2017 City of Ann Arbor Hazard Mitigation Plan Update - *Redacted*

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Draft - October 2017

Prepared by
Stantec Consulting Services

Stantec

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1 Introduction

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Background

Natural, man-made, and technological hazards are a part of the world around us. Natural hazards, such as flood, winter storms, and tornadoes, are inevitable, and there is little we can do to control their force and intensity. Further, given the changing climate, many areas experiencing greater frequency and intensity of hazards. The possibility of man-made and technological disasters, such as hazardous materials incidents, terrorism, and dam failure, are also present and must be planned for. While the focus of this hazard mitigation plan is natural hazards, we must consider all hazards to be legitimate and significant threats to human life, public safety, and property. Further, an all-hazards approach allows us to plan comprehensively for all threats.

The City of Ann Arbor is located in southeast Michigan and includes the University of Michigan. This area is vulnerable to a wide range of natural hazards such as floods, winter storms, earthquakes, and tornadoes. It is also vulnerable to human-caused hazards, including dam failure and hazardous material spills. These hazards threaten the life and safety of residents in the city and have the potential to damage or destroy both public and private property, disrupt the local economy, and impact the overall quality of life of individuals who live, work, and vacation in the City of Ann Arbor.

While the threat from hazard events may never be fully eliminated, there is much we can do to lessen their potential impact upon our community and our citizens. By minimizing the impact of hazards upon our built environment, we can prevent such events from resulting in disasters in our communities. The concept and practice of reducing risks to people and property from known hazards is generally referred to as *hazard mitigation*.

FEMA Definition of Hazard Mitigation:

"Any sustained action taken to reduce or eliminate the long-term risk to human life and property from hazards."

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Hazard mitigation techniques include structural measures (such as strengthening or protecting buildings and infrastructure from destructive forces of potential hazards) and non-structural measures (such as the adoption of sound land use policies, regulations, and creation of public awareness programs). **Mitigation has a strong return on investment, estimated at $4 return for every $1 invested.** It is widely accepted that the most effective mitigation measures are implemented at the local government level, where decisions on the regulation and control of development are ultimately made. A comprehensive mitigation approach addresses hazard vulnerabilities that exist today and in the foreseeable future. Therefore, it is essential

that projected patterns of future development and population change are evaluated and considered in terms of how that growth will affect a community's overall hazard vulnerability.

A key component in the formulation of a comprehensive approach to hazard mitigation is to develop, adopt, and update a local hazard mitigation plan. A hazard mitigation plan establishes the broad community vision and guiding principles for reducing hazard risk, and proposes specific mitigation actions to eliminate or reduce identified vulnerabilities. It also presents an opportunity to integration hazard mitigation and risk reduction principles into other community plans.

The *2017 City of Ann Arbor Hazard Mitigation Plan* represents the second city-specific hazard mitigation plan. Prior to this, the city was part of the Washtenaw County hazard mitigation plan. The 2017 Plan draws from the previous 2012 plan, and from other local policies that incorporate sustainable hazard mitigation principles into routine government activities. At its core, this plan recommends specific actions to minimize hazard vulnerability, reduce the risk profile of the city, and protect residents from losses. These mitigation actions go beyond simply recommending structural solutions to reduce existing vulnerability, such as elevation, retrofitting, and acquisition projects. Local policies on community growth and development, incentives for natural resource protection, and public awareness and outreach activities are examples of other actions considered to reduce the city's vulnerability to identified hazards. The plan remains a living document with implementation and evaluation procedures established to help achieve meaningful objectives and successful outcomes over time.

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Disaster Mitigation of 2000 and the Flood Insurance Reform Acts

In an effort to reduce the Nation's mounting natural disaster losses, the U.S. Congress passed the Disaster Mitigation Act of 2000 (DMA 2000) in order to amend the Robert T. Stafford Disaster Relief and Emergency Assistance Act. Section 322 of DMA 2000 emphasizes the need for state and local government entities to closely coordinate on mitigation planning activities and requires a hazard mitigation plan for any local government applying for federal mitigation grant funds. These funds primary fall under the Federal Emergency Management Agency (FEMA) Hazard Mitigation Assistance (HMA) program. Grant programs under HMA include the Hazard Mitigation Grant Program (HMGP), the Pre-Disaster Mitigation (PDM) program, and the Flood Mitigation Administration (FMA) program. Communities with an adopted and federally-approved hazard mitigation plan are pre-positioned to receive available mitigation funds before and after the next disaster strikes.

Additionally, the Flood Insurance Reform Act of 2004 (P.L. 108-264) created two new grant programs, Severe Repetitive Loss (SRL) and Repetitive Flood Claim (RFC) programs, and also modified the existing Flood Mitigation Assistance Program. One of the requirements of this Act is that a FEMA-approved Hazard Mitigation Plan is now required if communities wish to be eligible for these FEMA mitigation funding programs. As of 2014, these programed were merged into a single program now as the Flood Mitigation Assistance (FMA) program. This change was brought on by new, major federal insurance legislation that was

passed in 2012 under the Biggert-Waters Flood Insurance Reform Act (P.L. 112-141) which was subsequently revised by the 2014 Homeowner Flood Insurance Affordability Act.

Purpose

The purpose of the City of Ann Arbor Hazard Mitigation Plan Update is to:

- Update the existing City of Ann Arbor Hazard Mitigation Plan to demonstrate progress and reflect current conditions;
- Increase public awareness and education of hazards and hazard mitigation;
- Maintain grant eligibility for participating jurisdictions;
- Update plans in accordance with Community Rating System (CRS) requirements; and
- Maintain compliance with state and federal legislative requirements for local hazard mitigation plans.

Scope

The focus of the 2017 Ann Arbor Hazard Mitigation Plan Update is on those hazards determined to be "high" or "moderate" risks to the city, as determined through a detailed hazard risk assessment. All potential hazards warranted some analysis and assessment. Other hazards that pose a "low" or "negligible" risk will continue to be evaluated during future updates to the Plan, but they may not be fully addressed until they are determined to be of high or moderate risk. This enables the city to prioritize mitigation actions based on those hazards which are understood to present the greatest risk to lives and property.

The geographic scope (i.e., the planning area) for the Plan includes the City of Ann Arbor. This is a single jurisdiction plan.

Authority

The 2017 City of Ann Arbor Hazard Mitigation Plan Update has been developed in accordance with current state and federal rules and regulations governing local hazard mitigation plans and has been adopted in accordance to local procedures. Copies of the adoption resolution are provided in Appendix A. The Plan shall be routinely monitored and revised to maintain compliance with the following provisions, rules, and legislation:

- Section 322, Mitigation Planning, of the Robert T. Stafford Disaster Relief and Emergency Assistance Act, as enacted by Section 104 of the Disaster Mitigation Act of 2000 (P.L. 106-390);

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- FEMA's Mitigation Planning Final Rule published in the Federal Register on September 16, 2009, at 44 CFR Part 201; and
- Flood Insurance Reform Act of 2012 (P.L. 112-141 and the Homeowner Flood Insurance Affordability Act.

Summary of Plan Contents

This plan is designed to be as reader-friendly and functional as possible. While significant background information is included on the processes and studies used (i.e., risk assessment, capability assessment), this information is separated from the more meaningful planning outcomes or actions (i.e., mitigation strategy, mitigation action plan).

Section 2, ***Planning Process***, describes the process used to prepare the Plan, including the integration of Community Rating System requirements. It identifies members of the planning team and how the public and other stakeholders were involved. It also includes a summary for each of the key meetings along with any associated outcomes.

The ***Community Profile***, located in Section 3, provides a general overview of the City of Ann Arbor, including geographic, demographic, and economic characteristics. In addition, this section discusses building characteristics and land use patterns. This baseline information provides a snapshot of the planning area and helps local officials recognize those social, environmental, and economic factors that ultimately play a role in determining the city's vulnerability to hazards.

The ***Risk Assessment*** is presented in Section 4. This section serves to identify, analyze, and assess hazards that threaten the City of Ann Arbor. The risk assessment also attempts to define hazard risks that may uniquely or exclusively affect specific areas of the city.

The Risk Assessment begins by identifying hazards that threaten the City of Ann Arbor. Next, it establishes detailed profiles for each hazard, building on available historical data from the previous plan, past hazard occurrences, spatial extent, and probability of future occurrence. This section culminates in a hazard risk ranking based on conclusions regarding the frequency of occurrence, spatial extent, and potential impact highlighted in each of the hazard profiles (known as the Priority Risk Index). The vulnerability assessment uses available hazard data to evaluate vulnerability. FEMA's HAZUS®MH loss estimation methodology evaluates earthquake risk. In essence, the information generated through the risk assessment serves a critical function as the city seeks to determine the most appropriate mitigation actions to pursue and implement. The risk assessment enables the city to prioritize and focus its efforts on those hazards of greatest concern and those structures or planning areas facing the greatest risk.

The ***Capability Assessment***, found in Section 5, provides an inventory and analysis of existing plans, ordinances, and relevant documents. The purpose of this assessment is to identify any existing gaps, opportunities, or conflicts in programs or activities

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that may hinder hazard mitigation efforts and to identify those activities that should be built upon in establishing a successful and sustainable local hazard mitigation program. Specific capabilities addressed in this section include planning and regulatory capability, staff and organizational (administrative) capability, technical capability, fiscal capability, and political capability. Information was obtained through the use of a use of a Capability Assessment Survey.

The *Community Profile*, *Risk Assessment*, and *Capability Assessment* collectively serve as a basis for determining the goals for the City of Ann Arbor Hazard Mitigation Plan, each contributing to the development, adoption, and implementation of a meaningful and manageable *Mitigation Strategy* that is based on accurate background information.

The ***Mitigation Strategy***, found in Section 6, consists of broad goal statements (refined for the 2017 plan update) as well as an analysis of hazard mitigation techniques for the City of Ann Arbor to consider in reducing hazard vulnerabilities. The strategy provides the foundation for a detailed ***Mitigation Action Plan***, which links specific mitigation actions for each city service area, department, or community partner. This process locally-assigns implementation mechanisms and target completion dates. Together, these sections are designed to make the plan both strategic, through the identification of long-term goals, and functional, through the identification of immediate and short-term actions that will guide day-to-day decision-making and project implementation.

With this plan, the City of Ann Arbor is embarking on an innovative planning process to consider future hazard risks and projection in the risk assessment and mitigation strategies, including the integration of climate change. The plan emphasizes using program and policy alternatives to make Ann Arbor less vulnerable to natural hazards while improving the economic, social, and environmental health of the community. The concept of multi-objective planning was emphasized throughout the planning process, particularly in identifying ways to link, where possible, hazard mitigation policies and programs with complimentary community goals related to disaster recovery, housing, economic development, recreational opportunities, transportation improvements, environmental quality, land development, and public health and safety.

Plan Maintenance, found in Section 7, includes the measures that the City of Ann Arbor will take to ensure the Plan's continuous long-term implementation. The procedures also include the manner in which the Plan will be regularly evaluated and updated to remain a current and meaningful planning document.

Lastly, the **Appendices** provide documentation including: Appendix A: Adoption Resolution; Appendix B: Planning Tools; Appendix C: Plan Documentation; Appendix D: Community Rating System (CRS) Documentation; and Appendix E: Review Tool (federal Review Tool, State Review Tool, Climate Change Integration Review Tool).

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2 Planning Process

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Overview

Local hazard mitigation planning is the process of organizing community resources, identifying and assessing hazard risks, and determining how to best minimize or manage those risks. This process culminates in a hazard mitigation plan that identifies specific mitigation actions, each designed to achieve both short-term planning objectives and a long-term community vision.

To ensure the functionality of a hazard mitigation plan, responsibility is assigned for each proposed mitigation action to a specific individual, department, or agency along with a schedule or target completion date for its implementation (see Section 10: *Plan Maintenance*). Plan maintenance procedures are established for the routine monitoring of implementation progress, as well as the evaluation and enhancement of the mitigation plan itself. These plan maintenance procedures ensure that the plan remains a current, dynamic, and effective planning document over time that becomes integrated into the routine local decision making process.

Communities that participate in hazard mitigation planning have the potential to accomplish many benefits, including:

- saving lives and property,
- saving money,
- speeding recovery following disasters,
- reducing future vulnerability through wise development and redevelop in post-disaster recovery and reconstruction,
- expediting the receipt of pre-disaster and post-disaster grant funding, and
- demonstrating a firm commitment to improving community health and safety.

Typically, communities that participate in mitigation planning are described as having the potential to produce long-term and recurring benefits by breaking the repetitive cycle of disaster loss. A core assumption of hazard mitigation is that the investments made before a hazard event will significantly reduce the demand for post-disaster assistance by lessening the need for emergency response, repair, recovery, and reconstruction. Furthermore, mitigation practices will enable local residents, businesses, and industries to re-establish themselves in the wake of a disaster, getting the community economy back on track sooner and with less interruption.

The benefits of mitigation planning go beyond solely reducing hazard vulnerability. Mitigation measures such as the acquisition or regulation of land in known hazard areas can help achieve multiple community goals, such as preserving open space, maintaining environmental health, and enhancing recreational opportunities. Mitigation planning also helps communities adapt to the impacts of climate change, primarily through the recognizing and addressing the increased risk climate change adds to many natural hazards. Thus, it is vitally important that any local mitigation planning process be integrated with other

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concurrent local planning efforts, and any proposed mitigation strategies must take into account other existing community goals or initiatives that will help complement or hinder their future implementation.

History of Hazard Mitigation Planning in Ann Arbor

Ann Arbor has been engaged in planning since the passage of the Disaster Mitigation Act of 2000. Prior to 2012, the city participated in the Washtenaw County's Hazard Mitigation Plan as a participating jurisdiction. In 2012, the city developed a stand-alone citywide plan to address city-specific issues and vulnerability and meet associated grant deadlines. This 2012 version of the hazard mitigation plan, integrated the city's 2007 Flood Mitigation Plan (FMP). The FMP included a much more detailed flood analysis than had been included in the Washtenaw County hazard mitigation plan and was heavily focused on implementation. The FMP's strategies addressed the following areas: Mapping & Technology, Education and Outreach, Planning and Zoning, Regulation and Development Standards, Corrective Actions, Infrastructure, and Emergency Services. In 2017, the city received a planning grant which permitted contractor assistance for development of the 2017 Ann Arbor Hazard Mitigation Plan.

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Preparing the 2017 Hazard Mitigation Plan Update

Hazard mitigation plans are required to be updated every five years to remain eligible for federal mitigation funding. Since Ann Arbor's current hazard mitigation plan was adopted in 2012, this update must be adopted by Ann Arbor City Council and approved by FEMA by November 30, 2017. To meet this deadline, the city, led by the Office of Emergency Management, kicked-off the planning process in August 2017. To meet this aggressive schedule, the city hired Stantec Consulting Services, Inc. (Stantec), the consultant team, to provide professional mitigation planning services and to prepare the mitigation plan document for submittal to Michigan State Police – Emergency Management and Homeland Security, FEMA and City Council.

At the onset of the planning process, the city reviewed each section of the plan and opted to make significant revisions throughout. Thus, all sections were revised to develop a more concise and actionable plan. The city was motivated to develop a plan that was inclusive of input from a broad planning team (the Technical Advisory Committee), which is described further below, and of potential climate change impacts. The plan document itself also underwent substantial revision to better streamline the information. **Where climate change is incorporated, a globe icon was inserted.** The city also joined the Community Rating System (CRS) in May 2017 and was working to meet the planning requirements set forth via the CRS Coordinator's Manual.

The consultant team followed the latest mitigation planning process recommended by FEMA: Local Mitigation Planning Handbook (March 2013) and the Local Mitigation Plan Review Guide (October 2011). Additionally, the Local Mitigation Plan Review Tool, found in Appendix E, provides a detailed summary of FEMA's current minimum standards of acceptability for compliance with DMA 2000 and notes the location where each requirement is met within this Plan. These standards are based upon FEMA's Final Rule as published in the Federal Register in Part 201 of the Code of Federal Regulations (CFR). The state of Michigan also has state planning requirements for local hazard mitigation planning. As such, the Michigan State Police Emergency Management and Homeland Security Condensed Local Review Form (June 2015) was referenced during this plan update. Lastly, this plan adheres with Community Rating System (CRS) 510 elements as found in the 2017 National Flood Insurance Program, CRS Coordinator's Manual. The completed CRS 510 review guide, including the estimated scoring, is provided in Appendix E.

The process used to prepare this plan included twelve major steps that were completed over the course of approximately three months beginning in August 2017. Each of these planning steps (illustrated in **Figure 2.1**) resulted in critical work products and outcomes that collectively make up the plan. Specific plan sections, which required a significant updating, are further described in Section 1: *Introduction*.

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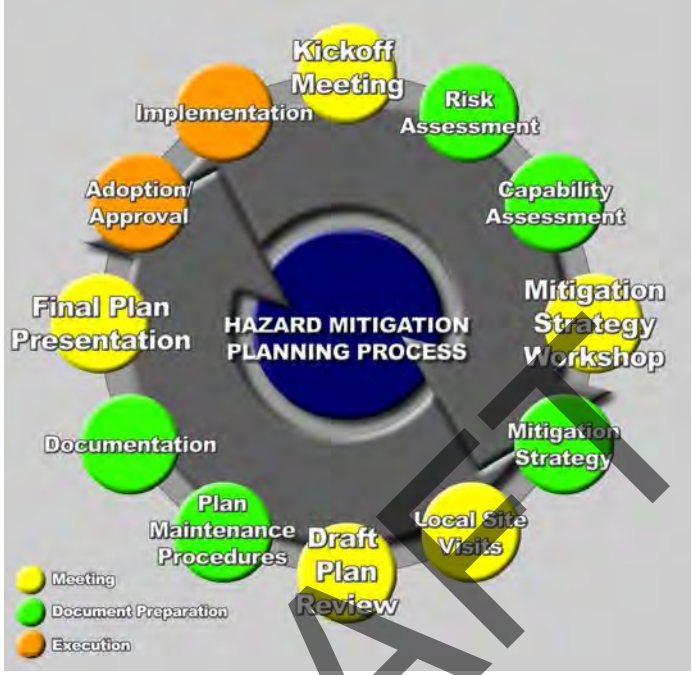
Figure 2.1: Mitigation Planning Process for Ann Arbor



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Community Rating System

The 2017 Ann Arbor Hazard Mitigation Plan Update and the associated planning process may help the city maintain and improve its status in the Community Rating System (CRS). The CRS is an incentive-based program that encourages counties and municipalities to undertake defined flood mitigation activities that go beyond the minimum requirements of the NFIP by adding extra local measures to provide protection from flooding. Ann Arbor is currently in CRS Class 7, which allows a 15% discount for NFIP policy premiums. CRS classes are based on how many credits the jurisdiction has earned through its flood mitigation efforts. The hazard mitigation planning process was designed to earn CRS credits for floodplain management planning outlined in Section 510 of FEMA's CRS Coordinator's Manual (2013). **Table 2.1** below demonstrates how Ann Arbor's hazard mitigation planning process complies with the CRS planning requirements and the planning requirements of the Disaster Mitigation Act of 2000.

Table 2.1: CRS 510 Planning Requirements versus DMA 2000 Hazard Mitigation Requirements

CRS Ten-Step Planning Process	Disaster Mitigation Act of 2000 Planning Requirements
1. Organize 2. Involve the Public 3. Coordinate	Planning Process (community profile, capability assessment, documentation)
4. Assess the Hazard 5. Assess the Problem	Risk Assessment
6. Set Goals 7. Review Possible Activities 8. Draft Action Plan	Mitigation Strategy
9. Adopt Plan	Plan Adoption
10. Implement, Evaluate, & Revise	Plan Review, Evaluation, & Implementation

To meet requirements of the Community Rating System and the Disaster Mitigation Act of 2000, the city ensured that the planning process was facilitated under the direction of a professional planner. Caroline Cunningham (Stantec) served as the project manager/lead planner for this project and is a member of the American Institute of Certified Planners (AICP). John Bucher, AICP, was also involved throughout the process and led the parallel CRS planning process. Of note, while all requirements of the CRS planning have been met, the process was not intended to maximize the available points given the timeframe. Estimated scoring can be found in Appendix E.

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Ann Arbor Technical Advisory Committee (TAC)

In order to guide the development of this plan, Ann Arbor created a Technical Advisory Committee (TAC), a community-based planning team made up of representatives from various city departments and other key stakeholders identified to serve as critical partners in the planning process. While some members of the TAC were engaged during the 2012 hazard mitigation planning process (e.g., emergency management director, floodplain administrator), the 2017 TAC was the first organized compilation of a planning body for the hazard mitigation planning process. The TAC includes members with the authority to regulate development (planning manager and floodplain manager) and regional agencies (Huron River Watershed Council), and other parties interested in mitigation (University of Michigan).

Beginning in August 2017, the TAC engaged in regular local meetings and planning workshops to discuss and complete tasks associated with preparing the plan. This working group coordinated on all aspects of plan preparation and provided valuable input to the process. In addition to regular meetings, committee members routinely communicated and were kept informed through an e-mail distribution list. Bi-weekly calls were held with the TAC. Agendas and minutes can be found in Appendix C.

Specifically, the tasks assigned to the TAC members included:

- participate in TAC meetings, bi-weekly call and workshops;
- provide best available data as required for the risk assessment portion of the plan;
- provide information that will help complete the Capability Assessment section of the plan and provide copies of any mitigation or hazard-related documents for review and incorporation into the plan;
- support the development and update of the Mitigation Strategy, including the design and adoption of goal statements;
- help design and propose appropriate mitigation actions for their department/agency for incorporation into the Mitigation Action Plan;
- review and provide timely comments on all study findings and draft plan deliverables; and
- support the adoption of the 2017 *Ann Arbor Hazard Mitigation Plan Update*.

Table 2.2 lists the members of the Ann Arbor TAC who were responsible for participating in the development of the plan. Committee members are listed in alphabetical order by last name.

Table 2.2: Members of Ann Arbor Technical Advisory Committee

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Name	Title	City Service Area/Agency
Andy Box	Assistant Fire Chief	Ann Arbor Fire Department
Samantha Brandfond	Director	VA Ann Arbor Healthcare System Emergency Management
Andrew Burchfield	Emergency Management Director	UM Public Safety and Security
Glen Dempsey	Building Official	Ann Arbor Construction and Building Department
Moonson River Eninsche	Human Services Supervisor	Washtenaw County Office of Community and Economic Development
Rebecca Esselman	Watershed Manager	Huron River Watershed Council
Mary Fales	Senior City Assistant Attorney	Ann Arbor City Attorney's Office
Dave Halteman	Emergency Services Director	Washetenaw County Office of the Sheriff
Jerry Hancock	Floodplain Coordinator	Ann Arbor Floodplain Administration and Stormwater Management
John Hradsky	Applications Specialist	Ann Arbor GIS
Mike Kennedy	Emergency Management Specialist	UM Division of Public Safety and Security
Michael Lambrecht	Intern	Washtenaw County Public Health Department
Josh Landefeld	Deputy Parks Manager	Ann Arbor Parks and Recreation
Jen Lawson	Water Quality Manager	Ann Arbor Floodplain Administration and Stormwater Management
Brett Lenart	Planning Manager	Ann Arbor City Planning Division
Molly Maciejewski	Public Works Manager	Ann Arbor Public Works - Transportation

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Name	Title	City Service Area/Agency
Matt Naud	Environmental Coordinator	Ann Arbor Office of Sustainability
Rick Norman	Emergency Management Director	Ann Arbor Office of Emergency Management
Andrea Plevek	Director	Washtenaw County Office of Community and Economic Development
Joanna Satterlee	City Communications Manager	Ann Arbor Public Information Office
Tom Shewchuk	ITSD Director	Ann Arbor GIS
Matt Warba	Assistant Manager	Ann Arbor Public Works
Lisa Wondrash	Communications Unit Manager (PIO)	Ann Arbor Public Information Office

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Plan Development Meetings

The preparation of this plan required a series of meetings and workshops for facilitating discussion, gaining consensus and initiating data collection efforts with local government staff, community officials, and other identified stakeholders (including neighboring jurisdictions, the public, and those involved in hazard mitigation activities. More importantly, the meetings prompted continuous input and feedback from relevant participants throughout the drafting stages of the plan. Public meetings were well-publicized to invite a broad range of stakeholders. The following is a summary of the key meetings and held during the development of the plan update.[1] Four main in-person meetings were conducted: TAC Kickoff Meeting, Public Kickoff Meeting, TAC Meeting #2/Mitigation Strategy Workshop, and Public Meeting #2, and the TAC Draft Review Meeting. In addition to these meetings, many routine discussions and additional meetings were held by local staff to accomplish planning tasks specific to their department or agency, such as the approval of specific mitigation actions for their department or agency to undertake and include in the Mitigation Action Plan.

[1] Copies of agendas, sign-in sheets, minutes, and handout materials for all meetings and workshops can be found in Appendix D.

August 2, 2017 TAC Plan Kickoff Meeting

TAC Kickoff Meeting - August 2, 2017

The TAC kick-off meeting was held at the Ann Arbor Fire Department on August 2, 2017, at 1:00pm. This meeting was facilitated by Caroline Cunningham, Josh Human, Ann Stevens, and Christina Hurley with Stantec. The purpose of the meeting was to provide an overview of hazard mitigation including possible techniques; gather local information; and review proposed project tasks, roles and responsibilities, and project schedule with the TAC.

The meeting began with introductions, followed by an overview of hazard mitigation planning. Ms. Cunningham began by reviewing the definition of mitigation as a hazard mitigation refresher. This was followed by an explanation of the need for a hazard mitigation plan, including an overview of local risk, state and federal hazard mitigation funding, and the community's recent and ongoing mitigation projects. She described the two primary factors new to this plan update: climate change and the Community Rating System (CRS). Ms. Cunningham explained that hazard mitigation plans are subject to a set of regulations from the Disaster Mitigation Act of 2000 and also undergo a review by the state (Michigan State Police, Emergency Management and Homeland Security) and FEMA Region V upon completion. Jerry Hancock, the City's Floodplain Manager, described an ongoing flood mitigation project reliant on federal funding.

Mr. Human then transitioned into the hazard review portion of the meeting. Ms. Hurley led a discussion on hazard identification to inform the final hazards list. She presented the existing hazards for the planning team to review and provided a list of hazards in the state hazard mitigation plan. It was decided that Fog would be added as a hazard and Celestial Impacts would be excluded. Removing the Wildfire hazard was discussed, as was moving Scrap Tire Fires under Hazardous Materials Incidents. It was also decided to combine all winter weather hazards into Severe Winter Weather, and to separate Extreme Cold and Extreme Heat into separate hazards.

Ms. Cunningham led a mapping exercise in which participants described where hazards occur and Ms. Stevens recorded the information on a map. Mapped hazards included areas of localized flooding, including a flood at Plymouth Road attributed solely to groundwater. Other locations included those involving hazardous materials. TAC members also pointed out areas of planned growth, noting redevelopment in the Allen Creek floodplain west of Main Street. Densifying areas include hundreds of new units approved on Nixon Road, and 600 new units in the approval process in an open space site at Maiden and Broadway which is both contaminated and in the floodplain. It was noted that growth is also occurring along the Washtenaw Avenue, Eisenhower Boulevard, Plymouth Road and Stadium Boulevard corridors.

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Mr. Human then transitioned to the mitigation strategy, describing goals and actions. He reviewed the goals developed for Ann Arbor and collected input on changes to be made. The goals were discussed with the TAC. Goal 4 was amended to include regional and higher education partnerships. The goals, developed with input from the TAC, are as follows:

- **Goal 1:** Increase the resilience of our city by protecting and reducing potential damage to our most vulnerable populations, natural and man-made infrastructure, and critical facilities.
- **Goal 2:** Increase the leadership and public awareness of current and projected risks and hazard mitigation actions.
- **Goal 3:** Incorporate hazard mitigation and climate change considerations into existing or future policies and capabilities.
- **Goal 4:** Increase community-wide hazard mitigation local, regional and statewide partnerships through building stronger relationships amongst higher education, government, businesses, and the public.
- **Goal 5:** Increase the resilience of the city by ensuring hazard mitigation and climate change initiatives receive consideration for funding.

Mr. Human then described the six hazard mitigation action categories (i.e., activities): prevention, emergency services, natural resource management, structural projects, public education and awareness, and property protection. He also described co-benefits. Ms. Cunningham then led the hazard mitigation category exercise. She explained that the categories are examples of mitigation activities they may want to implement. For the exercise, attendees were given an equal amount of fictitious money (representing $101 million in various denominations) and were asked to spend according to the desires or assumed city needs. The goal of the exercise is to determine what people may want grant money spent on in terms of mitigation needs or priorities in the city. The results were as follows:

- Prevention - $360M
- Emergency Services - $347M
- Natural Resource Management - $271M
- Structural Projects - $210M
- Public Education and Awareness - $171M
- Property Protection- $156M

After the money was spent, Ms. Cunningham asked the TAC to share what they had in mind when they "spent" their money. Examples included:

- Investing heavily in prevention because it could have a larger impact per dollar than the other mitigation techniques
- Investing less money in public awareness with the reasoning it is less expensive than the other mitigation techniques

Additional discussion (throughout the meeting) resulted in the following ideas/suggestions for actions:

- A2 Fix-It app – public awareness and viability during and after hazard events

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- Maintaining a functioning network during and after a hazard event
- Finalize Floodplain Development Ordinance
- Determine if data exists on inundation area of the Portage Lake (Portage Lake is upstream of the city). If not, conduct a study to determine if the city would be impacted.
- Groundwater regulations (none); last groundwater study completed in 1937; damaging flood(s) attributed to groundwater have occurred

Ms. Cunningham also explained that the amounts would be presented at the next TAC meeting. Further, the results would be used to help guide the mitigation strategy moving forward. Next, Mr. Human moved into the mitigation action tasks. There are four main tasks: review and update existing actions, evaluate alternatives, develop new actions, and prioritize actions. He described each task in detail, including the mitigation worksheets and how to complete them. It was noted that mitigation actions will be assigned to one or more of the six mitigation categories previously defined.

Ms. Cunningham then presented next steps, including a summary of roles and responsibilities for Stantec and the TAC. The next step was the public survey, followed by the mitigation strategy. She also provided next steps for the capability assessment, stakeholder meetings, and bi-weekly TAC calls. Ms. Cunningham wrapped up with a review of the major plan milestones, and asked if there were any questions. There was a question regarding data needs and transferring of data, in which it was conveyed that TAC members would be contacted with specific data requests in addition to the formal request made with GIS staff.

Public Kickoff Meeting - August 2, 2017

The Public Kickoff Meeting was held in Ann Arbor City Hall at 6:00pm on August 2, 2017. This meeting was facilitated by Caroline Cunningham, Josh Human, Ann Stevens, and Christina Hurley with Stantec. The purpose of the meeting was to provide an overview of hazard mitigation including possible techniques, gather local information, and review proposed project tasks and project schedule with the public. The meeting began with introductions, and this was followed by an overview of hazard mitigation planning. Ms. Cunningham began by reviewing the definition of mitigation. This was followed by an explanation of the need for a hazard mitigation plan, including an overview of local risk, state and federal hazard mitigation funding, and the community's recent and ongoing mitigation projects.

Jerry Hancock, the city's Storm Water and Floodplain Program Coordinator, described a phased flood mitigation project reliant on federal funding. Ms. Cunningham explained that hazard mitigation plans are subject to a set of regulations from the Disaster Mitigation Act of 2000 and also undergo a review by the state (Michigan State Police, Emergency Management and Homeland Security) and FEMA region V upon completion. She also emphasized the project's deadline and the expedited planning process needed to meet the deadline. She described the two primary factors new to this plan update: climate

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change and the Community Rating System (CRS). Ms. Cunningham then described the generalized hazard mitigation planning process and how it and how it correlates to the Community Rating System Ten Step Process.

Ms. Cunningham then gave an overview of identified hazards and asked if any should be excluded or if additional ones should be excluded. Comments regarded the dioxane plume, sewage spills in the Huron River, winter conditions including ice, localized flood hazard locations, loss of tree cover, policies allowing new buildings in the floodplain and urban heat. Other comments, regarding traffic including congested streets, were described as being out of the scope of this plan.

Mr. Human then transitioned to the mitigation strategy, describing goals and actions. He reviewed the draft goals developed for Ann Arbor and explained the changes to be made based on input from the Technical Advisory Committee. The draft goals are as follows:

1. Increase the resilience of our city by protecting and reducing potential damage to our most vulnerable populations, natural and man-made infrastructure, and critical facilities.
2. Increase the leadership and public awareness of current and projected risks and hazard mitigation actions.
3. Incorporate hazard mitigation and climate change considerations into existing or future policies and capabilities.
4. Increase community-wide hazard mitigation local, regional and statewide partnerships through building stronger relationships amongst higher education, government, businesses, and the public.
5. Increase the resilience of the city by ensuring hazard mitigation and climate change initiatives receive consideration for funding.

Next, Mr. Human described the six hazard mitigation action categories: prevention, emergency services, natural resource management, structural projects, public education and awareness, and property protection. Ms. Cunningham then led an ice breaker exercise. She explained that the categories are examples of mitigation activities they may want to implement. For the exercise, attendees were given an equal amount of fictitious money (representing $101 million in various denominations) and asked attendees to spend according to the desires or assumed city needs. The goal of the exercise is to determine what people may want grant money spent on in terms of mitigation need and priorities in the city. The results were as follows:

- Emergency Services - $41M
- Prevention - $135M
- Public Education and Awareness - $21M
- Natural Resource Management - $51M
- Structural Projects - $75M
- Property Projection- $81M

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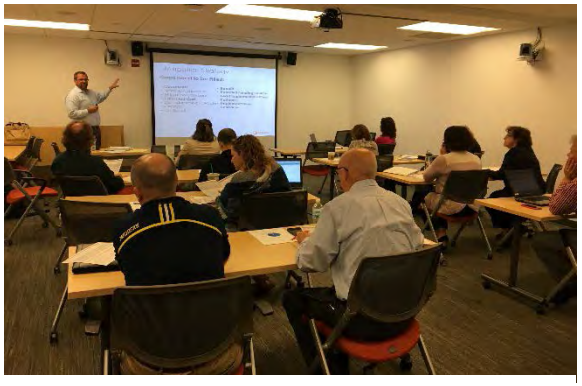
After the money was spent, Ms. Cunningham asked the participants to share what they had in mind when they "spent" their money. Examples included:

- Investing heavily in prevention so development in hazardous areas was avoided.
- Investing in prevention because it is inexpensive compared to having to address the issues later

Ms. Cunningham then presented next steps, including a summary of roles and responsibilities for Stantec, the Technical Advisory Committee, and the Public, including the public survey. Ms. Cunningham wrapped up with a review of the major plan milestones and asked if there were any questions. There was a comment regarding channels for advertising future meetings, including reaching out to MLive.

Mitigation Strategy Meeting – September 11, 2017



Mitigation Strategy Meeting – September 11, 2017

Technical Advisory Committee Mitigation Strategy Meeting was held at Ann Arbor City Hall on September 11, 2017 at 1:00pm. This meeting was facilitated by Caroline Cunningham Josh Human, John Bucher, Christina Hurley, and Ann Stevens. The purpose of the meeting was to provide an update of the project progress including schedule, public survey results, risk assessment and capability assessment findings, and to review and gather additional information on the mitigation actions from the old plan and new actions. The meeting began with introductions, and this was followed by an overview of schedule including project tasks, meetings and milestones. Ms. Cunningham noted the implications of the recent natural disasters on FEMA staff workload and the potential impact to the schedule (especially pertaining to plan review time at the state and FEMA).

Ms. Cunningham presented the need for on-going maintenance of the plan and the CRS points associated with the frequency of TAC meetings. It was agreed by the TAC that on-going meetings will be via bi-annual (two times a year). It was agreed that Rick Norman and/or Jerry Hancock will most likely facilitate these meetings. It was discussed whether the TAC should be formalized through City Council. This is not a quick process and the TAC team will review this further. How to incorporate on-going public involvement was also discussed. Ms. Cunningham mentioned opening at least one of the bi-annual meetings to the public and public outreach through social media. It was noted that if the TAC is formalized through City Council all meetings will be open to the public recorded and broadcasted except when they specifically have closed meetings per the open meeting act. A CRS annual report will be required as part of maintenance and that should be made available to the public as well.

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Ms. Cunningham then asked the TAC how the Mitigation plan will be integrated into other plans. Brett Lenart, Planning Manager, noted that integration of hazard mitigation and the mitigation plan results are considered on a case by case basis and identified at the onset of plan development. He also noted that capital projects are scored in relationship to hazard mitigation as appropriate. The city also includes a notice of the intent to plan to outside agencies and adjacent communities in their planning process. It was discussed that this could also be sent to the TAC for review.

Ms. Stevens then presented a synopsis of the public survey results. It was noted that this synopsis was a high-level overview of the results and that details of the survey results could be provided if anyone from the TAC would like more information on specific questions or responses. (Results can be found in Appendix D).

Ms. Hurley then presented the risk assessment results at a high level. Ms. Hurley reminded the TAC that the hazards included in the risk assessment were based on the hazards identified by the State of Michigan and refined by the TAC during the kick-off meeting in August. Nineteen natural, manmade and technological hazards are included in the risk assessment, but in the interest of time, only the natural hazards were discussed in the meeting. The hazards discussed were:

- Extreme Cold/Wind Chill
- Extreme Heat
- Fog
- Hail
- Lightning
- Severe Wind
- Tornado
- Severe Winter Weather
- Drought
- Flood
- Earthquake

For each hazard, Ms. Hurley presented the recent previous occurrences, location, probability, and past and potential impacts. The sources of this data were discussed and that it is likely these hazards occur more often but are not recorded to a national database such as the National Centers for Environmental Information (NCEI) Storm Events Database. Recording of future occurrences was discussed. Ms. Cunningham noted that when FEMA funds are applied for it would help them understand the previous occurrences and damage associated with them, especially in reference to specific structure mitigation. It was discussed that the bi-annual TAC meeting may provide a venue to capture these occurrences, and a more formalized process could also be discussed at this meeting.

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Ms. Hurley presented the priority risk index (PRI) and how the weighting factors apply. The PRI is used to rank hazards into high, moderate or low priority. How the identified hazards would fall within the index was presented. It was discussed whether public health concerns were a hazard as well as what constitutes an invasive species. Ms. Hurley said to be considered, a species would need to be non-native and able to out compete native species or result in damage to native species. It was also noted that public health was considered for all hazards. The TAC was in agreement with the rankings of hazards in the priority risk index.

Next, Mr. Bucher presented the capability assessment results. Mr. Bucher noted he review approximately 30 plans and regulations. First, he identified Ann Arbors strengths, what they are already doing well:

- Emergency management
- Sustainability and climate action
- Stormwater & floodplain management

Mr. Bucher went on to present areas that provide for opportunities for the city:

- Disaster recovery plan - pre-disaster plan to guide recovery and rebuilding after a disaster
- Continuity of operations - it was noted that the city has a department by department contingency plan. It was discussed these plans likely are out of date and the opportunity to coordinate these plans across departments
- Taking advantage of U of M and their hazard and climate related research
- Allen Creek Greenway (Treeline Urban Trail https://treelinea2.org/). It was stressed this is a trail project and not a stormwater management plan. Stormwater would be considered only where feasibility and as a secondary aspect of the project.
- Stormwater projects identified in the Stormwater Model Calibration and Analysis Project and incorporated into the Capital Improvement Plan.

Mr. Human went on to present mitigation strategies. Mr. Human presented the inter-relationship of goals, action plan, and actions. He reminded the team of the importance of the strategies for federal compliance to receive funding and the three funding sources; HMGP, PDM, and FMA and how they work. He noted the actions are not just for FEMA funding, some will be funded by the City and some actions may not require additional funding. Mr. Human presented the mitigation strategies and techniques. He noted mitigation actions fall into six categories but may have co-benefits between the categories. These categories are:

- Prevention
- Property Protection
- Structural Projects
- Emergency Services
- Natural Resource Protection

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- Public Education and Awareness

The results of the hazard mitigation category exercise during the kick-off meeting were reviewed. Next Mr. Human noted that he had gone through the old plan and identified approximately 140 action items. Many were duplicates and were thus combined with others. At this point, Mr. Human reviewed each of the 57 action items from the previous plan and the approximately 25 new actions proposed by the TAC for the plan update. He also noted that about 15 actions from the previous plan are considered complete. The TAC discussed each of the items below for all actions:

- Action
- Service Area
- Contact
- Comments
- Hazard Addressed
- Mitigation Category
- Estimated Cost
- Consideration of Climate Change
- Benefit
- Co-benefit
- Potential funding source
- Lead Implementer/other partners
- Schedule
- Linkage to Other Plans

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The TAC revised and updated many of the actions and determined several more to be complete. All changes and updates were captured "live" in an Excel spreadsheet and will be incorporated into the draft plan. Where tasks related to members of the TAC not present at the meeting, Mr. Human agreed to reach out to them after the meeting.

Public Mitigation Strategy and Draft Plan Review Meeting – September 11, 2017

The Public Mitigation Strategy Meeting was held at Ann Arbor City Hall on September 11, 2017, at 6:00pm. This meeting was facilitated by Caroline Cunningham, Josh Human, Ann Stevens, John Bucher and Christina Hurley. The purpose of the meeting was to provide an overview of hazard mitigation, plan progress to date, and review of the draft plan.

Ms. Cunningham began by reviewing the definition of mitigation. This was followed by an explanation of the need for a hazard mitigation plan, including an overview of local risk, state and federal hazard mitigation funding, and the community's recent

and ongoing mitigation projects. Ms. Cunningham explained that hazard mitigation plans are subject to a set of regulations from the Disaster Mitigation Act of 2000 and also undergo a review by the state (Michigan State Police, Emergency Management and Homeland Security) and FEMA Region V upon completion. She also emphasized the project's deadline and the expedited planning process needed to meet the deadline. She described the two primary factors new to this plan update: climate change and the Community Rating System (CRS).

Members of the public asked questions pertaining to the disaster declaration process, which was discussed as a group. There was general concern about when federal assistance would be needed in Ann Arbor and if additional fire stations or police stations needed to be built. The city's emergency management director and floodplain administrator assisted in answering these questions.

Ms. Cunningham then described the generalized hazard mitigation planning process. She explained each step of the planning process. The planning process included organizing resources, collecting data, documentation the plan, engaging the public, assessing capability and risks, developing a mitigation strategy, and implementing the plan. Each step of the process was reviewed in detail with attention to how Ann Arbor is completing the task for the plan update. The meeting was then opened up into an open house. Posters of the draft risk assessment and public survey were posted around the room for review. During the open house portion of the meeting members of the public reviewed the posters and the meeting facilitators were able to field questions specific to the poster subject matter. In addition, a copy of the draft plan to date was available for comment. No comments were received.

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TAC Draft Plan Review Meeting – September 28, 2017

The City of Ann Arbor plan underwent a current public, TAC, and state compliance review to expedite this requirement. During the September 28, 2017 bi-weekly call, the consultant team reviewed each of section of the plan with TAC members. This was primarily to get TAC members familiar with the plan and answer any questions about the review. The full drat was released to the TAC on October 2, 2017. A redacted draft was released to the public on October 2, 2017. The plan remained open for review until October XX, 2017. Any comments that are received after the state compliance review is completed will be considered for the next draft of this plan.

TAC Bi-Weekly Calls

The TAC was engaged in bi-weekly calls following the Kickoff Meeting. Agendas and minutes can be found in Appendix C.

Involving the Public

44 CFR Requirement
44 CFR Part 201.6(b)(1): The planning process shall include an opportunity for the public to comment on the plan during the drafting stage and prior to plan approval.

An important component of the mitigation planning process involved public participation. Individual citizen and community-based input provides the entire planning team with a greater understanding of local concerns and increases the likelihood of successfully implementing mitigation actions by developing community "buy-in" from those directly affected by the decisions of public officials. As citizens become more involved in decisions that affect their safety, they are more likely to gain a greater appreciation of the hazards present in their community and take the steps necessary to reduce their impact. Public awareness is a key component of any community's overall mitigation strategy aimed at making a home, neighborhood, school, business or entire city safer from the potential effects of hazards.

Public involvement during the development of the *Ann Arbor Hazard Mitigation Plan* was sought using three methods: (1) Two public meetings were held during the planning process (Public Kickoff Meeting; Public Mitigation Strategy and Plan Review Meeting, as described above); (2) a public survey was conducted (described below) which permitted open comment; and (3) copies of the draft Plan deliverables were made available and advertised for public review and comment on the city's website and in hard copy form in City Hall. The public was provided two opportunities to be involved in the development of the plan at two distinct periods during the planning process: (1) during the drafting stage of the Plan – two onsite public meetings; and (2) upon completion of a final draft Plan – draft plan review, but prior to official plan approval and adoption. In addition, the plan will be adopted via public meeting.

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Public Participation Survey

The Technical Advisory Committee was successful in getting citizens to provide input to the mitigation planning process through the use of the *Public Participation Survey*. The *Public Participation Survey* was designed to capture data and information from residents of the City of Ann Arbor might not be able to attend public meetings or participate through other means in the mitigation planning process.

Hard copies of the *Public Participation Survey* were made available in the lobby of Larcom City Hall. A link to an electronic version of the survey was also posted and advertised via the city's social media channels, the city's website, a Gov Delivery email (Figure 2.2), and the Huron River Watershed facebook page. Appendix C documents each of these advertisements.

Figure 2.2: Public Hazard Mitigation Planning Survey

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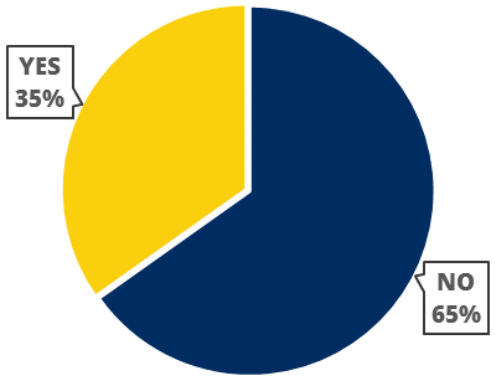
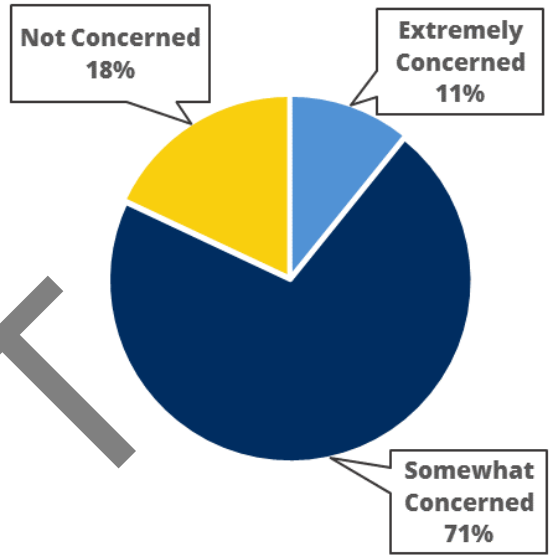
A total of 113 survey responses were received, which provided valuable input for the TAC to consider in the development of the plan update. Approximately 87 percent of respondents live in the City of Ann Arbor. Selected survey results are presented below. A copy of the survey is provided in Appendix B and a detailed summary of the survey results are provided in Appendix D.

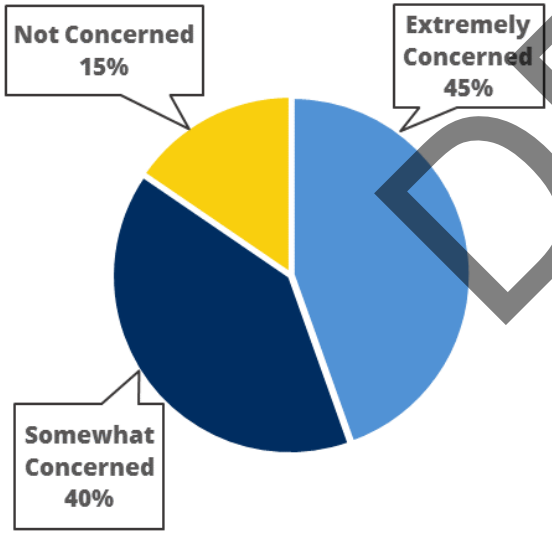
Have you ever experienced or been impacted by a disaster?



How concerned are you about the possibility of your community being impacted by a future disaster?



How concerned are you about the possibility of your community being impacted by climate change?



Are you interested in making your home or business more resistant to hazards?

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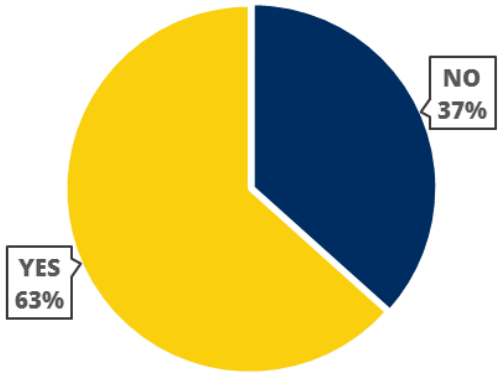
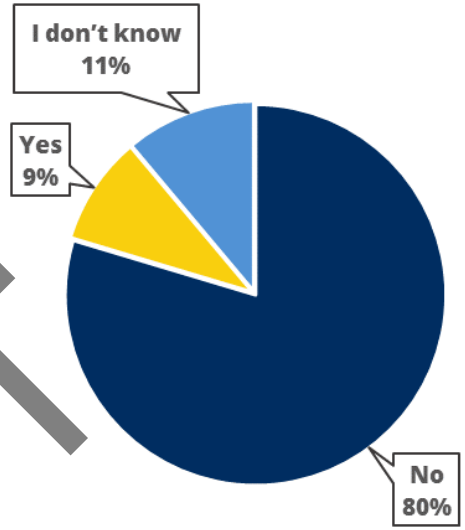
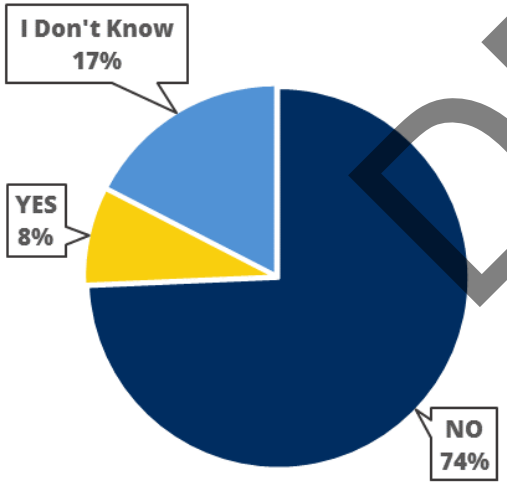
Are you interested in helping your community reduce the impact of climate change?



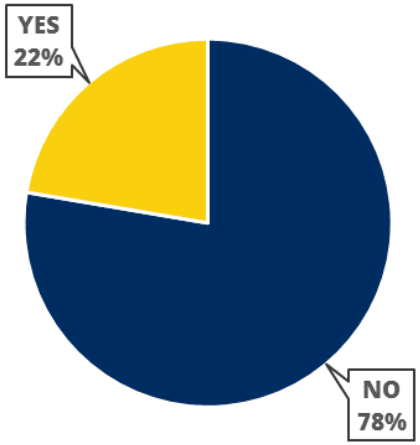
Do you have flood insurance?



Is your home or business located in a floodplain?



Do you know what offices to contact regarding reducing your risks to hazards or climate change in your area?



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Involving the Stakeholders

44 CFR Requirement
44 CFR Part 201.6(b)(2): *The planning process shall include an opportunity for neighboring communities, local and regional agencies involved in hazard mitigation activities, and agencies that have the authority to regulate development, as well as businesses, academia and other non-profit interests to be involved in the planning process.*

The TAC worked to provide an opportunity for a wide range of stakeholders, including opportunity for neighboring communities, agencies involved in hazard mitigation activities, agencies that have the authority to regulate development, private entities, and others to be involved in the planning process.

In order to involve a wide range of stakeholders, the city made a significant effort to broadly distribute the public survey, advertise public meetings, and solicit comments on the draft plan. These opportunities to be involved and offer input were provided for local officials, residents, businesses, academia, and other private interests in the city and surrounding areas throughout the local mitigation planning process.

Furthermore, the following activities demonstrate broad stakeholder involvement:

- The TAC included representation from the Huron River Watershed Council and the University of Michigan.
- Risk assessment data was leveraged from these sources, the state, and FEMA.
- Members of the planning team (including the Planning Manager and Floodplain Administrator) have the authority to regulate development through planning or code enforcement.
- The final draft plan was publicized on websites for stakeholder comment and review.

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Incorporation of Plans, Studies, and Technical Information

44 CFR Requirement
44 CFR Part 201.6(b)(3): Does the Plan describe the review and incorporation of existing plans, studies, reports, and technical information?

Several plans and studies have been leveraged during the development of this plan. Each section references these sources at the end of the section, which are primarily found in Section 3 through Section 5. Types of sources leveraged included:

- Local planning documents (e.g., floodplain management ordinances, land use plans)
- Local, state, federal hazard technical information (e.g., USGS Earthquake data, Hazus-MH)
- FEMA hazard mitigation plans and planning guidance

Local plans were also queried via a Local Capability Review Form which is discussed further in Section 5.

Documentation of Plan Progress

Progress in hazard mitigation planning is documented in this plan update. Since hazard mitigation planning efforts officially began with the development of the initial Hazard Mitigation Plans in the late 1990's/early 2000s, many mitigation actions have been completed and implemented by the city. These actions will help reduce the overall risk to natural hazards for the people and property in the City of Ann Arbor. The actions that have been completed are documented in the Mitigation Action Plan found in Section 6 and Appendix C.

In addition, community capability continues to improve with the implementation of new plans, policies and programs that help to promote hazard mitigation at the local level. The current state of local capabilities is captured in Section 5: ***Capability Assessment***. The city continues to demonstrate their commitment to hazard mitigation and hazard mitigation planning and have proven this through NFIP compliance, joining the CRS in May 2017, and an ongoing commitment to obtaining and implementing mitigation funding and projects, such as the Rail Road berm. A notable addition for this plan update was forming the TAC.

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- Introduction & History
- Geography & the Environment
- Population & Demographics
- Housing, Infrastructure, & Land Use
- Employment & Industry

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3 Community Profile

Section 3 Table of Contents

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Introduction and History

John Allen and Elisha Rumsey founded Ann Arbor in 1824 when they claimed 650 acres of land west of Detroit. Local lore is that the name Ann Arbor came from seeing their wives, Ann Allen and Mary Ann Rumsey, siting under an arbor built by their husbands. In 1833 the first charter of Ann Arbor was created. The charter allowed for a Township President and Council, the first Township President being John Allen. The city was made the Washtenaw County seat in 1827. When Michigan became a state in 1937, the State Legislature agreed to move the University of Michigan to Ann Arbor from Detroit. Ann Arbor became a city in 1851[i]. One of the nation's first zoning ordinances was developed for the city by Frederick Law Olmstead in 1923 as a result of growth (proceeding the nation's first ordinance in New York City, 1916)[ii].

Geography and the Environment

The City of Ann Arbor is in the lower Great Lakes Region of southeastern portion of Michigan. It is located in the on the Huron River approximately 40 miles west of Detroit. The county seat of Washtenaw County, the city is home to the University of Michigan. An orientation map is provided as **Figure 3.1**. The total land area of the city is approximately 28 square miles[iii].

The city's gentle rolling river valley topography ranges from approximately 750 feet above sea level downriver at Gallop Park to approximately 1,050 feet near Pauline Boulevard and Maple Road.

The city is a popular tourist destination well known for: its walkable downtown; many outdoor activities such as canoeing, tubing, biking, walking, and golfing; a variety of cultural opportunities at festivals, music venues, museums, and galleries; and dining and nightlife at a wide range of restaurants, brewpubs, and bars.

Ann Arbor enjoys a full four seasons climate with an average annual temperature of 49.55° Fahrenheit, average annual rainfall of 37.55 inches and average annual snowfall of 57 inches. The city enjoys a climate that is characterized by moderate winters normal for the lower Great Lakes Region with few hot, humid summer days. Summer temperatures average in the 80s and only occasionally rise above 90°.

The city averages 178 sunny days with the clearest part of the year being June-October. Spring average temperatures range from 27° to 60°, summer temperatures 53° to 83°, fall temperatures 33° to 74°, winter temperatures 17° to 35°. The coldest recorded temperature was -22° (January 1994) while the warmest temperature was 104° (August 1918)[iv].

Snowfall can occur October through April although greater snow averages occur December, January, and February. Most snowfall events in Ann Arbor result in less than an inch of fresh snow. On average, less than 20 days a year result in new snow

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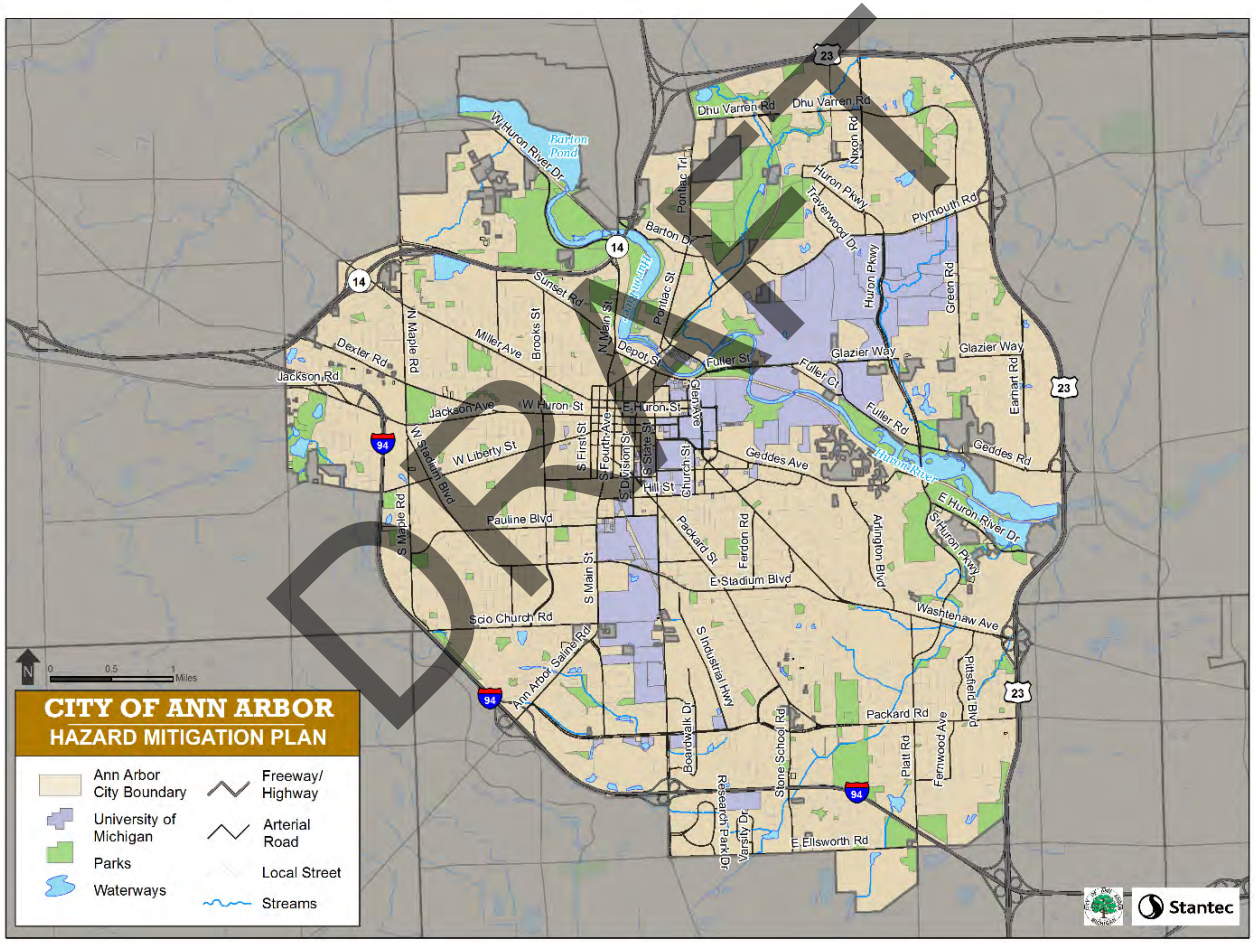
over an inch. Snowfall over 10 inches in one day are rare (although usually in January), while storms over 5 inches in a day occur a couple times a year. Over half of the winter months Ann Arbor typically has at least one inch of snow on the ground[v].

In recent decades, the climate has been gradually changing. Annual average temperatures in Ann Arbor warmed by 0.7°F from 1951-2014. In that time, annual average precipitation increased by 44 percent. Similarly, heavy precipitations days (in the top 1 percent of daily precipitation totals) increased by 41.2 percent from 1981-2010 when compared to 1951-1980.

Figure 3.1: City of Ann Arbor Base Map



Population and Demographics

The City of Ann Arbor is the largest jurisdiction in Washtenaw County and the sixth largest city by population in the State of Michigan. Between 2000 and 2010, the city experienced slight population decline; however, the American Community Survey 5-Year Estimates indicate an increase in 2010-2015 population. Population counts from the US Census Bureau for 1990, 2000, 2010, and 2015 for the city are presented in **Table 3.1**. Population projections for 2020-2040 are presented in **Table 3.2**.

Table 3.1: Population Counts

	1990 Census Population	2000 Census Population	2010 Census Population	2015 ACS Population	% Change 1990-2015
City of Ann Arbor	109,592	114,024	113,934	116,194	6%

Source: US Census Bureau

Table 3.2: Population Projections

	2020 Population Estimate	2025 Population Estimate	2030 Population Estimate	2035 Population Estimate	2040 Population Estimate	% Change 2020-2040
City of Ann Arbor	116,827	118,813	119,113	119,855	123,786	6%

Source: SEMCOG[vi]

Based on the 2015 Census, the median age of residents is 27.8 years. The racial characteristics of the city are presented in **Table 3.3**. Generally, whites make up the majority of the population for over 70 percent of the population. Asian Indian, Chinese, Filipino, Japanese, Vietnamese, and other Asian persons make up over 15 percent of the population.

Table 3.3: Demographics

	White Persons, Percent (2015)	Asian Persons, Percent (2015)	Black Persons, Percent (2015)	Other Race, Percent (2015)	Persons of Hispanic Origin, Percent (2015)*
City of Ann Arbor	72.3%	15.5%	7.4%	0.4%	4.4%

*Hispanics may be of any race, so also are included in applicable race categories.
Source: US Census Bureau

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Housing, Infrastructure and Land Use

Housing

According to the 2010 US Census, there were 49,789 housing units in the City of Ann Arbor, the majority of which are single family homes or townhomes. Housing information for the city is presented in **Table 3.4**. Owner occupied housing is less than 50 percent. Median gross rent is $1,063 while the median value of owner occupied housing units is $240,700 (2011-2015).

Table 3.4: Housing Characteristics

	Housing Units (2000)	Housing Units (2010)	Housing Units (2015)	Owner Occupied Units (2011-2015)	Median Home Value (2011-2015)
City of Ann Arbor	**47,218**	**49,789**	**49,982**	**44.8%**	**$240,700**

Source: US Census Bureau

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Infrastructure

Infrastructure is the fundamental facilities and systems serving the city. These include the transportation network, utilities, and community facilities that provide essential services to the city and residents.

Transportation

As illustrated in **Figure 3.1**, there are several major highways that ring the City of Ann Arbor, two interstates and one US highway. Interstate 94 (I-94) is part of the interstate highway system which runs primarily east-west from Montana to the eastern edge of Michigan leading to the International crossing at the Blue Water Bridge to Ontario, Canada. Locally, I-94 connects Ann Arbor to Jackson to the west and Ypsilanti to Detroit to the east. The highway passes along the southwestern extent of the city.

M-14 splits northerly from I-94 on the western side of Ann Arbor and crosses the Huron River to join with US-23. US-23 runs north-south along the eastern edge of the city till it joins with M-14 in Ann Arbor Township. The joint stretch of M-14/US-23 runs east-west along the northern edge of the city. M-14 continues to the east to connect Ann Arbor to Detroit and the northern suburbs of Wayne and Oakland County.

These highways, I-94, M-14 and US-23, are four-lane divided highways in the Ann Arbor area. There are also several surface state trunkline highways under the jurisdiction of the Michigan Department of Transportation (MDOT), these include Huron

Street, Washtenaw Avenue, and Main Street north of Huron Street[vii]. The city's Engineering Department is responsible for the network of city streets including public alleys, local, collector and arterial roads.

