NAVIGATING CLIMATE CHALLENGES IN THE QUAD CITIES

A Comprehensive Assessment and Paths to Resilience

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GLOSSARY

Term	Definition
100-year return period (or flood event)	This means there is a 1% chance of a flood occurring in any given year. Climate change is increasing the frequency of 100-year flood events in many parts of the country.
Biodiversity	Refers to the variety of life in a particular habitat
Climate change	Refers to significant and long lasting changes to Earth's weather patterns and average temperatures. This phenomenon occurs over a long period and is influenced by human activities like burning fossil fuels and deforestation, which ultimately lead to increased greenhouse gas emissions and subsequent changes in global climate conditions.
Coupled Model Intercomparison Project Phase 6 (CMIP6)	A collaborative effort that involves multiple global climate models to simulate and understand Earth's climate system. This initiative aims to improve our understanding of climate change, its potential impacts, and the reliability of climate projections. CMIP6 models are used to explore various scenarios of future greenhouse gas emissions and assess the potential outcomes of these scenarios on the Earth's climate.
Digital Elevation Model (DEM)	The ground elevation of different elements in the study region. These elevation data are subsequently used to determine the flow patterns of water within the region.
Flash flood	A sudden and intense flood that occurs in a short period of time. Flash floods can be dangerous because of their sudden onset and quick-moving waters.
Floodplain restoration	A type of restoration that returns the floodplain, the low-lying area adjacent to a river or stream, to its natural state. Successful restoration recreates natural water flow and features, which mitigates flooding.
Green roof	Plants and vegetation are grown on a rooftop, which provide insulation, reduced runoff, and improved energy efficiency for the building.
Higher emission scenario	Also referred to as SSP 585. This is the futuristic scenario that represents a high level of greenhouse gas emissions, leading to a substantial increase in global warming by 2100.
Ice jam	This occurs when large pieces of ice get stuck in a river and block water flow.
Lower emission scenario	Also referred to as SSP 126. This is the futuristic scenario that represents a relatively low level of greenhouse gas emissions. This scenario envisions a world with efforts to mitigate climate change impacts.
Major hydraulic structure	An engineered structure designed to manage water flow, often in large rivers. Examples include: floodwalls, locks and dams, hydraulic rams, flood control barriers, and levees.
Moderate emission scenario	Also referred to as SSP 245. This is the futuristic scenario that represents a relatively moderate level of greenhouse gas emissions. This scenario assumes that efforts to curb climate change impacts are being taken. The moderate emission scenario is known as the "middle of the road" forecast.

Term	Definition
Nature-based solution	These include conserving and restoring natural ecosystems, such as healthy wetlands, floodplains, and forests, as well as employing engineered systems designed to mimic natural system functions. Terms such as 'natural infrastructure' or 'green infrastructure' are types of nature-based solutions often used interchangeably in different contexts. Properly implemented, nature-based solutions can play an important role in community climate adaptation and resilience, while also providing economic, social, and environmental benefits and enhancing quality of life for community residents.
Nonpoint source pollution	Contaminants that enter water bodies from different sources across the landscape instead of a direct, identifiable source, like a pipe. Common examples include: fertilizer, sediment, household chemicals, excess nutrients (nitrogen and phosphorus), pet waste.
Peak discharge	Refers to the highest flow or volume of water in a river or stream during a specific period, typically associated with a flood event.
Permeable pavement	A type of pavement that allows water to pass through it, reducing surface runoff and increasing infiltration into the ground.
Rain garden	Gardens that help slow, capture, and clean stormwater by allowing it to pass through soil and plants. These local solutions help remove pollutants and reduce flooding.
Resilience	The ability of a community and its environment to handle and bounce back from stressors, like flooding.
Riparian buffer	A strip of vegetation along the banks of a water body, which is designed to protect water quality by filtering runoff, reducing erosion, and providing habitat.
Stormwater	The water that comes from rain or snow and flows over impervious surfaces, like streets and sidewalks, and does not soak into the ground. Flooding, pollution, erosion, and property damage can all result from uncontrolled stormwater runoff.
SWMM-HECRAS coupled model	A computerized system that combines two software tools, SWMM (Storm Water Management Model) and HEC-RAS (Hydraulic Engineering Center's River Analysis System). This integrated model is used to simulate and analyze the interaction between stormwater runoff and river hydraulics. It helps in understanding and managing water flow in urban areas, particularly during rainfall events, by considering both the surface water drainage (SWMM) and river channel hydraulics (HEC-RAS).
Urban heat island effect	The phenomenon that results in hotter cities (compared to rural areas) because of human activities and the way built infrastructure, like buildings and roads, absorb and trap heat.
Vegetative swale	A vegetated channel or depression in the ground designed to manage stormwater by absorbing rainwater into the ground.
Wetland	Wetlands are areas covered or saturated with water, either permanently or intermittently. Wetlands provide several benefits, including: habitat for diverse plants and animals; resupplying underground sources of drinking water; absorbing excess water during flood events; filtering and cleaning water; and providing spaces for outdoor recreation.

EXECUTIVE SUMMARY

Amidst growing climate challenges, the Quad Cities must navigate evolving environmental, social, and economic impacts for a resilient future.

Nestled at the convergence of the Mississippi and Rock Rivers, the Quad Cities form a vibrant community that spans southeastern Iowa's Davenport and Bettendorf to northwestern Illinois' Rock Island, Moline, and East Moline. Home to nearly 400,000 residents, the region thrives as a hub of manufacturing, commerce, and transportation.

Because of its proximity to the Mississippi River, the Quad Cities are also highly prone to flooding and other extreme weather events, posing risks to public safety, infrastructure, and the economy. Future climate hazards like wildfires, tornadoes, droughts, and extreme heat may further intensify these challenges, disproportionately impacting the community. Vulnerable groups, including those with lower socioeconomic status, Black, Indigenous, People of Color (BIPOC) communities, renters, people experiencing homelessness, immigrants, and people with disabilities will likely bear an unequal burden, underscoring the importance of collective action and support.

The purpose of this assessment is to provide Quad Cities' local leaders, decision-makers, and community members with regionally relevant information about the impacts of climate change. The assessment aims to empower communities to identify and pursue strategic investments, including nature-based solutions as appropriate, to enhance community resilience, support local economies, and foster healthy natural systems.

The main objectives of this assessment are: 1) assess and summarize the latest information regarding predicted climate impacts, including the regional economic and environmental risks associated with climate change; 2) identify strategies to help communities mitigate and adapt to climate change risks; and 3) foster communication within communities to evaluate community risks, resilience needs, and nature-based solutions available for the region.

This assessment used a combination of quantitative and qualitative approaches, including downscaling global climate models to provide local climate projections, conducting interviews, facilitating public input sessions, and reviewing existing scientific literature and planning documents.

The assessment used a set of Coupled Model Intercomparison Project Phase 6 (CMIP6) models to project future climate conditions in the Quad Cities. To simulate the flooding in the region, a flood model was developed for an area extending 28 miles upstream and 7.5 miles downstream to simulate flows from the Mississippi River. Simultaneously, Quad Cities stakeholders were engaged through multiple outreach efforts to provide input on current climate risks and solutions within their respective communities. Approximately 30 interviews were conducted with regional natural resource professionals, conservation staff from city municipalities, various non-profit organizations, and community leaders.

In addition to the stakeholder interviews, three public input sessions were conducted to obtain feedback on the preliminary findings of the draft assessment and offer further questions, concerns, and recommendations. Dedicated efforts were made during the stakeholder engagement process to include representation from identified vulnerable communities, especially those representatives of lower socioeconomic and BIPOC communities.

Some of the key findings from the assessment are as follows.

Climate Risks

Major climate risks emphasized by community leaders during stakeholder interviews included both flash flooding and river flooding, as well as concerns for more extreme heat events in the future.

Precipitation changes and flood risks

As the climate warms, precipitation patterns have become more variable, leading to increased flood risk in some areas and prolonged dry periods in others. These changes can affect agriculture, water resources, and the environment. The local landscape, existing flood control infrastructure, land use decisions, and urban development will also shape future flood hazards. By using future emission scenarios, which envision "low" and "high" greenhouse gas emission rates, climate scientists can predict (to a certain degree of certainty) future climate change impacts. Flood model simulations from this assessment reveal that areas close to the Mississippi River are becoming more prone to river floods due to increased rainfall and higher stream flows, especially in downstream regions, like Rock Island. Heavy rainfall events in 2080–2090 could bring floodwaters close to the I-74 Mississippi River Bridge and the downstream area of Rock Island, drastically affecting pedestrian and commercial transportation and adversely affecting the local economy.

Extreme heat

As climate change continues, the Quad Cities are expected to see more hot days (when temperature increases above 95°F) and extremely hot days (temperature increases above 100°F). The number of hot days will increase from three days at present to anywhere between 28-58 days based on the rate of global greenhouse gas emissions. In addition to rendering ecosystems uninhabitable for certain species, the change in extreme heat is likely to contribute to health issues, including respiratory problems, thereby reducing resilience and increasing the community's overall social vulnerability.

Climate Impacts

The impacts of these projected climate change risks have the potential to cause detrimental effects on key resources and assets within the Quad Cities.

Projected Environmental Impacts

Climate change is likely to significantly impact ecosystems in the Quad Cities region. Because of warmer, wetter springs and hotter, drier summers, forests like Loud Thunder Forest Preserve located in Rock Island County may experience altered habitat suitability for different tree species, potentially leading to an influx of non-native species. Wetlands, like Nahant Marsh and the Quad Cities Conservation Alliance Wetlands Center, face challenges with disruptions in their water balance, due to more frequent droughts and flash floods. Fish and other aquatic life may also be negatively impacted by rising temperatures and extreme rainfall. Rising temperatures and altered precipitation patterns will also impact agricultural yields; while the number of growing days may increase, high temperatures and increased flood risk can negatively impact crop management and yields.

Water Quantity and Quality

Water quality and quantity will see impacts related to extreme rainfall, drought, and upstream water use, also adversely affecting communities, plants, and animals that depend on the river. The frequency and intensity of precipitation is expected to increase in the region, leading to an increased risk of flooding. Increased runoff, as a result of more frequent and intense rainfall, can degrade water quality by mobilizing pollutants, commonly known as nonpoint source pollutants. For example, agricultural runoff, containing sediment, excessive nutrients (nitrogen and phosphorus), pesticides and chemicals from agricultural and industrial sources, already threatens river resources – a persistent concern among the key stakeholders in the Quad Cities. In addition to agricultural sources, urban sources like lawn fertilizers and pesticides, deicing salt, sewage overflow during storm events, and pet waste are common contributors to poor water quality.

Economy and Public Health

Climate change-induced flooding threatens the economic viability of the Quad Cities region. Locations like Cargill AgHorizons, Isle Casino Hotel Bettendorf, and portions of the Rock Island Arsenal face direct future flood risks. These at-risk places also include tourist spots, major attractions, and gathering grounds, generating economic revenue as well as opportunities for social cohesion among community members. By 2090, the annual flood risk under the high emission scenario significantly impacts critical transportation, like major roadways and bridges. Rising temperatures and warming winters will also continue to impact the Quad Cities' agricultural sector. Heat and water stress may reduce corn yields by mid-century, with declining soybean yields to follow. Warming temperatures will also shift where certain crops can grow in the region. An increase in extreme heat events also poses significant health risks, increasing the occurrence of severe heat-related illnesses like heat exhaustion and heat stroke.

Socially Vulnerable Populations

Climate risks vary based on a population's geographic location and social characteristics. Residents living and working in floodplains in Moline and East Moline and downtown Davenport along the Mississippi and Rock Rivers are more susceptible to flood risks at present. Social vulnerability, defined as the susceptibility of a social group to the adverse impacts of natural hazards, plays a critical role in the region's resilience planning. Downtown Quad Cities locations along the Mississippi mainstem and areas in East Moline stand out as the most vulnerable within the metro area. Outlying urban areas in the broader region also exhibit areas of high social vulnerability.

Nature-Based Solutions

Nature-based solutions include conserving and restoring natural ecosystems, such as healthy wetlands, floodplains, and forests, as well as employing engineered systems designed to mimic natural system functions. Often interchangeable with the terms "natural infrastructure" or "green infrastructure", nature-based solutions offer reliable, cost-effective, and efficient solutions to risk reduction while also building community resilience. Nature-based solutions should always be tailored to their location, function, and used in a cultural context. Identifying and implementing solutions will depend on community needs, priorities, and concerns. This assessment analyzed the impact of site-specific nature-based solutions on flood risks in the Quad Cities, demonstrating a substantial increase in infiltration and reduction in flooding.

In the Quad Cities, where climate risks are compounded by additional factors, such as the amount of impervious surfaces, upstream land uses (e.g., agriculture), and urban development, several stakeholders emphasized the need to look upstream and implement large-scale solutions. Rock Island, for example, is predominantly impacted by water coming from upstream and local urban runoff; any nature-based solutions implemented there will be greatly impacted by upstream discharge. The region also contributes to downstream impacts due to its location and associated tributaries.

Quad Cities community leaders are actively thinking about ecosystem restoration and nature-based solution opportunities. Solutions that were frequently mentioned during input sessions and interviews include:

Increase green space

Using old and newly vacant spaces in Davenport for green space, in particular the old YMCA location between Gaines and Second Street in Davenport and the recently vacant lot on North Main Street from an apartment building collapse. These alleys and vacant lots can be transformed into a green infrastructure network, providing access to nature and equitable open space for recreation.

Ravine restoration (through conservation easement), specifically in Rock Island, Moline, and East Moline

Restoring ravines by removing invasive species, re-establishing appropriate native species, and conserving these ecologically vital areas through easements will enhance their ability to perform ecosystem services, such as enhancing corridors for wildlife, managing stormwater circuits for heavy rainfall/flash flooding, and instilling environmental stewardship among residents.

Providing equitable access to the river

River access for communities of lower socioeconomic status or those within BIPOC communities is often lacking or viewed as unsafe. Projects such as developing a river path to connect East Moline (Watertown) to the river and exploring ways to make the river more accessible to those with disabilities was recommended by several stakeholders.

Natural infrastructure to curb "heat islands"

Extreme heat is one of the key concerns highlighted by the community memebrs in the Quad Cities and with the number of extreme heat days increasing, conversations have steered towards decreasing heat islands. Increasing treee coverage, especially in communities significantly affected by lower tree equity scores, could not only enhance the biodiversity of a city, but also help curbt he effects of extreme heat.

Conclusion

The Quad Cities' climate is changing. Climate models predict wetter, hotter conditions, leading to an increased risk of extreme events, like flooding and intense heat. In addition to environmental detriments, critical transportation infrastructure, public health, and the economy are directly threatened by climate change-induced flooding and heat.

This climate assessment aims to inform Quad Cities' communities and leaders about local climate change impacts, empowering them to pursue resilient solutions, including nature-based projects where appropriate. While nature-based approaches are not a one-size-fits-all solution, they are a valuable tool for addressing climate change impacts. Modeling has shown their effectiveness at reducing high flow and increasing water retention and infiltration into the ground, which can help reduce flood risk. It is critical, however, to co-create and implement all solutions with community members, tailoring projects to local needs and desires.

Community members are interested in understanding and addressing climate change impacts in the region. During the public input sessions, stakeholders identified several potential uses for this climate assessment:

- Utilizing findings to apply to grant funding or advocate for resilience and nature-based solution initiatives in their communities.
- Communicating with policy and decision-makers about the urgency of implementing nature-based solutions as part of a comprehensive solution.
- Understanding how city infrastructure and future business developments will further exacerbate climate risks and how these impacts will affect surrounding communities.
- Advocating for the creation of jobs specific to nature-based solutions (i.e., ensuring qualified contractors are available to assist homeowners and businesses with nature-based solutions).
- Serving as an educational resource that emphasizes the opportunity for nature-based solutions within various communities, businesses, and media outlets.
- Supporting a broader analysis that looks upstream to rural and agricultural impacts and opportunities.

Aerial view of the Quad Cities. (Shutterstock)

Historically, not all communities have been included in planning, designing, and executing projects impacting their resilience. If not implemented with careful community engagement, even nature-based projects, while environmentally beneficial, can have unintended negative consequences, like gentrification and displacement of primarily socially vulnerable communities.

Increased participation of and partnership with local stakeholders as community experts at every stage of planning - including project implementation and stewardship - lead to more equitable outcomes that align with local preferences. The Mississippi River Equity Vision[1] is an example of a Quad Cities-crafted document that seeks to align stakeholders in the pursuit of a clean and sustainable Mississippi River, focusing on the lived experience of underrepresented and historically marginalized community members.

While the region faces complex and growing climate challenges, the opportunities are palpable. Ongoing efforts, from community- to regional-driven plans, are working hard to address these challenges. This assessment can serve as an additional resource in leveraging science and community to build and maintain more resilient communities for all who call the Quad Cities home.

1 Centering the Lived Experiences & Voices of Communities of Color: Community-Informed Mississippi River Equity Vision & Final Report, 2023, Iman Consulting, LLC.

1 QUAD CITIES CONTEXT AND GOALS

SECTION SUMMARY

- Illinois and Iowa’s climates are changing; temperatures are rising, rainfall is increasing, droughts are more prolonged, and extreme events, like intense heat, are becoming more frequent.
- This assessment intends to better understand local impacts in the Quad Cities by downscaling climate models to simulate and project future climate impacts under different hypothetical scenarios.
- Quad Cities stakeholders were also engaged to provide local insights on climate issues, opportunities, and needs, helping align the climate assessment with regional interests.
- Nature-based solutions are a suite of tools for building climate resilience to future threats, however, these are not a one-size-fits-all solution; equitable practices, like participatory planning and implementation, are key to addressing longstanding, racist policies that exclude socially vulnerable communities.

The Quad Cities - home to nearly 400,000 residents and numerous businesses within the cities of Davenport and Bettendorf in southeastern Iowa and Rock Island, Moline, and East Moline in northwestern Illinois - are situated along the Mississippi River at its confluence with the Rock River. Here, the Mississippi River is a vital resource for manufacturing, commerce, and transportation while offering recreational and outdoor opportunities to the boaters, hunters, anglers, and birdwatchers.

Its proximity to the Mississippi River also makes the region exceptionally vulnerable to flooding and other extreme events. This area is no stranger to major flooding. In 2019, a nearly 23-foot flood height broke the all-time record flood crest of 1993 (National Weather Service, 2019). The river reaching 21.5 ft again in 2023 was not just a reminder of the 2019 flood, but also the ongoing and compounding risks the region faces in a changing climate.

Despite its vulnerability, the region has abundant natural features including creeks, forests, wetlands, and prairies. Protecting and restoring these natural assets can provide hazard risk reduction benefits while enhancing community resilience to future extreme events. These natural features also serve as habitat for local wildlife and fisheries, attract visitors and generate tourism revenues, and serve as an educational tool for youth, connecting the entire community to nature.

The purpose of this assessment is to equip leaders, decision-makers, and community members in the Quad Cities with locally relevant information about the impacts of climate change, empowering them to identify and pursue greater investments in the long-term resilience of their community, including through nature-based projects where appropriate. In doing so, the assessment aims to serve as a foundation for stakeholders to make informed choices and leverage funding opportunities for the present and future of the region.

Approximately 30 local natural resource professionals and community leaders, including conservation staff from municipalities, technical experts from local agencies, and non-profit organizations, were engaged in outreach efforts (interviews and public meetings) to gather stakeholder feedback on local needs, desires, and opportunities in the region. Dedicated efforts were made to include representation from vulnerable communities, especially those representative of Black, Indigenous, and People of Color (BIPOC) communities, as much as possible within the stakeholder engagement process.

The main objectives of this assessment are:

- Synthesize the latest information regarding climate change-related risks and consequent socio-economic and environmental regional impacts.
- Identify potential adaptation strategies to mitigate the impacts to communities and natural assets.
- Engage community experts to initiate conversations on community risks, resilience needs, and nature-based solutions available for the region.

1.1. The Bigger Picture

The Quad Cities are vulnerable to river flooding and extreme rainfall-induced flash flooding due to its proximity to the Mississippi and Rock Rivers. This flooding jeopardizes public safety and day-to-day operations, affecting city infrastructure, businesses, homes, and people. Present day flood events are attributed to snowmelt, frozen ground, ice jams, saturated soils, and rainfall. Climate change, which manifests as rising temperature, increased upstream snowmelt, and altered rainfall patterns, produces growing flood vulnerability. This ongoing trend is poised to continue, causing further disruptions within the community. Additionally, extreme weather events such as extreme heat, as well as wildfire, tornadoes, and droughts, will exacerbate the community's future vulnerability, lowering the ability of its residents to cope with the impacts. Not all community members will be equally impacted. Highly socially vulnerable population groups - lower socioeconomic groups, BIPOC communities, renters, unhoused communities, people with disabilities, and immigrant populations - will disproportionately face impacts compared to lesser vulnerable residents with greater access to financial and technical resources.

Resilience is a shared responsibility across multiple levels of government within the five cities and associated counties in the two-state expanse. Decisions around land use and floodplain management are subject to rules, regulations, and planning processes at various jurisdictions. While different agencies and organizations undertake resilience-related planning initiatives to respond to flooding and other extreme events, this can make for a confusing web to navigate. This assessment draws upon these ongoing efforts and encourages a broader perspective to expand the collective benefits that these plans can provide to the entire region.

A narrow scope of resilience planning can also result in missed opportunities for regional-scale comprehensive planning and, at worse, cause unintended consequences. For instance, Rock Island currently relies on levees for flood protection that obstructs river access. If the Rock Island levee fails, it can put 5,550 people and 1,669 structures at risk, causing damages equal to $1.26 billion. The probability of this levee failure is already ranked at moderate risk according to an analysis conducted by the Environmental Law and Policy Center (ELPC, 2020). The levee, which requires extensive monitoring and maintenance, was last assessed by the USACE in 2016 and continues to weaken with the recent flood events. While traditional flood mitigation solutions can help with severe flood events, long-term planning for climate resilience cannot solely rely on solutions that require a level of repair and maintenance that outpaces the impacts of climate change. Comprehensive and creative approaches like nature-based solutions that provide risk reduction benefits while building community resilience can help to ensure the long-term sustainability of the region along with existing solutions.

1.2. Regional Environmental Context and Associated Socio-Economic Benefits

Several natural features in the region offer an opportunity to build climate resilience. The region's features, such as wetlands, floodplains, forests, rivers, creeks, and open green spaces, provide protective services through slowing runoff, increasing floodplain water storage capacity, enhancing surface water infiltration to improve water quality, and reducing urban heat island effect, while also sequestering carbon dioxide. Figure 1 showcases the broad land cover in the region which includes a combination of croplands, grasslands and forests along with emergent wetlands surrounding the water bodies. In addition to their hazard risk reduction benefits, several studies have highlighted the importance of natural features in fostering a sense of community, improving overall quality of life and human health (Santiago Fink, 2016), promoting ecosystem biodiversity (Xie and Bulkeley, 2020), offering opportunities to recreate (Kabisch et al., 2016), and connecting the people with nature (Frantzeskaki, 2019). This, in turn, can instill a broader sense of environmental stewardship.

