CLIMATE AND SOCIO-ECONOMIC VULNERABILITY ASSESSMENT TEMPLATE

A GUIDE FOR PRIORITIZING THE UNIQUE NEEDS OF YOUR COMMUNITY WHEN PLANNING FOR CLIMATE CHANGE

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Climate and Socio-Economic Vulnerability Assessment Template

This Climate and Socio-Economic Vulnerability Assessment Template (Template) is designed to help your community undertake an assessment that integrates climate change, social and economic conditions, and local landscape features. By considering these factors together, you will be able to holistically plan for climate change in a way that meets the unique needs of your community.

To conduct your vulnerability assessment, we have created this Template document for you to fill in. After you fill it in, remove this Template introduction section, the highlighted instruction text and images, and add/change the logo and text on the cover. You will then have your community's Vulnerability Assessment report.

About this Template

This Template can be used to produce a community-wide assessment that compares the vulnerabilities of different local systems, service areas, or projects (referred to as "Elements" throughout this document) of your choosing.

We've already populated chapters with climate and socio economic data specific to your city within this Template to get you started. This information can be expanded with any additional data you want to include.

How to Use the Template

Start thinking about what "Elements" your community plans to assess (see scenarios below for guidance), and then go through this document, review the provided data, and add information section-by-section using the highlighted text to guide you.

Throughout this Template, text highlighted in yellow indicates a place where your City needs to add locally specific information. Text that is highlighted in blue represents guidance that we encourage you to consider as you populate the Template. In Chapter 7 you will be creating your Vulnerability Assessment using the data we provided and any additional information you added in previous chapters. Each step in Chapter 7 of this Template has a designated color *to match the corresponding tab* within a Climate and Socio-Economic Vulnerability Assessment Workbook, which serves as a companion tool to this Template. By using this Excel Workbook, you can post and view your information in a handy chart format and then transfer the information to the Template.

Quick Guide

Yellow Text = replace text with your city's information

Blue Text = information to guide you through the process of filling in this Template

📖 + **color text** = go to the Workbook, find the corresponding colored tab, and fill in

Optional Tool: The Workbook

The Climate and Socio-Economic Vulnerability Assessment Workbook (Workbook) is an Excel document that provides an alternative format for thinking through vulnerabilities that some users may find helpful for assessing and completing a local vulnerability assessment. The Workbook is particularly useful for communities that want to dive deeply into how climate change could impact individual elements of the local community. Note, however, that the Template can be completed without the use of the Workbook.

New Data Resoure: Socio-Economic Data Mapper

To help cities gather socio-economic data to put in this Template, we partnered with Headwaters Economics. They created a Socio-Economic Data Mapper for cities to graphically visualize, by census tract, various socio-economic demographics that increase local vulnerability in your City. This tool also allows users to download relevant GIS shape files for local analysis[1]. We used this data mapper to pre-populate this Template for your City.

Combined, these tools can help your community create a robust, locally relevant climate and socio-economic vulnerability assessment.

Suggested Use Scenarios

While there is no "right" way to complete this Template or the accompanying Workbook, below are a few suggested use scenarios. In the end, it will be up to your community's discretion to determine the best way to utilize these tools to help you understand your vulnerabilities and begin identifying locally appropriate adaptation actions. Be creative: combine these tools, and others, in whatever way is most appropriate for your community's needs.

- ***Use Scenario 1:*** A community wants to create a community-wide vulnerability assessment and has a steering committee of stakeholders to help guide the project.

For this community, we suggest starting with the Socio-Economic Data Mapper in order to understand local socio-economic conditions and where there are pockets of particularly vulnerable individuals. This information can then be used to expand the existing steering committee to ensure inclusion of representatives from the most at-risk communities. Once done, we recommend creating the scope for the vulnerability assessment by completing Section 7, Step 1 in the Template. Once the community has a stronger sense for what and whom to assess as part of the vulnerability assessment, we recommend using the Workbook to complete the requisite phases of the assessment. Results can then be copied into this Template, which can serve as the final vulnerability assessment.

- ***Use Scenario 2:*** A community wants to focus on how climate change could impact a specific sector or system, such as its stormwater system.

In this case, we suggest that the community start by using the Workbook to specifically outline how the various components of their stormwater system could be or already are vulnerable to climate change and socio-economic conditions. Results can be then be transferred into the Template, which can serve as a system-specific climate vulnerability assessment.

- ***Use Scenario 3:*** A community is just beginning to think about conducting a vulnerability assessment and is not sure where or how to begin.

For this community, we recommend reviewing this Template, in its entirety, to understand the various steps and components of the process as well as the climate and socio-economic context of the City. Once the community has a deeper understanding of what a vulnerability assessment entails, we recommend using Section 7, Step 1 in this Template to frame what and who will be assessed. From there, the community can use the Workbook and the Socio-Economic Data Mapper to dive more deeply into how the community, and its constituent parts, are vulnerable.

Acknowledgements

This Template and the associated Workbook and Socio-Economic Data Mapper would not be possible without the financial and procedural support of the Urban Sustainability Directors Network. Additional financial support for this project came from the Great Lakes Integrated Sciences and Assessment (GLISA). We'd like to thank all of the partners who worked to create the information within these various resources, including the Huron River Watershed Council, GLISA, and Headwaters Economics. Finally, we'd like to thank the cities that formally served on our steering committee, providing guidance to ensure these products were as useful and usable as possible. This includes the cities of: Ann Arbor, MI; Bloomington, IN; Cleveland, OH; Dearborn, MI; Evanston, IL; and Indianapolis, IN.

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PREPARING FOR CLIMATE CHANGE

CLIMATE CHANGE VULNERABILITY ASSESSMENT

CITY OF ANN ARBOR

An assessment of climate change, social and economic conditions, and local landscape features to ensure we are planning a secure future for all.

Executive Summary

[This is the placeholder for the executive summary of your report. We recommend you complete this section last.]

The climate in Ann Arbor is changing, and these changes are causing immediate threats to our citizens, our health, our economy, and our community's overall vitality. We know that over the last several years we have experienced a 0.7°F increase in average annual temperature, with spring experiencing the greatest amount of warming (a 1.7°F increase). Nighttime temperatures are rising, and the number of cold days (< 32°F) are declining. Annual precipitation is changing too: in the last several decades Ann Arbor has experienced a 44.2% increase in annual precipitation, with the greatest change happening in winter (75.4% increase, amounting to roughly an extra 4.4 inches). In addition, we have seen an increase in the frequency and intensity of severe storms, with the City experiencing a 41.2% increase in the number of heavy precipitation events (>2 inches in 24 hours) annually. These are just some of the changes that have led to serious impacts to our community's infrastructure, economy, social networks, cultural identity, and safety. These impacts are likely to be more extreme as the climate continues to change.

In light of this, the City of Ann Arbor has decided to plan for climate change, making sure we are considering what changes are projected to take place in the future and integrating that information into how we, as a City, operate. Guiding this work is a commitment to ensuring the health, safety, and general welfare of all Ann Arbor's residents – especially the frontline communities that are already experiencing a disproportionate share of the impacts associated with a changing climate. This Vulnerability Assessment is one important component of our City's efforts to create a more equitable and resilient community for all Ann Arbor residents – ensuring every resident is prepared for the current and future risks associated with a changing climate.

Within the pages of this report, readers will find more information about how changes in weather and long-term climate have already impacted Ann Arbor and details about projected changes in climate relevant to the City. Further, the report provides insights into what those changes might mean in terms of on-the-ground impacts, an assessment of Ann Arbor's overall vulnerability to these changes, and which segments of the community may be most vulnerable. Finally, this report provides some initial suggestions on what we, as a community, can do to prepare.

At a high level, we anticipate that climate change will exacerbate or create the following major impacts in Ann Arbor:

- [List of major changes and their impacts - or possibly a table with projected changes and impacts.]

In response to these projected changes and local impacts, the City of Ann Arbor has initially identified the following actions:

- [A list of prioritized climate adaptation actions.]

Implementing these and other actions to effectively and efficiently address our community's climate and socio-economic vulnerabilities will require an "all hands on deck" approach. That is why we invite you to join us as we move forward with creating a more resilient, thriving, and sustainable Ann Arbor for all.

Contents

About this Template 1

How to Use the Template 1

Optional Tool: The Workbook 1

New Data Resoure: Socio-Economic Data Mapper 1

Suggested Use Scenarios 2

Acknowledgements 2

1. What is a Vulnerability Assessment? 4

2. Socio-Economic Profile of Ann Arbor 6

A) Percent of population over 65 6

B) Percent of population under 5 7

C. Percent of community in poverty 8

D.) Percent of population with limited English proficiency 9

E.) Percent of non-white population 9

F.) Percent of households receiving public assistance 10

G.) Percent of households where mortgage is greater than 30% of household income 11

H.) Percent of those with disabilities 11

I.) Percent of renters 12

J.) Percent of population without a high school diploma 13

K.) Other Social Vulnerability Determinants 13

Cumulative Socio-Economic Vulnerability 13

3. Climate Change in the Great Lakes REgion and Ann Arbor 15

A. Climate Change Profile for the Great Lakes Region 15

B. Climate Change Profile for the City of Ann Arbor 17

4. Landscape Features That Affect Ann Arbor's Vulnerability 22

Landscape Features that Affect Extreme Heat Conditions 22

Ann Arbor's Heat Vulnerability Map 24

Landscape Features that Affect Flooding Exposure 24

Ann Arbor's Flooding Vulnerability Map 26

Other Factors That Influence Local Vulnerability 27

Summary of Landscape Vulnerability 27

5. Ann Arbor's Vulnerability Assessment Results 28

Step 1: Define Scope of Assessment 28

Step 2: Socio-Economic Analysis 33

Step 3: Exposure Analysis 35
Step 4: Landscape Analysis: Heat 37
Step 5: Landscape Analysis: Flooding 39
Step 6: Cumulative Impacts 41
Step 7: Sensitivity Assessment 43
Step 8: Adaptive Capacity Assessment 45
Step 9: Calculating Vulnerability 47
6. Next Steps 50
Conclusion 50
Acknowledgements 51

1. WHAT IS A VULNERABILITY ASSESSMENT?

As the climate continues to change, communities across the U.S. and the world are asking, "*How are these changes already affecting my community?*" and "*What local impacts might we experience from future changes in climate?*" To help answer these questions, communities are using a tool called a vulnerability assessment. A vulnerability assessment helps stakeholders identify:

1. What changes in climate are projected to happen and what those changes could mean in terms of local **impacts**,
2. The level of **exposure** the community has to potential changes,
3. How **sensitive** the various city and community systems are to projected changes in climate, and
4. What **capacity** those systems have to adapt.

Definition of Terms

Exposure: The presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected (IPCC 2014).

Sensitivity: The degree to which a system or species is affected, either adversely or beneficially, by climate variability or change. The effect may be direct (e.g., a change in crop yield in response to a change in the mean, range, or variability of temperature) or indirect (e.g., damages caused by an increase in the frequency of coastal flooding due to sea level rise) (IPCC, 2014).

Impact: Effects on natural and human systems such as lives, livelihoods, health, ecosystems, economics, societies, cultures, services, and infrastructure (IPCC, 2014).

Adaptive Capacity: The ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences (IPCC, 2014).

Vulnerability: The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt (IPCC, 2014).

Figure 1 provides a graphical depiction of how exposure, sensitivity, impacts, and adaptive capacity all combine to create vulnerability.

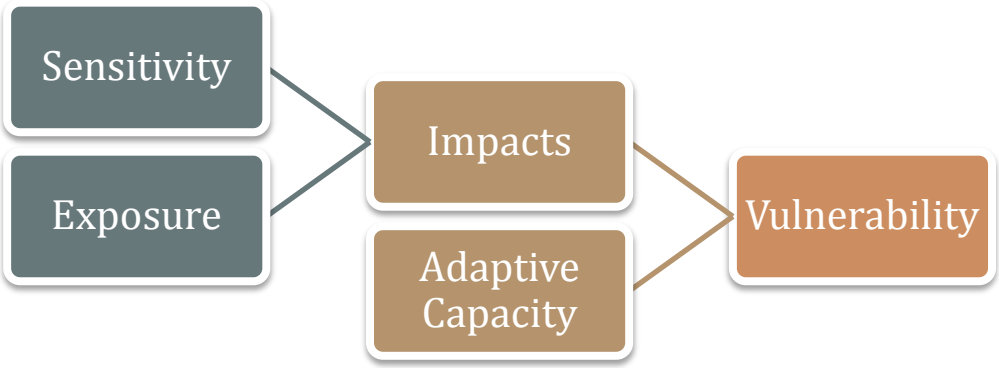


Figure 1: Graphical depiction of the various elements of vulnerability

Once completed, the results of a vulnerability assessment can be used to inform the types of actions a community should take to reduce vulnerabilities or seize on potential opportunities.

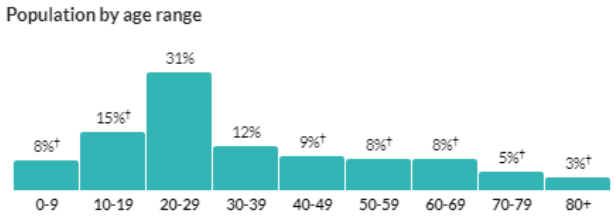
Currently, most existing vulnerability assessment guidance and tools have either limited or no discussion regarding the important role that a community's social and economic characteristics play in determining local vulnerability. Because of the critical importance social dynamics play in shaping our local community, the City of Ann Arbor partnered with fellow Midwestern cities, the Huron River Watershed Council, the Great Lakes Integrated Sciences and Assessment, and Headwaters Economics to develop a revised vulnerability assessment template that assesses our community's social, physical, cultural, economic, and environmental vulnerability to climate change. The result is the ***Climate and Socio-Economic Vulnerability Assessment Template*** **(Template).**

This updated Template allows cities across the U.S. to seamlessly combine projected changes in climate with local socio-economic characteristics to get a more holistic and relevant picture of their community's existing and future vulnerabilities. Here in Ann Arbor, we used this updated Template to inform our vulnerability assessment. We sincerely hope that other communities find the Template and our vulnerability assessment results valuable as they assess their local climate and socio-economic vulnerabilities. For the City of Ann Arbor, this document not only identifies our key vulnerabilities, but it outlines initial steps we will take to build resilience. We will use this document to help ensure that all our residents are safe, resilient, and thriving both today and in a climate-altered future.

2. SOCIO-ECONOMIC PROFILE OF ANN ARBOR

{Before getting into the assessment process itself it is important to understand the socio-economic context of your city. The following section serves as an overview of these factors for the City of Ann Arbor. This information will support a more thoughtful, comprehensive vulnerability assessment, ensuring stakeholders consider socio-economic factors in their calculation of local vulnerability.

Section Summary[2]***:***



Age

28

Median age

Income

$38,787

Per capita income

$60,745

Median household income

Ann Arbor is a unique and diverse city. It is this diversity that makes us great. [Insert statistics about diversity/demographics within the City.]

