



Exhibit A



Population Vulnerability Assessment and Climate Adaptation Framework

November 2017 Draft
May 2018 Final



Provided by:
**Minnesota Pollution
Control Agency**

Prepared by:





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Section 01

Introduction



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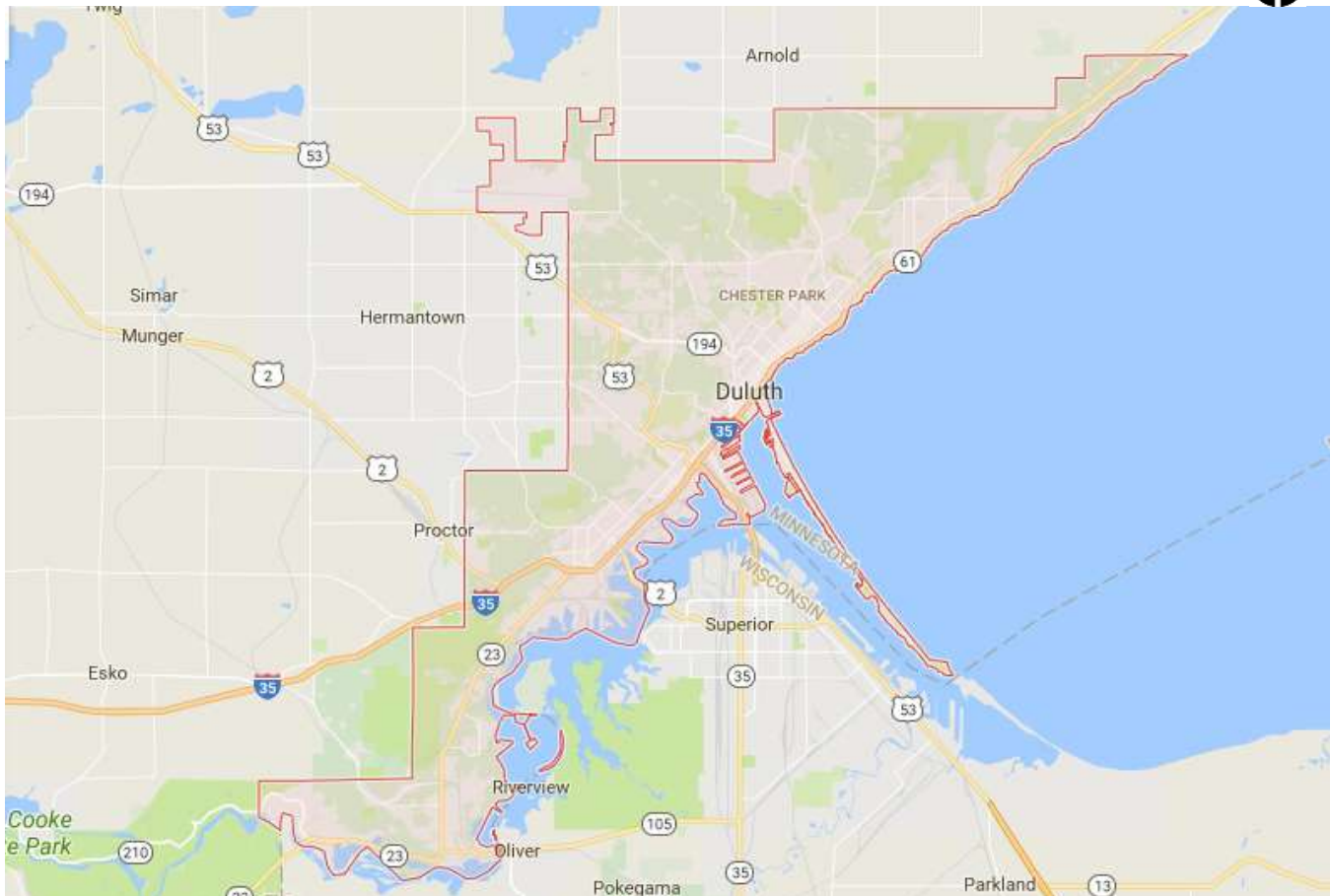
Introduction

Climate change is a global phenomenon that creates local impacts. While the science behind climate change is complex, many of the solutions to reducing impacts are already a part of Minnesota municipal government expertise. In many instances, responding to climate change does not require large scale changes to municipal operations, but simply requires adapting existing plans and policies to incorporate knowledge about changing levels of risk across key areas such as public health, infrastructure planning and emergency management.

Incorporating this knowledge not only protects our communities from growing risk, but climate adaptation strategies can also increase jobs, improve public health and the overall livability of our communities. Strategies which strengthen resilience in time of emergency also help communities thrive even more during good times.

City of Duluth

Area	87.3 sq miles 55,872 Acres
Parks, Recreation & Preserves	11,000 Acres
Population (2016)	86,293
Households (2016)	35,410
Employment (2016)	44,098



What is Climate Change Vulnerability?

According to the Intergovernmental Panel on Climate Change (IPCC), vulnerability is “the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes”. Vulnerability is a function of both impacts (the effects of climate change and variability on a given system or resource) as well as adaptive capacity (the ability of the economy, infrastructure, resources, or population to effectively adapt to such events and changes).

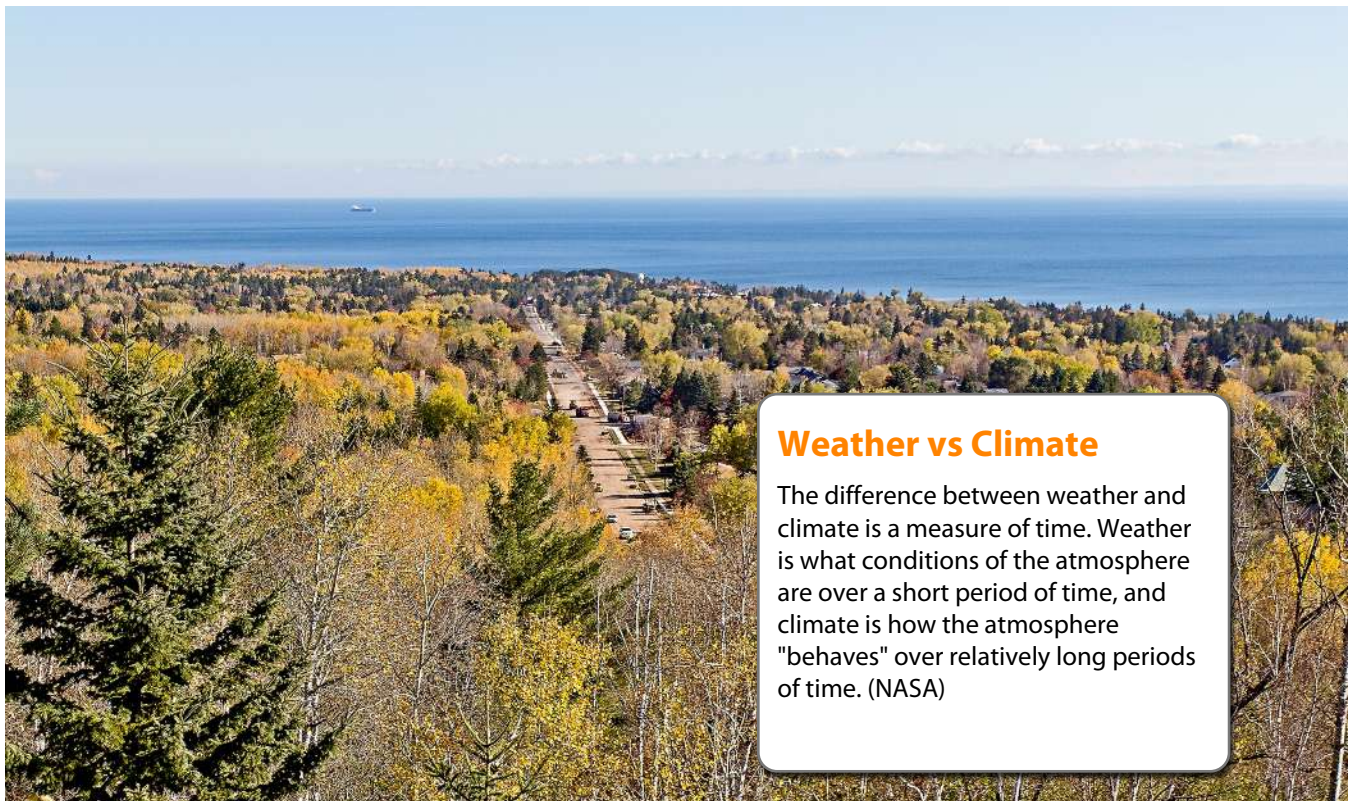
Why Study Climate Change Vulnerability?

Increases in the global surface temperature and changes in precipitation levels and patterns are expected to continue and intensify for decades, regardless of mitigation strategies currently being implemented. In turn, these changes in climate have impacts on the economy and health of local communities.

Weather and climate shape our economy. Temperature impacts everything from the amount of energy consumed to heat and cool homes and offices to the ability for some workers to work outside. Temperature and precipitation levels not only determine how much water we have to drink, but also the performance of entire economic sectors, from agriculture to recreation and tourism. Extreme weather events, like tornados, hail storms, droughts, and inland flooding can be particularly damaging. In the last ten years alone, extreme weather events have cost Minnesota and the Midwest \$96 billion in damage and resulting in 440 deaths. (NOAA National Centers for Environmental Information).

In addition, climate conditions effect the quality of life and life safety of communities – particularly those populations especially sensitive to climate impacts. Extreme weather events linked to climate change have the potential to harm community member health in numerous ways. Rising temperatures, for example, can result in a longer-than-average allergy season, erode air quality, and prolong the stay and increase the population of insects increasing the risk of vector-borne diseases. Climate impacts also exacerbate additional economic challenges that can directly impact the ability of at-risk populations to cope with the additional risks exacerbated by climate conditions while creating more exposure to dangerous living/working conditions and poor nutrition.

Strengthening community resilience is rooted in an on-going assessment of potential vulnerabilities, anticipating potential climate impacts, development and implementation of strategies to address those vulnerabilities, and in communication and outreach to the members of the community.



Weather vs Climate

The difference between weather and climate is a measure of time. Weather is what conditions of the atmosphere are over a short period of time, and climate is how the atmosphere "behaves" over relatively long periods of time. (NASA)



About This Report

This Population Vulnerability Assessment and Climate Adaptation Framework has been made possible by a 2017 Environmental Assistance Grant provided by the Minnesota Pollution Control Agency. This report seeks to:

- Increase awareness of potential climate impacts and population vulnerabilities.
- Increase inclusion of climate adaptation dialogue within City planning and decision making processes.
- Strengthen adaptive capacity based on the best available information on regional climate change projections and impacts.
- Outline priority risks, vulnerabilities, and possible near-term actions.
- Lay the foundation for the development of implementation plans that consider available resources and prioritize the most effective actions from a cost and benefit perspective.
- Prevent or reduce the risks to populations most vulnerable to the impacts of climate change.

The Population Vulnerability Assessment portion of this report describes how climate affects the region today, the changes and impacts expected over the coming decades, and identifies population vulnerabilities.

The Climate Adaptation Framework sections of this report recommend Adaptation Goals as well as a Menu of Adaptation Strategies. The City can enact these climate resilience goals and strategies to reduce the impact of climate change, improve public health, and expand the local economy. Across all of these goals, there are four priority areas of action.

- 1) Assess vulnerabilities - especially among populations most vulnerable to climate change impacts.
- 2) Train and educate local officials, planners, and community organizations
- 3) Incorporate climate vulnerabilities into existing planning documents.
- 4) Develop partnerships to fund on-going research and implementation

S e c t i o n

02

Climate Change In The Midwest



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Climate Change in The Midwest

According to the United States National Climate Assessment on the Midwest Region:

“In general, climate change will tend to amplify existing climate-related risks to people, ecosystems, and infrastructure in the Midwest. Direct effects of increased heat stress, flooding, drought, and late spring freezes on natural and managed ecosystems may be multiplied by changes in pests and disease prevalence, increased competition from non-native or opportunistic native species, ecosystem disturbances, land-use change, landscape fragmentation, atmospheric pollutants, and economic shocks such as crop failures or reduced yields due to extreme weather events. These added stresses, when taken collectively, are projected to alter the ecosystem and socioeconomic patterns and processes in ways that most people in the region would consider detrimental. Much of the region’s fisheries, recreation, tourism, and commerce depend on the Great Lakes and expansive northern forests, which already face pollution and invasive species pressure that will be exacerbated by climate change.

Most of the region’s population lives in cities, which are particularly vulnerable to climate change related flooding and life-threatening heat waves because of aging infrastructure and other factors. Climate change may also augment or intensify other stresses on vegetation encountered in urban environments, including increased atmospheric pollution, heat island effects, a highly variable water cycle, and frequent exposure to new pests and diseases. Some cities in the region are already engaged in the process of capacity building or are actively building resilience to the threats posed by climate change. The region’s highly energy-intensive economy emits a disproportionately large amount of the gases responsible for warming the climate.

Primary Issues for Midwest

1: Impacts to Agriculture

Increases will continue in growing seasons, likely boosting some crop yields. Increases in extreme weather, number of very-hot days, flooding, and days without precipitation will likely decrease other yields. Overall, Midwest productivity is expected to decrease through the century.

2: Forest Composition

Rising air and soil temperatures, and variability in soil moisture will stress tree species. Forest compositions will change as habitats are driven Northward by as much as 300 miles. Due to these ecosystem disruptions, the region’s forests may cease acting as a carbon sink,

3: Public Health Risks

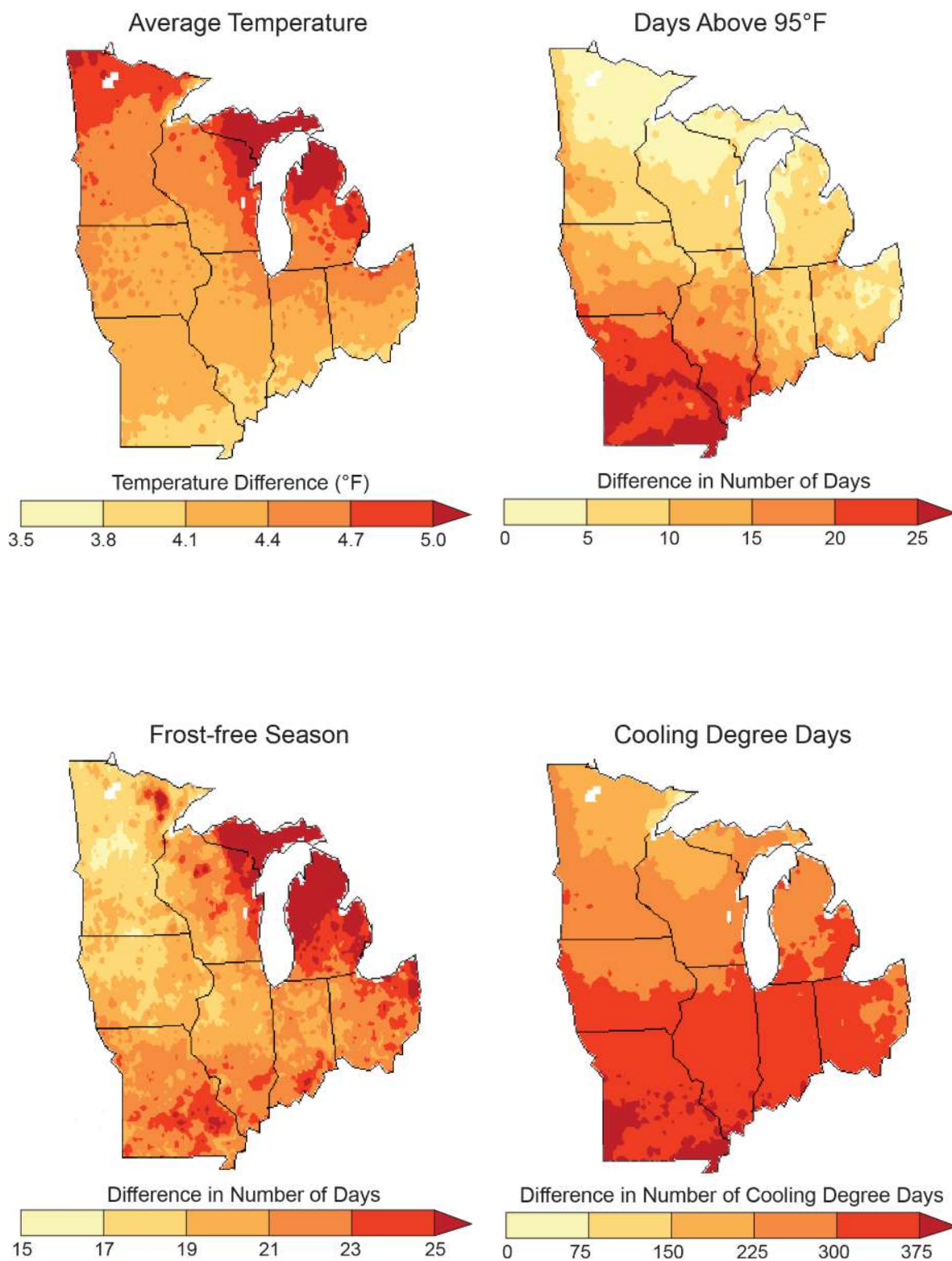
Increases incident rate of days over 95 degrees, and humidity are anticipated to contribute to degradations in air and water quality. Each of these will increase public health risk, especially for at-risk populations.

4: Increased Rainfall and Flooding

The frequency and size of extreme rainfall events and flooding has increased over the last century. In addition, the number of days without precipitation have increased. These trends are expected to continue, causing erosion, declining water quality, and impacts on human health, and infrastructure.

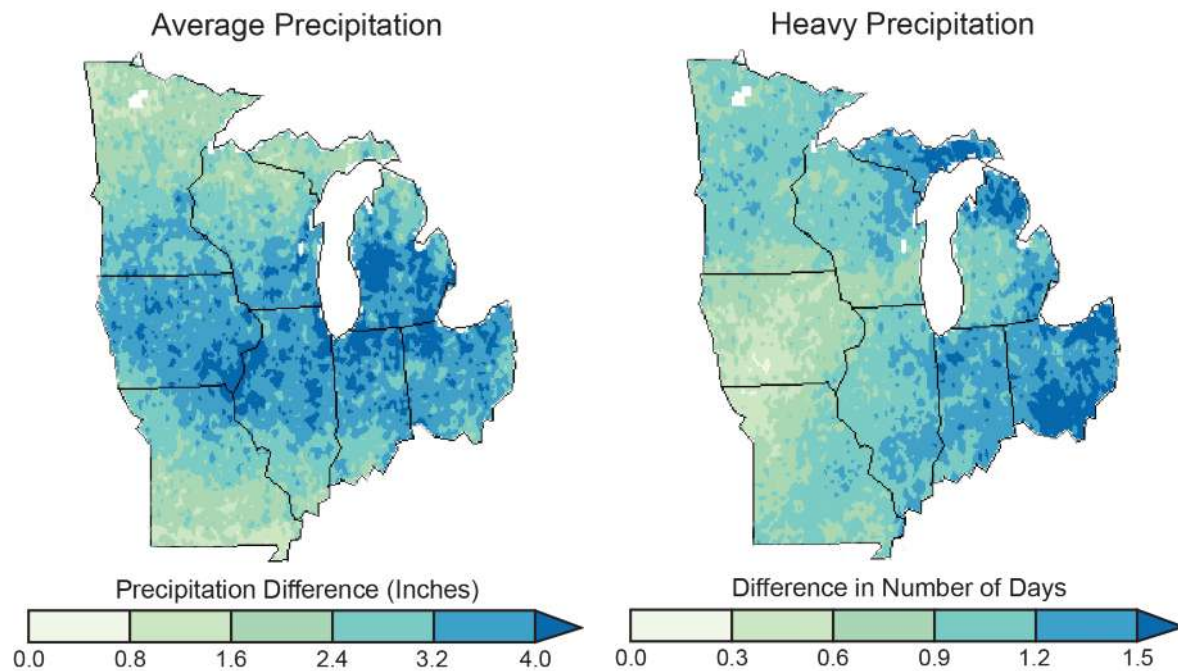
According to the US National Climate Assessment, based on current emissions trends, by mid-century (2040 - 2070) the Midwest region is projected to experience a climate that is...

Hotter...



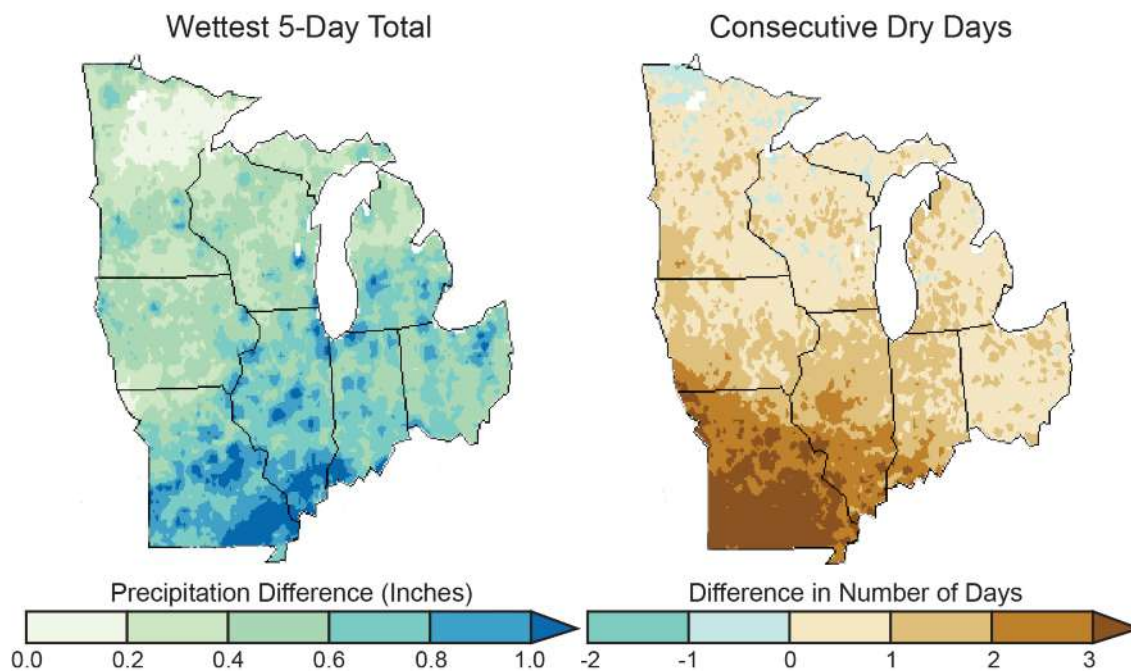
According to the US National Climate Assessment, based on current emissions trends, by mid-century (2040 - 2070) the Midwest region is projected to experience a climate that is...

Hotter...with more rain



The Midwest can expect continued increases in annual average precipitation, the number of days with heavy precipitation, making the wettest days of the year even wetter.

...and drought



The Midwest can also expect an increase in the average number of days between rainfall events. This, combined with heavier rain events which have a higher tendency of "runoff" means that the potential for drought and reduced water tables will increase .

S e c t i o n

03

Climate Change In Minnesota



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Climate Change in Minnesota

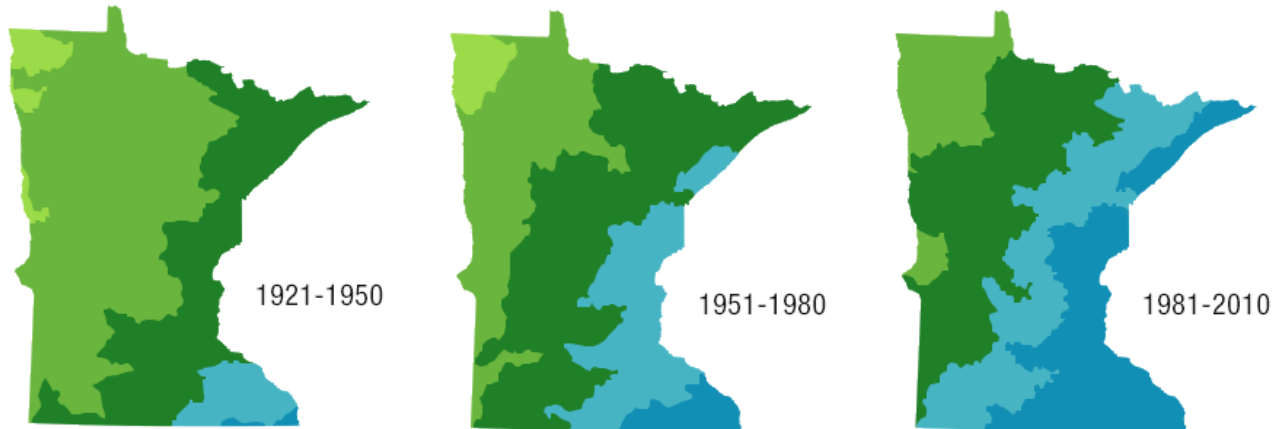
Annual Rainfall

According to the State of Minnesota Climatology office, DNR and the National Climate Assessment, the majority of the State receives 5-15% more annual rainfall than a century ago, with annual totals increasing at an average rate of just over a quarter inch per decade statewide since 1895.

(Graphic: Jaime Chrismar MPRnews.org)

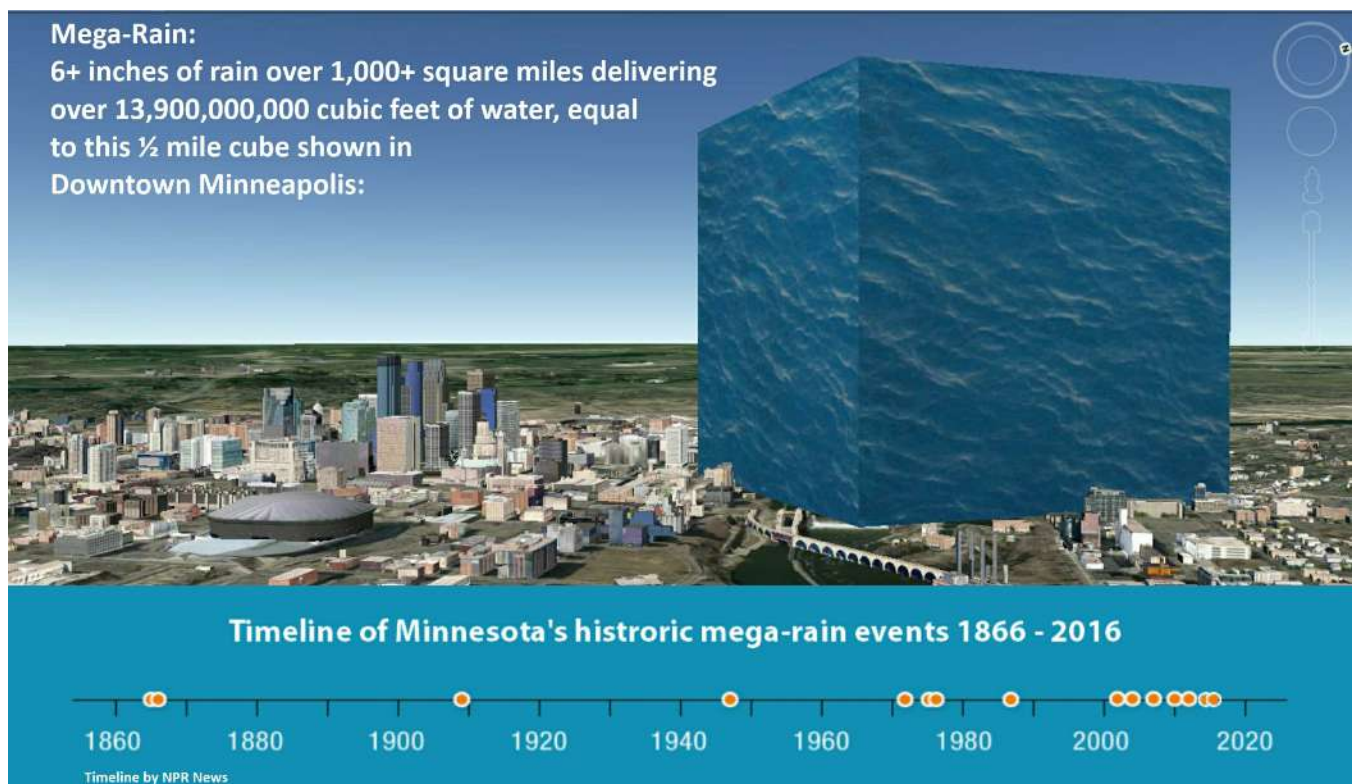
Precipitation change in Minnesota

Average Annual Rainfall



Mega-Rains

Since 1860 Minnesota has had 15 “Mega-rain” events. Seven of those storms have occurred since 2000, illustrating an increased rate of occurrence. Mega-Rain events represent a strain on stormwater infrastructure as they deliver a minimum of 13.9 billion cubic feet of rainwater over a very short time.

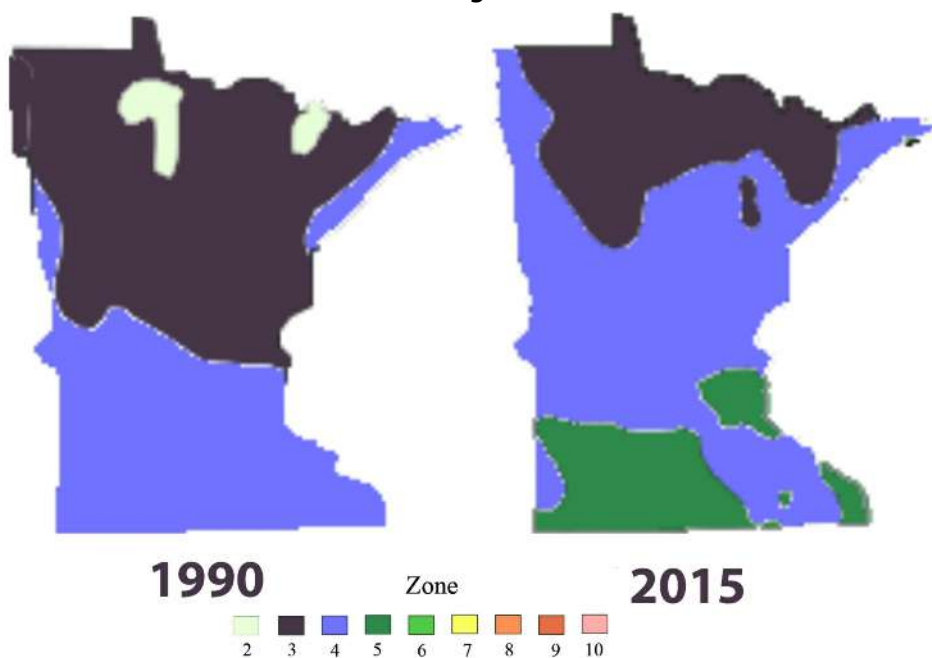


Changing USDA Zones

In addition to warmer weather, Minnesota is experiencing less spring snow cover in April resulting in more rapidly warming soil. The cumulative effects is a shift of USDA Hardiness zones to the North. In 1990 Oakdale was a Zone 4, today it is a Zone 5.

