
| Outagamie County | $30,132,000 | $6,314,000 | $7,813,000 | $1,386,000 | $45,645,000 |
| Ozaukee County | $81,875,000 | $18,146,000 | $5,862,000 | $2,145,000 | $108,028,000 |
| Pepin County | $8,615,000 | $2,331,000 | $217,000 | $91,000 | $11,254,000 |
| Pierce County | $15,310,000 | $2,289,000 | $2,135,000 | $317,000 | $20,051,000 |
| Polk County | $16,765,000 | $5,042,000 | $957,000 | $482,000 | $23,246,000 |
| Portage County | $7,332,000 | $707,000 | $323,000 | $306,000 | $8,668,000 |
| Price County | $5,903,000 | $236,000 | $458,000 | $86,000 | $6,683,000 |
| Racine County | $72,143,000 | $7,060,000 | $3,331,000 | $1,724,000 | $84,258,000 |

| County | Residential | Commercial | Industrial | Other | Total |
|---|---|---|---|---|---|
| Richland County | $34,168,000 | $5,762,000 | $2,480,000 | $2,008,000 | $44,418,000 |
| Rock County | $59,379,000 | $23,280,000 | $24,810,000 | $3,064,000 | $110,533,000 |
| Rusk County | $9,652,000 | $371,000 | $359,000 | $145,000 | $10,527,000 |
| Sauk County | $26,256,000 | $4,624,000 | $2,882,000 | $1,199,000 | $34,961,000 |
| Sawyer County | $21,297,000 | $2,275,000 | $860,000 | $118,000 | $24,550,000 |
| Shawano County | $3,451,000 | $115,000 | $112,000 | $76,000 | $3,754,000 |
| Sheboygan County | $25,497,000 | $5,764,000 | $2,175,000 | $1,030,000 | $34,466,000 |
| St. Croix County | $31,645,000 | $3,747,000 | $865,000 | $556,000 | $36,813,000 |
| Taylor County | $4,326,000 | $870,000 | $4,175,000 | $89,000 | $9,460,000 |
| Trempealeau County | $19,069,000 | $3,097,000 | $1,316,000 | $2,388,000 | $25,870,000 |
| Vernon County | $22,923,000 | $4,731,000 | $1,026,000 | $1,295,000 | $29,975,000 |
| Vilas County | $5,746,000 | $328,000 | $54,000 | $39,000 | $6,167,000 |
| Walworth County | $22,541,000 | $3,386,000 | $3,142,000 | $547,000 | $29,616,000 |
| Washburn County | $11,431,000 | $588,000 | $370,000 | $639,000 | $13,028,000 |
| Washington County | $65,232,000 | $25,204,000 | $15,631,000 | $3,335,000 | $109,402,000 |
| Waukesha County | $191,008,000 | $41,987,000 | $24,728,000 | $6,502,000 | $264,225,000 |
| Waupaca County | $18,974,000 | $5,989,000 | $1,181,000 | $891,000 | $27,035,000 |
| Waushara County | $2,814,000 | $187,000 | $80,000 | $208,000 | $3,289,000 |
| Winnebago County | $33,000,000 | $6,091,000 | $3,417,000 | $317,000 | $42,825,000 |
| Wood County | $13,374,000 | $1,520,000 | $2,648,000 | $944,000 | $18,486,000 |
| **Total** | **$1,974,371,000** | **$407,405,000** | **$246,242,000** | **$74,830,000** | **$2,702,848,000** |

Source: HAZUS-MH analysis conducted in 2021

**Table 3.3.3-9: Number of Damaged Buildings by County**

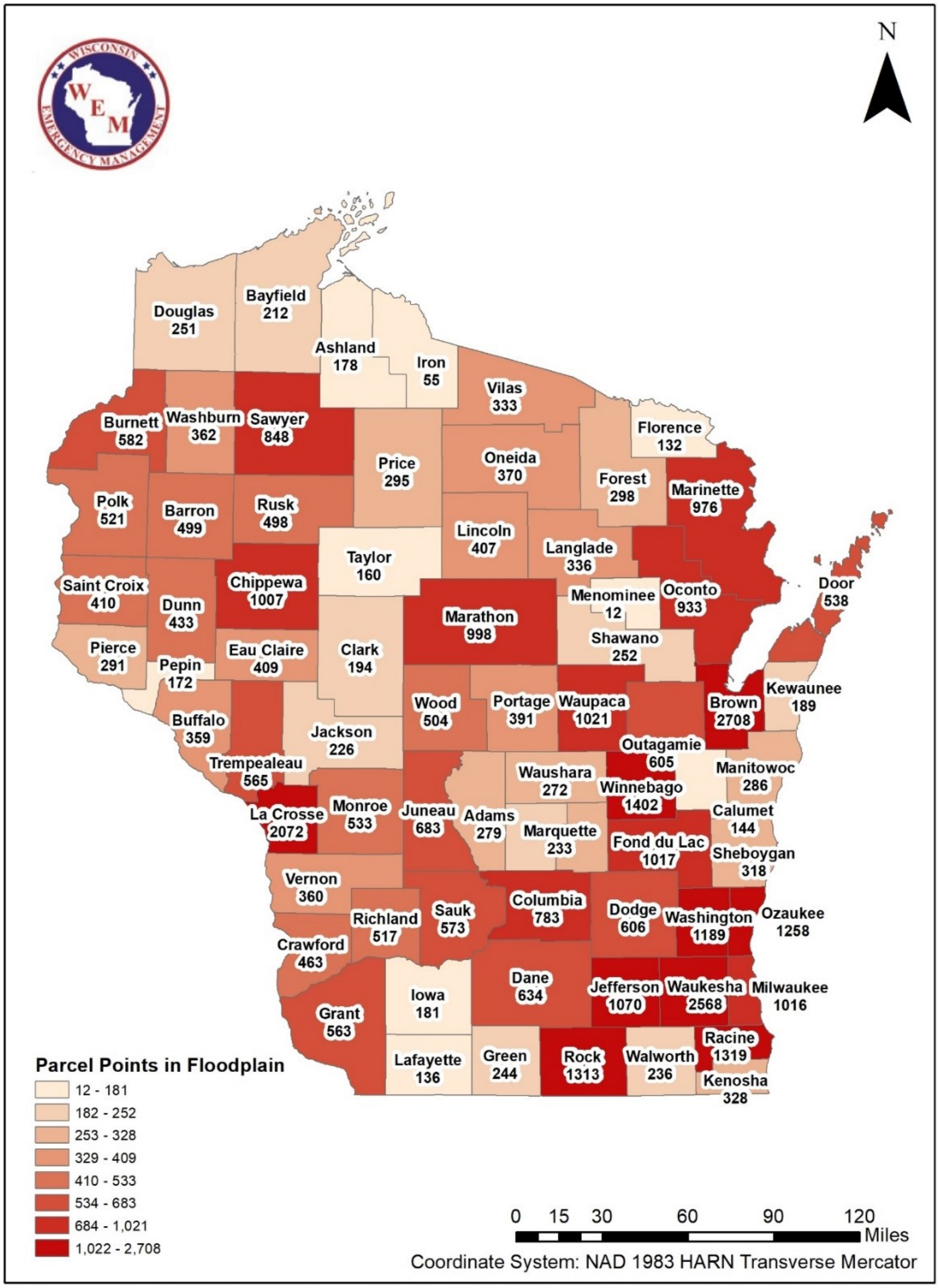
| County | Residential | Commercial | Industrial | Other | Total |
|---|---|---|---|---|---|
| Adams County | 59 | 0 | 0 | 0 | 59 |
| Ashland County | 22 | 1 | 0 | 0 | 23 |
| Barron County | 76 | 0 | 0 | 0 | 76 |
| Bayfield County | 9 | 0 | 0 | 0 | 9 |
| Brown County | 1,907 | 16 | 4 | 0 | 1,927 |
| Buffalo County | 67 | 0 | 0 | 0 | 67 |
| Burnett County | 90 | 0 | 0 | 0 | 90 |
| Calumet County | 42 | 0 | 0 | 0 | 42 |
| Chippewa County | 242 | 21 | 0 | 0 | 263 |
| Clark County | 20 | 0 | 0 | 0 | 20 |
| Columbia County | 270 | 0 | 0 | 0 | 270 |
| Crawford County | 269 | 5 | 0 | 0 | 274 |
| Dane County | 601 | 12 | 0 | 0 | 613 |
| Dodge County | 227 | 1 | 2 | 0 | 230 |
| Door County | 189 | 0 | 0 | 0 | 189 |
| Douglas County | 7 | 0 | 0 | 0 | 7 |

| County | Residential | Commercial | Industrial | Other | Total |
|---|---|---|---|---|---|
| Dunn County | 74 | 0 | 1 | 0 | 75 |
| Eau Claire County | 75 | 0 | 0 | 0 | 75 |
| Florence County | 2 | 0 | 0 | 0 | 2 |
| Fond du Lac County | 407 | 4 | 0 | 1 | 412 |
| Forest County | 37 | 0 | 0 | 0 | 37 |
| Grant County | 127 | 1 | 0 | 0 | 128 |
| Green County | 119 | 0 | 0 | 0 | 119 |
| Green Lake County | 77 | 1 | 0 | 0 | 78 |
| Iowa County | 32 | 0 | 0 | 0 | 32 |
| Iron County | 2 | 0 | 0 | 0 | 2 |
| Jackson County | 19 | 0 | 0 | 0 | 19 |
| Jefferson County | 314 | 2 | 5 | 1 | 322 |
| Juneau County | 104 | 0 | 0 | 0 | 104 |
| Kenosha County | 191 | 1 | 0 | 3 | 195 |
| Kewaunee County | 22 | 0 | 0 | 0 | 22 |
| La Crosse County | 1,119 | 4 | 4 | 0 | 1,127 |
| Lafayette County | 31 | 0 | 0 | 0 | 31 |
| Langlade County | 11 | 0 | 0 | 0 | 11 |
| Lincoln County | 52 | 0 | 0 | 0 | 52 |
| Manitowoc County | 90 | 0 | 0 | 0 | 90 |
| Marathon County | 303 | 3 | 3 | 1 | 310 |
| Marinette County | 231 | 3 | 1 | 0 | 235 |
| Marquette County | 42 | 1 | 0 | 0 | 43 |
| Menominee County | 2 | 0 | 0 | 0 | 2 |
| Milwaukee County | 808 | 4 | 18 | 0 | 830 |
| Monroe County | 165 | 0 | 0 | 0 | 165 |
| Oconto County | 168 | 0 | 6 | 0 | 174 |
| Oneida County | 32 | 0 | 0 | 0 | 32 |
| Outagamie County | 264 | 0 | 6 | 0 | 270 |
| Ozaukee County | 520 | 3 | 1 | 0 | 524 |
| Pepin County | 31 | 0 | 0 | 0 | 31 |
| Pierce County | 31 | 0 | 0 | 0 | 31 |
| Polk County | 93 | 8 | 0 | 0 | 101 |
| Portage County | 40 | 0 | 0 | 0 | 40 |
| Price County | 14 | 0 | 0 | 0 | 14 |
| Racine County | 572 | 5 | 0 | 0 | 577 |
| Richland County | 161 | 4 | 0 | 0 | 165 |
| Rock County | 513 | 16 | 11 | 3 | 543 |
| Rusk County | 28 | 0 | 0 | 0 | 28 |
| Sauk County | 106 | 2 | 0 | 0 | 108 |

| County | Residential | Commercial | Industrial | Other | Total |
|---|---|---|---|---|---|
| Sawyer County | 73 | 0 | 0 | 0 | 73 |
| Shawano County | 1 | 0 | 0 | 0 | 1 |
| Sheboygan County | 85 | 0 | 0 | 0 | 85 |
| St. Croix County | 118 | 1 | 0 | 0 | 119 |
| Taylor County | 17 | 2 | 8 | 0 | 27 |
| Trempealeau County | 160 | 7 | 0 | 3 | 170 |
| Vernon County | 60 | 1 | 0 | 0 | 61 |
| Vilas County | 44 | 0 | 0 | 0 | 44 |
| Walworth County | 177 | 1 | 0 | 0 | 178 |
| Washburn County | 50 | 0 | 0 | 0 | 50 |
| Washington County | 484 | 25 | 2 | 0 | 511 |
| Waukesha County | 1,449 | 13 | 1 | 3 | 1,466 |
| Waupaca County | 295 | 4 | 0 | 0 | 299 |
| Waushara County | 38 | 0 | 0 | 0 | 38 |
| Winnebago County | 476 | 0 | 1 | 0 | 477 |
| Wood County | 87 | 2 | 0 | 2 | 91 |
| **Total** | **14,740** | **174** | **74** | **17** | **15,005** |

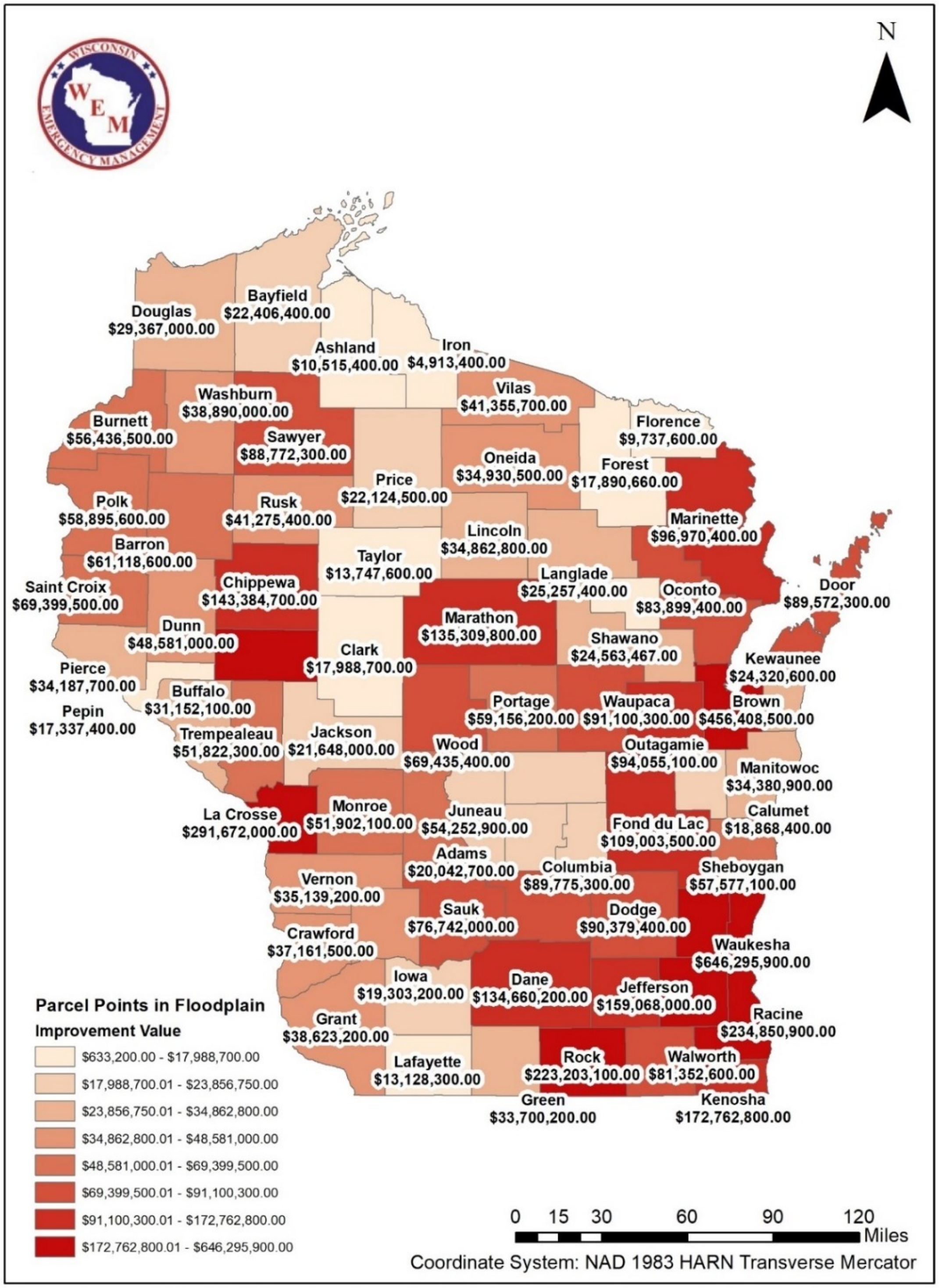
Source: HAZUS-MH analysis conducted in 2021

**Figure 3.3.3-2: Number of Parcel Points in the Floodplain by County**



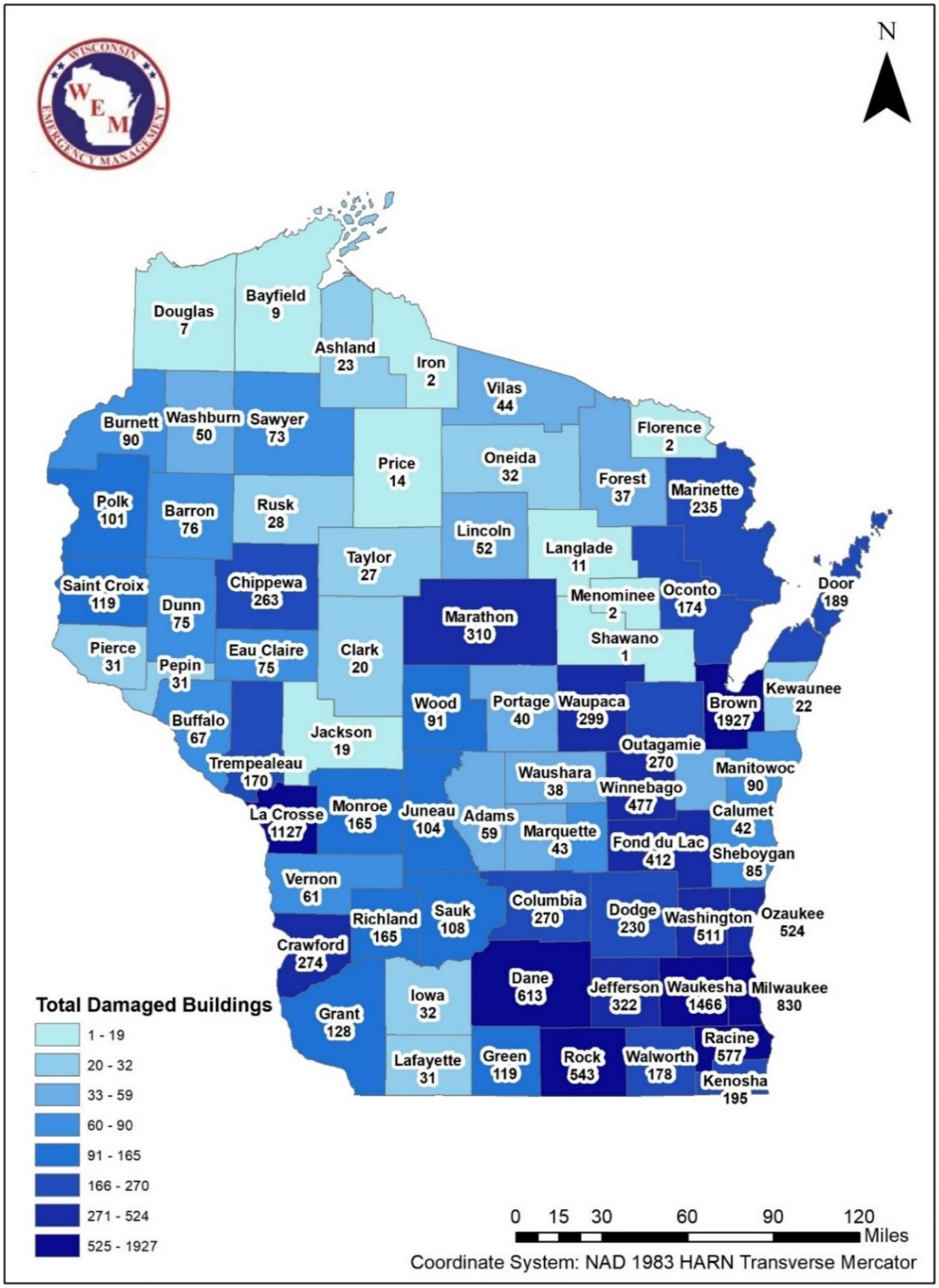

Sources: Hazus-MH, 2021; FEMA Map Service Center, 2021; Wisconsin Emergency Management, 2021; Wisconsin Department of Natural Resources 2021, Wisconsin State Cartographer's Office 2021

**Figure 3.3.3-3: Total Improved Value of Parcel Points in the Floodplain by County**



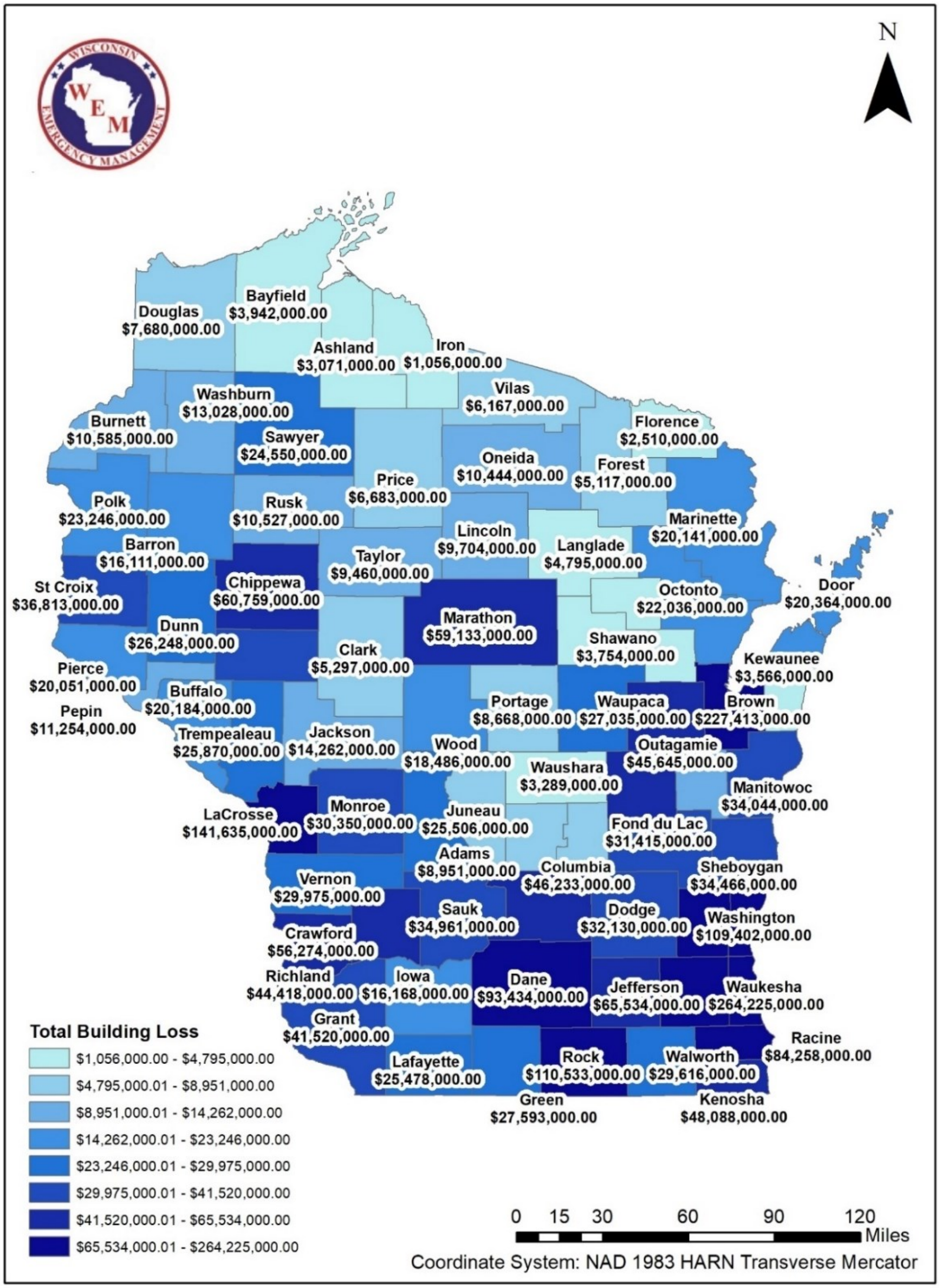

Sources: Hazus-MH, 2021; FEMA Map Service Center, 2021; Wisconsin Emergency Management, 2021; Wisconsin Department of Natural Resources 2021, Wisconsin State Cartographer's Office 2021

**Figure 3.3.3-4: Estimated Total Number of Damaged Buildings by County (# Damaged Buildings)**



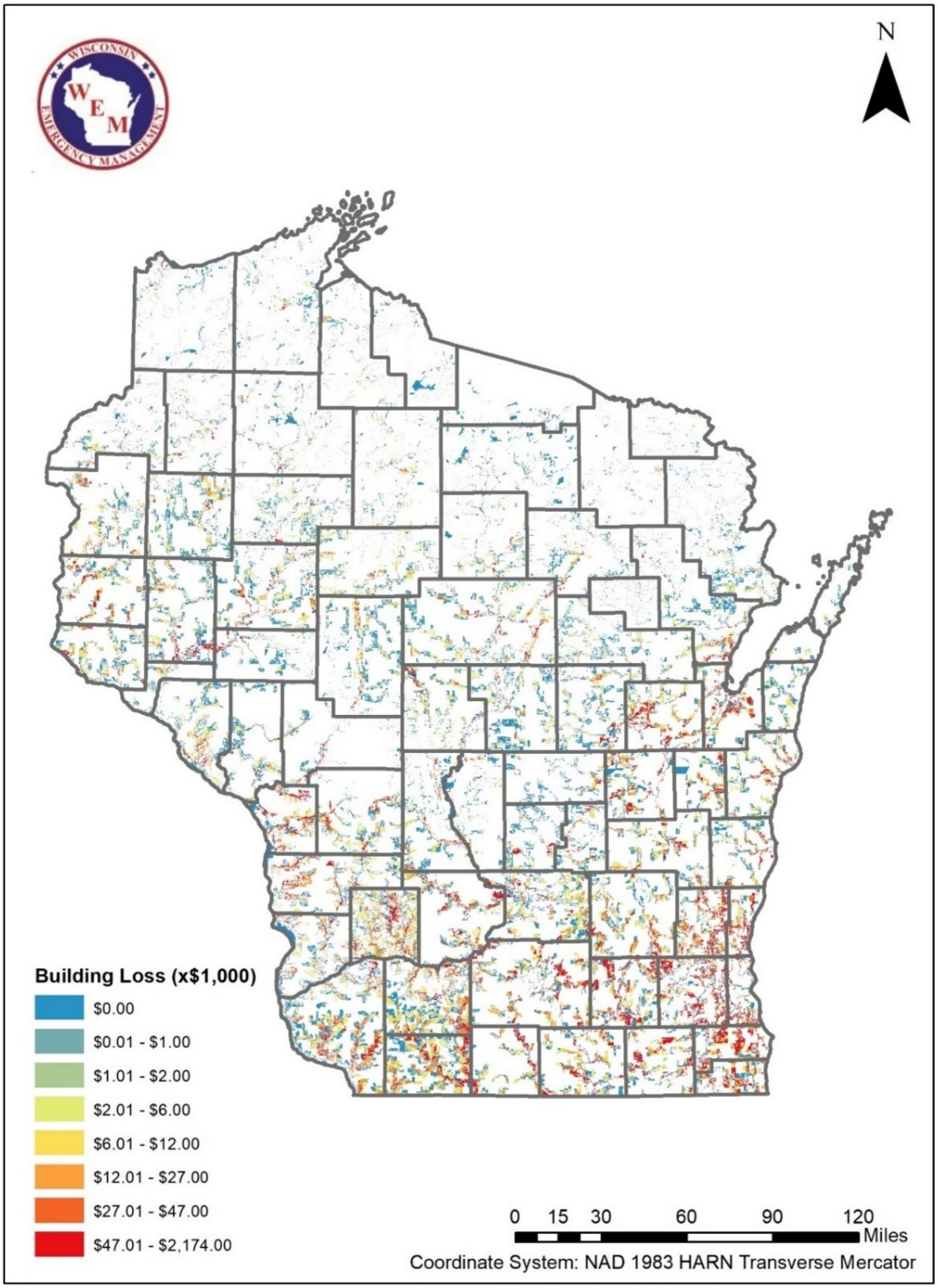

Sources: Hazus-MH, 2021; FEMA Map Service Center, 2021; Wisconsin Emergency Management, 2021; Wisconsin Department of Natural Resources 2021, Wisconsin State Cartographer's Office 2021

**Figure 3.3.3-5: Estimated Total Building Damages by County (Dollars)**




Sources: Hazus-MH, 2021; FEMA Map Service Center, 2021; Wisconsin Emergency Management, 2021; Wisconsin Department of Natural Resources 2021, Wisconsin State Cartographer's Office 2021

**Figure 3.3.3-6: Estimated Total Building Loss by Census Block (Dollars)**




Sources: Hazus-MH, 2021; FEMA Map Service Center, 2021; Wisconsin Emergency Management, 2021; Wisconsin Department of Natural Resources 2021, Wisconsin State Cartographer's Office 2021

*Vulnerability and Mitigation Potential*

To make informed mitigation decisions, it is necessary to review multiple types of information from a wide array of sources. There are many different approaches to characterizing flood risk and mitigation potential. Developing a comprehensive, holistic view of flooding in the state requires looking at different time scales – documenting past history and modeling potential future scenarios – and data levels – reviewing data for the state, counties, communities, and individual properties. When assessing mitigation potential, WEM considers a variety of other factors for each county, such as number of repetitive and severe repetitive loss properties, flood insurance claims, and involvement in past disaster declarations.

70 of Wisconsin's 72 counties have been included in at least one flood-related Presidential Disaster Declaration since 1991 (Table 3.3.3-10). The exceptions are Door and Kewaunee. Counties with double digit declarations since 1991 include Vernon, Crawford, Richland, La Crosse, Grant, and Clark. (Table 3.3.3-10; Figure 3.3.3-7). Communities within Kenosha, Sauk, Jefferson, Crawford, Vernon, Waukesha, Milwaukee, and Dane Counties (including the counties themselves) have received the greatest number of Hazard Mitigation Assistance grants (HMGP, PDM, and FMA) for completing flood-related projects and plans (Table 3.3.3-10; Figure 3.3.3-8).

The reduction of flood risk is attainable. States and tribes should be proactive to flood potential. This includes applying for grants to mitigate potential losses that promote resiliency. If a disaster occurs and HMGP funding is available, the community needs to take advantage of the opportunity of the funding. Local communities should explore options available through the Community Rating System and prioritize mitigation grants for properties that have repetitive loss because of flooding. Property owners should have flood insurance if they are in a high-risk area.

Wisconsin communities may use the results of this analysis to identify mitigation actions that protect structures on parcels that fall partially or completely within the SFHA. Different mitigation actions will work best in different places. The most effective way to eliminate flood risk is to prevent new development in the floodplain and remove existing structures where possible. Development can still connect residents to the waterfront through public parks, boat landings, and other uses that can withstand periodic inundation. For properties of historic or cultural significance, or in areas where it is not practical to diminish the tax base, flood damages may be avoided by elevating and/or floodproofing existing floodplain structures. Alternatively, communities may look to increase flood storage capacity in other parts of their watershed through open space preservation or the installation of detention basins, etc. Large structural projects may prove to be cost prohibitive for many communities and may not be feasible to install in areas that are already highly developed; levees, dams, berms and other large projects should be considered only when absolutely necessary.

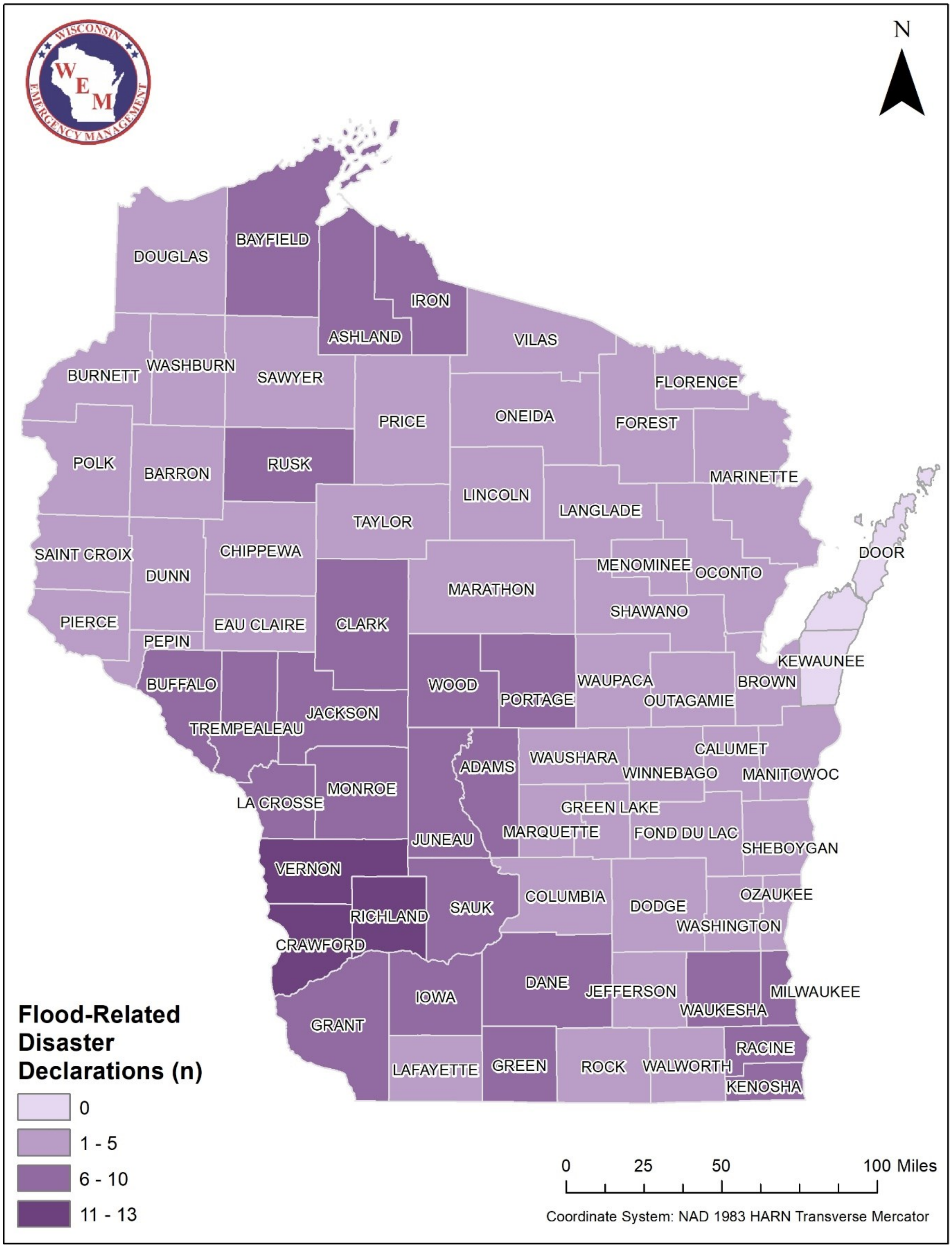
**Table 3.3.3-10: Number of Flood-Related Disaster Declarations and HMA Grants Awarded by County (1991 to 2020)**

| County | Flood-Related Disaster Declarations | Flood-Related HMA Grants |
|---|---|---|
| Adams | 8 | 0 |
| Ashland | 7 | 1 |
| Barron | 4 | 0 |
| Bayfield | 6 | 2 |
| Brown | 2 | 1 |
| Buffalo | 6 | 0 |
| Burnett | 5 | 0 |
| Calumet | 5 | 0 |
| Chippewa | 5 | 0 |
| Clark | 10 | 4 |
| Columbia | 5 | 2 |
| Crawford | 12 | 14 |
| Dane | 8 | 11 |
| Dodge | 4 | 0 |
| Door | 0 | 0 |
| Douglas | 5 | 5 |
| Dunn | 5 | 1 |
| Eau Claire | 2 | 7 |
| Florence | 2 | 1 |
| Fond Du Lac | 5 | 4 |
| Forest | 2 | 1 |
| Grant | 10 | 5 |
| Green | 6 | 2 |
| Green Lake | 4 | 0 |
| Iowa | 7 | 0 |
| Iron | 6 | 0 |
| Jackson | 9 | 1 |
| Jefferson | 5 | 14 |
| Juneau | 9 | 4 |
| Kenosha | 6 | 19 |
| Kewaunee | 0 | 0 |
| La Crosse | 10 | 1 |
| Lafayette | 5 | 10 |
| Langlade | 2 | 0 |
| Lincoln | 2 | 0 |
| Manitowoc | 1 | 0 |

| County | Flood-Related Disaster Declarations | Flood-Related HMA Grants |
|---|---|---|
| Marathon | 5 | 2 |
| Marinette | 2 | 0 |
| Marquette | 4 | 0 |
| Menominee | 2 | 0 |
| Milwaukee | 8 | 12 |
| Monroe | 9 | 3 |
| Oconto | 1 | 1 |
| Oneida | 3 | 0 |
| Outagamie | 4 | 0 |
| Ozaukee | 5 | 8 |
| Pepin | 4 | 1 |
| Pierce | 4 | 2 |
| Polk | 4 | 2 |
| Portage | 7 | 0 |
| Price | 3 | 0 |
| Racine | 7 | 1 |
| Richland | 11 | 4 |
| Rock | 5 | 2 |
| Rusk | 6 | 0 |
| Sauk | 7 | 15 |
| Sawyer | 4 | 1 |
| Shawano | 4 | 0 |
| Sheboygan | 3 | 1 |
| St Croix | 5 | 1 |
| Taylor | 4 | 0 |
| Trempealeau | 7 | 3 |
| Vernon | 13 | 13 |
| Vilas | 1 | 0 |
| Walworth | 3 | 1 |
| Washburn | 4 | 2 |
| Washington | 4 | 0 |
| Waukesha | 6 | 13 |
| Waupaca | 5 | 0 |
| Waushara | 5 | 1 |
| Winnebago | 4 | 2 |
| Wood | 7 | 0 |

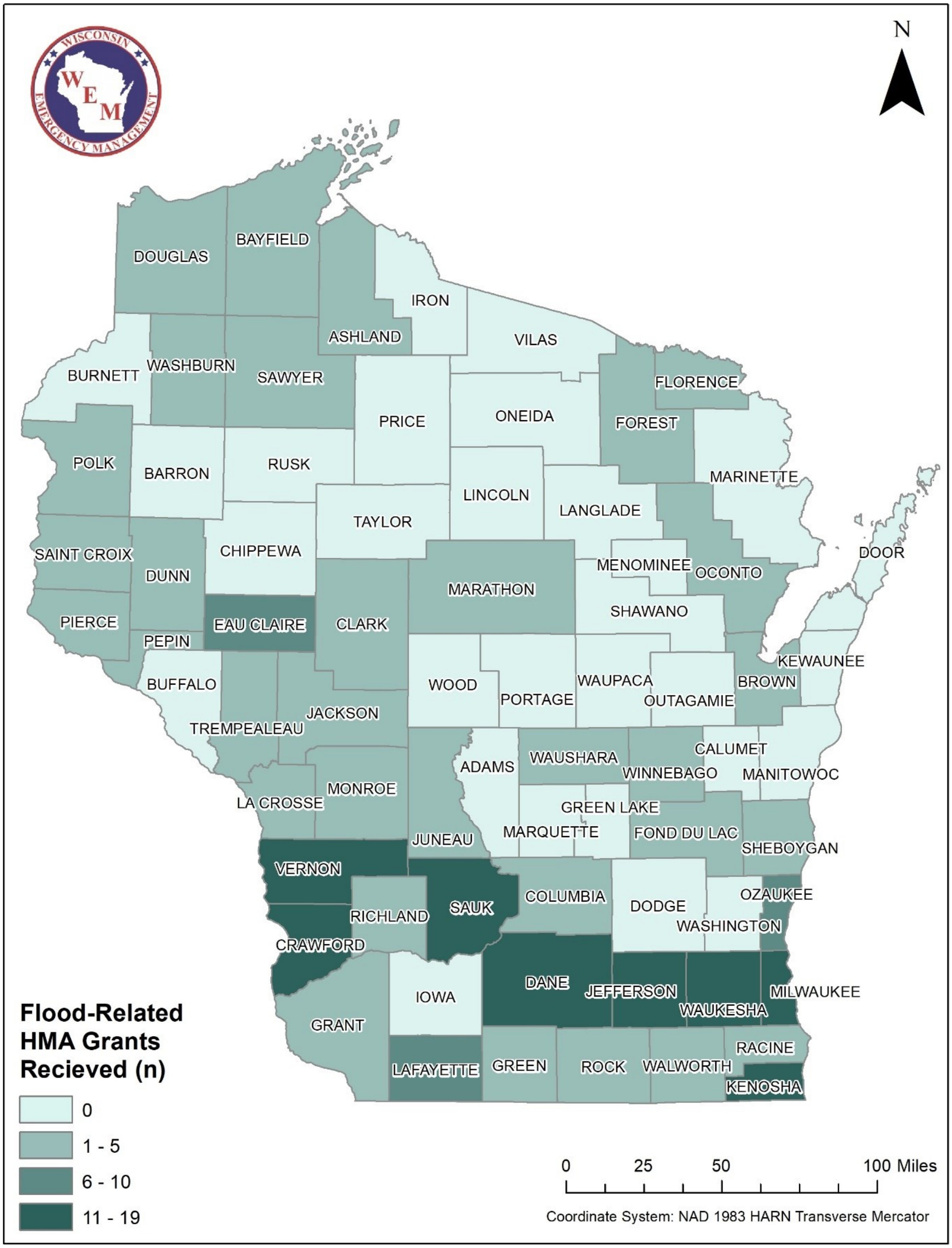
Source: WEM

**Figure 3.3.3-7: Flood-Related Disaster Declarations – DR 912 to DR 4477**




Source: WEM

**Figure 3.3.3-8: Number of Flood-Related HMA Grants by County**

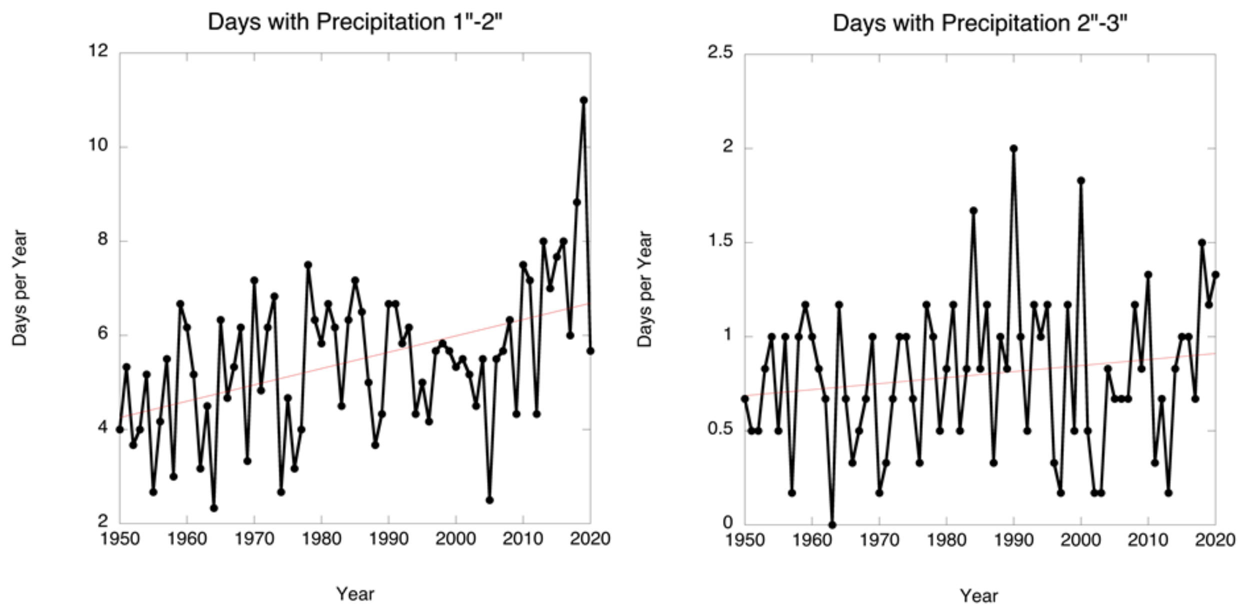



Source: WEM

### 3.3.4 Climate Change

As Wisconsin continues to become warmer and wetter, increased flooding is likely. Between 1950 and 2021 average temperatures in Wisconsin have warmed approximately 2.5° F and there has been an increase in statewide precipitation and large magnitude events (Figure 3.3.4-1). Climate change models suggest that by 2050 annual average temperatures in Wisconsin will increase 6° F and the frequency and magnitude of extreme rainfall events (3-5′′) will be enhanced. The spatial and temporal climate changes in temperature and precipitation will lead to much wetter conditions along a southeast-to-northwest transect, which includes the highly vulnerable region of southwest Wisconsin.

**Figure 3.3.4-1: Changes in Extreme Precipitation Occurrence for the 6-station Average (Milwaukee, Madison, La Crosse, Eau Claire, Wausau, Green Bay), 1950-2020**




Source: WICCI

The most destructive hazards impacting Wisconsin are weather dependent. The changing nature of extreme weather events result from a changing climate. As Wisconsin's climate changes, the potential for flooding increases. This, in part, exists because Wisconsin has thousands of miles of rivers and streams that serve to help transport flowing water during large rainfall events. However, the current hydrologic regime of streams is not large enough to encapsulate the high magnitude precipitation events that are occurring. Impacts of flooding in Wisconsin include infrastructure and property damage, mental health stress, injury and death, emergency evacuations, and negative impacts to the state's economy.

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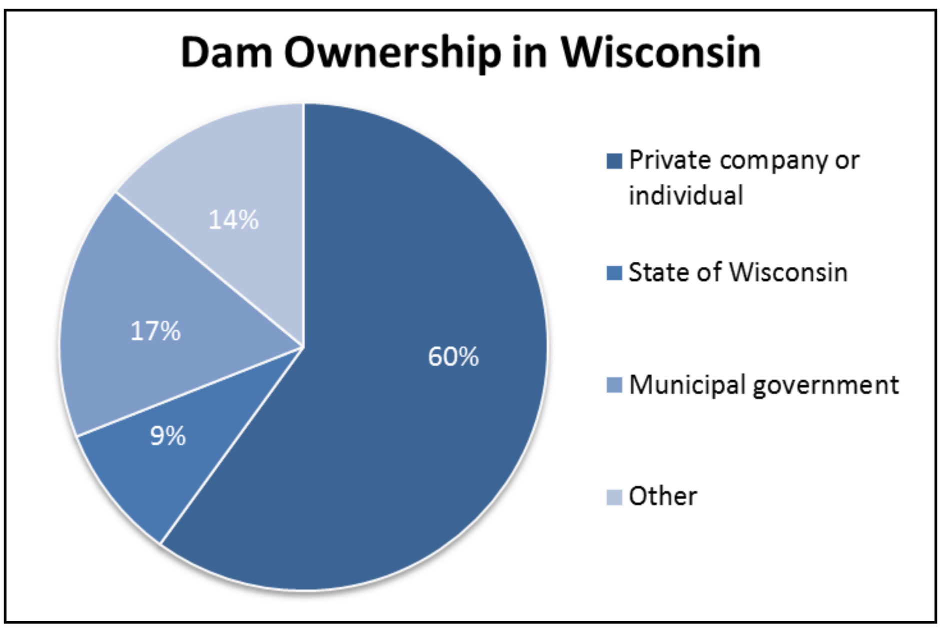
# 3.4 DAM FAILURE

## 3.4.1 Dam Failure

A **dam** is a barrier, typically constructed of earth, rock, concrete, or mine tailings, used to store, control, or divert water. The water impounded behind a dam is referred to as the **reservoir** and its volume is measured in acre-feet, with one acre-foot being the volume of water that covers one acre of land to a depth of one foot. Due to topography, even a small dam may have a reservoir containing many acre-feet of water. The water (or other liquid) stored behind a dam can have catastrophic downstream impacts if released suddenly due to dam failure or mis-operation.

Wisconsin's approximately 4,000 dams serve many purposes. Approximately 900 of the dams constructed since the late 19th century have since washed out or been removed. Many of these dams were originally used for logging and milling operations, though they are not typically used for this purpose anymore. Today, Wisconsin's dams are used for recreation, agricultural production and land management, electrical power generation, and erosion, water level, and flood control (DNR, 2015). Of the existing dams, 60% are owned by a company or private individual, 9% are owned by the State of Wisconsin, 17% are owned by municipal governments, and 14% are owned by other groups (Figure 3.4.1-1).

**Figure 3.4.1-1: Distribution of Dam Ownership in Wisconsin**




Source: Wisconsin DNR

A **dam failure** is the collapse, breach, or other failure of a dam that causes downstream flooding (FEMA, 1997). Dam failures usually occur when the spillway capacity is inadequate and water overtops the dam or when internal erosion through the dam foundation occurs (also known as piping). During a dam failure, a high-velocity, debris-laden wall of water can be released and rush downstream, damaging or destroying whatever is in its path. Dam failures may result from one or more the following:

- Prolonged periods of rainfall and flooding (the cause of most failures)
- Inadequate spillway capacity which causes overtopping flows
- Internal erosion
- Landslides into reservoirs
- High winds
- Flood debris blocking gates
- Erosion due to embankment or foundation leakage or piping
- Improper design or maintenance
- Negligent operation
- Failure of upstream dams
- Earthquakes

For emergency planning purposes, dam failures are categorized as either rainy day or sunny day failures. **Rainy day failures** involve periods of excessive precipitation leading to unusually high runoff. This high runoff increases the reservoir level, and if not controlled, the overtopping of the dam or excessive water pressure can lead to dam failure. Normal storm events can also lead to rainy day failures if water outlets are plugged with debris or otherwise made inoperable. **Sunny day failures** occur due to poor dam maintenance, damage/obstruction of outlet systems, or vandalism. This is the worst type of failure and can be catastrophic because the breach is unexpected and there may be insufficient time to properly warn downstream residents.

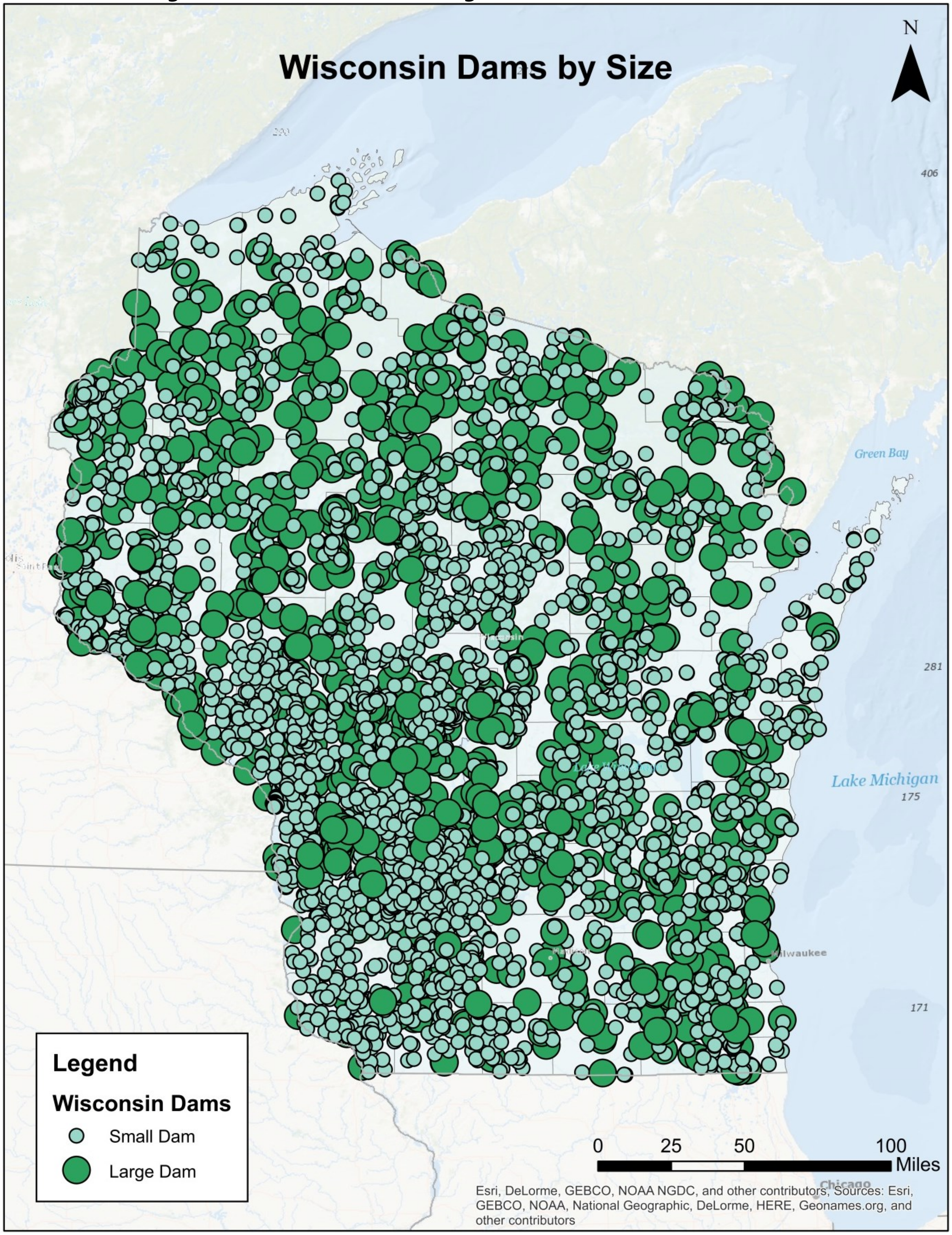
Among the 4,094 dams in Wisconsin, there is a wide variance in the potential to cause damage in the event of failure. Very few dams in Wisconsin were built primarily to protect people and property from floods. Most of the dams that provide a flood-control benefit are associated with large hydroelectric operations on major rivers where flood control is a secondary benefit, or they are PL-566 dams, which are dams built through the Watershed Protection and Flood Prevention Act of 1954. Wisconsin has 83 PL-566 dams, located mainly in the western part of the state. The PL-566 dams often hold little or no water in their reservoirs under normal conditions. Since these dams only hold significant amounts of water during floods, they present a special hazard as everyday water-related problems such as seepage cannot be readily seen and corrected. Almost all of Wisconsin's PL-566 dams are between 30 and 50 years old and are approaching the end of their useful life. Safety studies, maintenance, repairs, and/or rehabilitation are required in order to alleviate health and safety concerns for downstream developments (NRCS, 2016).

Dam regulation

Dams in Wisconsin are regulated at either the federal or state level of government. About 150 large hydroelectric dams are federally regulated, while most of the remaining 3,850 dams are regulated at the state level by the Wisconsin Department of Natural Resources (DNR). The state does not regulate dams that are not on a watercourse, that impound a liquid other than water, or that are associated with a cranberry operation.

State-regulated dams are classified by the DNR as either large or small. **Large dams** either have a structural height of over six feet and impound more than 50 acre-feet of water, or have a structural height of over 25 feet and impound more than 15 acre-feet. There are approximately 1,160 large dams in the state. Large dams are subject to mandatory inspection and design requirements due to their greater potential for impacting downstream areas in the event of a failure. The remaining dams are classified as **small dams**, and tend to be subject to less stringent regulation. Figure 3.4.1-2 displays the location of large and small State-regulated dams in Wisconsin. Notice the large concentration of small dams along the western part of the state.

**Figure 3.4.1-2: Location of Large and Small Dams in Wisconsin**




Source: Wisconsin DNR

### 3.4.2 History

Although sunny day failures do happen, many of Wisconsin's dam failure incidents have occurred during flood events. Minor damage, overtopping, and embankment erosion are common during periods of minor and major flooding. Examples of significant dam failure events from the Wisconsin DNR's dam incident database are presented in Table 3.x.x-1 (note: dam failures stemming from the 1993 floods are summarized in a separate table). The following history section summarizes dam failure incidents in Wisconsin by decade.

<u>1980-1989</u>

From 1980 to 1989 there were 13 significant dam failure incidents in the state. The most notable incident was the near overtopping of the 66-foot tall Orienta Falls power-generating dam on the Iron River in Bayfield County in 1985. The flood caused $500,000 damage to the dam, destroyed 3 bridges, took out telephone service, and washed culverts and roads away. There were no fatalities, but authorities evacuated two families downstream to prepare for potential dam collapse. Instead of spending for expensive repairs, the dam operator, Northern State Power, removed the dam and returned the river to its natural state.

<u>1990-1999</u>

Between 1990 and 1995, more than 75 Wisconsin dams failed. Many of these dam failures were associated with the Great Midwest Flood of 1993. Though none of these failures resulted in any loss of life, injuries and extensive property damage occurred during several events.

Excessive precipitation (nine inches of rain in four hours) in August 1990 stressed the 50-year-old Lake Tomah Dam (Monroe County), imperiling the lives of approximately 2,000 residents of the City of Tomah (Monroe County) who had to be evacuated from their homes. Municipal workers, volunteers, and Wisconsin National Guard personnel averted a breach by using more than 20,000 sandbags to reinforce the structure. A large crane was used to open the floodgates and the level of the lake dropped eight inches in one hour. The excess water emptied into the Lemonweir River, which overtopped its banks and rose approximately two inches per minute until it stabilized.

One of the more publicized 1993 incidents involved the Hatfield Dam (Jackson County). A power canal dike at the dam failed due to flooding. Initial reports from the area indicated that the main dam had failed, but this proved to be incorrect. A summary of dam washouts, overtopping, or damages associated with the 1993 floods is provided in Table 3.4.2-6.

<u>2000-2009</u>

Between 2000 and 2009 there were 13 significant dam failures in Wisconsin, seven of which occurred in 2007. On September 2, 2002, heavy rains occurred in the far western counties of Wisconsin. In the Village of Osceola, heavy rain caused an old milldam to breach, crashing floodwaters through a mobile home park. The torrent continued downstream, overtopping a second dam and causing extensive road damage.

In August of 2007, heavy rains severely affected southwest Wisconsin. In Vernon County, many dams were overwhelmed with debris (in the form of large, round hay bales) and water. The dams either failed, seeped water, or were under significant stress. In addition to the seven dam failures, major repairs needed to be made to at least 22 dams in Vernon County due to this event.

Severe flooding in 2008 stressed and overtopped many dams in southern Wisconsin. The flooding overtopped the shoreline of Lake Delton and washed five homes and part of County Highway A into the Wisconsin River. The Dell Creek Dam that had formed Lake Delton was left high and dry after the event, and the lake was reduced to a narrow stream. Throughout the 2008 storm event, Wisconsin DNR Dam Safety staff monitored over 200 stressed dams. Ultimately, 25 dams sustained damage that required repair or reconstruction, including four that were breached.

2010-2016

In the years since 2008, the state has experienced several dam failure incidents every year. Generally, these incidents have only had small, localized impacts. Between 2010 and 2016, there were two significant dam failures in Wisconsin, both in 2015, the Humbird dam and the Eleva Roller Mill dam.

2017-2021

In the 5 years since the 2016 Wisconsin State Hazard Mitigation Plan update, 21 dams have failed across the state, 12 of which failed in 2018.

On June 14-17, 2018, northwest Wisconsin experienced heavy rainfall and a major flooding event that caused three dam failures in Douglas County. Douglas County decided to remove the Cranberry Creek Flowage dam after this event.

In late August of 2018, the state experienced heavy rainfalls in central and southern Wisconsin and record flooding along sections of the Kickapoo river. Monroe County and Vernon County each experienced three dam failures due to the heavy rain.

Historical floods from 1880 to 1957 damaged agricultural lands and operations and infrastructure and urban areas of Coon Valley and Chaseburg. As part of the Coon Creek Flood Control Project in 1958, 14 flood control dams were built to each have the capacity to handle a rain event of four to six inches in a 24-hour period. On the night of August 27th, 2018, southwest Wisconsin received heavy rainfall for six to seven hours. There were reports of rainfall amounts of up to 11 inches in the Coon Creek Watershed area, greatly exceeding the capacity the dams were constructed to handle. Three of the seven dams in the Coon Creek Watershed failed and all seven were overtopped during the storm event. An unoccupied house was moved off its foundation. Agricultural lands and road crossings were damaged.

Nearby in the West Fork Kickapoo Valley, dams were also constructed in the mid-20th century for flood control. Two dams breached during the August 2018 storm event, the West Fork Kickapoo 1 dam at Jersey Valley Lake and the Mlsna. The Westby Fire Department evacuated residents living in Bloomingdale, a community downstream of both dams. There were five rescues at Bloomingdale on the morning of August 28th.

Following the 2018 dam failures, the Natural Resources Conservation Service (NRCS) conducted a cost-benefit analysis of the dams in Coon Creek Valley and West Fork Kickapoo Valley. Based on this analysis, the NRCS made a recommendation to decommission the flood control dams in Coon Creek and West Fork Kickapoo except West Fork Kickapoo 1 which was recommended to be rebuilt downstream.

**Figure 3.4.2-1: Mlsna dam following the heavy rains of Aug 27-28, 2018**

Source: Vernon County Land and Water Conservation Department

**Table 3.4.2-1: Summary of Significant Dam Incidents in Wisconsin, 1980 to 2021**

| Year | County | Dam | Event description |
|---|---|---|---|
| 1985 | Bayfield | *Port Wing* | Gate mechanism failure combined with high flows and debris during minor flooding led to embankment failure, major damage, and destruction of downstream powerhouse. |
| 1990 | Sauk | Leland | Major flooding washed out dam. |
| 1990 | Monroe | Tomah Lake | Failure to operate gates during major flooding resulted in overtopping, major damage. |
| 1994 | Burnett | Gomulake and Profitt | Major flooding caused a full breach of the emergency spillway, washing out Highway 35 downstream. |

| Year | County | Dam | Event description |
|---|---|---|---|
| 1994 | Sauk | Steinhorst and Coughlin | Piping along cutoff wall at embankment/fractured bedrock interface led to development of a 9-foot sinkhole. |
| 1995 | Waushara | Pine River | Minor flooding caused extensive overtopping of dam and downstream road and powerhouse. |
| 1995 | Juneau / Monroe | Potters Flowage/Lower Reservoir | Embankment failure during minor flooding led to overtopping and washing out of Highway 21 and damage to railroad crossing downstream. |
| 1995 | Waushara | Mount Morris | Minor flooding during construction on dam and abutting bridge led to embankment erosion. Damage to a crane, air compressor, road embankment, and downstream bridge. Upstream, high velocity flows washed out five large trees and undermined a house foundation, leading to evacuation of the house. |
| 1995 | Iron | Hazel Lake | Dam failure led to release of water upstream and piping through embankment; emergency action plan activated. |
| 2001 | Juneau | Robert, Arthur | Major flooding combined with rusted culvert washed out 60 feet of embankment. |
| 2002 | Polk | *Upper Osceola* | Flood and debris blockage caused overtopping during major flooding event, leading to embankment failure and flooding of homes. |
| 2007 | Vernon | Bad Axe 2 | Emergency spillway damaged during major flooding; evacuation downstream. |
| 2007 | Vernon | Bad Axe 12 | Major flooding led to flowage and erosion in auxiliary spillway; evacuation downstream. |
| 2007 | Vernon | Bad Axe 11 | Evacuation downstream during major flooding. |
| 2007 | Vernon | West Fork Kickapoo 4 | Damage to auxiliary spillway during major flooding, evacuation downstream. |
| 2007 | Vernon | West Fork Kickapoo 17 | Seepage through abutment during major flood caused erosion and danger of failure. Downstream Highway 56 was detoured, evacuation downstream. |
| 2007 | Vernon | West Fork Kickapoo 5 | Major flooding led to seepage and soil saturation in auxiliary spillway. Closure of County Highway Y and evacuation downstream; eventual blow out downstream. |

| Year | County | Dam | Event description |
|---|---|---|---|
| 2007 | Adams | Upper Camelot | Development of significant boil on downstream toe; emergency action plans activated, road closed, Lake Camelot and Lake Sherwood drawn down. |
| 2008 | Dodge | Lowell | More than 20,000 sandbags were put in place to prevent overtopping of embankments during major flooding. |
| 2008 | Columbia | Pardeeville | Partial breach during major flooding; evacuation downstream. |
| 2015 | Clark | Humbird | Major flood event caused riprap to settle behind abutment walls, leading to overtopping and scouring downstream. |
| 2015 | Trempealeau | Eleva Roller Mill | Major flood event led to overtopping and development of scour area on embankment. |
| 2018 | Price | Cranberry Creek | Dam breached overnight at principal spillway structure. Failure of spillway by piping. |
| 2018 | Waukesha | School Section Lake | Embankment failure. All stoplogs subsequently removed. Dam to remain drawn down until fixed or removed. |
| 2018 | Douglas | Cranberry Creek Flowage | Complete failure of left embankment and damage to principal concrete spillway with some uplift. |
| 2018 | Douglas | Pattison State Park | Left embankment (looking downstream) overtopped and failed causing a washout of the State Road 35 immediately downstream. Significant debris build up as a result of high flows, including large trees in principal spillway. |
| 2018 | Douglas | Radigan | Lack of gate operation likely contributed to increased pressure and pool elevation. Left embankment failure due to high flows. |
| 2018 | Vernon | Mlsna | High flows resulted in breach and failure of auxiliary spillway and abutment. |
| 2018 | Monroe | Coon Creek 21 | High flows resulted in breach and failure of auxiliary spillway and abutment. |
| 2018 | Monroe | Coon Creek 23 | High flows resulted in breach and failure of auxiliary spillway and abutment. |
| 2018 | Monroe | Coon Creek 29 | High flows resulted in breach and failure of auxiliary spillway and abutment. |
| 2018 | Sauk | Leland | Breach in embankment due to heavy rains the week prior. Plan to keep water level |

| Year | County | Dam | Event description |
|---|---|---|---|
| | | | several feet lower to prevent discharge through breach. |
| 2018 | Vernon | Hillsboro | Earthen embankment overtopped, causing extreme scour and erosion next to the left wing wall. |
| 2018 | Vernon | West Fork Kickapoo 1 | Complete failure and breach of the auxiliary spillway as a result of high flows. |

Source: Wisconsin DNR

**Table 3.4.2-2: Summary of 1993 Dam Failures/Damages**

| Season | County | Dam | Event |
|---|---|---|---|
| *Winter* | Juneau | Partridge Lake Dam | Dam washed out |
| *Spring* | Dodge | Lake Emily Dam | Dam washed out/damaged |
| | Dodge | Lowell Dam | Dam washed out/damaged |
| | Iowa | Cox Hollow Dam | Dam washed out/damaged |
| | Iowa | Wright Dam | Dam washed out/damaged |
| | Jefferson | Hebron Dam | Dam overtopped |
| | Jefferson | Upper Watertown Dam | Dam overtopped |
| | Marquette | Briggsville Dam | Dam washed out/damaged |
| | Racine | Waterford Dam | Dam washed out/damaged |
| | Sheboygan | Gooseville Dam | Dam washed out/damaged |
| *Summer* | Clark | Humbird Dam | Embankments washed out |
| | Columbia | Jordan Dam | Emergency repairs made to prevent embankment failure |
| | Columbia | Cambria Dam | Dam washed out |
| | Dodge | Fox Lake Dam | Embankment problems caused seepage |
| | Eau Claire | Dells Dam | Damage to waterwheel |
| | Eau Claire | Fairchild Dam | Dike overtopped, road washed out |
| | Eau Claire | Lake Dam | Dam washed out |
| | Eau Claire | Lake Eau Claire Dam | Gate broken in attempt to open it |
| | Eau Claire | Rock Dam | Dam washed out |
| | Jackson | ASP Cranberry Dikes | Two dikes washed out |
| | Jackson | Hatfield Dam | Dam washed out |
| | Jackson | Roberts Cranberry Dikes | Four dikes washed out |
| | Marquette | Packers Bay Dam | Embankment overtopped |
| | Oconto | Reservoir/Dummy Dams | Lake bypassed through low area, road damage |

**Table 3.4.2-2: Summary of 1993 Dam Failures/Damages**

| Season | County | Dam | Event |
|---|---|---|---|
| | Outagamie | Upper Appleton Dam | High head caused grout patch failure, seepage through wall |
| | Rock | Shopier Dam | Emergency repairs made to fill embankment breach |
| | Waupaca | Auld & Rohrer Dam | Contractor breached embankment to prevent spillway construction from failing |
| | Waupaca | Bass Lake Dam | Dam washed out |
| | Trempealeau | Blair Dam | Slow gate operation caused downstream road embankment erosion |

Source: Wisconsin DNR

### 3.4.3 Probability, Vulnerability, and Mitigation Potential

**Table 3.4.3-1: Hazard Ranking for Dam Failure**

| Evaluation Criteria | Description | Ranking |
|---|---|---|
| **Probability** | • 10% to 85% probability of occurrence each year. | Likely |
| **Vulnerability** | • Multiple measures are in place to prevent or protect against this hazard.<br>• Countermeasures have been tested and have demonstrated success in reducing the threat potential. | Medium |
| **Mitigation Potential** | • Mitigation measures are established.<br>• The State or counties have limited experience with the kinds of measures that may be appropriate to mitigate the hazard.<br>• Some mitigation measures are eligible for federal grants.<br>• There is a limited range of effective mitigation measures for the hazard.<br>• Mitigation measures are cost effective only in limited circumstances.<br>• Mitigation measures are effective for a reasonable period of time. | Medium |

<u>Probability</u>

Since 1917, the DNR has administered the Dam Safety program under Chapter 31 in the Wisconsin State Statutes, which regulates all dams and bridges affecting navigable waters in the State (Wisconsin Code § 31). Chapter NR 333 was recreated in 1985, changing the way that dam safety is enforced for large dams that are State-regulated in order "to minimize the danger to life, health, and property" (Wisconsin Code § NR 333.01). NR 333 mandates that all State-regulated large dams have an Emergency Action Plan (EAP) and an Inspection, Operation, and Maintenance (IOM) Plan which are approved in accordance with NR 333.

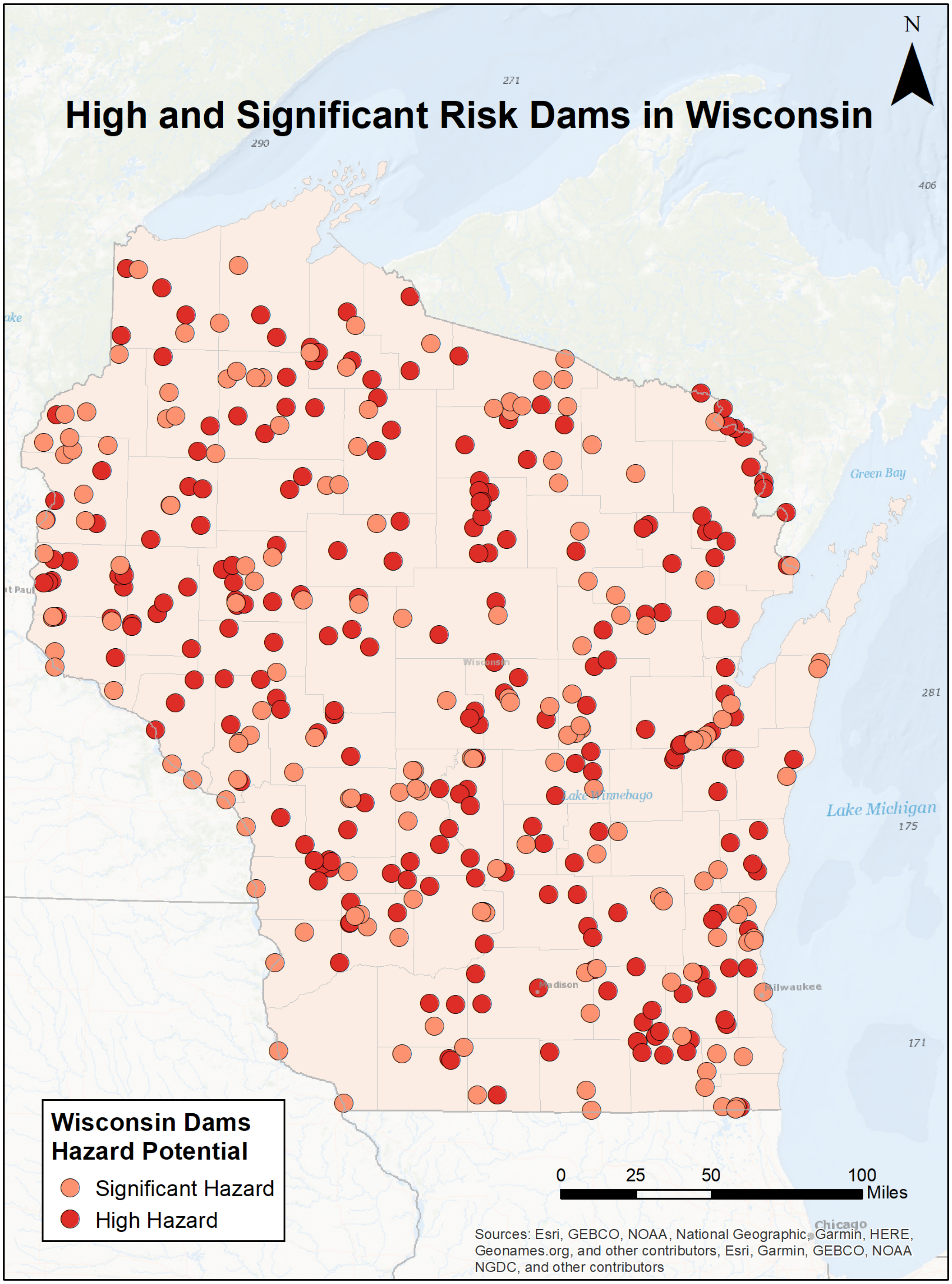
Under NR 333, the DNR assigns hazard ratings to large dams in the state. When assigning hazard ratings, DNR Dam Safety staff considers both the existing land use and land use controls (zoning) downstream of the dam. Dams are classified in one of three categories that identify their potential hazard to life and property:

1. **High hazard** – failure or mis-operation will cause loss of human life and significant property destruction
2. **Significant hazard** – failure or mis-operation of dam will result in no probably loss of human life but could result in appreciable property damage
3. **Low hazard** – failure or mis-operation would result in no probable loss of human life and only minimal property damage and loss of life is unlikely

Figure 3.4.3-1 shows the locations of dams in Wisconsin with high or significant hazard ratings. The map only includes dams for which the DNR has approved a dam failure analysis and rated the dam as high or significant hazard. There are several dams without dam failure analyses throughout the state. The majority of these are estimated to be low hazard potential. Of the dams shown on the map, very few high- or significant-hazard dams are near high population centers such as the Madison, Milwaukee, or Fox River Valley areas.

