DRAFT Climate Change Trends and Action Report

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BWSR is reducing printing and mailing costs by using the Internet to distribute reports and information to wider audiences. This report is available at http://www.bwsr.state.mn.us/native_vegetation/BWSR_Climate_Change.pdf and available in alternative formats upon request.

Why does climate change matter to BWSR?

The Minnesota Board of Water and Soil Resources (BWSR) mission is to improve and protect Minnesota's water and soil resources by working in partnership with local organizations and private landowners. With extreme weather patterns and disrupted natural cycles, climate change has the potential to decrease the ability of Minnesota landscapes to sustainably provide important environmental and economic benefits. Therefore, BWSR is working to integrate climate change considerations in programs and practices for conservation on private lands that make up approximately 75% of Minnesota's land area through wetland protection, conservation easements (retirement of marginal agricultural lands), and providing soil and water conservation grants. These programs play an important role in climate change prevention by preventing the release of stored carbon and methane in wetlands, sequestering carbon, decreasing nitrous oxide emissions from fertilizer and methane from manure, providing opportunities for bioenergy production, and increasing landscape resiliency. The following information is a summary of primary program areas and their role in climate mitigation and adaptation.

Lakeshore restoration in Carver County.

Forested bog in northern Minnesota.

Restored depressional wetland.

Wetland Protection (Administration of the Minnesota Wetland Conservation Act)

The primary goal of the Minnesota Wetland Conservation act is to achieve no net loss in the quantity, quality, and biological diversity of Minnesota's 10.6 million acres of existing wetlands. This is accomplished through avoiding direct or indirect impacts from activities that destroy or diminish wetlands and replacing wetland values where avoidance of such activity is not feasible and prudent. With wetlands holding large amounts of carbon and methane, these actions help protect against climate change. It is estimated that one acre of peatland contains, on average, 750 metric tons of carbon. Total emission of the carbon contained in just 1,000 acres of peatland would increase Minnesota carbon dioxide emissions by almost two percent (Anderson et.al. 2008).

Conservation Easements (Reinvest in Minnesota Reserve)

BWSR's RIM program is focused on the acquisition and enhancement of critical habitat in the predominantly agricultural areas of the state by converting marginal crop lands to permanent native vegetative cover. This includes a wide range of activities that increase resiliency to climate change, such as restoring wetlands, establishing riparian buffers, protecting sensitive ground water areas, planting critical winter cover for wildlife, preserving habitat for rare plant and animal species, protecting and restoring native prairie and grasslands, increasing pollinator habitat, and preserving spawning and reproduction areas for fish. This program also plays an important role in sequestering larger amounts of carbon. The retirement of marginal agricultual lands also decreases emissions from machinery and nitrous oxide emissions from fertilizers.

Soil and Water Conservation Grants

BWSR's soil and water conservation grant programs provide funding to local government units for the implementation of targeted conservation projects and practices in rural and urban landscapes. A wide variety of conservation practices sequester carbon and decrease nitrous oxide emissions from fertilizer, including: tree planting, grass planting, prairie and wetland restoration, windbreaks/shelterbelts, grassed waterways, contour buffer strips, filter strips, riparian buffers, critical area planting, and cover crops. These practices also increase landscape resiliency and often help protect agricultural fields (protecting productivity) from extreme weather events. Grants also fund nutrient management plans and anaerobic manure digesters that decrease nitrous oxide and methane emissions.

Grass waterway eroded from extreme precipitation

What are potential long-term trends and impacts from climate change?

The following passages are modified excerpts from pages 2 – 16 of the 2017 Interagency Climate Adaptation Team report "Adapting to Climate Change in Minnesota".

Minnesota's climate background

Minnesota's position near the center of North America, halfway between the Equator and the North Pole, subjects us to an exceptional variety of weather. During the course of a single year, most Minnesotans will experience blinding snow, bitter wind chills, howling winds, pounding thunderstorms, torrential rains, and heat waves, as well as dozens of bright and sunny days. Given the high variability that we expect from Minnesota's climate, it can be difficult to discern where, when, and how climatic conditions have changed in our state.

The conditions, however, have changed rapidly, and an overwhelming base of scientific evidence projects that Minnesota's climate will see additional significant changes through the end of the 21st century. Over the last several decades, the state has experienced substantial warming during winter and at night, with increased precipitation throughout the year, often from larger and more frequent heavy rainfall events. These changes alone have damaged buildings and infrastructure, limited recreational opportunities, altered our growing seasons, impacted natural resources, and affected the conditions of lakes, rivers, wetlands, and our groundwater aquifers that provide water for drinking and irrigation. The years and decades ahead in Minnesota will bring even warmer winters and nights, and even larger rainfalls, in addition to other climatic changes not yet experienced in the state.

Climate observations and trends in Minnesota: What has changed and what has not?

In 2014, the U.S. Global Change Research Program completed its third National Climate Assessment. This comprehensive scientific review of the state of climate change science demonstrated that the U.S. is already seeing increasing temperatures, larger rainfalls with increased flash-flooding, heavier snowstorms, more severe heatwaves, and worsening drought conditions in some areas. Within particular regions of the U.S., some of these observed changes are more intense, some are less intense, and some are negligible or not yet occurring.

Both the science summarized in the National Climate Assessment and high-quality climatic data show that in Minnesota and the Midwest, rising temperatures have been driven by a dramatic warming of winter and also nights, with both the frequency and the severity of extreme cold conditions declining rapidly. Annual precipitation increases have been punctuated by more frequent and more intense heavy rainfall events. The heaviest snowstorms have also become larger, even as winter has warmed (see Figure 1).

Several other changes noted elsewhere in the U.S. and world have not yet been observed in Minnesota. For instance, summer high temperatures have not increased in several decades, and heat waves have not worsened when compared to historical patterns. Droughts in Minnesota also have shown no long-term increase in magnitude, duration, or geographic coverage. Tornadoes, large hail, and damaging thunderstorm winds are difficult to compare historically but show a complex tendency toward more "outbreaks" consisting of multiple events at a time, though no increases in overall numbers or severity.

