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# Dane County Natural Hazard Mitigation Plan



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In Cooperation With  
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## 1.1 Purpose

Natural disasters can exact a heavy toll. In the past, 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. Natural hazards are an inevitable fact of life on planet Earth. Planning for natural hazards and implementing mitigation measures, however, can reduce the *impact* of such events when they do occur. Monetary losses can be reduced. Personal injury and loss of life can be reduced. The economic, social, and environmental impact on the community as a whole can be reduced.

This plan outlines a strategy with 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. This plan update also includes climate change as a factor in the planning process. In doing so, it hopes to account for the County's altered vulnerability to natural hazards in this changing climate and to plan strategies to reduce this vulnerability, before the next natural 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 the State highlights fourteen hazards as presenting a significant risk to the communities of Dane County. These hazards include:

- 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 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 strategy. 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 second update of the Dane County's Natural Hazards Mitigation Plan. The first version of the plan was adopted in May of 2005, with an update adopted in May of 2010. Much has changed since the previous versions of the plan were prepared. Most significantly:

- Many of the initial plan objectives have been accomplished or are well underway. This update identifies some of those actions taken and seeks to build on their success in reducing the long term vulnerability to natural hazards in Dane County.
- There have been significant changes in the County's capability and commitment to address natural hazards vulnerability. These include regulatory changes and updates, organizational changes in County government, new and updated plans and policies, and new information related to natural hazards and their effects on the people of Dane County. These changes and updates are incorporated into this plan.
- Climate change, once considered an issue for the distant future, has moved firmly into the present. Even subtle changes in climate pose significant risks to the well-being of county residents, the economy, and the environment. This plan update incorporates impacts of climate change into the hazard analysis and vulnerability assessment sections of the plan. The plan also incorporates adaption to changing natural conditions and natural hazards into the mitigation strategy and plan goals and objectives.

### 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 also 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 was 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 the 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 actions 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 also 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 that 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.

While this plan update was developed to meet the State and Federal planning requirements, it is also designed to meet the needs of the County and participating local units of government within the County.

## 1.5 Disaster Declaration History

Dane County has received Presidential disaster declarations on 15 occasions since 1976. That equates to a frequency of a receiving declared disaster nearly every three years:

Table 1.4.1 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)
1978	Flooding and Tornados	Presidential Disaster	\$180,000 (Public Assistance)

Year	Disaster Type	Declaration Type	Damage Assessment
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)

Source: Dane County Emergency Management

The major disaster declaration figures in Table 1.4.1 do not tell the whole story of damages caused by natural hazards in Dane County. While the figures do 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. In addition, federal disaster assistance programs have strict eligibility requirements. These figures show only a small fraction of the total losses incurred by the private sector—those that are uninsured. 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 was prepared as a multi-jurisdictional plan. All 61 local units of government in the County were invited to participate in the planning process. The decision whether or not to participate in this process was a local decision, based on local community needs. Communities have the options to not prepare a plan, to prepare a stand-alone plan for their jurisdiction, or to participate in a multi-jurisdiction or county-wide plan. Thirty-seven local governments have opted to participate in this effort.

Figure 1.6.1 Participating Local Jurisdictions

Cities	Villages	Townships
Edgerton	Belleville	Albion
Fitchburg	Blue Mounds	Berry
Madison	Brooklyn	Blue Mounds
Middleton	Cambridge	Christiana
Sun Prairie	Cottage Grove	Cottage Grove
Verona	Cross Plains	Dunn
	Deforest	Mazomanie
	Marshall	Montrose
	Mazomanie	Perry
	McFarland	Pleasant Springs
	Oregon	Roxbury
	Shorewood Hills	Springdale
	Waunakee	Sun Prairie
	Windsor	Vermont
		Verona
		Vienna
		Westport

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.

Counties neighboring Dane County were also invited to review and comment on the draft plan, prior to final adoption.

## 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 and 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 does not conflict with economic development. In fact, it is 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.

But sustainability means much more than that. 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.”

This is not a new concept, but the interpretation can be controversial. Even the interpretation of this seemingly simple definition is open to question: What should be sustained and for whom? How do we define equity? How are individual rights balanced with the common good? How is it even possible for present generations to live without somehow compromising future options? In a highly complex and interconnected world, how do we account for the unforeseen and unintended consequences of our actions? Who makes these decisions and by what mechanism can they be enforced? These are questions of values and the answers will vary widely from person to person and group to group.

This plan acknowledges that these are unanswered questions for further public discussion. Even so, the concept of sustainability is still 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 sustainability approach accomplishes this. 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 Yahara Lakes Advisory Group 2 (YLAG2)**

Early in 2011, the Department of Natural Resources (DNR) created the Yahara Lakes Water Level Advisory Group (YLAG2) to make recommendations regarding the water levels on the Yahara Lakes, including Mendota, Monona, Waubesa, Kegonsa and the Stoughton millpond.

In 2001, DNR convened the Yahara Lakes Advisory Group (YLAG1), with representatives from area governments, organizations and interests to discuss lake levels and other actions to reduce flooding. YLAG2's organized to review YLAG1 recommendations and discuss and evaluate current conditions. The groups charge was to examine the operation, physical constraints, and changing hydrology of the Yahara chain of lakes and make water level recommendations that balance public and private interests. Public interests include navigation, fish and wildlife habitat, water quality and natural scenic beauty. Private and cultural interests include historic values, riparian and business access and economic development. This was a stakeholder and public input driven process, with seven group meetings and one public comment meeting in 2012.

The YLAG2 group developed a series of recommendations on how to best manage the Yahara lakes as a system and to build consensus on the issue instead of fragmented approaches. The policy recommendations made by this group form the Yahara River and Chain of Lakes management strategies that are still in place today. The recommendations of the group are consistent with the goals and objectives described in the *Natural Hazards Mitigation Plan* update.

### **1.12.3 Dane County Sustainable Operations 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.

#### **1.12.4 Dane County Climate Change Action Plan**

In March of 2013, the Dane County Climate Change Action Council was created with the mission of ensuring that the Dane County government is better prepared for weather extremes brought on by global climate change. In the preparation of this plan, the Council facilitated an internal review of preparations and potential modifications to the county's operations and capital investments. Based on the internal review, this report identifies potential vulnerabilities to climate change, and provides sector based adaptation strategies.

The report addresses climate impacts for public health, public safety and emergency management, infrastructure and facilities, and Dane County lakes. The climate related risks within each sector are detailed and each are followed by “near term adaptations,” as well as methods for preparing for projected adaptations through planning and mitigation.

Three additional resiliency strategies are introduced which include: Collaborating for Security, Corridors of Sustainability, and Resilient Watersheds Partnerships.

- The *Collaborating for Security* strategy would aim to further coordinate emergency response and communications capacity, share information and technology with partners, and deepen collaborations on public safety strategies with other departments and governments.
- *Corridors of Sustainability* addresses county-wide coordination to strengthen infrastructure resiliency - which specifically will include integrated water management, energy efficiency, and ways to protect public health from climate change impacts.
- *Resilient Watershed Partnerships* is a collaborative strategy to engage watershed partners and the agricultural community by, first, coordinated restoration of important ecosystem functions to prevent agricultural runoff and flooding, and, second, by development of a resilient local food system.

Identified adaptation measures funded through the County's capital and operating budget process include a \$1 million allocation for infrastructure upgrades, updates to culverts that handle storm water, and the creation of an emergency sandbag fund for potential floods.

### **Dane County Climate Change Council**

The County's 2017 budget created a new Office of Energy and Climate Change and a new Council on Climate Change. This is the next step in the work Dane County initiated years ago which resulted in creation of the "Dane County Climate Action Plan." The Council includes representatives of local governments, business, utilities, and environmental advocates, working together to extend the work of county government. A recent agreement with the LaFollette School of Public Affairs at the University of Wisconsin will help the county assess the impact of the progress Dane County has made to date at reducing carbon emissions, increasing green energy production, and consumption, and making energy efficiency improvements to facilities. The new Office and Council will develop strategies to not only prepare locally for the effects of the changing climate, but also to better identify ways to reduce carbon emissions and promote further development of solar and clean, green energy production.

### **1.12.5 Stormwater Technical Advisory Committee**

During the time period of the preparation of this plan update, the Lakes and Watershed Commission and the Capital Area Regional Planning Commission 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.

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.

## 2.1 Plan Requirements

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.”<sup>1</sup>

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 range of organizations, researchers, and county agencies. Funding was secured through a Hazard Mitigation Grant Program (HMGP) planning grant from FEMA to enable a project assistant to be hired to facilitate the process and develop the plan. 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 guide the update process, facilitate the process, research and analyze hazards and risks, and coordinate planning with participating local jurisdictions. Dane County Emergency Management project staff also participated in regular meetings of the County’s Climate Change Staff Team to help assure consistency between the hazard mitigation planning and climate change adaptation efforts. Dane County Planning and Development staff also participated in the Climate Change Staff Team and the hazard mitigation planning process, thereby assuring coordination between these efforts and the policies and objectives described in the County’s Comprehensive Plan.

<sup>1</sup> FEMA, *Local Mitigation Plan Review Guide*, October 1, 2011

## 2.3 Hazard Mitigation Planning Team

The County's Hazard Mitigation Planning Team acted as expert advisors and decision makers. This team is informally referred to as the planning committee or the planning team in this document. The planning team was made up of representation from a wide range of County departments:

- Administration
- Dane County/UW Extension
- Emergency Management
- Land and Water Resources
- Land Information Office
- Planning and Development
- Public Health, Madison and Dane County
- Public Works, Highway, and Transportation
- Henry Vilas Zoo
- Capital Area Regional Planning Commission
- University of Wisconsin, Wisconsin Initiative on Climate Change Impacts (WICCI)

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

## 2.4 Local Jurisdiction Participation

To gain the involvement of local units of government, letters inviting participation in the plan were sent to the government leaders of all cities, villages, and towns in the County. Letters encouraged their participation and explained the planning process, the benefits of completing the planning process, and their local requirements if they chose to become involved. Numerous follow-up efforts were made by County staff to encourage participation. While all 61 local units of government were invited to participate, not all of them decided to do so.

The decision whether or not to participate in this process was a local decision, based on local community needs. Communities have the options to not prepare a plan, to prepare a stand-alone plan for their jurisdiction, or to participate in a multi-jurisdiction or county-wide plan. Thirty-seven local governments have opted to participate in this effort.

Expectations and requirements of local governments participating in the process include collaborating with the County planning team and County staff to:

- Dedicate adequate staff time to complete the process in a timely manner.
- Participate in countywide planning meetings.
- Establish a local steering committee.
- Complete a hazard profile and vulnerability assessment based on local conditions.
- Develop local problem statements.
- Develop a local mitigation strategy.
- Identify and prioritize specific goals, objectives, and action steps.
- Participate in public outreach activities and participate in at least one public meeting.
- Review and approve draft plan documents.
- Adopt the plan, when complete, through formal resolution.

Figure 2.4.1 Participating Local Jurisdictions

Cities	Villages	Townships
Edgerton	Belleville	Albion
Fitchburg	Blue Mounds	Berry
Madison	Brooklyn	Blue Mounds
Middleton	Cambridge	Christiana
Sun Prairie	Cottage Grove	Cottage Grove
Verona	Cross Plains	Dunn
	Deforest	Mazomanie
	Marshall	Montrose
	Mazomanie	Perry
	McFarland	Pleasant Springs
	Oregon	Roxbury
	Shorewood Hills	Springdale
	Waunakee	Sun Prairie
	Windsor	Vermont
		Verona
		Vienna
		Westport

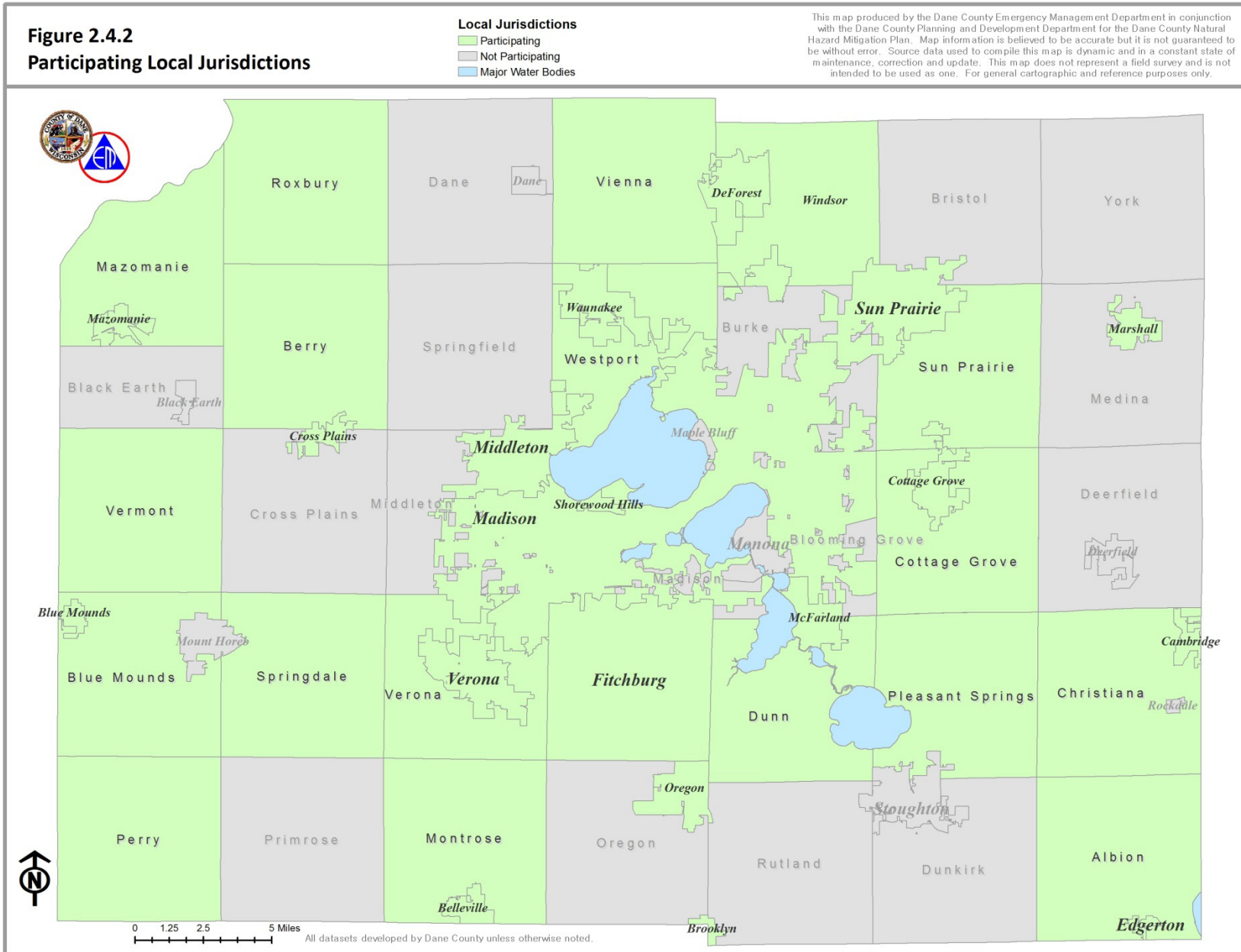
Each of these participating jurisdictions has a specific attachment to this plan. The local attachments describe particular risks and vulnerabilities and identify action items to be taken by the jurisdiction to reduce those risks. A list of specific local government participants and representatives is included in Appendix A.

Counties neighboring Dane County were also invited to review and comment on the draft plan, prior to final adoption.

### 2.4.1 Countywide Local Jurisdiction Planning Team

Participating local governments appointed at least one person to represent their jurisdiction on a countywide planning team. This team was charged with reviewing the plan process, providing ideas for County strategies, reviewing County strategies, acting as a liaison between Dane County and the local unit of government they represent, and working with their local unit of government to develop local mitigation strategies. Three countywide meetings were held between June, 2015 and November, 2015. A fourth meeting was held in February 2017 to the review and comment on the draft of this plan. During the planning process, County staff also communicated with members of this team through a variety of other means including face-to-face meetings, telephone calls, email correspondence, and sharing of materials on a project website.





## 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 planning team and establish work plan and planning process
  - 2. Identify governments interested in participating in the plan
  - 3. Establish a local jurisdiction planning team
  - 4. Meet with to review plan framework
  
- 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. Present analyses to local jurisdiction planning team and planning team and brainstorm solutions
  - 2. Develop County strategies within the planning team
  - 3. Assist in the development and incorporate local government 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 the plan to the County Board for adoption
  - 2. Submit specific appendices for adoption by participating governments
  - 3. Implement the plan
  - 4. Review and revise annually

This plan process makes an asserted and successful effort to incorporate many different voices into the plan process. Its 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 draft objectives.

## 2.6 Public Involvement

This plan assumes community input is essential in crafting a realistic and effective strategy. Stakeholders need to be empowered in the process at several levels to mitigate flooding problems. A public outreach steering subcommittee was formed to discuss outreach strategies utilized during the planning process.

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**Section 2: Planning Process**

This was comprised of members of Dane County Emergency Management, Dane County Administration, Dane County/UW Extension, and University of Wisconsin, Wisconsin Initiative on Climate Change Impacts (WICCI).

A public participation strategy was developed and public input was gathered early in the planning process, and repeatedly throughout the process. The public involvement materials prepared are attached as Appendix B. The public participation strategy relies upon several input tools for different circumstances to gather public input. Individual surveys, personal discussions, regional town hall meetings, and local board meetings were used, each with a purpose, be it to gather data, hear opinions, help determine recommendations, or guide the plan process.

**2.6.1 Public Meetings**

Public meetings were held at two steps in the planning process, initially in the risk identification and assessment stage and then again to review the draft Mitigation Strategies.

- Four regional meetings were held in January, 2016 in the following locations across the County: the City of Madison, the Village of Cambridge, and Town of Westport, and the Town of Montrose. These sites were chosen based upon local government officials' interest in being a part of the planning process, geographical distribution of sites around the County, and the County's desire to sample opinions from citizens in different area. The goal of these meetings was to update citizens on the progress of the mitigation plan and to give them the opportunity to review and comment on the initial findings of the planning process. The meetings also provided people an opportunity to express their concerns, and have a voice in setting priorities and developing countywide and local hazard mitigation strategies. Meeting materials are attached in Appendix B.
- A public meeting was held in the Village of Blue Mounds on April 20, 2016. The meeting primarily consisted of questions and discussion regarding hazard mitigation grant funding and how it related to the Village. Further discussion revolved around tornado shelters and the process other Dane County communities have followed to put in place a tornado shelter through hazard mitigation grant funding.
- A second round of four regional meetings as held in April, 2017 in the following communities: the City of Madison, the City of Verona, the Village of Cross Plains, and the City of Sun Prairie. Again, these sites were chosen in an attempt to provide an even distribution of locations around the county. The goal of the second round of public meeting was to update citizens on the progress of the plan and provide an opportunity for people to comment on the proposed mitigation strategies and actions in the plan. Meeting materials are attached in Appendix B.
- Three public meetings occurred in the final adoption stage. The Public Protection and Judiciary Committee met twice to consider the plan update, on July 25, 2107 and August 22, 2017. The County Board considered the plan for adoption on September 28, 2017. Meeting materials are attached in Appendix B.

In addition to these public meetings the participating jurisdictions assisted with public outreach by either advertising County-sponsored meetings with flyers, press releases, or websites, discussing the

plan at regularly scheduled planning commission meetings that were open to the public, or hosting a County-sponsored meeting.

### **2.6.2 Yahara Watershed Ecosystem Survey**

Dane County, through the mitigation planning team, partnered with the Water Sustainability and Climate Project at the University of Wisconsin-Madison on a survey of Yahara River Watershed residents. The primary purpose of the survey was to collect information on how Yahara watershed residents value ecosystem systems and what types of policies they favor to protect those services. The issues raised in the survey directly relate to the underpinnings of the County's hazard mitigation planning effort, especially in light of changing climate conditions:

- In light of a changing climate, how do the different ways people use and manage land and water affect the resilience and sensitivity of ecosystem services, or the benefits people derive from nature?
- How could regional governance adapt to better meet people's diverse land and water needs?
- How could changes in water and climate affect human well-being over time? Where are the vulnerabilities and the opportunities?

A total of 2,200 addresses were randomly selected to receive the survey. Of the 2,200 sampled households, a total of 1,136 returned the survey, for a response rate of 52%. Information on the Watershed Sustainability and Climate Project and results from the survey were used by the planning team to inform the draft mitigation strategies and actions prepared for the plan. Survey materials and selected results are included in Appendix B.

### **2.6.3 Climate Change Action Council Public Meetings**

Prior to the launch of this plan update, Dane County Climate Change Action Council held three public forums in June and July of 2013. Meetings were held in the City of Verona, the City of Monona, and the City of Middleton. These meetings were designed to elicit input from the public and local municipalities on vulnerabilities, adaptation strategies, and opportunities for collaboration between agencies and County and local government. Many of the concerns expressed during these sessions related directly to natural hazards and strategies to reduce the vulnerabilities associated with changing conditions and increasing risk. Information gathered during these public meetings and the Climate Change Action Council's planning process directly inform some of the strategies identified in this plan.

## **2.7 Coordination with Other Community Planning Efforts**

Coordination with other community planning efforts is also paramount to the success of this plan. Hazard mitigation planning involves identifying existing policies, tools, and actions that will reduce a community's risk and vulnerability from natural hazards. Dane County uses a variety of mechanisms, such as comprehensive plans and ordinances, to guide growth and development. Integrating existing planning efforts and mitigation policies and action strategies into this plan establishes a credible and comprehensive plan that ties into and supports other community programs. The development of this

plan incorporated information from the following existing plans, studies, reports, and initiatives as well as other relevant data from neighboring communities and other jurisdictions.

A search of County planning efforts and priorities has identified numerous areas where a multi-objective approach could reduce conflict and increase opportunities for mutual support. These include:

- Dane County Comprehensive Plan
- Local Comprehensive Plans
- Dane County Sustainable Operations Plan
- Dane County Climate Change Action Plan
- The Dane County Parks and Open Space Plan
- Dane County Water Quality Plan
- Farmland Preservation Plan
- Dane County Better Urban Infill Development (BUILD) Plan
- Community Development Block Grant Program
- Soil and Water Conservation Programs
- Yahara Lakes Advisory Group
- Dane County Emergency Response Plan

Other documents were reviewed and considered, as appropriate, during the collection of data to support the hazard identification, vulnerability assessment, and capability assessment steps of the planning process.

## 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 indicating the topography of the County.

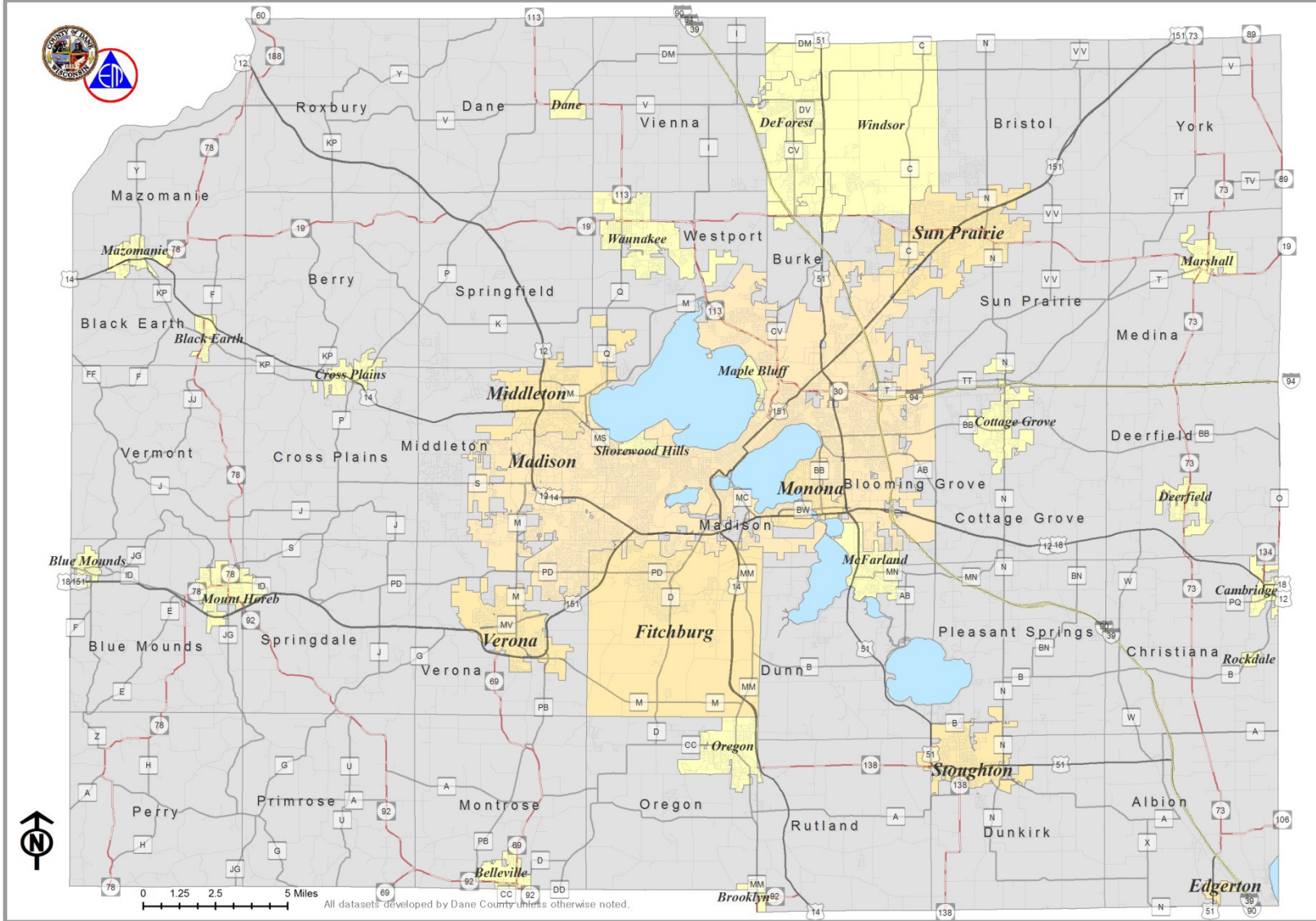
### 3.1.2 Surface Waters

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**  
**Local Units of Government**

- Interstate Highway
- County Highway
- City
- Township
- US Highway
- Local Road
- Village
- Major Water Body
- State Highway

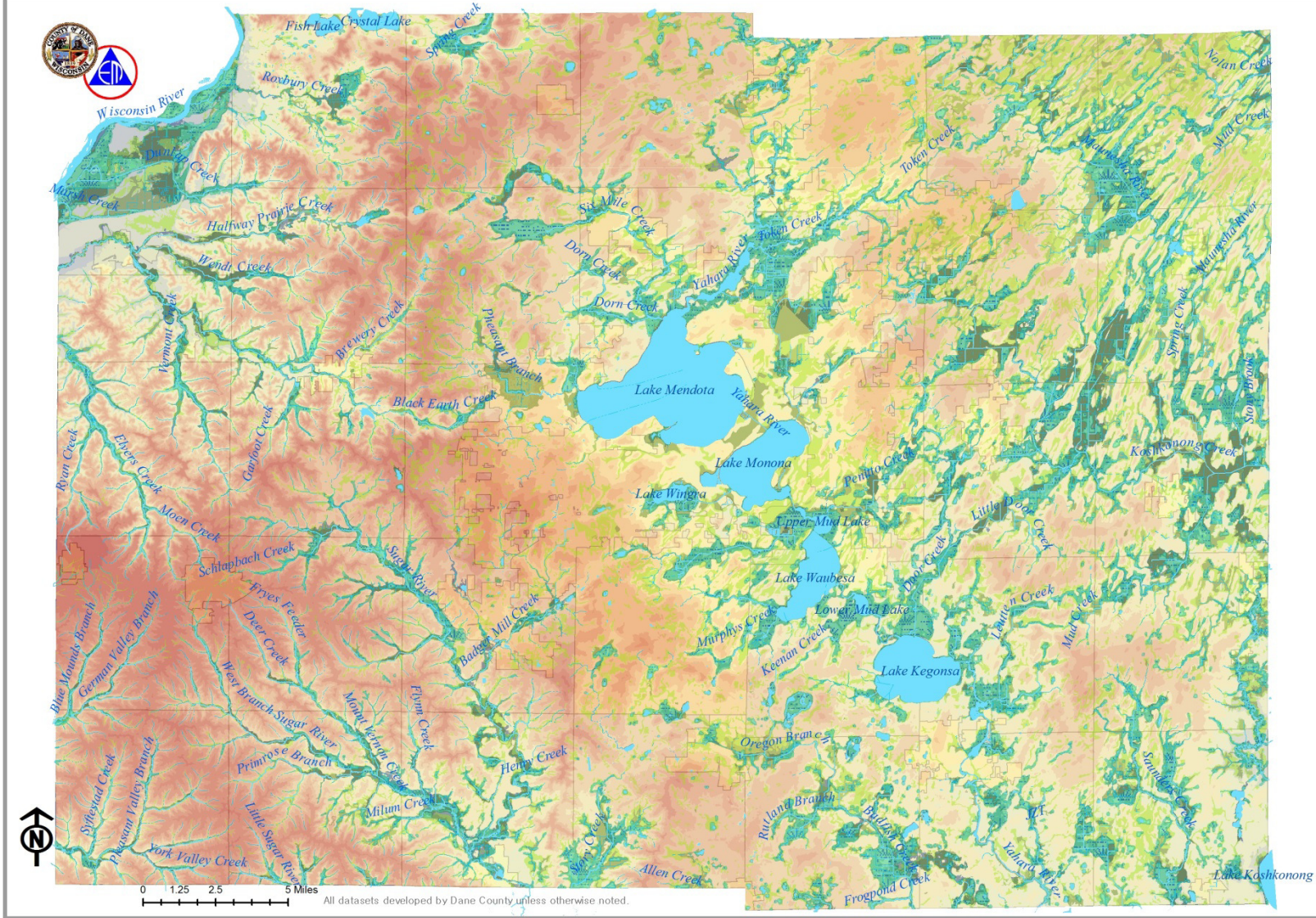
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**Figure 3.1.2**  
**Dane County Terrain Map**

- |  |  |  |
|--|--|--|
|  Lakes and Ponds    |  Wetland > 2 Acres    |  All Hydric Soil           |
|  Rivers and Streams |  Intermittent Stream  |  Predominantly Hydric Soil |
|  Floodplain         |  Constructed Drainage |  Hydric Soil Inclusions    |

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.