In order to fully understand how the City of Ann Arbor is resilient or vulnerable to climate change, we need to take a deep look at the social characteristics that make up our community. Using the *Socio-Economic Data Mapper (Data Mapper)* tool from Headwaters Economics, we analyzed ten characteristics that help explain our local vulnerability:

A) Percent of population over 65
B) Percent of population under 5
C) Percent of community in poverty
D) Percent of population with limited English proficiency
E) Percent of non-white population
F) Percent of households receiving public assistance
G) Percent of households where mortgage is greater than 30% of household income
H) Percent of disabled
I) Percent of renters
J) Percent of population without a high school diploma

A) Percent of population over 65

As of 2015, the City of Ann Arbor had 116,194 residents, 10.8% (12,541) of which were 65 years or older.[3] This is lower than the U.S. national average for residents over 65, which is 14.1%. Of this population, approximately 1,911 (1.6%) are 80 years or older. This is important to note because elderly populations are at increased risk of compromised health related to environmental hazards and climate change. In fact, age is the single greatest risk factor related to illness and death from extreme heat[4] and the elderly are more likely to have pre-existing medical conditions or compromised mobility, which reduces their ability to respond to extreme heat and extreme weather events[5] (which are both likely to become more frequent due to climate change). Finally, the increased likelihood of chronic disease,[6] combined with the fact that older adults are more susceptible to air pollution, which is expected to become worse due to climate change, makes them a uniquely vulnerable population.[7]

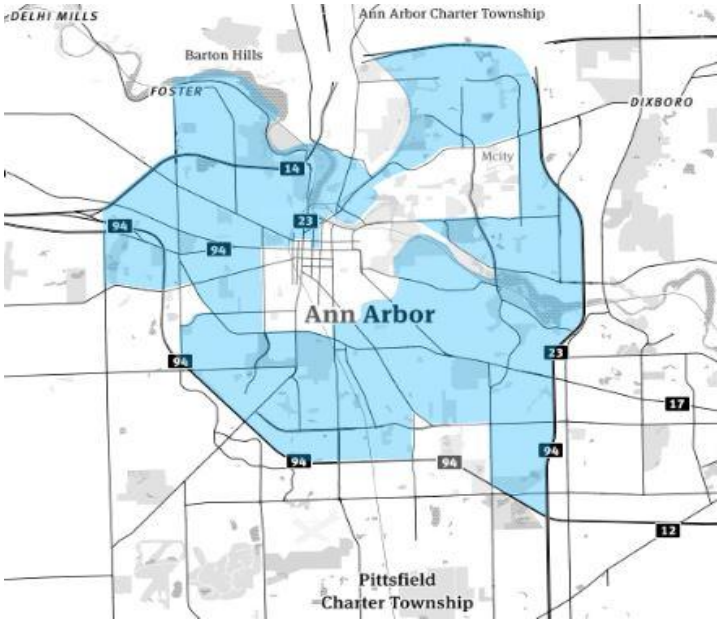


Figure X: Census Tracts in Ann Arbor where more than 14% of the population is 65 years of age or older (14% is the national average).

{This map was generated using the Data Mapper created by Headwaters Economics (accessible here). You can update this map with different values using the above link. You can also download this GIS data used to create this map in order to make your own map.}

All of these factors combined likely mean that the elderly require unique and/or additional services compared to younger residents. As such, understanding our community's age profile helps us determine the appropriate types of services and resources needed to ensure all of Ann Arbor's residents are able to survive and thrive in a climate-altered future.

B) Percent of population under 5

As of 2015, 4.3% (5,047) of the City of Ann Arbor's population was under 5 years of age. This is slightly lower than the national average (6.3%).[8] Knowing what percentage of our residents are under the age of five, and where they reside, is important because children's developing bodies are particularly sensitive to health problems and environmental stresses,[9] including those associated with climate change. Children also spend more time outside and have faster breathing rates than adults, so they are more at risk for respiratory problems related to things such as ground level ozone, airborne particulates, wildfire smoke, and allergens:[10] all of which can be exacerbated by climate change. Moreover, because their immune systems are not fully developed, children are more susceptible to infectious diseases,[11] including those that spread during natural disasters.

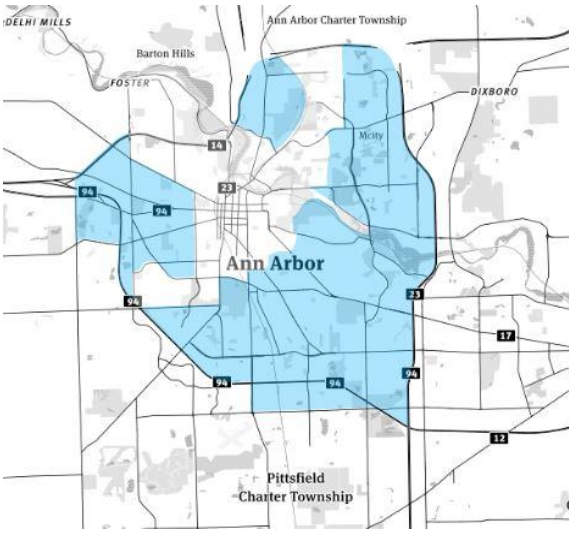


Figure X: Census Tracts where in Ann Arbor where more than 6% of the population is under 5 years of age (6% is the national average).

{This map was generated using the Data Mapper Tool (accessible here). You can update this map using different values using the above link. You can also download the GIS shape files and create your own map.}

Focusing our efforts on reducing youth vulnerability makes sense for a number of reasons, including the fact that childhood lays the foundation for lifelong health, meaning that poor health during childhood can significantly increase the likelihood of problems throughout adulthood.[12] With the rising cost of health care in the U.S., ensuring that we have a healthy, productive community is pivotal to not only our wellbeing, but also our social structure and our economy.

As we seek to ensure our youth are resilient to climate change, we need to pay particular attention to youth that are living in poverty. Children living in poverty are less likely to receive high-quality health care, meaning that they may be especially sensitive to changes in climate and the ensuing health impacts.[13] Children living in poverty are also more likely to live in vulnerable areas, including areas that have poor air quality, limited transit options, and homes that are less resilient to changing weather patterns. As we move forward with building community-wide resilience, care must be taken to ensure that children, especially those in poverty, are prioritized.

C. Percent of community in poverty

As of 2015, 24,732 City of Ann Arbor residents were living in poverty; 16,452 were classified as living in deep poverty (meaning they earn less than ½ of the federal poverty level). This represents 23.4% of the City's population that is living in poverty and 15.6% that is living in deep poverty. In addition, data shows that 0.8% of the City's residents (872) are both living in poverty and over the age of 65. All of these numbers are significantly above US national averages.[14]

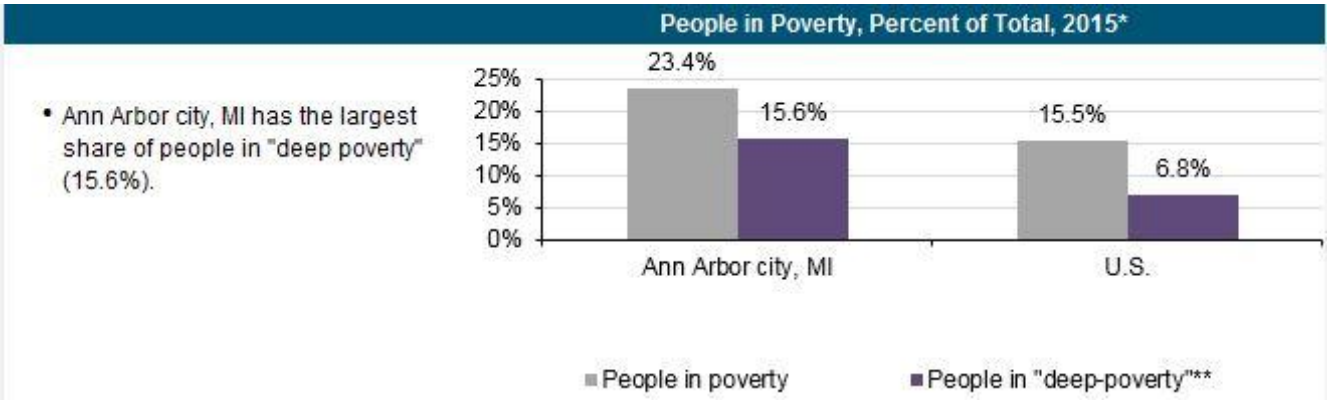


Table X: Percentage of residents living in poverty. {This table was taken from the Populations at Risk Tool created by Headwaters Economics (accessible here). If desired, consider deleting this table and inserting a GIS map denoting the distribution of the individuals living in poverty within your jurisdiction.}

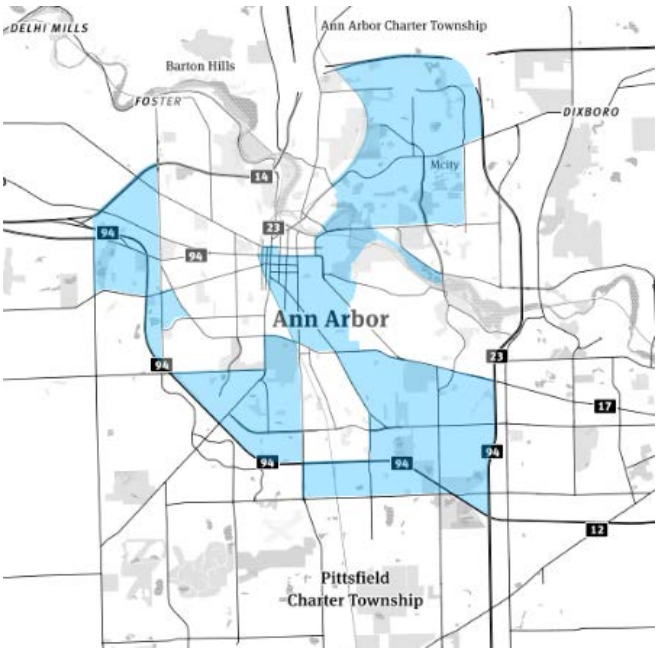


Figure X: Census Tracts in Ann Arbor where more than 11% of the families are living in poverty (11.3% is the national average).

{This map was generated using the Data Mapper tool (accessible here). You can update this map with different values using the above link. You can also download the GIS shape files and create your own community map using the link above.}

The above information focuses on the number of individuals living in poverty. In addition, we also analyzed the number of families living in poverty. As of 2015, 1,475 families (7.2%) in Ann Arbor lived in poverty. Of these, 1,026 had at least one child residing in their household, and 530 were households with a single mother (2.6% of all households). This rate of family poverty is lower than the national average (11.3% for families in poverty and 5.2% for single mother families in poverty).

Understanding the percent and location of those living in poverty is critical because low income is one of the strongest predictors of compromised health as well as an individual's ability to recover from disasters.[15] Moreover, we know that natural disasters disproportionately impact the poor because of things such as inadequate housing, social exclusion, a diminished ability to evacuate, lack of property insurance, and more acute emotional stress.[16] In addition, research has shown that low-income people are more likely to be overlooked during the emergency response period following a disaster.[17] Low-income populations are also more likely to live or work in areas with greater exposure to environmental hazards, including working in jobs that require outdoor labor.[18]

Income inequality within a community is also associated with poor health outcomes: residents in low-income neighborhoods tend to have higher incidences of asthma, depression, diabetes, heart

conditions, and emotional stress compared to higher-income neighborhoods.[19] Low-income households also have to make lifestyle compromises in order to make ends meet, such as choosing unhealthy foods, less food, substandard housing, or delayed medical care.[20] Having limited income may also mean that it is simply too expensive to run fans, air conditioners or heaters to manage indoor living temperatures, not to mention that many low-income residences are located in high crime areas, meaning that residents may feel unsafe opening their windows.[21] Finally, the poor are least likely to have health insurance, which further exacerbates their vulnerability to the negative health impacts associated with climate change such as deteriorating air quality, higher incidences of asthma, and increased allergens.[22]

D.) Percent of population with limited English proficiency

According to the US Census Bureau, in 2015, 1.9% of the Ann Arbor community did not speak English well (2,123 people). This is lower than the national average (4.5%).[23] Understanding the percentage and location of people with limited English proficiency is important because many, if not most aspects of life in the US require basic fluency in English. For example, knowing about and then accessing emergency services, learning about poverty reduction programs, or accessing health care all necessitate basic English proficiency. Research has found that limited English proficiency can:

- Limit a person's ability to effectively act during emergencies;[24]
- Make it harder to follow directions and interact with agencies, thereby limiting the amount of support available to respond to and recover from disasters of all types;[25]
- Make it harder for people to get higher wage jobs;[26] and
- Result in isolation from other segments of the US population, and social isolation can be a serious health risk.[27]

Figure X: Census Tracts in Ann Arbor where more than 5% of the population has limited English proficiency (4.5% is the national average).

{This map was generated using the Data Mapper tool (accessible here). You can update this map with different values using the above link or you can download the GIS data from this website and create your own local GIS maps.}

Because of these factors, it is important that we identify who within our population has limited English proficiency and work with trusted partners to ensure these populations have access to the information, tools, and resources they need to build resilience.

E.) Percent of non-white population

As of 2015, 27.7% of the population in Ann Arbor (32,144) identified as non-white. This is slightly higher than the national average (26.4%). Of this population, 7.4% (8,591) identified as Black or African American, 0.4% (482) identified as American Indian, and 19.9% (23,071) identified as "Other Races".[28] In addition, 4.4% (5,156) of Ann Arbor's residents identified as Hispanic.[29]

This information is important because race and ethnicity strongly correlate with disparities in health, exposure to environmental pollution, and vulnerability to natural hazards, including climate-related natural hazards.[30] More specifically:

- Research consistently finds race-based environmental inequities across many variables, including the tendency for minority populations to live closer to noxious facilities and Superfund sites, and to be exposed to pollution at greater rates than whites.[31]
- Across races, the rates of preventable hospitalizations are highest among black and Hispanic populations. Preventable hospital visits often reflect inadequate access to primary care. These types of

hospital visits are also costly and inefficient for the health care system.[32] Relative to other ethnicities and races, Hispanics and blacks are less likely to have health insurance: but rates of uninsured are dropping for both groups.[33]

- Compared to other races, blacks have higher rates of infant mortality, homicide, heart disease, stroke, and heat-related deaths.[34]
- Hispanics have higher rates of diabetes and asthma, compared to other ethnicities.[35]
- Minority communities often have less access to parks and nutritious food, and are more likely to live in substandard housing, all of which can negatively impact health outcomes.[36]
- Minorities tend to be particularly vulnerable to disasters and extreme heat events. This is due to language differences, housing patterns, variations in the quality of housing, community isolation, and cultural barriers.[37]
- Blacks and Hispanics, two segments of the population that are currently experiencing poorer health outcomes, are an increasing percentage of the U.S. population and our local community.[38]

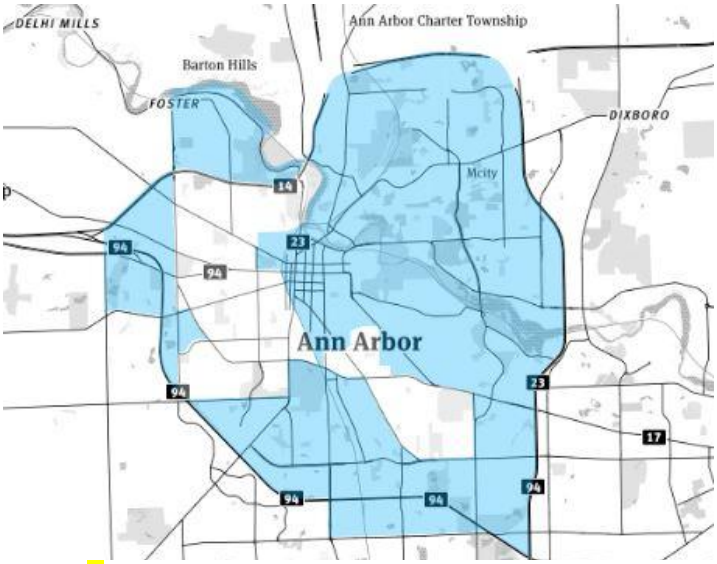


Figure X: Census Tracts in Ann Arbor where more than 26% of the population identifies as non-white (26.4% is the national average).

