REGIONAL CLIMATE VULNERABILITY ASSESSMENT

Localized Flood Risk

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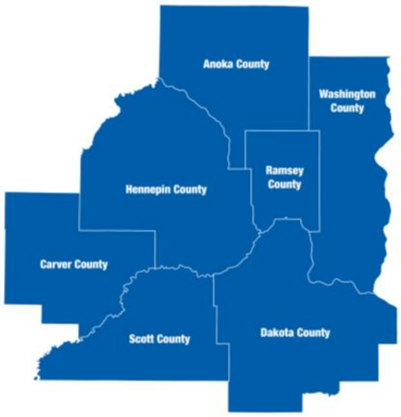

The Metropolitan Council is the regional planning organization for the seven-county Twin Cities area. The Council operates the regional bus and rail system, collects and treats wastewater, coordinates regional water resources, plans and helps fund regional parks, and administers federal funds that provide housing opportunities for low- and moderate-income individuals and families. The 17-member Council board is appointed by and serves at the pleasure of the governor.

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Introduction

Climate Change in Minnesota

In his 2016 State of the State address, Governor Mark Dayton made the following observation about climate change: “From kids concerned that pond hockey doesn’t start until January to farmers trying to predict growing seasons, to folks wondering why this year’s March blizzards have turned into sixty-degree days, many thousands of Minnesotans have expressed their concerns about the growing impacts of climate change.” The Governor wasn’t speaking of distant ice caps and threats to polar bears, but rather to climate changes that we are experiencing regionally and locally, right here in Minnesota.

The most recent National Climate Assessment (NCA) produced by the U.S. Global Change Research Program (2014), synthesizes climate change impacts by sector and by region. The Midwest regional chapter of the NCA Report highlights current and future impacts related to climate change within the Twin Cities metropolitan region. The fourth NCA is set to be released in late 2018.

Climatologists identify a diverse range of climate-related hazards, like drought, that can be exacerbated by climate change. This Climate Vulnerability Assessment (CVA) focuses on climate hazards related to **localized flooding** and **extreme heat.**

Setting future projections aside, the long-term trends of our Minnesota climate have been changing outside the bounds of typical, temporary variations. 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 Table 1). Heat waves will also likely occur with more frequency, coverage, and duration.

Table 1. Climate Change Trends in Minnesota through 2099*

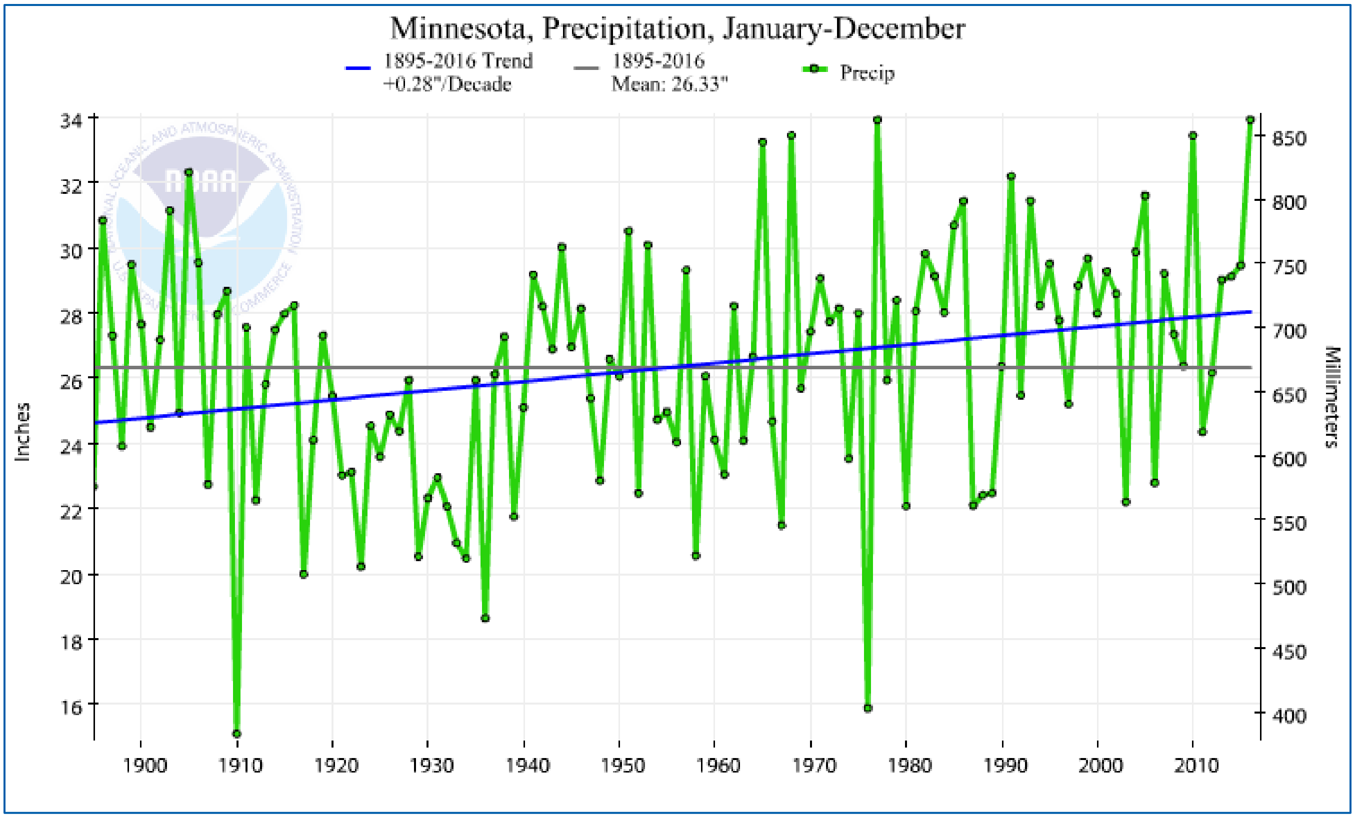
Hazard	*Projections Through 2099*	*Confidence in Projected Changes*
Warming Winters	Continued loss of cold extremes and dramatic warming of coldest conditions	**Highest**
Extreme Rainfall	Continued increase in frequency and magnitude; unprecedented flash-floods	
Heat Waves	More hot days with increases 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	

**Source: MN DNR State Climatology Office. Projected and expected trends among common weather hazards in Minnesota, and confidence that those hazards will change through the year 2099 in response to climate change. Graphic based on information from the 2014 National Climate Assessment.*

Extreme Rainfall

Precipitation has been increasing in Minnesota over the last century, as shown in Figure 1 which illustrates historic annual precipitation.