Figure 1

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

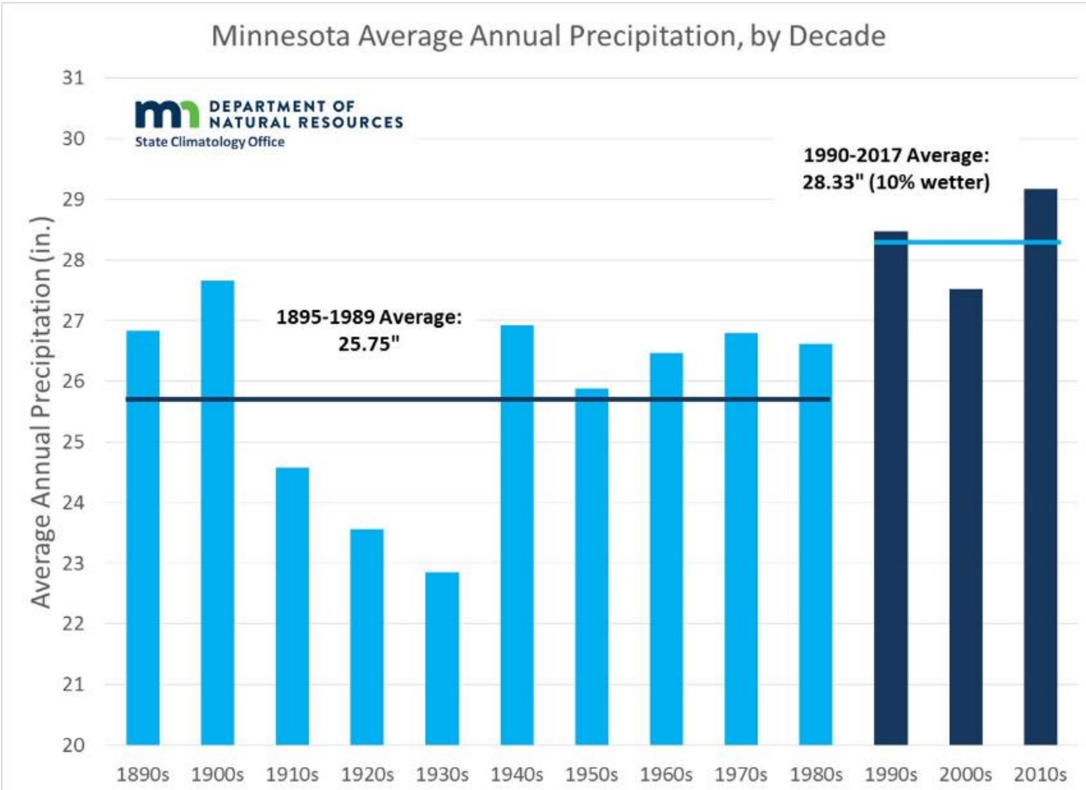
Snapshot of observed trends among common weather hazards in Minnesota, and confidence that those hazards are changing in response to climate change. Graphic based on information from 2014 National Climate Assessment and data analyzed by the Minnesota DNR State Climatology Office.

Increased precipitation

Higher temperatures globally have evaporated more surface and ocean water into the atmosphere, which in turn has provided more potential moisture for precipitating weather systems. This has resulted in more precipitation for Minnesota, which now finds itself in its wettest period in over 125 years of record. Since 1990, Minnesota has been 10% wetter on average than period 1895 to 1989 (see Figure 2).

This precipitation increase is found in all seasons, but spring and summer are becoming wetter at faster rates than fall and winter. Whereas temperature increases have been greatest in the northern parts of the state, precipitation increases have been well distributed geographically, and have somewhat favored southern Minnesota, which has better access to moisture from the Gulf of Mexico, and is more frequently near the "low-level jet" airflow (a relatively fast-moving zone of winds in the lower atmosphere) that influences precipitation production.

Figure 2



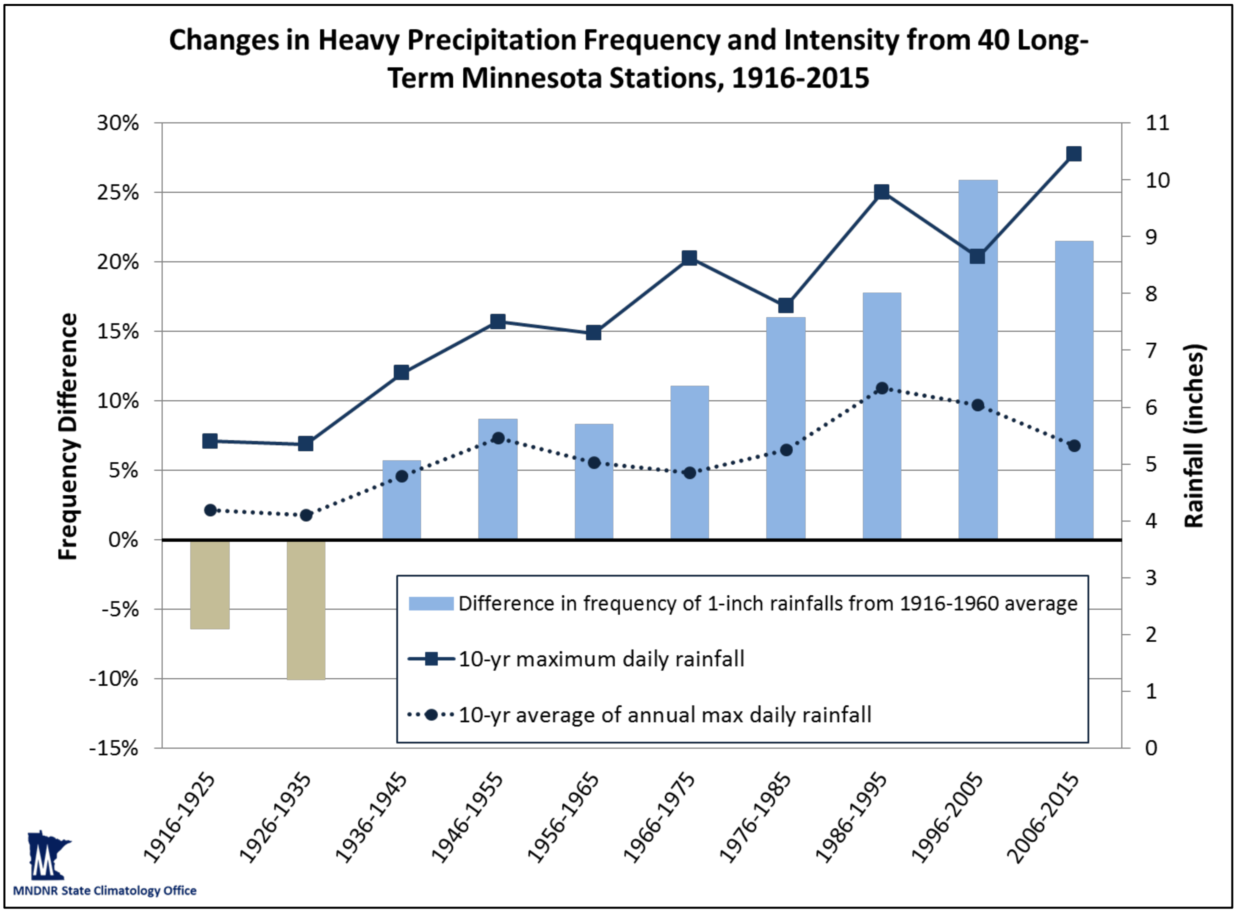
Statewide average annual precipitation, by decade, for the period 1895-2017. Please note that the 1890s and 2010s have fewer than 10 years of record. Source: Minnesota DNR State Climatology Office and National Oceanic and Atmospheric Administration (NOAA) Climate at a Glance (http://www.ncdc.noaa.gov/cag/)