{This map was generated using the Data Mapper tool (accessible here). You can update this map with different values using the above link or you can download the GIS data at this site and use it to create your own local map.}

Given these realities, it is important that the City of Ann Arbor ensures that we effectively integrate the needs, perspectives, and lived realities of our diverse population into our efforts to build resilience.

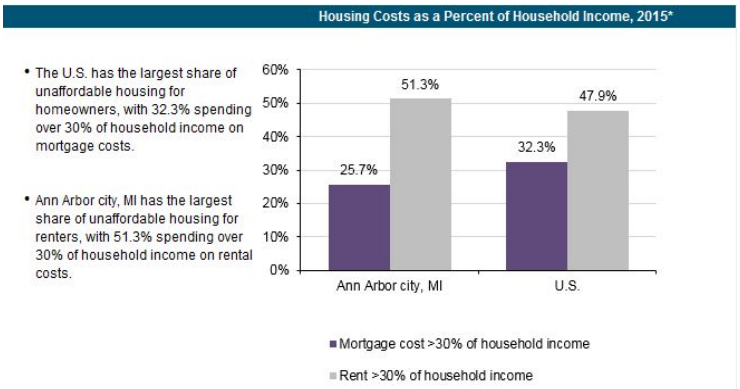


Table X: Comparison of the percentage of households in Ann Arbor and the U.S. that spend more than 30% of their income on rental fees or their mortgage.

{This table was taken from the Populations at Risk Tool (accessible here). If desired, delete this table and insert a GIS map denoting the distribution and location of the population paying more than 30% of household income on housing.}

F.) Percent of households receiving public assistance

As of 2015, 3,489 households within Ann Arbor (7.4%) received Food Stamps/SNAP assistance. This rate of Food Stamp/SNAP assistance is significantly lower than the national average, which is 13.2% of all U.S. households.[39] While this isn't the only form of public assistance, we have chosen Food Stamps/SNAP assistance as our indicator of public assistance because it is more widely known than the other types of assistance and, as such, there is a higher likelihood that at-need households are getting this assistance compared to the more obscure forms of public assistance.

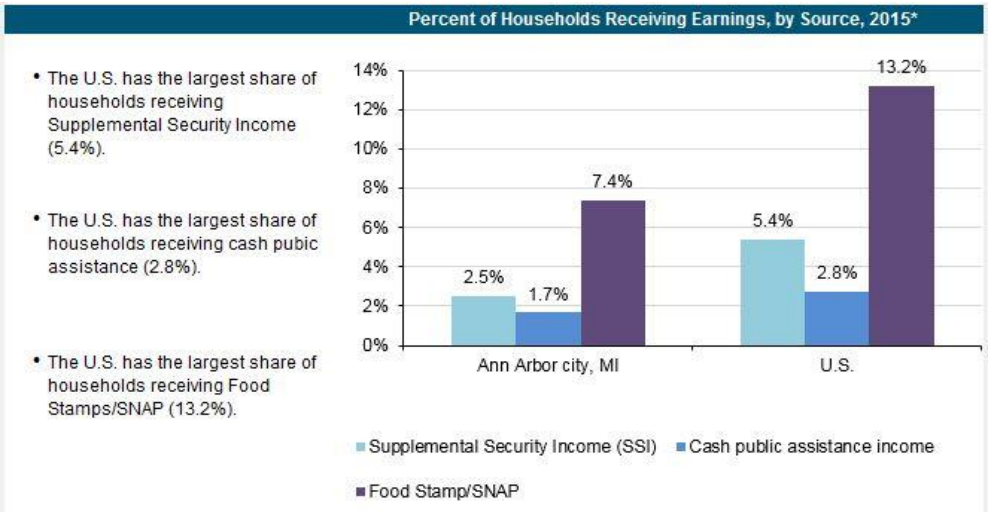


Table X: Percentage of households in Ann Arbor and in the U.S. that receive three types of public assistance.

{This table was taken from the Populations at Risk Tool (accessible here). If desired, delete this table and insert a GIS map denoting the distribution of the population receiving public assistance within your jurisdiction.}

Understanding the percentage and location of residents receiving public assistance is important because this information is indicative of households living in poverty or households with insufficient resources. For example, in 2011, families receiving public assistance spent, on average, 77% of their household budget to meet the basic necessities of housing, food, and transportation:[40] leaving little left to accommodate other important needs, including disaster preparedness, response, and recovery.

G.) Percent of households where mortgage is greater than 30% of household income

As of 2015, 3,670 households (25.7%) in Ann Arbor were paying more than the sustainable 30% of household income towards their mortgage and 13,375 households (51.3%) were paying more than the sustainable 30% of household income towards their rent. Rental costs are slightly above the national average and point to a troubling sign regarding the affordability of housing in Ann Arbor compared to the income being earned. The reason this is important is because the federal government considers families with housing costs that exceed 30% of their income to be "housing-cost burdened"[41] and therefore, to have less disposable income to spend on other necessities such as food, heating/cooling, transportation, healthcare, etc.

Research also shows that those households living in affordable housing (those spending less than 30% of household income on housing) are more stable and less likely to move frequently. This can enhance community vitality and cohesion, an important element of creating a more resilient Ann Arbor. In addition, this stability is linked to several positive health outcomes in children and young adults, such as improved emotional and behavioral problems, fewer pregnancies, reduced drug use, and a lower risk for depression.[42]

As we work to ensure that Ann Arbor is building resilience, we must be aware of the needs of all residents, including those with limited economic resources.

H.) Percent of those with disabilities

As of 2015, 8,082 residents of Ann Arbor were living with disabilities. This represents 7.0% of our total population; a figure lower than the national average of 12.4%.[43]

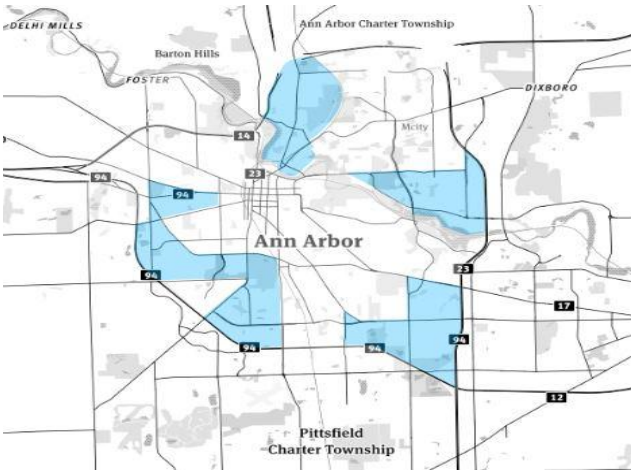


Figure X: Census Tracts in Ann Arbor where more than 12% of the population has a disability (12.4% is the national average).

{This map was generated using the Data Mapper tool (accessible here). You can update this map with different values using the above link or download GIS data directly from this site and use it to create another GIS map.}

Figure X: Census Tracts in Ann Arbor where more than 36% of the housing units were rentals (36.1% is the national average).

{The above map was generated using the Data Mapper tool (accessible here). You can update this map with different values using the above link or go to the website and download the GIS shape files and create your own local map.}

The reason we have chosen to analyze this indicator is that disabled people are subject to a series of health complications that are often significantly heightened due to environmental conditions. For example, limited mobility and being bed ridden raises heat mortality,[44] limited mobility can significantly delay and/or prevent effective evacuation during times of disaster, and extreme weather events can disrupt one's ability to get medical treatment, which can be disastrous for those with compromised health. These are only some of the heightened vulnerabilities faced by people with disabilities. Because of this, Ann Arbor is determined to incorporate the needs of the disabled into our attempts to create a more resilient community.

I.) Percent of renters

As of 2015, 55.2% of housing units in Ann Arbor were rentals; an additional 0.4% were mobile homes.[45] This rate is significantly higher than the national average of 36.1% for rentals, but less than the national average for mobile home residences.

For those that own a home, the median home value in Ann Arbor is currently $243,829. This figure represents a decrease in home value of $20,851 based on average home values in 2009.

Understanding what percentage of our population owns a home is important because home ownership contributes to well-being and stability. Home ownership also improves mental health, including increasing self-esteem, creating a heightened sense of control over one's living situation and financial security.[46] On the flip side, the financial stress associated with losing one's home is heightened by people's attachment to place and their neighborhoods.[47]

In terms of renters, studies have repeatedly shown that renters pay a larger proportion of their income in rent; rental rates have increased over the past 25 years with no sign of abatement.[48] This financial burden is exacerbated by the fact that rental homes are typically not well maintained with conditions such as dampness, mold, and exposure to toxic substances or allergens heightened for those residing in rental units.[49] Because of this, renters may pay even more to heat, cool, or make their rentals more accommodating, further exacerbating the financial impact associated with renting.

{If desired, insert a GIS map denoting the distribution and location of the rental, mobile home, and homeowner population within your community.}

Understanding the location and number of residents residing in rental versus mobile versus owned homes is important for determining how best to respond to climate-related impacts in a just and equitable manner.

J.) Percent of population without a high school diploma

As of 2015, 2,317 people in Ann Arbor did not have a high school diploma (3.6%). This is lower than the national average (13.3%)[50] but still a troubling statistic since high school completion is a common proxy for overall socio-economic circumstances. In particular, lack of education is strongly correlated with poverty and poor health. For example:

- People without a high school degree are more than twice as likely to live in inadequate housing compared to those with some college education.[51]
- Thirty-eight percent of Americans without a high school degree do not have health insurance, compared to 10 percent with a college degree.[52]
- The rate of diabetes is much greater for those without a high school degree. Incidence of this disease is more than double the rate of those who have education beyond high school.[53]
- Binge drinking is most severe among those without a high school degree. This demographic group had the highest rate of binge drinking across all measured categories (such as income, race, ethnicity, or disability status).[54]

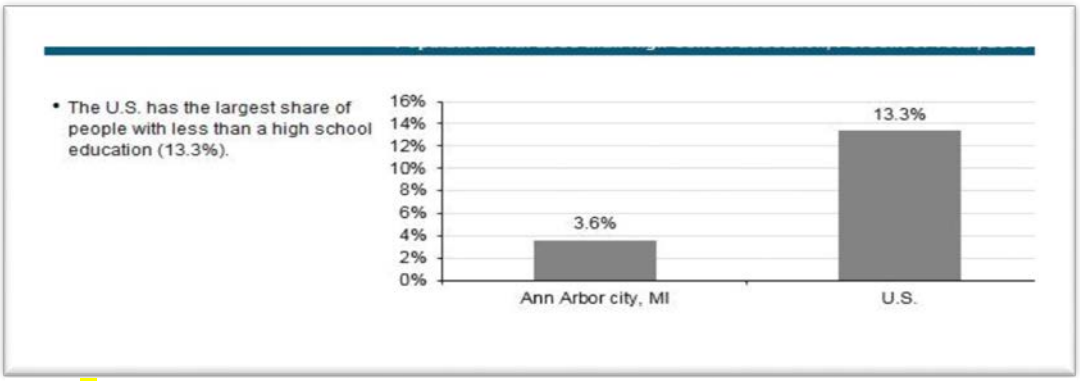


Table X: Comparison of individuals in Ann Arbor and the U.S. that have less than a high school education.

{This table was taken from the Populations at Risk Tool (accessible here). If desired, delete this table and insert a GIS map denoting the location of populations with less than a high school education within your local jurisdiction.}

K.) Other Social Vulnerability Determinants

[This section is intentionally left blank in case your community would like to incorporate other social determinants of vulnerability. Since you know your community best, use this space to include key characteristics that might influence whom is the most vulnerable within your jurisdiction. Some additional characteristics to consider include: percentage of population with asthma; percentage of low birth-weight infants; percentage of college students; percent of population without a vehicle (if you don't have frequent public transit); alternative financial breakdowns other than just the federal poverty line (this would be important if your community has pockets of affluence and a lot of people living on the margins); percentage of population participating in the labor market; percentage of people living alone - especially the elderly; percentage of population without health insurance; heat-related emergency department visits; heart attack hospitalizations; percentage of population that is obese; or any other indicators that are relevant to your community. You may also want to talk to your local school districts and public health officials to see what indicators they use to assess community sensitivity and, if relevant, include those indicators in your assessment.]

Cumulative Socio-Economic Vulnerability

Combining the findings from each of the previous sections, we were able to create a map denoting some of our must socio-economically vulnerable neighborhoods (Figure X). This figure identifies all the Census Tracts where the City of Ann Arbor has higher than the national average for all of the following variables: percentage of families in poverty; percentage of people with disabilities; percentage of households that rent; percentage of population under the age of five; percentage of population over the age of 65; percentage of population that is non-white; and percentage of population that has difficulty speaking English.

{You can use any data you would like to demonstrate cumulative socio-economic vulnerability. You could combine a smaller subset of variables into a single map, add in additional variables, or use different (e.g., lower or higher) values to highlight your community's socio-economic vulnerability. Regardless, the point of this section is to demonstrate how the various socio-economic variables profiled above combine into a cumulative look at your community's socio-economic vulnerabilities. For the map below, we used the Data Mapper tool (accessible here) to identify census tracts in Ann Arbor that were above the national average for every indicator outlined above.}

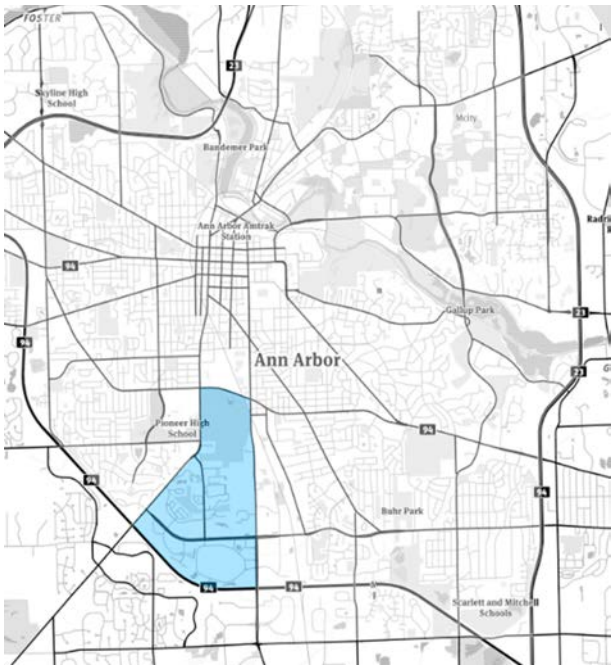


Figure X: Census Tracts within the City Ann Arbor that have the highest overall socioeconomic vulnerability. The map highlights all of the Census Tracts with higher than the national average for: percentage of families in poverty; percentage of people with disabilities; percentage of households that rent; percentage of population under the age of five; percentage of population over the age of 65; percentage of population that is non-white; and percentage of population that has difficulty speaking English.