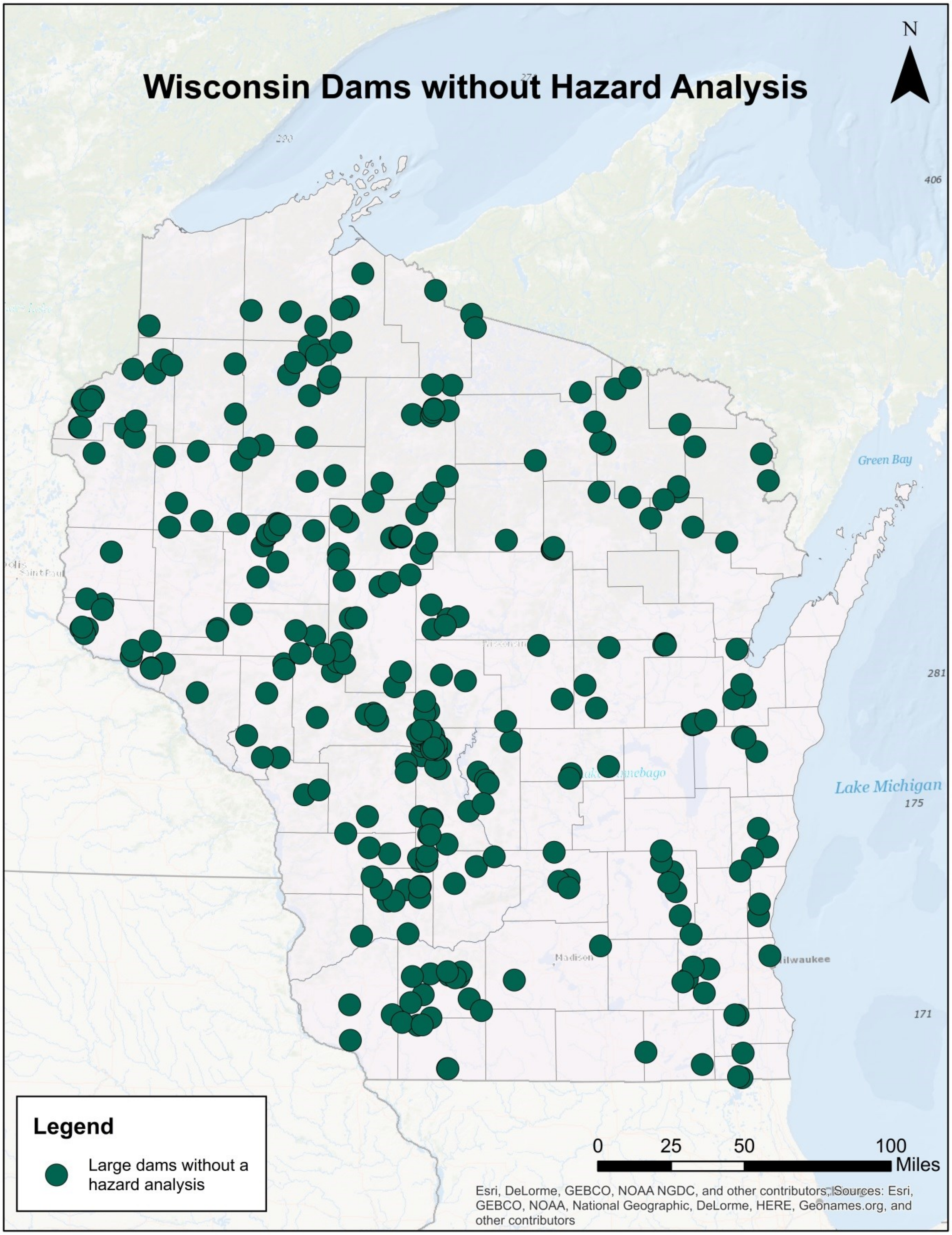
Figure 3.4.3-2 displays large, state-regulated dams that have not had a hazard analysis approved. A vast majority of these dams are estimated to have low hazard potential. The DNR Dam Safety program is working to get all analyses reviewed and approved over the next 10 years, giving the highest priority to dams estimated to be significant or high hazard.

**Figure 3.4.3-1: Location of High and Significant Hazard Dams in Wisconsin**




Source: Wisconsin DNR

**Figure 3.4.3-2: Wisconsin Dams Without a Hazard Analysis**




Source: Wisconsin DNR

Vulnerability and Mitigation Potential

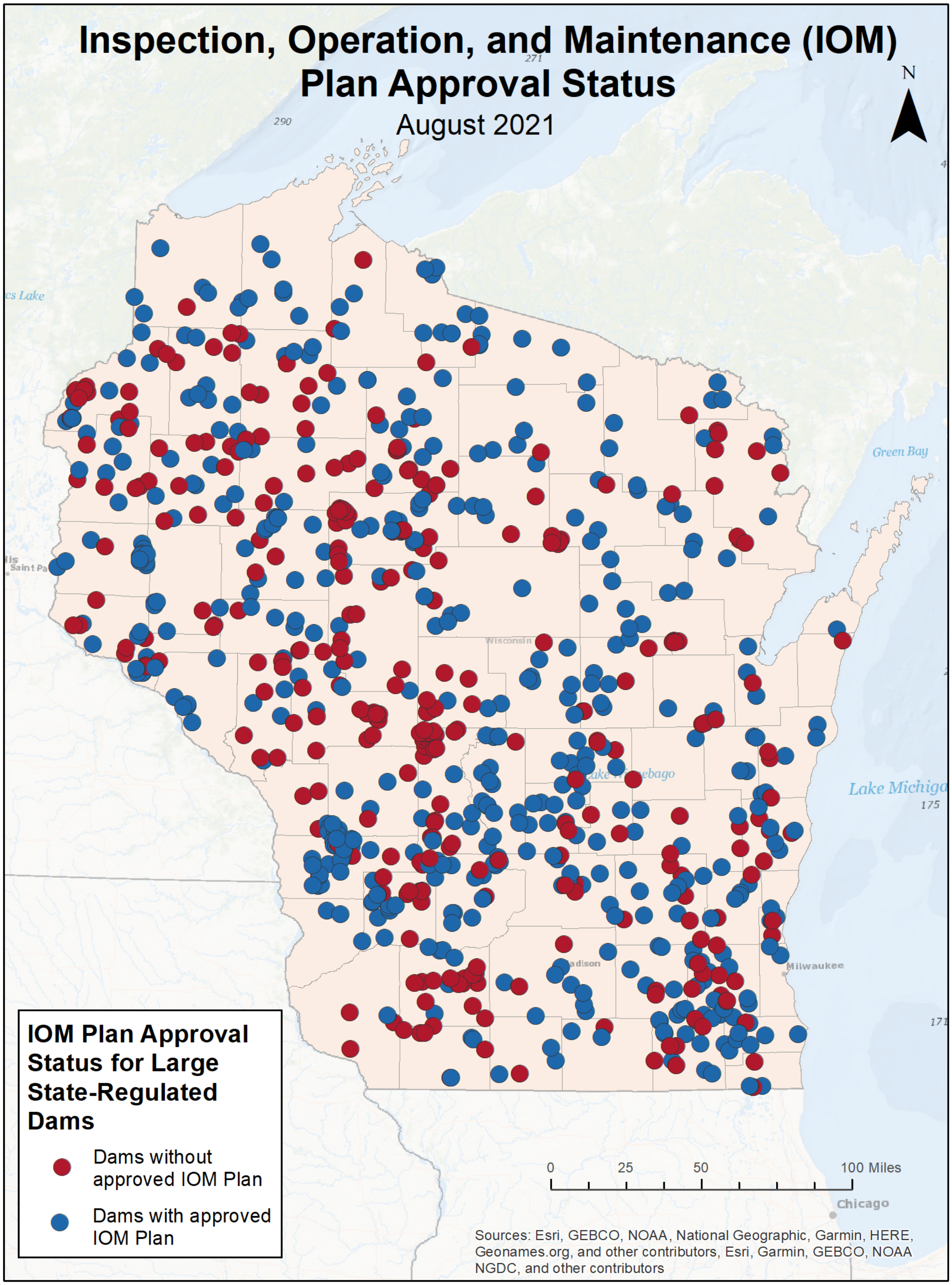
The economic impact of a dam or levee failure includes, but is not limited to, the cost to repair the structure, the flood damage resulting from the failure, and loss of income due to displaced businesses or workers. Though there have been very few dam failures in Wisconsin resulting injuries or loss of life, many existing dams require frequent repairs, and preventing potential failures due to maintenance issues is always a top concern. Dam Inspection Operation and Maintenance plans and Emergency Action Plans must also be approved in accordance with NR 333 for all large, state-regulated dams. IOMs and EAPs are evaluated for compliance in the following situations:

- When a new dam is being designed and constructed
- Within ten years of performing a hazard analysis on an existing dam
- When an existing dam is reconstructed
- After a dam failure analysis is approved by the DNR
- When a dam is adopted in a floodplain zoning ordinance
- When the DNR issues a department directive ordering a dam safety inspection

Figure 3.4.3-3 shows the approval status of IOM Plans for large, state-regulated dams. IOMs identify who is responsible for operating, inspecting, and maintaining a given dam. IOM plans describe the dam's structure and history, its operation during different flow rates, and its inspection and maintenance schedules. Many of Wisconsin's past dam incidents have involved failures due to deteriorated or nonfunctioning components. IOM planning represents an important mitigation action designed to help dam owners organize information, ensure proper maintenance, prevent dam failure, and ultimately protect life and property downstream. There are about 460 dams without approved IOM Plans as of June 2016. The state does not typically keep IOM Plans for federally regulated dams on file, so these dams are not represented in Figure 3.4.3-3.

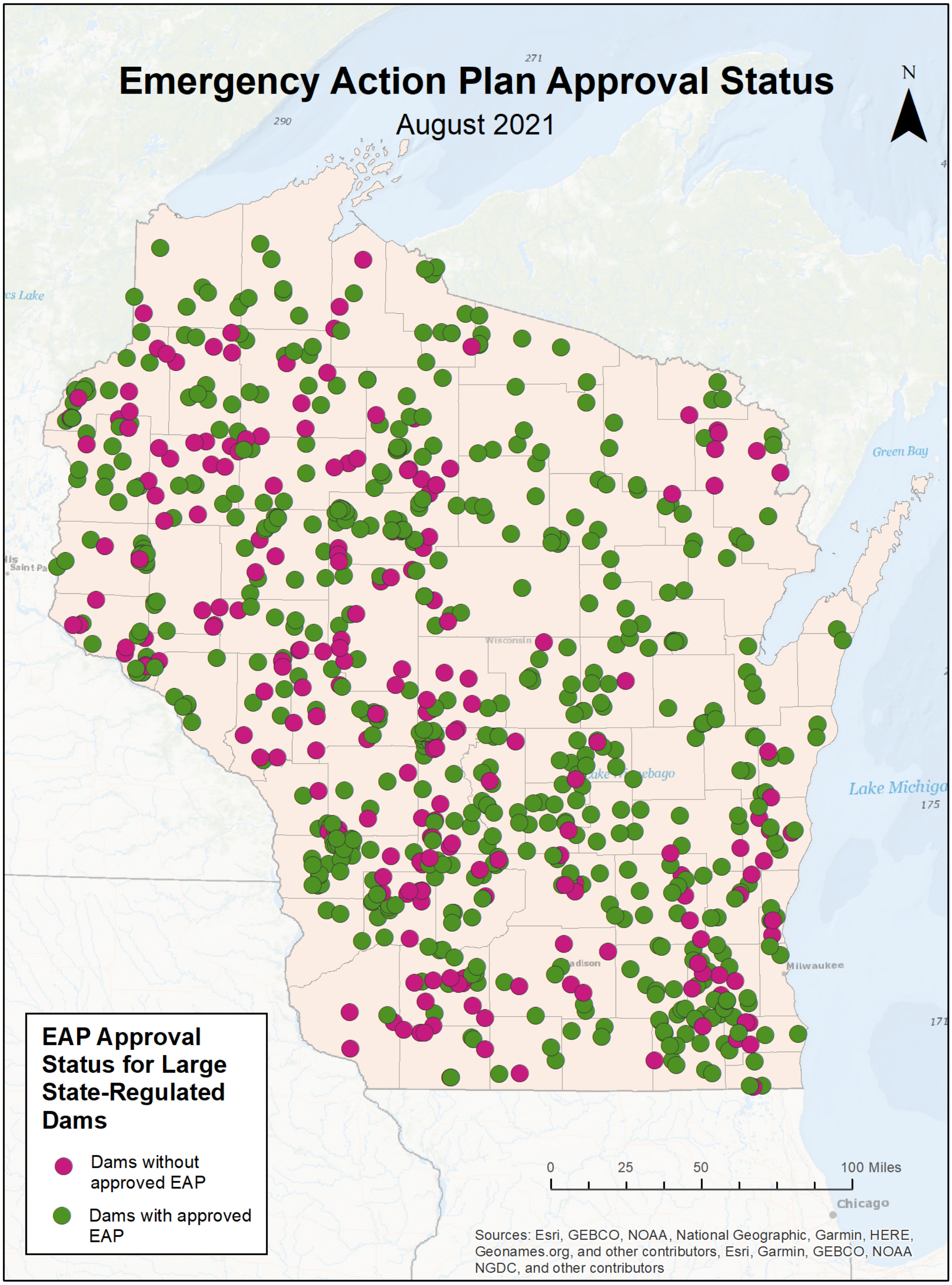
Figure 3.4.3-4 shows the EAP approval status for large, state-regulated dams. An EAP is a formal document unique to each dam which identifies potential emergency conditions and lays out specific procedures to mitigate problems, notify local emergency managers, and protect the affected population. Plans must be tailored to site-specific conditions as well as the requirements of the individual, agency, or organization that operates the dam. Both the EAP and IOM are important documents in the state and dam owner's efforts to eliminate the loss of life and reduce the risk of property damage in downstream areas which may result from a dam failure. The state is working towards 100% compliance for all state-regulated, large dams with a focus on high and significant hazards dams over the next several years.

**Figure 3.4.3-3: IOM Plan Approval Status, August 2021**




Source: Wisconsin DNR

**Figure 3.4.3-4: EAP Approval Status, August 2021**




Source: Wisconsin DNR

Dam Grant Programs

Wisconsin's dam owners can apply for funding through the Dam Grant Programs administered by the Wisconsin DNR.

Through the Municipal Dam Grant Program, municipalities can apply for dam maintenance, repair, reconstruction, or removal funds through the Municipal Dam Grant Program. This competitive cost-share program provides up to $400,000 to cover engineering and construction costs on dams owned by municipalities, counties, tribes, and public lake districts. The cost-share percentages vary from 33% to 100% according to project type and total cost. Privately-owned and federally-regulated dams are not eligible for assistance under this program.

A second grant program, the Removal Grant, provides any dam owner up to $50,000 to remove dams they no longer wish to maintain. Any entity with legal access can also apply for funding to remove dams that have been abandoned by their owner. The removal grants reimburse 100% of eligible costs up to the $50,000 grant maximum. Funding for eligible projects is awarded on a first-come, first-served basis.

In most State of Wisconsin biennial budgets since 2008, the DNR has received $4 million total for the Dam Grant programs; of this allocation, approximately $3.5 million was distributed to Municipal Dam Grant recipients, with the remaining $.5 million going toward the Dam Removal Grant program. In 2021, Wisconsin's biennial budget allocated $10 million total for the Dam Grant programs. While other state and federal programs have funded past dam projects, they were all limited-time programs and are no longer available to state dam owners.

*High Hazard Potential Dam (HHPD) Rehabilitation Grant Program*

In December of 2016, the president signed the "Water Infrastructure Improvements for the Nation Act" and a new grant program was added to FEMA's National Dam Safety Program: the High Hazard Potential Dams (HHPD) Rehabilitation Grant. The program mitigates loss of human life and significant property damage from failure or misoperation of dams with High Hazard Potential classification. Through the HHPD Rehabilitation Grant program, dam owners can apply for funding toward the repair, removal, or structural or nonstructural rehabilitation of eligible high hazard potential dams. In FFY19 and FFY20, FEMA awarded $10 million for the program nationally. The federal government appropriated $12 million to FEMA for the program for FFY21. A map of dams in Wisconsin with a high hazard rating is shown in Figure 3.4.3-1.

As of August 2021, the Wisconsin DNR is developing procedures for administration of the HHPD Rehabilitation Grant Program. The DNR is finalizing a standardized spreadsheet and query to prioritize which dams may warrant an application submittal in the future. This is being accomplished by developing an overall risk prioritization process, adding "operational status" and "operational status date" to the Wisconsin Dams Database, and analyzing other tools and criteria, including the data requested in the Notice of Funding Opportunity for high hazard potential dams.

The criteria for prioritization of high hazard potential dams will be similar to the criteria used in the DNR's Municipal Dam Grant Program Grant Application. These criteria include the following categories:

I. Hazard Potential
II. Purpose of the Project
III. Proactive Safety Measures
IV. Financial Considerations
V. Public Interest
VI. Inspections and Orders
VII. Ability to Proceed
VIII. Other Consideration

The Wisconsin DNR considers whether a dam poses a high or significant hazard, size of dam, land use controls downstream of the dam, Emergency Action Plan and Inspection, Operation, and Maintenance Plan measures among other factors in their priority ranking criteria for Municipal Dam Grant applications.

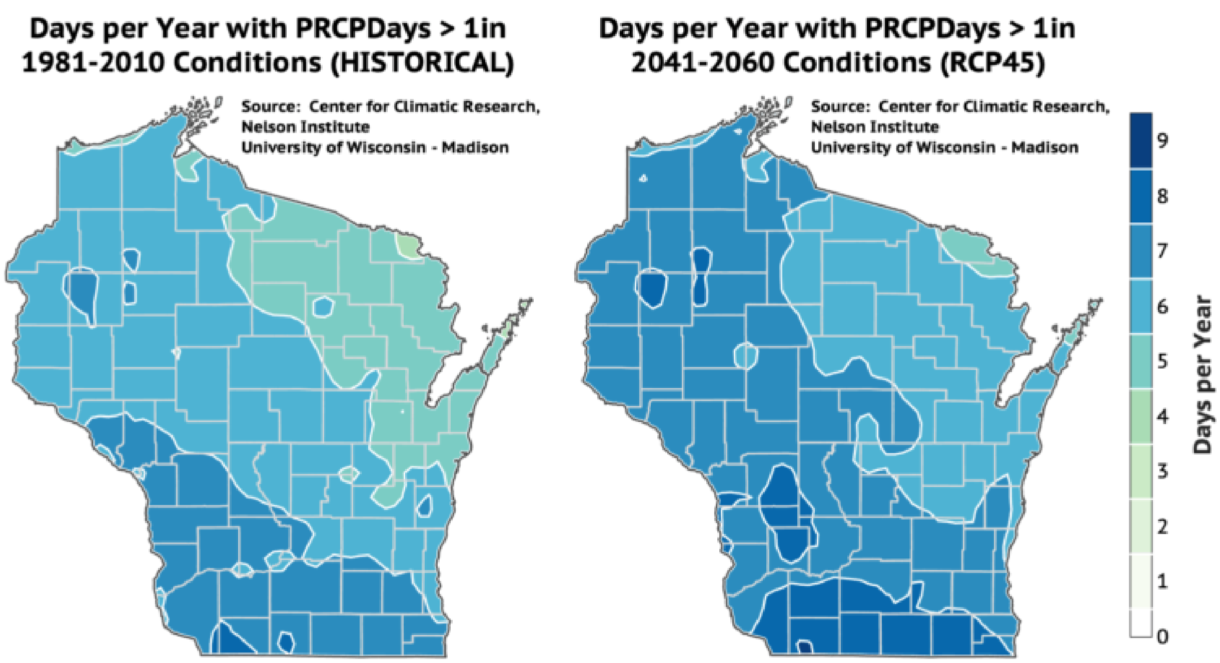
To address high hazard potential dams at the local level, local hazard mitigation plans address each county or tribe's risk of dam failure. 26 out of 83 counties and tribes listed dam failure in their top 5 hazards in their most recent hazard mitigation plans. Plan discussions of dam failure vary by county and tribe but plans typically include an identification of dams in the area, dam size and hazard potential. County and tribal areas that contain high hazard potential dams work with the DNR to create emergency action plans and to evaluate dams that may be eligible for the HHPD Rehabilitation Grant Program

### 3.4.4 Climate Change Impacts

The impacts of climate change on dams are indirect but may lead to an increase in dam failures and stress on dams. While dams require constant maintenance and repairs at average water pressures and reservoir volumes due to natural decay, many dams were not built to withstand the increasingly heavy rainfall events brought by climate change in Wisconsin.

Increased flood magnitudes test reservoirs and spillways at higher capacities and increase water pressure on dams leading to overtopping of dams and failures. State regulations for large dams are designed to anticipate major flood events. High, significant, and low hazard dams are required to have the capacity to handle a 1,000-year flood event, a 500-year flood event, and a 100-year flood event, respectively. However, annual precipitation and heavy rainfall events will continue to increase and Wisconsin's dams may require more mitigation measures to adapt to climate change. Figure 3.4.4-1 from the Wisconsin Initiative on Climate Change Impacts (WICCI) shows the projected days per year with more than 1 inch of precipitation in a day for 2041-2060 compared with 1981-2010 conditions. This precipitation modeling illustrates the statewide increase in heavy precipitation events that may cause more dams to fail in the future.

**Figure 3.4.4-1: Days Per Year with More than 1 Inch of Precipitation in a Day**




Source: WICCI

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# 3.5. LANDSLIDES AND LAND SUBSIDENCE

## 3.5.1 Nature of the Hazard

Specific disturbances on hillslopes lead to **landslides**, or the downward and outward movement of slopes. Heavy rains and saturated slopes are two of the most well documented catalyst for slope failure. Other contributing factors include the erosion of steep slopes because of flooding or wave action, snowmelt, earthquakes, volcanic eruptions, or anthropogenically induced changes on the slope, including building structures and land use change. The term landslides can be used to refer to a variety of events, including mudflows, mudslides, debris flows, rock falls, rockslides, debris avalanches, debris slides, and earth flows. Landslides may include any combination of natural rock, soil, or artificial fill, and are classified by the type of movement and the type of material. A combination of two or more landslide movements is referred to as a complex movement.

The types of movement include:

- **Slides** are downward displacements along one or more failure surfaces of soil or rock. The material may be a single intact mass or several pieces. The sliding may be rotational (turning about a point) or translational (movement roughly parallel to the failure surface). The most common type of slide is called a slump. A **slump** is a rotational slide occurring when a portion of a hillside moves downslope under the influence of gravity.
- **Flows** are rapid mass movements of loose soils, rocks, and organic matter that combine with air and water to form a downhill-flowing slurry mixture. Flows are distinguished from slides by high water content and velocities that resemble those of viscous liquids.
- **Lateral spreads** are large movements of rock, fine-grained soils (i.e., quick clays), or granular soils, distributed laterally. Liquefaction may occur spontaneously in loose, granular soils due to earthquake vibrations or changes in pore-water pressure.
- **Falls** and **topples** are masses of rock or other material that detach from a steep slope or cliff and free-fall, roll, or bounce downward. Falls and topples are typically rapid or extremely rapid. Earthquakes commonly trigger rock falls.

Almost any steep or rugged terrain can be susceptible to landslides under the right conditions. The most hazardous areas are steep slopes on ridges, hill, and mountains, incised stream channels, and slopes excavated for building and road construction. Slide potentials are enhanced where slopes are destabilized by construction or river erosion. Road cuts and other altered or excavated areas are particularly susceptible to landslides and debris flows. Rainfall and seismic shaking by earthquakes or blasting can trigger landslides. Trains can also generate ground vibrations equivalent to a 3.0 to 4.9 earthquake, causing ground disturbance and collapse.

Debris flows (also referred to as mudslides) generally occur during intense rainfall on saturated soil. They usually start on steep hillsides as soil slumps or slides that liquefy and accelerate to speeds as great as 35 miles per hour. Multiple debris flows may merge, gain volume, and travel long distances from their source, making areas downslope particularly hazardous. Surface runoff channels along roadways and below culverts are common sites of debris flows and other types of landslides.

In Wisconsin, the hilly terrain adjacent to the Mississippi River is especially prone to landslides. The bluffs of this so-called “driftless” region are formed primarily of sandstone and limestone bedrock covered by an ancient mix of clay and silt. Under most conditions, this provides a solid base for home building, though most counties restrict building to a slope of 20-30%. Homes that are built on “benches” may have much steeper areas above or below them. As water particles fill the space between silt particles, the silt and clay first become “plastic” and then “viscous.” When plastic, the soil will move when pressure (such as the weight of a home) is applied to it. When viscous, it begins to slow under its own weight like a glacier, only much more quickly.

Landslides often occur together with other major natural disasters, thereby exacerbating relief and reconstruction efforts. Floods and landslides are closely related, and both involve precipitation, runoff, and ground saturation that may be the result of severe thunderstorms. Earthquakes, though rare in Wisconsin, may cause landslides ranging from rock falls and topples, to massive slides and flows. Landslides into a reservoir may indirectly compromise dam safety or a landslide may even affect the dam itself. Wildfires may remove vegetation from hillsides, significantly increasing runoff and landslide potential.

Landslides are a widespread geologic hazard, occurring in every U.S. state and territory. The U.S. Geologic Survey (USGS) estimates that landslides cause 25 to 50 deaths and over $1 billion in damages each year in the United States. The costs of landslides are increasing rapidly as lands susceptible to failure are developed for highways, housing, industry, and recreation. Landslides pose serious threats to highways and structures that support fisheries, tourism, timber harvesting, mining, and energy production, as well as general transportation.

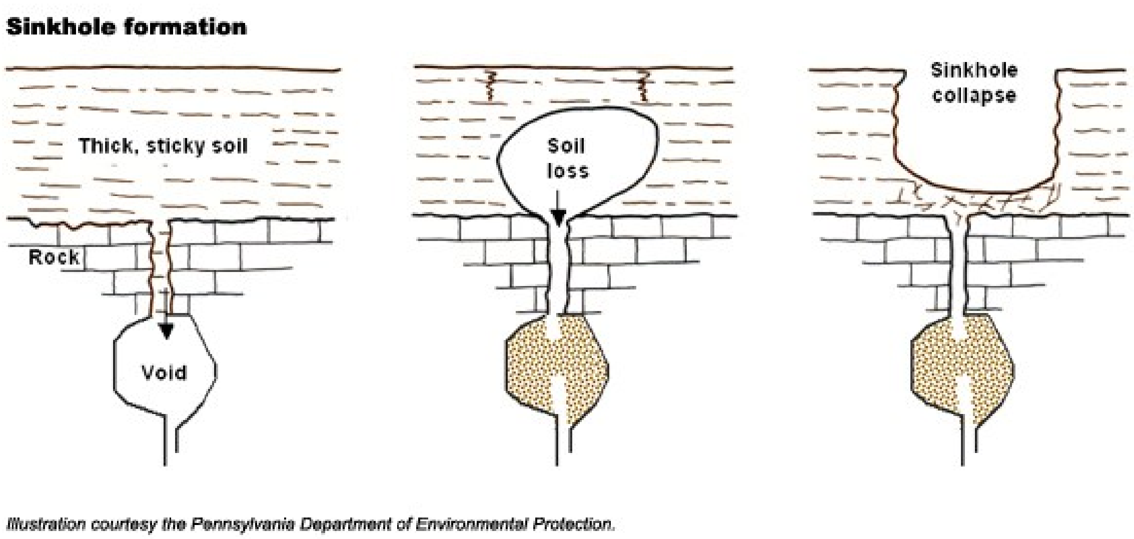
**Land subsidence** is defined as the gradual settling or sudden sinking of the Earth’s surface. Subsidence occurs when subsurface supports (i.e., bedrock or soils) fail, causing a loss of surface elevation. The gradual settling is primarily caused by human activities in relation to mining, drainage of soils, and groundwater depletion. The USGS notes that 80% of land subsidence in the U.S. results from groundwater use. Subsidence can also be caused by natural geologic conditions, including **sinkholes**. Sinkholes are depressions in the landscape that with no external surface drainage (Figure 3.5.1-1). In 1997, FEMA estimated that annual land subsidence and sinkholes account for an average of $125 million in damages. More recent estimates suggest around $300 million in annual damage, with most of this coming from Florida.

**Figure 3.5.1-1: A sinkhole outside of Eagle, Wisconsin**

Source: Wisconsin Geological and Natural History Survey (WGNHS)

Sinkholes causing land subsidence are caused from geologic properties of bedrock, called karst formations. **Karst formations** are prevalent in areas where carbonate bedrock, such as limestone or dolomite, is present. As the limestone or dolomite rock under the soil dissolves over time from rainfall or flowing groundwater, a hollow area may form underground into which surface soil can sink (Figure 3.5.1-2.).

**Figure 3.5.1-2: Sinkhole formation**




Source: WGNHS

Karst features also provide direct conduits to groundwater. Areas with karst conditions can be subject to groundwater contaminants from pollutants entering a sinkhole, fissure, or other karst features. Karst features should be identified and considered in a community, especially for land use planning, stormwater management, and hazardous materials planning, to avoid possible damage to structures or contamination of groundwater.

In certain parts of the Wisconsin, sinkholes are more likely to be caused by human activity. Some parts of southern and western Wisconsin have experienced sinkholes from collapsed, abandoned underground mines. Unfortunately, sinkholes are not well mapped in the state of Wisconsin and their vulnerability is not well known. In urban flooding and storm events, the Milwaukee area has had sinkholes occur in the middle of busy streets above storm sewers.

### 3.5.2 History

Landslides

Landslides will occur anywhere unstable slopes succumb to gravity. The most common location for landslides exists in southwest Wisconsin. The steep slopes and bluffs in the southwestern part of the state are particularly prone to mudslides, debris flows, and slumps. Landslides in Wisconsin generally occur because of high magnitude precipitation events that result in major floods. The trend of increased, and high magnitude precipitation in Wisconsin, will likely lead to enhanced slope failures. Below are a couple examples of historical slope failures having occurred between 2000 and 2016 in Wisconsin:

- In 2000, during Presidential Disaster Declaration DR-1332-WI, a home in Grant County was damaged when its foundation partially collapsed as the hillside slumped from heavy rainfall.

- In 2001, a home in the city of Superior (Douglas County) was endangered as the entire yard started slipping downhill toward the Nemadji River. Although the house was 100 yards from the river and not in the floodplain, stream bank erosion from spring flooding had caused the ground within 15 feet of the house to slide downhill. The city of Superior applied for and received funding through the Hazard Mitigation Grant Program (HMGP) under Disaster Declaration 1369 to purchase and demolished the threatened structure from the landowner.

- In 2007, the area along the Upper Mississippi River was hard hit by severe storms from August 18-19. Over two days, 11-15" of rainfall deluged the "coulee country" from Winona, MN to Genoa and Viroqua (Vernon County). Bridges were awash as creeks that were 20 feet wide under normal conditions expanded to widths of 100 feet, or in some cases, flooded entire valleys. Waterfalls gushing over the rocky bluff faces turned normally stable soils into gelatinous flows down 600-foot-high bluffs. Mudslides, a few carrying homes with them, covered major and minor roads. Highway 35 from Goose Island to Stoddard (Vernon County) was covered in mud and debris. Two homes slid onto Highway 35 south of La Crosse (La Crosse County). A third home near Chaseburg (Vernon County) was destroyed by a mudslide. One yard in the Goose Island area (La Crosse County) had 25 dump trucks of mud removed.

- In 2013, Southwestern Wisconsin was inundated with torrential rains during the week of June 21-27. The city of Boscobel (Grant County) received over 13 inches of rain that week, with 24-hour extremes reaching 7.79 inches. Flash flooding, damage to private and public property, power outages, and extensive road closures ensued. Many of the road closures were due to mudslides and washouts; in many areas, the mud was so thick that cleanup crews used snowplows to clear roadways. In addition to mudslides and washouts on county and local roads, Wisconsin Highway 35 was closed from Lynxville to Prairie du Chien due to mudslides and debris. A massive, 200-foot-long landslide buried Highway

61 with 25 feet of mud, rock, and debris in Crawford County near Boscobel. Luckily, no one was injured during the slide.

- In 2016, late September heavy rains and flooding overnight led to landslides in southwestern Wisconsin, where upwards of 7 inches of rain were received. A man was killed in Vernon County when his home was destroyed when part of a bluff slid downslope after days of precipitation.

Evidence of landslide occurrence between 2017 and 2021 is represented below. While only five examples are presented, it would have been possible to document others. These were selected because they are typical of the most significant landslides occurring throughout the year.

- In 2017, during the period of July 19-23 severe storms, straight-line winds, flooding, and landslides led to Presidential Disaster Declaration DR-4343 for 11 counties in west and southwest Wisconsin counties. Heavy rainfall over the four-day period triggered mudslides and closed roads.

- In 2018, during the period of August 17 to September 14 severe storms, tornadoes, straight-line winds, flooding, and landslides led to Presidential Declaration DR-4402 for 17 counties in Wisconsin. Landslides and erosion caused a hiatus in the operation of the Great Northern Railway in the Wisconsin Dells. Parts of the track were destroyed, and the full operation was stalled (Figure 3.5.2-1).

- In 2019, a severe thunderstorm brought 2-5 inches of precipitation on September 12 to the counties of Buffalo, Crawford, and Grant. The school districts of Boscobel and Wauzeka-Stuben were closed for a day because of landslides and flooding. The Crawford County Sheriff’s Office reported that numerous roads were impacted by landslides. In Grant County, material from landslides forced the closure of Highway 61 between Marietta Valley Road and Highway 133. In Iowa county, a mudflow occurred near the intersection of Highways 130 and 133.

- In 2020, a 4–8-inch precipitation event occurred over West-Central Wisconsin on August 27-28. A mudslide near Oakdale overtook a home and cause complete destruction of the residence (Figure 3.5.2-2). A section of a bluff failed which sent trees and mud into the structure. No one was home at the time of the incident.

- In 2021, approximately 12 inches of rain fell in Crawford County in late June. These rains led to two landsides bringing trees, mud, and rocks onto local roads. Early estimates of cleanup were $300,000.

**Figure 3.5.2-1: Heavy Rainfall Responsible for Landslides and Erosion that Shutdown the Great Northern Railway in 2018**

Source: Wisconsin news online

**Figure 3.5.2-2: Residential Home Destroyed by a Mudflow South of Oakdale, WI.**

Source: National Weather Service (NWS)

<u>Land Subsidence</u>

According to the USGS, subsidence is a global problem with 80% attributed to exploration of underground water and land development. Both rural and urban areas are known to subside. Sinkholes are one type of land subsidence that generally occurs over carbonate bedrock and provides a specific hazard to the state of Wisconsin. Below are several subsidence concerns facing Wisconsin.

- Parts of Milwaukee are beginning to show signs of subsidence. Much of Milwaukee was built on a marsh and 100-200 feet of glacial drift and fill. Early buildings were anchored into the water-laden sediment by wood pilings. Early engineers recognized that if the pilings remained wet, they would remain stable. Recently, however, it has been hypothesized that lower groundwater levels have exposed the pilings to oxygen, and they have begun to rot. It appears that a few of the downtown buildings are settling.

- Sinkholes commonly develop on carbonate bedrock and can create “holes” and depressions on the landscape. It is estimated that a few thousand small sinkholes exist in Wisconsin and 20-30 of the larger variety. One reason for the lack of large sinkholes is because the carbonate bedrock tends to be harder than that elsewhere. The largest and most pressing concerns about sinkholes is that they provide a conduit for pollution to enter the groundwater to adversely affect its quality.

## 3.5.3 Probability, Vulnerability, and Mitigation Potential

**Table 3.5.3-1: Hazard Ranking for Landslides**

| Evaluation Criteria | Description | Ranking |
|---|---|---|
| **Probability** | • Between 1% to <10% probability of occurrence each year. | Occasional |
| **Vulnerability** | • Minimal countermeasures are in place to prevent or protect against this hazard.<br>• Countermeasures may have potential but limited demonstrated history in reducing the threat potential.<br>• The nature of the hazard may limit the availability of countermeasures. | High |
| **Mitigation Potential** | • Mitigation methods are established.<br>• The State or counties have limited experience with the kinds of measures that may be appropriate to mitigate the hazard.<br>• Some mitigation measures are eligible for federal grants.<br>• There is a limited range of effective mitigation measures for the hazard.<br>• Mitigation measures are cost-effective only in limited circumstances.<br>• Mitigation measures are effective for a reasonably long period of time. | Medium |

**Table 3.5.3-2: Hazard Ranking for Land Subsidence**

| Evaluation Criteria | Description | Ranking |
|---|---|---|
| **Probability** | • <1% probability of occurrence each year. | Unlikely |
| **Vulnerability** | • Minimal countermeasures are in place to prevent or protect against this hazard.<br>• Countermeasures may have potential but limited demonstrated history in reducing the threat potential.<br>• The nature of the hazard may limit the availability of countermeasures. | High |
| **Mitigation Potential** | • Methods for reducing risk from the hazard are not well-established, are not proven reliable, or are experimental.<br>• The State or counties have little or no experience in implementing mitigation measures, and/or no technical knowledge of them.<br>• Mitigation measures are ineligible under federal grant programs.<br>• There is a very limited range of mitigation measures for the hazard, usually only one feasible alternative.<br>• The mitigation measures have not been proven cost-effective and are likely to be expensive compared to the magnitude of the damages caused by the hazard.<br>• The long-term effectiveness of the measure is not known or is known to be relatively poor. | Low |

Probability

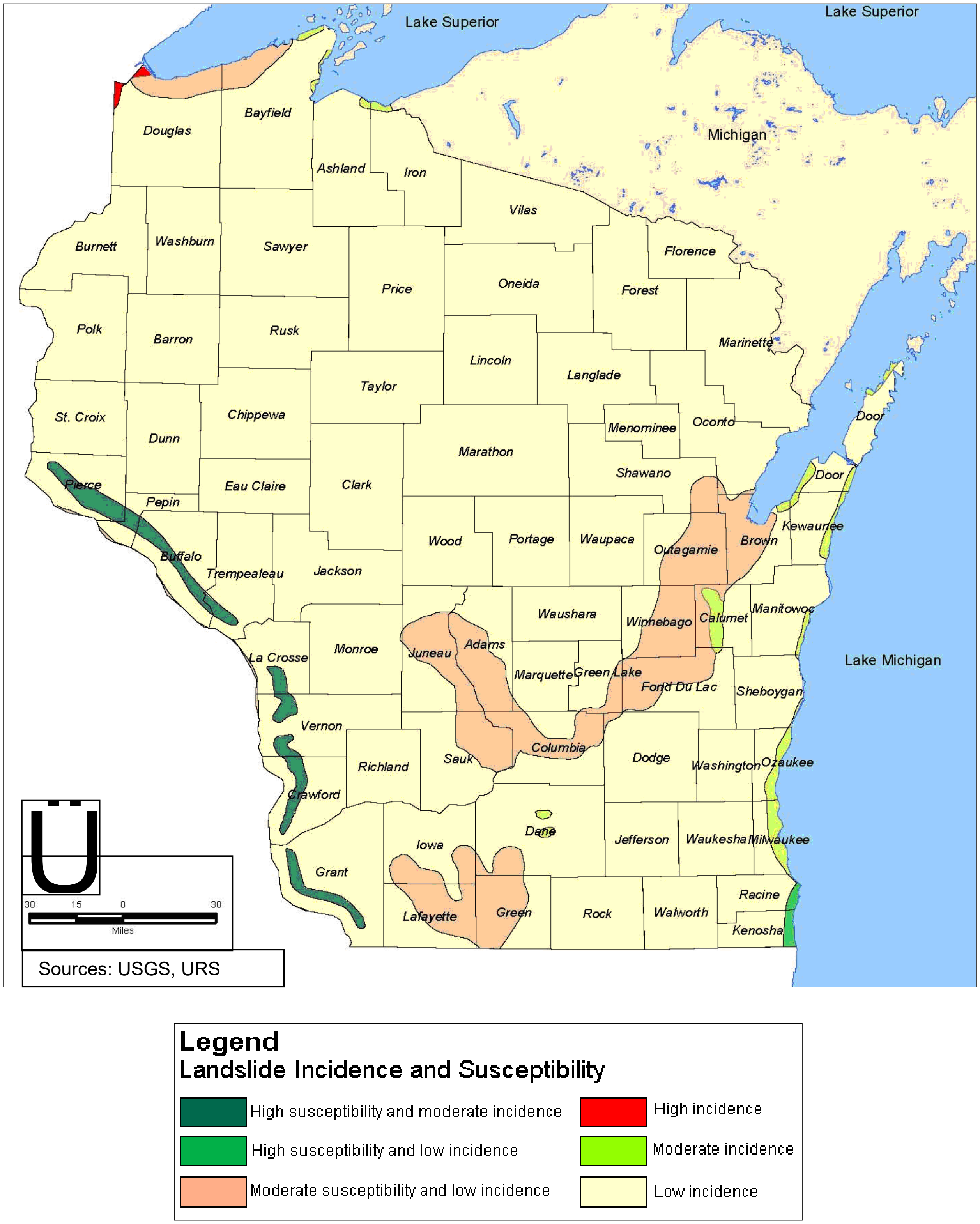
*Landslides*

Landslide probability is highly site-specific, and cannot be accurately characterized on a statewide basis, except in the most general sense. Thus, it is predicted that landslide probability is likely. Statewide analyses for potential have been performed by the USGS and the WGNHS.

Areas of landslide incidence and susceptibility in the state are shown in Figure 3.5.3-1. The area with the highest incidence is limited to Douglas County along the St. Louis River, near the City of Superior. Another area to highlight is the shoreline along Lake Michigan. Racine and Kenosha Counties are highly susceptible, due to coastal erosion, but experience low incidence. The rest of the Lake Michigan coastal counties (Door, Kewaunee, Manitowoc, Milwaukee, Ozaukee, and Sheboygan) experience moderate incidence of landslides.

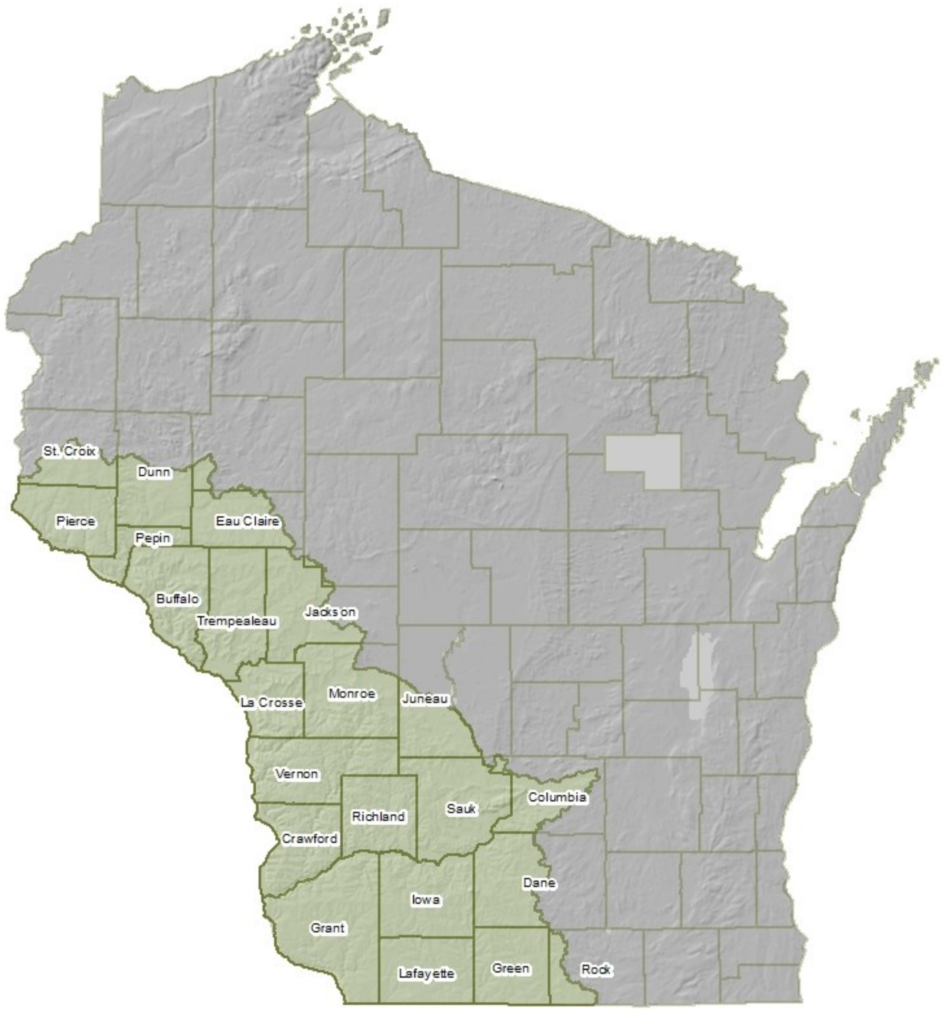
Areas with high susceptibility and moderate incidence of landslides exist in the Driftless Area (Figure 3.5.3-2). Counties that are considered high susceptibility and moderate incidence include Grant, Crawford, Vernon, La Crosse, Trempealeau, Buffalo, Pepin, and Pierce. In addition, there are 17 counties across the state that have moderate susceptibility and low incidence (Figure 3.5.3-3).

**Figure 3.5.3-1: Landslide Incidence and Susceptibility in Wisconsin**




Source: USGS, URS

**Figure 3.5.3-2: Driftless Region in Wisconsin**




Source: WEM

*Land Subsidence*

As previously defined, land subsidence is a gradual settling or sudden sinking of the earth's surface. Subsidence can occur over large areas, like coastal communities and large agricultural valleys, or it can be confined to small locations where the ground suddenly drops. The former is difficult to explain in terms of frequency in Wisconsin, whereas the latter is often associated with sinkholes. Land subsidence is not a widespread problem in Wisconsin. That is, its probability is unlikely. However, as already documented, Milwaukee faces subsidence in sections of its downtown.

The annual frequency of sinkholes is unknown, as only the large sinkholes are documented. Those that develop are relatively small (usually less than 10 feet across), as the dolomite in Wisconsin is not conducive to producing large sinkholes. Sinkholes that develop generally form in the spring as the snow is melting, but large-scale precipitation events can also lead to their formation. The most susceptible regions to sinkhole formation are shown in Figure 3.5.3-3. Though sinkholes have formed underneath the streets of Milwaukee, much of the state's carbonate bedrock lies under less urbanized areas. Because sinkhole formation occurs gradually below the surface, it is difficult to predict or detect sinkhole incidents before they happen.

Vulnerability and Mitigation Potential

*Landslides*

Landslides, particularly in the southwestern part of the state, have impacted many of Wisconsin's structures and infrastructure. The most common impact of landslides is damage to or closure of roadways. In a few instances, landslides have led to the sudden and sometimes deadly destruction of homes constructed on steep slopes. Often, slumps or slides will occur in stages, allowing property owners some time to act before their home is destroyed. Landslides in Wisconsin tend to be relatively small in extent and magnitude compared to the massive events that occur nationwide in the Appalachian Mountains, Rocky Mountains, Pacific Coastal Range, Alaska, and Hawaii.

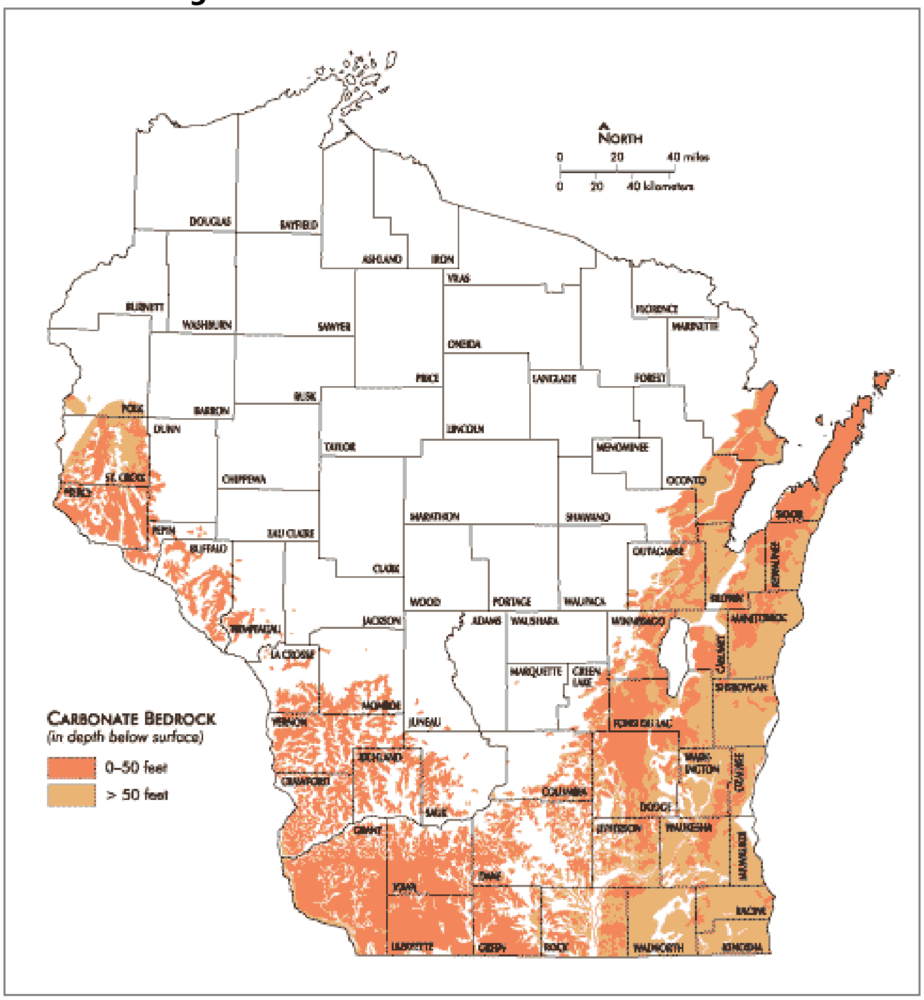
Few mitigation actions can guarantee stability in areas prone to slides, as these phenomena are caused by features such as bedrock and soil substrate that are difficult if not impossible to change. Acquisition is often the best option for the most at-risk properties; in areas where the risk is less severe, slope stabilization projects may be effective. Owners of properties with steep slopes may wish to install low-growing ground cover plantings and utilize flexible underground pipe fittings to prevent leaks that could lead to instability. In several areas where railroad tracks run between a river and bluffs, fences have been erected with sensors to detect rock falls that could otherwise damage or derail trains.

*Land Subsidence*

Land subsidence impacts include infrastructural, environmental, social, and economic. A few mitigation activities for both the gradual and sudden settling of earth's surface incudes: (1) improve the mapping of regions thought to be susceptible; (2) prohibit development in at-risk areas; (3) design buildings to prevent subsidence; and (4) monitoring underground mines.

Sinkholes and associated karst topography have numerous water quality impacts. Landscape depressions caused by sinkholes and the void space in rock allows for increased infiltration of surface water. High levels of pollutants have been identified in karst regions and thus mitigation is necessary to project water quality. Wellhead protection actions should be taken in karst areas to prevent groundwater contamination, especially in the parts of the state where the bedrock is less than 50 feet from the ground surface. Small sinkholes (less than 20 feet across) can be filled with different sizes of rock and cement if necessary. The WGNHS recommends fencing off large sinkholes and permanently preventing construction nearby; a small earthen berm can be constructed around the sinkhole to prevent unfiltered surface runoff from entering the groundwater supply through the sinkhole.

**Figure 3.5.3-3: Karst Potential in Wisconsin**




Source: WGNHS

### 3.5.4 Climate Change Impacts

Effects of Climate Change

Changes in mean annual precipitation and extreme magnitude events are likely to have a positive effect on landslide frequency. The gradual sinking of the landscape surface does not appear to be a large-scale climate change issue facing Wisconsin. Because precipitation is a key variable in the formation of sinkholes, the possibility exists that increased precipitation will lead to the development of more sinkholes in Wisconsin's most susceptible regions.

Landslides

The changing nature and structure of precipitation events in Wisconsin will likely lead to increased landslides in Wisconsin's most susceptible region, the Driftless Area (Figure 3.5.3-2). Counties within the Driftless Area include Lafayette, Iowa, Grant, Crawford, Richland, Vernon, Monroe, La Crosse, Trempealeau, Buffalo, Pepin, Eau Claire, Jackson, Pierce. Sauk, Iowa, and Dane.

Counties in the Driftless Area have witnessed multiple extreme precipitation events over the last decade resulting in high magnitude flooding and landslides. These extreme precipitation events (top 1 percent days) are unlikely to increase in magnitude and scope over the next 50 years. In part, predicting changes in extreme events is limited because of a small sample size. However, climate models suggest that 1–5-inch rainfall events will increase across the state, which will likely increase the frequency of slope failures. Crozier outlined direct changes and potential slope stability to precipitation, and a few are outlined below.

- An increase in annual and extreme precipitation will:
    - Increase the soil moisture content and thus require less rainfall for saturated conditions that could lead to slope instability.
    - Increase the weight of the soil, which decreases the shear strength/stress ratio.
    - Increase stream discharge will lead to increased bank erosion and the potential for undercutting of slopes.
    - Infiltration is likely to exceed subsurface drainage rates, which promotes a reduction in shear strength.

While increased annual and extreme precipitation are very likely to increase landslides, it is important to note that local landscape characteristics influence the susceptibility of slope failure. The depth to bedrock, bedrock type, steepness of slope, soil properties, water table elevation, vegetation, and manmade structures will influence the likelihood of landslides. The ability to accurately predict under what conditions and where landslides will occur is difficult. The scientific consensus, however, is that extreme precipitation events will increase the likelihood of slope failures in regions of high slopes, erodible soils, and weathered bedrock. The area of southwest Wisconsin is prone to increased slope failures, including mudflows and rock falls in the future.

Land Subsidence

Areas facing the largest threat of subsidence because of climate change exist in large urban settings and agricultural areas in dry climates. Subsidence largely exists in dry agricultural regions because water is being withdrawn from aquifers at a rate that exceeds recharge. In Wisconsin, subsidence from groundwater withdrawal has not been attributed to climate change.

Karst topography and their associated features of sinkholes and caves are a product of complex processes that include rock type, local relief, drainage, and climate. Because of the complex process of karst formation, the implications for climate change are not straightforward. In Wisconsin, limestone and dolomite exists in a V-shape wedge that includes the northeast, southeast, south, southwest, and west portions of the state. Much of the karst in Wisconsin exist in the lower soluble dolomite rock formations and thus presents less of a risk than other locations around the world where soluble limestone is easily weathered. However, as mean annual and extreme precipitation events in Wisconsin increase a greater chance of sinkholes could arise.

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# 3.6 COASTAL HAZARDS

## 3.6.1 Nature of the Hazard

According to the Environmental Protection Agency (EPA), the Great Lakes represent 21% of the world's fresh water supply and 84% of the U.S. supply. The natural resources and aesthetics offered by the Great Lakes have attracted shoreland development throughout Wisconsin's history. Based on 2017 data from the National Oceanic and Atmospheric Administration (NOAA), the total economy for the Great Lakes region generated $3.1 trillion in gross domestic product and employed 25.8 million people; this translates to 17.8% of U.S. employment.

The Great Lakes Coastal Resilience Planning Guide (GLCR) defines **consumptive use** of the lakes as "any quantity of water that is withdrawn from the Great Lakes system and not returned." Examples of consumptive use are drinking water for humans and livestock, irrigation, and industrial uses. More than 30 million people in the U.S. and Canada rely on the Great Lakes for drinking water. Comparatively, **non-consumptive use** is "any water withdrawal or in-stream use in which the entire quantity is returned to the system." This includes transportation, hydroelectric power generation, and water-based recreation.

The 15 counties that make up Wisconsin's Great Lake coast represent 19% of the state's land area and hold 36.8% of its population. Figure 3.6.1-1 outlines these counties. Coastal Wisconsin employs over 996,000 people annually, earning a total of over $48 billion in wages. The people and structures occupying the shores of Lakes Michigan and Superior face several natural hazards unique to these areas, including erosion of bluffs, banks, beaches, and near-shore lake beds. Flooding due to stormwater runoff, high lake levels, storm surges, and damage to shoreline structures from wave action are also applicable hazards.

**Figure 3.6.1-1: Great Lakes Coastal Erosion Areas in Wisconsin**


Source: Wisconsin Emergency Management (WEM)

Coastal Erosion

**Coastal erosion** is defined as the wearing a way of land or a lakebed. Erosion leads to the loss or displacement of material along coastlines, beaches, or dunes over a period, and can be influenced by both natural coastal processes and human activities.

**Natural processes:**

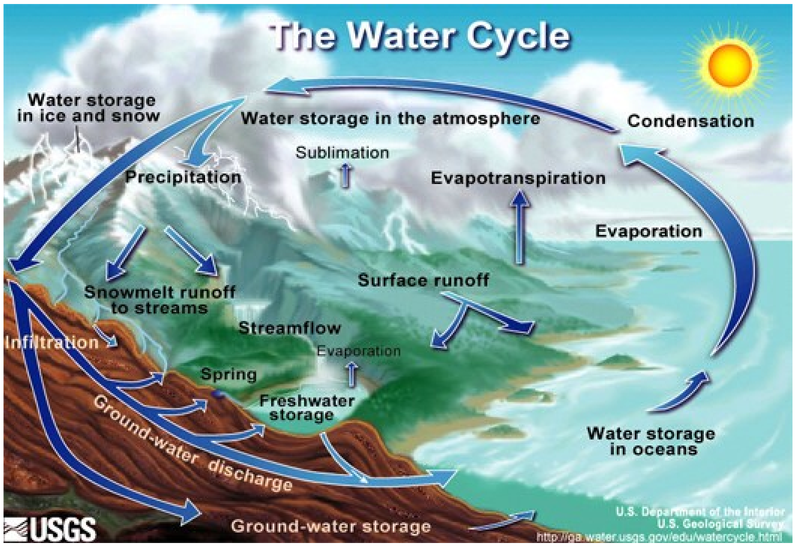
- Lake level changes
- Currents and tides
- Waves and storm surges
- Wind
- Flooding
- Orientation of shoreline
- Sediment influx
- Littoral processes
- Ice floes
- Overwash
- Freeze/thaw cycle

**Human activities:**

- Dredging
- Jetty and groin construction
- Seawalls and shoreline hardening
- Revetments
- Beach nourishment
- Boat wakes
- Construction of harbors
- Construction of sediment-trapping dams in river tributaries

The rate at which coastal erosion occurs is dependent on a complex web of factors. Cyclical changes in lake levels, disruption of beach-building material transport, and storms all influence the rate of erosion. Annual variability in wave climate and lake levels causes the rates of bluff and dune erosion along the shores of the Great Lakes to vary from near zero to tens of feet per year. Erosion rates can increase because of elevated groundwater levels, increased loads on bluff tops, loss of vegetation on slopes, or overland runoff. Lake ice running up onto the shore due to thawing or wave action can also exacerbate coastal erosion by damaging shore structures, removing vegetation, transporting sand, rock, and other debris, and eroding the base of steep banks, rendering them unstable and subject to landslides. Figure 3.6.1-2 outlines the hydrologic cycle, which is one of the main ways water is continually recycled and returned to the ecosystem. In the Great Lakes, evaporation from the lake surface is a major factor in this cycle.

**Figure 3.6.1-2: The Hydrologic Cycle**

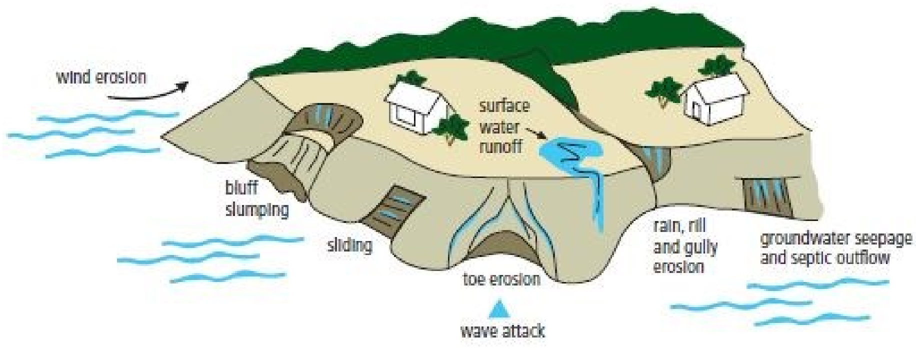



Source: U.S. Geological Survey (USGS)

Human activities that affect beach-building sediments also contribute to shoreline erosion. Navigational improvements, shoreline structures, and certain dredge material disposal practices deplete both tributary and shoreland sources of sediment. Removing these sediments from the shore system contributes to erosion.

Coastal erosion tends to be a gradual process. However, sudden slumps or bluff failures prompting emergency action do occur. These events, often precipitated by strong storms with high winds and/or heavy wave action, are rare. Figure 3.6.1-3 shows some of the causes and effects of coastal erosion on a slope.

**Figure 3.6.1-3: Causes and Effects of Coastal Erosion**




Source: Living on the Coast

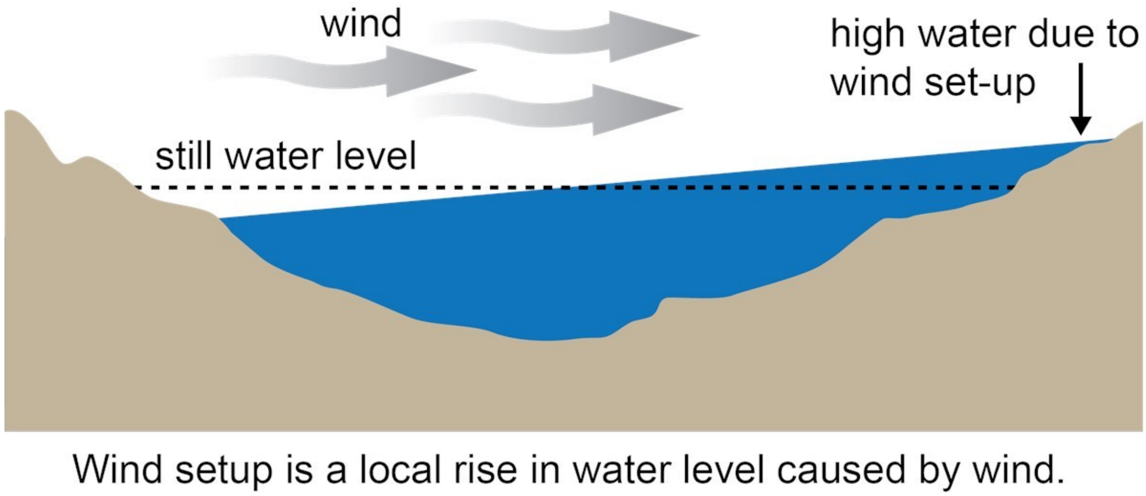
With nearly 80% of Wisconsin's shoreline affected by coastal erosion and bluff recession, recurring erosion presents a significant risk in almost every coastal county. Erosion rates tend to be highest along sand plains and high bluffs comprised of glacial till. On Lake Michigan, vulnerability to erosion is highest along the 185-mile stretch from the Illinois border to the Sturgeon Bay Canal in Door County, and in the bays and clay banks along the Door Peninsula. Erosion of the Lake Superior shoreline tends to be more localized. The highest risk of erosion exists along the high clay bluffs extending from Bark Point (Bayfield County) to Wisconsin Point (Douglas County), and from Iron County to the White River in Ashland County.

Coastal flooding

**Coastal flooding** occurs when excess water from precipitation, snowmelt, or storm surges overflows onto the shore. Storm surges cause a temporary rise in water level due to storm winds blowing across open water. The duration of the surge depends on how long the storm lasts; some surges can persist for an entire day. A **seiche** is an oscillation of the water in a lake that continues after the originating force has dissipated. In the Great Lakes, this phenomenon is typically caused by strong winds and changes in atmospheric pressure that push the water from one side of the lake to the other. After atmospheric conditions return to normal, the water rebounds to the other side and continues to oscillate back and forth until it loses momentum. Seiches produce effects like those of a storm surge but occur periodically and usually for a shorter duration. See Figure 3.6.1-4 for how wind-driven seiches form in the Great Lakes.

Wisconsin's low-lying areas along the Lake Michigan shoreline are particularly susceptible to coastal flooding, as observed in southern Kenosha County and along the western shore of Green Bay. Communities positioned on low terraces, such as those in Milwaukee, Ozaukee, and Brown Counties, are at a medium risk of flooding. High bluff areas are the least flood prone.

**Figure 3.6.1-4: How Wind-Driven Seiches Occur**




Source: NOAA

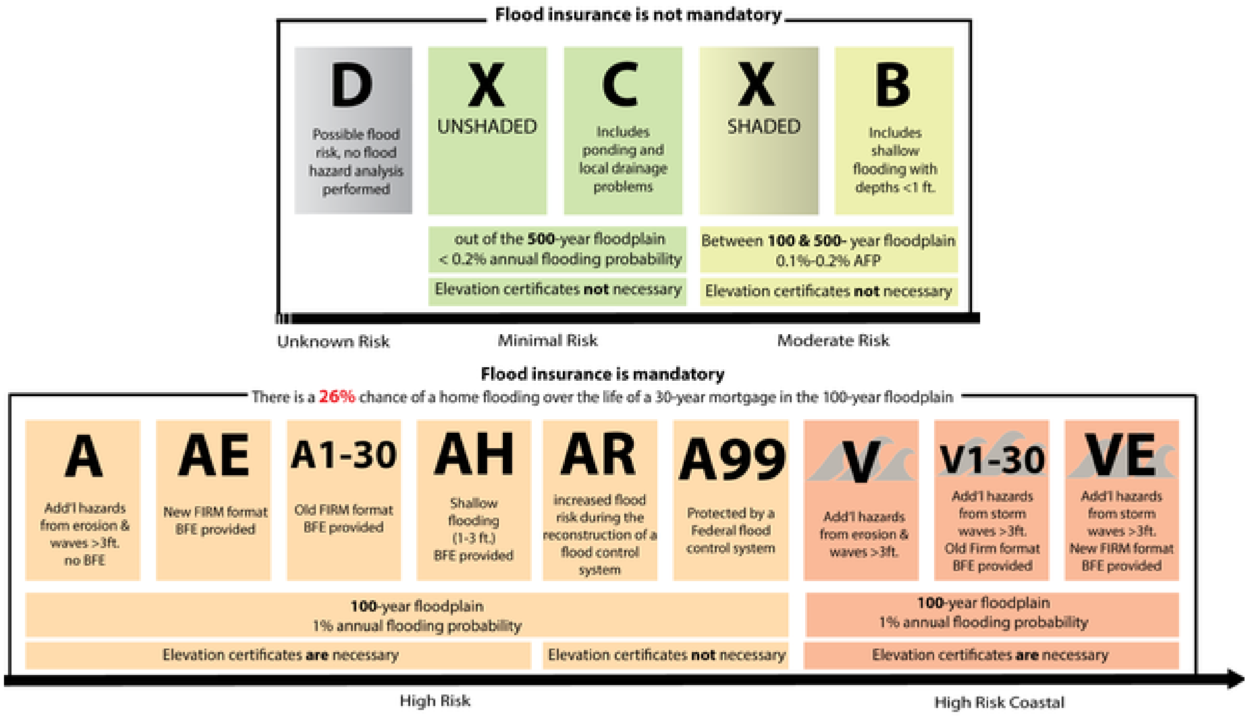
Wisconsin's low-lying areas along the Lake Michigan shoreline are particularly susceptible to coastal flooding, as observed in southern Kenosha County and along the western shore of Green Bay. Communities positioned on low terraces, such as those in Milwaukee, Ozaukee, and Brown Counties, are at a medium risk of flooding. High bluff areas are the least flood prone. Although the risk of coastal flooding is reduced when lake levels are low, lake levels are only one factor contributing to coastal flooding. Other factors include **wind set-up**, or the tendency for water levels to increase on downwind lakeshores, and decrease on upwind lakeshores, and **wave run-up**, the maximum vertical extent of the rush of water from a breaking wave onto a beach. Wave run-up is caused by wind but is also dependent on the shore profile. Waves form more readily where there is a shallow beach profile. Strong winds can cause or exacerbate coastal flooding in these areas.

*Coastal regulations*

Development in Great Lakes coastal areas is impacted by local, state, and federal regulations. Recent and impending changes at the state and federal levels will influence development patterns moving forward. The U.S. Army Corps of Engineers (USACE) has primary federal permitting authority for shoreline management projects under the Clean Water Act (CWA) and the Rivers and Harbors Act of 1899 (RHA).

FEMA also produces flood maps, known officially as **Flood Insurance Rate Maps (FIRMs)**, that show areas of high- and moderate- to low-flood risk. Communities use these maps to set minimum building requirements for coastal areas and floodplains; lenders use them to determine flood insurance requirements. FIRMs are free and available to the public through the FEMA Flood MapService Center. Figure 3.6.1-5 shows the classification of each zone, starting with Zone D (unknown risk) to Zone VE (high risk coastal). Please note, these are not official FEMA definitions.

**Figure 3.6.1-5: FIRM Zones**




Source: Wetlands Watch

FEMA is working on updated Flood Insurance Maps for coastal counties, including those in Wisconsin. Flood insurance is required for V and VE Zone structures, and floodplain management standards must be enacted in these areas. FEMA also requires V Zone structures to be elevated on pilings. According to the Wisconsin Department of Natural Resource's (DNR) Model Floodplain Ordinance from October 2021, "new construction and substantial improvement of buildings shall be elevated, consistent with SPS 321.34, on pilings or columns so that the bottom of the lowest horizontal structural member of the lowest floor (excluding the pilings or columns) is elevated to or above the Flood Protection Elevation (FPE)."

At the state level, Wisconsin Coastal Management Program (WCMP), under the Department of Administration (DOA) works with state, local, and tribal government agencies to manage the ecological, economic, and aesthetic assets of the Great Lakes coastal areas. WCMP publishes the Needs Assessment and Strategy every five years to identify where problems and opportunities exist in each of the nine "enhancement areas." **Enhancement areas** include wetlands, coastal hazards, public access, marine debris, cumulative and secondary impacts, special area management plans, ocean and Great Lakes resources, energy and government facility siting, and aquaculture.

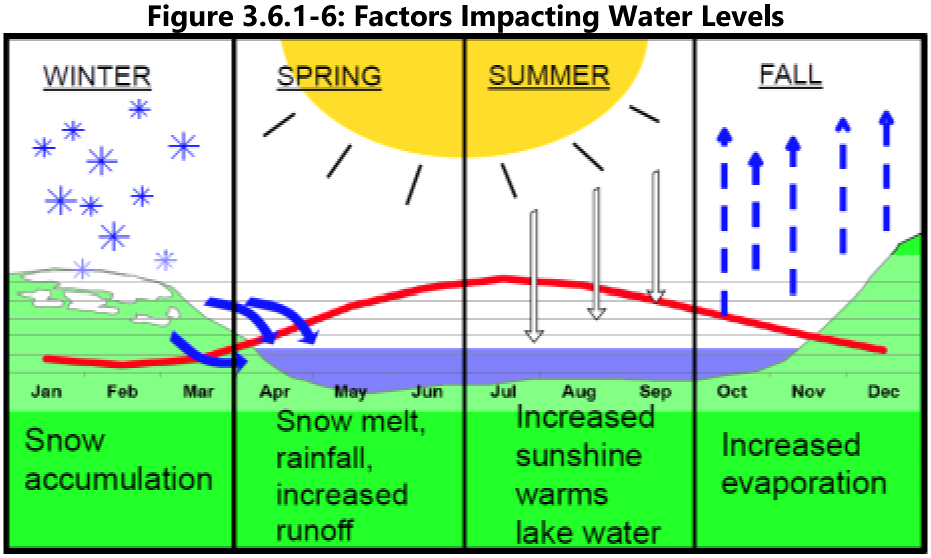
Lastly, for local regulations, both coastal communities and communities with inland lakes are working to adapt to changes in the statewide shoreland zoning standards (Chapter NR 115 of the Wisconsin Administrative Code). Act 55 passed in the summer of 2015 prohibits county and local zoning ordinances from establishing shoreland setbacks greater than the state minimum standard of 75 feet. Many local governments had previously enacted stricter setbacks to protect water resources from overdevelopment and pollution. While the long-term repercussions of Act 55 are still unfolding, counties have been able to find other ways to prevent development that is too close to the edge of the bluffs. Wisconsin Department of Natural Resources (DNR) and DOA staff are currently working with communities to amend their ordinances as required while still providing protection for shoreland structures and natural resources.

Lake Level Fluctuations

High water levels and increased wave action exacerbate both coastal erosion and coastal flooding issues. As lake levels rise, bluff recession rates also increase. Major storm events also lead to erosion because of increased wave action on the shoreline. The effects of wave-induced erosion are usually even greater during periods of high water. Lake level is therefore a significant factor in determining the rate of erosion along Wisconsin's coasts.

Water levels in the Great Lakes fluctuate on both a seasonal and long-term basis. 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 the open water. The highest seasonal levels are during the summer when snowmelt from the spring thaw and summer rains contributes to the water supply. Figure 3.6.1-6 breaks down the seasonal patterns below.