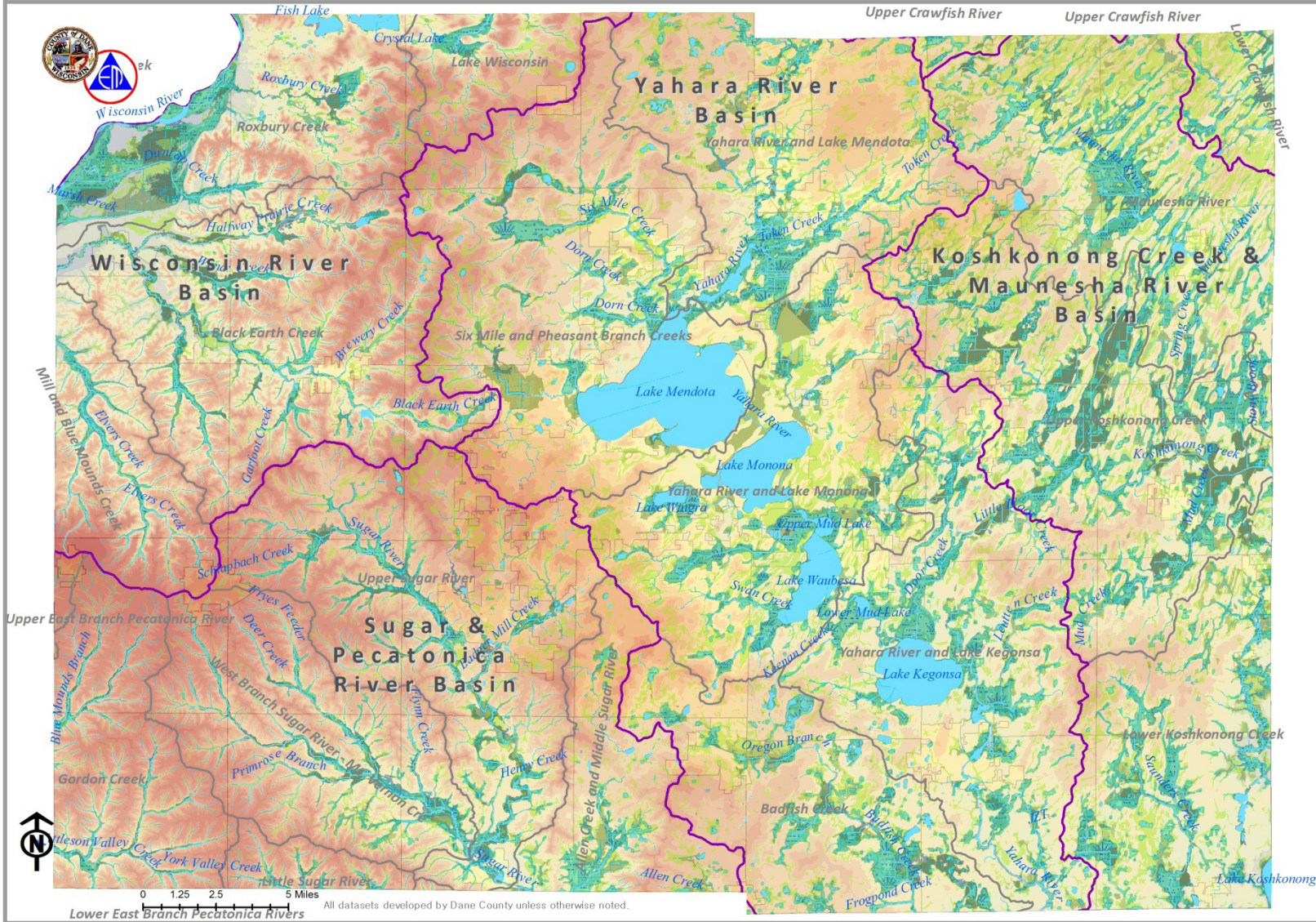




**Figure 3.1.3**  
**Dane County Watersheds**

- Watershed Boundary
- River Basins
- Rivers and Streams
- All Hydric Soil
- Predominantly Hydric Soil
- Hydric Soil Inclusions
- Lakes and Ponds
- Floodplain
- Wetland > 2 Acres

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.



### 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

#### 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 – Maunasha River Basin**

Nearly all of the land in the Koshkonong Creek-Maunasha 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 Maunasha River, and the Villages of Deerfield, Cambridge and Rockdale, located along Koshkonong Creek.

The Koshkonong Creek—Mauneshia 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 Mauneshia 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, drainageways, 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.<sup>1</sup> 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.

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<sup>1</sup> Capital Area Regional Planning Commission, *Dane County Wetland Resources Management Guide*, May 2008

## **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.

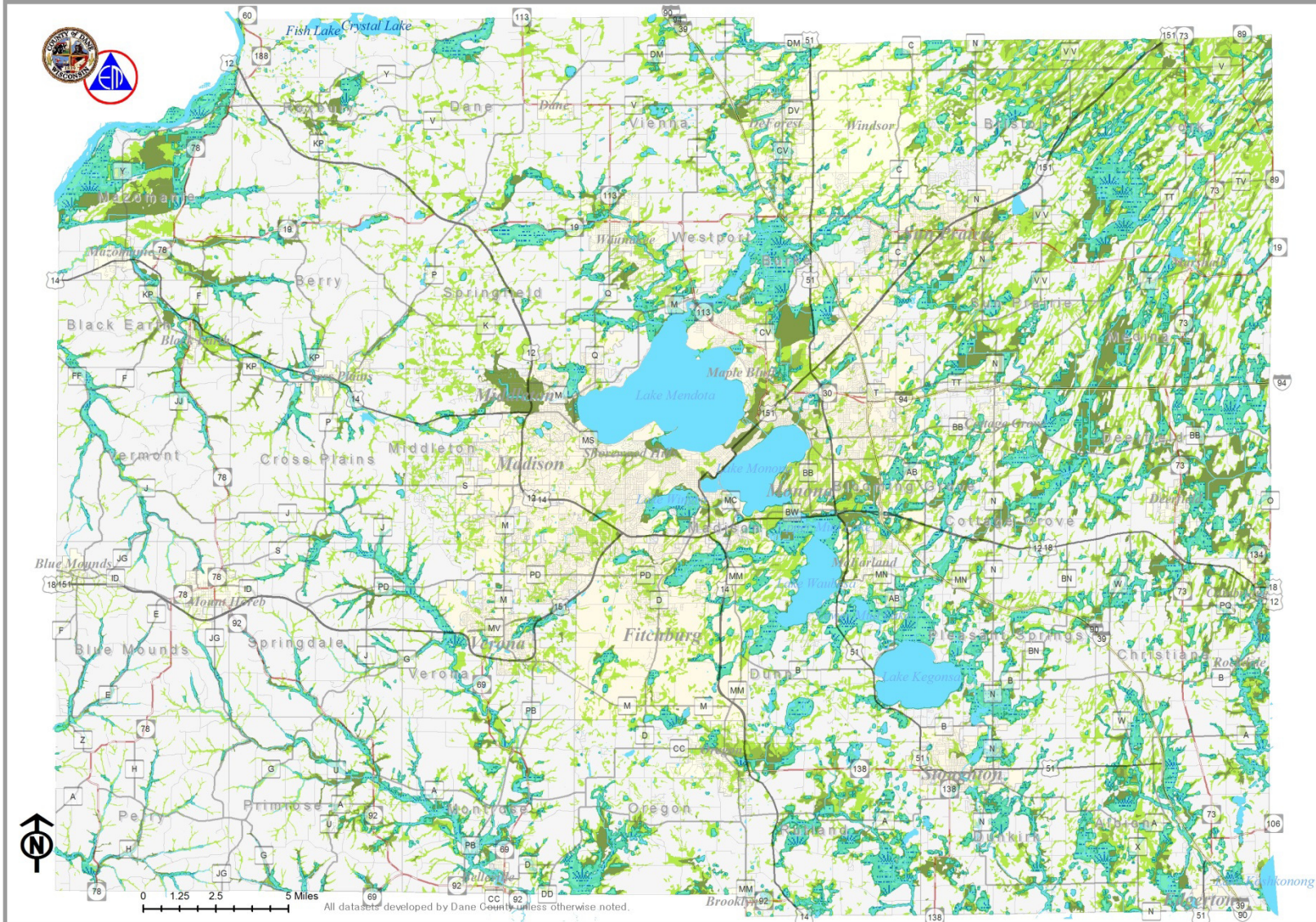
There are constraints to the effectiveness of infiltration and not all sites are suitable for intensive infiltration practices. Considerations include soil type, depth to bedrock, and depth to groundwater.

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**  
**Wetlands and Hydric Soils**

- Rivers and Streams
- Lakes and Ponds
- Wetland > 2 Acres
- All Hydric Soil
- Predominantly Hydric Soil
- Hydric Soil Inclusions
- City
- Village
- Township

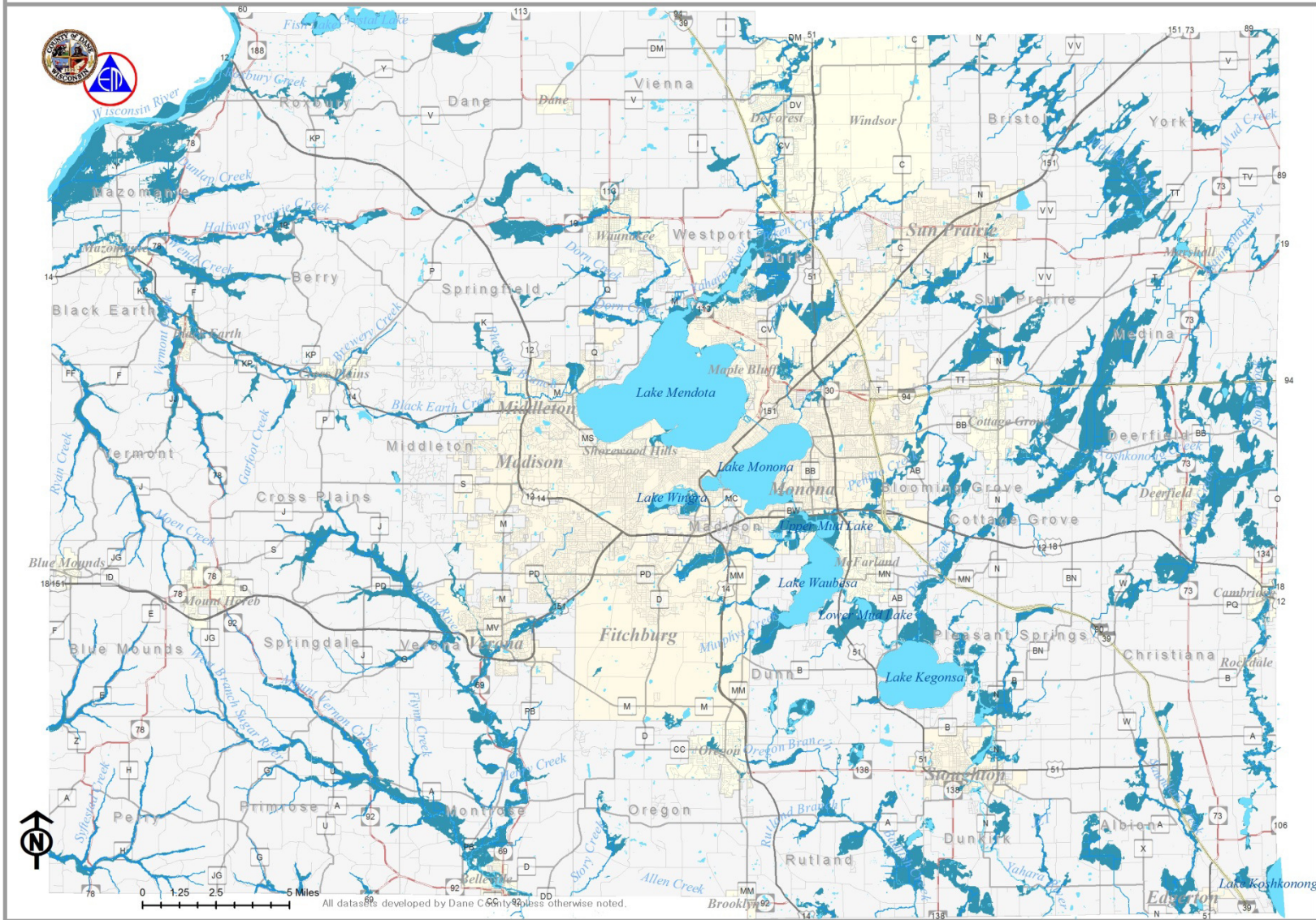
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**Figure 3.1.5**  
**Dane County Floodplains**

- 1 Percent Annual Flood Chance Area
- Lakes and Ponds
- City
- 0.2 Percent Annual Flood Chance Area
- Rivers and Streams
- Village
- Township

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## 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<sup>2</sup>

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.

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<sup>2</sup> Dane County Climate Change Action Council, *Dane County Climate Change and Emergency Preparedness*, September 2013

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.

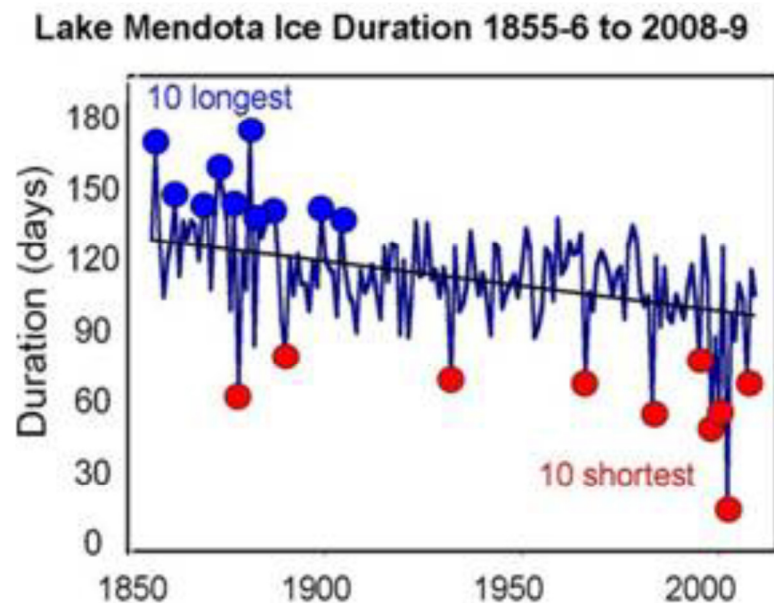
The projected increase in annual rainfall and more intense rain storms heighten the potential for significant soil erosion, affecting water resources and agriculture. Without appropriate adaptation measures, future soil erosion rates could double by 2050 compared to 1990 rates, which will likely increase 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

Figure 3.2.1 Lake Mendota Ice Cover



Source: Dane County Climate Change Action Council, *Dane County Climate Change and Emergency Preparedness*, September 2013

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 20 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 1980 to 2016.

Table 3.3.1 Dane County Population Data

Municipality	Population				1980-2016
	1980	1990	2000	2016	% Change
<b>Towns</b>					
Albion	1,918	1,964	1,823	1,965	2.5%
Berry	1,116	1,098	1,084	1,138	2.0%
Black Earth	406	365	449	485	19.5%
Blooming Grove	1,965	2,079	1,768	1,818	-7.5%
Blue Mounds	637	667	842	989	55.3%
Bristol	1,723	1,835	2,698	4,045	134.8%
Burke	2,967	3,000	2,990	3,339	12.5%
Christiana	1,209	1,182	1,313	1,253	3.6%
Cottage Grove	2,952	3,525	3,839	3,900	32.1%
Cross Plains	1,003	1,206	1,419	1,533	52.8%
Dane	945	921	968	1,003	6.1%
Deerfield	1,111	1,181	1,470	1,597	43.7%
Dunkirk	2,098	2,121	2,053	1,945	-7.3%
Dunn	4,966	5,274	5,270	4,956	-0.2%
Madison	6,162	6,442	7,005	6,277	1.9%
Mazomanie	1,007	982	1,185	1,102	9.4%
Medina	1,019	1,124	1,235	1,380	35.4%
Middleton	2,598	3,628	4,594	6,273	141.5%

Municipality	Population				1980-2016
	1980	1990	2000	2016	% Change
Montrose	1,024	1,032	1,134	1,092	6.6%
Oregon	1,798	2,428	3,148	3,231	79.7%
Perry	632	646	670	738	16.8%
Pleasant Springs	2,529	2,660	3,053	3,217	27.2%
Primrose	654	595	682	731	11.8%
Roxbury	1,491	1,536	1,700	1,841	23.5%
Rutland	1,393	1,584	1,887	1,995	43.2%
Springdale	1,279	1,258	1,530	1,948	52.3%
Springfield	2,379	2,650	2,762	2,805	17.9%
Sun Prairie	1,990	1,839	2,308	2,352	18.2%
Vermont	634	678	839	821	29.5%
Verona	2,259	2,137	2,153	1,983	-12.2%
Vienna	1,365	1,351	1,294	1,523	11.6%
Westport	2,748	2,732	3,586	4,000	45.6%
York	714	649	703	681	-4.6%
<b>Villages</b>					
Belleville *	1,203	1,349	1,795	1,848	53.6%
Black Earth	1,145	1,248	1,320	1,368	19.5%
Blue Mounds	387	446	708	920	137.7%
Brooklyn *	250	406	502	954	281.6%
Cambridge *	785	883	1,014	1,356	72.7%
Cottage Grove	888	1,131	4,059	6,512	633.3%
Cross Plains	2,156	2,362	3,084	3,696	71.4%
Dane	518	621	799	1,067	106.0%
Deerfield	1,466	1,617	1,971	2,423	65.3%
DeForest	3,367	4,882	7,368	9,223	173.9%
Maple Bluff	1,351	1,352	1,358	1,307	-3.3%
Marshall	2,363	2,329	3,432	3,864	63.5%
Mazomanie	1,248	1,377	1,485	1,667	33.6%
McFarland	3,783	5,232	6,416	7,946	110.0%
Mount Horeb	3,251	4,182	5,860	7,123	119.1%
Oregon	3,876	4,519	7,514	9,575	147.0%
Rockdale	200	235	214	213	6.5%
Shorewood Hills	1,837	1,680	1,732	1,928	5.0%
Waunakee	3,866	5,897	8,995	12,901	233.7%
Windsor	3,812	4,620	5,286	6,876	80.4%

Municipality	Population				1980-2016
	1980	1990	2000	2016	% Change
<b>Cities</b>					
Edgerton *			42	113	169.0%
Fitchburg	11,973	15,648	20,501	26,321	119.8%
Madison	170,616	190,766	208,054	242,216	42.0%
Middleton	11,848	13,785	15,770	18,810	58.8%
Monona	8,809	8,637	8,018	7,833	-11.1%
Stoughton	7,589	8,786	12,354	12,698	67.3%
Sun Prairie	12,931	15,352	20,369	31,810	146.0%
Verona	3,336	5,374	7,052	11,871	255.8%
County Total	323,545	367,085	426,526	508,395	57.1%

\* Indicates a municipality that crosses into an adjacent county. Only the population of the portion in Dane County is counted.

Source: 2016-2017 Dane County Directory, Dane County Clerk

### 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. Dane County is also showing significant population growth in younger age groups as well. Table 3.3.2 indicates a summary of Dane County population by age group.

Table 3.3.2 Dane County Population by Age Group, 2000 to 2015 Census Trends

Age Group (in Years)	2000 Census	2015 (Estimate)	2000-2015 Change
Under 5	25,818	31,217	20.9%
5 to 17	74,173	78,734	6.1%
18 to 24	57,151	72,014	26.0%
25 to 34	68,386	81,126	18.6%
35 to 44	70,108	68,889	-1.7%
45 to 54	60,220	68,289	13.4%
55 to 64	30,801	63,823	107.2%
65 to 74	20,211	37,838	87.2%
75 to 84	14,255	17,111	20.0%
85 or over	5,403	8,621	59.6%
Total Population	426,526	527,662	23.7%
Median Age	33.2	34.8	

Source: Census Reporter, <https://censusreporter.org/profiles/05000US55025-dane-county-wi/> accessed Jan, 2017.

### 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	Number of Households	Percent
Less than \$10,000	9,498	4.4%
\$10,000 to \$14,999	8,525	3.9%
\$15,000 to \$24,999	16,279	7.6%
\$25,000 to \$34,999	18,522	8.6%
\$35,000 to \$49,999	27,423	12.7%
\$50,000 to \$75,000	42,589	19.7%
\$75,000 to \$99,999	30,923	14.3%
\$100,000 to \$149,000	33,747	15.6%
\$150,000 to \$199,999	14,630	6.8%
\$200,000 or more	13,913	6.4%
Total Number of Households	216,049	100%
Median Household Income (in dollars)	\$65,202	

Source: Census Reporter, <https://censusreporter.org/profiles/05000US55025-dane-county-wi/> accessed Jan, 2017.

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

Poverty Status	Population	Percent
Population for whom poverty status is determined		
Under 5 years	3,600	11.5%
5 to 17 years	7,413	9.4%
18 to 24 years	24,562	34.1%
25 to 34 years	9,385	11.6%
35 to 44 years	3,538	5.1%
45 to 54 years	4,166	6.1%
55 to 65 years	2,762	4.3%
65 to 74 years	1,332	3.5%
75 years and older	1,282	14.9%
Total	58,040	11.4%

Source: Census Reporter, <https://censusreporter.org/profiles/05000US55025-dane-county-wi/> accessed Feb, 2017.

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 People 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 44,000 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 2015 census estimates.

Table 3.3.5 Number of People with Disabilities

Disability Status from the 2011 to 2015 Census Estimates	Number	Percent
Number of People with Hearing Difficulty		
Juvenile, under 18 years	551	0.5%
Adult, 18 years and over	12,589	2.7%
Number of People with Vision Difficulty		
Juvenile, under 18 years	482	0.4%
Adult, 18 years and over	5,969	1.4%
Number of People with Cognitive Difficulty		
Juvenile, under 18 years	2,879	2.6%
Adult, 18 years and over	7,753	1.9%
Number of People with Ambulatory Difficulty		
Juvenile, under 18 years	519	0.5%
Adult, 18 years and over	19,656	2.8%
Number of People with Self-Care Difficulty		
Juvenile, under 18 years	739	0.6%
Adult, 18 years and over	7,600	1.8%
Number of People with Independent Living Difficulty		
Adult, 18 years and over	15,684	3.8%

Source: American Fact Finder, US Census Bureau, Disability Characteristics Table, accessed Feb, 2017

### 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

<b>Ethnicity and Language Spoken from the 2015 Census Estimates</b>	<b>Number</b>	<b>Percent</b>
Total Population	510,198	
Born in the United States	468,954	91.9%
Foreign Born	41,244	8.1%
Europe	5,650	(1.1%)
Asia	18,931	(3.7%)
Africa	2,145	(0.4%)
Oceania	247	(.04%)
Latin America	12,950	(2.5%)
North America	1,278	(0.3%)
Language Spoken at Home		
Population 5 years and older	479,462	
Speak English only	426,241	88.2%
Speak Spanish	24,932	5.2%
Speak Indo-European Languages	11,986	2.5%
Speak Asian and Pacific Island Languages	17,740	3.7%
Speak Other Languages	1917	0.4%
Speak English “less than very well”	21,575	4.5%

Source: American Fact Finder, US Census Bureau, Disability Characteristics Table, accessed Feb, 2017

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



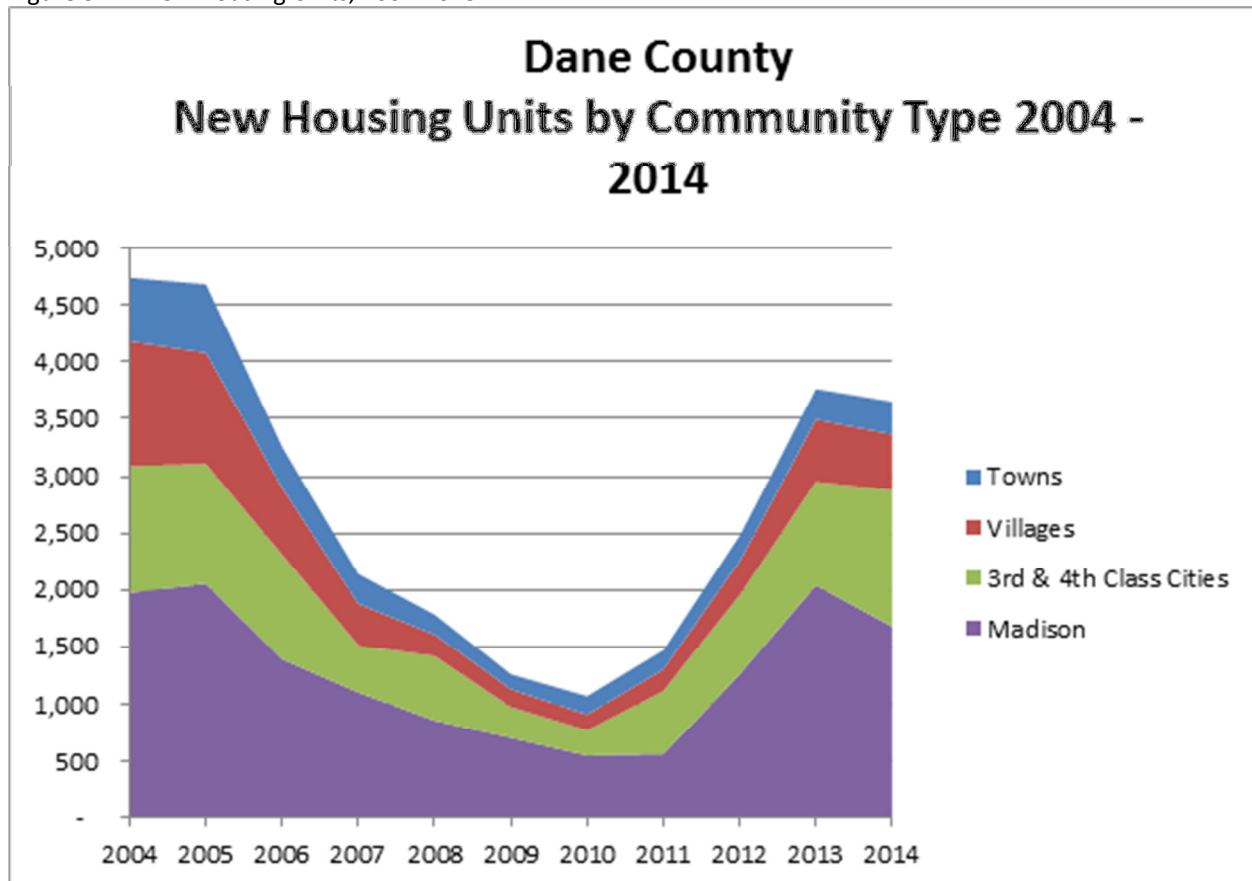
change and the supporting infrastructure improvements. Population growth and housing trends are compiled and published annually by the Capital Area Regional Planning Commission.

