Dane County
Natural Hazard Mitigation Plan

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1.1 Purpose

Natural disasters can cause severe disruptions and damage to communities. Natural hazards in Dane County have caused injury and loss of life, severe property damage, interruption of the delivery of vital goods and services, disruption of local economies, and environmental harm; they are an inevitable fact of life. Planning for natural hazards and implementing mitigation measures can reduce the *impact* of such events when they do occur. Monetary losses, personal injury, and loss of life can be reduced, and the economic, social, and environmental impacts on the community as a whole can be reduced.

This plan update also included both climate change and diversity factors as considerations in the planning process in an attempt to account for massive fluctuations in vulnerability.

This mitigation strategies outlined in this plan include specific programs and policies that can be implemented by Dane County and local units of government within Dane County to reduce the impact of natural hazards on people, structures, and the natural environment. The goal is to reduce vulnerabilities before the next disaster occurs.

1.2 Plan Scope

This plan has been prepared as a multi-hazard or "all-hazards" mitigation plan, with a focus on natural hazards (i.e. meteorological, geological, or hydrological hazards.) A review of past natural disasters in Dane County, and across Wisconsin highlights the following hazards as presenting a significant risk to the communities of Dane County:

- Dam Failure
- Drought
- Extreme Cold
- Extreme Heat
- Flood
- Fog
- Hail
- Land Slide, Erosion, and Sinkholes
- Lightning
- Tornado
- Wildfire
- Windstorm
- Winter Storm
- Emerging Hazards (harmful algal blooms, vector-borne disease, and invasive species)

The plan identifies and describes each of these hazards, also analyzing our vulnerability to each hazard. The *vulnerability assessment* (Chapter describes not only the physical characteristics of each hazard, but also the potential impact of each hazard on people, buildings, and the social and economic infrastructure of the communities of the County.

The *vulnerability assessment* is used as the basis for the County's mitigation strategies. The plan identifies goals and measures for hazard mitigation and risk reduction to make communities more disaster resistant and sustainable. In addition, mitigation actions can protect critical community facilities, reduce exposure to liability, and minimize community disruption.

1.3 Plan Update Summary

This plan is the third update of the Dane County's Natural Hazards Mitigation Plan. The first version of the plan was adopted in May 2005, with the first update adopted in May 2010 and the second in September 2017.

One significant change Dane County has made includes the establishment of the Dane County Office of Energy and Climate Change. This office has made significant contributions to improving both Dane County's approach to understanding the effects of climate change as well as actions Dane County and municipalities can take to mitigate the effects of climate change. This office has played a significant role shaping Dane County's natural hazard mitigation strategies.

30 municipalities participated in the update of Dane County's Natural Hazards Mitigation Plan. While the number of municipalities is less than the 2017 update, the proportion of Dane County's population within participating municipalities has grown. In 2017, 37 municipalities representing 79% of Dane County's population participated whereas 30 municipalities participated in the 2022 update representing 88% of Dane County's population.

1.4 Plan Requirements

This plan is designed to meet the requirements of the Federal Disaster Mitigation Act of 2000 (DMA 2000). The DMA 2000 established Federal hazard mitigation project funding mechanisms and new state and local planning requirements as conditions of project funding eligibility. The DMA 2000 provides specific criteria for the preparation and adoption of multi-jurisdictional, "all-hazards" mitigation plans by local governments to meet these requirements. The *Dane County Natural Hazard Mitigation Plan* is prepared to support the requirements of a mitigation plan for all participating local governments in the County. DMA requirements specify that the following elements must be included in the plan:

- The plan must document how the plan was prepared and who was involved in the planning process. Public involvement is essential.
- A risk assessment section should include:
    - Identification of the hazards likely to affect the area, noting data limitations and providing an explanation for eliminating hazards from further consideration.
    - A discussion of past events and description of their severity and resulting effects.

- A description of the local vulnerability to the described hazards in terms of the types and numbers of buildings, infrastructure, and critical facilities located in the jurisdiction.
- A description of the potential dollar losses to the vulnerable structures identified and a description of the methods used to calculate the estimate.
- A description of the vulnerability in terms of land use and development so that mitigation options can be considered in future land-use decisions.

- The plan must include a hazard mitigation strategy describing:
  - Goals to reduce or avoid long-term vulnerabilities to the identified hazards.
  - A range of specific mitigation actions and projects to be considered, with particular emphasis on new and existing buildings and infrastructure.
  - An action plan identifying how actions will be prioritized, implemented, and administered by the local jurisdiction. Prioritization must include a special emphasis on the extent to which benefits are maximized according to a cost benefit review of the proposed projects and their associated costs.
  - For multi-jurisdictional plans, there must be identifiable action items specific to the jurisdiction requesting FEMA approval of the plan.
- All local units of government included in the plan must participate in the planning process.
- Provisions for reviewing, monitoring and evaluating progress of the plan's implementation. The plan must be updated at least every five years and re-approved.
- Adoption by the local governing body. The plan must include documentation that the local governing body has formally adopted the plan. In a multi-jurisdictional plan, all participating local units of government seeking plan approval must individually adopt the plan.

In addition to the Federal planning requirements, Chapter 323 of the Wisconsin State Statutes requires the governing body of each county, town, and municipality within the state adopt an effective program of emergency management that is consistent with the state plan. This plan was developed with input and assistance from Wisconsin Emergency Management and is consistent with programs outlined in the State of Wisconsin Hazard Mitigation Plan.

This plan update has been developed to meet the State and Federal planning requirements in addition to the needs of Dane County and participating local units of government within the County.

1.5 Disaster Declaration History

Dane County has received Presidential disaster declarations on 17 occasions since 1976. That equates to a frequency of a receiving declared disaster nearly every three years:

Table 1.5.1 Disaster Declarations for Dane County (1971 – 2016)

Year	Disaster Type	Declaration Type	Damage Assessment
1976	Ice Storm	Presidential Disaster	$1.22 Million (Public Assistance)
1976	Drought	Presidential Emergency	$625 Million (statewide)

Year	Disaster Type	Declaration Type	Damage Assessment
1978	Flooding and Tornados	Presidential Disaster	$180,000 (Public Assistance)
1984	Tornados	Presidential Disaster	$775,394 (Public Assistance) $11.2 Million (Individual Assistance) Dane and Iowa Counties combined
1990	Flooding and Tornados	Presidential Disaster	$37,000 (Public Assistance) $30,343 (Individual Assistance)
1991	Severe Storms (Windstorm)	Presidential Disaster	$1.33 Million (Public Assistance)
1992	Tornados	Presidential Disaster	$163,000 (Public Assistance)
1993	Flooding	Presidential Disaster	$888,000 (Public Assistance) $1.44 Million (Individual Assistance) $22.6 Million (Total Damages)
1996	Flooding and Severe Storms	Local Sources	$940,000 (Public Assistance) $1.22 Million (Individual Assistance) $3.3 Million (Total Damages)
1998	High Winds and Severe Storms	Local Sources	$586,000 (Public Assistance)
2000	Severe Storms (Windstorm) and Flooding	Presidential Disaster	$940,000 (Public Assistance) $1.25 Million (Individual Assistance) $9.3 Million (Total Damages)
2000	Snow Emergency	Presidential Emergency	$586,000 (Public Assistance)
2004	Severe Storms and Tornados	Presidential Disaster	$1.5 Million (Public Assistance)
2005	Stoughton Area Tornado	State Disaster Fund and Local Sources	$ 1.92 Million (Public Expenses) 33.5 Million (Private Losses)
2007	Flooding	Presidential Disaster	FEMA PDA- $3,294,210 Private $1.64 Million (Public Assistance) 758 homes impacted
2008	Snow Emergency	Presidential Emergency	$1.44 Million (Public Assistance)
2008	Severe Storms, Tornados and Flooding	Presidential Disaster	$1.53 Million (Public Assistance) $1.76 Million (Individual Assistance) $1.64 Million (Housing Assistance) $120,000 other needs, 1,635 households requested aid Total damages $35,789,723
2011	Severe Winter Storm and Snowstorm	Presidential Disaster	$1.81 Million (Public Assistance)
2018	Severe Storms, Tornadoes, Straight-line Winds, Flooding, & Landslides	Presidential Disaster	$28,738,112.16 (Public Assistance) $8,902,520.27 (Individual Assistance) $8,003,898.67 (Total Housing Assistance) $898,621.60 (Other Needs)

Source: Dane County Emergency Management

The major disaster declaration figures in Table 1.5.1 do not tell the whole story of damages caused by natural hazards in Dane County. While the figures show that Dane County has experienced a variety of events that have caused major losses on a fairly regular basis, this significantly underestimates the total losses caused by natural hazards.

Almost every year there are significant weather events that cause major damages for which federal disaster assistance is not granted. The non-public sector figures show only uninsured losses incurred by the private sector – a small fraction of the total losses. Private sector losses, especially those covered by insurance, if tracked and compiled would make a significant contribution to these damage figures.

1.6 Multi-Jurisdictional Planning

This plan is prepared as a multi-jurisdictional plan. Municipal governments have the option to 1) not prepare a plan, 2) prepare a stand-alone plan for their jurisdiction, or 3) participate in a multi-jurisdiction or county-wide plan. All 61 local units of government in Dane County were invited to participate in the planning process. The decision whether or not to participate in this process was a local decision. Thirty local governments encompassing 88% of Dane County's population have opted to participate in this effort.

Figure 1.6.1 Participating Municipalities

Cities	Villages	Townships
Edgerton	Belleville	Cottage Grove
Fitchburg	Black Earth	Dunn
Madison	Blue Mounds	Oregon
Middleton	Brooklyn	Springdale
Monona	Cottage Grove	Springfield
Sun Prairie	Cross Plains	Verona
Verona	Dane	Vermont
	De Forest	Westport
	Marshall	
	Mazomanie	
	McFarland	
	Mt. Horeb	
	Shorewood Hills	
	Waunakee	
	Windsor	
7/8 participated	*15/20 participated*	*8/33 participated*

Each of these jurisdictions has a specific attachment to this plan. The local attachments describe particular risks and vulnerabilities, and identify action items to be taken by the jurisdiction to reduce those risks. Local jurisdiction participation is described in more detail in Section 2.4.

1.7 Conceptual Underpinnings

There are a number of basic concepts guiding the plan and the planning process. These principals provide the philosophical and conceptual underpinnings of the plan development process and the resulting hazard mitigation strategies.

1. *Human beings, not nature, are the cause of disaster losses*. What we call "natural hazards" are an integral part of the function of the natural environment. Efforts to reduce losses should focus on human behavior and expectations of the natural environment; these are the real causes of natural disaster losses. Natural disasters result from human decisions about how and where we choose to live and build.

2. *The County should make every attempt to plan for and adapt to a changing and increasingly uncertain world.* The interaction of human activity and the natural environment is becoming increasingly complex. The consequences of seemingly simple actions can produce highly complex and highly uncertain results. We have a choice to make. We can face that uncertainty by taking little or no action, responding to crisis as it occurs, and deferring the resulting problems to future generations. Or, we can prepare for a changing world, anticipating problems, shortening the response time, and taking action before issues become crises. This plan is based on the assumption that the latter is a preferred course of action.

3. *Changing climate patterns are likely to have a significant impact on natural hazards and their associated risks in Dane County.* Most risk assessments rely on the frequency and magnitude of past occurrences to make predictions about future conditions. In the context of changing climate, however, past occurrences are no longer a valid predictor of the likelihood and scale of future hazard events. Considering potential changes in future conditions is essential when developing mitigation strategies that will be adaptable and effective in reducing future disaster losses. In this sense, planning for and considering the effects of changing climate is an economic and social issue rather than strictly an environmental issue.

4. *The County should embrace the principles of sustainable development.* Our society's present energy and water resource usage patterns are unsustainable in the long-term. This has the potential to lead to ever increasing hazards and threats for future generations. Sustainability becomes more important as the population of the County continues to grow, demands for resources continue to increase, and the climate becomes more variable and long-term trends become less predictable. This correlates to two basic principles specific to the flood hazard:

    a. *The action of one property owner or community should not increase the flood risk of other property owners or communities*. Potential adverse impacts should be mitigated through community or watershed planning or other direct actions.

    b. *Water should be considered as a valuable resource rather than a hazard.* The County should promote good stewardship of our water resources in planning for the future. Good stewardship can make the most of this resource for us and for our children. Poor stewardship will lead to ever increasing hazards.

5. *This plan recognizes that discussions of natural hazard mitigation should be a public process.* Decisions made in this plan affect the public's safety and well-being. Every attempt should be made to involve the citizens of the County in identifying concerns and issues, generating ideas for addressing them, reaching agreement about how they will be resolved, how priorities will be determined, and ultimately what actions will be taken.

1.8 Mitigation in Relation to other Emergency Management Activities

Emergency management is often described as a cycle with four phases: preparedness, response, recovery, and mitigation. This concept provides a useful means of organizing the County's programs and policies regarding hazards management. As a hazards management process, however, these phases are integrated and are not entirely distinct from one another.

- *Preparedness* involves building an emergency response and management capability before a disaster occurs in order to facilitate an effective response when needed. Preparedness activities also include developing and maintaining warning systems, developing response plans and procedures, maintaining communications networks, establishing procedures for notifying and mobilizing response personnel, establishing mutual aid agreements, and developing an emergency operations center. Also essential to the County's preparedness efforts are programs for training emergency response personnel, exercising plans, and conducting public outreach.

- *Response* refers to the actions taken immediately before, during, and after an event occurs to save lives, minimize property damage, and aid in the recovery process. The activities carried on during the response phase typically involve public warning, evacuation and sheltering, fire suppression, search and rescue, emergency medical care, scene security and property protection. Other elements of response depend on the type of disaster and may include activities such as sand bagging to minimize flooding, closing roads, removal of debris from roads, shutting down power where there are downed electrical lines, attending to the needs of people with disabilities or other health concerns, and supplying emergency power and water. The effectiveness of a disaster response is very much a function of the quality of the planning, training, and exercising done during the pre-disaster preparedness phase.

- Disaster *recovery* involves short-term activities to restore vital support services and long-term activities to restore the community to normal. Typically, the first step in recovery is an assessment of the damages, which helps determine needs and set priorities. Recovery typically involves debris removal, repairing and reconstructing buildings and infrastructure, coordinating volunteers and donated goods, delivering disaster aid to individuals and families, and restoring vital community services. Again, the effectiveness and expedience of the recovery phase depends on the quality of the preparedness efforts and the level of coordination in the response. Recovery can take from days to years, depending on the magnitude of the disaster and the resources available to address the problems.

- Finally, *mitigation* refers to the policies and activities that will reduce the area's vulnerability to damage from future disasters. Generally, these measures are ones that can be put in place before a disaster occurs. There are a multitude of different types of mitigation programs that can be put in place. In general, mitigation activities can be broken into two categories, structural and non-structural.

1.9 Terminology

There are a number of terms used throughout this plan that have specific meanings. Many of these terms and concepts are related, but their definitions are distinct. For this reason, it is important to define what is meant by the various terms used in this plan. The terminology is particularly relevant, as the way in which the impacts are defined and measured often defines the nature of the policies and programs designed to mitigate those impacts. This plan will make every effort to use these terms consistently and deliberately.

1.9.1 Terminology: Hazard and Risk

- *Natural Hazard:* A naturally occurring event or physical condition that poses a potential threat to life, health, property, or environment.
- *Vulnerability:* The susceptibility of human settlements to the harmful impacts of natural hazards. The degree to which people, property, the environment, and social and economic activity are susceptible to injury, damage, disruption, or loss. For the purposes of this plan, the terms *Vulnerability* and *Exposure* to loss are essentially synonymous.
- *Risk:* The potential losses associated with a hazard, defined in terms of expected probability and frequency, exposure, and consequences. Assessing risk involves the estimated impact that a hazard would have on people, services, facilities, and structures in a community; the likelihood of a hazard event resulting in an adverse condition that causes injury or damage.
- *Acceptable Risk:* The level of disaster loss a society or community considers acceptable given existing social, economic, political, cultural, technical and environmental conditions. In this planning, it is important to recognize that individuals' perception of acceptable risk vary widely.
- *Hazard Mitigation*: Any sustained action taken to reduce or eliminate long-term risk to life and property from natural hazards.
- *Structural mitigation* measures minimize the effect of hazards on people, buildings, and infrastructure. This can include actions such as building dams and levees, flood proofing homes, constructing tornado shelters, and instituting building codes that require wind resistant construction.
- *Non-structural mitigation* measures typically concentrate on identifying hazard-prone areas and limiting their use. Examples may include land use zoning, the selection of building sites, tax incentives, insurance programs, relocation of residents to remove them from the path of a hazard, the establishment of warning systems, planning for at-risk populations, and education and outreach programs.

1.9.2 Terminology: Weather & Climate

- *Climate and Weather: Weather* is the mix of events that happen each day in the atmosphere, including temperature, cloud cover, rainfall, and humidity. In most places, weather changes from hour-to-hour, day-to-day, and season-to season. *Climate* is the average weather pattern in a certain location or region over a long period of time.
- *Climate Change* is change and projected change in climate; changes in the long term averages of daily weather resulting from an over-all warming of the planet.
- *Extreme Weather Events* are weather events that have severe impacts, typically happen infrequently, and vary from the norm in severity, intensity, or duration (e.g. droughts or floods that have historically occurred *on average* only once in 100 years or more). Extreme weather events are expected to become more frequent, consistent with the consequences of a warming planet and the resulting changing climate.
- *Climate Change Mitigation* refers to activities and actions taken to reduce emissions and stabilize the levels of heat-trapping gasses in the atmosphere with the intent of reducing the degree to which the planet warms and the climate actually changes. Climate change mitigation strategies and actions are beyond the scope of this plan.
- *Climate change adaptation* refers to strategies and actions taken adjust to changing climate conditions, reduce potential harm, take advantage of opportunities, or to otherwise cope with the consequences. This Natural Hazard Mitigation Plan is one element of the county's climate change adaptation strategy. The underlying assumptions related to managing the risk associated with many the hazards included in this plan include a climate change aspect. Understanding the links between climate change and these extreme events can help us plan for the future. That said, not all possible impacts of climate change are identified or addressed in this plan; many of these are simply beyond the scope of the plan.

1.9.3 Terminology: Disaster Impacts and Losses

Loss estimates from past events and projections for future losses serve as the basis for hazard mitigation efforts. It is important for policymakers at all levels of government to be aware of the total losses of disasters—and ideally of the extent to which those losses can be reduced by various mitigation strategies—so cost-effective mitigation strategies can be designed and implemented. The same is true for the private sector, where cost-effective mitigation measures can and should be used to reduce losses in future disasters.

- The *impact* of a disaster is the broadest term, and includes both economic and non-economic effects. For example, economic impacts include destruction to property and a reduction in income and sales. Non-economic effects include environmental consequences and psychological effects suffered by individuals involved in a disaster.
- The *losses* of a disaster represent negative economic impacts. These consist of direct losses that result from the physical destruction of buildings, crops, and natural resources and indirect losses that represent the consequences of that destruction, such as temporary unemployment and business interruption.

- The *costs* of a disaster typically refer to cash payouts by insurers and governments to reimburse the losses suffered by individuals and businesses.
- The *damages* caused by a disaster refer to physical destruction, measured by physical indicators, such as the numbers of deaths and injuries or the number of buildings destroyed. When valued in economic terms, damages become direct losses.

When assessing vulnerability and designing mitigation programs, it is also useful to distinguish between the physical destruction caused by the disaster and the consequences of that destruction. There are ways to break this down even further:

- *Primary direct losses* are those resulting from the immediate destruction of the event itself, such as water damage from a flood or structural damage from high winds.
- *Secondary direct losses* are those additional losses that occur as a result of the primary damage. Examples include tornado damage resulting in a hazardous materials release or downed overhead power lines as a result of falling tree limbs after an ice storm.
- *Indirect losses* are those that result from the consequences of the actual physical destruction. Indirect losses include: business losses due to direct physical damage to commercial structures or loss of infrastructure, loss of wages to employees, rippling effects due to the loss of wages as employees reduce their spending on other consumer products and services, the loss of function of critical facilities such as schools or health care facilities, and environmental damages.
- *Reimbursed and un-reimbursed losses*. Reimbursed losses are claims that are paid by private insurers or local, state, and federal governments. In contrast, un-reimbursed losses are the uncompensated impacts that victims must bear. Different types of disasters tend to produce different proportions of reimbursed and un-reimbursed losses. For example, a larger fraction of the total losses from flooding typically is un-reimbursed (primarily because ordinary homeowners insurance does not cover flooding and many homeowners choose not to purchase flood insurance coverage) as compared to a tornado where direct losses are typically insured.

1.10 Hazard Mitigation Project Funding

As of November 1, 2004 cities, villages, and counties not having a FEMA approved hazard mitigation plan will be ineligible for certain types of disaster assistance. Under the terms of the DMA, local governments affected by a federally declared disaster are still eligible for emergency aid without having a plan in place. However, those local units would be ineligible for FEMA funds to support hazard mitigation projects that are a part of the normal rebuilding and recovery process.

In addition to post-disaster mitigation funding, local preparation and FEMA approval of a mitigation plan provides participants the opportunity to apply for FEMA administered pre-disaster mitigation project funding. This is a competitive, national grant program designed to reduce over-all risks to the population and structures, as well as reducing the future reliance on federal funding for recovery after a disaster. There are strict applicant and project eligibility requirements that must be met in order for a local government to receive assistance through this program.

1.11 Sustainability, Resilience, and Natural Hazard Mitigation

In recent years, Dane County has placed greater emphasis on sustainability and building "disaster-resilient" communities. It is important to note that the concept of sustainability is not in conflict with economic development but is actually complimentary. By carefully identifying where and how communities are built, they are less likely to suffer the potentially devastating economic impacts associated with disasters. Disaster resilient communities suffer fewer impacts and are able to recover more readily than those that have not embraced hazard mitigation principles.

Disasters can have social consequences that undermine communities, including the loss of security and sense of well-being of affected individuals, stress and anxiety, diminished trust in local government, and disruption of familiar environments and daily routines. Economic vitality, including limiting economic losses associated with disasters is essential to sustainability.

Sustainability is a societal value. As put forth by the *World Commission on Environment and Development*, a working definition of sustainability is, "development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

The concept of sustainability is useful in forming the framework of a hazard mitigation program. Working toward sustainability can help reduce losses from disasters. Actions designed to mitigate disasters should also strengthen the community and build resilience to other social, economic, and environmental problems. A set of principles for sustainable hazard mitigation is proposed below:

- *Maintain and, if possible, enhance environmental quality.* Settlement in hazardous or environmentally sensitive areas has damaged or destroyed the capacity of those areas to moderate certain hazards. Draining wetlands, for example, has exposed more people to flooding while destroying the natural system that would have helped minimize the effects. Linking environmental quality to hazard mitigation is essential to assuring that these sorts of problems do not grow.
- *Foster local resiliency and responsibility.* Resiliency to disasters means a locale can withstand an extreme natural event without suffering devastating losses, damage, diminished productivity, or quality of life without a large amount of assistance from outside the community. Hazards should be approached as integral parts of the much larger contexts of environmental and social issues. The measures used to achieve resiliency will vary based on the types of hazards that are present, the local economic base, and the social factors that influence the local population's vulnerability (e.g. age, ethnicity, income level). Incorporating sustainable hazards mitigation criteria into new development plans and projects would make mitigation an on-going focus.
- *Recognize that vibrant local economies are essential*. Communities should take mitigation actions that foster a strong local economy rather than detract from one. The concept of sustainability does not inherently conflict with economic development. At the same time, a sustainable economy cannot be based on unlimited population growth, high consumption of natural resources, or dependence on non-renewable resources. Thus, there are immense political, social, and cultural barriers in the present system that must be faced.

- *Ensure inter- and intra-generational equity.* A sustainable community selects mitigation activities that reduce hazards across all ethnic, racial, and income groups, and between genders equally, now and in the future. The costs of today's advances should not be shifted onto later generations or less powerful groups. Future generations should also be considered as stakeholders in our planning process. Sustainable hazards mitigation would not defer costs and hazards to future generations without considering their implications and whether appropriate benefits would accompany them.
- *Adopt local consensus building.* A sustainable community selects mitigation strategies that evolve from full participation among all public and private stakeholders. The participatory process itself is as important as the outcome.

1.12 Relationship to Other Regional and Community Plans

The County's natural hazards mitigation plan is not a stand-alone effort. The natural hazards mitigation strategy has been developed and should be implemented in coordination with a broad range of other related efforts at the county and local level.

1.12.1 Comprehensive Planning

All of the jurisdictions in Dane County utilize some form of comprehensive land use or master planning, zoning, capital improvements planning, and building codes to guide and control local building and land development. The purpose of hazard mitigation planning is to identify community policies, actions, and tools for implementation over the long term that will result in a reduction in risk and potential for future losses community-wide. When conducted in coordination with other community planning, a mitigation plan will yield the most cost-effective and efficient results, optimal use of limited resources, and also serve to protect lives, property and natural resources.

Mitigation planning also enables communities and states to better identify sources of technical and financial resources outside of traditional venues. Hazard mitigation plans are most effective when coordinated with other community planning and development activities. Integrating mitigation concepts and policies into existing plans provides expanded means for implementing initiatives via well-established mechanisms. In the past, some communities have undertaken mitigation actions with good intentions but with little advance planning or coordination with other local plans. In other cases, better land use or development decisions addressing natural hazards may have been made in advance with careful consideration of the contributing factors of vulnerability and risk that natural hazards present to the community.

As comprehensive plans are reviewed and updated, and after mitigation strategies are developed, mitigation policies and activities should be incorporated into any of the plan elements. All comprehensive planning in Wisconsin should address a minimum of nine planning elements:

- Issues and Opportunities
- Housing

- Transportation
- Utilities and Community Facilities
- Agriculture, Natural, and Cultural Resources
- Economic Development
- Intergovernmental Cooperation
- Land Use
- Implementation

Each of these planning elements has a potential relation to hazard mitigation activities. A separate natural hazards element may also be desirable. Planning for future land uses by considering hazard constraints and opportunities, addressing environmental concerns, and incorporating hazard reduction into capital improvements and infrastructure elements are all potential mitigation opportunities.

1.12.2 Dane County Sustainable Operational Plan

Dane County government is pursuing a goal of becoming more environmentally, socially, and economically sustainable in its planning, operations, management, and policymaking. Over the last several years the county has initiated and implemented numerous efforts that are contributing to greater sustainability through energy conservation, greenhouse gas emission reductions, stormwater runoff reduction, renewable fuel vehicles, and employee wellness programs. This plan provides a more formal and comprehensive guideline for building on our existing efforts and achieving greater environmental, social, and economic sustainability across county departments and functions.

The *Dane County Government Sustainable Operations Plan* focuses on the county's internal operations and management and is intended to guide county leadership, elected officials, and county government staff in collectively carrying out the county's daily operations in a sustainable manner. It incorporates the county's adopted sustainability principles across virtually all operational areas of the county—the vehicles we drive, the energy and water we consume, the construction and operation of our buildings, the products we purchase, the way in which we view and handle our "used" materials—to create a more environmentally, economically, and socially sustainable county government now and into the future.

The comprehensive set of goals, objectives, and strategies identified in this plan are intended to be achievable by county staff. They are aimed at helping Dane County, as a government agency, transition to greater sustainability in its day-to-day operations. The plan is broken into eight key operational categories. Each category represents an operational aspect of county government that spans all departments and divisions, and for which numerous staff share some level of responsibility.

- Climate Change Mitigation & Adaptation
- Transportation & Vehicle Fleet
- Water
- Waste
- County Buildings & Facilities
- Purchasing
- Education & Outreach

- Employee Experience

Each operational category states a broad goal, objectives that have been identified to meet the goal, and a list of strategies identified to achieve the goal and objectives, including identification of parties responsible for implementation, timelines for implementation, and priority level.

1.12.3 Dane County Climate Action Plan

Dane County's Climate Action Plan (CAP) provides a science-based strategy to reduce greenhouse gas emissions and address ways the climate is already changing. *Today's Opportunity for a Better Tomorrow: 2020 Dane County Climate Action Plan* was published in 2020. The plan sets forth an ambitious set of climate goals for Dane County and lays out programs, policies, and projects that will enable the County to meet those goals. Using established best practices for carbon accounting, Dane County's CAP quantifies the county's baseline emissions and from there sets future emission goals. Most important, the CAP focuses on programs, policies and projects that will be most effective in meeting those goals.

In addition to reducing emissions, our Dane County's Climate Action Plan aims to:

- Increase the County's commitment to equity and justice.
- Deliver economic benefits to all parties.
- Improve health and wellness of all residents.
- Increase our ability to adapt and be resilient to a changing climate.
- Bridge the rural and urban divide, creating solutions that work for everyone in the county.
- Enhance our natural environments, delivering ecosystem benefits.

The Dane County CAP is a path toward sustainability, not just for county government but also the business community, homeowners, and other local governments. The result is Dane County's roadmap to determine how to best to reduce our greenhouse gas emissions.

2.1 Purpose

The Mitigation Plan update must include a "description of the process used to develop the mitigation plan—a systematic account about how the mitigation plan evolved from the formation of a planning team, to how the public participated, to how each section of the plan was developed, to what plans or studies were incorporated into the plan, to how it will be implemented." (FEMA, Local Mitigation Plan Review Guide, October 1, 2011)

Requirement	Description
44CFR 201.6 (b)	An open public involvement process is essential to the development of an effective plan. In order to develop a more comprehensive approach to reducing the effects of natural disasters, the planning process shall include:
44CFR 201.6(b)(1)	(1) An opportunity for the public to comment on the plan during the drafting stage and prior to plan approval;
44CFR 201.6(b)(2)	(2) An opportunity for neighboring communities, local and regional agencies involved in hazard mitigation activities, and agencies that have the authority to regulate development, as well as businesses, academia and other private and non-profit interests to be involved in the planning process; and
44CFR 201.6(b)(3)	(3) Review and incorporation, if appropriate, of existing plans, studies, reports, and technical information.
44CFR 201.6(c)(1)	[The plan shall document] the planning process used to develop the plan, including how it was prepared, who was involved in the process, and how the public was involved.

2.2 Planning Process Overview

Dane County's Department of Emergency Management coordinated this plan update effort. Department staff organized two groups: a County-level planning team and a local jurisdiction planning team. Subject matter expert advice and guidance was also sought from a broad range of organizations, researchers, and county agencies. Funding was secured through a Hazard Mitigation Grant Program (HMGP) planning grant from FEMA to support the hiring of a project assistant to assist in process facilitation and plan development. The project assistant was hired in partnership with the University of Wisconsin, Department of Urban and Regional Planning. The role of the project assistant was to help facilitate the plan update process, assist in both the data collection and data analysis (from both County and local municipalities), and assist participating municipalities with data collection and analysis issues.

Dane County Emergency Management project staff also participated in regular meetings of the County's Office for Energy and Climate Change to help assure consistency between the hazard mitigation planning and climate change adaptation efforts.

Dane County Planning and Development staff also participated in the hazard mitigation planning process to assure coordination between natural hazard mitigation plan update efforts and the policies and objectives described in the County's Comprehensive Plan.

2.3 Hazard Mitigation Planning Team

There were multiple teams that contributed to the development of the Dane County Natural Hazard Mitigation Plan. All provided their expertise and experience to support the process.

Dane County Steering Committee

The Steering Committee acted as expert advisors to support the process of updating the Natural Hazard Mitigation Plan. They supported the design of the planning process, identified the scope of plan, reviewed the risk assessment, helped form and refine mitigation strategies, and assisted with the prioritization of objectives. This core group included representation from a wide range of County departments and agencies:

- Office for Equity and Inclusion
- Office of Energy and Climate Change
- County Board Legislative Services
- Emergency Management
- Land and Water Resources
- Land Information Office
- Planning and Development
- Capital Area Regional Planning Commission

Dane County Plan Planning Team

The Planning Team consisted of representatives and decision makers from almost all Dane County Departments. These representatives brought both expertise in the specific fields and knowledge of Dane County capabilities to support mitigation activities; this included departments that have the ability to regulate development and activities associated with development in Dane County. This team supported Dane County's hazard analysis, risk assessment, and development of mitigation strategies. Dane County departments and agencies on this team included:

- DC Administration
- DC Alliant Energy Center
- DC Board of Supervisors
- DC Clerk
- DC Clerk of Courts
- DC Corporation Counsel
- DC Henry Villas Zoo
- DC Human Services
- DC Land & Water Resources
- DC Land Information Office
- DC Office for Equity & Inclusion
- DC Office of Energy & Climate Change
- DC Planning & Development
- DC Public Safety Communications
- DC Public Works, Highways, & Transportation
- DC Regional Airport
- DC Sheriff's Office
- DC Waste & Renewables

- NGO - Capital Area Regional Plan Commission
- NGO - Mad Metro Planning Organization
- Public Health Madison Dane County
- Utility - Alliant Energy
- Utility - Madison Metro Sewer District
- Utility - MG&E
- UW - WI Initiative on Climate Change Impacts
- UW Extension Office

Additional input was also routinely sought from other County departments through individual meetings. A full list of planning team members is included in *Appendix A*.

Municipal planning teams

Municipalities were responsible for developing their own planning teams to provide leadership and support to conduct local hazard analysis, risk assessments, problem statements, and mitigation strategies. The make-up of the local planning teams varied based on local needs and capabilities; some municipalities utilized their existing municipal board and / or standing committees while others organized committees to complete the local mitigation planning process. All had the opportunity to provide local experiences and input into municipal mitigation strategies.

2.4 Local Jurisdiction Participation

Emails were sent to the leadership (elected and employed) of all 61 Dane County municipalities inviting them to participate in this update of the Dane County Natural Hazard Mitigation Plan. The emails encouraged their participation and explained the planning process, the benefits of both participating and completing the planning process, and participation requirements if they chose to become involved. Numerous follow-up efforts were made by County staff to encourage participation.

The email clearly stated it was the municipality's choice to participate. Regarding natural hazard mitigation planning processes, the email outlined three options municipalities could choose:

- Creating their own stand-alone plan,
- Participating in the current update to the Dane County Natural Hazard Mitigation Plan, or
- Not producing or participating in any mitigation plan process.

Of the 61 municipalities in Dane County, 30 municipalities (comprising 88% of Dane County's population) completed the mitigation planning process.

Expectations and requirements of municipalities participating in the process included:

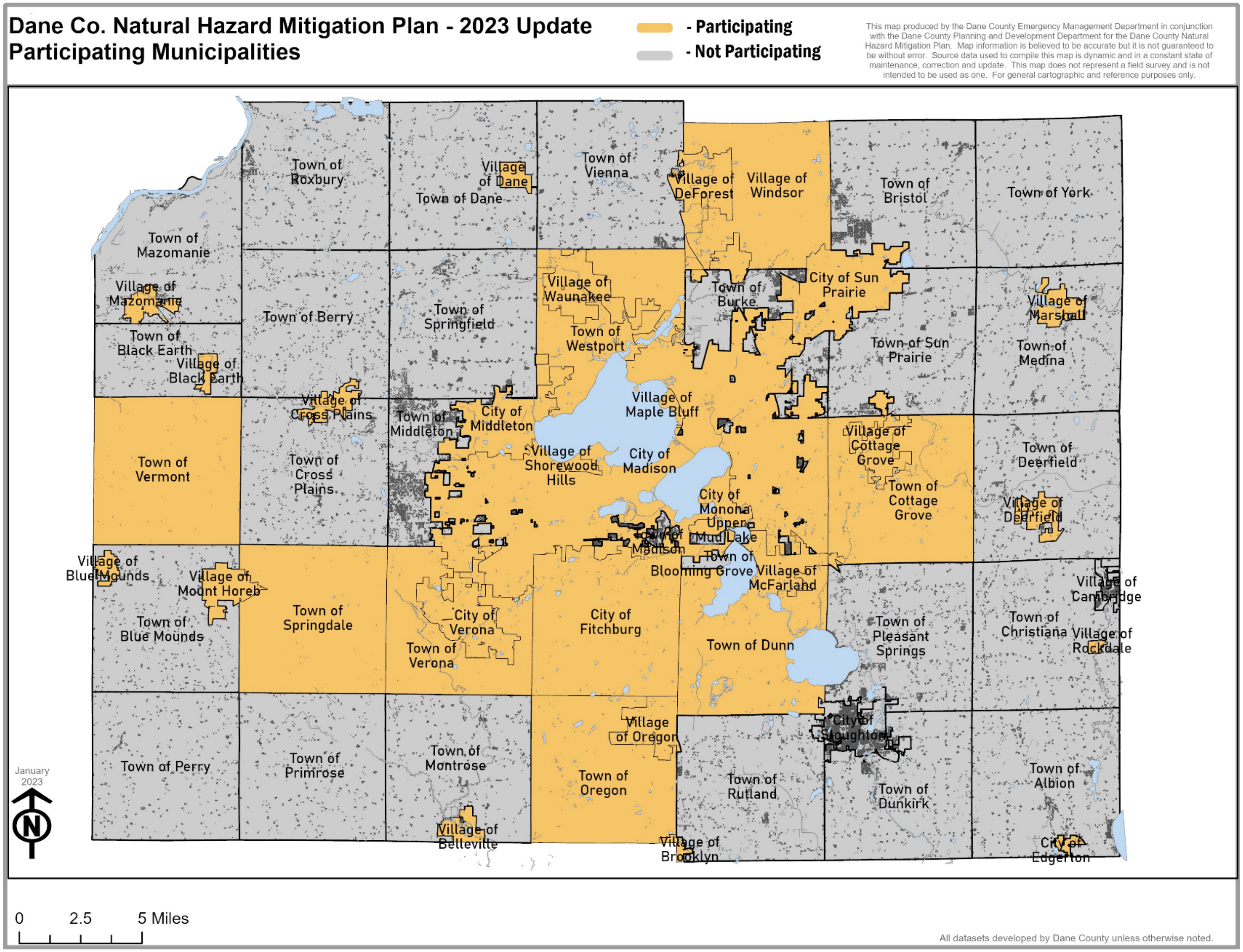
- Dedicating adequate staff time to complete the process in a timely manner.
- Participating in countywide planning meetings.
- Establishing a local steering committee.
- Completing a hazard profile and vulnerability assessment based on local conditions.

- Developing local problem statements.
- Developing at least one local mitigation strategy.
- Identifying and prioritizing specific goals, objectives, and action steps.
- Participating in public outreach activities and conducting at least one public meeting.
- Reviewing and approving draft plan documents.
- Adopting the plan, when complete, through formal resolution.

Figure 2.4.1 Participating Municipalities

Cities	**Villages**	**Townships**
Edgerton	Belleville	Cottage Grove
Fitchburg	Black Earth	Dunn
Madison	Blue Mounds	Oregon
Middleton	Brooklyn	Springdale
Monona	Cottage Grove	Springfield
Sun Prairie	Cross Plains	Verona
Verona	Dane	Vermont
	De Forest	Westport
	Marshall	
	Mazomanie	
	McFarland	
	Mt. Horeb	
	Shorewood Hills	
	Waunakee	
	Windsor	
7/8 participated	*15/20 participated*	*8/33 participated*

Each of these participating municipalities has a specific attachment to this plan. The local attachments describe particular risks and vulnerabilities, and identify mitigation activities to be taken by the municipality to reduce those risks. A list of specific local government participants and representatives is included in *Appendix A*.


Dane Co. Natural Hazard Mitigation Plan - 2023 Update
Participating Municipalities
- Participating
- Not Participating
This map produced by the Dane County Emergency Management Department in conjunction with the Dane County Planning and Development Department for the Dane County Natural Hazard Mitigation Plan. Map information is believed to be accurate but it is not guaranteed to be without error. Source data used to compile this map is dynamic and in a constant state of maintenance, correction and update. This map does not represent a field survey and is not intended to be used as one. For general cartographic and reference purposes only.
Town of Roxbury
Village of Dane
Town of Dane
Town of Vienna
Village of DeForest
Village of Windsor
Town of Bristol
Town of York
Town of Mazomanie
Village of Mazomanie
Town of Berry
Town of Springfield
Village of Waunakee
Town of Westport
Town of Burke
City of Sun Prairie
Village of Marshall
Town of Black Earth
Village of Black Earth
Town of Sun Prairie
Town of Medina
Village of Cross Plains
Town of Middleton
City of Middleton
Village of Maple Bluff
Village of Cottage Grove
Town of Deerfield
Town of Vermont
Town of Cross Plains
Village of Shorewood Hills
City of Madison
City of Monona
Town of Cottage Grove
Village of Deerfield
Upper Mud Lake
Town of Madison
Town of Blooming Grove
Village of McFarland
Village of Blue Mounds
Village of Mount Horeb
Village of Cambridge
Town of Blue Mounds
Town of Springdale
City of Verona
City of Fitchburg
Town of Verona
Town of Dunn
Town of Pleasant Springs
Town of Christiana
Village of Rockdale
Village of Oregon
City of Stoughton
Town of Perry
Town of Primrose
Town of Montrose
Town of Oregon
Town of Rutland
Town of Dunkirk
Town of Albion
Village of Belleville
Village of Brooklyn
City of Edgerton
January 2023
N
0 2.5 5 Miles
All datasets developed by Dane County unless otherwise noted.

2.5 Planning Process

The planning process for Dane County's plan update followed the DMA planning requirements and FEMA's associated guidance. The process is outlined below:

A. Initiate Planning Process
   1. Establish a steering committee and establish work plan and planning process
   2. Identify governments interested in participating in the plan
   3. Establish local jurisdiction planning teams
   4. Meet with all local jurisdiction planning teams to :
      a. Review plan framework and update process
      b. Identify and apply census data to shape a common picture of municipality's diversity factors and equity needs
      c. Identify methods to develop practical adaptations to climate change
      d. Methodology to develop quality problem statements
      e. Methodology to develop quality mitigation strategies

B. Risk Identification and Assessment
   1. Engage in public involvement process
   2. Identify what hazards need to be considered
   3. Profile past hazard events
   4. Profile hazards
   5. Assess vulnerabilities and risks

C. Mitigation Strategy
   1. Municipal planning teams review risk assessment, brainstorm solutions, and develop local mitigation strategies
   2. County Steering Committee engages all Dane County Departments to review risk assessment, brainstorm solutions, and develop county level mitigation strategies.
   3. Assist in the development and incorporation of local strategies
   4. Engage in public involvement process
   5. Edit strategies; compile resources needed to implement objectives
   6. Write draft plan

D. Review of the Plan
   1. Release plan to public and stakeholders, seek comments

2. Edit Plan, draft final document
3. Release plan to Wisconsin Emergency Management and FEMA for review

E. Plan Adoption and Maintenance
1. Submit specific appendices for adoption by participating governments
2. Submit the plan to the County Board for adoption
3. Implement the plan
4. Review and revise annually

This planning and update process made an asserted and successful effort to incorporate many different voices into the plan process. It strength not only lies in the diversity of perspectives it blends, but also in the power given to these voices. **Local units of government were given complete control over their mitigation strategies.**

Community input is essential in crafting realistic and effective mitigation strategies. Stakeholders were empowered throughout the update process to develop natural hazard mitigation strategies for their own communities. The public participation strategy relied on local activities and local steering committee engagement. Keeping the vast majority of municipal plan development responsibilities on a local level provided more opportunities for citizens to engage with and contribute to their local planning committees.

Draft mitigation strategies were posted on-line with appropriate associated contact information where the public could direct all questions and comments. Additionally, Dane County conducted three public meetings (two virtually and one in person) to allow for any questions and comments on the draft strategies from the community.

Each participating municipality developed their own planning committee. Municipal government officials were instructed to ensure the committees were both representative of their jurisdiction and would be engaged within their local community. Municipal governments constituted these committees as they saw fit.

Municipal planning committees were responsible for hosting at least one public comment session on their DRAFT mitigation strategies. At each of these publicly posted meetings, local planning committees presented the proposed mitigation strategies and received input as provided. Supporting local outreach efforts, Dane County posted all local DRAFT mitigation strategies and associated contact information on-line for public review; citizens could then provide their feedback directly to the local point of contact. Input from the public meetings and on-line posting was then incorporated into municipal draft mitigation strategies.

The County level mitigation strategies were presented at three publicly posted meetings (two virtual and one in person). At each meeting, the county mitigation strategies were presented and feedback was incorporated appropriately. County level mitigation strategies were also posted on-line for public review where citizens could submit their feedback via email to Dane County Emergency Management staff to be incorporated into the strategies.

Documentation of efforts to solicit public input can be found in Appendix B.

2.5.1 Municipal Mitigation Planning Activities

Dane County's Department of Emergency Management (DCEM) facilitated the mitigation planning process for the 30 participating municipalities. The following is listing of activities and timeframes for the development of municipal hazard mitigation planning activities:

June 16, 2021 – DCEM hosted the Kick-Off meeting for Dane County municipalities interested in participating in the 2023 Dane County Natural Hazard Mitigation Plan Update. The meeting was held virtually. A document (DC NHMP23 – Local Jurisdiction Data Collection and Process Handbook – See Appendix XX) was distributed along with a Letter of Commitment to be signed and returned to DCEM by July 30, 2022 for municipalities participating in the plan update process.

August 10, 2021 – DCEM hosted three remote meetings titled "How to DO It" providing an overview of the natural hazard mitigation plan development / update process for municipalities. These sessions laid out the requirements for municipalities to participate and produce their own municipal mitigation plan that would be a part of Dane County's multi-jurisdictional natural hazard mitigation plan. Included were meeting dates and material submission deadlines.

August 17 & 18, 2021 – DCEM hosted three remote meetings titled "Seeing Diversity and Understanding Differences in Equity in Your Community." This session included presentations from Dane County's Office for Equity and Inclusion and DCEM. DCEM produced a series of tabular information from census data specific to each community that identified differences in age, language, disabilities, race, poverty measures, and educational attainment. The session provided guidance as to understanding what the census data represents and what the implications of the census data have on risks to citizens (e.g. poverty's relationship to evacuation transportation).

August 26 & 27, 2021 – DCEM hosted three remote meeting titled "Practical Adaptations to Climate Change." These sessions focused on identifying what actions municipalities can take that would reduce risk to their community from factors of climate change. This session included presentations from Dane County's Office of Energy and Climate Change and Dr. Stephen Vavarus, Senior Scientist, Nelson Institute Center for Climatic Research, University of Wisconsin Madison. The session highlighted areas for consideration when addressing the impacts of climate change and providing a wide variety of practical options for addressing climate change such as flora planning and maintenance, pavement options, and public facility planning.

September 7, 2021 – DCEM hosted three remote workshops titled "Developing Quality Problem Statements." This session focused on defining a process for organizing data, information, and ideas into written statements that fully encapsulate the issues and risks faced by municipalities.

October 5, 2021 – DCEM hosted three remote workshops titled "Developing Quality Mitigation Strategies." This session focused on translating problem statements into practical actions that can reduce risks from natural hazards to municipalities.

November 11, 2021 – Deadline for municipalities to submit DRAFT mitigation strategies to DCEM for posting to the 2023 Natural Hazard Mitigation Plan Updated website specifically for the public to review and provide options for the public to provide input on the strategies.

December 15, 2021 – Deadline for municipalities to both host at least one public meeting where citizens could provide input on municipal DRAFT mitigation strategies and submit their finalized mitigation strategies that incorporated the public input they received from both the local public meeting and on-line posting.

2.5.2 County Mitigation Planning Activities

Dane County's Department of Emergency Management (DCEM) facilitated and lead the process for Dane County to update this natural hazard mitigation plan. Every Dane County Department was invited to participate as a member of the Dane County Work Group. Representatives were either department heads or their designees. All participants had the authority to speak for their departments. The following is listing of activities and timeframes for the development of county hazard mitigation planning activities:

September 9, 2021 – DCEM lead a remote meeting to provide an overview for the process DCEM organized to update the Dane County Natural Hazard Mitigation Plan. In the meeting, participants completed a hazard analysis. Guidance was given to complete worksheets supporting the update of Dane County's Capability Analysis and Vulnerability Assessments.

October 6, 2012 – DCEM lead a remote meeting to develop problem statements. The problem statements helped characterize and defined risks associated with natural hazards prioritized in the hazard analysis.

October 26, 2021 – DCEM lead a remote meeting to develop DRAFT mitigation strategies. All participants were introduced to strategic categories and the structure (goal, objectives, and policies / practices) of mitigation strategies. Based on the previously developed problem statements, participants provided information to develop updated mitigation strategies.

November 30 and December 1, 2021 – Public listening sessions were conducted by remotely and in person to receive input on Dane County's DRAFT mitigation strategies.

December 15, 2021 – Final comments due from DC departments on the DRAFT mitigation strategies.

2.6 Black Earth Creek Watershed

Communities along Black Earth Creek studied options to reduce flood risk and improve water quality through green infrastructure. Green infrastructure uses soil and vegetation to retain and infiltrate water. The scope of this project included examining the potential effects of building soil health, planting buffers on farmland, and adding permeable pavement or bio-retention in urban areas. It was supported by the Capital Area Regional Planning Commission (CARPC) who facilitated engagement between urban residents, rural residents, appropriate government agencies, and environmental project professionals to examine flood risks in the watershed and suggest practical solutions.

This project occurred concurrently with efforts to update Dane County's Natural Hazard Mitigation Plan. The resulting efforts are expected to complement each other and build cooperative relationships between local governments and property owners.

2.7 Coordination with Other Community Efforts

Dane County' Natural Hazard Mitigation Plan is an overarching document identifying and supporting the mitigation planning efforts across the county. By the nature of the Dane County Departments and local governments involved in the current update of this plan, their interests and efforts are clearly represented in this plan. Municipalities identified efforts to improve local service delivery, create efficiencies that contribute toward mitigation, and identified long term projects that reduce risks from natural hazards to residents. Dane County identified efforts to improve professional support and coordination with municipalities; activities that can improve the equitable distribution of services and resources before, during, and after disruptions by natural hazards; and more effectively coordinate between county and state agencies when working on public education efforts.

As the creation of this update was a collaborative effort between local and county level governments and agencies, this update of Dane County's Natural Hazard Mitigation Plan is a summary of coordinated efforts within and between municipal and county level governments and agencies.

This plan builds upon the momentum developed through previous and related planning efforts and mitigation programs. These additional planning efforts include:

- Dane County Comprehensive Plan
- Local Comprehensive Plans
- Dane County Sustainable Operations Plan
- The Dane County Parks and Open Space Plan
- Community Development Block Grant Program
- Soil and Water Conservation Programs
- Dane County Emergency Response Plan

2.8 Wisconsin Threat and Hazard Identification and Risk Assessment (THIRA)

A central tenant for all of Dane County' emergency planning and preparedness activities is the identification of hazards and determining the type and severity of risks posed from those hazards. Dane County utilized its own county level Hazard Analysis and, in consultation with Wisconsin Emergency Management, incorporated information from the Wisconsin Threat and Hazard Identification and Risk Assessment (THIRA) to shape the facilitation process guiding the Dane County Planning Team and municipal leaders through hazard assessments and risk analysis processes.

3.1 Physical Description

3.1.1 Geography

Dane County occupies 1,230 square miles in the heart of south central Wisconsin, 75 miles west of Milwaukee and 150 miles northwest of Chicago. Most of the land is very productive farmland. In the center of the County are the City of Madison, the state capital, and the main campus of the state university. As state government, the University, and the desire to experience the County's high quality of life have grown, so has the population. As a result, the City of Madison and other cities and villages have expanded into neighboring agricultural land and natural areas. In addition to the City of Madison, Dane County includes 8 cities, 20 villages and 33 townships. Figure 3.1.1 shows the political boundaries within the County.

Dane County has a varied and unique geologic and physiographic setting. The western part of the County, known as the valley and ridge or "driftless area" is the only part of the County not affected by the most recent glacial period. The area is characterized by steep ridges and valleys drained by fast-flowing streams, generally without natural lakes or impoundments. East of the driftless area is an area of glacial moraines, located at a major drainage divide where the headwaters of many tributaries of the Wisconsin River, Rock River, and Sugar and Pecatonica Rivers originate.

East of the moraines in the center of the County is the Yahara River Valley. Here deep glacial deposits dammed large valleys forming a chain of large lakes and wetlands. The Yahara River Valley is primarily glacial ground moraine, with extensive areas of peat and marsh deposits. Streams are generally flatter and more sluggish than those in the driftless area. The eastern part of the County is known as the drumlin and marsh physiographic area and consists primarily of general glacial deposits with extensive areas of marshes. This area includes many small drumlin hills interspersed with shallow glacial deposits, which created an extensive system of interconnected wetlands with poorly defined drainage. Small streams wind slowly through the lowlands. The only lakes in this area are small stream impoundments or shallow marshy lakes.

Figure 3.1.2 is a shaded relief map of the County indicting the topography of the County.

3.1.2 Surface Waters

Figure 3.1.3 shows the principal lakes and streams in Dane County, as well as the four major river basins, which include smaller-sized watersheds that drain to individual water bodies. The Dane County Water Quality Plan Summary Plan, Appendix B, published by the Dane County Regional Planning Commission contains a detailed description of the surface water systems of the County.

Figure 3. 1.1 Dane County Local Units of Government

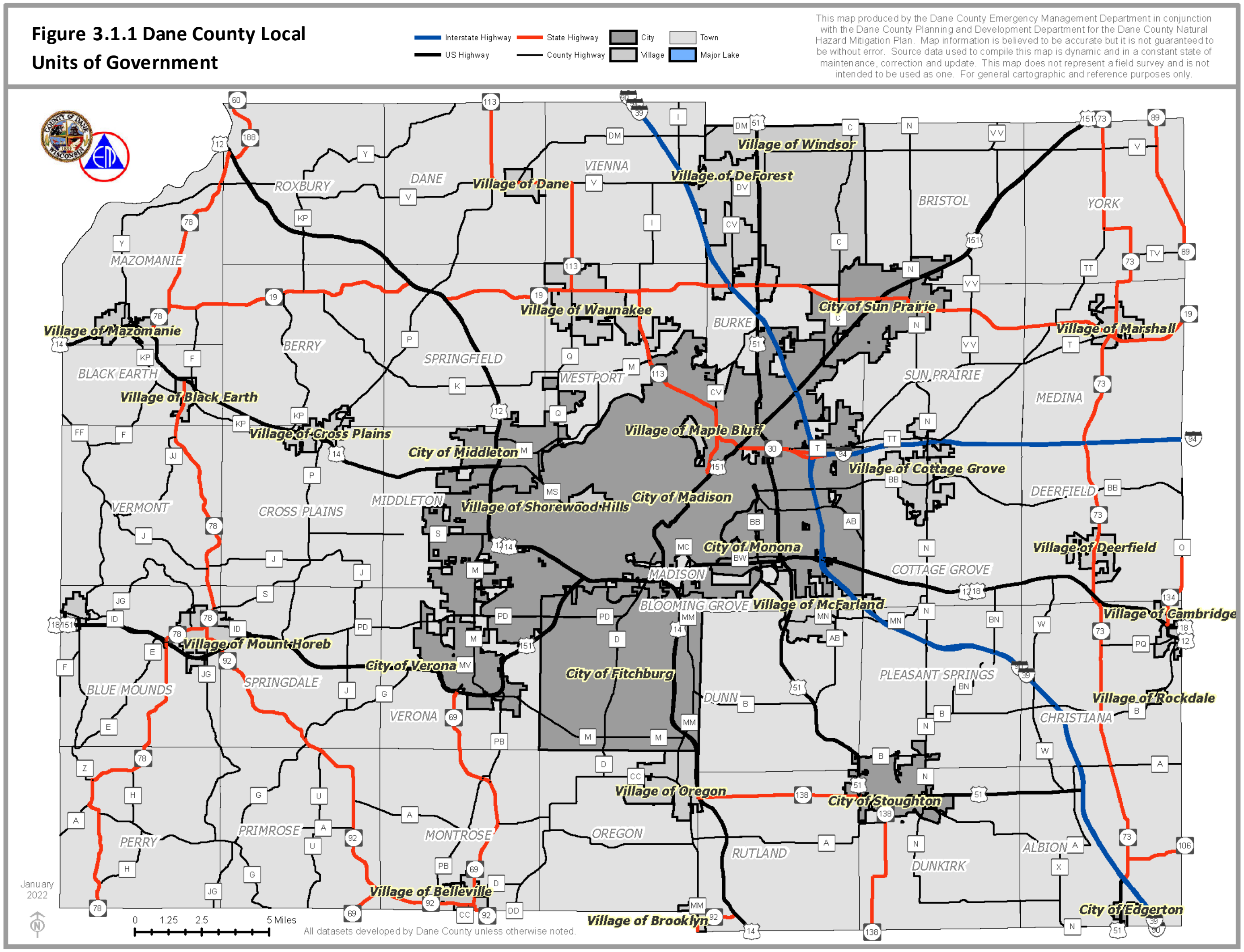


Figure 3.1.2 Dane County Terrain Map

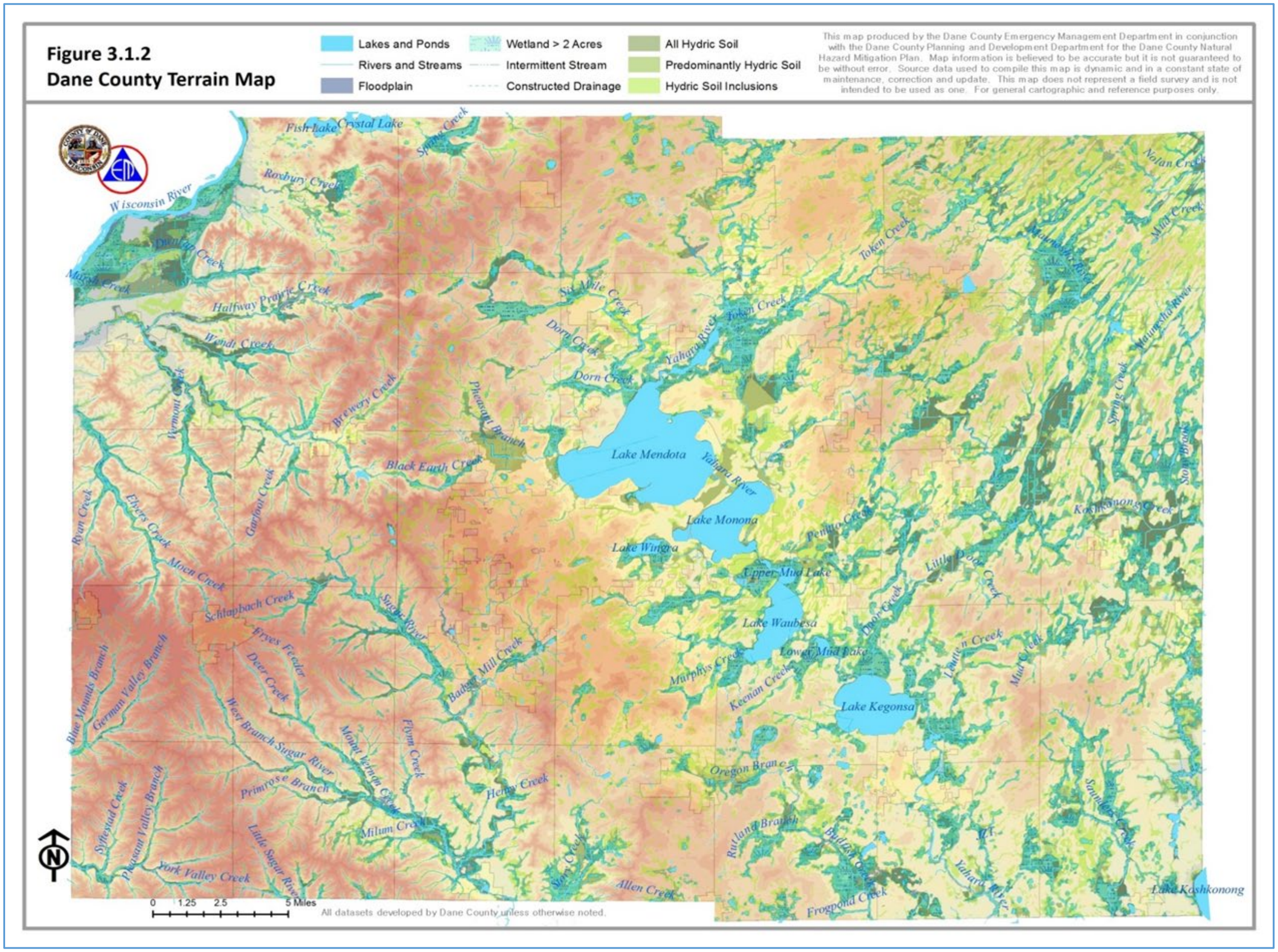
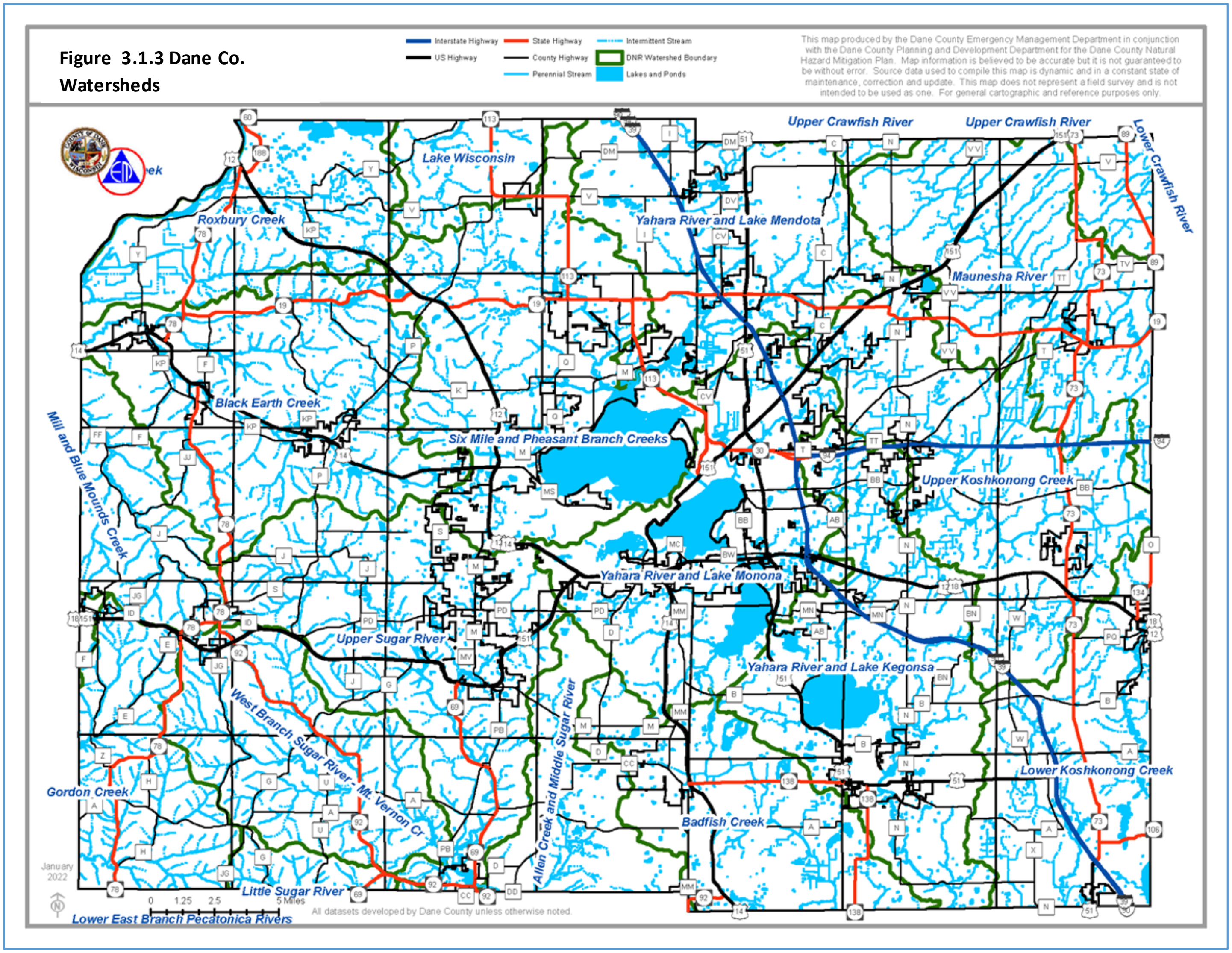


Figure 3.1.3 Dane County Watersheds



3.1.3 Major Drainage Basins

Wisconsin River Basin

The northern part of the Wisconsin River Basin includes the bottomlands and floodplain of the Wisconsin River Valley, a hillier moraine area to the east, and a drumlin-marsh glacial area east of the moraines. The Wisconsin River bottomlands include extensive wetland and marsh deposits underlain by deep alluvial deposits. A few streams and small, internally drained areas characterize the moraine areas with kettle holes occupied by marshes or small seepage lakes.

- *Fish Lake is* a high quality seepage lake occupying a valley of glacial outwash and alluvium. It covers 252 acres (313 acres including Mud Lake). It has a two-square-mile watershed, which is predominantly agricultural. On the west side of the lake, Dane County maintains a small park and boat landing. Lussier County Park is along the eastern shore. There are no surface inlets or outlets to the lake and it is primarily spring-fed.
- *Crystal Lake* is a small (approximately 571 acres), shallow, landlocked basin located about one-half mile east of Fish Lake. There is some residential and recreational development along the lakeshore, but most of the land surrounding the lake is farmland. The lake's watershed is less than five square miles. Since the predominant source of water to the lake is runoff, the water level in the lake fluctuates from year to year depending on the amount of precipitation

Depending the water levels, run off, and ground water level, water from Crystal lake drains overland, through the Town of West Point in Columbia County WI, into Fish Lake.

Sugar-Pecatonica Basin

This area is characterized by thin soils over bedrock, steep wooded slopes, and narrow stream valleys with alluvial deposits, few wetlands, and no natural lakes or impoundments. Land use is mostly rural and agricultural. Many of the wetlands along the Sugar River have been drained for agricultural use.

- *Lake Belle View* is a small impoundment on the Sugar River in the Village of Belleville. Sediment deposition from upstream areas had been a concern, prior to a large-scale River/Lake Separation Project completed in 2013 to help restore the lake. A 3200-foot berm constructed from dredged material now isolates the 40 acre lake from the high nutrient and suspended solid loads in the Sugar River for all but the largest flood events. In addition to removing four feet of accumulated sediment, dredging of the lake has resulted in restoring a maximum depth of 8-10 feet around the community park, grading to shallower areas to provide diverse fish habitat and outdoor recreational opportunities, as well as a hiking/biking trail along the length of the berm connecting the northern and southern portions of the village. In addition, approximately 30 acres on the river side of the berm has been restored to wetlands and upland habitat through native plantings and seeding.

Yahara River Basin

The surface water resources of the Yahara River Basin represent the most heavily used and highly valued in Dane County. The Yahara River Chain of Lakes – Mendota, Monona, Waubesa and Kegonsa – provide a spectacular setting for the County's central urban region, including the state capital, the main campus of the state university, and a majority of the County's population. The Yahara Lakes are by far the most heavily used recreational resource in the region, and their scenic beauty is one of the prized assets of Dane County.

Most of the Yahara River Basin is contained within Dane County. Much of the land in the basin north of Lake Mendota is devoted to agriculture, with a fairly high percentage of cropland. Rapid urban development is taking place and erosion from construction sites and runoff from urban land uses are of growing importance and concern in this part of the basin.

The central part of the basin – the area surrounding Lakes Mendota, Monona and Waubesa – is primarily urban, with limited agricultural uses on the fringe of the central urban area. The southern portion, including the area directly tributary to Lake Kegonsa, is predominantly agricultural. Only the communities of Stoughton and Oregon contribute any significant urban influence to the lower Yahara River.

- *Lake Mendota* is a large (9,800 acres) deep (maximum depth 83 feet) lake. Lake Mendota's watershed is primarily agricultural land; however, significant urban areas also drain to the lake.
- *Lake Monona* is a smaller lake (3,300 acres) with a maximum depth of 74 feet. Nearly all of the direct drainage to Lake Monona is from surrounding urban areas.
- *Lake Wingra* is a small (348-acre) shallow (maximum depth 21 feet) lake located in the middle of the urban area in the University Arboretum, which drains to Lake Monona.
- *Lake Waubesa* is a 2,100-acre lake (maximum depth of 38 feet) downstream from Lake Monona. The lake receives direct runoff from both urban and rural areas.
- *Lake Kegonsa* is a 3,200-acre lake (maximum depth of 32 feet) and is the furthest downstream of the Yahara Lakes. It is located outside of the central urban areas, and its direct watershed is primarily agricultural, with some development around the lake shoreline.

Other important water resources in the basin include the Yahara River and its tributaries: rural and urban streams draining directly to the lakes, including Token Creek, Sixmile Creek, Pheasant Branch Creek, Starkweather Creek, Nine Springs Creek, and Door Creek, as well as Lake Wingra in the University Arboretum, and large wetland areas, such as Cherokee Marsh and Door Creek Wetlands.

- *Badfish Creek* plays a major role in receiving all of the treated municipal wastewater generated in the basin and transmitting it around the lakes (approximately 42 mgd or 65 cfs in 2013). Because of the pumping and diversion of wastewater around the Yahara Lake System, the mean annual flow of the Yahara River has been reduced by approximately 30 percent. As a result, for every gallon of wastewater diverted to Badfish Creek approximately one gallon of streamflow is lost from the lower Yahara River.

Koshkonong Creek – Maunesha River Basin

Nearly all of the land in the Koshkonong Creek-Maunesha River Basin is agricultural. The City of Sun Prairie, located at the headwaters is the largest urban community in the basin. Other communities include the Village of Marshall, located on the Maunesha River, and the Villages of Deerfield, Cambridge and Rockdale, located along Koshkonong Creek.

The Koshkonong Creek—Maunesha River Basin includes many important and extensive wetland areas, such as the Deansville Marsh and the Mud Lake and Goose Lake wetlands. The Marshall Millpond is a small impoundment on the Maunesha River that supports active recreational use.

3.1.4 Environmentally Sensitive Areas

Resource protection in the region recognizes that land and natural resources perform critical environmental functions such as groundwater recharge and discharge, water quality improvement, erosion control, storage of floodwaters, wildlife habitat, and scenic beauty. Some lands are particularly vulnerable in urban and developing areas.

Resource Protection and Environmental Corridors

The approach to resource protection in Dane County is based primarily on a countywide system of continuous corridors. Most lands in need of protection are associated with stream valleys and other water features. The corridors also emphasize the importance of continuity of environmental systems and protection of the land/water edge. Local governments, the Capital Area Regional Planning Commission (CARPC), and state and federal agencies use the corridors to make decisions on the location of urban development and major facilities. The corridors are also used as the basis for open space and recreation planning and acquisition.

- *Environmental Corridors* are contiguous systems of open space in urban and urbanizing areas, that include environmentally sensitive lands and natural resources requiring protection from disturbance and development, and lands needed for open space and recreational use. They are based mainly on drainage ways and stream channels, floodplains, wetlands, steep slopes over 12.5%, and other resource features. Regional Planning Commission staff work with municipalities to delineate and map environmental corridors as part of the process for approving Urban Service Areas.
- *Resource Protection Corridors* as shown on the Planned Land Use Map of the *Dane County Comprehensive Plan*, include areas that are not suitable for structural development due to environmental sensitivity or because of the presence of fragile, irreplaceable resources. Resource Protection Corridors apply to areas outside Urban Service Areas as identified in the

Dane County Water Quality Plan. Resource Protection Corridor Overlays include the following categories of lands:

- Wetlands, as defined in state statute and including both the shoreland wetland and inland wetland districts under Chapter 11, Dane County Code.
- Shoreland setbacks and wetland buffers required under Chapter 11, Dane County Code.
- 1% regional floodplains, including the general floodplain district, floodway district and flood storage district, as described in Chapter 17, Dane County Code.
- Slopes exceeding 20%, except in towns with adopted town/county comprehensive plan language that specifically permits development on slopes of 20% or greater.
- Other areas identified in town, city or village plans adopted as part of the Dane County Comprehensive Plan, as areas specifically planned to protect natural or cultural resources, and where structural development is strictly limited.

The protection of public health, safety and property is an extremely important function of open space corridors, with significant economic implications, such as avoiding or preventing development in areas subject to flooding. Open space corridors include a variety of environmentally sensitive lands and resource features including: lakes, ponds and streams; wetlands; floodplains; shoreland buffer strips along streams, drainage ways, and wetlands.

Lakes, Ponds, and Streams

Lakes, ponds and streams are important water resources that provide a primary function in drainage and hydrologic balance. It is important to avoid development that adversely impacts these areas, since these water resources are necessary to convey runoff and flood flows. These areas are also heavily used for outdoor recreation, nature study and education. Swimming, boating, fishing, and nature study are among the most significant outdoor recreation activities in Dane County. These areas also represent significant wildlife habitat. Finally, lakes, ponds, and streams are important scenic features.

Existing and Historic Wetlands

Over 50 percent of the county's wetlands have been drained and are no longer a component part of the natural ecosystem. (Capital Area Regional Planning Commission, *Dane County Wetland Resources Management Guide*, May 2008) Approximately 36,000 acres were reported lost between 1901 and 1936. Between 1939 and 1961 the Wisconsin Conservation Department listed 22,678 wetland acres lost. Recent estimates using GIS indicate a total loss of 66,728 acres, or 56 percent of the original wetland acreage. Most of the drainage activity took place because it was widely believed that wetlands served no useful purpose and that the land could be more productive as an agricultural or urban use. However, it has since been recognized that wetlands are an integral part of a viable and diverse natural resource system. The mapped wetlands that remain are regulated under federal, state or local controls.

Wetlands are particularly important in protecting water resources, drainage, and hydrologic functions in that they provide temporary detention and storage of floodwaters and runoff, which reduces flood damage and maintains a hydrologic balance between ground and surface waters. Wetlands usually represent groundwater discharge areas, which help to maintain stream flows during dry weather conditions. Avoiding construction and development in wetlands is important since these areas are usually subject to flooding and exhibit unstable and compressible soils.

Wetlands also provide an important function in pollution control, outdoor recreation, scenic beauty, development buffers, and education opportunities. Also, wetlands, because they exist on the edge between land and water, are usually highly productive in plant and animal biodiversity.

Hydric soils, which formed over long periods under saturated (low-oxygen) conditions, are a good indication of the location of historic wetlands that may have been ditched, drained, cropped, or altered in some fashion. These soils possess unique characteristics even though the water is no longer present.

Figure 3.1.4 is a map of wetlands and hydric soils in Dane County.

Floodplains

The role of floodplains in performing a drainage and hydrologic function is also very important. Loss, due to development, of the flood conveyance and storage capacity provided by floodplains can result in increased flooding and damages both upstream and downstream. Figure 3.1.5 is a map indicating Dane County floodplains.

One of the primary reasons to protect floodplains from development is to protect public health, safety and property. Locating development in the floodplain exposes property such as buildings, streets and utilities to expensive flood damage, as well as exposing the resident population to significant risks to health and safety during floods. Providing pollution control is a secondary function, primarily through the mechanism of settling out sediment from slow-moving waters in flood fringe or storage areas.

Since floodplains are associated with water features, they can satisfy some outdoor recreation and education needs. Many active and passive recreational uses are compatible with floodplains, particularly for activities that don't require structures or facilities, which might be subject to damage.

Another secondary function of floodplains is to provide wildlife habitat. Since floodplains are associated with lakes and streams, they include the land/water edge, which is important in satisfying the food, water, and habitat needs of a wide variety of land and water based wildlife. In addition, floodplains have a continuous nature, and this continuity is extremely important in enhancing the value of open space for wildlife habitat.

Finally, as a feature of the natural landscape, floodplains also perform an important function in terms of enhancing scenic beauty and shaping urban form. While floodplains in and of themselves may not be particularly scenic, they are important in providing buffers between adjacent communities or incompatible land uses and provide logical boundaries for urban growth.

Infiltration and Groundwater Recharge

Stormwater management practices emphasizing stormwater infiltration and groundwater recharge have received significant attention in recent years. Infiltration practices can provide significant groundwater recharge, pollution control, and floodwater control benefits, depending on the degree of storage and infiltration achieved.

There are constraints to the effectiveness of infiltration and not all sites are suitable for intensive infiltration practices. Considerations include soil type, depth to bedrock, and depth to groundwater.

The most suitable sites for large-scale projects are those that are in undeveloped areas located close to urban service areas boundaries. Suitable soils consist of permeable silt loams, which may be excavated to reach more permeable loam and sandy loam materials. Groundwater and bedrock depths are not less than 10 feet and generally exceed 25 feet. As development pressures and urban service boundaries expand into these areas, careful consideration should be given in stormwater planning to preserving significant amounts of this land for infiltration and groundwater recharge purposes. The opportunity to develop infiltration practices in these areas should not be overlooked, since suitable site characteristics do not exist in all urbanizing areas.

Figure 3.1.4 Dane County Wetlands and Hydric Soils

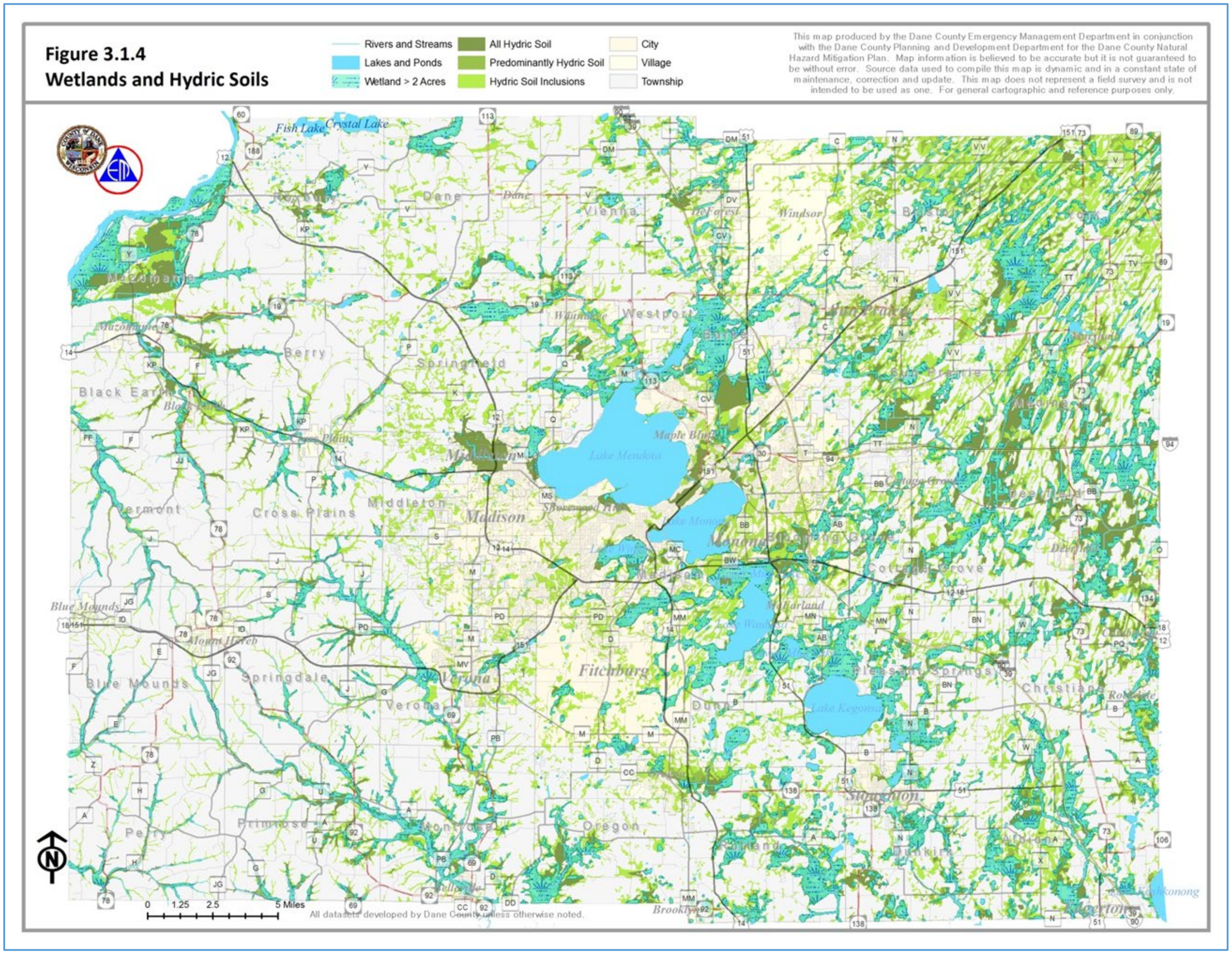
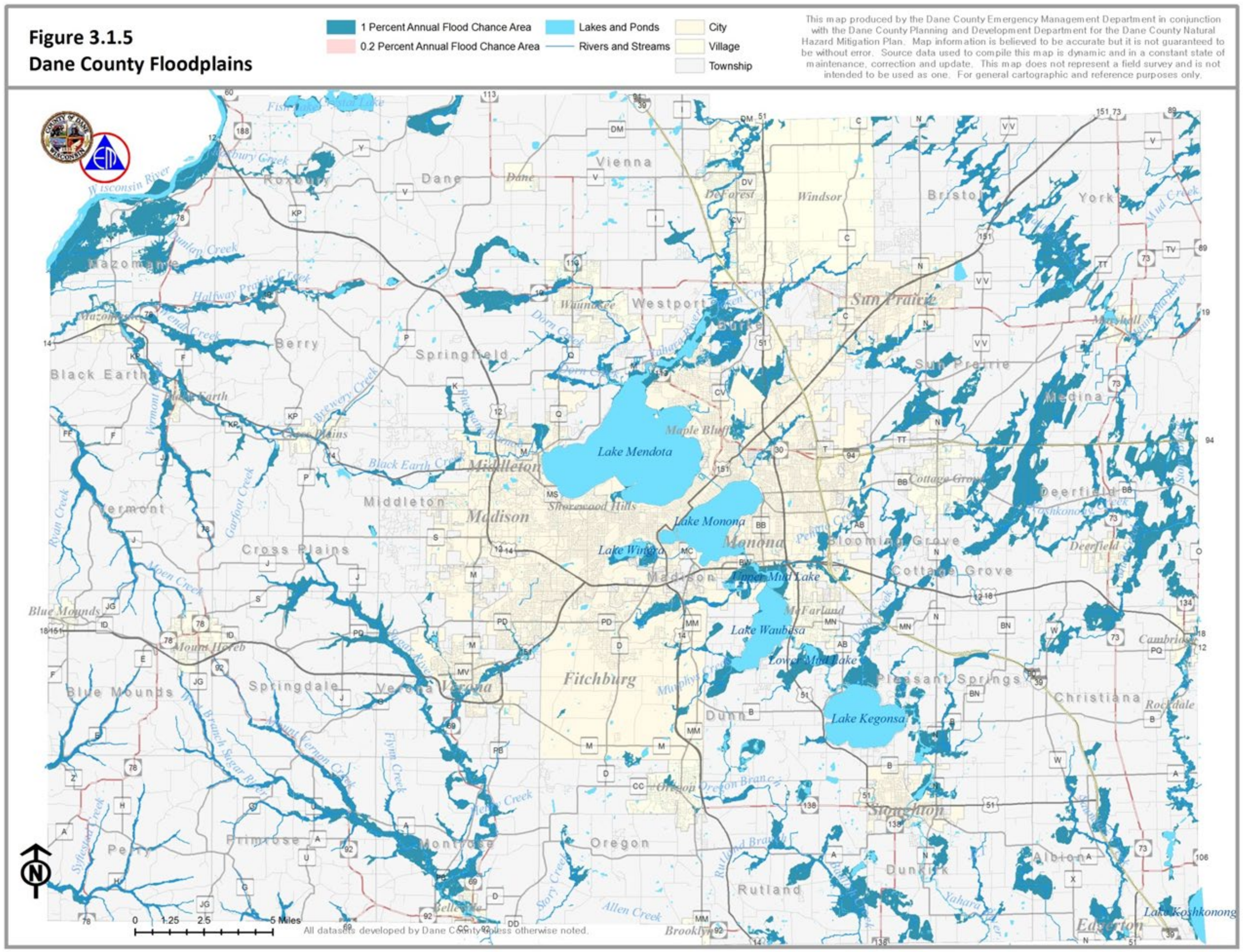


Figure 3.1.5 Dane County Floodplains



3.2 Climate

Dane County climate is typically continental—warm, humid summers and cold, snowy winters. About two-thirds of the annual precipitation falls during the growing season. It is normally adequate for vegetation, although drought is occasionally reported. The climate is most favorable for dairy farming and agriculture. The primary crops are corn, small grains, hay, and vegetables. The rapid succession of storms moving from west to east and southwest to northeast accounts for much of the climatic activity.

The most frequent air masses are of polar origin. Occasional outbreaks of arctic air affect the area during the winter months. Although northward moving tropical air masses contribute considerable cloudiness and precipitation, the true Gulf air mass does not reach this area in winter, and only occasionally at other seasons. Summers are pleasant, with only occasional periods of extreme heat or high humidity.

The average annual temperature in the County is 46°F. Temperature extremes range from an all-time high of 107°F, which was observed on July 14, 1936 to a record low of -37°F, which occurred on January 30, 1951. Winter temperatures (December-February) average near 20°F and summer temperatures (June-August) average in the upper 60s. Daily temperatures average below 32°F about 120 days of the year and above 40°F about 210 days of the year. The average seasonal snowfall is 50 inches. Average seasonal precipitation is 33 inches. There are no dry and wet seasons, but about 60 percent of the annual precipitation falls in the five months of May through September. Cold season precipitation is lighter, but lasts longer. Soil moisture is usually adequate in the first part of the growing season. During July, August and September, the crops depend on current rainfall, which is mostly from thunderstorms and tends to be erratic and variable. Average occurrence of thunderstorms is just under 7 days per month during this period.

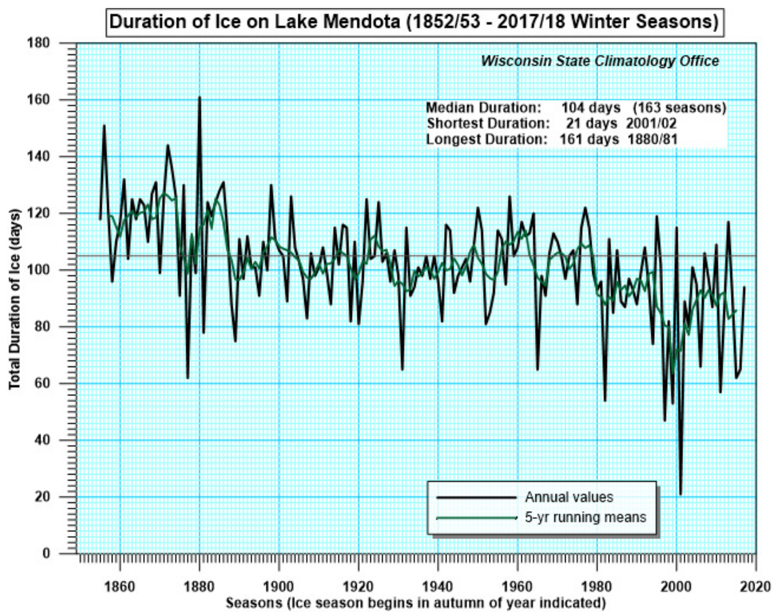
The ground is covered with 1 inch or more of snow about 60 percent of the time from December through February in an average winter. The soil is usually frozen from the first of December through most of March with an average frost penetration of 25 to 30 inches. The growing season averages 175 days.

3.2.1 Climate Change Trends

A wealth of temperature and precipitation data provide evidence that on average the State of Wisconsin has become warmer and wetter over the past 60 years. Historical temperature and precipitation patterns reflect this change across regions of the state. For instance, during the 1950-2006 period winter temperatures increased significantly in northwestern Wisconsin, and these increases extended into the central part of the state. Northwestern and central Wisconsin experienced 14 to 21 fewer nights with temperatures below zero degrees Fahrenheit. Other areas of the state saw reductions in subzero nights of seven days or less.

Future projections of temperature and precipitation patterns by University of Wisconsin-Madison climate scientists indicate that Wisconsin's warming trend will increase considerably in the decades ahead. By 2050, statewide annual average temperatures are likely to warm by 6-7°F. Today, daily high temperatures exceed 90 degrees about 12 times per year in southern Wisconsin. By 2050, the frequency of very hot days above 90 degrees is projected to triple.

Figure 3.2.1 Lake Mendota Ice Cover



Source: Clean Lake Alliance, Wisconsin State Climatology Office, 2019

We do not need to look as far away as the Arctic to view ice melting conditions. Lake Mendota is not staying ice covered as long as it once did. According to UW-Madison records, 150 years ago the ice cover lasted four months. Today the lake stays ice covered an average of three months. The winters with the 10 longest periods of ice cover all occurred before 1900, while the winters with the 10 shortest periods of ice cover occurred mostly in recent years.

While future precipitation patterns are more difficult to discern than temperature, the region is likely to continue its trend toward more precipitation overall, with the most probable increases in winter, spring and fall. Large storm events are also likely to increase in frequency during spring and fall. Statewide, the amount of precipitation that falls as rain rather than snow during the winter is also projected to increase significantly, with freezing rain more likely to occur.

The projected increase in annual rainfall and more intense rain storms heighten the potential for significant soil erosion, affecting water resources and agriculture. Without appropriate adaptation measures, future soil erosion rates could double by 2050 compared to 1990 rates, which will likely increase sediment and nutrient loading, more blue-green algal blooms in lakes and loss of biodiversity in wetlands. For agriculture, while warming temperatures in spring and fall would boost agricultural production by extending the growing season across the state, changes in rainfall patterns influence groundwater recharge, and any decrease in groundwater recharge could be compounded by increased demand for irrigation due to an extended growing season, or seasonal drought. These impacts are addressed more specifically in the hazard analysis and risk assessment section of the plan.

3.3 Population and Demographics

Hazard mitigation programs must consider the population demographics of the communities they are designed to protect. Some populations experience greater vulnerability from hazard events, not because they are more likely to experience an event, but because they may have decreased resources or physical abilities to respond. Research indicates that people living near or below the poverty level, the elderly, the physically or mentally disabled, and ethnic minorities tend to suffer more severe effects from disasters than the general population.

From a hazard mitigation standpoint, population growth and density are also relevant. Generally, growth means that more people are in the path of potential natural hazards, whether they are urban or rural areas. There is a balance, however, as new development may be more resistant to the impacts of natural hazards because buildings meet newer, more stringent codes for building safety.

Population growth and demographics are obviously related. With Dane County's rapid growth come an increasing number of potentially vulnerable people:

- Increasing numbers of older residents and residents with disabilities and other special needs.
- Increasing racial and ethnic diversity.
- Increasing numbers of individuals living on low or fixed incomes.

These trends present challenges in all phases of the management of natural hazards.

3.3.1 Population

More than 508,000 people live in Dane County, making it the second most populous county in the State. While the total population of the County has grown by more than 52 percent since 1990, the amount of growth has varied widely for the County's municipalities. In general, the towns and the City of Madison have grown more slowly, while the smaller cities and villages grew much more quickly. Table 3.3.1 summarizes the population growth trends from 1990 to 2021.

Table 3.3.1 Dane County Population Data

	Population				1990-2021
Municipality	**1990**	**2000**	**2016**	**2021**	**% Change**
TOWNS					
Albion	1,964	1,823	1,965	2,069	5.35
Berry	1,098	1,084	1,138	1,168	6.38

	Population				1990-2021
Municipality	**1990**	**2000**	**2016**	**2021**	**% Change**
Black Earth	365	449	485	510	39.73
Blooming Grove	2,079	1,768	1,818	1,622	-21.98
Blue Mounds	667	842	989	899	34.78
Bristol	1,835	2,698	4,045	4,447	142.34
Burke	3,000	2,990	3,339	3,265	8.83
Christiana	1,182	1,313	1,253	1,235	4.48
Cottage Grove	3,525	3,839	3,900	3,791	7.55
Cross Plains	1,206	1,419	1,533	1,494	23.88
Dane	921	968	1,003	934	1.41
Deerfield	1,181	1,470	1,597	1,684	42.59
Dunkirk	2,121	2,053	1,945	1,881	-11.32
Dunn	5,274	5,270	4,956	4,880	-7.47
Madison	6,442	7,005	6,277	6,236	-3.20
Mazomanie	982	1,185	1,102	1,074	9.37
Medina	1,124	1,235	1,380	1,344	19.57
Middleton	3,628	4,594	6,273	6,792	87.21
Montrose	1,032	1,134	1,092	1,064	3.10
Oregon	2,428	3,148	3,231	3,125	28.71
Perry	646	670	738	737	14.09
Pleasant Springs	2,660	3,053	3,217	3,078	15.71
Primrose	595	682	731	750	26.05
Roxbury	1,536	1,700	1,841	1,871	21.81
Rutland	1,584	1,887	1,995	1,977	24.81
Springdale	1,258	1,530	1,948	2,056	63.43
Springfield	2,650	2,762	2,805	2,929	10.53
Sun Prairie	1,839	2,308	2,352	2,391	30.02
Vermont	678	839	821	871	28.47
Verona	2,137	2,153	1,983	1,947	-8.89
Vienna	1,351	1,294	1,523	1,666	23.32
Westport	2,732	3,586	4,000	4,191	53.40
York	649	703	681	697	7.40
VILLAGES					
Belleville *	1,349	1,795	1,848	1,909	41.51

	Population				1990-2021
Municipality	1990	2000	2016	2021	% Change
Black Earth	1,248	1,320	1,368	1,493	19.63
Blue Mounds	446	708	920	948	112.56
Brooklyn *	406	502	954	1,026	152.71
Cambridge *	883	1,014	1,356	1,539	74.29
Cottage Grove	1,131	4,059	6,512	7,303	545.71
Cross Plains	2,362	3,084	3,696	4,104	73.75
Dane	621	799	1,067	1,117	79.87
Deerfield	1,617	1,971	2,423	2,507	55.04
DeForest	4,882	7,368	9,223	10,811	121.45
Maple Bluff	1,352	1,358	1,307	8,991	565.01
Marshall	2,329	3,432	3,864	1,368	-41.26
Mazomanie	1,377	1,485	1,667	3,787	175.02
McFarland	5,232	6,416	7,946	1,768	-66.21
Mount Horeb	4,182	5,860	7,123	7,754	85.41
Oregon	4,519	7,514	9,575	11,179	147.38
Rockdale	235	214	213	207	-11.91
Shorewood Hills	1,680	1,732	1,928	2,169	29.11
Waunakee	5,897	8,995	12,901	14,879	152.31
Windsor	4,620	5,286	6,876	8,754	89.48
CITIES					
Edgerton *	N/A	42	113	146	175.0%
Fitchburg	15,648	20,501	26,321	29,609	89.22
Madison	190,766	208,054	242,216	269,840	41.45
Middleton	13,785	15,770	18,810	21,827	58.34
Monona	8,637	8,018	7,833	8,624	-0.15
Stoughton	8,786	12,354	12,698	13,173	49.93
Sun Prairie	15,352	20,369	31,810	35,967	134.28
Verona	5,374	7,052	11,871	14,030	161.07
County Total	367,085	426,526	508,395	561,504	52.96

* Indicates a municipality within multiple counties. Only the population of the portion in Dane County is counted.
Source U.S. Census Bureau – 2021 Decennial Census, Prepared by DCEM

3.3.2 Age Trends

The vulnerability of age groups can vary significantly based on health, age, and income level. However, as a group, the elderly are more apt to lack the physical and economic resources necessary for response. The elderly, as a group are also more likely to suffer health related consequences and be slower to recover. Like most areas of the United States, the population of Dane County is aging. Table 3.3.2 indicates a summary of Dane County population by age group.

Table 3.3.2 Dane County Population by Age Group, 2015 to 2019 Census Estimate Trends

Age Group (in Years)	2015 Estimate	2019 Estimate	2015-2019 Change
Under 5 years	6.00%	5.50%	-8.3%
5 to 9 years	6.10%	5.56%	-8.9%
10 to 14 years	5.80%	5.77%	-0.5%
15 to 19 years	6.70%	6.52%	-2.7%
20 to 24 years	10.30%	10.08%	-2.1%
25 to 29 years	8.00%	8.47%	5.9%
30 to 34 years	7.80%	7.14%	-8.5%
35 to 39 years	6.60%	7.37%	11.7%
40 to 44 years	6.30%	6.26%	-0.7%
45 to 49 years	6.40%	5.84%	-8.7%
50 to 54 years	6.70%	5.69%	-15.1%
55 to 59 years	6.30%	5.71%	-9.4%
60 to 64 years	5.60%	5.93%	6.0%
65 to 69 years	4.00%	5.16%	29.0%
70 to 74 years	2.50%	3.48%	39.3%
75 to 79 years	1.80%	2.40%	33.3%
80 to 84 years	1.50%	1.44%	-3.9%
85 years and over	1.60%	1.67%	4.4%
Total Population	**1**	**546,695**	**N/A**
Median Age	**34.8**	**35**	**N/A**

Source: U.S. Census Bureau, American Community Survey, data.census.gov / accessed December, 2021..

3.3.3 Income Trends

Impoverished people may experience a greater impact from a natural disaster than members of the general population. In the United States, individual households are expected to use first, their own private resources to prepare for, respond to, and recover from disasters. This expectation automatically places low-income individuals and families at a disadvantage when dealing with these hazards. In addition, relative to higher income groups, people with low incomes tend to occupy more poorly built and inadequately maintained housing. In some cases, these types of housing are more susceptible to damages caused by natural hazards. Tables 3.3.3 and 3.3.4 summarize income and poverty levels in Dane County from 2015 census estimates.

Table 3.3.3 Dane County Household Income Levels

Household Income Level	% of all Households
Less than $10,000	3.5%
$10,000 to $14,999	3.3%
$15,000 to $24,999	6.1%
$25,000 to $34,999	7.4%
$35,000 to $49,999	10.7%
$50,000 to $74,999	17.4%
$75,000 to $99,999	14.3%
$100,000 to $149,999	20.1%
$150,000 to $199,999	8.1%
$200,000 or more	9.0%
Total Number of Households	**222,929**
Median Household Income ($)	**$77,504**

Source: U.S. Census Bureau, American Community Survey, data.census.gov / accessed December, 2021.

Table 3.3.4 Number of Individuals in Dane County Classified as Poverty Status

Poverty Status	Population	Percent
Under 18 years	**6,013**	**5.5%**
Under 5 years	1,283	4.3%
5 to 17 years	4,730	6.0%
Related children of householder under 18 years	5,738	5.3%
18 to 64 years	**40,654**	**11.7%**
18 to 34 years	29,930	20.2%
35 to 64 years	10,724	5.4%
60 years and over	**5,344**	**4.9%**
65 years and over	**3,518**	**4.6%**
Total	**50,185107,934**	N/A

Source: U.S. Census Bureau, American Community Survey, data.census.gov / accessed December, 2021.

Dane County's median income figure suggests that in general, the County is doing well financially. Even so, there are still more than 58,000 people living in households with incomes below the poverty level. This equates to more than 10% of the total population of Dane County. A large number of these families include young children and a significant number of the individuals are elderly.

3.3.4 Population with Disabilities

People with disabilities have a special stake in disaster planning because in broad terms, they tend to have more difficulty in responding to a hazard event than does the general population. Disabilities can vary widely in severity and permanence, making populations difficult to define and track. There is no "typical" disabled person. In addition, a disability is likely to be complicated by other factors such as age, economic disadvantage, or ethnicity. According to the U.S. Census, however, there are more than 80,176 people in Dane County who report some form of disability. This is a significant number of people and means that a relatively large number of people may need special assistance in responding to and recovering from a natural hazard event or disaster. Table 3.3.5 is a summary from 2019 census estimates.

Table 3.3.5 Number of People with Disabilities

Disability Status from the 2011 to 2015 Census Estimates	Number	Percent
With a hearing difficulty	**10,338**	**1.9%**
▪ Population under 18 years	311	0.3%
▪ Population 18 to 64 years	3,897	1.1%
▪ Population 65 years and over	6,130	8.1%
With a vision difficulty	**5,905**	**1.1%**
▪ Population under 18 years	663	0.6%
▪ Population 18 to 64 years	2,332	0.7%
▪ Population 65 years and over	2,910	3.8%
With a cognitive difficulty	**18,794**	**3.7%**
▪ Population under 18 years	2,383	3.0%
▪ Population 18 to 64 years	11,879	3.3%
▪ Population 65 years and over	4,532	6.0%
With an ambulatory difficulty	**20,953**	**4.1%**
▪ Population under 18 years	178	0.2%
▪ Population 18 to 64 years	8,925	2.5%
▪ Population 65 years and over	11,850	15.6%
With a self-care difficulty	**8,243**	**1.6%**
▪ Population under 18 years	257	0.3%
▪ Population 18 to 64 years	3,886	1.1%
▪ Population 65 years and over	4,100	5.4%
With an independent living difficulty	**15,943**	**3.7%**
▪ Population 18 to 64 years	7,907	2.2%
▪ Population 65 years and over	8,036	10.6%

Source: U.S. Census Bureau, American Community Survey, data.census.gov / accessed December, 2021.

3.3.5 Ethnicity and Language

A great deal of recent research has focused on the increased disaster vulnerability of ethnic minorities in the United States. Research shows that minorities are less likely to be involved in pre-disaster planning, experience higher mortality rates during an event, and their post-disaster recovery can be ineffective and is often characterized by cultural insensitivity. Racially, Dane County appears to be a relatively homogenous area; 89 percent of the population listed their race as “white” and more than 93 percent were born in the United States. That being said, there is a significant diversity of ancestry and spoken language represented in the people of Dane County. Table 3.3.6 is a summary of ethnicity and language spoken by Dane County residents.

Table 3.3.6 Ethnicity and Spoken Languages in Dane County

Household Language	Number	Percent
Total of Households	**229,760**	**100%**
English only	**204,011**	**88.79**
Spanish:	**10,355**	**4.51**
▪ Limited English speaking household	1,591	15.36
▪ Not a limited English speaking household	8,764	84.64
Other Indo-European languages:	**6,311**	**2.75**
▪ Limited English speaking household	290	4.60
▪ Not a limited English speaking household	6,021	95.40
Asian and Pacific Island languages:	**7,715**	**3.36**
▪ Limited English speaking household	2,078	26.93
▪ Not a limited English speaking household	5,637	73.07
Other languages:	**1,368**	**0.60**
▪ Limited English speaking household	188	13.74
▪ Not a limited English speaking household	1,180	86.26

Source: U.S. Census Bureau, American Community Survey, data.census.gov / accessed December, 2021.

Table 3.3.6 indicates that while most of the population of the County was born in the United States and speaks English, there is a significant number who have cultural and language barriers. This has important implications in emergency situations where managers must communicate vital information to all members of the population.

3.3.6 Growth and Development Trends

Dane County is expected to reach a total population of nearly 606,620 by the year 2040—an increase of more than 40 percent over the 2000 population. This basic trend of slightly greater proportions of new growth occurring in outlying urban communities compared to the central urban area is expected to continue into the future. New urban development is expected to occupy even greater land areas than older development. This is partly due to lower densities of new residential, industrial and commercial construction, and partly due to declining population density resulting from a trend toward smaller household sizes. Continued population, housing, and employment growth, creates pressure for land use change and the supporting infrastructure improvements. Population growth and housing trends are compiled and published annually by the Capital Area Regional Planning Commission.

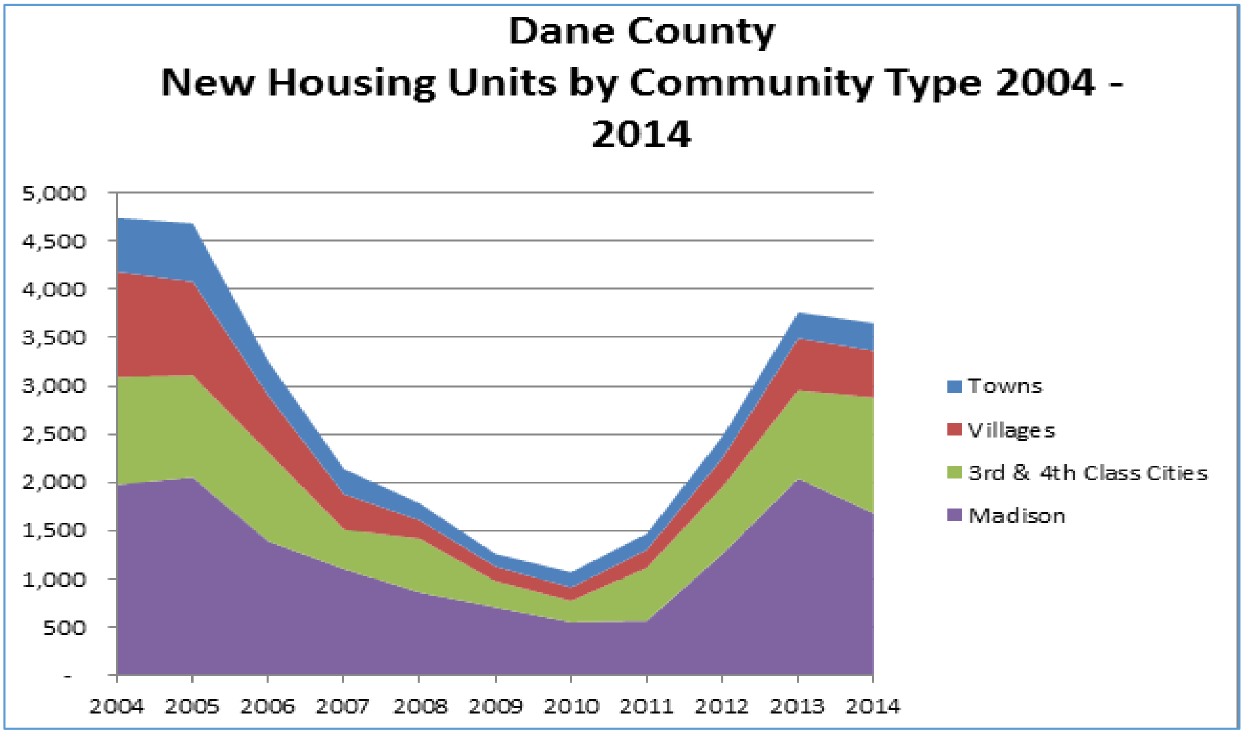
While jurisdictions continue to grow in population and size, zoning and other regulations are adjusted to address risks and local capabilities. While the number of persons and properties at risk from natural hazards is increasing, these increases as a percentage of the Dane County population has remained constant and or generally reduced with increases in local capabilities. Examples of increased capabilities include expanded storm water management facilities, current and past mitigation efforts to clear and increase capacity of local streams and rivers to accept storm water, more building code enforcement staff, and more first responders and staff to apply protective measures when needed.

3.4 Housing

3.4.1 Housing Growth

According to the U.S. Bureau of the Census, there was an estimated 229,760 households in Dane County at the end of 2019. Between 2000 and 2015, the County's year-round housing stock increased by 40,105 units, or 22 percent. The City of Madison made up 46 percent of the County's housing stock, compared with 54 percent in 1990. The composition of the County's housing stock has been changing in recent years. Although single-family housing makes up about 55 percent of housing within the County, the popularity of multifamily housing has been increasing. Though more people live in the central urban service areas of the County, the percentage of the population residing in outlying urban service areas is increasing. New housing construction mirrors this trend.

Figure 3.4.1 New Housing Units, 2004-2015



Source: Capital Area Regional Planning Commission

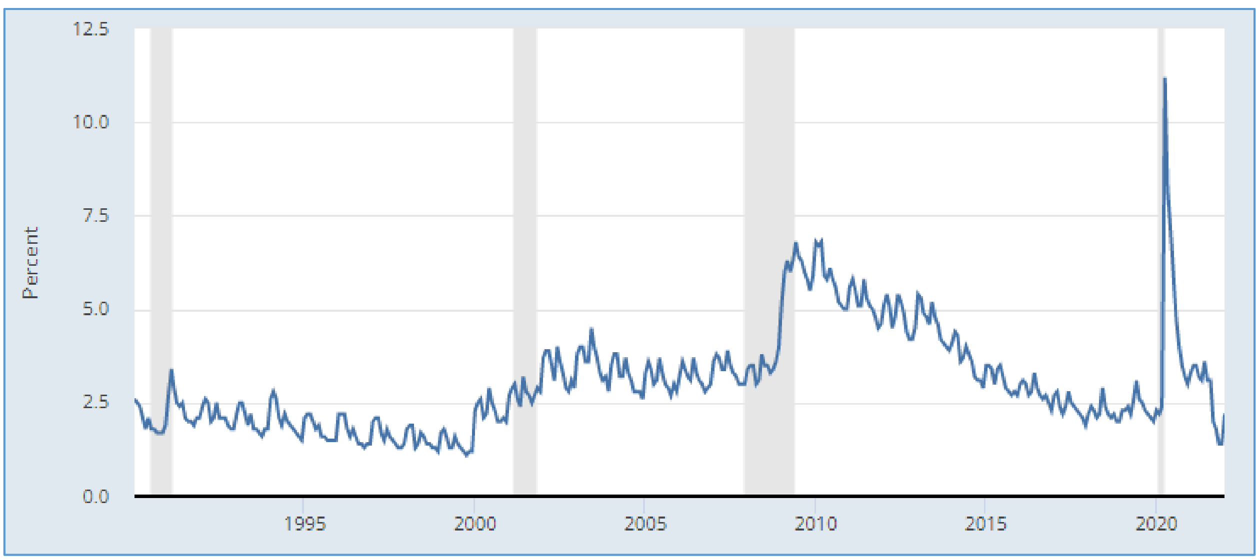
3.4.2 Future Housing Production

The Dane County Housing Initiative (DCHI) reported that the number of housing units has not grown in tandem to household income, population growth, or job growth. Rent has an annual growth rate of 2.3% despite the annual income growth being nearly half, at 1.3%. DCHI also states that despite Dane County producing over 25,000 housing units between the years of 2006-2017), the county still produced a deficit of 11,000 housing units relative to household growth. (2019 Housing Needs Assessment: Dane County and Municipalities, 2019 https://danehousing.countyofdane.com/housingreport#:~:text=There%20is%20a%20real%20shortage,units%20relative%20to%20household%20growth.)

3.5 Economy

Much of the County's population growth can be attributed to strong growth in the regional economy. The number of jobs in Dane County has typically followed the trend of growing faster than the population. In 2005 there were an estimated 297,213 jobs in the County. In 2020, the unemployment rate across the county increased by over 11 percent and quickly increased in the time following. Figure 3.5.1 shows the unemployment growth in Dane County since 1995

Figure 3.5.1 Dane County Average Annual Unemployment Rate



Source: U.S. Bureau of Labor Statistics, Federal Reserve Bank, 2021

Most economic activity and jobs (almost half) in the County are concentrated in the City of Madison. The regional economy has a base of employment in government and education, as Madison is the state capital and the home of the University of Wisconsin's main campus. The University in particular contributes in many ways to the local economy, most notably through its efforts to spin off high technology and biotechnology companies. High-tech now encompasses 7 percent of County employment.

Recent growth, however, has concentrated in the private sector, much of which has been occurring outside of the City of Madison. Government employment has declined as a share of the total from a third in 1980 to about one fourth in 2000. Service employment (26 percent of County total) is a strong contributor, particularly business and health services. Manufacturing (11 percent) and finance, insurance, and real estate (9 percent) employment also contribute significantly to the local economy.

Agriculture is also a significant contributor to Dane County's economy. Farming is diversified with a main emphasis on dairy farming. Field crops are mainly corn, oats, clover, and alfalfa, but barley, wheat, rye, and tobacco are also raised. Canning factories pack peas, sweet corn, and lima beans. Fruits are mainly apples, strawberries, and raspberries.

Led by dairy and livestock, Dane County is one of the State's top producers of grains, fresh market vegetables, and other value-added enterprises. Farmland comprises about 2/3 of Dane County's land area. Soil conditions and warm, wet summer climate help Dane County farmers produce enough agricultural products to sell nearly $300 million worth every year.

3.6 Land Use

The Dane County Master plan is part of the master plan for the County provided for by Wis. Stat. 66.945 (9) and (10), includes the following components:

- Dane County Water Quality Plan (2005, Capital Area RPC)
- Dane County Comprehensive Plan, including component town, village and city plans (2012, Dane County Board of Supervisors)
- Dane County Farmland Preservation Plan (2012, Dane County Board of Supervisors)
- Dane County Parks & Open Space Plan (2012, Dane County Parks Commission)

The Capital Area Regional Planning Commission conducts a land use inventory (LUI) every five years. In 2010, the LUI was expanded to include, for the first time, detailed data about rural land uses. The most significant land use trends are highlighted below:

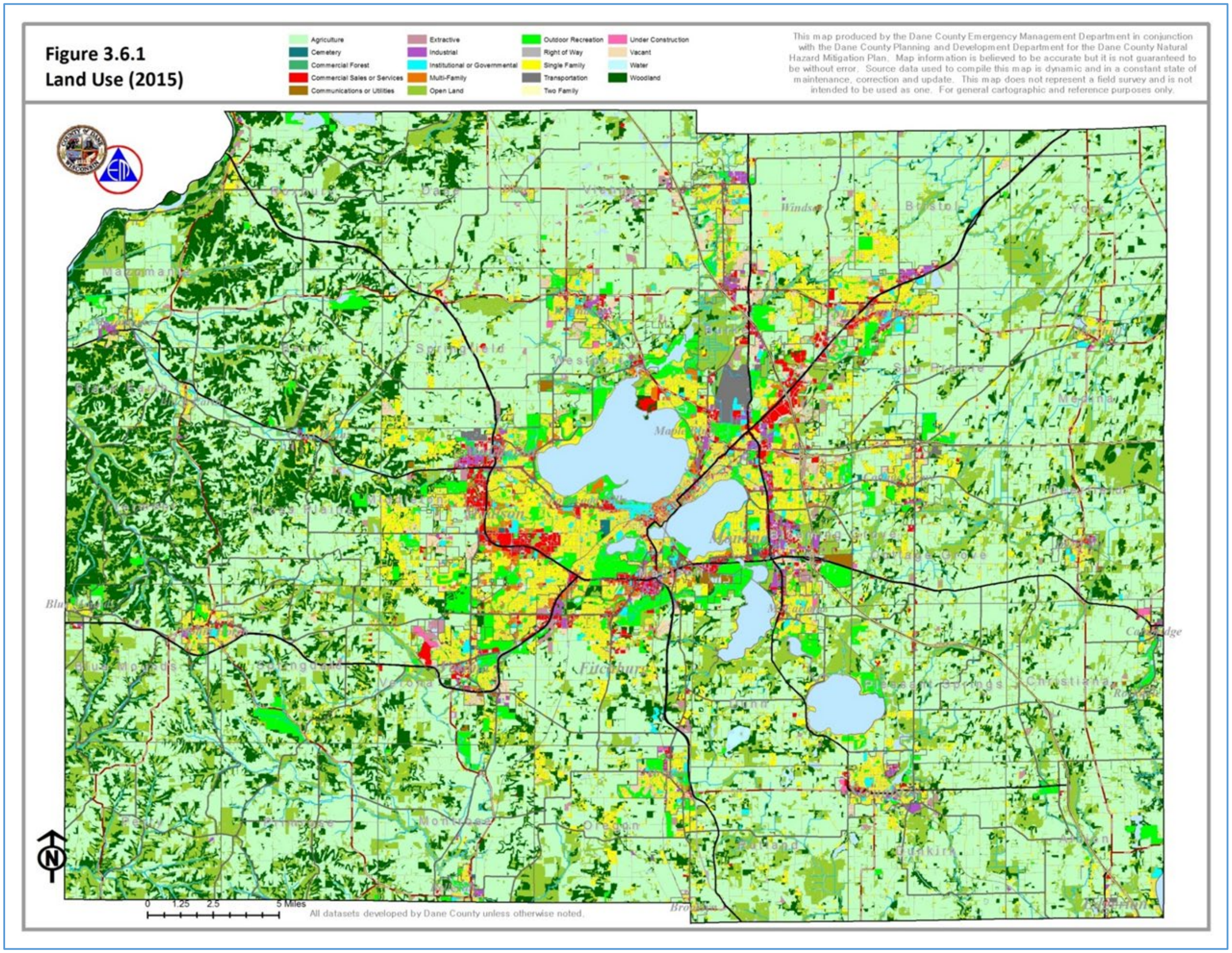
- The greatest amount of land in Dane County is agricultural, natural resource and undeveloped land at 635,886 acres in 2010, or over 80 percent of the total land area of the county. Developed land accounts for the remaining 20 percent, primarily residential, industrial and commercial land uses. The total developed area continues to increase each decade while the agricultural and undeveloped area continues to decrease. Cropland/pasture area has decreased partly due to urban development, but also due to increases in other undeveloped uses such as woodlands, open land, and vacant areas.

- Residential land uses account for the second largest classification of use (7.8 percent in 2010). Rates for residential use have slowed since peaks in the 1990s.
- Outdoor recreation has grown by 57.6% since 1990, reflecting increasing demand from a growing population.
- Commercial land use has also increased significantly since 1990. Almost all of the commercial land use in the County, 95 percent, is located within the incorporated communities of Dane County.
- The amount of land devoted to industrial uses has between 2005 and 2010. New industrial development has occurred primarily in cities and villages where public services are easily accessible.
- Institutional and governmental land uses have remained relatively constant over time (e.g., hospitals, schools, public buildings, churches, and cemeteries).
- The amount of land dedicated to communication and utilities, though a small percentage overall, has grown significantly since 2005, reflecting power line and communication tower development.

Land Use in Dane County is summarized by 19 categories. Summarized Land Use for 2020 is currently in process, and all information provided in this section is current to 2015 Land Use data. Figure 3.6.1 below demonstrates a map of 2015 land use in Dane County. Land Use categories are listed below alphabetically:

- Agriculture
- Cemetery
- Commercial Forest
- Commercial Sales or Services
- Communications or Utilities
- Extractive
- Industrial
- Institutional or Governmental
- Multi-Family
- Open Land
- Outdoor Recreation
- Right of Way
- Single Family
- Transportation
- Two Family
- Under Construction
- Vacant
- Water
- Woodland

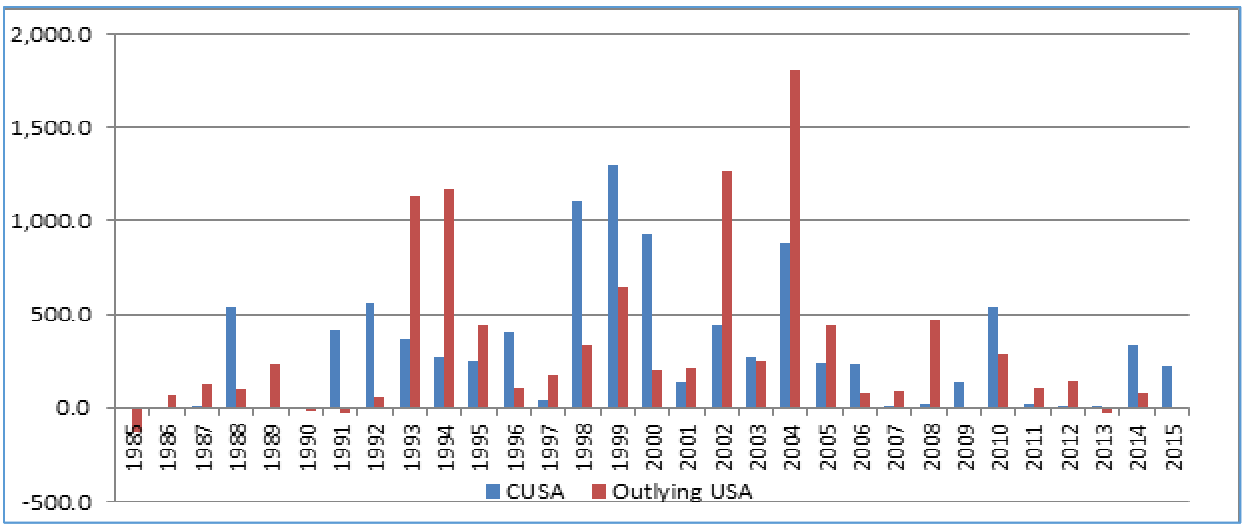
Figure 3.6.1 indicates 2015 land use categories.



3.6.1 Urban Service Areas

The Capital Area Regional Planning Commission (formerly the Dane County Regional Planning Commission) uses the concept of urban service areas as a planning tool. Urban service areas are those areas in and around existing communities that are most suitable for urban development and capable of being provided with a full range of urban services. (Urban services are those public services normally provided or needed in urban areas, including public water supply and distribution services, sanitary sewerage systems, higher levels of police and fire protection, solid waste collection, urban storm drainage, streets with curbs and gutters, street lighting, neighborhood facilities such as parks and schools, and urban transportation facilities such as sidewalks, taxi service and mass transit.) Figure 3.6.2 shows a recent history of urban service area amendments.

Figure 3.6.2 Urban Service Area Amendments: 1985 to 2015

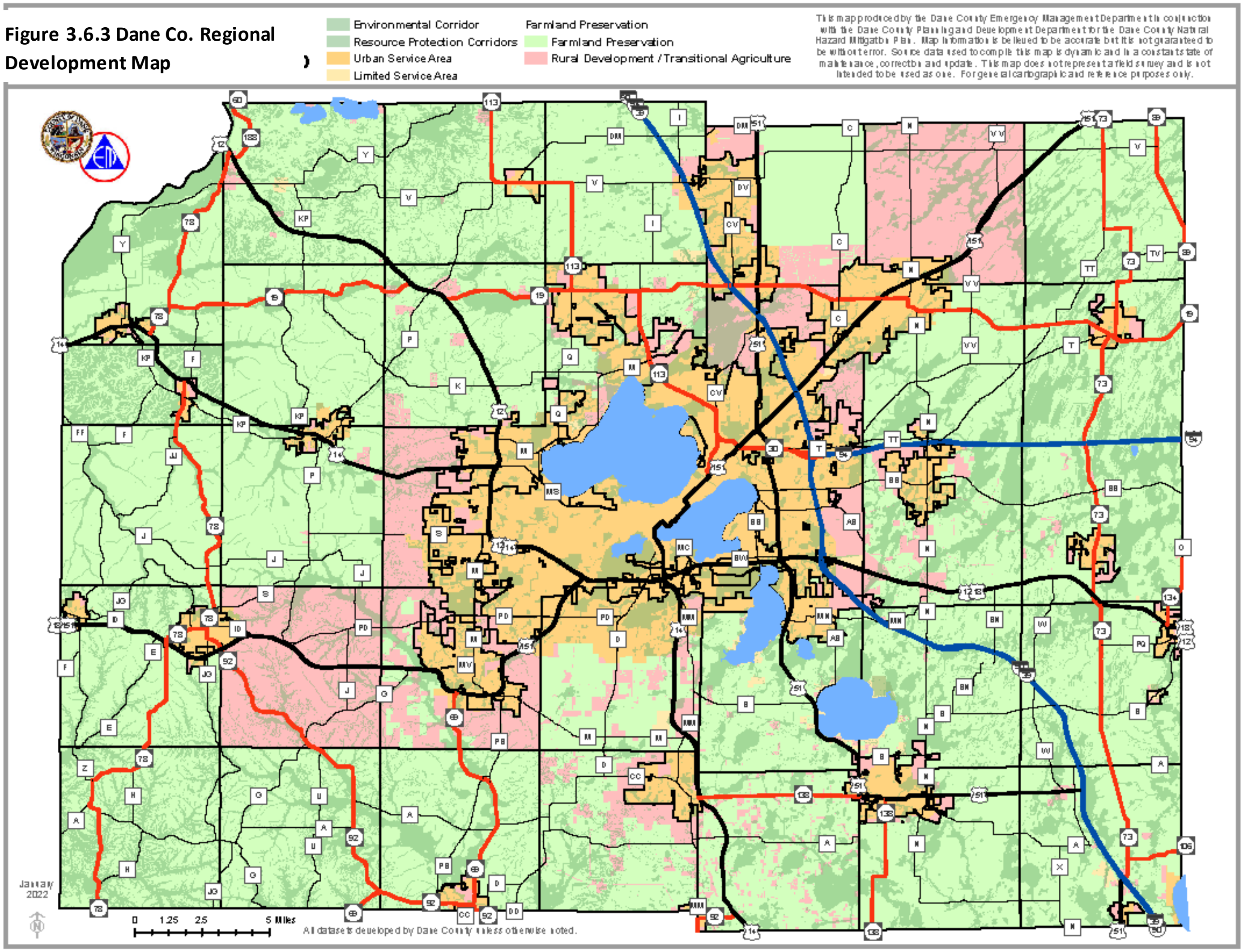


Source: Dane County Department of Planning and Development

The urban service area boundaries represent the outer limits of planned growth over the long-term planning period (at least 20 years) and include more than enough land to accommodate the anticipated growth. Twenty-five urban service areas have been designated and adopted in Dane County. Figure 3.10 indicates the adopted urban service areas.

The open space corridors shown on the Regional Development Plan Map (figure 3.6.3) include two distinct components: 1) Urban Environmental Corridors within USAs: and 2) Rural Resource Protection Areas in rural areas. Urban environmental corridors are a continuous open space system based on natural features and environmentally important lands such as streams, lakes, shore lands, floodplains, wetlands, steep slopes, woodlands, and parks and other publicly owned lands. Rural Resource protection areas are based primarily on floodplains, wetlands, and shoreland areas (land protected through zoning or other regulations), together with existing or proposed publicly owned or controlled lands.

Figure 3.6.3. DC Regional Development Map



3.7 Critical Facilities

Critical facilities are defined in this plan as physical structures that if damaged or destroyed compromise public health or safety, or are disproportionately vulnerable to natural disasters discussed in the plan, or house populations that are disproportionately vulnerable to natural disasters. These include the facilities described below.

3.7.1 Essential Infrastructure

Airports

Dane County is home to four paved runway airports: Dane County Regional Airport (DCRA) north of the City of Madison, Morey Airport outside the City of Middleton, Black Hawk Airfield in the Village of Cottage Grove, and Waunakee Airport in the Village of Waunakee. DCRA is the only airport that handles commercial airline traffic.

Utilities

Electrical Generation/Distribution Facilities – Dane County's electrical service is provided by numerous utilities and companies, which generate electricity, and own, maintain, and construct the distribution infrastructure.

- American Transmission Company owns, operates, monitors and maintains major transmission lines in the County and cooperates with local electric utilities in providing Dane County residents with electricity.
- Alliant Energy Corporation provides gas and electric services to communities in south-central Wisconsin, including parts of the Madison area—from Blue Mounds to Cambridge and from DeForest to Brooklyn.
- Madison Gas and Electric Co. (MG&E) provides electric service and natural gas for Madison, Monona, Fitchburg, Middleton, Cross Plains and other Dane County communities.
- Wisconsin Public Power, Inc. generates electricity and owns, operates, and improves electrical infrastructure for member utilities including Black Earth, Mazomanie, Mount Horeb, Stoughton, Sun Prairie, and Waunakee.

Natural Gas Supply – MG&E and Alliant Energy are the largest suppliers of natural gas in the County.

Water Utilities – Groundwater supplies almost all of the water in Dane County for household, commercial, and industrial uses. Public water supplies make up more than 75 percent of the total water usage in the County.

- There are 26 municipal water utilities operating more than 85 groundwater wells and pumping stations across the County.
- In rural settings, private wells serve over 75,000 residents and agricultural operations in the County.

Wastewater Treatment Facilities –

- The Madison Metropolitan Sewerage District serves approximately 300,000 people in the Madison area. Wastewater treatment for the entire district is performed at the Nine Springs Wastewater Treatment Plant. The District and its customers operate and maintain a combined total of 17 pumping stations and 169 lift stations lift stations in 5 cities, 7 villages, and 28 town sanitary/utility districts.
- In addition to MMSD, there are 17 municipal wastewater treatment facilities in the County. The wastewater collection and conveyance systems are operated and maintained locally.

Communications

Media Outlets – The Madison area broadcast stations are essential partners in the County's plans to communicate with the public before, during, and after a disaster. There are five broadcast television stations, one cable television system, and four radio groups with a total of 16 stations, as well as numerous independent radio stations that serve the Dane County area. Media outlets are extremely important component of the public safety infrastructure.