**Figure 3.6.1-6: Factors Impacting Water Levels**

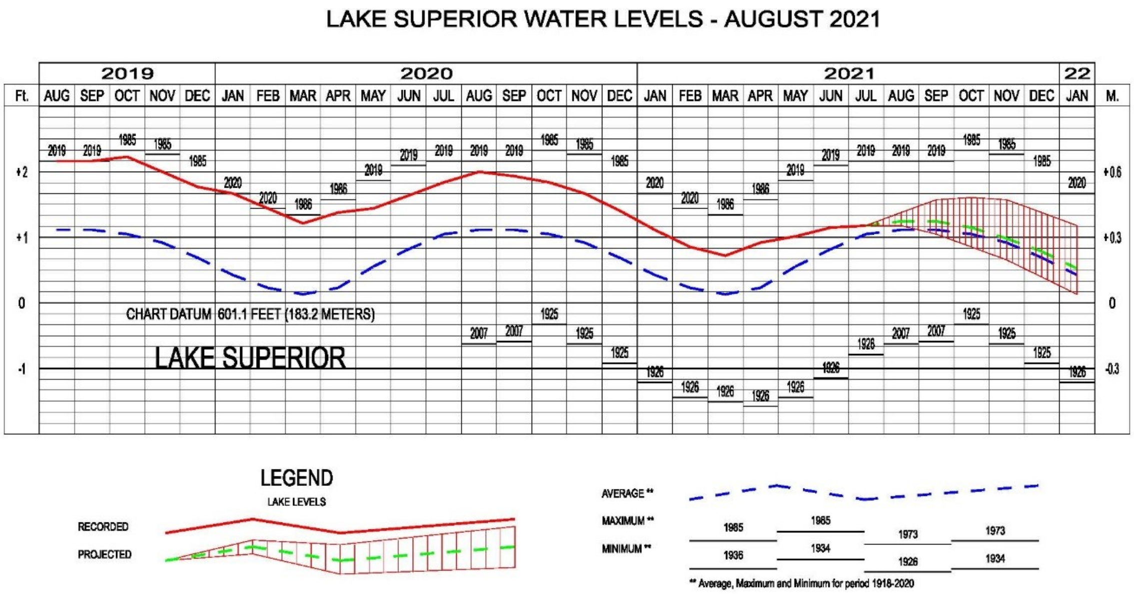



Source: USACE

Though low lake levels increase bluff stability, they pose problems for facilities that are dependent on constant access to water, such as marinas and nearshore water intakes. High lake levels heighten the existing risk in places vulnerable to coastal flooding, erosion, and/or ice jambs, while at the same time improving transport conditions for the shipping industry.

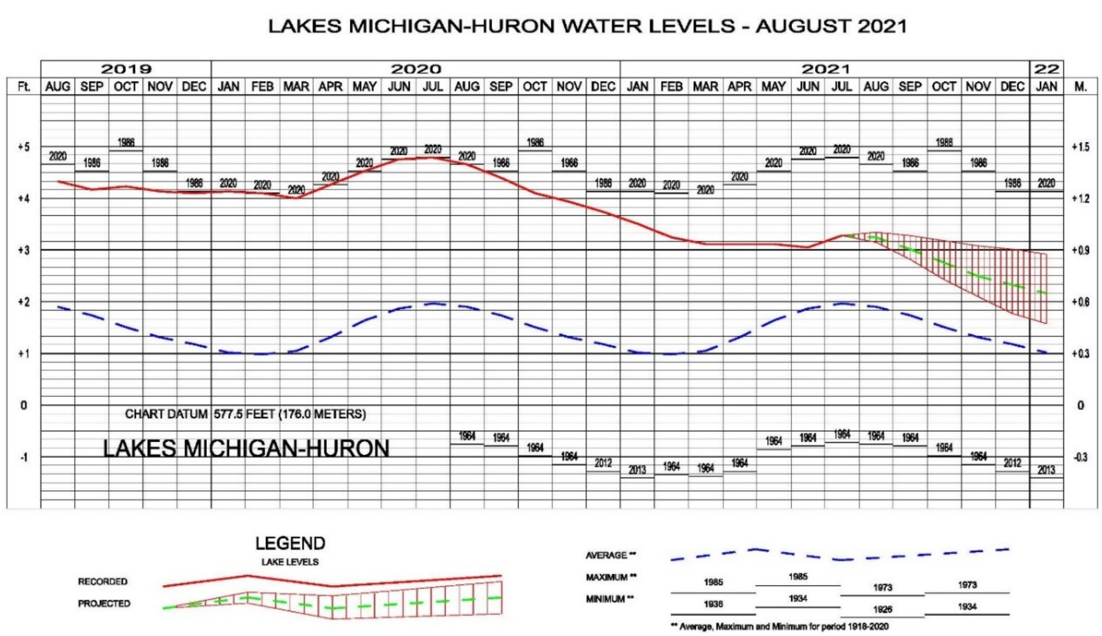
Figures 3.6.1-7 and 3.6.1-8 illustrate recent lake level trends and near-future projections for Lake Superior and Lakes Michigan-Huron. For Lake Superior, March 2021 represented a particularly low point, with water levels turning upwards towards their projected peak in October 2021. For Lake Michigan-Huron, there was a consistently low period, from March 2021 to early June 2021. However, since the middle of June 2021, these levels have increased and are projected to peak in August 2021.

**Figure 3.6.1-7: Lake Superior Water Levels: Two-Year Records and Six-Month Forecasts**




Source: USACE

**Figure 3.6.1-8: Lakes Michigan-Huron Water Levels: Two-Year Records and Six-Month Forecasts**




Source: USACE

### 3.6.2 History

All 15 coastal counties in Wisconsin experience bluff erosion, coastal flooding and storm surges, fluctuating water levels, and damage to shoreline structures along Lake Superior and Lake Michigan. Several important coastal events are highlighted below.

Bluff Erosion

2007

In 2007, Concordia University in the City of Mequon (Ozaukee County) completed implementation of a $12 million project to de-water the bluff, regrade its slope, and install shoreline revetments. The university, situated on a 130-foot-high bluff overlooking Lake Michigan, had previously experienced 20 years of erosion at a rate of one foot per year. Although the project was initially celebrated for the protection, aesthetics, and connection to the lake, downstream neighboring communities experienced erosion because of it. According to GLCR, to avoid these challenges in the future, Ozaukee County developed a zoning ordinance which prohibits development within unsafe distances from the edge of the bluff. This example demonstrates the complex nature of coastal erosion processes, emphasizes the need for an "easily replicable science-based methodology for determining safe coastal setback requirements in the Great Lakes basin," and underscores the critical need for cooperative efforts.

2019

In the fall of 2019, lakefront erosion in the village of Somers in Kenosha County reached a threatening level. One home (Figure 3.6.2-1) had dealt with bluff erosion along Lake Michigan for one and a half years. According to Kenosha News, an excessive amount of rain and near-record water levels caused a portion of the basement to slide off the bluff. Demolition of the entire property occurred the following Friday and cost approximately $50,000. This event was not isolated to a single home, however. Other parts of Somers experienced lakefront erosion during the multi-year high lake levels (Figure 3.6.2-2).

**Figure 3.6.2-1: Lakefront Erosion at Somers Home**

Source: Kenosha News

**Figure 3.6.2-2: Lakefront Erosion in Somers Village**

Source: View from Above – Wisconsin

<u>Coastal Flooding and Storm Surges</u>

<u>1973</u>

A notable coastal flooding event occurred on April 9, 1973. During a period of high lake levels, a "Nor-easter" storm blew through Green Bay, producing a storm surge that inundated the City of Green Bay's downtown area with four feet of water. In addition to flood damages, erosion occurred on the open coast. This so-called 500-year flood event generated millions of dollars in damages.

<u>1990</u>

In comparison to the 1973 event, storm surges can also cause severe flooding during periods of low lake levels. The largest recorded water level on Lake Michigan was observed at the southern tip of Green Bay during a storm in December 1990, when lake levels were only a couple feet above the all-time low. The second highest level recorded at the gage occurred during similar conditions in December 2009.

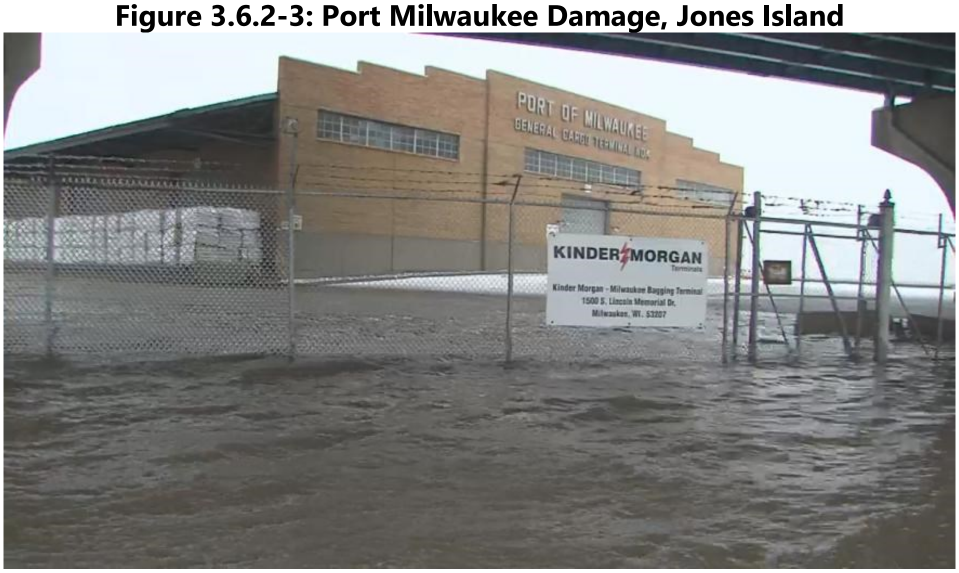
<u>2018</u>

A late season blizzard in northeast and northcentral Wisconsin took place from April 13-15, 2018. The NWS notes that winds of 35 to 50 mph created waves of 10 to 16 feet on Lake Michigan and eroded the shoreline along the western part of the lake. In Manitowoc, the S.S. Badger ferry experienced serious erosion under the docks and car ramp leading up the boat. Badger received $800K in grant money to fix the damage from this blizzard. However, just the year before, Badger had received $5 million in grant money to fix the old docks on both sides of the ferry’s route. This shows how quickly storm surges can damage coasts and the magnitude of their impacts on newly built structures.

<u>2020</u>

On January 10, 2021, a winter storm created significant damage along the Lake Michigan shoreline. The impacted counties included Kenosha, Milwaukee, and Racine. High winds, towering waves, and flooding caused millions of dollars of damage to the parks, structures, and ports along the lakeshore. Port Milwaukee (Figures 3.6.2-3 & 3.6.2-4) experienced some of the worst damage with estimated costs of $10.7 million. As a result of the storm, Governor Tony Evers declared a major disaster for the State of Wisconsin on February 10, 2020.

**Figure 3.6.2-3: Port Milwaukee Damage, Jones Island**




Source: CBS 58

**Figure 3.6.2-4: Port Milwaukee Damage, McKinely Marina**

Source: Milwaukee Journal Sentinel

<u>Lake Level Fluctuations</u>

Table 3.6.2-1 shows summary statistics of the water levels in Lake Superior and Lake Michigan-Huron. Both lakes have experienced higher than average water levels and some record highs in 2019 and 2020. Prior to these two years, lake levels remained below the long-term annual average for over a decade. According to the Great Lakes Integrated Sciences and Assessments (GLISA), this recent rise is primarily driven by several years of above average precipitation and high ice cover. Conversely, the record lows throughout the years are driven by warmer air and water temperatures, which results in more evaporation.

**Table 3.6.2-1: Summary of Lake Superior and Lake Michigan-Huron Water Levels (in feet), 1918-2020**

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **LAKE SUPERIOR** | | | | | | | | | | | | | |
| *2020* | *602.72* | *602.49* | *602.26* | *602.43* | *602.49* | *602.69* | *602.89* | *603.05* | *602.99* | *602.89* | *602.72* | *602.46* | *602.69* |
| **Mean** | **601.48** | **601.28** | **601.18** | **601.28** | **601.61** | **601.87** | **602.10** | **602.17** | **602.17** | **602.10** | **601.97** | **601.74** | **601.74** |
| Max | 602.72 | 602.49 | 602.40 | 602.62 | 602.92 | 603.15 | 603.22 | 603.22 | 603.22 | 603.38 | 603.31 | 603.05 | |
| | 2020 | 2020 | 1986 | 1986 | 2019 | 2019 | 2019 | 2019 | 2019 | 1985 | 1985 | 1985 | |
| Min | 599.84 | 599.61 | 599.54 | 599.48 | 599.61 | 599.90 | 600.26 | 600.43 | 600.46 | 600.72 | 600.43 | 600.13 | |
| | 1926 | 1926 | 1926 | 1926 | 1926 | 1926 | 1926 | 2007 | 2007 | 1925 | 1925 | 1925 | |
| **LAKES MICHIGAN-HURON** | | | | | | | | | | | | | |
| *2020* | *581.56* | *581.53* | *581.43* | *581.69* | *581.96* | *582.19* | *582.22* | *582.09* | *581.82* | *581.53* | *581.36* | *581.17* | *581.73* |
| **Mean** | **578.44** | **578.41** | **578.48** | **578.74** | **579.07** | **579.30** | **579.40** | **579.33** | **579.17** | **578.94** | **578.74** | **578.61** | **578.87** |
| Max | 581.56 | 581.53 | 581.43 | 581.69 | 581.96 | 582.19 | 582.22 | 582.09 | 581.96 | 582.35 | 581.96 | 581.56 | |
| | 2020 | 2020 | 2020 | 2020 | 2020 | 2020 | 2020 | 2020 | 1986 | 1986 | 1986 | 1986 | |
| Min | 576.02 | 576.08 | 576.05 | 576.15 | 576.57 | 576.64 | 576.71 | 576.67 | 576.64 | 576.44 | 576.28 | 576.15 | |
| | 2013 | 1964 | 1964 | 1964 | 1964 | 1964 | 1964 | 1964 | 1964 | 1964 | 1964 | 2012 | |

Source: USACE

### 3.6.3 Probability, Vulnerability, and Mitigation Potential

**Table 3.6.3-1: Hazard Ranking**

| Evaluation Criteria | Description | Ranking |
|---|---|---|
| **Probability** | • 10% to 85% probability of occurrence each year. | Likely |
| **Vulnerability** | • Multiple measures are in place to prevent or protect against this hazard.<br>• Countermeasures have been tested and have demonstrated success in reducing the threat potential | Medium |
| **Mitigation Potential** | • Methods for reducing risk from the hazard are technically reliable.<br>• The State or counties have experience in implementing mitigation measures.<br>• Mitigation measures are eligible under federal grant programs.<br>• There are multiple possible mitigation measures for the hazard.<br>• The mitigation measures are known to be cost-effective.<br>• The mitigation measures protect lives and property for a long period of time or are permanent risk reduction solutions | High |

Wisconsin's coastal counties range from very sparsely populated (e.g., Iron County) to highly urban (e.g., Milwaukee County). The following section divides The Great Lakes coast in Wisconsin into three sections based on population density characteristics. The population, population estimates, and percent changes are from 2010 Census data and vintage year estimates in 2019 (V2019):

- **Southeastern Coastal Counties**
  This area includes the four southern-most coastal counties: Kenosha, Racine, Milwaukee, and Ozaukee. Much of the southeast Wisconsin coast is part of the urban corridor that stretches between Milwaukee and Chicago. The southern counties include the coastal cities of Milwaukee, Cudahy, Oak Creek, and St. Francis in Milwaukee County. Mequon and Port Washington in Ozaukee County, and Kenosha (Kenosha County), and Racine (Racine County).

  The southeastern coastal counties experienced an overall population gain of 4.3%, with Milwaukee being the only county to experience a small population decrease of 0.2%. Kenosha and Racine experienced population growths of 0.7% and 0.5% respectively. Ozaukee had the most growth with a 3.3% population increase. The two largest cities in Ozaukee County – Mequon and Port Washington – both experienced ~5.5% increase in their populations. This is concerning since Ozaukee County's Coastal Resilience Self-Assessment indicates a high probability of several coastal hazard issues along the lakeshore where both cities are located.

- **Northern Lake Michigan Coastal Counties**

This area contains seven counties: Brown, Door, Kewaunee, Manitowoc, Marinette, Oconto, and Sheboygan. The northern Lake Michigan coastal Counties have a moderate population density of 118 people per square mile. This section includes the coastal cities of Algoma (Kewaunee County), Green Bay (Brown County), Kewaunee (Kewaunee County), Manitowoc (Manitowoc County), Marinette (Marinette County), Oconto (Oconto County), Sheboygan (Sheboygan County), Sturgeon Bay (Door County), and Two Rivers (Manitowoc County). Much of the shoreline borders Green Bay. Door County possesses the most extensive Great Lakes shoreline in Wisconsin at 240 miles.

Northern Lake Michigan coastal counties experienced a collective population decrease of 0.2%. Door, Kewaunee, Manitowoc, Marinette, and Sheboygan Counties lost 0.4%, 0.7%, 3.0%, 3.4%, and 0.1% respectively. Brown and Oconto saw increases of 6.7% and 0.7%.

In Brown County, Green Bay only experienced a 0.7% increase during the nine-year period. Two villages north of Green Bay – Howard and Suamico – experienced population gains of 15.8% and 15%. Together, these areas accounted for nearly one-fourth of the total county's population increase. According to the Bay-Lake Regional Planning Commission, the northwestern portion of Brown County (where Howard and Suamico are located) is one of the areas at greatest risk for coastal flooding.

- **Northwestern Coastal Counties**

  This area borders Lake Superior and includes the counties of Ashland, Bayfield, Douglas, and Iron. This section has a low population density of approximately 17.8 people per square mile. Northwestern counties include cities of Ashland (Ashland County), Bayfield (Bayfield County), Superior (Douglas County), and Washburn (Bayfield County).

  The northwestern coastal counties along Lake Superior experienced an overall loss of 9.7% of their population. While populations remain low in the cities and towns of Northwestern Wisconsin, the risk of coastal hazards are high. Population projections for the state predict that Douglas County is the most likely to experience a 7% growth by 2040.

Probability

All of Wisconsin's coastal counties experience coastal hazards. Many of the county-level plans identify a likely probability of coastal erosion, lake level fluctuations, and coastal flooding. However, it should be noted that coastal hazards are a function of rainfall and local conditions, making it difficult to accurately calculate general statewide probabilities.

*Lake Level Fluctuations*

The water levels of Lakes Superior and Michigan fluctuate seasonally each year. There is also a high probability of fluctuation occurring from year to year as lake levels are influenced by other variable factors such as precipitation, temperature, evaporation, and ice cover.

Changes in lake levels influence the rate of coastal erosion and occurrence of coastal flooding. The impacts of changing lake levels range from property damage to economic hardships, especially for the shipping industry. Tables 3.6.3-2 and 3.6.3-3 list the average, minimum, and maximum water levels in Lake Superior and Lake Michigan.

**Table 3.6.3-2: Lake Superior Water Levels**

**Lake Superior**

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2020 | 183.71 | 183.64 | 183.64 | 183.57 | 183.62 | 183.64 | 183.7 | 183.76 | 183.79 | 183.76 | 183.71 | 183.63 |
| Mean | 183.33 | 183.27 | 183.24 | 183.27 | 183.37 | 183.45 | 183.52 | 183.54 | 183.54 | 183.52 | 183.48 | 183.41 |
| Max | 183.71 | 183.64 | 183.61 | 183.68 | 183.77 | 183.84 | 183.86 | 183.86 | 183.86 | 183.91 | 183.89 | 183.81 |
| *Max Year* | *2020* | *2020* | *1986* | *1986* | *2019* | *2019* | *2019* | *2019* | *2019* | *1985* | *1985* | *1985* |
| *Min* | *182.83* | *182.76* | *182.74* | *182.72* | *182.76* | *182.85* | *182.96* | *183.01* | *183.02* | *183.1* | *183.01* | *182.92* |
| *Min Year* | *1926* | *1926* | *1926* | *1926* | *1926* | *1926* | *1926* | *2007* | *2007* | *1925* | *1925* | *1925* |

Source: USACE

**Table 3.6.3-3: Lake Michigan-Huron Water Levels**

**Lake Michigan-Huron**

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2020 | 177.26 | 177.25 | 177.22 | 177.3 | 177.38 | 177.45 | 177.46 | 177.42 | 177.34 | 177.25 | 177.2 | 177.14 |
| Mean | 176.31 | 176.3 | 176.32 | 176.4 | 176.5 | 176.57 | 176.6 | 176.58 | 176.53 | 176.46 | 176.4 | 176.36 |
| Max | 177.26 | 177.25 | 177.22 | 177.3 | 177.38 | 177.45 | 177.46 | 177.42 | 177.38 | 177.5 | 177.38 | 177.26 |
| *Max Year* | 2020 | 2020 | 2020 | 2020 | 2020 | 2020 | 2020 | 2020 | 1986 | 1986 | 1986 | 1986 |
| Min | 175.57 | 175.59 | 175.58 | 175.61 | 175.74 | 175.76 | 175.78 | 175.77 | 175.76 | 175.7 | 175.65 | 175.61 |
| *Min Year* | 2013 | 1964 | 1964 | 1964 | 1964 | 1964 | 1964 | 1964 | 1964 | 1964 | 1964 | 2012 |

Source: USACE

Vulnerability and Mitigation Potential

The WCMP's Needs Assessment and Strategy for 2021-2025 outlines three hazard groups and the associated geographic scope in Table 3.6.3-4. Most coastal county plans identify hazard 1, erosion, as their number one concern. For in-depth information related to a coastal county's risk level, review that county's local hazard mitigation plan. There is a link to each of the most recent plans in Table 3.6.3-9 at the end of this section.

**Table 3.6.3-4: Coastal Hazard Groups**

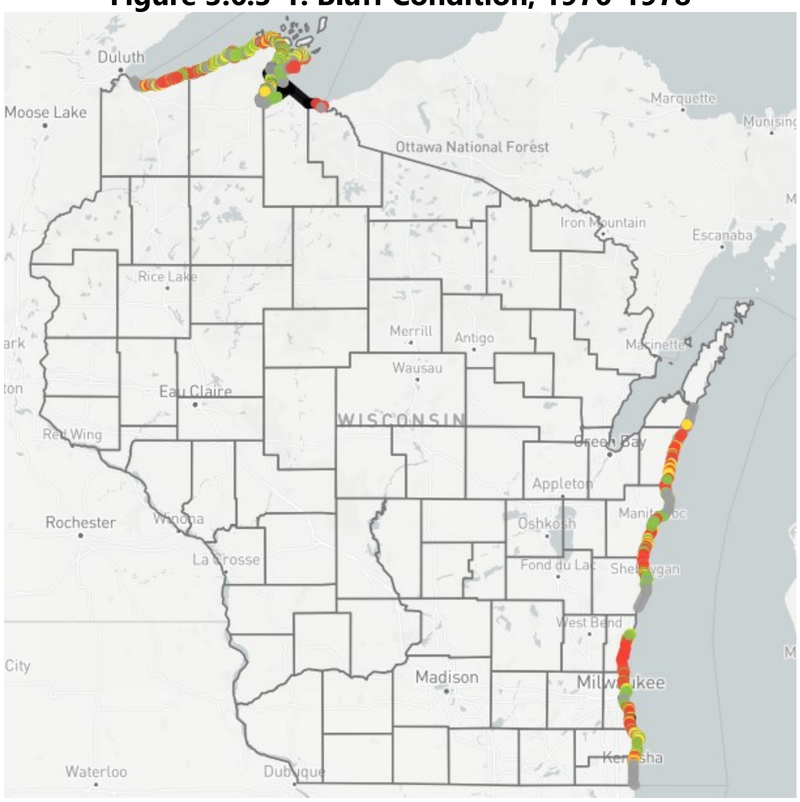
| | Type of Hazard | Geographic Scope (throughout coastal zone or specific areas most threatened) |
|---|---|---|
| Hazard 1 | Erosion (shoreline/toe erosion, bluff erosion, slumping, etc.) | Coast-wide, especially Counties of Kenosha, Racine, Milwaukee, Ozaukee, Sheboygan, Manitowoc, Kewaunee, Door, Brown, Bayfield, Ashland, and Douglas |
| Hazard 2 | Flooding | Coast-wide, especially southern Kenosha County, City of Milwaukee, Bay of Green Bay, City of Superior, Bark Bay, Chequamegon Bay |
| Hazard 3 | Coastal storms | Coast-wide |

Source: WCMP

*Bluff Erosion*

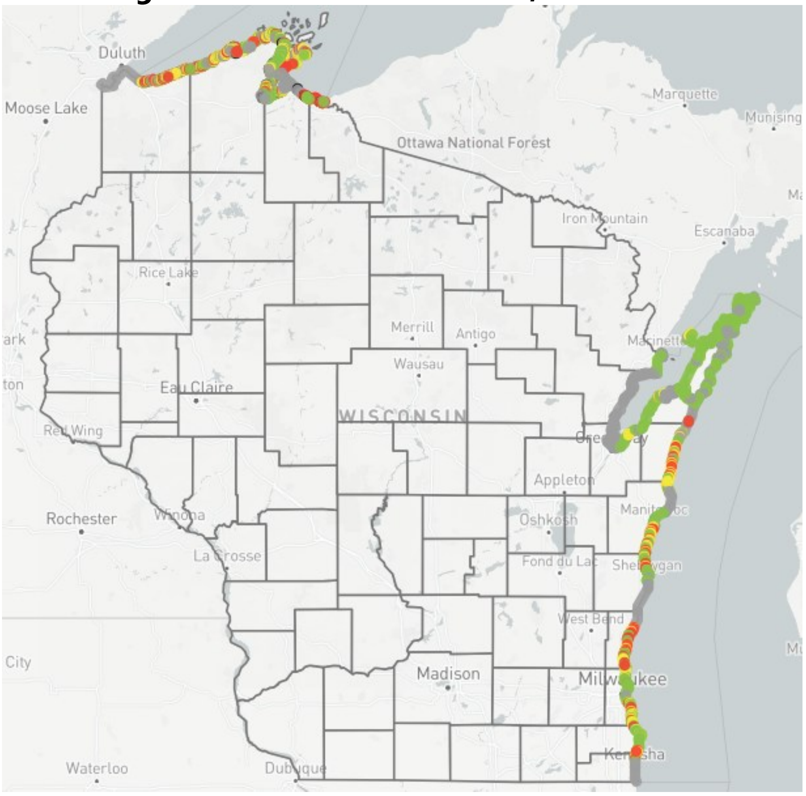
Figures 3.6.3-1-3.6.3-2 show the bluff conditions throughout the state for different time periods from the Wisconsin Shoreline Inventory. The different colors correlate to moderately stable (green), moderately unstable (yellow), and unstable/failing (red) bluffs. Grey indicates there is no bluff and black indicates no value.

**Figure 3.6.3-1: Bluff Condition, 1976-1978**



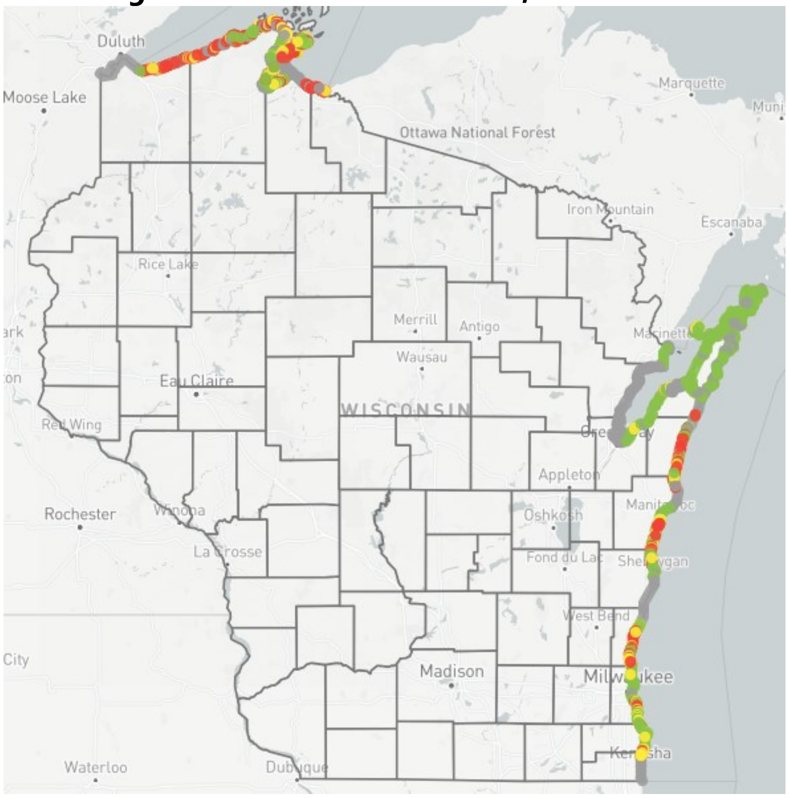

Source: Wisconsin Shoreline Inventory

**Figure 3.6.3-2: Bluff Condition, 2007-2008**




Source: Wisconsin Shoreline Inventory

**Figure 3.6.3-4: Bluff Condition, 2018-2019**



Source: Wisconsin Shoreline Inventory

What's most notable from the bluff progression during each of these timeframes is the concentration of unstable or failing bluffs in some of the most populous counties along the Lake Michigan shoreline. According to 2020 Census data, Manitowoc, Sheboygan, Ozaukee, Milwaukee, Racine, and Kenosha make up near 77% of the coastal community population. By comparing the 2007/2008 conditions to the 2018/2019 conditions, it is clear how many bluffs shifted from moderately unstable to unstable or failing in these regions during those ten years.

A contributing factor to this heightened erosion is the change in lake levels. For instance, Lake Michigan in 2008 was around 576 feet. In 2019, the levels were four feet higher at 580 feet. Similarily, for Lake Superior, levels were at an all-time low in August and September of 2007, and then an all-time high for May-Septmeber, 2019. Periods of low/high lake levels can significantly impact the likelihood of bluff erosion as wave run-up increases when the levels are high and vice versa.

*Coastal Flooding*

According to the Bay Lake Regional Planning Commission's *Guide to Hazard Mitigation Planning for Wisconsin Coastal Communities*, the Wisconsin counties at greatest risk for annual coastal flooding are Kenosha, Marinette, Oconto, Brown, Douglas (City of Superior), Bayfield County (Bark Bay and Chequamegon Bay), and Ashland County (Chequamegon Bay). Careful and strict enforcement of shoreland and floodplain ordinances will be the key to preventing losses in these areas. A medium risk for coastal flooding exists on the low terraces of Racine, Milwaukee, Ozaukee, Sheboygan, Manitowoc, Brown, Door, and Kewaunee Counties. There is a low risk for coastal flooding on high bluffs, which are found in Ozaukee, Sheboygan, Manitowoc, Brown, Door, and Kewaunee Counties.

*Flooding and Storm Surges*

Surges and seiches raise and lower water levels on a short-term basis; some historical surge and seiche events have been strong enough to cause ships to run aground. Vulnerability to flooding caused by surges and seiches is greatest at beaches that are open to the lake or that are located near bay entrances or shores of coastal rivers. The most intense surges happen in shallow bays exposed to long distances of open water; areas that have this topography and contain critical and/or vulnerable facilities and populations are at the greatest risk.

Because coastal erosion is site-specific, the effects of increased development and population growth are more easily measured in terms of risk and vulnerability. Although, the NOAA Office for Coastal Management has identified several broad economic and social impacts of coastal hazards. These include damage to coastal infrastructure, flooded marinas and docks, hazards to navigation, shrinking or alteration of beaches for recreational use, damage, and loss of private property, and solastalgia – distress caused by environmental change.

Mitigation actions that can be taken to prevent the above impacts. Wisconsin Sea Grant created a document in August 2017 that outlines 16 options under five different themes for Lake Michigan property owners to consider when addressing coastal hazards. Each of these themes and practices are outlined below in Table 3.6.3-5

**Table 3.6.3-5: Options and Resources for Lake Michigan Property Owners**

| Theme | Practices |
|---|---|
| Low impact | • Building relocation<br>• Mobile construction<br>• Green infrastructure/low-impact development |
| Bluff Stability | • Bluff top practices for stormwater and wastewater management<br>• Bluff dewatering<br>• Bluff vegetation and green infrastructure<br>• Bluff re-grading and terracing |
| Structural Shore Protection | • Revetment<br>• Seawall<br>• Groin |
| Nature-Based Shore Protection | • Living revetment/seawall<br>• Artificial beaches and beach nourishment |
| Collaboration and Facilitation | • Non-binding collaboration with neighbors<br>• Visioning and facilitated collaboration<br>• Dynamic concept mapping/vcaps<br>• Neighborhood associations |

Sources: Wisconsin Sea Grant, WEM

To read more about each of these practices in detail, see Adapting to a Changing Coast or *Selecting Suitable Vegetation for Enhancing Lake Michigan Coastal Bluff Stability in Southeastern Wisconsin.* No matter what action is selected, it is important to integrate projects at the community or regional level to maximize effectiveness and prevent unintended effects.

Potential Losses

GIS analysis of the Wisconsin Statewide Parcel Database to identify improved parcels in the high and low risk coastal erosion zones provided the basis for estimating potential losses from this hazard. The parcel database includes information such as total parcel value, improvement value, and property class for each digitized parcel in the state. The erosion risk zones were established based on the distance in miles from the coastal area boundary:

- **High Risk Erosion Zone** – the area within 1/4 mile of the coastal area boundary

- **Low Risk Erosion Zone** – the area within 1/2 mile of the coastal area boundary

Records from the GIS parcel layer were narrowed down to include only parcels containing improved structures. A buffer analysis was completed in ArcMap 10.7.1 to identify parcels within one quarter and one-half mile of the Lakes Superior and Michigan coasts. The results of this analysis were then sorted and summarized using Microsoft Excel.

**Table 3.6.3-6: Summary of Improved Structures in Coastal Erosion Zones by County**

| | High Risk Erosion Zone (0.25 from CAB) | | Low Risk Erosion Zone (0.50 miles from CAB) | |
|---|---|---|---|---|
| **County** | **Improved Parcels (n)** | **Value of Improvements (USD)** | **Improved Parcels (n)** | **Value of Improvements (USD)** |
| Ashland | 876 | $131,178,900.00 | 1,824 | $207,950,900.00 |
| Bayfield | 1,653 | $215,557,000.00 | 2,541 | $292,632,400.00 |
| Brown | 1,386 | $347,545,600.00 | 2,053 | $411,351,300.00 |
| Door | 9,603 | $3,577,781,700.00 | 13,504 | $2,679,691,400.00 |
| Douglas | 146 | $33,588,700.00 | 378 | $141,079,700.00 |
| Iron | 386 | $22,351,700.00 | 761 | $45,625,500.00 |
| Kenosha | 2,538 | $459,786,000.00 | 4,759 | $790,828,800.00 |
| Kewaunee | 1,402 | $235,077,900.00 | 2,215 | $241,051,000.00 |
| Manitowoc | 2,304 | $358,040,800.00 | 5,030 | $541,053,200.00 |
| Marinette | 2,263 | $340,421,968.00 | 4,028 | $428,711,550.00 |
| Milwaukee | 6,457 | $4,265,816,534.00 | 17,412 | $7,214,686,207.00 |
| Oconto | 490 | $73,100,100.00 | 569 | $52,231,700.00 |
| Ozaukee | 1,325 | $634,100,260.00 | 2,701 | $704,888,260.00 |
| Racine | 3,810 | $845,953,900.00 | 7,890 | $1,218,913,550.00 |
| Sheboygan | 2,882 | $605,205,700.00 | 5,659 | $740,143,400.00 |
| **Total** | **37,521** | **12,145,506,762** | **71,324** | **$15,710,838,867.00** |

Sources: Wisconsin Land Information Program (WLIP), WEM

With 9,603 improved parcels, Door County has the greatest number of vulnerable properties of all classes in the high-risk area, followed by Milwaukee (6,457) and Racine (3,810). Overall, Milwaukee County has the highest loss potential with over $4.2 billion in improvement value within ¼ mile of the Lake Michigan shoreline, followed by Door ($3.56 billion) and Racine ($845 million) counties.

The county with the greatest number of vulnerable improved parcels (all classes) in the low-risk area is Milwaukee (17,412), followed by Door County (13,504) and Racine County (7,890). Milwaukee County has the highest total loss potential in the low-risk erosion zone at $7.21 billion, followed by Door ($2.68 billion) and Racine ($1.22 billion) counties.

Property type (residential, commercial, or manufacturing) was determined using the Property Class field included in the Statewide Parcel Layer. The statewide database divides properties among eight statutory classifications: Residential, Commercial, Manufacturing, Agricultural, Undeveloped, Agricultural Forest, Productive Forest Land, and Other. In some cases, one parcel falls into multiple classes. For these parcels, the Statewide Parcel Layer lists all the applicable classes in the Property Class field. To avoid double-counting, this analysis only placed parcels with one class into the Residential, Commercial, or Manufacturing categories listed in Tables 3.6.3-7 and 3.6.3-8. The total number of parcels in each county listed in Table 3.6.3-6 includes all classes of parcels, including those with multiple classes.

Table 3.6.3-7 displays the loss estimation by property class for the high-risk erosion zone. Within areas subjected to high-risk erosion, Door County has the largest number of improved residential parcels (8,648), followed by Milwaukee (6,317), Racine (3,560), and Sheboygan (2,776). Counties with the highest number of improved commercial parcels are Door, Ashland, and Bayfield, with 927, 242, and 240 parcels, respectively. The top two counties for manufacturing parcels are Manitowoc, with 18, and Marinette, with 13.

**Table 3.6.3-7: High-Risk Erosion Zone Risk Assessment**

| | Improved Parcels (n) | | | Value of Improvements (USD) | | |
|---|---|---|---|---|---|---|
| **County** | **R** | **C** | **M** | **R** | **C** | **M** |
| Ashland | 610 | 242 | 8 | $56,443,000.00 | $95,937,200.00 | $5,421,300.00 |
| Bayfield | 1,237 | 240 | 4 | $264,757,300.00 | $57,188,200.00 | $873,500.00 |
| Brown | 1,351 | 30 | 3 | $207,576,100.00 | $21,190,600.00 | $1,844,500.00 |
| Door | 8,648 | 927 | 4 | $1,776,294,600.00 | $243,808,400.00 | $7,255,100.00 |
| Douglas | 133 | 11 | 2 | $21,961,100.00 | $3,546,100.00 | $1,300,800.00 |
| Iron | 251 | 82 | 2 | $12,423,100.00 | $10,052,700.00 | $287,000.00 |
| Kenosha | 2,403 | 133 | 2 | $377,573,100.00 | $81,545,800.00 | $667,100.00 |
| Kewaunee | 1,174 | 203 | 8 | $130,221,600.00 | $38,429,700.00 | $3,675,600.00 |
| Manitowoc | 2,101 | 173 | 18 | $199,547,700.00 | $61,147,700.00 | $14,645,000.00 |
| Marinette | 2,181 | 64 | 13 | $189,531,000.00 | $27,502,900.00 | $42,467,700.00 |
| Milwaukee | 6,317 | 138 | 2 | $2,538,426,743.00 | $788,641,000.00 | $2,171,000.00 |
| Oconto | 483 | 5 | 0 | $43,580,900.00 | $561,900.00 | $0.00 |
| Ozaukee | 1,217 | 98 | 4 | $345,972,460.00 | $31,366,300.00 | $1,205,400.00 |
| Racine | 3,560 | 239 | 8 | $530,551,000.00 | $119,447,850.00 | $19,781,000.00 |
| Sheboygan | 2,776 | 94 | 7 | $342,824,700.00 | $54,779,700.00 | $6,839,900.00 |
| **Total** | **34,442** | **2,679** | **85** | **$7,037,684,403.00** | **$1,635,146,050.00** | **$108,434,900.00** |

Sources: WLIP, WEM

Table 3.6.3-8 shows loss potential in low-risk erosion areas by property class. Milwaukee County has the largest number of residential (16,633) and second largest number of commercial properties (764) in the low-risk erosion zone. Door County has the second largest number of both residential properties (11,920) and largest number of commercial parcels (1,306). Manitowoc and Marinette counties have the most manufacturing parcels with 28 and 17 respectively.

**Table 3.6.3-8: Low-Risk Erosion Zone Risk Assessment**

| | Improved Parcels (n) | | | Value of Improvements (USD) | | |
|---|---|---|---|---|---|---|
| **County** | **R** | **C** | **M** | **R** | **C** | **M** |
| Ashland | 1,474 | 318 | 13 | $101,670,100.00 | $95,219,200.00 | $9,645,100.00 |
| Bayfield | 1,942 | 298 | 4 | $214,440,000.00 | $50,064,000.00 | $761,900.00 |
| Brown | 1,946 | 51 | 5 | $330,781,300.00 | $69,536,000.00 | $3,116,700.00 |
| Door | 11,920 | 1,306 | 11 | $2,306,355,300.00 | $317,076,300.00 | $12,048,900.00 |
| Douglas | 298 | 29 | 9 | $52,223,900.00 | $61,159,600.00 | $23,339,500.00 |
| Iron | 539 | 115 | 2 | $24,630,100.00 | $13,829,900.00 | $194,800.00 |
| Kenosha | 4,286 | 454 | 11 | $568,748,200.00 | $215,881,600.00 | $4,760,400.00 |
| Kewaunee | 1,832 | 258 | 13 | $171,298,800.00 | $48,266,700.00 | $6,949,300.00 |
| Manitowoc | 4,392 | 539 | 28 | $376,091,400.00 | $126,891,500.00 | $27,094,000.00 |
| Marinette | 3,483 | 265 | 17 | $277,682,550.00 | $76,571,200.00 | $44,125,700.00 |
| Milwaukee | 16,633 | 764 | 15 | $5,542,023,107.00 | $1,661,681,300.00 | $10,981,800.00 |
| Oconto | 484 | 5 | 0 | $44,359,200.00 | $561,900.00 | $0.00 |
| Ozaukee | 2,485 | 152 | 11 | $597,001,760.00 | $84,326,900.00 | $10,483,000.00 |
| Racine | 7,300 | 550 | 31 | $958,820,700.00 | $206,358,150.00 | $52,690,600.00 |
| Sheboygan | 5,205 | 376 | 12 | $558,194,200.00 | $157,662,600.00 | $11,531,100.00 |
| **Total** | **64,219** | **5,480** | **182** | **$12,124,320,617.00** | **$3,185,086,850.00** | **$217,722,800.00** |

Sources: WLIP, WEM

**Table 3.6.3-9: Coastal County Hazard Mitigation Plans**

| County | Years Valid | Link to Plan |
|---|---|---|
| Ashland | 2019-2024 | https://co.ashland.wi.us/vertical/sites/%7B215E4EAC-21AA-4D0B-8377-85A847C0D0ED%7D/uploads/Ashland_Haz_Mit_Plan_18_v6.pdf |
| Bayfield | 2018-2023 | http://www.cityofwashburn.org/uploads/7/0/4/7/70473445/updated_2018_bayfield_co_haz_mit.pdf |
| Brown | 2020-2025 | https://www.browncountywi.gov/i/f/files/Emergency-Management/All%20Hazards/FINAL%20AHMP%202020.pdf |
| Door | 2016-2021 | https://www.co.door.wi.gov/DocumentCenter/View/3615/Hazard-Mitigation-Plan_opt |
| Douglas | 2016-2021 | https://www.nwrpc.com/DocumentCenter/View/1323/DCHMP_4_17?bidId= |
| Iron | 2018-2023 | https://www.nwrpc.com/DocumentCenter/View/659/Draft-Updated-Plan-2018-with-Maps?bidId= |
| Kenosha | 2017-2022 | https://www.sewrpc.org/SEWRPCFiles/Publications/CAPR/capr-278-3rd-ed-kenosha-co-hazard-mitigation-plan-update.pdf |
| Kewaunee | 2020-2025 | http://cherrylan.kewauneeco.org/FTP/eoc/HazMitPlan2019v3.pdf |
| Manitowoc | 2020-2025 | https://www.co.manitowoc.wi.us/wp-content/uploads/2021/01/manitowoc-county-hazard-mitigation-plan-2020-2025.pdf |
| Marinette | 2020-2025 | https://www.marinettecounty.com/i_marinette/d/Emergency_Management/mitigation/05-29-20_final_hm_plan_2020-25.pdf |
| Milwaukee | 2019-2024 | https://www.sewrpc.org/SEWRPCFiles/Publications/CAPR/capr-282-3rd-edition-city-of-milwaukee-all-hazards-mitigation-plan.pdf |

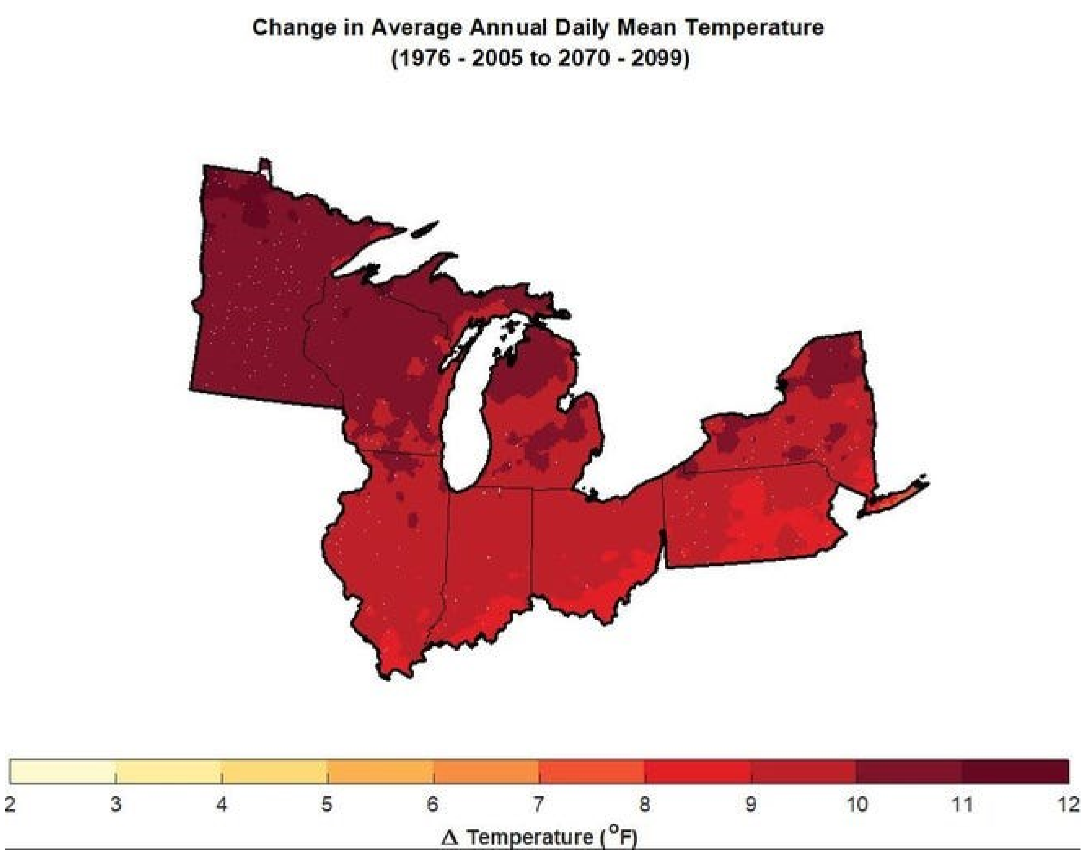
| | | |
|---|---|---|
| Oconto | 2021-2026 | https://drive.google.com/file/d/1RbQ4BH5Dm8Hs-UJ1- P0L3BuaCBeOr0Y/view |
| Ozaukee | 2020-2025 | https://www.sewrpc.org/SEWRPCFiles/Publications/CAPR/CAPR-332OzaukeeCountyHMPU.pdf |
| Racine | 2017-2022 | https://www.sewrpc.org/SEWRPCFiles/Publications/CAPR/capr-278-3rd-ed-kenosha-co-hazard-mitigation-plan-update.pdf |
| Sheboygan | 2020-2025 | https://www.sheboygancounty.com/home/showpublisheddocument/16380/637571040718670000 |

Source: WEM

### 3.6.4 Climate Change Impacts

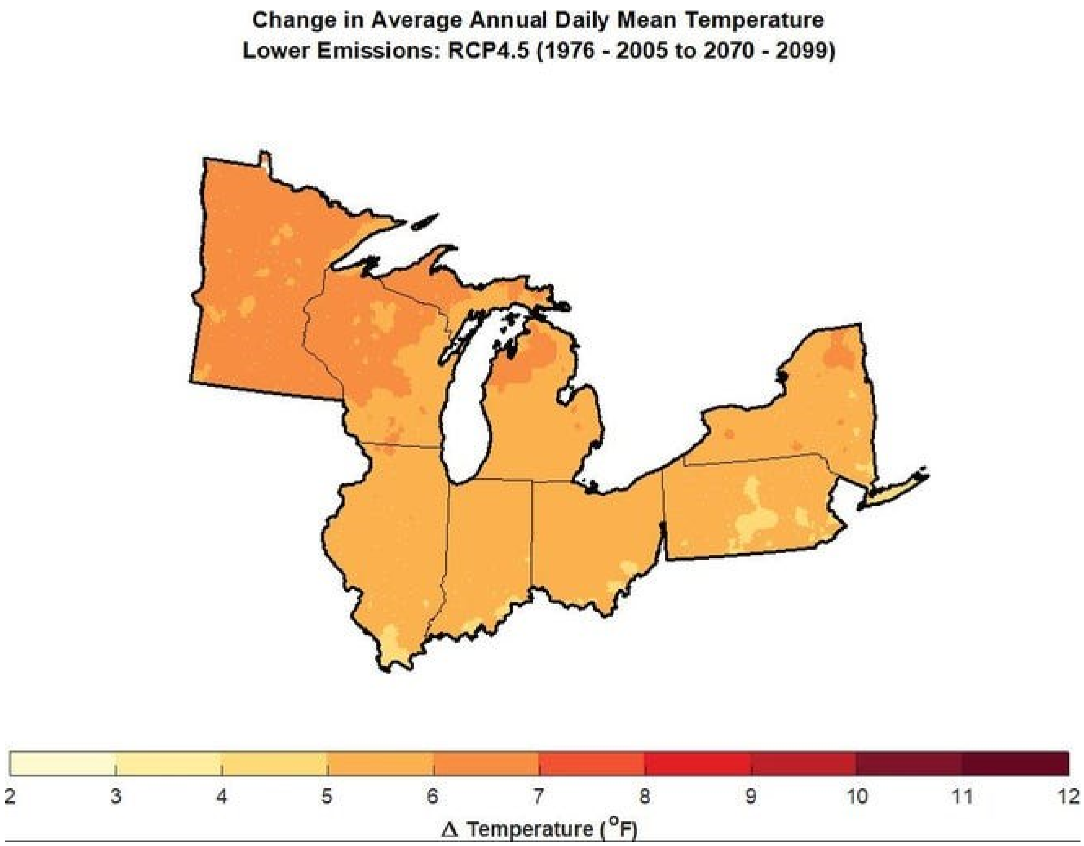
Increases in temperature and precipitation predicted by climate scientists will affect Great Lakes water levels. The interactions between these variables are complex, and there is considerable uncertainty as to what the overall impact to lake levels will be. On the one hand, warmer winter temperatures will reduce the amount of ice cover that forms over the Great Lakes in winter. This, coupled with hotter and drier summers, would increase evaporation from the lakes and ultimately decrease lake levels. However, increases in extreme precipitation are also predicted, which would generate a greater amount of runoff, leading in turn to higher water levels. Figure 3.6.4-1 and 3.6.4-2 show the projected changes in annual average temperature for the states bordering the Great Lakes. Figure 3.6.4-1 is a higher emissions scenario and Figure 3.6.4-2 is a lower emissions scenario. As shown in both images, the changes in temperatures for northern Wisconsin are slightly higher than those in southern and southeastern Wisconsin.

**Figure 3.6.4-1: Change in Average Annual Daily Mean Temperature, Higher Emissions Scenario**




Source: NOAA/NCEI

**Figure 3.6.4-2: Change in Average Annual Daily Mean Temperature, Lower Emissions Scenario**




Source: NOAA/NCEI

Ultimately, it is not yet possible to predict with any certainty how the interaction of these opposing factors will influence lake levels overall; they may cancel each other out, or they may exacerbate the highs and lows that we currently experience. GLCR notes that while future projections of lake levels vary, most indicate a greater decline in lake levels with increasing greenhouse gas emissions. If this prediction proves to be accurate, awareness of coastal hazards may fade as low lake levels slow the erosion rate and reduce incidences of storm damage. Lower average lake levels may encourage coastal development, potentially leading to problems during years when water levels are high.

When water levels are high, coastal erosion increases, especially when paired with stronger and more frequent storms. Changes in the freeze-thaw cycle and increasingly severe spring floods are also likely to contribute to increased flooding, erosion, and bluff instability. Given the recent problems with coastal erosion and bluff instability brought on during the current period of high lake levels, coastal communities will need to be more vigilant and proactive about protecting shoreline properties and infrastructure moving forward.

Regional watershed hydrology will also be driven by climate change and land use. Higher summer and fall air temperatures will increase evaporation during the growing season. This increase means that less water is stored in the landscape during the fall – potentially leading to soil deficits during another key growing season. According to a study from the Journal of Hydrology, soil moisture storage will decrease by about 8% in September and October by the end of the century under a high emissions scenario. Under the same scenario, projected soil moisture storage will increase by about 10% in February and March by the end of the century. Notably, the temperatures in the lakes are increasing faster than the surrounding air temperatures. Warmer water surface temperatures may increase the stratification of the lakes, decrease vertical mixing in the spring/winter, and lead to more low oxygen "dead zones" and harmful algal blooms. These changes directly impact both the recreational and economical uses of the Great Lakes. For example, winter activities and tourism will suffer due to reduced snow and ice cover. The species that currently inhabit the lakes, shorelines, and wetlands, may migrate away and forever alter the ecosystems. Finally, 10% of jobs in the Great Lakes are related to agriculture, fishing, and food production. As the climate changes in the Great Lakes region, many of these jobs and businesses are at risk.

Wisconsin's DOA notes that the fifteen coastal counties are projected to increase in population from 2020 to 2030 by 85,600 people, representing 23% of the overall projected growth in the State during this decade. Should this trend continue, increased growth and development can in turn increase the risk and vulnerability of counties as property values increase and areas that were once undeveloped undergo urbanization. These issues are especially pressing for communities that are under-resourced and in low-lying, flood-prone areas since the damages would be more extreme.

### 3.6.5 Sources

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# 3.7 DROUGHT AND EXTREME HEAT

## 3.7.1 Nature of the Hazard

While drought and extreme heat are two separate hazards, when they occur simultaneously, the impacts of both can be significantly exacerbated, so they are addressed together in this section of the plan.

Drought

**Figure 3.7.1-1: Sunburst Dairy, Belleville, WI, 2012**

Source: Reuters

**Drought** is the result of a natural decline in 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, low relative humidity, and extreme heat. The following four definitions are commonly used to describe different types of drought and demonstrate the complexity of the hazard:

1. **Meteorological drought:** Degree of dryness, expressed as a departure of the actual precipitation from the expected average or normal precipitation amount, based on monthly, seasonal, or annual time scales.
2. **Hydrological drought:** Effects of precipitation shortfalls on streamflows, and reservoir, lake, and groundwater levels.
3. **Agricultural drought:** Soil moisture deficiencies relative to water demands of crops.
4. **Socioeconomic drought (or water management drought):** Shortage of water due to the demand for water exceeding the supply.

The severity of a drought depends on several factors:

- Duration
- Intensity
- Geographic extent
- Water supply demands for both human use and vegetation

Drought is difficult to define in exact terms, due in part to the ways it differs from other hazards:

- The onset and end of a drought are difficult to determine because of the slow buildup of effects and the lingering impacts after its apparent end.
- There is no exact and universally-accepted definition, adding to the confusion of existence and severity.
- The impact of drought is less obvious and may be spread over a larger geographic area.

These characteristics have hindered the preparation of drought contingency or mitigation plans and can make it difficult to perform an accurate risk analysis.

The magnitude of a drought is measured using the **Palmer Drought Severity Index**. Factors like temperature, soil moisture, and precipitation are entered into an algorithm that returns results between -4 (extreme drought) and 4 (extremely moist) with zero being normal conditions. The index is effective at determining drought over a period of months, but less effective over shorter timeframes. Droughts are rated by the **US Drought Monitor** and put into the following categories based on five indicators including the Palmer Index and streamflow data:

- **D0: Abnormally Dry**
    - Going into drought:
        - Short-term dryness slowing planting and growth of crops or pastures
    - Coming out of drought:
        - Some lingering water deficits
        - Pastures or crops not fully recovered
- **D1: Moderate Drought**
    - Some damage to crops and pastures
    - Streams, reservoirs, or wells low, some water shortages developing or imminent
    - Voluntary water-use restrictions requested
- **D2: Severe Drought**
    - Crop or pasture losses likely
    - Water shortages common
    - Water restrictions imposed
- **D3: Extreme Drought**
    - Major crop and pasture losses
    - Widespread water shortages or restrictions
- **D4: Exceptional Drought**
    - Exceptional and widespread crop and pasture losses
    - Shortages of water in reservoirs, streams, and wells creating water emergencies

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 National Weather Service's (NWS) Climate Prediction Center publishes both Palmer Drought Severity and Crop Moisture indices for the country weekly.

Extreme Heat

**Extreme summer heat** is the combination of very high temperatures and exceptionally humid conditions. This heat is measured by the **heat index**, a scale that quantifies how hot it actually feels. At a heat index of 105 °F or higher, the heat is extreme enough to cause disorders associated with exposure to heat and/or physical activity. If such conditions persist for an extended period of time, it is called a **heat wave**. When extreme heat conditions are forecast, the National Weather Service (NWS) warns people and agencies to take precautions:

- **Excessive Heat Outlook:** Issued when conditions for an excessive heat event may occur in the next three to seven days; provides information for those who need to plan for heat (emergency management, public health officials, utility companies, etc.).
- **Excessive Heat Watch:** Issued when conditions for an excessive heat event will occur in the next 12 to 48 hours.
- **Excessive Heat Advisory:** Issued when the daytime heat index is expected to exceed 100°F in the next 36 hours; or if the heat index is expected to exceed 95°F for four consecutive days.
- **Excessive Heat Warning:** Issued when the heat index is expected to exceed 105°F during the day and 75°F throughout the night in the next 36 hours; or if the heat index is expected to exceed 100°F for four consecutive days.

Figure 3.7.1-2 shows the National Oceanic and Atmospheric Administration (NOAA) NWS heat index values. As indicated, the heat index is a function of the actual temperature and the relative humidity. The categories in light orange, dark orange, and red indicate when the heat index values are of concern and precautions should be taken limiting sun exposure and physical activity.

**Figure 3.7.1-2: NOAA's National Weather Service Heat Index**

**Temperature ($^{o}$F)**

| Relative Humidity (%) | 80 | 82 | 84 | 86 | 88 | 90 | 92 | 94 | 96 | 98 | 100 | 102 | 104 | 106 | 108 | 110 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 40 | 80 | 81 | 83 | 85 | 88 | 91 | 94 | 97 | 101 | 105 | 109 | 114 | 119 | 124 | 130 | 136 |
| 45 | 80 | 82 | 84 | 87 | 89 | 93 | 96 | 100 | 104 | 109 | 114 | 119 | 124 | 130 | 137 | |
| 50 | 81 | 83 | 85 | 88 | 91 | 95 | 99 | 103 | 108 | 113 | 118 | 124 | 131 | 137 | | |
| 55 | 81 | 84 | 86 | 89 | 93 | 97 | 101 | 106 | 112 | 117 | 124 | 130 | 137 | | | |
| 60 | 82 | 84 | 88 | 91 | 95 | 100 | 105 | 110 | 116 | 123 | 129 | 137 | | | | |
| 65 | 82 | 85 | 89 | 93 | 98 | 103 | 108 | 114 | 121 | 128 | 136 | | | | | |
| 70 | 83 | 86 | 90 | 95 | 100 | 105 | 112 | 119 | 126 | 134 | | | | | | |
| 75 | 84 | 88 | 92 | 97 | 103 | 109 | 116 | 124 | 132 | | | | | | | |
| 80 | 84 | 89 | 94 | 100 | 106 | 113 | 121 | 129 | | | | | | | | |
| 85 | 85 | 90 | 96 | 102 | 110 | 117 | 126 | 135 | | | | | | | | |
| 90 | 86 | 91 | 98 | 105 | 113 | 122 | 131 | | | | | | | | | |
| 95 | 86 | 93 | 100 | 108 | 117 | 127 | | | | | | | | | | |
| 100 | 87 | 95 | 103 | 112 | 121 | 132 | | | | | | | | | | |

**Likelihood of Heat Disorders with Prolonged Exposure or Strenuous Activity**

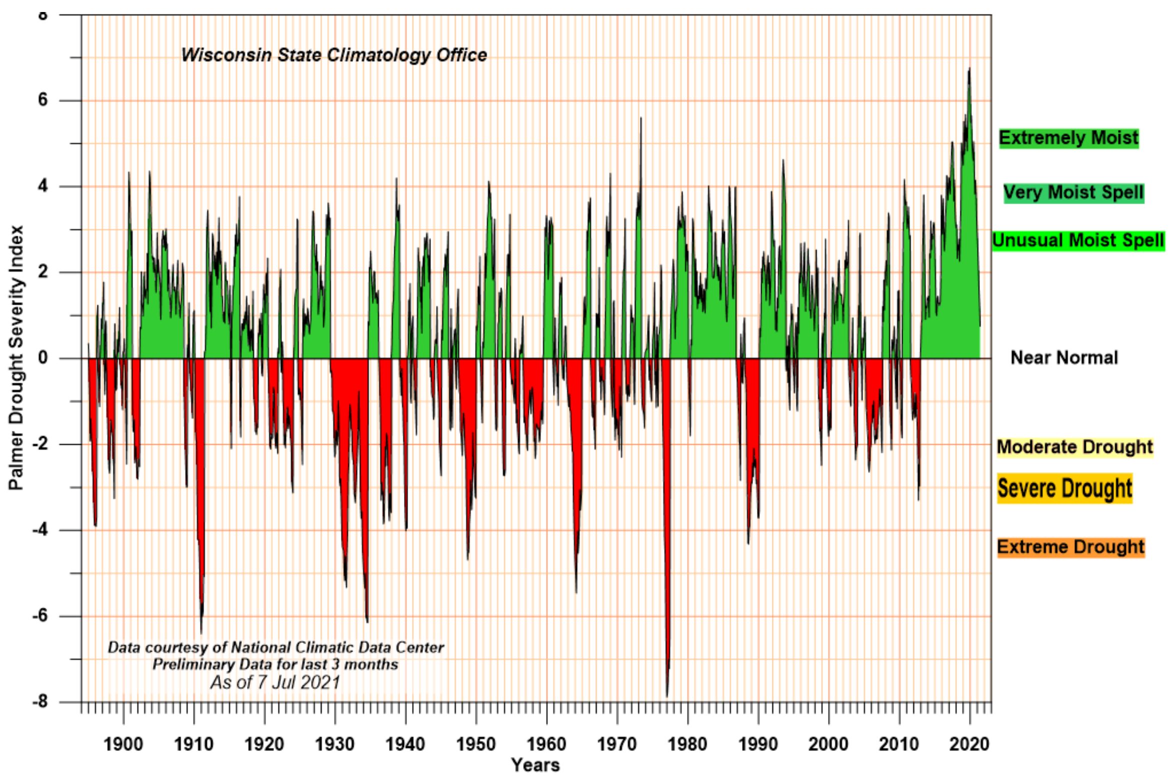
Caution Extreme Caution Danger Extreme Danger

Source: NOAA, NWS Milwaukee/Sullivan

### 3.7.2 History

Wisconsin has experienced several notable drought and extreme heat events in its history. Figure 3.7.2-1 shows the pattern of drought in Wisconsin from 1895 to 2021. A few of the most significant drought and extreme heat events are described below. For extreme heat events, it is important to note that it was not until 1979 that the NWS adopted the Heat Index Scale, forever changing the way heat waves were documented. Prior to this change, high temperatures were recorded but the overall impact of extended heat combined with high humidity was not.

**Figure 3.7.2-1: Wisconsin Statewide Average Palmer Drought Severity Index January 1895 - June 2021**

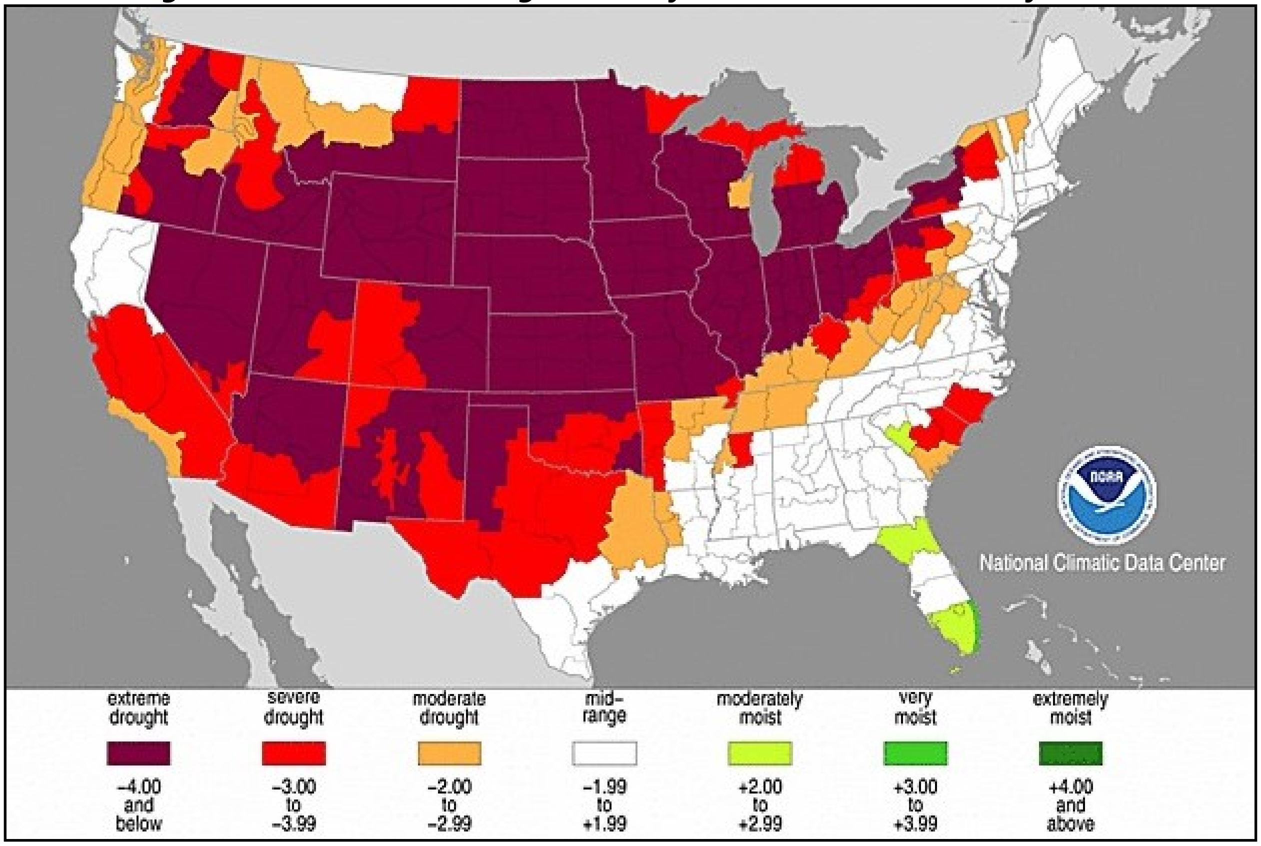



Source: Wisconsin State Climatology Office

<u>1929-1934</u>

The drought of 1929-1934 was one of the most significant droughts in Wisconsin history, considering its duration and severity. This drought had a 75-year recurrence interval in most of the state and a greater than 100-year recurrence interval in certain areas. As shown in Figure 3.4.2-1, much of the country experienced drought conditions through this time. The austere economic impacts of the Great Depression compounded its effects. The drought continued with somewhat decreased effect until the early 1940s in some parts of the state.

**Figure 3.7.2-2: Palmer Drought Severity Index, United States, July 1934**




Source: NOAA, National Centers for Environmental Information

In addition to the severe drought of the Dust Bowl years, extreme heat exacerbated the drought conditions and created additional hardship for the poverty-stricken during the Great Depression. The summer of 1936 saw some of the hottest temperatures on record for Wisconsin and the nation. Over 5,000 deaths were attributed to heat that year.

Most of Wisconsin's all-time highest daily temperatures were recorded during the Dust Bowl. On July 13, 1936, the highest temperature ever recorded in the state, 114 °F, occurred in Wisconsin Dells. Table 3.7.2-1 lists some additional Wisconsin cities that recorded their highest temperatures during the Dust Bowl.

**Table 3.7.2-1: Wisconsin Record High Temperatures Set During the Dust Bowl**

| Municipality | Temperature | Date | Municipality | Temperature | Date |
|---|---|---|---|---|---|
| Wisconsin Dells | 114°F | July 13, 1936 | Appleton | 107°F | July 14, 1936 |
| Mondovi | 110°F | July 14, 1936 | Madison | 107°F | July 14, 1936 |
| Richland Center | 110°F | July 14, 1936 | Oshkosh | 107°F | July 13, 1936 |
| Hatfield | 108°F | July 14, 1936 | Mather | 106°F | July 14, 1936 |
| La Crosse | 108°F | July 14, 1936 | Milwaukee | 105°F | July 24, 1934 |
| Lancaster | 108°F | July 14, 1936 | Green Bay | 104°F | July 13, 1936 |
| Viroqua | 108°F | July 13, 1936 | Medford | 104°F | July 13, 1936 |

Source: NWS, Milwaukee/Sullivan

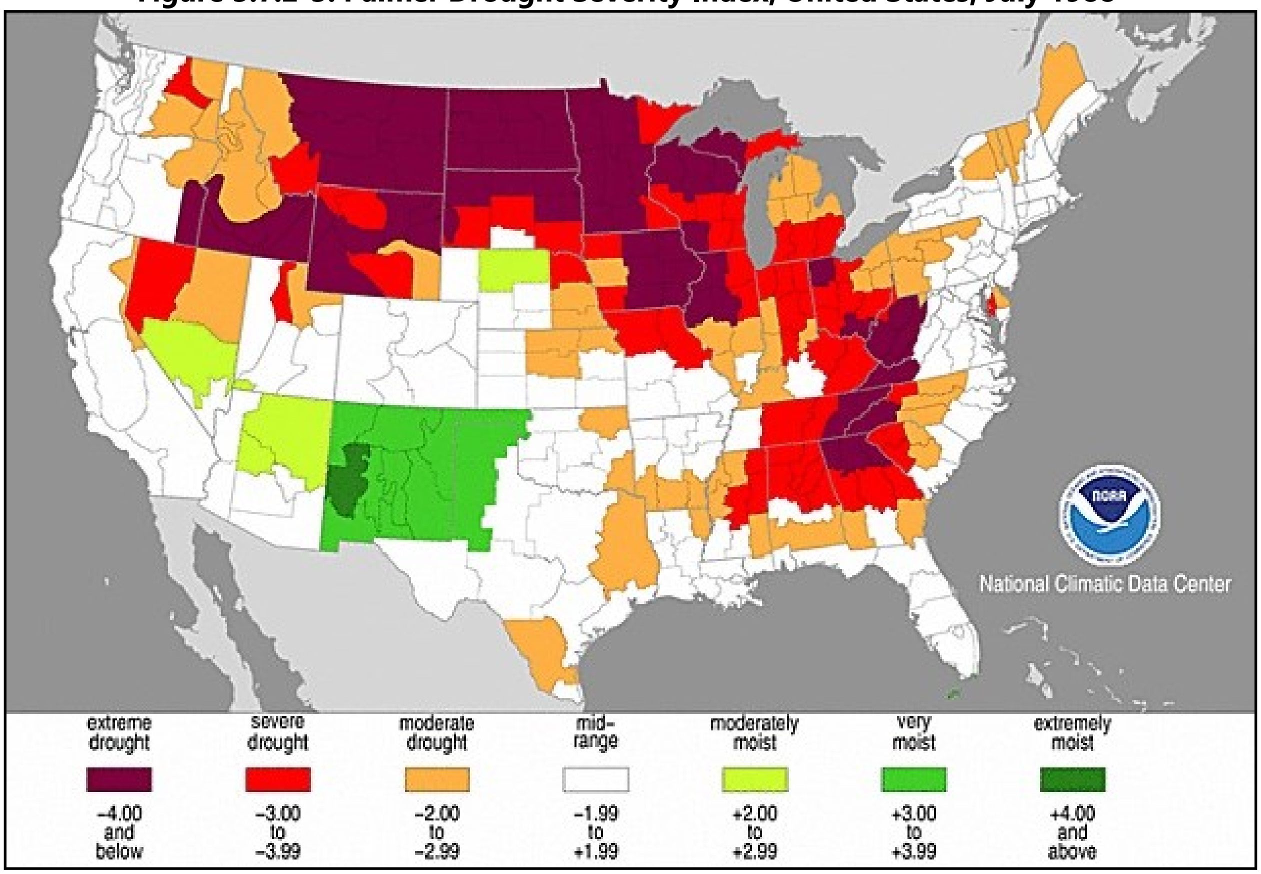
<u>1987-1989</u>

Another extremely dangerous drought was the North American Drought of 1988. Many people believed it to be the most severe ever experienced in Wisconsin and much of the Midwest. It was characterized not only by below normal precipitation, but also by persistent dry air and above normal temperatures.

Heatwaves killed an estimated 5,000 people nationwide and contributed to high livestock loss. Stream flow measuring stations indicated a drought recurrence interval of 75 to 100 years. The effects were most severe in north-central and northeastern Wisconsin.

The drought occurred early in the growing season and resulted in a 30-60% crop loss with state agricultural losses estimated at $1.3 billion. 52% of the state's 81,000 farms were estimated to have had crop losses of 50% or more, with 14% of farms suffering estimated losses of 70% or more. State and federal drought assistance programs helped Wisconsin farmers recover a portion of their losses. All Wisconsin counties were designated eligible for this drought assistance. In total, the drought in the central and eastern states caused an estimated $39 billion in damages. Figure 3.7.2-2 shows the Palmer Drought Severity Index for July 1988.

