Climate Risk & Vulnerability Assessment

City of South Bend

Summer 2023

INDIANA UNIVERSITY
ENVIRONMENTAL RESILIENCE INSTITUTE

OFFICE OF SUSTAINABILITY
SOUTH BEND, INDIANA

GEOS INSTITUTE

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Executive Summary

Introduction

From flooding to drought, reduced air quality, and extreme heat, South Bend has already been confronted with a changing climate. Understanding how climate change might exacerbate South Bend's risks and vulnerabilities to extreme weather is crucial to designing, developing, and delivering strategic solutions to achieve our vision of health, resilience, and sustainability. The Climate Risk and Vulnerability Assessment (CRVA) sets the stage for community discussions about how these issues may be addressed in the future.

Preparing for climate change is not an easy task — it requires action by every member of the community, as well as government, businesses, organizations, and others. The threat of climate change also presents us with opportunities. South Bend is in a position to harness its innovation, compassion, diversity, and strong community networks to make serious and systemic changes. Identifying the vulnerabilities that South Bend may be exposed to allows future actions to be prioritized so that our community members and future generations are protected.

What is Vulnerability?
The degree to which diverse systems including the built, natural, economic, social, and cultural environments of our community are at risk of being adversely affected.

Vulnerability encompasses a variety of elements including high sensitivity and lack of capacity to cope and adapt.

The CRVA report is based on local community values and reflects the expertise of residents, leaders, educators, and researchers from a workshop and survey that provided community input and feedback throughout the process. The Office of Sustainability's mission is to mobilize the community to address the climate emergency – through community collaboration we have identified, prioritized, and developed climate risks and vulnerabilities specific to South Bend.

South Bend's Changing Climate

Climate change may be a global phenomenon, but the impacts are felt at the local level. The region is expected to experience substantial impacts brought on by climate change. These impacts affect all sectors of our community, including human health, natural resources, infrastructure, emergency response, the economy, and others. Those who are already vulnerable in our community will be impacted the most.

Climate Trends Snapshot – South Bend

	HISTORICAL TRENDS (1950-2005)	MID-CENTURY PROJECTIONS (2034-2066)	LATE-CENTURY PROJECTIONS (2067-2099)	LATE-CENTURY PROJECTIONS *with reduced emissions*
Average annual temperature [3]	50° F	↑ 51.9° F to 59.4° F	↑ 54.8° F to 64.6° F	↑ 51.8° F to 60° F
Maximum temperature [4]	95.4° F	↑ 98.6° F to 107.8° F	↑ 99.9° F to 114.7° F	↑ 97.9° F to 108.3° F
Average daily minimum temperature [5]	40° F	↑ 42.2° F to 49.7° F	↑ 45.2° F to 55° F	↑ 42° F to 50.2° F
Average number of days per year above 95° F [4]	2	↑ 7 to 52	↑ 11 to 94	↑ 5 to 63
Number of days per year below freezing [4]	45	↓ 5 to 46	↓ 1 to 35	↓ 3 to 45
Snow Water Equivalent (in) [3]	0.4 in	↑↓ 0.0 in	↑↓ 0.0 in	↑↓ 0.1 in
Average annual precipitation (in) [3]	40"	↑↓ 29" to 56"	↑↓ 30" to 58"	↑↓ 29" to 57"
Annual days with precipitation over 1" [4]	4.2	↓ 4.2 to 7.5	↓ 4.9 to 10.4	↓ 4.2 to 7.7
Dry Days [4]	172	↑ 166 to 198	↑ 163 to 217	↑ 165 to 189

Table 1. Summary of climate trends expected for South Bend. Data from Climate Toolbox [3], CMRA [4], and Climate Explorer [5]. Refer to citations from section *Climate Change Trends Summary*.

Climate Equity and Our Community

Climate change threatens our people, resources, and overall quality of life, including the features and values that create our vibrant community. Community members value South Bend's friendly and kind environment, location, vibrancy, and opportunity.

While climate change affects everyone in the community, it impacts some residents far more than others. Climate change exacerbates many existing stressors related to health, income, and housing quality and availability. The impacts outlined in the CRVA address vulnerabilities to the entire community, with a focus on the needs of those on the frontlines.

Figure 1. Climate Action Workshop June 2023

Figure 2. South Bend Green Drinks at Pearl Park

Climate Vulnerabilities

This plan examines the climate vulnerabilities across five community systems: Transportation and Infrastructure, Natural Systems, Business and Economy, Health and Emergency Management, and Community Culture. Some of South Bend's top identified vulnerabilities include:

- **Storm recovery and resilience from a disruptive event (flooding, severe storms) potentially disrupting labor workers and low-income families**
- **Burden on public transportation system and riders under extreme heat circumstances**
- **Populations in the floodway at extreme risk if dam failure occurs from overtopping caused by heavy flooding**
- **Impact on historically native species from an increase in invasive species to the area**
- **Lack of affordable housing puts low socioeconomic, homeless, elderly, and middle-income populations at risk when faced with increasing energy bills, flood damage, and climate migration**
- **Urban forestry and shifting native species ranges**
- **Increased inequity in public health burdening low-income families and the health system**
- **Limited outdoor activity due to extreme heat affecting child development, outdoor workers, homeless, and tribal communities**

Introduction

South Bend is already experiencing the impacts of climate change with more extreme heat and flooding. Reducing greenhouse gas emissions is critical to avoid locking-in more extreme climate impacts. South Bend has adopted aggressive greenhouse gas emissions targets that reflect the seriousness of the challenge. South Bend has committed to reducing emissions by 45% by 2035. By 2050, all energy will be renewable.

Efforts to cut greenhouse gas emissions must go together with action to prepare for the changes that are already taking place. South Bend conducted the CRVA to determine the risks climate change poses and guide future steps to increase city resiliency.

A more resilient community will be better able to withstand and bounce back from extreme events, such as more intense heat waves, flooding, and drought. Climate action must also include the creation of thriving and resilient neighborhoods, families, businesses, cultural and faith communities, food systems, infrastructure, and other key community components.

Whole Community Resilience

Climate change affects everyone and everything in our community at the same time. As people start to make changes to adapt to climate change, some of these changes can have unintended consequences. Close coordination and communication are needed to prevent redundancy or conflicting actions. People will need to work together to ensure all sectors and populations of South Bend are protected.

***Figure 3* outlines the steps to creating Whole Community Resilience. The CRVA is step 3 of South Bend's process in updating the Climate Action Plan originally released in 2019. Following the CRVA are developing resilient strategies, creating the plan, implementing, and reassessing as needed to fit the needs of the South Bend community.**

Figure 3. The Whole Community climate resilience planning framework.

Stakeholder Workshop

Subject matter experts from a diversity of community sectors came together to identify vulnerabilities. In the workshop, participants reviewed future climate change projections and then identified and prioritized climate impacts across the five community systems: Built, Natural, Economic, Cultural, and Social. This workshop allowed the Office of Sustainability to understand what community leaders want to focus on in a changing climate. This information was also combined with broad public input collected via surveys.

In spring of 2024, the same stakeholders will be invited to give feedback on collaborative strategies developed to address the vulnerabilities identified in the first workshop. These strategies, along with input from the broader public, will form the foundation of the adaptation portion of South Bend's Climate Action Plan 2024.

Figure 4. Stakeholder workshop in July 2023

Mitigation vs. Adaptation

Mitigation: Efforts to reduce or prevent emissions from burning fossil fuels such as coal, oil, and natural gas

Ex. Reduced energy use, clean energy and transportation transition, increased tree canopy

Adaptation: Adjusting to the effects of climate change and preparing for projected impacts

Ex. Disaster preparedness, resilient buildings, green infrastructure, increased tree canopy

Community Surveys

Surveys were distributed across the community in a virtual format through The Office of Sustainability's Climate Action Ambassador program. 14 community leaders in the 2023 spring cohort hosted one-hour events to assist a group of participants in filling out the climate action survey: available in both English and Spanish. The survey now has over 450 responses. As results came in, it was evident that the most important focus for the update to the Climate Action Plan is the effect on human health and building equity across race and class. Survey participants have already seen climate changes take place in South Bend.

62% of survey respondents have already noticed an increase in average temperatures and record-breaking heat waves in South Bend.

Using This Report

This report provides information on the past and future climate trends of South Bend, an overview of the community, and information about the climate vulnerabilities across all sectors of the city. The Climate Action Plan 2024 will include the specific goals, strategies, and actions South Bend will use to address those vulnerabilities. It is important to note that this report represents an understanding of South Bend at one point in time. The information in this report should be used as a starting point for building climate resilience, with regular updates and revisions over time.

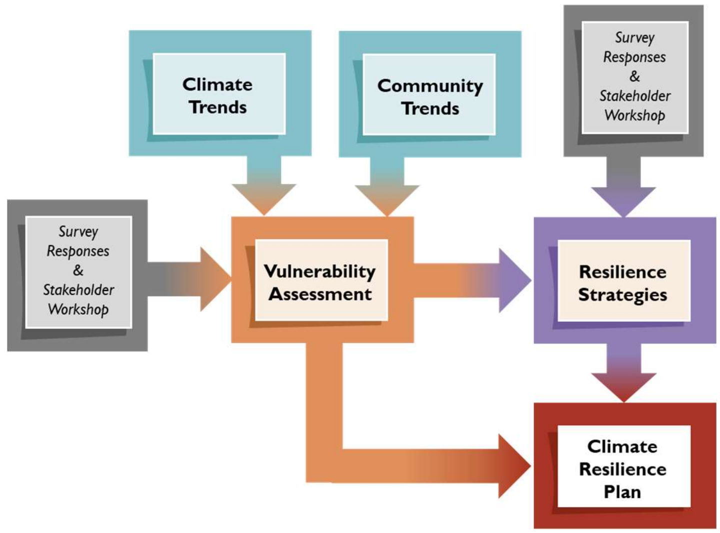

Figure 5. The components that comprise this report and future planning

This Vulnerability Assessment report is divided into three primary sections:

1. **Climate Trends**
2. **Community Trends**
3. **Climate Vulnerabilities**

Each section builds on the information from the previous, ensuring that the resulting strategies will be based on the best available information and address local priorities. This robust list of climate vulnerabilities was developed in collaboration with the community. The vulnerabilities are ranked by certainty, sensitivity, and adaptive capacity, which form the base of the *vulnerability index*.

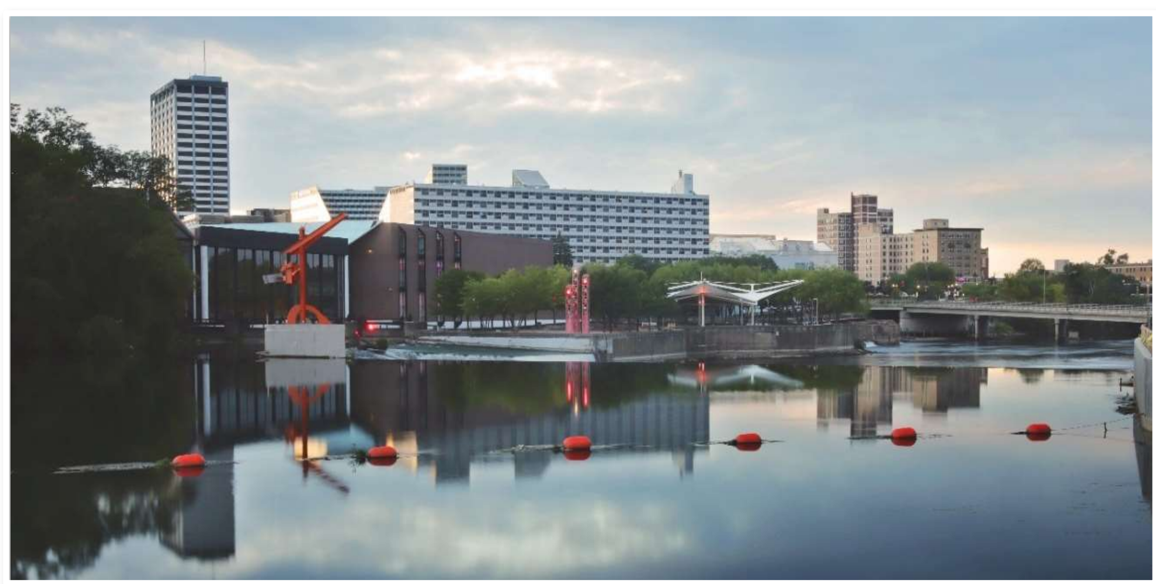

Figure 6. The City of South Bend from the St. Joseph River

Connecting Past and Present

The Climate Action Plan 2024 will build upon our efforts to date. As we look to the future, climate change will need to be considered in all decisions. In that consideration is the opportunity to plan for climate impacts in ways that make our community more equitable for people of different income levels and backgrounds.

South Bend's young people face a future very different from the past, with warmer temperatures, new precipitation patterns, and a faster rate of change. We have a responsibility to prepare for this future by building resilience across all parts of the community to allow people and nature to respond and adapt in positive ways.

Figure 7. 5-year timeline of sustainability efforts from the City of South Bend

South Bend has shown a commitment to addressing the climate emergency since 2008 when Mayor Stephen Lueke was one of 1,000 mayors across the country to sign the US Mayors Climate Protection Agreement. In 2014, Mayor Pete Buttigieg expanded the Energy Office into the Office of Sustainability. Efforts through the decade by both previous leaders led to the mayor's commitment to the Global Covenant of Mayors for Climate and Energy in 2018.

In 2019, the Office of Sustainability published its first climate action plan: Carbon Neutral 2050 that focused solely on mitigation efforts, reducing pollution in the energy and transportation sectors, the highest emitting sectors in South Bend. Since that point, the Office has relocated to the Department of Community Investment and installed numerous programs. Energy Assistance and Solar Savings Initiative (EASSI) is an ongoing program that assists community organizations in completing energy efficiency and/or solar projects. Upskill SB provides funding for residents to receive certifications in climate-focused up-skilling in fields of solar, energy efficiency, and sustainable building design. Other programs include Vibrant Places, Climate Action Ambassadors, and Smart Businesses Recycle.

Advancing Climate Equity

Climate change does not affect all residents evenly. Many people experience more severe impacts than others. Those who are most impacted often contributed the least to the problem. Climate inequities stem from the existing unequal distribution of social, political, and economic power.

Preparing South Bend for the impacts of climate change requires significant investment of time and resources across all parts of the community, including businesses, health, schools, infrastructure, community culture, and natural resources. Investments in climate solutions need to support and empower those who are most at risk. Unless climate equity is prioritized from the beginning, and power disparities recognized throughout the process, climate planning will likely default to existing inequitable and exclusionary patterns and approaches and prevent real progress.

Figure 8. Climate Action Workshop at South Bend Civil Rights Heritage Center in June 2023

What is Climate Equity?

Climate equity is a framework, a goal, and a process. It asks that the diversity of histories, abilities, and needs across community members be accounted for in the design and implementation of climate change solutions. Residents of South Bend have differing levels of ability to protect themselves from impacts. As climate change progresses, important work on social and environmental justice will increasingly need to focus on climate impacts.

Many residents of South Bend are disadvantaged due to lower income, race, language, gender, LGBTQ+ status, mobility, disability, housing status, health condition, age, etc. By engaging and empowering disadvantaged residents to take on leadership roles and become the recipients of much of the investment in climate resilience, existing inequities can begin to be corrected. All residents of South Bend benefit when those who are most vulnerable become more resilient and empowered.

More information about those on the frontline of climate change impacts in South Bend is included in the *Community Trends* section.

Equitable climate action must address historically disadvantaged and/or marginalized groups or populations by:

1. **Actively seeking direction**
2. **Prioritizing investment**
3. **Reducing stressors and preventing new stressors**
4. **Shifting power**

Climate Change Trends Summary

Climate change may be a global phenomenon, but the impacts are felt at the local level here, and all around the world. These impacts affect all sectors of our communities, including human health, natural resources, infrastructure, emergency response, and the economy.

South Bend's Climate is Already Changing

Climate change is impacting the city in many ways, primarily through flooding and heat waves. The city has experienced multiple flood events in recent years. In February 2018, the St. Joseph River crested at a historic 12.7 feet[1]. The city suffered flood damage to five pedestrian trails and its water filtration system, North Pumping Station, in Leeper Park. The wastewater treatment plant was inundated and had to shut down, with collected sewage bypassing the plant and directly discharging to the river. The city spent about $157,400 to remove flood debris, stabilize the river's banks, and repair pumps and electrical systems[1]. The impact of that single river flooding event led to the damage of nearly 2,000 homes across the region[1]. $1.2 million total was spent on flood repairs in 2018. The flood was considered a 2,400-year extreme flood event. The flood in 2016 was considered a 500-year extreme precipitation event that led to significant flooding and property damage. Extreme heat is also a growing challenge as we have an increasing number of days over 95°. The west side of South Bend in particular experiences greater heat island effect leading to much higher and disproportionate temperatures in the summer.