### 3.4 Housing

#### 3.4.1 Housing Growth

According to the U.S. Bureau of the Census, there were 220,503 housing units in Dane County at the end of 2015. 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

Since the late 1970s, over one-half of the County’s households have been one- or two-person households. This trend has led to a decrease in the County’s average household size. As households

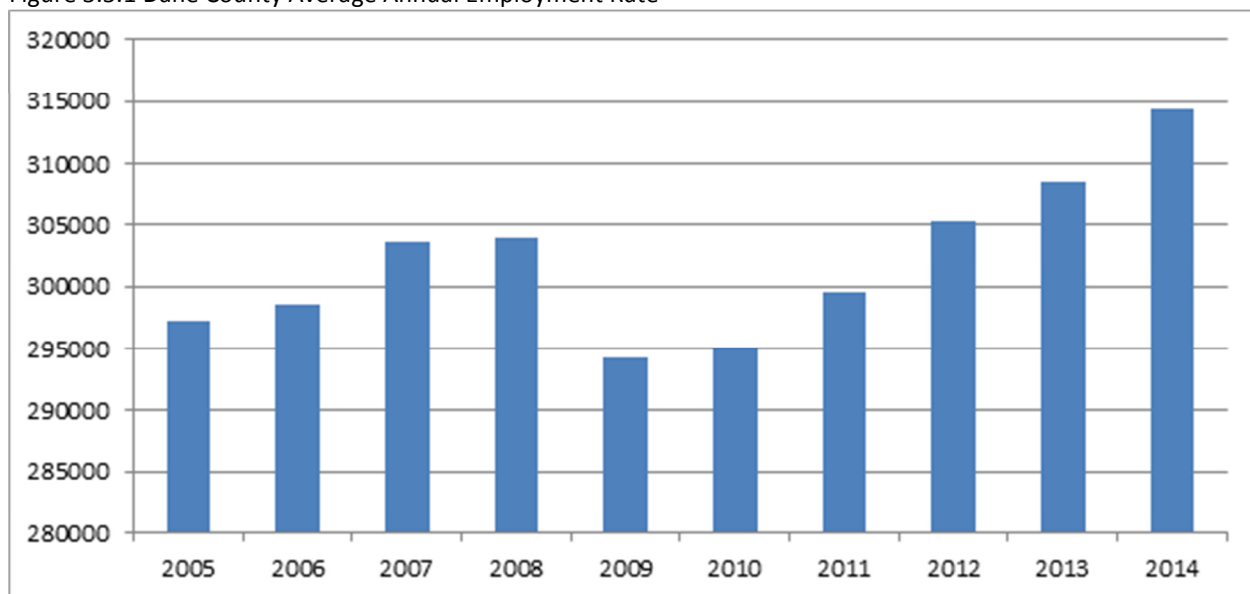
decline in size, the need for additional housing increases. The County will require over 201,000 housing units (occupied units plus vacant available units) by 2020. This means that 25,326 additional housing units would have to be constructed.

Figure 3.4.1 shows actual data for new construction between 2004 and 2014. Housing construction has followed national trends in recent years, peaking in 2004, with 4,742 new units, then dropping precipitously and bottoming-out in 2010 with a low of 1,070 new units constructed. Since 2010, new housing starts rebounded, led by a fivefold (524%) growth in new multifamily units between 2010 and 2013, before levelling off again in 2014. Total construction permits were issued for 3,651 new housing units in Dane County in 2014, a 30 percent decrease from the 3,763 permits issued in 2013. In 2014, single-family housing construction permits were down up by 2 percent from the previous year. Multifamily housing unit construction was down 24 percent from the previous year.

### 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 all of Dane County has been growing faster than the population. In 2005 there were an estimated 297,213 jobs in the County. By 2014, that number grew 61 percent to 314,412. Figure 3.5.1 shows employment growth in Dane County since 2005.

Figure 3.5.1 Dane County Average Annual Employment Rate



Source: Wisconsin Department of Workforce Development, Quarterly Census of Employment and Wages (QCEW)

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.

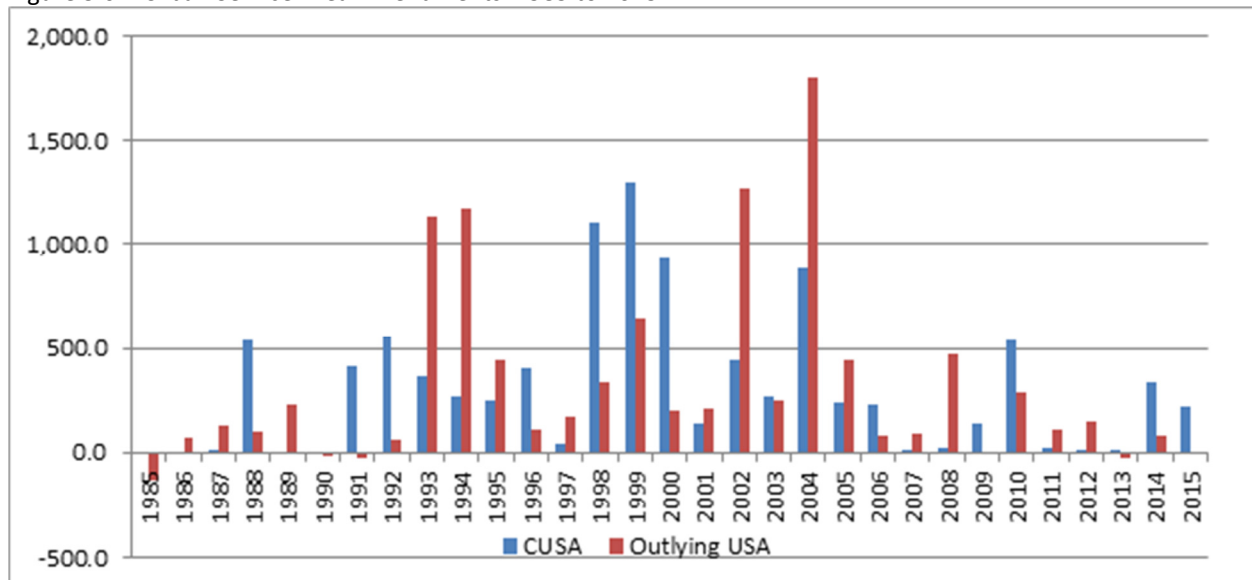
Figure 3.6.1 indicates 2015 land use categories.



### 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 3.6.1 shows a recent history of urban service area amendments.

Figure 3.6.1 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.

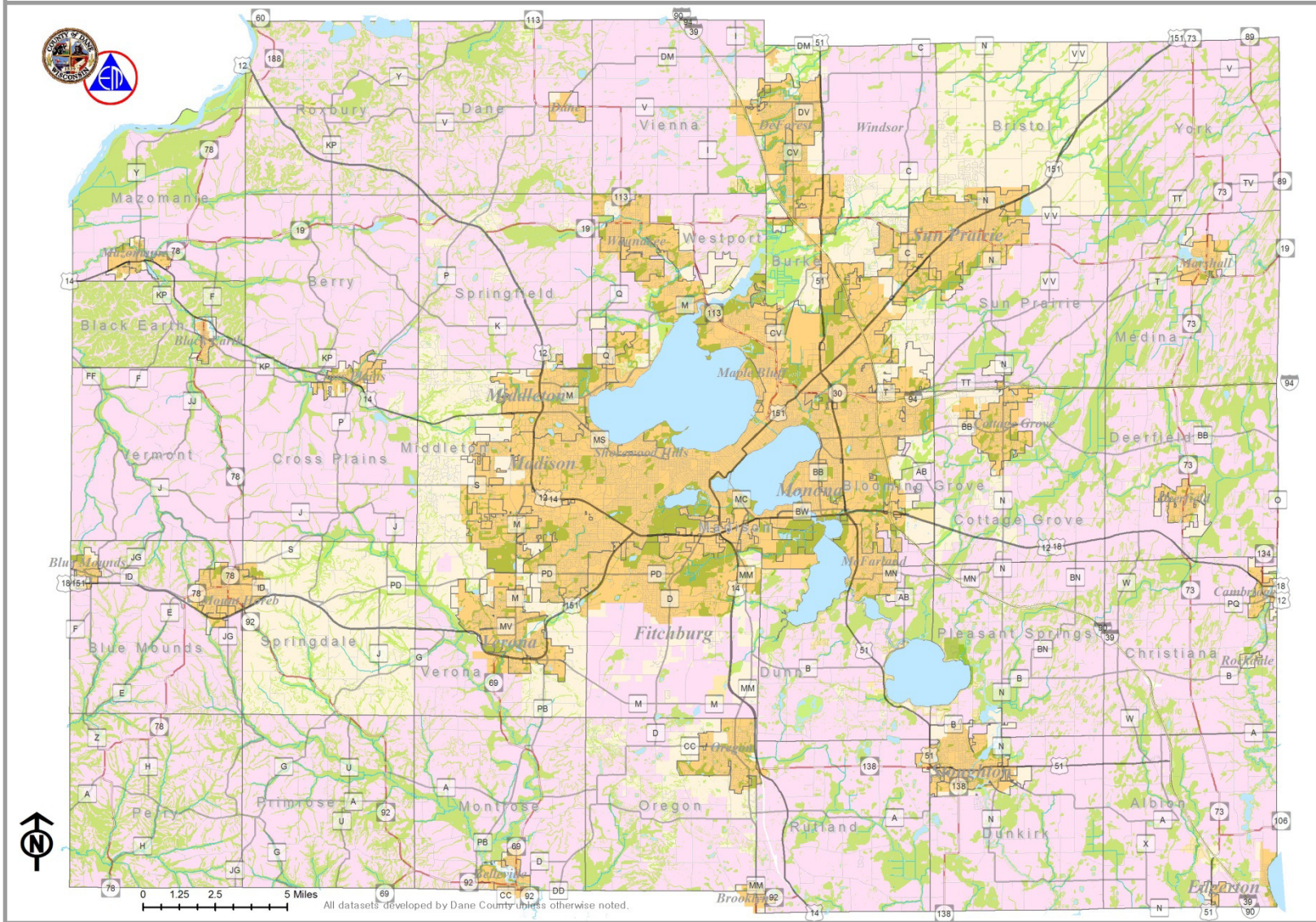
The open space corridors shown on the Regional Development Plan Map include two distinct components: 1) Urban Environmental Corridors within USAs: and 2) Rural Resource Protection Areas in rural areas. Urban environmental corridors are a continuous open space system based on natural features and environmentally 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.

Section 3: Dane County Profile

**Figure 3.6.2**  
**Regional Development**

- Lakes and Rivers
- Environmental Corridor
- Resource Protection Corridor
- Existing Boundaries
- Urban Service Area
- Limited Service Area
- Farmland Preservation
- Rural Development / Transitional Agriculture

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.



### 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.
- *Communications Towers.* There are approximately 220 communication towers in the County owned by governments, individuals, cellular phone companies, hospitals, universities, and television stations. They are instrumental for public safety communications, cellular phone use, television, radio, paging, messaging, and other communications.
- *Correctional Facilities.* In addition to the Dane County jail, there are five state operated correctional facilities in Dane County.
- *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.
- *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.



Section 3: Dane County Profile

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- *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.
- *Natural Gas Supply.* MG&E and Alliant Energy are the largest suppliers of natural gas in the County.
- *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.
- *Public Safety Facilities*
  - 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.
  - 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.
  - 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.

- *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.
- *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.

### 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.

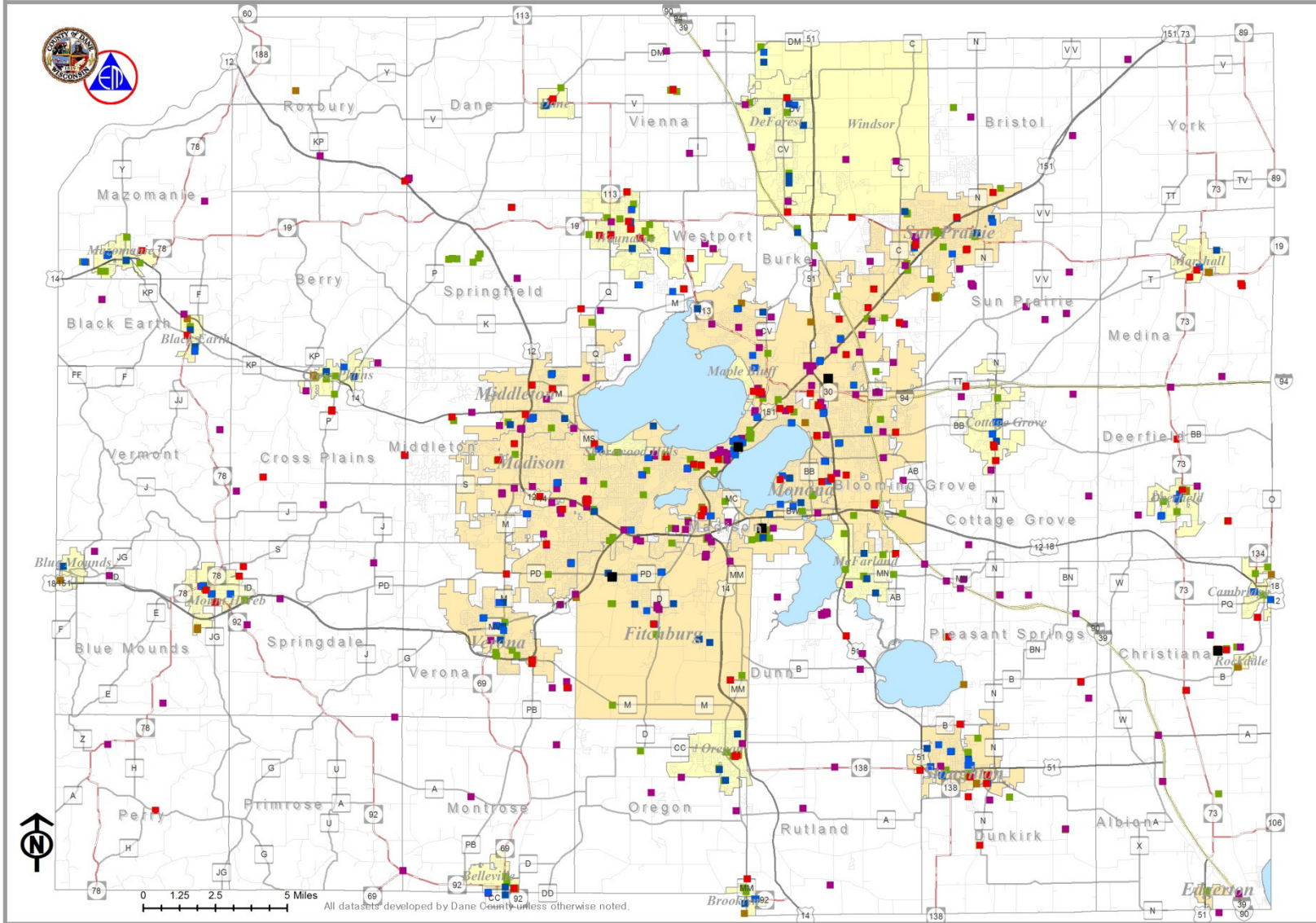
Historic properties and landscapes play a significant role in the region's communities. Buildings offer character and points of interest that cannot be replicated. They enhance the sense of place that makes a local unique and meaningful. Having symbols of the past deepen people's understanding of the 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: Utilities**

- Electrical Generation
- Municipal Water
- Communications
- Electrical Distribution
- Waste Water
- Other

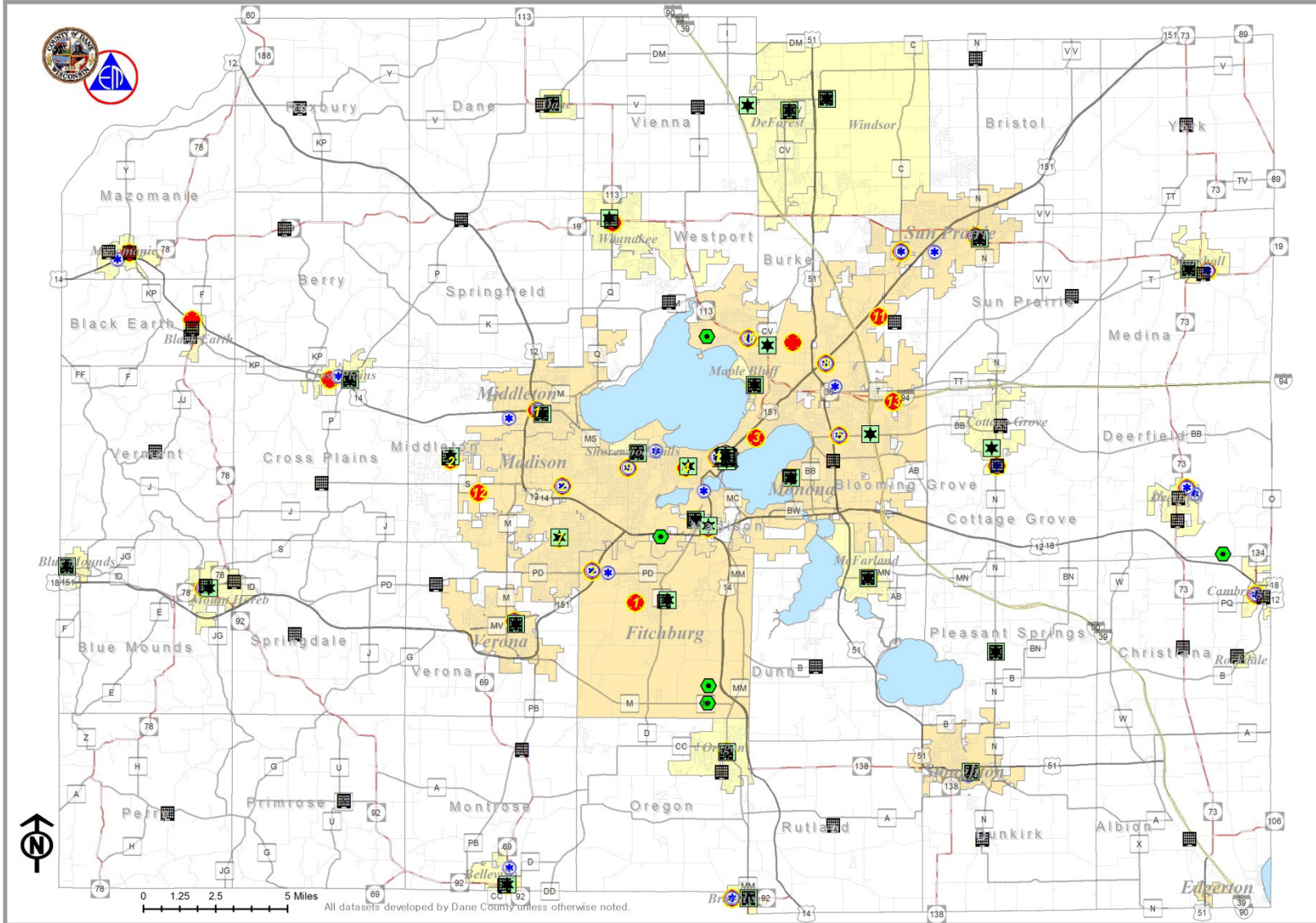
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**Figure 3.7.2**  
**Critical Infrastructure: Government**

-  State Capitol
-  Municipal Buildings
-  EMS Stations
-  Fire Stations
-  Law Enforcement Stations
-  Correctional Facilities

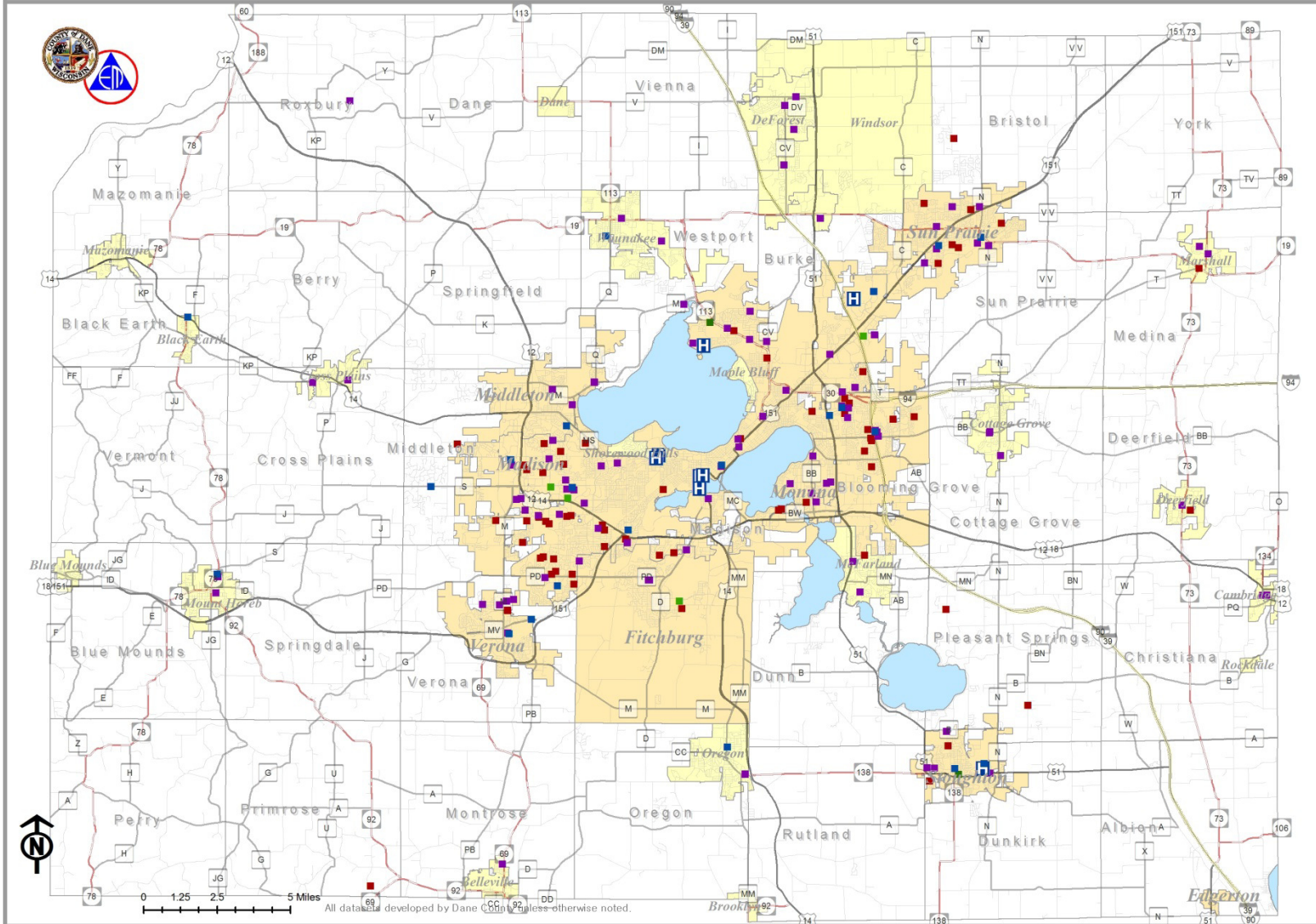
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**Figure 3.7.3**  
**Vulnerable Facilities: Health Care**

- H Hospital
- Community Based Residential Facility
- Hospice Care
- Adult Family Home
- Developmental Disabilities
- Nursing Home

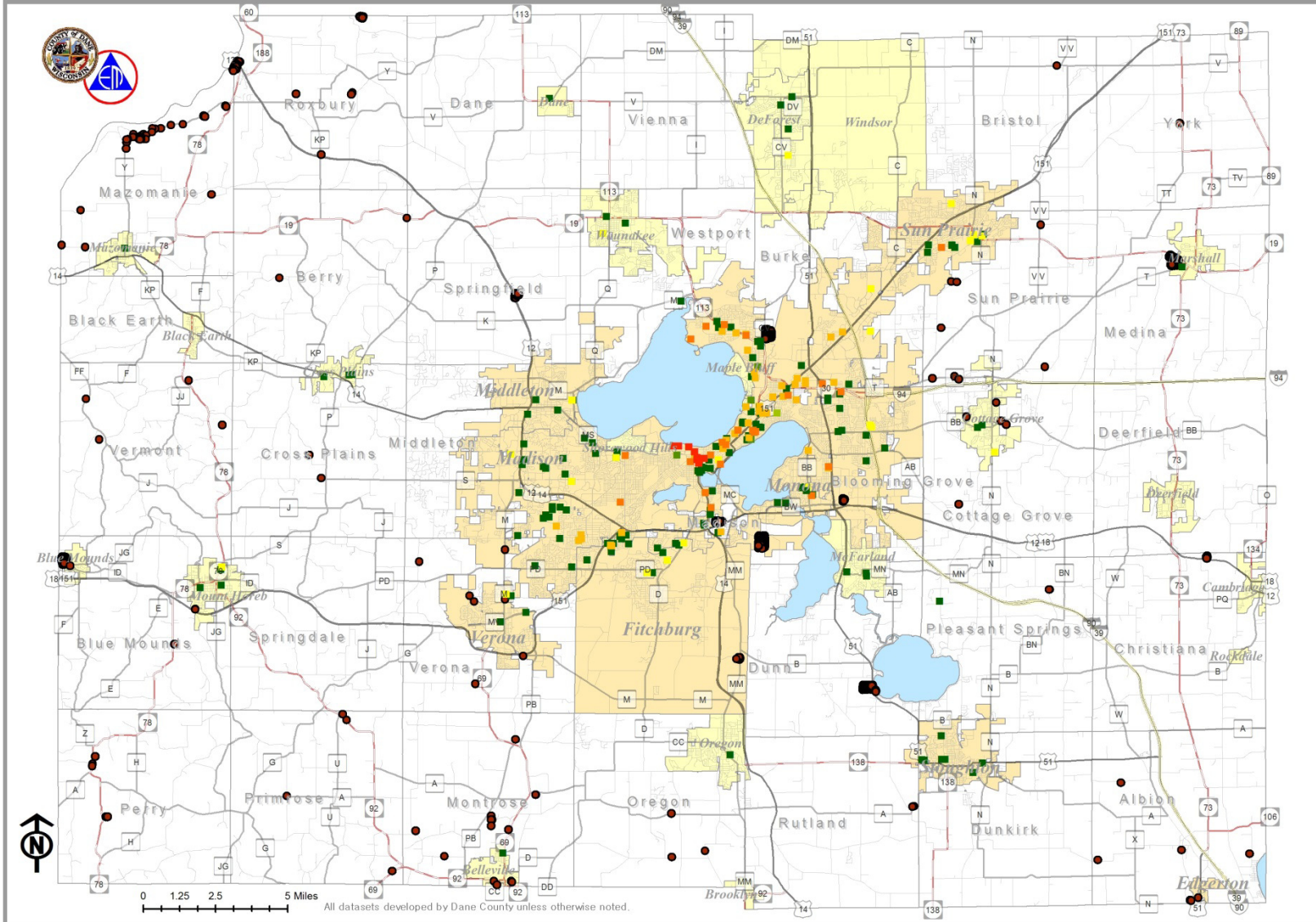
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**Figure 3.7.4**  
**Vulnerable Facilities: Housing**

- Manufactured Homes
- Federally Assisted Housing
- Residential Care Apartment
- Supportive Permanent Housing
- Juvenile Shelter Home
- Juvenile Group Home
- Transitional Housing
- UW Student Housing

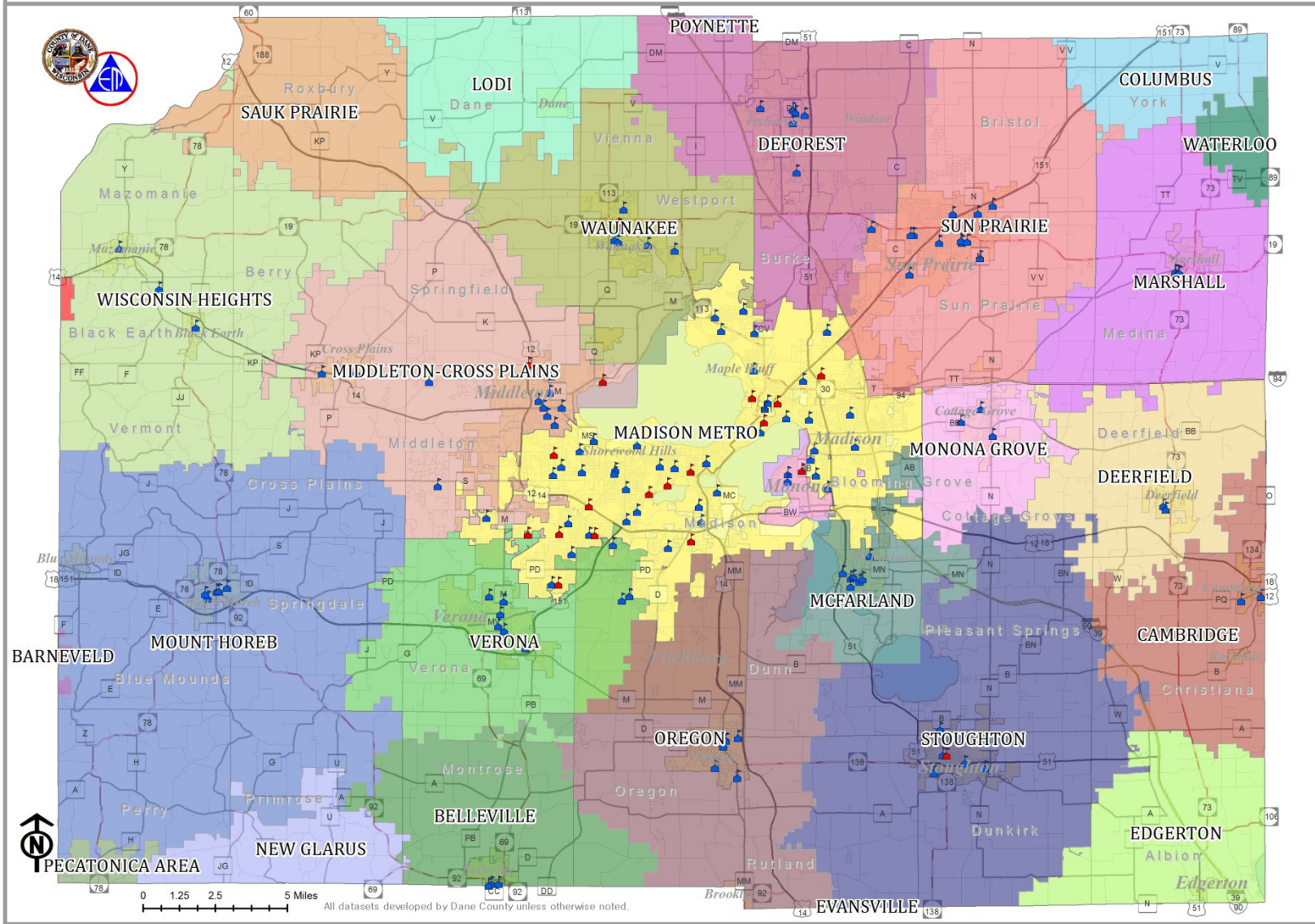
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**Figure 3.7.5**  
**Vulnerable Facilities: Schools and School Districts**

▲ Private School  
▲ Public School

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.