**Figure 3.7.2-3: Palmer Drought Severity Index, United States, July 1988**




Source: NOAA, National Centers for Environmental Information

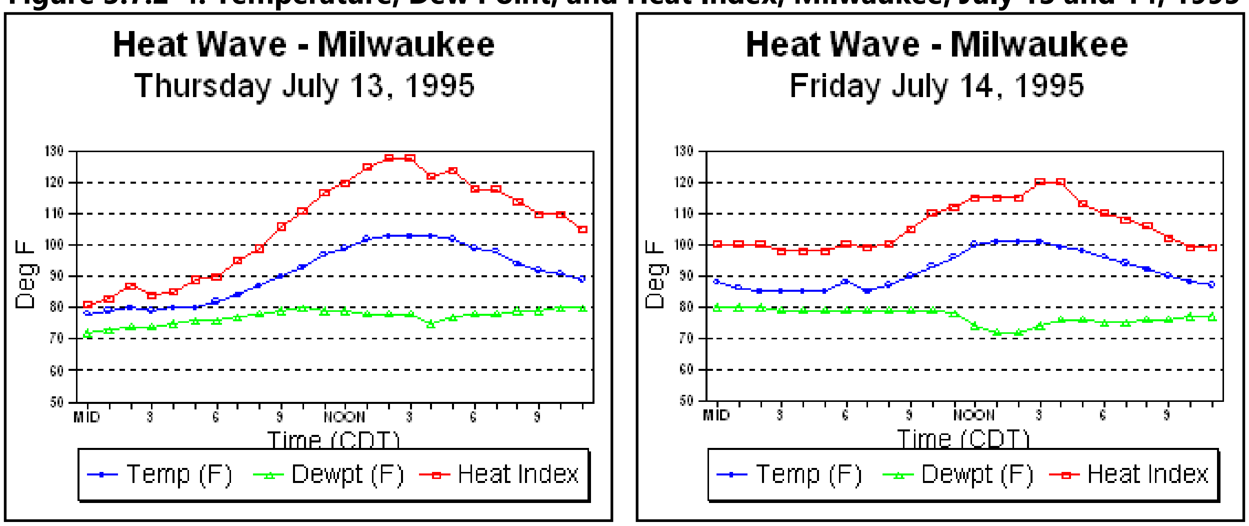
The impact of this drought on private and municipal water supplies was not as severe. Several municipal water utilities experienced maximum use of their water delivery systems. Many water utilities imposed some type of water-use reduction rules or restrictions, usually involving the limitation of lawn and yard watering.

<u>1995</u>

Two major heat waves occurred in Wisconsin in 1995, one in June, one in July. During the first heat wave, June 17-27, temperatures rose into the upper 90s with heat index values of 98 to 104 °F. Nine people in Wisconsin died directly from the heat. During the second heat wave, July 12-15, high temperatures ranged from 100 to 108 °F with heat index values between 120 and 130 °F. Wisconsin witnessed the greatest number of weather-related deaths in state history when the event caused 141 heat-related fatalities. 85 of the deaths were in Milwaukee.

The relative humidity during the second July heat wave produced heat index values which are rarely reached. The heat index values were the main contributing factor in the large number of fatalities. In urban areas, like Milwaukee County, heat index values were higher due to the concentration of buildings, concrete, and asphalt. This phenomenon is known as the **urban heat island effect**. Figure 3.7.2-4 shows the temperature, dew point, and heat index trend-lines for Milwaukee General Mitchell Field for July 13 and 14, 1995. Note that the heat index values barely fell below 100°F overnight on July 13.

**Figure 3.7.2-4: Temperature, Dew Point, and Heat Index, Milwaukee, July 13 and 14, 1995**




Source: NWS, Milwaukee/Sullivan

**Figure 3.7.2-5: Heat- and Drought-Affected Crops, Wisconsin, 2012.**

Source: New York Times

2012

Wisconsin experienced a major heat wave during the first seven days of July 2012, peaking July 4-6. The July 2012 heat wave was roughly as hot as the killer July 1995 heat wave, but less humid and longer.

Maximum air temperatures ranged from the upper 90s to 106 °F. However, it was cooler near Lake Michigan, Lake Superior and across the northern third of the state. Maximum heat indices peaked in the 100 to 115 °F range thanks to dew points reaching the mid-60s to mid-70s. There were several heat-related fatalities during this event and most likely several hundred people needed medical treatment.

Along with, and probably exacerbated by, the heat wave of 2012, a cruel drought affected nearly all of Wisconsin during the 2012 summer and fall seasons. The drought was generated by a large, warm blocking high of high pressure in the upper levels of the atmosphere which was centered over the middle of the nation in May and June. Part of this high pressure expanded north into the western Great Lakes region in July, forcing storms to stay mostly north of Wisconsin as the summer progressed.

The drought resulted in reduced crop yields and forced sell-off of some dairy and cattle herds. Alfalfa hay crops also suffered. The reduced quantity and increased cost of feed were factors in the livestock sales. There were many reports of wells running dry and some well depths had to be increased to find water.

The 2012 drought started across the southern third of counties in June and steadily expanded north during July and August. Eventually, the southern two-thirds of the state were in severe (D2) to extreme (D3) drought status. The drought continued into December due to a very dry November.

2016

Hot temperatures and very high dew point temperatures persisted over southern Wisconsin from Thursday, July 21st through Sunday, July 24th, 2016. Southern Wisconsin saw heat index values in the lower to mid-100s. There were 3 heat-related deaths in 2016.

2021

In June of 2021, several locations in Wisconsin set record high temperatures and much of Wisconsin was experiencing precipitation deficits. The below normal precipitation amounts created moderate to extreme drought conditions. Crops over far southern Wisconsin exhibited areas of stress. However, due to timely rain events, the agricultural conditions were not nearly as poor as those of the 2012 drought.

Deadly Extreme Heat Events

Table 3.7.2-2 summarizes heat-related deaths in the state from 1982 to 2015. Years with no heat-related deaths are not included in the table. Most of the fatalities in Wisconsin occurred during the two major heat wave events in June and July 1995. A death is considered direct if the medical examiner ruled that heat was the primary cause of death. If heat was a contributing factor (not the main cause), the examiner ruled that death indirect.

**Table 3.7.2-2: Heat-Related Deaths in Wisconsin, 1982-2015**

| Year | Direct | Indirect | Year | Direct | Indirect |
|---|---|---|---|---|---|
| 1986 | 1 | 0 | 2002 | 3 | 5 |
| 1988 | 1 | 0 | 2003 | 0 | 4 |
| 1993 | 2 | 0 | 2006 | 3 | 1 |
| 1995 | 82 | 72 | 2011 | 5 | 0 |
| 1997 | 1 | 0 | 2012 | 14 | 7 |
| 1999 | 13 | 8 | 2013 | 2 | 0 |
| 2001 | 10 | 5 | **TOTAL** | **137** | **102** |

Source: NWS, Milwaukee/Sullivan

In the years since the 2016 Wisconsin State Hazard Mitigation Plan update, the heat deaths in Wisconsin have been difficult to track using NWS recording methods. The Wisconsin Department of Health Services (DHS) has provided data on heat-related deaths; however, it is not separated into categories of direct and indirect. According to the DHS recording method, heat-related deaths are defined as any that occurred from May to September with an underlying or contributing cause of death from exposure to excessive natural heat and/or any with a contributing cause of death from the effects of heat and light. Table 3.7.2-3 summarizes heat-related deaths in the state from 2016 to 2020.

**Table 3.7.2-3: Heat-Related Deaths in Wisconsin, 2016-2020**

| Year | Number of Deaths |
|---|---|
| 2016 | 3 |
| 2017 | 2 |
| 2018 | 5 |
| 2019 | 5 |
| 2020 | 7 |
| **TOTAL** | **22** |

Source: DHS

From 1982 to 2020, 261 people have died in Wisconsin from heat-related causes. It is likely that this estimate is less than the actual total of heat-related deaths due to the difficulty of tracking heat-related death information.

### 3.7.3 Probability, Vulnerability, and Mitigation Potential

**Table 3.7.3-1: Hazard Ranking**

| Evaluation Criteria | Description | Ranking |
|---|---|---|
| Probability: Drought | • Between 1% to <10% probability of occurrence each year. | Occasional |
| Probability: Extreme Heat | • 10% to 85% probability of occurrence each year. | Likely |
| Vulnerability: Drought and Extreme Heat | • Minimal countermeasures are in place to prevent or protect against this hazard.<br>• Countermeasures may have potential but limited demonstrated history in reducing the threat potential.<br>• The nature of the hazard may limit the availability of countermeasures. | High |
| Mitigation Potential: Drought and Extreme Heat | • Methods for reducing risk from the hazard are not well-established, are not proven reliable, or are experimental.<br>• The State or counties have little or no experience in implementing mitigation measures, and/or no technical knowledge of them.<br>• Mitigation measures are ineligible under federal grant programs.<br>• There is a very limited range of mitigation measures for the hazard, usually only one feasible alternative.<br>• The mitigation measures have not been proven cost-effective and are likely to be very expensive compared to the magnitude of the damages caused by the hazard.<br>• The long-term effectiveness of the measure is not known or is known to be relatively poor. | Low |

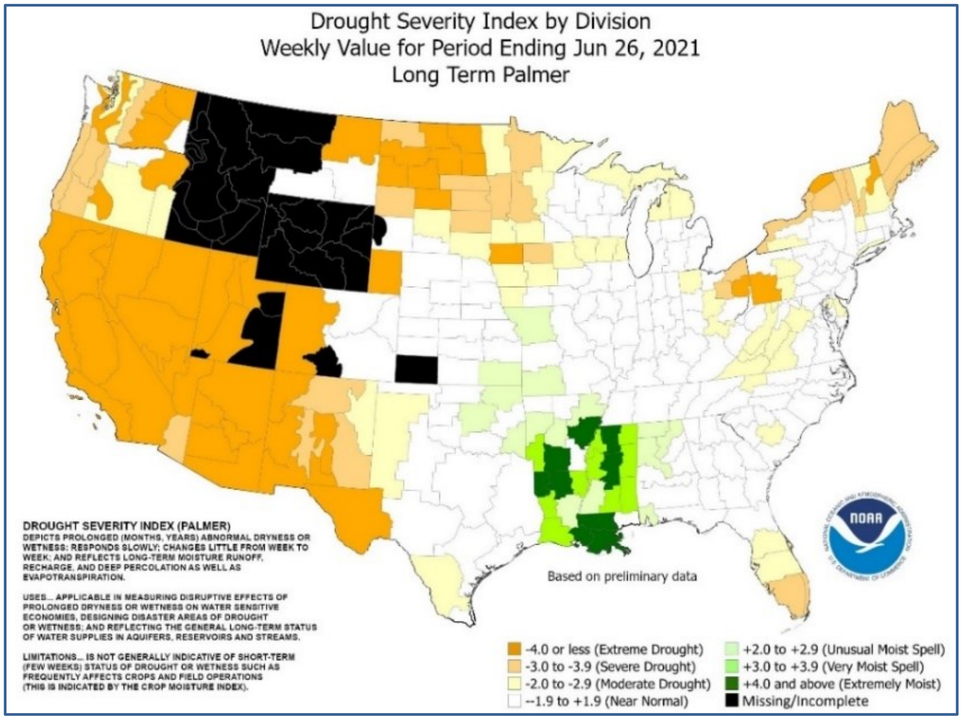
Probability

*Drought*

The future incidence of drought is highly unpredictable, it impacts the state occasionally, but not annually. Drought may also be localized, making it difficult to determine probability with any accuracy; however, the National Weather Service (NWS) and National Integrated Drought Information System (NIDIS) are improving methodologies for accurately forecasting drought conditions. Both organizations use a combination of current and historic precipitation, streamflow, groundwater levels, and crop data to perform short- and long-term forecasts.

The Palmer Drought Severity Index determines long-term drought forecasts, profiling several months at a time; however, it does not provide accurate short-term forecasts (several weeks). It uses a rating of zero as normal with drought shown in negative numbers and excessive moisture in positive numbers. The scale and conditions from June 2021 are pictured in Figure 3.7.3-1. The white and yellow shading over Wisconsin indicate that the state was experiencing near normal and moderate drought conditions. The NWS updates the Palmer Index weekly. Current Palmer Drought Severity Index information can be found online at the NWS Climate Prediction Center's Drought Monitoring website.

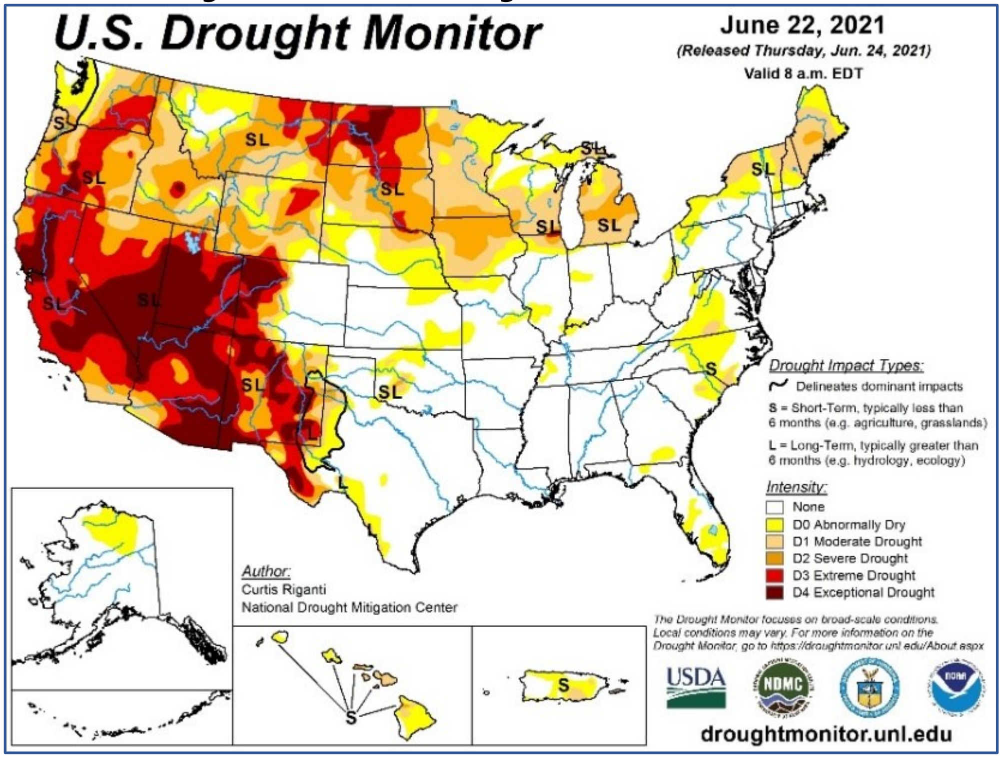
**Figure 3.7.3-1: Palmer Drought Severity Index, June 2021**




Source: NOAA, Climate Prediction Center

The US Drought Monitor indicates which parts of the country are experiencing short-term drought conditions (a weather pattern and precipitation deficit lasting a few weeks or months) in addition to long-term drought forecasts (a weather pattern and precipitation deficit lasting more than six months). The US drought Monitor can be accessed at the NIDIS website. Figure 3.7.3-2 shows the short-term drought conditions for mid-June 2021. The light orange shading indicates that there were moderate drought conditions across much of Wisconsin.

**Figure 3.7.3-2: US Drought Monitor, June 2021**



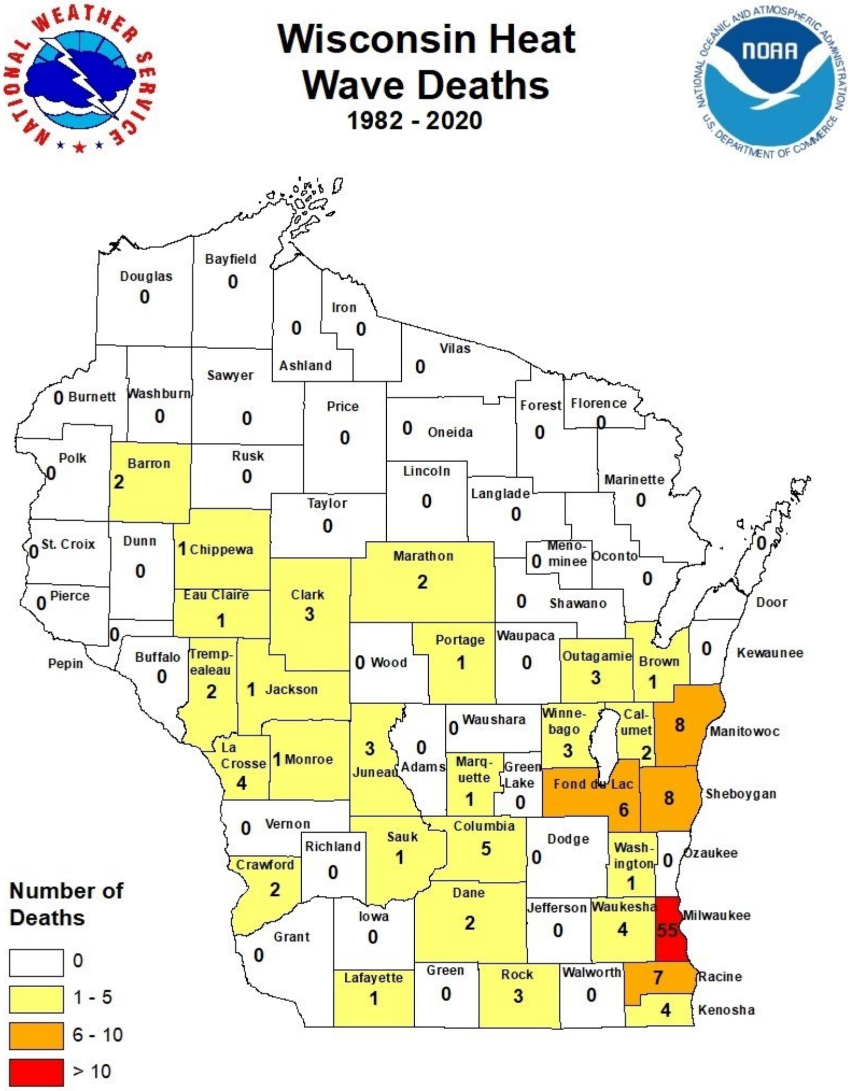

Source: US Drought Monitor

*Extreme Heat*

The probability of exceeding 89 °F in any given year is likely, but temperatures are not the only determinant of the impacts of heat. Other factors include humidity, duration, and timing of the extreme heat event. Extreme heat is widespread, generally affecting regions or multiple counties in each event.

Extreme heat is the deadliest type of severe weather in Wisconsin. Statewide there were 261 heat-related deaths between 1986 and 2020. This averages to 7.7 heat-related deaths per year. Figure 3.7.3-2 shows the direct heat-related deaths by county. A death is considered **direct** if the medical examiner ruled that heat was the primary cause of death. If heat was a contributing factor (not the main cause), the examiner ruled that death **indirect**.

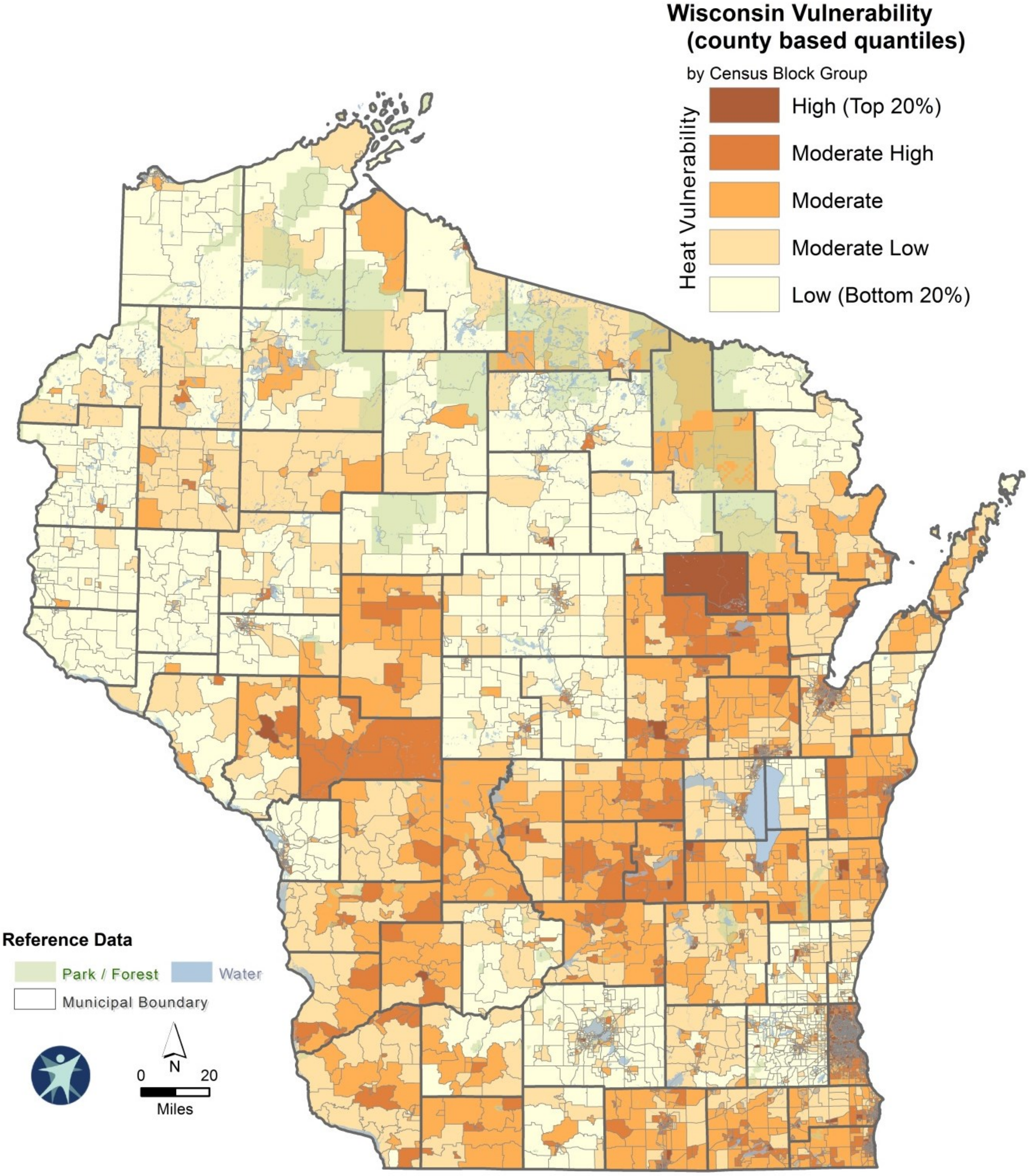
**Figure 3.7.3-2: Direct Heat Wave Deaths per Wisconsin County, 1982-2020**




Source: NWS, Milwaukee/Sullivan

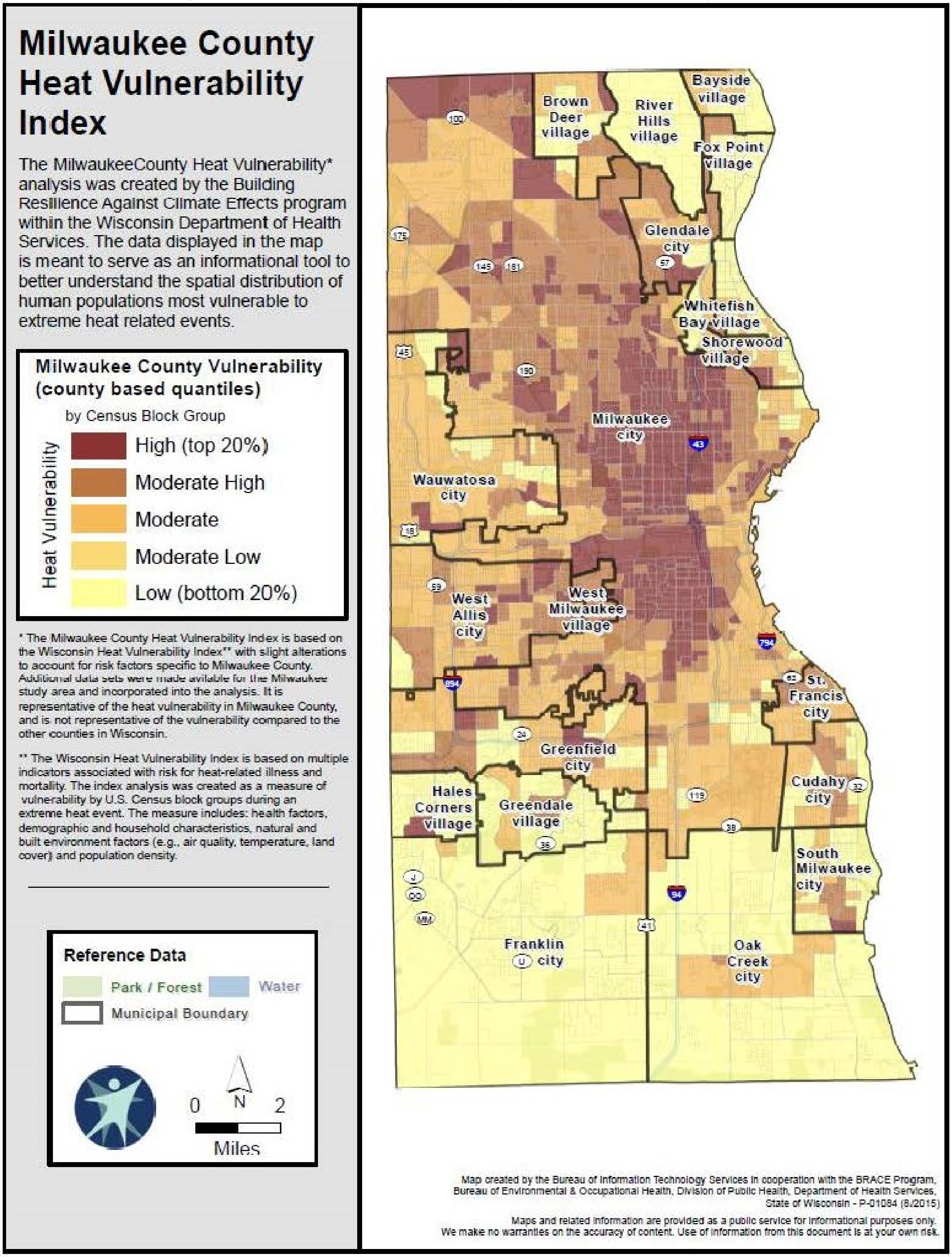
The Building Resilience Against Climate Effects (BRACE) program in the Wisconsin Department of Health Services has compiled heat vulnerability index maps for the state and each county. A combination of risk factors (population density, health factors, demographic and socioeconomic factors, and the natural and built environment) was used to create the maps. Figures 3.7.3-3 and 3.7.3-4 show the maps for the state and Milwaukee County. With its high population density, high poverty rate, and urban heat island effect, it is no surprise that Milwaukee County has a high vulnerability to extreme heat events and has experienced many heat-related fatalities.

**Figure 3.7.3-3: Wisconsin Heat Vulnerability Index**




Source: Department of Health Services, BRACE

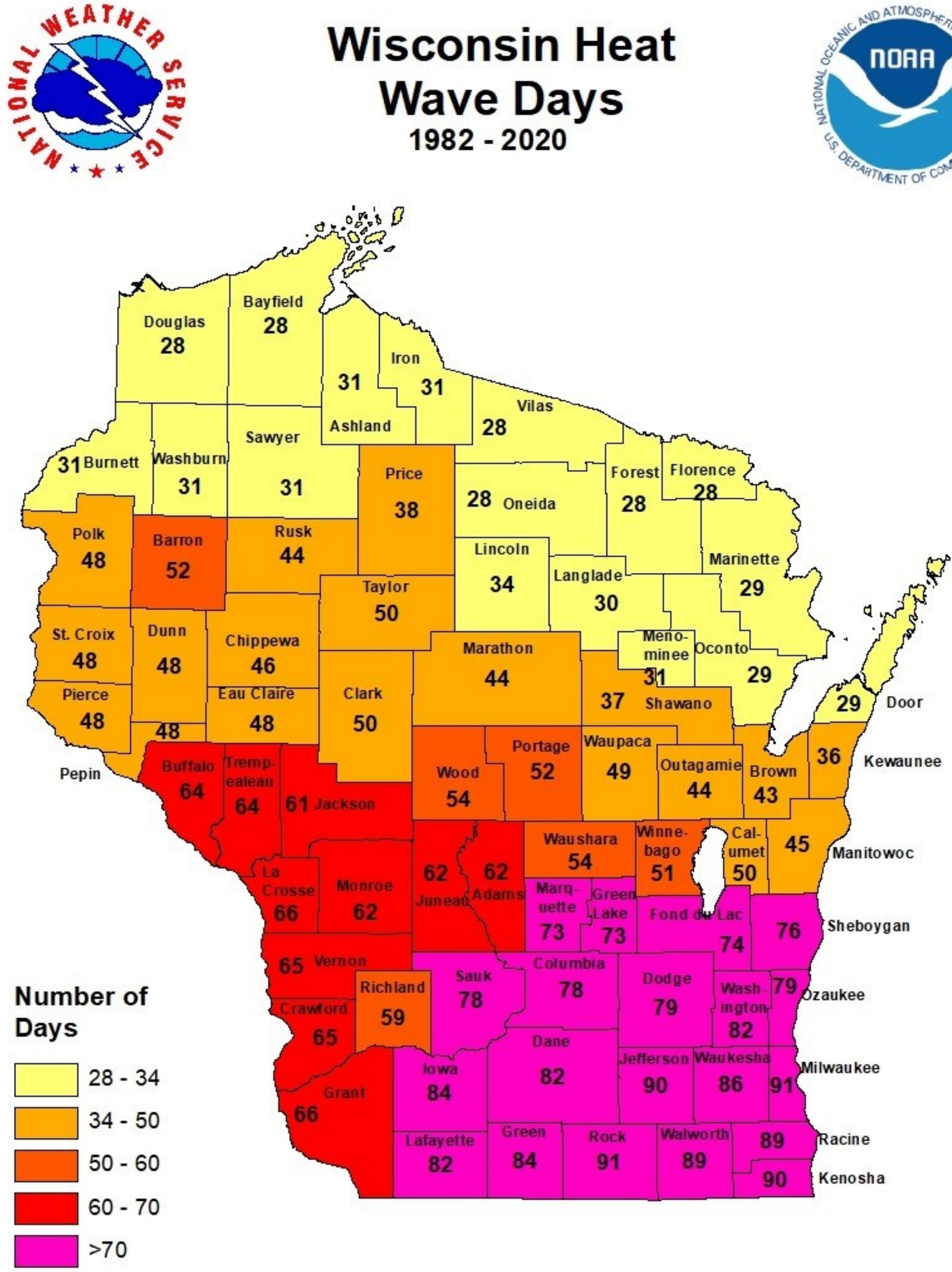
**Figure 3.7.3-4: Milwaukee County Heat Vulnerability Index**




Source: Department of Health Services, BRACE

Figures 3.7.3-5 and 3.7.3-6 highlight heat wave events in Wisconsin from 1982 to 2020. Figure 3.7.3-5 shows the heat wave days per county, indicating the number of calendar days in that time on which a heat advisory or excessive heat warning was issued. Southeastern Wisconsin has a higher likelihood of heat wave days, most counties experiencing at least 70 days total with a 2.1-day annual average.

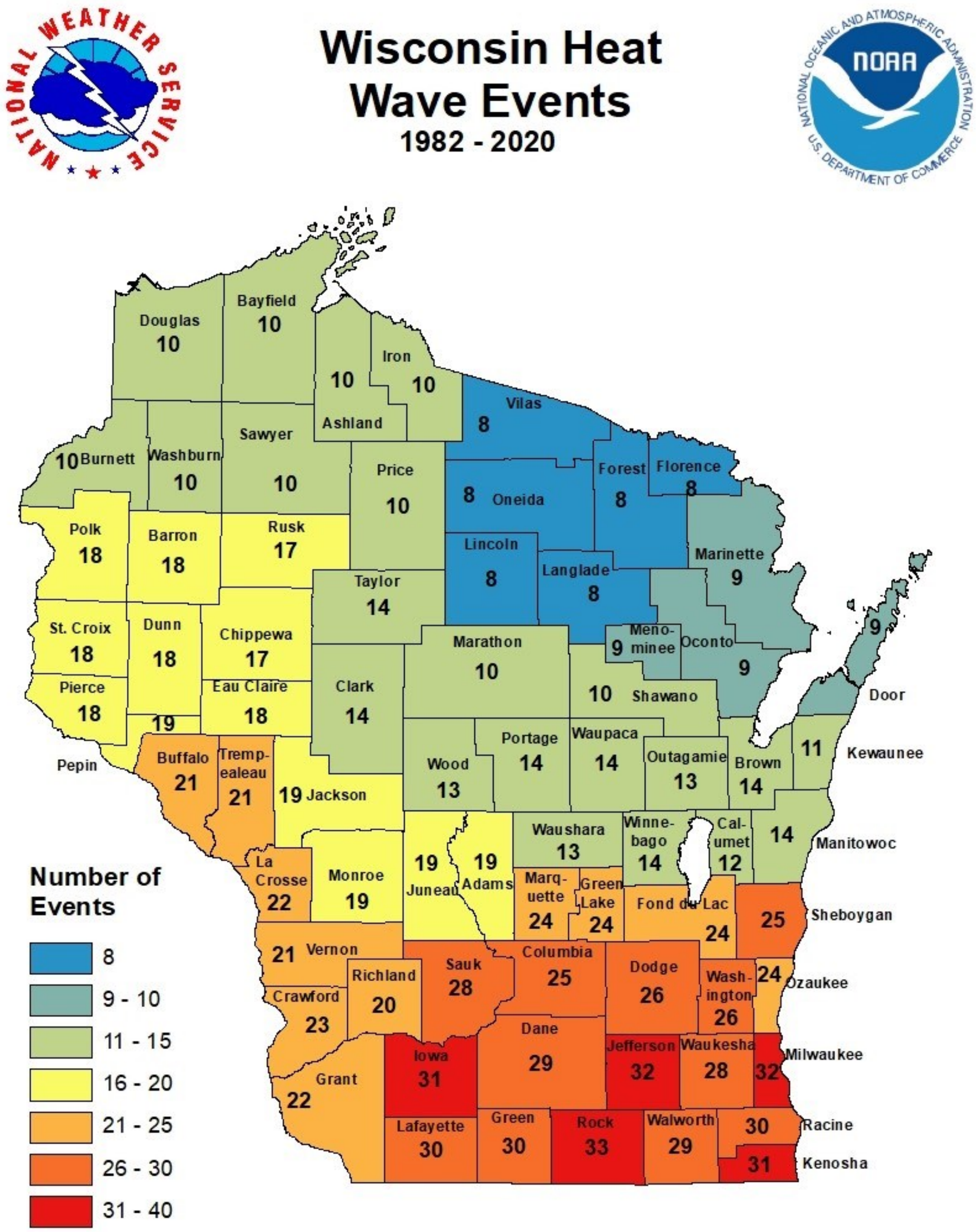
**Figure 3.7.3-5: Total Heat Wave Days per Wisconsin County, 1982-2020**




Source: NWS, Milwaukee/Sullivan

Figure 3.7.3-6 displays the number of heat wave events per county. This map, along with Figure 3.7.3-5, indicates that individual heat wave events tend to last for multiple days. In southeastern Wisconsin, where there are the most heat wave days and heat wave events, an event will last between 3.5 and 3.8 days, on average.

**Figure 3.7.3-6: Total Heat Wave Events per Wisconsin County, 1982-2020**




Source: NWS, Milwaukee/Sullivan

## Vulnerability

### *Drought*

The impacts of drought are varied and far-reaching. Droughts may cause a shortage of water for human and industrial consumption, hydroelectric power, recreation, and navigation. Water quality may decline, and the number and severity of wildfires may increase. As land is cleared by wildfire, loss of vegetation can result in flooding, even from average rainfall following drought conditions. Severe droughts may result in the loss of agricultural crops and forest products, undernourished wildlife and livestock, and lower land values.

Wisconsin is most vulnerable to agricultural drought. The state has approximately 14.3 million acres of farmland on 64,793 farms and was ranked eighth in the country in overall farm receipts, cash income the farm sector receives from commodity sales, in 2019. Even small droughts of limited duration can significantly reduce crop growth and yields, adversely affecting farm incomes and local economies.

### *Extreme Heat*

Extreme heat is of great concern since exposure causes serious life-threatening conditions. The risk to humans is grave, as more people die from heat than any other extreme weather event. The danger categories and heat disorders associated with the heat index values described in Section 3.4.1 are listed in Table 3.7.3-1. Note that caution should be taken when the heat index approaches 90 °F.

**Table 3.7.3-1: Heat Index and Associated Heat Disorders**

| Danger Category | | Heat Disorder | Heat Index Value (How Hot It Feels) |
|---|---|---|---|
| IV | Extreme Danger | Heatstroke or sunstroke highly likely with continued exposure. | >130°F |
| III | Danger | Sunstroke, heat cramps, or heat exhaustion likely; heat stroke possible with prolonged exposure and/or physical activity. | 105-130°F |
| II | Extreme Caution | Sunstroke, heat cramps, and heat exhaustion possible with prolonged exposure and/or physical activity. | 90-105°F |
| I | Caution | Fatigue possible with prolonged exposure and/or physical activity. | 80-90°F |

Source: NWS, Green Bay

There are different stages of heat disorders associated with exposure to heat:

- **Heatstroke:** An often fatal medical emergency occurring when the body’s responses to heat stress are insufficient to prevent a substantial rise in the body’s core temperature, typically exceeding 105 °F. Even with rapid cooling and treatment, the average fatality rate is 15%.

- **Heat Exhaustion:** A less serious medical condition characterized by dizziness, weakness, or fatigue. Body temperatures may be normal or slightly to moderately elevated. With fluid treatment, the prognosis is typically good.
- **Heat Syncope:** A sudden loss of consciousness typically associated with people exercising who are not acclimated to warm temperatures. It causes little or no harm to the individual.
- **Heat Cramps:** A condition that may occur in people unaccustomed to exercising in the heat.

In addition to affecting people, severe heat places significant stress on plant and animal life. Severe heat may reduce the yields of crops or contribute to crop loss. Similarly, livestock may become overheated leading to reduced milk production and other health problems.

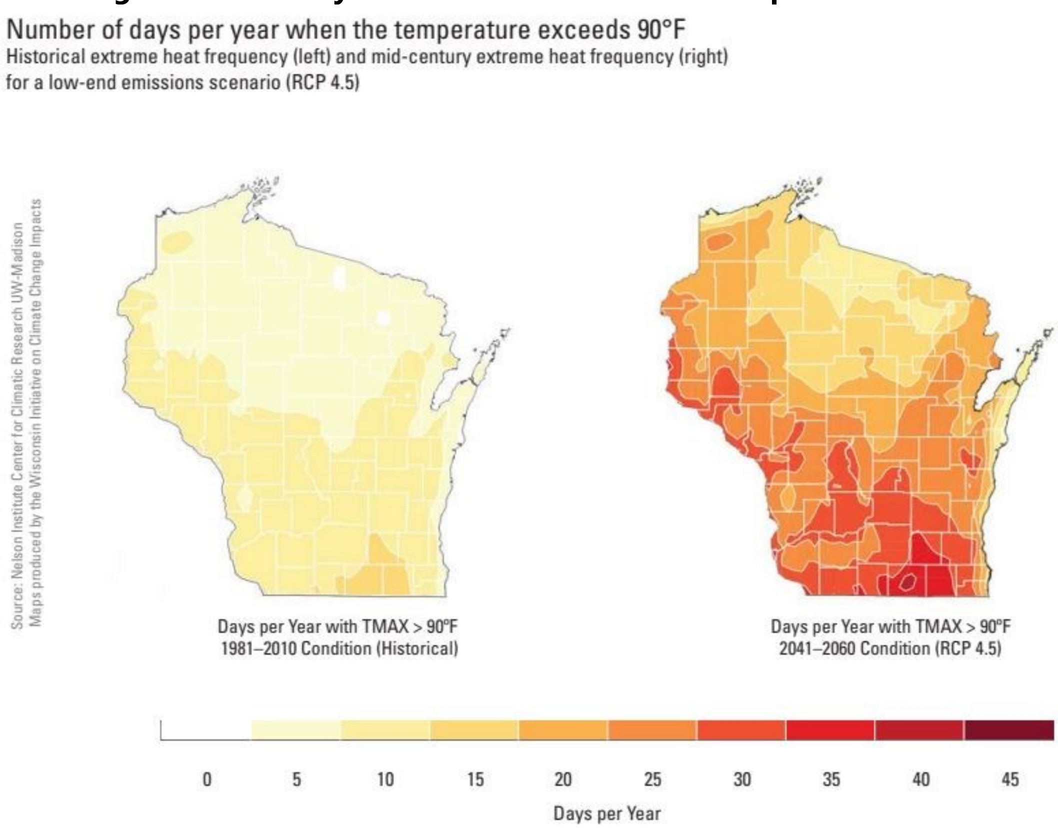
### 3.7.4 Climate Change Impacts

Extreme Heat

As average temperatures rise statewide, Wisconsin communities can expect to see longer summers and shorter winters. Northern Wisconsin will likely experience the greatest warming, but most of the state will grow warmer over the course of the next century, especially in the summer months. 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% wetter than summer in Milwaukee. Green Bay's climate will feel most like today's climate in Shiloh, Ohio where the typical summer is 6.2 °F warmer and 5.5% wetter than summer in Green Bay. A map of these climate analogs and more locations in Wisconsin can be accessed at the University of Maryland's Center for Environmental Science simulation portal.

Heat waves are 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 (Figure 3.7.4-1). By late century (2081-2100) under a "business as usual" high-emissions scenario, southern Wisconsin may experience 80 to 90 days per year with temperatures over 90 °F. Peak temperatures in 2050 are likely to reach 110-112 °F.

**Figure 3.7.4-1: Days Per Year with Maximum Temperature >90°F**



Source: Wisconsin Initiative on Climate Change Impacts

The impacts of extreme heat events are experienced most acutely by the elderly and other vulnerable populations. Due to the urban heat island effect, high temperatures are exacerbated in urban environments, which in turn tend to have higher concentrations of vulnerable populations. Higher demand for electricity as people try to keep cool amplifies stress on power systems and may lead to an increase in the number of power outages. Atmospheric concentrations of ozone occur at higher air temperatures, resulting in poorer air quality, while harmful algal blooms flourish in warmer water temperatures, resulting in poorer water quality.

Mitigation against the impacts of future temperature increase may include increasing education on heat stress prevention, organizing cooling centers, allocating additional funding to repair and maintain roads damaged by buckling and potholes, and reducing nutrient runoff that contributes to algal blooms. Local governments should also prepare for increased demand on public recreational facilities, utility systems, and healthcare centers. Improving energy efficiency in public buildings will also present an increasingly valuable savings potential.

Drought

The number of heavy rainfall events in Wisconsin is predicted to increase, yet researchers currently expect little change in mean annual precipitation, indicating that the periods between heavy rainfalls will be marked by an increasing number of dry days. The higher temperatures brought by climate change can increase the likelihood of droughts between rainfall events. Warmer temperatures can increase **evapotranspiration**, the process where water evaporates from the soil surface and is used by a plant during transpiration. This loss of water leads to drier soils and drought. Additionally, lack of soil moisture can contribute to hotter days. Instead of evaporating moisture which has a cooling effect, heat from the sun warms the soil and surrounding air.

The table in figure 3.7.4-2 shows the historically observed impacts of drought in Wisconsin generally seen with each category of U.S. Drought Monitor conditions. An increase in dry days between heavy rainfalls may increase these historically observed impacts.

**Figure 3.7.4-2: Drought Impacts in Wisconsin**

| Category | Historically observed impacts |
|---|---|
| D0 | Pasture and row crops are stressed |
| | Burn bans are implemented |
| | Lawns are brown; landscape and gardens require more frequent watering |
| | Lakes and rivers are lower than normal |
| D1 | Hay prices are high; people are selling horses |
| D2 | Crop yields are down; pasture growth is sparse; livestock are removed from grazing |
| | Water use is high; groundwater pumping increases |
| D3 | Producers feed cattle supplemental hay |
| | Agriculture economic losses are reported statewide |
| | Fairs have fewer entries |
| | Streamflow is reduced; water temperatures are warm; oxygen content is low; northern pike fish kill is reported |

Source: U.S. Drought Monitor

Agricultural operations are particularly vulnerable to drought. Grazing pastures and crop yields are reduced at any time during a crop's life cycle when a plant's evapotranspiration demand exceeds water supply from the soil. Drought stress hinders a crop's growth by reducing its ability to uptake and transport water and nutrients from the soil.  Reduced crop yields and grazing pasture areas cause direct economic losses to Wisconsin's farmers.

**Figure 3.7.4-3: Dairy cows graze near an irrigation system in Amherst, WI**

Source: University of Wisconsin Extension

Most farmers in the southern area of the state have traditionally relied on rainfall to support crop growth. Adapting to drought by pumping groundwater for irrigation can prove challenging in acquiring equipment. Competition for groundwater may arise between municipal and private wells. Drought also can also alter surface water supply by decreasing river and lake levels. Irrigation for agriculture can further lower these levels as surface water seeps into the ground.

Mitigation against future periods of drought between heavy rainfalls may include assessing vulnerability to drought risk, monitoring drought conditions, monitoring water supplies, and developing drought emergency plans. Additional mitigation strategies can include requiring water conservation measures, retrofitting water supply systems, preventing overgrazing, educating residents and farmers on water conservation practices, and purchasing crop insurance.

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# 3.8 WINTER STORMS AND EXTREME COLD

## 3.8.1 Nature of the Hazard

Winter storms vary in size and strength and include heavy snowstorms, blizzards, freezing rain, sleet, ice storms, and considerable blowing and drifting snow conditions that often close roads. Additionally, the combination of extremely cold temperatures and strong winds can result in dangerous wind chills that cause bodily injury like frostbite or even death due to exposure (hypothermia). Severe winter storms are known to cause unusually heavy rain or snowfall, high winds, extreme cold, and ice storms throughout the continental US.

Winter storms can be very disruptive to transportation and commerce. Trees, cars, roads, and other surfaces can develop a glaze of ice making conditions extremely hazardous to motorists and pedestrians. The most prevalent impacts of heavy accumulations of ice and snow are slippery roads and walkways leading to vehicle and pedestrian accidents; collapsed roofs from fallen trees, limbs, heavy ice, and snow loads; and fallen trees, telephone poles and lines, electrical wires, and communications towers. As a result of severe winter storms, power and telecommunications can be disrupted for days. Such storms can also cause high rainfall which, combined with snow melt, can cause flooding. See Section 3.2 for a discussion of flooding.

A variety of weather phenomena and conditions can occur during winter storms. The following are National Weather Service (NWS) approved descriptions of winter storm elements:

- **Heavy snowfall:** accumulation of four or more inches of snow in a 12-hour period or six or more inches in a 24-hour period.
- **Blizzard:** sustained wind or frequent wind gusts of at least 35 mph accompanied by considerable falling and/or blowing snow.
- **Ice storm:** freezing rain produces significant or damaging accumulations of ice, usually ¼" or thicker.
- **Freezing drizzle/freezing rain:** drizzle or rain that falls as a liquid but freezes into glaze upon contact with the ground or objects with a temperature of 32ºF or below.
- **Sleet:** pellets of ice composed of frozen or mostly frozen raindrops or refrozen partially melted snowflakes.
- **Wind chill:** measure of accelerated heat loss from exposed skin due to increased wind speeds.

  If the temperature is 0ºF with a 15-mph wind, the wind chill is -19ºF. At this wind chill, exposed skin can freeze in 30 minutes as shown in Figure 3.5.1-1. In general, the NWS regional offices will issue **Wind Chill Advisories** when wind chill values are expected to drop to -20 to -34ºF with winds at least 10 mph. Similarly, **Wind Chill Warnings** are issued in Wisconsin for wind chill values of -35ºF or lower with winds at least 10 mph.

Wind chill is calculated using the following formula, where T is the air temperature in degrees Fahrenheit and V is the wind speed in miles per hour:

Wind Chill (°F) = 35.74 + 0.6215(T) – 35.75($V^{0.16}$) + 0.4275(T)($V^{0.16}$)

**Figure 3.8.1-1: NWS Wind Chill Chart**

| Wind (mph) \ Temperature (°F) Calm | 40 | 35 | 30 | 25 | 20 | 15 | 10 | 5 | 0 | -5 | -10 | -15 | -20 | -25 | -30 | -35 | -40 | -45 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5 | 36 | 31 | 25 | 19 | 13 | 7 | 1 | -5 | -11 | -16 | -22 | -28 | -34 | -40 | -46 | -52 | -57 | -63 |
| 10 | 34 | 27 | 21 | 15 | 9 | 3 | -4 | -10 | -16 | -22 | -28 | -35 | -41 | -47 | -53 | -59 | -66 | -72 |
| 15 | 32 | 25 | 19 | 13 | 6 | 0 | -7 | -13 | -19 | -26 | -32 | -39 | -45 | -51 | -58 | -64 | -71 | -77 |
| 20 | 30 | 24 | 17 | 11 | 4 | -2 | -9 | -15 | -22 | -29 | -35 | -42 | -48 | -55 | -61 | -68 | -74 | -81 |
| 25 | 29 | 23 | 16 | 9 | 3 | -4 | -11 | -17 | -24 | -31 | -37 | -44 | -51 | -58 | -64 | -71 | -78 | -84 |
| 30 | 28 | 22 | 15 | 8 | 1 | -5 | -12 | -19 | -26 | -33 | -39 | -46 | -53 | -60 | -67 | -73 | -80 | -87 |
| 35 | 28 | 21 | 14 | 7 | 0 | -7 | -14 | -21 | -27 | -34 | -41 | -48 | -55 | -62 | -69 | -76 | -82 | -89 |
| 40 | 27 | 20 | 13 | 6 | -1 | -8 | -15 | -22 | -29 | -36 | -43 | -50 | -57 | -64 | -71 | -78 | -84 | -91 |
| 45 | 26 | 19 | 12 | 5 | -2 | -9 | -16 | -23 | -30 | -37 | -44 | -51 | -58 | -65 | -72 | -79 | -86 | -93 |
| 50 | 26 | 19 | 12 | 4 | -3 | -10 | -17 | -24 | -31 | -38 | -45 | -52 | -60 | -67 | -74 | -81 | -88 | -95 |
| 55 | 25 | 18 | 11 | 4 | -3 | -11 | -18 | -25 | -32 | -39 | -46 | -54 | -61 | -68 | -75 | -82 | -89 | -97 |
| 60 | 25 | 17 | 10 | 3 | -4 | -11 | -19 | -26 | -33 | -40 | -48 | -55 | -62 | -69 | -76 | -84 | -91 | -98 |

Frostbite Times: 30 minutes, 10 minutes, 5 minutes

Source: NOAA, NWS

### 3.8.2 History

There have been many noteworthy winter storms in Wisconsin. Table 3.8.2-1 shows some of the record-breaking events in the state's history. Several important winter storm and extreme cold events are highlighted below. Emphasis is placed on severe weather events that have occurred since the 2016 state plan update.

**Table 3.8.2-1: Wisconsin Record-Breaking Winter Events**

| Record | Location | County | Date | Magnitude |
|---|---|---|---|---|
| 24-hour snow accumulation | Neillsville | Clark | December 27-28, 1904 | 26 inches |
| Seasonal snow accumulation | Hurley | Iron | Winter 1996-97 | 301.8 inches/ 25.2 feet |
| Snowless streak | Milwaukee | Milwaukee | March 4-December 18, 2012 | 288 days |
| Coldest temperature | Couderay | Sawyer | February 4, 1996 | -55ºF |

<u>1922</u>

On February 21-23, 1922, Wisconsin experienced one of the worst ice storms in the state's history. There were widespread ice accumulations of one to two inches and reports of close to four inches. The southwest and south-central parts of the state were primarily impacted. The ice toppled an estimated 15,000 to 20,000 utility poles. Power, telegraph, and phone service were disrupted from two to 15 days. Trees used for timber and fruit production were damaged or killed. Estimated damages were $10 million, which was an incredible amount at the time (equivalent to $163 million in 2021[5]).

<u>1981-82</u>

Blizzard-like conditions occurred during winter 1981-82 when extremely cold temperatures were accompanied by wind speeds gusting to 50 mph. Wind chill factors reached -100ºF and severely affected the health and safety of those who ventured outdoors.

<u>2000</u>

December 2000 was one of the ten coldest Decembers on record throughout most of the state. In addition to low temperatures, record, or near-record snow depths of 15 to 34 inches occurred in much of the southern part of Wisconsin during December. 14 counties received a Presidential Emergency Declaration (EM-3163) as a result of the snowfalls. In total, these counties received over $5.4 million in federal funds to cover costs associated with snow removal and emergency response efforts.

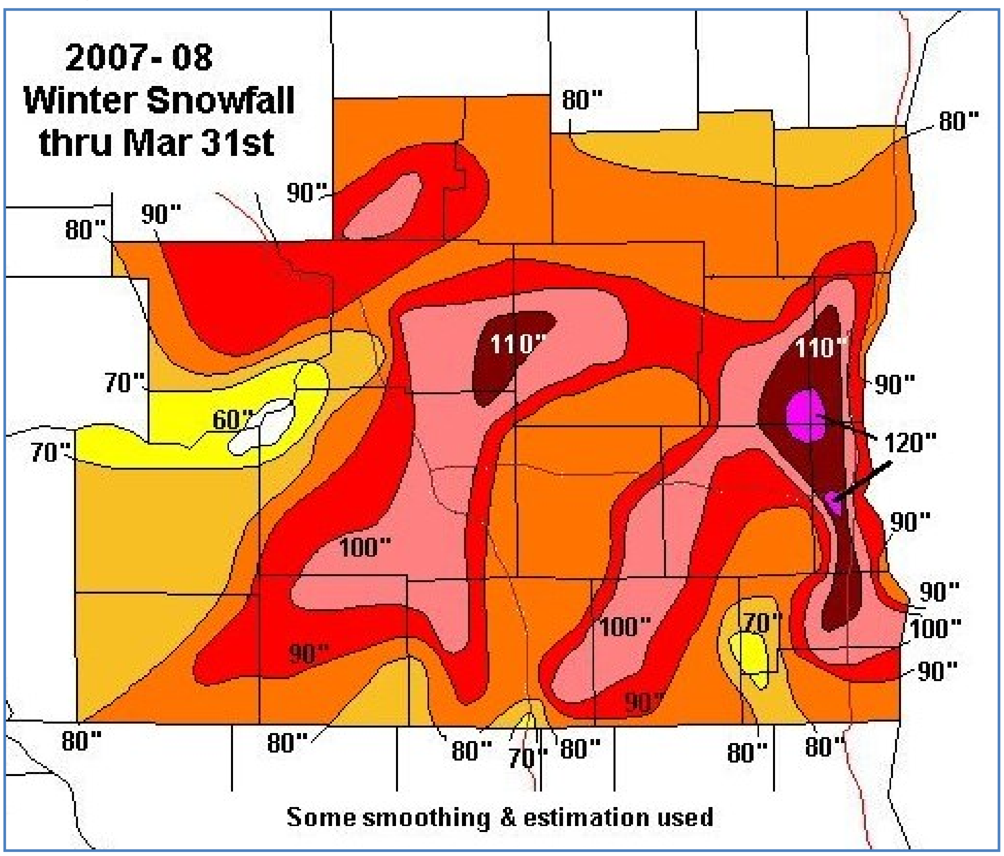
[5] Calculation performed using the US Bureau of Labor Statistics, Consumer Price Index Inflation Calculator: http://www.bls.gov/data/inflation_calculator.htm.

2007-08

The 2007-08 winter season was "one for the ages." Numerous winter storms, including two blizzards and four ice storms, pounded the southern half of the state. Winter snowfall totals of 70 to 122 inches across the southern counties established new all-time winter snowfall records at many locations. These totals were roughly 200% to 240% of normal, and many communities simply ran out of salt, or were unable to purchase additional supplies due to increased demand.

The worst storm of the winter occurred on February 5-6, 2008, southeast of a line from Dubuque, Iowa to Madison (Dane County) to Sheboygan (Sheboygan County). 12 to 21 inches of snow combined with northeast winds of 20 to 30 mph and some gusts up to 50 mph to create near-blizzard conditions. Rates of one to two inches of snowfall per hour were recorded at the height of the storm. Over 1,500 vehicles and trucks were stranded for ten to twenty hours due to snowfalls of up to 21 inches in that area. As a result of this storm, eleven counties (Dane, Dodge, Green, Jefferson, Kenosha, Milwaukee, Racine, Rock, Walworth, and Waukesha) received federal funds to help with costs of maintaining safe roads and providing emergency response in Presidential Emergency Declaration EM-3285. The 2007-08 winter season snowfall totals through the end of March 2008, across southern Wisconsin are shown in Figure 3.8.2-1.

**Figure 3.8.2-1: Southern Wisconsin Winter Snowfall Totals, 2007-2008**

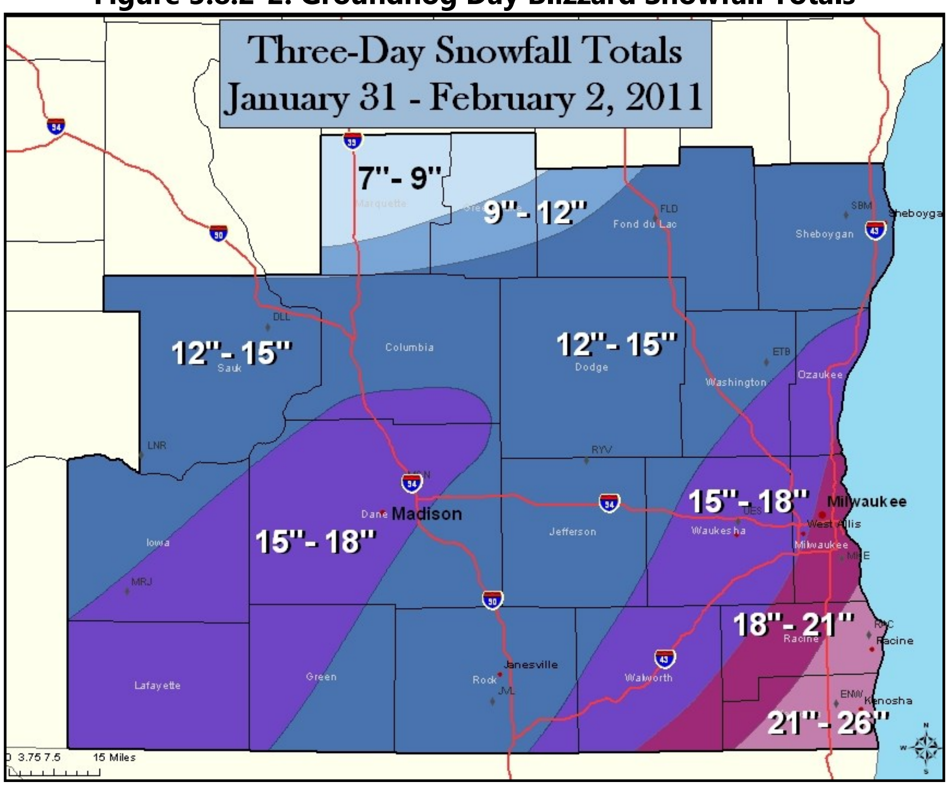



Source: NOAA's NWS, Milwaukee/Sullivan

2011

On February 1-2, 2011, southern Wisconsin was hit with the Groundhog Day Blizzard when a powerful low-pressure center passed south of the state. Figure 3.8.2-2 displays the total snowfall for the event. In Milwaukee, 19.8 inches snow fell from mid-afternoon Tuesday through Wednesday morning, the fourth highest amount for any 24-hour period. Other areas, such as West Bend, saw over 22 inches of snow. Adding to the danger, were blizzard-condition sustained winds of between 40 and 50 mph in many areas, with peak gusts of up to 55 mph in some locations. These winds caused snow drifts of three to eight feet in most areas, with report of drifts reaching 12 to 15 feet in many rural areas throughout southern Wisconsin. Wisconsin Emergency Management (WEM) issued a Civil Danger Warning, urging motorists to stay off roads to avoid dangerous driving conditions. 100 National Guardsmen were mobilized throughout the state to rescue motorists stranded along roadways and to run emergency shelters. The severe winter storm caused the declaration of a Federal Major Disaster (DR-1966), allowing 11 counties (Dane, Dodge, Grant, Green, Iowa, Kenosha, Lafayette, Milwaukee, Racine, Walworth, and Washington) to use Public Assistance funds for emergency work and the repair or replacement of disaster-damaged facilities.

**Figure 3.8.2-2: Groundhog Day Blizzard Snowfall Totals**




Source: NOAA's NWS, Milwaukee/Sullivan

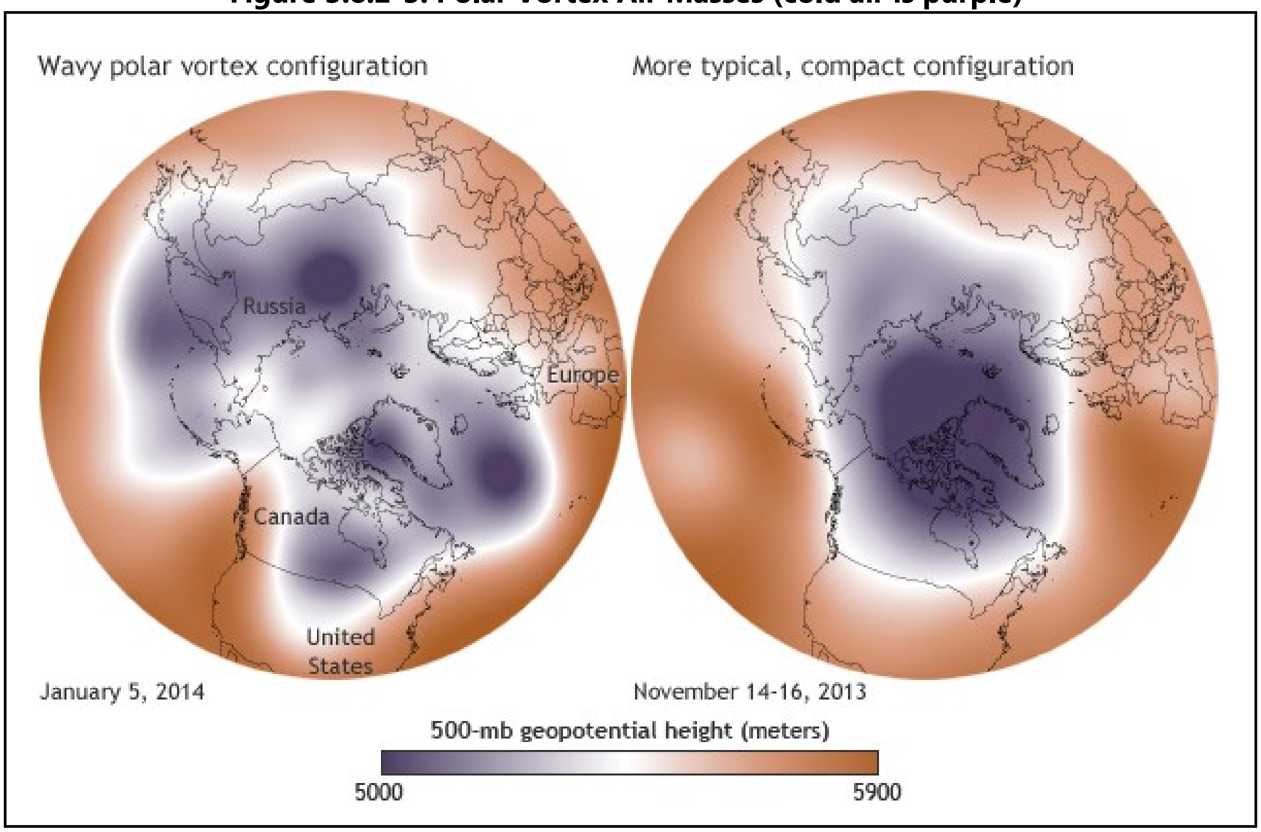
2014

In winter 2014, Wisconsin experienced a polar vortex. As shown in Figure 3.8.2-4, a polar vortex happens when the cold air cell that is usually centralized in the Arctic splits into smaller cells and those cells travel farther south, cooling the northern hemisphere continents more than normal and warming the Arctic. Both Green Bay and La Crosse saw the second and third coldest temperatures ever recorded for January and February. Statewide, it was the fifth coldest December (2013) through February (2014) stretch on record. 14 locations in the state set new record low average temperatures.

Unfortunately, the record cold temperatures also coincided with a propane shortage throughout the Midwest. Many residences in the rural parts of the state rely on propane for heat. When the shortage hit, many people had to move to shelters or stay with friends or relatives. Staying in other places was an option for some, but when home temperatures drop, permanent damage can occur like when water pipes freeze and burst. Because of the shortage, propane prices soared and those without standing contracts spent a lot more than they had planned on.

Additionally, water utility intakes on the Great Lakes became blocked with ice preventing the intake of water into the utility plants. The early and continued freezing of the Great Lakes negatively impacted shipping commerce.

**Figure 3.8.2-3: Polar Vortex Air Masses (cold air is purple)**




Source: NOAA, Climate.gov

<u>2017</u>

*January 16, 2017*

On January 16, 2017, freezing rain left a coating of ice ranging from ¼" to ½" on the ground and other surfaces in western Wisconsin. Area roads, parking lots, and sidewalks were all impacted as they were covered in a thick sheet of ice.

*February 23-25, 2017*

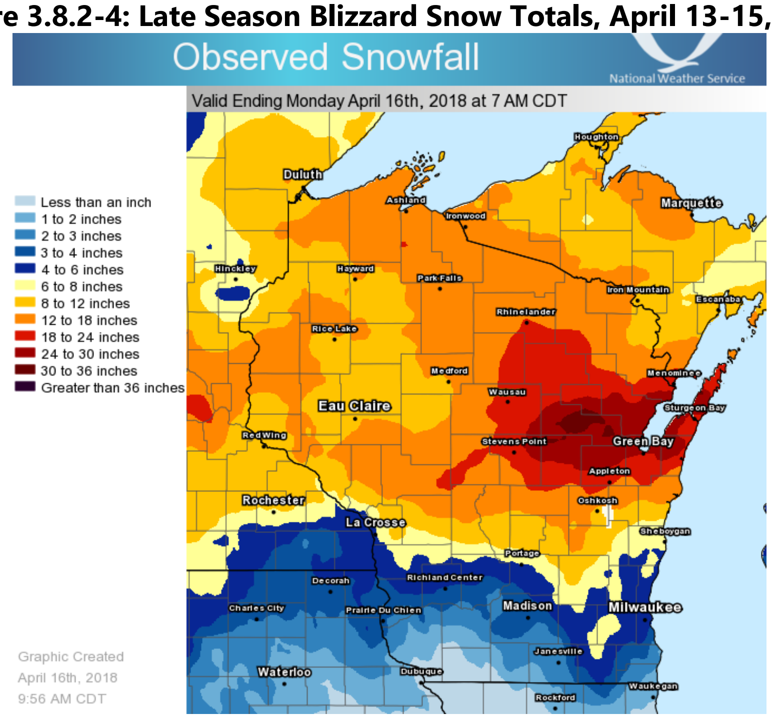
After a long stretch of unseasonably warm conditions, a winter storm swept through the state. From the morning of February 23 into the morning of February 25, 2017, the storm produced a mix of heavy snow, thunderstorms, sleet, and freezing drizzle. The heaviest snow fell across north-central Wisconsin with ranges of 6 to 13". There was some drifting as well as winds 30 to 40 mph.

<u>2018</u>

*April 13-15, 2018*

A historic late season blizzard rolled through northeast and north-central Wisconsin on April 13-15, 2018. Snowfall of 15 to 30" and winds gusting over 45 mph caused several roofs to collapse and sporadic power outages. The extreme conditions also created waves of 10 to 16 feet on Lake Michigan which contributed to erosion along the western shores of the lake (see Section 3.6.2 for full details of the effects of this storm surge). Figure 3.8.2-4 below shows the snowfall amounts throughout the state.

**Figure 3.8.2-4: Late Season Blizzard Snow Totals, April 13-15, 2018**



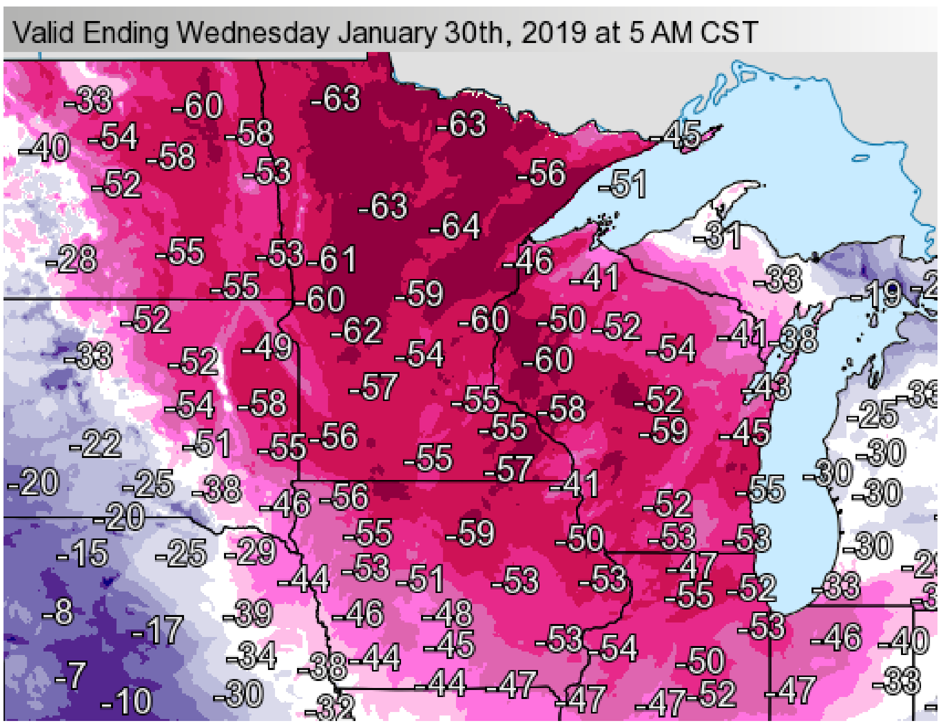
Source: NWS, Milwaukee/Sullivan

2019

*January 29-31, 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 due only 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. Figure 3.8.2-5 shows the wind chill temperatures on the morning the state of emergency was declared.

**Figure 3.8.2-5: Wind Chill Temperatures, January 30, 2019**




Source: NWS, Milwaukee/Sullivan

*February 23-24, 2019*

On February 23-24, 2019, a blizzard brought heavy snow (over one foot) from west central to northern Wisconsin. Half an inch of ice coated surfaces and winds of 50-60 mph occurred. These conditions brought blizzard and whiteout conditions to many areas – including ones that did not receive much snow. Nearby the city of Neenah, on I-41, a 131-car pileup made history as the largest traffic crash in the state.

2020

*January 10-12*

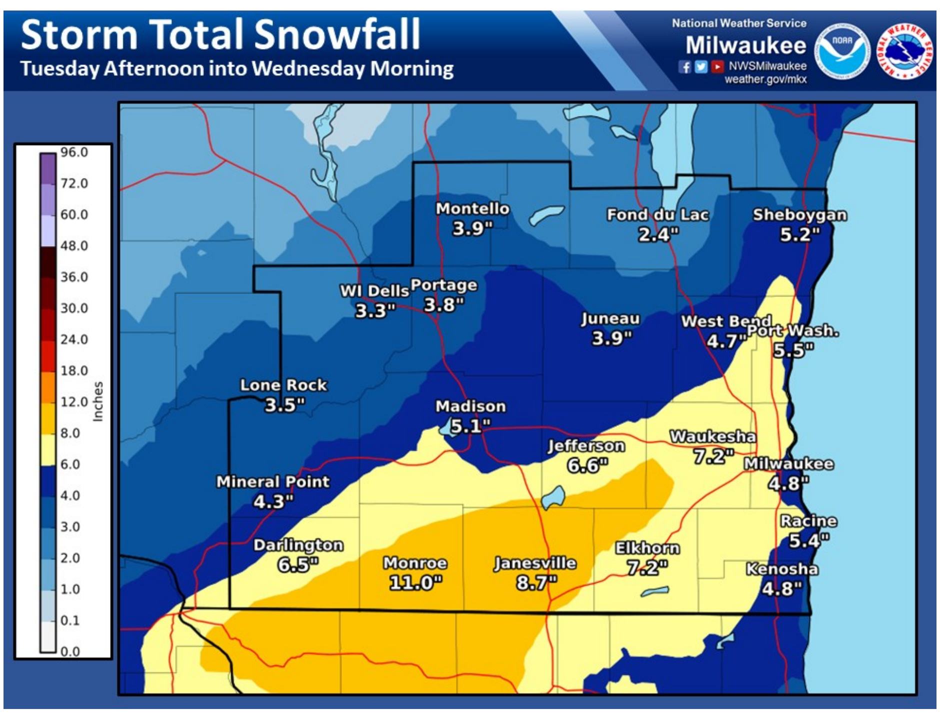
During the period of January 10-12, 2020, a severe winter storm and flooding impacted communities in Kenosha, Milwaukee, and Racine counties. On January 10 a winter storm brought a wintery mix of snow, freezing rain, and ice to much of eastern Wisconsin. On January 11, strong onshore winds gusting at 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 11, 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.

*December 29-30*

In southern and southeastern Wisconsin, a fast-moving winter storm brought 6 to 8 inches of snow in a span of 10 to 12 hours. A few higher amounts approaching 12 inches were reported in parts of Rock and Green counties. The speed of the storm limited snowfall in the area. Had the storm been slower, areas would have seen even higher snowfall amounts. This event was the first Winter Storm Warning of the 2020-2021 winter season for the area. Figure 3.8.2-6 shows the total snowfall accumulations from this winter storm.

**Figure 3.8.2-6: Storm Total Snowfall, December 30, 2020**




Source: NWS, Milwaukee/Sullivan

2021

*February 5-14*

In February 2021, Wisconsin experienced record and near record low temperatures. From February 5 to February 14, the average temperature was 0.2° F in Green Bay. The coldest record was -9.7° F over the same period in 1899. On February 7, Appleton, Wisconsin set a record low temperature of -20° F. On February 8, Antigo set a record low at -31° F and Rhinelander set a record low at -33° F. Several cities also set record lowest maximum temperatures. The extreme cold hindered travel across the state and the efficacy of road treatments.