The average annual temperature in South Bend has already increased 1.7° F from the 1950s to present day[2]. Average precipitation in South Bend has increased by 4.6" from the 1950s to present day[2] and snow water equivalent in snowfall has decreased approximately 0.2" from a historical base. Lastly, while wildfires are not familiar to South Bend, the effects of them from surrounding states may increase the number of air quality action days announced in the region.

Figure 9. South Bend Tribune storm track during 2018 flood event

Future Climate Change in South Bend

Atmospheric scientists created models that help us predict future climate. These Global Climate Models (GCMs) were adjusted to the local scale and help us understand how South Bend will be affected. South Bend's climate is expected to continue to change. If greenhouse gas emissions are reduced, this change is expected to level off in the mid-century. The Climate Trends Snapshot (Table 2) highlights the expected changes for continued business-as-usual emissions and reduced emissions.

Climate Trends Snapshot – South Bend

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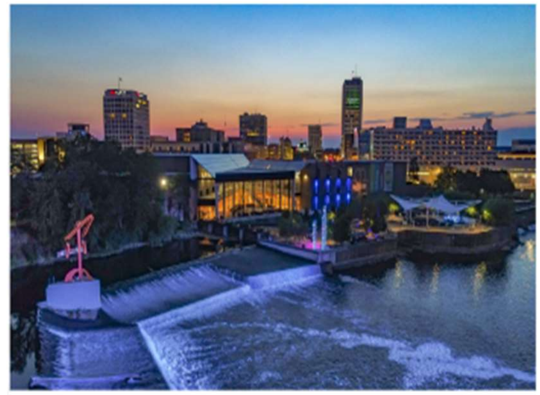
Table 2. Summary of climate trends expected for South Bend. Data from Climate Toolbox [3], CMRA [4], and Climate Explorer [5].

Community Trends Summary

Climate change threatens our people, resources, and overall quality of life. As South Bend works to develop a plan that will ensure long term climate resilience, it is important to identify the features and values that create our vibrant quality of life.

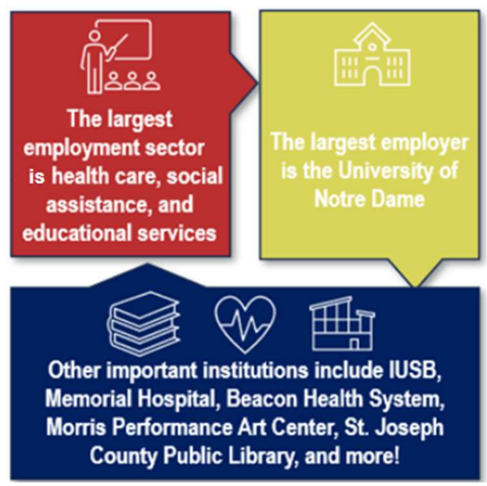


(https://www.visitsouthbend.com/)

This overview of basic community systems in South Bend provides a snapshot of how the community and its surrounding area function at the time this report is written. It was intended to support the climate change vulnerability assessment workshop process, and lead to robust strategies. More information about these community trends can be found in *Appendix 2: Community Trends.*

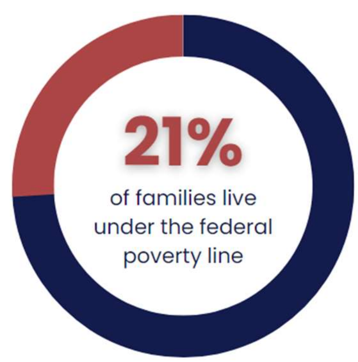
People and the Economy

- South Bend's population of 103,453 has increased 2.26% from its 2010 count of 101,168[6]
- 58.1% of residents identify as White, alone, 25.2% identify as Black or African American, alone, and 15.8% identify as Hispanic or Latino[6]
- The largest employment sector is Health Care, Social Assistance & Educational Services
- 20.9% of families are under the federal poverty line[6]
- Disadvantaged populations in South Bend include low-income neighborhoods, non-English speakers, people with disabilities, people without health care, and others



Nature and the Environment

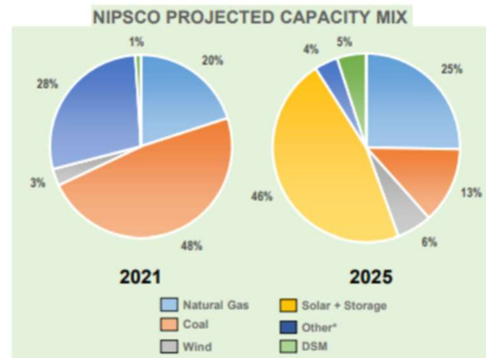
- The St. Joseph River flowing through downtown is prone to flooding during heavy rain events
- Climate change is increasing flood risk in the community
- Air quality will worsen from heat, second-hand wildfire smoke, ozone, and particulate matter



Water and Energy

- The city has combined stormwater and sewage sewers that will overflow into the river to help prevent sewage from backing up into people's homes[7]
- South Bend Municipal Utilities utilizes groundwater from the St. Joseph Tributary Valley System and St. Joseph and Hilltop aquifers as its sources for drinking water [7]

- Majority of residents and businesses get electricity from Indiana Michigan Power and NIPSCO, and natural gas from NIPSCO[8]
- The St. Joseph River provides hydropower energy to Notre Dame and offsets 9,700 tons of carbon dioxide annually, benefitting the university and surrounding community[9]
- Ongoing commercial and residential solar projects exist within the community



(NIPSCO 2021 Integrated Resource Plan)

Cultural Resources

- Cultural landmarks are showcased in The History Museum
- Historical landmarks include the Oliver Mansion, the Kizer House, the Birdsell Mansion, Copshaholm House Museum, and Rose Morey Lamport House
- South Bend land was first inhabited by the Potawatomi and Miami tribes. They occupied the area until the majority were forcibly removed in the 1840s[10]
- South Bend was an ideal location to settle due to its proximity to the Kankakee River that flowed into the Illinois River and then into the Mississippi[10]
- The Pokagon Band of Potawatomi's Community Development division wants to promote tribal development while protecting Mother Earth

(https://southbendin.gov/)

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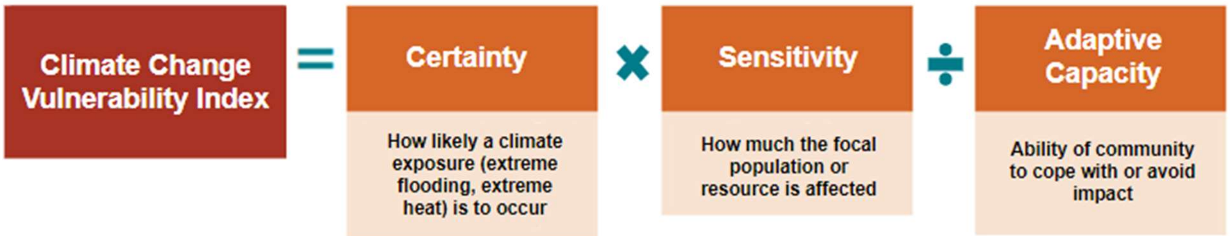
Climate Change Vulnerabilities

Climate impacts affect every person, structure, business, natural resource, and organization in South Bend. And yet, some will be impacted far more than others. Vulnerability depends on many factors, including ongoing stressors, potential climate impacts, and existing adaptive capacity.



This plan examines the vulnerabilities across five community systems:

Transportation and Infrastructure – **this includes all the built elements in the community such as stormwater, wastewater, and drinking water systems; transportation networks like roads and railways; energy production and distribution; communications towers; and homes, businesses, and other buildings.**

Natural Systems – **this includes all the aquatic and terrestrial ecosystems in our community. These may be public lands or privately owned, and include urban greenways such as parks, tree lawns, and residential yards.**

Business and Economy – **this includes the economic drivers of the community such as small business owners, large industry, agriculture, commercial spaces, recreation, and tourism.**

Figure 12. Solar Panel project site from EASSI program

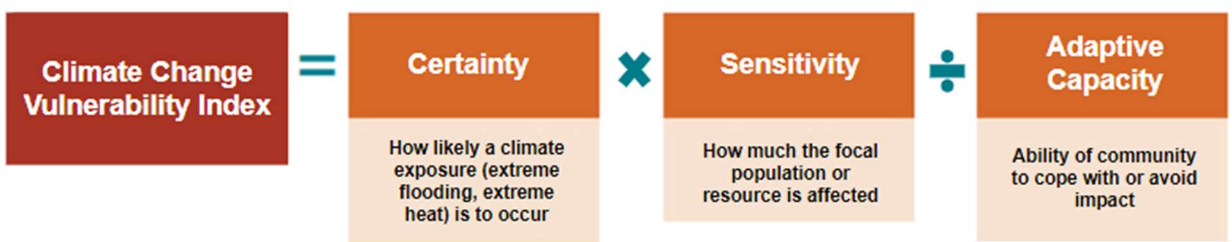
Health and Emergency Management - **this includes the health care system, law enforcement, emergency response services, and under-represented populations such as communities of color, people with disabilities, youth, elders, low-income workers, and those experiencing homelessness.**

Community Culture – **this includes education and schools, and all the specific ways that make a community special and feel like home to its residents, such as faith communities, civic organizations, local cultural groups, festivals, and events. This also includes any specific cultural practices or needs of the indigenous people in our community, as well as any immigrant populations.**

Climate Change Vulnerabilities in South Bend

Local experts from diverse sectors of the community created a list of impacts that the community may face under a changing climate. They identified a focal population or resource to the impact, then gave a rank to the sensitivity of the impact on that population. Next, they ranked the adaptive capacity of the city's ability to avoid or cope with the impact. These ranks were used to calculate a vulnerability index which determined the ranking of the top 10 vulnerabilities across five different community systems. For more information and details on this process, see *Appendix 3: Climate Vulnerability Assessment*.

Table 3. **The following populations and resources were identified as vulnerable to climate change. The vulnerabilities listed have been prioritized from a longer list based on certainty, sensitivity, and adaptive capacity. This list is not representative of all impacts identified during the workshop, and more impacts beyond this list will be considered during the strategy development phase. See *Appendix 4: Brainstormed Impacts from Workshop* for an unrefined list of all identified vulnerabilities.**



Rank	Impact	Focal Population(s)	Climate Hazard(s)
Based on climate change vulnerability index score	How the climate exposure affects the population or community	The population(s) or resource(s) most at risk to the impact	The specific climate trend or projection that is already causing or is expected to cause the impact

Severe Heat

Larger Storms

Increasing averages of temperature and precipitation

Flooding

Rank	Impact	Focal Population(s)	Climate Hazard(s)
1	Dam failure caused by overtopping during heavy flood event	Population in floodway	
2	Bank destabilization	People and infrastructure located on high banks	
3	Urban forests species may not be viable under future projections	Low-income; city landscape; wildlife species	
4	Extreme heat/heat index impact to homeless population and general population	Low-income; homeless; public transit riders; disabled; pre-existing health conditons; everyone	
5	Storm recovery and resilience from a disruptive event	Low-income; labor workers	
6	Increased inequity in public health	Low-income	
7	Invasive species increase causing impact to historically native species	Native species; sensitive species; endangered species	
8	Residential cooling demand and capacity	Low-income and elderly populations	
9	Child development affected by less time outside and participation in outdoor sports and activities	Youth	
10	Spread of pests and disease (ticks, plant diseases, etc.) that affect natural vegetation, street trees, gardens, and crops	Wildlife; city landscapes; humans	

Table 3. Top 10 impacts ranked by vulnerability index score

Conclusion

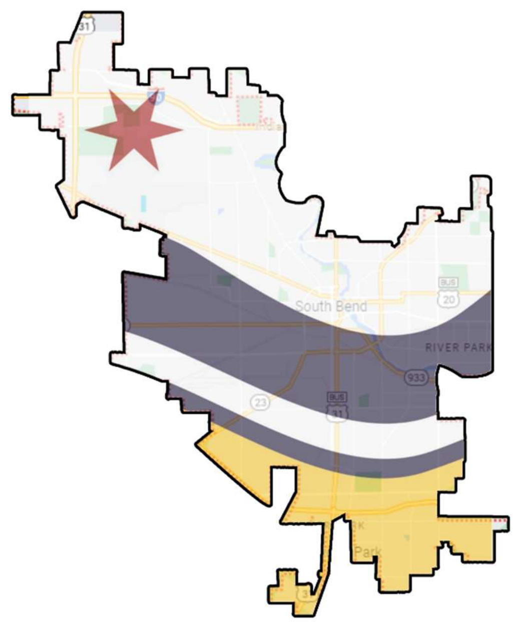
Taking the results from the CRVA, the Office of Sustainability will work to collaborate with stakeholders and leaders from the city and community to design resilient strategies. Strategies developed will include action steps and solutions to combat climate impacts South Bend may face in the near future. In the spring of 2024, the same participants from the first workshop will be invited to give feedback on collaborative strategies developed to address the vulnerabilities they identified.

Appendix I: Climate Change Trends Primer

People around the world are experiencing changing conditions that affect their daily lives. Many changes are due to human-caused climate change, resulting from combustion of fossil fuels and deforestation. Climate change is a global problem, yet the impacts and opportunities for action are local. As climate change accelerates with continued greenhouse gas emissions, local communities will need to be prepared for impacts and take action to protect people and the natural resources they depend on. Like other parts of the U.S., South Bend is experiencing rapid change in climate, and people are seeking strategies to increase safety, wellness, and resilience.

In South Bend, residents report local impacts and changes in water and air quality, seasons, and extreme events like heat waves and flooding. These changes can affect peoples' health, culture, and livelihoods. Local infrastructure such as roads and bridges are also at risk from severe heat, storms, and flooding. Many changes are already occurring, and more are expected to occur in the future.

If global action to greatly reduce greenhouse gas emissions is taken quickly, the long-term severity of climate change will be reduced, and local strategies to adapt will be more successful. In the near term, because of long-lasting greenhouse gases already emitted, drastic change will continue over the next few decades. Local action and planning to reduce the impacts of climate change are needed.



This climate change primer provides information on the expected trends and impacts specific to South Bend (Figure A1-1). Understanding climate change trends and impacts is the first step in identifying climate related risks and vulnerabilities. The next step will be to develop strategies that build overall resilience for both the people and natural resources of the region.

Climate change data and models

The Earth's climate is regulated by a layer of gases commonly referred to as greenhouse gases for their role in trapping heat and keeping the earth at a livable temperature. These gases include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and water vapor (H_2O). CO_2 plays an especially large role due to its long-lasting nature and amount compared to other gases. The atmospheric concentration of CO_2 has risen from 280 to more than 415 parts per million (ppm)[3] in the past century, driven largely by the burning of fossil fuel, deforestation, and other human activity.

Information from ice cores allows us a glimpse into CO_2 levels over hundreds of thousands of years. This data shows us that CO_2 has fluctuated between about 175 and 300 ppm over the last 800,000 years and the current level is far above anything detected in that time period. As CO_2 levels changed in the past, changes in temperature tracked closely and we can expect this relationship to continue in the future as CO_2 and other greenhouse gases continue to increase.

For over a century, we have known that increases in the concentration of greenhouse gases in the atmosphere result in warmer temperatures. Long-term tracking data from weather stations and other research support this expected trend. Traditional knowledge from indigenous communities around the globe also indicates that there has been substantial change in conditions over time, especially since the end of the last ice age.

In order to look at projected future climate, we use computer models based on our understanding of the Earth's climate. The Intergovernmental Panel on Climate Change (IPCC), which is made up of thousands of leading scientists from around the world, has created a suite of 25+ global climate models (GCMs) from different institutions with which to predict future trends.

The IPCC models were created independently and vary substantially in their output. Yet most of the uncertainty in future conditions comes not from the models themselves, but from estimating how much action will be taken to reduce greenhouse gas emissions in the future. The different possible greenhouse gas concentrations (called Regional Concentration Pathways, or RCPs), depend on whether the international community cooperates on reducing emissions.

In this report, we provide projections based on a lower emissions pathway where emissions are greatly reduced (RCP 4.5) and a higher emissions pathway where emissions are only slightly reduced (RCP 8.5) which is similar to the current global trajectory.

