REGIONAL WATER PLANNING FOR CLIMATE RESILIENCE

MIDWEST ECOREGION

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EXECUTIVE SUMMARY

This report on regional water planning for climate resilience considers the specific circumstances of the Midwest Ecoregion of the United States. In our analysis, we explore climate data resources across the state to discover ways in which climate change will severely impact or hinder communities in the Midwest, particularly those in Minnesota. Climate change will cause extreme rain events, increased temperatures, and drought in the ecoregion, which will overwhelm infrastructure and leave communities in disrepair if they are not well prepared. Through research on the One Water approach to water management (too much, too little, too dirty) and several regional entities in the Midwest Ecoregion, we suggest ways in which both regional and local planning strategies can coincide to assist communities and regions as they adapt to a changing climate. The proposed strategies are split between regional and local contexts as they epitomize two types of entities with different implementation policies. The regional strategies are: "Implementing adaptation on a broad scale", "Adapting regionally with urban green infrastructure", "Performing broad-scale monitoring", and "Performing species and community-specific assessments". The local strategies are: "Adapting at the local level with urban green infrastructure", "Supporting state climatologists", "Creating a framework for local government planning", and "Implementing short term solutions".

With the strategies in place, several local case studies were created to represent different types of areas. These case studies include the cities of Ramsey (rural), Oakdale (suburban), and Minneapolis (urban). All the case studies are in the Twin Cities Metropolitan Region and within the jurisdiction of the Metropolitan Council, a Council of Governments (COG) regional planning authority in Minnesota. These case studies revealed that every city has unique water planning for climate resilience requirements while still needing to play a role in the water management goals of the larger region; while cities have the ability to adapt to climate change through narrowed and site-specific strategies, a regional entity can enforce big-picture policies to get smaller entities to move toward a similar outcome: climate-resilient communities.

INTRODUCTION

In a recent survey of its members, the American Planning Association (APA) identified climate change as the most important issue that planning professionals are facing. Because of this, there is an effort to collect policy recommendations and best practices that promote climate resiliency in the areas of water management and planning. This year, the APA Regional and Intergovernmental Planning Division (RIPD) will create a guidebook on integrated water management and climate change. To support this guidebook, the APA RIPD needs regional case studies. This report serves as the first of these case studies, addressing how climate change will impact future water management practices in the Twin Cities to represent the Midwest ecoregion and serving as an example for the other regional case studies. It includes a description of the Midwest ecoregion, the projected impacts of climate change in the ecoregion, local water management cases, and adaptation and implementation strategies for climate resilience. To assist those in other ecoregions in creating their own case studies, a how-to manual accompanies this case study that documents the process we took to create it.

FRAMING WATER ISSUES AND ONE WATER

All water issues, including those discussed in the case studies contained in this report, fall within one of three categories: too much, too little, or too dirty (shorthand for compromised quality, could also result from nutrient deficiencies or temperature changes that harm organisms). The practices seen in current water systems are designed to deal with each of these categories seen within the region. Climate change poses a threat, however, by worsening the problems (i.e. the drier parts of the Western United States will face more drought) or by introducing one of these three core problems into regions which had previously only had to deal with one or both of the others (i.e. drought occurring in Minnesota, a traditionally wetter region).

Water policy is also complicated from the outdated separation and isolation of water issues. Planners put on blinders and only see water issues as they pertain to other projects, such as conducting an environmental impact statement for a new development, or long-term goals, such as improving public health. In response, many groups involved in water management, including the American Planning Association (Cesanek et al., 2017), have called for the use of the "One Water" approach. One Water asks planners to consider all water within a watershed -- whether it is groundwater, surface water, wastewater, storm runoff, or in any other form -- as connected and to manage it through an integrated approach to meet both human and ecological needs (Cesanek et al., 2017). One Water also provides 5 core principles that help planners use this approach in their work, which are:

1. Water supply, wastewater, and stormwater and natural water systems should be planned, operated, and managed as one system.
2. All aspects of the water system should be integrated into planning for the built environment, including the linkages with land use, energy, and transportation.
3. Water is a key amenity for the city [and/ or region], in terms of urban design and reinvestment.
4. Water planning is as important for the city [and/ or region] as is land-use and transportation planning.
5. One Water values equity, environmental justice, and respect for nature.

Additional differences between the conventional and integrated approaches are shown in Figure 2 (Cesanek et al., 2017, adapted from Philip et al., 2011).

THE MIDWEST ECOREGION

For the purposes of this case study and the larger guidebook on integrated water management and climate change, ecoregions have been defined to address the unique circumstances and climate change projections for each ecoregion. The Environmental Protection Agency divides North America into a number of different ecoregions of "general similarity in ecosystems and in the type, quality, and quantity of environmental resources" (United States Environmental Protection Agency). There are 4 levels of ecoregions, level 1 (with 15 ecoregions, as shown in Figure 1), level 2 (with 50 ecoregions), level 3 (with 182 ecoregions) and level 4. Minnesota contains 3 of the continent's ecoregions: eastern temperate forests, great plains, and northern forests. The Twin Cities metropolitan area itself is on the border of the great plains and eastern temperate forest ecoregions. Wisconsin, Illinois, Indiana, Ohio, Michigan, and Missouri also are mostly composed of eastern temperate forests, while Iowa, Kansas, Nebraska, and the Dakotas are mostly within the great plains ecoregion. The eastern temperate forest ecoregion is the ecoregion of most concern to this report, but covers much of the southeast, eastern seaboard, and inland Mid-Atlantic areas too. As such, not all the climate impacts and the climate adaptation strategies discussed will be applicable throughout the entirety of the ecoregion. Notably, the National Climate Assessment (U.S. Global Change Research Program, 2014), from which some of the climate projections in this report are taken, groups Minnesota with Wisconsin, Iowa, Missouri, Illinois, Indiana, Ohio, and Michigan to make up the Midwest. These states have more in common with each other than with the other states containing eastern temperate forests. For example, the states along the east coast will be threatened by sea level rise and intense hurricanes or tropical storms, problems which the Midwest will not face. Similarly, the southeast does not have as much snow in winter and has more extreme summertime high temperatures already, so they will face slightly different problems than Minnesota will. Readers from any state may find the contents of this report useful, but the projected impacts of climate change and the policy solutions that can respond to them will be most applicable to the Midwestern states.

PROJECTED IMPACTS OF CLIMATE CHANGE FOR THE TWIN CITIES

To understand how integrated water management within the Midwest ecoregion will need to adapt to address future climate conditions, it is necessary to review the current climate projections. For the purposes of this case study, the factors that will most impact water resources will be the focus. The volume of precipitation, drought patterns, and temperature changes will therefore be the most important aspects of the climate to evaluate.

As with many other places, the Midwest will see drastic changes in precipitation patterns and overall warmer temperatures. However, the exact nature of these changes differs from other regions and from what the average person might expect. So far, the temperature increases seen in Minnesota have not come from an increase in warmer days, but a decrease in extreme cold days. Minnesota's winters have become warmer, while the summers have seen less change (even seeing lower average summertime temperatures in the southern part of the state, see Figure 6). Minnesota has also seen precipitation changes which differ from what might be expected in other regions, such as the Southwest. Minnesota and the greater Midwest (U.S. Global Change Research Program, 2014) have seen, on average, more rainfall annually. Much of the increase in annual precipitation can be attributed to larger and more frequent extreme precipitation events, with the rainiest days contributing a large proportion of the total rainfall in a year (U.S. Global Change Research Program, 2014). Since freezing temperatures are common in Minnesota and in the Midwest during winter, it is also important to look at snow and other frozen precipitation. Though the observed climate trends include an increase in the number of heavy snow events, there is less confidence that this is linked to climate change. Minnesota has so far not experienced heat waves or drought, both of which would have had significant impacts on our water resources.

Future changes in Minnesota's climate differ from the observed trends, and therefore new water management strategies must be used to deal with new problems. The two most significant observed trends, lower average winter temperatures and the increased frequency and severity of large rain events, will continue through the end of the century. Since Minnesota has been dealing with these trends already, the adaptation measures used in water management to address these problems will provide a starting point for future practices. In contrast to the rainfall, there will be a decrease in large snowfall events, due to milder winter conditions. Since the spring snowmelt in Minnesota (and much of the greater Midwest) is a significant factor in water systems, the volume of water entering surface and groundwater bodies in spring will be less than it is currently. Unfortunately, drought and heat waves will also be seen in Minnesota within the coming decades. It is likely that there will be more hot days affecting more of the state for longer durations. And while precipitation events will be larger, the time between events may become longer, leading to drought conditions. Drought and heat waves, which are common in areas of the U.S. such as southern California and the Southwest, will be new to the Midwest. New water management strategies will need to be developed to deal with these problems, and case studies from other, more drought and heat wave prone areas of the country may provide useful insight. If current trends continue, Minnesota will see summers equivalent to those in present day Wisconsin by 2030 and those seen currently in Kansas by 2095 (Johnson and Polasky, 2003). Appendix A to this report contains visualizations of the climate trends discussed in this section, including observed and projected temperature and precipitation patterns.

Climate Impacts on Water Quality and Quantity

- Increased Temperatures (Too Much, Too Little, and Too Dirty)
    - Increased temperatures (especially in urban areas with large amounts of impermeable surface) can raise the temperature of stormwater runoff entering local water bodies. This can shock the living organisms within, killing them and disrupting the balance of natural ecosystem services.

  - Earlier peak streamflow from snowmelt (Bates et al., 2008)
  - Increased water "lost" to evaporation/ transpiration (Bates et al., 2008)
  - Increased water temperatures in lakes (Bates et al., 2008)
    - Decreased nutrients
    - Increased stratification
  - Degradation of water quality (Bates et al., 2008)
    - Algal blooms
    - Increased bacterial and fungal content
    - Reduced amount of dissolved oxygen
- Increased Rainfall (Too Much)
  - Water infrastructure, which includes sewer systems (often joined with stormwater systems) and water treatment plants may be overwhelmed by the volume of water generated during heavy downpours. (Environmental Protection Agency, 2017)
  - Stormwater runoff can contain sediment, nutrients, pollutants, trash, and other materials which will negatively impact water quality, harming the living organisms within and requiring treatment before human use. (EPA, 2017)
  - Heavy precipitation events may result in the exceeding of the soil's infiltration capacity, meaning that more water runs off the landscape and less enters the ground and groundwater sources (Bates et al., 2008).
  - Increased likelihood of flash floods and urban floods (Bates et al., 2008)
  - Increased erosion from increased runoff (Bates et al., 2008)
- Drought (Too Little)

MINNESOTA WATER PLANNING IN A REGIONAL CONTEXT

With an understanding of the impacts that climate change will bring, we can now consider how regional planning is framed and define a solid example of it in the Midwest Ecoregion. Across the United States, there are several examples of regional water planning in state-run departments and boards. Aside from those, though, other organizations exist. In Minnesota, we have a couple of different agencies. First, we have what are called Regional Development Commissions which are regional governments in Minnesota made up of a board of local elected officials from counties, cities, schools boards, public interest groups and transit systems that provide cooperation and coordination on broad regional issues ("About: Who Is Mado?", 2018). As their intent is to support local governments, they frequently provide a coordinating role and generally do not exercise any type of binding authority over local matters. However, in the Twin Cities, there is a similar organization that works like a Regional Development Commission, thereby bringing us to our second regional agency example. Deemed the Metropolitan Council, its history is deeply rooted in water quality and quantity concerns. Back when it was established in 1967, the Minnesota Legislature created the Metropolitan Council as a response to "growing concerns over septic tank wastewater contamination" ("Who We Are", 2018). However, since its founding, it was recognized that systematic problems existed which went beyond the limits of coordination of any one agency. This resulted in the eventual expansion of the Council's role and powers, merging it with transit and waste control commissions to become a singular, unified regional authority. Today, the Council is a regional policy-making body, planning agency, and provider of essential services for the Twin Cities metropolitan region ("Who We Are", 2018). The overarching purpose behind the Council is to establish a consensus about the needs of an area or region and the actions needed to solve local problems ("Who We Are", 2018). Regionally, the Metropolitan Council consists of seven counties: Anoka, Carver, Dakota, Hennepin, Ramsey, Scott, and Washington. Throughout this report, the Council will be further discussed as a running example of regional policy enforcement in Minnesota.