Three active rail lines run through Ann Arbor. Amtrak passenger service and Norfolk Southern freight traverse east-west on the Norfolk Southern rail lines. This rail line connects to Detroit to the east and Jackson, Battle Creek, Kalamazoo, and Chicago, Illinois to the west. The Great Lakes Central rail line runs north through Howell to Durand while the Ann Arbor Railroad runs south to Toledo, Ohio. Both provide freight service.[viii]

The Detroit Metropolitan Airport is the largest airport serving southeastern Michigan including Ann Arbor. The airport currently offers non-stop commercial flights on thirteen airlines to numerous destinations across the eastern US and Midwest, most major US cities, and to several international destinations[ix]. This airport is approximately 35 miles from Ann Arbor. Other major nearby airports include the Bishop International Airport in Flint and the Oakland County International Airport in Pontiac. Willow Run Airport in Van Buren Charter Township provides freight, corporate, and general aviation, but no large airlines fly out of this airport. Ann Arbor Municipal Airport is located in Pittsfield Township just outside of the city. The airport is owned and operated by the City of Ann Arbor and maintains a 3,500-foot concrete runway and a 2,750-foot turf runway to serve public and business flights, medical flights, flight instruction and charter service[x].

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Utilities

Electrical power in the city of Ann Arbor is provided by one public utility, DTE Energy. DTE and Consumers Energy have a shared territory for natural gas, although Ann Arbor is predominately served by DTE Energy[xi].

Water and sewer service is provided by the City of Ann Arbor through the Utilities Department. Water is sourced from the Huron River north of the city and municipal wells south of Ann Arbor at the Ann Arbor Municipal Airport. Approximately 85 percent of the water comes from the river. The water is treated at the Water Treatment Plant (WTP) and distributed throughout the City of Ann Arbor. The city supplies approximately 5 billion gallons of water a year. The city also supplies water to portions of Ann Arbor and Scio Townships. Wastewater (sewer) is collected and treated by the city at the Wastewater treatment plant in Ann Arbor Township west of the city. The plant also provides services for portions of Ann Abor, Pittsfield, and Scio Townships[xii].

Community Facilities

There are a number of public buildings and community facilities located throughout the City of Ann Arbor. According to the data collected for the vulnerability assessment (Section 4), there are 6 fire stations, 1 police station (the Justice Center), and 37 public schools located within the city limits.

There are two major hospital complexes in the City of Ann Arbor. The University of Michigan complex, U-M Medical Center – Ann Arbor (East Medical Drive), consists of multiple hospitals and centers including the University Hospital, University Hospital-South, Taubman Health Center, CS Mott Children's Hospital and Van Voigtlander Women's Hospital, Comprehensive Cancer Center, Cardiovascular Center, as well as several learning and research facilities. Across the Huron River at Wall Street, the University of Michigan Health System operates the Kellogg Eye Center[xiii].

East of the Medical Center on Fuller Road is the VA Ann Arbor Healthcare System complex operated by the U.S. Department of Veterans Affairs. In 2015 over 65,000 Veterans from Michigan and northwestern Ohio utilized the facility[xiv]. Saint Joseph Mercy Health System operates a 500 plus bed hospital and medical complex, St. Joseph Mercy Ann Arbor, approximately 2 miles east of Ann Arbor in Superior Township[xv]. In addition to the hospitals, there are numerous health centers and clinics spread throughout the city and adjacent townships operated by the University of Michigan and St. Joseph Mercy Health Systems.

There are numerous city and local parks in the Ann Arbor vicinity. Combined, these facilities offer recreational opportunities to area residents and millions of visitors each year. City of Ann Arbor Parks and Recreation operates over 170 parks and park facilities including the Ann Arbor Farmers Market, Ann Arbor Senior Center, two community centers, two canoe liveries, over 90 playgrounds, two golf courses, one indoor and one outdoor ice arenas, one indoor and three outdoor pools, Leslie Science and Nature Center, and Cobblestone Farm[xvi].

The Border to Border Trail (B2B) is an ongoing collaboration within Washtenaw County to construct a shared-use pathway linking Huron River Greenways. The City of Ann Arbor Parks and Recreation is an active part of this system having completed several legs within the city. The B2B trail is part of the State of Michigan's Iron Belle Trail - a network of trails that connect Detroit to Ironwood in the western upper peninsula[xvii].

Washtenaw County Parks operates two parks within the city: County Farm and Swift Run Parks. There are also numerous County parks and preserves in the surrounding communities including Parker Mills Park and Freeman and Goodrich Preserves just east of the City in Ann Arbor Township[xviii].

Huron-Clinton Metroparks, a regional park system, operates 13 parks along the Huron and Clinton Rivers in southeastern Michigan. The closest park is Delhi Metropark just northwest of the city along the Huron River[xix]. Nearby State of Michigan Parks and Wildlife Lands are Pinckney and Waterloo Recreation Areas and Chelsea State Game Area.

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The University of Michigan also has numerous recreation and open space facilities within the city and surrounding areas. Some are open to the public such as the Nichols Arboretum located along the Huron River on the eastern edge of the central campus.

Land Use

In general, the City of Ann Arbor is developed throughout the City limits and is generally where the county's population is concentrated. By area, the largest land use in the city is residential. Approximately 35 percent of the land area is devoted to single family residential use while approximately 6 percent is multiple family. Government and institutional uses account for approximately 18 percent; transportation, communication and utilities occupy approximately 17 percent; while open space including parks, recreation, natural and undeveloped area account for 11 percent[xx]. In the downtown area, many of the uses are mixed.

The State Street/South Main Street area south of downtown consists of a large share of city's commercial and office uses. Other commercial and office land uses are scattered throughout the City concentrated along major thoroughfares and freeway interchanges. The State Street/I-94 interchange area has a large concentration of commercial transportation including several hotels.

There is no heavy manufacturing in the city. Some light industry exists along North Main Street and the railroad tracks that run north to south through the city. Research uses are found in the State Street/I-94 area on the south side of town and the Plymouth Road area in the northeast side of town. A few small township islands exist within the city boundaries as shown in **Figure 3.1**. Under a boundary agreement with the adjacent Townships (Ann Arbor, Scio, and Pittsfield Townships) eventually these islands will be annexed into the city[xxi].

The University of Michigan is a major land owner within the city, and includes 19 schools and colleges, many of which rank among the top programs in the nation. Student enrollment for fall 2016 of undergraduate, graduate, and professional students was 44,718. The university provides housing to 9,500 undergraduate students in 18 residence halls and campus apartment buildings. The FY2016 operating revenues from the state appropriation, tuition, research grants and contracts, gifts and other sources is approximately $3.45 billion for the Ann Arbor campus[xxii]. Other higher education facilities in Ann Arbor include Concordia University and Cleary College (satellite campus).

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Employment and Industry

Ann Arbor's economy developed around the Huron River and its tributaries. Co-settler, John Allen, located a gristmill along Allen's Creek and soon after following settlers developed other mills, a tannery and general store. In 1827 the city became the county seat and the University of Michigan relocated here from Detroit in 1837[xxiii]. The completion of the Michigan Central Railroad's Detroit-Ann Arbor connection in 1839 symbolized the beginning of a new era of immigration, economic accessibility and growth for Ann Arbor and Washtenaw County[xxiv].

In general, the City of Ann Arbor has a diverse technology although somewhat more heavily reliant on the University of Michigan than the automotive industry in the surrounding region. The western extent of a high-technology corridor extending from Detroit along I-94 and M-14, the regions key industries include life sciences and health care, technology, data and information, and automotive and mobility. An increase in research, development or testing firms is also likely due to the proximity of the University of Michigan providing technical resources and an educated workforce[xxv]. According to SPARK Ann Arbor, the top regional employers are the University of Michigan, the Veterans' Administration, the City of Ann Arbor, and the Ann Arbor Public Schools (January 2017)[xxvi].

According to the Bureau of Labor Statistics, June 2017, the Ann Arbor metropolitan region had a nonfarm employment of 214,900 persons and a total labor force of 190,800 persons[xxvii]. Government employed 73,200 persons (34%), professional and business services 32,100 (15%), education and health services 27,300 (12.7%), trade, transportation, and utilities 25,700 (12%), leisure and hospitality 18,300 (8.5%), and manufacturing 15,100 (7%). In 2016, the annual mean wages in the Ann Arbor metropolitan region for all occupations was $56,160, compared to $47,350 for the State of Michigan[xxviii].

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- Introduction
- Sources of Information
- Risk Assessment Tools
- Hazard Information
- Hazard Profiles
- Summary of Analyzed Data
- Summary of Overall Vulnerability

4 Risk Assessment

Section 4 Table of Contents

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Introduction

This chapter provides a risk assessment of natural, technological and human-related hazards that could impact the City of Ann Arbor. All hazards include a profile and a vulnerability assessment. All hazards include a qualitative analysis of the city's vulnerability, when data permitted, a quantitative analysis was performed (including potential dollar losses).

The hazard profile includes a description of the nature of the hazard, past occurrences and damages, extent (or magnitude) of the hazard, and likelihood or probability of the hazard occurring in the future. Ann Arbor's assets have been examined to estimate the potential health, safety and property damages attributable to hazards in the vulnerability assessment. In addition, the 2017 update of the plan includes climate change considerations for each hazard.

Following the hazard profiles, a summary of the risk assessment for Ann Arbor is provided. This includes hazard ranking based on the Priority Risk Index (PRI), and a summary of key points on risk. The PRI is a tool used to measure the degree of risk for identified hazards in a planning area with consideration to probability, impact, spatial extent, warning time, and duration.

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Hazard Identification

Hazards were identified by reviewing the 2012 Ann Arbor Hazard Mitigation Plan, the effective Michigan State Hazard Mitigation Plan, and previous disaster declarations. Input from the Technical Advisory Committee (TAC) was also solicited and used to identify hazards.

Disaster Declarations

Since 1965, three hazard events have resulted in damage severe enough to warrant a federal Presidential Disaster Declaration in the planning area. Presidential Disaster Declarations are declared at the county-level; therefore, declarations made for Washtenaw County were considered as relevant to Ann Arbor. Details for these declarations are presented in **Table 4.1.**

Table 4.1 Historic Presidential Disaster Declarations for Washtenaw County

Date	Disaster Number	Description
04/14/1965	190	Tornadoes and Severe Thunderstorms

Date	Disaster Number	Description
09/08/1980	631	Severe Storms and Flooding
06/30/2004	1527	Michigan Severe Storms, Tornadoes, and Flooding

Hazard List

Hazard identification is the process of identifying the types of hazards that can affect the mitigation plan study area – The City of Ann Arbor. As this is a plan update to the city-wide plan that was adopted in 2012, hazards from that plan were reviewed along with hazards listed in the state plan. Input was gathered from the Technical Advisory Committee (TAC) to discern hazards that should be added or removed from those included in the last plan iteration and the Michigan State Hazard Mitigation Plan. Hazards were reviewed at the TAC Kickoff Meeting and finalized on a subsequent call. **Table 4.2** presents the final hazards list for this plan update and whether each hazard was recognized in the Michigan State Hazard Mitigation Plan and the 2012 Ann Arbor Hazard Mitigation Plan. **Table 4.3** indicates the hazards from the Michigan State Hazard Mitigation Plan that were excluded from this plan update and provides a justification for exclusion.

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Table 4.2 Hazards Identified for the 2017 Ann Arbor Plan Update

2017 Ann Arbor Plan Update Identified Hazards	Michigan SHMP Identified Hazard (YES/NO)	Included in 2012 Ann Arbor Plan (YES/NO)
NATURAL HAZARDS – WEATHER HAZARDS		
Extreme Cold/Wind Chill	YES	YES (as Extreme Temperatures)
Extreme Heat	YES	YES (as Extreme Temperatures)
Fog	YES	NO
Hail	YES	YES (as Convective Weather)
Lightning	YES	YES (as Convective Weather)
Severe Winter Weather	YES	YES (as Convective Weather)
Severe Winds	YES	YES (as Convective Weather)
Tornadoes	YES	YES (as Convective Weather)
NATURAL HAZARDS – HYDROLOGICAL HAZARDS		
Flood	YES (As Riverine Flood)	YES (as Riverine/Urban Flood)
Dam Failures	YES	YES
Drought	YES	YES

2017 Ann Arbor Plan Update Identified Hazards	Michigan SHMP Identified Hazard (YES/NO)	Included in 2012 Ann Arbor Plan (YES/NO)
NATURAL HAZARDS – ECOLOGICAL HAZARDS		
Invasive Species	YES	YES (as Infestation)
NATURAL HAZARDS – GEOLOGICAL HAZARDS		
Earthquakes	YES	YES
TECHNOLOGICAL HAZARDS – INDUSTRIAL HAZARDS		
Structure Fires	YES	YES

Table 4.3 Justification for Excluded Hazards

Michigan SHMP Identified Hazards (Excluded from 2017 Ann Arbor Plan Update)	Justification
NATURAL HAZARDS – WEATHER HAZARDS	
Ice and Sleet Storms	Covered under Severe Winter Weather
Snowstorms	Covered under Severe Winter Weather
NATURAL HAZARDS – HYDROLOGICAL HAZARDS	
Great Lakes Shoreline Hazards	Ann Arbor does not have shoreline on the Great Lakes; hazard was not included in 2012 plan.
NATURAL HAZARDS – ECOLOGICAL HAZARDS	
Wildfire	According to the USDA Wildfire Hazard Potential map, all of Ann Arbor is designated as either "non-burnable" or as having "very low" wildfire potential. No census blocks within the city are designated as wildland-urban-interface areas, and only three census blocks are indicated as medium density wildland-urban-intermix areas (with no high or low density intermix areas). In addition, the Technical Advisory Committee indicated that wildfires are not a hazard of concern. The 2012 Ann Arbor hazard mitigation plan indicated that wildfires do not have a great history of substantial local impacts, despite occurring in Washtenaw County.
NATURAL HAZARDS – GEOLOGICAL HAZARDS	
Subsidence	Technical advisory committee members agreed that subsidence is not an issue faced by the community, and noted that future subsidence is not anticipated. In the Michigan state hazard mitigation plan, Washtenaw County was not identified for potential subsidence hazards related to mining. In addition, the state plan designated Ann Arbor as being in an area where sinkholes are "absent or likely absent."

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Michigan SHMP Identified Hazards (Excluded from 2017 Ann Arbor Plan Update)	Justification
Celestial Impact	The Technical Advisory Committee agreed that celestial impacts are not of great concern to the community, and noted a lack of historical impacts. The Emergency Manager described one historic occurrence of solar weather interfering with communications equipment, but noted that impacts were not substantial or widespread. This hazard was not included in the 2012 Ann Arbor Plan.
TECHNOLOGICAL HAZARDS – INDUSTRIAL HAZARDS	
Scrap Tire Fires	There is no documented history of scrap tire fires in Ann Arbor. In addition, no scrap tire facilities are registered in Ann Arbor with the Michigan Department of Environmental Quality.
Oil and Natural Gas Well Accidents	Based on maps from the Michigan Department of Natural Resources, there are no oil and gas wells within Ann Arbor.
TECHNOLOGICAL HAZARDS – INFRASTRUCTURE PROBLEMS	
Infrastructure Failures	This hazard will be considered for all applicable hazards as a potential vulnerability.
Energy Emergencies	This hazard will be considered for all applicable hazards as a potential vulnerability.
Transportation Accidents	This hazard will be considered for all applicable hazards as a potential vulnerability.
HUMAN RELATED HAZARDS	
Catastrophic Incidents (National Emergencies)	National emergencies are not within the scope of this plan.
Nuclear Attack	This hazard is addressed under terrorism. In addition, mitigation of a nuclear attack would likely occur at the national level. Nuclear Power plan incidents are addressed under the Nuclear Power Plant Hazards
Public Health Emergencies	This will be a consideration for all applicable hazards as it relates to vulnerability.

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Sources of Information

Hazard information and data was collected for all hazards using hazard studies, geographic information systems (GIS) data, and descriptions of previous events. This information is cited throughout the plan.

Local Sources

Local sources used in the risk and vulnerability assessment include:

- City reports and studies
- City geospatial data
- Washtenaw County studies and reports applicable to the planning area
- Washtenaw County geospatial data

- Information gathered from Technical Advisory Committee meetings and calls
- Information gathered from interviews with local officials
- Information, data, and reports from the Huron River Watershed Council
- Reports, studies and memos from the University of Michigan and Michigan State University (Great Lakes Integrated Sciences and Assessments (GLISA) program, including the Cities Impacts and Adaptation Tool
- Ann Arbor 2012 Hazard Mitigation Plan
- Local news sources (e.g., M Live, Ann Arbor News)

State Sources

State sources used in the risk and vulnerability assessment include:

- The Michigan state hazard mitigation plan;
- Michigan state agency maps, data, reports, and webpages applicable to the planning area, including but not limited to those from the Michigan Department of Natural Resources, Michigan Department of Environmental Quality, and Michigan Emergency Management & Homeland Security

Federal Sources

Federal sources used in the risk and vulnerability assessment include agency studies, maps, geospatial data, and reports applicable to the planning area, including but not limited to the following:

- Federal Emergency Management Agency (FEMA) mapped flood hazards areas and NFIP statistics
- US Department of Agriculture (USDA) Forest Service wildfire hazard potential and wildland-urban interface data
- National Oceanic and Atmospheric Association (NOAA) National Centers for Environmental Information (NCEI) Storm Events Database
- US Climate Resilience Toolkit
- US Drought Monitor data
- Environmental Protection Agency (EPA) information
- US Geological Survey (USGS) data and information
- US DOT Pipeline Hazard Safety Administration data
- US Transportation Safety Administration information
- US Centers for Disease Control information
- US Global Change Research Program information and data

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Data Limitations

Although Ann Arbor has a wealth of available data, data limitations do constrict the risk analysis at certain points. Data limitations include:

- Previous occurrences for many hazards were gathered from the NOAA National Centers for Environmental Information Storm Events Database, which is not all-inclusive. Therefore, the occurrence of certain hazards is likely under-reported. In addition, data for certain hazards was only available at the county-level, and events specific to Ann Arbor could not be identified (noted in the hazard's profile). Additional sources for previous occurrences were considered when available.
- Building footprints obtained from the city are not linked to parcel data; therefore, building value could only be analyzed in terms of the parcel, not its associated building footprint.
- Several different sources of climate change data were used to analyze future risk. Different sources use different scenarios, geographic regions, and timelines therefore, projections are not always consistent. In addition, future conditions (e.g., emissions, radiative forcing, effects) are difficult to predict, and there is a known uncertainty associated with climate projections and models. Uncertainty differs for hazards, for instance, temperature models are considered more certain than precipitation models. For certain hazards, climate impacts were not available or were inconclusive.

Risk Assessment Tools

Hazard information was collected for all hazards under consideration using hazard studies, GIS data, and descriptions of previous events. This information is cited throughout the plan.

GIS and FEMA's Hazus-MH

GIS tools, including Hazus-MH provide a mechanism to perform quantitative analysis. Hazards that have specified geographic boundaries permit analysis using GIS. These hazards include:

- Flood
- Earthquake
- Hazardous Materials Incidents

The objective of the GIS-based analysis was to determine the estimated vulnerability of structures for the identified hazards in Ann Arbor using best available geospatial data. ESRI® ArcGIS™ 10.2 was used to assess hazard vulnerability utilizing digital hazard data, such as FEMA DFIRMs, building footprints, and tax assessor data. Using these data layers, hazard vulnerability

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can be assessed by estimating the number and of type of structures determined to be in identified geographic hazard area boundaries.

FEMA's Hazus-MH uses ESRI's ArcGIS platform for the flood and earthquake hazards. Hazus-MH ("Hazus") is a standardized loss estimation software program developed by FEMA. It is built upon an integrated GIS platform to conduct analysis at a regional level (i.e., not on a structure-by-structure basis). The Hazus risk assessment methodology is parametric, in that distinct hazard and inventory parameters (e.g., wind speed and building types) can be modeled using the software to determine the impact (i.e., damages and losses) on the built environment. The Ann Arbor Risk and Vulnerability Assessment utilized Hazus-MH to produce hazard damage loss estimations for hazards for the planning area. At the time this analysis was completed, Hazus-MH 4.0 was used to estimate potential damages from earthquake hazards using Hazus-MH methodology.

Huron River Watershed Council Climate Justice Index

The Climate Justice Index (CJI) is a GIS-based tool developed for analyzing the geographic distribution of climate change-induced hazards with consideration to socially vulnerable groups. All data used for this analysis, including index results, was obtained from the Huron River Watershed Council. The project was originally completed for the entire Huron River Basin by the Huron River Watershed Council and the University of Michigan, but was clipped to the City of Ann Arbor for use in this plan. The CJI ranks areas at the census tract level based on their concentration of socially vulnerable populations and exposure to climate-change induced flooding and contamination aggravated by floods. Ranks are from 1 to 5, where one is the least impacted by climate change, and five is the greatest. The CJI was created using equal weights from three indices: 1) the Climate Change-Induced Flooding Hazard Index (CCFHI), 2) the Environmental Hazard Index (EHI), and 3) the Social Vulnerability Index. Each of these indices is explained in more detail below.[i]

- **Climate Change-Induced Flood Hazard Index (CCFHI)** refers to the potential for increased flooding compared to baseline conditions. This model is based on the concept that warmer temperatures will reduce flooding due to drier conditions, and increased precipitation will increase flooding. Flooding potential is defined as the probability of daily streamflow volume exceeding bankfull, or maximum holding capacity. Daily stream flow volume was simulated using the Soil and Water Assessment Tool (SWAT). SWAT is designed to simulate water balance and stream flows at the watershed scale. Baseline conditions taken over a three-year period, along with climate change impacts from mean temperature and precipitation variation inputs were incorporated into the SWAT model.
- **Environmental Hazard Index (EHI)** serves as a proxy for water quality, assuming environmental hazard sites are susceptible to contaminating surface and groundwater resources during a flood event. The EHI includes Toxic Release Inventory (TRI) sites, EPA superfund sites, brownfield sites, landfills, hazardous waste sites, leaking underground storage tanks, and EPA Risk-Screening Environmental Indicators at the stream reach level.

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The CJI was developed using a 55-year simulation, including a 3-year baseline period. The CCFHI was developed at the subbasin, or creekshed, scale (see **Figure X**), while the SoVI was developed at the census tract level. The CCFHI was scaled to the census tract level using an area weighted method.[ii] The CCFHI does not attempt to define the 100-year flood using changing climate conditions, nor does it consider current and future flood control devices, such as levees or dams. Census tracts located wholly within a single subbasin were assigned the value for the subbasin, tracts located within multiple subbasins were assigned an CCFHI value using an area-weighted method.

Using multiple scenarios for temperature and precipitation increases, two impact scenarios were identified:

- **Low impact**: +2 degrees Celsius, +10 percent precipitation increase
- **High Impact**: +1degree Celsius, +20 percent precipitation increase

This plan uses includes results from the High Impact scenario to encourage mitigation based on scenarios with the most severe impacts. Results are included in the Flood hazard profile, but can also be used to inform mitigation actions for hazardous materials incidents.

Annualized Loss Estimation

Many of the hazards listed above have the potential to affect all current and future buildings and all populations. For many of the hazards listed above, no additional analysis was performed. When possible, annualized loss estimates were determined using the best available data on historical losses. Annualized loss is the estimated long-term weighted average value of losses to property in any single year in a specified geographic area. Annualized loss estimates were generated by totaling the amount of property damage over the period for which records were available, and calculating the average annual loss. Given the standard weighting analysis, losses can be readily compared across hazards providing an objective approach for evaluating mitigation alternatives.

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Priority Risk Index

The prioritization and categorization of identified hazards for Ann Arbor is based principally on the Priority Risk Index (PRI), a tool used to measure the degree of risk for identified hazards in a particular planning area. The PRI was used to assist the Ann Arbor Technical Advisory Committee in identifying hazards that pose the most significant threat to the city.

The PRI results provide a numerical value for each hazard, allowing hazards to be ranked against one another (i.e. the higher the PRI value, the greater the hazard risk). PRI values are obtained by assigning varying degrees of risk to five categories for each hazard: probability, impact, spatial extent, warning time and duration. Each degree of risk has been assigned a value (1 to 4) and a weighting factor.

To calculate the PRI value for a given hazard, the assigned risk value for each category is multiplied by the weighting factor. The sum of all five categories equals the final PRI value, as demonstrated in the example equation below:

PRI VALUE = [(PROBABILITY x .30) + (IMPACT x .30) + (SPATIAL EXTENT x .20) + (WARNING TIME x .10) + (DURATION x .10)]

According to the weighting scheme applied, the highest possible PRI value is 4.0. **Table 4.4** shows the weighting schemes for each category. By determining a value for each hazard that can be compared to other hazards threatening the planning area, hazards can be ranked with greater ease.

Many of the PRI categories are described within the hazard profiles. The final PRI results, including the calculated values for each hazard in Ann Arbor, are found at the end of this section in the "Summary of Hazard Risk," beginning on page X.

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Table 4.4 Priority Risk Index Scoring Criteria

PRI Category	DEGREE OF RISK Level	Criteria	Index	Assigned Weighing Factor
Probability	Unlikely	Less than 1percent annual probability	1	30 percent
	Possible	Between 1 and 10 percent annual probability	2	
	Likely	Between 10 and 90 percent annual probability	3	
	Highly likely	90 percent+ annual probability	4	
Impact	Minor	Only minor property damage and minimal disruption to government functions and services.	1	30 percent
	Limited	Minor injuries are possible. More than 10 percent of buildings damaged or destroyed.	2	
	Critical	Multiple deaths/injuries possible. More than 25 percent of buildings damaged or destroyed.	3	
	Catastrophic	High number of deaths/injuries possible. More than 50 percent of buildings damaged or destroyed.	4	
Spatial Extent	Negligible	Limited to one specific area.	1	20 percent
	Small	Small areas affected.	2	
	Moderate	Large areas affected.	3	
	Large	All areas affected.	4	
Warning Time	More than 24 hours	self-explanatory	1	10 percent
	12 to 24 hours	self-explanatory	2	
	6 to 12 hours	self-explanatory	3	
	less than 6 hours	self-explanatory	4	
Duration	less than 6 hours	self-explanatory	1	10 percent
	6 to 12 hours	self-explanatory	2	
	12 to 24 hours	self-explanatory	3	
	More than 24 hours	self-explanatory	4	

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Summary of Data Analyzed

The risk assessment relies on a range of data sources to provide accurate hazard impact data for the city. Data was collected from city, county, regional, state, and federal agencies and organizations. Parcel data, including improvement value, as well as building footprints were obtained from the city. Infrastructure data was also obtained from the city.

Descriptions of the data used in the vulnerability assessment is described below. Population data was obtained at the tract level from the US Census Bureau.

Parcel and Building Data

Table 4.5 shows the City of Ann Arbor provided GIS-based tax assessor parcel data, which contains building improvement values. The improved value is the assessed value of the structure and does not include land values. GIS-based building footprints were also obtained from the city. Where possible, a GIS intersection analysis will be performed using parcel data and hazard data to determine the number and value of properties at risk and to estimate losses. However, data limitations hinder the ability to conduct this analysis on all hazards (and many hazards impact the entire planning area). The following table indicates the number and value of total parcels in the planning area.

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Table 4.5 Ann Arbor Parcel and Building Data

Number of Parcels	Number of Improvements	Total Value of Improvements (2017 dollars)	Number of Building Footprints
32,420	29,496	$10,131,942,792	35,362

Infrastructure Data

The city provided GIS data for roads, bridges, and railroads. Value data was not provided for infrastructure.

Population Data

2015 population estimates were obtained from the US Census Bureau's 2011-2015 American Community Survey. Population estimates at the census tract level were joined to TIGER/Line shapefiles downloaded from the US Census Bureau website. Census data tables were then joined to TIGER/Line shapefiles to display population spatially. TIGER/Line shapefiles are available at the census tract level.

Hazard Profiles

The hazards profiles are presented in alphabetical order by category: Natural (weather, hydrological, ecological, geological); Technological; and Human-Caused Disasters.

NATURAL HAZARDS – WEATHER HAZARDS

- Extreme Cold/Wind Chill
- Extreme Heat
- Fog
- Hail
- Lightning
- Severe Winter Weather
- Severe Winds
- Tornadoes

NATURAL HAZARDS – HYDROLOGICAL HAZARDS

- Flood
- Dam Failures
- Drought

NATURAL HAZARDS – ECOLOGICAL HAZARDS

- Invasive Species

NATURAL HAZARDS – GEOLOGICAL HAZARDS

- Earthquakes

TECHNOLOGICAL HAZARDS – INDUSTRIAL HAZARDS

- Structure Fires

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44 CFR Requirement

44 CFR 201.6(c)(2)(i) and 44 CFR 201.6(c)(2)(iii): Does the Plan include a description of the type, location, and extent of all natural hazards that can affect each jurisdiction?

44 CFR 201.6(c)(2)(i): Does the Plan include information on previous occurrences of hazard events and on the probability of future hazard events for each jurisdiction?

44 CFR 201.6(c)(2)(ii): Is there a description of each identified hazard's impact on the community as well as an overall summary of the community's vulnerability for each jurisdiction?

As noted above, each hazard is profiled separately to describe the hazard and potential impacts to the city. Where data exists, specific information on location will also be included. When applicable, impacts from climate change are integrated throughout each hazard profile, including observed climate trends, projected impacts on hazard extent and future probability, and expected impacts on vulnerability. The profile for each hazard includes:

- Description: A scientific explanation of the hazard including potential magnitude (or severity) and impacts (including climate change considerations);
- Location: Geographical extent of the hazard;
- Previous occurrences: The number of previous impacts from the hazard in Ann Arbor in the past;
- Extent (or magnitude): The severity of the hazard in the past and potential severity in the future (including climate change considerations). Measures may include wind speed, wave height, or property damage, for example;
- Probability of future events: The likelihood of future events impacting the city (including climate change considerations). Given that an exact probability is often difficult to quantify, this characteristic is categorized into ranges to be used in hazard profiles (per the PRI criteria):
    - Unlikely: Less than 1 percent annual probability
    - Possible: Between 1 percent and 10 percent annual probability
    - Likely: Between 10+percent and 90 percent annual probability
    - Highly Likely: Greater than 90 percent annual probability
- Vulnerability Assessment: The vulnerability assessment investigates the potential number of and type of structures at risk, potential dollar loss, and potential impacts resulting from each hazard based on available data and information.
    - Impact of Infrastructure: The vulnerability of damage to infrastructure is described.
    - Impact on Life Safety, Health, Evacuation and Warning Procedures: This category relates to health and life safety hazards. Waring systems and evacuations prompted by hazards are described.
    - Impact of Public Health: Impacts to public health caused by hazards is described here.
    - Economic Impact: Typical impacts on businesses, utilities, and the city's tax base are described here.
    - Climate Change Considerations: A description of potential future conditions and how they may affect the hazard impacts.

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Extreme Cold/Wind Chill

Description

The term "extreme cold" can have varying definitions in hazard identification. It may or may not be associated with a winter storm. Generally, extreme cold events refer to a prolonged period of time (days) with extremely cold temperatures. An extreme cold event to the National Weather Service can refer to a single day of extreme or record-breaking day of sub-zero temperatures. Extended or single day extreme cold events can be hazardous to people and animals, and cause problems with buildings and transportation.

The Wind Chill Index (**Figure 4.1**)[iii] is a measure of the rate of heat loss from exposed skin caused by the combined effects of wind and cold. As the wind increases, heat is carried away from the body at a faster rate, driving down both the skin temperature and eventually the internal body temperature. Exposure to extreme wind chills can be life threatening. The NOAA chart shows the Wind Chill Index as it corresponds to various temperatures and wind speeds. As an example, if the air temperature is 5°F and the wind speed is 10 miles per hour, then the wind chill would be -10°F. As wind chills edge toward -19°F and below, there is an increased likelihood that continued exposure will lead to individuals developing cold-related health impacts.

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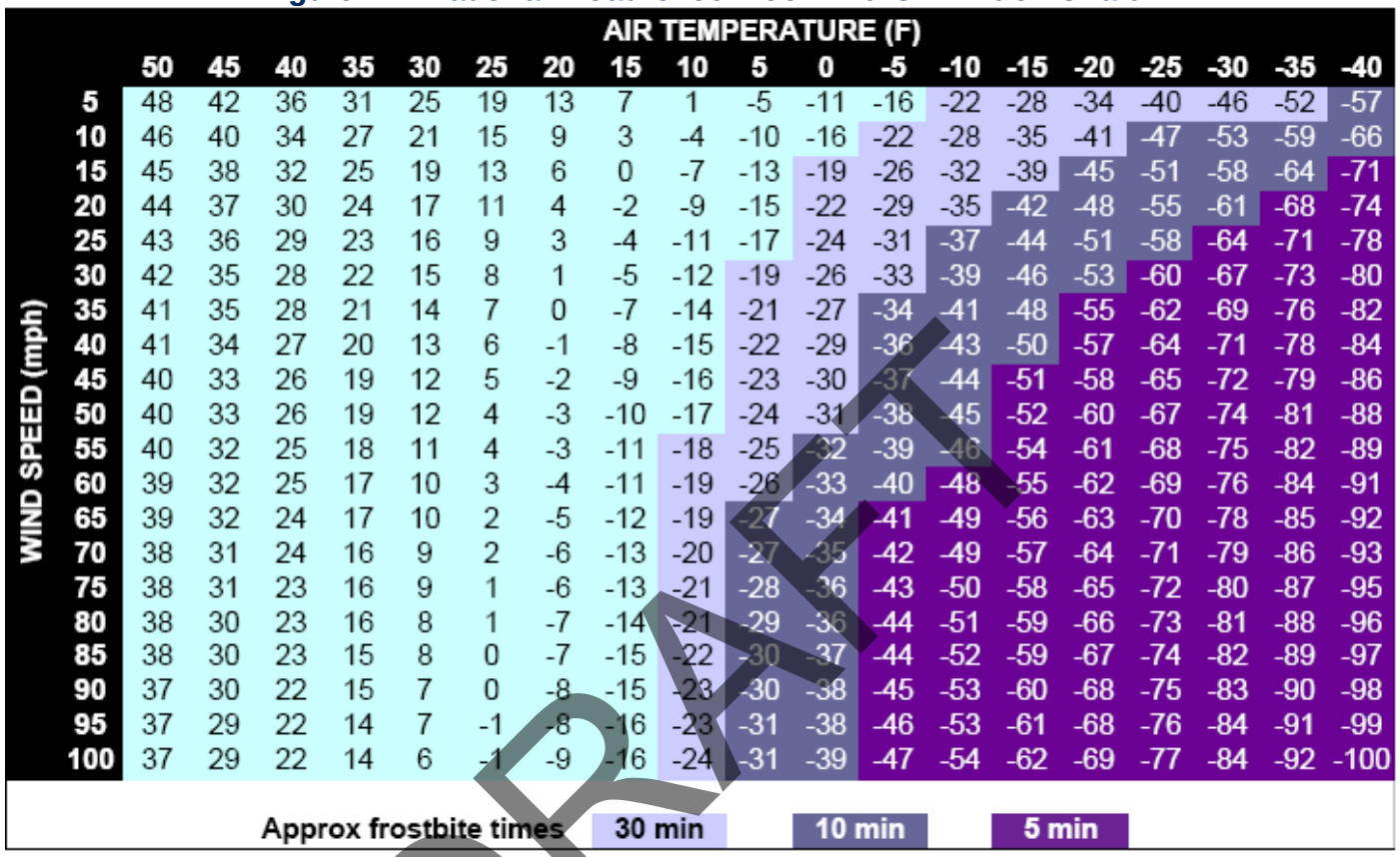
Figure 4.1: National Weather Service Wind Chill Index Chart



WIND SPEED (mph) \ AIR TEMPERATURE (F)	50	45	40	35	30	25	20	15	10	5	0	-5	-10	-15	-20	-25	-30	-35	-40
5	48	42	36	31	25	19	13	7	1	-5	-11	-16	-22	-28	-34	-40	-46	-52	-57
10	46	40	34	27	21	15	9	3	-4	-10	-16	-22	-28	-35	-41	-47	-53	-59	-66
15	45	38	32	25	19	13	6	0	-7	-13	-19	-26	-32	-39	-45	-51	-58	-64	-71
20	44	37	30	24	17	11	4	-2	-9	-15	-22	-29	-35	-42	-48	-55	-61	-68	-74
25	43	36	29	23	16	9	3	-4	-11	-17	-24	-31	-37	-44	-51	-58	-64	-71	-78
30	42	35	28	22	15	8	1	-5	-12	-19	-26	-33	-39	-46	-53	-60	-67	-73	-80
35	41	35	28	21	14	7	0	-7	-14	-21	-27	-34	-41	-48	-55	-62	-69	-76	-82
40	41	34	27	20	13	6	-1	-8	-15	-22	-29	-36	-43	-50	-57	-64	-71	-78	-84
45	40	33	26	19	12	5	-2	-9	-16	-23	-30	-37	-44	-51	-58	-65	-72	-79	-86
50	40	33	26	19	12	4	-3	-10	-17	-24	-31	-38	-45	-52	-60	-67	-74	-81	-88
55	40	32	25	18	11	4	-3	-11	-18	-25	-32	-39	-46	-54	-61	-68	-75	-82	-89
60	39	32	25	17	10	3	-4	-11	-19	-26	-33	-40	-48	-55	-62	-69	-76	-84	-91
65	39	32	24	17	10	2	-5	-12	-19	-27	-34	-41	-49	-56	-63	-70	-78	-85	-92
70	38	31	24	16	9	2	-6	-13	-20	-27	-35	-42	-49	-57	-64	-71	-79	-86	-93
75	38	31	23	16	9	1	-6	-13	-21	-28	-36	-43	-50	-58	-65	-72	-80	-87	-95
80	38	30	23	16	8	1	-7	-14	-21	-29	-36	-44	-51	-59	-66	-73	-81	-88	-96
85	38	30	23	15	8	0	-7	-15	-22	-30	-37	-44	-52	-59	-67	-74	-82	-89	-97
90	37	30	22	15	7	0	-8	-15	-23	-30	-38	-45	-53	-60	-68	-75	-83	-90	-98
95	37	29	22	14	7	-1	-8	-16	-23	-31	-38	-46	-53	-61	-68	-76	-84	-91	-99
100	37	29	22	14	6	-1	-9	-16	-24	-31	-39	-47	-54	-62	-69	-77	-84	-92	-100

Approx frostbite times: 30 min | 10 min | 5 min

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NOAA's Warnings and Advisories for Extreme Cold/Wind Chill

The Detroit/Pontiac NWS Weather Forecast Station has the following thresholds for wind chill:
A **Wind Chill Advisory** is issued if wind chill values drop between -15 and -24°F. A **Wind Chill Warning** is issued if wind chill values fall to -25°F or below.

Frostbite and **hypothermia** are both extreme cold-related impacts that result when individuals are exposed to extreme temperatures and wind chills, in many cases as a result of severe winter storms. The following describes the symptoms associated with each.

During exposure to extremely cold weather, the body reduces circulation to the extremities (e.g., feet, hands, nose, cheeks, ears, etc.) in order to maintain its core temperature. If the extremities are exposed, then this reduction in circulation coupled with the cold temperatures can cause the tissue to freeze. Frostbite is characterized by a loss of feeling and a white or pale appearance. At a wind chill of -19°F, exposed skin can freeze in as little as 30 minutes. Seek medical attention immediately if frostbite is suspected. It can permanently damage tissue and in severe cases can lead to amputation.

Hypothermia occurs when the body begins to lose heat faster than it can produce it. As a result, the body's temperature begins to fall. If an individual's body temperature falls below 95°F, then hypothermia has set in and immediate medical attention should be sought. Hypothermia is characterized by uncontrollable shivering, memory loss, disorientation, incoherence, slurred speech, drowsiness and exhaustion. Left untreated, hypothermia will lead to death. Hypothermia occurs most commonly at very cold temperatures, but can occur at cool temperatures (above 40°F) if an individual isn't properly clothed or becomes chilled.

Nationally, climate change is expected to result in increasing temperatures for all parts of the country. Climate scientists expect that warming temperatures will result in the coldest days being less cold which would reduce the extreme cold/wind chill hazard. Trends show temperature increases on cold days growing larger farther north across the United States.

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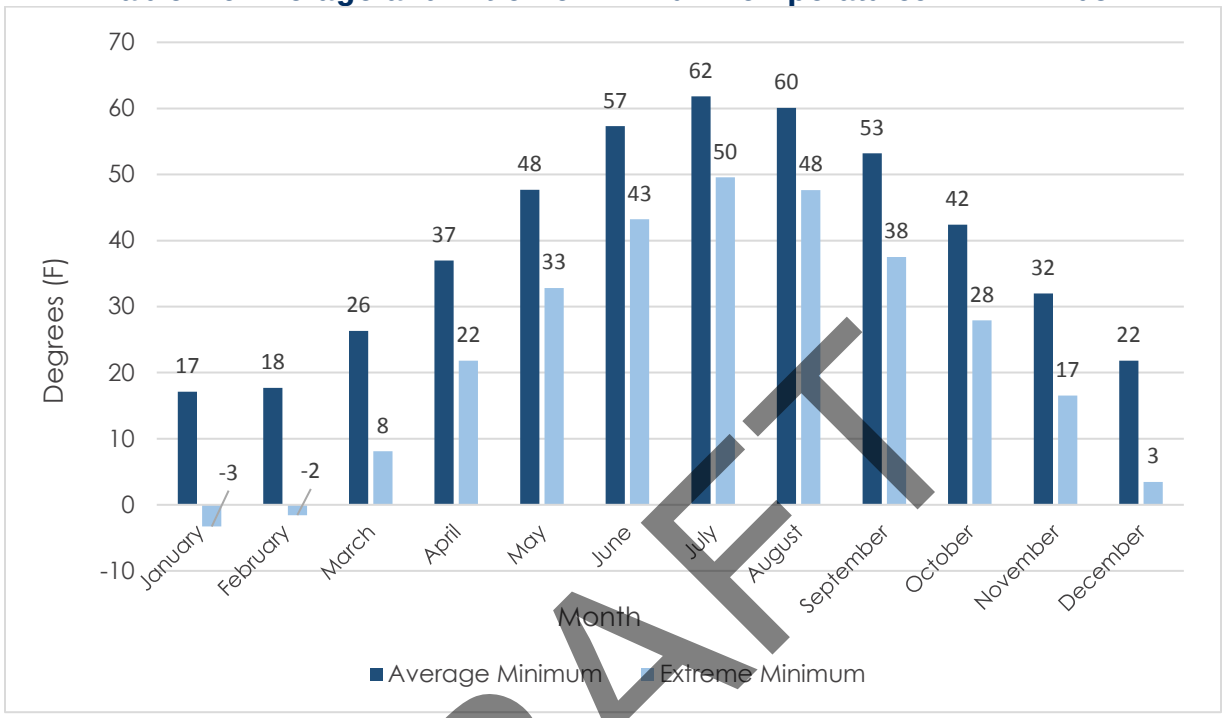
Location

It is assumed that all of Ann Arbor is uniformly exposed to the Extreme Cold/Wind Chill hazard.

Previous Occurrences

To understand extremes, it is beneficial to understand typical temperatures. **Table 4.6** shows average minimum temperatures and extreme minimum temperatures for Ann Arbor, as observed from a weather station at the University of Michigan. Average temperatures are freezing or below from November through March.

Table 4.6 Average and Extreme Minimum Temperatures in Ann Arbor



Source: Western Regional Climate Center, Ann Arbor U of M Station (200230)
*Based on records from 1880-2016

The NCEI Storm Events Database records extreme-heat events by county; city-specific data is not available. Therefore, all extreme cold events reported for Washtenaw County are included. According to NCEI, there has been a total of three extreme cold events in Washtenaw County since 1996; as cold temperatures are a regular occurrence during winter months in Ann Arbor events have likely gone unrecorded. These events resulted in no reported deaths or injuries in Ann Arbor, but did result in over $785,000 (2017 dollars) worth of property damage. Details for these events are included in **Table 4.7.**

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Table 4.7 Previous Extreme Cold/Wind Chill Occurrences in Ann Arbor

Date	Deaths/ Injuries	Property Damage (2017 dollars)	Details
12/21/2000	0/0	$785,103	Though the worst of the snow was over, the worst of the cold was just beginning. Temperatures never got out of single digits on the 22nd, with Detroit seeing a high of only 4 degrees, after a morning low of 3 below zero. Christmas morning dawned clear and frigid, with a morning low of 13 degrees below zero at Flint, setting an all-time mark for the month of December (the old record was -12 on Dec 23, 1989). Three nights later, Flint would give the new record a run for its money, coming up just short with a low of -11 on the 28th (this was still a new record for the day).The arctic weather would take a toll on pipes. Both Ypsilanti High School and Chelsea High School had pipes burst over Christmas weekend, damaging classrooms. Several buildings on the University of Michigan campus in Ann Arbor had similar ruptures, including the School of Dentistry and Wolverine Tower. The cold also hampered shipping interests. Ice formation was extremely rapid on the Great Lakes and the connecting waterways. Several freighters got stuck in ice on both the Detroit River and Lake St Clair, blocking the shipping channel and bringing dozens of ships to a halt. Icebreaker assistance was needed to free the freighters. Ferry service on the St Clair River between Michigan and Canada was also interrupted due to ice jams. Average temperatures for the month were 19.3 degrees in Detroit, 16.6 at Flint, and 17.2 in Saginaw. End result: the 4th coldest December of all time in Detroit, and the 2nd coldest at both Flint and Saginaw. Combined with the high snowfall totals, and it's safe to say: if you don't like cold and snow, then December of 2000 was the most miserable December in southeast Michigan history. No other December on record comes close to its combination of heavy snow and brutal cold.
1/14/2009	0/0	$0	An arctic airmass become firmly established over the Great Lakes region on January 14th and persisted through the 18th. Temperatures fell below zero all four days, with wind chill values in the 5 to 30 below range during the majority of the time. Detroit's low temperatures for January 14-18th were as follows: -3, -3, -15, -11.
2/14/2015	0/0	$0	Arctic airmass ushered in by northwest winds produced Wind Chills around 30 below zero across most of Southeast Michigan the early morning of February 15th. Temperatures of -5 to 5 above zero in the evening hours of February 14th coupled with northwest winds of 15 to 20 mph produced wind chills around 25 below zero. Although winds diminished to around 10 mph during the early morning hours of February 15th, temperatures bottomed between 5 to 15 below zero. The official lows at the climate sites were as follows: Detroit -8 degrees, Flint -11 degrees, and Saginaw -12 degrees. Temperatures slowly rose during the morning hours with corresponding wind chills climbing above -20 degrees during the afternoon hours.

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In addition to the events reported by NCEI, the 2012 Ann Arbor hazard mitigation plan listed the following historic extreme cold/wind chill events:

December 9, 1995
This date was especially severe as winds averaged 20 to 25 mph and resulted in Wind Chill Temperatures of -30 to -35 degrees.

Cold Wave of 1997
From January 17 to 19, 1997 the coldest weather of the winter occurred in southeast Michigan. Low temperatures reached -6 at Detroit Metro Airport.

Cold Wave of 2000
In late December 2000 after heavy snow had ended extreme cold temperatures invaded southeast Michigan, including the Ann Arbor area. Temperatures never got out of single digits on the 22nd, with Detroit seeing a high of only 4 degrees, after a morning low of -3. The arctic weather would take a toll on pipes. Ypsilanti High School in Washtenaw County had pipes burst over Christmas weekend, damaging classrooms. Several buildings on the University of Michigan campus in Ann Arbor had similar ruptures, including the School of Dentistry and Wolverine Tower. The end result was the 4th coldest December of all time in southeast Michigan. Combined with the high snowfall totals, and it's safe to say: if you don't like cold and snow, then December of 2000 was one of the most miserable Decembers in southeast Michigan history. No other December on record comes close to its combination of heavy snow and brutal cold.

Cold Wave of 2007
The worst cold wave event since the 1990s struck the southeast Michigan region on February 3, 2007 and did not let up until February 6, 2007. Wind Chill Temperatures ranged from -15 to -25 throughout almost the entire event, causing nearly every school district to cancel classes for one to two days. Hospitals reported numerous cold-related illnesses and frostbite cases. Area homeless shelters were filled to capacity. Frozen pipes and water main breaks occurred throughout the area, and flooding occurred in cases where these involved sprinkler system pipes. According to AAA, there were more than 20,000 vehicle service calls from Michigan due to the cold weather—more than had been seen for nearly 10 years.

Cold Wave of 2009
An arctic air mass become firmly established over the Great Lakes region on January 14, 2009 and persisted through the 18th producing the winter season's coldest temperatures. Temperatures fell below zero all four days, with wind chill values in the 5 to 30 below range during the majority of the time. Detroit's low temperatures for January 14-18th were as follows: -3, -3, -15, and -11.

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Extent

Extreme cold/wind chill extent can be defined with record lows and the NWS Wind Chill Index. The record temperature at the University of Michigan monitoring station is -22°F, occurring in January 1950. This correlates to frostbite exposure times of 10-30 minutes (**Figure 4.1**). According to the historic events from the previous plan, the most severe cold/wind chill event was a date on which the wind chill reached -35°F. This correlates to frostbite exposure times of 5-30 minutes on the NSW Wind Chill Index. However, colder events are possible.

Climate change has the potential make extreme cold/wind chill events in Ann Arbor less severe. According to data from the National Climate Assessment, by 2081-2100 the coldest days in Ann Arbor will increase by 6 to 7°F under a low emissions scenario and by more than 15°F under a high emissions scenario.[iv]

Probability of Future Occurrences

With only six recorded events since 1995, Ann Arbor experiences less than one event every three years. However, it is likely events have gone unreported, as cold temperatures are a regular occurrence during Ann Arbor's winter months.

In addition, projected temperature increases in Ann Arbor for 2041-2070, developed by GLISA and based on a high emissions scenario[v] indicate that Ann Arbor can expect a 4.5 to 5°F increase in average temperature. GLISA also projects winter temperature changes of 2.53 to 7.98°F for Ann Arbor based on the same scenario. Projected temperature increases could reduce the frequency of extreme cold/wind chill events in the future.

Considering minimal number of historic events, the likelihood of unreported or underreported events, and climate projections for increasing winter temperatures, the probability assigned the extreme cold/wind chill hazard is likely (between 10 percent and 90 percent annual chance).

Vulnerability Assessment

All of Ann Arbor, including current and future buildings, populations, infrastructure, and other assets, is vulnerable to severe winter storms hazards. Potential annualized loss from extreme cold/wind chill is estimated at $26,170 (2017 dollars). This figure is for Washtenaw County, as events were only reported at the county-level. Potential impacts are described below. Climate-related impacts to winter weather events are also described.

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Damage to Buildings

Extreme cold can result in damage to buildings when internal pipes freeze and burst. During one extreme cold event in Ann Arbor, damage from burst pipes caused almost $800,000 worth of damage to school and university buildings. All current and future buildings in Ann Arbor are considered at risk to extreme cold/wind chill.

Damage to Infrastructure

Extreme cold/wind chill can result in damage to infrastructure, including broken water mains and stress to concrete and asphalt. However, such events are not typical. All infrastructure in Ann Arbor is considered at risk to extreme cold.

Life Safety, Health, and Warning and Evacuation Procedures

All populations in Ann Arbor are considered at risk to extreme cold/wind chill. Extreme cold/wind chill can result in frostbite or hypothermia, even after only a few minutes of exposure. Certain populations, such as the elderly, young children, and those without access to an adequate heat source are considered at a higher risk to the impacts of extreme cold, which could include death. Some extreme cold/wind chill events may result in advisories for people to remain indoors to limit exposure. Evacuations are not likely for extreme cold events; however, people may be advised to remain indoors.

Public Health

Wide-scale impacts to public health from extreme cold/wind chill events are limited. Carbon Monoxide-related deaths are highest during extreme cold events, due to the increased use of gas-powered furnaces and alternative heating sources (e.g., generators, grills, and camp stoves) inside homes and buildings. Risk for fire and electric shock is also increases when using alternative heating and power sources, such as space heaters.[vi]

Economic Impact

Economic impacts from extreme cold/wind chill include repairs to burst pipes or degraded roads. In some cases, extreme cold may result in business disruptions if people remain inside and cannot get to work, to school, or to the store.

Climate Change Impacts

Climate change has the potential to decrease the magnitude and frequency of extreme cold/wind chill events in Ann Arbor. Projected temperature increases in Ann Arbor for 2041-2070, developed by GLISA and based on a high emissions scenario[vii] indicate that Ann Arbor can expect a 4.5 to 5°F increase in average annual temperature. GLISA also projects average winter temperature increases of 2.53 to 7.98°F for Ann Arbor based on the same scenario.

In addition, data from the National Climate Assessment indicates by 2081-2100 the coldest days in Ann Arbor will increase by 6 to 7°F under a low emissions scenario and by more than 15°F under a high emissions scenario.[viii]

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Projected temperature increases will likely reduce the frequency of extreme cold/wind chill events in the future. If the frequency and magnitude of extreme cold events are reduced, the impacts of extreme cold/wind chill events will likely be less severe as a result.

Extreme Heat

Description

Extreme heat is characterized by temperatures that hover 10 degrees or more above the average high temperature of a region for several days to several weeks. In comparison, a heat wave may occur when temperatures hover 10 degrees or more above the average high temperature for the region and last for an extended period. The actual temperature threshold depends on norms for the region.[ix]

Extreme heat events are usually a result of both high temperatures and high relative humidity. (Relative humidity refers to the amount of moisture in the air.) The higher the relative humidity or the more moisture in the air, the less likely that evaporation will take place. This becomes significant when high relative humidity is coupled with soaring temperatures. On hot days, the human body relies on the evaporation of perspiration or sweat to cool and regulate the body's internal temperature. Sweating does nothing to cool the body unless the water is removed by evaporation. When the relative humidity is high, then the evaporation process is hindered, robbing the body of its ability to cool itself.

NOAA's Warnings and Advisories for Extreme Heat

The Detroit/Pontiac NWS Weather Forecast Station has the following thresholds for heat waves:
A heat wave is a prolonged period of excessive heat and humidity. An **Excessive Heat Warning** is issued if the heat index equals or exceeds 105° for at least three consecutive hours. **Heat Advisories** are posted when the heat index is expected to exceed 100° for three consecutive hour and can be extended into the night if low temperatures are in the 70s or higher. **Excessive Heat Warnings** and **Heat Advisories** can be issued below criteria with additional guidance or a prolonged event is occurring or forecast.

The National Weather Service Weather Fatalities Database has records of heat-related fatalities beginning in 1986. Since 1986, there has been an approximate average of 131 heat-related deaths annually. Michigan averages about 5 heat-related deaths per year.[x] In an effort to raise the public's awareness of the hazards of extreme heat, the National Weather Service has devised the "Heat Index." The Heat Index Chart, shown in **Figure 4.2**, uses air temperature and humidity to determine the

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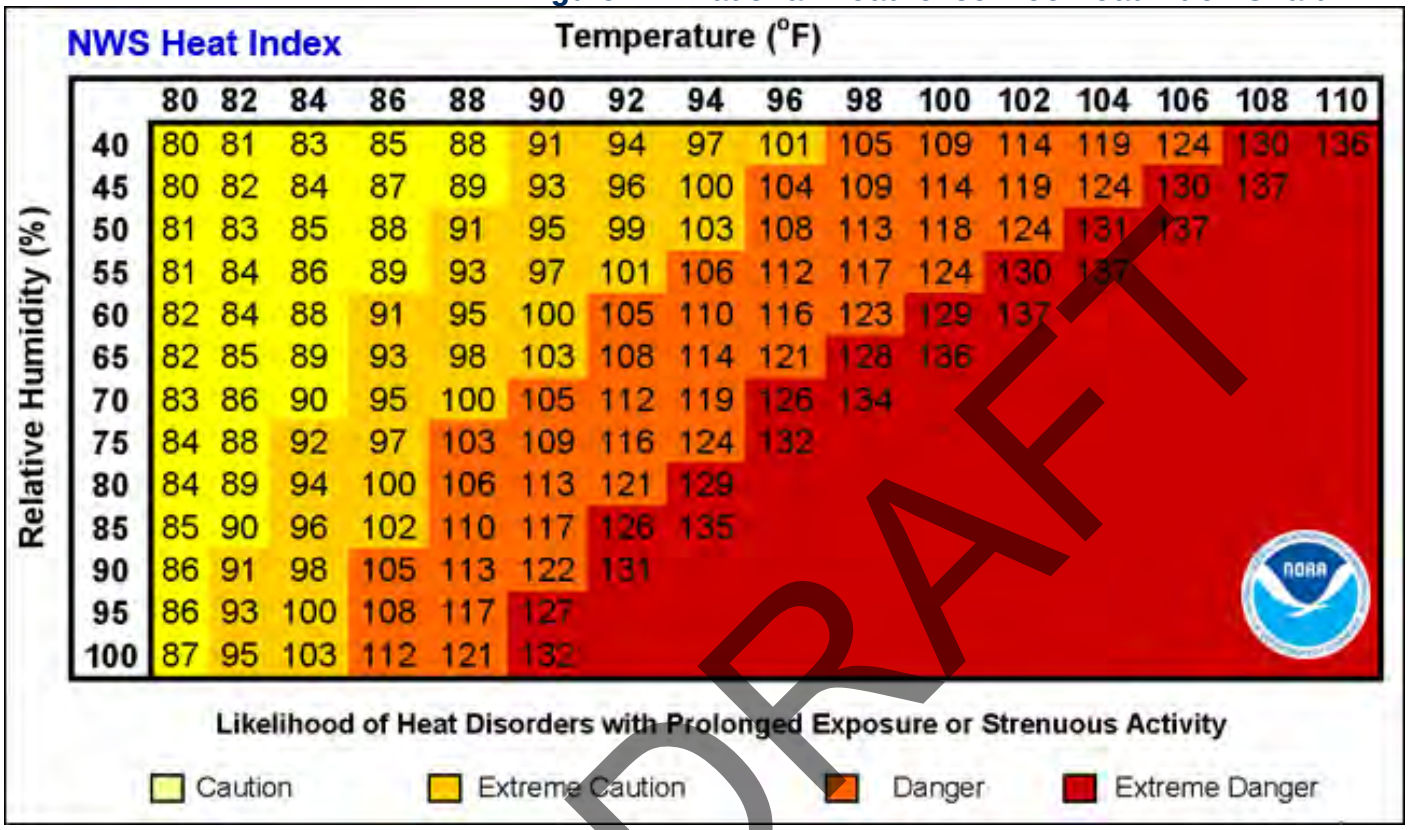
heat index or apparent temperature.[xi] In addition, information regarding the health dangers by temperature range is presented.

Figure 4.2: National Weather Service Heat Index Chart



Extreme Danger
Heat stroke or sunstroke highly likely

Danger
Sunstroke, muscle cramps, and/or heat exhaustion likely

Extreme Caution
Sunstroke, muscle cramps, and/or heat exhaustion possible

Caution
Fatigue possible

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Some of the heat dangers associated with extreme heat are described below. Some populations, such as the elderly and young, are more susceptible to heat danger than other segments of the population.

Heat Disorders: Heat disorders are illnesses caused by prolonged exposure to hot temperatures and are characterized by the body's inability to shed excess heat. These disorders develop when the heat gain exceeds the level the body can remove or if the body cannot compensate for fluids and salt lost through perspiration. In either case, the body loses its ability to regulate its internal temperature. All heat disorders share one common feature: the individual has been overexposed to heat, or over exercised for their age and physical condition on a hot day. The following describes the symptoms associated with the different heat disorders.

Sunburn: Sunburn is characterized by redness and pain of skin exposed too long to the sun without proper protection. In severe cases it can cause swelling, blisters, fever and headaches. It can significantly retard the skin's ability to shed excess heat.

Heat Cramps: Heat cramps are characterized by heavy sweating and painful spasms, usually in the muscles of the legs and possibly the abdomen. The loss of fluid through perspiration leaves the body dehydrated resulting in muscle cramps. This is usually the first sign that the body is experiencing trouble dealing with heat.

Heat Exhaustion: Heat exhaustion is characterized by heavy sweating, weakness, nausea, exhaustion, dizziness and faintness. Breathing may become rapid and shallow and the pulse weak. The skin may appear cool, moist and pale. Blood flow to the skin increases, causing blood flow to decrease to the vital organs. This results in a mild form of shock. If not treated, the victim's condition will worsen.

Heat Stroke (Sunstroke): Heat stroke is a life-threatening condition characterized by a high body temperature (106°F or higher). The skin appears to be dry and flushed with very little perspiration present. The individual may become mentally confused and aggressive. The pulse is rapid and strong. There is a possibility that the individual will faint or slip into unconsciousness. If the body is not cooled quickly, then brain damage and death may result.

Studies indicate that, all things being equal, the severity of heat disorders tend to increase with age. Heat cramps in a 17-year-old may be heat exhaustion in someone 40 and heat stroke in a person over 60. Elderly persons, small children, chronic invalids, those on certain medications and persons with weight or alcohol problems are particularly susceptible to heat reactions.

Nationally, climate change is expected to result in increasing temperatures for all parts of the country. According to the National Climate Assessment, average US temperatures have increased by 1.3°F to 1.9°F since 1895, when recordkeeping began. Since 1970, temperature increases have occurred rapidly. **Figure 4.3** shows changes in temperatures across the United States from 1991-2012, compared to the 1901-1960 average. Warming is projected for all parts of the country over the next several decades. The degree of warming will ultimately depend on greenhouse gas emissions. Warming will also vary by location; generally the farthest north regions are projected to experience the greatest amount of warming, with the southeast experienced the least. Depending on location, the US is expected to warm from 1 to 8°F under a lower emissions scenario and from 3 to 15+°F under a higher emissions scenario.[xii]

Warming temperatures have already had an impact on heat waves. In 2011 and 2012, the number of intense heat waves were almost triple the long-term average, and analyses from the National Climate Assessment show that climate change has increased the probability of heat waves.