A note about uncertainty

All models have uncertainty because complex processes are simplified, and assumptions are made about how the Earth's processes work. Therefore, different models show different trends in future climate. How much they agree or disagree with each other gives us information about uncertainty. The uncertainty is similar to other types of models that we use every day to make decisions about the future, including economic models, population growth models, and ecological system models.

Much of the data on future trends in this report are compiled from an "ensemble" or average across many GCMs, which have been adjusted or "downscaled" from the global scale (coarse) to local scales (fine) using climatological data that reflects variation across the local landscape. When ensembles are used, it is important to understand the range of variation among the different models, as it can be quite great. In general, precipitation projections are associated with higher uncertainty (more variation among models) while temperature projections are associated with lower uncertainty (more agreement among models). Also, short to medium-term projections have lower uncertainty than long-term projections.

Global Trends

Global climate is changing quickly compared to past climate change throughout the Earth's history. Larger storms and severe heat waves are increasing in both frequency and severity across most of the world[4].

The hottest year on record was 2016 (Figure A1-1). The average global temperature for 2016 was 1.7° F (about 1° C) above the 20th century average[4]. The last few years have also seen record-breaking, climate-related weather extremes. In the U.S., there were 18 weather- and climate-related events that cost more than $1 billion each in 2022, making it the third largest total on record ($165 billion) since 1980[5].

Models project continued average global warming of 5.0° to 10.2° F (2.8° to 5.7° C) by the end of this century and continued warming for the next two centuries if emissions continue to increase (Figure A1-2)[4]. Because higher latitudes (closer to the poles) warm faster than areas closer to the equator, the United States is expected to warm significantly more than the global average.

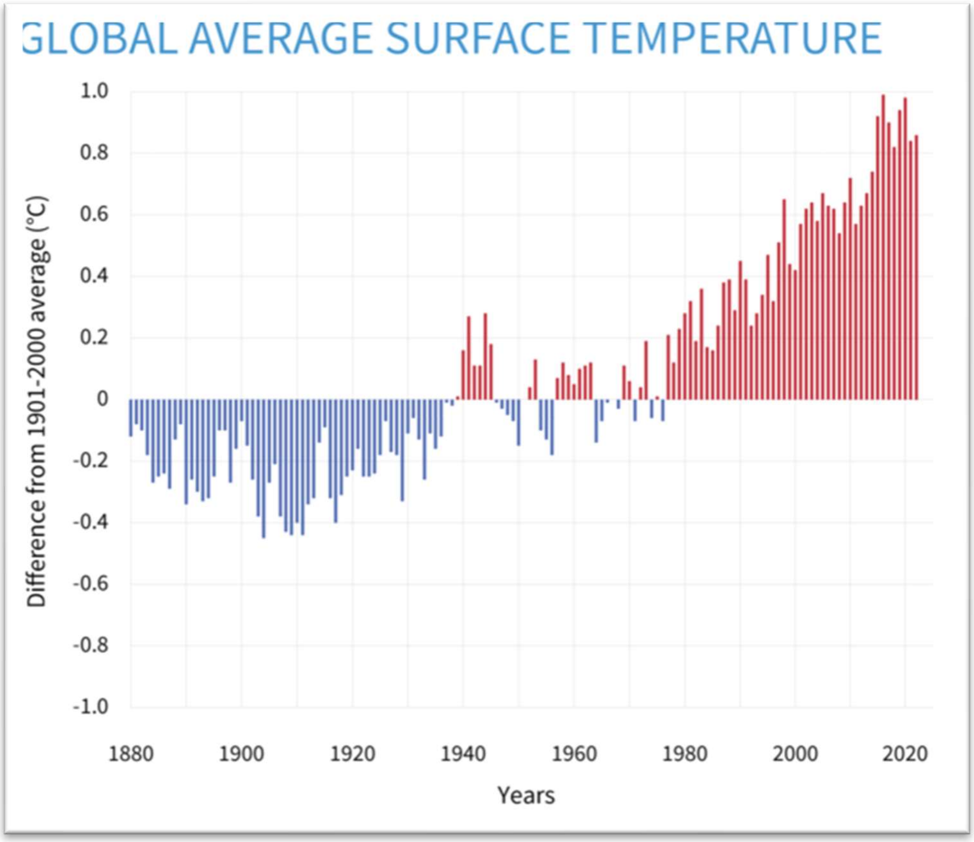


Figure A1-1. Yearly surface temperature compared to the 20th-century average from 1880–2022. Blue bars indicate cooler-than-average years; red bars show warmer-than-average years[6].

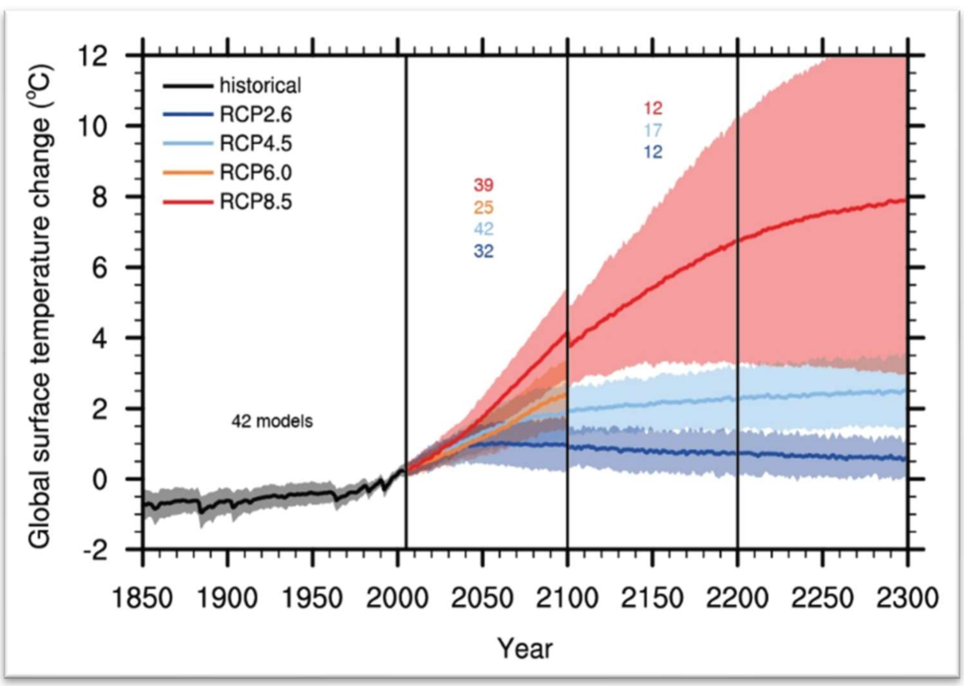


Figure A1-2. Global average surface temperature projections relative to 1986-2005. In this report, we provide projections based on a lower emissions pathway where emissions are greatly reduced (RCP 4.5) and a higher emissions pathway where emissions level off (RCP 8.5)[7].

Past and Future Trends in Indiana

Temperature

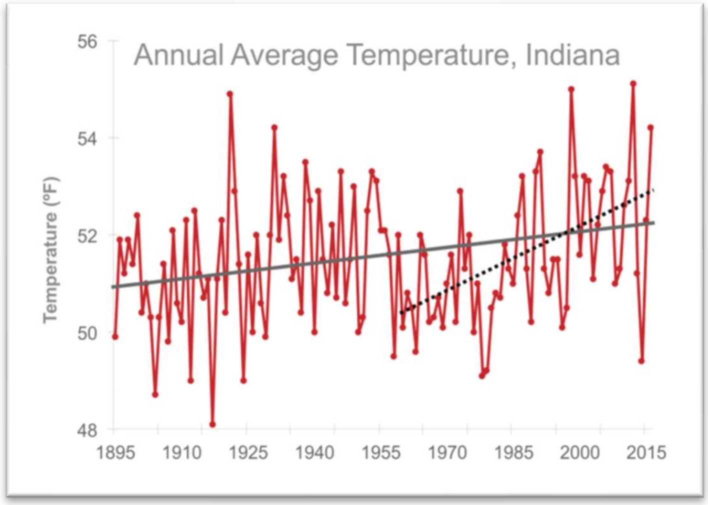


Figure A1-3. Statewide annual average temperature for Indiana from 1895 to 2016 is shown in red. The black solid line shows the increasing trend in annual temperature (0.1°F/decade) for the period from 1895 to 2016. The black dotted line shows the temperature trend since 1960 (0.4°F/decade) [8].

Since 1895, Indiana has seen an average temperature increase of approximately 1.2° F, or an average of 0.1° F per decade. However, since 1960, the average temperature increase is approximately 0.4° F, showing an increase in climate change's effects over time. By 2050, temperatures are projected to increase between 5-6° F under the medium and high emissions scenarios, respectively. By the end of the century, average temperatures are expected to be 6 to 10° F higher than the historical average (Widhalm et al., 2018).

Similarly, maximum temperatures have increased decade-on-decade as well, with a marked increase from 1960 to present. Maximum temperatures from 1960 to 2016 have increased by an average of 0.3° F per decade; from 1895 to 2016, maximum winter and spring temperatures have increased by an average of .1°F per decade. Extreme cold days (where the minimum temperature was below 5° F) and frost days have decreased from 1960 to 2016 by 8 and 9 days respectively. The northern third of Indiana is expected to experience the most significant increase, from an average of 13 per year to only six by 2050.

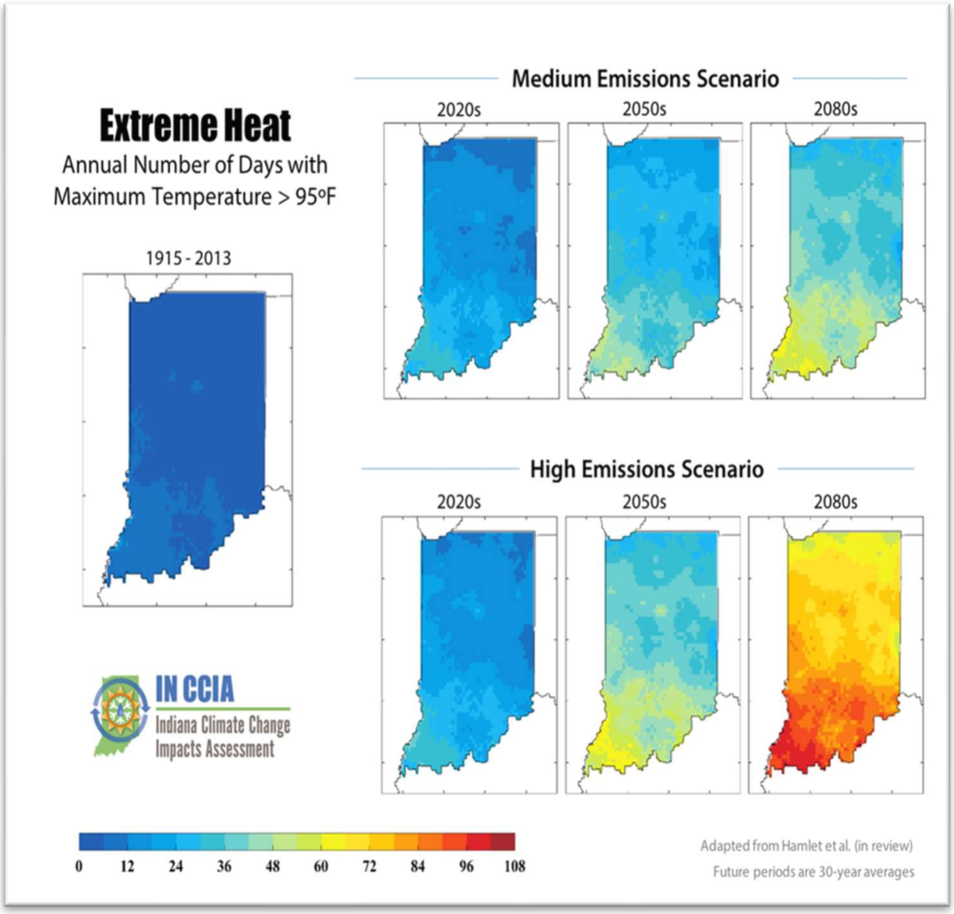


Figure A1-4. Maps showing the annual number of extreme heat days (maximum temperatures above 95°F) Image from Purdue University (n.d.) [9].

While there has not been an increase in extreme heat days (defined as days where the maximum temperature is over 95° F) from 1960 to 2016, they are projected to increase significantly in the future, from seven per year (present) to between 38 and 51 days per year by the end of the century.

Indiana's frost-free season has increased by nine days since 1895. By the middle of the century, the number of frost-free days is projected to increase by between 3.5 and 4.5 weeks.

Annual precipitation in Indiana has also increased significantly. This increase is not expected to fall evenly throughout the year - multiple climate models suggest a high likelihood of more precipitation during the winter and spring months, with less certainty about changes in precipitation during the summer and fall.

Indiana's risk of drought conditions in the future is also worsening. The frequency of drought conditions is expected to increase, particularly during the later parts of the growing season [10].

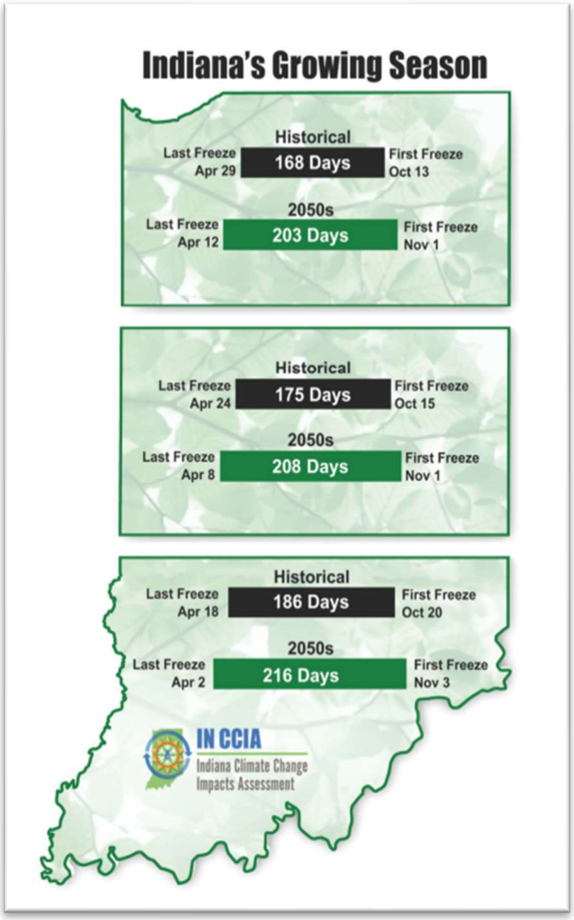


Figure A1-5. Growing season length and average first/last freeze dates for northern, central, and southern Indiana. "Historical" is the average for the period 1915 to 2013. For future projections, "2050s" represents the average of the 30-year period from 2041 to 2070 for the high emissions scenario. Image from Widhalm et al. [8]

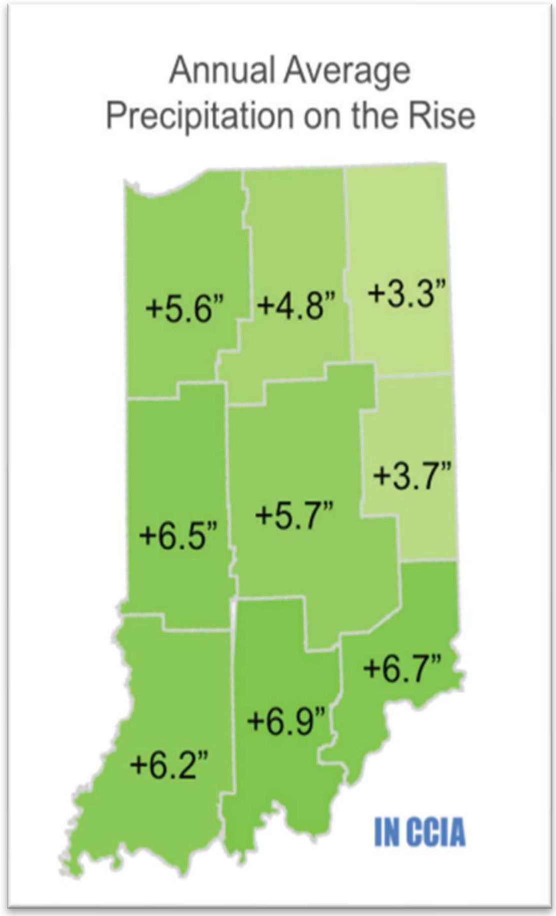


Figure A1-6. Increase in annual precipitation for Indiana's nine climate divisions, based on a linear trend, from 1985 to 2016. Image from Widhalm et al. [8]

Precipitation

Since 1895, precipitation has increased in Indiana by about 5.6", according to linear trend. Increasing precipitation events (shown in Figure A1-7) are becoming more common. Historically, extreme rain events occur when more than 0.86 inches of rain falls in a day. Since 1900, the number of days per year with extreme rain has been increasing by 0.2 days per decade on average.