Many of these features are protected, preserved, and managed through nature preserves and other types of protected lands (e.g., Nahant Marsh, Illiniwek Forest Preserve, Rock Island Forest Preserve), state parks (e.g., Black Hawk State Park), and local parks (e.g., Vander Veer Botanical Park, Duck Creek Park) (see Figure 2 for the spatial distribution of public lands and private protected areas). Nahant Marsh acts as a massive urban floodwater sponge, catching and filtering up to 2 billion gallons of water during peak flows on the Mississippi (Scientific American, 2019). The Marsh's community benefits stretch beyond flood reduction; it serves as an education center, providing residents with rare access to seasonally wet bottomland forest, marshland, and open water habitat. These sites also attract visitors, generating revenue through tourism and recreation. More than 6 million people visited the Quad Cities in 2023, resulting in $1.3 billion in revenues and employing close to 10,000 residents.

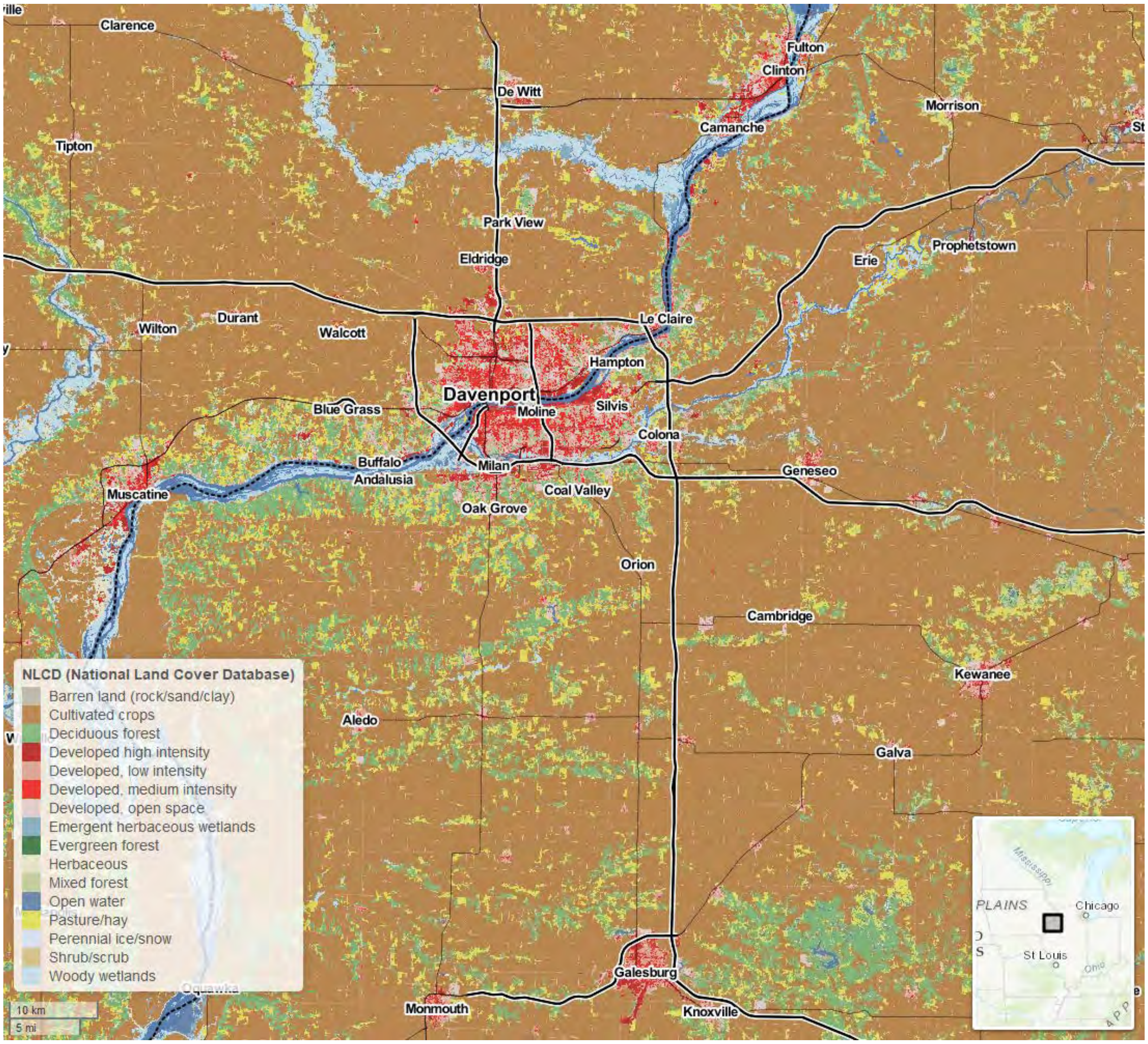


Figure 1. Broad land cover and vegetation types. *Cultivated cropland (brown) is the primary land use in the region surrounding the Quad Cities metro urbanized extent (red). A mixture of grasslands (yellow) and forests (green) exists just downriver (west) of the cities along the Mississippi River.*

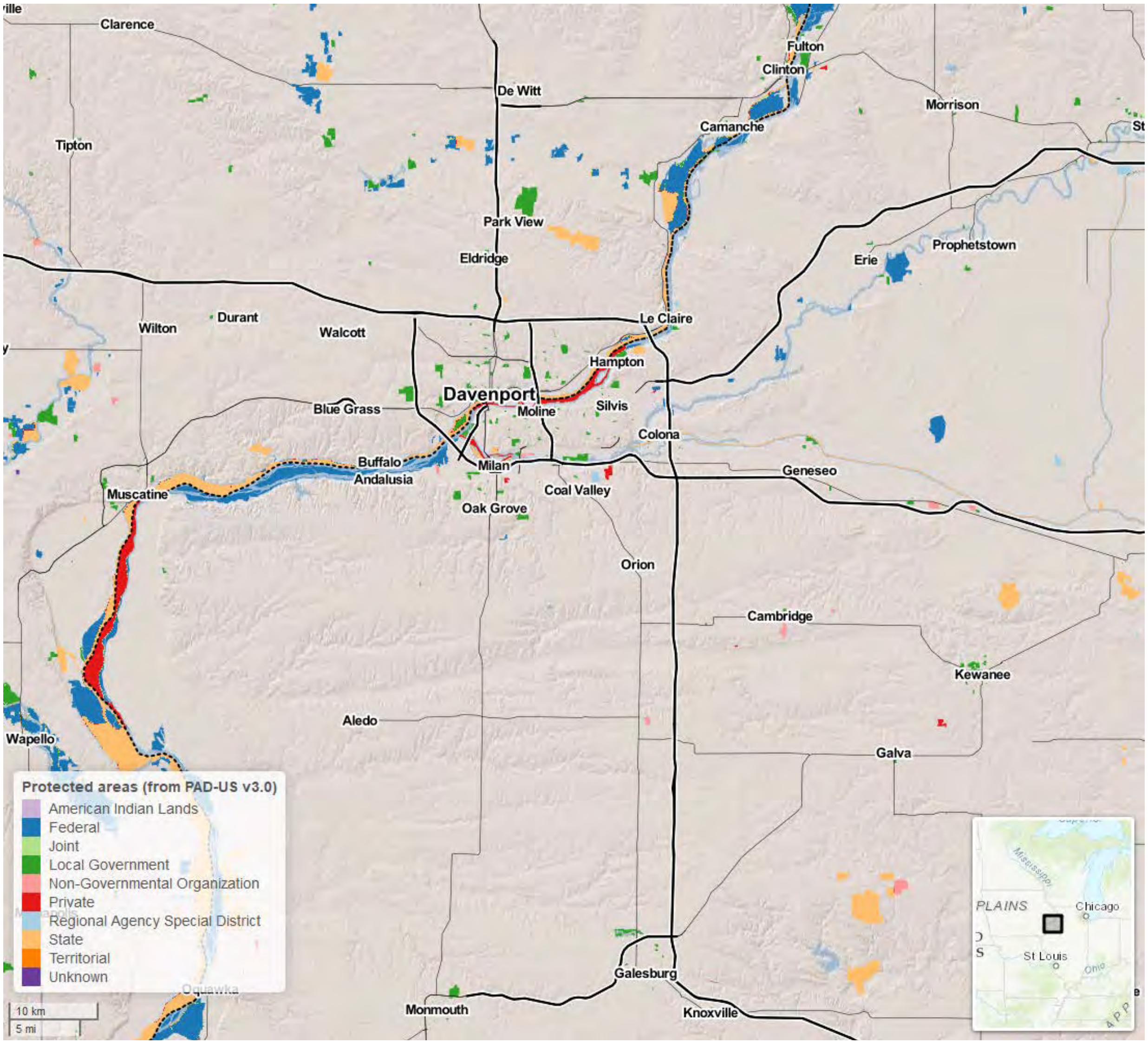


Figure 2: Public lands and private protected areas. *Along the Mississippi mainstem, there are several state and federal protected areas, including land managed by the U.S. Fish and Wildlife Services just west of Rock Island, IL (past the I-280 bridge), as well as the Princeton Wildlife Management Area farther upriver to the northeast of the Quad Cities. North of the Quad Cities, there is a long stretch of protected areas along the Wapsipinicon River, which drains into the Mississippi River at Princeton.*

1.3. State of Climate Science

Human activities, particularly greenhouse gas emissions from fossil fuel combustion and deforestation, drive global climate change. This phenomenon entails long-term alterations to average weather patterns, marked by rising temperatures, shifting precipitation patterns, and an increase in the frequency and severity of extreme weather events. Human-caused climate change has already caused global average temperatures to rise. The global annual average temperature has increased by 1.8° F (1.0° C) from 1901 through 2016, as calculated from instrumental records over both land and oceans (USGCRP, 2017). This trend is reflected in the contiguous United States, where the annual average temperature also rose by 1.8° F (1.0° C) from 1901 to 2016 and is expected to continue increasing.

While "weather" refers to a single day's atmospheric conditions, "climate" is the long-term average of weather over time in a particular region. Climate change poses a significant threat to the planet's

Flood waters rise to West 2nd street in Davenport, Iowa in April 2019. (Shutterstock)

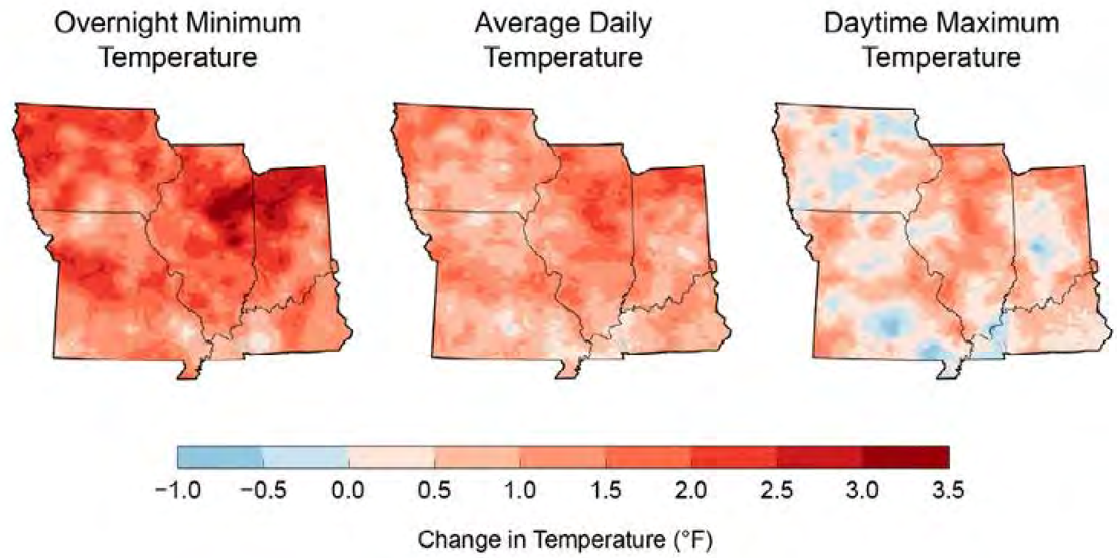
ecosystems, economies, and human well-being, with consequences ranging from flooding and precipitation changes to food and water scarcity, as well as increased risks of natural disasters leading to irreplaceable loss of biodiversity and putting communities at-risk. Addressing global climate change requires international cooperation, adopting sustainable practices, and rapidly reducing greenhouse gas emissions to limit the extent of future warming and mitigate its impacts.

Both Illinois and Iowa are already experiencing the effects of climate change, including more frequent heat waves, milder winters, and changing precipitation patterns (Wuebbles et al., 2021). As climate change progresses and global temperatures continue to rise, these impacts are expected to increase over time.

Several scientific assessments conclude consequential impacts of climate change on cities and rural communities in both Illinois and Iowa based on long-term historical change and projected changes into the future. For instance, the most recent National Climate Assessment highlighted the two states at high risk for increased riverine flood damage across the Midwestern US (Wilson et al., 2023). The Nature Conservancy, in partnership with the University of Illinois authors that contributed to this assessment, published a detailed overview of anticipated climate changes and predicted effects on hydrology, agriculture, human health, and native ecosystems in Illinois (Wuebbles et al., 2021). In Iowa, Frankson et al. (2022) synthesized observed and projected variability of climate change under different emission scenarios. Other resources, such as the USDA Midwest Climate Hub and Mississippi River Cities and Towns Initiative, provide a regional overview of climate change in the area. Below, we summarize the general shifts in climatic trends and potential impacts in Illinois and Iowa.

Climate Change in Illinois

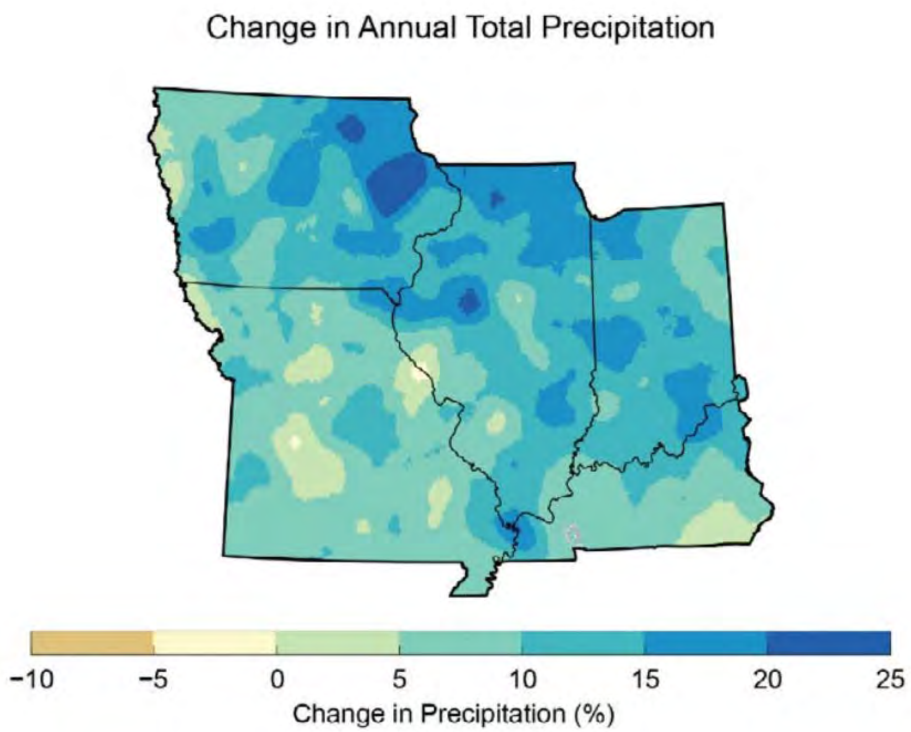
Rising Temperatures: Illinois has experienced an overall trend in warming over the past century; average daily temperatures have risen by 1–2°F across most areas of the state (Figure 3). Warming trends are more significant in spring and winter, with temperatures rising three and five times faster than in summer, respectively. This pattern suggests disproportionate warming between December and May over the past century. To forecast climate patterns until the year 2100, the Intergovernmental Panel on Climate Change created global future scenarios based on current greenhouse gas emissions, which are one of the primary drivers of climate change. Projections indicate that historical warming will persist into the middle and late 21st century, with slightly larger temperature changes anticipated in northern Illinois compared to southern Illinois. The projected temperature changes vary significantly based on the emission scenario, with annual average temperatures anticipated to rise by 3 to 4°F under the lower emission scenario and by 4 to 5°F under the higher emission scenario by the mid-21st century. The gap between scenarios further increases over time, with late 21st-century projections indicating increases of 4 to 5°F for the lower scenario and 8 to 9°F for the higher scenario. The extent of future temperature change depends on current and future emissions. Even so, consistent temperature increases are expected across Illinois.



Season	Overnight minimum temperature (°F)	Average daily temperature (°F)	Daytime maximum temperature (°F)
Winter	+3.0	+2.5	+2.2
Spring	+1.8	+1.6	+1.4
Summer	+1.7	+0.5	-0.7
Fall	+1.3	+0.8	+0.4

Figure 3: *Maps of observed changes (°F) for 1990–2019 relative to 1895–1924 for average overnight minimum temperature (left panel), average daily mean temperature (middle panel), and average daytime maximum temperature (right panel) for Illinois and some bordering states. (Wuebbles et al., 2021).*

Precipitation Changes: Climate change can result in altered precipitation patterns, potentially leading to more intense rainfall events, increased flood risk, and more extended dry periods. This can affect agriculture and water resources in the state. Illinois has experienced an overall increase in precipitation over the past century, with average annual precipitation rising by 10% to 20% in most areas. Total precipitation has increased across all seasons (Figure 4). Projections suggest increased annual precipitation across Illinois, with greater changes in the north compared to the south, particularly in the late 21st century. Overall precipitation increases vary by scenario, ranging from 0%–4% (lower scenario) and 3%–6% (higher scenario) by the mid-21st century. For the late 21st century, increases are expected to reach 2%–6% (lower scenario) and 4%–10% (higher scenario).



Season	Precipitation (inches)	Precipitation (%)
Winter	+0.54	8.5%
Spring	+1.33	12.5%
Summer	+1.55	14.3%
Fall	+1.33	15.9%

Figure 4: *Observed changes (%) in annual total precipitation for 1990–2019 relative to 1895–1924 for the Midwestern United States (Wuebbles et al., 2021).*

Extreme Weather Events: Climate change can lead to an increased frequency and intensity of extreme weather events, including severe storms and tornadoes, which can result in significant damage and pose risks to public safety. A warmer atmosphere holds more moisture, increasing the frequency and intensity of heavy rain and snow events.

Climate Change in Iowa

Rising Temperature: Temperatures in Iowa have risen more than 1°F since the beginning of the 20th century. Warming has been concentrated in the winter and fall, with less pronounced summer warming. Under a higher emissions pathway, historically unprecedented warming is projected during this century.

Precipitation Changes: Spring precipitation has been above average since 1990, affecting agriculture both positively (providing adequate soil moisture) and negatively (delays in spring planting). Spring precipitation is projected to increase by more than 15% across the state.

Extreme Weather Events: Future increases in the frequency and intensity of extreme precipitation events may increase the frequency and intensity of floods, while increases in evaporation rates due to rising temperatures may increase the intensity of naturally occurring droughts.

Temperature and precipitation changes coupled with an increase in the severity of extreme events will cause compounding impacts on agriculture, water resources, and ecosystems. For instance, warmer temperatures can extend the growing season for key crops, but increased weather variability and more extreme events, like floods or droughts, can pose risks to crop production. Uneven precipitation patterns and increased evaporation due to higher temperatures can decrease water availability. An increase in flashier precipitation can also deteriorate water quality by causing more sediments and nutrient loads, in turn impacting wildlife and aquatic life.

These changes in climate and their impacts on the social and ecological systems in Illinois and Iowa are discussed in detail in several studies (e.g., EPA, 2016; Frankson et al., 2022; Wilson et al., 2023; Wuebbles et al., 2021); however, the bi-state region of Quad Cities does not receive full attention in these state-specific analyses. This assessment intends to fill this gap by downscaling climate models to provide fine-scale projections, while applying and interpreting the existing science to the specific context of the Quad Cities.

Floodwaters in Quad Cities inundate a park. (Shutterstock)

1.4. Methods

Climate Modeling

The Discovery Partners Institute at University of Illinois used a set of Coupled Model Intercomparison Project Phase 6 (CMIP6) models to simulate and project future climate conditions in the Quad Cities. To more accurately assess temperature changes in the Quad Cities, 23 CMIP6 models were localized to the region. According to climate model projections, an average temperature increase of 1.5°C (2.7°F) is expected by the end of 2050, and a 2.8°C (5°F) increase is projected by the end of the century compared to the current scenario (1950-2022). Given the greater impact precipitation has on flooding in the Quad Cities, an emphasis was placed on precipitation and a subsequent flood model was developed based on the three future climate scenarios (SSPs 1-2.6, 245, and 5-8.5; Figure 5) from the Model for Interdisciplinary Research on Climate (MIROC6) model, which helps simulate and understand how various factors, like increased greenhouse gas emissions, might impact future climate conditions.

