THUNDERSTORM HAZARDS

Hazard Profile

Thunderstorms are one of the most common and most noticeable weather events of our atmosphere. Compared to other natural hazards, thunderstorms pose hazards and hazardous effects that most concern citizens throughout the City. Severe thunderstorms contain multiple dangers that can threaten safety and personal property in any part of the country and at any time of the year including flooding, lightning, and lightning induced wildfires, tornadoes, wind, and hail. Each of these thunderstorm elements will be discussed in greater detail later in this section.

Although thunderstorms can be fairly small, averaging approximately 10 to 15 miles in diameter with an average lifetime of 20 to 30 minutes, they can cause a tremendous amount of damage in this short timeframe. Strong frontal systems may spawn more than one squall line composed of many individual thunderstorm cells. These fronts can often be tracked across the entire state from west to east. Thunderstorms may occur singly, in clusters, or as part of a large line of storms. Thus, it is possible that several thunderstorms may affect an area in the course of a few hours. Fortunately, the area affected by any one of them is fairly small, and most of the time, the damage is rather light.

Severe thunderstorms can, however, cause injury or death and can also result in substantial property damage. Many hazardous weather events are associated with thunderstorms. Lightning is responsible for several fires around the world each year, as well as causing deaths when people are struck. Under the right conditions, rainfall from thunderstorms can cause flash flooding, which can change small creeks into raging torrents in a matter of minutes, washing away large boulders and man-made structures. Hail can damage cars and windows and can injure or kill humans and wildlife caught out in the open. Strong straight-line winds associated with thunderstorms can knock down trees and power lines. Thunderstorms may also cause power outages, disrupt telephone service and severely affect radio communications and surface/air transportation, which may seriously impair the emergency management capabilities of the affected jurisdictions.

Table 8.1 Superior's Thunderstorm Days

January	0.1
February	0.0
March	0.6
April	1.7
May	3.5
June	6.7
July	8.0
August	6.9
September	3.9
October	1.3
November	0.4
December	0.1
Total	**33.2**

Severe thunderstorms are defined as having one or more of the following:

- Winds in excess of 58 mph
- Hail at least 1 inch in diameter
- A tornado

A single cell storm, or pulse storm, typically do not produce severe weather and usually last 20 to 30 minutes. Pulse storms can produce severe weather elements such as downbursts, hail, heavy rainfall, and occasionally weak tornadoes. Multicell cluster storms are a group of cells moving as a single unit, with each cell in a different stage of the thunderstorm life cycle. Multicell storms can produce moderate size hail, flash floods and weak tornadoes. Multicell line storms consist of a line of storms with a continuous, well-developed gust front at the leading edge of the line. Also known as squall lines, these storms can produce small to moderate size hail, occasional flash floods and weak tornadoes. Supercells are defined as a thunderstorm with a rotating updraft; these storms can produce strong downbursts, large hail, occasional flash floods and weak to violent tornadoes.

The frequency of thunderstorms is measured in terms of 'thunderstorm days' or days on which thunderstorm activity is observed. The average number of thunderstorm days in Wisconsin range from 30 to 50, depending upon location. Superior has 33.2 normal thunderstorm days per year. Most thunderstorm days occur during the months of May through September. Most thunderstorms occur between the hours of 12 p.m. and 10 p.m.

Flooding from Thunderstorms

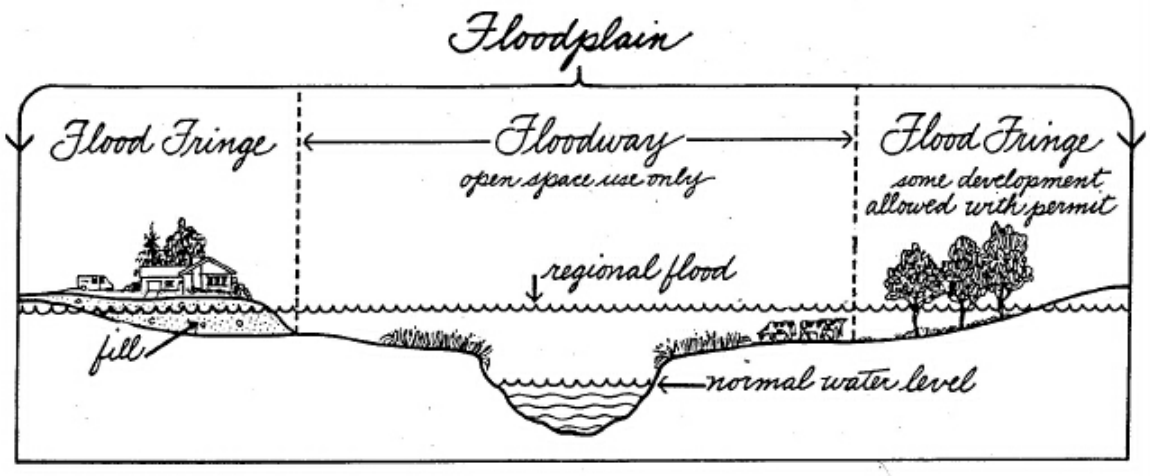
Flooding is partial or total inundation of normally dry land from the overflow of inland waters or rapid accumulation or run-off of surface waters from any source. Flooding severity is impacted by amount of rainfall (or other source of water such as melted snow), duration of rainfall, topography, land cover, frozen soil, soil saturation, reservoir/mill pond capacity, river or stream levels and frozen rivers or streams. Floods can be caused by the passage of frontal storms, thunderstorms, hurricanes, snowmelt or some combination of the above events. Flooding can occur in the spring due to snow melt and/or prolonged periods of heavy rain or saturation of clay soils.

Major floods in Wisconsin have usually been confined either to specific streams or to locations that receive intense rainfall in a short period of time. The City of Superior is no exception to this. Riverine flooding (overbank flooding) occurs when a stream, lake, or other body of water overflows its banks onto normally dry land. Stormwater flooding (overland flooding) occurs when stormwater pools in normally dry depressions in the land. Stormwater flooding events tend to strike quickly and end swiftly. Flash flooding is more difficult to distinguish and can be either riverine or stormwater flooding. The National Weather Service classifies flooding into two types: those that develop and crest over a period of approximately six hours (flooding) or more, and those that crest more quickly (flash flooding). Like stormwater flooding, flash flooding is typically the result of intense rainfalls possibly in conjunction with already saturated soils, though very sudden snow melts can also contribute to flash flooding.

Floodplains are the lowlands next to a body of water which has been or may be covered by floodwater during a 100-year flood, or regional flood, and includes the floodway and floodfringe areas. A 100-year flood is a flood that has a 1% chance of being equaled or exceeded in any given year. The floodway is the channel of a river or stream and those

portions of the floodplain adjoining the channel required to carry the regional flood discharge. Since it is associated with moving water, the floodway is the most dangerous part of the floodplain. The floodfringe is the portion of the floodplain outside of the floodway, which is covered by flood water during the regional flood and is generally associated with the storage of water rather than flowing water. The floodfringe is also that part of the floodplain in which development may be allowed in some communities, subject to floodplain development standards. The 100-year flood is used by the National Flood Insurance Program (NFIP) as the standard for floodplain management and to determine the need for flood insurance. Figure 8.1 show the aspects of a floodplain.

Figure 8.1 Aspects of a Floodplain



Wisconsin DNR

Based on a City survey, flooding is considered the most threatening hazard to residents and businesses in the City. Flooding can aggravate the erosion processes in the City. The clay soil upon which Superior is built has temperamental properties that make it very vulnerable to slumping, when large amounts of sediments move downhill under gravity. When dry, Superior's clay soils are very stable, but when going from dry to wet, have a shrink-swell property that contributes to the instability of the soil. The properties of the soil also limit absorption of stormwater, further aggravating the flooding. More information on the effects of erosion on the City can be found in the Erosion Hazards section of this Plan Update.