Regional Governing Structure

The Council serves as both a Metropolitan Planning Organization (MPO) and a Council of Governments (COG) in Minnesota dependent upon which topic you are discussing. Transportation is the only part of the Council that is considered an MPO. The rest of it, including its regional authority of water quality and quantity concerns, is a COG ("Who We Are", 2018). The work of COGs is generally performed through a bottom-up approach, making the efforts of local governments in the region just as important ("Who We Are", 2018).

The Met Council currently has 17 members, 16 of which represent a geographic district in the seven-county area with one chair who serves "at large." The districts are shown in Figure 3.

The way these districts were drawn historically is according to population and geographical characteristics (e.g. population percentage or presence of natural resources). Outlying districts encompass large tracts of rural land while the Minneapolis/St Paul districts are much smaller. Again, this is due to population percentages. In some cases, such as District 3, the district encompasses entire watersheds, including all accompanying tributaries. All members of the Council are appointed by the Governor of Minnesota and are reappointed with each new governor in office. The Minnesota Senate may confirm or reject each appointment. Additionally, elected officials and citizens can share their expertise with the Council by serving on 'key advisory committees' ("Council members & districts", 2018).

The Metropolitan Council is comprised of several different divisions that cover many areas of planning as well as harbor many unique purposes. First is the Regional Administration/Chair's Office which sets the goals and direction the Council will take the metro area. It also manages finances and makes budget decisions for how shared funding and grant programs are distributed throughout the region. Second is the transportation division which, as stated before, is run differently than the rest of the Council. This division includes Metro Transit, which provides most bus services and operates both light rail and commuter rail lines. The transportation division also includes staff that support the Council's role as the Metropolitan Planning Organization (MPO) for the region. It also analyzes and develops future transportation options; however, road and street corridor planning is left to the local county and city governments. Meanwhile, the highway system is planned in coordination with the Minnesota Department of Transportation. Back under the Council of Governments (COG) system, there are three more divisions that help to shape the future of the Twin Cities metro region. The Community Development division primarily involves land use, regional, urban, and community planning decision-making. It also develops and administers long-range vision plans as well as regional and municipal frameworks. Meanwhile, the treatment of drinking water and storm runoff are left to municipalities. Next, the Municipal Urban Service Area (or MUSA). MUSA is not technically a division, but rather an 'urban growth boundary' that limits services and infrastructure needed for development. Lastly, we have the Environmental Services division (also referred to as MCES). This division addresses water quality and quantity concerns. It also has full jurisdiction over sewage treatment and wastewater treatment systems within the MUSA boundary ("Who We Are", 2018).

ENFORCING A REGIONAL VISION: MUSA AND COMPREHENSIVE PLANNING

The Metropolitan Council can only implement its own policies in select situations (Carrie, 2001). One way is through land-use planning. The Metropolitan Land Use Planning Act of 1976 (found in §473 of the Minnesota Statutes) requires all cities within the seven-county metropolitan area (with some exceptions) to adopt comprehensive plans every ten years. These guiding documents establish a city's long-term goals, including land use changes and development plans. The Metropolitan Council works with communities within the region to promote regional goals, including those related to transportation, parks, water resources, and housing. The Metropolitan Council provides assistance to communities working on their plans, notably through the issuing of community specific system statements. These system statements are based on the regional comprehensive plans (currently Thrive MSP 2040), which address regional issues (transportation, wastewater services, and parks and open space), and explain the implications of these regional plans for each specific community. After a community drafts a comprehensive plan, it must be reviewed by the Metropolitan Council to ensure conformity with regional goals before being adopted. If a community does not pass the Metropolitan Council review and fails to adopt a comprehensive plan, then the Metropolitan Council can commence civil proceedings to enforce compliance, per §473.175.

The second enforcement tool that the Metropolitan Council uses to promote its regional goals is through the Metropolitan Urban Services Area, which is a region within the Seven County Metropolitan Area where the Metropolitan Council will provide regional services and facilities, such as the sewer system. Growth is focused here because of the availability of infrastructure and utilities necessary for new development.

METROPOLITAN COUNCIL'S CURRENT WATER PLANNING STRATEGIES

The Council has a regional water planning document currently available titled "*Thrive MSP 2040*". In it, they outline several key implementation strategies for effective integrated regional water planning at the watershed level. This approach would prove to be effective as it can address both watershed restoration concerns (such as improving impaired waters) and protecting waters through maintenance of water quality in unimpaired waters ("Thrive MSP 2040 Water Resources Policy Plan", 2015). These strategies are:

- Work with the watershed management structure in the metro area on issues that "transcend watershed organization boundaries" in order to prepare water management plans that promote the protection and restoration of local and regional water resources such as lakes, rivers, streams, wetlands, and groundwater.

- Make water resources management a critical part of land use decisions, planning protocols and procedures. This will help to ensure these plans are making progress toward achieving state and regional goals for protection and restoration of water resources.

- Provide technical and financial assistance to local governments and other partners on water issues and water management activities.

- Facilitate discussions on regional water issues.

- Provide technical information to watershed organizations regarding practices to use and incorporate into their plans that are about protecting and preserving water quality.

- Support educational efforts with agricultural communities through partnership opportunities on watershed issues.

Although these strategies are not directly related to climate change adaptation, the structure and enforcement ideas behind them help lay a groundwork for how regional entities can adopt climate adaptation strategies through collaborative and educational efforts with watershed organizations, agricultural communities, and local governments.

Aside from strategies, the Council's Thrive MSP 2040 local water plan discusses elements that local communities must include in their comprehensive plans. These elements require local water plans to include a summary of the priorities and problems in the community, a description of structural, nonstructural and programmatic actions to take to address the priorities and problems, and some clearly identified funding mechanisms to fix the problems previously summarized ("Thrive MSP 2040 Water Resources Policy Plan", 2015).

Additional in-depth elements help to round-out these primary requirements of local water plans and are essential to creating more defined requirements for communities to abide by ("Thrive MSP 2040 Water Resources Policy Plan", 2015). These elements help to address problems the community is having and how they are tackling those problems. One example of a problem is flooding, which is a predicted problem that climate change is expected to bring. Although these elements do not explicitly come out and say anything about climate change, they do relate to a degree on what communities currently need to do to prepare for inevitable problems if they are expected. These in-depth elements of local water plans are:

- An executive summary that summarizes the highlights of the local water plan.

- A summary of the appropriate water resource management-related agreements that have been entered into by the local community.

- A description of the existing and proposed physical environment and land use. Data may be incorporated by reference for other required elements of this section as allowed by the Watershed Management Organization (WMO). Not all WMO plans contain the level of detail needed for communities and so communities are required to provide additional information. Also, the plan must define drainage areas, volumes, rates, and paths of stormwater runoff.

    - Runoff rates are recommended for a 24-hour precipitation event with a return frequency of 1 or 2 years. And in situations where communities are known to have flooding issues, they are required to provide rate control for storms with other return frequencies such as 10, 25, or 100-year events.

- An assessment of existing or potential water resource-related problems. At a minimum, the local water plan should include an assessment of the problems related to water quality and quantity in the community and a list of any impaired waters within their jurisdiction as shown on the current Minnesota Pollution Control Agency (MPCA) 303d Impaired Waters list. If a Watershed Restoration and Protection Strategy (WRAPS) or TMDL study has been completed for the community, the community should include implementation strategies (that includes funding mechanisms) that will allow the community to carry out the recommendations and requirements from the WRAPS or TMDL specific to that community.

- A local implementation program/plan that includes prioritized nonstructural, programmatic and structural solutions to priority problems identified as part of the assessment completed for the previous element, above. Local official controls must be enacted within six months of the approval of the local water plan. The program/plan must include areas and elevations for stormwater storage adequate to meet performance standards or official controls established in the WMO plan(s) and define water quality protection methods adequate to meet performance standards or official controls. At a minimum, the plan should include:

- Information on the types of best management practices to be used to improve stormwater quality and quantity. A five-year establishment period is recommended for native plantings and bioengineering practices.

- The maintenance schedule for the best management practices. (The maintenance schedule in plans submitted by regulated Municipal Separate Storm Sewer System (MSA) communities must be consistent with BMP inspection and maintenance requirements of the MS4 Permit)

The local implementation plan should also clearly define the responsibilities of the community from that of the WMO(s) for carrying out the implementation components and should describe official controls and any changes to official controls. This means the final proposed control plan needs to include an erosion and sediment control ordinance consistent with NPDES Construction Stormwater permit requirements and other applicable state requirements, and it must identify ways to control runoff rates so that land-altering activities do not increase peak stormwater flow from the site for a 24-hour precipitation event with a return frequency of 1 or 2 years. Communities with known flooding issues may want to require rate control for more than one type of storm event (10-year, 25-year, 100-year, or 500-year). Control plans should consider the use of NOAA Atlas 14, Volume 8 (Precipitation Frequency Atlas of the United States) to calculate precipitation amounts and stormwater runoff rates. This is recommended because the Minnesota Pollution Control Agency uses NOAA Atlas 14 in calculations to determine whether the 1" standard has been met.

The control plan should also consider the adoption of the MPCA's Minimal Impact Design Standards (MIDS) performance goals and flexible treatment options. There is an application available for download called the MIDS calculator that helps communities with calculating the effectiveness of stormwater management best practices. If communities decide not to adopt MIDS, their plans should use stormwater practices that promote infiltration/filtration and decrease impervious areas through integrated stormwater management best practices where they can.

- Include a table that briefly describes each component of the implementation program and clearly details the schedule, estimated cost, and funding sources for each component including annual budget totals

- Include a table for a capital improvement program that goes by year and provides details of each contemplated capital improvement that also includes the schedule, estimated cost, and funding source

• And lastly, the local water supply plan must provide a section titled "Amendments to Plan" that establishes the process by which amendments may be made.

The elements of the local water supply plan set forth by the Metropolitan Council are beneficial to local communities in that they fulfill requirements set by the state in Minn. Stat. sec. 103G.291 subd. 3 and 4 as well as Minnesota Administrative Rules 4720.5280 ("Thrive MSP 2040 Water Resources Policy Plan", 2015). The elements also ensure that communities are better prepared to handle droughts and water emergencies as well as better equipped to resolve water conflicts. This is important when it comes to future climate change impacts as droughts and water emergencies could be disastrous if communities do not have any adaptation or implementation strategies in place that tackle this issue. Even further, the local water supply plan also allows for the submission of funding requests and new well expansions; giving communities the capacity and improved knowledge of their unique situations can help when drafting up proposals for grants and loan programs ("Thrive MSP 2040 Water Resources Policy Plan", 2015).