{Also consider adding a short description of how/if these findings align with local knowledge. Perhaps these are the areas that the city has already targeted for investment or redevelopment. Perhaps these are areas that are chronically underfunded. Perhaps the infrastructure regularly fails in these areas. Or maybe they are sources of great cultural diversity that the City wants to protect. The point is to add a few sentences to summarize what these findings suggest for how the City should move forward with integrating this information into how you think about vulnerability and how to plan to reduce it}.

In the next section we highlight our exposure to historic, current, and projected futures changes in weather and climate.

3. CLIMATE CHANGE IN THE GREAT LAKES REGION AND ANN ARBOR

A. Climate Change Profile for the Great Lakes Region

The climate of cities throughout the Great Lakes region is already changing. Rising temperatures are leading to more storm activity in our atmosphere, helping to fuel extreme weather and increased precipitation. While heat, drought, and other changes associated with climate change remain a concern for the future, many areas of the region are already facing challenges associated with more total precipitation and more frequent downpours.

Great Lakes Regional Summary

- Average air temperature in the Great Lakes region has increased by 2.0°F since the 1900s.
- Average air temperature is expected to rise 1.8°F to 5.4°F by 2050.
- Total annual precipitation has increased by 11% since 1900 in the region with significant intra-regional variation.
- The total volume of rain falling in the most extreme events has increased 37% since 1951.
- Total annual precipitation will likely increase in the future, though types of precipitation will vary (i.e., more winter precipitation in the form of rain).

Temperature

Average annual temperatures in the Great Lakes region have increased by 2.0°F since the 1900s, faster than the global and national rates. Most of this warming has been observed during the late spring and early winter, and in overnight low temperatures. The average temperature for the Great Lakes region is projected to increase in the future (1.8°F to 5.4°F by 2050), and many of the northern parts of the region will likely experience the most change with increases ranging from 4.5 to 6.0°F. The region is projected to see increases in the number of hot and very hot days, with projections indicating the southern portions of the region will see 15 to 35 more days over 95°F in an average year compared to the late 20th century.

Precipitation

The Great Lakes region has experienced changes in the frequency, amount, and form of precipitation. Total precipitation has increased by 11% since 1900 across the region, though this change varies within the region. Therefore, more local data should be used where available. In addition, heavy precipitation has increased rapidly throughout the region. Days seeing moderately heavy (1.25" or more) precipitation events have become 37% more frequent since 1951. Much of the region is projected to experience more average annual precipitation with total amounts ranging from an additional 2 to 6 inches per year by the mid-21st century. In addition, the Great Lakes themselves are projected to contribute more water vapor to the air. This increase in moisture combined with rising temperatures, which are necessary for storm formation, will likely produce more intense storms in the future.

Climate change will likely accelerate in the future.

The observed trends in temperature, precipitation, and seasonality are projected to continue or accelerate into the future. The rate of warming has been fastest during the winter, with some locations experiencing twice the annual warming rate of the Great Lakes region. Temperatures will continue to warm at a pace near or faster than the current

rate, and precipitation will likely continue to increase, though variability and multi-year dry periods should still be anticipated. By mid-century, summer and spring temperatures may have greater increases compared to fall and winter.

Preparing for the next normal, not a new normal.

The climate system is dynamic and will continue to change rapidly due to greenhouse gas emissions and inherent feedback systems. The challenges, priorities, and risks of the current or next generation climate will continually change and will affect all sectors. Importantly, climate and weather conditions will not change to a new set of static conditions. This means long-term planning efforts in all departments should regularly evaluate climate and be as flexible and adaptable as possible. Assessing vulnerabilities of a city's assets is a first step toward this goal.

The following table summarizes how various climate risk factors in the Great Lakes region are expected to change in the future. The number and direction of arrows indicate the relative projected trend for mid-century and end of century. A single arrow indicates a projected moderate increase or decrease by mid-century, and two arrows indicate a substantial increase or decrease by end of century.

CLIMATE CHANGE IN THE GREAT LAKES REGION

RISK	BY MID-CENTURY	BY END OF CENTURY	SUMMARY
Convective Weather (Severe Winds, Lightning, Tornadoes, Hail)	Uncertain*	Uncertain*	While extreme precipitation has increased in the region, specific severe weather types (e.g., tornadoes and hail) have remained relatively stable over time.
Severe Winter Weather (Ice/Sleet Storms, Snow Storms)	Uncertain*	↓	Warmer, shorter winters will reduce the length of winter and winter-related impacts. However, some areas may see more ice, sleet, freezing rain, and wet snow with slightly warmer winter temperatures.
Extreme Heat	↑	↑↑	The number of extremely hot days, those over 95°F and 100°F, will likely increase, though not as fast as in areas farther south. Overnight lows have warmed faster than daytime highs, which may lessen opportunities for relief during heat waves.
Extreme Cold	↓	↓↓	The number of extremely cold days (i.e., days below 10°F) have decreased in the region and are projected to decrease even more in the future.
Dam Failures	↑	↑↑	Stronger and more extreme precipitation events coupled with aging dam infrastructure will increase the probability of dam failure, if appropriate measures are not taken.

CLIMATE CHANGE IN THE GREAT LAKES REGION			
RISK	**BY MID-CENTURY**	**BY END OF CENTURY**	**SUMMARY**
Flood Hazards	↑	↑↑	Stronger and more extreme precipitation events will be more likely to overwhelm stormwater infrastructure without appropriate adaptation efforts.
Wildfires	Uncertain*	↑	Summer drought and the number of consecutive dry days may increase in the future, despite more precipitation annually, increasing the risk of wildfires.
Drought	Uncertain*	↑	Summer drought and the number of consecutive dry days may increase in the future.
Infestation	↑	↑	With shorter winters and longer growing seasons, conditions may become more suitable for invasive species and pests currently found elsewhere and distribute vector-borne illnesses.

**Boxes labeled uncertain reflect either a lack of available data to discern a trend or no apparent trend from existing data.*

The arrows in this table reflect a qualitative assessment made by the project team based on the best available data for the Great Lakes region. While these trends hold true for projections for most of the region, they should not be assumed to hold true for any particular location. Data used to make this assessment is provided by the NOAA Technical Report NESDIS 142-3 and the Third National Climate Assessment.

B. Climate Change Profile for the City of Ann Arbor

The following chart is a characterization of climate change at the city level. There will be trends in cities that may match or deviate from regional trends. This allows cities to consider unique challenges, vulnerabilities and opportunities associated with climate change.

Ann Arbor Summary

- Average air temperature in Ann Arbor has increased by 0.7°F since the 1900s.
- Average air temperature is expected to rise 3°F to 7°F by 2050.
- Total annual precipitation has increased by 44.2% since 1900.
- The total volume of rainfall in extreme events has increased 37% since 1981.
- Total annual precipitation will likely increase in the future, though types of precipitation will vary (i.e., more winter precipitation in the form of rain).

Climate Change in the City of Ann Arbor

	Historic (1951-2014)	Mid-Century Projections (High Emissions)	End of Century Projections (High Emissions)	Change Mid-century/End of century	Percent Change* Mid-century/End of century
Average Temperature	49.8°F	52.8 to 56.8°F	54.8 to 60.8°F	3 to 7°F / 5 to 11°F	6 to 14% / 10 to 22%
Winter (1981-2010)	27.1°F	28.1 to 32.1°F	30.1 to 36.1°F	1 to 5°F / 3 to 9°F	4 to 19% / 11 to 33%
Spring (1981-2010)	48.4°F	49.4 to 55.4°F	51.4 to 59.4°F	1 to 7°F / 3 to 11°F	2 to15% / 6 to 23%
Summer (1981-2010)	71°F	74 to 78°F	78 to 82°F	3 to 7°F / 7 to 11°F	4 to 10% / 10 to 16%
Fall (1981-2010)	52.2°F	55.2 to 59.2°F	59.2 to 63.2°F	3 to 7°F / 7 to 11°F	6 to 13% / 13 to 21%
Average Low Temperature	40.4°F	41.4 to 47.4°F	45.4 to 51.4°F	1 to 7°F / 5 to 11°F	3 to 17% / 12 to 27%
Average High Temperature	59.1°F	62.1 to 66.1°F	64.1 to 70.1°F	3 to 7°F / 5 to 11°F	5 to 12% / 9 to 19%
Days/Year Greater than 90°F	8 Days	20 to 44 Days	44 to 50 Days	12 to 36 Days/ 36 to 42 Days	150 to 450% / 450 to 525%
Days/Year Greater than 95°F	2 to 4 Days	6 to 20 Days	Not Available	4 to 16	200 to 400%
Days/Year Less than 32°F	122 Days	95 to 99 Days	Not Available	-27 to -23	-22 to -19%
Total Annual Precipitation	36.7 in.	38.7 to 40.7 in.	35.7 to 33.7 in.	2 to 4 in. / -1 to 7 in.	5 to 11% / -3 to 19%
Winter (1981-2010)	7.9 in.	6.9 to 10.9 in.	5.9 to 10.9 in.	-1 to 3 in. / -2 to 3 in.	-13 to 38% / -25 to 38%
Spring (1981-2010)	9.3 in.	8.3 to 12.3 in.	8.3 to 13.1 in	-1 to 3 in. / -1 to 4 in.	-11 to 32% / -11 to 43%
Summer (1981-2010)	11 in.	9 to 16 in.	8 to 14 in.	-2 to 5 in. / -3 to 3 in.	-18 to 46% / -27 to 27%
Fall (1981-2010)	9.4 in.	9.4 to 10.4 in.	8.4 to 12.4 in.	+0 to 1 in. / -1 to 3 in.	0 to 11%/ -11 to 32%
Heavy Precipitation Days(>1.25")	3.7 Days/Year	4.1 to 6.5 Days/Year	6.1 to 6.5 Days/Year	0.4 to 2.8 Day/Year /2.4 to 2.8 Days/Year	11 to 76%/ 65 to 76%

*Percent change is calculated as the difference between the projected values and the historic average, divided by the observation and multiplied by 100.

Data provided in this table is described in the "About the Data" section for "GHCN", "CMIP3", and "Dynamically Downscaling for the Midwest and Great Lakes Basin."

Temperature and Hot/Cold Extremes

Average Temperature

The average air temperature in Ann Arbor has risen since the 1900s, but has seen a moderate increase compared to other cities in the Great Lakes region. Annual average temperature has increased by 0.7°F from 1951 to 2014, with the current annual average temperature being 49.8°F. Average annual seasonal temperatures have also increased (except Fall, which experienced a decrease of 0.2°F), with spring experiencing the greatest increase of 1.7°F. Average temperatures in Ann Arbor are projected to increase 3.0 to 7.0°F by mid-century under a business as usual (i.e., high emissions) scenario, with the summer and fall having the greatest increases.

Hot Days

Days with temperature at or above 90°F are very common with multiple occurrences every year and no clear increasing or decreasing trend. Most years on record have experienced 2 to 4 consecutive days over 90°F, with events of 5 to 7 consecutive days occurring less frequently. By mid-century (i.e., 2050), models suggest an increase of anywhere from 12 to 36 more days per year over 90˚F, and an increase of 30 to 42 more days per year over 90°F by end of century. Models are not able, however, to tell us if those days will be consecutive or not.

Days with high temperatures at or above 95˚F have decreased since the 1930s. Events of consecutive days experiencing maximum temperatures over 95˚F have seen very little change and generally only occur every few years. These types of events are typically limited to 2 to 4 consecutive days, with a few occurrences of longer periods. By mid-century (i.e., 2050), models suggest an increase of 6 to 20 days over 95 and 4 to 16 days per year over 100˚F, and an increase of 8 to 28 days per year over 100°F by end of century. However, such hot days will not occur consecutively.

Heat waves can result from a combination of different drivers including high humidity, daily high temperatures, high nighttime temperatures, stagnant air movement, etc. In the future, models project an increase in the number of days experiencing high temperatures that could lead to additional heat waves, especially since air stagnation events are projected to increase. There is greater certainty that summer nighttime low temperatures will continue to increase, thereby making it more difficult to cool off at night during extended heat events. In addition, any periods of future drought will also contribute to extreme heat.

Cold Days

On average, Ann Arbor experiences 122 days per year that fall below freezing (32°F). Historical records show this number has decreased already. The city is projected to experience fewer nights below 32°F with decreases of 23 to 27 days by mid-century.

Days with temperatures at or below 10˚F are very common and have not experienced any clear trends over time. Consecutive days at or below 10˚F are frequent, and typically last for 2 to 7 days with less frequent occurrences lasting 8 to 15 days. In the future, there are projected to be even fewer very cold days, so this type of event will be even rarer.

Precipitation and Flood/Drought Indicators

Average Precipitation

The amount of total annual precipitation in Ann Arbor has increased by 44.2% (13.2”) from 1951 to 2014. An increase in precipitation was observed in all four seasons, with the winter seeing the greatest percentage increase of 75.4% (4.4”). Average precipitation in Ann Arbor is projected to increase by 2 to 4 inches by mid-century compared to current trends.

Precipitation - Historical

The frequency and intensity of severe storms has increased. Ann Arbor has seen a 41.2% increase in the number of heavy precipitation events (36 storms from 1951-1981 compared to 51 storms from 1981-2010). The southeastern part of Michigan is projected to experience on the order of 1 to 3 more days of heavy precipitation (events greater than 1.25”) per year.

Flooding results when rainfall volumes exceed the capacity of natural and built infrastructure to handle precipitation. Stormwater managers look at several different “design” storms (inches falling over a certain length of time) when designing and managing their systems. These “design” storms are effectively the probability of any given

amount of precipitation falling in a set period of time, based on historical experience. Monitoring over time shows that the volumes falling during these "design" storms are increasing. What this means is that the values used to build our existing infrastructure (Bulletin 71[55], used data through 1986, and NOAA Atlas 14[56] added 1987-2011) are dependent on fluctuating estimates of rainfall.

The table below helps illustrate this point by showing precipitation volumes in inches for both Bulletin 71 and Atlas 14 (Bulletin 71/Atlas 14) along with percent change between the two in brackets. All percent change values are positive which means they are larger in Atlas 14. This data shows how the "design" storm has changed over time.

***Please note**: this table does not show projections for how the design storm may change in the future due to climate change.*

PRECIPITATION FREQUENCIES FOR THE CITY OF ANN ARBOR							
	1-YR	**2-YR**	**5-YR**	**10-YR**	**25-YR**	**50-YR**	**100-YR**
1-hr	0.88/0.97 [10%]	1.06/1.14 [8%]	1.29/1.44 [12%]	1.47/1.70 [16%]	1.69/2.07 [22%]	1.87/2.38 [27%]	2.05/2.69 [31%]
12-hr	1.63/1.82 [12%]	1.97/2.06 [5%]	2.39/2.50 [5%]	2.72/2.90 [7%]	3.13/3.54 [13%]	3.46/4.09 [18%]	3.79/4.68 [23%]
24-hr	1.87/2.09 [12%]	2.26/2.35 [4%]	2.75/2.83 [3%]	3.13/3.26 [9%]	3.60/3.93 [9%]	3.98/4.50 [13%]	4.36/5.11 [17%]

Precipitation – Future

In the Great Lakes region, projected changes in seasonal mean precipitation span a range of increases and decreases. In the winter and spring, the region is projected to experience wetter conditions as the global climate warms. By mid-century, some of this precipitation may manifest in the form of increasing snowfall, but projected warmer conditions by end of century suggests such precipitation events will most likely be in the form of rainfall (USGCRP, 2017).