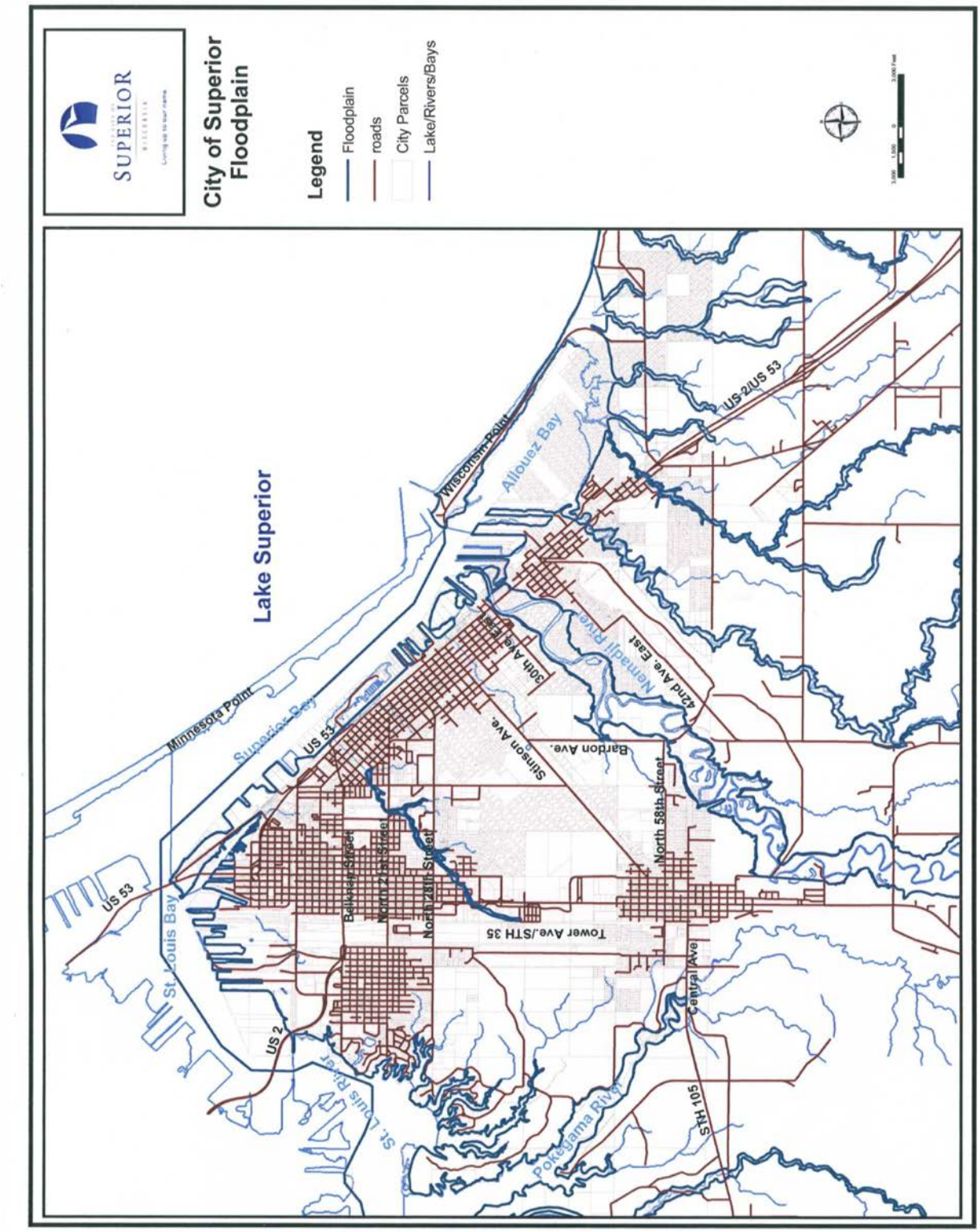
Landslides are typically triggered by periods of heavy rainfall or rapid snowmelt; however, the incidences of landslides and their impacts on people can be intensified by human activities. Grading for road construction and development can increase slope steepness. Grading and construction, excavation, drainage and groundwater alterations and changes in vegetation can decrease the stability of a hill slope by adding weight to the top of the slope, removing support at the base of the slope and increasing water content.

In 1968, Congress adopted the National Flood Insurance Act, which among other things created the National Flood Insurance Program (NFIP). This program allows property owners to purchase flood insurance if their community participates in the program. In

fact, certain homeowners must purchase flood insurance when their property is located in the regulatory floodplain and their mortgage meets certain criteria. The City has participated in the NFIP since 1978. The City participates by enforcing floodplain management to reduce future flood damage. Specifically, the City planning department handles the review for all development related to floodplain areas. If there is a project in question, the City planning department works with state or federal officials to get final authorization. Currently, 3 residences have NFIP insurance although only 1 is located in the floodplain. A NFIP study of 1977 reported the 100-year open coast flood elevation for Lake Superior at the City of Superior to be 603.4 feet. Because UW-Superior is a school, it is not required to participate in the NFIP.

Map 8.1 shows the City of Superior floodplain.

Map 8.1: City of Superior Floodplain



Historical Events

- In July 1909, a thunderstorm produced 6.93 inches of rain in 48 hours, causing thousands of dollars in damage to merchants and citizens.
- In May 1913, a thunderstorm produced 3.03 inches of rain in 4 hours, causing up to $500,000 in damages to property including flooded basements, retail goods and railroad tracks. Sewers overflowed, roads washed out in 18 inches of standing water, livestock drowned and Newton Creek overflowed. A home struck by lightning caused $200 in damage. This storm produced a 25-year rain event.
- In August 1935, a thunderstorm produced 2.60 inches of rain in 2 hours, causing sewers to overflow into homes and businesses and roads to wash out with 2 feet of standing water. This storm produced a 7-year rain event.
- In July 1949, a series of thunderstorms produced 5.02 inches of rain in 4 days, with wind and lightning that caused roads and bridges to wash out and soil failure that caused damage to vehicles. The Allouez district was isolated from the rest of the City and many basements were flooded as stormwater poured in from windows. Trees were washed out, blown down and struck by lightning.
- In September 1950, a thunderstorm produced 3.93 inches of rain in 48 hours, flooding basements and roads and clogging sewers with tree and leaf debris.
- In July 1952, a thunderstorm produced 2.17 inches of rain in 30 minutes, accompanied by wind gust up to 90 mph and ¼ inch hail. This storm was one in a series of severe storms that produced 3.5 inches of rain in 36 hours and over 7 inches of rain in 22 days. The storm uprooted trees causing secondary damage to sidewalks and power lines, destroyed fairground tents, flooded basements (3-4 feet deep), repeatedly washed out roads and caused economic damage to businesses as products stored in basements were damaged by flood waters. The Nemadji River flooded up to the street level. Basements flooded in homes that had never flooded before. $15,000-$20,000 damage was caused to road shoulders. Two homes were struck by lightning causing $50-100 damage each. This storm produced 100 year + rain event.
- In June 1953, a thunderstorm flooded the Nemadji River and Bluff Creek, blocking traffic on the south end of town.
- In July 1955, a thunderstorm produced 1.2 inches of rain in 3 hours, accompanied by 30-75 mph wind. Telephone poles were destroyed, transformers blown out by rain and lightning, trees toppled damaging houses, fires were ignited by lightning, telephone service was cut off and boats were broken loose from moorings in the harbor. This storm produced less than a 5-year storm event.
- In July 1957, a thunderstorm produced 2.9 inches of rain in 4 hours, causing road washouts, catch basins to cave in, flooded basements and businesses on Tower Avenue to flood up to 3 feet deep. This storm produced a 25-year rain event.
- In June 1958, a thunderstorm produced 5.9 inches of rain in 5 hours, flooding basements 5 feet deep, destroying newspaper press motors, flooding roads 5 feet deep with standing water, washing out river banks, causing fires from lightning strikes, flooding school tunnels, backing up sewers, washing out roads, flooding the library at the Superior State College and blowing out 3 sections of sewers from internal pressure. Lightning strikes caused $6,000 damage to a barn and $3,500 damage to a house. Lightning destroyed large electrical transformers and streetlights. Flooding

caused short circuit damage in buildings and vehicles. Residents and businesses used pumps to control basement flooding. This storm produced a 100 + rain event.

- In May 1964, a severe thunderstorm caused power poles to snap, trees to uproot and fall on homes and litter streets with debris, fires to ignite from lightning at the shipyard, airplanes to be destroyed, chimneys to be torn from roofs, a garage to be lifted from its foundation, windows to be blown out of storefronts and power outages.
- In September 1964, a thunderstorm produced 4.25 inches of rain in 24 hours, causing basement flooding and damage to catch basins. Lightning destroyed transformers causing power outages. This storm produced a 20-year rain event.
- In August 1978, a thunderstorm produced 4-6 inches of rain in 12 hours. Lightning struck a partially filled gasoline tank at the Murphy Oil Refinery, ripping a 20-foot gash in the tank, causing $350,000 in damage. The storm also caused automobiles to stall on flooded roads, roads to wash out and power outages from lightning strikes. This storm produced a 100 + rain event.
- In September 1979, a thunderstorm produced 1.5 inches of rain in 1 hour. The storm caused downed trees to damage cars, power lines, roads and buildings. The storm also caused power outages, destruction of new construction sites and some hail damage. This storm produced a 5-year rain event.
- In July 1979, a thunderstorm produced 3.3 inches of rain in 3 hours, causing $540,000 damage to the City, including over $100,000 damage to local retail stores, destruction of the Elk bowling alley, washed out railroad tracks and roads, the loss of 160 chickens, stalled cars in standing water on roads and basement flooding 2 to 3 feet deep. Lightning caused damage to transformers and power lines causing power outages. An oil spill resulted from a washed out separator, spilling 100 gallons of petroleum into Bear Creek. A chemical road binder was washed into a nearby creek. This storm produced a 100-year rain event.
- In September 1985, a 100-year thunderstorm produced 5.04 inches of rain in 5 hours, flooding basements (3-4 feet deep), overpasses, roads and highways. Newton and Bear creeks overflowed causing roads to flood and the creeks to become lakes. Cars stalled in over 12 inches of standing water. Accidents were caused by roads washing out at a 4 feet depth. Roads were littered with trees and debris. Moccasin Mike Road was completely washed out. Much of the damage was caused in South Superior, due mainly to the flat terrain that inhibits flow of water toward the Lake. Damage in the City was estimated at $1.9 million including state highway damages of $275,000, City street damage of $75,000, residential damage of $500,000, small business loss of $120,000, utility loss of $75,000 and government building loss of $10,000. The American Red Cross and the Federal Emergency Management Agency were called in to assist homeowners in damage relief. This storm produced a 100-year rain event.
- In September 1988, a thunderstorm produced 3.96 inches of rain in 24 hours, causing minor flooding and power outages. This storm produced a 15-year rain event.
- In September 1990, a thunderstorm produced 3.85 inches of rain in 12 hours, flooding basements, washing out roads, sinking a boat in the St. Louis River and causing sewer backups. The sewer backups released untreated sewage from a ruptured pipe and nearly drowned a dog tied up in a flooded basement. This storm produced a 25-year rain event.