Thrive MSP 2040 also includes proposed performance indicators to assist communities with quantifying the impact the program's policies are having and to help the Council reach its goals. This first set of indicators will be the test model that allows the Council to later create a more comprehensive set of indicators ("Proposed Performance Indicators for Thrive MSP 2040", 2015). But until then, the basic indicators represent distinct 'goal areas' which are: Land Use and Efficient Use of Infrastructure, Natural Resources, Transportation Choices and Accessibility, Housing Choices, Public Health and Parks, and the Principle of Equity. The only indicators that relate to water are under the Natural Resources goal area. These indicators are:

• "Household and employment growth in zones considered to be at risk of aquifer impairment, groundwater recharge areas, or regionally significant ecological areas"

and

• "Phosphorous, Nitrogen and Suspended Solids loads in the major river basins (Mississippi at Anoka and Lock and Dam #3, Minnesota at Jordan, St. Croix at Stillwater) compared to the total loads from Metropolitan Council wastewater treatment plants"

These indicators are currently not expansive enough to incorporate climate change. However, they are great at sustainably maintaining current water resources, which is a step in the right direction. If an additional goal area were to include climate change indicators, then the Council would be well on its way to achieving a well-adapted regional water and natural resource management plan.

THE COUNCIL'S REGIONAL SUSTAINABILITY GOAL

One major idea of *Thrive MSP 2040* is the idea that everything needs to be planned more sustainably. To that end, the Metropolitan Council has developed regional goals, including water sustainability, and has begun developing strategies to address the increasing localized flood risks through actions centered around the regional system plan elements: transportation and transit, parks and trails, wastewater and water resources, and housing (Metropolitan Council, 2018). These strategies are based on the National Climate Assessment projections for the Midwest region, which are also discussed in this report (U.S. Global Change Research Program, 2014). As the Metropolitan Council continues developing this resource, it could turn into a good example of regional strategies for addressing increased flooding in other regions of the Midwest ecoregion, which will face similar problems to those that will be seen in the Twin Cities.

Currently the only complete chapter of the Regional Climate Vulnerability Assessment on localized flood risk is the first chapter, which covers transportation and transit. This chapter addresses the impacts of flooding along specific transit and transportation routes throughout the region as well as proposed regional strategies headed by the Metropolitan Council (often through Metropolitan Transit) for addressing these impacts as floods worsen. These proposed strategies are listed below by type of transportation (Metropolitan Council, 2018).

- Regional Highway Network
    - Conduct an arterial assessment of vulnerable areas through collaboration with relevant road authority and stakeholders
    - Collaborate with relevant authorities and stakeholders to increase surface water infiltration, through green infrastructure practices where possible, in potential vulnerable areas
    - Plan for rerouting and alternative routes with agency and community partners
    - Facilitate the creation of a regional notification of road rerouting, similar to the Hennepin County Transportation Map
- Light Rail and Commuter Rail
    - Perform site review and audit of all Shallow & Primary rail segments
    - Document all flood areas that disrupt LRT operations and compare these to localized flooding data
    - Enact protocols for relief transit vehicles in advance of forecasted severe storms

- Assess localized flooding impacts on rail operations hardware using technical structure specifications for water infiltration
- Work with local jurisdictions and stakeholders to enact stormwater best management practices and ongoing maintenance in jurisdiction's right-of-way along LRT and commuter transit corridors
- Prioritize vulnerable station areas to communicate localized flooding potential to riders in a variety of formats and languages

- Bus Transit
  - Conduct a more detailed analysis and prioritization of all vulnerable routes and stops across the network
  - Develop rerouting plans for potential vulnerable areas on a route-by-route basis
  - Leverage local knowledge of experienced drivers for rerouting and temporary stop planning
  - Work with relevant local stakeholders to institute volunteer adopt-a-drain programs for local bus stops, using vulnerable routes and bus stop areas for prioritization
  - Prioritize vulnerable routes and bus stops to communicate localized flooding potential to riders in a variety of formats and languages
- Aviation
  - Collaborate with Metropolitan Airports Commission (MAC) to incorporate localized flood planning with existing riverine flood plans
  - Collaborate with MAC to work with local road authorities to reduce peak vulnerability on one or more access roads at St. Paul Downtown Airport
  - Expand its Climate Vulnerability Assessment Report to encompass reliever airports, with special emphasis on the St. Paul Downtown Airport
- Regional Bicycle Transportation Network
  - Convene a region-wide stakeholder planning group to assess the potential impacts of localized flooding on the RBTN network to inform current maintenance and future planning
  - Additionally, local stakeholders could:

- Assess viability and impact of access management (temporary closures) versus other solutions
- Analyze bicycle transportation alongside adaptation measures for co-use routes and transit hubs

This document also identifies five high-level outcomes which could serve as guidance for other regional governments, including those who may not be able to apply the strategies listed above due to differences in government structure and authority, which are:

1. Prioritize operations and asset management through verification of localized flooding vulnerability
2. Manage stormwater locally, on site, as much as possible
3. Ensure that flooding takes place only where it does the least damage
4. Ensure that public safety information is available for riders
5. Convene a regional stakeholder group and continue collaboration

ADAPTIVE STRATEGIES

Because communities use water for a wide array of purposes, it is important to note that these strategies encompass water utility, water quality, and ecosystem protection. Each idea holds a key and important purpose within this handbook to cover the array of problems created by climate change as well as providing a structured outline for communities to follow in the creation and revision of their water management plans. The strategies have been split according to regional and local adaptive styles.

Regional Strategies

Strategy 1 - Implementing adaptation on a broad scale

Where water resources cross boundaries, adaptation should be broad and less defined. In this instance, regional entities will become useful in protecting the quality and quantity of water available. The primary goals of broader scale adaptation systems include: increasing water supply and ecosystem services, decreasing water demand while increasing use efficiency, and improving flood protection (Hallegatte, 2008). Example actions that can be used to fulfill this strategy include engaging with senior political leaders, having periodic policy redevelopment, creating and maintaining multi-agency and stakeholder processes, and holding stronger accountability and enforcement measures of smaller communities (Pittock, 2011). An example of these goals and actions can be found in the One Watershed, One Plan program from the Minnesota Board of Water and Soil Resources. The board supports and promotes integrated water resource management that uses a watershed approach to solving soil and water resource issues. And so, in this program, they bring together different agencies that form the Local Government Water Roundtable (this includes the Association of Minnesota

Counties, Minnesota Association of Watershed Districts, and the Minnesota Association of Soil and Water Conservation Districts) (One Watershed, One Plan, 2018). The vision behind One Watershed, One Plan is to align local water planning with state strategies as they relate to watershed boundaries so that "targeted, prioritized, and measurable implementation plans" are created (One Watershed, One Plan, 2018). This allows the Board of Water and Soil Resources (a state agency) to hold stronger accountability and provide enforcement measures of smaller communities through strategic adaptation planning. The proposed transportation and transit strategies discussed in the previous section on the work of the Metropolitan Council fall under this broader strategy.

Strategy 2 - Adapting regionally with urban green infrastructure

Regional green infrastructure focuses on landscape ecology and connecting or building networks of large green spaces (usually as forests, parks, or streams) ("Regional Green Infrastructure at the Landscape Scale", 2017). This interconnectedness helps to provide ecosystem services to a larger area of stakeholders and assists in more effective climate adaptation, especially as it relates to increased precipitation. Essentially, more permeable landscaping results in more effective water retainment, like the no development sub-strategy. An example of this is the example of the Green Line light rail system in St. Paul, Minnesota, which includes permeable pavement, tree trenches, and biofiltration (Lindeke, 2014). This work was done by the Metropolitan Council as a means of adapting a larger area of transportation and water infrastructure to accommodate a greater amount of precipitation as well as to assist with groundwater recharge for water conservation purposes.

Strategy 3 - Perform broad-scale monitoring

Many sources discussed performing some form of monitoring. Therefore, it is necessary to support a network of monitoring stations for collecting important observations such as measuring rainfall, stream flows and water levels as well as surveillance programs for harmful algal blooms. Climate science that increases certainty around precipitation trends and patterns will assist in better short and long-term impact modeling. An example of this is Minnesota's Sentinel Lakes Program (SLP). In partnership with the Minnesota Pollution Control Agency, the Minnesota Department of Natural Resources aims to monitor the Sentinel Lakes region's major stressors as well as evaluate the impacts these stressors have on the biological, physical, and ecological features of lakes to promote sustainable best management practices (Reed et al, 2016). Additionally, the Environmental Services division of the Metropolitan Council performs similar assessments of surface water and works collaboratively with cities, counties, and watershed management organizations by providing a comprehensive database that allows these entities to better manage and protect surface water ("Environmental Services", 2018). They also bring in some assistance from citizens volunteering to expand upon current efforts and broaden the scope to be more inclusive of the Council's regione ("Environmental Services", 2018). Although the Met Council's primary goal with monitoring efforts has been to improve water quality, they have also been monitoring surface water levels for possible quantity concerns.

Strategy 4 - Perform species and community-specific assessments

Since water sustains both ecosystems and lifeforms on Earth, strategy 7 broadens adaptive planning to include species of animals into the assessment of local climate change impacts. This strategy considers climate change impacts on fish and how to mitigate those problems. The Met Council does not partake in these sorts of initiatives; however, the Minnesota Department of Natural Resources does. The DNR provides an excellent example of species-specific assessment with the native fish species, cisco. These fish are an important food source for other fish (pike, lake trout, walleye, etc.) and are therefore important to the ecosystem as a whole. However, because Minnesota is within the southernmost part of their range, cisco are especially vulnerable to climate change (Jiang, 2016). The longer and warmer summers would deplete oxygen in the deep lakes and would eventually lead to the cisco population dying off (Jiang, 2016). And the DNR has proven this to be true with records showing cisco numbers have been declining statewide since 1975 due to climate-driven stressors and not because of nutrient loading or invasions of non-native species (Zandlo, et al, 2011). Because of this, the DNR has been developing measures to reduce climate change's impact on cold-water fish (just like the cisco). Their methods include making note of their deep lake assets (ideally those with exceptional water quality as they would provide the best sanctuaries for cold-water fish in a warmer climate) and placing them into 'tiers' to define best, good, and poor-quality lakes for cold-water fish to reside in. The lakes in the best and good tiers are to become the home of cold-water fish in a time of crisis.

Local Strategies

Strategy 1 - Adapting at the local level with urban green infrastructure

Perhaps the best adaptation strategy for climate change is for local entities to incentivize the construction of green infrastructure; also referred to as Low Impact Development (LID). LID is a form of best practice in climate change adaptation for several reasons: it reduces the cost of stormwater management, creates attractive amenities in neighborhoods (could increase property values as well), and encourages rainwater to soak into the ground where it falls thereby creating less opportunities for pollutants to enter the water cycle (Bourdaghs, 2017). There are several examples of site-specific LID strategies that exist in the Midwest that the Minnesota Pollution Control Agency touched upon:

Stormwater capture and reuse is important as it pinpoints the purpose of green infrastructure: to mimic the pre-development site as it was before human intervention. This includes the ability to soak in as much rainwater as possible where it falls. Such green infrastructure includes rain gardens, green/vegetated roofs and other processes involving bioretention that help to control runoff while simultaneously cleaning stormwater as it flows through the system. Other green infrastructure that helps with controlling stormwater runoff and allows for the reuse of it are cisterns that hold large amounts of stormwater, send it through a system that cleans and reuses it to decrease municipal water demand. Incentive programs, like Minneapolis', that credit residents and businesses for installing any stormwater capture and reuse systems on their property are effective.

