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."[1]

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

[1] 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[2]:

- 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

[2] Wisconsin Administrative Code, NR 333.06

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

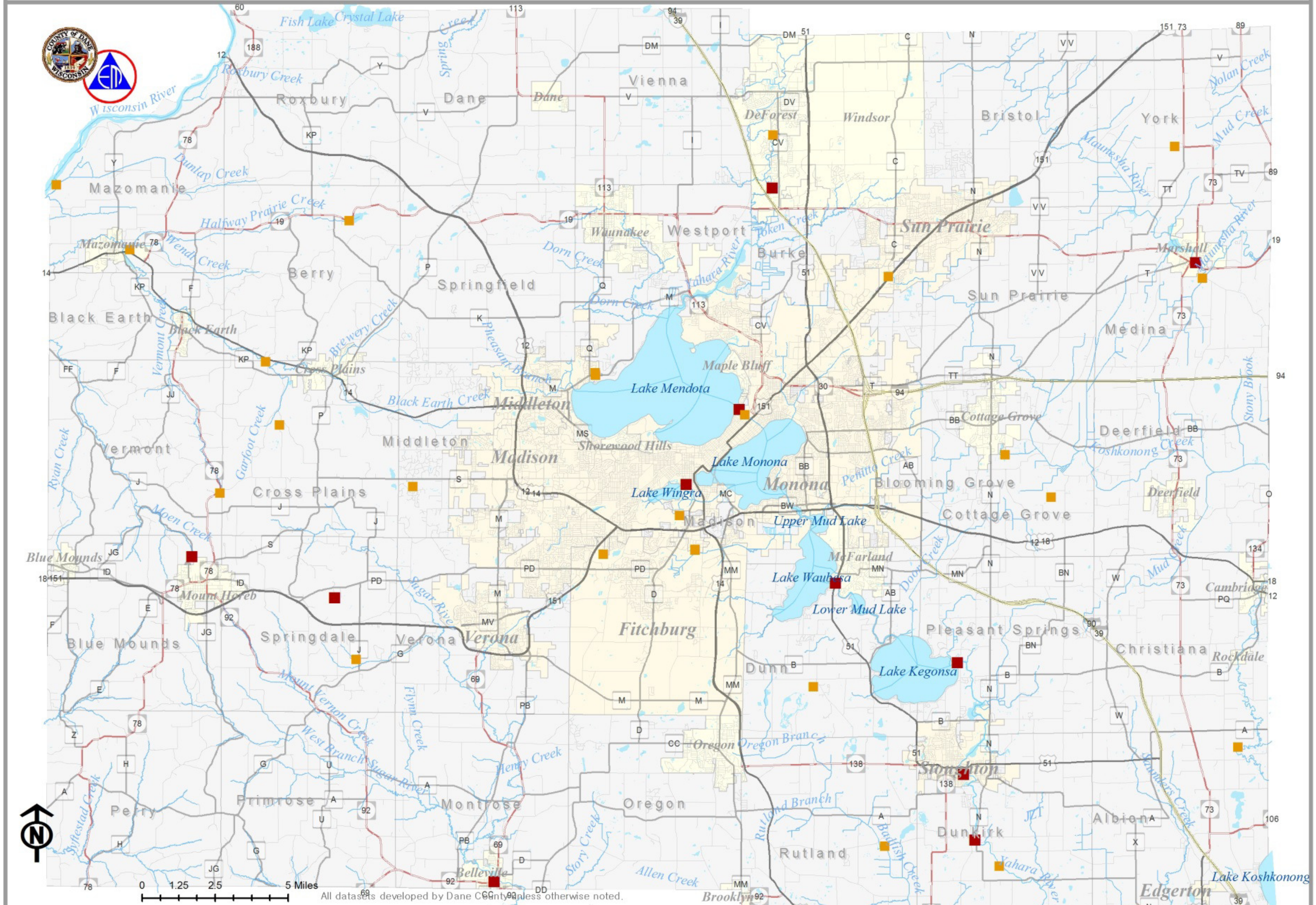
Dam Name/Impound	Hazard Rating	Max Storage (acre ft)	Height (ft)	Stream
Tenney Lock and Dam	High	160,000	5	Yahara River
Stewart Lake	High	90	23.8	Moen Creek
Marshall Grist Mill	Significant	1,100	11	Maunesha River
Belleville	Low	80	11	Sugar River
Brunner	Low	60	10	Sugar River Tributary
Dunkirk	Low	260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

Source: Wisconsin Department of Natural Resources

Figure 4.2.1
Dams in Dane County

Lakes and Ponds
Rivers and Streams
Large Dam
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 Project

Prairie du Sac Hydroelectric dam is located on the Wisconsin River just upstream of the Village of Prairie du Sac, on the border between Sauk and Columbia Counties. The dam is maintained and operated by Alliant Energy Company for the purpose of electric power generation. The Lake Wisconsin reservoir has a normal operating head of 38.5 feet. The normal surface area of Lake Wisconsin is approximately 9,000 acres, with a storage volume of 119,950 acre-feet. The *Prairie du Sac Hydroelectric*

Project Emergency Action Plan provides dam breach scenarios and flood inundation maps for failures under flood flow and normal “sunny day” flow conditions. This analysis indicates the potential for properties to be affected in the Towns of Roxbury and Mazomanie. Primary structures in the mapped flood shadow are shown in table 4.2.2.

Tenney Lock and Dam


Tenney Lock and Dam

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

Stewart Park Dam

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

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.[3]

- *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.[4]

[3] University of Nebraska at Lincoln, National Drought Mitigation Center, http://drought.unl.edu/droughtbasics/typesofdrought.aspx. Accessed May, 2017.
[4] 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.[5]

- *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.[6]

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.

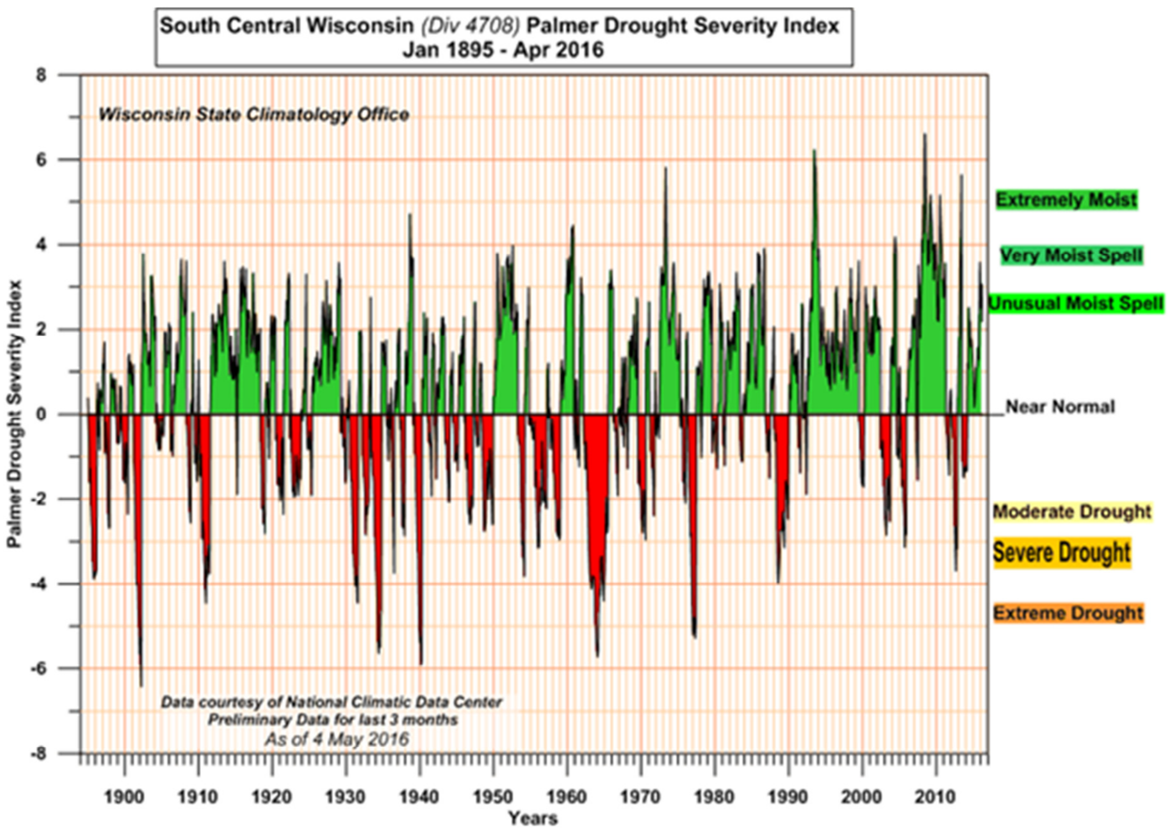
The advantage of the Palmer Index is that it is standardized to local climate, so it can be applied to any part of the country to demonstrate relative drought or rainfall conditions. The limitation is that it is not useful for short-term forecasts, and is not particularly useful in calculating supplies of water locked up in snow.[7]

[5] University of Nebraska at Lincoln, National Drought Mitigation Center, http://drought.unl.edu/droughtbasics/typesofdrought.aspx. Accessed May, 2017.
[6] University of Nebraska at Lincoln, National Drought Mitigation Center, "What is Drought? Understanding and Defining Drought".
[7] 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 began 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.

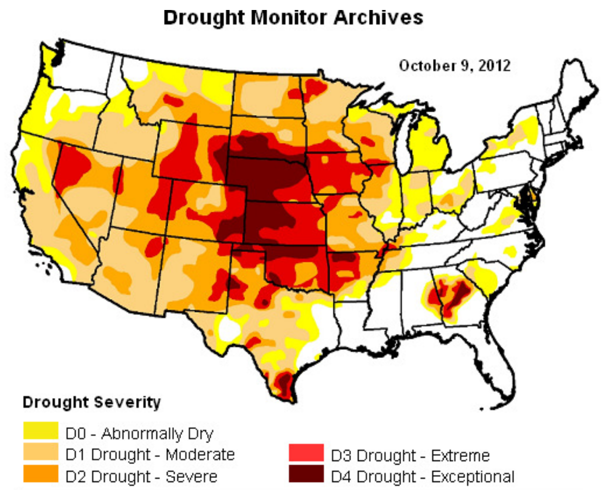
2007

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.[8]

Figure 4.3.2 2012 Drought Severity



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

Source: National Drought Mitigation Center

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.

[8] 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 advantages of advances in science and computer modeling technology. Wind-chill effects are shown in Figure 4.4.1, highlighting the dangers of wind-chill to exposed individuals.

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

Figure 4.4.1 Wind-Chill Factors

Temperature (°F)

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

Frostbite Times: 30 minutes, 10 minutes, 5 minutes

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

Where, T= Air Temperature (°F) V= Wind Speed (mph)

Effective 11/01/01

Source: National Weather Service

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 2nd. Service stations and the AAA were overwhelmed with requests for assistance. A new minimum temperature record of -29°F in Madison (now the February record) was set the 3rd.

January 17, 1997

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

January 5, 1999

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

December 18, 2005

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

February 3, 2007

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

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

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

January 15, 16, 2009
Arctic air blanketed southern Wisconsin and kept temperatures bitterly cold for a 48 hour period. Wind chills reached -35° to -45°F and actual temperatures briefly touched -30 °F. All 16 school districts in Dane County cancelled classes, as well as the University of Wisconsin. Compounding the problem were very slick stretches of road and intersections. Snowfall of almost two inches covered the icy patches making already slippery roads even more dangerous. Road crews worked around the clock to apply sand and salt, but the bitterly cold temperatures rendered the salt virtually useless. Dozens of cars and trucks were involved in slide offs, rollovers, and fender benders on area streets and highways.

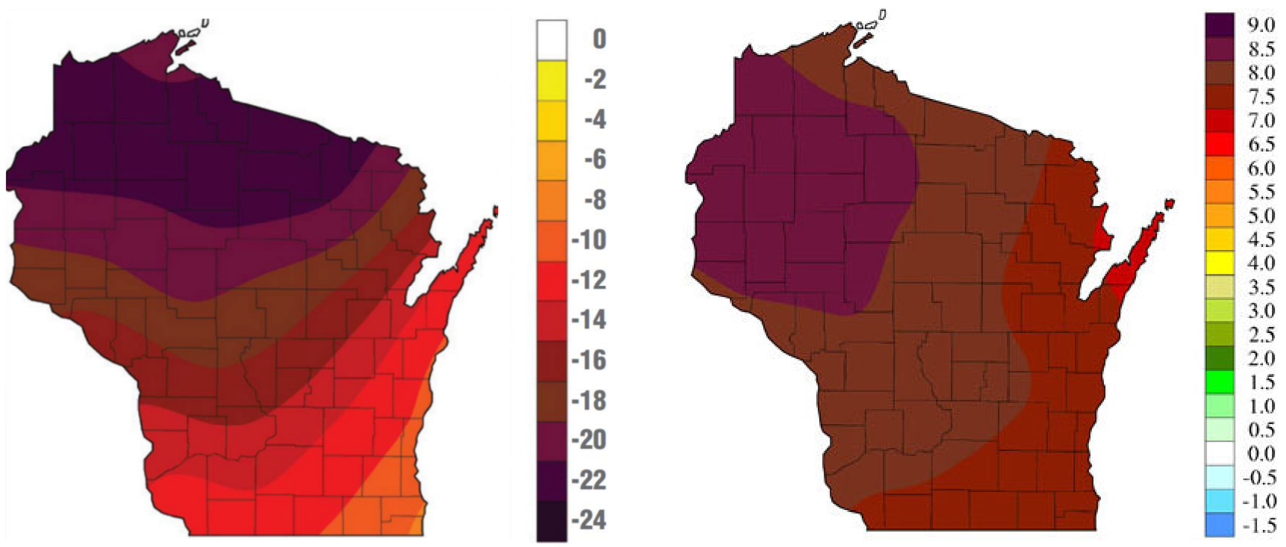
January 6, 7, 2014
An extreme cold wave of arctic air and brisk winds brought 40°F below wind chills to southern Wisconsin. Numerous school and business closings occurred. This cold wave and the continued cold through January, resulted in numerous water main breaks, especially in Madison and Milwaukee. A number of local water utilities advised residents leave water run continuously in order to prevent substantial damages associated with the repair of ruptured and frozen pipes. The cost associated with this protective measure was borne by the local water utilities and was a significant, unbudgeted cost. Local government costs to repair broken mains and pipes was estimated at just over $1.0 million in Dane County alone. The term “Polar Vortex” became a household phrase during the winter of 2014 as this nationwide cold snap affected a large portion of the country.

Madison Water Utility: January 8, 2014

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 it's 2011 report, *Wisconsin's Changing Climate: Impacts and Adaption*, WICCI projects that southern Wisconsin, Dane County included will experience an average winter time temperature increase of 7.5°F to 8°F by 2055. The region can also expect a decrease of 12 to 14 days with below zero low temperatures over this same time period. This is not to say that Dane County will not experience very cold temperatures in the future. These trends do indicate, however, that the likelihood of extreme cold events is generally decreasing.