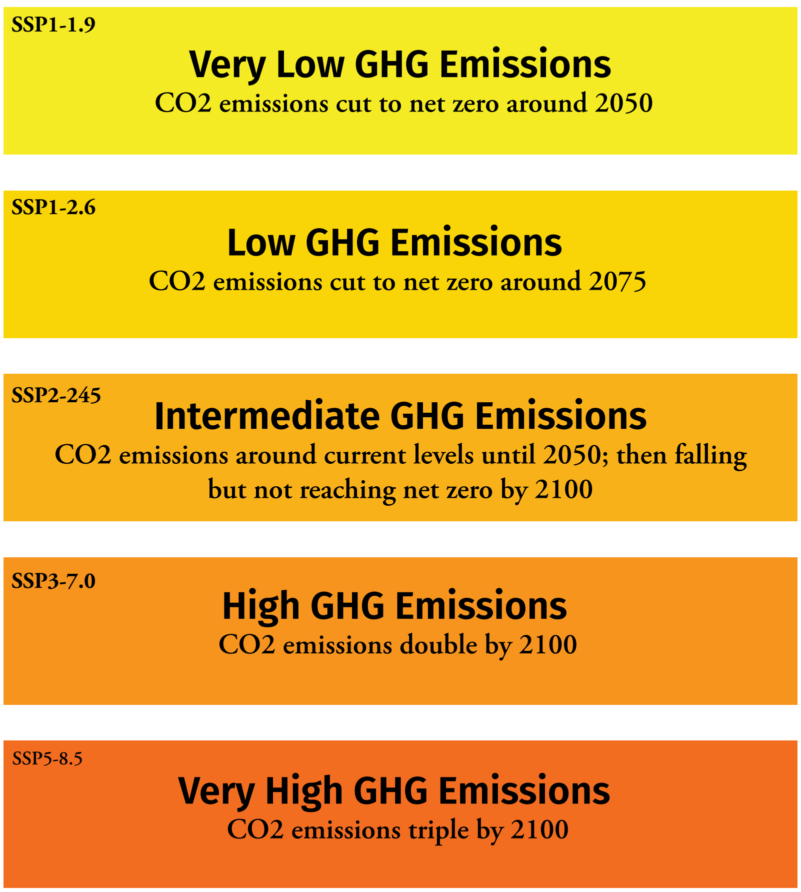


Figure 5. *General description of hypothetical climate change scenarios. (Tebaldi et al., 2021).*

To simulate flooding in the Quad Cities, a flood model was developed by using the framework shown in Figure 6 and examined an area extending 28 miles upstream and 7.5 miles downstream to simulate flows from the Mississippi River (Figure 7). These regions were considered based on the delineation performed using 1m DEM (Digital Elevation Model) obtained from the USGS. The flood model is developed using the SWMM-HECRAS coupled model wherein SWMM (Storm Water Management Model) is used to simulate 1D flows over the selected region and 2D simulations (for flood inundation) are performed on HECRAS (Hydraulic Engineering Center's River Analysis System) with 1m DEM as terrain. The terrain is overlaid using ArcGIS with other features, such as building footprints and height (Google Earth Engine generated maps), transportation (OpenStreetMap layers), forest cover (National Land Cover Database Land Use/Land Cover; NLCD LULC), open areas (NLCD LULC), and water bodies (NLCD LULC). Flood model development consists of data collection (open source datasets are used in this assessment), preprocessing, model simulations, calibration and validation (Appendix A), risk assessment, and stakeholder suggestions. A scenario analysis also examined regional flood risks without nature-based solutions (Figure 12) and with implementation (Figure 17).

There is inherent uncertainty in climate modeling. The development of the flood model relies on futuristic climate model scenarios incorporating these uncertainties in its predictions. These uncertainties predominantly involve delays in occurrence and variations in magnitude of rainfall and floods. The correction of these uncertainties is informed by using historical data within the climate models.

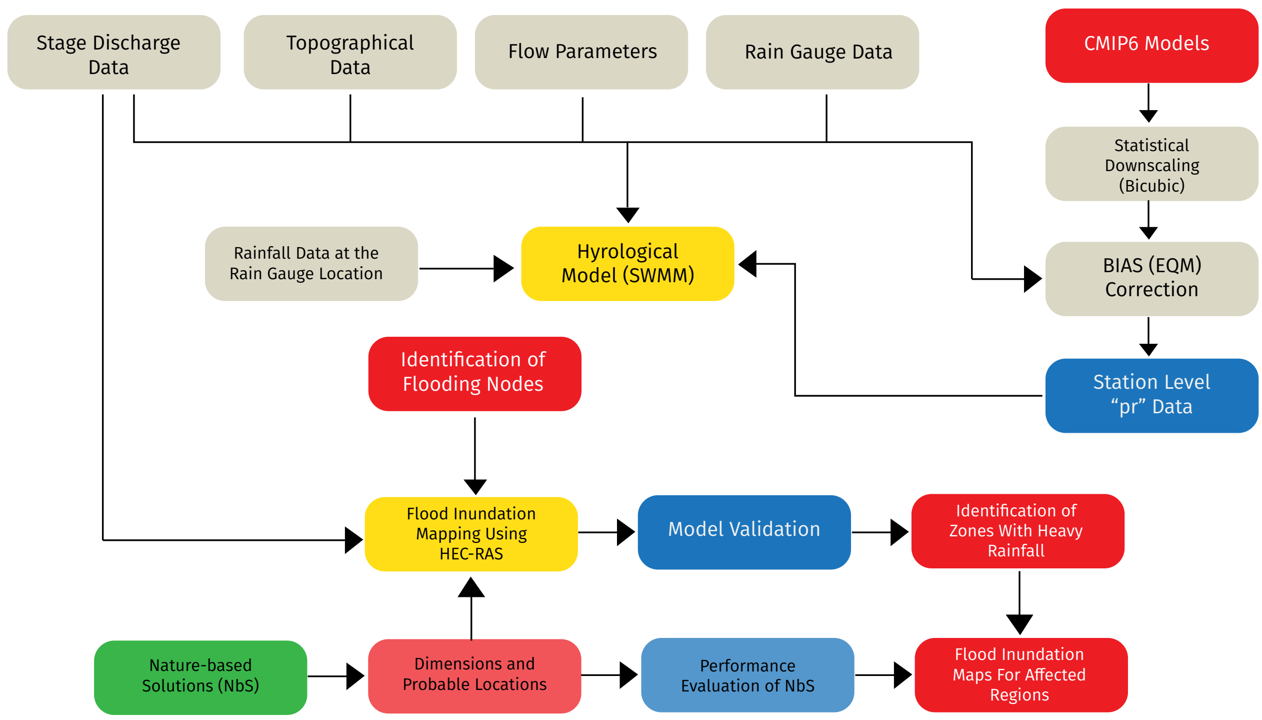


Figure 6. *The Discovery Partners Institute at University of Illinois developed this flood model framework to study future climate change impacts in the Quad Cities.*

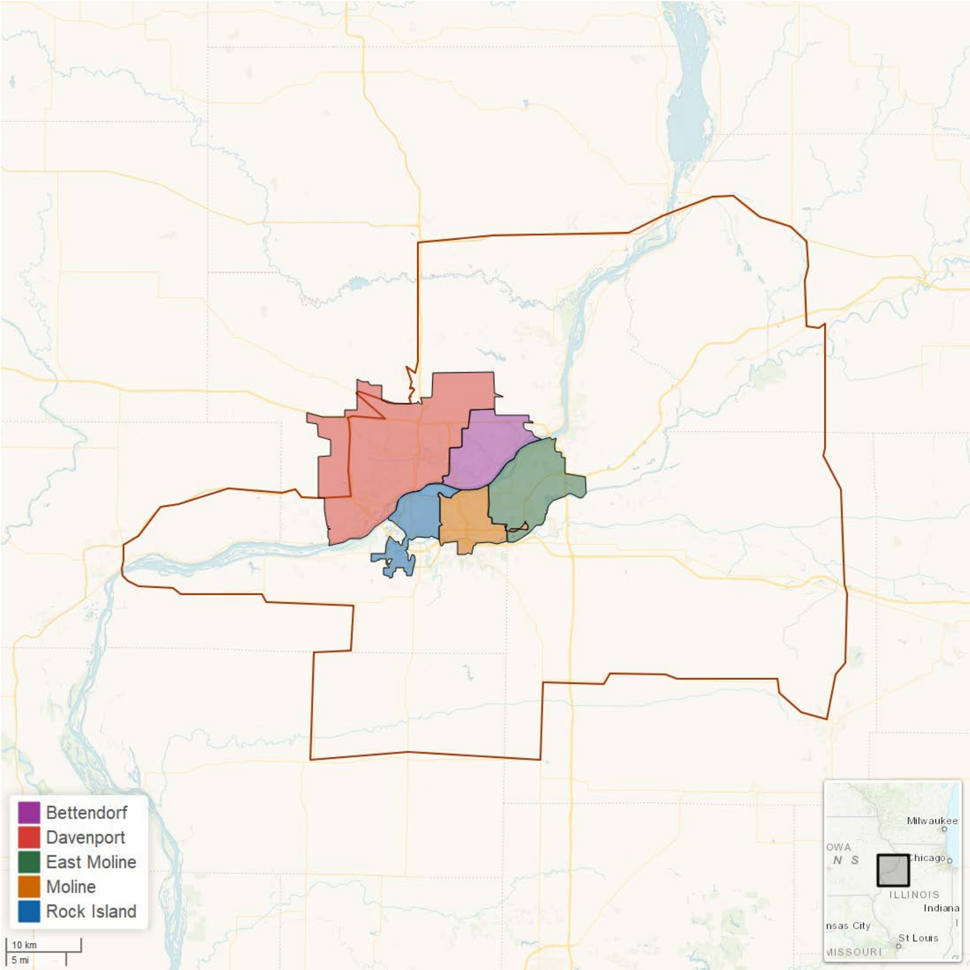


Figure 7. *The boundaries of the flood model created for the Quad Cities, which examined 28 miles upstream and 7.5 miles downstream from the region.*

Community Outreach

Prior to identifying the climate risks, impacts, and solutions included in this assessment, Quad Cities community members were engaged through multiple outreach efforts to provide input on current climate issues and their impacts on their respective communities. Approximately 30 interviews were conducted with regional natural resource professionals and community leaders. Interviewees included conservation staff from city municipalities. as well as technical experts from local agencies and various non-profit organizations.

In addition to the stakeholder interviews, three public input sessions were held at easily accessible locations across the Quad Cities to obtain feedback on the preliminary findings of the draft assessment and offer further questions, concerns, and recommendations based on the findings. The results of these sessions are discussed further in Section 5.2. Dedicated efforts were made to include representation from identified vulnerable communities, especially those representatives of lower socioeconomic and BIPOC communities within the stakeholder engagement process.

Members from the following organizations were able to lend time and expertise to the development of this assessment:

- American Rivers
- Nahant Marsh Education Center
- Living Lands & Waters
- Progressive Action for the Common Good
- Disaster Ready QC
- University of Illinois Extension
- U.S. Fish and Wildlife Service
- Bi-State Conservation Action Network (BiCAN)
- Western Illinois University
- City of Moline
- City of Davenport
- League of United Latin American Citizens
- Rock Island Soil and Water Conservation District
- Martin Luther King Center
- YMCA
- Scott County Health Department
- Ducks Unlimited
- River Action
- Hibiscus Ecological Services
- Wild Ones QC Chapter
- Niabi Zoo
- US Army Corps of Engineers
- Quad Cities Community Foundation
- The Lincoln Center QC (TMBC)
- Tapestry Farms
- Watertown Community Empowerment Organization
- NAACP
- Illinois Floodplain Community Justice Network
- Rock Island County Emergency Management Agency
- Scott County Emergency Management Agency
- City of Rock Island
- City of East Moline (city officials and city council members)
- Mississippi River Rights Coalition
- Partners of Scott County Watersheds
- Quad Cities Conservation Alliance Wetlands Center

Building relationships with underrepresented groups and city officials takes time, especially in a region where our organizations have no prior history of community engagement. Building long-term, meaningful relationships often includes trust-building through regular interactions and engagement over a significant period of time, as well as information sharing and working toward shared goals. Though initial outreach efforts were made, we were unable to establish relationships with representatives from all historically underrepresented groups, including Indigenous, farming, unhoused, refugee, and immigrant communities during this process; continued efforts will be made with these stakeholders to build trust within the organizations and communities as we disseminate this assessment, explore next steps, and continue building our presence in the region.

Box 1. Community Outreach Timeline

JULY | AUGUST | SEPTEMBER | OCTOBER

Site Visits
The authors visited vulnerable and resilient areas, such as the Rock Island Riverfront, Davenport Riverfront, and Nahant Marsh, which were identified during stakeholder interviews. Initial findings were shared with selected stakeholders and community organizations, and participants were informed of the next phase of community engagement planned for the following month.

Input Sessions
A draft assessment was shared with 36 stakeholders, and feedback was gathered on gaps and next steps, including ideas for implementation and dissemination of the report. Authors conducted two in-person sessions and a virtual session a week later.

One-on-one stakeholder interviews
Interviews were conducted virtually (via Zoom) with 30 stakeholders representing federal and local officials, including city council members, floodplain managers, emergency management personnel; as well as community groups, BIPOC organizations, nonprofit organizations, and academia. Feedback gathered from these interviews informed the climate assessment and modeling, from areas of value and interest to the current and future resilience efforts in the region.

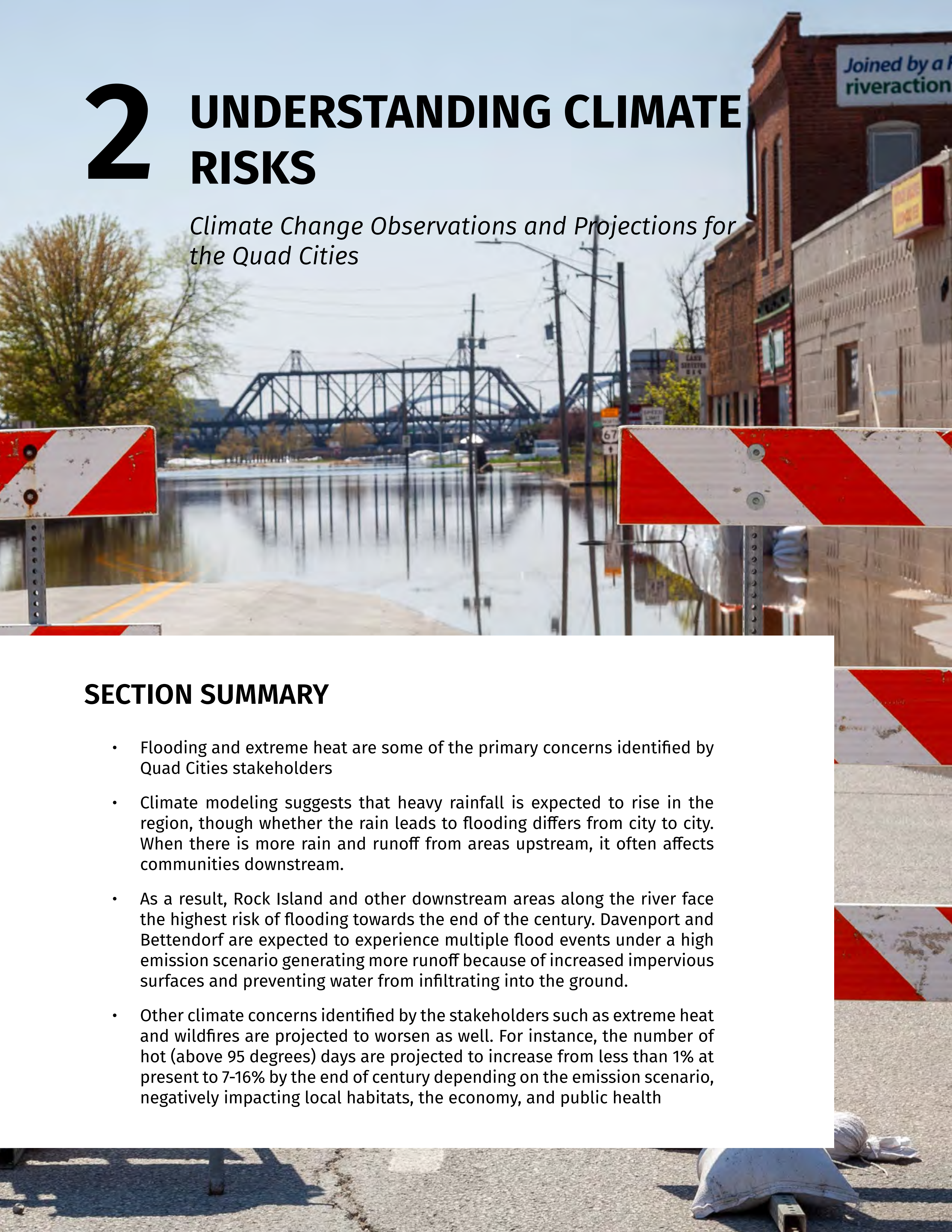
A view of the Mississippi River and downtown Davenport. (Silas Gilklay / Prarie Rivers Network)

1.5. Equity Considerations

Decades of racist housing and planning policies, like redlining, have left many communities, particularly those with low-income and historically marginalized populations, more vulnerable to flooding and other environmental stressors (Zavar & Fischer, 2021). These communities, including in the Quad Cities, have also been traditionally left out of conversations related to floodwalls planning as well as other typical flood mitigation solutions.

Natural infrastructure approaches, if not carefully implemented, can also result in unintended consequences, such as increased cost of housing and gentrification, displacing the very people it was intended to benefit (Bockarjova et al., 2020). Displaced residents often relocate to more hazardous areas, with adaptive capacities reduced by the loss of social networks, cultural ties, and community resources (Pathak et al., 2022). In addition to unintended outcomes, natural infrastructure projects, like parks and green roofs, have tended to primarily benefit wealthier, white communities where there is greater investment in public infrastructure and services (Solins et al., 2023). Achieving equitable outcomes for communities with a history of disinvestment or under-investment, however, can be difficult, even when prioritizing such communities for projects. Many federal agencies and programs, like the Federal Emergency Management Agency (FEMA), require a benefit-cost analysis to justify funding decisions. Subjective, incomplete, or flawed evaluations of a projects' cost-effectiveness can lead to unjust decisions and ultimately relatively lower investments in the communities most in need (Benincasa, 2019).

To unlock their full potential, nature-based solutions must be community-driven and supported, with a focus on participatory planning, design, and implementation (Siders, 2019). Projects that move forward with community buy-in and support also enjoy an enhanced community commitment in their long-term maintenance, upkeep, and building community-wide environmental stewardship and cohesion (Hunter & Harford, 2021).



2 UNDERSTANDING CLIMATE RISKS

Climate Change Observations and Projections for the Quad Cities

SECTION SUMMARY

- Flooding and extreme heat are some of the primary concerns identified by Quad Cities stakeholders
- Climate modeling suggests that heavy rainfall is expected to rise in the region, though whether the rain leads to flooding differs from city to city. When there is more rain and runoff from areas upstream, it often affects communities downstream.
- As a result, Rock Island and other downstream areas along the river face the highest risk of flooding towards the end of the century. Davenport and Bettendorf are expected to experience multiple flood events under a high emission scenario generating more runoff because of increased impervious surfaces and preventing water from infiltrating into the ground.
- Other climate concerns identified by the stakeholders such as extreme heat and wildfires are projected to worsen as well. For instance, the number of hot (above 95 degrees) days are projected to increase from less than 1% at present to 7-16% by the end of century depending on the emission scenario, negatively impacting local habitats, the economy, and public health

This section summarizes the major climate risks, emphasized by the community leaders during the stakeholder interviews conducted for this assessment. Flooding, both flash and river flooding, was the biggest climate concern for community members. The Discovery Partners Institute at University of Illinois downscaled future precipitation projections based on the latest global climate model (CMIP6) and analyzed Quad Cities-specific changes in flood extent based on rainfall changes. These projections are based on three different scenarios: lower emissions (SSP126), which represents a world with very low greenhouse gas emissions and ongoing climate change mitigation actions; intermediate emissions (SSP245), which envisions more emissions, but also takes into account actions taken to curtail climate change; and high emissions (SSP585), which represents a scenario with high levels of greenhouse gas emissions that severely exacerbate climate change impacts and present significant challenges to mitigation (Figure 5). Additionally, this section addresses other major concerns associated with climate change, such as extreme weather (like wildfire and drought) and extreme heat.

It is important to note that the findings of this assessment, like other similar analyses, are not static and uncertainty about future changes is inherent. These uncertainties stem from climate model limitations, future emission trajectories, and non-climatic factors (population changes, urban development) that will eventually determine the magnitude and rate of climate change. In Section 3 we examine what is at risk in the Quad Cities based on the projected climate change impacts discussed below.

2.1. Precipitation Changes

High-intensity precipitation events in the United States, particularly in the Northeast and Midwest, have intensified since 1901. These trends align with expectations for a warming climate and are likely to persist without substantial efforts to reduce greenhouse gas emissions. In Illinois and Iowa, precipitation patterns have become more variable, leading to increased flood risk in some areas and prolonged dry periods in others, affecting agriculture, water resources, and the environment. A detailed analysis by Wuebbles et al. (2021) and Frankson et al. (2022) explores precipitation trends in Illinois and Iowa, respectively.

In the Quad Cities, extreme weather events, such as heavy rainfall resulting in flooding, are a heightened risk. Climate change has been influencing precipitation patterns, introducing more variability and a higher likelihood of extreme events. The summer months (June, July, and August) typically see higher precipitation due to convective storms (e.g., thunderstorms) and occasional heavy rainfall. Winter months (December, January, and February) can also bring significant snowfall.

The distribution of precipitation patterns throughout the year are not linear, making predictions challenging. In the Quad Cities, there typically tends to be intense rainfall from April to December. Observations show higher precipitation beginning in mid-April and increasing through mid-June. Precipitation levels decrease in December (as shown in Figure 8), although climate change alters these patterns.