Reducing impervious surface coverage with permeable pavements is another common way to control the flow of excess stormwater during high rainfall periods. The Minnesota DOT has been looking into permeable pavements as a more sustainable approach to prolonging concrete/pavement lifespans and ensuring that water is still able to seep into the soil and recharge the groundwater supply. There are two types that are in use currently: permeable pavers and pervious pavement. Examples of pervious pavement are in suburban cities like Shoreview, Minnesota. Unfortunately, the city must maintain their pervious pavements by vacuuming out loose soil and rocks that clog up the void spaces in the pavement (Lindeke, 2014). This creates more work that other cities may not be able to handle, depending on the size of a project. In situations where extensive care is difficult to do, permeable pavers would be of more use. Extensive regional projects in Minnesota, such as the Green Line light rail route along University Avenue in the city of St Paul, utilized permeable pavers due to their less-demanding maintenance requirements (Lindeke, 2014).

Maintaining and expanding traditional infrastructure to control runoff from heavy storms will be the most cost-effective strategy for cities while still helping with adapting to climate changes. Heavy storms lead to overflow of the stormwater drains and pipes beneath cities, which brings up concerns on water quality issues. Another concern with the Midwest is snowmelt. Increased temperatures will increase the rate at which snow melts, inundating the stormwater system beyond its previously accepted capacity. Infrastructure planned and constructed around the idea of large storm events and rapid snowmelt is necessary. Some local examples in Minnesota include the Maplewood Mall Stormwater Retrofits and the City of Prior Lake's evolving water quality utility system which were recently updated to handle more intense rainfall and snowmelt (Vigness-Pint, 2010; Bintner, 2010).

Incorporating "better site design" principles to reduce impervious surface coverage and control runoff is another LID best practice for cities to use. Through current policies, cities can help to incentivize future ecological site design that considers the effects of climate change (mainly, the increase in precipitation). The City of Hanover's newly drafted ordinance pertaining to stormwater, sewer, and natural water resources contains a Stormwater Pollution Prevention Plan (SWPPP) requirement of all new construction activity within their jurisdiction and is a great example of how policy is shaping the future of ecological site design. Although this ordinance highlights more on water quality, it also considers the permeability of the surface area on all new construction sites and what the runoff volumes and peak discharge rates of these sites are - as well as requesting 100-year water levels and emergency overflow elevations for possible ponding area proposals on site. In short, it prepares the sites to be more readily able to handle an increase in precipitation rates and prevent nearby surface waters from becoming polluted. It also gives the city's planner(s) a better idea of what to expect for new construction plans and how they may affect their community on a broader scale outside of the site's boundaries in the future if and when a flooding event occurs, such as that created by climate change in the Midwest Ecoregion.

No development is also considered an LID to some extent. When no new construction takes place, environmental conditions remain in their natural state. This allows for water to flow where it wants to, maintains ecological diversity, and would dampen the effects of climate change on the community. Areas touched by humans are more affected by climate change than natural sites. This means human activity contributes and further hastens a community's demise. This is especially true where urban sprawl is prevalent. But if no new development occurs, then climate change becomes less of a problem down the road. Another approach to this sub-strategy is restoring properties to their natural state before development occurred on them. The more green space available, the more equipped a community will be to handle greater influxes of water.

Strategy 2 - Supporting state climatologists

For the state of Minnesota, the most recent study performed on climate change was in 2014. As such, more frequent updating of this information allows for adaptive measures to be more effective and accounts for variabilities that are not currently known. Funding initiatives for research efforts on climate change impacts in the Midwest ecoregion are a good way to provide support. According to Stephane Hallegatte in his 2008 research, the methodological approach by which local climatologists should consider would be to:

PERFORM detection and attribution studies to fully utilize currently available climate information. Similarly, this provides an estimate of how uncertainty will decrease in the future.

IDENTIFY and ASSESS uncertainty sources in climate and impact models (to better navigate the possibility of unexpected climate changes).

EXPLORE alternate scenarios and modelling approaches, to capture as much as possible the uncertainty on future climates.

An example of an entity that could be contacted for further communications on funding necessities is the American Association of State Climatologists (AASC). This is a nationwide organization that develops and delivers science-based climate services at both the state and local levels. A more local example in Minnesota is the State Climatology Office (SCO) which is an institutional associate member of the AASC and combines knowledge from both the Minnesota Department of Natural Resources and the University of Minnesota. The SCO members gather, archive, manage, and disseminate historical climate data to address questions revolving around the impact of climate in Minnesota. And each member oversees specific topical areas that climate plays a big role in. However, the office also heavily relies upon the data-gathering efforts of other public entities in the state as well.

Strategy 3 - Create a framework for local government planning

As drafted by the Wisconsin Initiative on Climate Change Impacts, there needs to be collaboration with entities like the League of Minnesota Cities, regional planning commissions, watershed districts, and other local government associations to expand efforts to help communities integrate climate adaptation strategies that provide greater confidence in local emergency management and hazard mitigation plans. Likewise, there needs to be a plan for future development and so factoring in climate change for land use will help guide development patterns. It is also suggested that ordinances and wetland/shoreland management programs be re-examined so that they account for fluctuating water levels. Lastly, communities should create or update their comprehensive plans and periodically revisit/revise these plans and implement ordinances as needed. This preventative approach will help with future adaptation requirements and will ease communities into a changing climate, preventing infrastructure projects from failing all at once and having a hard time funding the repairs simultaneously (Katt-Reinders et al, 2011). The Metropolitan Council's Local Planning Assistance unit within their community development department is a great example of a strong framework for local government planning. They coordinate reviews of local comprehensive plans and provide technical assistance to communities that are amending or working to carry out their plans. This assistance is provided through council sector representatives and through resources such as the local planning handbook. The council also offers assistance to cities for implementing local plans and programs and helps them in resolving issues that may arise. Another unit within the Metropolitan Council is the Regional Systems Planning and Growth unit, which is responsible for helping the Council form its regional growth plan (*Thrive MSP 2040*). This unit also helps to coordinate outreach efforts related to this plan.

Strategy 4 - Implement short term solutions

Whether it's species management or informing the public of risks, small things can be done in the moment to educate about the changing climate and the variability it brings with it. One example of a short-term solution is having fishery managers respond to changes in stream water temperatures. During warm years, they can substitute one species of fish that's more tolerant of warm water over another fish that is not as tolerant. Another example is having county sheriffs and conservation wardens and even weather reporters on the news provide some short-term risk advice on issues like thin-ice hazards on lakes or heat-related health risks.

PRINCIPLES OF ADAPTATION AND IMPLEMENTATION

The purpose of this Water Policy Handbook is to arm communities, both regional and local, with the proper tools and knowledge to implement plans as they relate to the relationship between water and climate change for their particular ecoregion. Like before, several implementation principles also crossed over between sources. The principles outlined below are to provide perspective in the decision-making process and to guide the implementation of the previously listed adaptive strategies.

Determine which actions to implement first. It is important for stakeholders to consider actionable strategies based on vulnerability of the particular resources they are trying to protect (lakes, streams, groundwater, etc.) and whether the action implemented will be successful in addressing their concerns. Thinking this way will help reduce risks and minimize future impacts due to climate change. Therefore, the first principle is to determine where strategic adaptation would be most effective and direct resources accordingly. In other words, based upon vulnerability, figure out which areas, communities, or regions are most affected by climate change overall.

Build flexibility into management practices. We are 'learning as we go'. Therefore, adaptive management practices would provide a more structured, iterative, decision-making process to allow communities to face uncertainty with the primary goal of reducing that uncertainty over time. Trial and error is key here. Therefore, it is necessary to understand that uncertainties exist, so allowing changes during implementation to face those uncertainties gives communities some room to work flexibly. This also leads to the incorporation of new climate information as communities move forward with their water management plans.

Choose strategies that increase resilience and provide benefits across all future climate scenarios. Some implemented strategies will have the potential to provide environmental benefits regardless of how the climate changes. These are often termed as 'no-regret' strategies. These actions have the capacity to build resilience without necessarily committing stakeholders and resources to large and grandeur future action plans.

Be precautionary with high vulnerability sites. Sometimes waiting is not the best course of action, especially in terms of high vulnerability, as this could lead to scenarios in which it becomes too late to do anything as the damage is already done. As long as threats of serious and irreversible damage have a high likelihood of occurring, a lack of certainty should not be an excuse to postpone cost-effective measures that would prevent degradation of the environment.

Adapt to variability and expect to work within it. There is an expectation of unusually warm and cool years and unusually wet and dry years in the future along with increased precipitation and increased temperatures. The management of threatened resources can be vastly improved by understanding the variability that climate change brings.

Consider restrictions and special circumstances of place-based impacts. Climate change impacts can vary spatially. Therefore, considering spatial relationships such as that of Native American tribes is crucial and necessary when adopting adaptation strategies.

Recognize the place of adaptation in the bigger picture. Adaptation is not meant to replace mitigation strategies. Instead, it merely helps us to adjust to our natural and built environments as they are and as they will be in the future. The adaptive strategies listed above are to be used in conjunction with proper and feasible mitigation techniques as they relate to water quality, utility, and ecosystem protection.

REGIONAL WATER PLANNING FOR CLIMATE RESILIENCE SCORECARD

To aid communities in assessing their water plans, a Water Planning for Climate Resilience Scorecard is included in Appendix B. The scorecard asks communities to look for language in their plans that aligns with the five One Water principles, the inclusion of strategies such as the eight adaptive strategies in the previous sections, recognizes that future climate conditions could present new water problems, and applies the characteristics of good planning outlined in the APA PAS Report 588, Planners and Water (2017). Points are awarded to the community based on the degree of inclusion of these ideas within existing plans and can identify gaps where communities can make improvements in future plans.

WATER MANAGEMENT CASES FROM THE TWIN CITIES METROPOLITAN AREA

Water planning for climate resilience will and should differ from city to city even within the same region or ecoregion. The case studies of Minneapolis, Oakdale, and Ramsey show how each city has used different water management approaches to address climate resilience. They will have the same climate changes but will experience them differently. These cities fall within the Twin Cities Seven County Metropolitan Area (that makes up the Metropolitan Council) and they represent urban, suburban, and rural areas that have a variety of water management concerns to plan for as the climate changes.

Minneapolis

Too Much | Too Little | **Too Dirty**

The City of Minneapolis scored very well on the Water Planning for Climate Resilience Scorecard. The City addresses every strategy, principle, and condition on the score card except for the "Supporting State Climatologists" strategy. For many of the strategies, principles, and conditions, Minneapolis scores high, particularly when it comes to green infrastructure and the One Water principles.