- In July 1991, a thunderstorm produced 4.07 inches of rain in 12 hours, flooding basements up to 1 foot deep. This storm produced a 25-year rain event.
- In July 1999, a 100-year storm produced 2.05 inches of rain in 4 hours, overwhelming City trunk sewers, damaging other public works facilities and equipment and flooding over 80 residences. This storm caused $574,000 in damage. This storm produced a 100-year rain event.
- In August of 2000, a 20-year storm hit Superior, producing 2.53 inches of rain in 3 hours. Among those reporting damages were the Douglas County Historical Society, which suffered damage to historical records stored in its basement and a jewelry store at the Mariner Mall. This storm produced a 25-year rain event.
- April 2001 saw unusually high precipitation for the City. Towards the end of the month, thunderstorms produced 3.92 inches of rain over 4 days, causing parts of the City to flood. Water rose to the steps of the Superior High School and all schools in Douglas County were closed for at least 1 day until the water receded. A federal disaster declaration was issued for several Wisconsin counties as a result of these storms, including Douglas County. Costs incurred by the wastewater treatment plant totaled $26,540. This cost included repairs to a road washed out at Lift Station 5. The Public Works Department also reported $8,533 in costs to control or mitigate water damage. This storm produced a 2-year rain event.
- During October 2005, significant flooding occurred in Superior as a result of heavy thunderstorms. The wastewater treatment plant received 88 calls for sewer flooding with a damage estimate of $280,000. Over a 72-hour period, the event totaled 5.01 inches of rain in South Superior, 7.36 inches in Billings Park and 7.58 inches at the wastewater treatment plant. This storm produced a 100-year rain event.
- In May 2006, the City of Superior received 2.49 inches of rain, starting on May 9th and continuing until May 14th. Combined with snow melt and probable frozen ground, the precipitation created flooded conditions at many locations. This event resulted in several service calls for basement flooding and sewer backups.
- On May 24, 2006, 1.5 inches of rain fell in less than a 24-hours period in the Superior area. There were several service calls and sewer backups.
- On October 8, 2007, the City of Superior experienced a significant rain event. The rain lasted from approximately 12:30 a.m. to 1:30 a.m. This rain event was of the 25 to 50-year magnitude for the wastewater treatment plant and along East 2nd Street (measured at Lift Station 6). Within the first hour, the City received 2.4 inches of rain. The average peak two-hour intensity on the citywide rain gauge was 1.99 inches. This corresponds to a 7+ year rain event according to the Department of Commerce Rainfall Frequency Atlas of the United States. The results from this rain event were 110 service calls, mainly concerned with basement flooding and ground surface flooding. Thirty-two liability claims were filed with the City of Superior. The majority of these claims were from the business district of Superior followed by the Central Park district of Superior. Property damage was reported in the thousands of dollars per location. The storm produced a 50-year rain event.
- On June 6, 2008, the City received 2.21 inches of rain. This caused flooding at several locations as well as overflow conditions that required filing Sanitary Sewer Overflow Reports at 4 different locations and sewer repair on 24th Avenue East and 4th Street.

- August 19, 2009, set a record rainfall of 2.89 inches for the City of Superior. Resulting from this rain event, the City responded to 7 service calls for basement and street flooding and required special pumping of leachate from the landfill due to overflow conditions.
- June 19-20, 2012, 8.1" of rainfall-more rain than has ever fallen on the City within a 24-hour period in record history-deluged the entire western end of the Lake Superior basin. Damages to roadways, sewer systems, public and private property for the City, UW-Superior and surrounding areas eclipsed $80 million.
- **Note:** According to a consensus of operators at the City of Superior Wastewater Treatment Plant, any time the City gets an inch or more of rain within a few hours, problems may arise at the plant. To mitigate these problems, certain areas need to be monitored continuously.

Probability & Predictability

Damaging flooding events are moderately probable, with a 2-5% chance of occurrence annually. Flooding may be predicted with reasonable notice using meteorological techniques to determine likely rainfall, intensity, and duration.

Thunderstorms can be detected using a variety of tools. Radars depict where rain and hail are located in the storm. Doppler radars also allow us to visualize how the wind is blowing within and near the storm. Some features of thunderstorms, such as the anvil that spreads out at the top of the storm, can be seen from satellites. Table 8.2 shows the rainfall frequency data for the City of Superior.

Table 8.2 City of Superior Storm Intensity (Rainfall Frequency) Data

	1 Year	2 Year	*3 Year	5 Year	*7 Year	10 Year	*15 Year	*20 Year	25 Year	50 Year	100 Year
30 Min.	*0.80"*	*0.95"*	*1.05"*	*1.24"*	*1.32"*	*1.44"*	*1.51"*	*1.58"*	*1.65"*	*1.84"*	*2.05"*
1 Hour	*0.98"*	*1.20"*	*1.32"*	*1.56"*	*1.66"*	*1.80"*	*1.88"*	*1.97"*	*2.05"*	*2.32"*	*2.56"*
2 Hour	*1.23"*	*1.47"*	*1.61"*	*1.88"*	*1.97"*	*2.11"*	*2.23"*	*2.35"*	*2.47"*	*2.85"*	*3.10"*
3 Hour	*1.30"*	*1.57"*	*1.73"*	*2.04"*	*2.16"*	*2.35"*	*2.46"*	*2.56"*	*2.67"*	*3.03"*	*3.30"*
6 Hour	*1.55"*	*1.84"*	*2.03"*	*2.41"*	*2.55"*	*2.76"*	*2.86"*	*2.97"*	*3.07"*	*3.56"*	*3.92"*
12 Hour	*1.83"*	*2.24"*	*2.44"*	*2.84"*	*3.02"*	*3.29"*	*3.45"*	*3.61"*	*3.77"*	*4.13"*	*4.71"*
24 Hour	*2.20"*	*2.54"*	*2.79"*	*3.28"*	*3.48"*	*3.79"*	*3.96"*	*4.13"*	*4.30"*	*4.85"*	*5.32"*

The 1,2,5,10,25,50, and 100-year storm values were scaled from TP-40 layouts.
*Indicates that the 3,7,15 and 20-year storm were computed by linear interpolation from the adjacent TP-40 data.
Reference: US Dept. of Commerce, Technical Paper No. 40; Rainfall Frequency Atlas of the United States for Durations from 30 Minutes to 24 hours and return periods from 1 to 100 years.

Dam Failure from Thunderstorms

FEMA describes a "dam" as an artificial barrier that has the ability to impound water, wastewater, or any liquid-borne material for the purpose of storage or control of water. Dams can fail for a number of reasons including overtopping caused by floods, acts of sabotage, or structural failure of materials used in dam construction. Dam failure causes downstream flooding.

The federal government has jurisdiction over most large dams in Wisconsin that produce hydroelectricity – approximately 5% or nearly 200 dams. The Wisconsin Department of Natural Resources (WI-DNR) regulates the rest of the dams.

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 approximately 3,800 large dams in the State of Wisconsin.

Dams are classified as Low, Significant or High Hazard. A dam is assigned a rating of High Hazard when its failure would put lives at risk. The "hazard" rating is not based on the physical attributes, quality or strength of the dam itself, but rather the potential for loss of life or property damage should the dam fail.