(Graphic: Arbor Day Foundation)

Hardiness Zone Changes in Minnesota

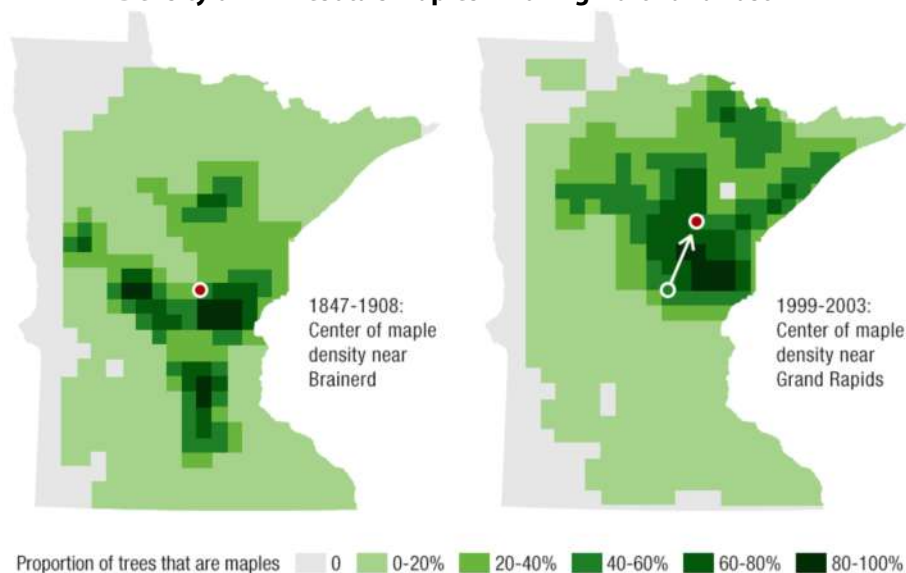


Trees Moving North

Maple forests, among other species, are moving northward, with the densest forests now occurring in the “arrowhead” section of the State rather than central region. Beyond the impacts on the ecosystem, this shift is expected to impact Minnesota’s Maple syrup production in the coming years.

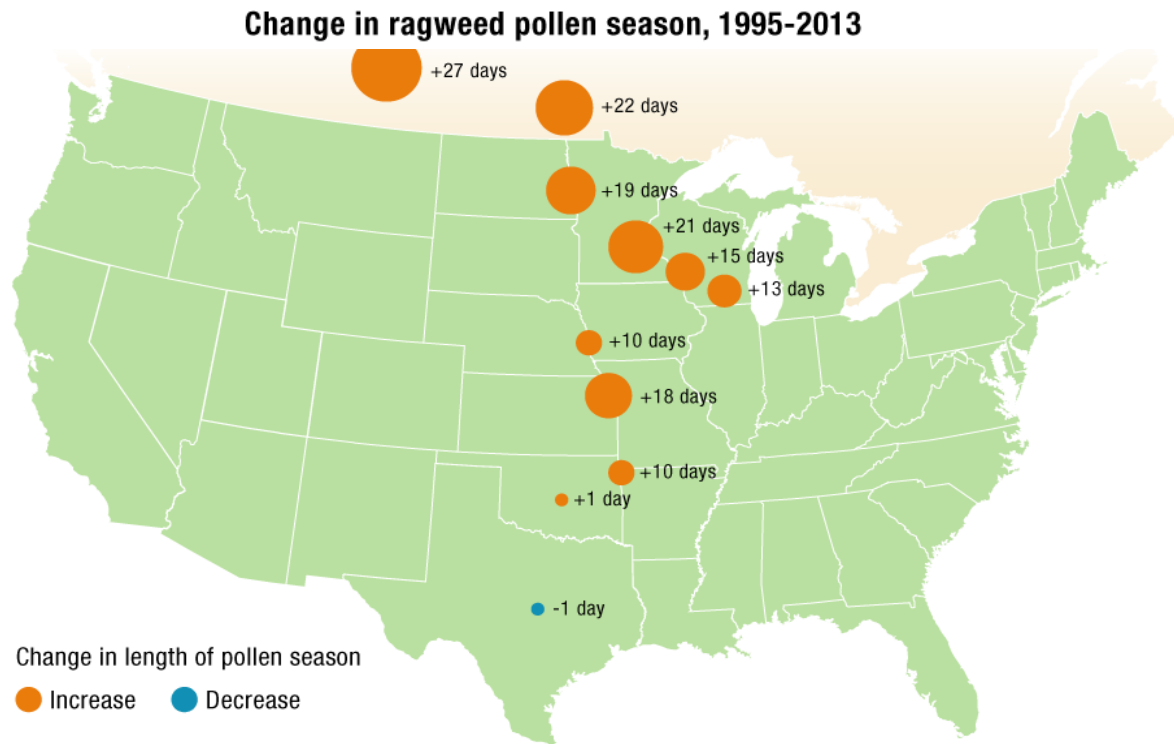
(Graphic: Jaime Chrismar MPRnews.org)

Density of Minnesota’s Maples - Moving North and East



Human Allergies

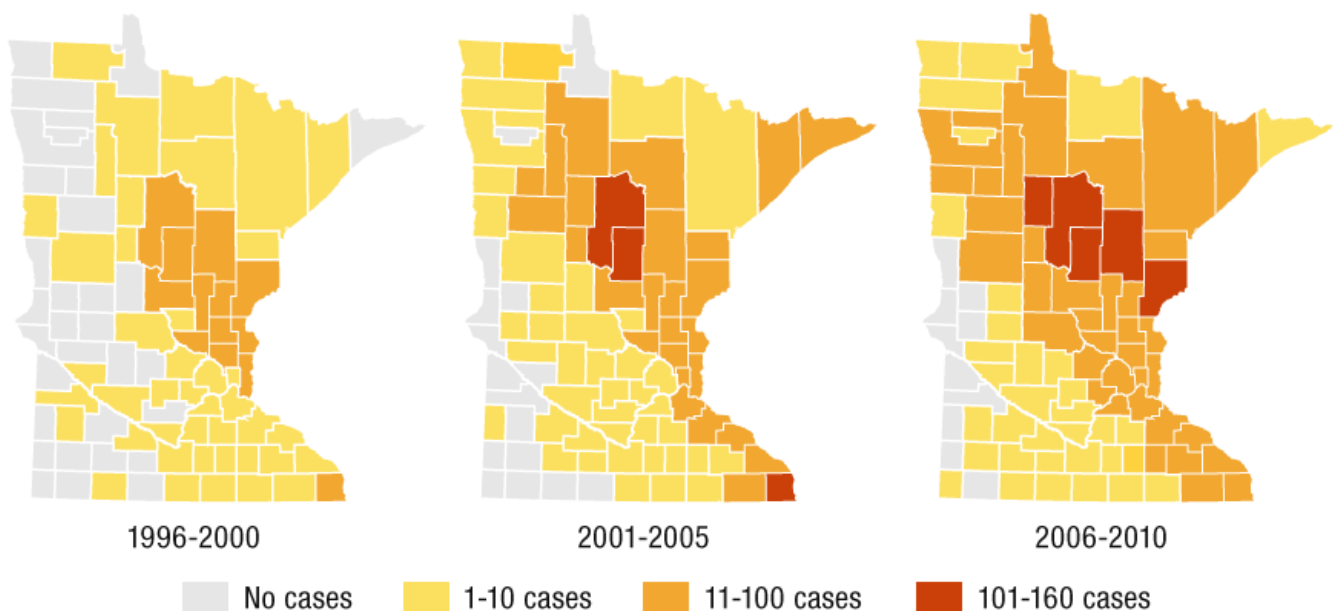
With the shift in hardiness zones and increasing growing season, increases in pollen quantity and duration have been experienced and projected to continue. Beyond inflammation and irritation associated with allergic reactions, some studies indicate pollen can affect the cardiovascular and pulmonary system. (Graphic: Jaime Chrismar MPRnews.org)



Vector Borne Disease

Vector borne diseases are spread through insects and are highly sensitive to climatic factors. Warmer weather influences survival and reproduction rates of vectors, in turn influencing the intensity of vector activity throughout the year. The increase in Lyme disease cases are an illustration of the impacts of a warming Minnesota climate will have on vector borne disease intensity. (Graphic: Jaime Chrismar MPRnews.org)

Distribution of Lyme disease cases by county of residence



Section 04

Local Climate Change



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Climate Change in Duluth

The climate in Duluth has already changed. From 1950 through 2015, the City has experienced an increase in annual average temperature, an increase in the number of heavy rain events, and a decrease in the number of days below 32 degrees. Over this 60 year period, the pace of change has increased from 1980 to 2010.

Some of the most significant changes in the climate relate to variability. Climate variability can be seen in the changes in annual precipitation for Duluth. Overall annual precipitation has increased, however, this increase is not evenly distributed throughout the year. Fall precipitation have increased 13%, while Spring, Summer and Winter precipitation have decreased as much as -10%.

Looking Back

**From 1950 through 2015,
Duluth has experienced:**

Increase in annual average temperature:	1.8°
Increase in annual precipitation:	11.1%
Increase in heavy precipitation events:	37%
Increase in Days above 95:	0 days
Decrease in Days below 32:	-8 days
Increase in growing season:	9 days

Storm Weather Events

Number of Events Reported In St Louis County:

From June 1997 to June 2007: **293 events**

From June 2007 to June 2017: **462 events - an increase of 58%**

Average Annual Storm Weather Economic Damage 1997-2017: **\$6,650,000**
(source: NOAA National Centers for Environmental Information)

The City's climate is anticipated to continue to warm through this century. Precipitation is anticipated to increase in Winter and Spring while projections for Summer and Fall range from a slight decrease to a significant increase. The primary changes to climate characteristics for the City include:

- Warmer annual average temperatures with a more significant warming in winter and summer months.
- Increase in extreme heat days.
- Increase in heavy rain fall events, with increase in flood potential.
- Increase in time between precipitation with increase in drought potential.
- Greater variability in temperature and precipitation trends.

To serve the same size population, the projected increase in air conditioning demand would require an increase in city-wide electricity consumption of: **128%**

Looking Forward

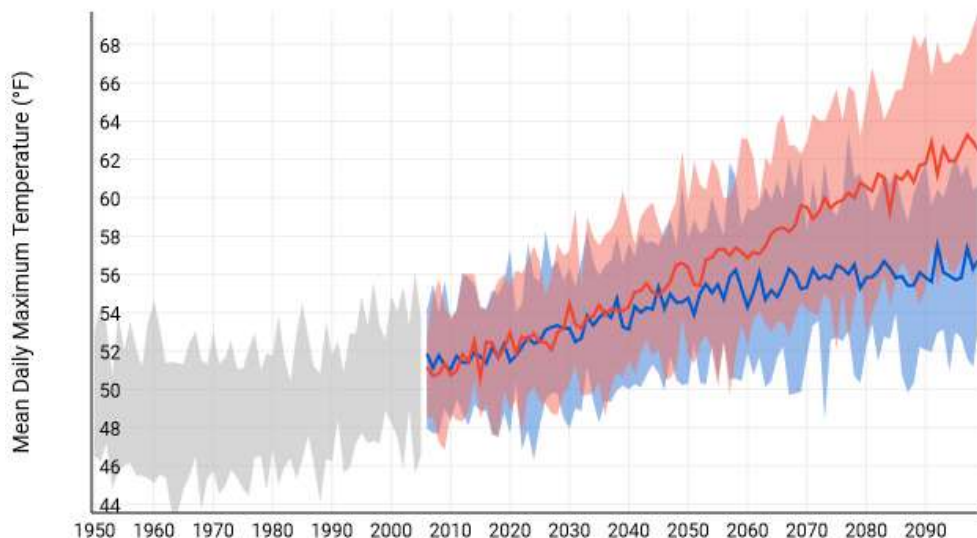
By 2100, Duluth Can Expect:

Increase in annual average temperature:	4-11°F
Increase in annual precipitation:	-2 to 20% <small>With Significant Seasonal Variation</small>
Increase in heavy precipitation events:	30%
Increase in Days above 95:	+23 days
Decrease in Days below 32:	-50 days
Increase in growing season:	30 days
Increase in Air Conditioning Demand:	514%

Mean Daily Maximum Temperature

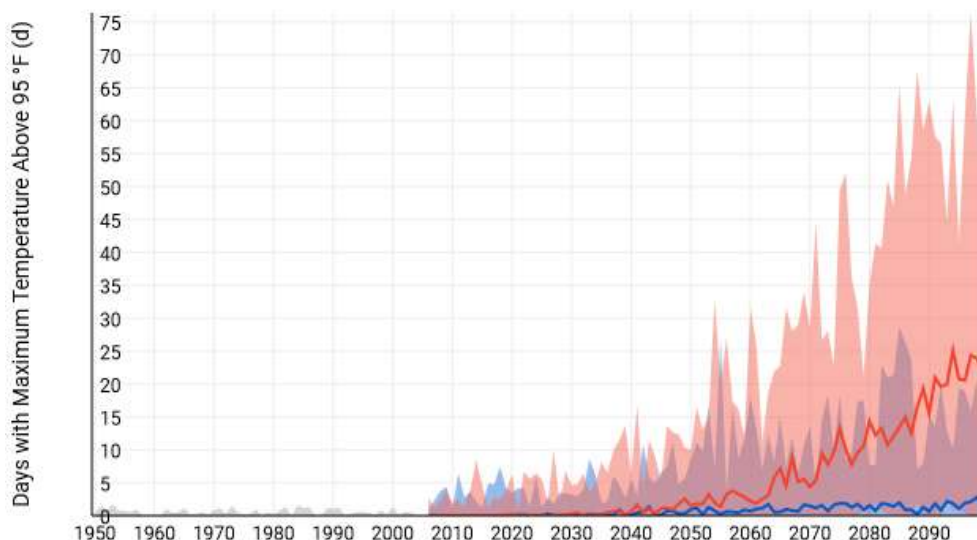
This chart shows observed average daily maximum temperatures for St Louis County from 1950-2010, the range of projections for the historical period, and the range of projections for two possible futures through 2100.

Maximum temperature serves as one measure of comfort and safety for people and for the health of plants and animals. When maximum temperature exceeds particular thresholds, people can become ill and transportation and energy infrastructure may be stressed.



Days with Maximum Temperature Above 95°F

This chart shows observed average number of days with temperatures above 95°F for St. Louis County from 1950-2010, the range of projections for the historical period, and the range of projections for two possible futures through 2100. The total number of days per year with maximum temperature above 95°F is an indicator of how often very hot conditions occur. Depending upon humidity, wind, and access to air-conditioning, humans may feel very uncomfortable or experience heat stress or illness on very hot days.



How To Read These Charts

Starting from the left and moving towards the right, the dark gray bars which are oriented vertically indicate observed historic values for each year. The horizontal line from which bars extend shows the county average from 1960-1989. Bars that extend above the line show years that were above average. Bars that extend below the line were below average. The lighter gray band, or area, shows the range of climate model data for the historical period – in other words, the lighter gray area shows the range of weather for the historic period.

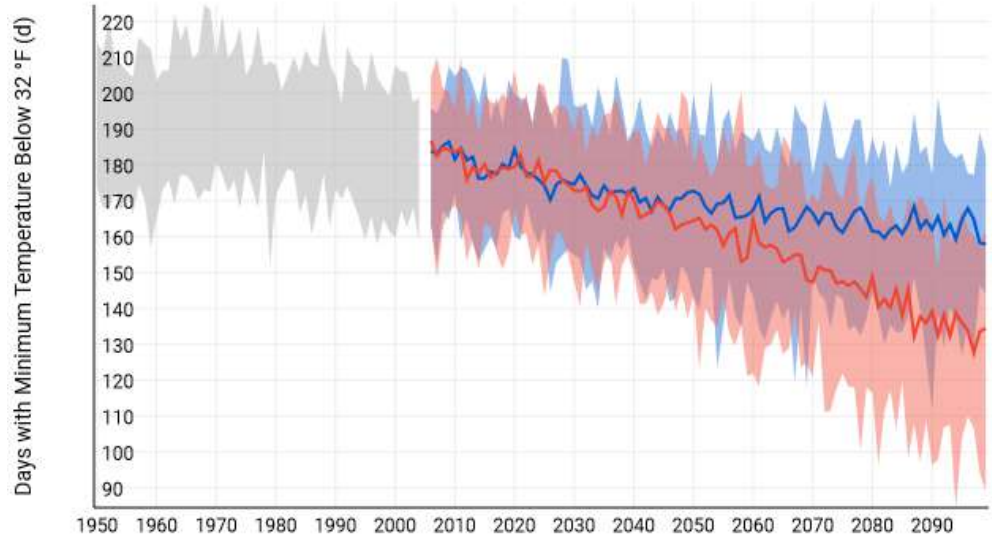
Starting from the left and moving right, the red toned band, or area, shows the range of future projections assuming global greenhouse gas emissions continue increasing at current rates. The darker red line shows the median of these projections. For planning purposes, people who have a low tolerance for risk often focus on this scenario.

The blue toned band, or area, shows the range of future projections for a scenario in which global greenhouse gas emissions stop increasing and stabilize. The darker blue line shows the median of these projections. Though the median is no more likely to predict an actual future than other projections in the range, both the red and blue lines help to highlight the projected trend in each scenario.

Days with Minimum Temperature Below 32°F

This chart shows observed average number of days with temperatures below 32°F for St. Louis County from 1950-2010, the range of projections for the historical period, and the range of projections for two possible futures through 2100. The total number of days per year with minimum temperature below 32°F is an indicator of how often cold days occur.

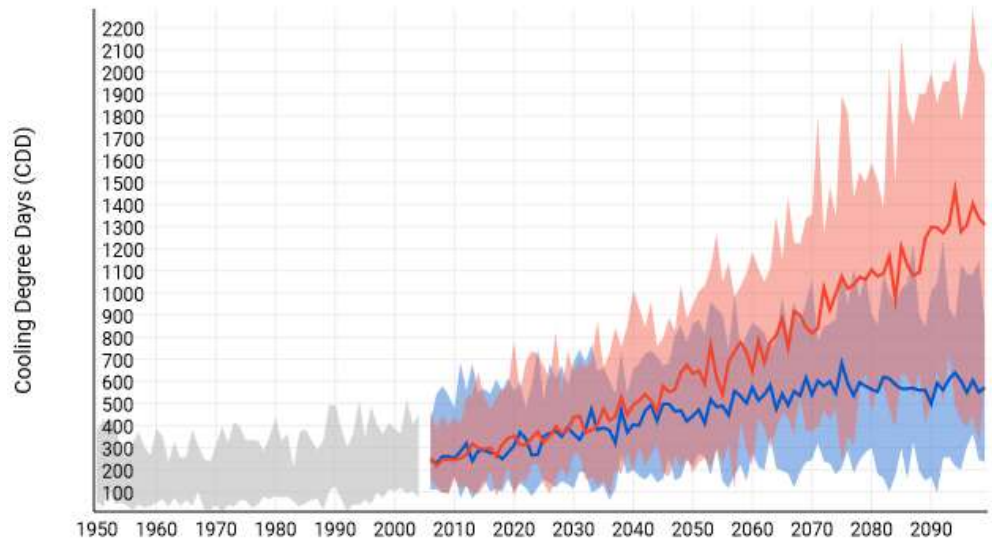
Winter recreation businesses depend on days with below-freezing temperatures to maintain snowpack. Additionally, some plants require a period of days below freezing before they can begin budding or blooming.



Cooling Degree Days

This chart shows observed average degree cooling days for St. Louis County from 1950-2010, the range of projections for the historical period, and the range of projections for two possible futures through 2100. The number of cooling degree days per year reflects the amount of energy people use to cool buildings during the warm season.

Cooling degree days are calculated using 65°F degrees as the base building temperature. On a day when the average outdoor temperature is 85°F, reducing the indoor temperature by 20 degrees over 1 day requires 20 degrees of cooling multiplied by 1 day, or 20 cooling degree days.



How To Read These Charts

Starting from the left and moving towards the right, the dark gray bars which are oriented vertically indicate observed historic values for each year. The horizontal line from which bars extend shows the county average from 1960-1989. Bars that extend above the line show years that were above average. Bars that extend below the line were below average. The lighter gray band, or area, shows the range of climate model data for the historical period – in other words, the lighter gray area shows the range of weather for the historic period.

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Section 05

City on The Move



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City on The Move

Projected changes in annual average temperatures and growing seasons will result in a change in the overall climate of Duluth. Summertime conditions for mid-twenty first century in Duluth are projected to be similar to the conditions currently felt 250-300 miles or further to the South.

According to the University of Michigan Climate Center, by 2040 summertime conditions in Duluth are anticipated to be similar to those today in Rochester, Minnesota; Saganaw, Michigan; and Worcester, Massachusetts.

(Source: University of Michigan Climate Center)

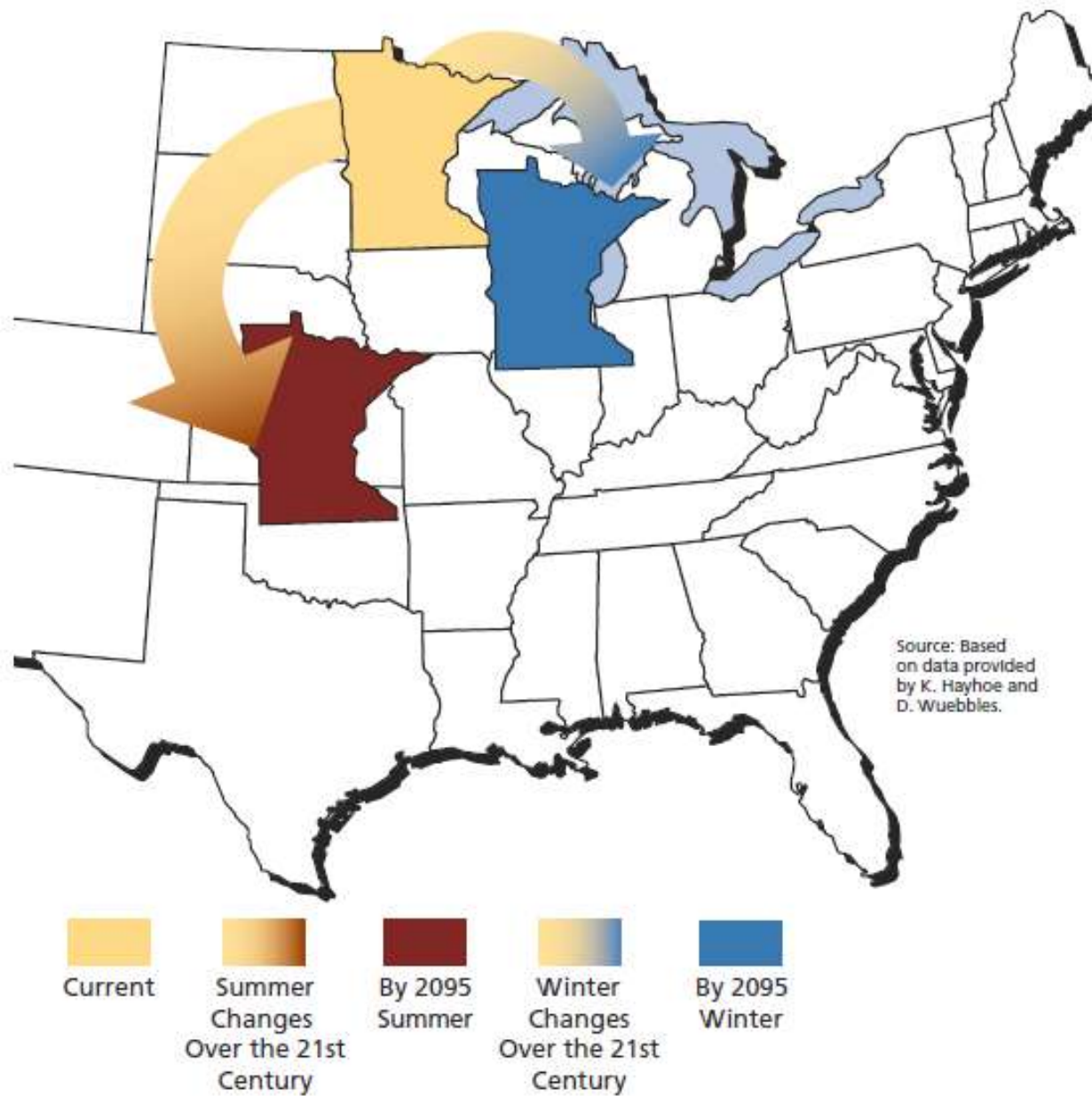
10
miles

Distance southward the City
of Duluth's climate
experience moves every year.

Which is equal to moving

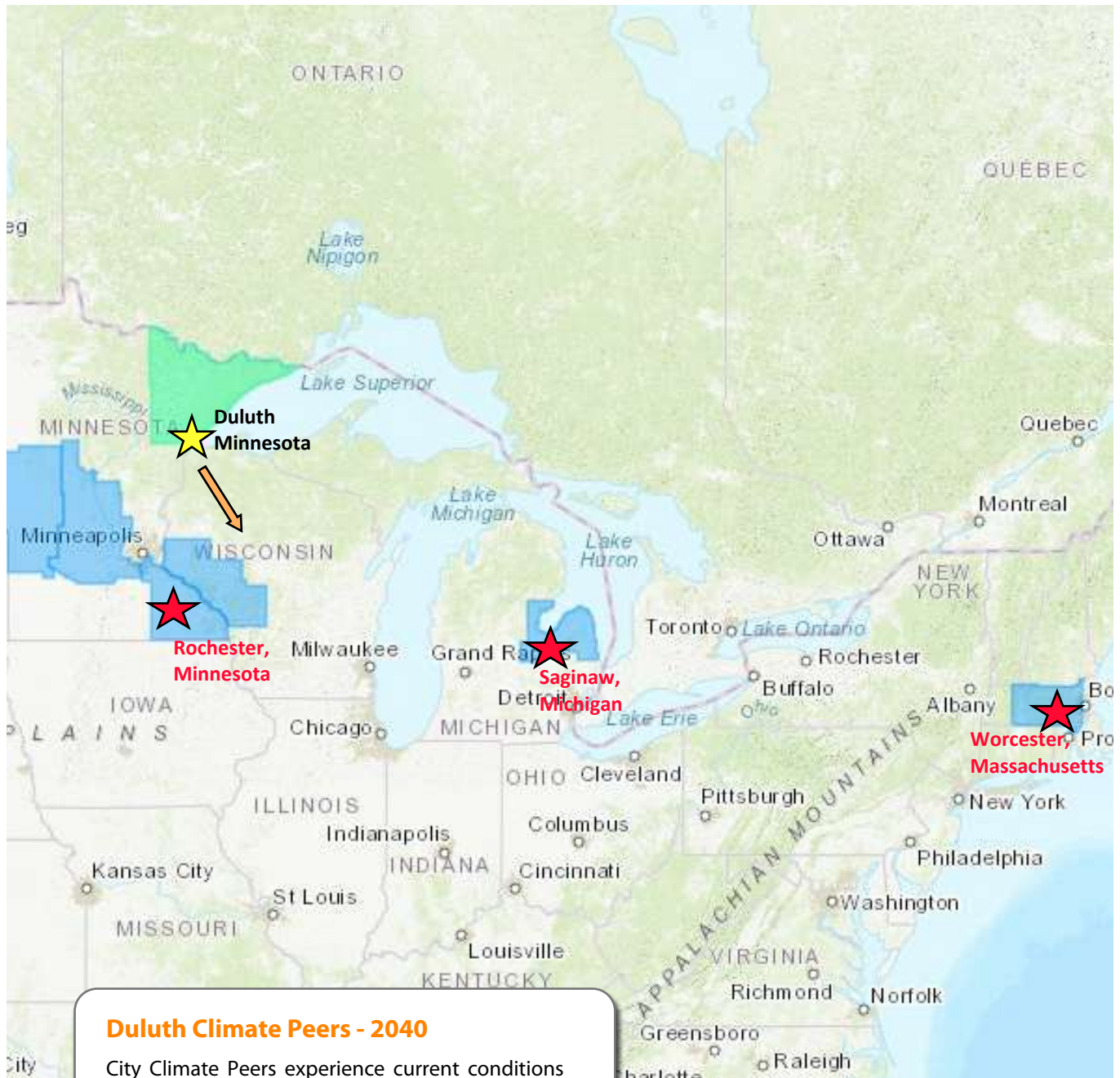
145
feet every day.

Photo by Minneapolis Northwest CVB via Flickr



Climate Peers - State of Minnesota 2095

State Climate Peers experience current conditions which match the projected conditions for the State of Minnesota by 2095. As temperatures continue to rise for Minnesota into the future, the State's climate will resemble that of States to the South more and more. Climate models predict that by 2095 summers in Minnesota will be more like the current summers of Kansas, while winters will be more like current winters in Illinois.



S e c t i o n

06

Climate Risks to The Population



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Climate Risks to the Population

The projected changes to the City's climate in the coming decades represent potential risks to residents. These risks are particularly acute in populations especially vulnerable to them such as children, seniors, and those with disabilities – see Vulnerable Populations section for more information. Below are some of more significant risks to the City's population:



Extreme Weather / Temperature:

Certain groups of people are more at risk of stress, health impacts, or death related to Extreme Weather events including heat stress, tornados, wind storms, lightning, wildfires, winter storms, hail storms, and cold waves. The risks of related to extreme weather events include traumatic personal injury (tornados, storms), carbon monoxide poisoning (related to power outages), asthma exacerbations (wildfires, heat stress), hypothermia/ frostbite (cold waves, winter storms), and mental health impacts.

Vulnerability to heat stress can be increased by certain variables including the presence of health conditions like diabetes and heart conditions; demographic and socioeconomic factors (e.g. aged 65 years and older living alone); and land cover (e.g. Low percentage tree canopy cover). Studies of heat waves and mortality in the United States demonstrate that increased temperatures or periods of extended high temperatures have increased heat-related deaths. During heat waves, calls to emergency medical services and hospital admissions have also increased.

According to the US National Climate and Health Assessment:

“While it is intuitive that extremes can have health impacts such as death or injury during an event (for example, drowning during floods), health impacts can also occur before or after an extreme event as individuals may be involved in activities that put their health at risk, such as disaster preparation and post-event cleanup. Health risks may also arise long after the event, or in places outside the area where the event took place, as a result of damage to property, destruction of assets, loss of infrastructure and public services, social and economic impacts, environmental degradation, and other factors. Extreme events also pose unique health risks if multiple events occur simultaneously or in succession in a given location, but these issues of cumulative or compounding impacts are still emerging in the literature.”

In addition, extreme weather can cause economic stress. Property damage, business closure, crop loss, job loss, and employment “down time” can all be caused by extreme storms, weather, and temperatures. These economic impacts can affect individuals, families, businesses, and communities at large.



Flood Vulnerability

According to the latest National Climate Assessment, the frequency of heavy precipitation events has already increased for the nation as a whole as well as for Minnesota specifically. These heavy rain events are projected to increase throughout Minnesota and are anticipated to be experienced by the City. Increases in both extreme precipitation and total precipitation have contributed to increases in severe flooding events in certain regions. Floods are the second deadliest of all weather-related hazards in the United States.

In addition to the immediate health hazards associated with extreme precipitation events when flooding occurs, other hazards can often appear once a storm has passed. Elevated waterborne disease outbreaks have been reported in the weeks following heavy rainfall, although other variables may affect these associations. Water intrusion into buildings can result in mold contamination that manifests later, leading to indoor air quality problems. Populations living in damp indoor environments experience increased prevalence of asthma and other upper respiratory tract symptoms, such as coughing and wheezing, as well as lower respiratory tract infections such as pneumonia, respiratory syncytial virus, and pneumonia.

Flooding causes economic stress. Property damage, business closure, crop loss, job loss, and employment “down time” can all be caused by extreme storms, weather, and temperatures. These economic impacts can affect individuals, families, businesses, and communities at large.

Air Quality Impacts



According to the published literature, air pollution is associated with premature death, increased rates of hospitalization for respiratory and cardiovascular conditions, adverse birth outcomes, and lung cancer. Air quality is indexed (AQI) by the U.S. Environmental Protection Agency (EPA) and Minnesota Pollution Control Agency to provide a simple, uniform way to report daily air quality conditions. Minnesota AQI numbers are determined by hourly measurements of five pollutants: fine particles (PM_{2.5}), ground-level ozone (O₃), sulfur dioxide (SO₂), nitrogen dioxide (NO₂), and carbon monoxide (CO). The levels of all of these pollutants can be affected by climate impacts as well as the greenhouse gas emissions which are driving Minnesota's changing climate impacts.