As an urban area, Minneapolis has different climate change related water management concerns than other cities in the Seven County Metropolitan Area. The City of Minneapolis captures all of its water from the Mississippi River, which runs through the larger metropolitan area. This means that good water management to keep the river healthy is vital. The primary projected climate changes are higher winter temperatures and more extreme rainfall events. Both will affect infrastructure in Minneapolis. Higher temperatures in the winter means more freezing and thawing cycles; this deteriorates roads more quickly, causes more potholes, and ultimately increases the cost to maintain the city streets. Another infrastructure concern is the capacity of holding and conveyance systems as well as the amount of impermeable surface in the city. With more frequent and more extreme rain events, the City's infrastructure will need to change to better handle extreme rain events without flooding and polluted runoff draining into the river. Like many older cities, Minneapolis has some remnants of a traditional combined sewer over water system; in large rain events that exceed capacity, the system discharges contaminated water directly in.

The City of Minneapolis is recognized for its efforts to incorporate green infrastructure throughout the City to better handle stormwater and reduce runoff into the river. One project that stands out is the Marquette and 2nd Downtown Streetscape Project (2009). The project included 48 blocks in downtown Minneapolis and replaced portions of the impermeable pavement with permeable pavers to allow infiltration and filtration through a Silva Cell integrated tree and stormwater management system. 167 new trees were planted, each within a Silva Cell group that can hold 3.3 cubic meters of stormwater. The project as a whole covers 1.1 acres but can collect the equivalent of a 1" rain fall event from a 5.7 acre watershed.

Marquette and 2nd Downtown Streetscape Project (2009)

The Minneapolis Climate Change Action Plan (2013) emphasizes green infrastructure; one of the goals of the plan is to "promote and strengthen green infrastructure and natural systems that can build resilience, sequester or reduce emissions, and improve neighborhoods". The City has recently acted upon this goal by installing a green roof on Minneapolis' City Hall. The green roof decreases the energy needs of the building while also providing stormwater management, vegetation to help mitigate the urban heat island effect, and pollinator habitat. The city has encouraged others to install green roofs as well by offering a reduction of at least 50% in stormwater utility fees for building owners who install them. The return on investment for a green roof coupled with the reduction in stormwater utility fees creates a great opportunity for green infrastructure and retrofits in Minneapolis.

Minneapolis City Hall and Green Roof

Oakdale

Too Much | **Too Little** | Too Dirty

The City of Oakdale is a suburb east of Saint Paul between the Mississippi River and the Saint Croix River. Just like Minneapolis, Oakdale addresses every strategy, principle, and condition on the scorecard except for the "Supporting State Climatologists" strategy. The City scored high on the strategies, principles, and conditions that can be addressed in plans. As a largely residential city that is almost completely built out, there is not much opportunity for green infrastructure except in small incremental steps.

Oakdale draws all of its water from six wells throughout the City. The water table in Oakdale and other surrounding cities is beginning to fall due to over-drawing from wells and lakes. If this trend continues, the City will need to create a plan to conserve water and/or begin drawing water from either the Mississippi or Saint Croix Rivers. Reduced water supplies combined with the projected drought will require careful management and communication with the community; perhaps restrictions on watering lawns, education on resident water conservation, and incentives for water-efficient appliances and rain gardens. At times, however there are predicted to be large rain events, and just like Minneapolis, the size of holding ponds and conveyance systems is not designed to manage the large rain events brought by climate change. Improving the stormwater management system will prevent flash flooding and promote stormwater capture and reuse as well as groundwater replenishment. Decreasing runoff from large rain events is also important to minimize polluted runoff into the already impaired Lake St. Croix and Kohlman Lake watersheds.

One example of successful and innovative stormwater management in Oakdale is the Tartan Crossing Pond. It is a shared stormwater management system that serves the surrounding mixed-use redevelopment site. The mixed-use site is relatively dense with roads, buildings, and parking lots covering much of the area. Some of the parking lots are partially permeable pavement and there are small rain gardens in the development, but to manage water from large rain events and prevent polluted runoff from entering the adjacent wetland, the pond was constructed. The pond provides form and function with an artistically designed tiered settlement and holding system, native perennial plantings, walking paths, interpretive signs, and picnic tables around the pond. It serves as a public park most of the time, but during large rain events, it retains large amounts of water to promote settlement and infiltration, replenishing the water table and cleaning runoff.

(SEH Consulting, 2015).

As the City of Oakdale completes their 2040 comprehensive plan, they have emphasized water resources resilience. Two good goals and some associated policies addressing resiliency in water resources that have been proposed for the plan are (City of Oakdale, 2018):

Ensure Water Capacity

- Monitor aquifer elevations to assure groundwater source of water is sustainable.
- Promote water conservation measures to reduce per capita consumption rates to less than 75 gallons per day for residential land uses and 90 gallons per day for the community at large.
- Promote the reuse of stormwater for irrigation.
- Adopt land use regulations that reduce the need for irrigation.

- Identify an alternative surface water supply source to wholly or partially reduce our reliance on groundwater.

Minimize Flooding

- Update the community Surface Water Management Plan model using the Atlas 14 hydrograph
- The level of protection adjacent to floodways, streams and channels and around all wetlands, ponds, detention basins and lakes shall be based on the critical-duration 100-year flood
- Non-trunk stormwater systems should be planned to provide discharge capacity for the critical duration runoff event that is not less than a 10-year frequency event
- Easements over floodplains, detention areas, wetlands, ditches and all other parts of the stormwater system should be obtained as areas develop or redevelop.
- Infiltration practices shall be promoted within the limitations imposed by construction practices, soil conditions, groundwater supply and recharge, safety, snow removal, maintenance and other issues.
- Where possible, regional pond areas, as opposed to individual on-site ponds, should be used to reduce flooding, to control discharge rates and to provide necessary storage volumes
- All developments must, to the extent determined by the City, provide land, funding or a combination of both to develop onsite or regional stormwater management facilities
- Identify location, elevation, and discharge capacity of emergency overflow swales.

Ramsey

Too Much | Too Little | Too Dirty

The City of Ramsey, as an exurb Northwest of the Twin Cities, addresses 7 out of 14 of the strategies, principles, and conditions on the scorecard. Ramsey scored highest on addressing current and future conditions and lowest on the adaptive strategies and One Water principles.

Ramsey already has 5% of its residences within FEMA 100-year flood zones. With climate change increasing large rain events, the flood zone will only grow. Therefore, the city will need to work with these residents and plan accordingly for this growth. Ramsey also faces similar problems to the ones that Oakdale faces, particularly a diminishing groundwater supply. Ramsey is consistently one of the top ten users of water in the Seven County Metropolitan Area; the Metropolitan Council and Minnesota Department of Natural Resources have expressed concern that the City of Ramsey may exceed their groundwater resources with continued development and water demand. The City has identified the Mississippi River as a potential water source as the groundwater supply becomes less viable, but conservation should be the first step in ensuring water supply (Anoka County, 2014). As climate change continues and Ramsey sees more and longer periods without rain followed by large rain events, the City will need to promote water conservation efforts and promote land use practices that promote stormwater capture and infiltration. Low-density single-family homes with large lawns to water, combined with the sandy soil of the Anoka Sand Plain that does not retain water, accounts for most of the high-water use (Anoka County, 2014).

Ramsey, unlike Oakdale, has approximately half of their residences using private wells and septic systems. This puts them at a disadvantage when it comes to managing for water conservation, as the residents are not paying for water by the amount they use. Because of this, a large part of their water management must be through communication with households off the water and sewer system. Ramsey does have a tiered pricing system for water, but the difference in each step up in water consumption levels is $0.03/gallon and likely not aggressive enough to create a valuable incentive for residents to decrease their water use. The City of Ramsey has created a Water Conservation Toolkit (City of Ramsey, 2017) for residents to access on the City Website that provides information on the importance of water conservation and real actions residents can take to minimize their water use. Additionally, they have worked with the Minnesota Department of Natural Resources to produce a water supply plan every three years since 2009 (City of Ramsey, 2015).

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APPENDIX A: FIGURES

Figure 1: U.S. Environmental Protection Agency Level 1 Ecoregions

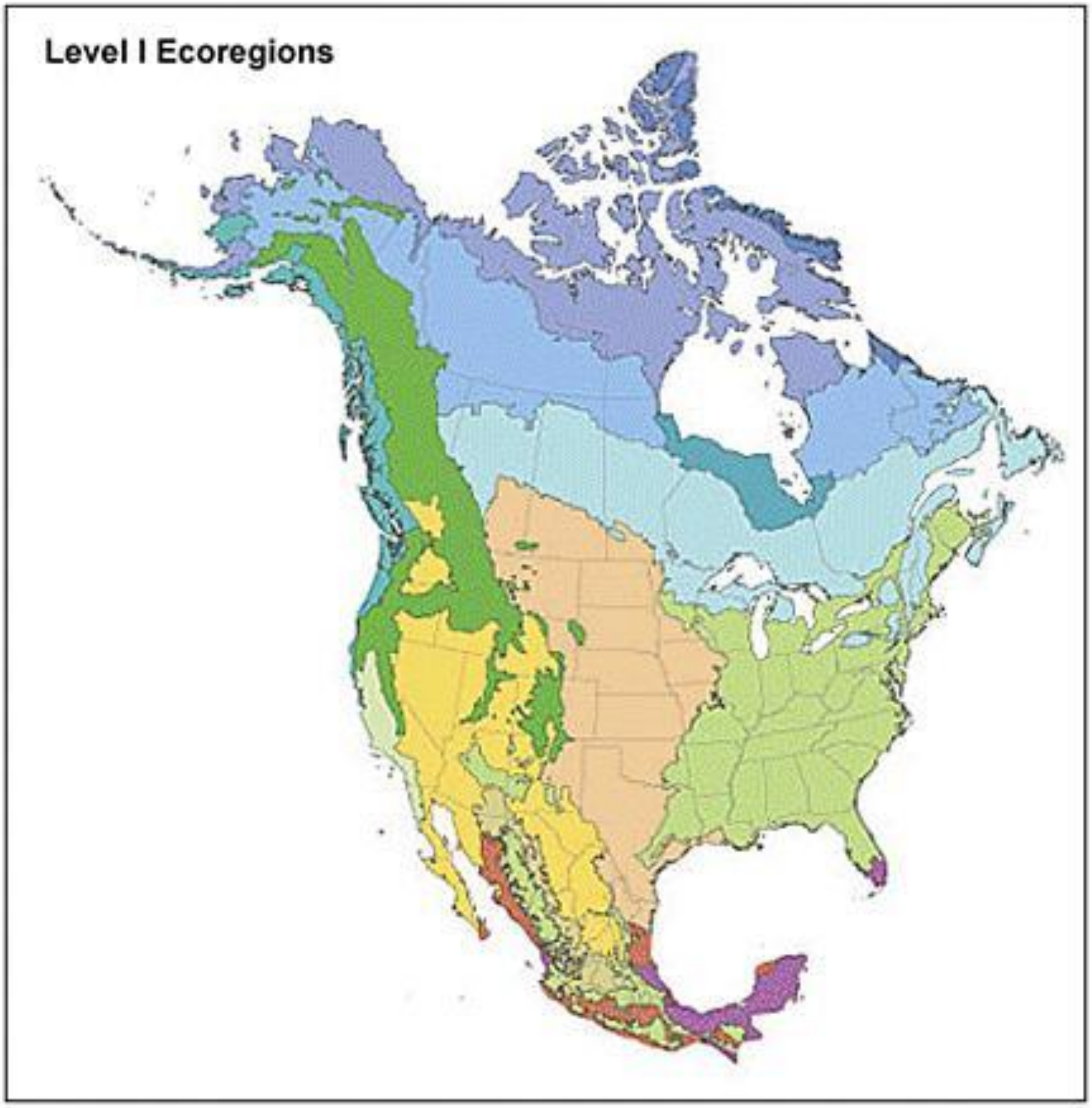


Figure 2: Differences Between Conventional Water Management and Integrated Water Management