Communications Towers – There are approximately 220 communication towers in the County owned by governments, individuals, cellular phone companies, hospitals, universities, and televisions stations. They are instrumental for public safety communications, cellular phone use, television, radio, paging, messaging, and other communications.

Public Safety Facilities

Public Safety Communications (911) Centers – The Dane County Public Safety Communications (911) Department provides countywide 911 emergency call-taking services. The County 911 Center provides dispatching and centralized communications services for the Dane County Sheriff's Department as well as 22 local law enforcement agencies. The 911 Center also provides communications and dispatching services to 27 local fire departments and 21 local EMS agencies.

- In addition to the Dane County communications center, the cities of Middleton, Monona, and Sun Prairie each own and operate their own local public safety answering point (PSAP). The local units of government are responsible for maintenance and operation of these facilities.
- Two municipalities, the cities of Fitchburg and Stoughton, own and operate local dispatch centers, but do not receive 911 calls.
- Two state agencies in the County, the University of Wisconsin Police and Security and the Capitol Police operate call-taking and dispatch centers for facilities under their jurisdiction.

Law Enforcement – There are 20 local law enforcement agencies within the County. The unincorporated areas of the County and several villages rely on the Dane County Sheriff's Office for law enforcement services.

Emergency Medical Services – Dane County has a cooperative program for Emergency Medical Services (EMS) to facilitate a uniform system of emergency medical care. The Dane County EMS regional system is composed of 22 local ambulance districts, which are formed by towns, villages, and cities.

Fire Departments – There are 37 fire stations in 28 fire districts in Dane County. However, 32 fire districts serve the County, as some districts cross the County jurisdictional border.

Public Works and Highway Garages – Public works buildings and highway garages contain staff and equipment critical to effective response to natural hazards. From County employees to snow removal equipment, these resources are instrumental in maintaining the functioning of government, businesses and everyday life after a natural disaster hits.

Town/Village/City Halls – Every unit of government in the County has a primary government building. This building is generally the town, village or city hall. There are 61 in all. These structures range from modified garages, to old school houses, to modern public buildings with the full range of amenities. These buildings serve as meeting and gathering spaces, locations for government staff, and as repositories for information and public records critical to the functioning of governments and communities.

National Guard – DCRA is adjacent to Truax Field which is home to the Air National Guard 115th Fighter Wing. The Army National Guard 147th Command Aviation Battalion is also located at Truax Field.

Correctional Facilities – In addition to the Dane County jail, there are five state operated correctional facilities in Dane County.

3.7.2 Vulnerable Facilities

- Campsites – Dane County contains approximately 258 overnight individual camping sites at 6 locations: Babcock, Brigham, Lake Farm, Token Creek, Mendota, and Kegonsa Parks. Dane County Parks Division manages all these sites with the exception of Kegonsa State Park, which is a state park managed by the Wisconsin Department of Natural Resources.
- Childcare Centers – Childcare centers as vulnerable facilities are those where there are eight or more children on site at any one time. These facilities, because of the relatively high child-to-adult ratio and length of time children spend at the facilities, are particularly vulnerable to the impacts of natural hazards. There are more than 500 day care centers serving over 20,000 children in Dane County.
- Community Based Residential Facilities (CBRF) – The term CBRF covers a wide range of facilities assisting people with a wide range of needs. They may house and assist people who are elderly, mentally ill, physically disabled, alcoholic or drug dependent, emotionally disturbed, have criminal records, or are infants. People within these facilities often have moderate to great difficulty in taking care of themselves. They may be entirely dependent upon aid workers in an emergency. CBRFs can be managed or owned by private corporations specializing in assisting special need populations, churches, non-profit organizations, or hospitals. There are 104 CBRFs in Dane County.
- Healthcare Facilities – Dane County has five major hospitals, Meriter Hospital, St. Mary's Hospital Medical Center, University of Wisconsin Hospital and Clinics, William S. Middleton Veterans Administration (V.A.) Hospital and Stoughton Hospital and Clinics. There are also four other smaller hospital facilities and more than 50 clinics and urgent care centers in the County.

- Historic Properties – There are 235 properties and districts listed on the National Register in Dane County, including 10 National Historic Landmarks. The County also contains historic parks, Native American effigy mound sites, and archeological districts.

  Historic properties and landscapes play a significant role in the region's communities. Buildings offer character and points of interest that cannot be replicated. They enhance the sense of place that makes a local unique and meaningful. Having symbols of the past deepen people's understanding of the place, time and culture in which they are living. This creates an identity for neighborhoods, downtowns, and rural areas that enhance the quality of life.

- Manufactured Homes – Once called mobile homes, the appropriate term is manufactured homes, because less than five percent of the homes are actually moved from their initial place of occupancy. There are approximately 2,300 manufactured home units in Dane County. Of these, almost 2,000 are sited in one of the eight "mobile home parks" located in Dane County. Manufactured homes are also located on individual parcels of land in rural areas of the County.
- Long-term Care Facilities – Commonly referred to as nursing homes, long-term care facilities house people who, because of health reasons are not able to live at home and care for themselves. Over 1,700 people are served by approximately 22 nursing homes in the County. People within these facilities often have great difficulty in taking care of themselves. They may be entirely dependent upon aid workers in an emergency.
- Schools – There are 176 schools in Dane County, including both public and private. There are nearly 75,000 students enrolled in the elementary, middle, and high schools of the County.
- Special Needs Housing – Special needs housing consists of about 75 apartment building facilities in the County serving about 2,500 people. The populations within these structures have limited capacities to function in everyday life and need assistance from care providers. This housing offers support services for the elderly, homeless, disabled, handicapped, or other residents with special needs. Support services may include case management, medical or psychological counseling and supervision, cleaning, childcare, transportation, and job training.

Figure 3.7.1 – Critical Infrastructure: Highways

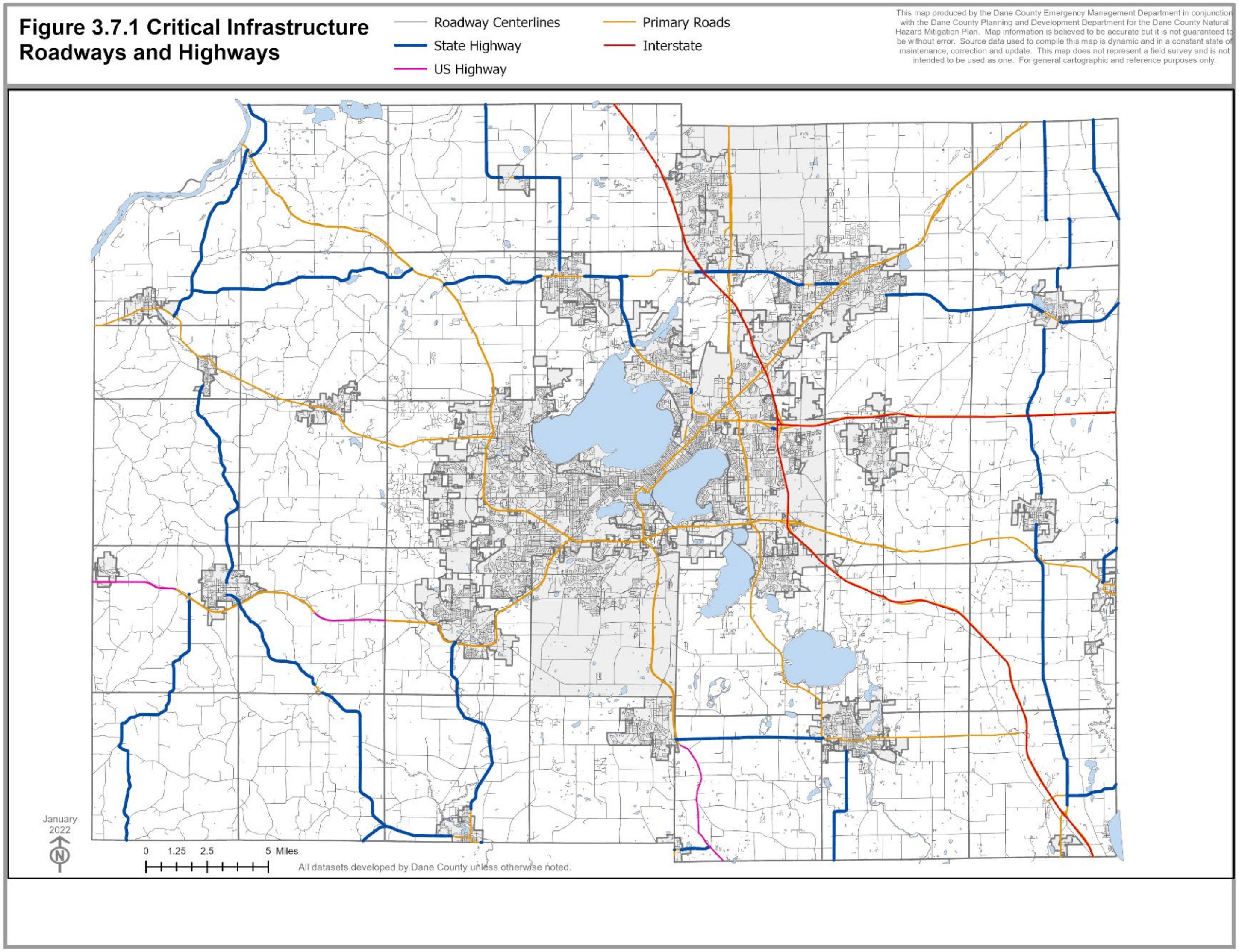


Figure 3.7.2 – Critical Infrastructure: Government Buildings

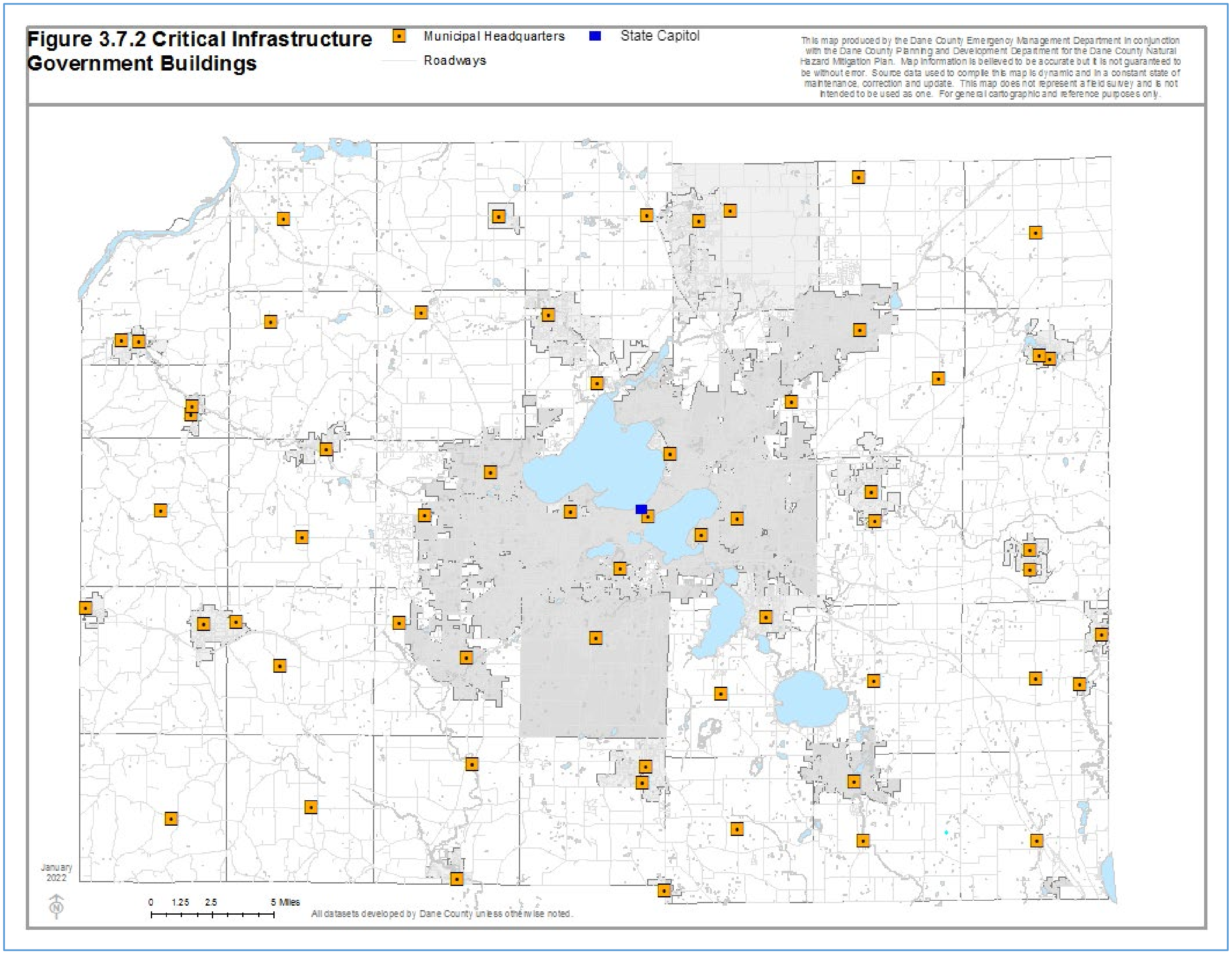


Figure 3.7.3 – Vulnerable Facilities: First Responder Facilities

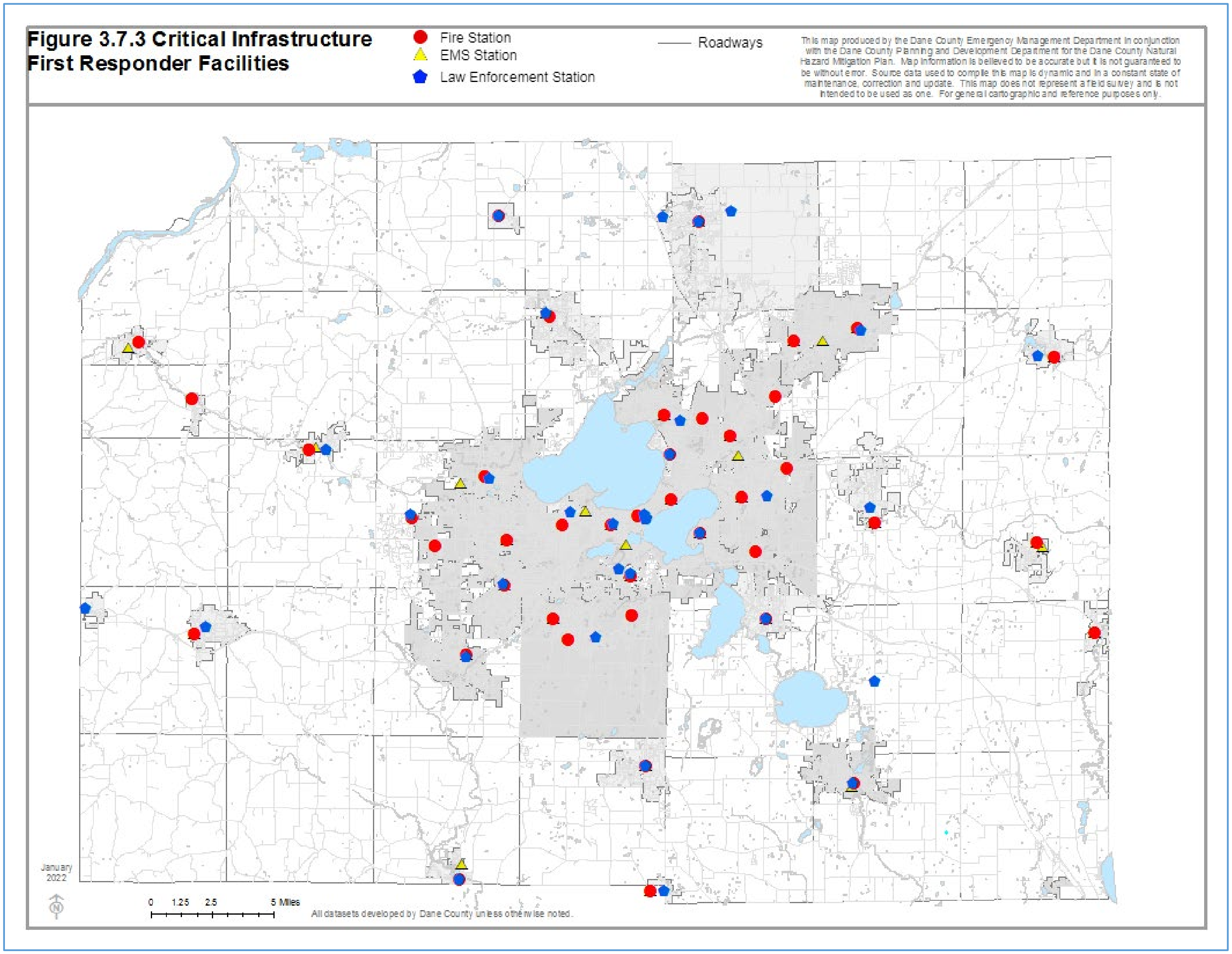


Figure 3.7.4 – Vulnerable Facilities: Utility Facilities

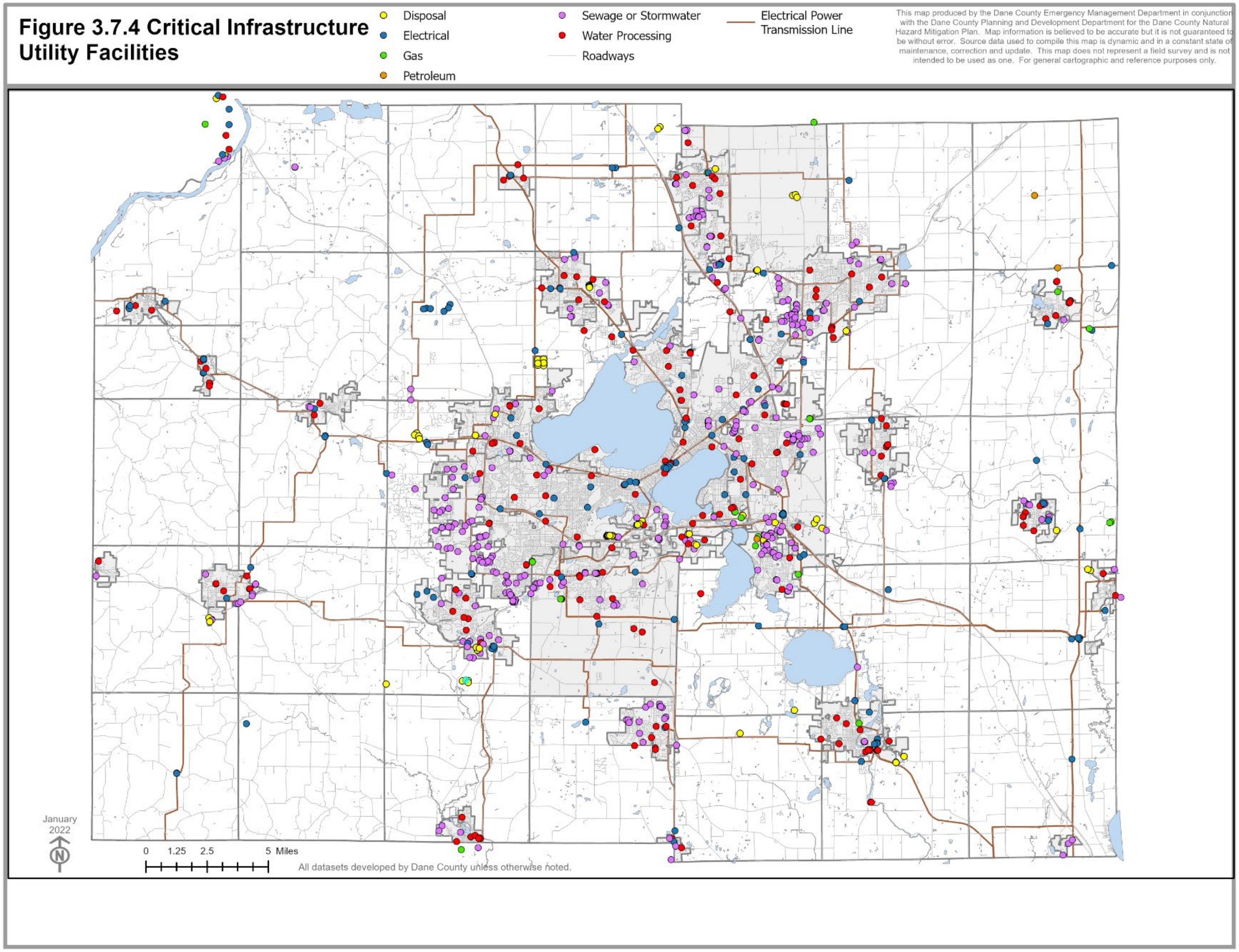


Figure 3.7.5 – Vulnerable Facilities: Telecommunications

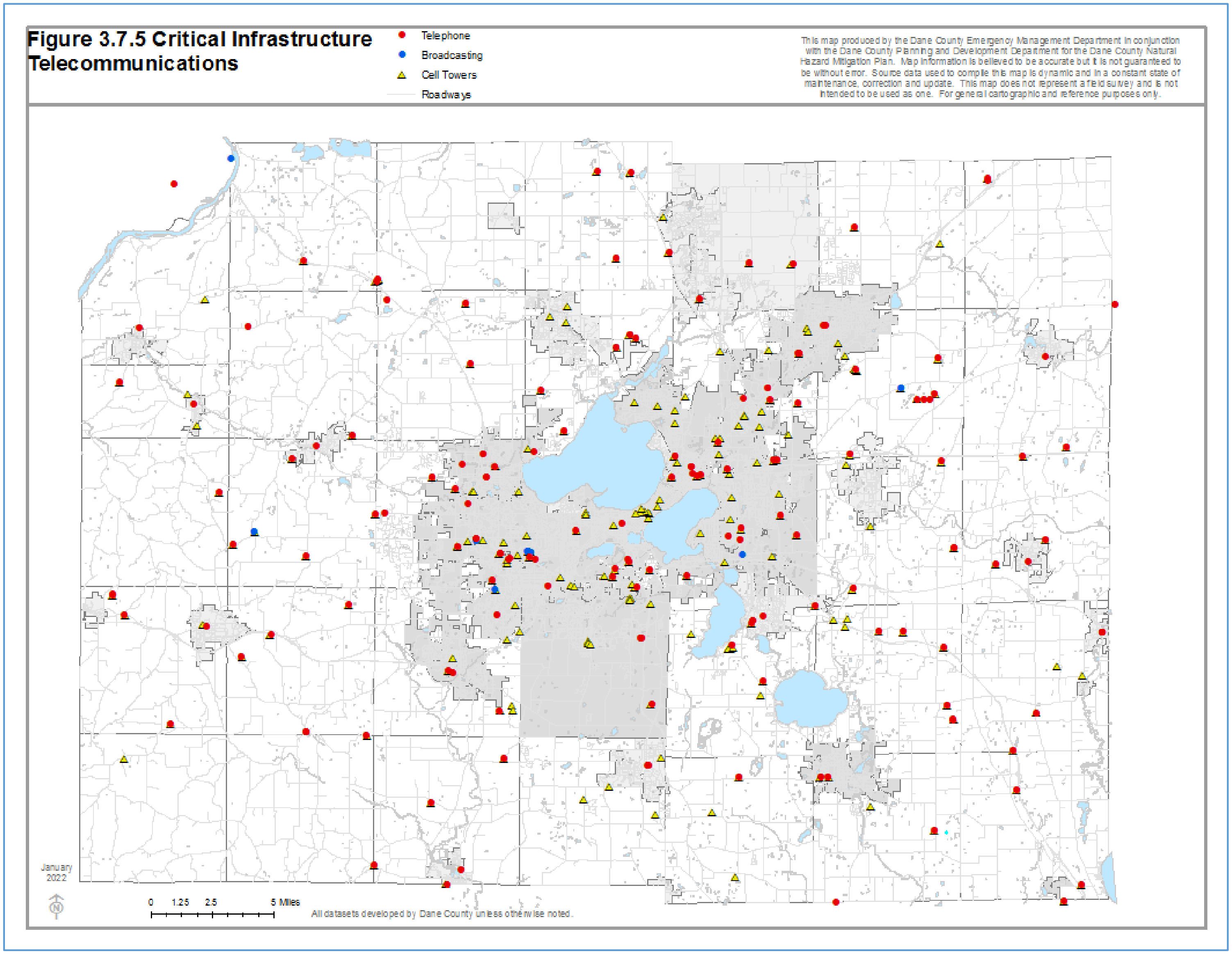


Figure 3.7.6 – Vulnerable Facilities: Healthcare

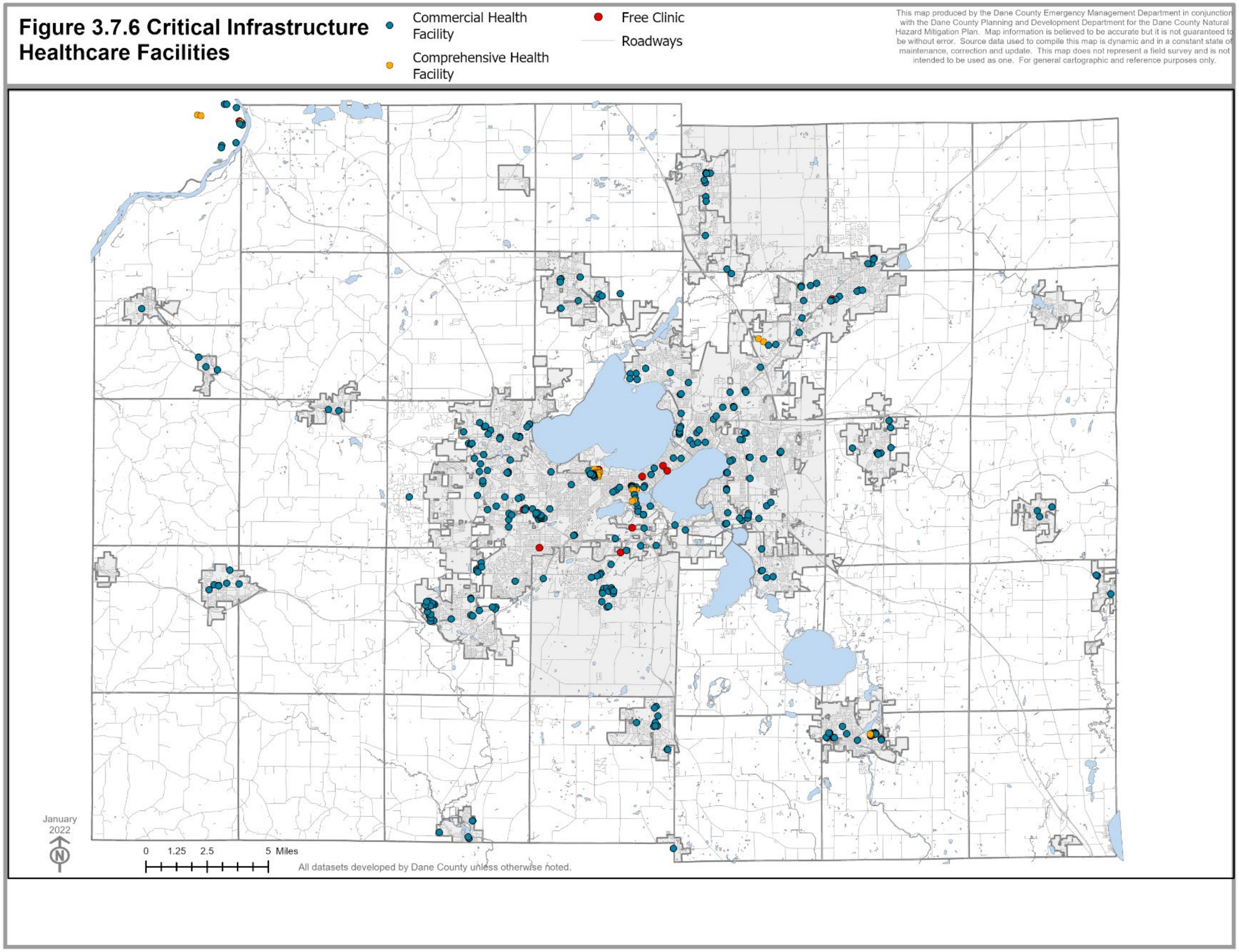
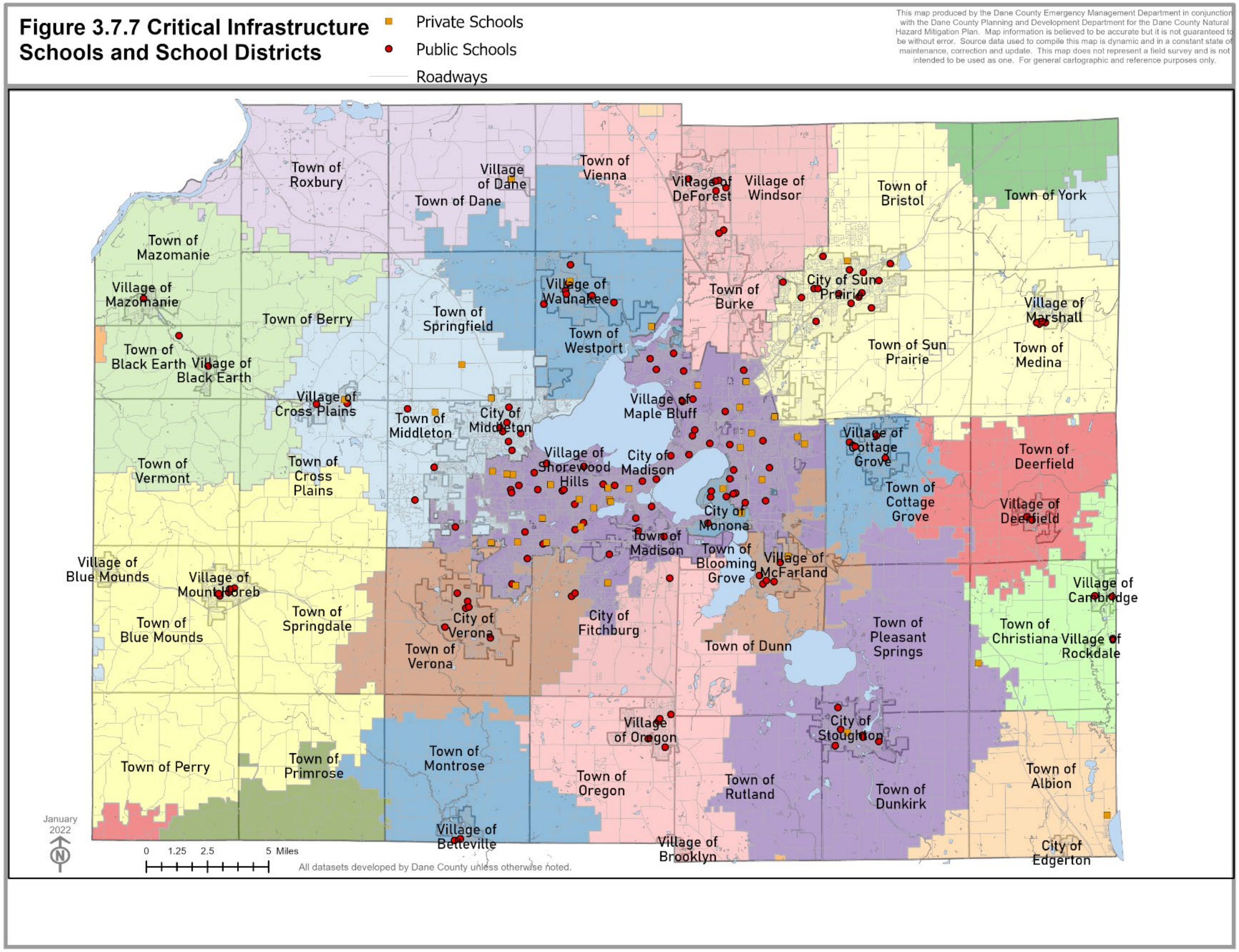


Figure 3.7.7 – Vulnerable Facilities: Schools & School Districts



4.1 OVERVIEW

The risk assessment provides the factual basis for the activities proposed in the strategy that will reduce losses from identified hazards. A quality risk assessment makes a clear connection between the community's vulnerability and the hazard mitigation actions." [FEMA – Local Mitigation Plan Review Guide, Oct. 1, 2011)]

Requirement	Description
44CFR 201.6(c)(2)(i)	[The risk assessment shall include a] description of the type, location and extent of all natural hazards that can affect the jurisdiction. The plan shall include information on previous occurrences of hazard events and on the probability of future hazard events.
44CFR 201.6(c)(2)(ii)	[The risk assessment shall include a] description of the jurisdiction's vulnerability to the hazards described in paragraph (c)(2)(i) of this section. This description shall include an overall summary of each hazard and its impact on the community. All plans approved after October 1, 2008 must also address NFIP insured structures that have been repetitively damaged by floods. The plan should describe vulnerability in terms of:
44CFR 201.6(c)(2)(ii)(A)	(A) The types and numbers of existing and future buildings, infrastructure, and critical facilities located in the identified hazard areas;
44CFR 201.6(c)(2)(ii)(B)	(B) An estimate of the potential dollar losses to vulnerable structures identified in … this section and a description of the methodology used to prepare the estimate.
44CFR 201.6(c)(2)(ii)(C)	(C) Providing a general description of land uses and development trends within the community so that mitigation options can be considered in future land use decisions.
44CFR 201.6(c)(2)(iii)	For multi-jurisdictional plans, the risk assessment section must assess each jurisdiction's risks where they vary from the risks facing the entire planning area.

The risk assessment process identifies and profiles relevant hazards and assesses the exposure of lives, property, and infrastructure to these hazards. The process allows for a better understanding of a jurisdiction's potential risk to natural hazards and provides a framework for developing and prioritizing mitigation actions to reduce risk from future hazard events.

This risk assessment followed the methodology described in the FEMA publication Understanding Your Risks—Identifying Hazards and Estimating Losses (FEMA 386-2, 2002), which breaks the assessment down to a four-step process:

1. Identify Hazards
2. Profile Hazard Events
3. Inventory Assets
4. Estimate Losses

4.1.1 Hazard Identification

The Dane County Hazard and Risk Analysis, an Appendix to the County's Emergency Response Plan served as the starting point for the initial risk assessment. Based on the Hazard Analysis and input from the local jurisdictions, the planning team considered 13 hazards from the previous version of the plan. The review re-examined these hazards and conducted additional research to identify other hazards which should be included in this document. Based on the recommendations by FEMA, the planning team, and historical records for Dane county, the following hazards (listed alphabetically), were considered during the plan update:

- Dam Failure
- Drought
- Earthquake
- Erosion
- Expansive Soils
- Flood
- Fog
- Hail
- Landslide
- Levee Failure
- Lightning
- Extreme Cold
- Extreme Heat
- Severe Thunderstorm
- Severe Winter Storm
- Subsidence
- Tornado
- Wildfire
- Windstorm
- Emerging Hazards
  - Algal Bloom*
  - Invasive Species*
  - Vector-Borne Disease*

* These are Hazards considered in addition to those identified in the 2010 version of the Natural Hazard Mitigation Plan. These are emerging hazards discussed in the context of changing climate and environmental conditions.

After conducting a review of Dane County's geographic location and climate, several of the natural hazards included in the initial composite list were discarded because they are not relevant to Dane County. These include: Avalanche, Costal Erosion, Coastal Storm, Earthquake, Expansive Soils, Hurricane, Tsunami, and Volcano. Earthquake was considered, but did not warrant a full hazard profile, as the probability of a damaging event is extremely low based on an analysis associated with the Wisconsin State Hazard Mitigation Plan. Severe Thunderstorm is not included because the damaging effects of such storms (hail, lightning, and high wind) are profiled as individual hazards as this better reflects the individual hazard risks and occurrences for Dane County. Levee failures were researched but there are no documented levees in Dane County, so the hazard was removed from the list. Landslides and Sinkholes and Erosion are addressed in a single chapter, due to their similar geologic characteristics.

4.1.2 Hazard Rankings and Priorities

The final hazards which are extensively profiled, including significant vulnerability assessment, risk analysis, and impact assessments, are listed below:

- Dam Failure
- Drought
- Earthquake
- Erosion
- Expansive Soils
- Flood
- Fog
- Hail
- Landslide
- Levee Failure
- Lightning
- Extreme Cold
- Extreme Heat
- Severe Thunderstorm
- Severe Winter Storm
- Subsidence
- Tornado
- Wildfire
- Windstorm
- Emerging Hazards

4.1.3 Hazard Rankings and Priorities

The hazards identified in Section 4.1.2 are each profiled and assessed individually. Much of the profile information came from the same sources used to identify the hazards during the initial planning effort in 2010 and updated in 2018. The information was reviewed for accuracy and applicability and updated where required. Significant occurrences of hazards that have occurred since the original plan's adoption in 2018 are also included in the updated hazard profiles. The hazard profiles in this section are organized in alphabetical order.

Each hazard is profiled in a similar format. This approach helps create a uniform planning basis and enables comparisons between the hazards. In general, the following methodology was used:

1. *Hazard Description* – This assessment includes a profile of the hazard and a discussion of past history, frequency of occurrence, severity, geographic areas that could be affected, and time factors such as predictability and speed of onset.

2. *Impact of Climate Change on Future Conditions* – The potential impacts of changing climate conditions on each individual hazard are described. This includes a description of trends and projections for future occurrences and an assessment of changes in vulnerability and risk associated with climate change.
3. *Impact Assessment* – Potential impacts are broken-out into two broad categories, direct impacts and indirect impacts. Based on past experiences in Dane County, in the State of Wisconsin, and nationwide, this is a qualitative discussion of the consequences that could be expected in the aftermath of each of the hazard events.
4. *Vulnerability Assessment* – Based on the potential impacts, the vulnerability of exposed structures, infrastructure, and people are described and mapped where relevant. Vulnerabilities are broken into two broad categories, at-risk populations, and critical facilities.
5. *Potential for future losses* – The particular method for determining the future loss potential varies from hazard to hazard. In general, however, the potential for future losses is an estimate of possible monetary losses based on a most probable case scenario and the impact analysis and vulnerability assessment for each hazard. Structural damage potential is based on the "improved value" of buildings from the Dane County parcel database. The potential loss of building contents and personal possessions is based on FEMA formulas and estimation methods where appropriate.
6. *Risk Summary* – Based on all of the information compiled in the vulnerability assessment, the planning team ranked the hazards to allow for quantitative comparison. Overall vulnerability for the hazard is measured in terms of geographic extent, impacts, magnitude and severity, probability of occurrence, and exposure. These findings are summarized in this section and analyzed to reveal an overall risk rating for the hazard.

4.2 DAM FAILURE

4.2.1 Description

A dam is a barrier constructed across a watercourse in order to store, control, or divert water. Dams are usually constructed of earth, rock, concrete, or mine tailings. The water impounded behind a dam is referred to as the reservoir and is typically 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. Dams serve many purposes, including agricultural uses; providing recreation areas; electrical power generation; and erosion, water level, and flood control.

A dam failure is the collapse, breach, or other failure of a dam that causes downstream flooding. 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). If internal erosion or overtopping cause a full structural breach, a high-velocity, debris-laden wall of water is released and rushes downstream, damaging or destroying whatever is in its path. Dam failures may result from one or more of the following:

- Prolonged periods of rainfall and flooding (the cause of most failures)
- Inadequate spillway capacity which causes excess overtopping flows
- Internal erosion due to embankment or foundation leakage or piping
- Improper maintenance
- Improper design
- Negligent operation
- Failure of upstream dams
- High winds (leading to wave erosion)

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 an unusually high runoff. This high runoff increases the reservoir of the dam 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.

The Wisconsin Department of Natural Resources (DNR) assigns hazard ratings to large dams within the State. Two factors are considered when assigning hazard ratings: existing land use and land use controls (zoning) downstream of the dam. Dams are classified, by law, in three categories that identify the potential hazard to life and property (WI Administrative Code, NR 333.06):

- A low hazard rating is assigned to those dams that have no development unrelated to allowable open space use in the hydraulic shadow where the failure or mis-operation of the dam would result in no probable loss of human life, low economic losses (losses are principally limited to the owners property), low environmental damage, no significant disruption of lifeline facilities, and have land use controls in place to restrict future development in the hydraulic shadow.
- A significant hazard rating is assigned to those dams that have no existing development in the hydraulic shadow that would be inundated to a depth greater than 2 feet and have land use controls in place to restrict future development in the hydraulic shadow. Potential for loss of human life during failure is unlikely. Failure or mis-operation of the dam would result in no probable loss of human life but can cause economic loss, environmental damage, or disruption of lifeline facilities.
- A high hazard rating is assigned to those dams that have existing development in the hydraulic shadow that will be inundated to a depth greater than 2 feet or do not have land use controls in place to restrict future development in the hydraulic shadow. This rating is assigned if loss of human life during failure or miss-operation of the dam is probable.

A dam with a structural height of over 6 feet and impounding 50 acre-feet or more, or having a structural height of 25 feet or more and impounding more than 15 acre-feet, is classified as a large dam.

There are eleven large dams and 25 small dams in Dane County. Of the eleven large dams, two are classified as “High” hazard, one is “Significant” hazard, and the remaining eight are “Low” hazard. The small dams are not officially classified, but would all meet the “Low” hazard criteria. In addition, there is one dam outside of Dane County, the Prairie du Sac Hydroelectric Dam on the Wisconsin River that does have the capacity to affect Dane County residents in a failure scenario.

Table 4.2.1 Large Dams in Dane County

Dam Name/Impound	Hazard Rating	Max Storage (acre ft.)	Height (ft.)	Stream
Tenney Lock and Dam	High	160,000	5	Yahara River
Stewart Lake	High	90	23.8	Moen Creek
Marshall Grist Mill	Significant	1,100	11	Maunesha River
Belleville	Low	80	11	Sugar River
Brunner	Low	60	10	Sugar River Tributary
Dunkirk	Low	260	13	Yahara River
Lake Kegonsa	Low	16,300	1	Yahara River
Babcock Park Lock and Dam	Low	50,000	1	Yahara River
Lake Windsor	Low	50	14	Yahara River Tributary
Lake Wingra	Low	2,600	3	Murphy Creek
Stoughton	Low	500	9	Yahara River
Prairie du Sac Hydroelectric Dam	High	193,200	40	Wisconsin River

Source: Wisconsin Department of Natural Resources

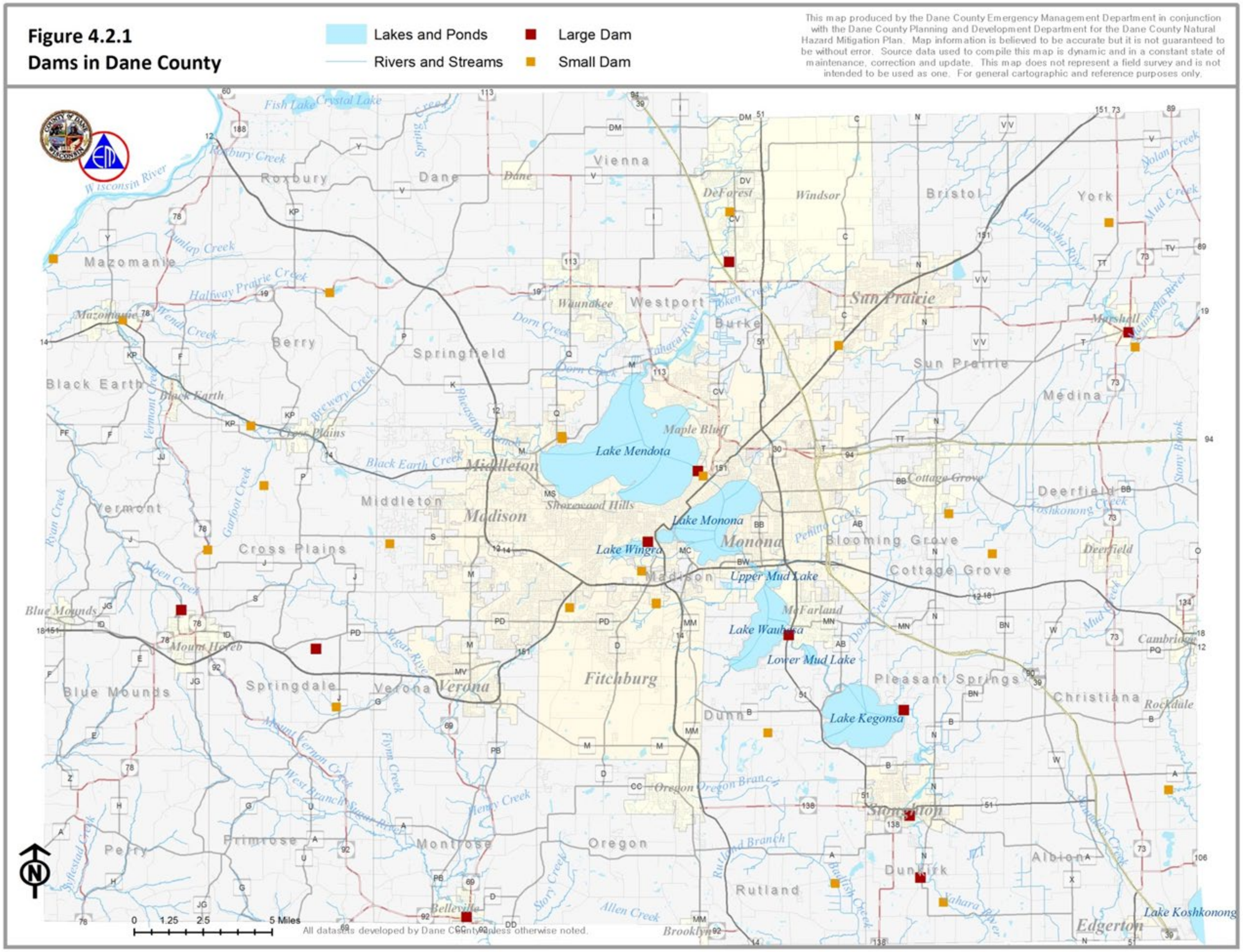
Emergency Action Plans

All Large dam owners are required by Wisconsin Administrative Code, NR 333.07 to develop an Emergency Action Plan describes potential downstream impacts and procedures to be followed in the event of a failure:

1. A notification flow chart identifying involved agencies, other dam owners both upstream and downstream and their phone numbers.
2. Emergency operation procedures.
3. An inundation map of the hydraulic shadow on a scale of 1" = 2000' or less that extends downstream to an elevation within one foot of the dam nonexistent profile.
4. Procedures for notification of all property owners affected by a dam failure and a list of their names, addresses and phone numbers.

Emergency Action Plan documents for the three “High” hazard dams affecting Dane County are on file with Dane County Emergency Management.

Figure 4.2.1 Dams in Dane County



4.2.2 Impact of Climate Change on Future Conditions

Climate change adds to the risk of dam failure in Dane County. The increased likelihood of intense rainfalls in the region is the main factor in this risk increase. While the dams in Dane County are designed to be resilient to these intense rainfalls, increased likelihood of these storms increases the number of times dams will be in circumstances that could lead to failure. Certainly there is no expectation that Dane County will experience a sharp, or any, increase in dam failures as the climate continues to change, but the increased storms is a reason to continue to maintain and monitor the County's dams.

Increased risks to dams associated with prolonged periods of rainfall and flooding are addressed in the flood hazard section.

4.2.3 Risk Assessment

The Emergency Action Plans for the dams classified as "High" hazard contain a detailed analysis of the potential impacts of a breach or failure. This impact analysis and risk assessment is summarized, but is not duplicated in this plan document.

Prairie du Sac Hydroelectric Project Dam

Prairie du Sac Hydroelectric dam is located on the Wisconsin River just upstream of the Village of Prairie du Sac, on the border between Sauk and Columbia Counties. The dam is maintained and operated by Alliant Energy Company for the purpose of electric power generation. The Lake

Wisconsin reservoir has a normal operating head of 38.5 feet. The normal surface area of Lake Wisconsin is approximately 9,000 acres, with a storage volume of 119,950 acre-feet. The Prairie du Sac Hydroelectric Project Emergency Action Plan provides dam breach scenarios and flood inundation maps for failures under flood flow and normal “sunny day” flow conditions. This analysis indicates the potential for properties to be affected in the Towns of Roxbury and Mazomanie. Primary structures in the mapped flood shadow are shown in table 4.2.2.

Tenney Lock and Dam

Tenney Dam is located on the southwest side of Lake Mendota in the City of Madison at Tenney Park. The dam is owned by Dane County and operated by the Land and Water Resources Department. Tenney Dam impounds Lake Mendota on the Yahara River, in the densely populated “Isthmus” area of the City of Madison. Tenney Dam is operated to maintain water levels within the target levels specified in the Wisconsin DNR’s lake level orders (3-SD-77-808). The Dane County Lake Level Management Guide for the Yahara Chain of Lakes describes dam operations and the strategies employed to comply with lake level orders. The dam has a height of 11 feet and a normal operating head of 5.1 feet. The dam breach analysis prepared for the Land and Water Resources Department is summarized in the Tenney Lock and Dam Emergency Response Handbook on file with Dane County Emergency Management. This analysis indicates the potential for properties to be affected in the City of Madison and the City of Monona. The analysis also indicates the potential for storm sewer back-flooding in lower lying areas of the Isthmus in Madison. Primary structures in the mapped flood shadow are shown in table 4.2.2.

Stewart Park Dam

Stewart Park Dam is located on the northeast side of Stewart Lake, just north of the Village of Mount Horeb in the Town of Blue Mounds. Stewart Park Dam impounds Stewart Lake on Moen Creek. The dam has a height of 33.5 feet and a normal operating head of 23.9 feet. Stewart Park is a Dane County Park and the dam is operated by the Dane County Land and Water Resources Department. The dam breach analysis prepared for the Land and Water Resources Department is summarized in the Stewart Park Dam Emergency Response Handbook on file with Dane County Emergency Management. This analysis indicates a limited potential for downstream properties to be affected in the Towns of Blue Mounds and Vermont. Primary structures in the mapped flood shadow are shown in table 4.2.2.

4.2.4 Impact Assessment

Dam failure analysis indicates that downstream flood depths would be in the 1 to 3 foot range in the event of a failure of one of the “high” hazard dams in Dane County. This is significant, but a dam failure is likely to lead to the major inundation associated with catastrophic failure seen in media images from other locations around the country.

Dam failure has the potential to result in consequences such as damages to existing public and private buildings, damage to infrastructure, loss of services from utilities,), loss of business income, displacement of individuals and businesses, emergency services (including road closure and evacuations), and possibly loss of life.

Table 4.2.2 Primary Structures in “High” Hazard Dam Flood Inundation Areas

Land Use Category	Prairie du Sac Hydroelectric Dam	Tenney Lock and Dam	Stewart Park Dam
Assembly		1	
Commercial Sales	1	30	
Commercial Services		32	
Education		1	
Government		2	
Industrial	3	31	
Recreation	2	9	
Religion		1	
Residential	273	591	1
Transportation		3	

Land Use Category	Prairie du Sac Hydroelectric Dam	Tenney Lock and Dam	Stewart Park Dam
Utility		9	
Total	279	710	1

Table 4.2.2 indicates the numbers of primary structures, by land use category, located in the inundation area downstream from each of the "High" hazard classification dams in Dane County. The data sources are the inundation maps from the dam breach analysis in the Emergency Action Plan for each dam combined with Dane County's building footprint inventory. The flood depth potential and individual building site elevations are not available in the breach analysis. It is, therefore, not possible to accurately determine the degree to which these structures and facilities would be actually be impacted in a failure.

4.2.5 Previous Occurrences

There have been no documented dam failures of significance in recent history in Dane County.

As human-built structures, hazards resulting from a dam failure are not, strictly speaking, natural hazards. As such, these dams are managed in order to minimize the potential threat of failure. These dams are routinely, if not continuously monitored. The dams are subject to regular inspections, are competently operated, and are maintained with public safety as the primary consideration.

Note: Catastrophic failures of dams have occurred in other areas of the country and in the State of Wisconsin. The June, 2008 failure at Lake Delton in neighboring Sauk County is an example. Although the Lake Delton Dam control structure did not fail, County Highway A in the Village of Lake Delton washed out, causing Lake Delton to empty into the Wisconsin River. Five homes were destroyed in the process. This underscores that while failures of this nature are rare events, the impacts to people and properties adjoining these facilities can be substantial.

4.3 DROUGHT

4.3.1 Description

There are a number of different ways to define drought. Generally, drought is a water shortage caused by a reduction in the amount of precipitation received over an extended period of time, usually a season or more in length. This deficiency results in a water shortage for some activity, group, agricultural or environmental sector.

The effects of a drought are aggravated by other factors such as high temperatures, high winds or low relative humidity. The severity of the impact of a drought depends on the duration, intensity, and geographic extent of the event, plus the regional demands on the water supply driven by human activities.

Drought is one of the most complex natural hazards because it is not a distinct event with a clearly defined beginning or end. It differs from other natural hazards in that it has an unusually slow onset, may affect multiple jurisdictions or counties simultaneously, and typically causes no structural damage. The effects impact various sectors in different ways and with varying intensity.

Categories of Drought

Droughts are categorized into four types based on the severity and impact of the occurrence and measured by the industries affected. These categories are meteorological, hydrological, agricultural, and socioeconomic. It is possible for these conditions to exist simultaneously.

1. Meteorological drought is the traditional conceptualization of a drought, and is defined solely on the basis of the degree of dryness. This is expressed as a relationship between actual precipitation and the expected average or normal amount, using a monthly, seasonal, or annual time scale. A meteorological drought considers only the physical attributes of the event and not the impact on social or environmental systems. (University of Nebraska at Lincoln, National Drought Mitigation Center, https://droughtmonitor.unl.edu/ Accessed December, 2021.)
2. Hydrological droughts examine the effects of precipitation shortfalls (including snowfall) on surface or subsurface water supply (e.g., stream flow, reservoir and lake levels, ground water). The frequency and severity of hydrological drought is often defined on a watershed or river basin scale. Hydrologists examine how these events impact the entire hydrologic system. Hydrological droughts are usually out of phase with or lag behind the occurrence of meteorological and agricultural droughts. It takes longer for

precipitation deficiencies to appear in components of the hydrological system such as soil moisture, stream flow, and ground water and reservoir levels than in other systems. As a result, the impacts of a hydrological drought are also out of phase with drought measurements in other economic sectors. For example, a precipitation deficiency may result in a rapid depletion of soil moisture that is almost immediately discernible to agriculturalists, but the impact of this deficiency on lake and stream levels may not affect fisheries or recreational uses for many months. (University of Nebraska at Lincoln, National Drought Mitigation Center, https://droughtmonitor.unl.edu/ Accessed December, 2021.)

3. Agricultural drought links various characteristics of meteorological and or hydrological drought to agricultural impacts. This view of drought focuses on precipitation shortages, differences between actual and potential evapotranspiration, soil water deficits, reduced groundwater or reservoir levels, and the relative effects on agricultural production. Since plant water demand depends on prevailing weather conditions, biological characteristics of the specific plant, its stage of growth, and the physical and biological properties of the soil, agricultural drought accounts for the variable susceptibility of crops during different stages of crop development from emergence to maturity. (University of Nebraska at Lincoln, National Drought Mitigation Center, https://droughtmonitor.unl.edu/ Accessed December, 2021.)
4. Socioeconomic definitions of drought associate the supply and demand of economic goods with elements of meteorological, hydrological, and agricultural drought. The supply of many economic goods such as water, forage, food grains, fish, and hydroelectric power depend on weather conditions. The natural variability of climate means that water supply is ample in some years but insufficient for human and environmental needs in other years. Socioeconomic drought occurs when the demand for an economic good exceeds supply as a result of a weather-related shortfall in water supply. (University of Nebraska at Lincoln, National Drought Mitigation Center, “What is Drought? Understanding and defining Drought.”)

Measuring Drought

There are numerous ways to measure the meteorological intensity of drought. Examples of some of the more common indices include percent of normal precipitation, the Palmer Drought Index (PDI), the Standardized Precipitation Index (SPI), and the Surface Water Supply Index (SWSI). For the purposes of this plan, The Palmer Index is used because it is the most effective in determining long-term drought (a matter of several months) and is commonly used by the Federal Government when measuring drought and determining drought-based aid eligibility. The Palmer Index is a measurement only of meteorological drought.

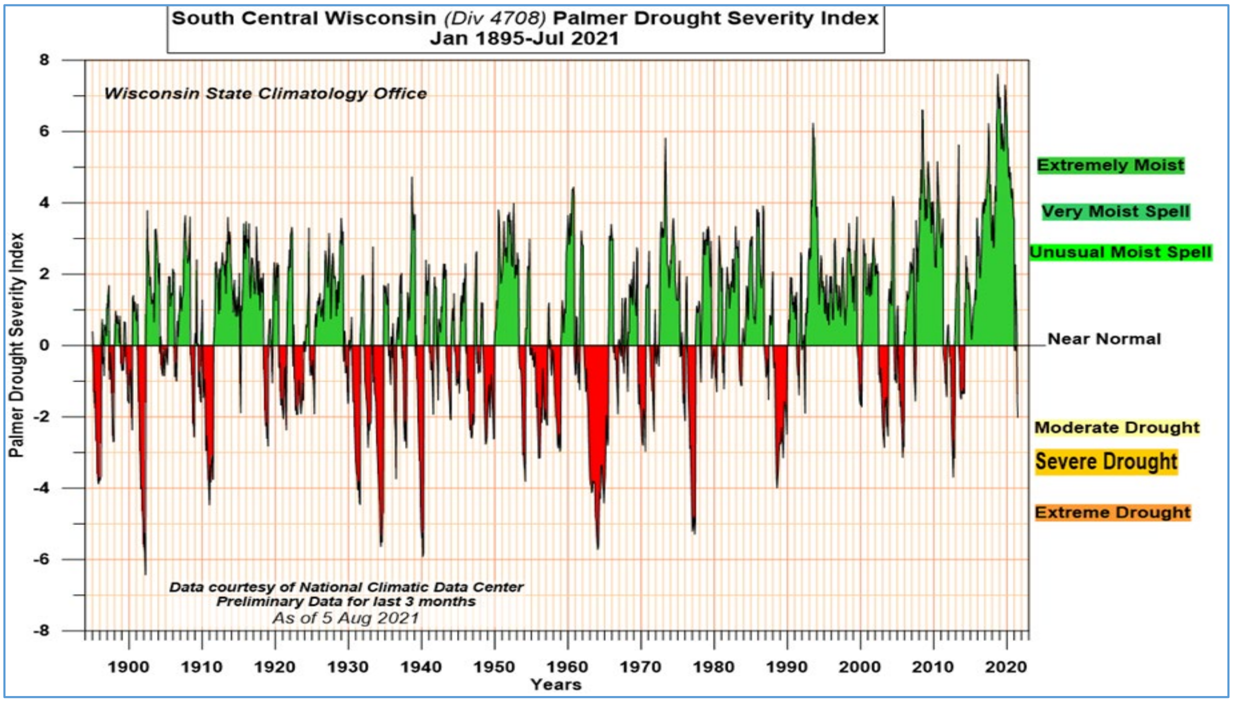
The Palmer Drought Index uses temperature and rainfall information to determine dryness or wetness over a period of time. The index is based on the supply-and-demand concept of the water balance equation, which takes into account not only the precipitation deficit at a specific location, but the water content of the soil as well. The values generated for the Palmer Index generally range from –6.0 to +6.0, with negative values indicating drier conditions and positive values indicating wetter conditions. A value range of -/+0.5 indicates “normal” conditions, while values greater than +4.0 or –4.0 indicate periods of extreme wetness or extreme drought, respectively.

The advantage of the Palmer Index is that it is standardized to local climate, so it can be applied to any part of the country to demonstrate relative drought or rainfall conditions. The limitation is that it is not useful for short-term forecasts, and is not particularly useful in calculating supplies of water locked up in snow. (University of Nebraska at Lincoln, National Drought Mitigation Center, “Handbook of Drought Indices”. Available online https://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1118&context=droughtfacpub Accessed December, 2021.)

4.3.2 Previous Occurrences

Figure 4.3.1 shows the average Palmer Index values from 1895 to 2021. Dane County has experienced Palmer Index values that would indicate extreme drought five times: 1930, 1933, 1938, 1962, and 1976. This graph takes into consideration all months of the year. Generally, Wisconsin experiences low quantities of precipitation accumulation in the winter months. This alone is not a problem, because demand for water is lowest during this time. However, drought in the summer months can cause financial loss or ruin for the agricultural and recreational sectors as the demand for water increases and the shortfalls become apparent.

Figure 4.3.1 Average Palmer Index for South Central Wisconsin



Source: National Climactic Data Center, 2021

1929-1934

The 1929-1934 drought was probably the most significant in Wisconsin history considering both the event's duration and severity. This drought had at least a 75-year recurrence interval in most of the State and over 100-year recurrence interval in certain areas. The austere economic aspects of the Depression compounded its effects. The drought continued with somewhat decreased effect until the early 1940s in some parts of the state.

1963-1964

The 1963-64 drought appears to have begun in 1962 when Dane County received only 21.63 inches of rain at Truax Field. 1963 had 26.19 inches and 1964 had 23.62 inches of rain. Normal yearly precipitation for 1869-2008 is 31.67 inches.

1976-1977

The drought of 1976-1977 was most severe in a wide band stretching from north to south across the state. Stream flow measuring stations recorded recurrence intervals from 10 to 30 years. Agricultural losses during this drought were estimated at $624 million. Sixty-four counties were declared federal drought areas and deemed eligible for assistance under the

Disaster Relief Act. Additionally, numerous private and municipal wells went dry. Federal assistance was used to help communities drill new wells and obtain new water supplies.

1987-1988

Some believe the drought of 1987-1988 was 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. Stream flow measuring stations indicated a recurrence interval of between 75 and 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 percent crop loss, with agricultural losses estimated at $1.3 billion. Fifty-two percent of the state's 81,000 farms were estimated to have crop losses of 50 percent or more, with 14 percent estimated having losses of 70 percent or more. A combination of state and federal drought assistance programs helped the state's farmers recover a portion of their losses. All Wisconsin counties were designated eligible for drought assistance.

The effect of this drought on municipal and private water supplies was not as severe as in 1976-77, with only a few reports of individual wells drying up. A number of 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 sprinkling and yard watering.

2002-2003

This drought extended during the summers of 2002 and 2003 over south central and southeast Wisconsin. Many farmers saw their corn crops wither and there were reports that soybeans stopped growing or the pods stopped filling. Alfalfa hay cutting also suffered. Grass growth slowed dramatically, or stopped altogether. Most locations received less than 1 inch of rain for the first 11 days of August. Madison's Truax Field only measured .61 inches of rain, all of which fell on a single day. Newspaper reports indicated that agricultural experts expected the corn crop yield at harvest time in the fall to be 1/2 to 2/3 of normal, and the outlook for soybeans was worse. Sweet corn yields were expected to be 20 to 30 percent below normal. Some farmers reported that their wheat crop died. Large cracks developed in many fields and the grasshopper populations were above normal. In addition, flowage on most rivers and streams was only 15 to 25 percent of normal for early August.

Only 0.87 inch of rain fell during August 2003 at Truax Field. Both the Milwaukee and Madison August monthly rainfall totals were 3.46 inches below normal. Conditions continued through the month of October 2003 across south-central and southeast Wisconsin. The entire area was in a moderate (D1) to severe drought (D2) status during the month of October. The monthly rainfall at Madison's Truax Field was 1.60 inches, or 0.58 below normal. Only 5 days received

0.10 inches or more of precipitation. Water levels in lakes, rivers, and streams remained below normal for the entire month, and at some spots they were near record-low levels. Newspaper reports indicated that some farmers didn't harvest much of anything in October.

2005

Drought conditions developed over south-central and southeast Wisconsin in July 2005, after the weather pattern turned quiet in mid and late June 2005. The drought classification for south-central and southeast Wisconsin worsened from D0 at the start of the month to severe drought (D2) on July 19, with the exception of the southeast corner consisting of Walworth, Racine, and Kenosha counties. The drought in these three counties worsened to extreme (D3) on July 19th. The drought was preceded by a long period of below-normal precipitation extending back to March 2005. Madison's Truax Field (Dane Co.) reported a 4.08 inch deficit from the beginning of March through the end of July.

A warm and dry August helped strengthen the drought. Rainfall deficits for August ranged from between 2.50 to 3.50 inches across the area. At Madison's Truax Field (Dane Co.), a 3.11 inch deficit was reported in August, setting the March through August deficit at 7.19 inches. Most of the precipitation observed occurred during the middle of the month, helping to relieve the drought status for the southeast corner of the state toward the end of August. The remainder of south-central and southeast Wisconsin remained in severe drought status (D2).

Drought conditions, both agricultural and hydrological, persisted through October over south-central and southeast Wisconsin. Most of south-central and southeast Wisconsin received less than 1 inch of rainfall (normal monthly rainfall is 2 to 2.5 inches) with monthly temperatures averaging about 2 to 3 degrees above normal. Consequently, the drought conditions didn't improve during the month. The drought rating at the end of the month was D2 (severe) in those counties along and south of a line from Madison to Milwaukee. D3 (extreme drought) conditions existed just south of the Wisconsin-Illinois border. D1 (severe drought) conditions existed over those counties north of a line from Madison to Milwaukee. Newspaper and weather reports indicated that due to the spotty nature of the just-completed warm-season convective showers, soil moisture conditions varied greatly across individual counties, resulting in varying yields. Harvest reports indicated that overall corn and soybean yields didn't suffer as much as originally expected in July. Undoubtedly there were monetary crop losses due to the drought; however estimations were unavailable from county/state agricultural agencies. Drought conditions continued across south-central and southeast Wisconsin through November, but did show improvement by the end of the month due to above normal precipitation.

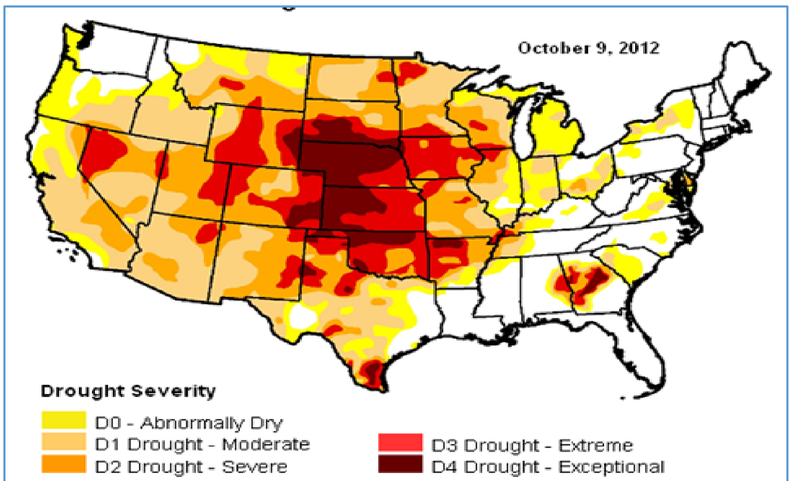
2007

Between January and July 2007, drought gradually returned to most of Wisconsin, spreading from north to south. The jet stream pattern kept low pressure systems and associated thunderstorms northwest of Wisconsin while summer temperatures averaged one to three degrees above normal. Eventually moderate (D1 rating) to extreme drought (D3 rating) covered 85% of the state. Only the southern tier of counties had normal conditions to abnormally dry conditions (D0 rating). Crop yields were reduced. Moderate to heavy rains across central and southern Wisconsin in August broke the back of the drought in those areas, but the drought only gradually left the northern part of the state by December 2007.

2012

In the summer of 2012 much of Wisconsin experienced an extreme drought, especially in the Southern portion of the State. The drought was severe enough that it drew comparisons to the drought of 1988. Higher than average temperatures and lower than average precipitation lead to extremely dry conditions for much of the State by late July. In August, the Southwest and Southcentral Wisconsin was considered to be in severe drought with Palmer values between -3.0 and -3.99, this range extended in October. Severe drought continued through November, before lessening later in the winter of 2013. Effects on 2012 crop yields were varied, corn yields were down 11 percent from 10 year averages (compared with 17 percent from the 1988 drought) while vegetable yields from spring planting was hit much harder with non-irrigated areas producing 50-80 percent less than anticipated yields. Later planted vegetables fared much better. While yields were down, most cropland was enrolled in federal crop insurance, lessening the financial blow to farmers. (Data from Wisconsin State Climatologist's Office)

Figure 4.3.2 2012 Drought Severity



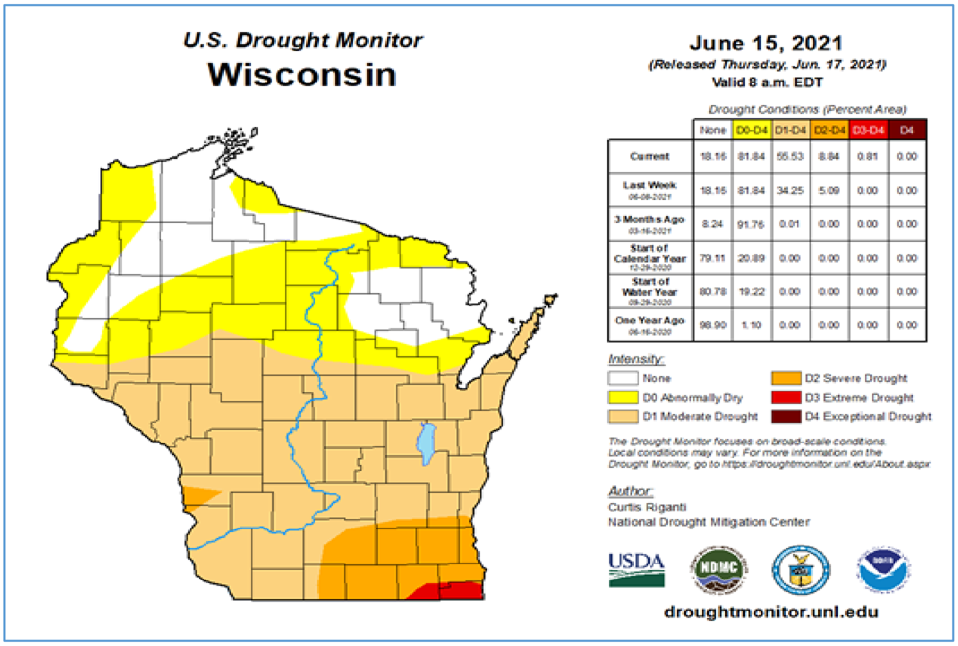
Week	Nothing	D0-D4	D1-D4	D2-D4	D3-D4	D4
October 2, 2012	24.10	75.90	64.58	40.07	20.12	6.07
October 9, 2012	23.28	76.72	63.55	39.91	20.15	6.18

Source: National Drought Mitigation Center

2021

In the late summer of 2021, specific areas of the southern region of Wisconsin have been identified as being in either a D1-D4 drought, with more than 0.81% of land being covered for 5 weeks consecutively. Dane county is primarily situated in a D2-3 drought zone. Throughout the fall of 2021 and into the winter of 2022, Wisconsin continued to experience a 2 to 7 inch precipitation deficit, which resulted in a consistent D0 to D1 drought for a period of over 6 months.

Figure 4.3.3 2021 Wisconsin Drought Severity



Source: U.S Drought Monitor, 2021

4.3.3 Impact of Climate Change on Future Conditions

The threat of drought is likely to increase in the coming years due to climate change. While Wisconsin is projected to experience more precipitation on average annually, the precipitation is likely to come in larger storm events, rather than being spread over time. Additionally, Wisconsin will continue to experience warmer temperatures. The increased temperatures are likely to exacerbate droughts that already occur periodically through increased evapotranspiration; leading to increased water loss from both surface and groundwater resources. Droughts are typically thought of as weather, however, long term patterns suggest that given the increased temperature and modest gains in precipitation, Wisconsin should expect more dry days in summers to come. As a result, the risk of drought is increasing due to these changes in the regional climate. Trends in rain fall patterns are discussed in greater detail in the flood hazard profile.

4.3.4 Impact Assessment

Direct Impacts

Dane County is most vulnerable to agricultural drought. In addition to the obvious losses associated with crop and livestock yields, drought is also associated with increases in insect infestations, plant disease and wind erosion. Droughts also bring increasing problems with insects and disease to forests and can reduce growth. The incidence of forest and grassland fires increases substantially during extended droughts.

Dane County is also vulnerable to hydrological drought. Hydrological impacts of a prolonged drought include lower water levels in the lakes and ponds of the County, reduced stream flow, degradation or loss of wetlands, decreased water quality, and lowering of the water table. In addition, the loss of vegetation and drying and hardening of the ground can result in flooding, even from average rainfall, as rainwater is unable to soak into the soil.

Indirect Impacts

The indirect impacts of drought are far reaching. The cascading effects of drought provide a more accurate picture of the drought's effect on the region and the nation. Unlike many other natural hazards, drought may extend indefinitely, but as with all disasters, the more prolonged the event, the greater the damage and indirect impacts. Less obvious impacts of agricultural drought include increased incidents of insect infestation, plant disease and wind erosion. These problems also impact forests and other wild areas, which can reduce levels of growth or result in large areas of dangerously dry vegetation, which in turn increases the risks for wildfires. The incidence of forest and grassland fires increases substantially during extended droughts. In addition, the loss of vegetation and drying and hardening of the ground can result in flooding, even from average rainfall, as rainwater is unable to soak into the soil.

The National Drought Mitigation Center (NDMC) at the University of Nebraska-Lincoln suggests examining indirect impacts of drought using three broad categories: economic, environmental, and social impacts. In Dane County, most economic impacts occur in agriculture and recreational sectors because these sectors rely on water supply and quality. The resulting income loss from these sectors creates ripples which impact a wide range of other aspects in the local economy. Retailers that supply these industries also face reduced business which in turn impacts suppliers and production levels. This loss of product turnover may lead to unemployment, increased credit risk, loss of tax revenue, and other economic considerations.

Depending on the severity, geographic extent and duration of a drought, every sector of a local economy could experience indirect social and economic impacts. Specific examples include:

- Agricultural Production
    - Reduced yields and crop loss due to water stress, insect infestation, and plant disease
    - Increased irrigation cost for crops
    - Reduced productivity of pastureland
    - Increased feed costs
    - Reduced milk production
    - High livestock mortality rates
    - Disruption of livestock reproduction cycles
    - Wind and water erosion of exposed topsoil
    - Cost of new or supplemental water supply
    - Income loss
- Recreation and Tourism
    - Damage to fish habitat and/or reduction of fish populations, especially trout and other cold-water stream fish
    - Income loss to manufacturers, suppliers, and retailers of recreational equipment, particularly fishing and boating equipment
- Water Utilities
    - Increased costs for development of new water sources e.g., cost to drill new, deeper wells
- Residential
    - Direct loss of trees, especially younger trees
    - Increased susceptibility of trees to wind damage
    - Increased risk of wildfire in rural areas
- General
    - Economic losses to businesses directly dependent on agricultural production e.g., farm cooperatives, food processors, and dairies
    - Unemployment from drought-related declines in production
    - Revenue losses to state, and local governments
    - Increased demand on disaster assistance programs
    - Increase in food prices

4.3.5 Vulnerability Assessment

The drought vulnerability of the people, buildings, and economy of Dane County is very difficult to quantify. Typically, structures and people are not directly vulnerable to drought, though secondary or indirect impacts may eventually increase vulnerability ratings. As discussed in the impacts section, the potential impacts for drought are systemic. However, some areas are more vulnerable overall than others and, therefore, benefit from adequate mitigation planning and implementation. For Dane County, the agricultural economy is the most vulnerable to drought and will benefit the most from mitigation efforts. Overall, property and people are not highly vulnerable to drought. Economic resources tied to agricultural production are extremely vulnerable to drought, with secondary vulnerabilities attributed to economic income based on recreational use of natural resources.

4.3.6 Potential for Future Loss

The level of analysis needed to calculate the potential for future drought losses is far beyond the scope of this plan. Future losses would be very difficult, if not impossible to estimate without a detailed study of the direct and indirect impacts of a drought. Given the occurrences of past droughts, it is reasonable to assume that there is real risk of a significant drought at some point in the future. A considerable portion of Dane County's economy is reliant on agriculture and is therefore, vulnerable to drought losses. There is, however, no readily available model or data that can be used to quantify that vulnerability. This is an area for additional study and is addressed in the recommendations of this plan.

4.4 EXTREME COLD / WIND CHILL

4.4.1 Description

Cold temperatures in winter are a basic fact of life in southern Wisconsin. Typically, extreme cold temperatures (cold waves) in Wisconsin are accompanied by an active wind that results in an additional wind chill factor. This combination is especially hazardous when temperatures are at least 20 degrees below normal (National Weather Service communication) during the winter season.

Extremely cold temperatures present a variety of problems and impact the population of Dane county both directly and indirectly. Extreme cold is a dangerous situation that can bring on health emergencies in susceptible people, such as those without shelter or who are stranded, or who live in a home that is poorly insulated or without heat. Additionally, extreme cold/wind chill affects agriculture, industry, commerce, and social activities. Extremely cold temperatures may precede, accompany, or follow a winter storm or it may occur during otherwise typical weather conditions.

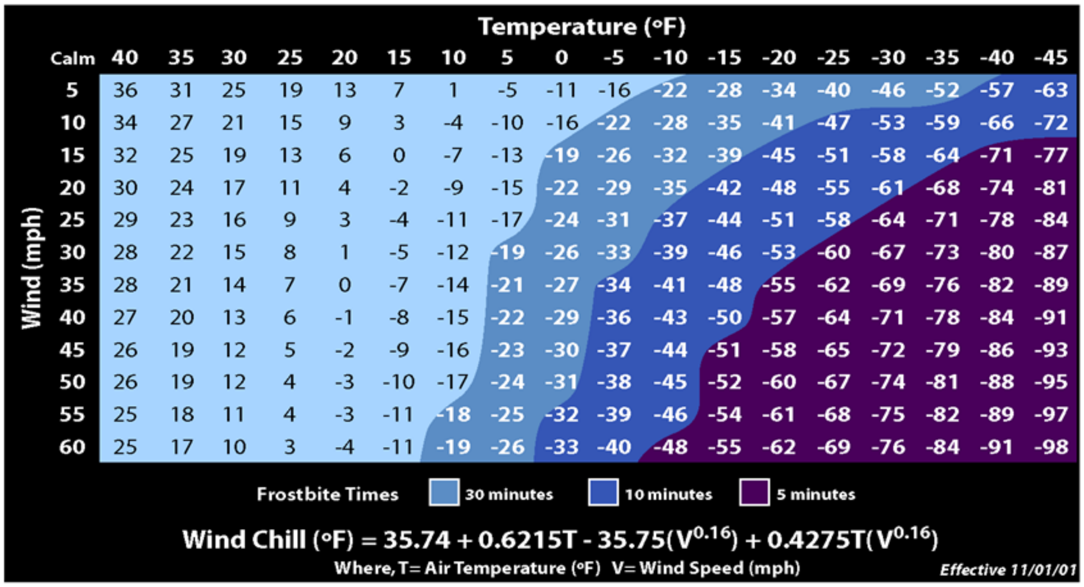
What constitutes extremely cold temperatures varies across different areas of the United States, based on normal climate temperatures for the time of year. In Wisconsin, cold temperatures are normal during the winter. When temperatures drop at least 20 degrees below normal winter lows, the cold is considered extreme and begins to impact the daily operations of the county. Extreme cold/wind chill impacts inanimate objects, plants, animals and water supplies.

Wind Chill

The effects of extremely cold temperatures are amplified by strong to high winds that can accompany winter storms. Wind-chill measures how wind and cold feel on exposed skin and is not a direct measurement of temperature. As wind increases, heat is carried away from the body faster, driving down the body temperature, which in turn causes the constriction of blood vessels, and increases the likelihood of severe injury or death to exposed persons. Animals are also affected by wind-chill however cars, buildings, and other objects are not. In 2001, the National Weather Service updated the wind-chill temperature index to take advantages of advances in science and computer modeling technology. Wind-chill effects are shown in Figure 4.4.1, highlighting the dangers of wind-chill to exposed individuals.

For Southern Wisconsin, including Dane County, the National Weather Service issues Wind Chill Advisories when wind chill values are expected to range from -20 to -34. A Wind Chill Warning is issued when wind chill values are expected to be -35 or lower.

Figure 4.4.1 Wind-Chill Factors



Temperature (°F)

Wind (mph)	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

Source: National Weather Service

4.4.2 Previous Occurrences

The National Weather Service and the NOAA National Centers for Environmental Information (NCEI) tracks weather extremes and the related consequences in greater detail. A search of the NCEI website provided the following descriptions of several extreme cold/wind chill and wind-chill events since 1994. These accounts are edited and annotated to reflect only Dane County information.

January 13, 1994

An extended period of extremely cold weather gripped the state. Brisk winds at times combined with record setting sub-zero temperatures down to 50 below zero at night to create wind-chill readings to 80 below zero. During the cold spell numerous schools closed for days at a time, businesses reduced hours, sporting events, winter fest activities, and local government meetings were cancelled. Also many water mains broke and vehicles refused to start. Some people received frostbite and suffered from hypothermia. Heat and power failed in many homes, businesses, and schools. Natural gas and heating oil was consumed at record levels.

December 9, 1995
Bitter-cold arctic air swept into Wisconsin on northwest winds of 20 to 40 mph. Temperatures dropped as much as 15°F in 15 minutes as the strong front moved through. Wind-chill values ranged from -25°F to -50°F. Hypothermia was a secondary cause (indirectly-related) for one death in Dane County. Many schools canceled evening activities, and retailers across the state reported very little shopping activity in spite of the upcoming Holidays. The AAA Club (3,000 calls) and service stations were overwhelmed with requests for assistance with stalled vehicles. There was also a scattering of frozen water pipes that resulted in flooded rooms or basements. At least six frozen water pipe incidents were noted in Dane County.

January 30 – February 4, 1996
After the previous days' ground blizzard, very cold arctic air poured into Southern Wisconsin on northwest winds of 10 to 25 mph. Wind-chills ranged from -35°F to -45°F. Overnight lows across Southern Wisconsin ranged from -5°F to -15°F. Arctic air continued to pour into Southern Wisconsin on northwest winds of 10 to 20 mph overnight. Morning lows dipped to -21°F in Madison. Wind-chills dropped into the -40°F to -60°F range as daytime temperatures never recovered to zero. Service stations were overwhelmed with calls for assistance, and hardware stores reported a booming business due to the demand for space heaters, snow blowers, and other cold-weather gear.

The episode continued through the first four days of February across south-central and southeast Wisconsin. Ending on the 4th, Madison registered 177 hours below the zero mark. Adding to the misery, wind-chills were in the minus 35°F to minus 60°F range many times during this event. Numerous water main pipes burst, and fiber optic cables froze disrupting telephone service. Schools were closed on the 2nd. Service stations and the AAA were overwhelmed with requests for assistance. A new minimum temperature record of -29°F in Madison (now the February record) was set the 3rd.

January 17, 1997
The coldest arctic air of the winter season enveloped southeast and south-central Wisconsin, resulting in many school closings and cancellation of evening activities. Maximum temperatures only reached zero in Madison, roughly 20 degrees below normal. Morning lows ranged from -7°F to -14°F. Coupled with northwest winds of 10 to 20 mph, wind-chills dropped to -30°F to -50°F.

January 5, 1999

The combination of an arctic high pressure ridge, a fresh, deep snow cover, clear skies, and light winds allowed temperatures to plunge to well below zero across south-central and southeast Wisconsin. Observed minimums include Stoughton -21°F, and -21°F in Madison. Thousands of calls to local AAA and car service centers were logged due to stalled vehicles. Maximum temperatures were only around zero.

December 18, 2005

The second cold snap of December 2005 was a contributing or secondary factor (indirect) in the death of a homeless man in Milwaukee. Media news reports indicated that some water pipes (outside faucet) froze on some homes across south-central and southeast Wisconsin. The average temperature across southern Wisconsin for the first 19 days of December 2005 was the coldest since the 1985. Across southern Wisconsin on December 18-19, 2005, maximum air temperatures were only in the teens and lows were around zero to 5 below zero, resulting in daily means around 15 to 17 below normal. In addition, cold temperatures occurred during the period of December 6-8, 2005, when daily means were around 20°F below normal (maximum temperatures in the teens and lows of zero to 10 below zero).

February 3, 2007

The coldest air and lowest wind-chills of the 2006-07 winter season affected south-central and southeast Wisconsin as a massive arctic high pressure pushed southeast through the Western Great Lakes Region over the 4-day period of February 3-6, 2007. Minimum air temperatures tumbled to -5F to -14F on February 3rd with Madison's Truax Field registering -11°F on the 3rd. Daytime maximum air temperatures on the 3rd ranged from 3°F to 10°F . Early morning low temperatures on the 4th ranged from -10°F to -15°F. Afternoon maximum temperatures on the 4th never reached the zero mark, totaling -3°F at Madison. The lowest minimum temperatures of the 4-day period occurred on February 5th. Maximum afternoon temperatures on the 5th ranged from -4°F to 6°F.

On February 3rd and 4th west to northwest winds generally clocked at 15 to 30 mph, which generated wind-chill values of -20°F to -30°F . Lower wind speeds of 5 to 20 mph were noted on February 5th and 6th. In general, the lowest wind-chill values were observed during the early morning hours on February 5th, in the -30°F to -34°F range, corresponding to the lowest air temperatures of the winter season. The cold temperatures resulted in a broken water main and electrical outage in the 100 block of West Main St. near the Madison Capitol Square early Saturday morning, February 3rd. Many public and private schools were closed on Monday and Tuesday, February 5th and 6th. It was the first time in 13 years that the Madison schools closed due to cold temperatures. Additionally, newspaper reports indicated that plumbers answered numerous frozen-pipe calls.

March 27, 2007

On March 27th, a large sink hole developed on State Street in Madison due to a large water main break. This was the 117th water main break in the city of Madison for March, 2007. Usually there is only about 6 to 12 in some of the rougher winter months. Very cold temperatures and little snow cover in the first part of March, 2007, allowed the ground to freeze deeper. Subsequent freeze-thaw periods forced the ground under streets to shift/move, resulting in the numerous water main breaks. Damage was estimated at $300,000.

January 15, 16, 2009

Arctic air blanketed southern Wisconsin and kept temperatures bitterly cold for a 48 hour period. Wind chills reached -35° to -45°F and actual temperatures briefly touched -30 °F. All 16 school districts in Dane County cancelled classes, as well as the University of Wisconsin. Compounding the problem were very slick stretches of road and intersections. Snowfall of almost two inches covered the icy patches making already slippery roads even more dangerous. Road crews worked around the clock to apply sand and salt, but the bitterly cold temperatures rendered the salt virtually useless. Dozens of cars and trucks were involved in slide offs, rollovers, and fender benders on area streets and highways.

January 6, 7, 2014

An extreme cold wave of arctic air and brisk winds brought 40°F below wind chills to southern Wisconsin. Numerous school and business closings occurred. This cold wave and the continued cold through January, resulted in numerous water main breaks, especially in Madison and Milwaukee. A number of local water utilities advised residents leave water run continuously in order to prevent substantial damages associated with the repair of ruptured and frozen pipes. The cost associated with this protective measure was borne by the local water utilities and was a significant, unbudgeted cost. Local government costs to repair broken mains and pipes was estimated at just over $1.0 million in Dane County alone. The term “Polar Vortex” became a household phrase during the winter of 2014 as this nationwide cold snap affected a large portion of the country.

Madison Water Utility: January 8, 2014

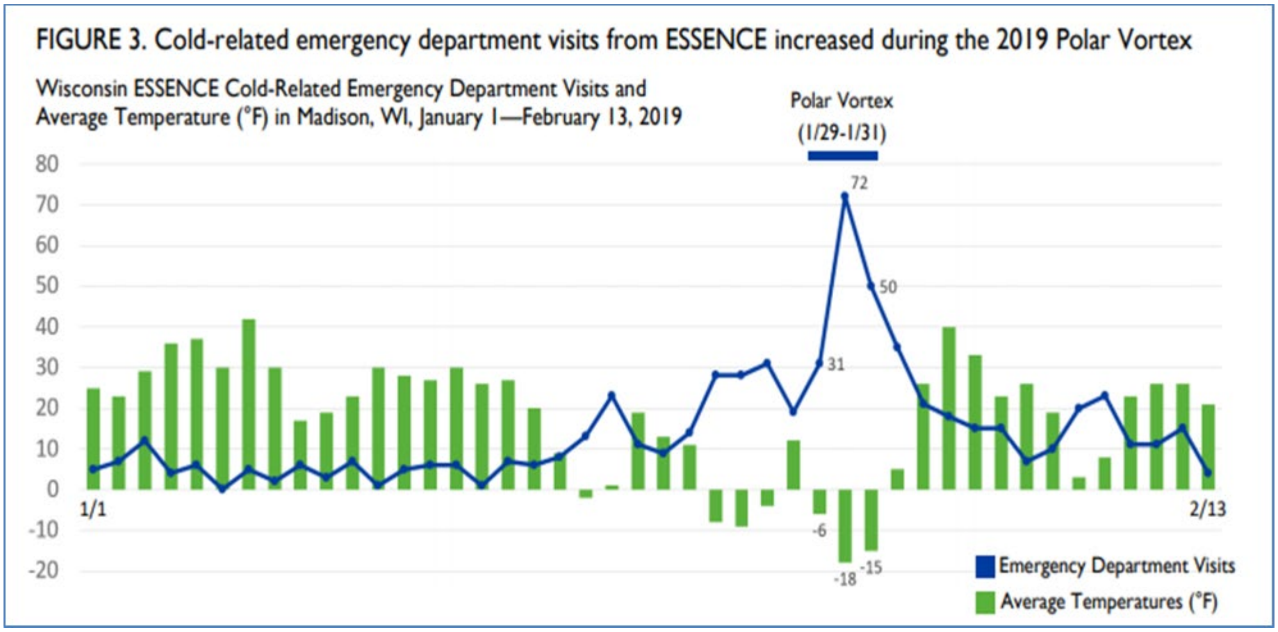
January – February 2015

In the winter of 2015, the National Weather Service issued a wind chill advisory on Tuesday January 6th, due to excessive cold. January to February of 2015 consisted of record breaking temperatures for Dane county, which consisted of an overall minimum of -12 degrees Fahrenheit. Daytime temperatures ranged between the single digits, and wind chill temperatures ranged between -15 and -40 degrees Fahrenheit. DCEM and Public Health of Madison/Dane County provided a joint release statement concerning measures to be taken in order to prevent further harm and loss of life.

January – February 2019

In the mid-winter of 2019, a polar vortex formed over the Midwestern region of the United States. The state of Wisconsin had record low temperatures in Dane and Milwaukee County, with wind chills as low as -55°F in Waukesha. This excessive cold event exhausted energy usage in the county, which resulted in extensive power outages. Over 11 deaths were recorded in relation to this excessive cold event, and health officials from the Department of Human Services believe this number may be an underestimate.

Figure 4.4.2 2019 Polar Vortex

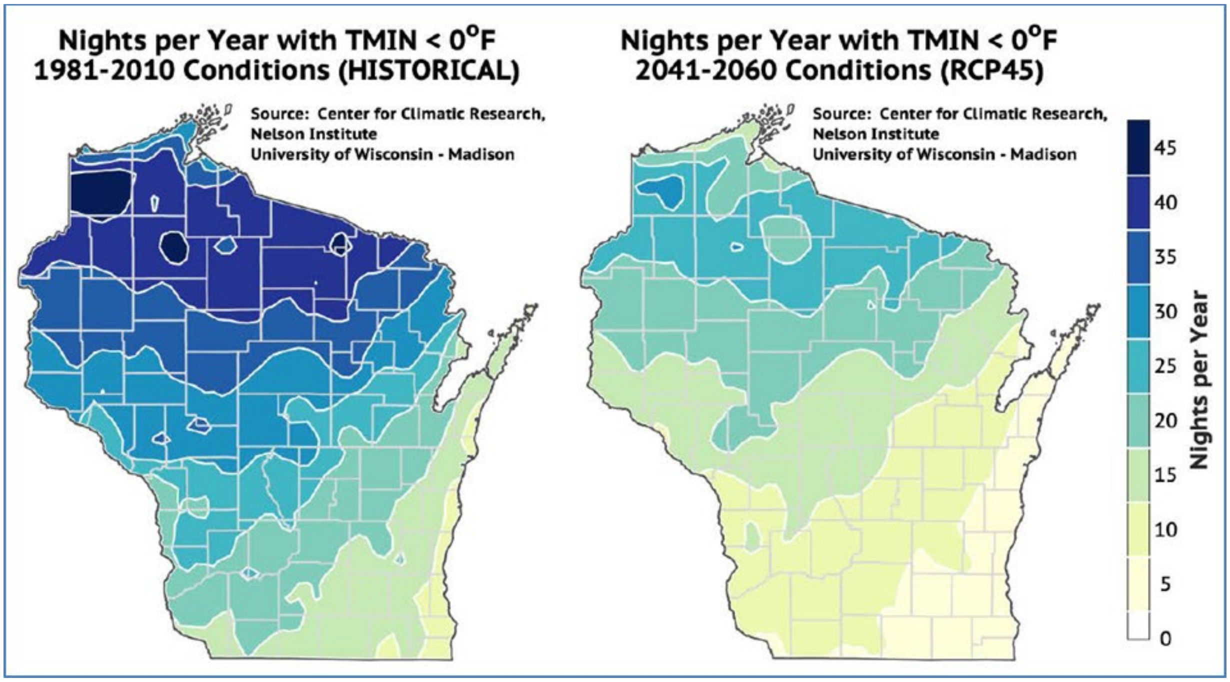


Source: Department of Human Services

4.4.3 Impact of Climate Change on Future Conditions

All indications are that the frequency and intensity of extreme cold events in southern Wisconsin are decreasing. Analysis performed by the Wisconsin Initiative on Climate Change Impacts (WICCI) indicates that Wisconsin already experiences fewer nights below 0°F than in 1950. In addition, the average winter temperature in Dane County has increased between 2°F and 3°F in the period between 1950 and 2006. Looking forward, WICCI models predict this warming trend to continue. In it's 2011 report, Wisconsin's Changing Climate: Impacts and Adaption, WICCI projects that southern Wisconsin, Dane County included will experience an average winter time temperature increase of 7.5°F to 8°F by 2055. The region can also expect a decrease of 12 to 14 days with below zero low temperatures over this same time period. This is not to say that Dane County will not experience very cold temperatures in the future. These trends do indicate, however, that the likelihood of extreme cold events is generally decreasing.

Figure 4.4.3 Projected Wintertime Temperature Changes in Wisconsin



Source: Wisconsin Initiative on Climate Change Impacts, 2020

4.4.4 Impact Assessment

Direct Impacts

Extreme cold is generally a regional phenomenon and Dane County is uniformly impacted when it occurs. The major threat of extreme winter cold temperatures is frostbite and exposure. Frostbite, if untreated, can lead to loss of a limb or limbs. Exposure can lead to death due to cardiac issues associated with the constricted blood vessels due to the body's reaction to the extreme cold. In cases of periods of prolonged cold, municipal water mains may break and water pipes may freeze and burst in buildings that are poorly insulated or without heat. There may also be numerous occurrences of vehicles that either will not start or stall once started due to the cold.

Indirect Impacts

The indirect social and economic impacts of extreme cold are minimal. There are stresses placed on human services programs that care for at-risk individuals and families, however those stresses are usually within the capacity to respond. Lack of availability of transportation due to non-starting or stalled vehicles may result in minor economic loss, as people are not able to get to work. No data exists to quantify these impacts.

4.4.5 Vulnerability Assessment

Population

While everyone is vulnerable to extreme cold/wind chill events, some populations are more vulnerable than others. Extreme cold/wind chill pose the greatest danger to outdoor laborers, such as highway crews, police and fire personnel, and construction. The elderly, children, people in poor physical health, and the homeless are also vulnerable to exposure. Overall, the population has a medium exposure to severe cold.

Property

Extreme cold/wind chill presents a minimal risk to the structures of Dane County. Property damage occurs occasionally when water pipes freeze and break. Homes without adequate insulation or heating may put owners at a higher risk for damages or cold-related injury. In cases of periods of prolonged cold, water pipes may freeze and burst in poorly insulated or unheated buildings. Extreme cold also takes a toll on municipal water systems, causing broken mains, and frozen or broken water meters and service laterals.

Broken Water Meter, Madison Water Utility: January 8, 2014

4.4.6 Potential for Future Losses

As can be seen from the past history data, extreme cold is an annual occurrence in Dane County. Property losses due to extreme cold/wind chill are typically minor and isolated. Direct impacts such as water breaks, which may cause water and flooding damage to structures and their contents, are the most likely source of potential property losses. The costs and losses from past extreme cold events, however, are not systematically collected and compiled. There is no available data on which to base a projection of the future loss potential.

Public education remains the primary means of mitigating the risks of extreme cold/wind chill, both to the population and for property protection.

4.5 EXTREME HEAT

4.5.1 Description

Excessive heat during the summer season is characterized by a combination of very high temperatures and exceptionally humid conditions. Humid or muggy conditions, which add to the discomfort of high temperature, occur when a dome of high atmospheric pressure settles over the southern part of the country and pulls hot, muggy air north into Wisconsin.

The National Weather Service defines Excessive Heat for southern Wisconsin when these conditions are observed: daytime heat index values of 105°F or higher with minimum night heat index values of 75°F or higher, for at least a 48-hour period. When these conditions are reached, the National Weather Service issues Excessive Heat Warnings. The National Weather Service issues Heat Advisories when daytime heat index values are expected to reach 100°F to 104°F. Should 4 consecutive days of heat index values of 100°F to 104°F be expected, an Excessive Heat Warning may be issued.

Heat Index

The National Weather Service uses the "Heat Index" as an estimate of how the weather "feels." The heat index is a function of relative humidity and actual air temperature. Figure 4.5.1 shows heat index values for a range of temperatures and humidity.

Figure 4.5.1 Heat Index Table

NWS Heat Index — Temperature (°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										

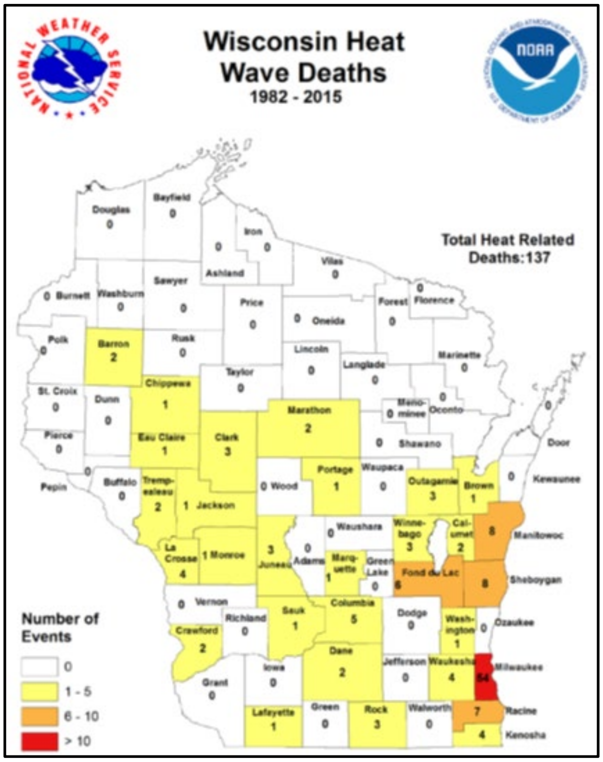
Likelihood of Heat Disorders with Prolonged Exposure or Strenuous Activity

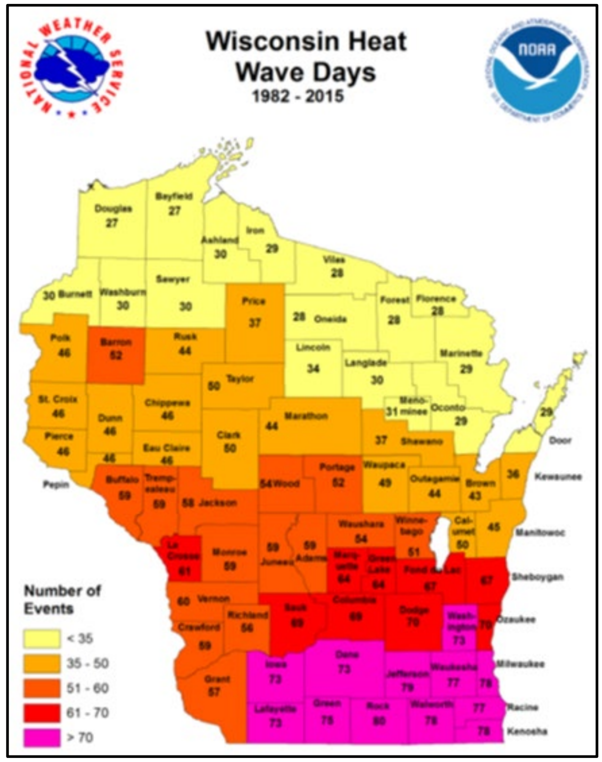
Caution | Extreme Caution | Danger | Extreme Danger

Source: National Weather Service (http://www.nws.noaa.gov/om/heat/heat_index.shtml)

4.5.2 Previous Occurrences

Figure 4.5.2 Wisconsin Heat Wave Days and Heat-Related Deaths, 1982 to 2015

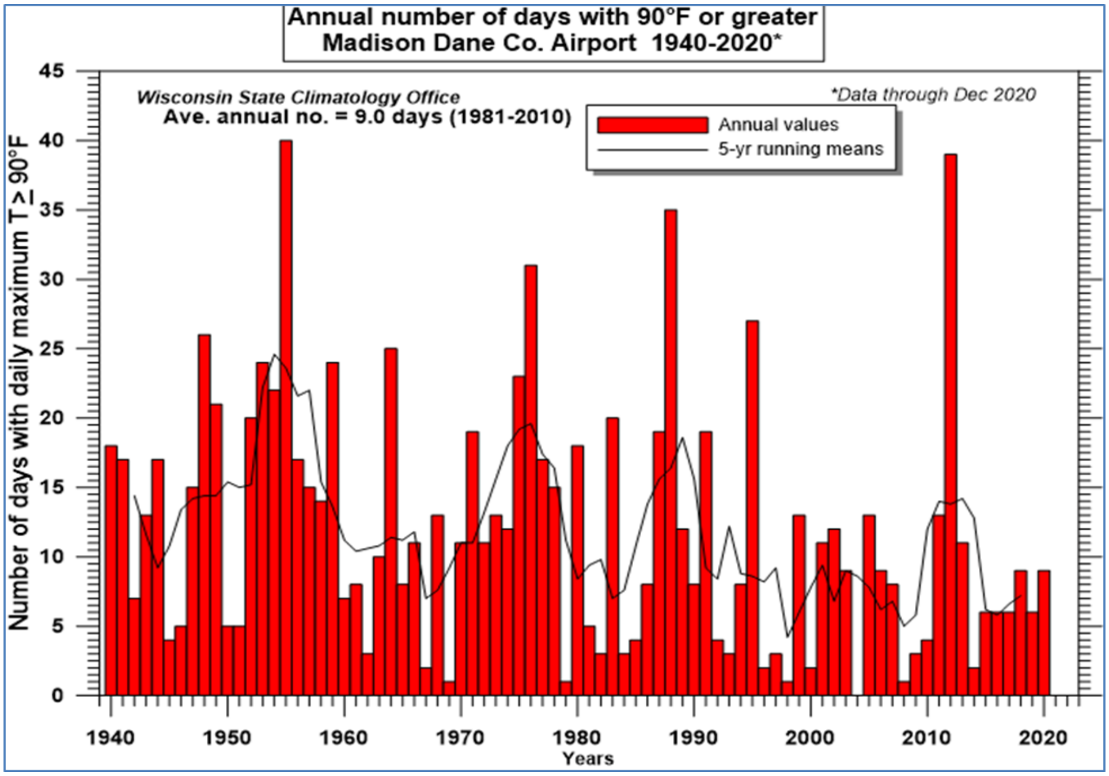




Source: National Weather Service, 1982-2015

Figures 4.5.2 illustrates the number of heat wave days and heat wave related deaths across Wisconsin. A heat wave day is calendar day in which heat advisory or excessive heat warning was issued. Note that Dane County ranks near the top for both categories. According to the Wisconsin State Climatology Office, Madison experiences 14 days above 90 degrees Fahrenheit per year. Figure 4.5.3 summarizes the temperature extreme data from the SCO from 1971 through 2013, showing for each month, the number of days with high temperatures above 90° Fahrenheit.

Figure 4.5.3: Number of Days above 90°F



Source: Wisconsin State Climatology Office Website, 2020

In more recent years, the National Weather Service and the NOAA National Centers for Environmental Information have been tracking weather extremes and their consequences in greater detail. A search of the NCEI website provided the following descriptions of several excessive heat events.

June and July 1995

Dane County experienced two periods of prolonged heat in the summer of 1995. From June 17-27, high temperatures were consistently into the 90°s F with heat index values ranging from 88°F to 104°F. During this period, statewide, 9 people died as a direct result of the heat. The second heat wave, July 12-15, resulted in the greatest number of weather related deaths in Wisconsin history. During this heat wave, 141 people died directly or indirectly from the heat, but no deaths were reported in Dane County. High temperatures were well into the 100°s, with heat index values of 120° to 130°F.

July 1999

A heat wave over the last two weeks of July, peaking on July 28-31, 1999 pushed local utility companies to the limit. There were no outages in the Dane County area, but there were records set for peak electrical demand. During these four days, high humidity and high temperatures well into the 90°s produced heat index values to over 110°F. Statewide, the heat was directly responsible for killing 8 people and indirectly responsible for another 6. Dane County had 1 heat-related death.

July 2001

Southern Wisconsin was affected by a heat wave at the end of July 2001. Afternoon heat index values on the 31st reached 110°F for several hours and stayed in the 85°F to 100°F range through the evening hours. Local utilities again reported new daily record peak demands for electricity. Statewide 15 died because of heat.

October 2003

A 6-month old female died in the city of Middleton. Heat was listed as a contributing cause, thus this death is indirectly related to excessive heat. Maximum temperatures in the Middleton area on October 7th and 8th were around 79°F, about 15 degrees above normal.

July and August 2006

A period of very hot and humid weather began on the evening of July 30th and continued into August 2nd. Overnight temperatures only fell to 70° to 75°F on the 30th, and soared into the 95° to 100°F range during the afternoon of July 31st. With dew points in the low to mid-70s, heat index values only dropped to about 75 overnight on July 30th, and peaked in the 105° to 110°F range across south-central and southeast Wisconsin during the afternoon of July 31st. An estimated 40 people in Milwaukee County were hospitalized due to heat-related symptoms. Ultimately, this stretch of "heat advisory" conditions resulted in two directly-related heat deaths in Milwaukee County where the urban heat-island effect is enhanced. Air temperatures only fell into the mid-70s across south-central Wisconsin during the early-morning of August 1st. Afternoon air temperatures soared into the 95° to 100°F range. With dew points in the low to mid-70s, heat index values only dropped into the lower 80s during the morning of the 1st, and peaked in the 105° to 110°F range across south-central and southeast Wisconsin during the afternoon of August 1st. The oppressive conditions continued during the overnight hours of August 1st with low temperatures around 80 degrees before a cold front swept through during the afternoon, ending the heat wave.

July 2011

A dome of hot and humid air over the southern and central Plains moved into Wisconsin from July 17th through July 21st. Temperatures climbed into the lower to mid-90s, which combined with muggy dew points in the middle 70s to lower 80s produce heat index values between 100°F and 110°F for four straight days. Three people were confirmed to have died due to the excessive heat: one each in the counties of Columbia, Marquette, and Sauk. It is estimated that about 25 people in Dane County received medical treatment for the heat.

July 2012

A hot air mass settled over southern Wisconsin at the start of July. 100-degree heat occurred in many locations for multiple days between July 2nd and July 6th. While humidity levels were relatively low, maximum heat indices climbed as high as 115. Milwaukee and Madison each recorded two of the top-ten hottest days on record on July 4th and July 5th. Indirect heat-related deaths included: a middle-aged man in Dane County, a middle-aged women in the city of Milwaukee and a middle-aged man in the city of Milwaukee. Hundreds of people received medical treatment due to illness related to the heat. The counties surrounding Dane had 4 days of 100 degrees or higher. Numerous new daily record highs were set as well as record high minimums. Although only one death was attributed in Dane county, it is believed several hundred injuries across multiple counties are linked to this singular heat event. The long duration of this excessive heat period makes this one of the four most dangerous heat waves to strike southern Wisconsin in recorded history.

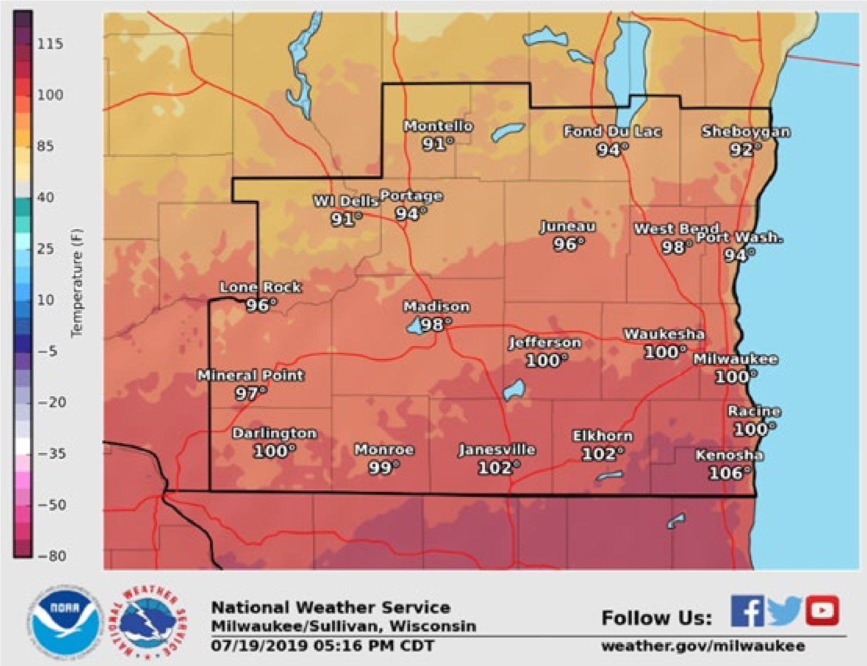
July 2016

In the mid-summer of 2016 from July 21st to July 24th, an excessive heat advisory was issued by the National Weather Service, due to dangerous highs for the three to four day period. The minimum Dew Point temperatures, which is used to determine how hot it actually “feels” outside, ranged from 60-70 degrees Fahrenheit and 70-80 at its highest. This range is considered incredibly humid and uncomfortable for the average Dew Point temperatures. The southern region of Wisconsin experienced heat index values in the lower to mid-100s, with certain locations seeing heat indices breaking 110 Fahrenheit in the far reaches of southeastern Wisconsin on Sunday.

July 2019

In the mid-summer of 2019, the National Weather Service detected a bubble of warm air traveling via the U.S. Southwest winds into southern Wisconsin. The daily high temperatures were elevated to 90+ degrees Fahrenheit, which triggered an excessive heat warning for a two day period starting July 19th, 2019. Approximately 14 counties fell into this advisory range, and Dane County was situated in the 98 degree Fahrenheit range for the maximum daily temperatures of the region.

Figure 4.5.4 Max. High Temperatures for Southern WI, 2019



Source: National Weather Service, Milwaukee-Sullivan

Excessive heat events from 2019 to 2021 do not appear in the National Centers for Environmental Information database (NCEI) due to differences in threshold standards for excessive heat classification.

4.5.3 Impact of Climate Change on Future Conditions

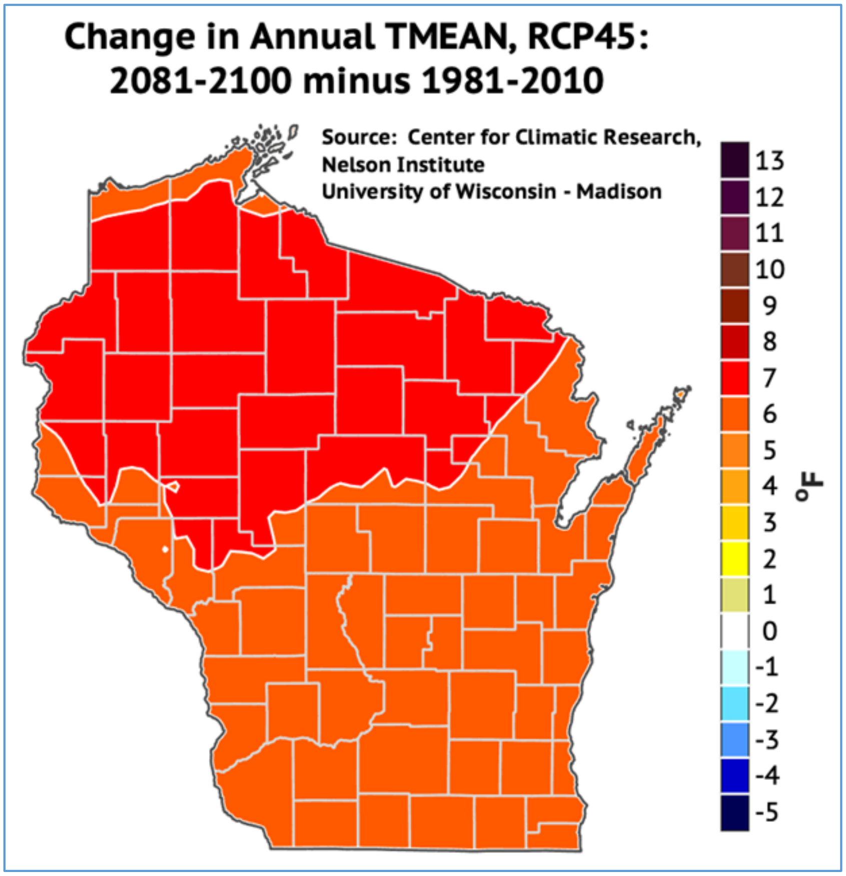
Excessive heat is one of the hazards in this plan that the Dane County community will be at greatest risk to in the coming decades as the climate changes. The changing climate will bring warmer average temperatures and, more dangerously, increased days above 90 degrees. As shown in Figure 4.5.5 WICCI projects an increased average annual temperature change of 5 degrees Fahrenheit by 2081 from 1981 levels in Dane County. This trend of more dangerously hot days has already begun, but will continue to accelerate.

As shown in the opening chapters of this plan, Dane County is continuing to rapidly grow its population, and in turn, it continues to turn previously undeveloped land into development that can increase the urban heat island effect. Research from UW-Madison on the urban heat island of Madison demonstrates that the phenomenon is real and presents an elevation of risk to those living in urban areas, especially vulnerable populations. In a changing climate, where the prospect of living nearly a month more under conditions above 90 degrees is a possibility, the urban heat island effect will only be exacerbated.

The risk for excessive heat is significantly increased as the climate changes. This rates as one of the most urgent hazards to find mitigation strategies for in this plan. The effect on public health could potentially be significant.

Heat mitigating development patterns should be encouraged to confront this increased risk.

Figure 4.5.5 Projected increase in days above 90 degrees Fahrenheit 1980-2055



Source: Wisconsin Initiative on Climate Change Impacts, 2020.

4.5.4 Impact Assessment

Direct Impacts

Adverse health outcomes associated with extreme temperatures include heatstroke, heat exhaustion, heat syncope, and heat cramps. Heatstroke is the most serious of these conditions and is characterized by rapid progression of lethargy, confusion, and unconsciousness. It is often fatal despite medical care directed at lowering body temperature. Heat exhaustion is a milder syndrome that occurs following sustained exposure to hot temperatures and results from dehydration and electrolyte imbalance; manifestations include dizziness, weakness, or fatigue, and treatment is supportive. Heat syncope and heat cramps usually are related to physical exertion during hot weather. (MMWR (1995) Heat-wave-related mortality—Milwaukee, Wisconsin. Morbidity and Mortality Weekly Report. July 1995. MMWR 1996;45(24):505-7)

While property impacts are generally minimal, there are frequent occurrences of road pavement buckling during periods of high heat. Heating causes the pavement to expand. When concrete slabs expand beyond the space in the joints they press against each other, causing the surface to buckle at the joint or in a weak spot within the slab. Pavement buckling is somewhat unpredictable, with the type and age of the concrete and temperatures as factures. Because asphalt is more elastic than concrete, it is generally less prone to buckling. Asphalt pavement will heave, however, if it is covering an older concrete roadbed or is under pressure from adjacent concrete.

Indirect Impacts

The indirect social and economic impacts of extreme heat are difficult to quantify. The primary stresses are on the electrical distribution system as demand increases to run air conditioning. Peak demand exceeding the local utility's capacity for supply can lead to blackout or brownout conditions. This has not occurred in Dane County however. The utilities supplying Dane County have worked closely with emergency response agencies and human services providers to develop plans for responding to planned and unplanned power outages in the County.

4.5.5 Vulnerability Assessment

Population

Everyone is vulnerable to excessive heat conditions, although some populations are more vulnerable than others. Excessive heat poses the greatest danger to outdoor laborers, such as highway crews and fire crews. The elderly, children, and people in poor physical health are also vulnerable to exposure to extreme temperatures. Mortality among elderly persons, persons with chronic conditions (including obesity), patients taking medications that predispose them to heatstroke (e.g., neuroleptics or anticholinergics), and persons confined to bed or who otherwise are unable to care for themselves are at greatest risk. Low-income individuals and families are also at greater risk of heat exposure than the general population.

People living in urban areas may be at greater risk from the effects of a prolonged heat wave than people living in rural regions. Asphalt and concrete retain heat longer and gradually release heat at night, which produces significantly higher nighttime temperatures in urban areas known as the urban heat island effect. This has large implications for vulnerable populations living in the County's urban areas, given the extent of the urban heat island effect, these populations are likely not experiencing nightly relief from high temperatures during heat waves.

There are segments of the population that are vulnerable to the potential indirect impacts of prolonged excessive heat, particularly the loss of electrical power. As a group, the elderly or disabled, especially those with home health care services rely heavily on an uninterrupted source of electricity. Resident populations in nursing homes, Community Based Residential Facilities, or other special needs housing may also be vulnerable if electrical outages are prolonged. If they do not have a back-up power source, rural residents and agricultural operations reliant on electricity for heating, cooling, and water supplies are also especially vulnerable to power outages.

Social isolation is a perhaps the most significant of the extreme heat risk factors. This can be mitigated through organized welfare checks as well "social capital" programs that build on informal relationships between friends, family members, and neighbors. People in Dane County are generally well connected to service agencies and other people in their communities. While the risk for mortality due to excessive heat does exist, the probability is low that Dane County would experience a large number of deaths such as that which occurred in Milwaukee and Chicago in the 1995.

The Wisconsin Department of Health Services' Building Resilience Against Climate Effects (BRACE) (Wisconsin Department of Health Services, https://www.dhs.wisconsin.gov/climate/wihvi.htm) program has developed a heat vulnerability index for Dane County. This is shown as Figure 4.5.8. The index measures heat vulnerability based on environmental, socioeconomic, population density, and health factors based on census block group data. The urban areas of the County tend to show the highest vulnerability.

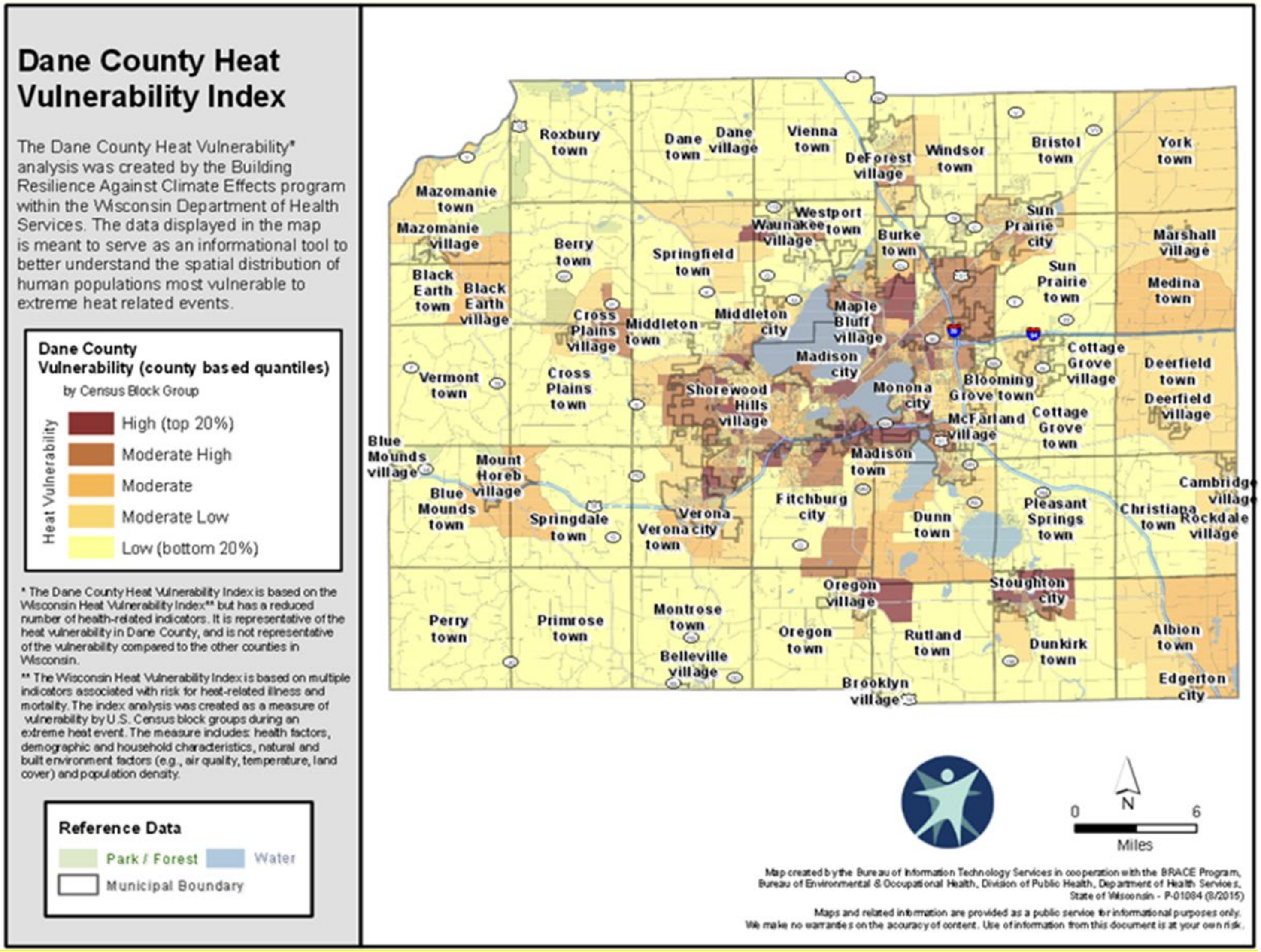
Property

Generally, property is not considered particularly vulnerable to excessive heat. Energy-inefficient buildings may be warmer, resulting in a higher exposure of the population, and personal landscaping and property may suffer from the effects of heat in a manner similar to drought. Cars may overheat, stranding motorists or damaging the vehicle itself and resulting in higher property damage costs. The overall vulnerability of general property is low.

4.5.6 Potential for Future Losses

The most vulnerable aspect of Dane County to excessive heat is the population. Due to climate trends, population exposure, and potential fatal impacts, the overall risk to excessive heat is a growing concern. 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. 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.

Figure 4.5.8 BRACE Program Heat Vulnerability Index for Dane County



4.6 FLOOD

4.6.1 Description

Flooding is one of Dane County's most complex and costly natural hazards.

Flooding is a natural occurrence in the hydrologic system. Throughout the past millennia, plant and animal species have evolved to depend upon occasional floods to renew the landscape. The structure of streams and lakes adapted to handle these changes in water flows. Steam channels meandered, lakes filled and receded seasonally, and water levels were stabilized through ample groundwater and wetland influences. Flooding is not a problem in and of itself. It requires an additional element – human habitation – to become a problem.

The problem of flooding in Dane County is complex and is not limited to mapped floodplains. Nor can the problem be described by any other single variable. The causes and problems of flooding differ widely across the County and there are many contributing factors; changing land use patterns, development in high-risk areas, stormwater management practices, complex hydrologic processes, and societal expectations and values all play a part. There are no simple solutions.

This plan recognizes the interconnected nature of water resources and the shortcomings of a plan that extracts a single element (flooding) from larger water management issues. The occurrence of flooding is only one element of a highly complex hydrologic system. Management of water resources is entwined in social and economic processes and values that are well beyond the scope of this plan. Though crucially important, these larger issues cannot be satisfactorily addressed in this plan. Rather, these issues should continue to be thoroughly discussed in the County's comprehensive planning process, or within the context of a regional comprehensive water management plan.

Flooding comes in a variety of forms in Dane County and not all flood management and flood mitigation strategies apply to all situations.

- *Riverine flooding* is the most common type of flooding, nationally and in the state of Wisconsin. Riverine flooding is also known as overbank flooding and is typified by floodplain flooding scenarios. Riverine floodplains range from narrow, confined channels in the steep valleys of mountainous and hilly regions, to wide, flat areas in plains and coastal regions. The amount of water in the floodplain is a function of the size and topography of the contributing watershed, the regional and local climate, and land use characteristics within the watershed. In steep valleys, flooding is usually rapid and deep, but of short duration, while flooding in flat areas is typically slow, relatively shallow, and may last for long periods of time.

  The cause of riverine flooding is typically prolonged periods of rainfall from weather systems covering large areas. These systems may saturate the ground and overload the rivers and reservoirs in numerous smaller basins that drain into larger rivers. Localized weather systems (i.e., thunderstorms), may cause intense rainfall over smaller areas, leading to flooding in smaller rivers and streams. Annual spring floods, due to the melting of snowpack, may affect both large and small rivers and areas.

- *Flash floods* involve a rapid rise in water level, high velocity, and large amounts of debris, which can lead to significant damage that includes the tearing out of trees, undermining of buildings and bridges, and scouring new channels. 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, covering of ground cover with impermeable surfaces, and construction of drainage systems.
- *Surface water flooding* or localized stormwater drainage floods may occur outside of recognized drainage channels or delineated floodplains due to a combination of locally heavy precipitation, a lack of infiltration, inadequate facilities for drainage and stormwater conveyance, and increased surface runoff. Surface water flooding is usually the result of high intensity rainfall, but can occur with lower intensity rainfall when the land has a low permeability and/or is already saturated. This can be an especially large problem in urban areas. Such events frequently occur in flat areas, particularly during winter and spring in areas with frozen ground, and also in urbanized areas with large impermeable surfaces.
- *Groundwater flooding* occurs when the water table rises above normally expected levels. This can be as a result of persistent rainfall that recharges aquifers until they are full, or may be a result of high river levels or lake driving water through near-surface soils. Compared to surface water flooding, groundwater flooding can last considerably longer, with incidents enduring anything from a week to several months.

Floodplains and the National Flood Insurance Program

Most homeowner's insurance policies do not cover damages caused by flooding. Flood loses are covered under a separate flood insurance policy sold through the National Flood Insurance Program (NFIP).

At the Federal level, floodplain regulation primarily falls to FEMA and the NFIP. Established in 1968, the NFIP 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.

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 flood proofing. 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 is two feet above the regional flood elevation.

Figure 4.6.2 Flood Insurance Rate Map (FIRM) sample

Source: FEMA Flood Map Service Center, https://msc.fema.gov

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 NR 116 exceed the minimum standards set by the NFIP in order 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. 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 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 NR 116 and 44 CFR 59-72 if the community wishes to participate in the NFIP. The Villages of Dane and Mt. Horeb do not participate in the NFIP because they do not have areas that are prone to surface flooding.