Figure 1 – Minnesota Annual Precipitation, 1895-2016*



**Source: NOAA National Centers for Environmental Information. Climate at a Glance: U.S. Time Series, Precipitation. (April 2017). Retrieved on April 27, 2017, from http://www.ncdc.noaa.gov/cag/*

The blue trend line in Figure 1 shows that annual precipitation amounts have been steadily increasing, which is compounded by increasing rainfall totals for specific, isolated storms. There has been a marked increase in what the State Climatologist terms, 'mega rain events.' These mega rain events are defined as a 6 inches or greater rainfall event covering at least 1000 square miles, with a peak rainfall amount of 8 inches or greater. Historically, fourteen of these mega rain events have been recorded since 1866, with half of these events occurring within the last fourteen years. A changing Minnesota climate has shown that more energy and more moisture in the atmosphere has the potential to create more rainfall.

These extreme rainfall trends put a strain on stormwater infrastructure and other surface water conveyance or retention efforts. Given the fact that much of the stormwater infrastructure within the Twin Cities metro was designed to convey surface water based on technical standards and rainfall estimations adopted in 1960, the increasing amount of rainfall occurring in short, intense periods, presents a challenge for communities and for the Metropolitan Council.

The National Climate Assessment states that the Midwest has already experienced a 37% increase in these larger rain events of 2.5 inches or greater (US Global Change Research Program, 2014). The extreme rainfall changes in the Midwest are only second to those of the Northeast US between 1958 and 2012.

Why Focus on Localized Flooding?

This assessment focuses on the climate hazard of localized flooding for several reasons, including:

1) Increases in extreme rainfall have already occurred, and this trend shows the highest probability of continuing in the future (See Table 1).

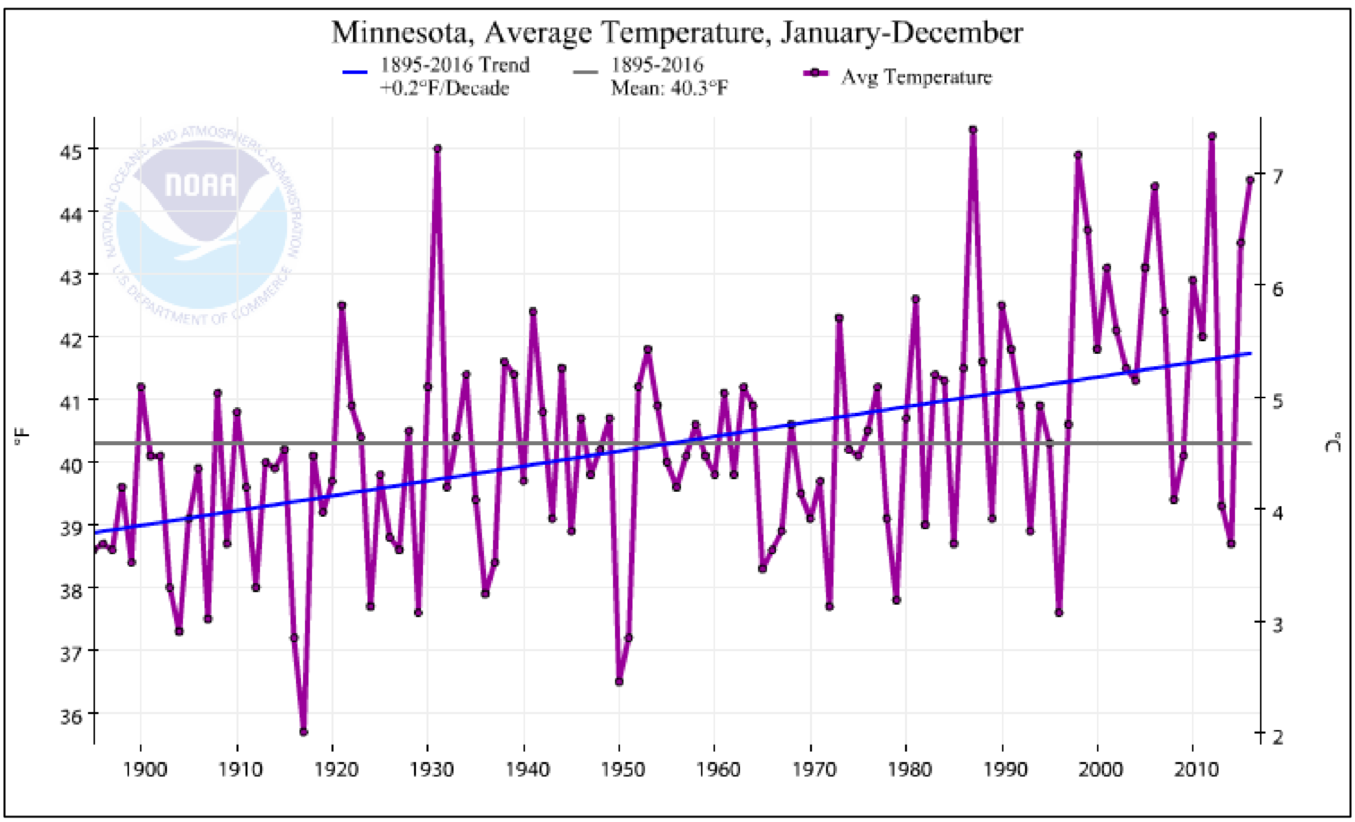
2) Council assets are susceptible to vulnerabilities from potential localized flooding, including disruptions to the transit system, increase in inflow/infiltration to our wastewater infrastructure, adverse effects to water supply and water quality, and health and safety concerns for the region, for our customers, and for our employees.

Until now, no regional screening tool has been created to assess the potential impacts from localized flooding. The assessment allows the Council to screen regional assets for potential flood risk and subsequent vulnerability. In addition, the data analysis could provide leverage in advancing further regional and local analysis and tools. For example, this assessment may advance the need for creating a regional stormwater dataset.

Extreme Heat

The second area of this assessment focuses on extreme heat. Minnesota's average temperatures have been increasing over the last century, as shown in Figure 3.