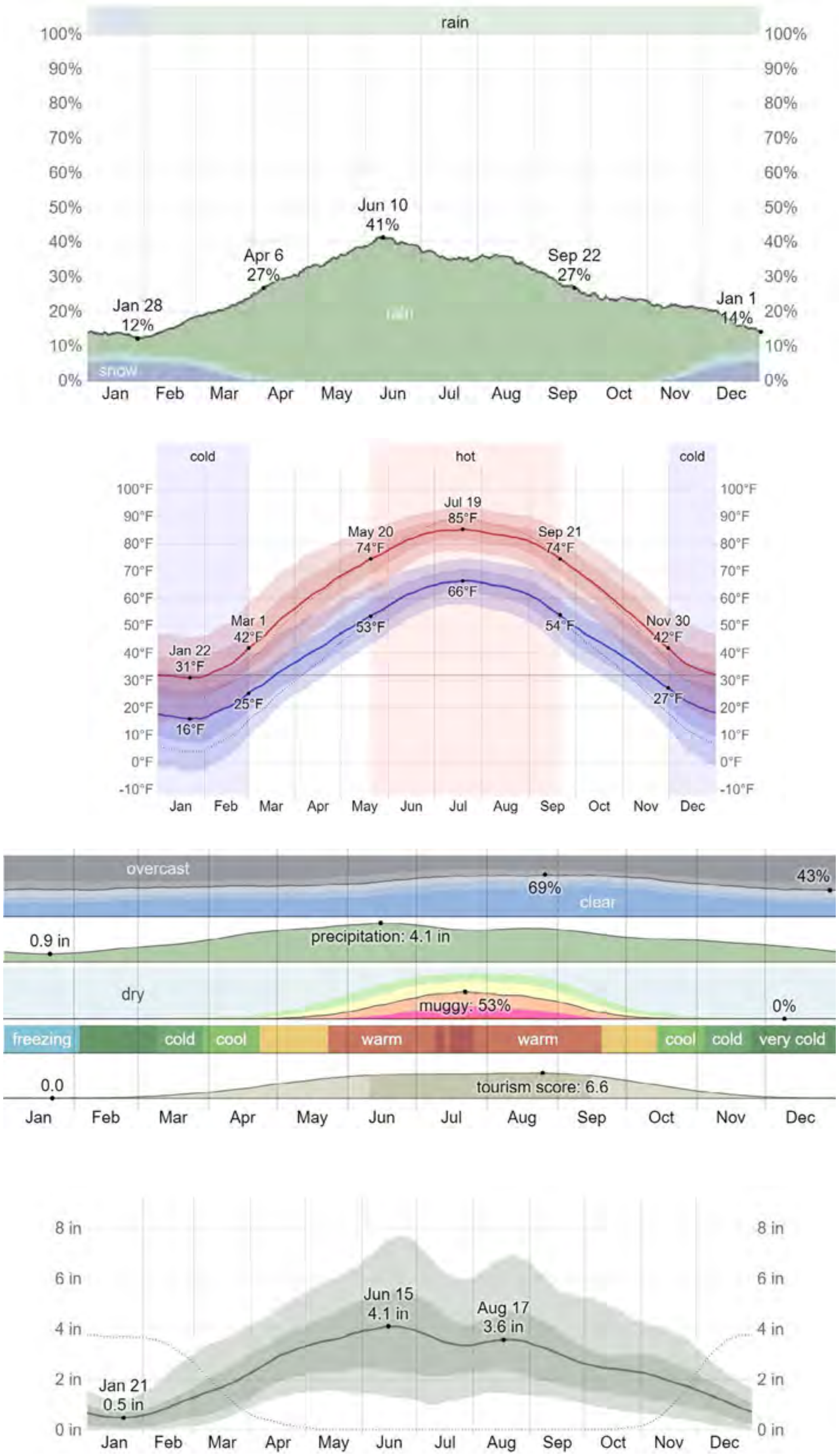


Figure 8: *Changes in the climatology of Rock Island showing the average change in daily precipitation, temperature and overall climate. These changes in Rock Island represent typical changes in climate across the Quad Cities. (Weather Spark)*

Analyzing the selected climate models and the extreme greenhouse gas emission scenario (SSP 585), Figure 9 shows the number of extreme precipitation events (above a three-inch threshold) per city. While the Quad Cities are generally expected to experience an increase in the number of extreme precipitation events, not every city will experience flooding the same way; flooding is not only triggered by rainfall, but is also influenced by local geography and land use. If it is raining upstream, the impact can be experienced downstream. According to the projections from the climate model (MIROC6), Bettendorf and Davenport are expected to have more extreme rainfall; however, the flood model shows that flooding from heavy rainfall will result in more flood events in downstream sections of the Quad Cities, like Centennial Bridge and Credit Island Park.

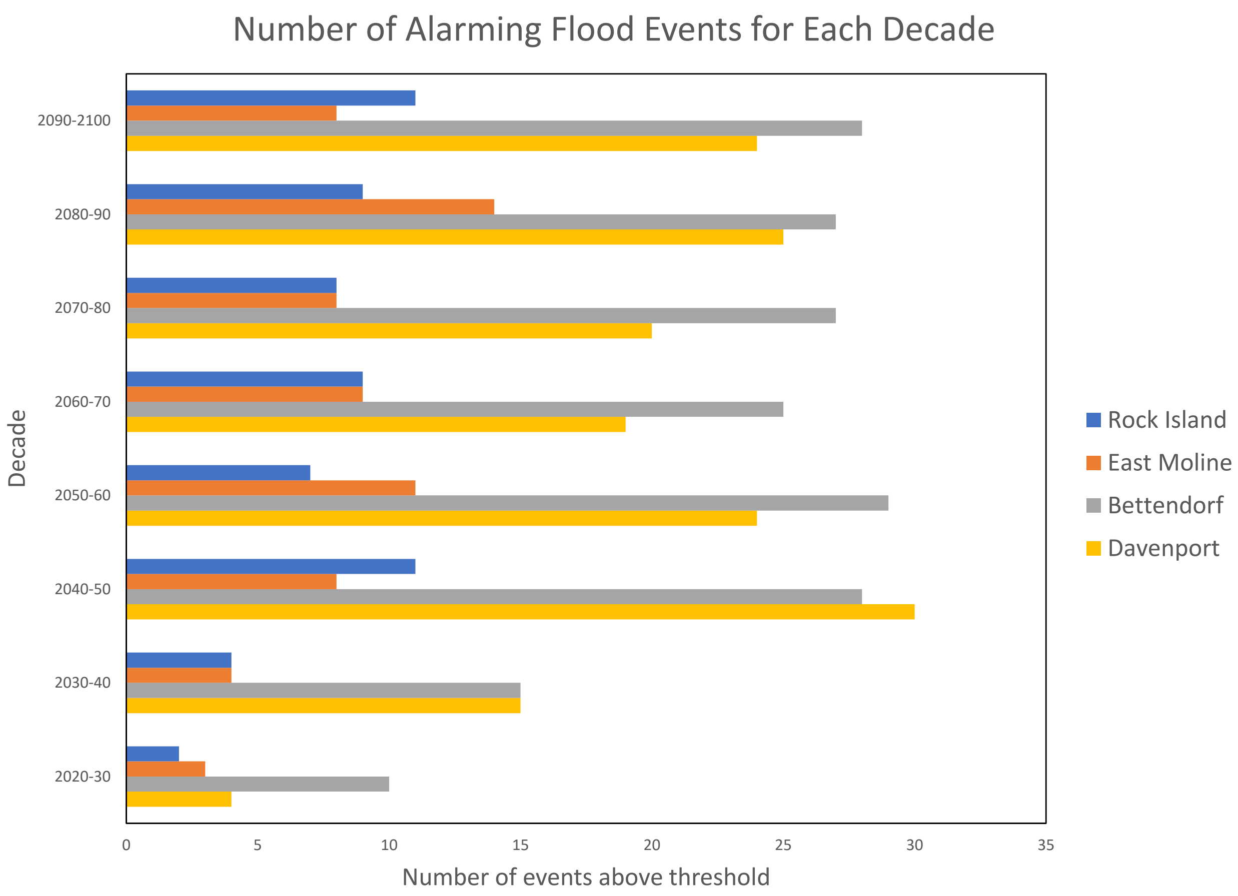


Figure 9. *The number of events that have precipitation above the “warning” situation per major Quad Cities localities. Per the National Weather Service: A warning is issued when a hazardous weather or hydrologic event is occurring, imminent, or likely. A warning means weather conditions pose a threat to life or property. People in the path of the storm need to take protective action. Note: East Moline data includes Moline.*

Figure 10 illustrates daily precipitation trends for Davenport through the end of the century (trends for other cities are provided in Appendix B). Detailed explanations about the precipitation patterns and instances of extreme precipitation (where precipitation surpasses a critical threshold of 3 inches per hour) in the modeling are discussed further for each city.

Davenport

Davenport exhibits two distinct scenarios: the northern portion experiences less rainfall than the southern part. The southern portion of Davenport experiences frequent changes in the precipitation due to the influence of the Mississippi River. Davenport is less prone to extreme rainfall (and thus, less vulnerable to flooding) until 2050 under the lowest emission scenario (SSP126). However, under the intermediate emission scenario (SSP245), Davenport might start facing extreme rainfall from 2040 onward, especially in the southern portion. In the extreme emission scenario (SSP585), Davenport will experience a major flood (100-year event) between 2060 to 2080, possibly leading to flooding events in the southern region, but there will be flood events almost every year (precipitation observed crossing threshold precipitation almost every year in Figure 10). Positioned near confluence points, the city also faces periodic flooding from nearby tributaries in addition to the mainstem flood issues at its riverfront.

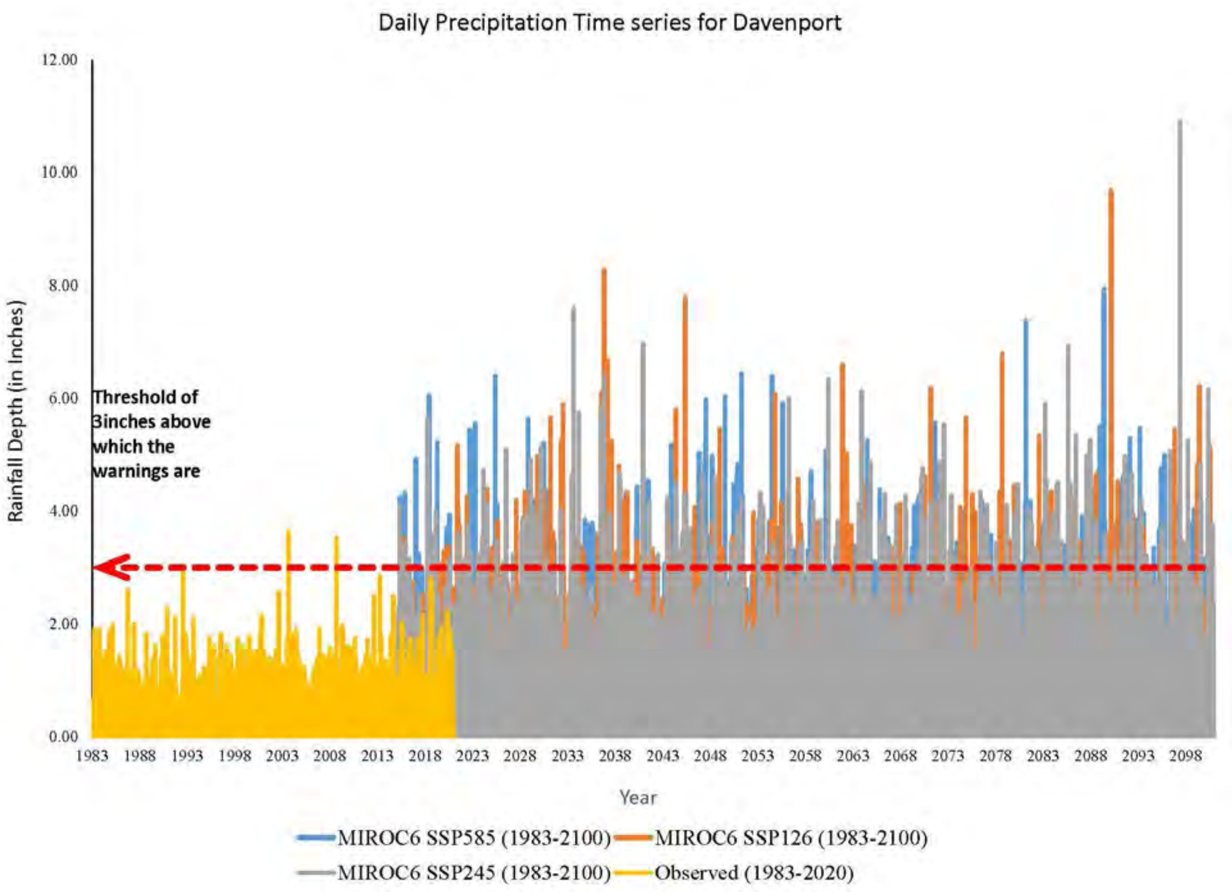


Figure 10. *Daily precipitation trends for Davenport: low emission scenarios (SSP126; orange); intermediate emissions scenarios (SSP245; gray); very high emission scenarios (SSP585; blue). The values above the threshold are critical and are considered as warnings for floods in flood model development.*

A view of the Mississippi River and Centennial Bridge from Schwiebert Riverfront Park in Rock Island. A temporary flood wall is in place as a precaution for flood protection. (Shutterstock)

Bettendorf

Under the lower emission scenario (SSP126), precipitation patterns in Bettendorf will not vary significantly, while the higher emission scenarios (SSP585) demonstrate substantial changes in precipitation, increasing the risk of multiple flood events near the shoreline. Bettendorf and Davenport are the two most developed urban areas out of the five major Quad Cities; as a result, they are expected to generate more runoff because of increased impervious surfaces preventing water from infiltrating into the ground. This translates into the potential for increased flood risk, both locally and downstream.

Moline and East Moline

Moline and East Moline rainfall events are similar to Bettendorf. In the first two decades (2030-2050), the region might have one or two extreme rainfall events. East Moline is more susceptible to flooding from tributaries than from the Mississippi River mainstem. In subsequent decades, the lower emission scenario (SSP126) suggests more frequent changes in rainfall patterns, but ones that do not result in flooding, with only occasional extremes. Under the higher emission scenario (SSP585), there is a possible increase in high rainfall and flooding events, though not significantly.

Rock Island

According to the selected climate models and scenarios, Rock Island is at greatest risk for flooding towards the end of the century. The area is significantly influenced by rainfall in and runoff from upstream areas, like Moline and Bettendorf. Additionally, in the event of levee or floodwall failures, Rock Island will be the first of the cities to face consequent impacts. The likelihood of flooding in Rock Island and nearby regions is more pronounced in areas near river fronts and downstream sections, especially under higher emission scenarios, with flooding events ranging from one-in-fifty (2% chance of occurring in any given year) to one-in-hundred-year (1% chance) in likelihood. Current trends indicate a trajectory more in line with the higher emission scenarios.

In this section, we explored the evolving rainfall patterns in the Quad Cities attributed to climate change across various emission scenarios. By incorporating these dynamic rainfall patterns and considering factors, such as topography, geomorphology, and developed areas, we developed flood models (see Section 1.4 for methods and Section 2.2 for further details). These flood models offer valuable insights into the spatial extent of floods in the region. Different nature-based solutions were then simulated to determine the most effective combination of nature-based solutions that can be applied in the region to reduce flood risk (discussed further in Section 4.1).

2.2. Present and Future Flood Risks

Predicting future flooding in the Quad Cities involves a range of factors, including global climate change, local weather patterns and precipitation changes, and land use. Because the Quad Cities are situated along the Mississippi River, the region is susceptible to both river and flash flooding and future risks will depend on several key elements. Climate change is a significant driver, potentially leading to increased rainfall intensity and more frequent extreme weather events, that heightens flood risk. Local topography, existing flood control infrastructure, land use decisions, and urban development will also shape future flood hazards.

Flooding can result from significant rainfall, insufficient drainage systems, or urbanization. Other factors, like melting snow, storm surges, or dam failures, can also contribute. Current drainage infrastructure and flood control measures may prevent flooding in some regions despite current rainfall patterns; however, dynamic factors like topography, soil type, land use, and local water management system capacity should be considered in flood risk assessments. While rainfall is a common factor associated with flooding, it doesn't mean that flooding will occur everywhere it rains (rainwater may runoff and impact downstream areas, for example). The relationship between rainfall and flooding is influenced by a combination of natural and human-made factors.

According to the flood model simulations, regions near the Mississippi River face increased susceptibility to river floods due to rising rainfall intensities and elevated streamflows, particularly from those originating from upstream areas. The changing climate contributes to a heightened flood risk downstream and places additional strain on critical infrastructure, like the I-74 Mississippi River Bridge. Operating policies of existing hydraulic structures on the river, and the potential flood impacts they may have, are not considered in this assessment due to data limitations and warrant further evaluation in the context of changing climate patterns. Additionally, land-use predictions indicate a significant increase in urban sprawl for high-emission scenarios (Chen et al., 2020). Future urban development is based on the Climate Change Initiative-Land Cover product for the 2015 baseline year, revealing that by 2100, 51–63% of newly expanded urban land will be converted from cropland.

A view of the Mississippi River and I-74 Mississippi River Bridge. (Silas Gilklay / Prairie Rivers Network)

Model Comparison

Figure 11 compares the flood model developed for this assessment with the Iowa Flood Center's model and demonstrates higher flood vulnerability in our model. The Iowa model is developed with the information on the flooding for different return periods using historical data. On the other hand, our model incorporated CMIP6 climate model scenarios to develop IDFs[1] and provide inundation for the "1% annual chance" flood event. Additionally, our model simulated flood inundation depth on a daily basis from 1950-2100 to show the flood propagation for each day at a resolution of 1m. Both Iowa and our model incorporate the sinks and blockages, buildings, existing water retention and hydraulic structures, and latest land use. We have additionally incorporated building height data from GLOBUS (the latest building footprint and height dataset) in our model which helps to provide building wide inundation depth at every timescale.

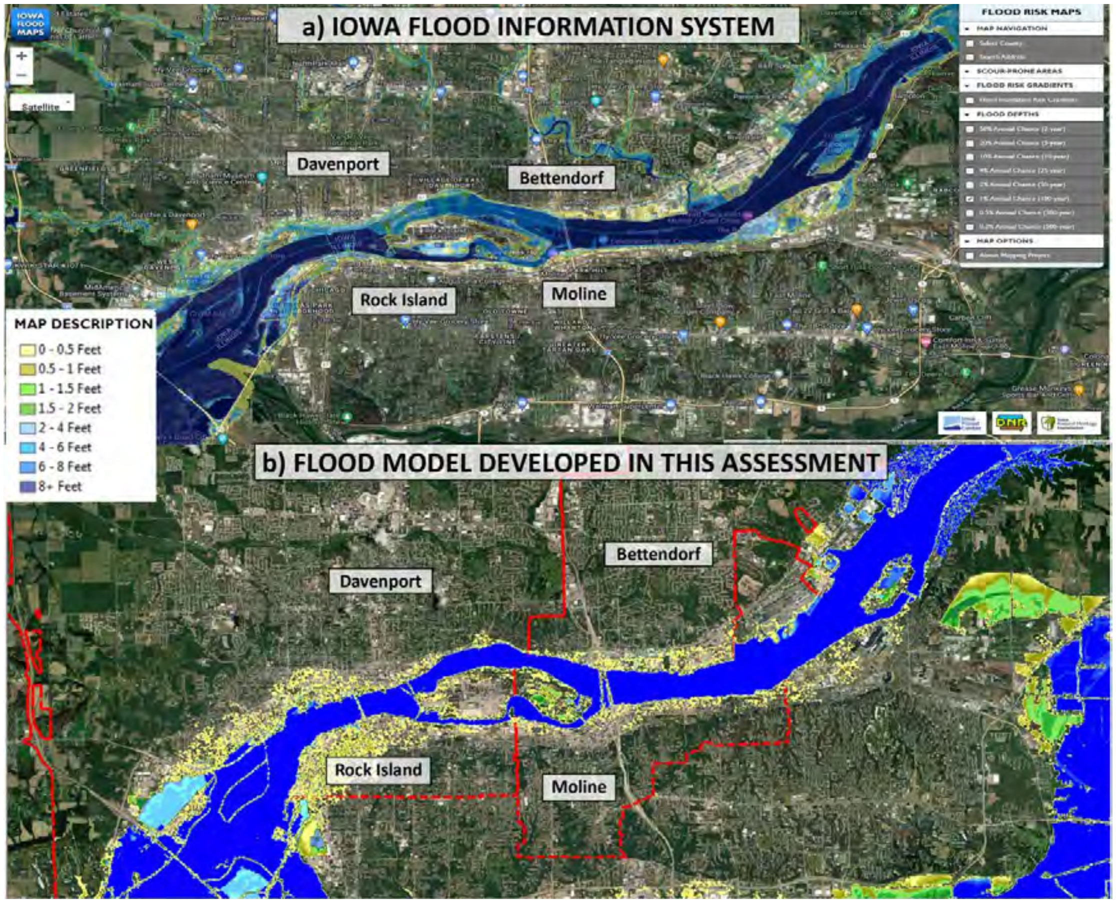


Figure 11. *A comparison of (a) Iowa Flood Information System (top) with the (b) flood model developed during this assessment (bottom). The figure shows a 100-yr return period flood model comparison.*

Flood formation in large rivers like the Mississippi River is complex because the river spans diverse regions with varying climates. It typically takes substantial precipitation, often paired with snowmelt, over weeks or months to generate large flows. Wuebbles et al. (2021) performed a detailed analysis of historical flooding in Illinois (pages 60-68 of the report); in accordance with the Illinois riverine flood studies, depicted in Figure 3.7 of Wuebbles et al. (2021), the Quad Cities are modeled under various climate change scenarios. Figure 12 illustrates changes in flooding patterns for the Quad Cities from present to 2100. Flood model outputs indicate that urban areas near the Mississippi River could

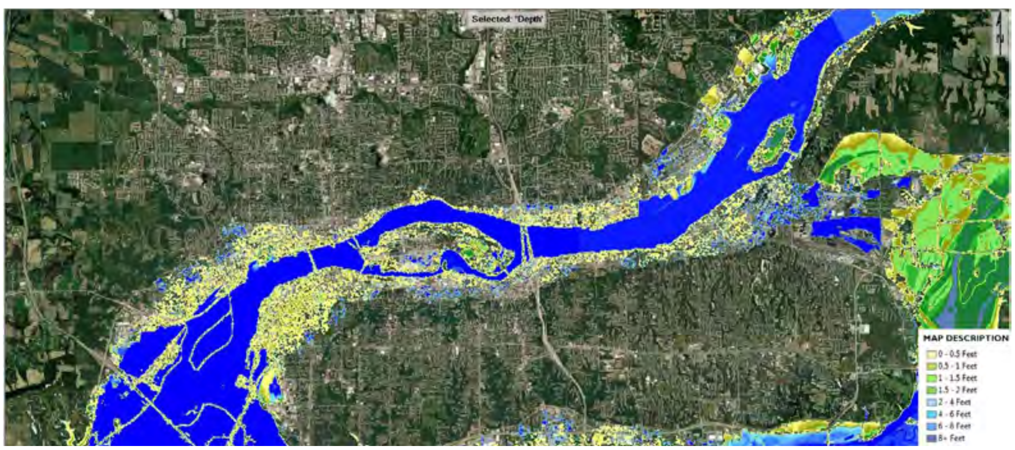
1. IDF or Intensity-Duration-Frequency curves are graphical tools that describe the likelihood of a range of extreme rainfall events within a given period of time.

experience runoff depths up to 11ft, potentially submerging the first two floors of buildings during extreme rainfall scenarios. For heavy rainfall events in the 2080–2090 decade, floodwaters may reach near the I-74 Mississippi River Bridge and downtown Rock Island. Additionally, a major flood event (100-yr return period) is projected for this decade, with an average expectation of three flash floods per decade. To help address these challenges, nature-based solutions are proposed for urban areas and open spaces, detailed in Section 4.