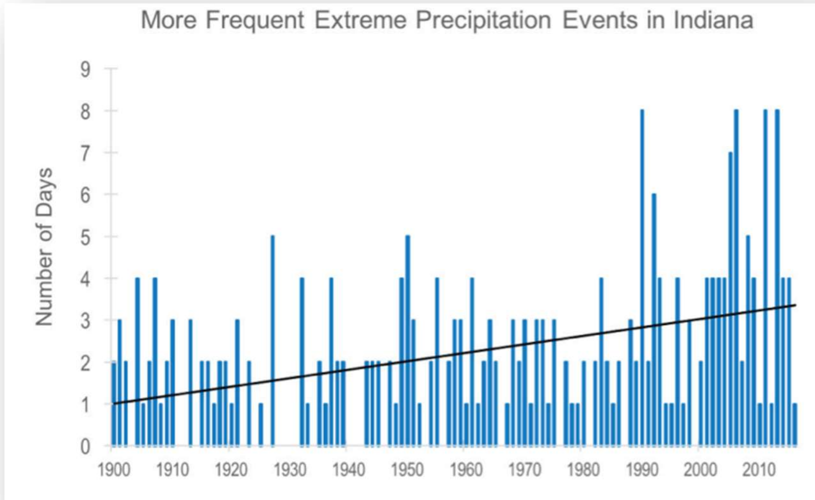


Figure A1-7. The number of days with precipitation events that exceed the 1900 to 2016 period's 99th percentile for Indiana (statewide average). The black line represents the trend line (0.2 days/decade) for the 1900 to 2016 period. Image from Widhalm et al. [8].

When and how precipitation is falling is also changing. In the near-future, precipitation is not projected to drastically change from historical trends. In the mid to late future projections for the century, as seen in images from Figure A1-8, projected precipitation patterns start to vary greatly. Fall, winter, and spring are modeled to be wetter seasons, and late summer is expected to be dryer. Snowfall has declined in Indiana and future precipitation in winter will more commonly be seen as rain.

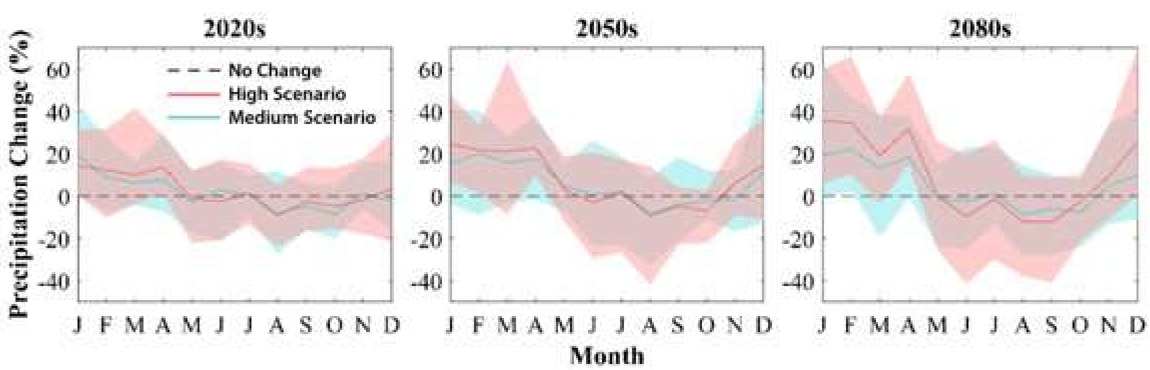


Figure A1-8. Projected changes in monthly average precipitation for Indiana for the 2020s (2011-2040), 2050s (2041-2070), and 2080s (2071-2100), relative to a 1971 to 2000 historical baseline. The solid red and blue lines show the 10-model average for the high and medium emissions scenarios, respectively. Shaded areas show the corresponding range of results across the 10 climate models. Image from Widhalm et al. [8].

South Bend Climate Trends

South Bend, like the rest of Indiana, has already experienced an increase in warming and precipitation events. These changes in climate are shown using historical weather station data downloaded from South Bend International Airport[2]. This primer also presents climate change projections specific to South Bend downloaded from Climate Toolbox[11], and St. Joseph County downloaded from CMRA[12] and Climate Explorer[13].

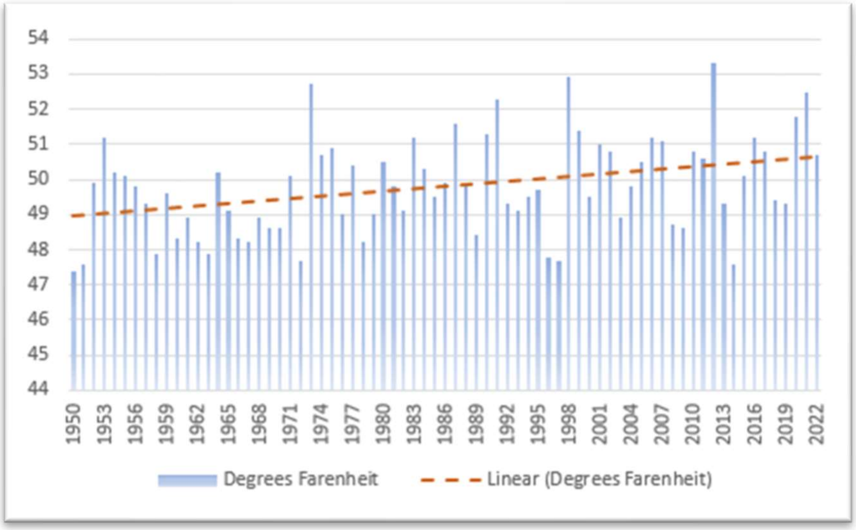


Figure A1-9. Average annual temperature (in degrees Fahrenheit) from 1950-2022 in South Bend, Indiana. Data from NOAA, South Bend International Airport [2]

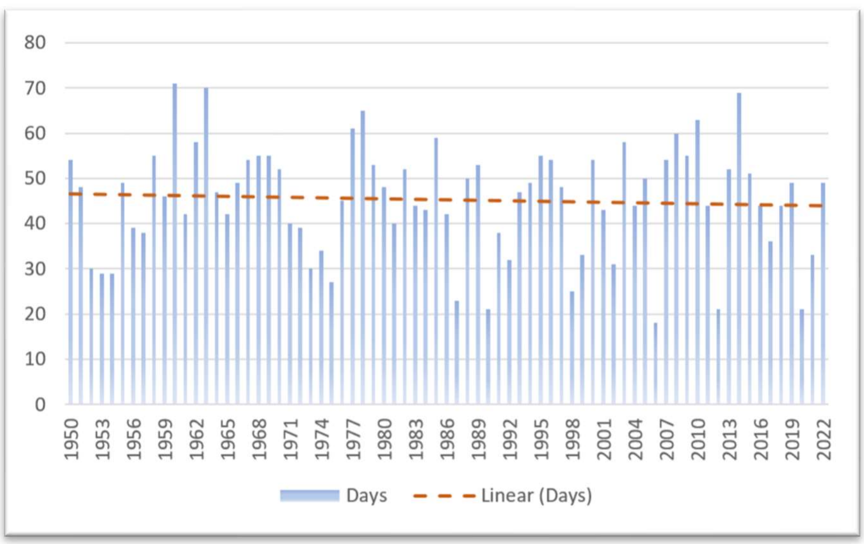


Figure A1-10. Average number of days per year with a maximum temperature (in degrees Fahrenheit) below 32° F from 1950-2022 in South Bend, Indiana. Data from NOAA, South Bend International Airport [2]

Temperature – **South Bend's average temperature is trending upward and has warmed approximately 1.7° F since the 1950s, averaging about 0.2 °F per decade (Fig. A1-9).**

The average number of days with a maximum temperature below 32° F has steadily declined, indicating a decrease in cold days (Fig. A1-10).

When looking at extreme cold events, extreme minimum temperatures have trended upwards from the 1950s by approximately 2° F, indicating a gradual decline in extreme cold events over the last 70 years. South Bend, on average, experiences 3 fewer days below 32° F than in 1950. When considering wind chill – a calculation of wind speed and temperature – and its effect on winter heating centers, wind chill will also decrease due to rising winter temperatures, but the effect of wind speed is unclear.

South Bend is projected to warm 2 – 10° F by mid-century (2033-2066) and 5 – 15° F by late-century (2066-2099) if emissions are not quickly and aggressively reduced on global scales. If emissions are reduced, warming could be limited to 1 – 6 °F by mid-century and 2 – 10 °F by late-century.

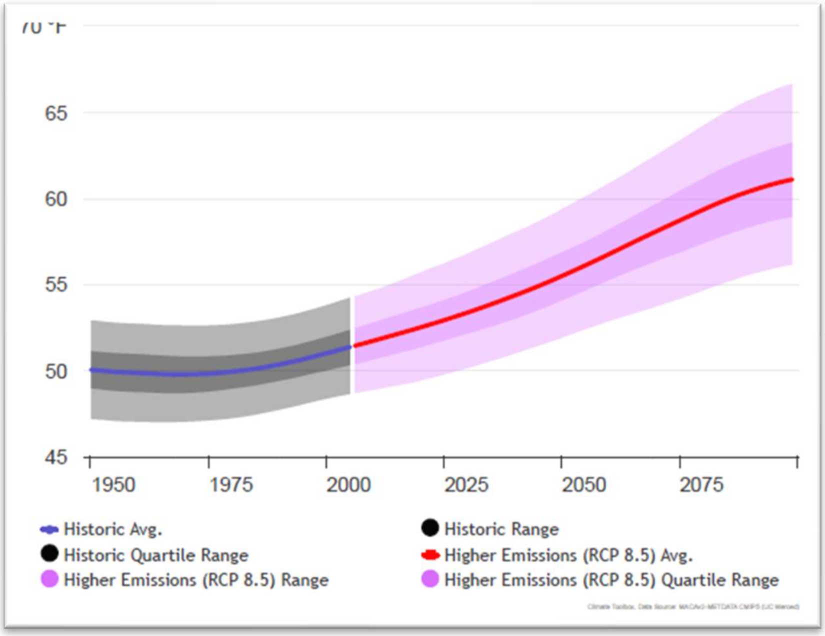


Figure A1-11. Average annual temperature across South Bend from 1950-2005 (observed) and projected out to 2099 (modeled). Graph from Climate Toolbox[11].

The number of extreme heat events is expected to increase substantially in the coming decades. In the city, the number of days above 90 °F could increase by more than a month, on average, by the 2050s. By the 2080s, they could increase by more than 2 months on average. The number of days over 100 °F, previously extremely rare, could occur, on average, 22 days per year, and heat indices over 100°F may occur 52 days per year (Fig. A1-12). Community-wide, there will be an increase in cooling degree days as the summer season begins earlier in the year and lasts longer into the fall.

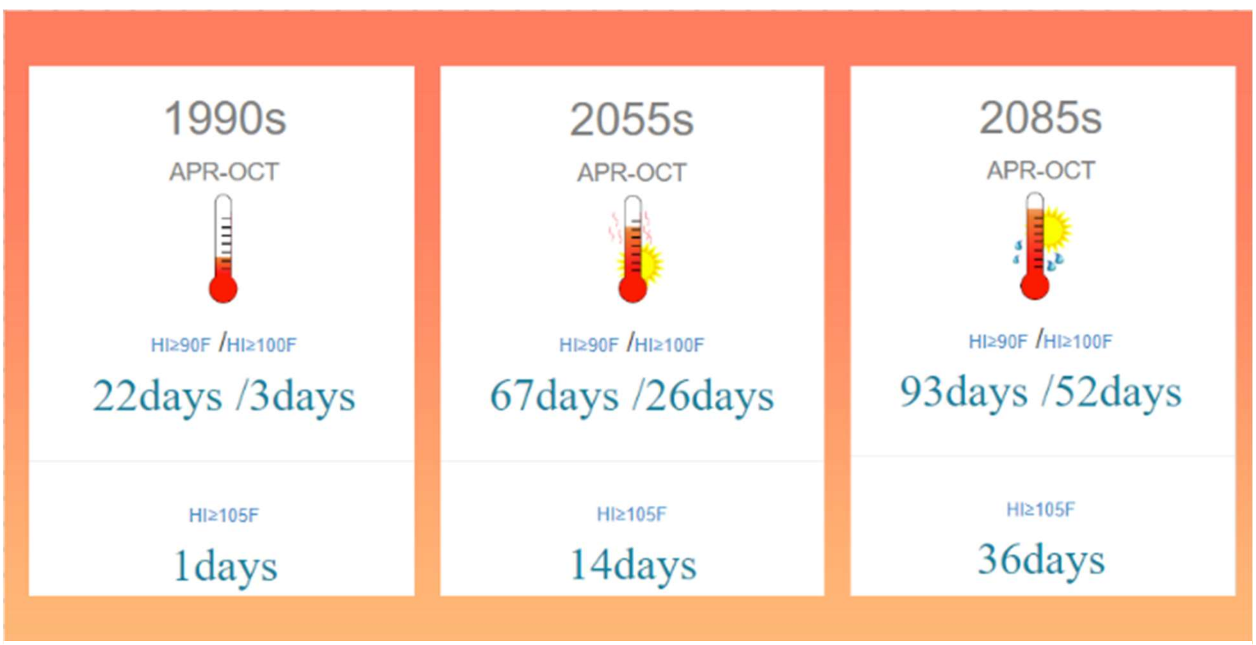


Figure A1-12. Average number of days per year in South Bend over 90° F and 100° F, assuming continued higher emissions. Graphic from Climate Toolbox[11].

Precipitation – Precipitation significantly varies year to year. Over the last 70 years, average precipitation in South Bend has increased approximately 4".

Precipitation projections vary among the different models, with some showing wetter conditions and others showing drier conditions. Overall, average precipitation may not change significantly (Fig. A1-13), but the timing and type of precipitation could change dramatically. As temperatures increase without a direct increase in precipitation, an increase in dry periods may also occur.

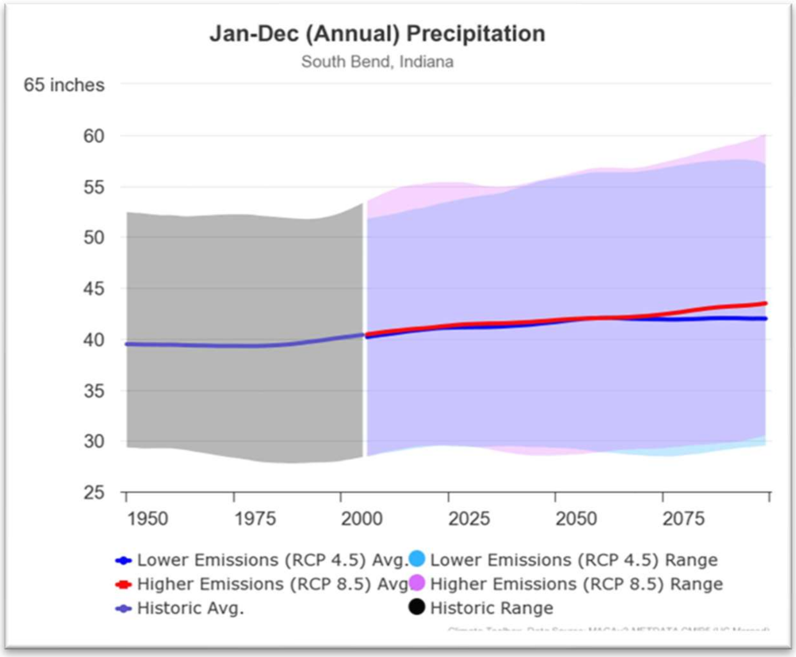


Figure A1-13. Average annual precipitation across South Bend from 1950-2005 (observed) and projected out to 2099 (modeled). Graph from Climate Toolbox[11].