## 3.8.3 Probability, Vulnerability, and Mitigation Potential

**Table 3.8.3-1: Hazard Ranking**

| Evaluation Criteria | Description | Ranking |
|---|---|---|
| Probability | • Occurs annually or assumed to occur at least once per year. Near 100% probability of occurrence each year. | Highly Likely |
| Vulnerability | • Minimal countermeasures are in place to prevent or protect against this hazard.<br>• Countermeasures may have potential but limited demonstrated history in reducing the threat potential.<br>• The nature of the hazard may limit the availability of countermeasures | High |
| Mitigation Potential | • Methods for reducing risk from the hazard are not well-established, are not proven reliable, or are experimental<br>• The state or counties have little or no experience in implementing mitigation measures, and/or no technical knowledge of them<br>• Mitigation measures are ineligible under federal grant programs<br>• There is a very limited range of mitigation measures for the hazard, usually only one feasible alternative<br>• The mitigation measures have not been proven cost-effective and are likely to be very expensive compared to the magnitude of the hazard<br>• The long-term effectiveness of the measures is not known, or is known to be relatively poor | Low |

Probability

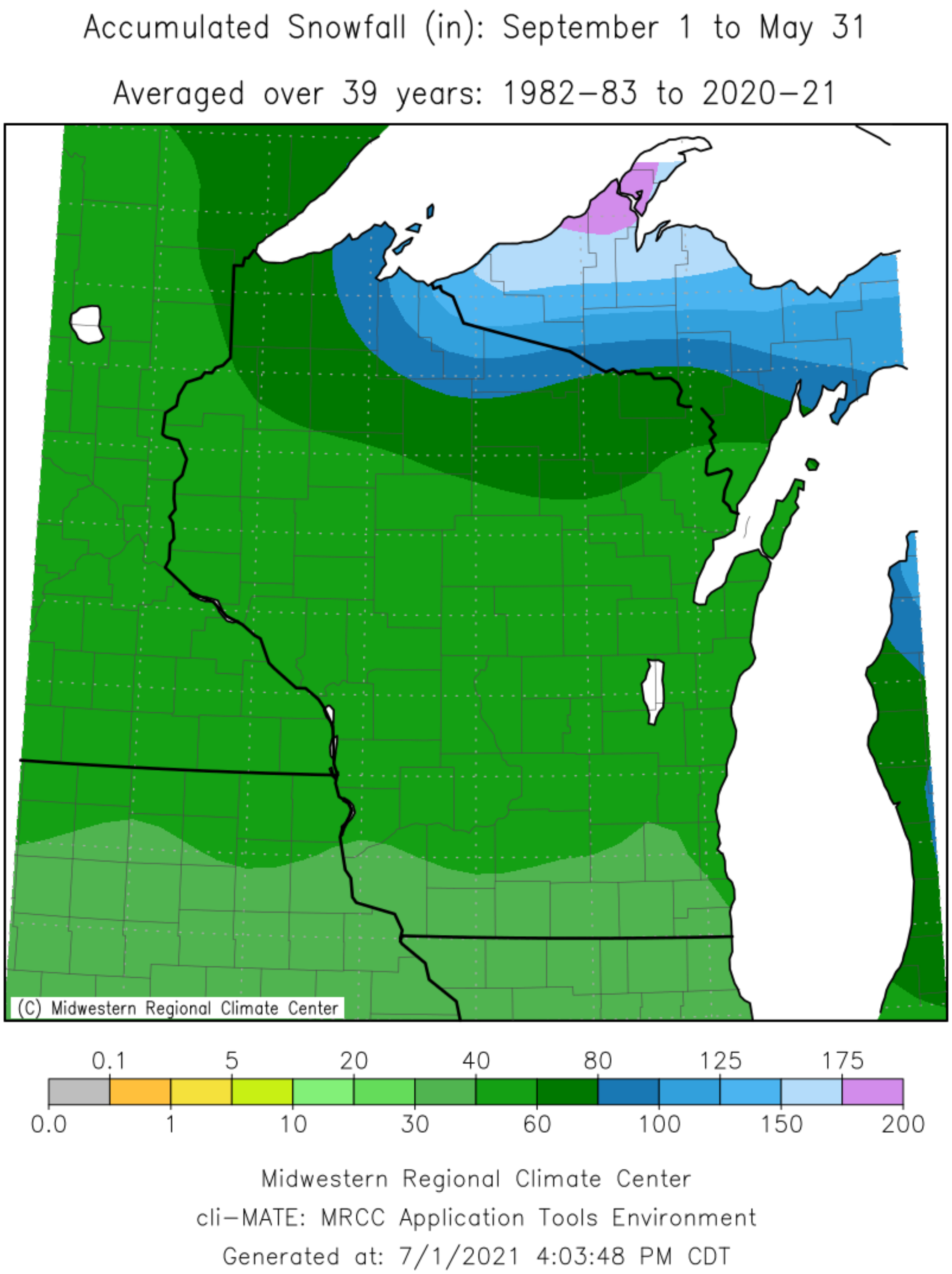
Generally, the winter storm season in Wisconsin runs from October through March. Severe winter weather has occurred, however as early as September and as late as the latter half of April and into May in some locations. Overall, there is a highly likely probability of winter storms and extreme cold each year in Wisconsin.

*Snowfall*

Much of the snowfall in Wisconsin occurs in small amounts of one to three inches per event. Heavy snowfalls that produce at least six inches of accumulation in one county happen on average about ten to 12 times per winter statewide. The northwestern and north central parts of the state can experience early and late season storms, while any part of Wisconsin can receive heavy mid-winter snows.

Seasonal snowfall in Wisconsin varies between the seasonal average of approximately 30 inches in the extreme south-central area of the state to over 100 inches in the Lake Superior snowbelt in Ashland and Iron counties. Average values in some areas of the Lake Superior snowbelt are much higher than 100 inches (upwards of 160 inches) but are very localized. Average annual snowfall across Wisconsin is shown in Figure 3.8.3-1. This data is for the 39-year period starting the winter of 1982-83 through the winter of 2020-21.

**Figure 3.8.3-1: Average Annual Snowfall in Wisconsin, 1982-83 to 2020-21**




Source: NOAA, NWS, Milwaukee/Sullivan

*Blizzards*

In Figure 3.8.3-2, the total number of Wisconsin blizzard events by county is shown for the winters from 1982-83 through 2020-21. Though the northern part of the state receives higher precipitation, more high-wind accumulations and drifting events occur in the southern half of the state, on average. Grant and Manitowoc counties have seen the most blizzards with nine each, while Dodge, Door, and Rock counties are just behind that with eight each.

*Ice Storms*

Ice and sleet storms can occur anytime throughout the winter season from October through April. Early and late season ice and sleet storms are generally restricted to northern Wisconsin. Otherwise, most of these storms occur from west central through northeast Wisconsin. On average, a major ice storm occurs with a frequency of about once every other year. In addition, between three and five instances of glazing (less than ¼" of ice accumulation) occur throughout Wisconsin during a normal winter. A county distribution of ice storms for the winters 1982-83 through 2019-20 is shown in Figure 3.8.3-3.

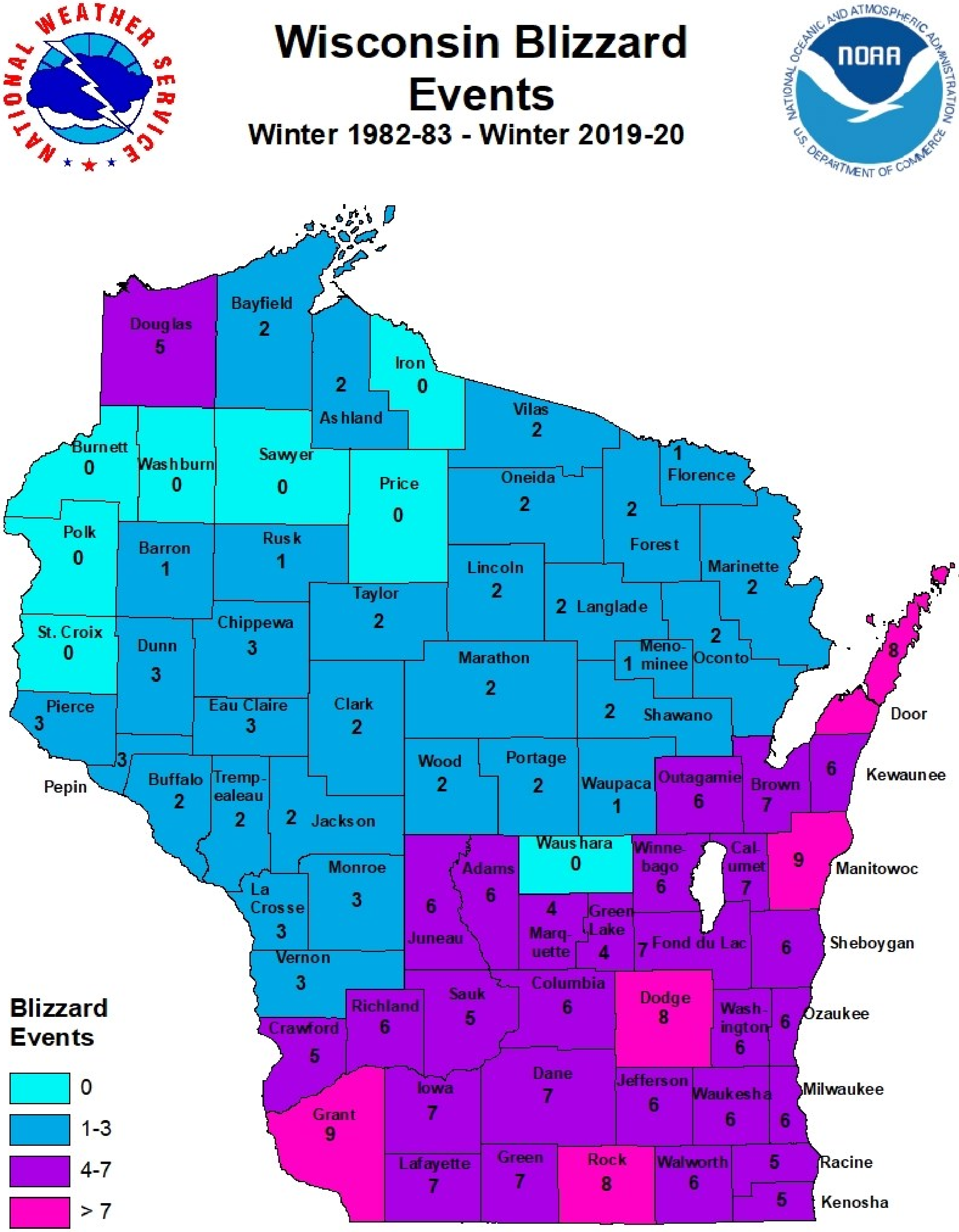
*Winter Storms*

In Figure 3.8.3-4, the total number of Wisconsin winter storm events by county is shown for the winters from 1982-83 through 2020-21. The northernmost counties in the state, Douglas, Bayfield, Ashland, Iron, and Vilas, saw the most winter storms.

*Yearly Average of Events*

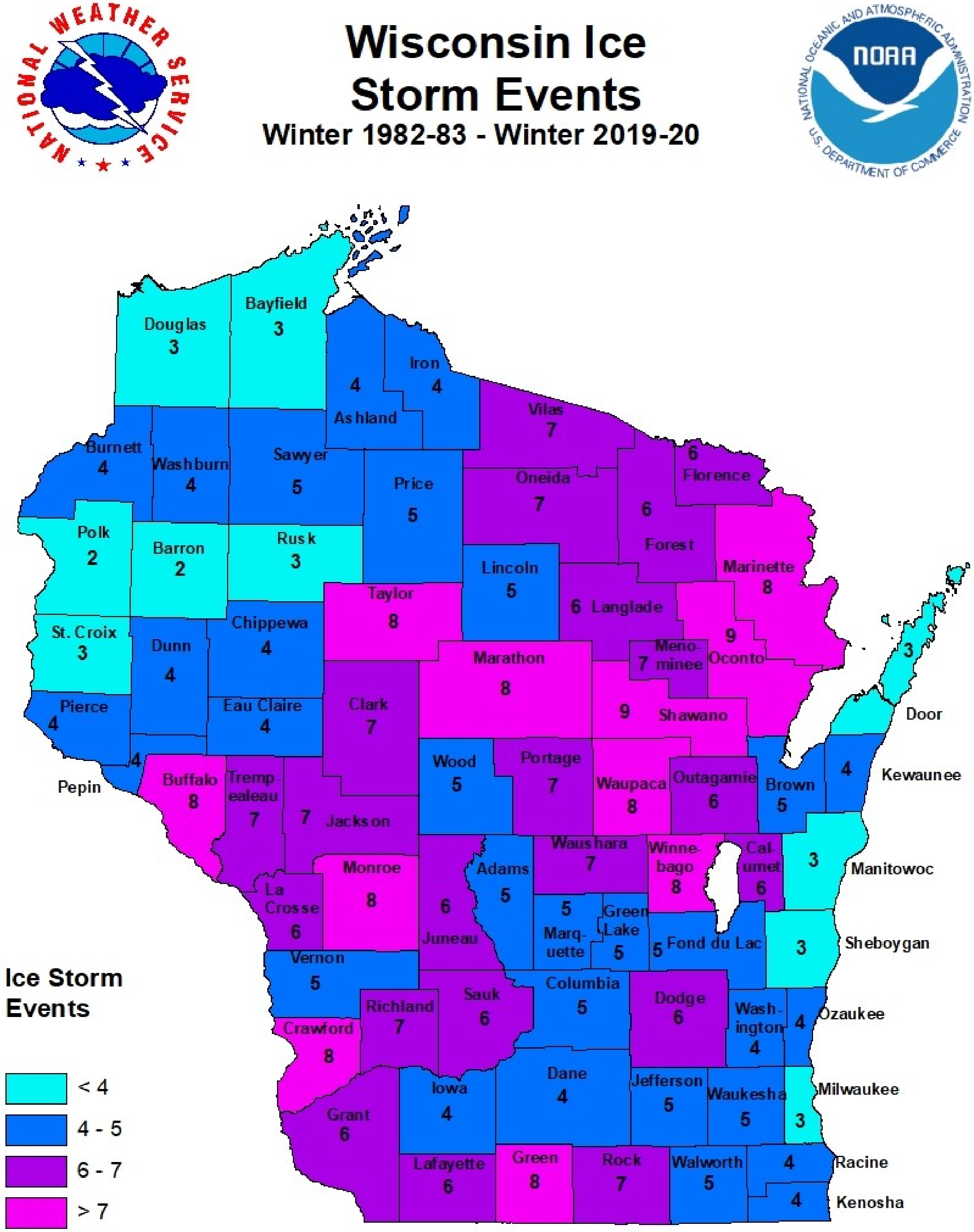
Figure 3.8.3-5 indicates a yearly average of severe winter weather events for each county from 1982-83 through 2015-16. This was calculated by dividing the total number of events by the number of winter seasons included. This map helps reveal the pattern of winter weather event probability, showing the highest likelihood in the northern counties of Douglas, Bayfield, Ashland, Iron, and Vilas.

**Figure 3.8.3-2: Wisconsin Blizzard Events by County, 1982-83 to 2019-20**



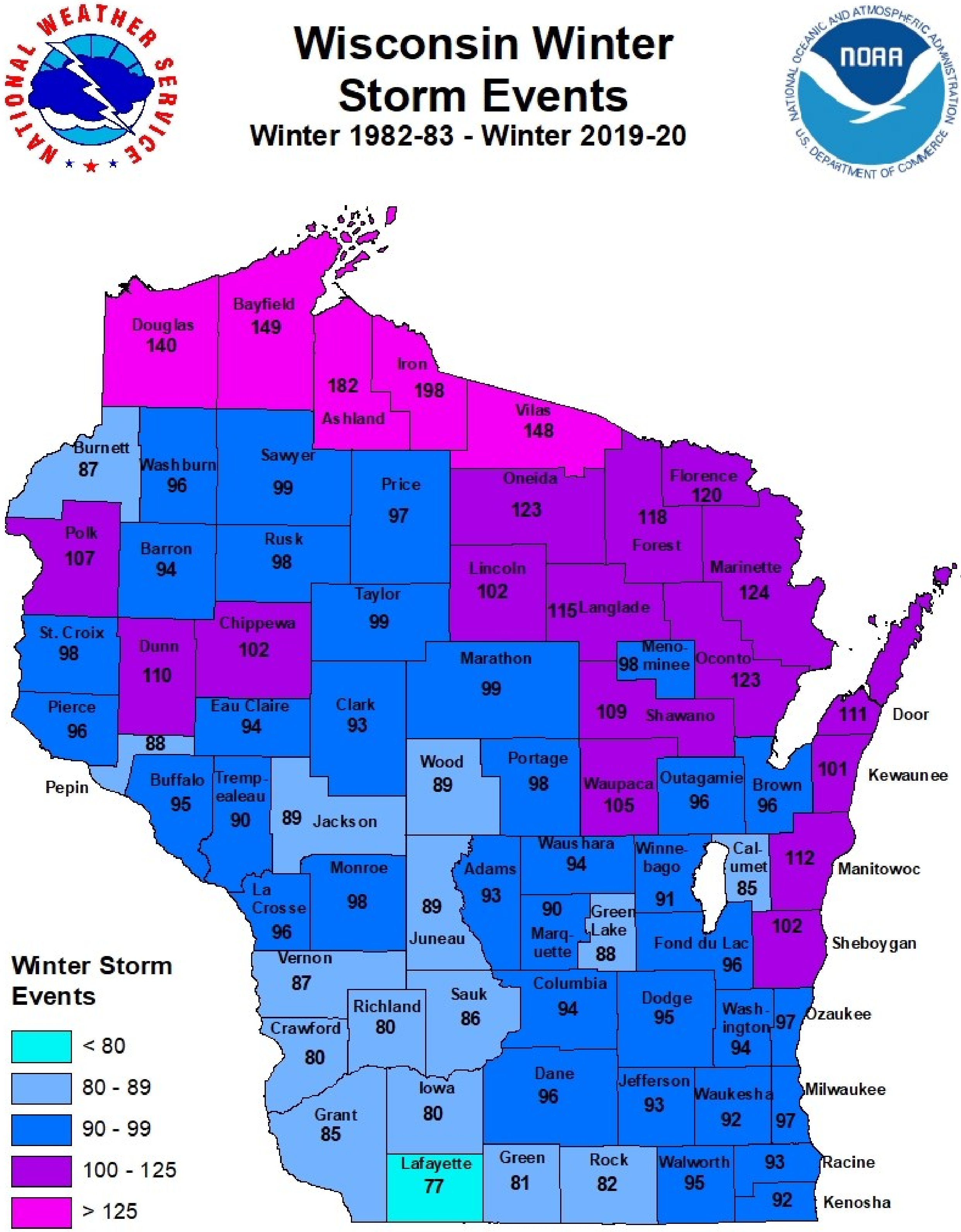

Source: NOAA, NWS, Milwaukee/Sullivan

**Figure 3.8.3-3: Wisconsin Ice Storms by County, 1982-83 to 2019-20**



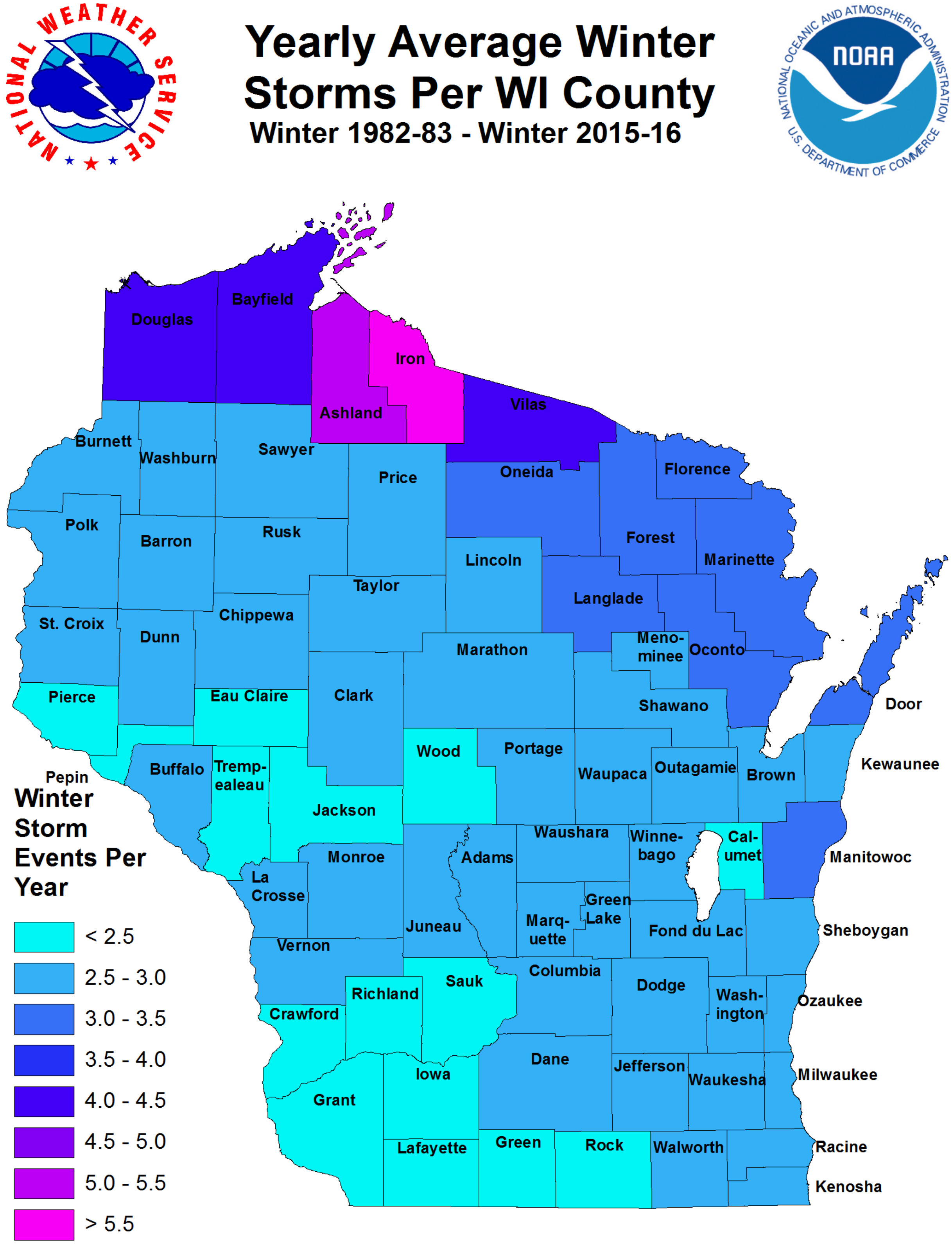

Source: NOAA, NWS, Milwaukee/Sullivan

**Figure 3.8.3-4: Wisconsin Total Winter Storm Events by County, 1982-83 to 2019-20**



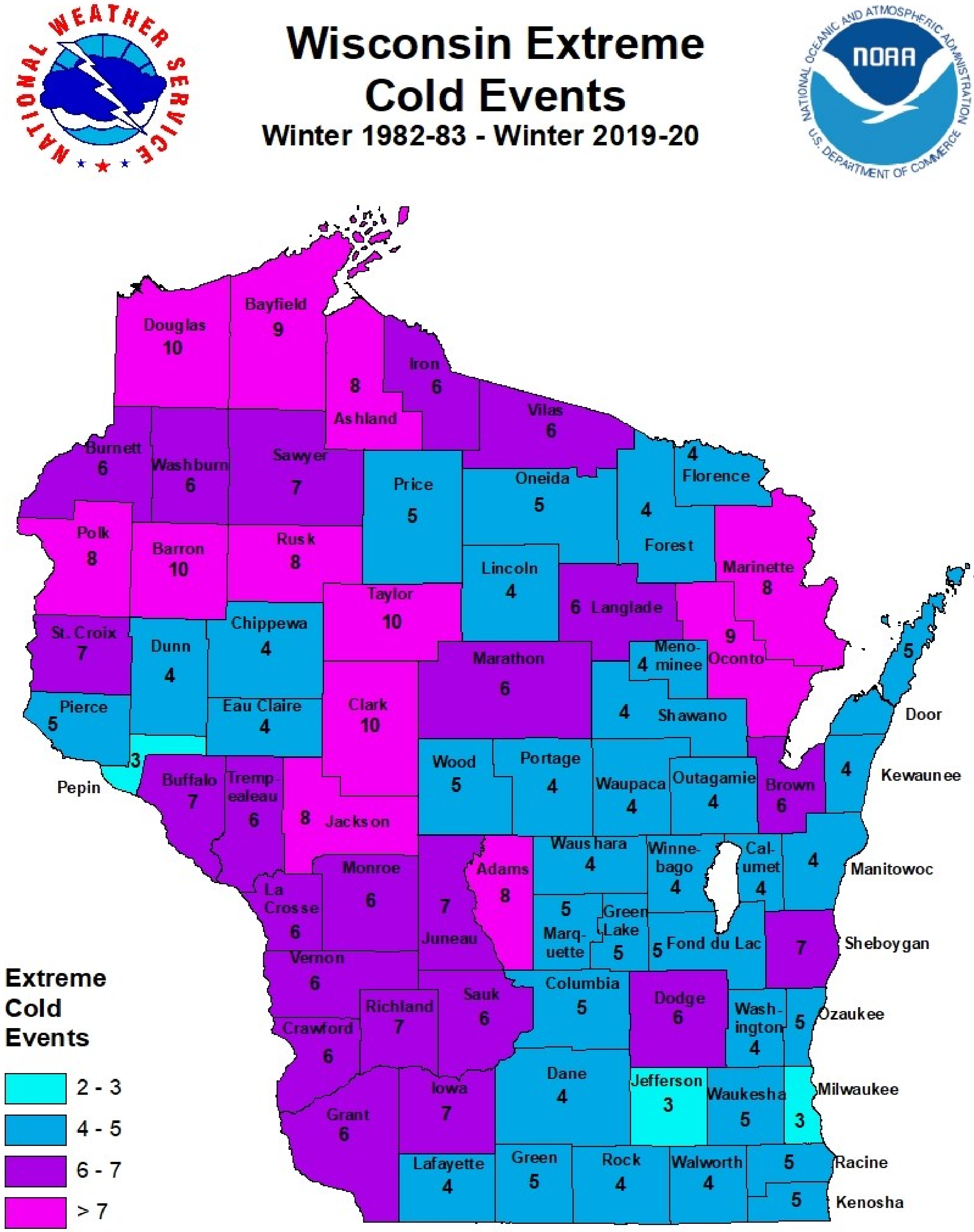

Source: NOAA, NWS, Milwaukee/Sullivan

**Figure 3.8.3-5: Wisconsin Average Annual Winter Weather Events by County, 1982-83 to 2015-16**




Source: NOAA, NWS, Milwaukee/Sullivan

**Figure 3.8.3-6: Wisconsin Extreme Cold Events by County, 1982-83 to 2019-20**




Source: NOAA, NWS, Milwaukee/Sullivan

*Winter Temperatures*

Figures 3.8.3-6, 3.8.3-7, and 3.8.3-8 show the winter (December through February) average temperatures, average number of days with below zero temperatures, and the average minimum lowest winter temperatures, respectively, statewide from 1971 through 2000 (best available data). These figures show that the northwestern and north central parts of the state – except the part along Lake Superior – experience the coldest temperatures and the southeastern and eastern parts of the state along Lake Michigan experience the least cold temperatures.

For winter weather overall, heavy snowfalls are likely to occur in northern Wisconsin in counties along Lake Superior. Although, based on snowfall totals across southern Wisconsin during the 2007-08 winter season, it is possible for seasonal totals of 150 inches or more to occur in southern and central Wisconsin; however, it is rare.

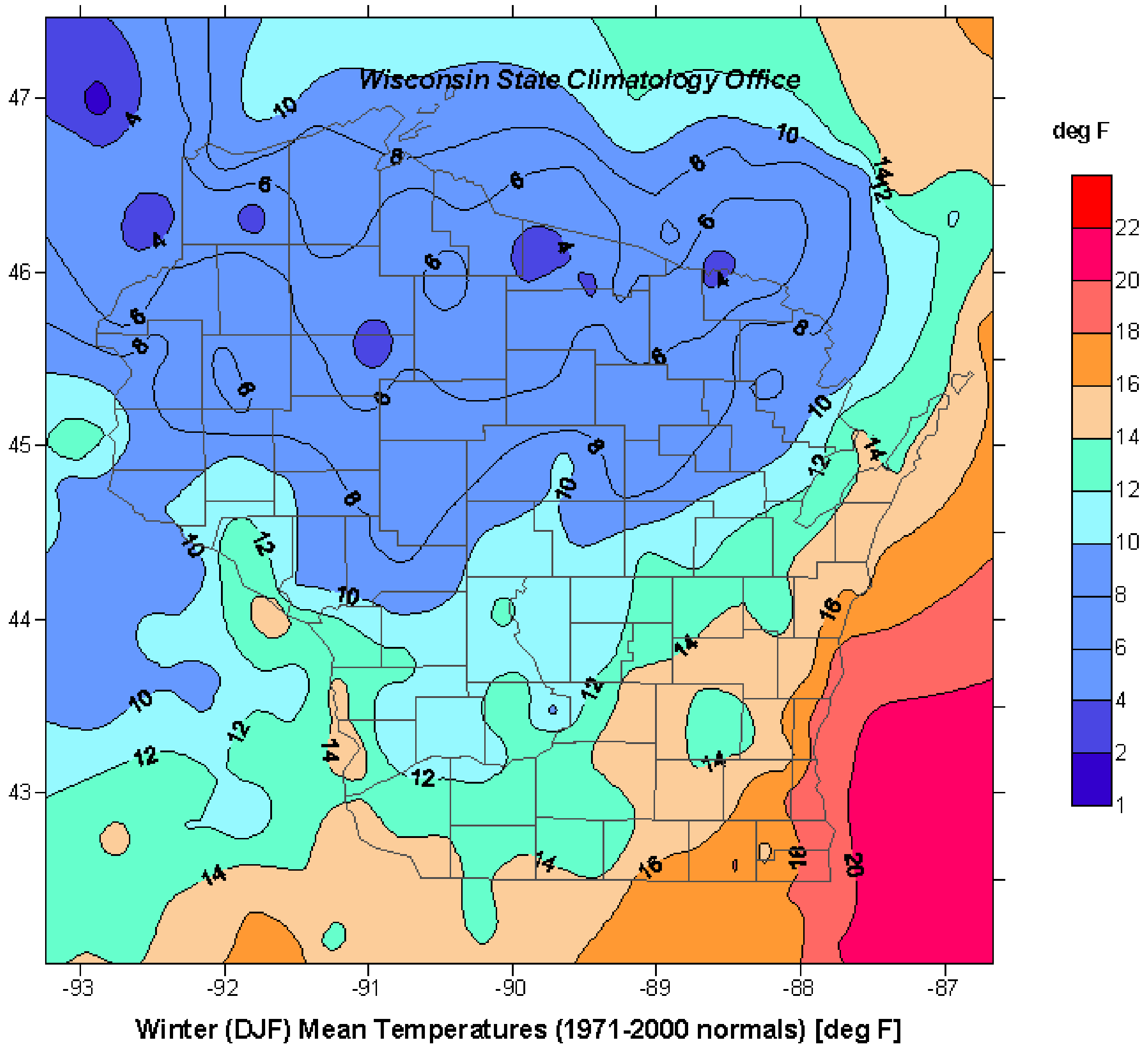
There is no clear pattern of the occurrence of ice storms throughout the state.

The lake effect from Lake Michigan and Lake Superior provides slightly warmer temperatures for those areas than those further inland, but also increases the likelihood of blizzards in the east and high snowfall in the north.

Vulnerability

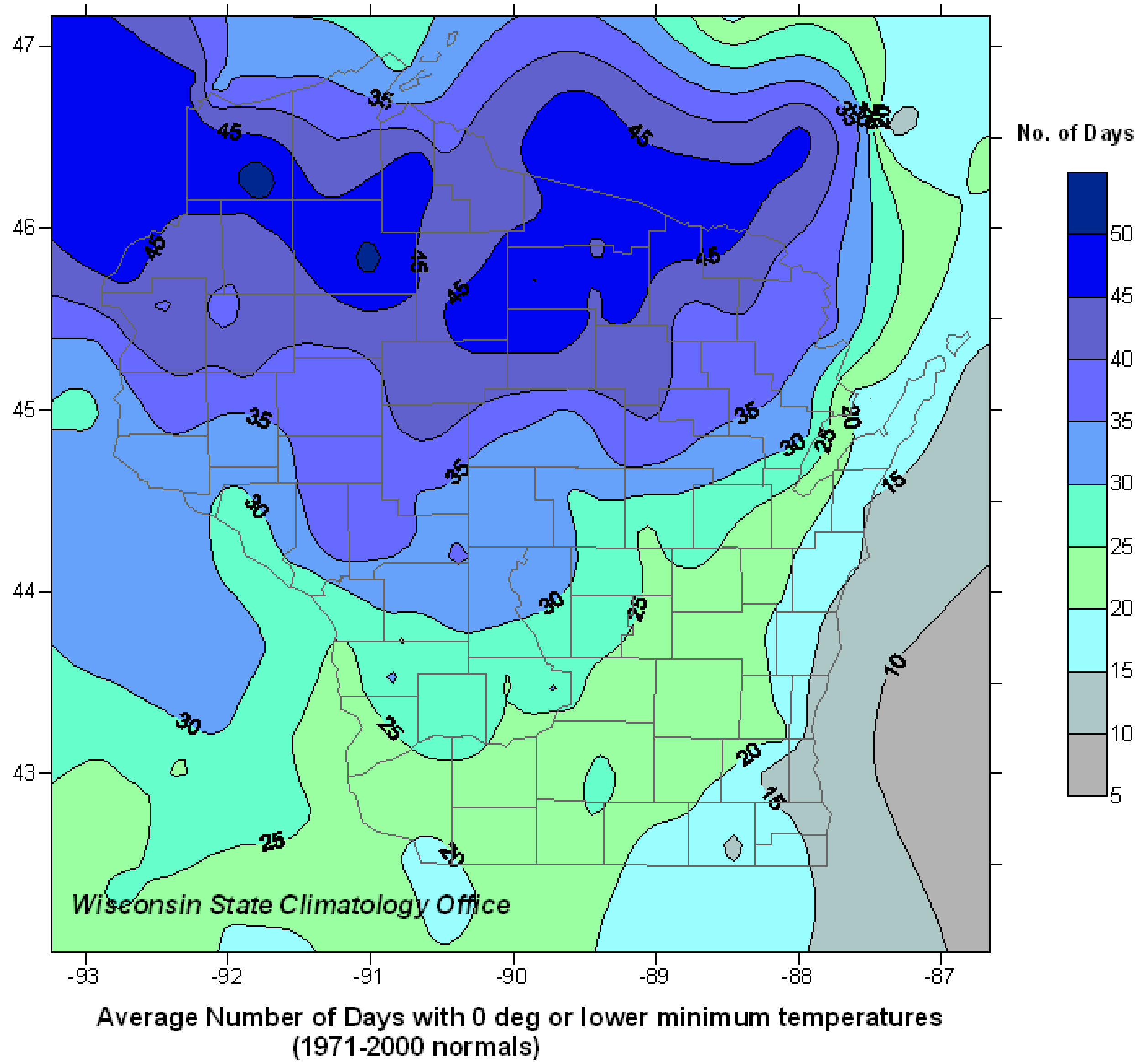
Heavy snow and ice storms can cause dangerous driving and walking conditions; traffic backups; damage to buildings, trees, utility poles and lines, and other structures; and power outages. High winds combined with extreme cold create unsafe conditions for people to be outside and can lead to frostbite, hypothermia, and death.

**Figure 3.8.3-6: Wisconsin Winter Average Temperatures, 1971-2000**



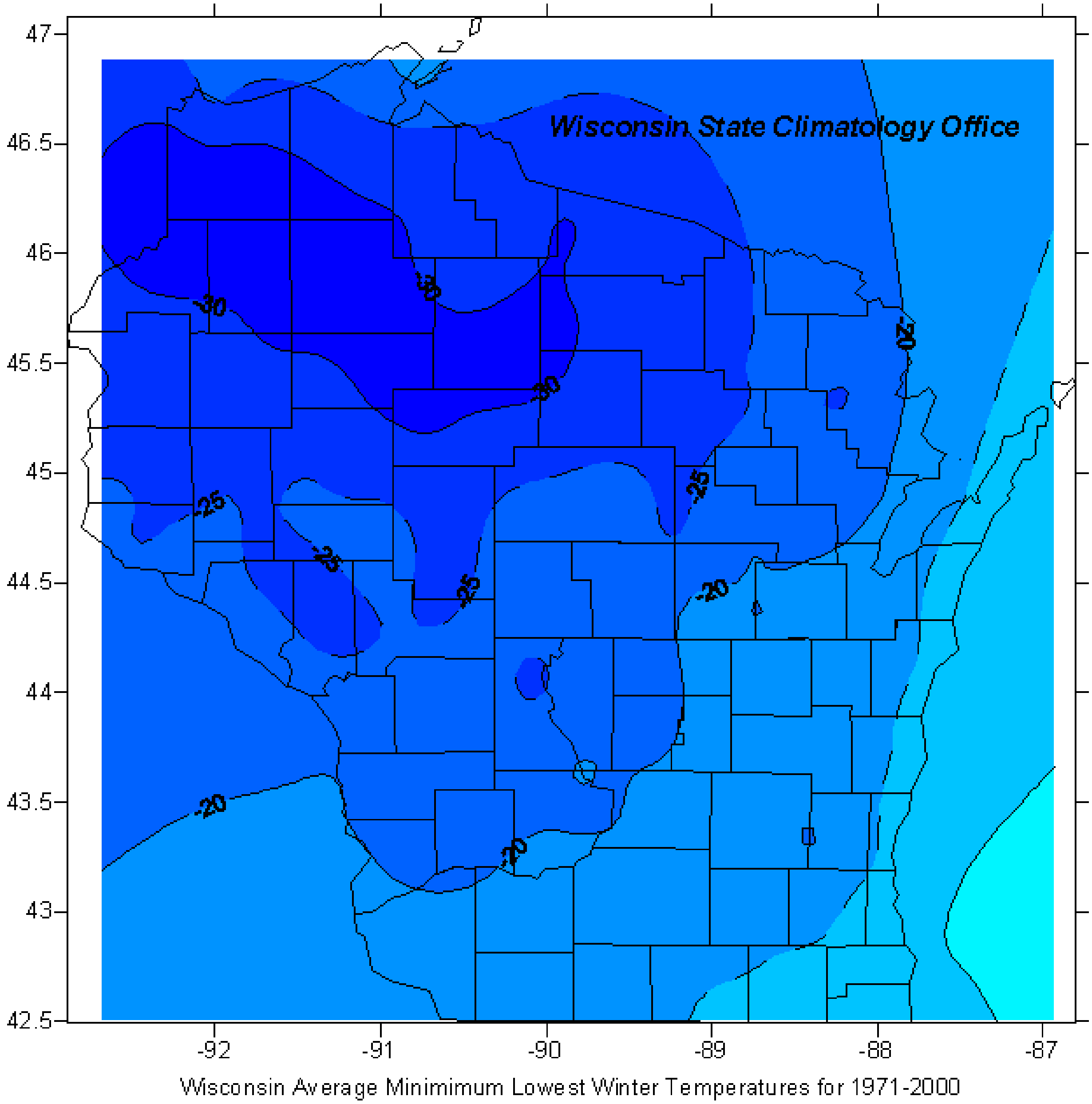

Source: Wisconsin State Climatology Office

**Figure 3.8.3-7: Wisconsin Average Days with Below Zero Lows, 1971 to 2000**




Source: Wisconsin State Climatology Office

**Figure 3.8.3-8: Wisconsin Average Lowest Minimum Winter Temperatures, 1971-2000**

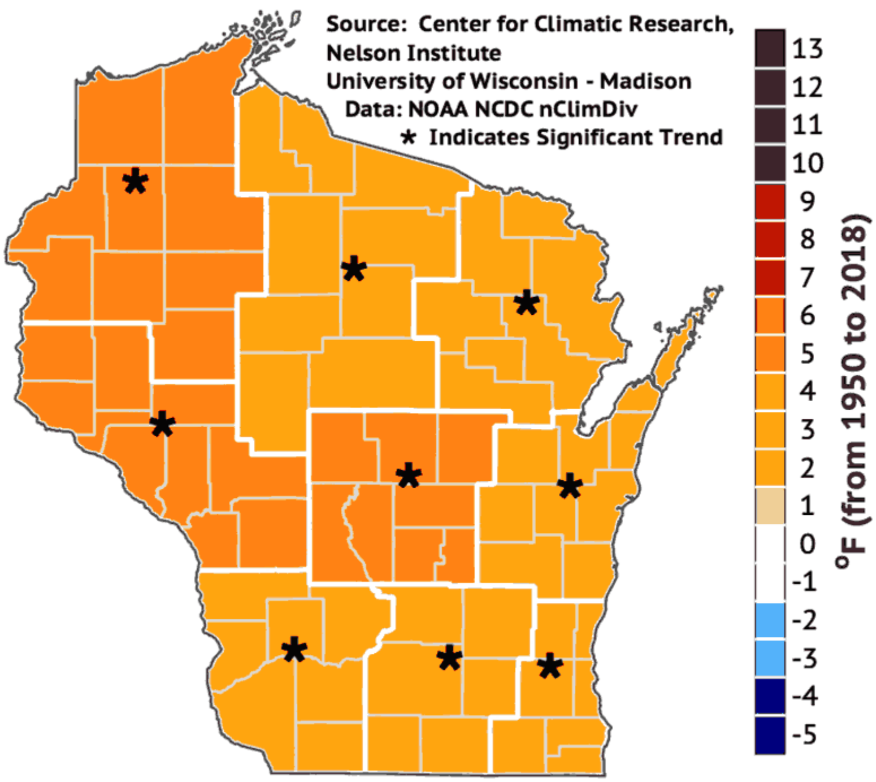



Source: Wisconsin State Climatology Office

### 3.8.4 Climate Change Impacts

The observed average temperature increase in the state has been highest for winter. Statewide, the temperatures have increased 2.5°F since 1950, with 4°F to 6°F increases in the northwest portion of the state, as seen in Figure 3.8.4-1. Wisconsin presently experiences fewer nights below 0°F than in 1950. Wisconsin's average growing season now lasts 12 days longer than it did in the 1950s. In other words, the "spring thaw" comes sooner, and the "fall freeze" comes later.

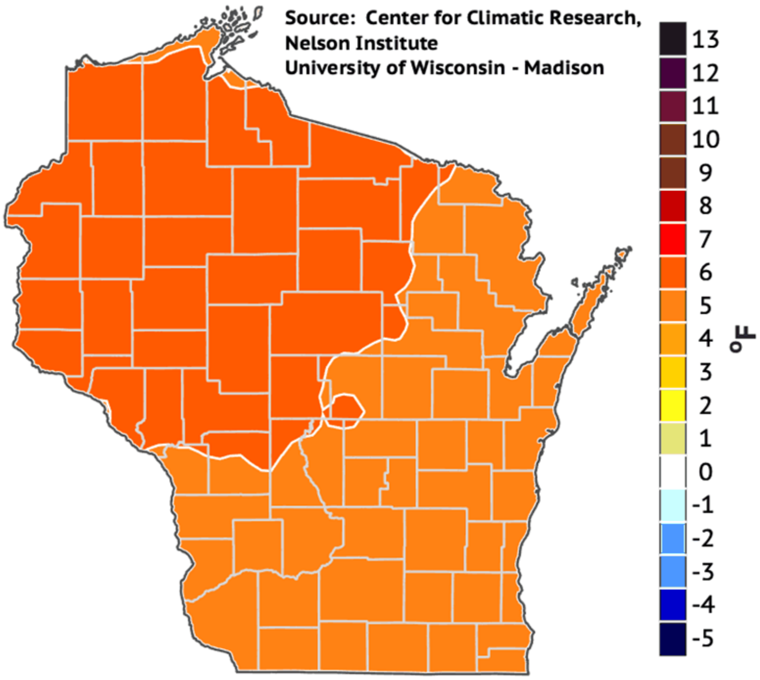
**Figure 3.8.4-1: Change in Winter Daily Average Temperature (°F) from 1950-2018**




Source: WICCI

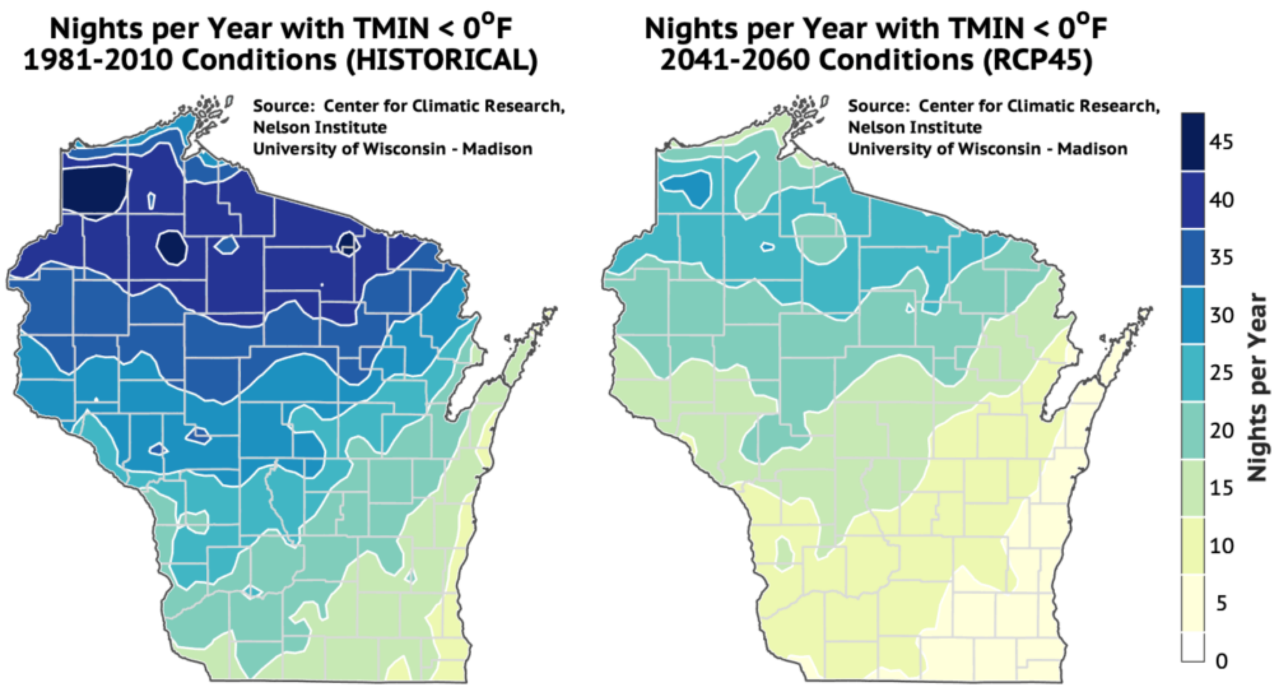
Looking toward the future, current models predict this winter warming trend to continue. According to WICCI's most recent predictions, Wisconsin's average winter temperatures will increase between four- and seven-degrees Fahrenheit by the mid-21st century (Figure 3.8.4-2). Additionally, the average number of nights each year with temperatures reaching below zero will decrease by between five and 15 nights (Figure 3.8.4-3). WICCI also predicts increases in wintertime precipitation, which could occur in the form of snow, rain, or freezing rain (Figure 3.8.4-4).

**Figure 3.8.4-2: Projected Change in Winter Daily Average Temperature (°F) from 1981-2010 Conditions to 2041-2060 Conditions**



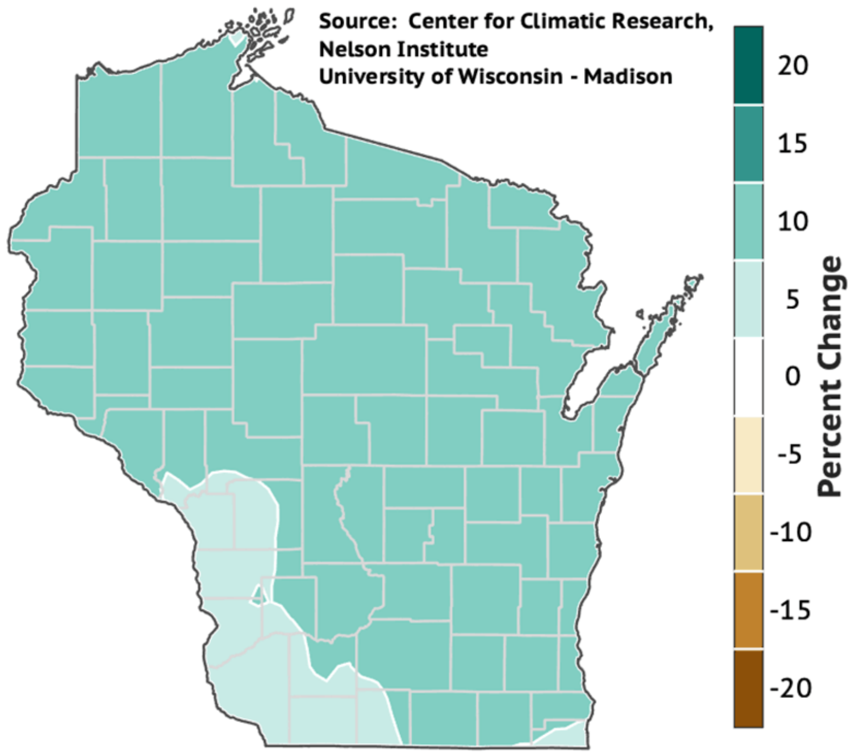

Source: WICCI

**Figure 3.8.4-3: Change in Nights per Year with Temperatures Below Zero (°F)**




Source: WICCI

**Figure 3.8.4-4: Projected Percent Change in Winter Average Precipitation from 1981-2010 Conditions to 2041-2060 Conditions**




Source: WICCI

A shorter overall winter season and fewer days of extreme cold may have both positive and negative indirect impacts. Warmer winter temperatures may result in changing distributions of native plant and animal species and/or an increase in pests and non-native species. Maple syrup production may also be affected by changes in winter weather patterns, which could have significant economic impacts as Wisconsin is the number four maple syrup producing state in the U.S.

Warmer winter temperatures will result in a reduction of lake ice cover. In addition to impacting human activities such as ice fishing, reduced lake ice cover impacts aquatic ecosystems by raising water temperatures. Water temperature is linked to dissolved oxygen levels and many other environmental parameters that affect fish, plant, and other animal populations. A lack of ice cover also leaves lakes exposed to wind and evaporation during a time of year when they are normally protected. On the Great Lakes, declining ice cover could lead to a benefit in the form of a longer commercial navigation season.

As both temperature and precipitation increase during the winter months, freezing rain will be more likely. Additional wintertime precipitation in any form will contribute to saturation and increase the risk and/or severity of spring flooding. A greater proportion of wintertime precipitation may fall as rain rather than snow; reduced snowpack may impact areas where winter tourism centered on cross-country skiing, snowmobiling, or other snow sports is part of the local economy.

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# 3.9 WILDFIRE

## 3.9.1 Nature of the hazard

Chapter 26.01(2) of the Wisconsin State Statutes defines **forest fires** as "uncontrolled, wild, or running fires occurring on forest, marsh, field, cutover, or other lands involving farm, city, or village property and improvements incidental to the uncontrolled, wild, or running fires occurring on forest, marsh, field, cutover, or other lands." They often begin unnoticed, can spread quickly, and are usually signaled by dense smoke that can fill the air for miles around. Wildfires in Wisconsin are primarily human caused by burning yard debris, arson, or campfires, for example. They can also be caused by natural events like lightning.

Types of Wildfires in Wisconsin

- **Interface or intermix fires** (also known as wildland-urban interface or WUI fires) occur in areas where both vegetation and structures provide fuel.
- **Firestorms** occur during extreme weather (i.e., high temperatures, low humidity, and high winds) with such intensity that fire suppression opportunities are limited. These events typically burn until the weather or fuel conditions change to reduce the fire spreading behavior.
- **Prescribed fires** occur with the intentional application of fire to wildland natural fuels, under specific environmental conditions, to accomplish planned land management objectives. They are a part of a fuel management strategy and one of the most complicated and complex operations to implement.

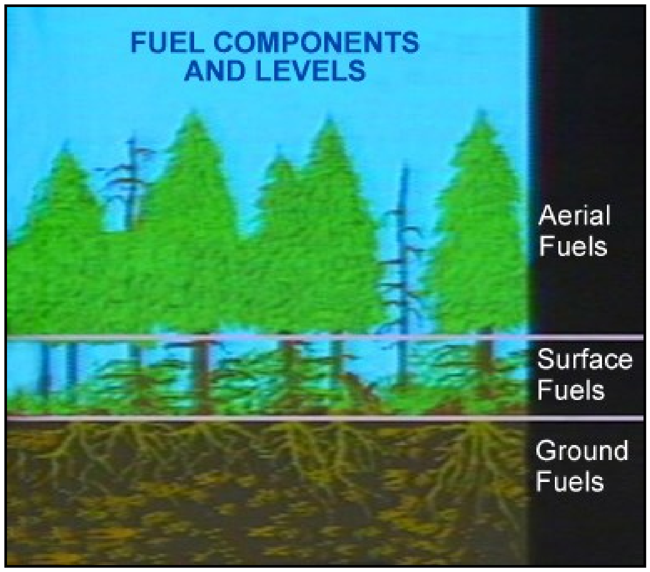
Factors Influencing Fire Behavior

*Fuels*

- Fuel is required for any fire to burn. Regarding wildfire, fuels may consist of the following:
    - Living vegetation: grass, shrubs, and trees
    - Dead plant material: dead trees, dried grass, fallen branches, pine needles, and leaves
    - Urban fuels: houses, vehicles, and other humanmade objects
- Fuels are arranged horizontally and vertically
    - **Horizontal** arrangement refers to the distribution of fuels over the landscape.
    - **Vertical** arrangement consists of the following (Figure 3.9.1-1):
        - **Aerial fuels** are green and dead materials in the upper forest canopy including treetops and branches, snags, and tall shrubs. **Crown fires** burn these aerial fuels and typically occur in conifer stands; this type of fire tends to be very intense and difficult to control.
        - **Surface fuels** are materials lying on or immediately above the ground including pine needles, leaves, grass, downed logs, stumps, tree limbs, and low shrubs.

- **Ground fuels** are combustible materials lying beneath the ground, including deep duff, roots, buried logs, and other organic matter. Fires in ground fuels are usually called **peat fires**.

**Figure 3.9.1-1: Fuel Components and Levels**




Source: Utah State University

*Weather*

- Temperature: Higher temperatures preheat fuels by driving off moisture, which allows fuels to burn faster.
- Relative humidity: Lower relative humidity and a lack of precipitation lower fuel moisture; dry fuels burn more easily than fuels with higher moisture content.
- Wind speed: Wind is the most important weather factor in wildfire risk because it both dries fuel and increases the supply of oxygen. Wind has the greatest influence on the rate and direction of fire spread. In Wisconsin, wind direction almost always changes in a clockwise rotation and winds tend to be strongest in the mid-afternoon.

*Topography*

- Slope: Steep slopes spread fire rapidly. Fire travels faster uphill and afternoon winds travel upslope as hot air rises, pushing fire even faster.
- **Aspect:** Aspect is the direction a slope faces. In Wisconsin, north-facing slopes tend to be more shaded with more moisture and heavier fuels, such as deciduous trees. South-facing slopes tend to be sunnier and drier, with more light fuels like grasses.

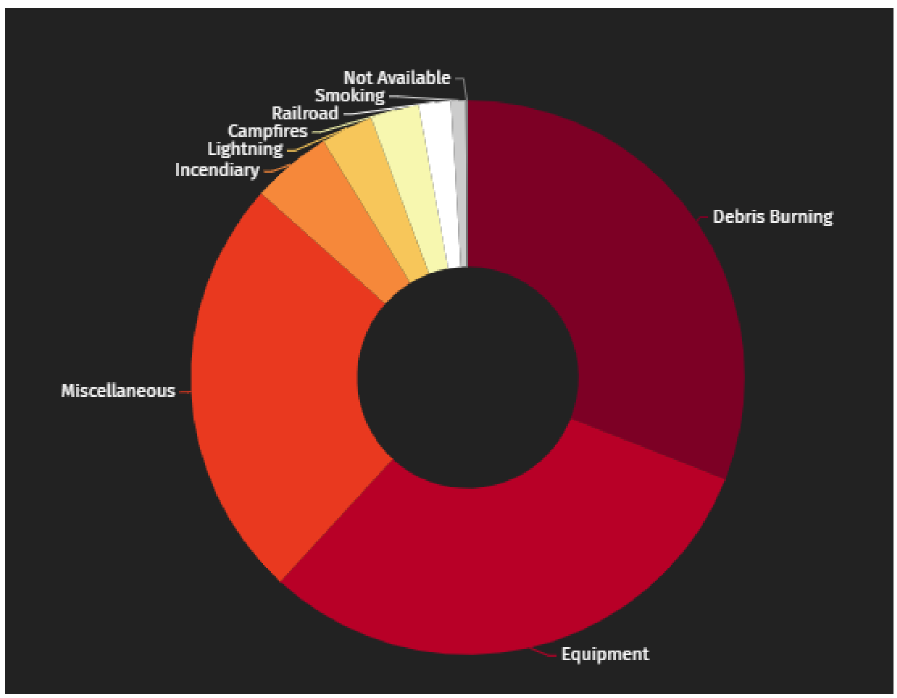
<u>Interaction with Other Hazards</u>

Certain natural hazards cause wildfires, some intensify them, and wildfires can intensify other natural hazards. In Wisconsin, the following hazards may interact with wildfires, altering the conditions in the fire:

- Severe thunderstorm wind events: Higher wind speeds increase the rate at which wildfires spread. The rate of spread varies directly with wind velocity. Additionally, high winds and downbursts can cause blowdowns, leaving downed trees and branches as fuel for wildfires. See Section 3.2.3 for more information about severe thunderstorms.
- Lightning: A cloud-to-ground lightning strike may cause a wildfire. See Section 3.2.6 for more information about lightning.
- Flooding: Wildfires clear vegetation from the landscape, decreasing the soil's ability to absorb moisture and removing obstructions that could slow floodwaters. This increases the likelihood of flooding in fire-ravaged areas. See Section 3.3 for more information about flooding.
- Landslides: Because wildfires remove vegetation and damage soils, flash runoff erosion is more likely and can contribute to landslides. See Section 3.5 for more information about landslides.

<u>Wildfire Management</u>

Figure 3.9.1-2: Wisconsin **2021 Wildfires by Cause**




Source: Fire Management Dashboard

Figure 3.9.1-2 shows the percent of Wisconsin wildfires attributed to each cause. Debris burning and equipment fires make up over half of the wildfire causes (~62%). The vast majority overall are caused by human error. When fires get out of control, wildfire management must be employed. **Wildfire management** involves the control, containment, and suppression of a wild or uncontrolled fire. If not promptly controlled, a wildfire may grow into an emergency or disaster. Even small fires can threaten lives, resources, and improved property. The indirect effects of wildfires can also be detrimental. In addition to charring vegetation and destroying forest resources, large, intense fires can harm the soil, waterways, and the land itself.

Firewise USA© Program

Firewise USA© is a national program designed to help fire-prone neighborhoods improve wildfire readiness. The program's emphasis is on acting before a wildfire occurs through personal responsibility and the development of local solutions. Three key reasons to join the Firewise program are:

1. Your neighborhood is within a designated Community at Risk to wildfire (more in Section 3.9.3).
2. Organization leaders and property owners are concerned about the impacts of wildfires.
3. Your neighborhood, fire department, and local DNR forestry managers are committed to the recognition process.

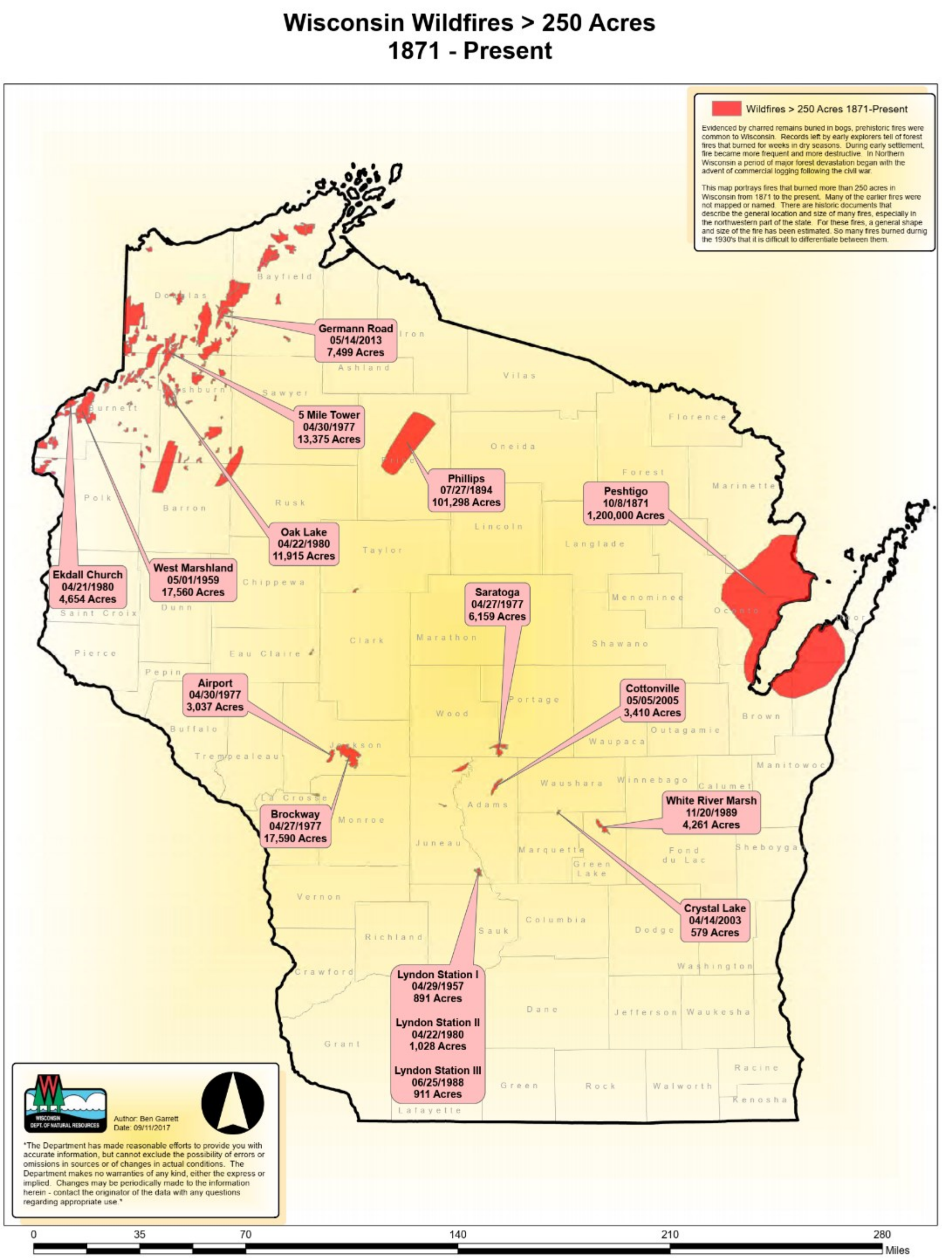
It is free and available to be earned by property owners' associations, camps, and other neighborhood groups. Once apart of Firewise, your organization will select a yearly wildfire risk reduction project and can apply for grant funds. One project per year is required to earn and maintain the Firewise recognition status. Previous project examples include: Firewise workshop or presentation, curbside chipping of brush, common area brush cleanup, educational materials, and homeowner wildfire risk assessments.

Firewise USA© recommendations are primarily focused on the **Home Ignition Zone (HIZ)** – an area extending 100 to 200 feet beyond each side of all buildings on a property. In a well-designed site, the HIZ should provide enough distance between buildings and a wildfire and should modify vegetation around the structure so it acts as a fire break instead of a spreading aid. Creating such defensible space increases the chance of buildings surviving wildfire without outside help. There are currently 12 Wisconsin communities in the Firewise program, mainly in the central part of the state.

## 3.9.2 History

While most of the wildfire starts in Wisconsin are quickly contained and kept to less than ten acres in size, Wisconsin has experienced catastrophic fires throughout its history. The DNR highlights the wildfire events described below as noteworthy wildfires in the state's history. All these instances are also portrayed in Figure 3.9.2-1 to show the size and impacts of each event.

**Figure 3.9.2-1 Wisconsin Wildfires, 1870-present**




Source: DNR

October 8, 1871

The most disastrous fire in Wisconsin's history was the Peshtigo Fire, which burned 1.2 million acres of forest in Northeast Wisconsin. The main counties affected were Oconto, Marinette, Shawano, Brown, Kewaunee, Door, and Manitowoc, as shown in Figure 3.9.2-2 to the right. It is said that the city of Peshtigo was lost in an hour. The fire was estimated to have caused $169 million in damages, displaced 3,000 people, killed 1,152 people, and left another 350 missing. This event was the greatest single loss of human life by fire in American history; however, the Great Chicago Fire occurred at the same time and received much more publicity. It is still unknown how the fire started, but surivor accounts indicate that railroad workers clearing land for tracks started a bush fire that soon became an inferno. Notably, the Peshtigo Fire had a low fire risk, but a high fire hazard. More on this distinction in Section 3.9.3.

**Figure 3.9.2-2: 1871 Peshtigo Fire**


Source: NWS

July 24, 1894

On July 27, 1894, the Phillips Fire burned over 100,000 acres in Price County. It destroyed 400 homes and much of the downtown area in the City of Phillips. 13 people died trying to escape by swimming across Long, Duroy, and Elk Lakes.

1930-34

In the dust bowl era, severe droughts ravaged the state. During this four-year period, about 2,950 fires burned 336,000 acres annually in Wisconsin.

May 1, 1959

Extreme fire conditions in Burnett County from a previously dry winter resulted in 17,560 acres burned and $200,000 of forest and property damage on May 1, 1959. While personnel were prepared and on standby for the threat of such fires, a structure fire that spread into a swamp required the help of virtually every available fire fighter, fire department, and heavy equipment in a four-county area.

1977

The entire state suffered two years of severe drought. Nearly 49,000 acres burned in 1977 alone. Over 170 structures were destroyed or damaged. Jackson, Washburn, Douglas, and Wood Counties were the worst hit. The Saratoga Fire in Wisconsin Rapids (Wood County) burned 6,159 acres and destroyed 90 buildings; the Brockway Fire in the Black River Falls area (Jackson County) burned 17,590 acres; and the Five-Mile Fire in Washburn and Douglas Counties burned

13,375 acres and destroyed 83 buildings. Total damages for the 1977 fires were over $2.4 million dollars.

April 21-23, 1980

Over two days in April, the Ekdall Church Fire in Burnett County and the Oak Lake Fire in Washburn County together burned over 16,000 acres and destroyed more than 200 buildings. Thousands of firefighters spanning across multiple fire departments, and a variety of vehicles/equipment were utilized to contain the fires. Figure 3.9.2-3 to the right shows the fire area for Ekdall Church.

**Figure 3.9.2-3: 1980 Ekdall Church Fire**


Source: Paul Fehrenbach

November 20, 1989

In Green Lake and Marquette counties, a human-caused wildfire burned 4,261 acres in the White River Marsh wildlife area which spans 12,000 acres.

April 14, 2003

The Crystal Lake Fire in Marquette and Waushara Counties burned 572 acres. Nearly 200 buildings were threatened, and several were destroyed. The fire started near a campground and was determined to have been caused by debris burning.

May 5, 2005

On May 5, 2005, the Cottonville Fire burned a swath 1.5 miles wide and seven miles long through the Towns of Big Flats, Preston, and Colburn (Adams County). It took nearly 200 personnel to suppress the wildfire in about 11 hours. Over 100 people were evacuated for several days while crews extinguished smaller fires. There were nine year-round residences, 21 seasonal homes, and at least 60 outbuildings destroyed in the 3,410-acre fire. 300 buildings were saved due to firefighting efforts.

May 14, 2013

In the afternoon of May 14, 2013, a logging crew accidentally started a fire while harvesting timber. The Germann Road Fire consumed 7,500 acres in 30 hours, destroyed 104 structures, and was one of the largest wildfires to hit the state in over 33 years. The affected areas were the Towns of Gordon and Highland in Douglas County, and the Town of Barnes in Bayfield County.

*Recent Fires in Wisconsin*

Fortunately, Wisconsin has been in a wet pattern for the last decade, so there have been fewer catastrophic wildfires to highlight since the 2016 update of the plan. Regardless, Table 3.9.2-1 below shows the 20 most significant fires in Wisconsin since 2016. These events were sorted by acres burned (largest to smallest) and summarized below for convenience.

**Table 3.9.2-1: Significant Fires in Wisconsin, 2016-2021**

| Fire Name | Origin Date | Acres Burned | County Name | Fire Danger Rating | Total Cost |
|---|---|---|---|---|---|
| MM | 4/3/2019 | 385.68 | Winnebago | High | $ 17,224.92 |
| County MM fire | 11/2/2020 | 320.2 | Winnebago | High | $ 20,962.84 |
| Hwy B | 11/8/2020 | 262.14 | Winnebago | High | $ 29,098.18 |
| Railroad 2 | 4/4/2021 | 257 | Juneau | Very High | $ 62,013.18 |
| Jefferson Marsh 1 | 4/7/2018 | 252.51 | Jefferson | Very High | $ 6,001.79 |
| 17th Fire | 4/18/2020 | 234.13 | Juneau | Very High | $ 36,367.13 |
| Marcy Rd | 4/2/2021 | 229.94 | Waukesha | Very High | $ 73,540.00 |
| Beaver Dam | 4/8/2018 | 148.93 | Dodge | Moderate | $ - |
| Pleasant Valley | 4/30/2018 | 122.28 | Eau Claire | Moderate | $ 15,224.15 |
| County Highway E | 4/3/2021 | 115.43 | Washburn | High | $ 8,979.33 |
| Hay Creek | 5/18/2018 | 104.59 | Clark | High | $ 14,864.60 |
| Bruce Mound | 4/29/2018 | 89.78 | Clark | High | $ 24,628.12 |
| Albatross | 4/3/2021 | 88.38 | Grant | Very High | $ 2,974.00 |
| Tichigan Marsh | 12/1/2020 | 76.88 | Racine | Low | $ 10,402.52 |
| Galilee Rd | 3/31/2021 | 74.83 | Waupaca | Very High | $ 12,398.49 |
| Dead River | 5/17/2021 | 72.59 | Marquette | High | $ 3,655.17 |
| Range Line | 4/4/2021 | 65.24 | Langlade | Very High | $ 6,997.97 |
| Mud Creek | 8/6/2020 | 60.96 | Waushara | Moderate | $ 13,916.83 |
| Pole Grove | 11/3/2020 | 45.23 | Jackson | High | $ 1,826.14 |
| Perch Lake Fire | 4/16/2019 | 43.99 | Washburn | Moderate | $ 1,009.30 |

Source: Fire Management Dashboard, WEM

Acres-burned is one way to categorize wildfires in the last five years, but it should be emphasized that most wildfires (~81%) are under ten acres and still cause significant damage to land and structures. While these are not highlighted in their own table, there is more information on the probability, vulnerability, and mitigation potential of both small and large fires in the next section.

### 3.9.3 Probability, Vulnerability, and Mitigation Potential

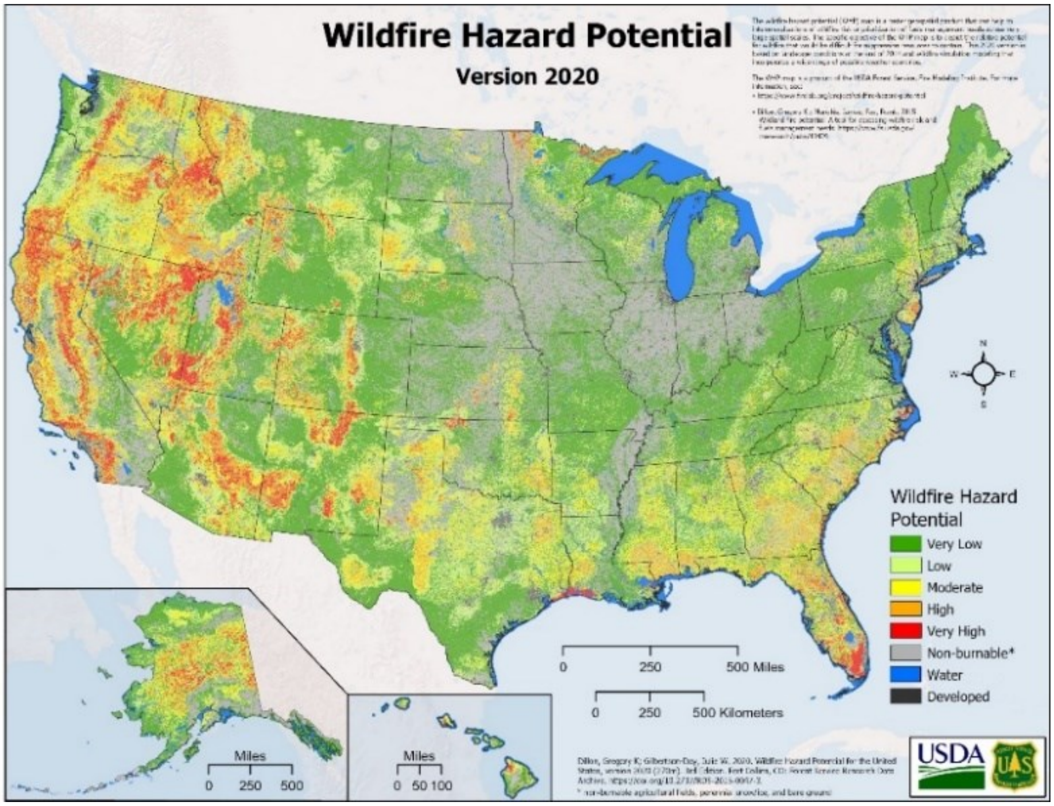
**Table 3.9.3-1: Hazard Ranking**

| Evaluation Criteria | Description | Ranking |
|---|---|---|
| Probability | • Occurs annually or assumed to occur at least once per year. Near 100% probability of occurrence each year. | Highly Likely |
| Vulnerability | • Multiple measures are in place to prevent or protect against this hazard.<br>• Countermeasures have been tested and have demonstrated success in reducing the threat potential | Medium |
| Mitigation Potential | • Mitigation methods are established<br>• The State or counties have limited experience with the kinds of measures that may be appropriate to mitigate the hazard<br>• Some mitigation measures are eligible for federal grants<br>• There is a limited range of effective mitigation measures for the hazard<br>• Mitigation measures are cost-effective only in limited circumstances<br>• Mitigation measures are effective for a reasonably long period of time | Medium |

The U.S. Department of Agriculture Forest Service defines **wildfire risk** as the potential loss of resources and assets to wildfire. It is "conceptualized jointly as the likelihood, intensity, and susceptibility to effects of wildfires on the highly valued resource and assets (HVRAs). **Wildfire hazard** is a "physical situation with the potential to cause damage to the HVRAs." Two measures of wildfire hazards are fireline intensity and flame length.