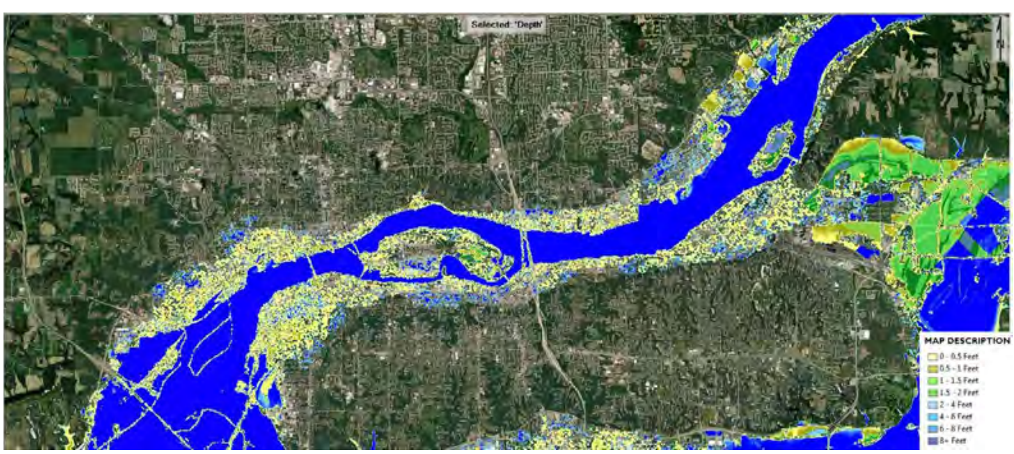
Figure 12 (A-C). *Changes in the flood inundation for the Quad Cities from 2030 to 2100.*

A. Early-Century (2030-2050)

B. Mid-Century (2050-2080)



C. End-of-Century (2080-2100)



2.3. Extreme Heat

Both extreme heat and cold can negatively impact social and natural systems. Extremely hot days are the leading cause of weather-related fatalities in the U.S. and contribute to both poor public health and economic stress. Even small declines in the occurrence of extremely cold winter temperatures, which are essential for some ecosystems and its dependent species, can cause dramatic changes to their structure and function (Osland et al., 2016). Extreme heat is one of the key concerns highlighted by the community members in the Quad Cities. Based on the NOAA's Climate Mapping for Resilience and Adaptation Tool, the table below (Tables 1 and 2) shows an increase in the annual number of hot days (when temperature increases above 95°F) and extremely hot days (when temperature increases above 100°F) under all future scenarios of climate change. The number of hot days will increase from three days at present to anywhere between 28-58 days based on the rate of global greenhouse gas emissions. In addition to rendering ecosystems uninhabitable for certain species (see Section 3.1), the change in extreme heat is likely to contribute to health issues, including respiratory problems, thereby reducing resilience and increasing the community's overall social vulnerability (see Sections 3.3, 3.4). Extreme heat can also cause work disruptions by reducing safe working conditions for outdoor labor, such as construction and agriculture, and disrupting daily operations through power outages, equipment failure, or transportation delays.

Table 1. *Future temperature thresholds for a low-emission scenario (based on Rock Island County).*

Temperature Thresholds	Modeled History	Early-Century (2040)	Mid-Century (2060)	End-of-Century (2100)
Annual days with maximum temperature > 95°F	3 days	12 days	19 days	28 days
Annual days with maximum temperature > 100°F	0 days	2 days	5 days	9 days

Table 2. *Future temperature thresholds for a high-emission scenario (based on Rock Island County).*

Temperature Thresholds	Modeled History	Early-Century (2040)	Mid-Century (2060)	End-of-Century (2100)
Annual days with maximum temperature > 95°F	3 days	15 days	27 days	58 days
Annual days with maximum temperature > 100°F	0 days	3 days	8 days	29 days

2.4. Other Extreme Events of Concern

The Quad Cities area is vulnerable to other extreme events, such as derechos, tornadoes, and drought. While not all are explicitly tied to climate change, changes in temperature and precipitation will impact the frequency and severity of some. For instance, rising temperatures contribute to longer, more severe wildfire seasons and increased drought risk. Drought conditions create ideal conditions for wildfires: dry trees and vegetation serve as fuel while low soil and air moisture facilitate rapid spread. The cities within the Quad Cities have varying wildfire risk, according to the USDA's Wildfire Risk to Communities Tool, which is based on existing land cover, housing units, and population extent (Figure 13). In general, Rock Island and Davenport face medium risk of wildlife, while Bettendorf and Moline and East Moline tend to have lower risk.

- Rock Island has a medium risk of wildfire—higher than 43% of communities in the US.
- Davenport has a medium risk of wildfire—higher than 47% of communities in the US.
- Bettendorf has a low risk of wildfire—lower than 60% of communities in the US.
- Moline/East Moline have a low risk of wildfire—lower than 73% of communities in the US.

Nahant Marsh, a 382-acre wetland preserve in southwest Davenport. (Nina Struss)

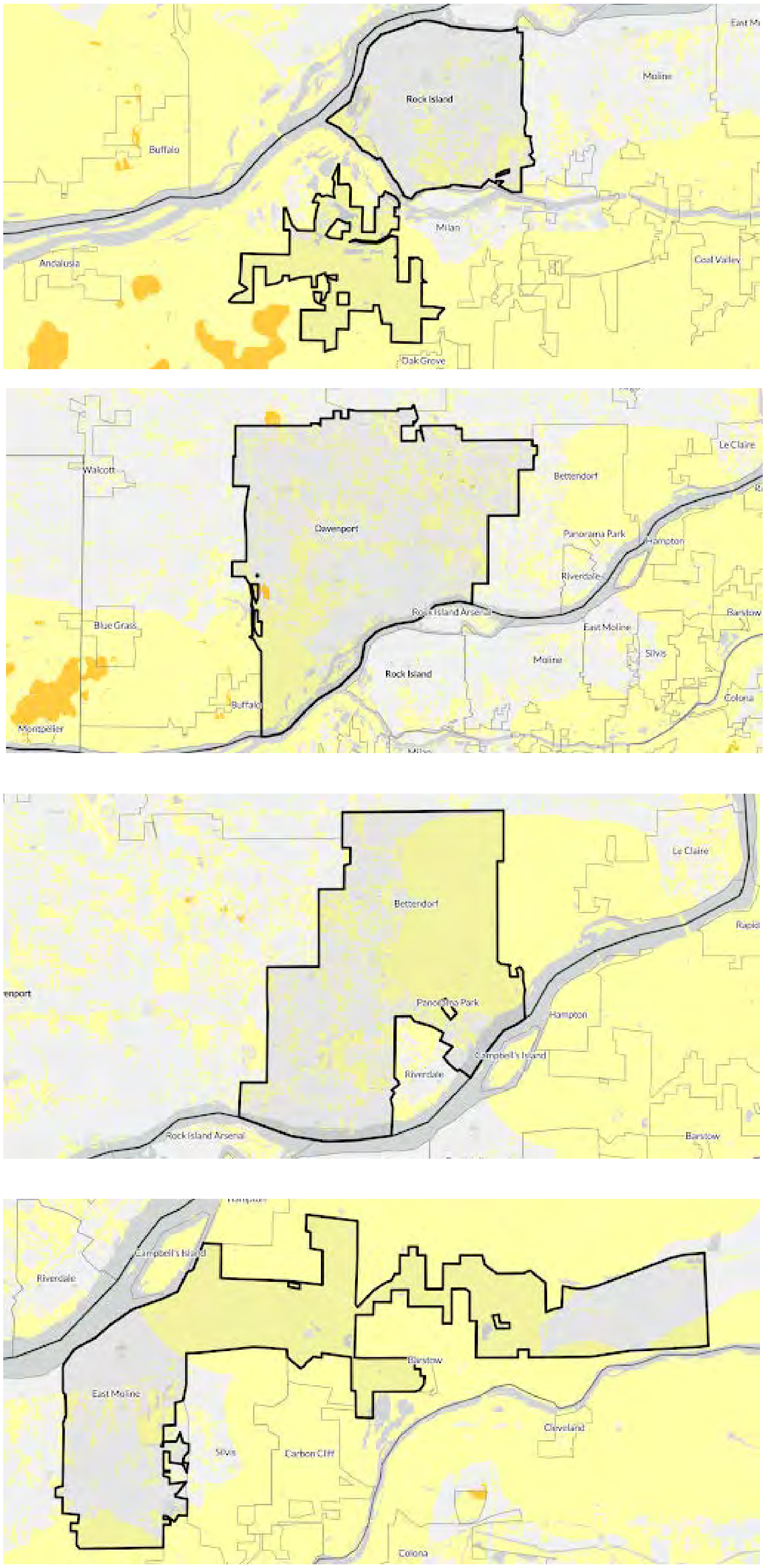
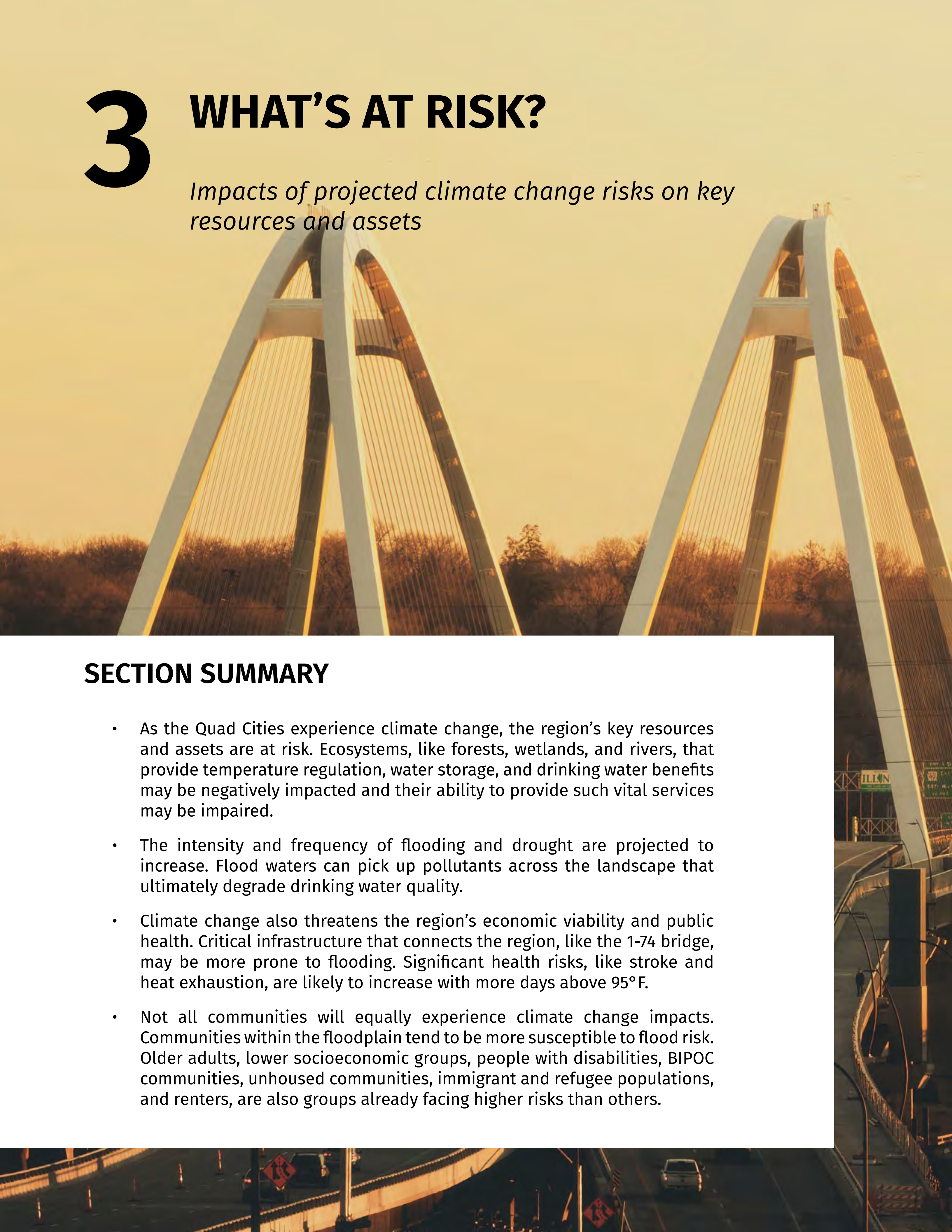


Figure 13 (A-D). *Wildfire risk to homes in the Quad Cities (Source: USDA's Wildfire Risk to Communities Tool).*

From top to bottom:
A. Rock Island
B. Davenport
C. Bettendorf
D. Moline/East Moline



3 WHAT'S AT RISK?

Impacts of projected climate change risks on key resources and assets

SECTION SUMMARY

- As the Quad Cities experience climate change, the region's key resources and assets are at risk. Ecosystems, like forests, wetlands, and rivers, that provide temperature regulation, water storage, and drinking water benefits may be negatively impacted and their ability to provide such vital services may be impaired.
- The intensity and frequency of flooding and drought are projected to increase. Flood waters can pick up pollutants across the landscape that ultimately degrade drinking water quality.
- Climate change also threatens the region's economic viability and public health. Critical infrastructure that connects the region, like the 1-74 bridge, may be more prone to flooding. Significant health risks, like stroke and heat exhaustion, are likely to increase with more days above 95° F.
- Not all communities will equally experience climate change impacts. Communities within the floodplain tend to be more susceptible to flood risk. Older adults, lower socioeconomic groups, people with disabilities, BIPOC communities, unhoused communities, immigrant and refugee populations, and renters, are also groups already facing higher risks than others.

3.1. Ecosystems and Associated Biodiversity

Due to increasing development and land use changes, ecologically significant areas in the region are declining. For example, by the early 1990s, only about 400,000 acres of Iowa's original 4 to 6 million acres of wetlands remained (NRCS, 2021). In Illinois, close to 85% of its original 8 million acres of wetlands were lost due to agricultural expansion and urban sprawl (NAWM, 2015). Despite the statewide conservation and restoration efforts (e.g., Iowa's addition of over 100,000 acres of wetlands in the past 15 years), this might not be sufficient for risk reduction and biodiversity benefits given the accelerating pace of climate change.

The escalating severity of flooding and rainfall directly disrupts the water balance of the wetlands. Even small changes in temperature can negatively impact the native flora and fauna that thrive in these systems. Beyond wetlands, other crucial areas like forests, streams, creeks, and prairies are at risk of flooding. Their biodiversity could also change because of shifts in the region's overall temperature and precipitation.

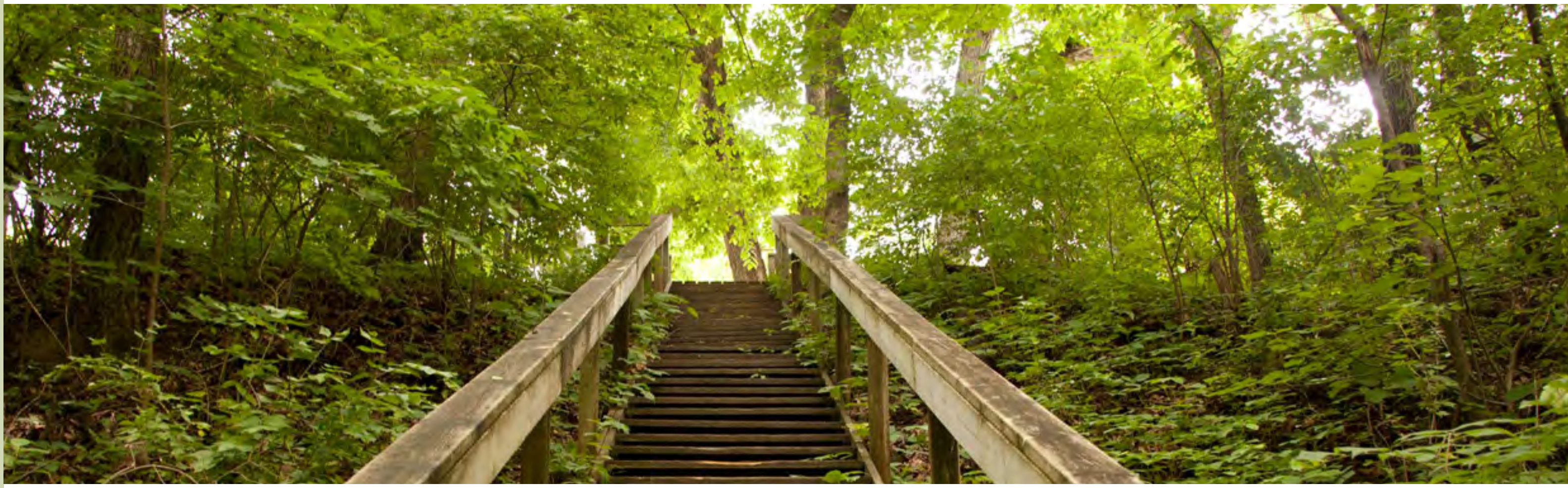
The impacts of climate change on key ecosystems and their biodiversity (based on Wuebbles et al., 2021) are summarized below:

Forests

Examples include Loud Thunder Forest Preserve, Martin Conservation Area, and Wildcat Den State Park; these forests provide air purification and wildlife habitat. Trees also assist in temperature regulation benefits, particularly in urban settings where their canopies can combat urban heat island effects.

- Projected changes in climate—warmer, wetter springs, followed by hotter, drier summers—are likely to increase habitat suitability for some tree species, while decreasing habitat suitability for others.
- Warmer temperatures may increase the number of new, non-native species, as plants, such as kudzu and Chinese privet, expand their ranges northward.
- Trees in the Quad Cities soaked an estimated 69 million gallons of storm runoff, absorbed nearly 3 million pounds of air pollution, and removed more than 100,000 tons of carbon pollution from the air annually (Climate Central, 2023). Loss of trees will also lead to losing these protective benefits provided by them.

Black Hawk State Historic Site, located in Rock Island, is a 208 acre park managed by the Illinois Department of Natural Resources and includes public use areas, prairie and a nature preserve. (Shutterstock)




Sylvian Island. (Nina Struss)

Wetlands

Examples include Nahant Marsh and QCCA Wetlands Center; they provide flood reduction and clean water benefits for communities.

- The most important climate-related impacts to wetlands will be driven by changes in water balance, including the increased likelihood of summer drought and increased frequency and severity of floods.
- Increased summer drying will impact small and ephemeral wetlands and wetland-dependent species, such as many amphibians, by decreasing wetland area and water permanence.
- Riparian wetlands will be impacted by the increased frequency and severity of major floods. Tree species composition in forested wetlands along watercourses will shift toward species that are more tolerant of prolonged flooding. The increased intensity in flooding is also likely to decrease the amount of time that water is stored in wetlands, thus decreasing the ability of wetlands to cleanse water of sediments and nutrients and reduce flooding.

Streams, rivers, lakes, and ponds

The Mississippi and Rock Rivers provide water supply, habitat, and drinking water benefits.

- As a result of climate change, air temperatures are projected to increase and short-duration heatwaves are expected to become more common and more intense, resulting in higher average water temperatures. Warmer water temperatures will alter the growth, survival, and reproduction of aquatic species, as well as predator–prey relationships. Models suggest that warmer water will reduce habitat availability and competitive abilities for cold and cool water fishes but maintain or increase habitat availability and enhance competitive abilities for warm water fishes.
- Increasing annual precipitation, coupled with more extreme precipitation events, is likely to result in higher average flow rates and more flooding. Higher peak flows are expected to favor stronger swimmers while resulting in challenges for weak swimmers, like bottom-oriented fish and small invertebrates. Increased peak flows will also impact aquatic habitats by causing substrate removal and transporting many species downstream to unfavorable habitats.
- Climate change is likely to cause increased periods of drought in Illinois and Iowa, which could reduce freshwater habitat connectivity.

Grasslands

Nachusa Grasslands and areas with native prairie plants like Nahant Marsh, Sunderbruch Park, and West Lake Park provide climate mitigation and stormwater management benefits.

- Changes in climate will affect grassland vegetation largely by shifting the amount and seasonal pattern of precipitation and soil water availability.
- Increased summer temperatures and evaporation may negatively affect grasslands by increasing loss of soil moisture, which will lead to decreased plant growth and reproduction.
- Native prairie plants adapted to survive periodic droughts and warmer temperatures will likely fare better than species not adapted to these conditions.

3.2. Water Quantity and Quality

The freshwater flowing downstream from rivers, bayous, and creeks influence the salinity, nutrients, and sediments of the Mississippi River in the Quad Cities. High flow events caused by extreme rainfall and melting glaciers, as well as low flow events caused by drought and upstream water use, are detrimental to the communities and plants and animals that depend on the river. As the climate continues to change, these extreme events will continue to intensify and impact downstream water quantity.

As noted above, precipitation changes are expected to rise in the region, posing an elevated flood risk. More frequent and intense rainfall may increase runoff, potentially compromising water quality by mobilizing pollutants across the landscape, often referred to as nonpoint source pollutants. For example, agricultural runoff, containing sediment, excessive nutrients (nitrogen and phosphorus), pesticides and chemicals from agricultural and industrial sources, already threatens river resources – a persistent concern among the key stakeholders in the Quad Cities. Iowa and Illinois have the highest combined flooding and nitrate risks in the Mississippi River Basin (Schilling et al., 2023). Exports of nonpoint source pollutants from cropland landscapes in these states have ranked highest among the basin in several studies (Jones et al., 2018; Tian et al., 2020). These nutrients accelerate the growth of algae and duckweed, which in turn reduces light penetration to the underwater aquatic vegetation that fish and aquatic life depend on (Olson et al., 2021). In the Quad Cities, where riverfront fishing is a common pastime, poor water quality can lead to unsafe fish consumption. High flows caused by localized extreme rainfall will continue to mobilize more nutrients. In addition to agricultural sources, urban sources like lawn fertilizer, deicing salt, and pet waste are common contributors to poor water quality.

3.3. Economy and Public Health

Climate change-induced flooding threatens the economic viability of the Quad Cities, as evidenced by previous flood events. According to the modeling framework developed in this assessment, areas near to the shoreline and major hydraulic structures (like the Rock Island levee) are at direct risk of future flood inundation. Several areas such as Cargill AgHorizons, Isle Casino Hotel Bettendorf, portions of Rock Island Arsenal Island, Martin Luther King Center, Vibrant Arena at the MARK, Lindsay Park Yacht Club, and many more, are prone to flooding in the early to end-of-the-century projections (Figure 12). These places also include tourist spots, major attractions, and gathering grounds, generating economic revenue as well as opportunities for social cohesion among community members. By 2090, the annual flood risk under the extreme scenario significantly impacts critical transportation, like major roadways and bridges. Bridge access to Iowa, Illinois, and Arsenal Island will be prone to flooding. These maps also indicate main roadways, such as Second Street in Davenport and River Drive in Moline and East Moline, are prone to flooding, in turn adversely impacting local businesses and community members. Given that the Quad Cities rely heavily on bi-state access through bridges, the region's economic viability would be greatly challenged if these bridges are inaccessible.