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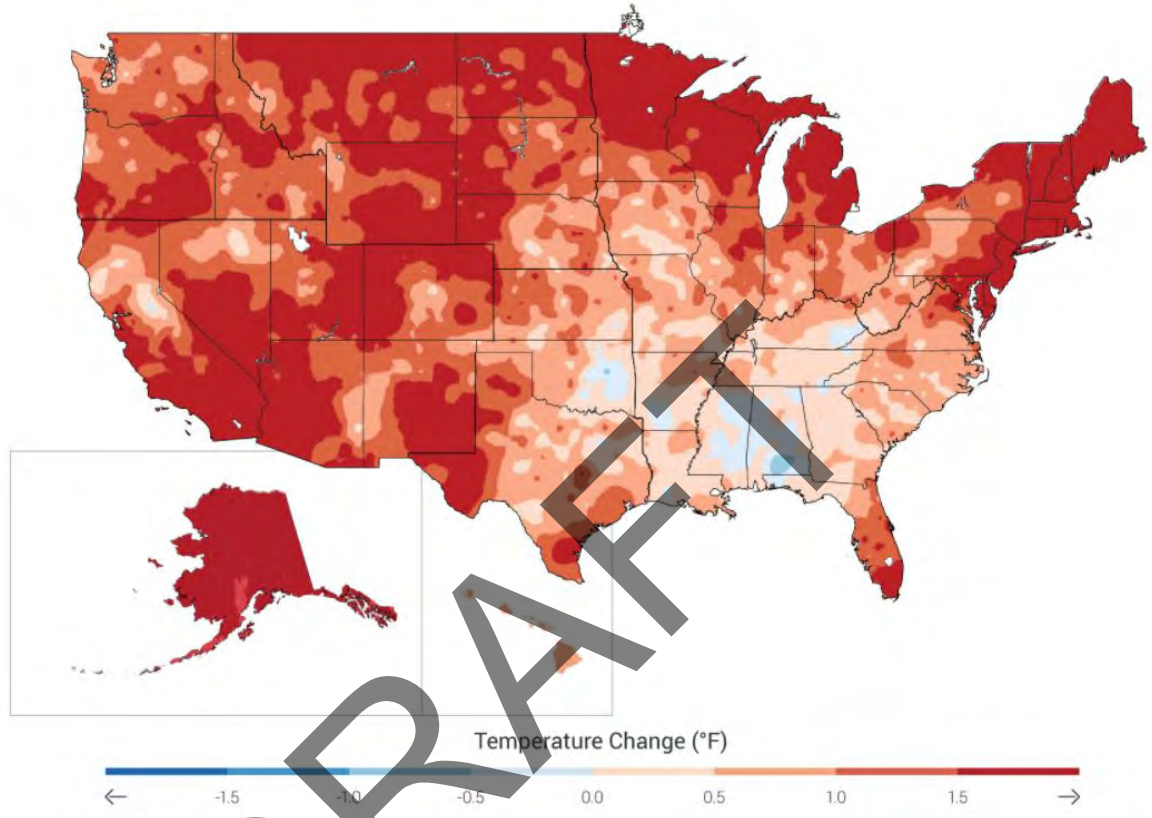
Figure 4.3: US Temperature Changes (1991-2012)



*Compared to the 1901-1960 average
Source: The Third National Climate Assessment

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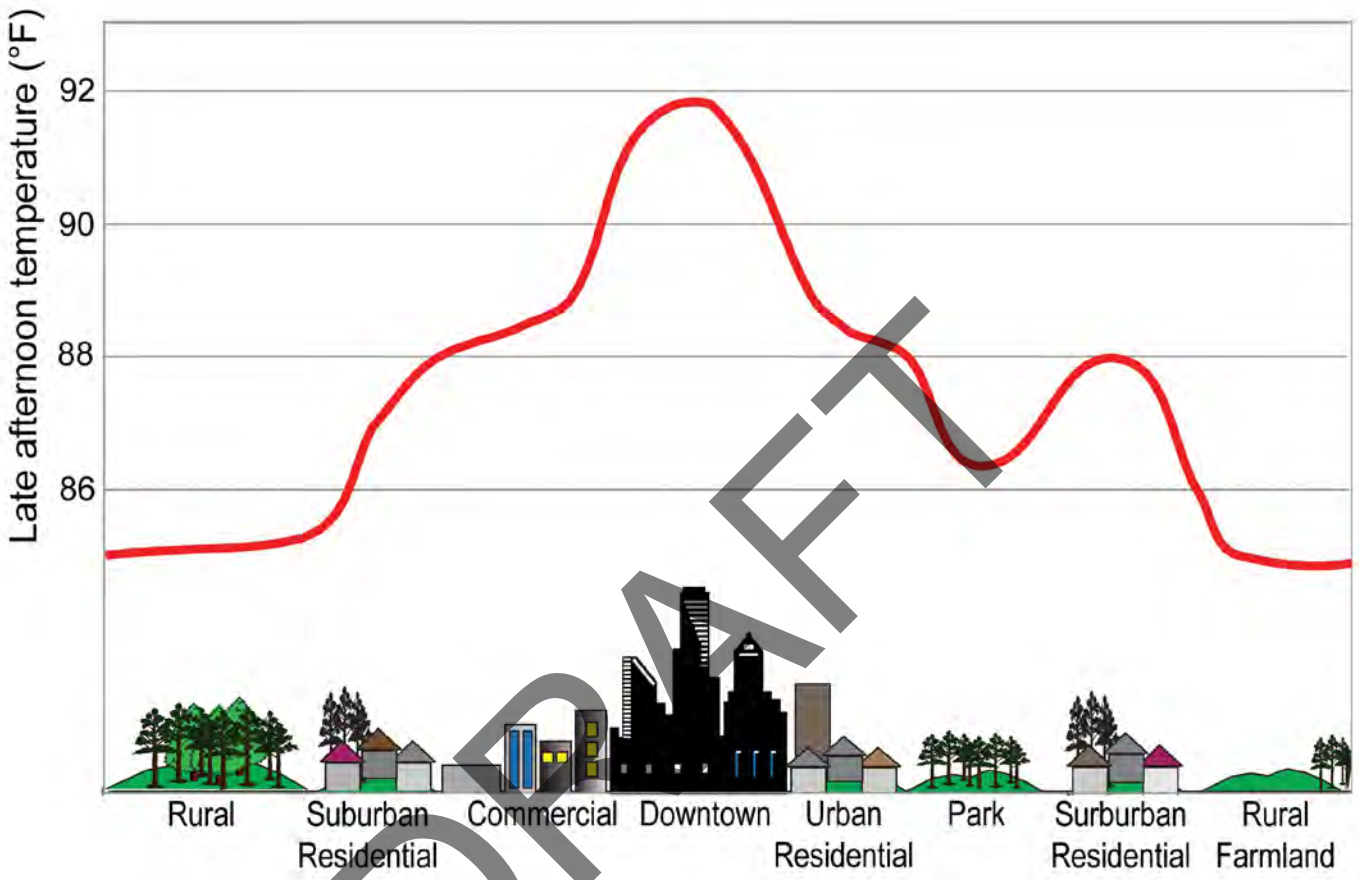
Extreme heat events can be exacerbated in localized places by what are known as "heat islands." Heat islands form when open land and vegetation is replaced with impermeable surfaces, such as concrete, asphalt, and building rooftops. On hot, sunny, days exposed surfaces can absorb and radiate heat, sometimes to temperatures 50 to 90 degrees Fahrenheit hotter than the air temperature.[xiii] In contrast, vegetated areas tend to remain close to air temperatures, and trees can provide shade for people, buildings, and automobiles. **Figure 4.4** demonstrates the temperature variations that can occur due to different types of land cover, resulting in heat islands in developed locations.[xiv]

Figure 4.4: The Urban Heat Island Effect



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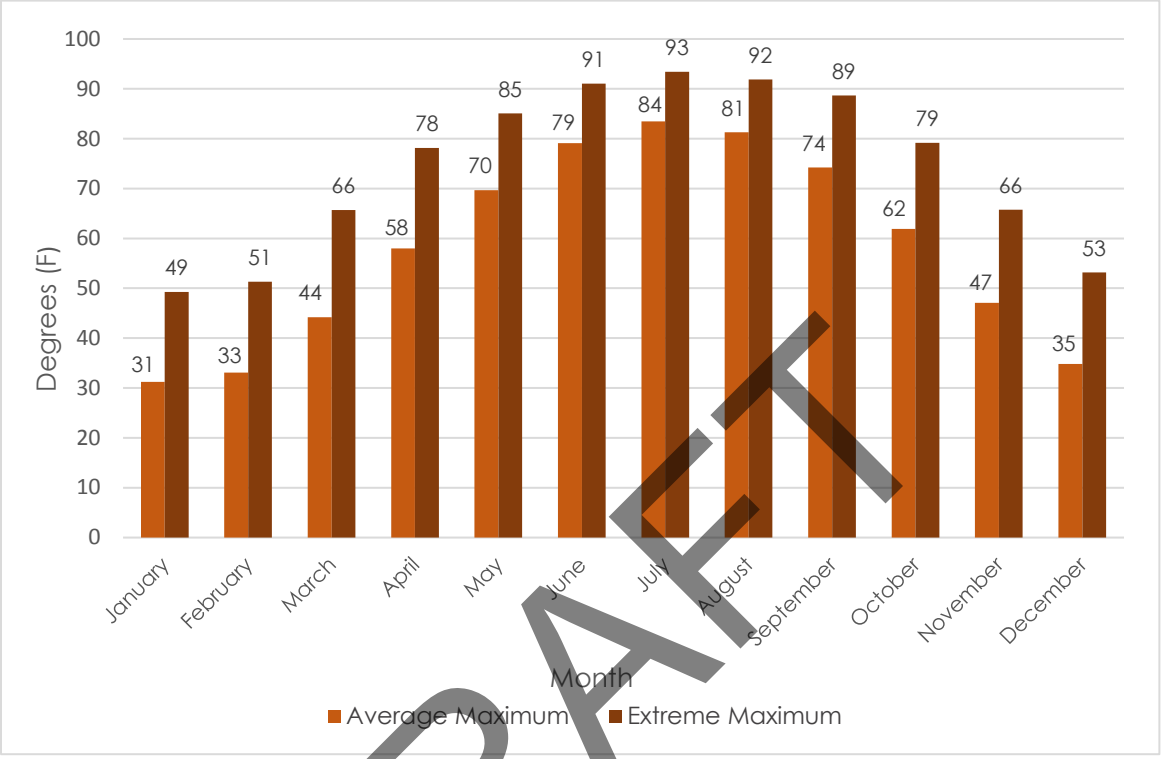
Location

The entire city is impacted by extreme heat events.

Previous Occurrences

To understand extremes, it is beneficial to understand typical temperatures. **Table 4.8** shows average maximum temperatures and extreme maximum temperatures for Ann Arbor, as observed from a weather station at the University of Michigan. Summer months, or June through August, are general the warmest months with average temperatures of 79°F to 81°F.

Table 4.8 Average and Extreme Maximum Temperatures in Ann Arbor



Source: Western regional Climate Center, Ann Arbor U of M Station (200230)
*Based on records from 1880-2016

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The NCEI Storm Events Database records extreme-heat events by county; city-specific data is not available. Therefore, all extreme heat events reported for Washtenaw County are included. According to NCEI, there has been a total of 12 extreme heat events in Washtenaw County since 1996. These events resulted in no deaths or damages in Ann Arbor, but did result in 17 injuries. Details for these events are included in **Table 4.9.** Descriptions are included for events resulting in injuries.

Table 4.9 Previous Extreme Heat Occurrences in Ann Arbor

Date	Deaths/ Injuries	Details
2/11/1999	0/0	--
7/4/1999	0/0	--
3/8/2000	0/0	--

Date	Deaths/ Injuries	Details
8/6/2001	0/2	A large high pressure ridge settled across the Great Lakes region during the first week of August. With this ridge in place, high temperatures soared well into the 90s across southeast Michigan. In addition to the heat, humidity levels rose significantly during the time period. The high heat and humidity allowed daytime heat indices to exceed 100 degrees four days in a row. In fact, heat advisories were in effect for all of southeast Michigan for the afternoons and evenings of the 7th, 8th, and 9th. During this time period, heat indices ranged from 105 to 110 degrees. The heat caused several people to seek emergency care for heat stroke and heat exhaustion. One fatality also occurred due to the heat when an Oak Park man was found suffering from severe heat exhaustion while locked in his car. Several hours later, he was pronounced dead at an area hospital. Thousands of power outages also occurred throughout the region as demand surpassed supply. Several factory workers across the area were sent home from work to escape the extreme heat. Many of those who were not, however, threatened to walk off the job as a result of not having air conditioning in their factories.
5/29/2006	0/4	An early season heat wave, leading to an unusually hot Memorial Day, resulted in dozens of people suffering from heat related illnesses. Near record to record setting high temperatures, in the low to mid 90's, sent some people to the hospital. The official high temperatures for the day ranged from 88 to 93 degrees. Of the 52 cooperative observer reports received for that day, including at least one report from each of the 17 counties in southeast lower Michigan, 50 of them reported a high above 90. They ranged from 89 (along the lakeshore) to 98 (at Midland), and averaged out at 94 degrees. Most of the month of May, leading up to this weekend, was well below normal. Combining this factor with temperatures at 20 to 30 degrees above the seasonal norms created very uncomfortable conditions. Conditions were further exacerbated by the combination of high humidity, light winds, and mostly clear skies. Nearly all of southeast lower Michigan reached 90 degrees by Noon EST. Heat indices were in the mid 90's throughout most of the day. According to local newspapers, at least 20 people, from across the entire region, were admitted to area hospitals for heat illnesses. This number was likely much larger. The relief from the heat did not come until after 1800 EST, when temperatures finally dropped back into the 80's.
7/29/2006	0/0	--
8/1/2006	0/0	--
7/4/2010	0/0	--
7/17/2011	0/0	--
6/28/2012	0/0	--
7/1/2012	0/5	High temperatures climbed to around 100 degrees across much of southeast Michigan during the afternoon hours of June 28th, with heat indices climbing between 100 and 110 degrees. This lead to an increase in heat related hospitalizations. Temperatures slowing came down during the evening hours, with drier air slowly filtering in. Although Friday June 29th ended up being hot with high temperatures in the low to mid 90s, the dry air helped to keep heat indices short of 100 degrees.
7/14/2013	0/6	A six day heat impacted Southeast Michigan July 14th through the 19th with high temperatures ranging from the upper 80s to mid 90s. Heat Indices were in the 90s for the most part, but Detroit Metro area hospitals reported an increase of 173 heat related illnesses during this stretch.

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In addition to the events reported by NCEI, the 2012 Ann Arbor hazard mitigation plan listed the following historic extreme heat events:

Heat Wave of 1936
During the second week of July 1936, a terrible heat wave struck Michigan, with temperatures exceeding 100 degrees for several days in a row including in the Ann Arbor area. The temperature peaked at 112 degrees in Mio in the northern Lower Peninsula, setting a state record that still stands today. The extreme heat was an "equal opportunity" killer, causing many healthy adults to succumb to the heat at work or in the streets. Also, because most people relied on iceboxes to keep their food fresh, many heat-related deaths and illnesses occurred when the ice melted, causing the food to spoil. Statewide, 570 people died from heat-related causes, including some in the Ann Arbor area. Nationally, the heat wave caused 5,000 deaths.

Heat Wave / Drought of 1988
The 1988 drought/heat wave in the Central and Eastern U.S. also greatly impacted Michigan, including the Ann Arbor area. Nationwide, the drought caused an estimated $40 billion in damages from agricultural losses, disruption of river transportation, water supply shortages, wildfires, and related economic impacts. The heat wave that accompanied the drought conditions was particularly long in Michigan – 39 days with 90 degree or better heat – eclipsing the previous record of 36 days recorded in the "dust bowl" days of 1934. During that 39-day stretch, the temperature in the Ann Arbor area topped the 100-degree mark on 5 occasions.

Heat Wave of 1995
During the period from July 11-27, 1995, the Central United States and many East Coast cities experienced a devastating heat wave. According to the National Oceanic and Atmospheric Administration, that heat wave caused 1,021 deaths - 465 of those occurring in the Chicago metropolitan area alone. Many of the deaths were low-income elderly persons living in residential units not equipped with air conditioning. Local utilities in Chicago were forced to impose controlled power outages because of excessive energy demands, and water suppliers reported very low levels of water in storage. Michigan experienced 28 heat-related fatalities in 1995, most of them occurring during the intense heat period in July. In addition to this tremendous human toll, the intense heat also caused the loss of tens of millions of cattle and poultry throughout the Midwest. This was the hottest summer on record for Southeast Michigan, in terms of having the highest average temperature in Detroit (74.5 degrees). The average August temperature was even higher, at 77 degrees, which set a new record.

Heat Wave of 2001
Extreme heat and humidity in the Midwest and Central Plains during parts of June, July and August sent heat stress index readings soaring well above 100 degrees Fahrenheit on many days. Communities across the region were forced to open "cooling centers" and take other steps in an attempt to avoid heat-related deaths among vulnerable segments of the

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population. Despite those efforts, heat-related deaths occurred in many areas – and unfortunately Michigan was no exception. On August 1 and August 8, heat advisories were issued in many areas in the southern Lower Peninsula, including the Ann Arbor region.

Heat Wave of 2006

A summer 2006 heat wave delivered the hottest weather the Ann Arbor region had experienced in at least 4 years. A 5 day stretch of temperatures at or above 90 degrees began on July 29th. A blanket of especially high heat and oppressive humidity settled over the area on July 31st, and remained relentless through August 2nd. Temperatures, on the 31st, soared above 90 by noon with heat indices over 100 degrees. Heat indices averaged between 105 and 110 degrees through the entire afternoon. Most significantly, Detroit Metro tied the all time record for the warmest minimum temperature, for any date, when it failed to record a temperature below 80 degrees on July 31st. This had happened only 3 other times in the previous 136 years of record keeping, and this was the first time in 64 years that it had happened again. The major power companies in the area reported an all-time record customer demand for power on the 31st. remarkably, very few heat related illnesses occurred during the event. Newspaper articles revealed an extremely high level of awareness and preparedness from the communities across southeastern Lower Michigan. A large number of cooling centers were made available to those in need as folks reportedly heeded the warnings and took extra precaution.

Heat Wave of 2012

During June and July of 2012, Ann Arbor experienced periods of extreme heat prompting Heat Advisories on June 26 and 27 with heat indices in the 100-105 degrees Fahrenheit, and actual temperatures of 99-100 degrees. A similar event occurred during the July 2 through July 7 time period with actual temperatures reaching the upper 90's to 102 degrees. Several area agencies and libraries opened their doors for cooling stations. A widespread power outage occurred in Ann Arbor in the South and Southwest portion of the city caused by severe thunderstorms. The American Red Cross provided ice and water to a functional needs apartment community and Emergency Services was prepared to shelter larger numbers of the population, however restoration of power was relatively quick.

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Extent

Extreme heat extent can be defined with record highs and the NWS Heat Index. The record temperature at the University of Michigan monitoring station is 105°F, occurring in July 1934, which was likely into the extreme danger level (Figure 4.2). Heat index can make the air feel even warmer.

Hotter events than those of the past are possible, especially with expected temperature increases due to climate change. According to the Great Lakes Adaptation Assessment for Cities, by 2030 Michigan's summer will be more like Ohio's, and by 2095, Michigan's summer will be more like northern Arkansas. Ann Arbor should not only prepare for the current extent experienced for extreme high temperatures, but also for those projected due to climate change. In addition, impacts from

urban heat islands could increase due to increased development and densification in Ann Arbor. Such impacts from urban heat islands could be reduced with through the increased use of mechanisms such as tree canopies and green roofs.

Probability of Future Occurrences

With 12 reported extreme heat events in 21 years, Ann Arbor experiences about one extreme heat event every two years (though it should be noted that summer temperatures in Ann Arbor regularly reach into those listed on the NSW Heat Index Chart (80°F and above). When determining future probability, the historic frequency must be considered along with projected future conditions. According to data from the Great Lakes Integrated Science Assessment (GLISA)[xv], 30 to 40 additional days per year with temperatures over 90°F are expected to occur in Ann Arbor from 2041-2070 (**Figure 4.5).** Similarly, the number of days per year with temperatures over 95°F are projected to increase by 5 to 10 days (**Figure 4.6**). Based on historic events are projected conditions, the probability assigned to the extreme heat hazard is likely (10 percent to 90 percent annual chance).

Vulnerability Assessment

All of Ann Arbor is vulnerable to extreme heat, including all current and future buildings, infrastructure, and populations. There are no associated dollar losses with the extreme heat hazard in the planning area. Future damages are expected to be negligible but are possible through power outages, for example. Despite limited potential for damages, there are serious health risks to the population. Potential impacts are described below. Climate-related impacts to extreme heat events are also described.

Damage to Buildings

Extreme heat events generally have limited impact on buildings. However, in some rare cases extreme heat can cause structures to collapse or buckle.

Damage to Infrastructure

Extreme heat events generally have minimal impact on infrastructure. Power consumption for air-conditioned environments could increase and thus stress utility infrastructure, resulting in blackouts. Ann Arbor currently experiences issues with electrical capacity during high-demand periods, and members of the TAC noted power outages during extreme heat events. In severe cases, heat can cause railroad tracks to expand. This is referred to as a heat kink in the rail line, and can result in disruptions or derailments. Heat can also cause pavement to expand.

Life Safety, Health and Evacuation and Procedures

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Ann Arbor, like most areas of the Midwest, is very vulnerable to extreme heat, particularly in the summer months. Urban areas are exposed more acutely to the dangers of extreme heat due to the urban heat island effect. Certain groups may be more vulnerable to the effects of extreme heat. Groups particularly vulnerable to extreme heat include:[xvi]

- Older adults who do not adjust as quickly to changes in temperature. Older adults are also more likely to be on medications or have chronic illnesses that affect the body's ability to regulate its temperature.
- Infants and children, who rely on others to keep them cool and hydrated.
- Athletes, who may be more likely to exercise and become dehydrated during extreme heat events.
- Outdoor workers, who have more exposure to extreme heat and are more likely to become dehydrated.

People are at risk for heat stroke or sun stroke, heat exhaustion, fatigue, and dehydration. Preparedness reduces the risks associated with this hazard. In cases of extreme heat:

- Stay indoors as much as possible to limit exposure (consider public buildings such as libraries, schools, movie theaters, or cooling centers if you do not have air conditioning);
- Limit alcoholic intake;
- Drink plenty of water, even if you do not feel thirsty;
- Do not leave children or pets in vehicles;
- Check on vulnerable populations;
- Arrange your day to avoid strenuous work during the warmest part of the day, if possible;
- Use an electric fan to vent hot air out or bring cool air in; and
- Wear loose-fitting clothing.

In addition to preparedness, Ann Arbor works to mitigate the impacts of extreme heat by increasing tree cover to reduce heat island impacts to the community. When considering health, street trees are especially useful for providing shade to pedestrians.

Public Health

Aside from the heat-induced health impacts described above, extreme heat negatively impacts air quality by increasing the amount of ground-level ozone (or smog). Worsened

Figure 4.5: Projected Change in Days Over 90°F, 2041-2070

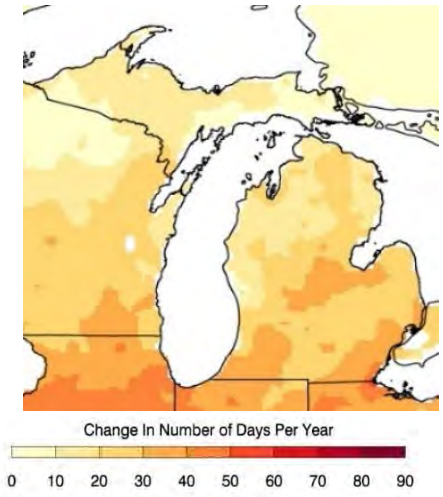
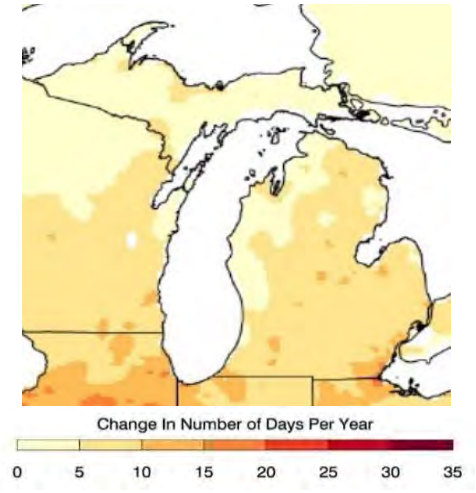


Figure 4.6: Projected Change in Days Over 95°F, 2041-2070



*Projected changes based on GLISA high emissions scenario (A2) analysis

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air quality can aggravate existing respiratory illnesses, and long-term exposure can result in decreased lung function[xvii]. Extreme heat can degrade water quality by heating water bodies directly or heating runoff that drains into them.

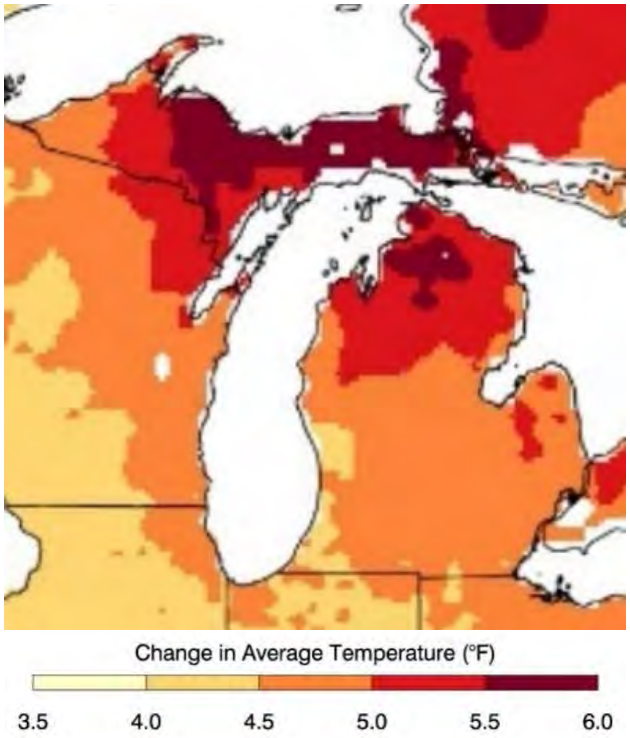
Economic Impact

Generally, economic impacts due to extreme heat are minimal. It is possible that indirect losses due to business interruption in the case of a power outage during an extreme heat event.

Climate Change Impacts

Based on reviewed sources, Ann Arbor will experience a summer temperature increase of approximately 2 to 8°F in this century. Therefore, it is likely climate change will impact the frequency and intensity of extreme heat events. **Figure 4.7** shows the projected annual temperature increases in Michigan for 2041-2070, developed by GLISA and based on a high emissions scenario.[xviii] Based on the map, Ann Arbor can expect a 4.5 to 5°F increase in annual average temperature. GLISA also projects summer temperature changes of 1.9 to 7.98°F for Ann Arbor based on the same scenario. Increases in the intensity and frequency of extreme heat events would exacerbate the life safety, health, and public health impacts described above.

Figure 4.7: Projected Change in Average Temperature, 2041-2070



*Projected changes based on GLISA high emissions scenario (A2) analysis

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Fog

Description

Fog forms near the ground when water vapor condenses into tiny liquid water droplets that remain suspended in the air. While many different processes can lead to fog formation, all fog is formed by saturated air. Air can become saturated when it is cooled to its to its dew point, or when evaporated moisture increases the air's water vapor content. Fog can form is a matter of minutes or hours. Fog is considered a hazard when it results in reduced visibility and, consequently, dangerous transportation conditions for air and ground travel. Localized fog is especially dangerous, as drivers can be caught by surprise. Fog is particularly hazardous at airports, where aircraft are attempting to land and take-off.

In addition, freezing fog (a hazard for which the National Weather Service issues special statements) can become hazardous by causing slickness on roadways in addition to low visibility, resulting in especially dangerous road conditions.

Location

It is assumed that all of Ann Arbor is uniformly exposed to fog hazards.

Previous Occurrences

Fog is a common occurrence in Ann Arbor, but typically dissipates by mid-morning. According to the NCEI Storm Events database, two fog events have been reported in Ann Arbor since 1996, which are presented below in **Table 4.10.** No injuries, deaths, or damages were associated with these events. However, it is assumed that many fog events go unreported; therefore, it is likely that a much greater number of fog occurrences has occurred since 1996.

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Table 4.10 Previous Fog Events in Ann Arbor

Date	Event Type	Event Details
10/26/2000	Dense Fog	On this morning, the dense fog was found in metro Detroit. The fog caused significant headaches for morning commuters, and delayed dozens of flights at Detroit Metropolitan Airport.
11/24/2006	Freezing Fog	A high-pressure system set up a favorable situation for fog formation. Light winds off of Lake Erie and Lake St Clair carried a marine layer of low clouds and dense fog inland across the Detroit area, mainly along and south of I-94. Visibilities were near zero at times during the rush hour traffic. Temperatures in the 20's allowed the dense fog to freeze on area roadways, creating slippery conditions and numerous accidents. By 1000 EST, temperatures had climbed above freezing and visibilities had begun to improve.

Extent

The extent of fog is difficult to measure. It could be measured in terms of thickness or visibility. However, such measurements are not consistently applied to fog events. The details for the fog event occurring on 11/24/2006 indicate that visibility was "near zero."

Probability of Future Occurrences

Although only two fog events for Ann Arbor were recorded in the NCEI database, fog is a regular occurrence for Ann Arbor. Therefore, the probability assigned for future fog events is highly likely (greater than 90 percent annual chance).

Vulnerability Assessment

Fog itself does not have a significant impact on buildings, infrastructure, health, and the economy. Fog becomes damaging when it results in reduced visibility. No dollar losses are associated with fog events in Ann Arbor; future losses from fog events are expected to be negligible.

Damage to Buildings

Direct building damages are not typically attributable to fog. The primary risks from fog involve the dangers of traveling under conditions of limited visibility. Fog resulting in vehicular crashes may result in damages to buildings.

Damage to Infrastructure

The primary risks from fog involve the dangers of traveling under conditions of limited visibility. Fog resulting in vehicular crashes may result in damages to infrastructure such as roads, guardrails, and utility poles.

Life, Safety, Health and Evacuation and Procedures

The primary risks from fog involve the dangers of traveling under conditions of limited visibility. During fog events, it is recommended that motorists delay travel until fog has dissipated. If travel is necessary, driving at reduced speeds, keeping safe distances, and use of fog lights is recommended. Fog also creates dangerous conditions for aircraft. The Federal Aviation Administration issues weather-related delays for commercial aircraft. The National Weather Service issues advisories for freezing fog events.

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Public Health

Fog on its own does not directly impact public health. However, fog may reduce visibility and can create dangerous traveling conditions. Transportation accidents involving a chemical release may cause great harm to the environment by releasing toxins into the soil, groundwater or air. (Please refer to the *Hazardous Materials* profile in this Section).

Economic Impact

Fog can impact air, marine, and land transportation, including travel on rail and roadways. Lingering dense fog has the result in minor business disruptions, especially those reliant on deliveries and transportation. In addition, fog has the potential to cause delayed or canceled flights.

Climate Change Impacts

Because fog can form from several different reasons, it is difficult to determine the impact that a changing climate will have on fog frequency and intensity. One way fog develops is when rain cools and moistens the air near the ground surface to the point that fog forms. Increases in precipitation are expected for Ann Arbor due to climate change. Therefore, it is possible that the frequency of fog events will increase as well.

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Hail

Description

Hailstorms are a potentially damaging outgrowth of severe thunderstorms. Early in the developmental stages of a hailstorm, ice crystals form within a low-pressure front due to the rapid rising of warm air into the upper atmosphere and the subsequent cooling of the air mass. Frozen droplets gradually accumulate on the ice crystals until they develop to a sufficient weight and fall as precipitation. Hail typically takes the form of spheres or irregularly-shaped masses greater than 0.75 inches in diameter. The size of hailstones is a direct function of the size and severity of the storm. High velocity updraft winds are required to keep hail in suspension in thunderclouds. The strength of the updraft is a function of the intensity of heating at the Earth's surface. Higher temperature gradients relative to elevation above the surface result in increased suspension time and hailstone size.[xix]

Hailstone size can range a great deal in size from 5 millimeters (mm) (approximately pea-sized) to greater than 100 mm (approximately melon-sized). Hailstones are categorized using the TORRO Hailstorm Intensity Scale (**Table 4.11**). Hailstone size descriptions are located in **Table 4.12**.

Hail annually causes more than $1 billion in damage to property and crops.[xx] It damages buildings and homes by perforating holes in roofs and shingles, breaking windows and denting siding, and damages automobiles by denting panels and breaking windows. Hail rarely causes any deaths; however, several dozen people are injured each year in the United States.

Table 4.11 TORRO Hailstorm Intensity Scale (in millimeters)

	Intensity Category	Typical Hail Diameter (mm)	Probable Kinetic Energy, J-m^2	Typical Damage Impacts	Size Code
H0	Hard Hail	5	0-20	No damage	1
H1	Potentially Damaging	5-15	>20	Slight general damage to plants, crops	1-3
H2	Significant	10-20	>100	Significant damage to fruit, crops, vegetation	1-4
H3	Severe	20-30	>300	Severe damage to fruit and crops, damage to glass and plastic structures, paint and wood scored	2-5
H4	Severe	25-40	>500	Widespread glass damage, vehicle bodywork damage	3-6
H5	Destructive	30-50	>800	Wholesale destruction of glass, damage to tiled roofs, significant risk of injuries	4-7
H6	Destructive	40-60		Bodywork of grounded aircraft dented, brick walls pitted	5-8
H7	Destructive	50-75		Severe roof damage, risk of serious injuries	6-9
H8	Destructive	60-90		Severe damage to multiple roof types (including sheet and metal); damage aircraft bodywork	7-10
H9	Super Hailstorms	75-100		Extensive structural damage (including concrete and wooden walls). Risk of severe or even fatal injuries to persons caught in the open	8-10
H10	Super Hailstorms	>100		Extensive structural damage (including destruction of wooden houses and damage to brick-built homes). Risk of severe or even fatal injuries to persons caught in the open	9-10

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Table 4.12 Hail Size Code Descriptions

Size Codes	Diameter	Relational Size
0	5-9	Pea
1	9-15	Mothball

Size Codes	Diameter	Relational Size
2	16-20	Marble, grape
3	21-30	Walnut
4	31-40	Pigeon's egg > squash ball
5	41-50	Golf ball > Pullet's egg
6	51-60	Hen's egg
7	61-75	Tennis ball > cricket ball
8	76-90	Large orange > Soft ball
9	91-100	Grapefruit
10	>100	Melon

Location

Hailstorms frequently accompany thunderstorms, so their locations and spatial extents coincide. It is assumed the city is uniformly exposed to severe thunderstorms; therefore, all areas of the city are equally exposed to hailstorms. According to the National Weather Service, Ann Arbor is located in an area of the United States that receives an average of six days per year with hail events (see **Figure 4.8** below).[xxi]

Figure 4.8: United States Average Number of Days per Year with Severe Hail Events

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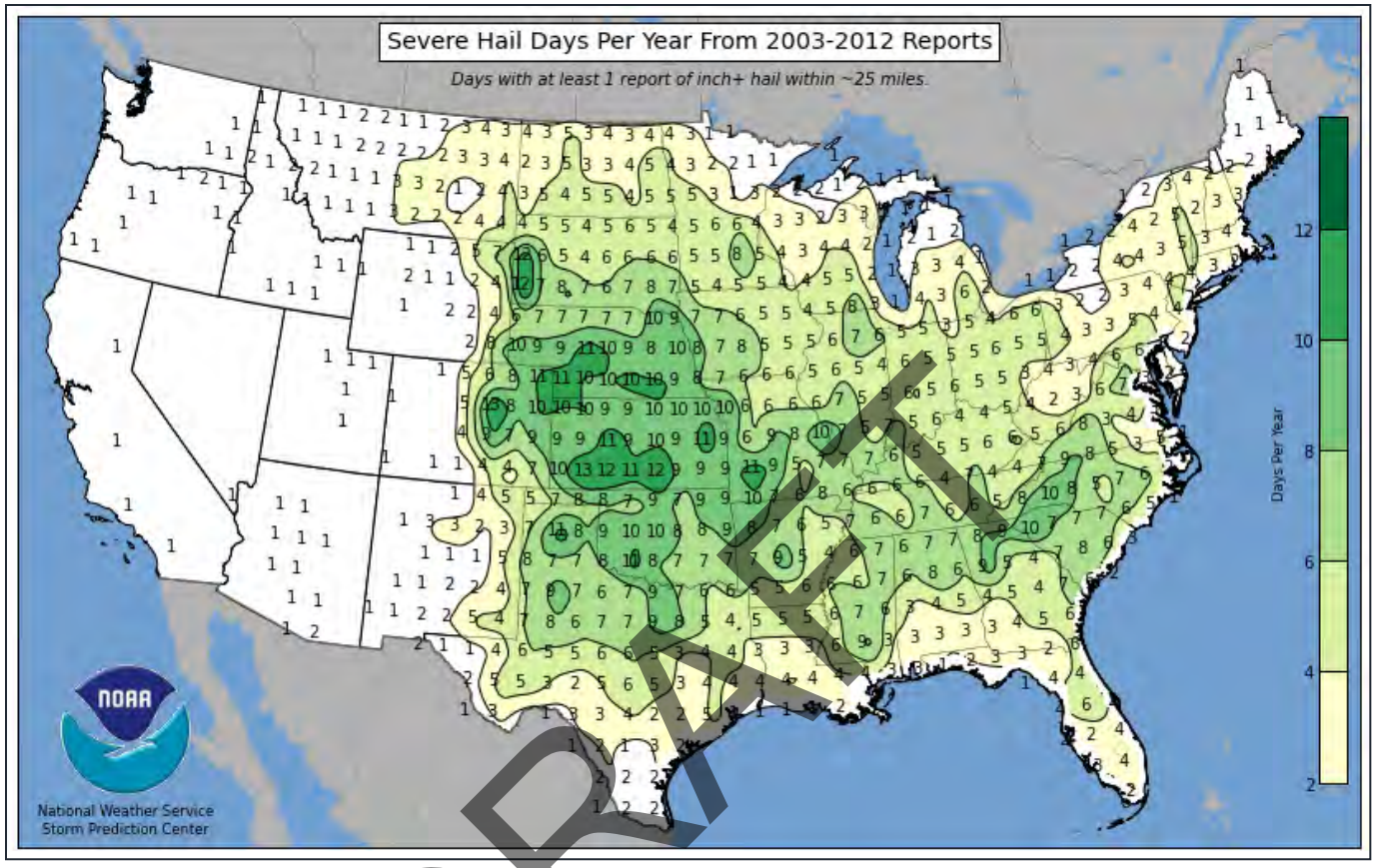

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Previous Occurrences

The National Centers for Environmental Information (NCEI) Storm Events Database reports hail information by county and, when the information is available, by town or by coordinate location. Of the 222 hail events reported for Washtenaw County between 1955 and 2017, 40 events occurred in Ann Arbor. None of these events resulted in reported deaths, injuries, or damages. However, it is likely that hail events and damages to private property were not reported to NCEI, especially during early years of reporting (only 3 of the 41 reported events occurred prior to 2000). Therefore, the number of events and resulting damages is likely higher than what is indicated. Detailed information on hail events reported in Ann Arbor are presented in **Table 4.13.**

Table 4.13 NCEI Historic Hail Events in Ann Arbor (1955-2017)

Date	Magnitude (inches)
4/27/1957	0.75
6/15/1974	0.75
9/25/1994	0.75
5/11/2000	0.75
6/29/2000	0.75
7/14/2000	0.75
4/9/2001	1.75
7/22/2002	1
5/5/2003	0.88
5/5/2003	1
5/5/2003	1.75
5/20/2004	1
5/20/2004	0.75
5/21/2004	0.75
5/21/2004	0.75
5/13/2005	0.75
3/31/2006	0.75
3/31/2006	0.75
4/22/2006	0.75
5/25/2006	0.75
6/27/2006	1.75
6/27/2006	0.75
6/27/2006	1
6/27/2006	1
6/27/2006	0.75
6/27/2006	0.75
9/13/2006	0.75
5/15/2007	1
5/15/2007	0.75
5/15/2007	0.75
5/15/2007	0.75

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Date	Magnitude (inches)
8/24/2011	0.75
3/15/2012	1.25
3/15/2012	0.75
3/15/2012	2
3/15/2012	1
3/15/2012	1
3/15/2012	1
3/15/2012	1.25
7/27/2014	1

Extent

Hail extent can be measured in terms of size, typically by diameter. According to the events reported in NCEI, the greatest extent hail reported in Ann Arbor was 2 inches on March 15, 2012. On the TORRO, scale, this this size (which equals approximately 51 millimeters) correlates to H6 or H7. According to the TORRO scale, hailstones of this size (about the size of a hen's egg) can cause serious injuries and damages to grounded aircraft, brick walls, and roofs. In noted be noted that greater extent hail is possible in Ann Arbor. For example, in Washtenaw County, the greatest extent hail reported was 2.75 inches, which occurred on two separate occasions. The effect of climate change on hail extent in Ann Arbor is uncertain, as detailed below in the *Probability* section.

Probability of Future Occurrences

With 41 reported events in 61 years, Ann Arbor experiences less than one hail reported hail event per year. As discussed above, it is likely that the number of events reported is lower than the number that occurred.

When possible, climate variability should be considered when determining the probability of future hazard events. Trends in convective storm occurrences due to climate change are subject to greater uncertainty than temperature-related trends (such as extreme heat and cold events).[xxii] Because hail is an outgrowth of severe thunderstorms, trends in hail frequency and intensity are directly related to trends in thunderstorm frequency and intensity. Although studies are still being performed, a recent study cited by the National Climate Assessment indicates an increase in the occurrence of atmospheric conditions conducive to severe thunderstorm formation. For the Great Lakes Region spring season, the study indicates increases of 1.2 to 2.4 days per season with severe thunderstorm environments.[xxiii] While it is difficult to quantify these trends in terms of future hail occurrences, they can be considered when determining future probability.

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Considering the rate of historic occurrences, the likelihood of unreported or underreported events, and climate projections for convective storm conditions, the probability assigned the hail hazard is likely (between 10 percent and 90 percent annual chance).

Vulnerability Assessment

Potential impacts to buildings, infrastructure, life safety, public heath, and the economy from the hail hazard are described below. Climate-related impacts to the hail hazard are also described. All current and future buildings, and populations are considered at risk to hail. No dollar losses are attributed to hail events in Ann Arbor, but future losses are possible.

Damage to Buildings

All current and future buildings in Ann Arbor are considered at-risk to the hail hazard. Hail is capable of causing damages to roofs, brick walls, and exposed glass and metal.

Damage to Infrastructure

In severe cases, hail has the potential to damage to exposed infrastructure, such as roads, sidewalks, bridges, and above-ground utilities. All exposed infrastructure in Ann Arbor is considered at-risk to hail.

Impact on Life Safety, Health, Warning and Evacuation Procedures

In extreme cases, hail can result in injuries and loss of life to persons caught in the open. It is unlikely that hail would result in an evacuation; however, in some events, people may be advised to take shelter until the event has passed.

Impact on Public Health

No special public health issues are attributable to hail.

Economic Impact

Hail can result in extensive property damages, including damage to cars, roofs, crops, and landscaping. Business interruptions are possible if people need to seek shelter until a hail event has passed.

Climate Change Impacts

Impacts on hail intensity (extent) due to climate change are uncertain. It is unknown if future climate conditions will result in different hailstone sizes on average. Research from the National Climate Assessment indicates a projected increase in the number of days with thunderstorm environments, which could lead to an increase in the number of hail occurrences in Ann

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Arbor. An increase in the frequency of events would increase the vulnerability of people, buildings, and infrastructure to the hail hazard.

Lightning

Description

Lightning is a discharge of electrical energy resulting from the buildup of positive and negative charges within a thunderstorm, creating a "bolt" when the buildup of charges becomes strong enough. This flash of light usually occurs within the clouds or between the clouds and the ground. A bolt of lightning can reach temperatures approaching 50,000 degrees Fahrenheit. Lightning rapidly heats the sky as it flashes but the surrounding air cools following the bolt. This rapid heating and cooling of the surrounding air causes the thunder, which often accompanies lightning strikes. While most often affiliated with thunderstorms, lightning may also strike outside of heavy rain and might occur as far as 10 miles away from any rainfall.

Lightning strikes occur in very small, localized areas. For example, they may strike a building, electrical transformer, or even a person. According to FEMA, lightning injures an average of 300 people and kills 80 people each year in the United States. Direct lightning strikes can also cause significant damage to buildings and infrastructure largely by igniting a fire. Lightning is also responsible for igniting wildfires that can result in widespread damages to property.

Location

Lightning occurs randomly, therefore it is impossible to predict where and with what frequency it will strike. It is assumed the city is uniformly exposed to lightning. Lightning flash data compiled by Vaisala, Inc. with data from 2007 through 2016 shows the frequency of lightning flashes per square kilometer per year (see **Figure 4.9**). Most areas in Ann Arbor have an average of 3 to 12 flashes per square mile per year.[xxiv]

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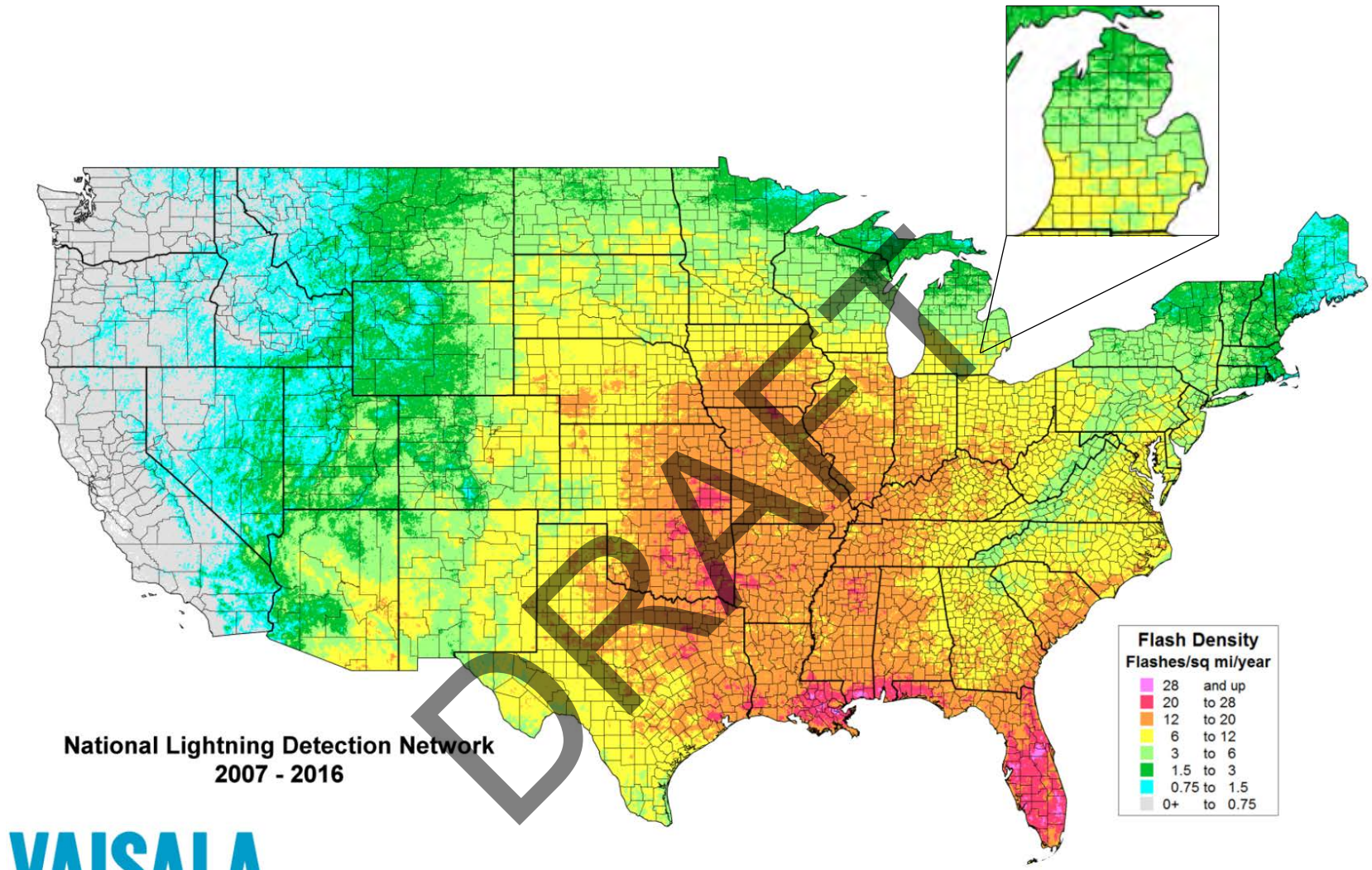
Figure 4.9: Vaisala, Inc Average Lightning Flash per Square Miles (2007-2016)



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Previous Occurrences

The NCEI Storm Events Database reports hail information by county and, when the information is available, by town or by coordinate location. Of the 21 lightning events reported for Washtenaw County between 1996 and 2017, 5 events occurred in Ann Arbor. These 5 events resulted in 1 death, 4 injuries, and over $2.1 million in property damages. It should be noted that additional lightning events have likely occurred and were not reported to NCEI; often only events with severe outcomes, such as injuries, deaths, or extensive damages, are reported. Therefore, the number of events and resulting damages are likely higher than what is indicated. Detailed information on lightning events reported in Ann Arbor are presented in **Table 4.14.**

Table 4.14 NCEI Historic Hail Events in Ann Arbor

Date	Deaths/ Injuries	Property Damage (2017 dollars)	Details
10/27/1997	0/0	$0	Lightning struck at transformer pole in Ann Arbor, knocking out power to about 500 Detroit Edison customers.
4/20/2000	0/2	$0	The storms were unusually prolific lightning producers for so early in severe weather season. During the mid to late afternoon hours, some of the storms moved repeatedly over the same areas. In addition, the thunderstorms seriously disrupted air travel at Detroit Metro Airport. Over 160 flights were cancelled, and all traffic at the airport was halted for a half hour period during the afternoon. A few power lines were downed here and there. **Two 18-year-old men were struck by lightning and briefly hospitalized.**
12/11/2000	0/0	$1,818,132	A **lightning strike ignited a large home** just northwest of Ann Arbor. The home was destroyed by fire.
9/19/2002	1/2	$0	**Three men were installing a roof at an apartment complex under construction when they were struck by lightning**. Two of the men were injured, while the third was later pronounced dead.
6/21/2006	0/0	$330,570	A lightning strike tore a large hole in the roof of an upscale home, causing extensive damage. Much of the upstairs portion of the home was destroyed. Total **Property damage was estimated at $200K** based on pictures included in the newspaper.

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Extent

One method for measuring lightning extent is flash density, or the number of flashes per square mile per year. According to **Figure 4.9**, Ann Arbor is in a part of Michigan that receives approximately 3 to 12 lightning flashes per square mile per year (though not all flashes result in a lightning strike). Lightning can also be measured in terms of damages incurred from an

event. The greatest amount of damage reported from a single lightning event in Ann Arbor was $1,818,132 (2017 dollars), when a lightning strike caused a house to catch fire. However, costlier events are possible.

Probability of Future Occurrences

With 5 reported lightning events in 21 years, the average historic rate of occurrence in for damaging lightning events in Ann Arbor is approximately one event every four years. However, county information suggests at least one event annually, and it is also likely that data is not inclusive of all events in the city. Lightning flashes and strikes are an annual occurrence, though all events may not result in damage.

When possible, climate variability should be considered when determining the probability of future hazard events. Trends in convective storm occurrences due to climate change are subject to greater uncertainty than temperature-related trends (such as extreme heat and cold events).[xxv] Because lightning is affiliated with severe thunderstorms, trends in lightning frequency and intensity are related to trends in thunderstorm frequency and intensity. Although studies are still being performed, a recent study cited by the National Climate Assessment indicates an increase in the occurrence of atmospheric conditions conducive to severe thunderstorm formation. For the Great Lakes Region spring season, the study indicates an increase of 1.2 to 2.4 days per season with severe thunderstorm environments from 2070-2099.[xxvi] While it is difficult to quantify these trends in terms of future lightning occurrences, they can be considered when determining future probability.

Considering the frequency of historic occurrences, the likelihood of unreported or underreported events, and climate projections for convective storm conditions, a probability of highly likely (greater than 90 percent annual chance) was assigned.

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Vulnerability Assessment

All current and future buildings, infrastructure, and populations are considered at risk to lightning in Ann Arbor. Potential annualized loss from lightning is estimated at $71,623 (2017 dollars). Specific impacts to buildings, infrastructure, life safety, public heath, and the economy from lightning are described below. Climate-related impacts to the lightning events are also described.

Damage to Buildings

All current and future buildings in Ann Arbor are considered at-risk to lightning. Lightning may result in structure fires and loss of electrical equipment. In addition, falling limbs caused lightning strikes to trees may damage buildings or vehicles.

Damage to Infrastructure

All current and future infrastructure in Ann Arbor is considered at-risk to lightning. Electrical systems, telecommunications equipment, and infrastructure exposed in open areas are especially vulnerable to lightning.

Life Safety, Health, Warning and Evacuation Procedures

Lightning is one of the leading causes of weather-related fatalities. From 2003 to 2012, lightning caused an average of 35 deaths per year in the U.S.[xxvii] Most lightning deaths and injuries in the United States occur in the summer months, when lightning frequency and outdoor activities reach a peak. All current and future populations in Ann Arbor are considered at risk to lightning. However, people who work outside or regularly engage in outdoor recreational activities are considered at a higher risk; more than one third of lightning strike deaths occur on farms. People engaged in outdoor activities during a lightning event can reduce vulnerability by taking appropriate precautions. If thunder is heard, people outdoors should seek shelter and wait 30 minutes after the last clap of thunder before leaving the shelter. When possible, coaches, referees, camp counselors or life guards should protect the safety of those outside by stopping activities in a prompt manner so that participants and spectators can get to a safe place.[xxviii]

Public Health

No special public health issues are attributable to lightning.

Economic Impact

Lightning can cause costly fire damage due to hitting trees and causing wildfires as well as causing stress on electrical systems. Communications can be disrupted by lightning, and signal disruptions due to lightning are common. In addition, communication lines, antennas, and towers can suffer damage from lightning. Businesses can also be affected by power outages.

Climate Change Impacts

Changes to lightning intensity (extent) and frequency due to climate change are uncertain. Research cited by the National Climate Assessment indicates a projected increase in the number of days with thunderstorm environments in the Great Lakes Region (1.2 to 2.4 days per season from 2070-2099), which could lead to an increase in the frequency of lightning flashes in Ann Arbor. Similarly, another study found evidence linking warmer air temperatures to increased lightning strikes by about 12 percent per degree Celsius of warming (give or take 5 percent[xxix]). Between 2041 and 2070, temperatures in Ann Arbor are expected to increase by approximately 4.5 to 5°F. An increase in the frequency of events would increase the vulnerability of populations, buildings, and infrastructure to the lightning hazard.

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Severe Winter Weather

Description

A winter storm is an event in which varieties of precipitation are formed that only occur at low temperatures, such as snow, sleet, freezing rain or ice. Snow storms generally occur with the clash of different types of air masses, with differences in temperature, moisture, and pressure; specifically when warm moist air interacts with cold dry air. Snow storms that produce a lot of snow require an outside source of moisture, such as the Gulf of Mexico or the Atlantic Ocean.

Severe winter weather typically results in a winter weather watch, warning, and/or advisory. During a severe winter weather event, one or more of the following types of weather occur:

Winter Storm: A snow storm is generally defined as snow accumulation of at least 8+ inches in 12+ hours or 6+ inches in 6 to 9 hours, and can be in combination with rain, freezing rain, sleet, wind, blowing snow, or cold.

Heavy Snow: A heavy snow storm is any winter storm that produces six inches or more of snow within a 48-hour period or less.

Blizzard: A blizzard is a severe snow storm with winds in excess of 35 mph and visibility of less than a 1/4 mile for more than 3 hours.

Frost/Freeze: Frost forms during freezing temperatures when the ground surface cools to a temperature colder than the dewpoint of adjacent air. When water vapor in the air above the ground surface condenses, it freezes due to low temperatures. Sustained temperatures below freezing are common during Ann Arbor's winter months, and the city is generally well prepared (see the *Extreme Cold/Wind Chill* profile for hazards relating to temperatures well below freezing). However, frost and freeze events can be detrimental when occurring outside of the expected winter season, such as early in the fall or late in the spring. These events can catch motorists off guard with slick road conditions, or damage crops and landscaping.

Ice Storm, Sleet, and Freezing Rain: An ice storm is defined as a storm with significant amounts of freezing rain and is a result of warm air in between two layers of cold air. With warmer air above, falling precipitation in the form of snow melts, then becomes either super-cooled (liquid below the melting point of water) or re-freezes. An ice storm typically has a coating of at least ¼ inch of ice, but may be up to ½ inch if winds are less than 15 miles per hour.

In the former case, super-cooled droplets can freeze on impact (freezing rain), while in the latter case, the re-frozen water particles are ice pellets (or sleet). Sleet is defined as partially frozen raindrops or refrozen snowflakes that form into small ice pellets before reaching the ground. They typically bounce when they hit the ground and do not stick to the surface. However, it does accumulate like snow, posing similar problems and has the potential to accumulate into a layer of ice on surfaces.

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Freezing rain, conversely, usually sticks to the ground, creating a sheet of ice on the roadways and other surfaces. Generally in Michigan, an ice storm is considered severe if there is an accumulation of ¼ inch or more of ice.

As the climate changes, winter precipitation is also expected to change. With warmer temperatures, it is more likely than rain will fall in place of snow, and mixed winter precipitation (such as freezing rain) will become more likely.[xxx]

Winter storms are defined differently in various parts of the country relevant to their standard weather. Two inches of snow may create serious disruptions to traffic in areas where snowfall is not expected; however, this may be considered a light dusting in regions where snowfall is typical. Therefore, there are multiple ways in which to measure a winter storm, based on snowfall, temperatures, wind speeds, societal impact, etc. Ann Arbor lies within the Detroit/Pontiac, MI NWS Forecast Office, which defines regional standards for severe winter weather events.

On the southern portion of Michigan's lower peninsula, the winter risk season starts in late November and runs through early April. However, it should be noted severe winter weather are possible outside of this window, and that mild snowfall and cold temperatures may also occur outside of the winter weather risk season.[xxxi]

In addition to precipitation associated with severe winter storms, extreme cold events, especially those caused by the combined effects of wind and cold temperatures, can occur during a severe winter storm. However, extreme cold events have been included as a separate hazard as they are not always associated with winter storms.

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Location

It is assumed that all of Ann Arbor is uniformly exposed to the severe winter weather hazard.

Previous Occurrences

The NCEI Storm Events Database records winter-related weather events by county; city-specific data is not available. Therefore, all winter weather events reported for Washtenaw County are included. According to NCEI, there has been a total of 56 severe winter weather events in Washtenaw County since 1996. In total, these events resulted in 1 injury, 1 death, over $6,242,600 in property damages (2017 dollars), and over $1,507,000 in crop damages (2017 dollars). The sole event resulting in crop damages was a frost/freeze event occurring in 2012, and it is likely this event occurred elsewhere in Washtenaw County as Ann Arbor does not have a significant amount of cropland. Summary details for these events are included in **Table 4.15,** and details for each reported event can be found in Appendix C**.**

Table 4.15 Previous Heavy Snow Occurrences in Ann Arbor

Event Type	Number of Occurrences	Deaths/Injuries	Property Damage (2017 dollars)
Blizzard	1	0/0	--
Frost/Freeze	2	0/0	$1,507,056
Heavy Snow	28	0/0	--
Ice Storm	3	0/1	$5,859,606
Winter Storm	17	0/0	--
Winter Weather	5	1/0	$383,047

Severe winter weather events in Ann Arbor are frequent. The events described below are the more serious events that have occurred within the recent past, as described by NCEI or the 2012 Ann Arbor Hazard Mitigation Plan.

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The Blizzard of 1978

A Presidential Emergency Declaration was granted for the entire state following a blizzard from January 26-27, 1978 when a severe snowstorm struck the Midwest, and Michigan was at the center of the storm (including the city of Ann Arbor). Dubbed a "white hurricane" by some meteorologists, the storm measured 2,000 miles by 800 miles and produced winds with the same strength of a small hurricane and tremendous amounts of snow. In Michigan, up to 34 inches of snow fell in some areas, and winds of 50-70 miles per hour piled the snow into huge drifts. At the height of the storm, it was estimated that over 50,000 miles of roadway were blocked, 104,000 vehicles were abandoned on the highways, 15,000 people were being cared for in mass care shelters, and over 390,000 homes were without electric power. Two days after the storm, over 90 percent of the state's road system was still blocked with snow, 8,000 people were still being cared for in shelters, 70,000 vehicles were stranded, and 52,000 homes were still without electricity.

Ice Storm of 1997

Low pressure tracked from the central Plains northeast across southeast lower Michigan late on the 13th through the 14th of March. The storm brought widespread precipitation to southeast Michigan from late on the 13th through midday on the 14th. North of Detroit, nearly all of the precipitation fell in the form of freezing rain, with small amounts of snow and sleet noted in a few spots. From Detroit and Ann Arbor south to the state-line, the freezing rain changed to rain, but not before heavy ice accumulations occurred. Total precipitation amounts ranged from 1.5 to nearly 2.5 inches from Detroit and Ann Arbor south to the Ohio state-line. From the northern suburbs of Detroit north to Flint and Port Huron, amounts ranged from 0.8 to 1.5 inches. North of that area, amounts ranged from 0.40 to 0.80 inches. In the Detroit Metropolitan area, the ice storm resulted in power outages to over 425,000 homes and businesses; the 3rd largest outage in history, and the worst ever for an ice storm. Several

thousand residents were without power for as long as 4 days. In addition to powerlines, falling trees damaged dozens of cars and houses throughout the area. Most were closed, and there were numerous auto accidents.[xxxii]

The Blizzard of 1999

A Presidential Emergency Declaration was granted for Washtenaw County following a blizzard on January 2, 1999 that brought over ten inches of snow to the area along with wind gusts to 45 MPH and extremely low wind chills. To compound the problem, heavy snows continued through the month, totaling almost 30 inches. These storms were responsible for numerous motor vehicle accidents, extreme traffic congestion, and government expenditure of an additional one million dollars for road maintenance and response costs. Snowfall amounts in Ann Arbor were 15 inches.

Snowstorms of 1999

In addition to the big snowstorms of January 2nd and 12th-13th, several smaller snow events occurred in the first half of January. By the middle of the month, snowfall was nearing historic proportions, with January of 1999 already among one of the snowiest months ever in southeast Michigan. Compounding the problem was a sustained cold spell during the first half of the month, which prevented any of the snow from melting. Some roofs across the area gave way under the immense weight of the snow, including one vacant building in Ann Arbor. Ice dams on roofs were another widespread problem. Heat escaping from homes melted some of the snow on the roof; as the meltwater ran down to the eaves, it refroze, as the eaves were not heated from underneath. Ice buildup on the eaves of roofs created ice dams; further meltwater had nowhere to go, and found its way through shingles and into ceilings. Tens of thousands of buildings suffered leaks, resulting in a barrage of calls to both roofers and insurance agents. Leakage got into the Clements Library of the University of Michigan in Ann Arbor, damaging or destroying several rare maps and atlases.

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The Blizzard of 2000

A Presidential Emergency Declaration was granted for Washtenaw County following a blizzard in December 2000. The severe winter storm produced record or near-record 24-hour snowfall levels in Washtenaw County, paralyzing the entire Ann Arbor region. High winds and frigid temperatures created blizzard conditions that lasted until late in the day on December 13. The storm produced great hardships for the area, resulting in many school closings for 2 to 4 days, including closing Eastern Michigan University for only the second time ever. Also, mail delivery the next day was spotty at best, and many businesses and government offices were closed. Another series of winter storms the following week dumped an additional foot or more of snow across southern Lower Michigan, increasing snow depths in the Ann Arbor area. The tremendous snow depths caused a host of public health and safety concerns across the region. The snow fell at such a steady rate in the area that public works crews worked at maximum capacity – often around the clock – for two weeks just to keep pace. The cumulative effects of the heavy snowfall, high winds, and severe cold temperatures that began on December 11 caused problems across the region for the next several weeks. The sheer volume of snow made it difficult to handle, and the process of clearing it out of

the way became difficult and expensive, as there was almost no place to put it. The winter storms of December 2000 produced the worst winter conditions to hit the Ann Arbor area, and Michigan in general since the statewide blizzards that occurred in January 1978 and January 1999.

The Ice Storm of 2002

The heaviest freezing rain of this event fell along a line from Ann Arbor to Detroit. Snowfall totals were as much as 12 inches in the cities of Ann Arbor and Dearborn Heights. After the snow had changed over to freezing rain, one quarter to one half of an inch of ice had accumulated onto trees and power lines by the evening of January 31st. The weight of the snow and ice on trees caused hundreds of tree limbs to break and even uprooted a few large trees. This did damage to dozens of homes and automobiles. Several people were also treated for heart attacks after shoveling heavy snow. Falling tree branches and the weight of the ice downed hundreds of power lines and left an estimated 290 thousand residents and businesses in the region without power, some of which had to wait several days for power to be restored.

The Ice Storm of 2007

An ice storm ensued from I-69 south to I-94. Widespread ice accumulations of a quarter to a half inch brought down numerous trees, power poles and power lines. Over 150,000 customers were without power at one time during the ice storm. Many were without power for 2 days, and some for over 3 days. Several senior homes lost power and 200 residents had to be evacuated from one of them. Most of the damage and associated power outages occurred between M59 and I94. Although roads were just warm enough to remain mainly wet, patchy slick spots and downed tree debris made traveling very hazardous. Damages to vehicles, homes, businesses, and electrical poles and transformers were reported. Downed power lines also sparked several garage fires. In addition, many businesses in the hardest hit areas reported losses due to the extended power outages.

The Blizzard of 2011

From February 1-2, 2011 a major winter storm occurred throughout much of Michigan including the Ann Arbor region. The storm brought 10 to 15 inches of snow and blizzard conditions to much of the area with wind gusts in excess of 40 mph combined with heavy snow to produce whiteout conditions and snowdrifts of 3 to 5 feet. Thunder accompanied the snow with snowfall rates exceeding two inches per hour. Many businesses, schools, and some government offices were closed the next day. Most main roads were plowed by the next day but some side streets were not cleared for a couple more days.

Based on NCEI reported events, a search of emergency declarations, and a search of local news sources, no additional historic severe winter weather events have occurred since the 2012 plan.

Freeze of 2012

A record warm March allowed many fruit blossoms to bloom early. Then temperatures dipping into the 20s in late April lead to severe damage of fruit crops.

