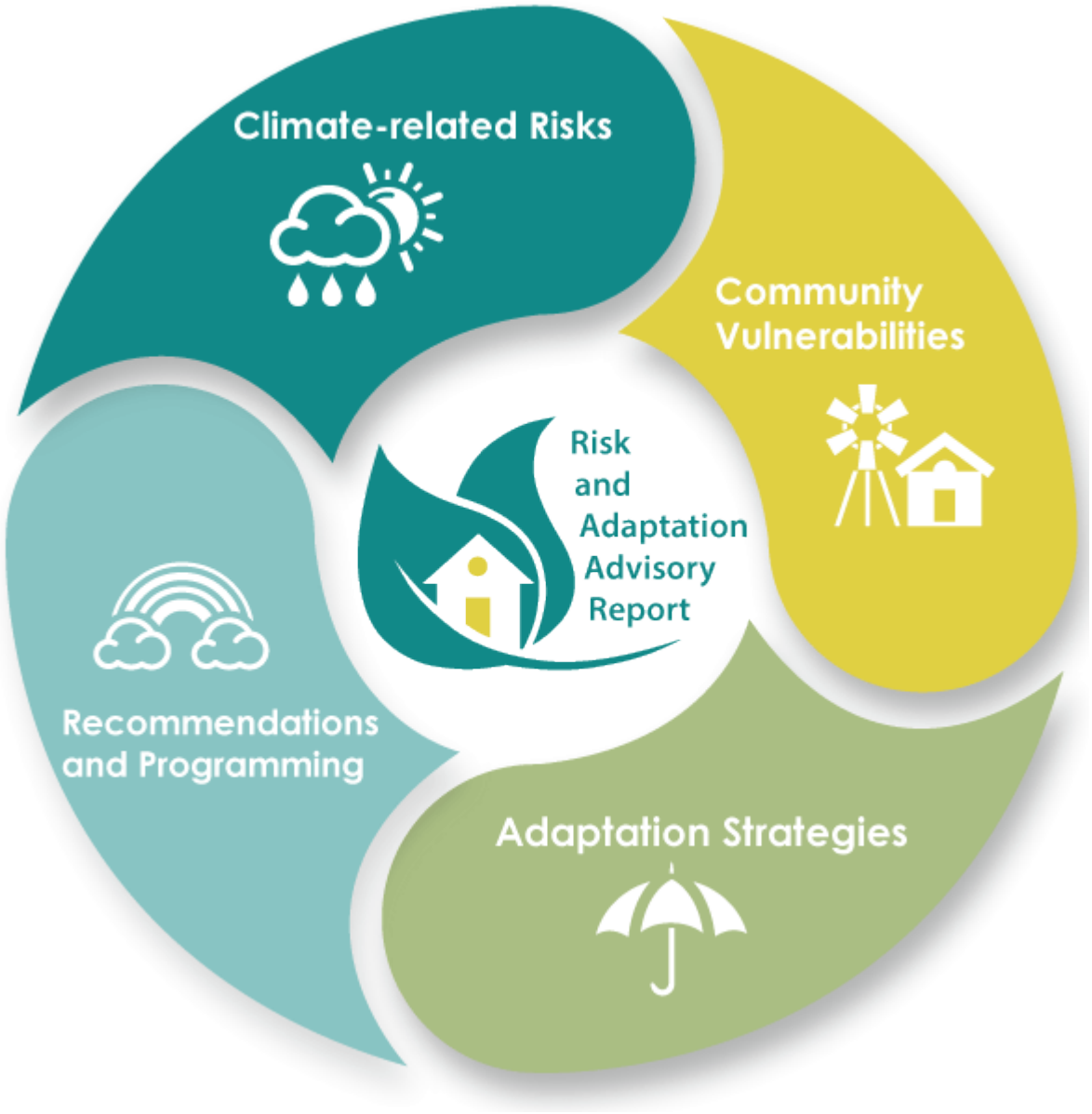

City of Northglenn, Colorado
August 2018

Adaptation Services Group

www.adaptationsg.com

ICLEI USA – Local Governments for Sustainability

www.icleiusa.org

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BACKGROUND INFORMATION

About ASG

Adaptation Services Group (ASG), is a Boulder, Colorado company offering risk assessments, adaptation plans and programs, climate change planning and mitigation programs to state and local governments focused on helping their residents and businesses become more resilient in the face of climate change. ASG programs feature a customer-centric approach to implementation, putting the client at the center of the process. These programs help create more resilient communities that are adapting to the changing climate.

The ASG team has deep expertise in climate mitigation and adaptation strategies and analysis, and we focus exclusively on the challenges presented by the changing climate for governments. ASG operates in close partnership with ICLEI USA – Local Governments for Sustainability - to provide implementation of community based adaptation programs in the areas of wildfire, seismic, flooding, energy and drought.

ASG's Risk Adaptation and Advisory Report

ASG's Risk Adaptation and Advisory Report (RAAR) is a unique report that connects the dots between academic research, climate modeling and community engagement. The RAAR is the first step in overall adaptation planning for a community. It provides a high-level view of the climate-related risks and hazards affecting community systems, as well as possible adaptation strategies and recommendations. The RAAR presents an introduction to planning for climate adaptation, which the community can then use as a foundation to build upon.

Seth Portner
Chief Executive Officer
Adaptation Services Group

Key Terms

Anthropogenic	Generated by human activity (specifically in reference to environmental change).
Climate Change	Significant changes in global temperature, precipitation, wind patterns and other measures of climate that occur over several decades or longer.
Climate Adaptation	Adjustments to natural or human systems in response to actual or expected climate change, including increases in the frequency or severity of weather-related disasters.
Changed Seasonal Patterns	Alteration of predictable weather patterns relied upon for agriculture, tourism and natural resource industries.
Drought	Persistent lack of rainfall over one or more seasons leading to the depletion of surface and groundwater reservoirs.
Extreme hot days	Days that are 5 degrees Celsius above normal.
Greenhouse gases (GHGs)	Atmospheric gases that trap incoming solar radiation and contribute to the warming of the Earth's surface. The principle GHGs are carbon dioxide, methane, nitrous oxide and ozone.
Groundwater flooding	Flooding of underground structures because of high water tables.
Hail	Damaging frozen precipitation associated with high intensity rain events.
Hazard mitigation	Actions taken to reduce loss of life and property by lessening the impacts of adverse events.
Heat waves	A period of at least 5 days where the temperature is at least 5 Celsius degrees above normal.
IPCC	Intergovernmental Panel on Climate Change
Rainstorms	Extreme precipitation event without substantial wind.
Reduced snowpack	Drought or temperature driven changes that reduce water reservoirs in the form of high elevation snow and ice.
Resilience	The ability to prepare for, absorb, recover from and more successfully adapt to adverse events.
Severe wind	Strong winds capable of property damage, dust storms and other hazards.

EXECUTIVE SUMMARY

Climate change, a widespread global occurrence, noticeably affects communities on a large scale but its effects can be felt down to the most localized level. It influences all sectors including transportation, public health, tourism, water and waste management and overall quality of life. Local governments around the country are working with their residents to develop plans for addressing climate adaptation. ASG works in partnership with these communities to envision the first steps toward creating and reaching a climate adaptation goal.

Through engagement with Northglenn and research, ASG identified and modeled (ASG uses several models – the dominant model is Temperate) the climate risks affecting Northglenn, CO. For Northglenn, model results displayed increasing average high and low temperatures. Maximum high temperatures and the number of extreme heat events also increased, while precipitation trends generally remained constant. This combination of increasingly warmer days with little to no change in precipitation could lead to drier overall conditions. Extreme heat and rising temperatures overall seemed to be the most pressing climate risks threatening Northglenn. The effects of climate change vary based on a variety of meteorological and regional factors which can be difficult to model. Increasing evaporation is often a result of increased temperatures which can in turn lead to increased humidity, average rainfall, and the frequency of heavy rainstorms; this is to say that continued severe weather is likely for Northglenn and Colorado's Front Range over time.

Adaptation recommendations were developed according to the identified risks, such as xeriscaping for drought, use of permeable pavement for flooding and implementing green roofs for extreme heat. These recommendations provide the support for Northglenn as they formulate their climate action plan and further explore climate adaptation strategies best suited for their community's needs.

The recommendations in this report are meant to inform Northglenn about possible solutions for climate-related issues. The RAAR is a preliminary report to highlight the likely major risks threatening a community based on climate projection models. It is not meant to serve as a comprehensive climate adaptation plan, but instead be a starting point for future planning. It also does not provide a comprehensive outlook for every climate related risks and threats affecting an area. There may be climate related risks that are not realized at the time this report

is written or cannot be captured accurately through climate modeling tools in creation of this report.

ASG's work with Northglenn revealed that the risks faced by the community are moderate even in comparison to other Front Range communities that may have more severe threats in the form of flood and fire. We also found that the community has already begun the process of adapting to climate change by modifying operations, pursuing water conservation, protecting the tree canopy and more. As a result of the modest risks and pro-active stance, we found Northglenn to be better positioned then many other neighboring communities with respect to adaptation.