There are no dams upstream of the Nemadji or Pokegama Rivers that would threaten the City. There is one dam upstream of the St. Louis River that may release high volumes of stormwater during significant rainfall or spring thaw events. This is the Fond du Lac Dam in Minnesota (National Inventory of Dams No. MN00603, Fond du Lac Development Project No. 23601 (01) St. Louis River Hydrologic Project, Minnesota Power and Light). Dam failure assessment for this dam at maximum capacity indicates that the wave front would take 4.5 hours to travel from the dam site to the outskirts of the City, however the water level would rise less than one foot in floodplains involving the City. The inundation area mapped for the dam does not include any part of the City. The widening of the river mouth and surrounding estuaries absorb much of the floodwaters, thus minimizing the affect on the lake level in St. Louis and Superior bays, unless the lake level in the harbor was already at or just below flood stage. The geographic area that would be most affected by a dam failure occurring simultaneously with flood stage levels in the Superior Harbor would be Billings Park and possibly the North End industrial park. Since normal lake level conditions are 2.3 feet below the flood stage, it is unlikely that this hazard would pose a significant threat.

Historical Events

There have been no dam failures affecting any part of the City of Superior since the Fond du Lac Dam has been in operation.

Probability & Predictability

Probability of a dam failure posing a hazard to the City of Superior is less than 1% in 100 years.

Lightning & Lightning Induced Wildfire from Thunderstorms

Lightning is a visible electric discharge produced by thunderstorms. Lightning can occur before, during, after, or not even associated with a rain event. A thunderstorm without rain produces dry lightning. Dry thunderstorms form so high in the sky that when the rain falls it evaporates before reaching the ground. Dry lightning conditions include a very dry layer of air between the cloud base and the ground, a high cloud base, 14,000 feet above

ground or more, and a high level of air instability. The lightning generated in the storm can reach the dry land below, even if the base of storm itself is two, three, or more miles high. Lightning can also occur during winter snowstorms, termed, “thundersnow”.

Many people apparently feel safe from lightning when not experiencing rain. In most years, lightning is the thunderstorm's greatest killer since lightning victims frequently are struck before or just after the occurrence of precipitation at their location. Lightning can strike humans directly or indirectly. A direct strike may occur to a person or to something they are holding. Indirect strikes can come as a side flash when a bolt strikes nearby and jumps to the person, through ground currents, from jewelry or clothing that catches fire, or from shockwaves or falls resulting from the strike.

Wildfire is another hazard of lightning. When lightning does strike a natural or manmade structure, a fire can be sparked. When dry lightning sparks and there's no rain falling to douse the flames, the fire hazard can be increased. Although wildfires are not an actual weather phenomenon, they can be directly related to lightning and other weather related elements. Gusty winds often accompany thunderstorms and can accelerate the spread of wildfires. Strong microburst winds, common with thunderstorms, can aggravate a smoldering fire into an active blaze. Thunderstorm winds tend to be erratic in direction and speed, posing the greatest threat to firefighters. Residential structures near the Superior Municipal Forest, with its vast forested area, would be most threatened by lightning induced wildfires.

Historical Events

- Wildfires caused by lightning have occurred in Douglas County in 1976 (7 fires), 1977 (2 fires), 1980 (5 fires), 1982 (2 fires), 1985 (3 fires), and 1991 (2 fires). There are no records of wildfires occurring in the City. However, the chance should not be discounted.
- In June 1898, lightning struck a chair factory, causing $40,000 damage to the factory, barn, dry kiln and materials.
- In May 1913, a thunderstorm accompanied by lightning caused $200 damage to a struck home.
- In August 1948, a thunderstorm produced 0.69 inches of rain accompanied by 30 mph winds and lightning. Lightning struck a house, ran through the telephone line and burned a man using the telephone.
- In June 1958, a thunderstorm produced 5.9 inches of rain in 5 hours. Lightning strikes caused $6,000 damage to a barn and $3,500 damage to a house. Lightning destroyed large electrical transformers and streetlights.
- In May 1964, a severe thunderstorm caused fires to ignite from lightning at the shipyard.
- In August 1978, a thunderstorm produced 4-6 inches of rain in 12 hours. Lightning struck a partially filled gasoline tank at Murphy Oil Refinery, ripping a 20-foot gash in the tank, causing $350,000 in damage.
- In June 1992, lightning struck the Bridgeview Motor Inn causing $500 damage to an outside transformer.

- In July 1992, lightning struck the roof of a house, causing $10,000 damage to the attic.
- On July 6, 1996, lightning struck a tank at Lakehead Pipeline causing $10,000 damage to a 16 million gallon tank.
- On July 8, 1996, lightning struck the chimney of a house and followed water pipes to the bathroom causing $500 electrical damage.
- On July 18, 1996, lightning struck the exterior of a garage causing $2,500 damage.
- On July 21, 1996, lightning struck the roof of a house causing $500 damage to the roof and dormer.
- In July 1997, lightning struck a home causing $500 damage. An arcing power line also resulted from this storm, however no further damages were reported.
- In August 1998, lightning struck an antenna mounted on a house causing $3,000 damage. During this same storm, a tree was stuck by lightning and started on fire.
- In July 1999, lightning struck a house causing damage.
- In September 1999, lightning struck the steeple of a church causing $500 damage.
- In March 2000, lightning struck the upstairs bathroom of a house and traveled through walls causing $15,000 damage to the attic and upper floor.
- August 2005, 16 area fire departments responded to a woodyard fire started by lightning in the Town of Parkland. Water needed to be brought in from Superior and the Amnicon River. The City of Superior brought in 86,000 gallons of water to fight the fire. It is estimated that 350 to 400 cords of wood were lost, at an estimated cost of $60,000.
- August 18, 2012, a lighting strike on Lake Superior beach injured eight people, including a 9-year old boy who later died.
- There have been no wildfire occurrences causing structural damage within the City.

Probability & Predictability

Based on research into local events, the probability of lightning causing damage to property in the City of Superior is moderate (2-5% annually).

Lightning can be predicted using advanced lightning prediction technology and identifying thunderstorm-provoking conditions. Fires caused by lightning can be predicted using lightning prediction methods and producing fire weather forecasts on a daily basis during the warm season.

The probability of an object being struck by lightning depends on the object's ground-surface area, height, and the striking distance between the storm and the object. This probability also must depend of the frequency of thunderstorm tracks for a given area. Research conducted by the National Lightning Detection Network and the National Lightning Safety Institute indicates that lightning may strike a given structure once every 17 years.

Tornados from Thunderstorms

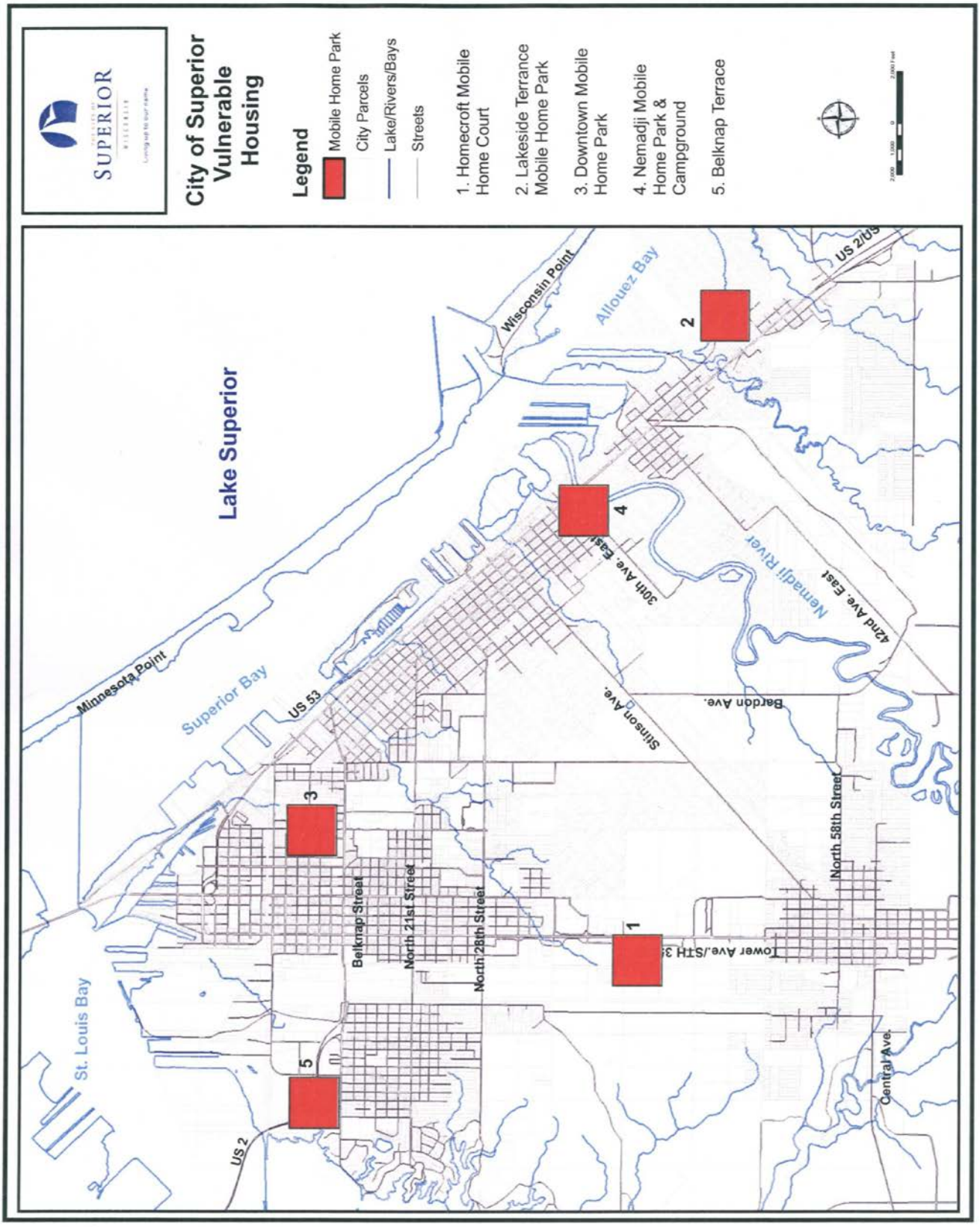
Tornadoes, rapidly rotating columns of air, are found in the central, southeast and northeast United States. Tornadoes can be essentially dry, accompanied by dust and debris, or they can be accompanied by rain or hail. They can occur individually or in families. Tornadoes may lift off the ground and touch down in a random pattern as they travel. They tend to cause the most damage where they touch down and damage tends to occur in patches.