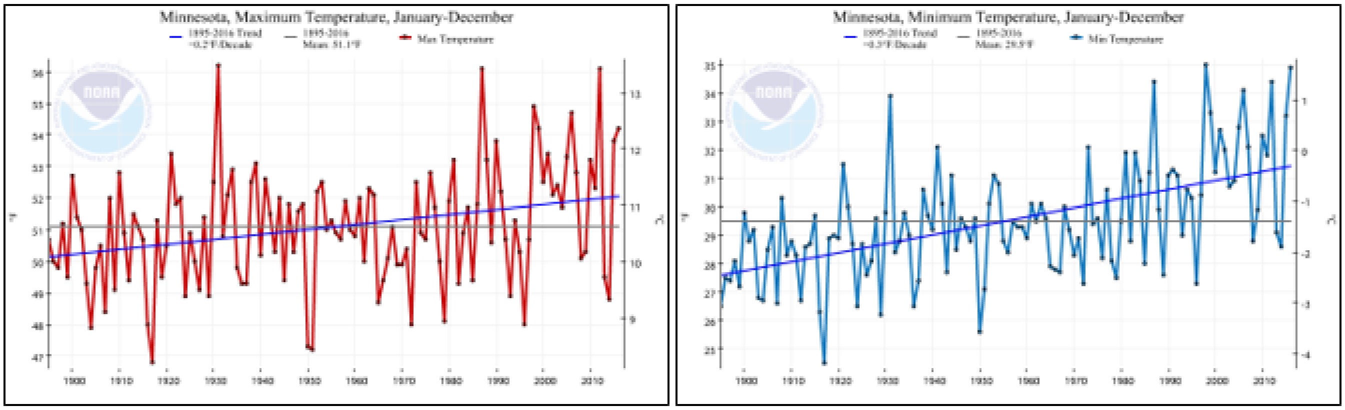
Figure 3 - Minnesota Average Temperature, 1895-2016*



**Source: NOAA National Centers for Environmental Information. Climate at a Glance: U.S. Time Series, Temperature. (April 2017). Retrieved on April 27, 2017, from http://www.ncdc.noaa.gov/cag/*

The blue trend line above shows a steady increase in average annual temperature over the last hundred years. It should be noted that the above graph does not demonstrate that Minnesota has seen an upward trend in the occurrence of heat waves, which is a period of unusually hot weather that typically lasts two or more days. Separating the data into average maximum and minimum temperatures, the increase in minimum (winter) temperatures becomes apparent in the blue trend line in Figure 4.

Figure 4 – Minnesota Maximum and Minimum Temperatures, 1895-2016*



**Source: NOAA National Centers for Environmental Information. Climate at a Glance: U.S. Time Series, Maximum Temperature & Minimum Temperature. (April 2017). Retrieved on April 27, 2017, from http://www.ncdc.noaa.gov/cag/*

Heat waves have been identified as a climate hazard carrying a high level of confidence in terms of their increasing likelihood during future summers in the state. To create strategies to address extreme heat, researchers seek to identify the factors that exacerbate extreme heat. This investigation has shown that higher temperatures are amplified in areas with higher concentrations of pavement and impervious surface, as these areas tend to absorb the residual heat and hold that heat longer than vegetation would. This effect is called the Urban Heat Island effect, or UHI. Buildings can block wind, preventing mitigation of this heat effect. The four components that make up the UHI are lack of vegetation, impervious surfaces, residual heat from cars and mechanical cooling, and building morphology.

Using remote sensing and satellite imagery, the Council has mapped heat vulnerability in the region, illustrating the land surface temperature during a three-day heat wave, on July 22, 2016. The map shows areas of extreme heat within the urban core area of the metro, while it also shows areas near parks and water bodies are significantly cooler. It is important to emphasize that the data details land surface temperature, as opposed to air temperature. Air temperature data can provide a better measure of potential heat impacts on human health. Due to data collection constraints, the use of land surface temperature has ensured that this analysis has full metropolitan coverage. In addition, the land surface temperature can be helpful in identifying land use and built environment strategies to reduce heat in specific locations.

Extreme heat analysis will form part of the CVA as a separate chapter. Due to the limitations of this dataset in assessing impacts to specific regional assets, the assessment will evaluate correlations between heat and two primary factors: vegetation and the built environment. The heat assessment will also evaluate human vulnerability to extreme heat.

Why Focus on Extreme Heat?

This assessment focuses on the climate hazard of increased incidence of extreme heat for several reasons, including:

1) Though heat waves have not shown an upward trend, increases in extreme heat will have a high probability of occurring in the future, beyond the year 2025, according the Minnesota State Climatology Office (Table 1).

2) Human vulnerability to extreme heat is of concern many in the region, particularly county public health departments and agency partners.

3) The data created for this assessment allows us to investigate the relationship between the overall built and natural environment and the UHI effect.

Until now, no screening tool with regional coverage has been created to identify extreme heat through UHI. This work could provide leverage in advancing analysis and tools in this area. For example, the University of Minnesota has developed an extensive sensor network which measures the UHI using air temperature. This land surface temperature map may spur further research and geographic coverage of the University's research in this area.

Connection to Regional Policy

Recognizing the importance of climate change mitigation, adaptation, and resilience, the Metropolitan Council will use climate impacts as a lens through which to examine all of its work. *Thrive MSP 2040* (Thrive), the metropolitan development guide, articulates that the Council will look for opportunities to use both its operational and planning authorities to plan for and respond to the effects of climate change, both challenges and opportunities. The Council is dedicated to expanding its support to local governments in climate change planning.

The Sustainability and Equity outcomes within Thrive, as well as the Building in Resilience land use policy, provide policy direction to produce a regional Climate Vulnerability Assessment to plan for and manage Council infrastructure with the aim of enhancing the lifespan of Council assets through a strategic and proactive planning approach. Beyond extending the life of Council assets and infrastructure, outcomes from this project may reduce Council costs through efficient front-end planning and targeted maintenance.

Thrive Outcomes

Thrive identifies Sustainability and Equity as two of five desired outcomes that define a shared regional vision. Planning for sustainability means providing leadership, information, and technical assistance to support local governments' consideration of climate change mitigation, adaptation and resilience. Climate change looms large as an issue with the potential to adversely affect the region in the absence of intentional and proactive planning to both mitigate and adapt to the impacts of a changing climate. Thrive states that "The Metropolitan Council will use equity as a lens to evaluate its operations, planning, and investments, and explore its authority to use its resources and roles to mitigate the place-based dimension of disparities by race, ethnicity, income, and ability" (p. 41). Strategies to adapt to or mitigate against climate hazards should always address equity and achieve equitable outcomes. This aim is especially relevant in formulating strategies to reduce the impact of climate hazards, as research has shown that the most vulnerable populations are often impacted the most by climate change.

Building in Resilience Land Use Policy

To achieve the five desired outcomes, the Council has identified seven land use policies to guide land use and regional development. The land use policy Building in Resilience seeks to develop local resiliency to the impacts of climate change. The Council's role in Building in Resilience includes identifying and addressing potential vulnerabilities in regional systems as a result of increased frequency and severity in temperature, precipitation, and extreme weather.

Technical Support

"It is at the local level of government where most climate change impacts occur. Local jurisdictions are where streets and homes are flooded, where infrastructure is installed, where potable water is supplied, and where building permits are issued. As a result, 'Main Street' is the nexus for climate change action" (APA, 2011).