ABOUT NORTHGLENN

Northglenn Climate Fast Facts

Climate: Northglenn enjoys a mild, sunny, and semi-arid climate.
Average July High Temp: 92
Average Jan. Low Temp: 19
*AccuWeather

Northglenn, CO is situated along the Front Range, which refers to the region along the eastern slope of the Rockies.

Being part of Colorado's Front Range Northglenn is experiencing an overall warming and drying trend in weather. High mountain desert, Colorado's high elevation and its position in the mid-latitudes among the Rocky Mountains dictates the region's dry climate. Colorado is known for its sporadic seasonal changes, low humidity and large ranges of temperature from day to night. Thunderstorms, particularly common in the spring and summer, tend to bring short, heavy showers with the possibility of hailstorms, flooding and lightning strikes.

METHODOLOGY AND SURVEY

To assess the hazards affecting the city of Northglenn, ASG team members met with members of the Northglenn Sustainability Committee to discuss the city's current risk status and create a plan of action. Northglenn stakeholders discussed their common values as well as the climate-related issues they currently face in their community. The background knowledge of the city staff pertaining to climate change and adaptation is interwoven throughout this report. Their insight into how the changing climate is already impacting city operations is integral to this report.

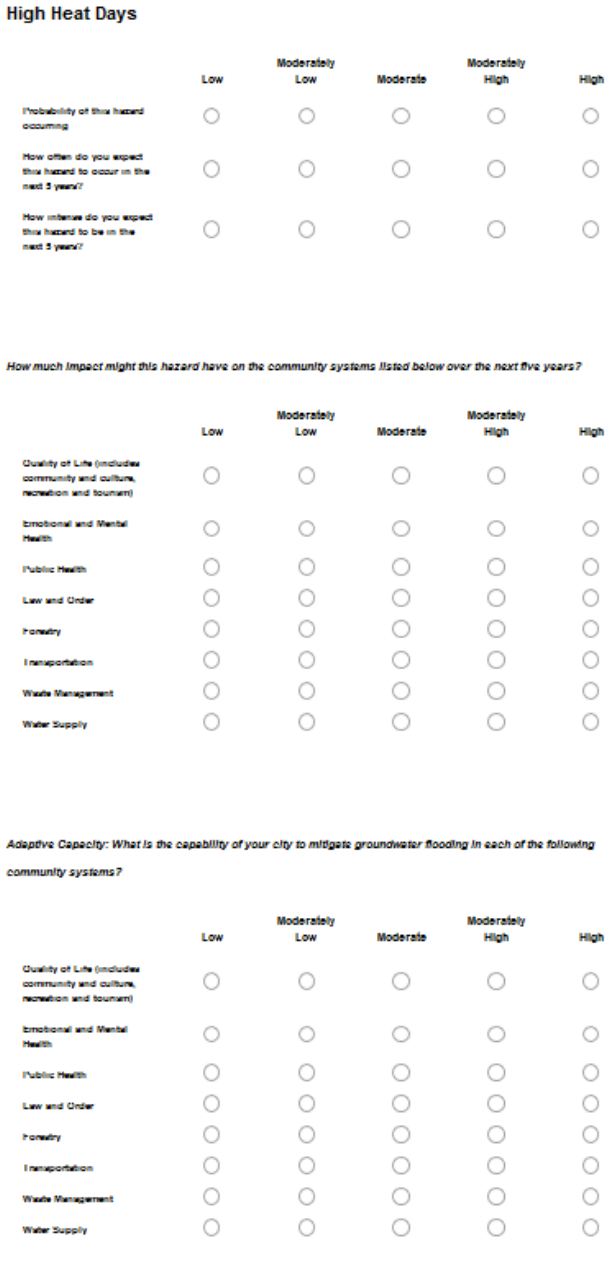
ASG utilized climate adaptation planning tools to create this specialized report specific to the city of Northglenn. ASG analyzed the hazards identified as climate threats alongside the valued community systems highlighted by Northglenn staff. The final report provides results for the adaptive need of each hazard.

Survey Results for Northglenn

In order to engage the community of Northglenn and accurately capture the values of the city stakeholders, ASG created and distributed a survey using the Climate Risk and Adaptation Framework and Taxonomy (CRAFT).

The purpose of the survey was to better understand the climate-related risks affecting the community. The stakeholders completing the survey needed to consider the frequency and intensity that each of the seven hazards would have over the next five years given their local and current knowledge of the climate, which the CRAFT framework utilizes to assess risk. Stakeholders were then asked to consider the impact each hazard would have on every community system and what they believed Northglenn's capability would be in the face of mitigating the effects of the hazards on community system. The survey offers insight into the city's current assessment of how difficult will it be for Northglenn to adapt to each hazard. Over time, this self—reported perceived risk may rise or fall, as programs and strategies are developed and implemented.

The complete survey and results from Northglenn are found on page 37.



High Heat Days

	Low	Moderately Low	Moderate	Moderately High	High
Probability of this hazard occurring	○	○	○	○	○
How often do you expect this hazard to occur in the next 5 years?	○	○	○	○	○
How intense do you expect this hazard to be in the next 5 years?	○	○	○	○	○

How much impact might this hazard have on the community systems listed below over the next five years?

	Low	Moderately Low	Moderate	Moderately High	High
Quality of Life (includes community and culture, recreation and tourism)	○	○	○	○	○
Emotional and Mental Health	○	○	○	○	○
Public Health	○	○	○	○	○
Law and Order	○	○	○	○	○
Forestry	○	○	○	○	○
Transportation	○	○	○	○	○
Waste Management	○	○	○	○	○
Water Supply	○	○	○	○	○

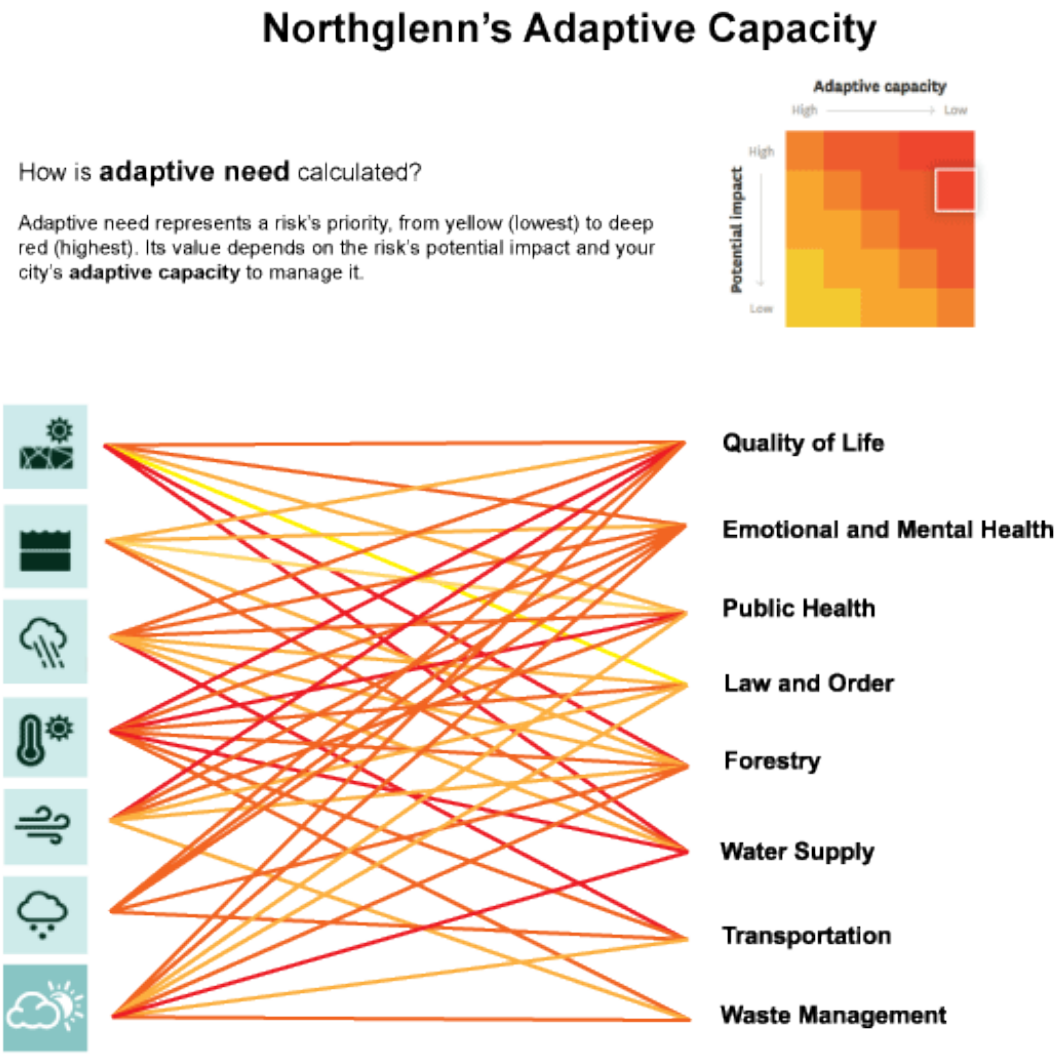
Adaptive Capacity: What is the capability of your city to mitigate groundwater flooding in each of the following community systems?