Communities must enforce Federal, state, and local floodplain ordinances and make FIRMs and FISs available to the public in order 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. (Wisconsin Emergency Management, Wisconsin Threat and Hazard Identification and Risk Assessment, 2021)

The NFIP also requires that local floodplain management regulations and codes contain minimum requirements that are not only for new structures, but also for existing structures with “substantial improvements” or repair of “substantial damage” after a flood. Local officials in communities that participate in the NFIP must determine whether proposed work in a regulated SFHA qualifies as a substantial improvement or repair of substantial damage (referred to as an “SI/SD determination”). If work on buildings constitutes SI/SD, then structures must be brought into compliance with NFIP requirements for new construction. The NFIP defines SI/SD as follows:

- Substantial improvement (SI) means any reconstruction, rehabilitation, addition, or other improvement of a structure, the cost of which equals or exceeds 50 percent of the market value of the structure before the “start of construction” of the improvement. This term includes structures that have incurred “substantial damage,” regardless of the actual repair work performed.
- Substantial damage (SD) means damage of any origin sustained by a structure whereby the cost of restoring the structure to its before-damaged condition would equal or exceed 50 percent of the market value of the structure before the damage occurred. Work on structures that are determined to be substantially damaged is considered to be substantial improvement, regardless of the actual repair work performed.

What is a “100-Year” Flood?

The studies used to generate the Flood Insurance Rate Maps are based on calculations of the probability of flooding occurring in any given year. Flood studies use data and modeling, as well as historical records to determine the potential for floods of a certain magnitude to occur. Such events are measured by their recurrence interval, e.g., a 100-year flood or a 500-year flood. These terms can be misleading. People often interpret the 100-year flood to mean once every 100 years. This is not correct. A 100-year flood could occur twice in the same year, two years in a row, or four times in 20 years.

The 100-year flood is a statistical term that refers to the likelihood of a flood of certain magnitude happening in any given year. This converts to a probability of 1% that a flood of this magnitude will occur.

The 100-year floodplain, or base flood shown on the FIRMs and regulated by the County's floodplain zoning ordinance is the 1% chance floodplain. This is the land area next to a water body that is assessed as having a 1% chance of being flooded in any given year. The terms "regional flood," "100-year flood," "1% chance flood," and "base flood" are essentially interchangeable. These terms all refer to a flood of the same magnitude and probability of occurrence

Floodplain Zoning

Dane County participates in the National Flood Insurance Program and is in full compliance with the provisions of the program. Chapter 17 of the Dane County Code of Ordinances is the County's floodplain zoning ordinance. The ordinance covers the floodway, flood fringe and a general floodplain districts that fall within the floodplain boundaries as shown on FEMA's Flood Insurance Rate Maps. Dane County floodplain zoning applies only in the unincorporated areas of the County and does not require approval of town boards. Cities and villages must adopt their own floodplain zoning ordinances. Chapter 17 meets or exceeds the standards defined in NR 116.

Stormwater Management

Dane County's Erosion Control and Stormwater Management Ordinance was designed to help protect the county's lakes, streams, wetlands and quality of life by reducing the negative impacts of sediment, rainfall, melting snow and other water runoff. The ordinance establishes countywide standards for the quantity and quality of water that runs off land under construction in urban and rural areas, including farms. It also provides flexibility in meeting those standards, recognizing the unique characteristics of each project and site. The Erosion Control and Stormwater Management Ordinance builds on the construction site erosion control requirements that have been in effect since 1995. The ordinance was adopted in 2001 by the Dane County Board and implemented in August 2002 through Chapter 14 of the Dane County Code.) The ordinance is not limited to unincorporated areas; it also applies in cities and villages. The ordinance is administered by Dane County for unincorporated areas and cities and villages that have not adopted standards at least as restrictive as the County's. Cities and villages that have developed their own standards that meet or exceed the County minimums administer these standards locally.

Effective January of 2006, revisions to the erosion control and stormwater management ordinance were made to meet state standards for infiltration and to make shoreland erosion control requirements of Chapter 11 consistent with Chapter 14. Dane County chose to adopt the state's infiltration standards, with few modifications. One significant change was a sunset date for the caps that limited that amount of area required to be dedicated to infiltration (State rules require only one percent of a residential site and two percent of a nonresidential site to be dedicated to infiltration). The other significant change was the elimination of the design storm approach (utilizing TR-55) to meet the infiltration requirements. The revised infiltration requirements were adopted in August of 2006, and are now effective.

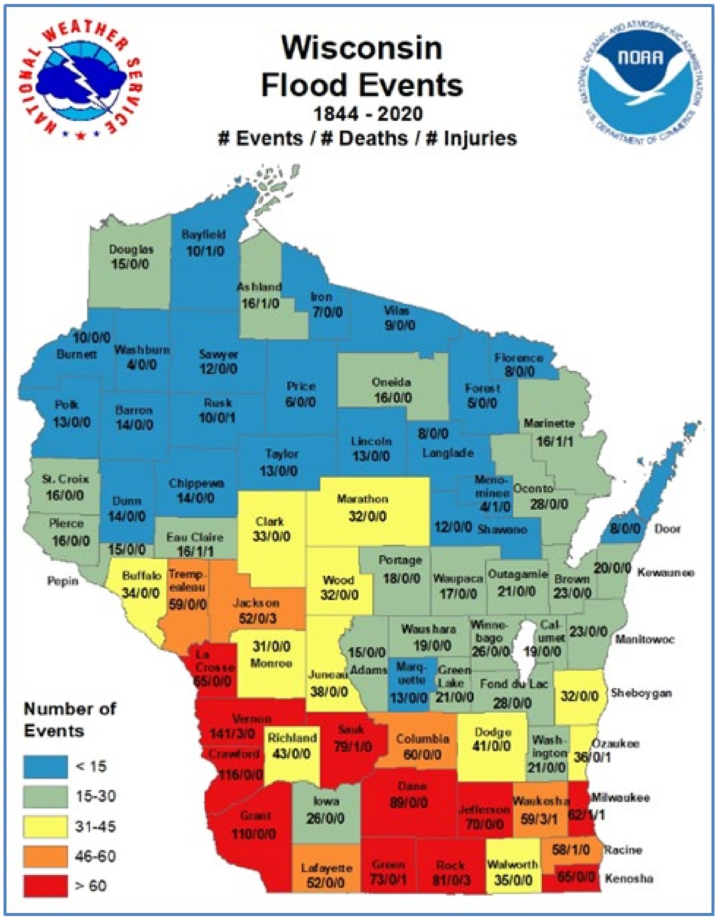
During the 2018 DCNHMP update, the Lakes and Watershed Commission and the Capital Area Regional Planning Commission (CARPC) established a Stormwater Technical Advisory Committee to evaluate the County's stormwater management strategies and make recommendations regarding flood risk reduction. The work group identified a number of limitations in the existing strategies and included a series of recommendations for modifying the Dane County Stormwater Ordinance. Throughout the planning process of the 2023 DCNHMP, CARPC and communities within the Black Earth Creek Watershed have led the Black Earth Creek Watershed Green Infrastructure Plan, a key watershed impacted in the 2018 Dane County floods. See more information in section 4.6.9.

While making recommendations regarding specific stormwater management regulatory practices is beyond the scope of the Hazard Mitigation Plan, the goals of these efforts are entirely consistent. Regular evaluation of the Stormwater Management Ordinance and an on-going effort to reduce stormwater runoff rates and volumes, have been identified objectives in the Plan since its initial inception. These efforts continue to be a priority.

4.6.2 Previous Occurrences

Dane County received Presidential disaster declarations for widespread flooding seven times since 1971. Significant damages were also recorded in 1996. Cumulative losses for these disasters exceed $65 million, including private, public and agricultural damages. Damage assessment summaries for those years are shown in Table 4.6.1. As shown, losses caused by widespread flooding have been substantial. Private and public losses shown as "estimated" are based on a compilation of local damage assessment figures. Public and private losses shown as "actual" are based on FEMA public and private assistance program payments. Agricultural losses are based on Dane County UW-Extension and USDA Farm Service Agency (FSA) estimates. Figure 4.6.3 shows the number of events, deaths and injuries related to flood events for the entire state of Wisconsin from 1844 to 2020. Dane County shows the third highest total for flood events statewide.

Figure 4.6.3 Significant Flood Events in Wisconsin



Source: National Weather Service

Table 4.6.1 Damages from major floods in Dane County (1971-2016)

Year	Disaster Type	Declaration Type	Damage Assessment
1978	Flooding and Tornados	Presidential Disaster	$180,000 (Public Assistance)
1990	Flooding and Tornados	Presidential Disaster	$37,000 (Public Assistance) $30,343 (Individual Assistance)
1993	Flooding	Presidential Disaster	$888,000 (Public Assistance) $1.44 Million (Individual Assistance) $22.6 Million (Total Damages, est.)
1996	Flooding and Severe Storms	Local Sources	$1.7 Million (Public Losses, est.) $6.8 Million (Private Losses, est.) $8.5 Million (Total Damages, est.)
2000	Severe Storms (Windstorm) and Flooding	Presidential Disaster	$940,000 (Public Assistance) $1.25 Million (Individual Assistance) $9.3 Million (Total Damages, est.)
2007	Flooding	Presidential Disaster	$0.6 Million (Individual Assistance) $1.64 Million (Public Assistance) $5.1 Million (Total Damages, est.)

Year	Disaster Type	Declaration Type	Damage Assessment
2008	Severe Storms, Tornados and Flooding	Presidential Disaster	$1.53 Million (Public Assistance) $1.76 Million (Individual Assistance) $1.64 Million (Housing Assistance) $120,000 (Other Needs)
2018	Severe Storms, Straight Line Winds, Tornados, Flooding, and Landslides	Presidential Disaster	$28,738,112.16 (Public Assistance) $8,902,520.27 (Individual Assistance) $8,003,898.67 (Total Housing Assistance) $898,621.60 (Other Needs)

Source: Dane County Emergency Management; * Federal Individual Assistance Payout; ** Federal Public Assistance Payout

A brief description of past flood events, and their impacts are listed below. More recent events are pulled from the National Centers for Environmental Information (NCEI) database.

1973

Flooding again comes to the Mississippi river as Wisconsin is declared a disaster area as one of 8 states that split $147 ($570) million in Federal aid. Then-governor Lucey estimated private and public damage at almost $2.3 ($8.9) million. Madison broke a 17-year-old, 24-hour rainfall record as streets and sewers flooded. The federal government began offering funding for repairs due to flooding, but only to those units of government with a floodplain ordinance. Dane County and most incorporated areas did not comply with Federal regulations at that time.

July 1978

Former President Jimmy Carter declared a flooding disaster for 16 southern and western Wisconsin counties—Dane included. In July, Wisconsin experienced rainfall that was 75 percent above normal. An estimated $53 ($139.8) million in damage was produced from a series of weekend storms July 8-9. Rain fell heavily throughout the state from May through September, producing a bumper crop for some farmers, but other farmers were not so lucky. In Dane County, about 9,000 acres of cropland on 800 farms were damaged in June and early July rains. Crop losses approached $2.1 ($5.5) million on 500 farms; corn and soybean crops were most severely damaged suffering $1.4 ($3.7) million in losses. Tobacco and cabbage losses were estimated at $700,000 ($1.8 million). Floodwater also eroded soil from fields and scattered debris, increasing costs to farmers. Residents in the City of Monona along Lake Monona also flooded.

Summer 1980

Heavy rains drenched central Wisconsin and Dane County. August rainfall broke the month's record, setting the bar at 9.49 inches. The National Weather Service issued numerous flash flood warnings. Madison Gas and Electric reported 15 power outages. Two hundred people were affected on Madison's west side and another 200 were affected in the Springfield area. Media outlets designated southern Wisconsin including Dane County as "rain alley."

July 1990

Torrential rains and flooding caused an estimated $14 ($18.4) million in damages in 14 counties in southern Wisconsin. In the City of Madison, 12 trees were lost due to high winds, storm sewers backed up. Several parts of the Military Ridge bicycle and hiking trail were washed out. Also, high water lifted a car off the ground on University Avenue and washed it across a parking lot. Businesses dependent upon water-based recreation lost money having to cancel boat trip due to high waters in rivers.

1993

Flooding was widespread across the County in the great Midwest flood of 1993. The flooding in 1993 was a result of above average precipitation for each month from March through August. The primary significance of the 1993 storm events was not the intensity, but the frequency. Most days during June and July had at least a minor rainfall event. Between June 28 and July 11, there were only two days out of 14 with no rain. There was also one significant individual storm during this time period, a 3.75-inch rainfall event on July 5, 1993. This was approximately a 5- to 10-year storm (10 percent to 20 percent annual probability) event. The total precipitation for this 14-day period was 7.86 inches while the average is 1.83 inches. Therefore, during most of June and July, the soils of the County remained saturated and did not have time to dry out between storms. This caused significant crop loss, and the resulting increased runoff raised most area rivers over flood stage and raised all of the Yahara Lakes to record or near record levels. Dane County received a presidential disaster declaration and was eligible for public and private assistance programs.

1996

The County experienced widespread flooding in 1996, largely as a result of a June 16-18 storm. Over this period of time, heavy rains fell over most of the region of southern Wisconsin. The National Weather Service recorded 5.25 inches of rain in Madison. The Sun Prairie Wastewater Treatment Plant recorded 5.77 inches over this same time period. Lake levels of the Yahara Chain of Lakes were within inches of all-time record highs and most rivers and streams were at or above flood stage. The flooding that resulted caused severe problems on agricultural lands as well as in the City of Madison, the City of Monona, the City of Sun Prairie, the Villages of Mazomanie and Black Earth. In the Department of Emergency Management's damage assessment, nearly every local unit of government in the County reported at least some damage to public and private facilities.

2000

The month of May 2000 was a particularly wet month in the southern half of the state. Data from the National Weather Service indicates that it was the wettest May ever recorded for most locations in southern Wisconsin, including Dane County. Generally, 8 to 12 inches of precipitation was measured, with some locations in Dane and Iowa Counties unofficially receiving between 16 and 18 inches. Normal rainfall for May is 3.14 inches. Finally, the wet rainy weather culminated in a series of severe thunderstorms and heavy rains that began on May 26 and continued into early June. Those storms dumped nearly 6 inches of rain on already saturated soils. This caused most, if not all of the rainfall to run off instead of infiltrating into the ground. The result pushed most area rivers over flood stage, raised all of the Yahara Lakes to record or near record levels, and caused severe, widespread flooding. Dane County received a presidential disaster declaration and was eligible for public and private assistance programs.

2001

2001 started very dry, beginning in the fall of 2000, with all regions of the state below 50 percent of the October precipitation average. Beginning in the winter, precipitation was highly variable and the state went through a series of wet and dry spells. However, by May the central and southern portions of the state had received 160 percent of normal precipitation. After a July dry spell, severe thunderstorms on August 1-2 dumped heavy rain over a large portion of Dane County. Most areas of the County received between 2 and 5 inches of rain. The heaviest rainfall was centered over the northwest portion of Dane County. An unofficial, but credible report to the National Weather Service indicated that an 11-inch capacity rain gage had overflowed in the Village of Black Earth. Flash flooding occurred in the Black Earth Creek with significant impact to the Villages of Black Earth and Mazomanie. Flash flooding also occurred in Roxbury Creek, causing a significant impact on the village area in the Town of Roxbury.

June 9-12, 2004

Scattered, widespread heavy rains across south-central and southeast Wisconsin during this period kept many rivers and streams at or above flood stage for most of the month. Monthly rainfall totals generally ranged from 4 to 7 inches across south-central and southeast Wisconsin. During this time, high water levels submerged most of the bottom-level land near rivers and streams; closed some major state highways; forced water into basements; damaged corn, soy bean, and alfalfa crops; delayed planting of entire fields; washed out gravel road shoulders; and damaged foundations of homes and businesses. In general, the flooding was the worst since 1993 on a widespread basis and locally in the past 25 to 30 years. Federal Disaster Declaration 1526 covered all 20 counties in south-central and southeast Wisconsin for storms, tornadoes, and flooding for the period of May 19-July 3, 2004. All counties qualified for "individual assistance". In Dane County, lake levels were 1 to 3 feet above normal. Minor basement flood damage to 127 homes, and major damage to 3 homes, was reported and property damages were estimated at $1 million. Estimated crop losses were $3 million.

July 27, 2006

A 1-in-a-100-year flash flood occurred from the west side of Madison to around the Capitol Square after 3 to 5 inches of rain fell within a 90 minute timeframe. There were no reports of injuries or deaths. The heavy rain resulted from slow-moving and back-building thunderstorms that essentially remained nearly stationary over the city of Madison. The hilly terrain and a typical urban setting of concrete and asphalt enable the runoff water to quickly overwhelm the storm sewers and concentrate water in low-lying areas of the city. Water depths reach to the top of small vehicles - 4 to 5 feet deep in spots. Many roads became impassable due to the flood waters, and many residential homes and businesses on or near the UW-Madison campus had flooded basement and first-floor flooding. Some basement apartment units had water depths of 6 to 8 feet. Nearly all campus buildings had flooding of varying degrees of intensity, and the Camp Randall football field sustained damage. Some campus buildings had flat roofs that quickly flooded as storm drains became plugged, which allowed water to run through the walls and ceilings of buildings. The buildings that sustained the most damage were the Memorial Union, Computer Sciences, and Veterinary Medicine. Numerous vehicles on or near the campus were damaged or totaled by the flood waters, and some were reported to be floating away. Unofficial rain gages measured 4.5 to 5 inches from just west of West High School up to the Capitol Square. WSR-88D Doppler rainfall estimates were in the 3 to 5 inch rain. Rainfall amounts quickly fell off to 1 to 1.5 inches near the south Beltline.

August 23 and August 24, 2006

A stagnant weather pattern on August 23rd and 24th resulted in waves of heavy rain and severe thunderstorms. A warm front pushed north during the afternoon of August 23rd. A very unstable air mass with moderate shear caused thunderstorms to break out during the afternoon and continue through most of the overnight as a warm front moved north through the area. After a brief respite of only 3 hours during the morning hours of August 24th, more storms developed during the late morning and afternoon hours. More heavy rain, large hail, damaging winds, and vivid lightning resulted from these storms. Urban flooding in Dane and Kenosha counties caused a few hundred thousand dollars in structural damage. Some two-day rainfall totals across Dane County include 5.70 inches in Oregon, 5.38 inches in Cottage Grove, 3.26 inches in Middleton, 2.77 inches at Beloit College, and 2.73 inches at Madison Truax Field.

August 22, 2007

Flash flooding occurred due to repeated thunderstorms with heavy rains on top of a saturated ground. From Madison to Sun Prairie many roads had fast-flowing water depths of 6 inches to 1 foot, and several were closed. Sandbagging also took place to control the flash flooding. A 1-hour rainfall total of 2.26 inches was measured by a spotter in Madison. Soil erosion and crop damage also occurred on several other farms in that area. Additionally, a few basements had water damage to contents. August, 2007, rainfall totals in inches include: 15.18 at Madison Truax Field, 14.58 at the UW-Charmany Farm, 14.92 at Mazomanie, 14.43 in Middleton, 18.48 near Mt. Horeb, 16.37 in Stoughton, 15.74 in Sun Prairie, and 13.49 at the UW Arboretum. Up to 20 inches may have fallen in the southwest corner of the county. During the afternoon and evening hours of August 22nd, the second round of storms for the calendar day moved across south-central and southeast Wisconsin. The clusters or short lines of storms moved east at a speed of about 30 knots (35 mph), and generated damaging downburst straight-line winds that toppled trees and power-lines, and heavy rains that triggered flash flooding. Synoptically, a stationary front stretched from northern Iowa to Wisconsin/Illinois border. Warm, moist, unstable air flowed north over the front in association with an upper-level short-wave trough, resulting in thunderstorm generation. Hourly rainfall rates peaked around 2 inches. By the end of August, 2007, many locations in south-central and southeast Wisconsin established new August rainfall records and all-time/any month rainfall records. Many locations measured 10 to over 20 inches for the month of August, 2007, or about 200 percent to over 400 percent of normal. Normal August precipitation in southern Wisconsin is about 4 to 4.25 inches.

June 7, 8, & 12, 2008

Heavy rains resulted in flash flooding as water reached depths of 3 feet or more and several cars stalled. This was the last of 6 flash floods in Dane County on 3 different days. The first one occurred on June 7th, the next two on June 8th, and the last three on June 12th. In all six cases, damage to homes, businesses, and crops was noted. It was nearly impossible to break down the damages by flash flood event. Therefore, the collective breakdown is provided in this last June 12th flash flood storm data entry for Dane County. Some farm fields remained flooded into early July. The breakdown for residential home losses were: 2,020 minimally affected, 248 with minor damage, 109 with major damage, and 3 destroyed (total of $6.797 million). The breakdown for business losses were: 152 with minor damage, and 3 with major damage (total of $677 thousand). Crop losses were estimated at $64.6 million. Public sector damage was about $6.067 million. Several roads and bridges sustained damage. A series of clusters of strong to severe storms ahead of a cold front moved east/northeast across south-central and southeast Wisconsin. Copious amounts of moisture were available that allowed repeated heavy rains. Additionally, there was sufficient vertical wind shear to allow for the generation of supercell thunderstorms with rotating updrafts that led to seven tornadoes in this part of the state of Wisconsin.

Spring, 2009

Flood problems began in early March, 2009 in some areas of the County, notably the northern portion. Road flooding and some residential flooding was reported in the towns of Vienna and Roxbury. Fish Lake and Crystal Lake in the Town of Roxbury were threatening residential properties with rising lake levels. Substantial rainfall on still-frozen ground may have been a contributing factor to this flooding. Several roads were underwater and closed around Crystal Lake. 22 Recreational vehicles or other structures at the Crystal Lake RV Resort and Campground were substantially damaged.

August 22, 2010

Parts of south-central and southeast Wisconsin experienced several rounds of record-setting torrential heavy rains during the afternoon and evening hours of July 22, 2010 that led to flash flooding and damage. During the afternoon, a persistent band of strong to severe thunderstorms developed and moved very slowly over south central and southeast Wisconsin through the evening hours. The individual storms were moving quite fast, about 40 to 50 mph, but the slow southward movement of the boundary these storms were developing along, resulted in storms repeatedly training, or moving, over the same area. Widespread 3 to 4 inch amounts were reported along and either side of the I-94 corridor, with locally higher amounts of 5 to 8 inches. Madison set a record for precipitation for the date at 3.62 inches. This beat the previous mark of 2.21 inches set in 1885. The 3.62 inches of rainfall ranks 13th for the most precipitation received in one day. Training thunderstorms produced 2.5 to 4.5 inches of rain in about two hours over mainly the northern half of the county. Street flooding stranded cars in Sun Prairie, various locations in the city of Madison, Oregon, Middleton and DeForest. Three to four feet of water covered the intersection of Commercial Avenue and Kroncke Road in Sun Prairie, stalling cars and filling some home basements and commercial buildings with water, damaging their contents.

June 21-27, 2013

During the period of June 21-28, 2013, parts of Wisconsin experienced historic 24-hr, 48-hr, 72-hr, and 7-day rainfall amounts which had a statistical frequency of about once every 100 to 500 years. Several rounds of thunderstorms with heavy rains occurred, with total weekly rain amounts of 6 to over 13 inches, and some 24-hr totals of 5 to over 7 inches. This resulted in river flooding, mud-slides, damaged buildings and closed roads. Some river gauge sites experienced major flooding levels and record crests. Hourly rainfall rates with some of the strongest storms reached 1 to 2 inches per hour which led to localized flash flooding. By the end of the June 21-27, 2013 period Madison had experienced its wettest year on record to date: 30.58 inches, or 14.81 inches above normal. Similar conditions existed at other locations in southwest and south-central Wisconsin. The Yahara River gage at Fulton set a new all-time crest on June 26th in the major flooding category at 12.06 feet, breaking the old record of 11.16 feet set on July 18, 1996

June 14, 2016

A surge of warm and moist air on a low level jet stream brought a large thunderstorm complex across southern WI from the evening into the early morning hours. Heavy rain and isolated flash flooding occurred. Highway F was flooded and closed between highway FF and Pleasant Valley Road due to the flash flooding of the east branch of Blue Mounds Creek. There were also shoulder washouts on highway F between Moyer Road and Zwettler Road. There were also shoulder washouts on highway JG between Little Norway Road and North Road. Approximately 5 to 7 inches of rain had fallen in about 5 hours.

July 21, 2016

Persistent warm and moist advection over an outflow boundary triggered thunderstorms over west central WI that organized into a large and slow moving squall line. The slow moving line of storms produced numerous areas of straight line wind damage and some areas of flash flooding over southern WI during the late afternoon and evening hours. Multiple intersections on the west to southwest side of Madison and in Middleton are flooded and impassable after 3 to 3.5 inches of rain in approximately 2 hours. Vehicles were stalled or stranded by the deep water. Water in some residential basements and some businesses flooded. 50,000 to 75,000 gallons of untreated wastewater was discharged into the public storm sewer system in Middleton.

2018

A severe storm swept across Dane County the evening of August 20, 2018 dumping up to 15" of rain in less than three hours. The heaviest rain occurred North of the City of Verona, on the West side of the cities of Madison and Middleton and along the US Hwy 14 / Black Earth Creek corridor. The storm flooded intersections, overwhelmed storm water drainage systems causing storm water to flow over roadways and into buildings, overtopped sanitary sewer lift stations causing sewer backups inside buildings, overflowed water retention features, and washed away multiple roadways and one two land bridge on U.S. Hwy 14 west of Black Earth.

The municipalities in the Black Earth Creek / U.S. HWY 14 corridor including the City of Middleton, Villages of Cross Plains, Black Earth, and Mazomanie, and the towns of Middleton, Cross Plains, Berry, Black Earth, and Mazomanie generally suffered damage from overland flooding to both public and private facilities. The Cities of Middleton and Madison suffered damage to public infrastructure and also a large concentration of sanitary sewer back-ups.

The vast majority (96% +) of Individual Assistance claims were outside of mapped flood plains.

Assessment of Past Flood Occurrences

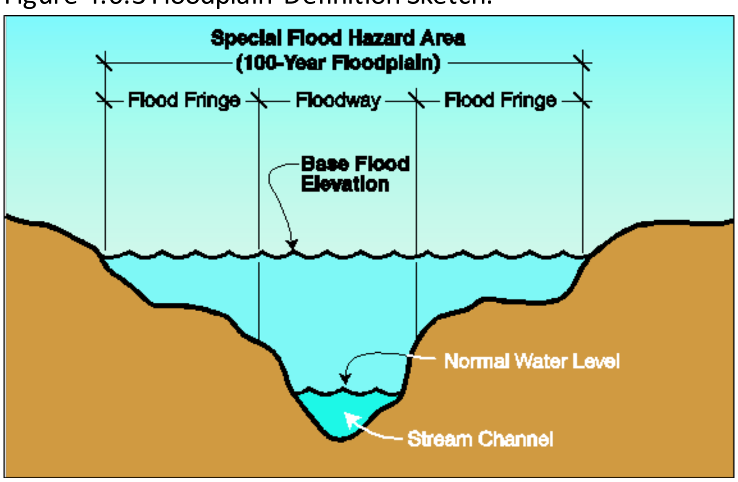
During the development of the initial Flood Mitigation Plan (2003) a comprehensive assessment of the impacts and problems associated with floods in Dane County was performed using a combination of government expertise, recorded events, and GIS spatial analysis. The results of this planning process are still used in flood mitigation strategy in Dane County today. An assessment of past flood events shows that there is a wide range of factors that contribute to flooding problems.

Development in Flood-Prone Areas (Areas with Inherent Flood Risk)

There are areas of the County that have an inherent risk of flooding and resulting flood damage if developed. These typically are areas that in their natural state, are associated with floodplains, low lying shore lands, wetlands (existing or drained) and steep slopes with highly erodible soils.

- *Floodplains*. Developing and building in areas with a natural flood risk is a well-documented cause of subsequent flood damages. The floodplain is very simply the land that has been or may be covered by floodwater during a flood. A cross-sectional view of a typical floodplain is illustrated in Figure 4.6.3. To build or develop in a floodplain exposes the owner to an inherent risk of flooding at some point in the future.

Figure 4.6.3 Floodplain Definition Sketch.



Source: FEMA, 2001.

The locations and delineation of floodplain boundaries are not a static representation of flood risk. Floodplains change over time. Though they are represented as a line on a Flood Insurance

Rate Map (FIRM), floodplains and flood risk are not black and white. The floodplain maps are designed to indicate areas with a risk of flooding, but those areas are constantly changing. Increasing impervious surface areas with new development, soil saturation, rainfall intensity, stream conditions, shoreland and wetland modifications (both restoration and degradation), and stormwater management practices all affect the extent to which flooding will occur.

In addition to this, there is a widely held perception that the 100-year floodplains shown on a FIRM represent a clear boundary of flood risk. On one side of the line, there is a flood risk, on the other side, there is not. This is not what the maps are intended to show. Flood risk is a continuous spectrum and the floodplains shown on the FIRM represent but one increment of that spectrum, the 1 percent probability of flooding. For regulatory and insurance purposes, a line has to be drawn somewhere. There is a danger in using this line as the end-all in determining flood risk. The maps are intended to represent the risk as accurately as possible, but they are merely a prediction of the extent of flooding that could occur in the future, based on a snapshot of present and past conditions.

- Hydric Soils. Though mapped/regulatory floodplains are a good predictor where flooding occurs, floodplains do not account for all of the flooding in the County. The location of certain soil types, hydric soils in particular, is also a good predicator of where flooding is likely to occur. Hydric soils are formed under conditions of saturation, flooding, or ponding long enough during the growing season to develop anaerobic conditions in the upper part. They are a good indicator of the historic locations of wetlands or other wet areas. As such, development in areas with hydric soils is another prime indicator of where flood damages are likely to occur, especially in areas where urbanization has not altered the natural hydrology of the area.
- Topography. The topography of the County affects the spatial extent of flooding. In the western portion of the County where topography is most exaggerated, flooding occurs in small areas, yet the water flow rate is much higher than in the eastern part of the County. There, landowners experience expansive flooding, since the water is able to spread across the landscape more easily. Topography and hydric soils are useful indicators of the frequency and extent of flooding outside the floodplain.

Figure 4.6.4 shows the locations of floodplains and hydric soils in Dane County.

Other Factors Contributing to Flood Losses

Traditional concepts of floodplain flooding and construction in known flood risk areas does not tell the whole story of flood losses and damages in Dane County. Dane County is primarily a drainage area. The County fully or nearly fully contains the headwaters of most of the rivers and streams that flow through and out of the County. While there are predictors of where floods will occur and the impacts that will result, there are a number of other factors that contribute to flood losses in the County.

- *Lake Levels*. The Yahara River chain of lakes runs directly through the most urbanized areas of Dane County. Flooding of streets and homes occurs in low areas surrounding the lakes when lake levels rise. Urbanization and increasing impervious surface areas tend to increase both the rate and the volume of stormwater runoff. Particularly in the case of the Yahara Lakes, it appears that the lakes are acting as a large wet detention basin, holding ever-increasing volumes of stormwater runoff. Flood problems associated with the high levels in the Yahara chain of lakes is exacerbated by slow drainage of the Yahara into the Rock River. Following periods of heavy rain, or sustained rains with saturated soils, the lake levels tend to rise rapidly, but take a long time to return back to normal levels. High water conditions can last for weeks at a time.

  - Annual maximum water levels of Lake Mendota have been generally increasing, with eight of the ten highest Mendota lake levels over the past 100 years occurring since 1978. The maximum annual levels of Lake Monona have also been generally increasing since about 1980, with seven of the ten highest Monona levels over the past 100 years occurring since 1993. These increases coincide with the increase in impervious surfaces from urban development in the watershed.
  - High levels on Lake Koshkonong have also resulting in significant property damage in the Town of Albion. In fact, there have been more flood insurance claims, and higher damage totals on Lake Koshkonong than any other single location in the County. Many of these properties have been elevated above the base flood elevation in accordance with NFIP and Wisconsin Administrative Code NR-116. Flood related problems still exist in this area and like the Yahara, these problems are exacerbated by slow drainage.
  - High lake levels in the Crystal Lake, Fish Lake, Mud Lake system in the Town of Roxbury have also been a source of flood damage to homes and roads. A number of mitigation actions have been implemented in this area, including acquisition and demolition of flood prone homes and the elevation of town roadbeds. The Fish, Crystal, and Mud Lake Rehabilitation District has also implemented a pumping system to reduce water elevation.

- *Impediments to the Flow of Water*. Changes in stream conditions and impediments to the flow of water were identified as a significant factor in increasing flood problems along the rivers and streams of the County. Impediments to flow reduce the overall capacity of the stream to convey water and cause water to back-up behind the blockage. These impediments include blockages caused by accumulation of sediment, over growth of weedy, non-native vegetation, or excessive debris in the stream channel. Reduced conveyance capacity and blockages can and do occur in all components of the natural and human-made components of the drainage system, including detention ponds, stream channels, drainage ditches and culverts.
- *Debris in the Drainage System*. Debris in streams has been identified as a significant problem in numerous areas of the County. Debris refers to a wide range of materials that may include tree limbs and branches that may accumulate naturally or garbage and trash that has been dumped into channels or drainage ditches. There is often a very fine line between debris that should be removed to improve conveyance capacity and natural material that is necessary for fish and wildlife habitat.
- *Silt and Sediment*. Silt and sediment has also been identified as a significant impediment to flow in numerous streams and ditches of the County. Farmlands and construction sites typically contain large areas of exposed soil. Surface water runoff can erode soils from these sites and

carry sediment into downstream waterways. Erosion also occurs along streambanks and shorelines as the volume and velocity of flow destabilizes the banks and washes away the soil.

Sediment suspended in the water tends to settle out where the flowing water slows down. It can clog storm sewers, culverts, and ditches and reduce the water conveyance capacity of rivers and streams. Not only is the drainage system less able to carry water, but the sediment in the water also reduces light, oxygen, and water quality and often carries agricultural chemicals and other pollutants into the water. The erosion control elements of the County's Stormwater Management and Erosion Control ordinance are designed to address these issues. Even with the ordinance in place, however, streams that are currently restricted by sediment will remain restricted unless the existing sediment is removed.

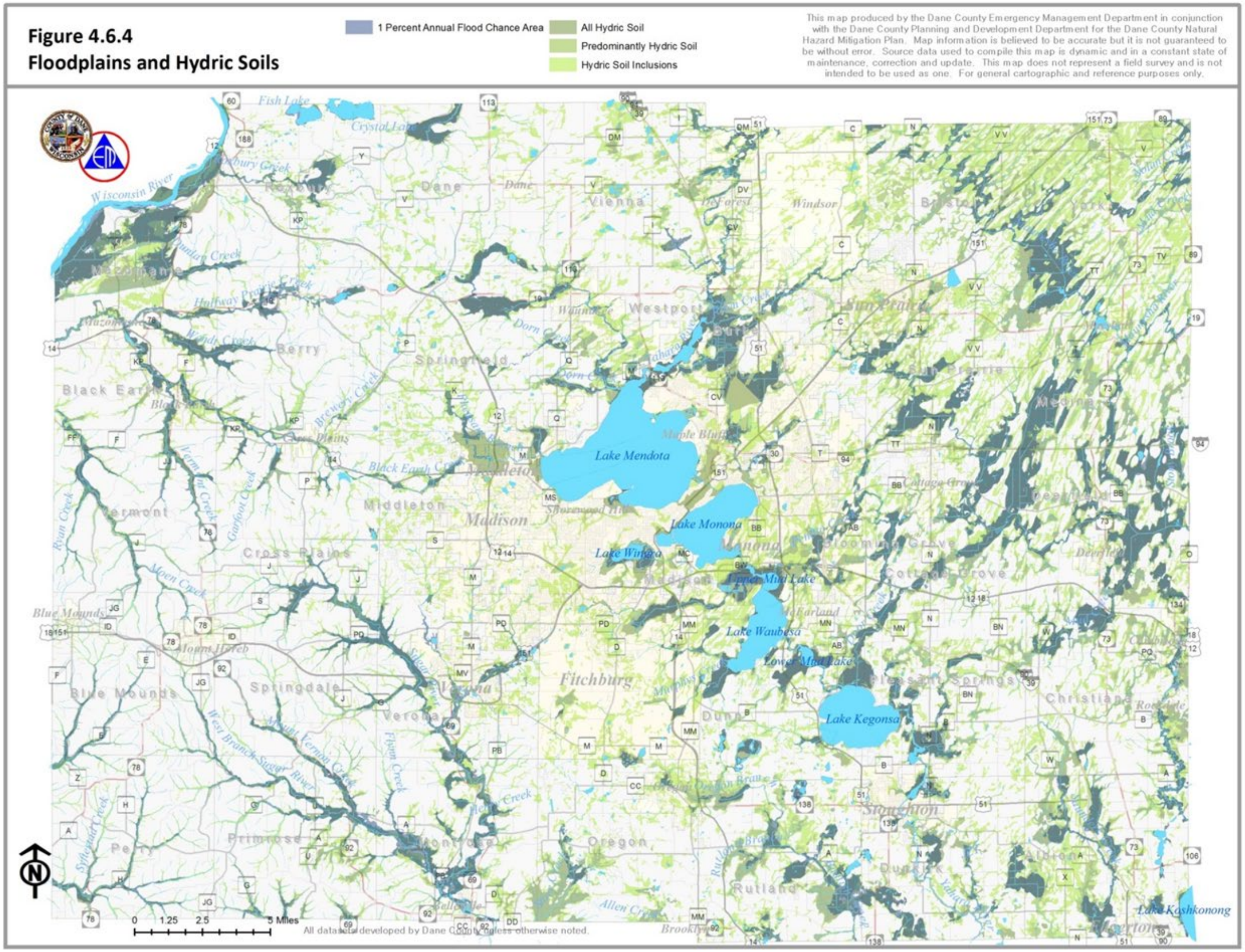
- Human Constructed Impediments to Flow. Bridges, culverts, and drainage ditches that are improperly sized have been noted as a significant factor in restricting the flow of water and exacerbating flood problems. This does not appear to be a systemic problem, but rather one that occurs in a few, specific isolated areas of the County.
- Loss of Wetlands. Wetlands are often found in floodplains and low-lying areas of a watershed. Many wetlands receive and store floodwaters, thus peak flows and volumes of floodwaters. Wetlands also serve as a natural filter, which helps to improve water quality. Wetland loss has affected all of Dane County. Wetlands have been tiled and drained to produce fertile farm fields and they have been filled and paved to prepare for development. Wetlands on the Yahara Chain of Lakes have also been lost during recent flood events as rising floodwaters detach and lift sections of marsh. The floating marsh sections have been subsequently removed to eliminate the navigational hazards they posed. Lakes in the Yahara Chain of Lakes have lost between half and nearly all of the wetlands associated with them since 1835.

  Healthy wetlands have the potential to store large volumes of floodwater. As wetlands become destroyed or degraded, their capacity to store water may be reduced. Water that would otherwise have been stored in the wetlands then contributes to increasing flood levels and flows. The maintenance and restoration of wetlands has the potential to be a very effective flood management tool.
- Stormwater Issues. Dane County is among the fastest growing and developing counties in the State of Wisconsin. The challenges of managing this rapid development are wide-ranging; however, one of the more significant impacts is the effect of development on the hydrology of the watershed. The effect of upstream development on downstream properties was widely recognized as significant contributing factor in Dane County's flood problems. In fact, development and other changes to the landscape in areas far outside the floodplain can have a profound impact on the magnitude and frequency of downstream flooding. This is a highly complex issue that includes elements of land-use decision-making, property rights, intergovernmental cooperation (or lack of), as well as the hydrology of the watershed and stormwater management practices. Many of these elements are well beyond the scope and charge of this Plan, however, the issues as related to stormwater management can at least be framed here.

- The Effects of Urbanization. Urbanization is one of the most severe land use impacts in terms of its lasting effects on hydrology, due to the much higher percentages of impervious or paved areas covering the land. Rural land surfaces are almost completely pervious, while about one-third of the land surface in urban areas is covered by rooftops and paved areas. The main effects of urbanization on the hydrology of an area include:
  - An increase in the total amount of rainfall running off the surface of the land.
  - A decrease in the amount of rainfall infiltrating into the soil.
  - More rapid runoff and much higher peak flows.
  - Reduced base flows in streams during dry weather periods.

  In addition to generating more surface runoff, which erodes the land surface and washes off more pollutants, the hydrologic effects of urbanization have less direct but more important downstream impacts. The increased peak storm runoff rates and reduced base flow associated with urbanization have serious negative impacts on receiving streams, usually resulting in erosion, sedimentation, streambank instability, and flooding. Combined with reduced base flow, the scenic, recreational and habitat values of the receiving streams can be seriously degraded unless a vigorous effort is made to provide management practices and programs to counter the effects of urbanization.

Figure 4.6.4 – Floodplains and Hydric Soils



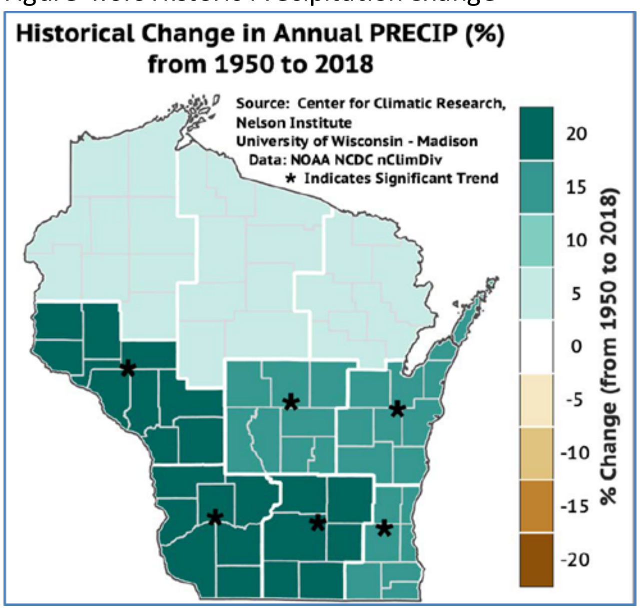
4.6.3 Impact of Climate Change on Future Conditions

The flood hazard in southern Wisconsin, including Dane County, is changing and all indications are that the risk is increasing. The Wisconsin Initiative on Climate Change Impacts (WICCI) is the primary source for the assessment of Dane County's changing flood risk.

Climate Trends

Wisconsin experienced a 10% increase in average annual precipitation over the 56-year period from 1950 to 2006. Wisconsin as a whole has become wetter, with an increase in annual precipitation of 3.1 inches. This observed increase in annual precipitation has primarily occurred in southern and western Wisconsin, while northern Wisconsin has experienced some drying. (WICCI, 2009). Dane County has seen an annual average increase in between 4.5 and 7 inches of precipitation over this time period. Figure 4.6.6 shows the statewide distribution of changes in annual average precipitation in this time period.

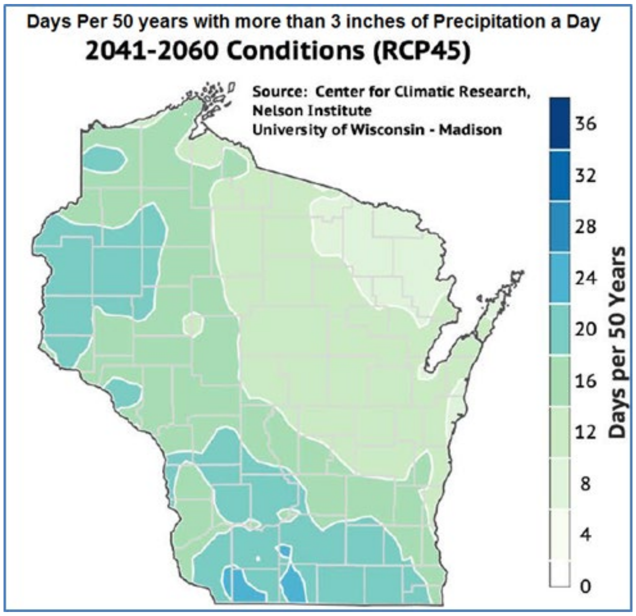
Figure 4.6.6 Historic Precipitation Change



In addition, both the frequency and magnitude of heavy rainfall events have been increasing. Madison, for example, has experienced a large number of intense precipitation events in the past decade: 24 days of two inches or more rainfall (compared with the previous maximum of 12 per decade since the 1950s) and nine days per decade of three inches or more rainfall (nearly as many as the previous five decades combined) (Wisconsin Initiative on Climate Change Impacts, Wisconsin's Changing Climate, Impacts and Adaptations, 2021).

Climate models suggest that these trends will continue, with an overall increase in wetter conditions and more intense rainfall. This trend is likely to lead to a subsequent increase in the severity and frequency of high flows and high water levels. Figure 4.6.7 indicates one model's projected change in annual average precipitation from 2041 to 2060.

Figure 4.6.7 Days per 50 years with more than 3 in Precipitation



Source: WICCI, 2021

Typically, heavy precipitation events of at least two inches occur roughly 12 times per decade (once every 10 months) in southern Wisconsin and 7 times per decade (once every 17 months) in northern Wisconsin. Based on one emission scenario, by the mid-21st century, Wisconsin may receive 2-3 more of these extreme events per decade, or roughly a 25% increase in their frequency. Figure 4.6.8 indicates the projected change in the frequency of 2" or greater precipitation events in days per decade in the 1981 to 2060 time period.

Seasonal Variations in Precipitation

(Wisconsin Initiative on Climate Change Impacts, Wisconsin's Changing Climate, Impacts and Adaptations, 2021)

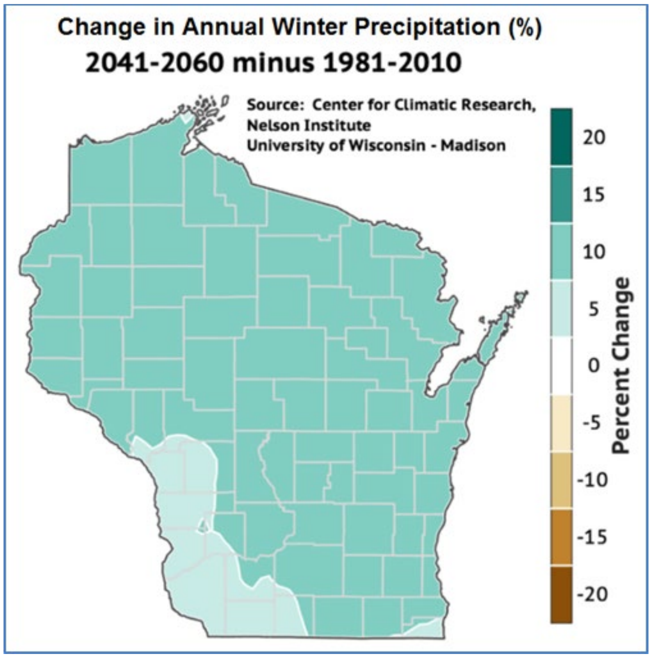
Spring: WICCI projections indicate trends more precipitation and more frequent intense events, especially during early spring. As in winter, early spring precipitation is more likely to fall as rain than as snow.

Summer: Summertime precipitation projections are less certain, with little agreement among climate models. This creates difficulty in predicting impacts from precipitation, or lack thereof, during summer.

Autumn: Fall precipitation is projected to increase slightly by the middle of the next century.

Winter: Winter precipitation is projected to increase. The amount of precipitation that falls as rain rather than snow is expected to increase significantly, and freezing rain is more likely to occur. As a result, snowfall, snowfall depth, and extent of snow cover are expected to decrease.

Figure 4.6.8 Change in Annual Winter Precipitation



Source: WICCI, Historic Trends and Projections, 2021

Uncertainty in Projecting Future Conditions

Although climate change effects are already being observed, the earth's climate is an immensely complex system. Although observations, theory, and climate models continue to improve, any attempt at predicting future climate conditions is bound to have uncertainty in the resulting projection. This uncertainty does not mean that scientists and climate experts don't know anything about future conditions. In fact, climate scientists have a great deal of certainty that human activities are causing the planet to warm and this warming is in turn, driving an increase in extreme weather events.

It is becoming clear that historic patterns can no longer be used to predict future climate conditions, particularly when it comes to stormwater management and flood risk management. Planning based on historical climate conditions that no longer exist can actually make the community more vulnerable to current and future conditions.

Implications

WICCI's most recent predictions indicate that annual average precipitation may continue to increase through 2060, including a higher incidence of more "extreme" rainfall events (those that generate more than six inches of precipitation in a 24-hour period). The expected increases in rainfall frequency and intensity are likely to put additional stress on natural hydrological systems and community stormwater systems. Floodplain developments and low income communities in urban areas are among the areas most vulnerable to increased flooding.

Heavier snowfalls in the winter will lead to intensified spring flooding, and groundwater levels will remain high even in non-floodplain areas. Such changes in climate patterns can lead to the development of compounding events that interact to create extreme conditions. This confluence of events was observed in 2008 and 2018, when saturated spring soils and a record late summer early fall rainfall combined to create the most damaging floods in state history. Some areas that are not in mapped floodplains may experience unexpected groundwater flooding, as observed during past flood events in Spring Green, and locally, in the Town of Vienna. Flooding caused by high groundwater levels typically recedes more slowly than riverine flooding, slowing the response and recovery process. Groundwater-fed rivers and streams are also likely to experience heightened flooding when groundwater levels are high.

Jurisdictions updating or installing stormwater management systems should consider potentially larger future discharge amounts when sizing culverts and drainage ways; storage capacity can also be increased by building retention basins to hold excess stormwater. Communities already prone to flooding should be prepared for a potential increase in facility closures and/or damages, as well as an increase in public demand for flood response and assistance. Natural features that experience repeated flooding may manifest changes in the form of stream bank instability and changing shoreline, floodplain, and wetland boundaries. Communities may also wish to plan for the potential loss of cropland and damage to both private property and public infrastructure such as bridges.

The environmental impacts of flooding include erosion, surface and groundwater contamination, and reduced water quality. The threat of more frequent flood events may thus be a concern particularly for communities who depend on lakes, rivers, or trout streams for tourism. Rural communities may experience increases in well contamination and road washouts, while urban areas may be particularly vulnerable to flash flooding as heavy rain events quickly overwhelm the ability of a more impermeable environment to absorb excess stormwater. (Wisconsin Emergency Management, Wisconsin Threat and Hazard Identification and Risk Assessment, 2021)

4.6.4 Impact Assessment

Because of the varied nature and widespread damage floods cause, this profile is not discussed in terms of direct and indirect potential impacts. Instead, each area that flooding impacts is broken down and explained, including an analysis of both direct and indirect impacts. Specific examples of how floods negatively impact Dane County are summarized below:

- Floods cause damage to private property that often creates financial hardship for individuals and families.
- Floods can cause injury and death.

- Floods cause damage to public infrastructure resulting in increased public expenditures and demand for tax dollars.
- Floods cause loss of personal income for agricultural producers that experience flood damages.
- Floods cause loss of income to businesses relying on recreational uses of County waterways.
- Floods cause emotional distress on individuals and families.

Most homeowner's policies do not cover damages caused by flooding. Flood loses are covered under a separate flood insurance policy sold through the National Flood Insurance Program (NFIP). Only a small percentage of home owners actually have flood insurance policies. This means that when flood damages do occur, the costs to repair and recover from the loss are uninsured losses that are borne almost entirely by the property owner.

Building Damage

In terms of numbers of people affected and total economic losses, damage to buildings, especially residences is usually the County's largest single flood problem. Due to the relatively shallow flood depths, soaking causes the most common type of damage inflicted by a flood. When soaked, many materials change their composition or shape. Wet wood will swell and, if dried too quickly, will crack, split or warp. Plywood can break apart. Gypsum drywall will fall apart if it is bumped before it dries out. The longer these materials are wet, the more moisture, sediment and pollutants they will absorb. Walls present a special problem: a "wicking" effect pulls water up through wood and wallboard, soaking materials several feet above the actual high-water line. Structural damage to buildings has not been a systemic problem in Dane County.

Soaking can also cause extensive damage to household and other building contents. Wooden furniture may become so badly warped that it cannot be used. Other furnishings such as upholstery, carpeting, mattresses, and books usually are not worth drying out and restoring. Electrical appliances and gasoline engines will not work safely until they are professionally dried and cleaned. In short, while a building may look sound and unharmed after a flood, the waters can cause a lot of damage. To properly clean a flooded building, the walls and floors should be stripped, cleaned, and allowed to dry before being recovered. This is expensive and can take weeks.

Sewer and Wastewater

Sewer and wastewater service and infrastructure are compromised during flooding events in many locations around the County. Sewer backups in residential basements are the primary result of overtaxed wastewater systems. Past surveys have identified 100's of residences that have had sewer backup problems. During major storm events, flows to the treatment plants increase, and in some cases triple due to water infiltration into the piping system. Failing pumps, and inflow meter damage, are also a problem.

Road, Shoulder, and Ditch Flooding

There are a number of areas of the county prone to flooding on roadways. A possible contributing factor is under-sized culverts that become damaged during high water flows. Very few bridges have been damaged though they may play a role in constricting water flows. This flooding, and often-associated road or ditch damage, inhibits emergency vehicle movement and could compromise public safety.

Farmland Flooding

Dane County is the one of the most fertile counties in the state of Wisconsin, and as a result farming plays a major role in the local economy. Flooding of farm fields and crop loss is an additional stress on an already highly stressed profession. The amount of crop loss in the County per acre varies across the landscape depending upon the topography—generally the more flat the land the more pervasive the problem. The east side of the County experiences relatively severe crop losses on occasion; the west side of the County, though not without this impact, is less affected. Crop loss is capricious—timing of storms, duration of standing water, and type of crops play a part. Prolonged flooding occurring while crops are immature can lead to total crop loss for a year. Corn, for instance, has difficulty withstanding flooded soil. Flooding of short duration or later in the growing season may have little or no effect on the harvest.

Erosion and Stream Pollution

Due to the agricultural character of rural Dane County, erosion is a concern. Ditches that once conveyed water quickly have become laden with soil, decreasing their capacity to convey water. Construction sites also contribute to siltation in streams. Siltation and trash also compromise stream quality.

Ongoing and successful stream restoration projects, and the depositing of organic materials in streams, increase woody matter in stream channels. The buildup of organic material slows water flows. Woody material builds up along the buttresses of bridges and other human-made obstructions in the river channels and alongside river channels themselves. While the slowing of water may be beneficial for downstream residents, areas where the build-ups occur increase the risk of flooding.

Public Health and Safety

There is very little available data on health problems caused by flooding in Dane County because data collection mechanisms are varied, particularly in terms of reported occurrences versus actual occurrences. The first impact comes from the water itself and is considered the direct impact of flooding. Floodwaters carry whatever was on the ground that the upstream runoff picked up, including dirt, oil, animal waste, and lawn, farm and industrial chemicals. This can contribute polluted waters to the receiving streams.

Floodwaters saturate the ground, which can lead to infiltration into sanitary sewer lines. When wastewater treatment plants exceed capacity, there is nowhere for the sewage to flow. Infiltration and lack of treatment lead to overloaded sewer lines that can back up into low lying areas and homes. Even though diluted by floodwaters, raw sewage can be a breeding ground for bacteria, such as E.coli, and other disease causing agents.

The second set of health concerns occur after the water is gone, and are considered indirect impacts of flooding. Stagnant pools become breeding grounds for mosquitoes, and wet areas of a building that have not been cleaned breed mold and mildew. A building that is not thoroughly and properly cleaned becomes a health hazard, especially for small children and the elderly. Another health hazard occurs when heating ducts in a forced-air system are not properly cleaned after inundation. When the furnace or air conditioner is turned on, mold and sediments left in the ducts are circulated throughout the building and breathed by the occupants.

Finally, flooding creates long-term psychological impacts on victims. The cost and labor needed to repair a flood-damaged home puts a severe strain on people, especially the unprepared and uninsured. There is also a long-term problem for those who know that their homes can be flooded again. The resulting stress on floodplain residents takes its toll in the form of aggravated physical and mental health problems. This is also considered an indirect impact of flooding.

4.6.5 Vulnerability Assessment

Population

Historical data yields little information on deaths or injuries by flooding and flash flooding in the County. This is likely due to the slow-rise nature of flooding around lakes and lowlands, giving people adequate time to evacuate. Most flood-related deaths and injuries around the country are associated with persons who try to drive vehicles into flooded roads and underestimate the depth and velocity of floodwaters.

There are also portions of the population that are especially vulnerable to the direct and indirect impacts of flooding. The quality of one’s housing and living conditions affects an individual’s vulnerability to flooding and extreme storms. Residents living in poor quality housing and populations without access to housing or a strong social network are at higher risk of adverse health impacts from flooding. Financially insecure households often lack the resources necessary to prepare for, mitigate, or recover from the health impacts of flood events. The impoverished are also less likely to have access to health networks and receive treatment for preventable conditions associated with the secondary impacts of flooding.

Property

Flooding of residential structures in Dane County is a major concern. This type of flooding has several causes: river flooding, high lake levels, sewer backups, stormwater runoff from urban areas as well as farmland, and high groundwater. Effects include flooded basements and first floor flooding. As the assessment of the 2008 flood claims information (in a subsequent section, beginning on page 4-52) shows, damages caused by flooding in Dane County is not restricted to mapped floodplains or any other readily identifiable indicator. Under the right (or wrong) conditions, intense heavy rains have the potential to overwhelm local drainage and stormwater systems just about anywhere in the county.

Unless a property owner has flood insurance, damages to buildings and building contents are typically uninsured losses.

4.6.6 Potential for Future Losses

Given the interplay of the contributing influences, the potential exists for flood damages to continue to rise. While the potential for future damages is difficult to calculate accurately, there are indicators and acceptable methods for estimating future losses. The Federal Emergency Management Agency recommends a methodology of estimating future losses based on an inventory of buildings and structures that lie within the flood hazard boundary of the 100-year flood event. This method does not capture the loss potential for structures not located in mapped floodplains. Those losses, however, are difficult to quantify and predict. The flood plain structure inventory provides a starting point for discussion and a standard means for estimating future losses.

Table 4.6.2 provides an estimate of the extent of damage from various flood depths on different types of structures. This table is from FEMA's cost-benefit analysis module and has been compiled based on flood damage data from across the country. To utilize this table, the approximate elevations of both the building first floor and the water level during the 100-year flood are needed. From the 100-year flood elevation, subtract the first floor elevation of the building. This figure then can be used to estimate the extent of damage to the type of building that would be flooded. For example, if the 100-year flood event elevation is approximately 848 feet above mean sea level and a one story home, with basement assessed at $112,000 has a first floor elevation of 844 feet, it is estimated that this four feet of flooding would cause 28 percent or $31,360 in damage to the building.

Table 4.6.2 Estimation of Flood *Damage to Structures*

First Floor Flood Depth (Feet)	One Story – No Basement (% of Building Damaged)	Two Story – No Basement (% of Building Damaged)	One or Two Story w/ Basement (% of Building Damaged)	Manufactured Home (% of Building Damaged)
-2	0	0	4	0
-1	0	0	8	0
0	9	5	11	8

First Floor Flood Depth (Feet)	One Story – No Basement (% of Building Damaged)	Two Story – No Basement (% of Building Damaged)	One or Two Story w/ Basement (% of Building Damaged)	Manufactured Home (% of Building Damaged)
1	14	9	15	44
2	22	13	20	63
3	27	18	23	73
4	29	20	28	78
5	30	22	33	80
6	40	24	38	81
7	43	26	44	82
8	44	29	49	82
>8	45	33	51	82

Source: Federal Emergency Management Agency. Estimation of damage potential to buildings based on flood depth relative to the first floor of the building. The negative numbers in the First Floor Flood Depth column indicate flood levels that are lower than the first floor of the building. The resulting flood damage potential is expressed as a percentage of the assessed value of the building.

Flooding also causes damages to the contents of buildings that are flooded. Table 4.6.3 provides a method for estimating the damage potential to building contents. Contents damage includes damage to furniture, appliances, clothing, and other incidental items not included in the building value.

Table 4.6.3 Estimation of Flood Damage to Building Contents

First Floor Flood Depth (Feet)	One Story – No Basement (% of Building Damaged)	Two Story – No Basement (% of Building Damaged)	One or Two Story with Basement (% of Building Damaged)	Manufactured Home (% of Building Damaged)
-2	0	0	6	0
-1	0	0	12	0
0	13.5	7.5	16.5	12
1	21	13.5	22.5	66
2	33	19.5	30	90
3	40.5	27	34.5	90
4	43.5	30	42	90
5	45	33	49.5	90
6	60	36	57	90
7	64.5	39	66	90

First Floor Flood Depth (Feet)	One Story – No Basement (% of Building Damaged)	Two Story – No Basement (% of Building Damaged)	One or Two Story with Basement (% of Building Damaged)	Manufactured Home (% of Building Damaged)
8	66	43.5	73.5	90
>8	67.5	49.5	76.5	90

Source: Federal Emergency Management Agency. Estimation of damage potential to building contents based on flood depth relative to the first floor of the building. The negative numbers in the First Floor Flood Depth column indicate flood levels that are lower than the first floor of the building. The resulting flood damage potential is expressed as a percentage of the total value of the building contents.

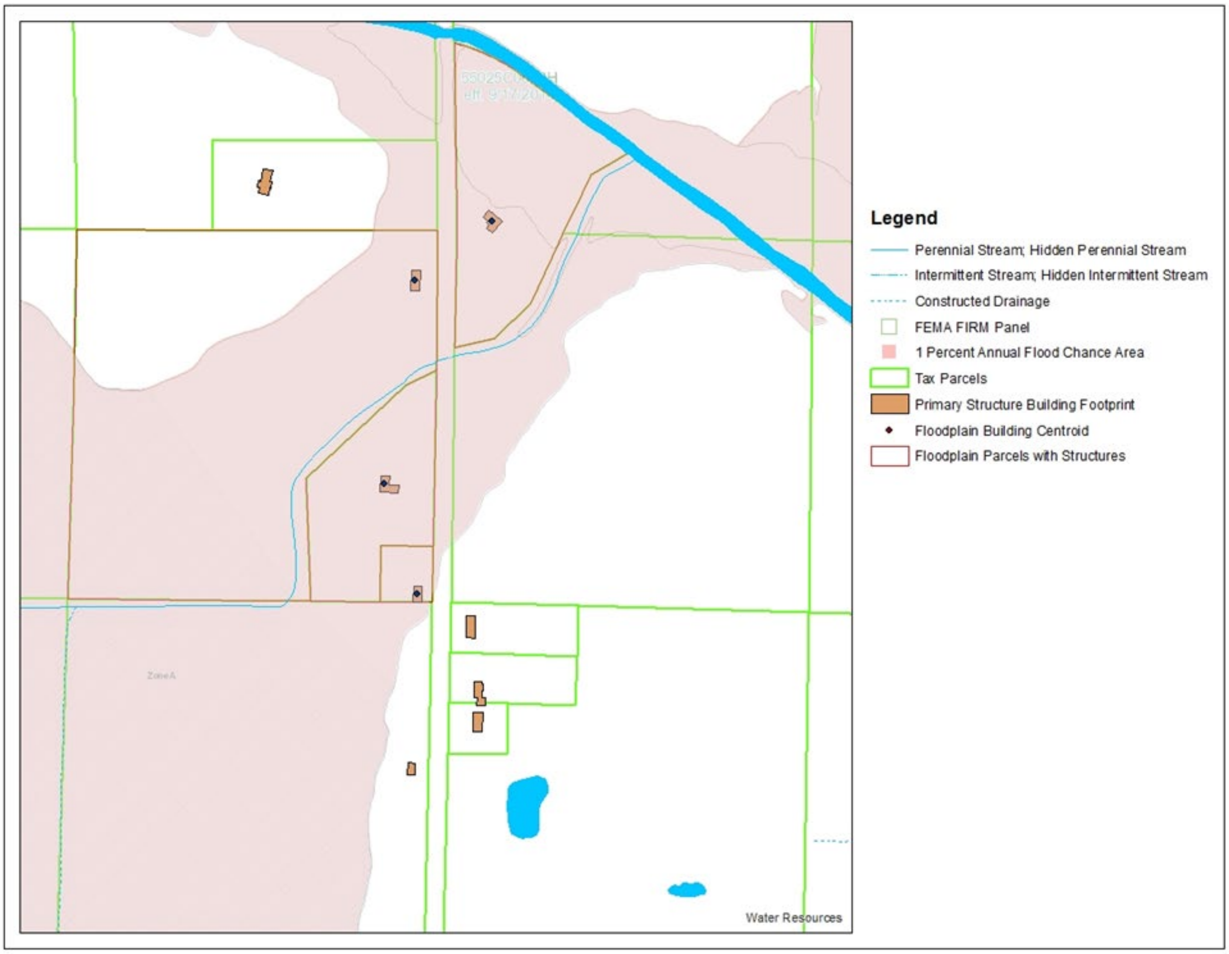
Structures in the Floodplain

A flood damage assessment for Dane County was estimated by using a comparison of a digital version of FEMA's Flood Insurance Rate Maps, Dane County tax parcel data, and Dane County's building footprint inventory. A preliminary assessment was conducted using a GIS overlay of these three data layers. This provided an initial inventory of 977 primary structures located within the mapped floodplains of the County. In order to potential for damages, the following data and assumptions were used:

- 100-year flood elevations at the location of each identified structure were derived from FEMA's Digital Flood Insurance Rate Map layer.
- Structure elevations were generated by interpolating the elevation from the County's 2-foot digital elevation model. Site specific survey data was not used for this analysis.
- Building values are derived from the assessed value of improvements contained within the County parcel data.
- The inventory is limited to buildings classified as "primary" structures only. Accessory buildings are not included in this assessment.
- Structures on tax exempt properties are included in the inventory. Property values for these buildings, however, are not available and are not assessed in the damage estimates.
- All identified at-risk structures are assumed to be buildings with basements.
- Building contents values are estimated based on table 4.6.3. This estimation is based on FEMA hazard assessment and planning guidelines.
- The damage potential for structures located within the A-Zone on the FIRM is unknown. A-Zones are areas where there is a mapped flood hazard, but no base flood elevations have been determined. The lowest first floor damage potential percentages in tables 4.6.2 and 4.6.3 were used for all Zone A structures (-2 feet).
- Zone AE are flood risk areas where the base flood elevation has been determined.
- Structures located within Zone X (no Special Flood Hazard Area) were eliminated from the inventory.

- This analysis was repeated for properties in the floodway and the 500-year flood plain for inclusion in the local plan attachments.

Figure 4.6.12 100-year Floodplain Structure Inventory and Loss Potential Sample Map



This is an approximation based on a preliminary analysis. Since the actual elevations of the identified structures are unknown, a detailed study would be necessary to determine the actual damages that would be incurred to these structures in a base flood. A summary of the resulting estimation of the future damage potential for a 100-year flood event is summarized in the tables that follow:

- Table 4.6.4 indicates the damage potential estimate by building land use category.
- Table 4.6.5 indicates the damage potential estimate by watershed.
- Table 4.6.6-7 indicates structures and damage potential estimate by local government jurisdiction.
- Figure 4.6.13 is an overview map of the locations of the identified structures.

Limitations of this Assessment

The evaluation of the potential for future losses based on a inventory of structures located within the boundaries of mapped flood hazard areas has a number of noteworthy limitations and biases. These limitations do not necessarily invalidate the assessment, but they are important to acknowledge.

1. The assessment is biased toward overestimating damages to primary structures in the mapped floodplains. This results from assumptions built into the analysis:
    a. All buildings in the floodplain are assumed to be single or two story homes with basements, except those known to be manufactured (mobile) homes or commercial structures. This generalization is necessary because data on the specific construction of each building is not available. The projected flood loss for buildings with basements is higher than that of buildings without basements.
    b. The estimated elevation of each building in the floodplain is projected using the County's GIS digital elevation model. This does not account for any site-specific mitigation activities on the property, such as flood proofing or elevation of the structure above the base flood elevation. Again, this generalization is necessary because site-specific data is not available. These mitigating factors would reduce losses, but are not accounted for in the analysis.
2. The assessment is biased toward underestimating damages to structures in the mapped floodplains due to other assumptions in the model:
    a. Only buildings identified as "Primary" structures in the County's building footprint inventory are included in the assessment. There are a great deal of buildings identified as "Accessory" buildings that are not included. This bias is mitigated to some extent by evaluating to total value of structural improvements on each property, thus combining the value of Primary and Accessory structures.
    b. The value of tax-exempt structures is not available and is not included in the assessment. This includes more than 125 properties, for which the value, if assessed, would be significant.
3. There are number of multi-unit buildings, primarily condominiums, for which the value of the flood affected portion of the building is difficult to assess. Assumptions used in the model have the potential for this to be a bias in either direction, potentially overestimating the damages on some buildings and underestimating the losses on others.
4. The assessment evaluates the loss potential for only those structures located within the mapped 100-year floodplain. As noted in past flood events, there are numerous other factors that influence flood losses in Dane County and damages to structures in the floodplain represent only a fraction of the total losses. This is a bias toward underestimating future flood losses.
5. The assessment does not account for changing conditions, particularly those due to climate change and urbanization in the watershed. While difficult to quantify, these factors are increasing the potential for future flood losses. This is a bias toward underestimating future flood losses.

6. Flooding is very rarely, if ever, uniformly damaging countywide. This assessment should be thought of as a countywide exposure to risk, not a projection of the countywide future losses in associated with a single flood event. Actual flood events are typically much more localized. Viewing this as a countywide damage potential creates a bias toward overestimating damages.

Table 4.6.4 Damage Potential Estimate for Structures in 100-year Floodplain – Summarized by Land Use Category

Land Use Category	# of Structures in the 100-YR Floodplain			Estimated Potential for Flood Damage (100-year Flood)				
	Zone A	Zone AE	Total	Assessed Value of Structures	Estimated Value of Contents	Estimated Damage to Contents	Estimated Damage to Structures	Estimated Loss Potential Total
Agriculture	1	1	2	$208,500	$208,500	$13,554	$9,036	$22,590
Assembly	2	1	3	$54,000	$54,000	$3,468	$2,312	$5,780
Commercial Sales	13	25	38	$14,374,100	$21,561,150	$2,055,447	$913,532	$2,968,979
Commercial Services	15	7	22	$10,782,100	$10,782,100	$745,661	$497,107	$1,242,768
Education	2	0	2	Not Available	Not Available	Not Available	Not Available	Not Available
Government	1	1	2	Not Available	Not Available	Not Available	Not Available	Not Available
Health	1	0	1	$135,500	$203,250	$12,195	$5,420	$17,615
Industrial	10	6	16	$12,233,500	$12,233,500	$1,876,049	$1,250,699	$3,126,748
Outdoor	6	8	14	$8,921,400	$8,921,400	$2,081,673	$1,387,782	$3,469,455
Religion	1	0	1	Not Available	Not Available	Not Available	Not Available	Not Available
Residential	325	530	856	$134,465,600	$67,232,800	$8,641,215	$11,729,042	$20,370,257
Transportation	2	14	16	$26,205,500	$39,308,250	$9,979,754	$4,435,446	$14,415,200
Utility	2	3	5	Not Available	Not Available	Not Available	Not Available	Not Available
Total	381	596	977	$207,380,200	$160,504,950	$25,409,015	$20,230,376	$45,639,391

Source: Dane County Emergency Management & Land Information Office Data, 2021

Table 4.6.5 Damage Potential Estimate for Structures in 100-year Floodplain – Summarized by Watershed, Sorted by Lowest to Highest Loss Potential

Watershed Name	# of Structures in the 100-YR Floodplain			Estimated Potential for Flood Damage (100-year Flood)				
	Zone A	Zone AE	Total	Assessed Value of Structures	Estimated Value of Contents	Estimated Damage to Contents	Estimated Damage to Structures	Estimated Loss Potential Total
Lower Crawfish River	0	1	1	$142,500	$71,250	$4,275	$5,700	$9,975
Lake Wisconsin	0	1	1	$170,500	$85,250	$25,575	$34,100	$59,675
Maunesha River	2	2	4	$382,200	$191,100	$26,297	$35,063	$61,360
Allen Creek and Middle Sugar River	2	3	5	$2,008,500	$1,004,250	$60,255	$80,340	$140,595
Upper Koshkonong Creek	13	5	18	$3,776,300	$3,581,600	$271,813	$226,941	$498,754
Mill and Blue Mounds Creek	3	5	8	$1,509,400	$1,558,600	$357,461	$177,685	$535,146
West Branch Sugar River - Mt. Vernon Creek	5	8	13	$1,356,600	$678,300	$271,302	$375,724	$647,026
Yahara River and Lake Mendota	30	10	40	$6,234,800	$3,815,300	$353,150	$320,400	$673,550
Gordon Creek	1	5	6	$7,131,400	$7,104,500	$448,866	$316,998	$765,864
Badfish Creek	6	21	27	$3,897,900	$1,948,950	$431,517	$586,774	$1,018,291
Six Mile and Pheasant Branch Creeks	72	54	126	$23,894,500	$17,139,450	$1,567,009	$1,540,002	$3,107,011
Yahara River and Lake Monona	71	103	174	$22,790,200	$11,782,200	$1,466,465	$1,830,038	$3,296,503
Yahara River and Lake Kegonsa	50	38	88	$8,980,300	$5,390,000	$1,481,576	$1,844,643	$3,326,219
Upper Sugar River	32	43	75	$16,339,700	$11,142,900	$2,271,481	$1,988,441	$4,259,922
Roxbury Creek and Lower Wisconsin River	16	180	196	$24,964,300	$15,564,000	$1,965,516	$2,360,348	$4,325,864

Watershed Name	# of Structures in the 100-YR Floodplain			Estimated Potential for Flood Damage (100-year Flood)				
	Zone A	Zone AE	Total	Assessed Value of Structures	Estimated Value of Contents	Estimated Damage to Contents	Estimated Damage to Structures	Estimated Loss Potential Total
Lower Koshkonong Creek	13	51	64	$36,873,300	$27,656,600	$3,085,986	$2,425,992	$5,511,978
Black Earth Creek	65	66	131	$46,927,800	$51,790,700	$11,320,472	$6,081,187	$17,401,659
Total	**381**	**596**	**977**	**$207,380,200**	**$160,504,950**	**$25,409,015**	**$20,230,376**	**$45,639,391**

Source: Dane County Emergency Management & Land Information Office Data, 2021

Table 4.6.6 Damage Potential Estimate for Structures in 100-year Floodplain – Summarized by Jurisdiction

Municipality	# of Structures in 100-YR Floodplain			Estimated Potential for Flood Damage (100-yr Flood)				
	Residential	Non-Residential	Total	Assessed Value of Structures	Estimated Value of Contents	Estimated Damage to Contents	Estimated Damage to Structures	Estimated Loss Potential Total
City								
Edgerton	0	0	0	$0	$0	$0	$0	$0
Fitchburg	1	0	1	$164,203	$82,102	$4,926	$6,568	$11,494
Madison	61	28	89	$72,714,415	$75,109,723	$14,481,554	$7,790,838	$22,272,392
Middleton	17	3	20	$12,489,815	$10,155,282	$643,096	$544,631	$1,187,727
Monona	52	7	59	$19,484,797	$13,721,338	$1,209,552	$1,294,420	$2,503,972
Stoughton	10	6	16	$3,786,283	$2,563,434	$309,280	$257,071	$566,350
Sun Prairie	6	1	7	$1,947,010	$1,001,241	$135,940	$179,034	$314,975
Verona	16	11	27	$4,036,234	$2,799,462	$457,535	$329,703	$787,238
Town								
Albion	50	2	52	$4,806,198	$2,477,465	$502,083	$647,602	$1,149,685
Berry	8	4	12	$1,717,723	$858,861	$153,534	$204,712	$358,247
Black Earth	0	0	0	$0	$0	$0	$0	$0
Blooming Grove	0	0	0	$0	$0	$0	$0	$0
Blue Mounds	5	0	5	$697,476	$348,738	$78,170	$104,227	$182,397
Bristol	0	0	0	$0	$0	$0	$0	$0
Burke	0	0	0	$0	$0	$0	$0	$0
Christiana	4	0	4	$726,759	$363,379	$33,600	$44,799	$78,399
Cottage Grove	5	0	5	$1,259,037	$629,519	$42,193	$56,258	$98,451
Cross Plains	6	0	6	$1,198,041	$599,021	$47,904	$63,872	$111,776
Dane	1	0	1	$331,058	$165,529	$57,108	$76,143	$133,251
Deerfield	0	0	0	$0	$0	$0	$0	$0
Dunkirk	7	1	8	$1,206,439	$603,220	$103,497	$137,996	$241,492
Dunn	94	4	98	$14,857,057	$8,537,617	$933,618	$1,051,738	$1,985,356
Madison	0	0	0	$0	$0	$0	$0	$0
Mazomanie	51	0	51	$4,713,046	$2,356,523	$328,917	$438,556	$767,472
Medina	1	0	1	$288,737	$144,368	$32,483	$43,310	$75,793
Middleton	0	0	0	$0	$0	$0	$0	$0
Montrose	20	4	24	$3,055,104	$2,029,443	$209,720	$199,324	$409,044
Oregon	0	0	0	$0	$0	$0	$0	$0

Perry	1	0	1	$167,850	$83,925	$5,035	$6,714	$11,749
Pleasant Springs	35	0	35	$5,130,184	$2,565,092	$216,176	$288,234	$504,409
Primrose	2	0	2	$266,968	$133,484	$20,712	$27,616	$48,328
Roxbury	145	1	146	$7,771,023	$3,885,512	$2,278,786	$3,238,366	$5,517,152
Rutland	6	0	6	$1,148,206	$574,103	$101,315	$135,087	$236,403
Springdale	8	2	10	$2,032,979	$1,316,387	$199,120	$199,515	$398,635
Springfield	0	0	0	$0	$0	$0	$0	$0
Sun Prairie	2	1	3	$602,667	$414,928	$24,896	$24,107	$49,002
Vermont	20	1	21	$2,758,633	$1,380,919	$222,355	$295,575	$517,930
Verona	7	1	8	$1,046,104	$559,959	$84,539	$104,599	$189,138
Vienna	0	0	0	$0	$0	$0	$0	$0
Westport	77	5	82	$20,643,279	$13,275,083	$1,465,869	$1,619,215	$3,085,084
York	2	0	2	$315,257	$157,628	$9,458	$12,610	$22,068
Village								
Belleville	9	3	12	$1,239,368	$628,027	$66,796	$88,393	$155,190
Black Earth	13	1	14	$2,182,928	$1,241,191	$97,676	$118,257	$215,934
Blue Mounds	0	0	0	$0	$0	$0	$0	$0
Brooklyn	0	0	0	$0	$0	$0	$0	$0
Cambridge	4	8	12	$2,014,526	$2,401,110	$517,889	$268,739	$786,629
Cottage Grove	0	0	0	$0	$0	$0	$0	$0
Cross Plains	36	11	47	$12,154,890	$9,362,665	$1,967,567	$1,474,003	$3,441,570
Dane	0	0	0	$0	$0	$0	$0	$0
Deerfield	0	0	0	$0	$0	$0	$0	$0
DeForest	5	0	5	$574,932	$287,466	$29,042	$38,723	$67,764
Maple Bluff	1	1	2	$359,678	$179,839	$10,790	$14,387	$25,177
Marshall	0	2	2	$195,585	$102,268	$7,076	$8,450	$15,526
Mazomanie	39	2	41	$4,557,241	$2,399,287	$264,138	$325,637	$589,775
McFarland	1	0	1	$19,669	$9,835	$590	$787	$1,377
Mount Horeb	0	1	1	$0	$0	$0	$0	$0
Oregon	8	7	15	$10,934,417	$9,691,292	$586,838	$444,524	$1,031,362
Rockdale	0	0	0	$0	$0	$0	$0	$0
Shorewood Hills	1	0	1	$0	$0	$0	$0	$0
Waunakee	14	4	18	$2,839,298	$1,801,703	$108,102	$113,572	$221,674
Windsor	4	0	4	$720,018	$360,009	$27,489	$36,652	$64,141
Total	**855**	**122**	**977**	**$229,155,121**	**$177,357,970**	**$28,076,964**	**$22,354,565**	**$50,431,529**

Source: Damage estimates calculated by Dane County Emergency Management & Land Information Office Data, 2021

Note: Why include the 500 year floodplain structures?

As reflected in table 4.6.9, over 90% of flood losses in the 2018 flood occurred outside of the 100 year floodplain. Our understanding of flood risk is changing within the context of climate change, and this table is set to form a basis for an investigative approach toward mitigating emerging risks. Flood damage potentials are not available for the 500 year floodplain due to data availability.

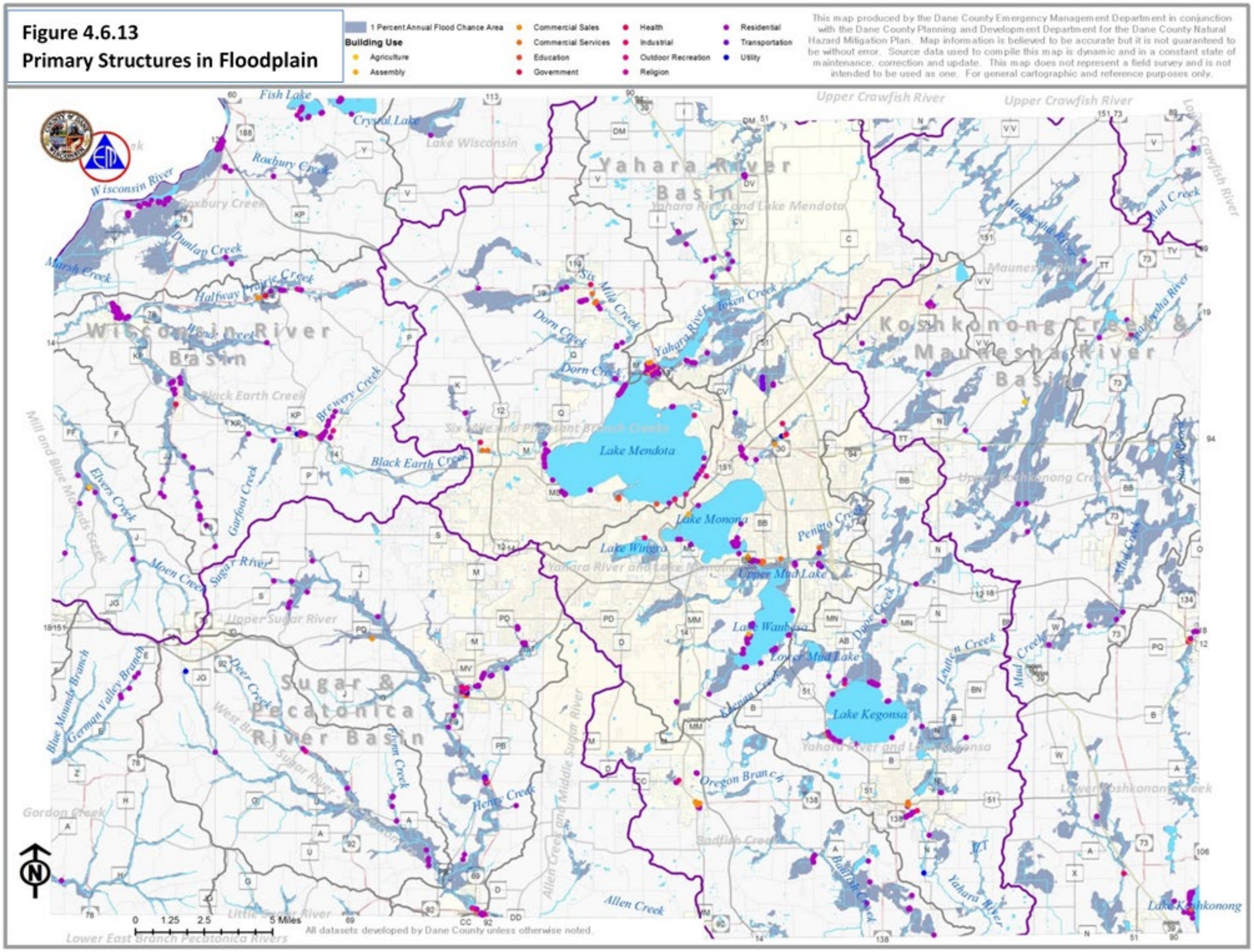
Table 4.6.7 Structures in 500-year Floodplain – Summarized by Jurisdiction

Municipality	Number of Structures in 500-year Floodplain		
	Residential	Non-Residential	Total
City			
Edgerton	0	0	0
Fitchburg	1	1	2
Madison	281	9	290
Middleton	121	4	125
Monona	201	6	207
Stoughton	9	3	12
Sun Prairie	22	2	24
Verona	60	5	65
Town			
Albion	65	3	68
Berry	8	3	11
Black Earth	1	1	2
Blooming Grove	1	1	2
Blue Mounds	6	1	7
Bristol	0	0	0
Burke	0	0	0
Christiana	3	1	4
Cottage Grove	5	1	6
Cross Plains	6	1	7
Dane	1	1	2
Deerfield	0	0	0
Dunkirk	8	1	9
Dunn	157	4	161
Madison	0	0	0
Mazomanie	61	3	64
Medina	5	3	8
Middleton	0	1	1
Montrose	27	5	32
Oregon	0	0	0

Municipality	Number of Structures in 500-year Floodplain		
	Residential	Non-Residential	Total
Perry	1	1	2
Pleasant Springs	62	3	65
Primrose	2	1	3
Roxbury	112	1	113
Rutland	6	1	7
Springdale	6	2	8
Springfield	4	1	5
Sun Prairie	2	1	3
Vermont	19	1	20
Verona	8	3	11
Vienna	4	1	5
Westport	93	3	96
York	1	2	3
Village			
Belleville	34	3	37
Black Earth	12	2	14
Blue Mounds	0	0	0
Brooklyn	0	0	0
Cambridge	6	4	10
Cottage Grove	0	0	0
Cross Plains	66	4	70
Dane	0	0	0
Deerfield	0	0	0
DeForest	13	3	16
Maple Bluff	1	1	2
Marshall	7	4	11
Mazomanie	40	2	42
McFarland	10	3	13
Mount Horeb	0	0	0
Oregon	26	4	30
Rockdale	1	1	2
Shorewood Hills	0	0	0
Waunakee	31	4	35
Windsor	6	2	8
Total	**1,622**	**180**	**1,802**

Source: Dane County Emergency Management & Land Information Office Data, 2021

Figure 4.6.13 Primary Structures in Floodplain



Flood Insurance Claims and Repetitive Losses

There are 74 properties in Dane County on record as having made a total of 108 flood insurance claims through the NFIP, totaling more than $2.4 million since 1978. Figure 4.6.13 shows the approximate locations of these properties. Locations are not shown in detail for privacy reasons. These are all residential properties with the exception of one commercial/office property.

A "Repetitive Loss" property is one that has received two or more flood insurance claim payments for at least $1,000 each in any 10 year period since 1978. There are sixteen "repetitive loss" properties in Dane County. Seven of the sixteen repetitive structures have been mitigated, two were elevated above the base flood elevation, and five were acquired and demolished. Of the remaining nine properties, only four maintain active NFIP policies. Repetitive loss properties are also indicated on Figure 4.6.14. Unmitigated repetitive loss properties with active polices are located in the following jurisdictions:

- City of Monona: One residential property
- Village of Black Earth: One residential property
- Town of Madison: One commercial property
- Town of Westport: One residential property

Repetitive loss properties are important to the National Flood Insurance Program because they account for one-third of national flood insurance claim payments. There are several FEMA programs that encourage communities to identify the causes of their repetitive losses and develop a plan to mitigate the losses. The repetitive loss properties in the County are scattered around the County, thus there are not many distinct repetitive loss "areas." Addressing the areas where these repetitive losses occur is both a County and national priority.

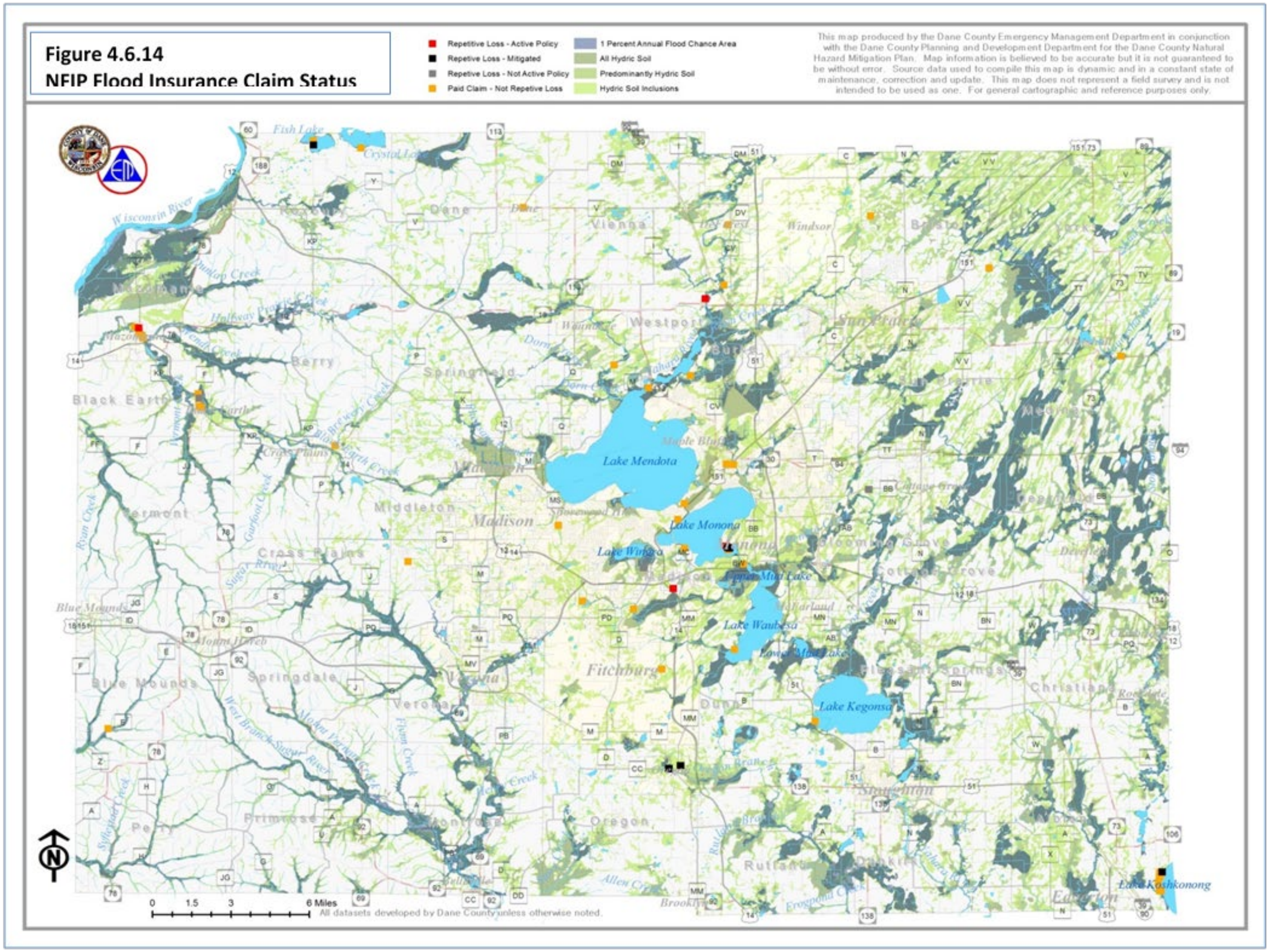
A "Severe Repetitive Loss" property is one that that have at least four NFIP payments over $5,000 each and the cumulative amount of such claims exceeds $20,000, or at least two separate claims payments with the cumulative amount exceeding the market value of the building. There are no severe repetitive loss properties in Dane County.

Flood insurance claims are summarized in Table 4.6.7, sorted by watershed from the least expensive total paid claims to the most. Watersheds having no claims are not listed in the table.

Table 4.6.7 Flood Insurance Claims Summary, From 1978 through 2018

Watershed	Municipality	Flood Year	Paid Claims Total
Gordon Creek	Town of Blue Mounds	2008	$5,062
Maunesha River	Town of Medina Town of Bristol	2000 2007, 2010	$11,484
Upper Sugar River	Town of Middleton	2016 2018	$12,210
Lake Wisconsin	Village of Dane	2007	$15,472
Badfish Creek	Village of Oregon	1978, 1981, 1982, 1984, 1996, 1999	$41,759
Yahara River and Lake Kegonsa	Town of Cottage Grove Town of Dunn	1978, 2007, 2008, 2014	$58,570
Yahara River and Lake Mendota	City of Madison Village of DeForest Village of Windsor Town of Westport	1993, 1996, 1998, 2004, 2007, 2008	$162,434
Roxbury Creek	Town of Roxbury	2001, 2002, 2008, 2014	$377,291
Yahara River and Lake Monona	City of Fitchburg City of Madison City of Monona Town of Dunn Town of Madison	1978, 1981, 1993, 1996,1997, 2000, 2001, 2008, 2014, 2016, 2018	$674,188
Six Mile and Pheasant Branch Creeks	City of Madison Town of Westport	2000, 2001, 2007, 2018	$848,208
Lower Koshkonong Creek and Lake Koshkonong	Town of Albion Town of Christiana	1980, 1982, 1993, 2008	$1,128,771
Black Earth Creek	Village of Black Earth Village of Cross Plains Village of Mazomanie	1993, 2001, 2004, 2007, 2008, 2018	$2,043,534

Figure 4.6.14 NFIP Flood Insurance Claims Status



2008 Flood Damage Analysis

The June 2008 flood event was the second most most damaging flood on record in Dane County. Dane County Emergency Management received flood insurance and FEMA Individual and Household Assistance claims data associated with the 2008 flood disaster to supplement the analysis of the flood hazard for this plan. The addresses of paid flood insurance claims and Individual and Household Assistance claims were located on GIS maps for further analysis and comparison with other flood hazard layers, such as the mapped floodplain and hydric soils layers.

There is a significant overlap between mapped flood plains and areas with hydric soils and most of the mapped floodplains are in areas characterized as hydric soils. This assessment takes care not to count these structures twice.

In general, the claims were in scattered locations around the County. The exceptions were clusters in the Villages of Deforest, Marshall and Sun Prairie and the City of Monona. There is also a significant cluster of claims in the Town of Cottage Grove. Figure 4.6.14 indicates the general locations of these properties. Privacy restrictions with the data prevent detailed maps of this analysis from being published in this plan. Interestingly, the majority did not intersect either of the mapped flood hazard areas. The breakdown resulted in the following assessment:

- Number of paid claims – FEMA Individual and Household Assistance: 1,627 ($1.76 million)
- Number of paid claims – National Flood Insurance: 28 ($1.38 million)
- Total number of paid claims: 1,655 ($3.14 million)
- Number of claims in the FIRM floodway: 4
- Number of claims in the FIRM 100-year flood hazard area: 38 (excluding floodway)
- Number of claims in the FIRM 500-year flood hazard area: 26
- Total number of claims in FIRM flood hazard areas: 68 (4% of the total)
- Number of claims in hydric soil types: 162 (10% of the total)
- Number of claims in soil types with hydric inclusions: 416 (25% of the total)
- None of the above: 1009 claims (61% of the total)

This preliminary analysis leads to some initial conclusions:

- Most of the flood damages occurred outside of the mapped floodplains.
- Stormwater drainage issues may be more of an issue than floodplain-related flooding.
- High groundwater table flooding may be more of an issue than floodplain-related flooding.
- Hydric soils areas do contribute to flood problems, but perhaps not as much as initially believed.
- Flood problems are more widely distributed across the County than mapped flood hazard areas would indicate.

- Existing mitigation efforts and floodplain management is generally working effectively in Dane County's mapped floodplains.

Additionally, the Individual and Household Assistance claims data does not distinguish between losses associated with floodwater, stormwater drainage, or high ground water and losses associated with sanitary sewer back flow into residential basements. Anecdotally, sanitary sewer back-ups have been identified as a problem in certain areas. It is not known to what extent sewer back-ups would account for the losses represented by these claims.

Finally, and perhaps most importantly, these numbers represent only a fraction of the actual losses experienced as a result of this flood event. Flood insurance claim payments and FEMA Individual and Household Assistance claims represent reimbursements for eligible expenses and losses. Eligible losses include only those repairs needed to make the home inhabitable safely:

Eligible Losses

- Structural parts of the home (foundation, outside walls, and roof)
- Windows, doors, floors, walls, ceilings, and cabinetry.
- Septic or sewage system
- Well or other water system
- Heating, ventilating, and air conditioning system
- Utilities (electrical, plumbing, and gas systems)

Ineligible losses:

- Non-structural components of the building
- Damage or loss of contents (furniture, items stored in the basement, etc.)
- Repairs to finished or unfinished basements that are not primary living space

Preliminary damage assessments conducted by local jurisdictions and compiled by Dane County Emergency Management indicated a total of 2,370 homes and 155 business damaged, with combines losses totaling more than $7.45 million. This indicates that approximately 40% of the losses were reimbursed by FEMA or the NFIP, with about 60% of the losses borne by the property owner.

While 60% of the FEMA paid claims in 2008 were located in areas outside of identifiable flood risk areas, from the perspective of the total number of primary structures in Dane County, a slightly different picture emerges.

Table 4.6.8 2008 Flood Damage Claims Summary

	Primary Structures in Dane County Building Footprint Inventory		2008 Paid Claims (FEMA Individual and Household Assistance plus Flood Insurance)	
Flood Risk Indicator	**Number of Primary Buildings**	**Percentage of Total**	**Number of Claims**	**Percentage of Total**
Mapped FIRM Flood Hazard Areas	997	0.69%	68	4.1%
Hydric Soil Types (Hydric plus hydric inclusions)	36,434	25.26%	578	34.9%
Not in an identified flood hazard area	106,795	74.05%	1009	60.1%
Total	**144,226**	**100%**	**1,655**	**1.1%**

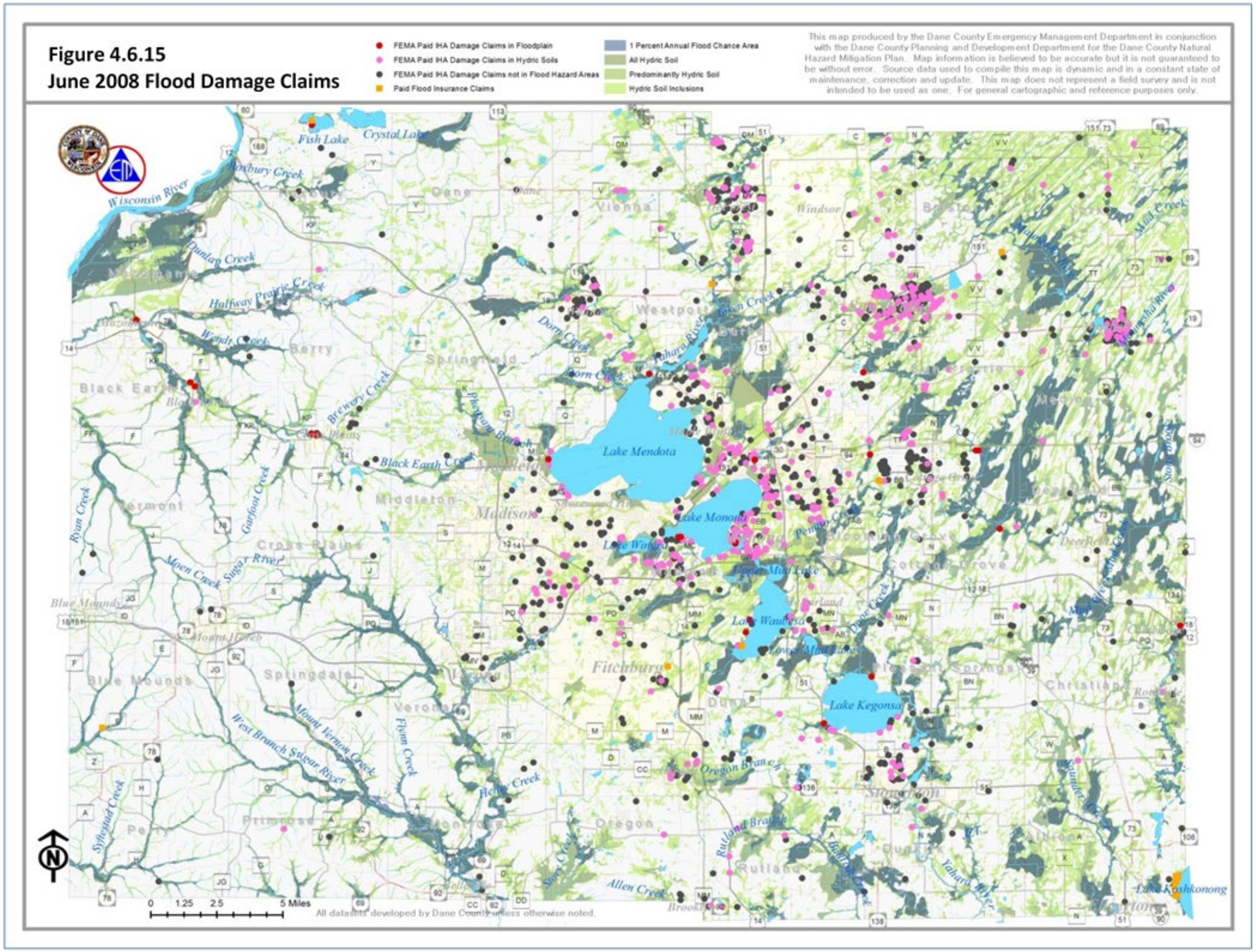
Source: FEMA Data - Claims estimates calculated by Dane County Emergency Management, 2017

From the perspective of a countywide analysis, there was a notably disproportionate amount of damage in areas with hydric soils and floodplains. While structures in the mapped floodplain areas represent less than 1% of the total number of primary buildings in Dane County, these locations represent more than 4% of the paid damage claims. Likewise, structures built in areas with hydric soils represent 25% of the buildings in Dane County, but represent almost 35% of the paid claims.

These are not dramatically disproportionate differences in the locations where damage occurred, but a higher level of flood risk is still apparent. Even so, with 60% of the damage claims occurring outside of these areas, it is clear that additional factors are in play. Flood damages are more widely distributed across the County than mapped flood hazard areas would indicate.

Likewise, in terms of public sector (county and local government) costs for response, repair of roads, rebuilding of damaged buildings, and other response and recovery activities, initial assessments conducted by the local jurisdictions and compiled by the County indicated a response and recovery cost totaling $6.07 million. FEMA Public Assistance reimbursed a total of $1.53 million to the County and local jurisdictions within the County. The Public Assistance program also has strict eligibility requirements and will only reimburse applicants for eligible costs. Assuming the initial assessments were reasonably accurate, Federal reimbursements made up approximately 22% of the costs, with 78% borne by responding local governments.

Figure 4.6.15 June 2008 Flood Damage Claims



Effect of Climate Change on Future Loss Potential

Regional climate model projections indicate a significant increase in both the frequency and magnitude of intense rain fall events in southern Wisconsin, including Dane County. (Wisconsin Initiative on Climate Change Impacts, Stormwater Working Group Report, 2011) Extreme rainfall events are getting larger and they are happening more often. These are on-going changes that are expected to continue, or even further accelerate in the future.

Dane County already faces enormous challenges in managing stormwater and reducing flood impacts. The complexity of this problem is exacerbated by changing weather patterns and trends of more frequent, high intensity rain storms. Stormwater and flood management systems are designed to manage water flows and volumes associated with a range of possible storm events. The respective rainfall depth, intensity and probabilities of those storm events are obtained from analysis of past storm events. This analysis, however, does not account for changing conditions.

Society's infrastructure is built to manage to acceptable levels the risks associated with excess precipitation, and has been traditionally designed and evaluated using historical precipitation and runoff data. Traditional strategies for managing high water conditions are based on either the use of infrastructure that conveys, stores, or protects against high water (i.e. stormwater management systems), or on plans and regulations that promote or require avoidance of high water conditions (i.e. floodplain zoning). Unless the planning, design, and management of these systems are modified to account for climate mediated changes in precipitation patterns, the risk of significant economic and environmental damage will increase.

While it has become clear that past conditions are not a good indicator of what we can expect in the future, a specific, precise projection is not available. A qualitative assessment, however, is possible. Unless appropriate adaption and mitigation strategies are implemented, increases in the frequency and severity of the following high water impacts can be expected (Wisconsin Initiative on Climate Change Impacts, Stormwater Working Group Report, 2011):

- Landslides and erosion of steep slopes during intense rainfall events.
- Impairment of roadways and bridges washed-out due to high water, slope failure, or washed out roadway shoulders.
- Groundwater flooding of property and cropland.
- Flood damage to urban streets, homes, and commercial structures due to inadequate runoff drainage systems.
- Failure of impoundments, dams, and stormwater detention ponds.
- Failure of rain gardens and other groundwater biofiltration Best Management Practices (BMPs) due to prolonged periods of saturated soils.

- Stormwater inflow and groundwater infiltration to sanitary sewers, resulting in sewer backflow into basements. This also results in untreated municipal wastewater overflowing into lakes and streams.
- Contamination of rural residential wellheads as a result of surface water and groundwater flooding.

A wide range of environmental impacts, water quality impacts, and indirect, secondary economic and social impacts are also exacerbated by this increasing flood hazard.

Future Loss Estimation based on the 2008 Flood of Record

While current methods of analysis can provide general trends, specific projections of the increasing magnitude of flood events is not available. This is problematic when attempting to design and engineer flood management systems that will meet future needs. Again, a qualitative assessment is possible.

Using the 2008 flood event as a model event, Table 4.6.8 indicates the estimated flood loss potential, with scenarios of increasing losses. These scenarios are based on increased magnitude of flood damages by percentage over the 2008 flood damage losses. This provides a general overview of how losses might increase as flood events get larger. This assessment is not intended to be predictive. Rather, this simply shows how flood damages and losses would change as flood events get more damaging, relative to the 2008 flood of record. For example, a flood causing twice as much damage as the 2008 flood event (100% increase) would equate to more than $30 million in 2017 dollars.

This method of estimating potential increases in flood damage with changing conditions also has limitations. It is an important distinction that Table 4.6.8 indicates costs associated with increases in flood damage relative to the 2008 flood event, not increases in flood magnitude. The relationship between increasing flood magnitude and the resulting damage is not linear. As flood magnitude increases, larger and larger areas, with more properties, structures, and infrastructure are affected. Flood depths also increase as a result, affecting those properties, structures and infrastructure to a greater degree. The number of locations affected increases, as does the severity of loss experienced at any given location. This leads to exponential increases in losses as flood magnitudes increase. At this point, there are too many variables for anything other than a qualitative assessment of the increasing flood risk.

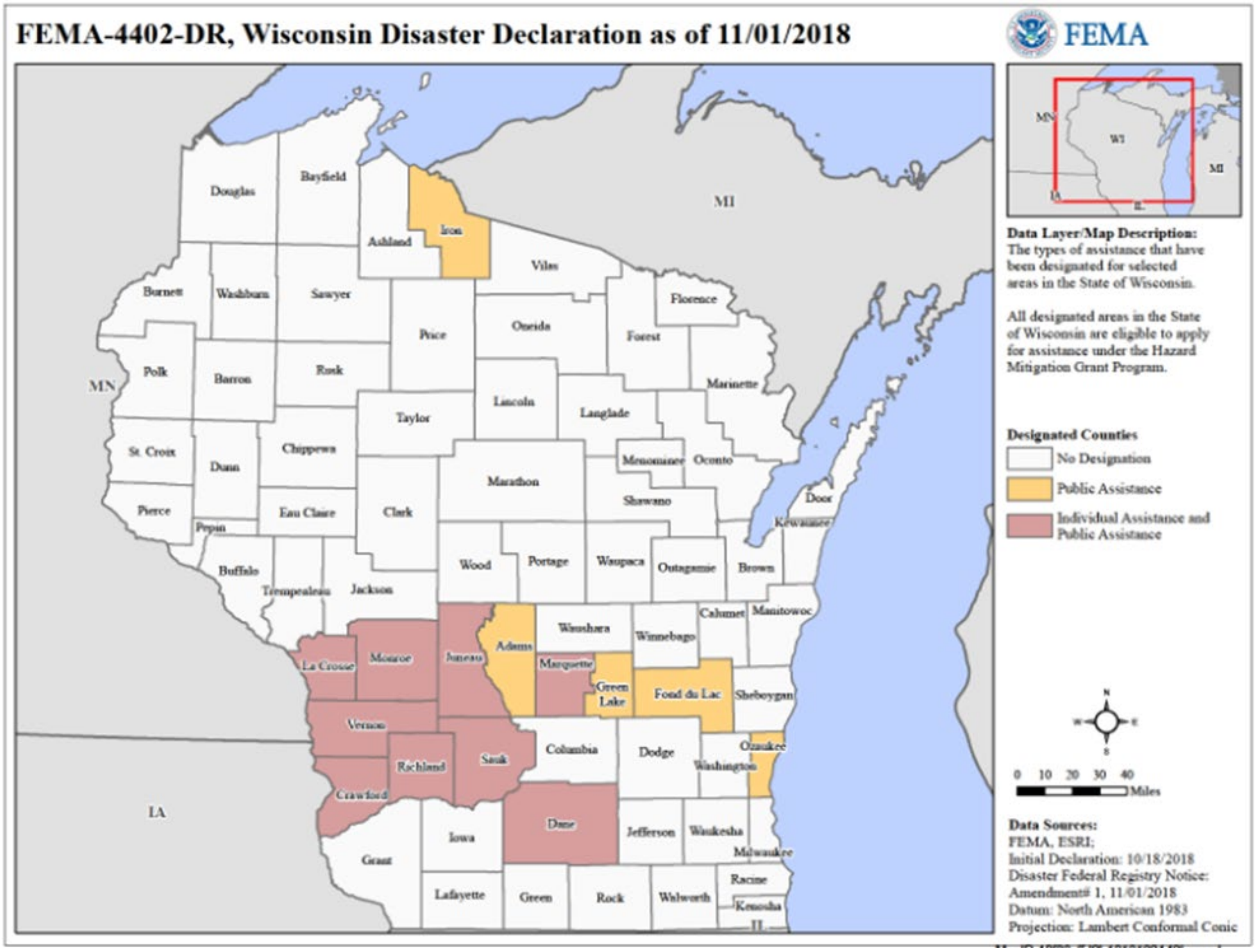
Table 4.6.8 Estimated Flood Loss Potential, with Scenarios of Increasing Losses. Scenarios Based on Increased Magnitude of Flood Damage by Percentage over 2008 Flood Damage

Category of Damages	2008 Flood Damages	Inflation Adjustment (2008 to 2017)	Increased Magnitude of Flood Damage (over 2008 flood losses)				
			10%	25%	50%	75%	100%
Number of Structures Affected	2,370		2,607	2,963	3,555	4,148	4,740
Private Sector Damage Assessment	$7,450,000	$8,330,000	$9,163,000	$10,412,500	$12,495,000	$14,577,500	$16,660,000
Number of FEMA Paid Individual and Household Assistance and NFIP Claims	1,655		1,821	2,069	2,483	2,896	3,310
IA and NFIP Paid Claims Amount	$3,140,000	$3,510,000	$3,861,000	$4,387,500	$5,265,000	$6,142,500	$7,020,000
Public Sector Damage Assessment	$6,070,000	$6,780,000	$7,458,000	$8,475,000	$10,170,000	$11,865,000	$13,560,000
FEMA Public Assistance Payments	$1,530,000	$1,710,000	$1,881,000	$2,137,500	$2,565,000	$2,992,500	$3,420,000
Federal Assistance Total	$4,670,000	$5,220,000	$5,742,000	$6,525,000	$7,830,000	$9,135,000	$10,440,000
Total Private and Public Sector Costs	$13,520,000	$15,110,000	$16,621,000	$18,887,500	$22,665,000	$26,442,500	$30,220,000

Source: Damage estimates calculated by Dane County Emergency Management, 2017

2018 Flood Damage Analysis

Figure 4.6.16 2018 Wisconsin Disaster Declaration Counties



Source: FEMA Designated Areas Map, 2021 https://www.fema.gov/disaster/4402/designated-areas

J – Description

The August 2018 flood event was the most damaging flood on record in Dane County. Dane County Emergency Management received flood insurance and FEMA Individual and Household Assistance claims data associated with the 2018 flood disaster to supplement the analysis of the flood hazard for this plan.

A severe storm swept through Dane County the evening of August 20, 2018. The storm dumped anywhere from several inches up to 15”+ (citizen reported). The most severe rain and flooding occurred in the Western portion of Dane County through the Black Earth Creek Watershed. Over the next 10 days, additional storms swept across Wisconsin causing major flooding in 13 additional counties across the state.

The majority of the flooding in Dane County occurred between Mazomanie and West Madison with the greatest impacts felt along the US Highway 14 corridor between Mazomanie and the City of Middleton. The vast majority of the requests (90%+) for Individual and Household Assistance came from properties outside of mapped flood plains.

The Individual and Household Assistance claims data does not distinguish between losses associated with floodwater, stormwater drainage, or high ground water and losses associated with sanitary sewer back flow into residential basements. Anecdotally, sanitary sewer back-ups have been identified as a problem in certain areas. It is not known to what extent sewer back-ups would account for the losses represented by these claims.

The data represented in this section represents only a fraction of the actual losses experienced as a result of this flood event. Flood insurance claim payments and FEMA Individual and Household Assistance claims represent reimbursements for eligible expenses and losses. Known ineligible losses include:

- Non-structural components of the building (e.g. sidewalks, retaining walls, driveway culverts, etc.)
- Damage or loss of contents (furniture, items stored in the basement, etc.)
- Repairs to finished or unfinished basements that are not primary living space.

2018 Flood Summary Statistics

Displayed in Table 4.6.9, an estimated 90% of total properties within Dane County that received relief due to the 2018 flooding event did not reside within the regulated floodplain.

Table 4.6.9 Properties Receiving Relief Within and Out of Regulated Floodplains

Category	Federal Funding Received ($)	Percent of Total Damages Paid (%)
Properties within regulated Floodplain	$400,620	10%
Properties out of regulated Floodplain	$3,497,252	90%

Source: Dane County Planning & Development 2018 Flood Analysis, 2018

This trend of property claims being outside of regulated floodplains is mirrored in both the 2008 flood, and the national scale. In response to the 2018, CARPC helped establish a fifteen member steering committee for the Black Earth Creek Watershed Green Infrastructure Plan to address both rural and urban vulnerabilities within the Black Earth Creek Watershed area (BECW). The stated goal is "To identify specific projects and practices that provide a quantifiable level of flood protection to communities, water quality benefits to Black Earth Creek and its tributaries, and recreational, economic, and ecological benefits to the watershed as a whole." (Black Earth Creek Watershed Green Infrastructure Plan, https://becw-greenplan-silvernail.hub.arcgis.com/)

The Village of Black Earth, the Village of Mazomanie, and the Village of Cross Plains voluntarily provided representatives for the BECW steering committee, as these communities represent key impacted areas within the eastern quadrant of Dane County during the 2018 flood. Four consulting entities are also members of the BECW committee.

The estimated FEMA payments per household in the BECW can be seen in Figure 4.6.17. Total and Average FEMA payment impacts to the whole county can be seen in Figures 4.6.18-19. Table 4.6.10 mirrors Table 4.6.8, in demonstrating future potential flood damage estimates, in addition to 2021 inflation rates.

Figure 4.6.17 Black Earth Creek Watershed - Average FEMA Payments per Household

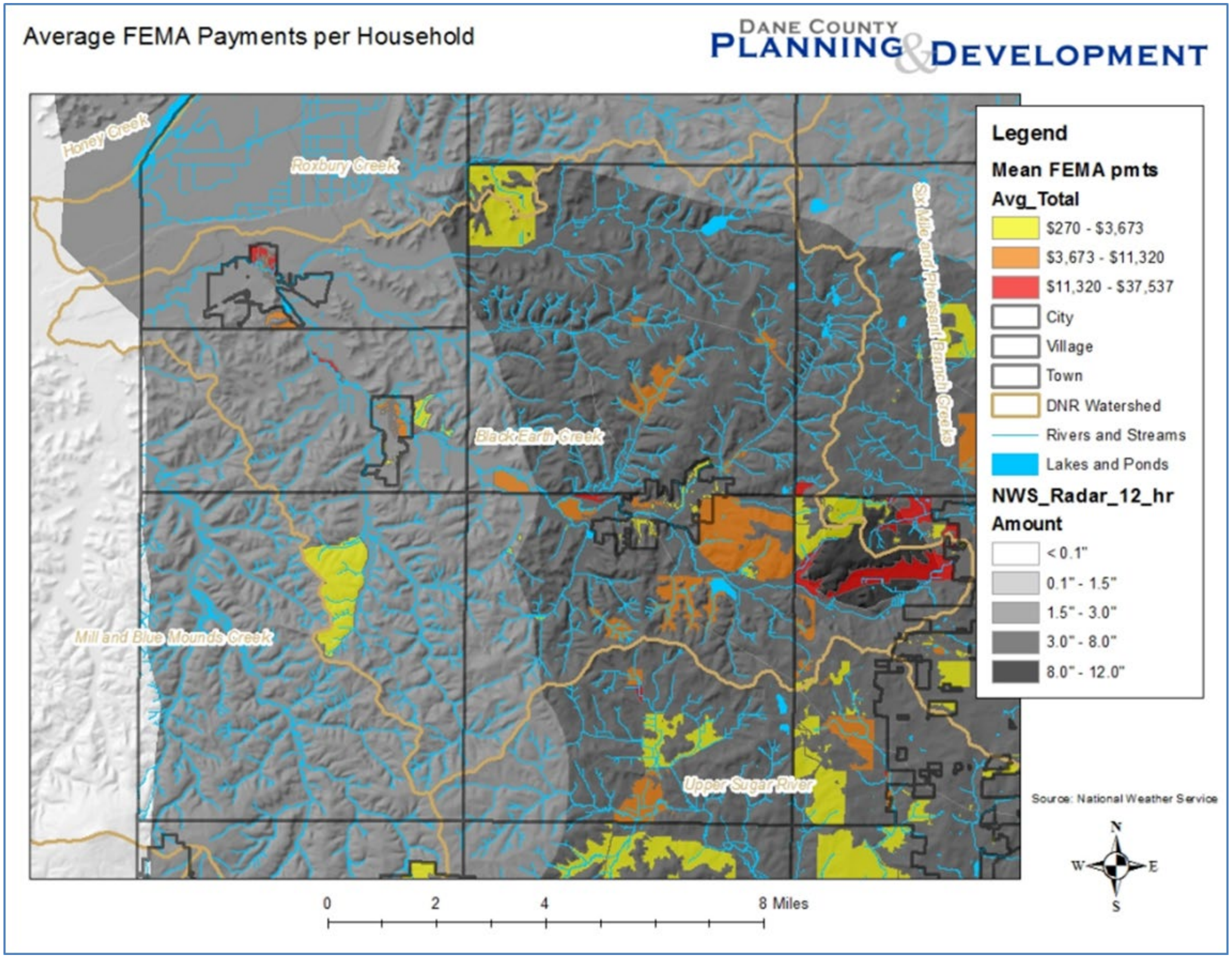


Figure 4.6.18 Dane County - Average FEMA Payments per Household

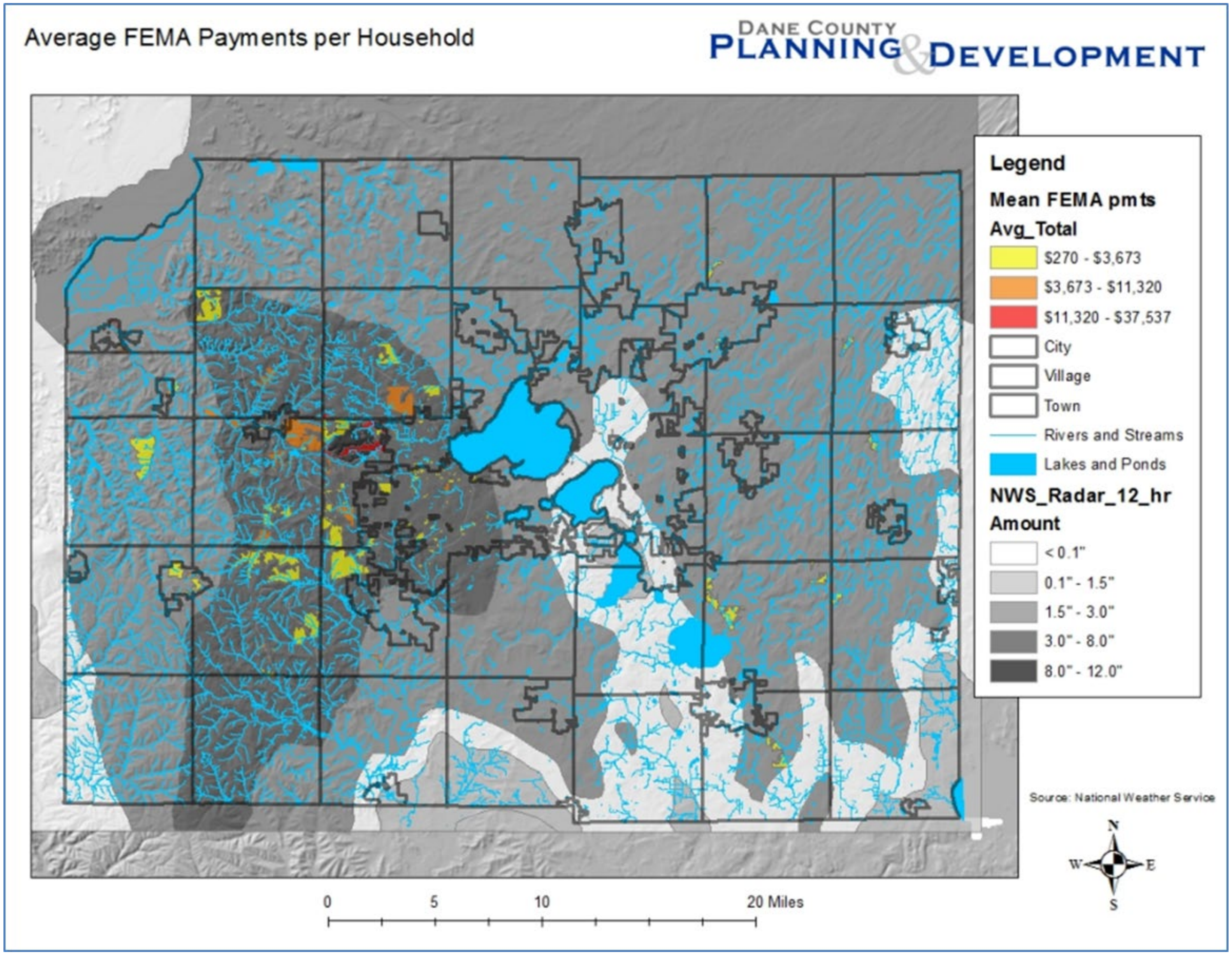


Figure 4.6.19 Dane County - Total FEMA Payments by Census Block

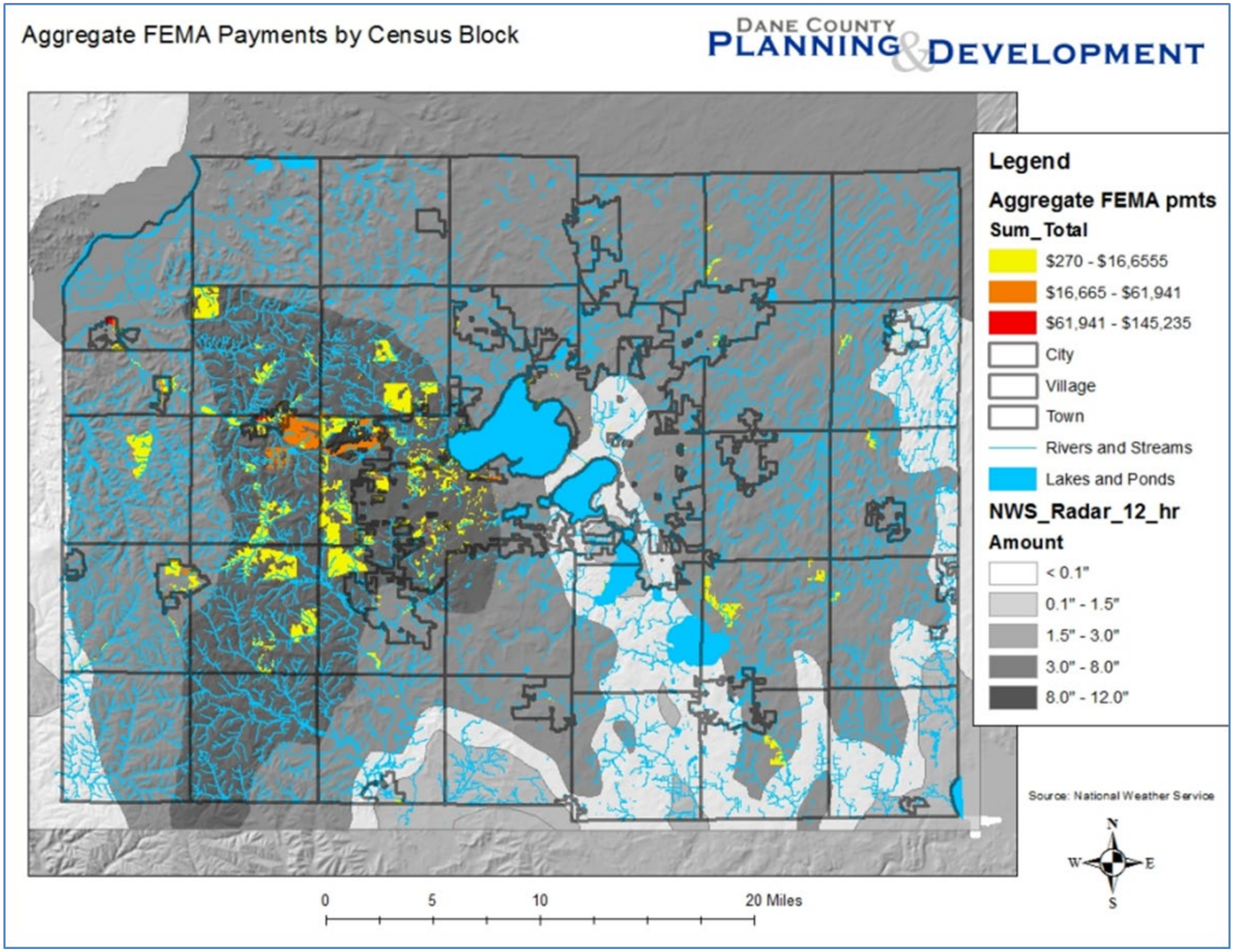


Table 4.6.10 Estimated Financial Loss Potential, with Scenarios of Increasing Losses. Scenarios Based on Increased Magnitude of Flood Damage & Inflation

Category of Damages	**2018 Flood Damages**	**Inflation Adjustment (2018 to 2022)**	**Increased Magnitude of Flood Damage (over 2018 flood losses)**				
			10%	**25%**	**50%**	**75%**	**100%**
Total Housing Assistance (HA) - Dollars Approved	$3,897,872	$4,364,191	$4,800,610	$5,455,239	$6,546,287	$7,637,334	$8,728,382
Public Sector Damage Assessment	$78,287,645	$87,653,529	$96,418,882	$109,566,911	$131,480,294	$153,393,676	$175,307,058
Private Sector Damage Assessment	$37,114,219	$41,554,351	$45,709,786	$51,942,939	$62,331,527	$72,720,114	$83,108,702
Total Private and Public Sector Damage Assessment	$115,401,864	$129,207,880	$142,128,668	$161,509,850	$193,811,820	$226,113,790	$258,415,760
Hazard Mitigation Grant Program (HMGP) - Dollars Obligated	$3,411,680	$3,819,833	$4,201,816	$4,774,791	$5,729,750	$6,684,708	$7,639,666
Grand Total	$238,113,280	$266,599,784	$293,259,762	$333,249,730	$399,899,676	$466,549,622	$533,199,568

Source: Calculated by Dane County Emergency Management, 2022

4.7 FOG

4.7.1 Description

Fog is a cloud made up of water droplets suspended in the air at the earth's surface. Fog forms when air is cooled to its dew point, which is the temperature at which air is saturated with moisture. When air reaches its dew point it condenses into very small particles, forming the tiny water droplets that create clouds. When this occurs very close to the ground, the event is called fog. The intensity and duration of fog varies with the location and type of fog. Severity ranges from early morning ground fog that burns off easily to prolonged valley fog that can last for days. Generally, strong winds prevent fog formation. The following list summarizes several possibilities for the formation, intensity, and duration of fog in the upper Midwest, as compiled in the "Hazardous Weather Resource Guide" by FEMA:

Ground Fog is associated with clear nights, stable air (winds less than 5 mph), and a small-temperature dew point range. It forms when heat radiates away from the ground, cooling the ground and surface air. When air cools to its dew point, fog forms, usually a layer of less than 100-200 feet. It is common in many areas of the United States and generally burns off from the morning sun.