These pollutants have a range of potential health impacts. Ozone exposure may lead to a number of adverse health effects such as shortness of breath, chest pain when inhaling deeply, wheezing and coughing, temporary decreases in lung function, and lower respiratory tract infections. Long-term exposure to fine particulate matter (also known as PM_{2.5}) is correlated with a number of adverse health effects. In fact, each 10 µg/m³ elevation in PM_{2.5} is associated with an 8% increase in lung cancer mortality, a 6% increase in cardiopulmonary mortality, and a 4% increase in death from general causes. The annual average of PM_{2.5} provides an indication of the long-term trends in overall burden, relevant to the long-term health effects. Increased surface temperatures are known to increase ground level ozone levels. The projected Minnesota climate change impacts of extreme heat, changes in precipitation, drought and wild fires can all cause increases in fine particulate matter, which in turn, can contribute to respiratory illness particularly in populations vulnerable to them.

The US EPA designates counties with unhealthy levels of air pollution as "Non attainment" areas and areas which are on the edge of unhealthy levels "maintenance" areas. The State of Minnesota has had multiple jurisdictions designated as "non attainment" areas, however as of 2002 all of these areas have re-met federal air quality requirements and are now maintenance areas. Air quality issues currently being addressed in State of Minnesota implementation plans include Carbon Monoxide, Sulfur Dioxide, and Particulate Matter. For current and forecasted air quality throughout the state or to download the State's air quality monitoring app visit: <https://www.pca.state.mn.us/air/current-air-quality>

Climate change is expected to affect air quality through several pathways, including production and potency of allergens and increase regional concentrations of ozone, fine particles, and dust. Some of these pollutants can directly cause respiratory disease or exacerbate existing conditions in susceptible populations, such as children or the elderly. Other air quality issues with health considerations include allergens, pollen, and smoke from wildfires (traces sufficient to cause respiratory impacts are capable of traveling great distances). Each of these are anticipated to be increased with climate change.

Vector-Borne Diseases



Vector-Borne diseases are diseases spread by agents such as ticks and mosquitoes. The projected climate change impacts in this region are anticipated to increase the spread of vector borne diseases such as West Nile virus, and Lyme disease by altering conditions that affect the development and dynamics of the disease vectors and the pathogens they carry. Rising global temperatures can increase the geographic range of disease-carrying insects, while increased rainfall, flooding and humidity creates more viable areas for vector breeding and allows breeding to occur more quickly. In addition, Minnesota's lengthening growing season and warming winters will increase the population of vector carrying insects as well as open the region up to new species.



Food Insecurity and Foodborne Diseases

According to former U.S. agriculture secretary Tom Vilsack, climate change is likely to destabilize cropping systems, interrupt transportation networks and trigger food shortages and spikes in food cost. According to the US National Climate Assessment for the Midwestern states: “In the next few decades, longer growing seasons and rising carbon dioxide levels will increase yields of some crops, though those benefits will be progressively offset by extreme weather events. Though adaptation options can reduce some of the detrimental effects, in the long term, the combined stresses associated with climate change are expected to decrease agricultural productivity.”

Nutritious food is a basic necessity of life, and failure to obtain sufficient calories, macronutrients (fats, proteins, carbohydrates), and micronutrients (vitamins, minerals) can result in illness and death. While malnutrition and hunger are typically problems in the developing world, Minnesota still has significant populations affected by insufficient food resources and under-nutrition. Food can be a source of foodborne illnesses, resulting from eating spoiled food or food contaminated with microbes, chemical residues or toxic substances. The potential effects of climate change on foodborne illness, nutrition, and security are mostly indirect but represent risks, especially for vulnerable populations.

The prevalence of food insecurity can be increased by a number of direct and indirect impacts of climate change. These changes may decrease agricultural productivity, increase crop failure, and cause reductions in food supply and increases in food prices and food insecurity. Some of the climate impacts which may increase food insecurity and foodborne diseases in Minnesota include:

- Extreme weather events and changes in temperature and precipitation can damage or destroy crops and interrupt the transportation and delivery of food
- Changes in agricultural ranges, practices and changing environmental conditions can reduce the availability and nutritional content of food supplies. For example, an increase in the use of pesticides leads to a decrease in nutritional content of food.
- Spread of agricultural pests and weeds may lead to an increased use of pesticides, herbicides, and fungicides.
- Extreme weather events, such as flooding, drought, and wildfires can contaminate crops and fisheries with metals, chemicals, and toxicants released into the environment.

Water Quality/Quantity



Water risks consist of both water quality as well as water quantity issues. Water quantity issues are clearly linked to precipitation levels and timing, water variability, as well as changes in water demand. Water demand itself can be increased not only by population changes but also as a result of climate changes such as increased temperatures and timeframes between rain events which increase demands on water consumption. In addition, water withdraw from ground water sources deplete aquifer capacities. Indirectly, the lack of water can cause pressure on agricultural productivity, increase crop failure, and cause reductions in food supply and increases in food prices and food insecurity. As a highly precious resource, all communities should look to increase water conservation regardless of the projected water stress levels of their immediate region, while communities in regions with a projected increase in water stress should view water conservation as a major long-term priority.

Water quality issues can be affected by climate impacts in a number of ways:

- Increased precipitation and rapid snow melt can result in flooding, which in turn increases the likelihood of water contamination from sources such as sewage as well as contaminants such as chloride, gasoline, oil, chemicals, fertilizers, and pesticides.
- Increased air and water temperatures can increase toxic algae blooms, decrease water oxygen levels, and cause changes in fish populations as well as increases in mercury concentrations in fish.
- Increased heavy rain events can result in increases in sediment, diminishing water quality.

Waterborne Illness



Waterborne diseases are caused by a variety of microorganisms, biotoxins, and toxic contaminants, which lead to devastating illnesses such as cholera, schistosomiasis and other gastrointestinal problems. Outbreaks of waterborne diseases often occur after a severe precipitation event (rainfall, snowfall). Because climate change increases the severity and frequency of some major precipitation events, communities could be faced with elevated disease burden from waterborne diseases. Increased frequency of intense extreme weather events can cause flooding of water and sewage treatment facilities, increasing the risk of waterborne diseases.

Section 07

Climate Impact Multipliers



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Climate Impact Multipliers

As the area's climate is projected to change (with increased heat, shortened winters, greater variability in weather and precipitation, increased storminess, annual rainfall as well as increased time frames between rain and drought conditions) there are physical characteristics of the community which can have a multiplying or mitigating affect on the impacts of climate vulnerabilities. Understanding and tracking the state of these characteristics will help identify some of the climate adaptive strategies appropriate for the City.

Climate Impact Multipliers are: Tree Canopy, Impervious Land Cover, Heat Island, and Water Stress. This section will review the general characteristics of each of these for the City.

In Section 10, these community characteristics will be re-visited in light of the Vulnerable Population

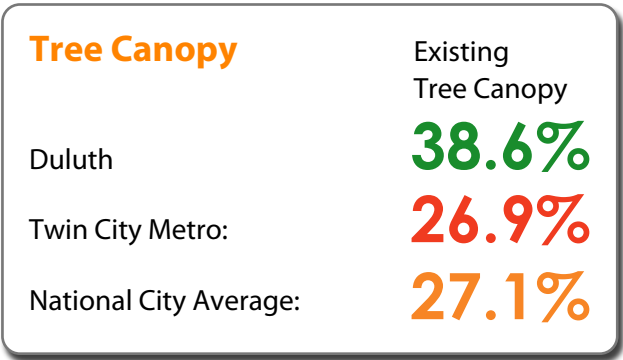
Climate Impact Multiplier - Tree Canopy

A healthy and extensive tree canopy within developed areas can mitigate the impacts of heat stress, water impacts, increased levels of precipitation and drought, and air quality impacts. “Urban forests” deliver a range of environmental, health, and social benefits. Shaded surfaces can be anywhere from 25°F to 45°F cooler than the peak temperatures of unshaded surfaces. Trees cool communities, reduce heating and cooling costs, capture and remove air pollutants including CO2 from the air; strengthen quality of place and local economies, improve the quality of stormwater entering rivers and streams, reduce stormwater infrastructure costs, improve social connections, positively contribute to property value, improve pedestrian/recreation experiences, reduce mental fatigue, improve overall quality of life for residents, and provide habitat to support biodiversity.

A healthy tree canopy mitigates heat stress in developed areas by providing direct shading on buildings and through transpiration cooling. Neighborhoods well shaded by street and yard trees can be up to 6-10 degrees cooler than neighborhoods without, reducing overall energy needs. Just three trees properly placed around a house can save up to 30% of energy use.

Duluth Tree Canopy

National Agriculture Imagery Program of the USDA captured 1 meter LIDAR imagery of many portions of the State of Minnesota, including the Duluth area. Using these and other images, EarthDefine created a SpatialCover Tree Canopy assessment product reviewing over 800 cities in the State. Below is the reported tree canopy cover for the City of Duluth as well as the Twin City metro region average and the National metro average.



Planting Climate Adaptive Trees

Tree canopies in Minnesota also have some vulnerabilities associated with the current and projected impacts of climate change. Trees have a degree of vulnerability to changes in temperature ranges, precipitation patterns, soil temperature and moisture levels, and changes to winter processes and growing season length. According to the US Forest service, urban forests are very susceptible to a number of climate change factors including species invasion, and insect and pathogen attack. These stressors will make it more difficult to preserve or increase canopy cover in Minnesota communities. Conducting tree canopy studies and creating climate adaptive tree canopy policies will help Minnesota communities in adapting to these stressors.

Species projected to have negative stressors in the Duluth region include American Elm, Black Cherry, Black Oak, Northern Red Oak, Aspen, and Sugar Maple. Extended drought conditions and warming winters may negatively impact some species such as Aspen, Sugar Maple, and Red Maple, and Basswood. Finally, increased growing seasons will result in taller trees which may be more susceptible to damage in extreme weather events. Boulevard, streetscape, and parking lot trees are particularly vulnerable due to decreased snow cover, increased freeze/thaw cycles, salt exposure, and increased chemical exposure.

See Appendix 2 of this report for Climate Adaptive Tree Species by Minnesota region. Climate Adaptive Tree Species should be considered for City tree planting policies and programs..

Climate Impact Multiplier - Impervious Land Cover

Impervious surfaces, including building and pavement surfaces, typically absorb solar radiation faster than pervious land coverings (grass, trees). This absorbed energy is typically retained throughout the day and then released slowly during the night. Consequently, ambient temperatures near building and paved areas are higher than grasslands and forest areas. The effects of higher levels of impervious surfaces impact not only large cities, but smaller cities and towns as well.

Increases in impervious cover can also dramatically increase the impact of so-called 100-year flood events. Typically, floods in areas of high impervious surfaces are short-lived, but extended flooding can stress trees, leading to leaf yellowing, defoliation, and crown dieback. If damage is severe, mortality can occur. In addition, flooding can lead to secondary attacks by insect pests and diseases. Some species are more tolerant of flooding than others.

Climate Impact Multiplier - Heat Island

Residents of cities and town centers are more at risk for heat-related illnesses than rural dwellers. The radiant heat trapped by impervious surfaces and buildings as well as heat generated by building mechanical systems, motorized equipment, and vehicles is known as the "Heat Island Effect". In larger cities, heat island effects create a micro-climate throughout the metro area while occupants of smaller cities and towns can still experience higher temperatures and decreased air movement due to the effects of surrounding buildings and impervious surfaces. This heat island effect serves to increase the impact of climate change effects in developed areas of all size populations, especially those with low or intermittent tree canopy coverage. A developed area's impervious surface characteristics, and tree canopy conditions combine to exacerbate or mitigate the community's heat island impacts.

Due to the heat island effect, developed areas are usually hotter and cool off less at night than non developed areas. Heat islands can increase health risks from extreme heat by increasing the potential maximum temperatures residents are exposed to and the length of time that they are exposed to elevated temperatures. The heat island effect can make developed areas one hardness zone warmer than the surrounding undeveloped area, allowing some more southern species to be planted. In addition to milder winters, however, heat island effects can also make summer temperatures higher, especially near dark pavements and buildings. Thus, some native plants that are becoming marginal for the area because of increased heat could experience negative effects.

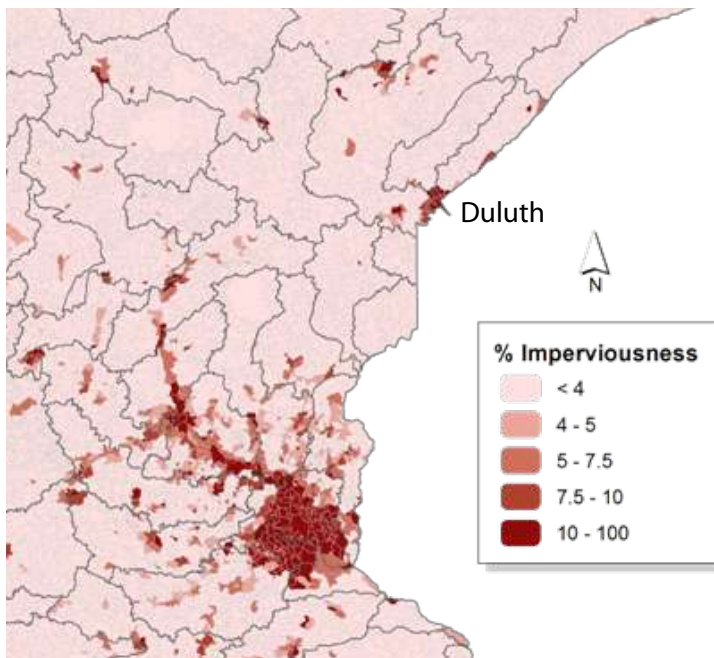
The heat index is a measure of how hot weather feels. Much like wind chills combine temperature and wind to provide a figure about how cold it is in winter, heat indices measure temperature and humidity. Research indicates that in rural areas or regions with significant agriculture, crops can impact heat island effect. Unlike many plants, corn transpires, or sweats, both day and night. Keeping humidity and heat high at night means there is little chance for relief. A University of Minnesota study released in 2016 shows farm crops can increase dew points and heat indices by as much as 5 degrees, while a Northern Illinois University climatologist David Changnon released a study in 2002 showing that modern-day heat waves probably are worse than a century ago because of crops.

Duluth Impervious Surface and Heat Island

The level of the urban heat island effect of a region is largely driven by the amount of impervious surface. Duluth's current impervious surface area ranges from 8% to 100%.

For comparison, the Minneapolis/St Paul metro area has an average impervious cover of 13.7%. The Twin City metro is the 9th top urban heat island zone in the country in terms of observed temperature differences between the urban area and surrounding rural areas, with temperatures up to 22 degrees hotter than the surrounding rural area, with an average year round temperature difference of 4.3 degrees. Though data does not yet exist for Duluth heat island temperature impacts, this comparison illustrates the order of magnitude heat island may be impacting the City.

(Source: University of Minesota Remote Sensing and Geospatial Lab, State of Minnesota DNR)



Impervious Surface Area

(University of Minnesota, 2002)

Total impervious area
State Wide: **1.88%**

Metro area: **13.7%**

Duluth: **10-100%**

Climate Impact Multiplier - Water Stress

Water stress occurs when the demand for water exceeds the available amount during a certain period or when poor quality restricts its use. Water stress causes deterioration of fresh water resources in terms of quantity (aquifer over-exploitation, dry rivers, etc.) and quality (eutrophication, organic matter pollution, saline intrusion, etc.). Overall water risks are impacted by projected changes in precipitation levels, seasonal and annual variability, flood and drought vulnerabilities, increased air and water temperature, and water use demand and supply.

Though most of these water stress influences are direct climate impacts, we call Water Stress a climate multiplier because the existence of water stress can greatly increase the overall impact of climate conditions such as extreme heat and overall population vulnerability. It has economic ramifications for individuals as well as the community as a whole which decrease resilience. Water stress affects recreational tourism, industrial productions, jobs, and income.

Water stress in developed areas is directly affected by a community's impervious surface, tree canopy/ground cover, and heat island characteristics. Higher temperatures and impervious surface run-off lead to increases in toxic algae blooms, more rapid evaporation, reduced water retention within the water table, increased demand for irrigation, and decreased lake/river levels. A review of a community's water stress includes the overall water stress, overall water risk, and flood vulnerability.

Overall water stress measures the ratio of total annual water withdrawals to total available annual renewable supply. This number accounts for upstream consumptive use. Higher values indicate more competition among users. Increases in projected water stress into the future indicate a potential for water shortage, conflict, or management challenge.

Overall water risk identifies areas with higher exposure to water-related risks and is an aggregated measure of physical risks related to quantity (flooding, drought, etc), physical risks related to water quality that may impact water availability (such as the percentage of available water that has been previously used and discharged upstream as wastewater where higher values indicate higher dependency on treatment plants and potentially poor water quality in areas that lack sufficient treatment infrastructure), and water regulatory and conflict risks.

As indicated by the inclusion of upstream conditions in the overall water risk calculation, it is extremely important to note that upstream communities can impact the water risk and stress of downstream communities. Failure to implement appropriate storm water management, flood management, and water conservation policies in one community can greatly impact the water stress of communities down stream. As a highly precious resource, all communities should look to increase water conservation regardless of the projected water stress levels of their immediate region, while communities in regions with a projected increase in water stress should view water conservation as a major long-term priority.

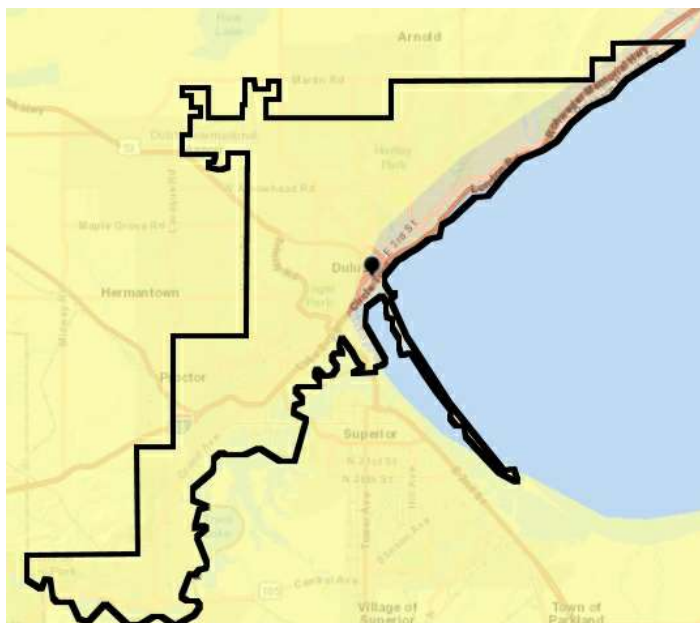
Duluth Water Stress (current)

Baseline water stress measures the ratio of total annual water withdrawals to total available annual renewable supply, accounting for upstream consumptive use. Higher values indicate more competition among users.

The current water stress in Duluth is “Low”
(Source: World Resources Institute)

Baseline Water Stress

- Low (<10%)
- Low to medium (10-20%)
- Medium to high (20-40%)
- High (40-80%)
- Extremely high (>80%)
- Arid & low water use
- No data



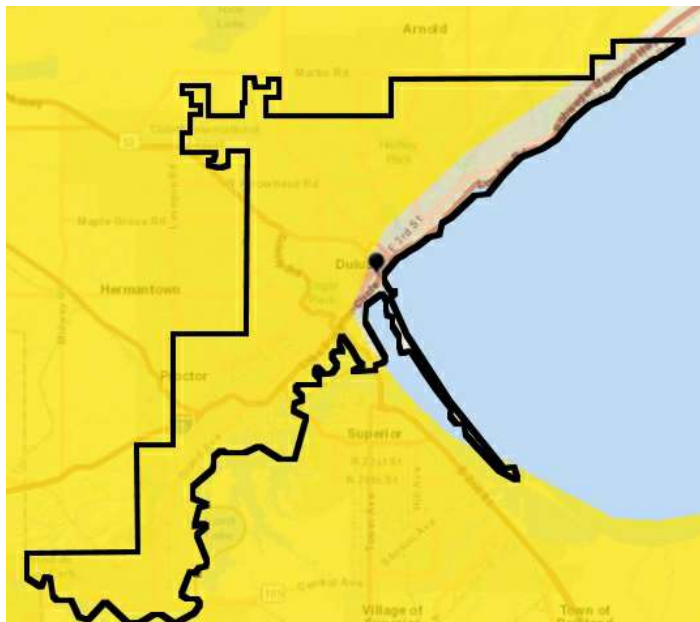
Duluth Overall Water Risk (current)

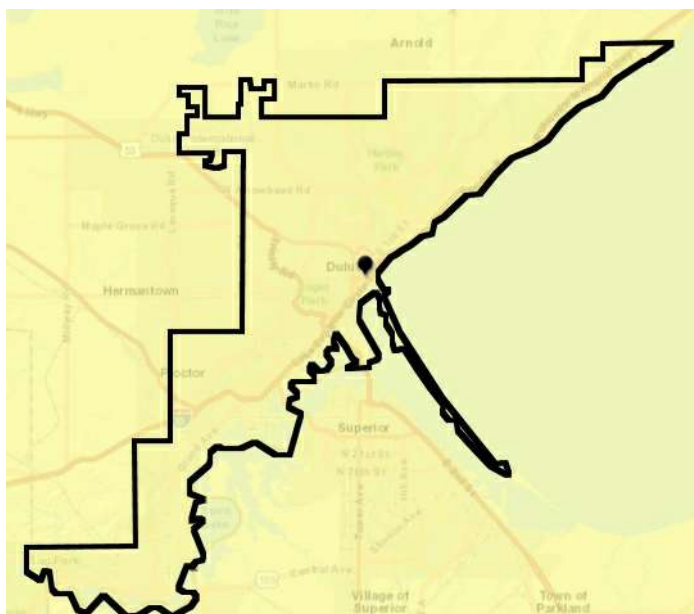
Overall water risk identifies areas with higher exposure to water-related risks and is an aggregated measure of all selected indicators from the Physical Quantity, Quality and Regulatory & Reputational Risk categories.

The current water risk in Duluth is “Low to Medium”
(Source: World Resources Institute)

Overall Water Risk

- Low risk (0-1)
- Low to medium risk (1-2)
- Medium to high risk (2-3)
- High risk (3-4)
- Extremely high risk (4-5)
- No Data



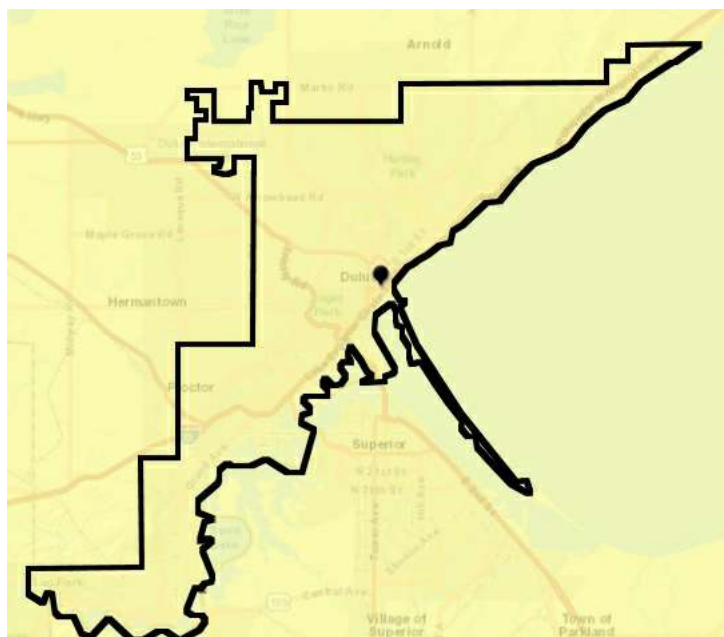
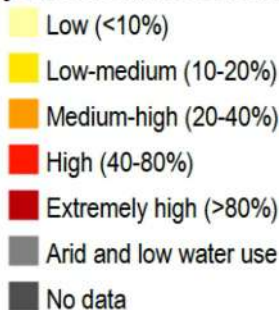


Projected Change in Duluth Water Stress (through 2040)

Projected change in water stress shows how development and/or climate change are expected to affect water stress, the ratio of water use to supply. The "business as usual" scenario (SSP2 RCP8.5) represents a world with stable economic development and steadily rising global carbon emissions.

The projected water stress in Duluth is "Low".
(Source: World Resources Institute)

Projected change in water stress (Value in year 2040 business as usual)



Projected Change in Duluth Water Demand (through 2040)

Projected change in water demand shows how development and/or climate change are expected to affect water demand. The "business as usual" scenario (SSP2 RCP8.5) represents a world with stable economic development and steadily rising global carbon emissions.

The projected water demand in Duluth is "Low".
(Source: World Resources Institute)

Projected change in water demand (Value in year 2040 business as usual)



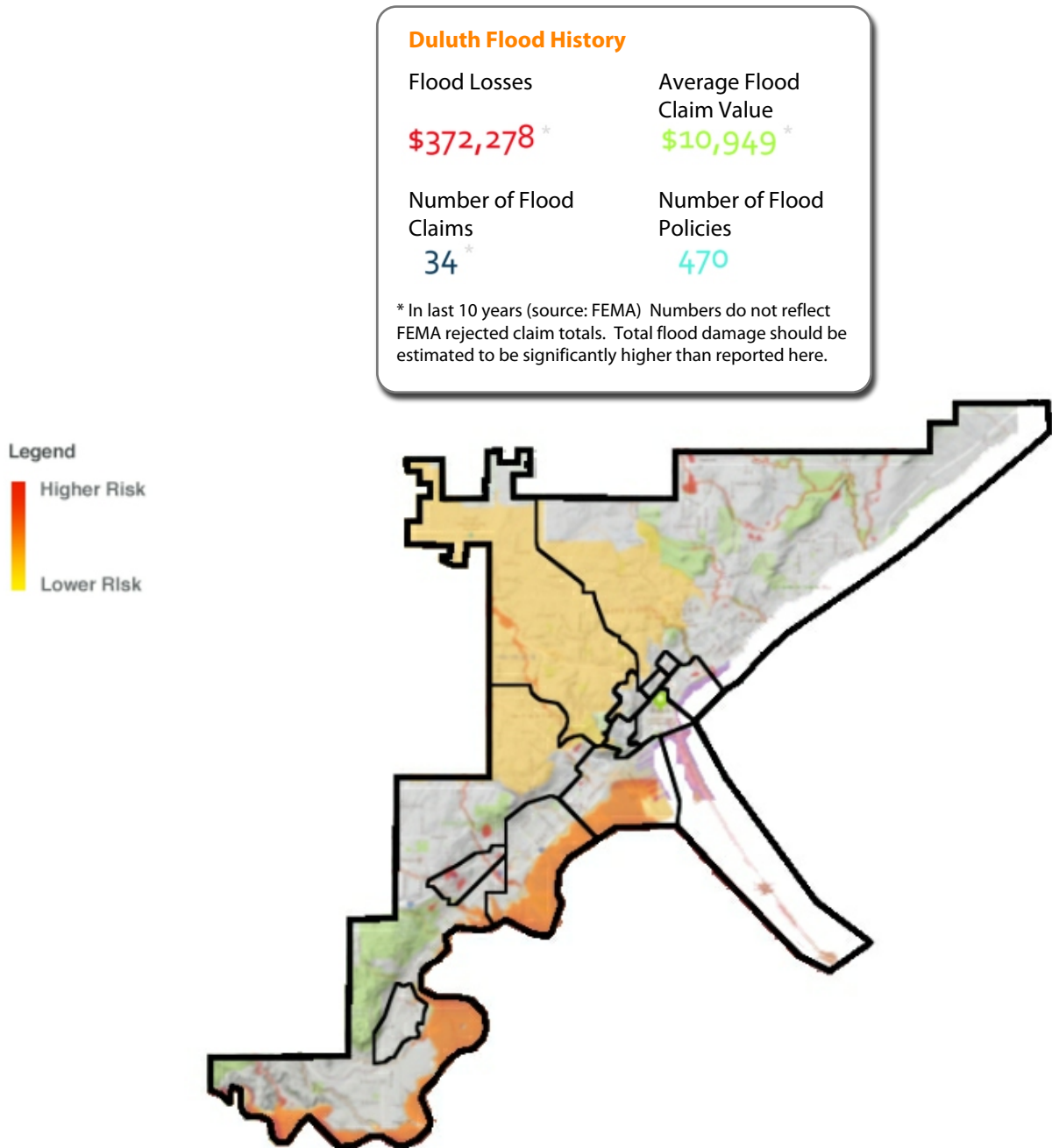
Duluth Flood Vulnerability

According to the US National Climate Assessment, the ten rainiest days can contribute up to 40% of the annual precipitation in the Minnesota region.

By 2070, the Duluth area can anticipate an increase of up to 20% in the total annual precipitation, while the amount of precipitation in summer and fall months may actually decline (source US National Climate Assessment). Under this scenario, it is likely that certain periods of the year, like spring, may be significantly wetter with storms producing heavier rains. In anticipation of that, it is appropriate to review the areas of the City with flood risk and to review current stormwater management capacity against future extreme rainfall event projections.

The map below shows the flood risk areas throughout the City as defined by FEMA . Flood risks illustrated relate to water surface elevations for 1% chance annual floods (“100 year flood event”). Areas shown relate to existing bodies of water as well as potential “flash flood” zones in low-lying areas.

(Source: National Flood Services)



S e c t i o n

08

Climate Resilience Indicators



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Climate Resilience Indicators

Similar to Climate Impact Multipliers, a community's overall resilience can have a multiplying or a mitigating affect on the population's ability to adapt to climate risks and rapidly recover from extreme weather events. Understanding and tracking the state of these Resilience Indicators will help identify some of the climate adaptive strategies appropriate for the City.

Resilience Indicators include: Economic Stress, Health Indicators, EPA Environmental Justice Screen, EPA Social Vulnerability Index, MPCA Environmental Justice Screen, Housing Burden

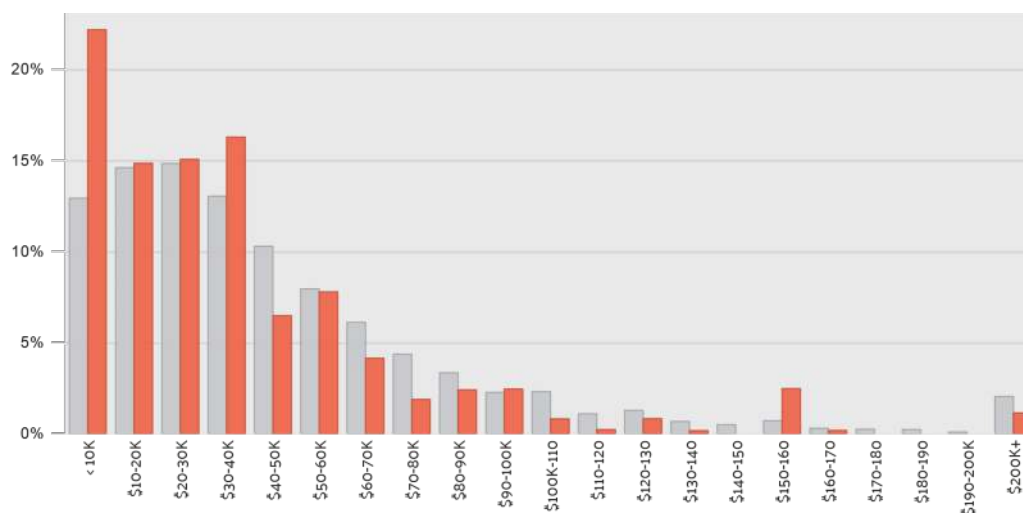
Duluth Resilience Indicators - Economic Stress

Economic stress within communities function as an impact multiplier. The issue is not limited to individuals – communities with large lower incomes or low tax bases, or low tax rates, can have a lag in infrastructure planning, maintenance, and redevelopment. These stressors on a city's planning capacity or activity decrease the ability for a community to prepare for and respond to climate stresses and vulnerabilities. In addition, a report by the World Health Organization points out that disadvantaged communities are likely to shoulder a disproportionate share of the burden of climate change because of their increased exposure and vulnerability to health threats.