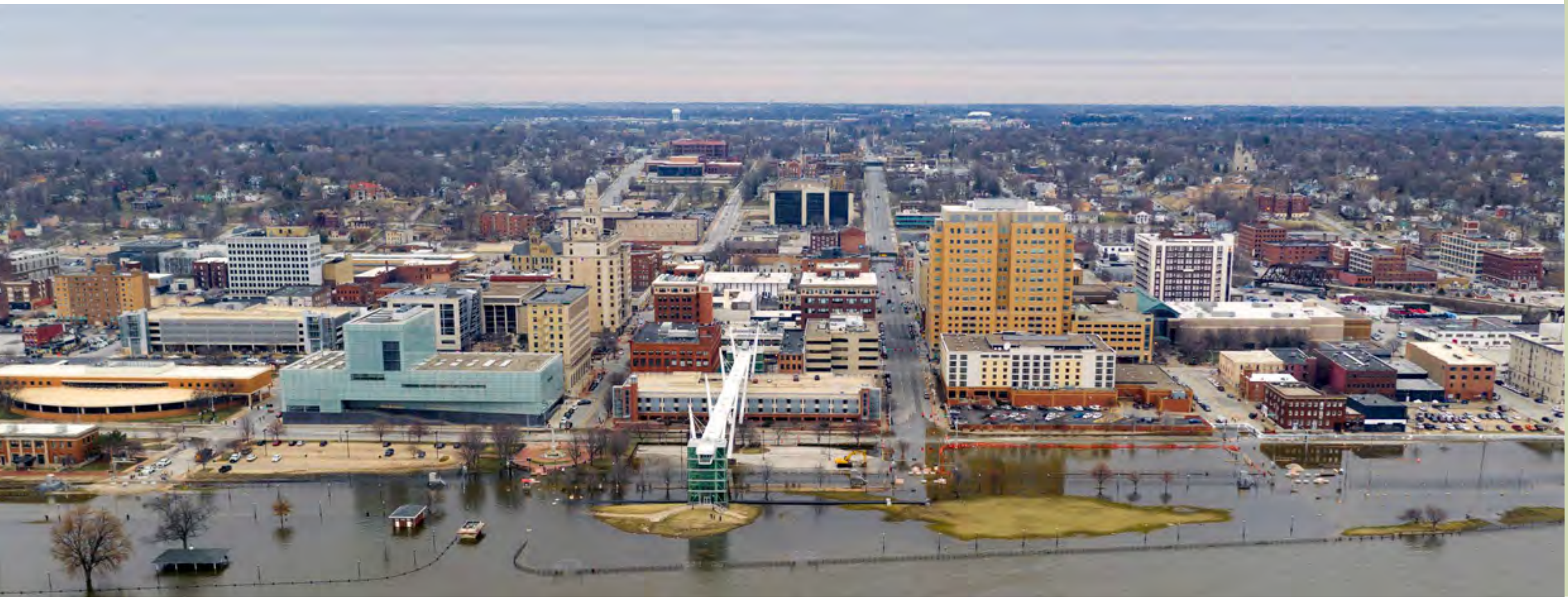
Climate change, especially rising temperatures and warming winters, will continue to impact the Quad Cities' agricultural sector. Heat and water stress are likely to reduce corn yields by mid-century, while soybean yields are expected to decline later in the century. Warming temperatures will shift plant hardiness zones northward, affecting the viability of certain fruits, vegetables, and nuts in the region (Wuebbels et al., 2021).

The increase in temperature, especially extreme heat, poses significant health risks, leading to a rise in severe heat-related illnesses such as heat exhaustion and heat stroke. It also extends the pollen season, triggering asthma, allergies, and other respiratory issues. These health impacts will disproportionately affect those with existing chronic diseases, particularly those without basic housing or health insurance, as discussed below.

3.4. Socially Vulnerable Populations

Climate risks vary based on a population's geographic location and social characteristics. For instance, residents living and working in floodplains in Moline and East Moline and downtown Davenport along the Mississippi and Rock Rivers are more susceptible to flood risks at present due to lack of protection. Several other factors contribute to how communities experience risks and opportunities for resilience, including funding and technical services. Social vulnerability, defined as the susceptibility of a social group to the adverse impacts of natural hazards, plays a critical role in the region's resilience planning. Figure 14 illustrates the level of vulnerability according to the Social Vulnerability Index, a metric adopted by the Federal Emergency Management Agency and the National Oceanic and Atmospheric Administration. Downtown Quad Cities locations along the Mississippi mainstem and areas in East Moline stand out as the most vulnerable within the metro area. Outlying urban areas in the broader region also exhibit areas of high social vulnerability. Certain groups, such as older adults, lower socioeconomic groups, BIPOC communities, unhoused communities, immigrant and refugee populations, and renters,

Aerial view of downtown Davenport during a major flood. (Shutterstock)



are identified as groups already facing higher risks than others. Table 3 provides indicators to assess the percentage of socially vulnerable population groups in Davenport, Rock Island, and East Moline, which tend to have a high concentration of vulnerable populations amongst the Quad Cities (U.S. Department of Commerce, 2020). These include an above-average percentage of people of color in Rock Island and East Moline and high percentages of people without a high school degree, living in poverty, renting property, and with disabilities in the three cities.

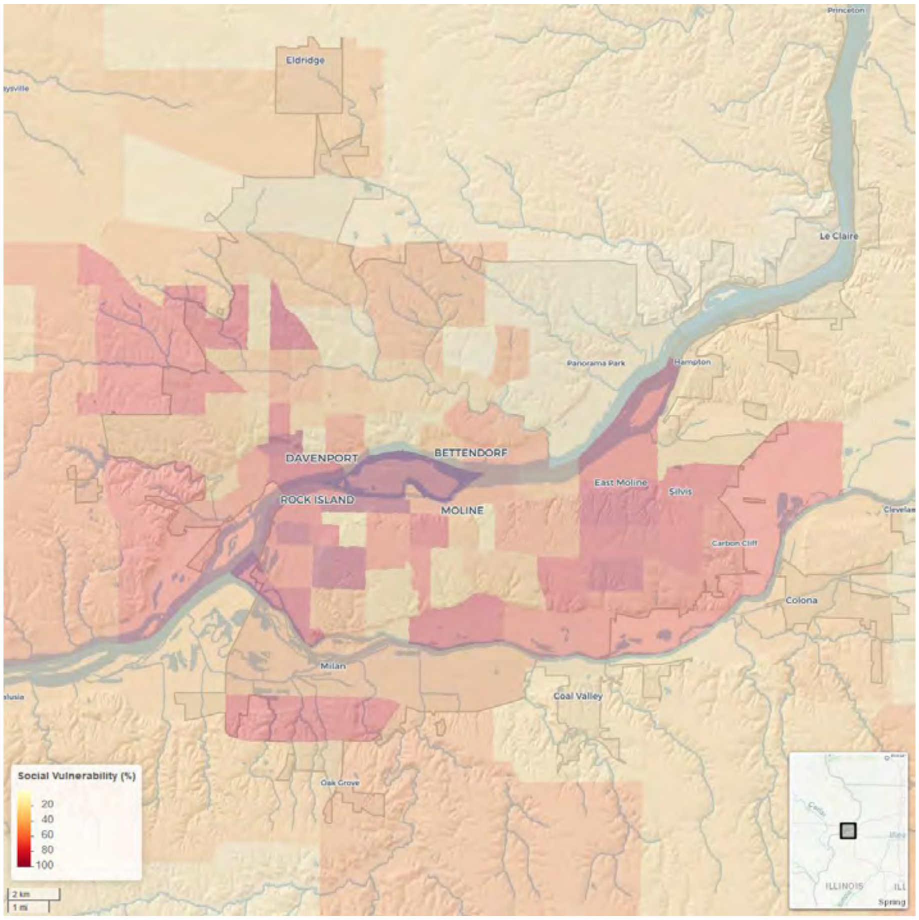
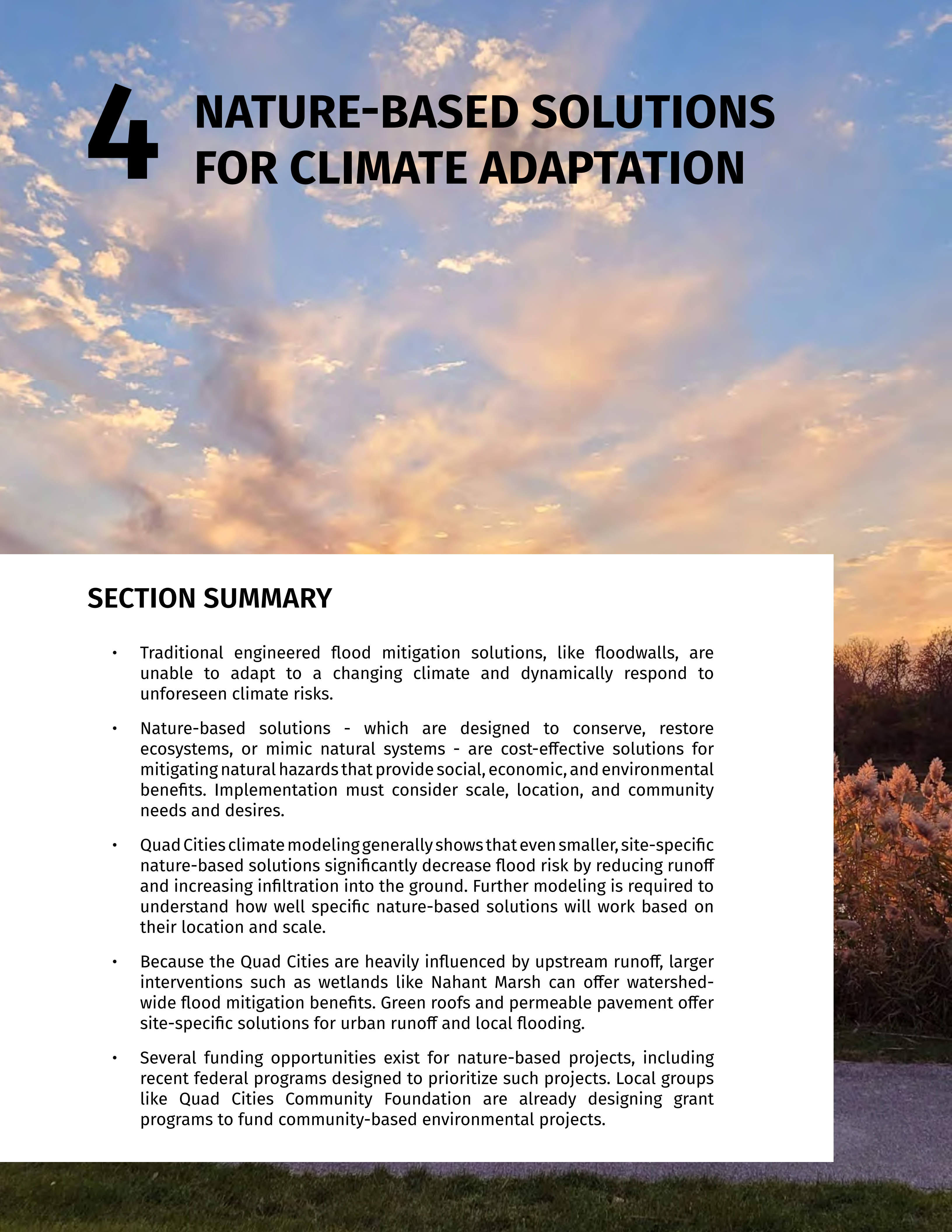


Figure 14. *Social vulnerability index over Illinois region developed by FEMA/NOAA.The darker the color, the higher the social vulnerability.*

Table 3. *Social vulnerability indicators for Davenport, Iowa and Rock Island and East Moline, Illinois.*

Social Vulnerability Indicators	Davenport	Rock Island	East Moline	U.S
People under 5 years	5.8%	5.3%	6.5%	5.9%
People over 65 years	11.8%	12.7%	17.4%	16.0%
People of color (including Hispanic)	39.5%	54.5%	44.9%	40.6%
People who don't speak English well	2.9%	3.8%	4.6%	4.1%
People without a highschool degree	12.5%	20.2%	15.0%	11.1%
Families in poverty	22.2%	22.8%	14.3%	8.9%
Housing units that are rentals	57.7%	63.2%	48.2%	35.4%
Households with no car	16.0%	26.1%	14.1%	8.3%
People with disabilities	15.7%	19.8%	18.1%	12.6%
People without health insurance	11.4%	9.2%	9.7%	8.5%



4 NATURE-BASED SOLUTIONS FOR CLIMATE ADAPTATION

SECTION SUMMARY

- Traditional engineered flood mitigation solutions, like floodwalls, are unable to adapt to a changing climate and dynamically respond to unforeseen climate risks.
- Nature-based solutions - which are designed to conserve, restore ecosystems, or mimic natural systems - are cost-effective solutions for mitigating natural hazards that provide social, economic, and environmental benefits. Implementation must consider scale, location, and community needs and desires.
- Quad Cities climate modeling generally shows that even smaller, site-specific nature-based solutions significantly decrease flood risk by reducing runoff and increasing infiltration into the ground. Further modeling is required to understand how well specific nature-based solutions will work based on their location and scale.
- Because the Quad Cities are heavily influenced by upstream runoff, larger interventions such as wetlands like Nahant Marsh can offer watershed-wide flood mitigation benefits. Green roofs and permeable pavement offer site-specific solutions for urban runoff and local flooding.
- Several funding opportunities exist for nature-based projects, including recent federal programs designed to prioritize such projects. Local groups like Quad Cities Community Foundation are already designing grant programs to fund community-based environmental projects.

Historically, most approaches to addressing risks from hazards have emphasized the use of structural or engineered solutions, such as levees, sea walls, and stormwater drainage channels. While sometimes necessary, the limitations of such hard infrastructure approaches in an era of rapid climate changes are becoming all too evident. These structures are unable to fully adapt to dynamic and unpredictable environmental changes. Managing river landscapes based on engineering and bio-geophysical sciences alone will fail to reduce vulnerability and unforeseen risks (Olson et al., 2021).

Nature-based solutions offer reliable, cost-effective, and efficient solutions to risk reduction while also building community resilience. These solutions are designed to leverage natural features and provide benefits such as water quality improvements, public access and recreation, wildlife habitat, and the creation of green jobs. Table 4 provides examples of nature-based solutions for mitigating different hazard concerns.

The analysis in Section 4.1 (Box 2) modeled flood risks with and without nature-based solutions in the Quad Cities region, showing a significant decrease in flood risks when employing site-specific green infrastructure measures. Nature-based solutions should always be tailored to their location, function, and used in a cultural context. Identifying and implementing specific solutions will depend on community needs, priorities, and concerns. Modeling results support their effectiveness in reducing flood risks in the region and their potential for increasing the quality of life for residents.

Table 4. *Examples of nature-based solutions for hazard risk reduction.*

Hazard	Conventional approaches	Natural and nature-based approaches	Examples
Inland flooding	Dams, dikes, levees, stream channelization, stormwater sewer, combined sewer, pumps	Floodplain and watershed restoration, green stormwater management, protecting floodplains from development	Levee setbacks and dam removal, wetland restoration, rain gardens, permeable surfaces, open space acquisition and protection, voluntary buyouts
Extreme heat and drought	Dams and reservoirs, air conditioning	Watershed restoration, urban green infrastructure, water conservation	Headwater stream and forest restoration, urban forestry, green roofs, cooling pavement, rainwater harvesting, xeriscaping, water-saving agricultural practices
Wildfires	Wholesale supression	Ecological forest management, learning to live with fire, reducing edge development in fire prone habitat	Fuel reduction treatments, prescribed fire, post-fire restoration, community planning and collaborative risk management, managed wildfires, update land use and zoning

4.1. Potential Nature-based Solutions in the Quad Cities

Several nature-based solutions are available to combat climate risks in the Quad Cities. This includes site-specific solutions, such as rain gardens, permeable pavements, green roofs, and waterfront parks, that help to combat localized flood risks, lower urban heat island effect, and provide community-wide benefits, such as recreation and access to nature. On the other hand, certain nature-based interventions will involve large-scale practices, such as floodplain restoration, conservation easements, or riparian buffers, that require combining a range of ecosystems like forests and rivers.

In the Quad Cities, where climate risks are compounded by outside factors such as the degree of impervious surfaces, upstream land uses (e.g., deforestation), and agricultural practices, several stakeholders emphasized the need to look upstream and implement large-scale solutions. For instance, Rock Island is predominantly impacted by water coming from upstream, in addition to local urban runoff; any nature-based solutions implemented will be greatly impacted by upstream discharge. The region also contributes to downstream impacts due to its location and associated tributaries.

East Moline is more susceptible to flooding from tributaries than from the Mississippi River mainstem. Davenport, positioned near confluence points, also faces periodic flooding from nearby tributaries in addition to the mainstem flood issues at its riverfront.

The appropriate choice of nature-based solutions in this region requires careful considerations of scale and location in light of changing climatic conditions. For instance, large-scale practices, like floodplain restoration, can notably reduce flood risk across the Quad Cities' interconnected watersheds by capturing upstream runoff. In contrast, stormwater management practices like permeable pavements will be more appropriate for site-specific flooding, runoff, and other more localized hazard concerns. Understanding the landscape and climate risks beyond the defined geographic scope is not only essential to successful nature-based projects, but also for facilitating upscaling and enhanced connectivity for ecosystems, wildlife, and community resilience to climate change.

Quad Cities community leaders are actively thinking about ecosystem restoration and nature-based solution opportunities. Some of these solutions include:

- **Increase green space:** Using old and newly vacant spaces in Davenport for green space, in particular the old YMCA location between Gaines and Second Street in Davenport and the recently vacant lot on North Main Street from an apartment building collapse. These alleys and vacant lots can be transformed into a green infrastructure network, providing access to nature and equitable open space for recreation.

- **Ravine restoration (through conservation easement), specifically in Rock Island, Moline, and East Moline:** Restoration of ravines by removing invasive species, re-establishing appropriate native species, and conserving these ecologically vital areas through easements will enhance their ability to perform ecosystem services, such as enhancing corridors for wildlife, managing stormwater circuits for instances of heavy rainfall/flash flooding, and instilling environmental stewardship among residents.

- **Providing equitable access to the river:** River access for communities of lower socioeconomic status or those within BIPOC communities is often lacking or viewed as unsafe. Projects such as developing a river path to connect East Moline (Watertown) to the river and exploring ways to make the river more accessible to those with disabilities was recommended by several stakeholders.

- **Natural infrastructure to curb "heat islands":** Extreme heat is one of the key concerns highlighted by the community members in the Quad Cities and with the number of extreme heat days increasing, conversations have steered towards decreasing heat islands. Increasing tree cover, especially in communities significantly affected by lower tree equity scores (for example, areas near Rock Island Arsenal, Western Illinois University, Trinity Medical Center, and Quad Cities International Airport) could not only enhance the environmental biodiversity of a city, but also help to curb the effects of extreme heat in an equitable manner (Figure 15).

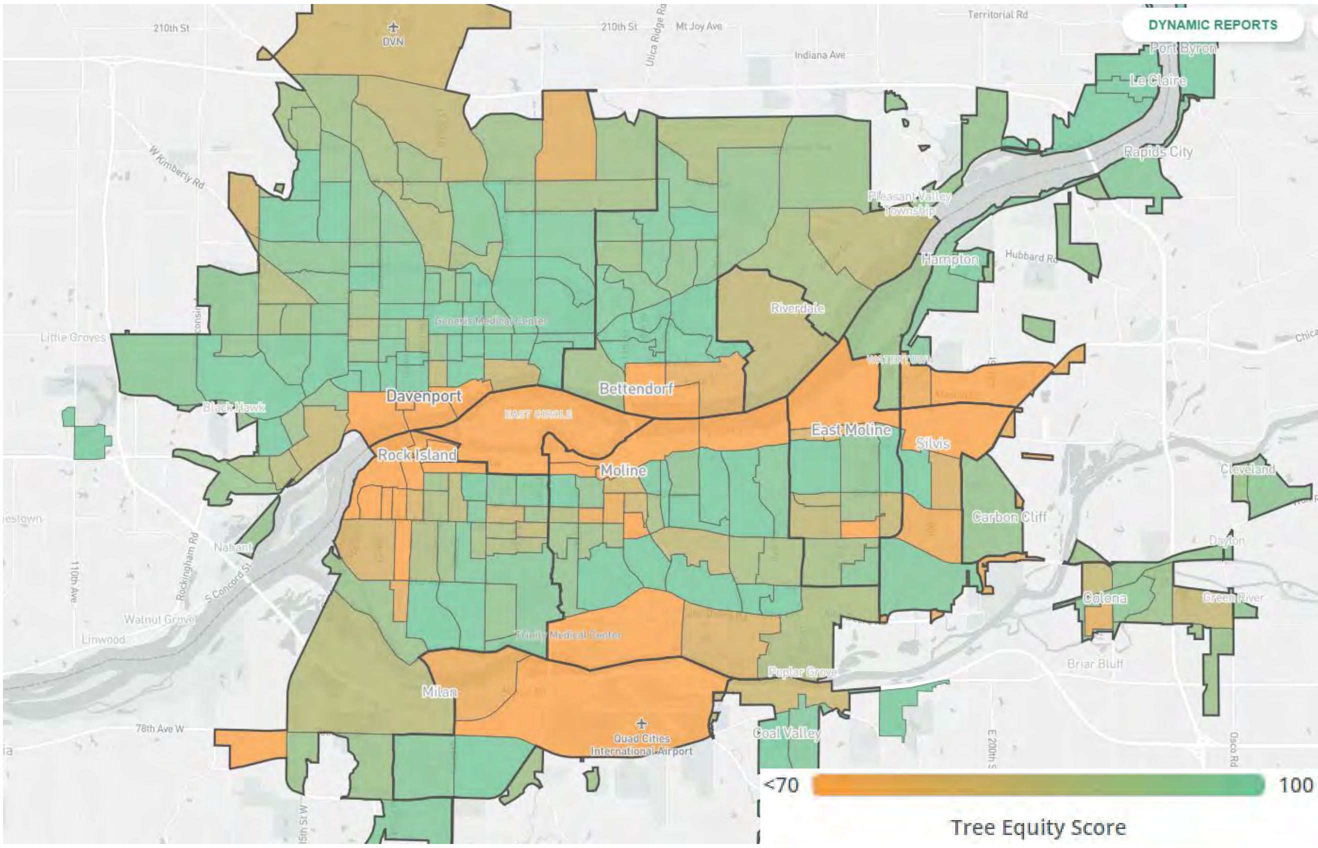


Figure 15. *Tree Equity Score for Quad Cities neighborhoods. Tree Equity Score measures how well the benefits of trees are reaching communities living on low-incomes, communities of color and others disproportionately impacted by extreme heat and other environmental hazards. The lower the score (orange), the greater priority for tree planting.*

Concrete examples of early successes of transformative adaptation can be a source of inspiration for designing new nature-based adaptation projects. Nahant Marsh, a 382-acre wetland preserve in southwest Davenport, is an excellent example of a nature-based solution providing community-wide benefits (e.g., outdoor access, wildlife viewing, and public education) while buffering floods. The Quad Cities Conservation Alliance (QCCA) Wetlands Center is another good example of a 58-acre protected natural wetland in East Moline maintained by the QCCA. The Center serves as both a flood water retention area and a wildlife habitat, supporting species like bees, butterflies, and osprey. It also offers recreational activities such as boating and kayaking, as well as research opportunities for local youth and researchers.