Heavy rainfall and unprecedented extremes

Heavy rainfall events in Minnesota are already becoming larger and more common, and have been contributing to an increasing share of annual precipitation in Minnesota. For instance, the state has 40 daily weather observing sites whose records stretch back more than 100 years. These long-term stations have shown a 20% increase in the annual number of 1-inch daily rainfalls, a 65% increase in the number of 3-inch rainfalls, and a 13% increase in the size of the heaviest rainfall of the year. Additionally, the single heaviest rainfall amount recorded per 10-year interval at those 40 sites has roughly doubled (from just over five inches to just over 10 inches) during that same period (see Figure 3).

Research specific to the Upper Midwest indicates that the physical mechanisms supporting heavy rainfall events in Minnesota are likely to have begun intensifying in response to climate change. This research also shows that these major events may be taking place earlier during the growing season than the historical average. Thus, in addition to increases in the frequency and intensity of heavy rainfall, its seasonal timing may be expanding across the calendar.

Figure 3



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.

In addition to increases in the frequency and magnitude of heavy rain, Minnesota has also seen a dramatic increase in large-coverage flash floods events in recent years. Since the year 2000, the state has had eight catastrophic “mega-rain events” — when at least six inches of rain falls on an area greater than 1,000 square miles. The years 2002 and 2016 both had two of these damaging rainstorms. By contrast, the 30 years from 1970 through 1999 saw only four. Incidentally, the mega-rains since 2000 have included the largest, earliest, and latest on record, suggesting that we are seeing not just an intensification, but also a lengthening of our heavy and extreme rainfall season.

Projected continued enhancement of extreme precipitation

In the years and decades ahead, winter warming and increased extreme rainfall will continue to be Minnesota’s two leading symptoms of climate change (see Figure 4).

Figure 4

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	

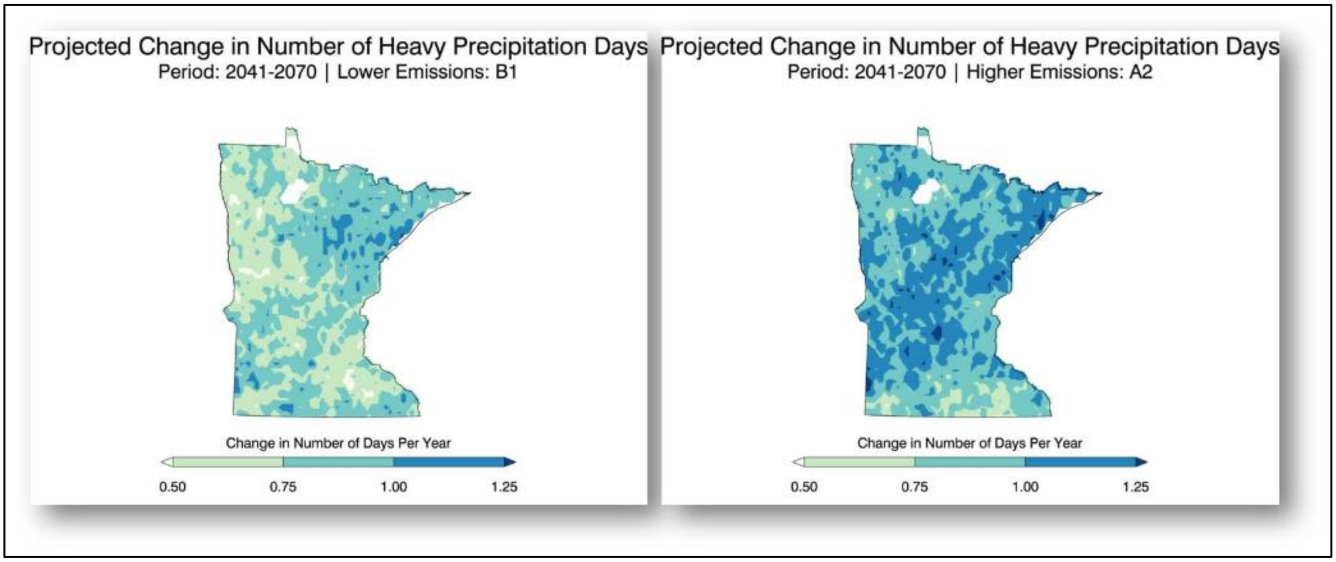
Lowest	Low	Moderately Low	Moderately High	High	Highest

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.

Greenhouse gas concentrations will continue rising through the century, and the air's ability to trap heat from the earth's surface will increase accordingly. As a result, winters, and cold conditions in particular, will continue warming well beyond historical bounds. Continued warming of the atmosphere will evaporate even more water into the air, further limiting the amount of cooling Minnesota will be able to achieve at night and during the winter. This increased water vapor will also enhance precipitating weather systems, continuing the trend toward more — and larger — heavy rainfall events (see Figure 5). Minnesota can expect unprecedented rainfall events during the remainder of the 21st century.

Figure 5



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

Impacts of climate change in Minnesota

The observed measurements and future projections described by the National Climate Assessment and the Minnesota State Climatology Office provide insight into climate trends that are impacting Minnesota now as well as those anticipated in the future. Complicating the varied impacts of climate change is that these changes also interact with and reinforce each other. For example, drought and heat may both contribute to wildfires, which may in turn lead to changes in plant and animal populations as well as other ecological shifts. Extreme precipitation may increase flooding, along with the potential for runoff or combined-sewer overflow and contamination of recreational and drinking water sources, which may already be in short supply due to drought. In addition, climate change will amplify the effects of existing public health and environmental challenges, such as impaired air quality, loss of wildlife habitat, invasive species, and limitations to clean water supplies.