## 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.”<sup>1</sup>

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

<sup>1</sup> FEMA, *Local Mitigation Plan Review Guide*, October 1, 2011

### 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
- Extreme Cold
- Extreme Heat
- Flood
- Fog
- Hail
- Landslide, Erosion, Sinkhole
- Lightning
- Tornado
- Wildfire
- Windstorm
- Winter Storm
- Emerging Hazards

### 4.1.3 Risk Assessment Methodology

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 2005 and updated in 2010. 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 2010 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<sup>2</sup>:

- 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

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<sup>2</sup> Wisconsin Administrative Code, NR 333.06

## Section 4: Risk Assessment

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 mis-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

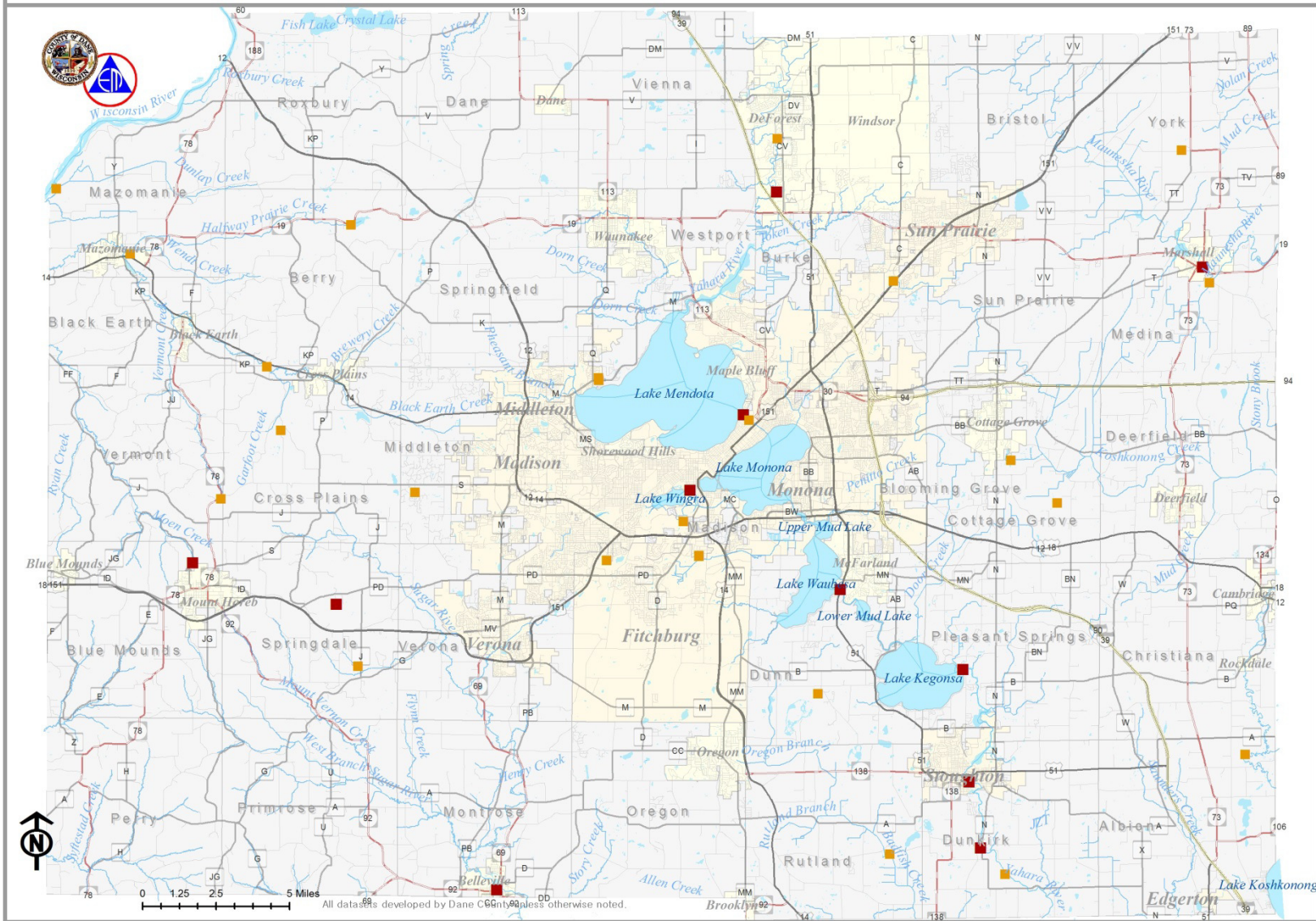
Dam Name/Impound	Hazard Rating	Max Storage (acre ft)	Height (ft)	Stream
Tenney Lock and Dam	High	160,000	5	Yahara River
Stewart Lake	High	90	23.8	Moen Creek
Marshall Grist Mill	Significant	1,100	11	Maunsha River
Belleville	Low	80	11	Sugar River
Brunner	Low	60	10	Sugar River Tributary
Dunkirk	Low	260	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

**Figure 4.2.1**  
**Dams in Dane County**

- Lakes and Ponds
- Large Dam
- Rivers and Streams
- Small Dam

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.



### Emergency Action Plans

All Large dam owners are required by Wisconsin Administrative Code, NR 333.07 to develop an *Emergency Action Plan* describes potential down stream 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.

#### 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*



Prairie du Sac Hydroelectric Project

## Section 4: Risk Assessment

*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



Tenney Lock and Dam

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.

### 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	
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.

### 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.

- *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.<sup>3</sup>
- *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.<sup>4</sup>

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<sup>3</sup> University of Nebraska at Lincoln, National Drought Mitigation Center, <http://drought.unl.edu/droughtbasics/typesofdrought.aspx>. Accessed May, 2017.

<sup>4</sup> Ibid.

- *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.<sup>5</sup>
- *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.<sup>6</sup>

### 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.<sup>7</sup>

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<sup>5</sup> University of Nebraska at Lincoln, National Drought Mitigation Center, <http://drought.unl.edu/droughtbasics/typesofdrought.aspx>. Accessed May, 2017.

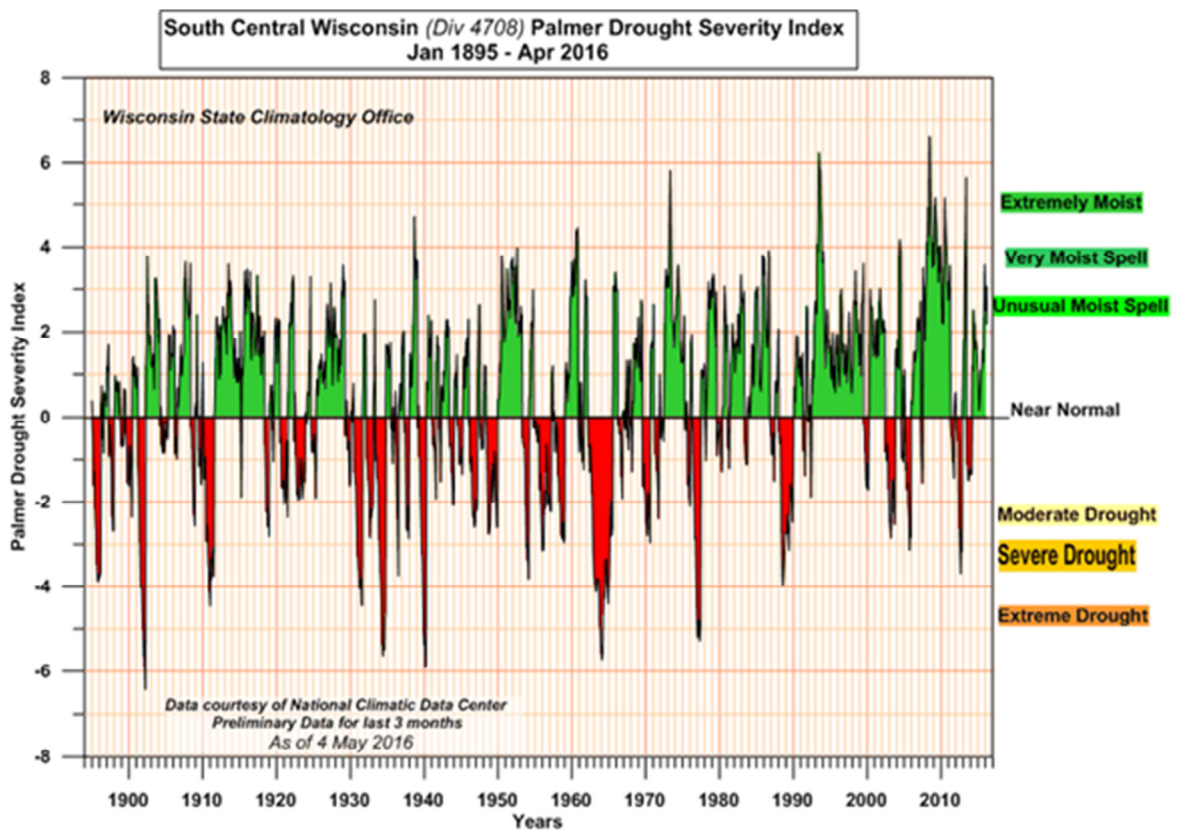
<sup>6</sup> University of Nebraska at Lincoln, National Drought Mitigation Center, “What is Drought? Understanding and Defining Drought”.

<sup>7</sup> University of Nebraska at Lincoln, National Drought Mitigation Center, “Handbook of Drought Indices”. Available online at <http://drought.unl.edu/Planning/Monitoring/HandbookofDroughtIndices.aspx>. Accessed May, 2017.

## Previous Occurrences

Figure 4.3.1 shows the average Palmer Index values from 1895 to 2016. 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: Wisconsin State Climatology Office

### 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.

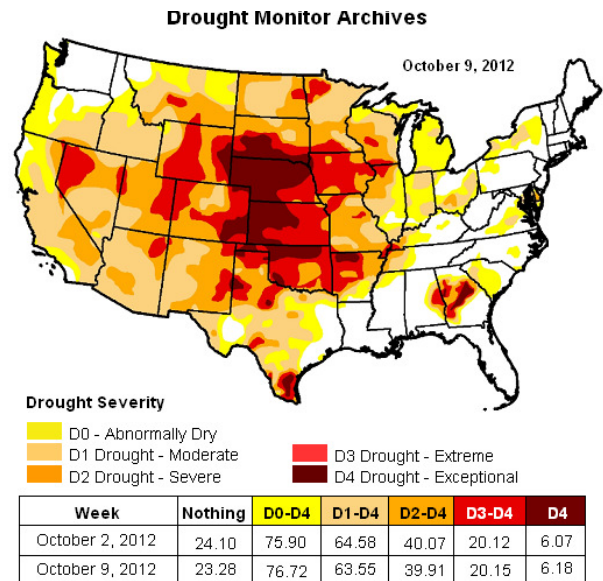
### **2007**

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.<sup>8</sup>

Figure 4.3.2 2012 Drought Severity



Source: National Drought Mitigation Center

**4.3.2 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.

**4.3.3 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.

<sup>8</sup> Data from Wisconsin State Climatologist’s Office

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 affect 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

#### **4.3.4 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.

#### **4.3.5 Potential for Future Losses**

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.

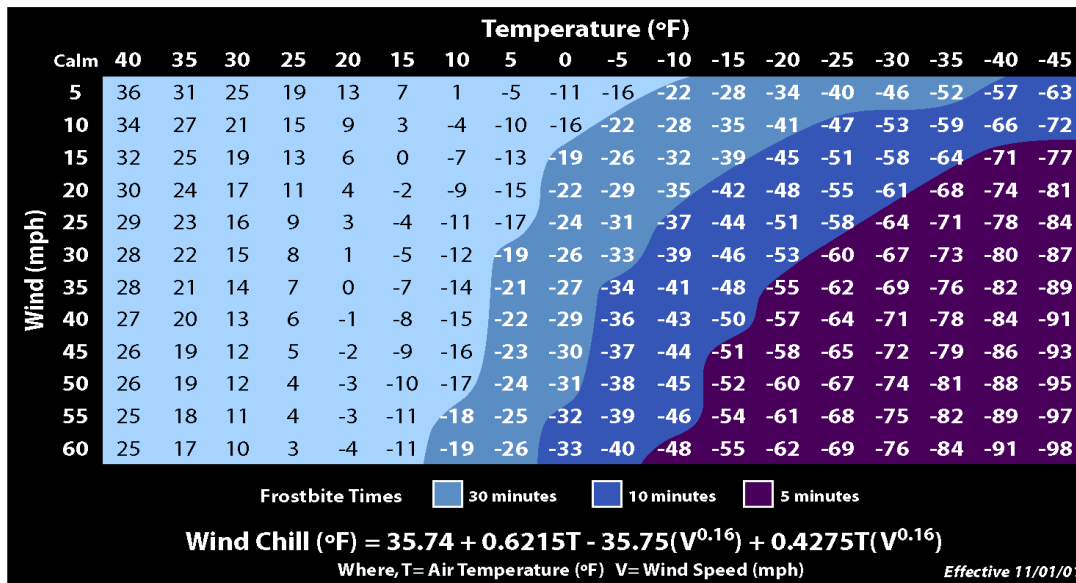
What constitutes extremely cold temperatures varies across different areas of the United States, based on normal climate temperatures for the time of year. In Wisconsin, cold temperatures are normal during the winter. When temperatures drop at least 20 degrees below normal winter lows, the cold is considered 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 advantage 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



Source: National Weather Service

**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 day's 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 2<sup>nd</sup>. 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 3<sup>rd</sup>.

**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 -5°F to -14°F on February 3<sup>rd</sup> with Madison's Truax Field registering -11°F on the 3<sup>rd</sup>. Daytime maximum air temperatures on the 3<sup>rd</sup> ranged from 3°F to 10°F. Early morning low temperatures on the 4<sup>th</sup> ranged from -10°F to -15°F. Afternoon maximum temperatures on the 4<sup>th</sup> never reached the zero mark, totaling -3°F at Madison. The lowest minimum temperatures of the 4-day period occurred on February 5<sup>th</sup>. Maximum afternoon temperatures on the 5<sup>th</sup> ranged from -4°F to 6°F.

## Section 4: Risk Assessment

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 roughest 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.

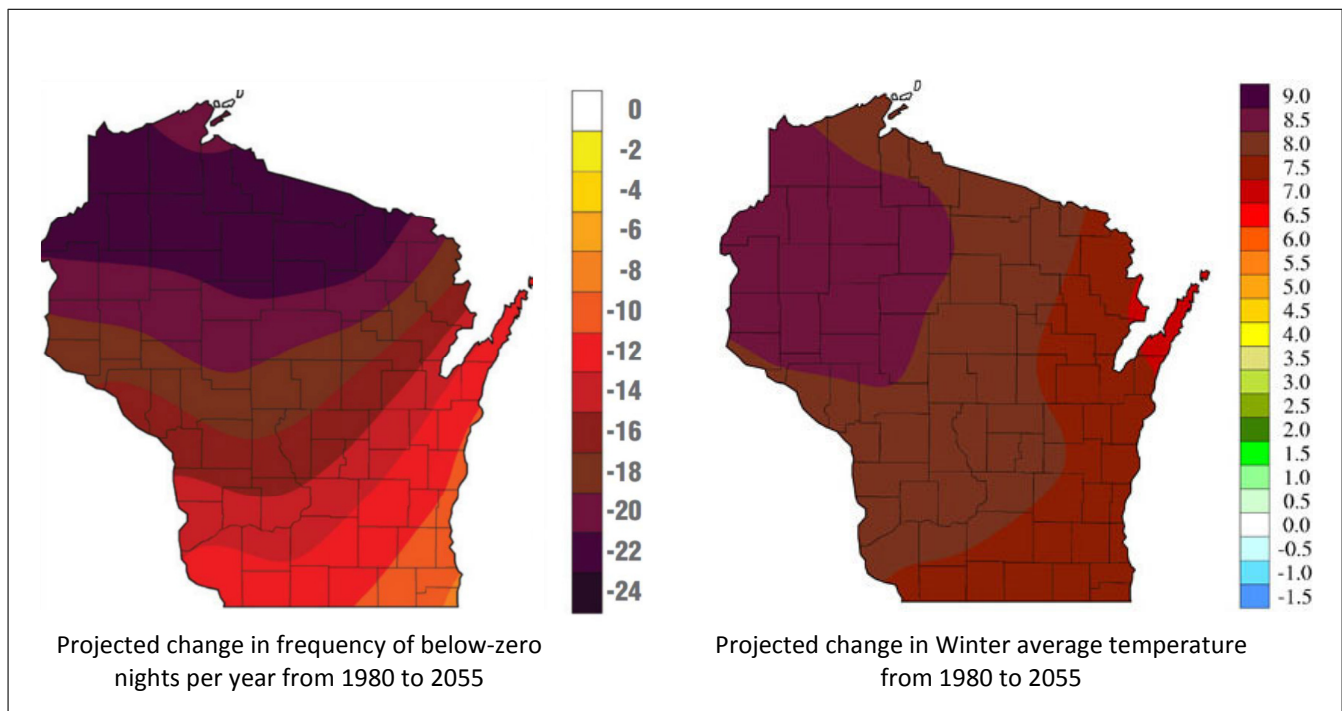


Madison Water Utility: January 8, 2014

#### 4.4.2 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 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. 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 4.4.2 Projected Wintertime Temperature Changes in Wisconsin



Source: Wisconsin Initiative on Climate Change Impacts, 2011

#### 4.4.3 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.

## 4.4.4 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

## 4.4.5 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

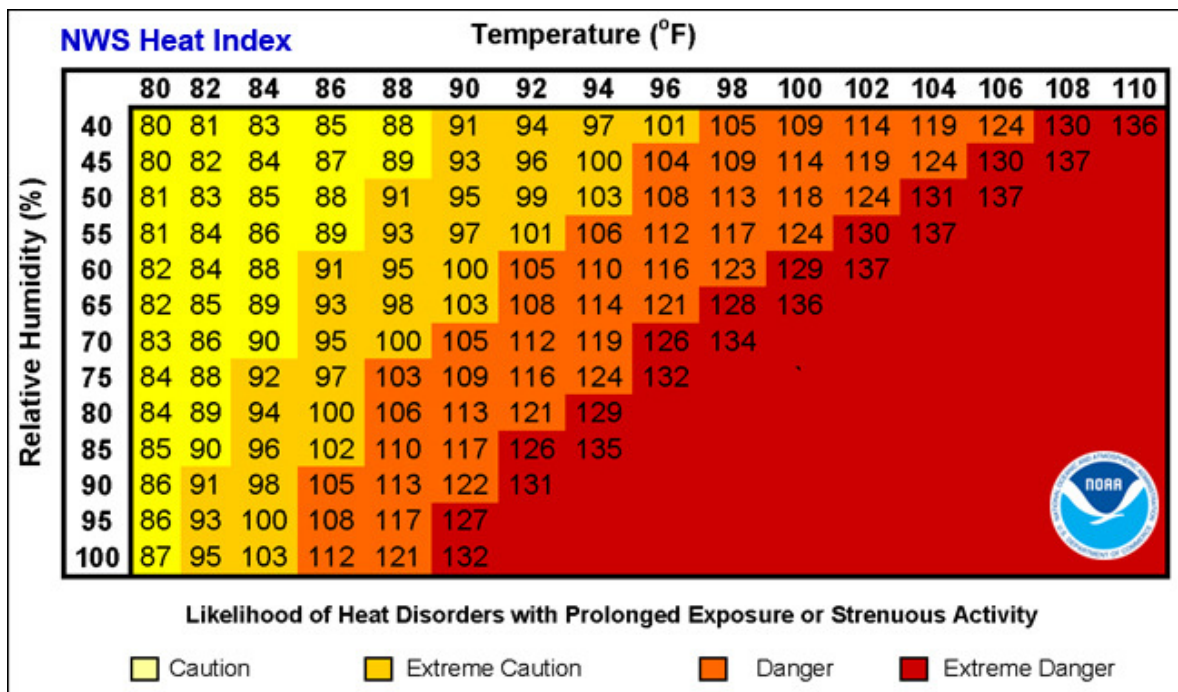
Excessive heat during the summer season is characterized by a combination of very high temperatures and exceptionally humid conditions. Humid or muggy conditions, which add to the discomfort of high temperature, occur when a dome of high atmospheric pressure settles over the southern part of the country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



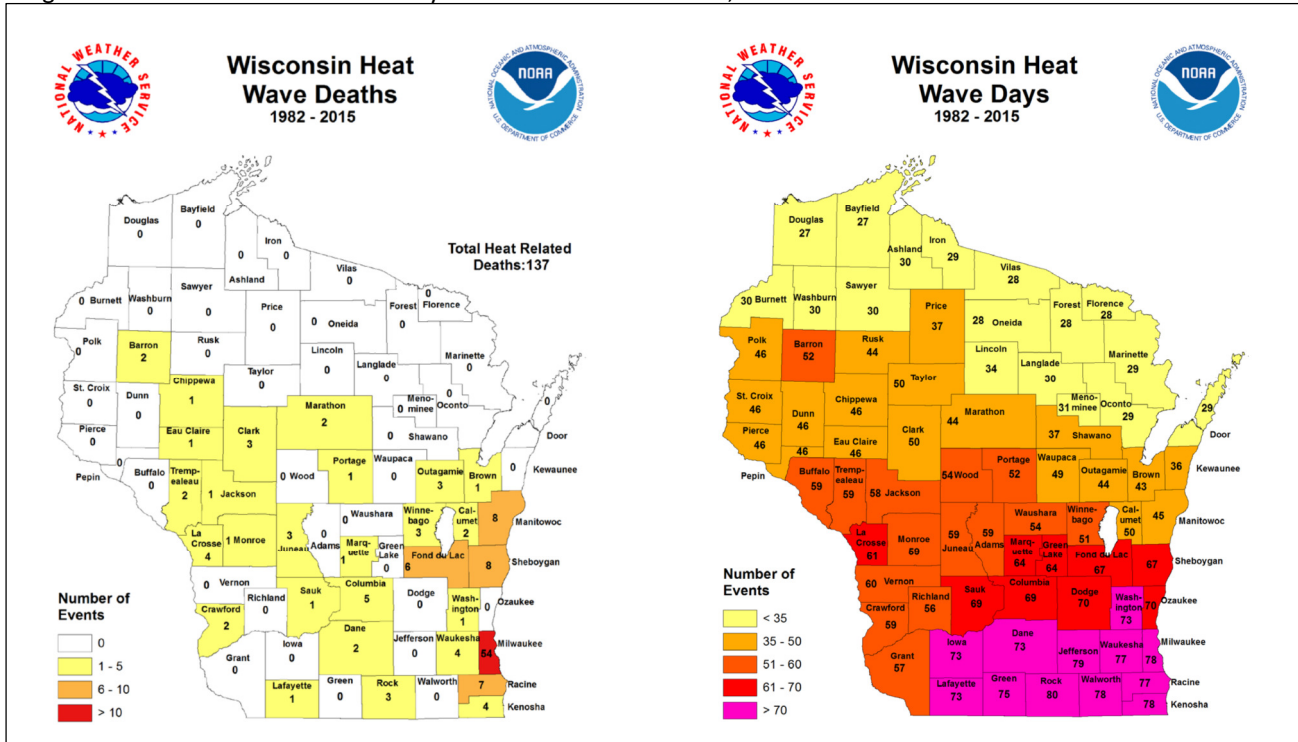
Source: National Weather Service: [http://www.nws.noaa.gov/om/heat/heat\\_index.shtml](http://www.nws.noaa.gov/om/heat/heat_index.shtml)



Previous Occurrences

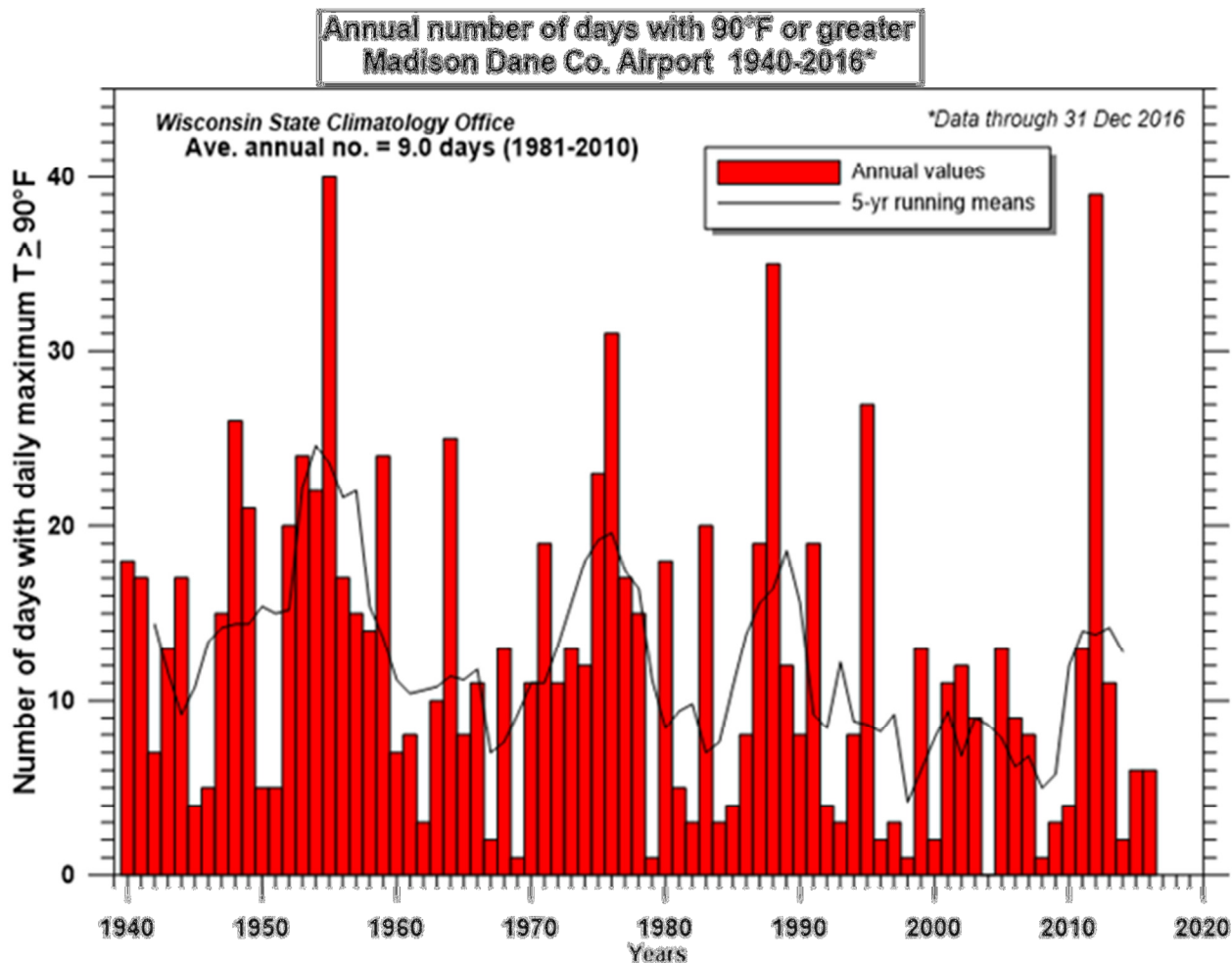
Figures 4.5.2 illustrates the number of heat wave days and heat wave related deaths across Wisconsin. A heat wave day is calendar day in which heat advisory or excessive heat warning was issued. Note that Dane County ranks near the top for both categories. According to the Wisconsin State Climatology 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 4.5.2 Wisconsin Heat Wave Days and Heat-Related Deaths, 1982 to 2015



Source: National Weather Service

Figure 4.5.3 Number of Days above 90°F



Source: Wisconsin State Climatology Office Website

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. 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.