Observed average snowfalls from 1950 to 2022 trend downward. A decline of about 16" over the last 70 years indicates less frequent snowfall across the winter season (Fig. A1-14). This means that the need for snowplow services in the winter will also decrease. It is important to note that snowfall is decreasing but precipitation is not. Precipitation in the winter is more likely to fall as rain, rather than snow. Heavy rainfall in winter and early spring can damage vegetation that has not yet bloomed and puts people at risk during cool months if they lose heating ability from extreme precipitation events.

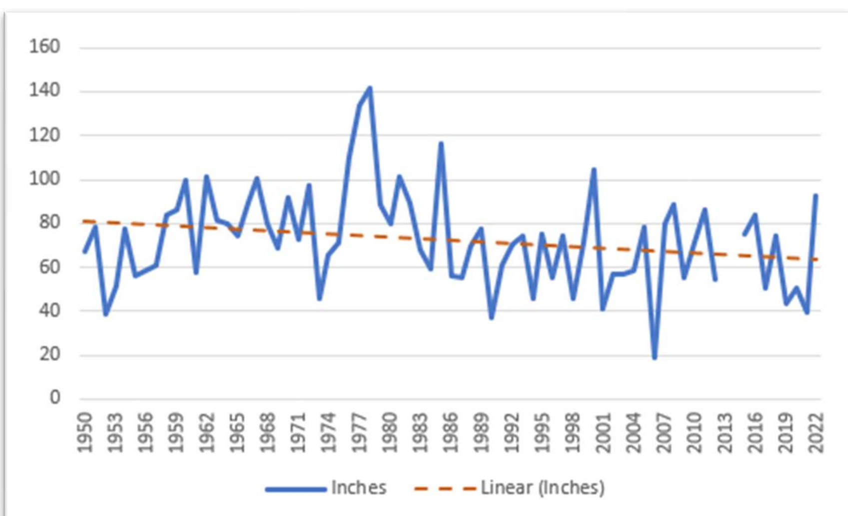


Figure A1-14. Average snowfall (in inches) from 1950-2022 in South Bend, Indiana. Data from NOAA, South Bend International Airport[2].

South Bend has already felt the effects of flooding in the past – river flooding, surface flooding, and ground-water flooding. The city experienced a 500-year extreme precipitation event in 2016 and a 2,400-year flood in 2018. Flooding is projected to increase in both frequency and intensity. There is estimated to be a 45% increase in the magnitude of the St. Joseph River 100-yr flood by late-century under a high emissions scenario (see figure A1-15).

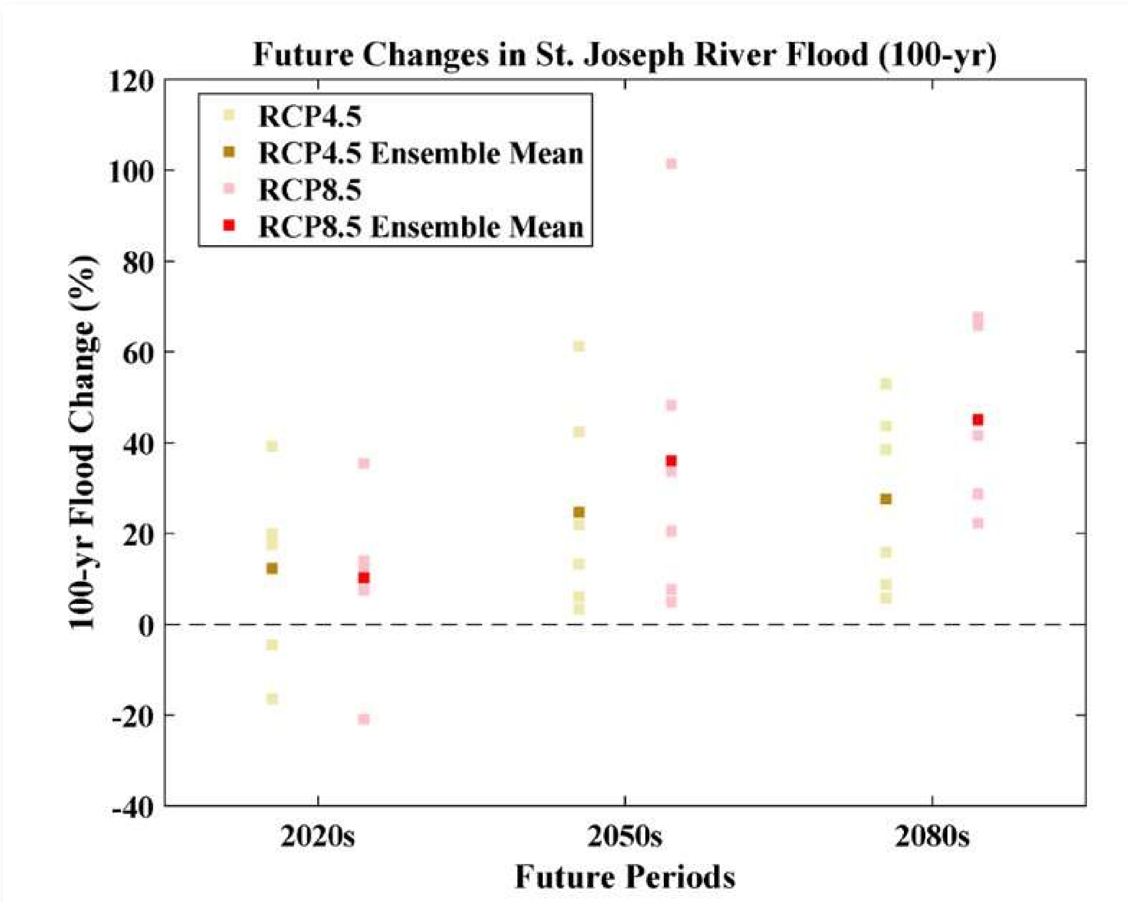


Figure A1-15. Scatter plot of St. Joseph River at Niles, MI Projected Changes in the 100-yr Flood. Graph from Dr. Alan Hamlet, University of Notre Dame.

Resources

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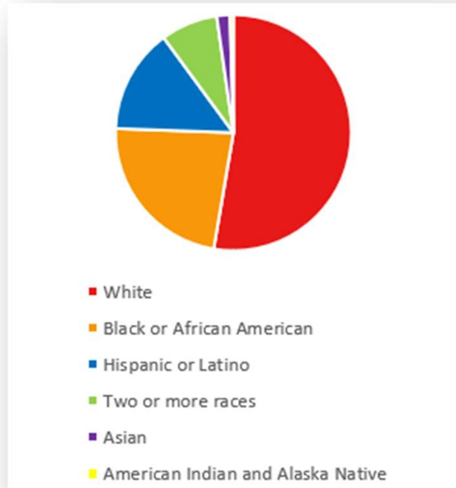
11. Climate Tool Box. https://climatetoolbox.org/
12. ArcGIS Living Atlas Assessment Tool.https://livingatlas.arcgis.com/assessment-tool/search
13. Climate Explorer. https://crt-climate-explorer.nemac.org/

Appendix 2: Community Trends Primer

People and the Economy

Population Trends

South Bend's population is 103,110 (2022). This is a slight decrease of 0.33% from 2020, but an overall increase of 1.88% from 2010[1].



About 58% of the population identifies as White, 25.2% as Black or African American, 15.8% as Hispanic or Latino, 8.6% as Two or More Races, 2% as Asian, and 0.5% as American Indiana and Alaska Native (2022)[1].

The city has a large population under 18 years, 26.9%, and 14% of South Bend's population is 65 years and over (2022). 14% of the population also speaks a language other than English at home[1].

Income, Housing, and Labor

The poverty rate in South Bend is nearly double the national average. About 20.9% of people in South Bend live in poverty (2022). The median household income was $46,002 and per capita income was $26,934 from 2017-2021. In comparison, the median value of owner-occupied housing units was $95,500 (2017-2021)[1].

The largest employment sector is Health Care, Social Assistance & Educational Services. The University of Notre Dame is the largest employer, providing over 5,000 jobs. Other top employers in this sector include Beacon Medical Group, South Bend Community School Corporation, and AM General. St. Joseph County is a major employment center for the region that attracts over 10,000 commuters[2].

Disadvantaged Populations

Some populations are more likely to be exposed to environmental contaminants, experience serious impacts during natural disasters, and/or experience discrimination or a lack of opportunity that other groups have. These are considered disadvantaged populations, and these same groups are, unfortunately, likely to experience an inordinate share of impacts associated with climate change.

South Bend has multiple low-income neighborhoods that include a high unemployment rate and a high percentage of families living in poverty. One example, shown in Figure A2-1, is a tract group of 1,641 people in South Bend that is in the 97th percentile for low-income. 73% of its population is unemployed and 34% of families are impoverished. Within this tract, 20% of the properties have flood risk and 99% of the area lacks tree canopy[3]. A lack of vegetation increases urban heat island effect (Fig. A2-2) and decreases natural flood prevention.

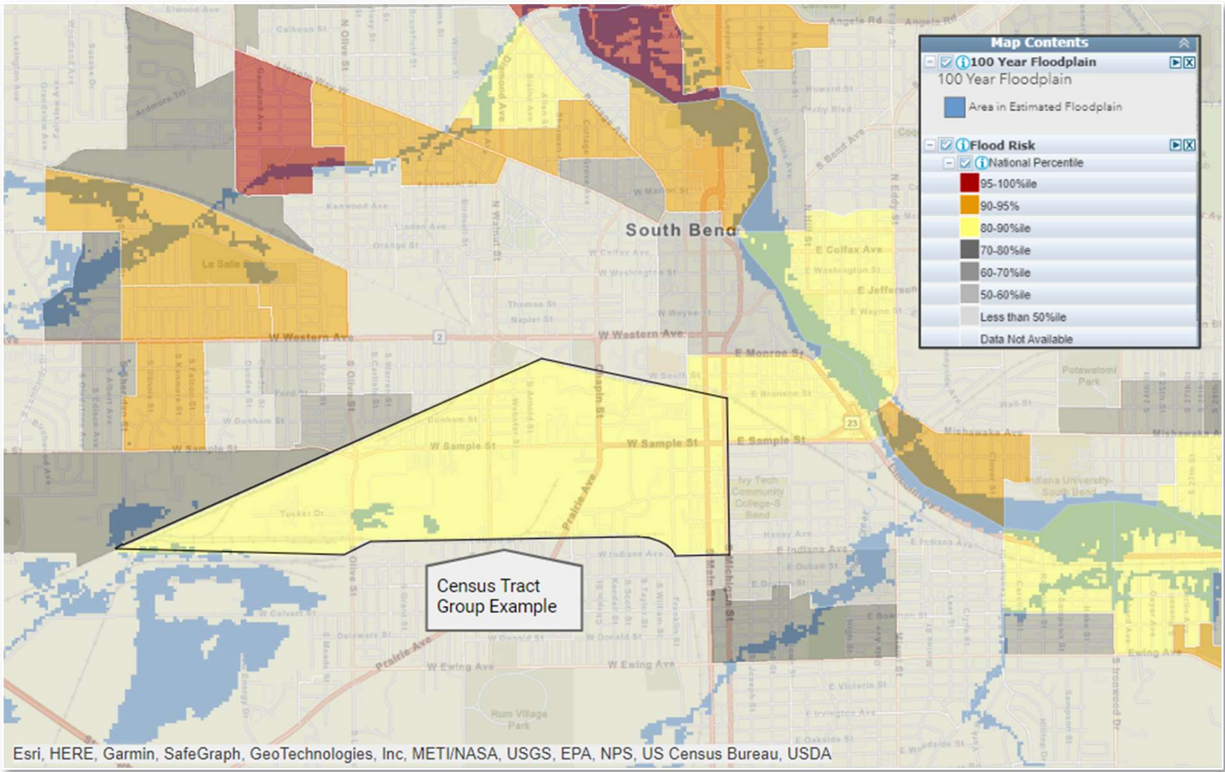


Figure A2-1. Map of South Bend area showing most vulnerable areas for flooding labeled by national percentile and areas in blue are estimated 100-year flood plain locations. Map from EJScreen, https://ejscreen.epa.gov/mapper/

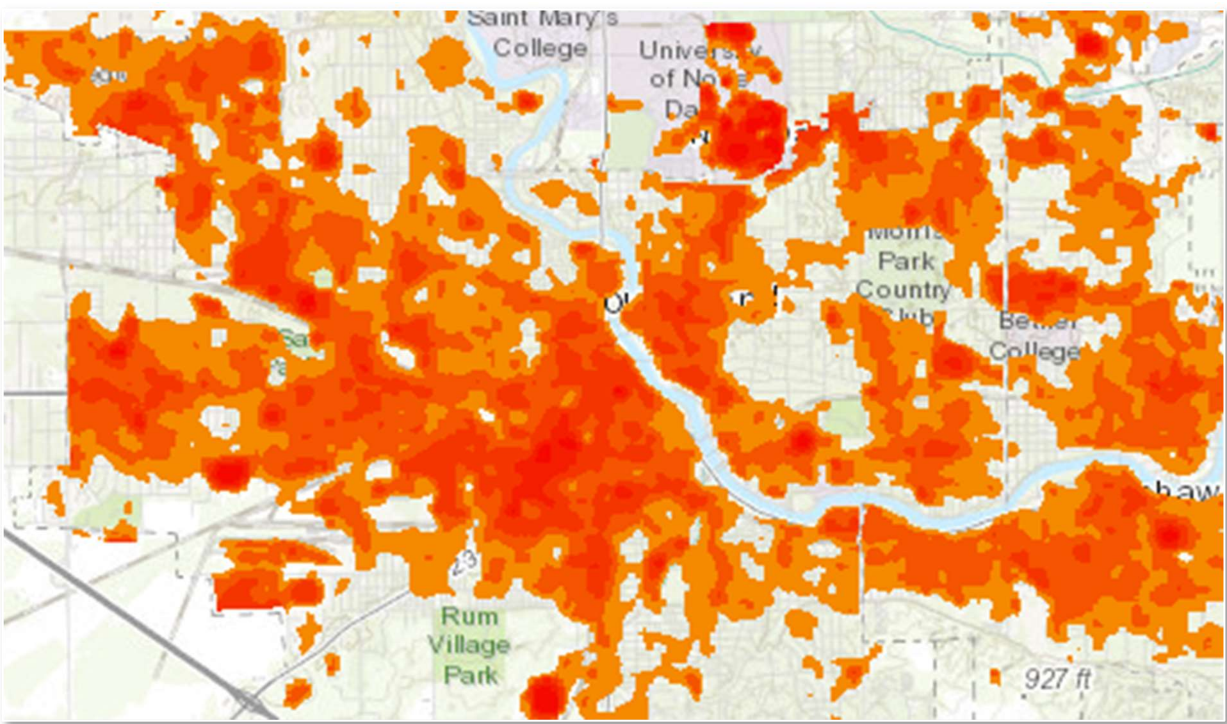


Figure A2-2. Urban heat island map of South Bend showing disproportionate impacts of extreme heat to the west side of the city. Map from The Trust for Public Land, Descartes Labs, USGS, https://southbend.maps.arcgis.com/home/item.html?id=4f6d72903c9741a6a6ee6349f5393572

Nature and Air

Physical Environment and Natural Systems

The natural environment of South Bend is what made the area into what it is today. South Bend is best known for its placement around the southern loop of the St. Joseph River that lends itself as habitat, recreation, and a source of hydro-electric energy.

The St. Joseph River flows more than 200 miles from south-central Michigan into northern Indiana. Numerous other rivers and creeks act as tributaries. South Bend, once made up of the largest inland wetland in the U.S., the Grand Kankakee Marsh, is now home to only a few known wetlands and habitats. Less than 1 percent of the original Kankakee Marsh remains today, so it is vital that South Bend protects its remaining wetlands. Nature preserves in the area include Chamberland Lake, Lydick Bog, and Elbel Park. These areas are vital habitats for extremely high numbers of birds, insects, mammals, plants, and other species. The wetland areas provide ecosystem services such as carbon sinks, cooling air, water filtration, flood banks, and biodiversity to the area. Other important ecosystems in the area are Bowman Creek, protected by Notre Dame, Bendix Meadows, protected by the Audubon Society, and Rum Village, protected by the City of South Bend.