As informed by climate data and trends, Minnesota state agencies are identifying significant current and future climate change impacts. These impacts, including variable and considerable changes in temperature and precipitation, are expected to have substantial effects on public health, community infrastructure, ecosystem health, environmental quality, and natural resource-based economies.

The following description of the impacts of extreme weather events summarizes some currently observed and anticipated impacts of climate change by ICAT member agencies.

Extreme weather events

Both observed climate data as well as future projections indicate increases in very heavy precipitation in Minnesota. Heavy precipitation events, storms, and flooding have significant impacts on Minnesota's communities and ecosystems. These include effects on water and soil resources, agriculture, drainage infrastructure, human health, stormwater management, wastewater treatment, solid waste management, and emergency response.

Climate change has the potential to impact the **quality of water and soil resources** throughout Minnesota.

- More frequent, heavier, or longer-duration rainfall events will **increase soil erosion and runoff**, thereby increasing deposition of sediment and contaminants in water bodies.
- More frequent extreme weather events will impact Minnesota agriculture, resulting in **increased runoff of fertilizers, pesticides, and sediment**, particularly from agricultural fields that do not have best management practices in place such as buffers, grassed waterways, and crop residue left on the fields. Field flooding can result. There are also costs to the state for disaster assistance, (e.g., the DNR's Flood Damage Reduction grant program) which will likely increase as a result of climate change.
- Damage to feed crops from extreme weather also affects livestock. Greater precipitation increases **challenges for applying manure** in an environmentally safe manner to fields. Flooding can also cause **overflow of manure storage basins** which have inadequate storage capacity, leading to contamination of nearby water bodies and death of aquatic organisms.
- Increased extreme weather events put additional pressure on the state's **drainage infrastructure**. There is a potential for more erosion within older drainage systems that do not have adequate outlets or erosion controls in place.
- Flash flooding from extreme precipitation can **damage the built environment**, affecting commercial and residential buildings, roads, parks, and stormwater infrastructure. Water-saturated soils can destabilize bluffs, trees, and utility poles.
- Flooding from increased average rainfall, rapid snowmelt, or localized, heavy rainfall can lead to **human health impacts** such as:
    - Persistent mold problems in homes and businesses.
    - Increases in food and water-borne illness
    - Food insecurity
    - Injury (particularly due to unsafe structures and clean-up efforts).
    - Interruption of medical and emergency services. .
    - Stress and mental health impacts due to trauma, displacement, and loss.
    - Death from drowning.
- Flooding **contaminates freshwater sources** with untreated or partially treated sewage and can contaminate food crops with waste from nearby livestock or wild animals, threatening food safety.
- Increased water flow from a flood may **disrupt municipal water supplies and sewage treatment facilities**, as well as private wells and on-site septic systems. **Flooding of private wells** is a particularly serious public health concern, given that, in general, well owners do not test or treat their water according to health-protective guidelines.
- Resources for flood recovery need to focus on immediate issues as well as full community recovery, which can take years.
- Changes in amount, frequency, and intensity of precipitation impact **stormwater management,** potentially exceeding the design capacity of stormwater treatment structures or impacting future structure design. Extreme weather also adds to challenges in monitoring water quality.

- Higher peak intensity rainfall events may result in **bypass of wastewater treatment facilities** or sanitary sewer overflows, leading to the release of minimally treated or untreated wastewater. Wastewater facility staff need to track changes in floodplain elevations as peak rainfall intensities increase so that treatment facility infrastructure can be protected during possible flood events.
- There is increased need to p**roperly clean up and manage solid waste, hazardous materials, and debris** after floods, storms, and other natural disasters. More frequent occurrences of natural disasters increase the demand for disaster remediation and coordination efforts, as well as for trained staff to meet these specific needs. Design standards for permitted waste management facilities are linked by rule to certain magnitudes of storm events (i.e., 25- or 100-year storms), and as storm severity increases, this impacts facility needs. There is accelerated use of existing waste management capacity due to more waste and debris resulting from extreme weather.
- Increasing numbers of floods and storms raise the need for **state support and response**. A greater demand for response from limited staff reduces time available for internal and external preparedness, including partnering and preparing with local units of government, state agencies, and industry. Infrastructure damage due to flooding and storms, such as flooded roads and power and communication technology outages, can disrupt emergency response in affected areas, which also has health impacts.
- **Populations particularly vulnerable to flooding and extreme weather events** include the elderly and those without the ability to evacuate when necessary. Long-term recovery from flooding and extreme weather events can be more difficult for low-income populations, especially in regards to housing and employment. Community infrastructure (cohesion, relationships, ability to respond as a whole) should be considered just as much as environmental and built infrastructure.

Specific threats to Minnesota's natural resources and BWSR programs

Observed Trends and Projected Impacts

Wetland Protection (Administration of the Minnesota Wetland Conservation Act)

- Wetland health has been impacted due to more frequent extreme water fluctuations and prolonged inundation of vegetation that favors invasive species and disrupt the life-cycle of aquatic organisms.
- Northern black ash swamps covering about one million acres in Minnesota may significantly change in structure due to emerald ash borer and the loss of black ash trees.

Wetland impacted by water level variation

Conservation Easements (Reinvest in Minnesota Reserve)

- State easements with aquatic systems may degrade due to changing hydrology conditions.
- Combinations of extreme storms, flooding, harmful insects, and invasive species will further degrade natural wetlands, prairies and forests.
- With climate change, the National Wildlife Federation concludes that there will be diminished numbers of migratory waterfowl, pheasants, moose, walleyes, northern pike and brook trout, and fish kills will likely become more prevalent (National Wildlife Federation 2013).
- Upland and wetland northern forests could significantly change in structure from the spread of woody invasive species such as common and glossy buckthorn and invasive honeysuckles, invasive insects, and changes in dominant tree species. Some areas may transition from northern coniferous forest to savanna (Frelich & Reich 2010)

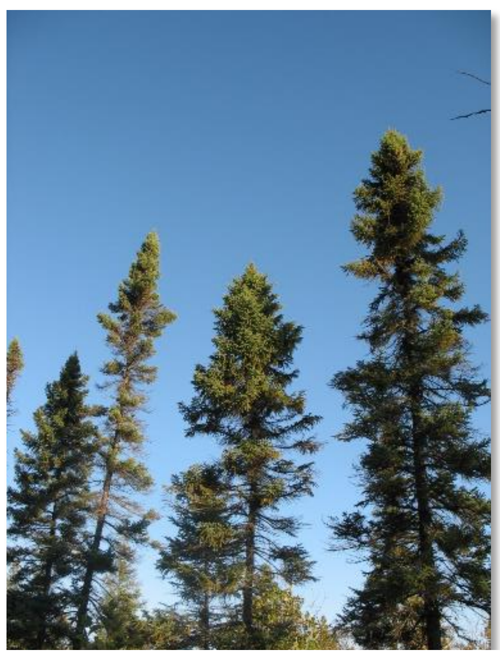
Invasive buckthorn changing the structure of a forest.