TABLE 2.1. DIFFERENCES BETWEEN CONVENTIONAL AND INTEGRATED URBAN WATER MANAGEMENT

Aspect of urban water management	Conventional approach	Integrated approach
Overall approach	Integration is by accident. Water supply, wastewater, and stormwater may be managed in the same agency as a matter of historical happenstance but physically the three systems are separated.	Physical and institutional integration is by design. Linkages are made between water supply, wastewater, and stormwater as well as other areas of urban development through highly coordinated management.
Collaboration with stakeholders	Collaboration = public relations. Other agencies and the public are approached when approval of a pre-chosen solution is required.	Collaboration = engagement. Other agencies and the public search together for effective solutions.
Choice of infrastructure	Infrastructure is made of concrete, metal, or plastic.	Infrastructure can also be green including soils, vegetation, and other natural systems.
Management of stormwater	Stormwater is a constant that is conveyed away from urban areas as rapidly as possible.	Stormwater is a resource that can be harvested for water supply and retained to support aquifers, waterways, and biodiversity.
Management of human waste	Human waste is collected, treated, and disposed of to the environment.	Human waste is a resource and can be used productively for energy generation and nutrient recycling.
Management of water demand	Increased water demand is met through investment in new supply sources and infrastructure.	Options to reduce demand, harvest rainwater, and reclaim wastewater are given priority over other sources.
Provide areas for scientific study and outdoor education	Complexity is neglected and standard engineering solutions are employed to individual components of the water cycle.	Diverse solutions (technological and ecological) and new management strategies are explored that encourage coordinated decisions between water management, urban design, and landscape architecture.

Figure 3: Metropolitan Council District Map ("Metropolitan Council Districts", 2014).

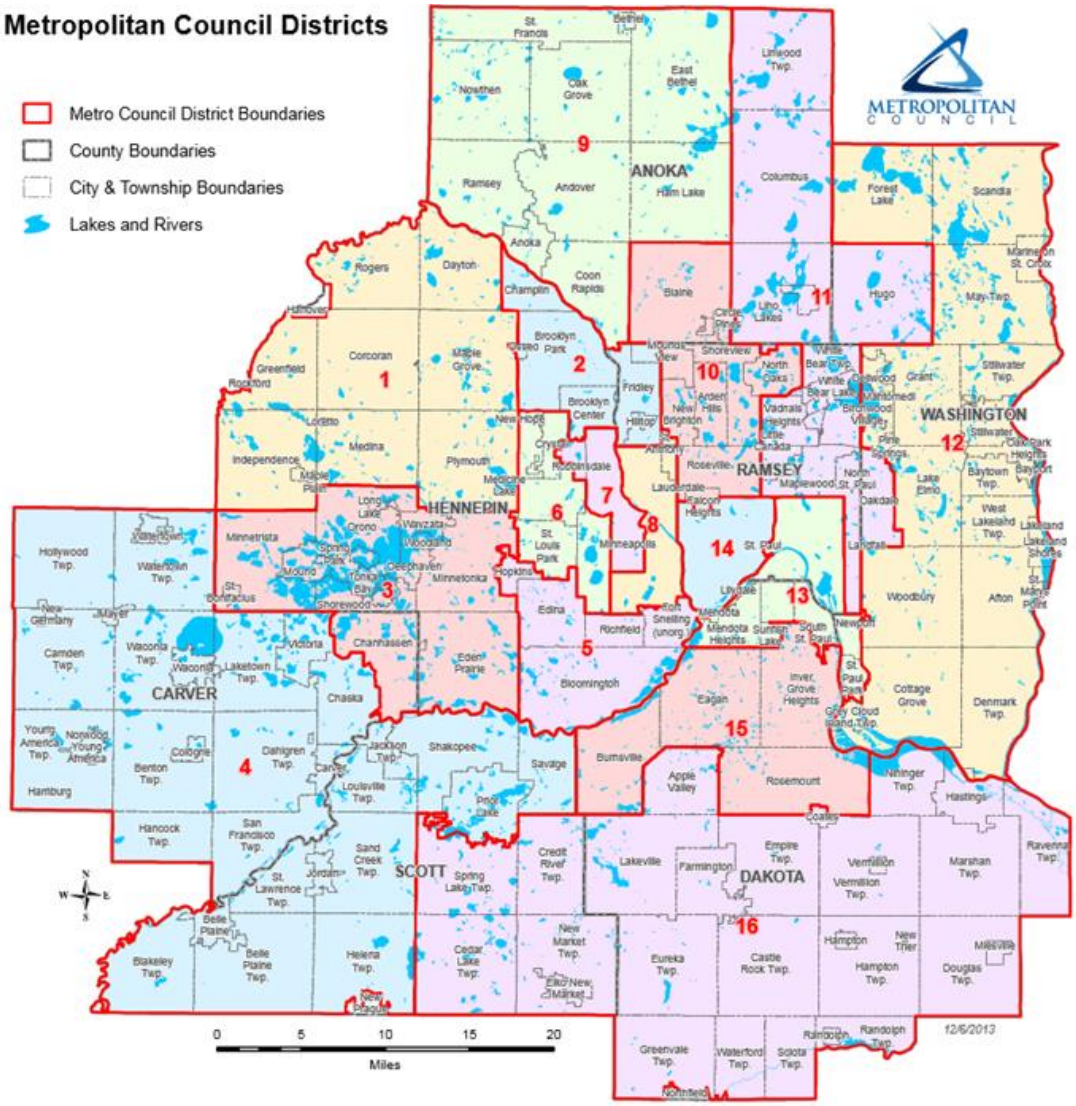


Figure 4: Observed Climate Trends (Moss et al., 2017)

Hazard	Observed Trend	Confidence Change is Occurring
Extreme cold	Rapid decline in severity & frequency	**Highest**
Extreme rainfall	Becoming larger and more frequent	
Heavy snowfall	Large events more frequent	**High**
Severe thunderstorms & tornadoes	Overall numbers not changing but tendency toward more "outbreaks"	**Moderately Low**
Heat waves	No recent increases or worsening	**Lowest**
Drought		

Confidence Scale

Lowest	Low	Moderately Low	Moderately High	High	Highest

Snapshot of observed trends among common weather hazards in Minnesota, and confidence that those hazards are changing in response to climate change. Graphic based on information from 2014 National Climate Assessment and data analyzed by the Minnesota DNR State Climatology Office.

The decline of extreme cold during winter, the increased frequency of heavy snowfall, and increased frequency and severity of extreme rain events are currently the biggest climate related water issues facing Minnesota. Many communities within the Twin Cities Metropolitan Region have planned or are currently planning around these issues. Drought and heat waves, which are other pressing issues in other parts of the United States, have not yet seen significant changes in frequency or severity due to climate change. Because of this, the region has not done much to address these issues through planning.

Figure 5: Projected Climate Trends Through 2099 (Moss et al., 2017)

Hazard	Projections through century	Confidence in projected changes
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	

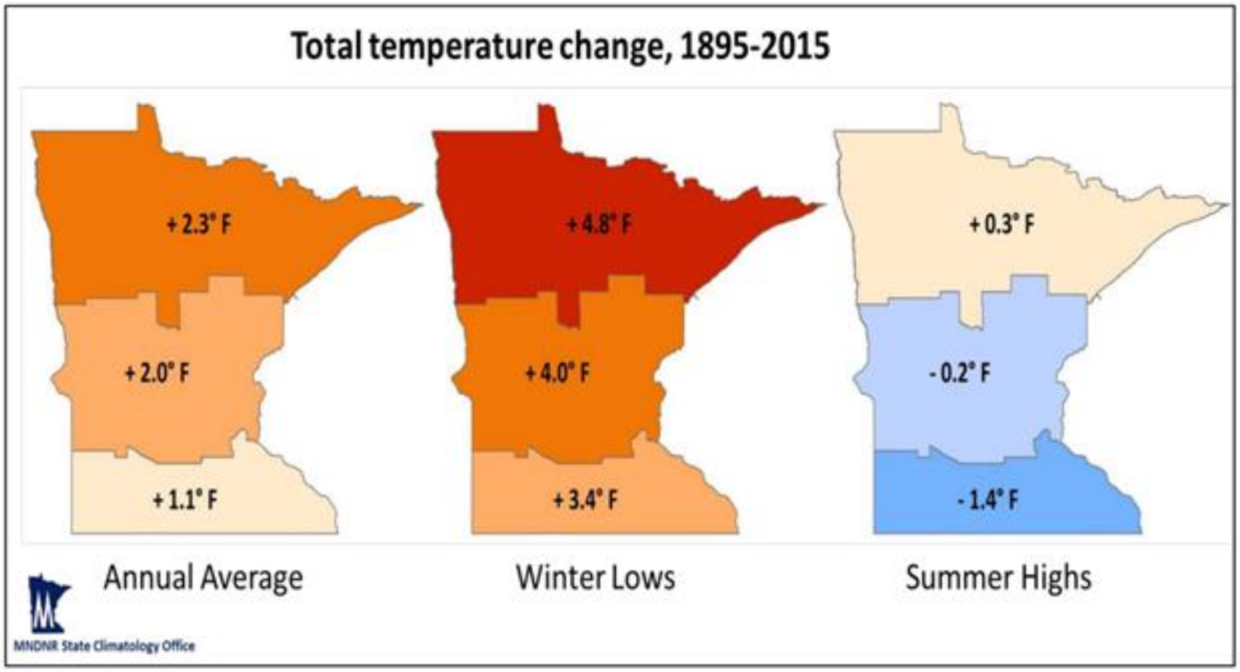
Lowest	Low	Moderately Low	Moderately High	High	Highest

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.