	Low	Moderately Low	Moderate	Moderately High	High
Quality of Life (includes community and culture, recreation and tourism)	○	○	○	○	○
Emotional and Mental Health	○	○	○	○	○
Public Health	○	○	○	○	○
Law and Order	○	○	○	○	○
Forestry	○	○	○	○	○
Transportation	○	○	○	○	○
Waste Management	○	○	○	○	○
Water Supply	○	○	○	○	○

RISK ASSESSMENT FOR NORTHGLENN

The answers from the survey were used as data points for the CRAFT framework ASG uses to assess the self-reported perceived risk. The model was populated to show trends through 2100, and the results show the forecast for each hazard.

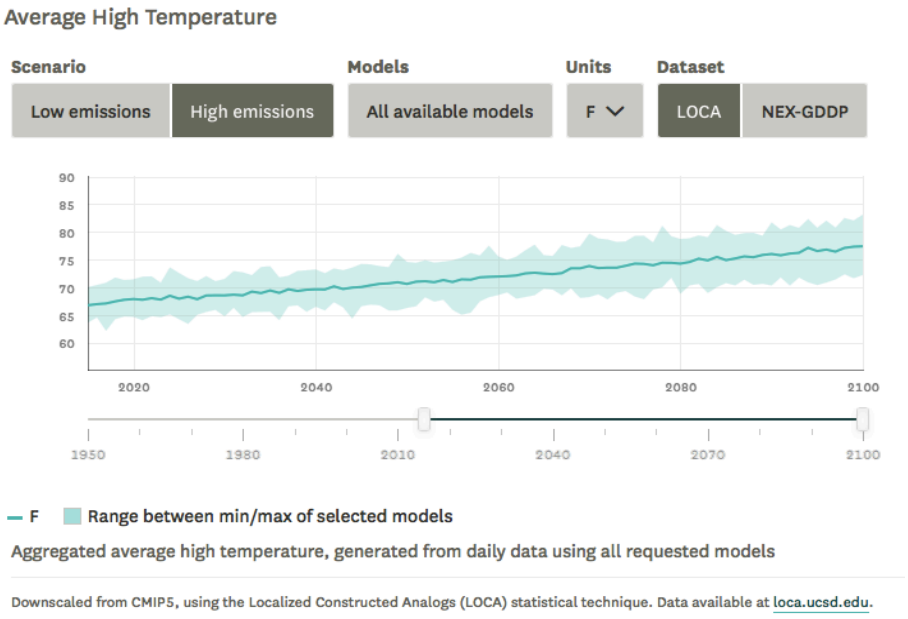
The following climate change data indicators demonstrate the probability and frequency of the primary hazards facing the city. The data comes from Localized Constructed Analogs (LOCA, 2018), and utilizes statistics to downscale climate model projections of the future climate. Each of the climate change indicators influence at least one hazard.



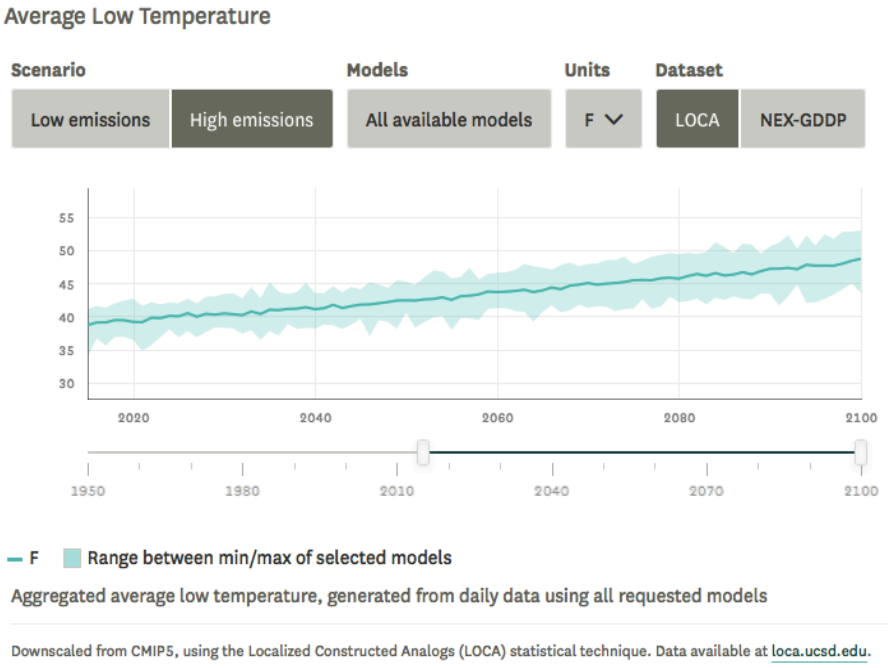
This graphic shows Northglenn staff's responses to the adaptive capacity of various risks in July 2018.

CLIMATE CHANGE INDICATORS

The following graphs show the climate change data indicators that will influence Northglen's risk in the coming years. High emissions scenarios are integrated throughout to reflect current high emissions conditions and to display the forecast if these conditions were to continue through the year 2100.

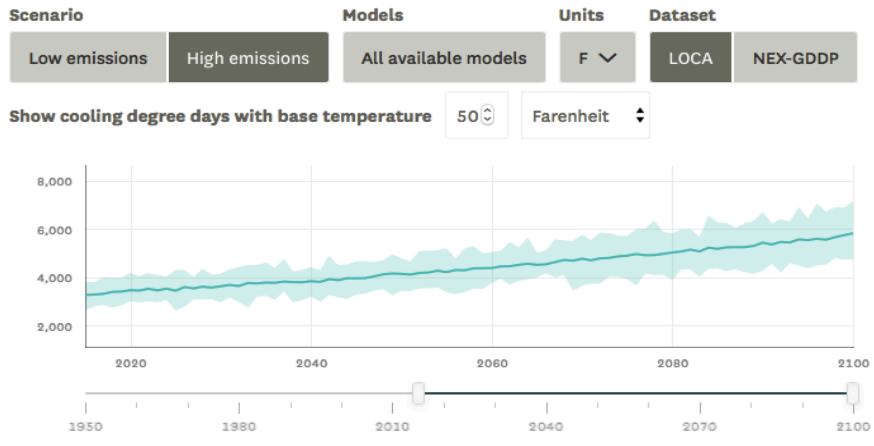


Average High Temperature: The average high temperature of Northglenn is predicted to increase from roughly 67 degrees F to 77 degrees F.



Average Low Temperature: Likewise, the average low temperature is expected to increase from 39 degrees F to 49 degrees F by 2100.

Cooling Degree Days

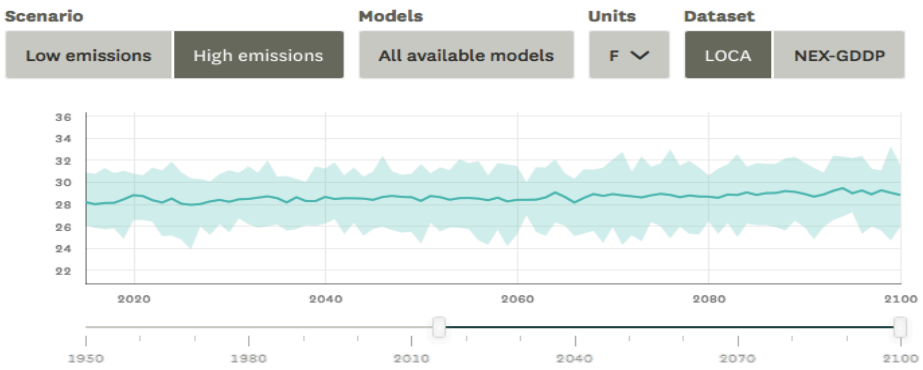


Total difference of daily average temperature to a reference base temperature

Downscaled from CMIP5, using the Localized Constructed Analogs (LOCA) statistical technique. Data available at loca.ucsd.edu.

Cooling Degree Days: Northglenn's need for cooling as measured by cooling degree days will increase from approximately 3,500 nearly 6,000 an increase of nearly 60%.

Diurnal Temperature Range

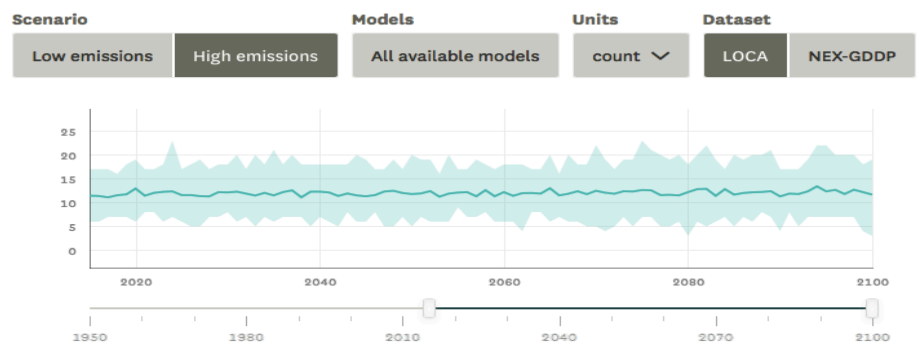


Average difference between daily max and daily min temperature

Downscaled from CMIP5, using the Localized Constructed Analogs (LOCA) statistical technique. Data available at loca.ucsd.edu.