Figure 4.4.2 Projected Wintertime Temperature Changes in Wisconsin



Projected change in frequency of below-zero nights per year from 1980 to 2055

Projected change in Winter average temperature from 1980 to 2055

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

NWS Heat Index — Temperature (°F)

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

Likelihood of Heat Disorders with Prolonged Exposure or Strenuous Activity

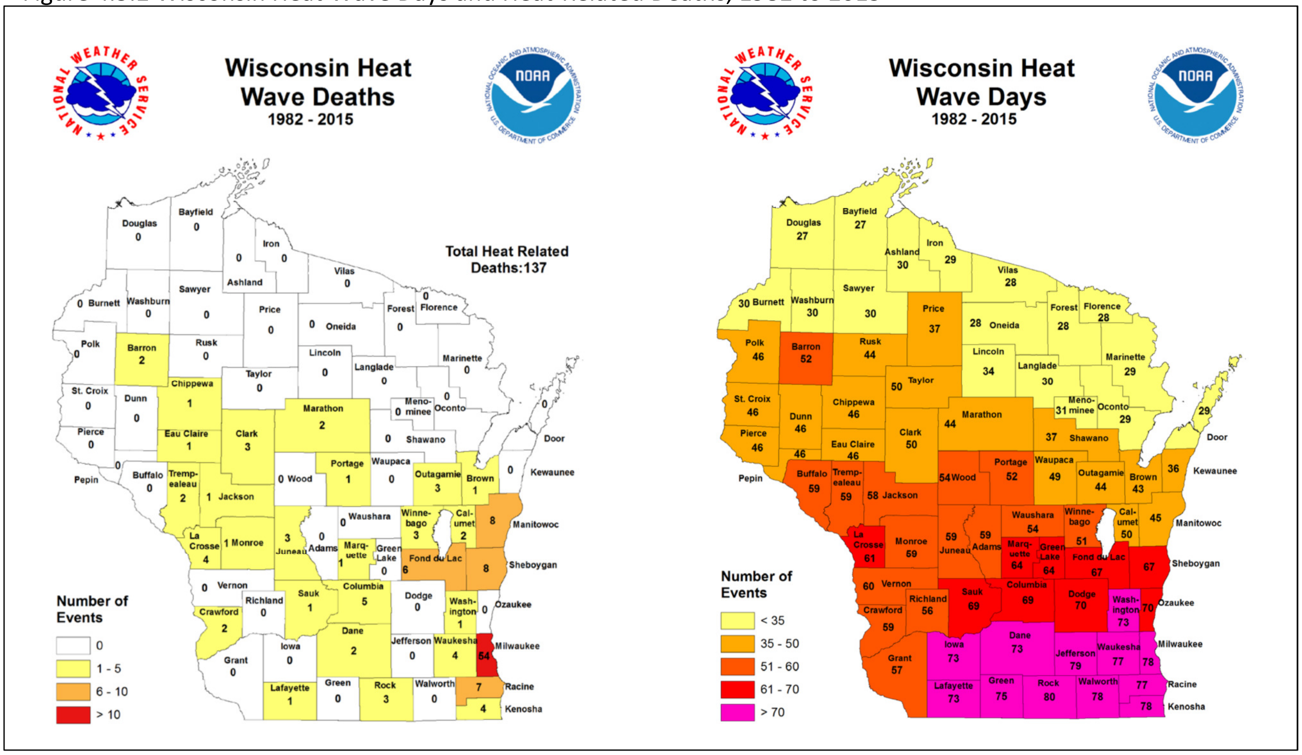
Caution | Extreme Caution | Danger | Extreme Danger

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

Previous Occurrences

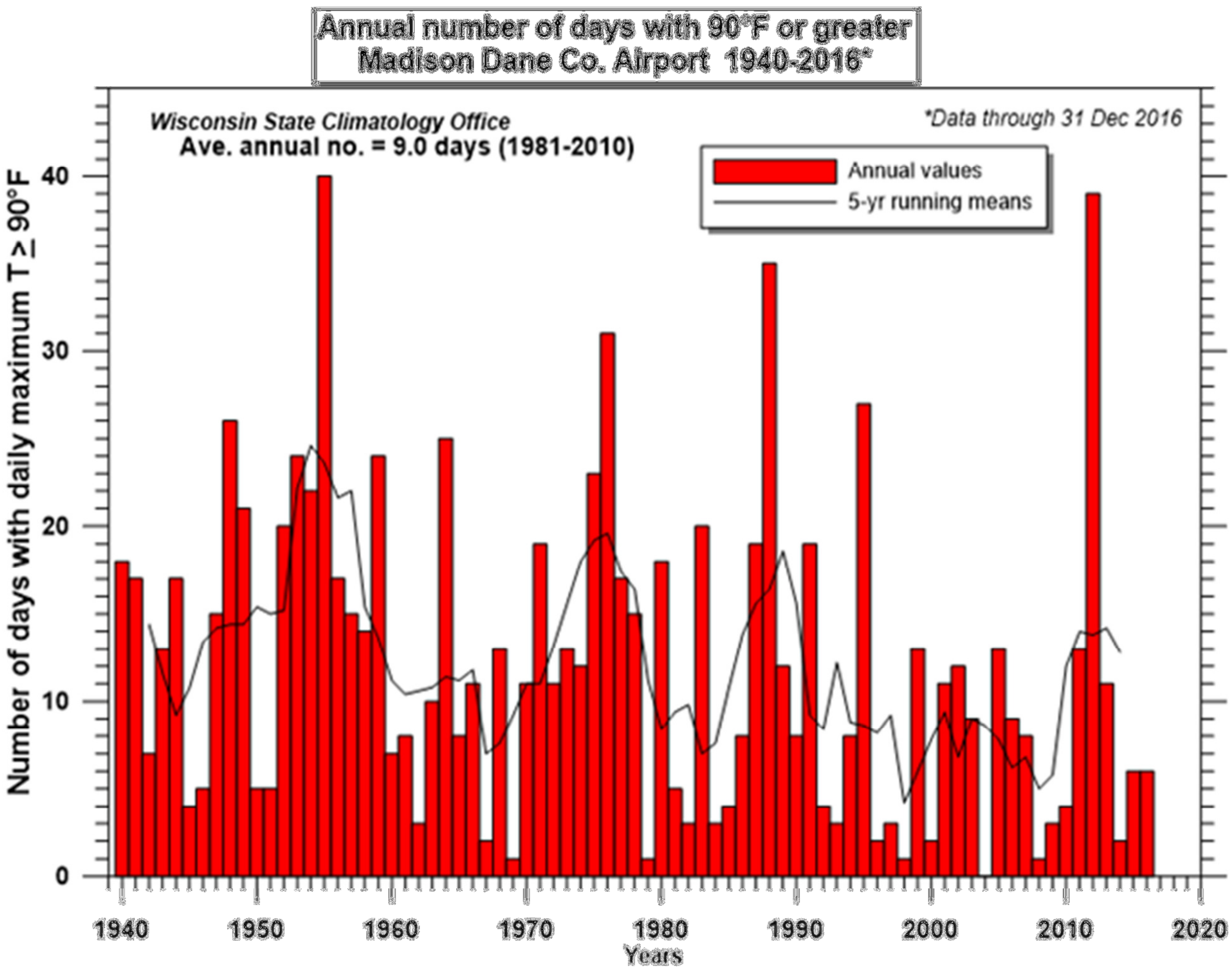
Figures 4.5.2 illustrates the number of heat wave days and heat wave related deaths across Wisconsin. A heat wave day is calendar day in which heat advisory or excessive heat warning was issued. Note that Dane County ranks near the top for both categories. According to the Wisconsin State Climatology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

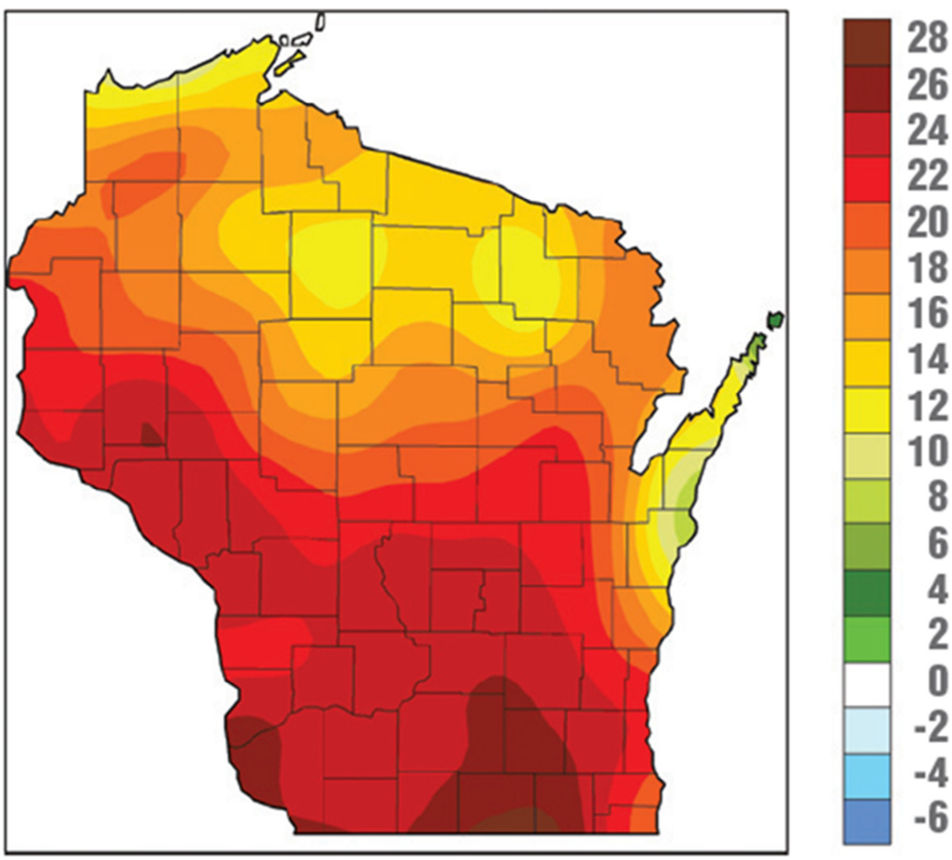
4.5.2 Impact of Climate Change on Future Conditions

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.[9]

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

Indirect Impacts

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

4.5.4 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

[9] 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)[10] 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

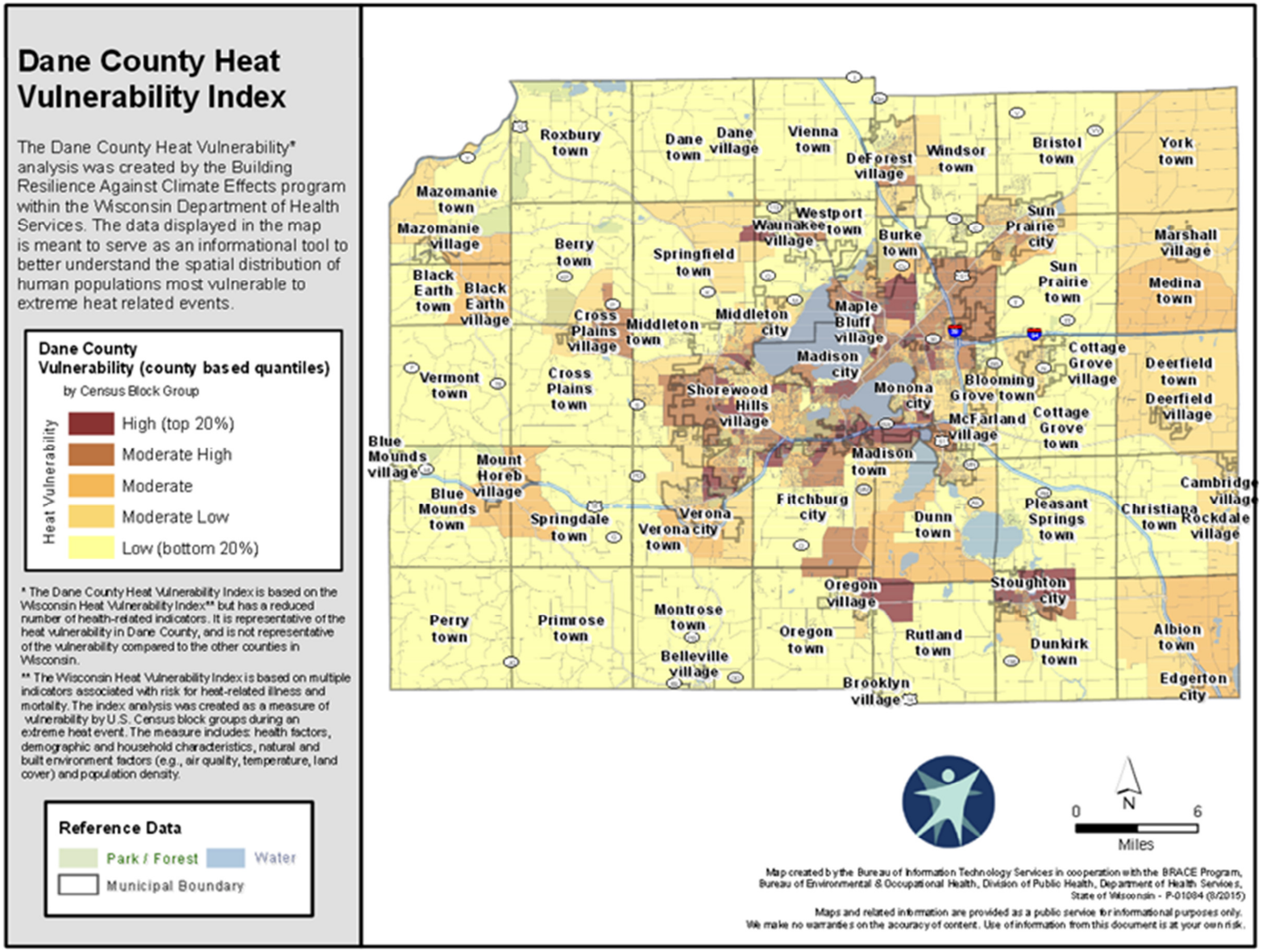
Generally, property is not considered particularly vulnerable to excessive heat. Energy-inefficient buildings may be warmer, resulting in a higher exposure of the population, and personal landscaping and property may suffer from the effects of heat in a manner similar to drought. Cars may overheat, stranding 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.

[10] Wisconsin Department of Health Services, https://www.dhs.wisconsin.gov/climate/wihvi.htm

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. Steam channels meandered, lakes filled and receded seasonally, and water levels were stabilized through ample groundwater and wetland influences. Flooding is not a problem in and of itself. It requires an additional element – human habitation – to become a problem.

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

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

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

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

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

- *Flash floods* involve a rapid rise in water level, high velocity, and large amounts of debris, which can lead to significant damage that includes the tearing out of trees, undermining of buildings and bridges, and scouring new channels. The intensity of flash flooding is a function of the intensity and duration of rainfall, steepness of the watershed, stream gradients, watershed vegetation, natural and artificial flood storage areas, and configuration of the streambed and floodplain. Urban areas are increasingly subject to flash flooding due to the removal of vegetation, covering of ground cover with impermeable surfaces, and construction of drainage systems.

- *Surface water flooding* or localized stormwater drainage floods may occur outside of recognized drainage channels or delineated floodplains due to a combination of locally heavy precipitation, a lack of infiltration, inadequate facilities for drainage and stormwater conveyance, and increased surface runoff. Surface water flooding is usually the result of high intensity rainfall, but can occur with lower intensity rainfall when the land has a low permeability and/or is already saturated. This can be an especially large problem in urban areas. Such events frequently occur in flat areas, particularly during winter and spring in areas with frozen ground, and also in urbanized areas with large impermeable surfaces.

- *Groundwater flooding* occurs when the water table rises above normally expected levels. This can be as a result of persistent rainfall that recharges aquifers until they are full, or may be a result of high river levels or lake driving water through near-surface soils. Compared to surface water flooding, groundwater flooding can last considerably longer, with incidents enduring anything from a week to several months.