Nationally, wildfire risk is highest in the western states where the largest, deadliest, and costliest wildfires occur. Figure 3.9.3-1 shows the U.S. wildfire risk. Although Wisconsin doesn't have as high of a wildfire risk as other parts of the country, there are wildfires in the state every year. If these are not handled quickly and appropriately, they can turn devastating.

**Figure 3.9.3-1: US Wildfire Risk, 2020**



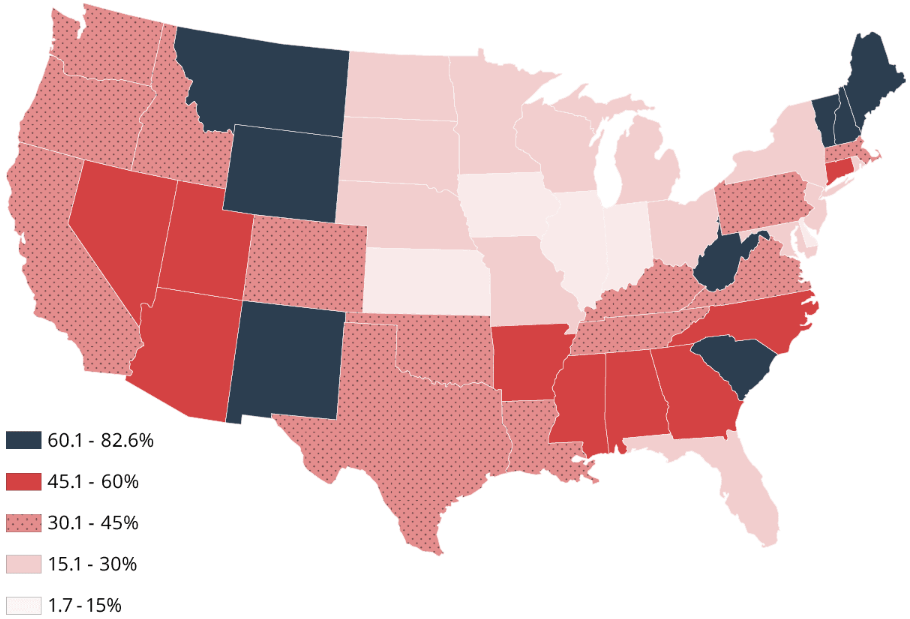

Source: U.S. Forest Service

*Wildland-Urban Interface (WUI) Fires*

Throughout the twentieth century, housing was concentrated mainly in larger metropolitan statistical areas. People began moving to the outer fringe of cities and suburbs in the latter part of the 1900s. As development into rural and wildland areas continues, the dynamics of fire suppression and control have changed drastically.

Wildfire danger grows as more homes and other manmade objects are situated in forests, grasslands, and other areas with highly flammable vegetation, creating what is known as the **wildland-urban interface (WUI)**. According to the U.S. Fire Administration, "the WUI is the zone of transition between unoccupied land and human development. It is the line, area, or zone where structures and other human development meet or intermingle with undeveloped wildland or vegetative fuels" Figure 3.9.3-2 shows the number of houses in the WUI as a percentage of total houses in the state. Wisconsin falls in the 15.1-30% range.

**Figure 3.9.3-2: Number of houses in the WUI relative to the total houses in the state (%)**

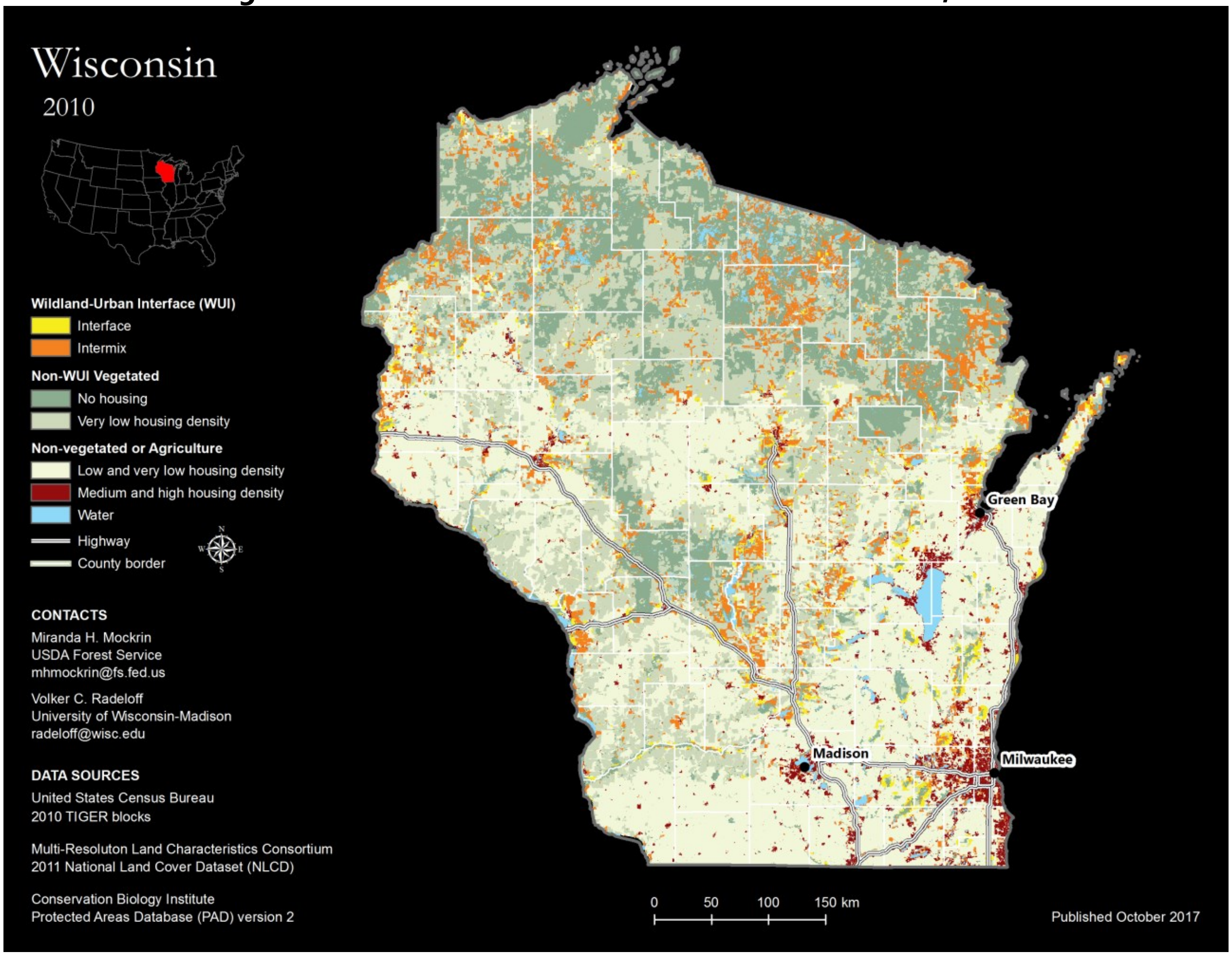



Source: U.S. Fire Administration

Until residents adapt to the dangers around them, fire officials continue their efforts to promote and protect the safety of people and property in WUI areas with highly flammable vegetation. The yellow areas are known as the **interface**, where housing is in the vicinity of a large area of dense wildland vegetation. The red areas are **intermix**, which refers to areas where housing and wildland vegetation intermingle. Much of northern and central Wisconsin have both interface and intermix areas.

There is particular concern with locating homes in remote areas where access roads and driveways are too narrow or sandy to allow emergency vehicles to properly service the homes. Furthermore, the addition of homes in the WUI increases danger through use of power lines, liquid propane tanks, hazardous materials, and increased vehicular traffic. A Proceedings of the National Academy of Sciences study on the rapid growth of the U.S. WUI claims that between 1990 and 2010, the proportion of WUI in Wisconsin increased from 14.5% of the landscape to 15.1%, with over 95% of this growth due to increases in houses. This trend is projected to continue. Figure 3.9.3-3below shows the most recent WUI for Wisconsin which is from 2010. An updated WUI is currently underway.

**Figure 3.9.3-3: Wildland Urban Interface in Wisconsin, 2010**




Source: SILVIS Lab, University of Wisconsin

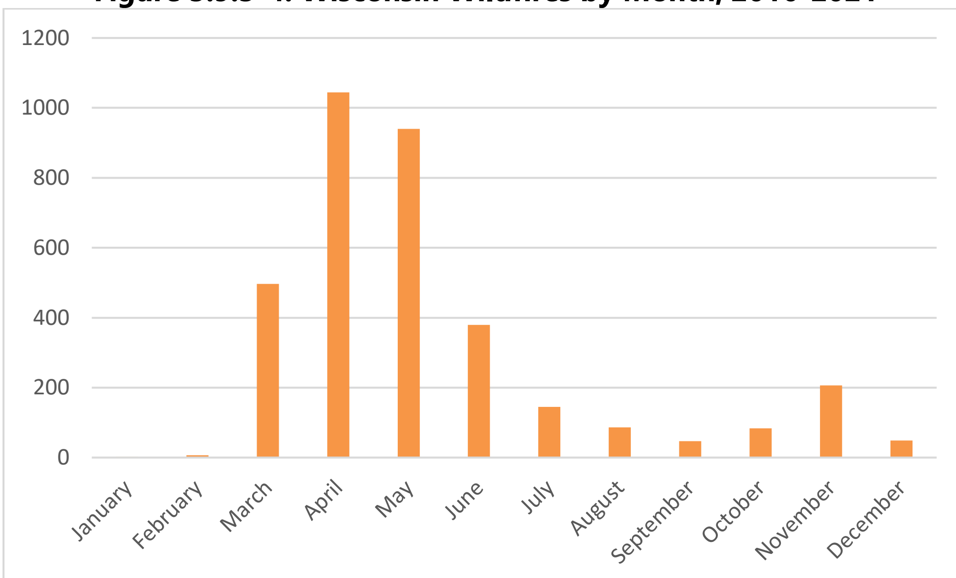
Another concern in the WUI areas is the number of available, skilled firefighters and equipment. Oftentimes, it is not keeping pace with the increase in rural development. In these fire-prone WUI areas, firefighters often work as volunteers, and may be unaware of the additional challenges posed by WUI fires in their communities, such as the need for evacuation plans or the simultaneous confrontation of structure fires and wildfires. That type of demand requires a high level of training which may not always be available. The National Fire Department Registry notes that Wisconsin is about 79% volunteer-based firefighters and 6% career-based firefighters; the remaining percent are a mixture of volunteer and career.

Probability

There is a highly likely probability that there will be wildfires each year in Wisconsin. Wildfire managers prioritize the protection of lives, property, and resources, in that order. Preventing damages relies heavily on educating residents of and visitors to WUI areas to avoid starting wildfires (see Section 3.9.1 for most common causes of Wisconsin wildfires) and to keep people and property safe when wildfires do occur.

Most Wisconsin wildfires occur in spring between March and June, with the highest incidence in April. One of the main drivers of spring wildfires in the Great Lakes area is the **'Spring Dip,'** which is when a dip in foliar moisture content occurs. More specifically, samples showed that the period of highest flammability occurred rapidly after the snow melt, which can vary widely during any given year. Figure 3.9.3-4 shows the number of wildfires that have happened in each month for the last five years.

**Figure 3.9.3-4: Wisconsin Wildfires by Month, 2016-2021**

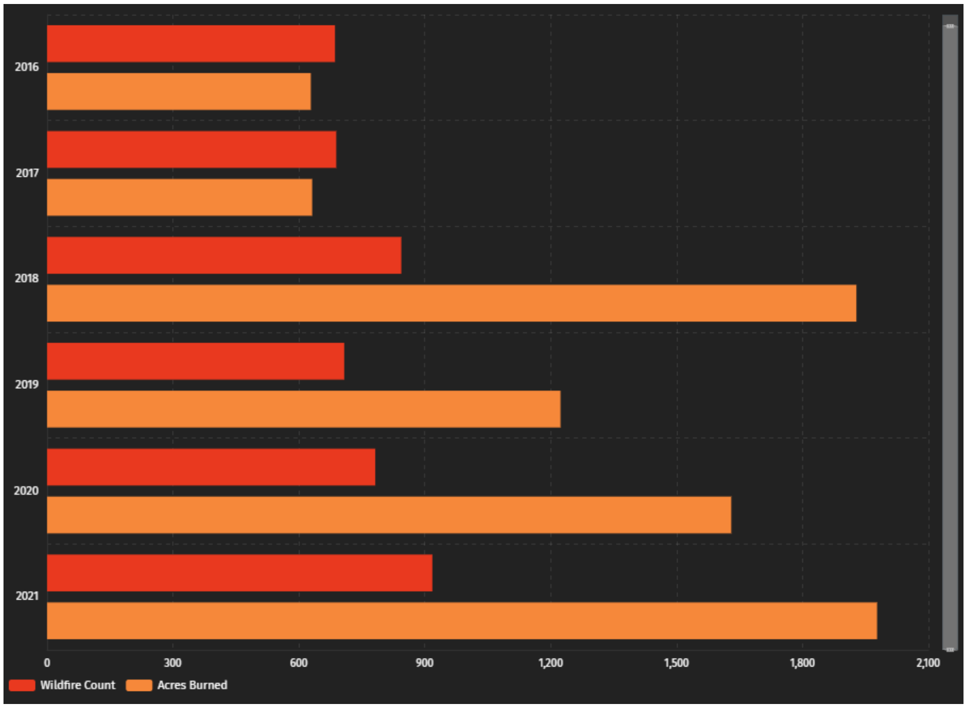



Source: Fire Management Dashboard, WEM

The season length and peak months vary from year to year. Land use, vegetation, amount of combustible materials present, and weather conditions (e.g., high wind, low humidity, and lack of precipitation) are the chief factors in determining the number of fires and acreage burned. Generally, fires are more likely when vegetation is dry from a winter with little snow and/or a spring and summer with sparse rainfall. However, the 2013 Germann Road fire (Section 3.9.2) is a good example of unlikely conditions still leading to a wildfire. Eric Martin, a DNR forest fire prevention specialist, notes that Wisconsin had 23 inches of snow 10 days prior to the wildfire. On the morning of the event, there was still snow on the ground and it even rained. Yet, by noon, the ground had quickly dried out and the vegetation became crunchy. This highlights how quickly the conditions can change to produce a wildfire, and the unpredictable nature of the hazard.

On average, over 637 wildfire events occur, and 962 acres are burned annually in Wisconsin causing thousands of dollars of damages to property and destroying natural resources. In the past five years, 2021 has seen the most wildfires, 918, and the most property burned, 1,977.57 acres. This is from current year to date (8/20/21) counts. Figure 3.9.3-5 shows these trends.

**Figure 3.9.3-5: Wildfire Count and Total Acres Burned by Year, 2016-2021**




Source: Fire Management Dashboard

<u>Vulnerability and Mitigation Potential</u>

*Communities-at-Risk*

In 2003, the National Association of State Foresters produced the Field Guidance for Identifying and Prioritizing **Communities-at-Risk (CARs)**. The purpose of the Guidance was to provide states with a nationally consistent approach for assessing and displaying the risks to communities from wildfire. The Wisconsin DNR, in cooperation with its federal and tribal partners, began working on a statewide assessment of CARs in 2004 which was finished in 2008.

CAR is a model used to identify broad areas of the state that are at relatively high risk of resource damage from wildfire. Results of the model can then be used by local governments developing Community Wildfire Protection Plans (CWPPs), and by the DNR to reduce local risks of wildland fire by prioritizing hazard mitigation and fire prevention efforts.

The approach used in this risk assessment model is based on the Methodology section of the Guidance document which recommends assessing and mapping four factors: 1) historic fire occurrence; 2) hazard; 3) values protected; and 4) protection capabilities. Modifications to this methodology were made to fit the data layers available for Wisconsin.

The DNR uses three factors to assess communities at risk from wildfire:

1. Hazard: The relative likelihood that an ignited wildfire will achieve sufficient intensity to threaten life or property based on land cover type and historic fire regime.
2. WUI (Values at Risk): The relative vulnerability of each 2000 census block to wildfire damage based on housing density and spatial relationships with undeveloped vegetation in the WUI. Wisconsin's WUI was layered with a weighted vegetation layer to accentuation proximity to flammable vegetation.
3. Ignition Risk: The relative likelihood of a wildfire ignition within a given 150m pixel based on historic fire occurrence, population density, and proximity to a potential ignition source.

Models were developed in GIS to create statewide grids representing each of the three input factors. Finally, a statewide composite grid was created using a weighted overlay of hazard (40%), WUI (30%), and ignition risk (30%). This composite grid represents CARs on a zero to nine scale of threat, with zero representing little to no threat (i.e. low or high density urban development) and nine representing a very high threat (i.e. a jack pine or red pine forest).

Statistical risk could then be calculated by municipal civil division (MCD). MCD was chosen since city or village boundaries change as land is annexed for planned development. This measure provided consistency in reporting and this is the level used in development of CWPPs.

Each of Wisconsin's 1,864 towns, villages, and cities was defined as a "community." Using a combination of natural breaks and field verification, quantitative markers were assigned for five threat levels: very low, low, moderate, high, and very high. Ultimately, those communities with a high or very high threat of wildfire, totaling 337 in the state, were designated CARs.

Communities in Wisconsin vary considerably in size, particularly when comparing northern, more rural communities, to southern, more urban, communities. Because of this variation in size, the potential for missing areas of high risk was great for larger towns. For this reason, the DNR incorporated a **Community-of-Concern (COC)** category, identifying those towns with portions of their land at high risk of wildfire, but which were not otherwise included as CARs. A COC was defined as a community that contained at least two contiguous square miles at high or very high risk of wildfire. 237 communities were designated COCs.

The breakdown of communities is shown in the table in Table 3.9.3-2 (from 2011) and in the map in Figure 3.9.3-6.

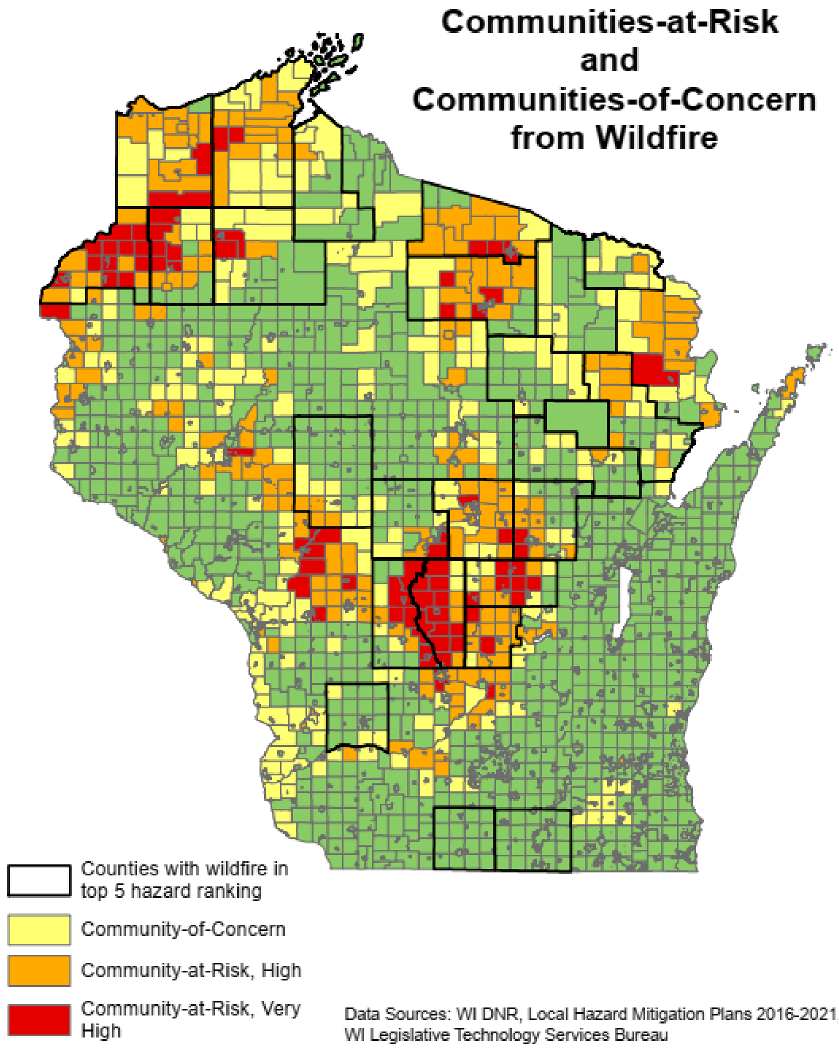
**Table 3.9.3-2: Wildfire Risk Levels of Wisconsin Communities**

| Risk Level | Number | % of Wisconsin Communities | Cities | Villages | Towns | % of Wisconsin Land Area |
|---|---|---|---|---|---|---|
| Very High (CAR) | 93 | 5% | 2 | 12 | 79 | 6% |
| High (CAR) | 244 | 13% | 10 | 47 | 187 | 16% |
| Concern (COC) | 237 | 13% | 8 | 6 | 223 | 20% |

| | | | | | | |
|---|---|---|---|---|---|---|
| **TOTAL** | **574** | **31%** | **20** | **65** | **489** | **42%** |

Source: DNR

**Figure 3.9.3-6: Communites-at-Risk and Communities-of-Concern from Wildfire**



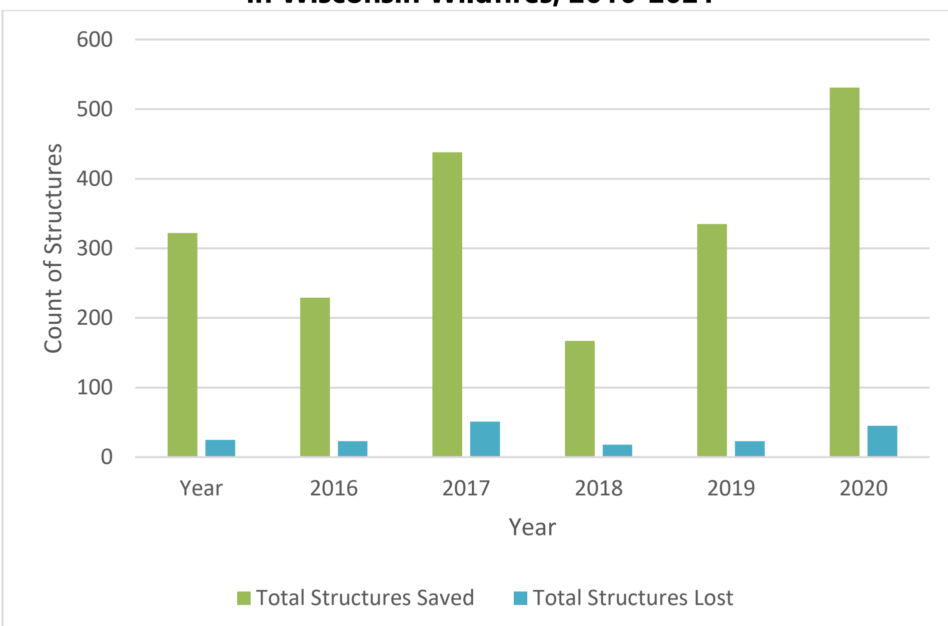

Source: DNR, Local Hazard Mitigation Plans, WI Legislative Technology Services Bureau

Wildfires cause significant injury, death, and damage to property. While there is little information about the number of injuries and fatalities from wildfires in Wisconsin, they simultaneously impact weather and the climate by releasing large amounts of carbon dioxide, carbon monoxide, and fine particulate matter into the atmosphere. The resulting air pollution can cause respiratory and cardiovascular problems for many individuals. According to NWS, “certain people are more likely to be affected with higher levels of fine particle pollution. Those include people with asthma, chronic obstructive pulmonary disease (COPD), heart disease, or high blood pressure. Children and older adults are also at risk. Anyone performing strenuous outdoor activities for extended periods can be at risk as well.” The fire does not have to occur in

Wisconsin for these effects to be felt. In the past, large wildfires out West and in Canada have influenced the air quality in the Midwest.

A recent inventory of Wisconsin land cover showed that just under 17 million acres, or 47%, is forested. Thus, the potential for property damage from wildfires increases each year as more properties are developed in woodland areas and higher numbers of people use these areas recreationally. Though dozens of structures in Wisconsin are destroyed by wildfire each year, hundreds more are saved through sound fire management techniques as depicted in Figure 3.9.3-7.

**Figure 3.9.3-7: Structures Saved and Lost in Wisconsin Wildfires, 2016-2021**

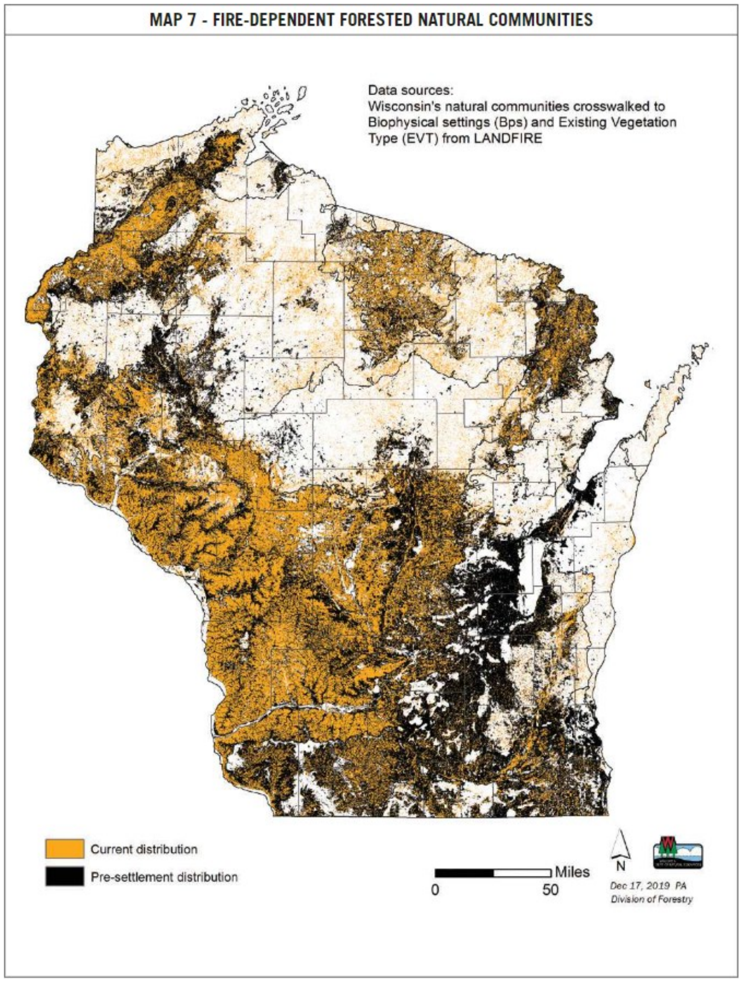



Source: Fire Management Dashboard, WEM

Wildfires extensively impact the economy of an affected area, especially the logging, recreation, and tourism industries. Major direct costs associated with wildfires are the expense of suppression, property loss, salvage and removal of downed timber and debris, and restoration of the burned area. According to the DNR, the average cost of fighting a wildfire in Wisconsin is $1000 depending on the suppression resources used. Exceptionally large fires require multiple fire departments and personnel from different agencies.

Beyond the direct risk to humans and properties, fires permanently affect landscapes – forever altering the existing ecosystems. Since landscapes have been shaped by wildfires for thousands of years, many native plants and animal species have evolved, adapted, and are often dependent on the reoccurrence of fire (Figure 3.9.3-8). The exact impacts vary based on the species in the area; however, it is important to know which types of plants and animals can withstand and even thrive, and which will suffer under fire conditions. In Wisconsin, a good resource to check which landscape your county is in is the DNR's Ecological Landscape's page.

**Figure 3.9.3-8: Fire-Dependent Forested Natural Communities**

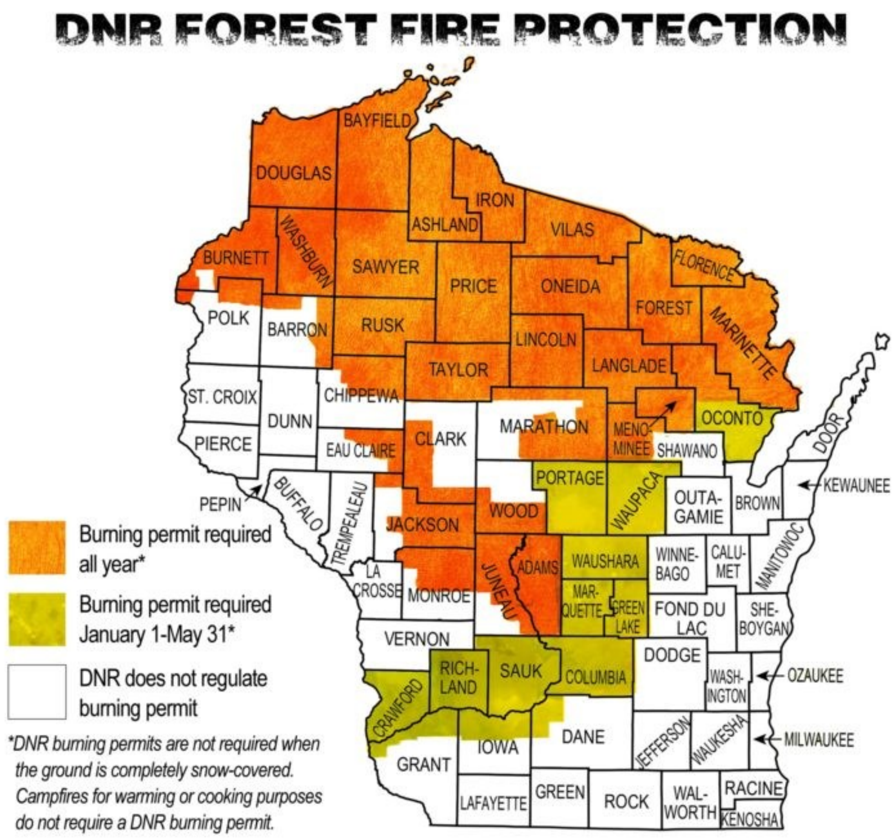



Source: Wisconsin 2020 Statewide Forest Action Plan

There are several established methods for mitigating wildfires in Wisconsin. One of the most common ways is prescribed fire, where fire is intentionally applied to a specific pre-planned area to accomplish land management objectives. Not only does this protect Wisconsin's native grassland, wetland, and savanna plant communities, but it can reduce the hazardous fuels that lead to extreme fires. Prescribed fires use **firebreaks**, which are permanent or temporary strips of bare or vegetated ground designed to allow for the removal and management of fuel. Firebreaks have been used in northwestern Wisconsin for many decades and can help protect landowners in fire-prone areas.

Another key prevention method is obtaining a proper burn permit and practicing responsible burning. Figure 3.9.3-9 below outlines the areas in Wisconsin that require these permits for part of the year or the entire year. Since most wildfires are human caused, understanding the risks and best practices will limit the number of accidents resulting from lack of information. There are a variety of educational resources available, most of which can be found on Wisconsin DNR's Fire Management homepage.

**Figure 3.9.3-9: Burn Permit Requirements**




Source: DNR

Finally, the DNR strongly advocates for communities to become Firewise certified and have a CWPP action plan in place. The Ready, Set, Go! Program works "in complimentary and collaborative fashion with the Firewise Communities and other public wildfire education efforts to amplify firefighters messages and provide wildfire preparedness tools." This Wildfire Action Guide, published by Ready, Set, Go! has information for homeowners in the WUI, highlights mitigation projects, and discusses action items for before, during, and after a wildfire occurs.

### 3.9.4 Climate Change Impacts

Climate change will have different effects depending on the nature of the ecosystem. The USDA Forest Service notes that woody ecosystems such as conifer forests, eucalypt woodlands, and flammable shrublands are most susceptible to weather-dependent fires which are exacerbated by long, hot, and dry periods. Conversely, fires in grass-fueled ecosystems burn intensely after unusually wet years.

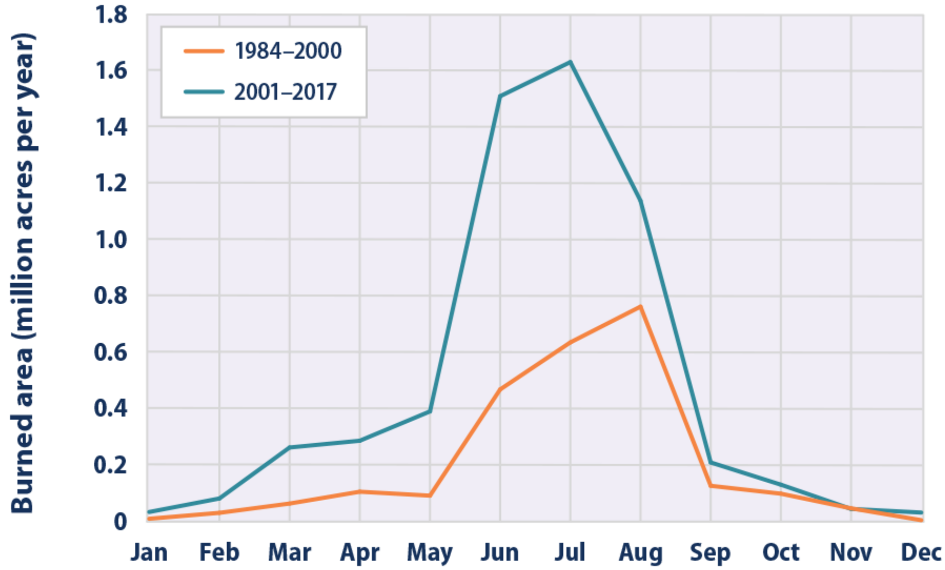
In Wisconsin, there are a mix of ecosystems, including forests, grasslands, prairies, and wetlands, so it is difficult to determine exactly how climate change will affect each of these regions. However, Wisconsin's 2020 Statewide Forest Action Plan states that "wildfires are expected to increase in both frequency and intensity and therefore burn more acres, particularly in boreal and temperate conifer forests. However, more wildfire could be beneficial for some forest types, such as jack pine and other fire-dependent systems." Wisconsin's Initiative on Climate Change Impacts (WICCI) 2050 Forestry report affirms this conclusion and highlights how the number of "red flag" days will increase. A red flag warning is issued when there is an increased risk of wildfire due to warm temperatures, very low humidity, and strong winds.

Many climate change models predict both an increase in temperatures and likelihood of droughts. At the same time, annual precipitation is said to increase by one to three inches by the end of the century. These two changes have conflicting implications for the occurrence of wildfires; however, one certainty is that the extremes will cause variability in wildfire risk and hazards, making it more important to closely monitor both past and current wildfire conditions. Furthermore, if there is an increase in severe thunderstorms, wildfires can also be impacted due to lightning ignitions and stronger winds making fire suppression more difficult.

Another potential shift from climate change in Wisconsin's forests is the increase in stress from forest pests, diseases, and non-native species. According to WICCI's 2050 report, "warmer winters may allow populations of insects to build more rapidly, and pests and diseases tend to be more damaging in situations where forests are already stressed due to drought or other factors." These impacts are oftentimes associated with tree morality, which heightens fire behavior. Similarly, urbanization and land use practices increase the number of fuels on the ground as trees are removed and debris is leftover. As with tree morality, buildup of fuels in fire-prone areas also increases the risk of fire.

Figure 3.9.4-1 shows a comparison of monthly burned area due to wildfires in the United States between 1984-2000 and 2001-2017. As shown, more recent wildfires are peaking earlier, in July, rather than in August. It's possible that this trend will continue as temperatures rise in the springtime.

**Figure 3.9.4-1: Comparison of Monthly Burned Area, 1984-2000 & 2001-2017**




Source: Monitoring Trends in Burn Severity (MTBS)

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# 3.10 RADIOLOGICAL RELEASE

The radiological release hazard can be described as the accidental or intentional release of radioactive material in sufficient quantity to constitute a threat to public health and safety. A radiological release could involve airborne radioactive material and/or radioactive contamination of the environment. The degree and area of a radiological release could vary greatly depending on the type and amount of the release as well as current and future weather conditions. Response to radiological release requires specialized personnel who have been properly trained and equipped.

## 3.10.1 Nature of the Hazard

The radiological release hazard includes:

- The accidental or intentional release from a nuclear power plant.
- The intentional release from a radiological dispersal device (RDD) or an improvised nuclear device (IND).

There are three active nuclear power plants that are located in or near the state. They are the Point Beach Nuclear Plant located adjacent to Lake Michigan and north of Two Rivers, Wisconsin; the Prairie Island Nuclear Generating Plant located along the Mississippi River in Welch, Minnesota; and the Byron Nuclear Generating Station located in Ogle County, Illinois.

In addition, there are three closed nuclear power plants with stored spent nuclear fuel rods that are located in or near the state. They are the Dairyland Power Cooperative located in Genoa, Wisconsin; the Zion Nuclear Generating Plant located adjacent to Lake Michigan in Zion, Illinois; and the Kewaunee Power Station in Carlton, Wisconsin.

The construction and operation of nuclear power plants is closely monitored and regulated by the Nuclear Regulatory Commission (NRC). Based on the redundant safeguards and robust secondary containment many analysts believe an incident that would result in the release of a large amount of radioactive material would most likely be caused by a deliberate act.

A radioactive dispersal device (RDD) is a device or mechanism that is intended to spread radioactive material from the detonation of conventional explosives or other means[6]. Another definition is a device that poses a threat to public health and safety through the malicious spread of radioactive material by some means of dispersion. The mode of dispersal typically conceived as an RDD is an explosive device coupled with radioactive material[7].

An Improvised Nuclear Device is a crude, yield-producing nuclear weapon fabricated from diverted fissile material[8]. Another definition is an illicit nuclear weapon bought, stolen, or

[6] Protective Action Guides and Planning Guidance for Radiological Incidents. EPA. March 2013
[7] Planning Guidance for Protection and Recovery Following Radiological Dispersal Device (RDD) and Improvised Nuclear Device (IND) Incidents. FEMA. Federal Register 73, no. 149 (August 1, 2008).
[8] Protective Action Guides and Planning Guidance for Radiological Incidents. EPA. March 2013

otherwise originating from a nuclear State, or a weapon fabricated by a terrorist group from illegally obtained fissile nuclear weapons material that produces a nuclear explosion[9].

A radiological release would likely result in massive social and economic disruptions in the affected areas. Access to and from an affected area would need to appropriately managed. Those individuals that received a high dose of radiation would require transportation, hospitalization, and lengthy supportive care. The number of fatalities would likely be low. However, special arrangements would be needed to handle and transport contaminated bodies. A decontamination of the affected area would be required. The cascading effects associated with a radiological release could cause major disruptions in transportation and other services nationwide.

These disruptions would be more widespread if the radiological release was located in a densely populated area or if radioactive material is carried downwind and/or downstream to a densely populated area. A radiological release affecting a densely populated area would quickly exceed local, state, and regional response capabilities. The rapid deployment of national assets such as Hazardous Material Teams, Emergency Medical Teams, and National Guard Weapons of Mass Destruction (WMD) Civil Support Team (CST) would be critical to response.

### 3.10.2 History

A release of radiological materials from a nuclear power plant has never occurred in Wisconsin or the region. Known events have occurred at Three Mile Island, Chernobyl, and Fukushima. In addition to these nuclear plant events there have been a number of radiological and nuclear related incidents around the world.

March 28, 1979, Three Mile Island Nuclear Generating Station

The Three Mile Island accident refers to a loss-of-coolant and partial nuclear meltdown that occurred on March 28, 1979 at the Three Mile Island Nuclear Generating Station, Unit 2, in Dauphin County, Pennsylvania. The accident was determined to be a result of human factors and mechanical failure. The partial meltdown resulted in the release of radioactive gases and iodine. Epidemiological studies have determined no link between the accident and the rate of cancer. There was no significant increase in radiation levels in the environment. Following the accident Unit 2 was too badly damaged and contaminated to resume operations. The reactor was gradually deactivated and permanently closed. Cleanup started in August 1979 and ended December 1993. Cleanup cost totaled approximately 1 billion dollars (unadjusted).

April 26, 1986, Chernobyl Nuclear Power Plant

The Chernobyl disaster refers to a nuclear accident that occurred on April 26, 1986, at the Chernobyl Nuclear Power Plant located near the city of Pripyat, Ukraine (at the time the Ukrainian Soviet Socialist Republic of the Soviet Union). The accident released radioactive

[9] Planning Guidance for Protection and Recovery Following Radiological Dispersal Device (RDD) and Improvised Nuclear Device (IND) Incidents. FEMA. Federal Register 73, no. 149 (August 1, 2008)

particles into the atmosphere spreading over a large area of the western Soviet Union and Europe. It has been estimated that the Soviet Union spent the equivalent of $18 billion dollars (unadjusted) on containment and decontamination. Thirty-one workers and emergency responders were killed in the accident and initial response. Long-term the number of deaths from radiation exposure may reach many thousand.

Currently the area around the Chernobyl site is one of the most radioactively contaminated areas in the world. The Chernobyl Exclusion Zone covers an area of approximately 1,000 sq. mi. where radioactive contamination from fallout is highest and public access and inhabitation are restricted.

September 1987, Goiania, Brazil

An old nuclear source was scavenged from an abandoned hospital. It was subsequently handled by many residents of Goiania, Brazil. Approximately 8% of the population presented with psychosomatic symptoms (rash on the neck and upper body, vomiting, diarrhea), 50 people ingested cesium, 28 sustained radiation skin burns, and 2 men, 1 woman, and 1 child died from acute gamma radiation exposure. The contamination was tracked over 40 city blocks and 85 homes, 41 of which were evacuated and 7 demolished. Cleanup generated 3,500 $m^3$ of radioactive waste and cost $20 million. Neighboring provinces boycotted products for a month. Tourism collapsed and economic losses totaled in the hundreds of millions of dollars.

1995, Moscow, Russia

Terrorists, believed to be Chechen rebels, created an RDD from dynamite and Cesuim-137 that had been removed from cancer treatment equipment. The device was buried in a park in Moscow. It was located and defused before it could be detonated.

2006, London, England

A former Soviet KGB agent who had defected to London, was poisoned by Polonium-210 in 2006. He was admitted to a London hospital feeling very ill, his health steadily declined and he died several weeks later. A subsequent investigation identified additional people and locations in London contaminated by Polonium. Thousands contacted the National Health Services out of concern.

November 2007 Pelindaba Nuclear Facility

Four armed men broke into the Pelindaba Nuclear Facility is South Africa. The facility stored enough weapons-grade uranium to make 25 bombs. The men spent 45 minutes inside the facility before they were discovered, and all four escaped. At the same time, a separate group unsuccessfully attempted to break into the facility. A week later, three suspects were arrested. Six Pelindaba security personnel were suspended, and an internal investigation was launched.

March 11, 2011, Fukushima I Nuclear Power Plant

The Fukushima Daiichi nuclear disaster refers to a nuclear accident at the Fukushima I Nuclear Power Plant located in Fukushima, Japan. The accident was a cascading event triggered by the Tohoke earthquake and tsunami on March 11, 2011. The tsunami destroyed emergency generators powering cooling systems leading to three nuclear meltdowns, release of radioactive material, and contamination of ground and sea water. To date, it has been estimated that Japan has spent the equivalent of $15 billion dollars on regional clean up and decontamination. However, the cleanup is on-going effort and total costs will not be known until decommissioning. There were no deaths directly attributed to accident. Long-term the number of cancer deaths from radiation exposure may reach many hundred.

<u>June 2011, Moldova</u>

Moldovan police seized stolen highly enriched uranium (HEU) from a gang by posing as a North African buyer. The gang's members had sought to sell the uranium that they reported was enriched to an unspecified refinement of the isotope uranium-235 for between $29 million and $144 million per kilogram.  Six people active in the former Soviet Union were arrested.

<u>July 2012, Knoxville, Tennessee</u>

Three anti-nuclear protesters broke into Y-12, a nuclear storage facility that contains the United States' primary supply of weapons-grade uranium. The protesters tripped the perimeter intrusion detection system and were confronted by heavily armed guards. The National Nuclear Security Administration (NNSA) will use lessons from this event to "further refine and improve [the] security posture at Y-12."

<u>December 2013, Mexico</u>

A truck containing a Category 1 cobalt-60 tele-therapy source was stolen in Mexico. Presumably the thieves were unaware of the truck's cargo. The source was located in a field two days later, where it had been stripped of its protective shielding but otherwise undamaged. One person showed signs of overexposure to the source. At least 60-70 additional people presented themselves for testing.

### 3.10.3 Probability, Impact, and Mitigation Potential

Despite the lack of historical occurrences within Wisconsin it is incumbent on the state to remain vigilant. Serious nuclear and radiological related incidents internationally have demonstrated the need to maintain active and viable plans to handle such incidents.

Federal, state, and local governments and utility personnel take extensive precautions to ensure that, should a radiological release occur, its impact on the safety and well-being of the general public and the environment will be minimal. These precautions include the development and continual testing of emergency plans, training of response personnel, coordination of response actions, and development and dissemination of emergency public information. A regular series of large, interagency drills and exercises takes place for each nuclear plant.

The Nuclear Regulatory Commission (NRC) has defined four sets of plant conditions, or emergency classifications that indicate the level of risk a nuclear event may pose to the public. Nuclear power plants, as well as research or test reactors, use the following emergency classifications to respond to incidents, in order of increasing severity:

<u>Emergency Classifications for Nuclear Power Plants</u>

1. **Notification of Unusual Event:** Events are in progress or have occurred that indicate potential degradation in the safety level of the plant. No release of radioactive material requiring offsite response or monitoring is expected unless further degradation occurs.
2. **Alert:** Events are in progress or have occurred that involve an actual or potential substantial degradation in the safety level of the plant. Any radioactive material releases from the plant are expected to be limited to a small fraction of amounts described in the Environmental Protection Agency (EPA) Protection Action Guides (PAGs).
3. **Site Area Emergency:** Events are in progress or have occurred that caused actual or likely major failures of plant functions needed to protect the public. Any radioactive material releases are not expected to exceed EPA PAGs except near the site boundary.
4. **General Emergency:** Actual or imminent substantial core damage or melting of reactor fuel with the potential for loss of containment integrity has occurred. Radioactive releases during a general emergency can be expected to exceed EPA PAGs for more than the immediate site area. It is important to note that the vast majority of events reported to the NRC are routine in nature and do not require incident response.

To help in developing a preplanned strategy for protective actions during an emergency, there are two emergency planning zones (EPZs) around each nuclear power plant. The size and shape of each zone is determined through planning that considers specific site conditions, unique geographical features, and area demographic information. Preplanned strategies for these EPZs helps to support activity beyond the zones in the unlikely event it would be needed. The NRC defines the EPZs as follows:

<u>Emergency Planning Zones</u>

1. **Plume Exposure Pathway:** This zone has a radius of about 10 miles from the reactor site. Predetermined protective action plans for this zone are designed to avoid or reduce dose from potential exposure of radioactive materials. These action plans include sheltering, evacuation, and the use of potassium iodide (KI) where appropriate.
2. **Ingestion Exposure Pathway:** This zone has a radius of about 50 miles from the reactor site. Predetermined protective action plans for this zone are designed to avoid or reduce dose from potential ingestion of radioactive materials. These action plans include a ban on contaminated food, water, and livestock.

Following the 1979 Three Mile Island accident, NRC regulations changed to require each nuclear power plant operator to submit the radiological emergency response plans of state and local governments within the 10-mile plume exposure pathway, as well as plans of state governments within the 50-mile ingestion pathway.

Federal, State, and Local Responsibilities

1. **Federal**: The Federal Emergency Management Agency (FEMA) and the NRC jointly share federal oversight responsibilities for nuclear power plants, as follows:
   a. The NRC evaluates emergency plans of the plants themselves, including adequacy and sufficiency of the plans, as well as the resources and equipment needed during an emergency. The NRC also issues nuclear power plant operating licenses, and takes enforcement actions such as levying violations, fines, or ordering the shutdown of operating reactors.
   b. FEMA develops the coordinated response of federal agencies to a nuclear power plant radiological emergency. It interfaces with state and local governments with regard to emergency preparedness. FEMA evaluates state and local emergency plans to ensure sufficiency and adequacy. The emergency preparedness training of state and local officials is a FEMA responsibility.
2. **State and Local:** State and local government officials are responsible for deciding and implementing appropriate protective actions for the public during a nuclear plant emergency. Protective actions include evacuation, sheltering-in-place, and/or taking KI pills. State and local officials should base their decisions on recommendations made by the nuclear plant operator and their respective state or local radiological or health organizations.

In Wisconsin, the Department of Health Services (WI DHS), Radiation Protection Section carries primary responsibility for the safety and health of the populace during radiological incidents. Wisconsin DHS is augmented by specially trained local responders, as well as regional hazardous material (Hazmat) teams and military assets when available. Of concern at the state and local level is the range of protective and detection equipment available to first responders. This has led to questions regarding equipment standardization and state and local preparedness.

The Wisconsin National Guard (WI NG) Weapons of Mass Destruction Civil Support Team (WMD CST), when deployed, addresses the consequences of the release involving chemical, biological, radiological, nuclear, or high-yield explosive (CBRNE) devices. The National Guard leverages its war-fighting capability to support the civil authorities by providing a disciplined, well-trained, and well-equipped organization to supplement local, state, and federal efforts to manage the potentially catastrophic effects of a CBRNE event. CSTs can provide special technical support to augment specific needs of the incident commander. CSTs are designed and trained to provide initial assessment of CBRNE events and advice and assistance.

The table in Table 3.10.3-1 lists other key federal radiological and nuclear resources.

**Table 3.10.3-1: Key Federal Radiological and Nuclear Resources**

| Agency | Description of Roles |
|---|---|
| Department of Homeland Security (DHS) | • Assumes domestic incident management responsibilities for deliberate attacks. |
| DHS/Customs and Border Patrol (CBP) | • Coordinates the federal response for incidents involving the inadvertent import of radioactive materials<br>• Maintains radiation detection equipment and nonintrusive inspection technology at ports of entry and Border Patrol checkpoints to detect the presence of radiological substances transported by persons, cargo, mail, or conveyance arriving from foreign countries<br>• Through its National Targeting Center, provides extensive analytical and targeting capabilities to identify and interdict suspected nuclear/ radiological materials. |
| DHS Domestic Nuclear Detection Office (DNDO) | • Provides R/N Program Assistance, including the deployment of Mobile Detection Deployment Units (MDDUs) and preparation of R/N Detection Supplemental Grant Guidance<br>• Coordinates the technical adjudication of a radiation detection alarm and recommends technical federal asset responses as required<br>• The DNDO Joint Analysis Center (JAC) may respond to a request for assistance in identifying unknown nuclear/radiological materials<br>• Supports the deployment of an enhanced global nuclear detection system to detect and report on attempts to import, possess, store, transport, develop, or use an unauthorized nuclear explosive device, fissile material, or radiological material in the United States. |
| DHS/U.S. Coast Guard (USCG) | • Coordinating agency for the federal response to incidents involving the release of nuclear/radioactive materials that occur in certain areas of the coastal zone, including incidents involving foreign or unknown sources of radioactive material<br>• Coordinates agency response for these incidents during the prevention and emergency response phase, and transfers responsibility for later response phases to the appropriate agency. |
| DHS/Transportation Security Administration (TSA) | • Develops policies to protect the nation's transportation systems<br>• Through the Office of Law Enforcement/Federal Air Marshal Service, runs the Visible Intermodal Prevention and Response Team (VIPR or VIPER), which supports law enforcement in the screening, search, and detection of various modes and routes of transportation (railways, airports, bus stations, ferries, tunnels, ports, subways, truck weigh stations, rest areas) and special events (National Special Security Events (NSSE), major sporting events, conventions, etc.)<br>• Deploys at the request of and collaboration with federal, state, and local transportation stakeholders to prevent and deter acts of terrorism against transportation systems<br>• Tools can include nuclear and radiological detection equipment, mobile drive-through x-ray detection machines, and transportation systems (air, land, sea) |

| | |
|---|---|
| Environmental Protection Agency (EPA) | • Coordinating agency for the federal environmental response to incidents that occur at facilities not licensed, owned, or operated by a federal agency or an NRC agreement state, or currently or formerly licensed facilities for which the owner/operator is not financially viable or is otherwise unable to respond<br>• Coordinating agency for the federal environmental response to incidents involving the release of nuclear/radioactive materials that occur in the inland zone and in areas of the coastal zone not addressed by DHS/USCG<br>• Maintains Protective Action Guidelines for radiological incidents, upon which many protective action decisions are made<br>• Conducts laboratory analysis for environmental sampling<br>• May provide support for radioactive waste storage and disposal, as well as removal of contaminated debris<br>• May support environmental remediation. |
| Nuclear Regulatory Commission (NRC) | • Coordinating agency for incidents at or caused by a facility or an activity that is licensed by the NRC or an NRC agreement state |
| Federal Radiological Monitoring and Assessment Center (FRMAC) | • Responsible for coordinating all environmental radiological monitoring, sampling, and assessment activities for the response<br>• DOE leads the FRMAC for the initial response, then transitions FRMAC leadership to EPA for site cleanup<br>• Established at or near the incident location, the FRMAC usually includes representatives from DOE, EPA, the Department of Commerce, the DHS National Communications System, the U.S. Army Corps of Engineers (USACE), and other federal agencies as needed<br>• Supports decontamination of federal, State, and local emergency responders and equipment integrating into the FRMAC. |
| Interagency Modeling and Atmospheric Assessment Center (IMAAC) | • Is an interagency center responsible for production, coordination, and dissemination of the federal consequence predictions for an airborne hazardous material release<br>• Provides the single federal atmospheric prediction of hazardous material concentration through a partnership with Departments of Energy, Defense, and Commerce (through the National Oceanic and Atmospheric Administration, or NOAA), EPA, NASA, and NRC<br>• Is an off-site resource that supports the incident response remotely. |
| Department of Health and Human Services (HHS) | • Coordinates federal support for external monitoring of people for radiation exposure<br>• Assists local and state health departments in establishing a registry of potentially exposed individuals, performing dose reconstruction, and conducting long-term monitoring of this population for potential long-term health effects<br>• If requested, coordinates federal support for population decontamination, performing monitoring for internal contamination, administering available pharmaceuticals for internal decontamination, and managing fatalities<br>• Provides available medical countermeasures through deployment of the Strategic National Stockpile. |
| HHS/Food and Drug Administration (FDA) | • Conducts food and agriculture laboratory analysis. |
| HHS/Center for Disease Control (CDC) | • Conducts laboratory analysis for bioassays. |

| | |
|---|---|
| Department of Agriculture (USDA) | • Provides support for assessment, control, and decontamination of contaminated animals<br>• Provides support for stabilization and disposition of contaminated animal carcasses<br>• Provides support for the assessment, stabilization, and disposal of contaminated animal products and plant materials. |
| Department of Defense (DOD) | • Provides Defense Support of Civil Authorities (DSCA) in response to requests for assistance<br>• May provide Weapons of Mass Destruction Civil Support Teams (WMD CSTs) and CBRN (chemical, biological, radiological, and nuclear) Enhanced Response Force Packages (CERFP) from the National Guard, CBRNE (chemical, biological, radiological, nuclear, and high-yield explosive) Consequence Management Response Forces (CCMRF), and/or DOD Advisory Teams. |
| DOD/U.S. Army Corps of Engineers (USACE) | • May provide support for radioactive waste storage and disposal<br>• May support radiological survey functions, gross decontamination, site characterization, contaminated water and debris management, and environmental and site remediation |
| Department of Justice (DOJ)/Federal Bureau of Investigation (FBI) | • Has lead responsibility for criminal investigations of terrorist acts or terrorist threats by individuals or groups inside the United States, or directed at U.S. citizens or institutions abroad<br>• Manages, leads, and coordinates all law enforcement and investigative activities in response to terrorist acts or threats |
| Other agencies that may play key roles include: DOE, Department of Commerce, FEMA, Department of the Interior, Department of Labor, Department of State, Department of Transportation, Department of Veterans Affairs, and National Aeronautics and Space Administration (NASA). | |

### 3.10.4 Catastrophic Scenario

A large urban area is preparing for an annual music festival scheduled for 11 days. Festival planners anticipate approximately 100,000 attendees each day on the festival grounds and an additional 300,000 in the vicinity of the festival. It is scheduled for the end of June through the beginning of July when the wind is forecast for 7 mph out of the southeast. Intelligence sources indicate slightly elevated threat levels for RDD attacks across the county, and warn that state and local jurisdictions should implement all prevention and detection capabilities available at high-priority and high-risk sites.

### 3.10.5 Summary Risk Analysis

The table in Table 3.10.5-1 provides a summary risk analysis for the radiological release hazard.

**Table 3.10.5-1: Radiological Release Summary Risk Analysis**

| Evaluation Criteria | Description | Ranking |
|---|---|---|
| **Risk to People, Property, Environment, and Operations** | | |

| | | |
|---|---|---|
| Probability/potential threat of occurrence | • The hazard occurs only very infrequently, generally less than every five years on a large scale, although localized events may be more frequent<br>• The hazard is generally very localized and on a small scale (i.e. sub-county level)<br>• A methodology for identifying event occurrences and/or severities is poorly established in the state, or is available only on a local basis | Low |
| Vulnerability | • Multiple, reliable, well-coordinated, countermeasures are in place to prevent or protect against this hazard.<br>• Countermeasures have an extensive demonstrated history of testing and success in significantly reducing the threat potential. | Low |
| Mitigation Potential | • Methods for reducing risk from the hazard are not well-established, are not proven reliable, or are experimental<br>• The State or counties have little or no experience in implementing mitigation measures, and/or no technical knowledge of them<br>• Mitigation measures are ineligible under federal grant programs<br>• There is a very limited range of mitigation measures for the hazard, usually only one feasible alternative<br>• The mitigation measures have not been proven cost-effective and are likely to be expensive compared to the magnitude of the damages caused by the hazard<br>• The long-term effectiveness of the measure is not known, or is known to be relatively poor | Low |
| **Impacts of Catastrophic Scenario** | | |
| Public | • Local and regional medical services are unable to manage the volume of injuries and fatalities.<br>• Mass evacuation, sheltering and care of displaced residents, medical patients, and vulnerable populations may be required. | High |
| Responders | • Local and mutual aid resources would be fully committed and significant state and federal assistance would be needed in order meet the needs of the incident.<br>• State and federal disaster declaration. | High |
| COOP, including delivery of services | • Minimal impact on government essential functions. | Low |
| Property, Facilities & Infrastructure | • Damage to property, facilities and infrastructure anticipated in impacted area.<br>• Some structures could be impacted for up to a year. Infrastructure damages would likely take longer than one week to repair. | High |
| Environment | • Widespread environmental damage over a large geographic area affecting several communities across a region.<br>• Significant damage to an ecologically sensitive area such as wetlands, rivers, lakes, or public water supply.<br>• Damage requires massive long-term remediation efforts of state and federal government. | High |

| | | |
|---|---|---|
| Economy | • Tremendous adverse impact affecting the livelihood of the region and possibly extending statewide.<br>• Long-term, cascading damage across multiple economic sectors requiring federal government assistance. | High |
| Public Confidence | • Long-term loss of confidence in government and society.<br>• Mass panic and major civil disturbances are possible. | High |
| | Aggregate Impact | High |

### 3.10.6 Sources – Agency Input and Research

The following agencies and document research assisted in providing subject matter expertise to this scenario's core capabilities.

1. Department of Homeland Security, Domestic Nuclear Detection Office
2. FEMA Region V Threat and Hazard Identification and Rick Assessment (THIRA)
3. Wisconsin Department of Health Services (WI DHS), Radiation Protection Section
4. Wisconsin Emergency Response Plan, Radiological Incident Annex

# 3.11 HAZARDOUS MATERIALS INCIDENT, INCLUDING FIXED FACILITIES AND TRANSPORTATION

A hazardous materials incident can be described as the uncontrolled release of hazardous materials capable of posing a risk to life, health, safety, property, or the environment. A hazardous materials incident is most often a result of accidents at fixed facilities or during transportation.

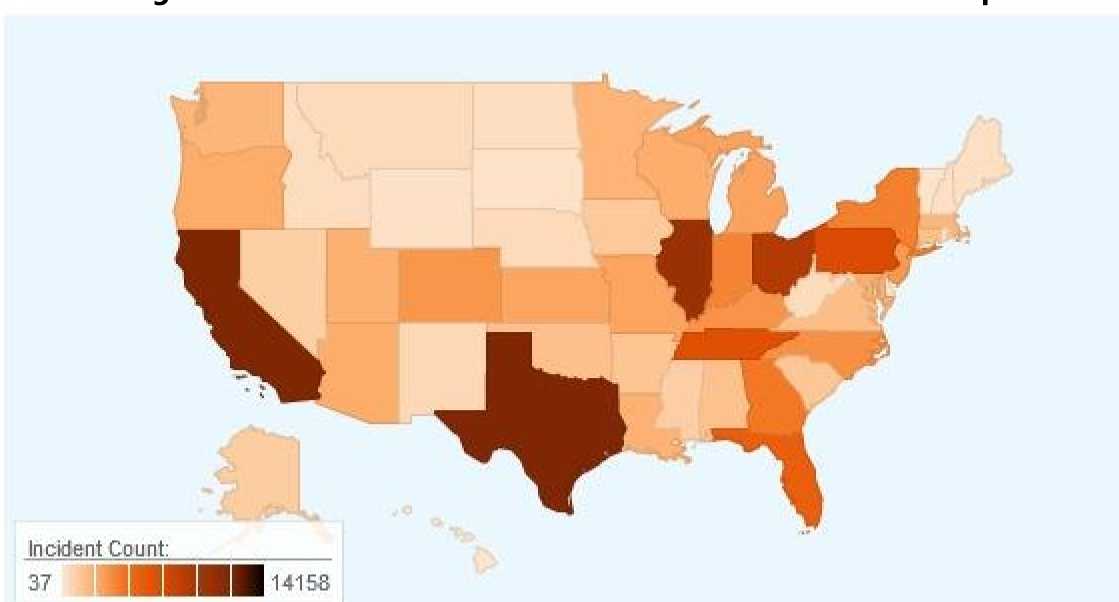
## 3.11.1 Nature of the Hazard

Hazardous materials are any solid, liquid, or gas that can pose a threat to human health and/or the environment due to being radioactive, flammable, explosive, toxic, corrosive, a biohazard, an oxidizer, an asphyxiant, or capable of causing severe allergic reactions. The release of hazardous materials can lead to property damage, short and long term health effects, serious injuries, and even death. Emergency response to incidents involving the release of hazardous materials may require fire, law enforcement, search and rescue, and hazardous materials units.

## 3.11.2 History

The vast majority of reported hazardous materials incidents result from the loading, unloading, and transportation of hazardous materials. The map in figure 3.11.2-1 indicates that Wisconsin over the past 10 years ranks toward the bottom third of states in total hazardous materials incidents.

**Figure 3.11.2-1: 2007 – 2016 Hazardous Materials Incident Map**




Source: Hazmat Intelligence Portal, U.S. Department of Transportation, Data as of 10/21/2016

Since 11071 Wisconsin has had a total of 10,958 reported hazardous materials transportation incidents[10]. This total is comprised of 10,498 highway incidents (95.8%), 266 rail incidents (2.4%), 188 air incidents (1.7%), 2 other incidents (>0.1%), and 0 water incidents (0.0%). The total cost for all reported incidents is approximately $57 million dollars. Approximately half of the amount ($26.6 million) is from the 1996 Weyauwega Train Derailment.

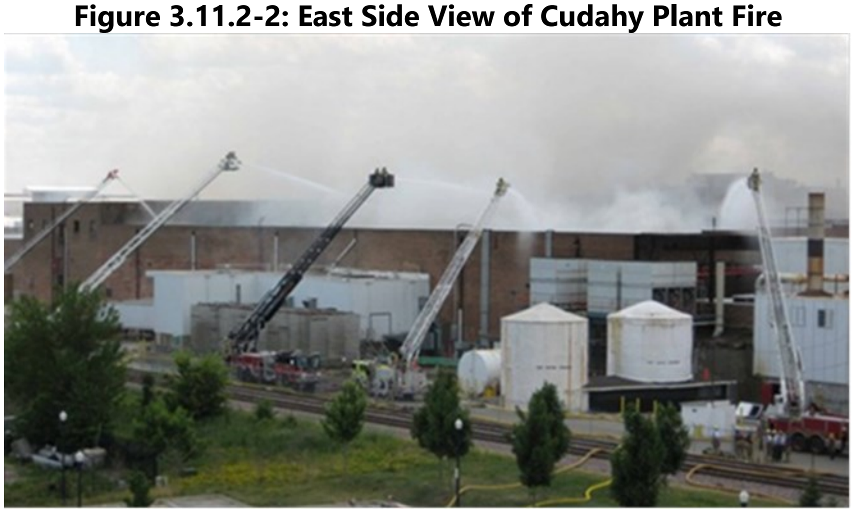
These incidents included 175 involving a crash or derailment, 68 causing or contributing to personal injury, 59 causing or contributing to an evacuation, 38 closing a major transportation artery or facility, and 7 causing or contributing to a fatality. The following describe a selection of notable incidents.

**July 5, 2009 Patrick Cudahy Meat Packing Plant Fire**

On July 5, 2009, in Cudahy, WI, the Patrick Cudahy meat packing plant was accidently set ablaze by two brothers celebrating Independence Day using a military parachute flare obtained through one of the brothers' recent U.S. Marine Corps service. The fire burned for several days and involved over 130 firefighters from 27 different departments in the near-suburban area of Milwaukee's south side. The historic plant was almost completely destroyed.

Acrid, thick black smoke changed to white smoke and back again as the fire burned through various parts of the factory. An ammonia explosion was successfully averted as ammonia gas used from refrigeration at the plant, extremely toxic and fatal if inhaled was contained in an area away from the fire.

**Figure 3.11.2-2: East Side View of Cudahy Plant Fire**



The smoke and threat of ammonia forced evacuation of over 18,000 local residents, of which 387 evacuees including 77 individuals with access and functional needs required sheltering by the American Red Cross (ARC). The city's water system was drained, as over 33 million gallons of water were sprayed on the fire that engulfed the sprawling 1.4 million square foot complex.

[10] Hazmat Intelligence Portal, U.S. Department of Transportation. Data as of 9/25/2016.

Later in the day, after no ammonia was detected in the air and the fire was brought under control, the evacuation order was lifted. Fortunately, few of the plant's 2,000 employees were present due to the Independence Day holiday.

**April 2, 2001 Green Bay Tanker Truck Collision**

On April 2, 2001 in Green Bay, WI, a northbound gasoline tanker truck operated by Condon Transport, Inc. was making a left turn (west bound) in heavy fog. Simultaneously, a passenger vehicle with four occupants heading east bound failed to stop at a stop sign and struck the tanker in its center as the tanker was negotiating the left-hand turn. The passenger vehicle sheared off the tankers wet lines and possibly punctured the tank itself (the tank appeared to have a fracture once lifted from the wreckage). Gasoline spilled into the passenger vehicle and caused an immediate fire, killing all four occupants.

**March 4, 1996 Weyauwega Trail Derailment**

On March 4, 1996, at about 5:50 a.m., a Wisconsin Central Limited (WC) train consisting of two locomotive units, 68 loaded freight cars, and 13 empty freight cars, derailed the 17th through 50th head cars at Weyauwega, Wisconsin. Sixteen of the derailed cars contained hazardous materials: two loaded with sodium hydroxide, seven loaded with liquefied petroleum gas (LPG), and seven loaded with propane.

**Figure 3.11.2-3: Overhead View of the Train Derailment**

Source: National Transportation Safety Board Report, CHI 96 FR 010, Derailment/Hazardous Material Release, Wisconsin Central, LTD, Weyauwega, Wisconsin, August 16, 1997.

The derailment resulted in a release of hazardous material that caught fire and consumed seven of the cars loaded with LPG and propane and threatened to ignite the remaining hazardous material cars. The fire also burned a local feed mill building. High tension electric lines were knocked down, and city water and natural gas services were disrupted. About 3,155 residents of the town were immediately evacuated from their homes, with over half remaining evacuated for the entire 16-day incident period. Major highway arteries – US Highways 10 and 110 – were closed, as well as all county roads leading into the area. There were no injuries directly attributable to the derailment, but three individuals suffered minor injuries during the evacuation. The costs associated with the accident exceeded $26 million.

Pieces of broken rail from the "heel" area of a switch point rail were recovered in the wreckage. The broken rail displayed failure characteristics which indicated that the fractures originated from a bolt hole crack. National Transportation Safety Board (NTSB) examination and analysis of the broken rails indicated that the bolt hole crack had been present for some time. The examination also revealed that the rails and joint bars displayed many characteristics that were indicative of problems in the joint and bolt hole area. These characteristics were telltale signs of a problem that should have been observed and acted upon by well-trained, vigilant track inspectors and their supervisors.

The WC Supervisor of Maintenance and the WC Manager of Maintenance were responsible for the inspection of the track at Weyauwega to insure compliance with Federal Railroad Administration (FRA) regulations on track safety standards. WC records indicated both were considered to be qualified track inspectors for FRA track safety standards. However, a review of their training records indicated that neither person had been recently trained in track safety standard compliance on the WC, nor had they recently received any FRA track safety standard competency testing. The National Transportation Safety Board investigation concluded that the cause of this accident was that the switch point rail broke due to an undetected bolt hole crack that progressed from improper maintenance because Wisconsin Central management did not ensure that the two employees responsible for inspecting the track structure were properly trained.

**June 30, 1992 Nemadji Train Derailment**

At 2:55 a.m. on June 30, 1992, 14 cars, 3 carrying hazardous materials, derailed and fell approximately 70 feet from the railroad bridge at Highway 35 into the Nemadji River, south of Superior, Wisconsin. The location of the incident was about 4.5 miles upriver from Lake Superior (46.42N, 092.02W). Three of the cars contained hazardous materials. Two of these cars were in the water; one remained on the bridge and at risk. One car containing 35,000 gallons of Benzene-dicyclo-pentadiene (or aromatic concentrates) ruptured and lost an estimated 15,000 gallons of product into the river. The second car in the river contained LPG (Liquefied Petroleum Gas) and remained intact. A car on the bridge containing Butadiene also remained intact. There was a light fog at the time of the incident, and initially, the local fire department ordered the evacuation of the lower areas of both Duluth and Superior. Immediate evacuation of approximately 50,000 residents of Superior, Wisconsin and Duluth, Minnesota was begun by local authorities because of the odorous and visible plume caused by the spill. Most of those evacuated were allowed to return to their homes on July 1. The weather was clear at time of the incident but rained on and off for 3 days, temperatures varied between 57-82°F, with winds out of the northwest at 10 knots. The evacuation zone of 1 mile radius was maintained until July 4.

### 3.11.3 Probability, Impact and Mitigation

Hazardous materials are present in most communities. These materials may be manufactured, transported, stored, used, and disposed of by a variety of users including business, industry, agriculture, universities, hospitals, utilities, and other facilities. To reduce the risk to the public and the environment these hazardous materials are highly regulated by state and federal agencies.

However, despite regulations and precautions accidental releases do occur. Most releases are the result of human error. Occasionally a release may be the result of natural causes. Regardless of the cause a release can cause severe harm to people or the environment and may require immediate response. Many programs and initiatives have been designed to mitigate, prepare for, respond to, and recover from hazardous material incidents including, but not limited to, the following.

**Emergency Planning and Community Right-to-Know Act (EPCRA)**

Wisconsin Emergency Management (WEM) / State Emergency Response Commission (SERC) is responsible for implementing the federal Emergency Planning and Community Right-to-Know Act (EPCRA), also known as the Superfund Amendments and Reauthorization Act (SARA) of 1986, at the state and local levels. WEM/SERC is also responsible for administering the Emergency Planning Grant that provides funding on a formula basis to county LEPCs for local planning and program administration and the Equipment Grant which provides matching funding for computer equipment and hazardous materials response equipment. Under 1991 WI Act 104 the WEM/SERC is also responsible for contracting with regional hazardous materials response teams as well as providing hazardous materials response equipment funding, on a matching basis, to the designated county hazardous materials response teams.

**EPCRA Compliance and Enforcement Program**

The Compliance Program staff offers technical assistance regarding the EPCRA requirements and compliance to facility owners/operators, LEPCs, County Emergency Management Directors, and other state and local agency staff. Assistance is provided to county LEPCs for outreach programs. Also educational materials and presentations are available for business and industry, highlighting program requirements. Compliance staff also conducts compliance reviews to identify potentially noncompliant facilities and conduct investigations.

WEM offers three grants administered by the EPCRA program.

**Planning Grant**

- The Planning Grant and the Emergency Management Performance Grant (EPMG) share the same plan of work.
- Local Emergency Planning Committees (LEPCs) must complete plan-of-work components to be reimbursed.

- Award is based on the annual Planning Grant Formula.
- Funded by EPCRA program revenue (fees).

**Computer & Hazmat Equipment**

- Maximum total award for counties with an eligible hazardous materials team is $10,000.
- Counties without a county level team are eligible for the computer portion only.
- The grant has an 80/20 match. The match can be in-kind or cash.
- Award criteria is based on an approved equipment list and funding available.
- Funding comes from state general program revenue (GPR).

**Hazardous Materials Emergency Preparedness (HMEP) Sub-Grant**

- Training and Planning grant funded by US DOT (EPCRA administers the planning portion).
- Purpose is to improve the delivery of EPCRA and enhance planning efforts with a focus on transportation.
- Training grants are to be used by HMEP subgrantees for the funding of training activities that enhance the capabilities of states, territories, and tribal governments.
- Training should be developed and delivered in accordance with requirements for emergency responders under National Fire Protection Association (NFPA) standard 472.
- Training grants are to be used by HMEP subgrantees for training public sector employees to respond safely and efficiently to accidents and incidents involving the transportation of hazardous materials.

**Local Emergency Planning Committee (LEPC)**

Each Wisconsin county is designated as an emergency planning district and has a Local Emergency Planning Committee (LEPC) to administer the local program. LEPC membership includes local elected officials, members of emergency response agencies (emergency management, fire, law enforcement, EMS, health, etc.), and representatives for transportation, public works, the media, community groups, environmental groups, and owners/operators of facilities. LEPCs are responsible for receiving and maintaining filings of facility submissions. They also maintain a county-wide emergency response plan, develop and maintain facilities' off-site emergency response plans and the county's hazard analysis for both fixed facilities and transportation. LEPCs assess the county hazmat response resources and equipment, respond to public requests for information under "community right-to-know" law, and conduct hazmat training and exercises. Wisconsin has annual exercise requirements and the LEPC attempts to involve facilities, response agencies, and other local officials in the exercises.