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Extent

Severe winter weather extent can be measured in several ways, including snowfall accumulations or damages. According to the Michigan state hazard mitigation plan, record snowfall in Ann Arbor was 15.8 inches, occurring on December 1, 1974. The most damages reported during a single winter-related weather event was during the ice storm of 1997, which reported caused over $5.3 million in property damages. It should be noted that more extreme winter weather events are possible for Ann Arbor.

Probability of Future Occurrences

Some type of severe winter weather is expected to strike the city every year. It is only a matter of how severe and how many such events might occur in a particular year that is difficult to predict in advance. Based on a reported 56 events in 21 years, Washtenaw County has historically experienced over 2.5 severe winter weather events per year. In addition, historic climate data shows that winter precipitation (December-February) in Ann Arbor is increasing over time, and the frequency of heavy precipitation events is also increasing. According to data from GLISA, winter precipitation in Ann Arbor increased by 75.4 percent from 1951 to 2014.

When determining future probability, the historic frequency must be considered along with projected future conditions. It is difficult to quantify the impact climate change will have on the future occurrence of severe winter weather events. According to a report from the Graham Sustainability Institute at the University of Michigan, winter precipitation in Michigan will increase between 5 percent and 20 percent by 2030, and between 5 percent and 25 percent by 2100.[xxxiii] In addition, the frequency of heavy precipitation events (24-hour and multi-day) will continue to increase, which could lead to an increase in the number of severe winter weather events. Although warmer temperatures may lead to more rainfall in place of snowfall, precipitation could be more likely fall as freezing rain.

Based on historic occurrences and future projections, the probability assigned to the severe winter weather hazard is highly likely (greater than 90 percent annual chance).

Vulnerability Assessment

All current and future buildings, infrastructure, and populations are considered at risk to severe winter weather. Potential annualized loss from severe winter weather events is estimated at $208,088 (2017 dollars). Specific impacts to buildings,

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infrastructure, life safety, public heath, and the economy from severe winter weather are described below. Climate-related impacts are also described.

Damage to Buildings

All current and future buildings are at-risk to severe winter weather. Downed trees and branches can cause damage to buildings and other structures. The weight of caused by heavy snowfall accumulation can cause roofs to collapse. In addition, ice dams can cause leaks and water damage to buildings. Ice dams occur when the bottom layer of snow or ice accumulated on a roof melts due to heat from the building, and runs off into eaves, where it refreezes. The refrozen water causes an ice dam.

Damage to Infrastructure

Winter precipitation and subsequent salting cause significant damage to roads and sidewalks. Cold temperatures result in freezing pipes that can rupture and leak. Snow and ice accumulations damage communication infrastructure and power lines. Resulting power outages can last for several days.

Life Safety, Health, Warning and Evacuation Procedures

Health hazards related to walking and snow removal are frequent and life-threatening. Falls, particularly to the elderly, can result in serious injury including fractures, broken bones, and shattered hips. Middle-aged and older adults are susceptible to heart attacks from shoveling snow.

Dangerous driving conditions frequently occur during and shortly after severe winter storms. While vehicular accidents are often caused by the driver's lapse in judgment, the weather and its impact on roads are also a major factor. Blowing snow, ice, and slush create slippery pavement making vehicle travel less safe during and immediately following winter storms. Blizzards can create whiteout conditions, resulting in low to no visibility of roadways. Icey road conditions cause automobile crashes, resulting in injuries and loss of life.

Severe winter weather can result in the need to close schools, airports, and employment centers. In extreme cases, sheltering and evacuations may be required, especially if prolonged power outages are expected.

According to data from the Washtenaw County Sheriff, between 1992 and 2015, the county experienced an average of 2.75 winter storm watches, 5.71 winter weather advisories, and 2.25 winter storm/snow warnings annually. It is unknown how many of these notices included Ann Arbor.

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Public Health

When severe winter weather strikes, cumulative impacts can result impact public health. Power outages can result in limited access to food, basic supplies, and an adequate heat source. Young children and the elderly are especially at risk. Exposure during winter weather, including stranded motorists or households without an adequate heat source, can result in hypothermia or frostbite.

Economic Impact

Loss of power during a severe winter storm means businesses and/or public facilities must close down. Loss of access due to snow or ice covered roads has a similar effect. There are also impacts when people cannot get to work, to school, or to the store. Flights are often canceled. Expenses to local, state, and federal governments to repair roads, power outages, and other damages resulting from severe winter weather can balloon quickly.

Climate Change Impacts

Climate change impact could have mixed impacts on winter weather in the city. Generally, more winter precipitation is expected in the future. Winter precipitation in Michigan will increase between 5 percent and 20 percent by 2030, and between 5 percent and 25 percent by 2100.[xxxiv] In addition, the frequency of heavy precipitation events (24-hour and multi-day) will continue to increase, which could lead to an increase in the number of severe winter weather events. The transition from snowfall to more freezing rain as temperatures warm could result in increased icy road conditions or refreezing of rain. Overall reduced snow cover and warmer winters could impact winter recreation and tourism.

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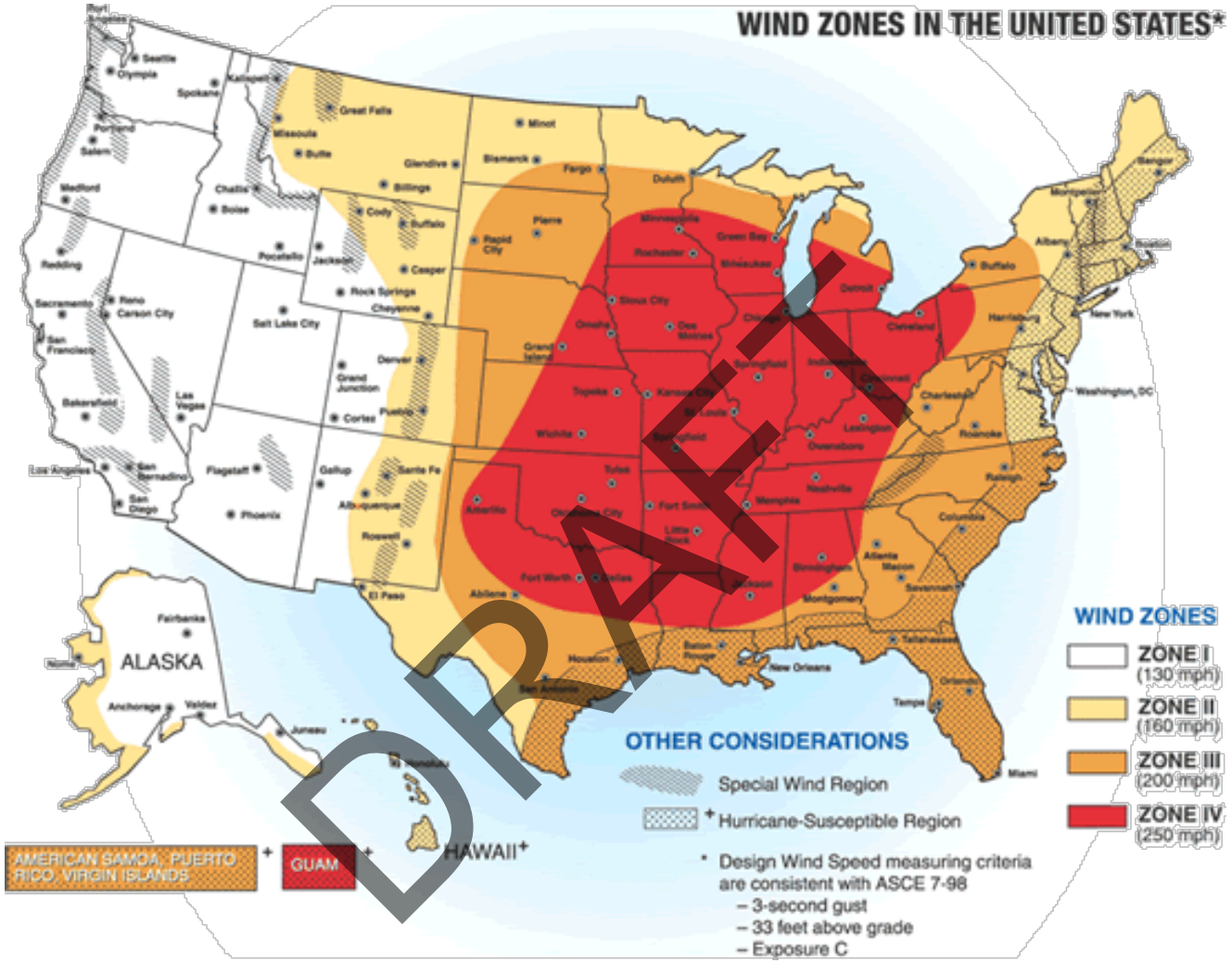
Severe Winds

Description

There are several types of wind hazards that affect the planning area. These include high or strong wind events and thunderstorm wind events (including straight line winds). Tornadoes are also wind events that impact the city, which are listed as separate hazards due to their impacts and hazard potential.

High Wind definitions can vary by region. In general, high wind events are those events greater than normal averages and have damage potential. Wind events are common throughout the United States. However, the severity varies depending on location. **Figure 4.10** below shows wind zones in the U.S. based on ASCE 7-98 criteria.[xxxv] These zones reflect the number and strength of extreme windstorms. According to the map, Ann Arbor is located in Wind Zone IV, which includes winds speeds up to 250 miles per hour.

Figure 4.10: ASCE 7-98 U.S. Wind Zones



The National Weather Service Center can issue a high wind advisory or warning. A wind advisory is issued when conditions are favorable for the development of high winds over all or part of the forecast area, but the occurrence is still uncertain. The criteria of a wind advisory are sustained winds of 31 to 39 mph and/or gusts 46 to 57 mph for any duration. A high wind warning is issued when sustained winds from 40 or higher are expected for at least one hour or any wind gusts are expected to reach

58 mph or more.[xxxvi] The definitions vary from state to state. Areas that frequently experience these high winds will not issue the advisory or warning. A Beaufort Wind Scale may also be used to describe wind severity as shown in **Table 4.16** below.

Table 4.16 The Beaufort Wind Scale[xxxvii]

Beaufort Number	Wind (Knots)	Description	On the Water	On Land
0	Less than 1	Calm	Sea surface smooth and mirror-like	Calm, smoke rises vertically
1	1-3	Light Air	Scaly ripples, no foam crests	Smoke drift indicates wind direction, still wind vanes
2	4-6	Light Breeze	Small wavelets, crests glassy, no breaking	Wind felt on face, leaves rustle, vanes begin to move
3	7-10	Gentle Breeze	Large wavelets, crests begin to break, scattered whitecaps	Leaves and small twigs constantly moving, light flags extended
4	11-16	Moderate Breeze	Small waves 1-4 ft. becoming longer, numerous whitecaps	Dust, leaves, and loose paper lifted, small tree branches move
5	17-21	Fresh Breeze	Moderate waves 4-8 ft taking longer form, many whitecaps, some spray	Small trees in leaf begin to sway
6	22-27	Strong Breeze	Larger waves 8-13 ft., whitecaps common, more spray	Larger tree branches moving, whistling in wires
7	28-33	Near Gale	Sea heaps up, waves 13-19 ft., white foam streaks off breakers	Whole trees moving, resistance felt walking against wind
8	34-40	Gale	Moderately high (18-25 ft.) waves of greater length, edges of crests begin to break into spindrift, foam blown in streaks	Twigs breaking off trees, generally impedes progress
9	41-47	Strong Gale	High waves (23-32 ft.), sea begins to roll, dense streaks of foam, spray may reduce visibility	Slight structural damage occurs, slate blows off roofs
10	48-55	Storm	Very high waves (29-41 ft.) with overhanging crests, sea white with densely blown foam, heavy rolling, lowered visibility	Seldom experienced on land, trees broken or uprooted, "considerable structural damage"
11	56-63	Violent Storm	Exceptionally high (37-52 ft.) waves, foam patches cover sea, visibility more reduced	
12	64+	Hurricane	Air filled with foam, waves over 45 ft., sea completely white with driving spray, visibility greatly reduced	

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Thunderstorms are associated with high wind because wind is typically one component of thunderstorms. Thunderstorms are very dangerous because of their ability to generate tornadoes, hailstorms, strong winds, flash flooding, and damaging

lightning. While thunderstorms can occur in all regions of the United States, they are most common in the central and southern states because atmospheric conditions in those regions are ideal for generating these powerful storms. In Michigan, thunderstorms are most common in the summer months.

Three conditions need to occur for a thunderstorm to form. First, it needs moisture to form clouds and rain. Second, it needs unstable air, such as warm air that can rise rapidly (this often referred to as the "engine" of the storm). Third, thunderstorms need lift, which comes in the form of cold or warm fronts, sea breezes, mountains, or the sun's heat. When these conditions occur simultaneously, air masses of varying temperatures meet, and a thunderstorm is formed. These storm events can occur singularly, in lines, or in clusters. Further, they can move through an area very quickly or linger for several hours.

Straight-line winds, which in extreme cases have the potential to cause wind gusts that exceed 100 miles per hour, are responsible for most thunderstorm wind damage. One type of straight-line wind, the downburst, can cause damage equivalent to a strong tornado and can be extremely dangerous to aviation.

According to the National Weather Service, more than 100,000 thunderstorms occur each year, though only about 10 percent of these storms are classified as "severe." A severe thunderstorm occurs when the storm produces one of three elements: 1) Hail of three-quarters of an inch; 2) Tornado; 3) Winds of at least 58 miles per hour.

Figure 4.11 illustrates thunderstorm hazard severity based on the annual average number of days with a thunderstorm event. According to the map, Ann Arbor experiences an average of 40 thunderstorm days per year.

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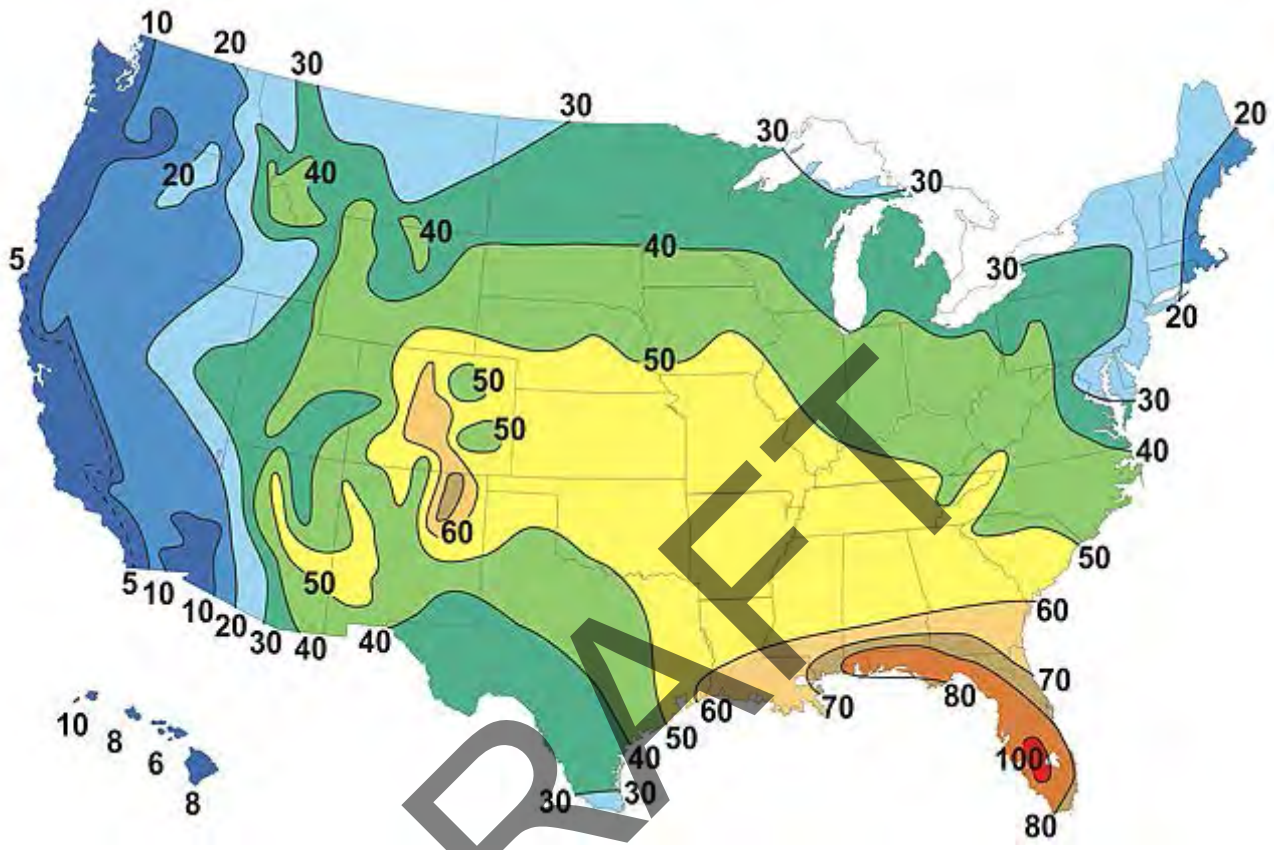
Figure 4.11: Average Number of Days with Thunderstorms (NOAA)



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Location

It is assumed that all of Ann Arbor is uniformly exposed to severe wind hazards.

Previous Occurrences

The National Centers for Environmental Information (NCEI) Storm Events Database reports wind event information by county and, when the information is available, by city or by coordinate location. Of the 452 wind events reported for Washtenaw County between 1955 and 2017, 66 events occurred in Ann Arbor, all of which were thunderstorm wind events, except for 3 high wind events. None of these events resulted in reported deaths or injuries. Reported damages from these events totaled $38,213,016 (2017 dollars). It is likely that some wind events and damages to private property were not reported to NCEI.

Therefore, the number of events and resulting damages is likely higher than what is indicated. Information on notable events in Ann Arbor are described below**.** Details for each reported event can be found in Appendix C.

July1998 Thunderstorms

On July 21, 1998 thunderstorms continued to intensify as they moved east into the densely-populated Ann Arbor-Ypsilanti area. Ann Arbor Municipal Airport measured a 75-mph wind gust, which blew two hangars off their foundations, damaged the doors of three hangars, and damaged several planes. At least 75 trees were downed in Ann Arbor, most on the south side of town. Overall, more than a thousand trees and five thousand power lines were downed in southeast Michigan. Over 600,000 businesses and residences lost power at some point. For Detroit Edison, this was the fourth worst weather system of all time regarding power outages. The power was out for over a week in spots. Damage in Ann Arbor was reported at $7,844,812 (2017 dollars).

December 1998 Thunderstorm

A thin line of showers and thunderstorms moved east across the state at about 50 mph. Many of the storms along the line produced wind damage. The result was a December severe weather episode - a rather uncommon event for Michigan. Most of the wind damage occurred immediately behind the line of convection, and the majority of the damage involved the downing of trees, large limbs, and power lines. Damage was a little heavier across Washtenaw and Wayne Counties. A 64-mph gust was measured at the University of Michigan in Ann Arbor, while Detroit Metropolitan Airport had a 60mph gust. Damage in Ann Arbor was reported at $305,076 (2017 dollars).

July 1999 Thunderstorm

A trough of low pressure moved east into the western Great Lakes by late morning, and thunderstorms ignited along the trough. These storms moved southeast into Michigan, and a large number of them became severe. A number of tents at the Ann Arbor Art Fair were demolished. The thunderstorm hazard resulted in over a hundred flights at Detroit Metropolitan Airport being either delayed or cancelled. Damage in Ann Arbor was reported at $59,585 (2017 dollars).

May 2000 Thunderstorm

Thunderstorms erupted in the region the night of May 9th. Most of the damage was in the form of trees, tree limbs, and power lines downed. The most substantial damage was in Washtenaw County. In Ann Arbor, falling trees crushed two cars. All told, over 40,000 people in southeast Michigan lost power at some point during the storms.

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April 2001 Thunderstorm
Thunderstorms ignited ahead of a cold front, and several became severe, producing sporadic wind damage. A tree and several large limbs were downed onto State Street, landing on two cars. Damage in Ann Arbor was reported at $16,047 (2017 dollars).

June 2006 Thunderstorm
A severe storm with strong downbursts tracked across Washtenaw County. Law Enforcement reported a tree blown down on car and six utility poles downed. $22,148 (2017 dollars) in damages were reported.

July 2006 Thunderstorm
The July 17th severe weather event would eventually go down as the largest and most destructive of the 2006 severe weather season. Intense thunderstorms fired along and ahead of a cold front working down from the northern Great Lakes and eventually developed into a large MCS by mid evening. $20,764 (2017 dollars) in damages were reported in Ann Arbor.

May 2014 Thunderstorm
This line of thunderstorms raced across the state bringing winds, heavy rain, and frequent lightning with numerous reports of trees down, power outages, and local flooding. A large tree was uprooted and fell onto detached garage. Damage in Ann Arbor was reported at $114,737 (2017 dollars).

November 2014 Windstorm
High winds occurred across Southeast Michigan during the afternoon of November 24. Peak winds gusted at 50 knots. Numerous downed trees and power lines were reported, which lead to power outages reaching close to 200,000 at the peak of the wind event. Damage in Washtenaw County was reported at $54,636 (2017 dollars).

February 2016 Windstorm
Strong southwest winds of 50 to 60 mph brought down trees, tree limbs, and power lines, mainly along the M-59 corridor and I-94 corridors of Southeast Michigan. DTE reported 117,000 customers were affected during the peak early Friday evening, with 75,000 customers remaining without power into Saturday the next day. Damage in Washtenaw County was reported at $4,120,000 (2017 dollars).

March 2017 Windstorm
On March 8, 2017, severe winds (not associated with a thunderstorm) with gusts of 60mph knocked down trees and power lines in Ann Arbor, causing widespread damages, with numerous reports of structural damage to buildings. There were also reports of brush fires and tractor-trailers flipped over around the area. Due to the extensive damage, many areas were without power for several days. Approximately 800,000 DTE customers and approximately 300,000 Consumers Energy customers were

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affected. The University of Michigan alone reported over $600,000 in damages. Damage in Washtenaw County was reported at $25,000,000 (2017 dollars).

Extent

Thunderstorm wind extent is measured in terms of wind speed. The greatest sustained wind reported in Ann Arbor was 80 knots, or 92 miles per hour. However, stronger gusts are possible. Extent can also be measured in terms of damage. The greatest amount of damage reported from a single thunderstorm wind event was $25 million (2017 dollars). However, costlier events are possible.

Probability of Future Occurrences

According to the Michigan state hazard mitigation plan, Ann Arbor is located in an area of Michigan that experiences an average of 34 thunderstorm days per year; similarly **Figure 4.11** shows Ann Arbor as being in a region of the country experiencing approximately 40 thunderstorm days annually. This is supported by NCEI data; with 66 reported events over 61 years, Ann Arbor experiences more than one wind event per year. However, it is likely NCEI data is not inclusive of all events that have occurred in the city. Thunderstorms are an annual occurrence, though all events may not result in damage.

When possible, climate variability should be considered when determining the probability of future hazard events. Trends in convective storm occurrences due to climate change are subject to greater uncertainty than temperature-related trends (such as extreme heat and cold events).[xxxviii] Because wind events in Ann Arbor are affiliated with severe thunderstorms, trends in wind event frequency and intensity are related to trends in thunderstorm frequency and intensity. Although studies are still being performed, a recent study cited by the National Climate Assessment indicates an increase in the occurrence of atmospheric conditions conducive to severe thunderstorm formation. For the Great Lakes Region spring season, the study indicates increases of 1.2 to 2.4 days per season with severe thunderstorm environments.[xxxix] While it is difficult to quantify these trends in terms of future wind event occurrences, they can be considered when determining future probability.

Considering the frequency of historic occurrences, the likelihood of unreported or underreported events, and climate projections for convective storm conditions, a probability of highly likely (greater than 90 percent annual chance) was assigned to the severe wind hazard.

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Vulnerability Assessment

All of Ann Arbor is vulnerable to severe storms due to the topography and movement of weather fronts through the area. Potential annualized loss from severe wind is estimated at $166,360 (2017 dollars), although this estimate included damages for several county-wide events. Specific impacts to buildings, infrastructure, life safety, public heath, and the economy from lightning are described below. All current and future buildings, infrastructure, and populations are considered at-risk to severe wind. Climate-related impacts to the lightning events are also described.

Damage to Buildings

All current and future buildings in Ann Arbor are considered at-risk to severe winds. Severe wind has the potential to blow shingles, siding, awnings, and other features off of buildings. Falling trees and tree limbs can damage structures. Objects picked up by wind can be hurled through the air, damaging structures and breaking windows when contact is made. In some cases, structures can be blown off foundations. This happened during the 1998 thunderstorm when two airport hangers were blown off their foundations at the Ann Arbor Airport. In addition, mobile homes are considered at a higher risk to severe wind. According to the TAC, Ann Arbor has one mobile home park. Proper anchoring can make mobile homes more resilient to severe wind.

Damage to Infrastructure

Severe winds can cause damage to infrastructure, including communications infrastructure, utility poles, and above ground power lines can be blown down.

Life Safety, Health, Warning and Evacuation Procedures

Severe winds can result in serious life safety impacts. People outside during severe wind events may be struck by falling trees and limbs, or by objects falling off buildings or being hurled through the air.

In the event that winds of 75 miles per hour are confirmed anywhere in Washtenaw County, the city's siren warming system will deploy. The system has 22 sirens throughout Ann Arbor, which provide total coverage throughout the city, as demonstrated by **Figure 4.12.**

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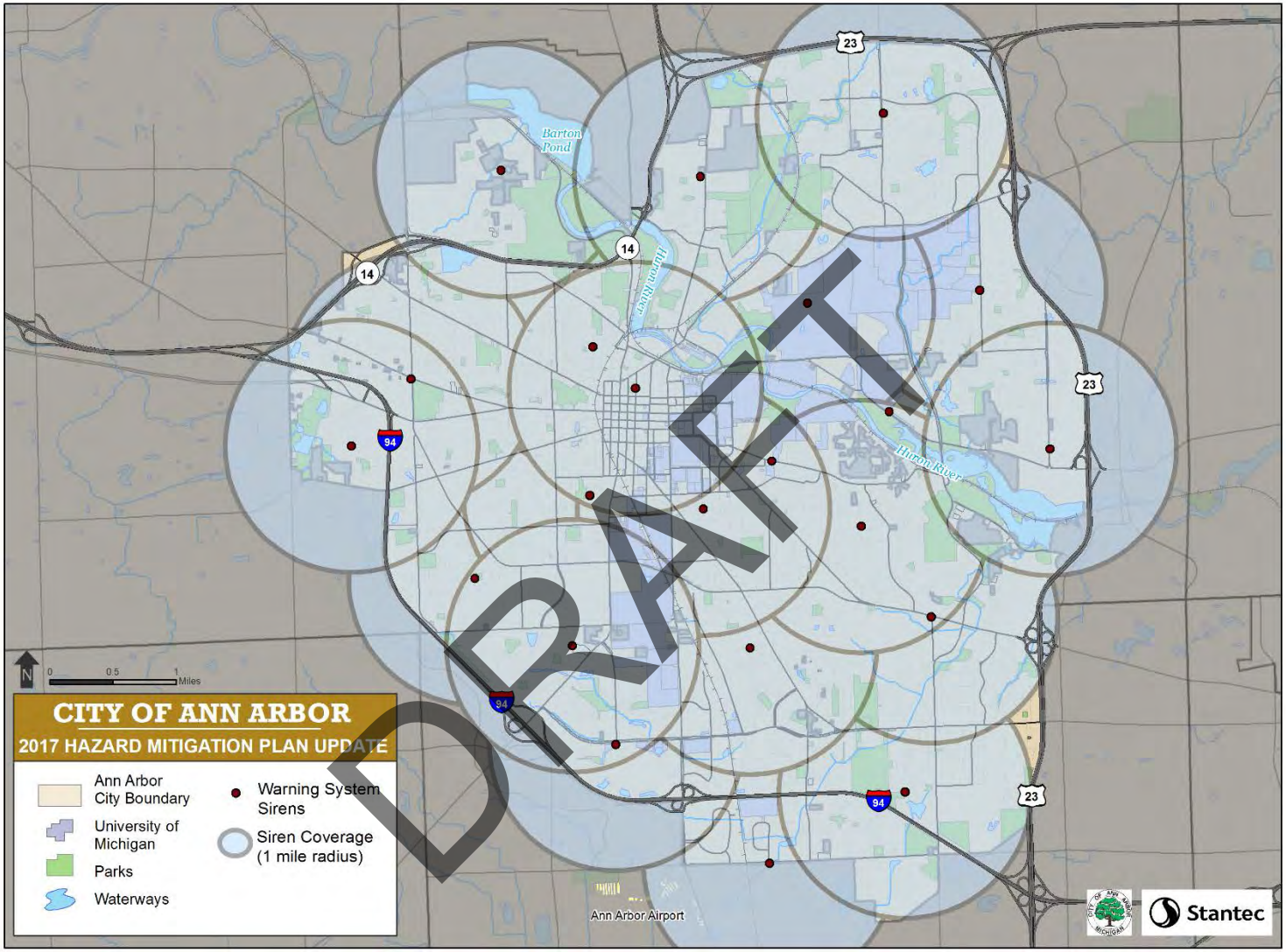
Figure 4.12: Ann Arbor Siren Warning System and Coverage Area



According to data from the Washtenaw County Sheriff, between 1992 and 2015, the county experienced an average of 0.67 wind watches, 2.96 wind advisories, and 0.96 wind warnings annually. In that same time, the county experienced an average of 8.71 severe thunderstorm watches and 9.25 severe thunderstorm warnings annually. It is unknown how many of these warnings included Ann Arbor.

Public Health
No special public health issues are attributable to lightning.

Economic Impact
Communication lines, antennas, and towers can suffer damage from wind and downed branches/trees. Damages to buildings, roads, and vehicles can be costly. Businesses interruptions can occur due to power outages. Flights may be delayed or canceled due to severe wind events.

Climate Change Impacts
Changes to severe wind intensity (extent) and frequency due to climate change are uncertain, and research is ongoing. Research cited by the National Climate Assessment indicates a projected increase in the number of days with thunderstorm environments in the Great Lakes Region (1.2 to 2.4 days per season from 2070-2099), which could lead to an increase in the frequency of thunderstorm wind events in Ann Arbor.

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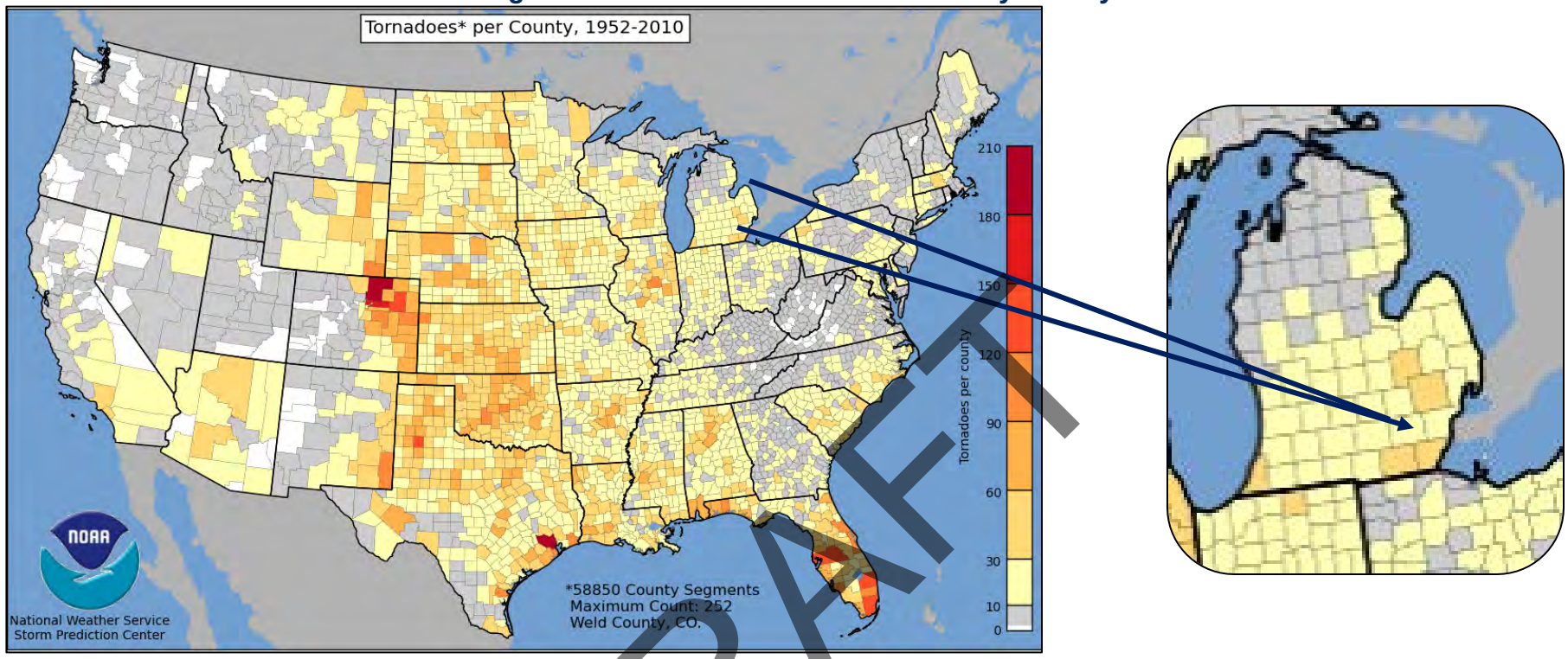
Tornadoes

Description
A tornado is a violent windstorm characterized by a twisting, funnel-shaped cloud extending to the ground. Tornadoes are most often generated by thunderstorm activity (but sometimes result from hurricanes and other tropical storms) when cool, dry air intersects and overrides a layer of warm, moist air forcing the warm air to rise rapidly. The damage caused by a tornado is a result of the high wind velocity and wind-blown debris, also accompanied by lightning or large hail. According to the National Weather Service, tornado wind speeds normally range from 40 miles per hour to more than 300 miles per hour. The most violent tornadoes have rotating winds of 250 miles per hour or more, are capable of causing extreme destruction, and can turning normally harmless objects into deadly missiles.

Each year, an average over 800 tornadoes are reported nationwide, resulting in an average of 80 deaths and 1,500 injuries. According to the NOAA Storm Prediction Center (SPC), the highest concentration of tornadoes in the United States has been in Oklahoma, Texas, Kansas and Florida, respectively. The Great Plains region of the Central United States favors the development of the largest and most dangerous tornadoes (earning the designation of "Tornado Alley"), counties in Florida and Colorado experienced the greatest number of tornadoes in all of the U.S. states. **Figure 4.13** shows tornado activity in the United States based on the number of recorded tornadoes per county from 1952 to 2010.[xl] According to the map, Washtenaw County, where Ann Arbor is located, experienced 10 to 30 recorded tornadoes over the 58-year period.

Figure 4.13: U.S. Tornado Occurrences by County



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Tornadoes are most likely to form in the late afternoon and early evening. Most tornadoes are a few dozen yards wide and touchdown briefly, but even small short-lived tornadoes can inflict tremendous damage. Highly destructive tornadoes may carve out a path over a mile wide and several miles long.

The destruction caused by tornadoes ranges from light to inconceivable depending on the intensity, size and duration of the storm. Typically, tornadoes cause the greatest damage to structures of light construction, including residential dwellings (particularly mobile homes). Tornadic magnitude is reported according to the Fujita and Enhanced Fujita Scales. Tornado magnitudes prior to 2005 were determined using the traditional version of the Fujita Scale, **Table 4.17**. The Enhanced Fujita Scale, used after 2005 (**Table 4.18**), identifies six different categories of tornadoes, EF0 through EF5. Tornado magnitudes that were determined in 2005 and later were determined using the Enhanced Fujita Scale.

Table 4.17 The Fujita Scale (effective prior to 2005)

F-SCALE NUMBER	INTENSITY	WIND SPEED	TYPE OF DAMAGE DONE
F0	GALE TORNADO	40–72 MPH	Some damage to chimneys; breaks branches off trees; pushes over shallow-rooted trees; damages to sign boards.
F1	MODERATE TORNADO	73–112 MPH	The lower limit is the beginning of hurricane wind speed; peels surface off roofs; mobile homes pushed off foundations or overturned; moving autos pushed off the roads; attached garages may be destroyed.
F2	SIGNIFICANT TORNADO	113–157 MPH	Considerable damage. Roofs torn off frame houses; mobile homes demolished; boxcars pushed over; large trees snapped or uprooted; light object missiles generated.
F3	SEVERE TORNADO	158–206 MPH	Roof and some walls torn off well-constructed houses; trains overturned; most trees in forest uprooted.
F4	DEVASTATING TORNADO	207–260 MPH	Well-constructed houses leveled; structures with weak foundations blown off some distance; cars thrown and large missiles generated.
F5	INCREDIBLE TORNADO	261–318 MPH	Strong frame houses lifted off foundations and carried considerable distances to disintegrate; automobile sized missiles fly through the air in excess of 100 meters; trees debarked; steel re-enforced concrete structures badly damaged.
F6	INCONCEIVABLE TORNADO	319–379 MPH	These winds are very unlikely. The small area of damage they might produce would probably not be recognizable along with the mess produced by F4 and F5 wind that would surround the F6 winds. Missiles, such as cars and refrigerators would do serious secondary damage that could not be directly identified as F6 damage. If this level is ever achieved, evidence for it might only be found in some manner of ground swirl pattern, for it may never be identifiable through engineering studies.

Table 4.18 The Enhanced Fujita Scale (effective 2005 and later)

EF-SCALE NUMBER	INTENSITY PHRASE	3 SECOND GUST	TYPE OF DAMAGE DONE
EF0	GALE	65–85 MPH	Some damage to chimneys; breaks branches off trees; pushes over shallow-rooted trees; damages to sign boards.
EF1	MODERATE	86–110 MPH	The lower limit is the beginning of hurricane wind speed; peels surface off roofs; mobile homes pushed off foundations or overturned; moving autos pushed off the roads; attached garages may be destroyed.

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EF-SCALE NUMBER	INTENSITY PHRASE	3 SECOND GUST	TYPE OF DAMAGE DONE
EF2	SIGNIFICANT	111–135 MPH	Considerable damage. Roofs torn off frame houses; mobile homes demolished; boxcars pushed over; large trees snapped or uprooted; light object missiles generated.
EF3	SEVERE	136–165 MPH	Roof and some walls torn off well-constructed houses; trains overturned; most trees in forest uprooted.
EF4	DEVASTATING	166–200 MPH	Well-constructed houses leveled; structures with weak foundations blown off some distance; cars thrown and large missiles generated.
EF5	INCREDIBLE	Over 200 MPH	Strong frame houses lifted off foundations and carried considerable distances to disintegrate; automobile sized missiles fly through the air in excess of 100 meters; trees debarked; steel re-enforced concrete structures badly damaged.

Tornado damage may include crop and property damage, power outages, environmental degradation, injury and death. Tornadoes are known to blow off roofs, move cars and tractor trailers, and demolish homes. Typically tornadoes cause the greatest damage to structures of light construction, such as residential homes.

In 1999, FEMA conducted an extensive damage survey of residential and non-residential buildings in Oklahoma and Kansas following an outbreak of tornadoes on May 3, 1999, which killed 49 people. The assessment found:

- The failure for many residential structures occurred where the framing wasn't secured to the foundation, or when nails were used as the primary connectors between the roof structure and the walls. A home in Kansas, for example, was lifted from its foundation. The addition of nuts to the foundation anchor bolts (connected to the wood framing) may have been all that was needed to prevent this.
- Roof geometry also played a significant role in a building's performance.
- Failure of garage doors, commercial overhead doors, residential entry doors or large windows caused a significant number of catastrophic building failures.
- Manufactured homes on permanent foundations were found to perform better than those that were not on solid foundation walls.

Tornadoes are most frequent in Michigan in the spring and early summer when warm, moist air from the Gulf of Mexico interacts with cold air from polar regions, resulting in severe thunderstorms. Most tornadoes in Michigan come from the

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southwest and travel northeast, and most occur in the southern part of the lower peninsula. From 1950-2009, Michigan has averaged 15 tornadoes and 4 tornado-related deaths per year.

Location

Tornadoes have the potential to strike anywhere. They are more common in open spaces (such as the plains in Tornado Alley). Tornadoes are rarer in areas where there are lots of hills or mountains. Once a touchdown occurs, it may only affect a small area or travel for miles, leaving substantial destruction in its path. Further, it is impossible to predict where and with what magnitude a tornado will strike.

Previous Occurrences

The National Centers for Environmental Information (NCEI) Storm Events Database reports tornado information by county and, when the information is available, by city or by coordinate location. Of the 28 tornado events reported for Washtenaw County between 1950 and 2017, 2 events occurred in Ann Arbor. Neither of these events resulted in deaths or injuries, and neither resulted in significant damages (under $100). The locations of tornado occurrences in Ann Arbor are shown in **Figure 4.14.** Detailed information on events reported in Ann Arbor are presented in **Table 4.19.**

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Figure 4.14: Historic Tornadoes in Ann Arbor

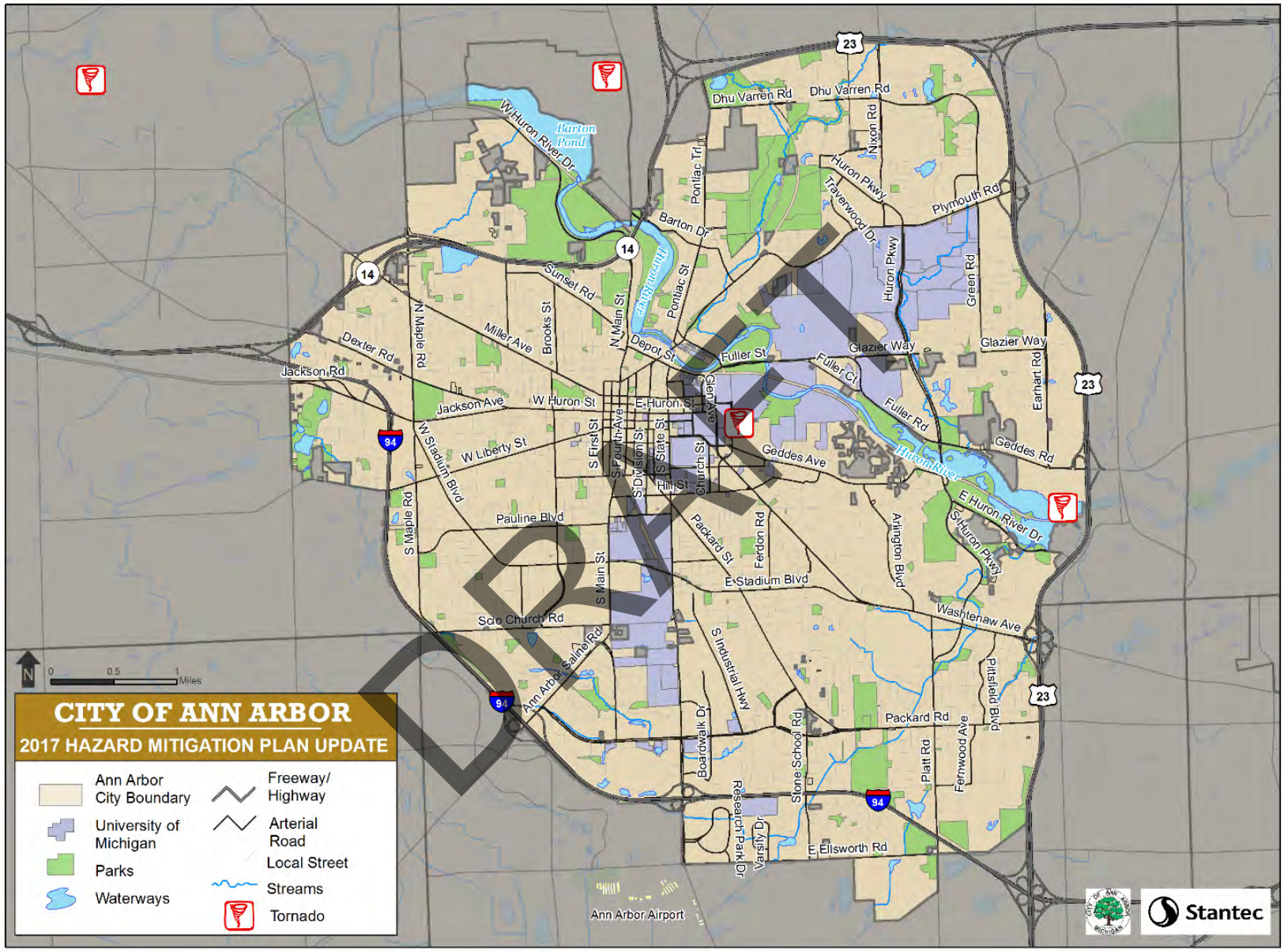

Table 4.19 NCEI Tornado Events in Ann Arbor

Date	Magnitude	Damages (2017 dollars)	Event Details
7/21/1983	F0	$30	Tornado was 0.1 miles long and 10 yards wide.
9/30/2006	F0	--	Washtenaw County Emergency Manager, trained spotters, and Michigan State Police all reported a weak tornado at the I94 and US23 interchange. The Tornado/cold air funnel was very brief and just kicked up some dirt with wind speeds estimated between 40 and 50 MPH. There were no injuries and no damages. Tornado was 0.2 miles in length and 25 yards wide.

Extent

The greatest extent tornado to impact Ann Arbor was an F0 on the Fujita Scale (40 to 75 miles per hour). However, more severe events are possible. For example, the greatest extent tornado to impact Washtenaw County was an EF3 on the Enhanced Fujita Scale (136 to 165 miles per hour), which resulted in just under $14 million in damages (2017 dollars). A single tornado event has the potential to be devastating.

Probability of Future Occurrences

With 2 reported tornado events in 67 years, Ann Arbor experiences less than one tornado every 30 years. It is possible that other, unrecorded tornadoes have occurred. Being in the Midwest, Ann Arbor is located in a region with high potential for tornadoes.

When possible, climate variability should be considered when determining the probability of future hazard events. Trends in convective storm occurrences due to climate change are subject to greater uncertainty than temperature-related trends (such as extreme heat and cold events), and research is ongoing.[xli] Because tornadoes are usually generated from thunderstorms, trends in tornado frequency and intensity are related to trends in thunderstorm frequency and intensity. Although studies are still being performed, a recent study cited by the National Climate Assessment indicates an increase in the occurrence of atmospheric conditions conducive to severe thunderstorm formation in the United States. For the Great Lakes Region spring season, the study indicates increases of 1.2 to 2.4 days per season with severe thunderstorm environments during 2070-2099.[xlii] While it is difficult to quantify these trends in terms of future tornado occurrences, they can be considered when assigning future probability.

Considering the above, a probability of possible (1 percent to 10 percent annual chance) was assigned.

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Vulnerability Assessment

All of Ann Arbor is vulnerable to tornadoes. The potential for loss of life and property damage are significant given the amount of built environment in the area. This vulnerability continues to increase as Ann Arbor continues to expend and densify. All current and future buildings, infrastructure, and populations are considered at-risk to tornadoes. Negligible dollar losses are attributed to tornado events in Ann Arbor, but substantial future losses are possible. Potential impacts to buildings, infrastructure, life safety, public heath, and the economy are described below. Climate-related impacts are also described.

Damage to Buildings

All current and future buildings in Ann Arbor are considered at-risk to tornadoes. Buildings located above-ground in the path of a tornado can suffer extensive damage and/or complete destruction. Although some buildings adjacent to a tornado's path can stand with little or no damage, debris hurled by the wind makes all buildings vulnerable to damage. Although all buildings are vulnerable to tornadoes, three types of structures are more likely to suffer damage:

- Mobile homes;
- Homes on crawlspaces (more susceptible to lift); and
- Buildings with large spans, such as airplane hangars, gymnasiums and factories.

Schools are a particular concern for two reasons:

1. They have large numbers of people present, either during school or as a storm shelter.
2. They have large span areas (open areas with high ceilings), such as gyms and theaters.

University of Michigan is particularly vulnerable to tornadoes given large number of students and employees present on campus at any given moment. A parallel can be drawn to the University of Alabama, which in April 2011 experienced an EF4 tornado that resulted in 36 fatalities, including several students and university employees. Due to damages and loss of life, the university cancelled the rest of the school year and delayed graduation.

Damage to Infrastructure

All infrastructure in Ann Arbor is considered at-risk to tornadoes. Above-ground infrastructure in the path of a tornado can suffer extensive damage and/or complete destruction. When roads close, there are usually other transportation routes available.

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Life Safety, Health, Warning and Evacuation Procedures

Tornadoes can have severe impacts on life safety. Tornadoes can occur without warning, and reaction time may be short. Injuries or loss of life can result when people out in the open are in or near a tornado's path; exposed individuals can be picked by tornado winds or struck by debris. People inside structures that are impacted by tornadoes may suffer injuries or death if trapped in a collapsed building or struck by flying or falling objects. Motorists should not attempt to drive during a tornado event. The Centers for Disease Control recommend that any person in the path of a tornado find shelter or a tornado safe-room immediately. Sheltering in a basement or under a sturdy object is recommended when a tornado safe-room is not an option. Head injuries are a common cause of death from tornadoes; therefore, individuals should attempt to protect their heads during tornado events.

In the event of a tornado warning anywhere in Washtenaw County, the city's siren warning system will activate. The warning system consists of 22 sirens providing coverage for the entire city as demonstrated in **Figure X** under this profile's equivalent in the *Severe Winds* profile.

According to data from the Washtenaw County Sheriff, between 1992 and 2015, the county experienced an average of 2.5 tornado watches and 1.42 tornado warnings annually. It is unknown how many of these notices included Ann Arbor.

Public Health

Public health issues from tornadoes can include water contamination, as well as potential for fire and gas leaks. Damages to certain exposed infrastructure, such as pipelines or septic tanks, can result in hazardous materials spills and leaks.

Economic Impact

When businesses and infrastructure are damaged by a tornado, the city may suffer economic loss. Heavily damaged businesses often must close, impacting business owners. Loss of business can alter the local economy depending on the duration of closures. In addition, the cost of repairs can severely affect businesses, and it is possible that small business owners may not be able to reopen at all. Power outages can affect a business, even if a business' structure is not damaged.

Public expenditures include search and rescue, shelters, and emergency protection measures. The large expenses are for repairs to public facilities and clean-up and disposal of debris. Many public facilities are insured, so the economic impact on the local treasury may be small.

Clean-up and disposal can be a larger problem (both structural and vegetative debris), especially if there is limited landfill capacity near the damage site.

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Climate Change Impacts

There is still some uncertainty as to the specific link between tornadoes and changing climatic conditions, and more research is needed to understand the full impact of climate change on tornadic activity. Due to the small scale of tornado events, observation and modeling can be challenging. Because tornadoes are usually generated from thunderstorms, trends in tornado frequency and intensity are related to trends in thunderstorm frequency and intensity. Although studies are still being performed, a recent study cited by the National Climate Assessment indicates an increase in the occurrence of atmospheric conditions conducive to severe thunderstorm formation in the United States. For the Great Lakes Region spring season, the study indicates increases of 1.2 to 2.4 days per season with severe thunderstorm environments during 2070-2099.[xliii]

Natural Hazards – Hydrologic

Drought

Description

Drought is conceptually defined by the National Drought Mitigation Center as "a protracted period of deficient precipitation resulting in extensive damage to crops, resulting in loss of yield." Although sometimes considered a rare and random event, drought is a normal, recurrent feature of climate. Climatic factors such as high temperatures, high wind, and low relative humidity are often associated with drought. Drought occurs in virtually all climatic zones, varying significantly from one region to another, and can be defined according to meteorological, hydrological, agricultural, socioeconomic, or ecological criteria, as categorized in **Table 4.20**.[xliv] Drought is differentiated based on the use and need for water.

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Table 4.20 Drought Classification Definitions

Drought Classification	Description
Meteorological Drought	The degree of dryness or departure of actual precipitation from an expected average or normal amount based on monthly, seasonal, or annual time scales. (Dry weather patterns dominate an area; can begin/end rapidly).
Hydrological Drought	The effects of precipitation shortfalls on stream flows and reservoir, lake, and groundwater levels. (Low water supply is evident; conditions take longer to develop and then recover.
Agricultural Drought	Soil moisture deficiencies relative to water demands of plant life, usually crops. (Crops significantly affected).
Socioeconomic Drought	The effect of demands for water exceeding the supply because of a weather-related supply shortfall.

Drought Classification	Description
Ecological Drought	A prolonged and widespread deficit in naturally available water supplies — including changes in natural and managed hydrology — that create multiple stresses across ecosystems

The severity of a drought depends on the degree of moisture deficiency, the duration, and the size and location of the affected area. It is generally difficult to pinpoint the beginning and the end of a drought. Because the impacts of a drought accumulate slowly at first, a drought may not be recognized until it has become well established. Even during a drought there may be one or two months with above average precipitation totals. These wet months do not necessarily signal the end of a drought and generally do not have a major impact on moisture deficits. Droughts can be short, lasting just a few months. Conversely, they can persist for several years before regional climate conditions return to normal. While drought conditions can occur at any time throughout the year, the most apparent time is during the summer months. Nationally, drought impacts often exceed $1 billion due in part to the sheer size of the areas affected.

Research supports that climate change will have significant impacts on drought frequency and intensity, which will vary by region. Higher temperatures lead to increased evaporation rates, including more loss of moisture through and plant leaves. Even in regions were precipitation does not decrease, increases in surface evaporation will lead to more rapid drying of soil if not offset by other changing factors, such as reduced wind speed or humidity. As soil dries out, a larger proportion of the sun's incoming heat will go toward heating soil and adjacent air rather than evaporating moisture, resulting in hotter temperatures and drier conditions.[xlv]

Human activities often exacerbate the impact of drought. For example, excessive water use can deplete groundwater supply or result in low reservoir levels. The City of Ann Arbor's water supply comes from the Huron River in addition to groundwater wells.

Measuring Droughts: There are several quantitative methods for measuring drought in the United States. How these indices measure drought depends on the discipline affected (e.g., agriculture, hydrology, meteorology, etc.) and the region being considered. Two main methods are the Palmer Drought Severity Index (PDSI) and the U.S. Drought Monitor. The PDSI was the first comprehensive drought index developed in the United States. The U.S. Drought Monitor is a relatively new index that combines quantitative measures with input from experts in the field. The U.S. Drought Monitor is used in this plan to assess drought occurrences in Ann Arbor.

U.S. Drought Monitor: The U.S. Drought Monitor is designed to provide the general public, media, government officials, and others with an easily understandable overview of weekly drought conditions across a county throughout the United States. The U.S. Drought Monitor is unique because it assesses multiple numeric measures of drought, including the PDSI and three

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other indices, as well as the interpretations of experts to create a weekly map depicting drought conditions across the United States. The U.S. Drought Monitor uses five drought intensity categories, D0 through D4, to identify areas of drought. These categories are shown in **Table 4.21**.

Table 4.21 U.S. Drought Monitor Categories

D0	**Abnormally Dry**	Going into drought: short-term dryness slowing planting, growth of crops or pastures. Coming out of drought: some lingering water deficits; pastures or crops not fully recovered
D1	**Moderate Drought**	Some damage to crops, pastures; streams, reservoirs, or wells low, some water shortages developing or imminent; voluntary water-use restrictions requested
D2	**Severe Drought**	Crop or pasture losses likely; water shortages common; water restrictions imposed
D3	**Extreme Drought**	Major crop/pasture losses; widespread water shortages or restrictions
D4	**Exceptional Drought**	Exceptional and widespread crop/pasture losses; shortages of water in reservoirs, streams, and wells creating water emergencies

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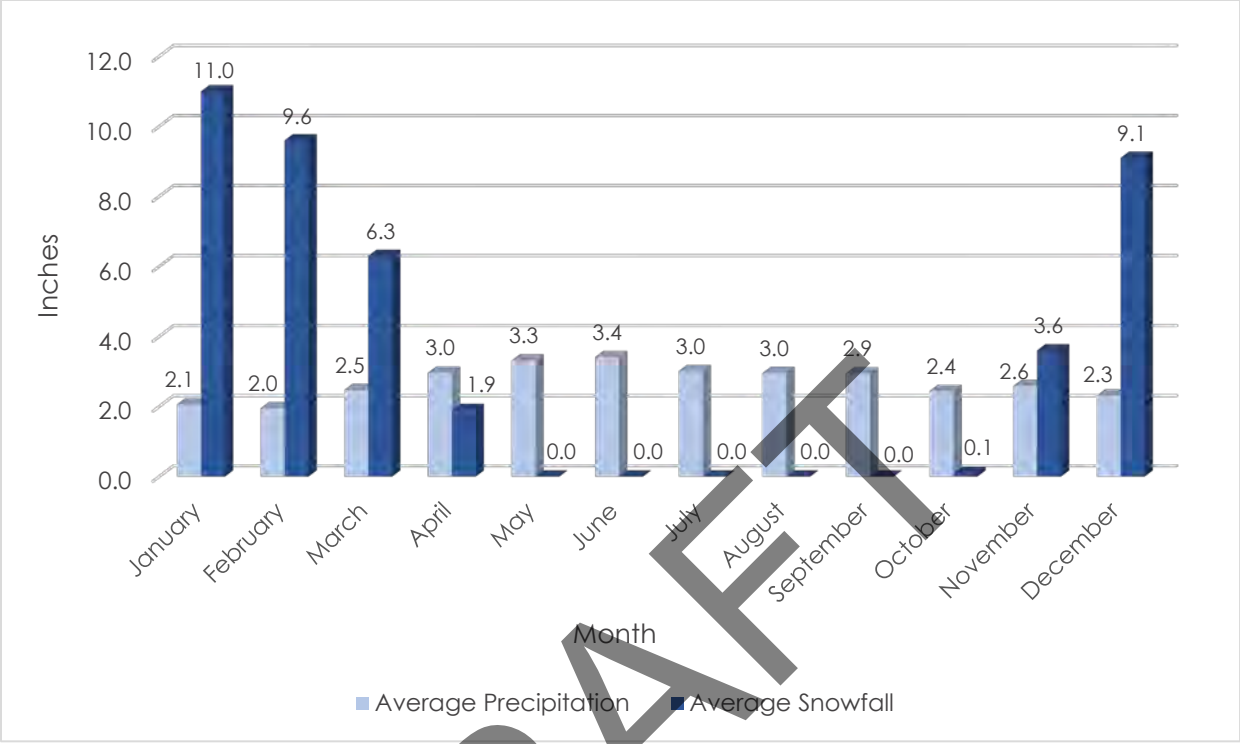
Location

A drought is a regional event that is not confined to geographic or political boundaries; it can affect several areas at once. It can also range in severity across those areas. All of Ann Arbor is at risk to drought occurrence and impacts.

Previous Occurrences

In order to understand the conditions of past drought, it can be helpful to understand the typical precipitation received each year. Ann Arbor experiences an annual average of 32.4 inches of precipitation and 41.6 inches of snowfall at the University of Michigan weather station. Monthly averages are shown in **Figure 4.15.**[xlvi]

Figure 4.15: Average Precipitation and Snowfall by Month in Ann Arbor



Source: Western regional Climate Center, Ann Arbor U of M Station (200230)
*Based on records from 1880-2016

The U.S. Drought Monitor was used to ascertain historical drought levels for Ann Arbor. The U.S. Drought Monitor reports data on drought conditions from 2000 through 2017. Drought conditions are reported by category as percentages. Therefore, it is possible that more than one drought category was reported in each week. In such cases, the highest drought category reported was used. This information is compiled and presented in **Table 4.22** below.

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Table 4.22 Historic Drought Conditions in Ann Arbor

Abnormally Dry **Moderate Drought** **Severe Drought** **Extreme Drought** **Exceptional Drought**

Year	Duration
2000	**Severe** (up to 2 weeks)
2001	**Moderate** (up to 1 week)

Year	Duration
2002	**Moderate** (up to 20 weeks)
2003	**Severe** (up to 10 weeks)
2004	**Moderate** (up to 2 weeks)
2005	**Moderate** (up to 5 weeks)
2006	**Normal** (52 weeks)
2007	**Moderate** (up to 5 weeks)
2008	**Abnormal** (up to weeks)
2009	**Normal** (52 weeks)
2010	**Moderate** (up to 4 weeks)
2011	**Abnormal** (up to 2 weeks)
2012	**Severe** (up to 4 weeks)
2013	**Abnormal** (up to 9 weeks)
2014	**Normal** (52 weeks)
2015	**Moderate** (up to 10 weeks)
2016	**Severe** (up to 1 week)
2017	**Abnormal*** (up to 6 weeks)

*Durations for 2017 include data from January through July

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In the study period, severe drought conditions occurred in 2000, 2003, 2012, and 2016. However, a notable trend is that drought conditions were present in 15 of the 18 years studied, possibly indicating a long-term issue.

In addition to data from the U.S. Drought Monitor, the 2012 Ann Arbor hazard mitigation plan describes two historic droughts that have impacted the city:

Heat Wave / Drought of 1988

The 1988 drought/heat wave in the Central and Eastern U.S. also greatly impacted Michigan, including the Ann Arbor area. Nationwide, the drought caused an estimated $40 billion in damages from agricultural losses, disruption of river transportation, water supply shortages, wildfires, and related economic impacts. The heat wave that accompanied the drought conditions was particularly long in Michigan – 39 days with 90 degree or better heat – eclipsing the previous record of 36 days recorded in the "dust bowl" days of 1934. During that 39-day stretch, the temperature in the Ann Arbor area topped the 100-degree mark on 5 occasions.

Drought of the 1960s

A period from 1962-1965 was the only clear and serious statewide drought event to take place since the 1930s, which partially demonstrates a general trend of lessening drought problems in Michigan (including the Ann Arbor area) during the second half of the 20th Century when compared with the first half. Nevertheless, this was definitely the worst drought event to strike Michigan since the 1930s. In this event, the entire Southern Lower Peninsula had to endure at least 30 consecutive drought months, many of which were at the D2 level, or worse. Again, there was a pattern in which the drought was felt more intensely the farther to the east one was located. Southeastern Michigan experienced 9 consecutive months at the exceptional D4 level of drought. The middle years of 1963-1964 were the worst phase of this event, for most parts of the state.

Droughts of the 1930s

Without a doubt, the "Dust Bowl" drought of the 1930s was the most famous drought ever to occur in the U.S. That drought was an ecological and human disaster of huge proportions. It was caused by misuse of the land combined with years with lack of rainfall. As the land dried up, great clouds of dust and sand, carried by the wind, covered everything and the term "Dust Bowl" was coined. As a result of this drought, millions of acres of farmland became useless, forcing hundreds of thousands of people to leave their farms and seek an existence elsewhere. Although exact figures were not kept, some researchers estimate that nearly $1 billion (in 1930s dollars) was provided in assistance to victims of the Dust Bowl drought. That event also ushered in a new era or farming and conservation programs and practices aimed at preventing a recurrence of a drought of the magnitude and impact of the Dust Bowl drought.

In Southwestern Michigan (including the Ann Arbor area), this "dust bowl" period took the form of a most severe statewide drought condition from 1930 to 1932, followed by a less severe period from 1933 to 1937, and finally a period of limited spotty problems between 1939 and 1940. Between 1930 and 1932, Michigan's 10th climate division experienced a severe level of drought for about 24 continuous months. The entire state was struck very hard by this event. During December and January of 1934-1935 the southeastern Michigan region set an all-time state record for the longest number of consecutive months under drought conditions—the 42 months between August 1933 and January 1937. Although the area had some months of relief in early 1938, drought conditions resumed by the end of the year for a period of 8 consecutive months; and then between 1939 and 1940, another 12-month period of drought followed.

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The Michigan state hazard mitigation plan lists historic drought occurrences by division. Ann Arbor is in Division 10, for which the following drought occurrences are listed:

- The most extreme drought was in March 1931, when the Palmer index hit a record low of -6.82.
- Lengthy drought incidents took place in:
  - 1895-1896 (8 months)
  - 1900-1902 (24 months)
  - 1913-1914 (12 months)
  - 1914-1915 (12 months)
  - 1925-1926 (13 months)
  - 1930-1932 (24 months)
  - 1933-1937 (42 months)
  - 1939-1940 (12 months)
  - 1952-1953 (8 months)

- 1953-1954 (17 months)
- 1963-1965 (35 months)
- 1971-1972 (15 months)
- 1998-1999 (9 months)

Extent

Extent can be defined by the highest drought monitor category: Exceptional Drought. The most severe drought on record for Ann Arbor occurred between 1963 and 1964, southeastern Michigan experienced nine consecutive Exceptional Drought months. It is also likely that exceptional drought status was reached during the 1930s droughts, and that these droughts were even more severe than those of the 1960s. Since the U.S. Drought Monitor began in 2000, there have been no reported weeks where all or part of Ann Arbor experienced Exceptional Drought. The highest drought category experienced by Ann Arbor during this time was Severe Drought (17 weeks total) in 2000, 2003, 2012, and 2016. However, drought events more severe than those occurring in the 1930s and 1960s are possible.