Box 2. Effectiveness of Nature-based Solutions

Modeled flood risk reduction benefits of specific approaches in the Quad Cities

The assessment analyzed the effectiveness of a few types of nature-based approaches by overlaying the flood risks with site-specific nature-based solutions, such as vegetative swales, permeable pavements, and green roofs. Nature-based solutions are simulated using EPA's SWMM (Storm Water Management Model) to assess the reduction in peak flow and the increase in infiltration capacity. Across each of the Quad Cities communities, the performance of these nature-based solutions was evaluated based on the predicted reduction in peak runoff and improvement in the infiltration capacity, as compared to the baseline absence of nature-based solutions. Some notable findings and trends from our analysis include:

- Across communities, a significant reduction in peak discharges and an increase in infiltration with the potential implementation of certain nature-based solutions, particularly in Rock Island and Moline (Tables 5 and 6).
- Based on the variations in the discharge values, along with changes or reductions in peak runoff from nature-based interventions, a combination of vegetative swales (covering 25% of the pervious area) and permeable pavement adjacent to all the roadways can help mitigate flood risk in the Bettendorf region. According to modeling results, if applied, this combination results in a 39% reduction in peak runoff and up to a 19% increase in infiltration capacity.
- Vegetative swales and green roofs are more effective than other measures in reducing peak discharges and increasing infiltration capacity in Rock Island and East Moline.
- Across communities, permeable pavement or rain gardens can help lessen the load on the sewer system and, to some extent, delay flood events. While installation is simpler compared to other solutions, maintenance is an additional challenge.

This analysis was intended to explore general trends in the efficacy of nature-based solutions to reduce localized flood risk and demonstrated a decrease in the number of flood events in the five major cities (Figure 16) and an overall decrease in flood extent (Figure 17). A more detailed analysis would be required based upon specifically proposed nature-based projects, as the citing and quantity of projects deployed would impact efficacy. However, the analysis does help showcase the effectiveness of particular nature-based approaches that can be applied at a site-specific scale.

Nahant Marsh. (Nina Struss)

Table 5. *Percentage of annual runoff reduced after implementation of nature-based solutions.*

Year	Precentage Reduction in Peak Discharge (E_{rmax})					
	Rock Island	Davenport	Bettendorf	Moline*	Flood Plains	Tributaries
2020	36.4	8.14	1.09	31.55	31	18.33
2030	56.55	18.06	22.38	5.1	10.26	14.03
2040	18.37	12.11	48.01	12.44	6.3	33.37
2050	39.57	8.16	10.32	51.46	47.5	9.01
2060	48.49	28.3	28.23	21.26	48.21	8.31
2070	29.44	16.21	13.33	55.12	12.17	41.25
2080	69.36	3.21	14.48	27.37	46	6.33
2090	40.4	1.02	2.37	34.05	34.32	22.25
2100	0.14	25.29	17.22	32.41	36.28	19.36

**Note: Moline includes East Moline.*

Table 6. *Percentage increase in infiltration capacity after implementation of nature-based solutions over each city.*

Year	Precentage Increase in Infiltration (E_{fp})					
	Rock Island	Davenport	Bettendorf	Moline*	Flood Plains	Tributaries
2020	21.14	24.21	16.17	6.04	31	15.24
2030	24.33	19.33	15.13	17.27	10.26	35.01
2040	29.29	1.29	20.25	19.16	6.3	24.18
2050	30.08	11.03	0.13	8.04	47.5	29.02
2060	4.01	19.31	6.25	26.18	48.21	20.33
2070	3.27	29.03	6.23	9.18	12.17	34.05
2080	25.04	10.31	21.18	26.05	46	1.17
2090	27.19	15.13	17.14	25.27	34.32	10.01
2100	8.25	18.34	27.02	7.16	26.28	19.3

**Note: Moline includes East Moline.*

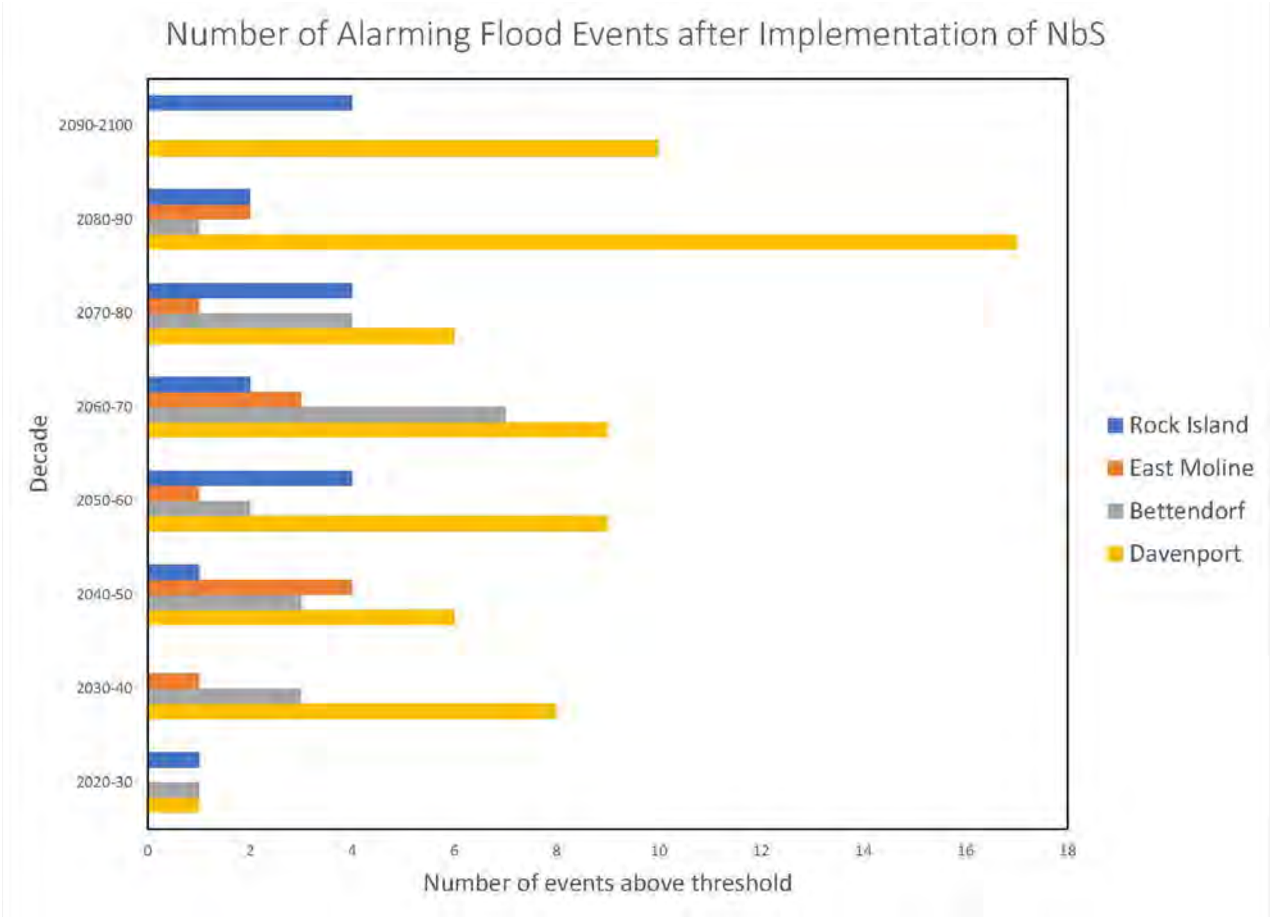
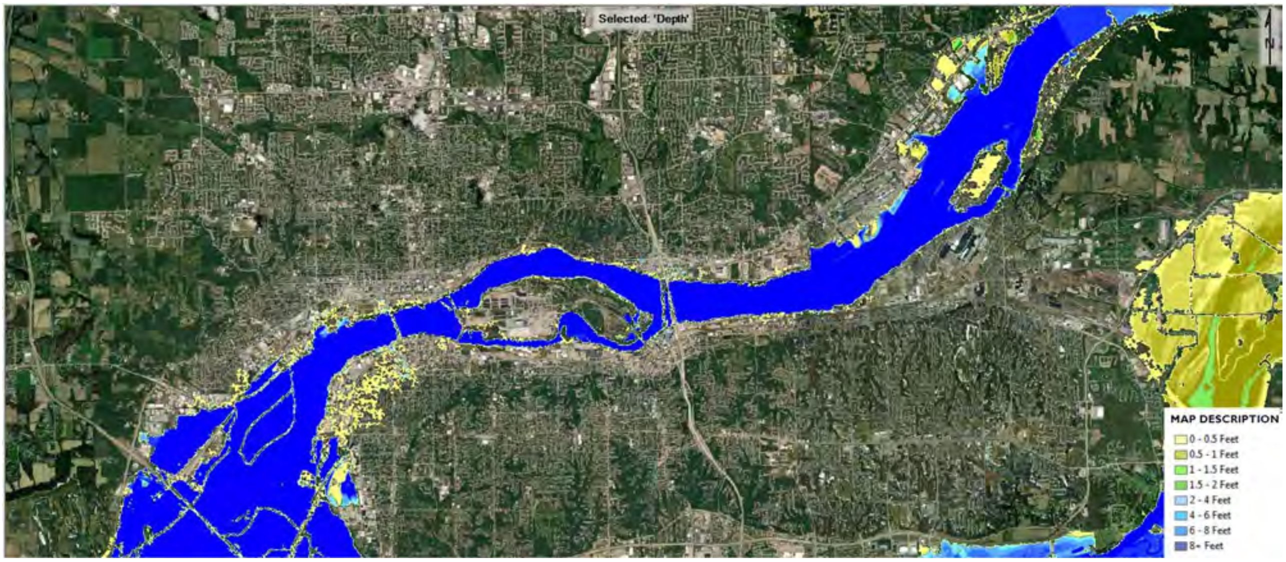


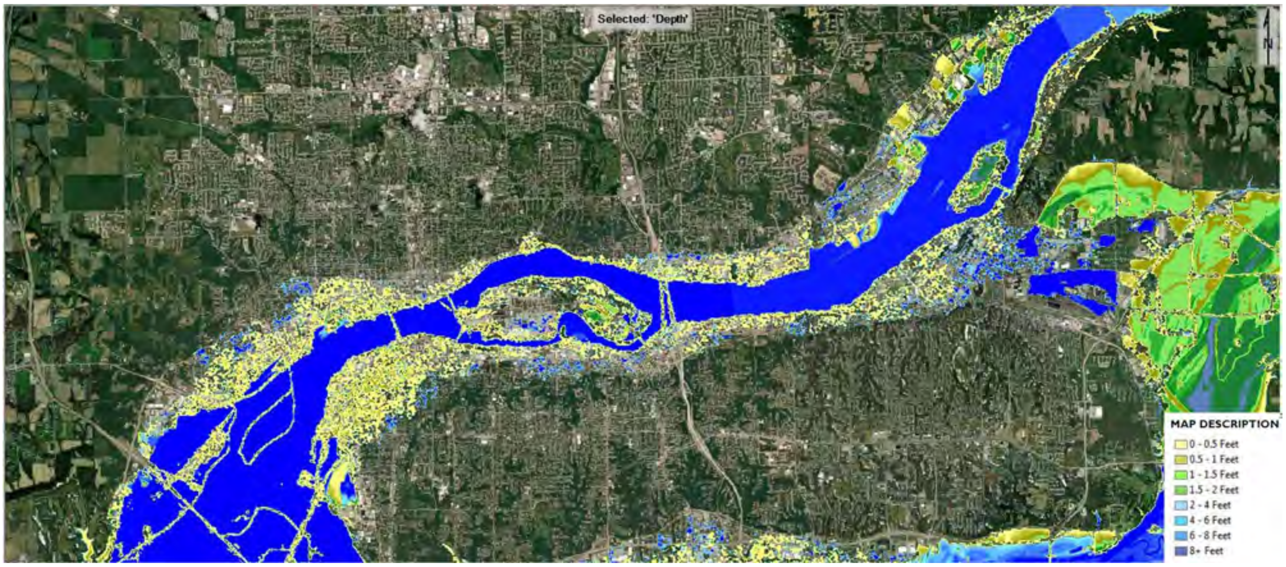
Figure 16. *The number of events that have precipitation above the "warning" situation per major Quad Cities localities after implementing nature-based solutions. Note: East Moline data includes Moline.*

Figure 17 (A-C). *Changes in the flood inundation of the Quad Cities with and without nature-based solutions. If nature-based solutions are implemented, approximately 37% of the inundated area can be protected (until 2100). Note: the exact locations of nature-based solutions need detailed assessment.*

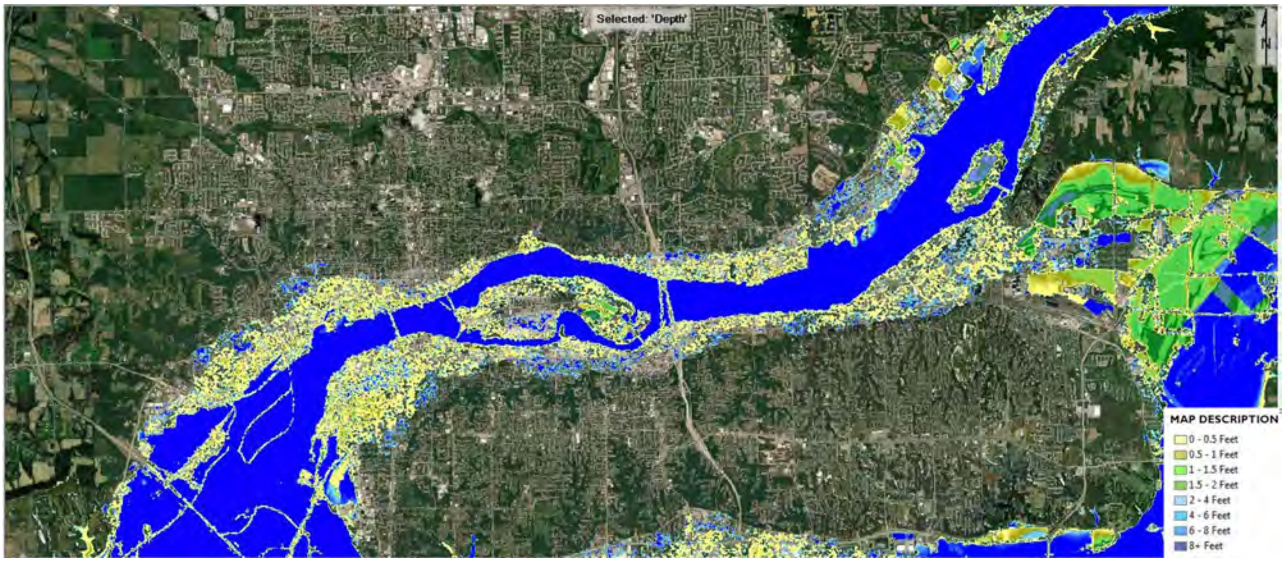
A. Early century (2030-2050) flood inundation without nature-based solutions (top) and with nature-based solutions (bottom).



B. Mid century (2050-2080) flood inundation without nature-based solutions (top) and with nature-based solutions (bottom).



C. End-of-century (2080-2100) flood inundation without nature-based solutions (top) and with nature-based solutions (bottom).

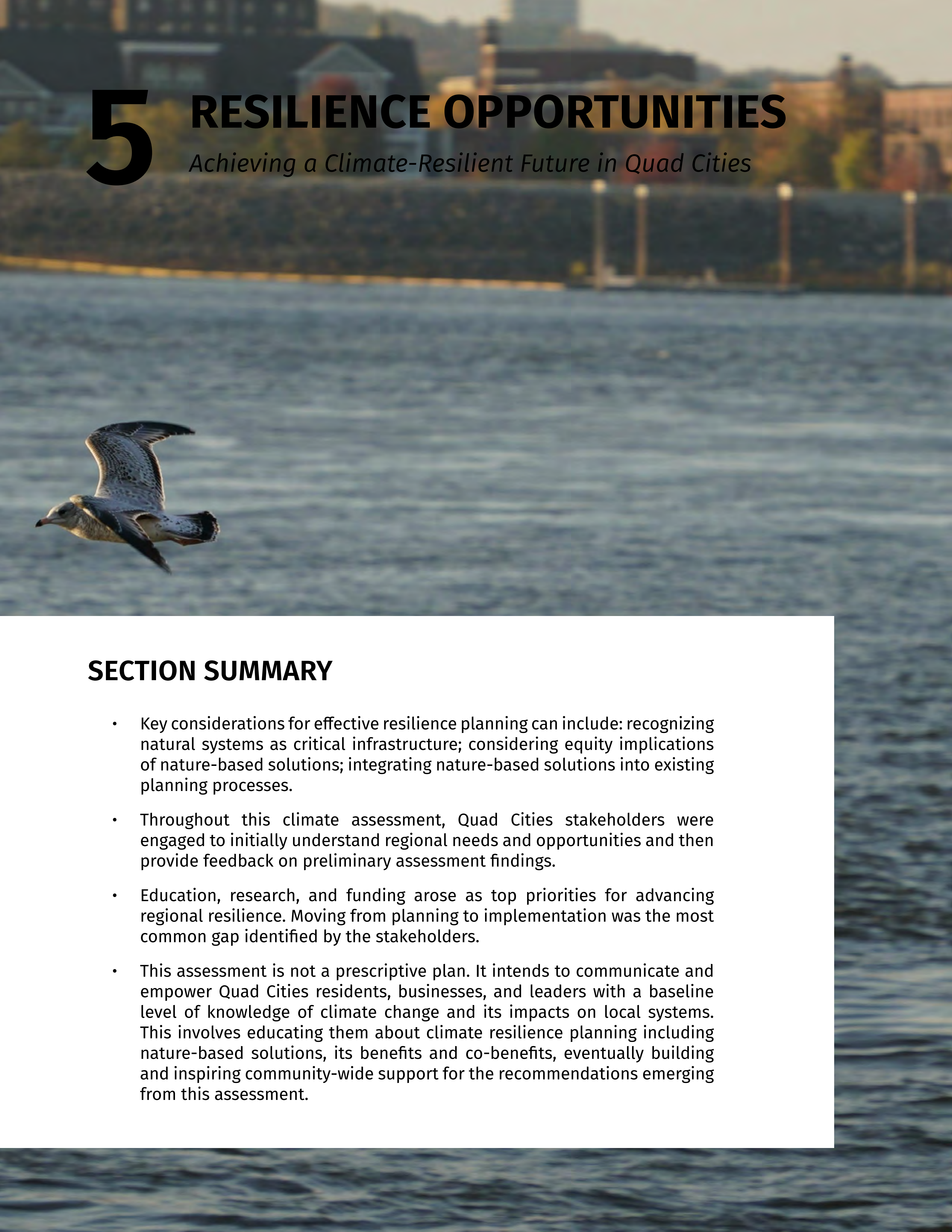


4.2. Funding Opportunities

Several funding opportunities exist to support project implementation. Communities and practitioners benefit from out-of-box thinking when leveraging these federal funding opportunities (FEMA, 2021). For example, some types of projects, such as stream restoration and wetland restoration, may be eligible for grants through the EPA's Nonpoint Source program, FEMA's hazard mitigation program funding, as well as for a new surface transportation resilience grant program (Promoting Resilient Operations for Transformative, Efficient, and Cost-saving Transportation, or PROTECT), authorized by the 2021 Bipartisan Infrastructure Law. The multiple co-benefits of nature-based solutions make them eligible for various grants, including less apparent opportunities. For instance, communities in New Jersey solicited the Department of Defenses' Readiness and Environmental Protection Integration program for a landscape-scale project that created an 11,000-acre buffer at Naval Weapons Station Earle, ultimately protecting and restoring 1.7 million acres of salt marshes and streams over five military bases. The National Wildlife Federation has created an interactive database for communities interested in pursuing federal funding and/or technical assistance for nature-based solutions. With passage of the Bipartisan Infrastructure Law (BIL) in 2021 and the Inflation Reduction Act (IRA) in 2022, there was a significant influx of federal funding for nature-based projects; the BIL and IRA both supplemented current programs and created new ones to address issues like climate change and environmental justice. The Funding Nature-based Solutions Database was designed to raise awareness of the number of federal programs funding natural solutions, including lesser known programs. Regularly updated to reflect the federal landscape, the database features different types of filters (e.g., cost-share requirements, recipient eligibility, support type) that help users find programs that best meet their unique needs.

Innovative funding opportunities that the region can investigate for projects include:

- Environmental Trust established through Quad Cities Cultural Trust
- Reimbursements and tax credits (for instance, Rock Island residents can receive reimbursement from the city for implementing rain gardens on their property based on the total square footage of the rain garden at a rate of $4 per square foot).
- The Quad Cities Community Foundation works to award grants to organizations residing in Rock Island County, Illinois and Scott County, Iowa. In particular, the Mark W. Schwiebert Fund for Environmental Studies Grant and the QC River Connections Grants allow for project support centered around environmental issues facing the Mississippi River in the Quad Cities; the latter was designed for funding BIPOC-led and serving organizations.



5 RESILIENCE OPPORTUNITIES

Achieving a Climate-Resilient Future in Quad Cities

SECTION SUMMARY

- Key considerations for effective resilience planning can include: recognizing natural systems as critical infrastructure; considering equity implications of nature-based solutions; integrating nature-based solutions into existing planning processes.
- Throughout this climate assessment, Quad Cities stakeholders were engaged to initially understand regional needs and opportunities and then provide feedback on preliminary assessment findings.
- Education, research, and funding arose as top priorities for advancing regional resilience. Moving from planning to implementation was the most common gap identified by the stakeholders.
- This assessment is not a prescriptive plan. It intends to communicate and empower Quad Cities residents, businesses, and leaders with a baseline level of knowledge of climate change and its impacts on local systems. This involves educating them about climate resilience planning including nature-based solutions, its benefits and co-benefits, eventually building and inspiring community-wide support for the recommendations emerging from this assessment.