Floodplains and the National Flood Insurance Program

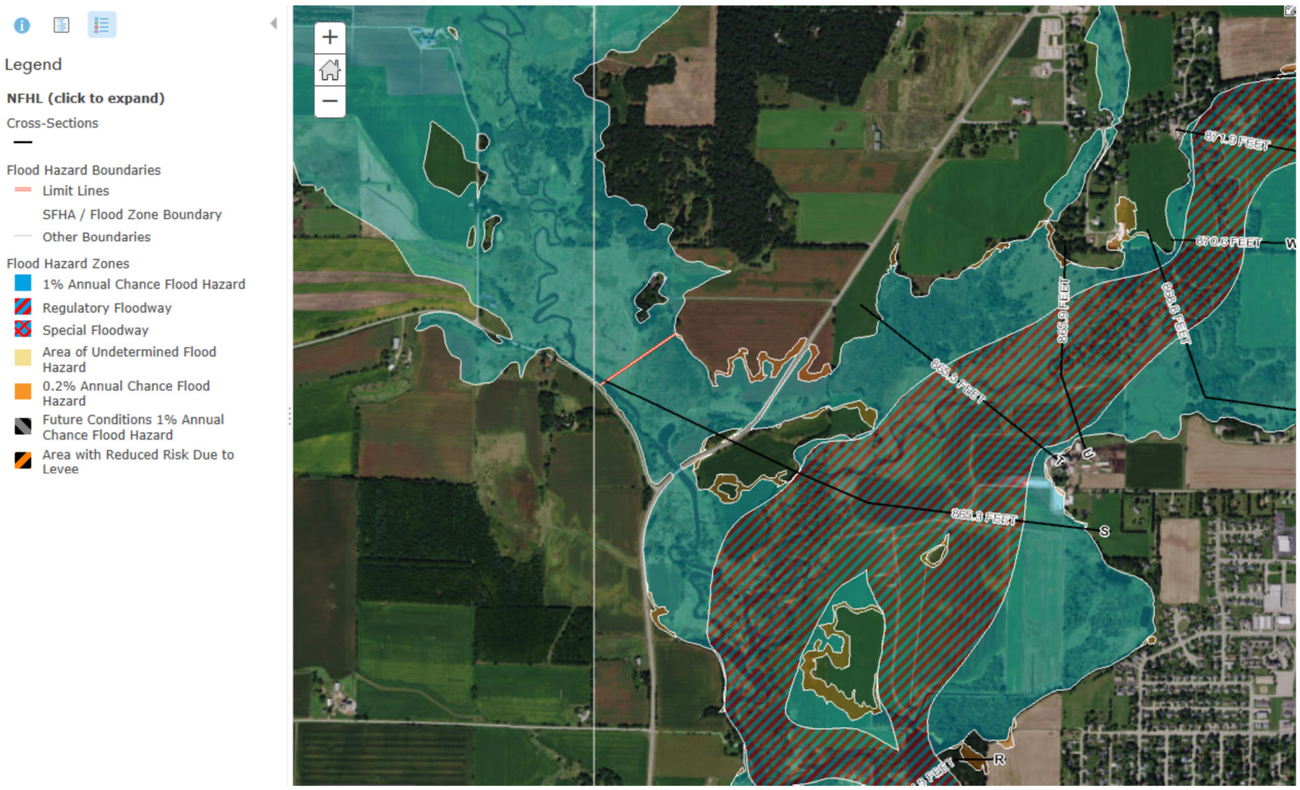
Most homeowner’s insurance policies do not cover damages caused by flooding. Flood loses are covered under a separate flood insurance policy sold through the National Flood Insurance Program (NFIP).

At the Federal level, floodplain regulation primarily falls to FEMA and the NFIP. Established in 1968, the NFIP administers the nationwide flood insurance program and sets standards for floodplain management as part of the requirements for participating in the program. NFIP requirements are outlined in 44 Code of Federal Regulations 59-72. Communities that elect to participate in the NFIP ensure the availability of federally-backed flood insurance policies for the homeowners, renters, and businesses in their jurisdiction.

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

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

Figure 4.6.1 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.[12]
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

[12] 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.

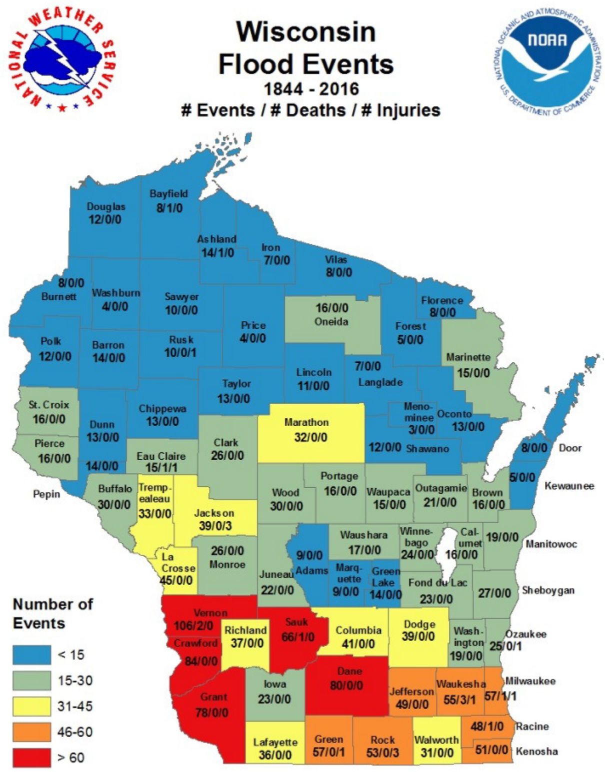
During the time period of the preparation of this plan update, the Lakes and Watershed Commission and the Capital Area Regional Planning Commission established a Stormwater Technical Advisory Committee to evaluate the County's stormwater management strategies and make recommendations regarding flood 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 Tornados	Presidential Disaster	$180,000 (Public Assistance)
1990	Flooding and Tornados	Presidential Disaster	$37,000 (Public Assistance) $30,343 (Individual Assistance)
1993	Flooding	Presidential Disaster	$888,000 (Public Assistance) $1.44 Million (Individual Assistance) $22.6 Million (Total Damages, est.)
1996	Flooding and Severe Storms	Local Sources	$1.7 Million (Public Losses, est.) $6.8 Million (Private Losses, est.) $8.5 Million (Total Damages, est.)
2000	Severe Storms (Windstorm) and Flooding	Presidential Disaster	$940,000 (Public Assistance) $1.25 Million (Individual Assistance) $9.3 Million (Total Damages, est.)
2007	Flooding	Presidential Disaster	$0.6 Million (Individual Assistance) $1.64 Million (Public Assistance) $5.1 Million (Total Damages, est.)
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) $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

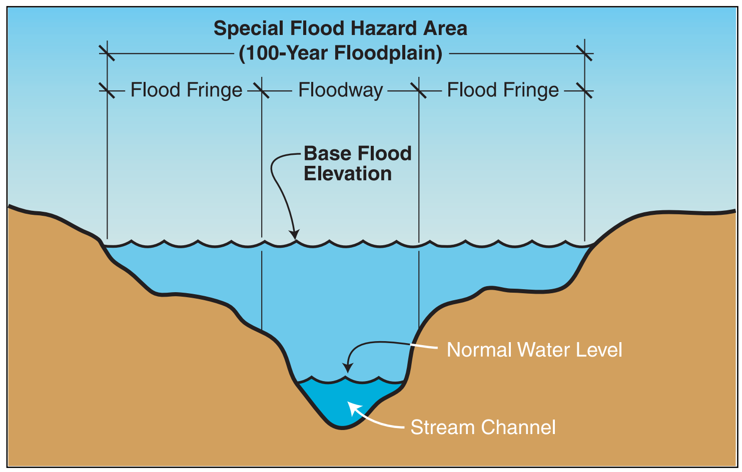
During the development of the initial Flood Mitigation Plan (2003) a comprehensive assessment of the impacts and problems associated with floods in Dane County was performed using a combination of survey, public meetings, interviews and GIS. The results of this planning process are still used in flood 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.

  Figure 4.6.3 Floodplain Definition Sketch.

  Source: FEMA, 2001.

  The locations and delineation of floodplain boundaries are not a static representation of flood risk. Floodplains change over time. Though they are represented as a line on a Flood Insurance Rate Map (FIRM), floodplains and flood risk are not black and white. The floodplain maps are designed to indicate areas with a risk of flooding, but those areas are constantly changing. Increasing impervious surface areas with new development, soil saturation, rainfall intensity, stream conditions, shoreland and wetland modifications (both restoration and degradation), and stormwater management practices all affect the extent to which flooding will occur.

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

- *Hydric Soils.* Though mapped/regulatory floodplains are a good predictor where flooding occurs, floodplains do not account for all of the flooding in the County. The location of certain soil types, hydric soils in particular, is also a good predicator of where flooding is likely to occur. Hydric soils are formed under conditions of saturation, flooding, or ponding long enough during the growing season to develop anaerobic conditions in the upper part. They are a good indicator of the historic locations of wetlands or other wet areas. As such, development in areas with hydric soils is another prime indicator of where flood damages are likely to occur, especially in areas where urbanization has not altered the natural hydrology of the area.

- *Topography.* The topography of the County affects the spatial extent of flooding. In the western portion of the County where topography is most exaggerated, flooding occurs in small areas, yet the water flow rate is much higher than in the eastern part of the County. There, landowners experience expansive flooding, since the water is able to spread across the landscape more easily. Topography and hydric soils are useful indicators of the frequency and extent of flooding outside the floodplain.

Figure 4.6.4 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 tiled and drained to produce fertile farm fields and they have been filled and paved to prepare for development. Wetlands on the Yahara Chain of Lakes have also been lost during recent flood events as rising floodwaters detach and lift sections of marsh. The floating marsh sections have been subsequently removed to eliminate the navigational hazards they posed. Lakes in the Yahara Chain of Lakes have lost between half and nearly all of the wetlands associated with them since 1835.

Healthy wetlands have the potential to store large volumes of floodwater. As wetlands become destroyed or degraded, their capacity to store water may be reduced. Water that would otherwise have been stored in the wetlands then contributes to increasing flood levels and flows. The maintenance and restoration of wetlands has the potential to be a very effective flood management tool.

- *Stormwater Issues.* Dane County is among the fastest growing and developing counties in the State of Wisconsin. The challenges of managing this rapid development are wide-ranging; however, one of the more significant impacts is the effect of development on the hydrology of the watershed. The effect of upstream development on downstream properties was widely recognized as significant contributing factor in Dane County's flood problems. In fact, development and other changes to the landscape in areas far outside the floodplain can have a profound impact on the magnitude and frequency of downstream flooding. This is a highly complex issue that includes elements of land-use decision-making, property rights, intergovernmental cooperation (or lack of), as well as the hydrology of the watershed and stormwater management practices. Many of these elements are well beyond the scope and charge of this Plan, however, the issues as related to stormwater management can at least be framed here.

- *The Effects of Urbanization.* Urbanization is one of the most severe land use impacts in terms of its lasting effects on hydrology, due to the much higher percentages of impervious or paved areas covering the land. Rural land surfaces are almost completely pervious, while about one-third of the land surface in urban areas is covered by rooftops and paved areas. The main effects of urbanization on the hydrology of an area include:

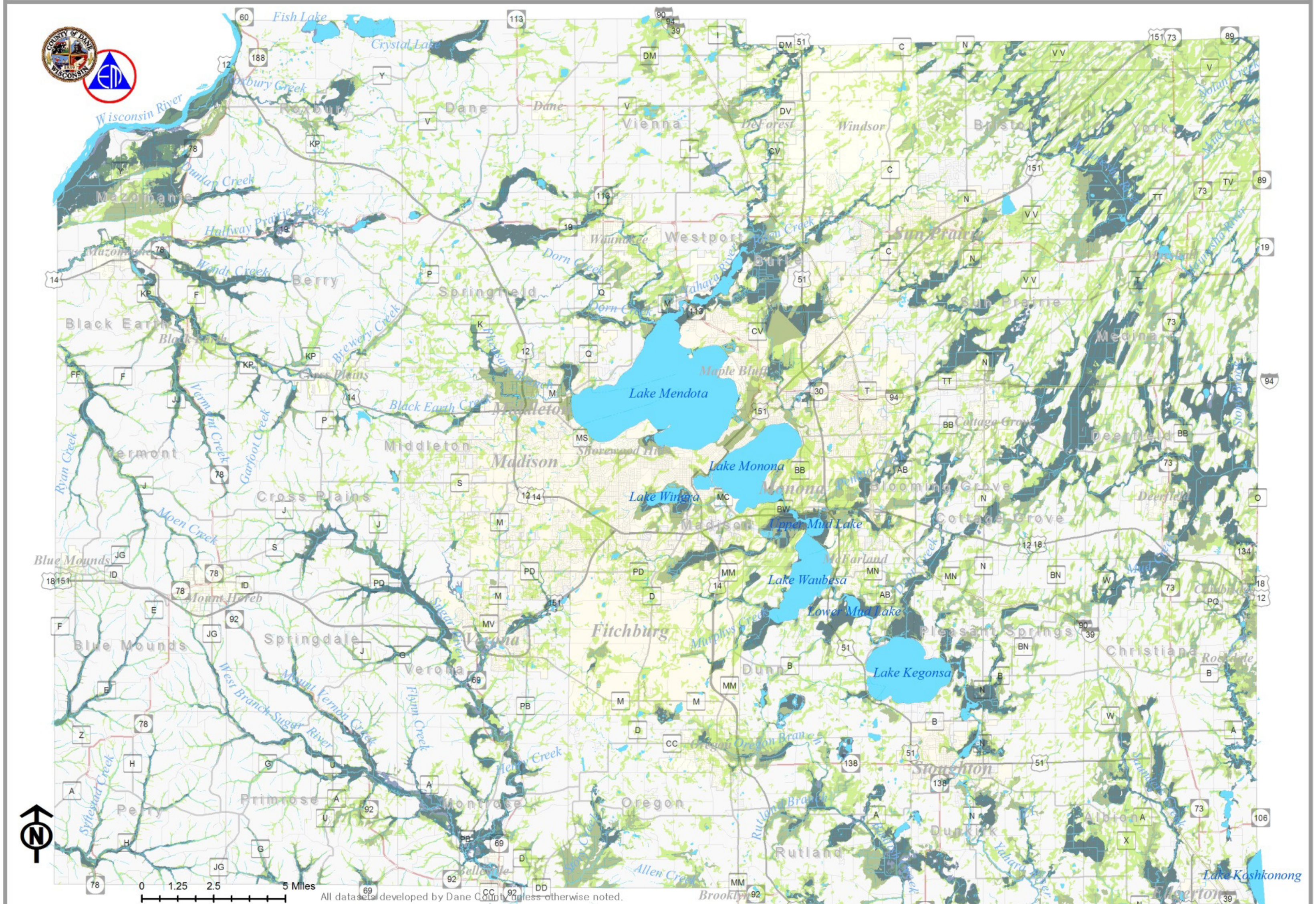
    - An increase in the total amount of rainfall running off the surface of the land.
    - A decrease in the amount of rainfall infiltrating into the soil.
    - More rapid runoff and much higher peak flows.
    - Reduced baseflows in streams during dry weather periods.