Probability of Future Occurrences

An exact probability is difficult to quantify given limited reporting period (18 years; 2000-2017). Drought conditions were reported in 15 out of 18 years for the city. This equate to a historic rate of occurrence of approximately 83 percent.

When determining future probability, the historic frequency must be considered along with projected future conditions. It is difficult to quantify the impact climate change will have on the future drought occurrence, as a number of factors, such as precipitation, humidity, and temperature, influence the formation of drought conditions. Drought is most likely to occur during summer months, when high temperatures increase the amount of surface evaporation. Summer temperatures in Ann Arbor are projected to increase 1.9 to 7.98°F degrees by 2041-2070. Further, a report from the Graham Sustainability Institute at the University of Michigan found that changes in summer precipitation in Ann Arbor are uncertain; precipitation could increase slightly, stay the same, or be reduced. These changes are likely to lead to an increase in summer droughts and up to a 30 percent decrease in soil moisture.[xlvii]

Based on historic frequency and projected future conditions, the probability of future drought occurrences is highly likely (greater than 90 percent annual chance). However, the probability of extreme of exceptional drought is less likely.

Vulnerability Assessment

Ann Arbor is generally considered a water-rich community, but has the potential to be significantly impacted by a drought. The atmospheric nature of drought and lack of specific boundaries make it difficult to quantify drought conditions. The

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majority of drought impacts, however, are not structural but societal in nature. A drought's impacts on society result from the interplay between a natural event and the demand people place on water supply.

Surface water levels in lakes, impoundments, and reservoirs can drop dramatically during drought. Groundwater supply can also be impacted. In Ann Arbor, recreational activities along the Huron River, such as canoeing, kayaking, tubing, and swimming have the potential to be impacted.

Damage to Buildings

As noted above, drought has minimal impacts on structures although it could have impacts on the functionality of the building if water supply is disrupted. In addition, structural issues could occur in the event that drought impacts building foundations or footings. There are no known losses associated with drought and buildings in Ann Arbor.

Damage to Infrastructure

Drought is expected to have minimal impacts on infrastructure. Green infrastructure, such as green stormwater infrastructure, may incur minor damages during drought occurrences if plants cannot resist drought.

Life Safety, Health, Warning and Evacuation Procedures

As drought is a slow developing hazard, it is unlikely to have significant impacts on life safety, and is not expected to result in warnings or evacuation. Drought occurrences may result in water use restrictions.

Public Health

Drought has the potential to impact public health by reducing the quality and quantity of available drinking water. While drought has never been severe enough to fully deprive the city of water, it is possible. In general, even a severe drought is unlikely to have detrimental impacts the health and safety of a community.

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Economic Impact

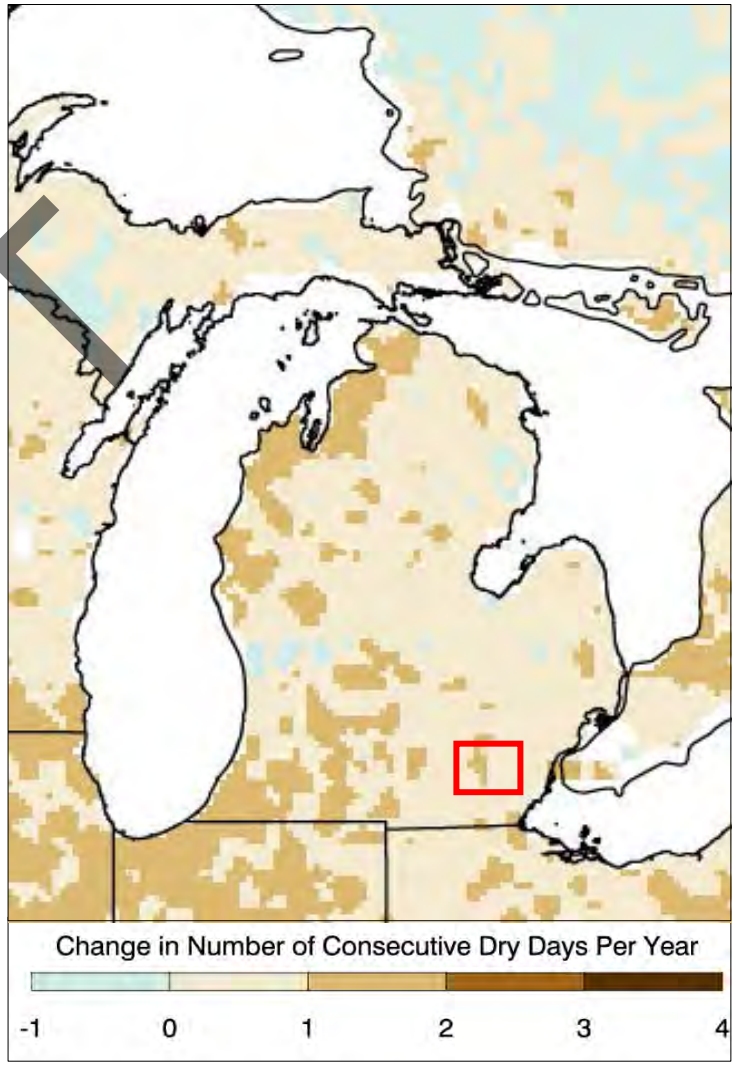
Drought can have (and has had) several economic impacts on the city. One of the most pronounced economic impacts is that on agricultural holdings, as water supply is imperative for regional crops and livestock. There is limited agriculture within the Ann Arbor city limits, but a regional drought could have severe impacts to food prices in Ann Arbor, and may even result in food shortages. Drought resulting in water shortage can also impact businesses (ranging from restaurants to manufacturing) which cannot operate without water. Lastly, in the case of a water shortage, the cost of water may increase (or the city may be forced to buy water from a water-rich area), which would have ripple effects in terms of a reduction in the local economic multiplier as money leaves the county.

Climate Change Impacts

In Ann Arbor, climate change is projected to result in increased summer droughts. Drought is most likely to occur during summer months, when high temperatures increase the amount of surface evaporation. Summer temperatures in Ann Arbor are projected to increase 4.5 to 5°F by 2041-2070. Warmer temperatures cause drought conditions by causing reduction in soil moisture. In addition, changes in summer precipitation in Ann Arbor are uncertain; precipitation could increase slightly, stay the same, or be reduced. These changes, especially in summer precipitation is reduced, are likely to lead to an increase in summer droughts and up to a 30 percent decrease in soil moisture.[xlviii] Further, maps produced by the Great Lakes Integrated Sciences + Assessments (GLISA)[xlix] shows that the number of consecutive dry days in Ann Arbor is projected to increase by 1-2 days from 2041 to 2070, as shown in **Figure 4.16.**

This information indicates that droughts in Ann Arbor could be more frequent and pronounced, which could lead to increased drought-related impacts on water quality and quantity, regional agriculture, local flora (such as Ann Arbor's tree canopy), and the local economy.

Figure 4.16: Projected Change in Consecutive Number of Dry Days



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Flood

Description

Flooding is a very frequent, dangerous and costly hazard. Globally, it accounts for 40 percent of all natural disasters and results in an average of over 6,500 deaths annually.[I] In the U.S., flooding results in an average of 86 deaths annually.[Ii] Nearly 90 percent of all presidential disaster declarations result from natural events where flooding was a major component. On average, flooding causes more than $2 billion in property damage each year in the United States. Floods cause utility damage and outages, infrastructure damage (both to transportation and communication systems), structural damage to buildings, crop loss, decreased land values and impede travel.

Flooding is the most common environmental hazard, due to the widespread geographical distribution of valleys and coastal areas, and the population density in these areas. The severity of a flooding event is typically determined by a combination of several major factors, including: stream and river basin topography and physiography; precipitation and weather patterns; recent soil moisture conditions; and the degree of vegetative clearing and impervious surface. Flooding events can be brought on by severe (heavy) rain. There are several types of flooding, which are presented below.

Flash Flooding: Flash floods occur within a few minutes or hours of heavy amounts of rainfall and can destroy buildings, uproot trees, and scour out new drainage channels. Heavy rains that produce flash floods can also trigger mudslides and landslides. Most flash flooding is caused by slow-moving thunderstorms or repeated thunderstorms in a local area, or by heavy rains from hurricanes and tropical storms (not applicable in Ann Arbor). Although flash flooding often occurs in mountainous areas, it is also common in urban centers where much of the ground is covered by impervious surfaces.

Sheet Flooding: Sheet flooding is a condition where storm water runoff forms a sheet of water to a depth of six inches or more. Sheet flooding and ponding are often found in areas where there are no clearly defined channels and the path of flooding is unpredictable. It is also more common in flat areas. Most floodplains are adjacent to streams or oceans; although, almost any area can flood under the right conditions where water may accumulate.

Urban Flooding: Urban flooding is usually caused by heavy rain over a short period of time. As land is converted from fields or woodlands to roads and parking lots, it loses its ability to absorb rainfall. Since sidewalks and roads are non-absorbent, rivers of water flow down streets and into sewers. Roads and buildings generate more runoff than forestland. Fixed drainage channels in urban areas may be unable to contain the runoff that is generated by relatively small, but intense, rainfall events. Urbanization increases runoff two to six times over what would occur on natural terrain. This high volume of water can turn parking lots into lakes, flood basements and businesses, and cause lakes to form in roads where drainage is poor or overwhelmed.

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Urban flooding, which can include flash flooding and sheet flooding, can also occur where there has been development within stream floodplains. This is partly a result of the use of waterways for transportation purposes in earlier times. Sites adjacent to rivers and coastal inlets provided convenient places to ship and receive commodities. The price of this accessibility has increased flooding in the ensuing urban areas. Urbanization intensifies the magnitude and frequency of floods by increasing impermeable surfaces, amplifying the speed of drainage collection, reducing the carrying capacity of the land and, occasionally, overwhelming sewer systems.

Riverine Flooding: Periodic flooding of lands adjacent to non-tidal rivers and streams (known as the floodplain) is a natural and inevitable occurrence. When stream flow exceeds the capacity of the normal watercourse, some of the above-normal stream flows onto adjacent lands within the floodplain. Riverine flooding is a function of precipitation levels and water runoff volumes within the watershed of a stream or river. According to USGS, the recurrence interval of a flood is defined as probability of an event in any given year (e.g. 1 percent annual chance). Flood magnitude increases with increasing recurrence interval.

In addition, there are several types of floodplains. These are identified areas of flood occurrence. However, not all flooding occurs in such areas. Localized urban flooding and flash flooding often occur outside of designated floodplain areas.

Floodplains: A floodplain is generally the land area susceptible to being inundated or flooded by water from any source (i.e., river, stream, lake, estuary, etc.). Floodplains are natural features of any river or stream. Streams that drain more than one square mile have their estimated floodplain areas mapped in most areas. The mapped floodplain areas are called the regulatory floodplain. The regulatory floodplain mapping is a result of the hydrologic (rainfall) and hydraulic (runoff) analysis of the watershed and stream.

The regulatory floodplain is also known as the 100-year floodplain, base flood elevation, 1.0-percent annual chance floodplain or the Special Flood Hazard Area. The 100-year floodplain is the land area that is su bject to a 1.0 percent or greater chance of flooding in any given year. The term "100-year flood" is often misinterpreted. The 100-year flood does not mean that it will occur once every 100 years. A 100-year flood has a 1/100 (1 percent) chance of occurring in any given year. A 100-year flood could occur two times in the same year or two years in a row. It is also possible not to have a 100-year flood event over the course of 100 years or more.

The floodway is portion of the floodplain required to convey the flood event. The flood fringe provides flood water storage. The floodway is the high velocity area and structures or obstructions in the floodway can increase flood heights. The floodway is regulated by the Michigan Department of Environmental Quality and local regulations. Michigan DEQ regulations prohibit residential construction in the floodway.[lii]

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While the 100-year (or base flood) is the standard most commonly used for floodplain management and regulatory purposes in the United States, the 500-year flood, also known as the 0.2-percent annual chance flood area, is the federal standard for protecting critical facilities, such as hospitals and power plants (when federally funded). A 500-year flood has a 1/500 (0.2 percent) chance of occurring in any given year. It is generally deeper than a 100-year flood and covers a greater amount of area; however, it is statistically less likely to occur.

Special Flood Hazard Area and Flood Insurance Rate Maps: A Special Flood Hazard Area (SFHA) shown on a Flood Insurance Rate Map (FIRM) is the regulatory floodplain. FIRMs are produced by FEMA. SFHAs are delineated on the FIRMs and may be designated as Zones A, AE, AO, AH, AR V, VE, A-99. Structures located in the SFHA are highly susceptible to flooding. Structures located in the SFHA A-Zones are required by lenders to purchase flood insurance. Anyone in a community that participates in the NFIP may voluntarily purchase flood insurance. The following SFHA zones are present within Ann Arbor:

- Zone A: Zone A is the flood insurance rate zone that corresponds to the 1.0-percent annual chance floodplains determined in the Flood Insurance Study by approximate methods. Because detailed hydraulic analyses are not performed for such areas, no Base Flood Elevations (BFEs) or depths are shown within this zone. Mandatory flood insurance purchase requirements apply.

- Zone AE: Zone AE is the flood insurance rate zone that corresponds to the 100-year floodplains determined in the Flood Insurance Study by detailed methods. In most instances, BFEs derived from the detailed hydraulic analyses are shown at selected intervals within this zone. Mandatory flood insurance purchase requirements apply.

In addition to SFHA zones, Zone X is also present in Ann Arbor. Zone X corresponds to areas outside of the 1.0 percent annual chance flood area, and includes areas in the 0.2 percent annual chance flood boundary and areas of minimal flood hazard.

Flooding can occur any time of year. The severity of flooding is determined by a combination of topography and physiography, ground cover, precipitation and weather patterns and recent soil moisture conditions. Flooding is also governed by the size and the nature of the stream's watershed. A watershed is the geographic area of land where all runoff drains to a common point. Ann Arbor is located within the Huron River Basin, and its landscape includes seven watersheds that flow into tributaries of the Huron River. Including Honey Creek, Allen Creek, Malletts Creek, Swift Run, the Huron River, Traver Creek, Millers Creek, and Fleming Creek, as depicted in **Figure 4.17.**

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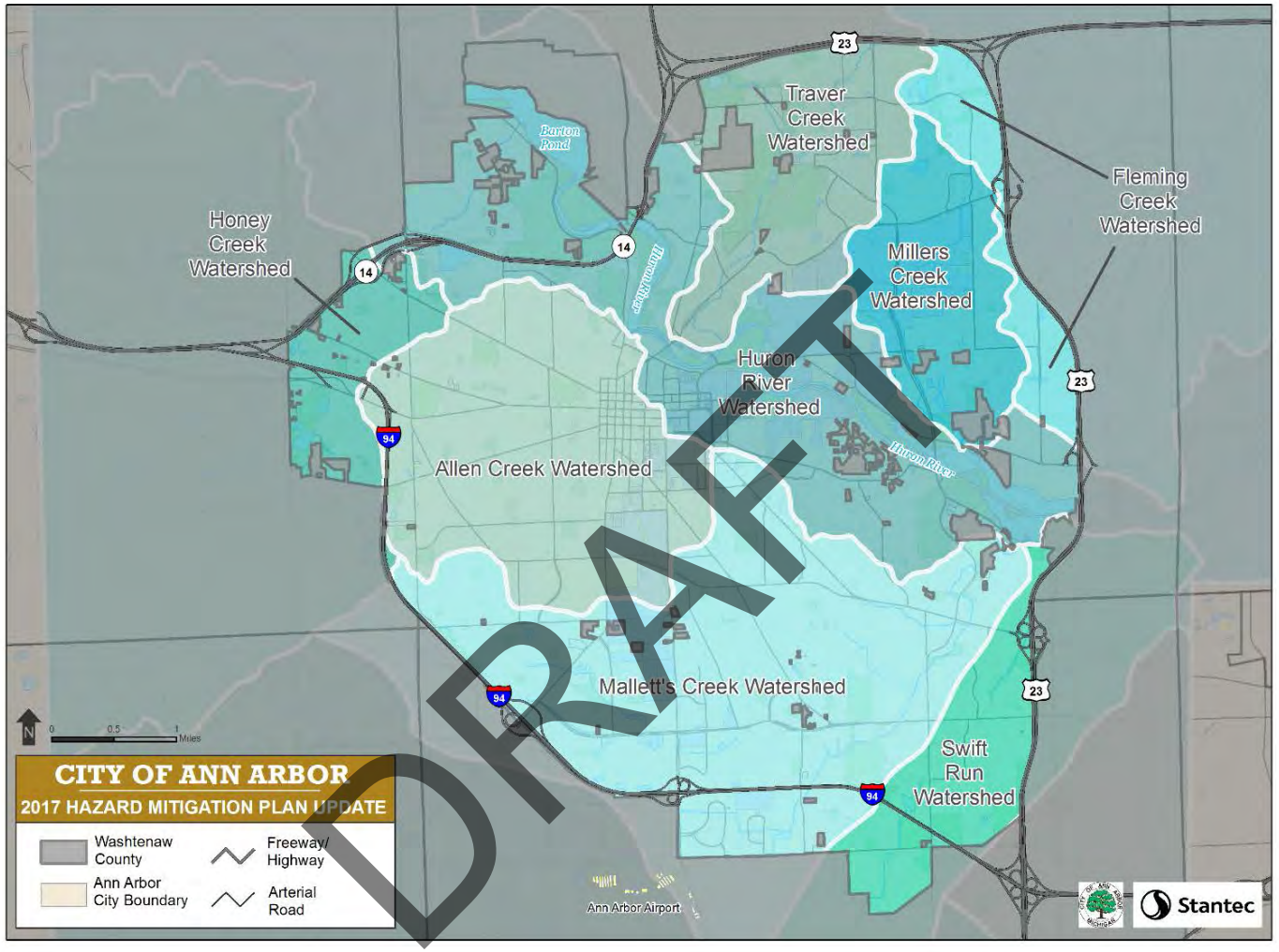
Figure 4.17: Ann Arbor Watersheds



The condition of the land in a watershed affects precipitation flows or infiltrates. For example, more rain will run off the land and into the streams if the terrain is steep, if the ground is already saturated from previous rains, if the watershed is significantly covered with impervious pavement and parking lots, or if depressional storage areas have been filled.[liii]

Scientists have established that climate change will have significant impacts on flood frequency and intensity, which will vary by region. Generally, higher temperatures will result in drier conditions and will reduce flood magnitude and frequency. Precipitation changes will vary across the United States. Generally, wet areas will get wetter and dry areas will get drier. Increased precipitation is typically associated with increased flood frequency and magnitude. What may have more of an effect on flooding is increasing heavy precipitation events. Heavy rainfall events have increased for most of the United States over the last several decades. The Midwest has experienced a 37 percent increase in the amount of precipitation falling in heavy rainfall events from 1958 to 2012, and climate projections suggest this trend will continue.[liv]

Location

The Washtenaw County DFIRMs, which include the City of Ann Arbor, indicate both the 1.0-percent annual chance (100-year) floodplain and 0.2-percent annual chance (500-year) floodplain areas in the city as shown in **Figure 4.18.** These DFIRMs became effective in 2013. In Ann Arbor, there are approximately 1,052 acres in the 1.0-percent annual chance flood area (including 747 acres in the floodway), and approximately 353 acres in the 0.2-percent annual flood chance area. In total, Ann Arbor has a total of 1,405 acres in FEMA floodplain areas, which corresponds to 7.6 percent of the city's total acreage.

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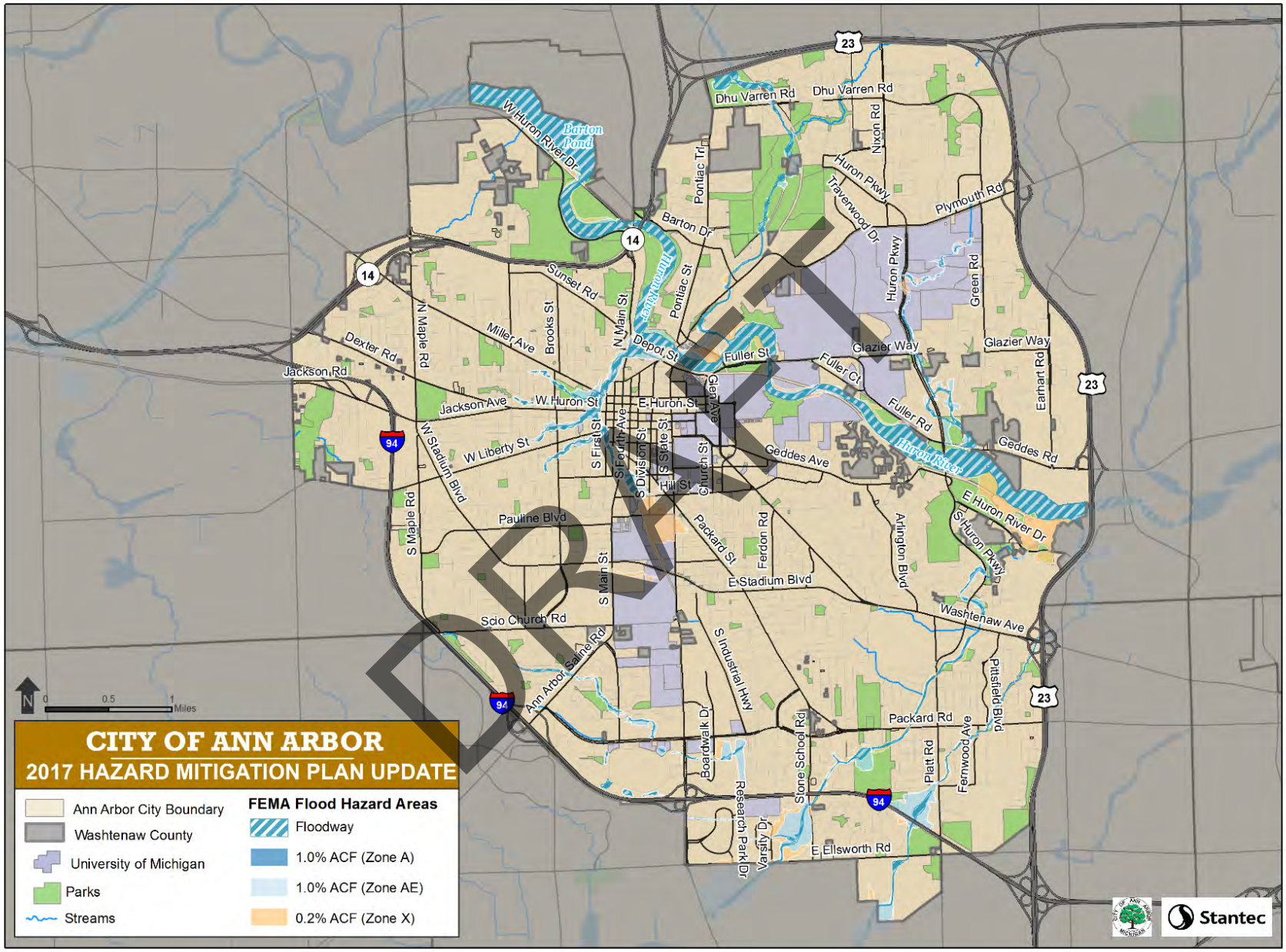
Figure 4.18: Ann Arbor FEMA Floodplain Areas



However, it should be noted that flooding outside of the FEMA designated flood areas is possible. A more severe event could easily exceed the 0.2-percent annual chance (500-year) floodplain boundaries shown. Urban flooding and sheet flooding are possible throughout the planning area.

In 2015, the city completed a 3-year stormwater model study (the SWMM Project) that analyzed the drainage system for the entire city. Among other objectives, the study used flow and water level data to simulate a 1-percent floodplain using a model called InfoSWMM, and compared model results to the FEMA regulatory floodplain. The study compared model results to FEMA FIRMs for the Allen, Malletts, Millers, Swift, and Traver creeksheds (floodplain/floodway associated with the Huron River was not included). Model results compared to the FEMA regulatory floodplain are shown in **Figure 4.19.** According to the study, there are two main areas where the FEMA FIRM maps and the InfoSWMM model results differ:

- Allen Creek south of Hill Street (**Figure 4.20)** – On the effective FEMA DFIRM, the area of Allen Creek located south of Hill Street is not included in the 1.0 percent annual flood chance area (it is included in the 0.2 percent annual chance flood area). Using the InfoSWMM model data, the floodplain delineation would extend south through Hoover and S. State Street.

- Upper Malletts Creek (**Figure 4.21)** – The scope of the existing FEMA floodplain delineation did not extend west of South Seventh Street because of tributary area size limitations in the mapping procedure. Using the citywide stormwater model for stormwater data would not have this restriction so the Upper Malletts Creek area was included in the delineation.

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Figure 4.19: Ann Arbor InfoSWMM Model Flood Hazard Area and FEMA SFHA Comparison

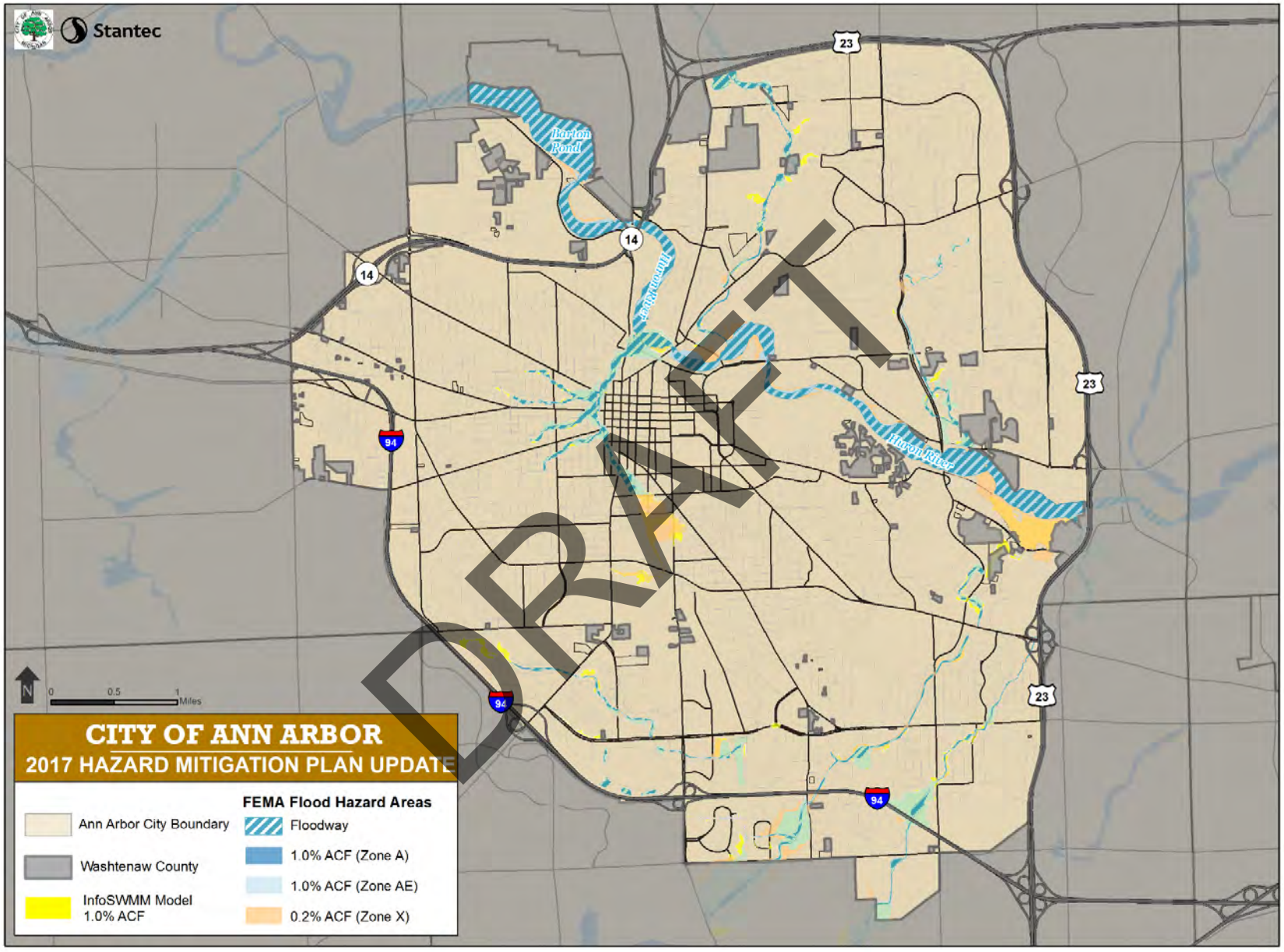

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Figure 4.20: Ann Arbor InfoSWMM Model Comparison – Allen Creek South of Hill Street

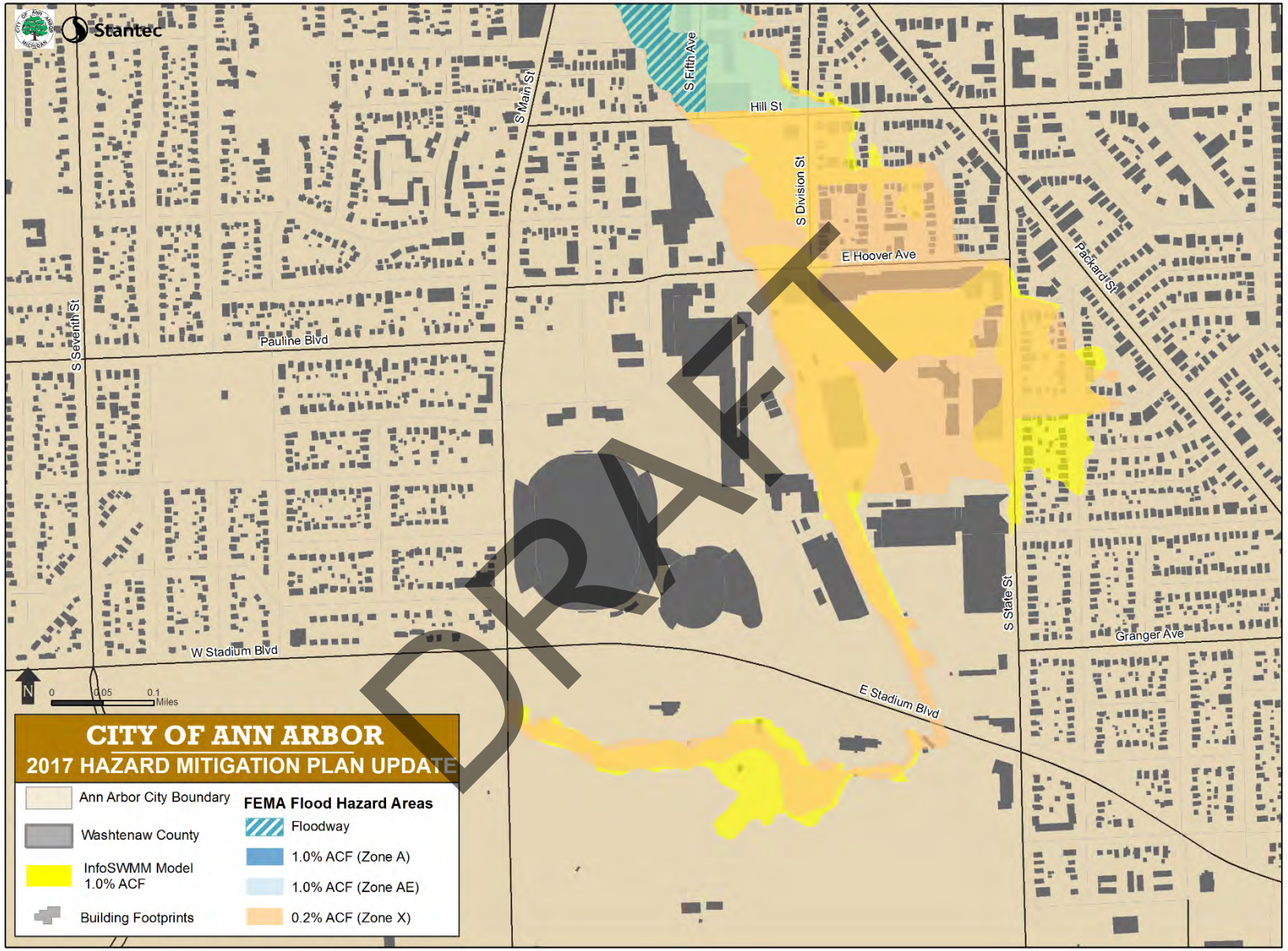
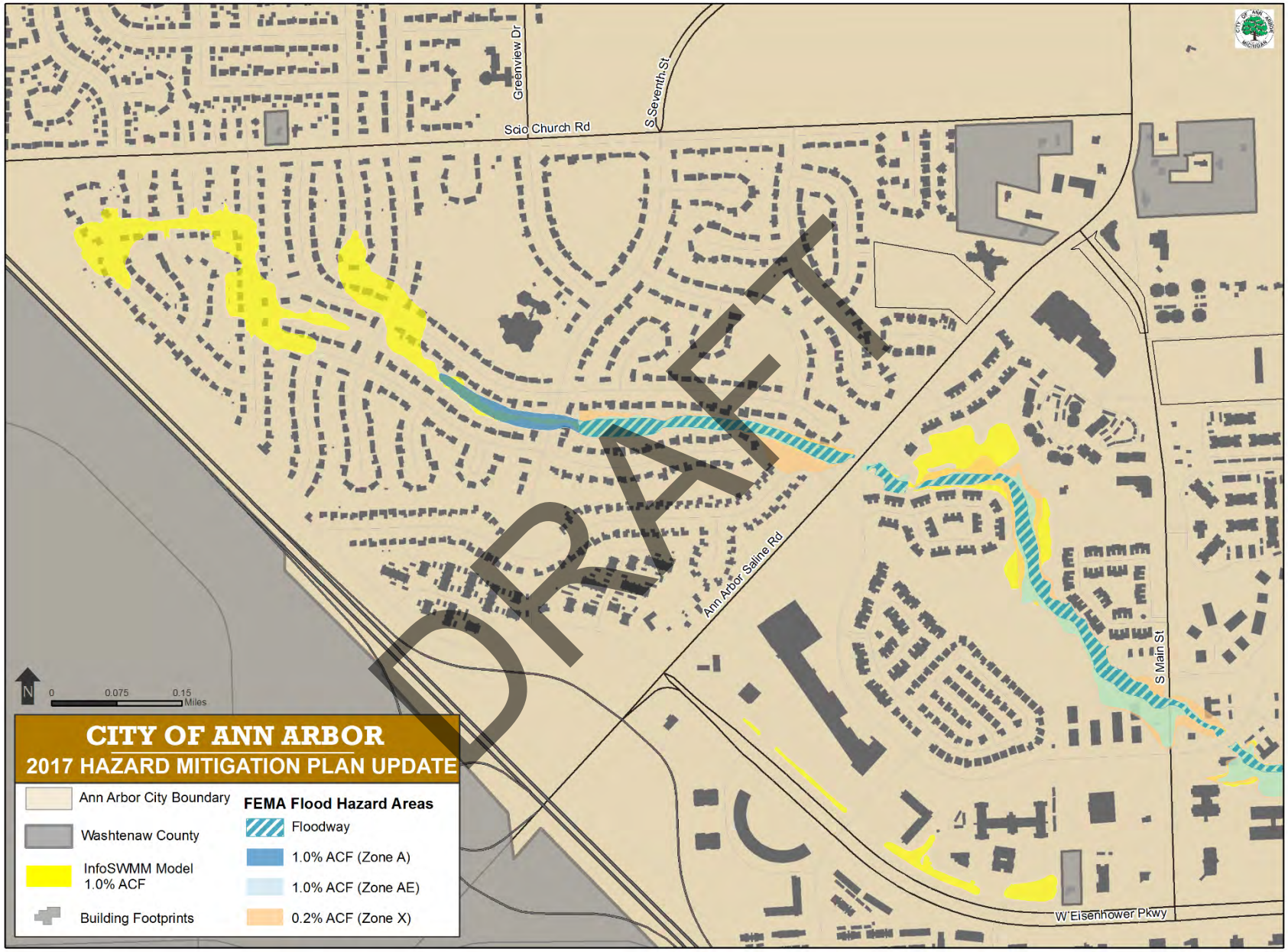


Figure 4.21: Ann Arbor InfoSWMM Model Comparison – Malletts Creek West of S. Seventh Street



In addition, the public and the Technical Advisory Committee were asked to identify areas that are subject to flooding, which are reported below in **Figure 4.22.** These areas were identified in three ways: 1) during a windshield tour with the Ann Arbor Emergency Manager; 2) during a map exercise with the Technical Advisory Committee; or 3) during the public Kickoff Meeting. Several of the flood locations noted by the TAC or the public are in FEMA floodplain areas, such as the floodplain associated with Allen Creek or the area near Briarwood Mall.

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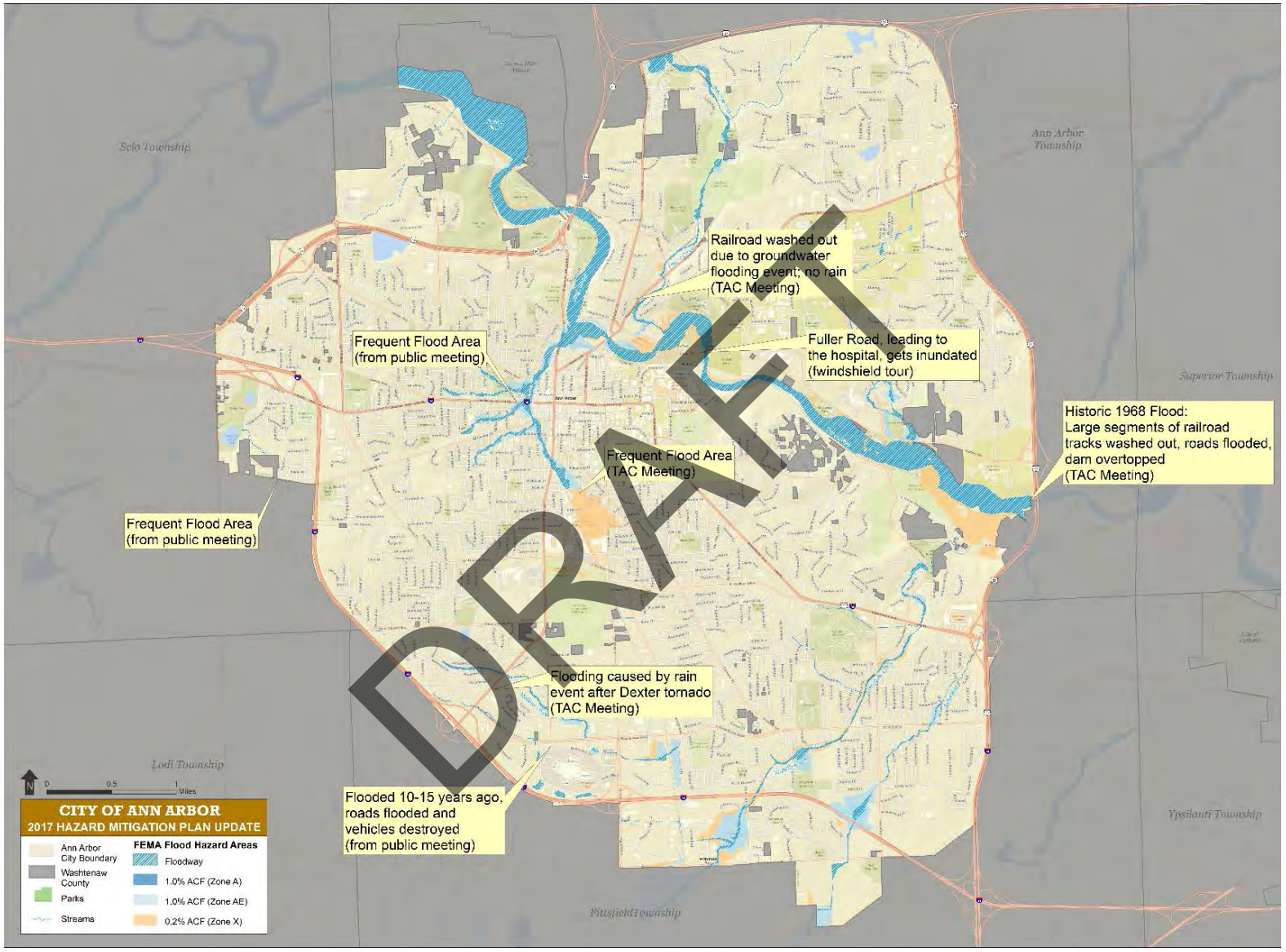
Figure 4.22: Additional Areas of Known Flood Occurrence



Previous Occurrences

Several outside data sources were used to assess past flood events in Ann Arbor: NCEI Storm Events Database and National Flood Insurance Policy (NFIP) claims data provided by the city. Descriptions of notable flood occurrences from the 2012 Ann Arbor hazard mitigation plan, as well as accounts from local news sources, the TAC, and the public, are also included.

Table 4.23 summarizes the previous flooding occurrences reported in Ann Arbor between 1996 and August 2017 by NCEI. Details for each reported event can be found in Appendix C. Out of 31 events recorded for Washtenaw County, 13 were reported in Ann Arbor. No injuries or fatalities were reported as a result of flooding. Just under $1.6 million (2017 dollars) in damages were reported.

Table 4.23 NCEI Reported Flood Events in Ann Arbor

Event Type	Number of Events	Deaths/Injuries	Property Damage (2017 dollars)
Flood	5	0/0	$107,195
Flash Flood	8	0/0	$1,484,628
Total	**13**	**0/0**	**$1,591,823**

Descriptions of notable flood events in Ann Arbor reported by NCEI and the 2012 Ann Arbor Hazard Mitigation Plan are presented below.

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June 1968 Flood Event

This event is considered one of the most severe flood events in Ann Arbor's history. Until the development of DEMA FIRMs in the 1980s, this flood was used to as a baseline for a 100-year flood in Ann Arbor. As measured at the University of Michigan, rainfall totals reached 5.28 inches (the current 100-year, 24-hour rainfall is 5.11 inches). Widespread damage occurred to buildings, bridges, dams, roads, and personal property. Hundreds of basements were flooded, and sewers were backed up throughout the city. Approximately 1,400 feet of railroad tracks were washed out, and multiple dams failed.[lv]

August 1998 Flash Flood

Thunderstorms and heavy rainfall developed over southeast Michigan. Ann Arbor received 4.12 inches of rain, which led to flooding in urban areas. In Ann Arbor, Mallets Creek rose out of its banks. The creek destroyed sidewalks in the Briarwood Mall area, and swept three cars into a retention pond. Some flooding also took place on the Athletic (South) Campus of the University of Michigan. Resulting damages were $1,394,633 (2017 dollars). This event was by far the costliest event reported by NCEI.

June 2000 Flood
Thunderstorms resulted in flooding over southeast Michigan. An Arbor received 2 to 3 inches of rain. Newport Road was closed after a culvert failed and the road collapsed. Westbound Interstate 94, on the west side of Ann Arbor, was closed for much of the 25th, as water covered the road. Resulting damages were $33,057 (2017 dollars).

July 2000 Flood
Up to three inches of rain fell on the south side of Ann Arbor, producing basement flooding and sewer backups. Resulting damages were $66,114 (2017 dollars).

September 2000 Flash Flood
Thunderstorms developed over southeast Michigan, leading to heavy rains. Many places had seen heavy rain the day before, and thus the area was quite vulnerable to flooding. In Washtenaw County, 2.26 inches of rain fell in Ann Arbor, after 1.32 inches the previous day. The storms had a broad impact. Ann Arbor had numerous stalled cars and flooded intersections, including a foot of water over Huron Street and Washtenaw Avenue. The heavy rain indirectly contributed to a fatality, when a female pedestrian was struck and killed by a University of Michigan bus during a blinding downpour. Regionally, over 30,000 households were affected by power outages. About one hundred flights out of Detroit Metro Airport were cancelled, and numerous people were stranded at the airport overnight due to the multitude of flooded roads in the area. Resulting damages were $66,114 (2017 dollars).

February 2001 Flood
The Huron River in Ann Arbor rose above flood stage of 15 feet at 9 pm on the 9th. The river crested at 15.7 feet at 2 am on the 11th.There was isolated road flooding across the county, with some cars stalled out in water. Resulting damages in Ann Arbor were $8,024 (2017 dollars).

June 2010 Flash Flood
Intense thunderstorm rain lead to rainfall totals of 3 to 7 inches, generally in a 12-hour period of less, which lead to flash flooding across a few counties in southeast Michigan. This is substantial, as the 100-year, 24-hour heavy rainfall event in Ann Arbor is 5.11 inches. Widespread flooding was reported in the Ann Arbor, with cars stranded on Jackson road and I-94. Resulting damages in Ann Arbor were $23,881 (2017 dollars).

Aside from the events detailed above, the city experienced additional 100-year flood events in 1902 and 1947, but little information was available regarding these events. In addition, flooding caused by water rising from a high groundwater table (i.e., seepage or groundwater flooding) has been documented in Ann Arbor.

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NFIP Considerations

The city became a member of the NFIP in 1982. NFIP data shows 327 active policies, and at 53 flood losses (32 closed) incurred as of June 30, 2017. A total of $281,600 was paid for those claims, averaging $8,800 paid per claim. Ann Arbor joined the Community Rating System (CRS) in May 2017, and participates as a Class 7. At the time of the city's previous hazard mitigation plan, 442 properties were covered under the NFIP. **Table 4.24** provides a summary of flood insurance claims paid for all flood events.

Table 4.24 Summary of Ann Arbor NFIP Properties and Flood Losses

Location	Number of NFIP Policies in Force	Insurance in Force ($)	Total Number of Flood Losses (Closed) Incurred	Total Claims Payments ($)	Average Payment ($)
City of Ann Arbor	327	$76,548,500	53 (32)	$281,600	$8,800

NFIP Repetitive Flood Loss (RL) Structures:

FEMA defines a "repetitive loss structure" as a flood-insured structure that has received two or more flood insurance claim payments of more than 25 percent of the market value within any 10-year period. The city's floodplain manager provided repetitive loss data as of August 2017. The data showed 7 RL structures throughout Ann Arbor. The previous version of this plan listed 4 properties, indicating an increase in RL properties. These RLs resulted in 20 losses total, and over $240,800 in payments, or an average of $12,000 per loss. RL property types include single family residential, other residential, and non-residential structures within the city. RL data is presented in **Table 4.25.** Ann Arbor does not have any severe RL properties.

Table 4.25 Ann Arbor NFIP RL Properties

Location	Number of Properties	Types of Properties	Total Number of Losses	Building Payments ($)	Content Payments ($)	Total Payments ($)	Average Payment ($)
City of Ann Arbor	7	Single Family Residential, Other Residential, and Non-Residential	20	192,338	48,480	240,819	$12,041

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Extent

Flood extent, or magnitude, can be defined in several ways including peak flow or discharge rate (cubic feet per second), height of flood waters, and damages. United States Geological Survey (USGS) stream gage data can often be used to determine the above factors. There are three USGS stream gages in Ann Arbor: one on the Huron River, a second on Allen Creek, and a third on Mallets Creek. Discharge rates were available for the Huron River gage; drainage area, discharge rates, and available flood stage data are shown in **Table 4.26**. Maximum discharge and maximum mean gage height are used to indicate extent. Median gage height data was not available.

Table 4.26 USGS Stream Gage Data for Ann Arbor

Water Feature	Median Discharge (cubic feet/second)	Max Discharge (cubic feet/second) (year)	Drainage Area (square miles)	Max Gage Height (feet/year)
Huron River	155	609 (2010)	729	17.5

In addition, injuries and loss of life and damages can be associated with the flood hazard.

Greater floods are possible, especially with increasing precipitation due to climate change and development pressure within the watershed. Increasing impervious cover results in increased runoff volumes and consequently, increased flooding. In addition, development within floodplains can, over time, increase base flood elevations as well as increasing the number of people and businesses located in flood hazard areas, resulting in more property damage, injuries, and loss of life.

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Probability of Future Occurrences

In the last 21 years, there have been 13 reported flood occurrences (Riverine and Flash Flood) according to NCEI. These records do not consider events that occurred prior to NCEI recorded (1996) or prior to the city joining the NFIP (1982). Further, many events go unreported.

Probability of flooding could increase with changing climate conditions. Increases in precipitation, especially in the frequency and intensity of extreme events, could increase the probability of flooding or that dams will fail or overtop. Warmer temperatures may negate some of the flooding effects of increased precipitation, but may also result in more snow falling as rain.

Based on the above, a probability of likely (between 10 and 90 percent annual chance) was assigned. While flooding, especially urban flooding, is a regular occurrence within Ann Arbor, it is possible to have years with no flood events and years with multiple flood events.

Natural Floodplain Functions

Environmental assets are important to consider when assessing flood risk and potential mitigation actions. Environmental assets may be used to leverage additional drainage or water storage capacity. Environmental assets also offer co-benefits. For example, wetland areas protect sensitive wildlife habitat while slowing and storing floodwater, and natural areas can serve both as recreation and water storage. Ann Arbor has several natural resources that are considered environmental assets. For example, the city has an above average tree canopy, and plans for its expansion are outlined in the city's Urban and Community Forest Management Plan. In addition, the Huron River and several of its tributaries run through the city, resulting in the presence of riverine habitat, riparian lands, and freshwater wetlands. Many of these areas in Ann Arbor are preserved as open space, parks, or greenways. Wetlands are areas in which soils are permanently or intermittently saturated. Wetlands are considered waters of the United States and are subject to the jurisdiction of the U.S. Army Corps of Engineers as well as the Michigan Department of Environmental Quality. The U.S. Fish and Wildlife Service may also have authority over any wetlands that provide habitat for endangered species.

Wetlands provide many valuable ecological services, including benefits to water quality, wildlife protection, recreation, and lastly, natural hazard mitigation. Wetlands provide water storage during flood peaks and slowly release floodwaters downstream. The flow of water is reduced in wetlands by soils, rocks, and vegetation. The reduction in floodwater velocity reduces the rate at which sediments are eroded, and may even allow sediments and other pollutants to settle out of the water column. However, wetlands cannot perform these functions when they become severely degraded or are filled and covered with impervious material. Therefore, protecting wetlands in their natural state, through parks, open space, or natural preserves, aids in flood mitigation.

Wetlands are often found in floodplains and low-lying areas of a watershed. Ann Arbor is home to many wetlands, including freshwater forested, emergent, riverine, lake, and pond wetlands. Types of wetlands within the city, as reported by the National Wetland Inventory (NWI), are presented in **Figure 4.23** overlayed by the city's parks and natural areas**.** In addition, **Figure 4.24,** shows wetlands in Ann Arbor available from the Michigan DEQ Wetland Mapper Tool, which includes NWI wetlands as well as state-identified wetlands. Ann Arbor has over 260 acres of open space, 126 of which are natural areas.

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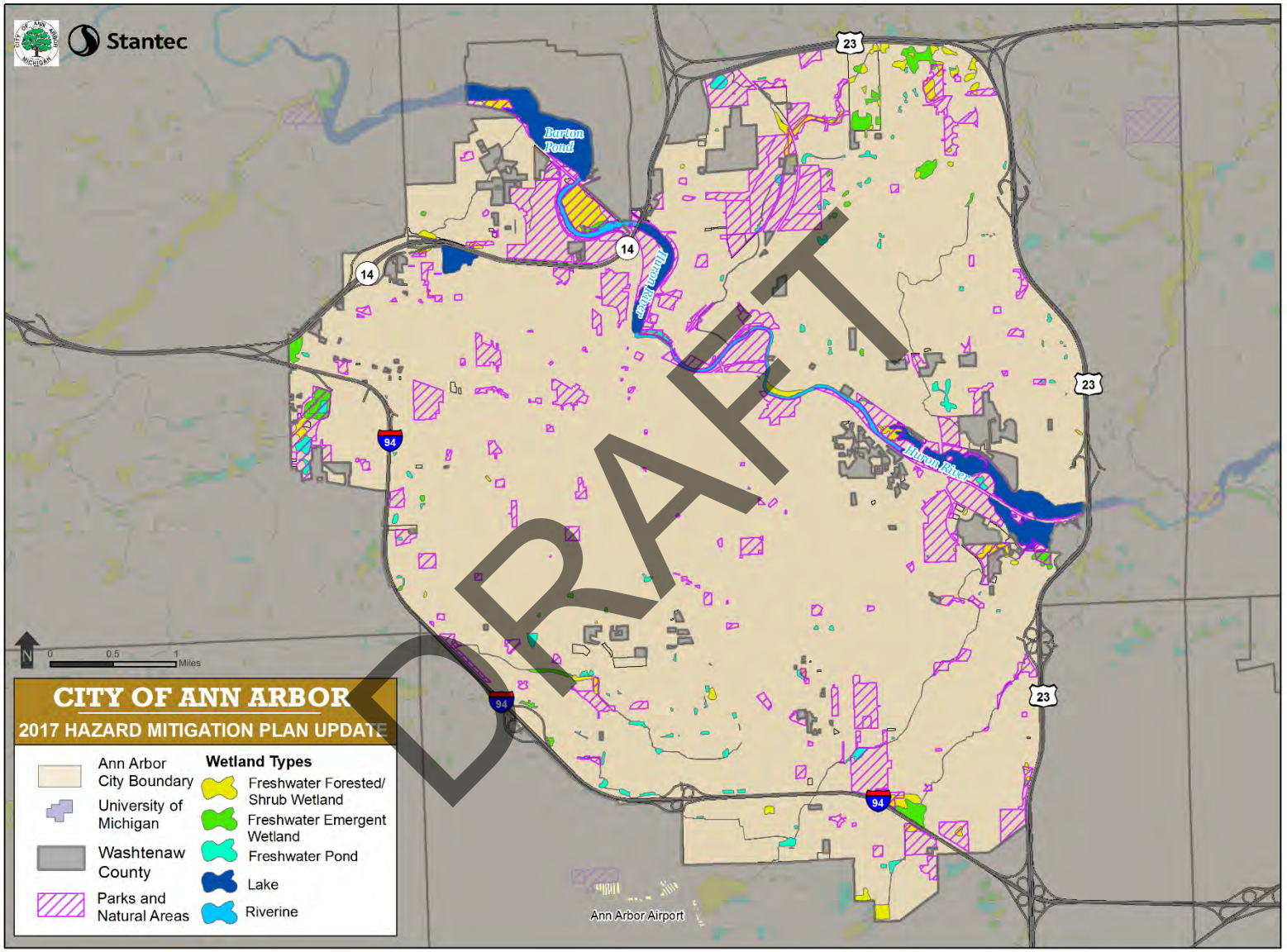
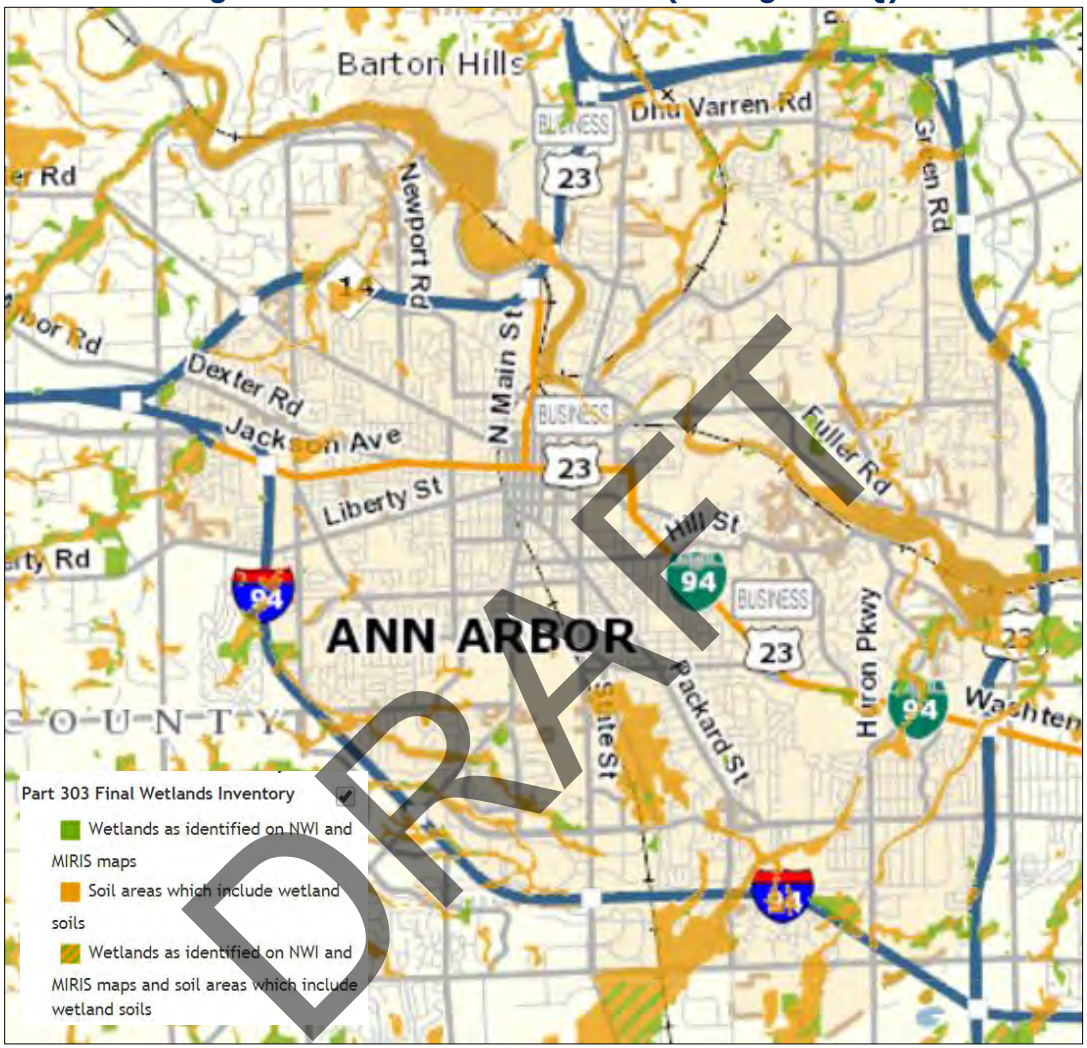
Figure 4.23: Ann Arbor NWI Wetlands and Parks



Source: U.S. Fish and Wildlife National Wetlands Inventory

Figure 4.24: Ann Arbor Wetlands (Michigan DEQ)



Vulnerability Assessment

With a growing population and increasing development, Ann Arbor is susceptible to increased flooding. Being aware of this fact, Ann Arbor has taken steps through the Ann Arbor Flood Mitigation Plan and comprehensive planning to protect against

new flood damages. Ann Arbor has also adopted stormwater management guidelines for public streets. These efforts are discussed in *Section 5: Capability Assessment*.

Despite these steps, Ann Arbor is still vulnerable to significant flooding due to existing development. Potential annualized loss from flooding is estimated at $47,590 (2017 dollars). GIS analysis was used to determine FEMA special flood hazard areas (A and AE Zones) cover approximately 2.2 square miles of the city (7.6 percent of the city's area). An examination of land parcel data and the digital FIRM (100-year floodplain map), shows 1,211 parcels of land that are either within or touch the FEMA mapped 100-year floodplain (3.7 percent). However, buildings outside of these areas are still at risk. In fact, a significant number of insurance claims are from properties outside of regulatory special flood hazards areas (FEMA 1.0 percent ACF). Recent events in Houston, TX estimated this figure as high as 80 percent. As a result, all current and future buildings, infrastructure, and populations in Ann Arbor are considered at risk to flooding.

Flooding concerns in the Huron River watershed are increasing as additional runoff is discharged by new development. In Ann Arbor, new development and densification of previously developed areas, including those within mapped flood hazard areas. As previously noted, flooding from water rising from a high water table is also a concern in several areas of the city.

Damage to Buildings

In order to assess flood risk, a GIS-based analysis was used to estimate exposure to flood events using Digital Flood Insurance Rate Map (DFIRM) data in combination with building footprint data and local tax assessor records for the city. Results from the city's InfoSWMM flood model were also reviewed. The determination of assessed value at-risk (exposure) was calculated using GIS analysis by summing the total assessed building values for improved properties that were confirmed to be located within or partially within an identified floodplain. The figures below highlight flood hazard areas.

- **Figure 4.25** shows building footprints located within the FEMA 1.0 percent area, FEMA 0.2 percent area (non-regulatory), and the InfoSWMM 1.0 percent area (non-regulatory).
- **Figure 4.26** shows building footprints within flood hazards areas in the downtown area, associated with Allen Creek and the Huron River.
- **Figure 4.27** shows building footprints in flood hazard areas located in the southern part of the city, associated with Mallets Creek and Swift Run.
- **Figure 4.28** show at risk buildings in the eastern part of the city, associated with Miller Creek and the Huron River.

The number of building footprints, parcels, improvements, and their associated value are presented in **Table 4.27.** It should be noted that for each flood hazard area, there are more improved parcels than building footprints; it can be deduced that the difference in these totals occurred when an improved parcel was partially located in a flood hazard area, but building(s) on that parcel were located out of the flood hazard area. This is an approximate analysis for planning purposes. This analysis does not account for building elevations. It should also be noted that flooding occurs outside of mapped floodplains.