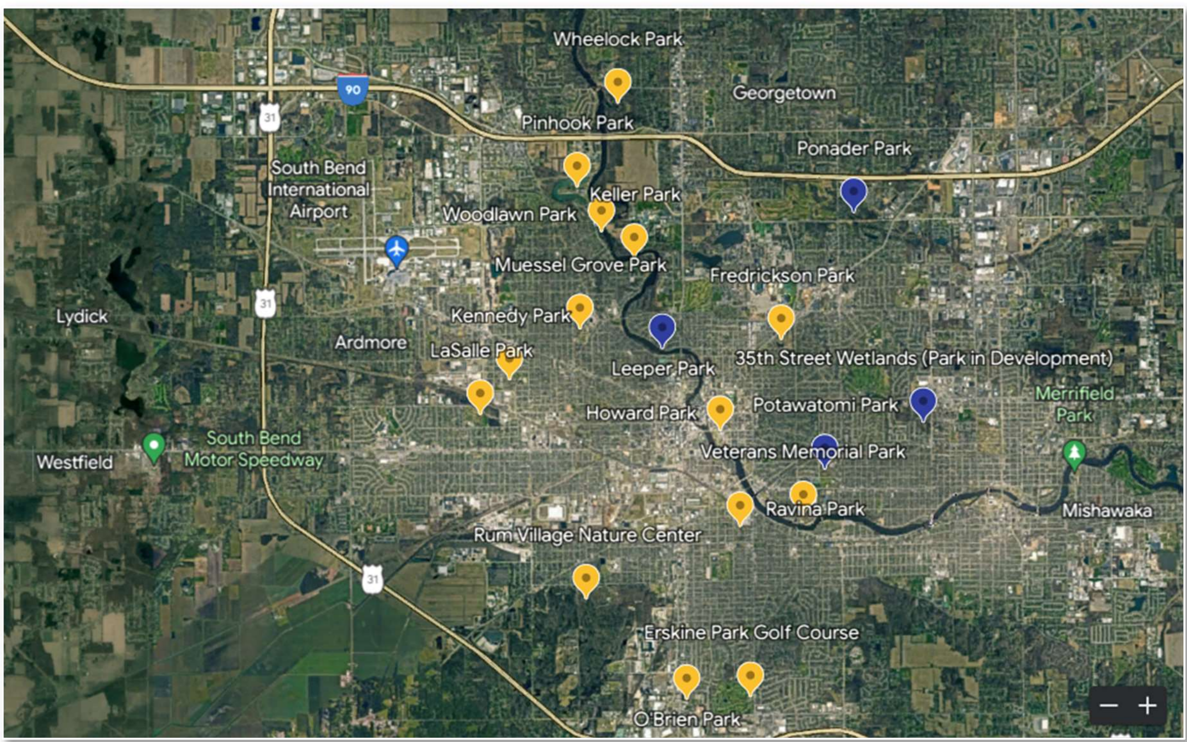


Figure A2-3. South Bend's labeled Ecologically Sensitive Parks identified by Venues Parks & Art's Department - Ecological Advocacy Committee in the Natural Resources Management Plan. Blue highlights Justice 40 areas and yellow is non-Justice 40. Map created by Barbara Dale using NRMP: https://sbvpa.org/wp-content/uploads/2021/03/2021NRMPFinal.pdf

Waterways are expected to undergo changes in the coming decades. Cool-season precipitation and extreme precipitation are increasing which causes an influx in river flow in the St. Joseph River. Stream hydrographs are expected to shift as snowmelt occurs earlier and summers become drier.

Air Quality

South Bend has moderate to good air quality overall. The Indiana Department of Environmental Management announces air quality action days when air quality indexes for ozone and particulate matter increase to an unhealthy value for sensitive groups and approach unhealthy values for all. In 2022, four action days were designated for ozone in North Central Indiana [5].

One known effect of a warming climate is an increased rate of ozone formation[6]. This will make it more difficult to meet state and federal standards, thereby requiring even more stringent cuts to emissions. Air quality action days are predicted to increase as temperatures rise, and as the number of wildfires increase around the country and smoke is moved across states. Already in 2023 (as of June 29th), the South Bend region has experienced 16 air quality action days (AQADs) – 7 for particulate matter and 9 for ozone – whereas in 2022, IDEM only announced 13 total AQADs across Indiana and only 4 specifically for ozone in the South Bend region.

Increased levels of ground level ozone lead to respiratory and heart disease. They are also linked to asthma. Many people are more sensitive to poor air quality, including infants, elders, and people with already compromised health. In the red areas shown below in Figure A2-4, nine tract groups are in the 95th to 100th percentile for adults with asthma. In this area alone, asthma affects over 2,000 people who are more sensitive to decreased air quality[7].

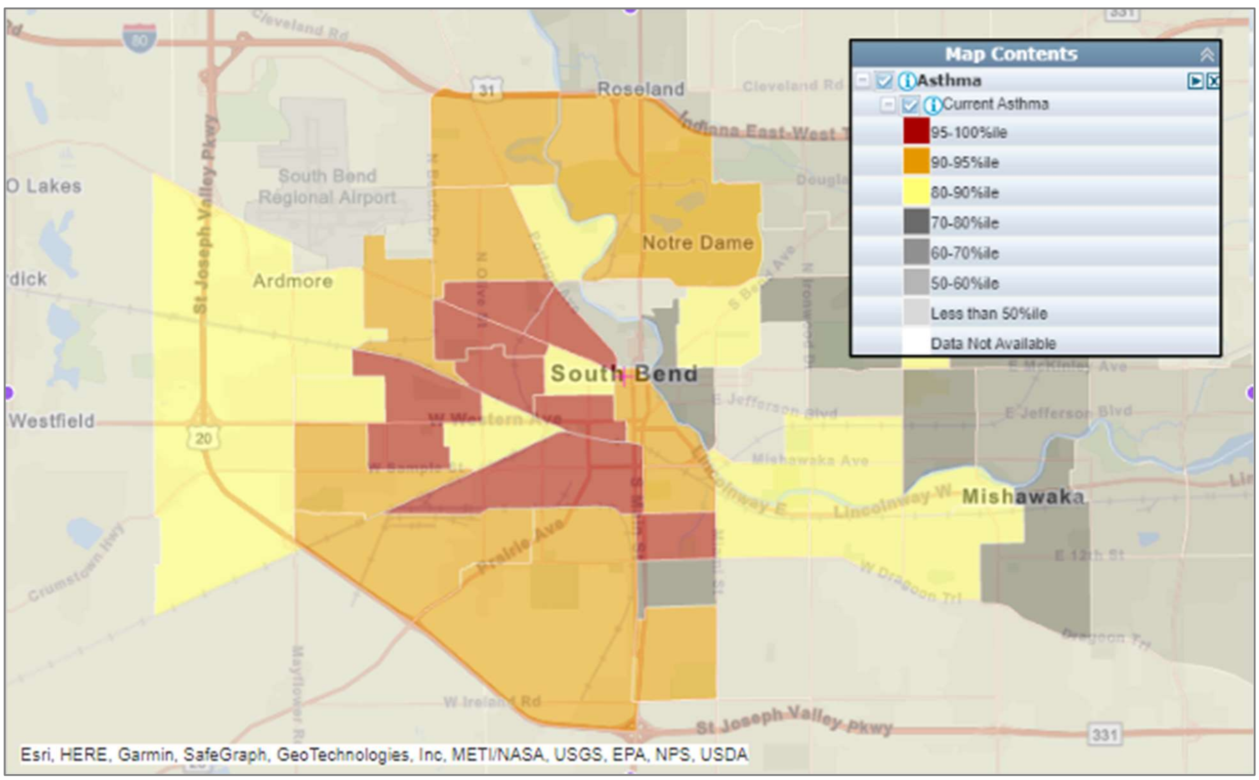


Figure A2-4. Map of South Bend area showing most vulnerable areas for adults with asthma labeled by national percentile. Map from EJScreen, https://ejscreen.epa.gov/mapper/

Structures, Energy, Communications

Water

South Bend residents receive their water through South Bend Municipal Utilities which utilizes groundwater from two aquifers – St. Joseph Tributary Valley System and Hilltop Aquifer System. Nine wellfields are available for use with a treatment plant at each[8].

South Bend Wastewater Treatment Plant discharges treated wastewater into the St. Joseph River per the National Pollutant Discharge Elimination System permit. The plant treats an average flow of 48 million gallons per day and can treat at least 77 million gallons a day under high flow[9].

The city has a combined sewer system that carries stormwater from precipitation events and wastewater from homes and businesses. While a combined sewer system is efficient in treating un-treated waters, during heavy rainfall or snow melts, the system can overflow [10]. To prevent overflowing into people's homes, the sewers may overflow into the river. This affects the water quality for humans and animals. As the frequency of extreme rain events increases with climate change, adjustments to stormwater infrastructure will need to be made.

Vulnerable areas that are increasingly susceptible to flooding based on past weather events are the North Shore Triangle Neighborhood and Leeper Park. Other areas including Keller Park and farming fields off the Indiana toll road are also in flood zones shown below in dark and light purple (Fig. A2-5).

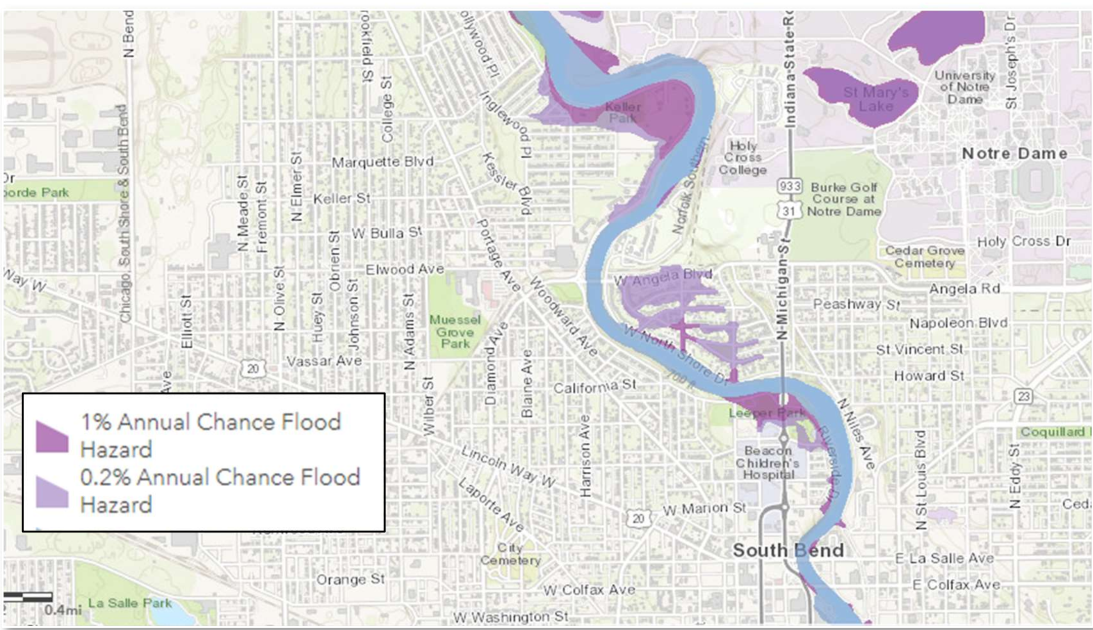


Figure A2-5. St. Joseph River most prominent river flood plain areas according to USA Flood Hazard Areas.

Energy

The majority of South Bend residents and businesses receive electricity from Indiana Michigan Power and NIPSCO, the state's second largest electric utility. NIPSCO is also Indiana's largest natural gas supplier and delivers natural gas to South Bend customers[11].

Climate change can affect energy system distribution, demand, and sourcing. Heat waves and severe storms can disrupt electrical transmission lines. Disruptions can be deadly, especially for elderly residents and people who cannot afford alternatives for heating and cooling.

As winters continue to warm and heating technology becomes more efficient, demand for natural gas for heating homes and buildings may also decline over time. Comparatively, electrical use for air conditioning is expected to increase.

South Bend is dedicated to reducing greenhouse gas emissions and has begun its exploration into alternative energy uses. South Bend wants to increase energy efficiency and transition to renewable energies, becoming carbon-neutral by 2050. There are ongoing commercial and residential solar projects to reach this goal producing at least 1.5 MW across South Bend.

The St. Joseph River is also utilized for hydropower energy. The University of Notre Dame uses energy produced from the river that offsets 9,700 tons of carbon dioxide annually[12].

Social Services

South Bend Police Department distributes police services across the city with its central station location on Sample Street. SBPD has 244 active officers[13].

The City of South Bend has 11 fire stations distributed across town with 256 full-time firefighters[14].

There are two hospitals in South Bend – A Rose Place which is on the west side of South Bend with 10 inpatient beds and Memorial Hospital located downtown with 421 inpatient beds[15]. Other hospitals are nearby in bordering cities such as Mishawaka, Indiana and Niles, Michigan.

There are 22 total public schools within South Bend school districts – 13 elementary schools, 5 middle schools, and 4 high schools (Adams, Clay, Riley, and Washington High Schools) [16].

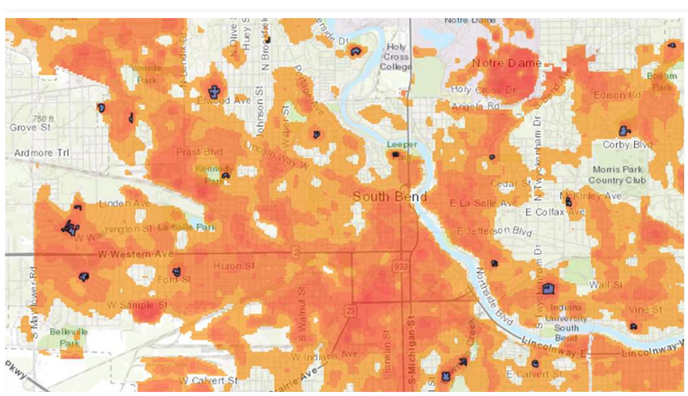


Figure A2-6. South Bend schools are outlined in black. Schools are in prominent heat island areas meaning higher temperatures for bus riders or playing outside. Data gathered by City of South Bend.

Community Culture

Residents of South Bend know they are home when they experience all four seasons, enjoy local outdoor recreations, indoor theatre, and of course, the beauty and activities provided by the St. Joseph River. From athletics to education to arts to the environment, South Bend has a wide range of activities and culture that has built a diverse city which people call home.


(South Bend Tribune, 2022)

Indoor arts and performances are brought by South Bend's Morris Performing Arts Center and Civic Theatre. Outdoor trails are found in St. Patrick's Park, Rum Village Park, and Pinhook Park. Along the St. Joseph River is the river lights plaza and the East Race Waterway. The city is also home to the South Bend Cub's at Four Winds Field.

South Bend's History Museum has numerous exhibits and tours showcasing the history of the city, including the Oliver Mansion. Other historical sites include Copshaholm House Museum, the Kizer House, the Birdsell Mansion, and Rose Morey Lamport house. Additional city landmarks in South Bend are the Studebaker Museum, an American wagon and automobile manufacturer originally based in the city, and the Civil Rights Heritage Center, a documentation of local civil rights history.

Community History

The St. Joseph River Valley was first inhabited by the Potawatomi and Miami tribes. They occupied the area until forcibly removed and almost entirely gone by the 1840s[17]. The Pokagon Band of Potawatomi today is committed to promoting tribal development and maintaining their community and government[18].

Four waves of demographic changes occurred following Native American removal that characterize much of South Bend's present population.

The land was settled due to its proximity to the Kankakee River[17]. From the Great Lakes, travelers were able to pass through the St. Joseph River down the Kankakee and into the Mississippi River. The site became a trading post because of the rich wildlife that lived along and in the St. Joseph River[17].

The first wave of settlers in the area was made up of people from the British Isles and a little bit of France and French-Canada[19]. Following this settlement, waves of immigrants arrived settling into the west side of South Bend and into neighborhoods that are similar to the present layout. In the mid-19th century, a large African American population grew in South Bend as part of the countrywide Great Migration of African Americans from the South to the northern states. The 1990s had a large wave of Hispanic immigrants that settled primarily on the west side of the city[19].

Conclusion

Communities around the United States and world are working to develop strategies to address the impacts associated with climate change. Due to greenhouse gas emissions already released, current trends associated with larger and more extreme temperatures, storms, and droughts are expected to continue for many decades. If emissions are quickly reduced, however, there is an opportunity for these extreme impacts to be avoided.

As South Bend prepares for significant changes to its surroundings and way of life, it will be important to increase the protection of disadvantaged populations. Those who are on the front lines for climate impacts have contributed the least to the problem and are our most vulnerable parts of the community to protect.

Protecting natural systems is also vitally important. Not only have they provided beauty and resources to South Bend, but they buffer us from direct climate change impacts.

Solutions to climate change such as renewable energy, more sustainable infrastructure, and environmental protections and restoration, have benefits to both people and the natural environment we rely on. Robust climate change solutions are win-win strategies across the entire community.