A tornado path averages 4 miles but may reach up to 300 miles in length. Widths average 300-400 yards, but tornadoes have cut swaths a mile or more in width, with severe tornadoes or groups of two or three funnels traveling together. On the average, tornadoes move between 25 and 45 miles per hour, but speeds over land of up to 70 mph have been reported. Tornadoes rarely last more than a couple of minutes over a spot or more than 15-20 minutes in a ten-mile area, but their short periods of existence do not limit their devastation.

All Wisconsin counties have recorded at least one tornado between 1844 and 2015. The southern and west-central portions of the state have the greatest number of occurrences.

Damages and death can be especially significant when tornadoes move through populated, developed areas. The destruction caused by tornadoes range from light to incredible depending on the intensity, size and duration of the storm. The location of tornadoes in Superior is random and unpredictable. Any area is as vulnerable as another although manufactured housing, mobile homes and people staying in campgrounds are especially susceptible to damage from wind and other storms. When compared to people living in homes built with conventional framed construction, people living in these types of housing are more vulnerable to injury or death in hazardous weather. People in campgrounds are even more defenseless to storm events than those living in manufactured or mobile homes. Map 8.2 shows the location of mobile home parks and campgrounds within the City of Superior.

Map 8.2: City of Superior Vulnerable Housing



The Enhanced Fujita Scale, also known as the "EF-Scale", measures tornado strength and associated damages. The EF-Scale is an update to the earlier Fujita Scale that was published in 1971. It classifies U.S. tornadoes into six intensity categories, as shown in Table 8.3, based upon the estimated maximum winds occurring within the wind vortex. The EF-Scale has become the definitive metric for estimating winds within tornadoes based upon the damage done to building and structures since it was implemented through the National Weather Service in 2007. Table 8.3 shows both the original Fujita Scale and Enhanced Fujita Scale and should be referenced in reviewing previous occurrences as tornado events prior to 2007 will follow the original Fujita Scale.

Table 8.3 Enhanced Fujita Scale

Original Fujita Scale F Number & 3 Second Gust (mph)	EF Number	3 Second Gust (mph)	Damage Description
F0 45-78	EF0	65-85	LIGHT DAMAGE: Some damage to chimneys; tree branches broken off; shallow-rooted trees pushed over; sign boards damaged.
F1 79-117	EF1	86-110	MODERATE DAMAGE: The lower limit is the beginning of hurricane wind speed. Rood surfaces peeled off; mobile homes pushed off foundations or overturned; moving autos pushed off roads.
F2 118-161	EF2	111-135	CONSIDERABLE DAMAGE: Roofs torn off from houses; mobile homes demolished; boxcars pushed over; large trees snapped or uprooted; light-objects missiles generated.
F3 162-209	EF3	136-165	SEVERE DAMAGE: Roofs and some walls torn off well-constructed houses; trains overturned; most trees in forest uprooted; heavy cars lifted off ground and thrown.
F4 210-261	EF4	166-200	DEVASTATING DAMAGE: Well-constructed houses leveled; structures with weak foundations blown off some distance; cars thrown; large missiles generated.
F5 262-317	EF5	Over 200	INCREDIBLE DAMAGE: Strong framed houses lifted off foundations and carried considerable distances to disintegrate; automobile-sized missiles fly through air in excess of 100 yards; trees debarked.

Historical Events

- In May 1914, a "cyclone" along the bay front caused $500,000 damage, killed one man, injured 5 men, destroyed a steamship and coal dock, blew off a house roof, flipped box cars and disabled telephone service.
- In May 1950, a "hurricane" was experienced from the northern tip of Superior through the eastern half of Superior. This storm caused more than $2 million damage and injured at least 14 people. Windows were blown out of City Hall and 28 stores on Tower Avenue, 3 coal bridges were destroyed, powerhouse stacks toppled, a 1500-foot building leveled, many chimneys and roofs destroyed. The Superior Civic Center was struck by lightning, leaving a hole in the roof and 20 feet of brick torn off. Fifty light poles were lost, transformers destroyed, tree branches blown down, telephone poles knocked over, water mains washed out, the stadium destroyed, bridges and roads closed and the sewer main plugged with debris.
- In June 1986, a thunderstorm equal to an F1 tornado produced ½ inch hail, funnel clouds and 85 mph winds. This storm ripped metal siding off a grain elevator, damaged ships moored in the harbor, ran ships aground on Hearding Island, caused $500,000 damage to Helmer Foods when the roof was torn off a building and resulted in $200,000 damage to a 50,000 gallon Amsoil storage tank containing synthetic fluids. The storm also blew down trees, radio towers, power lines, billboards, street

signs, building siding and 17 railcars containing coal. At least 40 homes were damaged by trees. People were stranded in boats on Lake Superior. Downed power lines arced, causing some fires. Three airplanes were destroyed at Bong Municipal Airport. Basements flooded due to electrical outages that disabled sump pumps.

- In July 1987, several funnel clouds were observed over Superior, however none touched down.
- On August 3, 2005, tornadoes were spotted in Hermantown, MN though none touched down. Lockdowns occurred at Mariner Mall, Superior YMCA and UW-Superior, where all patrons were sent to the lowest point in the building. Warnings in Superior were not formally declared, however they were formally declared for Hermantown and downtown Duluth. Impacts to the Dragon Boat Festival in Superior were minimal, but could have been significant. No damage was reported within the City limits. Lightning struck a lumberyard outside the City limits. Firefighting costs were estimated at $70,000 to $90,000.
- August 9, 2012, a tornado touched down on Minnesota Point. The tornado caused no serious damage, scoring only EF-O on the Fujita Scale with winds from 65-85 mph.

Probability & Predictability

Tornadoes are not always predictable, except that, when present, will accompany a thunderstorm. From past events, a tornado may be expected once every 25 years or with moderate probability (2-5% annually).

Wind from Thunderstorms

Wind events are prevalent in the City. Winds most commonly (> 45 days per year) come from northwesterly directions at 10-20 miles per hour (mph). Other common (> 40 days per year) winds are northeasterly at 3-10 mph. Wind off of Lake Superior can be most damaging, since air can flow for 200 miles over the lake without obstacles. Wind speed can exceed 40 mph and have been recorded as high as 100 mph. Winds may come at any time of year, alone or accompanying rain or snow.

Thunderstorm events are often accompanied by high winds. These forces are most often the cause of damage associated with thunderstorms. The two main types of thunderstorm produced winds are downbursts (i.e. straight-line winds), and derechos. A downburst is a small area of rapidly descending rain and rain-cooled air beneath a thunderstorm. Wind speeds associated with downbursts can reach 100 to 150 mph, similar to that of a strong tornado. The winds produced from a downburst often occur in one direction and the worst damage is usually on the forward side of the downburst. Derecho winds are created by the merging of many thunderstorm cells into a cluster or solid line extending for many miles. The width of such a storm can range from 20 to 65 miles and the length can reach 100 miles or more. The extreme velocity winds produced by a derecho can exceed 150 miles per hour and cause extensive damage. A recent example of the impact of derecho winds was observed following the storm event of July 4, 1999, which occurred in the area of the Minnesota's Boundary Waters Canoe Area Wilderness (BWCAW). This event was one of the largest blow downs in recorded North American history, similar in size and

severity to a F2 or F3 tornado. The storm impacted approximately 477,000 acres, when winds in excess of 90 mph hit the region.