The development of a Climate Vulnerability Assessment (CVA) report and CVA tools (consisting of shape files, data sets, and a replicable methodology) will complement the online *Local Planning Handbook* through ensuring that an online resource of CVA is available for communities to assist with comprehensive planning and resiliency planning more generally. The CVA will also improve the resource library within the *Local Planning Handbook* through the delivery of a CVA methodology and publicly available GIS data sets.

Project Need

Beyond the specific policy language within *Thrive MSP 2040* which identifies and authorizes this project work, there is a business need for the project. The Climate Change Impacts and Risk Analysis Project conducted by the U.S. EPA, identifies the high costs of inaction to mitigate and adapt to the effects of climate change. This study suggests that there is an economic imperative to mitigate and adapt in the face of climate change, given the fact that mitigation can lessen future climate impacts, and adaptation prepares for climate impacts currently occurring and likely to occur in the future. If an organization, community, or business delays with resilience planning, the future cost of adaptation will likely increase (EPA, 2015).

Through its operations and planning roles, the Council is committed to reducing its GHG emissions (mitigation) while protecting natural resources and water supply and quality. The Council operates and maintains wastewater infrastructure and plants, facilities, and a transit network. The Council also collaborates to plan for regional water quality and supply, the metropolitan transportation network, and regional parks and trails. Though many of these regional assets have been analyzed through a hazard mitigation or asset management process, they have not been measured through the lens of climate impacts and associated vulnerability.

Table 2 –Summary of Regional Assets

System or Focus	Assets	Council Role
Council-owned Housing	Housing	Owns & Maintains
Facilities	Buildings & Structures	Owns & Operates
Land Use	N/A	Planning & Collaboration with Stakeholders
Transit	LRT, Bus Network, Metro Mobility, & Commuter Rail	Owns & Operates; Collaboration with Stakeholders
Transportation	N/A	Planning & Collaboration with Stakeholders
Regional Parks & Trails	N/A	Planning & Collaboration with Implementing Agencies
Wastewater	Wastewater Treatment Plans, Interceptor Pipes, Lift Stations, Maintenance Holes	Owns & Operates
Water Quality	N/A	Planning & Collaboration with Stakeholders
Water Supply	N/A	Planning & Collaboration with Stakeholders

Project Description

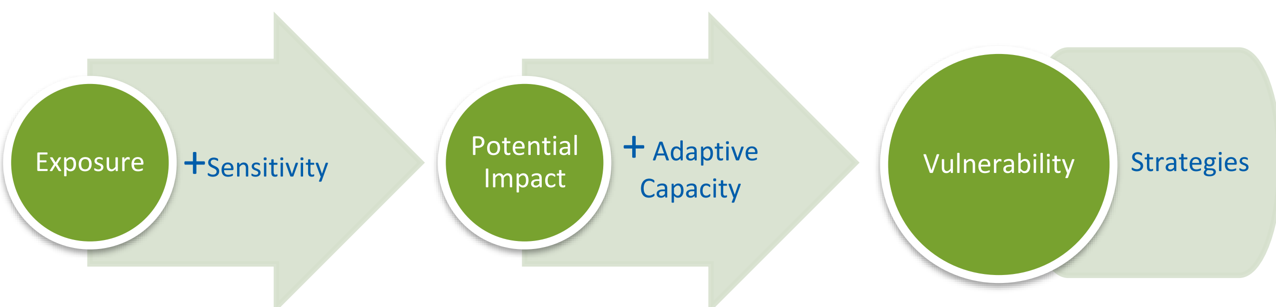
The CVA project supports the desired outcomes and land use policies identified in *Thrive MSP 2040* through the identification and analysis of potential vulnerabilities in regional systems resulting from increased frequency and severity of climate events.

The CVA is a tool that can assist in Council and community planning efforts in preparing and adapting to climate change because the CVA can reveal what systems (infrastructure, population, operations, etc.) are most vulnerable to currently occurring and, to some extent, expected climatic changes, depending upon factors such as exposure, sensitivity, and adaptive capacity of the analyzed asset.

The determination of vulnerability allows the Council and communities an opportunity to prioritize infrastructure improvements and maintain existing infrastructure investments. For example, extreme precipitation may cause localized flooding that impacts a particular asset. Or, an identified vulnerability may help a community focus its improvement of the urban tree canopy in areas where the stormwater system or roadways are most vulnerable to extreme heat.

There is no universal standard for conducting a CVA, and research suggests that results of such assessments can vary in terms of their utility and application (Graham McDowell et al, 2016). The following flowchart illustrates summarizes the Climate Vulnerability Assessment process

Figure 5 – Generalized CVA Process



Climate vulnerability assessments analyze climatic impacts on a series of determined indicators or assets. Each asset has an adaptive capacity to a potential impact. This adaptive capacity is a product of the exposure to the impact and the sensitivity of the asset to the impact. The product of the exposure/sensitivity and potential impact/adaptive capacity is a measure of the indicator's vulnerability. This measure of vulnerability can be used to create a targeted menu of adaptation strategies to better maintain, plan for, and manage Council assets.

Based on our choice of climate hazards, the diversity of assets, and data availability, we have defined the elements of the assessment equation in the following manner:

- **Exposure –** Exposure is a degree of climate stress upon a particular asset or indicator; it may be represented as either long-term change in climate conditions, or by a change in climate variability, including the magnitude and frequency of extreme events. Unless otherwise indicated in this assessment, sensitivity of a given asset is combined with exposure to produce a relative metric for asset risk.

- **Potential Impact –** The potential impact is a combination of exposure and sensitivity in light of a climate hazard. The potential impact can be offset by adaptive capacity, or its ability to bounce back.

- **Adaptive Capacity –** Adaptive Capacity is the ability of a system to adjust to changes, manage damages, take advantage of opportunities, or cope with consequences. This assessment does not consider adaptive capacity of assets, though this would provide a better estimate of specific vulnerability.