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Figure 4.25: Ann Arbor Structures Located in Floodplain Hazard Areas

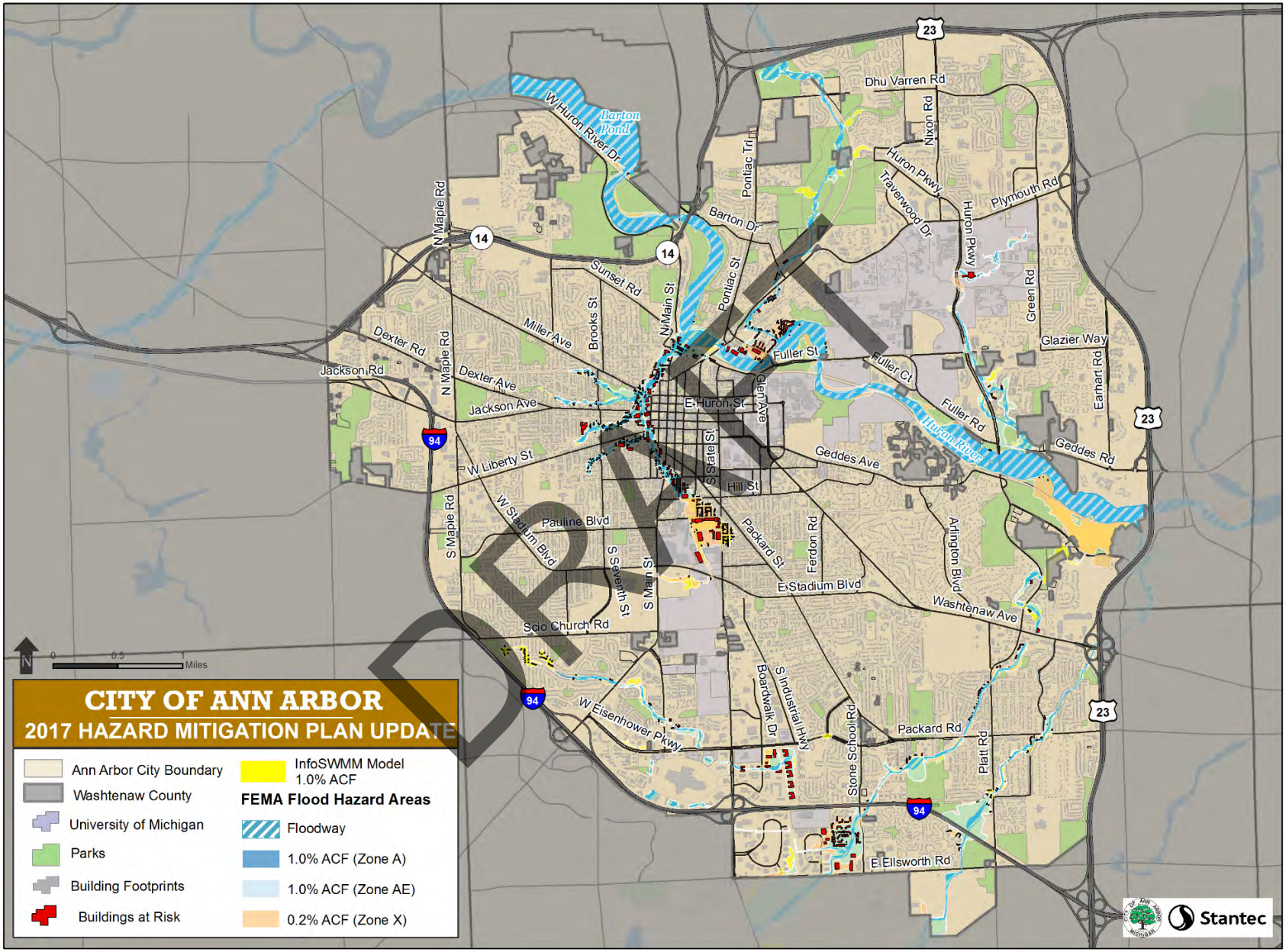

Figure 4.26: Structures Located in Floodplain Hazard Areas – Downtown/Allen Creek Area

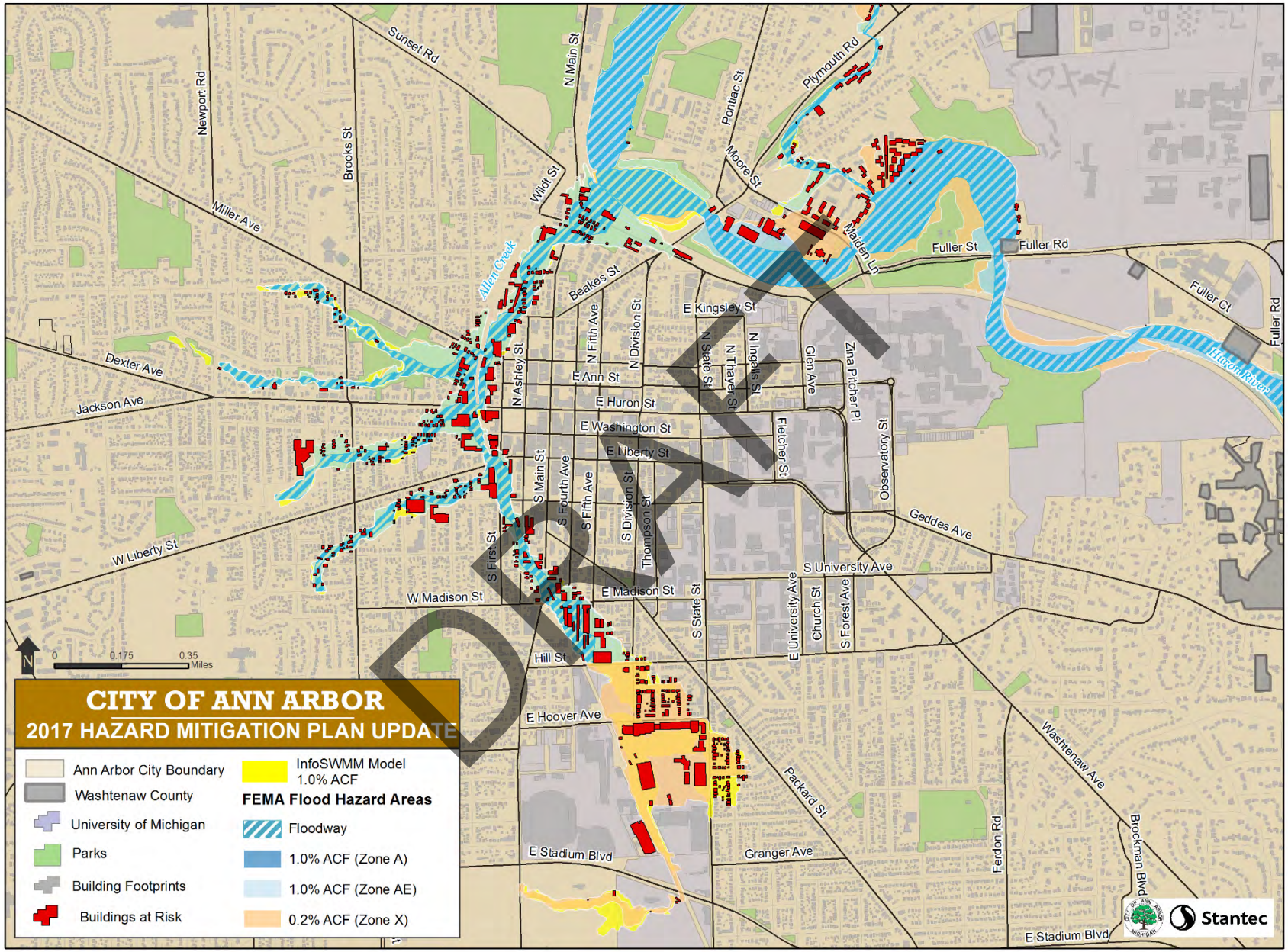

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Figure 4.27: Structures Located in Floodplain Hazard Areas – South Ann Arbor

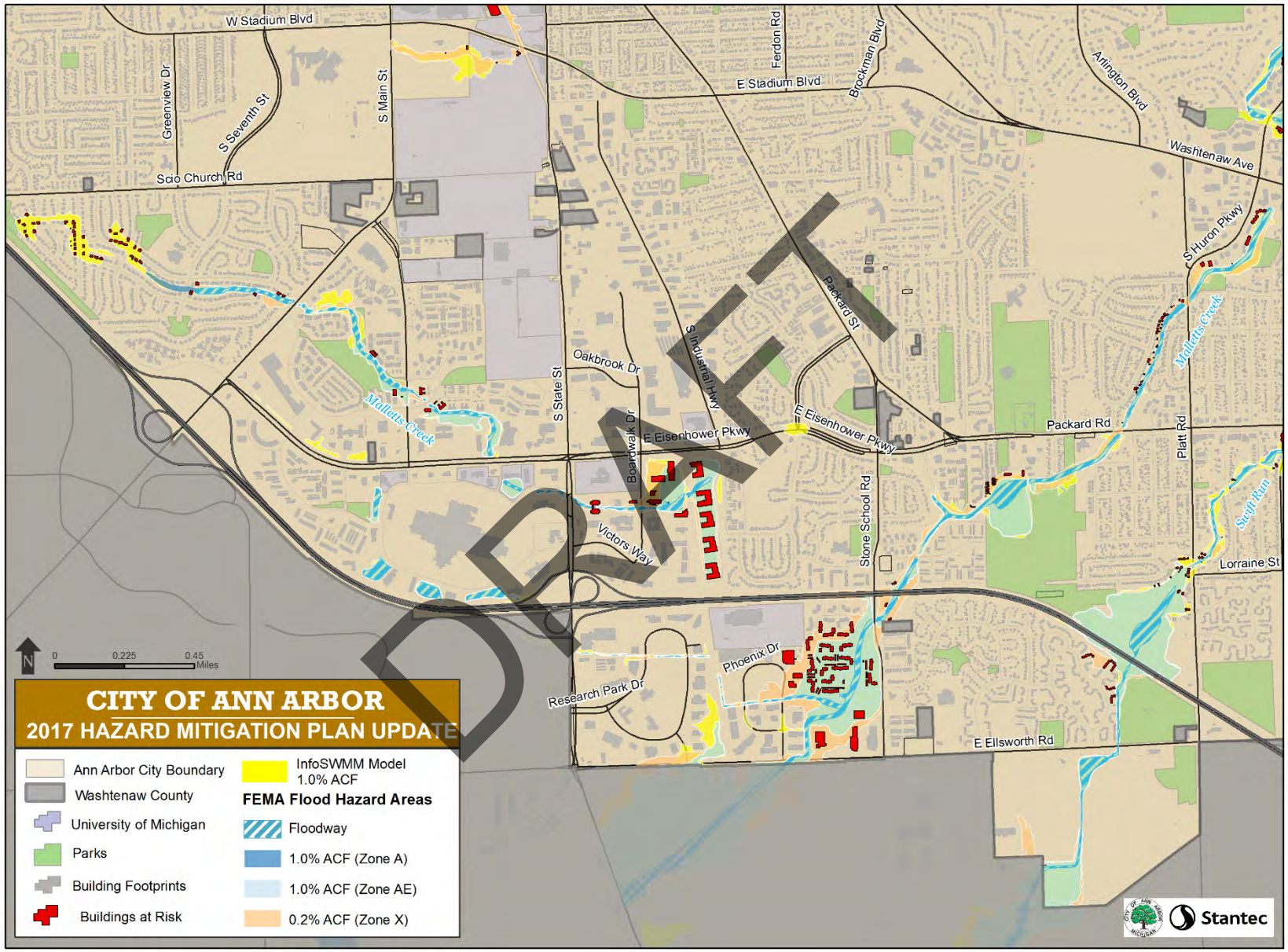

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Figure 4.28: Ann Arbor Structures Located in Floodplain Hazard Areas – Eastern Ann Arbor

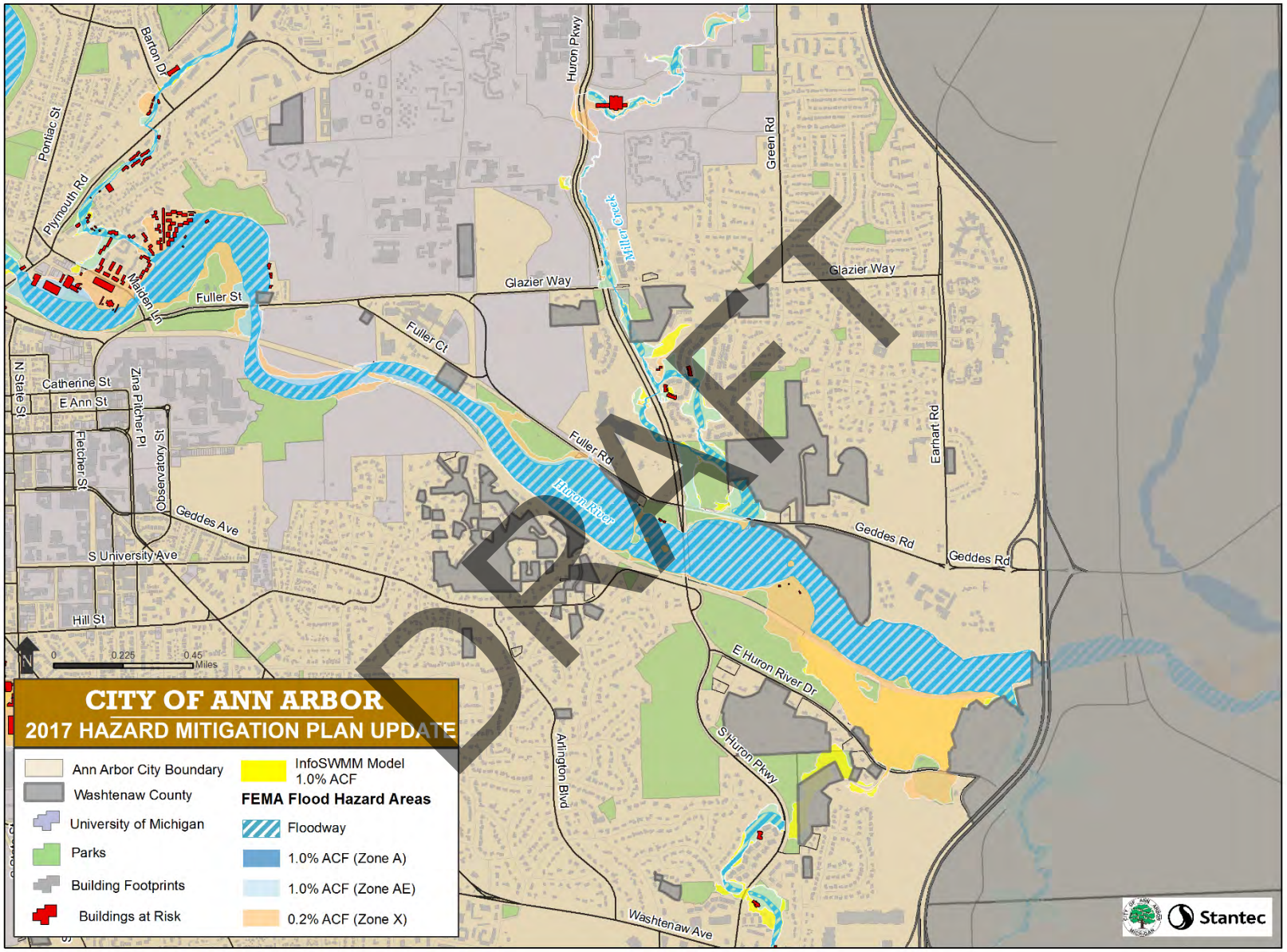

Table 4.27 Potentially At-Risk Parcels, Buildings, and Improvement Value in Floodplain Hazard Areas

Flood Hazard Area	Number of At-Risk Parcels	%	Number of At-Risk Improved Parcels	%	Value of At-Risk Improvements (2017 Dollars)	%	Number of At-Risk Building Footprints	%
FEMA 1.0 percent ACF Area	1,211	3.7%	953	3.2%	$868,639,880	8.6%	512	1.4%
FEMA 0.2 percent ACF Area	409	1.3%	356	1.2%	$165,255,743	1.6%	208	0.6%
InfoSWMM 1.0 percent ACF Area	184	0.6%	164	0.6%	$33,975,194	0.3%	74	0.2%
Total	**1,804**	**5.6%**	**1,473**	**5.0%**	**$1,067,870,817**	**10.5%**	**794**	**2.2%**

**The Ann Arbor InfoSWM 1.0percent ACF (non-regulatory) includes only parcels and building footprints that are not accounted for either the FEMA 1.0percent ACF or the FEMA 0.2percent ACF areas*
**Buildings and parcels partially within a flood hazard area were considered to be in that flood hazard area; where a building or parcel is located within the both the 1.0percent ACF and 0.2percent ACF, it was considered to be in the 1.0percent ACF to avoid double-counting. Data for parcels in the InfoSWMM flood area was obtained from the city.*
**Number and value of improvements is tied to parcels, not building footprints. Therefore, the improvement (i.e., building) on a parcel partially located in a flood hazard area may be located outside of the flood hazard area.*
**Improvement value for InfoSWMM parcels adjusted from 2012 tax values.*

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The data in the table above indicates that there are approximately 1,804 parcels potentially in or partially within floodplain areas, and that 1,473 of the parcels are improved. The improved value of property on these parcels is over $1 billion. Although 5 percent of improved parcels, and 2.2 percent of building footprints are located in flood areas, over 10 percent of Ann Arbor's total building improvement value is located on parcels within or partially within flood areas. Again, this total could include improvements located on a parcel within a flood hazard area in which the building itself is not within or wholly within the flood area. This methodology to assess potential flood damage includes some level of uncertainty. In the case of the parcel value analysis, building footprints were not connected to parcels, so flooding on the parcel was equated to damage. Also, this is improved value, which is not synonymous with insured or replacement value.

Structures exposed to flooding can be severely damaged. Building contents can be lost, damaged, or destroyed, and structures themselves can be compromised by floodwaters. Pressure from floodwater, especially as seepage through soil, can damage building foundations. After a flood, wooden structures may rot.

Development and Redevelopment Trends

In addition to current at-risk structures, future structures in the floodplain are also at risk. One way to assess potential future risk is to analyze future land uses designated for flood hazard areas. **Figure 4.29** shows generalized future land uses from Ann Arbor's Future Land Use Map overlayed with flood hazard areas. While much of the floodplain and floodway, especially that which is associated with the Huron River, are designated as open space, certain areas are designated for growth, such as high density residential, commercial, and institutional uses in the Allen Creek floodplain, and high density residential, industrial/research, and public uses in the floodplain associated with Malletts Creek.

Figure 4.29: Ann Arbor Future Land Uses in Floodplain Hazard Areas

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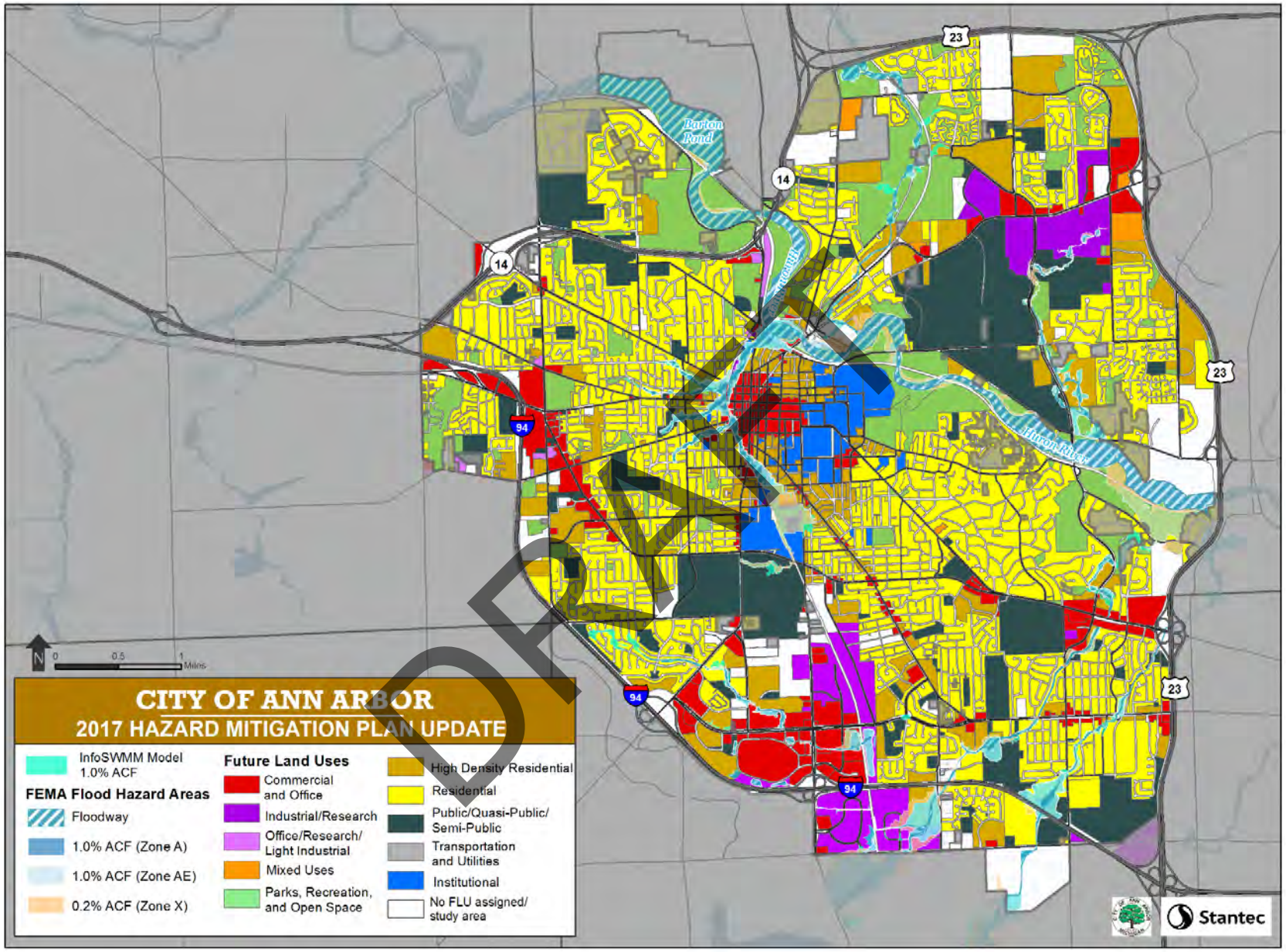
CITY OF ANN ARBOR
2017 HAZARD MITIGATION PLAN UPDATE
InfoSWMM Model 1.0% ACF
FEMA Flood Hazard Areas
Floodway
1.0% ACF (Zone A)
1.0% ACF (Zone AE)
0.2% ACF (Zone X)
Future Land Uses
Commercial and Office
Industrial/Research
Office/Research/ Light Industrial
Mixed Uses
Parks, Recreation, and Open Space
High Density Residential
Residential
Public/Quasi-Public/ Semi-Public
Transportation and Utilities
Institutional
No FLU assigned/ study area
Burton Pond
Huron River
Stantec

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In addition to the city's future land use map, high growth areas were identified by the TAC during a mapping exercise. These areas are presented in **Figure 4.30.** High growth areas in the floodplain include areas around Allen Creek, and an area north of downtown along the Huron River**.**

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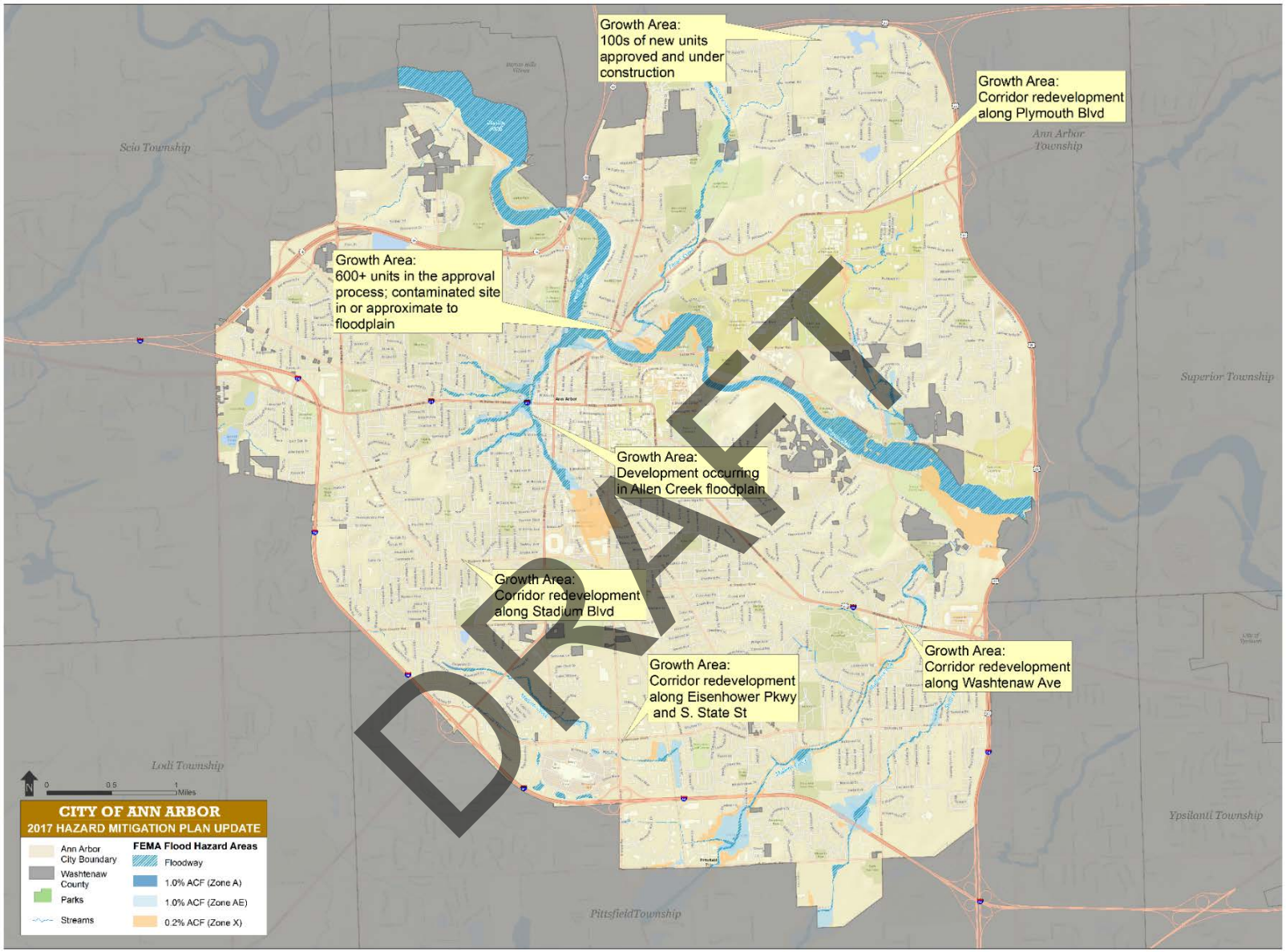
Figure 4.30: Ann Arbor High Growth Areas


Growth Area:
100s of new units approved and under construction
Growth Area:
Corridor redevelopment along Plymouth Blvd
Growth Area:
600+ units in the approval process; contaminated site in or approximate to floodplain
Growth Area:
Development occurring in Allen Creek floodplain
Growth Area:
Corridor redevelopment along Stadium Blvd
Growth Area:
Corridor redevelopment along Eisenhower Pkwy and S. State St
Growth Area:
Corridor redevelopment along Washtenaw Ave
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Scio Township
Ann Arbor Township
Superior Township
Lodi Township
Ypsilanti Township
Pittsfield Township
0 0.5 1 Miles
CITY OF ANN ARBOR
2017 HAZARD MITIGATION PLAN UPDATE
Ann Arbor City Boundary
Washtenaw County
Parks
Streams
FEMA Flood Hazard Areas
Floodway
1.0% ACF (Zone A)
1.0% ACF (Zone AE)
0.2% ACF (Zone X)

Life Safety, Health, Warning and Evacuation Procedures

The public often underestimates the dangers presented by floodwaters. Flooding is often localized to certain parts of a community (e.g., certain roads, intersections, or neighborhoods), and floodwaters can prevent normal access to buildings. This presents a danger when motorists and pedestrians attempt to traverse floodwaters. Motor vehicles and pedestrians can get swept up in flood currents, increasing the risk for drowning. Even in shallow waters, fast-moving currents can carry individuals or vehicles into deeper waters, where pressure from flowing water can prevent drivers from escaping submerged vehicles. As little as 6 inches of floodwater can move a vehicle, and as little as 2inches can move a person. In addition, floodwaters often conceal conditions that are a danger to those on foot, including electrical wires, debris, nails, and open manholes hidden beneath the surface. In addition, roads and bridges can be weakened by flood impacts, making them unsafe for travel.

While it is fortunate that Ann Arbor has not experienced a flood devastating enough to require evacuation for some time, this makes Ann Arbor more vulnerable if such an event were to occur. In communities that are not often required to evacuate, evacuation procedures may not be well-known to the public. During a large-scale flood event, residents may not be familiar with proper routes to lead them out of harm's way. Furthermore, Ann Arbor regularly experiences an influx of people for University of Michigan game days (upwards of 100,000 people). If a flood event were to occur on a game day, it is likely that visitors would not be familiar with evacuation routes. Exercises and road markers are ways communities can become familiar with evacuation procedures. On a positive note, the traffic management employed during game days helps keep local officials up to date on evacuation needs.

Figure 4.31 shows the population density (by census tract) overlayed with floodplain hazard areas in Ann Arbor based on the 2011-2015 American Community Survey. Estimating the population in flood hazard area based on the census tracts below is misleading. Even if the population in a flood hazard area was estimated using a census tract's population estimate, it is likely that populations may be concentrated outside of flood hazard areas. There are approximately 382 residential structures in the FEMA 1.0 percent flood area. According to American Community Survey 2011-2015 estimates, Ann Arbor averages a household size of 2.23 people per household. Therefore, it can be estimates that approximately 852 people are living within the FEMA regulatory floodplain. However, this is a planning-level analysis and does not account for structures with multiple units (such as apartment buildings). Therefore, the number of people in the floodplain could be much higher.

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Figure 4.31: Ann Arbor Population Density in FEMA Floodplain Hazard Areas

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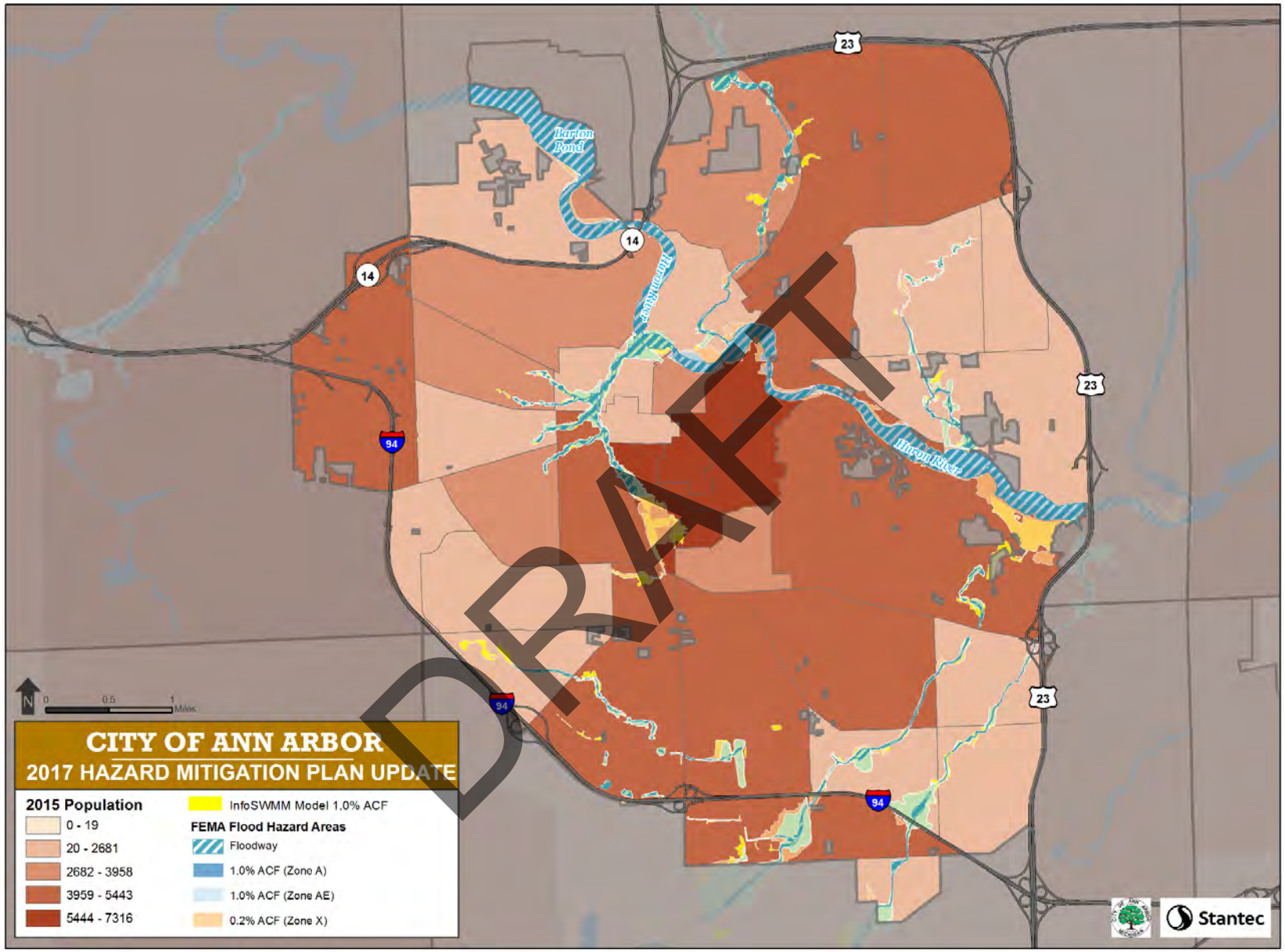

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According to data from the Washtenaw County Sheriff, between 1992 and 2015, the county experienced an average of 2.54 flood watches, 1.63 advisories, and 1.29 flood warnings annually. It is unknown how many of these notices included Ann Arbor.

Public Health

Floodwaters often contain contaminants such as bacteria and chemical hazards. Flooding often results in combined sewer overflows, resulting in sewage in floodwaters. Individuals traversing floodwaters or children playing in floodwaters contract diseases, injuries, and infections.

Structures exposed to floodwaters can also present public health hazards. Damaged electrical systems and natural gas tanks present risk of fire and explosions. Structures exposed to flooding may develop mold or wood rot. People with asthma, allergies, or breathing conditions may be at a higher risk to mold.[lvi]

Trains or trucks carrying hazardous materials during flood events have the potential spill or release hazardous materials due to crashes or derailments, which could negatively impact public health. Fixed-sites, such as factories or industrial facilities, can also release hazardous materials when their buildings are flooded.

Economic Impact

Flood damage to businesses is difficult to estimate. Businesses that are disrupted by floods often have to be closed. They lose their inventories, customers cannot reach them, and employees are often busy protecting or cleaning up their flooded homes. Business can be disrupted regardless of the business being located in the floodplain when customers and clients cannot reach their location. Business interruption is also forgone sales tax for the city. As with flooded roads, public expenditures on flood fighting, sandbags, fire department calls, clean-up and repairs to damaged public property affect all residents of the city, not just those in the floodplain.

Climate Change Impacts

Climate change could affect future flood impacts in Ann Arbor as data shows increasing precipitation trends for the city. Ann Arbor precipitation increased by 44.2 percent from 1951 to 2014.[lvii] Further, the frequency of severe precipitation events has increased in Ann Arbor over the last 30 years; the frequency of the 25-year, 24-hour storm event has increased by 9 percent, and the 100-year, 24-hour storm event has increased by 17 percent.[lviii] Further, heavy rainfall events have grown faster than total precipitation, meaning that more precipitation is concentrated in extreme rainfall events, which in turn could lead to increased flooding. According to the data from University of Michigan's GLISA, these trends will continue into future climate conditions. **Figure 4.32** shows the projected change in average precipitation from 2041-2070 under a high emissions scenario. According to the map, Ann Arbor will experience of 3 to 4 inches per year during the study period. **Figure 4.33** shows the projected change in extreme rainfall events from 2041-2070 under a high emissions scenario; according to the map, Ann Arbor will see an increase of 1.0-1.5 days per year during the study period. In addition, more snow falling as rain in the winter

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months, as temperatures warm, could increase precipitation totals. According to the Michigan state hazard mitigation plan, spring flooding could worsen as snowfall melting patterns change with increasing temperatures.

It should also be noted that warmer temperatures could negate some of the projected increases in precipitation by increasing evaporation and creating drier conditions, especially in the summer months. Future flood-risk will depend upon a number of future factors: realized increases in temperature combined with realized increases in precipitation and heavy rainfall events, as well as future development trends and adopted mitigation actions.

The Huron River Watershed Council, in collaboration with the University of Michigan, developed a Climate Justice Index (CJI) for the planning area. The CJI considers three factors: climate change-induced flooding, environmental hazards, and social vulnerability (see the Risk Assessment Tools subsection in the Section for methodologies). The CJI ranks areas at the census tract level based on their concentration of socially vulnerable populations and exposure to climate-change induced flooding and contamination aggravated by floods. Ranks are from 1 to 5, where one is the least impacted by climate change, and 5 is the greatest. A "High Impact" scenario (+1°C temper/+20 percent precipitation) was used to examine climate justice results for Ann Arbor. The baseline CJI (zero flooding increase) for Ann Arbor is presented in **Figure 4.34,** and the CJI under the High Impact scenario is presented in **Figure 4.35.** Under baseline conditions, most the city is ranked as a 3, with the exception of the northeastern corner, which is ranked as a 2. Under the High Impact climate scenario, the northeast, south and far west parts of the city are ranked as a 3, with the central and northern parts ranks as a 4. These results indicate that all census tracts will experience an increase in the number of flood days per year.

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Figure 4.32: Projected Change in Average Precipitation from 2041-2017

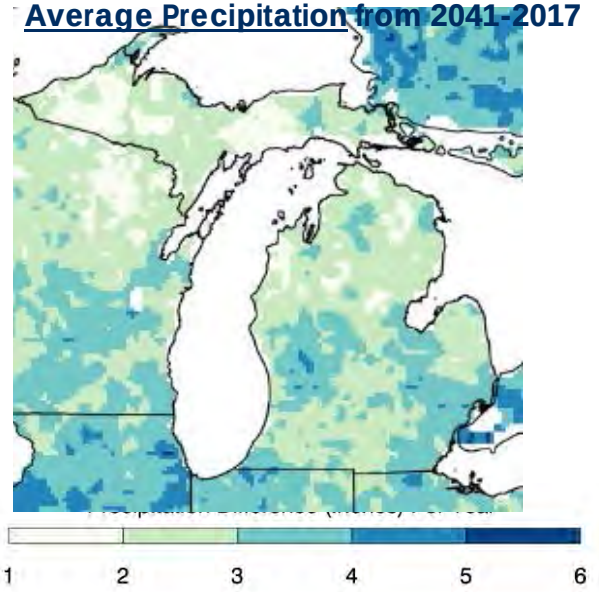


Figure 4.33: Projected Change in Extreme Rainfall Days from 2041-2017

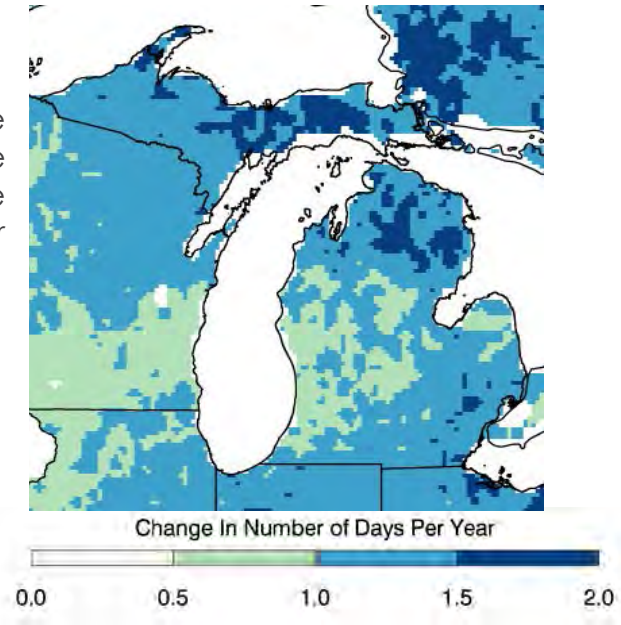


Figure 4.34: Ann Arbor Climate Justice Index Baseline Rankings

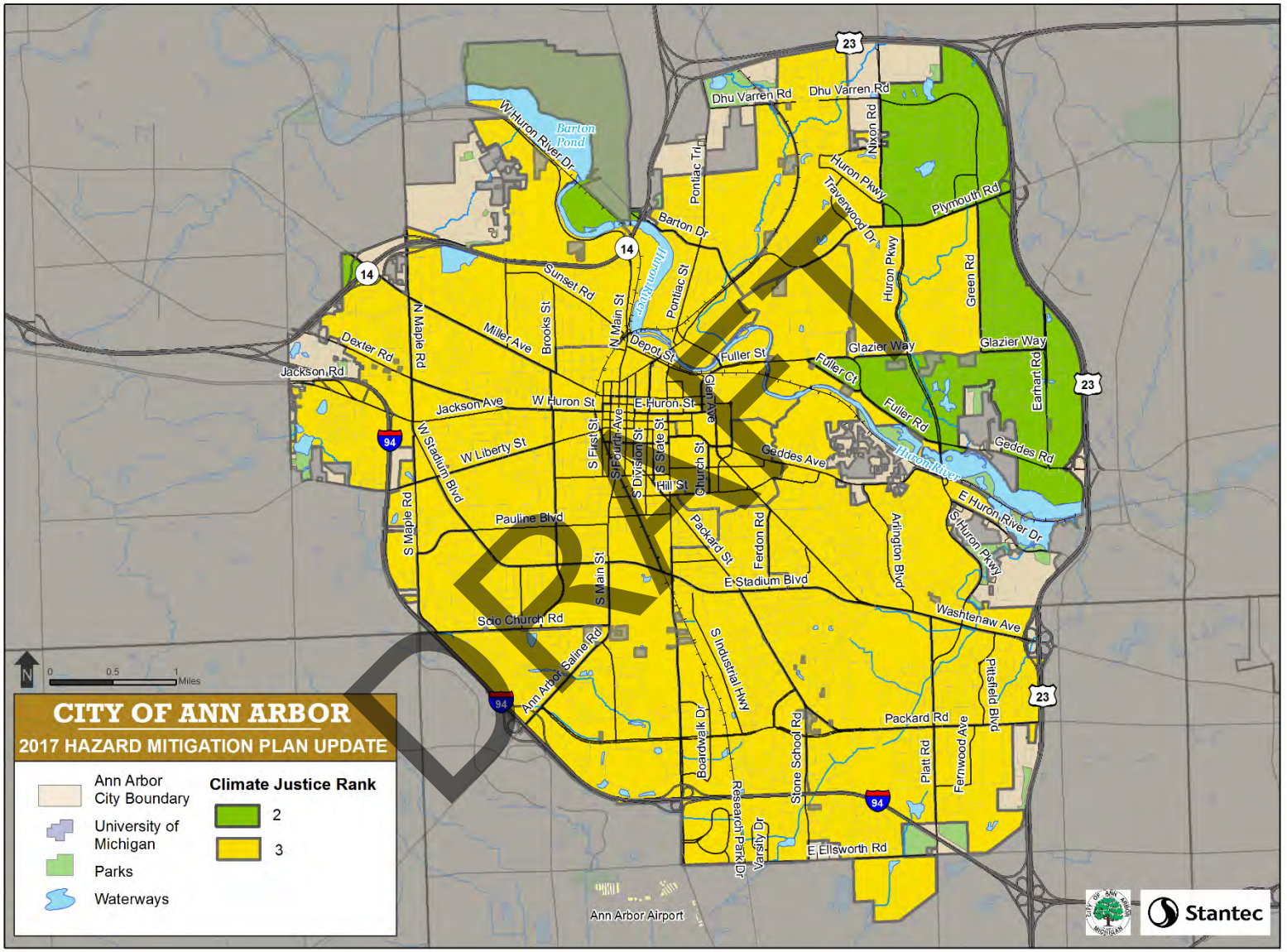
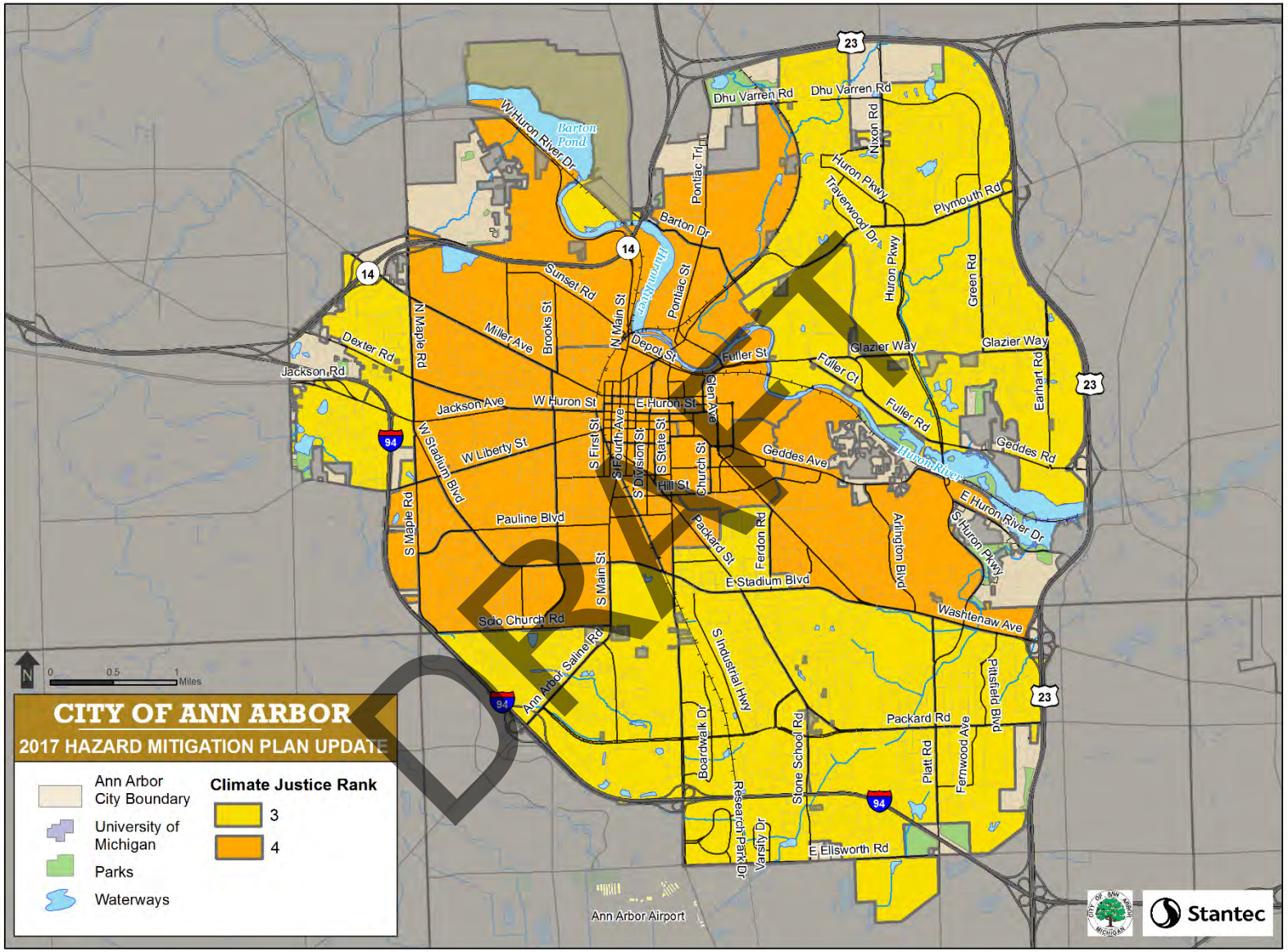


Figure 4.35: Ann Arbor High Impact Climate Justice Rankings



Invasive Species

Description

An invasive species is defined as a species that is (1) non-native (alien) to the ecosystem under consideration and (2) whose introduction causes or is likely to cause economic or environmental harm, or harm to human health. Invasive species can be plants, animals, and other organisms (e.g., microbes). Human actions are the primary consideration here as a means of invasive species' introduction (thus distinguishing the situation from natural shifts in the distribution of species). Nationally, the current environmental, economic, and health costs of invasive species were estimated as exceeding the costs of all other natural disasters combined.

Invasive species can be transported in many ways, such as on animals, vehicles, ships, commercial goods, produce, and clothing. Non-native species are the foundation of U.S. agriculture, and also are used to prevent erosion, to provide fishing and hunting opportunities, and as ornamental plants and pets, occasionally a non-native organism flourishes too well and causes unwanted economic, ecological, or human health impacts. The terms "invasive" or "nuisance" are used to describe such species. New environments may affect rates of reproduction, susceptibility to disease, and other features that affect a species' success. Consequently, a plant or animal that causes little damage to agriculture or natural ecosystems in one area may cause significant problems in another. Certain non-native species are very successful in their new habitats because they out-compete native plants or animals and have no natural controls (predators, diseases, etc.) in the new area. Well non-native species flourish, they can become invasive and event result in an infestation. At least 200 well-known, high-impact, non-native species are present in the United States. They range from the European gypsy moth and emerald ash borer to crabgrass, dandelions, and German cockroaches. Non-native species annually cost well over a billion dollars to control. Some even pose human health risks. Others, like the zebra mussel, threaten widespread disruption of ecosystems and the displacement or loss of native plants and animals.

The as the climate changes, native species are likely to be stressed under new conditions, leading to increased vulnerability to invasion from non-native species that are better able to complete in the climate, often without any natural predators.

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Location

It is assumed that all of Ann Arbor is exposed to invasive species.

Previous Occurrences

Ann Arbor is home to a large number of invasive species and pests. Invasive species that have a history of causing an infestation in the planning area include:

- Emerald Ash Borer (EAB) is an exotic wood boring beetle that was discovered in southeast Michigan in 2002. The beetle destroys the water and nutrient-carrying vessels, causing an infested tree to die within 2 to 3 years of infestation. Ann Arbor has removed nearly all publicly managed ash trees along streets and in mowed areas of parks; however dead ash trees still remain standing in city-managed natural areas. According to the Michigan Department of Agricultural and Rural Development, Washtenaw County was in a Quarantine area as of February 2016, which prohibits the transport of firewood (a vector for the spread of EAB) and the sale of ash trees at nursery and garden centers.[lix]

- Gypsy Moth Caterpillar and Gypsy moth are present throughout Michigan. The insect has four life stages: egg mass, caterpillar, pupa and moth. It is only in the caterpillar state of the gypsy moth life cycle that is destructive and a potential health concern. The caterpillars are serious tree defoliators; feeding on leaves of several hardwood trees including, oak, birch, basswood, apple and aspen. While healthy trees can usually withstand one or two defoliations without suffering permanent damage, older, diseased or stressed trees may not.

- Dutch Elm Disease Dutch Elm Disease is vascular disease of primarily American Elms. Trees are infected with the disease from elm bark beetles that carry the spores from diseased trees to healthy ones. The disease begins by killing branches but eventually the whole tree can succumb to the disease. Dutch elm disease began killing elm trees in Ann Arbor in the 1960's. Today, the city manages about 540 American elms larger than 8" in diameter. The average size of these trees is 20" DBH. Dutch elm disease still threatens the remaining elms and the city loses several dozen each year.

In addition to the pests listed above, the Ann Arbor Parks and Recreation Department maintains a list of invasive plant species present in the city, which can be found at: http://www.a2gov.org/departments/Parks-Recreation/NAP/Pages/InvasivePlants.aspx.

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Extent

The extent of invasive species and infestation can be measured in terms of invasive species population size or damages incurred by an invasive species. No population counts or damages figures were available for invasive species in Ann Arbor.

Probability of Future Occurrences

Since there are no detailed records of historical occurrences or detailed studies available, determining an accurate probability based on past events is not feasible. Once a non-native species becomes invasive, it is challenging to eradicate. Given the current number of invasive species in Ann Arbor, along with the threat of new or unknown invasive species

(especially due to climate change), the probability of the invasive species hazard is Ann Arbor was assigned a probability of high likely (greater than 90 percent annual chance).

Vulnerability Assessment

Ann Arbor is vulnerable to the impacts of invasive species. Invasive species have the potential to damage buildings and infrastructure as well as impact life safety, public health, and the local economy.

Damage to Buildings

The emerald ash borer has caused extensive damage to trees in Michigan, and those weakened trees have often collapsed and caused property damage. Dead trees become dry and brittle, and are especially prone to snap and falling during ice storms or when subject to high winds. While Ann Arbor does not have extensive forest lands, they do have a significant tree canopy within the city that could become vulnerable to invasive species, such as pests, diseases, or competing non-native trees.

Furthermore, some invasive plant species have the potential to overtake buildings and structures. For example, Kudzu, an invasive plant species in the southeastern U.S. (which is working its way north and west), is a vine plant that is known for overwhelming buildings and causing structural damage.

Damage to Infrastructure

Similar to potential damages to buildings, trees weakened by emerald ash borers can collapse and cause damage to surrounding infrastructure, including utility poles and power lines.

Life Safety, Health and Evacuation and Procedures

Invasive species can have a range of impacts on life safety and health, depending on the species and the severity of the infestation. Dead trees resulting from invasive pest infestations can fall, potentially causing injuries. Dead and decaying trees are also more prone to catching on fire. It is unlikely that an invasive species infestation would directly result in the need for evacuations.

Public Health

Invasive species can have a range of impacts on public health, depending on the species and the severity of the infestation. Invasive microbes have the potential to contaminate water sources, while invasive pests have the potential to spread disease to humans, plants, and livestock. Certain diseases carried by invasive species could wipe out large segments of an animal population, creating a potentially serious public health emergency and the need to properly (and rapidly) dispose of the dead animal carcasses.

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Economic Impact

Invasive species can have a devastating impact on local economies that are dependent on forestry, agriculture, horticulture, fishing, and eco-tourism. For example, quarantines placed on counties restrict certain host plants from being able to enter and leave an area, impacting forestry, nursery, and agricultural businesses. In addition, dead trees resulting from invasive pest infestations can be expensive to remove.

Climate Change Impacts

As the climate changes, the city will have to contend with a wide range of invasive species. Some existing species will adapt to changes, while others will not be able to thrive in new conditions. Climate change also brings about the threat of new species that could not exist in the previous climate but will thrive in future conditions. Different patterns of wildlife have already been observed as a result of the lengthening average growing season in Michigan. Species that had previously been found only in warmer areas to the south have started to appear in Michigan. Although the definition of invasive species specifically refers to human species introduction, to distinguish these patterns from naturally occurring ones, species transported by human action can be more likely to survive (and thus to become invasive) as climatic changes occur. Ann Arbor is observing a switch from its traditional tree cover of maple, beech, and birch to species like oak and hickory, which are generally associated more with its southern neighbors. **Figure 4.36** shows USDA Plant Hardiness Zone Maps from 1990 and 2012, which show that Ann Arbor's plant hardiness zone has shifted from Zone 5 to Zone 6 as the climate becomes warmer. In general, lower zone numbers are associated with colder climates and higher zone numbers with warmer climates.[lx]

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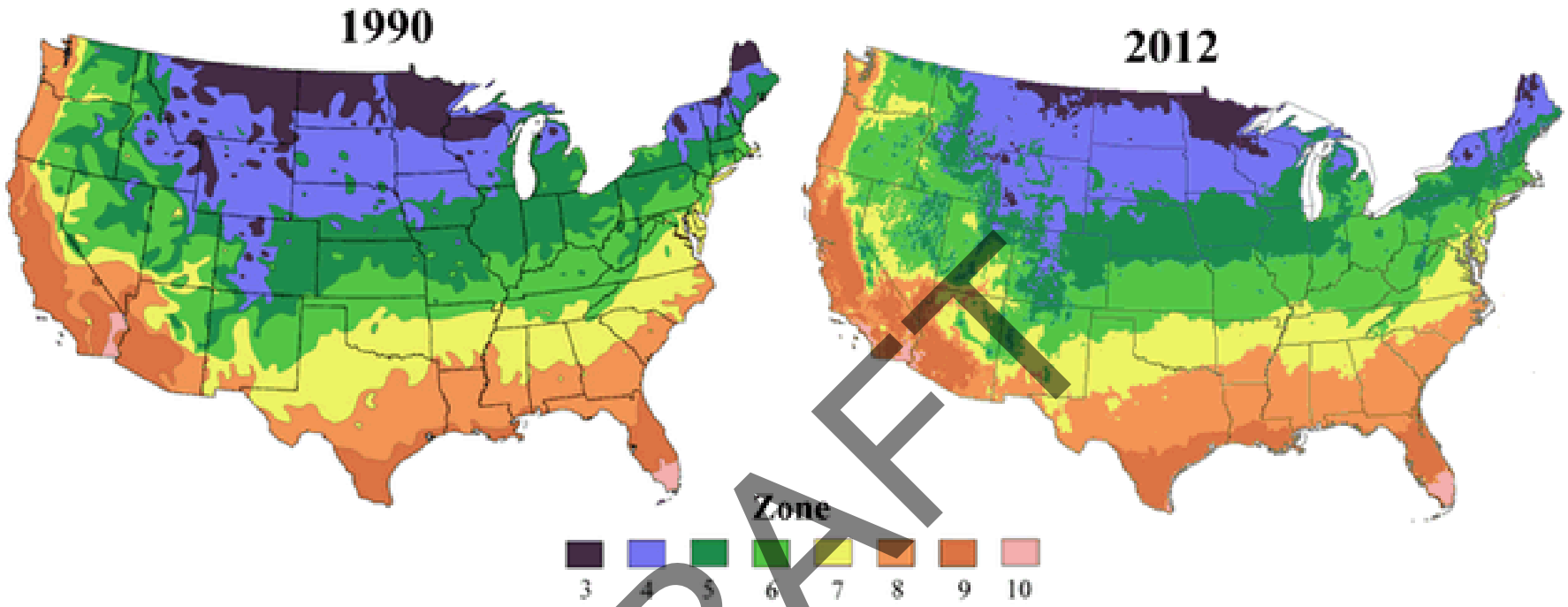
Figure 4.36: USDA Plant Hardiness Zone Maps, 1990 and 2012



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Natural Hazards – Geologic

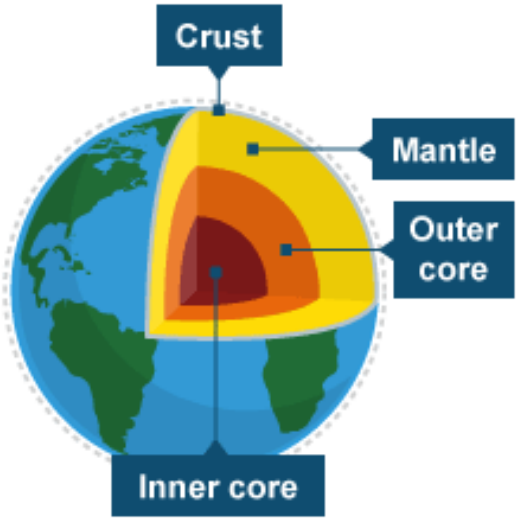
Earthquake

Description

Earthquakes are scientifically defined as the sudden release of strain (or displacement of rock) in the earth's crust, resulting in waves of shaking that radiate outward from the earthquake source. They may result from crustal strain, volcanism, landslides or the collapse of caverns. Earthquakes can occur underwater or on land. Earthquakes can affect hundreds of thousands of square miles. Their intensity ranges from very minor (shaking not detected by humans without instruments) to very violent (catastrophic in nature). Damages follow this intensity ranging from minor to catastrophic. Earthquakes also occur without warning, resulting in deaths and injuries.

To understand the nature of earthquakes, the composition of the earth must be explored. The earth is made up of four major layers and several sub layers (**Figure 4.37**)[lxi] a solid inner core, a liquid outer core, a semi-molten mantle, and the rocky crust (the thin outermost layer of the earth). The upper portion of the mantle combined with the crust forms the lithosphere. This area is susceptible to fractures and is referred to as a shell. The lithosphere breaks up into large slabs, known as tectonic plates. This area is where earthquakes occur.

Figure 4.37: Earth's Sub-Layers



There are approximately twelve major plates and several dozen more minor plates on the earth's crust, as shown in **Figure 4.38**. Plates are regions of the crust that continually move over the mantle. Areas where these plates meet, grind past each other, dive under each other, or spread apart, are called plate boundaries. Most earthquakes are caused by the release of stresses accumulated due to the sudden displacement of rock along opposing plates in the Earth's crust. The location below the earth's surface where the earthquake starts is known as the hypocenter or focus. The point on the earth's surface directly above the focus is the epicenter. The areas bordering the Pacific Plate, also known as the "Pacific Ring of Fire", are at a particularly high risk since most of the largest earthquake events of the last century have occurred in the region.

While earthquakes typically occur along plate boundaries, they can affect hundreds of thousands of square miles, causing damage to property (measured in the tens of billions of dollars), resulting in loss of life and injury to hundreds of thousands of persons, and disrupting the social and economic functioning of the affected area. The point where an earthquake starts is termed the focus or hypocenter and may be many miles to several hundred miles deep within the earth. The point at the surface directly above the focus is called the earthquake's epicenter. Earthquakes are measured in terms of their magnitude and intensity.

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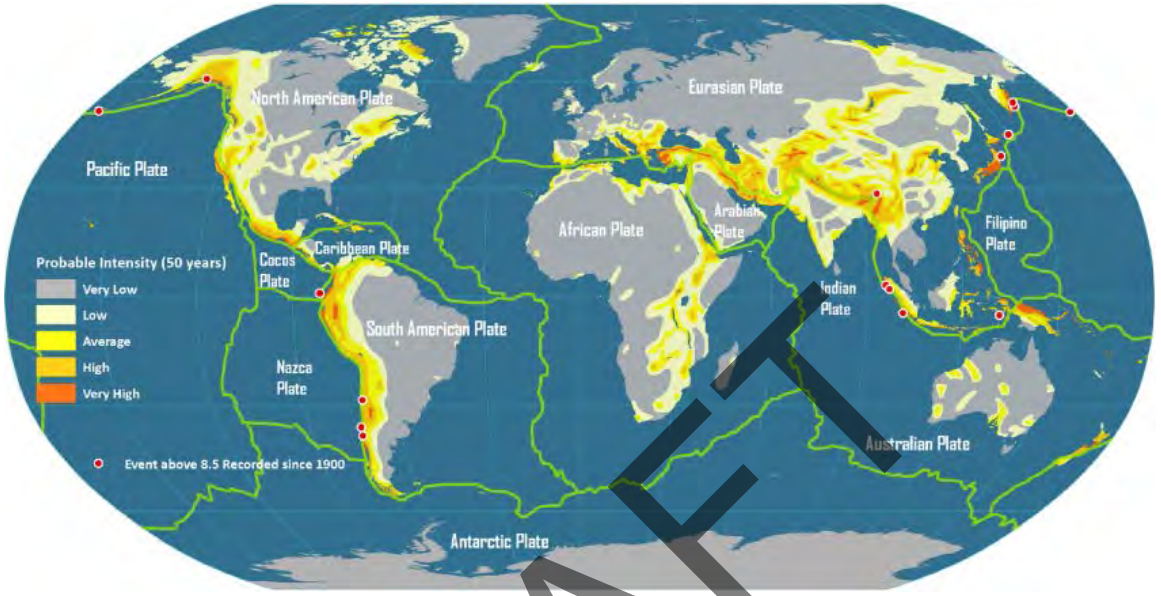
Figure 4.38: Global Plate Tectonics and Seismic Activity[lxii]



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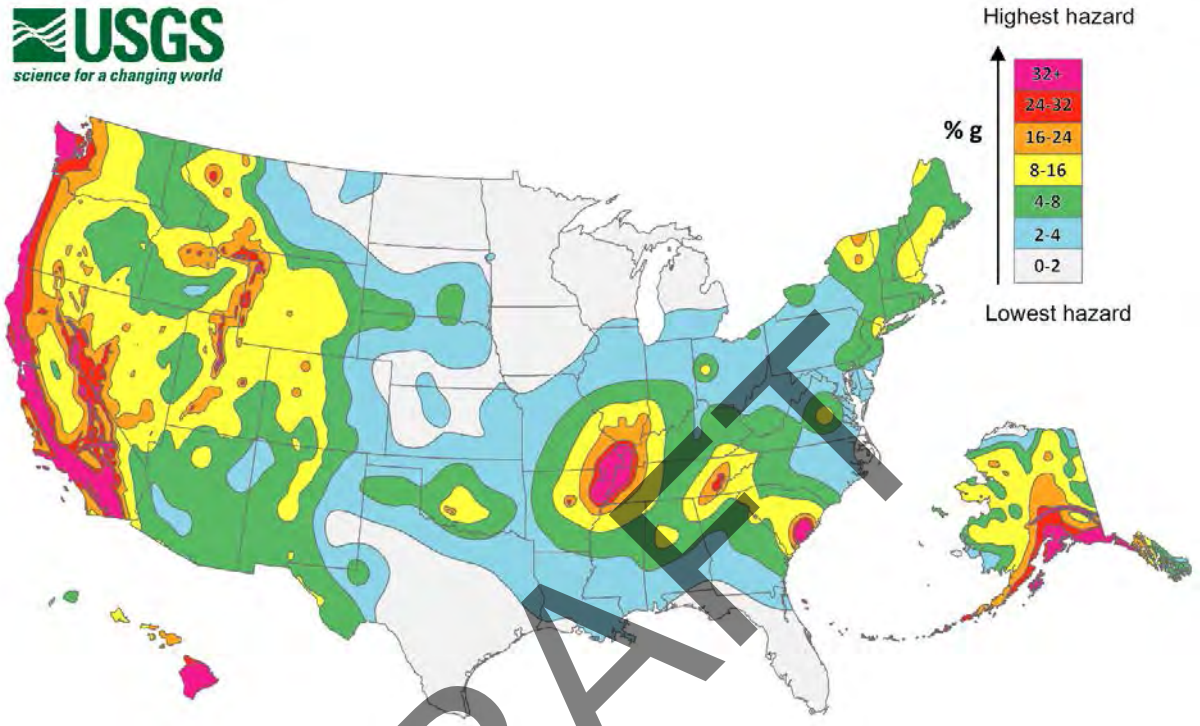
Most property damage and earthquake-related deaths are caused by the failure and collapse of structures due to ground shaking. The level of damage depends upon the amplitude and duration of the shaking, which are directly related to the earthquake size, distance from the fault, site, and regional geology. Other damaging earthquake effects include landslides, the down-slope movement of soil and rock (mountain regions and along hillsides), and liquefaction, in which ground soil loses the ability to resist shear and flows much like quick sand. In the case of liquefaction, anything relying on the substrata for support can shift, tilt, rupture, or collapse.

The greatest earthquake threat in the United States is along tectonic plate boundaries and seismic fault lines located in the central and western states; however, the Eastern United State does face moderate risk to less frequent, less intense earthquake events. **Figure 4.39** shows relative seismic risk for the United States.