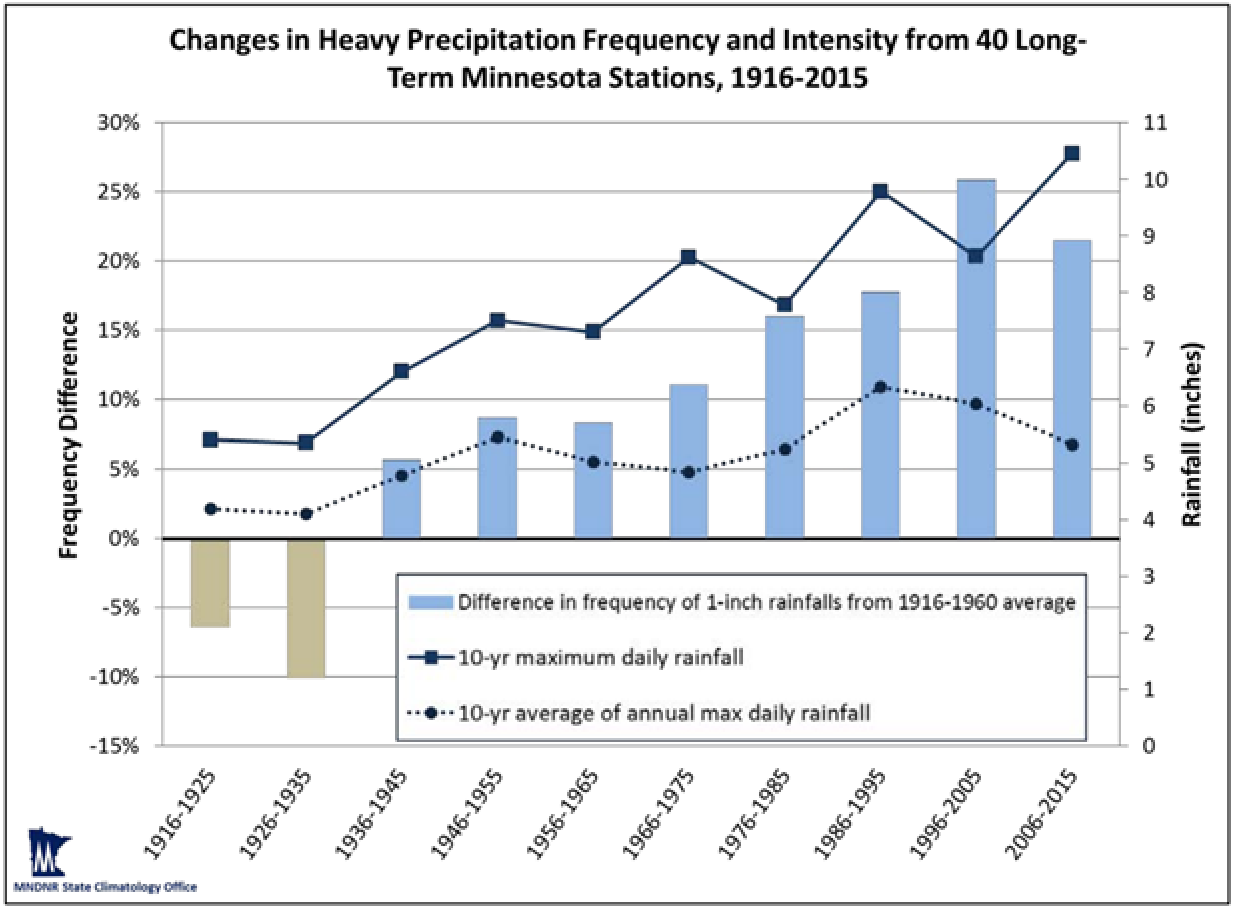
Through the remainder of the century, however, drought and heat waves will become more severe and more frequent, requiring the adoption of new water management strategies to address these issues. Other regions of the country which have experienced similar changes already, such as the southwest and parts of the southeast, may have developed regional strategies to address these problems already, and could provide guidance on the development of strategies in the Twin Cities and throughout the Midwest.

Figure 6: Observed Temperature Changes in Minnesota (Moss et al., 2017)



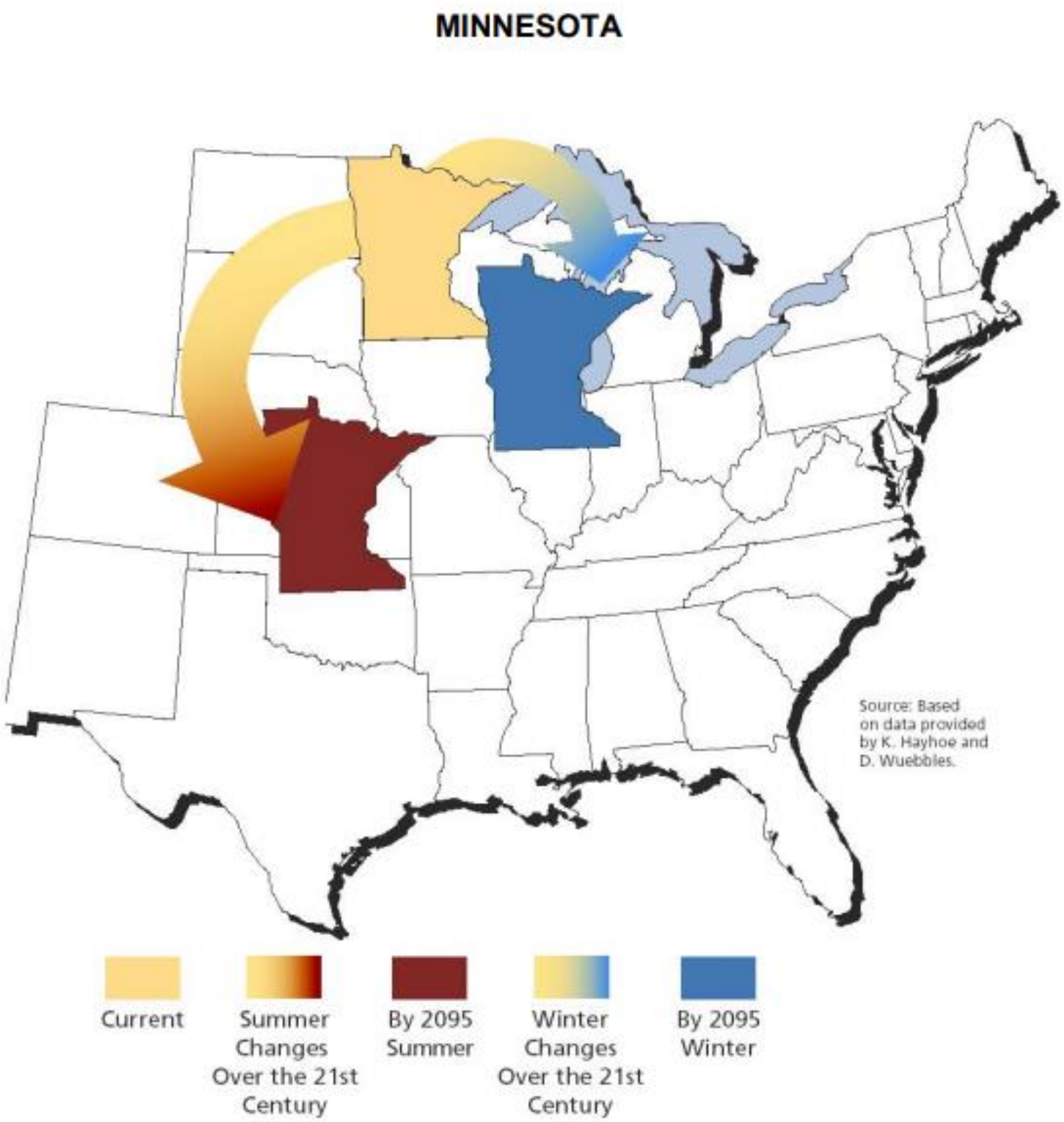
Comparisons of total change between 1895 and 2015 using 30-year averaging periods, for annual average temperature, winter low temperature, and summer high temperatures over the northern, central, and southern portions of the state. Values were obtained by subtracting the average of the first 30 years of record (1895-1924) from the average of the last 30 years of record (1986-2015). Each region is a blend of three climatic divisions, as defined by the National Centers for Environmental Information (https://www.ncdc.noaa.gov/monitoring-references/maps/us-climate-divisions.php), which is also the source for the divisional climate data used (http://www.ncdc.noaa.gov/cag/time-series). Maps prepared by Minnesota State Climatology Office.

Figure 7: Heavy Precipitation Changes (Moss et al., 2017)



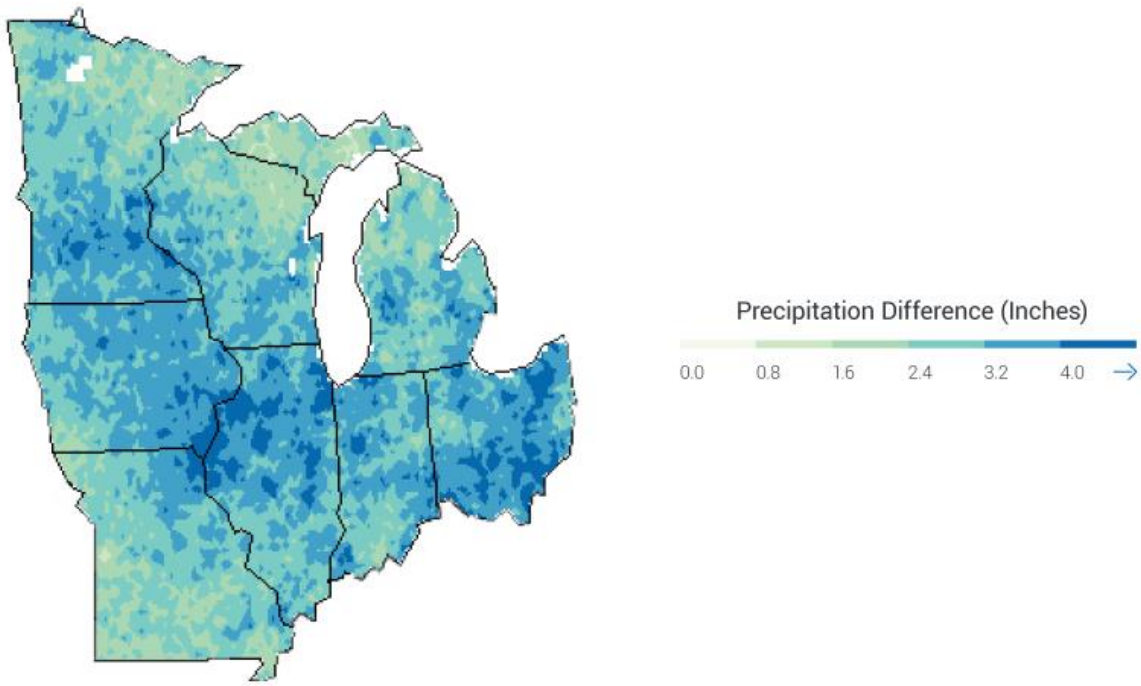
Changes in the frequency of one-inch rainfalls relative to the 1916-1960 average (vertical bars), from 40 long-term stations in Minnesota. Also shown are the 10-year average (lower dotted line, right axis) and 10-year maximum values (upper solid line, right axis) of the heaviest single rainfall amount recorded each year at any of the 40 stations. Note that the 10-year maximum value has doubled from just over five inches at the beginning of the record, to just over 10 inches at the end of the record. Courtesy of Minnesota State Climatology Office.