Historical Events

- In October 1949, tornado winds gusted to 95-102 mph for about 12 hours. Winds felled trees, tore off shingles and roofs and shattered plate glass windows, causing thousands of dollars in damage. Rain torrents washed windblown leaves into sewers, causing sewers to back up. Electrical wires were blown down causing power outages. Uprooted trees blew onto homes and streets. Damaged trees were salvaged for lumber.
- During two storms in April and May 1953, 33-55 mph winds persisted for 20 minutes to a full day, preventing ore boats from docking and loading. During the April storm, ore boats crashed against docks, causing damage to both the boats and the docks.
- In May 1955, 30-82 mph winds gusted for 12 hours damaging residential exteriors.
- In November 1958, 35-75 mph winds gusted for 8 hours, downing power lines and poles, trees and branches, telephone poles and fencing and brick pillars at the baseball field. Trees blocked roads. High waves halted shipping traffic in the Duluth-Superior Harbor.
- In May 1959, 45-93 mph winds gusted for 24 hours, blowing glass out of windows, downing tree limbs onto houses and streets, downing power and telephone lines and poles, tearing off roofs and doors. Marine advisories were issued involving Duluth-Superior Harbor shipping activity, forcing ships to anchor out in the lake as opposed to trying to maneuver through the entries and in the bay. Tugboats were not able to control the big ships against wind forces.
- In November 1960, 73 mph gusts lasted 24 hours, creating waves that washed out Quebec Pier, causing sleet to damaged power lines which caused power outages, breaking loose building trim and cutting off telephone service.
- In September 1978, 30-49 mph winds forced a camper traveling on the Blatnik Bridge to tip onto two wheels. A semi-trailer truck pulled between the camper and the prevailing winds, affording the vehicle shelter until both vehicles arrived safely on the other side. Also, during this storm, trees were uprooted and fell over onto houses.
- On June 7, 2007, a storm produced wind gusts up to 70 mps. Large trees were blown down and windows of a house were shattered by the strong thunderstorm winds.
- On July 11, 2007, high winds caused problems throughout the Superior area, with downed lines and trees. As many as 20,000 homes were without power for many hours. Small craft warnings and unsafe swimming conditions were issued. There were 12 fires caused by downed wires. Fire conditions were intensified because less than a half-inch of rain had fallen in the previous few months.
- On July 1, 2011, several lines of severe thunderstorms swept across parts of Minnesota and Wisconsin-Lake Superior area, Upper Michigan, Iowa and South Dakota. The first line of storms was especially severe and it produced a corridor of wind damage from northwest of Sioux Falls, South Dakota, all the way into northwest Wisconsin and western Lake Superior

Probability & Predictability

Wind may be predicted with reasonable notice using meteorological techniques to determine likely intensity and duration. Based on the last 60 years of recorded wind events, there is a 5% probability of having a significant (>72mph) wind event in any given year.

Table 8.4 City of Superior Wind Events

Date	Average Velocity (knots)	Maximum Gusts (knots)	Duration (hours)
March 13,1943	45	45	72
October 10, 1949	95	102	0.5
April 25, 1953	35	48	12
May 1, 1953	33	55	24
May 4, 1955	30	82	12
November 17, 1958	35	75	8
May 11, 1959	45	93	24
November 28, 1960	73	73	24
July 30, 1973	55	55	12
September 11, 1978	30	49	36
June 21, 1986	74	74	12
March 23, 1991	40	40	24
July 21, 1996	53	53	12
June 22, 1999	50	50	12
July 23, 1999	52	52	12
August 14, 2000	50	50	12
August 8, 2001	50	50	12
July 19, 2003	55	55	12
August 20, 2003	61	61	n/a
June 29, 2005	60	60	n/a
August 9, 2005	60	60	n/a
June 7, 2007	52	70	n/a
July 1, 2011	52	86	n/a

Source: National Climatic Data Center

Hail from Thunderstorms

Hail is a product of severe thunderstorms. It is formed when strong updrafts within the storm carry water droplets above the freezing level, where they remain suspended and continue to grow larger, until their weight can no longer be supported by the winds. Hailstones can vary in size, depending on the strength of the updraft.

The National Weather Service (NWS) uses the following descriptions when estimating hail size:

- pea size = 1/4 inch
- marble size = 1/2 inch
- dime size = 3/4 inch
- quarter size = 1 inch
- golf ball size = 1.75 inch
- baseball size = 2.75 inch

Individuals who serve as volunteer "storm spotters" for the NWS are located throughout the state and are instructed to report hail 3/4" (dime size) or greater. Large hailstones can fall at speeds faster than 100 mph. Hailstorms can occur throughout the year, however, the months of maximum hailstorm frequency are May through August.

Hailstorms can cause injury or loss of life, though more frequently, they cause significant damage to property.

Historical Events

Table 8.5 Hail Events in the City of Superior

Date	Diameter (in.)
May 20, 1970	1.75
May 21, 1974	1.75
July 5, 1994	1.00
August 23, 1998	1.75
August 1, 2002	0.88
April 18, 2004	1.00
July 28, 2006	0.75
May 14, 2007	1.00
September 21, 2007	0.75
August 28, 2008	1.00
May 5, 2009	0.75
May 10/11, 2011	1.00

Source: National Climatic Data Center

Probability & Predictability

Thunderstorms accompanied with hail are often included in advisories issued by the NWS. Large hail accompanies less than 1% of thunderstorms in the City and therefore has a low (<1%) probability of causing damage in the City.

Vulnerability Assessment

Damage incurred by the various hazards related to thunderstorms pose personal, structural, and economic threats to all natural and human resources in the City of Superior and the University of Wisconsin-Superior.

Persons stranded at home or on the road without emergency provisions are vulnerable to freezing, starvation, or other problems, especially if there is no power for heat, fans, or communications. The frequency of structural fires increases during storms, as residents turn to alternative methods of heat, especially during power outages.

Power outages disrupt many utility services, including telephone, television/radio, water pumps, sump pumps, water heaters, water mains and furnaces. The surges associated with power outages can fatally disrupt electronic equipment for critical facilities, businesses, homes and other facilities. Loss of electricity appears to be the greatest concern among Superior citizens.

Essentia Hospital of Superior is the only hospital in the City. There is a Mariner Medical Clinic: Urgent Care center at the Mariner Medical Clinic, a subsidiary of St. Luke's Hospital. The Veterans Administration Twin Ports Clinic is located in the City, just south of Essentia Hospital of Superior. There are several private clinics and specialty offices throughout the City, including the Lake Superior Community Health Center on Hill Avenue, Luke's I Emergency Medivac helicopter and Life Link III ambulance lease storage hangers at the Richard I. Bong Memorial Airport on Tower Avenue. These resources are threatened structurally by the hazards associated with thunderstorms, thus City residents are vulnerable to these resources being incapacitated. Luke's I Emergency Medivac helicopter is particularly vulnerable to wind, lightning, and tornadoes as well as to flooding and hail.

Gold Cross Ambulance Service is the primary mode of emergency transportation servicing Essentia Hospital of Superior and also Duluth hospitals. Their dispatch center in Rochester, Minnesota is directly linked to the Douglas County Communications Center and both monitor local weather advisories, watches and warnings. In the event of a severe weather watch, all on-duty crews are notified of the conditions. In the event of a severe weather warning, all on-duty and off-duty crews are notified and are put on standby. Gold Cross Ambulance Service cooperates with other emergency vehicle resources for vehicles and manpower in the event that a natural hazard results in increased casualties. During a hazardous weather event, such as a snowstorm or flood, non-emergency transport activities are cancelled and all calls are triaged. The Superior Station does have access to a four-wheel-drive ambulance stored in Duluth. Gold Cross dispatch works closely with the City Public Works Department and can request assistance from the City Streets Department. In the event of a power outage, operations can relocate to Essentia Hospital of Superior, as the Gold Cross Station does not have a back-up generator.

Loss of power due to multiple elements of thunderstorms can cause significant economic damage to manufacturing and industrial businesses in the City. Each time electrical

service is interrupted, even for a very short time; facilities such as Calumet Refinery must completely shut down their plant and restart once power has stabilized. This accounts for high product and productivity loss. Weather accounts for approximately 12% of the power interruptions suffered by Superior Water, Light, & Power (SWL&P) managed facilities. Of this 12%, 4% of the interruptions are attributed to lightning and 8% to wind. Loss of productivity related to storm damage poses significant economic threats to employees, businesses and industry, including productivity loss from power outages, as well as structural damage.

Some facilities have emergency generators, including Essentia Hospital of Superior and the Superior-Douglas County Government Center (where local and county police and the Douglas County Communication Center are housed), the main Fire Station on Tower Avenue, an Inter City Oil Station on Winter Street and University of Wisconsin-Superior. These generators help to maintain security and continuity of emergency response during critical times. Facilities such as Calumet refinery would not benefit from backup generators, as their facilities require continuous power sources and cannot switch between normal and emergency power without losses similar to not having a generator. The wastewater treatment plant has two portable backup generators to cover 16 sewer lift stations. The main treatment plant, however, does not have an emergency generator and thus is incapacitated during a power failure. In addition, the City Streets Department does not have an emergency generator. All City vehicles, including fire trucks and street maintenance equipment are fueled, repaired and maintained at this facility. An emergency generator is greatly needed at both of these facilities.