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19. https://www.southbendtribune.com/story/news/local/2015/05/17/south-bends-history-seen-in-five-periods-of-settleme/45863735/

Appendix 3: Climate Vulnerability Assessment

Cities and counties throughout the nation and world are working to reduce greenhouse gas emissions in efforts to prevent warming more than 1.5°C (2.7° F). This level of warming has been recognized by the international scientific community as an important threshold, below which we can avoid catastrophic and runaway climate change (IPCC, 2022).

Figure A3-1. South Bend School's students board a bus https://www.southbendtribune.com/story/ne

In addition to reducing greenhouse gases, however, communities need to respond to the changes already being felt and plan for those still to come. Because greenhouse gases can remain in the atmosphere for decades after release, our climate will continue to warm and we will experience impacts for many decades, even if we reduce emissions today.

While greenhouse gases are measured globally, climate change impacts are experienced locally. Each community feels climate change in a different way, depending on historic conditions and local climatic conditions and patterns of change. As these local impacts and changes worsen over time, we will need to prepare and protect our most vulnerable resources and populations from the impacts.

South Bend has already experienced changes in temperature, rainfall, and extreme weather events. As changes in climate continue, we can expect increasing severity and frequency of extreme heat, changes to precipitation patterns, and more frequent and intense flooding events. These changes are expected to become increasingly severe over the course of the century.

Figure A3-2. 2016 flood event in South Bend

Determining which resources and populations are most vulnerable to ongoing and future impacts of climate change is the first step in developing effective strategies and sound solutions. While this Climate Change Vulnerability Assessment presents sector-specific vulnerabilities to the community, it is important to also look at South Bend in a holistic way. Many of the vulnerabilities identified here cross diverse sectors and affect people of all different walks of life.

Methods

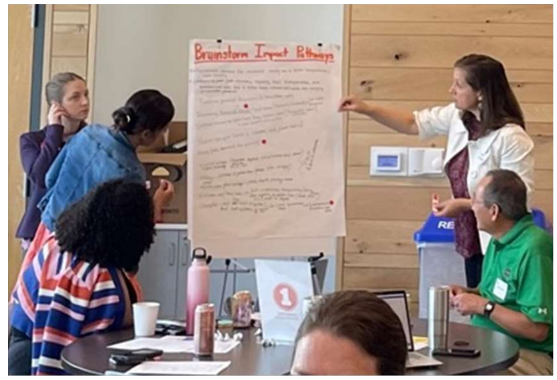

Figure A3-3. Participants identifying and prioritizing vulnerabilities at the stakeholder workshop.

On July 21st, 2023, a group of 49 local experts from diverse sectors of the community met for a three-hour vulnerability identification workshop. These stakeholders combined their local knowledge and expertise with information provided about climate science and model projections to identify and prioritize local vulnerabilities in the five primary systems of the community: Transportation and Infrastructure, Natural Systems, Business and Economy, Health and Emergency Management, and Community Culture.

The workshop participants were tasked with three activities in their breakout groups – identifying and brainstorming climate impacts, prioritizing their list by importance, and developing the vulnerability of each impact based on focal populations. Participants received a climate science presentation on the Indiana Climate Change Impacts Assessment and from this were able to identify impacts that are already underway as well as potential impacts that are expected in the future. See *Appendix 4* for an entire list of vulnerabilities identified.

For each identified vulnerability, participants collected the following information:

Exposure	The specific climate trend or projection that is already causing or is expected to cause the impact
Focal Populations	The specific neighborhood, population, area, or resource that is expected to be especially affected by the impact
Sensitivity	A relative measure of the degree of severity of the impact, given our understanding of the specific sector or population
Adaptive Capacity	The extent of existing resources, programs, or policies *already in place* to protect people or to respond to the changes with little disruption
Other Stressors and Indicators	A quality or trait related to the focal population that can be tracked to indicate the effectiveness or ineffectiveness (ongoing stressor) of actions taken to address this vulnerability

For each listed vulnerability, the Office of Sustainability identified the following:

Certainty	The relative certainty that the climate exposure(s) will occur

Transportation and Infrastructure

The transportation and infrastructure system covered in this vulnerability assessment for South Bend includes electricity, water, wastewater, and energy utilities as well as roads, bridges, and public buildings.

Identified climate change vulnerabilities to infrastructure in South Bend include:

Infrastructure and Flooding – **One of the major disruptions to infrastructure exacerbated by climate change is flooding. Flooding is expected to become more severe and frequent with climate change. Urban areas are susceptible to flooding because a high percentage of the surface area is composed of impervious streets, roofs, and parking lots where runoff occurs very rapidly. See *Appendix 2 of Community Primer* for relevant river flood risk maps. See *Climate Change Trends* for information on flooding that South Bend has already experienced.**

Large floods are often associated with sewer backups and collapsing combined sewer infrastructure. When a combined sewer and stormwater system gets overwhelmed, some sewage can go untreated. As climate change worsens and storms become even more extreme, dropping larger quantities of precipitation in shorter periods, older and outdated infrastructure will become even more at risk, also creating a risk for health and safety.

Figure A3-4. South Bend Wastewater Treatment Plant at the Peak of the 2018 Flood

As older infrastructure is updated, prices for housing may increase. Increased mandates for energy efficiency, sewer upgrades, extreme heat resistance, water conservation, natural shading, and other sustainability measures associated with combating climate change could result in fewer housing opportunities for lower income residents unless efforts are made to specifically address housing affordability.

Transportation Disruption – **South Bend is internally connected by public transportation (TRANSPO) buses and sidewalks, and externally by the South Shore train line. Increasing temperatures and flooding pose risks to these transportation networks, and more risk if there is a lack of network in some areas of the city. Without upgrades and replacements to stormwater infrastructure, damage to roads and increased flooding during extreme events is expected.**

Energy Disruption and Pricing – As temperatures rise and extreme weather events occur more frequently, electrical use is expected to rise with increased demand for air conditioning. New investments in energy production and distribution will be needed to meet peak demand. Because of the community's heavy reliance on fossil fuel-based energy, replacement of fossil fuels with renewable energy sources (in addition to energy conservation) is necessary to meet South Bend's greenhouse gas emissions targets. These new investments could result in higher prices, depending on the cost of new infrastructure and energy prices. Lower income residents could be impacted by increasing energy prices.

Extreme temperatures also reduce the efficiency and reliability of energy production and distribution. In addition, power outages are common during heat waves and extreme cold events, due to overburdening of the power grid. Power outages can put peoples' lives at risk as they leave them vulnerable to soaring temperatures. Older adults, low-income residents, and people with existing health problems are all at risk. If electric prices increase, even more residents will be unable to afford to cool their homes, putting them at risk during periods of severe heat.

Identified Vulnerabilities: Transportation and Infrastructure

The vulnerability assessment identified the following transportation/infrastructure-related vulnerabilities to South Bend

HIGH

- Surface flooding impact to home and business owners, low-income population, and infrastructure due to extreme high precipitation
- Dam failure and bridge collapse impact to floodway due to extreme high precipitation
- Bank destabilization and slipping impact on people and infrastructure located on high banks due extreme high precipitation

MEDIUM-HIGH

- Increasing electricity demand and cost of energy impact on utilities and low-medium income households due to extreme heat
- Heat stress to building and road infrastructure under extreme heat

MEDIUM

- Electricity demand and increasing cost of energy impact on local businesses
- Combined sewer overflows (CSOs) effect on floodplain areas and low-income populations due to extreme high precipitation
- Increased water into wastewater treatment plant (WWTP) due to high river/ inundated system effect on rate payers

MEDIUM-LOW

- Above ground utilities damaged by extreme weather
- Roads and sidewalks at risk due to flooding and extreme heat

Note: Vulnerability risk matrix ranking is determined from the combined scores for sensitivity and adaptive capacity.

Natural Systems

Climate change can have significant impacts on natural systems through increases in temperatures, extreme storms, and drought. Increasingly, one of the most important functions of natural systems is to provide a buffer against the impacts of climate change. Intact natural systems can reduce the impacts of extreme events, such as floods and drought, on local communities. Forest and ecosystem management to maximize natural function is increasingly becoming a priority.

The vulnerability assessment revealed that South Bend's natural systems are vulnerable to climate change in the following ways:

Overall Degradation of the Natural Environment and Loss of Species – Open space is a valued resource, providing a visual and physical connection to the natural environment. See *Appendix 2: Community Trends* for information on vital nature preserves in the South Bend area.

Like natural lands outside the city, natural lands and open space within city limits are increasingly being affected by climate change and will need to be managed for continued natural function. Some of the climate-related threats to parks and open spaces include pests that affect tree canopy species, drought that weakens vegetation, floods and large storms that knock down trees and destroy landscaping, and overall climate shifts that make existing vegetation incompatible with changing climate conditions.

Figure A3-5. The St. Joe River affected by drought in 2020
https://www.abc57.com/news/st-joe-river-levels-in-south-

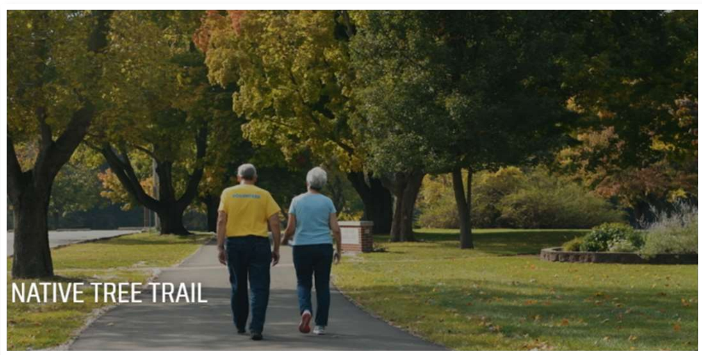

Figure A3-6. South Bend's Venues Parks & Arts Native Tree Trail
https://sbvpa.org/treetrail/

Degradation may also take place along riverbanks caused by extreme erosion and runoff. These instances would cause an increase in harm to aquatic life and habitat, eutrophication, and sedimentation.

As climate change progresses, more extremes are expected. This includes an increase in floods, drought, larger storms, severe heat waves, wind speeds, and hailstorms. Many of these extreme events will have impacts on species and their habitats.

Spread of Pests and Disease – Climate change is also expected to lead to increases in pests and disease, affecting natural areas, urban trees, and fish and wildlife. Gardens and crops could also experience reduced production due to extreme events, as well as pests and disease. With increase in temperatures, fewer nights below freezing, and stressed native vegetation, invasive species could decimate urban tree canopies and other vegetation.

Identified Vulnerabilities: Natural Systems

The vulnerability assessment identified the following natural systems-related vulnerabilities to South Bend

HIGH

- Impact on historically native species from increase in invasive species due to shifting average temperatures and precipitation patterns

MEDIUM-HIGH

- Water quality issues affecting humans and sensitive species due to extreme precipitation events
- Urban forests affected by insects, disease, drought, severe storms, and heat
- Plant species may not be viable under future projections
- Spread of pests and disease (ticks, plant diseases, etc.) that affect fish and wildlife, natural vegetation, street trees, gardens, and crops
- Worsening air quality from heat-induced formation of ozone and wildfire smoke

MEDIUM

- Degradation of aquatic systems, leading to loss of wildlife habitat and ecological function (water filtration, flood abatement, etc.)

MEDIUM-LOW

- Lower water levels in lakes, rivers, and streams affect fish and wildlife

Note: Vulnerability risk matrix ranking is determined from the combined scores for sensitivity and adaptive capacity.

Business and Economy

South Bend's economy is built on many different types of businesses and industries, ranging from large industry to small, local, and diverse businesses. See *Appendix 2: Community Trends* for information on South Bend's economy and tourist draws.

Climate change is expected to affect the local economy in numerous ways. Not only are transportation routes expected to be interrupted more frequently (see *Transportation and Infrastructure* section*)* but the cost of doing business is expected to rise from supply chain issues and energy demands.

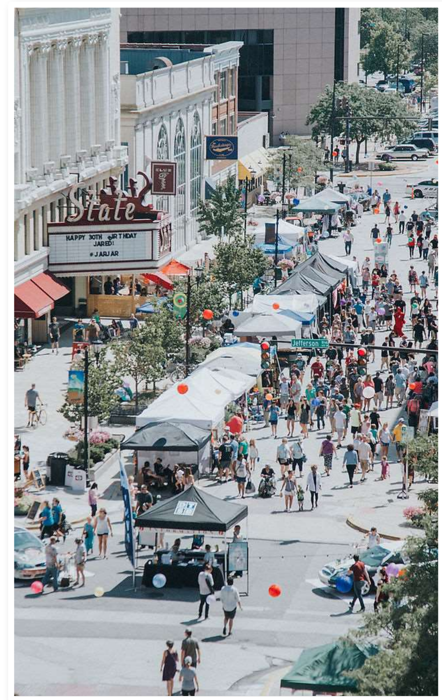

Figure A3-7. DTSB exploring downtown
https://www.downtownsouthbend.com/explore-downtown

Energy Costs – The cost of energy is likely to increase due to climate impacts, potentially affecting the cost of doing business in the region. With higher temperatures, demand for electricity is expected to increase as residents and businesses increasingly need air conditioning. Heavy reliance on coal and natural gas leaves the region vulnerable to increasingly volatile energy prices. As demand increases, costs could rise substantially to meet the need for new infrastructure investments. Taxpayers, small businesses, and utility rate payers are likely to feel this impact.

Transportation Interruptions – South Bend businesses and industry rely heavily on inexpensive, reliable, and efficient distribution of products throughout the nation. Businesses and industry may experience disruptions in transportation by air cargo, rail, and interstate shipping. As shipping reliability and the supply chain are increasingly impacted by extreme events, overall cost and profitability could be negatively affected, creating hardships for businesses and residents.

Extreme Heat Impacts on Outdoor Workers and Tourists – Increasing smoke and heat events may severely disrupt the productivity of outdoor workers in fields such as construction, agriculture, landscaping, forestry, and recreation. Those employment disruptions are likely to cause financial instability, particularly for low-income workers. Businesses may experience a higher turnover of workers in this situation along with increases in workers' compensation claims.

These same conditions may lead to a decline in tourism and recreation in downtown South Bend. It may cause less residents and visitors to travel downtown which can affect local businesses and customers.

Identified Vulnerabilities: Business and Economy

The vulnerability assessment identified the following business and economy-related vulnerabilities to South Bend

HIGH

- Outdoor workers at risk from smoke, heat, and wildfire
- Decline in tourism and recreation due to severe conditions
- Residential cooling demand and capacity affects low-income and elderly populations due to extreme heat conditions
- Storm recovery and resilience effect on labor workers and low-income populations

MEDIUM-HIGH

- Increasing cost of energy, due to higher demand, affecting local businesses
- Cost of upgrading electrical infrastructure on utility rate payers and small businesses due to increasing extreme heat conditions
- Supply chain issues caused by disruption to transportation networks and increased wait times impact on residents
- Homeowner displacement affecting low-income populations flood events
- Increased risk for **un-insured** residents in the floodplain/floodway

MEDIUM

- Transportation disruptions and traffic congestion during flood emergencies, affecting suburbs and businesses
- Supply chain issues caused by disruption to transportation networks and increased wait times impact on local businesses and chains
- Drought effect on farmers from extreme low precipitation
- Water supply effects caused by extreme low precipitation and increased water use by farming irrigation

MEDIUM-LOW

- Higher cost of doing business, due to rising energy and insurance costs, as well as disaster losses
- Residents/people less likely to come downtown due to extreme heat affects business and customers
- Floodplain/floodway revisions for **insured** residents

Note: Vulnerability risk matrix ranking is determined from the combined scores for sensitivity and adaptive capacity.

Health and Emergency Services

South Bend is not immune to global health risks from climate change. Existing health threats and inequities are expected to be exacerbated with climate change, while new and emerging threats also take hold. Extreme events are already occurring more frequently, and emergency services will be increasingly taxed as these events become even more common.

> *"Climate change is among the greatest health risks of the 21st Century. Rising temperatures and more extreme weather events cost lives directly, increase transmission and spread of infectious diseases, and undermine the environmental detriments of health, including clean air and water, and sufficient food."*
> **World Health Organization**

Heat-Related Illnesses and Mortality – One of the biggest health threats facing South Bend residents is the increasing incidence, severity, and longevity of heat waves. The number of days above 95° F sits at a historical average of 3 days per year. Projections indicate that by mid-century, Indiana could see an increase of 17-26 extreme heat days. By the 2080s, we could have as many as 29-61 days over 95° F.