Advection Fog is associated with horizontal wind, warm, humid air, and winter temperatures. It forms when wind pushes warm humid air over the cold ground or water, where it cools to the dew point and forms fog. Advection fog can cover wide areas of the central U.S. in winter. During the winter this is common when snow covers much of the Midwest. The snow cools the bottom portion of the moist air mass often resulting in condensation. This type of fog can be widespread, covering very large areas.

Evaporation Fog is associated with bodies of water. It forms as cold air blows over warmer water, causing the water to evaporate into the cold air, increasing the humidity to the dew point. Vapor condenses, forming a layer of fog 1 to 2 feet thick over the water. It can form over ponds and streams on fall days.

Precipitation Fog is associated with warmer rain and cooler air. It forms when rain evaporates, and the added vapor increases the air to its dew point. The vapor then condenses into fog. Precipitation fog forms on cool, rainy days.

4.7.2 Previous Occurrences

Fog is common occurrence in southern Wisconsin, including Dane County. Fog may occur anywhere in the County. Records indicate fog is most likely in the early morning or late evening. Dense fog occurs during every month of the year in Wisconsin. It is more common during the cooler months of September through April. During the fall and spring, fog is more common during the early morning hours and during the winter fog can occur anytime favorable conditions are present. Fog is a semi-regional phenomenon, affecting large portions of the county simultaneously. It may also form in patches, or uniformly across the entire region or county.

In more recent years, the National Weather Service and the NOAA National Centers for Environmental Information have been tracking weather extremes and their consequences in greater detail. A search of the NCEI website provided the following descriptions of several excessive heat events.

November 15, 2001
Dense fog developed overnight across parts of south-central and southeast Wisconsin, lowering visibilities to near zero to 1/4 mile. The lowest visibilities were found in river valleys west of a line from Madison (Dane Co.) to Beloit (Rock Co). Local air traffic was delayed until visibilities improved. Several vehicle accidents were noted in newspapers. In northwest Dane County near Mazomanie on Highway 78, the driver of a vehicle was killed when the vehicle struck a horse standing on the road (fatality indirectly related to fog). Visibility was reported to be about 10 feet around the accident time of about 1:45 a.m. on November 16th. Sixteen children were injured (indirectly related to fog) when a truck struck a Monticello (Green Co.) school bus at 7:46 am on the 16th. Poor visibility was an indirect factor in this accident.

February 20, 2002
Dense fog developed overnight across south central and southeast Wisconsin due to light rain and persistent, on-shore southeast to northeast winds. Visibility was reduced to 1/8 to 1/4 mile, especially in river valleys and other low spots. This led to several vehicle accidents and flight delays or cancellations at airports.

March 20, 2003
Dense fog developed early on March 20th, and dropped visibilities to 1/4 mile or less. Air traffic was delayed or grounded at both Milwaukee's Mitchell Field (Milwaukee Co.), and Dane County Regional Airport. Several school districts delayed school openings by 2 hours, and newspapers reported many vehicle accidents. The dense fog was the result of clear skies, a light south-southeast surface wind, and leftover, low-level moisture.

February 26, 2004
Dense fog developed overnight, resulting in visibilities of 1/4 mile or less. Newspaper reports indicated that many icy frost deposits occurred on roads and bridges. Snowmelt due to maximum temperatures in the mid to upper 30s on February 25th contributed the moisture needed to saturate the air as the night progressed. Newspaper reports indicated that some airplane flights were delayed and at least a dozen vehicle accidents occurred.

December 19, 2007
Dense freezing fog developed over parts of south-central and southeast Wisconsin and reduced visibilities to 1/8 to 1/4 mile. Untreated road and sidewalk surfaces were coated with thick rime/frost, as

well as trees and other cold-surface objects. Newspaper reported indicated that at least a dozen vehicle accidents occurred in each county listed in this event. Moist air moving over a cold, snow-covered terrain initiated the dense freezing fog. Several airline flights were delayed or canceled at Dane County Regional Airport.

January 6, 2008
Dense fog caused a 100 car pile-up traffic accident which stretched about 5 miles long along Interstate 39/90 in Dane County. There were many injuries, with approximately 54 individuals taken to area hospitals. Two indirect deaths were reported.

March 7, 2010
Dense fog developed across much of Southcentral and Southeast Wisconsin. Visibility dropped to ranges of several hundred yards to less than ¼ mile. Several flights were delayed and several vehicle accidents occurred according to local news.

December 2, 2012
Dense fog covering much of Southern Wisconsin reduced visibility to ¼ mile and persisted until 12 p.m. on December 3rd. Flights at several airports were delayed.

February 12, 2018
On February 12th, 2018, a 29 car pile-up with one fatality took place near the city of Verona, due to dense fog patches across southern Wisconsin. Local officials cited poor visibility as being the cause, as well as potentially slick road conditions. A day after the pile-up, Dane County Emergency Management (DCEM) issued a potential fog hazard warning, due to a freeze and melt cycle predicted by the National Weather Service. No other fatalities were recorded in relation to this event, however injuries from the car pile-up did follow. The fog event continued inconsistently for four days.

Source: Photo by Adam Bar, reported by WMTV

4.7.3 Impact of Climate Change on Future Conditions

Fog is already a regular occurrence, with Dense Fog Advisories issued for Dane County numerous times in any given year. There is not a readily available source of information to assess whether the incidence of fog will increase, decrease, or remain unchanged as a result of the warming climate.

4.7.4 Impact Assessment

Fog can be hazardous when the visibility is reduced to 1/4 mile or less. Thick fog reduces visibility, creating a hazard to motorists. The Wisconsin State Patrol rates dense fog as probably the most dangerous weather-related traffic hazard, with icy or snow-covered roads in second place. In Dane County alone, between 2010 and 2015, 272 accidents took place where fog was present at the accident site. Of those accidents, 92 people were injured and 3 were killed (WisDOT AADT for Site 131506. Available at: https://trust.dot.state.wi.us/roadrunner/) Table 4.7.1 is limited to Wisconsin Dept. of Transportation Data and summarizes these crashes by year.

Table 4.7.1 Fog Related Traffic Crashes in Dane County

Fog Related Crashes				
Year	**Fatal**	**Injury**	**Vehicle Damage**	**Total**
2010	1	24	55	80
2011	0	10	14	24
2012	0	13	30	43
2013	1	30	33	64
2014	1	10	33	44
2015*	0	5	12	17
Totals	**3**	**92**	**177**	**272**

Source: WisDOT Traffic Crashes and Weather Conditions for Dane County. From 2010-2015 Wisconsin Traffic Crash Facts. Available at http://wisconsindot.gov/Pages/safety/education/crash-data/crashfacts.aspx

Although the number of accidents and deaths are considered indirectly related to the actual weather conditions, they far exceed the number of people injured or killed due to tornadoes or floods for Dane County during this period. These accidents are considered indirectly related because law enforcement officials and the insurance industry assert that most accidents that occur in fog are the result of motorists following too close to the vehicle ahead of them and driving too fast for the weather conditions. The poor visibilities do not allow motorists to adjust when the vehicle in front stops or makes a quick turn.

Records of past incidents also report cases of flight delays or cancellations at Dane County Regional Airport due to dense fog. There is no accurate data available to quantify these reports or the financial losses that might be associated with these delays.

4.7.5 Vulnerability Assessment

Fog poses the greatest danger to people who are traveling on the highways of the County. Dane County has an extensive highway transportation system that includes three intersecting interstate highways, major federal and state highways, and County and local roads. With its central location in southern Wisconsin, there are numerous heavily used major thoroughfares in Dane County constituting nearly 3,500 miles of roadway in the County.

Air travel is also vulnerable to disruption due to dense fog. Records of past incidents report cases of flight delays or cancellations at Dane County Regional Airport due to severe weather and fog. The Dane County Regional Airport (DCRA) in Madison is the second largest airport in the State, providing service to commercial air passenger and cargo carriers, general aviation, and the military. Over 100 daily flights are provided on an average day. In 2015, 1.6 million passengers traveled through the DCRA. (Airport passenger numbers available at: http://www.transtats.bts.gov/airports.asp?pn=1&Airport=MSN&Airport_Name=Madison,%20WI:%20Truax%20Field&carrier=FACTS)

4.7.6 Potential for Future Losses

Fog poses no direct risk to the structures or facilities of Dane County.

The impacts of fog are indirect impacts, related to increased incidence of traffic accidents and travel delays. As demonstrated in the past history data, the occurrence of fog is common in Dane County. Increased public awareness of appropriate cautions to use in dense fog conditions may help to reduce traffic crashes resulting from vehicle operator errors.

4.8 HAIL

4.8.1 Description

Hail falls from thunderstorm clouds that extend miles high into extremely cold air. Updrafts bring raindrops from the bottom to the top of the cloud where they freeze into ice pellets. They then fall only to be blown back up where another coating of rain freezes to the hailstone and it grows larger, layer by layer. This layering affect can increase the size of hailstones, sometimes to the size of baseballs. Typically the stronger the updraft, the more times a hailstone repeats this cycle and consequently, the larger it grows. Once they reach a weight sufficient enough to overcome the updrafts, they fall to the ground. The hailstone reaches the ground as ice since it is not in the warm air below the thunderstorm long enough to melt before reaching the ground.

Hail tends to fall in swaths that may be 20-115 miles long and 5-30 miles wide. The swath is not normally a large, continuous bombardment of hail, but generally consists of a series of hail strikes that are produced by individual thunderstorm clouds traversing the same general area. Hail strikes are typically one-half mile wide and five miles long. They may partially overlap, but often leave completely undamaged gaps between them.

Dane County averages about 3 days with hail per year. The period of time with the most frequent occurrence of hail producing severe thunderstorms is May through September.

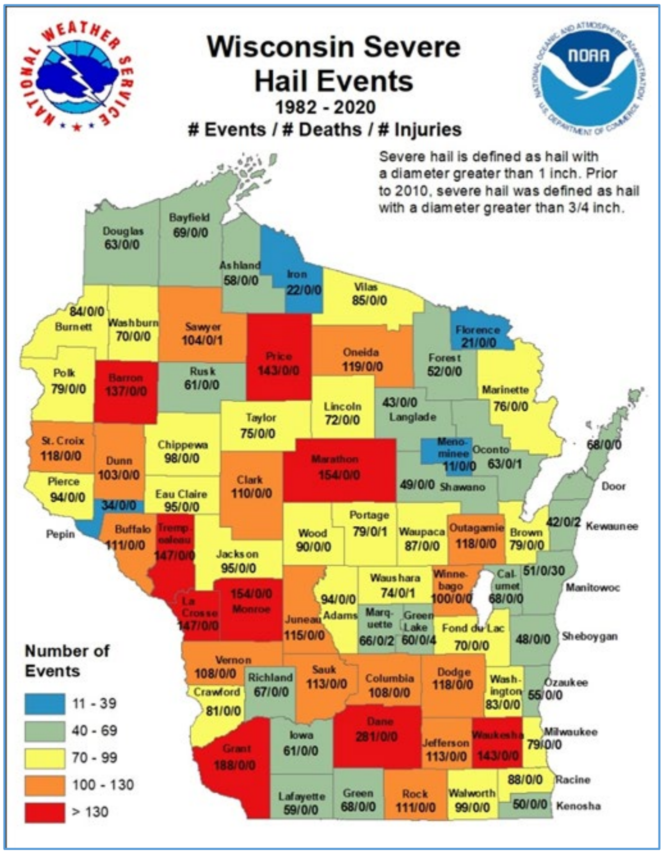
4.8.2 Previous Occurrences

The National Weather Service and the NOAA National Centers for Environmental Information (NCEI) maintains a listing of reported hail events, with a hail size greater than 0.75 inches, from 1950 through 2020. In Dane County, 262 hail events have been recorded. The largest hail size ever recorded in the County was four inches in diameter in July of 1960. Figure 4.8.1 indicated a summary of hail events, including deaths and injuries, statewide from 1982 to 2020. There have been no recorded deaths or injuries from hail in Dane County.

Hail events have occurred most frequently in June, July, and August, although hail has been reported with thunderstorms in every month of the year statewide. Considering Dane County as a whole, over an entire year, it is extremely likely a hailstorm will occur in any given year.

The NCEI database also provides a description of many of these events. The following is a sample from the most significant events where data is available.

Figure 4.8.1 Severe Hail Events in Wisconsin, 1982-2020



Source: National Weather Service, 2020

July 7, 1991

Dane County received a presidential disaster declaration for damages resulting from a storm on July 7, 1991. Winds topping 80 mph, hail, rain, and lightning caused extensive damage in Dane County. The storm left 60,000 people without electricity and downed so many tree branches that it took weeks for clean up to be completed. Dane County Regional Airport was estimated as receiving $4-5 million in damages losing some planes completely and severely damaging others. Twenty buildings were also damaged at the airport. Local farms sustained $3.1 million in damages to crops and buildings due to hail and high winds. Two people were reported injured in Dane County.

May 18, 2000

A supercell thunderstorm moved east/northeast across Iowa County. Hailstones up to 2.00 inches in diameter pelted and damaged many vehicles and home sidings, while stripping some of the corn and soybean crops. This storm then headed east into Dane County where it unleashed damaging straight-line winds in addition to large hail. Winds were estimated to reach hurricane-force level as the storm tore through Fitchburg where a home's garage was blown over. The storm then hit Madison with powerful winds and golf ball size hail. A Madison home's roof was torn off by the winds, and many large trees were felled. At least 200 vehicles sustained moderate to severe hail damage in Dane County.

August 11, 2002

A cluster of severe thunderstorms blossomed over western Dane County, resulting in wind, hail, and flash flood damage in the Pine Bluff area, west of the Madison metro-area. In the Pine Bluff area, hurricane-force downburst winds reached estimated speeds of 70 knots (80 mph), resulting in toppled trees and power lines. The fringe effects of this powerful macro-burst resulted in some tree damage north to the Cross Plains to Middleton area. The thunderstorm cluster also produced hail up to 2 inches in diameter in the Pine Bluff area, resulting in major damage to at least 100 vehicles, and to roofs and siding of homes.

April 13, 2006

A cluster of isolated severe thunderstorms hammered Dane County. Hailstones, some the size of tennis balls, hammered southern Wisconsin on Thursday night, denting cars and covering lawns as the storm moved west to east. The largest specimen, with a diameter of 4.25 inches, was found in Jefferson County. In southwestern Wisconsin, a weather service employee recorded 2.5-inch hail in Dodgeville around 9 p.m., and an Iowa County law enforcement officer saw hailstones 2.75 inches in diameter. In Madison, trained weather service spotters reported 2-inch hail on Fish Hatchery Road and 1.75-inch hail at West Towne Mall about 9:30 p.m. A few minutes later, other spotters reported 3-inch hail in Monona and Cottage Grove. Major damage was done to automobiles in Madison area. Homeowners suffered major damages as roofs and shingles were severely damaged by the hail. The hail damage estimate from this storm is reported at over $5.5 million.

August 24, 2006

Severe storms, with large hail and damaging, straight-line, downburst winds, developed ahead and along a cold front, which plowed east into an unseasonably warm, moist air mass over southern Wisconsin. The hail stones ranged from 3/4 inch to 2 inches in diameter, resulting in several vehicles receiving dents (in Lafayette, Sauk, and Dane County). The damaging winds were mostly in the 60 to 70 mph range resulting in numerous reports of uprooted trees. Dozens of power lines were pulled down as broken tree branches fell on them. The hail damage estimate from this storm is reported at over $2.0 million.

September 18, 2010

A strong cold front was slowly sagging through southern Wisconsin during the early morning hours of September 18th. Mid-level warm advection and frontogenesis ahead of a short wave moving through the region created forcing and elevated instability, as well as strong effective deep layer shear of 40 to 50 knots, that generated elevated thunderstorms behind the surface cold front. The thunderstorms produced hail showers, turning the ground white, with hail stones up to 1 inch in diameter. Trained spotters reported a 1 to 2 mile-wide swath of damage from hail showers that extended from north of Dodgeville, near Cross Plains, to just east northeast of Monona, dissipating near Interstate 90. Hundreds of vehicles were damaged; many homes had siding, window and screen damage; many trees were stripped of their leaves. The hail damage estimate from this storm is reported at over $1.0 million.

September 19, 2016
A line of thunderstorms formed along a stalling cold front and moved across southern WI. A severe thunderstorm within the line produced widespread hail damage on the southwest side of Madison and in Middleton. Thousands of insurance claims are anticipated due to hail damage to vehicles and properties.

4.8.3 Impact of Climate Change on Future Conditions

Damaging hail storms are already a regular occurrence. There is not a readily available source of information to assess whether the incidence of large hail will increase, decrease, or remain unchanged as a result of the warming climate. A qualitative argument can be made that more energy in the atmosphere resulting from increased concentrations of greenhouses would result in an increase of convective severe weather events such as hail storms. This is not borne out in currently available models, however. There is no clear trend to indicate whether or not this hazard is changing or will change significantly in the future.

4.8.4 Impact Assessment

While hail is usually a geographically isolated event, it is rarely isolated meteorologically. Hail almost always occurs in conjunction with a severe thunderstorm. Storms capable of producing large hail are also likely to produce lightning, high winds, heavy rain, and possibly tornadoes. Damages associated with these storms result from the combination of all of these factors.

Insurance industry representatives involved in this planning effort indicate that a large hailstorm is one of their greatest concerns in terms of potential losses and insurance payouts. Hailstorms can cause extensive property damage in both urban and rural settings. Most hailstorms produce marble size or smaller hailstones, which can damage crops, but do not typically cause damage to automobiles or buildings. Larger hailstones can destroy crops and can cause extensive damage to buildings, including roofs, windows, and siding. Vehicles and even aircraft can be a total loss. When windows or roofs are damaged due to hail, water damage from often accompanying heavy rain can be significant. A major hailstorm can cause cumulative damages to crops and personal property running into the millions of dollars. Serious injury and loss of human life, however, are rarely associated with hailstorms.

No deaths or injuries have been directly attributed to hail in Dane County. According to the NCEI database, financial losses in Dane County due to hail total over $9 million in property damages since 1999.

4.8.5 Vulnerability Assessment

In general, all Dane County agricultural crops, buildings, and vehicles are to some degree vulnerable to hail damage. The essential functions of the critical facilities are not likely to be impacted by hail. Nor are any at-risk populations any more vulnerable than the general population. When damaging hail occurs, it does not affect the entire county. Rather, it is a geographically isolated event, affecting only small areas of several square miles at any one time. In terms of crop losses, the actual damages that occur will depend on the type of crop and the growth stage of the plants when the hail occurs. In terms of property losses, the actual damages will depend on the housing density and density of automobiles in the impacted area. This is highly variable across the County. A storm with large hail over a crowded shopping mall parking lot on a Saturday afternoon will have a significantly different impact than the same storm over a suburban area in the evening when most of the cars are parked in garages. Likewise, a hailstorm in a rural area in the early spring when the plants are just emerging will have much less of an impact than a storm of the same intensity occurring later in the growing season when the plants are more susceptible to damage and when there is no time to replant if the crop is a total loss.

4.8.6 Potential for Future Losses

The potential for future losses due to hail damage is estimated based on an extrapolation of losses from past events. There are limitations to this method:

- Hail damage is not typically a meteorologically isolated occurrence. Damages occur in conjunction with high winds and heavy rain and storm damage estimates are usually cumulative of all of these effects. The NCEI website provides data on only a handful of events where significant hail damage estimates are isolated from other causes.
- The exposure to damage increases as the population of the County increases. Future damages may increase simply due an increase in the amount of exposed property.
- The damages resulting from a hailstorm depend greatly on where and when the storm hits. The use of average losses from past events does not account very well for these variables.

The NCEI database indicates that since 1999, Dane County has seen more than 80 hailstorms with hail size greater than .75 inches, 34 occurrences with hail at least 2 inches in diameter, and eleven of those events causing over $9.1 million in reported property damage. Of these storms, three events account for $8.5 million of the $9.1 million in recorded damages. Extrapolating from this information, over the 17-year period between 1999 and 2016, the average annual property damage from hail storms is approximately $535,000. Since the 2018 NHMP update, over 20 hail events have been cited in Dane County alone.

4.9 LANDSLIDES, EROSION, AND SINKHOLES

4.9.1 Description

Landslides, erosion, and sinkholes are geological phenomena that can pose a hazard to structures and people. Although none of these events are likely to cause a major natural disaster in Dane County, all three present some level of risk to the County's citizens.

Erosion and Landslides

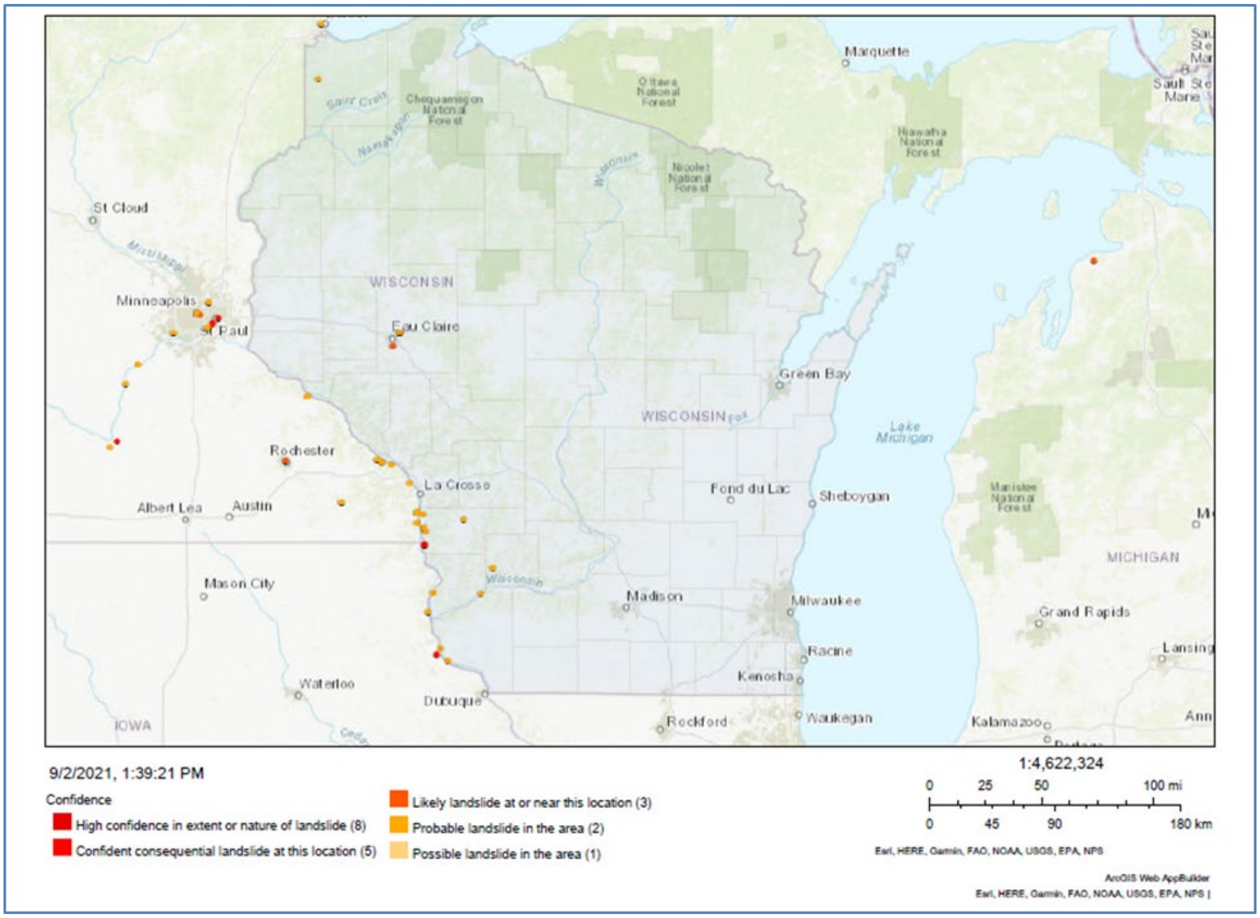
A landslide is a relatively sudden movement of soil and bedrock downhill in response to gravity. The movement of the soil can cause damage to structures by removing the support for the foundation of a building or by falling dirt and debris colliding with or covering a structure. Landslides can be triggered by heavy rain, bank or bluff erosion, or other natural causes.

Erosion is the detachment and movement of soils or rock fragments by water, wind, ice or gravity. Erosion may contribute to the likelihood and occurrence of landslides, particularly when stream banks or bluffs are eroded. The State Hazard Analysis from 2016 cites several examples where structures that were otherwise considered not vulnerable to landslides and flooding were endangered due to soil and streambank erosion.

According to the United States Geological Survey (USGS), "Landslides occur in every state and U.S. territory. The Appalachian Mountains, the Rocky Mountains and the Pacific Coastal Ranges and some parts of Alaska and Hawaii have severe landslide problems. Any area composed of very weak or fractured materials resting on a steep slope can and will likely experience landslides." (USGS "Landslides Hazard Program: Landslides 101." Available online at https://landslides.usgs.gov/learn/ls101.php last accessed December, 2021).

In Wisconsin, there have been instances of bluff slumping along the shore of Lake Michigan, rock fall along the bluffs of the Mississippi River and the collapsing of hillsides during heavy rainfall. Figure 4.9.1 indicates areas of landslide incidence and susceptibility. For Dane County, most of the land demonstrates both a low susceptibility and incidence. The southwest corner of the county demonstrates a moderate susceptibility and low incidence occurring, while a small portion just north of Madison demonstrates a high susceptibility and low incidence of occurrence. Steep slopes are another indicator of potential landslide problem areas, or areas that may have development constraints. Slopes greater than 12 percent are shown in Figure 4.9.2. The map indicates a concentration of these slopes in the southwestern, but also least populated area of the County.

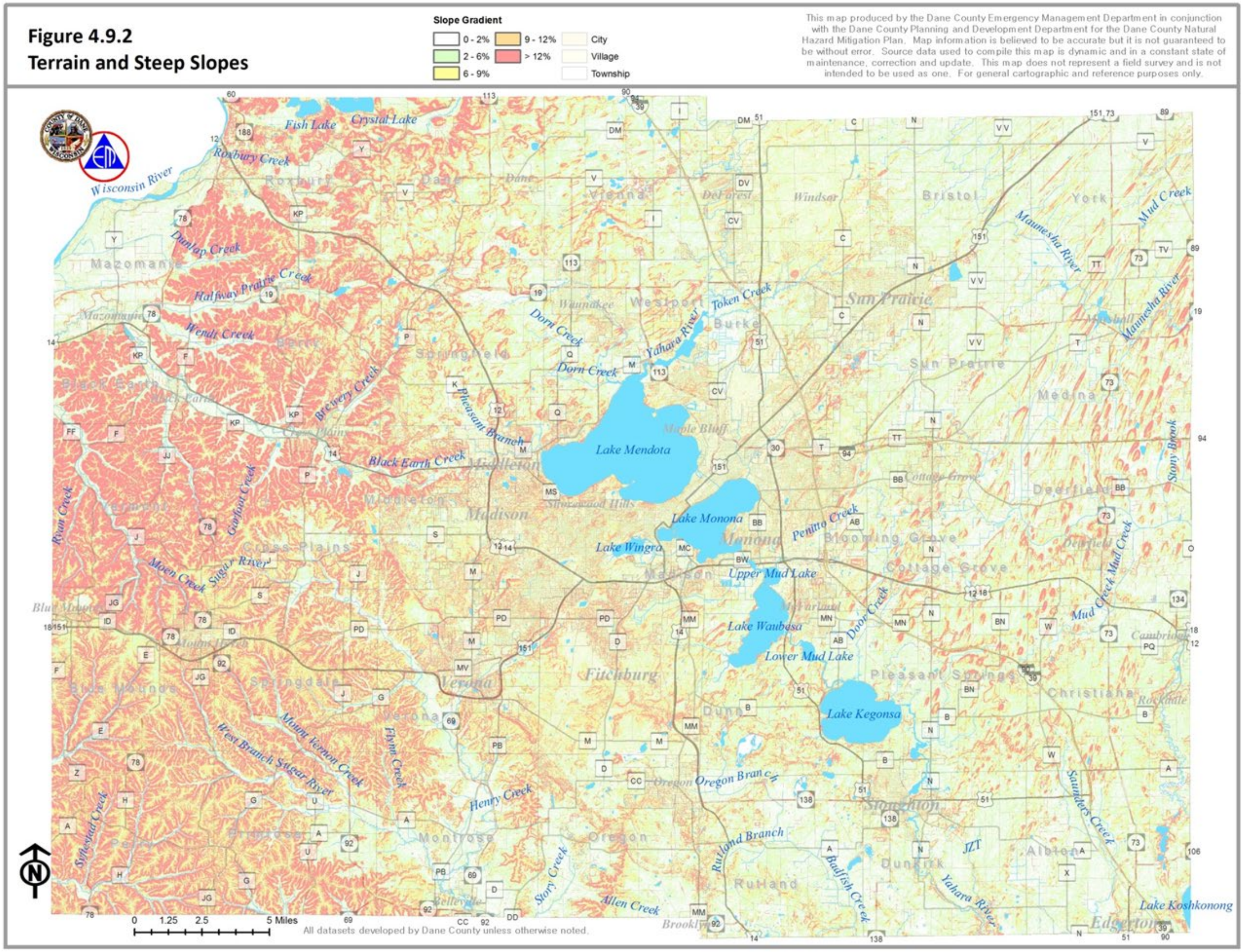
Figure 4.9.1 National Landslides Hazard Map – Wisconsin Focus



Source: USGS "Landslides Hazard Program" https://landslides.usgs.gov/hazards/nationalmap/index.php

Note: Susceptibility not indicated where same or lower than incidence. Susceptibility to landsliding was defined as the probable degree of response of [the area] rocks and soils to natural or artificial cutting or loading of slopes, or to anomalously high precipitation. High, moderate, and low susceptibility are delimited by the same percentages used in classifying the incidence of landsliding. Dane County is not in a landslide prone or vulnerable region.

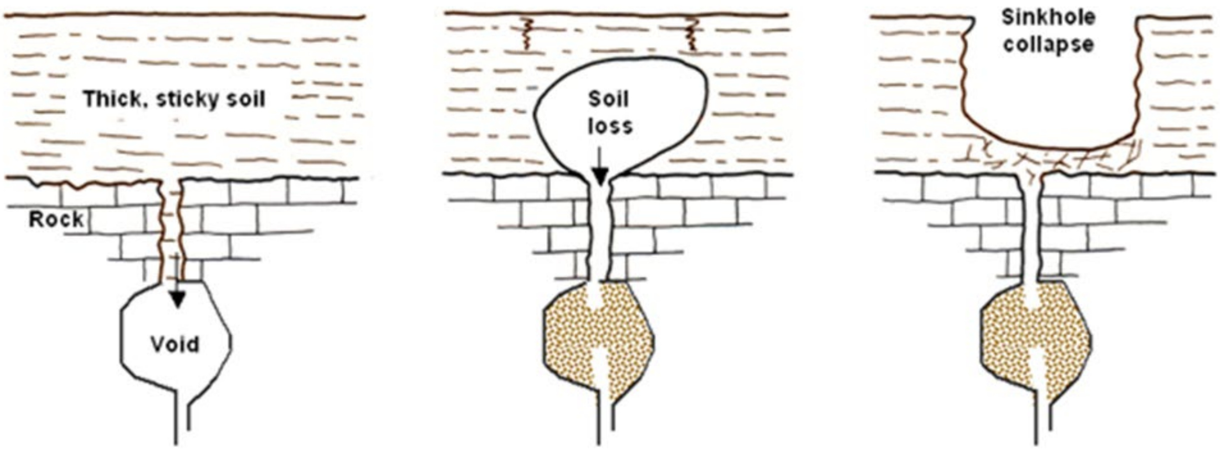
Figure 4.9.2 – Terrain and Steep Slopes



Sinkholes

Sinkholes are holes or depressions that form when water washes sediment down into cracks and voids in karst bedrock. Sinkholes form from the bottom up as the sediment immediately above the bedrock is the first to be washed into the voids. The land above a sinkhole often appears normal until a critical amount below has been washed away. When the soil surface can no longer support the weight, it collapses.

Figure 4.9.3 Sinkhole Formation Illustration



Source: Wisconsin Geological & Natural History Survey, http://wgnhs.uwex.edu/water-environment/karst-sinkholes/

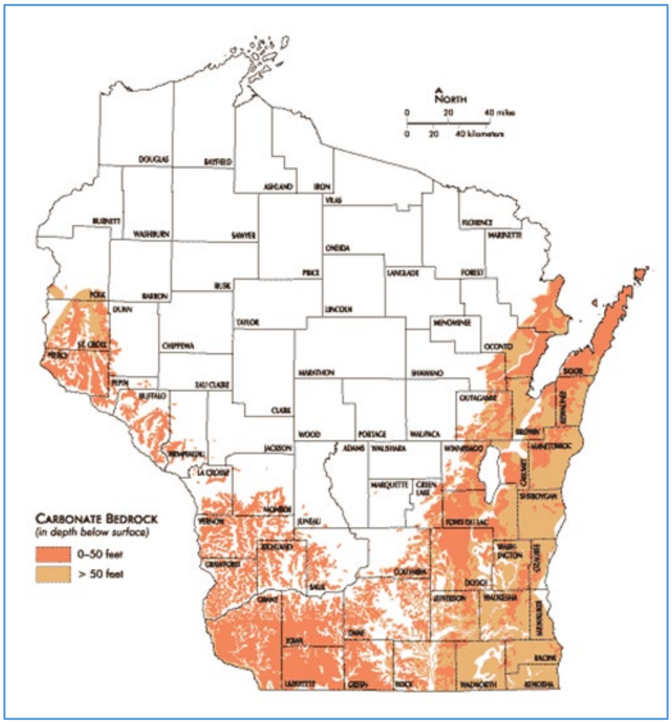
Karst" is a landscape created when water dissolves rocks. In Wisconsin, dolomite and some limestone are typical soluble rocks. The rocks are dissolved mostly along fractures and create caves and other conduits that act as underground streams. Water moves readily through these openings, carrying sediment (and pollutants) directly into our groundwater.

Karst landscapes may have deep bedrock fractures, caves, disappearing streams, springs, or sinkholes. These features can be isolated or occur in clusters, and may be open, covered, buried, or partially filled with soil, field stones, vegetation, water or other miscellaneous debris.

Not all sinkholes are the result of karst. Manmade sinkholes occur when a water main break washes sediment out of the area, creating a large cavity.

Areas with karst potential are indicated Figure 4.9.4. The majority of Dane County demonstrates a deeper karst potential, which indicates that the process occurs deeper than five feet below the surface. There are scattered shallow karst potential regions in the southwest corner of the County, consistent with the landslide susceptibility mapping and the presence of the "Driftless Area". The "Driftless Area" is primarily composed of southwestern Wisconsin, and portions of Minnesota and Illinois, categorized by the lack of glacial drift, or the deposits of debris left behind glaciers. Shallow karst potential indicates the potential for the karst process to occur anywhere between the surface and five feet below the surface.

Figure 4.9.4 Wisconsin Karst Potential



Source: Wisconsin Geological & Natural History Survey

4.9.2 Previous Occurrences

Examples of landslides and damaging erosion in the County are not detailed specifically, but are reflected in the numerous erosion controls and ordinances in the County. There are no documented occurrences of significant problems associated with naturally occurring sinkholes in Dane County available.

August 14, 2015
Some 300 residents of River's Edge Apartments in Madison were evacuated Friday after a privately-owned water pipe broke, causing a potential gas leak and a sinkhole that submerged several vehicles. Several other vehicles were damaged by the flooding in the area, including inside the underground garages.

Source: Wisconsin State Journal

Note: This sinkhole was caused by a broken water pipe and was not, strictly speaking, naturally occurring.

4.9.3 Impact of Climate Change on Future Conditions

The predicted increases in temperature will likely result in stronger and more frequent rainstorms. Current models predict increased frequency and intensity of extreme weather statewide, including more frequent, more intense precipitation events. These changes have the potential to increase the incidence and severity of flooding, erosion, and landslides/land subsidence. These issues are discussed in more detail in the flood hazard section.

4.9.4 Impact Assessment

Direct Impacts

Direct impacts of these hazards impact essential infrastructure and natural resources primarily, with additional, but less severe, impacts on critical facilities and response capabilities. Landslides can impact the integrity and navigability of roads, rail lines, and waterways by filling the passages with soil and debris. This impacts the direct usage of the transportation networks and creates secondary impacts on the movement of supplies and goods, including critical supplies such as medications and foodstuffs, between distribution points and commercial centers.

Landslides, erosion, and sinkholes could impact the ability of response capabilities to navigate between areas. Population, general property, and cultural or historic resources are only impacted directly on a case-by-case basis, where a landslide, sinkhole, or erosion event directly strikes these specific areas. There is no quantifiable way to assess these incident-specific impacts outside of actual occurrences. Examples may include sinkholes damaging structures or croplands, erosion changing previously protected structures into exposed properties for flooding, or landslides damaging physical properties.

Indirect Impacts

The indirect impacts of erosion augment the probability and likelihood of other hazards, including landslides and flooding. The effects on water ecology are also profound, but exceed the scope of this planning process. Landslides may indirectly impact the landscape, which may also have land use or recreational repercussions. Revenue losses are possible due to inaccessibility of affected areas, lost agricultural income due to field degradation, and loss income from natural resources such as parks and waterways due to contamination, damage, or destruction caused by landslides, sinkholes, or erosion.

4.9.5 Vulnerability Assessment

The overall exposure of the County to landslides and sinkholes are difficult to quantify, as the events generally impact specific buildings or aspects of land and the predictability of those is variable. However, some attempt below is made to examine potential vulnerability for planning and mitigation efforts. Erosion potentially affects a greater number of properties and facilities, but it is also a heavily mitigated hazard within the County, as demonstrated by the numerous zoning and erosion control ordinances.

Population

In general, the population is not overly vulnerable to landslides, sinkholes or erosion except for specific and unpredictable incidents.

Property

In general, a building structure is only vulnerable to landslides, sinkholes and erosion when it directly strikes the property. The County has several ordinances and controls in place to regulate the development and use of land to prevent most occurrences of damaging erosion. Building on steep slopes subject to landslide hazards are also regulated. The continued emphasis on zoning, “smart growth” community plans, and land use ordinances indicate that the County is pre-mitigating the potential for these hazards, rather than reacting to the hazards.

4.9.6 Potential for Future Losses

There is little data to base a future loss estimate on for these hazards. Generally, the anticipated loss is expected to be limited. This is largely due to the fact that the areas potentially at risk (southwest Dane County) are also the least developed areas of the County.

Plans for regulating potential sources of erosion, including stormwater, streambank, farming, and construction sites, appears multiple times in the Dane County Comprehensive Plan, indicating that mitigation efforts for erosion are ongoing.

4.10 LIGHTNING

4.10.1 Description

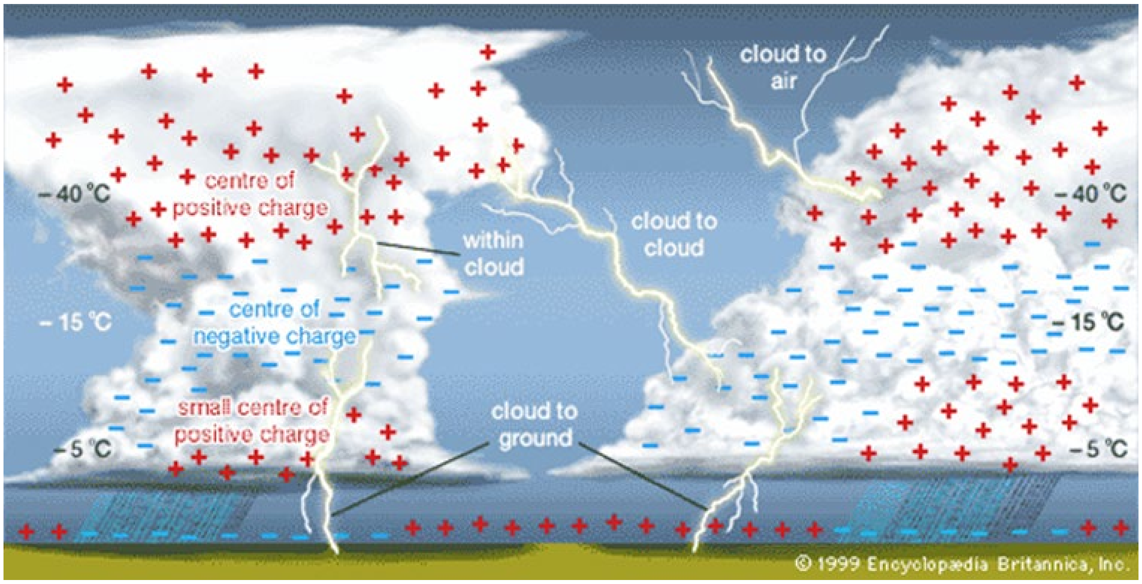
Lightning is caused by the attraction between positive and negative charges in the atmosphere, resulting in the buildup and discharge of electrical energy. This rapid heating and cooling of the air produces the shock wave that results in thunder. During a storm, raindrops can acquire extra electrons, which are negatively charged. These surplus electrons seek out a positive charge from the ground. As they flow from the clouds, they knock other electrons free, creating a conductive path. This path follows a zigzag shape that jumps between randomly distributed clumps of charged particles in the air. When the two charges connect, current surges through that jagged path, creating the lightning bolt. Each spark of lightning can reach over five miles in length, soar to temperatures of approximately 50,000 degrees Fahrenheit, and contain up to 100 million electrical volts.

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, rockets, very tall structures, and structures on mountains.

According to the National Weather Service, 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 it 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 4.10.1 Types of Lightning

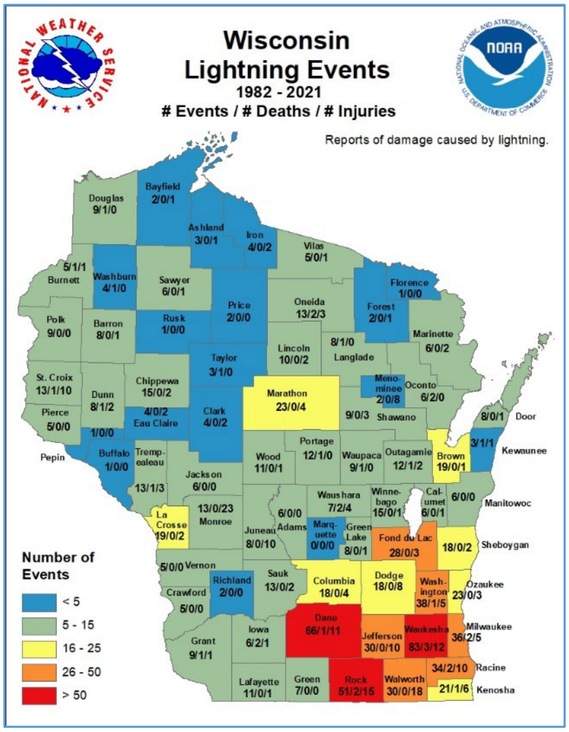


Source: Encyclopedia Britannica, Inc., http://whyfiles.org/2011/nothing-light-about-lightning/

High winds, rainfall, and a darkening cloud cover are warning signs for possible cloud-to-ground lightning strikes. While many lightning casualties happen at the onset of a storm, more than half of lightning deaths occur 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 exist when skies are clear. Lightning has been known to strike ten miles or more from the storm in an area with clear sky above. 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 these types of events with particular emphasis on adequate early warning. (Wisconsin Emergency Management, Wisconsin Threat and Hazard Identification and Risk Assessment, 2021)

4.10.2 Previous Occurrences

Figure 4.10.2 Wisconsin Lightening Events, 1992-2021



Source: National Weather Service

July 6, 2003

Lightning struck a home in Middleton, resulting in a roof/attic fire.

August 22, 2007

A thunder storm lightning strike to a utility pole caused a live wire to fall in a puddle of water at a bus stop as people were getting on a bus in Madison. Three people were killed and a fourth was injured.

August 27, 2007
A man playing golf Monday in Madison died after he was hit by lightning. The golfer sought shelter from the rain under a pine tree but was struck anyway. This was the second deadly incident caused by a lightning strike in Madison in a week.

June 2, 2010
A lightning strike ignited a fire that damaged areas of the second floor and attic of a home in the 3600 block of Wyndwood Way in the Town of Bristol.

October 12, 2016
Lightning struck the top of a Madison wastewater treatment plant causing a fire. The fire was quickly contained and extinguished by the local firefighters.

October 30, 2018
On October 30th, 2018, lightning directly struck a residence in the City of Middleton, on the 4500 block of Ellington way. The damages resulted in a total loss, which totaled up to $440,000 worth of damages. No fatalities or injuries were caused by this event.

July 7, 2020
On July 7th, 2020, lightning directly struck the residence of 100 Block West, Wilson Street, Madison Wisconsin. The City of Madison Fire Department put out a fire that was subsequently caused by the lightning strike, and it was estimated that about $50,000 worth of total damages were incurred. No fatalities or injuries were caused by this event.

4.10.3 Impact of Climate Change on Future Conditions

Damaging lighting and thunderstorms are already a regular occurrence. There is not a readily available source of information to assess whether the incidence of these storms will increase, decrease, or remain unchanged as a result of the warming climate. A qualitative argument can be made that more energy in the atmosphere resulting from increased concentrations of greenhouses would result in an increase of convective severe weather events such as thunderstorms. This is not borne out in currently available models, however. There is no clear trend to indicate whether or not this hazard is changing or will change significantly in the future.

4.10.4 Impact Assessment

Direct Impacts

Lightning always tries to follow the shortest, easiest path to earth, and often follows several paths simultaneously. Lightning strikes buildings or other objects because the materials in them provide easier paths to ground than the air. Lightning is more likely to strike on projecting objects such as trees, poles, wires or building steeples than on larger, flatter surfaces projecting to the same height or lower. Lone buildings are also primary targets. Lightning can enter a building through a direct strike, by striking a metal object attached to the building, by leaping over to the building after striking a nearby tree, or by following a power line or ungrounded wire fence attached to a building.

Lightning is often perceived as a minor hazard. The effects of lightning, however, can be significant, causing property damage, injury, and death. Damage from lightning occurs in a number of ways:

- Electrocution or severe electrical shock, and burns of humans and animals
- Vaporization of materials in the path of the strike
- Fire caused by the high temperatures associated with lightning
- Power surges that can damage electrical and electronic equipment

Lightning strikes are capable of causing intense, but very localized damage. In contrast to other hazards, lightning does not cause widespread disruptions with the community. Structural fires, localized damage to buildings, damage to electronics and electrical appliances, and electrical power and communications outages are typical consequences of a lightning strike.

When humans are struck by lightning, the result is deep burns at the point of contact mostly on the head, neck and shoulders. Approximately 70 percent of lightning survivors experience residual effects, most commonly affecting the brain (neuropsychiatric, vision and hearing). These effects can develop slowly, only becoming apparent much later. Death occurs in 20 percent of lightning strike victims. Nationwide, 85 percent of lightning victims are children and young men ages 10-35 engaged in recreation or work.

Indirect Impacts

The indirect social and economic impacts of lightning damage are typically associated with the loss of electrical power. Given our societies heavy reliance on electric power, any disruption in the supply, even for a short time period, can have significant consequences. The utilities supplying Dane County have worked closely with emergency response agencies and human services providers to develop plans for responding to planned and unplanned power outages in the County.

Lightning strikes on communications infrastructure, damaging equipment, and temporarily disrupting service are also an indirect impact. Communications towers typically have well-designed lightning protection systems and this is planned-for contingency.

Figure 4.10.5: Two-Way Radio Antenna, hit by lightning, blown off the tower.

Dane County Emergency Management, March 2017

4.10.5 Vulnerability Assessment

While national data shows that lightning almost causes more injuries and deaths than any other natural hazard except extreme heat, there doesn't seem to be any trend in the data to indicate that one segment of the population is at a disproportionately high risk of being directly affected. Anyone who is outside during a thunderstorm is at risk of being struck by lightning.

As with extreme heat, however, there are segments of the population that are especially vulnerable to the indirect impacts of lightning, particularly the loss of electrical power. As a group, the elderly or disabled, especially those with home health care services relying on rely heavily on an uninterrupted source of electricity. Resident populations in nursing homes, Community Based Residential Facilities, or other special needs housing may also be vulnerable if electrical outages are prolonged. If they do not have a back-up power source, rural residents and agricultural operations reliant on electricity for heating, cooling, and water supplies are also especially vulnerable to power outages.

Large outdoor gatherings (sporting events, concerts, campgrounds, etc.) are also particularly vulnerable to lightning strikes that could result in injuries and deaths. This vulnerability underscores the importance of developing site-specific emergency procedures for these types of events, with particular emphasis on adequate early warning. Early warning of lightning hazards, combined with prudent protective actions, can significantly reduce the likelihood of lightning-related injuries and deaths.

4.10.6 Potential for Future Losses

The potential for future losses due to lightning damage is estimated based on an extrapolation of losses from past events. There are limitations to this method:

- The exposure to damage increases as the population of the County increases. Future damages may increase simply due an increase in the amount of exposed property.
- The damages resulting from lightning depend greatly on where and when the storm hits. The use of average losses from past events does not account very well for these variables.
- Indirect impacts are not accounted for.
- While the estimation of future losses based on past events is unsophisticated, it still is a useful method of quantifying the damage potential.
- The only data source available is the NOAA, National Centers for Environmental Information (NCEI). It is highly likely that this dataset is incomplete and the actual losses and damages are underestimated.

The NCEI database indicates that between 1996 and 2021, Dane County has experienced 52 lightning events where property damage, personal injury or death has occurred. According to the NCEI, during this time period, damages totaled $2.68 million and there were 10 injuries and one direct fatality. Lighting was indirectly responsible for 3 deaths and one injury in 2007. Based on this history and assuming the losses could be proportionately spread over each incident, the estimated average loss per lightning strike event that causes damage is $51,538. Dane County averages 2.8 damaging strikes a year since 1996, which equates to an average annualized loss estimate of $148,887. Injuries occur every 2 years on average, and deaths every 20 years. Since 2018, one lightening event in the Village of Cross Plains resulted in two injuries, no deaths. Another lightening event was reported in October of 2018, resulting in property damage to a multi-dwelling unit and two injuries.

4.11 TORNADO

4.11.1 Description

A tornado is a violently rotating column of air (vortex), extending from the base of a convective cloud (usually cumulonimbus) to the ground. There may or may not be a visible condensation funnel (what most people refer to as the funnel cloud) associated with the tornado. Therefore, a tornado may be nearly invisible since one cannot see a vortex of rotating air. For a vortex to be classified as a tornado, it must be in contact with the ground and the cloud base. (American Meteorological Society, Glossary of Meteorology 2nd Edition. Available online at https://glossary.ametsoc.org/)

Tornadoes usually form under certain types of atmospheric conditions. They are more likely to occur in regions where there are strong contrasts in temperature and humidity across short distances. Nationally, these conditions are most common in the central plains of North America, east of the Rocky Mountains and west of the Appalachian Mountains. They occur mostly during the spring and summer, starting earlier in the south and later in the north. According to A Tornado Climatology of Wisconsin, the typical day with tornadoes usually begins with warm and humid conditions with a few fair-weather cumulus clouds developing vertically over time in the unstable air. Later the first sign of an approaching thunderstorm is observed—a high thin layer of ice clouds called cirrus blowing off the tops of the thunderstorm to the west. (National Severe Storms Laboratory "FAQ About Tornadoes." Available online at http://www.nssl.noaa.gov/research/tornadoes/)

Rotation in a thunderstorm begins when air entering the storm near the surface is blowing from different direction than air higher in the atmosphere. The rotation usually starts as a roll or horizontal rotation of the air in the lower 10,000 feet of the atmosphere. The warm updraft feeding the storm develops further, lifting one end of the rolling air and transforms the rotating mass into a vertical position. Most tornadoes rotate counterclockwise (cyclonically) in North America. Tornadoes may last for anywhere from a few minutes to up to an hour. The width of a tornado may range from a few yards to over a mile; the path of a tornado may range from a few hundred yards to hundreds of miles. (National Severe Storms Laboratory "FAQ About Tornadoes." Available online at http://www.nssl.noaa.gov/research/tornadoes/)

Through observational studies, T. Theodore Fujita created the Fujita Scale (commonly known as the "F Scale") in 1971 to classify tornadoes based on damage caused by the tornado in correlation to wind speed. However, over the years this scale has revealed several weaknesses and in 1992, Fujita published his memoirs called Mystery of Severe Storms which included an updated scale. This updated scale maintained the original classification of tornado wind speeds with damage assessments based on the type of structure. These improvements were incorporated by a committee convened by Texas Tech University (TTU) Wind Science and Engineering (WISE) Research Center to design the Enhanced Fujita Scale, commonly known as the EF Scale. One of the most important factors of the EF Scale is that it includes previous F Scale ratings to create consistency between the initial tornado databases, which stretch back into the 1950s, and the more contemporary measurement systems. This new system still uses wind estimates (not measurements) based on damage to assign scale ratings. It uses three-second gusts estimated at the point of damage based on a judgment of 8 levels of damage to one of 28 indicators (building types and materials). The estimates also vary with height and exposure.

A table showing the relationship between the original Fujita Scale and the Operational EF Scale, which was enacted as the standard measurement system in the United States beginning February 1, 2007, is presented in Table 4.11.1

Table 4.11.1 Fujita and Enhanced Fujita Scale Comparison

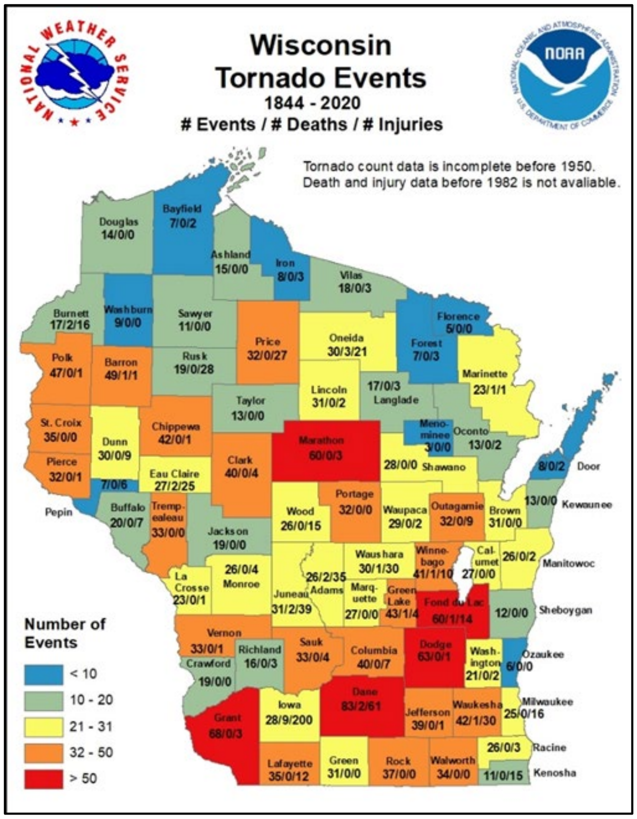
Fujita Scale			**Derived EF Scale**		**Operational EF Scale**	
F Number	Fastest 1/4-mile (mph)	3 Second Gust (mph)	EF Number	3 Second Gust (mph)	EF Number	3 Second Gust (mph)
0	40-72	45-78	0	65-85	0	65-85
1	73-112	79-117	1	86-109	1	86-110
2	113-157	118-161	2	110-137	2	111-135
3	158-207	162-209	3	138-167	3	136-165
4	208-260	210-261	4	168-199	4	166-200
5	261-318	262-317	5	200-234	5	Over 200

Source: National Weather Service. Available online at http://www.spc.noaa.gov/faq/tornado/ef-scale.html

Tornadoes are documented across Wisconsin, as demonstrated in Figure 4.11.2 Dane County currently has more reported tornado events than any other county in Wisconsin for the period of 1955-2020. This is partially due to the fact that Dane County is a large county– the larger the county the greater the chances that a tornado will occur within its boundaries. However, Southern Wisconsin tends to experience more tornadoes than northern Wisconsin since it is closer to the storm track that pulls warm and moist air up from the Gulf of Mexico. Warm, moist air is the fuel for thunderstorm development.

Figure 4.11.3 shows the tornado paths or, for short-duration events, the tornado touch-down points. This figure indicates that tornadoes occur in any portion of the county and often cross county lines. Despite this overall possibility of tornadoes, a single tornado does not impact the entire county simultaneously and damages less than five percent of the total county area in any given event (an extreme example: a 1-mile wide tornado going northeast along the 51-mile diagonal of Dane County would damage 51 square miles, or only 4.2% of the total county area).

Figure 4.11.2 Wisconsin Tornado Events, 1844-2020



Source: National Weather Service

Figure 4.11.3 Wisconsin Tornado Tracks/Steaks, 1950-2020

Source: NOAA, NWS, SVRGIS Geo-data, Wisconsin Map Developed by DCEM

Data from the National Weather Service (NWS), indicates that more tornadoes have affected Dane County in the past five decades, as compared to previous decades. However, much of this increase is due to greater documentation efforts by NWS meteorologists, especially from the 1980s to the present. Prior to the 1960s, unless a tornado struck a highly populated are in broad daylight, it likely went undocumented. Additionally, severe weather spotter and research videotapes of tornadoes in the past 20 years has shown that a tornado can be in progress, but a visible “funnel cloud” may be absent or poorly defined. In these cases, confirmation of a tornado is based on a rotating dirt/debris spray observed at ground and cloud-base rotation directly above. Table 4.11.4 provides a listing of Dane County tornadoes from the NCEI database.

Table 4.11.4 Dane County Tornadoes, 1955-2021

Date	Scale (F or EF)	Direct Deaths	Direct Injuries	Property Damage	Tornado Length (Miles)	Tornado Width (Yards)
4/18/1955	F2	0	0	$250,000	9.2	100
10/9/1958	N/A	0	0	$30	1	50
7/10/1966	F1	0	0	$25,000	0.1	33
6/11/1967	F2	0	0	$250,000	1.3	10
8/2/1967	F3	2	5	$25,000	0	200
4/20/1968	F2	0	0	$25,000	0.1	33
5/31/1969	F0	0	0	$2,500	1	50
6/4/1969	F2	0	0	$25,000	4.9	300
5/9/1970	F1	0	1	$25,000	1	100
10/9/1970	F2	0	0	$250,000	3.3	50
6/18/1971	F1	0	0	$25,000	1	100
9/4/1971	F1	0	0	$2,500	0.5	50
9/20/1972	F1	0	0	$25,000	0.5	50
3/11/1973	F1	0	0	$0	0.5	50
5/21/1974	F1	0	0	$250,000	2.3	50
6/4/1975	F3	0	0	$25,000	2.3	33
7/30/1976	F2	0	0	$0	0	33
6/15/1981	F2	0	0	$250,000	1	33
6/8/1984	F2	0	0	$2,500,000	3	50
5/30/1985	F2	0	0	$250,000	21	100
7/11/1986	F1	0	0	$250,000	0.8	50
5/8/1988	F2	0	1	$25,000	7	100
5/8/1988	F2	0	0	$250,000	16	173
6/14/1989	F1	0	0	$250,000	0.2	50
6/14/1989	F1	0	0	$250,000	0.2	50
6/14/1989	F0	0	0	$0	0.2	50
6/14/1989	F0	0	0	$0	0.1	23

Date	Scale (F or EF)	Direct Deaths	Direct Injuries	Property Damage	Tornado Length (Miles)	Tornado Width (Yards)
3/27/1991	F2	1	5	$2,500,000	12	440
5/22/1991	F0	0	0	$0	0.1	23
6/17/1992	F3	0	30	$25,000,000	16	400
7/4/1994	F0	0	0	$0	0.1	25
7/25/1997	F1	0	0	$130,000	1	100
7/25/1997	F1	0	1	$388,500	2.7	175
5/30/2003	F0	0	0	$0	3.1	25
5/23/2004	F0	0	0	$0	1	25
5/23/2004	F0	0	0	$0	1.3	25
6/23/2004	F0	0	0	$3,000	0.1	25
6/23/2004	F1	0	0	$1,490,000	7.8	200
7/11/2004	F0	0	0	$0	0.1	25
3/30/2005	F0	0	0	$2,000	0.2	50
8/18/2005	F3	1	23	$34,310,000	17	600
8/18/2005	F0	0	0	$0	2	30
8/18/2005	F1	0	0	$75,000	1.6	100
6/18/2006	F0	0	0	$0	0.1	20
6/7/2008	EF0	0	0	$0	0.45	25
6/7/2008	EF0	0	0	$0	0.21	25
6/7/2008	EF1	0	0	$429,000	3.83	150
6/12/2008	EF1	0	0	$0	4.41	100
6/12/2008	EF0	0	0	$0	2.56	50
6/21/2010	EF1	0	0	$15,000	0.16	40
7/22/2010	EF1	0	0	$1,000	1.53	30
7/22/2010	EF0	0	0	$0	3	30
7/22/2010	EF1	0	0	$20,000	4.18	75
7/22/2010	EF1	0	0	$5,000	1.46	75
7/22/2010	EF0	0	0	$0	0.22	30
6/8/2011	EF0	0	0	$100,000	17.15	100
8/8/2011	EF0	0	0	$0	1.21	20
6/16/2014	EF3	0	0	$14,000,000	0.96	100
6/16/2014	EF2	0	0	$5,000,000	0.22	200
6/16/2014	EF1	0	0	$300,000	1.49	300
6/18/2014	EF0	0	0	$0	0.16	30
6/29/2014	EF1	0	0	$50,000	2.32	500
10/07/2017	EF0	0	0	$250,000	9.7	33
08/9/2018	EF0	0	0	$50,000	0.25	8.3

Date	Scale (F or EF)	Direct Deaths	Direct Injuries	Property Damage	Tornado Length (Miles)	Tornado Width (Yards)
07/29/2021	EF0	0	0	Pending	2.47	125
07/29/2021	EF0	0	0	Pending	3.58	75

Source: Dane County Emergency Management, 2021

In more recent years, the National Weather Service and the NOAA National Centers for Environmental Information (NCEI) have been tracking weather extremes and their consequences in greater detail. A search of the NCEI website provided the following descriptions of several tornadoes from the past twenty years:

4.11.2 Previous Occurrences

June 1984

At approximately 12:41 am the 8th of June an F5 Tornado touched down in neighboring Iowa County, leveling Barneveld, a village of over 600 people. One of the few structures left standing was the water tower. The Barneveld Tornado remained on the ground throughout its entire 36-mile journey. Additionally, the path of the tornado's destruction was exceptionally wide, at times 300 yards.
Soon after touching down in Barneveld, the tornado headed on a northeast path into Dane County. The path of the tornado went through the Town of Vermont and through the Village of Black Earth, and the NCEI records indicate the Tornado had dissipated to F2 intensity by that time. Twenty-four homes were damaged and at least 8 were destroyed. Woodlots were plucked clean of foliage and branches, and some trees were uprooted from the ground. Once the tornado dispersed, nine people were left dead (all in Barneveld) and about 200 were left injured as a direct result of the storm. Total damages exceeded $66.3 million. Dane County damages totaled approximately $4.1 million. Dane County received a Presidential Disaster Declaration to assist with recovery costs from this storm.

June 1992

On June 17 at 12:06 pm, an F3 tornado struck Dane County. The tornado first touched down in the Village of Belleville, about 15 miles south of the City of Madison, and began its trek northeast touching down just east of Highway 69 damaging farm structures and killing livestock. It then headed into the City of Fitchburg leveling a subdivision (18 homes total) severely damaging the Oregon Correctional Facility, destroying 20 buildings. The tornado also did damage in the Town of Dunn, destroying numerous homes. Although no deaths were reported approximately 30 people sustained injury. An estimated 201 homes were damaged totaling $30.6 million in losses. Damages are estimated at 30 homes destroyed, 34 with heavy damage, 29 with medium damage, and more than 130 incurred minor damage. Dane County received a Presidential Disaster Declaration to assist with recovery costs from this storm.

August 18, 2005

A strong and destructive tornado spun up at 1715CST about 2.8 miles southeast of the geographic center of Fitchburg (or 2.0 miles north of center of Oregon), about 400 yards southwest of the intersection of CTH MM and Schnieder Rd. It continued east-southeast to the southern edge of Lake Kegonsa and tore through residential neighborhoods about 1/3 to 1/2 mile north of the towns of Dunn and Pleasant Springs, and far-northern Stoughton. It moved with Interstate 90/39, and stayed close to CTH A to its exit point at 1905CST where CTH A crosses into Jefferson County, about 2.8 miles south-southwest of Rockdale.

August 18, 2005 Tornado

Photo by Colin McDermott

One person was crushed to death in their basement from fireplace and chimney bricks that crashed through the floor. Twenty-three (23) other people were directly injured. In addition, Emergency Management officials received reports of 2 other indirectly-related deaths associated with this strong tornado. In these two cases, the people were already very ill or suffering from a life-ending disease. Injuries they received during the tornado contributed (secondary) to their death, but were not the primary cause of death, based on medical examiner reports. Consequently, these additional two deaths do not appear in the official death tally in the header strip of this event. Numerous homes, businesses, farm buildings, vehicles, power-lines, trees, and other personal effects were either damaged or destroyed along its path that grew to a maximum width of about 600 yards north of Stoughton. As for residential structures, 220 sustained minor damage, 84 had major damage, and 69 were destroyed. As for business structures, 6 sustained minor damage, 1 had major damage, and 1 was destroyed. As for agricultural structures, 5 sustained minor damage, 5 had major damage, and 40 were destroyed. The overall slow movement (the supercell moved at 12-17 knots, or 10-15 mph), coupled with structures that were not thoroughly reinforced (based on NWS damage survey), allowed the tornado's cyclonic winds to more severely damage buildings in its path. Consequently, although some of the worst damage resembled what would be left by a F4 tornado for well-built homes, this tornado was rated at the top of the F3 category with estimated winds near 174 knots (200 mph).

Total estimated damage amounts (directly-related) for private and public sectors combined was $35.06 M, broken down to $34.31 million in property damage and $750,000 in crop losses, for the tornado segment in Dane County. The $34.31 million in property damage was broken down to private losses (total of $32.29 million) and public losses (total of $2.02 million). The private losses included a total of $25.45 million for residential structures; $1.29 million for businesses; $4.25 million for agricultural structures; $1 million for damage to vehicles, boats, and other personal effects; $200,000 to agricultural machinery and tools; and $96,000 in public road system damage. The public losses making up part of the

$34.31 million consisted of $2.02 million in damage to public utility systems. The $750,000 in damage attributed to crop losses occurred on an estimated 1,550 acres of land. Additional monetary costs incurred in the public sector (totaling $1.84 million) which are considered indirectly-related damage expenses, and not included in the "direct" totals listed in the header-strip of this event, include: $1.38 million in debris clearance; $308,000 in protective measures; and miscellaneous damage/expenses of $144,000. Therefore, the grand total of direct and indirect damage amounts and expenses attributed to this tornado segment in Dane county totaled about $36.89 million. The State Disaster Fund provided relief aid for this disaster.

August 18, 2005 Tornado Damage

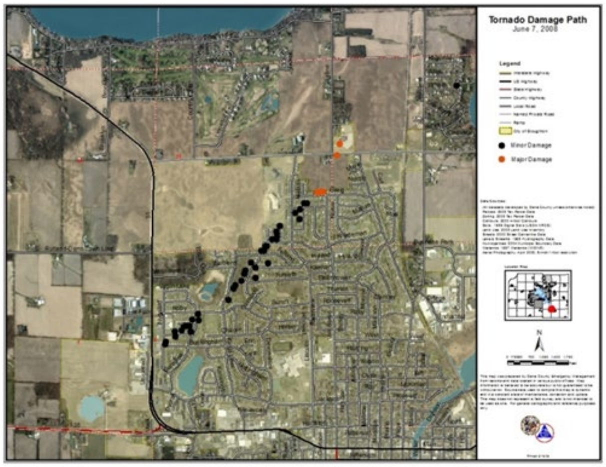
Source: Dane County Emergency Management

This was part of the largest single-day tornado outbreak in Wisconsin recorded history for south-central and southeast Wisconsin. A total of sixteen tornadoes were documented on this day.

June 7, 2008

This tornado moved from just west of Hults Road on the far western part of Stoughton northeast to a point northwest of the intersection of CTH B and CTH N. Based on the observed damage, it was probably a multiple-vortex tornado. In the Stoughton area, with respect to residential homes, it resulted in very minor damage to 24 homes, minor damage to 21 homes, and major damage to 3 homes. Additionally, 1 church sustained major damage, and 1 tobacco shed was destroyed. Total estimated property damage (roofs, siding, walls, windows) in the Stoughton area was $429,000.

June 7, 2008 Tornado Damage Path



Source: Dane County Emergency Management, 2017

June 12, 2008

This tornado in south-central Dane County was a continuation of a tornado that spun up mid-way between the city of New Glarus and the village of Postville in northwest Green County. It entered Dane County on the west side of the City of Belleville and then moved northeast through the Lake Belle View area and crossed STH 69 about 1 mile north of the County Line, and ultimately dissipated southeast of Basco, near CTH A. Luckily only tree damage occurred - of the uprooted tree or broken tree branch variety. Wind speed estimated at 83-87 knots (95-100 mph). The average path width in Dane County was about 60 yards.

June 16, 2014

A large storm produced several tornadoes and damaging straight line winds. One of those tornadoes was an EF3 with estimated winds of 140 mph hit the Country View Elementary School in Verona. The storm was at night, so no one was at the school, but it was severely damaged and needed to be rebuilt. The storm damaged 14 businesses and more than 250 homes, resulting in more than $14 million in damages and more than $5 million in public sector response and recovery costs. Most of these losses were in the City of Verona and the City of Madison. Fortunately, there were no injuries or deaths.

October 7, 2017

On October 7th 2017, and EF-0 tornado touched down in Eastern Madison in the early evening. The NWS reported that the maximum winds were up to 70-80 MPH. The width of the tornado was estimated to be around 50-100 yards, and the tornado was on the ground for approximately 4 miles. Roof and tree damage was discovered, and an auto shop was reportedly completely destroyed. No fatalities or injuries were reported in relation to this tornado event.

August 9, 2018

In the afternoon of August 9th, 2018, severe thunderstorms caused a brief EF-0 tornado to make contact with the Village of Deerfield for approximately 0.7 miles. The tornado was about 25 yards in length with average speeds of 80 MPH. No fatalities or injuries were reported in relation to this tornado event.

July 29, 2021

An outbreak of tornadoes was reported on July 29th, 2021 in Western Dane County, following severe thunderstorms and straight line winds. Two tornadoes ranging between EF-0 and EF-1 were found near the City of Verona, and two tornadoes also ranging between EF-0 and EF-1 were found near the Village of Cross Plains. An EF-1 tornado was also spotted in Southern Middleton. Over 10 tornadoes were spotted across the southern region of Wisconsin. This series of tornadoes were related to a national level tornado outbreak, observed across the northern United States. Minor damage to property caused by high winds was reported across Dane County, and no fatalities or injuries were reported in relation to this tornado event.

4.11.3 Impact of Climate Change on Future Conditions

Tornadoes are already a regular occurrence in Wisconsin and Dane County. There is not a readily available source of information to assess whether the incidence of these storms will increase, decrease, or remain unchanged as a result of the warming climate. A qualitative argument can be made that more energy in the atmosphere resulting from increased concentrations of greenhouses would result in an increase of convective severe weather events such as severe thunderstorms and tornadoes. This is not borne out in currently available models, however. There is no clear trend to indicate whether or not this hazard is changing or will change significantly in the future.

4.11.4 Impact Assessment

Direct Impact

The impacts of tornadoes are well documented. In fact, tornadoes are classified according to the damages they cause. Through observational studies, T. Theodore Fujita created the following scale in the late 1960's to classify tornadoes. The scale correlates wind speeds with damage: EF-0 is the weakest and EF-5 the strongest.

- *EF0 Category Tornado*: wind speeds between 65-85 mph – *Gale tornado* – Light damage. Some damage to chimneys; breaks twigs and branches off tress; pushes over shallow-rooted trees; damages signboards; some windows broken; hurricane wind speed begins at 73 mph.
- *EF1 Category Tornado*: wind speeds between 86-110 mph – *Moderate tornado* – Moderate damage. Peels surfaces off roofs; manufactured homes pushed off foundations or overturned; outbuildings demolished; moving autos pushed off the roads; trees snapped or broken.

- *EF2 Category Tornado*: wind speeds between 111-135 mph – *Significant tornado* – Considerable damage. Roofs torn off frame houses; manufactured homes demolished; frame houses with weak foundations lifted and moved; boxcars pushed over; large trees snapped or uprooted; light-object missiles generated.
- *EF3 Category Tornado*: wind speeds between 136-165 mph – *Severe tornado* – Severe damage. Roofs and some walls torn off well-constructed houses; trains overturned; most trees in forests uprooted; heavy cars lifted off the ground and thrown; weak pavement blown off roads.
- *EF4 Category Tornado*: wind speeds between 166-200 mph – *Devastating tornado* – Devastating damage. Well-constructed homes leveled; structures with weak foundations blown off some distance; cars thrown and disintegrated; large missiles generated; trees in forest uprooted and carried some distance away.
- *EF5 Category Tornado*: wind speeds over 200 mph – *Incredible tornado* – Incredible damage. Strong frame houses lifted off foundations and carried considerable distance to disintegrate; automobile-sized missiles fly through the air in excess of 300 ft (100 m); trees debarked; incredible phenomena will occur.

Indirect Impact

Secondary impacts of tornado damage often result from damage to infrastructure. Downed power and communications transmission lines, coupled with disruptions to transportation, create difficulties in reporting and responding to emergencies. These indirect impacts of a tornado can put tremendous strains on a community. In the immediate aftermath, the focus is on emergency services. Law enforcement activities focus on scene security. Fire and EMS personnel are needed to rescue the injured, put out any fires caused by broken gas lines or other similar hazards and assist in the clean-up. Utility crews will be needed to restore power, phone and other utility services. Highway and public works crews are needed to remove debris from roadways so other responders can get through to the victims and their property. Victims and their insurance agents need access to the properties so they can assess the damage and search for valuables or heirlooms.

As the response shifts to long-term recovery, to focus turns toward restoring the community back to normal. This can take years in some cases. The costs associated with the long-term recovery of a community are difficult to quantify, however the issues may include:

- Short-term
    - Debris Removal
    - Storage and distribution of donated goods
    - Coordination of volunteers
    - Site security
    - Restoration of the function of critical facilities
- Agricultural Production
    - Crop damage or loss

  - Loss of livestock
  - Damage to houses, barns, and other farm buildings
  - Damage to farm machinery
  - Income loss
- Urban, Residential, and Commercial
  - Damage to or destruction of buildings
  - Loss of commercial buildings and goods
  - Loss of trees and landscaping
  - Damage to and destruction of automobiles and trucks
  - Disruption and subsequent restoration of public infrastructure including communications, electrical power, drinking water, transportation.
- Health and Safety
  - Injuries
  - Fatalities
  - Mental and physical stress associated with loss of family, friends, and property
- General
  - Economic losses to businesses
  - Revenue losses to state, and local governments
  - Increased demand on disaster assistance programs

4.11.5 Vulnerability Assessment

In general, all Dane County buildings, critical facilities, and populations are vulnerable to tornado damage.

There are also segments of the population that are especially vulnerable to the indirect impacts of tornadoes, particularly the loss of electrical power. As a group, the elderly or disabled, especially those with home health care services relying on rely heavily on an uninterrupted source of electricity. Resident populations in nursing homes, Community Based Residential Facilities, or other special needs housing may also be vulnerable if electrical outages are prolonged. If they do not have a back-up power source, rural residents and agricultural operations reliant on electricity for heating, cooling, and water supplies are also especially vulnerable to power outages.

4.11.6 Potential for Future Losses

The potential for future losses due to tornado damage is estimated based on an extrapolation of losses from past events. There are limitations to this method:

- Every tornado is unique in location, duration, and intensity. It is impossible to predict with any degree of certainty where and when a tornado will strike. As a result, the risk of tornado occurrence is essentially uniform, countywide.
- The exposure to damage increases as the population of the County increases. Future damages may increase simply due an increase in the amount of exposed property. This method of estimation cannot account for increasing risk due to growth.
- Indirect impacts are not well accounted for.
- The damages resulting from a tornado depend greatly on where and when the storm hits. A severe tornado tracking through an undeveloped area may cause less damage than a weak tornado striking an urban or residential area.

While the estimation of future losses based on past events is unsophisticated, it still is a useful method of quantifying the damage potential. The following assumptions were made for this estimation:

- Based on National Weather Service and NCEI data spanning the time period of 1955 to 2016, the average tornado in Wisconsin is 3.7 miles long and 118 yards wide, and remains on the ground for an average of 7.1 minutes. The average affected area by a tornado equals 158 acres.
- Rounding up, the average intensity is EF2.
- Residential, commercial, and manufacturing and agricultural properties are evenly distributed across the County.
- The Enhanced Fujita Scale was designed with a "well-constructed" frame house as the standard for assessing failures in building construction. Due to the variability in the quality of construction and other factors, some buildings may experience less or more damage than others when exposed to F2 category wind speeds.

In addition to structural damage, building contents and personal property will also be damaged or destroyed as a result of a tornado. Approximations of the value of building contents are based on the FEMA estimates collected in Table 4.11.9.

Table 4.11.9 Building contents value as a percentage of parcel improvement

Occupancy	Contents Value (%)
Residential	50
Commercial (including retail, wholesale, professional, services, financial, entertainment & recreation)	100
Commercial (including hospital and medical office/clinic)	150
Industrial (including heavy, light, technology)	150
Industrial Construction	100
Agriculture	100
Religion/Non-Profit	100
Government Emergency Response	150
Government General Services	100

Occupancy	Contents Value (%)
Education Schools/Libraries	100
Education Colleges/Universities	150

Source: FEMA, Hazus, 2009

To account for the variations in construction and the actual distribution of residential, commercial, and manufacturing properties, a range of damage potentials, as collected in Table 4.11.4 were used. Calculations performed using these tables are presented as an average, with site-specific variations expected, but not easily quantified. They provide an "average expectation" or "typical impact".

Table 4.11.10 Average Loss Expected by Fujita Damage Scale

Fujita Scale	Damage Description	Percentage of Structure and Building Contents Value Lost due to Damage
EF0	Light damage. Some damage to shingles, soffits and fascia, siding, and windows.	0% to 5%
EF1	Moderate Damage. Roof surface peeled off; window breakage; attached garages may be destroyed.	5% to 20%
EF2	Considerable damage. Roofs torn off frame houses; light object missiles generated.	50% to 100%
EF3	Severe Damage. Roof and some walls torn off well-constructed houses.	100%
EF4 and above	Devastating Damage. Well-constructed houses leveled; structures with weak foundations blown off some distance; large missiles generated.	100%

Calculations performed using the above tables are presented as an average, with site-specific variations expected, but not easily quantified. They provide an "average expectation" or "typical impact". Table 4.11.11 below was developed using the process as described below.

Precursor Step: Total parcel count, improved parcel count, improved land value, and contents value can be developed by using parcel data and land use data from the Dane County Land Information Office (LIO). Parcel and land use data can be configured and joined using spatial analyst tools in ArcGIS Desktop 10.8 and all versions of ArcGIS Pro.

Step	Process	Example Calculation
1	Convert municipality's area to acres.	35.16 mi² → 22501.27 acres
2	Divide the average tornado area (540 Acres) by the municipal acreage. Convert to Percentage. This will be your **Percent of Area Impact.**	(540 / 22501.27)*100 = 2.41% (540 / 22501.27)*100 = 2.41%
3	Ensure that the percentage of area impact is In decimal form if you are doing these calculations outside of Microsoft Excel. Then, multiply improved parcel count with percentage of area impact. This will be your **Affected Structure estimate.**	2.41% → 0.0241 7474 * 2.41% = 179

Step	Process	Example Calculation
4	Add Improved land values with content values. This will be your **Total Exposure Value**.	3,742,236,500 + 1,871,118,250 = 5,613,354,730
5	Multiple total exposure value with percent area of impact. This will be your **Estimated High Loss**. *Note: in excel, you may need to reuse step 4's addition with parenthesis, and then multiply by percent area of impact, instead of multiplying by the total exposure value raw.*	5,613,354,730 * 0.0241 =135,281,849
6	Divide your estimated high loss value by 2. This will be your **Estimated Moderate Loss**.	135,281,849 / 2 =67,640,924
7	Divide your estimated high loss value by 2. This will be your **Estimated Low Loss**.	67,640,924 * 0.25 = 16,910,231

Source: Analysis developed by Dane County Emergency Management, 2021

Table 4.11.11 Tornado Damage Estimates, Sorted by Jurisdiction

Municipality	Number of Affected Structures	Improved Parcel Value ($)	Estimated Contents Value ($)	Total Property Exposure ($)	Affected Property Exposure ($) High Damage Range	Affected Property Exposure ($) Moderate Damage Range	Affected Property Exposure ($) Low Damage Range	Loss Ratio
Cities								
Edgerton	74	52915700	26,457,850	79,373,550	79,373,550	39,686,775	19,843,388	50%
Fitchburg	179	3742236500	1,871,118,250	5,613,354,750	134,712,864	67,356,432	33,678,216	1%
Madison	797	45808306300	22,904,153,150	68,712,459,450	730,177,417	365,088,709	182,544,354	1%
Middleton	556	3089424100	1,544,712,050	4,634,136,150	430,970,529	215,485,264	107,742,632	5%
Monona	985	1182462600	591,231,300	1,773,693,900	455,715,669	227,857,834	113,928,917	13%
Stoughton	784	1296868100	648,434,050	1,945,302,150	271,147,682	135,573,841	67,786,920	7%
Sun Prairie	710	3262932800	1,631,466,400	4,894,399,200	342,418,960	171,209,480	85,604,740	3%
Verona	508	8179690700	4,089,845,350	12,269,536,050	1,472,406,527	736,203,263	368,101,632	6%
Towns								
Albion	63	388436600	194,218,300	582,654,900	13,906,205	6,953,102	3,476,551	1%
Berry	39	365734800	182,867,400	548,602,200	12,913,245	6,456,622	3,228,311	1%
Black Earth	31	109328000	54,664,000	163,992,000	8,087,048	4,043,524	2,021,762	2%
Blooming Grove	171	216169868	108,084,934	324,254,802	52,985,058	26,492,529	13,246,264	8%
Blue Mounds	34	349165500	174,582,750	523,748,250	13,599,056	6,799,528	3,399,764	1%
Bristol	68	620436800	310,218,400	930,655,200	23,194,955	11,597,478	5,798,739	1%
Burke	127	508169400	254,084,700	762,254,100	41,856,541	20,928,270	10,464,135	3%
Christiana	43	312001600	156,000,800	468,002,400	11,331,808	5,665,904	2,832,952	1%
Cottage Grove	85	535192400	267,596,200	802,788,600	21,006,285	10,503,143	5,251,571	1%
Cross Plains	41	317912900	158,956,450	476,869,350	11,498,942	5,749,471	2,874,736	1%
Dane	35	281801900	140,900,950	422,702,850	10,179,914	5,089,957	2,544,979	1%
Deerfield	41	308494400	154,247,200	462,741,600	11,609,388	5,804,694	2,902,347	1%

Municipality	Number of Affected Structures	Improved Parcel Value ($)	Estimated Contents Value ($)	Total Property Exposure ($)	Affected Property Exposure ($) High Damage Range	Affected Property Exposure ($) Moderate Damage Range	Affected Property Exposure ($) Low Damage Range	Loss Ratio
Dunkirk	59	380819200	190,409,600	571,228,800	15,266,435	7,633,217	3,816,609	1%
Dunn	132	1334967700	667,483,850	2,002,451,550	59,648,215	29,824,108	14,912,054	1%
Madison	695	490510400	245,255,200	735,765,600	408,841,322	204,420,661	102,210,331	28%
Mazomanie	37	212261200	106,130,600	318,391,800	8,747,834	4,373,917	2,186,958	1%
Medina	45	309542500	154,771,250	464,313,750	11,766,291	5,883,145	2,941,573	1%
Middleton	178	1015354200	507,677,100	1,523,031,300	82,802,263	41,401,131	20,700,566	3%
Montrose	38	283627100	141,813,550	425,440,650	10,549,870	5,274,935	2,637,467	1%
Oregon	71	551136900	275,568,450	826,705,350	22,448,694	11,224,347	5,612,174	1%
Perry	29	181467000	90,733,500	272,200,500	6,370,152	3,185,076	1,592,538	1%
Pleasant Springs	82	734301950	367,150,975	1,101,452,925	28,208,365	14,104,182	7,052,091	1%
Primrose	29	191714800	95,857,400	287,572,200	6,777,808	3,388,904	1,694,452	1%
Roxbury	51	369598900	184,799,450	554,398,350	13,038,044	6,519,022	3,259,511	1%
Rutland	55	416841300	208,420,650	625,261,950	15,016,529	7,508,265	3,754,132	1%
Springdale	50	462059400	231,029,700	693,089,100	16,538,192	8,269,096	4,134,548	1%
Springfield	61	665211400	332,605,700	997,817,100	23,292,385	11,646,192	5,823,096	1%
Sun Prairie	62	448283800	224,141,900	672,425,700	19,077,915	9,538,958	4,769,479	1%
Vermont	29	261181700	130,590,850	391,772,550	9,222,220	4,611,110	2,305,555	1%
Verona	59	385760000	192,880,000	578,640,000	20,339,142	10,169,571	5,084,785	2%
Vienna	42	536281000	268,140,500	804,421,500	19,138,564	9,569,282	4,784,641	1%
Westport	97	829084900	414,542,450	1,243,627,350	50,401,878	25,200,939	12,600,470	2%
York	29	171248200	85,624,100	256,872,300	6,042,713	3,021,356	1,510,678	1%
Villages								
Belleville	542	167622000	83,811,000	251,433,000	128,028,242	64,014,121	32,007,060	25%
Black Earth	863	119692900	59,846,450	179,539,350	176,701,991	88,350,995	44,175,498	49%

Municipality	Number of Affected Structures	Improved Parcel Value ($)	Estimated Contents Value ($)	Total Property Exposure ($)	Affected Property Exposure ($) High Damage Range	Affected Property Exposure ($) Moderate Damage Range	Affected Property Exposure ($) Low Damage Range	Loss Ratio
Blue Mounds	529	221289400	110,644,700	331,934,100	319,506,259	159,753,130	79,876,565	48%
Brooklyn	422	64508900	32,254,450	96,763,350	96,763,350	48,381,675	24,190,838	50%
Cambridge	439	136197700	68,098,850	204,296,550	130,816,587	65,408,294	32,704,147	32%
Cottage Grove	494	520187200	260,093,600	780,280,800	170,232,817	85,116,409	42,558,204	11%
Cross Plains	755	346248200	173,124,100	519,372,300	260,804,996	130,402,498	65,201,249	25%
Dane	395	80310400	40,155,200	120,465,600	88,065,661	44,032,831	22,016,415	37%
Deerfield	469	209229200	104,614,600	313,843,800	122,878,371	61,439,186	30,719,593	20%
DeForest	396	1191923400	595,961,700	1,787,885,100	199,766,891	99,883,445	49,941,723	6%
Maple Bluff	717	250686300	125,343,150	376,029,450	376,029,450	188,014,725	94,007,363	50%
Marshall	649	2023747300	1,011,873,650	3,035,620,950	1,117,881,520	558,940,760	279,470,380	18%
Mazomanie	522	163518900	81,759,450	245,278,350	116,396,622	58,198,311	29,099,155	24%
McFarland	895	978873195	489,436,598	1,468,309,793	354,232,896	177,116,448	88,558,224	12%
Mount Horeb	776	609357660	304,678,830	914,036,490	239,010,116	119,505,058	59,752,529	13%
Oregon	776	1092577370	546,288,685	1,638,866,055	317,435,473	158,717,737	79,358,868	10%
Rockdale	152	17934500	8,967,250	26,901,750	26,901,750	13,450,875	6,725,438	50%
Shorewood Hills	760	352877700	176,438,850	529,316,550	529,316,550	264,658,275	132,329,138	53%
Waunakee	591	1508079300	754,039,650	2,262,118,950	281,774,873	140,887,436	70,443,718	6%
Windsor	110	914410500	457,205,250	1,371,615,750	40,447,117	20,223,559	10,111,779	1%

4.12 WILDFIRE

4.12.1 Description

Wildfire is any free burning and (at one time) out of control forest fire, grassland fire, rangeland fire, or urban-interface fire which consumes the natural fuels and spreads in response to its environment. While often considered as a destructive force, wildfires also play a positive role in nature by clearing underbrush, controlling insect populations, and depositing nutrients into the soil. Many plant species have evolved to cope with and take advantage of wildfires. Periodic, spatially-interrupted burn patterns lead to higher species diversity and healthier ecosystems. Unfortunately, when wildfires ignite in altered ecosystems (such as housing developments), the intensity, duration, and spread of the fire also change. Wildfire becomes a destructive force for ecosystems, resulting in heightened erosion conditions and other damages to the environment, in addition to the property damages sustained by human developments.

Certain conditions must be present for wildfires to take hold. The most common conditions include:

- Hot, dry, and windy weather
- Inability of the fire service to contain or suppress the fire
- Occurrence of multiple fires that overwhelm local resources
- Large fuel load

Once a fire has started, additional conditions will influence its behavior, including topography and land-use patterns.

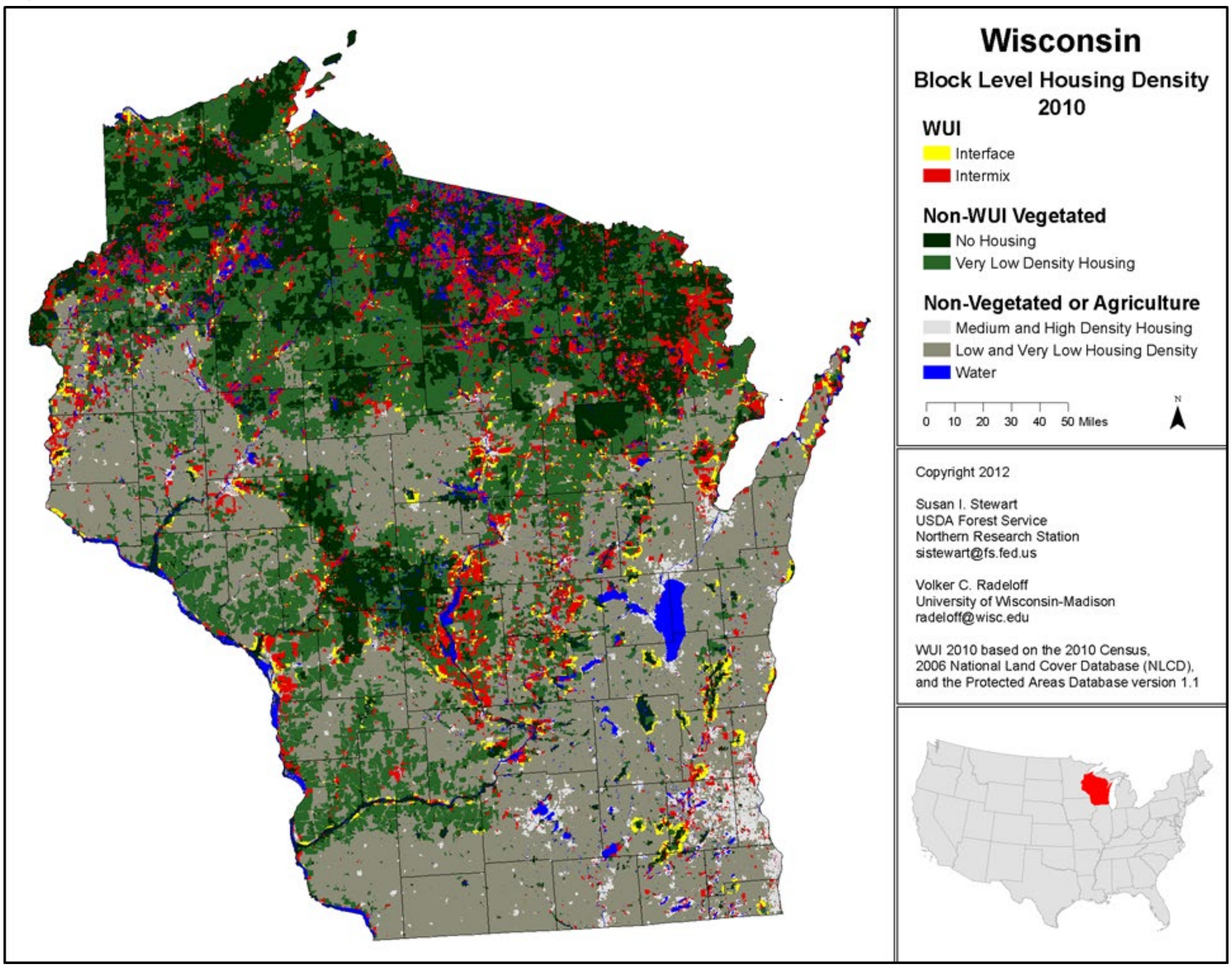
The vast majority of wildfires in Dane County are human-caused. Wildfires initiated by lightning are very rare. When wildfires do occur in Dane County it is also very rare that a home or business is lost. Wildfires are most common in the spring when brush is still brown and dry.

Most of the County is managed under a cooperative fire management program overseen by individual fire districts. The northwestern portion of the County is under state jurisdiction and classified as an “extensive fire area”, and includes the jurisdictions of the Towns of Roxbury, Vermont, Black Earth, Mazomanie, and Berry and the Village of Mazomanie. A portion of the Town of Blue Mounds is also included. In cooperative areas, data on wildfires is sparse and unorganized, which makes it essentially unavailable. Most of the data used in this assessment is derived from land under state jurisdiction for fighting wildfires. The ecology of the county lends itself to natural defenses from wildfires. Much of the county is covered by water or wetlands, or well developed with fire breaks.

Wildland-Urban Interface

Wildfire danger grows as more and 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 DNR, "the WUI can be a lone house in the middle of a forest, a subdivision on the edge of a pine plantation, or homes surrounded by grassland" (DNR, 2011). Locating manmade structures in areas that have burned naturally in the past both interrupts the natural recurrent cycle of wildfires and adds fuel to wildfires. (Wisconsin Emergency Management, Wisconsin Threat and Hazard Identification and Risk Assessment, 2021) Figure 4.12.1 shows Wisconsin's wildland-urban interface as of 2010.

Figure 4.12.1 Wisconsin Wildland-Urban Interface



Source: University of Wisconsin SILVIS Lab, http://silvis.forest.wisc.edu/maps/wui/2010/download, 2012, Accessed October, 2021

4.12.2 Previous Occurrences

Historically, the County contained fire-maintained plant communities such as prairies, oak savannas, oak or pine barrens, and oak woodlands. Fire occurrences ranged from annually to about once a decade. North facing slopes and areas with natural firebreaks (north and east of lakes and rivers) burned less frequently. The fires were frequent and burned lightly enough in the oak areas to prevent the death of mature, thick-barked trees. The jack pine areas usually experienced more severe, stand-killing crown fires which occurred less frequently than the oak and prairie fires. Current natural fire patterns are altered though deliberate fire suppression actions and the introduction of fuel breaks such as roads, developed areas and agricultural fields.

In 2003 there were two relatively large wildfires outside of the state managed area, the Deansville marsh fire that took place April 27 that burned 500 acres, and the Town of Dunn marsh fire on March 23 that burned 110 acres. Though these fires were large, they posed little threat to life and property.

Even within the context of recent fires, the chance of structural damage due to wildfire is extremely small. History shows that very few structures have ever been lost due to wildfires in the County. Easy accessibility to fires and low fuel loads give fire fighters the upper hand in battling blazes.

4.12.3 Impact of Climate Change on Future Conditions

Although precipitation totals are expected to increase overall, researchers predict that it will occur during fewer, more intense events. The periods in between intense rain or snowfalls may therefore be marked by a greater number of dry days. This coupled with longer summers, higher average temperatures, and concomitant increased evapotranspiration, may result in longer, drier conditions, which in turn raise the likelihood of wildfires. The wildfire risk is mitigated by the low wildland-urban interface risk in Dane County, on-going fire management practices, and well-established local fire response capacities.

4.12.4 Impact Assessment

The size of wildfires in Dane County range from approximately 500 acres to a fraction of acre, most fires cover about 3 acres. Woodland and open lands, land that has the potential for wildfire, make up about 22 percent of the total acreage in the County. Much of Dane County is agricultural or urban land. How a fire will burn within the natural areas of the County is a complex phenomenon affected by wind, air temperature, humidity, fuel loads, fuel moisture, and topography.

In densely wooded areas fires could destroy much in their path, fueled by high winds and high fuel loads. Other fires, such as those that might occur in a prairie ecosystem, burn cooler along the ground and leave a dappled pattern of untouched areas within burnt areas. Fire prediction, though greatly aided by the development of new computer modeling programs, remains an imprecise science.

Wildfire can also be destructive when it interfaces with urban areas. Burned structures due to wildfire in Dane County are extremely rare and the costs of fighting wildfires run only in the hundreds of dollars per response. Much of the wildfire in the County is fought by local fire departments, though the Department of Natural Resources at the state level also assists in fighting these fires.

4.12.5 Vulnerability Assessment

There are very few areas of the County where conditions indicate a high vulnerability to wildfires. Areas of higher relative vulnerability to wildfires are those in the urban/wildland interface, including:

- Areas where urban and suburban development is adjacent to open expanses of wild land areas.
- Mixed urban interface where isolated homes, subdivisions, or small communities are situated in predominantly wild land settings.
- Wild land/urban interface where islands of wild land vegetation occur inside a largely urban area.
- Areas that are hilly also can burn more readily. Fires run up hills igniting fuels more easily than on flat ground.

There is limited data indicating that general structures, critical facilities or populations have been or will be harmed by wildfire in the County. While the potential exists for damaging wildfires, many natural and man-made fuel breaks exist. Overall, the vulnerability of the County to wildfire is low.

4.12.6 Potential for Future Losses

While grassland and marsh fires are relatively common in the spring and fall seasons, wildland fires in Dane County that threaten or damage buildings or other structures are very rare.

The potential for future damages is estimated by extrapolating data from past events. Future damages are expected to be very similar to past damages, with annual losses due to wildfire ranging in only the hundreds of dollars. The number of fires and the acres burned do not indicate that wildfires and their impacts are increasing. This data is limited to areas of the County that is regulated under the state Department of Natural Resources and therefore is a limited data set on which to base loss estimations.

4.13 WINDSTORM

4.13.1 Description

Damaging winds occur relatively frequently across Wisconsin, usually in association with severe thunderstorms.

Severe thunderstorms develop powerful updrafts and downdrafts. An updraft of warm, moist air helps to fuel a towering cumulonimbus cloud reaching tens of thousands of feet into the atmosphere. A downdraft of relatively cool, dense air develops as precipitation begins to fall through the cloud. Winds in the downdraft can reach in excess of 100 miles per hour. When the downdraft reaches the ground it spreads out forming a gust front: the strong, often refreshing wind that kicks up just before the storm hits. As the thunderstorm moves through the area, the full force of the downdraft in a severe thunderstorm can be felt as horizontal, straight-line winds with speeds well over 50 miles per hour. (National Weather Service)

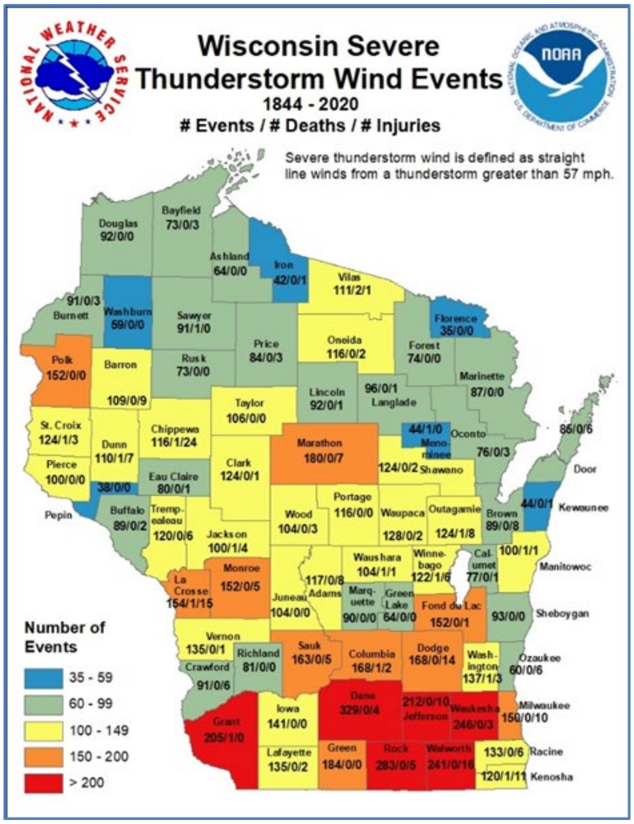
Straight-line winds are often responsible for most of the damage associated with a severe thunderstorm. Damaging straight-line winds occur over a range of scales. At one extreme, a severe single-cell thunderstorm may cause localized damage from a microburst, a severe downdraft extending not more than about two miles across. In contrast, a powerful thunderstorm complex that develops as a squall line can produce damaging winds that carve a path as much as 100 miles wide and 500 miles long.

4.13.2 Previous Occurrences

Severe Thunderstorms (wind greater the 57 mph) and high winds are a regular occurrence in Dane County. According to the National Weather Service, between 1970 and 2020, there were 329 events with winds over 57 mph, which is the equivalent of hurricane force winds.

The National Weather Service and the NOAA National Centers for Environmental Information (NCEI), formerly National Climatic Data Center (NCDC) maintains a listing of reported high wind events from 1844 through 2022. In more recent years, these records have been kept in greater detail, including a description of the event and the resulting impacts. The NCEI website provides the following description of a snap shot of high wind events affecting Dane County, including number of deaths and injuries.

Figure 4.13.1 Severe Thunderstorm Wind Events, 1844-2020



4.25

Source: National Weather service, NOAA, 2020

April 6, 1997

Strong gradient winds, enhanced by scattered snow showers (transfer of higher level momentum downward to surface by mixing), resulted in scattered damage reports. In Sun Prairie, the high winds, measured at 66 mph, blew open a glass door in a restaurant. The glass debris struck and injured an elderly woman, who died from the injuries the next day. The Madison TV-3 weather station recorded a peak wind gust of 71 mph at 1715 CST. In the Town of Dane, a gust of 61 mph was noted. Southeast of Mount Horeb, the high winds forced the collapse of a barn. A camper vehicle was tipped over on by the powerful winds on Highway 113. The high winds also toppled large trees in scattered areas across the entire county. One tree in Monona fell against a home and damaged its siding and windows. Power outages were noted. People described the wind-driven debris as "missiles flying through the air."

May 31, 1998

During the early morning hours of Sunday, May 31st, south-central and southeast Wisconsin experienced an unprecedented, widespread downburst wind event known as a "derecho." Incredibly powerful, hurricane-force straight-line winds, with peak gusts of 100 to 128 mph tore through 12 counties in this part of the state, while another 8 counties had peak gusts of 60 to 80 mph. Meteorologically, a solid squall line developed in southern Minnesota and gathered strength as it raced east with a translational speed of 50 to 60 mph across south-central and southeast Wisconsin. The squall line was orientated southwest to northeast and had many microbursts and macrobursts embedded in it. Utility companies and Emergency Managers stated that this was the most damaging, widespread, straight-line thunderstorm wind event to affect southern Wisconsin in the past 100 years. About 60,000 customers were without electricity in south-central Wisconsin, and about 170,000 in southeast Wisconsin. Some residences or businesses were without power for many as 6 days. Hundreds or motor vehicles were damaged or destroyed by falling trees and branches or collapsed garages. Dane County measured gust of 100 mph in Marshall, but peak gusts estimated at 110-120 mph based on damage. The hardest hit areas were Waunakee-DeForest, Sun Prairie, and Marshall. Cars were blown sideways off I-94 north of Madison. Two people injured in Marshall by flying debris as roof was torn off their home. A total of 300 residences had minor damage, 18 major, and 1 was destroyed. One business had minor damage, and 7 had major damage. Twenty farm buildings sustained minor damage, 12 major, and 15 were destroyed.

November 10, 1998

Screaming high winds raked south-central and southeast Wisconsin counties for about 17 hours, resulting in widespread damage to thousands of trees, homes, businesses, power poles, power lines, street lights, road signs, fences, flagpoles, barns, sheds, crops, boats, cars, trucks, campers, trains, airport hangars, and airplanes. Estimated monetary damages were $10.31 million in property damage and $1.625 million in crop damage. The sustained southwesterly winds of 30 to 40 mph gusted to 60 to 70 mph, with isolated gusts to around 80 mph. These relentless winds eventually caused 125,000 customers to lose electrical power. So many poles and lines were toppled that some customers were without power for 3 to 4 days. In Dane County an 87 year-old man was killed after being hit by a car that was blown sideways on the north side of Madison. Several businesses in Madison, Mt. Horeb, and Stoughton sustained damages. In Monona, a roof was torn off a multi-unit apartment building and four other nearby buildings were also damaged. Several dozen semi-trucks were overturned on I-90/94, US-18/151, and US 51 highways.

July 6, 2003

Two rounds of scattered severe convection affected south-central and southeast Wisconsin on Sunday, July 6, 2003. The first round occurred during the morning hours and the second during the late afternoon hours. Powerful, downburst, damaging, straight-line winds toppled large trees and/or power-lines, 4 weak tornadoes spun up, a separate funnel cloud was reported, and there were a couple occurrences of large hail. Detailed descriptions of the four tornadoes can be found in separate reports. Probably the hardest-hit area extended from Middleton (Dane Co.) to Maple Bluff. In the Maple Bluff area, 8 homes sustained minor wind damage, and toppled trees damaged a car and two boats or large branches during the morning round. Wind gusts in the Maple Bluff area were estimated to briefly reach 65 knots (75 mph). Lightning struck a home in Middleton, resulting in a roof/attic fire.

July 10 2008

Powerful thunderstorm wind gusts toppled large trees and broke branches that brought down some power-lines. In McFarland, a house was blown down, and tree debris damaged a restaurant. Two rounds of severe weather affected south-central and southeast Wisconsin on July 10th. An initial cluster of storms north of the Milwaukee area in Ozaukee County pulsed to severe limits and generated large hail up to 3/4 inch in diameter during the early afternoon hours. A second round of severe weather was associated with several clusters or short bowing segments of lines of storms that moved west to east across southern Wisconsin during the late afternoon and evening hours. Veering winds allowed for the development of rotating updrafts in a couple cells that generated two weak tornadoes. Otherwise, the severe weather type was powerful downburst winds.

June 8, 2011

Forcing along an advancing cold front moving into a warm, moist unstable air mass over the region produced severe thunderstorms with a tornado, damaging winds and large hail over south-central and southeast Wisconsin during the evening hours of June 8th. The instability produced supercell thunderstorms, with one of the cells developing an EF1 tornado over central Dane County that uprooted trees, felled power-lines, damaged three vehicles and crushed a garage. A cluster of supercell thunderstorms from Lafayette into Dane County then congealed into a bowing line that moved due east and created damaging wind gusts of 60 to 80 mph across much of the area along and south of Interstate-94. At the height of the event, over 27,000 customers had no electric power in Southeast Wisconsin, and probably another 15 to 20,000 customers in south-central Wisconsin lost power. Powerful thunderstorm winds pushed over dozens of large trees, and broken tree branches snapped several power-lines in a 5-mile-wide swath. In Stoughton, the winds knocked over an empty semi-trailer which then impacted and damaged two other trailers. Also, a road sign in Stoughton was pushed over at a 45-degree angle.

August 10, 2021

Severe thunderstorms produced extreme winds on the night of August 10th, 2021. Over 4,200 residents in Madison went without power, due to winds taking out power lines. Fallen trees and power lines caused minor property damage, as well as sidings and residential roofs.

4.13.3 Impact of Climate Change on Future Conditions

Severe thunderstorms associated with damaging winds, hail, and tornadoes are already a regular occurrence in Dane County. There is not a readily available source of information to assess whether the incidence of these events will increase, decrease, or remain unchanged as a result of the warming climate. A qualitative argument can be made that more energy in the atmosphere resulting from increased concentrations of greenhouses would result in an increase of convective severe weather events. This is not borne out in currently available models, however. There is no clear trend to indicate whether or not this hazard is changing or will change significantly in the future.

4.13.4 Impact Assessment

Past windstorms have caused extensive damage in Dane County. Since 1994, when the National Weather Service and the National Center for Environmental Information began recording damage estimates for Dane County, there have been more than 135 high wind and severe thunderstorm wind events. Damage estimates indicate cumulative totals of more than $8.1 million in property damage.

Damaging windstorm events may occur anywhere in Dane County. There are no geographic features within Dane County that naturally lower or increase the risk of a severe thunderstorm or windstorm event. Damage associated with a severe thunderstorm tends to be a geographically isolated event, affecting only small areas of several square miles at any one time.

Direct Impacts

The relative effects of wind speed are shown in table 4.13.1. Strong winds associated with severe thunderstorms or other phenomena can cause extensive damage and can result in deaths or injuries. Damage depends on both the wind speed and the nature of the objects in the path of the storm. Strong winds can turn debris and un-tethered objects into missiles. Even heavy vehicles can be rolled over. Homes and large buildings can sustain damage from the direct force of the wind. Broken windows and damaged roofs are common. Falling limbs and trees are also common and can contribute to property damages and downed power lines. Manufactured homes and metal sheds can be destroyed, particularly if they are not fastened to a foundation. Power and communications outages are also common, and storm debris in roads can disrupt transportation and delay emergency response vehicles.

Farm operations can also be heavily impacted by high winds. Winds can flatten farm crops such as corn and tobacco, and destroy orchard crops such as apples.

Table 4.13.1 Wind Speed and Damage Potential

Wind Speed (mph)	Wind Effects
25-31	Large branches in motion.
32-38	Whole trees in motion, inconvenience in walking against the wind.
39-54	Twigs and small branches break off trees, difficulty in walking against the wind, high profile vehicles such as trucks and motor homes may be difficult to control.
55-74	Potential damage to antenna structures, wind may push over shallow rooted trees, especially if the soil is saturated.
75-95	Potential for minor structural damage, particularly to manufactured homes, power lines, trees, and signs may be blown down.
96-110	Moderate structural damage to walls, roofs, and windows, trees blown down, and manufactured homes may be destroyed.
111-130	Extensive damage to walls, roofs, and windows, trees blown down, moving vehicles pushed off roads.

Wind Speed (mph)	Wind Effects
131-155	Extreme damage to structures and roofs, trees uprooted or snapped.
Greater than 155	Catastrophic damage, structures destroyed.

Source: National Weather Service Spotters Guidance

Indirect Impacts

The indirect social and economic impacts of wind damage are typically associated with the loss of electrical power. Given our societies heavy reliance on electric power, any disruption in the supply, even for a short time period, can have significant consequences. The utilities supplying Dane County have worked closely with emergency response agencies and human services providers to develop plans for responding to planned and unplanned power outages in the County.

4.13.5 Vulnerability Assessment

As with tornadoes, essentially all Dane County buildings, critical facilities, and populations are vulnerable to windstorm damage. Trailer park homes have the highest likelihood of experiencing increased damages.

Population

Some segments of the population are especially vulnerable to the indirect impacts of damaging wind, particularly the loss of electrical power. As a group, the elderly or disabled, especially those with home health care services relying on rely heavily on an uninterrupted source of electricity. Resident populations in nursing homes, Community Based Residential Facilities, or other special needs housing may also be vulnerable if electrical outages are prolonged. Without a back-up power source, rural residents and agricultural operations reliant on electricity for heating, cooling, and water supplies are also especially vulnerable to power outages.

Property

In terms of property losses, the actual damages will depend on the building density in the impacted area. This is highly variable across the County. A severe thunderstorm with high winds in an older residential area with older homes, large trees, and overhead utility lines will have a significantly greater impact with the same storm in a new development with lower building density, modern constructed buildings, small or newly planted trees, and underground power lines.

Power lines, communications networks, and other above-ground infrastructure are vulnerable to the effects of windstorms both directly and indirectly. The wind itself may damage the infrastructure, or the wind may damage tree branches and throw other debris into the air, which may cause secondary damage to buildings and critical facilities or capabilities. Emergency response vehicles with high profiles may be more exposed to high winds, which may hinder response times. In addition, wind may exacerbate dangerous conditions, such as fires, making response more difficult and dangerous. These are unlikely events but they are severe in occurrence. Overall, these assets have a medium to high vulnerability to windstorms.

4.13.6 Potential for Future Losses

The potential for future losses due to windstorm damage is estimated based on an extrapolation of losses from past events. There are limitations to this method:

- Every event is unique in location, duration, and intensity. Use of averages does not account for the potential of an extreme event that may occur only very rarely but has severe consequences.
- The exposure to damage increases as the population of the County increases. Future damages may increase simply due an increase in the amount of exposed property. This method of estimation cannot account for increasing risk due to growth.
- Indirect impacts are not well accounted for.
- The damages resulting from a windstorm event depend greatly on where and when the storm hits. A severe storm tracking through an undeveloped area may cause less damage than a weaker storm striking an urban or residential area. Likewise, a severe storm impacting an agricultural area in the early spring will have a very different impact than a storm of comparable intensity over the same area in late summer when the crops are near maturity. Extrapolation from past events does not account well for this variability.

While the estimation of future losses based on past events is unsophisticated, it still is a useful method of quantifying the damage potential. Since 1994, when the National Weather Service and the National Center for Environmental Information began recording damage estimates for Dane County, there have been more than 135 high wind and severe thunderstorm wind events. Damage estimates indicate cumulative totals of more than $8.1 million in property damage in this 22 year time period, without adjusting for inflation. Adjusted for inflation, this jumps to over $10 million. The annualized windstorm losses in Dane County equal $463,159.

The May 31, 1998 windstorm is considered the event of record, resulting in more than $3.9 million in losses in Dane County. Adjusted for inflation, this would equate to $6.8 million in losses in 2021 dollars.

4.14 WINTER STORM

4.14.1 Description

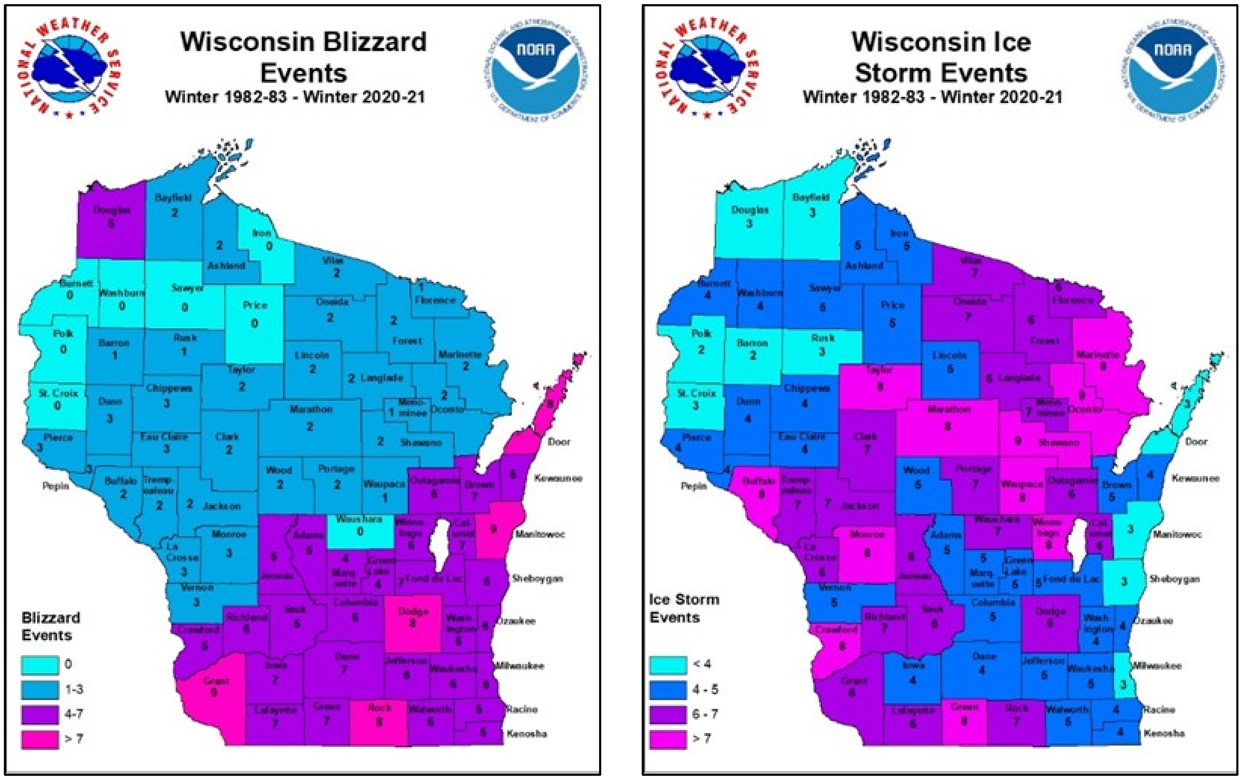
Winter storms occur when below freezing air on the ground and in clouds combine with moisture. Moisture is needed to form clouds and cause precipitation. A storm front lifts the moist air to form the clouds. Storms that affect Wisconsin develop over southeast Colorado, northwest Canada, and over the southern plains. These storms move toward the Midwest and use both the southward plunge of cold air from Canada and the northward flow of moisture from the Gulf of Mexico to produce heavy snow over the region. Alberta Clippers, which develop in the lee of the Canadian Rockies and move southeast toward Wisconsin, not only produce accumulating snow, but can also bring strong winds and extremely cold air to the state. Winter storms are defined by the following events:

- 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 damaging accumulations of ice, usually ¼” or thicker.

4.14.2 Previous Occurrences

According to the National Weather Service, between the winter of 1982-83 and the winter of 2020-21, there were 99 winter storm events, seven blizzard events, and four ice storm events affecting Dane County.

Figure 4.14.1 Blizzard and Ice Storm Events, 1982 – 2020-21



Source: National Weather Service

The history of past winter storm events was gathered from NCEI data, newspaper reports and other data sources as cited. Winter storms have caused problems for Dane County residents for as long as the area has been settled. Some of the most recent outstanding events are listed below.

March 1976

During March 4-11, a storm of freezing rain, snow, ice and wind combined into a severe ice storm that made its way across the southern portion of the state causing $50.4 million in damages statewide, at the time the most expensive natural disaster in Wisconsin history. This estimate is considered to be conservative. Unable to milk or water the cows, farming communities sustained the greatest losses. Farmers lost $17.3 million. Government damages were approximated at $8.4 million, private homes and businesses $11 million to, and utilities $13.7 million.

Of the 22 counties affected from the Mississippi River to Lake Michigan, Dane County was among the hardest hit. Approximately 10,000 residents lost electrical power, some for as long as 11 days. The City of Madison suffered a temporary water shortage as most of the City's water pumping stations went without power. Without heat, light, or water, many people stayed in emergency sleeping quarters prepared by the Red Cross.

Dane County damages for public, farm, and private/non-farm losses, in 1976 dollars, totaled $1.9 million, $1.8 million, and $1.0 million respectively. Total damages were estimated to be $4.78 million, excluding electric utility losses, which were $1.2 million for Madison Gas and Electric, and an undisclosed amount for Wisconsin Power and Light. (Based on a consumer price index inflation calculator, the $4.78 million in losses in 1976 would equate to more than $20.1 million in 2017.)

March 8, 1998

Near blizzard conditions brought parts of south-central and southeast Wisconsin to a standstill. The combination of heavy, wet snow, and northeast winds gusting to 40 to 50 mph, reduced visibilities occasionally to below 1/4 mile and created drifts of 8 to 15 feet in areas west and southwest of Madison. Based on newspaper accounts, there were approximately 800 motor vehicle accidents, dozens of toppled power lines, many school closings, and many road closures. Interstate 90/94 and State Highway 51 north of Madison were closed at the height of the storm. In addition, many airline flights and other commercial activities were postponed or cancelled.

December 2000

December 2000 was one of the 10 coldest Decembers on record for most of the state. In addition to the low temperatures, record or near record snow depths of 15-34" occurred in much of southern Wisconsin during December. As a result of record snowfalls, thirteen counties received a Presidential Emergency Declaration and were eligible to receive federal funds for extraordinary expenses associated with clearing roads and emergency response efforts. The counties declared in the snow emergency were Columbia, Dane, Door, Green, Kenosha, Kewaunee, Manitowoc, Milwaukee, Racine, Rock, Sheboygan, Walworth and Waukesha Counties. Local governments in Dane County received a total of $586,000 in federal disaster assistance.

February 5-6, 2008

A major winter storm impacted south-central and southeast Wisconsin on February 5-6, 2008, with the hardest hitting part of the storm during the morning of the 6th. This was a long duration event coupled with strong gusty winds and some thunder. Blowing and drifting snow compounded the effects of the heavy snow. Total new snow accumulations in excess of 12 inches occurred in the area southeast of a line from Dubuque, Iowa to Madison to Beaver Dam to West Bend to Sheboygan. Up to 16 inches fell in the area from Monroe and Janesville to the Port Washington and Milwaukee area, with isolated 18 to 21 amounts reported. Total snow amounts tapered off quickly to 4 inches north of Wisconsin Dells and an inch or less across far northwest Marquette county. Many roads become impassable due to the blowing and drifting snow. A major traffic backup occurred on Interstate 39/90 westbound south of Madison with as many as 2000 cars stranded for up to 12 hours. A Presidential Emergency was declared as a result of record snowfalls. Dane County and local governments within Dane County received a total of $1.44 million in federal disaster assistance.

December 8-9, 2009
A major winter storm impacted Southern Wisconsin Tuesday evening, December 8th, through Wednesday morning December 9th. Heavy snow fell over a large portion of the area (many areas reported thunder snow), with numerous locations reporting over a foot. The hardest hit area was across central Dane county, where 15" to 18" of snow fell. The 14.1" reported at Dane County Regional Airport was the 6th highest 2-day (calendar day for December 8 and 9) total reported since records began there in 1948.

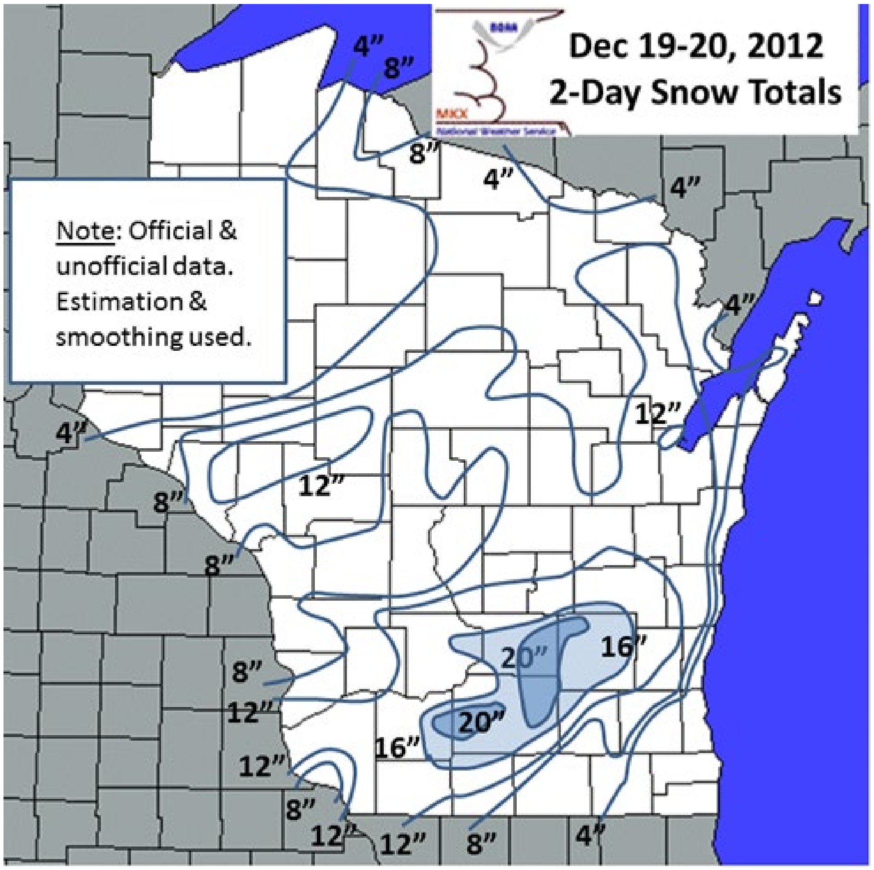
February, 2011
Southern Wisconsin was hit with the so-called Groundhog Day Blizzard when a powerful low pressure center passed south of the state. Most areas of Dane County saw between 14” and 18” inches of snow. Adding to the dangerous conditions were the blizzard-condition sustained wind of between 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 twelve to fifteen feet in many rural areas throughout southern Wisconsin. The severe winter storm caused the declaration of a Federal Major Disaster (DR-1966), allowing eleven 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. Dane County and local governments within Dane County recovered more the $1.81 million is response costs.

December, 2012
From the evening of December 19 to the night of December 20, 2012, a major winter storm descended on the south central portion of the state. Gusts of 35 to 50 mph combined with the snowy conditions resulted in low visibility and drifts of three to five feet. Many accidents were reported. Relatively warm temperatures of 29 to 33°F meant the snow was wet and heavy. Broken limbs and the sheer weight of the snow brought down many utility lines. Two-day snow totals (around 7 am 12/19 through 7 am 12/21) ranged from less than an inch along the Lake Michigan shoreline from Milwaukee south to Kenosha, to 12 to 22 inches in Dane County. The greatest 2-day snow totals (official & unofficial) include 21.9" in Cottage Grove, 21.5" in Mt. Horeb, 20.0" in Madison, 19.9" in Middleton, 19.6" in Portage 7SW, 19.0" at the Arlington UW Farm, and 18.8 inches in DeForest. Officially, Madison's Truax Field's 2-day total was 15.2”.

Scattered power outages were reported. Drifting and falling snow made plowing activities difficult or almost impossible at times. Road surfaces were either snow covered and/or icy inland away from Lake Michigan. Hundreds of vehicle accidents were reported, and many vehicles became stuck in snow drifts. The Wisconsin DOT reported roads in neighboring Rock County were nearly impassable Thursday.

The snow and blowing snow likely caused some road closures in rural areas. Northwest winds gusted to 40 to 50 mph during the afternoon and early evening hours of Thursday. These strong winds, along with falling and/or blowing snow, resulted in blizzard or near blizzard conditions in open and exposed areas, with visibilities reduced to one quarter mile or less.

Figure 4.14.2 Snowfall Totals, December 2012



Source: National Weather Service, Milwaukee/Sullivan

December 2016

A two pronged winter storm affected southern Wisconsin from December 16th to December 18th, 2016. The first round resulted in 2-5 inches of snow, and the second rounds resulted in 2-6 inches of snow. A wind chill of -24 degrees Fahrenheit was also reported. Snowfall affected all of Dane County, and snowfall estimates were calculated in the Madison Area. A winter storm advisory issued by Dane County lasted for four days. No known deaths or injuries were related to this winter storm event.