Figure 4.39: United States Earthquake Hazard Map



Source: United States Geological Survey

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Earthquake magnitude is measured using the Richter Scale, an open-ended logarithmic scale that describes the energy release of an earthquake through a measure of shock wave amplitude (**Table 4.28**)[lxiii]. Each unit increase in magnitude on the Richter Scale corresponds to a 10-fold increase in wave amplitude, or a 32-fold increase in energy. Beginning in 2002, the USGS began using Moment Magnitude as the preferred measure of magnitude for all USGS earthquakes greater than magnitude 3.5. This was primarily due to the fact the Richter Scale has an upper bound, so large earthquakes were difficult to measure. Moment Magnitude also has a scale, but no instrument is used to measure it. Instead, factors such as the distance the earthquake travels, the area of the fault, and land that was displaced (also known as "slip") are used to measure moment magnitude. **Table 4.29** shows the Moment Magnitude Scale.

Table 4.28 Richter Scale

RICHTER MAGNITUDES	EARTHQUAKE EFFECTS

<3.5	Generally not felt, but recorded.
3.5 - 5.4	Often felt, but rarely causes damage.
5.4 - 6.0	At most slight damage to well-designed buildings. Can cause major damage to poorly constructed buildings over small regions.
6.1 - 6.9	Can be destructive in areas up to about 100 kilometers across where people live.
7.0 - 7.9	Major earthquake. Can cause serious damage over larger areas.
8 or >	Great earthquake. Can cause serious damage in areas several hundred kilometers across.

Source: Federal Emergency Management Agency

Table 4.29 Moment Magnitude Scale

SCALE VALUES	EARTHQUAKE EFFECTS
<3.5	Very weak; unlikely to be felt
3.5 - 5.4	Generally felt; rarely causes damage
5.4 - 6.0	Will not cause damage to well-designed buildings; will damage poorly designed ones
6.1 - 6.9	Considered a "major earthquake" that causes a lot of damage
7.0 - 7.9	Large and destructive earthquake that can destroy large cities
8 or >	Large and destructive earthquake that can destroy large cities

Source: Federal Emergency Management Agency

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Intensity is most commonly measured using the Modified Mercalli Intensity (MMI) Scale based on direct and indirect measurements of seismic effects. The scale levels are typically described using roman numerals, ranging from "I" corresponding to imperceptible (instrumental) events to "XII" for catastrophic (total destruction). A detailed description of the Modified Mercalli Intensity Scale of earthquake intensity and its correspondence to the Richter Scale is given in **Table 4.30**. **Table 4.31** compares the Richter scale magnitudes and MMI magnitudes for several well-known historic earthquakes in the U.S.

Table 4.30 Modified Mercalli Intensity Scale for Earthquakes

SCALE	INTENSITY	DESCRIPTION OF EFFECTS	CORRESPONDING RICHTER MAGNITUDE
I	INSTRUMENTAL	Detected only on seismographs.	
II	FEEBLE	Some people feel it.	< 4.2
III	SLIGHT	Felt by people resting; like a truck rumbling by.	
IV	MODERATE	Felt by people walking.	
V	SLIGHTLY STRONG	Sleepers awake; church bells ring.	< 4.8
VI	STRONG	Trees sway; suspended objects swing, objects fall off shelves.	< 5.4
VII	VERY STRONG	Mild alarm; walls crack; plaster falls.	< 6.1
VIII	DESTRUCTIVE	Moving cars uncontrollable; masonry fractures, poorly constructed buildings damaged.	
IX	RUINOUS	Some houses collapse; ground cracks; pipes break open.	< 6.9
X	DISASTROUS	Ground cracks profusely; many buildings destroyed; liquefaction and landslides widespread.	< 7.3
XI	VERY DISASTROUS	Most buildings and bridges collapse; roads, railways, pipes, and cables destroyed; general triggering of other hazards.	< 8.1
XII	CATASTROPHIC	Total destruction; trees fall; ground rises and falls in waves.	> 8.1

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Table 4.31 Richter vs. Moment Magnitude Values

Earthquake	Richter Scale	Moment Magnitude
New Madrid, MO 1812	8.7	8.1
San Francisco, CA 1906	8.3	7.7
Prince William, AK 1964	8.4	9.2
Northridge, CA 1994	6.4	6.7

Location

An earthquake event would impact the entire planning area. Earthquakes can be felt and cause damage hundreds of miles from a fault. There are earthquake faults and earthquake risk areas that help define locations. There are no known active faults in Ann Arbor. The Grenville Front is a dormant regional fault zone that crosses underneath Washtenaw County, and is not a major concern.

The New Madrid Fault (New Madrid and Wabash Valley seismic zones) are the most significant seismic zones to threaten the city. **Figure 4.40** is a USGS map of the New Madrid and Wabash Valley seismic zones and shows earthquakes as circles.[lxiv] While Ann Arbor is not shown here, these are the major seismic zones nearest to the city, which is approximately 315 miles northeast of the zone. Red circles indicate earthquakes that occurred from 1974 to 2002 with magnitudes larger than 2.5 located using modern instruments (University of Memphis). Green circles denote earthquakes that occurred prior to 1974 (USGS Professional Paper 1527). Larger earthquakes are represented by larger circles.

Another seismic zone that presents a threat to the city is the Charlevoix-Kamouraska Seismic Zone (CSZ) in Quebec, Canada. The CSZ is one of the most seismically active regions in Canada, and runs along the St. Lawrence River (**Figure 4.41**).[lxv] The CSZ is approximately 400 miles northeast of Ann Arbor.

Figure 4.40: USGS New Madrid and Wabash Valley Seismic Zones

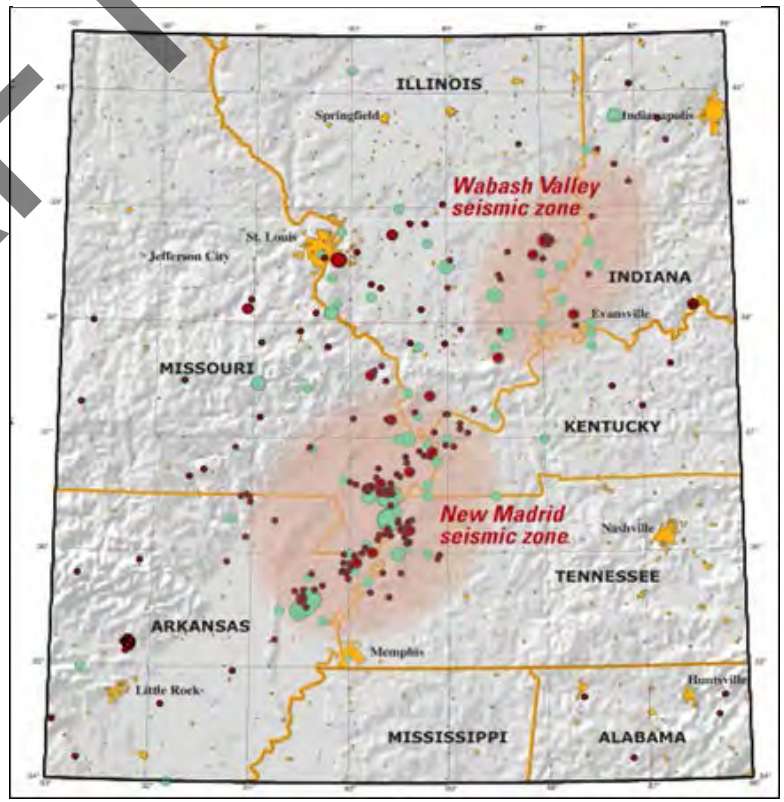

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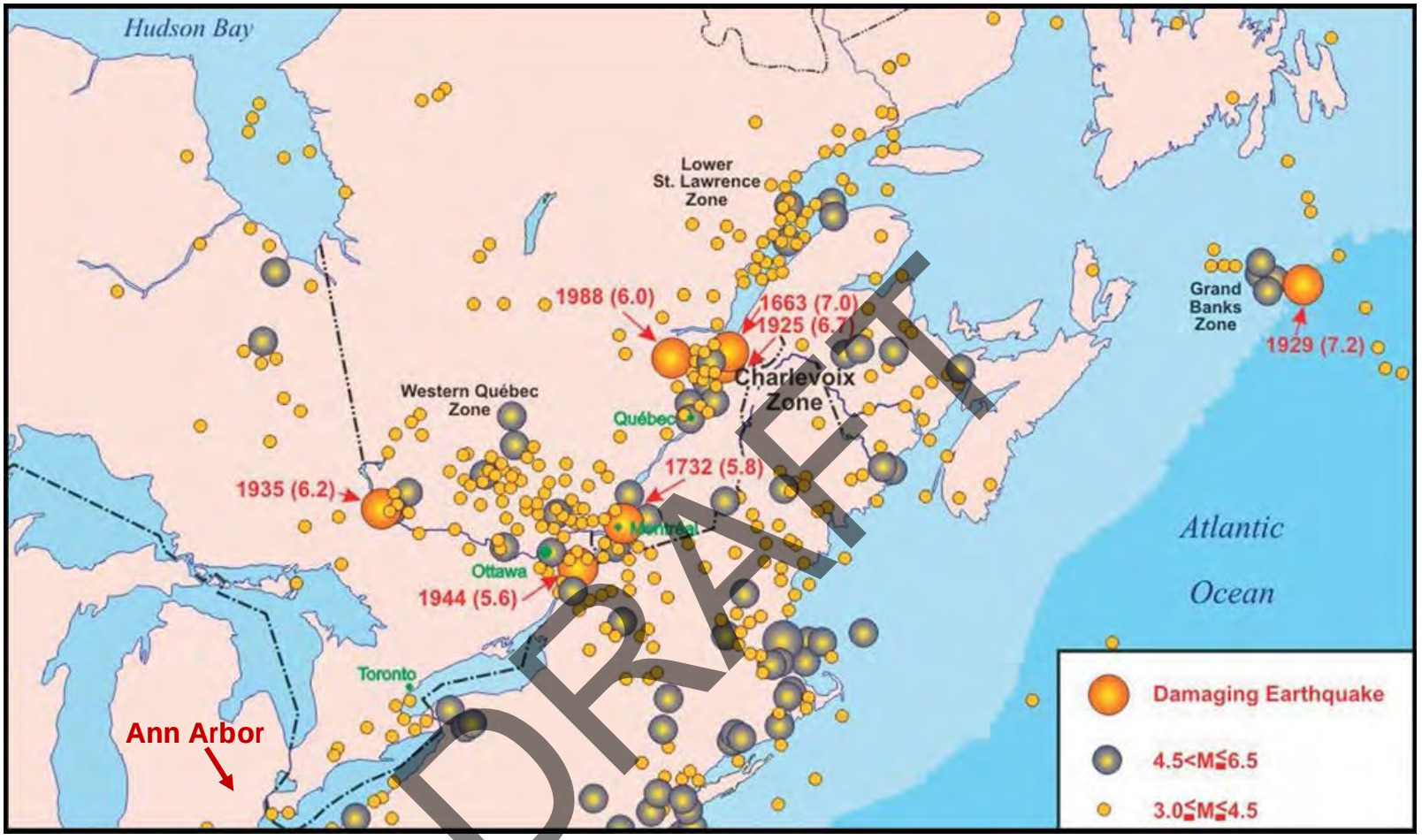
Figure 4.41: USGS New Madrid and Wabash Valley Seismic Zones



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In 2015, a 4.2 magnitude earthquake occurred 12 miles southeast of Kalamazoo, MI (approximately 90 miles west of Ann Arbor), leading researchers to discover a fault that runs between Kalamazoo and Coldwater, MI.

Earthquake science continues to evolve; it is possible that there are additional faults located under or near Ann Arbor. It is also possible for faults thought to be dormant to become active.

Previous Occurrences

Ann Arbor has a limited recorded history of earthquakes. Based on reviewed sources, Ann Arbor has experienced between 10 to 15 earthquakes since the 1880s. However, it is possible additional earthquakes have been felt in Ann Arbor, but were not documented as the city was not the primary impact area. **Table 4.32** shows earthquakes recorded in Ann Arbor between 1638 and 1985, as reported by NCEI.[lxvi] Eight earthquakes were reported; associated damages, deaths, or injuries were not reported.

Table 4.32 NCEI Reported Earthquakes in Ann Arbor, 1638-1985

Year	Magnitude	Modified Mercalli Intensity (MMI)
1886	--	5
1925	7	2
1935	--	3
1937	--	4
1937	5.5	3
1943	--	3
1947	--	3
1968	5.3	4

Several earthquakes occurring in Quebec's CSZ have been felt in Ann Arbor, including one in 1925 (6.7 magnitude) and another in 1935 (6.1 magnitude). The 1935 earthquake, called the Timiskaming Quake, had an MMI of VI at its epicenter, and an MMI of III in Ann Arbor (**Figure 4.42**).[lxvii] Although fault information is not provided with past occurrences in NCEI, it is assumed that the 1925 and 1935 quakes reported in the table above are the ones that occurred in the CSZ. Other earthquakes along CSZ that were likely felt in Ann Arbor include ones in 1663 (magnitude 7.0), 1732 (5.8), 1944 (magnitude 5.6), and 1988 (magnitude 6.0). The locations of these earthquakes are shown in the figure of the CSZ, above.

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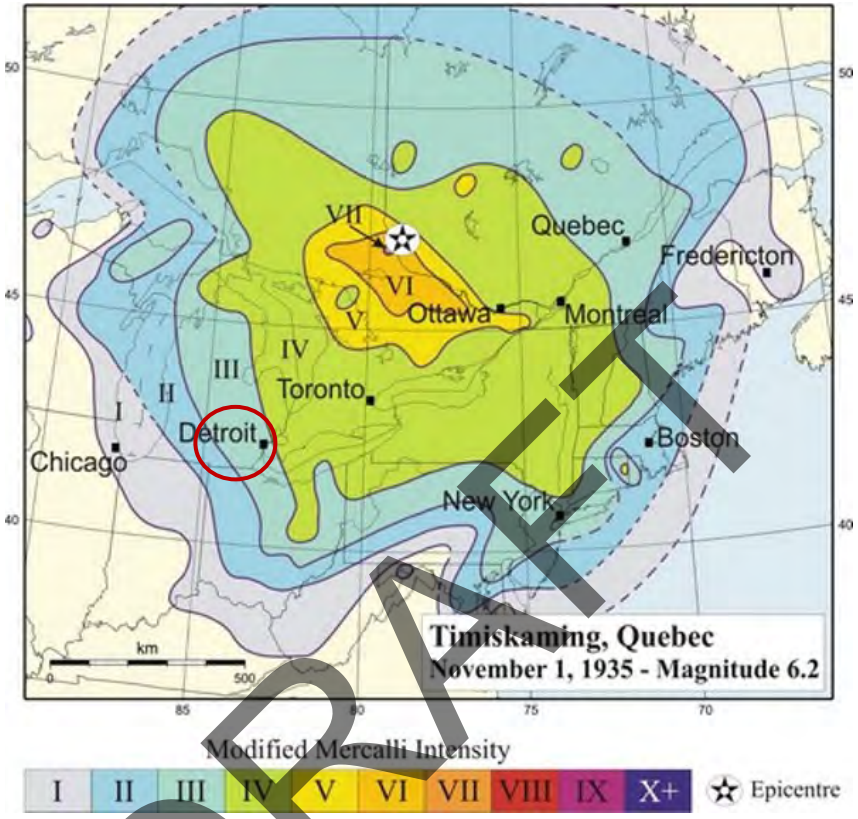
Figure 4.42: 1935 Timiskaming Earthquake Map



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More recently, a 4.2 magnitude earthquake occurred near Kalamazoo, MI, on May 2, 2015. According to **Figure 4.43**, the intensity of the earthquake in Ann Arbor was a II-IV on the MMI, equating to weak/light shaking and no damages. Similarly, a 5.2 magnitude earthquake occurred in southern Illinois on April 18, 2008. According to **Figure 4.44** the intensity of the quake in Ann Arbor was a I-III on the MMI, resulting in weak shaking and no damages. It is possible other earthquakes occurring in nearby locations were felt in Ann Arbor, but were not well-recorded due to lack of damages or shaking.

Figure 4.43: 2015 Kalamazoo Earthquake Location

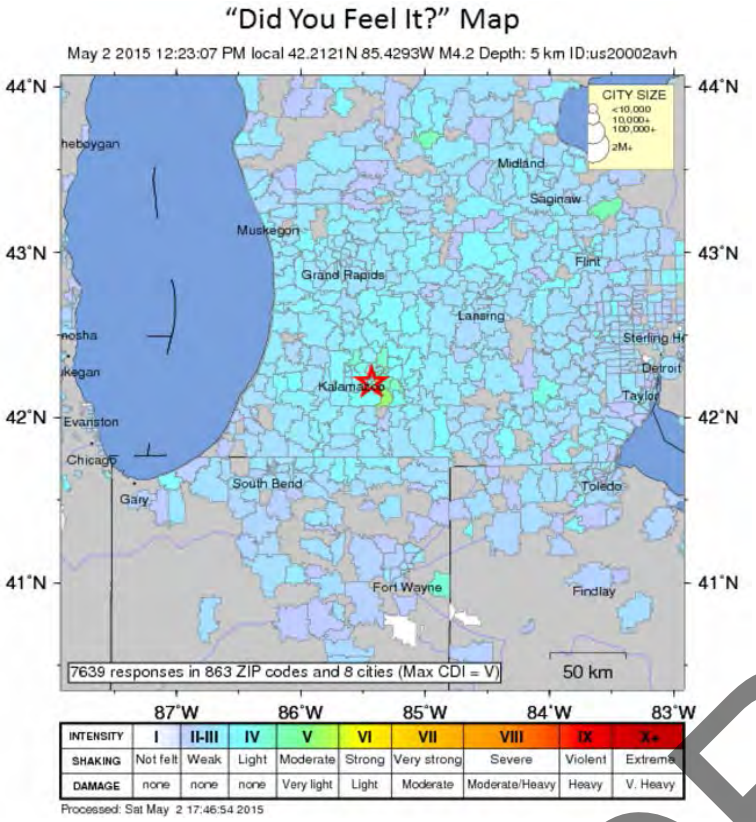
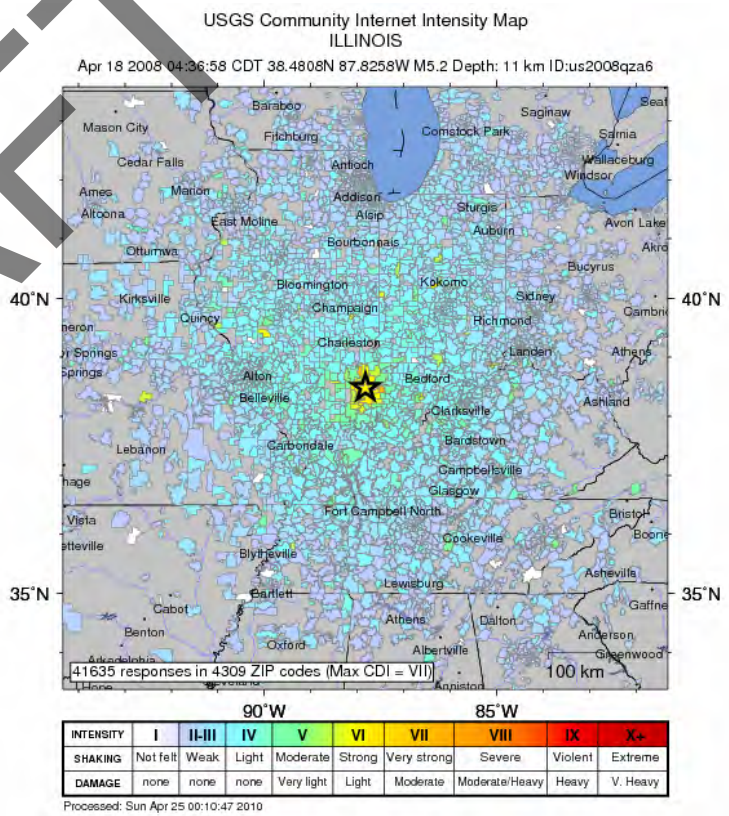


Figure 4.44: 2008 Illinois Earthquake Location



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Extent

There are several ways to measure the extent of an earthquake including magnitude and intensity experienced. Earthquake extent is difficult to determine given Ann Arbor's limited recorded history of earthquake events. From past events, the strongest magnitude earthquake to occur in Ann Arbor was a magnitude 7 in 1925, and the strongest intensity earthquake felt in Ann Arbor was a V (Slightly Strong; sleepers awake, church bells ring) on the Modified Mercalli Scale, which equates to light moderate and light damages. Greater extent events are possible, but in general damaging earthquakes are not common in the planning area.

Probability of Future Occurrences

The probability of significant, damaging earthquake events affecting Ann Arbor is unlikely. In fact, earthquake probably in general is difficult to estimate. Only 10 to15 earthquakes have been recorded as being felt in Ann Arbor over several hundred years; earthquakes are not regular occurrences for the city. However, the presence of two major seismic zones near the region suggest an increased likelihood. In addition, Ann Arbor and the surrounding region are composed of bedrock, which is better able to carry seismic energy than sandy soils, such as those on the west coast. Therefore, the probability assigned to this hazard was possible (1 to10 percent annual probability).

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Vulnerability Assessment

Earthquakes are considered a lower priority hazard in Ann Arbor. However, all current and future buildings, infrastructure, and populations in Ann Arbor are considered at-risk to earthquakes. Earthquake risk in Ann Arbor may be more significant than is currently assumed. While a catastrophic event is not likely, earthquakes that can be felt, and potentially result in light to moderate damage are feasible given the surrounding hazard areas.

Damage to Buildings

Although a catastrophic event is unlikely, it is still possible that an earthquake could result in damages to buildings in Ann Arbor. All current and future buildings are considered at risk to earthquakes.

As the Hazus model suggests below, and historical occurrences confirm, any earthquake activity in the area may inflict minor damage to the planning area but is unlikely to result in catastrophic, widespread losses.

For the earthquake hazard vulnerability assessment, an "arbitrary" scenario was created to estimate loss for the region. First, the 2015 Kalamazoo earthquake was replicated using the 4.2 magnitude. However, there were no losses with this event. So, a magnitude 5.5 event was simulated using the same epicenter of the actual event. This did produce losses in the city. The

results of the analysis were reported at the U.S. Census tract level deeming a jurisdictional-level result infeasible. Results, were instead weighted by census track for areas in the city. Estimated losses include building damage, content damage, relocation cost, income loss, rental income loss and wage loss.

Table 4.33 presents the results of the Hazus analysis.

Table 4.33 Simulated 5.5 Portage Earthquake Results

Location	Direct Economic Losses		Indirect Economic Losses				Total
	Building Damage	Content Damage	Relocation Cost	Income Loss	Rental Income Loss	Wage Loss	Total Loss
City of Ann Arbor	$8,592,665	$733,144	$1,872,593	$997,823	$1,205,950	$1,293,898	$14,696,073

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Damage to Infrastructure

In the event of an earthquake, there is potential for minor damages to the city's infrastructure, including all pipes, roads, bridges, railroads, dams, and utility poles. In earthquakes, damages to underground infrastructure, such as water and sewer systems and natural gas pipelines are especially vulnerable. In addition, in the event that a dam is damaged during an earthquake, there is potential for dam failure or an energy shortage (in the case of hydroelectric dams).

Life, Safety, Health and Evacuation and Procedures

It can be assumed that all existing future populations are at risk to the earthquake hazard. While a devastating earthquake is unlikely, injuries are possible if earthquake shaking causes items to fall off shelves or walls. Damages to structures or infrastructure could have impacts on the population. For instance, down power lines could result in power outages. Evacuations are unlikely for an earthquake event, but individuals should take cover under a heavy, sturdy object (such as a desk or table) in the event of an earthquake.

Public Health

Earthquakes that are strong enough to damage infrastructure may have public health impacts, such as contaminated water supply, fires from natural gas leaks, or prolonged power outages (which can especially impact public health when combined with extreme temperatures. Such an earthquake is unlikely in Ann Arbor, but possible.

Economic Impact

The economic impact of an earthquake in Ann Arbor would likely be limited to losses from damaged building contents (e.g., goods falling off shelves in grocery stores). However, business disruptions or costs for infrastructure repairs are possible. In general, the economic impact from earthquake events in Ann Arbor is minimal.

Climate Change Impacts

Climate Change is not considered to have a significant impact on earthquakes in Ann Arbor.

Technological Hazards

Structure Fires

Description

Structural fires are defined as the uncontrolled burning of any building—residential, agricultural, recreational, institutional, commercial, or industrial (MSP/EMHSD). Structural fires can originate from a number of sources, including faulty electric systems, natural gas leaks, arson, and improperly discarded cigarettes, candles, and incense. Structural fires are a common occurrence in Ann Arbor, but a catastrophic structural fire has not occurred in Ann Arbor in recent years (MSP/EMHSD; Washtenaw County Emergency Management). Within a city, it can sometimes be difficult to limit the spread of a major fire to surrounding buildings. Preventing the spread of a fire in this situation could be extremely challenging.

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Location

It is assumed that all of Ann Arbor is exposed to structure fires. Areas with clusters of wood-built structures or densely developed areas may be at higher risk.

Previous Occurrences

No additional serious structure fire occurrences were provided by the city. The following lists the following past events for serious structure fires:

- *Buildings Destroyed by Fire in 2003* On July 24, 2003 four buildings were destroyed by a fire within the city resulting in a significant effort by firefighters.
- *Apartment Complex Fire in 2006* On March 3, 2006 an apartment complex was heavily damaged by fire. There was one fatality and two others injured. Over 100 people were evacuated by the responding fire fighters.

- *Senior Citizen High Rise Fire August 2008* One Senior citizen was killed and over 50 seniors were displaced when a fire started in an occupied apartment complex for the elderly.
- *Historic Ypsilanti Building Destroyed in 2009* A historic building that was under renovation in Ann Arbor's neighboring city of Ypsilanti was destroyed by a large fire on the early morning of September 23, 2009. The building originally housed soldiers during the Civil War and was located in the downtown area known as Depot Town. The fire started on the second floor of the vacant three story building. Firefighters from several Ann Arbor area departments including Ann Arbor, Ypsilanti Township, Pittsfield Township, and Superior Township were at the scene for hours. There were no injuries reported. The fire appeared to be suspicious and was called a setback for plans to revitalize the neighborhood.
- *Building Fire in 2009* On the night of October 25, 2009 a large fire broke out near the University of Michigan campus near restaurants and bars along a crowded street. Fire crews immediately rushed to the scene and there were up to 55 firefighters actively fighting the fire. The fire became so large that an adjacent apartment building was evacuated due to fear of it spreading, resulting in approximately 600 students being temporarily displaced. Even though police officers had attempted to blockade the sidewalk, the crowds outside remained and onlookers were able to make their way to the scene through a passageway, between buildings across the street. While the fire burned on the west side of the street, the east side of the street remained a bustling night scene.
- *Fatal House Fire November 2009* Three people were killed in a residential house fire on the city's Westside. The house collapsed and was completely destroyed.
- *Student Housing Fire April 2010* One student was killed and other seriously burned. Pittsfield Fire Department was called through Mutual Aid to assist with RIT (Rapid Intervention Team, a team of two or more firefighters dedicated solely to search and rescue of other firefighters in distress) and overhaul.
- *House Fire January 2011* On January 29, 2011 a house was destroyed by fire. There were two fatalities, both of who were trapped inside. Firefighters tried to rescue the victims using thermal imaging cameras.

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Extent

The extent of structure fires is difficult to determine. In Ann Arbor, perhaps the greatest impact event was the 2009 University of Michigan fire, in which 600 students were displaced and 55 fire fighters were at the scene. However, more severe events are possible, especially given increasing density in Ann Arbor, along with the University of Michigan campus, and the large influx of people on game days.

Probability of Future Occurrences

The probability of structure fires is difficult to determine without complete data. Structure fires are a normal occurrence in most cities. Therefore, the probability assigned to this hazard is highly likely. However, events resulting in multiple fatalities or catastrophic damages are less likely.

Vulnerability Assessment

Potential impacts to buildings, infrastructure, life safety, public heath, and the economy from the structure fire hazard are described below. All current and future buildings , infrastructure, and populations are considered at risk to structure fires.

Damage to Buildings

Structure fires can cause significant damage to structures ranging from smoke and water damage to the total loss of one or multiple structures. Wooden buildings or densely developed areas may be at a higher risk, as fire may spread more quickly. Compliance with building and fire codes will greatly reduce buildings' vulnerability to structure fires.

Damage to Infrastructure

Structure fires that spread outward from their originating structure can damage infrastructure, such as utilities and bridges. Fires burning adjacent to infrastructure may damage structural integrity.

Life Safety, Health and Evacuation and Procedures

Structure fires present a serious hazard to life safety. People trapped in structures on fire may sustain injuries due to smoke inhalation or burns. Fatalities can occur during structure fire events. Buildings should follow building codes and requirements for smoke detectors to result in early detection and evacuation of structures on fire. Practicing fire drills can reduce impacts to life safety to speeding up the evacuation process in the event of a structure fire.

Public Health

Structure fires have a limited impact on overall public health. Large structure fire may result in reduced air quality due to smoke.

Economic Impact

Structure fires can have a severe economic impact due to building damages and business interruptions. Damages to certain structures, such historic buildings and entertainment centers (such as the University of Michigan Stadium), could have a farther-reaching economic impact on the community. Damages to public buildings from structure fires could result in a large expense for the city. In addition, structure fires that result in the closure of nearby businesses and roads could result in a reduction to the city's tax base.

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Climate Change Impacts

Direct impacts to the structure fire hazard from climate change are not anticipated.

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Summary of Overall Vulnerability

This section summarizes overall vulnerability by looking at several measures including the priority risk index, ranking of hazards and key points on vulnerability. A brief summary of the hazards that impact the City of Ann Arbor is provided below. The table lists impacts, number of occurrences and associated timeframe, spatial extent, probability and estimated losses to date.

Priority Risk Index Results

The PRI results are presented in the following table **(Table 4.34).** This information was used to rank hazards.

Table 4.34 PRI Results

Summary of PRI Results for Ann Arbor						
Hazard	Category/Degree of Risk					
	Probability	Impact	Spatial Extent	Warning Time	Duration	PRI Score
Extreme Cold/Wind Chill	Likely	Critical	Large	More than 24 Hours	Less than one week	3
Extreme Heat	Likely	Critical	Large	More than 24 Hours	Less than one week	3
Fog	Highly Likely	Minor	Moderate	Less than 6 Hours	Less than 6 hours	2.6
Hail	Likely	Limited	Moderate	Less than 6 Hours	Less than 6 hours	2.6
Lightning	Highly Likely	Critical	Negligible	Less than 6 Hours	Less than 6 hours	2.8
Severe Winter Weather	Highly Likely	Critical	Large	More than 24 Hours	Less than one week	3.3
Severe Wind	Highly Likely	Catastrophic	Moderate	12 to 24 Hours	Less than 24 hours	3.5
Tornado	Possible	Catastrophic	Small	Less than 6 Hours	Less than 6 hours	2.7
Drought	Highly Likely	Minor	Moderate	More than 24 Hours	More than one week	2.6
Flood	Likely	Critical	Moderate	6 to 12 Hours	Less than one week	3
Invasive Species	Highly Likely	Minor	Moderate	More than 24 Hours	More than one week	2.6
Earthquake	Possible	Minor	Moderate	Less than 6 Hours	Less than 6 hours	2
Structure Fire	Highly Likely	Critical	Negligible	Less than 6 Hours	Less than 6 hours	2.8

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Hazard Ranking

Hazards were ranked based on PRI results and knowledge of the area. The Ranking were reviewed and confirmed by the TAC.

Ranking	Hazard
HIGH	Severe Wind Severe Winter Weather

	Extreme Cold/Wind Chill Extreme Heat Flood Lightning Structure Fire
MODERATE	Tornado Hail Drought Fog Dam Failure
LOW	Earthquake Invasive Species

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Key Points on Vulnerability

In summary, all of the hazards addressed in this plan pose a threat to the City of Ann Arbor, including the assets and population within. There are several factors that influence vulnerability including building construction type, date of construction, social factors, time of occurrence, and capacity to respond, for example. The greatest hazards of concern in Ann Arbor are severe wind, severe winter weather, extreme temperatures (heat and cold), flooding, and lightning.

Based on the risk and vulnerability assessment analysis and input from the community, here are some key points on vulnerability:

- **Extreme heat** events in Ann Arbor are projected to increase with climate change. Additionally, extreme heat is exacerbated in urbanized areas due to heat islands. Ann Arbor is experiencing growth and redevelopment, and is almost built-out, making it vulnerable to urban heat island effects. Extreme heat has resulted in more recorded injuries in Ann Arbor than any other hazard.
- **Extreme Cold/Wind Chill** events may become less severe in the future due to a changing climate.
- **Flooding** may become more frequent due to 1) increased precipitation that is more concentrated into heavy precipitation events, and 2) increased development and impervious cover. The floodplain associated with Allen Creek is particularly vulnerable, as it is in one of Ann Arbor's most populated areas and development within the floodplain is ongoing. Warmer temperatures may negate some of the effects of increased precipitation on flooding.
- Losses from **severe wind** events are greater than previously assumed. The number the non-thunderstorm related wind events has increased in recent years.
- Ann Arbor has a substantial vulnerability to thunderstorm related-hazards, as there is potential for multiple hazards to occur at once as a result of a severe thunderstorm (including **severe wind**, **tornadoes**, **hail**, **lightning**, and **flooding** due to heavy precipitation are all potential outcomes of severe thunderstorms). Although research is ongoing, climate change may result in increased frequency of severe thunderstorms.
- Council's Climate Justice Index, HAZMAT incidents aggravated by flooding are likely to increase throughout the city with climate change.
- Although the potential for major damage is limited, the probability of **earthquake** occurrences may be greater than anticipated by the community.
- Climate change is likely to create conditions where some **non-native or invasive species** will thrive and out-compete native species. Similarly, some native species may struggle under new climate conditions. In particular, Ann Arbor is seeing a shift from native maple, beech, and birch canopy cover to hickory and oak trees.

In the following section, a mitigation strategy to reduce the risks to current and future populations and structures will be presented.

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- Capability Assessment Results
- Conclusions

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5 Capability Assessment

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Introduction

The purpose of conducting a capability assessment is to determine the ability of a local jurisdiction to implement a comprehensive mitigation strategy and to identify potential opportunities for establishing or enhancing specific mitigation policies, programs, or projects[i]. As in any planning process, it is important to try to establish which goals, objectives, and/or actions are feasible based on an understanding of the organizational capacity of those agencies or departments tasked with their implementation. A capability assessment helps to determine which mitigation actions are practical, and likely to be implemented over time, given a local government's planning and regulatory framework, level of administrative and technical support, amount of fiscal resources, and current political climate.

A capability assessment has two components: 1) an inventory of a local jurisdiction's relevant plans, ordinances, or programs already in place and 2) an analysis of its capacity to carry them out. Careful examination of local capabilities will detect any existing gaps, shortfalls, or weaknesses with ongoing government activities that could hinder proposed mitigation activities and possibly exacerbate community hazard vulnerability. A capability assessment also highlights the positive mitigation measures already in place or being implemented at the local government level, which should continue to be supported and enhanced through future mitigation efforts.

The Capability Assessment completed for the *2017 City of Ann Arbor Hazard Mitigation Plan* update serves as a critical planning step and an integral part of an effective hazard mitigation strategy. Coupled with the Risk Assessment, the Capability Assessment helps identify and target meaningful mitigation actions for incorporation in the Mitigation Strategy portion of this plan. Any potential shortcomings in the ability of the city to implement hazard mitigation is tied to the mitigation strategy in the form of actions selected by the planning team. It not only helps establish the goals and objectives for the region to pursue under this plan, but it also ensures that those goals and objectives are realistically achievable under given local conditions. Specific recommendations for actions that will improve Ann Arbor's ability to implement the hazard mitigation plan and increase resilience are offered at the conclusion of this section.

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Conducting the Capability Assessment

The Capability Assessment began with completion of a Capability Assessment Review Form by the plan's leadership team. The assessment form compiled information on a variety of "capability indicators" such as existing local plans, policies, programs, or ordinances that contribute to and/or hinder the city's ability to implement hazard mitigation and climate adaptation.[ii] Other indicators in the form are related to the city's fiscal, administrative, and technical capabilities, such as access to local budgetary and personnel resources for mitigation purposes. Evaluating the current political climate is an

important consideration with respect to hazard mitigation and climate adaptation. Capability information for the city was also updated based on information found in plans and local government websites.

At a minimum, results provide an extensive inventory of existing local plans, ordinances, programs, and resources that are in place or under development in addition to their overall effect on hazard loss reduction. However, the information can also serve to identify gaps, weaknesses, or conflicts that Ann Arbor can recast as opportunities for specific actions to be proposed as part of the hazard mitigation strategy. The results of this Capability Assessment provide critical information for developing an effective and meaningful mitigation strategy.

Capability Assessment Findings

The findings of the Capability Assessment are summarized in this Plan to provide insight into the relevant capacity of Ann Arbor to implement hazard mitigation activities. All information is based upon the review of existing plans, ordinances, and programs identified through the assessment form and review of the city's website.

Emergency Management

Hazard mitigation is widely recognized as one of the four primary phases of emergency management. The three other phases include preparedness, response, and recovery. Each phase is interconnected, as **Figure 5.1** illustrates. Opportunities to reduce potential losses through mitigation practices are often implemented before a disaster event strikes, such as elevation of flood prone structures or enforcement of policies that prevent and regulate development that is vulnerable to hazards. Mitigation opportunities will also be presented during immediate preparedness or response activities, such as installing storm shutters in advance of a hurricane, and certainly during the long-term recovery and redevelopment process following a hazard event.

Planning for each phase is a critical part of a comprehensive emergency management program and a key to the successful implementation of hazard mitigation actions. As a result, the Capability Assessment Review Form evaluated a range of emergency management plans in order to assess the Ann Arbor's willingness to plan and their level of technical planning proficiency.

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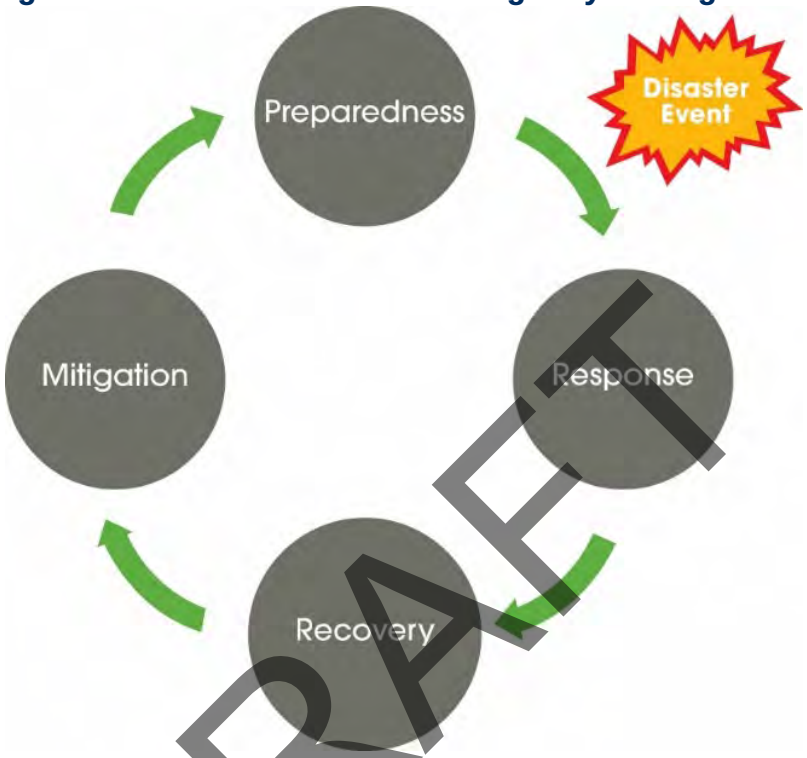
Figure 5.1: The Four Phases of Emergency Management



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Hazard Mitigation Plan: A hazard mitigation plan represents a community's blueprint for how it intends to reduce the impact of natural and human-caused hazards on people and the built environment. The essential elements of a hazard mitigation plan include a Risk Assessment, Capability Assessment, and Mitigation Strategy.

In 2012 Ann Arbor adopted its first **Hazard Mitigation Plan**. This plan replaced the Ann Arbor subsection of the Washtenaw County Hazard Mitigation Plan and integrated the 2007 City of Ann Arbor Flood Mitigation Plan. The 2007 plan recognized the many hazards shared with the county, while highlighting several hazards unique to the City of Ann Arbor. The 2012 Ann Arbor Hazard Mitigation Plan will be updated through this planning process. The 2012 Plan is a FEMA approved mitigation plan that has served the city well in acquiring funds and implementing mitigation projects. Many of the mitigation goals and over 80 mitigation actions in the 2012 plan will roll into the 2017 update. Several of the projects have been completed, including:

- Create marketing program to encourage citizen signup for CodeRED using not only landline telephone, but also cell (iPhone & Android), and email.
- Adopt Hazardous Spills Expense Recovery Ordinances.
- Assign city staff to apply hazard mitigation strategies to development, zoning, and policy decisions when applicable.
- Develop a critical technology infrastructure replacement plan, including identification of necessary funding, ensuring the planned replacement of critical technology infrastructure.
- Distribution of public education materials, such as flyers and website links regarding Family Emergency Preparedness Information and shelter information.

In March 2007, the Ann Arbor City Council approved the **Flood Mitigation Plan**. The Flood Mitigation Plan was Ann Arbor's first hazard mitigation plan and was an outcome of the city's subsection of the Washtenaw County Plan. The planning process included a much more detailed flood analysis than had been included in the Washtenaw County hazard mitigation plan and was heavily focused on implementation. The flood plan's strategies addressed the following areas: Mapping & Technology, Education and Outreach, Planning and Zoning, Regulation and Development Standards, Corrective Actions, Infrastructure, and Emergency Services.

Disaster Recovery Plan: A disaster recovery plan serves to guide the physical, social, environmental, and economic recovery and reconstruction process following a disaster. In many instances, hazard mitigation principles and practices are incorporated into local disaster recovery plans with the intent of capitalizing on opportunities to break the cycle of repetitive disaster losses. Disaster recovery plans can also lead to the preparation of disaster redevelopment policies and ordinances to be enacted following a hazard event. Ann Arbor has not yet adopted a disaster recovery plan.

Emergency Operations Plan: An emergency operations plan (EOP) outlines responsibilities and the means by which resources are deployed during and following an emergency or disaster. Ann Arbor completed a new EOP in 2017. The EOP was submitted for state approval in August 2017. The new EOP is NIMS and ICS compliant, following the structure of the National Response Framework. Ann Arbor Emergency Management is required to hold quarterly drills and annual exercises. The first exercise based on the new EOP was completed in August 2017. Ann Arbor has four high hazard dams (Barton, Argo, Geddes, & Superior) and an EOP is required each one. All four EOP's were updated in March 2016 and are compliant with Department of Homeland Security requirements. Ann Arbor holds annual functional exercises of the Barton Dam EOP, with full-scale exercises every five years.

Continuity of Operations Plan: A continuity of operations plan (COOP) establishes a chain of command, line of succession, and plans for backup or alternate emergency facilities in case of an extreme emergency or disaster event. Most departments within the Ann Arbor government have COOP, however they are not coordinated and are out-of-date. The city will benefit from updating those plans and integrating them into an overall COOP for the city.

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Evacuation Plan: An evacuation plan provides an evacuation strategy for all or part(s) of a jurisdiction in the event that a life safety threat or hazard occurs or is projected to occur. The evacuation plan is meant to facilitate the safe, timely, and efficient evacuation of an area. An evacuation plan provides a general outline of the expected roles, responsibilities, and evacuation-related response activities during an evacuation. Ann Arbor maintains an evacuation plan for the Barton Dam inundation area. An interactive webmap on the Ann Arbor Emergency Management website shows evacuation routes for the inundation area.

Planning and Regulatory Capability

Planning and regulatory capability is based on the implementation of plans, ordinances, and programs that demonstrate a local jurisdiction's commitment to guiding and managing growth, development, and redevelopment while maintaining the general welfare of the community. It includes emergency response and mitigation planning, comprehensive land use planning, and transportation planning; enforcement of zoning or subdivision ordinances and building codes and protection of environmental, historic, and cultural resources in the community. Although conflicts can arise, these planning initiatives present significant opportunities to integrate hazard mitigation principles into the local decision making process.

This assessment is designed to provide a general overview of key planning and regulatory tools and programs in Ann Arbor along with their potential effect on hazard mitigation. This information will help identify opportunities to address existing gaps, weaknesses, or conflicts with other initiatives in addition to integrating the implementation of this Plan with existing planning mechanisms where appropriate.

Table 7.1 provides a summary of relevant local plans, ordinances, and programs in place or under development in Ann Arbor. The status of each capability item is indicated with a symbol:

- A checkmark (✓) indicates that the given item is currently in place and being implemented; and
- An asterisk (*) indicates that the given item is currently being developed for future implementation.

Each of these local plans, ordinances, and programs should be considered available mechanisms for incorporating the requirements of the Ann Arbor Mitigation Plan. Items with the earth icon ( ) relate to climate mitigation and/or adaptation.

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Table 7.1: Relevant Plans, Ordinances, and Programs

Planning / Regulatory Tools	Ann Arbor
Hazard Mitigation Plan – 2017 Update	✔
Comprehensive Land Use Plan	✔
Floodplain Management Plan	✔

Planning / Regulatory Tools		Ann Arbor
Open Space Management Plan (or Parks & Rec/Greenway Plan)		✔
Stormwater Management Plan/Ordinance		✔
Natural Resource Protection Plan		✔
Flood Response Plan		
Climate Adaptation Plan		✔
Sustainability Plan		✔
Greenhouse Gas Reduction Plan (or Climate Action Plan)		✔
Emergency Operations Plan		✔
Continuity of Operations Plan		
Evacuation Plan		✔
Disaster Recovery Plan		
Capital Improvements Plan		✔
Economic Development Plan		
Historic Preservation Plan		
Flood Damage Prevention Ordinance		*
Zoning Ordinance		✔
Subdivision Ordinance		✔
Tree Removal/Replacement Ordinance		✔
Building Energy Efficiency Ordinance		
Unified Development Ordinance		
Post-Disaster Redevelopment Ordinance		
Building Code		✔
Fire Code		✔
National Flood Insurance Program (NFIP)		✔
NFIP Community Rating System		✔

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General Planning

The implementation of hazard mitigation activities often involves agencies and individuals beyond the emergency management profession. Stakeholders may include local planners, public works officials, economic development specialists, and others. In many instances, concurrent local planning efforts will help to achieve or complement hazard mitigation goals, even though they are not designed as such. Therefore, the Capability Assessment Review Form also asked questions regarding general planning capabilities and the degree to which hazard mitigation is integrated into other on-going planning efforts in Ann Arbor.

Comprehensive Land Use Plan: A comprehensive land use plan (master plan) establishes the overall vision for what a community wants to be and serves as a guide for future governmental decision making. Typically, a comprehensive plan contains sections on demographic conditions, land use, transportation elements, and community facilities. Given the broad nature of the plan and its regulatory standing in many communities, the integration of hazard mitigation measures into the comprehensive plan can enhance the likelihood of achieving risk reduction goals, objectives, and actions. The following documents constitute Ann Arbor's City Master Plan, which are described in more detail in the text that follows:

- Sustainability Framework (2013);
- Land Use Element (2009), including South State Street Corridor Plan (2013);
- Downtown Plan (2009);
- Transportation Plan Update (2009);
- Non-motorized Transportation Plan (2007) and Update (2013);
- Parks and Recreation Open Space Plan (2016); and
- Natural Features Master Plan (2004).

Several additional planning documents are to be used by the Planning Commission and Planning Staff as resource information in support of the City Master Plan. Plans with direct relationship to hazard mitigation and climate change include:

- Flood Mitigation Plan (2007);
- Capital Improvements Plan;
- Huron River and Impoundment Management Plan (2009);
- Climate Action Plan (2012);
- Allen Creek Greenway Task Force Report (2007);
- North Main Street/Huron River Corridor Vision for the Future Report (2013)

Sustainability Framework (2013). Ann Arbor's sustainability framework is a reorganization of 20 years of planning into one organized document that recognizes the broad spectrum of Ann Arbor's city plans, goals, and resolutions. Ann Arbor's sustainability framework lays out a set of 16 overarching goals that will help create a more sustainable Ann Arbor. These sustainability goals build on goals already developed through a variety of public processes - from city plans, council

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resolutions, and the council-approved ten environmental goals. These sustainability goals also include the three key aspects of sustainability – environment, economy, and equity and are organized into four theme areas: 1) climate and energy, 2) community, 3) land use and access, and 4) resource management.

Land Use Element (2009). The purpose of the Land Use Element of the City Master Plan is to provide information and guidance to city residents, decision-makers, developers, and property owners about land use planning issues that face the City of Ann Arbor. The land use element presents a series of goals, objectives and actions in two broad categories, Natural Systems and the Environment and Land Use. The element also includes sections devoted to specific areas of the city. The preservation and enhancement of natural systems is a theme throughout the element with several actions that specifically address protecting natural floodplain functions and improving stormwater infiltration. These actions include developing incentives to encourage the enhancement of natural features by developers and modifying city codes to restrict development in the floodway and floodplain. In the section devoted to Lower Town, the element states that, "No new buildings should be allowed in the Huron River flood plain/flood way that negatively impact flood storage capacity."

Downtown Plan (2009). This plan recognized the impact of storm water in the downtown area and the important role of street trees in helping manage runoff. One key component of the plan is the development of the Allen Creek Greenway. Several vacant parcels and potential redevelopment sites create the opportunity for the development of a greenway on the western edge of downtown. This plan includes an action from the Flood Mitigation Plan to reduce the potential for damage of streets, utilities and buildings in the Allen Creek floodplain. The plan also calls for a reduction in the use of non-renewable energy and to increase the amount of renewable energy sources in public infrastructure systems.

Transportation Plan Update (2009). The City of Ann Arbor Transportation Plan Update serves as a guide for improvements to the city's system of roads, sidewalks, paths, bike lanes, and public transit for the next twenty years. The plan presents 8 goals for the city's transportation. Goals that relate to hazard mitigation and climate adaptation include: 2) Protect and enhance the natural environment and energy resources, and the human and built environment; and 8) Promote green transportation improvements to reduce vehicle emissions. The plan calls for the use of best management practices and Low Impact Design techniques for stormwater runoff from streets, and other transportation infrastructure such as park and ride lots. The plan recognizes the need to accommodate planned growth without an increase in vehicle use or greenhouse gas emissions through promotion of other modes of travel and more compact, mixed use development.

Non-motorized Transportation Plan (2007) and Update (2013). The purpose of the plan is to identify the means to establish a physical and cultural environment that supports and encourages safe, comfortable and convenient ways for pedestrians and bicyclists to travel throughout the city and into the surrounding communities. It is further envisioned that this environment will result in a greater number of individuals freely choosing alternative transportation modes (walking, bicycling, mass transit, etc.), which will lead to healthier lifestyles, improved air and water quality, and a safer, more sustainable transportation system.

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While none of the goals and objectives relate directly to hazards or climate change, the increase in bicycle and pedestrian travel would result in a reduction in greenhouse gas emissions.

Parks and Recreation Open Space Plan (2016). The Parks and Recreation Open Space Plan (PROS) Plan is the city's vision for parks and recreation in Ann Arbor. The PROS Plan provides an inventory of existing parks and facilities, describes the relationship between the parks and recreation system and surrounding municipalities and recreation providers, identifies parks and recreation needs and deficiencies, and proposes major capital park projects for existing and new parks. One of the plan's goals is to foster environmental stewardship and sustainability, however the plan does not directly address hazards or climate change. Instead, the plan references the city's Natural Features Plan and the protection measures included in that plan.

Natural Features Master Plan (2004). The Natural Features Master Plan describes Ann Arbor's natural features, both publicly and privately owned, and sets forth policies to protect, restore and sustain them. This plan specifically addresses flooding along the Huron River, calling for adding flood storage capacity through acquisitions and native plantings, modifying codes to ensure best management practices are implemented in the floodplain and floodway, and restoring floodplains and wetlands. The plan also advocates for protecting steep slopes through code modifications, policy changes to improve groundwater recharge, and a variety of activities to help manage the impacts of climate change. Several implementation strategies from the Natural Features Master Plan will be incorporated into the mitigation strategy presented later in this plan.

Capital Improvements Plan (2018-2023). This Capital Improvements Plan (CIP) outlines a schedule of public service expenditures over the ensuing six-year period (fiscal years 2018–2023). The CIP does not address all of the capital expenditures for the city, but provides for large, physical improvements that are permanent in nature, including the basic facilities, services, and installations needed for the functioning of the community. These include transportation systems, utilities, municipal facilities and other miscellaneous projects. The recently completed Stormwater Modelling project resulted in the identification of several needed capital projects. This Plan includes several new projects that arose as a result of that effort, for example, the Edgewood/Snyder SWMM Area Stormwater project. In addition to the long list of stormwater projects, other hazard and climate related projects in the CIP include:

- New Fire Station A with Emergency Operations Center (EOC),
- Fire Station Generators,
- Facility Assessments - Energy Audits and Improvements,
- Open Space and Park Acquisitions,
- Northside Methane Collection System Upgrades,
- Natural Gas Fueling Installation, and
- Northside Methane Collection System Upgrades.

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Huron River and Impoundment Management Plan (2009). The Huron River and Impoundment Management Plan was developed to better understand the complex interrelationships among the Huron river ecology, community recreation preferences, the effect of dams on river processes, and the economic implications of different recommendations. Plan objectives that are directly related to hazards and climate change include:

- Ensure a healthy and sustainable aquatic ecosystem, including the river and its floodplain and watershed;
- Maintain an adequate drinking water supply;
- Minimize stormwater runoff and maximize infiltration;
- Management of the Shoreline and Riparian Corridor;
- Identify, protect, and enhance natural features, including native forest fragments, scenic vistas, greenways, and designated natural areas; and
- Anticipate and plan for the impact of large-scale forces such as climate change, development pressures and population changes.

The plan included a recommendation to remove the Argo Dam. One of the many identified benefits of removing the dam is the resulting reduction of the floodplain between Argo and Barton dams.

Climate Action Plan (2012). This Climate Action Plan identifies mid- and long-term greenhouse gas (GHG) reduction targets and a list of actions to achieve those targets. The Plan is intended to guide Ann Arbor decision makers in taking action to meaningfully reduce GHG emissions. The Plan also outlines the city's short-term goals and accomplishments to date. The Climate Actions section of the Plan is organized around four overarching themes that align with the City of Ann Arbor's Sustainability Framework. While all of the actions in the CAP address climate change, a few are particularly relevant to a FEMA hazard mitigation plan. Those actions include:

- Promote conversion to green roofs for commercial and industrial buildings;
- Support future funding for greenbelt land purchases around Ann Arbor;
- Increase residential and commercial rainwater capture and reuse;
- Increase forest canopy across public and private property;
- Design and implement urban stormwater infrastructure that enhances ecological functioning; and
- Develop a policy that requires private and municipal projects to plant shade trees and vegetation that help lower the heat island effect within the city.

The 2015 Climate Action Plan Progress Report outlines actions that are underway, in progress, or still getting started. Notable actions underway were:

- Green Streets Policy,
- Urban and Community Forest Management Plan,
- Stormwater Model Calibration and Analysis Project (see CIP),
- Revised Stormwater Standards, and

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- CodeRedTM Emergency Notification System.

Allen Creek Greenway Task Force Report (2007). The Allen Creek Greenway Task Force determined in 2007 that there can and should be an Allen Creek Greenway, and that, at a minimum, it should occupy the floodway portion of the city's sites in the Creek's floodplain. The vision for the Allen Creek Greenway is a path in a continuous, green open space following the floor of the Allen Creek valley along its length and joining the Huron River Greenway. The task force's report presents detailed recommendations for three city-owned sites in the Allen Creek floodplain. They include an urban garden, art and performance park, and a community green. The 2012 hazard mitigation plan references the Allen Creek Greenway Task Force Report and includes it in Project 44: Open Space Creation.

North Main Street/Huron River Corridor Vision for the Future Report (2013). The City of Ann Arbor's North Main-Huron River Corridor Vision Task Force (the "Task Force") developed a vision for the improvement of one of Ann Arbor's northern gateways and surrounding areas: to make the Corridor an identifiable, vibrant and unique destination that is connected to the community. One of the reports primary recommendations was that area of the 721 N. Main site within the floodway be included in the Allen Creek Greenway. This was also included in the 2012 hazard mitigation plan.

Economic Development Plan: An economic development plan provides a comprehensive overview of a community's economy. An economic development plan can set policies for a community's economic growth and identify strategies, programs, and projects to improve and maintain a community's economy. Economic development plans can also identify strategies to make the local economy more resilient, such as diversification and support for local businesses and local investment. Ann Arbor does not have a current economic development plan.

Historic Preservation Plan: An historic preservation plan is intended to preserve historic structures or districts within a community. An often overlooked aspect of the historic preservation plan is the assessment of buildings and sites located in areas subject to natural hazards and the identification of ways to reduce future damages. This may involve retrofitting or relocation techniques that account for the need to protect buildings that do not meet current building standards or are within a historic district that cannot easily be relocated out of harm's way. Ann Arbor does not currently have an historic preservation plan.

Zoning Ordinance: Zoning is the primary means by which land use is controlled by local governments. As part of a community's police power, zoning protects the public health, safety, and welfare throughout the jurisdiction. Since zoning regulations enable municipal governments to limit the type and density of development, a zoning ordinance can serve as a powerful tool when applied in identified hazard areas. Ann Arbor's municipal code includes the zoning ordinance and several additional policies and ordinances that directly address hazards and climate change, including:

- Subdivision and Land Use Control
- Green Streets

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- Wetlands Preservation
- Open Space and Land Use control
- Trees and Other Vegetation
- Stormwater System
- Storm Water Management and Soil Erosion and Sedimentation Control

Subdivision and Land Use Control. Ann Arbor's Subdivision and Land Use Control Ordinance requires city review and approval of the development of certain buildings, structures and land uses and the creation of new lots, all of which can be expected to have a significant impact on adjacent parcels and land uses, traffic patterns, natural features and the character of future development. The ordinance also provides for the preservation and management of significant natural features through city review, as well as to achieve harmonious relationships of buildings, structures and uses, both within a site and with adjacent sites; safe and convenient traffic movement, both within a site and in relationship to access streets; and appropriate public and private infrastructure.

Green Streets Policy. Ann Arbor City Council adopted a Green Streets Policy (Stormwater Management Guidelines for Public Street Construction and Reconstruction) in 2014 that sets stormwater infiltration standards for public streets. Public Streets Construction and Reconstruction projects in the City of Ann Arbor will use Green Infrastructure to infiltrate stormwater runoff from impervious areas that are disturbed. At a minimum, infiltration techniques implemented on the project shall be similar to those described in the Low Impact Development Manual for Michigan, Sept. 2008.

Wetlands Preservation. Preservation and enhancement of wetlands is essential to maintaining and improving the city's aesthetic character, its ecological stability, its economic well-being, its educational opportunities, and its quality of life. Wetlands are protected to help reduce damage to aquatic resources from erosion, turbidity, siltation, and contamination. They are protected to minimize the loss of native plants and animals, to help preserve biological diversity and to minimize the loss of wildlife habitat within the city, and to sustain many benefits wetlands can help provide - including flood control, stormwater storage and release, ground water recharge, and water quality improvement.

Open Space and Parkland Preservation. Ann Arbor's Open Space and Parkland Preservation Ordinance helps the city preserve and protect open space, natural habitats, parkland and the city's source waters inside and outside the city limits for benefit of residents of the City of Ann Arbor and in cooperation with the greater Ann Arbor community.

Trees and Other Vegetation. The City Administrator shall have the sole authority over the planting, maintenance and removal of trees in the street right-of-way and other city property. No person without written permission of the City Administrator shall plant, remove, break, spray or take any action which will injure or destroy any tree or shrub, the base of which is located in the street right-of-way or other city land.

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Stormwater System. This chapter establishes a stormwater utility for the purpose of conducting the city's stormwater management program to protect public health, safety, and welfare; provides for the proportional allocation to property owners of the necessary costs of the stormwater utility; permits the establishment and collection of just and equitable rates and charges to fund the stormwater utility; provides for credits, adjustments, exemptions and appeals; establishes regulations for the use of the stormwater system, and prescribes the powers and duties of certain municipal agencies, departments and officials.

Storm Water Management and Soil Erosion and Sedimentation Control. The purpose of this chapter is to control soil erosion and the resulting sediment; and to control the impact on water quality and quantity resulting from development and impervious surfaces within the City of Ann Arbor by requiring proper provisions for water disposal and the protection of soil surfaces during and after construction, in order to promote the safety, public health, convenience and general welfare of the community.

Unified Development Ordinance (UDO): A unified development ordinance is a local tool that combines traditional zoning and subdivision ordinances, along with other local regulations (e.g., design guidelines, sign regulation, stormwater management), into one document. UDOs can be used to improve efficiency and clarity in the land development process and to eliminate conflicting regulations. Ann Arbor does not have a unified development ordinance.

Building Codes, Fire Codes, Permitting, and Inspections: Building codes regulate construction standards. In many communities, permits, and inspections are required for new construction. Decisions regarding the adoption of building codes (that account for hazard risk), the type of permitting process required both before and after a disaster, and the enforcement of inspection protocols all affect the level of hazard risk faced by a community. Ann Arbor enforces the State of Michigan building code under the authority of the Stille-DeRossett-Hale Single State Construction Code Act PA 230 of 1972. Ann Arbor has adopted by reference the Washtenaw County Flood Insurance Study (FIS) and Flood Insurance Rate Maps (FIRMS) for the purposes of administration of the building code and to provide the content of the "Flood Hazards" section of Table R301.2(1) of the Michigan Residential Code.

The adoption and enforcement of building codes by local jurisdictions is routinely assessed through the Building Code Effectiveness Grading Schedule (BCEGS) program developed by the Insurance Services Office, Inc. (ISO).[iii] The results of BCEGS assessments are routinely provided to ISO's member private insurance companies, which in turn may offer ratings credits for new buildings constructed in communities with strong BCEGS classifications. The concept is that communities with well-enforced, up-to-date codes should experience fewer disaster-related losses and, as a result, should have lower insurance rates.

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In conducting the assessment, ISO collects information related to personnel qualification and continuing education as well as the number of inspections performed per day. This type of information combined with local building codes is used to determine a grade for that jurisdiction. The grades range from 1 to 10 with a BCEGS grade of 1 representing exemplary commitment to building code enforcement and a grade of 10 indicating less than minimum recognized protection. Ann Arbor's current BCEGS ratings are 4 for residential and 4 for commercial, both exceeding the threshold for achieving CRS Class 6.

Floodplain Management

Flooding represents the greatest natural hazard facing the nation. At the same time, the tools available to reduce the impacts associated with flooding are among the most developed when compared to other hazard-specific mitigation techniques. In addition to approaches that cut across hazards such as education, outreach, and the training of local officials, the *National Flood Insurance Program* (NFIP) contains specific regulatory measures that enable government officials to determine where and how growth occurs relative to flood hazards. Participation in the NFIP is voluntary for local governments; however, program participation is strongly encouraged by FEMA as a first step for implementing and sustaining an effective hazard mitigation program. It is therefore used as part of this assessment as a key indicator for measuring local capability.

Ann Arbor's Flood Management Overlay Ordinance is in development. However in March of 2012 the Ann Arbor City Council passed the Resolution to Manage Floodplain Development for the National Flood Insurance Program to allow participation in the NFIP. **Table 7.2** provides NFIP policy and claim information for Ann Arbor. The wording of the resolution is prescribed by FEMA and MDEQ and includes their minimum floodplain development regulations. Ann Arbor has completed several planning efforts that address flood mitigation including:

- Stormwater Model Calibration and Analysis Project (2015),
- Urban and Community Forestry Management Plan (2014),
- Huron River and Impoundment Management Plan (2009),
- Allen Creek Greenway Task Force Report (2007), and
- North Main Street/Huron River Corridor Vision for the Future Report (2013).

In order for a county or municipality to participate in the NFIP, they must adopt a local flood damage prevention ordinance that requires jurisdictions to follow established minimum building standards in the floodplain. These standards require that all new buildings and substantial improvements to existing buildings will be protected from damage by a 100-year flood event and that new development in the floodplain will not exacerbate existing flood problems or increase damage to other properties.