  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

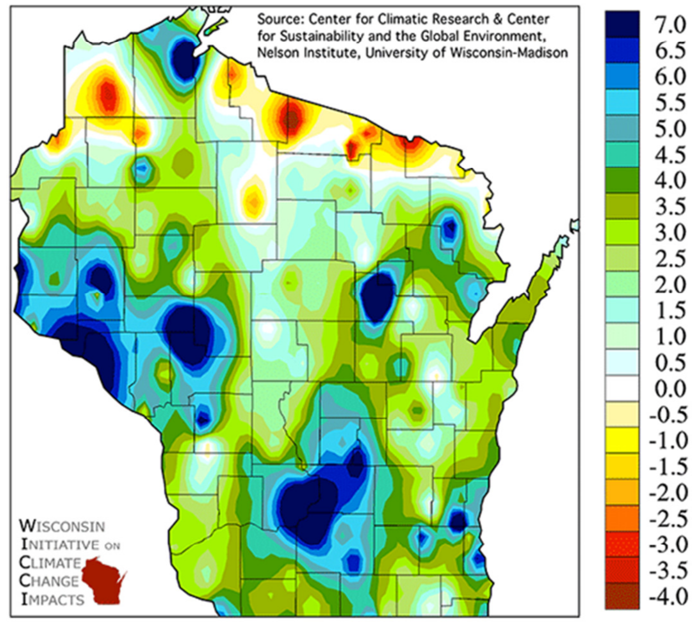
The flood hazard in southern Wisconsin, including Dane County, is changing and all indications are that the risk is increasing. The Wisconsin Initiative on Climate Change Impacts (WICCI) is the primary source for the assessment of Dane County's changing flood risk.

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.

Figure 4.6.5

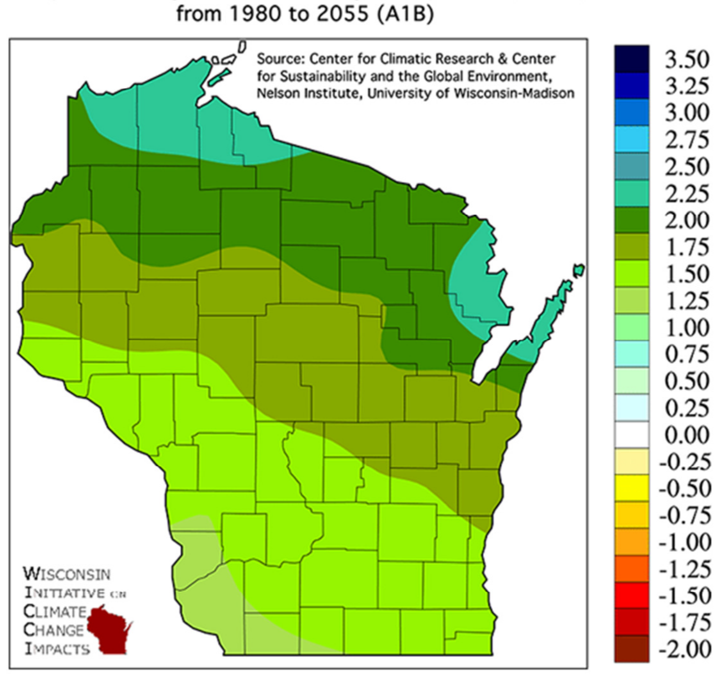
Change in Annual Average Precipitation (inches) from 1950 to 2006



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)[13]

Figure 4.6.6

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



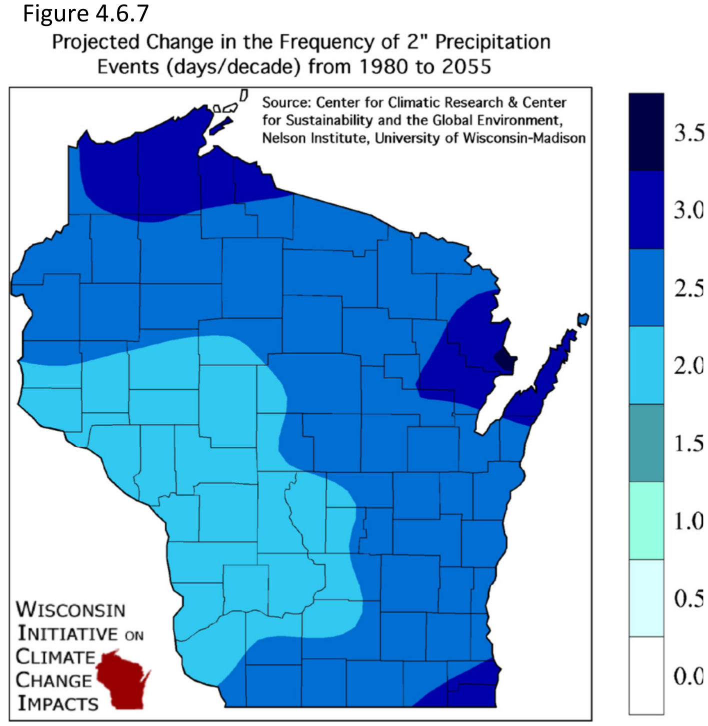
Climate models suggest that these trends will continue, with an overall increase in wetter conditions and more intense rainfall. This trend is likely to lead to a subsequent increase in the severity and frequency of high flows and high water levels. Figure 4.6.6 indicates one model's projected change in annual average precipitation from 1980 to 2055.

[13] 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[14]

Figure 4.6.7



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.

[14] 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.[15]

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.

[15] 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 loses are covered under a separate flood insurance policy sold through the National Flood Insurance Program (NFIP). Only a small percentage of home owners actually have flood insurance policies. This means that when flood damages do occur, the costs to repair and recover from the loss are uninsured losses that are borne almost entirely by the property owner.

Building Damage

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

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

Sewer and Wastewater

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

Road, Shoulder, and Ditch Flooding

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

Farmland Flooding

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

Erosion and Stream Pollution

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

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

Public Health and Safety

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

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

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

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

4.6.4 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

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	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.

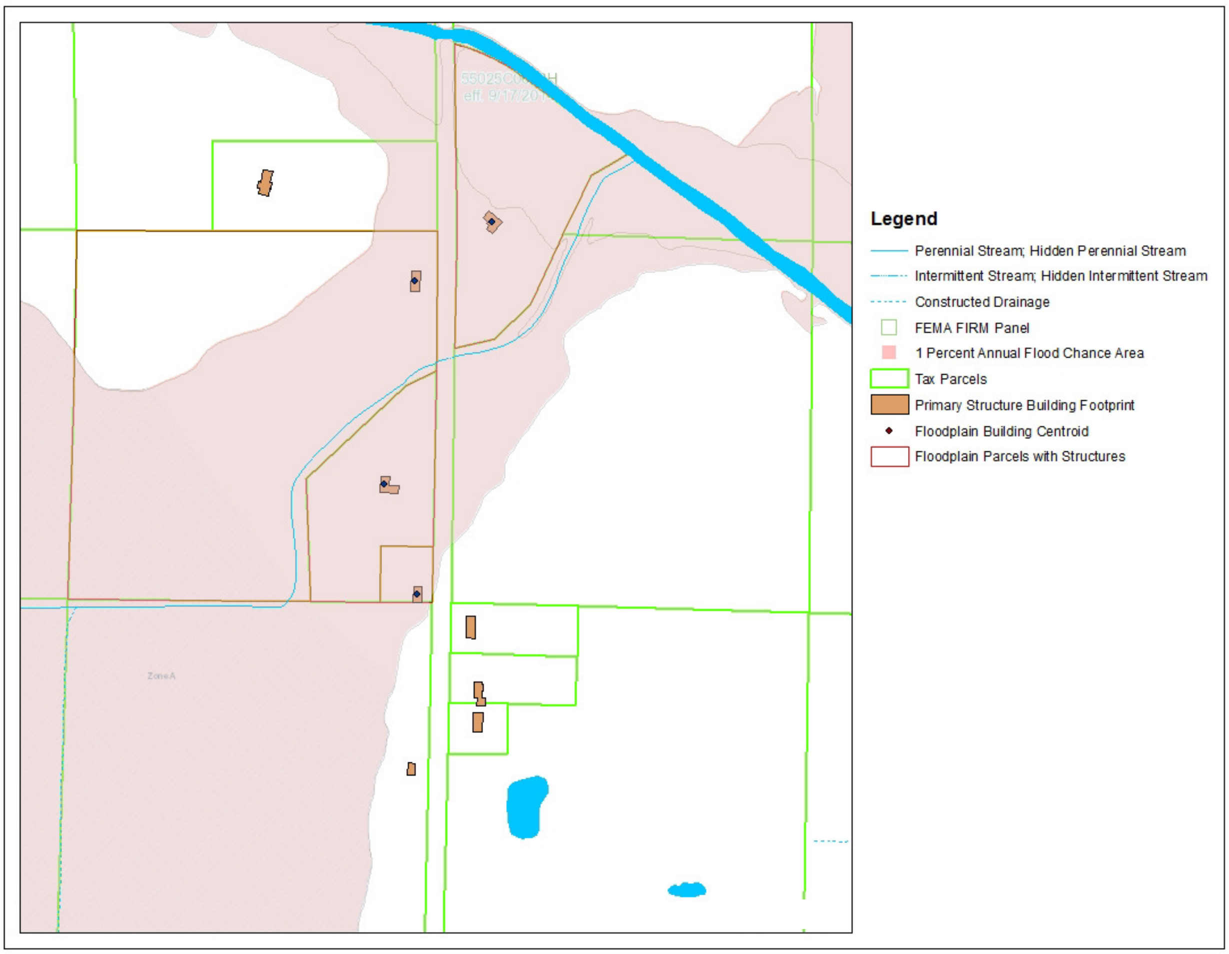
Structures in the Floodplain

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.

- 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.

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
Total	381	596	977	$207,380,200	$160,504,950	$25,409,015	$20,230,376	$45,639,391

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

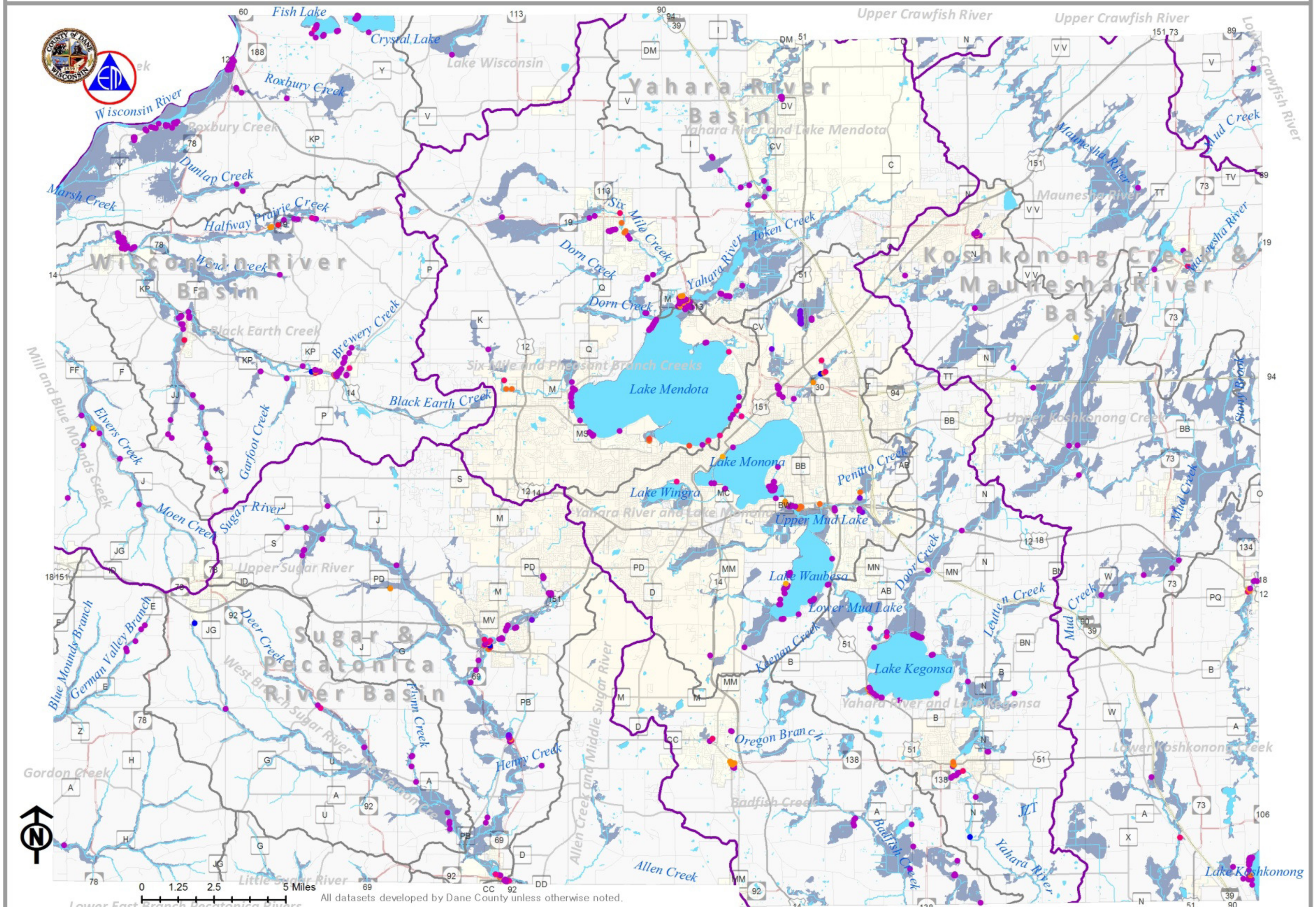
Table 4.6.6 Damage Potential Estimate for Structures in 100-year Floodplain – Summarized by Jurisdiction

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

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

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
Total	855	122	977	$207,380,200	$160,504,950	$25,409,015	$20,230,376	$45,639,391

Figure 4.6.9
Primary Structures in Floodplain



Flood Insurance Claims and Repetitive Losses

There are 74 properties in Dane County on record as having made a total of 108 flood insurance claims through the NFIP, totaling more than $2.4 million since 1978. Figure 4.6.10 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 polices are located in the following jurisdictions:

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

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

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

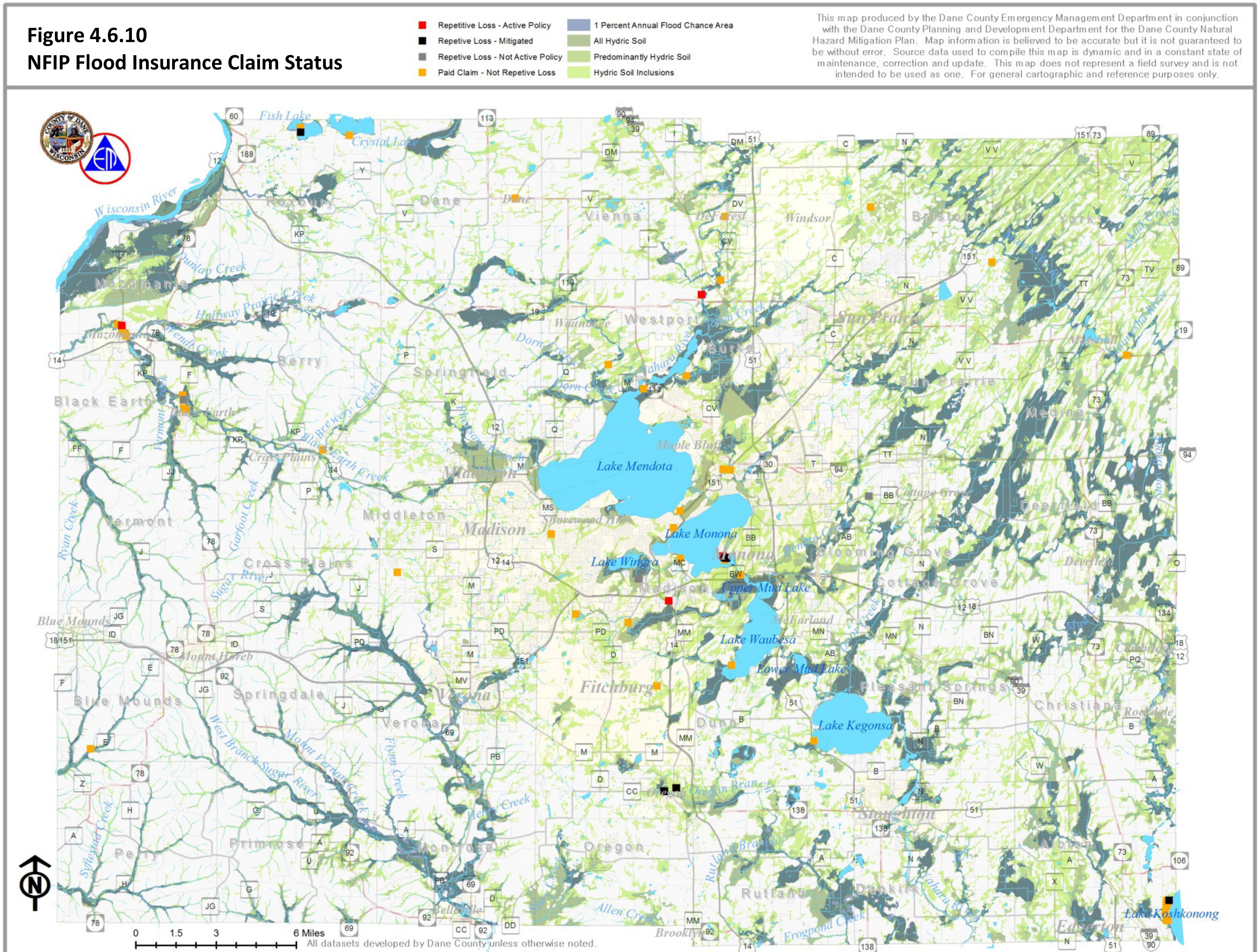
Flood insurance claims are summarized in Table 4.6.7, sorted by watershed from the least number of claims to the most. Watersheds having no claims are not listed in the table.