The county-wide emergency response plan includes: the county hazard analysis summary, a list of facilities storing hazardous materials, identification of transportation routes for extremely hazardous substances (EHS), procedures for notification or releases, response to releases, procedures for sheltering and evacuation, and a schedule for training and exercising. Individual facility off-site plans include: facility name and location, name of facility emergency planning coordinator with 24 hr. contact phone number, list of primary emergency responders, list of resources available from/at facility, list of outside resources available, hazard analysis of the facility with a vulnerability zone for release of EHS stored at facility, identification of special facilities (i.e., schools, hospitals, nursing homes, day care centers, etc.) within the zone, population protection procedures (sheltering and evacuation) and attachments. These plans are developed and maintained by the LEPC.

**Hazardous Materials Response Teams**

WEM contract and manages 22 Regional Hazardous Materials Response Teams. These teams provide a high level of hazardous materials response capabilities to local communities. The teams are divided into Task Forces: Northeast Task Force, Northwest Task Force, Southeast Task Force, and the Southwest Task Force. These Task Forces are then divided into Type I, Type II, and Type III teams, all with complimentary capabilities and training requirements.

The Wisconsin Hazardous Materials Response System may be activated for an incident involving a hazardous materials spill, leak, explosion, injury or the potential of immediate threat to life, the environment, or property. The Wisconsin Hazardous Materials Response system responds to the most serious of spills and releases requiring the highest level of skin and respiratory protective gear. This includes all chemical, biological, or radiological emergencies.

Local (County) Hazardous Materials Response Teams respond to chemical incidents which require a lower level of protective gear but still exceed the capabilities of standard fire departments. Forty counties currently have level 4 Hazardous Materials Response Teams. Those teams may provide assistance to surrounding counties and are approved by the Local Emergency Planning Committees.

## 3.11.4 Catastrophic Scenario

During a weekday at approximately 9:00 a.m., a delivery truck driver is filling a 49,000 lb. tank with a hazardous chemical at a major chemical company facility when he receives an important family emergency phone call. The driver rushes back into the truck and drives off, forgetting that the truck is still connected to the pump.

As the truck drives off, the emergency stop valve on the delivery truck is damaged due to the nozzle still being engaged in the tank. The truck driver quickly realizes that the damage is causing a major chemical release, and runs to the back of the truck to try to stop the leak; he is overcome by fumes and falls to the ground.

The chemical company employee assisting with the transfer is splashed by the chemical (especially on his gloved hands). He has no skin contact with the acid, but does inhale some fumes. The contaminated employee runs in and grabs the manager on his bare arm to have him call the E-Team. The manager then runs outside and finds the truck driver lying on the ground. The manager attempts to rescue the driver, but realizes that there are too many fumes and retreats back into the facility.

There is a release of 9,000 lbs. of the chemical over a 2-hour period, in addition to 4,500 lbs. of gas released into the ambient air. The winds are out of ESE at 3 miles per hour. The temperature is 72 degrees, with 80% cloud cover.

The facility sits adjacent to a major freeway running through a large metropolitan area. Directly across from the freeway is a university, which is in session. There are various public and private facilities within the projected plume area, where serious health problems could occur.

Approximately 20,000 individuals will need to be evacuated with sheltering space required for 30% of the evacuees. There is a possibility that another 60,000 individuals may need to be evacuated in the event the hazardous material cannot be contained due to changing atmospheric conditions.

### 3.11.5 Summary Risk Analysis

The table in Figure 3.11.5-1 provides a summary risk analysis for the hazardous materials incident hazard.

**Table 3.11.5-1: Hazardous Materials Incident Summary Risk Analysis**

| Evaluation Criteria | Description | Ranking |
|---|---|---|
| **Risk to People, Property, Environment, and Operations** | | |
| Probability/potential threat of occurrence | • The hazard impacts the state occasionally, but not annually<br>• The hazard is somewhat localized, affecting only relatively small or isolated areas when it occurs<br>• The methodology for identifying events is not well-established, or is not applied across the entire state | Medium |
| Vulnerability | • Multiple measures are in place to prevent or protect against this hazard.<br>• Countermeasures have been tested and have demonstrated success in reducing the threat potential. | Medium |

| | | |
|---|---|---|
| Mitigation Potential | • Mitigation methods are established.<br>• The State or counties have limited experience with the kinds of measures that may be appropriate to mitigate the hazard.<br>• Some mitigation measures are eligible for federal grants. There is a limited range of effective mitigation measures for the hazard.<br>• Mitigation measures are cost-effective only in limited circumstances.<br>• Mitigation measures are effective for a reasonably long period of time. | Medium |
| **Impacts of Catastrophic Scenario** | | |
| Public | • Local and regional medical services are unable to manage the volume of injuries and fatalities.<br>• Mass evacuation, sheltering and care of displaced residents, medical patients, and vulnerable populations may be required. | High |
| Responders | • Local and mutual aid resources would be fully committed and significant state assistance would be needed in order meet the needs of the incident.<br>• State disaster declaration. | Medium |
| COOP, including delivery of services | • State or local government mission essential functions impacted for less than 24 hours. | Low |
| Property, Facilities & Infrastructure | • Significant damage to critical infrastructure, public and private property over a localized area.<br>• Up to 10% of buildings and infrastructure in affected area damaged, and/or loss of lifeline services for up to 24 hrs. | Low |
| Environment | • Environmental damage affecting one or more communities within a county.<br>• Moderate damage to an ecologically sensitive area such as wetlands, rivers, lakes, or public water supply.<br>• Damage requires short- to medium-term remediation efforts of state and federal government. | Medium |
| Economy | • Medium-term effects to large portion of the jurisdiction's economy, possibly extending to the region.<br>• Damage to multiple economic sectors possibly requiring state or federal government assistance. | Medium |
| Public Confidence | • Medium and long-term effects including elevated stress, depression and behavioral health impacts for individuals in and out of impacted communities.<br>• Short- to medium term reduction of confidence in government in society.<br>• Civil disturbances in impacted communities may require law enforcement response. | Medium |
| | Aggregate Impact | Medium |

### 3.11.6 Sources – Agency Input and Research

The following agencies assisted in providing their expertise on the subject matter related to the core capabilities in this scenario.

1. Milwaukee County Emergency Management
2. Milwaukee Fire Department
3. Milwaukee Police Department
4. MABAS Wisconsin, Patrick Cudahy Fire – IMAS Report July, 2009
5. U.S. Department of Transportation (DOT), Pipeline and Hazardous Materials Safety Administration (PHMSA)

# 3.12 DISRUPTION OF LIFE LINES – ELECTRIC, FUEL, WATER, WASTEWATER

A disruption of life lines can be described as the failure of a critical public or private utility infrastructure that results in a loss of essential functions and/or services.

## 3.12.1 Nature of the Hazard

The vast majority of the public is dependent on public and private utility infrastructure to provide life-supporting services such as electricity, fuel, water, and wastewater. The disruption of one or more of these life line systems could have devastating consequences on the public. A disruption of life lines may be a secondary hazard resulting from the impacts of a natural, technological, or human-caused hazard.

A disruption of any life line can lead to a threat to the public health and safety if immediate actions are not taken. If the disruption were to involve more than one life line system or is large enough in scope and magnitude, whole communities or regions could be severely impacted. A disruption will often disproportionally impact the most vulnerable members of society such as the very young, the very old, those in poor health, and the poor or impoverished. Examples of disruptions include, but are not limited to such events as an electricity outage rendering fans and air conditioning inoperable during a period of extreme heat; shortage of fuel rendering furnaces inoperable during a period of extreme cold; damaged or malfunctioning water or wastewater treatment system exposing the public to a sanitation concerns; and, inadequate storm water system failing to protect an area from dangerous and damaging flooding.

**Electric**

Investor owned utilities supply the vast majority of power to Wisconsin electricity customers. Other suppliers include municipal utilities and power cooperatives. The relative amounts of power supplied by the three types of utilities have changed very little over the past 20 years. The table in Figure 3.12.1-1 lists kilowatt hour (kWh) and percentage of electricity supply by type of utility.

**Figure 3.12.1-1: Electricity Supply by Utility Type**

| | Private Utilities | | Municipal Utilities | | Power Cooperatives | | |
|---|---|---|---|---|---|---|---|
| Year | kWh | % | kWh | % | kWh | % | Total |
| 1970 | 21,515 | 87.1 | 2,160 | 8.7 | 1,040 | 4.2 | 24,715 |
| 1980 | 32,335 | 85.7 | 3,547 | 9.4 | 1,864 | 4.9 | 37,746 |
| 1990 | 41,653 | 84.7 | 5,263 | 10.7 | 2,282 | 4.6 | 49,198 |
| 2000 | 54,404 | 84.1 | 7,375 | 11.4 | 2,910 | 4.5 | 64,689 |
| 2010 | 57,183 | 83.2 | 7,759 | 11.3 | 3,810 | 5.5 | 68,752 |
| 2012 | 57,128 | 83.0 | 7,856 | 11.4 | 3,836 | 506 | 68,820 |
| | kWh in listed in millions | | | | | | |

Source: 2013 Wisconsin Energy Statistics, State Energy Office

The demand for electricity changes daily and seasonally. During peak times, the largest amount of electricity known as “peak load” is needed, but a “base load” of electricity is needed year-round. The industrial, residential, and commercial sectors all use a similar percentage of total electricity sales. The industrial sector accounts for 34.2%, commercial 33.0%, residential 30.5%, and agricultural 2.2%.

Because electricity cannot be stored easily, utilities must anticipate demand. Utilities meet this demand with in-state power plants and by purchasing electricity from power plants in other states. The balancing of supply and demand is required in order to maintain a reliable electric system. Maintaining reliable and economical electrical generation for the state depends on sufficient quantities of the right types of power plants operating together in a cost-effective manner. A diversity of energy resources also helps achieve stability of generation and prevents dependence on a specific fuel. The table in Figure 3.12.1-2 lists percentage of electricity supply by type of plant.

**Figure 3.12.1-2: Wisconsin Electric Generation by Type of Plant**

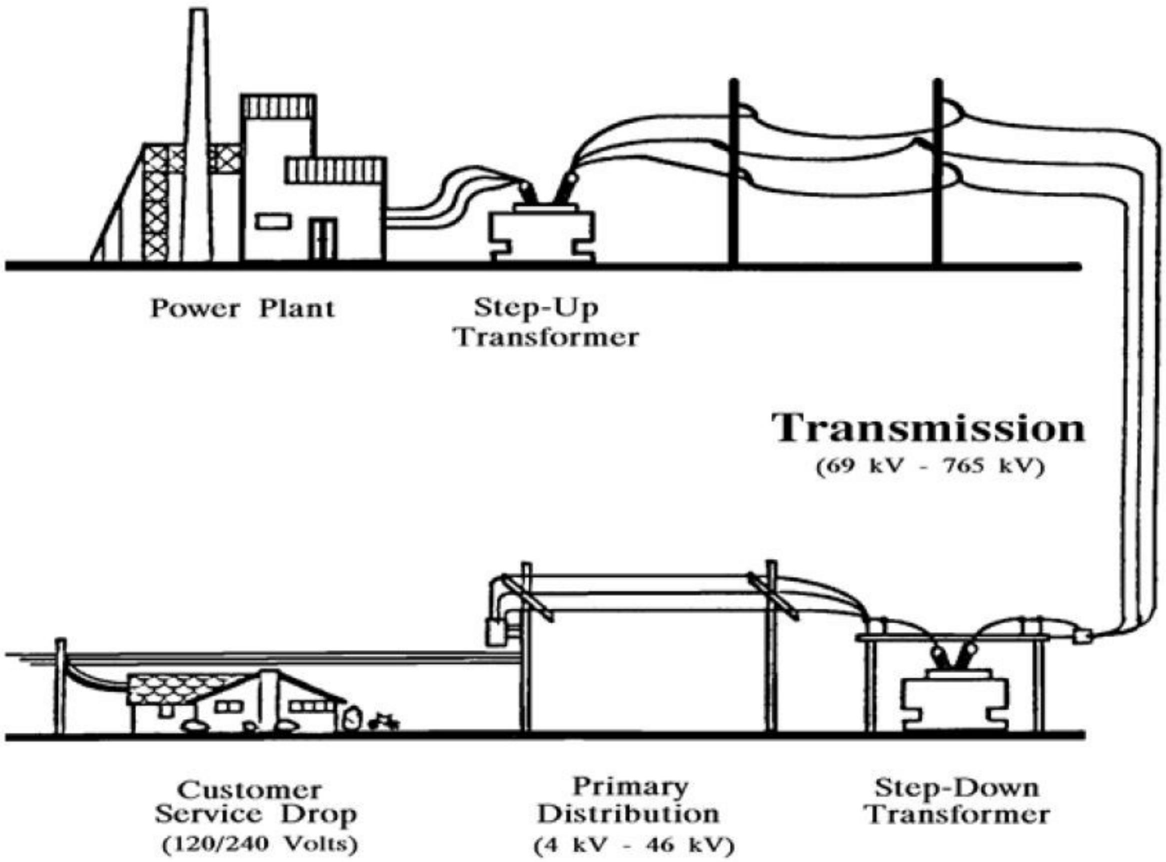
| Year | Coal | Nuclear | Hydro | Petroleum | Natural Gas | Renewables | Unknown Fuel | Total |
|---|---|---|---|---|---|---|---|---|
| 1990 | 61.1 | 14.0 | 4.9 | 3.6 | 12.0 | 1.4 | 2.9 | 100 |
| 2000 | 50.3 | 11.5 | 4.1 | 3.5 | 26.2 | 1.8 | 2.5 | 100 |
| 2010 | 43.0 | 9.1 | 2.7 | 3.9 | 36.3 | 5.1 | 0.0 | 100 |
| 2012 | 43.9 | 8.7 | 2.7 | 3.9 | 35.4 | 5.4 | 0.0 | 100 |
| Totals might not add due to rounding | | | | | | | | |

Source: 2013 Wisconsin Energy Statistics, State Energy Office

Since 1990 the data indicates the percentage of total electric production derived from coal has decreased from 61% to 44%. During this same time production from natural gas has increased from 12% to 35%. The kWh production from nuclear and hydro has generally stayed consistent from 1990 to 2012 but the increase in total kWh results in a percentage of total decrease. In addition, electric production from renewable sources has increased from just 1.4% to account for over 5% of total electric production. The renewables category includes biomass, methane from landfills and digesters, solar, and wind resources.

The transmission system must accommodate changing electricity supply and demand conditions, unexpected outages, planned shutdowns of generator or transmission equipment for maintenance, weather extremes, fuel shortages, and other challenges. Electricity flows from power plants, through transformers and transmission lines, to substations, distribution lines, and then finally to the electricity consumer. The diagram in Figure 3.12.1-3 depicts a simplified electric system.

**Figure 3.12.1-3: Simplified Electric System**

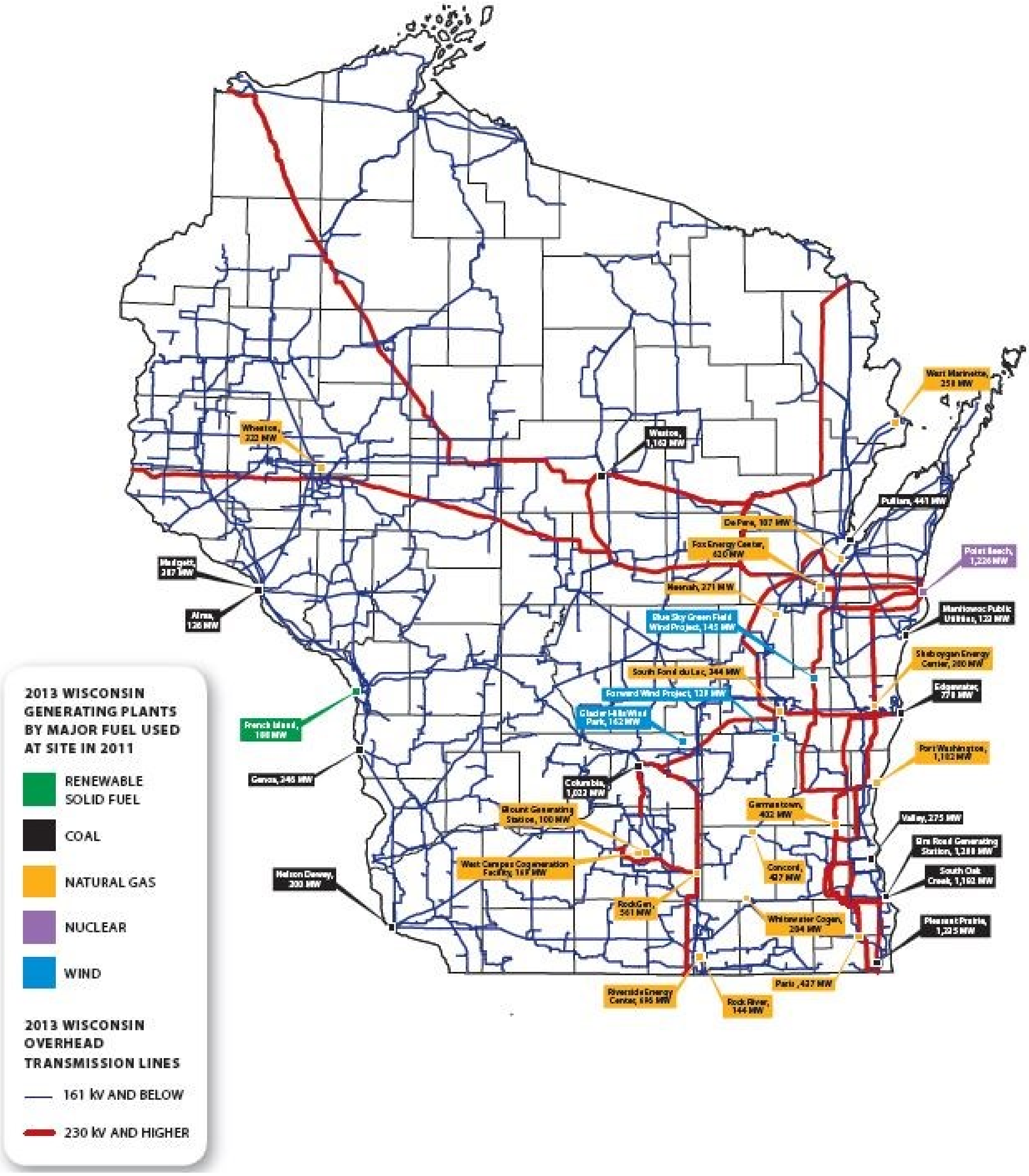



Source: Public Service Commission of Wisconsin, Electric09 (10/13)

The transmission grid includes not only transmission lines that run from power plants to where electricity is used, but also from transmission line to transmission line, providing a redundant system that helps assure the smooth flow of power. If a transmission line is taken out of service in one part of the power grid, the power reroutes itself through other power lines to continue delivering power. If adjacent transmission lines cannot handle the extra power flow, safety devices may switch them off to prevent damage. Severe overloads can lead to cascading outages and system-wide failure (i.e. a blackout). This is one of the disadvantages of the interconnectedness of the transmission grid.

The map in Figure 3.12.1-4 depicts the state's electric generating facilities over 100 Megawatts and electric transmission lines.

**Figure 3.12.1-4: 2013 Wisconsin Generating Plants And Overhead Transmission Lines**




Source: 2013 Wisconsin Energy Statistics, State Energy Office

There are approximately 12,000 miles of transmission lines in Wisconsin. The Wisconsin transmission system has a general electric flow from northwest to southeast through the state. The western part of Wisconsin is connected by high-voltage lines primarily from Minnesota. The southeastern part of Wisconsin is connected to northern Illinois by high-voltage lines. Imported electric is further addressed in the following fuel section.

**Fuel**

The state's fuel needs are primarily supplied by petroleum, coal, natural gas, imported electricity, nuclear energy, and renewables. The category of renewables includes hydroelectric generation, solar, biomass, biogas, and wind. The table in Figure 3.12.1-5 lists these fuels by percentage of total energy consumption.

**Figure 3.12.1-5: 2012 Wisconsin Energy Consumption by Fuel Type**

| Fuel | Percentage |
|---|---|
| Petroleum | 28.5 |
| Coal | 26.3 |
| Natural Gas | 26.0 |
| Imported electricity | 6.8 |
| Nuclear Energy | 6.7 |
| Renewables | 5.7 |
| Total | 100 |

Source: 2013 Wisconsin Energy Statistics, State Energy Office

The petroleum category includes gasoline, jet fuel, light distillate (such as kerosene), middle distillate (such as heating fuel and diesel fuel), residual fuel oil, and liquid propane gas (LPG). The primary use of petroleum fuel is transportation. Just over 88% of all petroleum is used for transportation.

The coal category includes both bituminous coal and sub-bituminous coal. Generally, the industrial and commercial sectors use bituminous coal with a high energy content. The utility sector uses sub-bituminous coal with a lower energy and sulfur content. Utilities mainly use low-sulfur coal to conform to regulations addressing sulfur emissions. The primary use of coal fuel is by electric utilities. Just over 91% of all coal is used by electric utilities.

The natural gas category includes natural gas, compressed natural gas (CNG), and liquefied natural gas (LNG). Natural gas is an important fuel source to many sectors. Natural gas is used by utilities for electric generation; by residential users for heating and other gas appliances (e.g. stove, dryer, water heater); and commercial and industrial user for heating and other uses. The largest user of natural gas is industry at 31.0%, followed by residential at 28.1%, electric utility at 21.7%, and commercial at 18.8%.

In Wisconsin the natural gas industry includes natural gas utilities, interstate pipelines, producers, and marketers. The natural gas utilities are the local distribution companies (LDCs). Interstate pipeline companies move the gas from the production area to the local utility. The natural gas producers and marketers produce or sell the gas to buyers such as the local utility.

The ANR Pipeline Company supplies 59.7% of the state's natural gas. The majority of this natural gas originates in Oklahoma and Louisiana. The Northern Natural Gas Company supplies 19.8% of the state's natural gas. The majority of this natural gas originates in Texas, Oklahoma, Kansas, and Alberta, Canada.

The imported electricity category represents the estimated resource energy used in other states or Canada to produce the electricity imported into Wisconsin. Historically, the state has imported, rather than exported, a small percentage of electricity. The table in Figure 3.12.1-6 lists percentage of imported electricity by year.

**Figure 3.12.1-6 Wisconsin Electric Imports**

| Year | Electric Imports |
|---|---|
| 1970 | -2.5% |
| 1975 | -1.7% |
| 1980 | -0.5% |
| 1985 | -0.1% |
| 1990 | 6.2% |
| 1995 | 7.7% |
| 1996 | 5.0% |
| 1997 | 8.0% |
| 1998 | 6.7% |
| 1999 | 6.0% |
| 2000 | 5.8% |
| 2001 | 7.2% |

| Year | Electric Imports |
|---|---|
| 2002 | 5.9% |
| 2003 | 5.1% |
| 2004 | 5.5% |
| 2005 | 7.3% |
| 2006 | 3.5% |
| 2007 | 5.2% |
| 2008 | 4.2% |
| 2009 | 4.2% |
| 2010 | 3.0% |
| 2011 | 4.1% |
| 2012 | 6.8% |

Source: 2013 Wisconsin Energy Statistics, State Energy Office

## Water

There are 582 public water utilities in Wisconsin. Of that number 78 are Class AB utilities serving 4,000 or more customers, 140 are Class C utilities serving from 1,000 to 4,000 customers, and 364 are Class D utilities serving fewer than 1,000 customers. Most are municipally owned, but five are private or investor-owned systems.

The majority of water utilities are sourced by groundwater (530) compared to surface water (52) as their primary water source. The amount of water pumped is more evenly split between groundwater (51%) compared to surface water (49%).[11]

[11] 2015 Wisconsin Water Fact Sheet, Public Service Commission of Wisconsin

**Wastewater**

Wisconsin has approximately 950 permitted sanitary sewage collection systems[12]. Discharges of untreated or inadequately treated sewage from any place in sewage collection systems are commonly referred to as sanitary sewer overflows (SSOs). Discharges of untreated sewage are a potential hazard to human health and can have significant impacts on water quality. Typically, SSOs occur as a result of either the entry of an excessive amount of precipitation and groundwater, known as infiltration/inflow (I/I), into the sewers or there is a mechanical, electrical, or structural failure in a component of the collection system. When a sewage collection system has insufficient capacity to transport the sewage from the I/I entering it, the system will relieve itself by overflowing from the sewer system at some point or backing up through a building sewer into a basement.

### 3.12.2 History

The following describe a selection of notable local, regional, and national incidents.

**March 4-5, 1976 Ice Storm**

On March 4-5, 1976 southern and eastern Wisconsin is impacted by a devastating ice storm. Ice accumulations ranged up to five inches on wires and tree limbs. High winds gusting to 60 mph worsened the situation. The storm brought down hundreds of utility poles, thousands of power and telephone lines, and a large number of trees. Up to 600,000 residences were directly affected and up to 100,000 were without power during the height of the storm. Some rural areas were without power for over 10 days. Twenty-one counties were included in a federal disaster declaration.

**August 14, 2003 Northeast Blackout**

The Northeast blackout of 2003 was a widespread power outage in the northeastern and Midwestern, United States and Ontario, Canada beginning just after 4:10 p.m. EDT. The primary cause was a software bug in the alarm system at a control room of the FirstEnergy Corporation, located in Ohio. Due to the lack of alarm operators were unaware of the need to re-distribute power after overloaded transmission lines hit unpruned foliage. This local failure cascaded into a widespread failure of the grid. According to the official analysis of the blackout by the U.S. and Canadian governments more than 508 generating units at 265 power plants shut down during the outage. Some power was restored by 11 p.m. Power was not restored for many others until 2 days later.

**2014 Winter**

[12] Wisconsin Department of Natural Resources, Programs for Sanitary Sewer Collection System, CMOM webpage accessed on 10/25/2016.

The harsh winter in 2014 led to a higher incidence of main breaks, and many utilities advised their customers to run their water to prevent further breaks and protect distribution systems "Non-revenue water" is water that is produced but does not generate sales to recover production costs. In 2014 non-revenue water accounted for about 24% of the water produced by water utilities in Wisconsin. This amount constitutes a 31% increase from 2013.

**2014 Winter Propane Shortage**

On January 25, 2014 Governor Walker signs Executive Order 130 declaring a State of Emergency in Response to Severe Winter Weather and a Propane Shortage. The shortage is believed to be the result of several factors including: high demand for propane in November to dry a large, late harvest of corn; disruption of pipeline delivery of propane to the Midwest; and record cold and snowstorms in upper Midwest increasing use of propane and interfering with truck and rail delivery. DHS reports three probable cold weather related deaths occurred in Ashland, Marquette, and Milwaukee Counties on Friday, January 3.

## 3.12.3 Probability, Impact and Mitigation

The disruption of life lines has and likely will again occur as a secondary hazard resulting from the impacts of a natural, technological, or human-caused hazard.

**Electric**

The Wisconsin transmission system can become congested under normal power flow conditions. In addition, there are many transmission lines in Wisconsin that are more than 60 years old, requiring upgrades or replacement. Multiple failures in one location can quickly affect the entire system, producing a large scale blackout. Fortunately, this does not happen very often.

Due to the 2003 blackout in the Northeast, the Federal Energy Regulatory Commission (FERC) passed mandatory reliability rules in 2005 which resulted in a series of new mandates including requirements for redundancy, reliability, and rigorous right-of-way maintenance.

**Fuel**

Wisconsin's natural gas utilities, or local distribution companies (LDCs) are regulated by the Public Service Commission (PSC). The rates and services of interstate pipeline companies, as well as the construction of new pipelines, is regulated by the Federal Energy Regulatory Commission (FERC)

**Water**

In general the state benefits from plentiful surface and ground water resources. However, these water resources are not always available in the quantity or quality that is needed for human uses. Many communities are facing serious water supply challenges based on increased demand, declining groundwater supplies, and aging infrastructure. The number of communities facing water challenges is expected to grow in the future. The Public Service Commission (PSC) of Wisconsin works with Wisconsin water utilities to incorporate water conservation and efficiency measures into water supply planning.

**Wastewater**

Sewers deteriorate over time and develop cracks, breaks, and blockages if not properly maintained. Aging, out-of-sight, out-of-mind sewer systems can be neglected and thus not be inspected or maintained on a regular basis.

The Wisconsin Department of Natural Resources (DNR) regulates municipal and industrial operations discharging wastewater to surface water or groundwater through the Wisconsin Pollutant Discharge Elimination System (WPDES) permit program. Plans for wastewater treatment facilities must be reviewed and approved by the DNR. All SSOs must be reported to the DNR within 24 hours followed by a written report within 5 days.

Wisconsin Administrative Code requires that all owners of collection systems develop and implement a Capacity, Management, Operation, and Maintenance (CMOM) Program. A CMOM Program is to assure that a sewage system is properly managed, operated, and maintained at all times; has adequate capacity to convey peak flows; and all feasible steps are taken to eliminate excessive infiltration and inflow from the system. A CMOM Program must mitigate the impact of overflows on waters of the state, the environment, and public health.

**Changing Future Conditions**

Deteriorating infrastructure is a current nationwide problem that is likely to be exacerbated by changing future conditions. Higher future temperatures, for example, would increase the demand for cooling homes, businesses, and public buildings, placing greater stress on power systems. Existing stormwater systems were designed based on past conditions that are now changing; many systems may quickly become inadequate if storms continue to become more frequent and/or intense.

Wisconsin communities should prepare for even greater stress on infrastructure systems that may already be outdated. Although declining infrastructure is a serious problem, it also presents an opportunity to improve and integrate existing systems so that they serve communities better and more efficiently.

### 3.12.4 Catastrophic Scenario

In early January, a cyber-attack against a key natural gas compressor station causes a shutdown of two pipelines in eastern Wisconsin, damaging pipeline infrastructure and forcing a rapid shutdown of natural gas power plants throughout the southwest, southeast, and east central regions. Coordinated physical attacks at substations in two urban areas trigger a power outage to approximately 80% of customers throughout five counties. The physical damage caused by the attacks is expected to take up to several weeks to completely repair. A total of 832,303 are without power and 1,164,000 without natural gas for over one week. Many critical infrastructure facilities have back-up generators, but roughly one-quarter of these operate on natural gas, and the remainder require fuel after 48-72 hours.

### 3.12.5 Summary Risk Analysis

The table in Figure 3.12.5-1 provides a summary risk analysis for the disruption of life lines hazard.

**Table 3.12.5-1: Disruption of Life Lines Summary Risk Analysis**

| Evaluation Criteria | Description | Ranking |
|---|---|---|
| **Risk to People, Property, Environment, and Operations** | | |
| Probability/potential threat of occurrence | • The hazard impacts the state occasionally, but not annually<br>• The hazard is somewhat localized, affecting only relatively small or isolated areas when it occurs<br>• The methodology for identifying events is not well-established, or is not applied across the entire state | Medium |
| Vulnerability | • Multiple, reliable, well-coordinated, countermeasures are in place to prevent or protect against this hazard.<br>• Countermeasures have an extensive demonstrated history of testing and success in significantly reducing the threat potential. | Low |
| Mitigation Potential | • Mitigation methods are established<br>• The State or counties have limited experience with the kinds of measures that may be appropriate to mitigate the hazard<br>• Some mitigation measures are eligible for federal grants<br>• There is a limited range of effective mitigation measures for the hazard<br>• Mitigation measures are cost-effective only in limited circumstances<br>• Mitigation measures are effective for a reasonable period of time | Medium |
| **Impacts of Catastrophic Scenario** | | |
| Public | • Minimal injuries and fatalities would be expected, but significant state and federal resources for mass care and shelter may be needed for populations without water, heat, or electricity. | Medium |
| Responders | • Local and mutual aid resources would be fully committed and significant state assistance would be needed in order meet the needs of the incident.<br>• State disaster declaration. | Medium |
| COOP, including delivery of services | • State and local government unable to deliver mission essential functions for longer than 7 days, major long-term relocation of staff and business operations necessary. | High |
| Property, Facilities & Infrastructure | • Loss of lifeline services for more than 7 days. | High |
| Environment | • Minimal impact on the environment is anticipated. | Low |

| | | |
|---|---|---|
| Economy | • Tremendous adverse impact affecting the livelihood of the region and possibly extending to statewide.<br>• Long-term, cascading damage across multiple economic sectors requiring federal government assistance. | High |
| Public Confidence | • Long-term loss of confidence in government and society.<br>• Mass panic and major civil disturbances requiring massive, sustained law enforcement response, curfews, and other security measures. | High |
| | Aggregate Impact | High |

### 3.12.6 Sources – Agency Input and Research

The following agencies and document research assisted in providing subject matter expertise to this scenario's core capabilities.


1. Public Service Commission of Wisconsin
2. Wisconsin Department of Natural Resources
3. Wisconsin State Energy Office
4. Wisconsin Initiative on Climate Change Impacts. "Impacts Presentation." Wisconsin Initiative on Climate Change Impacts. Accessed November 2016. http://www.wicci.wisc.edu/impacts.php#2.
5. *Wisconsin 2050: Scenarios of a State of Change.* August 20, 2016. Accessed October 2016. http://www.wicci.wisc.edu/resources/ClimateWI2050-Communites August 2016.pdf.
6. *Building Community Adaptation Strategies in Duluth,* presentation by Jodi Slick, Ecolibrium3, 28 January 2016.

# 3.13 EMERGING INFECTIOUS DISEASES (INCLUDING PANDEMICS)

Emerging infectious diseases, including pandemic influenza (flu), represent an irregular hazard with the potential to rapidly overwhelm a health care system. This hazard includes infectious diseases that may be transmitted among humans or between animals and humans; the reappearance of those infectious diseases once thought eradicated; new strains of known infectious diseases; and, previously unknown or unidentified infectious diseases. Despite extraordinary advances in development of countermeasures (diagnostics, therapeutics, and vaccines), the ease of world travel and increased global interdependence have added layers of complexity to containing these infectious diseases that affect not only the health but the economic stability of societies. Human immunodeficiency virus (HIV) infection and acquired immune deficiency syndrome (AIDS), severe acute respiratory syndrome (SARS), and the 2009 pandemic H1N1 influenza are only a few of many examples of emerging infectious diseases in the modern world.

## 3.13.1 Nature of the Hazard

Emerging infectious diseases pose a particular risk to urban and suburban communities due to the close environment in which people interact. An infectious disease may be transmitted by a variety of mechanisms, including airborne inhalation, food, liquids, bodily fluids, contaminated objects, ingestion, or vector-borne spread.

Some infectious diseases, such as flu, present seasonal threats to the public and require continual monitoring. A pandemic flu is an epidemic of an influenza virus that spreads on a worldwide scale and infects a large proportion of the world population. This is in contrast to the regular seasonal epidemics of flu.

A flu pandemic can occur when a new strain of the influenza virus is transmitted to humans from another animal species. [13]Historically, these new human-susceptible strains have arisen most commonly in pigs, chickens, and ducks. These animals form the cornerstone of livestock raised throughout the world for human consumption.

The most current and active threat comes from influenza type A strains that originate in birds and become readily transferable into other organisms. These viruses can be transmitted from wild birds to other bird species, causing outbreaks in domestic poultry. These viruses can also mutate into highly virulent strains that can infect humans, with the potential to cause human influenza pandemics. This should especially concern people who live in close proximity to livestock. The movement of influenza viruses throughout the world is thought to be caused in

[13] "Avian Influenza: Molecular Mechanisms of Pathogenesis and Host Range," Animal Viruses: Molecular Biology. Caister Academic Press.

part by bird migrations. However, commercial shipments of live birds, as well as human transnational travel transport a large number of pathogenic influenza strains.[14]

Influenza strains with the most rapid spread between birds and humans, posing a severe risk for a pandemic, are influenza A (H5N1) viruses. Of considerable concern is highly pathogenic avian influenza A H5N1 (HPAI A [H5N1]), commonly known as avian influenza or "bird flu." Viruses designated as highly pathogenic result in high mortality (up to 100 percent) within 48 hours. HPAI A (H5N1) is capable of killing tens of millions of birds as a direct result of infection, while hundreds of millions more must be destroyed by authorities to control the pathogen's spread.

The World Health Organization (WHO) currently considers HPAI A (H5N1) endemic in many bird populations globally, particularly in Southeast Asia and the Middle East.[15] Since 2004 the virus has caused millions of poultry deaths and severely impacted livelihoods, local economies, and international trade.

Fortunately, human-to-human spread of HPAI A (H5N1) has been rare. Most humans who become infected with the virus had close contact with H5N1-infected poultry or contaminated surfaces. By October 2011 the WHO had attributed more than 566 human cases and 300 deaths to HPAI A (H5N1).[16] The HPAI A (H5N1) is thought to pose the world's largest and gravest pandemic threat because of its ability to mutate rapidly in poultry, spread to humans, and high lethality.[17]

### 3.13.2 History

The United States and Wisconsin share a lengthy history shaped, in part, by the impacts of emerging infectious disease. Perhaps the most deadly disease epidemic in the United States and Wisconsin resulted in the devastation of the American Indian populations. These epidemics introduced and spread European diseases such as measles or smallpox to American Indian populations. Many archaeologists have speculated that these epidemics swept through the American Indians communities in Wisconsin long before European explorers reached the area.

**Smallpox and Measles**

Smallpox and measles were introduced to American Indian population by European explorers to the new world. In Wisconsin smallpox epidemics continued to affect many American Indian communities into the 1830s. Smallpox epidemics were not limited to American Indian populations. In August 1895 smallpox swept through the population on the south side of Milwaukee.

[14] Li, KS et al. (2004). Genesis of a highly pathogenic and potentially pandemic H5N1 influenza virus in eastern Asia, Nature **430** (6996): 209–13.
[15] http://www.who.int/mediacentre/factsheets/avian_influenza/en/index.html
[16] http://www.who.int/influenza/human_animal_interface/EN_GIP_LatestCumulativeNumberH5N1cases.pdf
[17] http://www.who.int/mediacentre/factsheets/avian_influenza/en/

**Malaria**

Malaria was common among French, British, and later American troops on the Wisconsin frontier. In the summer months malaria would often reach epidemic proportions. At Fort Crawford, 154 of the 199 men stationed there in the summer of 1830 had malaria.

**Cholera**

Cholera epidemics swept the United States and Wisconsin from 1832 to 1834, and again from 1849 to 1854. The worst of the cholera epidemics were centered in Milwaukee.

**1918 flu pandemic**

The 1918 flu pandemic, also known as the Spanish flu, was caused by the H1N1 influenza virus. To maintain morale World War I censors minimized reports of illness and mortality in Germany, Britain, France, and the United States. In neutral Spain the papers were free to report on the pandemic creating the false impression that the country was especially hard hit. The pandemic is believed to have infected 500 million people across the world and resulted in the deaths of 50 to 100 million. In Wisconsin the Spanish flu infected more than 100,000 and claimed more than 8,400 lives.

**1956-1958 Asian flu**

The 1956 to 1958 flu pandemic, also known as Asian flu, was caused by an H2N2 strain of the influenza A virus. The virus was first identified in Guizhou, China in early 1956 and lasted worldwide until 1958. The U.S. death toll is estimated at 69,800. Estimates of worldwide deaths vary widely depending on source. The World Health Organization has settled on approximately two million.

**1968-1969 Hong Kong flu**

The 1968 flu pandemic, also known as Hong Kong flu, was caused by an H3N2 strain of the influenza A virus. The first recorded outbreak was in Hong Kong. It is estimated to have killed one million people worldwide.

**2009 flu pandemic**

The most recent influenza pandemic was the 2009 H1N1 pandemic, which first entered the United States from Mexico. [18] The 2009 flu pandemic, also known as swine flu, involved the H1N1 influenza virus. The virus appeared to be a new strain of H1N1 combined with a Eurasian pig flu virus. Confirmed worldwide deaths totaled 14,286.

[18] CDC MMWR, April 30, 2009 / 58(Dispatch); 1-3 (http://www.cdc.gov/mmwR/preview/mmwrhtml/mm58d0430a2.htm).

**COVID-19 pandemic**

In December 209, China reported cases of an unknown pneumonia-like illness in Wuhan, China. It was discovered that this illness was caused by a coronavirus disease called SARS-CoV-2, also called COVID-19. The disease spread quickly, with the first confirmed case in the US in January 2020. In total, by November 2021, over 260 million cases of COVID-19 have been confirmed worldwide, causing almost 5.2 million deaths. In the US, nearly 800,000 people have perished from the disease.

Wisconsin's first confirmed case was in early February 2020. By November 2021, Wisconsin has had nearly 890,000 confirmed cases and over 9,000 deaths from COVID-19.

COVID-19 usually presents as an acute viral respiratory illness. Although the fatality rate is lower than earlier coronavirus variations, it is considered more infectious and caused a higher morbidity and mortality worldwide. Starting in 2021, vaccines have become widely available that help to decrease mortality rates in vaccinated individuals.

Since this pandemic is still ongoing, the writeup will be updated in the next plan update in hopes that the full picture will be clearer.

## 3.13.3 Probability, Impact, and Mitigation

The probability of emerging infectious diseases epidemics is unknown. An emerging infectious disease may be unaffected by existing immunities in a population and can therefore spread rapidly, infect large numbers of people in a short period of time, and cause high levels of mortality.

The real or perceived threat of an emerging infectious disease has the potential to disrupt normal public interactions. The impact of emerging infectious diseases can be mitigated by immunization; reporting, investigation, and surveillance; and response.

Immunizations, also called vaccinations, are one of the greatest achievements in public health. Vaccines prevent disease in people who receive them. If enough people in the community are vaccinated there is little opportunity for an outbreak to occur, protecting the entire community. Before vaccines, many children died from diseases like measles, pertussis (whooping cough), and Haemophilus influenza. Through the introduction of routine vaccinations, these and other vaccine-preventable diseases occur much less often in the United States.

The Wisconsin Department of Health Services (DHS) Wisconsin Electronic Disease Surveillance System (WEDSS) is a web-based system designed to facilitate reporting, investigation, and surveillance of communicable diseases in Wisconsin. State statute requires that a number of diseases and conditions considered to have significant public health impact must be promptly reported to the local health officer. Specifically, any health care provider who knows, or has reason to believe, a person treated or visited by him or her has a communicable disease is required to promptly report.

The Centers for Disease Control and Prevention (CDC) Health Alert Network (HAN) is the CDC's primary method of sharing cleared information about urgent public health incidents with public information officers; federal, state, territorial, and local public health practitioners; clinicians; and public health laboratories. Jurisdictional HAN programs connect all 50 states and the District of Columbia, 8 territories, and the Cities of Chicago, Los Angeles, and New York.

Specific plans and procedures have been developed to assist with the response including the Public Health Emergency Plan, Wisconsin Hospital Emergency Plan, Wisconsin Pandemic Influenza Operational Plan, Fatality Incident Response Plan, and the Regional Hospital Bioterrorism Preparedness Interim Stockpile Plan, and the Strategic National Stockpile Plan (SNS).

**Changing Future Conditions**

Higher temperatures and wetter conditions tend to increase mosquito and tick activity, leading to an increased risk of zoonotic diseases. Mosquitos are known to carry diseases such as West Nile virus (WNV), La Crosse/California encephalitis, Jamestown Canyon virus, St. Louis encephalitis, and Eastern equine encephalitis. The two major concerns associated with warmer and wetter conditions are that the mosquito species already found in Wisconsin and the diseases that they carry will become more prevalent, and that new species carrying unfamiliar diseases will start to appear for the first time.

Warmer winters with fewer hard freezes in areas that already see WNV-carrying mosquitos are likely to observe both a higher incidence of WNV and a longer WNV season, ultimately leading to an increase in human cases. Non-native mosquito species may move into Wisconsin if the climate becomes more suitable for them, bringing with them diseases such as Jamestown Canyon virus, Chikungunya, and Dengue Fever.

Ticks are also well-known disease vectors in Wisconsin, carrying pathogens such as Lyme disease, anaplasmosis, Ehrlichiosis, Powassan virus, and Babesiosis. Recent studies show that existing northwestern Wisconsin deer tick populations are expanding further south and east. Human cases of Lyme disease and other tickborne diseases have been detected in recent years, and an increase in reported cases of Ehrlichiosis around Eau Claire has been observed since 2008. The lone star tick is also poised to establish a larger population in Wisconsin and expand its range from the southeast part of the state into the central and northern regions.

Warmer, wetter weather can lead to an increase in algal blooms and declining beach health. An increase in flood events may also be associated with an increased incidence of mold problems in homes and businesses, as well as contamination of wells and surface waters due to sewer overflows and private septic system failures.

If these predictions come true, communities will have to contend with the human health impacts related to the increased prevalence of infectious diseases, heat waves, and changes in air and water quality. Public health officials will need to focus on spreading information and enacting pest and disease reduction. Floodprone communities will need to focus on continuously improving flood controls and mitigation strategies, including restricting building and chemical storage in floodplains, upgrading well and septic requirements, and providing water testing kits to residents.

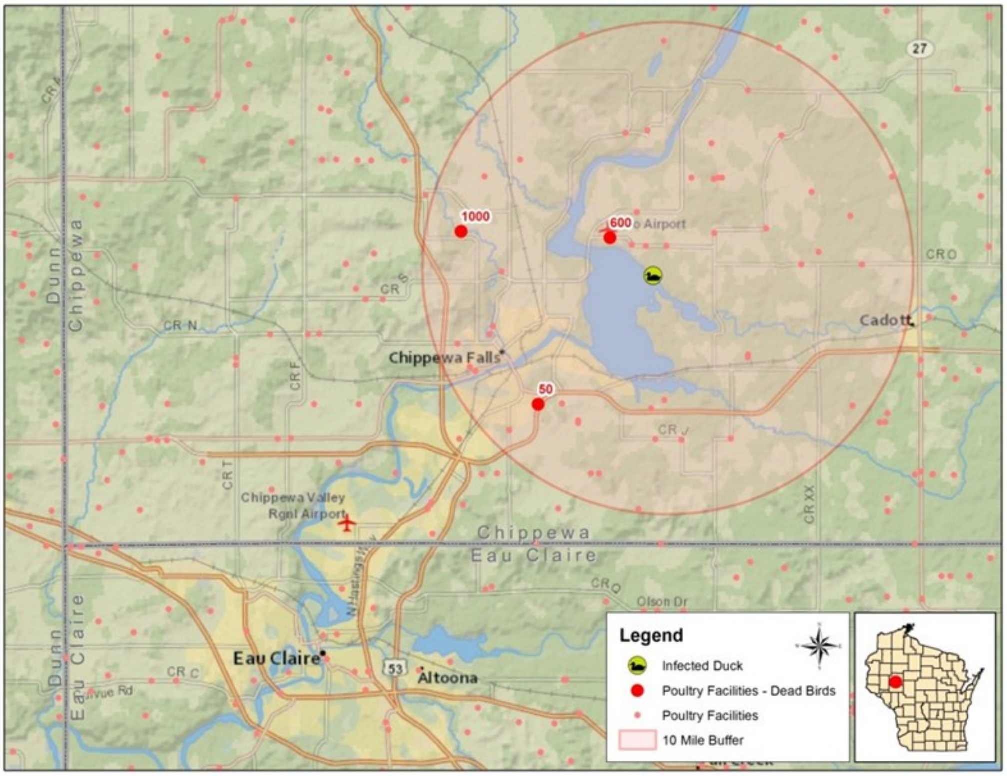
### 3.13.4 Catastrophic Scenario

In October, a concerned citizen contacts the Wisconsin Department of Natural Resources (DNR) regarding "an unusual number" of dead ducks at a state park in northwestern Wisconsin. Tests on 28 recovered migratory ducks confirm that the ducks died from a viral infection identified as influenza A (H5N1) (a.k.a. Avian Influenza or Bird Flu). Subsequently, the U.S. Department of Health and Human Services announces finding the influenza A (H5N1) virus in migratory birds in Wisconsin, Washington, California and Minnesota.

Within a week of initial virus identification in birds, Wisconsin diagnoses the first cases of Avian Influenza in humans. The influenza A (H5N1) virus specimens were collected from a 35-year-old woman and her infant daughter at an area hospital.

The Wisconsin Department of Agriculture, Trade, and Consumer Protection (DATCP) and U.S. Department of Agriculture (USDA) notify and visit farms within a 10-mile radius, identifying three poultry farms where increased poultry mortality has been noted. A state and local survey of the farms' employees identifies several persons with current influenza-like symptoms and others that had been ill within the previous weeks. The map in Figure 3.13.4-1 depicts the location and surrounding area of recovered H5N1 confirmed migratory bird deaths overlaid with a 10-mile radius.

**Figure 3.13.4-1: Location and 10-mile Radius of H5N1 Confirmed Migratory Bird Deaths**

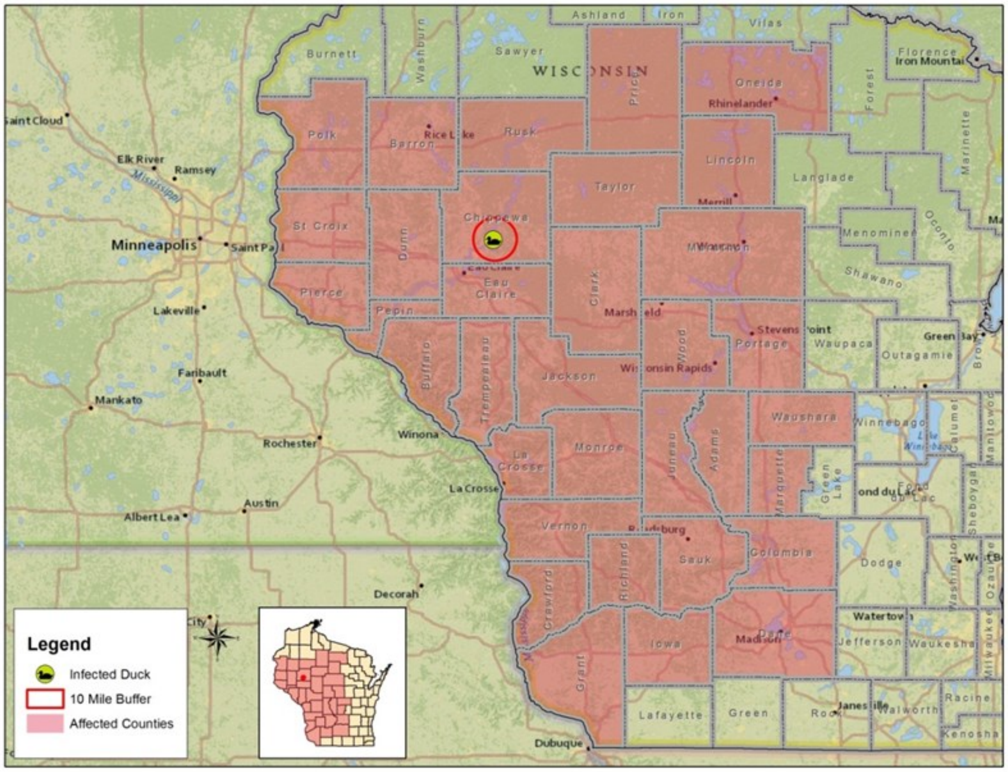



By mid-November, three hospitals in the area (total populations 99,879 and 62,778, respectively) report increased incidences of respiratory illness. At least four patients require the use of ventilators to survive. An investigation determines that the ill mother and daughter did not have direct contact with infected birds from the lake or farms, but did have contact with workers from the infected farms, leading to the conclusion that human-to-human transfer of the virus occurred.

By late December, influenza A (H5N1) illness is evident across the state and country. Hospitals locally and regionally are overwhelmed with ill patients seeking treatment. Ventilators are becoming scarce and worried-well are not showing up for work.

By the end of February, approximately 15% of the citizenry in 34 west-central Wisconsin counties have fallen ill with a fatality rate of approximately 4% for those that become infected. Hospitals and outpatient clinics in these counties exceed capacity while other counties statewide are at or near capacity from treating local cases and absorbing overflow from the west. The map in Figure 3.13.4-2 depicts the 34 H5N1 affected counties.

**Figure 3.13.4-2: H5N1 Affected Counties**




Statewide analysis indicates over 80,000 confirmed cases of influenza A (H5N1) (1.4% overall confirmed infection rate of Wisconsin's 5.7 million people) with countless others going unconfirmed due to lack of official diagnoses. Of those infected (confirmed and unconfirmed), approximately 4,000 die.

Human remains internment facilities in severely affected counties are overwhelmed; however, the state directs that remains must be handled locally to prevent contamination during transfer from the affected area. Counties must consider effecting mass burial or cremation of human remains to prevent further contamination of the non-infected population.

Medical staff shortages statewide are reported at 35% with rates of over 50% locally. Although essential infrastructure (water, power, gas/heat) remains functional, consistency in operation is severely degraded due to staff affected by the pandemic. Health care facilities and public health staff are exhausted and generally unable to respond effectively. Reports of chronic fatigue and burnout are widely reported with little or no relief available. Local pharmacies, health care providers and hospitals statewide report shortages of anti-viral medications as well as ventilators, gloves, masks, lab supplies, and other medical essentials.

The pandemic disrupts supply chains thus impacting availability of necessities. Looting and rioting is sporadic and concentrated in the severely impacted counties as people scramble to acquire needed supplies, such as food and water. Local law enforcement resources, already degraded due to illness, are consumed with matters such as unattended deaths and are unable to maintain social order and contain civil unrest in the hardest hit areas. Outside assistance is needed to address law enforcement shortfalls as well as to maintain on-scene protection and relief site security.

### 3.13.5 Summary Risk Analysis

The table in Figure 3.13.5-1 provides a summary risk analysis for the emerging infectious disease hazard.

**Table 3.13.5-1: Emerging Infectious Diseases Summary Risk Analysis**

| Evaluation Criteria | Description | Ranking |
|---|---|---|
| **Risk to People, Property, Environment, and Operations** | | |
| Probability/potential threat of occurrence | • The hazard impacts the state occasionally, but not annually<br>• The hazard is somewhat localized, affecting only relatively small or isolated areas when it occurs<br>• The methodology for identifying events is not well-established, or is not applied across the entire state | Medium |
| Vulnerability | • Multiple measures are in place to prevent or protect against this hazard.<br>• Countermeasures have been tested and have demonstrated success in reducing the threat potential. | Medium |
| Mitigation Potential | • Mitigation methods are established<br>• The State or counties have limited experience with the kinds of measures that may be appropriate to mitigate the hazard<br>• Some mitigation measures are eligible for federal grants<br>• There is a limited range of effective mitigation measures for the hazard<br>• Mitigation measures are cost-effective only in limited circumstances<br>• Mitigation measures are effective for a reasonable period of time | Medium |
| **Impacts of Catastrophic Scenario** | | |
| Public | • Large numbers of illnesses statewide are possible.<br>• Local and regional medical services are unable to manage the volume of patients needing treatment and hospitalization. | High |
| Responders | • Local medical services are unable to manage the volume of patients.<br>• Patients require transportation to regional medical facilities outside of the affected areas.<br>• Significant federal response would be mobilized, including Strategic National Stockpile assets. | High |
| COOP, including delivery of services | • State or local government mission essential functions may be impacted over the course of the outbreak due to employee absenteeism.<br>• Services would be degraded, but not would not completely stop. | Medium |
| Property, Facilities & Infrastructure | • Minimal impact on property and infrastructure. | Low |
| Environment | • Minimal impact on the environment. | Low |
| Economy | • Medium-term effects to a large portion of the state's economy across multiple sectors due to widespread illness and social distancing. | Medium |

| | | |
|---|---|---|
| Public Confidence | • Long-term loss of confidence in government and society.<br>• Curfews and other security measures may be required. | High |
| | Aggregate Impact | High |

### 3.13.6 Sources – Agency Input and Research

The following agencies and document research assisted in providing subject matter expertise to this scenario's core capabilities.


1. FEMA Region V Threat and Hazard Identification and Risk Assessment (THIRA)
2. Center for Disease Control.
3. Wisconsin Department of Agriculture, Trade, and Consumer Protection
4. Wisconsin Department of Health Services
5. Wisconsin Pandemic Influenza Operational Plan
6. Wisconsin Emergency Response Plan
7. Wisconsin Initiative on Climate Change Impacts. "Impacts Presentation." Wisconsin Initiative on Climate Change Impacts. Accessed November 2016. http://www.wicci.wisc.edu/impacts.php#2.
8. *Wisconsin 2050: Scenarios of a State of Change.* August 20, 2016. Accessed October 2016. http://www.wicci.wisc.edu/resources/ClimateWI2050-Communites August 2016.pdf.
9. https://www.dhs.wisconsin.gov/climate/diseases.htm

# 3.14 FOOD AND AGRICULTURE EMERGENCY

A food and agriculture emergency hazard can be described as any intentional or accidental threat to the state's food and agricultural products. This includes actions that represent both real and perceived threats to the state's food and agricultural products.

## 3.14.1 Nature of the Hazard

Wisconsin's history, identity, and economy are intimately connected to food and agricultural production. Wisconsin is known as "America's Dairyland" and is home to more than one million dairy cows. However, more than dairy is produced and processed in the state. Wisconsin ranks first in the nation for snap beans for processing, cheese, cranberries, ginseng, mink pelts, dry whey for humans, milk goats, and corn for silage. Agriculture contributes an estimated $88.3 billion annually to the state's economy and provides 11.9% of the state's employment.[19] A food and agricultural emergency has the potential to have a number of long-lasting negative effects on the state's economy, employment, and confidence in the food and agricultural sectors.

The food and agricultural emergency hazard includes intentional or accidental actions that threaten or disrupt the means of production or the quantity, quality, or safety of the state's food and agricultural products. This includes the introduction and spread of plant and animal pests and diseases. Specifically, diseases that have the potential to spread to humans (zoonotic diseases) such as brucellosis and rabies; that may spread from farm to farm such as foot-and-mouth disease (FMD) or pseudorabies; and diseases that cause other states and nations to close trade doors to our livestock and agricultural products such as avian influenza or tuberculosis.

## 3.14.2 History

The following describe a selection of notable local and international food and agriculture emergencies.

**December 1996 – May 1997, Berlin, Wisconsin**

The police chief of Berlin, Wisconsin, received an anonymous letter in late December 1996, claiming that feed products at National By-Products Incorporated had been tainted with a pesticide and that the police should expect "large scale animal mortality." National By-Products is a supplier for the Purina Mills animal feed plant in Fond du Lac, WI. On January 2, 1997 the Purina feed was tested and found to contain low levels of contamination (one or two parts per million). The following day, Purina stopped a shipment of 300 tons of feed bound for Wisconsin, Illinois, Iowa, and Michigan. Officials from the Wisconsin Department of Agriculture, Trade, and Consumer Protection announced that tallow stored at National By-Products Inc. had been deliberately contaminated with chlordane, an extremely toxic and persistent insecticide that was widely used in the U.S. between 1947 and the late 1980s. On September 14, 1999, Brian "Skip"

[19] Wisconsin Department of Agriculture, Trade and Consumer Protection website, Wisconsin Agricultural Statistics, Updated July 15, 2016.

Lea was indicted for product tampering after a police investigation found that he had twice contaminated the tallow. Lea owned a rival animal food processing facility, as well as dead livestock removal company.

**1998 Chilean Grape Scare**

The Chilean grape scare of 1989 resulted from the alleged contamination of Chilean grapes. On March 2 an individual telephoned the U.S. embassy in Santiago and claimed that some Chilean grapes contained cyanide. Following the threat it is alleged that 2 grapes were found to have been injected with cyanide. As a result the United States Food and Drug Administration banned imports of Chilean fruit and warned people not to eat grapes or Chilean fruit. The Chilean fruit export sector was thrown into panic and thousands of farm workers lost their jobs. The Chilean government was forced to provide temporary subsidies to offset more than $400 million in losses. Investigators found no traces of cyanide in any other fruit shipped from Chile. No individual or group has claimed responsibility.

**July 4, 1998, Middleton, WI**

On July 4, 1998 individual(s) conducted a daylight raid on the United Vaccines Laboratory located in Middleton, Wisconsin. The raid resulted in the release of animals and destruction of property. The individual(s) cut holes in the fence and released 310 ferrets and mink were released. In addition, equipment and windows were also destroyed. The slogan "Independence Day for Fur Farm Prisoners" was painted at the United Vaccines Laboratory. Joint Animal Liberation Front (ALF)/Earth Liberation Front (ELF) claimed responsibility.

**2001 United Kingdom Foot-and-Mouth Outbreak**

The outbreak of foot-and-mouth disease in the United Kingdom in 2001 caused a crisis in British agriculture and tourism. With the intention of controlling the spread of the disease public rights-of-way were closed. Over 10 million cows and sheep were killed in an eventually successful attempt to halt the disease. By the time that the disease was halted in October 2001 the crisis was estimated to have the United Kingdom $16 billion dollars (US).

### 3.14.3 Probability, Impact and Mitigation

Outbreaks of foreign animal diseases not previously occurring in the United States, such as avian influenza H5N1; or that have been previously eradicated, such as FMD; or that the United States is attempting to eradicate, such as pseudorabies and bovine tuberculosis, are very rare in Wisconsin. The state is, however, currently engaged in efforts to address a number of other well-known threats such as avian influenza (poultry), chronic wasting disease (deer and elk), and the destructive invasive species emerald ash borer, gypsy moth, and zebra mussel. The on-going local, state, and federal management efforts seek to control and minimize these and other threats.

Perhaps the greatest food and agricultural threat is the intentional (criminal or terrorism) spread of an animal disease such as FMD. The disease was eradicated in the United States 1929. In the unlikely event that Wisconsin experienced a criminal or terror related FMD outbreak it would have devastating financial, physiological, and economic impacts. FMD is a worldwide concern and many countries are dealing with the disease in their livestock populations. It is a severe, highly contagious viral disease. The FMD virus causes illness in cows, pigs, sheep, goats, deer, and other animals with divided hooves. Animal health, Incident Management Teams, dairy, swine, and goat industries, as well as law enforcement would likely be taxed beyond existing capabilities. Fortunately FMD is not a public health or food safety threat. However, due to misinformation and panic the psychological implications would be very impactful on dairy and meat consumers.

Most food and agriculture producers employ a variety of biosecurity measures, including but not limited to tracking access to production facilities in order to mitigate threats. This coupled with entities like the Wisconsin Statewide Information Center (WSIC) being vigilant about monitoring for possible criminal or terror attacks help to insure the low likelihood of such an event. Additional mitigating factors include, but are not limited to, the following.

**Animal Disease Reporting**

Veterinarians are legally required to report suspected cases of certain diseases to the Wisconsin Department of Agriculture, Trade and Consumer Protection (DATCP) or the U.S. Department of Agriculture. When veterinarians report these diseases, a state or federal veterinarian will investigate and, if necessary, submit samples to either the U.S. Veterinary Laboratory in Ames, Iowa, or to Plum Island Research Center in New York (for suspected foreign animal diseases). Until test results are available, the premises are likely to be quarantined.

**Plant Pests and Diseases**

The Bureau of Plant Industry, DATCP, monitors for plant pests and diseases in the state. The Bureau uses scientific surveys and routine inspections of licensed businesses to monitor for pests and diseases. It also enforces regulations to control and prevent introduction and spread of pests and diseases. Growers in Wisconsin can subscribe to the weekly Pest Bulletin to stay informed.

**Invasive Species**

In 2001 the Wisconsin Legislature directed the Department of Natural Resources (DNR) to establish a statewide program to control invasive species. The program and regulations are aimed at preventing new invasive species from getting to Wisconsin, and enabling quick action to control or eradicate those here but not yet established.

### 3.14.4 Catastrophic Scenario

Two members of a religious based terror group illegally entered the United States. Their goal is to introduce the Foot and Mouth Disease (FMD) virus obtained from infected animals in South America into U.S. beef and dairy herds. They hope to destroy worldwide confidence in the safety of U.S. beef and dairy exports providing the opportunity for beef and dairy producers from their region to fill the void created.

On September 3 a local veterinarian arrives at a livestock market in western Wisconsin to issue a Certificate of Veterinary Inspection (CVI) for a load of calves headed for Illinois. While there, a market employee asks him to look at a cull cow with sores in her mouth. The cow was dropped off the previous evening with two other cows. This morning the employee noticed that she would not eat and is drooling. The employee held her back, but the rest of that pen is ready to go through the ring in an hour. A total of 300 animals are scheduled to go through the ring today.

The District Veterinarian relays her findings to the Wisconsin State Veterinarian and the USDA Area Veterinarian in Charge (AVIC), who decide to send the samples Priority A for testing. Preliminary positive results for Foot and Mouth Disease (FMD) are relayed to the State Veterinarian. Based on the preliminary findings, and the compatible clinical signs, the State Veterinarian implements the state foreign animal disease response plan, and activates the joint USDA/DATCP Incident Management Team.

Animals that had already been sold and transported off the market grounds that day are traced to approximately 20 other farms in WI, and also several farms in MN, IA and IL. The livestock market has been quarantined, and a disease testing (surveillance) zone has been set up 6.2 miles surrounding the market.

### 3.14.5 Summary Risk Analysis

The table in Figure 3.14.5-1 provides a summary risk analysis for the food and agriculture emergency hazard.

**Table 3.14.5-1: Food and Agricultural Emergency Summary Risk Analysis**

| Evaluation Criteria | Description | Ranking |
|---|---|---|
| **Risk to People, Property, Environment, and Operations** | | |
| Probability/potential threat of occurrence | • The hazard impacts the state occasionally, but not annually<br>• The hazard is somewhat localized, affecting only relatively small or isolated areas when it occurs<br>• The methodology for identifying events is not well-established, or is not applied across the entire state | Medium |
| Vulnerability | • Multiple, reliable, well-coordinated, countermeasures are in place to prevent or protect against this hazard.<br>• Countermeasures have an extensive demonstrated history of testing and success in significantly reducing the threat potential. | Low |

| | | |
|---|---|---|
| Mitigation Potential | • Mitigation methods are established<br>• The State or counties have limited experience with the kinds of measures that may be appropriate to mitigate the hazard<br>• Some mitigation measures are eligible for federal grants<br>• There is a limited range of effective mitigation measures for the hazard<br>• Mitigation measures are cost-effective only in limited circumstances<br>• Mitigation measures are effective for a reasonable period of time | Medium |
| **Impacts of Catastrophic Scenario** | | |
| Public | • Local medical services are able to manage volume of injuries and fatalities but are near the limits of their capabilities.<br>• Only critically injured patients are diverted to facilities outside of the affected areas.<br>• Limited evacuations and sheltering may be required. | Low |
| Responders | • Significant federal and/or mutual aid from other states would be needed to meet the needs of the incident.<br>• Federal disaster declaration. | High |
| COOP, including delivery of services | • State or local government mission essential functions impacted for less than 24 hours. | Low |
| Property, Facilities & Infrastructure | • Significant damage to critical infrastructure, public and private property over a localized area.<br>• Up to 10% of buildings and infrastructure in affected area damaged, and/or loss of lifeline services for up to 24 hrs. | Low |
| Environment | • Environmental damage affecting one or more communities within a county.<br>• Moderate damage to an ecologically sensitive area such as wetlands, rivers, lakes, or public water supply.<br>• Damage requires short- to medium-term remediation efforts of state and federal government. | Medium |
| Economy | • Tremendous adverse impact affecting the livelihood of the region and possibly extending to statewide.<br>• Long-term, cascading damage across multiple economic sectors requiring federal government assistance. | High |
| Public Confidence | • Medium and long-term effects including elevated stress, depression and behavioral health impacts for individuals in and out of impacted communities.<br>• Short- to medium term reduction of confidence in government in society.<br>• Civil disturbances in impacted communities may require law enforcement response. | Medium |
| | Aggregate Impact | Medium |

### 3.14.6 Sources – Agency Input and Research

The following agencies assisted in providing their expertise on the subject matter related to the core capabilities in this scenario.

1. Department of Agriculture, Trade and Consumer Protection (DATCP)
2. Department of Natural Resources (DNR)
3. Department of Health Services (DHS)

# 3.15 CYBER-ATTACK

A cyber-attack can be described as the hostile use of information technology by individuals or groups for the purpose of financial gain or as an action to further a social or political agenda. This includes the use of information technology to threaten, exchange information, and/or organize and execute attacks against networks, computer systems, and infrastructure. Familiar attacks include, but are not limited to, unauthorized access to networks, infection of vulnerable systems by computer virus, web site defacing, and denial-of-service attacks.

## 3.15.1 Nature of the Hazard

A cyber-attack is a human caused hazard which can affect demographically and geographically diverse populations. In most cases a cyber-attack can be characterized as either being carried out for financial gain, directly or as a hired actor, or to further a social or political agenda.

An attack for financial gain may directly target financial institutions such as banks or credit unions. An attack may also be directed at business, research, or industrial targets for purposes of industrial espionage (theft of proprietary information or technology). In either case the perpetrators may ransom information back to the source to prevent dissemination to competitors or the public.

An attack to further a social or political agenda typically operates with the intent to gain access to sensitive or classified material. This information may be disseminated to the public with the intent to discredit or embarrassing the target. This is commonly referred to as “hacktivism”.

Since 2009 there has been an increase in cyber-attacks directed at power generation and oil companies. These attacks have used a variety of techniques such as spear-phishing, social engineering, Windows operating system bugs, and remote administration tools (RATs). None of these approaches are very advanced or hard to develop and manage. Although evidence suggests the growing trend in these attacks appears to target individual entities, instead of primary infrastructure, a mass coordinated attack cannot be discounted.

## 3.15.2 History

The cyber-attack hazard is rapidly evolving and any attempt to describe recent historical occurrences will be limited. The following describe a selection of notable local and international incidents.

**March 9, 2015 City of Madison**

On March 9, 2015 the city of Madison and Dane County experienced a cyber-attack following an officer-involved shooting. The cyber-attack was a denial-of-service attack which blocked or disrupted official communications, including email, and some police and fire dispatch services. Both a U.S. citizen calling himself “Bitcoin Baron” and the hacker activist group Anonymous claimed credit for the attack.

**December 23, 2015 Ukraine Power Companies**

On December 23, 2015, Ukrainian power companies experienced unscheduled power outages impacting approximately 225,000 customers. Reports indicate that the power outages were caused by remote cyber intrusions at three regional electrical power distribution companies. In addition, three other organizations, some from other critical infrastructure sectors, were intruded upon but did not experience operational impacts.

The cyber-attack was reportedly synchronized and coordinated, probably following extensive reconnaissance of the victim networks. During the cyber-attacks malicious remote operation of the breakers was conducted by multiple external humans using either existing RATs at the operating system level or remote industrial control system (ICS) client software via virtual private network (VPN) connections.

All three companies indicated that the actors wiped some systems by executing the KillDisk malware at the conclusion of the cyber-attack. The KillDisk malware erases selected files on target systems and corrupts the master boot record rendering systems inoperable. It is believed that this was done in an attempt to interfere with expected restoration efforts.

The tables in Figures 3.15.2-1, 2, 3, and 4 present the statistics for Wisconsin from pages 218-221 in the "2015 Internet Crime Report" produced by the Federal Bureau of Investigation (FBI), Internet Crime Complain Center (IC3).