Diurnal Temperature Range: The diurnal temperature range, showing the average difference between maximum daily temperatures and minimum daily temperatures, is predicted to stay relatively constant through 2100.

Dry Spells

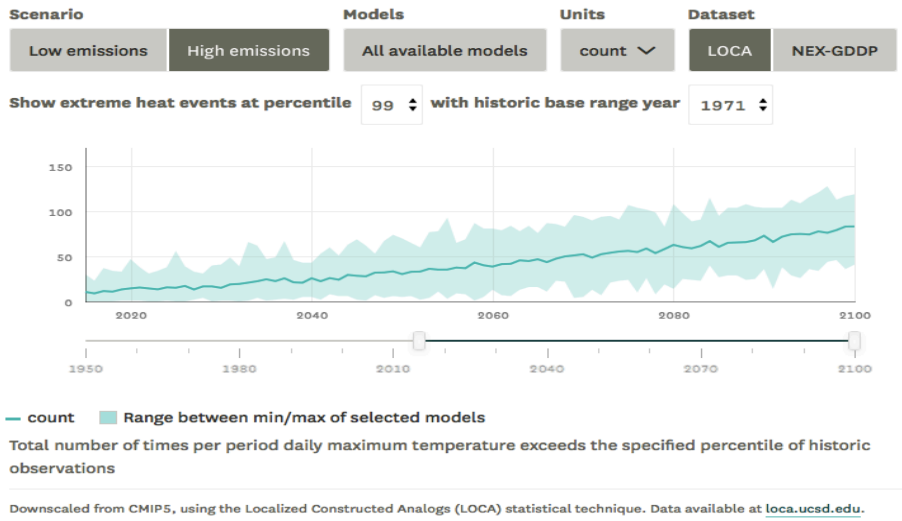


Total number of times per period that there are 5 or more consecutive days without precipitation

Downscaled from CMIP5, using the Localized Constructed Analogs (LOCA) statistical technique. Data available at loca.ucsd.edu.

Dry Spells: Dry spells, referring to 5 or more consecutive days without precipitation, is expected to stay around 11 per year.

Extreme Heat Events

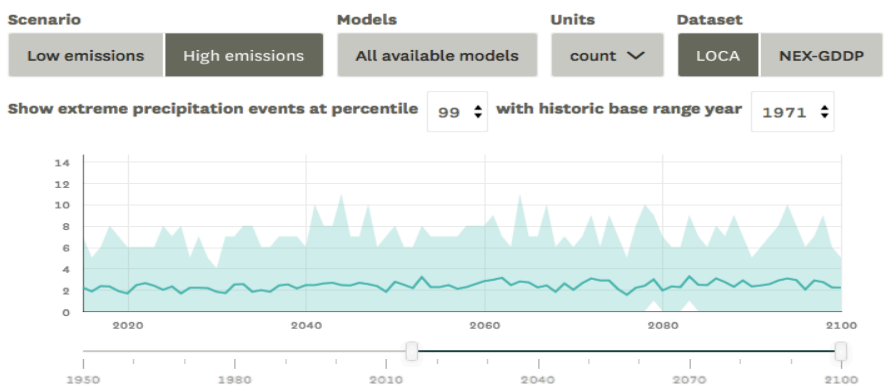


Total number of times per period daily maximum temperature exceeds the specified percentile of historic observations

Downscaled from CMIP5, using the Localized Constructed Analogs (LOCA) statistical technique. Data available at loca.ucsd.edu.

Extreme Heat Events: Extreme heat events, or the number of times temperatures exceed historical observations, will increase drastically from 11 times in 2018 to 84 in 2100.

Extreme Precipitation Events

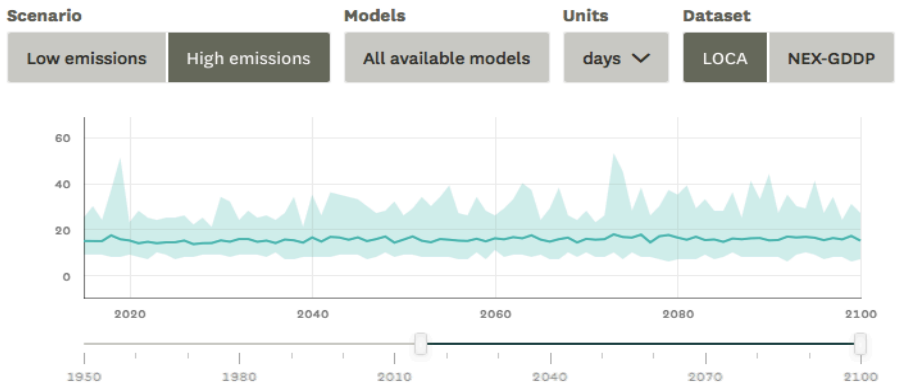


Total number of times per period daily average precipitation rate exceeds the specified percentile of historic observations

Downscaled from CMIP5, using the Localized Constructed Analogs (LOCA) statistical technique. Data available at loca.ucsd.edu.

Extreme Precipitation Events: Extreme precipitation events, the number of times precipitation events exceed historical observations, are likely to remain constant at 2 events annually.

Max Consecutive Dry Days

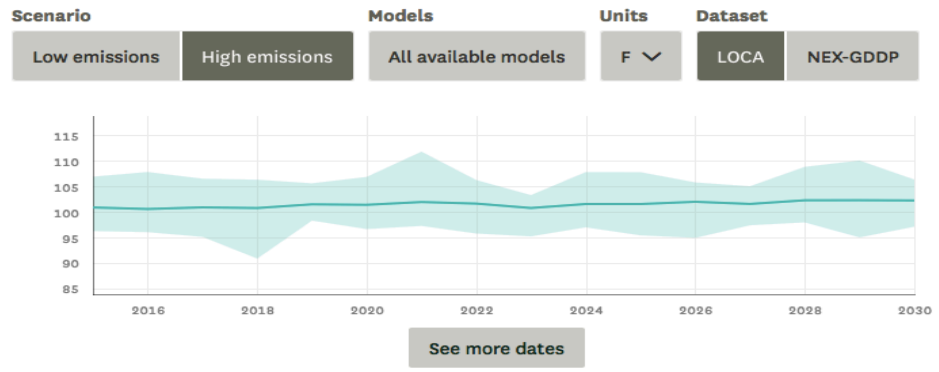


Maximum number of consecutive days with no precipitation

Downscaled from CMIP5, using the Localized Constructed Analogs (LOCA) statistical technique. Data available at loca.ucsd.edu.

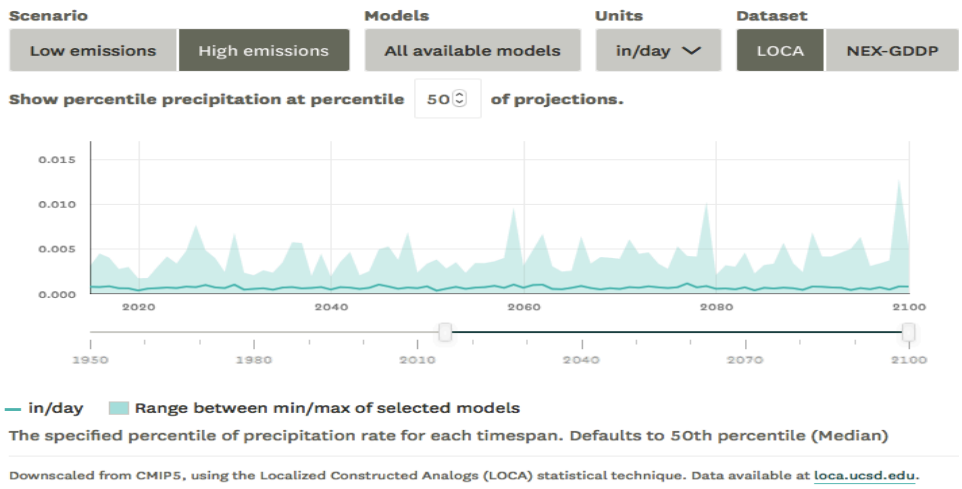
Max Consecutive Dry Days: From 2018 to 2100, there is predicted to be a maximum of 15 consecutive days with no precipitation.

Maximum High Temperature



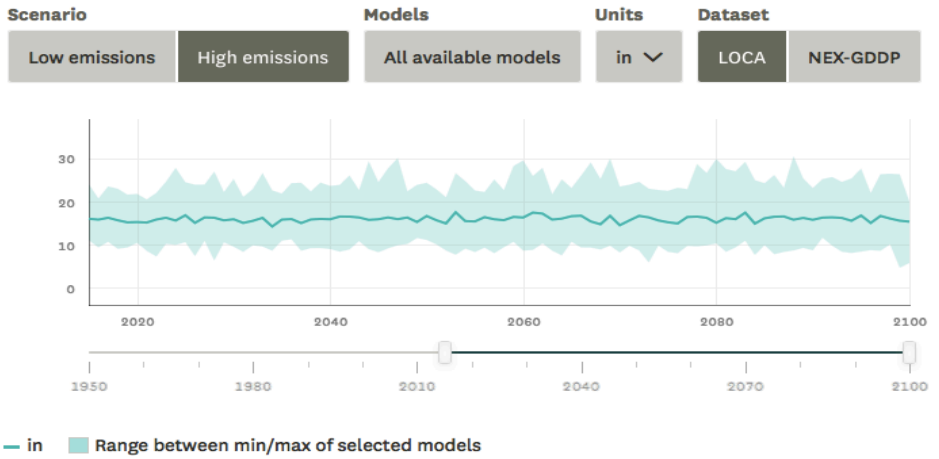
Maximum High Temperature: The maximum high temperature is predicted to increase 10 degrees from 101 in 2018 to 111 degrees F by 2100.