Soil and Water Conservation Grants

- There have been increased requests for assistance to repair and replace structures installed to manage water and improve habitat.
- Flooding has caused significant damage to private lands and conservation practice infrastructure in Minnesota.
- Conservation practices such as grassed waterways, filter strips, vegetated buffers, etc. have helped farmers retain topsoil and agricultural productivity during extreme weather events.

Large storm events and variable climate increase erosion and affect agricultural productivity.

- New National Oceanic and Atmospheric Administration rainfall frequency data (NOAA Atlas 14) has shown that the amount of rainfall for given storm frequencies (5-yr., 10-yr. etc.) has risen substantially in many areas of the U.S. in recent decades. This rainfall increase could generate approximately one third more runoff volume than estimated using the old data. The previous 100-year 24-hour event that generated approximately six inches of rainfall will now have a probability of occurring two to three times in 100 years (rather than once per 100 years).
- N_2O emissions from agricultural activities, primarily fertilizer application and other agricultural practices that increase nitrogen availability in the soil, increased by 12% between 2005 and 2016, (U.S. EPA 2018).
- Water quality in streams, rivers, wetlands, and lakes will likely degrade and/or be more challenging to restore, due to runoff from heavy rainfall, particularly in agricultural lands that are prone to erosion.
- Soil productivity and crop yields may decrease due to increased soil erosion and loss of organic content.



Climate change may lead to the transition from coniferous trees to deciduous trees in northern forests.

What has BWSR already done?

Over the years BWSR has played a significant role in decreasing greenhouse gas emissions by protecting wetlands, retiring marginal agricultural land and through soil and water conservation grants. Figure 5 below summarizes estimated benefits from BWSR programs from BWSR's beginning in **1987 through 2013**. The ranges in the table reflect a high degree of uncertainty in the amount of carbon sequestration that occurs under various practices, due to variations in local climate, land use, and land cover.

Wetland Protection (Administration of the Minnesota Wetland Conservation Act)

The Minnesota Wetland Conservation Act has been in place since 1991 and has significantly reduced the loss of wetland acres. Wetlands contain significant amounts of carbon that can be released to the atmosphere with wetland losses. Approximately 16,000 acres of wetland have been restored to replace wetland losses though wetland banking and on-site mitigation since the start of wetland conservation act, capturing approximately 35,000 – 111,000 metric tons of carbon dioxide per year.

Wetlands in Washington County.

Conservation Easements (Reinvest in Minnesota)

- 230,000 acres of marginal farm land have been restored (or CRP conversion to agriculture has been prevented) over the last 26 years, leading to the sequester of approximately 316,500 – 781,000 metric tons of carbon dioxide per year
- Reduction of nitrous oxide and carbon dioxide entering the atmosphere from fertilization, fertilizer production, and consumption of fossil fuels for farming marginal agricultural fields also contribute to total emission reductions.

Soil and Water Conservation Grants

- Restoration of native grassland on 23,265 acres and reforestation of 6,424 acres has led to sequestration of approximately 28,000 -56,000 metric tons of carbon dioxide per year.
- Reduction of nitrous oxide and carbon dioxide entering the atmosphere from fertilization, fertilizer production, and consumption of fossil fuels for farming marginal agricultural fields also contribute to total emission reductions.
- Nutrient management plans on 180,723 acres (assuming 44% in corn) are estimated to result in a 33% reduction in nitrogen fertilizer use, resulting in additional emission reductions.

Restored grassland

Figure 5. Estimated Carbon Dioxide Sequestration from Conservation Activities under BWSR Programs, 1987 - 2013

Activity	Acres Protected/ Restored (through 2013)	CO_2 sequestration per acre per year in metric tons	Cumulative CO_2 sequestration in metric tons
Wetland Protection (Wetland Conservation Act)			
WCA: Wetland restoration	16,000	0.6 – 1.9	35,000 – 111,000
RIM Easements			
Marginal farmland restored – sequestration in grasslands/wetlands[1]	230,000	0.3 – 0.6 grassland 0.6 – 1.9 wetlands	316,500 – 781,000
• Prevented NO_2 release[2]	101,200	0.66	66,790
• Prevented fertilizer production[2]	101,200	0.14	14,170
• Prevented fossil fuel consumption	230,000	0.04	9,200
Soil and Water Conservation Grants			
Grassland planted	23,265	0.3 – 0.6	7,000 – 14,000
Trees and shrubs planted	6,424	0.1 – 0.2	640 – 1,300
• Prevented NO_2 release[2]	13,063	0.66	8,620
• Prevented fertilizer production[2]	13,063	0.14	1,830
• Prevented fossil fuel consumption	29,689	0.04	520
• Reduction in fertilizer use on land with nutrient management plans[3]	180,723	0.66	17,320

Assumptions:
1. RIM easements are 75% grassland and 25% non-peatland wetlands
2. 44% of all prevented agriculture or modified agricultural land would be in fertilized corn
3. 33% reduction in nitrogen fertilizer use on land with nutrient management plans

References: Anderson et. al. 2008, EPA 2013, Pearson et. al. 2010.

How have BWSR's actions benefited Minnesotans and created jobs?

These conservation programs have many benefits to Minnesotans. In addition to mitigating climate change through carbon sequestration and decreased petroleum and fertilizer use, important environmental services such as hunting, fishing, bird watching, boating and swimming are provided. Conservation projects also support jobs to those involved in restoration planning and design, native seed production, construction, native seeding, vegetation management and regulatory and conservation program administration. In addition, the United States Fish and Wildlife Service's "National Survey of Fishing, Hunting and Wildlife Associated Recreation" finds that hunters, fishers, and wildlife watchers spent over $3.75 billion (2011) on their activities in Minnesota.

What is BWSR doing now to mitigate further climate change?