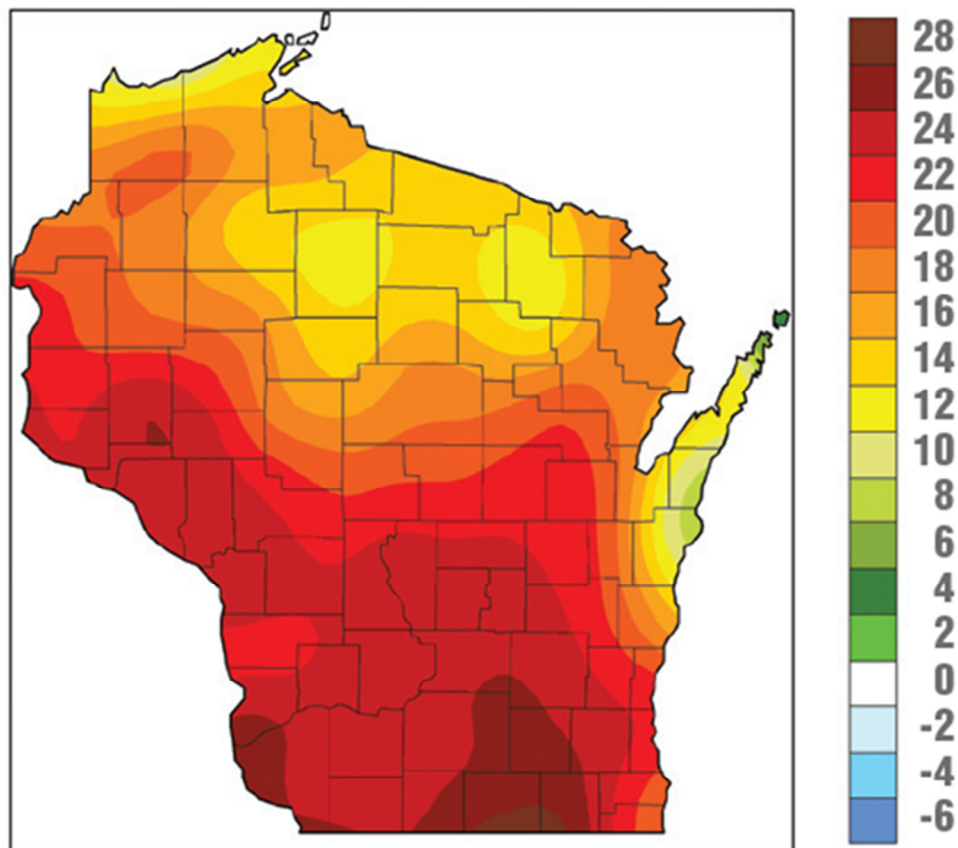
#### 4.5.2 Impact of Climate Change on Future Conditions

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 4.5.4 WICCI projects 22-26 more days above 90 degrees by 2055 from 1980 levels in Dane County. This trend of more dangerously hot days has already begun, but will continue to accelerate. To state this another way: by 2055 Dane County will likely be experiencing an average of nearly one month more of temperatures over 90 degrees compared to 1980.

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 4.5.4 Projected increase in days above 90 degrees Fahrenheit 1980-2055



Source: *Wisconsin's Changing Climate*, Wisconsin Initiative on Climate Change Impacts, 2011.

### 4.5.3 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.<sup>9</sup>

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 factors. 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.

### 4.5.4 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

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<sup>9</sup> MMWR (1995) Heat-wave-related mortality—Milwaukee, Wisconsin. Morbidity and Mortality Weekly Report. July 1995. MMWR 1996;45(24):505-7.

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)<sup>10</sup> program has developed a heat vulnerability index for Dane County. This is shown as Figure 4.5.5. 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.

#### **4.5.5 Potential for Future Losses**

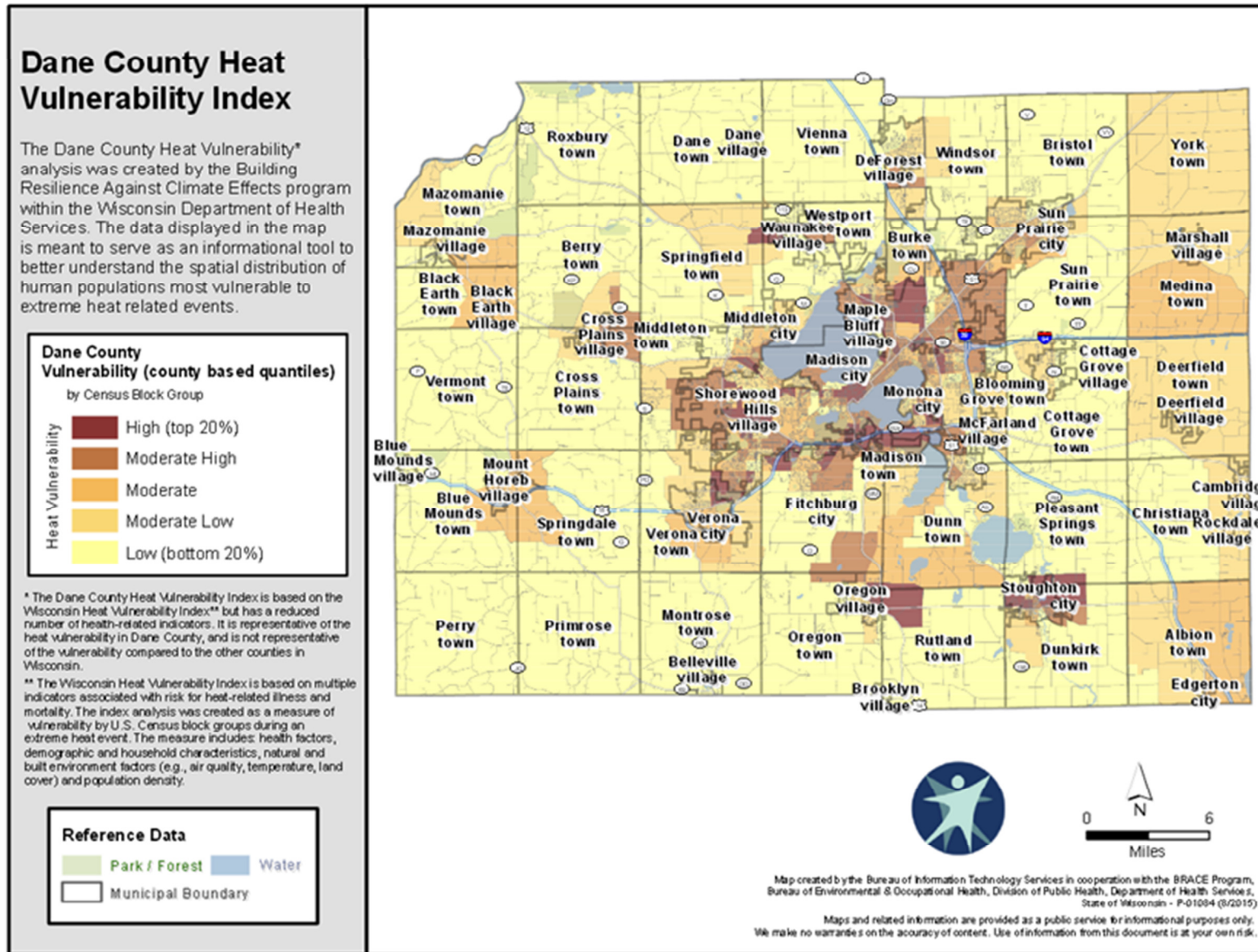
The most vulnerable aspect of Dane County to excessive heat is the population. Due to climate trends, population exposure, and potential fatal impacts, the overall risk to excessive heat is a growing concern. Mitigation against the impacts of future temperature increase may include increasing education 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.

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<sup>10</sup> Wisconsin Department of Health Services, <https://www.dhs.wisconsin.gov/climate/wihvi.htm>

Section 4: Risk Assessment

Figure 4.5.5 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. Stream 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 losses 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 4.6.1 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.

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.<sup>12</sup> 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

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<sup>12</sup> Wisconsin Emergency Management, *Wisconsin Threat and Hazard Identification and Risk Assessment*, 2016

### **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.

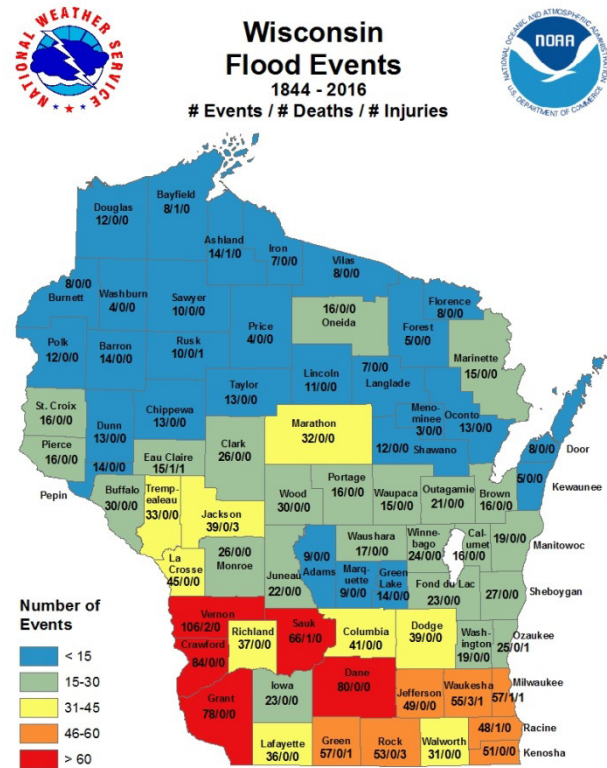
During the time period of the preparation of this plan update, the Lakes and Watershed Commission and the Capital Area Regional Planning Commission established a Stormwater Technical Advisory Committee to evaluate the County's stormwater management strategies and make recommendations regarding flood 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.

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.

**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 4.6.1 shows the number of events, deaths and injuries related to flood events for the entire state of Wisconsin from 1844 to 2016. Dane County shows the third highest total for flood events statewide.

Figure 4.6.2 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 Tornadoes	Presidential Disaster	\$180,000 (Public Assistance)
1990	Flooding and Tornadoes	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.)
2008	Severe Storms, Tornadoes and Flooding	Presidential Disaster	\$1.53 Million (Public Assistance) \$1.76 Million (Individual Assistance) \$1.64 Million (Housing Assistance) \$120,000 (Other Needs) \$35.7 Million (Total Damages, est.)

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. Accounts prior to 2002 are taken from the 2004 Dane County Flood Mitigation Plan. 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.

**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 survey, public meetings, interviews and GIS. 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.

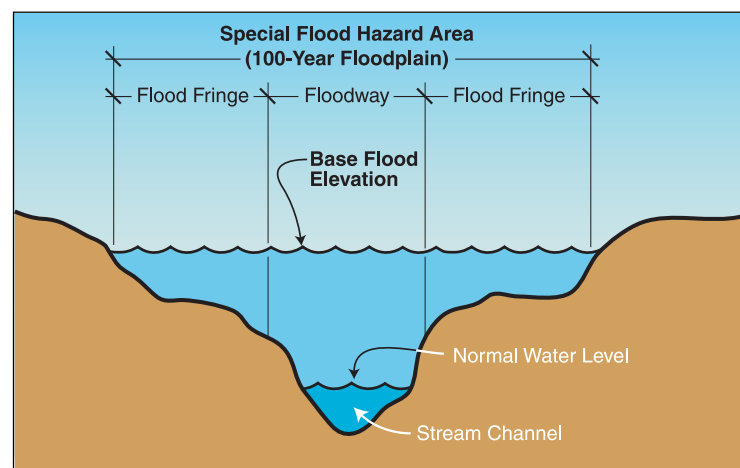
***Development in Flood-prone Areas (Areas with inherent flood risk)***

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.

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.

Figure 4.6.3 Floodplain Definition Sketch.



Source: FEMA, 2001.

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 predictor 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 on page 4-47 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 tilled 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.

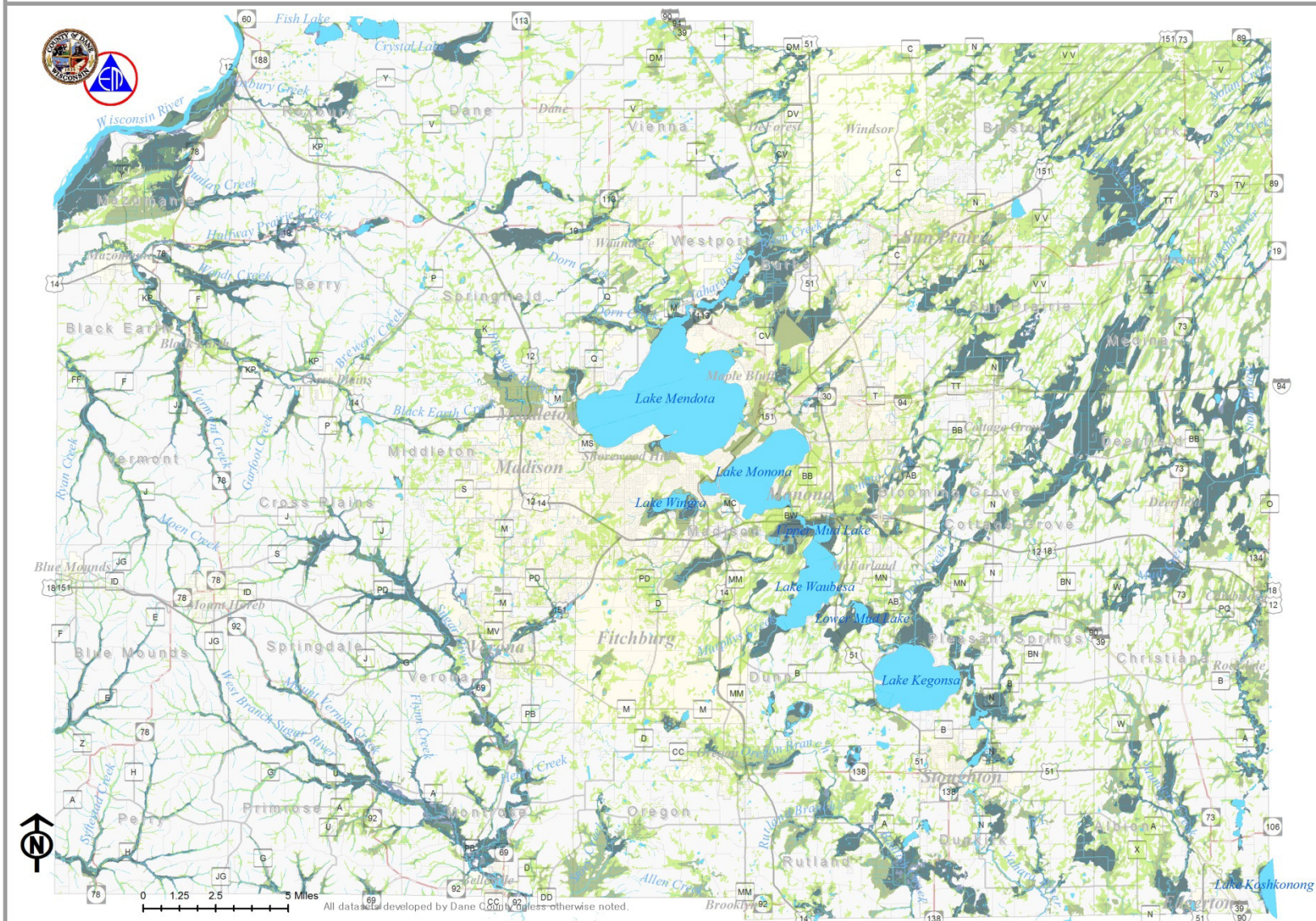
- *Stormwater Issues.* Dane County is among the fastest growing and developing counties in the State of Wisconsin. The challenges of managing this rapid development are wide-ranging; however, one of the more significant impacts is the effect of development on the hydrology of the watershed. The effect 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 baseflows 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**

- 1 Percent Annual Flood Chance Area
- All Hydric Soil
- Predominantly Hydric Soil
- Hydric Soil Inclusions

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.



### 4.6.2 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 4.6.5 shows the statewide distribution of changes in annual average precipitation in this time period.

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)<sup>13</sup>

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 4.6.6 indicates one model’s projected change in annual average precipitation from 1980 to 2055.

Figure 4.6.5  
Change in Annual Average Precipitation (inches) from 1950 to 2006

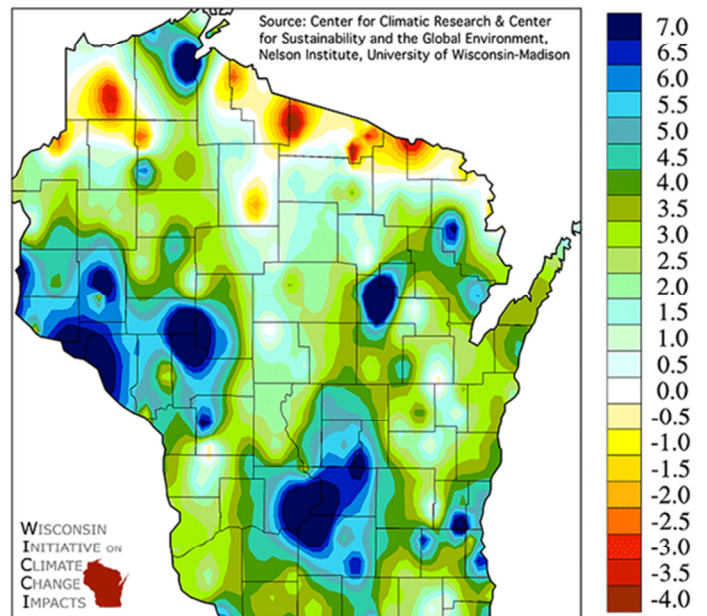
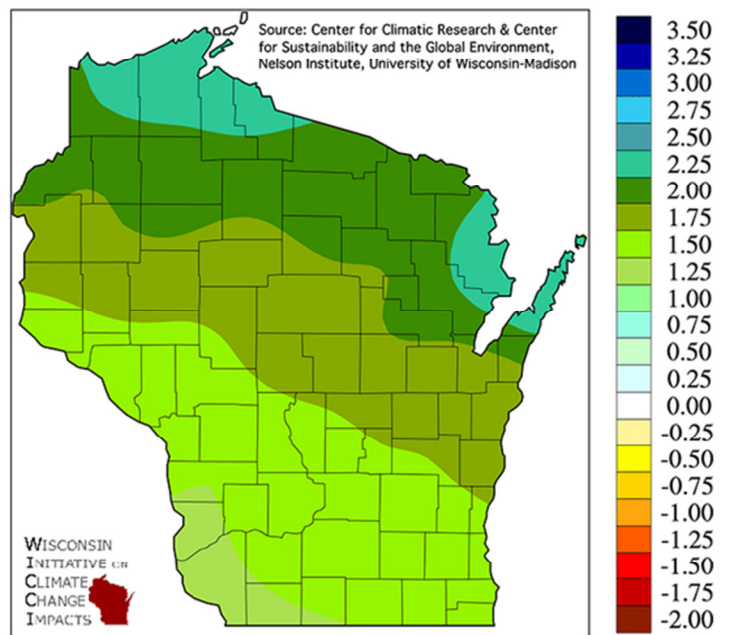


Figure 4.6.6  
Projected Change in Annual Average Precipitation (inches) from 1980 to 2055 (A1B)



<sup>13</sup> Wisconsin Initiative on Climate Change Impacts, *Wisconsin’s Changing Climate, Impacts and Adaptations*, 2011



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 4.6.7 indicates the projected change in the frequency of 2" or greater precipitation events in days per decade in the 1980 to 2055 time period.

#### *Seasonal Variations in Precipitation*<sup>14</sup>

**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.

**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.

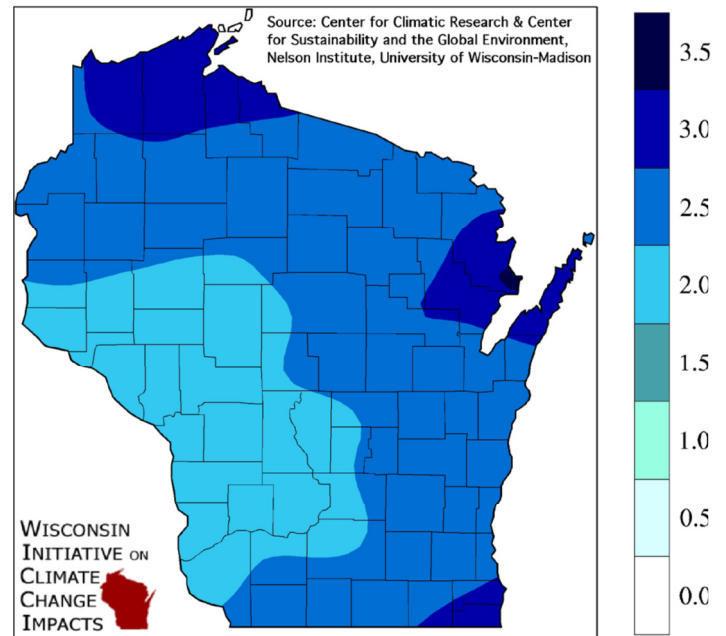
**Autumn:** Fall precipitation is projected to increase slightly by the middle of the next century.

#### **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.

Figure 4.6.7  
Projected Change in the Frequency of 2" Precipitation  
Events (days/decade) from 1980 to 2055



<sup>14</sup> Wisconsin Initiative on Climate Change Impacts, *Wisconsin's Changing Climate, Impacts and Adaptations*, 2011

## Implications

WICCI's most recent predictions indicate that annual average precipitation may continue to increase through 2050, 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, when saturated spring soils and a record summer rainfall combined to create the most damaging flood 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.<sup>15</sup>

### 4.6.3 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.

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<sup>15</sup> Wisconsin Emergency Management, *Wisconsin Threat and Hazard Identification and Risk Assessment*, 2016

- 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 losses 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 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 to 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.

#### **4.6.4 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.

#### **4.6.5 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

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

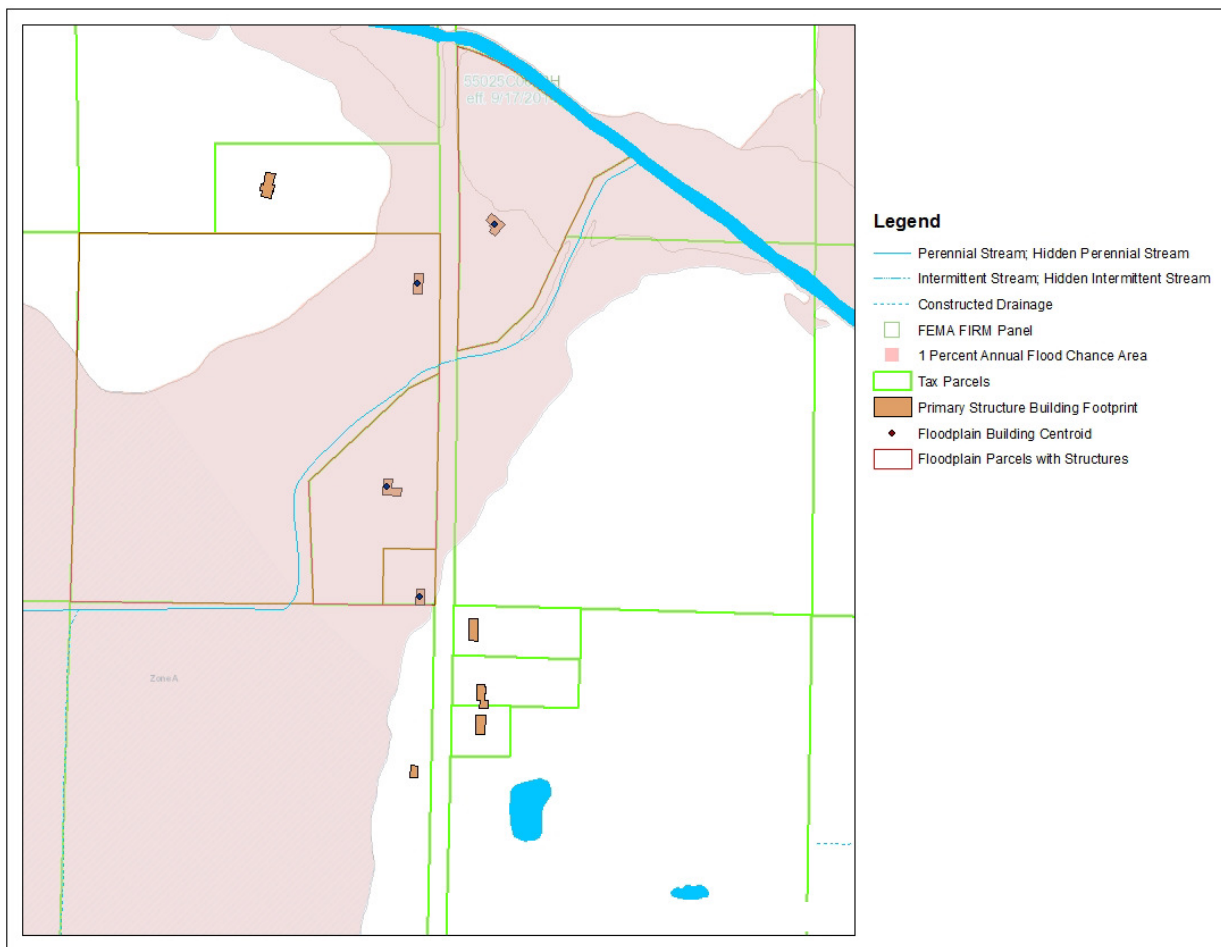
A flood damage assessment for Dane County was estimated by using a comparison of a digital version of FEMA's Flood Insurance Rate Maps, Dane County tax parcel data, and Dane County's building footprint inventory. A preliminary assessment was conducted using a GIS overlay of these three data layers. This 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.

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- 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 4.6.8 100-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 indicates the damage potential estimate by local government jurisdiction.
- Figure 4.6.9 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.