Percentile Precipitation



Percentile Precipitation: The percentile of precipitation rate is expected to remain relatively constant through 2100.

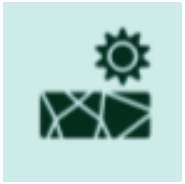
Total Precipitation



Total Precipitation: Total precipitation is expected to remain around 16 inches per year.

CLIMATE CHANGE RISKS AND ADAPTATION RECOMMENDATIONS

Drought



In the West, most of the water needed for agriculture and personal use comes from melted snowpack. Because of this reliability on a substantial snowpack, a lack of water could have dire consequences. Drought is defined as a persistent lack of rainfall over one or more seasons leading to the depletion of surface and groundwater reservoirs. Contributing factors include rainfall intensity, number of rainstorms, demand for water and the nature of the built environment (Centers for Disease Control and Prevention, 2010). As temperatures rise due to the changing climate, it will exacerbate the probability of drought. According to IPCC's 2007 Intergovernmental Panel on Climate Change (Pachauri, 2007), not only will drought-affected areas increase in extent, but the droughts themselves will increase in frequency. Drier areas are becoming drier and predicted areas of drought are increasing in size. Shifting storm patterns is one cause for the expansion of drought-prone areas.

> *"Throughout the West, less frequent and less severe drought conditions have occurred during the 20th century than revealed in the paleoclimate records over the last 1000 years. However, warming temperatures may have increased the severity of droughts and exacerbated drought impacts."*
>
> (Colorado Water Conservation Board, 2010)

The sectors most visibly affected by drought are agriculture, forestry and vegetation; however, public health and quality of life are also areas of concern (Pachauri, 2007). Communities with low-adaptive capacities to plan for drought may experience water stress. Drought may also bring about changes in livelihoods. Communities may feel the strain of parks no longer green and playing fields may turn brown without sufficient irrigation, droughts can be depressing to a community's spirit (Drought Effects, 2018). Northglenn discussed lower priority water rights, which may make an extended drought more impactful than for other Front Range communities.

Northglenn has been a proud member of Tree Cities USA for the past 28 years. Tree Cities USA is a community improvement program under the Arbor Day Foundation, whose purpose is to highlight the importance of city trees. The ash tree, a common tree in North America, is highly valued by the Northglenn community. The possibility of drought may threaten the growth and prosperity of Northglenn's ash trees.

> *By 2050, summer drought severity in Colorado is projected to be among the worst in the country.*
>
> http://statesatrisk.org/colorado/drought

Northglenn stakeholders identified drought as one hazard which has the potential to substantially affect forestry and water supply over the next five years. City stakeholders have also indicated that there is a moderately-low to low adaptive capacity for these factors. Because of this relationship, this indicates a priority area for Northglenn in adaptation planning.

Adaptation Recommendations for Drought

Drought is the persistent lack of rainfall that produces dry conditions and leads to reduced water resources. Drought adaptation solutions help to conserve water or remove the need for water use overall.

Restrictions on Water Use

During times of drought Northglenn can consider water restrictions as a good adaptation strategy. Limitations on how often water can be used for watering lawns and washing cars can be considered. Public educational campaigns with conservation recommendations (such as watering plants after sunset to avoid evaporation and help plants to better absorb water) can be rolled out prior to, and during drought events. Having a well thought out toolkit of water rationing strategies ready to go can alleviate city-wide water stress while still accommodating the needs of the individual community members and businesses during drought and dry conditions. Northglenn has active and effective water conservation strategies currently and these should be enhanced over time.

Reducing Overall Water Use

It is important to be conscious of overall everyday water use, regardless of a drought situation, to reduce waste. Individual action can include taking shorter showers, turning off faucets when not in use and operating the washing machine or dishwasher with only full loads.

Rainwater Harvesting

In places where there is sparse rainfall, rainwater harvesting may be beneficial. Rainwater harvesting involves using a bucket or similar container to collect rainfall as it happens with the intention of using the water at a later time. Recycled rainwater can be used instead of valuable potable, or drinkable, water for some daily activities. For example, toilet flushing accounts for roughly 35% of a household's overall water use (The Renewable Energy Hub, 2017). Water captured in a bucket in the shower can be used to water indoor plants. Water captured in rain barrels can be used to water gardens and lawns. If rainwater is used for tasks that do not necessarily require filtered water, then ultimately water costs are reduced dramatically. Some cities like Northglenn incentivize rain barrels for water storage.

Xeriscaping

Xeriscaping is a method of landscaping that minimizes the use of water. Public information campaigns can be rolled out to encourage community members and local landscapers to consider xeriscaping when replacing lawns and/or creating new yard and garden space. City grounds departments can reclaim water intensive landscapes with more drought-resistant plants over the long term. It is best to choose drought-resistant or low-water flowers, succulents, grasses and plants, while also being mindful of the soil, by choosing ones that lessen evaporation, and irrigation systems, by choosing one that applies the amount of water when you need it to. Mulch and compost have a high water-holding capacity as ground cover. Xeriscaping can be a low-maintenance solution to landscaping that is both visually appealing and environmentally-conscious (Colorado Waterwise, 2017). Northglenn can look into policies to incentivize/require xeriscaping for new construction. In addition, some communities make mulch and compost from waste products to avoid landfill tipping fees, and offer those materials to residents for their water-saving value.

Xeriscape Colorado is a program under Colorado WaterWise that specializes in promoting and educating about xeriscaping, Northglenn's use of Resource Central's programs to replace water intensive landscapes with low water landscapes is a great start.

Water Efficiency

Installing and using water efficient mechanisms in homes, businesses and other spaces can cut down on costs and water use. Water efficiency includes practices such as xeriscaping, but it also involves using innovative water efficiency technologies (American Rivers Inc., 2018).

According to American Rivers, these are some very basic steps community members can take toward long term water efficiency:

- Fixing leaks inside and outside the home, business or property
- Using rainwater, or otherwise non-potable water, for tasks that do not require filtered water. Examples: watering plants and flushing toilets.
- Updating appliances and fixtures, like toilets, faucets and showerheads, to high efficiency models. There are programs that provide rebates and discounts on water efficient appliances to help offset the upfront cost.
- Optimizing sprinkler systems. Landscapers can come out and fix and replace broken sprinkler heads. In some cases, drip systems can be set up to prevent top soil water evaporation.

Groundwater Flooding

Groundwater flooding is the flooding of underground structures due to high water tables. Groundwater flooding may become an issue in areas predicted to have increased precipitation in the coming years due to climate change. Increased groundwater may also lead to instability of the soil underground, leading to landslides and/or erosion.

Groundwater (recharge and discharge) is considered a sensitive and complex function because of its dependence on other climate factors, geology, the topography of the land and overall land use (Dragoni & Sukhija, 2008). Although there is a wealth of resources and research done on climate change, there is still much to learn on the connection to groundwater. Changing weather and precipitation patterns are adding to this issue (Holman, 2006). Modeling and remote sensing can be used to estimate the effects of climate change on hydrological systems. In order to gain a deeper understanding of the variations that may occur, the model must be internally consistent and agree with historical data.

More chaotic precipitation events (such as those experienced by Colorado's Front Range in September 2013) paired with the inability of the ground to store water puts a community at a high risk for flooding-related issues. When excess water cannot be drained, it becomes susceptible to contamination. Agricultural runoff and combined sewage overflows threaten water quality, public health and recreation (Center for Climate and Energy Solutions, 2018).

Green infrastructure can be used as an adaptation method to prepare for possible flooding events. Green infrastructure utilizes natural processes and materials in order to manage water in an urban environment. It mimics the natural movement of water through the hydrological cycle (U.S. Climate Resilience Toolkit, 2018).

Adaptation Recommendations for Groundwater Flooding

Groundwater flooding results from high water tables and increased rainfall. The solutions below will help to move excess water on the surface while providing ecological and environmental solutions for the city to consider.