The City also manages 25 recreation areas, a municipal golf course, three outdoor open space and special use areas and 13 waterfront recreation areas. Hazards exist in these areas as visitors are vulnerable to lightning strike, flash flooding, ground failure, hail, tornado, or other thunderstorm related elements. Many sites have appropriate shelter for protection against minor elements, but not against tornadoes. Citizens may also not be informed of weather conditions, especially if patterns change suddenly and visitors are caught off guard.

Flooding

Flooding from storms appears to be the primary concern for residents and property owners in the City. When stormwater collects in the yard, flows into homes or enters homes through sewer backups, structural damage is caused and may pose a health threat. When electrical power fails, structures with sump pumps to control flooding are vulnerable, as the sump pump fails with the electricity.

While flooding is a problem in the City of Superior, there are no repetitive loss properties, as defined by the Federal Emergency Management Agency (FEMA) and the NFIP. However, there are homes throughout the City that have made repetitive claims to the City of Superior for damages that have resulted from flooding. Properties have been reclaimed or repaired through City Department funds, the City's Redevelopment Authority program, or with funding from Community Development Block Grants.

While there are 3 residences in the City that carry NFIP insurance only 1 is actually in a floodplain. There are 198 improved residential parcels in the City that are located within or adjacent to the floodplain. Some of these parcels are located high on the bluffs of St. Louis Bay. Others are located along Superior Bay and various rivers, including the Nemadji River. Most of the commerical or non residential improved properties located within or adjacent to the floodplain are businesses associated with the Port of Superior. The clay soil and limited topography have very significant effects on how flood prone properties are, whether they lie in the mapped floodplain or not. The Halbert Steam Heating Plant, located on the University of Wisconsin-Superior campus, is the only critical facilities located in the floodplain.

A 2004 survey by Zenith Research Group Inc., found that 81.8% of respondants carry homeowner's insurance for damage caused by weather-related events. Of those insurance carrying respondents, 100% of those who live in a condominium, townhouse, or manufactured home had homeowner's insurance coverage for damage caused by natural, weather-related events.

Sewer backups during incidences with high rain or snowmelt volume are of concern to property owners in the City. Numberous claims have been made against the City in recent years for damages to basements, lower levels of buildings, contents, collapsed laterals and blown toilets during storms.

The City Stormwater and Administrative Manager-ESDPW applied for and received funding for a repetive loss property near Faxon Creek. This site had suffered repetitive flooding including to the homeowner's basement, in the last 10 years. With guidance from this Hazard Plan and utilizing awarded funding from FEMA, the City was able to purchase the site and mitigate the hazard.

Buildings may suffer structural collapse when the weight of rain water collects on flat-topped roofs. Other structural problems include verticle and horizontal cracking of foundations and basement walls. Some of this cracking is due to foundations settling, but damage can be increased as water seeps through the cracks, flowing into the basement and widening the cracks.

Wetlands and penetrable surfaces are natural sites for water storage and treatment. Pollutants can settle out via infiltration and be trapped among soils, releasing clean water into the watershed. Increased development reduces the amount of pervious area, thus decreasing the storage and treatment capacity of the soil.

To manage wet weather events, the City maintains both combined and separate storm sewers as well as 3 combined sewer treatment plants (CSTPs). The CSTP facilities are utilized during high run off events. The water in the CSTPs is either sent to the main plant for treatment after the run off event or can be treated on-site and discharged. The CSTPs have been instrumental in reducing/eliminating sewer back-ups in homes and businesses. In addition, the South Superior and the Billings Park combined sewer district have storm sewer interceptors that direct stormwater to detention basins that provides

treatment and attenuate peak flows. The city is planning for an additional detention basin in the Central Business District neighborhood.

Calumet refinery manages their stormwater onsite at either their wastewater treatment facility or their stormwater retention pond. Calumet also manages at least two fire ponds, where stormwater is collected and used to extinguish and/or prevent fires in the plant. Permit guidelines require facilities such as Calumet to maintain the design standard of their stormwater treatment facility to handle a ten-year storm event.

Natural resources in the City include 7,130 acres of wetlands (approximately 25% of the total land area), 4,500 acres of minimally-developed forest, a three-mile natural sand bar, over 49 miles of shore and several bays, rivers and streams, which flow to Lake Superior. Rivers and streams in the City are vulnerable to flooding and erosion processes. The Nemadji River normally runs between 4-5 feet deep. The flood stage for the river is 20 feet, though 16 feet will cause minor flooding of lowland areas. Depth of flow can increase to between 10 and 15 feet during the March to May snowmelt season. The Nemadji River exceeded its flood stage during storms in September 1985 (23.16 feet), April 1996 (20.45 feet), July 1999 (21.84 feet), April 2001 (24.39 feet) and October 2005 (21.23 feet).

Fuel and fuel oil distributors including local service and gas stations are vulnerable to flooding. Those stations with aboveground tanks must have a flood preparedness plan in place in the event of a flood. Many stations have underground tanks installed to prevent threats from lightning or tornadoes, but the tanks are impaired in the event of a flood when they cannot be refilled. The City has its own fuel pumps at the City Street Division site and in the case of an emergency there are plans in place for fuel usage.

City and school outdoor recreational fields are vulnerable to damages incurred by flooding. Flooding may kill natural turf or render it very sensitive to use. To protect these surfaces, facilities managed by both the Superior School District and Superior Parks and Recreation are often closed during heavy rain events.

Roads, culverts, and bridges are particularly vulnerable to erosion, especially during heavy rain or snowmelt events that may result in washouts. Roads on Wisconsin Point, on the Allouez bay side and areas of Moccasin Mike Road in Itasca, are threatened by coastal erosion of sand. Roads in the Superior Municipal Forest, including Billings Drive, also suffer from erosion due to overland runoff and weak clay soil properties.

Early spring flooding from early rain or snowmelt can leave standing water on roads that will freeze overnight when temperatures drop, making the morning commute particularly hazardous.

Dam Failure

There are few properties in the City that could be affected by failures of the Fond du Lac Dam, which is upstream of the St. Louis River. The low vulnerability is due to the fact

that City properties are situated along St. Louis Bay, beyond the estuary where the river empties into Spirit Lake.

Damaged structures may include private docks, boats, outbuildings, gardens, or other recreational structures. Fisherpersons and boaters may be vulnerable to the wave front, especially upstream. However, if they have proper communications on board, such as a portable weather radio, they would have up to 4 hours from the dam failure to seek safety, depending on their location.

Lightning and Lightning Induced Wildfire

Lightning may threaten any structure and strikes are not uncommon in the City. Boaters, swimmers and other outdoor sport participants are most at risk for being struck by lightning.

The City has vested numerous resources into its Urban Forest, which includes the trees planted throughout City streets and parks and the Superior Municipal Forest. In 1998 there were 4,348 trees from 62 species planted along the City's streets. The Superior Municipal Forest consists of 4,400 acres of relatively pristine boreal forest, willow/alder swale, upland conifer forest and riverine wetlands. These resources can be both threatened and can become a threat caused by elements associated with thunderstorms. Lightning can strike trees, causing crown fires that can spread wildly through the forest. These lightning induced fires can destroy trees, endanger those recreating in the forest and threaten homes in adjacent neighborhoods, including those near Kimball's, Kelly and Kilner bays.

High winds can intensify the threat of structural fires. If a fire is ignited in the Superior Municipal or Urban Forest, the fire could easily spread to nearby structures. There are nearly 3,300 improved, residential parcels located within one mile of the Superior Municipal Forest, including homes in Kimball's, Kilner and Kelly bays, South Superior and Billings Park. There are an approximately 369 improved commercial parcels located within one mile of the Superior Municipal Forest, including several discount, retail and construction businesses located along Tower Avenue. These structures may all be at risk of being involved in a wildfire ignited in the municipal forest, especially if high winds and high fuel accumulation increase the problem.

Urban wildfires are problematic in areas that have sustained increased development in vegetated areas. The Insurance Services Offices (ISO) recognizes that this kind of urbanization increases the threats of wildfire on homes. ISO notes that there are solutions to the challenges of these added threats, including hazard mapping, understanding fire behavior, public education, establishing fire-safe building codes and landscaping ordinances. Research has shown that fires can be prevented or their effects lessened based on the following issues: cleared space around structures, building construction, access to the site and whether defensive action is taken.

Lightning strikes to industrial facilities can pose additional threats if hazardous materials are on site. There are at least three incidences on record of strikes to Calumet refinery,

AMSOIL Petroleum and Enbridge Energy, which caused potentially hazardous spills. Lightning arresters have been installed on all transformers at the Calumet refinery to resist damage to electrical equipment in the event of a lightning strike.

Lightning and other thunderstorm related power outages are of critical concern to manufacturing facilities, including Calumet. Even minor power surges or failures, storm or otherwise, lead to a total plant shutdown of all processing machinery and pumps, as a safety practicum. This accounts for high product and productivity loss.