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

Land Use Category	Number of Structures in the 100-year 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
<b>Total</b>	<b>381</b>	<b>596</b>	<b>977</b>	<b>\$207,380,200</b>	<b>\$160,504,950</b>	<b>\$25,409,015</b>	<b>\$20,230,376</b>	<b>\$45,639,391</b>

## Section 4: Risk Assessment

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	Number of Structures in the 100-year 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
Maunsha 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
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

## Section 4: Risk Assessment

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

Municipality	Number of Structures in 100-year 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 of Edgerton	0	0	0	\$0	\$0	\$0	\$0	\$0
City of Fitchburg	1	0	1	\$148,600	\$74,300	\$4,458	\$5,944	\$10,402
City of Madison	61	28	89	\$65,804,900	\$67,972,600	\$13,105,479	\$7,050,532	\$20,156,011
City of Middleton	17	3	20	\$11,303,000	\$9,190,300	\$581,987	\$492,879	\$1,074,866
City of Monona	52	7	59	\$17,633,300	\$12,417,500	\$1,094,617	\$1,171,421	\$2,266,038
City of Stoughton	10	6	16	\$3,426,500	\$2,319,850	\$279,891	\$232,643	\$512,534
City of Sun Prairie	6	1	7	\$1,762,000	\$906,100	\$123,023	\$162,022	\$285,045
City of Verona	16	11	27	\$3,652,700	\$2,533,450	\$414,059	\$298,374	\$712,433
Town of Albion	50	2	52	\$4,349,500	\$2,242,050	\$454,374	\$586,065	\$1,040,439
Town of Berry	8	4	12	\$1,554,500	\$777,250	\$138,945	\$185,260	\$324,205
Town of Black Earth	0	0	0	\$0	\$0	\$0	\$0	\$0
Town of Blooming Grove	0	0	0	\$0	\$0	\$0	\$0	\$0
Town of Blue Mounds	5	0	5	\$631,200	\$315,600	\$70,742	\$94,323	\$165,065
Town of Bristol	0	0	0	\$0	\$0	\$0	\$0	\$0
Town of Burke	0	0	0	\$0	\$0	\$0	\$0	\$0
Town of Christiana	4	0	4	\$657,700	\$328,850	\$30,407	\$40,542	\$70,949
Town of Cottage Grove	5	0	5	\$1,139,400	\$569,700	\$38,184	\$50,912	\$89,096
Town of Cross Plains	6	0	6	\$1,084,200	\$542,100	\$43,352	\$57,803	\$101,155
Town of Dane	1	0	1	\$299,600	\$149,800	\$51,681	\$68,908	\$120,589
Town of Deerfield	0	0	0	\$0	\$0	\$0	\$0	\$0
Town of Dunkirk	7	1	8	\$1,091,800	\$545,900	\$93,662	\$124,883	\$218,545
Town of Dunn	94	4	98	\$13,445,300	\$7,726,350	\$844,903	\$951,799	\$1,796,702
Town of Madison	0	0	0	\$0	\$0	\$0	\$0	\$0
Town of Mazomanie	51	0	51	\$4,265,200	\$2,132,600	\$297,662	\$396,883	\$694,545

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Municipality	Number of Structures in 100-year 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
Town of Medina	1	0	1	\$261,300	\$130,650	\$29,396	\$39,195	\$68,591
Town of Middleton	0	0	0	\$0	\$0	\$0	\$0	\$0
Town of Montrose	20	4	24	\$2,764,800	\$1,836,600	\$189,792	\$180,384	\$370,176
Town of Oregon	0	0	0	\$0	\$0	\$0	\$0	\$0
Town of Perry	1	0	1	\$151,900	\$75,950	\$4,557	\$6,076	\$10,633
Town of Pleasant Springs	35	0	35	\$4,642,700	\$2,321,350	\$195,634	\$260,845	\$456,479
Town of Primrose	2	0	2	\$241,600	\$120,800	\$18,744	\$24,992	\$43,736
Town of Roxbury	145	1	146	\$7,032,600	\$3,516,300	\$2,062,250	\$2,930,648	\$4,992,898
Town of Rutland	6	0	6	\$1,039,100	\$519,550	\$91,688	\$122,251	\$213,939
Town of Springdale	8	2	10	\$1,839,800	\$1,191,300	\$180,199	\$180,557	\$360,756
Town of Springfield	0	0	0	\$0	\$0	\$0	\$0	\$0
Town of Sun Prairie	2	1	3	\$545,400	\$375,500	\$22,530	\$21,816	\$44,346
Town of Vermont	20	1	21	\$2,496,500	\$1,249,700	\$201,226	\$267,489	\$468,715
Town of Verona	7	1	8	\$946,700	\$506,750	\$76,506	\$94,660	\$171,166
Town of Vienna	0	0	0	\$0	\$0	\$0	\$0	\$0
Town of Westport	77	5	82	\$18,681,700	\$12,013,650	\$1,326,578	\$1,465,353	\$2,791,931
Town of York	2	0	2	\$285,300	\$142,650	\$8,559	\$11,412	\$19,971
Village of Belleville	9	3	12	\$1,121,600	\$568,350	\$60,449	\$79,994	\$140,443
Village of Black Earth	13	1	14	\$1,975,500	\$1,123,250	\$88,395	\$107,020	\$195,415
Village of Blue Mounds	0	0	0	\$0	\$0	\$0	\$0	\$0
Village of Brooklyn	0	0	0	\$0	\$0	\$0	\$0	\$0
Village of Cambridge	4	8	12	\$1,823,100	\$2,172,950	\$468,678	\$243,203	\$711,881
Village of Cottage Grove	0	0	0	\$0	\$0	\$0	\$0	\$0
Village of Cross Plains	36	11	47	\$10,999,900	\$8,473,000	\$1,780,604	\$1,333,939	\$3,114,543
Village of Dane	0	0	0	\$0	\$0	\$0	\$0	\$0
Village of Deerfield	0	0	0	\$0	\$0	\$0	\$0	\$0

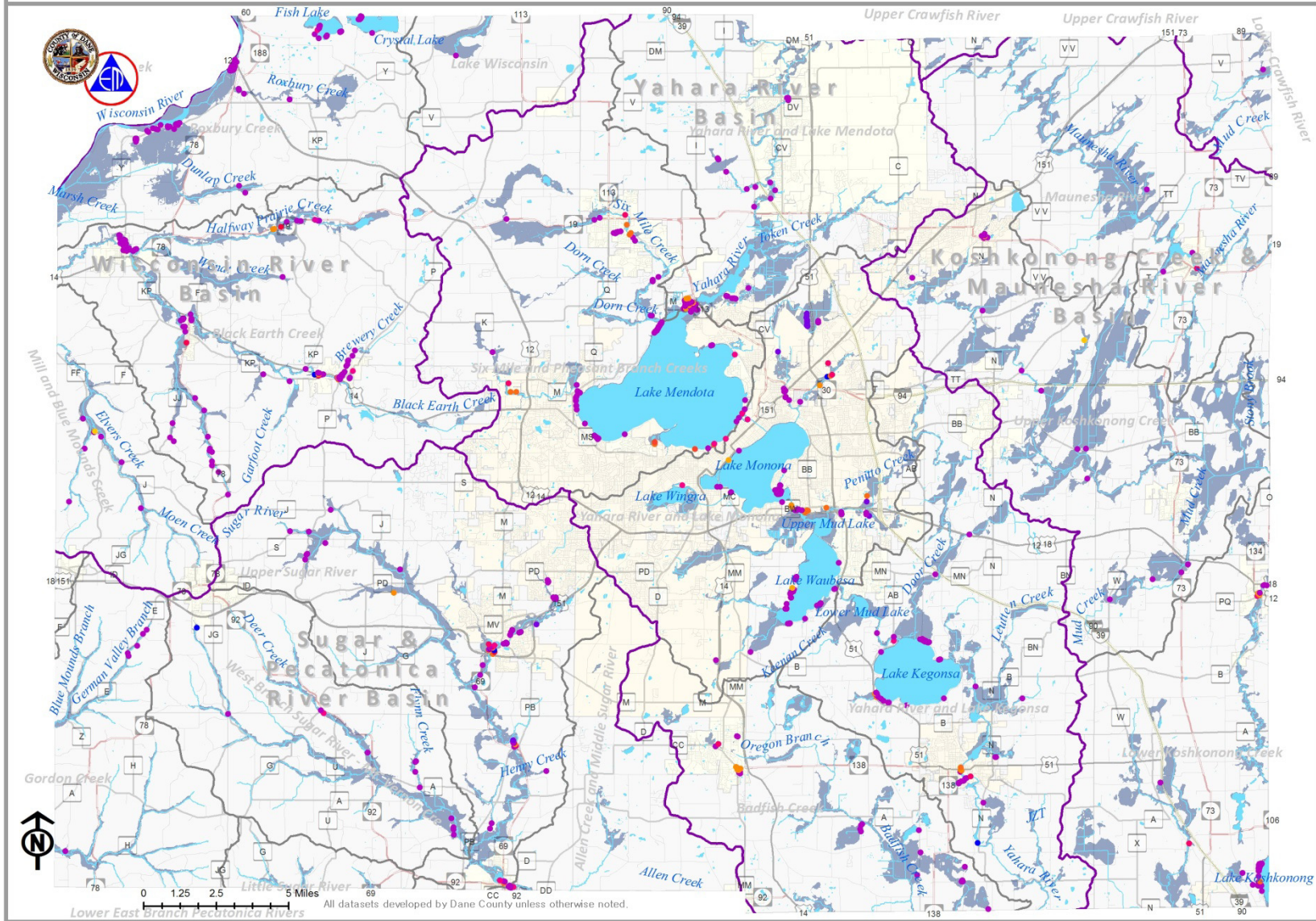
## Section 4: Risk Assessment

Municipality	Number of Structures in 100-year 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
Village of DeForest	5	0	5	\$520,300	\$260,150	\$26,282	\$35,043	\$61,325
Village of Maple Bluff	1	1	2	\$325,500	\$162,750	\$9,765	\$13,020	\$22,785
Village of Marshall	0	2	2	\$177,000	\$92,550	\$6,404	\$7,647	\$14,051
Village of Mazomanie	39	2	41	\$4,124,200	\$2,171,300	\$239,039	\$294,694	\$533,733
Village of McFarland	1	0	1	\$17,800	\$8,900	\$534	\$712	\$1,246
Village of Mount Horeb	0	1	1	\$0	\$0	\$0	\$0	\$0
Village of Oregon	8	7	15	\$9,895,400	\$8,770,400	\$531,075	\$402,284	\$933,359
Village of Rockdale	0	0	0	\$0	\$0	\$0	\$0	\$0
Village of Shorewood Hills	1	0	1	\$0	\$0	\$0	\$0	\$0
Village of Waunakee	14	4	18	\$2,569,500	\$1,630,500	\$97,830	\$102,780	\$200,610
Village of Windsor	4	0	4	\$651,600	\$325,800	\$24,877	\$33,169	\$58,046
<b>Total</b>	<b>855</b>	<b>122</b>	<b>977</b>	<b>\$207,380,200</b>	<b>\$160,504,950</b>	<b>\$25,409,015</b>	<b>\$20,230,376</b>	<b>\$45,639,391</b>

**Figure 4.6.9**  
**Primary Structures in Floodplain**

- |                                    |                     |                    |                |
|------------------------------------|---------------------|--------------------|----------------|
| 1 Percent Annual Flood Chance Area | Commercial Sales    | Health             | Residential    |
| Agriculture                        | Commercial Services | Industrial         | Transportation |
| Assembly                           | Education           | Outdoor Recreation | Utility        |
|                                    | Government          | Religion           |                |

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.





### 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 4.6.10 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 4.6.10.

Unmitigated repetitive loss properties with active policies 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 number of 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 2016

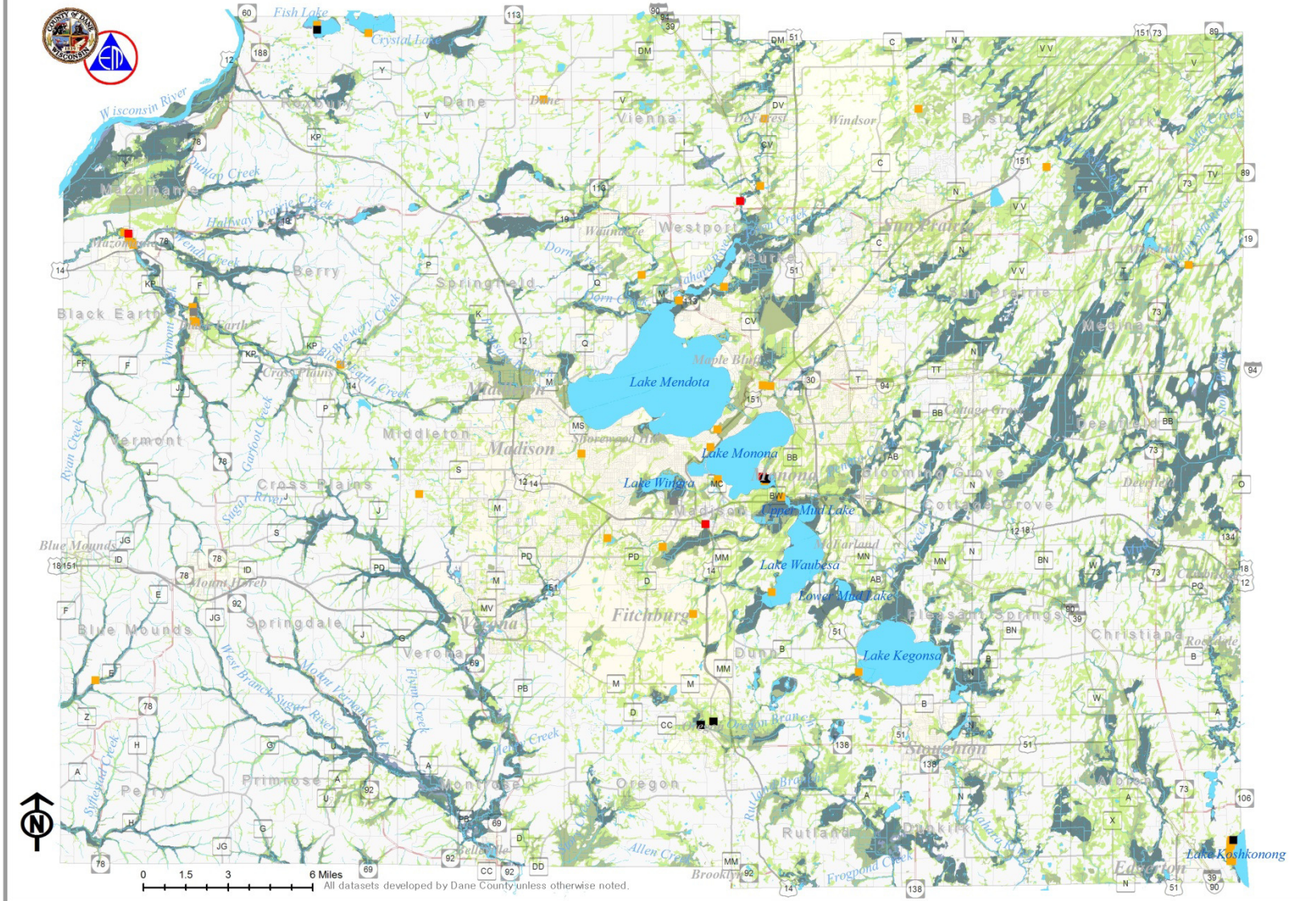
Watershed	Municipality	Flood Year	Number of Paid Claims	Paid Claims Total
Gordon Creek	Town of Blue Mounds	2008	1	\$5,062
Lake Wisconsin	Village of Dane	2007	1	\$15,472
Upper Sugar River	Town of Middleton	2016	1	\$12,210
Maunasha River	Town of Medina	2000	1	\$1,619
	Town of Bristol	2007, 2010	2	\$9,865
	Watershed Total		3	\$11,484
Six Mile and Pheasant Branch Creeks	City of Madison	2000	1	\$3,679
	Town of Westport	2001, 2007	2	\$32,245
	Watershed Total		3	\$35,924

<b>Watershed</b>	<b>Municipality</b>	<b>Flood Year</b>	<b>Number of Paid Claims</b>	<b>Paid Claims Total</b>
Roxbury Creek	Town of Roxbury	2001, 2002, 2008, 2014	6	\$377,291
Yahara River and Lake Kegonsa	Town of Cottage Grove	2007, 2008, 2014	1	\$1,118
	Town of Dunn	1978	6	\$57,452
	Watershed Total		7	\$58,570
Yahara River and Lake Mendota	City of Madison	1998	1	\$1,329
	Village of DeForest	1993, 1996	2	\$8,184
	Village of Windsor	1993	1	\$12,449
	Town of Westport	2004, 2007, 2008	4	\$140,473
	Watershed Total		8	\$162,434
Badfish Creek	Village of Oregon	1978, 1981, 1982, 1984, 1996, 1999	13	\$41,759
Black Earth Creek	Village of Black Earth	1993, 2001, 2004, 2007, 2008	6	\$12,998
	Village of Cross Plains	2001	1	\$1,724
	Village of Mazomanie	1993, 2001	8	\$11,230
	Watershed Total		15	\$25,952
Lower Koshkonong Creek and Lake Koshkonong	Town of Albion	1993, 2008	21	\$1,127,142
	Town of Christiana	1980, 1982	3	\$1,629
	Watershed Total		24	\$1,128,771
Yahara River and Lake Monona	City of Fitchburg	1981, 1996, 2008	5	\$18,407
	City of Madison	1978, 1996, 1997	5	\$7,631
	City of Monona	1993, 1996, 2000, 2001	8	\$47,363
	Town of Dunn	2008	1	\$5,476
	Town of Madison	1978, 1981, 1996, 2001, 2014, 2016	7	\$471,409
	Watershed Total		26	\$550,285

**Figure 4.6.10**  
**NFIP Flood Insurance Claim Status**

- Repetitive Loss - Active Policy
- Repetitive Loss - Mitigated
- Repetitive Loss - Not Active Policy
- Paid Claim - Not Repetitive Loss
- 1 Percent Annual Flood Chance Area
- All Hydric Soil
- Predominantly Hydric Soil
- Hydric Soil Inclusions

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.



## 2008 Flood Damage Analysis

The June 2008 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 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 4.6.11 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 :

- 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 include:

- 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 combined 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

Flood Risk Indicator	Primary Structures in Dane County Building Footprint Inventory		2008 Paid Claims (FEMA Individual and Household Assistance plus Flood Insurance)	
	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%

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.

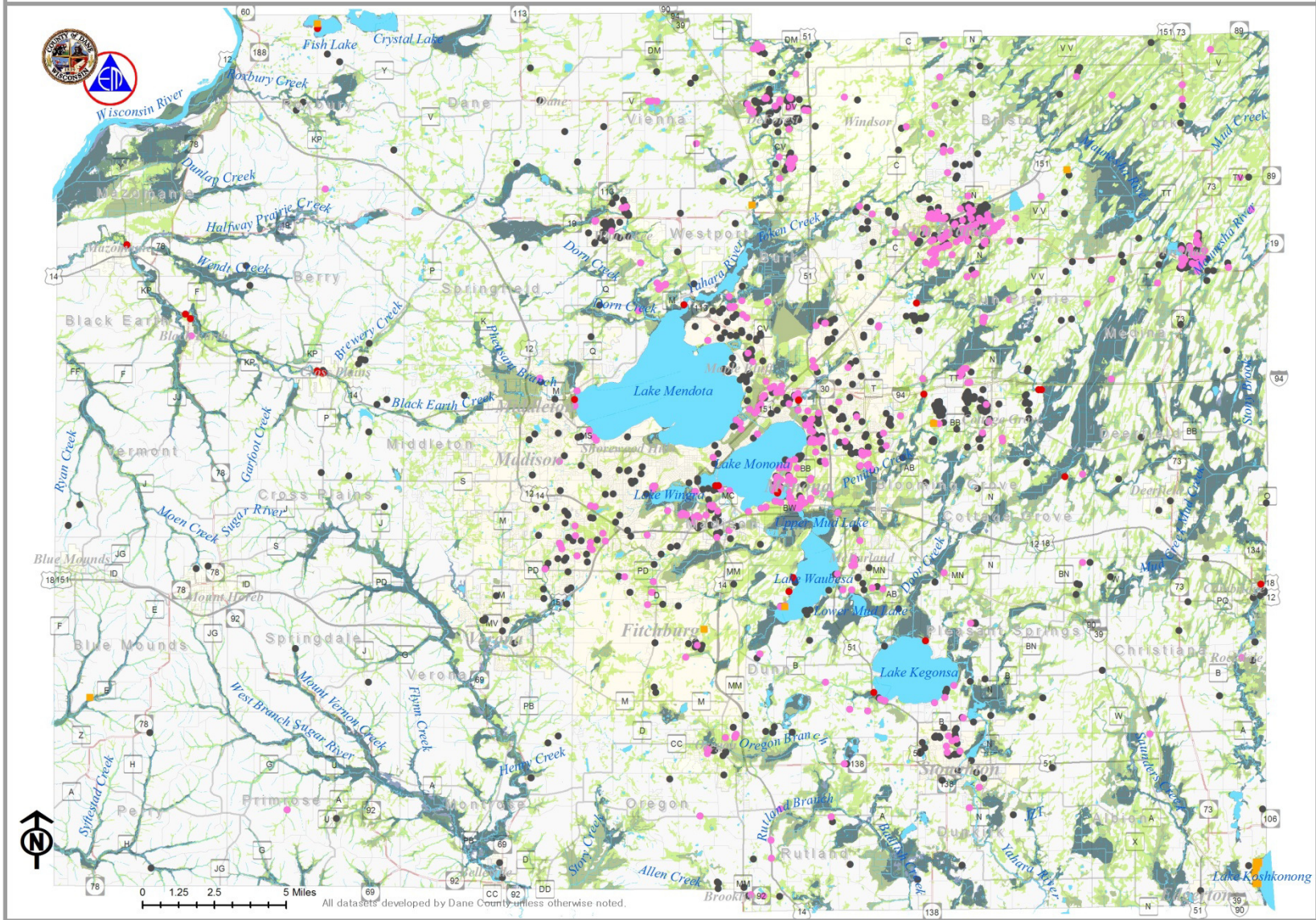
These are not dramatically disproportionate differences in the locations where damage occurred, but a higher level of flood risk is still apparent. Even so, with 60% of the damage claims occurring outside of these areas, it is clear that additional factors are in play. Flood damages are more widely distributed 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 4.6.11**  
**June 2008 Flood Damage Claims**

- FEMA Paid IHA Damage Claims in Floodplain
- FEMA Paid IHA Damage Claims in Hydric Soils
- FEMA Paid IHA Damage Claims not in Flood Hazard Areas
- Paid Flood Insurance Claims
- 1 Percent Annual Flood Chance Area
- All Hydric Soil
- Predominantly Hydric Soil
- Hydric Soil Inclusions

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.



### 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.<sup>16</sup> 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<sup>17</sup>:

- 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.

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<sup>16</sup> Wisconsin Initiative on Climate Change Impacts, *Stormwater Working Group Report*, 2011

<sup>17</sup> IBID



**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.

Section 4: Risk Assessment

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

## 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.

### 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.

**4.7.2 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.

**4.7.3 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.<sup>18</sup> Table 4.7.1 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
<b>Totals</b>	<b>3</b>	<b>92</b>	<b>177</b>	<b>272</b>

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.



<sup>18</sup> WisDOT AADT for Site 131506. Available at: <https://trust.dot.state.wi.us/roadrunner/>

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.

#### **4.7.4 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.<sup>19</sup>

#### **4.7.5 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.

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<sup>19</sup> Airport passenger numbers available at:  
[http://www.transtats.bts.gov/airports.asp?pn=1&Airport=MSN&Airport\\_Name=Madison,%20WI:%20Truax%20Field&carrier=FACTS](http://www.transtats.bts.gov/airports.asp?pn=1&Airport=MSN&Airport_Name=Madison,%20WI:%20Truax%20Field&carrier=FACTS)

## 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.

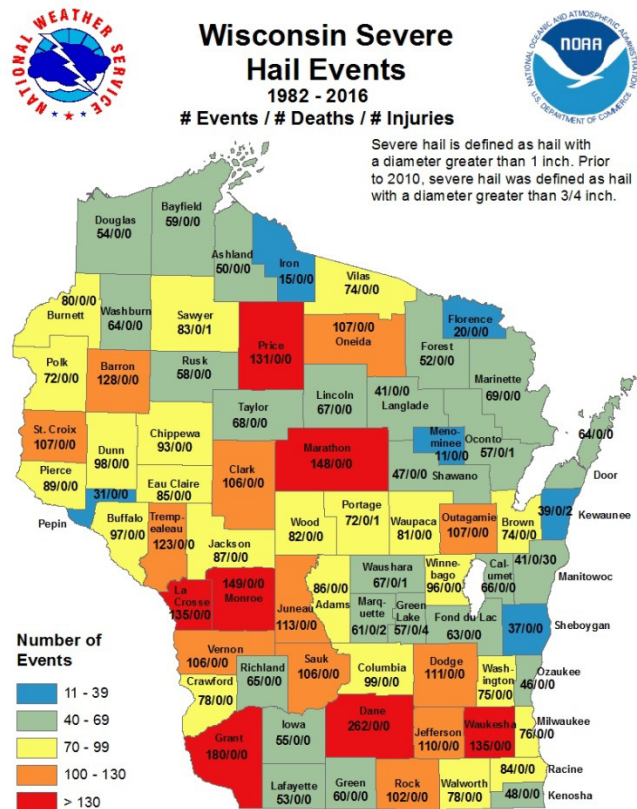
### Previous Occurrences

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 2016. 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 2016. 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



Source: National Weather Service

**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.

**4.8.2 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.

**4.8.3 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.

#### **4.8.4 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.

#### **4.8.5 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.

## 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.

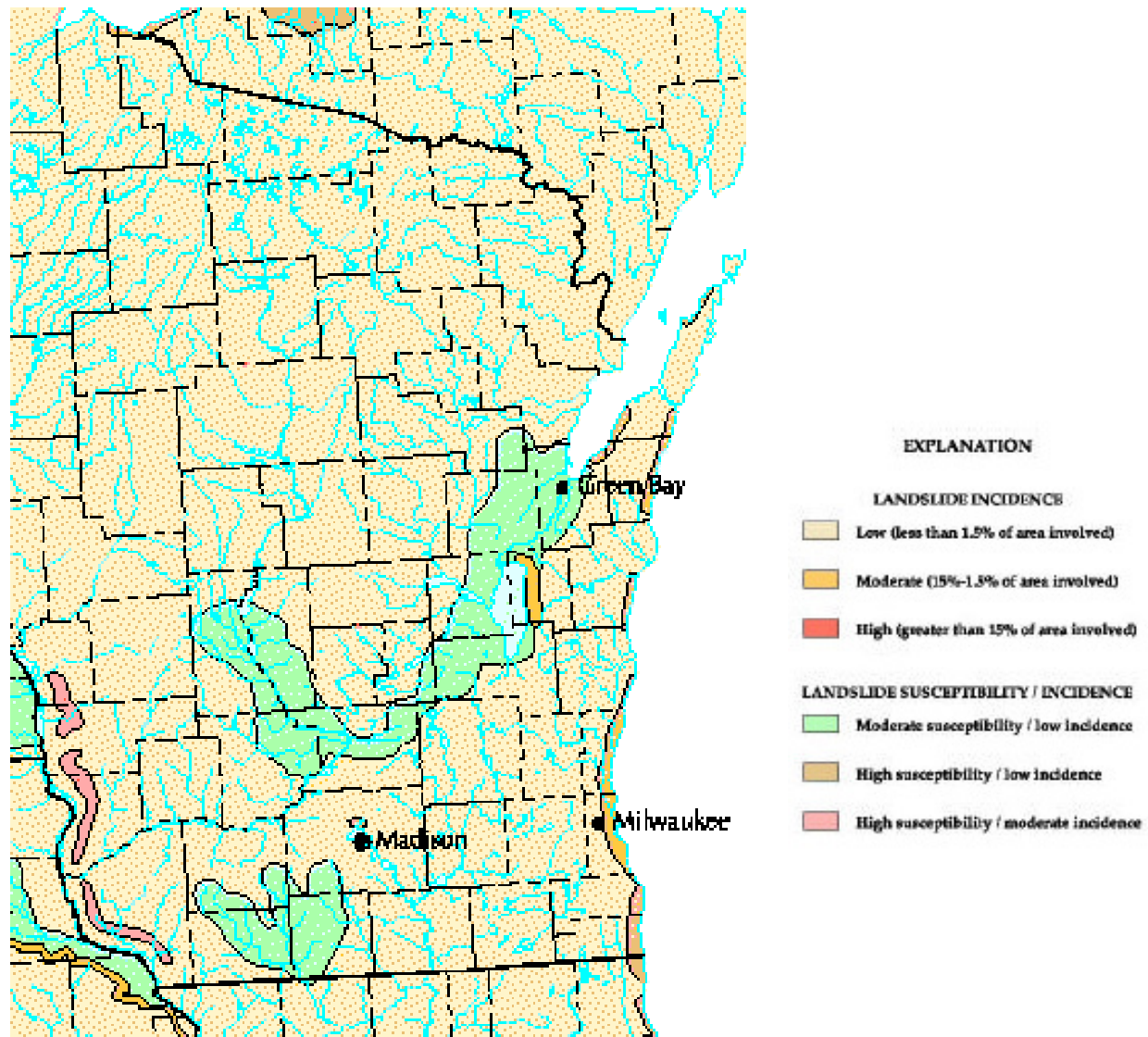
According to the United States Geological Survey (USGS), "Landslides occur in every state and U.S. territory. The Appalachian Mountains, the Rocky Mountains and the Pacific Coastal Ranges and some parts of Alaska and Hawaii have severe landslide problems. Any area composed of very weak or fractured materials resting on a steep slope can and will likely experience landslides."<sup>20</sup>

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.