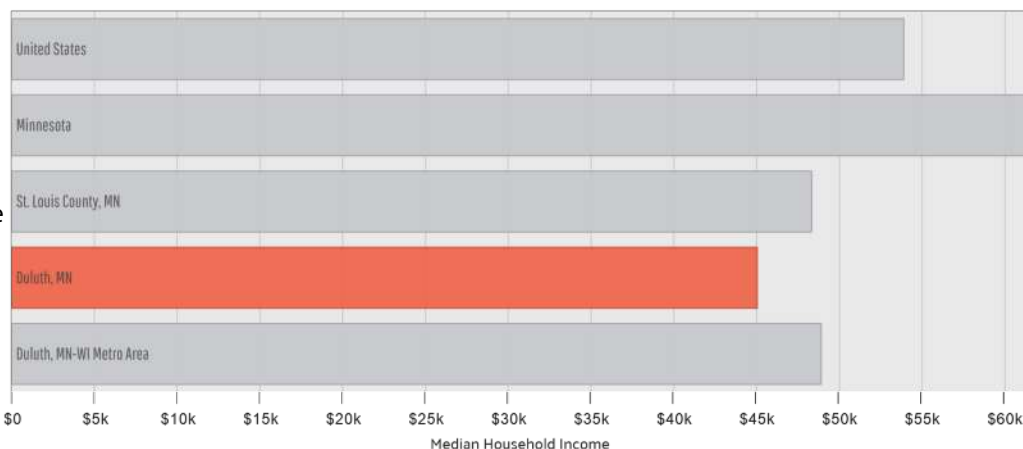
Wage Distribution Within Community

In 2015, the income inequality in Duluth was 0.517 according to the Gini calculation of the wage distribution. The Gini coefficient is a measure of statistical dispersion intended to represent the equality of a distribution, and is the most commonly used measure of inequality. Values range from 0 to 1, with 0 being perfect equality.

Income inequality in Duluth had a 2.27% growth from 2014 to 2015, which means that that wage distribution grew somewhat less even. The 2015 GINI for Duluth is lower than the State average of 0.476. In other words, wages are distributed less evenly in Duluth in comparison to the State average. The increase in income inequality may imply that quantity vulnerable populations living under economic stress may be increasing.



Median Household Income



Duluth Resilience Indicators - Health

The potential magnitude of the population climate risks outlined in section 6 “Local Climate Risks” can be anticipated by understanding current community resilience indicators. Resilience indicators which are higher locally than State or National averages may imply a potential weakness which could be exacerbated by the risks posed by projected climate change.

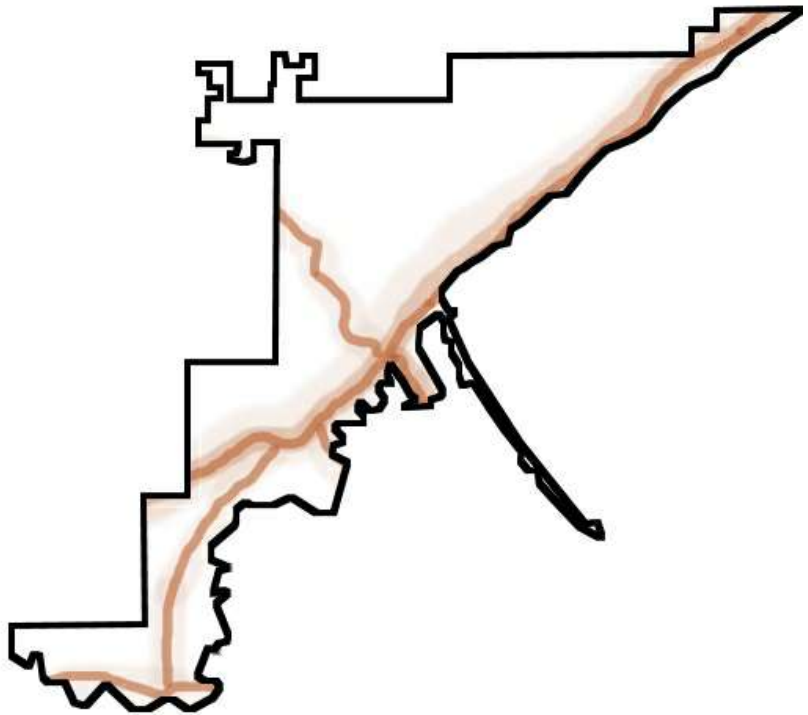
On the other hand, it should be understood that these community resilience indicators are usually only available at the granularity of County level. This means that the City should carefully consider potential implications for any community resilience indicator even if the local demographic appears "stronger" (lower percentage/value/percentile) than State or National levels.

	State	County
Poor/Fair Health	12%	15%
Uninsured	7%	7%
Asthma emergency department visits (per 10,000)	40.1	44.7
Pulmonary Disease Hospitalizations (COPD per 100,000)	15.8	17.5
Heart attack hospitalizations (per 100,000)	26.7	33.9

Health and Heavy Traffic

Vehicles are a significant and widespread source of air pollution in Minnesota communities. Heavy traffic and busy roads increase the relative health risks caused by all air pollutants coming from cars, trucks, and buses. When it gets hot outside, the impacts of pollution on health are even worse. Hotter summers influenced by climate change may mean more health problems for people living, working, or going to school in communities near major roadways. People who live, work, or attend schools near high-traffic roadways are more exposed to traffic-associated air pollutants. Even people passing through these areas while commuting, walking, or biking are more at risk.

The map to the right shows concentrations of on-road vehicle particulate pollution in the City of Duluth. Darker areas indicate higher traffic and, subsequently, potential higher levels of particulate pollution and locations posing greater risk to human health.



Duluth Resilience Indicators - EPA Environmental Justice Screen

EJSCREEN is an environmental justice mapping and screening tool that provides EPA with a nationally consistent dataset and approach for combining environmental and demographic indicators. All of the EJSCREEN indicators are publicly-available data. EJSCREEN simply provides a way to display this information and includes a method for combining environmental and demographic indicators into EJ indexes. Below are the EJSCREEN results for the City of Duluth. All values circled in orange are values in the upper 50 percentile for the State of Minnesota.

Selected Variables	Value	State Average	Percentile in State	EPA Region Average	Percentile in EPA Region	USA Average	Percentile in USA
Environmental Indicators							
Particulate Matter (PM 2.5 in $\mu\text{g}/\text{m}^3$)	7.29	9.27	5	10.1	2	9.14	14
Ozone (ppb)	32.2	35.8	1	37.6	0	38.4	3
NATA* Diesel PM ($\mu\text{g}/\text{m}^3$)	0.582	0.755	43	0.932	<50th	0.938	<50th
NATA* Air Toxics Cancer Risk (risk per MM)	33	36	44	34	<50th	40	<50th
NATA* Respiratory Hazard Index	1.4	2.2	33	1.7	<50th	1.8	<50th
Traffic Proximity and Volume (daily traffic count/distance to road)	200	350	74	370	66	590	62
Lead Paint Indicator (% pre-1960s housing)	0.6	0.32	81	0.39	74	0.29	81
Superfund Proximity (site count/km distance)	0.14	0.18	67	0.13	80	0.13	77
RMP Proximity (facility count/km distance)	0.33	0.74	44	0.81	47	0.73	51
Hazardous Waste Proximity (facility count/km distance)	0.01	0.12	15	0.091	4	0.093	6
Wastewater Discharge Indicator (toxicity-weighted concentration/m distance)	0.092	0.077	93	4.2	87	30	90

* The National-Scale Air Toxics Assessment (NATA) is EPA's ongoing, comprehensive evaluation of air toxics in the United States. EPA developed the NATA to prioritize air toxics, emission sources, and locations of interest for further study. It is important to remember that NATA provides broad estimates of health risks over geographic areas of the country, not definitive risks to specific individuals or locations. More information on the NATA analysis can be found at: <https://www.epa.gov/national-air-toxics-assessment>.

+ The hazardous waste environmental indicator and the corresponding EJ index will appear as N/A if there are no hazardous waste facilities within 50 km of a selected location.

RMP Proximity represents the potential for chemical accident based on the number of Risk Management Plan sites in area.

Duluth Resilience Indicators - EPA Social Vulnerability Index

Social vulnerability refers to the resilience of communities when confronted by external stresses on human health, stresses such as natural or human-caused disasters, or disease outbreaks. Reducing social vulnerability can decrease both human suffering and economic loss.

The Social Vulnerability Index (SVI) compares and ranks every community in the United States at the Census Tract level. Factors include poverty, lack of car access, and crowded housing. The SVI is developed by the Centers for Disease Control. The City of Duluth has areas in all four levels of vulnerability (lowest quartile through to highest quartile)

Duluth Resilience Indicators - MPCA Environmental Justice Screen

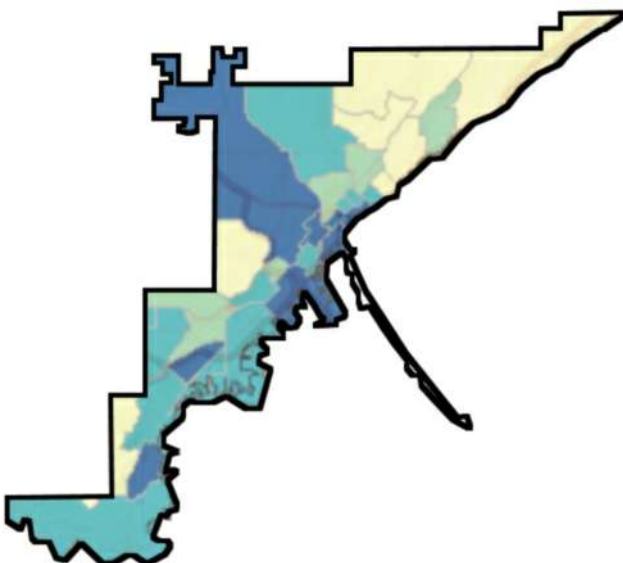
The Minnesota Pollution Control Agency is committed to making sure that pollution does not have a disproportionate impact on any group of people — the principle of environmental justice. This means that all people — regardless of their race, color, national origin or income — benefit from equal levels of environmental protection and have opportunities to participate in decisions that may affect their environment or health.

As an initial step the MPCA considers tribal areas and census tracts with higher concentrations of low income residents and people of color as areas of increased concern for environmental justice. This screening tool allows users to identify census tracts where additional consideration or effort is warranted to ensure meaningful community engagement and to evaluate the potential for disproportionate adverse impacts using three criteria:

- At least 40% of people reported income less than 185% of the federal poverty level
- 50% or more people of color
- Federally recognized tribal areas

EPA Social Vulnerability Index

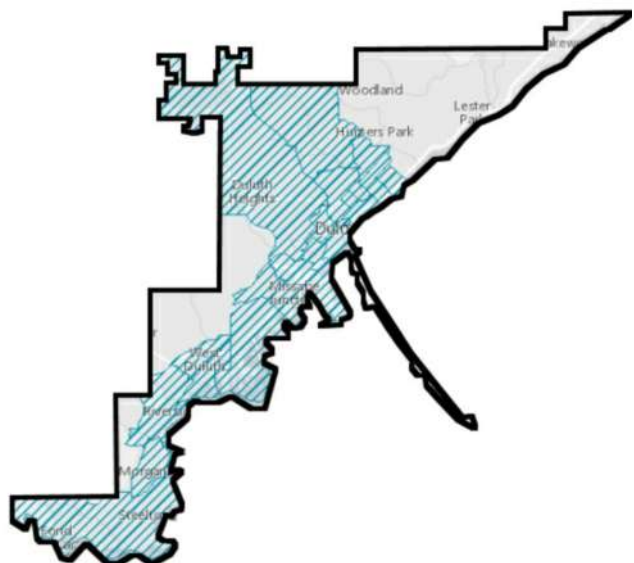
Legend



MPCA Environmental Justice Screen

Legend

- ▨ At least 40% of people reported income less than 185% of the federal poverty level
- 50% or more people of color
- Federally recognized tribal areas

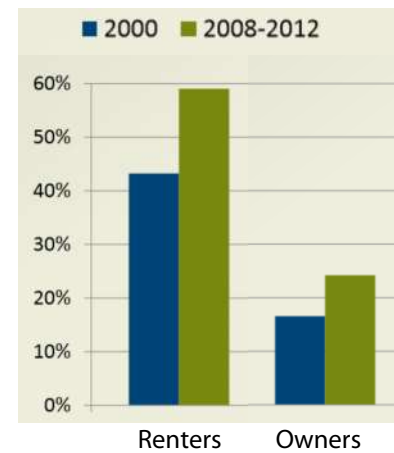


Duluth Resilience Indicators - Housing Burden

Housing burden can be understood as a household living with any of four housing problems: overcrowding, high housing cost, no kitchen, no plumbing. Households with housing burden can occur at any income level, though they may be more common in middle to lower income brackets. Housing burden factors, like other economic stress indicators, can challenge a household's capacity to respond to emergencies increasing that household's climate vulnerability.

A total of 24% of owners and nearly 60% of rental households are living under housing burden. Since 2000, the percentage of households experiencing cost burden has increased, especially among renters. Families living under housing cost burden are required to spend higher portions of their income on their rent or mortgage, frequently leaving too little to cover other family expenses such as utility costs, housing and equipment maintenance, appropriate medical care, etc.

These economic stressors impact a family's resilience under favorable circumstances, while the projected climate impacts can be anticipated to exacerbate the burden felt by these families. Extreme heat events will result in even higher utility costs, potential health impacts related to water and air quality issues and heat exposure require the ability to access appropriate healthcare. Additionally, the best preventative measures to make homes climate ready - such as improved insulation, air conditioning, improved energy efficiency, and well placed shade trees - require investment. Home owners living under housing cost burden are typically incapable of making these investments. Families with housing cost burden who rent, meanwhile, typically have little leverage to see to it that landlords make the investments needed to make buildings climate ready.



Percentage of Households Experiencing Housing Cost Burden in Duluth, for years 2000, 2008-2012

(Sources: US Census, Minnesota Housing Finance Agency)

Housing Type Impacts on Housing Burden

The type of structure a resident lives in can impact the level of housing burden experienced by community members. According to a 2005 study by the US Housing and Urban Development Agency, renters, on average, have 10% more of their monthly income going to utility costs. Those who live in mobile home type constructions often pay even more.

The Environmental and Energy Study Institute, indicates that mobile homes built before 1980 consume an average of 84,316 BTUs per square foot, 53 percent more than other types of homes. A study by the energy consultant group Frontier Associates found that residents in older manufactured homes may pay up to \$500 a month for electricity, or over 24% of average monthly income. Mobile homes are also less resilient to extreme temperatures, extreme weather, high winds, and tornado events.

Duluth Housing by Type and Occupancy

Housing Type	Housing Units			Owner-Occupied			Renter-Occupied		
	Number	% of Total	State Ave	Number	% of Total	State Ave	Number	% of Total	State Ave
1, detached	22,202	62.70%	67.00%	19,060	89.40%	85.30%	3,128	22.20%	20.80%
1, attached	1,062	3.00%	7.90%	618	2.90%	7.60%	437	3.10%	8.40%
2 apartments	2,443	6.90%	2.30%	341	1.60%	0.60%	2,099	14.90%	6.30%
3 or 4 apartments	1,664	4.70%	2.10%	171	0.80%	0.50%	1,479	10.50%	6.20%
5 to 9 apartments	1,098	3.10%	2.30%	107	0.50%	0.40%	1,000	7.10%	6.90%
10 or more apartments	6,020	17.00%	15.60%	192	0.90%	2.20%	5,833	41.40%	49.60%
Mobile home	921	2.60%	2.90%	810	3.80%	3.40%	99	0.70%	1.60%
Total Occupied Units	35,410			21,320	60.2%	71.7%	14,090	39.8%	28.3%

S e c t i o n

09

Vulnerable Populations in Duluth



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Vulnerable Populations in Duluth

Some groups face a number of stressors related to both climate and non-climate factors. For example, people living in impoverished urban or isolated rural areas, floodplains, and other at-risk locations such as areas of current or historically high levels of toxic chemical pollution are more vulnerable not only to extreme weather and persistent climate change but also to social and economic stressors. Many of these stressors can occur simultaneously or consecutively.

People or communities can have greater or lesser vulnerability to health risks depending on age, social, political, and economic factors that are collectively known as social determinants of health. Some groups are disproportionately disadvantaged by social determinants of health that limit resources and opportunities for health-promoting behaviors and conditions of daily life, such as living/working circumstances and access to healthcare services. Populations of concern are particularly vulnerable to climate change impacts. Heightened vulnerability to existing and projected climate impacts can be due to a sector of the population's exposure, sensitivity, or adaptive capacity to a climate impact.

The following pages map the populations particularly vulnerable to the risks of climate change impacts within the City of Duluth.



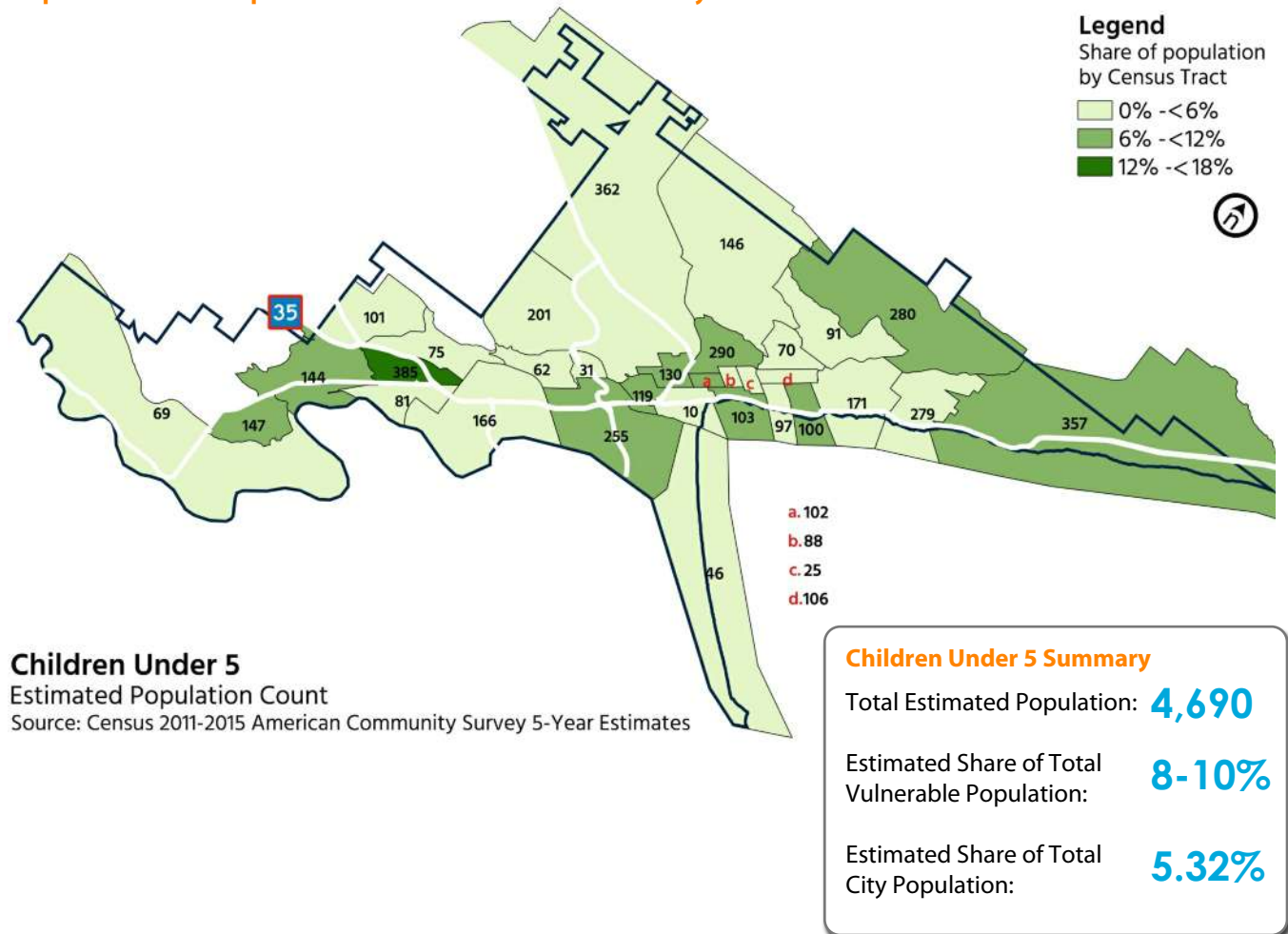
Children

According to the US Global Change Research Program “Children are vulnerable to adverse health effects associated with environmental exposures due to factors related to their immature physiology and metabolism, their unique exposure pathways, their biological sensitivities, and limits to their adaptive capacity. Children have a proportionately higher intake of air, food, and water relative to their body weight compared to adults. They also share unique behaviors and interactions with their environment that may increase their exposure to environmental contaminants such as dust and other contaminants, such as pesticides, mold spores, and allergens.”

Children are particularly sensitive to the following Climate Risks (see Section 6 for Climate Risk information):



Map of Vulnerable Population Distribution Within Community



Children Under 5

Estimated Population Count

Source: Census 2011-2015 American Community Survey 5-Year Estimates

Observations for Duluth

The estimated total child population under five for Duluth is 4,690. This vulnerable population makes up 5.32% of the City's total population. Children under five are most concentrated in the Central sections of the City along the I-35/MN 61 corridor. These sections represent the highest share of the total population of these tracts, though not always the highest estimated populations - ranging from 6% to 18% of the total population of those neighborhoods.

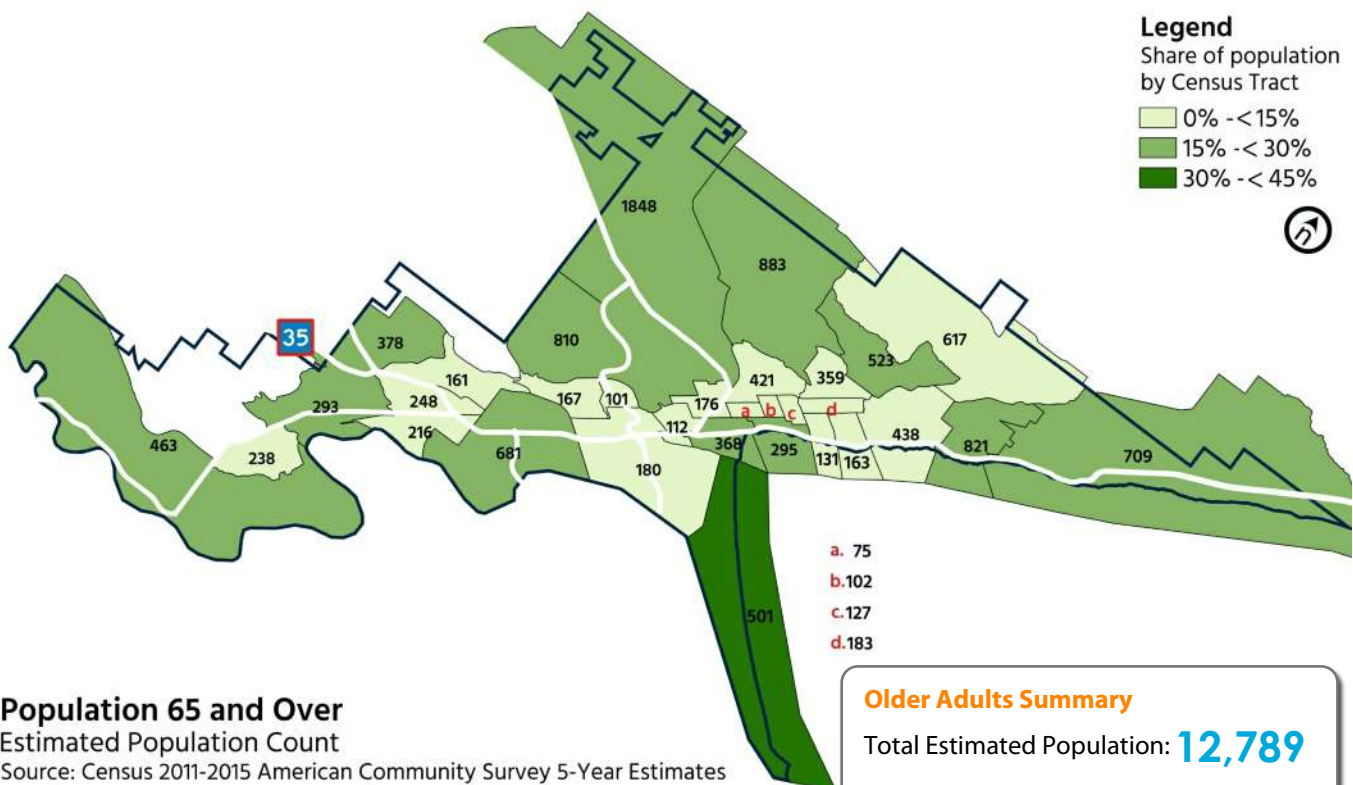
Older Adults (65 and over)

Older adults are also vulnerable to the health impacts associated with climate change and weather extremes. Vulnerabilities within older adults are not uniform due to the fact that this demographic is a diverse group with distinct subpopulations that can be identified not only by age but also by race, educational attainment, socioeconomic status, social support networks, overall physical and mental health, and disability status. According to the US Global Change Research Program “the potential climate change related health impacts for older adults include rising temperatures and heat waves; increased risk of more intense floods, droughts, and wildfires; degraded air quality; exposure to infectious diseases; and other climate-related hazards.”

Older Adults are particularly sensitive to the following Climate Risks (see Section 6 for Climate Risk information):



Map of Vulnerable Population Distribution Within Community



Observations for Duluth

The estimated total older adult population for Duluth is 12,789. This vulnerable population makes up 14.5% of the City's total population. Older adults make up at least 24% of the climate vulnerable individuals in Duluth. Older adults are most concentrated in the City's peripheral tracts. These sections represent the highest share of the total population of these tracts - ranging from 15% to 45% of the total population of those neighborhoods.

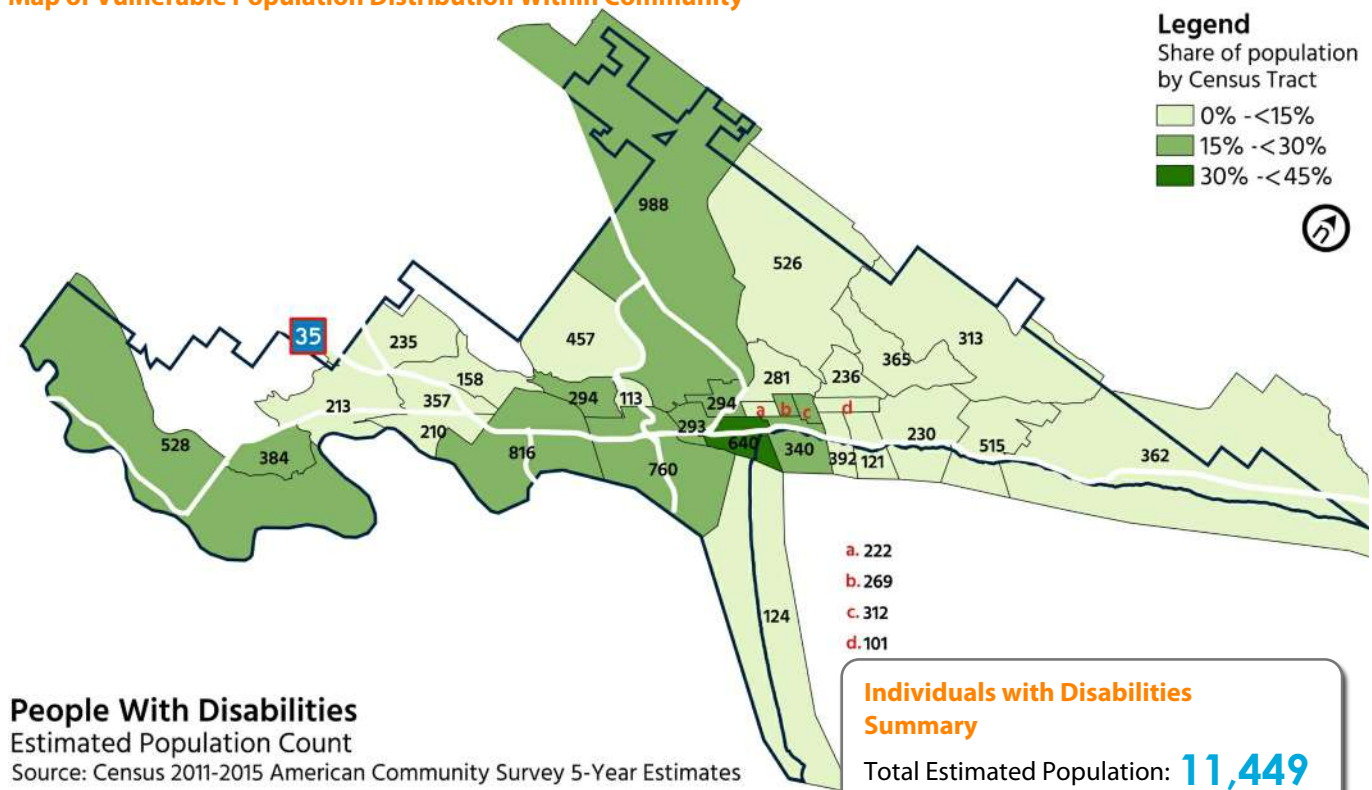
Individuals with Disabilities

People with disabilities experience disproportionately higher rates of social risk factors, such as poverty and lower educational attainment, that contribute to poorer health outcomes during extreme events or climate-related emergencies. These factors compound the risks posed by functional impairments and disrupt planning and emergency response. Of the climate-related health risks experienced by people with disabilities, perhaps the most fundamental is their “invisibility” to decision-makers and planners. Disability refers to any condition or impairment of the body or mind that limits a person’s ability to do certain activities or restricts a person’s participation in normal life activities, such as school, work, or recreation.

Individuals with disabilities are particularly sensitive to the following Climate Risks (see Section 6 for Climate Risk information):



Map of Vulnerable Population Distribution Within Community



Observations for Duluth

The estimated total population of individuals with disabilities for Duluth is 11,449. This vulnerable population makes up 12.99% of the City’s total population. Individuals with disabilities make up at least 1 in every 5 climate vulnerable individuals in Duluth. Individuals with disabilities are most concentrated in the Western and Northwestern sections of the City. These sections represent both the highest estimated population of individuals with disabilities as well as the highest share of the total population of these tracts - ranging from 15% to 45% of the total population of those neighborhoods.

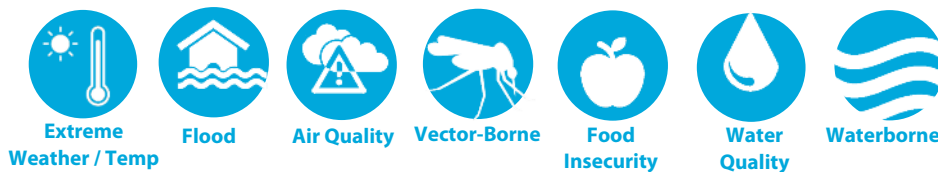
Individuals Under Economic Stress

Individuals and families living under economic stress are frequently the most adaptive demographic group in our communities. Those living under economic stress exhibit on-going adaptation capabilities simply navigating day-to-day challenges with less than needed resources. This adaptive capacity, however, is overwhelmed in times of emergency as lack of sufficient economic resources greatly reduce the range of options available in response to crisis. For those in poverty, weather-related disasters or family members falling ill can facilitate crippling economic shocks.

With limited economic adaptive capacity, this portion of our population is especially vulnerable to every projected climate impact. Frequently the most effective measures in avoiding extreme heat such as efficiently functioning air conditioning or high performing building enclosures are simply not available to those in poverty while many work in outdoor or industrial jobs which are particularly vulnerable to climate conditions. Diseases which may result from exposure to vector-borne, water-borne, and air-borne pathways may go untreated due to lack of medical access or ability to pay and may increase the level of economic stress due to missed work days or even loss of employment. Those living under economic stress usually carry a heavy housing cost burden, including higher utility costs. This burden can be exacerbated from damaged sustained by their home in extreme weather or flooding events.