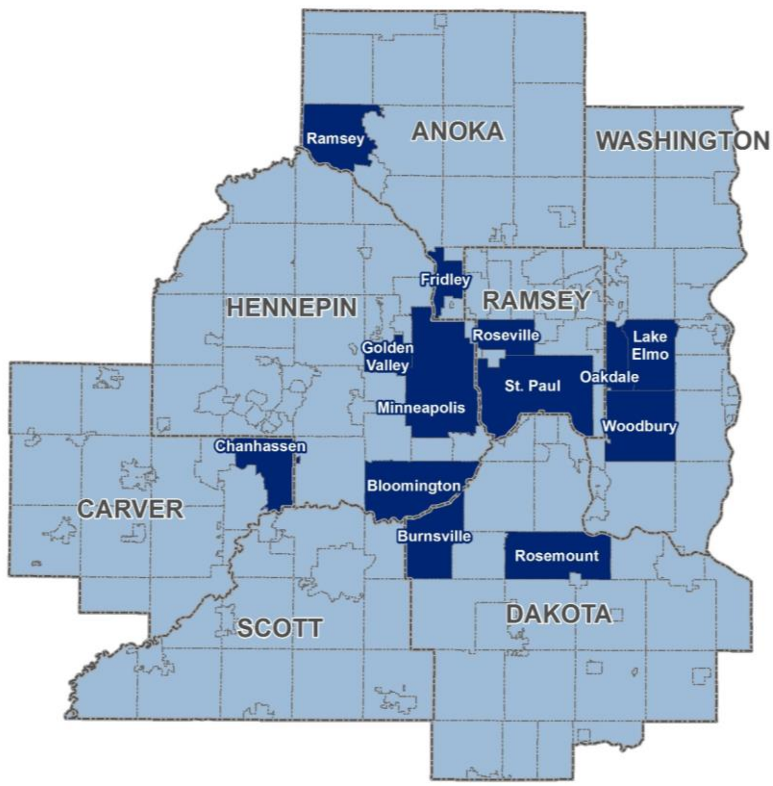
- **Vulnerability –** The degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity.

- **Strategies –** Strategies are recommended actions that consist of best practices to preserve or enhance system assets. These strategies will most often encompass adaptation to climate change impacts, but some may include mitigation measures, like tree planting to offset GHG emissions.

Focus Group

This CVA will ultimately provide analysis tools for both the Council and for communities. Therefore, the Council reached out to communities for feedback on the scoping phase of the project. An invitation for the focus group was sent to all 188 jurisdictions in the region. Twenty-one participants attended the focus group in July 2016, representing 13 cities and one county (Figure 6). The focus group participants provided helpful feedback for this project. The participants commented on the utility of the CVA in helping to foster conversation about, and supporting the need for, preparedness in their communities. They offered improvements for and criticisms of the project, potential application and its overall usefulness within city planning, adaptation strategies that could be employed throughout the region, and community needs for implementation.

Figure 6 – Focus Group Participants



The Focus Group also gave us insight into the CVA from a city's perspective, rather than from a larger, regional scale. We will incorporate this local perspective to inform the remaining CVA project work. The participants also expressed interest in an ongoing, close collaboration between cities to strengthen the actions and dialogue on resilience and adaptation planning in the region.

Deliverables

The key deliverables of this project include several CVA documents, separate parts and chapters. The project also consists of CVA tools (consisting of shape files, data sets, and a replicable methodology) which will complement the online *Local Planning Handbook* through ensuring an accessible resource of

CVA for communities to assist with comprehensive planning and resiliency planning more generally. The CVA will also improve the resource library within the online Local Planning Handbook through the delivery of a CVA methodology and publicly available GIS data sets.

This effort includes the following deliverables:

1) Climate Vulnerability Assessment report
   - Part 1: Localized Flood Risk (to be released as separate chapters)
     - Chapter 1: Transportation-Transit
     - Chapter 2: Regional Parks & Trails
     - Chapter 3: Wastewater & Water Resources
     - Chapter 4: Facilities & Council Housing
   - Part 2: Extreme Heat
   - Part 3: Human Vulnerability to Flooding and Extreme Heat

2) Integrate CVA tools into online *Local Planning Handbook*
   - Interactive, online mapping tools (data sets & shape files) available for public usage
   - Inclusion replicable methodology for conducting CVA
   - Monitor and update GIS data, as required

3) Provide in person and/or self-guided education opportunities for the use of CVA in local comprehensive planning processes, climate mitigation and adaptation policies, and creation of resiliency action plans

Localized Flooding Approach

The common understanding of flood impacts is related to riverway flooding, but there are actually different types of flooding. The purpose of this assessment is to consider a form of flooding that is occurring more often and is less understood – localized flooding. Localized flooding is often referred to as surface water flooding or pluvial flooding. Before describing our localized flooding (bluespot) approach, it is necessary to highlight existing forms of flood modeling and flood study.

Riverine Flooding

The Metropolitan Council Climate Vulnerability Assessment (CVA) examines risks due to two types of flooding: riverine flooding and localized flooding.

Riverine flooding is evaluated using the FEMA 100-year and 500-year floodplain information from FEMA Digital Flood Insurance Rate Maps (DFIRM). The CVA does not attempt to update the FEMA maps or evaluate the accuracy of the maps or appropriateness of the layers for future flooding due to changing climate. Rather, this project evaluates how to use the FEMA flood maps to investigate climate vulnerability on an asset-by-asset basis.

Atlas 14 Data

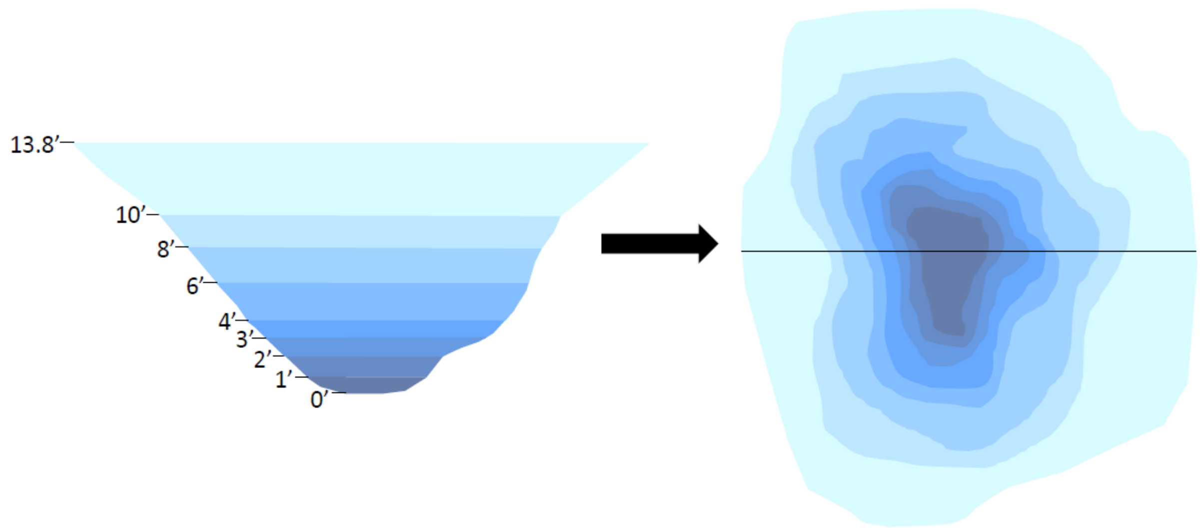
Atlas 14 is an update to precipitation frequency estimates (including depth and rainfall distribution) for the Midwestern states compiled and released by the National Oceanic and Atmospheric Administration (NOAA). It is used to estimate peak stormwater discharges and runoff volumes, which are used to design storm sewer and pond facilities, and estimate high water levels of ponds, small streams, county ditches and determine flood plain areas. Atlas 14 replaces the precipitation data under Technical Paper 40 (TP40). TP40 was published in 1960, and the new Atlas 14 data represents a more accurate measure of rainfall to assist in stormwater modelling. In Minnesota, watershed districts, watershed management organizations, and soil and water conservation districts, in collaboration with agencies and communities, are using the Atlas 14 data to better plan for present and future flooding events.