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
Maunesha River	Town of Medina Town of Bristol Watershed Total	2000 2007, 2010	1 2 3	$1,619 $9,865 $11,484
Six Mile and Pheasant Branch Creeks	City of Madison Town of Westport Watershed Total	2000 2001, 2007	1 2 3	$3,679 $32,245 $35,924

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

Figure 4.6.10
NFIP Flood Insurance Claim Status



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 know 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 combines losses totaling more than $7.45 million. This indicates that approximately 40% of the losses were reimbursed by FEMA or the NFIP, with about 60% of the losses borne by the property owner.

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

Table 4.6.8 2008 Flood Damage Claims Summary

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

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.

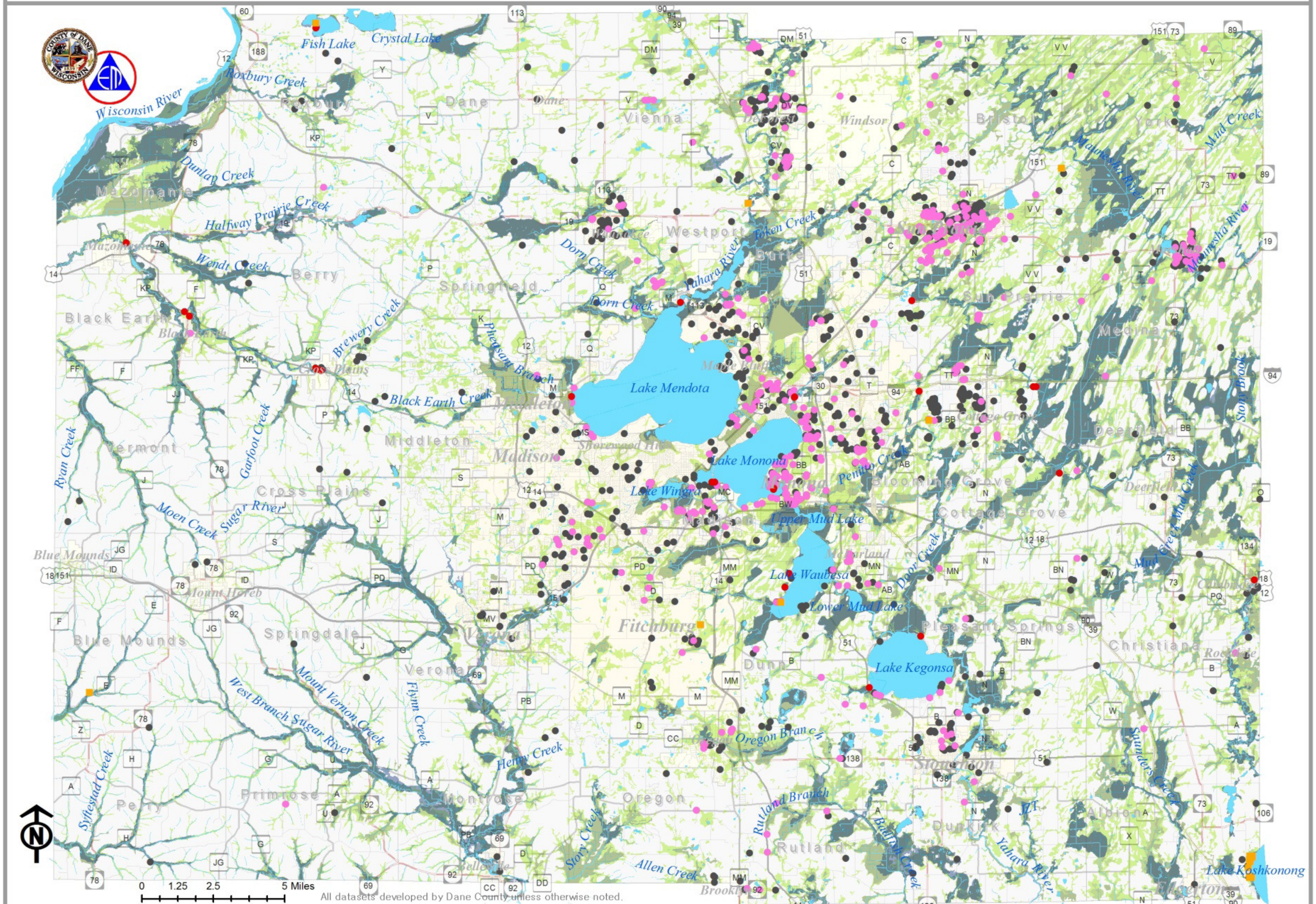
These are not dramatically disproportionate differences in the locations where damage occurred, but a higher level of flood risk is still apparent. Even so, with 60% of the damage claims occurring outside of these areas, it is clear that additional factors are in play. Flood damages are more widely distributed 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.[16] 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[17]:

- 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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[16] Wisconsin Initiative on Climate Change Impacts, *Stormwater Working Group Report*, 2011
[17] 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.

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.[18] 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
Totals	**3**	**92**	**177**	**272**

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

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

[18] 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.[19]

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.

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

4.8 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.

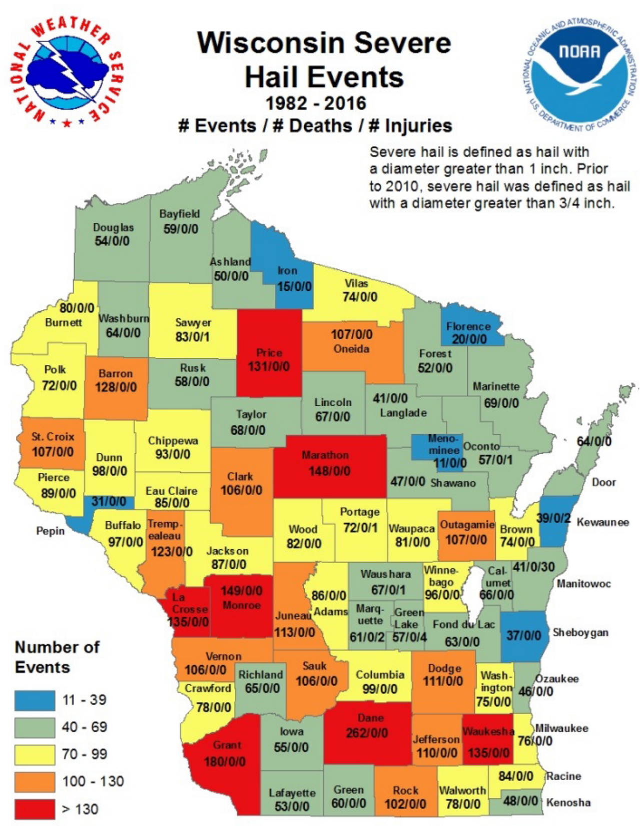
Previous Occurrences

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.

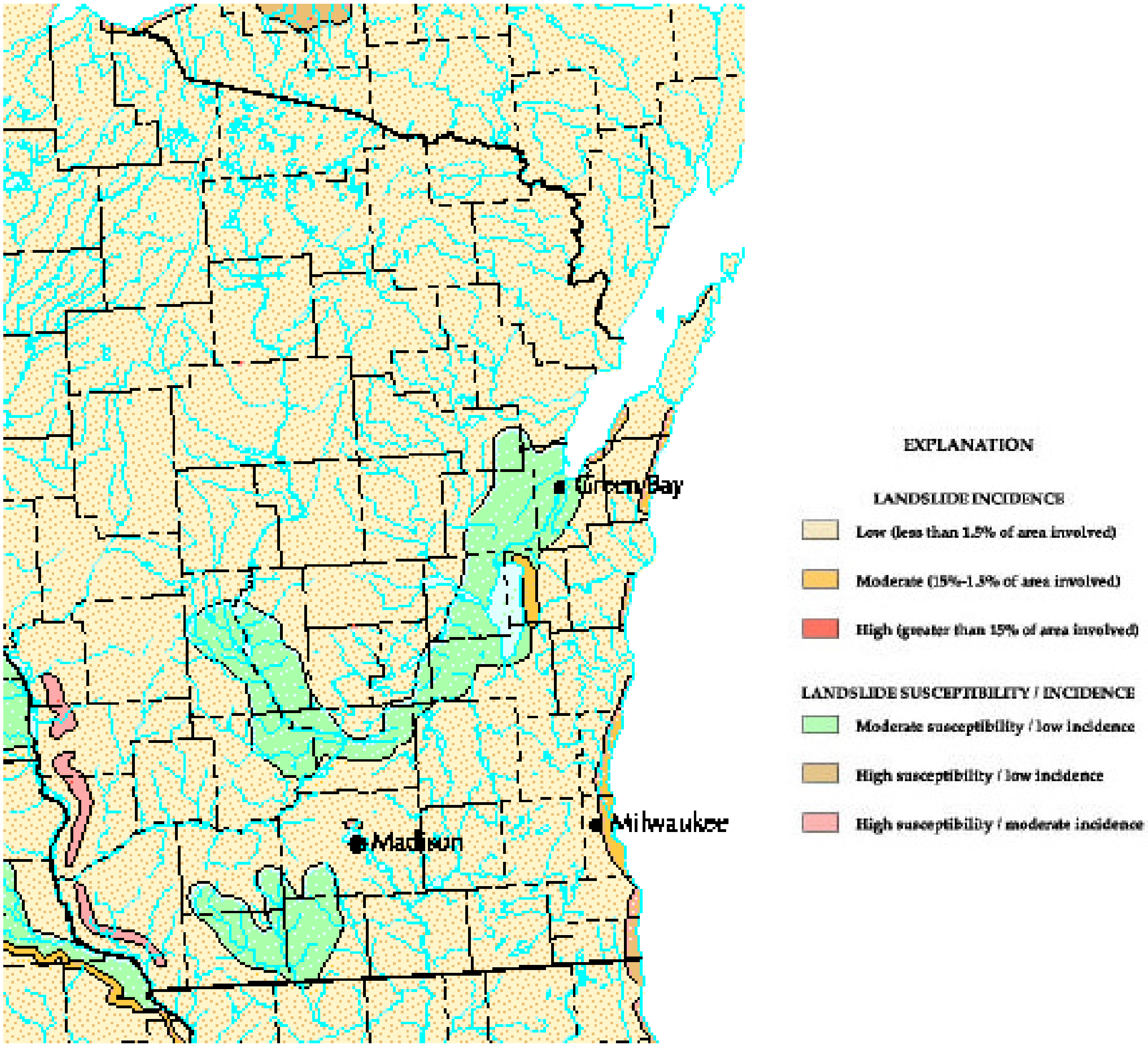
Erosion is the detachment and movement of soils or rock fragments by water, wind, ice or gravity. Erosion may contribute to the likelihood and occurrence of landslides, particularly when stream banks or bluffs are eroded. The State Hazard Analysis from 2016 cites several examples where structures that 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." [20]

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.

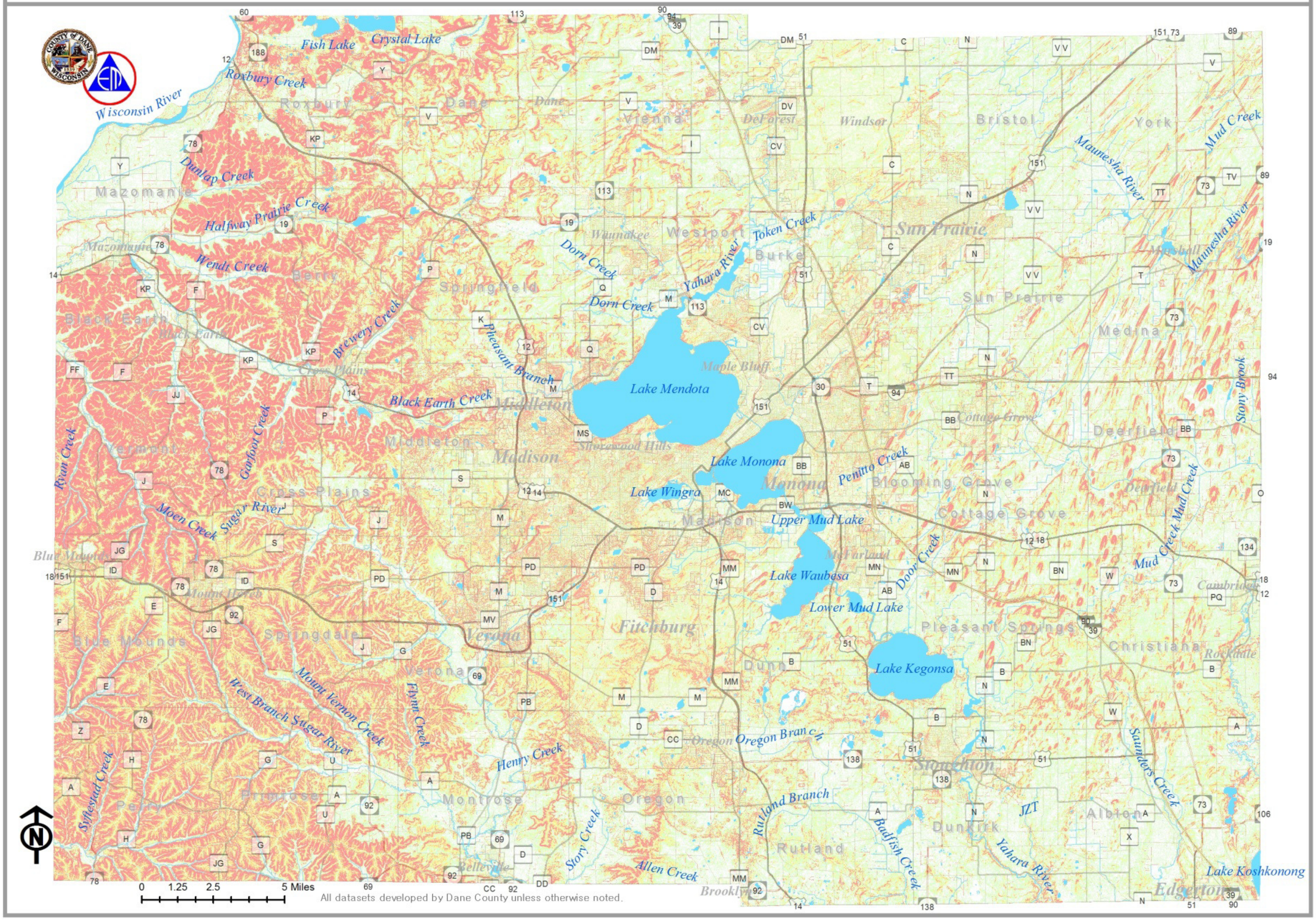
[20] USGS "Landslides Hazard Program: Landslides 101." Available online at https://landslides.usgs.gov/learn/ls101.php last accessed March, 2017.