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A key service provided by the NFIP is the mapping of identified flood hazard areas. Once completed, the Flood Insurance Rate Maps (FIRMs) are used to assess flood hazard risk, regulate construction practices, and set flood insurance rates. FIRMs are an important source of information to educate residents, government officials, and the private sector about the likelihood of flooding in their community.

TABLE 7.2: NFIP POLICY AND CLAIM INFORMATION

Location	Number of NFIP Policies in Force	Insurance in Force ($)	Total Number of Flood Losses (Closed) Incurred	Total Claims Payments ($)	Average Payment ($)
City of Ann Arbor	327	$76,548,500	53 (32)	$281,600	$8,800

Source: NFIP claims and policy information as of 6/30/2017; NFIP Community Status information as of 6/30/2017.

Community Rating System: An additional indicator of floodplain management capability is the active participation of local jurisdictions in the Community Rating System (CRS). The CRS is an incentive-based program that encourages counties and municipalities to undertake defined flood mitigation activities that go beyond the minimum requirements of the NFIP by adding extra local measures to provide protection from flooding. All of the 18 creditable CRS mitigation activities are assigned a range of point values. As points are accumulated and reach identified thresholds, communities can apply for an improved CRS class rating. Class ratings, which range from 10 to 1, are tied to flood insurance premium reductions as shown in **Table 7.2**. As class rating improves (the lower the number the better), the percent reduction in flood insurance premiums for NFIP policyholders in that community increases.

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TABLE 7.3: CRS PREMIUM DISCOUNTS, BY CLASS

CRS Class	Premium Reduction
1	45%
2	40%
3	35%
4	30%
5	25%
6	20%
7	15%
8	10%
9	5%
10	0

Source: *FEMA*

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Community participation in the CRS is voluntary. Any community that is in full compliance with the rules and regulations of the NFIP may apply to FEMA for a CRS classification better than class 10. The CRS application process has been greatly simplified over the past several years based on community comments. Changes were made with the intent to make the CRS more user-friendly and make extensive technical assistance available for communities who request it. Ann Arbor joined the CRS in May 2017and is currently a Class 7.

Continued Compliance with the NFIP

The City of Ann Arbor is in good standing with the NFIP and joined the CRS in May 2017 as a Class 9. This following plans and tools demonstrate a jurisdiction's commitment to ongoing NFIP compliance (based on Table 7.1 results).

Flood Damage Prevention Ordinance: A flood damage prevention ordinance establishes minimum building standards in the floodplain with the intent to minimize public and private losses due to flood conditions. Ann Arbor does not have a flood damage prevention ordinance. The city has been working for years to adopt this ordinance, but in the meantime, has remained compliant with the NFIP and CRS with the 2012 Resolution to Manage Floodplain Development for the National Flood Insurance Program.

Floodplain Management Plan: A floodplain management plan (or a flood mitigation plan) provides a framework for action regarding corrective and preventative measures to reduce flood-related impacts. This hazard mitigation plan update serves as the floodplain management plan and will comply with CRS requirements.

Natural Resource Protection Plan: A natural resource protection plan identifies the lands containing natural resources (e.g., forests, streams, wildlife habitat) within a jurisdiction, and provides policies for protecting those resources. These plans can also include regulations or guidelines for altering or developing land containing natural resources. Both the Parks Recreation and Open Space Plan (2016) and the Natural Features Master Plan (2004) deal with the identification and protection of natural resources.

Open Space Management Plan*:* An open space management plan is designed to preserve, protect, and restore largely undeveloped lands in their natural state and to expand or connect areas in the public domain such as parks, greenways, and other outdoor recreation areas. In many instances, open space management practices are consistent with the goals of reducing hazard losses, such as the preservation of wetlands or other flood-prone areas in their natural state in perpetuity. An Arbor's Parks Recreation and Open Space Plan (2016) is the city's open space management plan.

Stormwater Management Plan: A stormwater management plan is designed to address flooding associated with stormwater runoff. The stormwater management plan is typically focused on design and construction measures that are intended to reduce the impact of more frequently occurring minor urban flooding. Ann Arbor adopted the Storm Water Management and Soil Erosion and Sedimentation Control ordinance in 2000 and completed the Stormwater Model Calibration and Analysis Project (SWM) in 2015. Both efforts assist the city in stormwater management. The primary outcome of the SWM project was a calibrated stormwater model that includes stormwater conveyance systems beyond just stormwater pipes and open channels, including green infrastructure and the floodplain. One particular advantage to the model is that is includes areas of flooding outside the floodplain. The model was designed to help identify and prioritize stormwater projects to be included in the city's Capital Improvement Plan (CIP).

Urban and Community Forestry Management Plan (2014). The overarching goal of the Urban and Community Forestry Management Plan is to sustainably protect, preserve, maintain and expand Ann Arbor's tree canopy and urban and community forest. The plan includes 17 recommendations that will help increase the quality and size of the urban and community forest, which is an adaptive strategy to improve water quality and limit flooding by mitigating stormwater runoff.

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Administrative and Technical Capability

The ability of a local government to develop and implement mitigation projects, policies, and programs is directly tied to its ability to direct staff time and resources for that purpose. Administrative capability can be evaluated by determining how mitigation-related activities are assigned to local departments and if there are adequate personnel resources to complete these activities. The degree of intergovernmental coordination among departments will also affect administrative capability for the implementation and success of proposed mitigation activities.

Technical capability can be evaluated by assessing the level of knowledge and technical expertise of local government employees, such as personnel skilled in using Geographic Information Systems (GIS) to analyze and assess community hazard vulnerability. The Capability Assessment Review Form was used to capture information on administrative and technical capability through the identification of available staff and personnel resources. **Table 7.3** provides a summary of the Capability Assessment Review Form results for Ann Arbor with regard to relevant staff and personnel resources. A symbol was used to indicate the presence of staff member(s) with the specified knowledge or skill.

- A checkmark (✓) indicates the presence of a staff member(s) in Ann Arbor; and
- An asterisk (*) indicates that the resource is currently being considered.

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Table 7.4: Relevant Staff / Personnel Resources

Staff / Personnel Resources		Ann Arbor
Planners with knowledge of land development / land management practices		✔
Engineers or professionals trained in construction practices related to buildings and/or infrastructure		✔
Planners or engineers with an understanding of natural and/or human-caused hazards		✔
Planners or engineers with an understanding of climate change impacts		✔
Emergency Manager		✔
Floodplain Manager		✔
Sustainability or Climate Change Coordinator		✔
Locally Specific Climate Data		✔
Land Surveyors		✔
Scientists familiar with the hazards of the community		
Scientists familiar with the community's climate change impacts		
Staff with education or expertise to assess the community's vulnerability to hazards		✔
Personnel skilled in GIS and/or HAZUS		✔
Resource development staff or grant writers		

Ann Arbor's staff capabilities for implementing the hazard mitigation plan are exceptional. With the presence of the University of Michigan, the staff has access to scientists and research that can enhance those capabilities. The city would benefit from

having a staff person assigned to writing grant applications and securing additional resources. This position could be shared across multiple city departments, thus increasing the likelihood of funding projects with co-benefits.

Fiscal Capability

The ability of a local government to take action is closely associated with the amount of money available to implement policies and projects. This may take the form of outside grant funding awards or locally-based revenue and financing. The cost of mitigation policy and project implementation vary widely. In some cases, policies are tied primarily to staff time or administrative costs associated with creation and monitoring of a given program. In other cases, direct expenses are linked to an actual project, such as acquisition of flood-prone homes, which can require a substantial commitment from local, state, and federal funding sources.

The Capability Assessment Review Form was used to capture information Ann Arbor's fiscal capability through the identification of locally available financial resources. **Table 7.4** provides a summary of the results for Ann Arbor with regard to relevant fiscal resources. The status of each capability item is indicated with a symbol indicates that the given fiscal resource is locally available for hazard mitigation purposes (including match funds for state and federal mitigation grant funds:

- A checkmark (✓) indicates that the given item is currently available and being used;
- An asterisk (*) indicates that the given item is currently under consideration; and

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Table 7.5: Relevant Fiscal Resources

Fiscal Tool / Resources	Ann Arbor
Capital Improvement Programming	✔
Community Development Block Grants (CDBG)	✔
Special Purpose Taxes (or taxing districts)	✔
Gas / Electric Utility Fees	
Water / Sewer Fees	✔
Stormwater Utility Fees	✔
Development Impact Fees	
Tree Removal Fees	*
General Obligation, Revenue, and/or Special Tax Bonds	
Partnering Arrangements or Intergovernmental Agreements	

Political Capability

One of the most difficult capabilities to evaluate involves the political will of a jurisdiction to enact meaningful policies and projects designed to reduce the impact of future hazard events. Hazard mitigation may not be a local priority or may conflict with the community's growth and economic development goals. Therefore, the local political climate must be considered in designing mitigation strategies as it could be the most difficult hurdle to overcome in accomplishing their adoption and implementation.

The Capability Assessment Review Form was used to capture information on political capability of Ann Arbor. Previous planning efforts were reviewed for general examples of local political capability, such as guiding development away from identified hazard areas, restricting public investments or capital improvements within hazard areas, or enforcing local development standards that go beyond minimum state or federal requirements (i.e., building codes, floodplain management, etc.).

Ann Arbor's commitment to addressing hazards and climate change and political capability is demonstrated by the 2012 Hazard Mitigation Plan, the 2012 Climate Action Plan, and other plans, studies, and ordinance reviewed in this section. Perhaps more important is the inclusion of projects addressing impacts of hazards and climate change, as well as, greenhouse gas reduction actions in the city's Capital Improvement Plan. The city successfully funded several flood mitigation projects through grant awards and is transitioning the city's vehicles to electric power.

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Conclusion on Local Capability

A Capability Assessment examines local capabilities to detect any existing gaps or weaknesses within ongoing government activities that could hinder proposed mitigation activities and possibly exacerbate community hazard vulnerability. These gaps or weaknesses have been identified for Ann Arbor in the tables found throughout this section. The results of the Capability Assessment form part of the basis for the Mitigation Actions that are identified in Section 6; helping Ann Arbor to improve its ability to mitigate and adapt to the impacts of hazards and climate change.

The conclusions of the Risk Assessment and Capability Assessment serve as the foundation for the development of a meaningful hazard mitigation strategy. During the process of identifying specific mitigation actions to pursue, the city considered not only level of hazard risk, but also the existing capability to minimize or eliminate that risk. The list below outlines key capabilities Ann Arbor can address in the Mitigation Strategy.

Planning and Regulatory Capability

- Floodplain Damage Prevention Ordinance – Ann Arbor has begun developing a Floodplain Management Overlay. This overlay can significantly enhance Ann Arbor's ability to minimize the impact of flooding in the city.

Emergency Management

- Continuity of Operations Plan (COOP) – Updating and integrating the city's COOP plans will enhance the city's ability to function during an event and continue to provide services to residents. Similarly, businesses with COOPs return preserve jobs and offer needed goods and services following a hazard event.
- Disaster Recovery Plan - With the results of this plan's risk assessment, Ann Arbor will know where disasters are likely to occur and what is at risk. Preparing a plan pre-disaster for how to recover and rebuild in those areas that complements the economic development strategy is a small investment with potentially large rewards. Recovery will be smarter and faster with a recovery plan in place and can further the city's economic development goals.

Administrative and Technical Capability

- Grant Writer – Ann Arbor has a long list of unfunded projects in the Capital Improvement Plan and more are identified in this plan's mitigation strategy. Ann Arbor can increase its potential to fund those projects by assigning a staff person to pursue grants from FEMA and other funding agencies.

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i While the Final Rule for implementing the Disaster Mitigation Act of 2000 does not require a local capability assessment to be completed for local hazard mitigation plans, it is a critical step in developing a mitigation strategy that meets the needs of the region while taking into account their own unique abilities. The Rule does state that a community's mitigation strategy should be "based on existing authorities, policies, programs and resources, and its ability to expand on and improve these existing tools" (44 CFR, Part 201.6(c)(3)).
ii A copy of the Capability Assessment Review Form can be found in Appendix B.
iii Participation in BCEGS is voluntary and may be declined by local governments if they do not wish to have their local building codes evaluated.

- Introduction
- Mitigation Goals
- Identification & Analysis of Mitigation Techniques
- Updating the 2012 Mitigation Strategy
- Mitigation Action Prioritization
- Mitigation Action Plan

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6 Mitigation Strategy

Section 6 Table of Contents

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Introduction

The intent of the Mitigation Strategy is to provide the City of Ann Arbor with the goals that will serve as guiding principles for future mitigation policy and project administration along with an analysis of mitigation actions deemed obtainable to meet those goals and reduce the impact of identified hazards. It is designed to be comprehensive, strategic, and functional in nature:

- In being *comprehensive*, the development of the Mitigation Strategy includes a thorough review of all hazards and identifies extensive mitigation measures intended to not only reduce the future impacts of hazards, but also to help the city achieve compatible economic, environmental, and social goals.
- In being *strategic*, the development of the Mitigation Strategy ensures that all policies and projects proposed for implementation are consistent with pre-identified, long-term planning goals.
- In being *functional*, each proposed mitigation action is linked to established priorities and assigned to specific departments or individuals responsible for their implementation with target completion deadlines. When available, funding sources are identified that can be used to assist in project implementation.

The first step in designing the Mitigation Strategy includes the identification of mitigation goals. Mitigation goals represent broad statements that are consistent with the hazards identified within the plan. These goals set the blueprint for the Mitigation Strategy and allowed the stakeholders to vision what they wanted to achieve over the next five year period.

The second step involves the identification, consideration, and analysis of available mitigation measures (i.e., activities, policies, etc.) that lead to identifying mitigation actions that will help achieve the identified mitigation goals. These actions include both hazard mitigation policies (such as the regulation of land in known hazard areas through a local ordinance) and hazard mitigation projects that seek to address specifically targeted hazard risks (such as the acquisition and relocation of a repetitive loss structures). Alternative mitigation measures will continue to be considered as future mitigation opportunities are identified, as data and technology improve, as mitigation funding becomes available, and as this Plan is maintained over time.

The third and last step in designing the Mitigation Strategy section is the development of the Mitigation Action Plan. The Mitigation Action Plan represents an explicit and functional plan for each action and is the most essential outcome of the mitigation planning process. The Mitigation Action Plan includes a prioritized listing of proposed hazard mitigation actions (policies and projects) for the 2017 City of Ann Arbor Hazard Mitigation Plan to complete. Each action has accompanying information, such as those departments or individuals assigned responsibility for implementation, potential funding sources,

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and an estimated target date for completion. The Mitigation Action Plan provides those departments or individuals responsible for implementing mitigation actions with a clear roadmap that also serves as an important tool for monitoring success or progress over time. The cohesive collection of actions listed in the Mitigation Action Plan can also serve as an easily understood menu of mitigation policies and projects for those local decision makers who want to quickly review the recommendations and proposed actions of the Plan and potentially integrate with other planning documents.

In preparing the 2017 Mitigation Action Plan, members of the City of Ann Arbor Technical Advisory Committee (TAC) considered the overall hazard risk and capability to mitigate the effects of hazards as recorded through the risk and capability assessment process. The adopted mitigation goals were also considered when developing each action item. Lastly, a thorough review of the Mitigation Strategy from the 2012 City of Ann Arbor Hazard Mitigation Plan was completed in order to see progress and align it to the current re-formatted Mitigation Strategy section.

Updating the 2012 Mitigation Strategy

In keeping with FEMA requirements for hazard mitigation plan updates, the mitigation actions identified in the previous City of Ann Arbor Hazard Mitigation Plan were evaluated. The 2012 Mitigation Strategy section was formatted in a way that the city did not want to replicate. In fact, in the previous Plan the term 'mitigation actions' was not used within the Plan. A variety of formats (3), lengths and descriptions (Goals, Mitigation Strategies, Mitigation Strategy: Projects and others) were used to represent potential mitigation actions.

The existing Mitigation Section was reviewed and reworked in an iterative process with the consultant team and TAC. During the first attempt to complete this process the consultant team identified over 140 labeled mitigation strategies and goals. There was significant redundancy, variation of length, labeling and complexity amongst the different formats. In addition, several key requirements were missing from many of the potential actions outlined in the 2012 Mitigation Strategy including: identification of the agency responsible for implementation, potential funding sources, benefits consideration, and implementation schedules. The variation of formats and missing components necessitate the significant rework of the 2017 Mitigation Strategy. While significant changes were employed to provide a more usable and actionable Mitigation Strategy, the TAC recognized that there was useful information found in the previous plan. Each item was reviewed and subsequently re-organized into the new 2017 Mitigation Action Plan to ensure that, as feasible, existing goals and actions were reviewed and edited for the current plan. The TAC was heavily involved in reworking this section and identifying what now are identified as 'mitigation actions'.

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Updating the 2017 Mitigation Goals

44 CFR Requirement
44 CFR Part 201.6(c)(3)(i): The mitigation strategy shall include a description of mitigation goals to reduce or avoid long-term vulnerabilities to the identified hazards.

The primary goal of all local governments is to promote the health, safety, and welfare of its citizens. In keeping with this standard and promoting a proactive approach to disaster management and risk reduction, the City of Ann Arbor reviewed, combined, amended, and ultimately defined five goal statements for the 2017 plan update. These goals will be used as a blue print for local hazard mitigation planning. As noted above, the 2012 Mitigation Strategy, including the goals, was organized in a way that was difficult to follow and not a format that the city wanted to replicate. As a result, the TAC made significant changes to their existing goals in order to make them more aligned to hazard mitigation planning, easier to comprehend and reflective of current priorities within the city (including the incorporation of climate change considerations). The consultant team used information gathered from the previous plan and discussions with the TAC to recommend a set of goals to the TAC. These were initially introduced, reviewed, and amended at the TAC Kickoff Meeting (August 2, 2017). The goals were further refined and ultimately approved at the first TAC bi-weekly call (August 17, 2017). (Of note, specific changes can be found in the meeting notes found in Appendix C.). The TAC unanimously approved the following goals for the 2017 hazard mitigation plan update at the TAC Mitigation Strategy Meeting (September 11, 2017) presented in **Table 6.1**.

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Table 6.1: Ann Arbor Hazard Mitigation Plan Goals

Goal Number	Goal
Goal 1	Increase the **resilience** of our city by protecting and reducing potential damage to our most vulnerable **populations**, **natural and man-made infrastructure**, and **critical facilities**.
Goal 2	**Increase the leadership and public awareness of current and projected risk and hazard mitigation action.**
Goal 3	Incorporate hazard mitigation and climate change considerations into existing or future **policies** and **capabilities**.
Goal 4	**Increase community-wide hazard mitigation partnerships through building stronger relationships amongst local, regional and statewide governmental entities, businesses, higher education entities and the public.**
Goal 5	Increase the resilience of the city by ensuring hazard mitigation and climate change initiatives receive consideration for **funding.**

Updating the 2017 Mitigation Actions

The initial review of the 2012 Mitigation Strategy was completed with assistance from the consultant team and city leads. As noted above, over 140 goals and strategies were initially identified. These were further reviewed to reduce redundancies and reformat the layout, which resulted in the creation of just over 80, now labeled mitigation actions, for update in the 2017 Mitigation Action Plan. At this point the consultant team developed a process for members of the TAC to review the 2012 mitigation actions to help further refine the list as well as provide information for new actions.

In order to ensure the TAC and consultant team captured what mitigation activity had taken place over the last five years it was crucial to receive feedback from the TAC members. An excel file 'TAC_Mitigation_Action_Worksheet' was created with two tabs, tab one included the 2012 refined mitigation actions and tab two included a place for the TAC to provide new mitigation actions. An instruction sheet, found in Appendix B, was provided that described the information needed to update the identified actions. Questions for each action included the following:

- Comments & Status
- Proposed Action Description
- Site and Location
- History of Damages
- Hazards Addressed
- Mitigation Category
- Estimated Cost
- Benefits
- Consideration of Climate Change
- Co-Benefits
- Potential Funding Sources
- Lead Implementer/Other Partners
- Implementation Schedule
- Linkage to Other Plans

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The majority of these questions are standard, however the City of Ann Arbor wanted to make sure that there was a focus on Climate Change within this plan as well as a discussion of Co-Benefits for each mitigation actions. These concepts were discussed at the two onsite TAC meetings along with the ongoing biweekly TAC calls. In attempt to make sure these concepts

were considered and represented within the Mitigation Strategy the following questions were asked and captured within Mitigation Action Plan:

- Consideration of Climate Change: Does the action consider climate change?
- Co-Benefits: Does the action consider Co-Benefits?

The TAC was provided three weeks to review the 'TAC_Mitigation_Action_Worksheet' and provide feedback on the identified 2012 actions. During this three-week period, the consultant team also had individual "offices hour" calls to discuss actions with particular agencies, as well as detailed discussions about the Mitigation Strategy on the bi-weekly TAC calls. Multiple members of the TAC provided substantial feedback that allowed the consultant team to further refine the 2012 list to 57 mitigation actions. In addition, the TAC provided information on 25 new mitigation actions they wanted to pursue.

The last step in revising the Mitigation Strategy was accomplished at the September 11, 2017 TAC Mitigation Strategy meeting (see Appendix C for meeting notes). At this meeting the TAC members were provided the opportunity to collectively review each 2012 mitigation action and each new mitigation action. By reviewing actions collectively as a group, the TAC efficiently provided missing required information and ensured there were no conflicts between different city service areas. Through this process, the final Mitigation Action Plan was developed as presented at the end of this section.

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Mitigation Action Implementation Success

It is important to document the mitigation successes that have occurred over the last five years. While the 2012 Mitigation Strategy format made this a bit difficult to follow and capture in a traditional manner, the TAC was still able to capture multiple (19) completed mitigation actions that had been identified in the 2012 plan as found in Appendix C. Some highlights include the following:

- The acquisition of FEMA Hazard Mitigation Grant Program (HMGP) and Michigan Department of Transportation (MDOT) funds for the removal of berm located between Depot Street and the Huron River.
- Developed a county-wide Heat Plan.
- Acquired FEMA Hazard Mitigation Grant Program (HMGP) funding to acquire multiple structures (219 W. Kingsley and 721 N. Main St.).
- Developed a 24/7 automated monitoring process that notifies staff of critical infrastructure failures.
- Completed new emergency response plan, including plans for flooding.
- Completed public education materials for Family Emergency Preparedness Information in multiple languages.

Identification and Analysis of Mitigation Techniques

44 CFR Requirement

44 CFR Part 201.6(c)(3)(ii): *The mitigation strategy shall include a section that identifies and analyzes a comprehensive range of specific mitigation actions and projects being considered to reduce the effect of each hazard, with particular emphasis on new and existing buildings and infrastructure.*

In formulating the Mitigation Strategy for the City of Ann Arbor Hazard Mitigation Plan, a wide range of activities were considered to help advance the established five mitigation goals, in addition to addressing any specific hazard concerns. In order to help the community and the TAC understand what mitigation activities to consider, the consultant team presented the following six broad categories of mitigation techniques: Prevention, Property Protection, Natural Resource Protection, Structural Projects, Emergency Services, and Public Awareness and Education. Presenting mitigation activities examples under these category types helped the decision makers understand the kinds of activities addressed under a Hazard Mitigation Plan. The following provides example activities presented under each category:

Prevention

Preventative activities are intended to keep hazard problems from getting worse, and are typically administered through government programs or regulatory actions that influence the way land is developed and buildings are built. They are particularly effective in reducing a community's future vulnerability, especially in areas where development has not occurred or capital improvements have not been substantial. Examples of preventative activities include:

- Planning and zoning
- Building codes
- Open space preservation
- Floodplain regulations
- Stormwater management regulations
- Drainage system maintenance
- Capital improvements programming
- Riverine / fault zone setbacks

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Property Protection

Property protection activities involve the modification of existing buildings and structures to help them better withstand the forces of a hazard, or removal of the structures from hazardous locations. Examples include:

- Acquisition
- Relocation
- Building elevation
- Critical facilities protection
- Retrofitting (e.g., windproofing, floodproofing, seismic design techniques, etc.)
- Safe rooms, shutters, shatter-resistant glass
- Insurance

Natural Resource Protection

Natural resource protection activities reduce the impact of natural hazards by preserving or restoring natural areas and their protective functions. Such areas include floodplains, wetlands, steep slopes, and sand dunes. Parks, recreation, or conservation agencies and organizations often implement these protective measures. Examples include:

- Floodplain protection
- Watershed management
- Riparian buffers
- Forest and vegetation management (e.g., fire resistant landscaping, fuel breaks, etc.)
- Erosion and sediment control
- Wetland preservation and restoration
- Habitat preservation
- Slope stabilization

Structural Projects

Structural mitigation activities are intended to lessen the impact of a hazard by modifying the environmental natural progression of the hazard event through construction. They are usually designed by engineers and managed or maintained by public works staff. Examples include:

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- Reservoirs
- Dams / levees / dikes / floodwalls
- Diversions / detention / retention
- Channel modification
- Storm sewers

Emergency Services

Although not typically considered a "mitigation" technique, emergency service activities do minimize the impact of a hazard event on people and property. These commonly are actions taken immediately prior to, during, or in response to a hazard event. Examples include:

- Warning systems
- Evacuation planning and management
- Emergency response training and exercises
- Sandbagging for flood protection
- Installing temporary shutters for wind protection

Public Education and Awareness

Public education and awareness activities are used to advise residents, elected officials, business owners, potential property buyers, and visitors about hazards, hazardous areas, and mitigation techniques they can use to protect themselves and their property. Examples of measures to educate and inform the public include:

- Outreach projects
- Speaker series / demonstration events
- Hazard map information
- Real estate disclosure
- Library materials
- School children educational programs
- Hazard expositions
- Social Media

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Mitigation Action Prioritization

Mitigation action prioritization emphasizes the extent to which benefits are maximized, according to a review of the proposed projects and their associated costs. Through the Benefit-Cost Prioritization Matrix **(Table 6.2.)**, the higher the action's benefit, and the lower the cost, the more cost beneficial and higher priority the mitigation action was determined to be for the city.

For each mitigation action, the TAC was asked to rank (Very High, High, Moderate & Low) the potential benefits based on the following criteria:

- Effect on overall risk to life and property
- Ease of implementation / technical feasibility
- Political and community support
- Funding availability
- Continued compliance with the NFIP
- Consideration of Climate change
- Provision of co-benefits

Next, the TAC was asked to provide rough cost estimates that were scored based on which category they fell within.

- Low Estimated Cost ($0 - $4,999)
- Moderate Estimated Cost ($5000 - $49,999)
- High Estimated Cost ($50,000 - $249,999)
- Very High Estimated Cost ($250,000 - Above)

Once the benefit and costs of the actions were determined, the consultant team convened to calculate the priority of each action item based on the following Benefit-Cost Prioritization Matrix **(Table 6.2.)**. This decision-making chart assigns a simplified benefit-cost prioritization ranking for each mitigation action item. Those mitigation action items that receive a higher-ranking signal projects that should potentially receive more attention. Inversely, projects that are estimated to be higher in cost with a lower benefit receive a lower-ranking. It should be noted that this methodology provides a simplistic Benefit-Cost model and depending on the action item a more detailed Benefit-Cost model maybe needed in the future.

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Table 6.2: Benefit-Cost Prioritization Matrix

Prioritization Matrix					
		Benefit			
		D (Low)	C (Moderate)	B (High)	A (Very High)
Estimated Cost	Very High	Low	Low	Medium	High
	High	Low	Medium	Medium	Very High
	Moderate	Low	High	High	Very High
	Low	Medium	High	Very High	Very High

2017 Mitigation Action Plan

The TAC and consultant team designed the 2017 Mitigation Strategy in a manner that followed a more traditional and standardized format.

- Identify Goals
- Identify Actions
- Develop a Mitigation Action Plan

As mentioned, the Mitigation Strategy section of the 2012 City of Ann Arbor Hazard Mitigation Plan was in need of significant changes to accommodate city desires, priorities and a more actionable plan. The 2017 Mitigation Action Plan represents a review and refinement of the 2012 strategies as well as a capture of new mitigation actions that the TAC and members of the community wanted to achieve.

The mitigation actions were organized by Mitigation Technique Categories (Prevention; Property Protection; Natural Resource Protection; Structural Projects; Emergency Services; Public Education and Awareness). By organizing the mitigation actions by mitigation technique categories one can see that there was a broad range of mitigation action types captured within this plan. **Table 6.3** provides a breakdown of how many mitigation actions there are per mitigation technique category, while **Table 6.4** presents the entire Action Plan.

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Table 6.3: Number of Mitigation Action by Technique Category

Mitigation Category	Number of Actions
Emergency Services	16
Natural Resource Protection	5
Prevention	15
Property Protection	9
Public Education/Awareness	11
Structural Projects	1
Total	**57**

The following key elements are captured within the Mitigation Action Plan to help the city comprehend and track each action over the next five years.

- Action Number
- Action Description
- Comments & Status
- Hazard(s) Addressed
- Consideration of Climate Change
- Co-Benefits
- Estimated Cost
- Benefit
- Priority
- Potential Funding Source
- Lead Implementer/Other Partners
- Implementation Schedule
- Linkage to Other Plans

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Table 6.4: 2017 Mitigation Action Plan

#	Action Description	Hazard(s) Addressed	Consideration of Climate Change	Co-Benefits	Estimated Cost	Benefit	Priority	Potential Funding Source	Lead Implementer/ Other Partners	Implementation Schedule	Linkage to Other Plans	Comments & Status
Emergency Services												
1	Create a communication plan to distribute to hazardous material transporters, outlining the safest and most preferred routes through and to various destination points in the City.	HazMat	No	None captured	Moderate	High	High	Unknown	Ann Arbor Fire Department, OEM	2022	None captured	**NEED ANDY RESPONSE**
2	Participate in the Washtenaw County Hazardous Materials Response Authority, including the Pollution Prevention Program, Emergency Preparedness Plan and LEPC.	HazMat	No	Yes, affects health, safety, environmental health, transportation safety; part of NPDES permit (MS4 requirements)	Low	High	Very High	Homeland Security Grant Funds (EMPG)	Ann Arbor Fire Department, OEM	2022	AAFD Hazmat Response Plan	The city is participating and will continue.
3	Consider up-to-date technology when equipment is purchased, to provide better on-scene performance.	Structure Fires and HazMat	No	None captured	Moderate	High	High	Unknown	Ann Arbor Fire Department	2022	None captured	**OEM awareness; A foam suppression ATV has been added to the city's vehicle fleet, for easy access to small structure fires at densely populated events such as football games. Cost - lowest responsible bidder. NEED ANDY RESPONSE**
4	Maintain and monitor dams as described in Federal and State regulations.	Dam Failure, Terrorism, Flood	Yes, increased flooding could cause new stress on dams.	Yes, water Sector, energy, recreation and greenspace.	Moderate	High	High	WTP Budget, Grants	WTP, Huron River Watershed Council	2022	Dam Emergency Action Plans, Dam Security Assessments, Surface Water Intake Protection Plan	Barton Hydro Dam EAP is exercised regular according to FERC requirements. All dams have a security assessment.

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#	Action Description	Hazard(s) Addressed	Consideration of Climate Change	Co-Benefits	Estimated Cost	Benefit	Priority	Potential Funding Source	Lead Implementer/ Other Partners	Implementation Schedule	Linkage to Other Plans	Comments & Status
5	Secure grant funding and line item budgeting for hazard mitigation activities and planning to assure the implementation of the strategies included within the Hazard Mitigation Plan.	All Hazards	Yes, the city could see an increase in disaster activity.	Yes, all sectors	Very High	Very High	High	Hazard Mitigation Grants, Capital Improvements Plan	OEM	Dependent on funding	All City Plans, Ann Arbor Emergency Response Plan	Grant Funding - Annual Budget Process, CIP integration for Emergency Operations Center. This could benefit from the hiring of a grant writer or having a dedicated staff person assigned to this task.
6	Ensure the city's siren coverage and warning systems are assessed and maintained.	Weather hazards, Dam Failure and Terrorism	Yes, the region of Ann Arbor is trending toward having an increase in severe thunderstorms in the future.	Yes, siren warning can be used for severe thunderstorms, tornados, hazardous material spill, and national threats.	High ($65,000)	Very High	Very High	Operating Budget (Currently $65K has been budgeted)	OEM, Ann Arbor IT Department	2022 (Annually for next 5 budget cycles)	Ann Arbor Emergency Response Plan	City has budgeted funding for continued assessment, upgrades, and repairs to siren warning system over the next 5 years.
	Redacted											
8	Assure that roads are plowed promptly during snowstorms and that plow routes are continually evaluated for effectiveness.	Severe Winter Weather	Yes, generally more winter precipitation is expected.	None captured	Very High	High	Medium	Operating budget	Public Works	2022	None captured	Goal - streets cleared within 24 hours of a 4 inch snowfall; no plowing if snow is less than 3.

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#	Action Description	Hazard(s) Addressed	Consideration of Climate Change	Co-Benefits	Estimated Cost	Benefit	Priority	Potential Funding Source	Lead Implementer/ Other Partners	Implementation Schedule	Linkage to Other Plans	Comments & Status
9	Explore the opportunity of building two new fire stations (A & B). Fire station A will also house a new and improved emergency operations center.	All Hazards	Yes, with the potential for more disasters this is needed.	Yes, re-location of fire station will lessen response times to the city, current EOC does not have adequate capabilities.	Very High (A $4.3M, B $2.7M)	Very High	High	Operating budget, Potential grants	Ann Arbor Fire Department, OEM	A 2021, B 2023	None captured	New Action that is being discussed within the Capital Improvements Projects budget.
10	Continue refinement of evacuation planning for Barton Dam failure to include emergency response vehicle routing (ingress and egress), staging and turn arounds.	Flood, Dam Failure, and Terrorism	Yes, as related to weather and potential larger rain events.	Yes, dam sector, transportation, recreation and energy.	Low	Very High	Very High	Operating budget	OEM	2018	Ann Arbor Emergency Response Plan, Barton Dam EAP	New Action
11	Continue Refinement of evacuation planning for the City with focus on downtown, special events, and University of Michigan football.	Terrorism and All Hazards	Yes, as related to weather	Yes, safety, reduction in traffic accidents, increased capabilities for emergency services.	Low	Very High	Very High	Operating budget	OEM, Ann Arbor Fire Department, Ann Arbor Police Department, University of Michigan	2019	Ann Arbor Emergency Response Plan, Michigan Stadium EOP	New Action
12	Evaluate backup power sources for street lights and signals be integrated along evacuation routes and high tra ffic areas.	All Hazards	Yes, the region of Ann Arbor is trending toward having an increase in severe thunderstorms in the future.	Yes, more efficient power for our street lights could enhance the citizens feeling of safety.	Moderate	High	High	Operating budget	Public Works, OEM, Engineering	2022	None captured	New Action
13	Develop a new Continuity of Government Plan. The city has documented procedures but need to be synthesized into a formal COG's.	All-Hazards	No	None captured	High	High	Medium	Operating budget	OEM	2022	None captured	New Action

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#	Action Description	Hazard(s) Addressed	Consideration of Climate Change	Co-Benefits	Estimated Cost	Benefit	Priority	Potential Funding Source	Lead Implementer/ Other Partners	Implementation Schedule	Linkage to Other Plans	Comments & Status
14	Develop a pre-disaster Recovery Plan that will guide recovery and redevelopment efforts following a disaster.	All-Hazards	No	None captured	High	High	Medium	Grant funding	OEM	Grant dependent	None captured	New Action
	Redacted											
16	Formally adopt the Technical Advisory Committee by resolution to help manage hazard mitigation activities.	All-Hazards	Yes, increased weather events cause the need to take hazard mitigation more seriously therefore this group needs to be solidified.	Yes, having this group in place will allow the key stakeholders to understand what each group is working and allow for future collaboration and the more co-benefits.	Low	Very High	Very high	Operating budget	OEM	2018	Members of the TAC	New Action

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#	Action Description	Hazard(s) Addressed	Consideration of Climate Change	Co-Benefits	Estimated Cost	Benefit	Priority	Potential Funding Source	Lead Implementer/ Other Partners	Implementation Schedule	Linkage to Other Plans	Comments & Status
Natural Resource Protection												
17	Protect and attain funding for natural features like green space and green infrastructure in the floodplain.	Floods	Yes, flooding potential is expected to get worse within the region due to climate change.	Yes, water quality and drinking water protection	High	High	Medium	DEQ 319 grants. Watershed Management Implementation Grants	Systems Planning Unit, HWRC	2022	Middle Huron Watershed Management Plan	Partner with HRWC- revision of watershed management plan for sub basins of the Huron River system in Ann Arbor. Already funded strategies in the WMP that qualify for DEQ 319 funds. Instituted a Green Street Policy, 400 rain garden credits within the storm water utility, developing a Green Infrastructure Report.
18	Consider a program to encourage dedication of open space in the floodway and floodplain.	Floods	Yes, flooding potential is expected to get worse within the region due to climate change.	None captured	High	Moderate	Medium	Unknown	Systems Planning Unit, City Attorney, Planning	2022	http://www.a2gov.org/departments/systems-planning/programs/Pages/Allen-Creek-Greenway-Master-Plan-Project.aspx	No movement on this item. City maintains per capita park land ratio; option for "requested parks contribution" in place. Purchase of development rights was discussed and no State enabling legislation is available to deal with PDR at this time.
19	Explore opportunities of linking and advancing Green Infrastructure projects through city's Greenway Plan.	Floods	Yes, heat mitigation and migration corridors are additional climate adaptation benefits.	Yes, water quality, ecosystem protection, drinking water and recreation.	Low	Moderate	High	Unknown	HRWC	2022		Allen Creek Greenway Plan is near complete and recommendations were made for stormwater management opportunities.

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#	Action Description	Hazard(s) Addressed	Consideration of Climate Change	Co-Benefits	Estimated Cost	Benefit	Priority	Potential Funding Source	Lead Implementer/ Other Partners	Implementation Schedule	Linkage to Other Plans	Comments & Status
20	Review the regions Watershed Management Plans and incorporate recommendations that are consistent with flood mitigation objectives into future revisions of the Ann Arbor Hazard Mitigation Plan (and other plans, as opportunities arise).	Floods	Yes, flooding potential is expected to get worse within the region due to climate change.	None captured	Low	Moderate	Medium	DEQ 319	HRWC	2022	Huron River Watershed Management Plan	Currently funded revision of Ann Arbor portion of the Huron River Watershed Management Plan led by HRWC 2017-2019. Also UM led WMP development for School Girls Glen.
21	Conduct Watershed Management Planning studies for the key watersheds located within the region and incorporate recommendations that are consistent with flood mitigation objectives into future revisions of the Ann Arbor Hazard Mitigation Plan (and other plans, as opportunities arise).	Floods	Yes, flooding potential is expected to get worse within the region due to climate change.	None captured	High	Moderate	Medium	DEQ 319	HRWC	2022	None captured	Still needs to be done based on complaints within certain watershed areas.
Prevention												
22	Hire additional building inspection staff to ensure that new building permits are reviewed for the use of up-to-date fire-resistant technologies. Explore incentive-based programs to encourage residents and business owners to install fire-resistant technologies when building or remodeling a structure.	Structure Fires	No	Yes, more staff equals more efficiency.	High	High	Medium	Building permit revenues, Incentives from private industry	Architects and Owners, Building department	2022	None captured	Constantly in progress
23	Use code enforcement programs to ensure that heating and cooling equipment is maintained and installed.	Extreme Cold, Extreme Heat	Yes, the region is expected to experience an increase temperature which will directly affect the cooling systems within the city.	Yes, the maintenance of heating and cooling systems will have a positive effect on the efficiencies of the systems.	Moderate	Low	Low	Building, Housing Rentals	Building Department	2022	None captured	Constantly in progress

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#	Action Description	Hazard(s) Addressed	Consideration of Climate Change	Co-Benefits	Estimated Cost	Benefit	Priority	Potential Funding Source	Lead Implementer/ Other Partners	Implementation Schedule	Linkage to Other Plans	Comments & Status
24	The Fire Prevention Division is taking a more proactive role in performing fire safety inspections. Continue to enforce industrial, fire, and safety regulations. Ensure that regular inspections of all SARA Title III sites take place. Work with Washtenaw County's Pollution Prevention Program to ensure that facilities that store, manage or produce hazardous materials are using best management practices, and thus facilitate information exchange between the facility, the Fire Department, and the Hazardous Materials Response Team.	HazMat	No	None captured	Low	High	Very High	Unknown	Ann Arbor Fire Department	2022	None captured	**NEED ANDY RESPONSE**
25	As part of inspection programs, distribute materials to residents that includes fire safety practices.	Structure Fires	No	None captured	Moderate	Moderate	High	Operating budget	Ann Arbor Fire Department	2022	None captured	**NEED ANDY RESPONSE**
26	Continue to implement available features of the city wide notification system for use during city-wide disaster events. Include the development of trainings and protocols for disaster team (911 Center Dispatchers and other key Department leaders).	All Hazards	Yes, climate could bring more frequent hazard occurrences within the area.	None captured	Moderate	Very High	Very High	Operating budget	OEM	2022	None captured	The City is currently exploring technologies for notification of National Weather Events. This is not just specific to CodeRED. City began CodeRED in 2003 and has continued to implement new features.
27	Implement the Urban and Community Forest Management Plan recommendations such as, a pruning cycle to increase the health of trees to reduce their susceptibility to infestation and negative effects on the power grid and increasing the tree canopy to help with the heat island effect.	Hail, Severe Winter Weather, Lightening, Severe Winds, Tornados, Extreme Cold, Extreme Heat	Yes, climate could bring more frequent severe weather hazard occurrences within the area.	None captured	Very High ($600,000-800,000/year)	High	Medium	Stormwater Utility	Urban Forestry	2027 (10 year annual cycle)	Urban Forestry Master Plan	Tree inventory in 2009 and continuous funding for tree pruning program.

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#	Action Description	Hazard(s) Addressed	Consideration of Climate Change	Co-Benefits	Estimated Cost	Benefit	Priority	Potential Funding Source	Lead Implementer/ Other Partners	Implementation Schedule	Linkage to Other Plans	Comments & Status
28	Set up an interdepartmental committee/taskforce charged with the review of planning documents with respect to hazard mitigation.	All Hazards	Yes, review of planning documents should consider climate change as part of the mitigation discussion.	Yes, review of planning documents should consider climate change as part of the mitigation discussion and provides a framework for building on/sharing existing goals.	Low	Low	Medium	Operating budget	Planning	2022	None captured	Completed on a per-plan basis; Master Plan Sub-committee of Planning Commission and Planning Commission approved documents.
29	Develop a list of changes and revisions that can be made to include hazard mitigation strategies in the City's land use plans.	All Hazards	Yes, consider climate projects and future floodplain	Yes, provides a framework for building on/sharing existing goals.	Low	Low	Medium	Operating budget	Planning	2022	None captured	Completed on a per-plan basis; Master Plan Sub-committee of Planning Commission and Planning Commission approved documents.

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#	Action Description	Hazard(s) Addressed	Consideration of Climate Change	Co-Benefits	Estimated Cost	Benefit	Priority	Potential Funding Source	Lead Implementer/ Other Partners	Implementation Schedule	Linkage to Other Plans	Comments & Status
30	Approve the draft Floodplain Management Overlay Ordinance to provide residents, property owners and decision makers with the opportunity to consider floodplain and floodway land use independently of other zoning decisions. Key mitigation actions incorporated under this ordinance include: • Prohibit residential use in the floodway • Prohibit or limit other uses in the floodway • Establish standards for redevelopment in the floodway • Prohibit or limit artificial obstructions in the floodway and flood fringe (Critical Facilities, Mobile Homes, HAZMAT, Accessary Structures, Fences, and others) • Prohibit Critical Facilities in the floodplain and the 0.2% special flood hazard area • Authorized fill or structure below the base flood elevation shall be compensated for and balanced by a hydraulically equivalent excavation. • Consider regulating within the floodplain and floodway to a higher standard requiring structures to be built at 1 to 2 feet above the 0.2% annual event elevation to acknowledge climate change. • Market value for substantial improvement calculations shall be based on true cash value as shown on the official City of Ann Arbor Tax Assessor's records.	Floods	Yes, flooding potential is expected to get worse within the region due to climate change.	Yes, improved water quality and river hydrology. Reduced property loss and related expenses for residents.	Low	Very High	Very High	Stormwater utility fund, Operating budget	Systems Planning Unit, Planning, Attorney's Office	2019	None captured	A draft ordinance has been mostly written, but has not been vetted by other City Staff. Many of the other flood related actions were rolled up into this one. This is a Very high priority.

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#	Action Description	Hazard(s) Addressed	Consideration of Climate Change	Co-Benefits	Estimated Cost	Benefit	Priority	Potential Funding Source	Lead Implementer/ Other Partners	Implementation Schedule	Linkage to Other Plans	Comments & Status
	• Substantial improvements will be counted cumulatively over a ten year period.											

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#	Action Description	Hazard(s) Addressed	Consideration of Climate Change	Co-Benefits	Estimated Cost	Benefit	Priority	Potential Funding Source	Lead Implementer/ Other Partners	Implementation Schedule	Linkage to Other Plans	Comments & Status
31	Enhance the availability of critical technology infrastructure shared by the City of Ann Arbor and Washtenaw County, including primary and secondary data centers and common technology.	All Hazards	No	Yes, enhanced technology will enhance the efficiency of every department including the ability to respond and recovery from disasters.	High	High	Medium	IT budget	City IT, Washtenaw county IT	2022	None captured	In-Progress as it is standard practice to remediate older technology for new.
32	Develop a shared technology recovery plan that provides access to critical systems through a common data recovery platform in case of a primary data center failure.	All Hazards	No	None captured	High	High	Medium	IT budget	City IT	2020	None captured	In-Progress as we have some recovery plans in place as well as a secondary data center (not a "HOT" site), but need to develop a more comprehensive plan.
33	Evaluate new technology (like effective call-down systems) as it becomes available, to assure that the most effective notification systems are in place.	All Hazards	No	None captured	Moderate	Moderate	High	IT budget	City IT	2022	None captured	This is done on an on-going and proactive basis.
34	Continue to monitor source and finished water for indicators of disease-causing organisms.	Invasive Species	No	None captured	Moderate	High	High	Unknown	Washtenaw county Public Health	2022	None captured	Continuous, testing beyond federal and state requirements

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#	Action Description	Hazard(s) Addressed	Consideration of Climate Change	Co-Benefits	Estimated Cost	Benefit	Priority	Potential Funding Source	Lead Implementer/ Other Partners	Implementation Schedule	Linkage to Other Plans	Comments & Status
35	Revise asset management plans to consider climate impacts and make operational adjustments such as increased maintenance and monitoring and accelerated infrastructure refurbishment schedules.	All Hazards	Yes	Yes, a revised asset management plan will provide more efficiencies within our infrastructure and save the citizens money that can be invested elsewhere.	Moderate	Moderate	High	Unknown	Systems Planning	2019	None captured	New Action
36	Implement actions identified in the City of Ann Arbor Stormwater Model Calibration and Analysis Project.	Flood	Yes, the region of Ann Arbor is trending toward having an increase in flooding in the future.	None captured	Moderate	Moderate	High	Stormwater Utility	Systems Planning	2022	None captured	New Action
					Property Protection							
37	Review opportunities to develop saferooms where vulnerabilities are identified.	Tornado, Severe Winds	Yes, the region of Ann Arbor is trending toward having an increase in severe thunderstorms in the future.	None captured	High	Moderate	Medium	Private, Hazard Mitigation Grants	OEM	2022	None captured	New Action
38	Evaluate the structural integrity of traffic signals, aerial fiber, power lines, signs, and other infrastructure that may become at risk of failure due to severe weather.	Hail, Severe Winter Weather, Lightening, Severe Winds, Tornados, Extreme Cold	Yes, climate could bring more frequent severe weather hazard occurrences within the area.	None captured	Very High	High	Medium	Operating budget	Public works, Urban Forestry	2022	None captured	Aerial fiber

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#	Action Description	Hazard(s) Addressed	Consideration of Climate Change	Co-Benefits	Estimated Cost	Benefit	Priority	Potential Funding Source	Lead Implementer/ Other Partners	Implementation Schedule	Linkage to Other Plans	Comments & Status
39	Consider acquiring properties (particularly Repetitive Loss and Severe Repetitive Loss properties) for acquisition within the floodplain and floodway.	Floods	Yes, as potential for flooding becomes higher acquisition may become more necessary.	Yes, if floodprone properties are acquired this will help reduce our response and recovery costs.	Very High	Very High	High	Currently setting aside $100,000 per year for 75/25% FEMA grant. HMA grants	Systems Planning Unit, OEM	2022	None captured	Increase the importance of this item. We have been successful at structure removal: 219 W. Kingsley (2012), 2 industrial building at 721 N. Main St (2013), Current grant for 128 Felch St (owner may back out), grant application just submitted for 208 Chapin St.
40	Conduct a flood audit to evaluate which publicly owned properties should be protected by flood insurance.	Floods	Yes, flooding potential is expected to get worse within the region due to climate change.	Yes, if floodprone properties have the proper insurance it could reduce the city's recovery costs.	Moderate	High	High	Operating budget	Systems Planning Unit, OEM	2022	None captured	No movement on this item.
	Redacted											
42	Require new or updated critical facilities to be designed with redundant operating systems, such as microgrids.	All Hazards	No	None captured	Very High	High	Medium	Operating budget, Grants	OEM, Public Works, Systems Planning	2022	None captured	New Action
43	Evaluate mitigation strategies for improving power distribution (e.g., burying power lines) to improve chances of maintaining power during storm events.	Severe Winter Weather, Hail, Lightening, Severe Winds, Tornados	Yes, the region of Ann Arbor is trending toward having an increase in severe thunderstorms in the future.	Yes, more resilient power grid will be attractive to businesses and future citizens.	Moderate	High	High	DTE budget, Operating budget	DTE, Engineering, Planning	2022	None captured	New Action

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#	Action Description	Hazard(s) Addressed	Consideration of Climate Change	Co-Benefits	Estimated Cost	Benefit	Priority	Potential Funding Source	Lead Implementer/ Other Partners	Implementation Schedule	Linkage to Other Plans	Comments & Status
44	Identify best practices for the installation and management of flood proofing of all communications infrastructure at risk of water damage.	Flood, Dam Failure, and Terrorism	Yes, the region of Ann Arbor is trending toward having an increase in flooding in the future.	Yes, reduced vulnerabilities within our communication systems will allow our citizens more access to important information.	Moderate	High	High	Unknown	Systems Planning, Engineering, IT	2019	None captured	New Action
45	Ensure proper anchors for manufactured home units are installed via building code requirements.	Tornado, Severe Winds	Yes, the region of Ann Arbor is trending toward having an increase in severe thunderstorms in the future.	Yes, proper building codes reduce property damages.	High	Moderate	Medium	Private, Hazard Mitigation Grants	Owners, Building Department	2022	None captured	Anchoring of manufactured units is addressed at the installation of new units being added or on renovation of existing units as building code requires.
Public Education & Awareness												
46	Provide public education on remediation of household hazardous waste that could cause secondary hazard effects in identified vulnerable areas (e.g. floodplains).	Flood, HazMat	Yes, larger rain events expected that could bring more risk to areas where HazMat are stored.	Yes, ecological and water quality benefits to floodplain contamination cleanup and MS4	Low	High	Very High	Hazard Mitigation Grants, Operating budgets	City Environmental, Systems Planning, Ann Arbor Fire Department, Metro HAZMAT Response	2022	None captured	Multi-faceted project involving several departments, with a public education element. Would be better served through Floodplain Manager emergency management awareness.
47	Complete regular training events for all departments and staff integral to effective hazard response and mitigation as well as schedule awareness training for the City Council, the Planning and Environmental Commissions, and the Environmental and	All Hazards	Yes, include climate preparedness training. Also, scenario planning for extreme natural hazards or multiple hazard scenarios more likely given climate change projections.	Yes, all sectors	Low	Very High	Very High	Operating budget	OEM	2022 (On a quarterly basis)	Ann Arbor Emergency Response Plan	May need discussion outside of quarterly OEM exercises.

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#	Action Description	Hazard(s) Addressed	Consideration of Climate Change	Co-Benefits	Estimated Cost	Benefit	Priority	Potential Funding Source	Lead Implementer/ Other Partners	Implementation Schedule	Linkage to Other Plans	Comments & Status
	Emergency Management Teams.											
48	Inform commissions and planning committees of hazard mitigation strategies.	All Hazards	Yes, depending on plan topic.	Yes, shares cross-initiative awareness with other committees (beyond staff).	Low	Moderate	High	Operating budget	Planning	2022	None captured	In Progress - include hazard mitigation strategies in ongoing education/awareness with planning committees.
49	Provide floodplain 101 training to city staff and elected officials to foster a greater understanding of flood issues.	Floods	Yes, training should include climate change primer and implications for floodplain management.	Yes, as the city potentially becomes more vulnerable to flooding there will be a need for more knowledge of proper floodplain management.	low	Moderate	High	Operating budget	Systems Planning Unit	2022	None captured	Jerry Hancock is a CFM (since 2005) and has been doing this but would like to do more of it.
50	Working with public education entities develop a hazard mitigation/floodplain management education program to cover many of the issues associated with floodplain management and hazard mitigation.	Floods, All Hazards	Yes, training should include climate change primer and implications for floodplain management.	Yes, if the populous is more educated on their risks this will help reduce our recovery costs.	Moderate	High	High	Unknown	Systems Planning Unit, Red Cross	2022	None captured	None provided
51	Working in collaboration with CRS requirements continue to develop a robust flood public information campaign using the potential following elements: brochures, mailings, displays, articles, videos,	Floods	Yes, flooding potential is expected to get worse within the region due to climate change.	None captured	Moderate	Moderate	High	Unknown	Systems Planning Unit, Red Cross, HRWC, CTN - Rain Ready Program	2022	None captured	Some of these items have been worked on but it was determined that more could be completed.

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#	Action Description	Hazard(s) Addressed	Consideration of Climate Change	Co-Benefits	Estimated Cost	Benefit	Priority	Potential Funding Source	Lead Implementer/ Other Partners	Implementation Schedule	Linkage to Other Plans	Comments & Status
	signs, presentations, and emergency action plans.											
52	Use the public library's as a central location where residents can go to access important public documents and other information like handbooks, maps, and other publications that address hazard mitigation.	Floods	Yes, flooding potential is expected to get worse within the region due to climate change.	None captured	Low	Low	Medium	Unknown	Systems Planning Unit, Ann Arbor District Library	2022	None captured	None provided
53	Publicize information about the special needs registry and how residents with special needs can register themselves.	All Hazards	No	Yes, this can help our disaster response community be more efficient and save time and dollars spent with responding to this populous.	Low	High	Very High	Unknown	Community & Economic Development	2022	None captured	New Action
	Redacted											
	Redacted											

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#	Action Description	Hazard(s) Addressed	Consideration of Climate Change	Co-Benefits	Estimated Cost	Benefit	Priority	Potential Funding Source	Lead Implementer/ Other Partners	Implementation Schedule	Linkage to Other Plans	Comments & Status
56	Incorporate climate forecasts and utilize worst case scenarios in vulnerability assessments.	All Natural Hazards	Yes, climate forecasts are consistently changing and needed to be added to our vulnerability assessments.	Yes, more informed models will reduce the city's overall risks.	Moderate	Moderate	High	Grants	OEM, HRWC	2022	None captured	New Action
					Structural Projects							
57	Assess the need for repairs on bridges that are critical for emergency response, and make culvert replacements where necessary.	All-Hazards	Yes, building specifications should consider more extreme heat and larger rain events so infrastructure can handle increased threat.	None captured	High	High	Medium	Operating budget	Public Works	2022	None captured	This is an on-going effort through the Annual bridge inspections program.

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- Implementation & Integration
- Monitoring, Evaluation, & Enhancement
- Continued Public Involvement

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7 Plan Maintenance

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44 CFR Requirement

44 CFR Part201.6(c)(4)(i):
The plan shall include a plan maintenance process that includes a section describing the method and schedule of monitoring, evaluating and updating the mitigation plan within a five-year cycle.

44 CFR Part 201.6(c)(4)(ii):
The plan maintenance process shall include a process by which local governments incorporate the requirements of the mitigation plan into other planning mechanisms such as comprehensive or capital improvement plans, when appropriate

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Implementation and Integration

Implementation

Each agency, department, or other partner participating under the City of Ann Arbor Hazard Mitigation Plan is responsible for implementing specific mitigation actions as prescribed in the Mitigation Action Plan. Every proposed action listed in the Mitigation Action Plan is assigned to a specific "lead" agency or department in order to assign responsibility and accountability and increase the likelihood of subsequent implementation.

In addition to the assignment of a local lead department or agency, an implementation time period or a specific implementation date has been assigned in order to assess whether actions are being implemented in a timely fashion. The city will seek outside funding sources to implement mitigation projects in both the pre-disaster and post-disaster environments. When applicable, specific potential funding sources have been identified for proposed actions listed in the Mitigation Action Plan.

The TAC intends to meet bi-annually (twice a year) moving forward. This frequency of meeting will also assist in implementation. A key agenda item will be to determine which actions are being implemented by members of the TAC.

Integration

The city will integrate this Hazard Mitigation Plan into relevant city government decision-making processes, plans, or mechanisms, where feasible. This includes integrating the requirements of the Hazard Mitigation Plan into other local planning documents, processes, or mechanisms, such as comprehensive or capital improvement plans, when appropriate.

The members of the TAC will remain charged with ensuring that the goals and mitigation actions of new and updated local planning documents for their agencies or city service areas are consistent, or do not conflict with, the goals and actions of the Hazard Mitigation Plan, and will not contribute to increased hazard vulnerability in the city.

Since the previous plan was adopted the city has worked to integrate the hazard mitigation plan into other planning mechanisms where applicable/feasible. Examples of how this integration has occurred have been documented in Section 7: Capability Assessment. Specific examples of how integration has occurred include:

- Integrating the mitigation plan into creation of new floodplain management overlay ordinance;
- Integrating the mitigation plan into reviews and updates for the Community Rating System;

Opportunities to further integrate the requirements of this Plan into other local planning mechanisms shall continue to be identified through future planning effort. The city planning manager outlined the mechanisms underway and under consideration:

- Integration of the city's mitigation plan is considered on a case by case basis and identified at the onset of plan development.
- Integration of city's mitigation plan as an element of the comprehensive plan.
- Capital improvement projects are scored on a variety of factors including: **1) Safety/Compliance/Emergency Preparedness; 2) Funding 3) Coordination with Other Projects; 4) Innovation; and 5) Partnerships.** This scoring matrix can be found in Appendix C.
- Per State of Michigan enabling legislation (e.g., Municipal Planning Act and the Township Planning Act), when the city undertakes a master planning process, the city communicates their intent to outside agencies, adjacent jurisdictions, utilities and other entities at the start of a planning process. The draft document is also distributed to these stakeholders for comment. The City will evaluate expanding this distribution process, beyond the minimum prescribed by law, to include the TAC, or other stakeholders to best capture the data, information, and concern pertaining to hazard mitigation.

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Monitoring, Evaluation and Enhancement

Periodic revisions and updates of the Hazard Mitigation Plan are required to ensure that the goals of the Plan are kept current, taking into account potential changes in hazard vulnerability and mitigation priorities. In addition, revisions may be necessary to ensure that the Plan is in full compliance with applicable federal and state regulations. Periodic monitoring and evaluation of the plan will also ensure that specific mitigation actions are being reviewed and carried out according to the Mitigation Action Plan.

The TAC shall meet bi-annually (twice a year) to monitor and evaluate the progress attained and to revise, where needed, the activities set forth in the plan. These meetings will also assist in fulfilling elements of the 510 Community Rating System requirements. The bi-annual meetings provide the TAC with an opportunity to:

- Evaluate those actions that have been successful;
- Document hazard occurrences and impacts;
- Explore the possibility of documenting potential losses avoided due to the implementation of specific mitigation measures; and
- Identify any new or additional vulnerabilities that may be faced by the City and may need to be addressed in a future update of this plan.

The findings and recommendations of the TAC shall be documented in the form of a report that can be shared with interested stakeholders, including City Council members (and the public at least once annually). The TAC will also meet following any disaster events warranting a reexamination of the mitigation actions being implemented or proposed for future implementation. This will ensure that the Plan is continuously updated to reflect changing conditions and needs within the city. The City Floodplain Manager and Emergency Manager will be responsible for reconvening the TAC for these reviews.

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Five Year Plan Review and Update

The Plan will be thoroughly reviewed by the TAC every five years in alignment with federal regulations. This update is also used to determine whether there have been any significant changes in the city that may, in turn, necessitate changes in the types of mitigation actions proposed, goals, or priorities. New development in identified hazard areas, an increased exposure to hazards, an increase or decrease in capability to address hazards, and changes to federal or state legislation are examples of factors that may affect the necessary content of the Plan. The Ann Arbor Emergency Management Director will be responsible for reconvening the TAC and conducting the five-year review.

Upon completion of the review and update/amendment process, the City of Ann Arbor Hazard Mitigation Plan will be submitted to the State Hazard Mitigation Officer at the Michigan State Police, Division of Emergency Management and

Homeland Security for final review and approval in coordination with the Federal Emergency Management Agency. Once an "approved pending adoption" status has been issued by FEMA, City Council can then review, approve and adopt the plan. The city review consists of review by the Environmental Planning Commission, Planning Commission with final approval by City Council.

Disaster Declaration

Following a disaster declaration, the City of Ann Arbor Hazard Mitigation Plan may be revised as necessary to reflect lessons learned, or to address specific issues and circumstances arising from the event. It will be the responsibility of the City of Ann Arbor Emergency Management Director to reconvene the TAC and ensure the appropriate stakeholders are invited to participate in the plan revision and update process following declared disaster events.

Plan Amendment Process

Unique circumstances, such as availability of critical data or an omission, may necessitate a plan amendment. Upon the initiation of the amendment process, the city will forward information on the proposed change(s) to all interested parties including, but not limited to, all directly affected city service areas, community partners, residents, and businesses. Information, will also be forwarded to Michigan State Police, Division of Emergency Management and Homeland Security, and FEMA. This information will be disseminated in order to seek input on the proposed amendment(s) for no less than a 45-day review and comment period (unless circumstances necessitate a shorter review).

At the end of the 45-day review and comment period, the proposed amendment(s) and all comments will be forwarded to the TAC for final consideration. The TAC will review the proposed amendment along with the comments received from other parties, and if acceptable, the TAC will submit a recommendation for the approval and adoption of changes to the plan.

In determining whether to recommend approval or denial of a plan amendment request, the following factors will be considered by the TAC:

- There are errors, inaccuracies, or omissions made in the identification of issues or needs in the plan.
- New issues or needs have been identified which are not adequately addressed in the plan.
- There has been a change in information, data, or assumptions from those on which the plan is based.

If the TAC opts to move forward with the amendment, the revised plan must be reviewed and approved by the state and FEMA. City Council will also need to approve the revised plan. Prior to adoption, City Council shall hold a public meeting. The City Council will review the recommendation from the TAC (including the factors listed above) and any oral or written comments received at the public hearing. Following that review, the governing bodies will take one of the following actions:

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- Adopt the proposed amendments as presented;
- Adopt the proposed amendments with modifications;
- Refer the amendments request back to the TAC for further revision; or
- Defer the amendment request back to the TAC for further consideration and/or additional hearings.

Continued Public Involvement

44 CFR Requirement
44 CFR Part 201.6(c)(4)(iii): The plan maintenance process shall include a discussion on how the community will continue public participation in the plan maintenance process

Public participation is an integral component to the mitigation planning process and will continue to be essential as this Plan evolves over time. Public involvement procedures were reviewed as part of the 2017 plan update. As described above, significant changes or amendments to the Plan shall require a public hearing prior to any adoption procedures. When the TAC is formalized by resolution, bi-annual TAC meetings will also be open to the public. In addition, Ann Arbor regularly posts information about hazard and risk assessment on city communication channels (e.g., social media and e-newsletters). This is led by the Public Information Officer. The city also maintains a hazard mitigation planning website that can be used to provide updates and post the most current version of the plan:
https://www.a2gov.org/departments/emergency-management/Pages/Hazard-Mitigation-Plan-.aspx

By keeping the plan available on the city's website with an invitation and instructions on providing feedback, public awareness and comment opportunities will be maintained on a round-the-clock basis, 365 days per year.

Other efforts to involve the public in the maintenance, monitoring, evaluation, and revision process will be made as necessary. These efforts may include:

- Advertising TAC meetings on the city website, social media channels, local newspapers, public bulletin boards and/or city office buildings;
- Designating willing and voluntary citizens and private sector representatives as official members of the TAC;

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- Utilizing available city channels and local media to update the public on any maintenance and/or periodic review activities taking place;
- Keeping a current version on the hazard mitigation plan in public libraries and the emergency management office.

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