Wetland Protection (Wetland Conservation Act)

- Continued protection of Minnesota wetlands through administration of the Wetland Conservation Act, preventing the release of stored carbon though organic matter decomposition following drainage.
- Restoration of high quality, diverse, and resilient wetlands to replace wetland losses. Evidence suggests more carbon is sequestered by a richer mix of native species (such mixed forests) and communities are more stable over time. BWSR has developed technical resources to help practitioners restore diverse and resilient landscapes such as the Minnesota Wetland Restoration Guide and BWSR's Native Vegetation Establishment and Enhancement Guidelines.
- Restoration of forested wetlands (particularly white cedar and tamarack swamps) through planting and hydrology restoration in northern Minnesota.

Lakeshore buffer in Washington County.

Conservation Easements (Reinvest in Minnesota)

- BWSR is securing easements on approximately 5,000 - 8,000 acres per year that accomplish a significant amount of carbon and decrease emissions from machinery and fertilizer use.
- Re-enrollment of CRP into conservation programs preventing loss of landscapes where carbon sequestration has been occurring for many years.
- Sequestering and protecting stored carbon by promoting restoration of high functioning and sustainable conservation prairies and wetlands in key corridors and complexes informed by the Minnesota Prairie Conservation Plan and other key plans.

- Protecting stored carbon by preserving natural shoreline forest lands around shallow wild rice production lakes via permanent riparian easements in northern Minnesota forest region.
- Sequestering carbon by converting floodplain lands from crop production to permanent native floodplain forest cover in areas that have been frequently flooded.

Soil and Water Conservation Grants

- Sequestering carbon and decreasing nitrous oxide emissions from fertilizer by promoting cover crops and conservation tillage through soil health initiatives.
- Planting perennial native vegetation that adds organic matter to the soil, slows the flow of water and provides habitat for pollinators and other species.

Grant/Information Links:

Wetland Protection (Administration of the Minnesota Wetland Conservation Act):
http://www.bwsr.state.mn.us/cs/index.html
Conservation Easements (Reinvest in Minnesota): http://www.bwsr.state.mn.us/easements/index.html;
http://www.bwsr.state.mn.us/grants/RIM_services.html
Soil and Water Conservation Grants: http://www.bwsr.state.mn.us/cleanwaterfund/index.html;
http://www.bwsr.state.mn.us/cs/index.html; http://www.bwsr.state.mn.us/cs/index.html;
http://www.bwsr.state.mn.us/cs/index.html
Disaster Recovery Assistance: http://www.bwsr.state.mn.us/grants/DRAP.html

What is BWSR doing now to adapt to climate change?

Local Water Management Planning

BWSR supports and promotes integrated water resources management that uses a watershed approach to solve soil and water resource issues and considers the potential for more extreme weather events and their implications for the water and land resources. This includes the use of design standards for stormwater and conservation projects that address larger precipitation events. A new white paper on "Adaptation to Extreme Precipitation in Minnesota" has been developed.

Restored wetland with diverse wet meadow plantings.

Wetland Protection and Restoration

Wetland and upland buffer restoration and protection conducted through the Reinvest in Minnesota (RIM) Reserve Program and federal partnerships, Wetlands Conservation Act implementation, and Clean Water Fund projects, help to restore and maintain water retention, runoff reduction, wildlife habitat, and water quality in Minnesota. This, in turn, enhances adaptation to climate change. The ecosystem services provided by wetlands also protect against intense storm events and periods of drought. Associated upland buffers protect wetland ecosystems, and provide landscape connectivity and other functions that promote landscape resiliency. Restoration projects also increase carbon sequestration that can increase infiltration rates and store water on the landscape.

Cover crops play an important role in improving water quality

Agricultural Conservation Practices

BWSR promotes a variety of conservation practices in agricultural areas that promote soil health and the ability of soils to capture and store rainfall, store carbon and decrease heat absorption from tilled ground. Examples of conservation practices that minimize impacts from larger storms include cover crops, field terraces, no-till farming, buffer strips, retention areas, and constructed wetlands.

Multipurpose Drainage Management

BWSR promotes and supports implementation of traditional and new conservation practices for multiple purposes, including conservation drainage and drainage water management practices. These practices help reduce runoff and nutrient loss, avoid runoff concentration, protect areas where runoff concentrates, reduce peak flows to reduce erosion, maintain agricultural productivity, improve water quality and habitat, and reduce flooding. Multipurpose drainage practices help make working lands as well as artificial and natural drainage systems more resilient to high intensity rainfall.

Increasing Landscape Resiliency

A variety of restoration and land management strategies are promoted for conservation projects to increase resiliency to extreme storms and other landscape stressors. Some basic principles for increased resiliency include:

1) Restoring healthy natural systems where they can have the greatest landscape benefits.
2) Decreasing fragmentation of intact plant communities, and creating habitat corridors.
3) Restoring plant communities and vegetation that fit current and expected project site conditions.
4) Promoting individual species for projects that can handle expected conditions and provide ecological functions.
5) Promoting species diversity to increase resiliency and promote habitat for a wide range of wildlife species including pollinators.
6) Using deep rooted plants to promote infiltration and groundwater recharge.
7) Restoring high quality habitat for pollinators and other beneficial insects.
8) Managing invasive species across geographic and ownership boundaries to minimize their competitive advantage.
9) Adapting project design, implementation and management approaches based on project experience.
10) Taking a long-term view to the management of natural resources.

See Appendix C and the web-based Landscape Resiliency Toolbox for further details. BWSR's Native Vegetation Establishment and Enhancement Guidelines includes specific guidance on seed sourcing in relation to climate change.

Adaptive Landscape Management

Disturbances associated with climate change can give invasive species a competitive advantage over native species. BWSR's Cooperative Weed Management Area (CWMA) program is focused on forming local organizations that share invasive species management expertise and resources across ownership boundaries. CWMAs are also focusing on controlling emerging weed threats that benefit from warming climate such as woody invasive species that are invading northern forests. By promoting adaptive landscape management practices such as forest management and prescribed burning, BWSR is also working to increase the landscape's ability to sequester carbon and withstand large rain events.

Northern Forest Management

BWSR is working through partnerships to protect the integrity of northern forests. Recent efforts include the protection of wild rice lakes and surrounding forests through the RIM Program, an effort to protect and restore while cedar wetlands that are becoming less common, and support of CWMAs in northern

Minnesota to address emerging weed threats. BWSR also promotes managing forests for high diversity to adapt to climate variation, large storms, diseases, and pathogens.