February 8, 2018

In the late winter of 2018, an unexpected snow storm hit the Madison area for a total of 5-7 inches of snow. The NWS placed Dane County under a winter storm warning into the late morning of February 9th, 2018. The advisory expired, and a four inch increase was estimated when compared to the original forecasted amount of 3-5 inches.

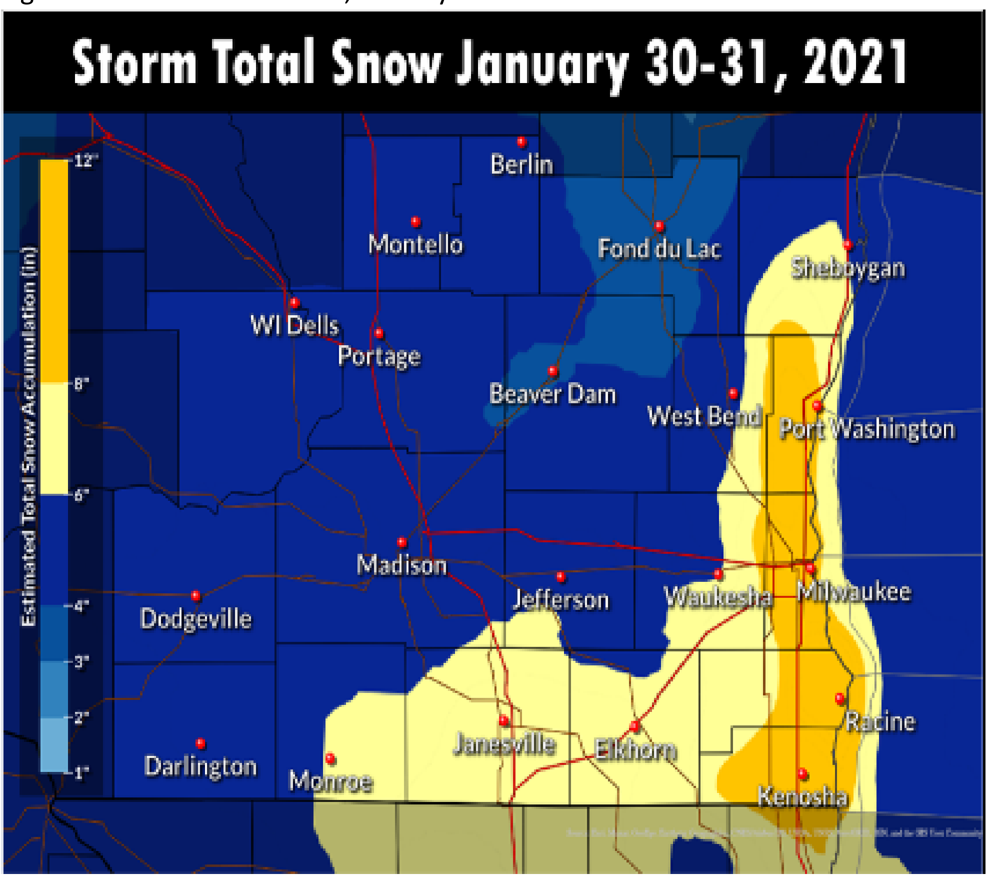
February 12, 2019

On February 12th of 2019, a blanketing of snow hit across Wisconsin, for an average of up to 16 inches in central and southern Wisconsin. Dane County had an average snowfall accumulation of 8-16 inches. This beat the February 12th, 1923 record by more than half. Dane County deputies reported multiple car slide offs. Minor damage to vehicles were reported, and no fatalities were reported in relation to this event.

December 2020

In the early winter of 2020, a major winter storm affected parts of southern Wisconsin. Over five inches of snow was estimated to have been dumped in Dane County within a few hours, and the snow event continued for about 2-3 days, from December 29th to December 31st.

Figure 4.14.3 Snowfall Totals, January 2021



Source: National Weather Service, Milwaukee/Sullivan

January 2021

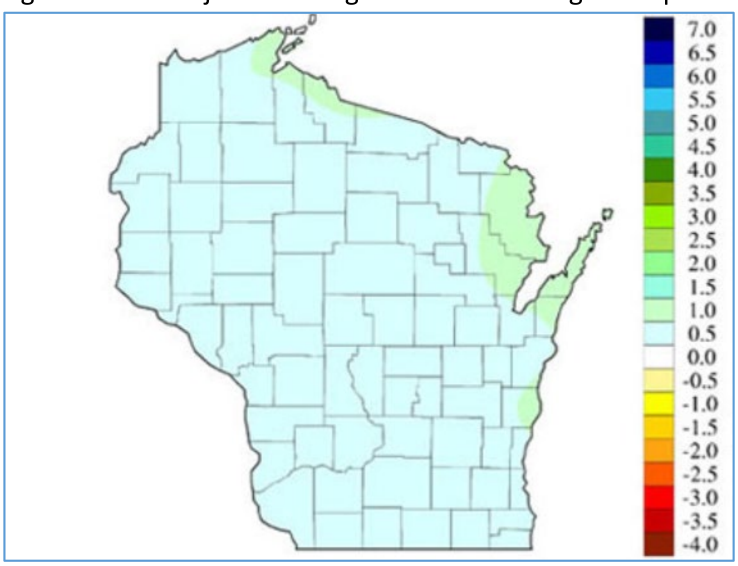
In mid-winter of 2021, a snow storm hit the southern and eastern regions of Wisconsin. In Dane County, the snow storm deposited about four inches of snow, which pushed Dane County's 2021's annual snowfall count past the average annual inches per year. After this snow storm event, Dane County's went to 31.2 inches of snowfall for the season, while the average is 30.1 inches. This storm event lasted from January 29th to January 30th.

4.14.3 Impact of Climate Change on Future Conditions

As discussed in the "Extreme Cold" section, the increase observed average temperature has been highest in the winter months. Looking forward, WICCI models predict this warming trend to continue. In its 2011 report, Wisconsin's Changing Climate: Impacts and Adaption, WICCI projects that southern Wisconsin, Dane County included will experience an average winter time temperature increase of 7.5°F to 8°F by 2055. The region can also expect a decrease of 12 to 14 days with below zero low temperatures over this same time period.

WICCI also predicts a slight increase in wintertime precipitation for southern Wisconsin. Depending on conditions at the time of the event, this could occur in the form of snow, rain, or freezing rain. As both temperature and precipitation increase during the winter months, occurrences of freezing rain may be more likely.

Figure 4.14.4 Projected Change in Winter Average Precipitation (inches)



Source: Wisconsin Initiative on Climate Change Impacts

4.14.4 Impact Assessment

The occurrence of major snowstorms, ice storms, and blizzards can have a considerable impact on communities, utilities and transportation systems. Ice storms often produce extensive damage over large regions. The impacts of an ice storm are amplified when frigid temperatures follow the storm. Snow and ice can accumulate on roads, highways, railroads, and airport runways and can bring transportation to a halt. Ice on telephone and power lines can cause them to break as can tree branches. Power outages may last for days, and in some cases, it may be weeks before power is restored to more remote rural areas. As people have become increasingly dependent on electricity for heating and cooking, the possibility of experiencing a loss of electricity for an extended period has become more critical. While some of the direct impacts of ice or heavy snowstorms are easily identified, these can produce a wide range of indirect impacts. Many of these are summarized below.

Direct Impacts

Ice or heavy accumulations of snow, particularly with blowing and drifting, can devastate the roadway system. Roads can become impassable with heavy icing or as snow accumulates faster than it can be cleared. Snow and ice resulting in icy road conditions lead to major traffic accidents and numerous minor accidents. Similarly, if roads and streets are icy or snow covered, it is also difficult for emergency service personnel to travel and may pose a secondary threat to life safety if police, fire, and EMS crews cannot respond to calls.

Ice or heavy accumulations of snow also require vast amounts of overtime on the part of County and local highway and streets departments to remove snow and melt ice. Heavy accumulations of snow on rooftops can cause roofs to collapse, resulting in possible injury or death to those inside the building as well as devastating the contents of the building. Ice storms or high winds in winter storms can cause extensive loss of overhead utility lines due to buildup either on the lines or on adjacent trees that either collapse due to the weight or blow down onto the utility lines. Services such as telephone, electricity, and cable TV are most seriously affected by winter storms.

Indirect Impacts

The indirect impacts are what separate an ordinary winter snowstorm, even a heavy snow, from a disaster. Heavy accumulations of snow or ice can bring down trees, utility lines, and communications towers. This can disrupt communications and electrical power for days while utility companies repair the damage. Loss of power, in conjunction with impassible roads can isolate people in rural areas and essentially shut down urban areas, effectively paralyzing the entire region.

Also, many of the deaths that occur are indirectly related to the storm itself. Many of these results are from traffic accidents, heart attacks while shoveling snow, or hypothermia from prolonged exposure to the cold. Other examples of indirect impacts include:

- Agricultural losses. Livestock, particularly dairy cattle can be highly vulnerable to the impacts of an ice storm, especially if freezing conditions exist for a long time and are accompanied by an extensive power outage. Daily operations are dependent on electricity for milking and watering the animals. Loss of revenue or even disease and death of the animals can result.
- Home Health Care Services. Recipients of home health care services, particularly in rural areas face disruption of services in the aftermath of an ice or heavy snowstorm. Providers may have difficulty in reaching patients due to debris or downed power lines blocking roadways.

Electrically powered life support equipment will fail to operate in a power outage. This can have dire consequences to the patient if the outage is prolonged.

- Communications. Telecommunications can be disrupted due to a variety of factors. Most telephone and cellular carriers have emergency back-up power supplies for primary equipment. In many cases, the back-up power supply is designed to provide power for 48-hours or less. In the prolonged power outages possible with a major ice storm, this equipment will fail when the fuel for the generator runs out or the back-up batteries become discharged. Overhead telephone lines are also susceptible to the same problems as overhead electrical lines. The consequences of communications failure can be far reaching. Coordination of the public safety response to the event relies heavily on the ability to communicate. The response is invariably hampered when these systems fail.
- Public water supply and wastewater treatment. Water supply pumps and wastewater lift stations are vulnerable to prolonged loss of power. Many of these have back-up power supply for short-term power outages. An ice storm, however, has the potential to cause power outages that may last for days.
- Severely damaged trees. Ice or exceedingly heavy snow can cause substantial damage to trees in urban and rural areas. Damaged or fallen trees in urban areas block roads and sidewalks and can take down power lines. Downed or fallen trees in rural areas can lead to fire hazards in subsequent years as dead trees add to the fuel load. In either case, removal of downed trees and branches can be a significant problem and cost.
- Residential impacts. Loss of power for residential use can lead to a loss of household heating, freezing and bursting water pipes leading to loss of fresh water supply and flooded basements, sewage back-up, and the loss of the ability to cook food.
- Provisions. As is common in many disasters, supplies of flashlights, batteries, bottled water, fuel, and food supplies can become depleted in the area immediately affected by the storm. This creates a particular stress on low-income individuals and families that are not able to stock-up on these supplies.
- Economic loss. Dane County residents rely heavily on roadways and automobiles to commute to and from their jobs. When employees cannot get to their jobs, commerce can be affected, especially if the situation lasts for days. In addition, all of the primary and indirect impacts of a major snow or ice storm can have cascading economic consequences. These losses are difficult to quantify, but full recovery from a regional severe winter storm can take years.

4.14.5 Vulnerability Assessment

Since severe winter storms are regional in nature, virtually the entire County is likely to be affected. The vulnerability of the people, buildings, and economy of the County is very difficult to quantify. Virtually the entire social and economic structure of the region is impacted when major winter storms occur.

There are, however, segments of the population that are vulnerable to the potential indirect impacts of a severe winter storm, particularly the loss of electrical power. As a group, the elderly or disabled, especially those with home health care services relying on rely heavily on an uninterrupted source of electricity. Resident populations in nursing homes, Community Based Residential Facilities, or other special needs housing may also be vulnerable if electrical outages are prolonged. If they do not have a back-up power source, rural residents and agricultural operations reliant on electricity for heating and water supplies are also especially vulnerable to power outages.

Essential Infrastructure

The physical structures which comprise essential infrastructure are also vulnerable. Severe winter weather, particularly a significant ice storm has the potential to disrupt the availability of services from essential infrastructure, including utility delivery (gas, electric and water), telephone service, and emergency response personnel capabilities. Ice storms or high winds in winter storms can cause extensive loss of overhead utility lines due to buildup either on the lines or on adjacent trees that either collapse due to the weight or blow down onto the utility lines. Services such as telephone, electricity, and cable TV are frequently affected by winter storms.

In 2009, Sidney Sperry and Steven Piltz (http://www.spia-index.com/aboutUs.php) developed the Sperry-Piltz Ice Accumulation Index (SPIA Index) to quantify potential damages and vulnerability of electric utility infrastructure in an ice storm. The index accounts for the combination of radial ice and wind in the resulting damage projections.

The Sperry-Piltz Ice Accumulation Index, or "SPIA Index" – Revised September, 2009

ICE DAMAGE INDEX	RADIAL ICE AMOUNT (inches)	WIND (mph)	DAMAGE AND IMPACT DESCRIPTIONS
0	< 0.25	< 15	Minimal risk of damage to exposed utility systems; no alerts or advisories needed for crews, few outages.
1	0.10 – 0.25	15 - 25	Some isolated or localized utility interruptions are possible, typically lasting only a few hours. Roads and bridges may become slick and hazardous.
	0.25 – 0.50	> 15	
2	0.10 – 0.25	25 - 35	Scattered utility interruptions expected, typically lasting 12 to 24 hours. Roads and travel conditions may be extremely hazardous due to ice accumulation.
	0.25 – 0.50	15 - 25	
	0.50 – 0.75	< 15	
3	0.10 – 0.25	> = 35	Numerous utility interruptions with some damage to main feeder lines and equipment expected. Tree limb damage is excessive. Outages lasting 1 – 5 days.
	0.25 – 0.50	25 - 35	
	0.50 – 0.75	15 - 25	
	0.75 – 1.00	< 15	
4	0.25 – 0.50	> = 35	Prolonged & widespread utility interruptions with extensive damage to main distribution feeder lines & some high voltage transmission lines/structures. Outages lasting 5 – 10 days.
	0.50 – 0.75	25 - 35	
	0.75 – 1.00	15 - 25	
	1.00 – 1.50	< 15	
5	0.50 – 0.75	> = 35	Catastrophic damage to entire exposed utility systems, including both distribution and transmission networks. Outages could last several weeks in some areas. Shelters needed.
	0.75 – 1.00	> = 25	
	1.00 – 1.50	> = 15	
	> 1.50	Any	

(Categories of damage are based upon combinations of precipitation totals, temperatures and wind speeds/directions.)

4.14.6 Potential for Future Losses

The winter storm of record is the 1976 ice storm. The potential for future damages is estimated by assuming similar impacts as those caused by this storm. Dane County damages for public, farm, and private/non-farm losses, in 1976 dollars, totaled $1.9 million, $1.8 million, and $1.0 million respectively. Total damages were estimated to be $4.78 million, excluding electric utility losses, which were $1.2 million for Madison Gas and Electric, and an undisclosed amount for Wisconsin Power and Light. Based on a consumer price index inflation calculator, the $4.78 million in losses in 1976 would equate to more than $20.1 million in 2017. (This figure does not include losses to utilities, which would be substantial.)

4.15 EMERGING HAZARDS

4.15.1 Description

The planning process identified a number of additional hazards that had not been addressed in previous versions of the plan. These are emerging concerns related to warming climate conditions and changing environmental conditions. In some cases, these are new or growing concerns of secondary hazards related to the hazards addressed in this plan (e.g. decreasing water quality in the lakes after a flood, leading to harmful algal blooms) in other cases, they are entirely distinct (e.g. increase in vector-borne illness such as West Nile disease which is transmitted by mosquitos). The concerns identified and discussed in the planning process included:

- Air pollution, increasing temperatures, changing circulation patterns, and other processes combine to increase ground-level ozone, which affects respiratory health.
- Heavy rains and flooding can overwhelm sewer and stormwater systems, leading to a rise in water pollution and the risk of waterborne diseases such as cryptosporidium and giardia.
- Warmer water temperatures and an overabundance of nutrients can lead to rapidly reproducing populations of cyanobacteria, also known as blue-green algae, in lakes and ponds. Some blue-green algae produce toxins that are harmful to humans and animals. Algal blooms also deplete oxygen levels and block sunlight for other organisms, causing a disruption in the aquatic ecosystem. Harmful algal blooms are responsible for numerous beach closures on lakes in Dane County.

Blue-green algae bloom

- Changes in temperatures and precipitation could result in an increase in disease-carrying insects, including ticks and mosquitoes. This means people may be at a greater risk for contracting vector-borne diseases, such as Lyme disease and West Nile encephalitis.
- The spread of invasive and exotic species; plants animals, and pests can cause significant harm to native ecosystems and to humans. Addressing or mitigating changing environmental

conditions associated with the spread of invasive species is well beyond the scope of this plan. The spread of invasive species, such as wild parsnip (pastinaca sativa), which can be harmful to human health, have been identified as a specific concern. (Wild parsnip grows along roadsides and other disturbed areas. Chemicals in the plant can cause potentially serious burn-like inflammation on the skin when exposed to sun light.)

4.15.2 Impact and Vulnerability Assessment

These are emerging hazards for which there is not a great deal of risk assessment data available. The potential impacts of climate change on health would most likely arise from a combination of human and environmental factors. While everyone has some degree of vulnerability, it is likely that risks are not evenly distributed among our population; some groups are more vulnerable than others (the very young, the elderly, the economically disadvantaged, and those whose health is already compromised).

This is an area for further monitoring and study.

4.16 RISK SUMMARY

4.16.1 Hazard Ranking

As part of the update process, all local jurisdiction participants and planning committee members were asked to rank their relative concern about these hazards, using their own experiences and judgment to assign numeric values. This served as the preliminary hazard ranking process for the plan update, which provided focus and scope for the hazard mitigation planning committee and the update team. The hazard identification and ranking is a means to quantify and compare the characteristic of each of the hazards, and identify those that are most significant for planning purposes.

1. Attributes of the hazard itself. These are factors related to the natural occurrence of each hazard, without any consideration of potential impacts.
    a. Area of Impact – does the event occur in isolated areas, affecting only a single unit of government, a wider area, affecting multiple units of government, or a regional, affecting the entire County or many counties?
    b. Past History, Probability of Future Occurrence – based on past experience, how likely is it that an extreme event will occur in the future?
    c. Short-Term Time Factors – to what extent is the event predictable in the short term? Is there enough warning time to allow people to act to protect themselves and their property?
2. Direct impacts on people and property. These are rankings of the short-term, immediate effects of each hazard, based on past events.
    a. Impact on General Structures - to what extent could an extreme event impact the buildings and infrastructure of the County?
    b. Impact on Critical Facilities – to what extent could critical facilities be impacted? The impact on critical facilities is an important measure of the extent to which the essential functions of government and the local economy could be disrupted.
    c. Impact on Vulnerable Populations – to what extent could people with special needs be impacted? This is an important measure of the immediate human needs that would be created in the initial response to the event.
3. Indirect or secondary impacts. The potential for long-term, far reaching impacts of each event are difficult to quantify, however, these broad categories were used:
    a. Social Impact – to what extent could the hazard disrupt individual lives and the social structure of the community?
    b. Economic Impact – to what extent could business and industry be disrupted?
    c. Severity of Other Associated Secondary Hazards – does the hazard have the capacity to create other, secondary hazards and how severe could those secondary hazards be? For example, an ice storm causing a long-term, wide-area power outage.

Table 4.16.1 summarizes the hazard ranking process conducted by the planning committee and local government participants. Hazards are listed in order of ranking. The rankings indicated in table 4.16.1 are the averages of the individual rankings of the planning team members and local jurisdiction participants. This is based on experience and judgement of more than 40 people involved in the planning process. Nevertheless, this is a subjective assessment, based on these individuals' perceptions of risk. This ranking is provided as a starting point for discussion and should not be interpreted as a scientific or objective analysis of risk.

Table 4.16.1 Hazard Ranking Summary

	Name of Break-Out Sub-Group:										
Rank	**Hazard**	**Hazard Attributes**			**Impact Attributes**						
					Primary Impact (Short Term - Life and Property)			**Secondary Impact (Long Term – Community Impacts)**			
		Area of Impact	Past History, Probability of Future Occurrence	Short Term Time Factors	Impact on General Structures	Impact on Critical Facilities	Impact on At-Risk Populations	Social Impact	Economic Impact	Severity Of Other Associated Secondary Hazards	**Total of Row Values**
		(1-5)	*(1-5)*	*(1-5)*	*(0-5)*	*(0-5)*	*(0-5)*	*(0-5)*	*(0-5)*	*(0-5)*	
9	Dam / Levee Failure	2.2	1.6	1.7	2.9	3.0	2.4	2.1	2.2	2.1	**20.2**
5	Extreme Cold	4.8	4.8	2.2	2.6	3.0	4.8	2.9	2.7	2.6	**30.4**
4	Extreme Heat	4.8	4.8	2.2	2.2	3.3	4.9	3.1	2.8	2.6	**30.7**
8	Drought	4.1	4.0	1.4	0.6	1.3	1.8	1.9	4.1	2.7	**21.9**
1	Flood	4.2	5.0	4.0	4.6	4.5	4.4	4.2	4.2	4.0	**39.1**
10	Fog	3.2	3.8	3.9	0.4	1.2	1.2	1.8	1.6	1.8	**18.9**
7	Hail Storm	2.3	4.5	3.2	3.1	1.9	1.8	1.6	2.9	1.8	**23.1**
13	Landslide / Sink Holes	0.8	0.9	2.3	2.3	1.2	1.2	1.3	1.4	1.0	**12.4**
11	Lightning	1.4	3.7	2.8	1.6	1.8	1.6	1.1	0.9	2.0	**16.9**
2	Tornado	2.6	4.4	4.5	4.2	3.7	4.0	3.9	4.3	4.3	**35.9**
12	Wildfire	1.5	1.3	1.9	2.3	2.0	1.7	1.9	2.0	2.0	**16.6**
6	Windstorm	3.1	3.9	3.0	3.5	3.0	3.0	2.7	2.9	3.4	**28.5**
3	Winter Storm	4.7	4.6	2.8	3.4	3.8	4.5	3.3	2.9	3.4	**33.4**

4.16.2 Summary of Trends and Key Issues

The planning committee's analysis of the vulnerability assessment, past events in Dane County, experience, and case studies from other locales yields the following issues and concerns:

Dam Failure

- The probability of dam failure in Dane County is low, however, the potential impacts to people and property could be substantial.
- Dam failure analysis indicates that downstream flood depths would be in the 1 to 3 foot range in the event of a failure of one of the "high" hazard dams in Dane County. This is significant, but a dam failure is likely to lead to the major inundation associated with catastrophic failure seen in media images from other locations around the country.
- Areas of greatest risk include:
  - The Town of Roxbury and the Town of Mazomanie along the Wisconsin River.
  - The Isthmus area of the City of Madison and shoreline areas of the City of Monona, including the Belle Isle and Pirate Island areas.
- Mitigation opportunities and actions are essentially the same as those identified for the flood hazard.
- While still a low probability occurrence, the increasing likelihood of extreme rainfall events associated with changing climate conditions does increase the potential for dam failure in the future.
- The dam failure risk is reduced by regular inspections, competent operation, and maintenance with public safety as the primary consideration.

Drought

- Dane County is vulnerable to the effects of an extended drought.
- Droughts can have a wide range of direct and indirect impacts that can affect a broad cross section of society and the natural environment.
- There is a general lack of awareness of the potential impacts of a sustained severe drought.
- The lack of comprehensive water management policies can exacerbate the impacts of an extended drought.
- There are great difficulties in predicting at what point a dry spell will become a drought. As a result, the response, if any, is often ad hoc and can be disorganized.
- The risk of drought is increasing due to changes in the regional climate.

Extreme Cold

- Extreme cold is an annual occurrence in Dane County.
- Water pipes in homes are susceptible to freezing and breakage during prolonged periods of extreme cold.
- Municipal water mains are susceptible to breakage during periods of extreme cold.
- People who are homeless are vulnerable to exposure during periods of extreme cold.

Extreme Heat

- While property impacts are generally minimal, there are frequent occurrences of road pavement buckling during periods of high heat. Concrete pavement is generally more prone to buckling than asphalt.
- The National Weather Service ranks extreme heat as the number one weather-related killer, nationwide and in the State of Wisconsin. These statewide and national trends have not been experienced in Dane County, where the numbers of heat-related deaths remains low.
- Heat exacerbates other underlying risk factors and the high heat is almost always an indirect cause of death.
- While everyone feels the effects of extreme heat, not everyone experiences the same level of risk. There is a range of factors that lead to an increased vulnerability of heat-related illness or death, including pre-existing health conditions, socio-economic status, and natural and built environmental factors.
- Social isolation is a perhaps the most significant of the extreme heat risk factors. This can be mitigated through organized welfare checks as well "social capital" programs that build on informal relationships between friends, family members, and neighbors.
- Due to climate tends, population exposure, and potentially fatal impacts, the overall risk of excessive heat is a growing concern.

Flood

- Flood damage occurs frequently in Dane County. Floods have caused:
    - Damage to private property that often creates financial hardship for individuals and families.
    - Damage to public infrastructure resulting in increased public expenditures and demand for tax dollars.
    - Loss of income for agricultural producers that experience flood damages.
    - Loss of income to businesses relying on recreational uses of County waterways.
    - Emotional distress on individuals and families.

- The potential for personal injury and death.

- Financially, flood losses have resulted from:
    - Flooded basements and first-floor flooding of residential, commercial, and institutional buildings.
    - Sewer backups into basements of residential, commercial, and institutional buildings.
    - Structural damage to buildings.
    - Damage to personal belongings and other contents of buildings.
    - Road, shoulder and ditch washouts.
    - Crop loss.
- Unless a property owner has flood insurance, damages to buildings and building contents are typically uninsured losses and costs for repair and replacement are typically borne by the property owner.
- Dane County is a drainage area. With a few exceptions, Dane County contains the headwaters of the rivers and streams flowing out of the County. This means that the rainfall that becomes the floodwater that causes damage started here – it didn't come from somewhere else. This presents both opportunities and challenges in reducing flood risk.
- Flooding issues in Dane County are complex and involve the interaction of a number of contributing factors, including but not limited to:
    - Changing land use patterns.
    - Historical and on-going modifications to the landscape that affect the flow of water.
    - Soils and topography.
    - Natural and constructed impediments to the flow of water.
    - Development in high risk areas.
    - Stormwater management practices.
    - Complex natural hydrologic processes.
- The complexity and interrelatedness of flooding with many other variables make it very difficult to establish an objective and complete comprehension of the problem.
- Flooding comes in a variety of forms in Dane County and not all flood management and flood mitigation strategies apply to all situations.
- Riverine flooding and the associated mapped flood hazard (i.e. NFIP floodplain maps) areas are only a partial indicator of the flood risk in Dane County.
- Floodplain zoning and construction standards have been effective loss avoidance strategies.
- The flood risk is increasing and can be expected to continue to increase as a result of warming climate conditions and changing rainfall patterns.
- Effective adaptation to this changing risk requires systematic changes to the County's water management strategies.

- Flood Insurance Studies and Flood Insurance Rate Maps are developed based on analysis of past flood events. These maps do not account for changing climate conditions, nor do they account for changing flood risks associated with urbanization and increasing land areas covered by impervious surfaces.

Fog

- Increased number of serious of fatal traffic crashes occur when fog is a contributing factor.
- Although traffic crashes and deaths are typically considered indirectly related to fog, the numbers far exceed the number of people harmed by any other natural hazard addressed in this plan.
- Dense fog can result in flight delays and cancellations at airports.
- Fog poses no risk to structures or facilities in Dane County.
- There is not a readily available source of information to assess whether the incidence of fog will increase, decrease, or remain the same as a result of the warming climate.

Hail

- No deaths or injuries have ever been directly attributed to hail strikes in Dane County.
- Financial losses due to hail damage can be significant.
- Automobiles are particularly vulnerable to damage.
- Crops are particularly vulnerable to damage at certain times in the growing season.
- Commonly used roofing and siding materials are not resistant to hail impact, resulting in the potential for widespread damage due to large hail.
- There is not a readily available source of information to assess whether the incidence of hail will increase, decrease, or remain the same as a result of the warming climate.

Landslides, Erosion, and Sinkholes

- The geology of Dane County is such that there is some potential for landslides, sinkholes and significant erosion. The overall susceptibility in the County, however, is low.
- There are no documented occurrences of significant problems associated with naturally occurring landslides or sinkholes in Dane County.
- Climate models predict increased frequency and intensity of extreme weather statewide, including more frequent, more intense precipitation events. These changes may lead to increased incidences and severity of flooding, erosion, and landslides/land subsidence.

Lightning

- Lightning strikes and resulting electrical surges can damage unprotected electronic equipment.
- Lightning strikes and resulting electrical surges can damage the electrical distribution system and cause power outages.
- Lightning striking buildings can cause structure fires.
- Lightning strikes can cause injury and/or death.
- There is not a readily available source of information to assess whether the incidence of lightning will increase, decrease, or remain the same as a result of the warming climate.

Tornado

- In general, all buildings, critical facilities, and populations are vulnerable to tornado damage.
- The Multi-Hazard section contains additional summary information on issues and concerns associated with tornadoes.
- There is not a readily available source of information to assess whether the incidence of tornadoes will increase, decrease, or remain the same as a result of the warming climate.
- A strong tornado in a densely populated area has the greatest future damage/loss potential of all of the hazards assessed in this plan.

Wildfire

- While wildfires have occurred, the conditions that lead to large, uncontrolled fires generally does not exist in Dane County.
- Wildfires in Dane County are typically grassland fires and marsh fires, not large forest fires.
- The wildfire risk in Dane County is limited to relatively small areas where urban and suburban subdivisions or small communities are situated adjacent to grass land or marshy areas.
- Grassland and marsh fires are relatively common in the spring and fall seasons, however, wildfires in Dane County rarely result in losses to homes and businesses.
- The vast majority of wildfires in Dane County are human caused.
- The incidence of wildfires can be expected to increase as a result of the warming climate and changing rainfall patterns, however the risk to structures remains low.

Windstorm

- In general, all buildings, critical facilities, and populations are vulnerable to wind damage to some degree.

- The Multi-Hazard section contains additional summary information on issues and concerns associated with tornadoes.
- There is not a readily available source of information to assess whether the incidence of severe thunderstorms and other windstorms will increase, decrease, or remain the same as a result of the warming climate.

Winter Storm

- Severe winter storms have the potential to halt all transportation – countywide. This includes that of emergency services vehicles and first responders.
- Motorists and travelers can become stranded on the highways of the County.
- Winter storm events can pose a serious threat to the residents of Dane County. Many fatalities during winter storms are the unsuspecting dangers that include heart attacks while shoveling snow and improper use of space heaters.
- Severe winter storms can completely shut down businesses and government, while isolating residents in their homes for days and sometimes weeks.
- Ice storms or high winds in winter storms can cause extensive loss of overhead utility lines due to buildup on either the lines or on adjacent trees that either collapse due to the weight or blow down onto the utility lines.
- The disruption of electrical power distribution systems can have a wide range of secondary, potentially long-term impacts.
- The Multi-hazard section contains additional summary information on issues and concerns associated with winter storms and ice storms.
- Climate models predict and increase in wintertime precipitation for southern Wisconsin. Depending on conditions at the time of the event, this can occur as snow, rain, or freezing rain. As both temperature and precipitation increase during the winter, occurrences of freezing rain are becoming more likely. The resulting risk of a damaging ice storm is increasing.

Emerging Hazards

- Trends toward a warmer, wetter climate lead to increases in risks to human health above and beyond those traditionally considered as “natural hazards.”
- Air pollution, increasing temperatures, changing circulation patterns, and other processes combine to increase ground-level ozone, which affects respiratory health.
- Heavy rains and flooding can overwhelm sewer and stormwater systems, leading to a rise in water pollution and the risk of waterborne diseases such as cryptosporidium and giardia.
- Warmer water temperatures and an overabundance of nutrients can lead to harmful algal blooms, in lakes and ponds.

- Changes in temperatures and precipitation could result in an increase in disease-carrying insects, including ticks and mosquitoes. This means people may be at a greater risk for contracting vector-borne diseases, such as Lyme disease and West Nile encephalitis.
- The spread of invasive species, such as wild parsnip (pastinaca sativa), which can be harmful to human health, have been identified as a specific concern.
- This is an area for further monitoring and study.

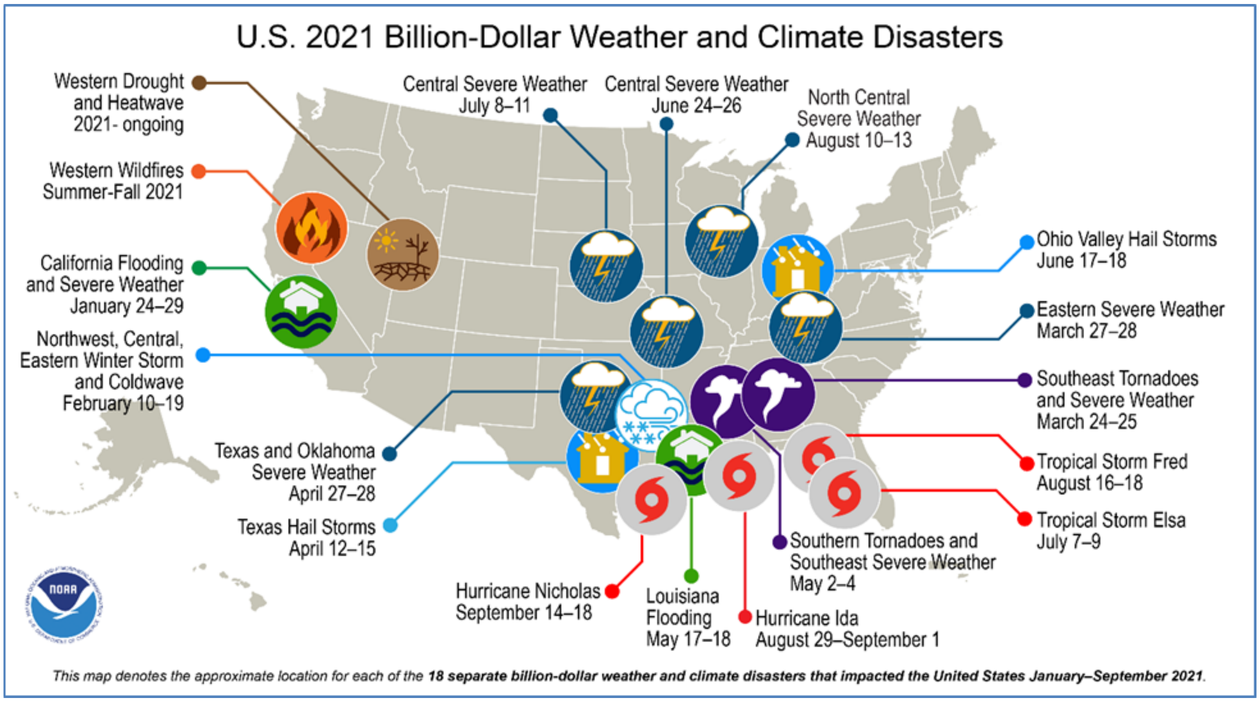
Multi-Hazard Issues

- Overhead power and telephone lines are vulnerable to damage by ice and wind.
- Homes are often damaged due to falling tree limbs in wind and ice storms.
- Tree damage leads to many secondary losses, such as road blockage, downed power lines, and hindered emergency response.
- Manufactured homes are especially vulnerable to many of the hazards, but particularly high winds and tornadoes. Most manufactured homes do not have safe rooms. Some mobile home parks have storm shelters, but most do not.
- Agricultural operations and critical facilities are particularly vulnerable to extended loss of electric power.
- Loss of electrical power is, in many cases, the cause of significant secondary consequences of a hazard event. Overhead electrical lines are particularly vulnerable to many of the natural hazards in Dane County.
- Individuals in a home-health care situation are particularly vulnerable to loss of electrical power.
- Manufactured homes, buildings with wide span roofs such as shopping malls or school gymnasiums are also particularly vulnerable to high winds.
- Falling trees and branches cause damage to power lines, block streets, damage buildings, inhibit emergency access, and is a major contributor to storm debris problems.

4.16.3 Catastrophic Scenarios

In addition to compiling the type of severe weather data referenced previously in the hazard analysis, NOAA's National Centers for Environmental Information (NCEI) tracks and evaluates large-scale climate and weather events in the US (and globally) that have great economic and social impacts. In their assessment, Billion-Dollar Weather and Climate Disasters, NCEI states that "In 2021 (as of October 8), there have been 18 weather/climate disaster events with losses exceeding $1 billion each to affect the United States. These events included 1 drought event, 2 flooding events, 9 severe storm events, 4 tropical cyclone events, 1 wildfire event, and 1 winter storm event. Overall, these events resulted in the deaths of 538 people and had significant economic effects on the areas impacted. The 1980–2020 annual average is 7.1 events (CPI-adjusted); the annual average for the most recent 5 years (2016–2020) is 16.2 events (CPI-adjusted).. The total cost of these 208 events exceeds $1.1 trillion." The 18 events that occurred in 2021 are shown on the map in Figure 4.16.1.

Figure 4.16.1 U.S. 2021 Billion-Dollar Weather & Climate Disasters



Source: NOAA, National Centers for Environmental Information website, https://www.ncdc.noaa.gov/billions/ , 2021

A significant number of the 208 events identified are related to tropical storms and large wildfires which do not present a threat in our region of the country. There are four scenarios identified, however, where there is a risk of a regional catastrophic disaster that could have impacts in Dane County far greater than have occurred in the past. These include:

- Extreme rainfall and major flooding.
- Strong (EF4 or EF5), long track tornado affecting a densely populated urban area.
- Regional, multi-year extreme drought.
- Regional ice storm resulting in a long-term, widespread electrical power outage.

Events such as these would have profound impacts on the communities affected, far beyond that which we have experienced in the past. The recovery process would take years to return the economy and community to "normal."

To be clear, this plan is not predicting the occurrence of an event of this nature in Dane County in the immediate future. The probability of these extreme events remains low. There is a precedent for events of this nature, however, and while low, the probability of occurrence is not zero. Attention is being called to these events because a risk assessment based solely on the severity of past occurrences in

Dane County has a narrow view. Because events on this scale have not occurred recently in Dane County, does not mean that they never will. Widening the view presents an entirely different perspective of the risk potential. To maximize community resilience, hazards management and mitigation strategies should be developed with the widest practical view.

Also, it is important to acknowledge that our current risk management tools and processes probably already are outdated. For example, most risk management models are typically retrospective and do not account for climate change impacts we are experiencing today. As climate change effects are exacerbated, we will be even further behind the curve, our mitigation efforts will prove insufficient, and our response and recovery operations will suffer. These catastrophic scenarios and examples from other areas of the country offer a perspective of the scope and scale of potential future vulnerabilities.

4.16.4 Individual Perceptions of Risk of Natural Hazards

Individuals assess risk and the probability of being harmed (either physically or financially) very differently from the quantitative analysis described in the previous sections of this plan. The perceptions of individual members of the public have increasing importance as planning methods, such as the one used in this plan incorporate public input to greater degrees.

Though one of the purposes of the County vulnerability analysis is to aid the public in making policy decisions, citizens are often skeptical of “expert” opinion. As a result, they are more likely to depend upon their own experiences and knowledge as a basis for decision-making. Their reliance on their own opinions and experiences has both positive and negative aspects.

On the positive side, the public perception of risk tends to be broader than what traditionally comes out of technical studies. People often give greater emphasis to latent or diffused risks and incorporates social costs readily into their judgments. They also tend to give greater emphasis to risks that affect multiple generations and focus on mitigating risks when the exposure to risk is involuntary, that is, the person did not place him or herself in harm’s way.

Individuals, however, do not evaluate probabilities of risk in what is called “rational” ways. People over- and underestimate risks in several ways. People tend to ascribe risks to un-risky events when they can be easily categorized with events that have great probabilities of occurring. Individuals also link risk with events depending upon the ease in which harm can be imagined coming from an event. Additionally, when faced with new information that contradicts their beliefs people often move incrementally to adjust their position to the new information. People will generally overestimate the consequences of changing their beliefs and underestimate the consequences of maintaining their beliefs.

There may also be a perception that governments will provide adequate services to individuals before, during and after disasters, and that individual preparation is therefore unnecessary. Though governments at every level will prepare for and respond to such disasters to the best of their capabilities, it is important that individuals take responsibility for their own wellbeing. Governments cannot decrease risks sufficiently to protect everyone from every conceivable natural disaster. It is necessary for families and individual citizens to take additional steps decrease their own risk. These variables in individual risk assessments both bias decision-making and provide information that cannot easily be described by an economic analysis.

Importantly, the biases mentioned in individual risk assessments may be no greater and no less powerful than numerous assumptions made in quantitative risk analyses. Neither way of understanding the world of natural disasters is completely accurate. It should be noted that this plan is influenced by both individual and quantitative assessments of risk. This plan makes attempts to compensate for these shortcomings by making readers aware of them.

4.1 OVERVIEW

The risk assessment provides the factual basis for the activities proposed in the strategy that will reduce losses from identified hazards. A quality risk assessment makes a clear connection between the community's vulnerability and the hazard mitigation actions." [FEMA – Local Mitigation Plan Review Guide, Oct. 1, 2011)]

Requirement	Description
44CFR 201.6(c)(2)(i)	[The risk assessment shall include a] description of the type, location and extent of all natural hazards that can affect the jurisdiction. The plan shall include information on previous occurrences of hazard events and on the probability of future hazard events.
44CFR 201.6(c)(2)(ii)	[The risk assessment shall include a] description of the jurisdiction's vulnerability to the hazards described in paragraph (c)(2)(i) of this section. This description shall include an overall summary of each hazard and its impact on the community. All plans approved after October 1, 2008 must also address NFIP insured structures that have been repetitively damaged by floods. The plan should describe vulnerability in terms of:
44CFR 201.6(c)(2)(ii)(A)	(A) The types and numbers of existing and future buildings, infrastructure, and critical facilities located in the identified hazard areas;
44CFR 201.6(c)(2)(ii)(B)	(B) An estimate of the potential dollar losses to vulnerable structures identified in … this section and a description of the methodology used to prepare the estimate.
44CFR 201.6(c)(2)(ii)(C)	(C) Providing a general description of land uses and development trends within the community so that mitigation options can be considered in future land use decisions.
44CFR 201.6(c)(2)(iii)	For multi-jurisdictional plans, the risk assessment section must assess each jurisdiction's risks where they vary from the risks facing the entire planning area.

The risk assessment process identifies and profiles relevant hazards and assesses the exposure of lives, property, and infrastructure to these hazards. The process allows for a better understanding of a jurisdiction's potential risk to natural hazards and provides a framework for developing and prioritizing mitigation actions to reduce risk from future hazard events.

This risk assessment followed the methodology described in the FEMA publication Understanding Your Risks—Identifying Hazards and Estimating Losses (FEMA 386-2, 2002), which breaks the assessment down to a four-step process:

1. Identify Hazards
2. Profile Hazard Events
3. Inventory Assets
4. Estimate Losses

4.1.1 Hazard Identification

The Dane County Hazard and Risk Analysis, an Appendix to the County's Emergency Response Plan served as the starting point for the initial risk assessment. Based on the Hazard Analysis and input from the local jurisdictions, the planning team considered 13 hazards from the previous version of the plan. The review re-examined these hazards and conducted additional research to identify other hazards which should be included in this document. Based on the recommendations by FEMA, the planning team, and historical records for Dane county, the following hazards (listed alphabetically), were considered during the plan update:

- Dam Failure
- Drought
- Earthquake
- Erosion
- Expansive Soils
- Flood
- Fog
- Hail
- Landslide
- Levee Failure
- Lightning
- Extreme Cold
- Extreme Heat
- Severe Thunderstorm
- Severe Winter Storm
- Subsidence
- Tornado
- Wildfire
- Windstorm
- Emerging Hazards
  - Algal Bloom*
  - Invasive Species*
  - Vector-Borne Disease*

* These are Hazards considered in addition to those identified in the 2010 version of the Natural Hazard Mitigation Plan. These are emerging hazards discussed in the context of changing climate and environmental conditions.

After conducting a review of Dane County's geographic location and climate, several of the natural hazards included in the initial composite list were discarded because they are not relevant to Dane County. These include: Avalanche, Costal Erosion, Coastal Storm, Earthquake, Expansive Soils, Hurricane, Tsunami, and Volcano. Earthquake was considered, but did not warrant a full hazard profile, as the probability of a damaging event is extremely low based on an analysis associated with the Wisconsin State Hazard Mitigation Plan. Severe Thunderstorm is not included because the damaging effects of such storms (hail, lightning, and high wind) are profiled as individual hazards as this better reflects the individual hazard risks and occurrences for Dane County. Levee failures were researched but there are no documented levees in Dane County, so the hazard was removed from the list. Landslides and Sinkholes and Erosion are addressed in a single chapter, due to their similar geologic characteristics.

4.1.2 Hazard Rankings and Priorities

The final hazards which are extensively profiled, including significant vulnerability assessment, risk analysis, and impact assessments, are listed below:

- Dam Failure
- Drought
- Earthquake
- Erosion
- Expansive Soils
- Flood
- Fog
- Hail
- Landslide
- Levee Failure
- Lightning
- Extreme Cold
- Extreme Heat
- Severe Thunderstorm
- Severe Winter Storm
- Subsidence
- Tornado
- Wildfire
- Windstorm
- Emerging Hazards

4.1.3 Hazard Rankings and Priorities

The hazards identified in Section 4.1.2 are each profiled and assessed individually. Much of the profile information came from the same sources used to identify the hazards during the initial planning effort in 2010 and updated in 2018. The information was reviewed for accuracy and applicability and updated where required. Significant occurrences of hazards that have occurred since the original plan's adoption in 2018 are also included in the updated hazard profiles. The hazard profiles in this section are organized in alphabetical order.

Each hazard is profiled in a similar format. This approach helps create a uniform planning basis and enables comparisons between the hazards. In general, the following methodology was used:

1. *Hazard Description* – This assessment includes a profile of the hazard and a discussion of past history, frequency of occurrence, severity, geographic areas that could be affected, and time factors such as predictability and speed of onset.

2. *Impact of Climate Change on Future Conditions* – The potential impacts of changing climate conditions on each individual hazard are described. This includes a description of trends and projections for future occurrences and an assessment of changes in vulnerability and risk associated with climate change.
3. *Impact Assessment* – Potential impacts are broken-out into two broad categories, direct impacts and indirect impacts. Based on past experiences in Dane County, in the State of Wisconsin, and nationwide, this is a qualitative discussion of the consequences that could be expected in the aftermath of each of the hazard events.
4. *Vulnerability Assessment* – Based on the potential impacts, the vulnerability of exposed structures, infrastructure, and people are described and mapped where relevant. Vulnerabilities are broken into two broad categories, at-risk populations, and critical facilities.
5. *Potential for future losses* – The particular method for determining the future loss potential varies from hazard to hazard. In general, however, the potential for future losses is an estimate of possible monetary losses based on a most probable case scenario and the impact analysis and vulnerability assessment for each hazard. Structural damage potential is based on the "improved value" of buildings from the Dane County parcel database. The potential loss of building contents and personal possessions is based on FEMA formulas and estimation methods where appropriate.
6. *Risk Summary* – Based on all of the information compiled in the vulnerability assessment, the planning team ranked the hazards to allow for quantitative comparison. Overall vulnerability for the hazard is measured in terms of geographic extent, impacts, magnitude and severity, probability of occurrence, and exposure. These findings are summarized in this section and analyzed to reveal an overall risk rating for the hazard.

4.2 DAM FAILURE

4.2.1 Description

A dam is a barrier constructed across a watercourse in order to store, control, or divert water. Dams are usually constructed of earth, rock, concrete, or mine tailings. The water impounded behind a dam is referred to as the reservoir and is typically 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. Dams serve many purposes, including agricultural uses; providing recreation areas; electrical power generation; and erosion, water level, and flood control.

A dam failure is the collapse, breach, or other failure of a dam that causes downstream flooding. 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). If internal erosion or overtopping cause a full structural breach, a high-velocity, debris-laden wall of water is released and rushes downstream, damaging or destroying whatever is in its path. Dam failures may result from one or more of the following:

- Prolonged periods of rainfall and flooding (the cause of most failures)
- Inadequate spillway capacity which causes excess overtopping flows
- Internal erosion due to embankment or foundation leakage or piping
- Improper maintenance
- Improper design
- Negligent operation
- Failure of upstream dams
- High winds (leading to wave erosion)

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 an unusually high runoff. This high runoff increases the reservoir of the dam 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.

The Wisconsin Department of Natural Resources (DNR) assigns hazard ratings to large dams within the State. Two factors are considered when assigning hazard ratings: existing land use and land use controls (zoning) downstream of the dam. Dams are classified, by law, in three categories that identify the potential hazard to life and property (WI Administrative Code, NR 333.06):

- A low hazard rating is assigned to those dams that have no development unrelated to allowable open space use in the hydraulic shadow where the failure or mis-operation of the dam would result in no probable loss of human life, low economic losses (losses are principally limited to the owners property), low environmental damage, no significant disruption of lifeline facilities, and have land use controls in place to restrict future development in the hydraulic shadow.
- A significant hazard rating is assigned to those dams that have no existing development in the hydraulic shadow that would be inundated to a depth greater than 2 feet and have land use controls in place to restrict future development in the hydraulic shadow. Potential for loss of human life during failure is unlikely. Failure or mis-operation of the dam would result in no probable loss of human life but can cause economic loss, environmental damage, or disruption of lifeline facilities.
- A high hazard rating is assigned to those dams that have existing development in the hydraulic shadow that will be inundated to a depth greater than 2 feet or do not have land use controls in place to restrict future development in the hydraulic shadow. This rating is assigned if loss of human life during failure or miss-operation of the dam is probable.

A dam with a structural height of over 6 feet and impounding 50 acre-feet or more, or having a structural height of 25 feet or more and impounding more than 15 acre-feet, is classified as a large dam.

There are eleven large dams and 25 small dams in Dane County. Of the eleven large dams, two are classified as “High” hazard, one is “Significant” hazard, and the remaining eight are “Low” hazard. The small dams are not officially classified, but would all meet the “Low” hazard criteria. In addition, there is one dam outside of Dane County, the Prairie du Sac Hydroelectric Dam on the Wisconsin River that does have the capacity to affect Dane County residents in a failure scenario.

Table 4.2.1 Large Dams in Dane County

Dam Name/Impound	Hazard Rating	Max Storage (acre ft.)	Height (ft.)	Stream
Tenney Lock and Dam	High	160,000	5	Yahara River
Stewart Lake	High	90	23.8	Moen Creek
Marshall Grist Mill	Significant	1,100	11	Maunesha River
Belleville	Low	80	11	Sugar River
Brunner	Low	60	10	Sugar River Tributary
Dunkirk	Low	260	13	Yahara River
Lake Kegonsa	Low	16,300	1	Yahara River
Babcock Park Lock and Dam	Low	50,000	1	Yahara River
Lake Windsor	Low	50	14	Yahara River Tributary
Lake Wingra	Low	2,600	3	Murphy Creek
Stoughton	Low	500	9	Yahara River
Prairie du Sac Hydroelectric Dam	High	193,200	40	Wisconsin River

Source: Wisconsin Department of Natural Resources

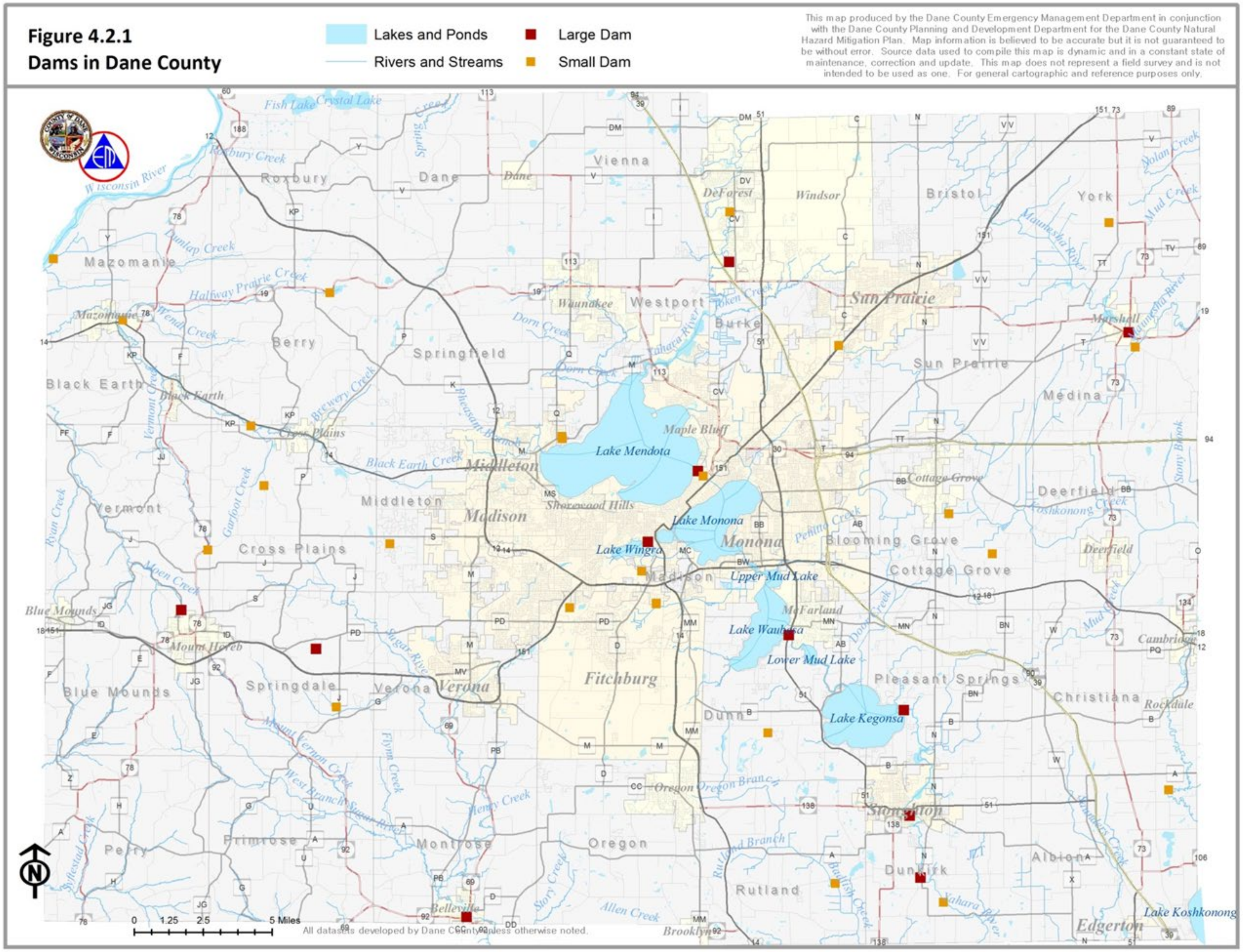
Emergency Action Plans

All Large dam owners are required by Wisconsin Administrative Code, NR 333.07 to develop an Emergency Action Plan describes potential downstream impacts and procedures to be followed in the event of a failure:

1. A notification flow chart identifying involved agencies, other dam owners both upstream and downstream and their phone numbers.
2. Emergency operation procedures.
3. An inundation map of the hydraulic shadow on a scale of 1" = 2000' or less that extends downstream to an elevation within one foot of the dam nonexistent profile.
4. Procedures for notification of all property owners affected by a dam failure and a list of their names, addresses and phone numbers.

Emergency Action Plan documents for the three “High” hazard dams affecting Dane County are on file with Dane County Emergency Management.

Figure 4.2.1 Dams in Dane County



4.2.2 Impact of Climate Change on Future Conditions

Climate change adds to the risk of dam failure in Dane County. The increased likelihood of intense rainfalls in the region is the main factor in this risk increase. While the dams in Dane County are designed to be resilient to these intense rainfalls, increased likelihood of these storms increases the number of times dams will be in circumstances that could lead to failure. Certainly there is no expectation that Dane County will experience a sharp, or any, increase in dam failures as the climate continues to change, but the increased storms is a reason to continue to maintain and monitor the County's dams.

Increased risks to dams associated with prolonged periods of rainfall and flooding are addressed in the flood hazard section.

4.2.3 Risk Assessment

The Emergency Action Plans for the dams classified as "High" hazard contain a detailed analysis of the potential impacts of a breach or failure. This impact analysis and risk assessment is summarized, but is not duplicated in this plan document.

Prairie du Sac Hydroelectric Project Dam

Prairie du Sac Hydroelectric dam is located on the Wisconsin River just upstream of the Village of Prairie du Sac, on the border between Sauk and Columbia Counties. The dam is maintained and operated by Alliant Energy Company for the purpose of electric power generation. The Lake

Wisconsin reservoir has a normal operating head of 38.5 feet. The normal surface area of Lake Wisconsin is approximately 9,000 acres, with a storage volume of 119,950 acre-feet. The Prairie du Sac Hydroelectric Project Emergency Action Plan provides dam breach scenarios and flood inundation maps for failures under flood flow and normal “sunny day” flow conditions. This analysis indicates the potential for properties to be affected in the Towns of Roxbury and Mazomanie. Primary structures in the mapped flood shadow are shown in table 4.2.2.

Tenney Lock and Dam

Tenney Dam is located on the southwest side of Lake Mendota in the City of Madison at Tenney Park. The dam is owned by Dane County and operated by the Land and Water Resources Department. Tenney Dam impounds Lake Mendota on the Yahara River, in the densely populated “Isthmus” area of the City of Madison. Tenney Dam is operated to maintain water levels within the target levels specified in the Wisconsin DNR’s lake level orders (3-SD-77-808). The Dane County Lake Level Management Guide for the Yahara Chain of Lakes describes dam operations and the strategies employed to comply with lake level orders. The dam has a height of 11 feet and a normal operating head of 5.1 feet. The dam breach analysis prepared for the Land and Water Resources Department is summarized in the Tenney Lock and Dam Emergency Response Handbook on file with Dane County Emergency Management. This analysis indicates the potential for properties to be affected in the City of Madison and the City of Monona. The analysis also indicates the potential for storm sewer back-flooding in lower lying areas of the Isthmus in Madison. Primary structures in the mapped flood shadow are shown in table 4.2.2.

Stewart Park Dam

Stewart Park Dam is located on the northeast side of Stewart Lake, just north of the Village of Mount Horeb in the Town of Blue Mounds. Stewart Park Dam impounds Stewart Lake on Moen Creek. The dam has a height of 33.5 feet and a normal operating head of 23.9 feet. Stewart Park is a Dane County Park and the dam is operated by the Dane County Land and Water Resources Department. The dam breach analysis prepared for the Land and Water Resources Department is summarized in the Stewart Park Dam Emergency Response Handbook on file with Dane County Emergency Management. This analysis indicates a limited potential for downstream properties to be affected in the Towns of Blue Mounds and Vermont. Primary structures in the mapped flood shadow are shown in table 4.2.2.

4.2.4 Impact Assessment

Dam failure analysis indicates that downstream flood depths would be in the 1 to 3 foot range in the event of a failure of one of the "high" hazard dams in Dane County. This is significant, but a dam failure is likely to lead to the major inundation associated with catastrophic failure seen in media images from other locations around the country.

Dam failure has the potential to result in consequences such as damages to existing public and private buildings, damage to infrastructure, loss of services from utilities,), loss of business income, displacement of individuals and businesses, emergency services (including road closure and evacuations), and possibly loss of life.

Table 4.2.2 Primary Structures in "High" Hazard Dam Flood Inundation Areas

Land Use Category	Prairie du Sac Hydroelectric Dam	Tenney Lock and Dam	Stewart Park Dam
Assembly		1	
Commercial Sales	1	30	
Commercial Services		32	
Education		1	
Government		2	
Industrial	3	31	
Recreation	2	9	
Religion		1	
Residential	273	591	1
Transportation		3	

Land Use Category	Prairie du Sac Hydroelectric Dam	Tenney Lock and Dam	Stewart Park Dam
Utility		9	
Total	279	710	1

Table 4.2.2 indicates the numbers of primary structures, by land use category, located in the inundation area downstream from each of the "High" hazard classification dams in Dane County. The data sources are the inundation maps from the dam breach analysis in the Emergency Action Plan for each dam combined with Dane County's building footprint inventory. The flood depth potential and individual building site elevations are not available in the breach analysis. It is, therefore, not possible to accurately determine the degree to which these structures and facilities would be actually be impacted in a failure.

4.2.5 Previous Occurrences

There have been no documented dam failures of significance in recent history in Dane County.

As human-built structures, hazards resulting from a dam failure are not, strictly speaking, natural hazards. As such, these dams are managed in order to minimize the potential threat of failure. These dams are routinely, if not continuously monitored. The dams are subject to regular inspections, are competently operated, and are maintained with public safety as the primary consideration.

Note: Catastrophic failures of dams have occurred in other areas of the country and in the State of Wisconsin. The June, 2008 failure at Lake Delton in neighboring Sauk County is an example. Although the Lake Delton Dam control structure did not fail, County Highway A in the Village of Lake Delton washed out, causing Lake Delton to empty into the Wisconsin River. Five homes were destroyed in the process. This underscores that while failures of this nature are rare events, the impacts to people and properties adjoining these facilities can be substantial.

4.3 DROUGHT

4.3.1 Description

There are a number of different ways to define drought. Generally, drought is a water shortage caused by a reduction in the amount of precipitation received over an extended period of time, usually a season or more in length. This deficiency results in a water shortage for some activity, group, agricultural or environmental sector.

The effects of a drought are aggravated by other factors such as high temperatures, high winds or low relative humidity. The severity of the impact of a drought depends on the duration, intensity, and geographic extent of the event, plus the regional demands on the water supply driven by human activities.

Drought is one of the most complex natural hazards because it is not a distinct event with a clearly defined beginning or end. It differs from other natural hazards in that it has an unusually slow onset, may affect multiple jurisdictions or counties simultaneously, and typically causes no structural damage. The effects impact various sectors in different ways and with varying intensity.

Categories of Drought

Droughts are categorized into four types based on the severity and impact of the occurrence and measured by the industries affected. These categories are meteorological, hydrological, agricultural, and socioeconomic. It is possible for these conditions to exist simultaneously.

1. Meteorological drought is the traditional conceptualization of a drought, and is defined solely on the basis of the degree of dryness. This is expressed as a relationship between actual precipitation and the expected average or normal amount, using a monthly, seasonal, or annual time scale. A meteorological drought considers only the physical attributes of the event and not the impact on social or environmental systems. (University of Nebraska at Lincoln, National Drought Mitigation Center, https://droughtmonitor.unl.edu/ Accessed December, 2021.)
2. Hydrological droughts examine the effects of precipitation shortfalls (including snowfall) on surface or subsurface water supply (e.g., stream flow, reservoir and lake levels, ground water). The frequency and severity of hydrological drought is often defined on a watershed or river basin scale. Hydrologists examine how these events impact the entire hydrologic system. Hydrological droughts are usually out of phase with or lag behind the occurrence of meteorological and agricultural droughts. It takes longer for

precipitation deficiencies to appear in components of the hydrological system such as soil moisture, stream flow, and ground water and reservoir levels than in other systems. As a result, the impacts of a hydrological drought are also out of phase with drought measurements in other economic sectors. For example, a precipitation deficiency may result in a rapid depletion of soil moisture that is almost immediately discernible to agriculturalists, but the impact of this deficiency on lake and stream levels may not affect fisheries or recreational uses for many months. (University of Nebraska at Lincoln, National Drought Mitigation Center, https://droughtmonitor.unl.edu/ Accessed December, 2021.)

3. Agricultural drought links various characteristics of meteorological and or hydrological drought to agricultural impacts. This view of drought focuses on precipitation shortages, differences between actual and potential evapotranspiration, soil water deficits, reduced groundwater or reservoir levels, and the relative effects on agricultural production. Since plant water demand depends on prevailing weather conditions, biological characteristics of the specific plant, its stage of growth, and the physical and biological properties of the soil, agricultural drought accounts for the variable susceptibility of crops during different stages of crop development from emergence to maturity. (University of Nebraska at Lincoln, National Drought Mitigation Center, https://droughtmonitor.unl.edu/ Accessed December, 2021.)
4. Socioeconomic definitions of drought associate the supply and demand of economic goods with elements of meteorological, hydrological, and agricultural drought. The supply of many economic goods such as water, forage, food grains, fish, and hydroelectric power depend on weather conditions. The natural variability of climate means that water supply is ample in some years but insufficient for human and environmental needs in other years. Socioeconomic drought occurs when the demand for an economic good exceeds supply as a result of a weather-related shortfall in water supply. (University of Nebraska at Lincoln, National Drought Mitigation Center, “What is Drought? Understanding and defining Drought.”)

Measuring Drought

There are numerous ways to measure the meteorological intensity of drought. Examples of some of the more common indices include percent of normal precipitation, the Palmer Drought Index (PDI), the Standardized Precipitation Index (SPI), and the Surface Water Supply Index (SWSI). For the purposes of this plan, The Palmer Index is used because it is the most effective in determining long-term drought (a matter of several months) and is commonly used by the Federal Government when measuring drought and determining drought-based aid eligibility. The Palmer Index is a measurement only of meteorological drought.

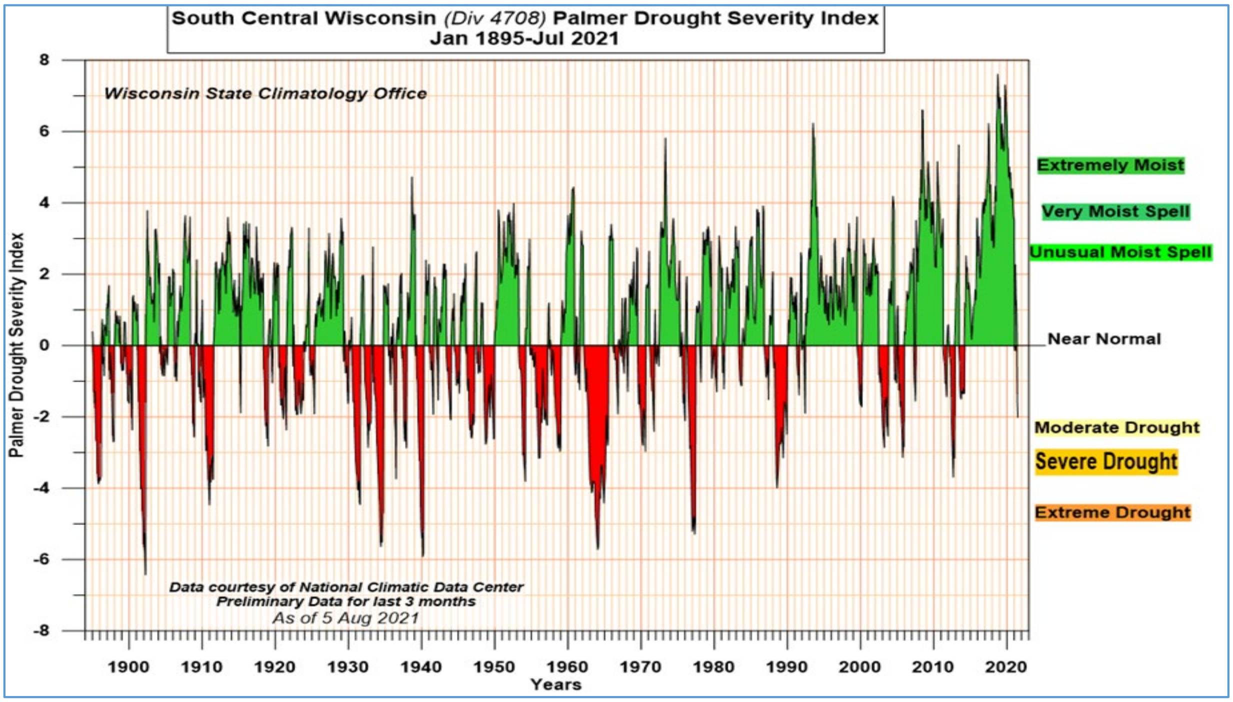
The Palmer Drought Index uses temperature and rainfall information to determine dryness or wetness over a period of time. The index is based on the supply-and-demand concept of the water balance equation, which takes into account not only the precipitation deficit at a specific location, but the water content of the soil as well. The values generated for the Palmer Index generally range from –6.0 to +6.0, with negative values indicating drier conditions and positive values indicating wetter conditions. A value range of -/+0.5 indicates “normal” conditions, while values greater than +4.0 or –4.0 indicate periods of extreme wetness or extreme drought, respectively.

The advantage of the Palmer Index is that it is standardized to local climate, so it can be applied to any part of the country to demonstrate relative drought or rainfall conditions. The limitation is that it is not useful for short-term forecasts, and is not particularly useful in calculating supplies of water locked up in snow. (University of Nebraska at Lincoln, National Drought Mitigation Center, “Handbook of Drought Indices”. Available online https://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1118&context=droughtfacpub Accessed December, 2021.)

4.3.2 Previous Occurrences

Figure 4.3.1 shows the average Palmer Index values from 1895 to 2021. Dane County has experienced Palmer Index values that would indicate extreme drought five times: 1930, 1933, 1938, 1962, and 1976. This graph takes into consideration all months of the year. Generally, Wisconsin experiences low quantities of precipitation accumulation in the winter months. This alone is not a problem, because demand for water is lowest during this time. However, drought in the summer months can cause financial loss or ruin for the agricultural and recreational sectors as the demand for water increases and the shortfalls become apparent.

Figure 4.3.1 Average Palmer Index for South Central Wisconsin



Source: National Climactic Data Center, 2021

1929-1934

The 1929-1934 drought was probably the most significant in Wisconsin history considering both the event's duration and severity. This drought had at least a 75-year recurrence interval in most of the State and over 100-year recurrence interval in certain areas. The austere economic aspects of the Depression compounded its effects. The drought continued with somewhat decreased effect until the early 1940s in some parts of the state.

1963-1964

The 1963-64 drought appears to have begun in 1962 when Dane County received only 21.63 inches of rain at Truax Field. 1963 had 26.19 inches and 1964 had 23.62 inches of rain. Normal yearly precipitation for 1869-2008 is 31.67 inches.

1976-1977

The drought of 1976-1977 was most severe in a wide band stretching from north to south across the state. Stream flow measuring stations recorded recurrence intervals from 10 to 30 years. Agricultural losses during this drought were estimated at $624 million. Sixty-four counties were declared federal drought areas and deemed eligible for assistance under the

Disaster Relief Act. Additionally, numerous private and municipal wells went dry. Federal assistance was used to help communities drill new wells and obtain new water supplies.

1987-1988

Some believe the drought of 1987-1988 was 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. Stream flow measuring stations indicated a recurrence interval of between 75 and 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 percent crop loss, with agricultural losses estimated at $1.3 billion. Fifty-two percent of the state's 81,000 farms were estimated to have crop losses of 50 percent or more, with 14 percent estimated having losses of 70 percent or more. A combination of state and federal drought assistance programs helped the state's farmers recover a portion of their losses. All Wisconsin counties were designated eligible for drought assistance.

The effect of this drought on municipal and private water supplies was not as severe as in 1976-77, with only a few reports of individual wells drying up. A number of 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 sprinkling and yard watering.

2002-2003

This drought extended during the summers of 2002 and 2003 over south central and southeast Wisconsin. Many farmers saw their corn crops wither and there were reports that soybeans stopped growing or the pods stopped filling. Alfalfa hay cutting also suffered. Grass growth slowed dramatically, or stopped altogether. Most locations received less than 1 inch of rain for the first 11 days of August. Madison's Truax Field only measured .61 inches of rain, all of which fell on a single day. Newspaper reports indicated that agricultural experts expected the corn crop yield at harvest time in the fall to be 1/2 to 2/3 of normal, and the outlook for soybeans was worse. Sweet corn yields were expected to be 20 to 30 percent below normal. Some farmers reported that their wheat crop died. Large cracks developed in many fields and the grasshopper populations were above normal. In addition, flowage on most rivers and streams was only 15 to 25 percent of normal for early August.

Only 0.87 inch of rain fell during August 2003 at Truax Field. Both the Milwaukee and Madison August monthly rainfall totals were 3.46 inches below normal. Conditions continued through the month of October 2003 across south-central and southeast Wisconsin. The entire area was in a moderate (D1) to severe drought (D2) status during the month of October. The monthly rainfall at Madison's Truax Field was 1.60 inches, or 0.58 below normal. Only 5 days received

0.10 inches or more of precipitation. Water levels in lakes, rivers, and streams remained below normal for the entire month, and at some spots they were near record-low levels. Newspaper reports indicated that some farmers didn't harvest much of anything in October.

2005

Drought conditions developed over south-central and southeast Wisconsin in July 2005, after the weather pattern turned quiet in mid and late June 2005. The drought classification for south-central and southeast Wisconsin worsened from D0 at the start of the month to severe drought (D2) on July 19, with the exception of the southeast corner consisting of Walworth, Racine, and Kenosha counties. The drought in these three counties worsened to extreme (D3) on July 19th. The drought was preceded by a long period of below-normal precipitation extending back to March 2005. Madison's Truax Field (Dane Co.) reported a 4.08 inch deficit from the beginning of March through the end of July.

A warm and dry August helped strengthen the drought. Rainfall deficits for August ranged from between 2.50 to 3.50 inches across the area. At Madison's Truax Field (Dane Co.), a 3.11 inch deficit was reported in August, setting the March through August deficit at 7.19 inches. Most of the precipitation observed occurred during the middle of the month, helping to relieve the drought status for the southeast corner of the state toward the end of August. The remainder of south-central and southeast Wisconsin remained in severe drought status (D2).

Drought conditions, both agricultural and hydrological, persisted through October over south-central and southeast Wisconsin. Most of south-central and southeast Wisconsin received less than 1 inch of rainfall (normal monthly rainfall is 2 to 2.5 inches) with monthly temperatures averaging about 2 to 3 degrees above normal. Consequently, the drought conditions didn't improve during the month. The drought rating at the end of the month was D2 (severe) in those counties along and south of a line from Madison to Milwaukee. D3 (extreme drought) conditions existed just south of the Wisconsin-Illinois border. D1 (severe drought) conditions existed over those counties north of a line from Madison to Milwaukee. Newspaper and weather reports indicated that due to the spotty nature of the just-completed warm-season convective showers, soil moisture conditions varied greatly across individual counties, resulting in varying yields. Harvest reports indicated that overall corn and soybean yields didn't suffer as much as originally expected in July. Undoubtedly there were monetary crop losses due to the drought; however estimations were unavailable from county/state agricultural agencies. Drought conditions continued across south-central and southeast Wisconsin through November, but did show improvement by the end of the month due to above normal precipitation.

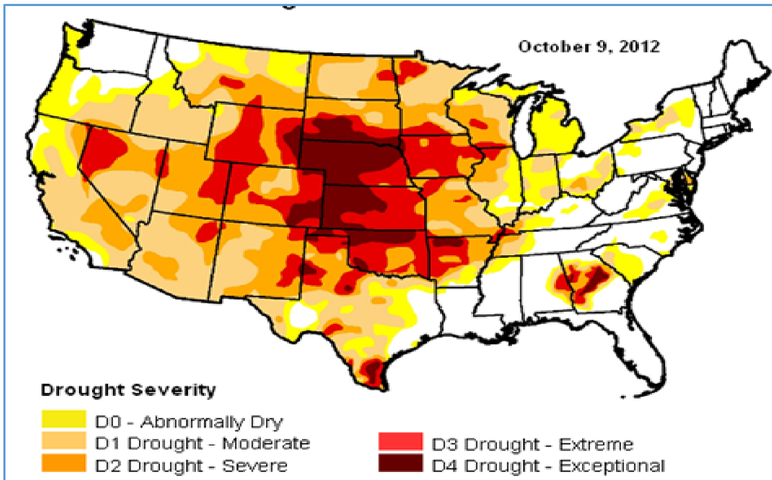
2007

Between January and July 2007, drought gradually returned to most of Wisconsin, spreading from north to south. The jet stream pattern kept low pressure systems and associated thunderstorms northwest of Wisconsin while summer temperatures averaged one to three degrees above normal. Eventually moderate (D1 rating) to extreme drought (D3 rating) covered 85% of the state. Only the southern tier of counties had normal conditions to abnormally dry conditions (D0 rating). Crop yields were reduced. Moderate to heavy rains across central and southern Wisconsin in August broke the back of the drought in those areas, but the drought only gradually left the northern part of the state by December 2007.

2012

In the summer of 2012 much of Wisconsin experienced an extreme drought, especially in the Southern portion of the State. The drought was severe enough that it drew comparisons to the drought of 1988. Higher than average temperatures and lower than average precipitation lead to extremely dry conditions for much of the State by late July. In August, the Southwest and Southcentral Wisconsin was considered to be in severe drought with Palmer values between -3.0 and -3.99, this range extended in October. Severe drought continued through November, before lessening later in the winter of 2013. Effects on 2012 crop yields were varied, corn yields were down 11 percent from 10 year averages (compared with 17 percent from the 1988 drought) while vegetable yields from spring planting was hit much harder with non-irrigated areas producing 50-80 percent less than anticipated yields. Later planted vegetables fared much better. While yields were down, most cropland was enrolled in federal crop insurance, lessening the financial blow to farmers. (Data from Wisconsin State Climatologist's Office)

Figure 4.3.2 2012 Drought Severity



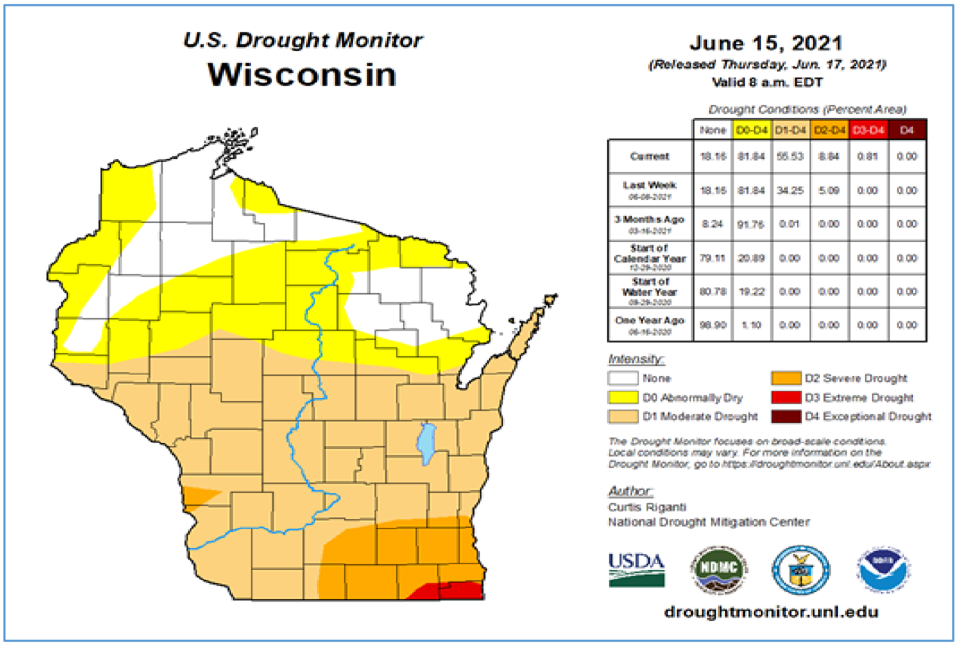
Week	Nothing	D0-D4	D1-D4	D2-D4	D3-D4	D4
October 2, 2012	24.10	75.90	64.58	40.07	20.12	6.07
October 9, 2012	23.28	76.72	63.55	39.91	20.15	6.18

Source: National Drought Mitigation Center

2021

In the late summer of 2021, specific areas of the southern region of Wisconsin have been identified as being in either a D1-D4 drought, with more than 0.81% of land being covered for 5 weeks consecutively. Dane county is primarily situated in a D2-3 drought zone. Throughout the fall of 2021 and into the winter of 2022, Wisconsin continued to experience a 2 to 7 inch precipitation deficit, which resulted in a consistent D0 to D1 drought for a period of over 6 months.

Figure 4.3.3 2021 Wisconsin Drought Severity



Source: U.S Drought Monitor, 2021

4.3.3 Impact of Climate Change on Future Conditions

The threat of drought is likely to increase in the coming years due to climate change. While Wisconsin is projected to experience more precipitation on average annually, the precipitation is likely to come in larger storm events, rather than being spread over time. Additionally, Wisconsin will continue to experience warmer temperatures. The increased temperatures are likely to exacerbate droughts that already occur periodically through increased evapotranspiration; leading to increased water loss from both surface and groundwater resources. Droughts are typically thought of as weather, however, long term patterns suggest that given the increased temperature and modest gains in precipitation, Wisconsin should expect more dry days in summers to come. As a result, the risk of drought is increasing due to these changes in the regional climate. Trends in rain fall patterns are discussed in greater detail in the flood hazard profile.

4.3.4 Impact Assessment

Direct Impacts

Dane County is most vulnerable to agricultural drought. In addition to the obvious losses associated with crop and livestock yields, drought is also associated with increases in insect infestations, plant disease and wind erosion. Droughts also bring increasing problems with insects and disease to forests and can reduce growth. The incidence of forest and grassland fires increases substantially during extended droughts.

Dane County is also vulnerable to hydrological drought. Hydrological impacts of a prolonged drought include lower water levels in the lakes and ponds of the County, reduced stream flow, degradation or loss of wetlands, decreased water quality, and lowering of the water table. In addition, the loss of vegetation and drying and hardening of the ground can result in flooding, even from average rainfall, as rainwater is unable to soak into the soil.

Indirect Impacts

The indirect impacts of drought are far reaching. The cascading effects of drought provide a more accurate picture of the drought's effect on the region and the nation. Unlike many other natural hazards, drought may extend indefinitely, but as with all disasters, the more prolonged the event, the greater the damage and indirect impacts. Less obvious impacts of agricultural drought include increased incidents of insect infestation, plant disease and wind erosion. These problems also impact forests and other wild areas, which can reduce levels of growth or result in large areas of dangerously dry vegetation, which in turn increases the risks for wildfires. The incidence of forest and grassland fires increases substantially during extended droughts. In addition, the loss of vegetation and drying and hardening of the ground can result in flooding, even from average rainfall, as rainwater is unable to soak into the soil.

The National Drought Mitigation Center (NDMC) at the University of Nebraska-Lincoln suggests examining indirect impacts of drought using three broad categories: economic, environmental, and social impacts. In Dane County, most economic impacts occur in agriculture and recreational sectors because these sectors rely on water supply and quality. The resulting income loss from these sectors creates ripples which impact a wide range of other aspects in the local economy. Retailers that supply these industries also face reduced business which in turn impacts suppliers and production levels. This loss of product turnover may lead to unemployment, increased credit risk, loss of tax revenue, and other economic considerations.

Depending on the severity, geographic extent and duration of a drought, every sector of a local economy could experience indirect social and economic impacts. Specific examples include:

- Agricultural Production
  - Reduced yields and crop loss due to water stress, insect infestation, and plant disease
  - Increased irrigation cost for crops
  - Reduced productivity of pastureland
  - Increased feed costs
  - Reduced milk production
  - High livestock mortality rates
  - Disruption of livestock reproduction cycles
  - Wind and water erosion of exposed topsoil
  - Cost of new or supplemental water supply
  - Income loss
- Recreation and Tourism
  - Damage to fish habitat and/or reduction of fish populations, especially trout and other cold-water stream fish
  - Income loss to manufacturers, suppliers, and retailers of recreational equipment, particularly fishing and boating equipment
- Water Utilities
  - Increased costs for development of new water sources e.g., cost to drill new, deeper wells
- Residential
  - Direct loss of trees, especially younger trees
  - Increased susceptibility of trees to wind damage
  - Increased risk of wildfire in rural areas
- General
  - Economic losses to businesses directly dependent on agricultural production e.g., farm cooperatives, food processors, and dairies
  - Unemployment from drought-related declines in production
  - Revenue losses to state, and local governments
  - Increased demand on disaster assistance programs
  - Increase in food prices

4.3.5 Vulnerability Assessment

The drought vulnerability of the people, buildings, and economy of Dane County is very difficult to quantify. Typically, structures and people are not directly vulnerable to drought, though secondary or indirect impacts may eventually increase vulnerability ratings. As discussed in the impacts section, the potential impacts for drought are systemic. However, some areas are more vulnerable overall than others and, therefore, benefit from adequate mitigation planning and implementation. For Dane County, the agricultural economy is the most vulnerable to drought and will benefit the most from mitigation efforts. Overall, property and people are not highly vulnerable to drought. Economic resources tied to agricultural production are extremely vulnerable to drought, with secondary vulnerabilities attributed to economic income based on recreational use of natural resources.

4.3.6 Potential for Future Loss

The level of analysis needed to calculate the potential for future drought losses is far beyond the scope of this plan. Future losses would be very difficult, if not impossible to estimate without a detailed study of the direct and indirect impacts of a drought. Given the occurrences of past droughts, it is reasonable to assume that there is real risk of a significant drought at some point in the future. A considerable portion of Dane County's economy is reliant on agriculture and is therefore, vulnerable to drought losses. There is, however, no readily available model or data that can be used to quantify that vulnerability. This is an area for additional study and is addressed in the recommendations of this plan.

4.4 EXTREME COLD / WIND CHILL

4.4.1 Description

Cold temperatures in winter are a basic fact of life in southern Wisconsin. Typically, extreme cold temperatures (cold waves) in Wisconsin are accompanied by an active wind that results in an additional wind chill factor. This combination is especially hazardous when temperatures are at least 20 degrees below normal (National Weather Service communication) during the winter season.

Extremely cold temperatures present a variety of problems and impact the population of Dane county both directly and indirectly. Extreme cold is a dangerous situation that can bring on health emergencies in susceptible people, such as those without shelter or who are stranded, or who live in a home that is poorly insulated or without heat. Additionally, extreme cold/wind chill affects agriculture, industry, commerce, and social activities. Extremely cold temperatures may precede, accompany, or follow a winter storm or it may occur during otherwise typical weather conditions.

What constitutes extremely cold temperatures varies across different areas of the United States, based on normal climate temperatures for the time of year. In Wisconsin, cold temperatures are normal during the winter. When temperatures drop at least 20 degrees below normal winter lows, the cold is considered extreme and begins to impact the daily operations of the county. Extreme cold/wind chill impacts inanimate objects, plants, animals and water supplies.

Wind Chill

The effects of extremely cold temperatures are amplified by strong to high winds that can accompany winter storms. Wind-chill measures how wind and cold feel on exposed skin and is not a direct measurement of temperature. As wind increases, heat is carried away from the body faster, driving down the body temperature, which in turn causes the constriction of blood vessels, and increases the likelihood of severe injury or death to exposed persons. Animals are also affected by wind-chill however cars, buildings, and other objects are not. In 2001, the National Weather Service updated the wind-chill temperature index to take advantages of advances in science and computer modeling technology. Wind-chill effects are shown in Figure 4.4.1, highlighting the dangers of wind-chill to exposed individuals.

For Southern Wisconsin, including Dane County, the National Weather Service issues Wind Chill Advisories when wind chill values are expected to range from -20 to -34. A Wind Chill Warning is issued when wind chill values are expected to be -35 or lower.

Figure 4.4.1 Wind-Chill Factors

Temperature (°F)

Wind (mph) / 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

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

Where, T= Air Temperature (°F) V= Wind Speed (mph)

Effective 11/01/01

Source: National Weather Service

4.4.2 Previous Occurrences

The National Weather Service and the NOAA National Centers for Environmental Information (NCEI) tracks weather extremes and the related consequences in greater detail. A search of the NCEI website provided the following descriptions of several extreme cold/wind chill and wind-chill events since 1994. These accounts are edited and annotated to reflect only Dane County information.

January 13, 1994

An extended period of extremely cold weather gripped the state. Brisk winds at times combined with record setting sub-zero temperatures down to 50 below zero at night to create wind-chill readings to 80 below zero. During the cold spell numerous schools closed for days at a time, businesses reduced hours, sporting events, winter fest activities, and local government meetings were cancelled. Also many water mains broke and vehicles refused to start. Some people received frostbite and suffered from hypothermia. Heat and power failed in many homes, businesses, and schools. Natural gas and heating oil was consumed at record levels.

December 9, 1995

Bitter-cold arctic air swept into Wisconsin on northwest winds of 20 to 40 mph. Temperatures dropped as much as 15°F in 15 minutes as the strong front moved through. Wind-chill values ranged from -25°F to -50°F. Hypothermia was a secondary cause (indirectly-related) for one death in Dane County. Many schools canceled evening activities, and retailers across the state reported very little shopping activity in spite of the upcoming Holidays. The AAA Club (3,000 calls) and service stations were overwhelmed with requests for assistance with stalled vehicles. There was also a scattering of frozen water pipes that resulted in flooded rooms or basements. At least six frozen water pipe incidents were noted in Dane County.

January 30 – February 4, 1996

After the previous days' ground blizzard, very cold arctic air poured into Southern Wisconsin on northwest winds of 10 to 25 mph. Wind-chills ranged from -35°F to -45°F. Overnight lows across Southern Wisconsin ranged from -5°F to -15°F. Arctic air continued to pour into Southern Wisconsin on northwest winds of 10 to 20 mph overnight. Morning lows dipped to -21°F in Madison. Wind-chills dropped into the -40°F to -60°F range as daytime temperatures never recovered to zero. Service stations were overwhelmed with calls for assistance, and hardware stores reported a booming business due to the demand for space heaters, snow blowers, and other cold-weather gear.

The episode continued through the first four days of February across south-central and southeast Wisconsin. Ending on the 4th, Madison registered 177 hours below the zero mark. Adding to the misery, wind-chills were in the minus 35°F to minus 60°F range many times during this event. Numerous water main pipes burst, and fiber optic cables froze disrupting telephone service. Schools were closed on the 2nd. Service stations and the AAA were overwhelmed with requests for assistance. A new minimum temperature record of -29°F in Madison (now the February record) was set the 3rd.

January 17, 1997

The coldest arctic air of the winter season enveloped southeast and south-central Wisconsin, resulting in many school closings and cancellation of evening activities. Maximum temperatures only reached zero in Madison, roughly 20 degrees below normal. Morning lows ranged from -7°F to -14°F. Coupled with northwest winds of 10 to 20 mph, wind-chills dropped to -30°F to -50°F.

January 5, 1999

The combination of an arctic high pressure ridge, a fresh, deep snow cover, clear skies, and light winds allowed temperatures to plunge to well below zero across south-central and southeast Wisconsin. Observed minimums include Stoughton -21°F, and -21°F in Madison. Thousands of calls to local AAA and car service centers were logged due to stalled vehicles. Maximum temperatures were only around zero.

December 18, 2005
The second cold snap of December 2005 was a contributing or secondary factor (indirect) in the death of a homeless man in Milwaukee. Media news reports indicated that some water pipes (outside faucet) froze on some homes across south-central and southeast Wisconsin. The average temperature across southern Wisconsin for the first 19 days of December 2005 was the coldest since the 1985. Across southern Wisconsin on December 18-19, 2005, maximum air temperatures were only in the teens and lows were around zero to 5 below zero, resulting in daily means around 15 to 17 below normal. In addition, cold temperatures occurred during the period of December 6-8, 2005, when daily means were around 20°F below normal (maximum temperatures in the teens and lows of zero to 10 below zero).

February 3, 2007
The coldest air and lowest wind-chills of the 2006-07 winter season affected south-central and southeast Wisconsin as a massive arctic high pressure pushed southeast through the Western Great Lakes Region over the 4-day period of February 3-6, 2007. Minimum air temperatures tumbled to -5F to -14F on February 3rd with Madison's Truax Field registering -11°F on the 3rd. Daytime maximum air temperatures on the 3rd ranged from 3°F to 10°F . Early morning low temperatures on the 4th ranged from -10°F to -15°F. Afternoon maximum temperatures on the 4th never reached the zero mark, totaling -3°F at Madison. The lowest minimum temperatures of the 4-day period occurred on February 5th. Maximum afternoon temperatures on the 5th ranged from -4°F to 6°F.

On February 3rd and 4th west to northwest winds generally clocked at 15 to 30 mph, which generated wind-chill values of -20°F to -30°F . Lower wind speeds of 5 to 20 mph were noted on February 5th and 6th. In general, the lowest wind-chill values were observed during the early morning hours on February 5th, in the -30°F to -34°F range, corresponding to the lowest air temperatures of the winter season. The cold temperatures resulted in a broken water main and electrical outage in the 100 block of West Main St. near the Madison Capitol Square early Saturday morning, February 3rd. Many public and private schools were closed on Monday and Tuesday, February 5th and 6th. It was the first time in 13 years that the Madison schools closed due to cold temperatures. Additionally, newspaper reports indicated that plumbers answered numerous frozen-pipe calls.

March 27, 2007

On March 27th, a large sink hole developed on State Street in Madison due to a large water main break. This was the 117th water main break in the city of Madison for March, 2007. Usually there is only about 6 to 12 in some of the rougher winter months. Very cold temperatures and little snow cover in the first part of March, 2007, allowed the ground to freeze deeper. Subsequent freeze-thaw periods forced the ground under streets to shift/move, resulting in the numerous water main breaks. Damage was estimated at $300,000.

January 15, 16, 2009

Arctic air blanketed southern Wisconsin and kept temperatures bitterly cold for a 48 hour period. Wind chills reached -35° to -45°F and actual temperatures briefly touched -30 °F. All 16 school districts in Dane County cancelled classes, as well as the University of Wisconsin. Compounding the problem were very slick stretches of road and intersections. Snowfall of almost two inches covered the icy patches making already slippery roads even more dangerous. Road crews worked around the clock to apply sand and salt, but the bitterly cold temperatures rendered the salt virtually useless. Dozens of cars and trucks were involved in slide offs, rollovers, and fender benders on area streets and highways.

January 6, 7, 2014

An extreme cold wave of arctic air and brisk winds brought 40°F below wind chills to southern Wisconsin. Numerous school and business closings occurred. This cold wave and the continued cold through January, resulted in numerous water main breaks, especially in Madison and Milwaukee. A number of local water utilities advised residents leave water run continuously in order to prevent substantial damages associated with the repair of ruptured and frozen pipes. The cost associated with this protective measure was borne by the local water utilities and was a significant, unbudgeted cost. Local government costs to repair broken mains and pipes was estimated at just over $1.0 million in Dane County alone. The term “Polar Vortex” became a household phrase during the winter of 2014 as this nationwide cold snap affected a large portion of the country.

Madison Water Utility: January 8, 2014

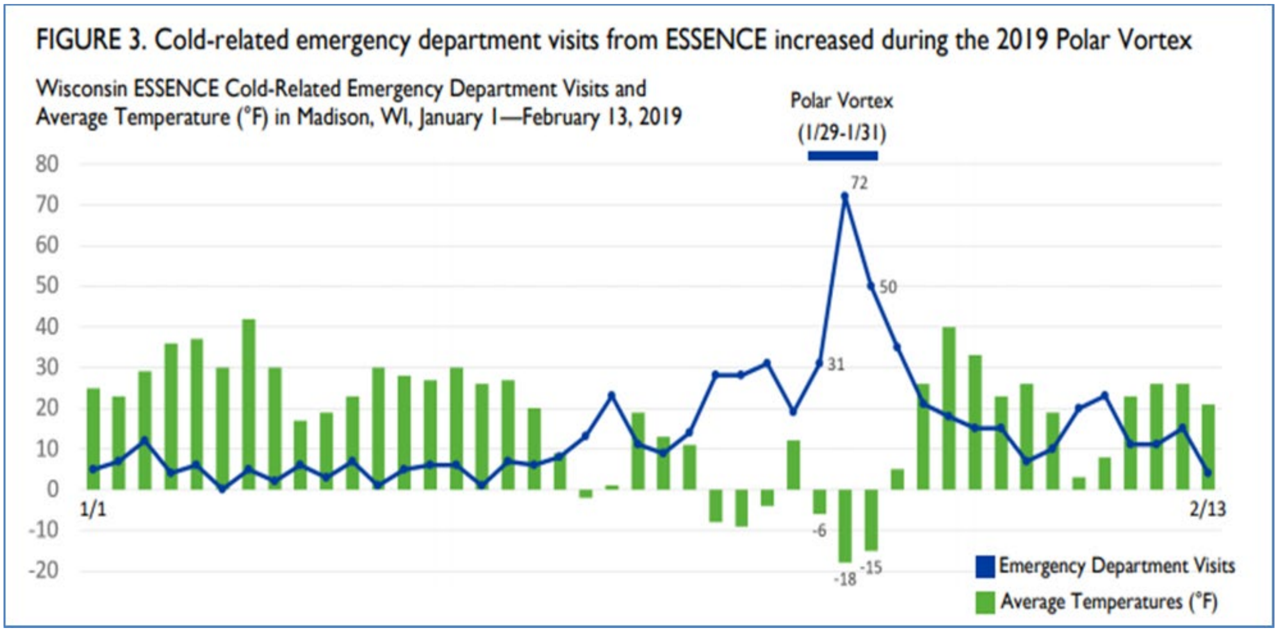
January – February 2015

In the winter of 2015, the National Weather Service issued a wind chill advisory on Tuesday January 6th, due to excessive cold. January to February of 2015 consisted of record breaking temperatures for Dane county, which consisted of an overall minimum of -12 degrees Fahrenheit. Daytime temperatures ranged between the single digits, and wind chill temperatures ranged between -15 and -40 degrees Fahrenheit. DCEM and Public Health of Madison/Dane County provided a joint release statement concerning measures to be taken in order to prevent further harm and loss of life.

January – February 2019

In the mid-winter of 2019, a polar vortex formed over the Midwestern region of the United States. The state of Wisconsin had record low temperatures in Dane and Milwaukee County, with wind chills as low as -55°F in Waukesha. This excessive cold event exhausted energy usage in the county, which resulted in extensive power outages. Over 11 deaths were recorded in relation to this excessive cold event, and health officials from the Department of Human Services believe this number may be an underestimate.

Figure 4.4.2 2019 Polar Vortex

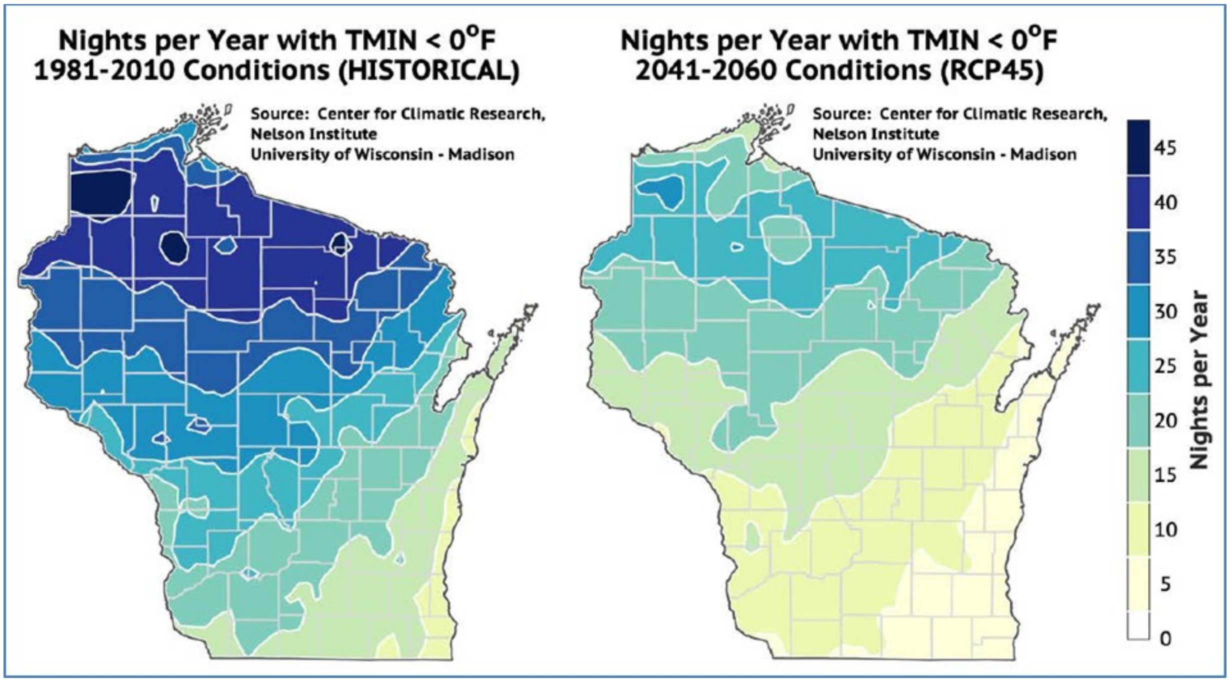


Source: Department of Human Services

4.4.3 Impact of Climate Change on Future Conditions

All indications are that the frequency and intensity of extreme cold events in southern Wisconsin are decreasing. Analysis performed by the Wisconsin Initiative on Climate Change Impacts (WICCI) indicates that Wisconsin already experiences fewer nights below 0°F than in 1950. In addition, the average winter temperature in Dane County has increased between 2°F and 3°F in the period between 1950 and 2006. Looking forward, WICCI models predict this warming trend to continue. In it's 2011 report, Wisconsin's Changing Climate: Impacts and Adaption, WICCI projects that southern Wisconsin, Dane County included will experience an average winter time temperature increase of 7.5°F to 8°F by 2055. The region can also expect a decrease of 12 to 14 days with below zero low temperatures over this same time period. This is not to say that Dane County will not experience very cold temperatures in the future. These trends do indicate, however, that the likelihood of extreme cold events is generally decreasing.

Figure 4.4.3 Projected Wintertime Temperature Changes in Wisconsin



Source: Wisconsin Initiative on Climate Change Impacts, 2020

4.4.4 Impact Assessment

Direct Impacts

Extreme cold is generally a regional phenomenon and Dane County is uniformly impacted when it occurs. The major threat of extreme winter cold temperatures is frostbite and exposure. Frostbite, if untreated, can lead to loss of a limb or limbs. Exposure can lead to death due to cardiac issues associated with the constricted blood vessels due to the body's reaction to the extreme cold. In cases of periods of prolonged cold, municipal water mains may break and water pipes may freeze and burst in buildings that are poorly insulated or without heat. There may also be numerous occurrences of vehicles that either will not start or stall once started due to the cold.

Indirect Impacts

The indirect social and economic impacts of extreme cold are minimal. There are stresses placed on human services programs that care for at-risk individuals and families, however those stresses are usually within the capacity to respond. Lack of availability of transportation due to non-starting or stalled vehicles may result in minor economic loss, as people are not able to get to work. No data exists to quantify these impacts.

4.4.5 Vulnerability Assessment

Population

While everyone is vulnerable to extreme cold/wind chill events, some populations are more vulnerable than others. Extreme cold/wind chill pose the greatest danger to outdoor laborers, such as highway crews, police and fire personnel, and construction. The elderly, children, people in poor physical health, and the homeless are also vulnerable to exposure. Overall, the population has a medium exposure to severe cold.

Property

Extreme cold/wind chill presents a minimal risk to the structures of Dane County. Property damage occurs occasionally when water pipes freeze and break. Homes without adequate insulation or heating may put owners at a higher risk for damages or cold-related injury. In cases of periods of prolonged cold, water pipes may freeze and burst in poorly insulated or unheated buildings. Extreme cold also takes a toll on municipal water systems, causing broken mains, and frozen or broken water meters and service laterals.

Broken Water Meter, Madison Water Utility: January 8, 2014

4.4.6 Potential for Future Losses

As can be seen from the past history data, extreme cold is an annual occurrence in Dane County. Property losses due to extreme cold/wind chill are typically minor and isolated. Direct impacts such as water breaks, which may cause water and flooding damage to structures and their contents, are the most likely source of potential property losses. The costs and losses from past extreme cold events, however, are not systematically collected and compiled. There is no available data on which to base a projection of the future loss potential.

Public education remains the primary means of mitigating the risks of extreme cold/wind chill, both to the population and for property protection.

4.5 EXTREME HEAT

4.5.1 Description

Excessive heat during the summer season is characterized by a combination of very high temperatures and exceptionally humid conditions. Humid or muggy conditions, which add to the discomfort of high temperature, occur when a dome of high atmospheric pressure settles over the southern part of the country and pulls hot, muggy air north into Wisconsin.

The National Weather Service defines Excessive Heat for southern Wisconsin when these conditions are observed: daytime heat index values of 105°F or higher with minimum night heat index values of 75°F or higher, for at least a 48-hour period. When these conditions are reached, the National Weather Service issues Excessive Heat Warnings. The National Weather Service issues Heat Advisories when daytime heat index values are expected to reach 100°F to 104°F. Should 4 consecutive days of heat index values of 100°F to 104°F be expected, an Excessive Heat Warning may be issued.

Heat Index

The National Weather Service uses the "Heat Index" as an estimate of how the weather "feels." The heat index is a function of relative humidity and actual air temperature. Figure 4.5.1 shows heat index values for a range of temperatures and humidity.

Figure 4.5.1 Heat Index Table

NWS Heat Index — Temperature (°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										

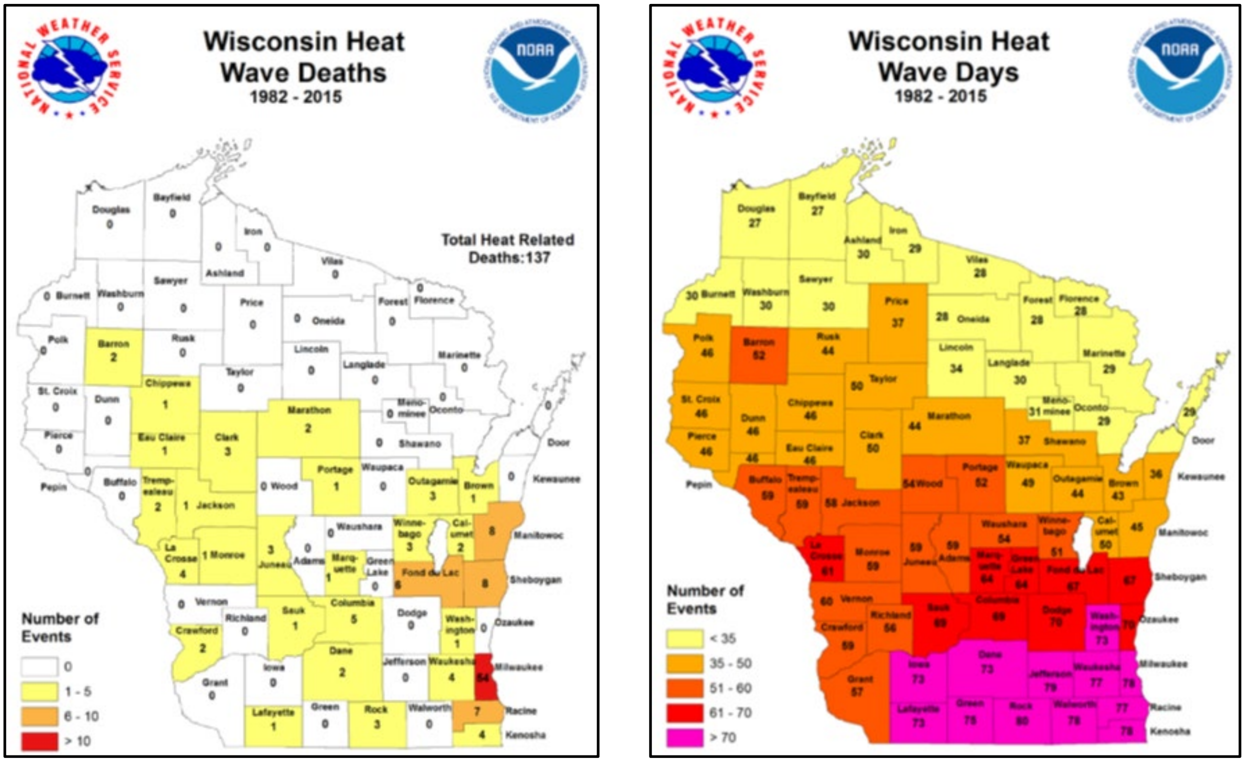
Likelihood of Heat Disorders with Prolonged Exposure or Strenuous Activity

Caution | Extreme Caution | Danger | Extreme Danger

Source: National Weather Service (http://www.nws.noaa.gov/om/heat/heat_index.shtml)

4.5.2 Previous Occurrences

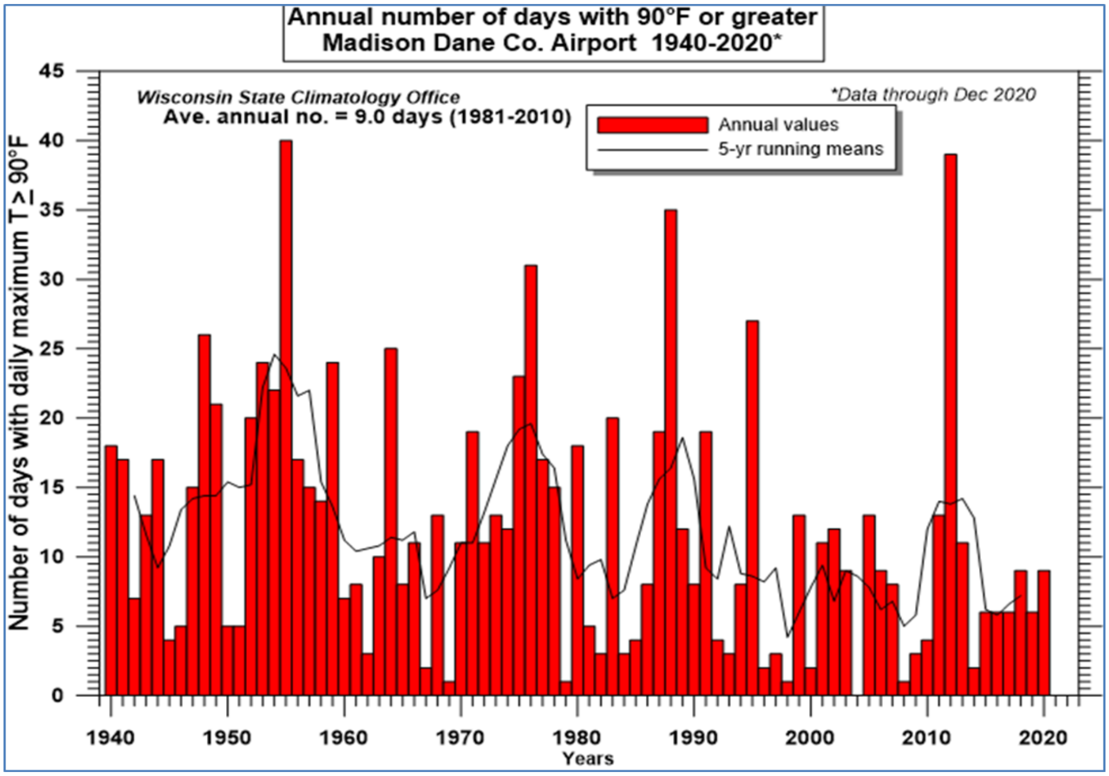
Figure 4.5.2 Wisconsin Heat Wave Days and Heat-Related Deaths, 1982 to 2015



Source: National Weather Service, 1982-2015

Figures 4.5.2 illustrates the number of heat wave days and heat wave related deaths across Wisconsin. A heat wave day is calendar day in which heat advisory or excessive heat warning was issued. Note that Dane County ranks near the top for both categories. According to the Wisconsin State Climatology Office, Madison experiences 14 days above 90 degrees Fahrenheit per year. Figure 4.5.3 summarizes the temperature extreme data from the SCO from 1971 through 2013, showing for each month, the number of days with high temperatures above 90° Fahrenheit.

Figure 4.5.3: Number of Days above 90°F



Source: Wisconsin State Climatology Office Website, 2020

In more recent years, the National Weather Service and the NOAA National Centers for Environmental Information have been tracking weather extremes and their consequences in greater detail. A search of the NCEI website provided the following descriptions of several excessive heat events.

June and July 1995

Dane County experienced two periods of prolonged heat in the summer of 1995. From June 17-27, high temperatures were consistently into the 90°s F with heat index values ranging from 88°F to 104°F. During this period, statewide, 9 people died as a direct result of the heat. The second heat wave, July 12-15, resulted in the greatest number of weather related deaths in Wisconsin history. During this heat wave, 141 people died directly or indirectly from the heat, but no deaths were reported in Dane County. High temperatures were well into the 100°s, with heat index values of 120° to 130°F.

July 1999

A heat wave over the last two weeks of July, peaking on July 28-31, 1999 pushed local utility companies to the limit. There were no outages in the Dane County area, but there were records set for peak electrical demand. During these four days, high humidity and high temperatures well into the 90°s produced heat index values to over 110°F. Statewide, the heat was directly responsible for killing 8 people and indirectly responsible for another 6. Dane County had 1 heat-related death.

July 2001

Southern Wisconsin was affected by a heat wave at the end of July 2001. Afternoon heat index values on the 31st reached 110°F for several hours and stayed in the 85°F to 100°F range through the evening hours. Local utilities again reported new daily record peak demands for electricity. Statewide 15 died because of heat.

October 2003

A 6-month old female died in the city of Middleton. Heat was listed as a contributing cause, thus this death is indirectly related to excessive heat. Maximum temperatures in the Middleton area on October 7th and 8th were around 79°F, about 15 degrees above normal.

July and August 2006

A period of very hot and humid weather began on the evening of July 30th and continued into August 2nd. Overnight temperatures only fell to 70° to 75°F on the 30th, and soared into the 95° to 100°F range during the afternoon of July 31st. With dew points in the low to mid-70s, heat index values only dropped to about 75 overnight on July 30th, and peaked in the 105° to 110°F range across south-central and southeast Wisconsin during the afternoon of July 31st. An estimated 40 people in Milwaukee County were hospitalized due to heat-related symptoms. Ultimately, this stretch of "heat advisory" conditions resulted in two directly-related heat deaths in Milwaukee County where the urban heat-island effect is enhanced. Air temperatures only fell into the mid-70s across south-central Wisconsin during the early-morning of August 1st. Afternoon air temperatures soared into the 95° to 100°F range. With dew points in the low to mid-70s, heat index values only dropped into the lower 80s during the morning of the 1st, and peaked in the 105° to 110°F range across south-central and southeast Wisconsin during the afternoon of August 1st. The oppressive conditions continued during the overnight hours of August 1st with low temperatures around 80 degrees before a cold front swept through during the afternoon, ending the heat wave.

July 2011

A dome of hot and humid air over the southern and central Plains moved into Wisconsin from July 17th through July 21st. Temperatures climbed into the lower to mid-90s, which combined with muggy dew points in the middle 70s to lower 80s produce heat index values between 100°F and 110°F for four straight days. Three people were confirmed to have died due to the excessive heat: one each in the counties of Columbia, Marquette, and Sauk. It is estimated that about 25 people in Dane County received medical treatment for the heat.

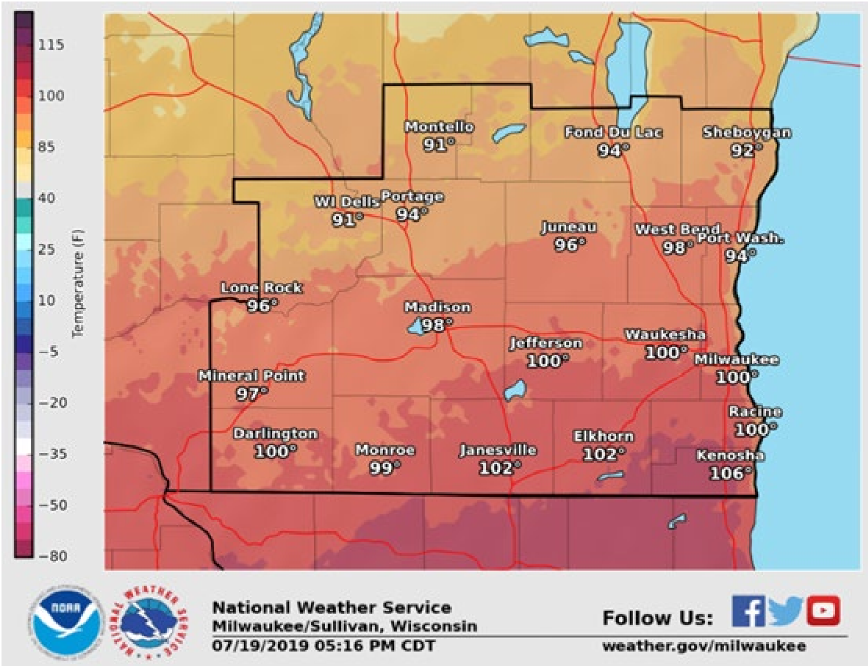
July 2012

A hot air mass settled over southern Wisconsin at the start of July. 100-degree heat occurred in many locations for multiple days between July 2nd and July 6th. While humidity levels were relatively low, maximum heat indices climbed as high as 115. Milwaukee and Madison each recorded two of the top-ten hottest days on record on July 4th and July 5th. Indirect heat-related deaths included: a middle-aged man in Dane County, a middle-aged women in the city of Milwaukee and a middle-aged man in the city of Milwaukee. Hundreds of people received medical treatment due to illness related to the heat. The counties surrounding Dane had 4 days of 100 degrees or higher. Numerous new daily record highs were set as well as record high minimums. Although only one death was attributed in Dane county, it is believed several hundred injuries across multiple counties are linked to this singular heat event. The long duration of this excessive heat period makes this one of the four most dangerous heat waves to strike southern Wisconsin in recorded history.

July 2016
In the mid-summer of 2016 from July 21st to July 24th, an excessive heat advisory was issued by the National Weather Service, due to dangerous highs for the three to four day period. The minimum Dew Point temperatures, which is used to determine how hot it actually “feels” outside, ranged from 60-70 degrees Fahrenheit and 70-80 at its highest. This range is considered incredibly humid and uncomfortable for the average Dew Point temperatures. The southern region of Wisconsin experienced heat index values in the lower to mid-100s, with certain locations seeing heat indices breaking 110 Fahrenheit in the far reaches of southeastern Wisconsin on Sunday.

July 2019
In the mid-summer of 2019, the National Weather Service detected a bubble of warm air traveling via the U.S. Southwest winds into southern Wisconsin. The daily high temperatures were elevated to 90+ degrees Fahrenheit, which triggered an excessive heat warning for a two day period starting July 19th, 2019. Approximately 14 counties fell into this advisory range, and Dane County was situated in the 98 degree Fahrenheit range for the maximum daily temperatures of the region.

Figure 4.5.4 Max. High Temperatures for Southern WI, 2019



Source: National Weather Service, Milwaukee-Sullivan

Excessive heat events from 2019 to 2021 do not appear in the National Centers for Environmental Information database (NCEI) due to differences in threshold standards for excessive heat classification.

4.5.3 Impact of Climate Change on Future Conditions

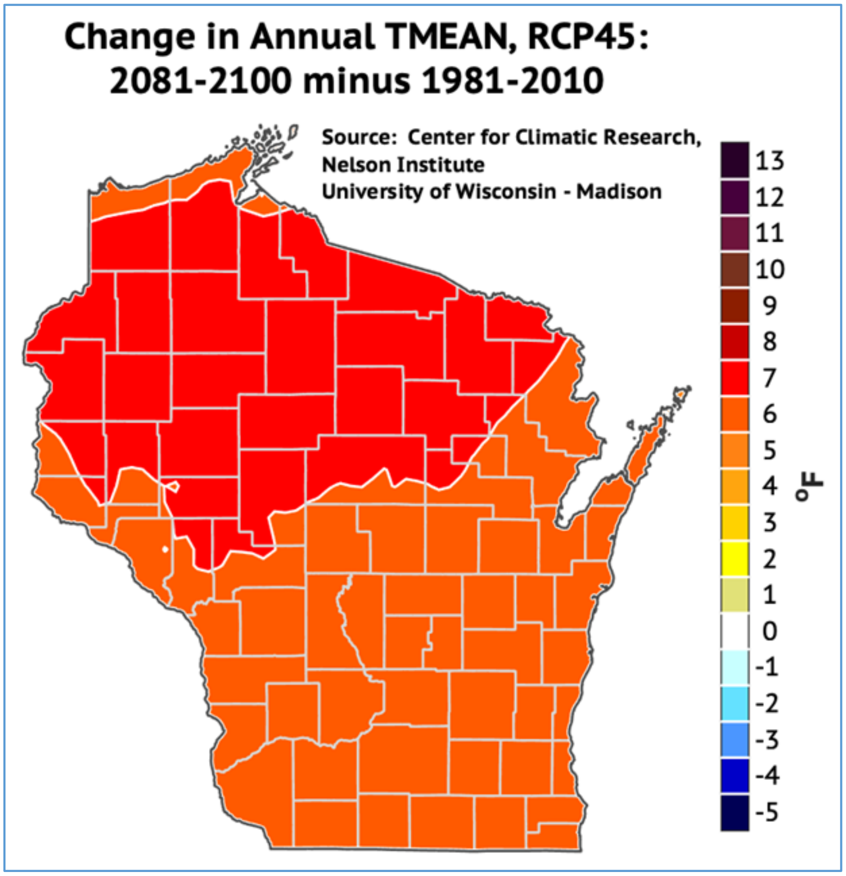
Excessive heat is one of the hazards in this plan that the Dane County community will be at greatest risk to in the coming decades as the climate changes. The changing climate will bring warmer average temperatures and, more dangerously, increased days above 90 degrees. As shown in Figure 4.5.5 WICCI projects an increased average annual temperature change of 5 degrees Fahrenheit by 2081 from 1981 levels in Dane County. This trend of more dangerously hot days has already begun, but will continue to accelerate.

As shown in the opening chapters of this plan, Dane County is continuing to rapidly grow its population, and in turn, it continues to turn previously undeveloped land into development that can increase the urban heat island effect. Research from UW-Madison on the urban heat island of Madison demonstrates that the phenomenon is real and presents an elevation of risk to those living in urban areas, especially vulnerable populations. In a changing climate, where the prospect of living nearly a month more under conditions above 90 degrees is a possibility, the urban heat island effect will only be exacerbated.

The risk for excessive heat is significantly increased as the climate changes. This rates as one of the most urgent hazards to find mitigation strategies for in this plan. The effect on public health could potentially be significant.

Heat mitigating development patterns should be encouraged to confront this increased risk.

Figure 4.5.5 Projected increase in days above 90 degrees Fahrenheit 1980-2055



Source: Wisconsin Initiative on Climate Change Impacts, 2020.

4.5.4 Impact Assessment

Direct Impacts

Adverse health outcomes associated with extreme temperatures include heatstroke, heat exhaustion, heat syncope, and heat cramps. Heatstroke is the most serious of these conditions and is characterized by rapid progression of lethargy, confusion, and unconsciousness. It is often fatal despite medical care directed at lowering body temperature. Heat exhaustion is a milder syndrome that occurs following sustained exposure to hot temperatures and results from dehydration and electrolyte imbalance; manifestations include dizziness, weakness, or fatigue, and treatment is supportive. Heat syncope and heat cramps usually are related to physical exertion during hot weather. (MMWR (1995) Heat-wave-related mortality—Milwaukee, Wisconsin. Morbidity and Mortality Weekly Report. July 1995. MMWR 1996;45(24):505-7)

While property impacts are generally minimal, there are frequent occurrences of road pavement buckling during periods of high heat. Heating causes the pavement to expand. When concrete slabs expand beyond the space in the joints they press against each other, causing the surface to buckle at the joint or in a weak spot within the slab. Pavement buckling is somewhat unpredictable, with the type and age of the concrete and temperatures as factures. Because asphalt is more elastic than concrete, it is generally less prone to buckling. Asphalt pavement will heave, however, if it is covering an older concrete roadbed or is under pressure from adjacent concrete.

Indirect Impacts

The indirect social and economic impacts of extreme heat are difficult to quantify. The primary stresses are on the electrical distribution system as demand increases to run air conditioning. Peak demand exceeding the local utility's capacity for supply can lead to blackout or brownout conditions. This has not occurred in Dane County however. The utilities supplying Dane County have worked closely with emergency response agencies and human services providers to develop plans for responding to planned and unplanned power outages in the County.

4.5.5 Vulnerability Assessment

Population

Everyone is vulnerable to excessive heat conditions, although some populations are more vulnerable than others. Excessive heat poses the greatest danger to outdoor laborers, such as highway crews and fire crews. The elderly, children, and people in poor physical health are also vulnerable to exposure to extreme temperatures. Mortality among elderly persons, persons with chronic conditions (including obesity), patients taking medications that predispose them to heatstroke (e.g., neuroleptics or anticholinergics), and persons confined to bed or who otherwise are unable to care for themselves are at greatest risk. Low-income individuals and families are also at greater risk of heat exposure than the general population.

People living in urban areas may be at greater risk from the effects of a prolonged heat wave than people living in rural regions. Asphalt and concrete retain heat longer and gradually release heat at night, which produces significantly higher nighttime temperatures in urban areas known as the urban heat island effect. This has large implications for vulnerable populations living in the County's urban areas, given the extent of the urban heat island effect, these populations are likely not experiencing nightly relief from high temperatures during heat waves.

There are segments of the population that are vulnerable to the potential indirect impacts of prolonged excessive heat, particularly the loss of electrical power. As a group, the elderly or disabled, especially those with home health care services rely heavily on an uninterrupted source of electricity. Resident populations in nursing homes, Community Based Residential Facilities, or other special needs housing may also be vulnerable if electrical outages are prolonged. If they do not have a back-up power source, rural residents and agricultural operations reliant on electricity for heating, cooling, and water supplies are also especially vulnerable to power outages.

Social isolation is a perhaps the most significant of the extreme heat risk factors. This can be mitigated through organized welfare checks as well "social capital" programs that build on informal relationships between friends, family members, and neighbors. People in Dane County are generally well connected to service agencies and other people in their communities. While the risk for mortality due to excessive heat does exist, the probability is low that Dane County would experience a large number of deaths such as that which occurred in Milwaukee and Chicago in the 1995.

The Wisconsin Department of Health Services' Building Resilience Against Climate Effects (BRACE) (Wisconsin Department of Health Services, https://www.dhs.wisconsin.gov/climate/wihvi.htm) program has developed a heat vulnerability index for Dane County. This is shown as Figure 4.5.8. The index measures heat vulnerability based on environmental, socioeconomic, population density, and health factors based on census block group data. The urban areas of the County tend to show the highest vulnerability.