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<sup>20</sup> USGS "Landslides Hazard Program: Landslides 101." Available online at <https://landslides.usgs.gov/learn/l101.php> last accessed March, 2017.

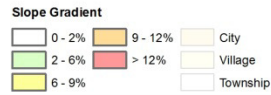
Figure 4.9.1 National Landslides Hazard Map



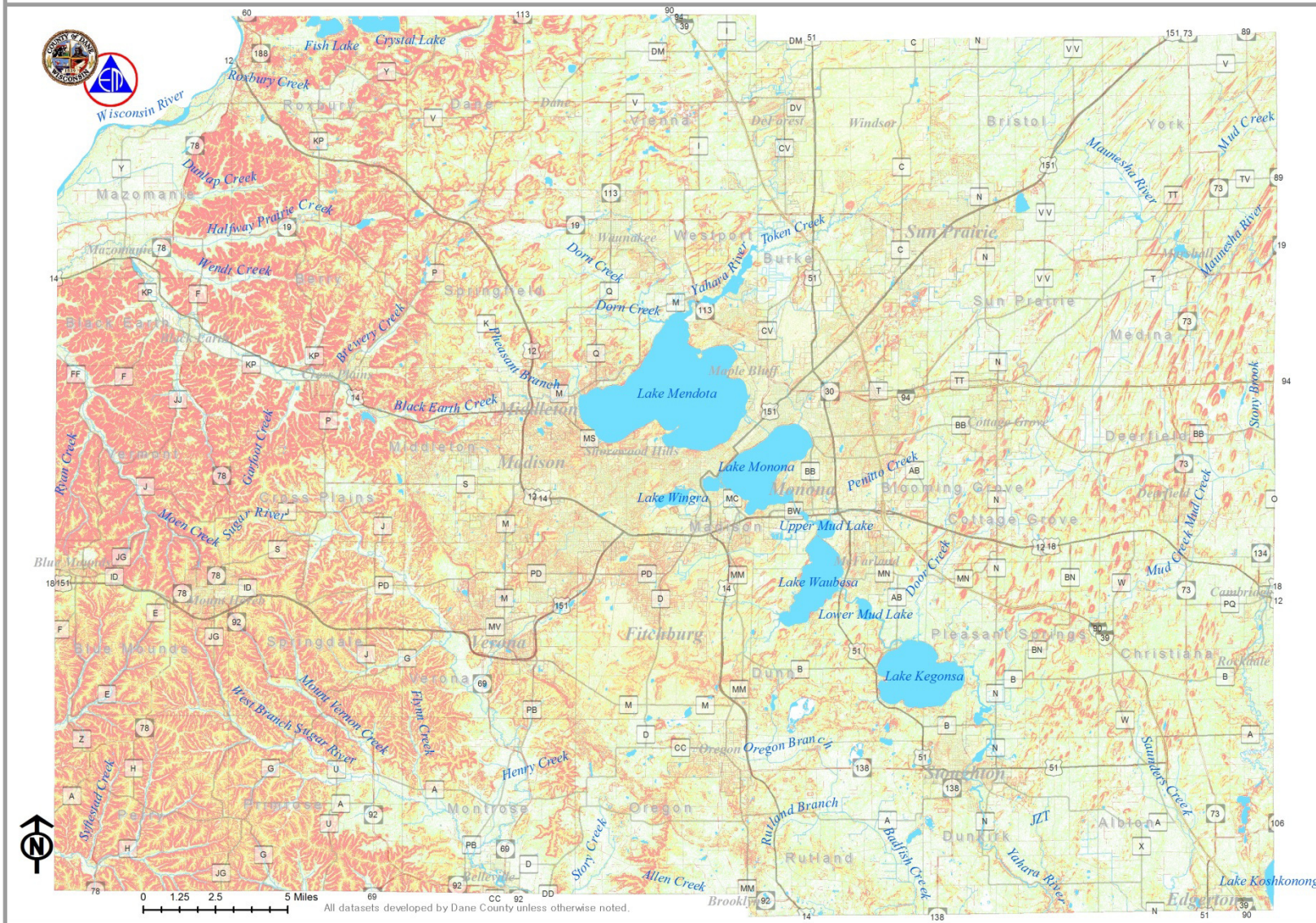
Source: USGS "Landslides Hazard Program" <https://landslides.usgs.gov/hazards/nationalmap/index.php>

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. Some generalization was necessary at this scale, and several small areas of high incidence and susceptibility were slightly exaggerated.

**Figure 4.9.2**  
**Terrain and Steep Slopes**



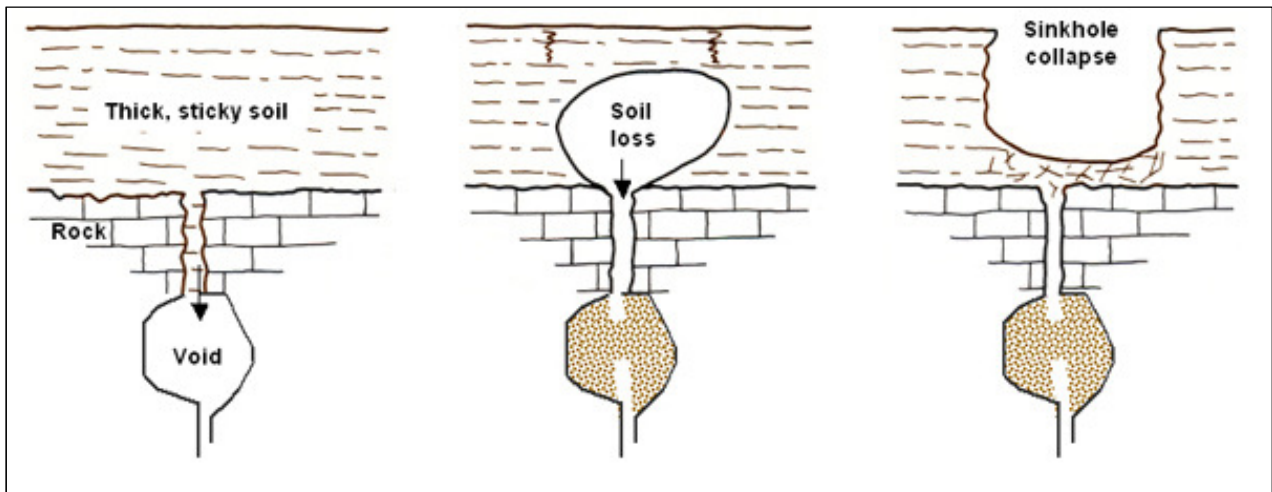
This map produced by the Dane County Emergency Management Department in conjunction with the Dane County Planning and Development Department for the Dane County Natural Hazard Mitigation Plan. Map information is believed to be accurate but it is not guaranteed to be without error. Source data used to 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.



**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/>

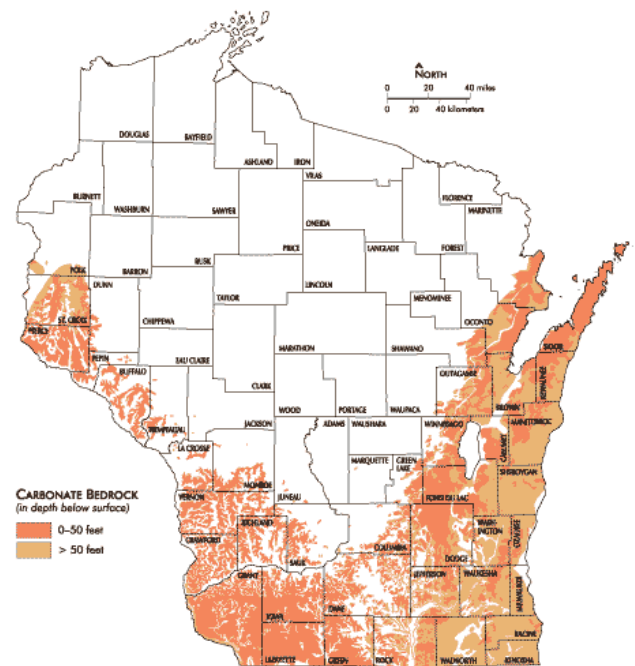
Karst” is a landscape created when water dissolves rocks. In Wisconsin, dolomite and some limestone are typical soluble rocks. The rocks are dissolved mostly along fractures and create caves and other conduits that act as underground streams. Water moves readily through these openings, carrying sediment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

Figure 4.9.4 Wisconsin Karst Potential



Source: Wisconsin Geological & Natural History Survey

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.

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



Source: Wisconsin State Journal

### 4.9.2 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.

### 4.9.3 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.

### **4.9.4 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.

### **4.9.5 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

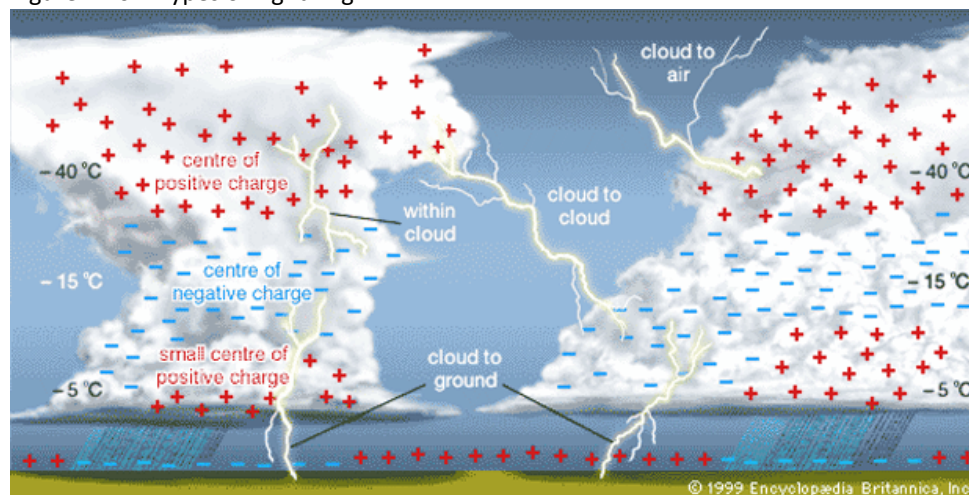
Lightning is caused by the attraction between positive and negative charges in the atmosphere, resulting in the buildup and discharge of electrical energy. This rapid heating and cooling of the air produces the shock wave that results in thunder. During a storm, raindrops can acquire extra electrons, 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 lightning 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: Encyclopædia 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.<sup>21</sup>

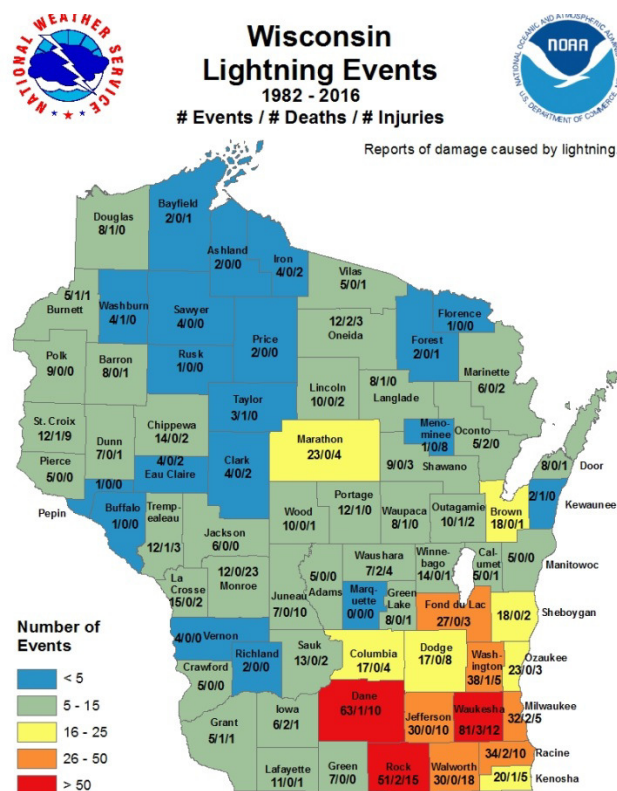
### Previous Occurrences

Lightning occurs with most severe thunderstorms, but does not always produce damages. The probability of lightning occurring in the County is quite high due to the high number of severe thunderstorms in the County; however, the site-specific incidence of lightning is considered low because of the extremely localized nature of the hazard.

In Dane County, there were 63 reported lightning incidents between 1982 and 2015. During this period, 1 death and 10 injuries from lightning were reported in the County. These numbers are likely underestimated because injury from lightning is suspected to often go unreported.

Dane County also has a relatively high frequency of property loss due to lightning. During the 20-year period from 1996 to 2016, there were 49 documented cases of property damage from lightning strikes, resulting in more than \$1.9 million in losses (NOAA, 2016). It is likely that these numbers also underestimate damages as many incidents may go undocumented in the NOAA, National Centers for Environmental Information (NCEI)

Figure 4.10.2 Wisconsin Lightning Events, 1982-2016



Source: National Weather Service

<sup>21</sup> Wisconsin Emergency Management, *Wisconsin Threat and Hazard Identification and Risk Assessment, 2016*

**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.

**4.10.2 Impact of Climate Change on Future Conditions**

Damaging lightning 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.

**4.10.3 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

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- 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.

#### 4.10.4 Vulnerability Assessment

While national data shows that lightning 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

Figure 4.10.3: Two-Way Radio Antenna, hit by lightning, blown off the tower.



Dane County Emergency Management, March 2017

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.

#### **4.10.5 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 2016, Dane County has experienced 49 lightning events where property damage, personal injury or death has occurred. According to the NCEI, during this time period, damages totaled \$1.9 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 \$39,000. Dane County averages 2.5 damaging strikes a year since 1996, which equates to an averaged annualized loss estimate of \$95,000. Injuries occur every 2 years on average, and deaths every 20 years.

## 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 can not 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.<sup>22</sup>

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.<sup>23</sup>

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.<sup>24</sup>

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.

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<sup>22</sup> American Meteorological Society, *Glossary of Meteorology* 2nd Edition. Available online at <http://msglossary.allenpress.com/glossary>

<sup>23</sup> National Severe Storms Laboratory “FAQ About Tornadoes.” Available online at <http://www.nssl.noaa.gov/research/tornadoes/>

<sup>24</sup> Ibid.

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

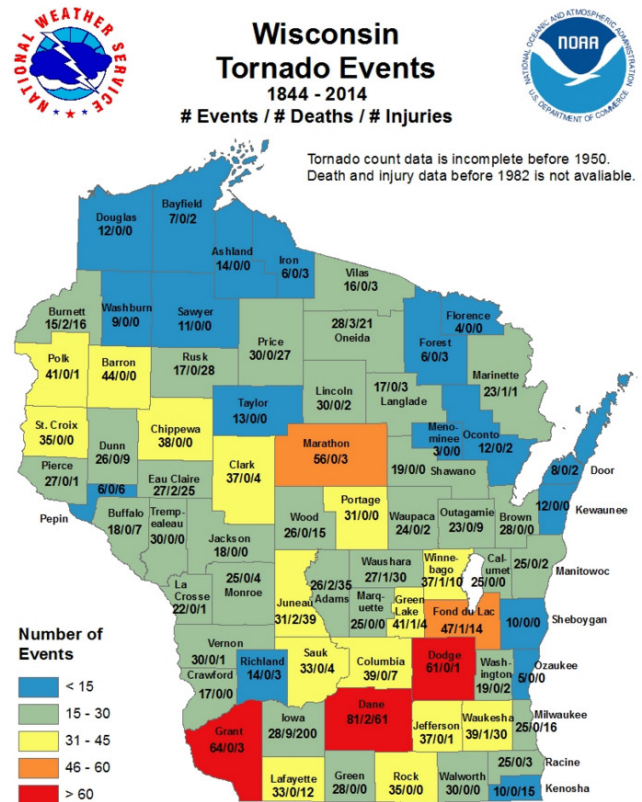
Fujita Scale			Derived EF Scale		Operational EF Scale	
F Number	Fastest 1/4-mile (mph)	3 Second Gust (mph)	EF Number	3 Second Gust (mph)	EF Number	3 Second Gust (mph)
0	40-72	45-78	0	65-85	0	65-85
1	73-112	79-117	1	86-109	1	86-110
2	113-157	118-161	2	110-137	2	111-135
3	158-207	162-209	3	138-167	3	136-165
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 4.11.1 Dane County currently has more reported tornado events than any other county in Wisconsin for the period of 1955-2016. 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 4.11.2 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 4.11.1 Wisconsin Tornado Events, 1844-2016



Source: National Weather Service

Figure 4.11.2 Wisconsin Tornado Tracks, 1950-2015



Source: NOAA, NWS, Milwaukee/Sullivan, Accessed in *Wisconsin Threat and Hazard Identification and Risk Assessment*, Wisconsin Emergency Management, 2016

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 area 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 4.11.2 provides a listing of Dane County tornadoes from the NCEI database.



Table 4.11.2 Dane County Tornadoes, 1955-2016

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		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
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

Date	Scale (F or EF)	Direct Deaths	Direct Injuries	Property Damage	Tornado Length (Miles)	Tornado Width (Yards)
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

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:

#### 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).

## Section 4: Risk Assessment

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



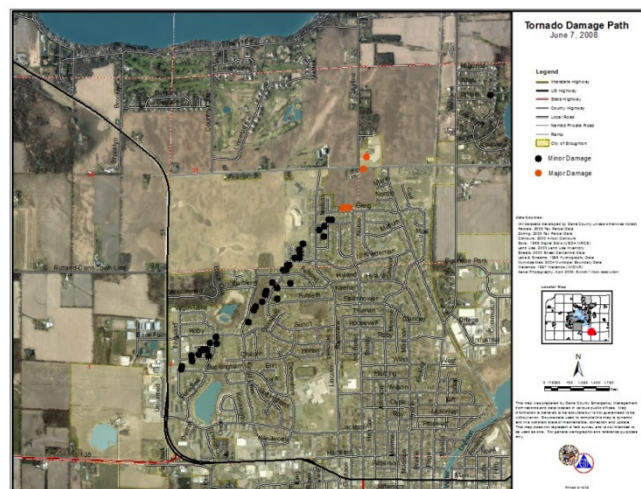
Dane County Emergency Management

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



Dane County Emergency Management

**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.

#### **4.11.2 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.

#### **4.11.3 Impact Assessment**

##### **Direct Impacts**

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 trees; 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.

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- *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 Impacts**

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

#### **4.11.4 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.

#### **4.11.5 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:

## Section 4: Risk Assessment

- 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 4.11.3.

Table 4.11.3 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
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 4.11.4 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".

In order to calculate the property damaged by the average tornado, the number of residences, commercial and manufacturing structures affected by the area of the average tornado was determined for each municipality and the County. The average tornado area was divided by each municipality's area, resulting in a percent of area impacted, or affected area. Multiplying the improved value plus content value of all structures by the percent affected area yields the exposure of affected property. Multiplying the affected area by the number of improved parcels yields an estimate of the number of structures impacted. Final loss ranges are calculated by multiplying the exposed property value by 50 percent for the moderate and 100 percent for the high, based on the average impacts in Table 4.11.4. A low damage estimate was calculated using a value of 25 percent of the exposed property value. The expected losses from this average tornado, by jurisdiction, can be referenced in each jurisdictional annex. A summary table by jurisdiction is provided in Table 4.11.5. The loss ratio analysis was conducted on the moderate damage range. The loss ratio is the estimated loss divided by the total exposed value. The higher the ratio, the more difficult it would be for the community to recover from the event.

Using these estimations, the damage potential range for an F2 tornado with an average track length of 3.7 miles and width of 118 yards ranges from just over \$400,000 in the Town of York to over \$4 billion in the most densely populated areas of the City of Madison. This includes only losses directly due to the tornado's destruction. Government emergency response and recovery costs and indirect impacts are not included in these figures.

Table 4.11.5 Tornado Damage Estimates, Sorted by Jurisdiction Name

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
City of Edgerton	46	\$19,325,100	\$9,662,550	\$28,987,650	\$28,987,650	\$14,493,825	\$7,246,913	50.0%
City of Fitchburg	271	\$16,615,826,400	\$8,307,913,200	\$24,923,739,600	\$598,135,785	\$299,067,892	\$149,533,946	1.2%
City of Madison	1,436	\$302,201,662,100	\$151,100,831,050	\$453,302,493,150	\$4,817,048,412	\$2,408,524,206	\$1,204,262,103	0.5%
City of Middleton	626	\$2,542,701,300	\$1,271,350,650	\$3,814,051,950	\$354,703,430	\$177,351,715	\$88,675,857	4.6%
City of Monona	780	\$795,860,088	\$397,930,044	\$1,193,790,132	\$306,720,832	\$153,360,416	\$76,680,208	12.8%
City of Stoughton	643	\$869,538,200	\$434,769,100	\$1,304,307,300	\$181,802,041	\$90,901,020	\$45,450,510	7.0%
City of Sun Prairie	882	\$8,209,214,200	\$4,104,607,100	\$12,313,821,300	\$861,492,027	\$430,746,013	\$215,373,007	3.5%
City of Verona	501	\$1,622,572,300	\$811,286,150	\$2,433,858,450	\$292,075,353	\$146,037,676	\$73,018,838	6.0%
Town of Albion	25	\$140,429,900	\$70,214,950	\$210,644,850	\$5,027,454	\$2,513,727	\$1,256,863	1.2%
Town of Berry	12	\$118,602,400	\$59,301,200	\$177,903,600	\$4,187,575	\$2,093,787	\$1,046,894	1.2%
Town of Black Earth	11	\$40,775,000	\$20,387,500	\$61,162,500	\$3,016,148	\$1,508,074	\$754,037	2.5%
Town of Blooming Grove	123	\$129,605,720	\$64,802,860	\$194,408,580	\$31,767,455	\$15,883,728	\$7,941,864	8.2%
Town of Blue Mounds	10	\$97,817,700	\$48,908,850	\$146,726,550	\$3,809,736	\$1,904,868	\$952,434	1.3%
Town of Bristol	37	\$333,076,500	\$166,538,250	\$499,614,750	\$12,452,025	\$6,226,012	\$3,113,006	1.2%
Town of Burke	77	\$322,474,200	\$161,237,100	\$483,711,300	\$26,561,329	\$13,280,664	\$6,640,332	2.7%
Town of Christiana	14	\$91,769,100	\$45,884,550	\$137,653,650	\$3,333,027	\$1,666,514	\$833,257	1.2%
Town of Cottage Grove	40	\$264,379,900	\$132,189,950	\$396,569,850	\$10,376,903	\$5,188,451	\$2,594,226	1.3%
Town of Cross Plains	15	\$139,769,900	\$69,884,950	\$209,654,850	\$5,055,492	\$2,527,746	\$1,263,873	1.2%
Town of Dane	9	\$72,287,100	\$36,143,550	\$108,430,650	\$2,611,326	\$1,305,663	\$652,831	1.2%
Town of Deerfield	16	\$108,928,200	\$54,464,100	\$163,392,300	\$4,099,231	\$2,049,615	\$1,024,808	1.3%

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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
Town of Dunkirk	22	\$135,854,100	\$67,927,050	\$203,781,150	\$5,446,174	\$2,723,087	\$1,361,544	1.3%
Town of Dunn	70	\$809,057,000	\$404,528,500	\$1,213,585,500	\$36,149,793	\$18,074,897	\$9,037,448	1.5%
Town of Madison	902	\$434,685,200	\$217,342,600	\$652,027,800	\$362,310,915	\$181,155,458	\$90,577,729	27.8%
Town of Mazomanie	14	\$80,210,700	\$40,105,350	\$120,316,050	\$3,305,691	\$1,652,845	\$826,423	1.4%
Town of Medina	14	\$94,323,600	\$47,161,800	\$141,485,400	\$3,585,417	\$1,792,708	\$896,354	1.3%
Town of Middleton	123	\$722,190,800	\$361,095,400	\$1,083,286,200	\$58,894,751	\$29,447,375	\$14,723,688	2.7%
Town of Montrose	13	\$87,775,300	\$43,887,650	\$131,662,950	\$3,264,914	\$1,632,457	\$816,228	1.2%
Town of Oregon	34	\$272,684,400	\$136,342,200	\$409,026,600	\$11,106,875	\$5,553,438	\$2,776,719	1.4%
Town of Perry	8	\$55,542,400	\$27,771,200	\$83,313,600	\$1,949,740	\$974,870	\$487,435	1.2%
Town of Pleasant Springs	37	\$277,971,600	\$138,985,800	\$416,957,400	\$10,678,338	\$5,339,169	\$2,669,584	1.3%
Town of Primrose	8	\$52,801,800	\$26,400,900	\$79,202,700	\$1,866,734	\$933,367	\$466,683	1.2%
Town of Roxbury	17	\$133,406,600	\$66,703,300	\$200,109,900	\$4,706,078	\$2,353,039	\$1,176,519	1.2%
Town of Rutland	20	\$156,484,300	\$78,242,150	\$234,726,450	\$5,637,280	\$2,818,640	\$1,409,320	1.2%
Town of Springdale	20	\$201,370,500	\$100,685,250	\$302,055,750	\$7,207,524	\$3,603,762	\$1,801,881	1.2%
Town of Springfield	28	\$286,134,900	\$143,067,450	\$429,202,350	\$10,019,017	\$5,009,508	\$2,504,754	1.2%
Town of Sun Prairie	27	\$181,382,100	\$90,691,050	\$272,073,150	\$7,719,200	\$3,859,600	\$1,929,800	1.4%
Town of Vermont	10	\$75,656,000	\$37,828,000	\$113,484,000	\$2,671,383	\$1,335,691	\$667,846	1.2%
Town of Verona	27	\$162,188,700	\$81,094,350	\$243,283,050	\$8,551,376	\$4,275,688	\$2,137,844	1.8%
Town of Vienna	15	\$151,258,700	\$75,629,350	\$226,888,050	\$5,398,055	\$2,699,027	\$1,349,514	1.2%
Town of Westport	75	\$449,354,900	\$224,677,450	\$674,032,350	\$27,317,264	\$13,658,632	\$6,829,316	2.0%
Town of York	8	\$45,521,200	\$22,760,600	\$68,281,800	\$1,606,274	\$803,137	\$401,568	1.2%

## Section 4: Risk Assessment

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
Village of Belleville	408	\$131,803,400	\$65,901,700	\$197,705,100	\$100,670,303	\$50,335,152	\$25,167,576	25.5%
Village of Black Earth	542	\$74,653,400	\$37,326,700	\$111,980,100	\$110,210,417	\$55,105,208	\$27,552,604	49.2%
Village of Blue Mounds	353	\$139,189,300	\$69,594,650	\$208,783,950	\$200,966,935	\$100,483,468	\$50,241,734	48.1%
Village of Brooklyn	365	\$49,831,500	\$24,915,750	\$74,747,250	\$74,747,250	\$37,373,625	\$18,686,813	50.0%
Village of Cambridge	386	\$103,559,800	\$51,779,900	\$155,339,700	\$99,468,197	\$49,734,098	\$24,867,049	32.0%
Village of Cottage Grove	476	\$465,948,700	\$232,974,350	\$698,923,050	\$152,483,106	\$76,241,553	\$38,120,777	10.9%
Village of Cross Plains	673	\$253,044,000	\$126,522,000	\$379,566,000	\$190,600,672	\$95,300,336	\$47,650,168	25.1%
Village of Dane	300	\$72,319,200	\$36,159,600	\$108,478,800	\$79,302,782	\$39,651,391	\$19,825,696	36.6%
Village of Deerfield	379	\$133,772,800	\$66,886,400	\$200,659,200	\$78,563,526	\$39,281,763	\$19,640,882	19.6%
Village of DeForest	356	\$622,506,600	\$311,253,300	\$933,759,900	\$104,332,382	\$52,166,191	\$26,083,096	5.6%
Village of Maple Bluff	588	\$205,734,700	\$102,867,350	\$308,602,050	\$308,602,050	\$154,301,025	\$77,150,513	50.0%
Village of Marshall	498	\$1,505,153,600	\$752,576,800	\$2,257,730,400	\$831,419,710	\$415,709,855	\$207,854,928	18.4%
Village of Mazomanie	322	\$102,101,800	\$51,050,900	\$153,152,700	\$72,678,477	\$36,339,238	\$18,169,619	23.7%
Village of McFarland	706	\$669,281,200	\$334,640,600	\$1,003,921,800	\$242,198,294	\$121,099,147	\$60,549,573	12.1%
Village of Mount Horeb	692	\$541,222,800	\$270,611,400	\$811,834,200	\$212,285,383	\$106,142,691	\$53,071,346	13.1%
Village of Oregon	685	\$723,267,800	\$361,633,900	\$1,084,901,700	\$210,136,932	\$105,068,466	\$52,534,233	9.7%
Village of Rockdale	98	\$12,133,900	\$6,066,950	\$18,200,850	\$18,200,850	\$9,100,425	\$4,550,213	50.0%
Village of Shorewood Hills	698	\$345,499,583	\$172,749,792	\$518,249,375	\$518,249,375	\$259,124,687	\$129,562,344	50.0%