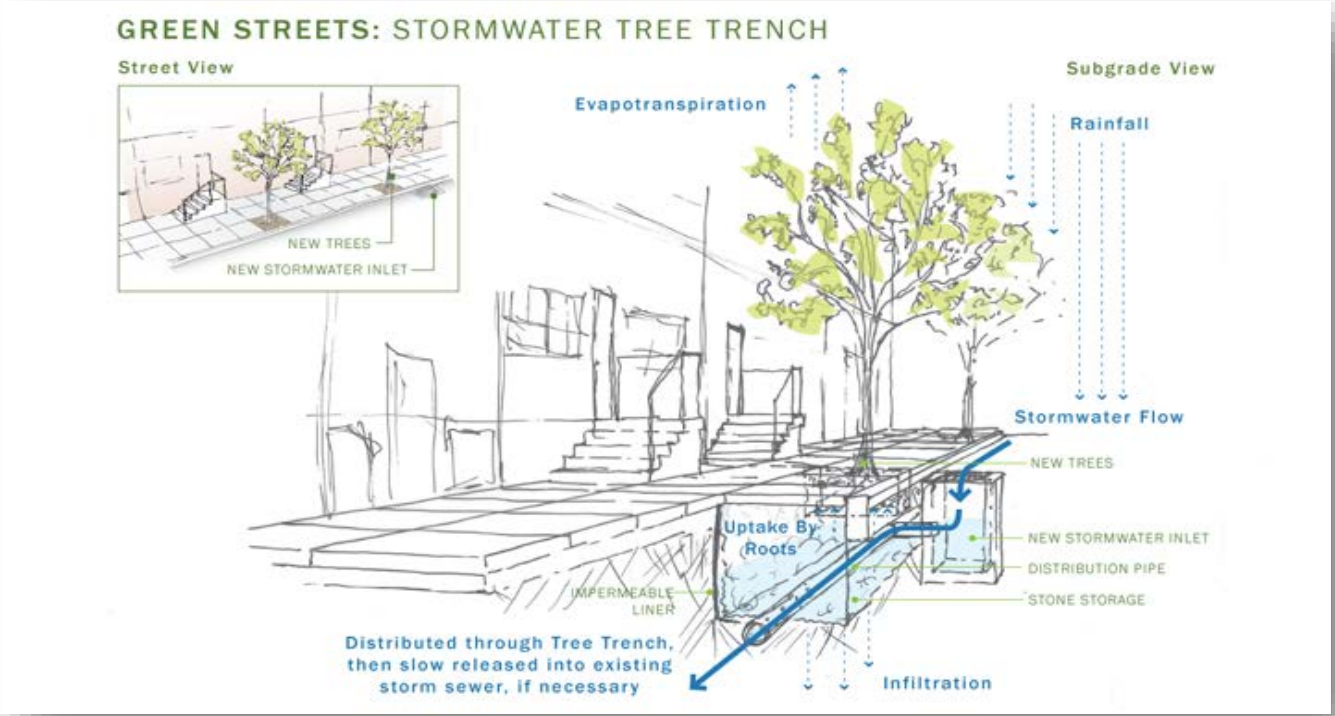
Permeable Pavement

Permeable, or porous, pavement allows for water to pass through it and mimics water's natural movement on the ground's surface. The structure of the pavement with different layers, captures loose sediment and stops it from getting into water sources underground. Using permeable pavement reduces the effect of urban heat and excess runoff that could overwhelm storm water systems. The Green Building Alliance outlines several types of permeable pavement for different purposes (Green Building Alliance, 2018). A few of these are:

- plastic grids: used to reinforce parking lots and driveways and allow for 100% porosity.
- interlocking concrete pavers: can be designed into a pattern with gravel filling in spaces.
- porous asphalt: used on highways.

Planting trees for water management

Trees have a multitude of benefits, including assisting in the natural hydrological process. Planting trees in areas that are prone to groundwater flooding and at the street-edge can lessen the strain that excess precipitation would have on storm water systems and the ground below.



Philadelphia, PA has created a storm water tree trench system that connects trees to an underground system. This system utilizes a type of permeable gravel to filter the incoming water. Here, it can be taken up by the roots or can continue flowing through the sewage system (Philly Watersheds, 2017).

Proactive Flood Management

Northglenn can consider providing flood protection programs for residents, especially those who are vulnerable or in the most need. Programs and policies may include restricting development in floodplains, setting a buffer zone for new construction and conducting a full watershed analysis to determine those areas within the city most prone to flooding and heavy rainfall.

Rainstorms

Models do not necessarily show increased precipitation in coming years, however the changing climate and unpredictability of precipitation events on the Front Range could make severe rainstorms a possibility.

Frequency and severity of rainstorms can increase over time with changing weather patterns. Increased rainfall is strongly related to flooding events and groundwater saturation. Increased precipitation can overwhelm septic tanks and sewage systems.

> *"In all parts of Colorado, no consistent long- term trends in annual precipitation have been detected. Variability is high, which makes detection of trends difficult. Climate model projections do not agree whether annual mean precipitation will increase or decrease by 2050."*
>
> *Colorado Water Conservation Board*

Bacteria, viruses and chemicals can induce the contamination of clean water sources on the surface or underground, which leads to increased chance of illness and gastrointestinal issues in humans.

Similar to groundwater flooding, increased precipitation can create strains on the ground's ability to absorb excess water. Water management is a major concern for areas currently affected by these issues and should be a priority for Northglenn in the future.

Green infrastructure can be used by the city to adapt to more severe and frequent rainstorms and alleviating issues with water management (U.S. Environmental Protection Agency, 2018).

Adaptation Recommendations for Rain Storms

Climate change has the potential to influence more frequent and more severe rain storms. The excess precipitation can overwhelm water management systems and cause water contamination, so solutions should work to alleviate these issues.

Rain Gardens and Bio Swales

Rain gardens and bio swales are natural features that are built into the surrounding environment to manage excess runoff and precipitation. Rain gardens are shallow basins that are filled with plants and other natural features and are mostly used in mostly residential settings. Bio swales are similar to rain gardens in that they manage excess runoff with the use of vegetation or xeriscaping. However, they are linear in shape as opposed to a shallow basin. This allows for placement alongside streets or driveways and therefore manage more water.

Extreme Hot Days

Increasing evidence has highlighted the fact that globally averaged rising temperatures are due in part to anthropogenic factors (Pachauri, 2007). Civilization's addition of greenhouse gases in recent years has greatly contributed to the warming of the climate. Increases in temperature and duration of warmer days has heightened concern about greenhouse gases and their ability to trap heat. Because of this awareness, local governments are utilizing strategies to offset the effect of greenhouse gases. The Front Range of Colorado is forecast to have a climate more similar to Albuquerque, NM over the coming decades, as clearly demonstrated in the climate models.

Climate change is contributing to longer, hotter and more severe heat waves. In Colorado specifically, the annual temperature has increased dramatically since 1970. Observing an increase in average annual temperature may be difficult to discern, however days of extreme heat may be more noticeable. Heat tends to linger more in urban, man-made environments due to the urban heat island effect.

> *"According to multiple independent measurements, Colorado temperatures have increased by approximately two degrees (F) between 1977 and 2006."*
>
> *"Climate models project Colorado will warm by 2.5F by 2025 and 4F by 2050, relative to the 1950–99 baseline."*
>
> *Colorado Water Conservation Board*

Extreme heat has a wide range of negative impacts on society. According to the Center for Climate and Energy Solutions, extreme heat causes the most deaths when compared to other weather-related hazards. In addition, over 60,000 Americans suffer from acute heat-related illnesses every summer (Center for Climate and Energy Solutions, 2018). Public health, in general, becomes more of a concern during hotter days due to the spike in air pollution, a concern specifically called out by Northglenn. Air pollution is caused by the increase in ground-level ozone that is produced in the presence of more heat and the sun's ultraviolet rays. The interaction between volatile organic compounds (from car exhaust, for example) and nitrous oxides, a product of burning fossil fuels, creates the harmful ground-level ozone (United States Environmental Protection Agency, 2017). Air quality is diminished and creates an unhealthy

environment for those suffering from respiratory issues. Specifically the very young and the elderly are vulnerable populations that Northglenn will have to increasingly consider over time as the interaction between extreme heat conditions and the urban heat island effect and air pollution driven by hotter days that will continue to place a burden on communities on the Front Range.

Vulnerable Populations

It is arguably the most vulnerable populations that are experiencing the heaviest burden in the face of the changing climate. Low-income populations, the homeless and the elderly are more susceptible to air pollution and heat-related risks. This is because they do not have access to adequate ventilation and air conditioning. Exposure and proximity to hazardous living situations is also more common for these populations. Mental health issues, as well as issues pertaining to the criminal justice system can be exacerbated during periods of extended high heat. Providing community resources for "escape" from heat is a common strategy for local governments

(Harlan & Ruddel, 2010).

Hotter days and heat waves also have an effect on the societal aspects of a community. In Northglenn, the city has changed work schedules for park and outdoor workers to avoid being outdoors in high heat. Recreation schedules, i.e. for sports games, have also been changed for this reason. Northglenn expressed concerns about how longer summers and hotter days would impact the fabric of the community, events and overall quality of life. The research on this subject is just emerging, and Northglenn is active in considering how heat will change the community's schedules. Continuing to evolve the community's thinking about what constitutes appropriate activities during high heat is important.

Adaptation Recommendations for Extreme Hot Days

Northglenn, like many other cities around the country, has been experiencing hotter than usual summers and generally, warmer temperatures each year. While changing the Earth's temperature is not within reach, adapting to the hotter temperatures and finding ways to cool the surrounding environment on a local scale is attainable.