This bluespot, localized flooding analysis does not use Atlas 14 data to project flood risk based on rainfall totals for various rain events. The purpose of the bluespot analysis is to provide communities and agencies with another tool that can be used to screen areas of potential localized flood risk. Bluespot analysis can be used in conjunction with Atlas 14 data and FEMA floodplain information to add rigor to assessment work.

Bluespot (Localized Flooding)

Following an example from the Danish Road Institute, our team evaluated localized flooding in low spots on the landscape, which the Danish study called “bluespots” (Danish Road Institute, 2010). Bluespots are areas that are expected to flood during short-term, extreme rain events. The Council’s bluespot analysis uses information about the topography of the earth contained in the State of Minnesota’s 3-meter digital elevation model (DEM) built from the state’s LIDAR data. Bluespots are determined solely based on depressions in the DEM; no data of existing stormwater infrastructure is considered because this information does not currently exist at a regional scale. Using the Hydrology toolset within Spatial Analyst of ArcGIS 10.3.1, low points in the landscape are identified and depressions are filled with water. From this information, the maximum water rise in a bluespot is determined, along with the surface area that will flood when the water in a bluespot rises to certain heights. To illustrate, an example bluespot is shown below in Figure 7. The bluespot has a max water rise of 13.8 feet before it spills over to the next bluespot. A vertical cross-section of the bluespot is shown on the left, and the aerial view of the bluespot on the right.

Figure 7 – Bluespot Cross-Section and Aerial Example

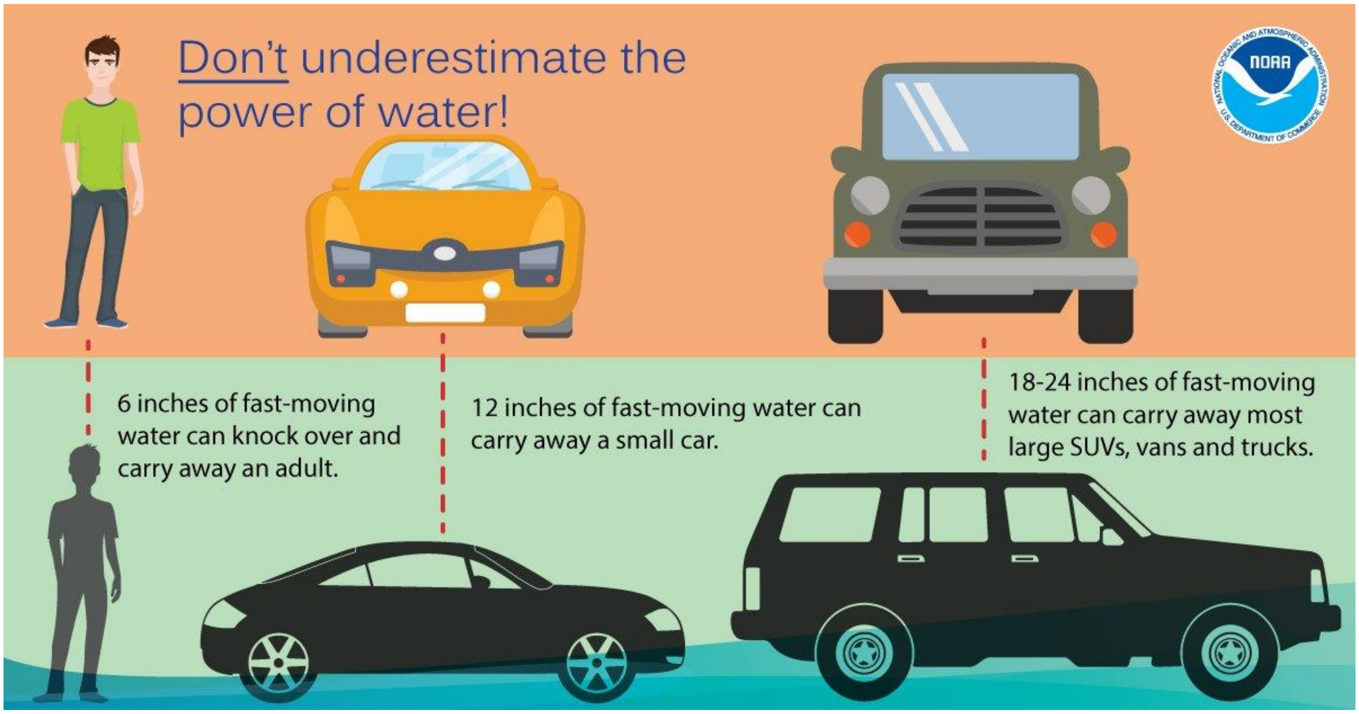


Bluespots were categorized as either “Shallow” or a range of water rise (0-1 foot, 1-2 feet, etc.). Shallow bluespots are those with a maximum depth of 3 inches to 1 foot that are generally low risk for all assets in this analysis. When water rises to the maximum depth of a bluespot, it spills over to the next bluespot, so the water rise can never get higher than the maximum depth. Imagine a bathtub: no matter how much water you add to a bathtub, it can never rise above the tub’s overflow because the water just flows out of the drain above that height.

Depressions with a depth less than 3 inches were not included as bluespots because of their low risk and because they were within the range of error of the source data.

Using several sources and internal subject matter experts, the team selected a cut-off for shallow bluespots of 1 foot. As illustrated in the NOAA-produced graphic below differing levels of floodwaters, even at apparently shallow levels, can pose risks for vehicles and pedestrians (Figure 8).

Figure 8 – NOAA Flood Hazard Infographic



(National Weather Service, 2017)

Bluespots below 1 foot in depth can be a danger to pedestrians, and certain assets can be undermined by small depths of water, such as infrastructure damage due to submergence, or any ponded water at all. Bluespots below 1 foot in depth are of lower risks to vehicles.