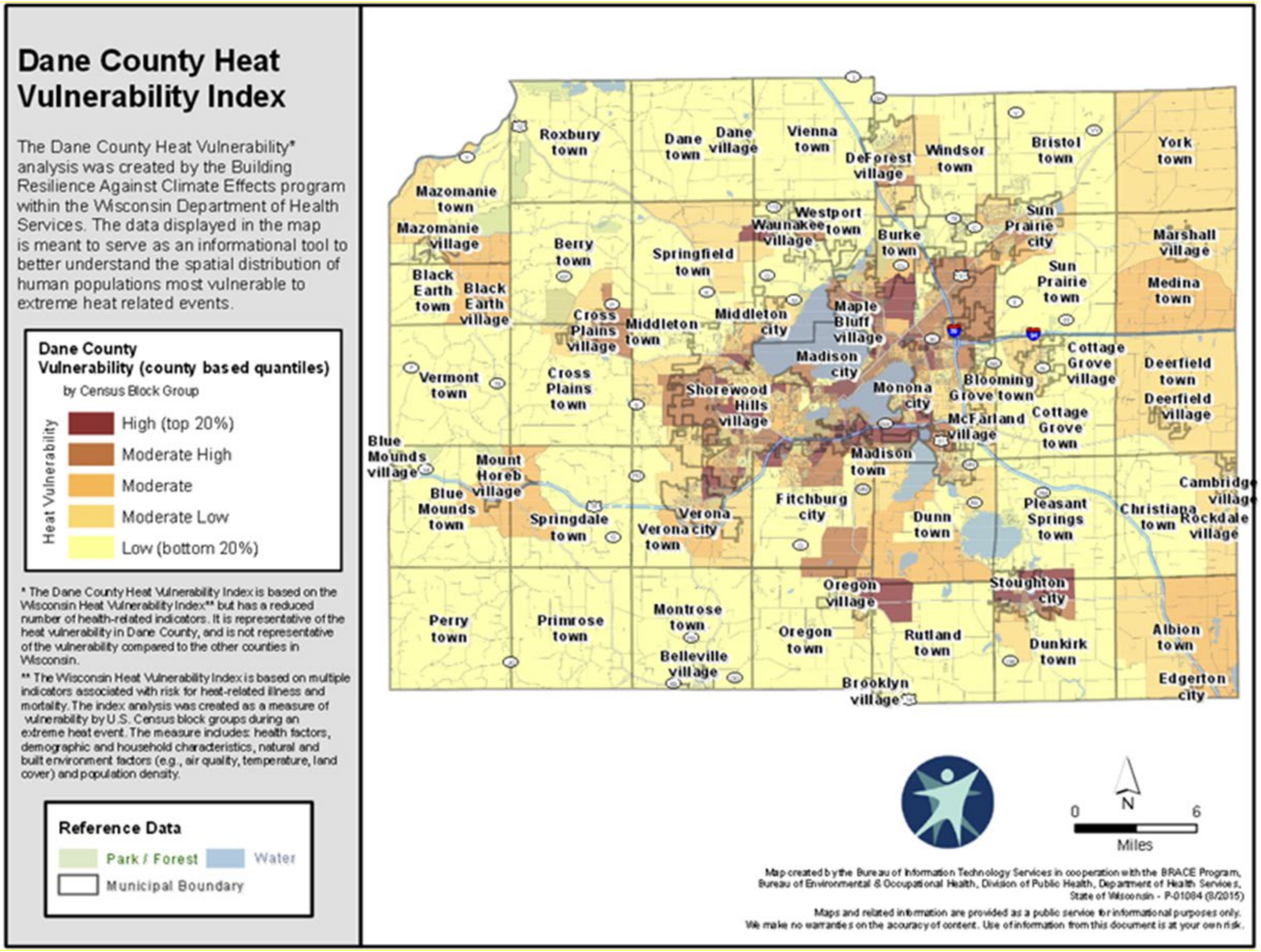
Property

Generally, property is not considered particularly vulnerable to excessive heat. Energy-inefficient buildings may be warmer, resulting in a higher exposure of the population, and personal landscaping and property may suffer from the effects of heat in a manner similar to drought. Cars may overheat, stranding motorists or damaging the vehicle itself and resulting in higher property damage costs. The overall vulnerability of general property is low.

4.5.6 Potential for Future Losses

The most vulnerable aspect of Dane County to excessive heat is the population. Due to climate trends, population exposure, and potential fatal impacts, the overall risk to excessive heat is a growing concern. 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. 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.

Figure 4.5.8 BRACE Program Heat Vulnerability Index for Dane County



4.6 FLOOD

4.6.1 Description

Flooding is one of Dane County's most complex and costly natural hazards.

Flooding is a natural occurrence in the hydrologic system. Throughout the past millennia, plant and animal species have evolved to depend upon occasional floods to renew the landscape. The structure of streams and lakes adapted to handle these changes in water flows. Steam channels meandered, lakes filled and receded seasonally, and water levels were stabilized through ample groundwater and wetland influences. Flooding is not a problem in and of itself. It requires an additional element – human habitation – to become a problem.

The problem of flooding in Dane County is complex and is not limited to mapped floodplains. Nor can the problem be described by any other single variable. The causes and problems of flooding differ widely across the County and there are many contributing factors; changing land use patterns, development in high-risk areas, stormwater management practices, complex hydrologic processes, and societal expectations and values all play a part. There are no simple solutions.

This plan recognizes the interconnected nature of water resources and the shortcomings of a plan that extracts a single element (flooding) from larger water management issues. The occurrence of flooding is only one element of a highly complex hydrologic system. Management of water resources is entwined in social and economic processes and values that are well beyond the scope of this plan. Though crucially important, these larger issues cannot be satisfactorily addressed in this plan. Rather, these issues should continue to be thoroughly discussed in the County's comprehensive planning process, or within the context of a regional comprehensive water management plan.

Flooding comes in a variety of forms in Dane County and not all flood management and flood mitigation strategies apply to all situations.

- *Riverine flooding* is the most common type of flooding, nationally and in the state of Wisconsin. Riverine flooding is also known as overbank flooding and is typified by floodplain flooding scenarios. Riverine floodplains range from narrow, confined channels in the steep valleys of mountainous and hilly regions, to wide, flat areas in plains and coastal regions. The amount of water in the floodplain is a function of the size and topography of the contributing watershed, the regional and local climate, and land use characteristics within the watershed. In steep valleys, flooding is usually rapid and deep, but of short duration, while flooding in flat areas is typically slow, relatively shallow, and may last for long periods of time.

  The cause of riverine flooding is typically prolonged periods of rainfall from weather systems covering large areas. These systems may saturate the ground and overload the rivers and reservoirs in numerous smaller basins that drain into larger rivers. Localized weather systems (i.e., thunderstorms), may cause intense rainfall over smaller areas, leading to flooding in smaller rivers and streams. Annual spring floods, due to the melting of snowpack, may affect both large and small rivers and areas.

- *Flash floods* involve a rapid rise in water level, high velocity, and large amounts of debris, which can lead to significant damage that includes the tearing out of trees, undermining of buildings and bridges, and scouring new channels. 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, covering of ground cover with impermeable surfaces, and construction of drainage systems.
- *Surface water flooding* or localized stormwater drainage floods may occur outside of recognized drainage channels or delineated floodplains due to a combination of locally heavy precipitation, a lack of infiltration, inadequate facilities for drainage and stormwater conveyance, and increased surface runoff. Surface water flooding is usually the result of high intensity rainfall, but can occur with lower intensity rainfall when the land has a low permeability and/or is already saturated. This can be an especially large problem in urban areas. Such events frequently occur in flat areas, particularly during winter and spring in areas with frozen ground, and also in urbanized areas with large impermeable surfaces.
- *Groundwater flooding* occurs when the water table rises above normally expected levels. This can be as a result of persistent rainfall that recharges aquifers until they are full, or may be a result of high river levels or lake driving water through near-surface soils. Compared to surface water flooding, groundwater flooding can last considerably longer, with incidents enduring anything from a week to several months.

Floodplains and the National Flood Insurance Program

Most homeowner's insurance policies do not cover damages caused by flooding. Flood loses are covered under a separate flood insurance policy sold through the National Flood Insurance Program (NFIP).

At the Federal level, floodplain regulation primarily falls to FEMA and the NFIP. Established in 1968, the NFIP 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.

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 flood proofing. 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 is two feet above the regional flood elevation.

Figure 4.6.2 Flood Insurance Rate Map (FIRM) sample

Source: FEMA Flood Map Service Center, https://msc.fema.gov

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 NR 116 exceed the minimum standards set by the NFIP in order 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. 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 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 NR 116 and 44 CFR 59-72 if the community wishes to participate in the NFIP. The Villages of Dane and Mt. Horeb do not participate in the NFIP because they do not have areas that are prone to surface flooding.

Communities must enforce Federal, state, and local floodplain ordinances and make FIRMs and FISs available to the public in order 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. (Wisconsin Emergency Management, Wisconsin Threat and Hazard Identification and Risk Assessment, 2021)

The NFIP also requires that local floodplain management regulations and codes contain minimum requirements that are not only for new structures, but also for existing structures with "substantial improvements" or repair of "substantial damage" after a flood. Local officials in communities that participate in the NFIP must determine whether proposed work in a regulated SFHA qualifies as a substantial improvement or repair of substantial damage (referred to as an "SI/SD determination"). If work on buildings constitutes SI/SD, then structures must be brought into compliance with NFIP requirements for new construction. The NFIP defines SI/SD as follows:

- Substantial improvement (SI) means any reconstruction, rehabilitation, addition, or other improvement of a structure, the cost of which equals or exceeds 50 percent of the market value of the structure before the "start of construction" of the improvement. This term includes structures that have incurred "substantial damage," regardless of the actual repair work performed.
- Substantial damage (SD) means damage of any origin sustained by a structure whereby the cost of restoring the structure to its before-damaged condition would equal or exceed 50 percent of the market value of the structure before the damage occurred. Work on structures that are determined to be substantially damaged is considered to be substantial improvement, regardless of the actual repair work performed.

What is a "100-Year" Flood?

The studies used to generate the Flood Insurance Rate Maps are based on calculations of the probability of flooding occurring in any given year. Flood studies use data and modeling, as well as historical records to determine the potential for floods of a certain magnitude to occur. Such events are measured by their recurrence interval, e.g., a 100-year flood or a 500-year flood. These terms can be misleading. People often interpret the 100-year flood to mean once every 100 years. This is not correct. A 100-year flood could occur twice in the same year, two years in a row, or four times in 20 years.

The 100-year flood is a statistical term that refers to the likelihood of a flood of certain magnitude happening in any given year. This converts to a probability of 1% that a flood of this magnitude will occur.

The 100-year floodplain, or base flood shown on the FIRMs and regulated by the County's floodplain zoning ordinance is the 1% chance floodplain. This is the land area next to a water body that is assessed as having a 1% chance of being flooded in any given year. The terms "regional flood," "100-year flood," "1% chance flood," and "base flood" are essentially interchangeable. These terms all refer to a flood of the same magnitude and probability of occurrence

Floodplain Zoning

Dane County participates in the National Flood Insurance Program and is in full compliance with the provisions of the program. Chapter 17 of the Dane County Code of Ordinances is the County's floodplain zoning ordinance. The ordinance covers the floodway, flood fringe and a general floodplain districts that fall within the floodplain boundaries as shown on FEMA's Flood Insurance Rate Maps. Dane County floodplain zoning applies only in the unincorporated areas of the County and does not require approval of town boards. Cities and villages must adopt their own floodplain zoning ordinances. Chapter 17 meets or exceeds the standards defined in NR 116.

Stormwater Management

Dane County's Erosion Control and Stormwater Management Ordinance was designed to help protect the county's lakes, streams, wetlands and quality of life by reducing the negative impacts of sediment, rainfall, melting snow and other water runoff. The ordinance establishes countywide standards for the quantity and quality of water that runs off land under construction in urban and rural areas, including farms. It also provides flexibility in meeting those standards, recognizing the unique characteristics of each project and site. The Erosion Control and Stormwater Management Ordinance builds on the construction site erosion control requirements that have been in effect since 1995. The ordinance was adopted in 2001 by the Dane County Board and implemented in August 2002 through Chapter 14 of the Dane County Code.) The ordinance is not limited to unincorporated areas; it also applies in cities and villages. The ordinance is administered by Dane County for unincorporated areas and cities and villages that have not adopted standards at least as restrictive as the County's. Cities and villages that have developed their own standards that meet or exceed the County minimums administer these standards locally.

Effective January of 2006, revisions to the erosion control and stormwater management ordinance were made to meet state standards for infiltration and to make shoreland erosion control requirements of Chapter 11 consistent with Chapter 14. Dane County chose to adopt the state's infiltration standards, with few modifications. One significant change was a sunset date for the caps that limited that amount of area required to be dedicated to infiltration (State rules require only one percent of a residential site and two percent of a nonresidential site to be dedicated to infiltration). The other significant change was the elimination of the design storm approach (utilizing TR-55) to meet the infiltration requirements. The revised infiltration requirements were adopted in August of 2006, and are now effective.

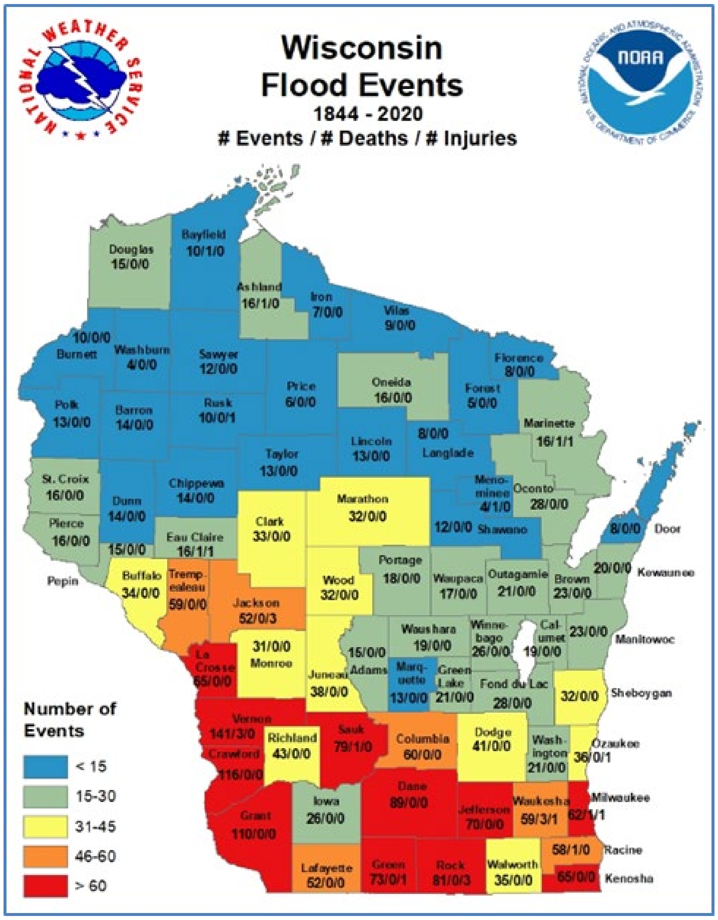
During the 2018 DCNHMP update, the Lakes and Watershed Commission and the Capital Area Regional Planning Commission (CARPC) established a Stormwater Technical Advisory Committee to evaluate the County's stormwater management strategies and make recommendations regarding flood risk reduction. The work group identified a number of limitations in the existing strategies and included a series of recommendations for modifying the Dane County Stormwater Ordinance. Throughout the planning process of the 2023 DCNHMP, CARPC and communities within the Black Earth Creek Watershed have led the Black Earth Creek Watershed Green Infrastructure Plan, a key watershed impacted in the 2018 Dane County floods. See more information in section 4.6.9.

While making recommendations regarding specific stormwater management regulatory practices is beyond the scope of the Hazard Mitigation Plan, the goals of these efforts are entirely consistent. Regular evaluation of the Stormwater Management Ordinance and an on-going effort to reduce stormwater runoff rates and volumes, have been identified objectives in the Plan since its initial inception. These efforts continue to be a priority.

4.6.2 Previous Occurrences

Dane County received Presidential disaster declarations for widespread flooding seven times since 1971. Significant damages were also recorded in 1996. Cumulative losses for these disasters exceed $65 million, including private, public and agricultural damages. Damage assessment summaries for those years are shown in Table 4.6.1. As shown, losses caused by widespread flooding have been substantial. Private and public losses shown as "estimated" are based on a compilation of local damage assessment figures. Public and private losses shown as "actual" are based on FEMA public and private assistance program payments. Agricultural losses are based on Dane County UW-Extension and USDA Farm Service Agency (FSA) estimates. Figure 4.6.3 shows the number of events, deaths and injuries related to flood events for the entire state of Wisconsin from 1844 to 2020. Dane County shows the third highest total for flood events statewide.

Figure 4.6.3 Significant Flood Events in Wisconsin



Source: National Weather Service

Table 4.6.1 Damages from major floods in Dane County (1971-2016)

Year	Disaster Type	Declaration Type	Damage Assessment
1978	Flooding and Tornados	Presidential Disaster	$180,000 (Public Assistance)
1990	Flooding and Tornados	Presidential Disaster	$37,000 (Public Assistance) $30,343 (Individual Assistance)
1993	Flooding	Presidential Disaster	$888,000 (Public Assistance) $1.44 Million (Individual Assistance) $22.6 Million (Total Damages, est.)
1996	Flooding and Severe Storms	Local Sources	$1.7 Million (Public Losses, est.) $6.8 Million (Private Losses, est.) $8.5 Million (Total Damages, est.)
2000	Severe Storms (Windstorm) and Flooding	Presidential Disaster	$940,000 (Public Assistance) $1.25 Million (Individual Assistance) $9.3 Million (Total Damages, est.)
2007	Flooding	Presidential Disaster	$0.6 Million (Individual Assistance) $1.64 Million (Public Assistance) $5.1 Million (Total Damages, est.)

Year	Disaster Type	Declaration Type	Damage Assessment
2008	Severe Storms, Tornados and Flooding	Presidential Disaster	$1.53 Million (Public Assistance) $1.76 Million (Individual Assistance) $1.64 Million (Housing Assistance) $120,000 (Other Needs)
2018	Severe Storms, Straight Line Winds, Tornados, Flooding, and Landslides	Presidential Disaster	$28,738,112.16 (Public Assistance) $8,902,520.27 (Individual Assistance) $8,003,898.67 (Total Housing Assistance) $898,621.60 (Other Needs)

Source: Dane County Emergency Management; * Federal Individual Assistance Payout; ** Federal Public Assistance Payout

A brief description of past flood events, and their impacts are listed below. More recent events are pulled from the National Centers for Environmental Information (NCEI) database.

1973

Flooding again comes to the Mississippi river as Wisconsin is declared a disaster area as one of 8 states that split $147 ($570) million in Federal aid. Then-governor Lucey estimated private and public damage at almost $2.3 ($8.9) million. Madison broke a 17-year-old, 24-hour rainfall record as streets and sewers flooded. The federal government began offering funding for repairs due to flooding, but only to those units of government with a floodplain ordinance. Dane County and most incorporated areas did not comply with Federal regulations at that time.

July 1978

Former President Jimmy Carter declared a flooding disaster for 16 southern and western Wisconsin counties—Dane included. In July, Wisconsin experienced rainfall that was 75 percent above normal. An estimated $53 ($139.8) million in damage was produced from a series of weekend storms July 8-9. Rain fell heavily throughout the state from May through September, producing a bumper crop for some farmers, but other farmers were not so lucky. In Dane County, about 9,000 acres of cropland on 800 farms were damaged in June and early July rains. Crop losses approached $2.1 ($5.5) million on 500 farms; corn and soybean crops were most severely damaged suffering $1.4 ($3.7) million in losses. Tobacco and cabbage losses were estimated at $700,000 ($1.8 million). Floodwater also eroded soil from fields and scattered debris, increasing costs to farmers. Residents in the City of Monona along Lake Monona also flooded.

Summer 1980

Heavy rains drenched central Wisconsin and Dane County. August rainfall broke the month's record, setting the bar at 9.49 inches. The National Weather Service issued numerous flash flood warnings. Madison Gas and Electric reported 15 power outages. Two hundred people were affected on Madison's west side and another 200 were affected in the Springfield area. Media outlets designated southern Wisconsin including Dane County as "rain alley."

July 1990

Torrential rains and flooding caused an estimated $14 ($18.4) million in damages in 14 counties in southern Wisconsin. In the City of Madison, 12 trees were lost due to high winds, storm sewers backed up. Several parts of the Military Ridge bicycle and hiking trail were washed out. Also, high water lifted a car off the ground on University Avenue and washed it across a parking lot. Businesses dependent upon water-based recreation lost money having to cancel boat trip due to high waters in rivers.

1993

Flooding was widespread across the County in the great Midwest flood of 1993. The flooding in 1993 was a result of above average precipitation for each month from March through August. The primary significance of the 1993 storm events was not the intensity, but the frequency. Most days during June and July had at least a minor rainfall event. Between June 28 and July 11, there were only two days out of 14 with no rain. There was also one significant individual storm during this time period, a 3.75-inch rainfall event on July 5, 1993. This was approximately a 5- to 10-year storm (10 percent to 20 percent annual probability) event. The total precipitation for this 14-day period was 7.86 inches while the average is 1.83 inches. Therefore, during most of June and July, the soils of the County remained saturated and did not have time to dry out between storms. This caused significant crop loss, and the resulting increased runoff raised most area rivers over flood stage and raised all of the Yahara Lakes to record or near record levels. Dane County received a presidential disaster declaration and was eligible for public and private assistance programs.

1996

The County experienced widespread flooding in 1996, largely as a result of a June 16-18 storm. Over this period of time, heavy rains fell over most of the region of southern Wisconsin. The National Weather Service recorded 5.25 inches of rain in Madison. The Sun Prairie Wastewater Treatment Plant recorded 5.77 inches over this same time period. Lake levels of the Yahara Chain of Lakes were within inches of all-time record highs and most rivers and streams were at or above flood stage. The flooding that resulted caused severe problems on agricultural lands as well as in the City of Madison, the City of Monona, the City of Sun Prairie, the Villages of Mazomanie and Black Earth. In the Department of Emergency Management's damage assessment, nearly every local unit of government in the County reported at least some damage to public and private facilities.

2000

The month of May 2000 was a particularly wet month in the southern half of the state. Data from the National Weather Service indicates that it was the wettest May ever recorded for most locations in southern Wisconsin, including Dane County. Generally, 8 to 12 inches of precipitation was measured, with some locations in Dane and Iowa Counties unofficially receiving between 16 and 18 inches. Normal rainfall for May is 3.14 inches. Finally, the wet rainy weather culminated in a series of severe thunderstorms and heavy rains that began on May 26 and continued into early June. Those storms dumped nearly 6 inches of rain on already saturated soils. This caused most, if not all of the rainfall to run off instead of infiltrating into the ground. The result pushed most area rivers over flood stage, raised all of the Yahara Lakes to record or near record levels, and caused severe, widespread flooding. Dane County received a presidential disaster declaration and was eligible for public and private assistance programs.

2001

2001 started very dry, beginning in the fall of 2000, with all regions of the state below 50 percent of the October precipitation average. Beginning in the winter, precipitation was highly variable and the state went through a series of wet and dry spells. However, by May the central and southern portions of the state had received 160 percent of normal precipitation. After a July dry spell, severe thunderstorms on August 1-2 dumped heavy rain over a large portion of Dane County. Most areas of the County received between 2 and 5 inches of rain. The heaviest rainfall was centered over the northwest portion of Dane County. An unofficial, but credible report to the National Weather Service indicated that an 11-inch capacity rain gage had overflowed in the Village of Black Earth. Flash flooding occurred in the Black Earth Creek with significant impact to the Villages of Black Earth and Mazomanie. Flash flooding also occurred in Roxbury Creek, causing a significant impact on the village area in the Town of Roxbury.

June 9-12, 2004

Scattered, widespread heavy rains across south-central and southeast Wisconsin during this period kept many rivers and streams at or above flood stage for most of the month. Monthly rainfall totals generally ranged from 4 to 7 inches across south-central and southeast Wisconsin. During this time, high water levels submerged most of the bottom-level land near rivers and streams; closed some major state highways; forced water into basements; damaged corn, soy bean, and alfalfa crops; delayed planting of entire fields; washed out gravel road shoulders; and damaged foundations of homes and businesses. In general, the flooding was the worst since 1993 on a widespread basis and locally in the past 25 to 30 years. Federal Disaster Declaration 1526 covered all 20 counties in south-central and southeast Wisconsin for storms, tornadoes, and flooding for the period of May 19-July 3, 2004. All counties qualified for "individual assistance". In Dane County, lake levels were 1 to 3 feet above normal. Minor basement flood damage to 127 homes, and major damage to 3 homes, was reported and property damages were estimated at $1 million. Estimated crop losses were $3 million.

July 27, 2006

A 1-in-a-100-year flash flood occurred from the west side of Madison to around the Capitol Square after 3 to 5 inches of rain fell within a 90 minute timeframe. There were no reports of injuries or deaths. The heavy rain resulted from slow-moving and back-building thunderstorms that essentially remained nearly stationary over the city of Madison. The hilly terrain and a typical urban setting of concrete and asphalt enable the runoff water to quickly overwhelm the storm sewers and concentrate water in low-lying areas of the city. Water depths reach to the top of small vehicles - 4 to 5 feet deep in spots. Many roads became impassable due to the flood waters, and many residential homes and businesses on or near the UW-Madison campus had flooded basement and first-floor flooding. Some basement apartment units had water depths of 6 to 8 feet. Nearly all campus buildings had flooding of varying degrees of intensity, and the Camp Randall football field sustained damage. Some campus buildings had flat roofs that quickly flooded as storm drains became plugged, which allowed water to run through the walls and ceilings of buildings. The buildings that sustained the most damage were the Memorial Union, Computer Sciences, and Veterinary Medicine. Numerous vehicles on or near the campus were damaged or totaled by the flood waters, and some were reported to be floating away. Unofficial rain gages measured 4.5 to 5 inches from just west of West High School up to the Capitol Square. WSR-88D Doppler rainfall estimates were in the 3 to 5 inch rain. Rainfall amounts quickly fell off to 1 to 1.5 inches near the south Beltline.

August 23 and August 24, 2006

A stagnant weather pattern on August 23rd and 24th resulted in waves of heavy rain and severe thunderstorms. A warm front pushed north during the afternoon of August 23rd. A very unstable air mass with moderate shear caused thunderstorms to break out during the afternoon and continue through most of the overnight as a warm front moved north through the area. After a brief respite of only 3 hours during the morning hours of August 24th, more storms developed during the late morning and afternoon hours. More heavy rain, large hail, damaging winds, and vivid lightning resulted from these storms. Urban flooding in Dane and Kenosha counties caused a few hundred thousand dollars in structural damage. Some two-day rainfall totals across Dane County include 5.70 inches in Oregon, 5.38 inches in Cottage Grove, 3.26 inches in Middleton, 2.77 inches at Beloit College, and 2.73 inches at Madison Truax Field.

August 22, 2007

Flash flooding occurred due to repeated thunderstorms with heavy rains on top of a saturated ground. From Madison to Sun Prairie many roads had fast-flowing water depths of 6 inches to 1 foot, and several were closed. Sandbagging also took place to control the flash flooding. A 1-hour rainfall total of 2.26 inches was measured by a spotter in Madison. Soil erosion and crop damage also occurred on several other farms in that area. Additionally, a few basements had water damage to contents. August, 2007, rainfall totals in inches include: 15.18 at Madison Truax Field, 14.58 at the UW-Charmany Farm, 14.92 at Mazomanie, 14.43 in Middleton, 18.48 near Mt. Horeb, 16.37 in Stoughton, 15.74 in Sun Prairie, and 13.49 at the UW Arboretum. Up to 20 inches may have fallen in the southwest corner of the county. During the afternoon and evening hours of August 22nd, the second round of storms for the calendar day moved across south-central and southeast Wisconsin. The clusters or short lines of storms moved east at a speed of about 30 knots (35 mph), and generated damaging downburst straight-line winds that toppled trees and power-lines, and heavy rains that triggered flash flooding. Synoptically, a stationary front stretched from northern Iowa to Wisconsin/Illinois border. Warm, moist, unstable air flowed north over the front in association with an upper-level short-wave trough, resulting in thunderstorm generation. Hourly rainfall rates peaked around 2 inches. By the end of August, 2007, many locations in south-central and southeast Wisconsin established new August rainfall records and all-time/any month rainfall records. Many locations measured 10 to over 20 inches for the month of August, 2007, or about 200 percent to over 400 percent of normal. Normal August precipitation in southern Wisconsin is about 4 to 4.25 inches.

June 7, 8, & 12, 2008

Heavy rains resulted in flash flooding as water reached depths of 3 feet or more and several cars stalled. This was the last of 6 flash floods in Dane County on 3 different days. The first one occurred on June 7th, the next two on June 8th, and the last three on June 12th. In all six cases, damage to homes, businesses, and crops was noted. It was nearly impossible to break down the damages by flash flood event. Therefore, the collective breakdown is provided in this last June 12th flash flood storm data entry for Dane County. Some farm fields remained flooded into early July. The breakdown for residential home losses were: 2,020 minimally affected, 248 with minor damage, 109 with major damage, and 3 destroyed (total of $6.797 million). The breakdown for business losses were: 152 with minor damage, and 3 with major damage (total of $677 thousand). Crop losses were estimated at $64.6 million. Public sector damage was about $6.067 million. Several roads and bridges sustained damage. A series of clusters of strong to severe storms ahead of a cold front moved east/northeast across south-central and southeast Wisconsin. Copious amounts of moisture were available that allowed repeated heavy rains. Additionally, there was sufficient vertical wind shear to allow for the generation of supercell thunderstorms with rotating updrafts that led to seven tornadoes in this part of the state of Wisconsin.

Spring, 2009

Flood problems began in early March, 2009 in some areas of the County, notably the northern portion. Road flooding and some residential flooding was reported in the towns of Vienna and Roxbury. Fish Lake and Crystal Lake in the Town of Roxbury were threatening residential properties with rising lake levels. Substantial rainfall on still-frozen ground may have been a contributing factor to this flooding. Several roads were underwater and closed around Crystal Lake. 22 Recreational vehicles or other structures at the Crystal Lake RV Resort and Campground were substantially damaged.

August 22, 2010

Parts of south-central and southeast Wisconsin experienced several rounds of record-setting torrential heavy rains during the afternoon and evening hours of July 22, 2010 that led to flash flooding and damage. During the afternoon, a persistent band of strong to severe thunderstorms developed and moved very slowly over south central and southeast Wisconsin through the evening hours. The individual storms were moving quite fast, about 40 to 50 mph, but the slow southward movement of the boundary these storms were developing along, resulted in storms repeatedly training, or moving, over the same area. Widespread 3 to 4 inch amounts were reported along and either side of the I-94 corridor, with locally higher amounts of 5 to 8 inches. Madison set a record for precipitation for the date at 3.62 inches. This beat the previous mark of 2.21 inches set in 1885. The 3.62 inches of rainfall ranks 13th for the most precipitation received in one day. Training thunderstorms produced 2.5 to 4.5 inches of rain in about two hours over mainly the northern half of the county. Street flooding stranded cars in Sun Prairie, various locations in the city of Madison, Oregon, Middleton and DeForest. Three to four feet of water covered the intersection of Commercial Avenue and Kroncke Road in Sun Prairie, stalling cars and filling some home basements and commercial buildings with water, damaging their contents.

June 21-27, 2013

During the period of June 21-28, 2013, parts of Wisconsin experienced historic 24-hr, 48-hr, 72-hr, and 7-day rainfall amounts which had a statistical frequency of about once every 100 to 500 years. Several rounds of thunderstorms with heavy rains occurred, with total weekly rain amounts of 6 to over 13 inches, and some 24-hr totals of 5 to over 7 inches. This resulted in river flooding, mud-slides, damaged buildings and closed roads. Some river gauge sites experienced major flooding levels and record crests. Hourly rainfall rates with some of the strongest storms reached 1 to 2 inches per hour which led to localized flash flooding. By the end of the June 21-27, 2013 period Madison had experienced its wettest year on record to date: 30.58 inches, or 14.81 inches above normal. Similar conditions existed at other locations in southwest and south-central Wisconsin. The Yahara River gage at Fulton set a new all-time crest on June 26th in the major flooding category at 12.06 feet, breaking the old record of 11.16 feet set on July 18, 1996

June 14, 2016

A surge of warm and moist air on a low level jet stream brought a large thunderstorm complex across southern WI from the evening into the early morning hours. Heavy rain and isolated flash flooding occurred. Highway F was flooded and closed between highway FF and Pleasant Valley Road due to the flash flooding of the east branch of Blue Mounds Creek. There were also shoulder washouts on highway F between Moyer Road and Zwettler Road. There were also shoulder washouts on highway JG between Little Norway Road and North Road. Approximately 5 to 7 inches of rain had fallen in about 5 hours.

July 21, 2016

Persistent warm and moist advection over an outflow boundary triggered thunderstorms over west central WI that organized into a large and slow moving squall line. The slow moving line of storms produced numerous areas of straight line wind damage and some areas of flash flooding over southern WI during the late afternoon and evening hours. Multiple intersections on the west to southwest side of Madison and in Middleton are flooded and impassable after 3 to 3.5 inches of rain in approximately 2 hours. Vehicles were stalled or stranded by the deep water. Water in some residential basements and some businesses flooded. 50,000 to 75,000 gallons of untreated wastewater was discharged into the public storm sewer system in Middleton.

2018

A severe storm swept across Dane County the evening of August 20, 2018 dumping up to 15" of rain in less than three hours. The heaviest rain occurred North of the City of Verona, on the West side of the cities of Madison and Middleton and along the US Hwy 14 / Black Earth Creek corridor. The storm flooded intersections, overwhelmed storm water drainage systems causing storm water to flow over roadways and into buildings, overtopped sanitary sewer lift stations causing sewer backups inside buildings, overflowed water retention features, and washed away multiple roadways and one two land bridge on U.S. Hwy 14 west of Black Earth.

The municipalities in the Black Earth Creek / U.S. HWY 14 corridor including the City of Middleton, Villages of Cross Plains, Black Earth, and Mazomanie, and the towns of Middleton, Cross Plains, Berry, Black Earth, and Mazomanie generally suffered damage from overland flooding to both public and private facilities. The Cities of Middleton and Madison suffered damage to public infrastructure and also a large concentration of sanitary sewer back-ups.

The vast majority (96% +) of Individual Assistance claims were outside of mapped flood plains.

Assessment of Past Flood Occurrences

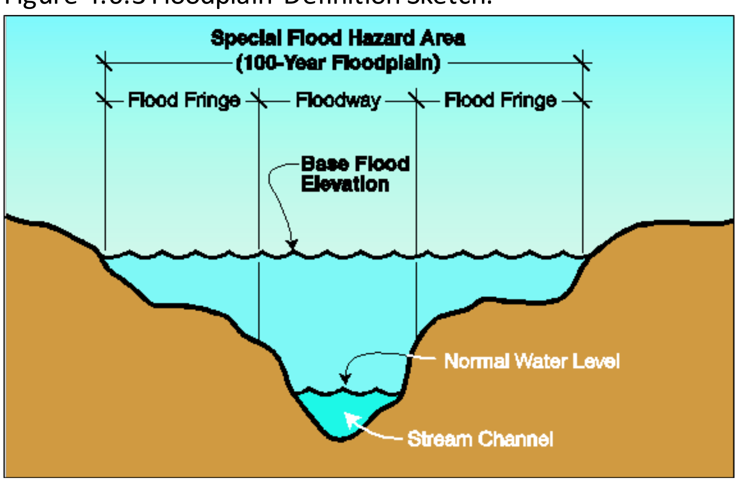
During the development of the initial Flood Mitigation Plan (2003) a comprehensive assessment of the impacts and problems associated with floods in Dane County was performed using a combination of government expertise, recorded events, and GIS spatial analysis. The results of this planning process are still used in flood mitigation strategy in Dane County today. An assessment of past flood events shows that there is a wide range of factors that contribute to flooding problems.

Development in Flood-Prone Areas (Areas with Inherent Flood Risk)

There are areas of the County that have an inherent risk of flooding and resulting flood damage if developed. These typically are areas that in their natural state, are associated with floodplains, low lying shore lands, wetlands (existing or drained) and steep slopes with highly erodible soils.

- *Floodplains*. Developing and building in areas with a natural flood risk is a well-documented cause of subsequent flood damages. The floodplain is very simply the land that has been or may be covered by floodwater during a flood. A cross-sectional view of a typical floodplain is illustrated in Figure 4.6.3. To build or develop in a floodplain exposes the owner to an inherent risk of flooding at some point in the future.

Figure 4.6.3 Floodplain Definition Sketch.



Source: FEMA, 2001.

The locations and delineation of floodplain boundaries are not a static representation of flood risk. Floodplains change over time. Though they are represented as a line on a Flood Insurance

Rate Map (FIRM), floodplains and flood risk are not black and white. The floodplain maps are designed to indicate areas with a risk of flooding, but those areas are constantly changing. Increasing impervious surface areas with new development, soil saturation, rainfall intensity, stream conditions, shoreland and wetland modifications (both restoration and degradation), and stormwater management practices all affect the extent to which flooding will occur.

In addition to this, there is a widely held perception that the 100-year floodplains shown on a FIRM represent a clear boundary of flood risk. On one side of the line, there is a flood risk, on the other side, there is not. This is not what the maps are intended to show. Flood risk is a continuous spectrum and the floodplains shown on the FIRM represent but one increment of that spectrum, the 1 percent probability of flooding. For regulatory and insurance purposes, a line has to be drawn somewhere. There is a danger in using this line as the end-all in determining flood risk. The maps are intended to represent the risk as accurately as possible, but they are merely a prediction of the extent of flooding that could occur in the future, based on a snapshot of present and past conditions.

- Hydric Soils. Though mapped/regulatory floodplains are a good predictor where flooding occurs, floodplains do not account for all of the flooding in the County. The location of certain soil types, hydric soils in particular, is also a good predicator of where flooding is likely to occur. Hydric soils are formed under conditions of saturation, flooding, or ponding long enough during the growing season to develop anaerobic conditions in the upper part. They are a good indicator of the historic locations of wetlands or other wet areas. As such, development in areas with hydric soils is another prime indicator of where flood damages are likely to occur, especially in areas where urbanization has not altered the natural hydrology of the area.
- Topography. The topography of the County affects the spatial extent of flooding. In the western portion of the County where topography is most exaggerated, flooding occurs in small areas, yet the water flow rate is much higher than in the eastern part of the County. There, landowners experience expansive flooding, since the water is able to spread across the landscape more easily. Topography and hydric soils are useful indicators of the frequency and extent of flooding outside the floodplain.

Figure 4.6.4 shows the locations of floodplains and hydric soils in Dane County.

Other Factors Contributing to Flood Losses

Traditional concepts of floodplain flooding and construction in known flood risk areas does not tell the whole story of flood losses and damages in Dane County. Dane County is primarily a drainage area. The County fully or nearly fully contains the headwaters of most of the rivers and streams that flow through and out of the County. While there are predictors of where floods will occur and the impacts that will result, there are a number of other factors that contribute to flood losses in the County.

- *Lake Levels*. The Yahara River chain of lakes runs directly through the most urbanized areas of Dane County. Flooding of streets and homes occurs in low areas surrounding the lakes when lake levels rise. Urbanization and increasing impervious surface areas tend to increase both the rate and the volume of stormwater runoff. Particularly in the case of the Yahara Lakes, it appears that the lakes are acting as a large wet detention basin, holding ever-increasing volumes of stormwater runoff. Flood problems associated with the high levels in the Yahara chain of lakes is exacerbated by slow drainage of the Yahara into the Rock River. Following periods of heavy rain, or sustained rains with saturated soils, the lake levels tend to rise rapidly, but take a long time to return back to normal levels. High water conditions can last for weeks at a time.

  - Annual maximum water levels of Lake Mendota have been generally increasing, with eight of the ten highest Mendota lake levels over the past 100 years occurring since 1978. The maximum annual levels of Lake Monona have also been generally increasing since about 1980, with seven of the ten highest Monona levels over the past 100 years occurring since 1993. These increases coincide with the increase in impervious surfaces from urban development in the watershed.
  - High levels on Lake Koshkonong have also resulting in significant property damage in the Town of Albion. In fact, there have been more flood insurance claims, and higher damage totals on Lake Koshkonong than any other single location in the County. Many of these properties have been elevated above the base flood elevation in accordance with NFIP and Wisconsin Administrative Code NR-116. Flood related problems still exist in this area and like the Yahara, these problems are exacerbated by slow drainage.
  - High lake levels in the Crystal Lake, Fish Lake, Mud Lake system in the Town of Roxbury have also been a source of flood damage to homes and roads. A number of mitigation actions have been implemented in this area, including acquisition and demolition of flood prone homes and the elevation of town roadbeds. The Fish, Crystal, and Mud Lake Rehabilitation District has also implemented a pumping system to reduce water elevation.

- *Impediments to the Flow of Water*. Changes in stream conditions and impediments to the flow of water were identified as a significant factor in increasing flood problems along the rivers and streams of the County. Impediments to flow reduce the overall capacity of the stream to convey water and cause water to back-up behind the blockage. These impediments include blockages caused by accumulation of sediment, over growth of weedy, non-native vegetation, or excessive debris in the stream channel. Reduced conveyance capacity and blockages can and do occur in all components of the natural and human-made components of the drainage system, including detention ponds, stream channels, drainage ditches and culverts.
- *Debris in the Drainage System*. Debris in streams has been identified as a significant problem in numerous areas of the County. Debris refers to a wide range of materials that may include tree limbs and branches that may accumulate naturally or garbage and trash that has been dumped into channels or drainage ditches. There is often a very fine line between debris that should be removed to improve conveyance capacity and natural material that is necessary for fish and wildlife habitat.
- *Silt and Sediment*. Silt and sediment has also been identified as a significant impediment to flow in numerous streams and ditches of the County. Farmlands and construction sites typically contain large areas of exposed soil. Surface water runoff can erode soils from these sites and

carry sediment into downstream waterways. Erosion also occurs along streambanks and shorelines as the volume and velocity of flow destabilizes the banks and washes away the soil.

Sediment suspended in the water tends to settle out where the flowing water slows down. It can clog storm sewers, culverts, and ditches and reduce the water conveyance capacity of rivers and streams. Not only is the drainage system less able to carry water, but the sediment in the water also reduces light, oxygen, and water quality and often carries agricultural chemicals and other pollutants into the water. The erosion control elements of the County's Stormwater Management and Erosion Control ordinance are designed to address these issues. Even with the ordinance in place, however, streams that are currently restricted by sediment will remain restricted unless the existing sediment is removed.

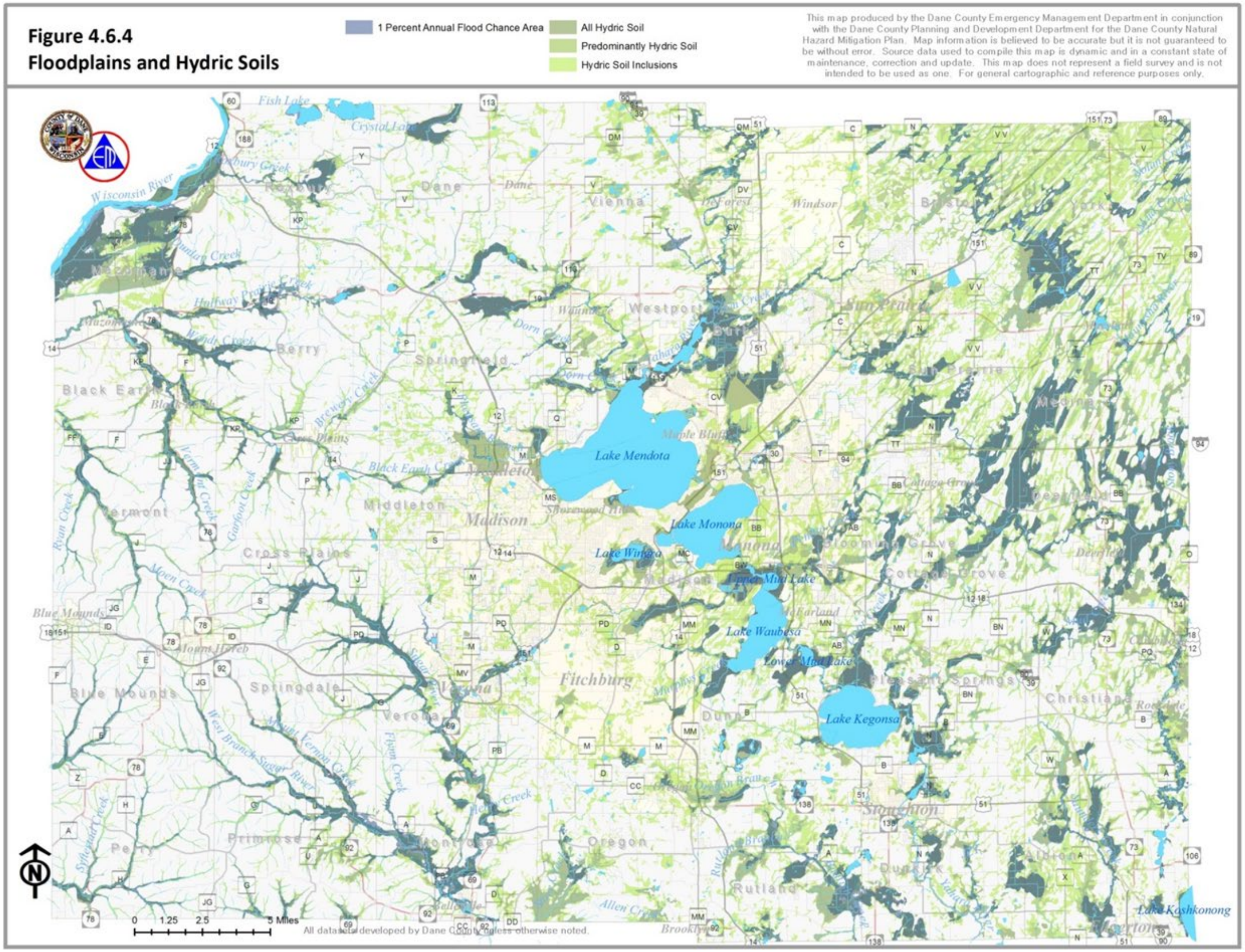
- Human Constructed Impediments to Flow. Bridges, culverts, and drainage ditches that are improperly sized have been noted as a significant factor in restricting the flow of water and exacerbating flood problems. This does not appear to be a systemic problem, but rather one that occurs in a few, specific isolated areas of the County.
- Loss of Wetlands. Wetlands are often found in floodplains and low-lying areas of a watershed. Many wetlands receive and store floodwaters, thus peak flows and volumes of floodwaters. Wetlands also serve as a natural filter, which helps to improve water quality. Wetland loss has affected all of Dane County. Wetlands have been tiled and drained to produce fertile farm fields and they have been filled and paved to prepare for development. Wetlands on the Yahara Chain of Lakes have also been lost during recent flood events as rising floodwaters detach and lift sections of marsh. The floating marsh sections have been subsequently removed to eliminate the navigational hazards they posed. Lakes in the Yahara Chain of Lakes have lost between half and nearly all of the wetlands associated with them since 1835.

  Healthy wetlands have the potential to store large volumes of floodwater. As wetlands become destroyed or degraded, their capacity to store water may be reduced. Water that would otherwise have been stored in the wetlands then contributes to increasing flood levels and flows. The maintenance and restoration of wetlands has the potential to be a very effective flood management tool.
- Stormwater Issues. Dane County is among the fastest growing and developing counties in the State of Wisconsin. The challenges of managing this rapid development are wide-ranging; however, one of the more significant impacts is the effect of development on the hydrology of the watershed. The effect of upstream development on downstream properties was widely recognized as significant contributing factor in Dane County's flood problems. In fact, development and other changes to the landscape in areas far outside the floodplain can have a profound impact on the magnitude and frequency of downstream flooding. This is a highly complex issue that includes elements of land-use decision-making, property rights, intergovernmental cooperation (or lack of), as well as the hydrology of the watershed and stormwater management practices. Many of these elements are well beyond the scope and charge of this Plan, however, the issues as related to stormwater management can at least be framed here.

- The Effects of Urbanization. Urbanization is one of the most severe land use impacts in terms of its lasting effects on hydrology, due to the much higher percentages of impervious or paved areas covering the land. Rural land surfaces are almost completely pervious, while about one-third of the land surface in urban areas is covered by rooftops and paved areas. The main effects of urbanization on the hydrology of an area include:
    - An increase in the total amount of rainfall running off the surface of the land.
    - A decrease in the amount of rainfall infiltrating into the soil.
    - More rapid runoff and much higher peak flows.
    - Reduced base flows in streams during dry weather periods.

  In addition to generating more surface runoff, which erodes the land surface and washes off more pollutants, the hydrologic effects of urbanization have less direct but more important downstream impacts. The increased peak storm runoff rates and reduced base flow associated with urbanization have serious negative impacts on receiving streams, usually resulting in erosion, sedimentation, streambank instability, and flooding. Combined with reduced base flow, the scenic, recreational and habitat values of the receiving streams can be seriously degraded unless a vigorous effort is made to provide management practices and programs to counter the effects of urbanization.

Figure 4.6.4 – Floodplains and Hydric Soils



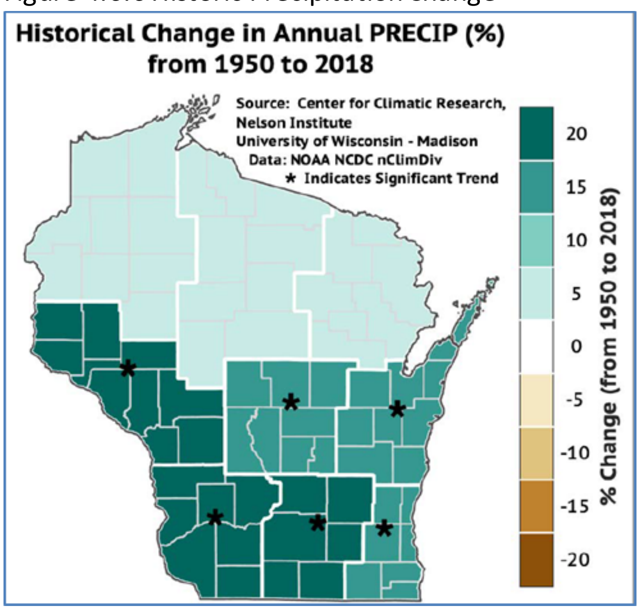
4.6.3 Impact of Climate Change on Future Conditions

The flood hazard in southern Wisconsin, including Dane County, is changing and all indications are that the risk is increasing. The Wisconsin Initiative on Climate Change Impacts (WICCI) is the primary source for the assessment of Dane County's changing flood risk.

Climate Trends

Wisconsin experienced a 10% increase in average annual precipitation over the 56-year period from 1950 to 2006. Wisconsin as a whole has become wetter, with an increase in annual precipitation of 3.1 inches. This observed increase in annual precipitation has primarily occurred in southern and western Wisconsin, while northern Wisconsin has experienced some drying. (WICCI, 2009). Dane County has seen an annual average increase in between 4.5 and 7 inches of precipitation over this time period. Figure 4.6.6 shows the statewide distribution of changes in annual average precipitation in this time period.

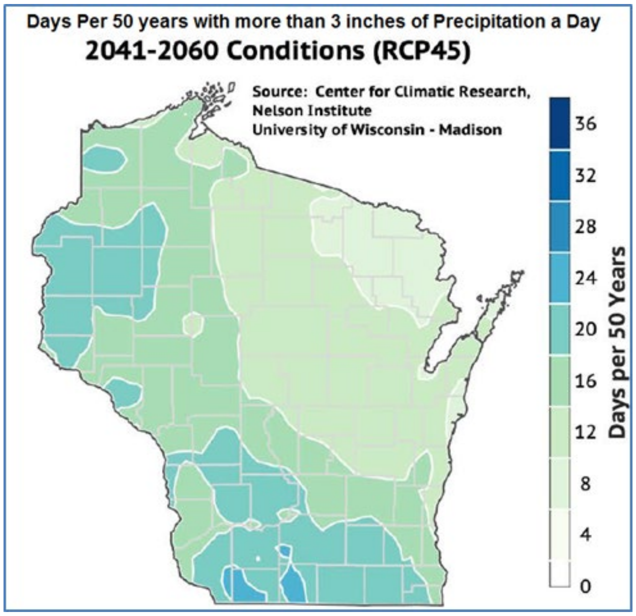
Figure 4.6.6 Historic Precipitation Change



In addition, both the frequency and magnitude of heavy rainfall events have been increasing. Madison, for example, has experienced a large number of intense precipitation events in the past decade: 24 days of two inches or more rainfall (compared with the previous maximum of 12 per decade since the 1950s) and nine days per decade of three inches or more rainfall (nearly as many as the previous five decades combined) (Wisconsin Initiative on Climate Change Impacts, Wisconsin's Changing Climate, Impacts and Adaptations, 2021).

Climate models suggest that these trends will continue, with an overall increase in wetter conditions and more intense rainfall. This trend is likely to lead to a subsequent increase in the severity and frequency of high flows and high water levels. Figure 4.6.7 indicates one model's projected change in annual average precipitation from 2041 to 2060.

Figure 4.6.7 Days per 50 years with more than 3 in Precipitation



Source: WICCI, 2021

Typically, heavy precipitation events of at least two inches occur roughly 12 times per decade (once every 10 months) in southern Wisconsin and 7 times per decade (once every 17 months) in northern Wisconsin. Based on one emission scenario, by the mid-21st century, Wisconsin may receive 2-3 more of these extreme events per decade, or roughly a 25% increase in their frequency. Figure 4.6.8 indicates the projected change in the frequency of 2" or greater precipitation events in days per decade in the 1981 to 2060 time period.

Seasonal Variations in Precipitation
(Wisconsin Initiative on Climate Change Impacts, Wisconsin's Changing Climate, Impacts and Adaptations, 2021)

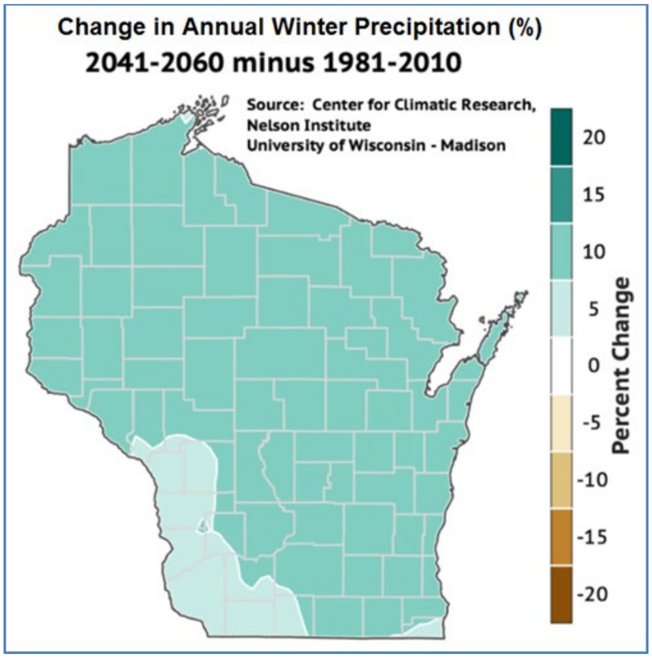
Spring: WICCI projections indicate trends more precipitation and more frequent intense events, especially during early spring. As in winter, early spring precipitation is more likely to fall as rain than as snow.

Summer: Summertime precipitation projections are less certain, with little agreement among climate models. This creates difficulty in predicting impacts from precipitation, or lack thereof, during summer.

Autumn: Fall precipitation is projected to increase slightly by the middle of the next century.

Winter: Winter precipitation is projected to increase. The amount of precipitation that falls as rain rather than snow is expected to increase significantly, and freezing rain is more likely to occur. As a result, snowfall, snowfall depth, and extent of snow cover are expected to decrease.

Figure 4.6.8 Change in Annual Winter Precipitation



Source: WICCI, Historic Trends and Projections, 2021

Uncertainty in Projecting Future Conditions

Although climate change effects are already being observed, the earth's climate is an immensely complex system. Although observations, theory, and climate models continue to improve, any attempt at predicting future climate conditions is bound to have uncertainty in the resulting projection. This uncertainty does not mean that scientists and climate experts don't know anything about future conditions. In fact, climate scientists have a great deal of certainty that human activities are causing the planet to warm and this warming is in turn, driving an increase in extreme weather events.

It is becoming clear that historic patterns can no longer be used to predict future climate conditions, particularly when it comes to stormwater management and flood risk management. Planning based on historical climate conditions that no longer exist can actually make the community more vulnerable to current and future conditions.

Implications

WICCI's most recent predictions indicate that annual average precipitation may continue to increase through 2060, including a higher incidence of more "extreme" rainfall events (those that generate more than six inches of precipitation in a 24-hour period). The expected increases in rainfall frequency and intensity are likely to put additional stress on natural hydrological systems and community stormwater systems. Floodplain developments and low income communities in urban areas are among the areas most vulnerable to increased flooding.

Heavier snowfalls in the winter will lead to intensified spring flooding, and groundwater levels will remain high even in non-floodplain areas. Such changes in climate patterns can lead to the development of compounding events that interact to create extreme conditions. This confluence of events was observed in 2008 and 2018, when saturated spring soils and a record late summer early fall rainfall combined to create the most damaging floods in state history. Some areas that are not in mapped floodplains may experience unexpected groundwater flooding, as observed during past flood events in Spring Green, and locally, in the Town of Vienna. Flooding caused by high groundwater levels typically recedes more slowly than riverine flooding, slowing the response and recovery process. Groundwater-fed rivers and streams are also likely to experience heightened flooding when groundwater levels are high.

Jurisdictions updating or installing stormwater management systems should consider potentially larger future discharge amounts when sizing culverts and drainage ways; storage capacity can also be increased by building retention basins to hold excess stormwater. Communities already prone to flooding should be prepared for a potential increase in facility closures and/or damages, as well as an increase in public demand for flood response and assistance. Natural features that experience repeated flooding may manifest changes in the form of stream bank instability and changing shoreline, floodplain, and wetland boundaries. Communities may also wish to plan for the potential loss of cropland and damage to both private property and public infrastructure such as bridges.

The environmental impacts of flooding include erosion, surface and groundwater contamination, and reduced water quality. The threat of more frequent flood events may thus be a concern particularly for communities who depend on lakes, rivers, or trout streams for tourism. Rural communities may experience increases in well contamination and road washouts, while urban areas may be particularly vulnerable to flash flooding as heavy rain events quickly overwhelm the ability of a more impermeable environment to absorb excess stormwater. (Wisconsin Emergency Management, Wisconsin Threat and Hazard Identification and Risk Assessment, 2021)

4.6.4 Impact Assessment

Because of the varied nature and widespread damage floods cause, this profile is not discussed in terms of direct and indirect potential impacts. Instead, each area that flooding impacts is broken down and explained, including an analysis of both direct and indirect impacts. Specific examples of how floods negatively impact Dane County are summarized below:

- Floods cause damage to private property that often creates financial hardship for individuals and families.
- Floods can cause injury and death.

- Floods cause damage to public infrastructure resulting in increased public expenditures and demand for tax dollars.
- Floods cause loss of personal income for agricultural producers that experience flood damages.
- Floods cause loss of income to businesses relying on recreational uses of County waterways.
- Floods cause emotional distress on individuals and families.

Most homeowner's policies do not cover damages caused by flooding. Flood loses are covered under a separate flood insurance policy sold through the National Flood Insurance Program (NFIP). Only a small percentage of home owners actually have flood insurance policies. This means that when flood damages do occur, the costs to repair and recover from the loss are uninsured losses that are borne almost entirely by the property owner.

Building Damage

In terms of numbers of people affected and total economic losses, damage to buildings, especially residences is usually the County's largest single flood problem. Due to the relatively shallow flood depths, soaking causes the most common type of damage inflicted by a flood. When soaked, many materials change their composition or shape. Wet wood will swell and, if dried too quickly, will crack, split or warp. Plywood can break apart. Gypsum drywall will fall apart if it is bumped before it dries out. The longer these materials are wet, the more moisture, sediment and pollutants they will absorb. Walls present a special problem: a "wicking" effect pulls water up through wood and wallboard, soaking materials several feet above the actual high-water line. Structural damage to buildings has not been a systemic problem in Dane County.

Soaking can also cause extensive damage to household and other building contents. Wooden furniture may become so badly warped that it cannot be used. Other furnishings such as upholstery, carpeting, mattresses, and books usually are not worth drying out and restoring. Electrical appliances and gasoline engines will not work safely until they are professionally dried and cleaned. In short, while a building may look sound and unharmed after a flood, the waters can cause a lot of damage. To properly clean a flooded building, the walls and floors should be stripped, cleaned, and allowed to dry before being recovered. This is expensive and can take weeks.

Sewer and Wastewater

Sewer and wastewater service and infrastructure are compromised during flooding events in many locations around the County. Sewer backups in residential basements are the primary result of overtaxed wastewater systems. Past surveys have identified 100's of residences that have had sewer backup problems. During major storm events, flows to the treatment plants increase, and in some cases triple due to water infiltration into the piping system. Failing pumps, and inflow meter damage, are also a problem.

Road, Shoulder, and Ditch Flooding

There are a number of areas of the county prone to flooding on roadways. A possible contributing factor is under-sized culverts that become damaged during high water flows. Very few bridges have been damaged though they may play a role in constricting water flows. This flooding, and often-associated road or ditch damage, inhibits emergency vehicle movement and could compromise public safety.

Farmland Flooding

Dane County is the one of the most fertile counties in the state of Wisconsin, and as a result farming plays a major role in the local economy. Flooding of farm fields and crop loss is an additional stress on an already highly stressed profession. The amount of crop loss in the County per acre varies across the landscape depending upon the topography—generally the more flat the land the more pervasive the problem. The east side of the County experiences relatively severe crop losses on occasion; the west side of the County, though not without this impact, is less affected. Crop loss is capricious—timing of storms, duration of standing water, and type of crops play a part. Prolonged flooding occurring while crops are immature can lead to total crop loss for a year. Corn, for instance, has difficulty withstanding flooded soil. Flooding of short duration or later in the growing season may have little or no effect on the harvest.

Erosion and Stream Pollution

Due to the agricultural character of rural Dane County, erosion is a concern. Ditches that once conveyed water quickly have become laden with soil, decreasing their capacity to convey water. Construction sites also contribute to siltation in streams. Siltation and trash also compromise stream quality.

Ongoing and successful stream restoration projects, and the depositing of organic materials in streams, increase woody matter in stream channels. The buildup of organic material slows water flows. Woody material builds up along the buttresses of bridges and other human-made obstructions in the river channels and alongside river channels themselves. While the slowing of water may be beneficial for downstream residents, areas where the build-ups occur increase the risk of flooding.

Public Health and Safety

There is very little available data on health problems caused by flooding in Dane County because data collection mechanisms are varied, particularly in terms of reported occurrences versus actual occurrences. The first impact comes from the water itself and is considered the direct impact of flooding. Floodwaters carry whatever was on the ground that the upstream runoff picked up, including dirt, oil, animal waste, and lawn, farm and industrial chemicals. This can contribute polluted waters to the receiving streams.

Floodwaters saturate the ground, which can lead to infiltration into sanitary sewer lines. When wastewater treatment plants exceed capacity, there is nowhere for the sewage to flow. Infiltration and lack of treatment lead to overloaded sewer lines that can back up into low lying areas and homes. Even though diluted by floodwaters, raw sewage can be a breeding ground for bacteria, such as E.coli, and other disease causing agents.

The second set of health concerns occur after the water is gone, and are considered indirect impacts of flooding. Stagnant pools become breeding grounds for mosquitoes, and wet areas of a building that have not been cleaned breed mold and mildew. A building that is not thoroughly and properly cleaned becomes a health hazard, especially for small children and the elderly. Another health hazard occurs when heating ducts in a forced-air system are not properly cleaned after inundation. When the furnace or air conditioner is turned on, mold and sediments left in the ducts are circulated throughout the building and breathed by the occupants.

Finally, flooding creates long-term psychological impacts on victims. The cost and labor needed to repair a flood-damaged home puts a severe strain on people, especially the unprepared and uninsured. There is also a long-term problem for those who know that their homes can be flooded again. The resulting stress on floodplain residents takes its toll in the form of aggravated physical and mental health problems. This is also considered an indirect impact of flooding.

4.6.5 Vulnerability Assessment

Population

Historical data yields little information on deaths or injuries by flooding and flash flooding in the County. This is likely due to the slow-rise nature of flooding around lakes and lowlands, giving people adequate time to evacuate. Most flood-related deaths and injuries around the country are associated with persons who try to drive vehicles into flooded roads and underestimate the depth and velocity of floodwaters.

There are also portions of the population that are especially vulnerable to the direct and indirect impacts of flooding. The quality of one’s housing and living conditions affects an individual’s vulnerability to flooding and extreme storms. Residents living in poor quality housing and populations without access to housing or a strong social network are at higher risk of adverse health impacts from flooding. Financially insecure households often lack the resources necessary to prepare for, mitigate, or recover from the health impacts of flood events. The impoverished are also less likely to have access to health networks and receive treatment for preventable conditions associated with the secondary impacts of flooding.

Property

Flooding of residential structures in Dane County is a major concern. This type of flooding has several causes: river flooding, high lake levels, sewer backups, stormwater runoff from urban areas as well as farmland, and high groundwater. Effects include flooded basements and first floor flooding. As the assessment of the 2008 flood claims information (in a subsequent section, beginning on page 4-52) shows, damages caused by flooding in Dane County is not restricted to mapped floodplains or any other readily identifiable indicator. Under the right (or wrong) conditions, intense heavy rains have the potential to overwhelm local drainage and stormwater systems just about anywhere in the county.

Unless a property owner has flood insurance, damages to buildings and building contents are typically uninsured losses.

4.6.6 Potential for Future Losses

Given the interplay of the contributing influences, the potential exists for flood damages to continue to rise. While the potential for future damages is difficult to calculate accurately, there are indicators and acceptable methods for estimating future losses. The Federal Emergency Management Agency recommends a methodology of estimating future losses based on an inventory of buildings and structures that lie within the flood hazard boundary of the 100-year flood event. This method does not capture the loss potential for structures not located in mapped floodplains. Those losses, however, are difficult to quantify and predict. The flood plain structure inventory provides a starting point for discussion and a standard means for estimating future losses.

Table 4.6.2 provides an estimate of the extent of damage from various flood depths on different types of structures. This table is from FEMA's cost-benefit analysis module and has been compiled based on flood damage data from across the country. To utilize this table, the approximate elevations of both the building first floor and the water level during the 100-year flood are needed. From the 100-year flood elevation, subtract the first floor elevation of the building. This figure then can be used to estimate the extent of damage to the type of building that would be flooded. For example, if the 100-year flood event elevation is approximately 848 feet above mean sea level and a one story home, with basement assessed at $112,000 has a first floor elevation of 844 feet, it is estimated that this four feet of flooding would cause 28 percent or $31,360 in damage to the building.

Table 4.6.2 Estimation of Flood *Damage to Structures*

First Floor Flood Depth (Feet)	One Story – No Basement (% of Building Damaged)	Two Story – No Basement (% of Building Damaged)	One or Two Story w/ Basement (% of Building Damaged)	Manufactured Home (% of Building Damaged)
-2	0	0	4	0
-1	0	0	8	0
0	9	5	11	8

First Floor Flood Depth (Feet)	One Story – No Basement (% of Building Damaged)	Two Story – No Basement (% of Building Damaged)	One or Two Story w/ Basement (% of Building Damaged)	Manufactured Home (% of Building Damaged)
1	14	9	15	44
2	22	13	20	63
3	27	18	23	73
4	29	20	28	78
5	30	22	33	80
6	40	24	38	81
7	43	26	44	82
8	44	29	49	82
>8	45	33	51	82

Source: Federal Emergency Management Agency. Estimation of damage potential to buildings based on flood depth relative to the first floor of the building. The negative numbers in the First Floor Flood Depth column indicate flood levels that are lower than the first floor of the building. The resulting flood damage potential is expressed as a percentage of the assessed value of the building.

Flooding also causes damages to the contents of buildings that are flooded. Table 4.6.3 provides a method for estimating the damage potential to building contents. Contents damage includes damage to furniture, appliances, clothing, and other incidental items not included in the building value.

Table 4.6.3 Estimation of Flood Damage to Building Contents

First Floor Flood Depth (Feet)	One Story – No Basement (% of Building Damaged)	Two Story – No Basement (% of Building Damaged)	One or Two Story with Basement (% of Building Damaged)	Manufactured Home (% of Building Damaged)
-2	0	0	6	0
-1	0	0	12	0
0	13.5	7.5	16.5	12
1	21	13.5	22.5	66
2	33	19.5	30	90
3	40.5	27	34.5	90
4	43.5	30	42	90
5	45	33	49.5	90
6	60	36	57	90
7	64.5	39	66	90

First Floor Flood Depth (Feet)	One Story – No Basement (% of Building Damaged)	Two Story – No Basement (% of Building Damaged)	One or Two Story with Basement (% of Building Damaged)	Manufactured Home (% of Building Damaged)
8	66	43.5	73.5	90
>8	67.5	49.5	76.5	90

Source: Federal Emergency Management Agency. Estimation of damage potential to building contents based on flood depth relative to the first floor of the building. The negative numbers in the First Floor Flood Depth column indicate flood levels that are lower than the first floor of the building. The resulting flood damage potential is expressed as a percentage of the total value of the building contents.

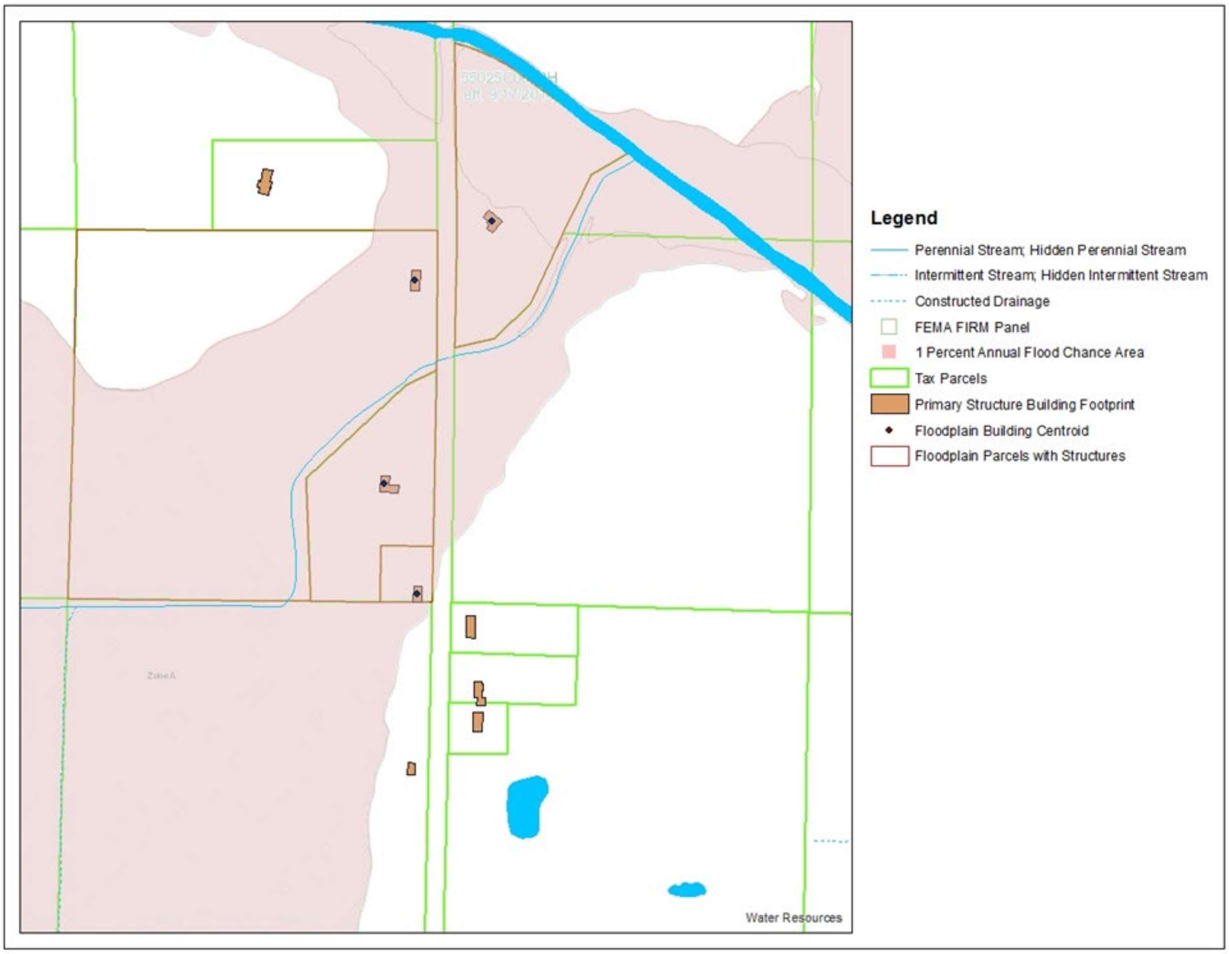
Structures in the Floodplain

A flood damage assessment for Dane County was estimated by using a comparison of a digital version of FEMA's Flood Insurance Rate Maps, Dane County tax parcel data, and Dane County's building footprint inventory. A preliminary assessment was conducted using a GIS overlay of these three data layers. This provided an initial inventory of 977 primary structures located within the mapped floodplains of the County. In order to potential for damages, the following data and assumptions were used:

- 100-year flood elevations at the location of each identified structure were derived from FEMA's Digital Flood Insurance Rate Map layer.
- Structure elevations were generated by interpolating the elevation from the County's 2-foot digital elevation model. Site specific survey data was not used for this analysis.
- Building values are derived from the assessed value of improvements contained within the County parcel data.
- The inventory is limited to buildings classified as "primary" structures only. Accessory buildings are not included in this assessment.
- Structures on tax exempt properties are included in the inventory. Property values for these buildings, however, are not available and are not assessed in the damage estimates.
- All identified at-risk structures are assumed to be buildings with basements.
- Building contents values are estimated based on table 4.6.3. This estimation is based on FEMA hazard assessment and planning guidelines.
- The damage potential for structures located within the A-Zone on the FIRM is unknown. A-Zones are areas where there is a mapped flood hazard, but no base flood elevations have been determined. The lowest first floor damage potential percentages in tables 4.6.2 and 4.6.3 were used for all Zone A structures (-2 feet).
- Zone AE are flood risk areas where the base flood elevation has been determined.
- Structures located within Zone X (no Special Flood Hazard Area) were eliminated from the inventory.

- This analysis was repeated for properties in the floodway and the 500-year flood plain for inclusion in the local plan attachments.

Figure 4.6.12 100-year Floodplain Structure Inventory and Loss Potential Sample Map



This is an approximation based on a preliminary analysis. Since the actual elevations of the identified structures are unknown, a detailed study would be necessary to determine the actual damages that would be incurred to these structures in a base flood. A summary of the resulting estimation of the future damage potential for a 100-year flood event is summarized in the tables that follow:

- Table 4.6.4 indicates the damage potential estimate by building land use category.
- Table 4.6.5 indicates the damage potential estimate by watershed.
- Table 4.6.6-7 indicates structures and damage potential estimate by local government jurisdiction.
- Figure 4.6.13 is an overview map of the locations of the identified structures.

Limitations of this Assessment

The evaluation of the potential for future losses based on a inventory of structures located within the boundaries of mapped flood hazard areas has a number of noteworthy limitations and biases. These limitations do not necessarily invalidate the assessment, but they are important to acknowledge.

1. The assessment is biased toward overestimating damages to primary structures in the mapped floodplains. This results from assumptions built into the analysis:
    a. All buildings in the floodplain are assumed to be single or two story homes with basements, except those known to be manufactured (mobile) homes or commercial structures. This generalization is necessary because data on the specific construction of each building is not available. The projected flood loss for buildings with basements is higher than that of buildings without basements.
    b. The estimated elevation of each building in the floodplain is projected using the County's GIS digital elevation model. This does not account for any site-specific mitigation activities on the property, such as flood proofing or elevation of the structure above the base flood elevation. Again, this generalization is necessary because site-specific data is not available. These mitigating factors would reduce losses, but are not accounted for in the analysis.
2. The assessment is biased toward underestimating damages to structures in the mapped floodplains due to other assumptions in the model:
    a. Only buildings identified as "Primary" structures in the County's building footprint inventory are included in the assessment. There are a great deal of buildings identified as "Accessory" buildings that are not included. This bias is mitigated to some extent by evaluating to total value of structural improvements on each property, thus combining the value of Primary and Accessory structures.
    b. The value of tax-exempt structures is not available and is not included in the assessment. This includes more than 125 properties, for which the value, if assessed, would be significant.
3. There are number of multi-unit buildings, primarily condominiums, for which the value of the flood affected portion of the building is difficult to assess. Assumptions used in the model have the potential for this to be a bias in either direction, potentially overestimating the damages on some buildings and underestimating the losses on others.
4. The assessment evaluates the loss potential for only those structures located within the mapped 100-year floodplain. As noted in past flood events, there are numerous other factors that influence flood losses in Dane County and damages to structures in the floodplain represent only a fraction of the total losses. This is a bias toward underestimating future flood losses.
5. The assessment does not account for changing conditions, particularly those due to climate change and urbanization in the watershed. While difficult to quantify, these factors are increasing the potential for future flood losses. This is a bias toward underestimating future flood losses.

6. Flooding is very rarely, if ever, uniformly damaging countywide. This assessment should be thought of as a countywide exposure to risk, not a projection of the countywide future losses in associated with a single flood event. Actual flood events are typically much more localized. Viewing this as a countywide damage potential creates a bias toward overestimating damages.

Table 4.6.4 Damage Potential Estimate for Structures in 100-year Floodplain – Summarized by Land Use Category

Land Use Category	# of Structures in the 100-YR Floodplain			Estimated Potential for Flood Damage (100-year Flood)				
	Zone A	Zone AE	Total	Assessed Value of Structures	Estimated Value of Contents	Estimated Damage to Contents	Estimated Damage to Structures	Estimated Loss Potential Total
Agriculture	1	1	2	$208,500	$208,500	$13,554	$9,036	$22,590
Assembly	2	1	3	$54,000	$54,000	$3,468	$2,312	$5,780
Commercial Sales	13	25	38	$14,374,100	$21,561,150	$2,055,447	$913,532	$2,968,979
Commercial Services	15	7	22	$10,782,100	$10,782,100	$745,661	$497,107	$1,242,768
Education	2	0	2	Not Available	Not Available	Not Available	Not Available	Not Available
Government	1	1	2	Not Available	Not Available	Not Available	Not Available	Not Available
Health	1	0	1	$135,500	$203,250	$12,195	$5,420	$17,615
Industrial	10	6	16	$12,233,500	$12,233,500	$1,876,049	$1,250,699	$3,126,748
Outdoor	6	8	14	$8,921,400	$8,921,400	$2,081,673	$1,387,782	$3,469,455
Religion	1	0	1	Not Available	Not Available	Not Available	Not Available	Not Available
Residential	325	530	856	$134,465,600	$67,232,800	$8,641,215	$11,729,042	$20,370,257
Transportation	2	14	16	$26,205,500	$39,308,250	$9,979,754	$4,435,446	$14,415,200
Utility	2	3	5	Not Available	Not Available	Not Available	Not Available	Not Available
Total	381	596	977	$207,380,200	$160,504,950	$25,409,015	$20,230,376	$45,639,391

Source: Dane County Emergency Management & Land Information Office Data, 2021

Table 4.6.5 Damage Potential Estimate for Structures in 100-year Floodplain – Summarized by Watershed, Sorted by Lowest to Highest Loss Potential

Watershed Name	# of Structures in the 100-YR Floodplain			Estimated Potential for Flood Damage (100-year Flood)				
	Zone A	Zone AE	Total	Assessed Value of Structures	Estimated Value of Contents	Estimated Damage to Contents	Estimated Damage to Structures	Estimated Loss Potential Total
Lower Crawfish River	0	1	1	$142,500	$71,250	$4,275	$5,700	$9,975
Lake Wisconsin	0	1	1	$170,500	$85,250	$25,575	$34,100	$59,675
Maunesha River	2	2	4	$382,200	$191,100	$26,297	$35,063	$61,360
Allen Creek and Middle Sugar River	2	3	5	$2,008,500	$1,004,250	$60,255	$80,340	$140,595
Upper Koshkonong Creek	13	5	18	$3,776,300	$3,581,600	$271,813	$226,941	$498,754
Mill and Blue Mounds Creek	3	5	8	$1,509,400	$1,558,600	$357,461	$177,685	$535,146
West Branch Sugar River - Mt. Vernon Creek	5	8	13	$1,356,600	$678,300	$271,302	$375,724	$647,026
Yahara River and Lake Mendota	30	10	40	$6,234,800	$3,815,300	$353,150	$320,400	$673,550
Gordon Creek	1	5	6	$7,131,400	$7,104,500	$448,866	$316,998	$765,864
Badfish Creek	6	21	27	$3,897,900	$1,948,950	$431,517	$586,774	$1,018,291
Six Mile and Pheasant Branch Creeks	72	54	126	$23,894,500	$17,139,450	$1,567,009	$1,540,002	$3,107,011
Yahara River and Lake Monona	71	103	174	$22,790,200	$11,782,200	$1,466,465	$1,830,038	$3,296,503
Yahara River and Lake Kegonsa	50	38	88	$8,980,300	$5,390,000	$1,481,576	$1,844,643	$3,326,219
Upper Sugar River	32	43	75	$16,339,700	$11,142,900	$2,271,481	$1,988,441	$4,259,922
Roxbury Creek and Lower Wisconsin River	16	180	196	$24,964,300	$15,564,000	$1,965,516	$2,360,348	$4,325,864

Watershed Name	# of Structures in the 100-YR Floodplain			Estimated Potential for Flood Damage (100-year Flood)				
	Zone A	Zone AE	Total	Assessed Value of Structures	Estimated Value of Contents	Estimated Damage to Contents	Estimated Damage to Structures	Estimated Loss Potential Total
Lower Koshkonong Creek	13	51	64	$36,873,300	$27,656,600	$3,085,986	$2,425,992	$5,511,978
Black Earth Creek	65	66	131	$46,927,800	$51,790,700	$11,320,472	$6,081,187	$17,401,659
Total	**381**	**596**	**977**	**$207,380,200**	**$160,504,950**	**$25,409,015**	**$20,230,376**	**$45,639,391**

Source: Dane County Emergency Management & Land Information Office Data, 2021

Table 4.6.6 Damage Potential Estimate for Structures in 100-year Floodplain – Summarized by Jurisdiction

Municipality	# of Structures in 100-YR Floodplain			Estimated Potential for Flood Damage (100-yr Flood)				
	Residential	Non-Residential	Total	Assessed Value of Structures	Estimated Value of Contents	Estimated Damage to Contents	Estimated Damage to Structures	Estimated Loss Potential Total
City								
Edgerton	0	0	0	$0	$0	$0	$0	$0
Fitchburg	1	0	1	$164,203	$82,102	$4,926	$6,568	$11,494
Madison	61	28	89	$72,714,415	$75,109,723	$14,481,554	$7,790,838	$22,272,392
Middleton	17	3	20	$12,489,815	$10,155,282	$643,096	$544,631	$1,187,727
Monona	52	7	59	$19,484,797	$13,721,338	$1,209,552	$1,294,420	$2,503,972
Stoughton	10	6	16	$3,786,283	$2,563,434	$309,280	$257,071	$566,350
Sun Prairie	6	1	7	$1,947,010	$1,001,241	$135,940	$179,034	$314,975
Verona	16	11	27	$4,036,234	$2,799,462	$457,535	$329,703	$787,238
Town								
Albion	50	2	52	$4,806,198	$2,477,465	$502,083	$647,602	$1,149,685
Berry	8	4	12	$1,717,723	$858,861	$153,534	$204,712	$358,247
Black Earth	0	0	0	$0	$0	$0	$0	$0
Blooming Grove	0	0	0	$0	$0	$0	$0	$0
Blue Mounds	5	0	5	$697,476	$348,738	$78,170	$104,227	$182,397
Bristol	0	0	0	$0	$0	$0	$0	$0
Burke	0	0	0	$0	$0	$0	$0	$0
Christiana	4	0	4	$726,759	$363,379	$33,600	$44,799	$78,399
Cottage Grove	5	0	5	$1,259,037	$629,519	$42,193	$56,258	$98,451
Cross Plains	6	0	6	$1,198,041	$599,021	$47,904	$63,872	$111,776
Dane	1	0	1	$331,058	$165,529	$57,108	$76,143	$133,251
Deerfield	0	0	0	$0	$0	$0	$0	$0
Dunkirk	7	1	8	$1,206,439	$603,220	$103,497	$137,996	$241,492
Dunn	94	4	98	$14,857,057	$8,537,617	$933,618	$1,051,738	$1,985,356
Madison	0	0	0	$0	$0	$0	$0	$0
Mazomanie	51	0	51	$4,713,046	$2,356,523	$328,917	$438,556	$767,472
Medina	1	0	1	$288,737	$144,368	$32,483	$43,310	$75,793
Middleton	0	0	0	$0	$0	$0	$0	$0
Montrose	20	4	24	$3,055,104	$2,029,443	$209,720	$199,324	$409,044
Oregon	0	0	0	$0	$0	$0	$0	$0

Perry	1	0	1	$167,850	$83,925	$5,035	$6,714	$11,749
Pleasant Springs	35	0	35	$5,130,184	$2,565,092	$216,176	$288,234	$504,409
Primrose	2	0	2	$266,968	$133,484	$20,712	$27,616	$48,328
Roxbury	145	1	146	$7,771,023	$3,885,512	$2,278,786	$3,238,366	$5,517,152
Rutland	6	0	6	$1,148,206	$574,103	$101,315	$135,087	$236,403
Springdale	8	2	10	$2,032,979	$1,316,387	$199,120	$199,515	$398,635
Springfield	0	0	0	$0	$0	$0	$0	$0
Sun Prairie	2	1	3	$602,667	$414,928	$24,896	$24,107	$49,002
Vermont	20	1	21	$2,758,633	$1,380,919	$222,355	$295,575	$517,930
Verona	7	1	8	$1,046,104	$559,959	$84,539	$104,599	$189,138
Vienna	0	0	0	$0	$0	$0	$0	$0
Westport	77	5	82	$20,643,279	$13,275,083	$1,465,869	$1,619,215	$3,085,084
York	2	0	2	$315,257	$157,628	$9,458	$12,610	$22,068
Village								
Belleville	9	3	12	$1,239,368	$628,027	$66,796	$88,393	$155,190
Black Earth	13	1	14	$2,182,928	$1,241,191	$97,676	$118,257	$215,934
Blue Mounds	0	0	0	$0	$0	$0	$0	$0
Brooklyn	0	0	0	$0	$0	$0	$0	$0
Cambridge	4	8	12	$2,014,526	$2,401,110	$517,889	$268,739	$786,629
Cottage Grove	0	0	0	$0	$0	$0	$0	$0
Cross Plains	36	11	47	$12,154,890	$9,362,665	$1,967,567	$1,474,003	$3,441,570
Dane	0	0	0	$0	$0	$0	$0	$0
Deerfield	0	0	0	$0	$0	$0	$0	$0
DeForest	5	0	5	$574,932	$287,466	$29,042	$38,723	$67,764
Maple Bluff	1	1	2	$359,678	$179,839	$10,790	$14,387	$25,177
Marshall	0	2	2	$195,585	$102,268	$7,076	$8,450	$15,526
Mazomanie	39	2	41	$4,557,241	$2,399,287	$264,138	$325,637	$589,775
McFarland	1	0	1	$19,669	$9,835	$590	$787	$1,377
Mount Horeb	0	1	1	$0	$0	$0	$0	$0
Oregon	8	7	15	$10,934,417	$9,691,292	$586,838	$444,524	$1,031,362
Rockdale	0	0	0	$0	$0	$0	$0	$0
Shorewood Hills	1	0	1	$0	$0	$0	$0	$0
Waunakee	14	4	18	$2,839,298	$1,801,703	$108,102	$113,572	$221,674
Windsor	4	0	4	$720,018	$360,009	$27,489	$36,652	$64,141
Total	**855**	**122**	**977**	**$229,155,121**	**$177,357,970**	**$28,076,964**	**$22,354,565**	**$50,431,529**

Source: Damage estimates calculated by Dane County Emergency Management & Land Information Office Data, 2021

Note: Why include the 500 year floodplain structures?
As reflected in table 4.6.9, over 90% of flood losses in the 2018 flood occurred outside of the 100 year floodplain. Our understanding of flood risk is changing within the context of climate change, and this table is set to form a basis for an investigative approach toward mitigating emerging risks. Flood damage potentials are not available for the 500 year floodplain due to data availability.

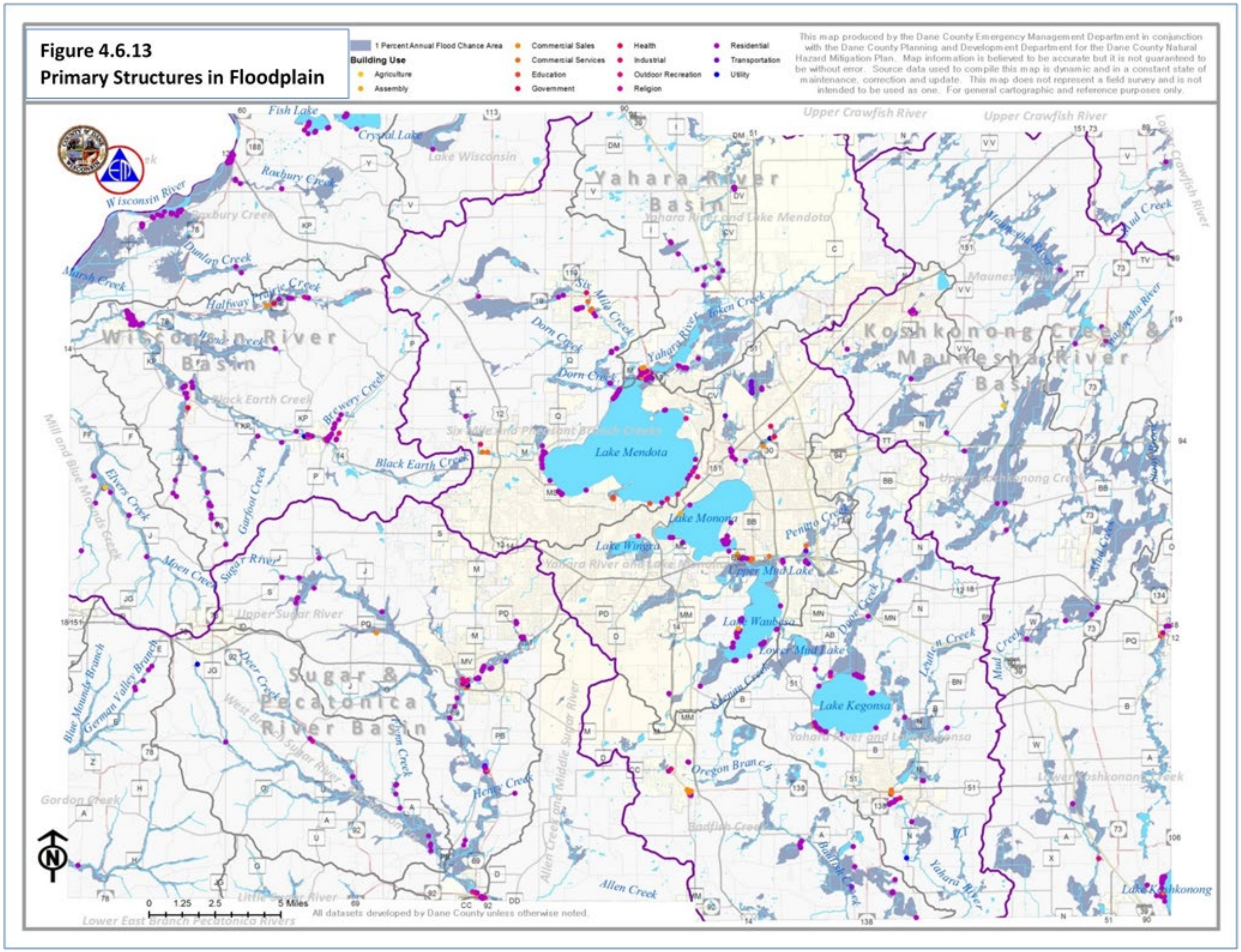
Table 4.6.7 Structures in 500-year Floodplain – Summarized by Jurisdiction

Municipality	Number of Structures in 500-year Floodplain		
	Residential	Non-Residential	Total
City			
Edgerton	0	0	0
Fitchburg	1	1	2
Madison	281	9	290
Middleton	121	4	125
Monona	201	6	207
Stoughton	9	3	12
Sun Prairie	22	2	24
Verona	60	5	65
Town			
Albion	65	3	68
Berry	8	3	11
Black Earth	1	1	2
Blooming Grove	1	1	2
Blue Mounds	6	1	7
Bristol	0	0	0
Burke	0	0	0
Christiana	3	1	4
Cottage Grove	5	1	6
Cross Plains	6	1	7
Dane	1	1	2
Deerfield	0	0	0
Dunkirk	8	1	9
Dunn	157	4	161
Madison	0	0	0
Mazomanie	61	3	64
Medina	5	3	8
Middleton	0	1	1
Montrose	27	5	32
Oregon	0	0	0

Municipality	Number of Structures in 500-year Floodplain		
	Residential	Non-Residential	Total
Perry	1	1	2
Pleasant Springs	62	3	65
Primrose	2	1	3
Roxbury	112	1	113
Rutland	6	1	7
Springdale	6	2	8
Springfield	4	1	5
Sun Prairie	2	1	3
Vermont	19	1	20
Verona	8	3	11
Vienna	4	1	5
Westport	93	3	96
York	1	2	3
Village			
Belleville	34	3	37
Black Earth	12	2	14
Blue Mounds	0	0	0
Brooklyn	0	0	0
Cambridge	6	4	10
Cottage Grove	0	0	0
Cross Plains	66	4	70
Dane	0	0	0
Deerfield	0	0	0
DeForest	13	3	16
Maple Bluff	1	1	2
Marshall	7	4	11
Mazomanie	40	2	42
McFarland	10	3	13
Mount Horeb	0	0	0
Oregon	26	4	30
Rockdale	1	1	2
Shorewood Hills	0	0	0
Waunakee	31	4	35
Windsor	6	2	8
Total	**1,622**	**180**	**1,802**

Source: Dane County Emergency Management & Land Information Office Data, 2021

Figure 4.6.13 Primary Structures in Floodplain



Flood Insurance Claims and Repetitive Losses

There are 74 properties in Dane County on record as having made a total of 108 flood insurance claims through the NFIP, totaling more than $2.4 million since 1978. Figure 4.6.13 shows the approximate locations of these properties. Locations are not shown in detail for privacy reasons. These are all residential properties with the exception of one commercial/office property.

A “Repetitive Loss” property is one that has received two or more flood insurance claim payments for at least $1,000 each in any 10 year period since 1978. There are sixteen “repetitive loss” properties in Dane County. Seven of the sixteen repetitive structures have been mitigated, two were elevated above the base flood elevation, and five were acquired and demolished. Of the remaining nine properties, only four maintain active NFIP policies. Repetitive loss properties are also indicated on Figure 4.6.14. Unmitigated repetitive loss properties with active polices are located in the following jurisdictions:

- City of Monona: One residential property
- Village of Black Earth: One residential property
- Town of Madison: One commercial property
- Town of Westport: One residential property

Repetitive loss properties are important to the National Flood Insurance Program because they account for one-third of national flood insurance claim payments. There are several FEMA programs that encourage communities to identify the causes of their repetitive losses and develop a plan to mitigate the losses. The repetitive loss properties in the County are scattered around the County, thus there are not many distinct repetitive loss “areas.” Addressing the areas where these repetitive losses occur is both a County and national priority.

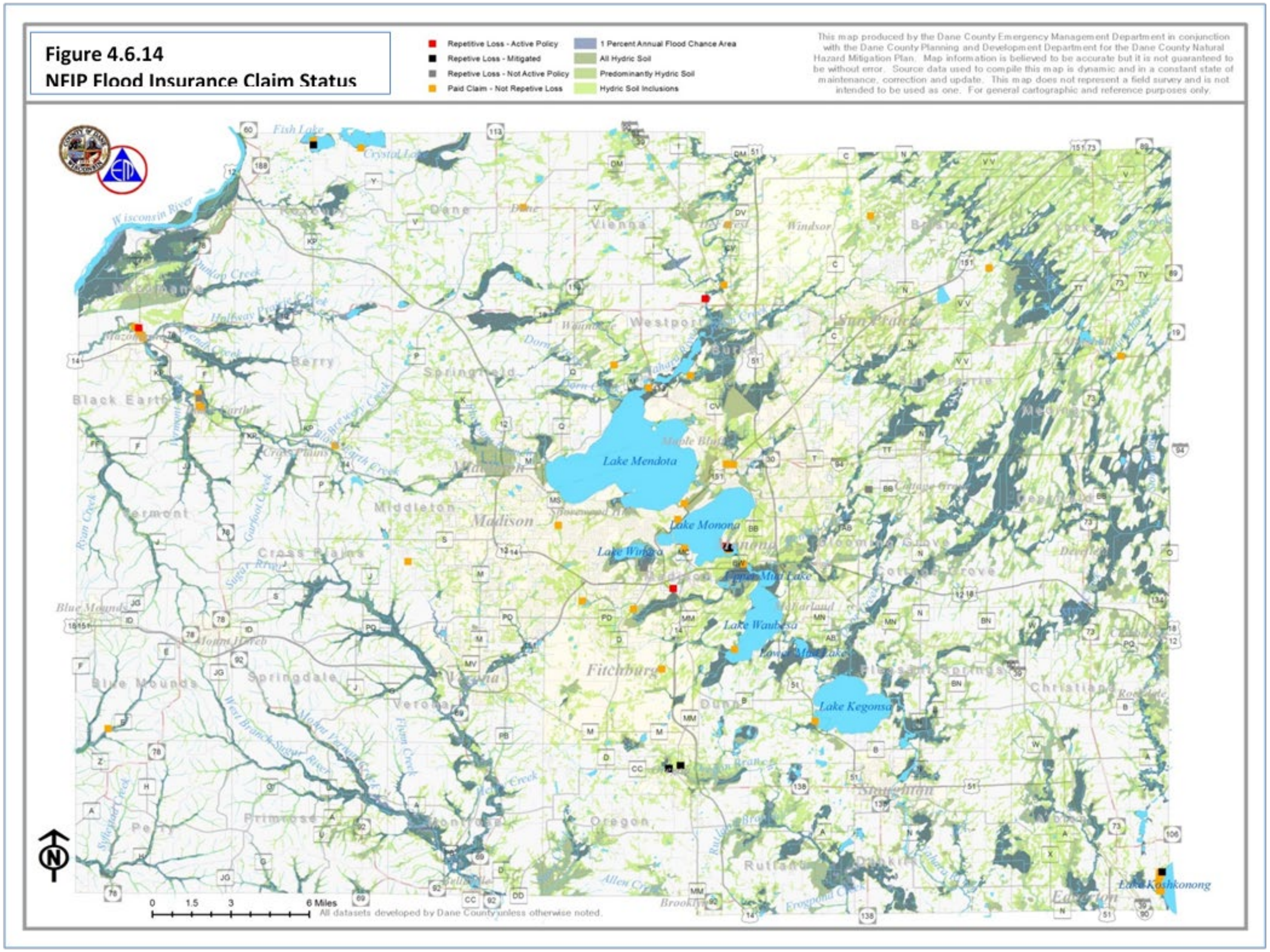
A “Severe Repetitive Loss” property is one that that have at least four NFIP payments over $5,000 each and the cumulative amount of such claims exceeds $20,000, or at least two separate claims payments with the cumulative amount exceeding the market value of the building. There are no severe repetitive loss properties in Dane County.

Flood insurance claims are summarized in Table 4.6.7, sorted by watershed from the least expensive total paid claims to the most. Watersheds having no claims are not listed in the table.

Table 4.6.7 Flood Insurance Claims Summary, From 1978 through 2018

Watershed	Municipality	Flood Year	Paid Claims Total
Gordon Creek	Town of Blue Mounds	2008	$5,062
Maunesha River	Town of Medina Town of Bristol	2000 2007, 2010	$11,484
Upper Sugar River	Town of Middleton	2016 2018	$12,210
Lake Wisconsin	Village of Dane	2007	$15,472
Badfish Creek	Village of Oregon	1978, 1981, 1982, 1984, 1996, 1999	$41,759
Yahara River and Lake Kegonsa	Town of Cottage Grove Town of Dunn	1978, 2007, 2008, 2014	$58,570
Yahara River and Lake Mendota	City of Madison Village of DeForest Village of Windsor Town of Westport	1993, 1996, 1998, 2004, 2007, 2008	$162,434
Roxbury Creek	Town of Roxbury	2001, 2002, 2008, 2014	$377,291
Yahara River and Lake Monona	City of Fitchburg City of Madison City of Monona Town of Dunn Town of Madison	1978, 1981, 1993, 1996,1997, 2000, 2001, 2008, 2014, 2016, 2018	$674,188
Six Mile and Pheasant Branch Creeks	City of Madison Town of Westport	2000, 2001, 2007, 2018	$848,208
Lower Koshkonong Creek and Lake Koshkonong	Town of Albion Town of Christiana	1980, 1982, 1993, 2008	$1,128,771
Black Earth Creek	Village of Black Earth Village of Cross Plains Village of Mazomanie	1993, 2001, 2004, 2007, 2008, 2018	$2,043,534

Figure 4.6.14 NFIP Flood Insurance Claims Status



2008 Flood Damage Analysis

The June 2008 flood event was the second most most damaging flood on record in Dane County. Dane County Emergency Management received flood insurance and FEMA Individual and Household Assistance claims data associated with the 2008 flood disaster to supplement the analysis of the flood hazard for this plan. The addresses of paid flood insurance claims and Individual and Household Assistance claims were located on GIS maps for further analysis and comparison with other flood hazard layers, such as the mapped floodplain and hydric soils layers.

There is a significant overlap between mapped flood plains and areas with hydric soils and most of the mapped floodplains are in areas characterized as hydric soils. This assessment takes care not to count these structures twice.

In general, the claims were in scattered locations around the County. The exceptions were clusters in the Villages of Deforest, Marshall and Sun Prairie and the City of Monona. There is also a significant cluster of claims in the Town of Cottage Grove. Figure 4.6.14 indicates the general locations of these properties. Privacy restrictions with the data prevent detailed maps of this analysis from being published in this plan. Interestingly, the majority did not intersect either of the mapped flood hazard areas. The breakdown resulted in the following assessment:

- Number of paid claims – FEMA Individual and Household Assistance: 1,627 ($1.76 million)
- Number of paid claims – National Flood Insurance: 28 ($1.38 million)
- Total number of paid claims: 1,655 ($3.14 million)
- Number of claims in the FIRM floodway: 4
- Number of claims in the FIRM 100-year flood hazard area: 38 (excluding floodway)
- Number of claims in the FIRM 500-year flood hazard area: 26
- Total number of claims in FIRM flood hazard areas: 68 (4% of the total)
- Number of claims in hydric soil types: 162 (10% of the total)
- Number of claims in soil types with hydric inclusions: 416 (25% of the total)
- None of the above: 1009 claims (61% of the total)

This preliminary analysis leads to some initial conclusions:

- Most of the flood damages occurred outside of the mapped floodplains.
- Stormwater drainage issues may be more of an issue than floodplain-related flooding.
- High groundwater table flooding may be more of an issue than floodplain-related flooding.
- Hydric soils areas do contribute to flood problems, but perhaps not as much as initially believed.
- Flood problems are more widely distributed across the County than mapped flood hazard areas would indicate.

- Existing mitigation efforts and floodplain management is generally working effectively in Dane County's mapped floodplains.

Additionally, the Individual and Household Assistance claims data does not distinguish between losses associated with floodwater, stormwater drainage, or high ground water and losses associated with sanitary sewer back flow into residential basements. Anecdotally, sanitary sewer back-ups have been identified as a problem in certain areas. It is not known to what extent sewer back-ups would account for the losses represented by these claims.

Finally, and perhaps most importantly, these numbers represent only a fraction of the actual losses experienced as a result of this flood event. Flood insurance claim payments and FEMA Individual and Household Assistance claims represent reimbursements for eligible expenses and losses. Eligible losses include only those repairs needed to make the home inhabitable safely:

Eligible Losses

- Structural parts of the home (foundation, outside walls, and roof)
- Windows, doors, floors, walls, ceilings, and cabinetry.
- Septic or sewage system
- Well or other water system
- Heating, ventilating, and air conditioning system
- Utilities (electrical, plumbing, and gas systems)

Ineligible losses:

- Non-structural components of the building
- Damage or loss of contents (furniture, items stored in the basement, etc.)
- Repairs to finished or unfinished basements that are not primary living space

Preliminary damage assessments conducted by local jurisdictions and compiled by Dane County Emergency Management indicated a total of 2,370 homes and 155 business damaged, with combines losses totaling more than $7.45 million. This indicates that approximately 40% of the losses were reimbursed by FEMA or the NFIP, with about 60% of the losses borne by the property owner.

While 60% of the FEMA paid claims in 2008 were located in areas outside of identifiable flood risk areas, from the perspective of the total number of primary structures in Dane County, a slightly different picture emerges.

Table 4.6.8 2008 Flood Damage Claims Summary

	Primary Structures in Dane County Building Footprint Inventory		2008 Paid Claims (FEMA Individual and Household Assistance plus Flood Insurance)	
Flood Risk Indicator	**Number of Primary Buildings**	**Percentage of Total**	**Number of Claims**	**Percentage of Total**
Mapped FIRM Flood Hazard Areas	997	0.69%	68	4.1%
Hydric Soil Types (Hydric plus hydric inclusions)	36,434	25.26%	578	34.9%
Not in an identified flood hazard area	106,795	74.05%	1009	60.1%
Total	**144,226**	**100%**	**1,655**	**1.1%**

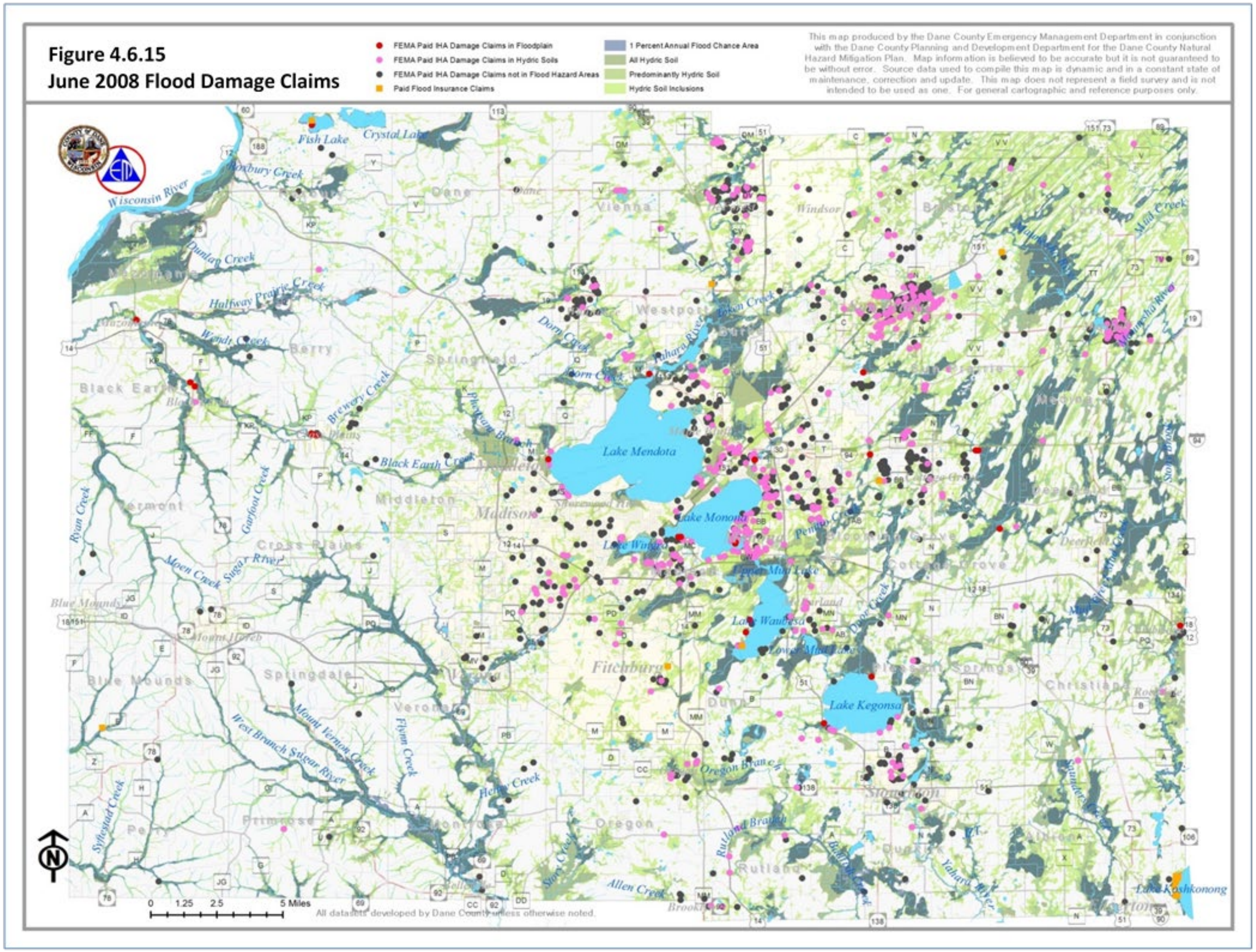
Source: FEMA Data - Claims estimates calculated by Dane County Emergency Management, 2017

From the perspective of a countywide analysis, there was a notably disproportionate amount of damage in areas with hydric soils and floodplains. While structures in the mapped floodplain areas represent less than 1% of the total number of primary buildings in Dane County, these locations represent more than 4% of the paid damage claims. Likewise, structures built in areas with hydric soils represent 25% of the buildings in Dane County, but represent almost 35% of the paid claims.

These are not dramatically disproportionate differences in the locations where damage occurred, but a higher level of flood risk is still apparent. Even so, with 60% of the damage claims occurring outside of these areas, it is clear that additional factors are in play. Flood damages are more widely distributed across the County than mapped flood hazard areas would indicate.

Likewise, in terms of public sector (county and local government) costs for response, repair of roads, rebuilding of damaged buildings, and other response and recovery activities, initial assessments conducted by the local jurisdictions and compiled by the County indicated a response and recovery cost totaling $6.07 million. FEMA Public Assistance reimbursed a total of $1.53 million to the County and local jurisdictions within the County. The Public Assistance program also has strict eligibility requirements and will only reimburse applicants for eligible costs. Assuming the initial assessments were reasonably accurate, Federal reimbursements made up approximately 22% of the costs, with 78% borne by responding local governments.

Figure 4.6.15 June 2008 Flood Damage Claims



Effect of Climate Change on Future Loss Potential

Regional climate model projections indicate a significant increase in both the frequency and magnitude of intense rain fall events in southern Wisconsin, including Dane County. (Wisconsin Initiative on Climate Change Impacts, Stormwater Working Group Report, 2011) Extreme rainfall events are getting larger and they are happening more often. These are on-going changes that are expected to continue, or even further accelerate in the future.

Dane County already faces enormous challenges in managing stormwater and reducing flood impacts. The complexity of this problem is exacerbated by changing weather patterns and trends of more frequent, high intensity rain storms. Stormwater and flood management systems are designed to manage water flows and volumes associated with a range of possible storm events. The respective rainfall depth, intensity and probabilities of those storm events are obtained from analysis of past storm events. This analysis, however, does not account for changing conditions.

Society's infrastructure is built to manage to acceptable levels the risks associated with excess precipitation, and has been traditionally designed and evaluated using historical precipitation and runoff data. Traditional strategies for managing high water conditions are based on either the use of infrastructure that conveys, stores, or protects against high water (i.e. stormwater management systems), or on plans and regulations that promote or require avoidance of high water conditions (i.e. floodplain zoning). Unless the planning, design, and management of these systems are modified to account for climate mediated changes in precipitation patterns, the risk of significant economic and environmental damage will increase.

While it has become clear that past conditions are not a good indicator of what we can expect in the future, a specific, precise projection is not available. A qualitative assessment, however, is possible. Unless appropriate adaption and mitigation strategies are implemented, increases in the frequency and severity of the following high water impacts can be expected (Wisconsin Initiative on Climate Change Impacts, Stormwater Working Group Report, 2011):

- Landslides and erosion of steep slopes during intense rainfall events.
- Impairment of roadways and bridges washed-out due to high water, slope failure, or washed out roadway shoulders.
- Groundwater flooding of property and cropland.
- Flood damage to urban streets, homes, and commercial structures due to inadequate runoff drainage systems.
- Failure of impoundments, dams, and stormwater detention ponds.
- Failure of rain gardens and other groundwater biofiltration Best Management Practices (BMPs) due to prolonged periods of saturated soils.

- Stormwater inflow and groundwater infiltration to sanitary sewers, resulting in sewer backflow into basements. This also results in untreated municipal wastewater overflowing into lakes and streams.
- Contamination of rural residential wellheads as a result of surface water and groundwater flooding.

A wide range of environmental impacts, water quality impacts, and indirect, secondary economic and social impacts are also exacerbated by this increasing flood hazard.

Future Loss Estimation based on the 2008 Flood of Record

While current methods of analysis can provide general trends, specific projections of the increasing magnitude of flood events is not available. This is problematic when attempting to design and engineer flood management systems that will meet future needs. Again, a qualitative assessment is possible.

Using the 2008 flood event as a model event, Table 4.6.8 indicates the estimated flood loss potential, with scenarios of increasing losses. These scenarios are based on increased magnitude of flood damages by percentage over the 2008 flood damage losses. This provides a general overview of how losses might increase as flood events get larger. This assessment is not intended to be predictive. Rather, this simply shows how flood damages and losses would change as flood events get more damaging, relative to the 2008 flood of record. For example, a flood causing twice as much damage as the 2008 flood event (100% increase) would equate to more than $30 million in 2017 dollars.

This method of estimating potential increases in flood damage with changing conditions also has limitations. It is an important distinction that Table 4.6.8 indicates costs associated with increases in flood damage relative to the 2008 flood event, not increases in flood magnitude. The relationship between increasing flood magnitude and the resulting damage is not linear. As flood magnitude increases, larger and larger areas, with more properties, structures, and infrastructure are affected. Flood depths also increase as a result, affecting those properties, structures and infrastructure to a greater degree. The number of locations affected increases, as does the severity of loss experienced at any given location. This leads to exponential increases in losses as flood magnitudes increase. At this point, there are too many variables for anything other than a qualitative assessment of the increasing flood risk.

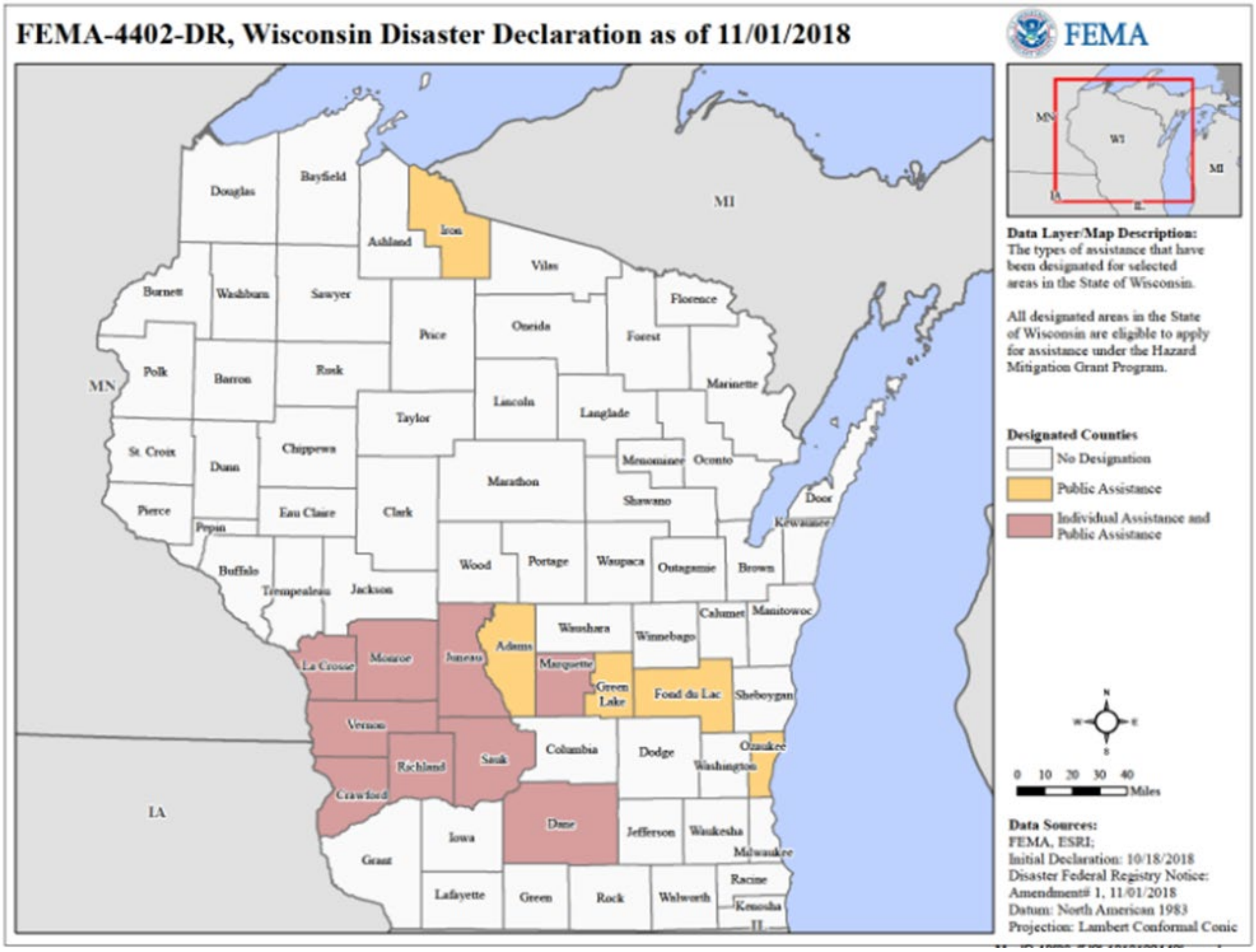
Table 4.6.8 Estimated Flood Loss Potential, with Scenarios of Increasing Losses. Scenarios Based on Increased Magnitude of Flood Damage by Percentage over 2008 Flood Damage

Category of Damages	2008 Flood Damages	Inflation Adjustment (2008 to 2017)	Increased Magnitude of Flood Damage (over 2008 flood losses)				
			10%	25%	50%	75%	100%
Number of Structures Affected	2,370		2,607	2,963	3,555	4,148	4,740
Private Sector Damage Assessment	$7,450,000	$8,330,000	$9,163,000	$10,412,500	$12,495,000	$14,577,500	$16,660,000
Number of FEMA Paid Individual and Household Assistance and NFIP Claims	1,655		1,821	2,069	2,483	2,896	3,310
IA and NFIP Paid Claims Amount	$3,140,000	$3,510,000	$3,861,000	$4,387,500	$5,265,000	$6,142,500	$7,020,000
Public Sector Damage Assessment	$6,070,000	$6,780,000	$7,458,000	$8,475,000	$10,170,000	$11,865,000	$13,560,000
FEMA Public Assistance Payments	$1,530,000	$1,710,000	$1,881,000	$2,137,500	$2,565,000	$2,992,500	$3,420,000
Federal Assistance Total	$4,670,000	$5,220,000	$5,742,000	$6,525,000	$7,830,000	$9,135,000	$10,440,000
Total Private and Public Sector Costs	$13,520,000	$15,110,000	$16,621,000	$18,887,500	$22,665,000	$26,442,500	$30,220,000

Source: Damage estimates calculated by Dane County Emergency Management, 2017

2018 Flood Damage Analysis

Figure 4.6.16 2018 Wisconsin Disaster Declaration Counties



Source: FEMA Designated Areas Map, 2021 https://www.fema.gov/disaster/4402/designated-areas

J – Description

The August 2018 flood event was the most damaging flood on record in Dane County. Dane County Emergency Management received flood insurance and FEMA Individual and Household Assistance claims data associated with the 2018 flood disaster to supplement the analysis of the flood hazard for this plan.

A severe storm swept through Dane County the evening of August 20, 2018. The storm dumped anywhere from several inches up to 15”+ (citizen reported). The most severe rain and flooding occurred in the Western portion of Dane County through the Black Earth Creek Watershed. Over the next 10 days, additional storms swept across Wisconsin causing major flooding in 13 additional counties across the state.

The majority of the flooding in Dane County occurred between Mazomanie and West Madison with the greatest impacts felt along the US Highway 14 corridor between Mazomanie and the City of Middleton. The vast majority of the requests (90%+) for Individual and Household Assistance came from properties outside of mapped flood plains.

The Individual and Household Assistance claims data does not distinguish between losses associated with floodwater, stormwater drainage, or high ground water and losses associated with sanitary sewer back flow into residential basements. Anecdotally, sanitary sewer back-ups have been identified as a problem in certain areas. It is not known to what extent sewer back-ups would account for the losses represented by these claims.

The data represented in this section represents only a fraction of the actual losses experienced as a result of this flood event. Flood insurance claim payments and FEMA Individual and Household Assistance claims represent reimbursements for eligible expenses and losses. Known ineligible losses include:

- Non-structural components of the building (e.g. sidewalks, retaining walls, driveway culverts, etc.)
- Damage or loss of contents (furniture, items stored in the basement, etc.)
- Repairs to finished or unfinished basements that are not primary living space.

2018 Flood Summary Statistics

Displayed in Table 4.6.9, an estimated 90% of total properties within Dane County that received relief due to the 2018 flooding event did not reside within the regulated floodplain.

Table 4.6.9 Properties Receiving Relief Within and Out of Regulated Floodplains

Category	Federal Funding Received ($)	Percent of Total Damages Paid (%)
Properties within regulated Floodplain	$400,620	10%
Properties out of regulated Floodplain	$3,497,252	90%

Source: Dane County Planning & Development 2018 Flood Analysis, 2018

This trend of property claims being outside of regulated floodplains is mirrored in both the 2008 flood, and the national scale. In response to the 2018, CARPC helped establish a fifteen member steering committee for the Black Earth Creek Watershed Green Infrastructure Plan to address both rural and urban vulnerabilities within the Black Earth Creek Watershed area (BECW). The stated goal is "To identify specific projects and practices that provide a quantifiable level of flood protection to communities, water quality benefits to Black Earth Creek and its tributaries, and recreational, economic, and ecological benefits to the watershed as a whole." (Black Earth Creek Watershed Green Infrastructure Plan, https://becw-greenplan-silvernail.hub.arcgis.com/)

The Village of Black Earth, the Village of Mazomanie, and the Village of Cross Plains voluntarily provided representatives for the BECW steering committee, as these communities represent key impacted areas within the eastern quadrant of Dane County during the 2018 flood. Four consulting entities are also members of the BECW committee.

The estimated FEMA payments per household in the BECW can be seen in Figure 4.6.17. Total and Average FEMA payment impacts to the whole county can be seen in Figures 4.6.18-19. Table 4.6.10 mirrors Table 4.6.8, in demonstrating future potential flood damage estimates, in addition to 2021 inflation rates.