Law Enforcement

Studies have shown that crime actually increases during times of warm temperatures days. This pattern may result in more police phone calls and disorderly conduct in the future. Northglenn may need to increase law enforcement during summer months and especially during extended heat waves in the future.

> *Researchers from Drexel University studying crime data from 2006-2015 in Philadelphia have found a positive correlation between warmer temperatures and increased crime. Crime was found to be the highest during May through September. To go even further, they were higher on the hottest days. One of the reasons for this correlation may be that more people are outdoors during warmer days, therefore increasing the probability for crime.*
>
> *Science Daily, September 25, 2017*

Cooling Centers

Exposure to several days of extreme heat has the potential to cause a large number of deaths in a short time period. Providing access to air conditioning can prevent heat-related illness and death *(Centers for Disease Control, 2017)*. Low-income populations may have limited access to air conditioning or may be hesitant to operate air conditioning and cooling units due to potentially high electricity costs during peak heat hours. Cooling centers can provide a cool environment for these individuals. Cooling centers are a relatively low-cost strategy that can utilize existing infrastructure and personnel and can be relatively easily implemented by Northglenn during spells of high heat. Northglenn could also consider developing public heat safety education campaigns to be rolled out in late spring and early summer months. Additional cooling strategies such as wellness checks for vulnerable populations and hydration stations in public spaces can also be considered.

Green Roofs

While green roofs are a possible solution to the urban heat island effect, its benefits extend well beyond that. A green roof is essentially a vegetated and irrigated system on a building's roof. Some of the benefits of green roofs are highlighted below (Getter & Rowe, 2006), (Green Roofs for Healthy Cities, 2017):

- A green roof replaces the impervious surface of the original roof with plants, grasses and trees that can provide a natural green space in an otherwise built environment.
- Using natural elements on the roof can alleviate or slow storm water runoff.
- Green roofs provide a cooling effect for the building by increasing the albedo (or reflectivity) of the surface. Instead of incoming solar radiation being absorbed by a dark

concrete or metal roof, the heat is partially absorbed by the vegetation. Evapotranspiration from the plant surfaces also contribute to an overall cooling effect.

- This cooling effect is noticeable and cools the surrounding air temperature and the inside temperature as well. The building using the green roof uses less energy for air conditioning and other cooling mechanisms because it does not get as warm inside the building.
- Plants contribute to the reduction of CO2 (through photosynthesis) and pollutants (through filtration) in the air, thus improving overall air quality.
- Depending on the extensiveness of the green roof, it may be used as an accessible public green space and could include features such as a community garden or playground.
- Adding a green roof can increase marketability and can also count toward green building certifications, such as LEED (Leadership in Energy and Environmental Design).

Green Spaces and Tree Planting

The loss of trees from the urban environment is an unfortunate effect of development and various climate related threats such as Emerald Ash Borer (EAB). Trees provide a wide range of benefits including natural cooling and shade in areas prone to extreme heat. By replacing asphalt, concrete and other man-made spaces with trees and vegetation, it can lower the area's air temperature. According to the EPA, shaded surfaces may be 20–45°F cooler than the peak temperatures of unshaded materials (U.S. Environmental Protection Agency, 2016). Evapotranspiration, alone or in combination with shading, can help reduce peak summer temperatures by 2–9°F. Northglenn is well aware of the value of their tree canopy, and understands the threats to their specific tree species as a result of changing climate.

When developing future tree protection programs, Northglenn should prioritize areas that are most affected by extreme heat and plant trees there first. Care should be taken to plant trees and vegetation with larger canopies and in areas that absorb the most insolation—i.e. parking lots and streets. Northglenn can continue to encourage tree planting within the community by hosting public events centered around tree education. Northglenn could hold a tree- planting event at a local park to bring the community together and also educate the public about the importance of green spaces in a changing climate.

Energy Efficiency

Energy efficiency and reducing demand for electricity overall is a critical strategy for utilities and communities to hedge against the utility reaching peak load during high heat events

created by cooling appliances. By reducing the overall demand for electricity through installing more efficient lighting, cooling, increasing building envelope efficiency and other tactics free up generational capacity to be available for high heat days and increased cooling demand that will become necessary as Northglenn experiences higher temperatures.

"Cool" Pavement and Roofs

Incoming solar radiation (also known as insolation) is absorbed by the Earth's surface every day. Surfaces absorb and reflect insolation differently based on their albedo value, which ranges between 0 and 1. Surfaces that have an albedo closer to 0 will absorb more insolation, and are usually warmer in temperature and darker in color. Surfaces with an albedo closer to 1 will reflect more insolation and are cooler in temperature and lighter in color (U.S. Environmental Protection Agency, 2016).

In built environments, it is increasingly important to create cooler surfaces and areas in the face of a warming climate. Cool pavements and roofs are a way in which communities can reduce the radiation being absorbed and therefore influence a cooling effect on the surrounding environment.

Roofs, whether on commercial or residential buildings, are often made with darker materials. By installing cool roof technologies or painting roofs white (or a lighter color), you can create a cooler local climate and reduce energy use as well. Similar to green roofs, cool roofs absorb less insolation therefore transfer less heat to the building below. This results in lower cooling costs.

Cool pavements are also a possible solution to extreme heat conditions in a community. Like cool roofs, cool pavements are meant to reduce absorption of insolation.

Interestingly, researchers from Ernest Orlando Lawrence Berkeley National Laboratory determined that increasing the amount of solar reflectance by 10% could decrease surface temperature by 7 degrees.

Severe Wind

It is widely known that severe wind is destructive and brings about substantial economic and social costs. Whether paired with thunderstorms or hurricanes or occurring strictly as a severe wind event, wind damages affect infrastructure for buildings and transportation, power lines, agriculture and forestry. Falling debris and trees can cause a hazard for humans and animals as well. With the changing climate, it is possible that even more destructive wind gusts and patterns may occur. Increase in waste production from landscaping, fencing and other materials is a likely outcome from wind events.

> "Severe wind is more likely to occur during the winter due to the larger latitudinal temperature difference in the northern and southern U.S. The Chinook winds, warmer drier winds moving west coming off the Rocky Mountains, can have gusts up to 100mph. Areas near Denver, Boulder, Fort Collins and Colorado Springs are especially vulnerable to these winds and their destructive capability."
>
> weather.gov/bou/highwind

There are many ways in which a community can adapt and prepare for more frequent severe wind events. Some suggested strategies are reviewing existing building codes and adopting higher standards for building codes, specifically for regions currently experiencing high wind. Structural improvements include anchor bolts, bracing, interlocking roof shingles and impact resistant windows (FEMA, 2013). Utilizing GIS and modeling tools to identify areas prone to severe wind is a first step in helping the community to develop a plan for severe wind adaptation.

Adaptation Recommendations for Severe Wind

In order to protect community members, building codes (particularly for older buildings) should be reviewed to ensure that they are protected against wind damage.

Updating Building Codes

Adopting the International Building Code, International Residential Code and International Code Council-600 Standard (for high-wind regions) might considered. Requiring the use of

specific design elements, such as interlocking shingles on roofs, is especially important in heavy wind-prone areas.

Structural Improvements

The community should encourage the installation of structural improvements that will mitigate severe wind damage. Some of these additions include structural braces, impact-resistant glass for windows and anchor bolts. Finding innovative ways to use natural elements and shapes in designs for new construction could minimize damage, cost and falling debris.

To prepare for a severe wind event, Northglenn should educate the public around making structural improvements, but also making sure the surrounding environment reduces the risk for wind damage as well. This involves trimming trees near the home and power lines. Northglenn expressed concerns around how wind interacts with waste creation, and considering how to manage waste after wind events will be important especially if current waste disposal services change over time.

Hail

Hail, a form of frozen precipitation associated with severe summertime thunderstorms, is known to cause significant damage to vehicles, property and crops. According to NOAA's historical event data for Adams and Weld county, damage from a just a single Colorado hail storm can result in over $100 million in property damage and over $20 million in crop damage (University of Oklahoma, 2018).

In climate research, there is a vast knowledge of larger scale weather events. Knowledge of thunderstorms and hailstorms, both smaller scale meteorological events, is limited. There is evidence from climate models that show favorable conditions for severe thunderstorm development, which could in turn increase the chance for hailstorms. However, the ability to model such small-scale events is difficult. Because of this, there is a limitation in discerning how these events will change with a changing climate (European Environment Agency, 2017).

The best course of action is to observe and take note of which areas are currently most prone to thunderstorms and hailstorms and implement adaptation strategies there. To minimize hail damage, new construction can include incorporating structural braces, hail resistant roofs and laminated glass for windows (FEMA, 2013). Raising awareness about what to during a

hailstorm and notifying the public about when hailstorms are most likely to occur is also increasingly significant.

Adaptation Recommendations for Hail

Hail, the frozen precipitation that is often associated with summer thunderstorms in Colorado causes damage to property, vehicles, trees and crops. It is important to make changes in order to prevent extensive damage and costly repairs.

Installing laminated windows

Because hail has the ability to crack or shatter glass upon impact, making sure that windows are able to withstand that impact is important. Laminated glass is able to hold together when struck with an object. The inner layer of laminated glass prevents the glass from being broken into large pieces, that could potentially cause harm. Laminated glass should be required for windows in places prone to hail, in order to avoid expensive repairs in the future.