Those in economic stress are also frequently food insecure. In Minnesota, food insecurity affects 10.6% of all households have limited access to grocery stores according to the USDA. Many of the projected climate change impacts are likely to effect agricultural production and distribution, which in turn, may cause spikes in food costs and increase food and nutrition insecurity among those in economic stress.

Individuals experiencing economic stress are particularly sensitive to the following Climate Risks:



Map of Vulnerable Population Distribution Within Community

See maps on next page.

Observations for Duluth

The estimated total population in economic stress for Duluth is 17,468 with 40% being families and 60% being individuals. This vulnerable population makes up 19.81% of the City's total population. Those living in economic stress make up more than 1 in every 3 climate vulnerable individuals in Duluth.

Residents living in economic stress are most concentrated in the Western, Northwestern, and Central sections of the City. These sections represent both the highest estimated economically stressed population as well as the highest share of the total population of these tracts - ranging from 30% to 95% of the total population of those neighborhoods.

Economic Stress Summary

Total Estimated Population: **17,468**

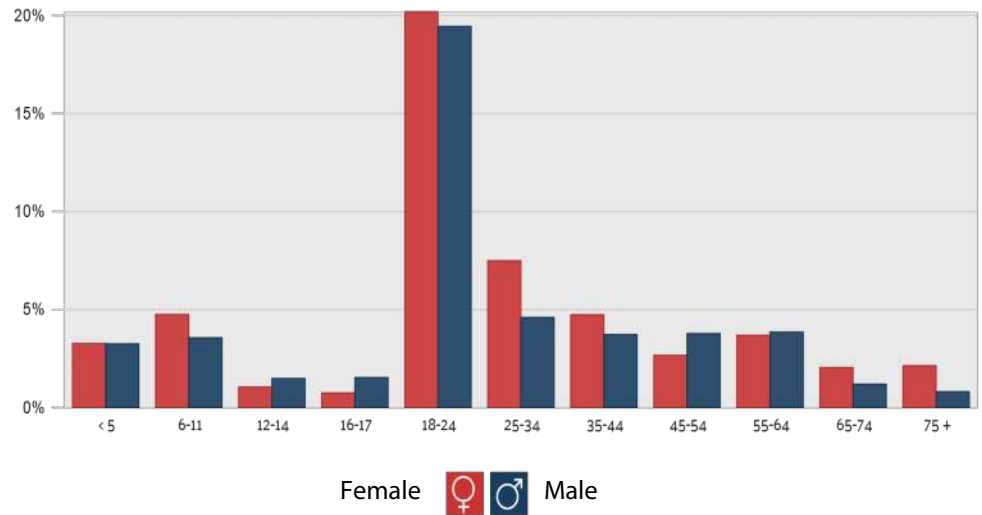
Estimated Share of Total Vulnerable Population: **34-36%**

Estimated Share of Total City Population: **19.81%**

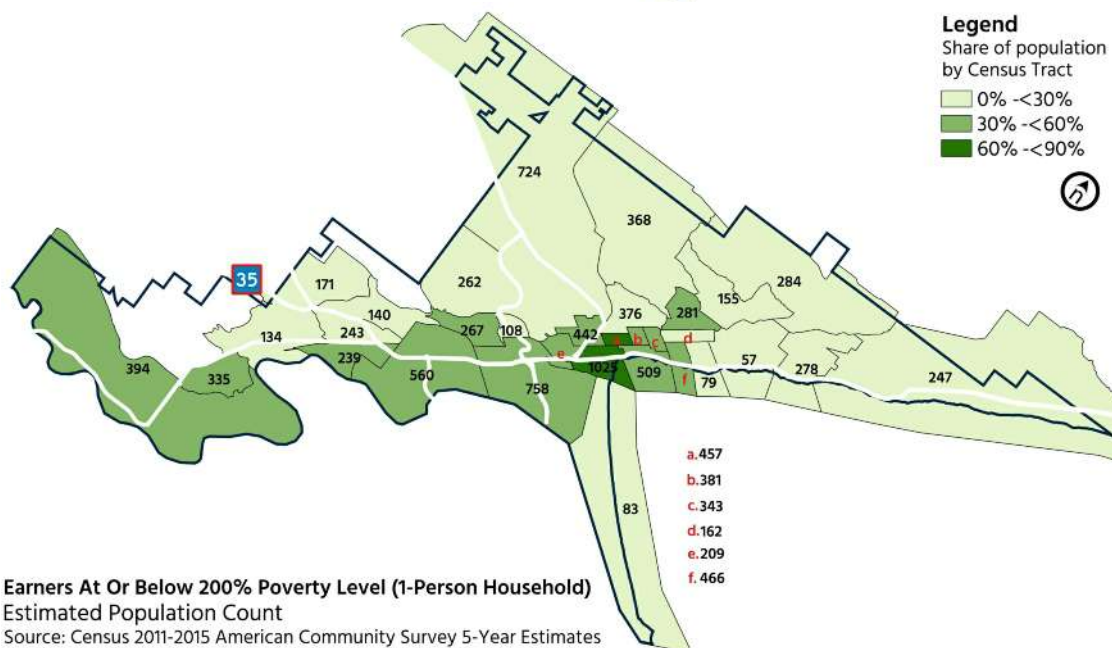
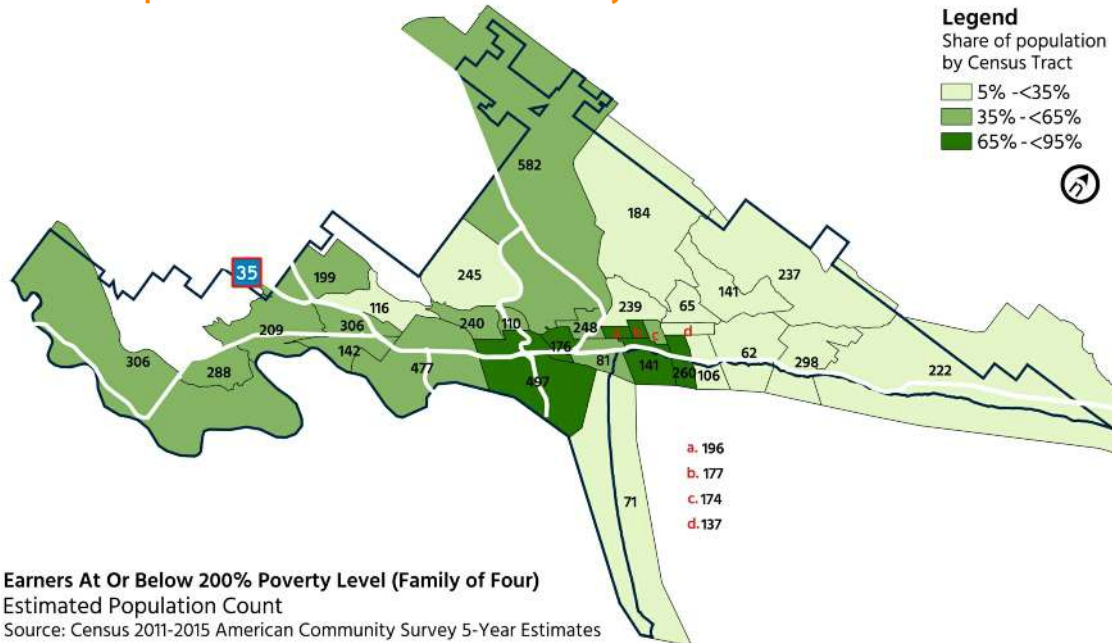
Poverty by Age and Gender

The largest demographic living in poverty in Duluth is Female 18-24, followed by Male 18-24 and then Female 25-34.

The Census Bureau uses a set of money income thresholds that vary by family size and composition to determine who classifies as impoverished. If a family's total income is less than the family's threshold than that family and every individual in it is considered to be living in poverty.



Map of Vulnerable Population Distribution Within Community



People of Color and Limited English Populations

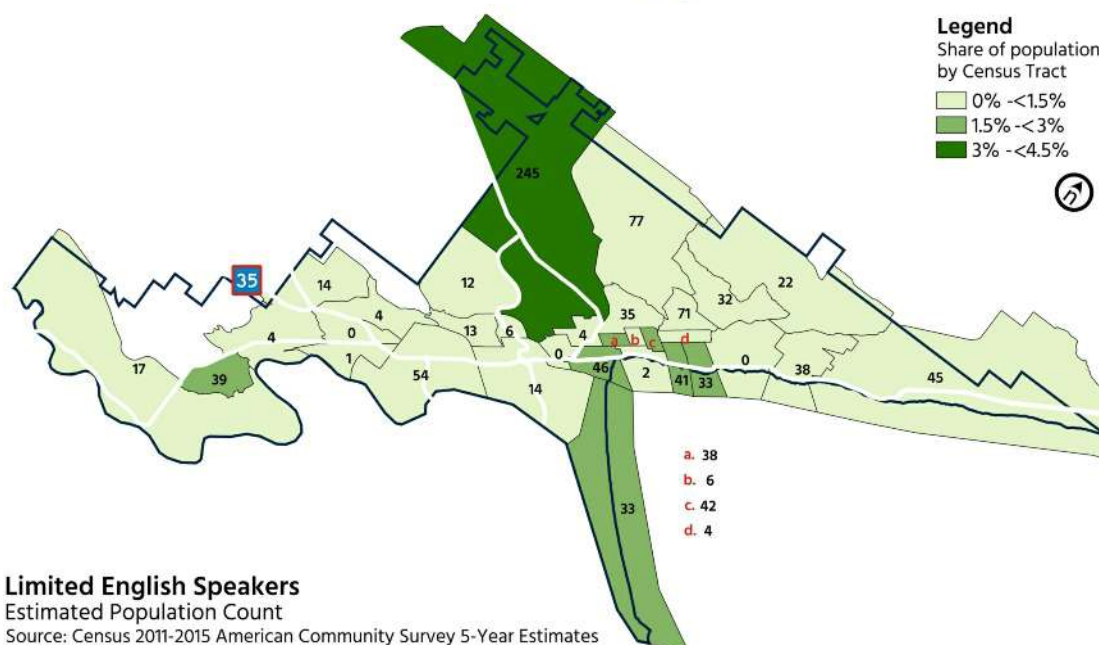
These populations are at increased risk of exposure given their higher likelihood of living in risk-prone areas, areas with older or poorly maintained infrastructure, or areas with an increased burden of air pollution. In addition, according to the Center for Disease Control and the National Health Interview Survey these portions of our population also experience higher incidence of chronic medical conditions which can be exacerbated by climate change impacts. These populations may also be impeded from preparing, responding, and coping with climate related health risks due to socioeconomic and education factors, limited transportation, limited access to health education, and social isolation related to language barriers.

Though not specifically a “person of color” category, individuals with limited English frequently overlap with populations of color. Individuals with limited English language skills may be more socially isolated. Their limited English also likely limits their access to public information and notifications, potentially resulting in a knowledge gap related to community resources, programs, or education which may be relevant in preparing for and recovering from climate impacts. In addition, communication barriers may create challenges for limited English speakers in understanding critical information or instructions given in public address during an extreme weather event.

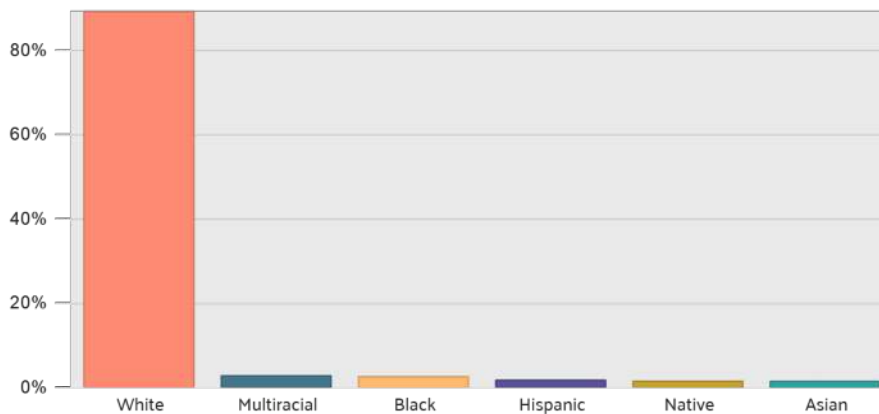
People of Color may be particularly sensitive to the following Climate Risks:



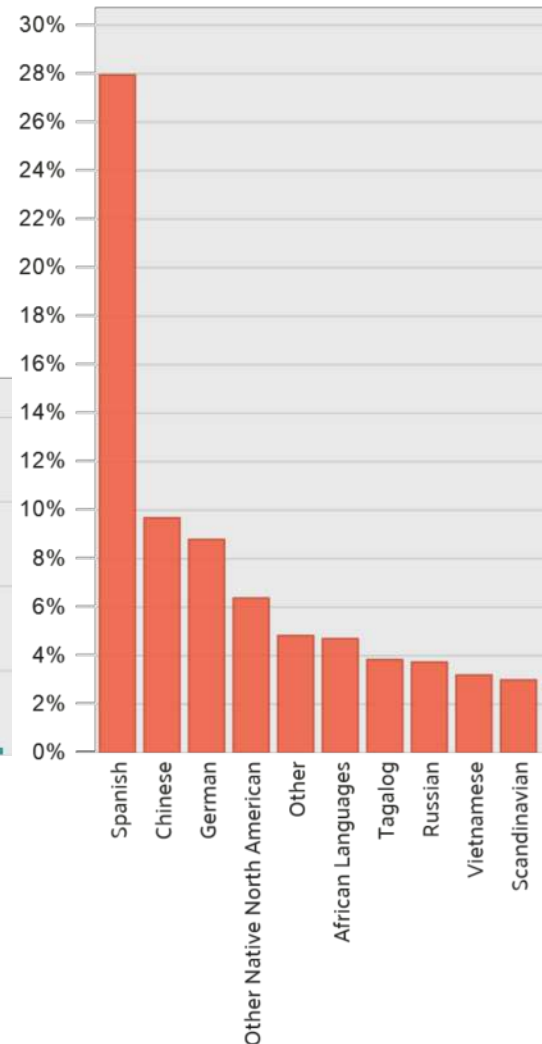
Map of Vulnerable Population Distribution Within Community



Breakdown of Race and Ethnicity



Breakdown of Primary Language



Observations for Duluth

The estimated total population of people of color in Duluth is 8,551 with approximately 27% being African-American, 18.8% Hispanic, 16.5% Native American, 16% Asian, and the balance being Multiracial. This vulnerable population makes up 9.7% of the City's total population and 1/6th of all climate vulnerable individuals in Duluth.

Populations of color are most concentrated in the Central and North Western sections of the City. These sections represent both the highest estimated economically stressed population as well as the highest share of the total population of these tracts - ranging from 12% to 36% of the total population of those neighborhoods

There are an estimated 992 limited English speakers in the City of Duluth. Assuring key communications related to community resources, safety, emergency, and extreme weather preparedness is equally accessible to community residents with limited English is important for overall community resilience. The City should review its current and future communications for translation opportunities targeting the city's non-English primary languages to the greatest extent feasible. The top four languages spoken are Spanish, Chinese, German, and Native American dialects - representing more than 53% of all languages spoken by limited English speakers.

People of Color Summary

Total Estimated Population: **8,551**

Estimated Share of Total Vulnerable Population: **15-18%**

Estimated Share of Total City Population: **9.7%**

At-Risk Workers

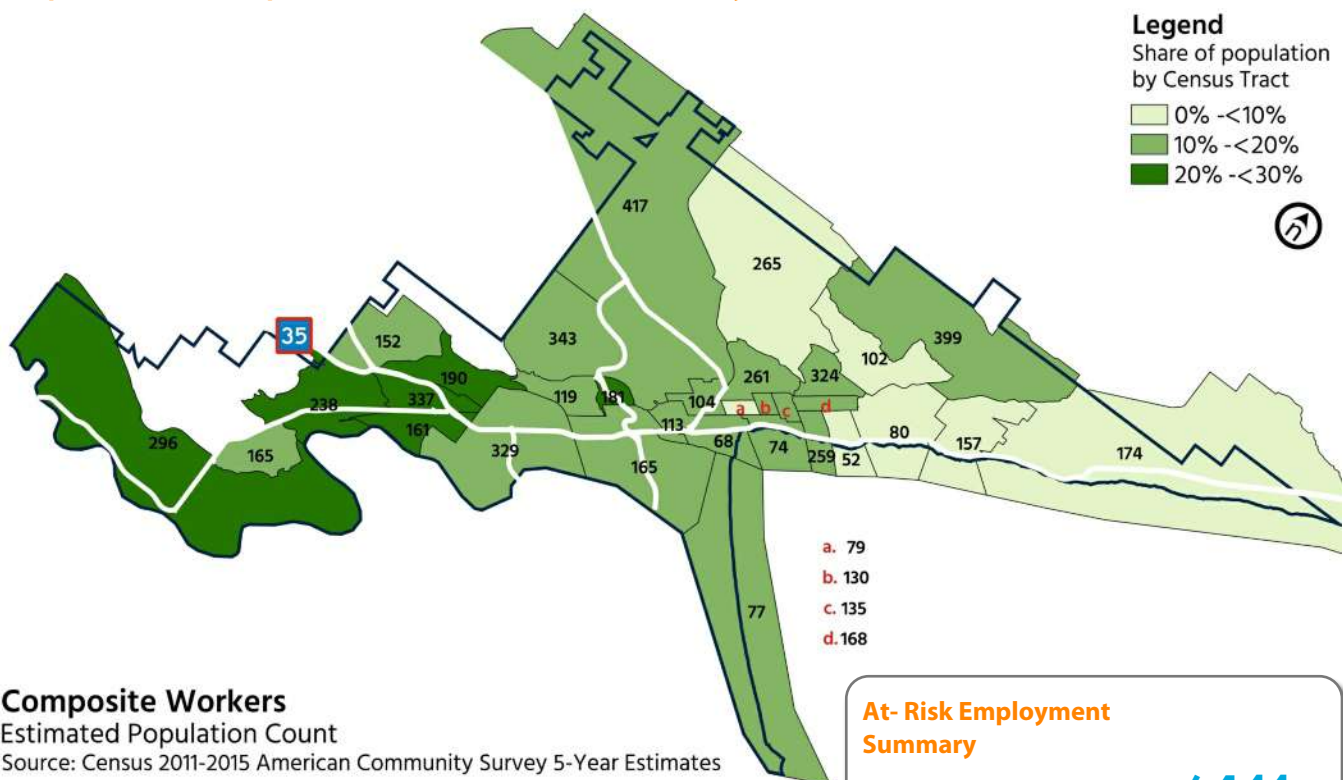
Climate change will increase the prevalence and severity of occupational hazards related to environmental exposure. As our climate changes, we may also experience the emergence of new work related risks. Climate change can be expected to affect the health of outdoor workers through increases in ambient temperature, more prevalent and longer-lasting heat waves, degraded air quality, extreme weather, vector-borne diseases, and industrial exposures. Workers affected by climate change include farmers, ranchers, and other agricultural workers; laborers exposed to hot indoor work environments; construction workers; paramedics, firefighters and other first responders; and transportation workers.

For individuals employed in climate vulnerable jobs who also fall within other vulnerable population categories, the health effects of climate change can be cumulative. For these individuals, the risks experienced in their work can be exacerbated by exposures associated with poorly insulated housing and lack of air conditioning. Workers may also be exposed to adverse occupational and climate-related conditions that the general public may be more able to avoid, such as direct exposure to extreme heat, extreme weather events, low air quality, or wildfires.

Individuals employed in at-risk occupations may be particularly sensitive to the following Climate Risks:



Map of Vulnerable Population Distribution Within Community



Composite Workers

Estimated Population Count

Source: Census 2011-2015 American Community Survey 5-Year Estimates

Observations for Duluth

The estimated total Duluth residents employed in at-risk occupations is 6,114, nearly 14% of all Duluth residents who are employed, and almost 7% of the City's total population. At-risk workers make up at least 1 in every 8 climate vulnerable individuals in the City. At-risk workers are most concentrated in the Western, Northwestern, and Central sections of the City, making up to 30% of the total population of those neighborhoods. The largest at-risk worker categories are employed in construction/extraction, production, and transportation jobs.

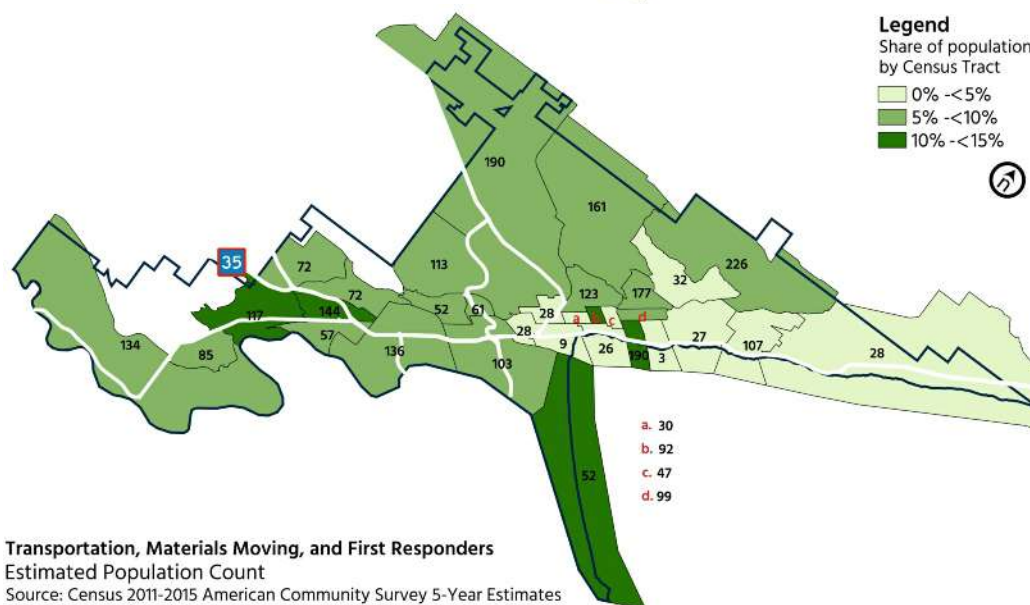
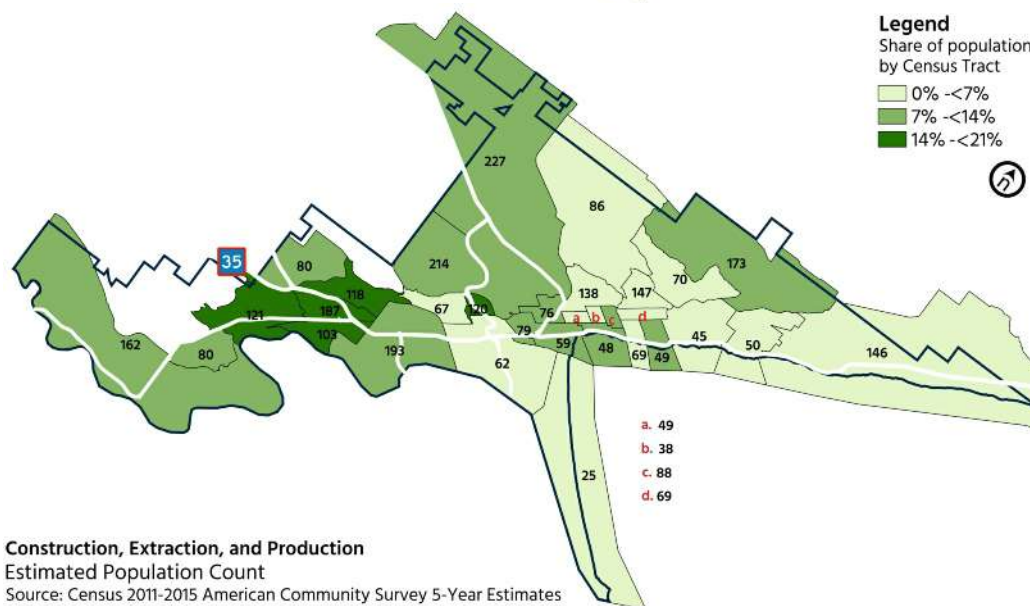
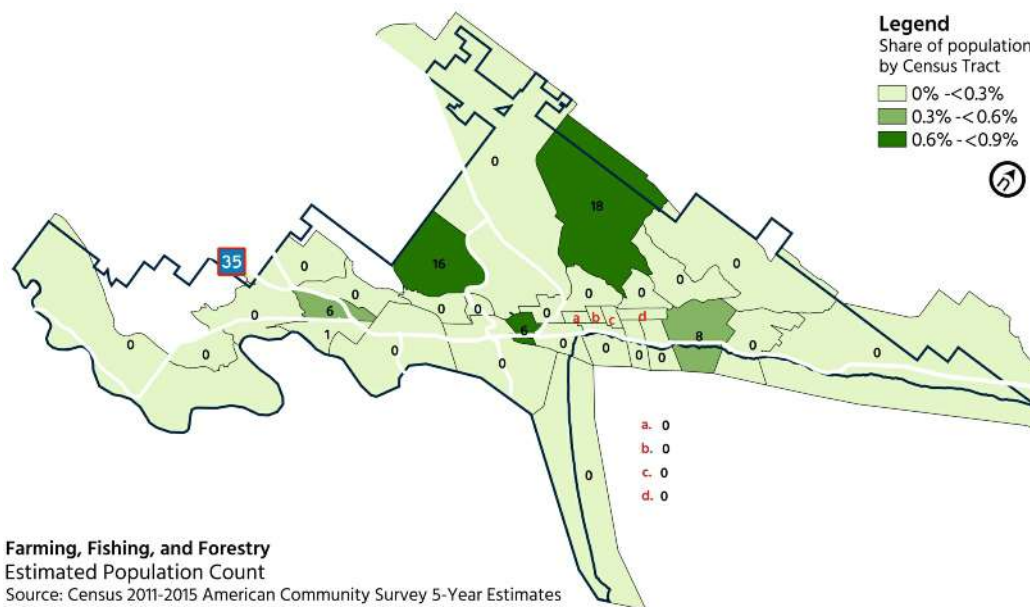
At-Risk Employment Summary

Total Estimated Population: **6,144**

Estimated Share of Total Vulnerable Population: **11-13%**

Estimated Share of Total City Employment: **13.9%**

Estimated Share of Total City Population: **6.93%**



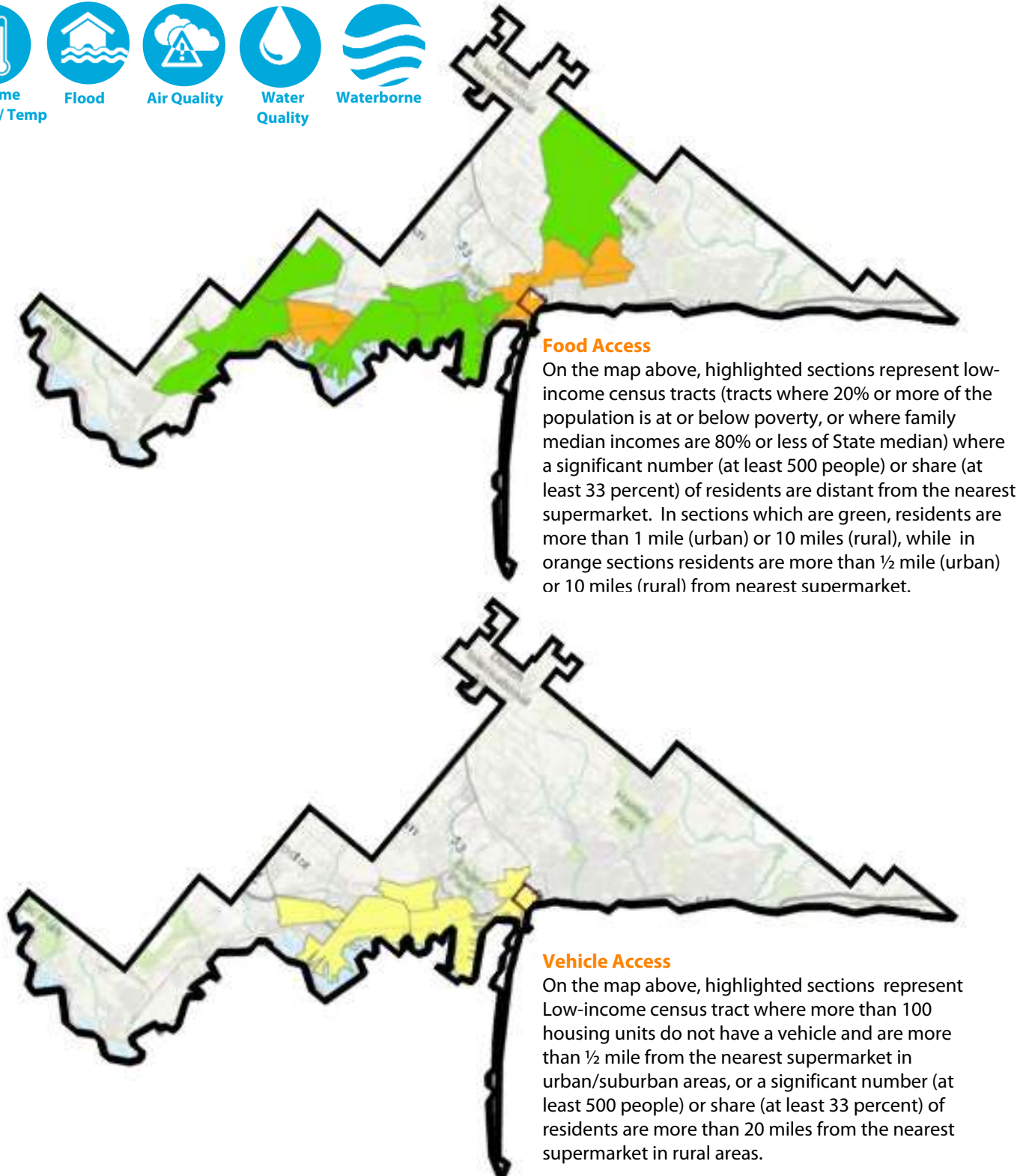
At-Risk Occupations Breakdown

This series of maps illustrates the breakdown of workers employed in the primary at-risk occupation categories. From 2014 to 2015, employment in Duluth, MN grew at a rate of 3%, from 42,812 employees to 44,098 employees.

Individuals with Possible Food Insecurity

Climate change affects agriculture in a number of ways, including through changes in average temperatures, rainfall, and extreme weather events and heat; changes in pests and diseases; changes in atmospheric carbon dioxide and ground-level ozone concentrations. These effects can be anticipated regionally as well as worldwide to become more pronounced by mid-century. As the food distribution system becomes more stressed, individuals with less readily available access are more likely to be negatively impacted by the resulting cycles of food shortages and food price increases.