Heavy precipitation events of more than 2" in a day (i.e., 24-hour period) are projected to increase by no more than one day (0.25 to 1 days) by mid-century and increase by slightly more (0.75 to 1.25 days) by end of century. Precipitation events of more than 3" in a day are projected to increase by less than half a day (0.15 to 0.45 days) by mid-century and increase by slightly more (0.3 to 0.75 days) by end of century.

There has been a slight decreasing trend in historic heavy hourly snowfall (events with snowfall over 1") with varying year-to-year conditions, and little to no change in hourly snowfall exceeding 2". Warmer temperatures in the future will cause some winter precipitation to transition from snow to rain over time. Annual snowfall is projected to decrease by 5" to 25" by mid-century, and decrease by 15" to 35" by end of century.

Drought, defined here as periods of 3 weeks with less than 0.45" of rainfall, has been highly variable year-to-year, with slight decreasing trends in summer and fall events and a slight increasing trend in spring events. In the future, even though more annual precipitation is projected overall, more is anticipated to fall in shorter, extreme events. Thus, there will be longer periods of time that experience no rainfall, increasing the potential for drought.

In the following chapter we look at local landscape features that influence our exposure and overall vulnerability to climate change in Ann Arbor.

About the Climate Change in the Great Lakes Region and Ann Arbor Data

Coupled Model Intercomparison Project (CMIP) Version 3. The future (mid-century) climate projections for Ann Arbor are based on the Coupled Model Intercomparison Project Version 3 (CMIP3) A2 emissions scenario, representing "business as usual" high emissions scenario. These data were selected because they were used in the Third National Climate Assessment (Melillo et. al., 2014). More information is available at: https://www.wcrp-climate.org/wgcm-cmip

"Dynamical Downscaling for the Midwest and Great Lakes Basin." Future projections are based on the dynamically downscaled data set for the Great Lakes region developed by experts at the University of Wisconsin-Madison. There are a total of six downscaled models that represent how a variety of different variables are projected to change (mid-century, 2040-2059, compared to the recent past, 1980-1999). The ranges are comprised of the lowest and highest values from all six dynamically downscaled data sets. The regional data are available for download at: http://nelson.wisc.edu/ccr/resources/dynamical-downscaling/index.php.

National Oceanic and Atmospheric Administration National Centers for Environmental Information Global Historical Climatology Network Station Observations (GHCN). More information about this station located in Ann Arbor, MI from 1981-2010 is available at: https://glisa.umich.edu/station/c00200230

"National Oceanic and Atmospheric Administration ThreadEx Long-Term Station Extremes for America". ThreadEx is a data set of extreme daily temperature and precipitation values for 270 locations in the United States. For each day of the year at each station, ThreadEx provides the top 3 record high and low daily maximum temperatures, the top 3 record high and low daily minimum temperatures, the top 3 daily precipitation totals, along with the years the records were set for the date (NCAR, 2013). ThreadEx data for the Detroit area from 1966 to 2016: http://threadex.rcc-acis.org/

4. LANDSCAPE FEATURES THAT AFFECT ANN ARBOR'S VULNERABILITY

{Below are a number of landscape features that can be used to help understand local place-based vulnerability. You are free to add in additional factors should you have more specific information that affects your local vulnerability to heat or flooding. You are also welcome to add in additional climate-related impacts (e.g., changing disease patterns, shifting ecosystems) and the local landscape features that exacerbate your vulnerability to these impacts. In some cases you may not have the local information needed to fully assess your place-based landscape vulnerability. In that case, consider including the background information about why and how certain landscape features influence vulnerability, but indicate that your city is not currently tracking these features so is unable, at this time, to include them in your vulnerability assessment. You can include the tracking of these variables as one of your key adaptation actions and then, in the future, you can use these variables to get a more nuanced look at your local vulnerabilities.}

Section Summary

- Local features influence heat impacts, including: impervious surfaces, urban heat island, and vegetation coverage.
- By combining the aforementioned factors, we were able to generate a holistic assessment of where in Ann Arbor local landscape features may affect our vulnerability to heat. Results showed that [Insert short summary of results from heat landscape analysis].
- Local landscape features influence flooding impacts, including: floodplain location and extent, elevation, slope, landscape cover, and stormwater asset conditions.
- By combining the aforementioned factors, we were able to generate a holistic assessment of where in Ann Arbor local landscape features affect vulnerability to flooding. Results showed that [Insert short summary of results from flooding landscape analysis].

In addition to our socio-economic composition and projected changes in climate, certain features related to the way Ann Arbor is designed and our physical environment make us more or less vulnerable to climate change. This section explores a number of these landscape characteristics or features that affect the vulnerability of our residents and our systems to both extreme heat and flooding. We chose to look specifically at our local vulnerability to heat and flooding because those are the two largest climate impacts we expect to continue experiencing in a climate-altered future. {If you are looking at other impacts, insert that information here.}

Landscape Features that Affect Extreme Heat Conditions

Extreme heat is the number one weather-related killer in the United States.[57] The majority of people who have traditionally died from heat exposure die in their homes, generally in environments with little or no air conditioning. Extreme heat has the most negative impact on adult populations aged 50+, with men being notably more vulnerable to heat exposure and death than women.

Extreme heat can be exacerbated by local environmental conditions, especially the urban heat island. An urban heat island is a phenomenon whereby urban regions experience warmer temperatures than their rural surroundings.[58] Some of the reasons for the localized urban heat island include: reduced vegetation in urban areas; the materials used to build in urban areas; and urban geometry.

Because of the very real and serious threats posed by extreme heat to Ann Arbor residents, we have chosen to look at three local landscape indicators that increase our vulnerability to heat [Note: update the list below based on which indicators your local community chooses to use. You are welcome to add in others if you have the relevant data]:

a) *Vegetation Coverage: Normalized Difference Vegetation Index*
b) *Impervious Land Cover*
c) *Urban Heat Island Effect*

a) Vegetation Coverage: Normalized Difference Vegetation Index

Many urban areas have a lower percentage of green space, compared to rural regions. Since trees and vegetation provide shade, which helps lower surface temperatures, the lower percentage of green space in urban areas can directly translate into higher temperatures compared to more vegetated rural areas. In addition trees and other vegetation help reduce air temperatures through a process called evapotranspiration, in which plants release water to the surrounding air, dissipating ambient heat. In urban areas with limited green space, the value of shading and evapotranspiration is limited, particularly when compared to more rural or less developed regions, thereby contributing to elevated urban surface and air temperatures.

To determine the amount and location of vegetation throughout Ann Arbor we used data from the United States Geological Survey's (USGS) Normalized Difference Vegetation Index (NDVI), which is a measure of "greenness". We downloaded a Landsat 8 aerial image from USGS Earth Explorer and processed it into a NDVI image with ArcMap.[59] The results from this analysis can be found in Figure X. {If your local community doesn't have this information, you may be able to find some relevant data at the **USGS Earth Explorer** website.}

[Insert map of vegetation coverage in your community.]

[Add in a short description of the results of your vegetation mapping. For example, which neighborhoods or areas have the highest coverage of vegetation? Which areas have the least coverage? Does this correlate with some local knowledge such as areas known to have a higher urban heat island or areas the city has already targeted for future tree plantings due to their low vegetation coverage?]

b) Impervious Land Cover

In contrast to vegetated areas, we know that impervious surfaces, surfaces made from materials that do not absorb precipitation (e.g., asphalt, concrete, brick) are extremely effective at trapping heat. Given this, the City of Ann Arbor also mapped the location and percentage of impervious land coverage throughout our community (Figure x). {If your local community doesn't have this information, you may be able to find some relevant data at the **USGS Earth Explorer** website.}

[Insert map of impervious land cover in your community.]

[Add in a short description of the results of your impervious land cover mapping. For example, which neighborhoods or areas have the highest percentage of impervious surface coverage? Which areas have the least? Do these results correlate with local knowledge such as the areas with the highest amount of impervious surface being downtown and the areas with the lowest amount of impervious surface being in more affluent residential areas?]

c) Urban Heat Island Effect

Most urban areas consist of roads, roofs, buildings, and other materials that, traditionally, have low solar reflectance and high heat capacity. Solar reflectance (also known as albedo) is the percentage of solar energy reflected by a surface. Darker surfaces, which tend to abound in urban areas, have lower solar reflectance values compared to lighter surfaces meaning that they reflect less and absorb more of the sun's energy. This absorbed heat increases surface temperatures and contributes to the formation of urban heat islands. According to the US EPA, "another important property of building material that influences heat island development is a material's heat capacity, which refers to its ability to store heat. Many building materials frequently used in urban areas, such as steel and stone, have high heat capacities. As a result, cities are typically more effective at storing the sun's energy as heat within their infrastructure."[60] As an example, studies have shown that downtown metropolitan areas can absorb and store twice the amount of heat compared to rural surroundings during the daytime.[61]

Using information from [Insert name of source], we were able to determine the local urban heat island effect throughout the City of Ann Arbor. [Add in more detail about whatever data set you are using. For example, what does it show? Who generated the data? What scale is it at (e.g., city-wide or by Census tract)? It is for a given day or an average of a specific summer or year? How many sensors were used to collect this data and were they located across your community or in a small set of locations? What were the rural locations you used to determine the difference in temperature between your community and the rural areas (e.g., to determine what your local urban heat island amount is?]

Figure X shows Ann Arbor's urban heat island.

[Insert map of urban heat island in your community.]

{If your local community doesn't have this information, you may be able to find some relevant data at the **USGS Earth Explorer** website.}

[Add in a short description of the results of your urban heat island mapping. For example, which neighborhoods or areas are warmest? Which areas are coolest? Does this correlate with some local knowledge such as the warmest areas are in the industrial portions of town and the coolest are neighborhoods that have high vegetative coverage?]

d) [Other]

[If you have other landscape features that influence heat, please enter them here.]

Ann Arbor's Heat Vulnerability Map

By combining the above maps,[62] we were able to identify the specific areas of our community that are particularly sensitive to heat (Figure X).

[Insert map combining impervious land coverage, urban heat island, and vegetation coverage in your community.]

As can be seen from this map, [Insert a short description about the results denoted in your above map. Profile which neighborhoods or regions of the city have the highest vulnerability to heat based on local landscape features. Consider discussing the areas that have the lowest vulnerability. This doesn't need to be a detailed analysis but do point out a few key things that will help inform your final vulnerability assessment.]

Landscape Features that Affect Flooding Exposure

Flooding is one of the most common and pervasive climatological impacts to affect the City of Ann Arbor. Every year we experience numerous localized flooding events. These events can cause property damage, road closures, economic disruptions, and other issues. Larger events have far reaching implications for our local economy, transportation systems, and health and safety. Nationally, flood deaths are highest in adults over the age of 50

(although 20-30 years old also have a fairly high vulnerability to flooding-related deaths and injuries).[63] Males are notably more vulnerable to flooding-related deaths, particularly those tied to flash flooding events.[64]

Because of the acute vulnerability we have in Ann Arbor, we want to understand what local landscape features enhance or reduce our local vulnerability to flooding. The following factors are important elements of understanding our local vulnerability to flooding events [Update the list below based on which indicators your local community chooses to use. You are welcome to add in others if you have the relevant data]:

a) Location of Floodplains
b) Elevation
c) Slope
d) Land Cover (vegetation and impervious cover)
e) Stormwater Asset Conditions

a) Location of Floodplains

Because we know that certain areas of our community are already susceptible to flooding, we used our 100-year and 500-year floodplains as an indicator of future flooding risk. Using data from the Federal Emergency Management Agency (FEMA), we were able to identify areas within Ann Arbor that lie within both the 100 and 500-year floodplains (Figures X and Z). Land within the 100-year floodplain has a 1% chance of flooding each year. Land within the 500-year floodplain has a 0.2% chance of flooding in any given year. However, we know that climate change is altering these frequencies, making the likelihood of flooding in any given year significantly greater. As such, we thought it important to use both the 100 and the 500-year floodplains as these represent our current and likely future flood risks.

[Insert the two maps denoting the location of the 100-year and 500-year floodplains in your community.]

Based on the flood risk denoted in figures X and Z, [Insert description of your findings. For example, what percentage of your city is in the 100-year floodplain? What percentage is in the 500-year floodplain? Are there certain parts of your city that are always vulnerable or areas that you are surprised to see on the map (e.g., downtown, economic centers, cultural sites, critical facilities)?]

b) Elevation

Understanding the elevation of various areas of our city helps us to understand which areas might be more prone to future flooding. Recognizing that, we used data from the City's GIS office to map the elevation above sea level for the entire city. We used 2-foot contour lines to denote changes in elevation. As shown in Figure X, [Insert information about results. For example, is the majority of your city as the same elevation? Does the elevation map mirror the floodplain map? Are there surprising findings? Certain areas that are particularly low elevation that warrant discussion?].

[Insert Figure X here.]

c) Slope

Slope is the degree of incline or tilt that exists between two points. Understanding slope can help us determine which areas might be particularly susceptible to runoff and erosion from major rain events. Using a Digital Elevation Model raster layer provided by the City's GIS department, we were able to map slope throughout the city. Based on results, we grouped slope into three categories:

1) Areas with less than 12% slope;
2) Areas with slope between 12-18%; and
3) Areas with more than 18% slope.

This classification is based on development restrictions described in the City's Code of Ordinances [Update the slope levels to mirror what is in your city's code of ordinances, if anything].[65]

[Insert Figure X here.]

As shown in Figure X, [Insert relevant findings. For example, you may determine that slope is not an important feature to consider in your community. Alternatively, you may highlight certain areas of the city that have major changes in slope that are worthy of notice as they may be pockets of future flooding risk.]

d) Land Cover

Land cover is an important factor affecting flood potential (as well as heat potential as discussed above). Impervious surfaces and low vegetative covering are indicators of runoff potential. We know that when precipitation falls on impervious surfaces, such as roads, streets, sidewalks, and buildings, it is unable to infiltrate into the soil. Conversely, the greater portion of vegetation cover present, the more precipitation may infiltrate the soil, and thus, the less precipitation moves through the city as run-off. Because of this, the City of Ann Arbor has decided to use impervious surface coverage and vegetation coverage as indicators of local landscape vulnerability to flooding.

[Insert maps on impervious surface and vegetation cover, which were created above, into this section.]

As shown in the above figures, [Insert any commentary regarding major findings. You can also repeat some of the high level findings discussed in the heat section].

e) Stormwater Asset Conditions

The quality (age, condition, capacity) and design of our city's stormwater infrastructure is another important element that influences our flooding potential. For the purposes of this landscape assessment, we chose to look at the condition of the various elements of our stormwater system, known as our stormwater asset map. For example, current best practices in our state dictate that all stormwater infrastructure should be built to handle a 10-year storm event. In Ann Arbor, however, we are striving to build all stormwater infrastructure to the current 100-year storm event - since we know the frequency and intensity of storms are changing due to climate change, we want to make sure we are effectively preparing. With that in mind, we conducted an analysis to determine what type of storm events our various stormwater assets can handle as well as the overall condition of our stormwater system.

[Insert Figure X.]

Results (Figure X), show that [Insert a short description of what you found through your analysis. Maybe you see that storm infrastructure recently replaced is designed to a 100-year storm event while older infrastructure is designed for a 2-year storm event. Maybe you have identified some strategic weaknesses in your stormwater system worth noting. Regardless of what you find, call out the results and add a short discussion about what this means for your community's goal of ensuring you are prepared for both existing and future flooding events].

f) Other

[If you have other landscape features that influence flooding, please enter them here.]