Bluespots with a maximum depth greater than 1 foot are of greater concern than shallow bluespots. because water can rise beyond 1 foot, there is increased danger to people and vehicles, as well as increased potential for impact on properties and infrastructure. For bluespots with a 1-foot maximum depth or greater, the danger depends on how high the water rises. An individual bluespot might be able to fill up to a maximum depth of 10 feet, but it is much more likely to partially fill up during a smaller storm than to fill all the way to 10 feet during a catastrophic storm. Both situations are dangerous, but the relative risk of the bluespot filling 4 or 10 feet can vary significantly. Our analysis does not predict the likelihood of a certain bluespot filling over another, nor does it predict the likelihood of partial to complete filling or where the bluespot will likely be the deepest and most dangerous.

Flood Hazard Categorization & Symbology

To streamline the analysis and to better assess the relative flood hazard and vulnerability of our assets, the Council categorized the bluespots in groups of 1-foot increments of water rise. Assigning risk based on the bluespots is based on the Council's identified needs and potential risks. A community or an agency may wish to categorize flood depths in a different manner to better suit their own asset evaluation.

For Council assets, bluespots have been categorized into four flood hazards: Shallow, Primary, Secondary, and Tertiary. As stated previously, Shallow bluespots are separate, isolated low areas generally considered low risk, but this depth may still be a concern for certain types of infrastructure. The remaining 3 flood hazards are usually contiguous and represent the deeper bluespots of the Flood Impact Zone (FIZ). Primary are the first areas to fill with water (after the stormwater infrastructure has been overwhelmed). Secondary are the second areas to fill, and Tertiary are the last areas to fill.

Table 3 – Flood Impact Zone (FIZ) and Bluespot Symbology

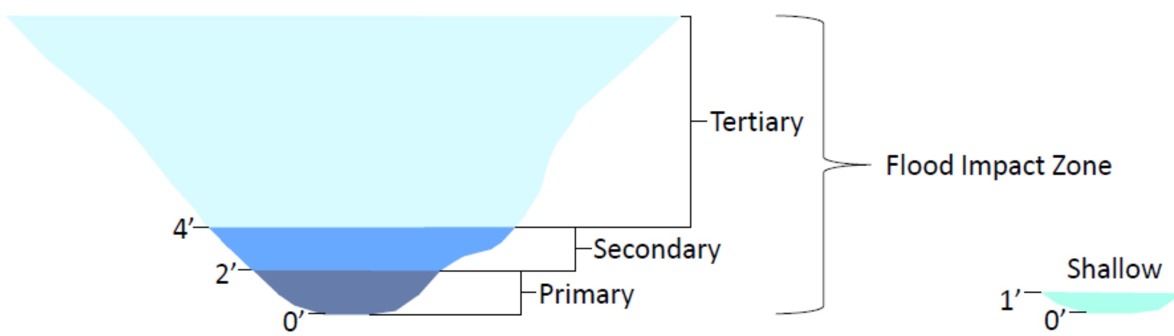
Bluespot Depth	Flood Hazard Category	Bluespot Symbology
3in -1 foot	Shallow	
0-1 feet	Primary	
1-2 feet	Primary	
2-3 feet	Secondary	
3-4 feet	Secondary	
4-6 feet	Tertiary	
6-8 feet	Tertiary	
8-10 feet	Tertiary	
>10 feet	Tertiary	

Isolated 3in – 1ft Bluespots (3in -1 foot row)

Flood Impact Zone (FIZ) (0-1 feet through >10 feet rows)

Every bluespot is different and has different stormwater infrastructure and a unique depth to volume relationship. That means one bluespot might fill up to 2 feet with a 2-year rain event, while another bluespot will not fill at all during a 100-year rain event. These bluespot flood zones were selected to assign general or potential risk, with the understanding that in-depth analysis using stormwater infrastructure information should be completed for bluespots of particular interest. Figure 9 shows a cross section of a bluespot using the Flood Impact Zone hazard categorization.

Figure 9 – Bluespot Cross-Section using Council Categorization



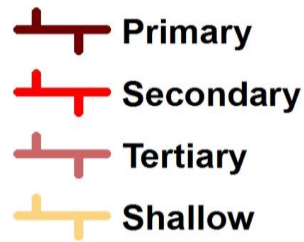
Vulnerability Symbology and Assessment

In all cases in this report, the asset vulnerability is always shown using a red palette. This color scheme is used to display the system locations impacted by the intersection or overlay with the bluespots. Depending on the asset being evaluated, we either used a binary determination of vulnerability ('in' or 'out' of a bluespot) or a weighted determination.

Binary 'In' or 'Out' Determination of Vulnerability

For some assets, the Council performed its analysis based on whether the asset was 'in' or 'out' of a bluespot. In these cases, the vulnerability is based entirely on the hazard level, with Primary being the greatest flood hazard and therefore creating the highest vulnerability (shown in deep red). The legend example in Figure 10 shows the color scheme for this type of analysis.

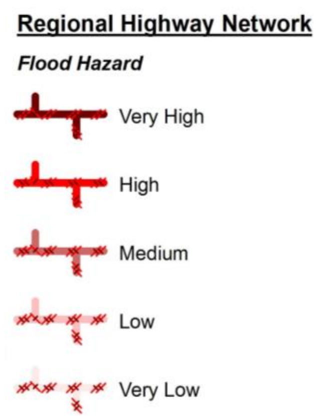
Figure 10 – Binary Determination of Vulnerability



Weighted Determination of Vulnerability

The Council assigned a level of vulnerability, from 'very low' to 'very high' using a sensitivity/exposure matrix for analysis of certain assets (see Figure 11). For instance, we placed a high weighting on arterial roads with a higher classification because the sensitivity and exposure of these areas to flood impact creates a higher vulnerability.

Figure 11 – Weighted Vulnerability based on Sensitivity/Exposure



Asset Flood Analysis

Each asset is analyzed independently and should be treated as such. The depth of flooding that affects one asset may not affect another asset in the same manner.

Project Limitations

The project focuses on identification of vulnerable areas, infrastructure, populations, and assets. However, give the regional scale of the assessment and other limitations, the assessment does not accomplish what a more localized, scaled down assessment can achieve. The reader should be aware of the project limitations regarding the data, discretion on the evaluation, and level of detail in the project, as detailed below.

Data

- The project scope reflects data availability and data application. For instance, the absence of a region-wide stormwater dataset limits our ability to rigorously analyze potential localized flooding impacts.
- There is difficulty in obtaining reliable and verifiable data to inform the study, and the Council has refined the scope of this project in recognition of these constraints.
- The data used in this assessment is static. The analysis represents a snapshot in time and is not dynamic. The assessment will need to be renewed to remain current and relevant to everyday planning and investment decisions.