**Figure 3.15.2-1: 2015 Wisconsin Internet Crime Report, Victims**

# Wisconsin

## Victim Demographics

| Age Range | Male Count | Male Loss | Female Count | Female Loss | Total Count | Total Loss |
|---|---|---|---|---|---|---|
| Under 20 | 68 | $ 41,707 | 51 | $ 24,822 | 119 | $ 66,529 |
| 20 - 29 | 327 | $ 365,248 | 287 | $ 136,117 | 614 | $ 501,365 |
| 30 - 39 | 329 | $ 446,409 | 317 | $ 289,959 | 646 | $ 736,368 |
| 40 - 49 | 319 | $ 734,987 | 335 | $ 2,825,270 | 654 | $ 3,560,257 |
| 50 - 59 | 357 | $ 1,528,629 | 376 | $ 835,323 | 733 | $ 2,363,952 |
| Above 60 | 392 | $ 1,823,153 | 269 | $ 1,050,375 | 661 | $ 2,873,528 |
| Totals | 1,792 | $ 4,940,132 | 1,635 | $ 5,161,867 | 3,427 | $ 10,101,998 |

## Crime Type by Victim Count

| Crime Type | Victim Count | Crime Type | Victim Count |
|---|---|---|---|
| Non-Payment/Non-Delivery | 714 | Misrepresentation | 46 |
| 419/Overpayment | 401 | Malware/Scareware | 45 |
| Identity Theft | 374 | Ransomware | 45 |
| Personal Data Breach | 275 | Corporate Data Breach | 40 |
| Extortion | 244 | IPR/Copyright and Counterfeit | 25 |
| Credit Card Fraud | 216 | Denial of Service | 17 |
| Harassment/Threats of Violence | 212 | Civil Matter | 15 |
| Other | 209 | Crimes Against Children | 15 |
| Advanced Fee | 185 | Investment | 15 |
| Phishing/Vishing/Smishing/Pharming | 179 | Virus | 13 |
| Auction | 177 | Re-shipping | 11 |
| Employment | 172 | Charity | 5 |
| Confidence Fraud/Romance | 156 | Gambling | 2 |
| Real Estate/Rental | 140 | Health Care Related | 2 |
| Government Impersonation | 112 | Terrorism | 2 |
| Business Email Compromise | 101 | Criminal Forums | 1 |
| No Lead Value | 86 | Hacktivist | 1 |
| Lottery/Sweepstakes | 61 | | |

## Descriptors*

| | |
|---|---|
| Social Media | 257 |
| Virtual Currency | 24 |

**These descriptors are used by the IC3 for tracking purposes only and are only available after another crime type has been selected.*

Source: 2015 Internet Crime Report, Federal Bureau of Investigation (FBI), Internet Crime Complain Center (IC3)

**Figure 3.15.2-2 2015 Wisconsin Internet Crime Report, Crime by Loss**

# Wisconsin continued

## Crime Type by Loss (Victim Location)

| Crime Type | Loss Amount | Crime Type | Loss Amount |
|---|---|---|---|
| Confidence Fraud/Romance | $ 3,180,380 | Misrepresentation | $ 69,461 |
| Business Email Compromise | $ 1,996,541 | IPR/Copyright and Counterfeit | $ 66,444 |
| Non-Payment/Non-Delivery | $ 1,338,590 | Extortion | $ 56,279 |
| Personal Data Breach | $ 811,795 | Malware/Scareware | $ 32,624 |
| Real Estate/Rental | $ 591,640 | Phishing/Vishing/Smishing/Pharming | $ 26,911 |
| Advanced Fee | $ 537,098 | Re-shipping | $ 13,899 |
| Investment | $ 496,421 | Ransomware | $ 9,102 |
| Identity Theft | $ 461,186 | Denial of Service | $ 6,800 |
| 419/Overpayment | $ 295,178 | Charity | $ 6,344 |
| Employment | $ 290,220 | Crimes Against Children | $ 3,040 |
| Credit Card Fraud | $ 266,238 | Gambling | $ 2,540 |
| Auction | $ 218,158 | Virus | $ 100 |
| Harassment/Threats of Violence | $ 208,795 | Criminal Forums | $ - |
| Government Impersonation | $ 187,625 | Hacktivist | $ - |
| Civil Matter | $ 158,829 | Health Care Related | $ - |
| Other | $ 148,536 | No Lead Value | $ - |
| Corporate Data Breach | $ 146,427 | Terrorism | $ - |
| Lottery/Sweepstakes | $ 90,128 | | |

## Descriptors*

| Descriptor | Loss Amount |
|---|---|
| Social Media | $ 2,638,270 |
| Virtual Currency | $ 48,302 |

**These descriptors are used by the IC3 for tracking purposes only and are only available after another crime type has been selected.*

Source: 2015 Internet Crime Report, Federal Bureau of Investigation (FBI), Internet Crime Complain Center (IC3)

**Figure 3.15.2-3 2015 Wisconsin Internet Crime Report, Crime by Type**

# Wisconsin continued

## Crime Type by Subject Count

| Crime Type | Subject Count | Crime Type | Subject Count |
|---|---|---|---|
| Non-Payment/Non-Delivery | 248 | Civil Matter | 11 |
| Identity Theft | 108 | IPR/Copyright and Counterfeit | 9 |
| Harassment/Threats of Violence | 87 | Government Impersonation | 7 |
| Auction | 85 | Lottery/Sweepstakes | 6 |
| Personal Data Breach | 71 | Crimes Against Children | 4 |
| Credit Card Fraud | 69 | Denial of Service | 4 |
| 419/Overpayment | 59 | Investment | 4 |
| Confidence Fraud/Romance | 47 | Malware/Scareware | 4 |
| Other | 46 | Charity | 3 |
| Advanced Fee | 45 | Health Care Related | 2 |
| Real Estate/Rental | 43 | Virus | 2 |
| No Lead Value | 42 | Criminal Forums | 1 |
| Misrepresentation | 34 | Re-shipping | 1 |
| Employment | 30 | Gambling | 0 |
| Extortion | 21 | Hacktivist | 0 |
| Phishing/Vishing/Smishing/Pharming | 19 | Ransomware | 0 |
| Corporate Data Breach | 18 | Terrorism | 0 |
| Business Email Compromise | 17 | | |

## Descriptors*

| Descriptor | Count |
|---|---|
| Social Media | 83 |
| Virtual Currency | 1 |

**These descriptors are used by the IC3 for tracking purposes only and are only available after another crime type has been selected.*

Source: 2015 Internet Crime Report, Federal Bureau of Investigation (FBI), Internet Crime Complain Center (IC3)

**Figure 3.15.2-4 2015 Wisconsin Internet Crime Report, Crime by Loss**

**Wisconsin** continued

**Crime Type by Loss (Subject Location)**

| Crime Type | Loss Amount | Crime Type | Loss Amount |
|---|---|---|---|
| Misrepresentation | $ 759,480 | Charity | $ 11,640 |
| Civil Matter | $ 751,029 | Employment | $ 11,546 |
| Credit Card Fraud | $ 522,924 | Malware/Scareware | $ 10,100 |
| Confidence Fraud/Romance | $ 522,245 | Denial of Service | $ 10,000 |
| Non-Payment/Non-Delivery | $ 512,857 | Extortion | $ 8,896 |
| Personal Data Breach | $ 426,158 | Virus | $ 7,220 |
| Identity Theft | $ 401,628 | Crimes Against Children | $ 3,000 |
| Business Email Compromise | $ 216,445 | Lottery/Sweepstakes | $ 1,325 |
| Real Estate/Rental | $ 187,245 | IPR/Copyright and Counterfeit | $ 968 |
| Harassment/Threats of Violence | $ 115,762 | Criminal Forums | $ - |
| Advanced Fee | $ 104,155 | Health Care Related | $ - |
| Investment | $ 89,850 | No Lead Value | $ - |
| Government Impersonation | $ 82,093 | Phishing/Vishing/Smishing/Pharming | $ - |
| Auction | $ 72,968 | Gambling | $ - |
| Other | $ 63,862 | Hacktivist | $ - |
| 419/Overpayment | $ 51,318 | Ransomware | $ - |
| Re-shipping | $ 43,883 | Terrorism | $ - |
| Corporate Data Breach | $ 38,833 | | |

**Descriptors***

| | |
|---|---|
| Social Media | $ 382,270 |
| Virtual Currency | $ 30,000 |

**These descriptors are used by the IC3 for tracking purposes only and are only available after another crime type has been selected.*

Source: 2015 Internet Crime Report, Federal Bureau of Investigation (FBI), Internet Crime Complain Center (IC3)

### 3.15.3 Probability, Impact and Mitigation

Efforts to determine probability and impact for this hazard are limited by inadequate historical precedence, an evolving variety of attack mediums, and an increasingly large number of potential targets. However, the pervasive presence of information technology likely assures a high probability of occurrence. The hazard impact will vary greatly depending on the intended purpose of the attack, type of attack, and target or targets of attack. The state has undertaken a number of efforts to mitigate the potential impacts of future attacks.

The Wisconsin Department of Justice (DOJ)/Wisconsin Statewide Information Center (WSIC) serves as the state's primary fusion center. The WSIC gathers information from numerous sources and produces intelligence products for federal, state, and local government agencies, the private sector, and the public.

The Wisconsin Department of Administration (DOA), Division of Enterprise Technology Enterprise Service Desk (DET ESD) monitors the state cyber-domain on a 24-hour basis for threats or disruptions using a variety of automated systems. DET ESD notifies the state chief information security officer of any detected or suspected threat or attack against state information technology assets. In addition, DOA, DET has started to train cyber-response teams specifically to support local units of government in Wisconsin. These State, Local, Tribal, and Territorial (SLTT) teams will develop deep technical skills available to assist local units of government. Through grant funding provided by the U.S. Department of Homeland Security the program is working to initially stand up three teams. The future goal is the formation of one team to be located in each of WEM's six regions.

The Wisconsin National Guard (WI NG) plays a key role in the state's overall cyber strategy. The WI NG maintains a Computer Network Defense Team which collaborates with other cyber security professionals across industries. The WI NG has also partnered with the Illinois National Guard to stand up a cyber protection team.

### 3.15.4 Catastrophic Scenario

On December 1 the DOJ/WSIC begins to see information posted on social media indicating an unspecified cyber threat to power companies operating within the state. The December 1 threat initiates a wide ranging, and often confused, exchange on social media. Over the next four weeks supporters and detractors engage in a heated debate on the subject of power generation, transmission, and use in the state and the nation.

On the evening of December 31 an unknown actor(s) begin a cyber-attack on the Badger State Power Company. The Badger State Power Company serves approximately 250,000 customers in central Wisconsin. Social media posts indicate that the targeting of Badger State Power Company and timing of the attack were meant as a statement with Badger State Power Company representing the state and the New Year as a resolution to reduce use of fossil fuels. Unintentionally, the attack also occurs during a period of extreme cold temperatures. High temperatures are expected to remain in the single digits for several days.

On the morning of January 1 a small number of Badger State Power Company customers lose electricity. The affected customers begin calling the company to report the power outage. The company begins investigating the unexplained outage and working to restore service. As the day progresses the situation worsens. By the end of the day approximately 100,000 customers have lost power. Thousands of calls, texts, and emails overwhelm the company's telephone and email systems. The extreme cold temperatures displace those residents that primarily rely on electricity for heating, cooking, and hot water.

The disruption of electrical service disables traffic signals in the affected area. The lack of traffic control in urbanized areas significantly increases travel times and accidents. Calls for service quickly overwhelm local emergency medical, fire, and law enforcement.

Many government agencies and hospitals are able to continue providing critical services on emergency generator back-up systems. However, these emergency generator back-up systems are limited by available fuel supply typically limited to 24-, 48- or 72-hours. Few businesses in the affected areas are similarly equipped and are forced to close. This immediately degrades local access to food, fuel, supplies, and other necessities.

Badger State Power Company, other state power companies, state, and federal entities work tirelessly to restore electrical service to affected customers. During this time unexplained encrypted network traffic on the industrial control system (ICS) is discovered. A review of available information suggests that vulnerability on the ICS was exploited to manipulate other system components. It is speculated that the yet unknown manipulation of one or more of these system components is responsible for the outages.

After five days the source of the fault has yet to be determined and many of the 100,000 remain without power. Public information and communication has become extremely challenging. Television, radio, mobile telephone, and internet are all severely limited by the widespread power outage and continuing demand on backup power sources such as batteries and generators.

### 3.15.5 Summary Risk Analysis

The table in Figure 3.15.5-5 provides a summary risk analysis for the cyber-attack hazard.

**Table 3.15.5-1: Cyber-attack Summary Risk Analysis**

| Evaluation Criteria | Description | Ranking |
|---|---|---|
| **Risk to People, Property, Environment, and Operations** | | |
| Probability/potential threat of occurrence | • The hazard has impacted the state numerous times on an annual basis<br>• The hazard is widespread, generally affecting regions or multiple counties in each event<br>• There is a reliable methodology for identifying events and locations | High |

| | | |
|---|---|---|
| Vulnerability | • Multiple measures are in place to prevent or protect against this hazard.<br>• Countermeasures have been tested and have demonstrated success in reducing the threat potential. | Medium |
| Mitigation Potential | • Mitigation methods are established<br>• The State or counties have limited experience with the kinds of measures that may be appropriate to mitigate the hazard<br>• Some mitigation measures are eligible for federal grants<br>• There is a limited range of effective mitigation measures for the hazard<br>• Mitigation measures are cost-effective only in limited circumstances<br>• Mitigation measures are effective for a reasonable period of time | Medium |
| **Impacts of Catastrophic Scenario** | | |
| Public | • Local medical services are able to manage volume of injuries and fatalities but are near the limits of their capabilities.<br>• Only critically injured patients are diverted to facilities outside of the affected areas.<br>• Limited evacuations and sheltering may be required. | Low |
| Responders | • Local and mutual aid resources would be fully committed and significant state assistance would be needed in order meet the needs of the incident. State disaster declaration. | Medium |
| COOP, including delivery of services | • State or local government mission essential functions impacted for 1-7 days, temporary relocation of business operations may be necessary. | Medium |
| Property, Facilities & Infrastructure | • Significant damage to critical infrastructure, public and private property over a large area.<br>• 10-50% of buildings and infrastructure in affected area damaged or destroyed in affected area, and/or loss of lifeline services for up to 1-7 days. | Medium |
| Environment | • Environmental damage limited to a single community or small geographic area.<br>• Damage requires short-term remediation efforts by local and state government. | Low |
| Economy | • Medium-term effects to large portion of the jurisdiction’s economy, possibly extending to the region.<br>• Damage to multiple economic sectors possibly requiring state or federal government assistance. | Medium |
| Public Confidence | • Medium and long-term effects including elevated stress, depression and behavioral health impacts for individuals in and out of impacted communities. | Medium |

| | | |
|---|---|---|
| | • Short- to medium term reduction of confidence in government in society.<br>• Civil disturbances in impacted communities may require law enforcement response. | |
| | Aggregate Impact | Medium |

### 3.15.6 Sources – Agency Input and Research

The following agencies and document research assisted in providing subject matter expertise to this scenario's core capabilities.

1. American Transmission Company
2. Dane County Emergency Management
3. FEMA Region V Threat and Hazard Identification and Risk Assessment (THIRA)
4. National Level Exercise 2012 After Action Report
5. Wisconsin Department of Administration, Division of Enterprise Technology
6. Wisconsin Emergency Response Plan, Cyber Incident Annex

# 3.16 DOMESTIC TERRORISM, INCLUDING ACTIVE SHOOTER INCIDENTS, CIVIL DISTURBANCES

Terrorism can be described as the threat or use of violence, by individuals or groups, to create fear for the purpose of furthering or achieving a political goal. This section considers the hazard of terrorism as well as those criminal activities that may appear as terrorism such as an active shooter incident, civil disturbance, or sabotage.

## 3.16.1 Nature of the Hazard

Terrorism is a human made hazard that can involve the threat or use of various forms of violence. Those engaged in terrorism generally seek maximum public exposure, rather than maximum damage, to create and spread fear. Terrorism can affect a much larger population than those who are directly attacked by taking advantage of media and social media opportunities.

Terrorism is a crime, but not all criminals are terrorists. A political goal specifically distinguishes terrorism from other criminal activity. However, the fear, public exposure, and required emergency response of some types of criminal activity may sufficiently resemble terrorism as to be similarly addressed.

For the purpose of this section the hazard of terrorism, active shooter, and civil disturbances are defined as follows:

**Domestic Terrorism**

The United States Code defines domestic terrorism as "activities that involve acts dangerous to human life that are a violation of the criminal laws of the United States or of any State; and appear: to be intended to intimidate or coerce a civilian population; to influence the policy of a government by intimidation or coercion; or to affect the conduct of a government by mass destruction, assassination, or kidnapping; and occur primarily within the territorial jurisdiction of the United States."

**Active Shooter**

The Department of Military Affairs (DMA), Joint Forces Headquarter (JFHQ) Physical Security Plan, Annex L, defines an active shooter as "an individual or group actively engaged in killing or attempting to kill people in a confined and populated area."

**Civil Disturbances**

The United States Code defines civil disorder as "any public disturbance involving acts of violence by assemblages of three or more persons, which causes an immediate danger of or results in damage or injury to the property or person of any other individual.

Terrorism, and criminal activities that may appear as terrorism, is a hazard that must be considered for all large events. Wisconsin is known for its many large events, which occur mostly in the summer months. The state also has very popular professional and college sports teams. These events attract large numbers of people in compacted areas. Some sporting events and festivals held in the state draw crowds as large as 300,000 people at one time.

### 3.16.2 History

The following describe a selection of incidents illustrating both the "lone wolf" and domestic terrorist threat to Wisconsin.

**August 14, 1970, University of Wisconsin - Madison**

Source: UW-Madison Archives, 9/1, 7778-M #27, August 24, 1970.

The Sterling Hall Bombing was committed by four young people as a protest against the University's research connections with the US military during the Vietnam War. It resulted in the death of a university physics researcher and injuries to three others.[20]

**July 20, 2000, Rhinelander, Wisconsin**

Five individuals associated with the Earth Liberation Front (ELF) damage or destroy 500 trees that were part of a research experiment and defaced U.S. Forest Service vehicles with references to ELF. The individuals targeted the Forest Service facility because it was the location of genetic research experiment designed to make trees more disease resistant. Researchers indicated that the trees were naturally bred (not bioengineered) to grow faster and resist diseases. Court determined damages exceeded $400,000.

[20] http://en.wikipedia.org/wiki/Sterling_Hall_bombing

**March 12, 2005, Brookfield, Wisconsin**

A member of the Living Church of God fired into the congregation, killing 7 before taking his own life at a Sheraton Hotel in Brookfield, Wisconsin. Four other were wounded, one critically. No motive was determined by police. Authorities examined possible religious connections to the shooting, but other motive including job loss and mental health issues are likely.

**August 5, 2012, Oak Creek, Wisconsin**

A local subject thought to be a white supremacist shot 9 people, killing 6 before taking his own life at a Sikh Temple on a Sunday morning. The incident was classified as an act of domestic terrorism by federal officials.

**October 21, 2012, Brookfield, Wisconsin**

A mass shooting at the Azana Spa located in Brookfield, Wisconsin. The shooter was the estranged husband of a spa employee. He shot 7 people, killing 3 including his wife, before taking his own life.

### 3.16.3 Probability, Impact and Mitigation

On an annual basis the US Department of Homeland Security (DHS) Office of Intelligence and Analysis (I&A) releases a Risk Assessment for each of the Metropolitan Statistical Areas (MSAs). In Fiscal Year (FY) 2016 the DHS/I&A used a threat methodology model to assign MSAs into one of four categories. The DHS/I&A Risk Assessments for State, the Milwaukee MSA, and the Madison MSA are useful tools for determining the probability, impact, and mitigation of terrorism and civil disturbances incidents as viewed from the Federal level. Specifically, the Risk Assessment threat corresponds to probability; consequence corresponds to impact; and vulnerability relates to the mitigation measures that State has applied through the years.

Threat Level 1 represented the highest threat level and Threat 4 represented the lowest threat level. An MSA with a Threat Level 1 has consistent range of past plots and identified by international and domestic terrorists as a threat. The DHS/I&A also assigned states and territories into one or three categories. Threat Level 1 represented the highest threat level and Threat Level 3 represented the lowest threat level.

The Milwaukee – Waukesha –West Allis (MWWA) MSA has been categorized as a Threat Level 3. DHS has assessed that international and domestic terrorists, as well as Homegrown Violent Extremists (HVEs), may have the intent to attack MWWA. Their judgment is based upon limited past threat reporting or non-specific past threat reporting. They do not rule out a future attack, there just isn't a clear desire to attack MWWA based upon previous reporting. The table in Figure 3.16.3-1 presents information for the MWWA MSA.

**Table 3.16.3-1: MWWA Threat Ranking**

| **Relative Risk Score** | **This UASI** | **Rank FY15** | **Rank FY16** |
|---|---|---|---|
| Total | 1.09 | 42 | 41 |
| **Threat** (30% of Relative Risk Score) | **This UASI** | **Level FY15** | **Level FY16** |
| Total | 3 | 3 | 3 |
| **Vulnerability Index** (20% of Relative Risk Score) | **This UASI** | **Rank FY15** | **Rank FY16** |
| Targeted Infrastructure Index (10%) | 2.30 | 37 | 38 |
| Border Index (10%) | 0.09 | 54 | 56 |
| Total | 60.68 | 57 | 58 |
| **Consequence Index** (50% of Relative Risk Score) | **This UASI** | **Rank FY15** | **Rank FY16** |
| Population Index (30%) | 0.95 | 35 | 35 |
| Economic Index (13%) | 8.72 | 37 | 37 |
| National Infrastructure Index (5%) | 6.77 | 43 | 39 |
| National Security Index (2%) | 1.98 | 79 | 80 |
| Total | 3.69 | 42 | 41 |

Source: FY2016 Risk Assessment, US Department of Homeland Security (DHS) Office of Intelligence and Analysis (I&A)

The Madison MSA has been assigned as a Threat Level 4 MSA. DHS has assessed that international and domestic terrorists, and HVE's, are unlikely to attack Madison. It is stated that they do not discount the possibility of an attack; there simply is an absence of specific, credible threat information regarding Madison. The table in Figure 3.16.3-2 presents information for the Madison MSA.

**Table 3.16.3-2: Madison MSA Threat Ranking**

| **Relative Risk Score** | **This UASI** | **Rank FY15** | **Rank FY16** |
|---|---|---|---|
| Total | 0.44 | 79 | 78 |
| **Threat** (30% of Relative Risk Score) | **This UASI** | **Level FY15** | **Level FY16** |
| Total | 4 | 4 | 4 |
| **Vulnerability Index** (20% of Relative Risk Score) | **This UASI** | **Rank FY15** | **Rank FY16** |
| Targeted Infrastructure Index (10%) | 2.30 | 37 | 38 |
| Border Index (10%) | 0.00 | 90 | 91 |
| Total | 60.66 | 67 | 69 |
| **Consequence Index** (50% of Relative Risk Score) | **This UASI** | **Rank FY15** | **Rank FY16** |
| Population Index (30%) | 0.38 | 61 | 60 |
| Economic Index (13%) | 3.95 | 63 | 63 |
| National Infrastructure Index (5%) | 4.51 | 64 | 56 |
| National Security Index (2%) | 2.02 | 81 | 79 |
| Total | 1.83 | 74 | 73 |

Source: FY2016 Risk Assessment, US Department of Homeland Security (DHS) Office of Intelligence and Analysis (I&A)

A state with a Threat Level 1 is assessed that terrorists and HVEs have intent to attack these states to cause economic damage and mass causalities from highly credible reporting. Wisconsin, as a whole, is considered a Threat Level 3. DHS assesses that while terrorists and HVEs may have interest in attacking Wisconsin, threat reporting and activity is limited in credibility and specificity. The table in Figure 3.16.3.-3 presents information for the State of Wisconsin.

**Table 3.16.3-3: State of Wisconsin Threat Ranking**

| **Relative Risk Score** | **This State** | **Rank FY15** | **Rank FY16** |
|---|---|---|---|
| Total | 1.84 | 23 | 23 |
| **Threat** *(30% of Relative Risk Score)* | **This State** | **Level FY15** | **Level FY16** |
| Total | 3 | 3 | 3 |
| **Vulnerability Index** *(20% of Relative Risk Score)* | **This State** | **Rank FY15** | **Rank FY16** |
| Targeted Infrastructure Index (10%) | 6.59 | 27 | 26 |
| Border Index (10%) | 20.05 | 33 | 33 |
| Total | 66.52 | 25 | 24 |
| **Consequence Index** (50% of Relative Risk Score) | **This State** | **Rank FY15** | **Rank FY16** |
| Population Index (30%) | 1.85 | 23 | 23 |
| Economic Index (13%) | 12.67 | 20 | 20 |
| National Infrastructure Index (5%) | 13.51 | 24 | 24 |
| National Security Index (2%) | 6.35 | 34 | 34 |
| Total | 6.92 | 24 | 24 |

Source: FY2016 Risk Assessment, US Department of Homeland Security (DHS) Office of Intelligence and Analysis (I&A)

## 3.16.4 Catastrophic Scenario

A large urban area holds an annual multiple day music festival during the summer. On the second to last day of the festival the weather is seasonable and pleasant encouraging a large turnout. By evening approximately 100,000 are in attendance on the festival grounds and an additional 300,000 in the vicinity of the festival.

Just before the start of a fireworks show a single actor ("lone wolf" or homegrown violent extremist) attacks a densely crowded area of the festival grounds. The attacker is armed with a handgun and multiple magazines as well as a body-borne improvised explosive device (BBIED) (e.g., suicide vest) fabricated with homemade explosives.

The attacker begins by firing at those people in the crowd nearest and most convenient. The first shots produce a very limited reaction from the crowd. Many in the crowd are unfamiliar with the sound of a handgun and confuse the noise with the beginning of the fireworks show. As the shooting continues the realization that something is wrong spreads through the crowd creating confusion and fear. After running out of ammunition the attacker rushes towards an exit congested with those fleeing and detonates the suicide vest. First responders are immediately overwhelmed as they work to secure the area and treat the survivors.

Almost immediately after the start of the attack numerous people in the crowd begin reporting on the attack using social media. The explosion and immediate aftermath are recorded on cell phone video and uploaded to social media. The video is quickly reported on by national and international news. Event organizers and state and local officials are immediately overwhelmed with requests for information.

The investigation following the attack identifies the attacker as a local male in his twenties. It is believed that he became radicalized by extremist web sites. The investigation indicates that he planned the attack in the weeks leading up to the event and made several pre-operational planning or surveillance visits to the festival area in the days prior to the attack. He was also able to use the internet to acquire the weapons, materials, and knowledge used in the attack. The pre-operational financing, planning, and surveillance would be difficult or impossible to detect.

The attack resulted in numerous direct and indirect injuries to festival goers and widespread panic in the crowd including 40 fatalities, 358 major casualties, and 620 minor casualties. An additional 4,500 individuals suffer from psychological effects for experiencing the incident.

### 3.16.5 Summary Risk Analysis

The table in Figure 3.16.5-1 provides a summary risk analysis for the terrorism hazard.

**Table 3.16.5-1: Terrorism Summary Risk Analysis**

| Evaluation Criteria | Description | Ranking |
|---|---|---|
| **Risk to People, Property, Environment, and Operations** | | |
| Probability/potential threat of occurrence | • The hazard occurs only very infrequently, generally less than every five years on a large scale, although localized events may be more frequent<br>• The hazard is generally very localized and on a small scale (i.e. sub-county level)<br>• A methodology for identifying event occurrences and/or severities is poorly established in the state, or is available only on a local basis | Low |
| Vulnerability | • Multiple, reliable, well-coordinated, countermeasures are in place to prevent or protect against this hazard.<br>• Countermeasures have an extensive demonstrated history of testing and success in significantly reducing the threat potential. | Medium |
| Mitigation Potential | • Methods for reducing risk from the hazard are not well-established, are not proven reliable, or are experimental<br>• The State or counties have little or no experience in implementing mitigation measures, and/or no technical knowledge of them<br>• Mitigation measures are ineligible under federal grant programs<br>• There is a very limited range of mitigation measures for the hazard, usually only one feasible alternative | Low |

| | | |
|---|---|---|
| | • The mitigation measures have not been proven cost-effective and are likely to be expensive compared to the magnitude of the damages caused by the hazard<br>• The long-term effectiveness of the measure is not known, or is known to be relatively poor | |
| **Impacts of Catastrophic Scenario** | | |
| Public | • Local medical services are unable to manage the volume of injuries and fatalities.<br>• Patients require transportation to regional medical facilities outside of the affected areas. | High |
| Responders | • Significant federal and/or mutual aid from other states would be needed to meet the needs of the incident.<br>• A federal disaster declaration would be expected. | High |
| COOP, including delivery of services | • Impact on COOP would be low unless government facilities receive a direct attack. | Low |
| Property, Facilities & Infrastructure | • Some damage to property and facilities in the localized area of the attack. | Low |
| Environment | • Minimal impact on the environment. | Low |
| Economy | • Negative impact to local economic activity in the short-term. Direct effects limited to the local community. | Medium |
| Public Confidence | • Major loss of confidence in government and society. Possible panic and major civil disturbances requiring sustained law enforcement response and other security measures. | High |
| | Aggregate Impact | High |

### 3.16.6 Sources – Agency Input and Research

The following agencies assisted in providing their expertise on the subject matter related to the core capabilities in this scenario.

1. City of Milwaukee Fire Department
2. City of Milwaukee Police Department
3. Department of Homeland Security, Office of Intelligence and Analysis
4. Federal Bureau of Investigation, Joint Terrorism Task Force
5. Milwaukee County Emergency Management
6. Milwaukee County Medical Examiner
7. Southeastern Wisconsin Threat Analysis Center
8. Wisconsin Department of Health Services
9. Wisconsin Statewide Intelligence Center

# 4.0 CRITICAL FACILITIES

The State's most valuable and critical assets are the employees working with or in a state owned or operated building, infrastructure, or facility. To minimize the risk to personnel and disruption to agency mission essential functions, many State agencies have developed emergency plans. However, an emergency plan cannot fully mitigate the negative impacts to state services that can result from the interruption or degradation of access or service associated with a building, infrastructure, or facility.

## 4.1 History

The 2011 State of Wisconsin Hazard Mitigation Plan (WHMP) included a strategy to address the vulnerability of state assets. The strategy proposed gathering detailed information on all state owned or operated facilities for the purpose of developing a database of asset information. The asset database would be used to identify critical facilities and conduct a risk assessment based on those critical facilities. The strategy proposed an ambitious program including data collection, site visits, development of a secure database, and additional staffing.

The data collection portion of the strategy was piloted with the Department of Corrections (DOC). The pilot project involved the development, distribution, collection, and processing of a questionnaire that required very specific information regarding each structure. The DOC collected information on 471 buildings within 25 different institutions, centers, and schools. The buildings included critical and non-critical buildings. The DOC pilot project successfully collected detailed information on department assets. The results of the risk scores:

- 18 buildings were rated "low"
- 166 buildings were rated "medium to low"
- 257 buildings were rated "medium"
- 30 buildings were rated "medium high"
- 0 buildings were rated "high"

Of the 30 buildings rated "medium high" risk when looking at the buildings' vulnerability to floods. Half of the buildings were non-critical such as storage sheds, cellars, and garages. The other buildings were considered critical infrastructure because of the service they provide such as residence hall, barrack, and power plants.

The post-pilot review indicated that full implementation of the proposed strategy for all state-owned or operated facilities across all state agencies would be time and resource intensive and result in excess information collection.

## 4.2 Requirements

A state owned or operated critical facilities risk assessment is a required element for the 2021 update of the WHMP. A simplified methodology based on the requirements described in 44 CFR §§201.4(c)(2)(ii) and 201.4(c)(2)(iii) was used for this critical facilities risk assessment. The table in Figure 4.2-1 captures FEMA's guidance for meeting these requirements.

**Figure 4.2-1: Federal Guidance Critical Facilities Risk Assessment**

| Element | Requirements |
|---|---|
| S5. Does the risk assessment address the vulnerability of state assets located in hazard areas and estimate the potential dollar losses to these assets? [44CFR §§201.4(c)(2)(ii) and 201.4(c)(2)(iii)]<br><br>**Intent:** To understand vulnerability of assets critical for state resilience as a basis for identifying and prioritizing mitigation actions. | a. The risk assessment must include an analysis of the potential impacts of hazard events to state assets and a summary of the assets most vulnerable to the identified hazards. These assets may be located in the identified hazard areas or affected by the probability of future hazard events.<br>b. The risk assessment must estimate potential dollar losses to state assets located in identified hazard areas.<br><br>Vulnerability and potential losses are not a list or inventory of state facilities but the summary of the potential impacts to those assets from the identified hazards. Factors affecting vulnerability may include asset use and function as well as construction type, age, or intended use.<br><br>State assets may include state-owned or operated buildings, infrastructure, and critical facilities.<br><br>Critical facilities means structures that the state determines must continue to operate before, during, and after an emergency and/or hazard event and/or are vital to health and safety. Examples of critical facilities may include, but are not limited to:<br><br>• Emergency operations centers, police and fire stations, and storage facilities (including data storage).<br>• Structures that house occupants with restricted mobility or access and/or functional needs, such as hospitals, institutions, and shelters.<br>• Utility generating, transmission, and storage facilities and related infrastructure, such as power and/or water treatment plants.<br>• Transportation facilities, such as ports, airports, roads, railroads, bridges, and/or tunnels. |

Source: State Mitigation Plan Review Guide, FEMA

### 4.2.1 Methodology

Consistent with this guidance the following methodology was used to identify state owned or operated critical facilities and infrastructure for the purpose of developing a state critical facilities risk assessment.

Inventory of Assets

Wisconsin Emergency Management (WEM) identified the Wisconsin Department of Administration (DOA) and the University of Wisconsin (UW) System as the best available sources of information on state owned and operated assets. The DOA provided WEM with an all-agencies inventory of assets in an Excel format spreadsheet. This inventory included assets ranging from small storage sheds to large multi-story office buildings. The inventory also included a list of 268 building renovation projects and, security, energy, and life safety upgrades as separate line items, particularly within the DOC. These were not counted as facilities for this assessment. The inventory totaled 6,783 critical and non-critical state owned and buildings, infrastructure, and facilities. Each asset included data such as agency name, institution name, building (asset) name, location, and replacement cost.

The data provided by the UW-System and DOA contains three notable limitations: first, the inventory did not include the state owned and operated roads and bridges that comprise the state highway system. Second, the facility types identified in each data set did not match the categories identified in the State Hazard Mitigation Plan Review Guide. Due to this shortcoming, WEM staff had to conduct a line-by-line review of the facilities to appropriately categorize them. Finally, the DOC data included in the DOA data included building renovations, energy upgrades, security system upgrades, window replacements, and other building improvements as separate line items.

Identification of Critical Facilities and Data Scrub

The process of identifying critical facilities involved several steps:

1. Consolidate data from the UW-System and the DOA.
2. Scrub the list to identify any building remodels, security updates, renovations, window replacements, or other non-addition improvements to ensure they are not counted as facilities.
3. Conduct a building number match between the 2016 list of critical facilities and the 2020 data set using Microsoft Excel. This match enabled staff reviewing the list to quickly identify facilities deemed critical in the 2016 plan.
4. Review facilities that matched the 2016 Hazard Mitigation Plan and ensure they are still considered "critical." This review resulted in some differences between this version and the 2016 version.
5. Review all other data to determine which are facilities should be included as "critical" based on their function or value to the state.
6. Assign facility types to all facilities considered "critical" in the spreadsheet. The identification of critical facilities was based on the 2011 WHMP definition amended consistent with the State Mitigation Plan Review Guide 2015. The resulting definition of critical facilities is as follows:
   **Critical facilities** are state-owned [or operated][21] facilities deemed essential due to their function, size, service area, uniqueness, delivery of vital services, and for the protection of the health and safety of citizens including buildings and infrastructure that meet characteristics such as:

   - Communications facilities;
   - Correctional facilities and other custodial facilities, including facility utility services;
   - Utility services, including: electrical power generation, heating, wastewater treatment, water treatment, etc.;
   - Hospitals and other medical facilities, including: group homes, shelters, mental health facilities, etc.;
   - Major State government facilities that house key state operations;
   - Critical military facilities; and

[21] From State Mitigation Plan Review Guide, FEMA, Effective March 2016

- Emergency response facilities, including: law enforcement, security, fire, etc.
- [Transportation facilities such as ports, airports, roads, railroads, bridges, and/or tunnels.][22]
- 2021 State Additions to Definition: State owned assets worth more than $100,000,000 dollars.

Addition of Location Information

The data provided by the DOA and the UW System did not include latitude or longitude information. The only location data included was the street address of the facilities. WEM's Geographic Information System (GIS) analyst used a geolocation tool to convert street addresses into latitude and longitude information for all 1,070 critical facilities. Further, if critical assets could be reasonably identified on aerials photographs the latitude and longitude information was added. Location information was sourced from agency information, web sources, and Google™ Maps. This type of correction was primarily applied to communications tower sites as their street address often reflected a point a significant distance from the facility itself.

Critical Facilities and Special Flood Hazard

The inventory of assets information was manipulated using the ESRI GIS to identify critical facilities located in a FEMA-designated special flood hazard area (SFHA). The GIS analysis sought to identify the number and value of critical facilities located in the SFHA.

Assessment

WEM used the combination of tables, charts, and GIS maps to analyze location and potential threats to the identified critical facilities.

## 4.3 Summary of Assets

The following is a summary of state owned and operated assets based on the inventory of assets developed using the methodology described in the previous section. The summary is not intended to be a list or inventory of all state owned and operated assets.

The table in Figure 4.3-1 lists the total number of assets, critical assets, replacement cost, and average replacement cost by agency. More than half of all assets are identified as Department of Natural Resources (DNR) assets, with 2,734 assets. The UW-System assets made up the other majority with 1,956 assets. Approximately 15.7%, or 1,070, of the total assets are designated as critical facilities. The largest percentage 41%, or 440, of the critical facilities are identified with the DOC.

[22] From State Mitigation Plan Review Guide, FEMA, Effective March 2016

The total replacement cost of critical facilities is approximately $7.47 billion dollars. Over 87% of this amount is comprised of assets from 4 agencies: the DOC at 26%, or $1.9 billion; the UW-System at 40%, or $2.9 billion; the DOA at 14%, or $1.07 billion; and the Department of Health Services (DHS) at 7%, or $540 million.

**Figure 4.3-1: Assets by Agency**

| Agency | Total Number of Assets | % of All Assets | Number of Critical Assets | % of all Critical Assets | Replacement Value of Critical Facilities | % of Replacement Cost of All Critical Facilities | Average Replacement Cost Per Critical Facility |
|---|---|---|---|---|---|---|---|
| Department of Administration | 69 | 1.0% | 28 | 2.6% | $1,075,612,319 | 14% | $38,414,726 |
| Department of Agriculture, Trade and Consumer Protection | 3 | 0.0% | 1 | 0.1% | $23,995,972 | 0% | $23,995,972 |
| Department of Corrections | 773 | 11.4% | 440 | 41.1% | $1,913,033,420 | 26% | $4,347,803 |
| Department of Health Services | 268 | 4.0% | 99 | 9.3% | $539,667,616 | 7% | $5,451,188 |
| Department of Military Affairs | 284 | 4.2% | 145 | 13.6% | $370,554,034 | 5% | $2,555,545 |
| Department of Natural Resources | 2734 | 40.3% | 6 | 0.6% | $90,141,427 | 1% | $15,023,571 |
| Department of Public Instruction | 27 | 0.4% | 26 | 2.4% | $86,296,136 | 1% | $3,319,082 |
| Department of Revenue | 4 | 0.1% | 2 | 0.2% | $27,965,482 | 0% | $13,982,741 |
| Department of Transportation | 224 | 3.3% | 158 | 14.8% | $74,488,249 | 1% | $471,445 |
| Department of Veterans Affairs | 95 | 1.4% | 6 | 0.6% | $32,997,242 | 0% | $5,499,540 |
| Department of Workforce Development | 6 | 0.1% | 5 | 0.5% | $230,182,128 | 3% | $46,036,426 |
| Educational Communications Board | 38 | 0.6% | 37 | 3.5% | $19,565,812 | 0% | $528,806 |
| Historical Society | 251 | 3.7% | 0 | 0.0% | $0 | 0% | N/A |
| State Fair Park | 49 | 0.7% | 0 | 0.0% | $0 | 0% | N/A |
| University of Wisconsin System | 1956 | 28.8% | 117 | 10.9% | $2,986,220,742 | 40% | $25,523,254 |
| Board of Commissioners of Public Lands | 2 | 0.0% | 0 | 0.0% | $0 | 0% | N/A |
| Total | 6783 | 100% | 1070 | 100% | $7,470,720,578 | 100% | N/A |

Source: WEM; DOA; UW, 2021

The DOC manages risk through the Office of Special Operations, Preparedness and Emergency Response Section (PERS). This section provides a systemic structure for Department-wide emergency preparedness, education, training, response, and management. This includes:

- Continuity of Operations Planning (COOP)
- Emergency Operations Plans
- Emergency Operations Center
- Preparedness and Operations
- National Incident Management System (NIMS) compliance
- Incident Management Team (IMT) operations
- Comprehensive exercise program and training
- Security and operational audits
- Vulnerability assessments
- Work stoppage and disturbance planning
- Resource allocation and policy development

The UW-System is one of the largest systems of public higher education in the country, serving approximately 165,000 students each year and employing more than 39,000 faculty and staff statewide. The system is made up of 13 four-year universities, and 26 campuses, and the statewide UW-Extension. In general, the universities and college campuses plan and prepare to manage the local risks. In 2003, the UW-Madison Police Department established an Emergency Management Unit for mitigation, planning, response, and recovery. The unit is responsible for the UW-Madison campus and several other UW System campuses.

The DHS manages risk through the Division of Enterprise Services, Office of Facilities, Safety and Risk Management. This office provides space planning; and coordinates staff moves, fleet management, parking, and Continuity of Operations planning and implementation.

The table in Figure 4.3-2 lists the number, replacement cost, and average replacement cost of critical facilities by facility type. A total of 1,070 assets are designated as critical facilities with a replacement cost of approximately $7.4 billion dollars. Approximately 40% of all assets are classified as correctional facilities. It would cost approximately $1.9 Billion to replace these assets, which is also the highest total replacement cost of all categories. However, facilities classified as "Major State Government" facilities and "Other Essential Facilities" on average, have a replacement value (per facility) of $38 million and $31 million respectively. "Correctional Facilities" have an average replacement value of approximately $4.5 million. The roughly 9-fold difference in average replacement cost is largely due to a significant number of critical support facilities that exist at each large correctional institution that are not present at large state government headquarters buildings or the state capitol.

**Figure 4.3-2: Critical Facilities by Facility Type**

| Facility Type | Count | % | Replacement Cost | Average Replacement Cost |
|---|---|---|---|---|
| Communications Facility | 184 | 17.2% | $185,834,400 | $1,009,970 |
| Correctional Facility | 435 | 40.7% | $1,941,314,140 | $4,462,791 |
| Critical Military Facility | 143 | 13.4% | $369,418,716 | $2,583,348 |
| Emergency Response Facility | 21 | 2.0% | $32,878,297 | $1,565,633 |
| Hospital and other Medical Facility | 115 | 10.7% | $1,343,961,836 | $11,686,625 |
| Major State Government | 37 | 3.5% | $1,420,568,195 | $38,393,735 |
| Other Essential Facilities | 46 | 4.3% | $1,459,199,099 | $31,721,720 |
| Transportation Facility | 2 | 0.2% | $1,716,419 | $858,209 |
| Utility Services | 87 | 8.1% | $715,829,476 | $8,227,925 |
| Total | 1070 | 100.0% | $7,470,720,578 | $11,167,773 |

Source: WEM; DOA; UW, 2021

The table in Figure 4.3-3 lists the total number of assets, critical assets, replacement cost, and average replacement cost by County. Note, a handful of facilities fall within Winona County, and Houston County, and St. Louis County, all of which are in Minnesota.

As may be expected the highest concentration of all state assets are located near to the seat of state government located in Dane County. Specifically, 14% or 949 of all state assets are located in Dane County. The rest of the assets are largely concentrated around the state's larger correctional facilities, campgrounds, and at the various UW-System campuses.

Similarly, the highest concentrations of critical facility assets are in or near Dane County. Specifically, 18.7% or 200 critical facilities are in Dane County. Dodge, Grant, and Waukesha Counties have the next highest concentrations at approximately 4% of the state's critical assets each.

The replacement cost by county also illustrates the concentration of critical facility assets located in or near Dane County. 59% the total replacement cost of critical facility assets is concentrated in Dane County. This equates to approximately $4.5 billion dollars. The next highest amount is 5.1% or $379 million dollars is in Dodge County (2 large state prison complexes).

**Figure 4.3-3 Assets by County**

| County | Total Assets | % of All Assets | Total # of Critical Assets | % of Critical Assets | Replacement Cost of Critical Facilities | % Replacement Cost of Critical Facilities | Average Replacement Cost |
|---|---|---|---|---|---|---|---|
| Adams | 24 | 0.4% | 4 | 0.4% | $509,999 | 0.0% | $127,500 |
| Ashland | 63 | 0.9% | 5 | 0.5% | $4,223,182 | 0.1% | $844,636 |
| Barron | 15 | 0.2% | 4 | 0.4% | $2,564,141 | 0.0% | $641,035 |
| Bayfield | 67 | 1.0% | 8 | 0.7% | $1,792,087 | 0.0% | $224,011 |
| Brown | 155 | 2.3% | 40 | 3.7% | $175,041,982 | 2.3% | $4,376,050 |
| Buffalo | 22 | 0.3% | 3 | 0.3% | $272,210 | 0.0% | $90,737 |
| Burnett | 45 | 0.7% | 2 | 0.2% | $238,811 | 0.0% | $119,405 |
| Calumet | 54 | 0.8% | 2 | 0.2% | $1,277,026 | 0.0% | $638,513 |
| Chippewa | 115 | 1.7% | 38 | 3.6% | $216,147,914 | 2.9% | $5,688,103 |
| Clark | 11 | 0.2% | 6 | 0.6% | $2,755,957 | 0.0% | $459,326 |
| Columbia | 226 | 3.3% | 11 | 1.0% | $87,360,178 | 1.2% | $7,941,834 |
| Crawford | 61 | 0.9% | 24 | 2.2% | $44,625,072 | 0.6% | $1,859,378 |
| Dane | 949 | 14.0% | 200 | 18.7% | $4,451,818,027 | 59.6% | $22,259,090 |
| Dodge | 281 | 4.1% | 119 | 11.1% | $379,483,645 | 5.1% | $3,188,938 |
| Door | 217 | 3.2% | 5 | 0.5% | $1,075,793 | 0.0% | $215,159 |
| Douglas | 158 | 2.3% | 14 | 1.3% | $26,549,342 | 0.4% | $1,896,382 |
| Dunn | 107 | 1.6% | 11 | 1.0% | $22,867,799 | 0.3% | $2,078,891 |
| Eau Claire | 104 | 1.5% | 21 | 2.0% | $40,327,579 | 0.5% | $1,920,361 |
| Florence | 12 | 0.2% | 2 | 0.2% | $260,523 | 0.0% | $130,262 |
| Fond du Lac | 98 | 1.4% | 28 | 2.6% | $104,663,021 | 1.4% | $3,737,965 |
| Forest | 5 | 0.1% | 2 | 0.2% | $124,865 | 0.0% | $62,432 |
| Grant | 270 | 4.0% | 9 | 0.8% | $79,475,791 | 1.1% | $8,830,643 |
| Green | 31 | 0.5% | 3 | 0.3% | $2,181,140 | 0.0% | $727,047 |
| Green Lake | 7 | 0.1% | 0 | 0.0% | $0 | 0.0% | N/A |
| Iowa | 99 | 1.5% | 5 | 0.5% | $1,288,305 | 0.0% | $257,661 |
| Iron | 21 | 0.3% | 2 | 0.2% | $333,853 | 0.0% | $166,926 |
| Jackson | 78 | 1.1% | 18 | 1.7% | $67,329,513 | 0.9% | $3,740,529 |
| Jefferson | 78 | 1.1% | 8 | 0.7% | $26,289,410 | 0.4% | $3,286,176 |
| Juneau | 142 | 2.1% | 31 | 2.9% | $212,546,411 | 2.8% | $6,856,336 |
| Kenosha | 92 | 1.4% | 12 | 1.1% | $39,927,295 | 0.5% | $3,327,275 |
| Kewaunee | 10 | 0.1% | 0 | 0.0% | $0 | 0.0% | N/A |
| La Crosse | 76 | 1.1% | 5 | 0.5% | $15,428,557 | 0.2% | $3,085,711 |
| Lafayette | 90 | 1.3% | 3 | 0.3% | $619,377 | 0.0% | $206,459 |
| Langlade | 20 | 0.3% | 2 | 0.2% | $719,426 | 0.0% | $359,713 |
| Lincoln | 81 | 1.2% | 27 | 2.5% | $55,742,373 | 0.7% | $2,064,532 |
| Manitowoc | 41 | 0.6% | 0 | 0.0% | $0 | 0.0% | N/A |
| Marathon | 64 | 0.9% | 11 | 1.0% | $18,926,916 | 0.3% | $1,720,629 |
| Marinette | 64 | 0.9% | 5 | 0.5% | $1,059,738 | 0.0% | $211,948 |
| Marquette | 31 | 0.5% | 0 | 0.0% | $0 | 0.0% | N/A |
| Menominee | 0 | 0.0% | 0 | 0.0% | $0 | 0.0% | N/A |
| Milwaukee | 176 | 2.6% | 25 | 2.3% | $284,748,048 | 3.8% | $11,389,922 |

| County | Total Assets | % of All Assets | Total # of Critical Assets | % of Critical Assets | Replacement Cost of Critical Facilities | % Replacement Cost of Critical Facilities | Average Replacement Cost |
|---|---|---|---|---|---|---|---|
| Monroe | 50 | 0.7% | 17 | 1.6% | $40,993,417 | 0.5% | $2,411,377 |
| Oconto | 16 | 0.2% | 0 | 0.0% | $0 | 0.0% | N/A |
| Oneida | 142 | 2.1% | 10 | 0.9% | $5,300,978 | 0.1% | $530,098 |
| Outagamie | 31 | 0.5% | 6 | 0.6% | $8,572,834 | 0.1% | $1,428,806 |
| Ozaukee | 39 | 0.6% | 2 | 0.2% | $407,182 | 0.0% | $203,591 |
| Pepin | 0 | 0.0% | 0 | 0.0% | $0 | 0.0% | N/A |
| Pierce | 128 | 1.9% | 7 | 0.7% | $11,945,637 | 0.2% | $1,706,520 |
| Polk | 97 | 1.4% | 3 | 0.3% | $337,767 | 0.0% | $112,589 |
| Portage | 119 | 1.8% | 9 | 0.8% | $28,936,994 | 0.4% | $3,215,222 |
| Price | 20 | 0.3% | 5 | 0.5% | $3,649,016 | 0.0% | $729,803 |
| Racine | 148 | 2.2% | 68 | 6.4% | $296,412,439 | 4.0% | $4,359,006 |
| Richland | 7 | 0.1% | 3 | 0.3% | $312,476 | 0.0% | $104,159 |
| Rock | 31 | 0.5% | 19 | 1.8% | $39,507,126 | 0.5% | $2,079,322 |
| Rusk | 7 | 0.1% | 1 | 0.1% | $51,882 | 0.0% | $51,882 |
| Sauk | 160 | 2.4% | 2 | 0.2% | $703,066 | 0.0% | $351,533 |
| Sawyer | 96 | 1.4% | 11 | 1.0% | $12,452,691 | 0.2% | $1,132,063 |
| Shawano | 15 | 0.2% | 4 | 0.4% | $589,180 | 0.0% | $147,295 |
| Sheboygan | 174 | 2.6% | 57 | 5.3% | $79,150,212 | 1.1% | $1,388,600 |
| Saint Croix | 75 | 1.1% | 5 | 0.5% | $6,896,725 | 0.1% | $1,379,345 |
| Taylor | 10 | 0.1% | 1 | 0.1% | $43,903 | 0.0% | $43,903 |
| Trempealeau | 26 | 0.4% | 0 | 0.0% | $0 | 0.0% | N/A |
| Vernon | 40 | 0.6% | 0 | 0.0% | $0 | 0.0% | N/A |
| Vilas | 149 | 2.2% | 4 | 0.4% | $1,376,907 | 0.0% | $344,227 |
| Walworth | 140 | 2.1% | 18 | 1.7% | $61,711,182 | 0.8% | $3,428,399 |
| Washburn | 74 | 1.1% | 5 | 0.5% | $1,466,766 | 0.0% | $293,353 |
| Washington | 34 | 0.5% | 7 | 0.7% | $22,433,200 | 0.3% | $3,204,743 |
| Waukesha | 273 | 4.0% | 10 | 0.9% | $41,942,643 | 0.6% | $4,194,264 |
| Waupaca | 76 | 1.1% | 6 | 0.6% | $15,462,773 | 0.2% | $2,577,129 |
| Waushara | 85 | 1.3% | 14 | 1.3% | $112,941,797 | 1.5% | $8,067,271 |
| Winnebago | 177 | 2.6% | 42 | 3.9% | $286,543,176 | 3.8% | $6,822,457 |
| Wood | 77 | 1.1% | 13 | 1.2% | $18,004,215 | 0.2% | N/A |
| Houston | 4 | 0.1% | 4 | 0.4% | $1,958,550 | 0.0% | N/A |
| St. Louis | 1 | 0.0% | 0 | 0 | $0 | 0.0 | N/A |
| Winona | 2 | 0.0% | 2 | 0.2% | $20,540 | 0.0% | N/A |
| Total | 6783 | 100% | 1070 | 100.0% | $7,470,720,578 | 100.0% | N/A |

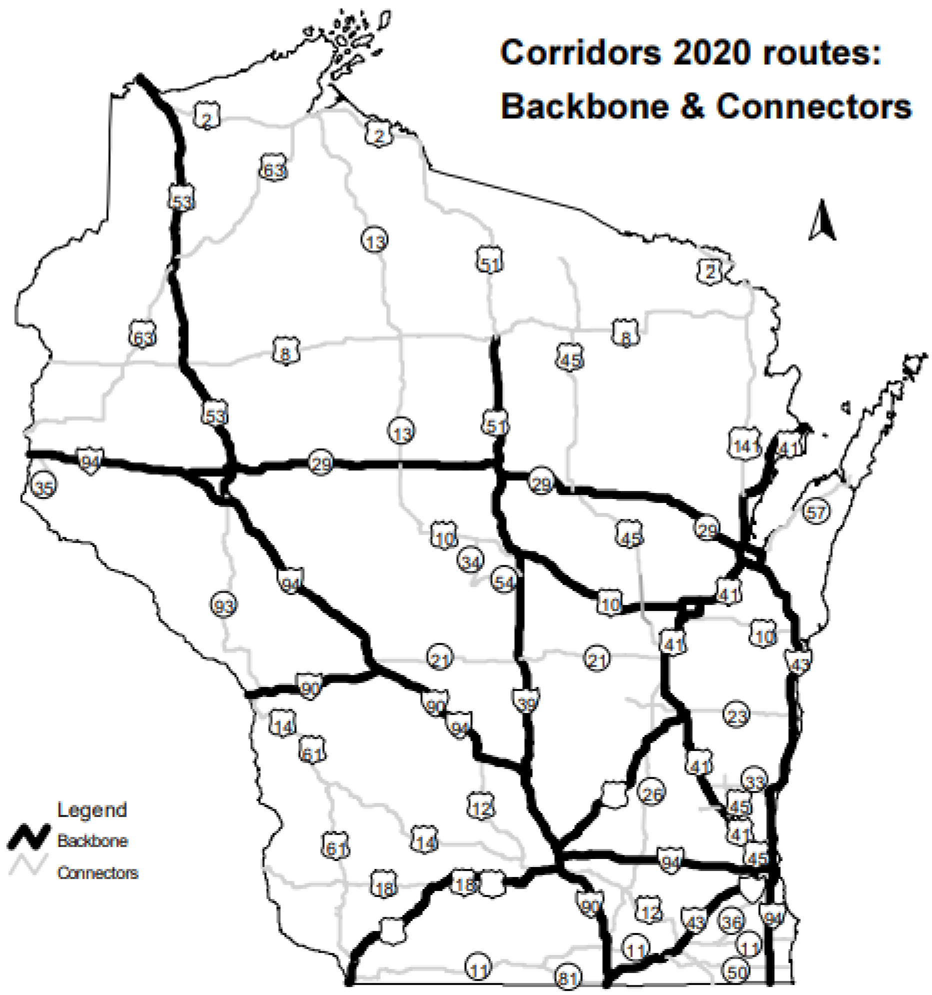
Source: WEM; DOA; UW, 2021

### 4.3.1 State Highway System

The summary tables presented in Figure 4.3-1, 4.3-2, and 4.3-3 do not include information on the state owned or operated assets that comprise the state highway system. This system includes the following:

- 11,800 miles of State Trunk Highway Routes
- 5,977 miles of National Highway System (Includes State Trunk Highways and Local Jurisdiction Roadways)
- Over 5,000 bridges on state highway routes.
- The map in Figure 4.3.1-1 depicts the state highway system.

**Figure 4.3.1-1: State Highway System**




Sources: Wisconsin State Highway Plan 2020; Wisconsin Vehicle Miles of Travel by Highway System - 2018

The state highway system is a small (approximately 10%) but important portion of the larger state highway network. The state highway network is comprised of approximately 115,145 miles of state and local public roads. Most of this network (approximately 90%) is owned and maintained by the local jurisdiction (county, city, village, or town) in which they are located.

## 4.4 Vulnerability and Potential Losses

A key component of this plan is the identification of those state owned or operated critical facilities that are vulnerable to various types of hazards. An indicator of vulnerability and potential loss is past federal Public Assistance (PA) data.

WEM downloaded data from OpenFEMA, FEMA's data delivery platform to share data with the public. Using the "Public Assistance Funded Project Details" dataset (data last updated in July 2021), analysts sorted the data to save only project worksheets from Wisconsin and those that had "Statewide" in the county column. This resulted in 650 project worksheets. Ideally, only projects from State agencies should use that code; however, WEM noted multiple errors in the dataset. As a result, analysts only included those projects that could be validated with internal Wisconsin PA data, reducing the number of validated OpenFEMA projects to 504 total. WEM further reduced the number of projects by eliminating projects that covered the costs to manage grants (e.g., "Category Z" for Management Costs). Figure 4.4-1 summarizes the findings of this analysis. Note that this information may differ from official publications on other public websites. This data is not intended to be used for official federal financial reporting.

**Figure 4.4-1: Federal Public Assistance to Wisconsin State Agencies**

| PA Category of Work | Description | # of Project Worksheets | Amount |
|---|---|---|---|
| **Category A: Debris Removal** | Costs to clear public roads, public improved property and damaged materials placed on the roadside. | 84 | $ 3,649,633 |
| **Category B: Emergency Protective Measures** | Actions taken to protect lives and property during a disaster response (e.g. safety barricades, signs, area security, sandbagging, staffing an emergency operations center) | 100 | $ 9,805,062 |
| **Category C: Roads and Bridges** | Work to repair eligible roads, bridges, shoulders, ditches, culverts, and signs. | 43 | $ 1,347,623 |
| **Category D: Water Control Facilities** | Work to repair publicly owned dams, drainage channels, and pumping facilities. | 31 | $ 404,425 |
| **Category E: Buildings and Equipment** | Work to repair or replace public buildings, including contents and systems, and heavy equipment or vehicles | 10 | $ 186,755 |
| **Category F: Utilities** | Work to repair water treatment and delivery, power generation, power distribution, sewage collection/treatment, and communication facilities | 2 | $ 69,396 |
| **Category G: Parks, Recreational Facilities, and Other** | Repair and restoration of parks, playgrounds, trails, etc. | 145 | $ 4,313,508 |
| **TOTAL** | | 415 | $ 19,776,403 |

Source: FEMA; Public Assistance (PA) data from August 1999 to July 2021

Typically, permanent repairs that fall in Categories D, E, and F, are considered the most important in terms of public safety and critical facilities, as they include things like repairing electric generation and transmission, drinking water infrastructure, and sewage treatment facilities. There may facilities in Categories A and C that could be considered critical, but without detailed analysis of which roads and water crossings were included, it is difficult to determine if they repaired roads that are considered critical facilities. This is due to fact that most roads that were damaged in recent Wisconsin disasters are unpaved gravel roads and are not likely to be the most critical to maintain EMS, fire, and public safety access, and only serve limited number of residences or other buildings. Additionally, repairs to major collector roads and interstates are not eligible in the PA program; these routes are considered the most critical in the communities across the state and are not included in the data. Assuming that Categories D through F are the only projects written for state-owned critical facilities, this means that a small fraction of PA project worksheets, or about 10% of them, are written to repair State-owned critical facilities.

Based on the PA data from OpenFEMA, of the 415 project worksheets for State agencies, 394 of them were written to repair damage that took place during a severe storm, flooding, and tornado declarations. These disaster types were combined in this analysis because very rarely are single disaster types named as the sole cause of Wisconsin's disaster declarations. In fact of the 35 Federal disaster or emergency declarations received since the passing of the Stafford Act, 28 of them are caused by a combination of those three causes –they are all interconnected (e.g. a tornado cannot happen without a severe storm; flooding often accompanies severe weather).

Consideration of this information can be used to guide the development and implementation of cost-effective mitigation measures. These measures will help to reduce or eliminate identified vulnerabilities to the most critical assets of state government. Ideally this will help ensure that these state assets remain operational in times of disaster or emergency to provide for the continuation of emergency operations, continuity of government, critical public safety, health care, transportation and educational functions, and the provision of other essential services to the public

**Severe Weather**

At the county level, National Weather Service (NWS) data has identified Dane, Dodge, Grant, Fond du Lac, and Marathon County with the highest number of tornado events from 1844 to 2021. Dane, Rock, Walworth, Waukesha, and Jefferson had the highest number of severe thunderstorm wind events. Dane, Grant, Waukesha, Monroe, La Crosse, and Marathon had the highest number of severe hail events. The table in Figure 4.4-2 lists the counties with the highest number of assets, critical facilities, and replacement cost of critical facilities potentially at risk from severe weather.

**Figure 4.4-2: Assets at Risk from Severe Weather**

| County | Total # of Assets | # of Critical Facilities | Replacement Cost of Critical Facilities |
|---|---|---|---|
| Dane | 949 | 174200 | $4,451,818,027 |
| Dodge | 281 | 119 | $379,483,645 |
| Grant | 270 | 9 | $79,475,791 |
| Jefferson | 78 | 8 | $26,289,410 |
| La Crosse | 76 | 5 | $15,428,557 |
| Marathon | 64 | 11 | $18,926,916 |
| Monroe | 50 | 17 | $40,993,417 |
| Rock | 31 | 19 | $39,507,126 |
| Walworth | 140 | 18 | $61,711,182 |
| Waukesha | 273 | 10 | $41,942,643 |

Source: WEM; DOA; UW, 2021

## Flooding

Flooding has been identified as a principal cause of damage in 26 of 31 of Presidential Disaster Declarations in Wisconsin since the passing of the Stafford Act after 1988. As noted in Table 3.3.3-10 in Section 3.3.3 the counties with the highest number of flood-related disaster declarations include those listed below in Figure 4.4-3. Since these counties have had the highest number of FEMA declarations, we compared the number of assets, critical facilities, and replacement costs of state-owned critical facilities potentially at risk from flooding.

**Figure 4.4-3: Assets at Risk from Flooding**

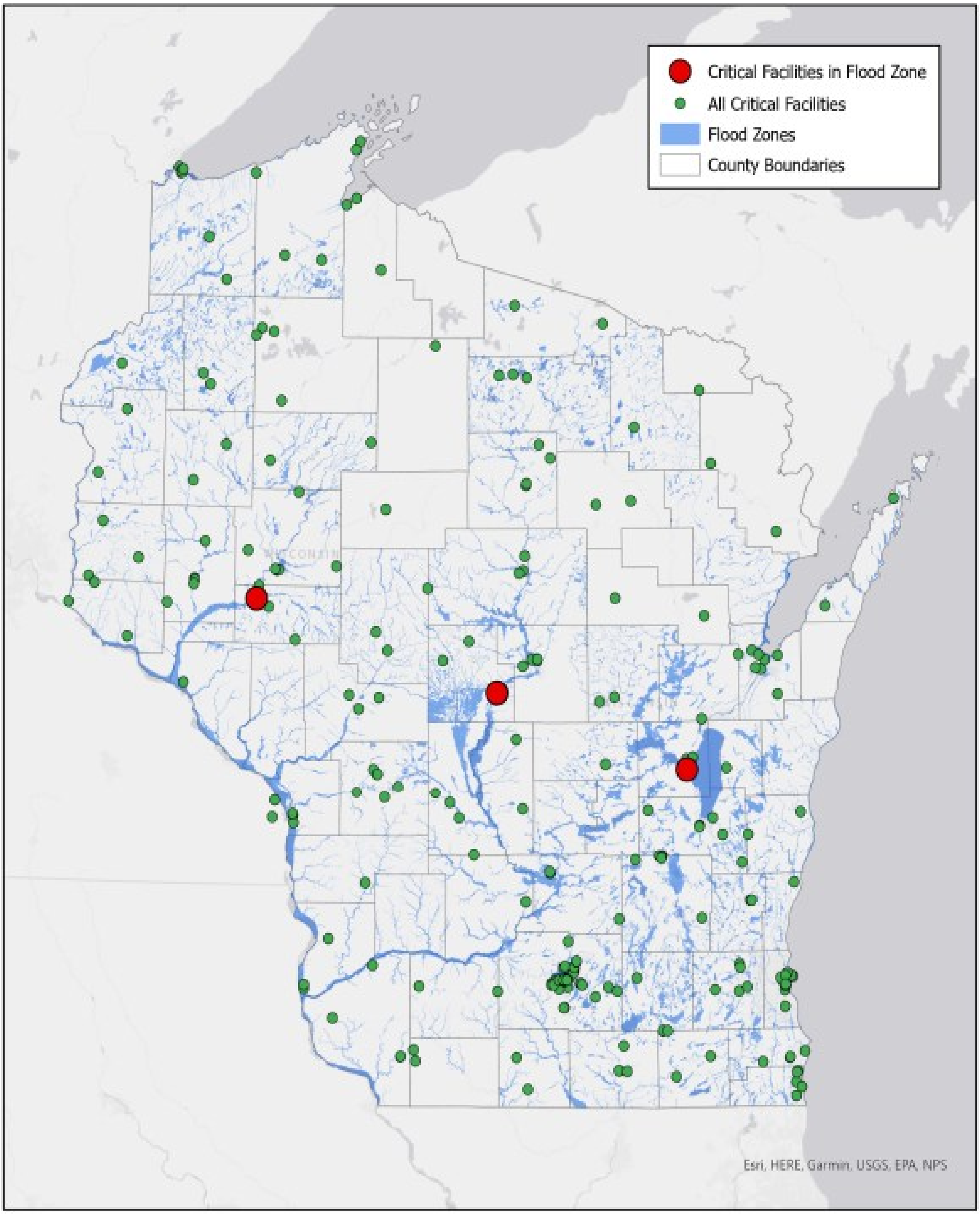
| County | # of Flooding Disasters | Total # of Assets | # of Critical Facilities | Replacement Cost of Critical Facilities |
|---|---|---|---|---|
| Vernon | 13 | 40 | 0 | $0 |
| Crawford | 12 | 61 | 24 | $44,625,072 |
| Richland | 11 | 7 | 3 | $312,476 |
| Clark | 10 | 11 | 6 | $2,755,957 |
| Grant | 10 | 270 | 9 | $79,475,791 |
| La Crosse | 10 | 76 | 5 | $15,428,557 |
| Jackson | 9 | 78 | 18 | $67,329,513 |
| Juneau | 9 | 142 | 31 | $212,546,411 |
| Monroe | 9 | 50 | 17 | $40,993,417 |

Source: WEM; DOA; UW, 2021

The threat of flooding is typically not considered a county-wide or community-wide threat. Flooding is most associated with floodplains or lowlands adjacent to water bodies. FEMA partners with Tribal Nations, States, and communities through the Risk Mapping, Assessment, and Planning (Risk MAP) program to identify flood hazards, assess flood risks, and provide accurate data. This data is incorporated into Flood Insurance Rate Maps (FIRMs).

WEM used ESRI GIS to better understand where the critical facilities intersected with mapped floodplains. The map in Figure 4.4-4 depicts the critical facilities with latitude and longitude and digital FIRMs.

**Figure 4.4-4: Assets in the Floodplain**




| Agency | Institutio | Building | Critical | Facility | County | Address | City | State | Zip |
|---|---|---|---|---|---|---|---|---|---|
| University of Wisconsin | EAU CLAIRE | LIFT STATION | Yes | Utility Services | EAU CLAIRE | 101 ROOSEVELT AVE | Eau Claire | WI | 54701-4063 |
| University of Wisconsin | OSHKOSH | HAZARDOUS WASTE STORAGE | Yes | Other Essential Facilities | WINNEBAGO | 1155 ROCKWELL AVENUE | Oshkosh | WI | 54901-0000 |
| Administration | Administrative Facilities | STATE OFFICE-WIS RAPIDS ADDN | Yes | Major State Government | WOOD | 1681 SECOND AVE. SOUTH | WISCONSIN RAPIDS | WI | 54495-4768 |
| Administration | Administrative Facilities | WIS RAPIDS STATE OFFICE BLDG | Yes | Major State Government | WOOD | 1681 SECOND AVENUE SOUTH | WISCONSIN RAPIDS | WI | 54495-4768 |
| Military Affairs | Wisconsin Rapids Armory | ARMORY-WISCONSIN RAPIDS | Yes | Critical Military Facility | WOOD | 1710 Second Ave South | WISCONSIN RAPIDS | WI | 54495-5699 |
| Military Affairs | Wisconsin Rapids MVSB | MVSB-WIS RAPIDS | Yes | Critical Military Facility | WOOD | 1710 Second Ave South | WISCONSIN RAPIDS | WI | 54495-5699 |

Source: WEM, DOA, UW, 2021

The GIS analysis identified 6 critical facilities in three locations that intersect with the special flood hazard area. Note, not all counties have digital FIRM information available. The table in Figure 4.4-6 shows the 6 identified assets and their replacement costs.

**Figure 4.4-6: Critical Facilities Located in the Floodplain**

| County | Asset | Replacement Value |
|---|---|---|
| Eau Claire | Lift Station – UW Eau Claire | $355,132 |
| Winnebago | Hazardous Waste Storage – UW Oshkosh | $367,248 |
| Wood | Wisconsin Rapids State Office Building | $10,562,124 |
| Wood | Wisconsin Rapids State Office Building (addition) | $3,545,966 |
| Wood | Armory – Wisconsin Rapids | $1,245,677 |
| Wood | Motor Vehicle Storage Building – Wisconsin Rapids | $952,538 |

Source: WEM, DOA, UW, 2021

A further review of the Wood County Land Information website indicates that a small portion of the Wisconsin Rapids State Office Building and addition are inside the flood plain. The armory facilities also fall within the floodplain. Total replacement cost of critical state assets located in the flood plane is approximately $17 million dollars, or 0.2% of the replacement cost of all critical state assets.

## Wildfires

Wildfires have been identified as an ongoing threat to both rural areas and wildland urban interface (WUI) communities. Using Wisconsin DNR's fire management dashboard, Wisconsin Emergency Management reviewed wildfire records from Nov 11th, 1991 to Nov 11th, 2021 to analyze fire risk by county. Wisconsin Emergency Management used this method to identify Burnett, Marinette, Adams, Juneau, Oneida, Portage, Sauk, Waushara, Oconto, and Waupaca as the counties with the greatest risk of wildfire based on the number of occurrences. Most of these counties are also in the top 10 for acreage burned in the same time-period. The table in Figure 4.4-7 lists the counties with the highest number of assets, critical facilities, and replacement cost of critical facilities potentially at risk from wildfires.

**Figure 4.4-7: Assets at Risk from Wildfires**

| Top 10 Counties | # of Wildfires | Total # of Assets | # of Critical Facilities | Replacement Cost of Critical Facilities |
|---|---|---|---|---|
| Burnett | 255 | 45 | 2 | $238,811 |
| Marinette | 238 | 64 | 5 | $1,059,738 |
| Adams | 220 | 24 | 4 | $509,999 |
| Juneau | 198 | 142 | 31 | $212,546,411 |
| Oneida | 180 | 142 | 10 | $5,300,978 |
| Portage | 180 | 119 | 9 | $28,936,994 |
| Sauk | 176 | 160 | 2 | $703,066 |
| Waushara | 165 | 85 | 14 | $112,941,797 |
| Oconto | 161 | 16 | 0 | $0 |
| Waupaca | 160 | 76 | 6 | $15,462,773 |

Sources: Wildfire Dashboard; WEM; DOA; UW, 2021

Combined, there are 83 critical facilities located within the top-ten counties at risk for wildfires worth approximately $377 million, which is roughly 5% of the replacement value of all critical state facilities.  Wisconsin Emergency Management acknowledges that wildfires are not limited to these ten counties and that other state assets may be at risk depending multiple factors. These factors include but are not limited to:  Where the wildfire starts in proximity to state assets, the conditions at the time the fire occurs, and the response capability in the jurisdiction.

**Drought and Extreme Heat**

Drought and extreme heat are a serious threat to people, animals, and plants. Drought and extreme heat can stress lifelines (electric, fuel, water, and wastewater) and indirectly affect state critical facilities. However, the hazard generally does not represent a direct threat to state critical facilities.

**Winter Storms and Extreme Cold**

Winter Storms and extreme cold are a serious threat to people, animals, and plants. Winter storms and extreme cold can disrupt transportation, stress lifelines (electric, fuel, water, and wastewater) and negatively affect state critical facilities. In instances of excessive snow or sustained periods of extreme cold this could include damage from snow loads or frozen plumbing.  All areas of the state are susceptible to extreme cold.  Bayfield, Taylor, Ashland, and Clark Counties experienced the greatest number of extreme cold events in the state of Wisconsin between November 1991 and November 2021.   Grant, Richland, Trempealeau, Buffalo, and Florence counties lead the state in terms of the number of winter storms over the same time. Future analysis may be able to determine which facilities are susceptible to potential roof collapse due to winter storms, but it fell outside the scope of this year’s review.

**Coastal Erosion**

Coastal erosion affects all 15 coastal counties. Coastal erosion is usually a gradual process. However, sudden incidents prompting emergency action do occur. The hazard does not currently pose a threat to state critical facilities. Future development of specific coastal erosion location information may better define potential threats to state critical facilities.

**Radiological Release**

The radiological release hazard is most closely associated with the nuclear power plants located in or near the state. The counties of Kewaunee, Pierce, and Manitowoc are located within a 10-mile radius of a nuclear power plant. The table in Figure 4.4-10 lists the counties with the highest number of assets, critical facilities, and replacement cost of critical facilities potentially at risk from radiological release.

**Figure 4.4-10 Assets at Risk from Radiological Release**

| County | Total # of Assets | # of Critical Facilities | Replacement Cost of Critical Facilities |
|---|---|---|---|
| Kewaunee | 10 | 0 | $0 |
| Manitowoc | 41 | 0 | $0 |
| Pierce | 128 | 7 | $11,945,637 |

Source: WEM; DOA; UW, 2021

**Hazardous Materials Incident**

Hazardous materials are present in most communities and not geographically specific. The extensive use and transportation of these hazardous materials presents a state-wide threat. Future development of more detailed hazardous material incident location information may better define potential threats to state critical facilities.

**Disruption of Lifelines**

The disruption of lifelines (electric, fuel, water, and wastewater) could potentially threaten the use and operation of all state critical assets. However, the disruption of lifelines is often a secondary hazard resulting from the impacts of a natural, technological, or human-cause hazard.

**Emerging Infectious Diseases**

Emerging infectious diseases are a serious threat to people and animals. In addition, emerging infectious diseases can stress the health care system and indirectly affect state critical facilities. However, the hazard generally does not represent a direct threat to state critical facilities.

**Food and Agriculture Emergency**

A food and agriculture emergency is a serious threat to people, animals, and the environment. In addition, a food and agriculture emergency could indirectly affect state critical facilities. However, the hazard generally does not represent a direct threat to state critical facilities.

**Cyber-Attack**

All state owned or operated critical facilities are potentially threated by cyber-attack.

**Terrorism**

All state owned or operated critical facilities are potentially threated by terrorism.

## 4.5 Mitigation Potential

It is the intention of WEM to use the data collected in this update to promote the continued assessment of the state structure inventory to better understand the vulnerability of these assets to all threats and hazards. Further, the following steps have been developed to assess the mitigation potential for at-risk critical facilities.

1. Review and Revise State Structure Inventory

    a. WEM will continue to work with the DOA and other state agencies to review and revise the state structure inventory. This may include the review and revision of asset information such as use, location, and replacement value.

2. Assessment of Critical Facilities

    a. WEM will continue to review and assess the state structure inventory in an effort to validate facilities identified as critical based on use information. Additional attention will be directed at those critical facilities with an identified replacement value of over $1,000,000. The threshold value of $1,000,000 is intended to identify those critical assets that may be the most difficult and costly for the State of Wisconsin to replace. Additionally, physical security and cybersecurity assessments may be completed on certain critical facilities.

3. Refine Risk and Vulnerability

    a. WEM will continue to work with other state agencies through the Wisconsin Silver Jackets Hazard Mitigation Team and the Governor's Homeland Security Council's Interagency Working Group to further refine risk and vulnerability to critical facilities. Non-critical facilities will be designated as a low priority for further analysis and data collection. Critical facilities with a replacement value over $1,000,000 will be designated as a higher priority for further analysis and data collection.

4. Prioritize

    a. WEM will evaluate the vulnerability to specific hazards (high, medium, low). WEM will also evaluate if the above criteria are sufficient for evaluating risk to State-owned and operated critical facilities. This continued assessment is intended to maintain and improve the understanding of the vulnerability of assets critical for state resilience. This information will be used as a basis for identifying and prioritizing mitigation actions.