Figure 4.6.17 Black Earth Creek Watershed - Average FEMA Payments per Household

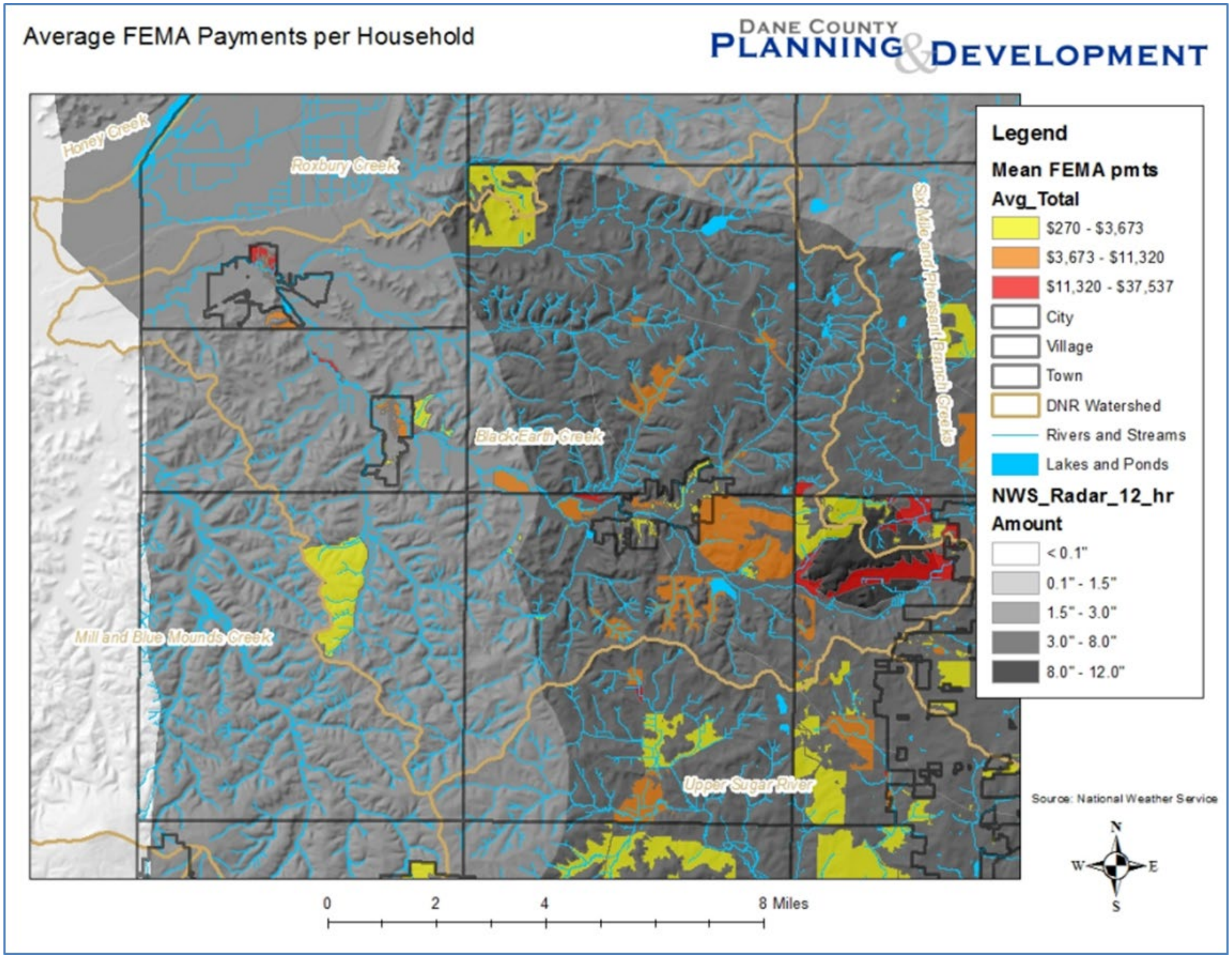


Figure 4.6.18 Dane County - Average FEMA Payments per Household

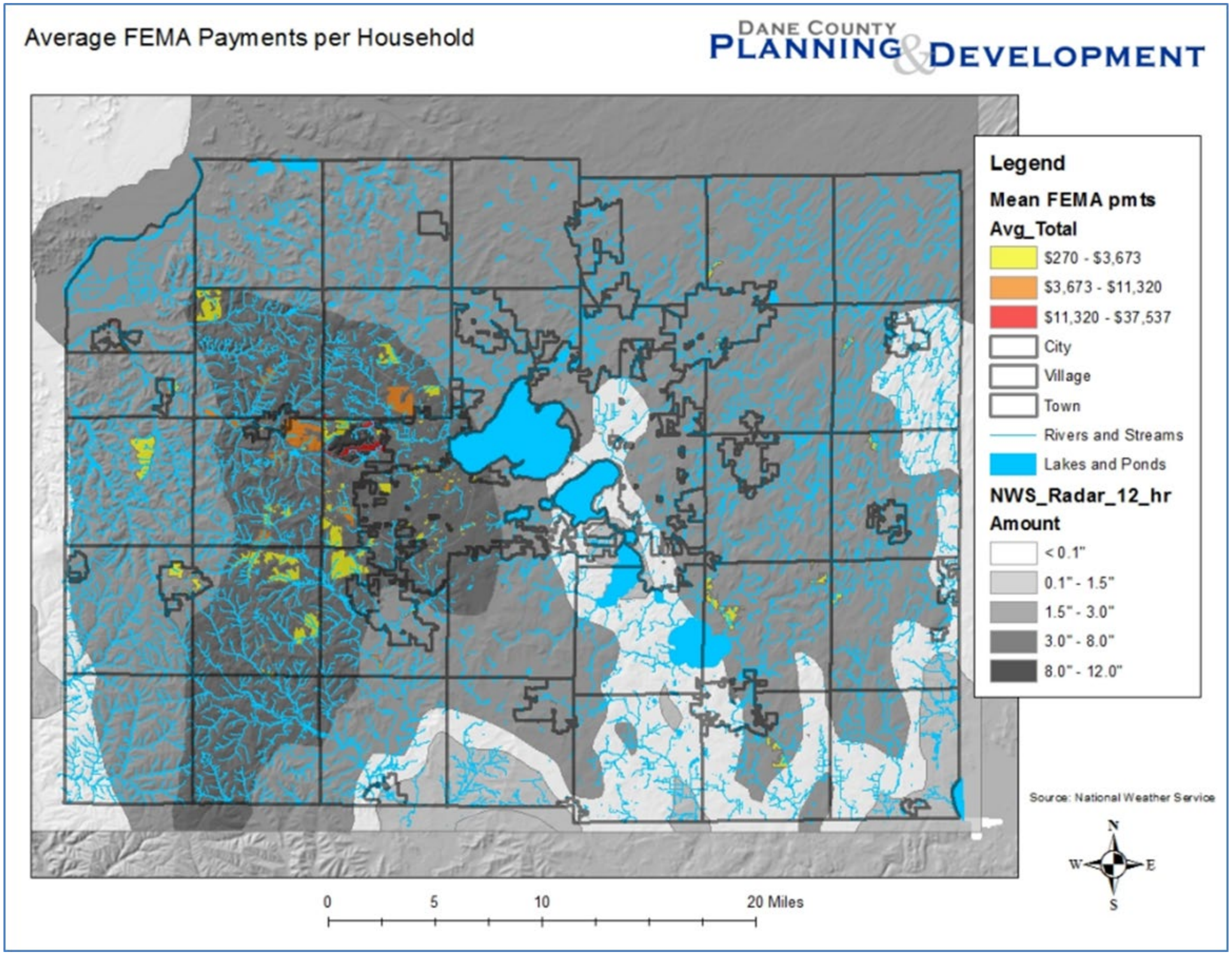


Figure 4.6.19 Dane County - Total FEMA Payments by Census Block

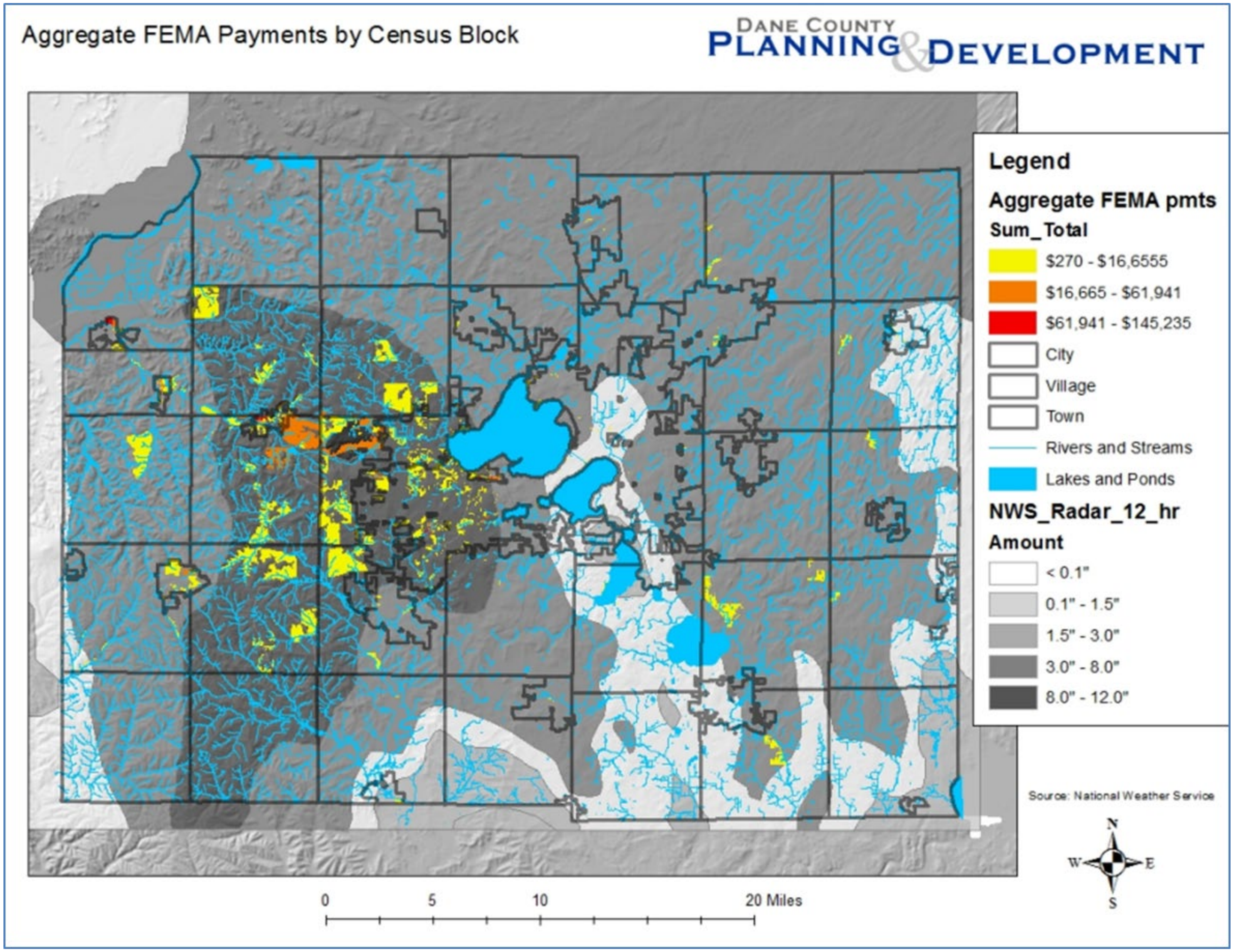


Table 4.6.10 Estimated Financial Loss Potential, with Scenarios of Increasing Losses. Scenarios Based on Increased Magnitude of Flood Damage & Inflation

Category of Damages	2018 Flood Damages	Inflation Adjustment (2018 to 2022)	Increased Magnitude of Flood Damage (over 2018 flood losses)				
			10%	25%	50%	75%	100%
Total Housing Assistance (HA) - Dollars Approved	$3,897,872	$4,364,191	$4,800,610	$5,455,239	$6,546,287	$7,637,334	$8,728,382
Public Sector Damage Assessment	$78,287,645	$87,653,529	$96,418,882	$109,566,911	$131,480,294	$153,393,676	$175,307,058
Private Sector Damage Assessment	$37,114,219	$41,554,351	$45,709,786	$51,942,939	$62,331,527	$72,720,114	$83,108,702
Total Private and Public Sector Damage Assessment	$115,401,864	$129,207,880	$142,128,668	$161,509,850	$193,811,820	$226,113,790	$258,415,760
Hazard Mitigation Grant Program (HMGP) - Dollars Obligated	$3,411,680	$3,819,833	$4,201,816	$4,774,791	$5,729,750	$6,684,708	$7,639,666
Grand Total	$238,113,280	$266,599,784	$293,259,762	$333,249,730	$399,899,676	$466,549,622	$533,199,568

Source: Calculated by Dane County Emergency Management, 2022

4.7 FOG

4.7.1 Description

Fog is a cloud made up of water droplets suspended in the air at the earth's surface. Fog forms when air is cooled to its dew point, which is the temperature at which air is saturated with moisture. When air reaches its dew point it condenses into very small particles, forming the tiny water droplets that create clouds. When this occurs very close to the ground, the event is called fog. The intensity and duration of fog varies with the location and type of fog. Severity ranges from early morning ground fog that burns off easily to prolonged valley fog that can last for days. Generally, strong winds prevent fog formation. The following list summarizes several possibilities for the formation, intensity, and duration of fog in the upper Midwest, as compiled in the "Hazardous Weather Resource Guide" by FEMA:

Ground Fog is associated with clear nights, stable air (winds less than 5 mph), and a small-temperature dew point range. It forms when heat radiates away from the ground, cooling the ground and surface air. When air cools to its dew point, fog forms, usually a layer of less than 100-200 feet. It is common in many areas of the United States and generally burns off from the morning sun.

Advection Fog is associated with horizontal wind, warm, humid air, and winter temperatures. It forms when wind pushes warm humid air over the cold ground or water, where it cools to the dew point and forms fog. Advection fog can cover wide areas of the central U.S. in winter. During the winter this is common when snow covers much of the Midwest. The snow cools the bottom portion of the moist air mass often resulting in condensation. This type of fog can be widespread, covering very large areas.

Evaporation Fog is associated with bodies of water. It forms as cold air blows over warmer water, causing the water to evaporate into the cold air, increasing the humidity to the dew point. Vapor condenses, forming a layer of fog 1 to 2 feet thick over the water. It can form over ponds and streams on fall days.

Precipitation Fog is associated with warmer rain and cooler air. It forms when rain evaporates, and the added vapor increases the air to its dew point. The vapor then condenses into fog. Precipitation fog forms on cool, rainy days.

4.7.2 Previous Occurrences

Fog is common occurrence in southern Wisconsin, including Dane County. Fog may occur anywhere in the County. Records indicate fog is most likely in the early morning or late evening. Dense fog occurs during every month of the year in Wisconsin. It is more common during the cooler months of September through April. During the fall and spring, fog is more common during the early morning hours and during the winter fog can occur anytime favorable conditions are present. Fog is a semi-regional phenomenon, affecting large portions of the county simultaneously. It may also form in patches, or uniformly across the entire region or county.

In more recent years, the National Weather Service and the NOAA National Centers for Environmental Information have been tracking weather extremes and their consequences in greater detail. A search of the NCEI website provided the following descriptions of several excessive heat events.

November 15, 2001
Dense fog developed overnight across parts of south-central and southeast Wisconsin, lowering visibilities to near zero to 1/4 mile. The lowest visibilities were found in river valleys west of a line from Madison (Dane Co.) to Beloit (Rock Co). Local air traffic was delayed until visibilities improved. Several vehicle accidents were noted in newspapers. In northwest Dane County near Mazomanie on Highway 78, the driver of a vehicle was killed when the vehicle struck a horse standing on the road (fatality indirectly related to fog). Visibility was reported to be about 10 feet around the accident time of about 1:45 a.m. on November 16th. Sixteen children were injured (indirectly related to fog) when a truck struck a Monticello (Green Co.) school bus at 7:46 am on the 16th. Poor visibility was an indirect factor in this accident.

February 20, 2002
Dense fog developed overnight across south central and southeast Wisconsin due to light rain and persistent, on-shore southeast to northeast winds. Visibility was reduced to 1/8 to 1/4 mile, especially in river valleys and other low spots. This led to several vehicle accidents and flight delays or cancellations at airports.

March 20, 2003
Dense fog developed early on March 20th, and dropped visibilities to 1/4 mile or less. Air traffic was delayed or grounded at both Milwaukee's Mitchell Field (Milwaukee Co.), and Dane County Regional Airport. Several school districts delayed school openings by 2 hours, and newspapers reported many vehicle accidents. The dense fog was the result of clear skies, a light south-southeast surface wind, and leftover, low-level moisture.

February 26, 2004
Dense fog developed overnight, resulting in visibilities of 1/4 mile or less. Newspaper reports indicated that many icy frost deposits occurred on roads and bridges. Snowmelt due to maximum temperatures in the mid to upper 30s on February 25th contributed the moisture needed to saturate the air as the night progressed. Newspaper reports indicated that some airplane flights were delayed and at least a dozen vehicle accidents occurred.

December 19, 2007
Dense freezing fog developed over parts of south-central and southeast Wisconsin and reduced visibilities to 1/8 to 1/4 mile. Untreated road and sidewalk surfaces were coated with thick rime/frost, as

well as trees and other cold-surface objects. Newspaper reported indicated that at least a dozen vehicle accidents occurred in each county listed in this event. Moist air moving over a cold, snow-covered terrain initiated the dense freezing fog. Several airline flights were delayed or canceled at Dane County Regional Airport.

January 6, 2008

Dense fog caused a 100 car pile-up traffic accident which stretched about 5 miles long along Interstate 39/90 in Dane County. There were many injuries, with approximately 54 individuals taken to area hospitals. Two indirect deaths were reported.

March 7, 2010

Dense fog developed across much of Southcentral and Southeast Wisconsin. Visibility dropped to ranges of several hundred yards to less than ¼ mile. Several flights were delayed and several vehicle accidents occurred according to local news.

December 2, 2012

Dense fog covering much of Southern Wisconsin reduced visibility to ¼ mile and persisted until 12 p.m. on December 3rd. Flights at several airports were delayed.

February 12, 2018

On February 12th, 2018, a 29 car pile-up with one fatality took place near the city of Verona, due to dense fog patches across southern Wisconsin. Local officials cited poor visibility as being the cause, as well as potentially slick road conditions. A day after the pile-up, Dane County Emergency Management (DCEM) issued a potential fog hazard warning, due to a freeze and melt cycle predicted by the National Weather Service. No other fatalities were recorded in relation to this event, however injuries from the car pile-up did follow. The fog event continued inconsistently for four days.

Source: Photo by Adam Bar, reported by WMTV

4.7.3 Impact of Climate Change on Future Conditions

Fog is already a regular occurrence, with Dense Fog Advisories issued for Dane County numerous times in any given year. There is not a readily available source of information to assess whether the incidence of fog will increase, decrease, or remain unchanged as a result of the warming climate.

4.7.4 Impact Assessment

Fog can be hazardous when the visibility is reduced to 1/4 mile or less. Thick fog reduces visibility, creating a hazard to motorists. The Wisconsin State Patrol rates dense fog as probably the most dangerous weather-related traffic hazard, with icy or snow-covered roads in second place. In Dane County alone, between 2010 and 2015, 272 accidents took place where fog was present at the accident site. Of those accidents, 92 people were injured and 3 were killed (WisDOT AADT for Site 131506. Available at: https://trust.dot.state.wi.us/roadrunner/) Table 4.7.1 is limited to Wisconsin Dept. of Transportation Data and summarizes these crashes by year.

Table 4.7.1 Fog Related Traffic Crashes in Dane County

Fog Related Crashes				
Year	**Fatal**	**Injury**	**Vehicle Damage**	**Total**
2010	1	24	55	80
2011	0	10	14	24
2012	0	13	30	43
2013	1	30	33	64
2014	1	10	33	44
2015*	0	5	12	17
Totals	**3**	**92**	**177**	**272**

Source: WisDOT Traffic Crashes and Weather Conditions for Dane County. From 2010-2015 Wisconsin Traffic Crash Facts. Available at http://wisconsindot.gov/Pages/safety/education/crash-data/crashfacts.aspx

Although the number of accidents and deaths are considered indirectly related to the actual weather conditions, they far exceed the number of people injured or killed due to tornadoes or floods for Dane County during this period. These accidents are considered indirectly related because law enforcement officials and the insurance industry assert that most accidents that occur in fog are the result of motorists following too close to the vehicle ahead of them and driving too fast for the weather conditions. The poor visibilities do not allow motorists to adjust when the vehicle in front stops or makes a quick turn.

Records of past incidents also report cases of flight delays or cancellations at Dane County Regional Airport due to dense fog. There is no accurate data available to quantify these reports or the financial losses that might be associated with these delays.

4.7.5 Vulnerability Assessment

Fog poses the greatest danger to people who are traveling on the highways of the County. Dane County has an extensive highway transportation system that includes three intersecting interstate highways, major federal and state highways, and County and local roads. With its central location in southern Wisconsin, there are numerous heavily used major thoroughfares in Dane County constituting nearly 3,500 miles of roadway in the County.

Air travel is also vulnerable to disruption due to dense fog. Records of past incidents report cases of flight delays or cancellations at Dane County Regional Airport due to severe weather and fog. The Dane County Regional Airport (DCRA) in Madison is the second largest airport in the State, providing service to commercial air passenger and cargo carriers, general aviation, and the military. Over 100 daily flights are provided on an average day. In 2015, 1.6 million passengers traveled through the DCRA. (Airport passenger numbers available at: http://www.transtats.bts.gov/airports.asp?pn=1&Airport=MSN&Airport_Name=Madison,%20WI:%20Truax%20Field&carrier=FACTS)

4.7.6 Potential for Future Losses

Fog poses no direct risk to the structures or facilities of Dane County.

The impacts of fog are indirect impacts, related to increased incidence of traffic accidents and travel delays. As demonstrated in the past history data, the occurrence of fog is common in Dane County. Increased public awareness of appropriate cautions to use in dense fog conditions may help to reduce traffic crashes resulting from vehicle operator errors.

4.8 HAIL

4.8.1 Description

Hail falls from thunderstorm clouds that extend miles high into extremely cold air. Updrafts bring raindrops from the bottom to the top of the cloud where they freeze into ice pellets. They then fall only to be blown back up where another coating of rain freezes to the hailstone and it grows larger, layer by layer. This layering affect can increase the size of hailstones, sometimes to the size of baseballs. Typically the stronger the updraft, the more times a hailstone repeats this cycle and consequently, the larger it grows. Once they reach a weight sufficient enough to overcome the updrafts, they fall to the ground. The hailstone reaches the ground as ice since it is not in the warm air below the thunderstorm long enough to melt before reaching the ground.

Hail tends to fall in swaths that may be 20-115 miles long and 5-30 miles wide. The swath is not normally a large, continuous bombardment of hail, but generally consists of a series of hail strikes that are produced by individual thunderstorm clouds traversing the same general area. Hail strikes are typically one-half mile wide and five miles long. They may partially overlap, but often leave completely undamaged gaps between them.

Dane County averages about 3 days with hail per year. The period of time with the most frequent occurrence of hail producing severe thunderstorms is May through September.

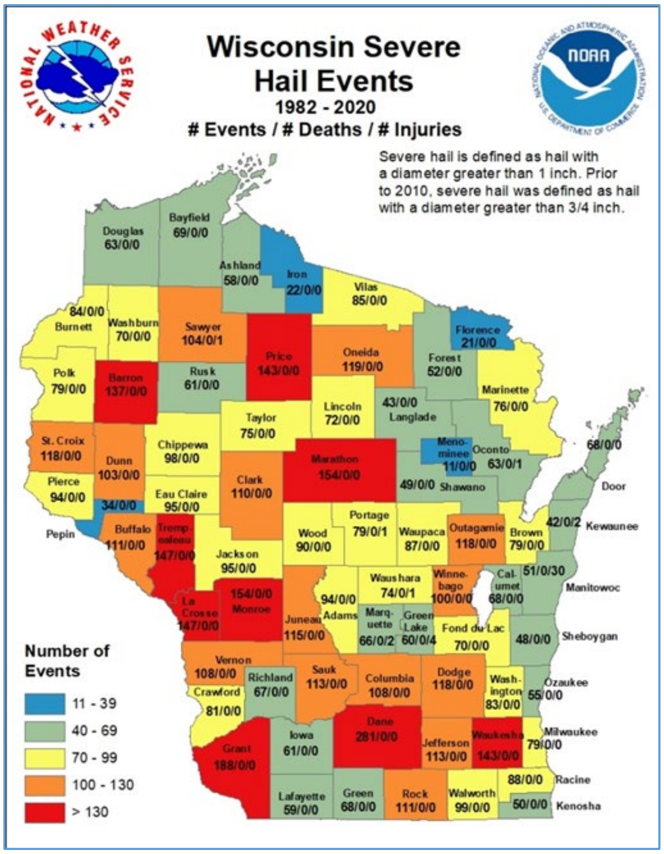
4.8.2 Previous Occurrences

The National Weather Service and the NOAA National Centers for Environmental Information (NCEI) maintains a listing of reported hail events, with a hail size greater than 0.75 inches, from 1950 through 2020. In Dane County, 262 hail events have been recorded. The largest hail size ever recorded in the County was four inches in diameter in July of 1960. Figure 4.8.1 indicated a summary of hail events, including deaths and injuries, statewide from 1982 to 2020. There have been no recorded deaths or injuries from hail in Dane County.

Hail events have occurred most frequently in June, July, and August, although hail has been reported with thunderstorms in every month of the year statewide. Considering Dane County as a whole, over an entire year, it is extremely likely a hailstorm will occur in any given year.

The NCEI database also provides a description of many of these events. The following is a sample from the most significant events where data is available.

Figure 4.8.1 Severe Hail Events in Wisconsin, 1982-2020



Source: National Weather Service, 2020

July 7, 1991

Dane County received a presidential disaster declaration for damages resulting from a storm on July 7, 1991. Winds topping 80 mph, hail, rain, and lightning caused extensive damage in Dane County. The storm left 60,000 people without electricity and downed so many tree branches that it took weeks for clean up to be completed. Dane County Regional Airport was estimated as receiving $4-5 million in damages losing some planes completely and severely damaging others. Twenty buildings were also damaged at the airport. Local farms sustained $3.1 million in damages to crops and buildings due to hail and high winds. Two people were reported injured in Dane County.

May 18, 2000

A supercell thunderstorm moved east/northeast across Iowa County. Hailstones up to 2.00 inches in diameter pelted and damaged many vehicles and home sidings, while stripping some of the corn and soybean crops. This storm then headed east into Dane County where it unleashed damaging straight-line winds in addition to large hail. Winds were estimated to reach hurricane-force level as the storm tore through Fitchburg where a home's garage was blown over. The storm then hit Madison with powerful winds and golf ball size hail. A Madison home's roof was torn off by the winds, and many large trees were felled. At least 200 vehicles sustained moderate to severe hail damage in Dane County.

August 11, 2002

A cluster of severe thunderstorms blossomed over western Dane County, resulting in wind, hail, and flash flood damage in the Pine Bluff area, west of the Madison metro-area. In the Pine Bluff area, hurricane-force downburst winds reached estimated speeds of 70 knots (80 mph), resulting in toppled trees and power lines. The fringe effects of this powerful macro-burst resulted in some tree damage north to the Cross Plains to Middleton area. The thunderstorm cluster also produced hail up to 2 inches in diameter in the Pine Bluff area, resulting in major damage to at least 100 vehicles, and to roofs and siding of homes.

April 13, 2006

A cluster of isolated severe thunderstorms hammered Dane County. Hailstones, some the size of tennis balls, hammered southern Wisconsin on Thursday night, denting cars and covering lawns as the storm moved west to east. The largest specimen, with a diameter of 4.25 inches, was found in Jefferson County. In southwestern Wisconsin, a weather service employee recorded 2.5-inch hail in Dodgeville around 9 p.m., and an Iowa County law enforcement officer saw hailstones 2.75 inches in diameter. In Madison, trained weather service spotters reported 2-inch hail on Fish Hatchery Road and 1.75-inch hail at West Towne Mall about 9:30 p.m. A few minutes later, other spotters reported 3-inch hail in Monona and Cottage Grove. Major damage was done to automobiles in Madison area. Homeowners suffered major damages as roofs and shingles were severely damaged by the hail. The hail damage estimate from this storm is reported at over $5.5 million.

August 24, 2006

Severe storms, with large hail and damaging, straight-line, downburst winds, developed ahead and along a cold front, which plowed east into an unseasonably warm, moist air mass over southern Wisconsin. The hail stones ranged from 3/4 inch to 2 inches in diameter, resulting in several vehicles receiving dents (in Lafayette, Sauk, and Dane County). The damaging winds were mostly in the 60 to 70 mph range resulting in numerous reports of uprooted trees. Dozens of power lines were pulled down as broken tree branches fell on them. The hail damage estimate from this storm is reported at over $2.0 million.

September 18, 2010

A strong cold front was slowly sagging through southern Wisconsin during the early morning hours of September 18th. Mid-level warm advection and frontogenesis ahead of a short wave moving through the region created forcing and elevated instability, as well as strong effective deep layer shear of 40 to 50 knots, that generated elevated thunderstorms behind the surface cold front. The thunderstorms produced hail showers, turning the ground white, with hail stones up to 1 inch in diameter. Trained spotters reported a 1 to 2 mile-wide swath of damage from hail showers that extended from north of Dodgeville, near Cross Plains, to just east northeast of Monona, dissipating near Interstate 90. Hundreds of vehicles were damaged; many homes had siding, window and screen damage; many trees were stripped of their leaves. The hail damage estimate from this storm is reported at over $1.0 million.

September 19, 2016
A line of thunderstorms formed along a stalling cold front and moved across southern WI. A severe thunderstorm within the line produced widespread hail damage on the southwest side of Madison and in Middleton. Thousands of insurance claims are anticipated due to hail damage to vehicles and properties.

4.8.3 Impact of Climate Change on Future Conditions

Damaging hail storms are already a regular occurrence. There is not a readily available source of information to assess whether the incidence of large hail will increase, decrease, or remain unchanged as a result of the warming climate. A qualitative argument can be made that more energy in the atmosphere resulting from increased concentrations of greenhouses would result in an increase of convective severe weather events such as hail storms. This is not borne out in currently available models, however. There is no clear trend to indicate whether or not this hazard is changing or will change significantly in the future.

4.8.4 Impact Assessment

While hail is usually a geographically isolated event, it is rarely isolated meteorologically. Hail almost always occurs in conjunction with a severe thunderstorm. Storms capable of producing large hail are also likely to produce lightning, high winds, heavy rain, and possibly tornadoes. Damages associated with these storms result from the combination of all of these factors.

Insurance industry representatives involved in this planning effort indicate that a large hailstorm is one of their greatest concerns in terms of potential losses and insurance payouts. Hailstorms can cause extensive property damage in both urban and rural settings. Most hailstorms produce marble size or smaller hailstones, which can damage crops, but do not typically cause damage to automobiles or buildings. Larger hailstones can destroy crops and can cause extensive damage to buildings, including roofs, windows, and siding. Vehicles and even aircraft can be a total loss. When windows or roofs are damaged due to hail, water damage from often accompanying heavy rain can be significant. A major hailstorm can cause cumulative damages to crops and personal property running into the millions of dollars. Serious injury and loss of human life, however, are rarely associated with hailstorms.

No deaths or injuries have been directly attributed to hail in Dane County. According to the NCEI database, financial losses in Dane County due to hail total over $9 million in property damages since 1999.

4.8.5 Vulnerability Assessment

In general, all Dane County agricultural crops, buildings, and vehicles are to some degree vulnerable to hail damage. The essential functions of the critical facilities are not likely to be impacted by hail. Nor are any at-risk populations any more vulnerable than the general population. When damaging hail occurs, it does not affect the entire county. Rather, it is a geographically isolated event, affecting only small areas of several square miles at any one time. In terms of crop losses, the actual damages that occur will depend on the type of crop and the growth stage of the plants when the hail occurs. In terms of property losses, the actual damages will depend on the housing density and density of automobiles in the impacted area. This is highly variable across the County. A storm with large hail over a crowded shopping mall parking lot on a Saturday afternoon will have a significantly different impact than the same storm over a suburban area in the evening when most of the cars are parked in garages. Likewise, a hailstorm in a rural area in the early spring when the plants are just emerging will have much less of an impact than a storm of the same intensity occurring later in the growing season when the plants are more susceptible to damage and when there is no time to replant if the crop is a total loss.

4.8.6 Potential for Future Losses

The potential for future losses due to hail damage is estimated based on an extrapolation of losses from past events. There are limitations to this method:

- Hail damage is not typically a meteorologically isolated occurrence. Damages occur in conjunction with high winds and heavy rain and storm damage estimates are usually cumulative of all of these effects. The NCEI website provides data on only a handful of events where significant hail damage estimates are isolated from other causes.
- The exposure to damage increases as the population of the County increases. Future damages may increase simply due an increase in the amount of exposed property.
- The damages resulting from a hailstorm depend greatly on where and when the storm hits. The use of average losses from past events does not account very well for these variables.

The NCEI database indicates that since 1999, Dane County has seen more than 80 hailstorms with hail size greater than .75 inches, 34 occurrences with hail at least 2 inches in diameter, and eleven of those events causing over $9.1 million in reported property damage. Of these storms, three events account for $8.5 million of the $9.1 million in recorded damages. Extrapolating from this information, over the 17-year period between 1999 and 2016, the average annual property damage from hail storms is approximately $535,000. Since the 2018 NHMP update, over 20 hail events have been cited in Dane County alone.

4.9 LANDSLIDES, EROSION, AND SINKHOLES

4.9.1 Description

Landslides, erosion, and sinkholes are geological phenomena that can pose a hazard to structures and people. Although none of these events are likely to cause a major natural disaster in Dane County, all three present some level of risk to the County's citizens.

Erosion and Landslides

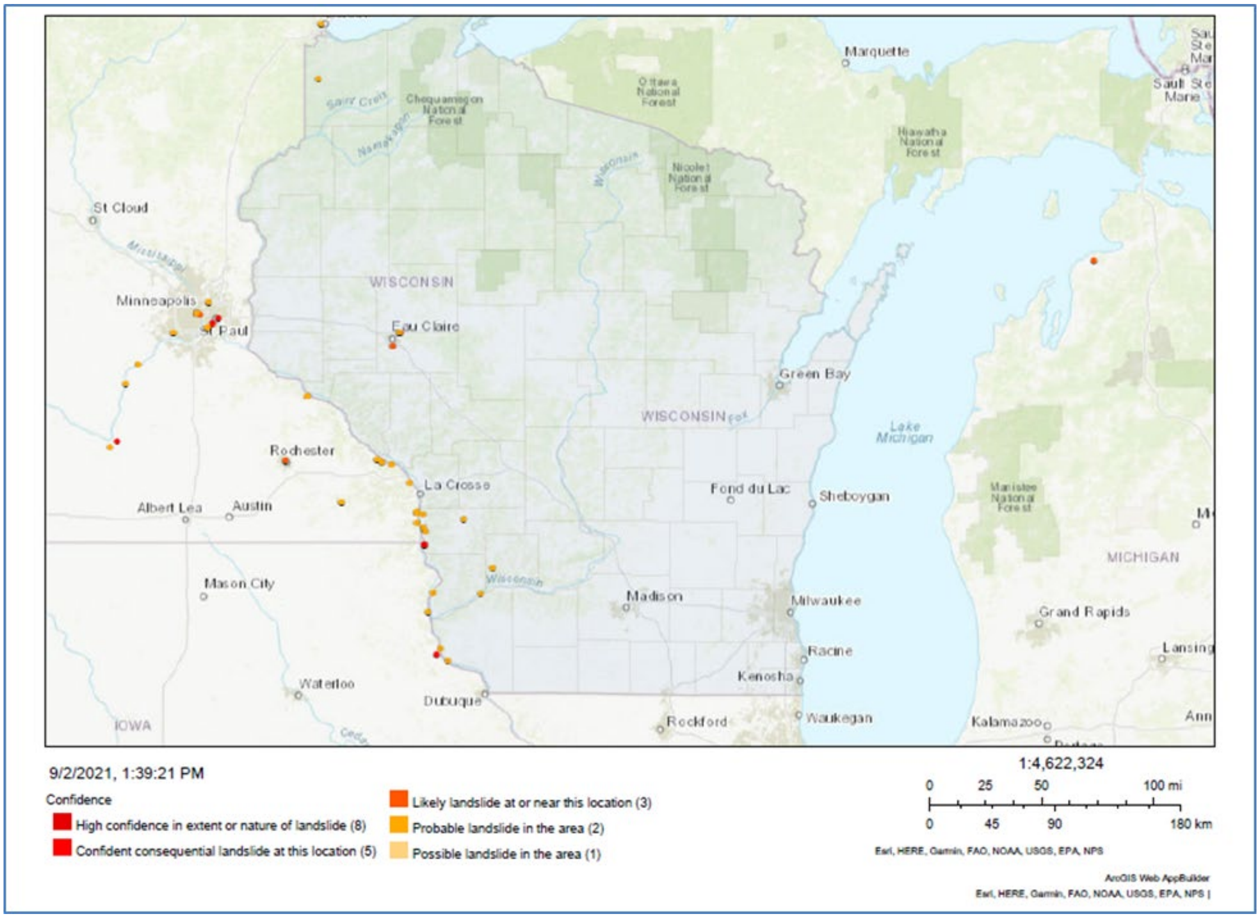
A landslide is a relatively sudden movement of soil and bedrock downhill in response to gravity. The movement of the soil can cause damage to structures by removing the support for the foundation of a building or by falling dirt and debris colliding with or covering a structure. Landslides can be triggered by heavy rain, bank or bluff erosion, or other natural causes.

Erosion is the detachment and movement of soils or rock fragments by water, wind, ice or gravity. Erosion may contribute to the likelihood and occurrence of landslides, particularly when stream banks or bluffs are eroded. The State Hazard Analysis from 2016 cites several examples where structures that were otherwise considered not vulnerable to landslides and flooding were endangered due to soil and streambank erosion.

According to the United States Geological Survey (USGS), "Landslides occur in every state and U.S. territory. The Appalachian Mountains, the Rocky Mountains and the Pacific Coastal Ranges and some parts of Alaska and Hawaii have severe landslide problems. Any area composed of very weak or fractured materials resting on a steep slope can and will likely experience landslides." (USGS "Landslides Hazard Program: Landslides 101." Available online at https://landslides.usgs.gov/learn/ls101.php last accessed December, 2021).

In Wisconsin, there have been instances of bluff slumping along the shore of Lake Michigan, rock fall along the bluffs of the Mississippi River and the collapsing of hillsides during heavy rainfall. Figure 4.9.1 indicates areas of landslide incidence and susceptibility. For Dane County, most of the land demonstrates both a low susceptibility and incidence. The southwest corner of the county demonstrates a moderate susceptibility and low incidence occurring, while a small portion just north of Madison demonstrates a high susceptibility and low incidence of occurrence. Steep slopes are another indicator of potential landslide problem areas, or areas that may have development constraints. Slopes greater than 12 percent are shown in Figure 4.9.2. The map indicates a concentration of these slopes in the southwestern, but also least populated area of the County.

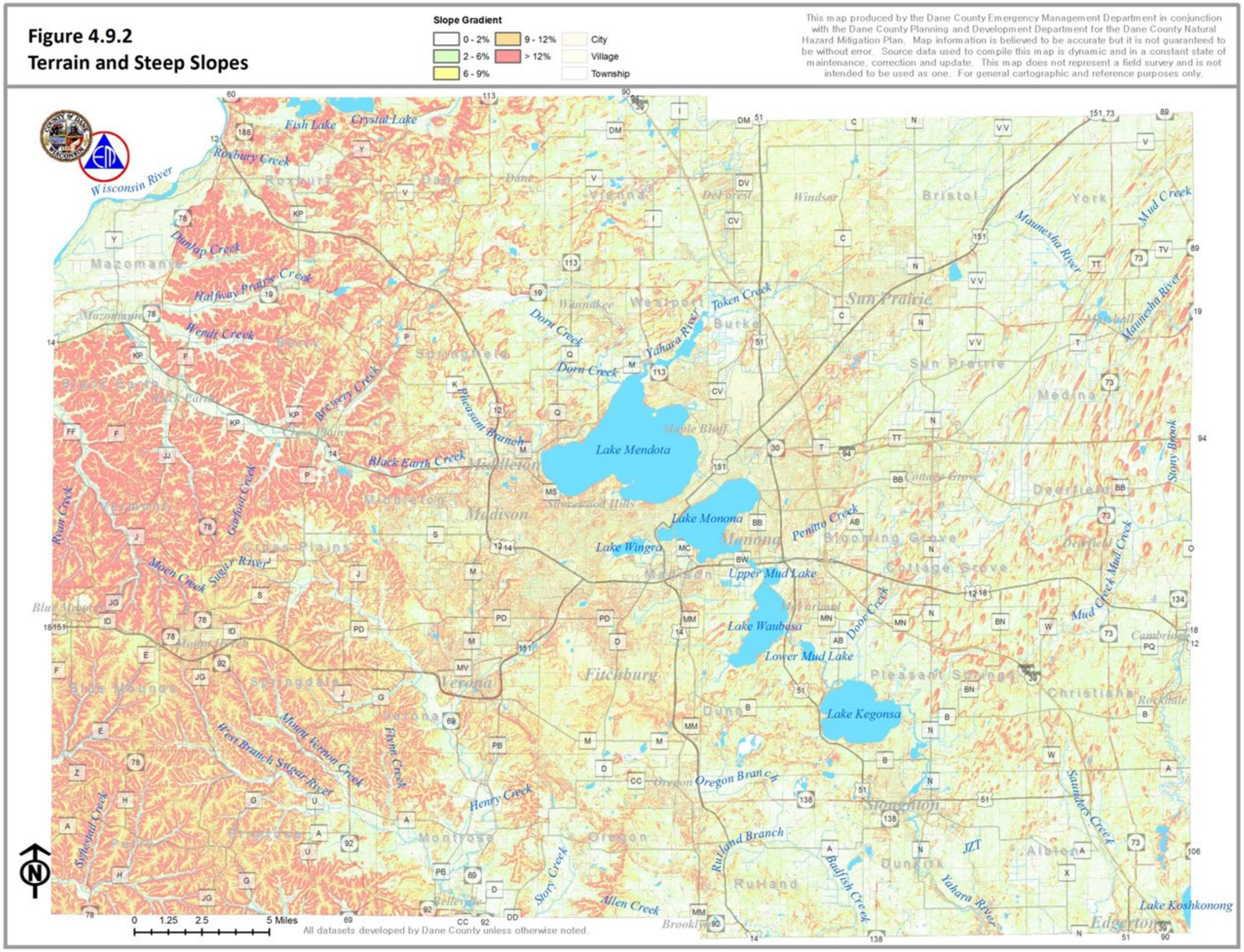
Figure 4.9.1 National Landslides Hazard Map – Wisconsin Focus



Source: USGS "Landslides Hazard Program" https://landslides.usgs.gov/hazards/nationalmap/index.php

Note: Susceptibility not indicated where same or lower than incidence. Susceptibility to landsliding was defined as the probable degree of response of [the area] rocks and soils to natural or artificial cutting or loading of slopes, or to anomalously high precipitation. High, moderate, and low susceptibility are delimited by the same percentages used in classifying the incidence of landsliding. Dane County is not in a landslide prone or vulnerable region.

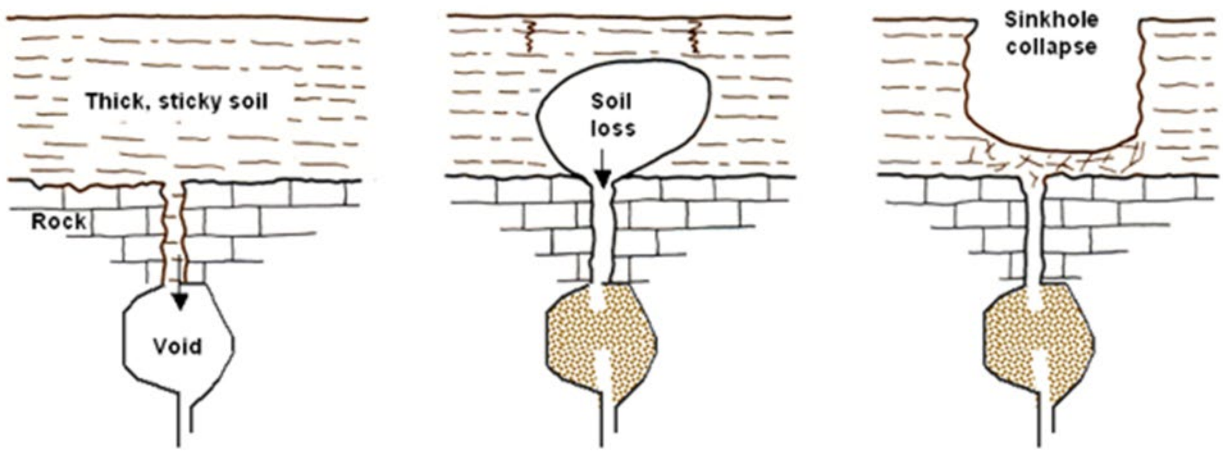
Figure 4.9.2 – Terrain and Steep Slopes



Sinkholes

Sinkholes are holes or depressions that form when water washes sediment down into cracks and voids in karst bedrock. Sinkholes form from the bottom up as the sediment immediately above the bedrock is the first to be washed into the voids. The land above a sinkhole often appears normal until a critical amount below has been washed away. When the soil surface can no longer support the weight, it collapses.

Figure 4.9.3 Sinkhole Formation Illustration



Source: Wisconsin Geological & Natural History Survey, http://wgnhs.uwex.edu/water-environment/karst-sinkholes/

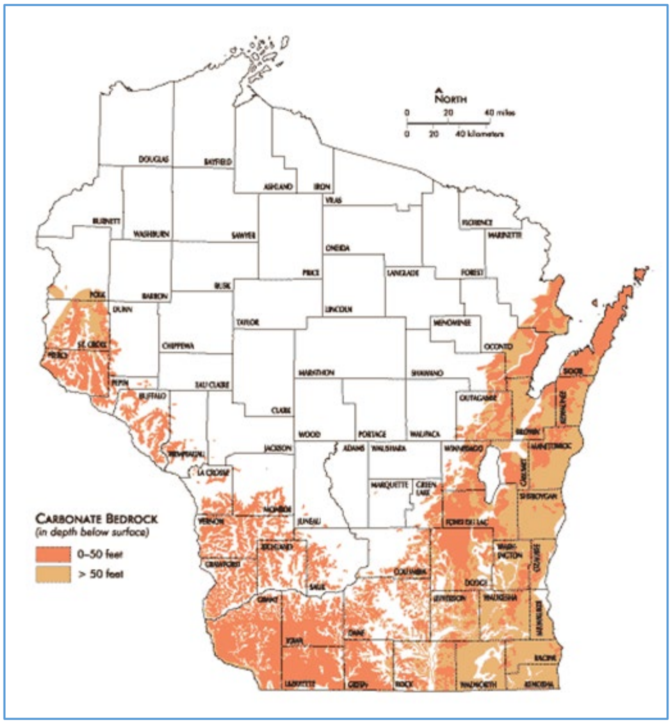
Karst" is a landscape created when water dissolves rocks. In Wisconsin, dolomite and some limestone are typical soluble rocks. The rocks are dissolved mostly along fractures and create caves and other conduits that act as underground streams. Water moves readily through these openings, carrying sediment (and pollutants) directly into our groundwater.

Karst landscapes may have deep bedrock fractures, caves, disappearing streams, springs, or sinkholes. These features can be isolated or occur in clusters, and may be open, covered, buried, or partially filled with soil, field stones, vegetation, water or other miscellaneous debris.

Not all sinkholes are the result of karst. Manmade sinkholes occur when a water main break washes sediment out of the area, creating a large cavity.

Areas with karst potential are indicated Figure 4.9.4. The majority of Dane County demonstrates a deeper karst potential, which indicates that the process occurs deeper than five feet below the surface. There are scattered shallow karst potential regions in the southwest corner of the County, consistent with the landslide susceptibility mapping and the presence of the “Driftless Area”. The “Driftless Area” is primarily composed of southwestern Wisconsin, and portions of Minnesota and Illinois, categorized by the lack of glacial drift, or the deposits of debris left behind glaciers. Shallow karst potential indicates the potential for the karst process to occur anywhere between the surface and five feet below the surface.

Figure 4.9.4 Wisconsin Karst Potential



Source: Wisconsin Geological & Natural History Survey

4.9.2 Previous Occurrences

Examples of landslides and damaging erosion in the County are not detailed specifically, but are reflected in the numerous erosion controls and ordinances in the County. There are no documented occurrences of significant problems associated with naturally occurring sinkholes in Dane County available.

August 14, 2015
Some 300 residents of River's Edge Apartments in Madison were evacuated Friday after a privately-owned water pipe broke, causing a potential gas leak and a sinkhole that submerged several vehicles. Several other vehicles were damaged by the flooding in the area, including inside the underground garages.

Source: Wisconsin State Journal

Note: This sinkhole was caused by a broken water pipe and was not, strictly speaking, naturally occurring.

4.9.3 Impact of Climate Change on Future Conditions

The predicted increases in temperature will likely result in stronger and more frequent rainstorms. Current models predict increased frequency and intensity of extreme weather statewide, including more frequent, more intense precipitation events. These changes have the potential to increase the incidence and severity of flooding, erosion, and landslides/land subsidence. These issues are discussed in more detail in the flood hazard section.

4.9.4 Impact Assessment

Direct Impacts

Direct impacts of these hazards impact essential infrastructure and natural resources primarily, with additional, but less severe, impacts on critical facilities and response capabilities. Landslides can impact the integrity and navigability of roads, rail lines, and waterways by filling the passages with soil and debris. This impacts the direct usage of the transportation networks and creates secondary impacts on the movement of supplies and goods, including critical supplies such as medications and foodstuffs, between distribution points and commercial centers.

Landslides, erosion, and sinkholes could impact the ability of response capabilities to navigate between areas. Population, general property, and cultural or historic resources are only impacted directly on a case-by-case basis, where a landslide, sinkhole, or erosion event directly strikes these specific areas. There is no quantifiable way to assess these incident-specific impacts outside of actual occurrences. Examples may include sinkholes damaging structures or croplands, erosion changing previously protected structures into exposed properties for flooding, or landslides damaging physical properties.

Indirect Impacts

The indirect impacts of erosion augment the probability and likelihood of other hazards, including landslides and flooding. The effects on water ecology are also profound, but exceed the scope of this planning process. Landslides may indirectly impact the landscape, which may also have land use or recreational repercussions. Revenue losses are possible due to inaccessibility of affected areas, lost agricultural income due to field degradation, and loss income from natural resources such as parks and waterways due to contamination, damage, or destruction caused by landslides, sinkholes, or erosion.

4.9.5 Vulnerability Assessment

The overall exposure of the County to landslides and sinkholes are difficult to quantify, as the events generally impact specific buildings or aspects of land and the predictability of those is variable. However, some attempt below is made to examine potential vulnerability for planning and mitigation efforts. Erosion potentially affects a greater number of properties and facilities, but it is also a heavily mitigated hazard within the County, as demonstrated by the numerous zoning and erosion control ordinances.

Population

In general, the population is not overly vulnerable to landslides, sinkholes or erosion except for specific and unpredictable incidents.

Property

In general, a building structure is only vulnerable to landslides, sinkholes and erosion when it directly strikes the property. The County has several ordinances and controls in place to regulate the development and use of land to prevent most occurrences of damaging erosion. Building on steep slopes subject to landslide hazards are also regulated. The continued emphasis on zoning, “smart growth” community plans, and land use ordinances indicate that the County is pre-mitigating the potential for these hazards, rather than reacting to the hazards.

4.9.6 Potential for Future Losses

There is little data to base a future loss estimate on for these hazards. Generally, the anticipated loss is expected to be limited. This is largely due to the fact that the areas potentially at risk (southwest Dane County) are also the least developed areas of the County.

Plans for regulating potential sources of erosion, including stormwater, streambank, farming, and construction sites, appears multiple times in the Dane County Comprehensive Plan, indicating that mitigation efforts for erosion are ongoing.

4.10 LIGHTNING

4.10.1 Description

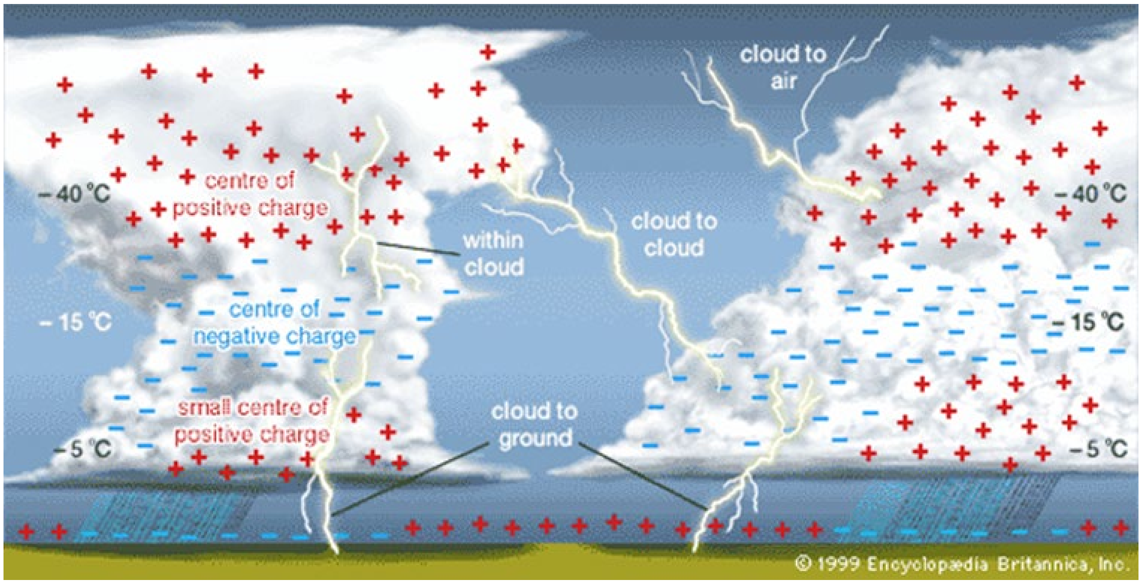
Lightning is caused by the attraction between positive and negative charges in the atmosphere, resulting in the buildup and discharge of electrical energy. This rapid heating and cooling of the air produces the shock wave that results in thunder. During a storm, raindrops can acquire extra electrons, which are negatively charged. These surplus electrons seek out a positive charge from the ground. As they flow from the clouds, they knock other electrons free, creating a conductive path. This path follows a zigzag shape that jumps between randomly distributed clumps of charged particles in the air. When the two charges connect, current surges through that jagged path, creating the lightning bolt. Each spark of lightning can reach over five miles in length, soar to temperatures of approximately 50,000 degrees Fahrenheit, and contain up to 100 million electrical volts.

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, rockets, very tall structures, and structures on mountains.

According to the National Weather Service, 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 it 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 4.10.1 Types of Lightning

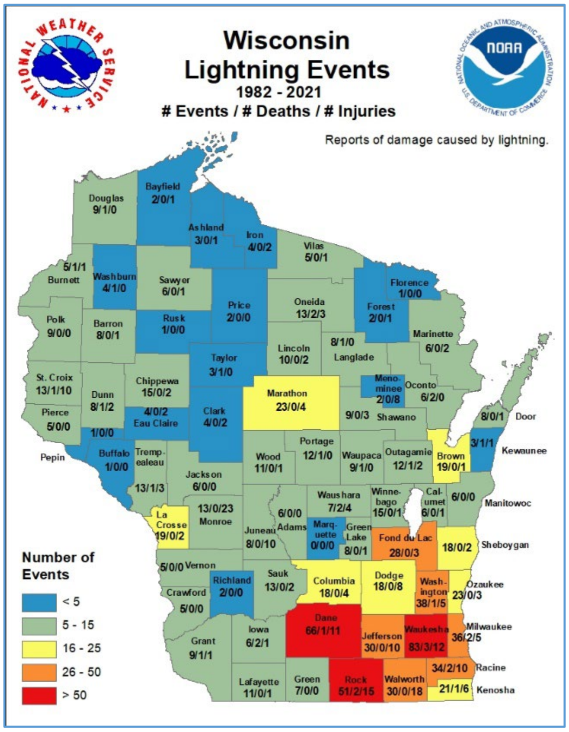


Source: Encyclopedia Britannica, Inc., http://whyfiles.org/2011/nothing-light-about-lightning/

High winds, rainfall, and a darkening cloud cover are warning signs for possible cloud-to-ground lightning strikes. While many lightning casualties happen at the onset of a storm, more than half of lightning deaths occur 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 exist when skies are clear. Lightning has been known to strike ten miles or more from the storm in an area with clear sky above. 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 these types of events with particular emphasis on adequate early warning. (Wisconsin Emergency Management, Wisconsin Threat and Hazard Identification and Risk Assessment, 2021)

4.10.2 Previous Occurrences

Figure 4.10.2 Wisconsin Lightening Events, 1992-2021



Source: National Weather Service

July 6, 2003

Lightning struck a home in Middleton, resulting in a roof/attic fire.

August 22, 2007

A thunder storm lightning strike to a utility pole caused a live wire to fall in a puddle of water at a bus stop as people were getting on a bus in Madison. Three people were killed and a fourth was injured.

August 27, 2007
A man playing golf Monday in Madison died after he was hit by lightning. The golfer sought shelter from the rain under a pine tree but was struck anyway. This was the second deadly incident caused by a lightning strike in Madison in a week.

June 2, 2010
A lightning strike ignited a fire that damaged areas of the second floor and attic of a home in the 3600 block of Wyndwood Way in the Town of Bristol.

October 12, 2016
Lightning struck the top of a Madison wastewater treatment plant causing a fire. The fire was quickly contained and extinguished by the local firefighters.

October 30, 2018
On October 30th, 2018, lightning directly struck a residence in the City of Middleton, on the 4500 block of Ellington way. The damages resulted in a total loss, which totaled up to $440,000 worth of damages. No fatalities or injuries were caused by this event.

July 7, 2020
On July 7th, 2020, lightning directly struck the residence of 100 Block West, Wilson Street, Madison Wisconsin. The City of Madison Fire Department put out a fire that was subsequently caused by the lightning strike, and it was estimated that about $50,000 worth of total damages were incurred. No fatalities or injuries were caused by this event.

4.10.3 Impact of Climate Change on Future Conditions

Damaging lighting and thunderstorms are already a regular occurrence. There is not a readily available source of information to assess whether the incidence of these storms will increase, decrease, or remain unchanged as a result of the warming climate. A qualitative argument can be made that more energy in the atmosphere resulting from increased concentrations of greenhouses would result in an increase of convective severe weather events such as thunderstorms. This is not borne out in currently available models, however. There is no clear trend to indicate whether or not this hazard is changing or will change significantly in the future.

4.10.4 Impact Assessment

Direct Impacts

Lightning always tries to follow the shortest, easiest path to earth, and often follows several paths simultaneously. Lightning strikes buildings or other objects because the materials in them provide easier paths to ground than the air. Lightning is more likely to strike on projecting objects such as trees, poles, wires or building steeples than on larger, flatter surfaces projecting to the same height or lower. Lone buildings are also primary targets. Lightning can enter a building through a direct strike, by striking a metal object attached to the building, by leaping over to the building after striking a nearby tree, or by following a power line or ungrounded wire fence attached to a building.

Lightning is often perceived as a minor hazard. The effects of lightning, however, can be significant, causing property damage, injury, and death. Damage from lightning occurs in a number of ways:

- Electrocution or severe electrical shock, and burns of humans and animals
- Vaporization of materials in the path of the strike
- Fire caused by the high temperatures associated with lightning
- Power surges that can damage electrical and electronic equipment

Lightning strikes are capable of causing intense, but very localized damage. In contrast to other hazards, lightning does not cause widespread disruptions with the community. Structural fires, localized damage to buildings, damage to electronics and electrical appliances, and electrical power and communications outages are typical consequences of a lightning strike.

When humans are struck by lightning, the result is deep burns at the point of contact mostly on the head, neck and shoulders. Approximately 70 percent of lightning survivors experience residual effects, most commonly affecting the brain (neuropsychiatric, vision and hearing). These effects can develop slowly, only becoming apparent much later. Death occurs in 20 percent of lightning strike victims. Nationwide, 85 percent of lightning victims are children and young men ages 10-35 engaged in recreation or work.

Indirect Impacts

The indirect social and economic impacts of lightning damage are typically associated with the loss of electrical power. Given our societies heavy reliance on electric power, any disruption in the supply, even for a short time period, can have significant consequences. The utilities supplying Dane County have worked closely with emergency response agencies and human services providers to develop plans for responding to planned and unplanned power outages in the County.

Lightning strikes on communications infrastructure, damaging equipment, and temporarily disrupting service are also an indirect impact. Communications towers typically have well-designed lightning protection systems and this is planned-for contingency.

Figure 4.10.5: Two-Way Radio Antenna, hit by lightning, blown off the tower.

Dane County Emergency Management, March 2017

4.10.5 Vulnerability Assessment

While national data shows that lightning almost causes more injuries and deaths than any other natural hazard except extreme heat, there doesn't seem to be any trend in the data to indicate that one segment of the population is at a disproportionately high risk of being directly affected. Anyone who is outside during a thunderstorm is at risk of being struck by lightning.

As with extreme heat, however, there are segments of the population that are especially vulnerable to the indirect impacts of lightning, particularly the loss of electrical power. As a group, the elderly or disabled, especially those with home health care services relying on rely heavily on an uninterrupted source of electricity. Resident populations in nursing homes, Community Based Residential Facilities, or other special needs housing may also be vulnerable if electrical outages are prolonged. If they do not have a back-up power source, rural residents and agricultural operations reliant on electricity for heating, cooling, and water supplies are also especially vulnerable to power outages.

Large outdoor gatherings (sporting events, concerts, campgrounds, etc.) are also particularly vulnerable to lightning strikes that could result in injuries and deaths. This vulnerability underscores the importance of developing site-specific emergency procedures for these types of events, with particular emphasis on adequate early warning. Early warning of lightning hazards, combined with prudent protective actions, can significantly reduce the likelihood of lightning-related injuries and deaths.

4.10.6 Potential for Future Losses

The potential for future losses due to lightning damage is estimated based on an extrapolation of losses from past events. There are limitations to this method:

- The exposure to damage increases as the population of the County increases. Future damages may increase simply due an increase in the amount of exposed property.
- The damages resulting from lightning depend greatly on where and when the storm hits. The use of average losses from past events does not account very well for these variables.
- Indirect impacts are not accounted for.
- While the estimation of future losses based on past events is unsophisticated, it still is a useful method of quantifying the damage potential.
- The only data source available is the NOAA, National Centers for Environmental Information (NCEI). It is highly likely that this dataset is incomplete and the actual losses and damages are underestimated.

The NCEI database indicates that between 1996 and 2021, Dane County has experienced 52 lightning events where property damage, personal injury or death has occurred. According to the NCEI, during this time period, damages totaled $2.68 million and there were 10 injuries and one direct fatality. Lighting was indirectly responsible for 3 deaths and one injury in 2007. Based on this history and assuming the losses could be proportionately spread over each incident, the estimated average loss per lightning strike event that causes damage is $51,538. Dane County averages 2.8 damaging strikes a year since 1996, which equates to an average annualized loss estimate of $148,887. Injuries occur every 2 years on average, and deaths every 20 years. Since 2018, one lightening event in the Village of Cross Plains resulted in two injuries, no deaths. Another lightening event was reported in October of 2018, resulting in property damage to a multi-dwelling unit and two injuries.

4.11 TORNADO

4.11.1 Description

A tornado is a violently rotating column of air (vortex), extending from the base of a convective cloud (usually cumulonimbus) to the ground. There may or may not be a visible condensation funnel (what most people refer to as the funnel cloud) associated with the tornado. Therefore, a tornado may be nearly invisible since one cannot see a vortex of rotating air. For a vortex to be classified as a tornado, it must be in contact with the ground and the cloud base. (American Meteorological Society, Glossary of Meteorology 2nd Edition. Available online at https://glossary.ametsoc.org/)

Tornadoes usually form under certain types of atmospheric conditions. They are more likely to occur in regions where there are strong contrasts in temperature and humidity across short distances. Nationally, these conditions are most common in the central plains of North America, east of the Rocky Mountains and west of the Appalachian Mountains. They occur mostly during the spring and summer, starting earlier in the south and later in the north. According to A Tornado Climatology of Wisconsin, the typical day with tornadoes usually begins with warm and humid conditions with a few fair-weather cumulus clouds developing vertically over time in the unstable air. Later the first sign of an approaching thunderstorm is observed—a high thin layer of ice clouds called cirrus blowing off the tops of the thunderstorm to the west. (National Severe Storms Laboratory "FAQ About Tornadoes." Available online at http://www.nssl.noaa.gov/research/tornadoes/)

Rotation in a thunderstorm begins when air entering the storm near the surface is blowing from different direction than air higher in the atmosphere. The rotation usually starts as a roll or horizontal rotation of the air in the lower 10,000 feet of the atmosphere. The warm updraft feeding the storm develops further, lifting one end of the rolling air and transforms the rotating mass into a vertical position. Most tornadoes rotate counterclockwise (cyclonically) in North America. Tornadoes may last for anywhere from a few minutes to up to an hour. The width of a tornado may range from a few yards to over a mile; the path of a tornado may range from a few hundred yards to hundreds of miles. (National Severe Storms Laboratory "FAQ About Tornadoes." Available online at http://www.nssl.noaa.gov/research/tornadoes/)

Through observational studies, T. Theodore Fujita created the Fujita Scale (commonly known as the "F Scale") in 1971 to classify tornadoes based on damage caused by the tornado in correlation to wind speed. However, over the years this scale has revealed several weaknesses and in 1992, Fujita published his memoirs called Mystery of Severe Storms which included an updated scale. This updated scale maintained the original classification of tornado wind speeds with damage assessments based on the type of structure. These improvements were incorporated by a committee convened by Texas Tech University (TTU) Wind Science and Engineering (WISE) Research Center to design the Enhanced Fujita Scale, commonly known as the EF Scale. One of the most important factors of the EF Scale is that it includes previous F Scale ratings to create consistency between the initial tornado databases, which stretch back into the 1950s, and the more contemporary measurement systems. This new system still uses wind estimates (not measurements) based on damage to assign scale ratings. It uses three-second gusts estimated at the point of damage based on a judgment of 8 levels of damage to one of 28 indicators (building types and materials). The estimates also vary with height and exposure.

A table showing the relationship between the original Fujita Scale and the Operational EF Scale, which was enacted as the standard measurement system in the United States beginning February 1, 2007, is presented in Table 4.11.1

Table 4.11.1 Fujita and Enhanced Fujita Scale Comparison

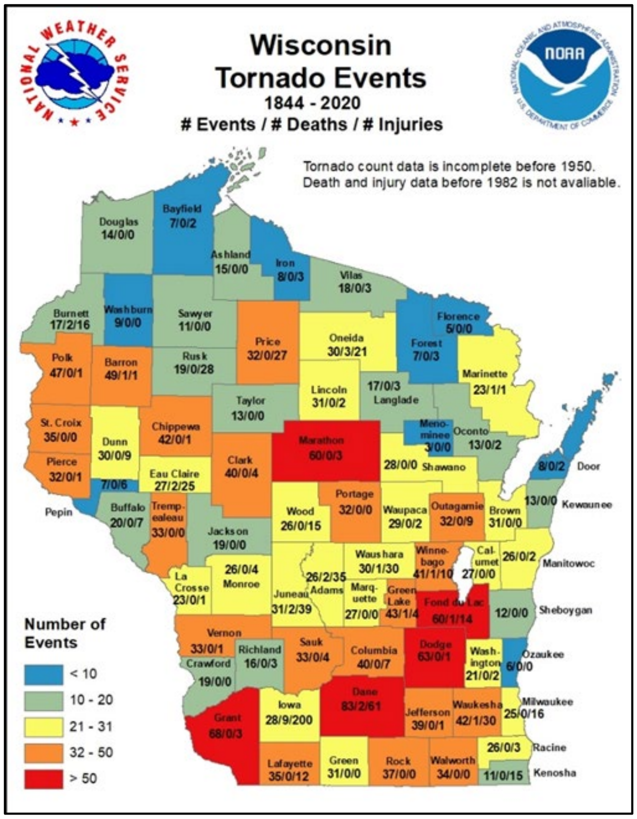
Fujita Scale			**Derived EF Scale**		**Operational EF Scale**	
F Number	Fastest 1/4-mile (mph)	3 Second Gust (mph)	EF Number	3 Second Gust (mph)	EF Number	3 Second Gust (mph)
0	40-72	45-78	0	65-85	0	65-85
1	73-112	79-117	1	86-109	1	86-110
2	113-157	118-161	2	110-137	2	111-135
3	158-207	162-209	3	138-167	3	136-165
4	208-260	210-261	4	168-199	4	166-200
5	261-318	262-317	5	200-234	5	Over 200

Source: National Weather Service. Available online at http://www.spc.noaa.gov/faq/tornado/ef-scale.html

Tornadoes are documented across Wisconsin, as demonstrated in Figure 4.11.2 Dane County currently has more reported tornado events than any other county in Wisconsin for the period of 1955-2020. This is partially due to the fact that Dane County is a large county– the larger the county the greater the chances that a tornado will occur within its boundaries. However, Southern Wisconsin tends to experience more tornadoes than northern Wisconsin since it is closer to the storm track that pulls warm and moist air up from the Gulf of Mexico. Warm, moist air is the fuel for thunderstorm development.

Figure 4.11.3 shows the tornado paths or, for short-duration events, the tornado touch-down points. This figure indicates that tornadoes occur in any portion of the county and often cross county lines. Despite this overall possibility of tornadoes, a single tornado does not impact the entire county simultaneously and damages less than five percent of the total county area in any given event (an extreme example: a 1-mile wide tornado going northeast along the 51-mile diagonal of Dane County would damage 51 square miles, or only 4.2% of the total county area).

Figure 4.11.2 Wisconsin Tornado Events, 1844-2020



Source: National Weather Service

Figure 4.11.3 Wisconsin Tornado Tracks/Steaks, 1950-2020

Source: NOAA, NWS, SVRGIS Geo-data, Wisconsin Map Developed by DCEM

Data from the National Weather Service (NWS), indicates that more tornadoes have affected Dane County in the past five decades, as compared to previous decades. However, much of this increase is due to greater documentation efforts by NWS meteorologists, especially from the 1980s to the present. Prior to the 1960s, unless a tornado struck a highly populated are in broad daylight, it likely went undocumented. Additionally, severe weather spotter and research videotapes of tornadoes in the past 20 years has shown that a tornado can be in progress, but a visible “funnel cloud” may be absent or poorly defined. In these cases, confirmation of a tornado is based on a rotating dirt/debris spray observed at ground and cloud-base rotation directly above. Table 4.11.4 provides a listing of Dane County tornadoes from the NCEI database.

Table 4.11.4 Dane County Tornadoes, 1955-2021

Date	Scale (F or EF)	Direct Deaths	Direct Injuries	Property Damage	Tornado Length (Miles)	Tornado Width (Yards)
4/18/1955	F2	0	0	$250,000	9.2	100
10/9/1958	N/A	0	0	$30	1	50
7/10/1966	F1	0	0	$25,000	0.1	33
6/11/1967	F2	0	0	$250,000	1.3	10
8/2/1967	F3	2	5	$25,000	0	200
4/20/1968	F2	0	0	$25,000	0.1	33
5/31/1969	F0	0	0	$2,500	1	50
6/4/1969	F2	0	0	$25,000	4.9	300
5/9/1970	F1	0	1	$25,000	1	100
10/9/1970	F2	0	0	$250,000	3.3	50
6/18/1971	F1	0	0	$25,000	1	100
9/4/1971	F1	0	0	$2,500	0.5	50
9/20/1972	F1	0	0	$25,000	0.5	50
3/11/1973	F1	0	0	$0	0.5	50
5/21/1974	F1	0	0	$250,000	2.3	50
6/4/1975	F3	0	0	$25,000	2.3	33
7/30/1976	F2	0	0	$0	0	33
6/15/1981	F2	0	0	$250,000	1	33
6/8/1984	F2	0	0	$2,500,000	3	50
5/30/1985	F2	0	0	$250,000	21	100
7/11/1986	F1	0	0	$250,000	0.8	50
5/8/1988	F2	0	1	$25,000	7	100
5/8/1988	F2	0	0	$250,000	16	173
6/14/1989	F1	0	0	$250,000	0.2	50
6/14/1989	F1	0	0	$250,000	0.2	50
6/14/1989	F0	0	0	$0	0.2	50
6/14/1989	F0	0	0	$0	0.1	23

Date	Scale (F or EF)	Direct Deaths	Direct Injuries	Property Damage	Tornado Length (Miles)	Tornado Width (Yards)
3/27/1991	F2	1	5	$2,500,000	12	440
5/22/1991	F0	0	0	$0	0.1	23
6/17/1992	F3	0	30	$25,000,000	16	400
7/4/1994	F0	0	0	$0	0.1	25
7/25/1997	F1	0	0	$130,000	1	100
7/25/1997	F1	0	1	$388,500	2.7	175
5/30/2003	F0	0	0	$0	3.1	25
5/23/2004	F0	0	0	$0	1	25
5/23/2004	F0	0	0	$0	1.3	25
6/23/2004	F0	0	0	$3,000	0.1	25
6/23/2004	F1	0	0	$1,490,000	7.8	200
7/11/2004	F0	0	0	$0	0.1	25
3/30/2005	F0	0	0	$2,000	0.2	50
8/18/2005	F3	1	23	$34,310,000	17	600
8/18/2005	F0	0	0	$0	2	30
8/18/2005	F1	0	0	$75,000	1.6	100
6/18/2006	F0	0	0	$0	0.1	20
6/7/2008	EF0	0	0	$0	0.45	25
6/7/2008	EF0	0	0	$0	0.21	25
6/7/2008	EF1	0	0	$429,000	3.83	150
6/12/2008	EF1	0	0	$0	4.41	100
6/12/2008	EF0	0	0	$0	2.56	50
6/21/2010	EF1	0	0	$15,000	0.16	40
7/22/2010	EF1	0	0	$1,000	1.53	30
7/22/2010	EF0	0	0	$0	3	30
7/22/2010	EF1	0	0	$20,000	4.18	75
7/22/2010	EF1	0	0	$5,000	1.46	75
7/22/2010	EF0	0	0	$0	0.22	30
6/8/2011	EF0	0	0	$100,000	17.15	100
8/8/2011	EF0	0	0	$0	1.21	20
6/16/2014	EF3	0	0	$14,000,000	0.96	100
6/16/2014	EF2	0	0	$5,000,000	0.22	200
6/16/2014	EF1	0	0	$300,000	1.49	300
6/18/2014	EF0	0	0	$0	0.16	30
6/29/2014	EF1	0	0	$50,000	2.32	500
10/07/2017	EF0	0	0	$250,000	9.7	33
08/9/2018	EF0	0	0	$50,000	0.25	8.3

Date	Scale (F or EF)	Direct Deaths	Direct Injuries	Property Damage	Tornado Length (Miles)	Tornado Width (Yards)
07/29/2021	EF0	0	0	Pending	2.47	125
07/29/2021	EF0	0	0	Pending	3.58	75

Source: Dane County Emergency Management, 2021

In more recent years, the National Weather Service and the NOAA National Centers for Environmental Information (NCEI) have been tracking weather extremes and their consequences in greater detail. A search of the NCEI website provided the following descriptions of several tornadoes from the past twenty years:

4.11.2 Previous Occurrences

June 1984

At approximately 12:41 am the 8th of June an F5 Tornado touched down in neighboring Iowa County, leveling Barneveld, a village of over 600 people. One of the few structures left standing was the water tower. The Barneveld Tornado remained on the ground throughout its entire 36-mile journey. Additionally, the path of the tornado's destruction was exceptionally wide, at times 300 yards.
Soon after touching down in Barneveld, the tornado headed on a northeast path into Dane County. The path of the tornado went through the Town of Vermont and through the Village of Black Earth, and the NCEI records indicate the Tornado had dissipated to F2 intensity by that time. Twenty-four homes were damaged and at least 8 were destroyed. Woodlots were plucked clean of foliage and branches, and some trees were uprooted from the ground. Once the tornado dispersed, nine people were left dead (all in Barneveld) and about 200 were left injured as a direct result of the storm. Total damages exceeded $66.3 million. Dane County damages totaled approximately $4.1 million. Dane County received a Presidential Disaster Declaration to assist with recovery costs from this storm.

June 1992

On June 17 at 12:06 pm, an F3 tornado struck Dane County. The tornado first touched down in the Village of Belleville, about 15 miles south of the City of Madison, and began its trek northeast touching down just east of Highway 69 damaging farm structures and killing livestock. It then headed into the City of Fitchburg leveling a subdivision (18 homes total) severely damaging the Oregon Correctional Facility, destroying 20 buildings. The tornado also did damage in the Town of Dunn, destroying numerous homes. Although no deaths were reported approximately 30 people sustained injury. An estimated 201 homes were damaged totaling $30.6 million in losses. Damages are estimated at 30 homes destroyed, 34 with heavy damage, 29 with medium damage, and more than 130 incurred minor damage. Dane County received a Presidential Disaster Declaration to assist with recovery costs from this storm.

August 18, 2005

A strong and destructive tornado spun up at 1715CST about 2.8 miles southeast of the geographic center of Fitchburg (or 2.0 miles north of center of Oregon), about 400 yards southwest of the intersection of CTH MM and Schnieder Rd. It continued east-southeast to the southern edge of Lake Kegonsa and tore through residential neighborhoods about 1/3 to 1/2 mile north of the towns of Dunn and Pleasant Springs, and far-northern Stoughton. It moved with Interstate 90/39, and stayed close to CTH A to its exit point at 1905CST where CTH A crosses into Jefferson County, about 2.8 miles south-southwest of Rockdale.

August 18, 2005 Tornado

Photo by Colin McDermott

One person was crushed to death in their basement from fireplace and chimney bricks that crashed through the floor. Twenty-three (23) other people were directly injured. In addition, Emergency Management officials received reports of 2 other indirectly-related deaths associated with this strong tornado. In these two cases, the people were already very ill or suffering from a life-ending disease. Injuries they received during the tornado contributed (secondary) to their death, but were not the primary cause of death, based on medical examiner reports. Consequently, these additional two deaths do not appear in the official death tally in the header strip of this event. Numerous homes, businesses, farm buildings, vehicles, power-lines, trees, and other personal effects were either damaged or destroyed along its path that grew to a maximum width of about 600 yards north of Stoughton. As for residential structures, 220 sustained minor damage, 84 had major damage, and 69 were destroyed. As for business structures, 6 sustained minor damage, 1 had major damage, and 1 was destroyed. As for agricultural structures, 5 sustained minor damage, 5 had major damage, and 40 were destroyed. The overall slow movement (the supercell moved at 12-17 knots, or 10-15 mph), coupled with structures that were not thoroughly reinforced (based on NWS damage survey), allowed the tornado's cyclonic winds to more severely damage buildings in its path. Consequently, although some of the worst damage resembled what would be left by a F4 tornado for well-built homes, this tornado was rated at the top of the F3 category with estimated winds near 174 knots (200 mph).

Total estimated damage amounts (directly-related) for private and public sectors combined was $35.06 M, broken down to $34.31 million in property damage and $750,000 in crop losses, for the tornado segment in Dane County. The $34.31 million in property damage was broken down to private losses (total of $32.29 million) and public losses (total of $2.02 million). The private losses included a total of $25.45 million for residential structures; $1.29 million for businesses; $4.25 million for agricultural structures; $1 million for damage to vehicles, boats, and other personal effects; $200,000 to agricultural machinery and tools; and $96,000 in public road system damage. The public losses making up part of the

$34.31 million consisted of $2.02 million in damage to public utility systems. The $750,000 in damage attributed to crop losses occurred on an estimated 1,550 acres of land. Additional monetary costs incurred in the public sector (totaling $1.84 million) which are considered indirectly-related damage expenses, and not included in the "direct" totals listed in the header-strip of this event, include: $1.38 million in debris clearance; $308,000 in protective measures; and miscellaneous damage/expenses of $144,000. Therefore, the grand total of direct and indirect damage amounts and expenses attributed to this tornado segment in Dane county totaled about $36.89 million. The State Disaster Fund provided relief aid for this disaster.

August 18, 2005 Tornado Damage

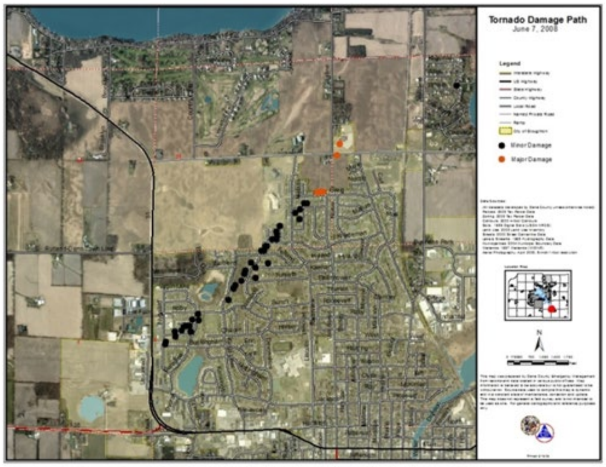
Source: Dane County Emergency Management

This was part of the largest single-day tornado outbreak in Wisconsin recorded history for south-central and southeast Wisconsin. A total of sixteen tornadoes were documented on this day.

June 7, 2008

This tornado moved from just west of Hults Road on the far western part of Stoughton northeast to a point northwest of the intersection of CTH B and CTH N. Based on the observed damage, it was probably a multiple-vortex tornado. In the Stoughton area, with respect to residential homes, it resulted in very minor damage to 24 homes, minor damage to 21 homes, and major damage to 3 homes. Additionally, 1 church sustained major damage, and 1 tobacco shed was destroyed. Total estimated property damage (roofs, siding, walls, windows) in the Stoughton area was $429,000.

June 7, 2008 Tornado Damage Path



Source: Dane County Emergency Management, 2017

June 12, 2008

This tornado in south-central Dane County was a continuation of a tornado that spun up mid-way between the city of New Glarus and the village of Postville in northwest Green County. It entered Dane County on the west side of the City of Belleville and then moved northeast through the Lake Belle View area and crossed STH 69 about 1 mile north of the County Line, and ultimately dissipated southeast of Basco, near CTH A. Luckily only tree damage occurred - of the uprooted tree or broken tree branch variety. Wind speed estimated at 83-87 knots (95-100 mph). The average path width in Dane County was about 60 yards.

June 16, 2014

A large storm produced several tornadoes and damaging straight line winds. One of those tornadoes was an EF3 with estimated winds of 140 mph hit the Country View Elementary School in Verona. The storm was at night, so no one was at the school, but it was severely damaged and needed to be rebuilt. The storm damaged 14 businesses and more than 250 homes, resulting in more than $14 million in damages and more than $5 million in public sector response and recovery costs. Most of these losses were in the City of Verona and the City of Madison. Fortunately, there were no injuries or deaths.

October 7, 2017

On October 7th 2017, and EF-0 tornado touched down in Eastern Madison in the early evening. The NWS reported that the maximum winds were up to 70-80 MPH. The width of the tornado was estimated to be around 50-100 yards, and the tornado was on the ground for approximately 4 miles. Roof and tree damage was discovered, and an auto shop was reportedly completely destroyed. No fatalities or injuries were reported in relation to this tornado event.

August 9, 2018
In the afternoon of August 9th, 2018, severe thunderstorms caused a brief EF-0 tornado to make contact with the Village of Deerfield for approximately 0.7 miles. The tornado was about 25 yards in length with average speeds of 80 MPH. No fatalities or injuries were reported in relation to this tornado event.

July 29, 2021
An outbreak of tornadoes was reported on July 29th, 2021 in Western Dane County, following severe thunderstorms and straight line winds. Two tornadoes ranging between EF-0 and EF-1 were found near the City of Verona, and two tornadoes also ranging between EF-0 and EF-1 were found near the Village of Cross Plains. An EF-1 tornado was also spotted in Southern Middleton. Over 10 tornadoes were spotted across the southern region of Wisconsin. This series of tornadoes were related to a national level tornado outbreak, observed across the northern United States. Minor damage to property caused by high winds was reported across Dane County, and no fatalities or injuries were reported in relation to this tornado event.

4.11.3 Impact of Climate Change on Future Conditions

Tornadoes are already a regular occurrence in Wisconsin and Dane County. There is not a readily available source of information to assess whether the incidence of these storms will increase, decrease, or remain unchanged as a result of the warming climate. A qualitative argument can be made that more energy in the atmosphere resulting from increased concentrations of greenhouses would result in an increase of convective severe weather events such as severe thunderstorms and tornadoes. This is not borne out in currently available models, however. There is no clear trend to indicate whether or not this hazard is changing or will change significantly in the future.

4.11.4 Impact Assessment

Direct Impact

The impacts of tornadoes are well documented. In fact, tornadoes are classified according to the damages they cause. Through observational studies, T. Theodore Fujita created the following scale in the late 1960's to classify tornadoes. The scale correlates wind speeds with damage: EF-0 is the weakest and EF-5 the strongest.

- *EF0 Category Tornado*: wind speeds between 65-85 mph – *Gale tornado* – Light damage. Some damage to chimneys; breaks twigs and branches off tress; pushes over shallow-rooted trees; damages signboards; some windows broken; hurricane wind speed begins at 73 mph.
- *EF1 Category Tornado*: wind speeds between 86-110 mph – *Moderate tornado* – Moderate damage. Peels surfaces off roofs; manufactured homes pushed off foundations or overturned; outbuildings demolished; moving autos pushed off the roads; trees snapped or broken.

- *EF2 Category Tornado*: wind speeds between 111-135 mph – *Significant tornado* – Considerable damage. Roofs torn off frame houses; manufactured homes demolished; frame houses with weak foundations lifted and moved; boxcars pushed over; large trees snapped or uprooted; light-object missiles generated.
- *EF3 Category Tornado*: wind speeds between 136-165 mph – *Severe tornado* – Severe damage. Roofs and some walls torn off well-constructed houses; trains overturned; most trees in forests uprooted; heavy cars lifted off the ground and thrown; weak pavement blown off roads.
- *EF4 Category Tornado*: wind speeds between 166-200 mph – *Devastating tornado* – Devastating damage. Well-constructed homes leveled; structures with weak foundations blown off some distance; cars thrown and disintegrated; large missiles generated; trees in forest uprooted and carried some distance away.
- *EF5 Category Tornado*: wind speeds over 200 mph – *Incredible tornado* – Incredible damage. Strong frame houses lifted off foundations and carried considerable distance to disintegrate; automobile-sized missiles fly through the air in excess of 300 ft (100 m); trees debarked; incredible phenomena will occur.

Indirect Impact

Secondary impacts of tornado damage often result from damage to infrastructure. Downed power and communications transmission lines, coupled with disruptions to transportation, create difficulties in reporting and responding to emergencies. These indirect impacts of a tornado can put tremendous strains on a community. In the immediate aftermath, the focus is on emergency services. Law enforcement activities focus on scene security. Fire and EMS personnel are needed to rescue the injured, put out any fires caused by broken gas lines or other similar hazards and assist in the clean-up. Utility crews will be needed to restore power, phone and other utility services. Highway and public works crews are needed to remove debris from roadways so other responders can get through to the victims and their property. Victims and their insurance agents need access to the properties so they can assess the damage and search for valuables or heirlooms.

As the response shifts to long-term recovery, to focus turns toward restoring the community back to normal. This can take years in some cases. The costs associated with the long-term recovery of a community are difficult to quantify, however the issues may include:

- Short-term
    - Debris Removal
    - Storage and distribution of donated goods
    - Coordination of volunteers
    - Site security
    - Restoration of the function of critical facilities
- Agricultural Production
    - Crop damage or loss

  - Loss of livestock
  - Damage to houses, barns, and other farm buildings
  - Damage to farm machinery
  - Income loss
- Urban, Residential, and Commercial
  - Damage to or destruction of buildings
  - Loss of commercial buildings and goods
  - Loss of trees and landscaping
  - Damage to and destruction of automobiles and trucks
  - Disruption and subsequent restoration of public infrastructure including communications, electrical power, drinking water, transportation.
- Health and Safety
  - Injuries
  - Fatalities
  - Mental and physical stress associated with loss of family, friends, and property
- General
  - Economic losses to businesses
  - Revenue losses to state, and local governments
  - Increased demand on disaster assistance programs

4.11.5 Vulnerability Assessment

In general, all Dane County buildings, critical facilities, and populations are vulnerable to tornado damage.

There are also segments of the population that are especially vulnerable to the indirect impacts of tornadoes, particularly the loss of electrical power. As a group, the elderly or disabled, especially those with home health care services relying on rely heavily on an uninterrupted source of electricity. Resident populations in nursing homes, Community Based Residential Facilities, or other special needs housing may also be vulnerable if electrical outages are prolonged. If they do not have a back-up power source, rural residents and agricultural operations reliant on electricity for heating, cooling, and water supplies are also especially vulnerable to power outages.

4.11.6 Potential for Future Losses

The potential for future losses due to tornado damage is estimated based on an extrapolation of losses from past events. There are limitations to this method:

- Every tornado is unique in location, duration, and intensity. It is impossible to predict with any degree of certainty where and when a tornado will strike. As a result, the risk of tornado occurrence is essentially uniform, countywide.
- The exposure to damage increases as the population of the County increases. Future damages may increase simply due an increase in the amount of exposed property. This method of estimation cannot account for increasing risk due to growth.
- Indirect impacts are not well accounted for.
- The damages resulting from a tornado depend greatly on where and when the storm hits. A severe tornado tracking through an undeveloped area may cause less damage than a weak tornado striking an urban or residential area.

While the estimation of future losses based on past events is unsophisticated, it still is a useful method of quantifying the damage potential. The following assumptions were made for this estimation:

- Based on National Weather Service and NCEI data spanning the time period of 1955 to 2016, the average tornado in Wisconsin is 3.7 miles long and 118 yards wide, and remains on the ground for an average of 7.1 minutes. The average affected area by a tornado equals 158 acres.
- Rounding up, the average intensity is EF2.
- Residential, commercial, and manufacturing and agricultural properties are evenly distributed across the County.
- The Enhanced Fujita Scale was designed with a "well-constructed" frame house as the standard for assessing failures in building construction. Due to the variability in the quality of construction and other factors, some buildings may experience less or more damage than others when exposed to F2 category wind speeds.

In addition to structural damage, building contents and personal property will also be damaged or destroyed as a result of a tornado. Approximations of the value of building contents are based on the FEMA estimates collected in Table 4.11.9.

Table 4.11.9 Building contents value as a percentage of parcel improvement

Occupancy	Contents Value (%)
Residential	50
Commercial (including retail, wholesale, professional, services, financial, entertainment & recreation)	100
Commercial (including hospital and medical office/clinic)	150
Industrial (including heavy, light, technology)	150
Industrial Construction	100
Agriculture	100
Religion/Non-Profit	100
Government Emergency Response	150
Government General Services	100

Occupancy	Contents Value (%)
Education Schools/Libraries	100
Education Colleges/Universities	150

Source: FEMA, Hazus, 2009

To account for the variations in construction and the actual distribution of residential, commercial, and manufacturing properties, a range of damage potentials, as collected in Table 4.11.4 were used. Calculations performed using these tables are presented as an average, with site-specific variations expected, but not easily quantified. They provide an "average expectation" or "typical impact".

Table 4.11.10 Average Loss Expected by Fujita Damage Scale

Fujita Scale	Damage Description	Percentage of Structure and Building Contents Value Lost due to Damage
EF0	Light damage. Some damage to shingles, soffits and fascia, siding, and windows.	0% to 5%
EF1	Moderate Damage. Roof surface peeled off; window breakage; attached garages may be destroyed.	5% to 20%
EF2	Considerable damage. Roofs torn off frame houses; light object missiles generated.	50% to 100%
EF3	Severe Damage. Roof and some walls torn off well-constructed houses.	100%
EF4 and above	Devastating Damage. Well-constructed houses leveled; structures with weak foundations blown off some distance; large missiles generated.	100%

Calculations performed using the above tables are presented as an average, with site-specific variations expected, but not easily quantified. They provide an "average expectation" or "typical impact". Table 4.11.11 below was developed using the process as described below.

Precursor Step: Total parcel count, improved parcel count, improved land value, and contents value can be developed by using parcel data and land use data from the Dane County Land Information Office (LIO). Parcel and land use data can be configured and joined using spatial analyst tools in ArcGIS Desktop 10.8 and all versions of ArcGIS Pro.

Step	Process	Example Calculation
1	Convert municipality's area to acres.	35.16 mi² → 22501.27 acres
2	Divide the average tornado area (540 Acres) by the municipal acreage. Convert to Percentage. This will be your **Percent of Area Impact.**	(540 / 22501.27)*100 = 2.41% (540 / 22501.27)*100 = 2.41%
3	Ensure that the percentage of area impact is In decimal form if you are doing these calculations outside of Microsoft Excel. Then, multiply improved parcel count with percentage of area impact. This will be your **Affected Structure estimate.**	2.41% → 0.0241 7474 * 2.41% = 179

Step	Process	Example Calculation
4	Add Improved land values with content values. This will be your **Total Exposure Value**.	3,742,236,500 + 1,871,118,250 = 5,613,354,730
5	Multiple total exposure value with percent area of impact. This will be your **Estimated High Loss**. *Note: in excel, you may need to reuse step 4's addition with parenthesis, and then multiply by percent area of impact, instead of multiplying by the total exposure value raw.*	5,613,354,730 * 0.0241 =135,281,849
6	Divide your estimated high loss value by 2. This will be your **Estimated Moderate Loss**.	135,281,849 / 2 =67,640,924
7	Divide your estimated high loss value by 2. This will be your **Estimated Low Loss**.	67,640,924 * 0.25 = 16,910,231

Source: Analysis developed by Dane County Emergency Management, 2021

Table 4.11.11 Tornado Damage Estimates, Sorted by Jurisdiction

Municipality	Number of Affected Structures	Improved Parcel Value ($)	Estimated Contents Value ($)	Total Property Exposure ($)	Affected Property Exposure ($) High Damage Range	Affected Property Exposure ($) Moderate Damage Range	Affected Property Exposure ($) Low Damage Range	Loss Ratio
Cities								
Edgerton	74	52915700	26,457,850	79,373,550	79,373,550	39,686,775	19,843,388	50%
Fitchburg	179	3742236500	1,871,118,250	5,613,354,750	134,712,864	67,356,432	33,678,216	1%
Madison	797	45808306300	22,904,153,150	68,712,459,450	730,177,417	365,088,709	182,544,354	1%
Middleton	556	3089424100	1,544,712,050	4,634,136,150	430,970,529	215,485,264	107,742,632	5%
Monona	985	1182462600	591,231,300	1,773,693,900	455,715,669	227,857,834	113,928,917	13%
Stoughton	784	1296868100	648,434,050	1,945,302,150	271,147,682	135,573,841	67,786,920	7%
Sun Prairie	710	3262932800	1,631,466,400	4,894,399,200	342,418,960	171,209,480	85,604,740	3%
Verona	508	8179690700	4,089,845,350	12,269,536,050	1,472,406,527	736,203,263	368,101,632	6%
Towns								
Albion	63	388436600	194,218,300	582,654,900	13,906,205	6,953,102	3,476,551	1%
Berry	39	365734800	182,867,400	548,602,200	12,913,245	6,456,622	3,228,311	1%
Black Earth	31	109328000	54,664,000	163,992,000	8,087,048	4,043,524	2,021,762	2%
Blooming Grove	171	216169868	108,084,934	324,254,802	52,985,058	26,492,529	13,246,264	8%
Blue Mounds	34	349165500	174,582,750	523,748,250	13,599,056	6,799,528	3,399,764	1%
Bristol	68	620436800	310,218,400	930,655,200	23,194,955	11,597,478	5,798,739	1%
Burke	127	508169400	254,084,700	762,254,100	41,856,541	20,928,270	10,464,135	3%
Christiana	43	312001600	156,000,800	468,002,400	11,331,808	5,665,904	2,832,952	1%
Cottage Grove	85	535192400	267,596,200	802,788,600	21,006,285	10,503,143	5,251,571	1%
Cross Plains	41	317912900	158,956,450	476,869,350	11,498,942	5,749,471	2,874,736	1%
Dane	35	281801900	140,900,950	422,702,850	10,179,914	5,089,957	2,544,979	1%
Deerfield	41	308494400	154,247,200	462,741,600	11,609,388	5,804,694	2,902,347	1%

Municipality	Number of Affected Structures	Improved Parcel Value ($)	Estimated Contents Value ($)	Total Property Exposure ($)	Affected Property Exposure ($) High Damage Range	Affected Property Exposure ($) Moderate Damage Range	Affected Property Exposure ($) Low Damage Range	Loss Ratio
Dunkirk	59	380819200	190,409,600	571,228,800	15,266,435	7,633,217	3,816,609	1%
Dunn	132	1334967700	667,483,850	2,002,451,550	59,648,215	29,824,108	14,912,054	1%
Madison	695	490510400	245,255,200	735,765,600	408,841,322	204,420,661	102,210,331	28%
Mazomanie	37	212261200	106,130,600	318,391,800	8,747,834	4,373,917	2,186,958	1%
Medina	45	309542500	154,771,250	464,313,750	11,766,291	5,883,145	2,941,573	1%
Middleton	178	1015354200	507,677,100	1,523,031,300	82,802,263	41,401,131	20,700,566	3%
Montrose	38	283627100	141,813,550	425,440,650	10,549,870	5,274,935	2,637,467	1%
Oregon	71	551136900	275,568,450	826,705,350	22,448,694	11,224,347	5,612,174	1%
Perry	29	181467000	90,733,500	272,200,500	6,370,152	3,185,076	1,592,538	1%
Pleasant Springs	82	734301950	367,150,975	1,101,452,925	28,208,365	14,104,182	7,052,091	1%
Primrose	29	191714800	95,857,400	287,572,200	6,777,808	3,388,904	1,694,452	1%
Roxbury	51	369598900	184,799,450	554,398,350	13,038,044	6,519,022	3,259,511	1%
Rutland	55	416841300	208,420,650	625,261,950	15,016,529	7,508,265	3,754,132	1%
Springdale	50	462059400	231,029,700	693,089,100	16,538,192	8,269,096	4,134,548	1%
Springfield	61	665211400	332,605,700	997,817,100	23,292,385	11,646,192	5,823,096	1%
Sun Prairie	62	448283800	224,141,900	672,425,700	19,077,915	9,538,958	4,769,479	1%
Vermont	29	261181700	130,590,850	391,772,550	9,222,220	4,611,110	2,305,555	1%
Verona	59	385760000	192,880,000	578,640,000	20,339,142	10,169,571	5,084,785	2%
Vienna	42	536281000	268,140,500	804,421,500	19,138,564	9,569,282	4,784,641	1%
Westport	97	829084900	414,542,450	1,243,627,350	50,401,878	25,200,939	12,600,470	2%
York	29	171248200	85,624,100	256,872,300	6,042,713	3,021,356	1,510,678	1%
Villages								
Belleville	542	167622000	83,811,000	251,433,000	128,028,242	64,014,121	32,007,060	25%
Black Earth	863	119692900	59,846,450	179,539,350	176,701,991	88,350,995	44,175,498	49%

Municipality	Number of Affected Structures	Improved Parcel Value ($)	Estimated Contents Value ($)	Total Property Exposure ($)	Affected Property Exposure ($) High Damage Range	Affected Property Exposure ($) Moderate Damage Range	Affected Property Exposure ($) Low Damage Range	Loss Ratio
Blue Mounds	529	221289400	110,644,700	331,934,100	319,506,259	159,753,130	79,876,565	48%
Brooklyn	422	64508900	32,254,450	96,763,350	96,763,350	48,381,675	24,190,838	50%
Cambridge	439	136197700	68,098,850	204,296,550	130,816,587	65,408,294	32,704,147	32%
Cottage Grove	494	520187200	260,093,600	780,280,800	170,232,817	85,116,409	42,558,204	11%
Cross Plains	755	346248200	173,124,100	519,372,300	260,804,996	130,402,498	65,201,249	25%
Dane	395	80310400	40,155,200	120,465,600	88,065,661	44,032,831	22,016,415	37%
Deerfield	469	209229200	104,614,600	313,843,800	122,878,371	61,439,186	30,719,593	20%
DeForest	396	1191923400	595,961,700	1,787,885,100	199,766,891	99,883,445	49,941,723	6%
Maple Bluff	717	250686300	125,343,150	376,029,450	376,029,450	188,014,725	94,007,363	50%
Marshall	649	2023747300	1,011,873,650	3,035,620,950	1,117,881,520	558,940,760	279,470,380	18%
Mazomanie	522	163518900	81,759,450	245,278,350	116,396,622	58,198,311	29,099,155	24%
McFarland	895	978873195	489,436,598	1,468,309,793	354,232,896	177,116,448	88,558,224	12%
Mount Horeb	776	609357660	304,678,830	914,036,490	239,010,116	119,505,058	59,752,529	13%
Oregon	776	1092577370	546,288,685	1,638,866,055	317,435,473	158,717,737	79,358,868	10%
Rockdale	152	17934500	8,967,250	26,901,750	26,901,750	13,450,875	6,725,438	50%
Shorewood Hills	760	352877700	176,438,850	529,316,550	529,316,550	264,658,275	132,329,138	53%
Waunakee	591	1508079300	754,039,650	2,262,118,950	281,774,873	140,887,436	70,443,718	6%
Windsor	110	914410500	457,205,250	1,371,615,750	40,447,117	20,223,559	10,111,779	1%

4.12 WILDFIRE

4.12.1 Description

Wildfire is any free burning and (at one time) out of control forest fire, grassland fire, rangeland fire, or urban-interface fire which consumes the natural fuels and spreads in response to its environment. While often considered as a destructive force, wildfires also play a positive role in nature by clearing underbrush, controlling insect populations, and depositing nutrients into the soil. Many plant species have evolved to cope with and take advantage of wildfires. Periodic, spatially-interrupted burn patterns lead to higher species diversity and healthier ecosystems. Unfortunately, when wildfires ignite in altered ecosystems (such as housing developments), the intensity, duration, and spread of the fire also change. Wildfire becomes a destructive force for ecosystems, resulting in heightened erosion conditions and other damages to the environment, in addition to the property damages sustained by human developments.

Certain conditions must be present for wildfires to take hold. The most common conditions include:

- Hot, dry, and windy weather
- Inability of the fire service to contain or suppress the fire
- Occurrence of multiple fires that overwhelm local resources
- Large fuel load

Once a fire has started, additional conditions will influence its behavior, including topography and land-use patterns.

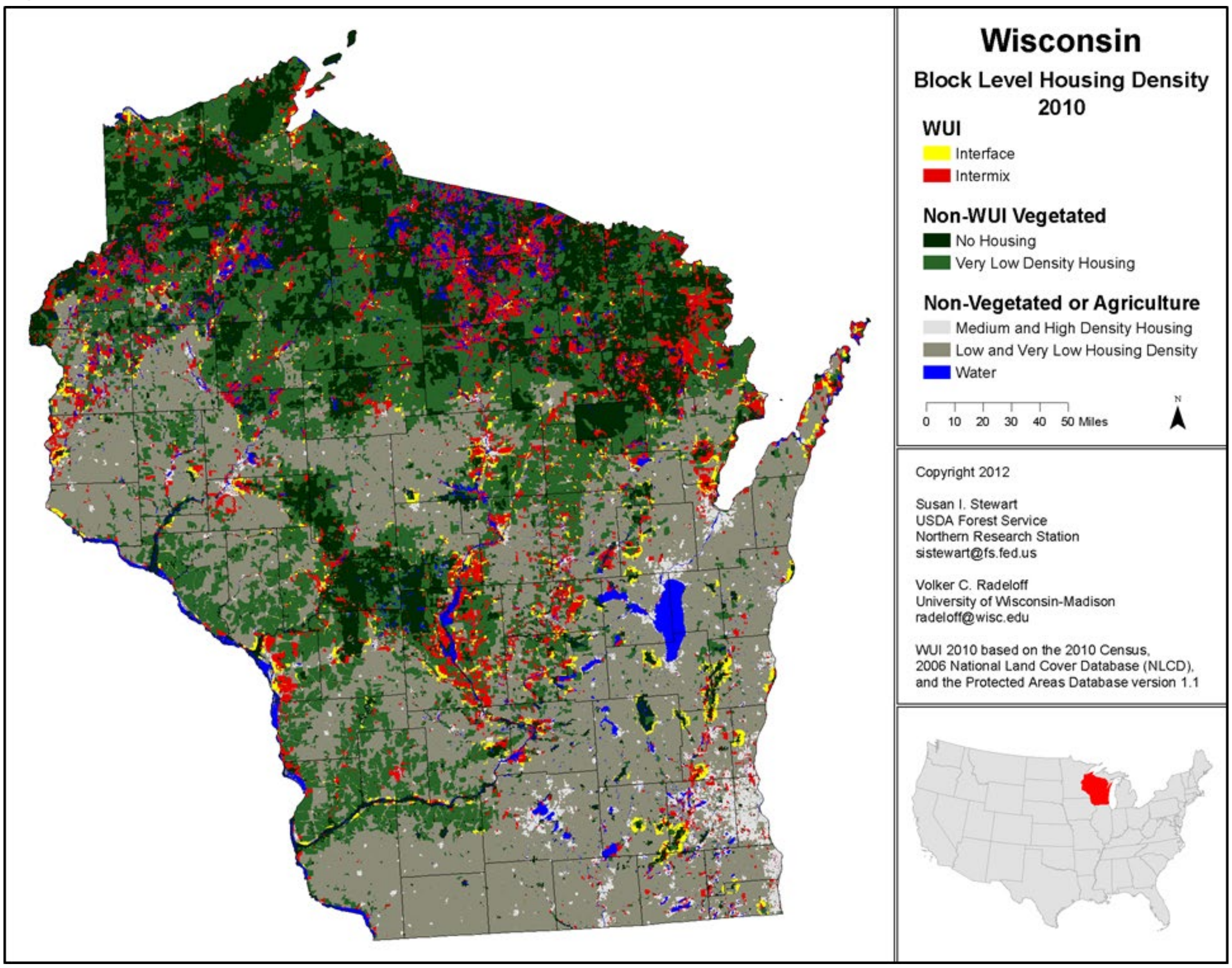
The vast majority of wildfires in Dane County are human-caused. Wildfires initiated by lightning are very rare. When wildfires do occur in Dane County it is also very rare that a home or business is lost. Wildfires are most common in the spring when brush is still brown and dry.

Most of the County is managed under a cooperative fire management program overseen by individual fire districts. The northwestern portion of the County is under state jurisdiction and classified as an “extensive fire area”, and includes the jurisdictions of the Towns of Roxbury, Vermont, Black Earth, Mazomanie, and Berry and the Village of Mazomanie. A portion of the Town of Blue Mounds is also included. In cooperative areas, data on wildfires is sparse and unorganized, which makes it essentially unavailable. Most of the data used in this assessment is derived from land under state jurisdiction for fighting wildfires. The ecology of the county lends itself to natural defenses from wildfires. Much of the county is covered by water or wetlands, or well developed with fire breaks.

Wildland-Urban Interface

Wildfire danger grows as more and 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 DNR, "the WUI can be a lone house in the middle of a forest, a subdivision on the edge of a pine plantation, or homes surrounded by grassland" (DNR, 2011). Locating manmade structures in areas that have burned naturally in the past both interrupts the natural recurrent cycle of wildfires and adds fuel to wildfires. (Wisconsin Emergency Management, Wisconsin Threat and Hazard Identification and Risk Assessment, 2021) Figure 4.12.1 shows Wisconsin's wildland-urban interface as of 2010.

Figure 4.12.1 Wisconsin Wildland-Urban Interface



Source: University of Wisconsin SILVIS Lab, http://silvis.forest.wisc.edu/maps/wui/2010/download, 2012, Accessed October, 2021

4.12.2 Previous Occurrences

Historically, the County contained fire-maintained plant communities such as prairies, oak savannas, oak or pine barrens, and oak woodlands. Fire occurrences ranged from annually to about once a decade. North facing slopes and areas with natural firebreaks (north and east of lakes and rivers) burned less frequently. The fires were frequent and burned lightly enough in the oak areas to prevent the death of mature, thick-barked trees. The jack pine areas usually experienced more severe, stand-killing crown fires which occurred less frequently than the oak and prairie fires. Current natural fire patterns are altered though deliberate fire suppression actions and the introduction of fuel breaks such as roads, developed areas and agricultural fields.

In 2003 there were two relatively large wildfires outside of the state managed area, the Deansville marsh fire that took place April 27 that burned 500 acres, and the Town of Dunn marsh fire on March 23 that burned 110 acres. Though these fires were large, they posed little threat to life and property.

Even within the context of recent fires, the chance of structural damage due to wildfire is extremely small. History shows that very few structures have ever been lost due to wildfires in the County. Easy accessibility to fires and low fuel loads give fire fighters the upper hand in battling blazes.

4.12.3 Impact of Climate Change on Future Conditions

Although precipitation totals are expected to increase overall, researchers predict that it will occur during fewer, more intense events. The periods in between intense rain or snowfalls may therefore be marked by a greater number of dry days. This coupled with longer summers, higher average temperatures, and concomitant increased evapotranspiration, may result in longer, drier conditions, which in turn raise the likelihood of wildfires. The wildfire risk is mitigated by the low wildland-urban interface risk in Dane County, on-going fire management practices, and well-established local fire response capacities.

4.12.4 Impact Assessment

The size of wildfires in Dane County range from approximately 500 acres to a fraction of acre, most fires cover about 3 acres. Woodland and open lands, land that has the potential for wildfire, make up about 22 percent of the total acreage in the County. Much of Dane County is agricultural or urban land. How a fire will burn within the natural areas of the County is a complex phenomenon affected by wind, air temperature, humidity, fuel loads, fuel moisture, and topography.

In densely wooded areas fires could destroy much in their path, fueled by high winds and high fuel loads. Other fires, such as those that might occur in a prairie ecosystem, burn cooler along the ground and leave a dappled pattern of untouched areas within burnt areas. Fire prediction, though greatly aided by the development of new computer modeling programs, remains an imprecise science.

Wildfire can also be destructive when it interfaces with urban areas. Burned structures due to wildfire in Dane County are extremely rare and the costs of fighting wildfires run only in the hundreds of dollars per response. Much of the wildfire in the County is fought by local fire departments, though the Department of Natural Resources at the state level also assists in fighting these fires.

4.12.5 Vulnerability Assessment

There are very few areas of the County where conditions indicate a high vulnerability to wildfires. Areas of higher relative vulnerability to wildfires are those in the urban/wildland interface, including:

- Areas where urban and suburban development is adjacent to open expanses of wild land areas.
- Mixed urban interface where isolated homes, subdivisions, or small communities are situated in predominantly wild land settings.
- Wild land/urban interface where islands of wild land vegetation occur inside a largely urban area.
- Areas that are hilly also can burn more readily. Fires run up hills igniting fuels more easily than on flat ground.

There is limited data indicating that general structures, critical facilities or populations have been or will be harmed by wildfire in the County. While the potential exists for damaging wildfires, many natural and man-made fuel breaks exist. Overall, the vulnerability of the County to wildfire is low.

4.12.6 Potential for Future Losses

While grassland and marsh fires are relatively common in the spring and fall seasons, wildland fires in Dane County that threaten or damage buildings or other structures are very rare.

The potential for future damages is estimated by extrapolating data from past events. Future damages are expected to be very similar to past damages, with annual losses due to wildfire ranging in only the hundreds of dollars. The number of fires and the acres burned do not indicate that wildfires and their impacts are increasing. This data is limited to areas of the County that is regulated under the state Department of Natural Resources and therefore is a limited data set on which to base loss estimations.

4.13 WINDSTORM

4.13.1 Description

Damaging winds occur relatively frequently across Wisconsin, usually in association with severe thunderstorms.

Severe thunderstorms develop powerful updrafts and downdrafts. An updraft of warm, moist air helps to fuel a towering cumulonimbus cloud reaching tens of thousands of feet into the atmosphere. A downdraft of relatively cool, dense air develops as precipitation begins to fall through the cloud. Winds in the downdraft can reach in excess of 100 miles per hour. When the downdraft reaches the ground it spreads out forming a gust front: the strong, often refreshing wind that kicks up just before the storm hits. As the thunderstorm moves through the area, the full force of the downdraft in a severe thunderstorm can be felt as horizontal, straight-line winds with speeds well over 50 miles per hour. (National Weather Service)

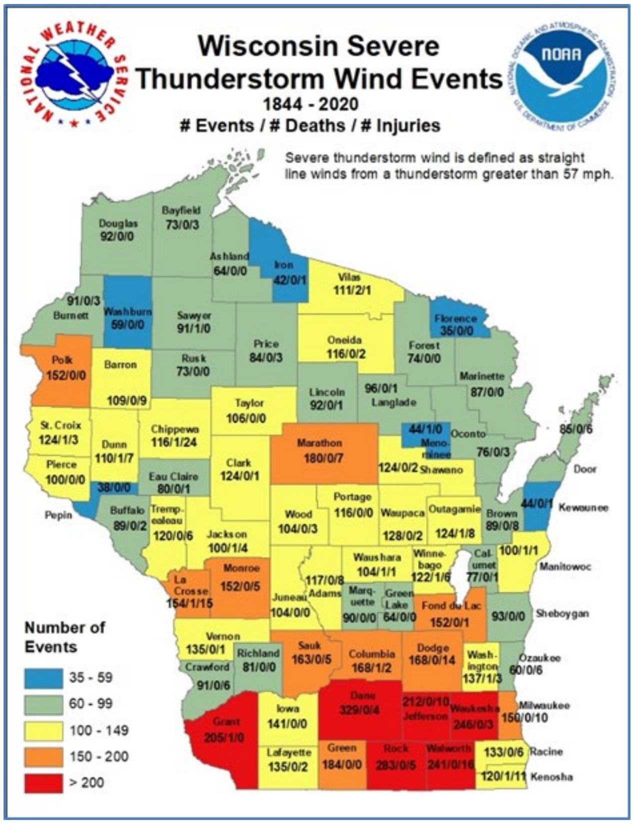
Straight-line winds are often responsible for most of the damage associated with a severe thunderstorm. Damaging straight-line winds occur over a range of scales. At one extreme, a severe single-cell thunderstorm may cause localized damage from a microburst, a severe downdraft extending not more than about two miles across. In contrast, a powerful thunderstorm complex that develops as a squall line can produce damaging winds that carve a path as much as 100 miles wide and 500 miles long.

4.13.2 Previous Occurrences

Severe Thunderstorms (wind greater the 57 mph) and high winds are a regular occurrence in Dane County. According to the National Weather Service, between 1970 and 2020, there were 329 events with winds over 57 mph, which is the equivalent of hurricane force winds.

The National Weather Service and the NOAA National Centers for Environmental Information (NCEI), formerly National Climatic Data Center (NCDC) maintains a listing of reported high wind events from 1844 through 2022. In more recent years, these records have been kept in greater detail, including a description of the event and the resulting impacts. The NCEI website provides the following description of a snap shot of high wind events affecting Dane County, including number of deaths and injuries.

Figure 4.13.1 Severe Thunderstorm Wind Events, 1844-2020



4.25

Source: National Weather service, NOAA, 2020

April 6, 1997

Strong gradient winds, enhanced by scattered snow showers (transfer of higher level momentum downward to surface by mixing), resulted in scattered damage reports. In Sun Prairie, the high winds, measured at 66 mph, blew open a glass door in a restaurant. The glass debris struck and injured an elderly woman, who died from the injuries the next day. The Madison TV-3 weather station recorded a peak wind gust of 71 mph at 1715 CST. In the Town of Dane, a gust of 61 mph was noted. Southeast of Mount Horeb, the high winds forced the collapse of a barn. A camper vehicle was tipped over on by the powerful winds on Highway 113. The high winds also toppled large trees in scattered areas across the entire county. One tree in Monona fell against a home and damaged its siding and windows. Power outages were noted. People described the wind-driven debris as "missiles flying through the air."

May 31, 1998

During the early morning hours of Sunday, May 31st, south-central and southeast Wisconsin experienced an unprecedented, widespread downburst wind event known as a "derecho." Incredibly powerful, hurricane-force straight-line winds, with peak gusts of 100 to 128 mph tore through 12 counties in this part of the state, while another 8 counties had peak gusts of 60 to 80 mph. Meteorologically, a solid squall line developed in southern Minnesota and gathered strength as it raced east with a translational speed of 50 to 60 mph across south-central and southeast Wisconsin. The squall line was orientated southwest to northeast and had many microbursts and macrobursts embedded in it. Utility companies and Emergency Managers stated that this was the most damaging, widespread, straight-line thunderstorm wind event to affect southern Wisconsin in the past 100 years. About 60,000 customers were without electricity in south-central Wisconsin, and about 170,000 in southeast Wisconsin. Some residences or businesses were without power for many as 6 days. Hundreds or motor vehicles were damaged or destroyed by falling trees and branches or collapsed garages. Dane County measured gust of 100 mph in Marshall, but peak gusts estimated at 110-120 mph based on damage. The hardest hit areas were Waunakee-DeForest, Sun Prairie, and Marshall. Cars were blown sideways off I-94 north of Madison. Two people injured in Marshall by flying debris as roof was torn off their home. A total of 300 residences had minor damage, 18 major, and 1 was destroyed. One business had minor damage, and 7 had major damage. Twenty farm buildings sustained minor damage, 12 major, and 15 were destroyed.

November 10, 1998

Screaming high winds raked south-central and southeast Wisconsin counties for about 17 hours, resulting in widespread damage to thousands of trees, homes, businesses, power poles, power lines, street lights, road signs, fences, flagpoles, barns, sheds, crops, boats, cars, trucks, campers, trains, airport hangars, and airplanes. Estimated monetary damages were $10.31 million in property damage and $1.625 million in crop damage. The sustained southwesterly winds of 30 to 40 mph gusted to 60 to 70 mph, with isolated gusts to around 80 mph. These relentless winds eventually caused 125,000 customers to lose electrical power. So many poles and lines were toppled that some customers were without power for 3 to 4 days. In Dane County an 87 year-old man was killed after being hit by a car that was blown sideways on the north side of Madison. Several businesses in Madison, Mt. Horeb, and Stoughton sustained damages. In Monona, a roof was torn off a multi-unit apartment building and four other nearby buildings were also damaged. Several dozen semi-trucks were overturned on I-90/94, US-18/151, and US 51 highways.

July 6, 2003

Two rounds of scattered severe convection affected south-central and southeast Wisconsin on Sunday, July 6, 2003. The first round occurred during the morning hours and the second during the late afternoon hours. Powerful, downburst, damaging, straight-line winds toppled large trees and/or power-lines, 4 weak tornadoes spun up, a separate funnel cloud was reported, and there were a couple occurrences of large hail. Detailed descriptions of the four tornadoes can be found in separate reports. Probably the hardest-hit area extended from Middleton (Dane Co.) to Maple Bluff. In the Maple Bluff area, 8 homes sustained minor wind damage, and toppled trees damaged a car and two boats or large branches during the morning round. Wind gusts in the Maple Bluff area were estimated to briefly reach 65 knots (75 mph). Lightning struck a home in Middleton, resulting in a roof/attic fire.

July 10 2008

Powerful thunderstorm wind gusts toppled large trees and broke branches that brought down some power-lines. In McFarland, a house was blown down, and tree debris damaged a restaurant. Two rounds of severe weather affected south-central and southeast Wisconsin on July 10th. An initial cluster of storms north of the Milwaukee area in Ozaukee County pulsed to severe limits and generated large hail up to 3/4 inch in diameter during the early afternoon hours. A second round of severe weather was associated with several clusters or short bowing segments of lines of storms that moved west to east across southern Wisconsin during the late afternoon and evening hours. Veering winds allowed for the development of rotating updrafts in a couple cells that generated two weak tornadoes. Otherwise, the severe weather type was powerful downburst winds.

June 8, 2011

Forcing along an advancing cold front moving into a warm, moist unstable air mass over the region produced severe thunderstorms with a tornado, damaging winds and large hail over south-central and southeast Wisconsin during the evening hours of June 8th. The instability produced supercell thunderstorms, with one of the cells developing an EF1 tornado over central Dane County that uprooted trees, felled power-lines, damaged three vehicles and crushed a garage. A cluster of supercell thunderstorms from Lafayette into Dane County then congealed into a bowing line that moved due east and created damaging wind gusts of 60 to 80 mph across much of the area along and south of Interstate-94. At the height of the event, over 27,000 customers had no electric power in Southeast Wisconsin, and probably another 15 to 20,000 customers in south-central Wisconsin lost power. Powerful thunderstorm winds pushed over dozens of large trees, and broken tree branches snapped several power-lines in a 5-mile-wide swath. In Stoughton, the winds knocked over an empty semi-trailer which then impacted and damaged two other trailers. Also, a road sign in Stoughton was pushed over at a 45-degree angle.

August 10, 2021

Severe thunderstorms produced extreme winds on the night of August 10th, 2021. Over 4,200 residents in Madison went without power, due to winds taking out power lines. Fallen trees and power lines caused minor property damage, as well as sidings and residential roofs.

4.13.3 Impact of Climate Change on Future Conditions

Severe thunderstorms associated with damaging winds, hail, and tornadoes are already a regular occurrence in Dane County. There is not a readily available source of information to assess whether the incidence of these events will increase, decrease, or remain unchanged as a result of the warming climate. A qualitative argument can be made that more energy in the atmosphere resulting from increased concentrations of greenhouses would result in an increase of convective severe weather events. This is not borne out in currently available models, however. There is no clear trend to indicate whether or not this hazard is changing or will change significantly in the future.

4.13.4 Impact Assessment

Past windstorms have caused extensive damage in Dane County. Since 1994, when the National Weather Service and the National Center for Environmental Information began recording damage estimates for Dane County, there have been more than 135 high wind and severe thunderstorm wind events. Damage estimates indicate cumulative totals of more than $8.1 million in property damage.

Damaging windstorm events may occur anywhere in Dane County. There are no geographic features within Dane County that naturally lower or increase the risk of a severe thunderstorm or windstorm event. Damage associated with a severe thunderstorm tends to be a geographically isolated event, affecting only small areas of several square miles at any one time.

Direct Impacts

The relative effects of wind speed are shown in table 4.13.1. Strong winds associated with severe thunderstorms or other phenomena can cause extensive damage and can result in deaths or injuries. Damage depends on both the wind speed and the nature of the objects in the path of the storm. Strong winds can turn debris and un-tethered objects into missiles. Even heavy vehicles can be rolled over. Homes and large buildings can sustain damage from the direct force of the wind. Broken windows and damaged roofs are common. Falling limbs and trees are also common and can contribute to property damages and downed power lines. Manufactured homes and metal sheds can be destroyed, particularly if they are not fastened to a foundation. Power and communications outages are also common, and storm debris in roads can disrupt transportation and delay emergency response vehicles.

Farm operations can also be heavily impacted by high winds. Winds can flatten farm crops such as corn and tobacco, and destroy orchard crops such as apples.

Table 4.13.1 Wind Speed and Damage Potential

Wind Speed (mph)	Wind Effects
25-31	Large branches in motion.
32-38	Whole trees in motion, inconvenience in walking against the wind.
39-54	Twigs and small branches break off trees, difficulty in walking against the wind, high profile vehicles such as trucks and motor homes may be difficult to control.
55-74	Potential damage to antenna structures, wind may push over shallow rooted trees, especially if the soil is saturated.
75-95	Potential for minor structural damage, particularly to manufactured homes, power lines, trees, and signs may be blown down.
96-110	Moderate structural damage to walls, roofs, and windows, trees blown down, and manufactured homes may be destroyed.
111-130	Extensive damage to walls, roofs, and windows, trees blown down, moving vehicles pushed off roads.

Wind Speed (mph)	Wind Effects
131-155	Extreme damage to structures and roofs, trees uprooted or snapped.
Greater than 155	Catastrophic damage, structures destroyed.

Source: National Weather Service Spotters Guidance

Indirect Impacts

The indirect social and economic impacts of wind damage are typically associated with the loss of electrical power. Given our societies heavy reliance on electric power, any disruption in the supply, even for a short time period, can have significant consequences. The utilities supplying Dane County have worked closely with emergency response agencies and human services providers to develop plans for responding to planned and unplanned power outages in the County.

4.13.5 Vulnerability Assessment

As with tornadoes, essentially all Dane County buildings, critical facilities, and populations are vulnerable to windstorm damage. Trailer park homes have the highest likelihood of experiencing increased damages.

Population

Some segments of the population are especially vulnerable to the indirect impacts of damaging wind, particularly the loss of electrical power. As a group, the elderly or disabled, especially those with home health care services relying on rely heavily on an uninterrupted source of electricity. Resident populations in nursing homes, Community Based Residential Facilities, or other special needs housing may also be vulnerable if electrical outages are prolonged. Without a back-up power source, rural residents and agricultural operations reliant on electricity for heating, cooling, and water supplies are also especially vulnerable to power outages.

Property

In terms of property losses, the actual damages will depend on the building density in the impacted area. This is highly variable across the County. A severe thunderstorm with high winds in an older residential area with older homes, large trees, and overhead utility lines will have a significantly greater impact with the same storm in a new development with lower building density, modern constructed buildings, small or newly planted trees, and underground power lines.

Power lines, communications networks, and other above-ground infrastructure are vulnerable to the effects of windstorms both directly and indirectly. The wind itself may damage the infrastructure, or the wind may damage tree branches and throw other debris into the air, which may cause secondary damage to buildings and critical facilities or capabilities. Emergency response vehicles with high profiles may be more exposed to high winds, which may hinder response times. In addition, wind may exacerbate dangerous conditions, such as fires, making response more difficult and dangerous. These are unlikely events but they are severe in occurrence. Overall, these assets have a medium to high vulnerability to windstorms.

4.13.6 Potential for Future Losses

The potential for future losses due to windstorm damage is estimated based on an extrapolation of losses from past events. There are limitations to this method:

- Every event is unique in location, duration, and intensity. Use of averages does not account for the potential of an extreme event that may occur only very rarely but has severe consequences.
- The exposure to damage increases as the population of the County increases. Future damages may increase simply due an increase in the amount of exposed property. This method of estimation cannot account for increasing risk due to growth.
- Indirect impacts are not well accounted for.
- The damages resulting from a windstorm event depend greatly on where and when the storm hits. A severe storm tracking through an undeveloped area may cause less damage than a weaker storm striking an urban or residential area. Likewise, a severe storm impacting an agricultural area in the early spring will have a very different impact than a storm of comparable intensity over the same area in late summer when the crops are near maturity. Extrapolation from past events does not account well for this variability.

While the estimation of future losses based on past events is unsophisticated, it still is a useful method of quantifying the damage potential. Since 1994, when the National Weather Service and the National Center for Environmental Information began recording damage estimates for Dane County, there have been more than 135 high wind and severe thunderstorm wind events. Damage estimates indicate cumulative totals of more than $8.1 million in property damage in this 22 year time period, without adjusting for inflation. Adjusted for inflation, this jumps to over $10 million. The annualized windstorm losses in Dane County equal $463,159.

The May 31, 1998 windstorm is considered the event of record, resulting in more than $3.9 million in losses in Dane County. Adjusted for inflation, this would equate to $6.8 million in losses in 2021 dollars.

4.14 WINTER STORM

4.14.1 Description

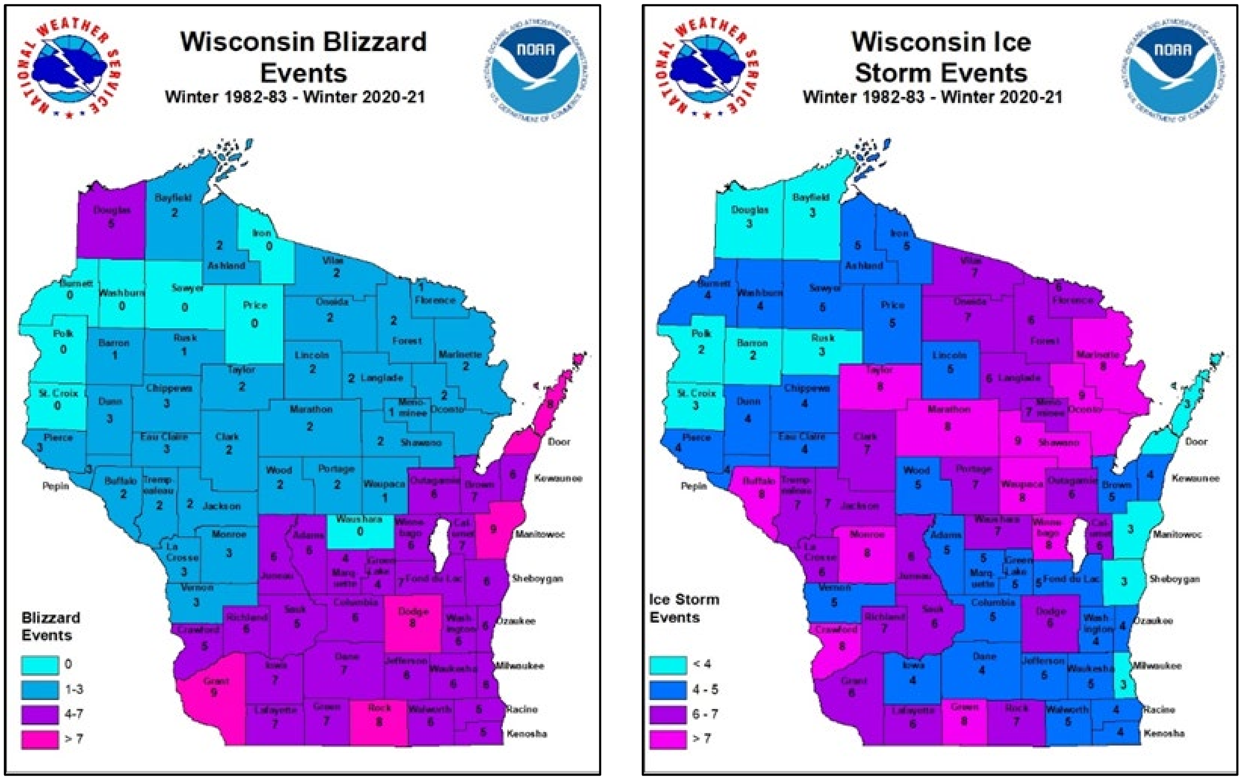
Winter storms occur when below freezing air on the ground and in clouds combine with moisture. Moisture is needed to form clouds and cause precipitation. A storm front lifts the moist air to form the clouds. Storms that affect Wisconsin develop over southeast Colorado, northwest Canada, and over the southern plains. These storms move toward the Midwest and use both the southward plunge of cold air from Canada and the northward flow of moisture from the Gulf of Mexico to produce heavy snow over the region. Alberta Clippers, which develop in the lee of the Canadian Rockies and move southeast toward Wisconsin, not only produce accumulating snow, but can also bring strong winds and extremely cold air to the state. Winter storms are defined by the following events:

- 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 damaging accumulations of ice, usually ¼" or thicker.

4.14.2 Previous Occurrences

According to the National Weather Service, between the winter of 1982-83 and the winter of 2020-21, there were 99 winter storm events, seven blizzard events, and four ice storm events affecting Dane County.

Figure 4.14.1 Blizzard and Ice Storm Events, 1982 – 2020-21



Source: National Weather Service

The history of past winter storm events was gathered from NCEI data, newspaper reports and other data sources as cited. Winter storms have caused problems for Dane County residents for as long as the area has been settled. Some of the most recent outstanding events are listed below.

March 1976

During March 4-11, a storm of freezing rain, snow, ice and wind combined into a severe ice storm that made its way across the southern portion of the state causing $50.4 million in damages statewide, at the time the most expensive natural disaster in Wisconsin history. This estimate is considered to be conservative. Unable to milk or water the cows, farming communities sustained the greatest losses. Farmers lost $17.3 million. Government damages were approximated at $8.4 million, private homes and businesses $11 million to, and utilities $13.7 million.

Of the 22 counties affected from the Mississippi River to Lake Michigan, Dane County was among the hardest hit. Approximately 10,000 residents lost electrical power, some for as long as 11 days. The City of Madison suffered a temporary water shortage as most of the City's water pumping stations went without power. Without heat, light, or water, many people stayed in emergency sleeping quarters prepared by the Red Cross.

Dane County damages for public, farm, and private/non-farm losses, in 1976 dollars, totaled $1.9 million, $1.8 million, and $1.0 million respectively. Total damages were estimated to be $4.78 million, excluding electric utility losses, which were $1.2 million for Madison Gas and Electric, and an undisclosed amount for Wisconsin Power and Light. (Based on a consumer price index inflation calculator, the $4.78 million in losses in 1976 would equate to more than $20.1 million in 2017.)

March 8, 1998

Near blizzard conditions brought parts of south-central and southeast Wisconsin to a standstill. The combination of heavy, wet snow, and northeast winds gusting to 40 to 50 mph, reduced visibilities occasionally to below 1/4 mile and created drifts of 8 to 15 feet in areas west and southwest of Madison. Based on newspaper accounts, there were approximately 800 motor vehicle accidents, dozens of toppled power lines, many school closings, and many road closures. Interstate 90/94 and State Highway 51 north of Madison were closed at the height of the storm. In addition, many airline flights and other commercial activities were postponed or cancelled.