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
Village of Waunakee	561	\$1,057,409,400	\$528,704,700	\$1,586,114,100	\$197,570,114	\$98,785,057	\$49,392,529	6.2%
Village of Windsor	76	\$461,759,600	\$230,879,800	\$692,639,400	\$20,425,011	\$10,212,506	\$5,106,253	1.5%

## 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.

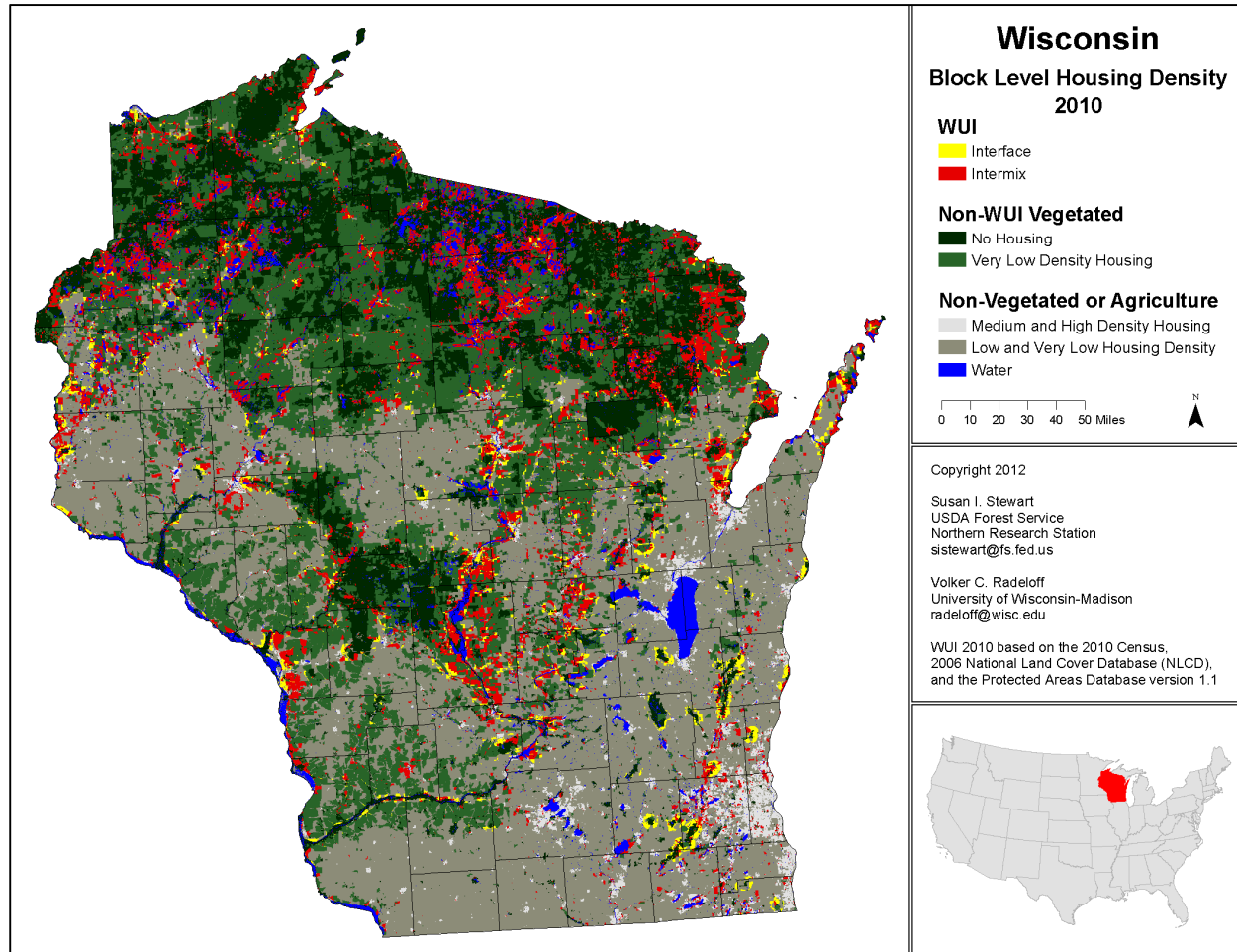
Most of the County is managed under a cooperative fire management program overseen by individual fire districts. The northwestern portion of the County is under state jurisdiction and classified as an “extensive fire area”, and includes the jurisdictions of the Towns of Roxbury, Vermont, Black Earth, 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.<sup>25</sup> 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 March, 2017

### 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.

<sup>25</sup> Wisconsin Emergency Management, *Wisconsin Threat and Hazard Identification and Risk Assessment*, 2016

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.

#### **4.12.2 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.

#### **4.12.3 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.

#### **4.12.4 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.



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**Section 4: Risk Assessment**

- 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.

**4.12.5 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 hundred's 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.

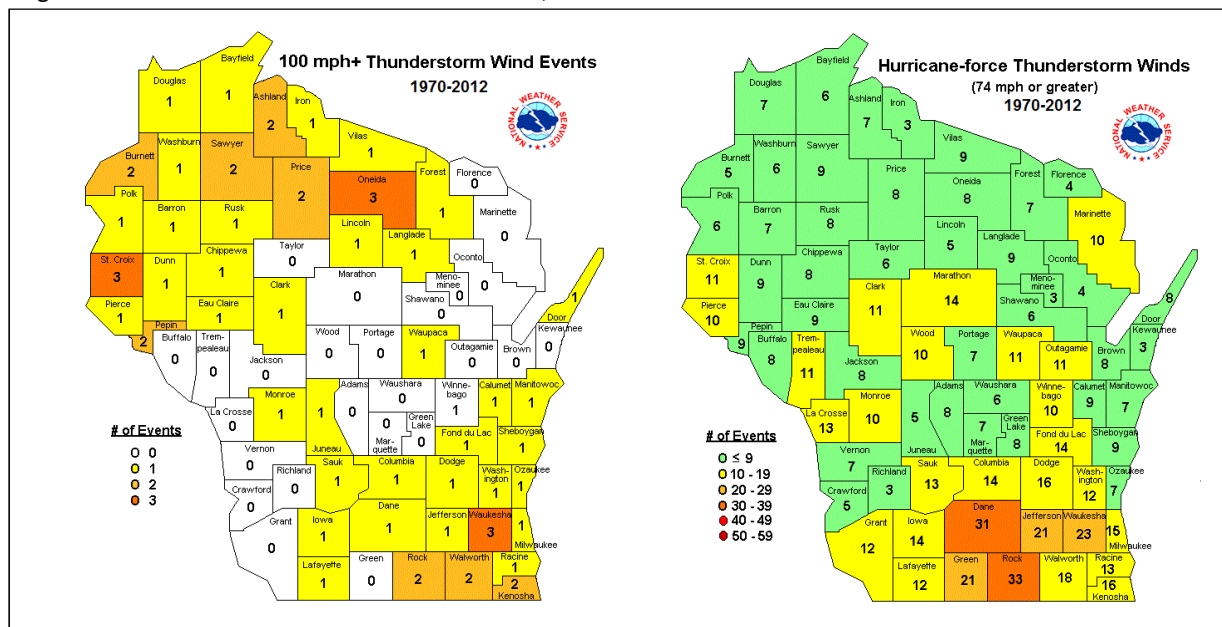
Severe thunderstorms develop powerful updrafts and downdrafts. An updraft of warm, moist air helps to fuel a towering cumulonimbus cloud reaching tens of thousands of feet into the atmosphere. A downdraft of relatively cool, dense air develops as precipitation begins to fall through the cloud. Winds 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.<sup>26</sup>

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.

#### 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 2012, there were 31 events with winds over 74 mph (hurricane force winds) and one case of winds over 100 mph.

Figure 4.13.1 Severe Thunderstorm Wind Events, 1970-2012



Source: National Weather Service

<sup>26</sup> National Weather Service

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 1950 through 2016. The NCEI database lists more than 217 severe thunderstorm and high wind events in Dane County over this period. 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.

**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 of 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.

**4.13.2 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.

### 4.13.3 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.
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.

### 4.13.4 Vulnerability Assessment

As with tornadoes, essentially all Dane County buildings, critical facilities, and populations are vulnerable to windstorm damage.

#### 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.

### 4.13.5 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.

Section 4: Risk Assessment

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- 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 \$5.7 million in losses in 2017 dollars.

## 4.14 Winter Storm

### 4.14.1 Description

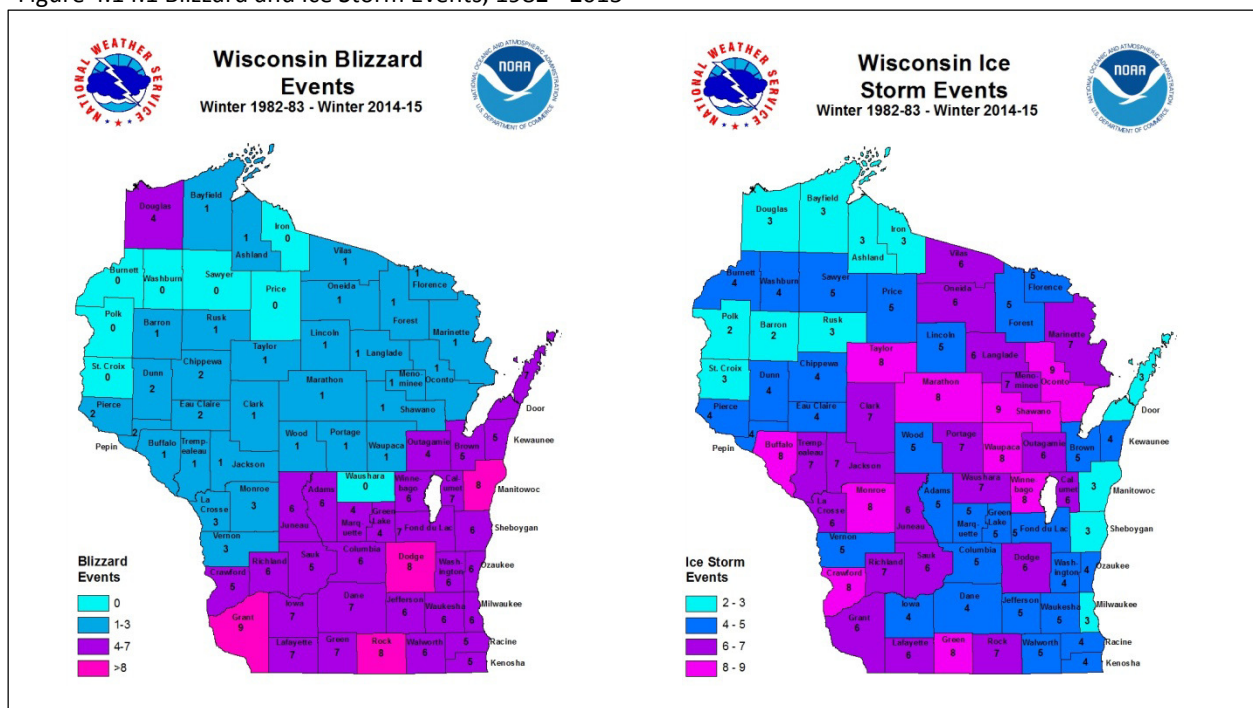
Winter storms occur when below freezing air on the ground and in clouds combine with moisture. Moisture is needed to form clouds and cause precipitation. A storm front lifts the moist air to form the clouds. Storms that affect Wisconsin develop over southeast Colorado, northwest Canada, and over the 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.

### Previous Occurrences

According to the National Weather Service, between the winter of 1982-83 and the winter of 2014-15, there were 103 winter storm events, seven blizzard events, and four ice storm events affecting Dane County.

Figure 4.14.1 Blizzard and Ice Storm Events, 1982 - 2015



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.

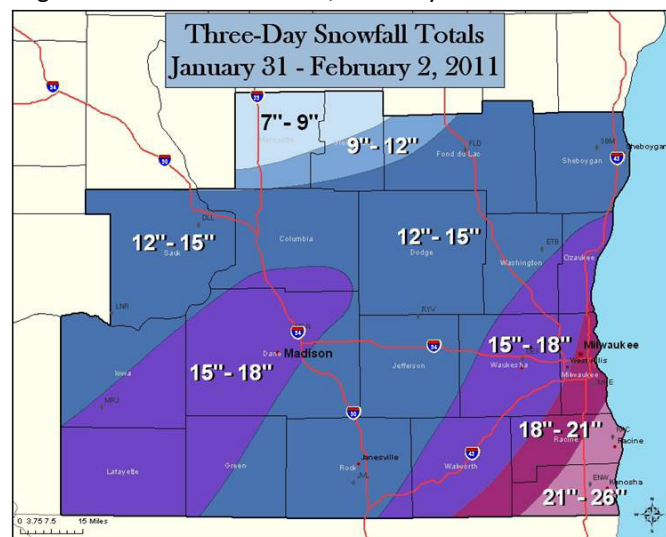
### December 8-9, 2009

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 in response costs.

Figure 4.14.2 Snowfall Totals, February 2011



Source: National Weather Service, Milwaukee/Sullivan

### 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,

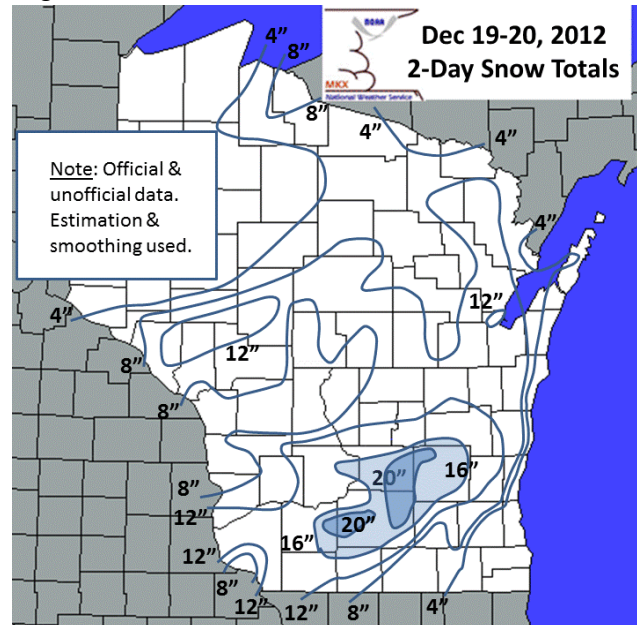
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19.0" at the Arlington UW Farm, and 18.8 inches in DeForest. Officially, Madison's Truax Field's 2-day total was 15.2".

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 4.14.3 Snowfall Totals, December 2012



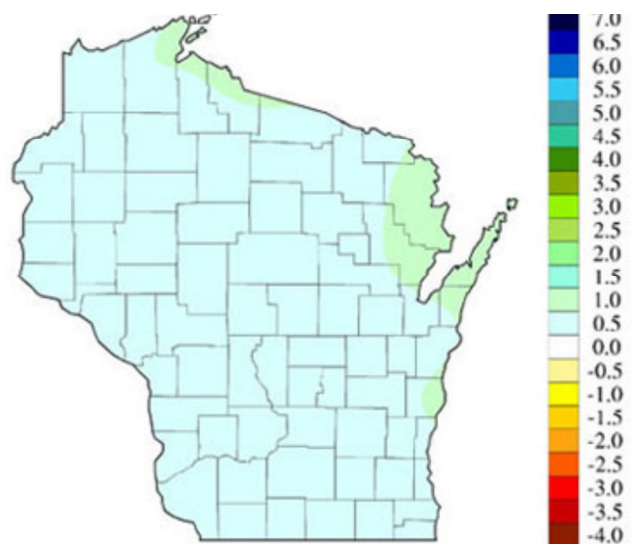
Source: National Weather Service, Milwaukee/Sullivan

**4.14.2 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 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.

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

### 4.14.3 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.

#### **4.14.4 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.

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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<sup>27</sup> 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
<b>0</b>	< 0.25	< 15	Minimal risk of damage to exposed utility systems; no alerts or advisories needed for crews, few outages.
<b>1</b>	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	
<b>2</b>	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	
<b>3</b>	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	
<b>4</b>	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	
<b>5</b>	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.)

<sup>27</sup> <http://www.spia-index.com/aboutUs.php>

**4.14.5 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.
- 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



Blue-green algae bloom



Wild Parsnip, Photo Kitty Kohout



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

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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 50 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**

Hazard*	Hazard Attributes Rating: (1-5)			Impact Attributes Rating: (0-5)						Total	Rank
				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		
Tornado (1)	3	4	4	4	4	4	4	4	4	35	1
Flood (2)	3	4	4	4	3	3	3	4	4	32	2 (tied)
Winter Storm (3)	5	5	3	3	3	4	3	3	3	32	2 (tied)
Extreme Cold (6)	4	4	3	2	2	4	3	3	3	28	4
Windstorm (4)	3	3	3	3	3	3	2	3	3	26	5
Extreme Heat (5)	4	4	3	1	1	4	3	3	3	26	6
Hail (10)	3	3	3	3	2	2	2	3	2	22	7
Lightning (8)	2	3	3	3	2	2	2	2	3	21	8
Dam Failure (7)	2	1	3	3	2	2	2	3	2	20	9
Drought (9)	4	3	2	1	1	1	2	4	2	19	10
Wildfire (12)	2	1	2	2	2	2	2	2	2	19	11
Fog (13)	3	3	3	1	1	1	1	1	1	15	12
Landslide, Erosion Sinkhole (12)	1	1	3	2	1	1	1	1	1	12	13

\* Ratings from the 2010 Plan process are indicated in parenthesis in the Hazard title column.

### 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.
- The frequency and intensity of extreme cold events is generally decreasing due to warming climate conditions. This is not to say that Dane County will not experience very cold conditions in the future, but the risk is decreasing.

**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 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 trends, 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.

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- 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.
  - Societal expectations and values and widely differing and often opposing points of view.
- 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 or 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.



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**Section 4: Risk Assessment**

- 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 an 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.

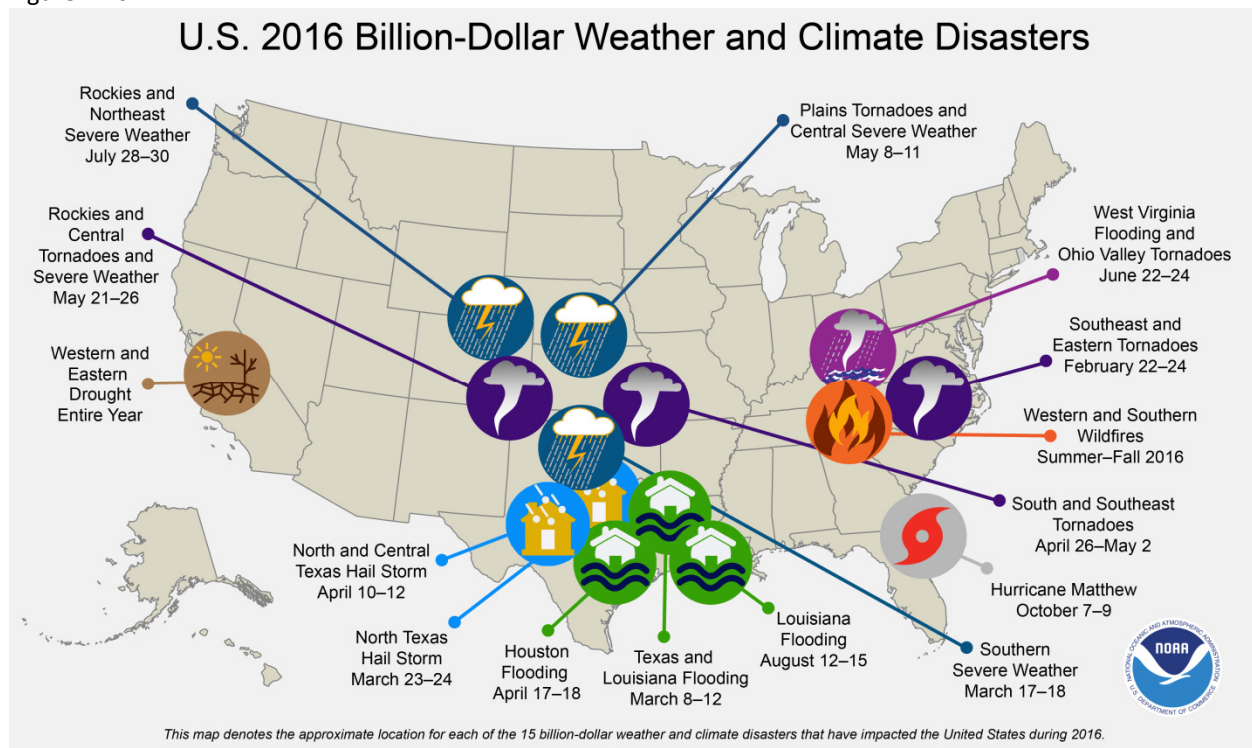
**Multi-Hazard Issues**

- 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 "The U.S. has sustained 208 weather and climate disasters between 1980 and 2016 in which overall damages/costs reached or exceeded \$1 billion. The total cost of these 208 events exceeds \$1.1 trillion. The 15 events that occurred in 2016 are shown on the map in Figure 4.16.1.

Figure 4.16.1



Source: NOAA, National Centers for Environmental Information website, <https://www.ncdc.noaa.gov/billions/>

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.

<b>Dane County Hazard Mitigation Planning Team</b>		
<b>Department</b>	<b>Name</b>	<b>Title</b>
Administration	David Merritt	Director, Policy & Program Development
Alliant Energy Center	Mark Clarke	Director
Capital Area Regional Planning Commission	Michael Kakuska	Senior Environmental Planner
Dane County Regional Airport	Bradley Livingston	Director
Dane County Regional Airport	Brent McHenry	Director of Marketing
Dane County/UW Extension	Mindy Habecker	Natural Resource/Community Development Educator
Emergency Management	Charles Tubbs	Director
Jeff Halter	Henry Vilas Zoo	Deputy Zoo Director
Land and Water Resources	Kevin Connors	Director
Land and Water Resources	Jeremy Balousek	Water Resources Engineering Division Manager
Land and Water Resources	John Reimer	Stormwater Engineer
Land Information Office	Fred Iausly	Senior GIS Analyst
Planning and Development	Todd Violante	Director
Planning and Development	Brian Standing	Senior Planner
Public Health, Madison and Dane County	Douglas Voegli	Director, Division of Environmental Health
Public Works, Highway, and Transportation	Jerry Mandli	Commissioner/Director
Public Works, Highway, and Transportation	Pamela Dunphy	Deputy Commissioner
Emergency Management	David Janda	Assistant Director, Lead Planner
Emergency Management	Phillip Rynish	Project Assistant, Lead Local Jurisdiction Planner
Wisconsin Emergency Management	Katie Sommers	Advisory
Wisconsin Initiative on Climate Change Impacts	David Liebl	Advisory

<b>Local Jurisdiction Participants</b>		
<b>Department</b>	<b>Name</b>	<b>Title</b>
City of Edgerton	Ramona Flanigan	City Administrator
City of Edgerton	Tom Hartzell	Public Works Director
City of Fitchburg	Chad Brecklin	Police Lieutenant
City of Fitchburg	Ryan Jesberger	Police Sergeant
City of Madison	JoJo O'Brien	City Engineering
City of Madison	Greg Fries	City Engineering
City of Madison	Mike Dailey	City Engineering/Deputy City Engineer
City of Madison	Ed Ruckriegel	Fire Marshall

<b>Local Jurisdiction Participants</b>		
<b>Department</b>	<b>Name</b>	<b>Title</b>
City of Madison	Phil Gadke	Madison Metro/Safety Supervisor
City of Middleton	Charles Foulke	Chief of Police
City of Middleton	Mike Davis	City Administrator and Director of Community Dev.
City of Sun Prairie	Scott Faust	Assistant Chief/Emergency Management Coordinator
City of Sun Prairie	Patrick Anhalt	Chief/Emergency Management Director
City of Verona	Bill Burns	City Administrator
City of Verona	Bernie Coughlin	Police Chief
Village of Belleville	Gary Ziegler	Trustee; EMS Director
Village of Belleville	April Little	Village Administrator
Village of Blue Mounds	Jeff Twing	Police Lieutenant
Village of Blue Mounds	Andrew Rose	Police Chief
Village of Brooklyn	Carol Strause	Clerk-Treasurer
Village of Brooklyn	Leif Spilde	Emergency Management Director
Village of Cambridge	Lisa Moen	Administrator/Treasurer
Village of Cambridge	Steve Strauss	Village President
Village of Cottage Grove	JJ Larson	Director of Public Works
Village of Cottage Grove	Matt Giese	Village Administrator
Village of Cross Plains	Tom Janssen	Police Chief
Village of Cross Plains	Caitlin Steve	Clerk/Treasurer
Village of DeForest	Mark Roffers	Consultant
Village of DeForest	Colette Spranger	Consultant
Village of DeForest	Dan Furseth	Police Chief
Village of DeForest	Robert Henze	Police Chief, Retired
Village of Marshall	Lee Hellenbrand	Chief of Police
Village of Marshall	Deanna Chadwick	Office Manager
Village of Mazomanie	Susan Dietzen	Clerk/Treasurer
Village of Mazomanie	Mark Giesler	Public Works Director
Village of Mazomanie	Peter Huebner	Administrator
Village of McFarland	Charles Di Piazza	Emergency Management Director
Village of Oregon	Gary Disch	Assistant Director of Public Works
Village of Oregon	Brian Uhl	Police Chief
Village of Shorewood Hills	Karl Frantz	Administrator
Village of Shorewood Hills	David Sykes	Public Safety--Emergency Services Coordinator
Village of Waunakee	Kevin Plendl	Police Chief
Village of Waunakee	Kevin Even	Village Engineer
Village of Windsor	Christine Capstran	Clerk

<b>Local Jurisdiction Participants</b>		
<b>Department</b>	<b>Name</b>	<b>Title</b>
Village of Windsor	Tina Bulteris	Finance Director/Treasurer/Office Manager
Village of Windsor	Christine Capstran	Clerk
Town of Albion	Julie Hanewall	Clerk/Treasurer
Town of Albion	Thad Andrews	Supervisor
Town of Albion	Pat Tesar	Supervisor
Town of Berry	Brenda Kahl	Clerk/Treasurer
Town of Berry	Joe Krutchen	Supervisor
Town of Blue Mounds	Helen Kahl	Clerk
Town of Blue Mounds	Al Antonson	Supervisor
Town of Blue Mounds	Dennis Jelle	Town Chair
Town of Christiana	Jim Lowrey	Supervisor
Town of Christiana	Gary Rattmen	Town Chair
Town of Cottage Grove	Kim Banigan	Clerk
Town of Cottage Grove	Mike DuPlayee	Supervisor
Town of Dunn	Cathy Hasslinger	Clerk/Treasurer
Town of Mazomanie	Melissa Lohre	Clerk
Town of Montrose	Julie Bigler	Clerk
Town of Montrose	Roger Hodel	Town Chairperson
Town of Perry	Mary L. Price	Clerk
Town of Perry	Mick Klein Kennedy	Supervisor
Town of Pleasant Springs	Maria Hougan	Clerk/Treasurer
Town of Pleasant Springs	Mary Haley	Town Chair
Town of Roxbury	Robert Pings	Clerk
Town of Roxbury	Nick Ganser	Supervisor
Town of Roxbury	Ervin Breunig	Town Chair
Town of Springdale	Ed Eloranta	Town Chair
Town of Springdale	Vicki Anderson	Town Clerk
Town of Sun Prairie	Wes Dorshorst	Lead Highway Patrolman
Town of Sun Prairie	Lyle Updike	Town Chairman
Town of Vermont	Karen Carlock	Municipal Clerk
Town of Vermont	Barbara Grenlie	Town Chair
Town of Verona	John Wright	Clerk/Treasurer
Town of Verona	Amanda Arnold	Planner/Administrator
Town of Vienna	Steve Ruegsegger	Clerk
Town of Vienna	Lonnie Breggeman	Town Chair
Town of Westport	Tom Wilson	Attorney/Administrator/Clerk-Treasurer
Town of Westport	Bob Anderson	Deputy Clerk-Treasurer