Figure 8: Minnesota's Shifting Climate Profile (Johnson and Polasky, 2003)



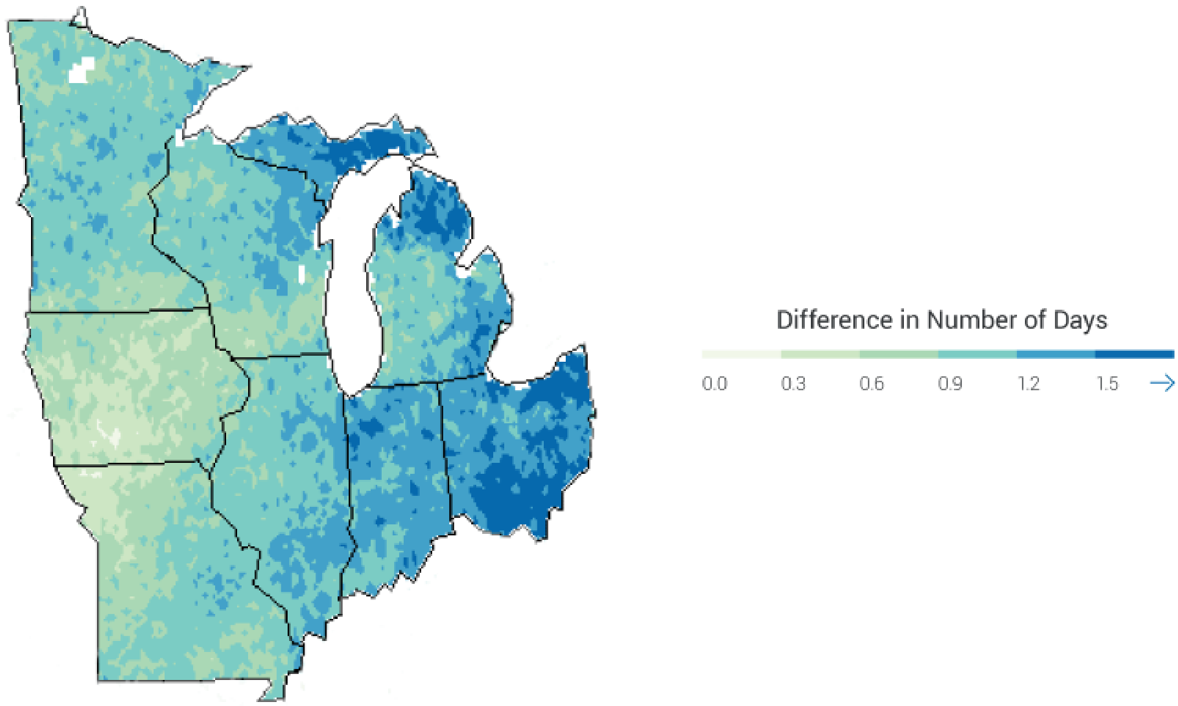
So far, the greatest amount of warming has occurred during the winter (see Figure 6). However, by 2095, Minnesotan summers will feel like those currently felt in Kansas, while the winters will be similar to those currently experienced in Wisconsin.

Figure 9: Differences in total annual precipitation (U.S. Global Change Research Program, 2014)



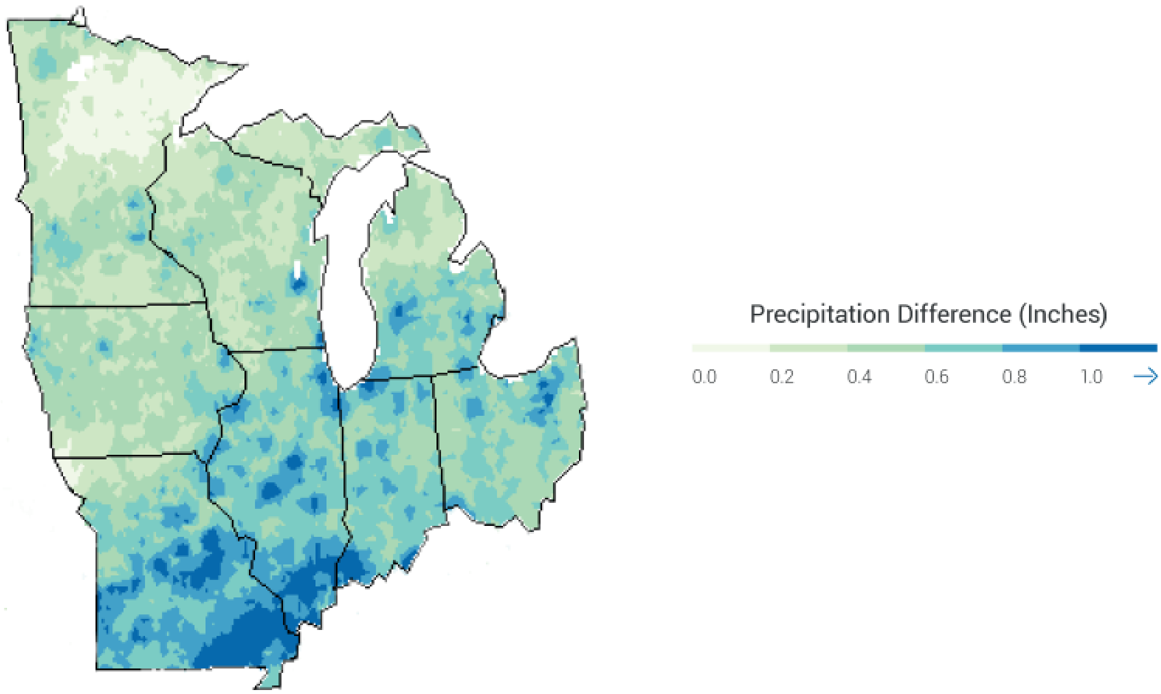
“Precipitation patterns affect many aspects of life, from agriculture to urban storm drains. These maps show projected changes for the middle of the current century (2041-2070) relative to the end of the last century (1971-2000) across the Midwest under continued emissions (A2 scenario). [This figure shows] the changes in total annual average precipitation. Across the entire Midwest, the total amount of water from rainfall and snowfall is projected to increase.”

Figure 10: Change in Days with Heavy Precipitation (U.S. Global Change Research Program, 2014)



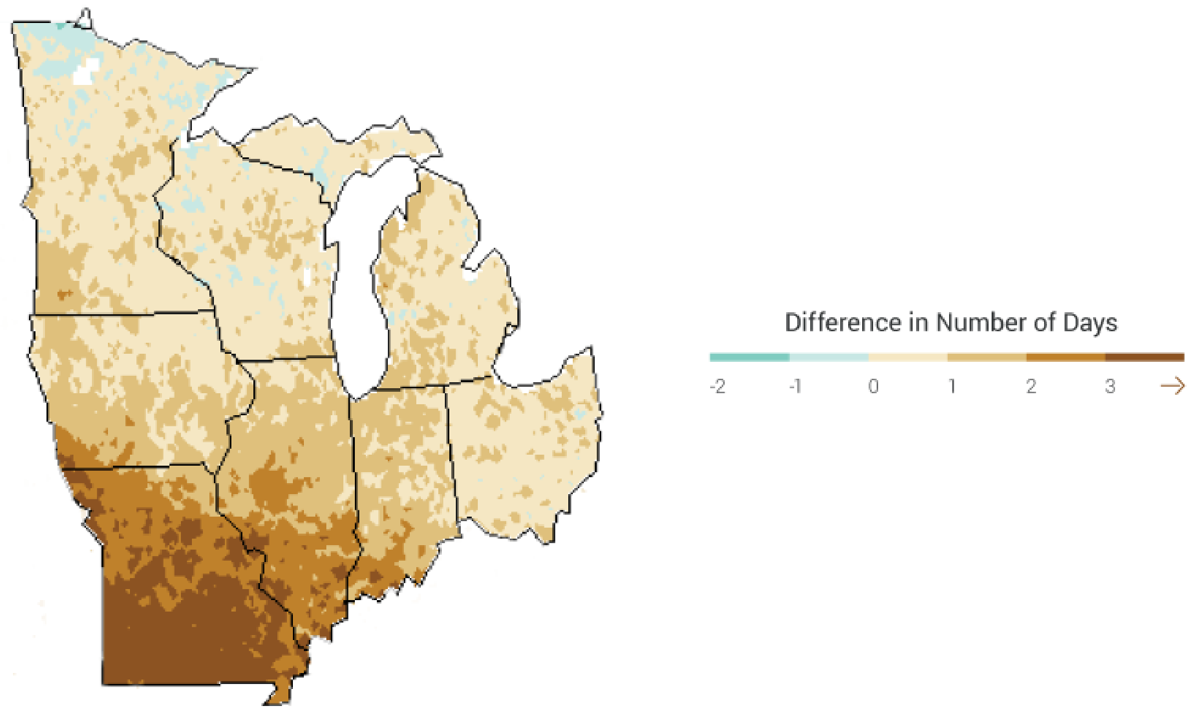
"[This figure shows the] increase in the number of days with very heavy precipitation (top 2% of all rainfalls each year). Both [Figure 10 and Figure 11] indicate that heavy precipitation events will increase in intensity in the future across the Midwest."

Figure 11: Change in the amount of rainfall in wettest days (U.S. Global Change Research Program, 2014)



“[This figure shows the] increases in the amount of rain falling in the wettest 5-day period over a year.”

Figure 12: Change in number of dry days (U.S. Global Change Research Program, 2014)



"[This figure shows the] change in the average maximum number of consecutive days each year with less than 0.01 inches of precipitation. An increase in this variable has been used to indicate an increase in the chance of drought in the future. (Figure source: NOAA NCDC / CICS-NC)."

WATER PLANNING FOR CLIMATE RESILIENCE SCORECARD

HOW WELL IS YOUR CITY OR REGION PLANNING FOR WATER AND CLIMATE CHANGE?

This scorecard will help you gauge where you fall in planning for water management and climate change and which areas you can improve upon. Before you begin, make sure you know what the projected impacts of climate change are for your area.

To get you thinking, which categories of water issues do the city or region face under the current and future climate conditions?

	Too Much	Too Little	Too Dirty
Current Climate			
Future Climate			

ONE WATER PRINCIPLES

Do your water management plans/practices follow or address the One Water Principles?
Scoring: 0 = Not Present, 1 = Present but Limited, 2 = Present and Robust

Principles	Score	Comments
Water supply, wastewater, stormwater and natural water systems should be planned, operated, and managed as one system.		
All aspects of the water system should be integrated into planning for the built environment, including the linkages with land use, energy, and transportation.		
Water is a key amenity for the city, in terms of urban design and reinvestment.		
Water planning is as important for the city as is land-use and transportation planning.		
One Water values equity, environmental justice, and respect for nature.		
One Water Principles Total Score		

CURRENT AND FUTURE CONDITIONS

Do your water management plans/practices address current and future conditions?
Scoring: 0 = Not Present, 1 = Present but Limited, 2 = Present and Robust

Do your plans address…	Score	Comments
Current Climate Conditions		
Future Climate Conditions		
Current and Future Conditions Total Score		

ADAPTIVE STRATEGIES

Do your water management plans/practices employ these adaptive strategies?
Scoring: 0 = Not Present, 1 = Present but Limited, 2 = Present and Robust

Adaptive Strategies	Score	Comments
Implementing adaptation on a broad scale		
Adapting at the local level with urban green infrastructure		
Supporting state climatologists		
Create a framework for local government planning		
Implement short term solutions		
Perform broad-scale monitoring		
Perform species and community-specific assessments		
Adaptive Strategies Total Score		

TOTALING AND ASSESSING YOUR SCORE	
One Water Principles Total Score	/10
Current and Future Conditions Total Score	/4
Adaptive Strategies Total Score	/14
Your Total Score	/28

Find your total score and assess how well you did. Prioritize the areas that you scored zero to make sure you have addressed every strategy, principle, and condition. Once you have addressed each of them, work on making your plans and practices more robust.