December 2000

December 2000 was one of the 10 coldest Decembers on record for most of the state. In addition to the low temperatures, record or near record snow depths of 15-34" occurred in much of southern Wisconsin during December. As a result of record snowfalls, thirteen counties received a Presidential Emergency Declaration and were eligible to receive federal funds for extraordinary expenses associated with clearing roads and emergency response efforts. The counties declared in the snow emergency were Columbia, Dane, Door, Green, Kenosha, Kewaunee, Manitowoc, Milwaukee, Racine, Rock, Sheboygan, Walworth and Waukesha Counties. Local governments in Dane County received a total of $586,000 in federal disaster assistance.

February 5-6, 2008

A major winter storm impacted south-central and southeast Wisconsin on February 5-6, 2008, with the hardest hitting part of the storm during the morning of the 6th. This was a long duration event coupled with strong gusty winds and some thunder. Blowing and drifting snow compounded the effects of the heavy snow. Total new snow accumulations in excess of 12 inches occurred in the area southeast of a line from Dubuque, Iowa to Madison to Beaver Dam to West Bend to Sheboygan. Up to 16 inches fell in the area from Monroe and Janesville to the Port Washington and Milwaukee area, with isolated 18 to 21 amounts reported. Total snow amounts tapered off quickly to 4 inches north of Wisconsin Dells and an inch or less across far northwest Marquette county. Many roads become impassable due to the blowing and drifting snow. A major traffic backup occurred on Interstate 39/90 westbound south of Madison with as many as 2000 cars stranded for up to 12 hours. A Presidential Emergency was declared as a result of record snowfalls. Dane County and local governments within Dane County received a total of $1.44 million in federal disaster assistance.

December 8-9, 2009

A major winter storm impacted Southern Wisconsin Tuesday evening, December 8th, through Wednesday morning December 9th. Heavy snow fell over a large portion of the area (many areas reported thunder snow), with numerous locations reporting over a foot. The hardest hit area was across central Dane county, where 15" to 18" of snow fell. The 14.1" reported at Dane County Regional Airport was the 6th highest 2-day (calendar day for December 8 and 9) total reported since records began there in 1948.

February, 2011

Southern Wisconsin was hit with the so-called Groundhog Day Blizzard when a powerful low pressure center passed south of the state. Most areas of Dane County saw between 14" and 18" inches of snow. Adding to the dangerous conditions were the blizzard-condition sustained wind 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 twelve to fifteen feet in many rural areas throughout southern Wisconsin. The severe winter storm caused the declaration of a Federal Major Disaster (DR-1966), allowing eleven 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. Dane County and local governments within Dane County recovered more the $1.81 million is response costs.

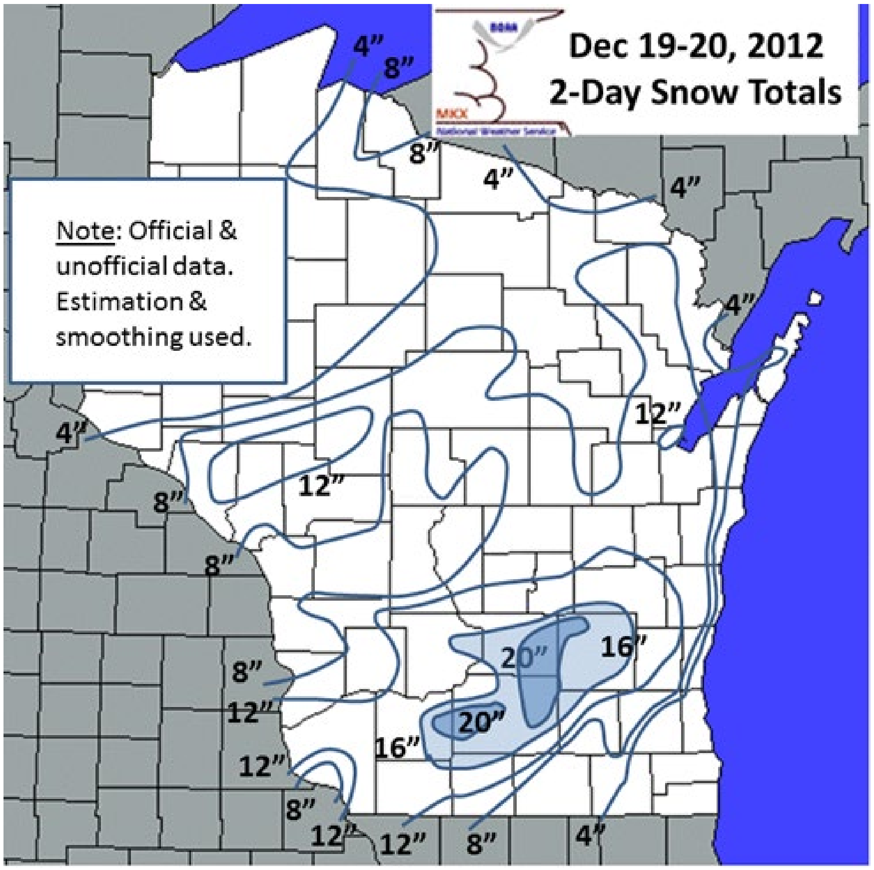
December, 2012

From the evening of December 19 to the night of December 20, 2012, a major winter storm descended on the south central portion of the state. Gusts of 35 to 50 mph combined with the snowy conditions resulted in low visibility and drifts of three to five feet. Many accidents were reported. Relatively warm temperatures of 29 to 33°F meant the snow was wet and heavy. Broken limbs and the sheer weight of the snow brought down many utility lines. Two-day snow totals (around 7 am 12/19 through 7 am 12/21) ranged from less than an inch along the Lake Michigan shoreline from Milwaukee south to Kenosha, to 12 to 22 inches in Dane County. The greatest 2-day snow totals (official & unofficial) include 21.9" in Cottage Grove, 21.5" in Mt. Horeb, 20.0" in Madison, 19.9" in Middleton, 19.6" in Portage 7SW, 19.0" at the Arlington UW Farm, and 18.8 inches in DeForest. Officially, Madison's Truax Field's 2-day total was 15.2".

Scattered power outages were reported. Drifting and falling snow made plowing activities difficult or almost impossible at times. Road surfaces were either snow covered and/or icy inland away from Lake Michigan. Hundreds of vehicle accidents were reported, and many vehicles became stuck in snow drifts. The Wisconsin DOT reported roads in neighboring Rock County were nearly impassable Thursday.

The snow and blowing snow likely caused some road closures in rural areas. Northwest winds gusted to 40 to 50 mph during the afternoon and early evening hours of Thursday. These strong winds, along with falling and/or blowing snow, resulted in blizzard or near blizzard conditions in open and exposed areas, with visibilities reduced to one quarter mile or less.

Figure 4.14.2 Snowfall Totals, December 2012



Source: National Weather Service, Milwaukee/Sullivan

December 2016

A two pronged winter storm affected southern Wisconsin from December 16th to December 18th, 2016. The first round resulted in 2-5 inches of snow, and the second rounds resulted in 2-6 inches of snow. A wind chill of -24 degrees Fahrenheit was also reported. Snowfall affected all of Dane County, and snowfall estimates were calculated in the Madison Area. A winter storm advisory issued by Dane County lasted for four days. No known deaths or injuries were related to this winter storm event.

February 8, 2018

In the late winter of 2018, an unexpected snow storm hit the Madison area for a total of 5-7 inches of snow. The NWS placed Dane County under a winter storm warning into the late morning of February 9th, 2018. The advisory expired, and a four inch increase was estimated when compared to the original forecasted amount of 3-5 inches.

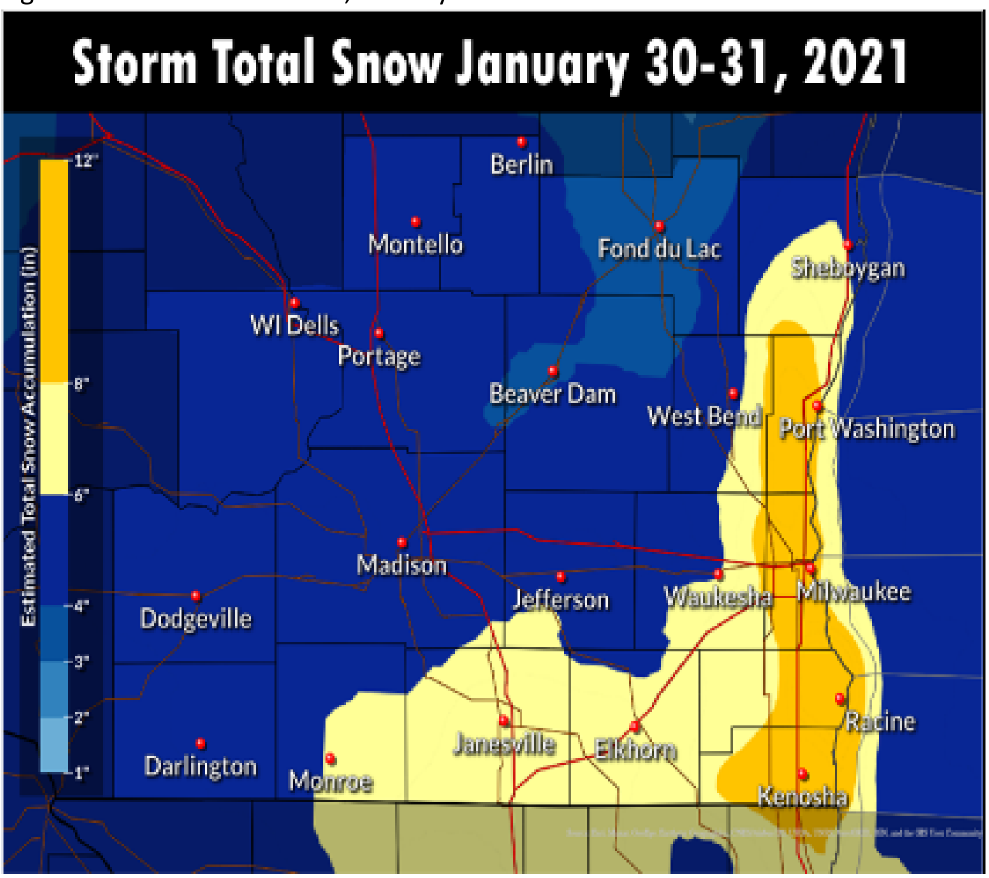
February 12, 2019

On February 12th of 2019, a blanketing of snow hit across Wisconsin, for an average of up to 16 inches in central and southern Wisconsin. Dane County had an average snowfall accumulation of 8-16 inches. This beat the February 12th, 1923 record by more than half. Dane County deputies reported multiple car slide offs. Minor damage to vehicles were reported, and no fatalities were reported in relation to this event.

December 2020

In the early winter of 2020, a major winter storm affected parts of southern Wisconsin. Over five inches of snow was estimated to have been dumped in Dane County within a few hours, and the snow event continued for about 2-3 days, from December 29th to December 31st.

Figure 4.14.3 Snowfall Totals, January 2021



Source: National Weather Service, Milwaukee/Sullivan

January 2021

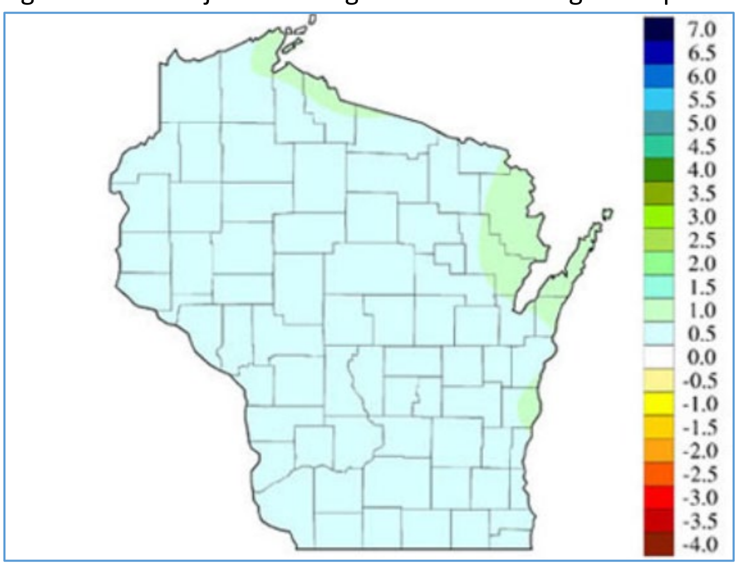
In mid-winter of 2021, a snow storm hit the southern and eastern regions of Wisconsin. In Dane County, the snow storm deposited about four inches of snow, which pushed Dane County's 2021's annual snowfall count past the average annual inches per year. After this snow storm event, Dane County's went to 31.2 inches of snowfall for the season, while the average is 30.1 inches. This storm event lasted from January 29th to January 30th.

4.14.3 Impact of Climate Change on Future Conditions

As discussed in the "Extreme Cold" section, the increase observed average temperature has been highest in the winter months. Looking forward, WICCI models predict this warming trend to continue. In its 2011 report, Wisconsin's Changing Climate: Impacts and Adaption, WICCI projects that southern Wisconsin, Dane County included will experience an average winter time temperature increase of 7.5°F to 8°F by 2055. The region can also expect a decrease of 12 to 14 days with below zero low temperatures over this same time period.

WICCI also predicts a slight increase in wintertime precipitation for southern Wisconsin. Depending on conditions at the time of the event, this could occur in the form of snow, rain, or freezing rain. As both temperature and precipitation increase during the winter months, occurrences of freezing rain may be more likely.

Figure 4.14.4 Projected Change in Winter Average Precipitation (inches)



Source: Wisconsin Initiative on Climate Change Impacts

4.14.4 Impact Assessment

The occurrence of major snowstorms, ice storms, and blizzards can have a considerable impact on communities, utilities and transportation systems. Ice storms often produce extensive damage over large regions. The impacts of an ice storm are amplified when frigid temperatures follow the storm. Snow and ice can accumulate on roads, highways, railroads, and airport runways and can bring transportation to a halt. Ice on telephone and power lines can cause them to break as can tree branches. Power outages may last for days, and in some cases, it may be weeks before power is restored to more remote rural areas. As people have become increasingly dependent on electricity for heating and cooking, the possibility of experiencing a loss of electricity for an extended period has become more critical. While some of the direct impacts of ice or heavy snowstorms are easily identified, these can produce a wide range of indirect impacts. Many of these are summarized below.

Direct Impacts

Ice or heavy accumulations of snow, particularly with blowing and drifting, can devastate the roadway system. Roads can become impassable with heavy icing or as snow accumulates faster than it can be cleared. Snow and ice resulting in icy road conditions lead to major traffic accidents and numerous minor accidents. Similarly, if roads and streets are icy or snow covered, it is also difficult for emergency service personnel to travel and may pose a secondary threat to life safety if police, fire, and EMS crews cannot respond to calls.

Ice or heavy accumulations of snow also require vast amounts of overtime on the part of County and local highway and streets departments to remove snow and melt ice. Heavy accumulations of snow on rooftops can cause roofs to collapse, resulting in possible injury or death to those inside the building as well as devastating the contents of the building. Ice storms or high winds in winter storms can cause extensive loss of overhead utility lines due to buildup either on the lines or on adjacent trees that either collapse due to the weight or blow down onto the utility lines. Services such as telephone, electricity, and cable TV are most seriously affected by winter storms.

Indirect Impacts

The indirect impacts are what separate an ordinary winter snowstorm, even a heavy snow, from a disaster. Heavy accumulations of snow or ice can bring down trees, utility lines, and communications towers. This can disrupt communications and electrical power for days while utility companies repair the damage. Loss of power, in conjunction with impassible roads can isolate people in rural areas and essentially shut down urban areas, effectively paralyzing the entire region.

Also, many of the deaths that occur are indirectly related to the storm itself. Many of these results are from traffic accidents, heart attacks while shoveling snow, or hypothermia from prolonged exposure to the cold. Other examples of indirect impacts include:

- Agricultural losses. Livestock, particularly dairy cattle can be highly vulnerable to the impacts of an ice storm, especially if freezing conditions exist for a long time and are accompanied by an extensive power outage. Daily operations are dependent on electricity for milking and watering the animals. Loss of revenue or even disease and death of the animals can result.
- Home Health Care Services. Recipients of home health care services, particularly in rural areas face disruption of services in the aftermath of an ice or heavy snowstorm. Providers may have difficulty in reaching patients due to debris or downed power lines blocking roadways.

Electrically powered life support equipment will fail to operate in a power outage. This can have dire consequences to the patient if the outage is prolonged.

- Communications. Telecommunications can be disrupted due to a variety of factors. Most telephone and cellular carriers have emergency back-up power supplies for primary equipment. In many cases, the back-up power supply is designed to provide power for 48-hours or less. In the prolonged power outages possible with a major ice storm, this equipment will fail when the fuel for the generator runs out or the back-up batteries become discharged. Overhead telephone lines are also susceptible to the same problems as overhead electrical lines. The consequences of communications failure can be far reaching. Coordination of the public safety response to the event relies heavily on the ability to communicate. The response is invariably hampered when these systems fail.
- Public water supply and wastewater treatment. Water supply pumps and wastewater lift stations are vulnerable to prolonged loss of power. Many of these have back-up power supply for short-term power outages. An ice storm, however, has the potential to cause power outages that may last for days.
- Severely damaged trees. Ice or exceedingly heavy snow can cause substantial damage to trees in urban and rural areas. Damaged or fallen trees in urban areas block roads and sidewalks and can take down power lines. Downed or fallen trees in rural areas can lead to fire hazards in subsequent years as dead trees add to the fuel load. In either case, removal of downed trees and branches can be a significant problem and cost.
- Residential impacts. Loss of power for residential use can lead to a loss of household heating, freezing and bursting water pipes leading to loss of fresh water supply and flooded basements, sewage back-up, and the loss of the ability to cook food.
- Provisions. As is common in many disasters, supplies of flashlights, batteries, bottled water, fuel, and food supplies can become depleted in the area immediately affected by the storm. This creates a particular stress on low-income individuals and families that are not able to stock-up on these supplies.
- Economic loss. Dane County residents rely heavily on roadways and automobiles to commute to and from their jobs. When employees cannot get to their jobs, commerce can be affected, especially if the situation lasts for days. In addition, all of the primary and indirect impacts of a major snow or ice storm can have cascading economic consequences. These losses are difficult to quantify, but full recovery from a regional severe winter storm can take years.

4.14.5 Vulnerability Assessment

Since severe winter storms are regional in nature, virtually the entire County is likely to be affected. The vulnerability of the people, buildings, and economy of the County is very difficult to quantify. Virtually the entire social and economic structure of the region is impacted when major winter storms occur.

There are, however, segments of the population that are vulnerable to the potential indirect impacts of a severe winter storm, particularly the loss of electrical power. As a group, the elderly or disabled, especially those with home health care services relying on rely heavily on an uninterrupted source of electricity. Resident populations in nursing homes, Community Based Residential Facilities, or other special needs housing may also be vulnerable if electrical outages are prolonged. If they do not have a back-up power source, rural residents and agricultural operations reliant on electricity for heating and water supplies are also especially vulnerable to power outages.

Essential Infrastructure

The physical structures which comprise essential infrastructure are also vulnerable. Severe winter weather, particularly a significant ice storm has the potential to disrupt the availability of services from essential infrastructure, including utility delivery (gas, electric and water), telephone service, and emergency response personnel capabilities. Ice storms or high winds in winter storms can cause extensive loss of overhead utility lines due to buildup either on the lines or on adjacent trees that either collapse due to the weight or blow down onto the utility lines. Services such as telephone, electricity, and cable TV are frequently affected by winter storms.

In 2009, Sidney Sperry and Steven Piltz (http://www.spia-index.com/aboutUs.php) developed the Sperry-Piltz Ice Accumulation Index (SPIA Index) to quantify potential damages and vulnerability of electric utility infrastructure in an ice storm. The index accounts for the combination of radial ice and wind in the resulting damage projections.

The Sperry-Piltz Ice Accumulation Index, or "SPIA Index" – Revised September, 2009

ICE DAMAGE INDEX	RADIAL ICE AMOUNT (inches)	WIND (mph)	DAMAGE AND IMPACT DESCRIPTIONS
0	< 0.25	< 15	Minimal risk of damage to exposed utility systems; no alerts or advisories needed for crews, few outages.
1	0.10 – 0.25	15 - 25	Some isolated or localized utility interruptions are possible, typically lasting only a few hours. Roads and bridges may become slick and hazardous.
	0.25 – 0.50	> 15	
2	0.10 – 0.25	25 - 35	Scattered utility interruptions expected, typically lasting 12 to 24 hours. Roads and travel conditions may be extremely hazardous due to ice accumulation.
	0.25 – 0.50	15 - 25	
	0.50 – 0.75	< 15	
3	0.10 – 0.25	> = 35	Numerous utility interruptions with some damage to main feeder lines and equipment expected. Tree limb damage is excessive. Outages lasting 1 – 5 days.
	0.25 – 0.50	25 - 35	
	0.50 – 0.75	15 - 25	
	0.75 – 1.00	< 15	
4	0.25 – 0.50	> = 35	Prolonged & widespread utility interruptions with extensive damage to main distribution feeder lines & some high voltage transmission lines/structures. Outages lasting 5 – 10 days.
	0.50 – 0.75	25 - 35	
	0.75 – 1.00	15 - 25	
	1.00 – 1.50	< 15	
5	0.50 – 0.75	> = 35	Catastrophic damage to entire exposed utility systems, including both distribution and transmission networks. Outages could last several weeks in some areas. Shelters needed.
	0.75 – 1.00	> = 25	
	1.00 – 1.50	> = 15	
	> 1.50	Any	

(Categories of damage are based upon combinations of precipitation totals, temperatures and wind speeds/directions.)

4.14.6 Potential for Future Losses

The winter storm of record is the 1976 ice storm. The potential for future damages is estimated by assuming similar impacts as those caused by this storm. Dane County damages for public, farm, and private/non-farm losses, in 1976 dollars, totaled $1.9 million, $1.8 million, and $1.0 million respectively. Total damages were estimated to be $4.78 million, excluding electric utility losses, which were $1.2 million for Madison Gas and Electric, and an undisclosed amount for Wisconsin Power and Light. Based on a consumer price index inflation calculator, the $4.78 million in losses in 1976 would equate to more than $20.1 million in 2017. (This figure does not include losses to utilities, which would be substantial.)

4.15 EMERGING HAZARDS

4.15.1 Description

The planning process identified a number of additional hazards that had not been addressed in previous versions of the plan. These are emerging concerns related to warming climate conditions and changing environmental conditions. In some cases, these are new or growing concerns of secondary hazards related to the hazards addressed in this plan (e.g. decreasing water quality in the lakes after a flood, leading to harmful algal blooms) in other cases, they are entirely distinct (e.g. increase in vector-borne illness such as West Nile disease which is transmitted by mosquitos). The concerns identified and discussed in the planning process included:

- Air pollution, increasing temperatures, changing circulation patterns, and other processes combine to increase ground-level ozone, which affects respiratory health.
- Heavy rains and flooding can overwhelm sewer and stormwater systems, leading to a rise in water pollution and the risk of waterborne diseases such as cryptosporidium and giardia.
- Warmer water temperatures and an overabundance of nutrients can lead to rapidly reproducing populations of cyanobacteria, also known as blue-green algae, in lakes and ponds. Some blue-green algae produce toxins that are harmful to humans and animals. Algal blooms also deplete oxygen levels and block sunlight for other organisms, causing a disruption in the aquatic ecosystem. Harmful algal blooms are responsible for numerous beach closures on lakes in Dane County.

Blue-green algae bloom

- Changes in temperatures and precipitation could result in an increase in disease-carrying insects, including ticks and mosquitoes. This means people may be at a greater risk for contracting vector-borne diseases, such as Lyme disease and West Nile encephalitis.
- The spread of invasive and exotic species; plants animals, and pests can cause significant harm to native ecosystems and to humans. Addressing or mitigating changing environmental

conditions associated with the spread of invasive species is well beyond the scope of this plan. The spread of invasive species, such as wild parsnip (pastinaca sativa), which can be harmful to human health, have been identified as a specific concern. (Wild parsnip grows along roadsides and other disturbed areas. Chemicals in the plant can cause potentially serious burn-like inflammation on the skin when exposed to sun light.)

4.15.2 Impact and Vulnerability Assessment

These are emerging hazards for which there is not a great deal of risk assessment data available. The potential impacts of climate change on health would most likely arise from a combination of human and environmental factors. While everyone has some degree of vulnerability, it is likely that risks are not evenly distributed among our population; some groups are more vulnerable than others (the very young, the elderly, the economically disadvantaged, and those whose health is already compromised).

This is an area for further monitoring and study.

4.16 RISK SUMMARY

4.16.1 Hazard Ranking

As part of the update process, all local jurisdiction participants and planning committee members were asked to rank their relative concern about these hazards, using their own experiences and judgment to assign numeric values. This served as the preliminary hazard ranking process for the plan update, which provided focus and scope for the hazard mitigation planning committee and the update team. The hazard identification and ranking is a means to quantify and compare the characteristic of each of the hazards, and identify those that are most significant for planning purposes.

1. Attributes of the hazard itself. These are factors related to the natural occurrence of each hazard, without any consideration of potential impacts.
    a. Area of Impact – does the event occur in isolated areas, affecting only a single unit of government, a wider area, affecting multiple units of government, or a regional, affecting the entire County or many counties?
    b. Past History, Probability of Future Occurrence – based on past experience, how likely is it that an extreme event will occur in the future?
    c. Short-Term Time Factors – to what extent is the event predictable in the short term? Is there enough warning time to allow people to act to protect themselves and their property?
2. Direct impacts on people and property. These are rankings of the short-term, immediate effects of each hazard, based on past events.
    a. Impact on General Structures - to what extent could an extreme event impact the buildings and infrastructure of the County?
    b. Impact on Critical Facilities – to what extent could critical facilities be impacted? The impact on critical facilities is an important measure of the extent to which the essential functions of government and the local economy could be disrupted.
    c. Impact on Vulnerable Populations – to what extent could people with special needs be impacted? This is an important measure of the immediate human needs that would be created in the initial response to the event.
3. Indirect or secondary impacts. The potential for long-term, far reaching impacts of each event are difficult to quantify, however, these broad categories were used:
    a. Social Impact – to what extent could the hazard disrupt individual lives and the social structure of the community?
    b. Economic Impact – to what extent could business and industry be disrupted?
    c. Severity of Other Associated Secondary Hazards – does the hazard have the capacity to create other, secondary hazards and how severe could those secondary hazards be? For example, an ice storm causing a long-term, wide-area power outage.

Table 4.16.1 summarizes the hazard ranking process conducted by the planning committee and local government participants. Hazards are listed in order of ranking. The rankings indicated in table 4.16.1 are the averages of the individual rankings of the planning team members and local jurisdiction participants. This is based on experience and judgement of more than 40 people involved in the planning process. Nevertheless, this is a subjective assessment, based on these individuals' perceptions of risk. This ranking is provided as a starting point for discussion and should not be interpreted as a scientific or objective analysis of risk.

Table 4.16.1 Hazard Ranking Summary

	Name of Break-Out Sub-Group:										
Rank	**Hazard**	**Hazard Attributes**			**Impact Attributes**						**Total of Row Values**
					Primary Impact (Short Term - Life and Property)			**Secondary Impact (Long Term – Community Impacts)**			
		Area of Impact	Past History, Probability of Future Occurrence	Short Term Time Factors	Impact on General Structures	Impact on Critical Facilities	Impact on At-Risk Populations	Social Impact	Economic Impact	Severity Of Other Associated Secondary Hazards	
		(1-5)	*(1-5)*	*(1-5)*	*(0-5)*	*(0-5)*	*(0-5)*	*(0-5)*	*(0-5)*	*(0-5)*	
9	Dam / Levee Failure	2.2	1.6	1.7	2.9	3.0	2.4	2.1	2.2	2.1	**20.2**
5	Extreme Cold	4.8	4.8	2.2	2.6	3.0	4.8	2.9	2.7	2.6	**30.4**
4	Extreme Heat	4.8	4.8	2.2	2.2	3.3	4.9	3.1	2.8	2.6	**30.7**
8	Drought	4.1	4.0	1.4	0.6	1.3	1.8	1.9	4.1	2.7	**21.9**
1	Flood	4.2	5.0	4.0	4.6	4.5	4.4	4.2	4.2	4.0	**39.1**
10	Fog	3.2	3.8	3.9	0.4	1.2	1.2	1.8	1.6	1.8	**18.9**
7	Hail Storm	2.3	4.5	3.2	3.1	1.9	1.8	1.6	2.9	1.8	**23.1**
13	Landslide / Sink Holes	0.8	0.9	2.3	2.3	1.2	1.2	1.3	1.4	1.0	**12.4**
11	Lightning	1.4	3.7	2.8	1.6	1.8	1.6	1.1	0.9	2.0	**16.9**
2	Tornado	2.6	4.4	4.5	4.2	3.7	4.0	3.9	4.3	4.3	**35.9**
12	Wildfire	1.5	1.3	1.9	2.3	2.0	1.7	1.9	2.0	2.0	**16.6**
6	Windstorm	3.1	3.9	3.0	3.5	3.0	3.0	2.7	2.9	3.4	**28.5**
3	Winter Storm	4.7	4.6	2.8	3.4	3.8	4.5	3.3	2.9	3.4	**33.4**

4.16.2 Summary of Trends and Key Issues

The planning committee's analysis of the vulnerability assessment, past events in Dane County, experience, and case studies from other locales yields the following issues and concerns:

Dam Failure

- The probability of dam failure in Dane County is low, however, the potential impacts to people and property could be substantial.
- Dam failure analysis indicates that downstream flood depths would be in the 1 to 3 foot range in the event of a failure of one of the "high" hazard dams in Dane County. This is significant, but a dam failure is likely to lead to the major inundation associated with catastrophic failure seen in media images from other locations around the country.
- Areas of greatest risk include:
    - The Town of Roxbury and the Town of Mazomanie along the Wisconsin River.
    - The Isthmus area of the City of Madison and shoreline areas of the City of Monona, including the Belle Isle and Pirate Island areas.
- Mitigation opportunities and actions are essentially the same as those identified for the flood hazard.
- While still a low probability occurrence, the increasing likelihood of extreme rainfall events associated with changing climate conditions does increase the potential for dam failure in the future.
- The dam failure risk is reduced by regular inspections, competent operation, and maintenance with public safety as the primary consideration.

Drought

- Dane County is vulnerable to the effects of an extended drought.
- Droughts can have a wide range of direct and indirect impacts that can affect a broad cross section of society and the natural environment.
- There is a general lack of awareness of the potential impacts of a sustained severe drought.
- The lack of comprehensive water management policies can exacerbate the impacts of an extended drought.
- There are great difficulties in predicting at what point a dry spell will become a drought. As a result, the response, if any, is often ad hoc and can be disorganized.
- The risk of drought is increasing due to changes in the regional climate.

Extreme Cold

- Extreme cold is an annual occurrence in Dane County.
- Water pipes in homes are susceptible to freezing and breakage during prolonged periods of extreme cold.
- Municipal water mains are susceptible to breakage during periods of extreme cold.
- People who are homeless are vulnerable to exposure during periods of extreme cold.

Extreme Heat

- While property impacts are generally minimal, there are frequent occurrences of road pavement buckling during periods of high heat. Concrete pavement is generally more prone to buckling than asphalt.
- The National Weather Service ranks extreme heat as the number one weather-related killer, nationwide and in the State of Wisconsin. These statewide and national trends have not been experienced in Dane County, where the numbers of heat-related deaths remains low.
- Heat exacerbates other underlying risk factors and the high heat is almost always an indirect cause of death.
- While everyone feels the effects of extreme heat, not everyone experiences the same level of risk. There is a range of factors that lead to an increased vulnerability of heat-related illness or death, including pre-existing health conditions, socio-economic status, and natural and built environmental factors.
- Social isolation is a perhaps the most significant of the extreme heat risk factors. This can be mitigated through organized welfare checks as well "social capital" programs that build on informal relationships between friends, family members, and neighbors.
- Due to climate tends, population exposure, and potentially fatal impacts, the overall risk of excessive heat is a growing concern.

Flood

- Flood damage occurs frequently in Dane County. Floods have caused:
    - Damage to private property that often creates financial hardship for individuals and families.
    - Damage to public infrastructure resulting in increased public expenditures and demand for tax dollars.
    - Loss of income for agricultural producers that experience flood damages.
    - Loss of income to businesses relying on recreational uses of County waterways.
    - Emotional distress on individuals and families.

  - The potential for personal injury and death.
- Financially, flood losses have resulted from:
  - Flooded basements and first-floor flooding of residential, commercial, and institutional buildings.
  - Sewer backups into basements of residential, commercial, and institutional buildings.
  - Structural damage to buildings.
  - Damage to personal belongings and other contents of buildings.
  - Road, shoulder and ditch washouts.
  - Crop loss.
- Unless a property owner has flood insurance, damages to buildings and building contents are typically uninsured losses and costs for repair and replacement are typically borne by the property owner.
- Dane County is a drainage area. With a few exceptions, Dane County contains the headwaters of the rivers and streams flowing out of the County. This means that the rainfall that becomes the floodwater that causes damage started here – it didn't come from somewhere else. This presents both opportunities and challenges in reducing flood risk.
- Flooding issues in Dane County are complex and involve the interaction of a number of contributing factors, including but not limited to:
  - Changing land use patterns.
  - Historical and on-going modifications to the landscape that affect the flow of water.
  - Soils and topography.
  - Natural and constructed impediments to the flow of water.
  - Development in high risk areas.
  - Stormwater management practices.
  - Complex natural hydrologic processes.
- The complexity and interrelatedness of flooding with many other variables make it very difficult to establish an objective and complete comprehension of the problem.
- Flooding comes in a variety of forms in Dane County and not all flood management and flood mitigation strategies apply to all situations.
- Riverine flooding and the associated mapped flood hazard (i.e. NFIP floodplain maps) areas are only a partial indicator of the flood risk in Dane County.
- Floodplain zoning and construction standards have been effective loss avoidance strategies.
- The flood risk is increasing and can be expected to continue to increase as a result of warming climate conditions and changing rainfall patterns.
- Effective adaptation to this changing risk requires systematic changes to the County's water management strategies.

- Flood Insurance Studies and Flood Insurance Rate Maps are developed based on analysis of past flood events. These maps do not account for changing climate conditions, nor do they account for changing flood risks associated with urbanization and increasing land areas covered by impervious surfaces.

Fog

- Increased number of serious of fatal traffic crashes occur when fog is a contributing factor.
- Although traffic crashes and deaths are typically considered indirectly related to fog, the numbers far exceed the number of people harmed by any other natural hazard addressed in this plan.
- Dense fog can result in flight delays and cancellations at airports.
- Fog poses no risk to structures or facilities in Dane County.
- There is not a readily available source of information to assess whether the incidence of fog will increase, decrease, or remain the same as a result of the warming climate.

Hail

- No deaths or injuries have ever been directly attributed to hail strikes in Dane County.
- Financial losses due to hail damage can be significant.
- Automobiles are particularly vulnerable to damage.
- Crops are particularly vulnerable to damage at certain times in the growing season.
- Commonly used roofing and siding materials are not resistant to hail impact, resulting in the potential for widespread damage due to large hail.
- There is not a readily available source of information to assess whether the incidence of hail will increase, decrease, or remain the same as a result of the warming climate.

Landslides, Erosion, and Sinkholes

- The geology of Dane County is such that there is some potential for landslides, sinkholes and significant erosion. The overall susceptibility in the County, however, is low.
- There are no documented occurrences of significant problems associated with naturally occurring landslides or sinkholes in Dane County.
- Climate models predict increased frequency and intensity of extreme weather statewide, including more frequent, more intense precipitation events. These changes may lead to increased incidences and severity of flooding, erosion, and landslides/land subsidence.

Lightning

- Lightning strikes and resulting electrical surges can damage unprotected electronic equipment.
- Lightning strikes and resulting electrical surges can damage the electrical distribution system and cause power outages.
- Lightning striking buildings can cause structure fires.
- Lightning strikes can cause injury and/or death.
- There is not a readily available source of information to assess whether the incidence of lightning will increase, decrease, or remain the same as a result of the warming climate.

Tornado

- In general, all buildings, critical facilities, and populations are vulnerable to tornado damage.
- The Multi-Hazard section contains additional summary information on issues and concerns associated with tornadoes.
- There is not a readily available source of information to assess whether the incidence of tornadoes will increase, decrease, or remain the same as a result of the warming climate.
- A strong tornado in a densely populated area has the greatest future damage/loss potential of all of the hazards assessed in this plan.

Wildfire

- While wildfires have occurred, the conditions that lead to large, uncontrolled fires generally does not exist in Dane County.
- Wildfires in Dane County are typically grassland fires and marsh fires, not large forest fires.
- The wildfire risk in Dane County is limited to relatively small areas where urban and suburban subdivisions or small communities are situated adjacent to grass land or marshy areas.
- Grassland and marsh fires are relatively common in the spring and fall seasons, however, wildfires in Dane County rarely result in losses to homes and businesses.
- The vast majority of wildfires in Dane County are human caused.
- The incidence of wildfires can be expected to increase as a result of the warming climate and changing rainfall patterns, however the risk to structures remains low.

Windstorm

- In general, all buildings, critical facilities, and populations are vulnerable to wind damage to some degree.

- The Multi-Hazard section contains additional summary information on issues and concerns associated with tornadoes.
- There is not a readily available source of information to assess whether the incidence of severe thunderstorms and other windstorms will increase, decrease, or remain the same as a result of the warming climate.

Winter Storm

- Severe winter storms have the potential to halt all transportation – countywide. This includes that of emergency services vehicles and first responders.
- Motorists and travelers can become stranded on the highways of the County.
- Winter storm events can pose a serious threat to the residents of Dane County. Many fatalities during winter storms are the unsuspecting dangers that include heart attacks while shoveling snow and improper use of space heaters.
- Severe winter storms can completely shut down businesses and government, while isolating residents in their homes for days and sometimes weeks.
- Ice storms or high winds in winter storms can cause extensive loss of overhead utility lines due to buildup on either the lines or on adjacent trees that either collapse due to the weight or blow down onto the utility lines.
- The disruption of electrical power distribution systems can have a wide range of secondary, potentially long-term impacts.
- The Multi-hazard section contains additional summary information on issues and concerns associated with winter storms and ice storms.
- Climate models predict and increase in wintertime precipitation for southern Wisconsin. Depending on conditions at the time of the event, this can occur as snow, rain, or freezing rain. As both temperature and precipitation increase during the winter, occurrences of freezing rain are becoming more likely. The resulting risk of a damaging ice storm is increasing.

Emerging Hazards

- Trends toward a warmer, wetter climate lead to increases in risks to human health above and beyond those traditionally considered as “natural hazards.”
- Air pollution, increasing temperatures, changing circulation patterns, and other processes combine to increase ground-level ozone, which affects respiratory health.
- Heavy rains and flooding can overwhelm sewer and stormwater systems, leading to a rise in water pollution and the risk of waterborne diseases such as cryptosporidium and giardia.
- Warmer water temperatures and an overabundance of nutrients can lead to harmful algal blooms, in lakes and ponds.

- Changes in temperatures and precipitation could result in an increase in disease-carrying insects, including ticks and mosquitoes. This means people may be at a greater risk for contracting vector-borne diseases, such as Lyme disease and West Nile encephalitis.
- The spread of invasive species, such as wild parsnip (pastinaca sativa), which can be harmful to human health, have been identified as a specific concern.
- This is an area for further monitoring and study.

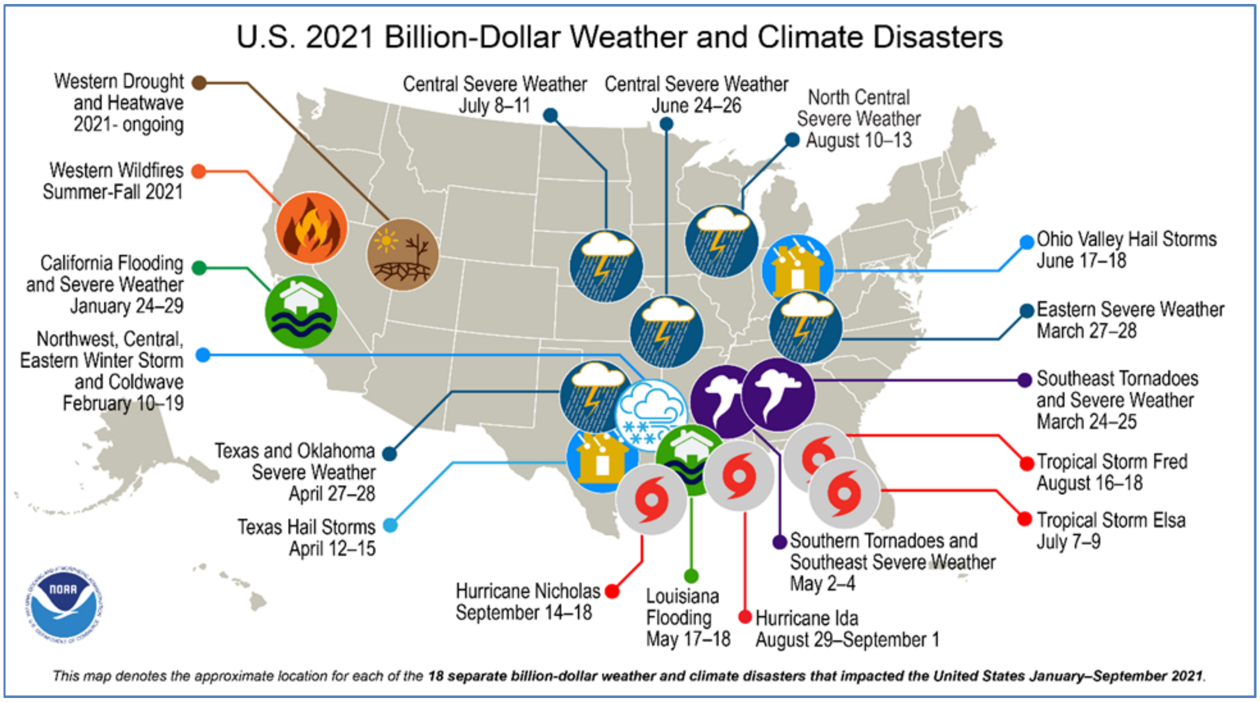
Multi-Hazard Issues

- Overhead power and telephone lines are vulnerable to damage by ice and wind.
- Homes are often damaged due to falling tree limbs in wind and ice storms.
- Tree damage leads to many secondary losses, such as road blockage, downed power lines, and hindered emergency response.
- Manufactured homes are especially vulnerable to many of the hazards, but particularly high winds and tornadoes. Most manufactured homes do not have safe rooms. Some mobile home parks have storm shelters, but most do not.
- Agricultural operations and critical facilities are particularly vulnerable to extended loss of electric power.
- Loss of electrical power is, in many cases, the cause of significant secondary consequences of a hazard event. Overhead electrical lines are particularly vulnerable to many of the natural hazards in Dane County.
- Individuals in a home-health care situation are particularly vulnerable to loss of electrical power.
- Manufactured homes, buildings with wide span roofs such as shopping malls or school gymnasiums are also particularly vulnerable to high winds.
- Falling trees and branches cause damage to power lines, block streets, damage buildings, inhibit emergency access, and is a major contributor to storm debris problems.

4.16.3 Catastrophic Scenarios

In addition to compiling the type of severe weather data referenced previously in the hazard analysis, NOAA's National Centers for Environmental Information (NCEI) tracks and evaluates large-scale climate and weather events in the US (and globally) that have great economic and social impacts. In their assessment, Billion-Dollar Weather and Climate Disasters, NCEI states that "In 2021 (as of October 8), there have been 18 weather/climate disaster events with losses exceeding $1 billion each to affect the United States. These events included 1 drought event, 2 flooding events, 9 severe storm events, 4 tropical cyclone events, 1 wildfire event, and 1 winter storm event. Overall, these events resulted in the deaths of 538 people and had significant economic effects on the areas impacted. The 1980–2020 annual average is 7.1 events (CPI-adjusted); the annual average for the most recent 5 years (2016–2020) is 16.2 events (CPI-adjusted).. The total cost of these 208 events exceeds $1.1 trillion." The 18 events that occurred in 2021 are shown on the map in Figure 4.16.1.

Figure 4.16.1 U.S. 2021 Billion-Dollar Weather & Climate Disasters



Source: NOAA, National Centers for Environmental Information website, https://www.ncdc.noaa.gov/billions/ , 2021

A significant number of the 208 events identified are related to tropical storms and large wildfires which do not present a threat in our region of the country. There are four scenarios identified, however, where there is a risk of a regional catastrophic disaster that could have impacts in Dane County far greater than have occurred in the past. These include:

- Extreme rainfall and major flooding.
- Strong (EF4 or EF5), long track tornado affecting a densely populated urban area.
- Regional, multi-year extreme drought.
- Regional ice storm resulting in a long-term, widespread electrical power outage.

Events such as these would have profound impacts on the communities affected, far beyond that which we have experienced in the past. The recovery process would take years to return the economy and community to "normal."

To be clear, this plan is not predicting the occurrence of an event of this nature in Dane County in the immediate future. The probability of these extreme events remains low. There is a precedent for events of this nature, however, and while low, the probability of occurrence is not zero. Attention is being called to these events because a risk assessment based solely on the severity of past occurrences in

Dane County has a narrow view. Because events on this scale have not occurred recently in Dane County, does not mean that they never will. Widening the view presents an entirely different perspective of the risk potential. To maximize community resilience, hazards management and mitigation strategies should be developed with the widest practical view.

Also, it is important to acknowledge that our current risk management tools and processes probably already are outdated. For example, most risk management models are typically retrospective and do not account for climate change impacts we are experiencing today. As climate change effects are exacerbated, we will be even further behind the curve, our mitigation efforts will prove insufficient, and our response and recovery operations will suffer. These catastrophic scenarios and examples from other areas of the country offer a perspective of the scope and scale of potential future vulnerabilities.

4.16.4 Individual Perceptions of Risk of Natural Hazards

Individuals assess risk and the probability of being harmed (either physically or financially) very differently from the quantitative analysis described in the previous sections of this plan. The perceptions of individual members of the public have increasing importance as planning methods, such as the one used in this plan incorporate public input to greater degrees.

Though one of the purposes of the County vulnerability analysis is to aid the public in making policy decisions, citizens are often skeptical of “expert” opinion. As a result, they are more likely to depend upon their own experiences and knowledge as a basis for decision-making. Their reliance on their own opinions and experiences has both positive and negative aspects.

On the positive side, the public perception of risk tends to be broader than what traditionally comes out of technical studies. People often give greater emphasis to latent or diffused risks and incorporates social costs readily into their judgments. They also tend to give greater emphasis to risks that affect multiple generations and focus on mitigating risks when the exposure to risk is involuntary, that is, the person did not place him or herself in harm’s way.

Individuals, however, do not evaluate probabilities of risk in what is called “rational” ways. People over- and underestimate risks in several ways. People tend to ascribe risks to un-risky events when they can be easily categorized with events that have great probabilities of occurring. Individuals also link risk with events depending upon the ease in which harm can be imagined coming from an event. Additionally, when faced with new information that contradicts their beliefs people often move incrementally to adjust their position to the new information. People will generally overestimate the consequences of changing their beliefs and underestimate the consequences of maintaining their beliefs.

There may also be a perception that governments will provide adequate services to individuals before, during and after disasters, and that individual preparation is therefore unnecessary. Though governments at every level will prepare for and respond to such disasters to the best of their capabilities, it is important that individuals take responsibility for their own wellbeing. Governments cannot decrease risks sufficiently to protect everyone from every conceivable natural disaster. It is necessary for families and individual citizens to take additional steps decrease their own risk. These variables in individual risk assessments both bias decision-making and provide information that cannot easily be described by an economic analysis.

Importantly, the biases mentioned in individual risk assessments may be no greater and no less powerful than numerous assumptions made in quantitative risk analyses. Neither way of understanding the world of natural disasters is completely accurate. It should be noted that this plan is influenced by both individual and quantitative assessments of risk. This plan makes attempts to compensate for these shortcomings by making readers aware of them.

5.1 Plan Requirements

"The mitigation strategy serves as the long-term blueprint for reducing the potential losses identified in the risk assessment. The Stafford Act directs Local Mitigation Plans to describe hazard mitigation actions and establish a strategy to implement those actions. Therefore, all other requirements for a Local Mitigation Plan lead to and support the mitigation strategy. The mitigation strategy includes the development of goals and prioritized hazard mitigation actions. Goals are long-term policy statements and global visions that support the mitigation strategy. A critical step in the development of specific hazard mitigation actions and projects is assessing the community's existing authorities, policies, programs, and resources and its capability to use or modify local tools to reduce losses and vulnerability from profiled hazards.

In the plan update, goals and actions are either reaffirmed or updated based on current conditions, including the completion of hazard mitigation initiatives, an updated or new risk assessment, or changes in State or local priorities." (FEMA, Local Mitigation Plan Review Guide, October 1, 2011)

Requirement	Description
44CFR 201.6 (c)(3)	[The plan shall include the following:] A mitigation strategy that provides the jurisdiction's blueprint for reducing the potential losses identified in the risk assessment, based on existing authorities, policies, programs, and resources, and its ability to expand on and improve these existing tools.
44CFR 201.6 (c)(3)(i)	[The hazard mitigation strategy shall include a] description of mitigation goals to reduce or avoid long-term vulnerabilities to the identified hazards.
44CFR 201.6 (c)(3)(ii)	[The hazard mitigation strategy shall include a] section that identifies and analyzes a comprehensive range of specific mitigation actions and projects being considered to reduce the effects of each hazard, with particular emphasis on new and existing buildings and infrastructure. All plans approved by FEMA after October 1, 2008, must also address the jurisdiction's participation in the NFIP, and continued compliance with NFIP requirements, as appropriate.
44CFR 201.6 (c)(3)(ii)	[The hazard mitigation strategy shall include an] action plan, describing how the action identified in paragraph (c)(3)(ii) of this section will be prioritized, implemented, and administered by the local jurisdiction. Prioritization shall include a special emphasis on the extent to which benefits are maximized according to a cost benefit review of the proposed projects and their associated costs.
44CFR 201.6 (c)(3)(iv)	For multi-jurisdictional plans, there must be identifiable action items specific to the jurisdiction requesting FEMA approval or credit of the plan.
44CFR 201.6 (c)(4)(ii)	[The plan shall include a] process by which local governments incorporate the requirements of the mitigation plan into other planning mechanisms such as comprehensive or capital improvements, when appropriate.

5.2 Capability Assessment

Dane County has the regulatory authority and non-regulatory capability to implement the mitigation strategy identified in this plan. Wisconsin counties are general purpose units of local government and administrative arms of the state. Dane County provides services through 2,300 elected and civil service employees. Dane County is governed by a county executive and a county board of supervisors. As the policy-making body of county government, the Board of Supervisors enacts county ordinances, levies taxes, and appropriates money for services. The County Executive is a chief executive officer of the county, directing the activities of 18 departments. The Department of Emergency Management is the lead agency on this plan development and implementation. The Department has a staff of nine, with the department head appointed by the County Executive.

Dane County's 2017 budget authorizes $587.1 million in expenditures for operations, which is financed by $357.2 million of program revenues, $57.1 million of county sales taxes, and $169.9 million of county property tax levy funds. The separate Capital Budget is $50.6 million, which is financed by borrowing proceeds.

5.2.1 Regulatory Authority

Regulatory tools include floodplain and shoreland zoning ordinances and a comprehensive erosion control and stormwater management ordinance. Local governments within the county have similar authorities and ordinances. County and local shoreland and floodplain zoning authorities are determined by state statute. Through the Lakes and Watershed Commission, Dane County has unique authority to establish standards for local regulations and ordinances to protect water resources that apply within cities and villages as well as the unincorporated areas of the County. For example, the provisions of the County erosion control and stormwater management ordinance apply to the entire geographical area of Dane County. In addition, many communities have established local stormwater utilities to set standards for design and maintenance of facilities.

Additionally, the Land Suitability section of the County's Land Division and Subdivision Regulations gives the Zoning and Natural Resources Team of the County Board the authority to restrict division or subdivision of land that is unsuitable for development due to flooding or potential flooding, soil limitations, inadequate drainage, or other conditions likely to be harmful to the health, safety or welfare of future residents or users of the area, or harmful to the community or the County.

County ordinances relevant to natural hazards management include:

- Chapter 11 of the Dane County Code of Ordinances is the County's Shoreland, Shoreland-Wetland and Inland-Wetland ordinance
- Chapter 14 is Dane County's Manure Management, Erosion Control, and Stormwater Management ordinance
- Chapter 17 is Dane County's Floodplain Zoning Ordinance
- Chapter 75 is the County's Land Division and Subdivision ordinance.

Note: Building codes are established by the State of Wisconsin, through Wisconsin Administrative Code and the Wisconsin Department of Safety and Professional Services (SPS). The Uniform Dwelling Code is contained in SPS 320-325. Commercial Building Codes are described in SPS 361-366.

5.2.2 Non-Regulatory Actions

Managing natural hazards risk also involves a wide range of non-regulatory actions. Dane County has the long-standing partnerships with stakeholders necessary to implement every step in this process, from data collection and assessment to implementation. The County has well-established relationships with citizens, local governments and elected officials, the National Weather Service, climate scientists and researchers, local meteorologists, builders, realtors, economic development organizations, and numerous watershed associations' friends groups and other natural resources groups that are acting to protect and improve water resources in Dane County.

5.3 Natural Hazard Mitigation Goals and Objectives

Dane County's hazard mitigation planning team developed the county level mitigation strategies. Each participating municipality developed their own municipal-specific mitigation strategies. Dane County strategies were the result of a design team (representatives from all Dane County departments) participating in the risk assessment process, problem statement development, and identification of natural hazard mitigation goals and objectives. Municipal mitigation strategies were developed by local mitigation steering committees who attended remote training on diversity and equity in local communities, practical adaptations to climate change, developing problem statements, and developing mitigation strategies. All mitigation strategies were developed from both professional expertise, local experience, and public input (November and December 2021). The mitigation goals in this plan are consistent with the statewide goals identified in the State of Wisconsin Mitigation Plan.

All mitigation strategies have an identified goal with specific objectives for each strategy. Each mitigation strategy is designed to identify a clear outcome and the actions needed to attain that outcome. Municipal mitigation strategies are included in their individual mitigation plan (See *Attachments*).

Actions identified in the objectives had the following criteria:

- Requires no more technology or technical expertise than what is currently available.
- Requires no more staff or governmental resources than what is already available.
- Is expected to have wide political support.
- Can be legally implemented by the lead jurisdiction or agency.
- Is cost-effective. There is no other effective, cheaper alternative, and there is no other objective that pursues the same specific result.
- Makes progress toward sustainability in mitigating impacts of natural hazards.
- Makes significant progress toward mitigating natural hazards.

- Considers the cost of taking no action.
- Correlates with vulnerability analysis and problem statements.

The current mitigation strategies are organized differently than previous versions of this plan. While the appearance may be difference, there are clear connections and continuation of mitigation efforts from previous strategies to the current ones. See *Appendix D* for a crosswalk between previous and current mitigation strategies as well as progress toward previous mitigation strategies.

5.3.1 Prioritization and Mitigation Actions

All mitigation strategies are expected to be acted upon within the capabilities of Dane County agencies. The prioritization of action on each of these strategies is based on lead and partner department capacities. At least some actions on all strategies can be taken without additional funding. Personal experience and current conditions can be expected to guide the level of activity on each strategy.

Mitigation Strategy #1:	***Assess DC Comprehensive Plan for impacts from climate change***
Strategic category:	Prevention

Goal:

Review the Dane County Comprehensive Plan to assess where the impacts of climate change could affect the elements of the plan and develop strategies to address the impacts of climate change within the Comprehensive Plan.

Objectives:

1. Develop best practices for reviewing the Dane County Comprehensive Plan through a lens of climate change.
    a. *Responsible Party* – DC Planning & Development
    b. *Funding source* – N/A (expenses covered under existing budget allocation)
    c. *Completion date* – Summer 2022

2. Develop process for Dane County government to support the application of the best practices in the municipal review/update process.
    a. *Responsible Party* – DC Planning & Development
    b. *Funding source* – NA (expenses covered under existing budget allocation)
    c. *Completion date* – Summer 2022

Mitigation Strategy #2:	**Cross-Community Wastewater Strategy**
Strategic category:	Property Protection, Natural Resource Protection

Goal:

With regional partners, develop an infrastructure improvement strategy focused on new development's impacts on waste water systems to ensure the waste water system is resilient and support additional development.

Objectives:

1. Conduct regional conversations regarding wastewater infrastructure and further development to ensure the multi-jurisdictional wastewater system maintains resiliency and capacity.
   a. *Responsible Party* – Madison Metro Sewerage District (MMSD) and local partners.
   b. *Funding source* – N/A
   c. *Completion date* – Winter 2022

Mitigation Strategy #3:	**Emergency Procedures to Protect Critical DC Facilities from Flood Conditions.**
Strategic category:	Prevention

Goal:

Develop emergency procedures to reduce the risk to people using, and equipment in critical Dane County facilities that could be affected by flooding.

Objectives:

1. Determine criteria to define "critical."
   a. *Responsible Party* – DC Planning & Development (DCP&D), DC Land Information Office (DCLIO), and DC Administration (DCA)
   b. *Funding source* – N/A (expenses covered under existing budget allocation)
   c. *Completion date* – Summer 2022

2. Identify critical Dane County facilities that have been affected by and/or could be affected by flooding conditions.
   a. *Responsible Party* – DCP&D, PDLIO, DCA
   b. *Funding source* – N/A (expenses covered under existing budget allocation)
   c. *Completion date* – Summer 2022

3. Develop emergency procedures that will protect the users and occupants of critical Dane County Facilities when threatened by flooding.
   a. *Responsible Party* – DCP&D, PDLIO, DCA
   b. *Funding source* – N/A (expenses covered under existing budget allocation)
   c. *Completion date* – Summer 2022

4. Promulgate these procedures throughout Dane County departments so they can be utilized when needed.
   a. *Responsible Party* – DCA
   b. *Funding source* – N/A (expenses covered under existing budget allocation)
   c. *Completion date* – Fall 2022

Mitigation Strategy #4: Expand Green Infrastructure Practices

Strategic category: Prevention, Public Education and Awareness

Goal:

Expand green infrastructure practices across Dane County to increase infiltration and limit damage from big precipitation events.

Objectives:

1. Use existing research (TNC/DNR Wetlands by Design study) to further identify and map opportunities for flood mitigation.
   a. *Responsible Party* – Capital Area Regional Planning Commission (CARPC), Dane County Land and Water Resources (DCL&WR), Madison Metro Sewerage District (MMSD), Dane County Office of Energy and Climate Change (DCECC), Dane County Land Information Office (DCLIO)
   b. *Funding source* – N/A
   c. *Completion date* – Summer 2022

2. Develop / adjust existing policy to restore wetlands and floodplains; and encourage green roofs and permeable surfaces.
   a. *Responsible Party* – CARPC, DCL&WR, MMSD, DCECC, DCLIO
   b. *Funding source* – N/A
   c. *Completion date* – Winter2022

3. Identify the best locations and practices for storing snow to minimize salt dilution and maximize ground infiltration verses running off into surface water sources.
   a. *Responsible Party* – CARPC, DCL&WR, MMSD, DCECC, DCLIO, and Dane County Public Works Highways and Transportation (DCPWHT)
   b. *Funding source* – N/A
   c. *Completion date* – Winter 2023

4. Develop and promulgate documentation outlining green construction practices and criteria for a "green construction rating system" that can reduce water runoff, heat island effects, improve energy efficiency, and other assorted construction-based mitigation practices (e.g. green roofs, permeable pavements, etc.) for residential structure best-practices to be used by both developers and home owners with a specific considerations for affordable housing.
   a. *Responsible Party* – CARPC, DCL&WR, MMSD, DCECC, DCLIO
   b. *Funding source* – N/A
   c. *Completion date* – Winter 2023

Mitigation Strategy #5:	**Expand Tree Canopy**
Strategic category:	Natural Resource Protection

Goal:

Using existing and incoming data, support both Dane County and municipal efforts to sustain and expand tree canopy and flora for the purposes of reducing flood impact potential and reducing heat island effects.

Objectives:

1. Organize a group of interested parties that have some capacity to affect tree canopies and flora across Dane County. Membership could include parks, public works, and planning & development departments.
   a. *Responsible Party* – Capital Area Regional Planning Commission (CARPC), Dane County Office of Energy and Climate Change (DCE&CC), Dane County Land and Water Resources (DCL&WR), Dane County Planning and Development (DCP&D)
   b. *Funding source* – N/A
   c. *Completion date* – Spring 2022

2. Utilizing the Capital Area Regional Planning Commission (CARPC) multi-year tree canopy data set, develop goals for sustaining and increasing tree canopy and flora on public and private lands.
   a. *Responsible Party* – CARPC, DCE&CC, DCL&WR, DCP&D
   b. *Funding source* – N/A
   c. *Completion date* – Fall 2022

3. Develop process for assessing both tree health and identifying appropriate tree replacement for unhealthy trees.
   a. *Responsible Party* – DCL&WR
   b. *Funding source* – N/A
   c. *Completion date* – Fall 2022

4. Develop a promulgation strategy for interested agencies to apply the newly developed goals to both sustain and increase tree canopy and flora.
   a. *Responsible Party* – CARPC, DCE&CC, DCL&WR, DCP&D
   b. *Funding source* – N/A
   c. *Completion date* – Fall 2022

Mitigation Strategy #6: **Mold Abatement Assistance**

Strategic category: Property Protection

Goal:

Increase capacity to support citizen's mold abatement capabilities.

Objectives:

1. Determine methodology to increase effectiveness and capacity to convey mold abatement information to residents who have suffered flooding.
   a. *Responsible Party* – Public Health Madison Dane County (PHMDC)
   b. *Funding source* – N/A
   c. *Completion date* – Summer 2022

2. Identify local agencies (governmental, non-governmental, and volunteer) that can provide flood victims with mold abatement supplies.
   a. *Responsible Party* – PHMDC
   b. *Funding source* – N/A
   c. *Completion date* – Fall 2022

3. Build partnerships with local agencies (governmental, non-governmental, and volunteer) to promote mold abatement best practices.
   a. *Responsible Party* – PHMDC
   b. *Funding source* – N/A
   c. *Completion date* – Fall 2022

Mitigation Strategy #7:	**Preparedness Education thru Coordinated Outreach**
Strategic category:	Public Education and Awareness

Goal:

Develop coordinated and concurrent outreach campaigns across Dane County departments specific to natural hazards including flooding, tornados, winter storms, excessive cold, and excessive heat events. Campaigns will promote personal preparedness specific to household safety and security focusing on the topics of personal emergency plans, personal health awareness, food security, household flood risk reduction measures, and flood insurance.

Objectives:

1. Identify / develop both materials and distribution processes for all participating Dane County departments to utilize in a coordinated fashion for multiple public education campaigns.
   a. *Responsible Party* – Dane County Emergency Management (DCEM), Dane County Board of Supervisors (DC Sup), Univ. of Wisconsin Extension Office (UW Ext), Dane County Land and Water Resources (DC L&W), Dane County Planning and Development (DCP&D), Dane County Human Services (DCHS), Dane County Office for Equity and Inclusion (DCOEI), Dane County Executive (DCEx)
   b. *Funding source* – (N/A)
   c. *Completion date* – Summer 2022

2. Identify communication barriers (e.g. language, distribution sources, etc.) and strategies to minimize them when conducting public information campaigns.
   a. *Responsible Party* – DCEM, DC Sup, UW Ext, DCL&W, DCP&D, DCHS, DCOEI, DCEx
   b. *Funding source* – N/A.
   c. *Completion date* – Initiate coordinated campaigns by Fall 2022

3. Utilizing both Wisconsin Emergency Management and the National Weather Service campaign dates, all departments will develop an plan to actively promote their information in a coordinated and concurrent manner.
   a. *Responsible Party* – DCEM, DC Sup, UW Ext, DCL&W, DCP&D, DCHS, DCOEI, DCEx
   b. *Funding source* – N/A.
   c. *Completion date* – Initiate coordinated campaigns by Fall 2022

Mitigation Strategy #8: **Protection of Natural Environmental Flood Buffers**

Strategic category: Natural Resource Protection

Goal:

Identify actions that will preserve green space and buffer areas to wetlands and other natural areas for the purpose of minimizing flood damage.

Objectives:

1. Identify water levels that cause damage and destruction to wetlands and natural areas.
   a. *Responsible Party* – Dane County Land and Water Resources (DCL&WR), Dane County Land Information Office (DCLIO)
   b. *Funding source* – N/A
   c. *Completion date* – Summer 2022

2. Identify green spaces / buffer areas that could increase flood protections for wetlands and natural areas.
   a. *Responsible Party* – DCL&WR
   b. *Funding source* – N/A
   c. *Completion date* – Spring 2023

3. Identify procedures and actions that would allow the identified green spaces / buffer areas to protect wetlands and natural areas from flood damage.
   a. *Responsible Party* – DCL&WR
   b. *Funding source* – N/A
   c. *Completion date* – Fall 2023

Mitigation Strategy #9:	**Protective Spaces in Dane County Parks**
Strategic category:	Property Protection, Prevention

Goal:

Not all Dane County parks have structures that could protect users from severe weather; park facilities vary greatly. A study will be conducted to identify both the variety / volume of protective space needs and procedures to make protective spaces available to park users. The study will identify the physical capacity of existing spaces, capacities needed to provide protection from severe weather to park users, and capabilities / operational practices required to make protective spaces available to park users. The study will provide practical guidance for park users to seek protective spaces.

Objectives:

1. Identify parameters for a study to both evaluate protective space needs in Dane County parks and identify limitations in current Dane County Parks Department capabilities. Parameters may include, but are not limited to, the capacities of existing spaces to withstand high winds and the process to make these spaces available to park users in a timely manner.
    a. *Responsible Party* – Dane County Land and Water Resources (DCL&WR), Dane County Emergency Management (DCEM)
    b. *Funding source* – N/A
    c. *Completion date* – Summer 2022

2. Identify a funding source and submit a Request for Proposals to develop such a study.
    a. *Responsible Party* – DCL&WR
    b. *Funding source* – N/A
    c. *Completion date* – Following the development of a Request for Proposals.

Mitigation Strategy #10:	**Real-Time Hazard Map**
Strategic category:	Public Education and Awareness

Goal:

Determine the feasibility of developing a real-time, on-line map to communicate verified hazards /impacts from hazards across Dane County so residents have accurate and timely information to make decisions regarding their safety.

Objectives:

1. Identify parameters for hazards that can be communicated to the public in real time.
    a. *Responsible Party* – Dane County Land Information Office (DCLIO), Dane County Land and Water Resources (DCL&WR)
    b. *Funding source* – N/A
    c. *Completion date* – Spring 2022

2. Identify sources of real-time information including other Dane County departments.
    a. *Responsible Party* – DCLIO , DCL&WR, Dane County Emergency Management (DCEM)
    b. *Funding source* – N/A
    c. *Completion date* – Summer 2022

3. Develop methodology to collect, apply, and maintain accurate information that reflects condition across Dane County in real-time.
    a. *Responsible Party* – DCLIO, DCL&WR, DCEM
    b. *Funding source* – N/A
    c. *Completion date* – Fall 2022

Mitigation Strategy #11: **Reduce Potential for Sewer Back-Up**

Strategic category: Property Protection

Goal:

Improve sanitary sewer infrastructure to minimize sanitary sewer back-up into structures through the provision of back-up power capability at main district stations and sewer treatment plant.

Objectives:

1. Identify back-up power requirements and specifications for regional sanitary sewer facilities.
   a. *Responsible Party* – Madison Metro Sewerage District (MMSD), Dane County Land and Water Resources (DCL&WR)
   b. *Funding source* – Annual budget, grant funds to conduct engineering study
   c. *Completion date* – After generator sizing and site placement is determined.

2. Work with communities served by main district stations to identify both permitting requirements to provide improvements.
   a. *Responsible Party* – MMSD, DCL&WR, local governments.
   b. *Funding source* – N/A.
   c. *Completion date* – Winter 2023

3. Secure funding to facilitate system improvements.
   a. *Responsible Party* – MMSD, DCL&WR, local governments.
   b. *Funding source* – TBD
   c. *Completion date* – as funding becomes available.

Mitigation Strategy #12: Develop a Social & Environmental Justice Model

Strategic category: Prevention, Public Education and Awareness

Goal:

Develop a model to chart social and environmental justice data in relation to housing and income that can be utilized during and following a disaster to provide better insight into needs assessment and recovery efforts.

Objectives:

1. Identify data sources to support social justice inputs into the model such as the Federal Centers for Disease Control's Social Vulnerability Index.
   a. *Responsible Party* – DC Human Services (DCHS), DC Planning & Development (DCP&D), DC Officer for Equity & Inclusion (DCOEI)
   b. *Funding source* – N/A (expenses covered under existing budget allocation)
   c. *Completion date* – Summer 2022

2. Identify data sources to support environmental justice inputs into the model.
   a. *Responsible Party* – DCHS, DCP&D, DCOEI
   b. *Funding source* – N/A (expenses covered under existing budget allocation)
   c. *Completion date* – Summer 2022

3. Collect and model housing and income data from across Dane County on the census block level.
   a. *Responsible Party* – DCHS, DCP&D, DCOEI
   b. *Funding source* – N/A (expenses covered under existing budget allocation)
   c. *Completion date* – Summer 2022

4. Develop model that can demonstrate relationships and causalities between housing, income, social justice needs, and environmental justice needs.
   a. *Responsible Party* – DCHS, DCP&D, DCOEI
   b. *Funding source* – N/A (expenses covered under existing budget allocation)
   c. *Completion date* – Fall 2022

5. Identify methodology to apply modeling to emergency response and recovery activities.
   a. *Responsible Party* – DCHS, DCP&D, DCOEI
   b. *Funding source* – N/A (expenses covered under existing budget allocation)
   c. *Completion date* – Summer 2022

Mitigation Strategy #13:	**Water Quality Testing Capacity**
Strategic category:	Prevention

Goal:

Develop the ability to scale up water quality testing capacity in times of emergency.

Objectives:

1. Identify current capacity to test water quality samples under varying staffing, facility, and out-sourcing conditions.
    a. *Responsible Party* – PHMDC
    b. *Funding source* – N/A (expenses covered under existing budget allocation)
    c. *Completion date* – Summer 2022

2. Identify target capacity levels under varying conditions.
    a. *Responsible Party* – PHMDC
    b. *Funding source* – N/A (expenses covered under existing budget allocation)
    c. *Completion date* – Summer 2022

3. Determine methodology to expand local capacity to test water quality.
    a. *Responsible Party* – PHMDC
    b. *Funding source* – N/A (expenses covered under existing budget allocation)
    c. *Completion date* – Summer 2022

Mitigation Strategy #14: Update / Augment Flood Plain Information

Strategic category: Prevention, property protection

Goal:

Develop information and materials for municipalities and Dane County residents that includes lessons learned from climate change to better communicate flood risk by property location.

Objectives:

1. The Capital Area Regional Planning Commission (CARPC), Metropolitan Madison Planning Organization (MPO), and Dane County Department of Planning and Development (DCP&D), and Dane County Office of Energy and Climate Change (DCE&CC) meet to identify options for improving publicly available information.
    a. *Responsible Party* – Capital Area Regional Planning Commission (CARPC) will organize the meeting.
    b. *Funding source* – N/A
    c. *Completion date* – Spring 2022

2. Connect with FEMA's National Flood Insurance Program (NFIP) to identify process to update Flood Insurance Rate Maps (FIRMs).
    a. *Responsible Party* – CARPC & DCP&D
    b. *Funding source* – N/A
    c. *Completion date* – Summer 2022

5.4 Mitigation Alternatives

This contains background and reference information on mitigation strategies, and the common alternatives that could be used in Dane County. This section also contains additional reference material for the mitigation options to the various hazards in Dane County.

5.4.1 Residential Property Protection Measures

There are many things that residential property owners can do to protect their homes and buildings from the effects of natural hazards, from simple inspections and maintenance to fully integrating hazard resistance into the design of new construction. All of these options have benefits and limitations that have to be weighed against the risks and cost of the effort. The individual property owner would normally implement these protective measures, although, in many cases, government agencies can provide technical and financial assistance. Dane County's role in this process is as a facilitating and coordinating entity. The County can assist by establishing public-private partnerships, providing information to property owners, and applying for grants where appropriate.

Incorporating hazard-resistant features into a new home is typically easier and more cost effective than retrofitting an existing home. In general, the time to invest in a stronger, more resistant home is when it is being built. Other opportunities are during major remodeling projects or when repairing a previously damaged building. Central to the County's mitigation strategy is to use these "windows of opportunity" to encourage property owners to incorporate hazard mitigation measures into the design of new homes or the rebuilding or remodeling of existing homes.

Protecting Homes from Wind Damage

Of the natural hazards affecting Dane County, tornadoes and high winds have the greatest potential to cause major building damage. Winds usually cause damage to homes and other buildings in one of two ways. Damage typically occurs when structural or non-structural elements of the building cannot resist the forces of the wind or when flying debris impacts the building. Types of wind damage most typically encountered include:

- Roof covering and decking. Roof covering damage can occur anywhere along the surface of the roof where the shingles are not adequately fastened to the decking or where the decking is not adequately fastened to the roof trusses.
- Overhangs and porch roofs. High winds can exert extreme forces on the underside of an overhanging roof. In general, overhanging roofs are not designed to handle these forces and fail due to uplift. These failures typically occur when the roof overhang is unsupported or when the porch columns are not adequately connected to the roof beams and anchored to the deck.

- Gable end roofs. Gable end roofs are those with two sloped roof surfaces and a vertical wall at each end. Gable end roofs are usually supported by a series of parallel roof trusses or parallel rafters. Gable end roof failures typically occur at the end walls where the trusses do not have enough support to keep them from blowing inward or being sucked outward from the building.
- Roof frame connections to walls. Tornadoes or high straight-line winds can and often do completely blow off the entire roof of buildings. This occurs because of an inadequate connection of the roof framing to the exterior load-bearing walls. In many cases where roofs are entirely blown off, the roof frame was connected to the walls by "toe-nails." Toe nailing alone is not sufficient to withstand the up-lifting force of a high wind event.
- Wall frame connection to the foundation. Wall frames typically connected to the foundation at the bottom stud of the wall frame, which is connected to the sill plate and then to the foundation wall or concrete slab. Failures can occur where the wall frame is connected to the sill plate by toe-nails. Failures can also occur if the sill plate is not adequately bolted to the foundation or slab.
- Garages. Garage doors are another weak point in a typical building design. Garage doors can be damaged when the force of the wind blows the door inward or when the tracks supporting the door fail. Failure of the garage door can lead to an increased wind pressure inside the garage, resulting in severe damage or destruction of the garage itself and to the building it is attached to.
- Windows. Windows are typically damaged by high wind pressure or impact by wind-borne debris.
- Siding. Siding can be damaged by wind-borne debris or it can fail where it is not adequately connected to the walls. Siding failure usually occurs at a corner or edge where wind pressures can take hold and peel off the panels.

Mitigation measures to address these problems focus on the concept of a "continuous load path." A load path is a series of structural components and connections that resists any type of force on the building. A continuous load path is one that transfers the forces or loads from structural component to structural component until they are transferred to the ground. If the load path remains continuous while the load is applied, no structural damage will occur. If there is a break in the load path, damage will occur. The connections between the structural components are typically the weakest link in the path and are where most failures occur. Wind hazard mitigation measures, therefore, are likely to be most effective when focused on reinforcing the connections between the structural components of the building.

Structural mitigation measures for wind hazards include:

- Secure roof sheathing to trusses using screws and properly secure shingles.
- Increase the strength of the roof to wall connections by using mechanical fasteners or "hurricane clips" to anchor the roof trusses to the load-bearing walls.
- Increase the strength of the roof to wall connections by extending the wall sheathing to the top plate and nailing the sheathing to the top plate and wall studs.

- Brace the roof framing of gable end roofs.
- Increase the strength of the foundation to wall connections by using mechanical fasteners to connect the wall framing to the sill plate and the sill plate to the foundation.
- Increase the strength of the foundation to wall connections by extending the wall sheathing to the sill plate and nailing the sheathing to both the wall studs and the sill plate.
- Anchor overhanging and porch roofs to the building with mechanical fasteners, connecting the roof truss to the columns and the columns to the floor deck or foundation.
- Replace or reinforce garage doors.

These measures are intended to strengthen residential buildings to resist the high winds associated with severe thunderstorms and the periphery of tornadoes. These measures, even if properly implemented, will not make a building capable of withstanding a direct hit from a tornado. A homeowner with basic construction skills can implement some of these techniques. Others require the expertise of skilled tradesmen, architects, and structural engineers. Furthermore, it is essential that the local building inspector approves all mitigation measures and that they be in compliance with building codes and ordinances.

Protecting Homes from Flooding

Actions and strategies for the Hazard Mitigation Plan have been continually evaluated and revised through public and professional input. Some of the variables that shaped the development and refinement of the goals and objectives were: implementation feasibility, citizen priorities and input, role of the County in the plan, political acceptability, grant requirements, scope of the plan, and current data about hydrologic systems. This section describes alternative actions that were considered in the process of refining final recommendations. The most effective elements within the alternatives were carried forth based upon the analysis of the action within the framework of the aforementioned variables.

- *Building Acquisition and/or Relocation*. Removing a home from a high-risk area is the surest way to protect it from flooding. In areas subject to flash flooding or deep floodwaters, removing homes from harms way is far and away the safest approach. There are two ways that this can be done; the homeowner can relocate the home to a more appropriate location or the home can be acquired by the local government and demolished. In either case, provisions should be made for the property to revert to open space or some other use that will not be harmed when flooding occurs. Building acquisition can be an expensive option and may not be attractive to local governments or homeowners. However, removing structures from floodplains is a high priority of several federal and state programs and funding assistance is available. Public interest in these programs is likely to increase when flooding is occurring or in the immediate aftermath of a significant flood.
- *Building Elevation*. Raising a home above flood level is the next best protective measure when removal is not an option. When a building has been elevated, water flows under the building, causing little or no damage to the building or its contents. Raising buildings above flood level can be a complicated and expensive process, however it is often cheaper than acquisition and is less

disruptive to the neighborhood. This may be a viable option for property owners who are unwilling to relocate. Many federal and state programs can also be applied to building elevation projects.

- *Flood Barriers*. Flood barriers can be built around homes or neighborhoods to keep floodwaters from reaching the buildings. Barriers built of soil are called berms. Barriers built of concrete or steel are called floodwalls. Barriers are a less secure flood protection measure than building elevation because the protected homes may be effectively below the level of the floodwater. Also, when floodwaters are present for more than a few hours, water will seep under the barrier. Pumps are needed to handle seepage and leaks. Barriers must be placed so that they do not create flooding or drainage problems on neighboring properties and they cannot be constructed in the floodway. State and federal programs may be available to offset some of the costs of building barriers, but this type of project is not a priority in those programs.
- *Floodproofing*. There are several different techniques available for floodproofing buildings. Dry floodproofing refers to any one of several methods of sealing a building to ensure that floodwater cannot get inside. Wet floodproofing means letting the water in and removing everything that could be damaged by the water.
    - *Dry floodproofing* is appropriate only for homes on a concrete slab with no basement. All areas below the flood level are made watertight. Walls are coated with waterproofing compounds or plastic sheeting and windows and doors are closed and sealed permanently or with removable shields or sandbags.
    - *Wet floodproofing* is an effective means of protecting belongings and mechanical equipment located in the basement. It is really nothing more than moving things in the basement to an elevation where they will not be damaged. Structural components below the flood level are replaced with materials that are not subject to water damage. For example, concrete block walls can be used instead of wood studs and gypsum drywall. The furnace, water heater, and laundry are permanently moved to a higher floor. Where the flooding is not deep, these appliances can be raised on blocks or platforms. Light, moveable items that are stored in the basement can be moved if there is enough warning time. Wet floodproofing is one of the least expensive options available to a homeowner. Significant damages can be prevented simply by moving furniture and mechanical equipment out of the basement.
- *Sewer Back-flow Prevention*. Cross connections between the sanitary and storm sewers and infiltration and inflow can overload the sanitary sewers during a storm. Buildings that have downspouts, footing drain tile, and/or a sump pump connected to the sanitary sewer service may be flooded inside during heavy local rains and may be contributing to sanitary sewer back-up problems at other buildings. These cross connections should be disconnected. Rainwater and surface water should be directed out onto the ground where it will flow away from the building.

  A number of other approaches may be used to protect a structure against sewer backup. These approaches should receive increased emphasis for all buildings that have experienced previous sewer back-up problems.

    - Floor drain plugs

  - Floor drain stand-pipes
  - Overhead sewers
  - Backflow protection valves
  - Sanitary sewer pumps for below grade building areas (basements)

- *Warning Systems*. Advance warning of flood conditions is essential for an effective response. A warning system has three basic components, threat detection, communications links, and emergency management. In an effective warning system, no one of these components is any more or less important than any other; they must be integrated into one system. Threats must be detected, that information must be communicated to those who must assess it and decisions must be made on how best to manage the situation.

  There are areas on small rivers in the County that are subject to flash flood or near flash flood conditions. These areas have no specialized flood warning system in place. On larger rivers, this service is provided by the National Weather Service in conjunction with USGS monitoring stations. On smaller rivers, such as Black Earth Creek and its tributaries, locally established rainfall and river gages are needed to establish a flood threat recognition system. In the absence of a gaging system on small streams, the best threat recognition system is to have local personnel monitor rainfall and stream conditions. While specific flood crests and times will not be predicted, this approach will provide advance notice of potential local or flash flooding. Communications links and flood management procedures must also be established.

- *Flood Insurance*. Flood Insurance has the advantage that, as long as the policy is in force, the property is protected and no human intervention is needed for the measure to work. Although most homeowners' insurance policies do not cover a property for flood damage, an owner can insure a building for damage by surface flooding through the National Flood Insurance Program (NFIP).

  Flood insurance is required for properties with federally-backed mortgages that are in a regional floodplain, as shown on the adopted Flood Insurance Rate Map (FIRM). Flood insurance ins optional for properties that are in moderate- or low-risk areas as shown on the adopted FIRM. Historically, flood damage has occurred throughout Dane County, not just in the mapped floodplains. Homeowners may wish to carry flood insurance even if their property is not in a high-risk area on the FIRM. Typically, insurance premiums in low-risk or moderate-risk areas are steeply discounted.

  Flood insurance coverage is provided for insurable buildings and their contents damaged by a "general condition of surface flooding" in the area. Building coverage is for the structure. This includes all things that typically stay with the building when it changes ownership, including:

  - Utility equipment, such as a furnace or water heater
  - Wall-to-wall carpeting
  - Built-in appliances

  - Wallpaper and paneling

  Contents coverage is also for the removable items inside an insurable building. A renter can take out a policy with contents coverage, even if there is no structural coverage.

  Flood insurance is available through the NFIP if a local unit of government is in good standing with the program. Dane County, representing the unincorporated areas of the County, is currently participating and is in good standing with the program.

- *Response Planning*. There are a great number of actions that communities can take to reduce damages when flooding occurs, but these efforts must be coordinated and well planned to be effective.

  Typical components of a flood response plan include:

  - Activating an emergency operations center
  - Closing streets or bridges
  - Shutting off power to threatened areas
  - Filling and placing sandbags or other flood barriers
  - Monitoring water levels
  - Providing security and other protection measures
  - Assisting cleanup and recovery
  - Providing information to the public

  An emergency action plan ensures that all bases are covered and that the response activities are appropriate for the expected threat. These plans should be developed in coordination with the agencies or offices that are given various responsibilities.

  Emergency response plans should be updated annually to keep contact names and telephone numbers current and to make sure that supplies and equipment that will be needed are still available. They should be critiqued and revised after disasters and exercises to take advantage of the lessons learned and changing conditions. The end result is a coordinated effort implemented by people who have experience working together so that available resources will be used in the most efficient manner.

  Finally, individual citizens also have a role to play in responding to flooding and protecting their property. In order to do this, people need a straightforward way to get response information and guidance and request assistance if needed. Open lines of communication are needed between the County, local units of government, and individual citizens. In past flood events, communications processes did exist, but they were often ad hoc, not well publicized, and cumbersome to users.

These lines of communication should be two-way. Devising effective solutions to flooding requires an understanding of the constantly changing flooding conditions in the County. Providing better avenues for communication will allow the County and local governments to respond quickly to flooding, and over time, understand more completely the flooding patterns in the County and how they are evolving over time. Citizens are a valuable source for this information. Analysis of the information gathered during flood events could be used to prevent future damages and to inform citizens of the types of flooding problems in their vicinity, with a forecast of approximate future risk coupled with specific recommendations to decrease their risk.

Protecting Homes from Hail Damage

The roof of a home is typically the area that is most vulnerable to hail damage. When large hail occurs, it can shred shingles and lead to water damage inside the home. Hail damage to roof materials can be mitigated through the selection and use of impact resistant materials. This is a cost effective measure only in new construction or when re-roofing an existing building.

The Underwriters Laboratory (UL) rates roofing materials for impact resistance under the 2218 standard. The standard provides a classification rating from Class 1 being the least resistant to damage and Class 4 having the highest resistance. The Institute for Business and Home Safety (IBHS) recommends use of Class 3 or Class 4 impact resistant materials to protect against hail damage.

Lightning Protection

Electrical surges from lightning can damage or destroy household electronic devices. Appliances and electronic equipment such as computers, TV's, VCR's, and DVD players are especially vulnerable. Power surges can enter the home through a number of different paths, including the cable TV or satellite dish cable, the incoming telephone lines, or the incoming electrical service line. Lightning and electrical surges can also cause a shock hazard or fire hazard if protective steps are not taken.

Surge protection devices can prevent the damages from most power surges. There are two basic types:

- Service entrance surge protection devices which are mounted at or near the incoming electrical service box and protect from surges coming through the incoming electrical power line, incoming telephone line, and cable TV or satellite dish cable.
- Point-of-use surge protection devices, which are used to directly protect specific appliances and include the types that plug into a wall outlet (computer power strips). These should be used to protect expensive electronics such as computers, TV's and stereos.

These measures will protect from most in-coming power surges. There is, however, no device that will protect against all power surges. A direct lightning strike to the home's electrical system will very likely be too great for the surge protector to handle.

When building a new home or remodeling, properly organizing the electrical circuits can reduce the exposure of power surges to sensitive equipment. Circuits intended for use by sensitive electronic should be isolated from those used for powering large appliances. When remodeling, it is also important to upgrade the electrical system to assure that the overall system and all outlets are properly grounded. Plug-in type surge protectors will not work if the outlet is not properly grounded. Surge protectors at the service entrance will not work if the overall system is not properly grounded.

Protecting Manufactured Homes

Manufactured homes are relatively lightweight compared to conventional residential construction and often have flat sides and ends, making them particularly vulnerable to high winds. However, there are steps that can be taken to protect property and people.

- Tie-downs and anchors. Manufactured homes are not usually installed with permanent foundations, but instead sit on short piers. Wind can get under a manufactured home and lift it up. In addition, winds passing over the top of the home can also create an uplift force. Tie-downs and anchors are needed to resist these forces. Tie-downs are straps or cables that are either secured to the building's steel frame or are placed over the top of the building and secured at either end. Some types of manufactured home use both methods to secure the building. Ground anchors are plates or augers imbedded in the soil to which the tie-down cables are secured. Properly applied, these systems are a cost-effective way to limit structural failure.
- Storm shelters. Even though a manufactured home may be well anchored, residents should have shelter available to protect them from severe thunderstorm winds and tornadoes. Accessible community shelters should be available in manufactured home communities (mobile home parks). Residents of isolated manufactured homes not located in developments should consider investing in a smaller, personal storm shelter. Storm shelters are available commercially or they can by custom designed and built on-site. FEMA's published standards and performance criteria provide guidance for selecting or designing a shelter.

5.4.2 Commercial Property Protection Measures

According to the Institute for Business and Home Safety, at least one-fourth of all businesses that close because of a disaster never reopen. Small businesses are especially vulnerable, because few of them have the resources or knowledge to assess disaster risks and develop comprehensive mitigation and recovery plans. Business losses can come in many forms, from direct physical losses and building damage to loss of vital records and computer files to indirect losses due to the unavailability of vital supplies.

As with residential properties, there are many things that business owners can do to protect their business investment, employees, and customers from the impacts of a disaster. Many of the hazard mitigation concepts described for residential properties also apply to commercial structures. There are differences in some cases, however due to the relative size and construction methods of commercial buildings and facilities.

Protecting Commercial Buildings from Wind

The concepts of wind resistance and structural mitigation described for protecting homes from wind damage also generally apply to business facilities. Commercial buildings, however, are usually built using different construction methods from residential buildings. FEMA provides the following recommendations for strengthening commercial buildings:

- *When re-roofing*, assure that contractors adhere to the Factory Mutual Research Corporation's FM 4470 Class 1 performance standard for commercial roofs. This standard includes performance tests for impact resistance, wind uplift, fire, water leakage, weathering, and corrosion.
- *Reinforce double entry doors*. Many commercial buildings are equipped with double entry doors. These are convenient because they span a wider opening than a single door, but they are usually not as strong as a single door and are therefore susceptible to wind damage.
- *Secure metal siding and metal roofing*. The metal roofing and siding of pole barn type buildings are vulnerable to damage either when wind pulls of panels due to weak fasteners or when windborne debris punctures the panel.
- *Secure built-up and single-ply roofs*. Built-up and single-ply roofs are common on commercial buildings. Built-up roofs consist of multiple layers of felt and asphalt; single-ply roofs consist of one waterproof membrane. These roofs are often damaged when high winds tear away the metal edge flashing or coping around the perimeter of the roof. Once the flashing or coping is gone, the wind can peel back the roofing material and expose the interior of the building to the elements.
- *Avoid aggregate ballast roof coverings*. This roof type is most vulnerable to wind damage and the ballast materials can become windborne, further damaging nearby structures. To mitigate the vulnerability of displaced ballast, the roof can be covered with a membrane that secures all of the ballast to the roof.
- *Maintain EIFS Walls*. For buildings with Exterior Insulation Finishing System (EIFS) walls, a type of wall often used for commercial buildings, one example of wind protection is inspecting and maintaining the walls. An EIFS wall typically consists of several layers of materials sandwiched together into a single panel, which is attached to a substrate mounted on the wall studs. The exterior of an EIFS wall is water-resistant, but the wall can be weakened by moisture that becomes trapped behind the wall. The source of this moisture is usually leaks around doors and windows and where the wall joins the roof. Once an EIFS wall has been weakened in this way, it is more likely to be torn off or penetrated by high winds and windborne debris. If wind enters a building, the likelihood of severe structural damage increases, and the contents of the building will be exposed to the elements.

- *Reinforce Concrete Masonry Unit (CMU) walls*. Concrete masonry unit load bearing walls (CMU) are a common construction type in commercial buildings that are only a few stories high. The structures may be constructed without reinforcing steel, or with reinforcing steel within the walls. Most buildings constructed with CMU exterior walls prior to the 1980s are not likely to have reinforcing in the walls. Similarly, many buildings constructed after the 1980s may have only horizontal joint reinforcing, with no vertical reinforcing placed within the cells of the CMU. As a result, a continuous load path does not exist in these buildings and they are vulnerable to damage from strong winds capable of exerting lateral and uplift forces on the buildings. Typical failures are due to wind forces that push the wall into the building, pull the CMU wall out of the building, or pull the wall apart along the mortar joints. If the weight of the building and roof system is not adequate to resist the wind forces, the CMU block walls fail along their joints and fall apart. This leads to the progressive collapse of roofs, adjacent walls, and other building elements. Additionally, the connections between the roof system and the supporting walls are often incapable of resisting uplift forces.
- *Reinforce brick masonry walls*. Brick masonry buildings are typically constructed without reinforcing steel in the walls and have un-reinforced brick masonry walls along the perimeter of the building. Roof and floor systems either span from exterior wall to exterior wall, or are supported by interior load bearing wood frame walls. Typical brick wall failures are very similar to CMU wall failures and damages tend be similar.
- *Secure roof mounted mechanical units and vents*. Roof top equipment units can be either damaged in place by windborne debris or were dislodged from their anchorages (if any) by wind forces. Although it is not practical to protect these units from damage associated with windborne debris, it is practical to design and anchor the units to resist wind forces. Damaged roof top mechanical units are a hazard during high wind events for several reasons. First, when mechanical units are displaced, an opening on the roof is created, which exposes the building interior to wind forces, windborne debris, and rain. Second, displaced units can damage the roof covering and/or the roof deck. Finally, if units are completely removed from their roof location, they may fall and injure individuals adjacent the building.

It is important to note that these measures are intended to strengthen commercial and public buildings to resist high winds associated with thunderstorms, downbursts, and the straight-line winds that are on the periphery of a tornado. The measures are presented as guidelines for mitigation or as examples of successful mitigation. Commercial design and construction requires the involvement of a design professional, such as an architect and/or a structural engineer, and thus these mitigation strategies are intended to guide the design professional and they are not intended to dictate or imply that there is only one acceptable solution. These mitigation measures, if implemented, will help a building resist high winds, but additional mitigation is required if the building is meant to function as a storm shelter capable of preventing loss of life.

Furthermore, it is of utmost importance that the local building inspector approves all mitigation measures.

Backup Electrical Power

Many of the critical facilities and much of essential infrastructure identified in the vulnerability assessment are commercial operations. In many cases, the primary concern is not necessarily storm damage to the facility itself, but rather loss of the essential function and community services provided by the facility. As has been stated, power outages following natural hazard events are common and can last for days or even weeks. As a result, even businesses and other critical facilities that are not severely damaged can suffer losses because of the interruption in the power supply. Organizations that install backup or emergency power sources can minimize these losses. Essential operations in this setting include:

- Heating, ventilation, and air conditioning systems.
- Industrial equipment and major appliances such as freezers and refrigerators.
- Lights, computers, and office equipment.
- Pumps including sump pumps, sprinkler system pumps, well water pumps.
- Alarm systems.
- Pumping systems at public utilities such as wastewater lift stations and water wells.
- Water supply and milking operations on dairy farms.

The same basic concepts apply to both residential and commercial applications, with the main distinction being the scale and increased generation capacity of the system.

Electric Power Utilities

Many power outages occur because of damage or downed power lines. Burying power lines is one way to reduce the number of power outages in the County. Utilities do bury lines for new development, though there still remain many overhead power lines. There are many issues that have to be addressed, both for the utility company and for the local customers for burying power lines to be a cost effective option.

Business Recovery Planning

Developing a business recovery plan is one of the most important actions a business owner can take to minimize disruption. Business recovery planning is often thought of in terms of information technology and backup, off-site storage, and recovery of critical computer data. A comprehensive business recovery plan, however, is much more than that. Business recovery planning is a process that should be integrated into the overall business plans of the organization. There are many different ways to approach business recovery planning, but a basic plan should include at least the following elements:

- *Risk assessment*. An assessment of the potential risks to the business that could result from disasters or emergency situations is the basis of the planning effort. It is necessary to consider all the possible incidents and the impact each may have on the organization's ability to continue to deliver its normal business services.
- *Emergency preparations*. Many organizations have a wide range of existing procedures for dealing with various types of unusual situations. The plan should contain a brief summary of each of the procedures that are already in place, including the issues that are relevant in the event of handling an emergency disaster situation. These would probably include: IT data protection, security, and recovery procedures, property security, emergency contact information, emergency evacuation and sheltering procedures, fire regulations and procedures, and other health and safety considerations.
- *Backup strategies*. The plan should identify the back-up and preventive strategies that would be appropriate for each aspect of the business activities. This section should include: IT systems and data, personnel, critical vendors and suppliers, and documents and vital records.
- *Emergency response*. The plan should identify actions that will be taken to interface with public sector emergency services, assess and report damages, assess potential business impacts.
- *Business recovery actions*. The business recovery actions involve the restoration of normal business operations after an emergency or disaster. The efficiency and effectiveness of the procedures contained within this section could have a direct bearing on the organization's ability to survive the emergency. Considerations include: power and utilities, buildings and facilities, communications systems, IT systems, production and other equipment, warehouse stock, sales and customer service, and human resources.

5.4.3 Stormwater Management Strategies

While they are closely related, stormwater management and flood management are not the same. Flood management means dealing with or preventing the problems presented when streamflows exceed stream capacities and floodwaters move out of the stream channel and lake banks due to excessive volume. Stormwater management deals with the ability of stormwater runoff to reach the stream channels of the watershed without local ponding and street, yard, and basement flooding due to increased flow rate.

To prevent exacerbating flood problems, stormwater management systems must be coordinated within the watershed. This is important because the flood elevations along the major stream channels will determine the configuration, sizing, and performance of the local drainage systems. Coordination is needed to reduce the cumulative downstream impacts of numerous drainage systems.

On the community level, the combination of new stormwater control standards for new developments and actions by individual property owners can transform stormwater from a hazard to a resource. Options for individual property owners include:

- *Rain gardens*. Rain gardens are shallow depressions (3-4 inches to two feet) planted with native wildflowers and other plants that soak up rainwater or melted snow from your rooftop, driveway and lawn. The gardens allow water to infiltrate into the soil rather than becoming runoff. A rain garden can soak up to 30% more water than a traditional lawn. This helps to protect the quality of water downstream by preventing runoff from getting to the storm drains and helps reduce the chances for local flooding.
- *Cisterns and rain barrels*. Another option is to collect roof runoff by directing the roof downspout to a cistern or rain barrel. Cisterns and rain barrels are intended to collect and store rainwater rather than channeling it to nearby rivers and streams. Cisterns are typically large storage tanks. Rain barrels are smaller, designed to collect water from a residential roof and can often be installed by individual homeowners. Rainwater collected in these containers can be later used to water lawns and gardens, flush toilets, or wash cars. The collected water can also be released slowly for infiltration between rains.

Commercial Stormwater Management Strategies

Water quality concerns have intensified, and stormwater management practices have come under scrutiny, as development occurs on an increasing percentage of the available land area in the County. With more stringent design requirements, costs for traditional conveyance systems have risen sharply. Due to their size and scale, many new commercial construction projects are subject to the County's Erosion Control and stormwater Management Ordinance. The Dane County Land and water Resources Department maintains the Dane County Erosion Control and Stormwater Practices Manual, to assist landowners, developers, and consultants to meet the requirements of the ordinance. The manual is available on line.

As a mitigation strategy, stormwater management practices that allow natural infiltration to occur as close as possible to the original area of rainfall are preferable to traditional conveyance systems. By engineering terrain, vegetation, and soil features to perform this function, costly conveyance systems can be avoided, and the landscape can retain more of its natural hydrological function. There are a variety of methods for handling runoff in order to reduce the volume of runoff and decentralize water flows. This is usually best accomplished by creating a series of smaller retention or detention areas that allow localized filtration rather than carrying runoff to a remote collection area. In addition to cisterns and rain gardens described previously, some common structural and non-structural methods that may be applied to commercial developments include:

- *Grass swales*. Grass swales can provide an alternative to curb and gutter systems by using grasses or other vegetation to reduce runoff velocity and allow filtration, while high volume flows are channeled away safely. In areas where salts are commonly used for winter de-icing, careful attention must be paid to selecting plant species which are salt tolerant.
- *Filter strips*. Filter strips can be incorporated within parking lots or other areas to collect flow from large impervious surfaces. They may direct water into vegetated detention areas or sand filters that capture pollutants and gradually discharge water over a period of time.

- *Disconnected impervious areas*. Disconnected impervious areas direct water flows from structures, driveways, or street sections, into separate localized detention cells rather than combining them in drainpipes with other runoff. Disconnecting the flow limits the velocity and overall amount of conveyed water that must be handled by end-of-pipe facilities.
- *Rooftop gardens*. Rooftop gardens or green roofs can provide a service similar to rain gardens, absorbing rainwater rather than directing it to the traditional stormwater infrastructure. Green roofs allow the cultivation of plants over much of a roof surface. This coverage, and the numerous underlying layers needed to sustain the plants and protect the building, shields the underlying roof structure from the elements. In most cases, considerable strengthening and modification to the underlying roof is needed in order to support the soil medium and plants.

Not all sites can effectively utilize these options. Soil permeability, slope, and water table characteristics may limit the potential for local infiltration. Also, in urban areas, and areas with existing high contaminant levels, use of infiltration techniques may be not be appropriate. When considering use of the alternatives it is important to keep in mind that they often require more precise engineering for soil characteristics, filtration rates, water tables, native vegetation, and other site features than do traditional stormwater management techniques. Participation of environmental consultants and planners is critical from the beginning of the project.

5.4.4 Flood Impact on Roads

Flood impact on roadways is a common problem in Dane County. Forty percent of sites reported by survey respondents indicated that flooding in their jurisdiction included flooding of roadways. Following Presidential disaster declarations for flooding, a high percentage of Public Assistance funding made available to local jurisdictions was for repair and rebuilding of flood-damaged roads.

There are two primary impacts associated with town road and County highway flooding. Repairing washed out roads costs local governments money. And flooded roads present a hazard to public safety. Water over roads is dangerous to motorists and if it is deep enough can cause areas to become isolated and inaccessible to emergency response vehicles.

Problems with roads are just one symptom of a systematic problem. In some cases, elevating a road to protect it from flooding can cause water to dam up behind it, exacerbating the upstream problem. In other cases, installing larger culverts can cause increased flow, which if unmitigated, can exacerbate downstream problems. Other contributing factors to these problems include the lack of systematic ditch maintenance policies and funding, roads located in low lying or inherently wet areas, improperly sized culverts, and inconsistent coordination with planners and developers when designing water conveyance structures across or next to rural roads. Mitigation strategies include:

- Reduce the flow of floodwaters over roads by evaluating road elevation and culvert sizing standards for construction and upgrade for all County roads, but especially for roads in low lying or flood prone areas.

- Develop road shoulder, ditch, and bridge maintenance and upgrade standards to prevent floodwater and stormwater from damaging or washing-out roads and making them impassible.
- Formalize a process for considering water flow along and under roadways as one component of the overall water conveyance system.

5.4.5 Other Water Management Strategies

Integral the County's water management and flood management strategy is the idea that the County and local jurisdictions should take any action possible to "minimize the potential for increasing flooding and flood-related problems within Dane County and in areas affected by Dane County drainage." This goal was identified in the initial version of the County's Flood Mitigation Plan (2004). While the flood mitigation plan has been incorporated into this, more broad "all-hazards" plan, this goal remains a guiding principle.

Many aspects of flooding and flood management are interconnected and cannot be addressed as though they exist in a vacuum. There are links with groundwater issues, water quality issues, habitat protection, land use, economic development, recreational use, disaster preparedness, and stormwater management. Flood management has to be considered as an integral component of the County's approach to living with and cooperating with its environment. This would keep flood losses to a minimum and maintain our water resources for generations to come.

The County should better integrate flood management and overall water management considerations into the land use and development plans. Comprehensive plans should consider the entire watershed and address multiple community issues and concerns. Included in this effort should be the development and adoption of better methods of quantifying the economic benefits of natural and cultural resources.

- *Land Conservation*. Keeping the floodplain open and free from development is the best approach to preventing flood damage. Preserving open space is beneficial to the public in many ways. Preserving floodplains, wetlands, and natural water storage areas helps maintain the existing stormwater storage capacities of an area. These sites can also serve as recreational areas, greenway corridors, provide habitat for local flora and fauna, and protect water quality.

  Open space preservation should not be limited to floodplains, as some upland areas within a watershed may be key to limiting runoff that will worsen flooding problems in adjacent or downstream lowlands. A significant increase in runoff from surrounding uplands will raise the base flood elevation and enlarge the floodplain boundary. Therefore, the amount of land maintained as open space will directly affect the level of flood hazard.
- *Maintenance of Conveyance Channels*. By modifying channel conveyance, more water is carried away at a faster rate. Modifications generally include making a channel wider, deeper, smoother or straighter. Siltation and debris in streams and ditches was cited as a significant problem in the flood mitigation plan survey. Options available include:
  - Dredging to remove silt and other debris.

- Stream straightening or widening.
- Constructing diversion channels that send floodwaters to a different location.
- Cleaning out streams to remove debris such as undesirable vegetation, garbage and downed trees.

Each of these options has advantages and disadvantages that have to be weighed against the flood risk and the impact on the environment. Because modifications of this kind convey water faster to other locations, they are appropriate only for small local problems where the receiving stream or river has sufficient capacity to handle the additional volume and flow of water.

To minimize the downstream impacts, channel modifications should be utilized in conjunction with a range of other techniques, recognizing the function of the entire system. A combination of restored wetland detention, vegetated swales, infiltration trenches and management practices that increase infiltration (reducing runoff), and improve water quality can be implemented in conjunction with stormwater system improvements. These types of projects can have multiple benefits

- *Project and Program Coordination*. In any planning process, boundaries have to be drawn to define the scope of the effort. Conceivably, planning for flood management and stormwater management could be based on areas defined by new subdivisions, governmental jurisdictions, or watersheds. There are important reasons for watershed level planning where possible:
    - A watershed is a natural description of the area of land that drains into a lake, stream, or other body of water. The term describes an interconnected system of water conveyance. Municipal borders or other political jurisdictions may coincide with some of these natural features, but their boundaries are artificial. The flow of water does not respect these boundaries.
    - Flood management and stormwater management should form a single integrated system over the entire watershed. The streams and waterways of a watershed must be capable of carrying present and future runoff loads generated by all of the existing and future planned development patterns within the watershed. Development patterns and land use are not controlled by watershed factors, but can and do have major effects on watershed problems. Land use changes and water management practices upstream can have significant impacts on downstream areas. In many cases part of the solution to a downstream problem may be found in changes to the way water is managed upstream.
    - Many "Friends" or constituency groups or other associations are organized on a watershed basis. There is a potential to partner on projects with these groups if the effort is designed to benefit the entire watershed.

The County is uniquely situated to coordinate and facilitate projects on a watershed level. In fact, facilitating multi-jurisdictional efforts was identified in the public input process as one of the primary roles of the County. Many of the ideas expressed in other recommendations of this plan assume the role of the County as a facilitating agent. This policy makes that assumption explicit.

There are two distinct components identified in this plan, inter-departmental coordination, inter-governmental coordination.

- Inter-Departmental Coordination. The purpose of inter-departmental coordination is to tap into the experience and expertise of professionals in multiple departments in order to avoid redundancy of effort and capitalize on on-going efforts.
- Inter-Governmental Coordination. Through the planning process it became clear that multi-jurisdictional flooding problems are pervasive throughout the County. Flooding does not respect municipal boundaries and many of the most severe flooding problems are cross-boundary ones. The purpose of this coordination is to address these problems as specific projects.

Though the County has limited authority in cities and villages, their participation in the plan is crucial to its success. Furthermore, the Hazard Mitigation Planning Team is in a position to facilitate coordination activates between units of government, including funding for projects. This plan offers the opportunity for all units of government to engage in the plan by their designing specific multi-jurisdictional projects that are consistent with the recommendations of the Plan. Coordination at the project level will help Dane County avoid the site specific, individualized actions that have been marginally successful in the past. Additionally, by combining projects under the auspices of a single plan, projects may be able to obtain funding without having to compete against other municipalities within the County. Involving different levels of government also allows for the pooling of resources, thereby increasing the chance of project completion and success.

5.4.6 Urban Heat Island Mitigation

The implementation of green roofs and parking lots is a cost-effective way to manage increased temperatures in urban areas known as the Urban Heat Island effect. By constructing these projects in high-impact areas or incentivizing their construction through grants to municipalities, Dane County can build long-term resilience to climate change. (County-Level Emission Reduction and Adaptation Policy Alternatives, 2017.)

By painting roofs white, incentivizing rooftop gardens, or installing green parking lots, ambient air temperatures can be reduced by two to four degrees, which reduces heat-induced mortality. Maintaining urban tree canopies can also be an effective means of mitigating the urban heat island effect.

5.4.7 Information and Education

Effective hazards management can only be achieved if people are well educated on the issues and how they are related. Members of the public, political leaders, professionals, developers, etc. have to understand the implications of the decisions they are making. Good decision-making implies that people have good, accurate information on which to base those decisions.

5.5 Sample so Success

Dane County and the local jurisdictions within the County have a long history of taking action to reduce vulnerabilities to natural hazards and adapt to changing conditions. The following is a list of some of those accomplishments. This is only a snapshot and is by no means a complete list.

- Dane County, in partnership with all 61 local jurisdictions has distributed over 18,000 NOAA All-hazard radios to jurisdictions at cost.
- Dane County has established a pilot buyout program for repetitive flood loss properties.
- The Village of Oregon completed a buyout of 7 homes that had repetitive flooding, utilizing FEMA and CDGB funds.
- The City of Monona received FEMA grant to install a stormwater pumping system.
- The City of Monona received FEMA funding to do a detailed flood risk assessment of the Belle Isle area.
- The County created a comprehensive website developed to provide private property owners and local government with information on flood hazard mitigation.
- The County worked with the National Weather Service to install an automated gage at Black Earth Creek at Mazomanie.
- The Town of Dunn built a tornado shelter in Bayview Heights, a manufactured home development.
- The City of Madison built a tornado shelter in Highland Manor, a manufactured home development.
- Flood mitigation and flood risk reduction objectives were included in the most recent update of the County's Comprehensive Plan.
- The Town of Roxbury improved and raised a number of flood prone roads near Fish Lake and Crystal Lake.
- Numerous flood prone homes were elevated in the Town of Albion along Lake Koshkonong
- The County acquired a number of flood prone homes in the Town of Roxbury along Fish Lake and Rice Lake in the Town of Albion.
- The County and Wisconsin DNR organized two iterations of the Yahara Lakes Advisory Group to make recommendations on management strategies.
- The Land and Water Resources Department developed the Yahara INFOS system to model and better manage the Yahara River and Chain of Lakes as an integrated system.

- The Madison Metropolitan Sewerage district organized the Yahara WINs system in an effort to reduce phosphorus and improve water quality.
- This City of Monona received grant funding to elevate a number of homes in the Belle Isle area.
- The Town of Vienna received grant funds and implemented a project to improve drainage and reduce flood impact to Town and County roads.
- Dane County received grant funds and implemented a project to improve grounding and lightning protection on outdoor warning sirens.
- The City of Sun Prairie received grant funds and implemented a project to install sanitary sewer backflow prevention devices.
- The Village of DeForest received grant funds and implemented a project to update sanitary sewer systems and install storm water detention ponds.
- The Hamlet of Morrisonville received grant funds to update sanitary sewer infrastructure to alleviate long standing sewer backflow problems.
- Dane County routinely purchases land for conservation purposes that are consistent with the flood mitigation objectives in this plan. Most recently this includes 130 acres along the Yahara River in the Town of Westport, north of Madison.
- Dane County captures natural gas emissions from its landfill. The captured bio-natural gas is in turn used to power compressed natural gas vehicles and used to produce enough renewable electricity to power 4,000 homes.
- The County created the Office of Climate Energy and Climate Change and the Dane County Council on Climate Change.
- Dane County owns the two largest municipal solar arrays in the State of Wisconsin.
- Over two years, Dane County replaced 56 aging outdoor sirens with new units and improved siren coverage in areas having significant numbers of people with low to moderate income.
- Dane County implemented a project to upgrade culverts under County highways to improve stormwater conveyance and reduce damage to roadways.
- The Lakes and Watershed Commission and the Capital Area Regional Planning Commission established a Stormwater Technical Advisory Team to evaluate the County's stormwater management strategies and make recommendations regarding flood risk reduction.

5.6 Implementation

Even the casual reader of this plan will notice that almost nowhere in the recommendations is there a discussion of feasibility or project cost. This is not an oversight. Rather, this is a result of the scope and scale of this plan. This was a broad planning effort and this document is intended to provide a comprehensive view of the general issues associated with natural hazards in Dane County. Through Countywide analysis, the mitigation plan presents multi-faceted solutions to a series of multi-faceted problems. With a few exceptions, the plan does not make any attempt to present a specific solution to a specific problem or a specific area. This is not possible given the scale of this planning effort. Rather, the plan describes a wide range of possible methods and projects and provides general guidelines for assigning priorities.

That being said, the plan does provide a framework, in the form of objectives, for implementing the various recommendations. In that sense, each of these objectives is a point for further study and planning. This also is a function of the Countywide scale of plan. The plan is the first step in laying-out, in broad terms, what needs to be done to minimize the occurrence and impact of natural hazards in the County. The engineering studies, implementation costs, and benefit-cost analysis of specific projects will come at future points in the process.

5.6.1 Project Feasibility and Cost Effectiveness

The plan describes a wide range of possible methods and projects and provides general guidelines for assigning priorities. As solutions and projects are identified, each must be subjected to an analysis of feasibility and cost effectiveness. This is a necessary condition for obtaining FEMA or other federal or state funding assistance. FEMA has a strict set of requirements for mitigation project funding:

- Projects must be technically feasible and ready to implement.
- Structural projects must include engineering studies with the project application so the FEMA can independently evaluate the effectiveness and feasibility of the proposed project.
- All projects must be cost effective and substantially reduce the risk of future damage, hardship, loss, or suffering. All projects must have a benefit-cost ratio of 1.0 or greater in FEMA's Benefit-Cost Analysis (BCA).
- All projects must be in conformance with the current natural hazard of flood mitigation plan.
- All flood-related projects must be located in a community that is participating and in good standing with the National Flood Insurance Program.

Technical assistance on completing the analysis and submitting project grant applications is available from FEMA. These considerations must be included in the on-going project analysis that will take place as this plan is implemented.

Even without the FEMA project requirements, and evaluation of cost effectiveness and technical feasibility is necessary to assure the success of the project. These are very basic considerations, but a 1.0 or greater BCA result is not the only measure of the value of a project. Nor is it the only measure of the potential for success or failure of a project. These issues also exist within a social and political context. There are other questions besides cost and technical feasibility that must be answered, or at least addressed, when evaluating options:

- How should scarce public resources, both financial and staff time, be allocated in a way that is equitable and fair?

- What are the constraints beyond technical and financial? Are there legal constraints or time constraints? Is there staff available to initiate and manage the project?
- Are there special interest groups that will impose restrictions on (or assist in implementing) the project?
- Who should benefit from the project?
- How will priorities be assigned when evaluating alternatives?
- By what measure do intangibles such as environmental quality or recreational potential factor into the discussion?
- How will these decisions me made?

These factors make it essential that this effort be a publicly open process involving as many stakeholder groups as possible.

5.6.2 Continued Public Involvement

The effort that produced this plan was an open process and the implementation must be as well. It's success depends on it. Full implementation of many of the objectives would require a range of possible actions on the part of county government, including:

- Stakeholder partnerships
- County Board and County Executive policy changes
- Ordinance amendment
- Capital expenditure
- Operating budget expenditure
- Staff time dedication
- Project grant application and acceptance

These activities all have public input and review built into the process. This plan was prepared with the idea that the citizens served by the entities developing the plan should have a voice in determining the priorities identified in the plan. The notion that every citizen has a right to participate in the process of making local government decisions is part of culture in Dane County government. Significant financial, time, and energy investments will be required to complete the planning effort. Given these investments, Dane County regards broad public participation in the process as an essential strategy for implementing actions that are supported by the public. Routinely used tools for gathering public and stakeholder input include:

- Stakeholder workgroups and partnerships
- Public meetings

- Websites
- Surveys
- Open houses
- Public comment period prior to open meetings
- Personal contact

Any or all of these methods will be employed as specific objectives in the plan are implemented.

5.6.3 Funding Assistance

There are numerous options available to Dane County for the financing of a flood mitigation program. The identification of potential funding sources, including sources other than those at the local level is an integral part of the implementation of a successful mitigation plan. However, funding programs and opportunities are constantly changing. The following list of existing programs and funding sources includes those that appear to be potentially applicable to Dane County directly or to municipalities within Dane County.

Federal Emergency Management Agency (FEMA) Unified Hazard Mitigation Assistance (HMA) Grant Programs

FEMA has unified its guidance for the various grant programs that fund mitigation projects. These programs include the Flood Mitigation Assistance, Hazard Mitigation Grant Program, Building Resilient Infrastructure and Communities (BRIC) Grant Program, Severe Repetitive Loss and Repetitive Flood Claims grants. More information on these programs can be referenced on the FEMA.gov website.

Federal Emergency Management Agency (FEMA) – Public Assistance Program

The Public Assistance Program can provide limited assistance for hazard mitigation projects. Funding under this program is provided for repair of public infrastructure damaged during an event that results in a Presidential Major Disaster Declaration. The Public Assistance Program is authorized under the Robert T. Stafford Disaster Relief and Emergency Assistance Act. The Public Assistance Program will provide up to 75 percent of the project costs, with the balance of the costs shared by the State of Wisconsin (12.5 percent) and the local project grantee (12.5 percent).

Eligible categories for public assistance include costs incurred for emergency work such as debris removal and emergency protective measures or permanent work of a restorative nature such as repairing damage to roads and bridges, water treatment and control systems, or publicly owned buildings or utilities. Mitigation measures are eligible if the work to restore public infrastructure is done in such a way as to improve the facility in order to prevent or minimize future damages.

U.S. Department of Housing and Urban Development – Community Development Block Grants

The Wisconsin Community Development Block Grant (CDBG) program is funded by HUD and administered by Wisconsin Departments of Administration and Commerce. The CDBG program can provide funding for a variety of flood mitigation activities, including disaster relief and acquisition and relocation of structures. CDBG housing grants are awarded annually through a competitive process. Eligible projects must have sustained damage and must benefit low- and moderate-income persons. In addition, CDBG emergency assistance grants may be provided for mitigation activities following a local disaster, even if a Presidential Major Disaster has not been declared. Most Dane County communities are eligible for CDBG funds, based on priorities established in a Consolidated Plan approved by the Dane County Board of Supervisors and HUD.

Wisconsin DNR Municipal Flood Control Grant Program

This program provides 70% cost sharing grants to cities, villages, towns and metropolitan sewerage districts to acquire or flood proof structures, purchase easements, restore riparian areas, or construct flood control structures. Applications would be ranked based on avoided flood damages, restoration or protection of natural and beneficial functions of water bodies, use of natural flood storage techniques or environmentally sensitive detention ponds and enhanced recreational opportunities. Eligible activities, in priority order include:

- Acquisition and removal of structures that, due to zoning restrictions, can not be rebuilt or repaired.
- Acquisition and removal of structures in the 100 year floodplain.
- Acquisition and removal of repetitive loss or substantially damaged structures.
- Acquisition and removal of other flood damaged structures.
- floodproofing and elevation of structures.
- Riparian restoration projects, including removal of dams and other artificial obstructions.
- Restoration of fish and native plant habitat, erosion control and streambank restoration projects.
- Acquisition of vacant land, or perpetual conservation or flowage easements to provide additional flood storage or to facilitate natural or more efficient flood flows.
- Construction of structures for the collection, detention, retention, storage, and transmission of stormwater and groundwater for flood control and riparian restoration projects.
- Preparation of flood insurance studies and other flood mapping projects.

6.1 Plan Requirements

"In order to continue to be an effective representation of the jurisdiction's overall strategy for reducing its risks from natural hazards, the mitigation plan must reflect current conditions. This will require an assessment of the current development patterns and development pressures as well as an evaluation of any new hazard or risk information. The plan update is an opportunity for the jurisdiction to assess its previous goals and action plan, evaluate progress in implementing hazard mitigation actions, and adjust its actions to address the current realities.

Where conditions of growth and revisions in priorities may have changed very little in a community, much of the text in the updated plan may be unchanged. This is acceptable as long as it still fits the priorities of their community, and it reflects current conditions. The key for plan readers to recognize a good plan update is documentation of the community's progress or changes in their hazard mitigation program, along with the community's continued engagement in the mitigation planning process." (FEMA, Local Mitigation Plan Review Guide, October 1, 2011)

Requirement	Description
44CFR 201.6 (d)(3)	A local jurisdiction must review and revise its plan to reflect changes in development, progress in local mitigation efforts, and changes in priorities, and resubmit if for approval within 5 years in order to continue to be eligible for mitigation project grant funding.
44CFR 201.6 (c)(4)(i)	[The plan maintenance process shall include a] section describing the method and schedule of monitoring, evaluating, and updating the mitigation plan within a five-year cycle.
44CFR 201.6 (c)(4)(iii)	[The plan maintenance process shall include a] discussion on how the community will continue public participation in the plan maintenance process.
44CFR 201.6 (c)(5)	[The plan shall include…] Documentation that the plan has been formally adopted by the governing body of the jurisdiction requesting approval of the plan (e.g., City Council, County commissioner, Tribal Council). For multi-jurisdictional plans, each jurisdiction requesting approval of the plan must document that it has been formally adopted.

6.2 Plan Adoption

The purpose of formally adopting this plan is to secure buy-in from Dane County and participating jurisdictions, raise awareness of the plan, and formalize the plan's implementation. The governing body for each participating jurisdiction has adopted this local hazard mitigation plan by passing a resolution. A copy of the generic resolution and the executed copies are included in Appendix C, Adoption Records. The plan will be updated and re-adopted by participating jurisdictions within the five-year update cycle.

6.2.1 Implementation

With adoption of this plan, Dane Count Departments and participating municipal governments will be tasked with plan implementation and maintenance. This effort will be led by Dane County Emergency Management. The Dane County Departments and primary and secondary municipal contacts are expected to see the plan successfully carried out and to report to the community governing boards and the public on the status of plan implementation and mitigation opportunities. Responsibilities include:

- Act as a forum for hazard risk reduction issues.
- Pursue the implementation of mitigation actions.
- Keep the concept of mitigation in the forefront of community decision-making by identifying plan recommendations when other community goals, plans, and activities overlap, influence, or directly affect increased community vulnerability to disasters.
- Maintain a vigilant monitoring of multi-objective cost-share opportunities to help the community implement the plan's recommended actions for which no current funding exists.
- Monitor and assist in implementation and update of this plan.
- Report on plan progress and recommended changes to the Dane County Board of Supervisors.
- Inform and solicit input from the public.

Other duties include reviewing and promoting mitigation proposals, considering stakeholder concerns about hazard mitigation, passing concerns on to appropriate entities, and posting relevant information on the County website and local newspapers.

6.2.2 Incorporation into Existing Planning Mechanisms

Another important implementation mechanism that is highly effective and low-cost is incorporation of the hazard mitigation plan recommendations and their underlying principles into other County and municipal plans and mechanisms. Hazard mitigation is most successful when it is incorporated into the day-to-day functions and priorities of government and development. As stated previously, implementation through existing plans and/or programs is recommended, where possible. This point is re-emphasized here. The County and participating entities already have existing policies and programs to reduce losses to life and property from natural hazards. These are summarized in this plan's capability assessment and in the jurisdictional annexes. This plan builds upon the momentum developed through previous and related planning efforts and mitigation programs and recommends implementing projects, where possible, through these other program mechanisms. These existing mechanisms include:

- Dane County Comprehensive Plan
- Local Comprehensive Plans
- Dane County Sustainable Operations Plan

- The Dane County Parks and Open Space Plan
- Community Development Block Grant Program
- Soil and Water Conservation Programs
- Dane County Emergency Response Plan

Implementation and incorporation into existing planning mechanisms will require both inter-departmental coordination and inter-governmental coordination. The purpose of inter-departmental coordination is to tap into the experience and expertise of professionals in multiple departments in order to avoid redundancy of effort and capitalize on on-going efforts. Through the planning process it became clear that multi-jurisdictional hazard problems, such as flooding, are pervasive throughout the County. Flooding does not respect municipal boundaries and many of the most severe flooding problems are cross-boundary ones. The purpose of this coordination is to address these problems as specific projects. The County is uniquely situated to coordinate and facilitate projects on a watershed level. In fact, facilitating multi-jurisdictional efforts was identified in the public input process as one of the primary roles of the County. Many of the ideas expressed in other recommendations of this plan assume the role of the County as a facilitating agent. This policy makes that assumption explicit.

Though the County has limited authority in cities and villages, their participation in the plan is crucial to its success. Furthermore, members of the planning team are in a position to facilitate coordination activates between units of government, including funding for projects. This plan offers the opportunity for all units of government to engage in the plan by their design of specific multi-jurisdictional projects that are consistent with the recommendations of the plan. Coordination at the project level will help Dane County avoid the site specific, individualized actions that have been marginally successful in the past. Additionally, by combining projects under the auspices of a single plan, projects may be able to obtain funding without having to compete against other municipalities within the County. Involving different levels of government also allows for the pooling of resources, thereby increasing the chance of project completion and success.

6.3 Maintenance, Monitoring, and Updating

6.3.1 Plan Maintenance

Plan maintenance implies an ongoing effort to monitor and evaluate plan implementation and to update the plan as required or as progress, roadblocks, or changing circumstances are recognized. The strategy for implementation of this plan is outlined within the recommendations of the previous section. In addition, the plan will require periodic evaluation to determine if revision is necessary. Dane County's Department of Emergency Management will conduct an annual evaluation of the plan. At a minimum, the evaluation will consider the following:

- A review of the goals, policies, and objectives to determine whether they remain an appropriate approach to the problems they are intended to address.
- The progress of the program activities toward achieving the specific mitigation objectives.

- The problems encountered in the implementation of the specific activities.
- Evaluation and refinement of the specific activities based on the evaluation of the problems encountered.
- Review of possible funding sources that could be applied to future efforts.
- Review of the public input process to ensure that citizens' concerns are heard in the implementation and evaluation process.

6.3.2 Performance Monitoring

Updates to this plan will follow the latest FEMA and WEM planning guidance. Evaluation of progress can be achieved by monitoring changes in vulnerabilities identified in the plan. Changes in vulnerability can be identified by noting:

- Decreased vulnerability as a result of implementing recommended actions.
- Increased vulnerability as a result of failed or ineffective mitigation actions.
- Increased vulnerability as a result of new development (and/or annexation).
- Increased vulnerability as a result of changing environmental and climate conditions.

The planning team will use the following process to evaluate progress and any changes in vulnerability as a result of plan implementation:

- A representative from the responsible entity identified in each mitigation measure will be responsible for tracking project status and provide input on whether the project as implemented meets the defined objectives and is likely to be successful in reducing vulnerabilities.
- If the project does not meet identified objectives, the appropriate department / agency will determine what alternate projects may be implemented.
- New projects identified will require an individual assigned to be responsible for defining the project scope, implementing the project, and monitoring success of the project.
- Projects identified as potential mitigation strategies will be reviewed during the monitoring and update of this plan to determine feasibility of future implementation.

6.3.3 Plan Updates

Updates to this plan will:

- Consider changes in vulnerability due to project implementation.
- Document success stories where mitigation efforts have proven effective.
- Document areas where mitigation actions were not effective.
- Document any new hazards that may arise or were previously overlooked.
- Document hazard events and impacts that occurred within the five-year period.
- Incorporate new data or studies on hazards and risks.
- Incorporate new capabilities or changes in capabilities.
- Incorporate documentation of continued public involvement.
- Incorporate documentation to update the planning process that may include new or additional stakeholder involvement.
- Incorporate growth and development-related changes to building inventories.
- Incorporate new project recommendations or changes in project prioritization.
- Include a public involvement process to receive public comment on the updated plan prior to submitting the updated plan to WEM/FEMA.
- Include re-adoption by all participating entities following WEM/FEMA approval.

6.3.4 Update Schedule

In order to track progress and update the mitigation strategies identified in the action plan, Dane County Emergency Management will revisit this plan annually. Dane County Emergency Management is responsible for initiating this review and convening appropriate members of the team as needed.

Following a disaster or a major event, Dane County will review and update this plan to reflect the status of current mitigation efforts; expand the plan as necessary; and to address new issues, recommendations, and activities based on the impacts of the current disaster. Any substantive changes to the plan will be presented for formal approval to the County Board, through the Public Protection and Judiciary Committee.

This plan will be updated, approved, and adopted within a five-year cycle as per Requirement §201.6(c)(4)(i) of the Disaster Mitigation Act of 2000. Updates to this plan will follow the most current FEMA and WEM planning guidance.