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.

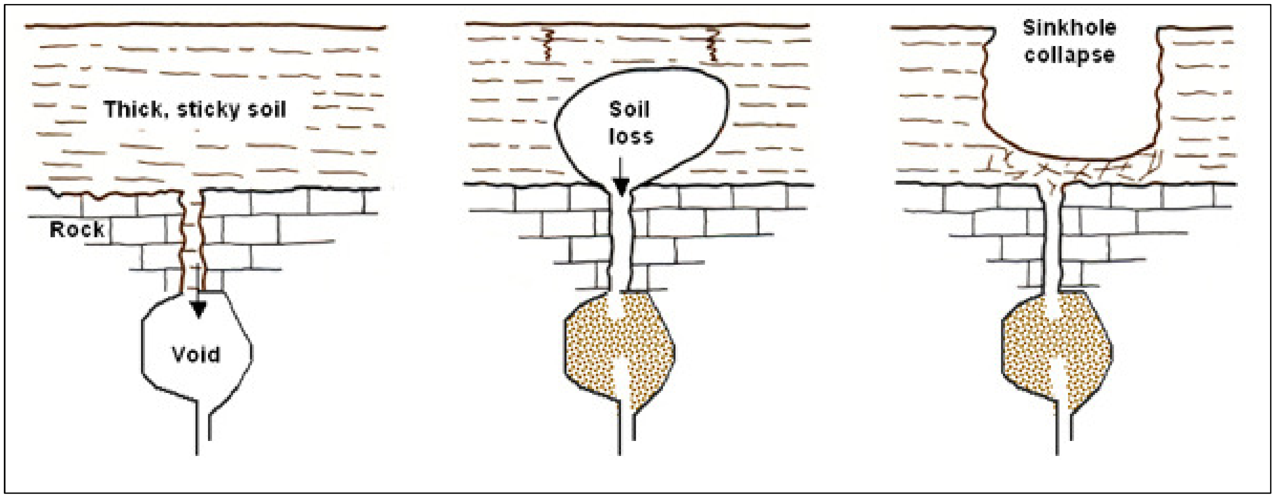
Figure 4.9.2
Terrain and Steep Slopes



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.

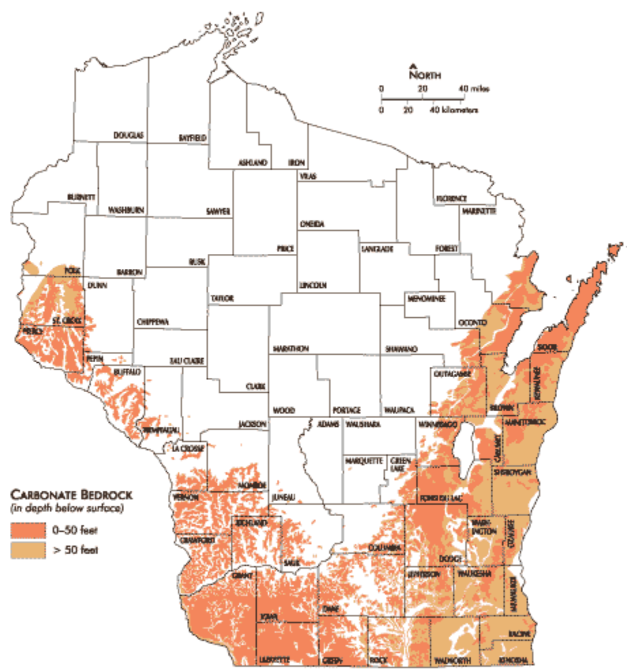
Figure 4.9.3 Sinkhole Formation Illustration



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.

Figure 4.9.4 Wisconsin Karst Potential



Source: Wisconsin Geological & Natural History Survey

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

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

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

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

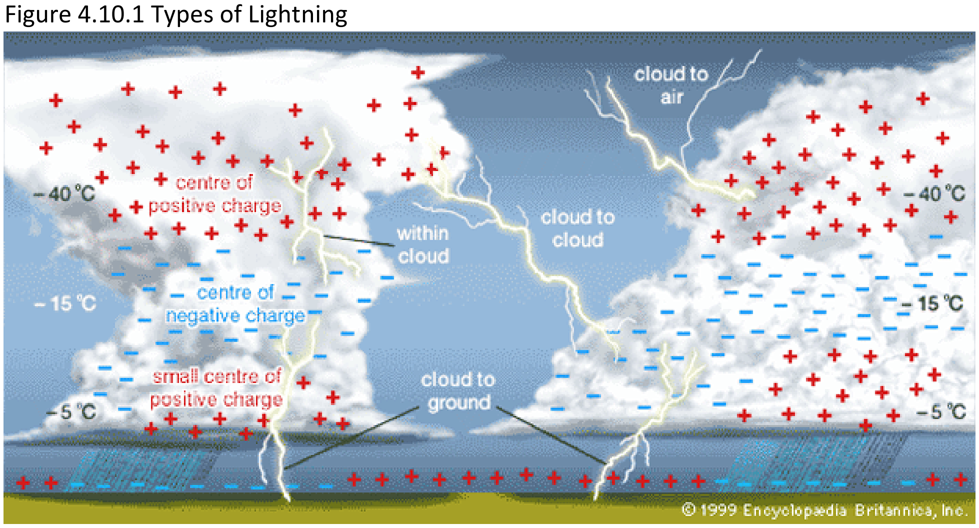
Lightning is caused by the attraction between positive and negative charges in the atmosphere, resulting in the buildup and discharge of electrical energy. This rapid heating and cooling of the air produces the shock wave that results in thunder. During a storm, raindrops can acquire extra electrons, 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 lighting can occur too, transferring a net positive charge from the upper portion of a cloud to the ground. Although much less common, positive lightning can be more dangerous. Because it must travel a longer distance to reach the ground, the electrical field is stronger which means the strike can have a longer duration with a charge ten times that of a negative lightning strike.

Figure 4.10.1 Types of Lightning



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

High winds, rainfall, and a darkening cloud cover are warning signs for possible cloud-to-ground lightning strikes. While many lightning casualties happen at the onset of a storm, more than half of lightning deaths occur after a thunderstorm has passed. The lightning threat diminishes after the last sound of thunder, but may persist for more than 30 minutes. When thunderstorms are in the area, but not overhead, the lightning threat can exist when skies are clear. Lightning has been known to strike ten miles or more from the storm in an area with clear sky above. Large outdoor gatherings are particularly vulnerable to lightning strikes that could result in injuries and deaths. This vulnerability underscores the importance of developing site-specific emergency procedures for these types of events with particular emphasis on adequate early warning.[21]

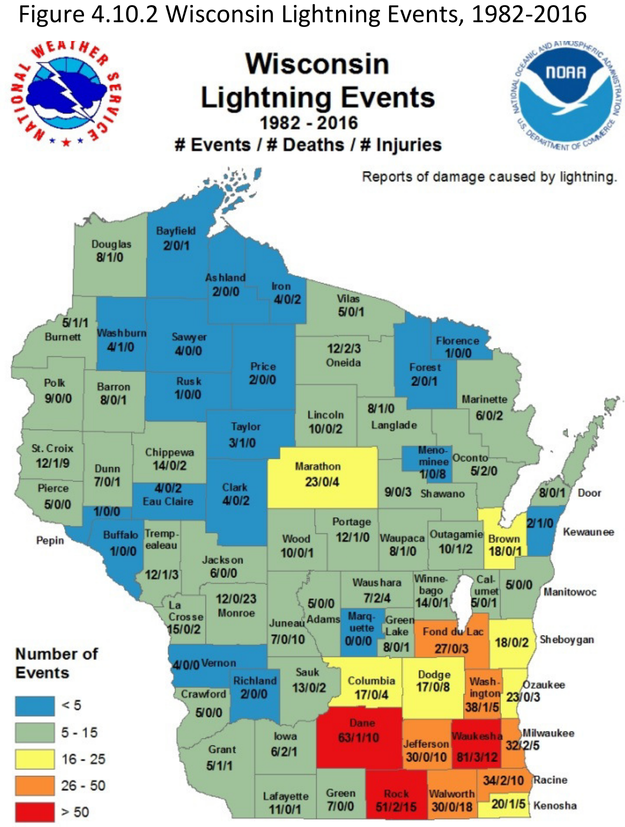
Previous Occurrences

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

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

4.10.3 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

- Fire caused by the high temperatures associated with lightning
- Power surges that can damage electrical and electronic equipment

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

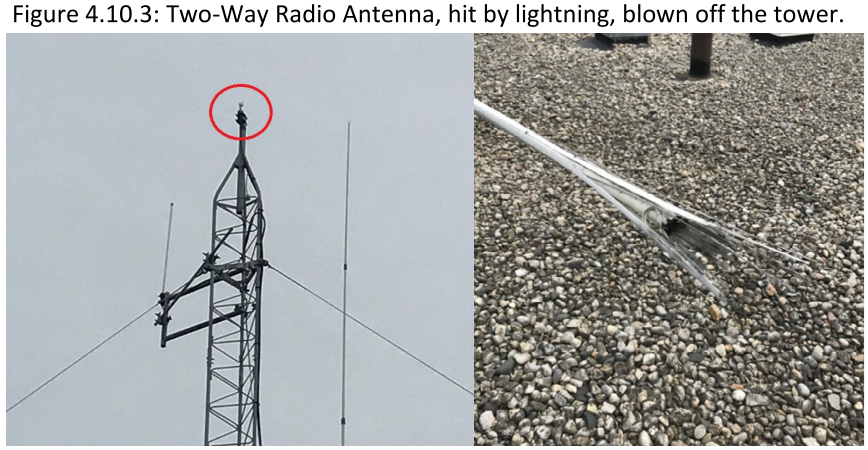
When humans are struck by lightning, the result is deep burns at the point of contact mostly on the head, neck and shoulders. Approximately 70 percent of lightning survivors experience residual effects, most commonly affecting the brain (neuropsychiatric, vision and hearing). These effects can develop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

Indirect Impacts

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

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

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



Dane County Emergency Management, March 2017

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 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.[22]

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.[23]

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.[24]

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.

[22] American Meteorological Society, Glossary of Meteorology 2nd Edition. Available online at http://amsglossary.allenpress.com/glossary
[23] National Severe Storms Laboratory "FAQ About Tornadoes." Available online at http://www.nssl.noaa.gov/research/tornadoes/
[24] 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

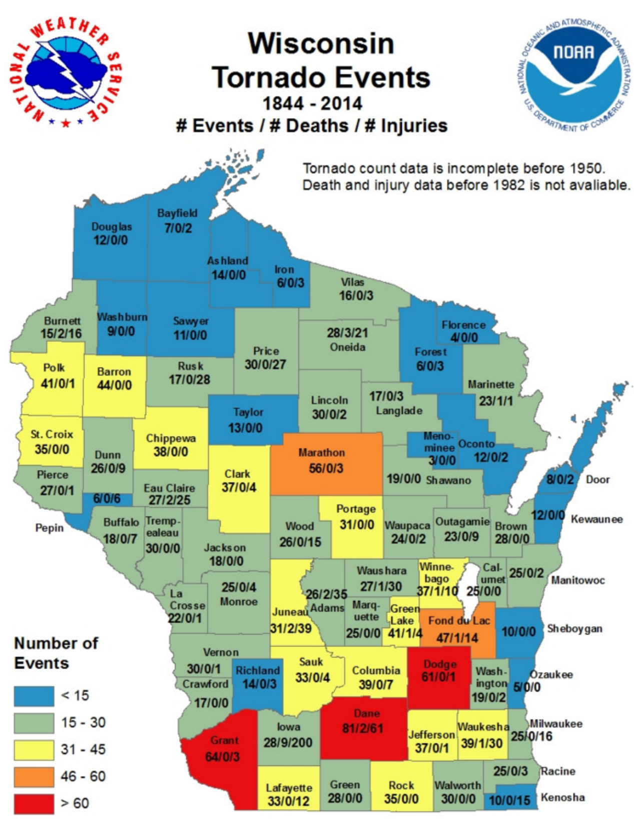
Fujita Scale			**Derived EF Scale**		**Operational EF Scale**	
F Number	Fastest 1/4-mile (mph)	3 Second Gust (mph)	EF Number	3 Second Gust (mph)	EF Number	3 Second Gust (mph)
0	40-72	45-78	0	65-85	0	65-85
1	73-112	79-117	1	86-109	1	86-110
2	113-157	118-161	2	110-137	2	111-135
3	158-207	162-209	3	138-167	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 are in broad daylight, it likely went undocumented. Additionally, severe weather spotter and research videotapes of tornadoes in the past 20 years has shown that a tornado can be in progress, but a visible “funnel cloud” may be absent or poorly defined. In these cases, confirmation of a tornado is based on a rotating dirt/debris spray observed at ground and cloud-base rotation directly above. Table 4.11.2 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).

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

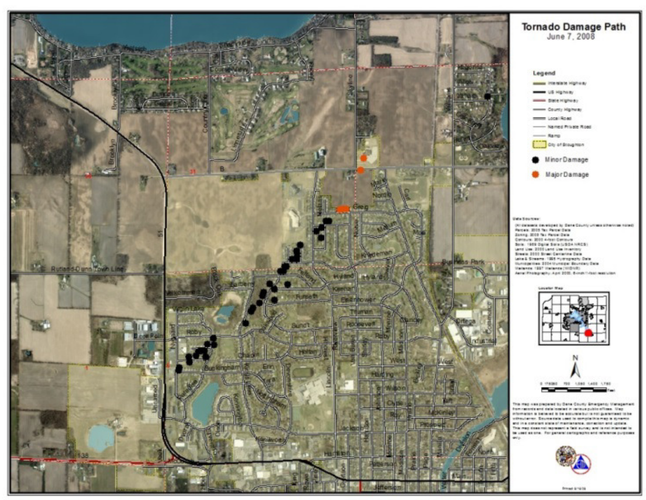
Dane County Emergency Management

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 tress; pushes over shallow-rooted trees; damages signboards; some windows broken; hurricane wind speed begins at 73 mph.

- *EF1 Category Tornado*: wind speeds between 86-110 mph. Moderate tornado. Moderate damage. Peels surfaces off roofs; manufactured homes pushed off foundations or overturned; outbuildings demolished; moving autos pushed off the roads; trees snapped or broken.

- *EF2 Category Tornado*: wind speeds between 111-135 mph. Significant tornado. Considerable damage. Roofs torn off frame houses; manufactured homes demolished; frame houses with weak foundations lifted and moved; boxcars pushed over; large trees snapped or uprooted; light-object missiles generated.

- *EF3 Category Tornado*: wind speeds between 136-165 mph. Severe tornado. Severe damage. Roofs and some walls torn off well-constructed houses; trains overturned; most trees in forests uprooted; heavy cars lifted off the ground and thrown; weak pavement blown off roads.

- *EF4 Category Tornado*: wind speeds between 166-200 mph. Devastating tornado. Devastating damage. Well constructed homes leveled; structures with weak foundations blown off some distance; cars thrown and disintegrated; large missiles generated; trees in forest uprooted and carried some distance away.