Individuals experiencing food insecurity may be particularly sensitive to the following Climate Risks:

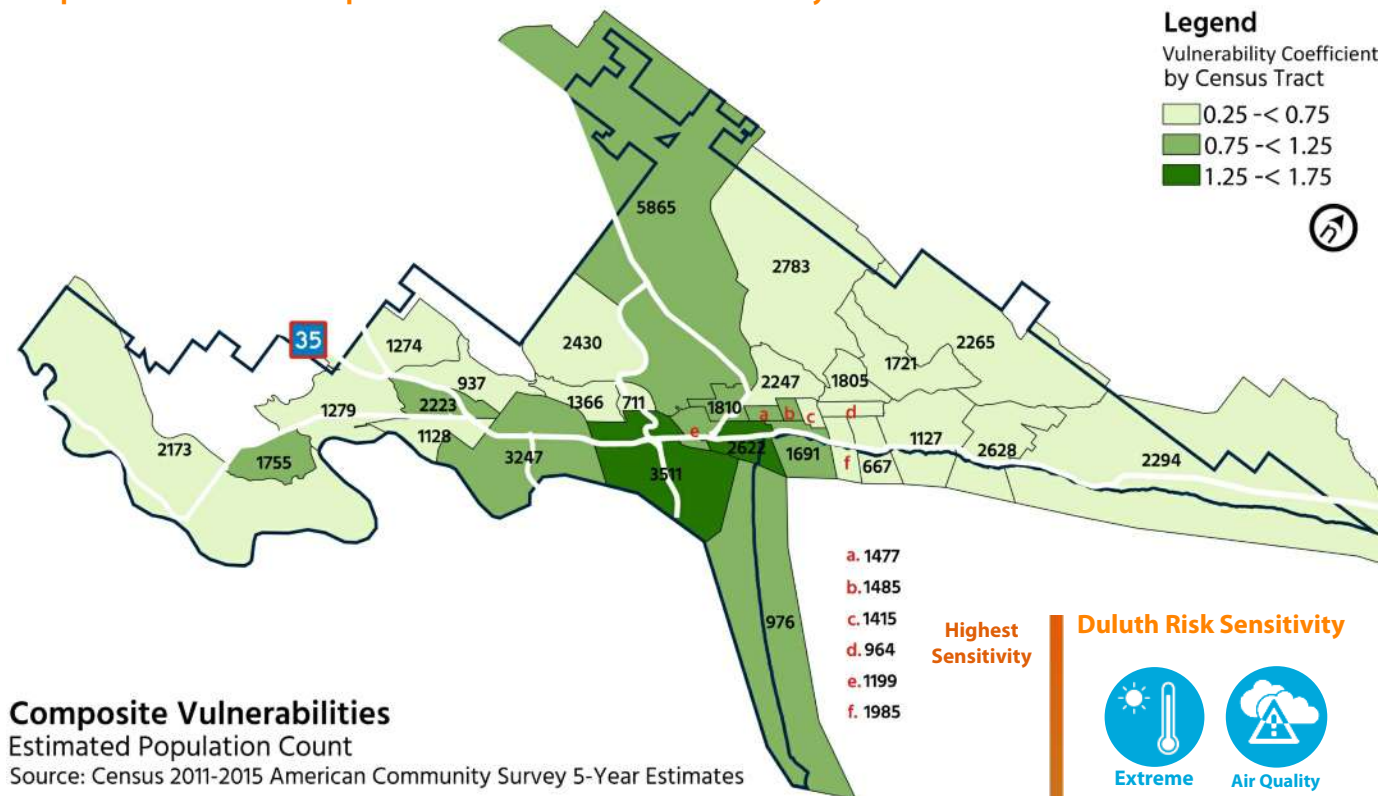


Composite Vulnerabilities

The map below provides a composite mapping of all vulnerable populations illustrated in this section. It should be noted that it is possible for individuals to be members of more than one vulnerable population. For example, an individual may be both an adult over age 65 as well as an individual living below 200% of poverty level. Consequently, the “Estimated Population” counts provided on this composite vulnerabilities map may not be accurate, but the numbers represented here provide a reasonable estimate of the magnitude of total vulnerable populations in each census tract. This composite view of vulnerable populations is also useful in identifying those climate risks which may be most impactful to the most vulnerable individuals.

As indicated in the map below, the census tracts can be ordered from fewest instances of population vulnerability to most instances of population vulnerability (Total Population Vulnerability). The Vulnerability Coefficient represents the ratio of total instances of population vulnerabilities to the total population within the census tract where higher numbers represent a higher prevalence of vulnerabilities within the census tract population.

Map of Total Vulnerable Population Distribution Within Community



Vulnerability Risk Sensitivity

Based on the total estimated population count for each vulnerable population and considering the risks each demographic is most sensitive to, the population vulnerabilities can be considered from highest sensitivity (more vulnerable individuals) to lowest (fewer vulnerable individuals) sensitivity.

It should be noted that risks which appear to have lower sensitivity levels should not be considered irrelevant for the community. To the right is a possible ordering of risk sensitivity for the City of Duluth.

Regional Comparison of Duluth Vulnerable Populations

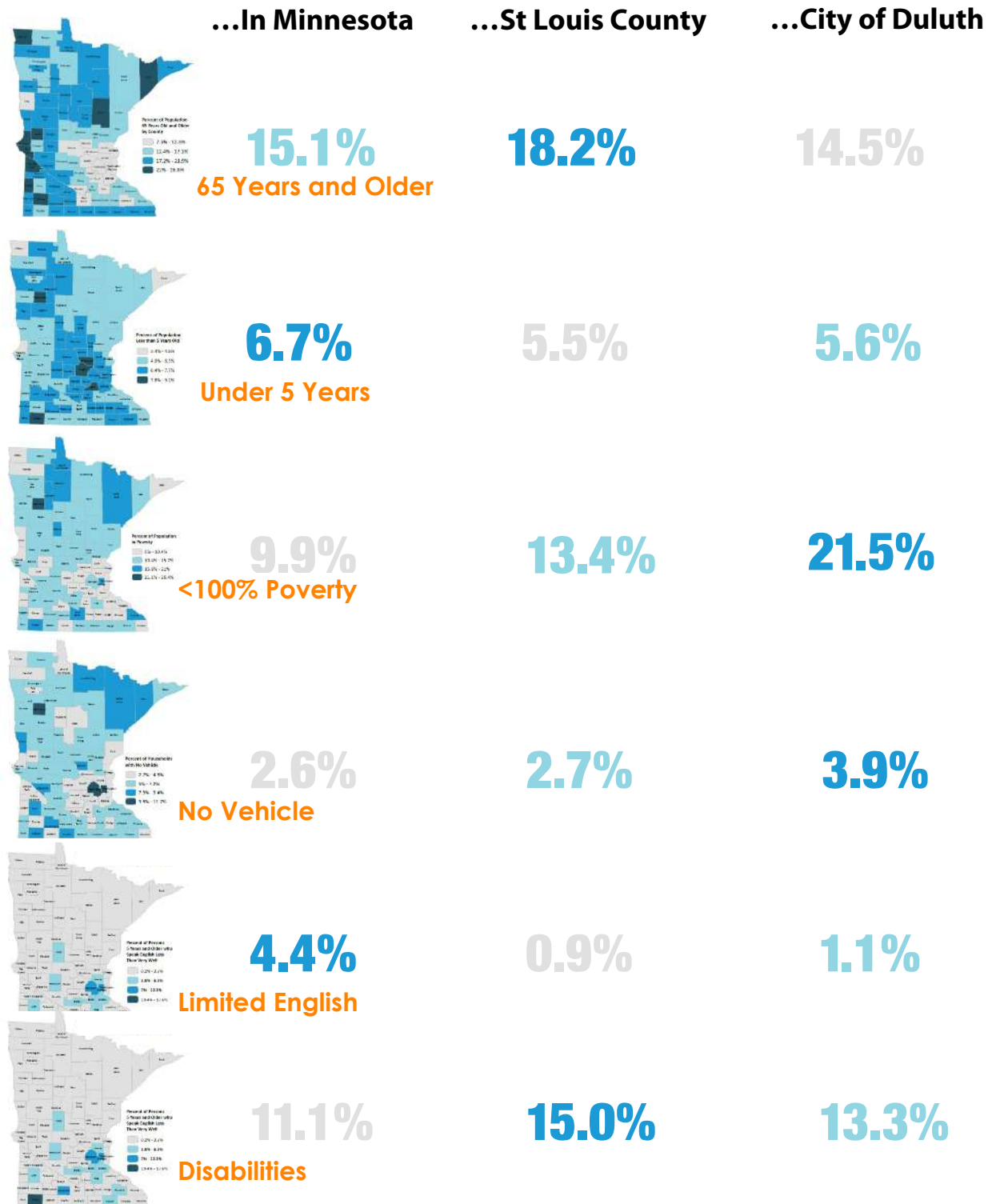
The graphics below compare the percentage of population for some of the most vulnerable groups in Minnesota, St Louis County, and the City of Duluth. This comparison is one of three primary ways in which this report analyzes the vulnerable population data. For more information see the “Findings” section of this report.

Based on this comparison to the greater metropolitan area and the State, groups of particular concern for the City are:

Lower Income Families/Individuals; Individuals Without Vehicle Access; People with Disabilities; and Seniors

(Source: State of Minnesota Department of Health and US Census Data)

Vulnerable Population Comparisons:



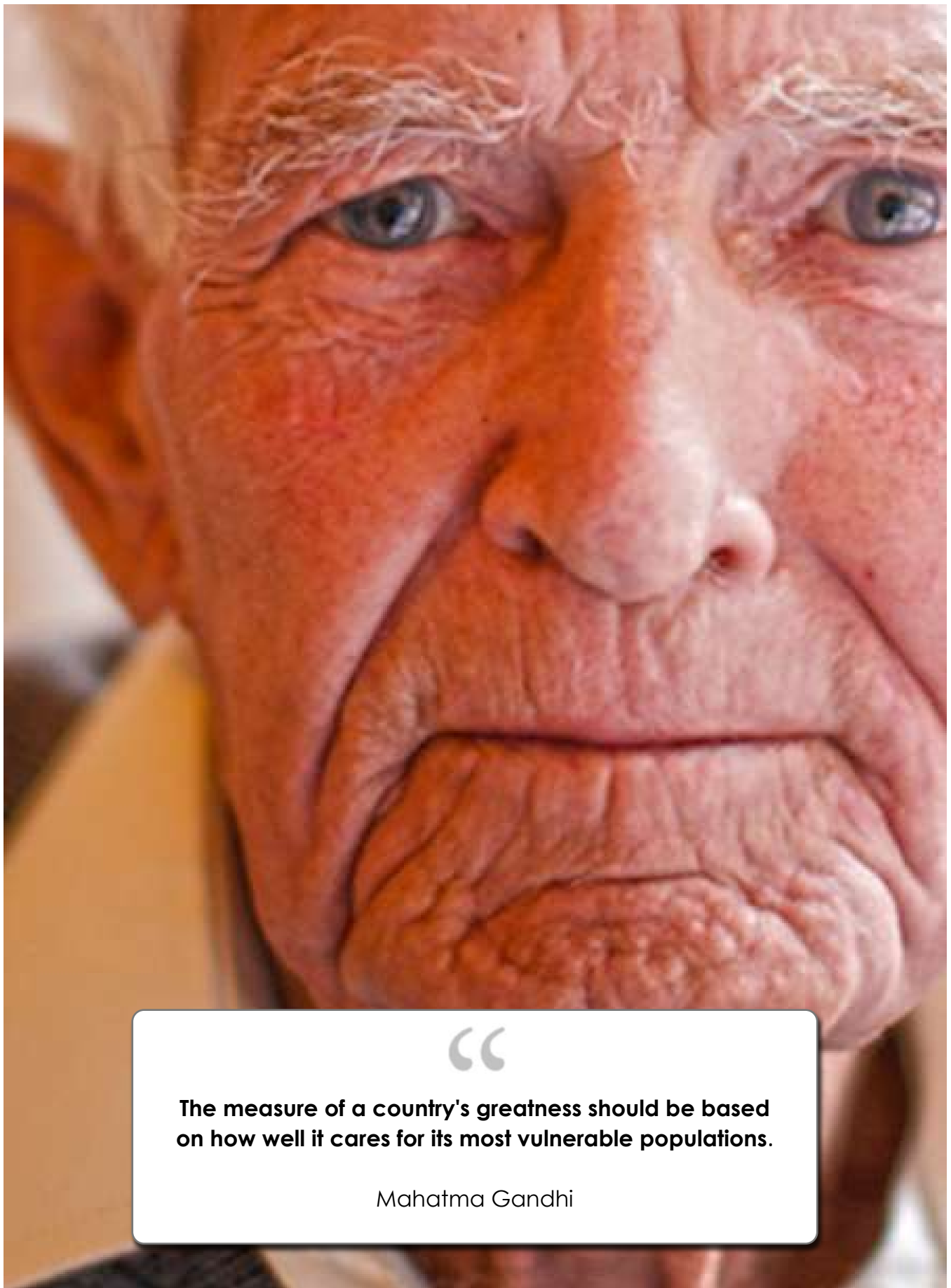
S e c t i o n

10

Findings



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“

The measure of a country's greatness should be based on how well it cares for its most vulnerable populations.

Mahatma Gandhi

Findings - Vulnerable Poppulations

Climate change impacts will affect everyone and City policies and actions should consider climate adaptive needs of the entire community. As with all planning efforts climate adaptation benefits from analysis in order to assist in establishing priorities for initial efforts. An effort to structure a prioritization should not be seen as an attempt to discard the need to address climate impacts for any population within the City - whether or not it is defined as one of the "vulnerable" populations. Prioritization, however, is necessary to ensure the greatest impact and effectiveness of limited City resources. To assist in prioritization, this report reviews the community Vulnerable Populations data through the following "filters":

Highest
Sensitivity

Comparing Vulnerable Populations Within The City of Duluth

Population	Estimated Total	Share
Children	4,690	8-10%
Older Adults	12,789	24-26%
Disabled	11,449	21-24%
Economic Stress	17,468	34-36%
People of Color	8,551	15-18%
At Risk Workers	6,114	11-13%

Based on this view of City of Duluth population vulnerabilities, those living in Economic Stress, Older Adults, and individuals with Disabilities represent those with the most significant vulnerabilities.

Regional comparison of City of Duluth Vulnerable Populations

As detailed at the end of Section 9, a comparison of the City of Duluth's vulnerable populations can be made against the same population groupings regionally and State-wide.

Based on this comparison to the County and the State, groups of comparative concern for the City are:

Economic Stress

Limited Transportation (No Vehicle)

Individuals with Disabilities

Older Adults

Comparing Vulnerability by Census Tract (highest 12 Census Tracts)

Tract	Vuln Pop	% of Vuln	Coefficient
3	5.865	12.3%	0.79
12	1.485	3.0%	0.89
16	1.477	3.01%	1.01
17	1.691	3.41%	1.15
18	1.810	3.65%	0.96
19	2.692	5.37%	1.67
20	1.199	2.42%	0.84
22	976	2.03%	0.86
33	2.223	4.48%	0.88
37	1.755	3.61%	0.94
156	3.511	7.10%	1.21
158	3.247	6.65%	0.85

Census Tracts 19, 156, 17, 16, 18, 37, 12, 33, 22, 158, 20, and 3 have the highest levels of impact sensitivities, totaling 57% of vulnerable population.

Comparing Risk Sensitivities Across City of Duluth

This comparison is based on the total estimated count for each vulnerable population and considers the particular risks each demographic is most sensitive to. The result is an accounting of the risks with the greatest number of sensitive individuals (see Section 9 for more info)

The risks with the highest sensitivities are:

Extreme Temp / Weather

Air Quality Impacts

Flood

Food Insecurity

Vectorborne Diseases

Lowest
Sensitivity

Summary of Vulnerable Population Findings

Based on the above review the City's adaptive efforts may be most effective by prioritizing strategies which address the climate risks of Extreme Temp/Weather, Air Quality Impacts, Flood risks, Food Insecurity, and Vectorborne Diseases. Particular attention should be paid to strategies which are most effective for those in Economic Stress, limited transportation (no vehicle), individuals with Disabilities, and Older Adults. Geographically, priority should be given the City's Census Tracts of 19, 156, 17, 16, 18, 37, 12, 33, 22, 158, 20, and 3 (see maps on pages 10-4 and 10-5 for tract locations)

Findings - City's Climate Impact Multipliers

Based on the summary of vulnerable population findings from the previous page, it is appropriate to re-visit some of the City's Climate Impact Multiplier characteristics defined in Section 7 to determine which, if any, of those characteristics should be addressed in the City's prioritized Adaptation and Resilience Goals and Strategies. A review of these characteristics in light of the vulnerable population findings will enable a prioritization of strategies and geographic focus for addressing the combination of anticipated climate impacts and the community's climate impact multiplier and vulnerable population characteristics.

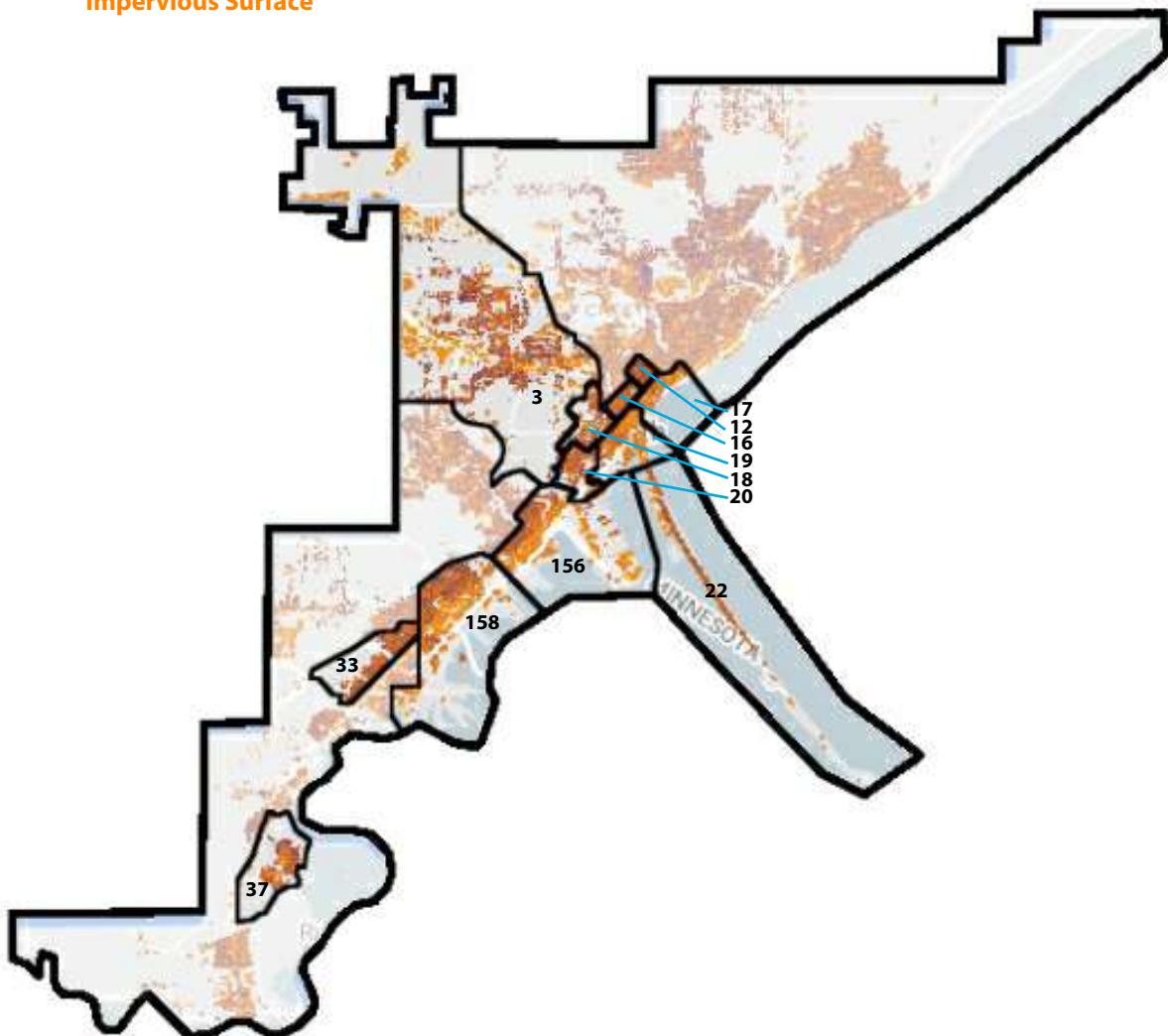
Based on the City's vulnerable population findings, a review of the City's Climate Impact Multiplier characteristics provides:

Findings - Impervious Surface, Tree Canopy, and Heat Island

The City's average existing Tree Canopy coverage of 38.6% is better than the Twin City Metro area and national averages. The graphic below illustrates building density and exposure within the City. Darker colors represent increased shading on buildings while lighter colors represent increased sun exposure. The Census Tracts with the highest population vulnerabilities and impact sensitivities as established in Section 10, page 1-3, are highlighted.

Areas which have both higher density and higher solar exposure (lighter color) are areas likely to experience micro climate heat island effects and would benefit from anti-heat island strategies particularly those in the tracts with the highest impact sensitivities (tracts highlighted on graphic).

Impervious Surface

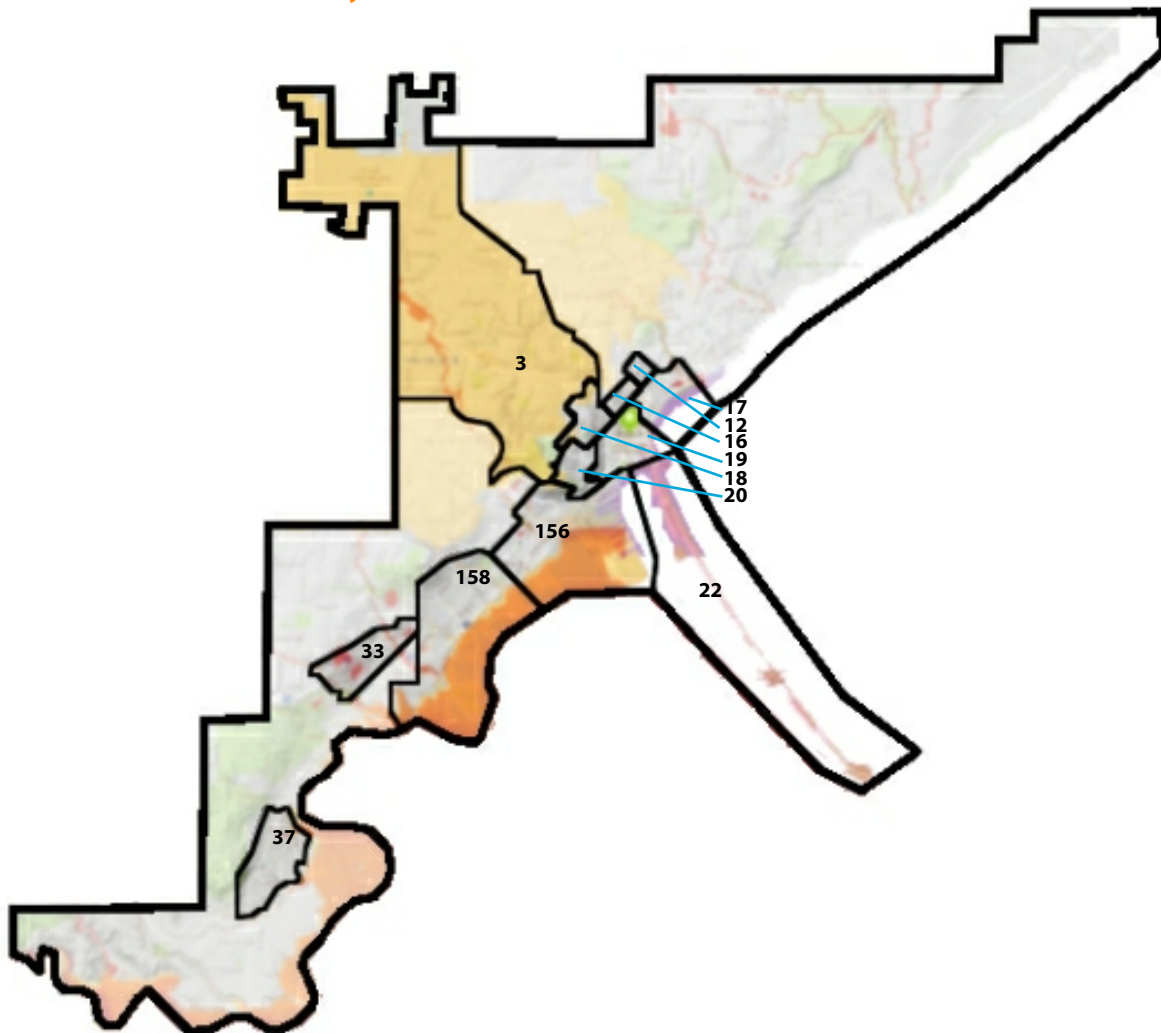


Findings - Flood Vulnerability

The graphic below illustrates FEMA flood vulnerable areas with darker shades representing higher flood risk levels. The Census Tracts with the highest impact sensitivities are highlighted. This graphic indicates that many of areas of higher flood risk appear in the tracts with the highest impact sensitivities. These sections may benefit from flood mitigation strategies. Those which overlap with the higher exposure areas illustrated in the Impervious Surface, Tree Canopy, and Heat Island graphic would likely also benefit from strategies which increase tree canopy and pervious land cover.

Additionally, all communities should review their susceptibility to flash flooding which can occur in a variety of geographic areas beyond FEMA designated flood zones. Flash flood vulnerabilities can be identified by using the Blue Spot mapping method. Over the last ten years, the City of Duluth has experienced 9 flooding and flash flooding events with a total of over \$2,000,000 in reported damages as reported by NOAA. (Numbers do not reflect FEMA rejected claim totals. Total flood damage should be estimated to be significantly higher than reported here.)

Flood Vulnerability



Findings - Climate Resilience Indicators

Based on the City's increased risk sensitivity of Air Quality the EPA Environmental Indicators of particular concern are Particulate Matter (PM 2.5) in which Duluth ranks in the 14th percentile nationally, Ozone in which Duluth ranks in the 3rd percentile nationally, and Diesel Particulate Matter in which Duluth ranks in the <50th percentile nationally. Breathing in particles causes inflammation in our respiratory and circulatory system. These pollutants can make it harder to breathe; it can cause asthma-like symptoms - of particular concern with St Louis County's high instance of asthma emergency department visits. High rates of particulate matter pollution have been linked to higher rates of cancer, heart disease, stroke, and early on-set dementia.

The primary source for particulate matter pollution is vehicle emissions and incomplete fossil fuel combustion for heating, cooling, and energy generation. The Clean Diesel Program provides support for projects that protect human health and improve air quality by reducing harmful emissions from diesel engines. This program includes grants and rebates funded under the Diesel Emissions Reduction Act (DERA). Duluth's proximity to high traffic volumes is in the 74th percentile for the State and the 62nd percentile nationally.

Potential health effects of PM exposure, increased risk of:

impaired respiratory function
chronic cough
bronchitis
chest illness
chronic obstructive pulmonary disease (COPD)
pneumonia
cardiovascular diseases
allergic disease and asthma
cardiopulmonary diseases
cancer

Summary of Climate Impact Multiplier and Climate Resilience Findings

In addition to the strategy priorities outlined in the Summary of Vulnerable Population Findings, the City should look to prioritize strategies which address the City's Climate Impact Multiplier characteristics and opportunities. These community characteristics will benefit from strategies which: increase pervious surfaces, tree canopy cover, and greenscaping; mitigate flood hazards; and increase Air Quality, particularly from stationary and mobile fossil fuel use.



Photo: SVR Design

S e c t i o n

1 1

Recommendations



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Recommendations

Recommended Adaptation and Resilience Goals

The following are recommended overall goals for increasing the climate resilience for the City of Duluth. These goals are based on the anticipated climate impacts for the City as well as the vulnerable populations present in the City. Some of the goals and strategies identified in this report will require new City policies or program development. Many others have some existing City, County, and State policies already underway which relate to them. A detailed review of all existing policies against the goals and the strategies recommended in this report should be conducted and policy modifications integrated.

In prioritizing the implementation of the goals and strategies which follow, the City of Duluth should:

- Consider available resources and opportunities to leverage new resources.
- When budget, staff, or schedule restrictions limit strategy implementation capacity, apply strategies with a priority towards vulnerable populations and tracts/areas with higher vulnerable populations (see Section 10, page 10-3 for further information)
- Consider the associated carbon emission reduction opportunities and other co-benefits of strategies.
- Study the anticipated equity impacts of strategies.
- Consider the urgency and window of opportunity.
- Conduct appropriate outreach and engagement efforts with community residents and businesses for community feedback and buy-in.
- Identify departments / staff capable of taking the lead for strategy implementation. Integrate implementation plans into a routine working plan that is reviewed and revised regularly (every 2 to 5 years recommended).
- Whenever possible select strategies that provide everyday benefits in addition to climate risk reduction. These forms of strategies are known as “no regrets strategies” and they can be justified from economic, social, and environmental perspectives whether natural hazard events or climate change hazards take place or not.
- Explore possible use and effectiveness of existing City owned facilities and properties to meet emergency shelter and cooling center functions

Climate Adaptation and Resilience Goals

Goals are organized based on the primary anticipated climate change impacts they address. Detailed strategies for each goal are identified in the next section.



Goals To Build Capacity For Preparing For And Responding To Population Risks Of Climate Change Impacts

- Goal C1 - Incorporate climate change preparedness activities into existing local government plans and programs as a means to increase resilience while minimizing costs.
- Goal C2 - Improve effectiveness of on-going adaptation measures.
- Goal C3 - Strengthen emergency management capacity to respond to weather-related emergencies.
- Goal C4 - Improve the capacity of the community, especially populations most vulnerable to climate change risks, to understand, prepare for and respond to climate impacts.
- Goal C5 - Enhance resilience of critical city operations.
- Goal C6 - Enhance city's capacity for adaptation implementation.
- Goal C7 - Secure funding to support City's adaptation efforts.



Goals Responding to Heat Stress And Extreme Weather

- Goal H1 - Strengthen emergency management capacity to respond to heat stress and extreme weather.
- Goal H2 - Minimize health issues caused by extreme heat days, especially for populations most vulnerable to heat.
- Goal H3 - Improve the capacity of the community, especially populations most vulnerable to climate change risks, to understand, prepare for and respond to high heat and extreme weather.
- Goal H4 - Decrease the urban heat island effect, especially in areas with populations most vulnerable to heat.
- Goal H5 - Enhance resilience of community tree canopy and park/forest land
- Goal H6 - Enhance the resilience of buildings within the community to extreme heat, weather, and energy and fuel disruptions.
- Goal H7 - Improve the energy efficiency and weatherization of homes and businesses to reduce energy costs and carbon pollution.
- Goal H8 - Expand access to distributed solar energy in low-income communities in order to lower energy bills, increase access to air conditioning, and decrease carbon pollution levels.
- Goal H9 - Enhance resilience of local businesses to extreme weather.
- Goal H10 - Strengthen social cohesion and networks to increase support during extreme weather events.
- Goal H11 - Increase the resilience of natural and built systems to adapt to increased timeframes between precipitation and increased drought conditions.
- Goal H12 - Enhance the reliability of the grid during high heat events to minimize fires, brownouts and blackouts.

Climate Adaptation and Resilience Goals (continued)



Goals Responding to Air Quality Impacts

Goal A1 - Reduce auto-generated particulate matter, tailpipe pollutants, waste heat, and ozone formation.

Goal A2 - Increase and maintain air quality for residents and businesses.



Goals Responding To Flood Vulnerability

Goal F1 - Strengthen emergency management capacity to respond to flood-related emergencies.

Goal F2 - Increase the resilience of the natural and built environment to more intense rain events and associated flooding.



Goals Responding To Vector-Borne Disease Risks

Goal V1 - Manage the increased risk of disease due to changes in vector populations.



Goals Responding To Food Insecurity and Foodborne Disease Risks

Goal FI-1 - Increase food security for residents, especially those most vulnerable to food environment.

(Rural communities) Goal A3 - Increase resilience of croplands, farms, and farmers within community.



Goals Enhancing Economic Resilience In Support of Climate Resilience

Goal E1 - Leverage the economic development opportunities of the Green Economy

Goal E2 - Enhance community resilience through economic resilience

Goal E3 - Including Economic Resilience in Emergency Response Planning

Recommended Menu of Adaptation and Resilience Strategies

Adaptive capacity can be broadly defined as the ability of a system to adjust, limit, and cope with potential hazards due to climate change. Potential measures of adaptive capacity include access to financial resources, health infrastructure, and technology. Adaptive capacity also refers to the ability of a system to reduce hazardous exposures, which can be measured by the implementation of government programs, initiatives, or policies.

To meet the recommended Adaptation goals outlined in the previous section, this report provides a range of potential adaptation strategies. This Menu of Adaptation and Resilience Strategies should form the basis for a Climate Adaptation Implementation planning effort. The planning effort should include a detailed review of the City's existing policies and community resources. The Climate Adaptation Implementation planning effort should include appropriate community engagement to share information about population vulnerabilities to the changing climate and to solicit feedback on the final adaptation strategies. The final Climate Adaptation Implementation Plan should include a detailed implementation schedule and should identify responsible parties for each strategy to be implemented.