Even more important than daytime highs are nighttime low temperatures. When nighttime temperatures do not cool below 75° F, core body temperature does not cool enough to protect people from the heat, which can lead to increased mortality. People who already suffer from chronic disease are particularly vulnerable.

Many of South Bend's residents are already vulnerable to heat waves due to pre-existing health conditions such as asthma (see *Appendix II: Community Trends Primer* for asthma prevalence map), and with increasing temperatures, more people will become vulnerable. People in areas with less tree canopy coverage (Fig. A3-9) and less access to air conditioning are highly vulnerable. South Bend has 22% tree canopy coverage, leaving much of the city vulnerable to higher temperatures. Lower income neighborhoods and communities of color often have even fewer trees, putting these communities at higher risk. Elderly people are very sensitive to heat, as are infants and people with existing health conditions. See *Appendix 1: Climate Change Trends Primer* for more information on climate change trends and projections for Indiana and South Bend.

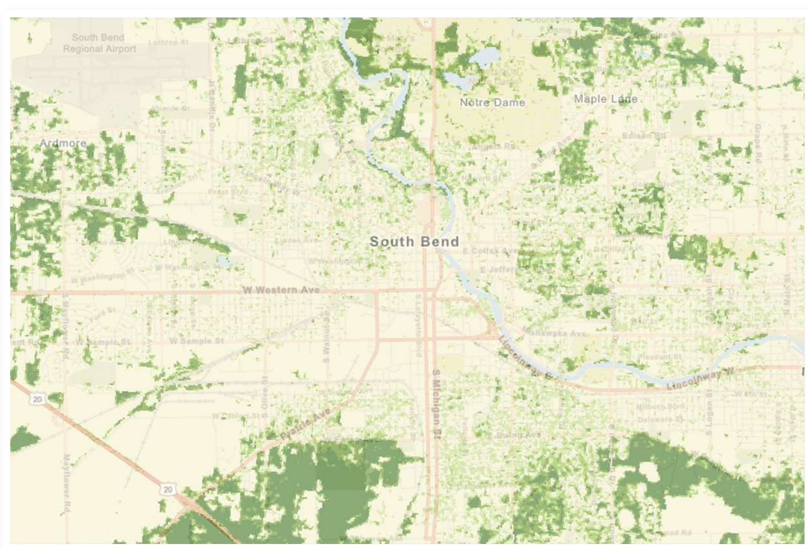

Figure A3-9. National Land Cover Database (NLCD) of tree canopy coverage in South Bend, Indiana

Flooding – Severe thunderstorms are a major source of catastrophic loss. Increasing convective potential energy and strong winds associated with climate change indicate that severe thunderstorms are likely to increase. Severe storms can cause energy outages and flooding. During energy outages, some of the most vulnerable populations include medically sensitive populations and elders, because the loss of power can lead to exposure to extreme heat or cold, as well as failure of vital medical equipment.

Flooding affects many neighborhoods throughout South Bend. People most vulnerable to flood impacts include those living in high flood risk areas, and especially those with limited mobility, such as elders, homeless, and people without vehicles. Flood areas can be exposed via river or surface flooding.

Overburdened health care system and non-profit organizations – A primary climate change vulnerability identified for South Bend is the potential for an overburdened health care system tasked with responding to outbreaks and extreme events. An influx of climate refugees could exacerbate this issue even more. Recurring disasters, such as flooding, disease outbreaks, and heat waves, could overwhelm the current capacity. Vulnerable populations include elderly residents, people who live in flood-prone areas, non-English speaking populations, people without health insurance, homeless populations, and those with already compromised health.

An existing lack of services, including in-home support services, may also be exacerbated. Extreme conditions and events are expected to lead to declines in overall health and struggles to remain independent. Elderly residents and people with disabilities are especially vulnerable.

Identified Vulnerabilities: Health & Emergency Services

The vulnerability assessment identified the following health and emergency services-related vulnerabilities to South Bend

HIGH

- Health emergency events from heat waves, particularly affecting people with compromised health, mental health issues, elderly, low income, people residing in high crime areas, outdoor workers, homeless people, and immigrants (especially non-English speaking).
- Limited outdoor activity effect on children, outdoor workers, elderly, and adults

MEDIUM-HIGH

- Air quality declines due to higher temperatures and ground level ozone formation, leading to more respiratory and heart disease

MEDIUM

- Overburdened health care industry unable to provide comprehensive care due to recurring extreme events and ongoing trauma care
- Groundwater flooding effect on flood zone residents, low-income populations, and their homes due to extreme high precipitation
- River flooding effect on residents in the river floodplain due to extreme high precipitation

Note: Vulnerability risk matrix ranking is determined from the combined scores for sensitivity and adaptive capacity.

Community Culture

The character of South Bend comes from the local history and culture that has developed over many generations. South Bend's natural environment and early commerce drove settlements of the land, which helps us understand the neighborhoods that are present today, with continued legacies in terms of culture, race, education, and opportunity. See *Appendix II: Community Trends Primer* for more information on South Bend's early settlement and cultural make up.

Today, South Bend is a thriving center for many families, business owners, non-profits, and industries. Community members identified at the stakeholder workshop that they love South Bend because of its size, proximity to other cities, the St. Joe River access and amenities, and northern Indiana's four-season climate. South Bend's community, kind people, and opportunity make the city home for its residents.

Figure A3-10. Community values populated at stakeholder workshop in July 2023

School and youth experience – Young people in South Bend participate in many outdoor sports and school activities that will be affected by heat and larger storms, leading to a lifetime of poorer health among young people and a loss of nature-based recreational values and activities. Recess for younger students will also be affected, which is a crucial aspect of child development.

Quality of Life and Sustainable Lifestyles – South Bend's overall quality of life is vulnerable to climate change impacts. Heat and severe storms could keep people indoors, reduce their connection with nature, and negatively impact their mental health. Tourism may decline, resulting in less revenue and fewer government services. If schools are impacted, families may move away from the area, further exacerbating the issue. Finally, residents that are paying more for housing, energy, and food, may not have the capacity to invest in more sustainable lifestyles, like energy efficient windows, electric cars, and locally produced food. Given the poverty rate in South Bend, particular attention will be made to low-income homeowners in the strategy development phase.

As climate change solutions are developed, an opportunity arises to develop adaptation strategies that prioritize equity as a major outcome. Careful consideration of governance systems and policies, as well as entrenched systems of power that create relative advantages and disadvantages and make certain populations more and/or less vulnerable to climate change is vital. This demands that resilience strategies be developed that not only address climate change vulnerabilities, but also the intersecting factors that make some populations more prone to experiencing direct and indirect impacts, along with the intentional allocation of resources to support sustainable solutions and enhanced resilience capacity for populations that need it most.

Climate migration – South Bend is situated in northern Indiana where climate conditions are not yet as extreme as southern and coastal states. The city also has an abundant water supply that makes the area more desirable. As other states experience immediate effects from extreme heat and sea level rise, climate migration may become increasingly prominent to the region. It is important to note that tribal community locations will not shift, and low-income households cannot afford to move either. Climate migration will put pressure on resources and exacerbate problems of affordable housing.

Access to local food and crucial services – As extreme heat becomes more common in South Bend, those not within proximity of local groceries or other crucial services may be more at risk. Analyzing who is in range of these resources is vital because standing in extreme heat will not be a safe option as people wait for the bus or opt to walk somewhere. South Bend residents without access to a vehicle will be more affected. Cooling centers will need to be more spread out and abundant community-wide for all residents, but especially those that are homeless or without A/C.

Figure A3-11. Downtown South Bend Red Table Plaza Series – an outdoor event that brings people together in the summer for live music and community gathering. https://www.abc57.com/news/dtsb-red-table-plaza-series-begins-with-a-luau-party

Identified Vulnerabilities: Community Culture

The vulnerability assessment identified the following community culture-related vulnerabilities to South Bend

HIGH

- Climate migration effect on low-income refugees

MEDIUM-HIGH

- Climate migration effect on local low-income residents
- Decreased access to local food and crucial services due to drought and extreme heat
- Food shortage effect on low-income individuals due to drought
- Lack of sustainability lifestyle and behaviors, leading to overall lower resilience to challenges and extreme events, such as drought, heat, and flooding
- Impact on native plants, local gardens, and the ability to grow food due to drought effects

MEDIUM

- Loss of outdoor recreation and nature-based culture, leading to cultural shift throughout the community and especially among young people, due to extreme heat
- School and youth experience affected by storms, heat, and loss of outdoor sports and recreation which affects students and families
- Impacts to hunting, fishing, and gathering for tribal community due to extreme heat and precipitation effects

MEDIUM-LOW

- Food shortage effect on high-income individuals due to drought

Note: Vulnerability risk matrix ranking is determined from the combined scores for sensitivity and adaptive capacity.

Conclusions

Climate change is a global threat with locally unique impacts for communities. Because each region is affected differently, and each community has a unique combination of existing vulnerabilities and assets, it is vital to develop climate change solutions at the local level. Some of the most important vulnerabilities to South Bend include storm recovery and resilience from disruptive events such as flooding and severe storms, health impacts associated with heat and air quality, exacerbated impacts to populations and resources already under stress, and degradation of natural systems that are vital to the health and well-being of residents and natural ecosystems. The most vulnerable residents and resources are generally those with the least adaptive capacity to deal with the additional impacts of climate change.

The international scientific community agrees that keeping average warming at the global level below 1.5°C (2.7° F) is vital to protect young people and future generations from catastrophic and runaway climate change. Emissions reductions are the first and most important step to preventing many of the worst impacts on the community. However, many impacts are already occurring and need to be addressed to protect people and resources throughout the community.

Because climate change affects all sectors and resources, actions must be coordinated to increase overall resilience. Without coordination, actions in one sector or population could shift impacts to other sectors or populations, especially those who are already most vulnerable. Truly co-beneficial solutions to climate change address economic and social inequities, increase ecological health and resilience, and collaborate across diverse groups and resources.

The CRVA Report has outlined the climate vulnerabilities and impacts that are of importance to and a priority of community members who attended a stakeholder workshop in July 2023. These identified vulnerabilities alongside their respective focal populations, sensitivity, and adaptive capacity will better inform the second phase of the process: resilience strategy building.

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Appendix 4: Brainstormed Impacts from Workshop

Listed in Table *3: Top 10 Prioritized Vulnerabilities* in the section *Climate Change Vulnerabilities,* and throughout the report, are modified vulnerabilities refined to categories and standards set within this report for what a climate vulnerability is. It is important to note that there was much overlap between workshop breakout groups and additional stressors identified, which are not highlighted in the report. Listed below, by breakout groups, is an unrefined list of identified impacts to climate effects in South Bend.

GROUP 1: BUILT SYSTEM (Energy/Sustainability)

1	Power outages and storm damage - economic impact, clean up, insurance costs, education impact, time off work
2	Increasing financial stress and heat stress to vulnerable and unhoused
3	Increased demand for residential cooling due to hotter temperatures and more humidity
3	Drought effect on local food systems
4	Impacts to power plant efficiency, capacity, fuel transportation, and transmission lines due to hotter temps, extreme heat events, and changing precipitation patterns
4	Continued reliance on fossil fuels during extreme events - Renewable sources affected
5	Extreme cold/heavy snow: salt ineffective, transportation/safety; less capacity to address snow (fewer private plower)
6	More peak demand for energy
6	Utilities - resilience of power lines
6	Drought affects ag which affects irrigation which lowers groundwater table impacting infrastructure (foundations/sink holes)
7	Premature pavement degradation (+ freeze/thaw cycle)
7	Natural gas plant failure in extreme cold, power lines affected by ice
7	Wastewater plant outage

GROUP 2: BUILT SYSTEM (Transportation/Planning)

1	Increase bike/ped Infrastructure
2	Run off from imperviable surfaces
2	Floodplain revisions
3	Zoning/permitting requirements for mitigation
4	Land use for stormwater retention, urban green space
5	Addressing transportation routes, mitigate temp effects
5	EV Chargin Bottlenecks
6	Increased vehicular traffic (climate refugees)
6	Employer incentivizing active transportation
6	Surfaces reactions to heat

Group 3: Built System (Infrastructure)

1	Dams at risk, bridges at risk (inundation)
2	Bank destabilization from saturation
3	Increased CSOs and decreased water quality in river
4	Durability of road materials from extreme heat and freeze thaw
4	Neighborhoods with high groundwater more risk
4	Increased basement flooding as river rises
4	Insurance costs especially for vulnerable and poor
5	Increased demand for affordable housing as people migrate from the cost, south, and private housing costs (insurance and utilities increasing)
5	Extreme weather affecting broadband (above ground utilities)
6	WWTP inundation
6	WWTP treating more clear water
6	Water/WW utility rates
6	Tree damage from storms and extremes
6	Capacity of electrical system to maintain operations in extreme heat/storms as more things become electrified (homes, cars)

Group 4: Natural System

1	Impact on native/invasive plant ranges - use plants for adaptation
2	Urban forestry impacts - huge losses of tree canopy and reconfiguring of communication
2	Impacts of seasonality on pests -> increased use in pesticides/herbicides
3	Increased water quality issues - erosion and sedimentation (affects fish, eutrophication, timing of the runoff)
3	Opportunities for wetland restoration (soil carbon sequestration, stormwater mitigation)
3	Impacts to air quality/fire risk
4	Issues with stormwater and wastewater treatment capacity
5	Extreme heat and drought - groundwater mining or recharging??
5	Challenges to wildlife
6	Increased use of natural areas - potential for overuse
6	Impacts to outdoor professions
6	Impacts to cold-water streams and biota
6	Green infrastructure in general - opportunities
6	Threats of monocultures which amplify other adverse factors

Group 5: Economic System

1	Cost of upgrading city infrastructure to taxpayers
2	People less likely to come downtown (heat/precip.)
2	Homeowner displacement because of events or increase costs of living
2	Supply chain stressors during extremes (generators, A/C, pumps)
2	Building solar downtown -> vulnerable grid can lead to blackout
3	Less likely to develop in some areas or difficulty to build (precip.)
3	increased heating and cooling for all
3	Cost of adapting public transit
4	Changes to urban tree growth -> reduce mature trees
5	Higher insurance rates (precip.)
6	Changing development permitting (higher foundation, pump systems)
6	Microclimate migration around town (more paved -> more trees)
6	Unpredictable weather disrupts outdoor public programming
6	Disruption of access to commercial/neighborhood centers
6	Change in workforce needs with adaptive infrastructure (permeable pavers, water pumps)

Group 6: Social System (Emergency Management)

1	Impacts to homeless population; Impacts to vulnerable populations (elderly, children)
2	Combined sewer overflow
3	Groundwater flooding affects development choices
4	Smoke from wildfires; air quality impacts
5	Irrigation needs
5	Degradation of pavement

Group 7: Social System (Health/Education)

1	Hard top temperatures increase, too much asphalt without tree canopy, lack of groundwater drainage
1	Lack of affordable housing -> educational disruption and high cost for transferring students
2	Inequity in public health since some households cannot afford resiliency/adaptation measures (eg. ground water backup, heat pumps, A/C)
2	Increase disparity between high/low income
2	Negative impact to education from high temps, social isolation
3	Increased injury and fatalities due to extreme heat, especially children, the elderly, low-income households, and those with pre-existing health conditions
3	Hunger -> more expensive food
3	Increased injury/fatalities due to extreme heat -> public transportation in TRANSPO busses and shelters
4	Endangerment of native plants, vegetation
4	Increased heat -> children staying at home -> increased childcare needs, less time outside -> higher risk for mental health challenges
4	Low-income households cannot afford increased utility bills in summer -> hotter temps in homes

Group 8: Social System (Cultural/Non-Profit)

1	Long term impact on limited outdoor activity (youth and children) which is essential for brain development
1	Tribes not moving/low income folks can't move; getting priced out/off land because of climate refugees or climate drive migration
2	Food shortages
3	Government decision making issues
3	Stress on infrastructure (ex. stormwater)
4	Impacts to homeless population under extreme heat days affecting # of summer cooling centers
4	Impact on hunting, fishing, and gathering which is dependent for livelihood
4	Disruption in food chain process
4	Increased cost of heating and cooling -> money and nervous system stress
5	Less walking/biking - more car use - more pollution
5	Small businesses losing clients and challenges with staying affordable (with food shortages/price increases)
6	Governments and municipalities coming up with policies on the quick
6	Mental health impacts because of lack of outdoor activities
6	Heat connection to violence
6	More processed foods/less nutrient dense meals for public feeding programs
6	Flight cancellations and travel disruptions
6	Increased use of disposables