- The Council does not have data sources for locally-owned infrastructure. The Council's work on CVA will primarily assess Council assets.
- The LIDAR data which creates the digital elevation model (DEM) needed for the bluespot data layer is from 2011. Developments or topographical changes that occurred after 2011 may not show accurate bluespots. Also, there are some areas within the data that may not be correct due to other errors within the data.

Discretion

- The assigning of hazard thresholds was determined internally and is discretionary, based primarily through staff discussions and review of agency literature on, for instance, flooding hazards at various depths.
- The weighting of hazards in relation to exposure/sensitivity values was determined internally and is discretionary, varied by asset, and was decided through discussions with subject matter experts.

Detail

- The basemaps are useful as a screening and planning tool for community or stakeholder use. We encourage users to perform more site-specific analysis to ground-truth data. Users are encouraged to create their own hazard thresholds, vulnerability weightings, and strategies based on their own priorities and scope.

Glossary of Terms and Acronyms Used in this Report

CVA Terms

Adaptation – Adaptation focuses on how to change policies and practices to adjust to the effects of climate change.

Adaptive Capacity – Adaptive Capacity is the ability of a system to adjust to changes, manage damages, take advantage of opportunities, or cope with consequences. This assessment does not consider adaptive capacity of particular assets, though this would provide a better estimate of specific vulnerability.

Asset – For the purposes of this analysis, Asset refers to a part of a system – for example, a piece of infrastructure, a bus route, or an arterial roadway.

Bluespot – The bluespot analysis is based on a Danish Road Institute study which uses a GIS fill tool to inundate topographical areas with water to assess areas potentially at risk of flooding. The Council assigned levels of hazard to different flood increments for its bluespot data layer.

Climate – Climate consists of the average weather conditions at a particular place over a long period of time.

Climate Change – A change in global or regional climate patterns that can be identified (e.g., by using statistical tests) and lasts for an extended period, typically decades or longer. According to the Intergovernmental Panel on Climate Change (IPCC), climate change may be due to natural internal processes or external forces such as modulations of the solar cycles, volcanic eruptions, and persistent anthropogenic changes to the composition of the atmosphere or in land use.

Equity – Equity connects all residents to opportunity and creates viable housing, transportation, and recreation options for people of all races, ethnicities, incomes, and abilities so that all communities share the opportunities and challenges of growth and change. For our region to reach its full economic potential, all of our residents must be able to access opportunity. Our region is stronger when all people live in communities that provide them access to opportunities for success, prosperity, and quality of life.

Exposure – Exposure is a degree of climate stress upon a particular asset or indicator; it may be represented as either long-term change in climate conditions, or by changes in climate variability, including the magnitude and frequency of extreme events. In the case of this assessment, sensitivity of a given asset is combined with exposure to produce a relative metric for asset risk.

Flood Impact Zone – The remaining 3 flood hazards divide up the deeper bluespots and make up the Flood Impact Zone (FIZ). Primary are the first areas to fill with water (after the stormwater infrastructure has been overwhelmed). Secondary are the second areas to fill, and Tertiary are the last areas to fill.

Flood Hazard – For this assessment, the Flood Hazards refer to our groupings of bluespots into depth increments, from Shallow to Tertiary.

Hazard Mitigation – Hazard Mitigation is defined as any sustained action taken to reduce or eliminate the long-term risk to life and property from hazard events. It is an on-going process that occurs before, during, and after disasters and serves to break the cycle of damage and repair in hazardous areas.

Indicator – Indicator is used interchangeably with the term 'asset.' When the term 'indicator' is used, it typically refers to a particular demographic or social group.

Mitigation – Mitigation focuses on minimizing contributions to climate change – for example, reducing energy use that leads to greenhouse gas emissions.

Potential Impact – The potential impact is a combination of exposure and sensitivity in light of a climate hazard. The potential impact can be offset by adaptive capacity (bounce back).

Resilience – Resilience recognizes the difficulty of predicting what the impacts of climate change will be and emphasizes increasing our flexibility to survive and thrive regardless of how climate change develops. Resilience is the ability of a social or ecological system to bounce back after experiencing a shock or stress. Resilient systems are usually characterized by flexibility and persistence.

Sensitivity – The degree to which a built, natural, or human system will be impacted by changes in climate conditions. In the case of this assessment, sensitivity of a given asset is combined with exposure to produce a relative metric for asset risk

System – Systems that are analyzed are comprised of assets. For instance, the transportation system is comprised of different road classifications, all of which would be considered assets within the system.

Thrive MSP 2040 **–** Thrive is the Regional Development Framework for the Twin Cities Metropolitan Region. The policy document was adopted in 2014.

Strategies – Strategies are recommendations based on best practices for asset management.

Sustainability – Sustainability means projecting our regional vitality for generations to come by preserving our capacity to maintain and support our region's well-being and productivity over the long-term.

Urban Heat Island Effect – An urban heat island (UHI) is an urban area or metropolitan area that is significantly warmer than its surrounding rural areas due to human activities. The main cause of the urban heat island effect is from the modification of land surfaces. Waste heat generated by energy usage is a secondary contributor.

Vulnerability – The degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity.

Weather – The daily conditions of the atmosphere in terms of temperature, atmospheric pressure, wind, and moisture.

Acronyms

BNSF – Burlington Northern Santa Fe Railroad
BRT – Bus Rapid Transit
CFR – Code of Federal Regulations
CVA – Climate Vulnerability Assessment
DEM – Digital Elevation Model
DFIRM – Digital Flood Insurance Rate Map
GIS – Geographic Information Systems
GHG – Greenhouse Gas
FEMA – Federal Emergency Management Administration
FAA – Federal Aviation Administration
FIZ – Flood Impact Zone
FRA – Federal Railroad Association
ICS – Incident Command System
LiDAR - Light Detection and Ranging
LGU – Local Governmental Unit
LST – Land Surface Temperature
LRT – Light Rail Transit
MAC – Metropolitan Airports Commission
MC-MTS – Met Council - Metropolitan Transportation Systems
MSP – Minneapolis-St. Paul International Airport
MVTA – Minnesota Valley Transit Authority
NOAA – National Oceanic and Atmospheric Administration
NIMS – National Incident Command System
RBTN – Regional Bicycle Transportation Network
SOP – Standard Operative Procedure
SSPP – System Safety Program Plan
TCC – Transit Control Center
TPP – 2040 Transportation Policy Plan
TP40 – Technical Paper 40 - Rainfall Frequency Atlas
UHI – Urban Heat Island Effect

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