Strategies To Build Capacity For Preparing For And Responding To Population Risks Of Climate Change Impacts

Goal C1 - Incorporate climate change preparedness activities into existing local government plans and programs as a means to increase resilience while minimizing costs.

C1-1

Adopt climate change adaptation actions which fulfill other societal goals, such as sustainable development, disaster risk reduction, or improvements in quality of life, and can therefore be incorporated into existing decision-making processes. These are called “no regrets” actions.

C1-2

Address climate change adaptation and mitigation (to help reduce the need to adapt more and possibly beyond human capacity in the future) in locally meaningful ways in the local comprehensive plan.

C1-3

Consider populations most vulnerable to heat and living in urban heat islands when making decisions about tree planting, protection and maintenance, green infrastructure placement, and access to vegetated open spaces and natural areas of City owned land.

C1-4

Establish a multi-jurisdiction/multi-department adaptive management coordination team to: review emerging climate research, trends and regulations at least once a year.

C1-5

Utilize an equity framework or lens to ensure preparation actions are implemented in ways that deliver more equitable outcomes and prioritize populations most vulnerable to climate change impacts.

C1-6

As appropriate, coordinate with or require health and safety service providers to support recommendations of this Population Vulnerability Assessment (e.g., provide education and resources about climate risks to populations most vulnerable to climate change impacts and development of continuity of operations plans).

C1-7

Continue to pursue energy efficiency opportunities to minimize impacts from rising energy costs and increased cooling demands in City and County owned and operated facilities.

C1-8

Train public health officials, urban planners and emergency responders about the specific community risks from climate change (priority).

C1-9

Complete a Climate Adaptation and Action Plan identifying finalized climate adaptation strategies as well as climate mitigation (greenhouse gas emission and energy reduction) strategies. Include community engagement process and detailed implementation plan.

Goal C2 - Improve effectiveness of on-going adaptation measures.

C2-1

Establish a community engagement effort to develop a detailed climate adaptation implementation plan.

C2-2

Involve all vulnerable populations in the community to develop relevant parts of the plan, specifically taking into account the need to engage trusted leaders, meet in locations perceived as safe and convenient and at available times for those demographics, and providing transportation, childcare, and wage support as needed.

Goal C3 - Strengthen emergency management capacity to respond to weather-related emergencies.

C3-1

Train emergency responders on the risks from climate change and engage them in the process of adaptation planning and resiliency.

C3-2

Coordinate with city, county, and state emergency managers by sharing this report and engage them for response and communication planning coordination.

C3-3

Develop, test, train, and update emergency response plans that address hazards likely to become more frequent or intense as the climate changes, including flood and extreme heat. Plan for projected increases in weather-related emergencies, especially high-heat days, and the resulting potential for increased violence, mental illness, chemical dependency and addiction.

C3-4

Promote equity in hazard mitigation, and emergency response and recovery activities, and consider populations most vulnerable to weather-related emergencies in all plans and exercises, including evacuation routes, transportation for vulnerable population groups, shelter in place locations, back-up power operations, extended access to fuel/power sources and drinking water, etc.

C3-5

After weather-related emergency events, assess response to identify effectiveness, deficiencies and resources needed to build future resilience.

C3-6

Through training, educational materials and other resources, strengthen capabilities of individuals and organizations that assist in disaster response as well as community/cultural groups to prepare for potential climate change impacts, including disproportionate impacts on populations most vulnerable to climate change risks.

C3-7

Create map of key infrastructure vulnerabilities and level of risk.

C3-8

During Hazard Mitigation Plan Update process include climate change risk assessment and incorporate climate adaptation strategies into planning process.

Goal C4 - Improve the capacity of the community, especially populations most vulnerable to climate change risks, to understand, prepare for and respond to climate impacts.

C4-1

Create and make available an Emergency Response Toolkit offering tips and suggestions for residents to increase their emergency preparedness.

C4-2

Outreach to local community groups representing vulnerable populations outlined in this document (churches, minority representatives, senior center and supportive groups, etc.) and develop a coordinated communication plan to reach vulnerable populations.

C4-3

Link low-income populations, communities of color, older adults and people with disabilities to services that help reduce safety, health and financial risks associated with climate change impacts.

C4-4

Build capacity and leadership within communities most vulnerable to climate change impacts by promoting, supporting and leveraging community-specific strategies, projects and events.

C4-5

Invest in research projects that identify local vulnerabilities and the most appropriate region-specific strategies.

Goal C5 - Enhance resilience of critical city operations.

C5-1

Establish mutual aid agreements with neighboring law enforcement, fire, first responders and utilities.

C5-2

Conduct climate change impacts and adaptation training for law enforcement, fire, first responders, and utilities.

C5-3

Develop emergency response plans that include information on increased risks and vulnerabilities from climate change.

C5-4

Explore feasibility of establishing a solar micro-grid serving community facilities and supporting critical operations power backup.

C5-5

Decrease impervious areas and increase the total eco-roof acreage of public buildings (green roof, cool roof, etc.).

Goal C6 - Enhance city's capacity for adaptation implementation.

C6-1

Engage in available support for local leaders to establish or enhance emergency shelters:
<https://www.disasterassistance.gov/get-assistance/community-leaders?queryString=shelter%20housing>

C6-2

Participate in programs that evaluate and share city practices and provide technical support, such as the GreenStep Cities program and the Regional Indicators Initiative.

C6-3

Identify funding and financing opportunities to pay for adaptation and resiliency planning and project implementation

C6-4

Create cross jurisdictional partnerships that pool resources to protect vulnerable assets and increase capacity to respond to emergencies.

C6-5

Identify staff responsible for City preparedness, emergency response, and recovery efforts for each type of event and risk identified in this report.

Goal C7 - Secure funding to support City's adaptation efforts.

C7-1

Explore development of sustainability / carbon / or climate fund.

C7-2

Develop a list of projects and a list of potential grant or other funding opportunities.

C7-3

Examine how existing funding sources can be leveraged to enhance resilience and climate adaptation.

C7-4

Leverage Community Development Block Grants from the Department of Housing and Urban Development (HUD) to invest in resilient and equitable communities:

https://www.hud.gov/program_offices/comm_planning/communitydevelopment ;
<https://www.hudexchange.info/programs/cdbg-state/state-cdbg-program-eligibility-requirements/>
<https://www.hudexchange.info/grantees/minnesota/?program=2>



Strategies Responding to Heat Stress And Extreme Weather

Goal H1 - Strengthen emergency management capacity to respond to heat stress and extreme weather.

H1-1

Plan and establish alternative or on-site power supply.

H1-2

Develop energy management plans for key facilities and cooling centers.

H1-3

Identify key risk areas and infrastructure that is at risk from high heat or extreme weather. Train and educate emergency responders about this risk.

H1-4

Develop, test, train, and update emergency response plans that address hazards likely to become more frequent or intense as the climate changes, including heat stress and extreme weather.

H1-5

Create map of key infrastructure vulnerabilities and level of risk.

H1-6

Make emergency communications available in multiple languages and platforms. The City's top non-English languages should be addressed in the multiple-language communication plan. Platforms used should focus specifically on reaching the City's top vulnerable populations identified in this report.

H1-7

Develop communication plan, methods, and pathways for when community power and communication systems are non-functional.

Goal H2 - Minimize health issues caused by extreme heat days, especially for populations most vulnerable to heat.

H2-1

Create a Heat Response Plan, in coordination with the County if appropriate, based on Minnesota Department of Health Extreme Heat Toolkit - (mid-cost)

H2-2

Partner with community-based organizations and local service providers to seniors and people with disabilities to assess the need for and coordinate the operation of cooling environments, including extended hours of Senior Center Operations, which are culturally appropriate and readily accessible (low-mid cost).

H2-3

Improve the energy efficiency of homes, apartments and commercial buildings to keep interiors cool, improving the comfort and safety of occupants and reducing the need for summer air conditioning. Encourage the planting of trees and vegetation on the south and west sides of homes and buildings to reduce summer heat gain (mid-cost). Job creation opportunity.

H2-4

Ensure public safety staff is properly trained to recognize and respond to physical and behavioral signs of heat related illness (mid-low cost).

H2-5

Create a reverse 911 call system where public health officials call vulnerable individuals during extreme heat events (mid-low cost).

H2-6

Create an interactive and easy to use website that maps all area cooling centers and provides advice and information on how to stay safe during high heat events (mid-cost).

H2-7

Provide travel vouchers to vulnerable individuals to use during high heat emergencies since lack of transportation is highly correlated to heat vulnerability (mid cost).

H2-8

Provide indoor cooling centers and outdoor cooling stations (mid-cost).

H2-9

Implement a heat alert and response program to prevent heat-related illness and death (mid-cost).

H2-10

Increase in heat education at community centers, parks, pools, and City facilities (low-cost).

H2-11

Make air conditioned public facilities available during poor air quality days and high heat days

Goal H3 - Improve the capacity of the community, especially populations most vulnerable to climate change risks, to understand, prepare for and respond to high heat and extreme weather.

H3-1

Expand the capacity to educate health care providers to recognize and report patterns of heat-related illnesses and injuries, and to inform the public about preventive actions.

H3-2

Provide education and resources about climate risks to the public, especially those most vulnerable to potential impacts of high-heat and extreme weather, via communication platforms typically relied upon for information by those populations.

H3-3

Develop and distribute culturally appropriate and accessible materials about extreme heat and related respiratory-illness, especially to populations most vulnerable to those impacts, via communication platforms typically relied upon for information by those populations.

Goal H4 - Decrease the urban heat island effect, especially in areas with populations most vulnerable to heat.

H4-1

Develop an outreach campaign coordinated with local social non-profits and community groups to help build awareness of heat island risks and establish a foundation for action,.

H4-2

Identify vulnerable urban tree canopy and street tree sections and develop policies to incentivize, encourage, or require strategic tree planting for heat island mitigation (mid-cost).

H4-3

Develop policies and programs which decrease impervious surfaces, especially in neighborhoods of increased vulnerable populations (high-cost).

H4-4

Research, evaluate and pilot porous paving, de-paving, vegetation and/or more reflective surfaces in parking areas to reduce and cool impervious surfaces, particularly in urban heat island areas with populations most vulnerable to heat (high-cost).

H4-5

Add or modify park plantings in under-served areas, and increase maintenance to sustain mature tree canopy, decrease tree hazards and delay tree replacement needs (mid-cost).

H4-6

Reduce generation of waste heat from buildings by promoting and incentivizing building energy efficiency measures (low-cost).

H4-7

Consider building and development standards/policies/ordinances (applicable to public buildings, to PUDs, and to private-sector buildings which receive public funding/resources) to increase vegetative cover and increase the solar reflective quality of surfaces (mid-cost).

H4-8

Explore creation of a Heat Island Reduction Incentive / Award program. Incentives and awards from governments, utilities, and other organizations can be an effective way to spur individual heat island reduction actions. Incentives might include below-market loans, tax breaks, product rebates, grants, and giveaways. (Determine the optimum balance for achieving climate adaptation goals of incentives vs. potential loss of tax base needed to accomplish those goals.) Awards can reward exemplary work, highlight innovation, and promote solutions across the public and private sectors.

H4-9

Create incentive programs for cool roofs and green roofs. Develop policies/ordinances (for public buildings, PUDs, and private-sector buildings which receive public funding/resources) that require all new roofs meet cool roof standards if applicable. Utilize reach code if adopted as option for State Building Code. (See CA Title 24 Cool Roof Requirement as an example:

<http://www.energy.ca.gov/title24/coolroofs/documents/COOLROOF-REQUIREMENTS.PDF>) (mid-cost)

H4-10

In areas where increased tree canopy is not feasible or appropriate, design and build shading structures (high-cost).

Goal H5 - Enhance resilience of community tree canopy and park/forest land

H5-1

Conduct a City Tree Canopy and Land Cover Survey to determine the extent, quality, and opportunities for the City's tree canopy (low-cost).

H5-2

Evaluate the impact of the City's tree codes and modify to enhance protection of city's tree canopy (mid-cost).

H5-3

Develop a tree planting incentive program for residents, include a maintenance plan as part of the program (low-mid cost).

H5-4

Apply the latest climate and forestry science to develop a climate adaptive ready tree species list for use in City plantings/replacements as well as for communication to residents, building owners, and developers (low-cost). <https://www.extension.umn.edu/garden/yard-garden/trees-shrubs/recommended-trees-for-minnesota/index.html>

H5-5

Apply the latest climate science in revision of urban tree canopy goals for the City and address tree canopy disparities in neighborhoods where populations most vulnerable to heat live (low-cost).

H5-6

Participate in State and Federal urban forestry assistance programs as available (funding opportunity)

H5-7

Build community gravel beds to raise bare root tree stock with more fibrous root systems that have greater resilience at lower cost for transplantation to parks and boulevards:

<http://www.mntreesource.com/gravel-beds.html>

H5-8

Create a Citizen Pruner program that assists city staff focused on large tree removals and mature trees by having residents help young trees grow properly and not become public safety hazards:

<http://www.mntreesource.com/citizen-pruner.html>

Goal H6 - Enhance the resilience of buildings within the community to extreme heat, weather, and energy and fuel disruptions.

H6-1

Make a property-assessed clean energy (PACE) program available for conservation and renewable energy (low cost).

H6-2

Promote businesses and residents exploring making their building sites solar resilient:

<http://solarresilient.org/>

H6-3

Adopt policies to incentivize building owners to increase the resilience of existing and new buildings with resilience strategies such as elevated HVAC and electrical off basement floor, installation of backflow preventers, tree maintenance, permeable pavements, energy conservation and on-site renewable energy generation, and safe rooms.

Goal H7 - Improve the energy efficiency and weatherization of homes and businesses to reduce energy costs and carbon pollution.

H7 - 1

Explore development of a Living Buildings or Living Community district: <https://living-future.org/lcc/>

H7-2

Create a building weatherization program that includes a job training component:

<https://risingsunenergy.org/>

H7-3

Promote the Weatherization Assistance Program to lower income families and homeowners:

<https://mn.gov/commerce/consumers/consumer-assistance/weatherization/>

Goal H8 - Expand access to distributed solar energy in low-income communities in order to lower energy bills, increase access to air conditioning, and decrease carbon pollution levels.

H8 -1

Participate in federal, state, and local utility programs that incentivize the implementation of wind and solar power generation (low-cost).

H8-2

Consider promoting the development or use of community solar gardens (CSGs) by public and private entities to enable fuller and more economic use of the community's solar resource, including participating as subscribers, assisting in marketing CSG opportunities for economic development, or providing sites for gardens (low cost).

H8-3

Establish NET Metering and/or a Solar Feed-in-Tariff as part of the local utility to expand local rooftop solar (mid-cost).

H8-4

Fight energy poverty by bringing no-cost solar energy systems to low-income families on public energy assistance: <https://www.rreal.org/solar-assistance>

H8-5

Explore Solar+Storage for low- and moderate-income communities:
<https://www.cesa.org/projects/energy-storage-technology-advancement-partnership/>

Goal H9 - Enhance resilience of local businesses to extreme weather.

H9-1

Identify local measures to address impacts to local economies, local resources, and infrastructure systems as a result of more frequent or severe weather events.

H9-2

Identify local initiatives as cost-saving measures that may, as a result, lower energy consumption, reduce the generation of greenhouse gas emissions, preserve water supply, reduce municipal waste, or increase participation in recycling programs.

H9-3

Identify the unique challenges faced by local businesses during extreme weather events.

Goal H10 - Strengthen social cohesion and networks to increase support during extreme weather events.

H10-1

Strengthen City's Heat Response Plan through collaboration with community stakeholders and populations most vulnerable to heat.

H10-2

Work with health care and social services providers to ensure their ability to provide appropriate services during extreme heat events.

H10-3

Work with community groups, churches, synagogues, and mosques that serve vulnerable populations to develop targeted support and outreach about the dangers of heat (mid-low cost)

H10-4

Set up call trees and block networks to check on neighbors during/after extreme weather events especially involving grid disruption.

H10-5

Improve the safety and walkability of neighborhood sidewalks to increase foot traffic and opportunities for community interaction and easy access to neighborhood businesses.

H10-6

Increase affordability and accessibility of transit options to improve ridership and strengthen facial recognition among residents in the neighborhood.

Goal H11 - Increase the resilience of natural and built systems to adapt to increased timeframes between precipitation and increased drought conditions.

H11-1

Determine stormwater volume requirements meeting anticipated future storm levels and identify stormwater management systems and infrastructure not capable of meeting projected needs. Prioritize upgrades required and implement. (mid-cost) (should be top priority)

H11-2

Adopt innovative techniques such as vegetated streets to provide habitat diversity and connectivity co-benefits while improving stormwater management. (mid-high cost)

Goal H12 - Enhance the reliability of the grid during high heat events to minimize fires, brownouts and blackouts.

H12-1

Work with local electric utilities to conduct a grid capacity and conditions assessment. Assessment recommendations should also identify renewable energy capacities and potentials including renewable energy back up.



Strategies Responding to Air Quality Impacts

Goal A1 - Reduce auto-generated particulate matter, tailpipe pollutants, waste heat, and ozone formation.

A1-1

Add bike racks around neighborhood businesses and community gathering places to reduce vehicle exhaust from driving and idling. (Medium cost)

A1-2

Install roadside vegetation that creates effective barriers to prevent drifting of air pollutants to adjacent schools and residences. (Medium cost)

A1-3

Conduct a Public Transit and bike infrastructure study and establish appropriate community wide bike infrastructure (low cost).

A1-4

Measure City transportation connectivity using Center for Neighborhood Technology's AllTransit index. Other indices also exist for walkable neighborhoods, commuting by bicycle, and commuting by walking (low).

A1-5

Develop and implement an Electric Vehicle "EV Ready" strategy plan (low cost).

A1-6

Reduce generation of waste heat from mobile sources by promoting and incentivizing public transit, biking and walking. (low-mid cost)

A1-7

Plan, design and maintain infrastructure to accommodate emerging autonomous vehicle technology and shared-ride economy strategies.

Goal A2 - Increase and maintain air quality for residents and businesses.

A2-1

Improve the weatherization and ventilation of homes, apartments and commercial buildings. Weatherization or retrofitting may include: installing storm windows, weather stripping, caulking, insulation. Methods of ventilating buildings and maintaining acceptable thermal conditions using resilient or passive design strategies should be a priority.

A2-2

Promote public awareness of air quality considerations and improvement strategies.

A2-3

Create a building weatherization program that includes a job training component (<https://risingsunenergy.org/>)

A2-4

Promote the Weatherization Assistance Program to lower income families and homeowners: <https://mn.gov/commerce/consumers/consumer-assistance/weatherization/>

A2-5

Establish a Green Roof policy to promote and advance the development of green roofs on existing buildings and new construction. Encourage rooftop garden / farm installations which advance food security. For a review of existing greenroof policies throughout the US review: http://www.traversecitymi.gov/downloads/green_roof_policies_incentives_programs_case_studies_32014.pdf

A2-6

Enhance street scape plantings and tree canopies, especially in areas of high traffic volumes.

A2-7

Explore use of the EPA Midwest Clean Diesel Program resources to create enhanced City policies and ordinances. The Clean Diesel Program provides support for projects that protect human health and improve air quality by reducing harmful emissions from diesel engines. This program includes grants and rebates funded under the Diesel Emissions Reduction Act (DERA).

<https://www.epa.gov/cleandiesel/midwest-clean-diesel-initiative>

A2-8

Explore use of the EPA Midwest Clean Diesel Program Funding to create incentives and support for City Operations and community businesses in the transition of fleets to Clean Diesel fleets. The Clean Diesel Program provides support for projects that protect human health and improve air quality by reducing harmful emissions from diesel engines. This program includes grants and rebates funded under the Diesel Emissions Reduction Act (DERA). <https://www.epa.gov/cleandiesel/midwest-clean-diesel-initiative>

A2-9

Conduct education and outreach on the health impacts of air pollution, longer allergy seasons, and extreme heat events.



Strategies Responding To Flood Vulnerability

Goal F1 -

Strengthen emergency management capacity to respond to flood-related emergencies.

F1-1

Plan and establish alternative or on-site power supply, especially those from renewable resources such as Solar.

F1-2

Develop energy management plans for water supply and wastewater treatment facilities and infrastructure.

F1-3

Build flood barriers to protect infrastructure, especially water and waste water infrastructure.

F1-4

Identify key risk areas and the infrastructure that is at risk from flooding. Train and educate emergency responders about this risk.

F1-5

Develop, test, train, and update emergency response plans that address hazards likely to become more frequent or intense as the climate changes, including flash flooding and unseasonal riverine flooding.

F1-6

Create map of key infrastructure vulnerabilities and level of risk.

F1-7

Incorporate trees and vegetation into complete street design.

Goal F2 -

Increase the resilience of the natural and built environment to more intense rain events and associated flooding.

F2-1

Identify and address vulnerabilities in local infrastructure as a result of increased frequency and severity of storms and rainfall. (Mid cost).

F2-2

Determine stormwater volume requirements meeting anticipated future storm levels and identify stormwater management systems and infrastructure not capable of meeting projected needs. Prioritize upgrades required and implement. Integrate upgrades into already scheduled maintenance programs and budgets. (Mid cost)

F2-3

Review city codes, drainage rules, and surface waterways to evaluate their ability to protect and improve stream flows, seeps, springs, wetland function, water quality including temperature, vegetation and habitat, and stormwater management during periods of extreme heavy rain. Use the Natural Resource Inventory and other data to track gains and losses, and propose revisions as necessary.

F2-4

Explore new and support expansion of voluntary programs promoting increased on-site storm water management such as rain gardens and impervious surfaces (low-cost).

F2-5

Adopt a storm water credit system to incentivize on-site management.

F2-6

Provide education and resources about climate risks to the public, especially those most vulnerable to potential impacts of flooding.

F2-7

Provide education to residents on what actions they can take to reduce their risk to extreme precipitation events and flash flooding.



Goal V1 -

Strategies Responding To Vector-Borne Disease Risks

Manage the increased risk of disease due to changes in vector populations.

V1-1

Identify and prioritize risks from current and projected extreme precipitation that threaten local infrastructure, environmental quality, health, ecosystems, public safety, and economic development (low-cost). (Part of first priorities)

V1-2

Develop and distribute culturally appropriate and accessible materials about vector-borne disease prevention.

V1-3

Expand the capacity to educate health care providers to recognize and report patterns of vector-borne disease illnesses and injuries, and to inform the public about preventive actions.

V1-4

Create and maintain a Response Plan for emerging vector-borne diseases, including increased capacity for health services that are triggered by certain case thresholds.

V1-5

Adopt/enforce codes/ordinances requiring window screens, especially for rental housing facilities.

V1-6

Strengthen insect-control efforts in areas of the city with more vulnerable populations and/or increased standing water, including water collected in abandoned refuse/tires/furnishings/etc

V1-7

Conduct education and outreach on the health impacts of vector-borne disease and strategies for avoidance.

V1-8

Strengthen insect-control efforts in areas of the city with more vulnerable populations and/or increased standing water, including water collected in abandoned refuse/tires/furnishings/etc.



Goal FI-1 -

Strategies Responding To Food Insecurity And Foodborne Disease Risks

Increase food security for residents, especially those most vulnerable to food environment.

FI1-1

Conduct a detailed Food Security Assessment to determine food insecurity conditions within the City, target areas within the City for improvement, and identify detailed strategies to increase food security within City.

FI1-2

Expand the prevalence of community gardens and family gardens through the continued development, improvement, and communication of the City's urban agriculture policies and ordinances (low-cost).

FI1-3

Promote local food production, sales, and consumption and review City Codes to remove barriers for urban farming including innovative solutions such as aquaponics, hydroponics, indoor agriculture, vertical farms, etc.

FI1-4

Develop policies and ordinances which promote, encourage, or require permaculture landscaping in lieu of “traditional” lawn oriented landscaping.

FI1-5

Develop edible landscape zones for city-controlled properties and street boulevard zones where practicable (low-mid cost). (Could be similar or lower cost than existing landscaping)

FI1-6

Continue to support, collaborate on, and implement invasive species control programs (low-cost).

FI1-7

Develop pollinator friendly policies including promotion of pollinator habitats on public and private land as well as policies which restrict and eliminate neonicotinoid pesticides (low-cost).

FI1-8

Attract and promote grocery store and food market investment in food desert sections of the City. Collaborate with neighboring communities to maximize coverage. (Major priority)

FI1-9

Identify, map and prioritize food insecure areas and populations.



Strategies Enhancing Economic Resilience In Support of Climate Resilience

Goal E1 - Leverage the economic development opportunities of the Green Economy

E1-1

Leverage Community Development Block Grants from the Department of Housing and Urban Development, or HUD, to invest in resilient and equitable communities

E1-2

Conduct a Climate Economy Economic Development Assessment to identify economic development potential of climate adaptation, climate mitigation, and energy action planning.

E1-3

Develop job training programs focused on building resiliency- solar construction, weatherization, etc.

E1-4

Conduct a Community-Wide Renewable Energy Potentials Study for the City. Study should identify economic development opportunities as well as economic savings/impacts of expansion of renewable energy infrastructure within the City.

E1-5

Foster small business and green business development, particularly those which increase renewable energy, climate mitigation and adaptation resources within the community.

Goal E2 - Enhance community resilience through economic resilience

E2-1

Conduct a planning effort focused on identifying economic vulnerabilities and opportunities, especially those affecting the city’s vulnerable populations. Identify economic resilience strategies and strengthen public-private economic communications, especially with targeted group businesses (minority-owned, veteran owned, economically disadvantaged, etc). Possible example process:

<https://www.eda.gov/ceds/>

E2-2

Explore opportunities to broaden the City’s economic base with diversification initiatives, such as targeting the development of emerging clusters or industries that (a) build on the region’s unique assets and competitive strengths; and (b) provide stability during downturns that disproportionately impact any single cluster or industry

E2-3

Work with community businesses to explore the creation of an incentivized “buy local” campaign to enhance resilience of small local businesses.

Goal E3 - Including Economic Resilience in Emergency Response Planning

E3-1

Make sure key business infrastructure is recognized in the City and County's general hazard mitigation plan and emergency response plan.

E3-2

Analyze how risks and hazards identified in this report and the City / County's emergency response plan may impact the economic community. Conduct outreach to industry groups and public-private partnerships to promote private sector investment addressing them

E3-3

Explore use of geographic information systems (GIS) to link with municipal business licenses, tax information, and other business establishment data bases to track local and regional "churn" and available development sites as well as integrated hazard information to make rapid post-incident impact assessments.

E3-4

Ensure redundancy in telecommunications and broadband networks to protect commerce and public safety in the event of natural or manmade disasters

E3-5

Facilitate in-person discussions with community businesses to build relationships and prepare City's business community for risks and hazards identified in this report and the City / County's emergency response plan, and identify the businesses and infrastructure that are most vulnerable to disaster.



Section

12

Possible Funding



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Possible Funding

Many of the strategies for increasing climate resilience can be done for little to no costs. Some strategies, however, come with a cost which may be more than the City can cover within the desired implementation timeframe. Increasingly, funding for local climate adaptation and resilience projects must draw on a range of public and private financing. For instance, groups may apply for federal grant funding, work through public/private partnerships, and/or fund projects through local taxes.

In the United States, a range of government entities and private foundations offer financial and technical resources to advance local adaptation and mitigation efforts. For your convenience, we've listed some of them here.

EPA Smart Growth Grants and Other Funding

The U.S. Environmental Protection Agency's Office of Sustainable Communities occasionally offers grants to support activities that improve the quality of development and protect human health and the environment.

<https://www.epa.gov/smartgrowth/epa-smart-growth-grants-and-other-funding>

Partnership for Sustainable Communities

The U.S. Department of Housing and Urban Development (HUD), U.S. Department of Transportation (DOT), and the U.S. Environmental Protection Agency (EPA) work together to help communities nationwide improve access to affordable housing, increase transportation options, and lower transportation costs while protecting the environment. The site's map of grants shows information on awards already made through Partnership programs.

<https://www.sustainablecommunities.gov/partnership-resources>

<https://www.sustainablecommunities.gov/content/grants-your-community>

FEMA (Federal Emergency Management Agency) Preparedness (Non-Disaster) Grants

FEMA provides state and local governments with preparedness program funding to enhance the capacity of their emergency responders to prevent, respond to, and recover from a range of hazards.

<https://www.fema.gov/preparedness-non-disaster-grants>

FEMA Hazard Mitigation Assistance

FEMA's Hazard Mitigation Assistance grant programs provide funding to protect life and property from future natural disasters. <https://www.fema.gov/hazard-mitigation-assistance>

- [Hazard Mitigation Grant Program \(HMGP\)](https://www.fema.gov/hazard-mitigation-grant-program) assists in implementing long-term hazard mitigation measures following a major disaster. <https://www.fema.gov/hazard-mitigation-grant-program>
- [Pre-Disaster Mitigation \(PDM\)](https://www.fema.gov/pre-disaster-mitigation-grant-program) provides funds for hazard mitigation planning and projects on an annual basis. <https://www.fema.gov/pre-disaster-mitigation-grant-program> <https://www.fema.gov/pre-disaster-mitigation-grant-program>
- [Flood Mitigation Assistance \(FMA\)](https://www.fema.gov/flood-mitigation-assistance-grant-program) provides funds for projects to reduce or eliminate risk of flood damage to buildings that are insured under the National Flood Insurance Program (NFIP) on an annual basis. <https://www.fema.gov/flood-mitigation-assistance-grant-program>

Drought Recovery Information

This page from the National Integrated Drought Information System describes support that may be available through federal agencies for both short- and long-term impacts of drought. Links lead to information regarding financial and technical assistance, disaster assistance programs, economic injury loans, and assistance in implementing conservation practices. <https://www.drought.gov/drought/search/site/resources%20OR%20recovery>

Clean Diesel Program

The Clean Diesel Program provides support for projects that protect human health and improve air quality by reducing harmful emissions from diesel engines. This program includes grants and rebates funded under the Diesel Emissions Reduction Act (DERA). <https://www.epa.gov/cleandiesel>

USDA Natural Resources Conservation Service

NRCS offers voluntary programs to eligible landowners and agricultural producers to provide financial and technical assistance to help manage natural resources in a sustainable manner.

<https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/>

Programs include:

- The **Agricultural Management Assistance Program** helps agricultural producers use conservation to manage risk and address natural resource issues through natural resources conservation.
<https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/programs/financial/ama/?cid=stelprdb1242818>
- **Conservation Innovation Grants** offer funding opportunities at the state level to stimulate the development and adoption of innovative conservation approaches and technologies that leverage federal investment in environmental enhancement and protection.
<https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/cig/>
- The **Conservation Stewardship Program** helps agricultural producers maintain and improve their existing conservation systems and adopt additional conservation activities to address priority resources concerns. Participants earn CSP payments for conservation performance—the higher the performance, the higher the payment.
<https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/programs/financial/csp/?cid=stelprdb1242683>
- The **Environmental Quality Incentives Program** provides financial and technical assistance to agricultural producers in order to address natural resource concerns and deliver environmental benefits, such as improved water and air quality, conserved ground and surface water, reduced soil erosion and sedimentation, or improved or created wildlife habitat.
<https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/programs/financial/eqip/?cid=stelprdb1242633>

Federal Funding Compendium for Urban Heat Adaptation

The Georgetown Climate Center produced an in-depth document that collected and analyzed information relating to 44 separate federal programs that could support cities and states in reducing the impacts of urban heat. While federal funding sources are often dependent on appropriations, this list may be useful for finding federal funding opportunities for climate-related work.