- *EF5 Category Tornado*: wind speeds over 200 mph. Incredible tornado. Incredible damage. Strong frame houses lifted off foundations and carried considerable distance to disintegrate; automobile-sized missiles fly through the air in excess of 300 ft (100 m); trees debarked; incredible phenomena will occur.

Indirect 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:

- 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%

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%

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.

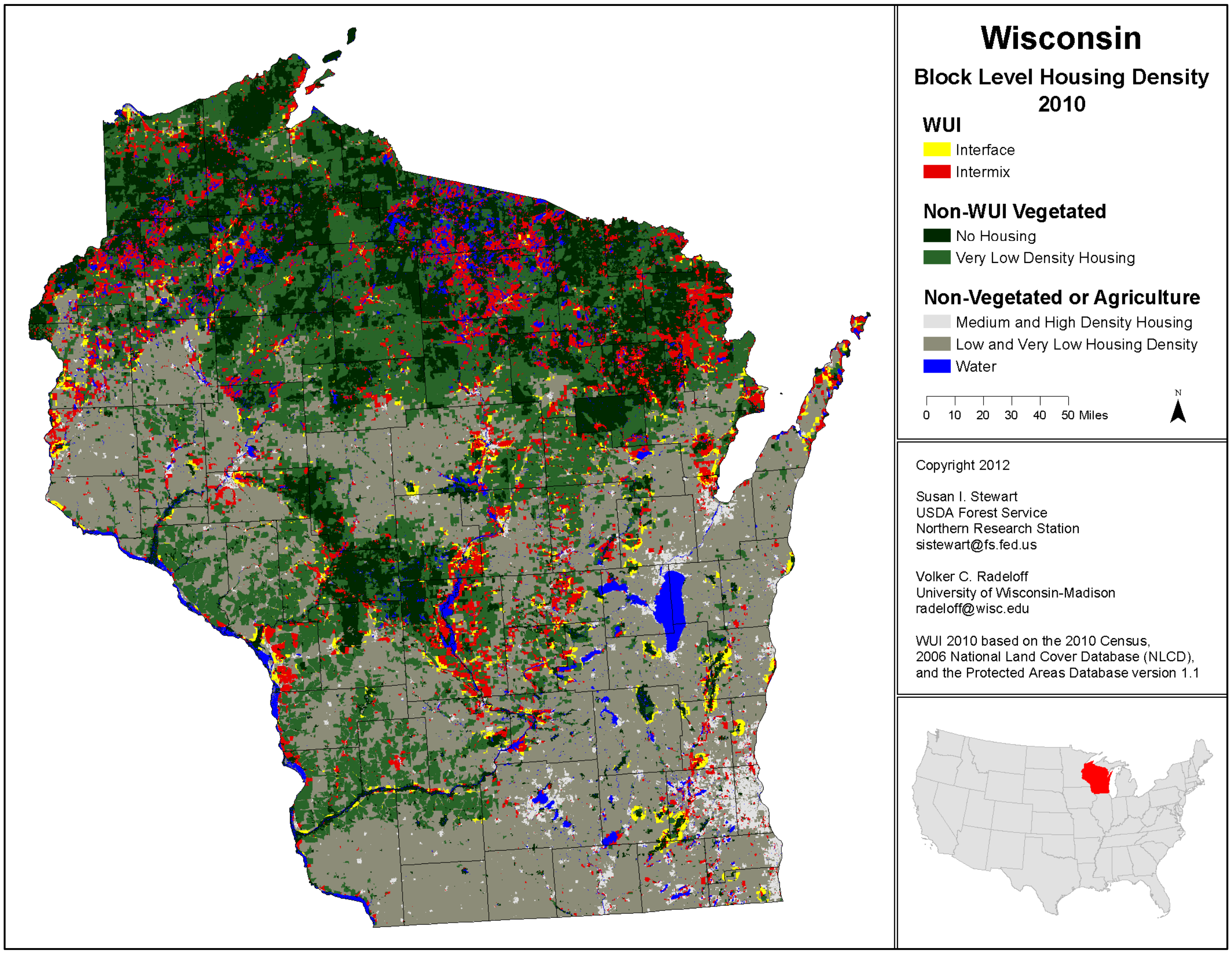
The vast majority of wildfires in Dane County are human-caused. Wildfires initiated by lightning are very rare. When wildfires do occur in Dane County it is also very rare that a home or business is lost. Wildfires are most common in the spring when brush is still brown and dry.

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.[25] 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.

[25] 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.

- 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.

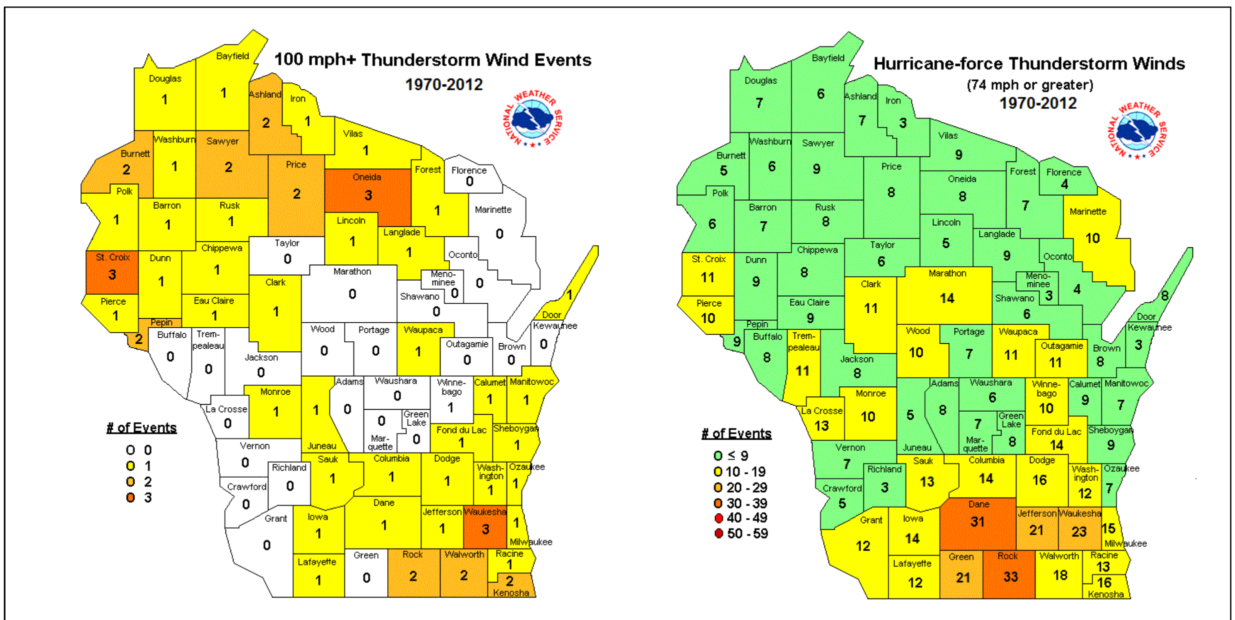
Severe thunderstorms develop powerful updrafts and downdrafts. An updraft of warm, moist air helps to fuel a towering cumulonimbus cloud reaching tens of thousands of feet into the atmosphere. A downdraft of relatively cool, dense air develops as precipitation begins to fall through the cloud. Winds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

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

[26] 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 or motor vehicles were damaged or destroyed by falling trees and branches or collapsed garages. Dane County measured gust of 100 mph in Marshall, but peak gusts estimated at 110-120 mph based on damage. The hardest hit areas were Waunakee-DeForest, Sun Prairie, and Marshall. Cars were blown sideways off I-94 north of Madison. Two people injured in Marshall by flying debris as roof was torn off their home. A total of 300 residences had minor damage, 18 major, and 1 was destroyed. One business had minor damage, and 7 had major damage. Twenty farm buildings sustained minor damage, 12 major, and 15 were destroyed.

November 10, 1998

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

Stoughton sustained damages. In Monona, a roof was torn off a multi-unit apartment building and four other nearby buildings were also damaged. Several dozen semi-trucks were overturned on I-90/94, US-18/151, and US 51 highways.

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

July 10 2008
Powerful thunderstorm wind gusts toppled large trees and broke branches that brought down some power-lines. In McFarland, a house was blown down, and tree debris damaged a restaurant. Two rounds of severe weather affected south-central and southeast Wisconsin on July 10th. An initial cluster of storms north of the Milwaukee area in Ozaukee County pulsed to severe limits and generated large hail up to 3/4 inch in diameter during the early afternoon hours. A second round of severe weather was associated with several clusters or short bowing segments of lines of storms that moved west to east across southern Wisconsin during the late afternoon and evening hours. Veering winds allowed for the development of rotating updrafts in a couple cells that generated two weak tornadoes. Otherwise, the severe weather type was powerful downburst winds.

June 8, 2011
Forcing along an advancing cold front moving into a warm, moist unstable air mass over the region produced severe thunderstorms with a tornado, damaging winds and large hail over south-central and southeast Wisconsin during the evening hours of June 8th. The instability produced supercell thunderstorms, with one of the cells developing an EF1 tornado over central Dane County that uprooted trees, felled power-lines, damaged three vehicles and crushed a garage. A cluster of supercell thunderstorms from Lafayette into Dane County then congealed into a bowing line that moved due east and created damaging wind gusts of 60 to 80 mph across much of the area along and south of Interstate-94. At the height of the event, over 27,000 customers had no electric power in Southeast Wisconsin, and probably another 15 to 20,000 customers in south-central Wisconsin lost power. Powerful thunderstorm winds pushed over dozens of large trees, and broken tree branches snapped several power-lines in a 5-mile-wide swath. In Stoughton, the winds knocked over an empty semi-trailer which then impacted and damaged two other trailers. Also, a road sign in Stoughton was pushed over at a 45-degree angle.

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.

- 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

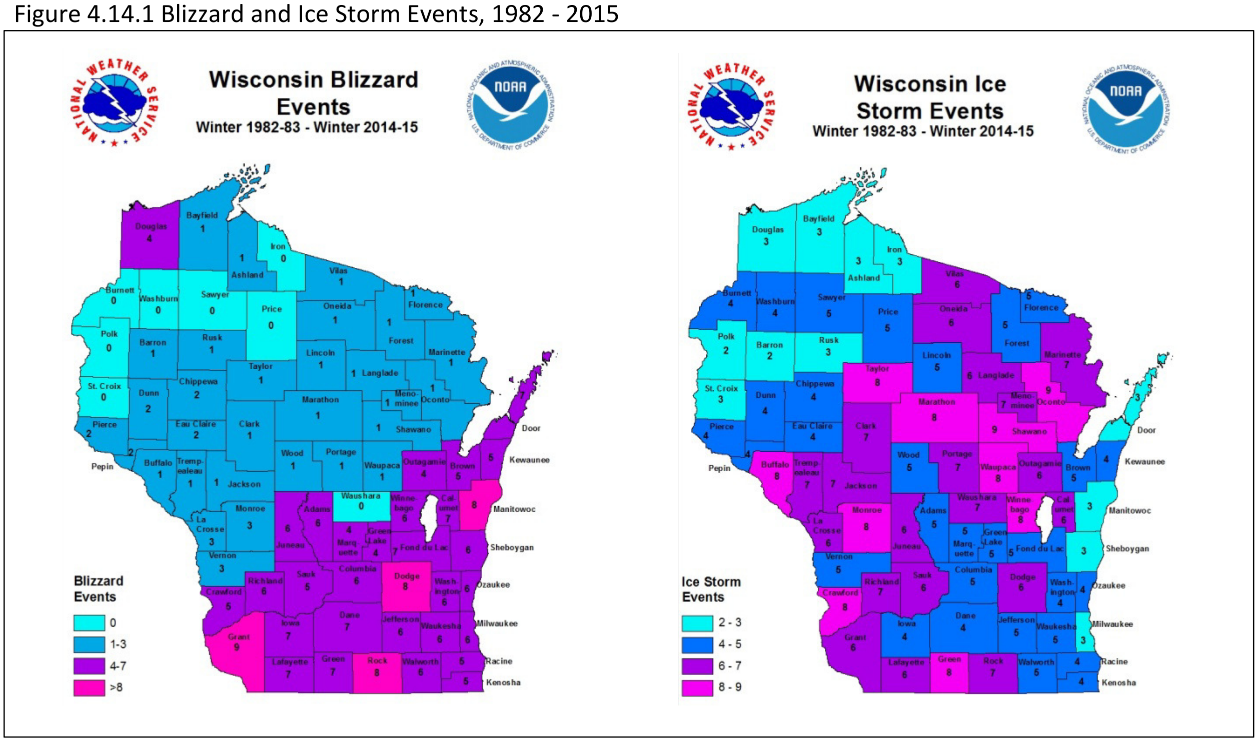
Winter storms occur when below freezing air on the ground and in clouds combine with moisture. Moisture is needed to form clouds and cause precipitation. A storm front lifts the moist air to form the clouds. Storms that affect Wisconsin develop over southeast Colorado, northwest Canada, and over the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

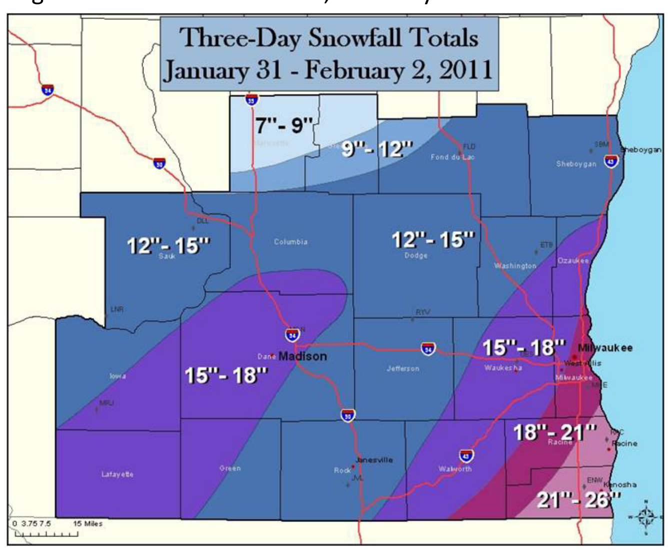
February 5-6, 2008
A major winter storm impacted south-central and southeast Wisconsin on February 5-6, 2008, with the hardest hitting part of the storm during the morning of the 6th. This was a long duration event coupled with strong gusty winds and some thunder. Blowing and drifting snow compounded 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 is response costs.