Resilience planning can help prepare the Quad Cities in the face of future climate-related uncertainties and risks. Managing for resilience now can improve the capacity of communities and natural features to adapt and adjust to future changes posed by a changing climate. Building resilience through political consensus, planning, and finance takes time. In the Quad Cities, however, there is no time for decision-makers and community leaders to wait-and-see.

As discussed in the earlier section, nature-based solutions provide a promising avenue for enhancing climate and community resilience for the Quad Cities. However, moving the needle on specific projects requires significant planning, coordination, and funding. Growing community capacity and cohesion to build social acceptance and ensure long-term maintenance of these projects, while supporting jobs, training, and the policy landscape, can make nature-based solutions a preferred choice within the community. This section provides a set of recommendations and key considerations for implementing future restoration and adaptation strategies to address the adverse impacts of climate change and associated implications to critical natural and economic assets. It also identifies stakeholder-identified restoration priorities, including priority geographies and strategies for restoration.

5.1. Key Considerations for Implementation

The National Wildlife Federation, through our work on climate adaptation and resilience, have identified the following seven "key considerations" for communities to use in the design and application of nature-based solutions (Pathak et al., 2022).

1. Recognize natural systems and processes as critical infrastructure. This should include natural systems that provide essential ecosystem services including protective benefits from hazards, such as flooding, erosion, stormwater, and extreme heat. Recognize, too, the non-material value (e.g., cultural, aesthetic, spiritual) of biodiversity and natural ecosystems.

2. Consider climate impacts on priority natural assets. Ecosystems are themselves being affected by changing climatic conditions, and those vulnerabilities and risks should be understood and addressed in community-based adaptation and resilience planning.

3. Consider equity implications in the design and application of nature-based solutions. To avoid unintentional consequences, such as displacement of disadvantaged communities, nature-based solutions should be planned and implemented with the engagement of local stakeholders and residents.

4. Ensure that nature-based solutions yield net positive biodiversity benefits. Nature-based solutions should not only provide protective value to communities, but should also yield net biodiversity benefits, for instance through using regionally appropriate designs and materials (e.g., native plants).

5. Seek to protect or restore critical natural infrastructure. This can involve protection of still intact natural systems, restoration of degraded systems, use of nature-based designs in engineered systems, and/or integration of natural (green) and engineered (gray) approaches in hybrid infrastructure.

6. Give natural features and processes space to function. Consider how and where climate change may increase community exposures to potentially hazardous natural processes. Don't create new hazards or exacerbate existing risks through inappropriate siting of new development and infrastructure, and consider where—and when—existing infrastructure may need decommissioning or relocation.

7. Integrate nature-based solutions into existing planning processes. Mainstreaming nature-based

solutions into existing programs, policies, and planning processes can facilitate adoption, successful implementation, and funding of these approaches.

5.2. Quad Cities Community-Identified Recommendations for Advancing Resilience

The recommendations outlined in this section were identified through the outreach efforts as part of this assessment. Stakeholder interviews provided an overview of existing resilience planning in the region. Education, research, and funding arose as top priorities for advancing resilience in the Quad Cities, according to the interviews conducted as part of this work. Three public input sessions then delved deeper into these specific recommendations soliciting stakeholder feedback on the key priorities.

Below we outline nine specific recommendations identified and prioritized in the public input sessions to support education, research, and funding for advancing climate resilience. These recommendations are intended for various stakeholders, ranging from small communities to city-wide decision-makers. They emphasize the importance of support through interdisciplinary partnerships that can leverage planning, funding, and technical resources.

Education

To build resilient communities that can develop and implement projects and withstand projected climate changes and extreme events by:

1. Building community resilience and program cohesion through comprehensive planning efforts. Examples could include a Quad Cities Climate Resilience Plan and/or Quad Cities Climate Action Plan rooted in principles from the Mississippi River Equity Vision. Employ Community Resilience Champions to discuss, share, and transfer knowledge and opportunities.

2. Supporting climate training and place-based learning for schools, technical experts, and other audiences. Outreach and behavioral interventions, particularly to local youth, to improve climate change and resilience understanding through community centers, churches, local resources, and social media/media outlets.

3. Enhancing collaboration and coordination through education to align city officials, policy and conservation experts, nonprofits, and philanthropic interests, specifically looking at projects to increase equitable access to natural resources and form ecological corridors to enhance resilience and increase biodiversity.

4. Focusing on education to foster advocacy for regulatory and policy initiatives supporting both local and statewide planning initiatives, such as the Illinois State Water Plan.

Research

To support an enhanced understanding of climate change, nature-based projects, and eventually, project identification by:

1. Collecting baseline climate information on future projections that builds on this assessment and includes community leaders from the areas most adversely affected by climate change in the conversations.

2. Identifying on-the-ground projects and quantifying their benefits for reducing climate hazard risks and supporting community resilience.

Funding

To invest in a climate-resilient future and safeguard natural features, communities, and wildlife by:

1. Supporting research and education efforts (as outlined above) based on community needs and priorities.
2. Planning for project identification that results in community-led and community-preferred nature-based solutions.
3. Implementing nature-based solutions through a combination of interdisciplinary stakeholders including natural resource managers, technical experts, social scientists, hazard risk/resilience managers, non-profit partners, and community leaders and members.

Education, research, and funding do not happen in silos and many of these recommendations should work in parallel or be complementary to each other. Due to limited funding availability, communities may need to prioritize what is feasible within the time and resources available. Through stepwise planning, communities can strategically pursue available funding while building momentum for future funding and larger-scale resilience solutions. It is important for the communities of the Quad Cities to look upstream and identify where water quality and flooding challenges emerge and how natural features, such as wetlands, can be beneficial in these areas that impact downstream communities.

Implementing these solutions will require broader support and momentum beyond the Quad Cities. Moving from planning to implementation was the most common gap identified during the public input session. Stakeholders were interested in specific ideas and plans for implementation that are most viable for the region. While this assessment is not a prescriptive tool or plan, the identified recommendations lay the foundation for moving towards project identification and implementation. Through understanding their own climate risks compounded by climate change, Quad Cities community members and leaders can determine their resilience vision and play an active role in advocating for these approaches at both the local and state level.

5.3. Conclusion

The Quad Cities' climate is changing. Climate models predict wetter, hotter conditions, leading to an increased risk of extreme events, like flooding and intense heat. In addition to environmental detriments, critical transportation infrastructure, public health and safety, and the economy are directly threatened by climate-induced flooding and heat.

The purpose of this climate assessment is to equip the Quad Cities' communities and leaders with important information about the local impacts of climate change. The goal is to empower communities to identify and pursue greater investments that foster long-term community resilience, including through nature-based solutions when suitable. While nature-based approaches are not a cure-all solution, they are a valuable tool for sustainability. Modeling has shown their effectiveness at reducing high flow and increasing water infiltration into the ground, which can help reduce flood risk. It is critical, however, to co-create and implement solutions with community members, tailoring projects to local needs and desires.

Quad Cities community members are interested in understanding and addressing climate change impacts in their region. During the public input sessions, stakeholders identified several potential uses of this climate assessment including:

- Utilizing findings to apply to grant funding or advocate for nature-based solution initiatives in their communities.

- Communicating with policy and decision-makers the urgency of implementing nature-based solutions as part of a comprehensive solution.
- Understanding how city infrastructure and future business developments will further exacerbate climate risks and how these impacts will affect surrounding communities.
- Advocating for the creation of jobs specific to nature-based solutions (i.e., ensuring qualified contractors are available to assist homeowners and businesses with nature-based solutions).
- Serving as an educational resource that emphasizes the opportunity for nature-based solutions within various communities, businesses, and media outlets.
- Supporting a broader analysis that looks upstream to rural and agricultural impacts and opportunities.

Historically, not all communities have been included in planning, designing, and executing projects impacting their resilience. If not implemented with careful community engagement, even nature-based projects, while environmentally beneficial, can have unintended negative consequences, like gentrification and displacement of primarily socially vulnerable communities.

Increased participation of and partnership with local stakeholders as community experts at every stage of planning - including implementation and stewardship - lead to more equitable outcomes that align with local preferences. The Mississippi River Equity Vision is an example of a Quad Cities-crafted document that attempts to align stakeholders in the pursuit of a clean and sustainable Mississippi River, drawing on the lived experience of underrepresented and historically marginalized community members. The document provides additional implementation ideas based on various priorities, including increasing equitable river access, improving water quality, and integrating Indigenous and Western conservation practices. In a complex, multi-jurisdiction and two-state expanse, the Mississippi River Equity Vision aims to promote behavior change and unite the region by providing community-informed aspirations for ongoing and future planning efforts.

While the Quad Cities faces complex and growing climate challenges, community interest and opportunities are palpable. Ongoing efforts, from community- to regional-driven plans, are working hard to address these challenges. This assessment hopes to be an additional resource in leveraging science and community to build and maintain a more resilient Quad Cities for all.

A child plays in a meadow in Iowa. (NWF)

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APPENDIX A: MODEL CALIBRATION AND VALIDATION

The model is calibrated using the historical precipitation from 1983 to 2014 wr.t stations: 05448000, 05420500, 05422470, 05446500, 05447500, daily timescales. Missing data are filled using AEMO methodology proposed by Budamala et al. (2023). The model performance metrics are: RMSE (12.7%), NSE (0.76), MBE (18%), and RSR (0.43). The model falls under the satisfactory range as per goodness of fit approach. When the model is simulated for the 2015 flood event, the flooding scenario generated from the model showed flooding at many locations in and around Quad Cities. These locations are further validated with social media and newspaper reports.

Model Performance based on Observed Data

Year	Station ID	Correlation Coefficient	RMSE (%)	NSE	PBIAS (%)	Acceptable Range	Model Status
	05448000	0.24	12.76	0.78	9.18	0.00<NSE<0.5 0, PBIAS>25	Very Good
	05420500	0.73	11	0.81	5.14	Inadequate Model 0.5<NSE<0.65, 15<PBIAS<25	Very Good
1983-2023	05422470	0.47	21.57	0.91	8.36	Good Model	Very Good
	05446500	0.69	4.769	0.71	18.25	0.65<NSE<0.75, 10<PBIAS<1 Fair Model	Good
	05447500	0.56	7.94	0.7	17.12	0.75<NSE<1.00, 0<PBIAS<10 Very Good Model	Good

APPENDIX B: DAILY PRECIPITATION TIME SERIES FOR BETTENDORF, MOLINE, AND ROCK ISLAND

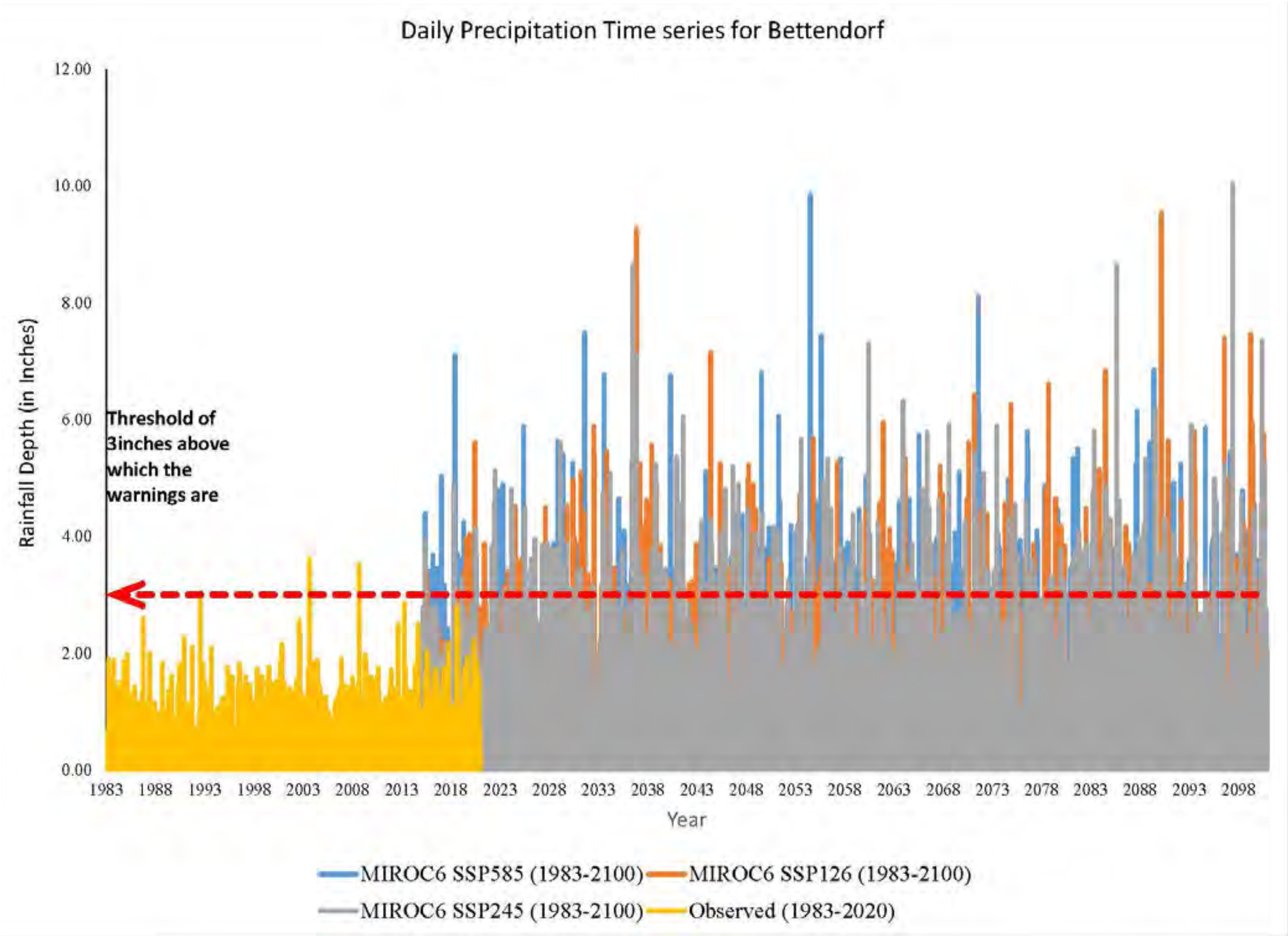

Figure 1. *Trend of daily precipitation for Bettendorf: low emission scenarios (SSP126; orange); intermediate emissions scenarios (SSP245; gray); very high emission scenarios (SSP585; blue). The values above the threshold are critical and are considered as warnings for floods in flood model development.*

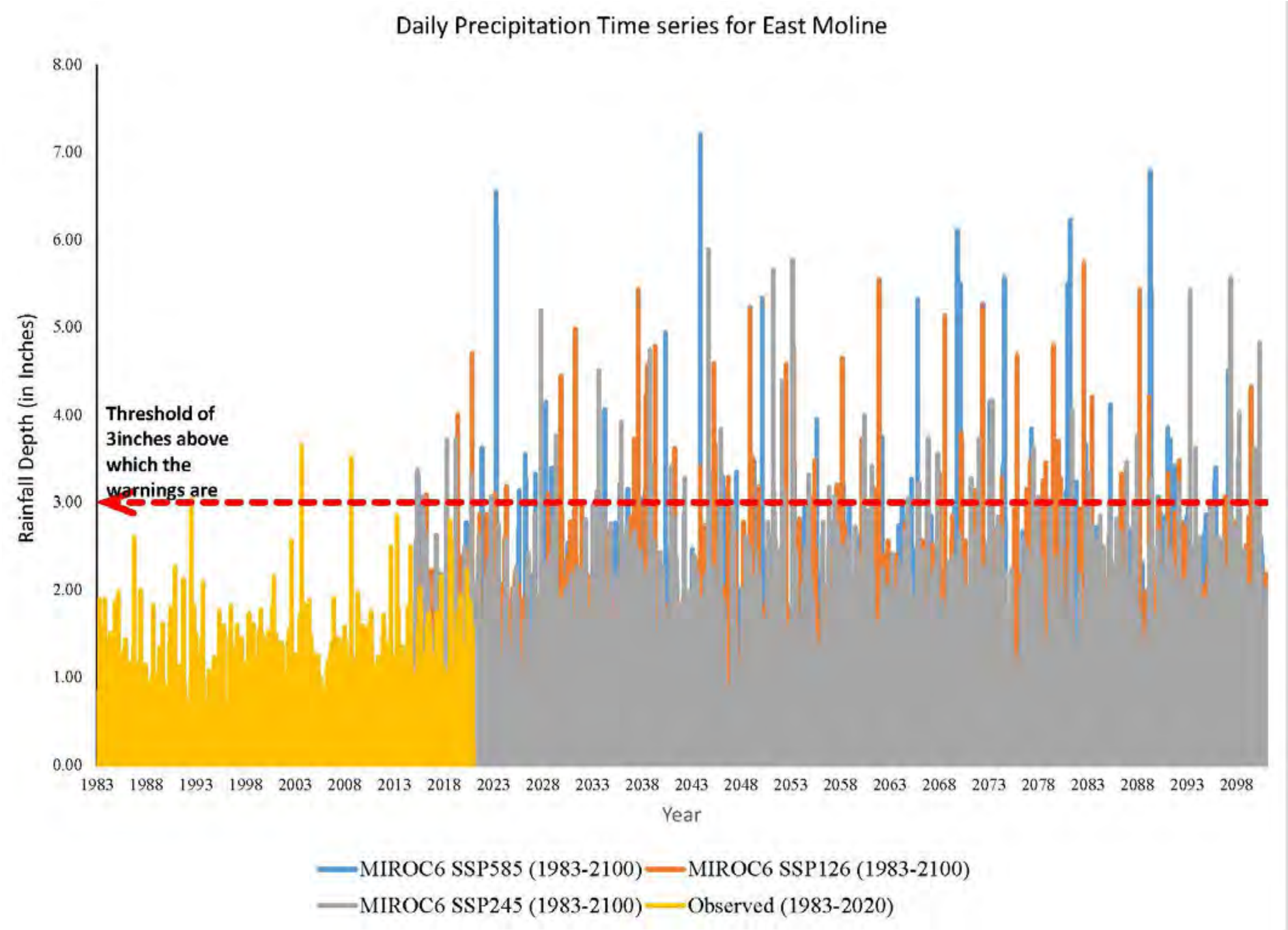

Figure 2. *Trend of daily precipitation for Moline and East Moline: low emission scenarios (SSP126; orange); intermediate emissions scenarios (SSP245; gray); very high emission scenarios (SSP585; blue). The values above the threshold are critical and are considered as warnings for floods in flood model development. Tributary flooding also plays an important role in flood model development and cumulative impacts are analyzed in flood model development. Note: East Moline data includes Moline.*

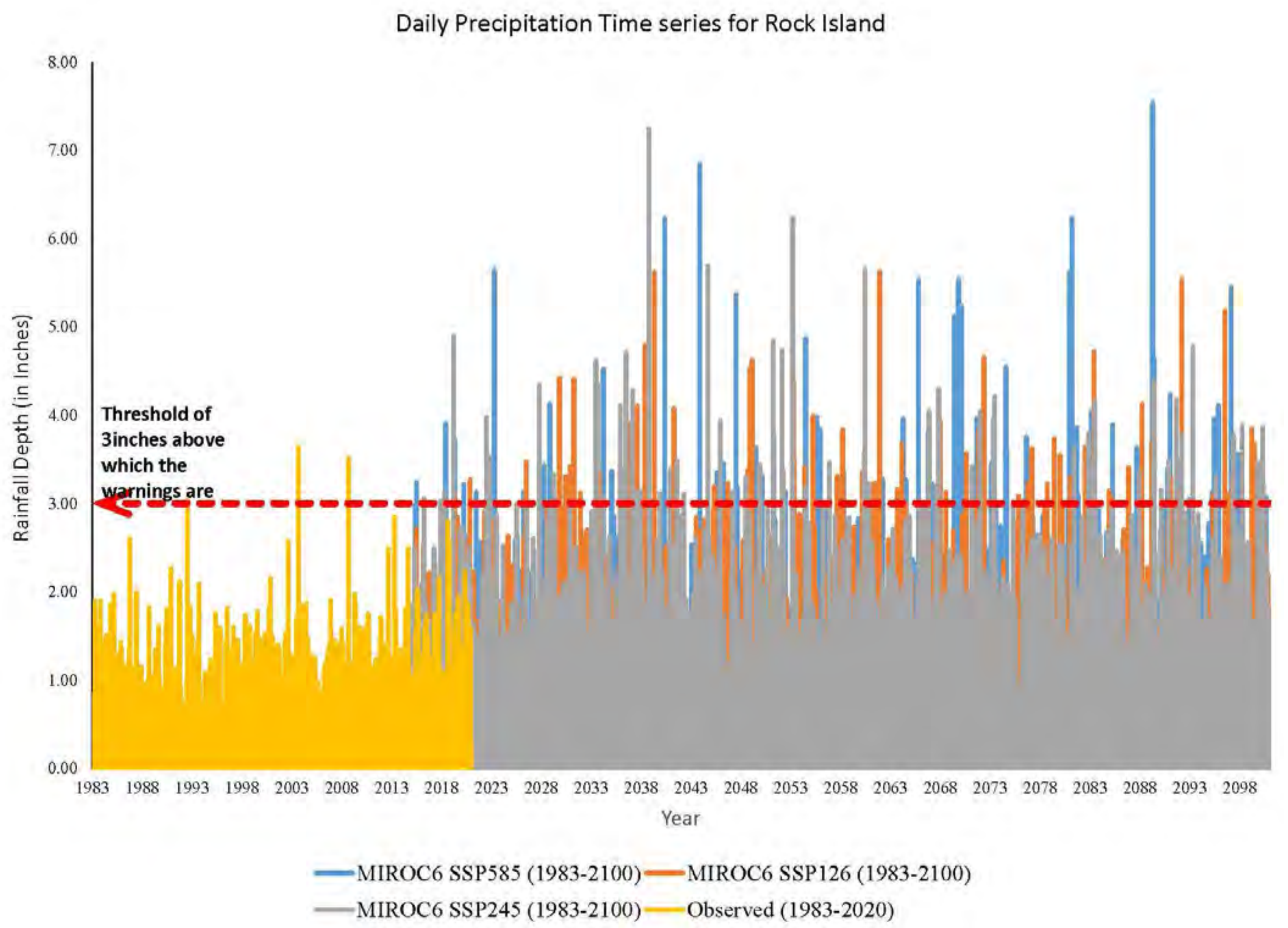

Figure 3. *Trend of daily precipitation for Rock Island: low emission scenarios (SSP126; orange); intermediate emissions scenarios (SSP245; gray); very high emission scenarios (SSP585; blue). The values above the threshold are critical and are considered as warnings for floods in flood model development. The Rock Island region will also be impacted by upstream regions in the Quad Cities. The cumulative impact is further shown in flood model outputs.*