Ann Arbor's Flooding Vulnerability Map

By combining the above maps,[66] we are able to identify areas of our community that are particularly sensitive to flooding (Figure X).

[Insert map combining the above variables for landscape vulnerability to flooding]

As can be seen from this map, [Insert a short description about the results denoted in your above map. Profile which neighborhoods or regions of the city have the highest vulnerability to flooding based on local landscape features.

Consider discussing the areas that have the lowest vulnerability. This doesn't need to be a detailed analysis but do point out at least a few key things that will help inform your final vulnerability assessment].

Other Factors That Influence Local Vulnerability

In addition to the factors discussed above, there are a series of local environmental conditions that can affect vulnerability to extreme heat, flooding, and other climate-related impacts. For example, factors such as the number and location of impaired water bodies, the location of hazardous waste sites, the current condition of drinking water (especially data related to contaminants), and the location of solid waste sites and generators are all important factors that can influence neighborhood-level vulnerability to extreme events. {If you want to include this section, you'll need to provide a short description of the other factors that you have chosen to integrate into your local landscape analysis. In addition to describing them, you'll ideally want to include a map that denotes the location of these and other major environmental characteristics that could affect local vulnerability. If this isn't an option, you'll likely want to indicate that you plan to identify the location of these other factors in the future.}

Summary of Landscape Vulnerability

The results in this section shed light on some of the local characteristics that can reduce or increase our community's vulnerability to flooding and extreme heat. Based on the cumulative results from this section, we know that [Insert a short description of your overall results. For example, is there a neighborhood extremely vulnerable to both heat and flooding? Or perhaps there are certain neighborhoods that have a disproportionate amount of negative characteristics (e.g., impaired water bodies and toxic sites; or those in the floodplain, built on a brownfield site, and with steep slopes) that makes them uniquely vulnerable to extreme events and climate change? Regardless, include a few short sentences to tie up this section and help the reader understand how local landscape features enhance or reduce your vulnerability to climate change].

In the next section we use all the previous information to complete our vulnerability assessment.

5. ANN ARBOR'S VULNERABILITY ASSESSMENT RESULTS

Using the information outlined in the previous sections, the City of Ann Arbor completed a vulnerability assessment. A vulnerability assessment is a process that helps determine the extent to which our city and its major elements are susceptible to harm from climate change. Our vulnerability assessment helps us understand:

1. What changes in climate are projected to happen and what those changes could mean in terms of local **impacts**,
2. The level of **exposure** the community has to potential changes and impacts,
3. How **sensitive** the various city and community systems are to projected changes in climate, and
4. What **capacity** those systems have to adapt.

To undertake our vulnerability assessment, we engaged in nine steps, each outlined below.

Step 1: Define Scope of Assessment

📖 **+ Step 1** This section is designated red to correspond with the red tab in the Workbook. (This Workbook is an optional companion tool that you can use to gather data to fill in this section.) An example of a Workbook table can be found at the end of this section.

{The first step is to establish the scope for your vulnerability assessment. Below we provide guidance on how to do this by providing three examples for how your community may want to determine what is included in your assessment.

For the purpose of Ann Arbor's vulnerability assessment, we chose to focus on X primary areas within our city. These cover our built, natural, social, cultural, and governmental assets and services ("elements") - the things that make Ann Arbor a great place to live, work, and play. The remainder of this section provides a short description of the elements evaluated as part of our vulnerability assessment.

{Below we present three possible ways you could populate the *Step 1 Scope of Assessment* table in the Workbook.
Example 1: The first is for a community looking to complete a community-wide, multi-system vulnerability assessment. In this case, we outline the high-level systems and topics that could be evaluated as part of the vulnerability assessment.

Example 2: In the second example, we highlight the specific components of a single system that a city may want to assess the vulnerability of. This table is an example of what a community may create if they are focusing on conducting a vulnerability assessment for a single sector or system.

Example 3: The third example is of a specific project that a city may want to assess the vulnerability of. In this case, a community may want to use the tool, as needed, to ensure that vulnerability is factored into final project design.

It is up to you and your stakeholders to determine what the proper scope is for your vulnerability assessment. Whatever you choose to include in your analysis, make sure to input those items into the table, deleting the existing text or replacing the table completely with one of your own making.}

Engagement Tip: Consider forming a committee, composed of diverse voices from the government and community to help you establish the scope for the vulnerability assessment.

Example 1: Possible Elements to Include in a Community-Wide Vulnerability Assessment for Multiple Systems				
Built Systems	**Natural Systems**	**Social Systems & Vulnerable Populations**	**Cultural Systems**	**Critical Government Services**
Water quality and quantity; water pipes; pumps, intakes, water treatment plants	Parks, green space, vacant land, natural infrastructure, cemeteries	The elderly	Historic sites, buildings on the historic register, Landmark Districts	Emergency services such as fire, ambulance, police
Wastewater and stormwater pipes, pumps, green infrastructures, wastewater treatment plants, combined sewer overflows, storage tunnels	Riparian areas, rivers, streams, lakes, wetlands, flood zones, waterfront	Youth - those 5 and under; those 18 and under	Convention center, fields, stadiums, monuments	Waste collections, energy production, snow removal, transportation, road maintenance
Roads, highways, bridges, public transit, transit centers, bike infrastructure, port, freight rail, industrial river, airports	Street trees	People with chronic disease, poor health, and disabilities.	Museums, performing arts venues, theaters, playhouses, comedy clubs	Health systems, hospitals, community health centers, County human health services, Red Cross locations
Buildings such as city hall, fire station, schools, critical facilities, public housing units	Urban gardens, farms and greenhouses	People living in poverty, low income households	Community gathering spots such as libraries, recreation centers, community development corporations, places of worship, barbershops.	
Municipal solid waste landfills, transfer station, construction and demolition, landfills/recycling stations	Aquatic life	People of color, renters, and section 8/public housing residents.		
Brownfields, superfund sites, NPDES locations	Commercial fishing industry, recreational fishing industry	Limited English proficiency speakers		
Business districts, employment hubs		Flood prone neighborhoods		
Energy infrastructure, power lines, power generation facilities, substations, natural gas distribution, back-up generators, *micro grid, renewable energy generators		Fire risk neighborhoods		
Information and communication systems such as telephone lines, network cables, radio infrastructure, broadband				
Food terminal, food bank, food retail stores, farmers markets				

Example 2: Possible Elements to Include in a System-Specific Community-Wide Vulnerability Assessment	
Stormwater System Element	**Type of System**
Street – curb gutter	Built System
Inlets	Built System
Outflows	Built System
Conveyance – pipes	Built System
Conveyance - swales	Natural System
Underground storage	Built System
Above ground storage (wetlands)	Natural System
Street trees	Natural System
Small green infrastructure	Natural System
Large green infrastructure	Natural System
Treatment swirl	Built System
Residential street trees in floodplain	Natural System
Commercial street trees in floodplain	Built System
Employees – public works	Social Systems and Vulnerable Populations
General public	Social Systems and Vulnerable Populations
Vulnerable populations	Social Systems and Vulnerable Populations
Budget	Government Services
Receiving water ecology	Natural System
Creek	Natural System

Example 3: Possible Elements to Include in a Project-Specific Vulnerability Assessment
Specific Project: Bridge Replacement
Bridge design and specifications
Evacuation routes
Retirement community
Construction workers

Description and Location of Built Systems in Ann Arbor

[In this section, provide a short description of the built systems you intend to evaluate as part of your vulnerability assessment. To the extent possible, include a map that denotes the location of key built systems you plan to evaluate.

This section doesn't need to be long but should give the reader a sense of what is and is not included in your vulnerability assessment. If relevant, also explain why you omitted certain built systems from your analysis.

Description and Location of Natural Systems in Ann Arbor

[In this section, provide a short description of the natural systems you intend to evaluate as part of your vulnerability assessment. To the extent possible, include a map that denotes the location of key natural systems you plan to evaluate.

This section doesn't need to be long but should give the reader a quick sense of what is and is not included in your vulnerability assessment. If relevant, also explain why you omitted certain natural systems from your analysis.]

Description and Location of Social Systems and Vulnerable Populations in Ann Arbor

[In this section, provide a short description of the social systems and vulnerable populations you intend to evaluate as part of your vulnerability assessment.

Since we have a section on the socio-economic profile of your City, you can just direct your reader to this section to learn more about the geographical location and rationale for including certain populations in your analysis. If relevant, also explain why you omitted certain individuals from your analysis.]

Description and Location of Cultural Systems in Ann Arbor

[In this section, provide a short description of the cultural systems you intend to evaluate as part of your vulnerability assessment. To the extent possible, include a map that denotes the location of key cultural systems you plan to evaluate.

This section doesn't need to be long, but should give the reader a quick sense of what is and is not included in your vulnerability assessment. If relevant, also explain why you omitted certain cultural systems from your analysis.]

Description and Location of Government Services in Ann Arbor

[In this section, provide a short description of the governmental services you intend to evaluate as part of your vulnerability assessment. To the extent possible, include a map that denotes the location of key governmental services you plan to evaluate.

This section doesn't need to be long, but should give the reader a quick sense of what is and is not included in your vulnerability assessment. If relevant, also explain why you omitted certain governmental services from your analysis.]

Cumulative Vulnerability Assessment Scope

[Consider inserting a map that combines all of the above elements into one master map. This will give the reader a quick visual of all of the things included in your community's vulnerability assessment.] Or provide a text summary of your scope.

Table X provides a sample of the systems and system elements evaluated as part of the City of Ann Arbor's vulnerability assessment process and their geographical location.

{The table below was generated using the Workbook. You are welcome to use the Workbook (Step 1 'Scope of Assessment' sheet) or another tool/platform to complete this step of the vulnerability assessment. Also note that we just focused on stormwater and emergency management systems and their subcomponents for all the following examples. Your specific table will look different depending on what elements you choose to include in your vulnerability assessment.} Replace this table with your own.

Scope of Vulnerability Assessment				
Ref #	City	System or Project Name	System or Project Component	Geographical Distribution of System or Project Component (Census Tract, if applicable)
Example1	Ann_Arbor	Stormwater	Conveyance pipes	Not_Applicable vs. All_Ann_Arbor
Example2	Ann_Arbor	Stormwater	Street trees	Not_Applicable vs. All_Ann_Arbor
Example3	Ann_Arbor	Stormwater	Public works employees	Not_Applicable vs.

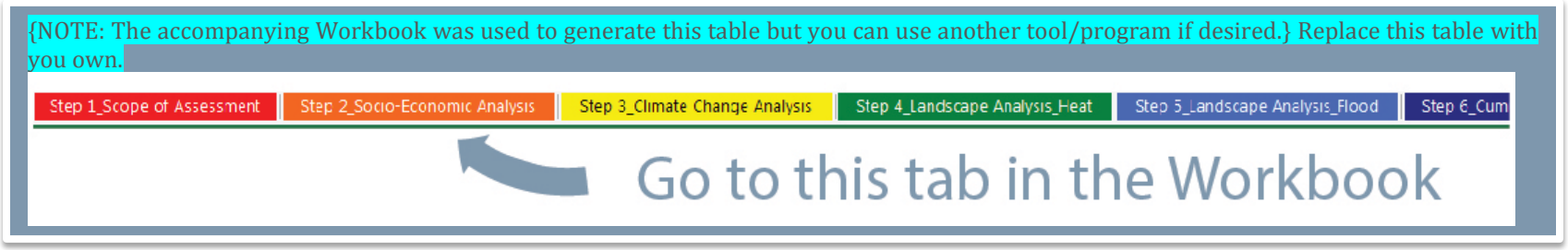
Step 2: Socio-Economic Analysis

📖 **+ Step 2** This section is designated orange to correspond with the orange tab in the Workbook. An example can be found on the next page. (This Workbook is an optional companion tool that you can use to gather data to fill in this section.)

The second step of our assessment focused on compiling and analyzing socio-economic information, at the pertinent geographical scale, for the various elements evaluated as part of our vulnerability assessment. To do this, we built upon the data outlined in Chapter 2 to more deeply understand who could be affected by each of the elements evaluated in our vulnerability assessment. Guiding this section were two key questions:

1. How will socio-economic vulnerability influence the elements being evaluated in our vulnerability assessment?
2. How will the elements (i.e., the thing being evaluated as part of our vulnerability assessment) impact (i.e., help or hinder) socio-economic vulnerability?

Table X below demonstrates the results from this step of our assessment for a subset of the stormwater and emergency management systems.



Details		Socio-Economic Vulnerability												
System or Project Component	Geographical Distribution of System or Project Component (Census Tract, if applicable)	% of Population Over 65	% of Population Under 5	% of Community in Poverty	% of Population with Limited English Proficiency	% of Non-White Population	% of Households Receiving Food Stamps/ SNAP	% of Households Where Mortgage is >30% of HH Income	% Disabled	% of Renters	% of Population Without a High School Diploma	Other Social Vulnerability Variables (add any that are relevant)	How Will Socio-Economic Vulnerability Influence This Project or System Component?	How Will This Project or System Component Impact (e.g., help or hinder) Socio-Economic Vulnerability?
Conveyance pipes	Not_Applicable	0	0	0	0	0	0	0	0	0	0		There is a high percentage of renters living in poverty in this region, which will influence how we advertise about the project. The higher percentage of disabled also means we need to design contingency plans for sidewalk access and road crossing while we work on conveyance pipe replacement.	Investing in better conveyance systems will reduce localized flooding, which could help drive up property values, which could disproportionatel impact the poor who are living on the margins in this neighborhood. On the positive, the reduced risk of flooding is a benefit for all residents, especially the poor, disabled, and renters who may not have the resources to recover.
	vs.													
	All_Ann_Arbor	10.8	4.3	23.4	1.9	27.7	11.6	25.7	7	55.2	3.6			
Street trees	Not_Applicable	0	0	0	0	0	0	0	0	0	0		There is a high number of youth and elderly individuals in this area. We should strategically target our street tree planting to areas where these populations are concentrated since we know they disproportionately suffer from extreme heat events, which are mitigated with street trees.	Street trees can help reduce loalized flooding while also addressing the urban heat island in this neighborhood. This area, however, has a fairly lov poverty rate and is an area of regular investment by the city. As we look forward, we need to be more intentional in planting trees in traditionally underserved areas.
	vs.													
	All_Ann_Arbor	10.8	4.3	23.4	1.9	27.7	11.6	25.7	7	55.2	3.6			
Public works employees	Not_Applicable	0	0	0	0	0	0	0	0	0	0		The fact that nearly 1/4 people in Ann Arbor are living in poverty and the same percentage is paying more than 30% on their home expenses indicates that all public works employees need to be sensitive to questions and concerns raised by the community about the cost of creating and maintaining public works projects.	With growing poverty and growing disparities, ou employees need to be better trained to prioritize projects that advance equity considerations and t address public comments.
	vs.													
	All_Ann_Arbor	10.8	4.3	23.4	1.9	27.7	11.6	25.7	7	55.2	3.6			

Step 3: Exposure Analysis

📖 **+ Step 3** This section is designated yellow to correspond with the yellow tab in the Workbook. An example can be found on the next page. (This Workbook is an optional companion tool that you can use to gather data to fill in this section.)

The third step in our assessment was the compilation and analysis of pertinent climate change information to understand how the various elements being evaluated as part of our vulnerability assessment could be or already are exposed and impacted by a changing climate.