Flood damage in southeastern Minnesota

Disaster Response

Flooding has caused significant damage to private lands and conservation practice infrastructure in Minnesota. Since 2000, BWSR has provided $53 million for flooding in southeast, northeast and northwest Minnesota through the Disaster Recovery Assistance Program, with a focus on rebuilding infrastructure that will be resilient to future storms.

Case Study

Restored wetlands and prairies provide important strategies for adapting to climate change by increasing the resiliency of watersheds. The Ellefson Group Wetland Restoration in Norman County was a combined effort by four landowners and state, federal, and local agencies. The site was previously farmland that frequently had crop failure due to flooding. Through hydrology restoration and the planting of diverse seed mixes the site was restored to 448 aces of restored prairie and wetland and contains eight wetland basins. It now provides a refuge to a wide range of wildlife including pollinators, amphibians, reptiles, shorebirds and waterfowl. The site also decreases downstream flooding by detaining water from large storms. Surface runoff from the site is estimated to be reduced by 88%.

BWSR action steps to guide future direction

1) Further guide the implementation of plan content requirements for **One Watershed, One Plan** with a focus on climate mitigation and adaptation.

- BWSR guidance for plan development includes language that states: "Planning partners are strongly encouraged to consider the potential for more extreme weather events and their implications for the water and land resources of the watershed in the analysis and prioritization of issues. While these events cannot be predicted with certainty as to time and occurrence, the meteorological record shows increased frequency and severity of extreme weather events, which has a direct effect on issues in local water planning".
- Continue to work with partners developing plans in new watersheds to incorporate climate adaptation planning for landscape resiliency to more extreme precipitation events. BWSR will develop sample language to be included in plans and will conduct outreach about resiliency strategies summarized in the white paper "Resiliency Actions for Extreme Precipitation in Minnesota".

2) Use the Minnesota Prairie Conservation Plan, the Nature Conservancy's Resilient Landscapes Tool, and other key landscape ecology planning documents when selecting **conservation and restoration practices in habitat complexes and corridors** to promote resiliency to landscape stressors and to provide refuge for wildlife species. These documents will help guide the development of planting plans for RIM easements and other conservation lands.

3) Update **tracking of carbon sequestration and emission reductions** of BWSR-funded conservation projects using eLINK and other tools. Partner with other agencies on carbon tracking-related efforts, as well as with advisors from the National Climate Alliance Natural and Working Lands Initiative.

- In winter of 2019, BWSR will complete update of tracking system and include updated numbers in this report. Continue collaboration with partners to update numbers regularly.

4) Continue updating information in BWSR's **Native Vegetation Establishment and Enhancement Guidelines a**bout plant selection, establishment and management considerations to maximize climate adaptation and mitigation.

- The Guidelines are currently being updated, with a focus on promoting plant species diversity to increase landscape resiliency and enhance habitat for a wide range of wildlife species, including pollinators.
- The Guidelines also identify individual plant species that can handle expected conditions at project sites, such as drought-adapted prairie species and rhizomatous emergent plants for fluctuating water levels.

5) Provide information to local governments about practices~~,~~ policies and programs they can promote to address climate mitigation and adaptation, including design standards and approaches to assessing sites and updating water plans.

- BWSR's Landscape Resiliency Toolbox and Landscape Resiliency and Climate Adaptation webpage are being updated in January of 2019 to guide local government partners about key practices, policies and programs.
- A white paper on "Adapting to Extreme Precipitation in Minnesota" has also been developed.

6) Further promote **practices that provide year-round cover** on agricultural fields such as no-till and strip-till farming, cover crops and perennial vegetation to promote soil health and the ability of soils to capture and store rainfall, reduce runoff and erosion, store carbon, and decrease heat absorption from tilled ground.

- In the past few years, cover crops have been recognized as a new cost share-eligible practice. BWSR will continue to promote their use.
- Based on the Working Lands Watershed Restoration Feasibility Study, promote a pilot program to encourage and support transition of marginal lands to harvestable perennial crops, with a focus on source water protection areas.
- Promote the Minnesota Agricultural Water Quality Certification Program, a voluntary program designed to accelerate adaption of on-farm conservation practices that protect soils and restore water quality in Minnesota's lakes and rivers. Producers who implement and maintain approved farm management practices will be certified and in turn assured that their operation meets the state's water quality goals and standards for a 10-year period.

7) Increase focus on **tree planting in urban areas and previously forested areas** to sequester carbon, improve air quality, reduce stormwater runoff, decrease the heat island effect in urban areas, control erosion, promote biodiversity and stabilize watersheds.

- Provide strategies for urban forests and reforestation in the update of BWSR's Landscape Resiliency Toolbox.

8) Promote and support implementation of **conservation drainage and drainage water management practices,** as well as water storage at various scales, that help reduce runoff and nutrient loss, avoid runoff concentration, protect concentrated flow areas, reduce peak flows to reduce erosion, maintain agricultural productivity, improve water quality and habitat, and reduce flooding.

- Provide outreach about the updated **Minnesota Public Drainage Manual** and redesigned BWSR Drainage webpage, as well as the Clean Water Fund Multipurpose Drainage Management Program and other potential sources of technical and financial assistance.

9) Increase focus on the restoration of **high quality pollinator habitat** to support declining pollinator populations. Pollinators play a key role in supporting landscape resiliency by pollinating about 30% of crops and 70% of native plants that in turn provide many landscape functions.

- Through BWSR's Pollinator Initiative, incorporate high quality pollinator habitat into BWSR programs, collaborate with local conservation partners, and provide guidance and technical resources for pollinator efforts. BWSR is working with other agencies and organizations on an initiative that would offer landowners incentives to convert excess lawn areas to pollinator habitat, which will also have benefits for carbon sequestration.

11) Investigate and implement methods to **restore wetlands and lakes that are more resilient to landscape stressors,** with improved site assessment, installation and maintenance techniques.

- Refine and increase the use of BWSR's Wetland Resiliency Calculator.
- In northern Minnesota, protect stored carbon by preserving natural shorelines around shallow wild rice production lakes via permanent riparian easements.
- Focus on restoration of high quality, diverse, and resilient wetlands to replace wetland losses. Evidence suggests that more carbon is sequestered by a richer mix of native species (such as mixed forests) and communities are more stable over time.

12) Use **adaptive management strategies** to maintain landscapes in a way that will increase landscape resiliency and increase climate mitigation.