Installing hail proof roofs and siding

It is just as important to protect the siding and roof of the property with hail-resistant materials. Doing this will ensure that hail will cause minimal damage.

Installing carports and covered garage space

The impact of hailstones has the potential to cause extensive damages to vehicles if they are not protected. Installing covered parking spaces and carports if possible could eliminate much of the vehicle damage often associated with hailstorms. Colorado has experienced severe hailstorms in the past, costing billions of dollars in damages to both property and cars.

Changing Seasonal Patterns

The Earth experiences predicted changes every season, however research has shown the negative impact that climate change has on this natural routine.

As mentioned before, Northglenn has a strong cultural connection to the ash tree. It is understood in Colorado that the ash tree is being threatened by the emerald ash borer (EAB), a non-native invasive insect species whose young feeds on the inner bark of ash trees. The

EAB, found in 33 states across the country, as well as Canada, has cost millions of dollars in damage and is also responsible for killing millions of ash trees as well. The EAB is unable to survive in extremely cold temperatures, however, there are few locations that can sustain these temperatures to kill the emerald ash borer. Rising temperatures across the country are making it easier for the EAB to thrive and continue invading ash trees. According to researchers, there are regions in Canada that would be able to hold cold enough temperatures that would prevent invasion but outside of this, the ash tree population would be severely affected by EAB (Mary A. Jamieson, 2012) (Emerald Ash Borer Information Network, 2011) (Colorado Department of Agriculture, 2014).

The changing climate not only affects the biological functions that rely on seasonality, but societal and cultural functions are affected as well. As mentioned before, warmer temperatures are already impacting the timing of work schedules and planning of public works projects in Northglenn. Recreation and tourism are also heavily dependent on weather conditions and seasonality, as well as the traveler comfort and preference (Sustainable Development of Tourism, 2018).

It is imperative to raise awareness of changing seasonal patterns and the changing climate, more broadly. Extreme weather and climate change-related events are already widely known to affect the quality of life and public health (Centers for Disease Control, 2018). However, mental health is also a growing concern. Anxiety, depression and post-traumatic stress disorder may result from a severe storm, flooding or other event (U.S. Climate Resilience Toolkit, 2018). In anticipation of these events, communities should find ways in order to educate the public about climate change and its effects on the surrounding environment and make resources available for support, aid and communication.

Adaptation Recommendations for Changing Seasonal Patterns

Seasonal patterns that were once easy to predict are increasingly becoming difficult to forecast. It is necessary to adapt with these climatic changes so that daily life, economic activity and community life are minimally impacted.

Increasing public education and awareness

Raising awareness and encouraging education in the face of the changing climate is an integral part of climate adaptation. In order to develop ways in which a community should adapt to

climate risks, leaders must first learn about specific risks affecting them and research solutions. On a smaller scale, community members can make mindful decisions to take climate actions in their every day life to lessen their impact on the environment.

Diversifying Seasonal Tourism and Recreation

Locations that are heavily dependent on one specific type of recreation or tourism attraction based around climate conditions may need to expand their options in the future. For example, Northglenn expressed the how much the community life relied on and revolved around summer sports fields, parks and other assets that can be imperiled by climate change. Even the ability to hold certain events can be impacted as we see the manifestation of the climate models in temperatures previously unseen in Northglenn.

Flexible Municipal Operations

Northglenn is already recognizing and adapting to changing conditions by modifying schedules both daily, and seasonally. Continuing to evaluate when work and other community operations will happen based on climate trends will be required as heat, but also less severe cold, with impact how and when work happens.

CONCLUSION

Northglenn, Colorado's focus on their residents' quality of life, community engagement and commitment to a vibrant community will necessitate continual attention to the changing climate in the coming years. Overall, Northglenn's adaptive capacity as a city is enviable by even Front Range standards. Emerging climate threats are reasonable compared with even close in neighbors where fire and flood dominate. A lower overall threat level positions Northglenn well in the time to come.

Northglenn's adaptive capacity is better than that of most cities. Many of Northglenn's threats can be mitigated with relatively low-cost/no-cost policy and behavior change strategies. Compared to other Front Range communities that may face insurmountable barriers to adapting to climate change, Northglenn is very well positioned. The Risk and Adaptation Advisory Report (RAAR) finds that though higher heat and drier overall environment will be the dominant risks that impact Northglenn, focused efforts around changing community behaviors such as timing of events, scheduling of staff and municipal projects, consumption of resources, protecting trees and other approaches can largely mitigate the changing climate.

Specific actions for Northglenn include focusing on enhancing their already important and relevant water conservation programs and considering further deeper water conservation strategies for the future. Anticipating the community needs around high-heat will become more important in coming years. Developing strategies for vulnerable populations for access to cooling and creating a reliable safety network to be able to connect with seniors and others during times of high-heat will be helpful. Continuing to evolve municipal operations to account for heat, and knowing that some cherished community events may need to evolve to avoid high temperatures.

SUMMARY OF HAZARDS AND RECOMMENDATIONS FOR NORTHGLENN

Icon	Hazard	Recommendations
	Drought	• restrictions on water use • reducing overall water use • rainwater harvesting • xeriscaping • water efficiency
	Groundwater Flooding	• permeable pavement • planting trees for water management • proactive flood management
	Rainstorms	• rain gardens and bio swales
	Extreme Hot Days	• law enforcement • cooling centers • green roofs • planting/protecting trees and increase green spaces • energy efficiency • cool pavement and roofs
	Severe Wind	• updating building codes for new construction • structural improvements
	Hail	• installing laminated windows • installing hail proof roofs and siding • installing carports and covered garage space
	Changing Seasonal Patterns	• increasing public education and awareness • diversifying seasonal tourism and recreation • flexible municipal operations

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SURVEY RESULTS

Hazard	Community System	Risk Probability	Risk Frequency	Risk Intensity	Risk Impact Magnitude	Risk Adaptive Capacity
Changed seasonal patterns	Emotional and mental health	mod high	increasing	increasing	moderate	mod low
Changed seasonal patterns	Forestry	mod high	increasing	increasing	moderate	mod low
Changed seasonal patterns	Law and order	mod high	increasing	increasing	low	low
Changed seasonal patterns	Public health	mod high	increasing	increasing	mod low	mod low
Changed seasonal patterns	Quality of life	mod high	increasing	increasing	moderate	mod low
Changed seasonal patterns	Transportation	mod high	increasing	increasing	low	low
Changed seasonal patterns	Waste management	mod high	increasing	increasing	mod high	moderate
Changed seasonal patterns	Water supply	mod high	increasing	increasing	mod high	low
Drought	Emotional and mental health	high	increasing	increasing	mod high	moderate
Drought	Forestry	high	increasing	increasing	high	mod low
Drought	Law and order	high	increasing	increasing	low	mod high
Drought	Public health	high	increasing	increasing	moderate	moderate
Drought	Quality of life	high	increasing	increasing	mod high	moderate
Drought	Water supply	high	increasing	increasing	high	low
Extreme hot days	Emotional and mental health	high	increasing	increasing	high	moderate
Extreme hot days	Forestry	high	increasing	increasing	mod high	mod low
Extreme hot days	Law and order	high	increasing	increasing	moderate	mod low
Extreme hot days	Public health	high	increasing	increasing	high	mod low
Extreme hot days	Quality of life	high	increasing	increasing	high	mod low
Extreme hot days	Transportation	high	increasing	increasing	moderate	mod low
Extreme hot days	Waste management	high	increasing	increasing	mod high	moderate
Extreme hot days	Water supply	high	increasing	increasing	high	low
Groundwater flooding	Emotional and mental health	mod low	increasing	increasing	mod low	mod low
Groundwater flooding	Forestry	mod low	no change	no change	low	low
Groundwater flooding	Public health	mod low	no change	no change	mod low	moderate
Groundwater flooding	Quality of life	mod low	no change	no change	low	low
Groundwater flooding	Water supply	mod low	no change	no change	mod low	low
Hail	Emotional and mental health	high	increasing	increasing	moderate	mod low
Hail	Forestry	high	increasing	increasing	moderate	mod low
Hail	Public health	high	increasing	increasing	moderate	low
Hail	Quality of life	high	increasing	increasing	moderate	mod low
Hail	Transportation	high	increasing	increasing	mod low	low
Rain storms	Emotional and mental health	high	increasing	increasing	mod low	low
Rain storms	Forestry	high	increasing	increasing	low	low
Rain storms	Law and order	high	increasing	increasing	mod low	mod low

Rain storms	Public health	high	increasing	increasing	moderate	low
Rain storms	Quality of life	high	increasing	increasing	moderate	low
Rain storms	Transportation	high	increasing	increasing	mod high	low
Rain storms	Water supply	high	increasing	increasing	low	low
Severe wind	Emotional and mental health	high	increasing	increasing	mod high	mod low
Severe wind	Forestry	high	increasing	increasing	moderate	moderate
Severe wind	Law and order	high	increasing	increasing	low	low
Severe wind	Public health	high	increasing	increasing	mod low	low
Severe wind	Quality of life	high	increasing	increasing	mod high	low
Severe wind	Waste management	high	increasing	increasing	mod low	mod low