The intent of this step is to understand responses to two key questions:

1. How will projected changes in climate influence the elements being evaluated as part of our vulnerability assessment?
2. How will the elements (i.e., the thing being evaluated as part of our vulnerability assessment) impact (i.e., help or hinder) projected changes in climate?

Table X below demonstrates the results from this step of our assessment for a subset of the stormwater and emergency management systems.

{NOTE: The accompanying Workbook was used to generate this table but you can use another tool/program if desired.) Replace this table with your own.

Project Description				Climate Vulnerability						
Ref #	City	System or Project Name	System or Project Component	Variable of Interest	Sub-Variables of Interest	Historical/Current	Mid-Century Projected Changes	% Change Between Historic and Mid-Century Future	How Will Projected Changes in Climate Influence This Project or System Component?	How Will This Project or System Component Impact (e.g., help or hinder) Projected Changes?
Example 1	Ann_Arbor	Stormwater	Conveyance pipes	Temperature	Avg Annual Temp	49.8°F	52.8 to 56.8°F	6 to 14%	More precipitation falling during extreme events means that our system may be overwhelmed. We will have to change designs to be able to withstand the future 100 year storm event as opposed to the current 20 year storm event.	If not designed to address future extreme events, these pipes could actually enhance vulnerability by ensuring we have more localized flooding. If designed with future conditions in mind, the pipes may actually reduce future flooding vulnerability.
				Temperature	Winter Avg Temp	27.1°F	28.1 to 32.1°F	4 to 19%		
				Temperature	Summer Avg Temp	71°F	74 to 78°F	4 to 10%		
				Precipitation	Total Annual Precip	36.7 in.	38.7 to 40.7 in	5 to 11%		
				Precipitation	Spring Avg Precip	9.3 in.	8.3 to 12.3 in.	-11 to 32%		
Example 2	Ann_Arbor	Stormwater	Street trees	Temperature	Avg Annual Temp	49.8°F	52.8 to 56.8°F	6 to 14%	With the shifting hardiness zones, we need to ensure we are planting trees that are viable in our new climate. We also need to make sure our trees are properly rooted, perhaps deeper than usual, when first planted so that they can take root and survive during a heavy precipitation event.	Street trees can help mitigate the urban heat island effect and cool the area. We just need to be sure to plant trees that can survive and thrive in our new temperature and hardiness zone. We also need to be cognizant of shifting diseases and how that might affect the vitality of the species we plant.
				Temperature	Summer Avg Temp	71°F	74 to 78°F	4 to 10%		
				Temperature	Winter Avg Temp	27.1°F	28.1 to 32.1°F	4 to 19%		
				Precipitation	Total Annual Precip	36.7 in.	38.7 to 40.7 in	5 to 11%		
				Precipitation	Summer Avg Precip	11 in.	9 to 16 in.	-18 to 46%		

Step 4: Landscape Analysis: Heat

📖 **+ Step 4** This section is designated green to correspond with the green tab in the Workbook. An example can be found on the next page. (This Workbook is an optional companion tool that you can use to gather data to fill in this section.)

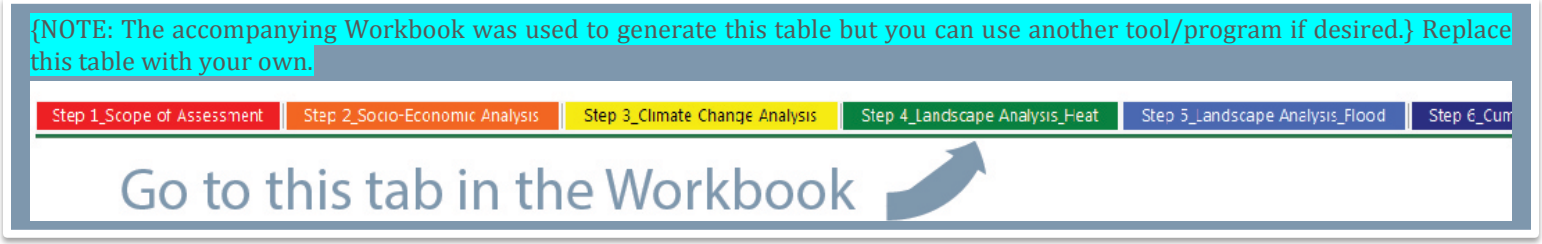
The fourth phase of our assessment included compiling and analyzing pertinent information needed to understand how the various elements being evaluated in our vulnerability assessment could be or already are exposed to heat. To do this, we collected information, to the extent available, on: percent impervious land cover; urban heat island effect; and normalized difference vegetation index. Where possible, we used data at the census tract level. When not available, we used citywide data.

Once data was compiled we used two questions to guide our assessment of each element's vulnerability to heat:

1. How do local landscape features influence the element's vulnerability to heat?
2. How will each element exacerbate or reduce landscape vulnerability to heat?

Table X below demonstrates the results from this element of our assessment for a subset of the stormwater system and emergency management system.

{NOTE: The accompanying Workbook was used to generate this table but you can use another tool/program if desired.} Replace this table with your own.



cription		Landscape Vulnerability: Heat					
System or Project Component	Geographical Distribution of System or Project Component (Census Tract, if applicable)	Landscape Variables That Could Affect Your Community's Local Vulnerability to Heat - Add any locally available data (see Template for more info)				How Do Local Landscape Features Influence This Project or System Component's Vulnerability to Heat?	How Will This Project or System Component Exacerbate or Reduce Landscape Vulnerability to Heat?
Conveyance pipes	Not_Applicable	Percent Impervious Land Cover	Normalized Difference Vegetation Index			We will need to be careful about preserving as much natural vegetation as we can during the pipe replacement process.	We could potentially increase the localized urban heat island effect if we are not intentional about preserving and/or replacing existing vegetation and/or if we contribute to the percentage of impervious coverage in the area.
		40	35				
Street trees	Not_Applicable	Percent Impervious Land Cover	Normalized Difference Vegetation Index	Urban Heat Island Effect (in Degrees)		The high impervious surface concentration in this area could place additional heat burden on the street trees. We'll have to be considerate in what trees we pick to plant in this neighborhood so they can tolerate the heat.	Street trees can help reduce the localized urban heat island effect, providing positive value to the residents.
		40	35	3-5 °F			
Public works employees	Not_Applicable	Percent Impervious Land Cover	Normalized Difference Vegetation Index	Urban Heat Island Effect (in Degrees)		Public works employees, especially our outdoor workers, are exposed to increased temperatures due to the urban heat island effect. We need to take precautions to ensure they remain cool and safe while conducting outdoor work.	Public works employees are a potential source of innovative thinking as it pertains to designing and maintaining the city's infrastructure. We need to find more ways to harness their ideas.
		40	35	3-5 °F			

Step 5: Landscape Analysis: Flooding

📖 **+ Step 5** This section is designated blue to correspond with the blue tab in the Workbook. An example can be found on the next page. (This Workbook is an optional companion tool that you can use to gather data to fill in this section.)

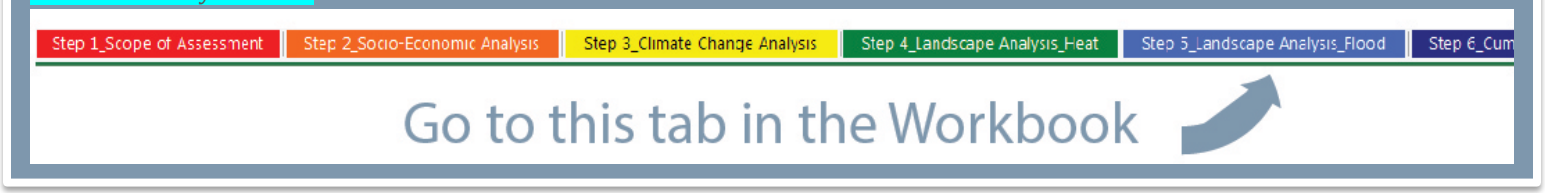
The fifth step in our vulnerability assessment focused on compiling and analyzing pertinent information needed to understand how the various elements being evaluated in our vulnerability assessment could be or already are exposed to flooding. To do this, we collected information, to the extent available, on: elevation; whether or not the system was in the floodplain; slope; percent impervious land cover; and the storm event capacity and condition of infrastructure in the region. Where possible, we used data on the census tract level. When not available, we used citywide data.

Once data was compiled we used two questions to guide our assessment of each element's vulnerability to flooding:

1. How do local landscape features influence the element's vulnerability to flooding?
2. How will each element exacerbate or reduce landscape vulnerability to flooding?

Table X below demonstrates the results from this step of our assessment for a subset of the stormwater system and emergency management system.

{NOTE: The accompanying Workbook was used to generate this table but you can use another tool/program if desired.} Replace this table with your own.



		Landscape Vulnerability: Flooding							
System or Project Component	Geographical Distribution of System or Project Component (Census Tract, if applicable)	Landscape Variables That Could Affect Your Community's Local Vulnerability to Flooding -add any locally available data. (see Template for more info)						How Do Local Landscape Features Influence This Project or System Component's Vulnerability to Flooding?	How Does This Project or System Component Exacerbate or Reduce Landscape Vulnerability to Flooding?
Conveyance pipes	Not_Applicable	Elevation	In Floodplain (Y/N)	Slope (e.g., less than 12%; between	Percent Impervious Land Cover	Storm Event Capacity of Infrastructure		The high amount of impervious surface coverage in the area may mean increased demand on the system. Knowing that it is only designed for the 20 year storm may also mean the system could be overtaxed fairly frequently, leading to	If we design the new stormwater conveyance system to handle a 100-200 year flooding event, it will be able to significant reduce the likelihood of localized flooding in this area.
		6 feet below	N	Less than 12%	21.5	20 yr			
Street trees	Not_Applicable	Elevation	In Floodplain (Y/N)	Slope (e.g., less than 12%; between	Percent Impervious Land Cover	Storm Event Capacity of Infrastructure		The amount of impervious surface, combined with stormwater infrastructure built to a 10-year storm means that the street trees are facing significant flooding potential. This is potentially burdening the trees and removing necessary topsoil.	If more trees are planted, they may be able to help reduce localized flooding by absorbing excess water.
		ground level	Y	Less than 12%	40	10 yr			
Public works employees	Not_Applicable	Elevation	In Floodplain (Y/N)	Slope (e.g., less than 12%; between	Percent Impervious Land Cover	Storm Event Capacity of Infrastructure		The high percentage of impervious land cover means that the city is likely to experience more localized flooding events, particularly as the climate changes.	Our employees are well positioned to help reduce flooding impacts; we should also consider implementing a regular training program to provide more guidance on effective strategies for reducing localized flooding.
		ground level	Y	Less than 12%	34	10 yr			

Step 6: Cumulative Impacts

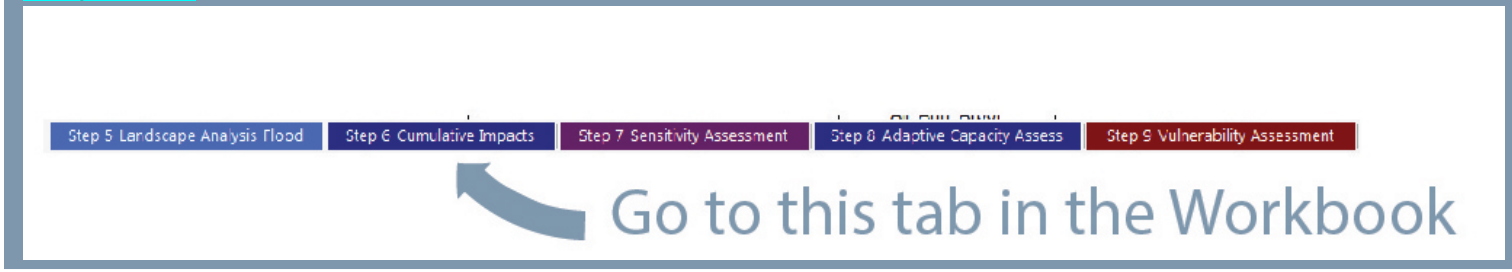
📖 **+ Step 6** This section is designated navy blue to correspond with the navy blue tab in the Workbook. An example can be found on the next page. (This Workbook is an optional companion tool that you can use to gather data to fill in this section.)

The sixth step in our analysis combined the information and analysis done in steps 2-5 to gather a holistic sense for the different ways each element evaluated as part of our assessment was impacted by socio-economic considerations, changes in climate, and local landscape features. Once we had combined all of this information, we then asked the following question:

1. How will the element affect socio-economic, climate, and landscape features?
2. How will socio-economic, climate, and landscape features affect the element?

Table X below demonstrates the results from this step of our assessment for a subset of the stormwater system and emergency management system.

{NOTE: The accompanying Workbook was used to generate this table but you can use another tool/program if desired.}Replace this table with your own.



Project Description				Cumulative Impacts
Ref #	City	System or Project Name	System or Project Component	Based On All Analysis Completed So Far, Summarize How This Project or System Component: 1) Will Be Affected By and 2) Will Affect Socio-Economic, Climate, and Landscape Features.
Example1	Ann_Arbor	Stormwater	Conveyance pipes	The high rate of renters living in poverty in the region, combined with the high percentage of disabled, means that we need to be thoughtful and intentional in our public planning process as well as our implementation process (ensuring we maintain sidewalk connectivity, for example). We also need to ensure that we are replacing old pipes with new ones that can withstand the future 100 year flood (not the historic 20 year flood). During the design and implementation process, we need to be cognizant to save and potentially increase the amount of vegetation or else we risk increasing the local heat island effect. Finally, we need to work with residents to understand how the reduced risk of flooding may impact property values, leading to a potential displacement of those living on the margins. To the fullest extent possible, we need to try to mitigate this impact.
Example2	Ann_Arbor	Stormwater	Street trees	The high percentage of youth and elderly in this area, along with the high impervious surface, means it a strategic area for street tree investment. This is because these two populations are particularly vulnerable to extreme heat. However, this area is also affluent and an area where the city regularly invests. We need to be thoughtful about how and where we invest, especially with stagnant budgets. As we plant or replace trees in this area, we also need to ensure the trees are viable given climate shifts. This includes planting for the new hardiness zone and making sure we take into consideration shifts in vector borne diseases during our selection process. We also need to dig a bit deeper to root the trees as we expect more extreme precipitation which could disrupt the roots and topsoil. Lastly, we need to think about the holistic stormwater design in this area since most of the physical infrastructure is only built to withstand the historic 10 year flooding event, which is now our 2 year event.
Example3	Ann_Arbor	Stormwater	Public works employees	We have great public works employees in the city. However, with growing disparities between the haves and the have nots in our city, we need to ensure our employees are trained to integrate equity into their thinking and are better equipped to talk to the public about how we are being good stewards of their tax dollars. With increases in temperature, we are likely to place additional strain on our employees. This will likely necessitate changes in how we operate such as more breaks, shorter shifts, and less time outside. We also need to build a public works system that allows us to prioritize projects based on the greatest need and

Step 7: Sensitivity Assessment

📖 **+ Step 7** This section is designated purple to correspond with the purple tab in the Workbook. An example can be found on the next page. (This Workbook is an optional companion tool that you can use to gather data to fill in this section.)

The seventh step of our assessment focused on the sensitivity of each element evaluated to the impacts identified in the previous step. Sensitivity is the degree to which a system and its constituent parts (e.g., built, natural, human, cultural, administrative) can be or are affected by changes in climate conditions or specific climate impacts. For example, a building built in the 500-year floodplain with flood-proofing measures is much less sensitive to a flood than one in the 100-year floodplain with no flood proofing measures.