Figure 4.14.2 Snowfall Totals, February 2011



Source: National Weather Service, Milwaukee/Sullivan

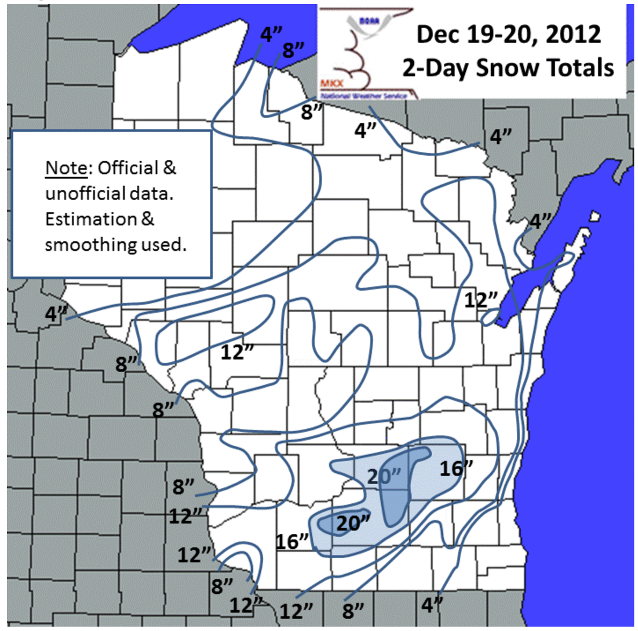
December, 2012
From the evening of December 19 to the night of December 20, 2012, a major winter storm descended on the south central portion of the state. Gusts of 35 to 50 mph combined with the snowy conditions resulted in low visibility and drifts of three to five feet. Many accidents were reported. 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,

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

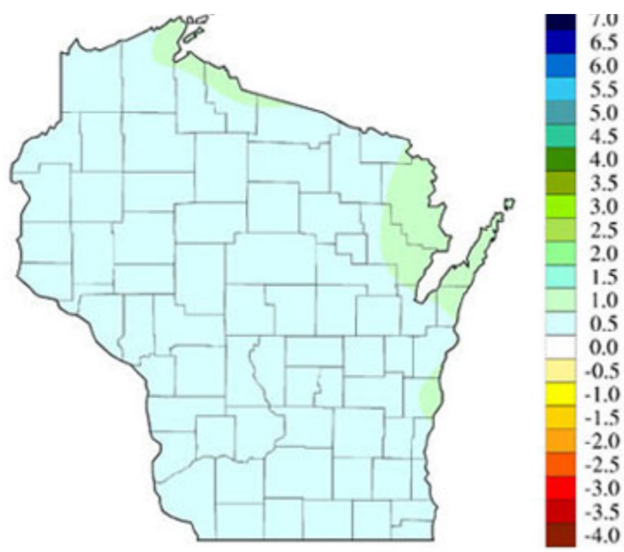


Source: National Weather Service, Milwaukee/Sullivan

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.

Figure 4.14.4 Projected Change in Winter Average Precipitation (inches)



Source: Wisconsin Initiative on Climate Change

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.

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.

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[27] developed the Sperry-Piltz Ice Accumulation Index (SPIA Index) to quantify potential damages and vulnerability of electric utility infrastructure in an ice storm. The index accounts for the combination of radial ice and wind in the resulting damage projections.

The Sperry-Piltz Ice Accumulation Index, or "SPIA Index" – Revised September, 2009

ICE DAMAGE INDEX	RADIAL ICE AMOUNT (inches)	WIND (mph)	DAMAGE AND IMPACT DESCRIPTIONS
0	< 0.25	< 15	Minimal risk of damage to exposed utility systems; no alerts or advisories needed for crews, few outages.
1	0.10 – 0.25	15 - 25	Some isolated or localized utility interruptions are possible, typically lasting only a few hours. Roads and bridges may become slick and hazardous.
	0.25 – 0.50	> 15	
2	0.10 – 0.25	25 - 35	Scattered utility interruptions expected, typically lasting 12 to 24 hours. Roads and travel conditions may be extremely hazardous due to ice accumulation.
	0.25 – 0.50	15 - 25	
	0.50 – 0.75	< 15	
3	0.10 – 0.25	> = 35	Numerous utility interruptions with some damage to main feeder lines and equipment expected. Tree limb damage is excessive. Outages lasting 1 – 5 days.
	0.25 – 0.50	25 - 35	
	0.50 – 0.75	15 - 25	
	0.75 – 1.00	< 15	
4	0.25 – 0.50	> = 35	Prolonged & widespread utility interruptions with extensive damage to main distribution feeder lines & some high voltage transmission lines/structures. Outages lasting 5 – 10 days.
	0.50 – 0.75	25 - 35	
	0.75 – 1.00	15 - 25	
	1.00 – 1.50	< 15	
5	0.50 – 0.75	> = 35	Catastrophic damage to entire exposed utility systems, including both distribution and transmission networks. Outages could last several weeks in some areas. Shelters needed.
	0.75 – 1.00	> = 25	
	1.00 – 1.50	> = 15	
	> 1.50	Any	

(Categories of damage are based upon combinations of precipitation totals, temperatures and wind speeds/directions.)

[27] 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.

Blue-green algae bloom

- Changes in temperatures and precipitation could result in an increase in disease-carrying insects, including ticks and mosquitoes. This means people may be at a greater risk for contracting vector-borne diseases, such as Lyme disease and West Nile encephalitis.

- The spread of invasive and exotic species; plants animals, and pests can cause significant harm to native ecosystems and to humans. Addressing or mitigating changing environmental conditions associated with the spread of invasive species is well beyond the scope of this plan. The spread of invasive

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

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 a perhaps the most significant of the extreme heat risk factors. This can be mitigated through organized welfare checks as well "social capital" programs that build on informal relationships between friends, family members, and neighbors.
- Due to climate tends, population exposure, and potentially fatal impacts, the overall risk of excessive heat is a growing concern.

Flood

- Flood damage occurs frequently in Dane County. Floods have caused:
    - Damage to private property that often creates financial hardship for individuals and families.
    - Damage to public infrastructure resulting in increased public expenditures and demand for tax dollars.
    - Loss of income for agricultural producers that experience flood damages.
    - Loss of income to businesses relying on recreational uses of County waterways.
    - Emotional distress on individuals and families.
    - The potential for personal injury and death.
- Financially, flood losses have resulted from:
    - Flooded basements and first-floor flooding of residential, commercial, and institutional buildings.
    - Sewer backups into basements of residential, commercial, and institutional buildings.
    - Structural damage to buildings.
    - Damage to personal belongings and other contents of buildings.
    - Road, shoulder and ditch washouts.
    - Crop loss.
- Unless a property owner has flood insurance, damages to buildings and building contents are typically uninsured losses and costs for repair and replacement are typically borne by the property owner.
- Dane County is a drainage area. With a few exceptions, Dane County contains the headwaters of the rivers and streams flowing out of the County. This means that the rainfall that becomes the floodwater that causes damage started here – it didn't come from somewhere else. This presents both opportunities and challenges in reducing flood risk.

- Flooding issues in Dane County are complex and involve the interaction of a number of contributing factors, including but not limited to:
  - Changing land use patterns.
  - Historical and on-going modifications to the landscape that affect the flow of water.
  - Soils and topography.
  - Natural and constructed impediments to the flow of water.
  - Development in high risk areas.
  - Stormwater management practices.
  - Complex natural hydrologic processes.
  - 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 of fatal traffic crashes occur when fog is a contributing factor.
- Although traffic crashes and deaths are typically considered indirectly related to fog, the numbers far exceed the number of people harmed by any other natural hazard addressed in this plan.
- Dense fog can result in flight delays and cancellations at airports.
- Fog poses no risk to structures or facilities in Dane County.
- There is not a readily available source of information to assess whether the incidence of fog will increase, decrease, or remain the same as a result of the warming climate.

Hail

- No deaths or injuries have ever been directly attributed to hail strikes in Dane County.
- Financial losses due to hail damage can be significant.
- Automobiles are particularly vulnerable to damage.
- Crops are particularly vulnerable to damage at certain times in the growing season.
- Commonly used roofing and siding materials are not resistant to hail impact, resulting in the potential for widespread damage due to large hail.
- There is not a readily available source of information to assess whether the incidence of hail will increase, decrease, or remain the same as a result of the warming climate.

Landslides, Erosion, and Sinkholes

- The geology of Dane County is such that there is some potential for landslides, sinkholes and significant erosion. The overall susceptibility in the County, however, is low.
- There are no documented occurrences of significant problems associated with naturally occurring landslides or sinkholes in Dane County.
- Climate models predict increased frequency and intensity of extreme weather statewide, including more frequent, more intense precipitation events. These changes *may* lead to increased incidences and severity of flooding, erosion, and landslides/land subsidence.

Lightning

- Lightning strikes and resulting electrical surges can damage unprotected electronic equipment.
- Lightning strikes and resulting electrical surges can damage the electrical distribution system and cause power outages.
- Lightning striking buildings can cause structure fires.
- Lightning strikes can cause injury and/or death.
- There is not a readily available source of information to assess whether the incidence of lightning will increase, decrease, or remain the same as a result of the warming climate.

Tornado

- In general, all buildings, critical facilities, and populations are vulnerable to tornado damage.
- The Multi-Hazard section contains additional summary information on issues and concerns associated with tornadoes.
- There is not a readily available source of information to assess whether the incidence of tornadoes will increase, decrease, or remain the same as a result of the warming climate.
- A strong tornado in a densely populated area has the greatest future damage/loss potential of all of the hazards assessed in this plan.

Wildfire

- While wildfires have occurred, the conditions that lead to large, uncontrolled fires generally does not exist in Dane County.
- Wildfires in Dane County are typically grassland fires and marsh fires, not large forest fires.
- The wildfire risk in Dane County is limited to relatively small areas where urban and suburban subdivisions or small communities are situated adjacent to grass land or marshy areas.
- Grassland and marsh fires are relatively common in the spring and fall seasons, however, wildfires in Dane County rarely result in losses to homes and businesses.
- The vast majority of wildfires in Dane County are human caused.
- The incidence of wildfires can be expected to increase as a result of the warming climate and changing rainfall patterns, however the risk to structures remains low.

Windstorm

- In general, all buildings, critical facilities, and populations are vulnerable to wind damage to some degree.

- The Multi-Hazard section contains additional summary information on issues and concerns associated with tornadoes.
- There is not a readily available source of information to assess whether the incidence of severe thunderstorms and other windstorms will increase, decrease, or remain the same as a result of the warming climate.

Winter Storm

- Severe winter storms have the potential to halt all transportation – countywide. This includes that of emergency services vehicles and first responders.
- Motorists and travelers can become stranded on the highways of the County.
- Winter storm events can pose a serious threat to the residents of Dane County. Many fatalities during winter storms are the unsuspecting dangers that include heart attacks while shoveling snow and improper use of space heaters.
- Severe winter storms can completely shut down businesses and government, while isolating residents in their homes for days and sometimes weeks.
- Ice storms or high winds in winter storms can cause extensive loss of overhead utility lines due to buildup on either the lines or on adjacent trees that either collapse due to the weight or blow down onto the utility lines.
- The disruption of electrical power distribution systems can have a wide range of secondary, potentially long-term impacts.
- The Multi-hazard section contains additional summary information on issues and concerns associated with winter storms and ice storms.
- Climate models predict and increase in wintertime precipitation for southern Wisconsin. Depending on conditions at the time of the event, this can occur as snow, rain, or freezing rain. As both temperature and precipitation increase during the winter, occurrences of freezing rain are becoming more likely. The resulting risk of a damaging ice storm is increasing.

Emerging Hazards

- Trends toward a warmer, wetter climate lead to increases in risks to human health above and beyond those traditionally considered as "natural hazards."
- Air pollution, increasing temperatures, changing circulation patterns, and other processes combine to increase ground-level ozone, which affects respiratory health.
- Heavy rains and flooding can overwhelm sewer and stormwater systems, leading to a rise in water pollution and the risk of waterborne diseases such as cryptosporidium and giardia.
- Warmer water temperatures and an overabundance of nutrients can lead to harmful algal blooms, in lakes and ponds.
- Changes in temperatures and precipitation could result in an increase in disease-carrying insects, including ticks and mosquitoes. This means people may be at a greater risk for contracting vector-borne diseases, such as Lyme disease and West Nile encephalitis.
- The spread of invasive species, such as wild parsnip (pastinaca sativa), which can be harmful to human health, have been identified as a specific concern.
- This is an area for further monitoring and study.

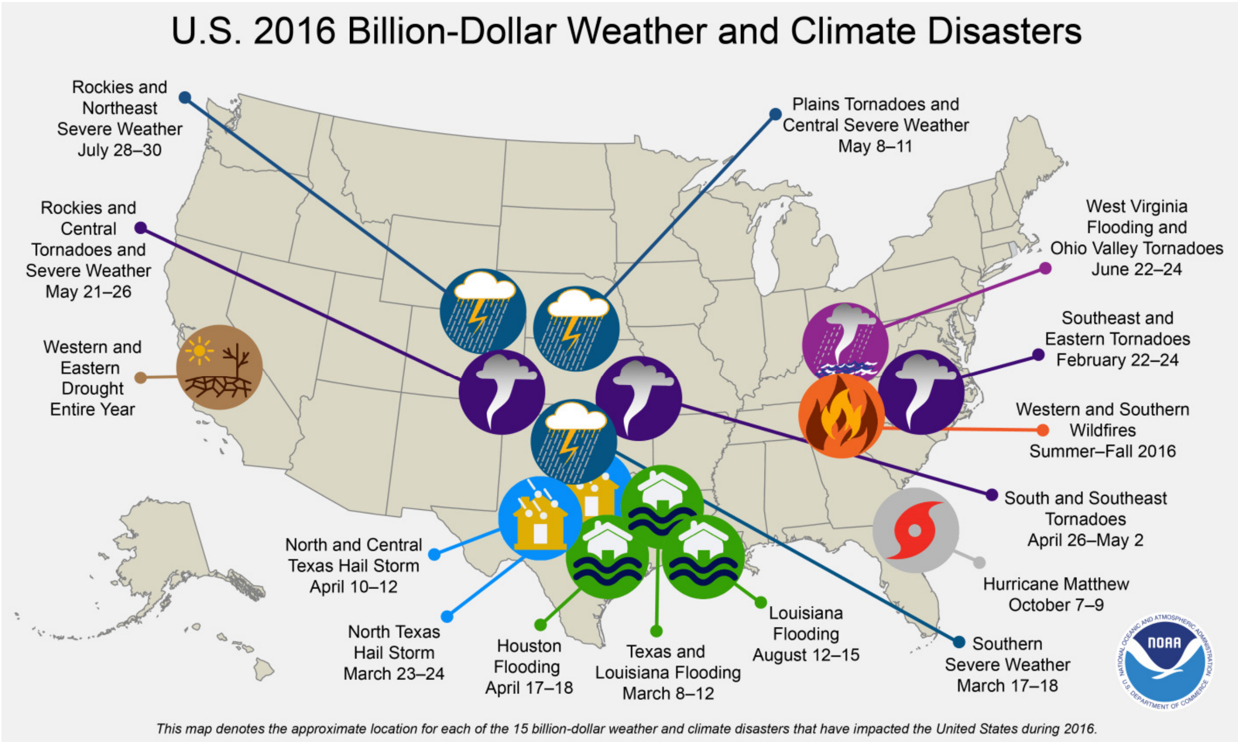
Multi-Hazard Issues

- Overhead power and telephone lines are vulnerable to damage by ice and wind.
- Homes are often damaged due to falling tree limbs in wind and ice storms.
- Tree damage leads to many secondary losses, such as road blockage, downed power lines, and hindered emergency response.
- Manufactured homes are especially vulnerable to many of the hazards, but particularly high winds and tornadoes. Most manufactured homes do not have safe rooms. Some mobile home parks have storm shelters, but most do not.
- Agricultural operations and critical facilities are particularly vulnerable to extended loss of electric power.
- Loss of electrical power is, in many cases, the cause of significant secondary consequences of a hazard event. Overhead electrical lines are particularly vulnerable to many of the natural hazards in Dane County.
- Individuals in a home-health care situation are particularly vulnerable to loss of electrical power.
- Manufactured homes, buildings with wide span roofs such as shopping malls or school gymnasiums are also particularly vulnerable to high winds.
- Falling trees and branches cause damage to power lines, block streets, damage buildings, inhibit emergency access, and is a major contributor to storm debris problems.

4.16.3 Catastrophic Scenarios

In addition to compiling the type of severe weather data referenced previously in the hazard analysis, NOAA's National Centers for Environmental Information (NCEI) tracks and evaluates large-scale climate and weather events in the US (and globally) that have great economic and social impacts. In their assessment, *Billion-Dollar Weather and Climate Disasters*, NCEI states that "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.