<http://www.georgetownclimate.org/files/report/Federal%20Funding%20Compendium%20for%20Urban%20Heat%20Adaptation.pdf>

Tribal Climate Change Guide to Funding, Science, Programs and Adaptation Plans

This sortable spreadsheet can help tribes find potential funding sources and other resources. Maintained by University of Oregon. <http://tribalclimateguide.uoregon.edu/>

Kresge Environment Program

The Kresge Foundation Environment Program seeks to help communities build resilience in the face of climate change. They invest in climate resilience through two primary strategies:

1. Accelerating place-based innovation through support to efforts that are anchored in cities and have a strong potential to serve as models.
2. Building the climate-resilience field by supporting activities to disseminate and bring to scale promising climate-resilience approaches. <http://kresge.org/programs/environment>

Quadratec Cares 'Energize The Environment' Grant Program

This program offers two \$3,500 grants per year, one each in the spring and fall, to an individual or group implementing a program designed to benefit the environment. Examples of projects the program may fund include trail building or restoration, community environmental educational projects, and youth educational engagement events. Proposers write and submit a 1000-1600 word essay to apply for the grants. Entries for the fall grant are due on June 30th; entries for the spring grant are due October 30th. <https://www.quadratec.com/page/quadratec-cares-grant-program>

Wildlife Conservation Society's Climate Adaptation Fund

This fund supports projects that demonstrate effective interventions for wildlife adaptation to climate change. <http://wscclimateadaptationfund.org/>

Climate Solutions University

The Climate Solutions University aids rural communities by offering training, expertise, and support in climate adaptation planning through a peer-learning network. In the past, the organization has offered two distance-learning programs: the Climate Adaptation Plan Development Program focuses on forest and water resource resilience, and the Climate Adaptation Plan Implementation Program supports participants in moving the plan into action. <http://www.mfpp.org/csu/>

Open Space Institute Resilient Landscape Initiative

The Resilient Landscapes Initiative, supported by the Doris Duke Charitable Foundation, offers two types of grants for specified locations in the eastern United States. The group's Capital Grants help land trusts and public agencies increase the conservation of resilient landscapes in areas that represent critical climate priorities. The group's Catalyst Grants help land trusts and public agencies build the knowledge base of key audiences and advance the practical application of climate science. <https://www.openspaceinstitute.org/funds/resilient-landscapes-funds>

Section

13

Conclusions and Next Steps



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“

It's a collective endeavour. It's a collective accountability.

Christine Lagarde, Managing Director, IMF

The City of Duluth has already seen climate changes. The projections for the City's climate by the middle of this century indicate continued increases in temperatures. Additionally, precipitation patterns are anticipated to change, providing an increase in the overall rainfall as well as an increase in the number of days without rain - exacerbating both flooding and drought potential.

The projected changes to Duluth climate represent stressors for both the environment and people. Urban tree canopies as well as urban populations have unique vulnerabilities associated with the projected climate changes for the City of Duluth.

Next Steps

We recommend that the City of Duluth conduct and develop a Adaptation Implementation Plan. This effort should focus on refining and applying the adaptation strategies included in this report to the specific geographic features, habitats, city infrastructure, and city neighborhoods with higher concentrations of the demographic sectors most vulnerable to the projected climate change risks. An implementation planning effort should focus on a community outreach process to develop support for the finalized strategies as well as to begin the process of developing public awareness and engagement in implementing the adaptation strategies.

Specific recommended next steps are:

- 1) Integrate appropriate content, findings, and recommendations from this Population Vulnerability and Climate Adaptation Framework into the City's Comprehensive Plan.
- 2) Identify resources within the community which serve, or can serve, as emergency shelters and cooling centers. Evaluate each resource.
- 3) Conduct a "Blue spot" flash flood mapping, or Flood Index assessment of community to identify potential flash flood prone zones within community based on mid-century projected rainfall volumes.
- 4) Assess community's water system for flood resilience and water borne disease risk and preparedness.
- 5) Engage City Staff in reviewing the data and findings of this report for feedback.
- 6) Engage the public for review of key concepts and data of this report and for feedback on adaptation goals and strategies. The City could include a review of Climate Mitigation strategies in this effort as well (energy efficiency, renewable energy, and greenhouse gas emission reduction strategies).
- 7) Develop a Climate Adaptation Implementation Plan. The Implementation Plan should include:
 - A) Refinement and finalization of City Adaptation Goals and Strategies.
 - B) Delineation of the individuals and departments responsible for the implementation of each strategy.
 - C) Identification of how the implementation of each strategy will be monitored / reported, and appropriate metrics for measurement of effectiveness of strategy.
 - D) Development of a Climate Vulnerability Communication Strategy for English as well as limited English speakers. The Communication Strategy should target the primary languages identified in Section 9, Page 9-9 of this report. Strategies should include development of translated messages as well as the development/expansion of trusted and effective communication pathways to reach all key English and non-English speaking demographic groups in the City.

S e c t i o n

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Appendix 1 Local Climate Risks to the Environment



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Climate change projections for the City represent potential risks. The types of risks can be organized into risks to the environment and ecosystems and risks to the population. The following is an overview of the potential risks posed by climate change for the region:

Climate Risks to the Environment

Warmer summers

Pollution control risks:

Wildfires may lead to soil erosion

Habitat risks

Greater evaporation

lower groundwater tables

Switching public water supply between surface and groundwater sources may affect the integrity of water bodies

Fish Wildlife and Plant risks:

Species that won't tolerate warmer summers may die/migrate

Biota at the southern limit of their range may disappear from ecosystems

Species may be weakened by heat and become out-competed

Essential food sources may die off or disappear, affecting the food web

Species may need to consume more water as temperature rises

Recreation and Public Water Supply Risks

More people using water for recreation may raise the potential for pathogen exposure

Warmer temperatures may drive greater water demand

Evaporation losses from reservoirs and groundwater may increase

Warmer winters

Pollution Control risks:

Increased fertilizer and pesticide use due to longer growing season.

Warmer winters result in more ice and freeze thaw resulting in greater chloride application and more permanent damage to local water bodies due to increased salt concentrations.

Habitat risks:

Less snow, more rain may change the runoff/infiltration balance; base flow in streams may change

Changing spring runoff with varying snow.

Fish Wildlife and Plant risks:

Species that used to migrate away may stay all winter and species that once migrated through may stop and stay

Pests may survive winters that used to kill them and Invasive species may move into places that used to be too cold

Some plants need a "setting" cold temperature and may not receive it consistently

A longer growing season may lead to an extra reproductive cycle

Food supplies and bird migrations may be mistimed

Recreation and Public Water Supply Risks

Summer water supplies that depend on winter snow pack may be reduced or disappear

Cold places may see more freeze/thaw cycles that can affect infrastructure

Warmer water

Pollution Control risks:

Temperature criteria for discharges may be exceeded (thermal pollution)

Warmer temperatures may increase toxicity of pollutants

Higher solubility may lead to higher concentration of pollutants

Water may hold less dissolved oxygen

Higher surface temperatures may lead to stratification

Greater algae growth may occur

Parasites, bacteria may have greater survival or transmission

Habitat risks:

Warmer water may lead to greater likelihood of stratification

Desired fish may no longer be present

Warmer water may promote invasive species or disease

Fish Wildlife and Plant risks:

Newly invasive species may appear

Habitat may become unsuitably warm, for a species or its food

Heat may stress immobile biota

Oxygen capacity of water may drop

Climate Risks to the Environment

Some fish reproduction may require cold temperatures; other reproductive cycles are tied to water temperature
Parasites and diseases are enhanced by warmer water

Fish resource food harvesting, Recreation, and Public Water Supply Risks
Harmful algal blooms may be more likely
Fishing seasons and fish may become misaligned
Desired recreational fish may no longer be present
Invasive plants may clog creeks and waterways
Changes in treatment processes may be required
Increased growth of algae and microbes may affect drinking water quality

Increased drought

Pollution Control risks:

Critical-low-flow criteria for discharging may not be met
Pollutant concentrations may increase if sources stay the same and flow diminishes
Pollution sources may build up on land, followed by high-intensity flushes

Habitat risks:

Groundwater tables may drop
Base flow in streams may decrease
Stream water may become warmer
Increased human use of groundwater during drought may reduce stream baseflow
New water supply reservoirs may affect the integrity of freshwater streams

Fish Wildlife and Plant risks:

Species may not tolerate a new drought regime (birch family)
Native habitat may be affected if freshwater flow in streams is diminished or eliminated

Recreation and Public Water Supply Risks

Freshwater flows in streams may not support recreational uses
Groundwater tables may drop
Maintaining passing flows at diversions may be difficult

Increased storminess

Pollution Control risks:

Combined sewer overflows may increase
Treatment plants may go offline during intense floods
Streams may see greater erosion and scour
Urban areas may be subject to more floods
Flood control facilities (e.g., detention basins, manure management) may be inadequate
High rainfall may cause septic systems to fail

Habitat risks:

The number of storms reaching an intensity that causes problems may increase
Stronger storms may cause more intense flooding and runoff
Turbidity of surface waters may increase
Increased intensity of precipitation may yield less infiltration
Stream erosion may lead to high turbidity and greater sedimentation
Lower pH from NPS pollution may affect target species

Fish Wildlife and Plant risks:

Greater soil erosion may increase turbidity and decrease water clarity
Greater soil erosion may increase sediment deposition in estuaries, with consequences for benthic species

Recreation and Public Water Supply Risks

More frequent or more intense storms may decrease recreational opportunities
Greater nonpoint source pollution may impair recreation
Water infrastructure may be vulnerable to flooding
Flood waters may raise downstream turbidity and affect water quality

(Source: USEPA "Being Prepared for Climate Change A Workbook for Developing Risk-Based Adaptation Plans")

S e c t i o n

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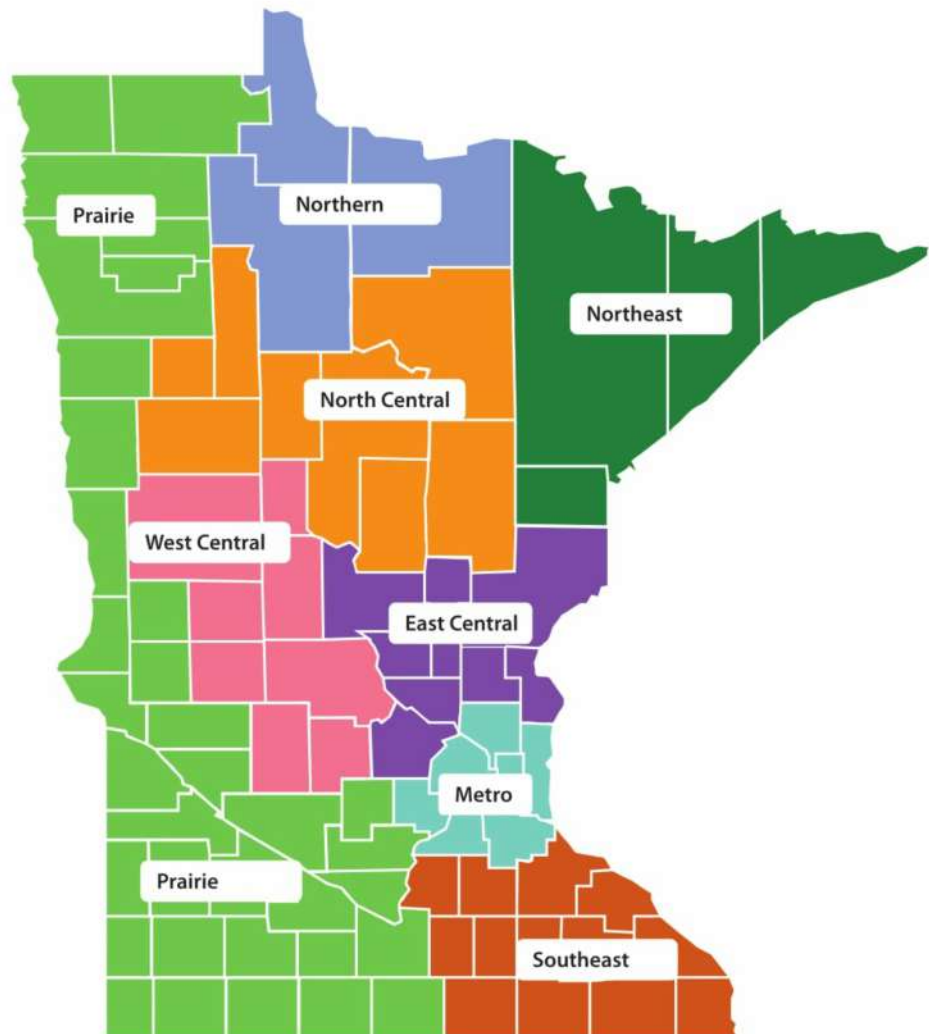
Appendix 2 Climate Adaptive Tree Species



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Trees Likely to Thrive in Minnesota's Changing Climate

The trees listed on the following page are native tree species most likely to have the greatest increase of abundance from today through 2099. These species are anticipated to have appropriate habitat requirements based on the US Forest Service Climate Change models. The map below defines regions of Minnesota in color code. To see which trees are anticipated to be climate adaptive for your region look for trees shown on the following page with a matching color square.



Information and Graphics by:



Minnesota Pollution
Control Agency





American Elm



Basswood



Black Cherry



Black Oak



Black Walnut



Boxelder



Bur Oak



Eastern Cottonwood



Hackberry



Jack Pine



Northern Red Oak



Quaking Aspen



Red Maple



Silver Maple



Sugar Maple



White Oak



White Pine



Check local tree ordinance before planting your tree.

Invasive trees and trees with low disease or insect tolerance were eliminated from the list.

S e c t i o n

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Appendix 3

Excerpt from
*Adapting to Climate
Change in
Minnesota*



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Confidence that climate change has already impacted common Minnesota weather/climate hazards

<u>Confidence</u>	<u>Hazard</u>	<u>Recent & Current Observations</u>
Highest	Extreme cold	Rapid decline in severity, frequency
	Extreme rainfall	Becoming larger and more frequent
Moderately High	Heavy snowfall	Large events more frequent
Low	Severe thunderstorms & tornadoes	Historical comparisons difficult; Few major tornadoes in MN since late 2010
Lowest	Heat waves	No recent increases or worsening
	Drought	

Source: MN DNR State Climatology Office - February 2018

Note, This chart, issued in February 2018 by the State Climatology Office is an updated version of charts provided in "Adapting to Climate Change in Minnesota", excerpts of which follow.



Confidence that climate change will impact common Minnesota weather/climate hazards beyond 2025

<u>Confidence</u>	<u>Hazard</u>	<u>Expectations beyond 2025</u>
Highest	Extreme cold	Continued rapid decline
	Extreme rainfall	Unprecedented events <u>expected</u>
High	Heat waves	Increases in severity, coverage, and duration expected
Moderately High	Drought	Increases in severity, coverage, and duration possible
Moderately Low	Heavy snowfall	Large events less frequent as winter warms
Moderately Low	Severe thunderstorms & tornadoes	More “super events” possible, even if frequency decreases

Source: MN DNR State Climatology Office - February 2018

Note, This chart, issued in February 2018 by the State Climatology Office is an updated version of charts provided in "Adapting to Climate Change in Minnesota", excerpts of which follow.

Adapting to Climate Change in Minnesota

2017 Report of the Interagency Climate Adaptation Team

Report Excerpt



May 2017

Projected climate changes in Minnesota

Continued rapid loss of cold weather extremes and enhancement of extreme precipitation

In the years and decades ahead, winter warming and increased extreme rainfall will continue to be Minnesota's two leading symptoms of climate change (see Figure 7).

Figure 7

<u>Hazard</u>	<u>Projections through century</u>	<u>Confidence in projected changes</u>
Extreme cold	Continued loss of cold extremes and dramatic warming of coldest conditions	Highest
Extreme rainfall	Continued increase in frequency and magnitude; unprecedented flash-floods	
Heat waves	More hot days with increases in severity, coverage, and duration of heat waves	High
Drought	More days between precipitation events, leading to increased drought severity, coverage, and duration	Moderately High
Heavy snowfall	Large events less frequent as winter warms, but occasional very large snowfalls	Moderately low
Severe thunderstorms & tornadoes	More "super events" possible, even if frequency decreases	

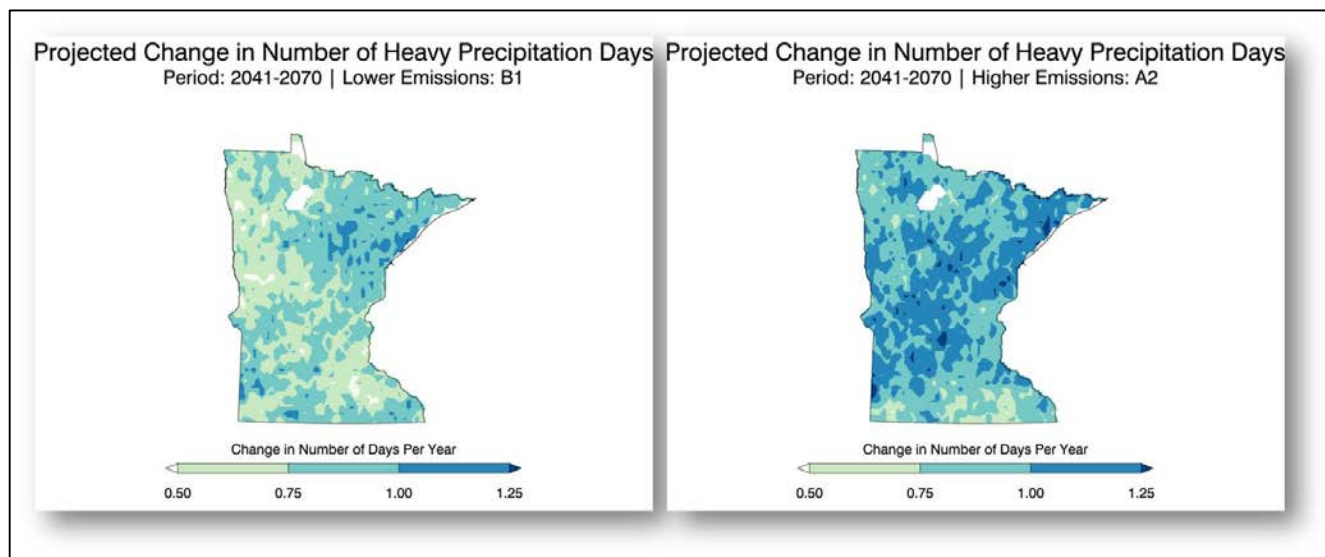
Lowest	Low	Moderately Low	Moderately High	High	Highest
---------------	------------	-----------------------	------------------------	-------------	----------------

Confidence Scale

Snapshot of projected and expected trends among common weather hazards in Minnesota, and confidence that those hazards will change (further) through the year 2099 in response to climate change. Graphic based on information from 2014 National Climate Assessment, and data analyzed by the Minnesota DNR State Climatology Office.

Greenhouse gas concentrations will continue rising through the century, and the air's ability to trap heat from the earth's surface will increase accordingly. As a result, winters, and cold conditions in particular, will continue warming well beyond historical bounds. Continued warming of the atmosphere will evaporate even more water into the air, further limiting the amount of cooling Minnesota will be able to achieve at night and during the winter. This increased water vapor will also enhance precipitating weather systems, continuing the trend toward more — and larger — heavy rainfall events (see Figure 8). Minnesota can expect unprecedented rainfall events during the remainder of the 21st century.

Figure 8



Projected changes by mid-century in number of days annually with heavy rainfall, defined as the upper 2% of daily precipitation for the 1971-2000 climate period. Left image is the “ensemble” or model average for a lower emissions scenario. The right image is the same, but for a higher emissions scenario. Images derived from output used for the 2014 National Climate Assessment, courtesy of GLISA (Great Lakes Integrated Science + Assessments).

More hot days likely and more drought possible

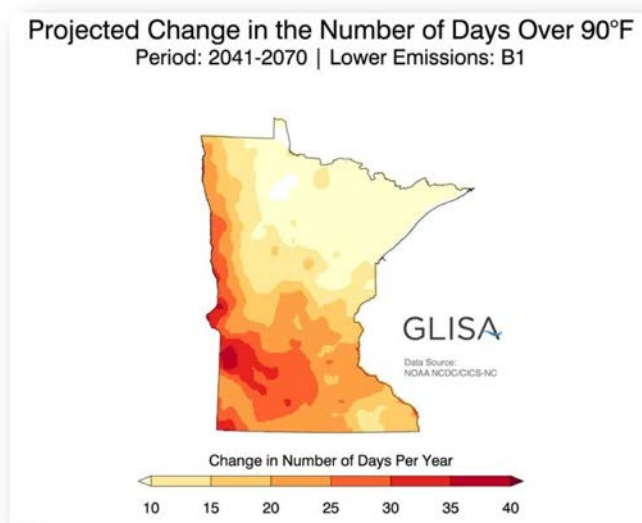
Climate models used in the 2014 National Climate Assessment project that Minnesota will have a greater tendency toward extreme heat, especially by the middle of the 21st century. Even the lower-emissions scenarios lead to significantly more hot days than Minnesota experiences presently (see Figure 9).

This projected increase is a likely outgrowth of the warmer winters, which will provide warmer baseline conditions during transition into summer, making it much easier to attain extremes of heat.

The future drought situation in Minnesota is less clear and appears to depend on how much greenhouse gas concentrations increase by mid-century (see Figure 10).

The majority of models used for the 2014 National Climate Assessment indicate that although drought will remain a part of Minnesota’s climate, the state will continue growing wetter through the century. In lower-emissions scenarios, these models project no significant change statewide in the number of consecutively dry days between precipitation events — indicating that climate change will not significantly increase drought likelihood in a given year.

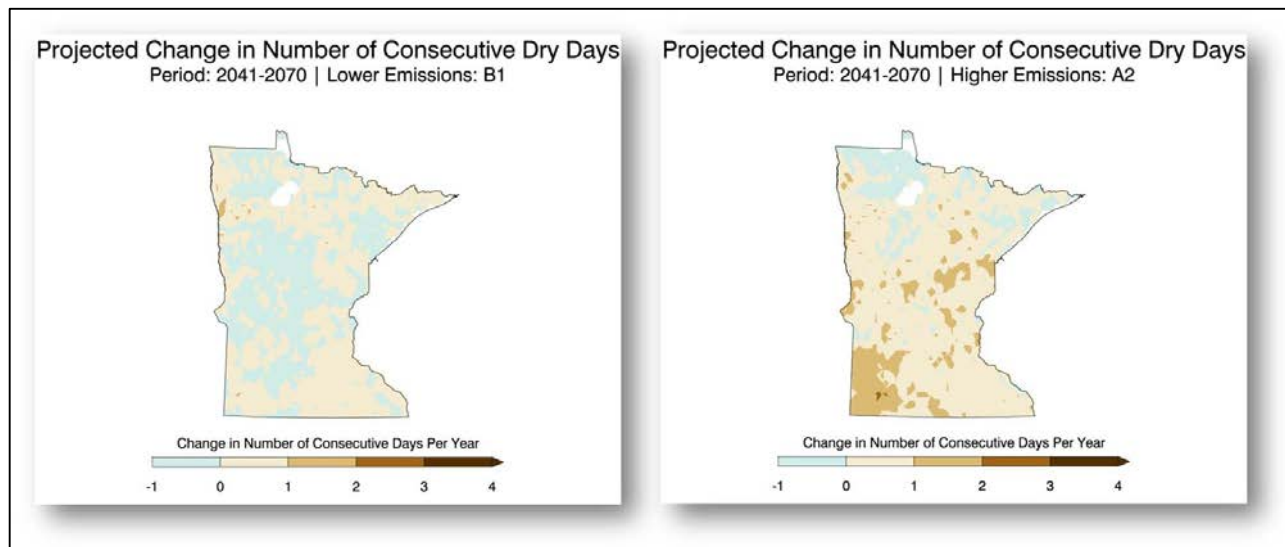
Figure 9



Projected changes by mid-century in number of days annually with high temperatures above 90°F, relative to the 1971-2000 climate period. Projection uses the “ensemble” or model average for a lower emissions scenario. Image derived from output used for the 2014 National Climate Assessment, courtesy of GLISA (Great Lakes Integrated Science + Assessments).

When these same models are run with higher emissions scenarios, however, they depict Minnesota becoming more prone to dry periods. Combined with dramatic increases in hot days, these dry periods would increase Minnesota's short-term, and possibly even long-term drought risk, suggesting that drought indeed could become worse as a result of climate change.

Figure 10



Projected changes by mid-century in annual average number of dry days between precipitation events. More consecutive dry days would suggest greater potential for at least short-term drought. Note that lower emissions scenario (left) yields no net change statewide, while higher emissions result in a nearly statewide increase. Both images show the “ensemble” or model averages given emissions scenarios. Images derived from output used for the 2014 National Climate Assessment, courtesy of GLISA (Great Lakes Integrated Science + Assessments).

Other hazards

The science is unclear about what will happen to the frequency and severity of tornadoes, damaging thunderstorms, and ice storms in Minnesota. It is clear that Minnesota will continue to experience all of these throughout the century, though research suggests their frequencies may decrease. Tornadoes and damaging thunderstorm hazards may become more concentrated on fewer days, indicating the potential for more “outbreaks,” even major ones, in the years and decades ahead. However, the body of research into these hazards remains quite limited, and projections of future trends will change as more research is completed.

S e c t i o n

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Appendix 4 Data References and Resources



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The following are data references and resources used for this report:

Section 1 Introduction

State of Minnesota, Department of Natural Resources
https://www.dnr.state.mn.us/climate/climate_change_info/index.html
http://glisa.umich.edu/media/files/Minn-StPaulMN_Climatology.pdf
US Climate Resilience Toolkit
<https://toolkit.climate.gov/>
Metropolitan Council, Local Planning Handbook
<https://lphonline.metc.state.mn.us/commportal>
Intergovernmental Panel on Climate Change
<http://www.ipcc.ch/>
NOAA National Centers for Environmental Information
<https://www.ngdc.noaa.gov/>
NASA
https://www.nasa.gov/mission_pages/noaa-n/climate/climate_weather.html

Section 2 Climate Change in the Midwest

US Climate Resilience Toolkit
<https://toolkit.climate.gov/>
US National Climate Assessment
<https://nca2014.globalchange.gov/>

Section 3 Climate Change in Minnesota

US Climate Resilience Toolkit
<https://toolkit.climate.gov/>
US National Climate Assessment
<https://nca2014.globalchange.gov/>
State of Minnesota, Department of Natural Resources
https://www.dnr.state.mn.us/climate/climate_change_info/index.html
http://glisa.umich.edu/media/files/Minn-StPaulMN_Climatology.pdf
https://www.dnr.state.mn.us/climate/summaries_and_publications/mega_rain_events.html
Minnesota Public Radio:
<https://www.mprnews.org/story/2015/02/02/climate-change-primer>
US EPA (January 2017 Snapshot)
<https://19january2017snapshot.epa.gov/climatechange.html>
<https://www.epa.gov/sites/production/files/2016-09/documents/climate-change-mn.pdf>

Section 4 Local Climate Change

NOAA National Centers for Environmental Information
<https://www.ncdc.noaa.gov/stormevents/choosedates.jsp?statefips=27%2CMINNESOTA>
University of Michigan, Climate Center
<http://graham-maps.miserver.it.umich.edu/ciat/home.xhtml>
US Climate Resilience Toolkit, Climate Explorer
<https://toolkit.climate.gov/climate-explorer2/>
Minnesota Public Radio:
<https://www.mprnews.org/story/2015/02/02/climate-change-primer>
Minnesota Pollution Control Agency:
<https://www.pca.state.mn.us/featured/minnesotas-new-normal-%E2%80%93-heavy-rains-%E2%80%93-poses-new-challenges>
US Climate Resilience Toolkit
<https://nca2014.globalchange.gov/report/our-changing-climate/heavy-downpours-increasing#tab2-images>
US National Climate Assessment
<https://nca2014.globalchange.gov/report/our-changing-climate/heavy-downpours-increasing#statement-16556>
Environment Minnesota Research and Policy Center
<https://environmentminnesota.org/sites/environment/files/reports/When%20It%20Rains,%20It%20Pours%20vMN.pdf>
Union of Concerned Scientists
<http://www.climatehotmap.org/global-warming-locations/minneapolis-st-paul-mn-usa.html>
DOE Databook
<http://www.asicontrols.com/wp-content/uploads/2014/05/11.jpg>

Section 5 City on The Move

University of Michigan, Climate Center
<http://graham-maps.miserver.it.umich.edu/ciat/home.xhtml>
State of Minnesota Pollution Control Agency

Section 6 Climate Risk to The Population

National Climate Assessment
<https://nca2014.globalchange.gov/highlights/report-findings/human-health>
US Global Change Research Program
<https://health2016.globalchange.gov/populations-concern>
Centers for Disease Control and Prevention
<https://www.cdc.gov/climateandhealth/brace.htm>
American Public Health Association
<http://thenationshealth.aphapublications.org/content/46/9/1.1>

Section 7 Climate Impact Multipliers

University of Minnesota, Remote Sensing and Geospatial Analysis Laboratory Department of Forest Resources
https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&ved=0ahUKEwjMqOyh5oLaAhUn8IMKHbW7BZIOFgg7MAE&url=https%3A%2F%2Fconservancy.umn.edu%2Fbitstream%2Fhandle%2F11299%2F183470%2F2015_UTC_report.pdf%3Fsequence%3D5%26isAllowed%3Dy&usg=AOvVaw0G7D-T2uTs4BCDli0-r1_2

Earth Define
<https://www.arcgis.com/home/webmap/viewer.html?webmap=e3d71d9cbb5e4a6cbe39cc48aa49c582>

State of Minnesota Pollution Control Agency
https://www.pca.state.mn.us/sites/default/files/trees_like_y_to_thrive.pdf

University of Minnesota Remote Sensing and Geospatial Analysis Laboratory
<https://rs.umn.edu/datalayers>
http://land.umn.edu/maps/impervious/landbrowse.php?year_imp=2000&type=county&county

State of Minnesota Department of Natural Resources
https://www.dnr.state.mn.us/whaf/about/scores/hydrology/impervious.html#imperv_calc

Department of Soil, Water, and Climate, University of Minnesota
<https://www.swac.umn.edu/urban-heat>

World Resources Institute, Aqueduct Water Risk Atlas
<http://www.wri.org/applications/maps/aqueduct-atlas/#x=8.00&y=0.44&s=ws!20!28!c&t=waterrisk&w=def&g=0&i=BWS-16!WSV-4!SV-2!HFO-4!DRO-4!STOR-8!GW-8!WRI-4!ECOS-2!MC-4!WCG-8!ECOV-2!&tr=ind-1!prj-1&l=3&b=terrain&m=group>

FEMA
<https://msc.fema.gov/portal/search>
National Flood Services
<http://www.floodtools.com/Map.aspx>

Section 8 Climate Resilience Indicators

United States Census Bureau
<https://factfinder.census.gov/faces/nav/jsf/pages/index.xhtml>
Data USA
<https://datausa.io/>
County Health Rankings & Roadmaps Program
<http://www.countyhealthrankings.org/app/minnesota/2017/overview>

Minnesota Pollution Control Agency
<http://mpca.maps.arcgis.com/apps/MapSeries/index.html?appid=f5bf57c8dac24404b7f8ef1717f57d00>
US EPA Environmental Justice Screen
<https://ejscreen.epa.gov/mapper/>
Centers for Disease Control
<https://svi.cdc.gov/map.aspx?txtzipcode=55428&btnzipcode=Submit>

Metropolitan Council, Local Planning Handbook
<https://lphonline.metc.state.mn.us/commportal>
Harvard University, Joint Center for Housing Studies
<http://www.jchs.harvard.edu/research/interactive-maps>

Section 9 Vulnerable Populations

United States Census Bureau
Census 2011-2015 American Community Survey 5-Year Estimates
<https://factfinder.census.gov/faces/nav/jsf/pages/index.xhtml>
United States Census Bureau, Quick Facts Table
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See also references and resources for Section 6 Climate Risk to The Population

Section 10 Findings

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See also references and resources for Section 6 Climate Risk to The Population
See also references and resources for Section 7 Climate Impact Multipliers
See also references and resources for Section 8 Climate Resilience Indicators
See also references and resources for Section 9 Vulnerable Populations



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