The Superior Wastewater Treatment Plant may be vulnerable to lightning strikes. Motors that operate the facility are very costly and can be affected by lightning strikes. To mitigate the potential damage, phase protection has been installed to protect the 3-phase power motors. With phase protection, when any one phase fails, the motor shuts off before damage to the motor occurs. In addition to phase protection, motors at the main plant and CSTPs have ground fault interrupter (GFI) protection. These motors have power factor correction to protect from fluctuations in their power supplies. Also, there are two portable generators available for use on municipal lift stations throughout the City. However, these generators are outdated and impermanent. To protect these facilities, automatic generators at the lift stations and backup power for the main treatment plant is needed.

Tornado and High Wind

A secure structure should offer shelter from most direct tornado strikes. Incredible damage (EF5) tornadoes are capable of leveling a well anchored, solidly constructed home. This City has never experienced this class of tornado. Most of the damage caused by tornadoes is indirect and caused by wind and wind blown projectiles.

Utilities, including telephone, electricity and wastewater can be adversely affected by windstorms. Tree branches that break off during summer and winter windstorms can tangle with electricity and telephone lines and cause disruption of service. This can affect main lines which would disrupt service to a large number of buildings, or feeder lines which would either affect service locally, disrupting service to one or a few individual buildings. Many communities bury utility lines in order to mitigate these effects. This option is not suitable for the City since the ground is frozen nearly 6 months out of the year, making winter maintenance and repair more difficult and costly. There are buried lines in some areas of the City, including at the UW-Superior, along Tower Avenue and in South Superior.

Fuel and fuel oil distributors, including local service and gas stations, are vulnerable to tornadoes. Many stations have underground tanks installed to prevent tornado damage.

Essentia Hospital of Superior has a severe weather policy that dictates roles and procedures in the event of severe weather, including tornadoes, when they are announced. The Gold Cross Ambulance service is responsible for transporting patients to the facility in any type of weather.

The Richard I. Bong Memorial Airport is a critical facility that houses the Luke's I Emergency Medivac helicopter and Life Link III ambulance. Aircraft are particularly vulnerable to wind. An aircraft entering a microburst will encounter strong headwinds followed by strong tailwinds as it flies from one side of the microburst to the other. If the pilot compensates for the headwind (to decrease lift) a bit too much, then the aircraft will lose lift in the tailwind and quickly strike the ground. The municipal airport may be used as safe harbor for aircraft avoiding a storm.

Ships entering and exiting the Duluth-Superior Harbor through either the Duluth Ship Canal or the Superior Entry must prepare for high wind conditions inside and outside the harbor. Many ships will anchor outside either entry to wait out the storm, rather than try to maneuver ships through the narrow entries. Dock and pier facilities may also warn ships against attempting to load during high winds to prevent damage to docks and loading equipment. Ships may also choose to remain tied to a dock rather than depart during a windstorm, until the winds subside. These actions are generally determined by the ship's captain rather than by the dock facility.

While many of the docking facilities and port equipment are located along the northern tip and northeastern facing edge of the City, these structures are placed and engineered with winds in mind. For example, the BNSF Allouez docks are aligned with the prevailing northeasterly winter winds, as are the boats stored on land at Barker's Island Marina.

Hazards from wind are of greatest concern to the Barker's Island Marina facility. Northeasterly winter gales may threaten boats stored on dry-dock. Summer storms can affect a greater number of people and vessels. Vessels may access the marina via the Superior Entry. For small craft maneuvering through the entry, high winds can pose a big challenge, however no accidents are on record at the marina. In an isolated incident, one vessel in dry storage was knocked off its cradle during severe straight-line winds. The marina has endured storms involving winds in excess of 70 mph with little to no damage to its facilities or moored vessels.

Small craft advisories are made by the National Weather Service based on wind speed and wave activity on Lake Superior. These small craft advisories issue warning against travel by small boats or other recreational activity on Lake Superior when winds reach or exceed 22-33 knots (25-38 mph), gusts greater than 25 knots and/or waves reach 4 feet. Boaters using the marina can check with Barker's Island Marina staff for weather information, though many vessels are equipped with on-board radios which receive weather and Coast Guard information and advisories. Boaters may leave a float plan with the harbormaster.

Operations at the Burlington Northern-Santa Fe railroad and dock facility in the Allouez neighborhood of East Superior are vulnerable to high winds. Aerial conveyor belts that transport taconite from storage areas to the loading dock are elevated above the yards and over Highway 2 (East 2nd Street) and the neighborhood of Allouez, where several homes are located. The operations of these structures are controlled by a remote sensor on the

machinery that measures wind speeds. When wind speeds reach 50 mph, the operation automatically shuts down and an alarm sounds. When this occurs, the equipment, including stackers raised high in the air, are locked down and braced against the prevailing winds, thus protecting the equipment and other property around it.

Wind damage to City trees can hamper the health and quality of the Superior Municipal Forest, provide fuel for wildfires and can impede access into and around the forest when branches and uprooted trees block roads and trails. When wind causes tree branches to snap, they can cause damage by getting tangled into power lines and/or falling onto buildings, streets, or other property. Leaf and other tree debris can clog the storm and combined sewer systems causing street and yard flooding.

Hail

There are several car dealerships in the City that have experienced significant hail damage. There are also a few large greenhouses in the City, including those at the Challenge Center and at UW-Superior.

Future Development

Future development in the City of Superior is detailed in the 2010-2030 Superior Comprehensive Plan, on file with the City of Superior. Future development would not be impacted any differently than now exists from thunderstorm hazards. New development is governed by state standards, as well as local policy and legislation.

Loss & Replacement Estimates

Thunderstorms and thunderstorm related hazards have the potential to affect any or all parts of the City. Structurally, damage may range from millions of dollars to billions, in the event of a catastrophic event. A number of improved parcels are located within or adjacent to the NFIP designated floodplain. UW-Superior's heating plant is the only critical facility located within the floodplain. Thunderstorm and thunderstorm related hazards can affect the entire City equally.

The estimated potential loss for structural property in the event of a flood would be 20% of the total improvement value in the City or $280 million (Table 8.6). This value considers that many homes that have basements would sustain flood damage.

More extensive damage may be done in the event of flood related landslides in coastal or riverine areas of the City. Based on the low probability of any significant or major erosion events occurring in the City and the extent of damage experienced during previous events, the damage from a significant future event may result in a residential structural loss of approximately 10% of the total improvement value as well as approximately 5% or more loss of land value. This potential damage would total nearly $84 million to structures and over $8 million in damage to land. Landslides in coastal or riverine areas, which have occurred on the Nemadji River, may pose larger potential losses, as homes may sustain a higher percent of damage and the property may have to be completely mitigated to prevent further loss. If the City were forced to mitigate 25% of

residences on coastal or riverine parcels, the potential total value loss would be approximately $40 million.

Table 8.6 Values of all Improved Parcels

Parcel Land Classification	Total Parcels	Acreage	Land Value	Improvement Value	Total Value
Residential	10,213	2,836	$161,215,600	$841,248,600	$1,002,464,200
Commercial	1,776	2,140	$155,586,300	$562,982,300	$718,568,600
Manufacturing	408	853	$250,900	$1,324,300	$1,575,200
Federal	8	23	n/a	n/a	n/a
State	89	397	n/a	n/a	n/a
County	2,435	3,789	n/a	n/a	n/a
City	1,327	7,465	n/a	n/a	n/a
Other	1,535	2,292	$9,543,200	$50,796,500	$60,339,700

Source: City of Superior's GIS data of parcels.

Table 8.7 Values of Improved Residential & Commercial Parcels Intersecting the Floodplain

Parcel Land Classification	Total Parcels	Land Value	Improvement Value	Total Value
Residential	388	$17,426,400	$49,416,900	$66,843,300
Commercial	160	$33,734,100	$104,698,700	$138,432,800

Source: City of Superior's GIS data of parcels that intersect the city floodplain.

Should a wildfire originating inside the Superior Municipal Forest spread to properties within one mile of the forest boundaries, nearly thousands of residential and hundreds of commercial properties would be threatened. Based on lack of prior incidents and high potential damage, the estimated losses for a significant wildfire event would be 10% of the improvement value of these properties or over $40-50 million.

Table 8.8 Values of Improved Residential & Commercial Parcels Within 1-mile of the Superior Municipal Forest

Parcel Land Classification	Total Parcels	Acreage	Land Value	Improvement Value	Total Value
Residential	3,367	984	$65,236,300	$318,748,600	$383,984,900
Commercial	513	709	$56,159,500	$162,967,100	$219,126,600

Source: City of Superior's GIS data of parcels located within 1 mile of the Superior Municipal Forest.

Severe winds can threaten operations and equipment in all port manufacturing and shipping facilities. In addition, severe winds can cause direct damage to trees and indirect damage to power lines, telephone lines, and buildings. The cost of this damage can range from thousands to millions of dollars, depending on the severity of the storm.