To determine how sensitive each of our elements were, we answered three questions:

1. What, if any existing stresses affect this element?
2. How might demand for this element change given impacts identified in Step 6?
3. What, if any, limiting factors does this element have that make it more sensitive?

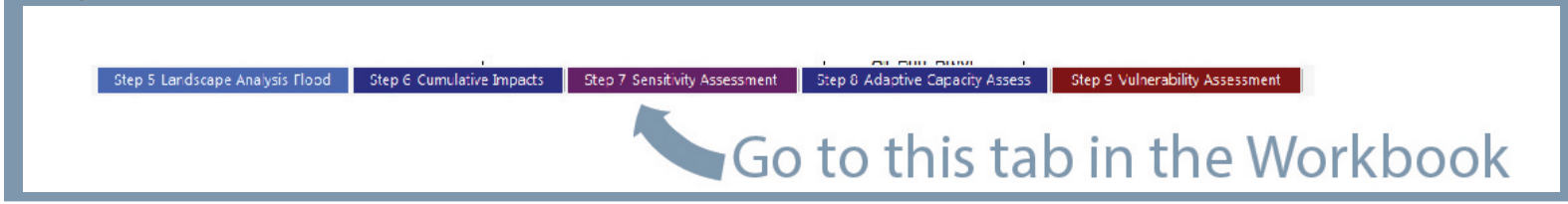
We answered these questions for each of the Elements included in the scope of our assessment. The responses to these three questions were used to assign a sensitivity score for each element. We used the qualitative evaluation criteria provided in Figure X to assign sensitivity scores.

Figure X: Sensitivity Levels	
S0	System will not be affected by the climate-related impact
S1	System will be minimally affected by the climate-related impact
S2	System will be somewhat affected by the climate-related impact
S3	System will be largely affected by the climate-related impact
S4	System will be greatly affected by the climate-related impact

Results from this analysis found that we have a particularly high sensitivity (scores of S3-S4) for our [Insert results from the sensitivity analysis here. Include any specific details or nuances that you think are worth calling attention to. You may also want to talk about the Elements that showed moderate sensitivity (S2) and those likely to have limited sensitivity to climate-related impacts (S0-S1)].

Table X below demonstrates the results from this step of our assessment for a subset of the stormwater system and emergency management system.

{NOTE: The accompanying Workbook was used to generate this table but you can use another tool/program if desired.}Replace this table with your own.



Project Description				Sensitivity Assessment			
Ref #	City	System or Project Name	System or Project Component	What, If Any Existing Stresses Affect This Project or System Components?	How Might Demand For This Project or System Component Change Given Impacts Identified in Columns E?	What, If Any, Limiting Factors Does This Project or System Component Have? (e.g., think about how projected impacts might influence the Project or System Component's operational thresholds)	How Sensitive is This Project or System Component to Projected Changes in Climate? (e.g., Sensitivity Score)
Example1	Ann_Arbor	Stormwater	Conveyance pipes	Our pipes are old and badly in need of repair or replacement.	With increases in heavy precipitation projected, we know that the demand and strain on our system is likely to increase.	Increasing demand will only further strain our system and may even lead to system failure in certain parts. This could lead to more localized flooding.	S2 - System will be somewhat affected by the climate-related impact
Example2	Ann_Arbor	Stormwater	Street trees	Lack of support for maintenance, emerald ash borer, and damage from residents.	As heat continues to rise, we may see more demand for street trees throughout the city. We are already doing a good job distributing more, but demand may rise, particularly in underserved areas.	Maintenance is the biggest limiting factor	S2 - System will be somewhat affected by the climate-related impact

Step 8: Adaptive Capacity Assessment

📖 **+ Step 8** This section is designated navy blue to correspond with the second navy blue tab in the Workbook. An example can be found on the next page. (This Workbook is an optional companion tool that you can use to gather data to fill in this section.)

The eighth step of our assessment focused on the adaptive capacity of each element to the impacts identified in the previous step. Adaptive capacity is a measure of the ability of an element (e.g., institutions, humans, infrastructure, species) to adjust to potential damage, to take advantage of opportunities, or to cope with consequences. Some of the most important factors influencing the adaptive capacity of an element are access to and control over natural, social, physical, and financial resources. This includes things such as knowledge (or access to knowledge), good health, financial resources, ability to migrate (e.g., resources, space, lack of competition), redundant systems, access to social safety nets, and overall social connectivity.

To determine the adaptive capacity each of the elements evaluated in our vulnerability assessment have, we answered five questions:

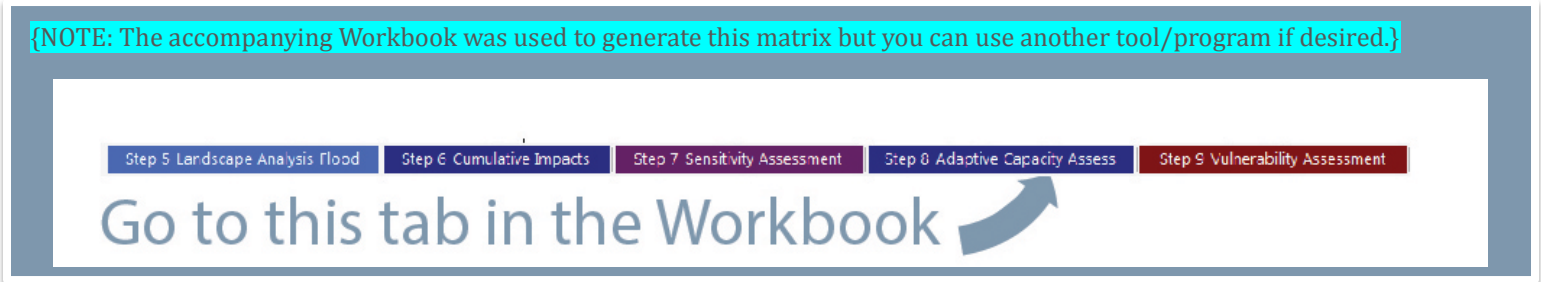
1. Does the element currently have what it will need to adapt to the impacts identified?
2. Can the element accommodate projected climate impacts with minimum disruption or costs?
3. If not, what does the element need to help it adapt to the identified impacts?
4. What is needed in order to help the element adapt to identified impacts?
5. Is the element already stressed in ways that will limit its ability to accommodate identified impacts?

Responses to these questions were then used to assess how adaptive each of the elements evaluated were to projected changes in climate. We used the qualitative evaluation criteria provided in Figure X to assign these adaptive capacity scores. Figure X provides a sample of our results from this element of our analysis.

Adaptive Capacity Levels	
AC0	System is not able to accommodate or adjust to projected changes in climate
AC1	System is minimally able to accommodate or adjust to projected changes in climate
AC2	Systems is somewhat able to accommodate or adjust to projected changes in climate
AC3	System is mostly able to accommodate or adjust to projected changes in climate
AC4	System is able to accommodate or adjust to projected changes in climate in a beneficial way

Results from this analysis found that we have a particularly low adaptive capacity (scores of AC0-AC1) for our [Insert results from the adaptive capacity analysis here. Include any specific details or nuances that you think are worth calling attention to. You may also want to talk about the elements that showed moderate adaptive capacity (AC2) and those likely to have high adaptive capacity to climate-related impacts (AC3-AC4)].

Table X below demonstrates the results from this step of our assessment of the adaptive capacity of our selected elements.



Project Description				Adaptive Capacity Assessment					
Ref #	City	System or Project Name	System or Project Component	Does The Project or System Component Have What It Will Need to Adapt to The Impacts Identified in Column E?	What Does The Project or System Component Need To Help it Adapt To The Impacts Identified in Column E?	What Would You Need In Order To Provide What The Project or System Component Needs To Adapt To The Impacts Identified in Column E?	Can The Project or System Component Accommodate Projected Impacts Identified in Column E With minimum Disruption or Costs?	Is The Project or System Component Already Stressed In Ways That Will Limit Its Ability To Accommodate Impacts Identified in Column E?	How Adaptive Is The Project or System Component To Projected Impacts in Column E? (e.g., adaptive capacity score)
Example1	Ann_Arbor	Stormwater	Conveyance pipes	We have the technology and know how to adapt, and we also should have the revenue to replace pipes as part of the regular maintenance cycle to ensure they are up to future standards.	It would be ideal to have capital now to update all of our old infrastructure to future standards.	We would likely have to do a bond issue to get the revenue needed to update our stormwater infrastructure at scale.	No - not without investments in upgrades. In fact, without those investments, the system will continue to fail.	Yes - we are already operating at max capacity and the system is regularly overtaxed during heavy storm events.	AC1 - System is minimally able to accommodate or adjust to projected changes in climate
Example2	Ann_Arbor	Stormwater	Street trees	In the short-term, yes. In the long-term many of our street tree species may prove to be unviable in our climate.	Assisted migration and the planting of new trees that can live in our new climate zone.	Funding, public education (especially when removing trees that are diseased), and public support.	Most likely no, at least not in the long-term. In the short-term, yes.	Modestly. During high heat days we see increased stress on our street trees and we expect that to continue in a changing climate.	AC1 - System is minimally able to accommodate or adjust to projected changes in climate
Example3	Ann_Arbor	Stormwater	Public works employees	Public works employees mostly have what they will need to adapt, as long as our organizational and institutional systems stay flexible.	More training, flexible work hours, more breaks, and proper cooling materials.	More funding, engagement with the public, and support from leadership to institute flexible management and behavioral activities.	In the short-term, yes. In the long-term, no.	Not particularly.	AC3 - System is mostly able to accommodate or adjust to projected changes in climate

Step 9: Calculating Vulnerability

📖 **+ Step 9** This section is designated red to correspond with the red tab in the Workbook. An example can be found on the next page. (This Workbook is an optional companion tool that you can use to gather data to fill in this section.)

The final step in our vulnerability assessment was combining the sensitivity and adaptive capacity scores into a vulnerability score. Using Figure X below, we were able to determine which elements within our community were the most vulnerable (red) and which were the least vulnerable (green).

Use this chart to fill in your relative vulnerability matrix based on climate sensitivity and adaptive capacity assessment from Steps 7 and 8. Warmer colors (orange and red) represent higher vulnerability and cooler colors (yellow and green) represent lower vulnerability.

		Sensitivity: Low → High				
		S0	S1	S2	S3	S4
Adaptive Capacity: High ↓ Low	AC4					
	AC3					
	AC2					
	AC1					
	AC0					

To fill in this chart, we recommend using the Workbook

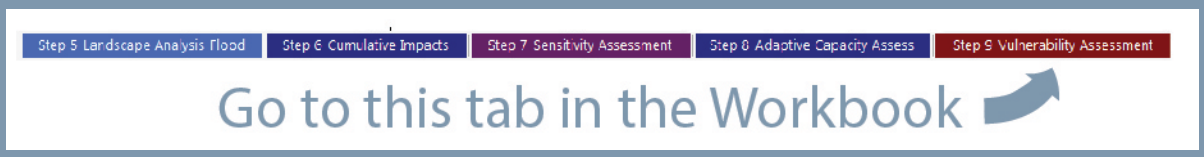


Figure X shows the results for our citywide vulnerability assessment.

		Sensitivity: Low to High				
		S0	S1	S2	S3	S4
Adaptive Capacity	AC4					
High	AC3		*Public works employees	*Emergency personnel		
Low	AC2				*Wetlands	
	AC1			*Conveyance pipes *Street trees *Road network	*Stormwater budget *Communications network	
	AC0					*Vulnerable populations – stormwater *Vulnerable populations – emergency services

This assessment found that [Insert short description of findings. What are the most vulnerable elements? What are the least vulnerable? You can talk about how socio-economic conditions, or landscape features unique to your community helped to enhance or limit your vulnerability. This is your chance to lay out your results in greater detail for your reader. Also, please note that an accompany Workbook can help you go through all elements outlined in this section].

[Input the results from your analysis into each of the cells in the matrix below. For example, if you found that your stormwater system (or perhaps a specific stormwater project), had a sensitivity score of S3 and an adaptive capacity score of AC1, you would write "stormwater system" into the orange square one row from the bottom.]

6. NEXT STEPS

This document represents an important step in building resilience to climate change in Ann Arbor. To truly prepare, however, we need to implement actions that will reduce our local vulnerability and enhance our resilience. Through the course of this vulnerability assessment, we identified a handful of initial actions that can lay the foundation for longer-term adaptation planning and action. These actions include:

- [Include a list of some initial actions your community identified during the planning process to start reducing vulnerability and/or enhancing resilience. These may include monitoring actions, planning actions, policy changes, changes in practice and behavior, technology changes, or others.]

These, however, are just initial actions. We know far more thought and planning are needed to design a cohesive strategy for enhancing local resilience to climate change. In our quest to create a more resilient Ann Arbor, we are prepared to immediately undertake the following actions:

1. Present this vulnerability assessment to City Council and seek formal adoption.
2. Initiate a formal adaptation planning process that includes a diversity of community stakeholders.
3. Align our vulnerability reduction efforts with our community's multi-hazard mitigation planning and disaster risk reduction efforts.
4. Align our vulnerability reduction efforts with other relevant community planning and action initiatives, including [Insert the names of other plans or planning processes or initiatives that you hope to align with].
5. Annually report on progress implementing the strategies identified in this plan and others related to reducing local vulnerability.
6. Every 5 years, revise this assessment based on new information (e.g., changes to climate science) and any relevant changes to community priorities. As part of this review process, include metrics that denote how our community's overall vulnerability to climate change has evolved. This may take the form of revising our community's landscape vulnerability as well as our socio-economic vulnerability to see if there have been notable changes. We may also identify, through public input processes, a number of other key metrics we'd like to track to measure reductions in vulnerability. To the fullest extent possible, we will regularly track and report on these metrics so that we can demonstrate how our community's vulnerability is changing.
7. Begin and/or enhance collaboration with peer communities in the region in order to foster greater regional resilience towards climate change and natural disasters.
8. Share successes and lessons learned with our peers to help foster greater resilience not only in our community but also in the region, across the state, and throughout the nation.

Conclusion

Preparing for climate change is a process, not an outcome. This plan represents an important step in that process for the City of Ann Arbor. Our success in preparing for climate change will depend on whether the strategies identified in this plan and those developed through a formal adaptation planning process are implemented, and whether an iterative process is established to frequently revisit this plan and all the other plans and programs used to manage the way we live, work, play, and operate in our city. We, as a City, are committed to working with all residents, business, and interested stakeholders to make sure we build a thriving, sustainable, and resilient Ann Arbor. It's time to get to work!

Acknowledgements

This Template and the associated Workbook and Socio-Economic Data Mapper would not be possible without the financial and procedural support of the Urban Sustainability Directors Network. In addition, we'd like to thank all of the partners who worked to create the information within these various resources, including the Huron River Watershed Council, the Great Lakes Integrated Sciences and Assessment, and Headwaters Economics. Finally, we'd like to thank the cities that formally served on our steering committee, providing guidance to ensure these products were as useful and usable as possible. This includes the cities of: Ann Arbor, MI; Bloomington, IN; Cleveland, OH; Dearborn, MI; Evanston, IL; and Indianapolis, IN.

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[64] For more information, see: *http://www.nws.noaa.gov/om/hazstats/flood16.pdf.*
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[66] For more details on our methodology to combine maps, please see page 56 of this document.