- Promote long-term monitoring and management of wetlands to control invasive species and promote plant diversity and study the long-term resiliency of restored wetlands and how wetland functions change over time.
- Promote Cooperative Weed Management Areas (CWMAs), local organizations that provide a mechanism for sharing invasive species management expertise and resources across jurisdictional boundaries in order to achieve widespread invasive species prevention and control in a broader geographic region.
- Increase focus on controlling emerging weed threats that are benefitting from a warming climate, such as woody invasive species that are starting to invade northern forests.
- Promote landscape management practices such as forest management and prescribed burning that can increase the landscape's ability to sequester carbon. Soils rich in organic carbon are better able to withstand large rain events.

Native prairie sequesters large quantities of carbon in perennial vegetation and deep plant roots.

Appendix A: Summary of Recent Climate Reports

NOAA Atlas 14 – New National Oceanic and Atmospheric Administration rainfall frequency data (NOAA Atlas 14) show that the amount of rainfall for given frequencies has risen substantially.

Minnesota Environment and Energy Report Card (2017) – Minnesota's climate is changing rapidly with increasing temperatures, especially in winter and at night, and with increasing frequency of extreme precipitation. Winter lows in northern Minnesota have increased 40% faster than in southern Minnesota.

Minnesota Sea Grant – Since 1980 surface water temperatures on Lake Superior in summer has warmed twice as much as the air above it. Over the winter, the area of the lake covered by ice is decreasing by about .5% per year. Ice cover in Lake Superior has decreased from 23% to 12% over the last century.

Fourth National Climate Assessment (2018) – Concludes that by mid-century, the average temperature of the Midwest Region will increase by 4.21°F under a lower-emissions scenario to 5.29 °F under a higher emissions scenario, relative to the average for 1976 to 2005. Increasing heavy rains are leading to more soil erosion and nutrient loss on Midwestern cropland.

Intergovernmental Panel on Climate Change – Human activities are estimated to have caused approximately 1.0°C of global warming above pre-industrial levels, and global warming is likely to reach 1.5 C at mid-century if it continues at the current rate. At continental, regional and ocean basin scales, numerous long-term changes in climate have been observed. These include changes in arctic temperatures and ice, widespread changes in precipitation amounts, ocean salinity, wind patterns and aspects of extreme weather including droughts, heavy precipitation, heat waves and the intensity of tropical cyclones.

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Appendix C: Strategies for Restoring Resilient, Functional Landscapes

The following information summarizes strategies for restoring landscapes that are resilient to climate change and other stressors and will provide important landscape functions and services into the future. These strategies borrow from the disciplines of conservation, ecological restoration, landscape ecology, and sustainable farming and are key methods for developing landscapes that are resilient to climate change.

1) **Strategic Site Selection –** Work with project partners to identify the functions that are most beneficial for an individual landscape and where projects should be located to best provide those functions. It many cases this involves restoring habitat complexes or buffering key water resources or plant communities to restore natural, nutrient cycling and plant and animal populations. Site projects in locations where ecological stressors such as un-natural water fluctuations, decreasing water tables, or invasive species will not significantly detract from key functions into the future.

2) **Designing for Multiple Functions –** Be strategic in the selection of primary and secondary goals. Be hydrology selective in making certain functions a priority, but remember that multiple functions including wildlife habitat, plant diversity, food production, stormwater treatment, soil quality and nutrient cycling can often be accomplished at once.

3) **Making Landscape Connections –** Establish strong connections through landscapes. Create habitat and genetic dispersal corridors and decrease landscape fragmentation. Or, create a network of conservation practices in agricultural areas. Pulling together small parts plays a key role in restoring landscape resiliency and providing refugia for pollinators and other at-risk species.

4) **Matching Plant Communities to the Site –** Match your targeted vegetation to the native plant community that best fits the topography, soils, hydrology, and climate conditions (including the potential future climate) of your site. Also restore natural hydrologic regimes to aquatic and wetland systems. Historic plant community information can be used as a guide for decision making. Determine the kinds of native wildlife that live in the area or migrate through, and include native plants natural to the site that will provide food and shelter for many animal species.

5) **Restoring and Maintaining Diversity –** Plant diversity (and structural diversity of plant communities)supports wildlife species and increases resiliency by helping plant communities and agricultural systems to continue functioning as intact systems during climate variation. Filling niches with native species also prevents the establishment of invasive species. Restoring natural disturbances such as prescribed fire, grazing and water fluctuations plays a key role in maintaining diversity. In addition to plant species diversity protect genetic diversity of individual plant species by using site appropriate sources that can adapt to future conditions.

6) **Working with Ecological Adaptation –** Natural plant communities have the ability to adapt. They develop a natural dynamic though genetic adaptation, succession and natural colonization. Incorporate these processes into projects to complement restoration efforts, provide desired ecological functions, and buffer the community during future changes in climate and associated disturbance. Assisted migration may be needed in some ecosystems to help maintain plant community integrity.

7) **Providing Habitat for Pollinators and other Beneficial Insects –** Pollinators and other insects play an essential role in supporting ecosystems by pollinating around 70% of flowering plants and providing food sources for a wide range of wildlife species. Support insect populations by minimizing pesticide use, buffering natural areas and diverse plantings from pesticide exposure, restoring habitat complexes and wide natural corridors, increasing plant diversity, and restoring clean water sources.

8) **Effective Water Management, Treatment and Use –** A variety of practices including perennial crops, conservation tillage, conservation drainage, cover crops, buffer strips, infiltration basins, raingardens and wetland restoration help manage water resources. Incorporate these practices in urban and rural landscapes to reduce runoff, recharge groundwater, maintain agricultural productivity, improve water quality, and reduce flooding. Promote the wise use of water resources and the use of catchment systems to help ensure adequate supplies into the future.

9) **Preserving and Restoring Soil Health –** Soils that have good soil structure, organic content and microorganism populations translate into healthy and productive ecological and cultural landscapes. Soil health can be restored through planting cover crops, no-till farming, and establishing perennial vegetation.

NRCS

10) **Managing Invasive Species Across Boundaries –** Invasive species are effective at dispersal, giving them an advantage in adapting to climate change. Plan to work in partnerships and manage invasive species across ownership boundaries to restore resilient landscapes.

11) **Practicing Adaptive Management–** Adjust management practices based on monitoring efforts and experience with successes and failures to improve the long-term effectiveness of management practices and resiliency of plant communities. Practices such as prescribed burning, water level management and prescribed grazing may replicate natural disturbances and promote diversity and resiliency.

12) **Learning from Project Experience –** Information about project successes and innovative practices is valuable. What practices provide the most benefits in our landscapes? What common activities are not worth the cost or, worse, make a problem worse? BWSR's "What's Working" information summarizes real-world outcomes.